Proceedings of a workshop held at ECMWF

Thirteenth Workshop
on
Meteorological Operational Systems

31 October – 4 November 2011

European Centre for Medium-Range Weather Forecasts
Shinfield Park, Reading RG2 9AX, UK

April 2012

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II WORKSHOP PROGRAMME

Monday 31 October 2011

Session 1 Use and interpretation of medium and extended range forecast guidance

Erik Andersson, ECMWF
Development of ECMWF forecasting systems

Michel Jean, Meteorological Service of Canada
Progress and the future directions of the Canadian weather and environmental prediction systems

Xueshun Shen, Center for Numerical Prediction, China Meteorological Administration
Introduction of medium and extended range forecast system and their applications in CMA

Mireille Mayoka, Météo-France
Use of ECMWF products at Météo-France

Ingeborg Smeding, Meteo Consult BV
Use of ECMWF products at MeteoGroup – focus on Road Forecasting

Tuesday 1 November 2011

Stephan Siemen, ECMWF
Mapping meteorological data beyond the meteorological domain

Iain Russell, ECMWF
Metview 4: Enhanced functionalities for observation monitoring

David Boddie, Norwegian Meteorological Institute (met.no)
Diana – Ideas on standards and future directions

Jozef Matula, IBL Software Engineering
Visual Weather web services

Gerhard Eymann, Deutscher Wetterdienst (DWD)
Recent developments of the meteorological workstation NinJo

Antoine Lasserre-Bigorry, Météo-France
Synopsis project: from Synergie to Synergie-next

David Bright, NOAA/NWS/NCEP/Aviation Weather Center
The NCEP application of ensemble information across multiple scales and user groups

David Novak, National Centers for Environmental Prediction / Hydrometeorological Prediction Center
Emerging trends in the role of the forecaster

Li Yuet Sim, Hong Kong Observatory
Application of NWP products and meteorological information processing system in Hong Kong

Laura Ferranti, ECMWF
The new ECMWF seasonal forecasting system 4

Warwick Norton and Dan Rowlands, Cumulus/PCE Investors
First impressions of System 4 seasonal forecasts

James Belanger and Violeta Toma, School of Earth and Atmospheric Sciences
Customized daily to seasonal predictions for the energy sector using ECMWF forecasts

Wednesday 2 November 2011

Harald Lemmin, Deutscher Wetterdienst (DWD)
GRIB data handling with SKY at Deutscher Wetterdienst

Gheorghe Stancalie, National Meteorological Administration of Romania
Spatial data architecture operational management in Romania

José Aravéquia, CPTEC/INPE
The use of SMS at CPTEC's suites alongside the supercomputer's replacement

Stephen Pascoe, Science and Technology Facilities Council, Rutherford Appleton Laboratory
The CEDA web processing service for rapid deployment of earth system data services

Richard Engelen, ECMWF
Towards operational GMES atmosphere services: MACC/MACC-II global production at ECMWF

Rashid Kashif, World Food Programme
Forecasting for Emergency Preparedness and Response

David Richardson, ECMWF
The WMO Severe Weather Forecast Demonstration Project

Khalid Muwembe, Uganda Meteorological Department
Using ECMWF products in support of mobile weather alert pilot project over Lake Victoria in Uganda

Samsom Kahsay, National Meteorological Agency
Method of short and medium weather forecast in NMA

Working Groups

Thursday 3 November 2011

Akira Ito, Japan Meteorological Agency
JMA Coupled Ensemble Prediction System for seasonal forecast

Paulo Nobre, National Institute for Space Research – INPE / Center for Weather Forecast and Climate Studies – CPTEC
Extended weather forecast and seasonal climate prediction at INPE-CPTEC

Tim Hewson, Met Office
GLOSEA4 – the Met Office's new integrated monthly / seasonal forecast system

David Richardson, ECMWF
Ensemble applications: TIGGE archive and the multi-disciplinary GEOWOW project

Cihan Sahin, ECMWF
ecCharts

Andrea Montani, HydroMeteoClimate Regional Service ARPA-SIMC
Recent developments and plans for the COSMO-LEPS system

Helmut Frank, Deutscher Wetterdienst (DWD)
Generating boundary values for the COSMO-DE-EPS

Steve Foreman, World Meteorological Organization
Making information accessible – WMO Information System

Cristian Codorean, ECMWF
The ERA-CLIM data server

Marie-Francoise Voidrot, Météo-France
The work of the MetOcean Domain working group of the OGC

Sandor Kertesz, ECMWF
Metview 4 – bringing OGC services to the desktop

Stephan Siemen, ECMWF
OGC web services showcase – how they can help forecasters

Friday 4 November 2011

Ken Mylne, Met Office
Ensemble applications and integration with deterministic post-processing

Ervin Zsótér, Hungarian Meteorological Service
Developments towards multi-model based forecast product generation

Florian Pappenberger, ECMWF
Floods, droughts and fires: Demonstrating the value of ECMWF forecasts in hydrology

Plenary Discussion
How can web services improve the work of forecasters?

Presentations from Working Groups

III WORKSHOP REPORT

Use and development of Meteorological Operational Systems

Erik Andersson, Baudouin Raoult, David Richardson, Stephan Siemen

The 13th biennial Workshop on Meteorological Operational Systems was held at ECMWF from 31 October to 4 November 2011. The workshop:

- Reviewed recent developments in the use and interpretation of medium- and extended-range weather forecasts.
- Addressed the data management and visualisation requirements.

This year there was an additional focus on the use of meteorological data in multi-disciplinary applications and international initiatives aimed at making meteorological data readily accessible to wider user communities.

As well as the presentations and discussions there was a session that showcased new meteorological data processing and visualisation systems and updates to existing applications.

The workshop was attended by nearly 60 participants from Meteorological Services, the World Meteorological Organization (WMO), the United Nations World Food Programme (WFP), research institutions and commercial weather services coming from 24 worldwide countries.

During the week two working groups were established. The follow-ing are some of the key points raised by the working groups.

Use and interpretation of medium and extended range forecast guidance

There has been an increase in the amount of data used in the forecasting process (e.g. EPS, multiple models, range of parameters) and more automation in weather forecast production. Consequently, the forecasters cannot manually prepare and assess all data that is available – there is a need to focus on the 'important' aspects. Also there is a trend in the forecaster's role from basic weather forecasting to impact forecasting and decision support. It is therefore important for forecasters not only to account for uncertainty but also to communicate that uncertainty to users.

As a result of the growing range of application areas where weather forecast data is only one element of an integrated multi-disciplinary approach (e.g. civil protection, health, agriculture, energy and transport), there are requirements for data from different sources. The main challenge is the huge (sometimes overwhelming) amounts of data. It may be difficult to find what is required (or what is available). Also it is important to know the quality and the reliability of the data.

In the operational forecasting environment there may be a requirement for traceability of decisions to answer the questions concerning what data was used and the source of that data. Overall uncertainty information needs to be propagated through the production process to all users to assess risks.

Data management and visualization

It is often difficult to find WMS (Web Mapping Services), even for testing purposes. In addition, popular free WMS services easily get swamped which makes such services unreliable and unsuitable for operational activities. Also it was noted that from January 2012 WIS (WMO Information System) catalogues are available. As these contain lists of datasets and services they can be used to advertise the availability of meteorological data. Meteorological workstations will need a built-in link to these catalogues (SRU/Z39.50).

There was a general feeling that the meteorological community will not drastically change its working practices due to the novel WMS. Current systems are fast and reliable, though users might move to using WMS to get access to new products. It appears , however, that it is worthwhile the meteorological community continuing to invest time and efforts in OGC standards, particularly as their use is mandated by EU's INSPIRE directive.

Public web-services are free, but the products provided are not reliable for operational activities. Achieving operational use of web-services will require service level agreements (SLAs) between parties. High availability can be achieved when multiple centres provide backups of each others' services, but there might be a need to use a dedicated network link in order to guarantee good service.

Data quality work is on-going in WMO. Different providers could have different ways of describing their data quality. Perhaps users could be asked to provide indication of their confi-dence in the data through user-based rating systems.

The 13th biennial Workshop on Meteorological Operational Systems. The workshop was attended by nearly 60 participants from 24 countries. As well as the presentations and discussions there was a session that showcased new meteorological data processing and visualisation systems and updates to existing applications

Conclusion from the plenary session

The meteorological community needs to continue investing efforts in OGC standards. More volunteers are required to speed up the process and more focus should go to WCS and WFS (Catalogue and Feature Services). This will solve some limitations of WMS and extend the range of possible products.

Operational systems evolve at a slow pace, so more time is needed before we start seeing operational web services. It is expected that most of the current technical difficulties will disappear with time, and solutions will be found by other communities.

Existing data distribution practices will continue to exists as they are (e.g. 'push' methods, in particular for critical data) because they are very reliable. But uptake of web services will really start when new products are only available this way.

Operational web services will require service level agreements (SLAs) and backup procedures. Finding reliable ways of providing users with data quality information is paramount. Also meteorological datasets and services must be publicised in WIS catalogues and forecaster workstations should be provided with access to these catalogues directly.

The final plenary session concluded an informative and successful workshop.

All the presentations and workshop reports can be found at:

- www.ecmwf.int/newsevents/meetings/workshops/2011/MOS13/index.htm

WORKSHOP PLENARY

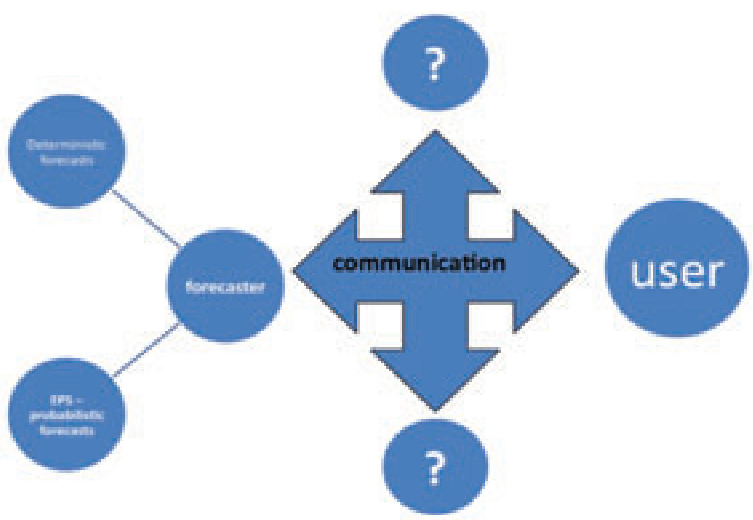
Working Group on use and interpretation of medium and extended range forecast guidance

Discussion topics

- The evolving role of the forecaster
- Increasing automation in weather forecast production
- Forecasters' role in communicating to users and providing decision support
- Mutidisciplinary applications
- Growing range of application areas where weather forecast data is only one element of integrated approach
- What are the challenges?
- Where does the forecaster fit in?
- Accounting for uncertainty
- Uncertainty information has to be propagated through to the final decision making

Evolving role of forecaster

- Increase in amount of data (information) in forecasting process (EPS, multiple models, range of parameters, …)
- Increasing automation in weather forecast production
- The forecasters cannot manually prepare and QC all data
- Need to focus on the "important" aspects
- Trend in the forecaster's role from basic weather forecasting to impact forecasting (decision support)
- It is important for the forecasters to account for uncertainty (role in risk assessment)
- Communication with the user is essential to understand their requirements
    - Weather forecast information is only one element of integrated multi-disciplinary approach to meet the users needs



Weather forecasting in multi-disciplinary applications

- Growing range of application areas where weather forecast data is only one element of integrated multi-disciplinary approach
    - Civil protection, health, agriculture, energy, transport, …
- Requirements for data from different sources
    - for forecasters
    - Weather data for end users
- Case-dependent; difficult to generalize

Weather forecasting in multi-disciplinary applications: Challenges

- Huge (overwhelming?) amounts of data
- Difficult to find what you need (or what there is)
- Important to know quality/reliability of the data
- Need to integrate additional information with weather data
- Traceability of decisions (what data was used? why?)
- Cost, access restrictions

Weather forecasting in multi-disciplinary applications: role of forecaster

- Forecaster can provide advice on weather but are not experts in other areas relevant for the users activities
- Need to combine the forecasters input with non-meteorological data from other sources to be able to make decisions (Who does this?)
- Communication is essential
  - Must be 2-way between forecaster and user, but may need to involve discussion with providers of other relevant information
  - It was noted that "decision support" is not the same as "decision making": weather forecasters can provide a valuable service in decision support
  - How to process the information to guide decisions?
  - This depends on the user and application so difficult to give general guidance. But uncertainty information needs to be propagated through the process to provide risk assessment

Working group on data management and visualization

Discussion topics

- Past discussions have focussed on graphical representation of data. Now attention has moved to data discovery and catalogues:
  - How do data producers advertise their data?
  - As a data consumer, how does one discover these catalogues?
  - How can these catalogues be presented to the end-user (GUI, usability etc.)?
  - What constraints exist (data quality, legal aspects, data policies, service level etc.)?
- At this workshop four years ago it was decided that the use of OGC standards would provide some of these answers.
  - What has been achieved since then?
  - Did these standards fulfil their promise?
  - What alternatives exist?

Available WMS servers and catalogues?

- Difficulties to find WMS services, even for testing.
- Use Google to find WMS catalogues
  - Not very fruitful
  - Many broken links
- Easy for popular free services to get swamped (e.g. NASA blue marble)
  - This make these services unreliable
- Advertising your data
  - WIS catalogues will be available in January 2012
    - Will contain list of datasets and services
  - Workstations need a built-in link to these catalogues (SRU/Z39.50)

OGC in meteorology: current status

- OGC standards only used within organisations
  - Organisation have control of the whole stack
    - Forest fire data provided by WMS to fire services
    - Malaysian services using a purely web services based system
  - Next release of NinJo will include a WMS support

Why the slow (?) uptake

- Too few available services to allow combination of data (we have not reach critical mass, chicken-and-egg issue). The benefit cannot yet be seen.
- Lack of need: users seem to be happy as they are.
  - User do not know what exists
  - Problem is that users cannot discover servers
- Met. community will not change its working practices
  - Slow to move technical systems and users; current systems are fast and reliable;
  - But, users might move in order to get new products
- Marketing problem: need more communication, training.

Should we continue investing time and efforts in OGC standards?

- Mandated by INSPIRE
- There is demand from insurance companies to climatological data. The other big clients are aviation (SESAR and NextGEN) and defence
- WMS will provide faster to access to large data (e.g. EPS data)
  - WMS can be seen as a "data reduction" system
- We will see with web services what we have seen with web sites:
  - The web managed to scale, so will the WMS in due time.
  - Technologies will be developed to solve the issues we are currently facing

Quality of service

- Public web-services on the Internet are free.
  - They can suffer from DoS attacks. They can be down at any time
  - Products may change or disappear
  - Owner have no obligations towards they users. They cannot be relied on for operations
- Operational use of web-services will need SLAs between parties
- Users have to be ready if services are not available
- High availability can be achieved when centres have backups of each others' services
  - Aviation is planning such a thing (Washington/London).
  - WMS catalogue has built-in mechanism for giving a number of servers where the data is available
  - WIS catalogue should have this information
- May have to have a dedicated network in order to guarantee good service
- Monitoring will be needed

What does 'data quality' mean? How do you measure it? Difficult!

- Data quality work is on-going in WMO (WIGOS)
- Different providers could have different ways of describing their data quality (e.g. geographers qualify the quality of the data, the meteorological community give quality of the process.)
- Quality could also depend on type of use
- How do we notify the user if, for example, the quality of the data has changed?
- Can we trust the quality information given by the data provider?
- How to compare quality information from different providers?
- URL can give an indication of confidence of quality (e.g. ".gov")
- Usage can also increase confidence
  - What about asking other users?
  - This is solved on the Internet by using a user based rating system (Amazon, Expedia, Trip Advisor, iTunes, ….)

Conclusion

- We should continue investing efforts in OGC standards
  - More volunteers are required to speed up the process.
  - More focus should go to WCS & WFS. This will solve some limitations of WMS, e.g. styling and re-projection, and will extend the range of possible products.
- Operational systems evolve at a slow pace, more time is needed before we start seeing operational web services
- Most of the current technical difficulties will disappear with time, and solutions will be found by other communities
- Existing practices will continue to exists as they are (e.g. 'push' methods, in particular for critical data), because they are very reliable.
- Uptake of web-services will really start when new products are only available this way (especially the ability to provide faster access to large amount of information without transferring it over the network).
- Operational systems will require SLAs and backup procedures
- Finding reliable ways of providing users with data quality information is paramount
- Meteorological datasets and services must be publicized in WIS catalogues
- Forecaster workstations should provided access to these catalogues directly

IV LECTURES (names indicate presenters only)

Development of ECMWF forecasting systems

Erik Andersson, ECMWF

1. The operational forecast system

The operational forecast system at ECMWF consists of the following main components

- High resolution deterministic forecast: twice per day, 16 km 91-level, to 10 days ahead
- Ensemble forecast (EPS): twice daily, 51 members, 30/60 km 62-level, to 15 days ahead
- Monthly forecast: twice a week (Mondays and Thursdays), 51-members, 30/60 km 62 levels
- Seasonal forecast (System 4): once a month, 51-members, 80 km 62 levels, to 7 months ahead

All components are coupled to a wave model. The monthly extension of the EPS is coupled to an ocean model with a near-real time ocean analysis. The Seasonal forecasting system is coupled to an ocean model based on an ocean analysis running a few days behind real time.

The main upgrades to the operational systems in the last two years are listed in the table below.

Date	Label	Description
Nov 2010	Cy36r4	Five-species prognostic microphysics scheme All-sky improvements of microwave radiance assimilation New soil-moisture analysis scheme New snow analysis and the use of higher resolution NESDIS data Changes to the EPS perturbations (introduction of a spectral stochastic backscatter scheme)
May 2011	Cy37r2	Use of background error variances from the ensemble of data assimilations by the deterministic 4D-Var Improvements to the new cloud scheme Improvements to the assimilation of satellite data Model-level data in GRIB edition 2
10 Oct 2011		Monday run of the monthly system
8 Nov 2011		Seasonal forecasting System 4
15 Nov 2011	Cy37r3	Significant modifications of the cloud and convection schemes as well as surface roughness in the model physics. Active assimilation of NEXRAD rainfall accumulations over the USA. Addition of infrared sounder radiances to constrain the ozone analysis. Improvements of the snow analysis. Activation of a temperature bias correction for aircraft. Replacement of the HOPE ocean model by NEMO. and introduction of the NEMOVAR ocean assimilation scheme in the EPS.

2. Performance of ECMWF forecasts

In the context of ECMWF's Strategy 2011-2020, a set of two primary and four supplementary headline scores has been defined for the evaluation of long term trends in forecast performance. The aim of the new set of scores is to assess performance for various forecast lead times, for the traditional upper-air fields, as well as surface weather parameters such as precipitation and wind gusts. These headline scores are shown in Figure 1. Four of the headline scores are expressed in terms of the lead time at which the score reaches a specific threshold value. The threshold values have been chosen so as to target the verification to the relevant forecast range for each measure of skill.

In the top panel of Figure 1, the blue line shows the monthly mean scores for the high-resolution deterministic forecast, and the red line shows the 12-month means. The trend in EPS performance is illustrated in the second panel of Figure 1. Each point on the curves is the lead time at which the 3-month mean (blue lines) or 12-month mean (red line) of the continuous ranked probability skill score falls below 25% for northern hemisphere extratropics. The very high scores achieved during 2010, compared with previous years, have been maintained through 2011.

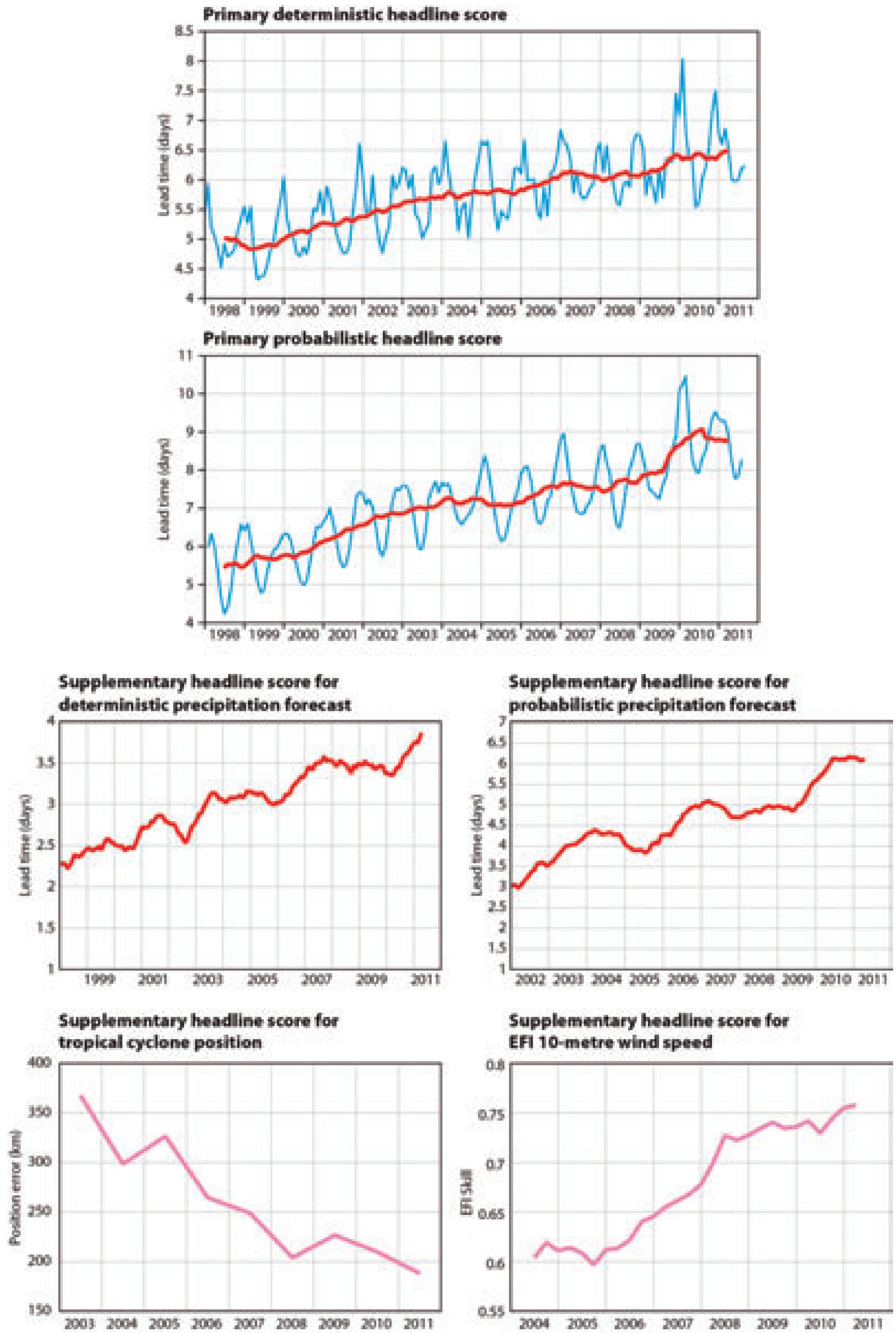


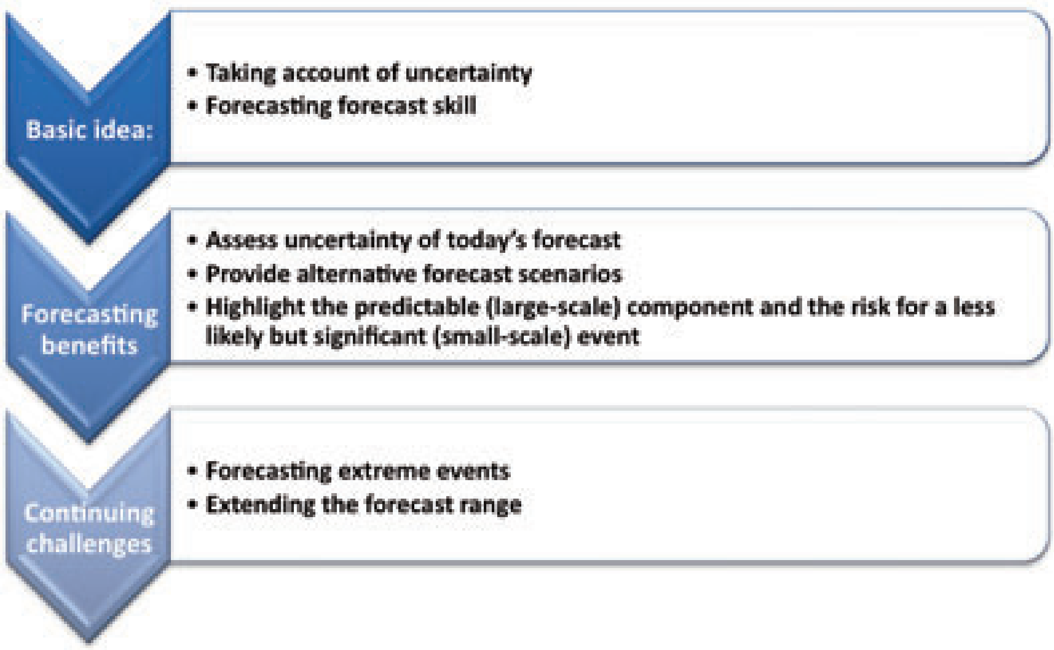
Figure 1 Summary of the two primary and four supplementary headline scores adopted by Council in June 2011 to monitor the trends in forecast performance.

The new supplementary headline scores for deterministic and probabilistic precipitation forecasts are shown in the two panels on the third row of Figure 1. The increase in skill of the deterministic forecast in 2010 is associated with the five-species prognostic microphysics scheme introduced in November 2010 (cycle 36r4); the increase in skill of the EPS forecast between mid-2009 and mid-2010 is associated with the EPS resolution increase on 26 January 2010 (cycle 36r1). Due to the averaging, step-wise changes in model skill appear as gradual changes over 12 months in the plots.

The supplementary headline scores for severe weather are shown in the bottom two panels of Figure 1. The left panel shows the mean position error (km) of the 3-day deterministic forecast for all tropical cyclones occurring globally in 12-month periods ending on 31 October; verification is against the position reported in real-time via the Global Telecommunication System (GTS). The position error reached its lowest ever value this year. The right panel shows the skill of the extreme forecast index (EFI) for 10 m wind speed at forecast day 4 (final point includes summer, June–August 2011. It shows a continual improving trend.

3. The ensemble prediction system

The basic ideas, the forecasting benefits and the ongoing challenges for probabilistic forecasting were reviewed.



4. Workshop focus on "multi-disciplinary applications"

The current workshop focuses on multidisciplinary use of meteorological data, including the technical solutions to facilitate exchange of data and charts across a wide user community. ECMWF is involved in international initiatives such as the OGC Met/Ocean working group, and participated in EU-funded projects such as GEOWOW with a strong multi-disciplinary component. See the contributions on these specific topics, as well as the summary of the plenary discussion devoted to this topic.

Progress and Future Directions of the Canadian Weather and Environmental Prediction Systems

Michel Jean+, Gilbert Brunet*, Bertrand Denis+, Martin Charron*, André Méthot+, Richard Hogue+, Kirk Johnstone+ and Pierre Pellerin*1 2

Introduction

The Meteorological Service of Canada (MSC), which is part of Environment Canada (EC), is amongst the most automated meteorological and hydrological services in the world. The MSC's area of responsibility is one of the largest of all weather services worldwide, serving one of the most weather-affected societies on the planet. The MSC is uniquely challenged with the combination of a small financial resource base, an enormous area of responsibility, and the severity and diversity of Canadian weather. In spite of these challenges, the MSC has matured over the last 140 years into an extremely successful organization. Today, it is positioned alongside the worlds leading weather services; a remarkable achievement considering its relatively modest funding envelop. This achievement is the result of many years of strategic investments in research and applied sciences, the smart use of technology and the optimum utilization of resources.

Over the next few years, while in the midst of limited resources, the MSC will move forward by making strategic investments in key areas that will result in a significant increase in its scientific and technological capability. The MSC has selected a number of key areas in which to invest, and translated these into specific initiatives which will move forward as key elements of its overall strategic direction. These 'signature projects' span the range of research, operations, and services. This paper outlines the major components of MSC's strategy, describes its key initiatives, and provides an update on the MSC's direction over the next 10 years.

Our vision

To face the future Environment Canada will strive to implement a strategic vision for its weather and environmental services that responds to the emerging environmental, societal and political landscapes and realities by:

- Strengthening and adapting our operational, monitoring, predictive and alerting capacity;
- Providing Canadians with end-to-end seamless weather and climate services at all time scales to support decision-making as part of an adaptation strategy to changing weather and climate conditions; and
- Enhancing our services to meet the emerging demands for weather and environmental services in Canada, for instance over its vast Northern Territory, in support of safety and security and economic prosperity.

To put some context about the service level that is provided to Canadians, here are some facts:

- Throughout the entire year, Canadians experience high-impact weather. Stretching from the Pacific to the Atlantic Ocean and extending over its Northern areas, Canadian weather events generate significant media interest;
- Annually EC produces 1.5 million weather forecasts, 15,000 severe weather warnings, 500,000 aviation forecasts and 200,000 marine, ice and sea-state forecasts;
- The MSC's WeatherOffice website attracts over 50% of all government web visitors – on the order of 50 million visitors per month; and
- Over 90% of Canadians access EC weather information on a daily basis with 50% using it to conduct their daily business.

How to realize a vision, with efficiency

To keep pace with the evolving user needs within a tight financial situation, the Canadian Weather and Environmental Prediction System will continue to evolve as efficiently as possible. Efforts to gain efficiencies began over a decade ago with the development of a unified numerical weather prediction model known at the GEM (Environmental Multi-Scale) model. The GEM is designed to run in different configurations; it now covers spatiotemporal scales from urban to climate scale. Figure 1 indicates the different configurations that the GEM is currently run, either experimentally or on an operational basis, at the Canadian Meteorological Centre (CMC). The MSC's strategic decision to utilize a single but robust modelling framework for most of it's Numerical Weather Prediction (NWP) system has fostered more efficient use of it's R&D resources; continuing to find these efficiencies is paramount during these times of scarce human and financial resources. The GEM model was developed through a close collaboration between the CMC and the Meteorological Research Division (MRD) of Environment Canada.

Collaborating with international partners has been another key element of EC's strategy to maximize its return on investment to improve forecast products. For instance, the signing of the North American Ensemble Forecast System (NAEFS) agreement between Mexico, the USA and Canada in November 2004 has fostered a fruitful partnership. The exchange of EPS outputs between Canada and the USA provides each country with outputs of their neighbour ensemble prediction system at very little cost. The result is a doubling of the ensemble members which would have cost millions of dollars in R&D if it were done "in-house". This collaborative approach also supports operational contingencies between the two countries. Another benefit comes in coordinating and sharing the R&D activities that help the participating countries improve their respective forecast system. In addition, investing in projects such as the TIGGE research associated with the THORPEX initiative of the World Weather Research Programme (WWRP) has paid dividends. In addition to maximizing each countries return on investment, this collaborative approach accelerates progress as we work together towards a common goal. Another example of our strategic decision to collaborate with international partners is our involvement in the the development of the Ninjo workstation. The MSC is an active partner in the Ninjo Project Consortium with Germany, Switzerland and Denmark. Our quest for continuous improvement, increased efficiency and excellence is being driven by our client orientation and our Quality Management System (QMS). The MSC QMS is now certified to the ISO9001 standard. This provides a higher level of assurance to our clients, partners and stakeholders that we meet a recognized, international quality standard. This approach fosters greater internal accountability and decision-making; it also provides a framework for measuring and improving our over-all performance from the perspective of our clients.

To help us in managing and delivering projects in a structured, coordinated and optimal manner, we have begun to adopt the Prince II project management approach. In addition, we have form a senior executive management board call the 'Innovation Committee' that is responsible for providing strategic oversight to the research-development-operations-services innovation cycle. This committee ensures that proposed innovative projects, that are relevant to our priorities, are fully supported through the technical transfer process to operations. The technical transfer process itself is managed through a specific scientific committee which ensures that technical improvements to the operational NWP systems are sound and respect our high standards.

Recent progress

The Canadian Meteorological Centre (CMC) has recently implemented several improvements to our operational modeling capability:

- A fully coupled atmosphere-ocean-ice regional short-term forecast system was implemented this year over the Gulf of St-Lawrence. It is the first worldwide operational system of this kind. Its development has been done through collaboration between the department of Environment and the department of Fisheries and Oceans;
- The Global Deterministic Prediction System has been improved to reduce the tropical cyclone false alarm rate. This implementation was done in July 2011, just in time for the hurricane season; and
- The Global Ensemble Assimilation (EnKF) and forecast system was upgraded August 2011. The two main changes to the assimilation components are: the number of ensemble members has been doubled (from 96 to 192) and additional satellite data are now assimilated in the stratosphere. The main changes for the forecast component are a resolution increase from 100 km to 66 km horizontally and a resolution increase vertically from 28 to 40 levels.

In addition, the following changes were implemented at the time of this workshop:

- A new continental Regional Ensemble Prediction System (33 km resolution);
- A new one-tier (fully coupled) multi-seasonal forecast system (up to 12 months). It will replace the current two-tier (uncoupled) seasonal forecast system as well as the statistical (CCA) multi-seasonal forecast system;
- A 200% increase in the data volume assimilated in the deterministic systems (Global & Regional systems): more IASI, AIRS and SSMIS channels, reduced horizontal thinning for satellite radiances, humidity from aircraft, etc.;
- A new Global Sea Surface Temperature analysis;
- A new High-Resolution Deterministic Prediction System running twice daily at 2.5 km resolution over Western Canada (spring 2012); and
- An upgraded Regional Deterministic Prediction System (continental): 4D-VAR assimilation system; resolution upgraded from 15 km to 10 km (spring 2012).

Where we are heading: the next 10 years

Over the last few years, it became obvious that we needed to re-think the way we operate, in particular how the synergy between our highly-automated numerical prediction systems and the operational forecasters could be maximized to better meet our client expectations. To address this challenge a Concept of Operations is being developed for the prediction component of the MSC. It will be supported by a strong and innovative Research and Development investment in NWP as articulated below.

A new Concept of Operations

The outcome of this major effort is viewed as essential to the development of the prediction system and its ability to effectively meet client requirements now and in the future. It will guide the transformation and future delivery of Environment Canada's operational weather and environmental prediction services. The concept utilizes thinking from a number of fora where forecasters expressed and discussed their vision of the future. The concept is envisaged to be gradually implemented over the next 10 years. The implementation will be phased, practical and dependent on the availability of resources, science and technology advancements and organizational readiness, amongst various factors. It will be a key component of the Canadian multi-hazard, early warning system.

Some of the drivers for the overall changes include:

- Significant (past, present and expected) changes in client requirements;
- Significant changes in observational data and information;
- A continuing rapid evolution in technology – clients (e.g. mobile), internet, etc.; and
- Limited flexibility/adaptability in current systems.
- Some key elements of the Concept of Operations vision are: a nationally common Information Pool holding all data (national, international, analyses, model results, predictions and forecaster decisions). The system will enable operational meteorologists focussing on adjacent areas, or from different programs such as aviation or public, to work collaboratively on their forecasts in a seamless fashion;
- The system will rely on continuing improvements to numerical weather prediction systems to meet client needs. Using an applications-based framework, the Information Pool will satisfy client requirements for routine and unique products and services. Applications will be used to create and push products (as required by our mandate) to our clients. In addition, the system will enable clients to selectively retrieve environmental data and prediction information from the pool as required;
- Performance measurement (including verification) will continue to be used throughout the prediction process to assess quality and enable effective decision making about changes to the prediction system. Such systematic evaluation will be used to guide the implementation of new methods/technologies/models as well as the intervention by operational meteorologists; and
- Teamwork skills and technical tools to support inter-office communication and collaboration will be developed. These competencies and tools will be used to foster greater collaboration on various prediction challenges; including realigning responsibilities between forecast offices to address short and long-term needs. System resilience and contingency will be improved as, subject to the availability of trained personnel, the system will support "prediction for anywhere from anywhere."

The numerical weather and environmental prediction systems of the future

Over the past 40 years, Environment Canada's investments in numerical weather prediction have allowed the Meteorological Service of Canada to emerge as one of the most automated weather services in the world. As we move forward, numerical modeling will continue to be the cornerstone of our weather and environmental forecasting systems. Research and Development in NWP will support the new Concept of Operations presented above and to address other environmental issues related to our mandate.

More than ever, the demand for either direct NWP data or for forecaster added-value predictions is expected to continue to grow significantly as the range of products and the forecast quality increase. Concerning the latter, it is expected that over the next 10 years the predictive skill of the atmospheric models will likely be increased by 1 day, i.e. the 3-day forecasts 10 years from now will be as accurate as today's 2-day forecasts. To fulfill all these requirements, scientific innovations and strong numerical infrastructures, including adequate High-Performance Computing (HPC) facilities, will be needed.

In the coming 5 to 10 years, emphasis will be put on increasing:

1) Our ability to better predict high-impact and severe events on multiple space and time scales; and
2) The range of available products through model coupling (atmosphere-land-urban-ocean-ice-hydrology-chemistry).

High-impact and severe events

Since several of the most important weather parameters for the public and many sectors of the economy are precipitation, wind and surface temperature, the improvement of the prediction accuracy of these parameters is essential in the prediction of natural disasters such as floods, high winds, heavy precipitations, major winter storms, etc. Thrust to improve these predicted variables, and the related high impact weather, will require models operating at higher resolution to obtain more detailed and accurate predictions. In other words, to adequately simulate and predict high-impact and severe events with numerical models, resolution (grid point spacing) is a key factor. This is why research and development divisions at Environment Canada will strive to increase all model resolutions in the coming years, as well as refining the representation of physical processes needed at these higher resolutions. These goals are strategically linked to the High-Performance Computing (HPC) facility that is available at our organization. In fact, our ability to run numerical models at higher resolution for ever more precise and complex atmospheric models for 24/7 operational weather forecast and warning operations will strongly depend on accessibility to unprecedented supercomputing capacity. In other words, HPC will continue to be the cornerstone of numerical weather and environmental prediction.

Global scale forecast systems

Within 7 to 10 years, the global prediction system will reach resolutions that are common at the regional scale today. These types of resolution will enable the capacity to significantly improve medium-range forecasts, for example, hurricanes and their extratropical transitions. It will further support the simulation with higher accuracy of the global atmospheric transport of hazardous material such as volcanic ash and radioactive contaminants. In addition, it will allow a more precise monitoring of the state of the atmosphere, amongst other things.

Regional scale forecast systems

High-impact and severe weather events occurring at the regional scale (for example, heavy precipitation in summer) needs even higher resolutions to be adequately predicted. For this reason, the resolution of the regional prediction system will be significantly increased within the next 5 years.

Local scale forecast systems

During the 2012-2013 timeframe, EC's kilometer-scale non-hydrostatic GEM-LAM model will gradually become operational. Currently run at 2.5 km, its coverage will increase to encompass Canada in its entirety by 2014-2015. Furthermore, an urban scale numerical modeling system capable of simulating flow through urban canyons (with a resolution as high as a few meters) is expected to be available to run over major Canadian cities. A prototype of that modeling framework is already available at the Canadian Meteorological Centre for atmospheric dispersion applications for emergency response. Other urban environmental applications are envisaged to deal with specific health issues such as poor air quality near industrial neighborhoods and urban island heat effect during intense heat wave.

In parallel with the above model developments, an ambitious project of delivering high-resolution (sub-kilometer-scale) surface and near-surface (atmospheric surface layer) numerical forecasts over Canada within 7 years will provide significant improvement of key severe weather elements such as surface temperature and winds, blowing snow and blizzard conditions and fog to list a few.

State-of-the-art nowcasting tools exploiting these high-resolution modeling systems, as well as ever increasing observational data from Earth Observation platforms, will also be implemented.

Ensemble Prediction System (EPS)

Decision makers as well as forecasters can take advantage of weather and environmental prediction tools that reflect the probability of occurrence of events. EPSs have existed for that purpose for close to 15 years, but their use as a powerful decision-making tool has yet to be fully developed. To date, EPS outputs have had limited application; they are used by operational forecasters, and some specific (and rare) users, with high levels of expertise, to assess some form of confidence in weather forecasts. In the coming years, a significant increase in the utilization of ensemble systems by forecasters, specialized clients, and stakeholders is expected to aid the decision-making process. One aspect that has probably slowed down the use of ensemble information is the relatively low resolution, but this is changing with the introduction of a regional EPS. In addition to an increase of resolution, improvements will come from both the model and data assimilation components of the EPSs, by using larger number of ensemble members, and through much better post-processing of EPS outputs. This will develop the capacity to compute representative probabilities for a large array of environmentally related events, going from pure atmospheric parameters to those related to hydrology, sea-state conditions, energy production and distribution sectors, public and health services, etc.

For the coming years, ensemble prediction systems at the global and regional scales will reach resolutions that permit their use for severe event forecasting. In particular, a regional ensemble prediction system reaching a resolution of about 10 km within 5 years will become a primary tool for short-range weather prediction.

Simply stated, ensemble forecasting is poised to become a major forecasting tool at Environment Canada.

Coupling models to predict a wider range of physical and chemical phenomena

The coupling of the atmosphere with the hydrosphere (oceans, lakes, ice) and land surfaces within the same forecast system provides more faithful representation of the interactions taking place between the atmosphere and the rest of the Earth-system. In addition to contributing to the improvement of atmospheric prediction, these coupled models will also provide significant benefits when developing new products and services. For example, the coupling of atmospheric prediction models with ocean and ice prediction models will significantly improve the forecasts of sea state conditions and fog over oceans, which are very important variables to the Department of Fisheries and Oceans and to Search & Rescue operations by the Canadian Coast Guard. For the same reason, the explicit treatment of certain chemical constituents in atmospheric models will help both air quality prediction and atmospheric prediction.

Numerical forecasts of the oceans and sea-ice for all Canadian costal areas and globally will become available to forecasters and clients as Environment Canada's capabilities become operational by 2013/14. A coupled forecasting system is already operational over the Gulf of St.Lawrence. Monthly and seasonal numerical forecasts of Arctic sea-ice conditions are expect within a year or two. This will change in a radical fashion the work currently being done by our Canadian Ice Service.

The reliability of monthly and seasonal predictions is expected to greatly increase due to increased resolution, ocean-sea-ice coupling, and improved land surface processes. Similar statements can be made for longer range forecasts such as multi-seasonal to multi-annual predictions for which air-sea-ice coupling is essential to correctly take into account inter-annual variability such as ENSO.

In this context of coupled environmental modelling covering widespread spatial and time scales, and due to the explosion of remote sensing capability, data assimilation techniques will be facing unprecedented challenges.

All this represents a number of NWP paradigm shifts, most of which are already occurring. These shifts involve moving:

- From weather prediction only toward multi-parameter integrated environmental prediction;
- From a deterministic to a full probabilistic approach of forecasting the future state of our environment; and
- Toward ultra-high spatiotemporal resolution closer to the human scale.

These paradigm shifts will enable us to meet the current and emerging needs of our clients. We expect greater demand for applications from key market sectors: agriculture, fisheries, forestry, health, energy, transportation, ecosystem, emergency response, etc. In addition, scientific and technology challenges will need to be addressed. Environment Canada, through its key components (MSC, Science and Technology, Information Technology) will continue to demonstrate excellence, building on our successful achievements in the past to help navigate into the future.

Key elements for the future roadmap

The MSC, working in collaboration with its Environment Canada partners, has identified key strategic priorities that support its vision and mandate. These priorities, called "Signature Projects", which cut across three branches of EC (MSC, Science & Technology, and Information Technology), were developed to address key vulnerabilities and to improve and modernize delivery of our core public mandate. The eight Signature Projects are:

1. Meteorological Areas initiative (Arctic regions)
2. Air Quality and Health Related Services
3. Next Generation Weather Forecasting System (based on the Concept of Operations)
4. Re-engineering the Weather Warning and Service Delivery System
5. Networks of Networks – A Modern Day Monitoring Strategy

6. High Performance Computing
7. Water Availability and Climate Services
8. Integrated Environmental Prediction Strategy

The numerical weather and environmental prediction system, supported by a strong HPC infrastructure, is at the center of these inter-connected Signature Projects (Figure 2). In particular, the Next Generation Weather Forecasting system as well as the Integrated Environmental Prediction Strategy will directly benefit from R&D advances in the field of NWP. Numerical modelling innovations will also play a significant role within the Water (hydrology) and Climate Prediction Services as well as within the Air Quality and Health Related Services.

Conclusion

As the MSC celebrates 140 years of providing an essential service to Canadians, it has positioned itself to move into the future with confidence. Aware of the unique challenges we face, we have made strategic decisions that will ensure we remain a world class meteorological service as we deliver on our mandate. We will continue to advance on the foundation we have laid down: fostering scientific innovation, improving efficiency, exercising our quality management system, maintaining a strong client orientation, adopting best practices, remaining competitive, establishing collaborative partnerships, and investing in our infrastructure and high performance technologies. These attributes will continue to define the MSC in the years to come.

Acknowledgements

It would be impossible to list all the contributors to the various components of the systems that have been described in this paper. The authors wish to thank all staff of Environment Canada Meteorological Service of Canada, Science and Technology Branch and Corporate Services Branch whose work and dedication were instrumental in achieving our objectives and preparing our future. Through their efforts we are improving our service to Canadians and find our organization in a better position to support the global meteorological enterprise.

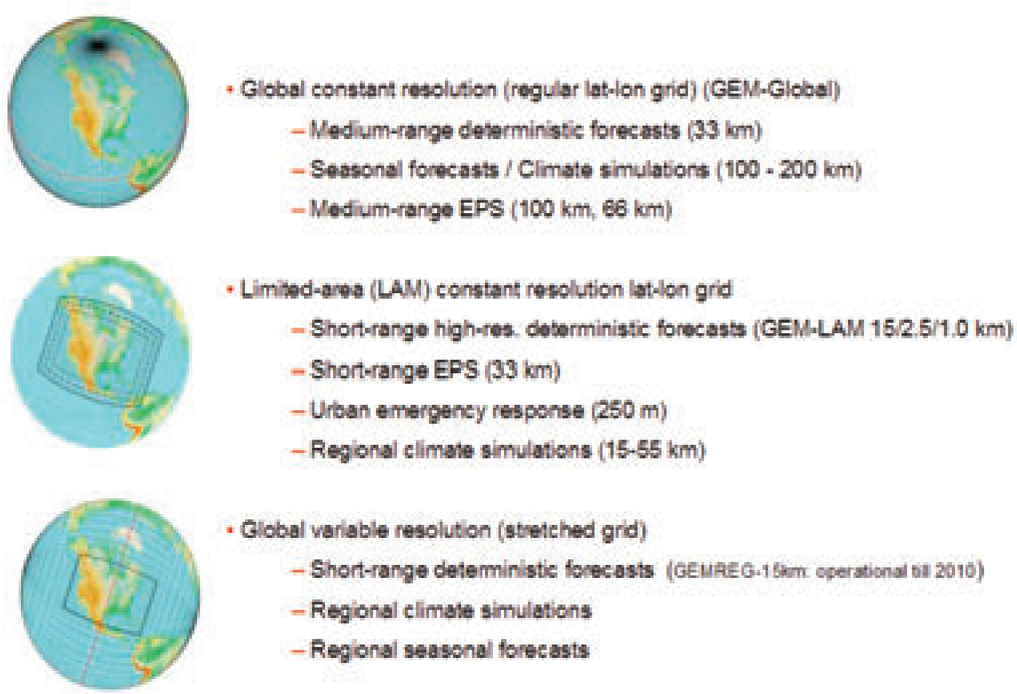


Figure 1 The Canadian Global Environmental Multi-Scale (GEM) model with its main configurations and applications.

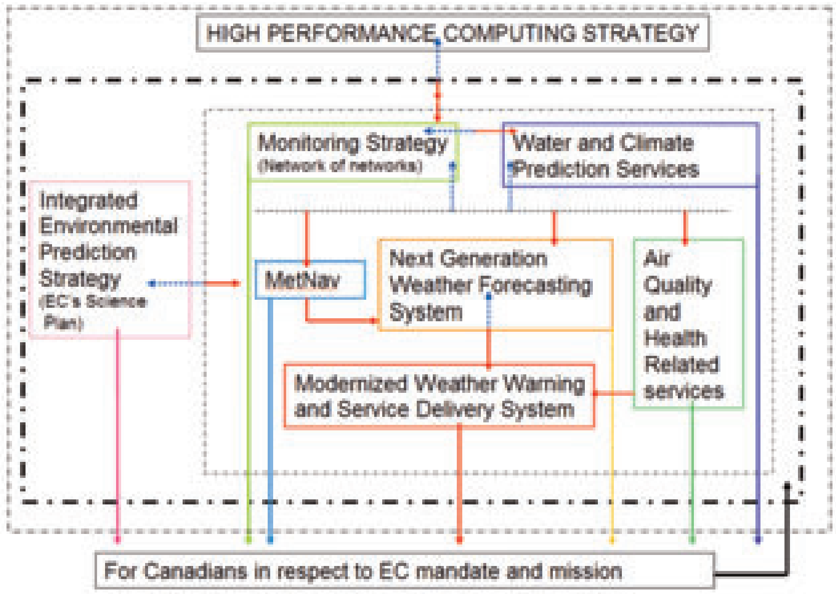


Figure 2 The MSC Signature Projects and their inter-connections.

Introduction of medium and extended range forecast systems and their applications in CMA

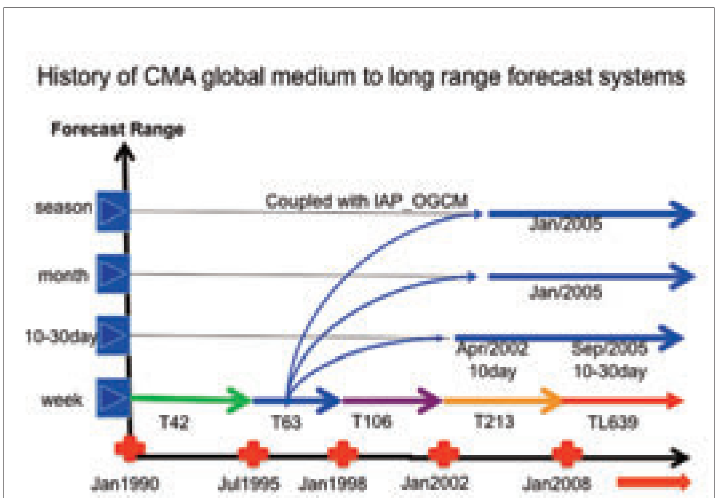
Xueshun Shen, Center for Numerical Prediction, China Meteorological Administration

The China Meteorological Administration (CMA) started the medium-range (?10days) forecast since 1991 based on the global NWP system. The CMA medium-range forecast system provides forecast guidance twice daily, including a deterministic forecast run at TL639L60 and an ensemble prediction system run at T213L31 with 15 members. Based upon the grid point products of global NWP, the National Meteorological Center (NMC) conducts use and interpretation by using MOS and other statistical methods, and issues the official forecast. A coupled atmosphere-ocean model has been developed, and put into operation for monthly to seasonal forecast since 2005. The coupled system is run at T63L16 of AGCM andL30 of OGCM. There are two kinds of monthly-scale forecast, one is monthly forecast issued at 28th every month, another is 30-day forecast issued every 5-day. These two forecasts are based on the AGCM ensemble run with persistent SSTA. CMA also provides seasonal forecast mainly for the flood season (JJA) and cold season (DJF and MAM), which are issued at 15th April and 15th November respectively. The seasonal forecast is based on the ensemble run of coupled system with 48 members (8 atmosphere and 6 ocean perturbations).

In July 2007, CMA implemented a new global forecast system (GRAPES_GFS) based on the self-developed grid point global model and 3DVAR system. At present, GRAPES_GFS is at the pre-operational test. And, in 2011, a new coupled system for longer-range predictions is being developed based on the Beijing Climate Center Climate System Model (BCC_CSM).

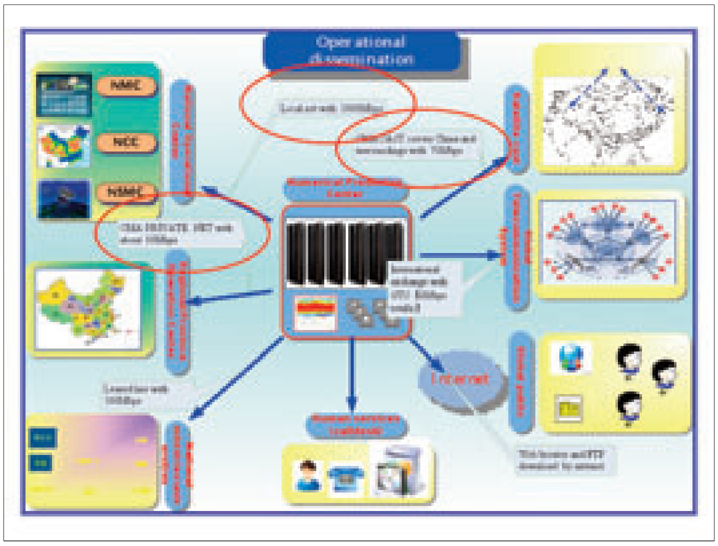
Contents

1. Medium and extended range forecast services in CMA
2. Supporting NWP systems
3. Development



Medium and Extended Range Forecast Services

Kind of Forecast	Date of Issue	Forecast Model
1-week	00UTC & 12UTC, every day	• T_L639L60 • T213L31ensemble with fixed SST (since 2006)
10-30day forecast	• End of every pentad: 10day fcst. • End of every 10-day: 20-day fcst.	T63L16ensemble with persistent SSTA
1-month forecast	• 28th of each month: monthly forecast • 1st, 6th, 11th, 16th, 21th, 26th of each month: 30-day forecast	T63L16ensemble with persistent SSTA
3-month forecast	28th of the month	CGCM
Flood season forecast (JJA)	1 April	CGCM
Annual forecast (DJF, MAM)	1 November	CGCM



Medium range forecast system

1-week forecast

Based on T639 deterministic forecast

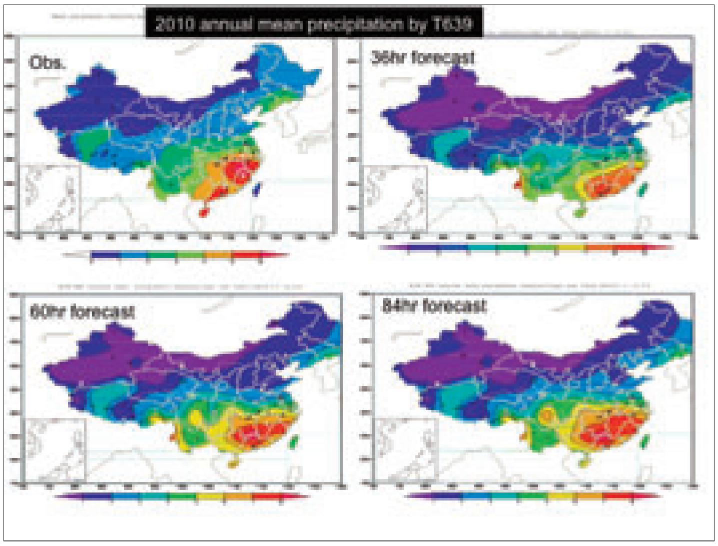
	Global Spectral Model (T_L639L60)
Forecast range	Short- and Medium-range forecast
Forecast domain	Global
Horizontal resolution	T_L639(0.28125 deg)
Vertical levels / Top	60 0.1 hPa
Forecast Hours (Initial time)	240 hours(00、12 UTC) 84 hours (06、18 UTC)
Initial Condition	Global Analysis (NCEP GSI)

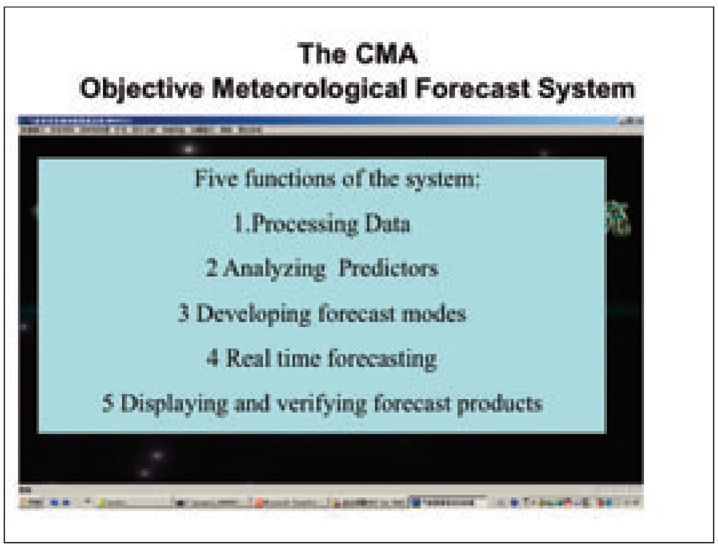
T639 DA: GSI/NCEP

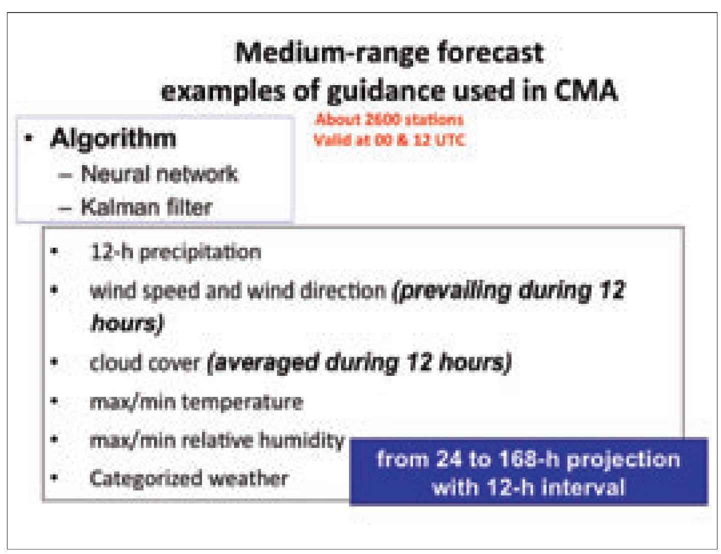
(grid-point statistical interpolation: *Wan-Shu Wu, R. James Purser and David F. Parrish, 2002*)

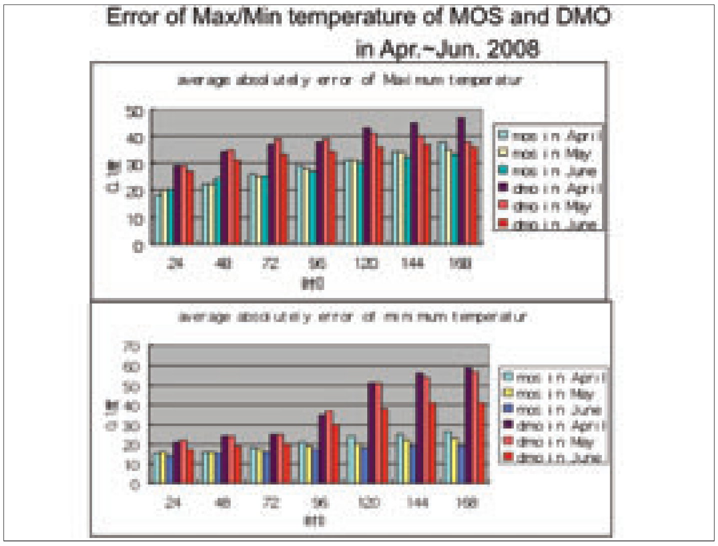
	Global Analysis
Analysis scheme	GSI 3DVAR
Analysis time	00, 06, 12, 18 UTC
Data cut-off time	3 hours 29 minutes(00, 12 UTC) 5 hours 45 minutes (06, 18 UTC) [Early Analysis] 10 hours (00, 12 UTC) 7 hours 40 minuts (06, 18 UTC) [Cycle Analysis]
Resolution	TL639L60
Assimilation window	-3 hours to +3 hours of analysis time

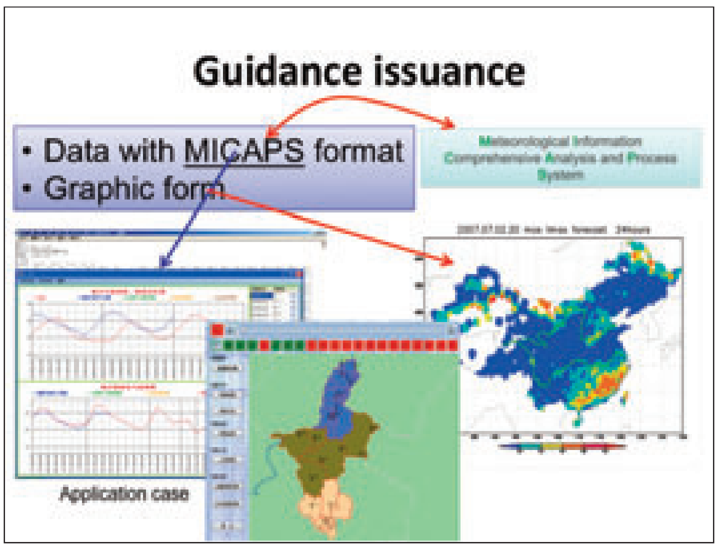
Conventional data
radiosondes,
aircraft,
synop,
ship,
buoy,
AMVs-Infrared
Satellite data
NOAA-15,-18 AMSUA
NOAA-15, AMSUB
NOAA-18, MHS

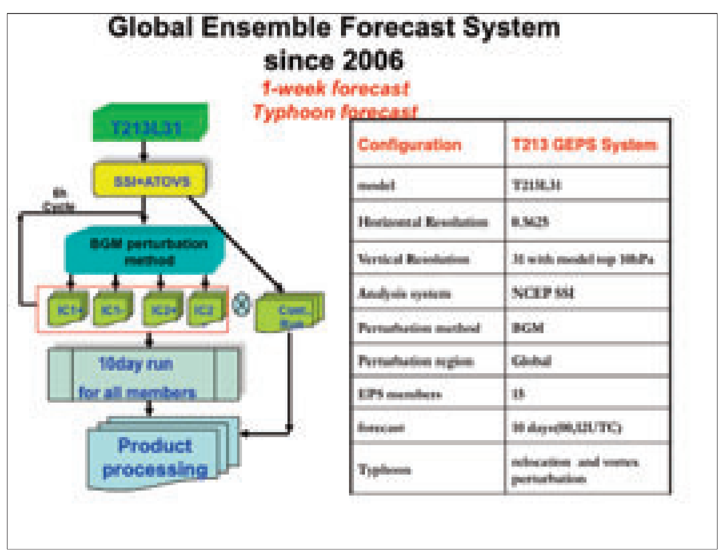

2010 annual mean precipitation by T639
Obs.
36hr forecast
60hr forecast
84hr forecast

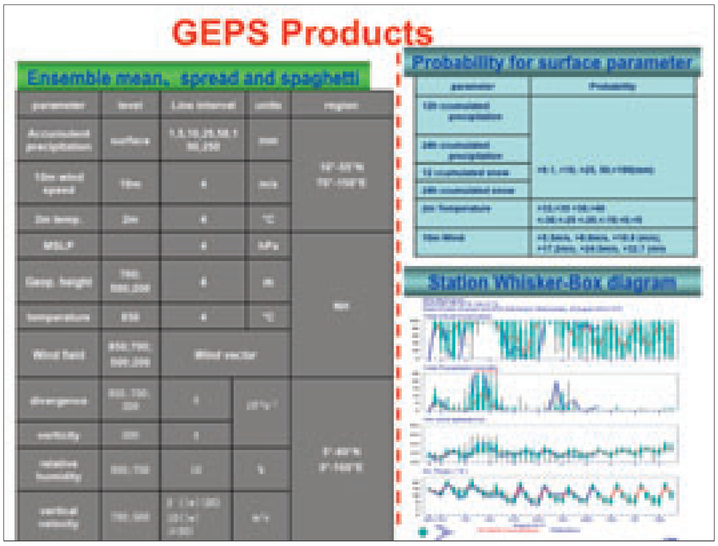

The CMA
Objective Meteorological Forecast System
Five functions of the system:
1.Processing Data
2 Analyzing Predictors
3 Developing forecast modes
4 Real time forecasting
5 Displaying and verifying forecast products

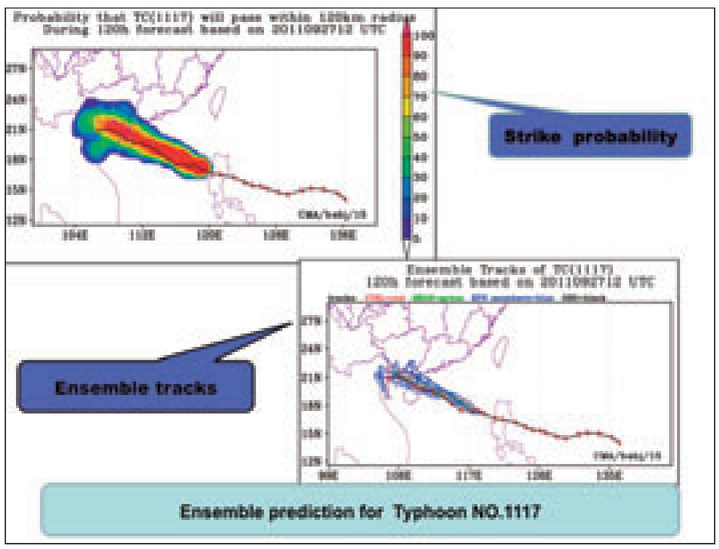

Medium-range forecast
examples of guidance used in CMA
About 2600 stations
Valid at 00 & 12 UTC
• Algorithm
– Neural network
– Kalman filter
• 12-h precipitation
• wind speed and wind direction (prevailing during 12 hours)
• cloud cover (averaged during 12 hours)
• max/min temperature
• max/min relative humidity
• Categorized weather
from 24 to 168-h projection
with 12-h interval


Error of Max/Min temperature of MOS and DMO
in Apr.~Jun. 2008
average absolutely error of Maximum temperatur
mos in April
mos in May
mos in June
dmo in April
dmo in May
dmo in June
24
48
72
96
120
144
168
average absolutely error of minimum temperatur


Guidance issuance
• Data with MICAPS format
• Graphic form
Meteorological Information Comprehensive Analysis and Process System
Application case

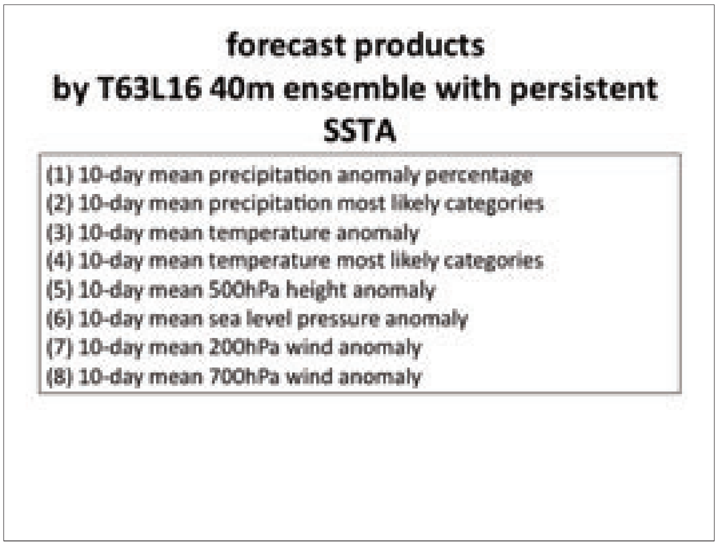

Global Ensemble Forecast System
since 2006
1-week forecast
Typhoon forecast
T213L31
SSI+ATOVS
6h Cycle
BGM perturbation method
10day run
for all members
Product processing
Configuration
T213 GEPS System
model
T213L31
Horizontal Resolution
0.5625
Vertical Resolution
31 with model top 10hPa
Analysis system
NCEP SSI
Perturbation method
BGM
Perturbation region
Global
EPS members
15
forecast
10 days(00,12UTC)
Typhoon
relocation and vortex perturbation

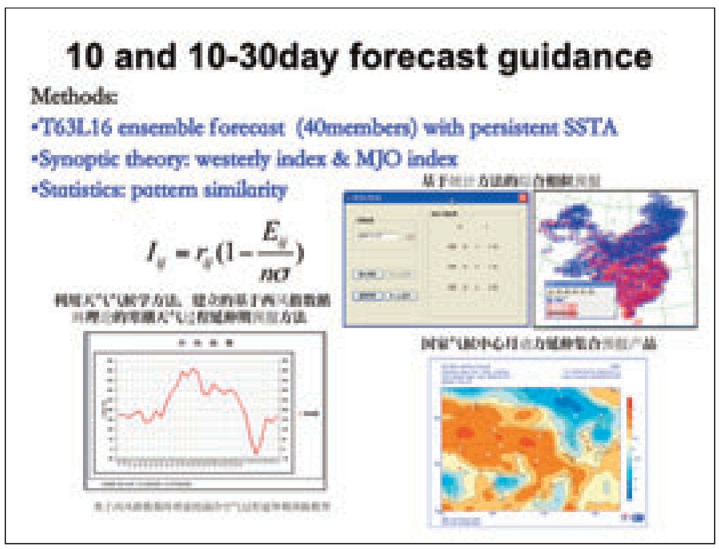


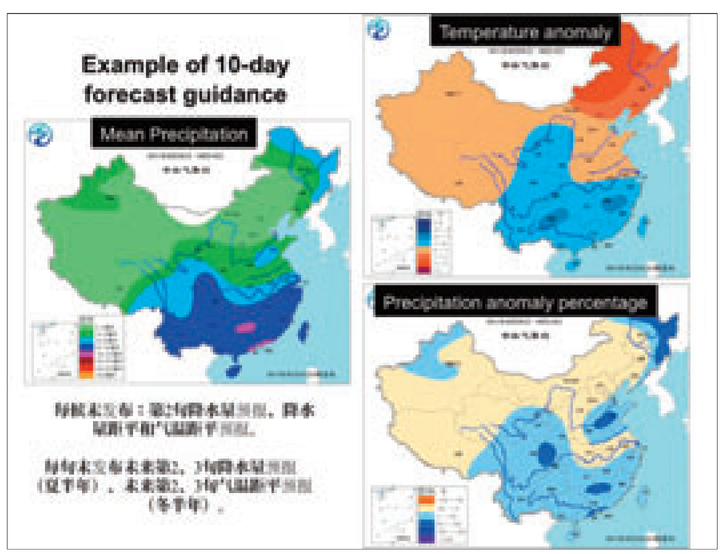


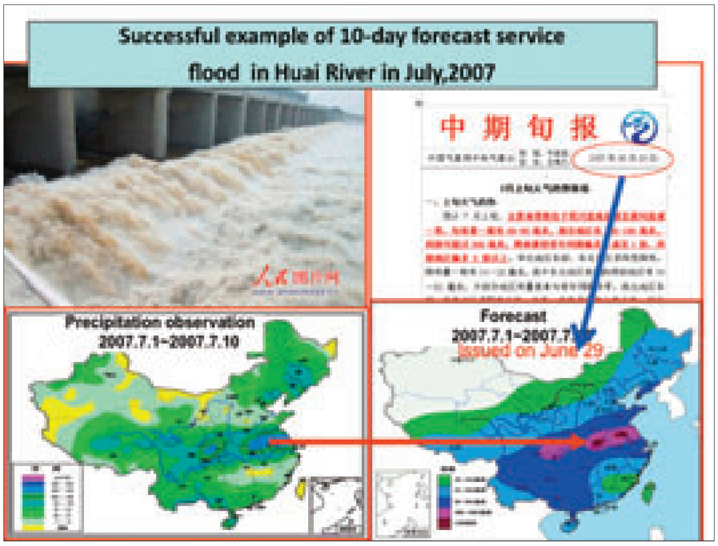
10 and 10-30 day forecast model

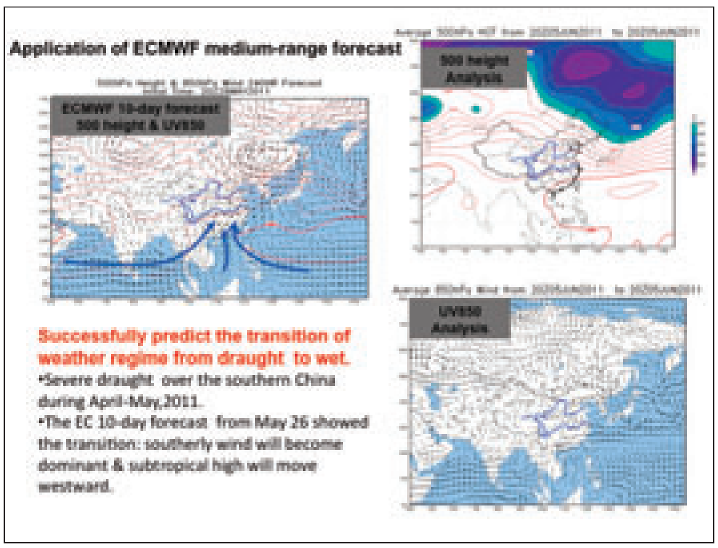
Horizontal resolution	T63 (~1.875° Gaussian grid)
Vertical levels	16 (Top Layer Pressure:25hPa)
Time integration range	45 days
Executing frequency	Once every pentad
Ensemble size	40 members
Initial values & perturbation method	CMA global analysis SV & Lagged Average Forecast (LAF) method
SST	Persisted anomaly
Land surface Parameters	Initial conditions of land parameters are provided by climatology

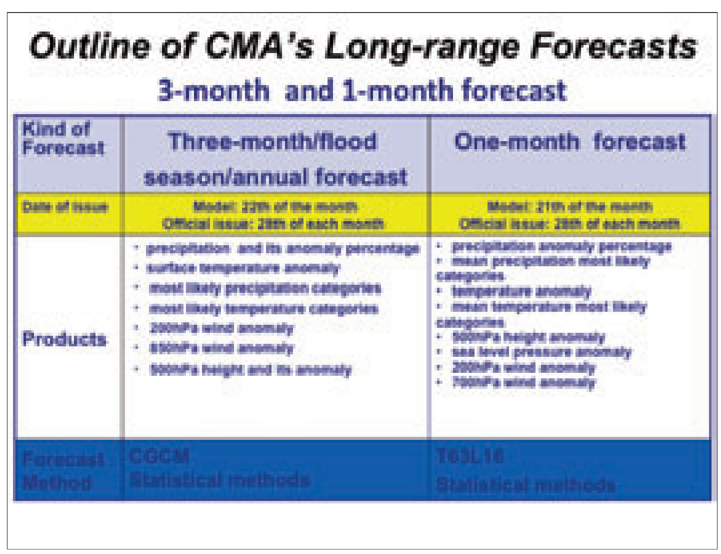

forecast products
by T63L16 40m ensemble with persistent SSTA
(1) 10-day mean precipitation anomaly percentage
(2) 10-day mean precipitation most likely categories
(3) 10-day mean temperature anomaly
(4) 10-day mean temperature most likely categories
(5) 10-day mean 500hPa height anomaly
(6) 10-day mean sea level pressure anomaly
(7) 10-day mean 200hPa wind anomaly
(8) 10-day mean 700hPa wind anomaly


10 and 10-30day forecast guidance
Methods:
•T63L16 ensemble forecast (40members) with persistent SSTA
•Synoptic theory: westerly index & MJO index
•Statistics: pattern similarity
$I_{ij} = r_{ij}(1 - \frac{E_{ij}}{n\sigma})$


Example of 10-day forecast guidance
Mean Precipitation
Temperature anomaly
Precipitation anomaly percentage







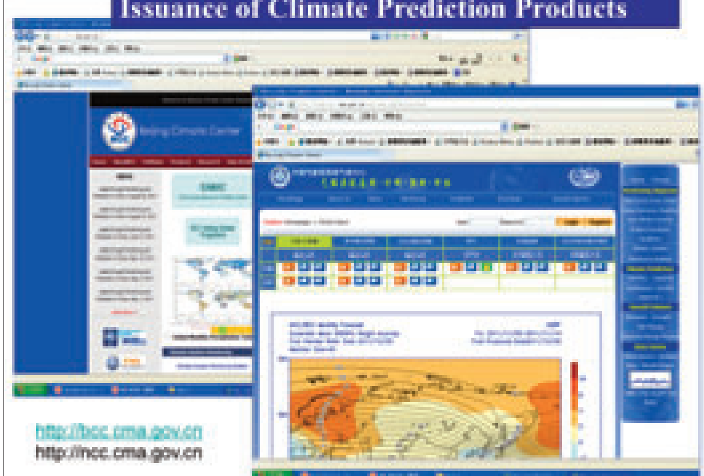
Kind of Forecast	Three-month/flood season/annual forecast	One-month forecast
Date of issue	Model: 22th of the month Official issue: 28th of each month	Model: 21th of the month Official issue: 28th of each month
Products	· precipitation and its anomaly percentage · surface temperature anomaly · most likely precipitation categories · most likely temperature categories · 200hPa wind anomaly · 850hPa wind anomaly · 500hPa height and its anomaly	· precipitation anomaly percentage · mean precipitation most likely categories · temperature anomaly · mean temperature most likely categories · 500hPa height anomaly · sea level pressure anomaly · 200hPa wind anomaly · 700hPa wind anomaly
Forecast Method	CGCM Statistical methods	T63L16 Statistical methods

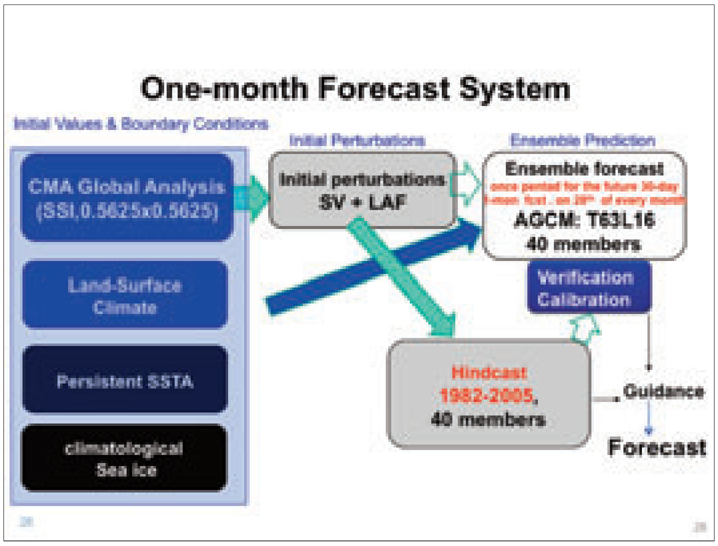
Other Guidance Products for long-range forecast based on the CGCM ensemble

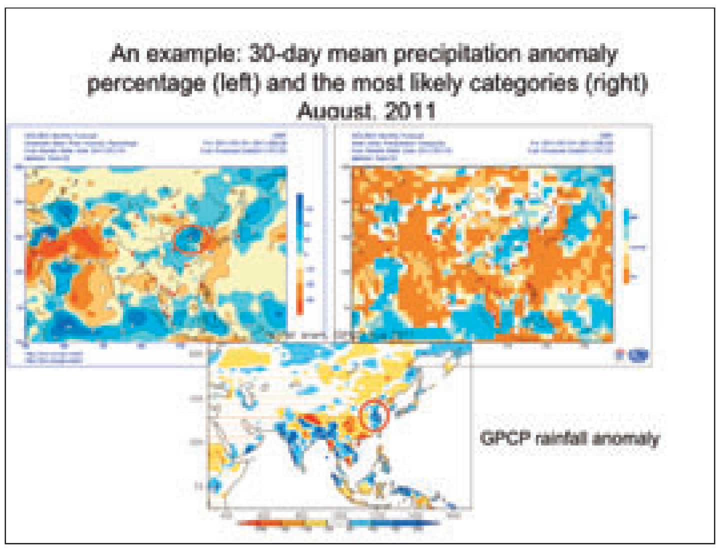
- Monthly/Seasonal precipitation and temperature
- Tropical cyclone frequency
- Cold air activities
- Climate condition of crop seeding
- First frost date
- Monsoon onset and withdraw date and its intensity
- Forest and grassland fireproofing
- Sand storm frequency
- and ......

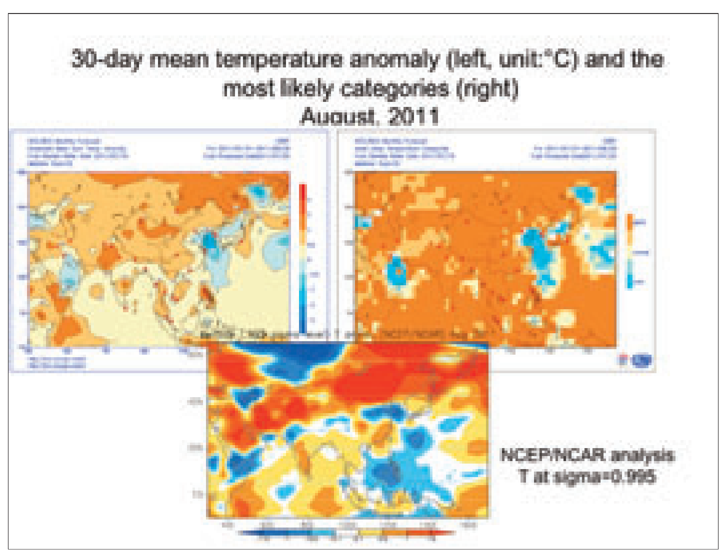
Issuance of Climate Prediction Products

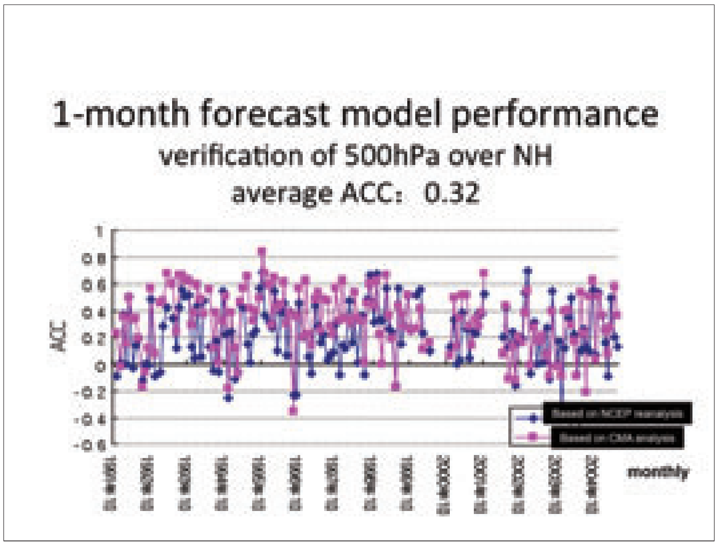
Issuance of Climate Prediction Products

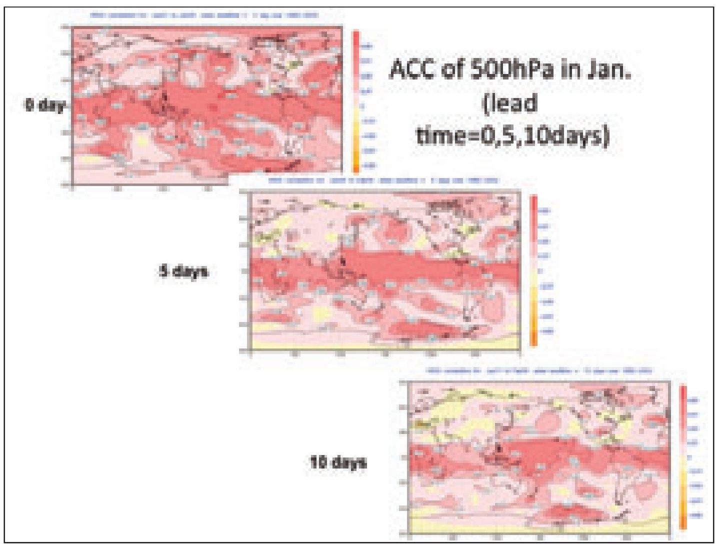


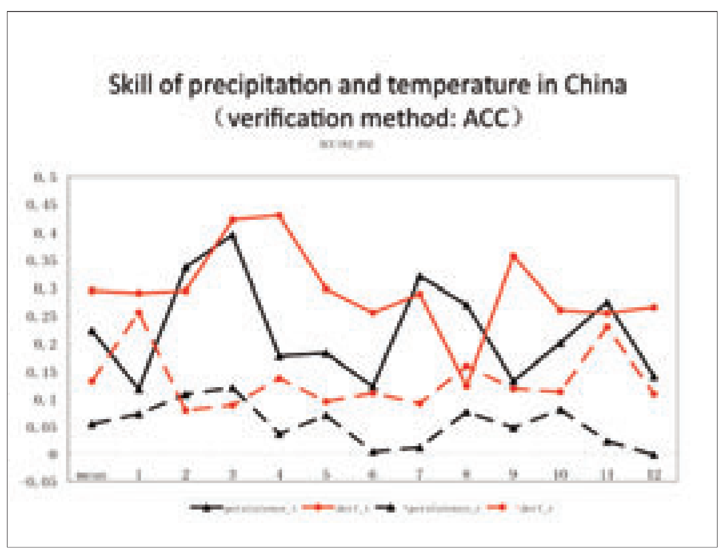

One-month Forecast System
Initial Values & Boundary Conditions
Initial Perturbations
Ensemble Prediction
CMA Global Analysis
(SSI,0.5625x0.5625)
Initial perturbations
SV + LAF
Ensemble forecast
AGCM: T63L16
40 members
Land-Surface
Climate
Verification
Calibration
Persistent SSTA
Hindcast
1982-2005,
40 members
Guidance
climatological
Sea ice
Forecast

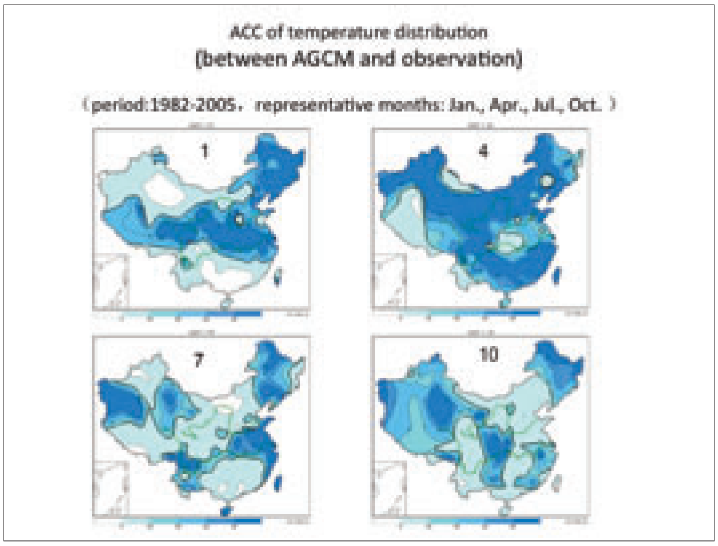

An example: 30-day mean precipitation anomaly
percentage (left) and the most likely categories (right)
August, 2011
GPCP rainfall anomaly

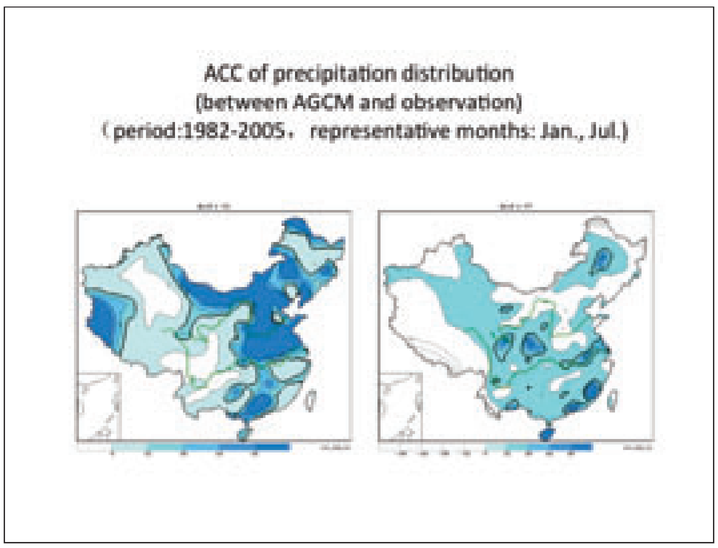

30-day mean temperature anomaly (left, unit:°C) and the
most likely categories (right)
August, 2011
NCEP/NCAR analysis
T at sigma=0.995

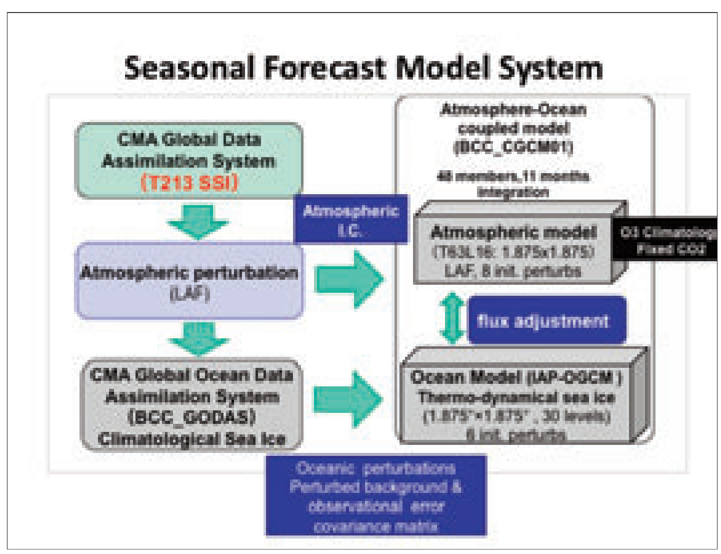

1-month forecast model performance
verification of 500hPa over NH
average ACC：0.32
ACC
Based on NCEP reanalysis
Based on CMA analysis
monthly

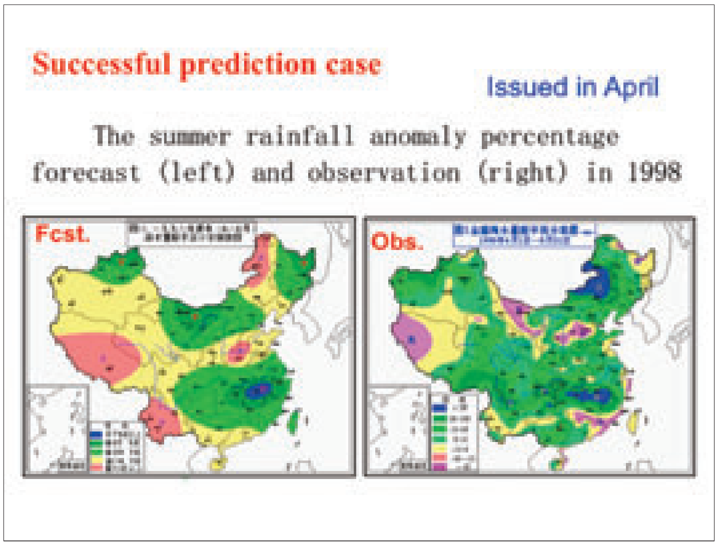

ACC of 500hPa in Jan.
(lead
time=0,5,10days)
0 day
5 days
10 days

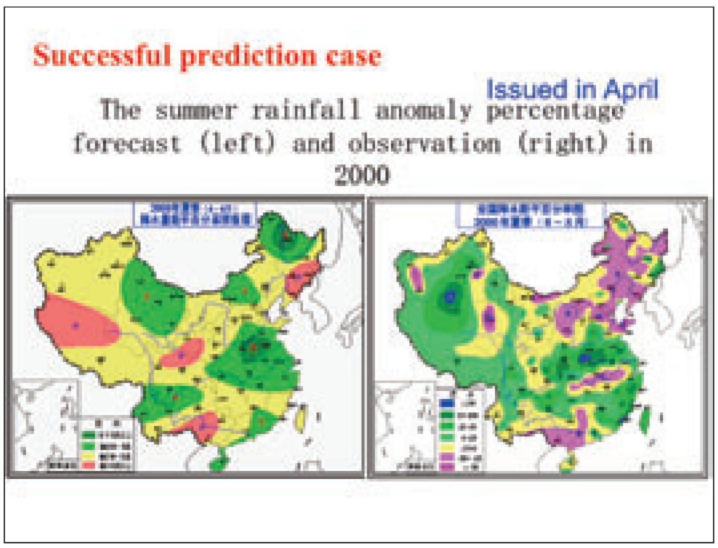

Skill of precipitation and temperature in China
（verification method: ACC）

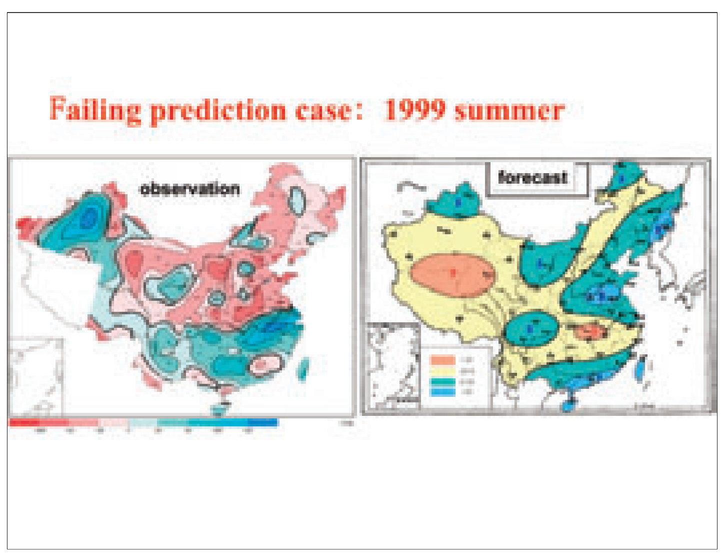

ACC of temperature distribution
(between AGCM and observation)
（period:1982-2005，representative months: Jan., Apr., Jul., Oct. ）
1
4
7
10

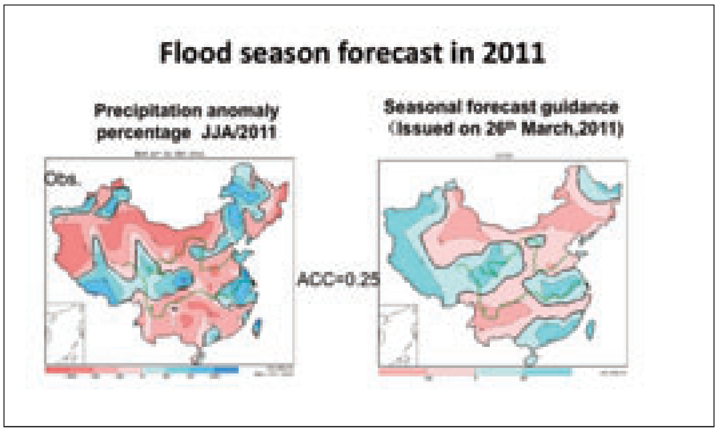

ACC of precipitation distribution
(between AGCM and observation)
（period:1982-2005，representative months: Jan., Jul.)


Seasonal Forecast Model System
CMA Global Data Assimilation System (T213 SSI)
Atmospheric I.C.
Atmospheric perturbation (LAF)
CMA Global Ocean Data Assimilation System (BCC_GODAS) Climatological Sea Ice
Atmosphere-Ocean coupled model (BCC_CGCM01)
48 members,11 months integration
Atmospheric model (T63L16: 1.875x1.875) LAF, 8 init. perturbs
flux adjustment
Ocean Model (IAP-OGCM) Thermo-dynamical sea ice (1.875°×1.875° , 30 levels) 6 init. perturbs
Oceanic perturbations Perturbed background & observational error covariance matrix


Successful prediction case
Issued in April
The summer rainfall anomaly percentage forecast (left) and observation (right) in 1998
Fcst.
Obs.


Successful prediction case
Issued in April
The summer rainfall anomaly percentage forecast (left) and observation (right) in 2000


Failing prediction case: 1999 summer
observation
forecast



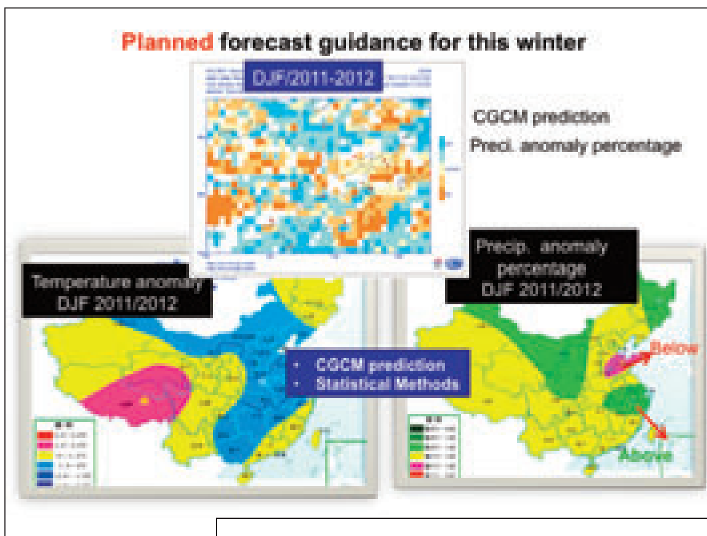
CGCM performance

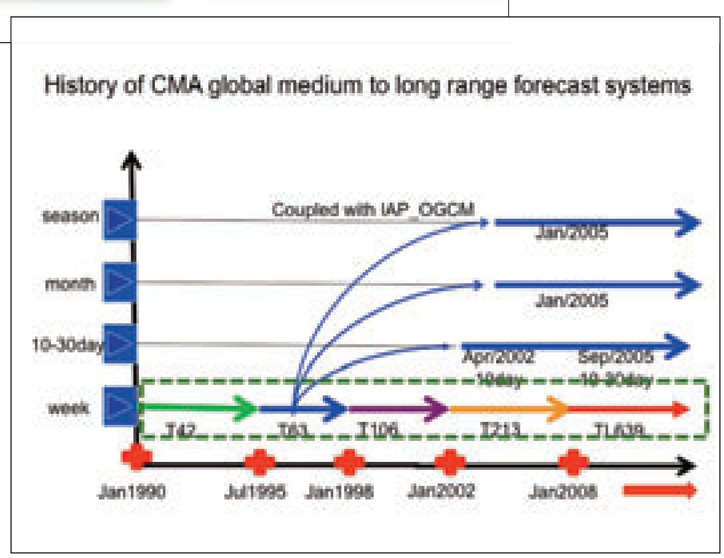
Anomaly Correlation coefficients

(Initial Condition : Mar, Period of Forecast: JJA)

Averaged period:1983-2002

	Global	N. H.	E. Asia
Z_{500}	0.20	0.18	0.21
T_{850}	0.07	0.07	0.15





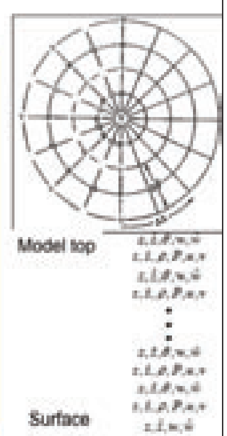
GRAPES: Global and Regional Assimilation & Prediction System
since 2001

A Unified Global and Regional NWP System

- Global model
- Meso-scale model
- Global VAR
- Regional VAR

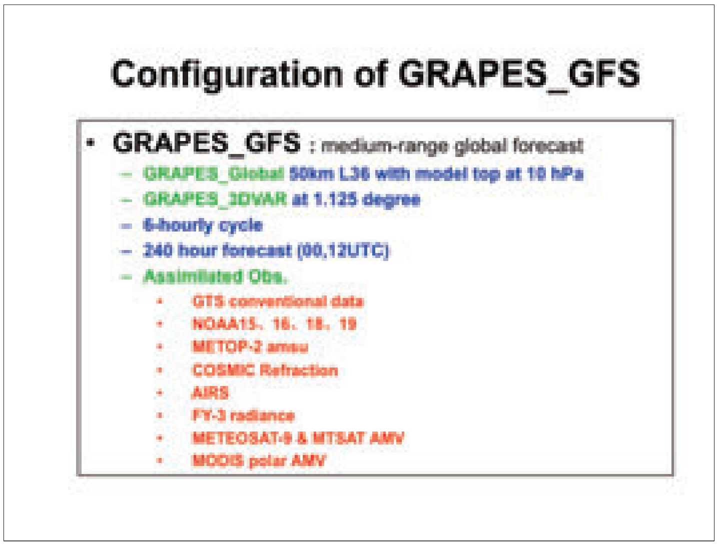
Unified
GRAPES Model Dynamic Core

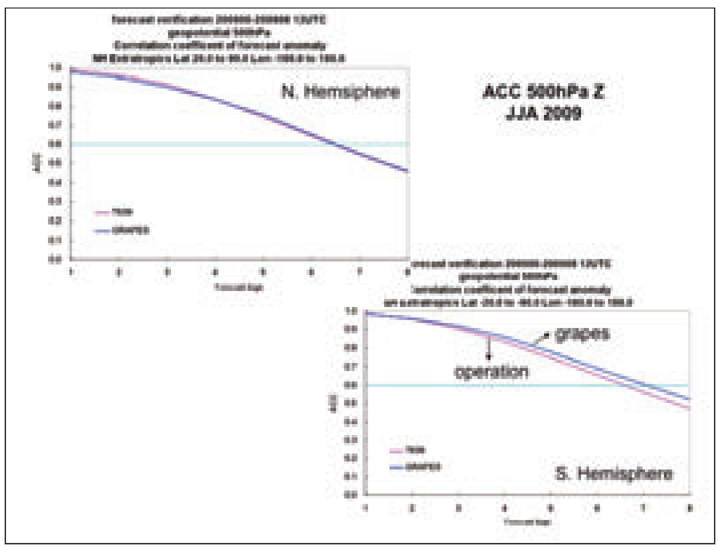
- Fully compressible equations with shallow atmosphere approximation
- 2-time-level semi-implicit semi-Lagrangian (SISL) time-stepping
- QMSL or CSLR for scalar advection
- 3D vector form for momentum equations
- Height-based terrain-following coordinate
- Option of hydrostatic and non-hydrostatic
- Arakawa-C grid but V at poles
- Charney-Phillips vertical grid
- GCR for Helmholtz Eq.
- Spherical & polar effects of trajectory calculation
- Quasi-cubic interpolation
- Mass fixer → $\int \frac{(\pi + \Delta\pi)^{C_v/R_d} dV}{\theta} = M_{total}$
- Polar filter

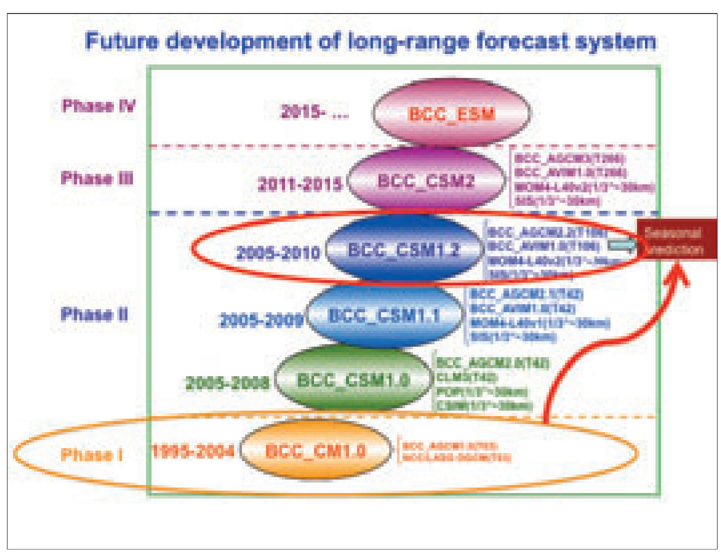


Model physics package

- Physics
  - Radiation:
    - RRTMG LW(V4.71)/SW(V3.61)
  - Cumulus:
    - Simplified Arakawa Schubert with modified entrainment and detrainment rates
  - Microphysics: CMA two-moment microphysics with macro consideration
  - Cloud: Xu & Randall diagnostic cloud
  - Land surface: CoLM
  - Gravity wave drag:
    - Kim & Arakawa 1995; Lott & Miller 1997; Alpert, 2004
  - Small scale orographic form drag : Beljaars, Brown & Wood(2004)


Configuration of GRAPES_GFS
• GRAPES_GFS : medium-range global forecast
– GRAPES_Global 50km L36 with model top at 10 hPa
– GRAPES_3DVAR at 1.125 degree
– 6-hourly cycle
– 240 hour forecast (00,12UTC)
– Assimilated Obs.
• GTS conventional data
• NOAA15、16、18、19
• METOP-2 amsu
• COSMIC Refraction
• AIRS
• FY-3 radiance
• METEOSAT-9 & MTSAT AMV
• MODIS polar AMV


N. Hemisphere
ACC 500hPa Z
JJA 2009
grapes
operation
S. Hemisphere


Future development of long-range forecast system
Phase IV
2015- ...
BCC_ESM
Phase III
2011-2015
BCC_CSM2
2005-2010
BCC_CSM1.2
Phase II
2005-2009
BCC_CSM1.1
2005-2008
BCC_CSM1.0
Phase I
1995-2004
BCC_CM1.0

Use of ECMWF products at Météo-France

Mireille Mayoka, Météo-France, Deputy Head of General Forecast Department

1) Severe weather forecasts for D+2 and D+3

Severe weather forecast at Météo-France, for the next 24 hours, is based since 2001 upon a procedure called "vigilance", which has proved generally successful: it is composed of a "vigilance" watch map, displaying a coloured watch level for each administrative unit, complete with follow-up forecast bulletins in case of significant danger.

Recent improvements in numerical weather prediction, and especially ensemble prediction, enable to forecast dangerous weather phenomena at a longer range. That's why national and regional forecasters issue severe weather forecasts for Day+2 (D+2) and Day+3 (D+3) since 2007 : this experimental production, which presentation has been modified in 2010, has proved relevant.

The method is based on an estimation of the risk of dangerous weather phenomena, at the scale of administrative regions, for each day (D+2, D+3). The phenomena considered are violent winds, heavy rain, violent thunderstorms and snow / ice. Forecasters select a risk index among four levels : no risk (0), unlikely (1), likely (2), certain (3).

The final product shows the risk of remarkable phenomena in terms of probabilities, corresponding to the reliability of the chosen index for each parameter. The charts for D+2 and D+3, complete with a comment, are available on an internal Webpage (figure 3) and sent by email to a few governmental services since 2010, in order to evaluate the potential usefulness of this product and to adjust it to the users' needs.

The estimation of the risk is based on deterministic model outputs, and more and more multi-ensemble outputs. Forecasters compare products from different ensemble models, available on an internal Website :

- probabilities and percentiles, which are complementary products (figure 1);
- spaghetti diagrams Z500 which give a good estimation of the spread of an ensemble, and also spaghetti diagrams MSLP which are vey useful to forecast the location of a depression (figure 2) ;
- postage stamp maps which give a quick look on the EPS members and can help to see alternative scenarios.

The figures below show ensemble products from EPS (ECMWF) and PEARP (French ensemble model) used to forecast the storm Xynthia in February 2010, 3 days before.

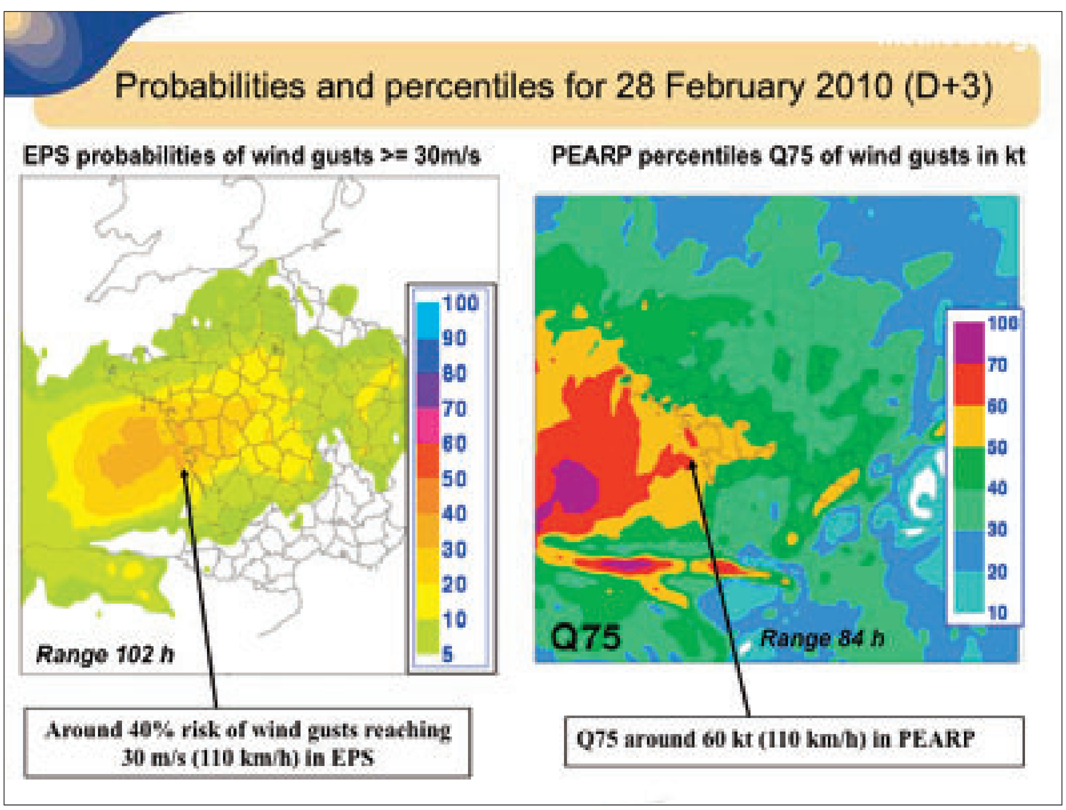


Figure 1 Probabilities and percentiles for 28 February 2010 (D+3)

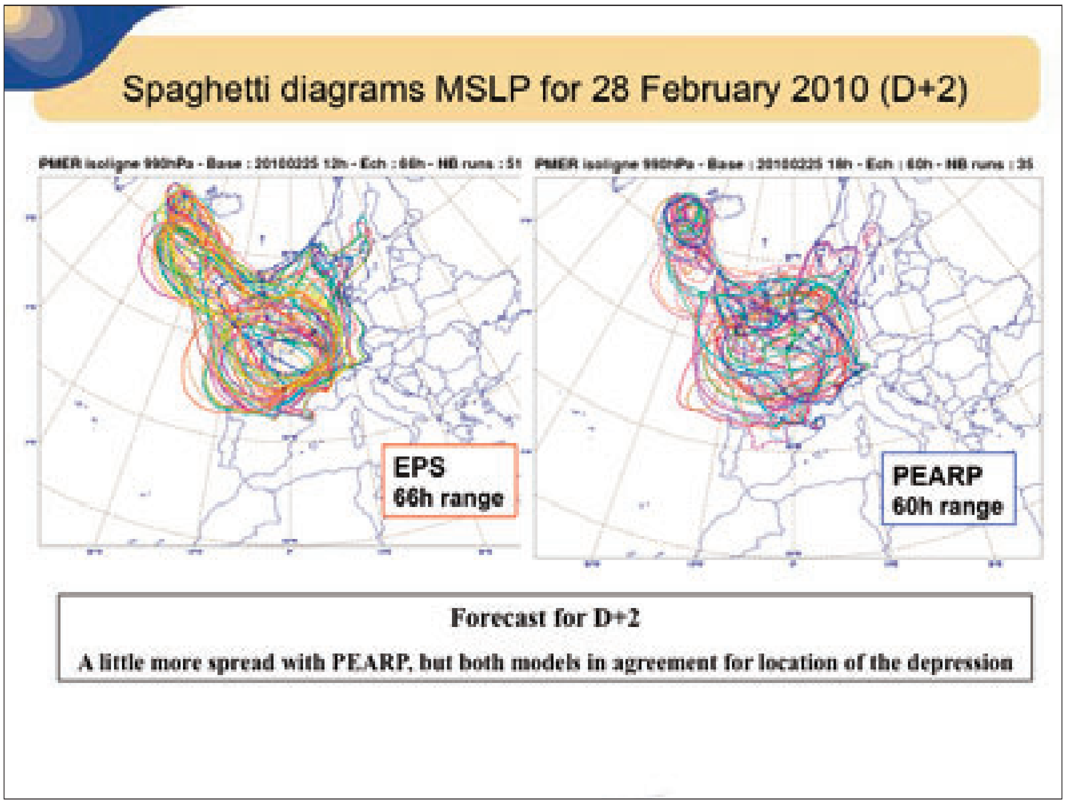


Figure 2 Spaghetti diagrams MSLP for 28 February 2010 (D+2)

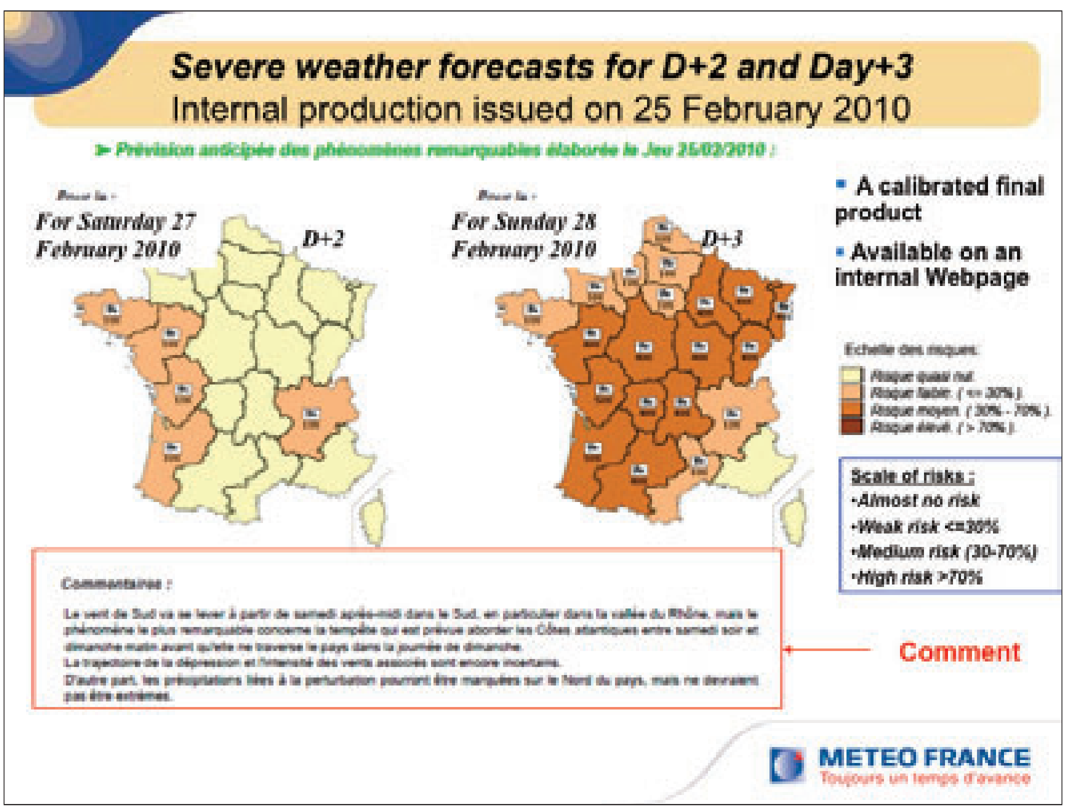


Figure 3 Severe weather forecasts for D+2 and Day+3, Internal production issued on 25 February 2010

2) Medium and extended range forecasts

At medium range, from Day+4 to Day+9, daily forecasts over France are based mostly on EPS. Forecasters display different EPS products on their Synergie workstation and on the internal Website :

- ensemble mean geopotential and probabilities charts (precipitations, wind, humidity…) are used to define the most likely scenario at supra-synoptic scale ;
- spaghetti diagrams Z500, which give a good estimation of the spread of the ensemble, are used for estimation of the forecast uncertainty ;
- EPS plumes and EPS grams are used to adapt the scenario to local weather parameters.

Forecasters compare successive EPS runs for a defined field, like ensemble mean ZT500. They also compare EPS outputs to NCEP outputs (figure 4) : a coherence between both spaghettis Z500 can confirm for example the analysis of EPS spread.

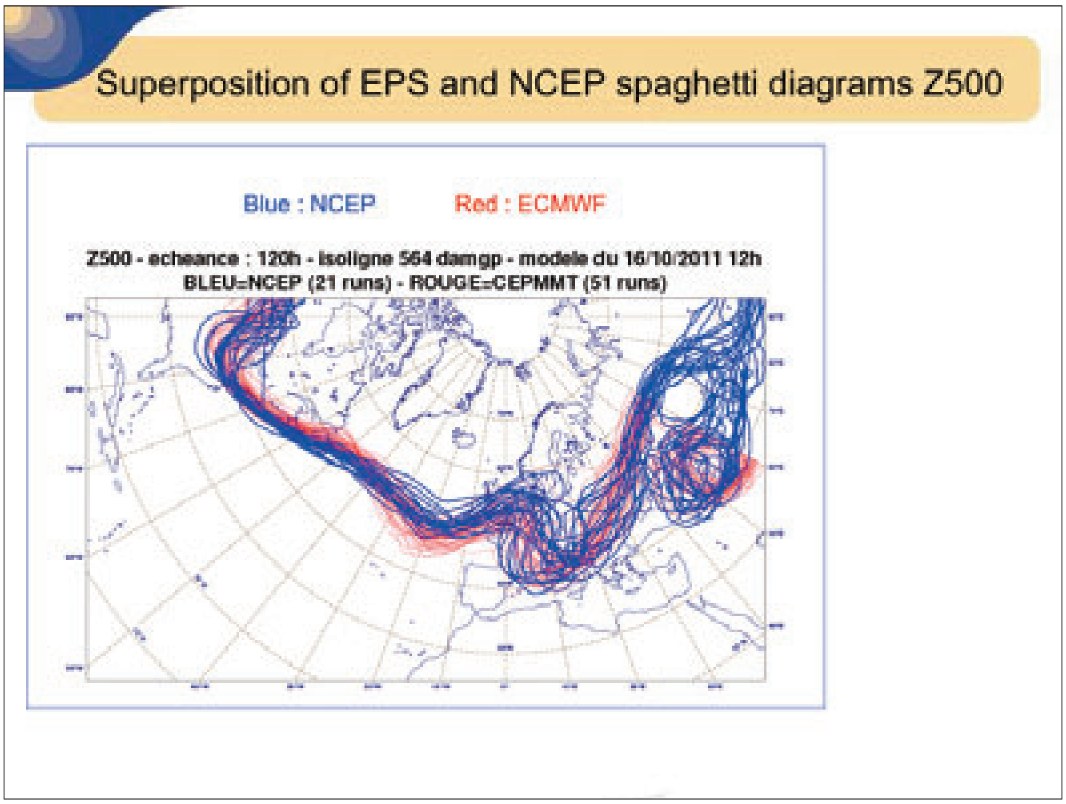


Figure 4 Superposition of EPS and NCEP spaghetti diagrams Z500

At last, after mixing different kind of information, and according to his experience, the national forecaster fixes the most likely scenario and the forecast confidence over France. He issues forecast charts using weather symbols, risk symbols and a confidence index (for D+4 to D+7), selected from a scale of 5 numbers.

The verification of national medium range weather forecasts for D+4 to D+7 (figure 5) shows that a good signal for the large scale is got from the EPS products and that the forecast is well translated by the forecasters into the production, in terms of weather symbols but also for dangerous phenomena.

Human interpretation of EPS products has proved relevant for synthesis of global and local data, synthesis of the most likely weather-type, and also to bring out risk of dangerous phenomena like strong winds, snow or thunderstorms.

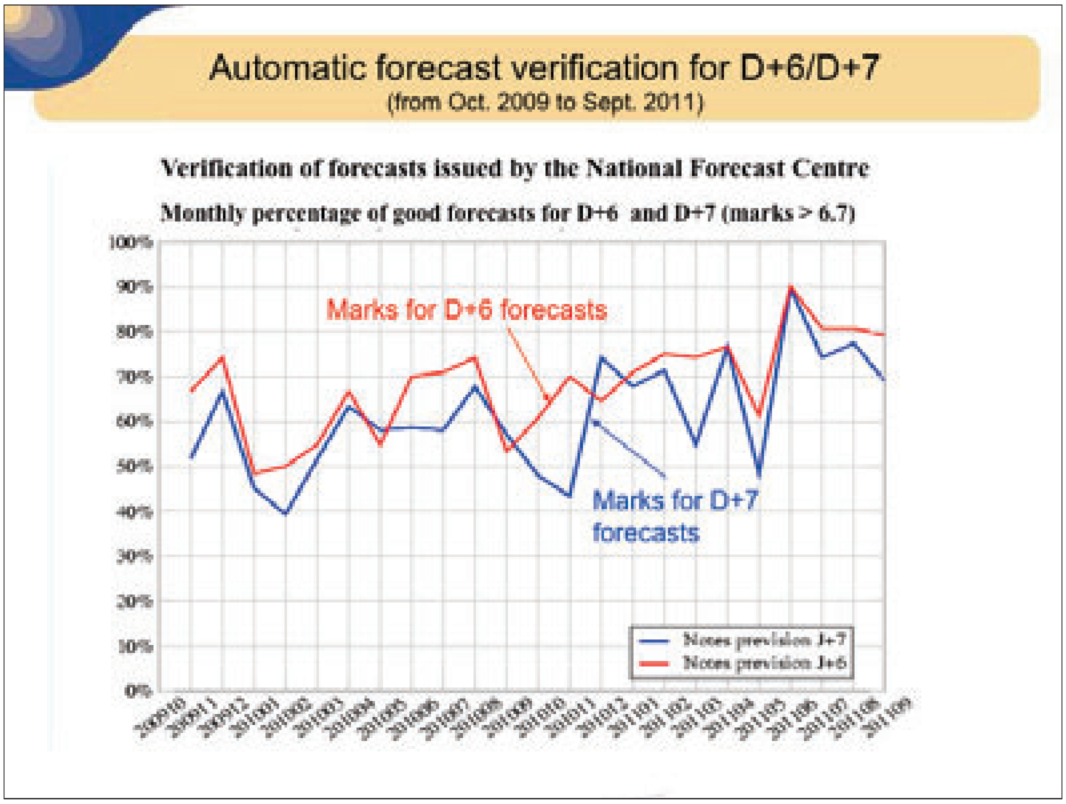


Figure 5 Automatic forecast verification for D+6/D+7 (from Oct. 2009 to Sept. 2011)

3) Feedback on ecCharts

Forecasters from the National Forecast Centre have tested the EPS products available on the new ECMWF Website ecCharts during Summer 2011.

They found several tools very interesting : map navigation and zoom, data availability menu, time navigator, city-finder. They explored the different ECMWF graphical products, like time series, meteograms and interactive probabilities maps.

To make this web based service even more useful, they would like an improvement of the response time and also some more products and tools, especially spaghetti diagrams (Z500 and MSLP), vertical profiles and cuts, and also the possibility of superposition of successive runs.

Finally they hope that these new services will be integrated into their Synergie-next forecaster workstation.

4) Tropical cyclone forecast (uncertainty circles)

In the South West Indian Ocean, forecasters from the Regional Specialized Meteorological Centre (RSMC) La Réunion use EPS products for tropical cyclone forecast. These products have been proved reliable for track forecasts and also for an estimation of the forecast uncertainty, which are both important for risk managers and public agencies. On line forecasts from different ensembles including EPS are available on an external Website for the South West Indian Ocean Meteorological Centres.

Several tropical cyclone forecast centers issue an uncertainty information around their official track forecasts, generally using the climatological distribution of position error. However, such methods are not able to convey an information that is case-dependent.

Therefore, RSMC La Réunion has developed a new technique to measure and to display the uncertainty of (around) its official track forecast until 3 days lead time, with uncertainty circles based on EPS : the dispersion of cyclone positions in the EPS is extracted and translated at the RSMC forecast position.

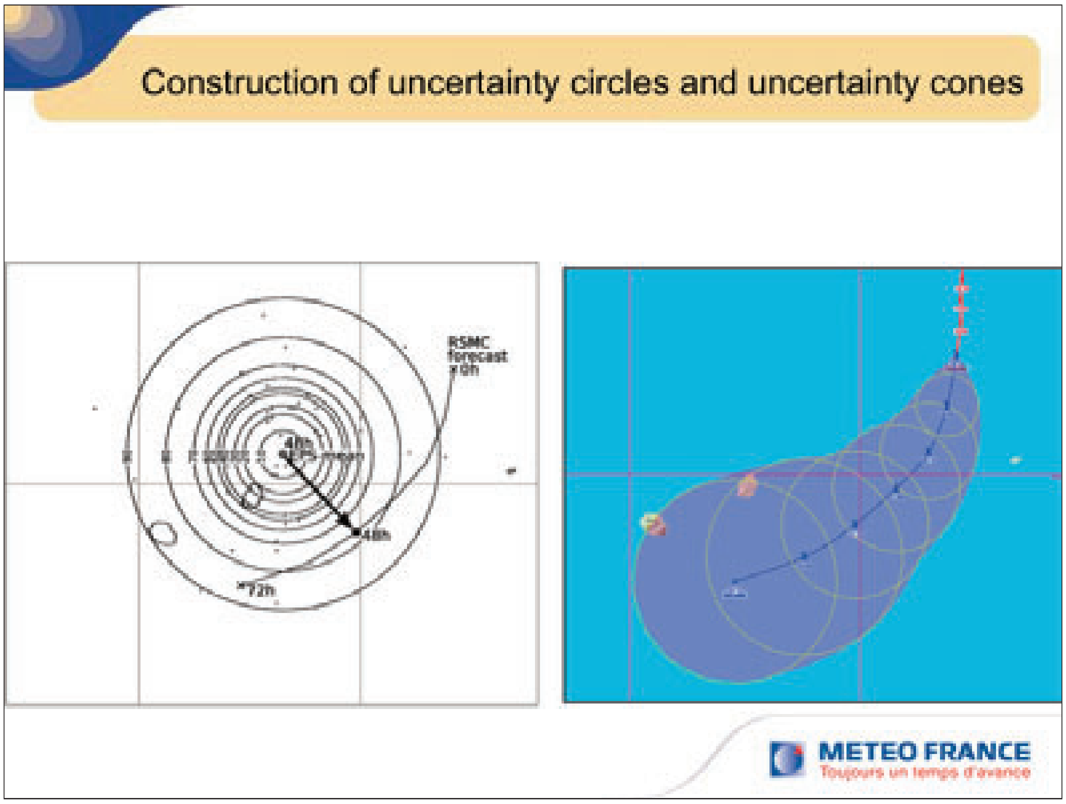


Figure 6 Construction of uncertainty circles and uncertainty cones

The verification of this technique[1] has showed firstly that the probabilistic forecasts have better scores than the climatology. Secondly, the skill of uncertainty circles – built by fixing the probability at 75% – at detecting the small and the large error values is assessed: at least until the 3-days term for large errors, and only until 2-days lead time for small radii.

[1] T. Dupont, M. Plu, P. Caroff, and G. Faure, 2011: Verification of ensemble-based uncertainty circles around tropical cyclone track forecasts, American Metoeorological Society, Weather and Forecasting, Volume 26, Number 5 (October 2011).

Use of ECMWF products at MeteoGroup - focus on Road Forecasting

Ingeborg Smeding, Meteo Consult b.v.

Short abstract

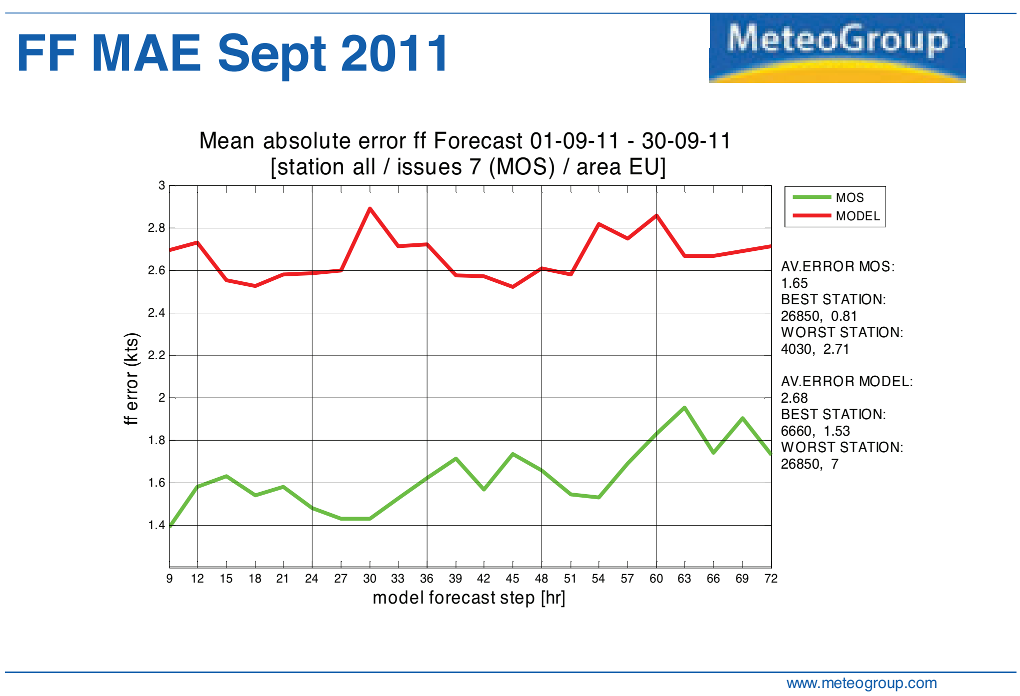
At Meteo Consult, part of MeteoGroup, ECMWF model data is widely used in many different applications. We will present some general applications, like the MOS system (Model Output Statistics) and downscaling. However, the focus of the presentation will be on road forecasting. MeteoGroup has developed a site-based road surface temperature forecasting model. Road surface temperatures can differ several degrees on a very short distance due to local effects. In order to get more insight in the local temperature differences and to develop safer gritting routes, Meteogroup has developed a system for route based temperature forecasting.

Extended abstract

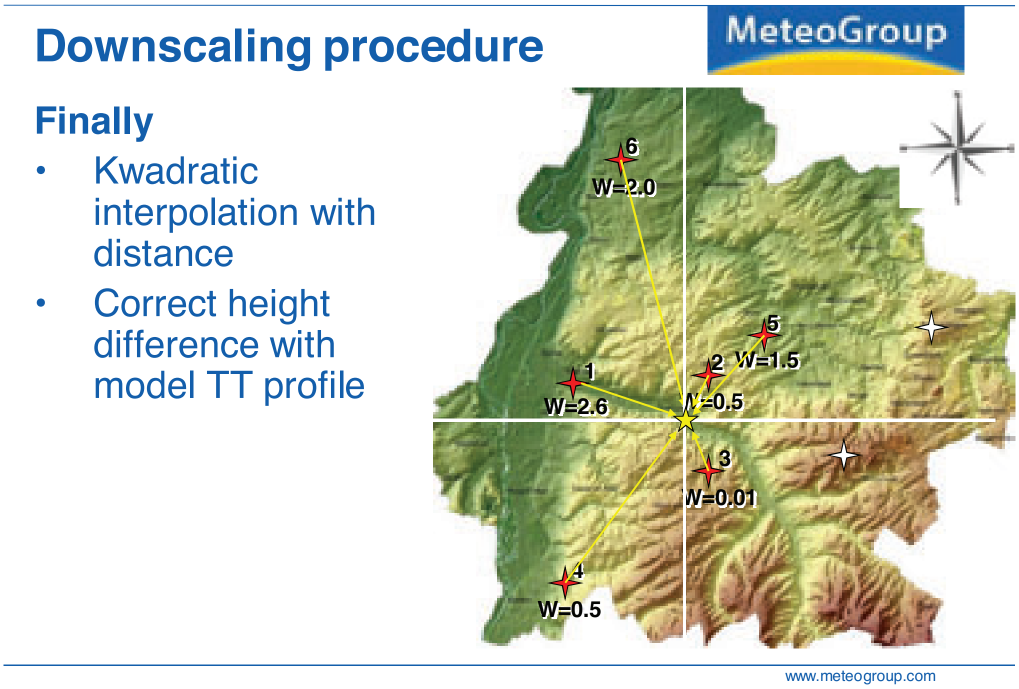
Meteo Consult is part of the MeteoGroup. MeteoGroup, part of the Press Association, is active in many countries. The main research department is situated in the Netherlands, however there are also some research people in Germany and UK. For more information on the research activities of MeteoGroup, the website http://research.meteogroup.com can be consulted. Examples of products are a sophisticated multi-model MOS system and its associated downscaling technique, energy forecasts (wind and solar power), 3 km WRF hindcasts and operational forecasts using ECMWF input, road forecasts, leaf fall model and various consultancies.

The multi-model MOS system of MeteoGroup combines the strengths of 4 different models (ECMWF, EPS, GFS and UKMO) into one forecast system. By means of linear and logistic regression a 15-day forecast is made for many general meteorological elements. This forecast is the basis of almost all MeteoGroup products. For creating a MOS for a station, at least 1 year of historic measurement and model data is needed. For each station, element and forecast period a unique MOS equation is calculated.

The strong point of MOS is that local characteristics are included in the forecast. Raw model mean absolute error (MAE) can be significantly reduced by using a multi-model MOS system. Below an example for the MOS and raw ECMWF model MAE for wind speed for a selection of European stations in September 2011.



When no observations are available, no MOS equations can be created. Therefore the downscaling system has been developed. Based on surrounding MOS sites, a forecast for a random location can be derived. This is done based on topographical information like orography and distance to the coast. Wind direction is also taken into account. Finally a smart interpolation based on distances and assigned weights, calculates the final forecast value.

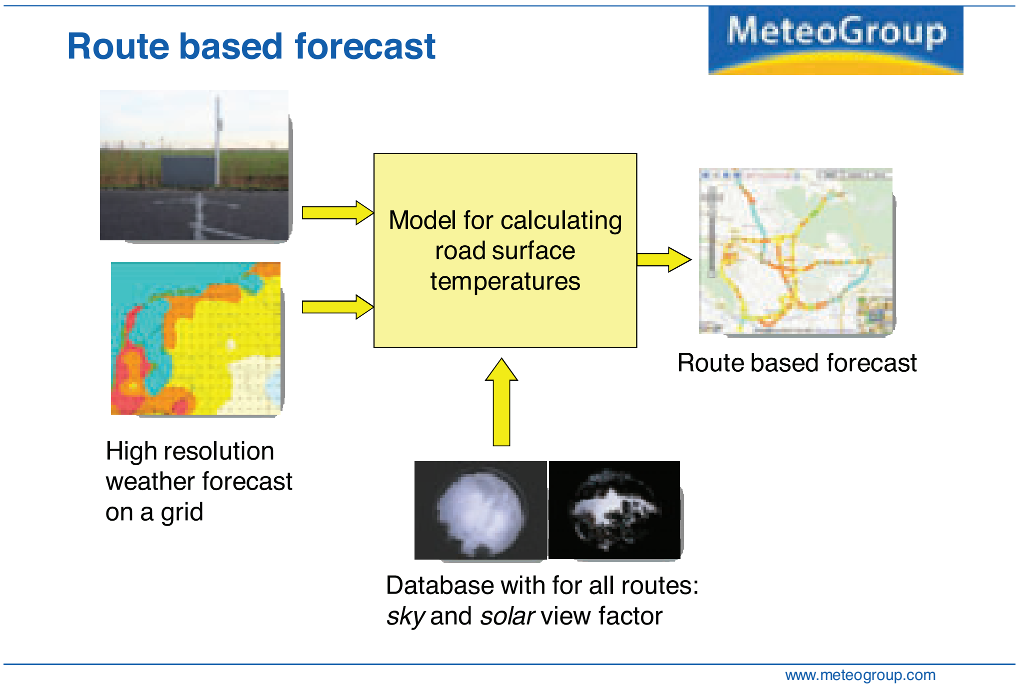


The quality of downscaling is highly dependent on the quality and quantity of surrounding MOS stations. A disadvantage is that – unlike MOS – local properties (like a shielded location) are not incorporated in the forecast.

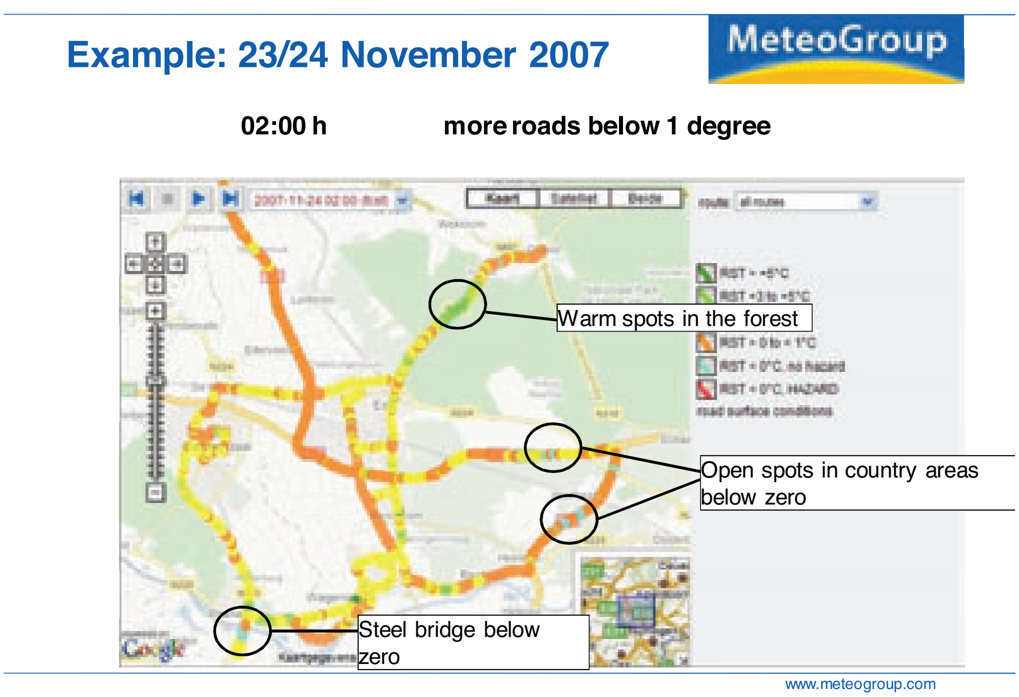
The final forecast is continuously manually corrected by local forecasters based on their experience. This forecast product is the input for derived products like the road model. The road model is a combined physical and statistical model. The physical part is based on the energy balance method. Input elements are general weather elements like air temperature, cloudiness and wind speed. Output is a road surface temperature and condition forecast. The statistical part of the road model is again based on historical observations. With the statistical part the distinction between sun and shadow road sensors can be made. The road model produces a point forecast.

Due to environmental differences, large local differences in road surface temperatures can exist, up to 5°C at small distance. Road sites are usually placed on the coldest parts of a gritting route. In cases around 0°C, the entire road will be treated in the same way. This is not always useful; reduction is possible. Therefore a route based forecast is developed to get insight in the forecasted local road surface temperature differences.

Main input for a route based forecast is skyview and sunview. Skyview is a measure for how shielded a location is. Sunview gives information on the hours where a road section is in the shadow or sun. This information is combined with a high resolution weather forecast on a grid (based on MOS and downscaling) and road station observations. Result is a route based forecast for road surface temperature and condition. See the model flowchart below.



An example of a route based forecast is showed below. Warm spots in the forest are still between 3 and 5°C, whereas a cold bridge is already cooled down below 0°C.



Currently there are some pilot projects running with the route based forecasts. The final idea is to use the forecast for dynamic gritting or dynamic routes. Dynamic gritting means that the salt amount is adjusted based on the temperature forecast. Relatively warm spots get less salt compared to colder road sections. This has both environmental and financial benefits. Another option is the use of dynamic routes. Based on the road surface temperature forecast, the most efficient gritting route can be calculated. Technology is available to communicate the route based forecast to the spreader and adjust the salt amount to the temperature forecast.

Mapping meteorological data beyond the meteorological domain

Stephan Siemen and Sylvie Lamy-Thépaut (ECMWF)

The ECMWF's Magics++ graphics library is well known in the meteorological domain. Its design and programming interface are specialised for users in the field of meteorology. With the increasing need to be interoperable with the world of Geographical Information Systems (GIS), Magics was adapted to be able to generate maps which can be easily integrated into these systems. These developments fitted well into Magics new object oriented design (see figure 1) and its flexibility to be used in various setups (see figure 2).

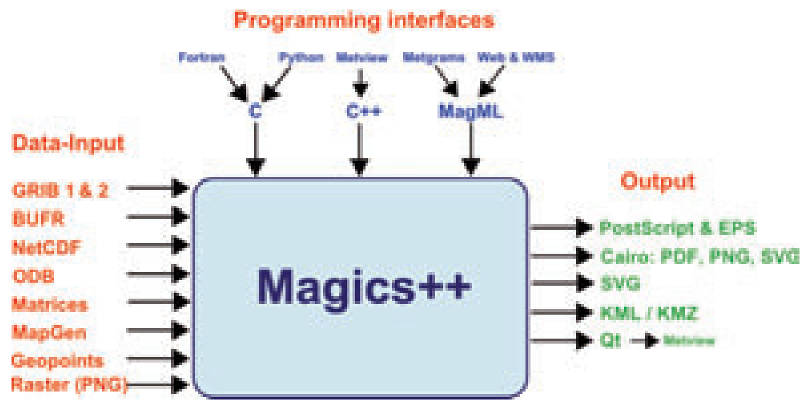


Figure 1 Black Box diagram of Magics++. The flexibility of its design allows an easy integration of new input/output formats and programming interfaces.

To be more interoperable, formats such as shape files for coastlines and software packages such as Proj4 from the GIS community were integrated.

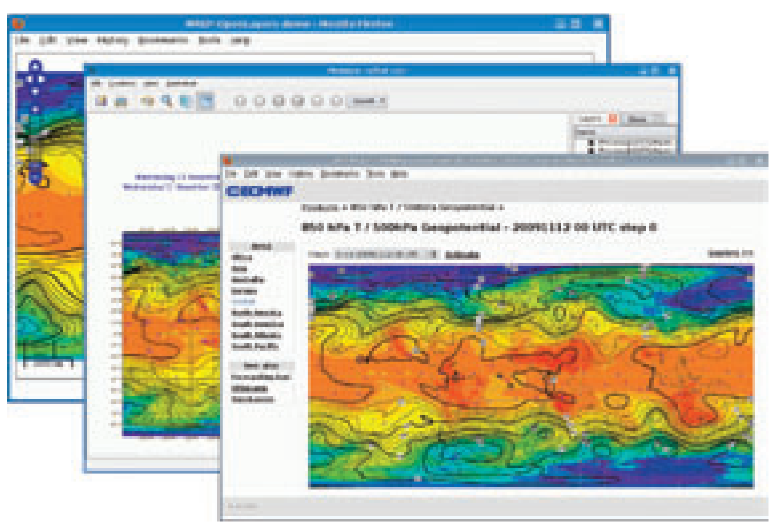


Figure 2 Magics's outputs can be used through different setups. Here Magics++ plots are shown on OpenLayers (through WMS, back), Metview desktop and static web page (front). Not shown are the high quality maps Magics++ can generate for printing.

The integration of Proj4 into Magics++ represented a major step forward in increasing interoperability when overlaying maps from other systems. Figure 3 presents some showcases of this new ability. This will mean that services built on top of Magics++, such as the ECMWF Web Map Service (WMS), can offer more projections which follow GIS standards (e.g. EPSG).

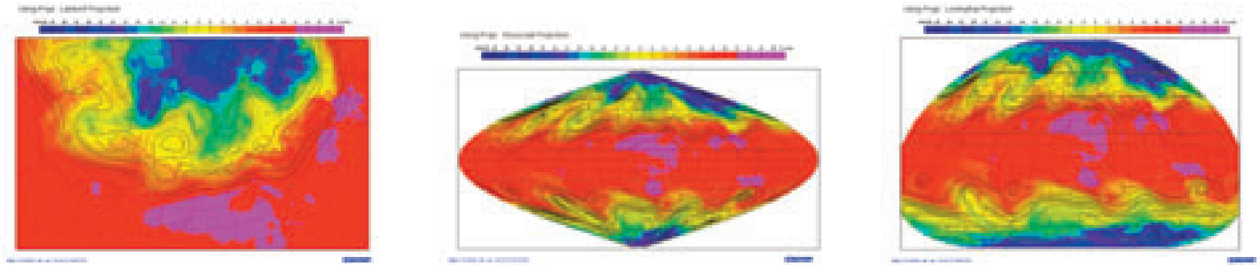


Figure 3 Magics++ plots showcasing the flexibility of new geographical projections, thanks to Proj4.

Very important for the use of Magics++ generated maps in other non-meteorological domains is to support mainstream file formats. In the past Magics only supported output in PostScript. This format was ideal in the Unix world of high quality printing, but is now mostly obsolete when it comes to web and desktop applications. Magics++ has therefore in recent years added support for standard web formats such as PNG and KML (figure 4). KML is widely used in GIS and by the general public through tools, such Google Earth and Google Maps.

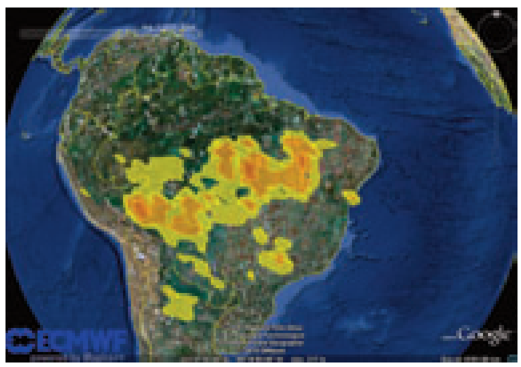


Figure 4 Example of KML output generated for the MACC project by Magics++.

Another output format now supported by Magics++ is the Scalable Vector Graphics (SVG) format. This format is a standard defined by the W3C web standards consortium and part of the new web technologies themed as HTML 5. The format tries to bring the advantages of vector formats (pristine quality and scalable graphics) to the web. Magics++ has extensive support for SVG (see figures 5 and 6).

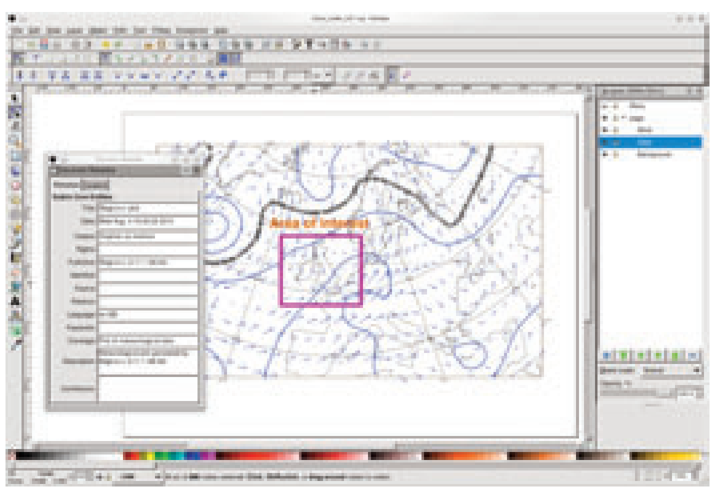


Figure 5 A Magics++ generated plot opened in the SVG editor Inkscape. SVG allows the user to easily edit the plot afterwards (here by adding a box and text to the plot). Magics++ adds meta information to the plot which editors, such as Inkscape, can display (see dialogue box).

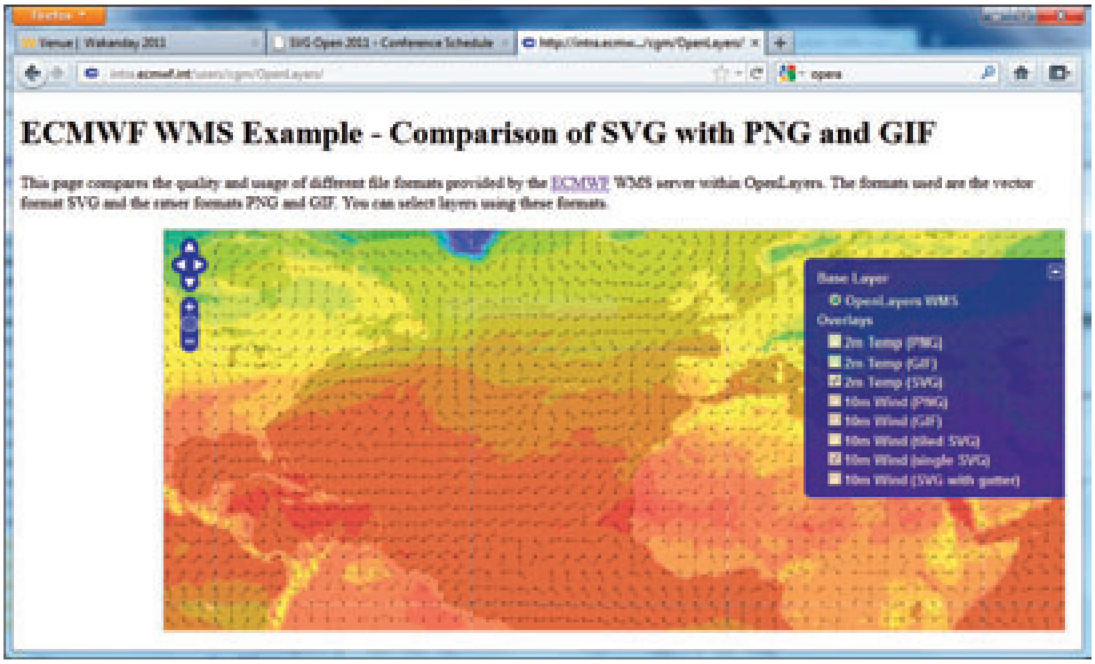


Figure 6 SVG map tiles, generated by Magics++ on the ECMWF WMS server, in OpenLayers.

Conclusion

The new developments of Magics++ take advantage of already well-established code, conventions and data sets from the GIS community and therefore not only increase the interoperability with other plotting systems but will also reduce the maintenance effort of Magics++.

Metview 4: Enhanced functionalities for observation monitoring

Iain Russell, Meteorological Visualisation Section, ECMWF

Abstract

Metview is ECMWF's meteorological workstation software for accessing, manipulating and visualising data, incorporating both an interactive and a batch mode. It is used by analysts and researchers, inside and outside ECMWF, to analyse observation, analysis and model data.

Metview 4 is the latest generation, built on ECMWF core libraries such as GRIB_API, MARS, ODB and Magics. Its enhanced feature set includes many new ways to interact with observation data, making it an ideal tool for observation monitoring. In particular, its ability to handle ECMWF's ODB data has been greatly expanded to include retrieval, processing and interactive display.

Introduction to Metview

Metview is an interactive meteorological application designed to provide the means to access, filter, examine, manipulate, visualise and overlay data of various types from various sources.

It was developed as part of a co-operation between ECMWF, INPE/CPTEC (Brazilian National Institute for Space Research / Centre for Weather Forecasts and Climate Studies), with assistance from Météo-France.

Metview was conceived as having a modular architecture, where modules can be run on difference machines. Modules can be seen as 'mini applications' which sit on top of Metview's kernel, providing both essential and optional functionality. Through this method, Metview can be easily extended by the addition of new modules.

Version 4 of Metview had its first export release in September 2010, and brings together core software packages from ECMWF: GRIB_API, ODB, Magics, MARS and Emoslib.

Standard software libraries such as Qt, Motif and PNG are used within Metview, easing its portability within the UNIX world. Metview has been installed on UNIX systems such as IBM's AIX and various Linux distributions such as SuSE, RedHat and Ubuntu.

Using Metview

Metview can be run in either of two ways: interactively or in batch mode. The interactive user interface is an icon-driven drag-and-drop style interface. Figure 1 shows Metview's user interface in a typical working environment.

Every concept in Metview is represented by an icon. For instance, a GRIB file is displayed as an icon which can, through a right-click menu, be visualised or have its meta-data displayed. Plotting attributes are grouped together and called visual definitions; for example, a Contour Plotting icon contains all of the parameters that can be specified when plotting contours. Such icons can be edited through an intelligent icon editor which ensures that only sensible combinations of parameters are entered.

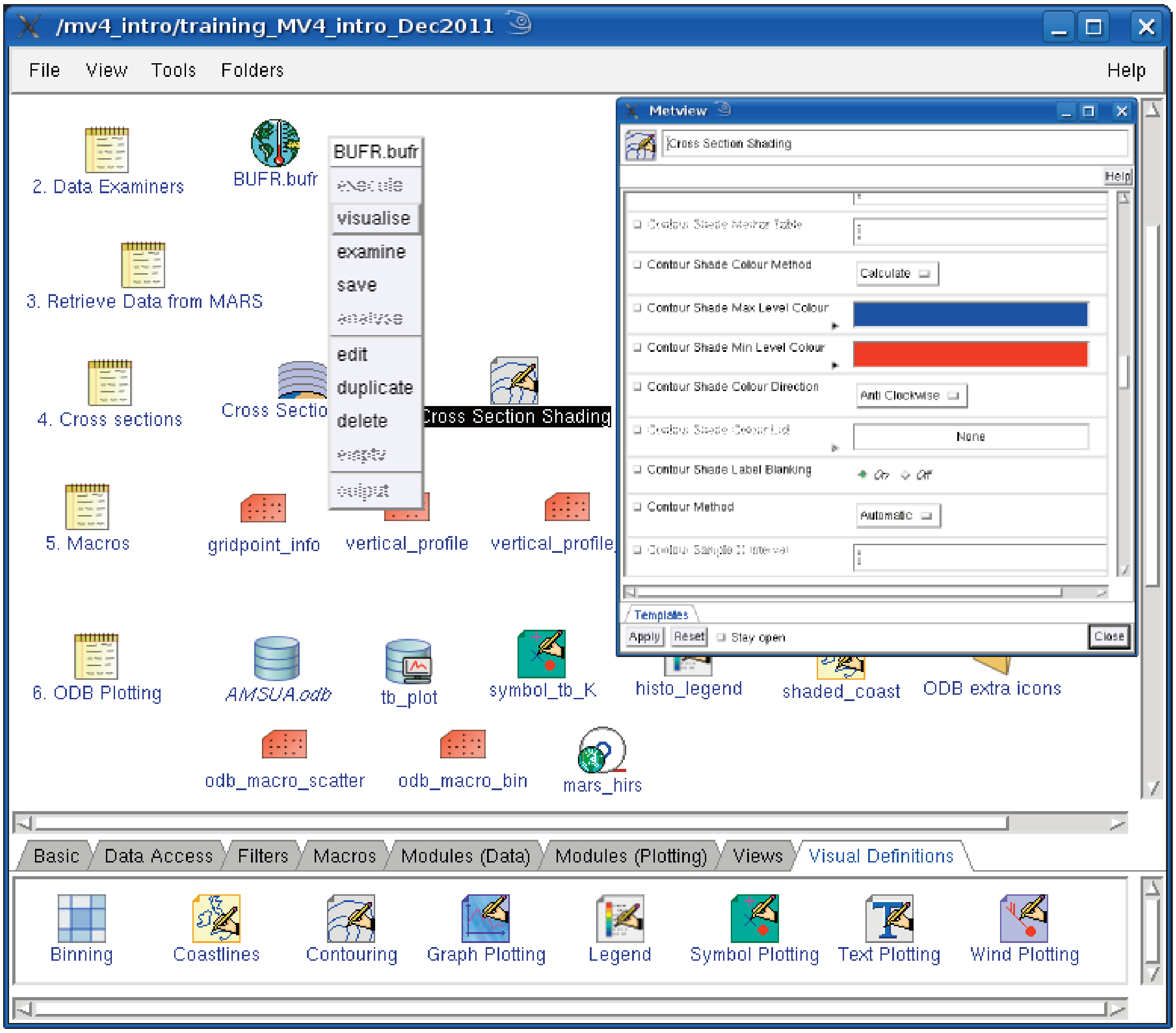


Figure 1 The Metview working environment

Metview Macro is a high-level, meteorologically-oriented scripting language, extendable with user-written C++ or Fortran code. All of Metview's tasks which produce plots or derived data can be written or saved as macros for interactive or batch usage. The supplied Macro editor has the powerful capability of converting any Metview icon into the equivalent Macro code; a user may edit an icon and then drag it into the Macro editor which will generate the code, saving time and ensuring that the code is valid.

Display Window

Built with Magics++ and Qt, Metview's Display Window provides the means to visualise and investigate data. Among its features are a magnifying glass, a cursor data inspection tool and a frame list showing configurable columns of meta-data (Figure 2). More detailed statistics and histograms for visible data are also available in the development version (Figure 3).

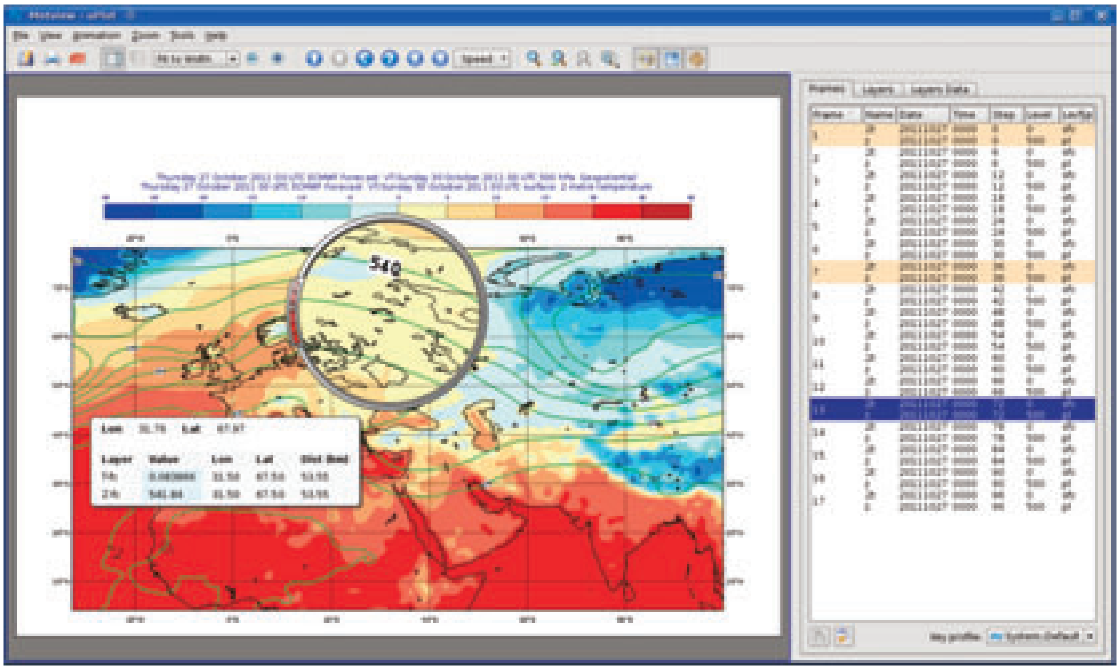


Figure 2 Metview's Display Window provides a powerful environment for investigating data

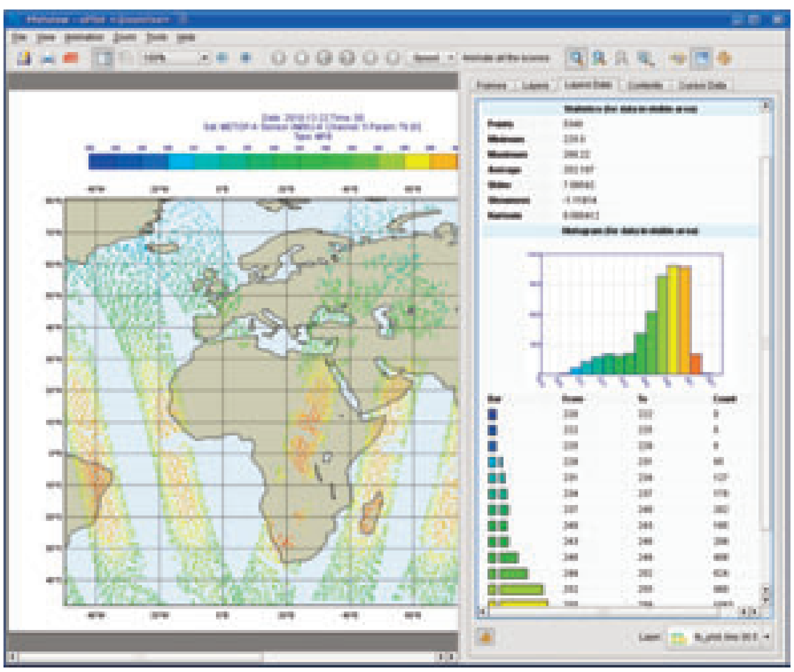


Figure 3 A separate tab shows detailed information about the selected data layer

ODB Support in Metview

ODB is ECMWF's Observational DataBase software, designed for the storage and retrieval of high-volume observational data. From the user's point of view, an ODB database can be seen as a table of columns as shown in Figure 4. Data can be queried using the ODB/SQL language, providing a flexible way to create a subset of data. ODB replaced BUFR observation feedback in ECMWF's MARS archive on 15th November 2011.

Metview's full range of data functionality supports ODB data, as illustrated in Figure 5.

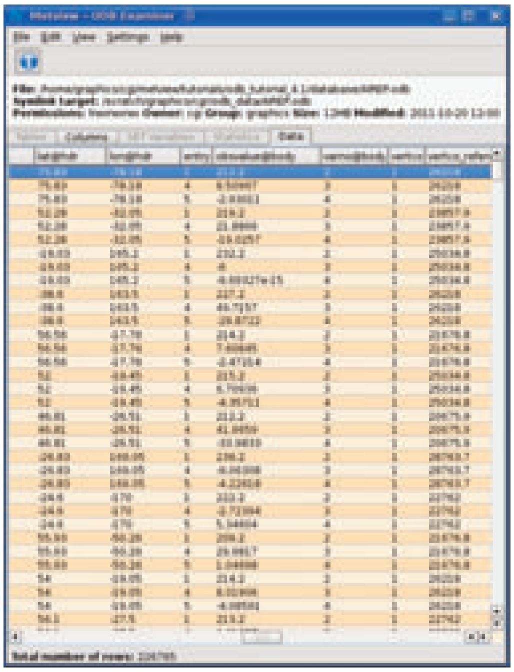


Figure 4 An ODB viewed in Metview's ODB Examiner

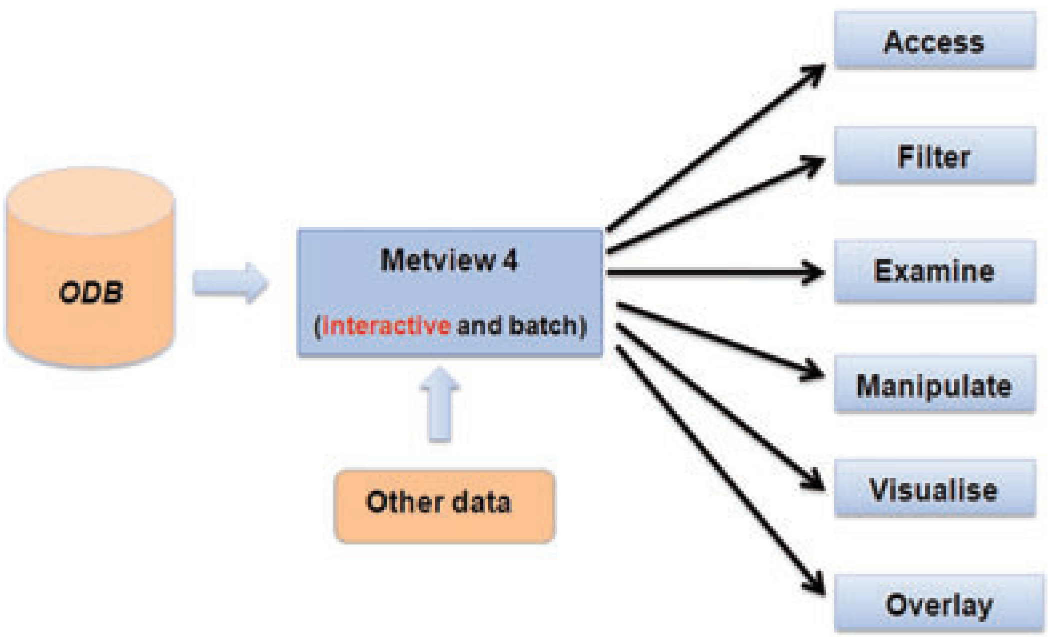


Figure 5 Metview provides comprehensive functionality for working with ODB data

Access: Metview can access ODB data through either the file system or retrieved from MARS, providing a user interface to help construct the query.

Filter: The ODB/SQL language allows Metview users to select and manipulate data from an ODB.

Examine: Metview's ODB Examiner module, as shown in Figure 2, allows easy viewing and sorting of data. It can show meta-data about the columns and display the actual columns of data themselves.

Manipulate: The ODB/SQL language allows some opportunity for simple manipulation during the filtering stage. For more advanced manipulation, or combination with other data, Metview's Macro language provides the necessary tools. ODB data columns can be read into vector variables, allowing numerical processing functionality – see Figure 6 for an example. Columns of textual data are read into lists of strings.

Visualise: Some formats, such as GRIB, are easy to visualise in Metview - just right-click | Visualise. This is because they are quite constrained in their contents and have enough standardised meta-data for a program to understand how they should be plotted. ODBs can contain large numbers of columns, so which ones do we want to plot? How do we want to plot them - on a map, as a scatter plot, as a matrix? The ODB Visualiser icon provides the means to specify these things; examples of resulting plots are shown in Figure 7. Metview provides visualiser icons for other data formats that require the same treatment, currently netCDF, ASCII tables and user-input lists of data. This functionality is new to Metview 4.1. An additional legend style was added to Magics for the purpose of displaying a histogram of the data as also shown in Figure 7; this also works for other data types, showing how enhancements made for observation monitoring can positively impact other areas of Metview (and Magics).

Overlay: Metview's overlay facilities allow ODB data to be visualised in the same plot as other data; just drop a data icon into the Display Window in order to perform the overlay.

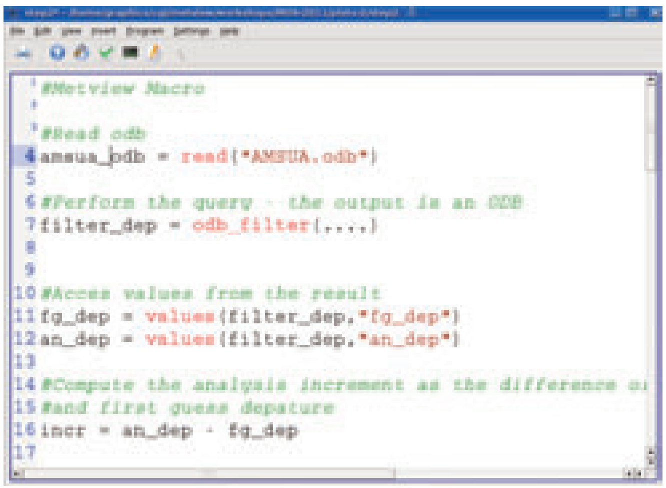


Figure 6 A portion of a macro code which reads, filters and manipulates ODB data

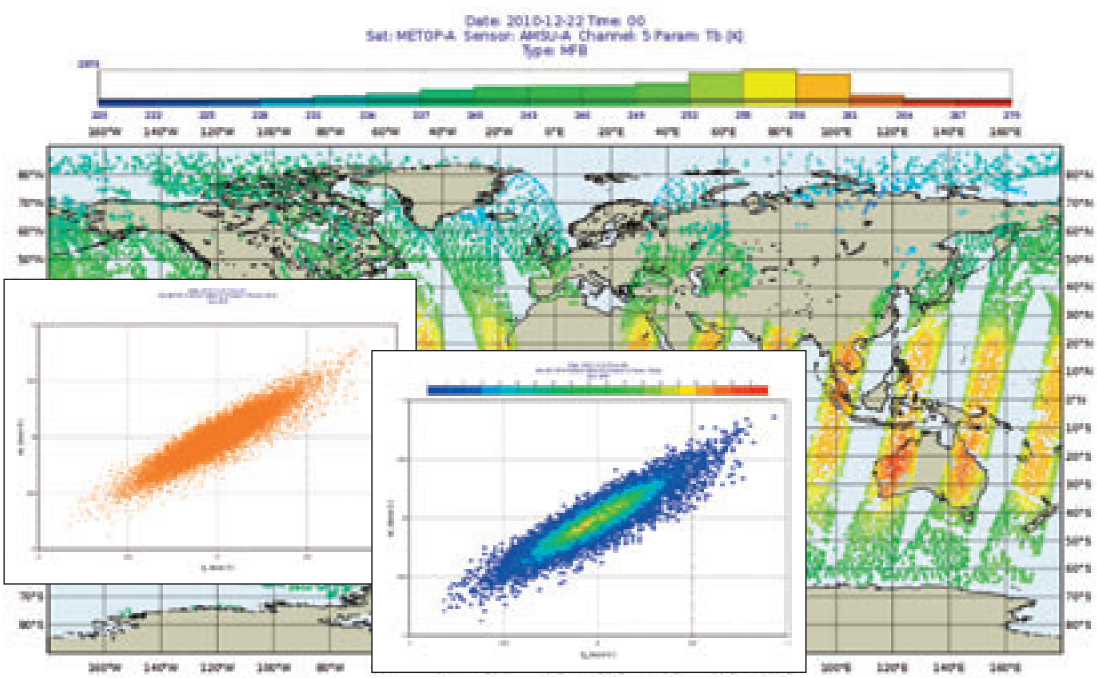


Figure 7 Three different ways to visualise data from the same ODB: as scattered geographical points (back), as an 'xy scatterplot' (middle) and as a 'binned xy scatterplot' (front). Visual definitions have been added to these plots. The geographical plot demonstrates the legend's histogram mode.

Next Steps

Usage of Metview 4 for handling ODB data is still in the early stages, and has so far been limited to internal use at ECMWF. The details of the interface have already undergone some revisions, and as users start to delve more deeply into their data, Metview will almost certainly need to evolve to satisfy requirements; but in doing so, any improvements should be generic enough that they also benefit the handling of other data types as well.

For More Information

The Metview web pages, including tutorials on using ODB data with Metview can be found at:

http://www.ecmwf.int/publications/manuals/metview/

Diana – ideas on standards and future directions

David Boddie, Norwegian Meteorological Institute (met.no)

Abstract

Diana is an open source visualisation tool that plays a key role in a suite of meteorological workstation software used for forecasting and research at met.no.

In this document, we examine the use of meteorological and technological standards in Diana, from common file formats and libraries to integration with online services. We discuss the impact of technology choices on future development and explore ideas for ways to consolidate and expand existing features.

Overview

Diana provides an environment for analysis and exploration of data from observations and numerical weather forecasting models, enabling researchers and forecasters to combine data from many sources together as layers in a dynamic user interface (Figure 1). Like other comparable tools, various map data formats are supported, and maps can be displayed using a set of standard projections.

Diana is an operational tool that is integrated into a forecasting system, allowing meteorologists to interact with the field data generated by numerical models, annotate maps, and create products for publication.

The application is released under a Free Software license; the libraries that it builds upon are also released under Free and Open Source licenses. This includes software written by both met.no and various third parties. Diana is developed in cooperation with the Swedish Meteorological and Hydrological Institute (SMHI); it is used in both a governmental setting and in the private sector.

The application itself is written in C++ and relies on a number of technologies to provide support for common standards in the meteorological world. In order to maintain a stable platform for users of the software at met.no, releases of Diana are produced for Long Term Support (LTS) releases of the Ubuntu operating system.

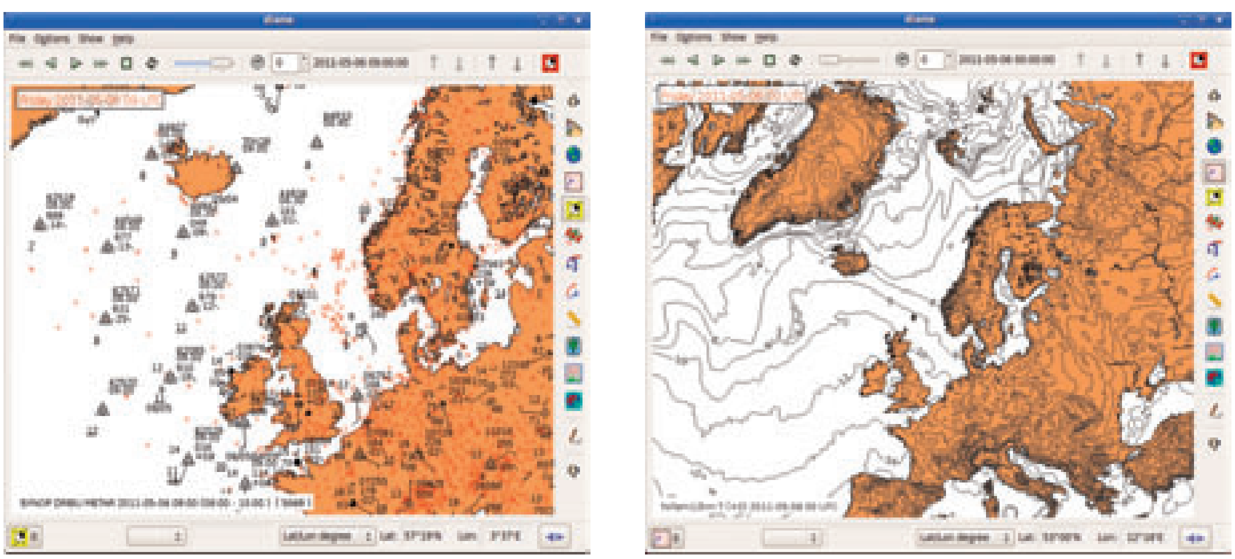


Figure 1 Example representations of observations and fields in Diana.

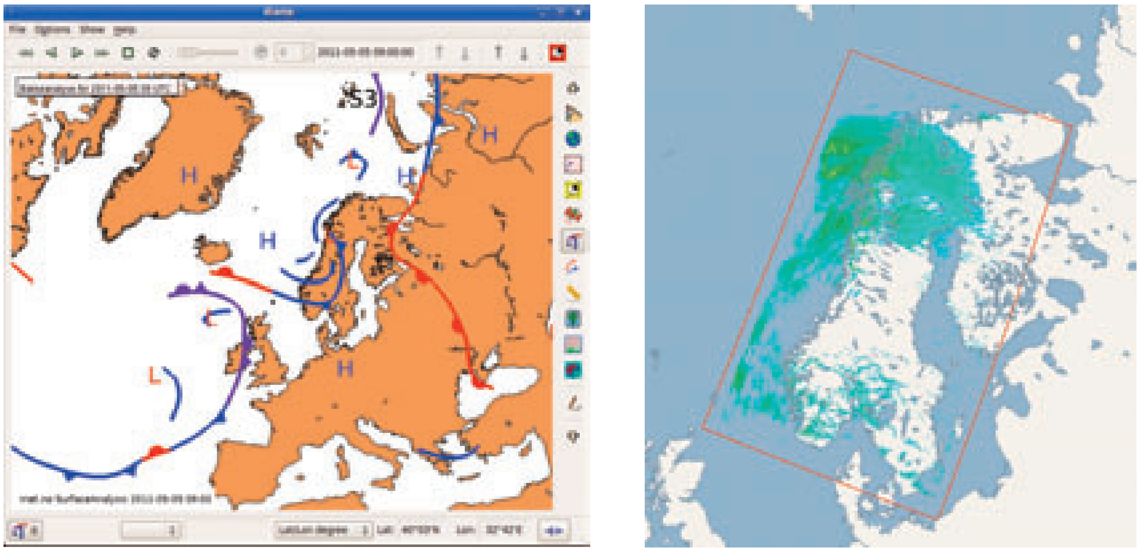


Figure 2 Objects added to a map for explanatory purposes; Web Map Service image generated by Diana.

Standards and Technologies

Traditionally, some of the data formats supported by Diana have been proprietary or ad-hoc standards created out of necessity. However, as more data is shared between institutions and with the public, a growing collection of open standards have emerged, and many of the most important ones are supported by Diana, either directly or through the use of support libraries.

For example, Felt files describing fields and MiTIFF files containing radar or satellite images are being superseded by NetCDF and GeoTIFF files respectively. These replacement formats and other standard formats, such as BUFR for observations, HDF5 for data storage and encapsulation, GRIB for gridded data and Shapefile for geographic areas, are also read using freely available third party libraries.

Diana uses the Fimex library[1] to read formats such as Felt, NetCDF and GRIB, where some processing or reprojection may be required. This introduces a layer of abstraction that should make it easier for Diana to support additional formats in the future. Fimex can also access data via the Data Access Protocol (DAP) protocol, using the OpeNDAP framework, enabling data to be obtained from sites such as the met.no THREDDS service[2].

A collection of general technologies are used to create the workstation's user interface and perform integration with the user's environment. The graphical user interface is built using the Qt framework[3], rendering is performed using the system's OpenGL API, and printed output can be produced in PostScript and PDF formats. Libraries from the Boost project[4] are used throughout to provide low-level, common datatypes.

Additional technologies are used to communicate with databases and services for the purpose of creating forecasting products. PostgreSQL client libraries are used to access the met.no Weather Database for the purpose of retrieving data for the Profet grid editor[5] that is part of Diana. Information about changes made to the grid system are communicated to the database via CORBA using omniORB[6].

Future Plans

As Diana acquires more features and the need for interoperability with other tools increases, it is useful to evaluate existing technologies for adoption. This can help to reduce maintenance costs, improve compatibility with other tools, and lead to additional features and benefits, such as improved performance.

One example where standardisation around an existing technology would be beneficial is in the use of a generic geometry library or framework in Diana and other related applications. Currently, different applications use different sets of C++ classes to describe geometric concepts, such as points, lines and polygons. Additionally, these concepts may be given different representations.

Commonly used frameworks such as Boost.Geometry[7] or SpatiaLite[8], as well as the adoption of standard file formats such as Well-Known-Text[9], may be able to help us to consolidate our existing solutions for geometry handling around a well-maintained core set of technologies. Evaluation of available technologies remains a consideration as we gradually improve our applications, and begin to use them in new environments.

As users increasingly use the World Wide Web as an interface to applications and data sources, support for technologies such as Web Map Service (WMS) become more important. Diana has already been used to create content for such services (Figure 2), and it is expected that further developments in this area are needed to meet the expectations of researchers and meteorologists.

References

[1] File Interpolation, Manipulation and EXtraction library: http://wiki.met.no/fimex

[2] Thredds at Met.no: http://thredds.met.no

[3] Qt Project: http://www.qt-project.org

[4] Boost C++ libraries: http://boost.org

[5] Audun Christoffersen, 2010. Developments on the operational systems at met.no, 21st European Working Group on Operational meteorological Workstations (EGOWS). http://www.ecmwf.int/newsevents/meetings/workshops/2009/MOS_12/

[6] omniORB: http://omniorb.sourceforge.net

[7] Boost.Geometry: http://www.boost.org/libs/geometry

[8] SpatiaLite: http://www.gaia-gis.it/spatialite

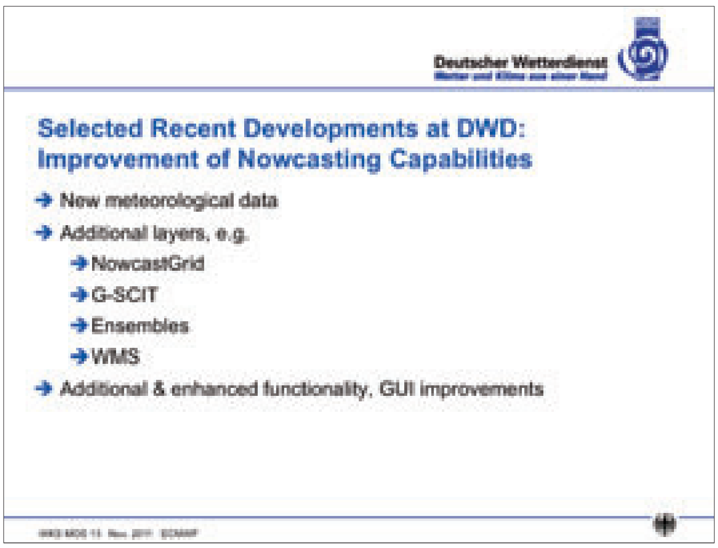
[9] Open Geospatial Consortium, Inc., 2001. OpenGIS Implementation Specification: Coordinate Transformation Services, Revision 1.00, p.18. http://www.opengeospatial.org/docs/01-009.pdf

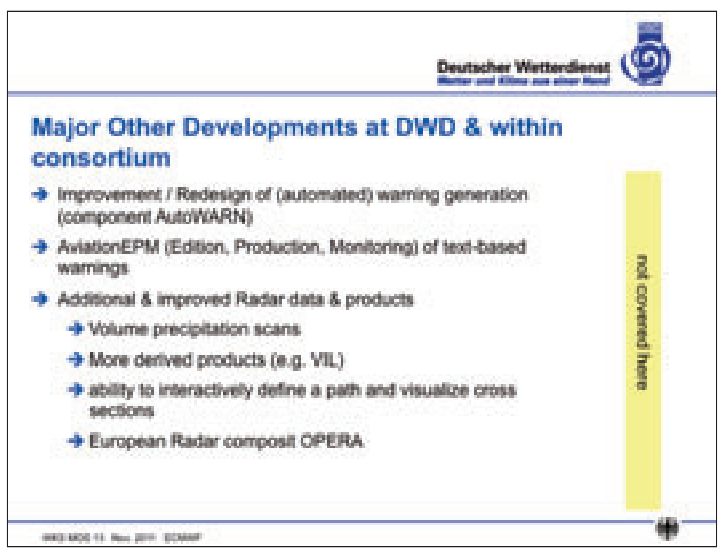
Recent developments of the meteorological workstation NinJo

Gerhard Eymann, Deutscher Wetterdienst (DWD)

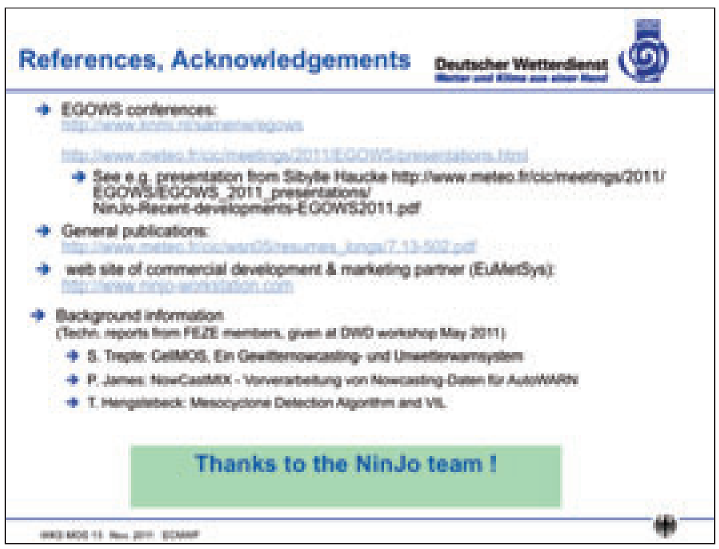
The presentation is focused on selected recent developments at DWD and the NinJo consortium. The ability to handle and visualize nowcast data was enhanced considerably. These data arise from postprocessing of forecast data and improved analysis of Radar data.

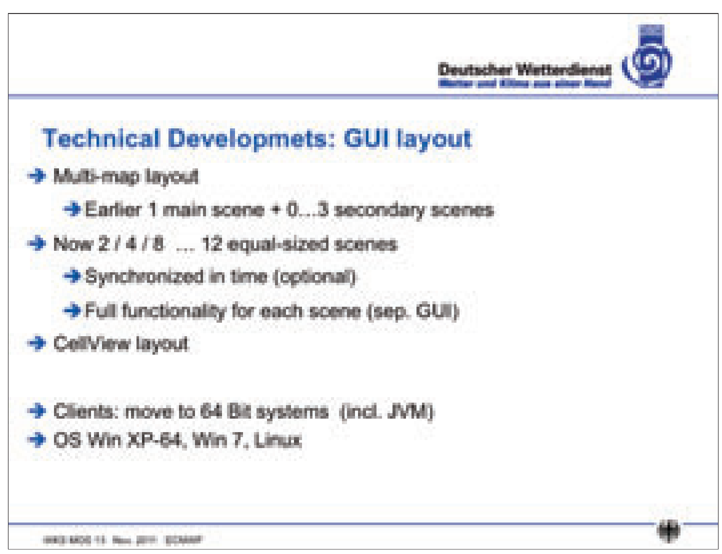
Also introduced are technical improvements with respect to the GUI and configuration. These include a more flexible way of arranging graphically interactive windows and maintance the configuration. Efforts have been undertaken to monitor the quality of graphical output in a statistical way, in particular for the batch production process.

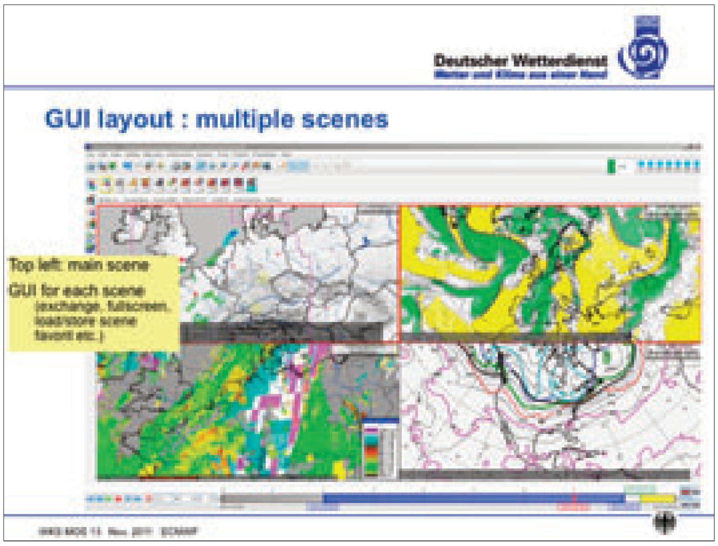


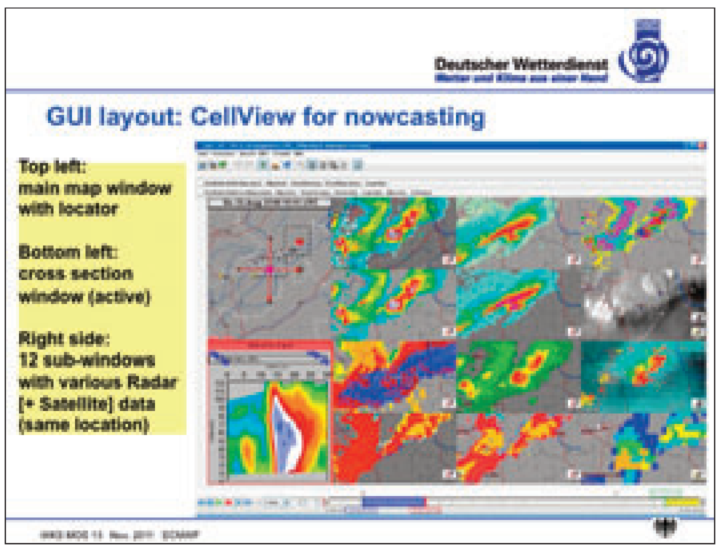


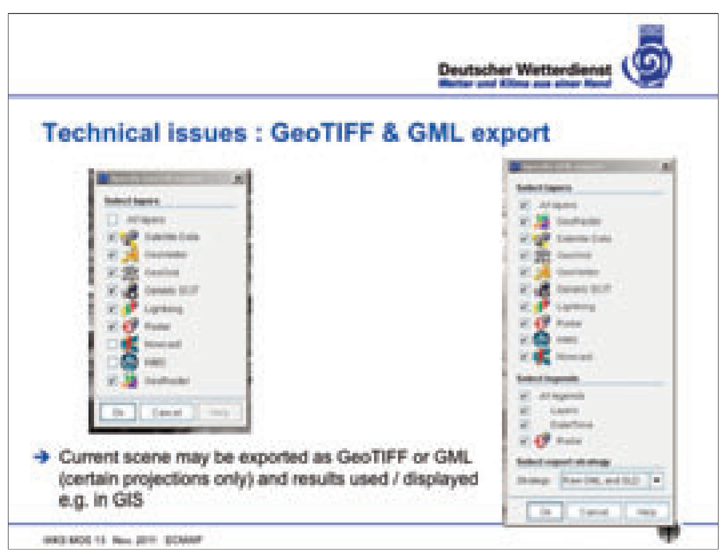

Deutscher Wetterdienst
Wetter und Klima aus einer Hand
Major Other Developments (cont'd)
Considerable extensions of Interactive Graphical Editor / Product Workbench
Satellite layer: volcanic ash products
NinJo Batch: off-line graphic products
Batch Test Suite (BTS): automatic test of products
Regression tests
Web-based GUI
... and much more
not covered here


References, Acknowledgements
Deutscher Wetterdienst
Wetter und Klima aus einer Hand
EGOWS conferences:
http://www.knmi.nl/samenw/egows
http://www.meteo.fr/cic/meetings/2011/EGOWS/presentations.html
See e.g. presentation from Sibylle Haucke http://www.meteo.fr/cic/meetings/2011/EGOWS/EGOWS_2011_presentations/NinJo-Recent-developments-EGOWS2011.pdf
General publications:
http://www.meteo.fr/cic/wsn05/resumes_longs/7.13-502.pdf
web site of commercial development & marketing partner (EuMetSys):
http://www.ninjo-workstation.com
Background information
(Techn. reports from FEZE members, given at DWD workshop May 2011)
S. Trepte: CellMOS, Ein Gewitternowcasting- und Unwetterwarnsystem
P. James: NowCastMIX - Vorverarbeitung von Nowcasting-Daten für AutoWARN
T. Hengstebeck: Mesocyclone Detection Algorithm and VIL
Thanks to the NinJo team !


Deutscher Wetterdienst
Wetter und Klima aus einer Hand
Technical Developmets: GUI layout
Multi-map layout
Earlier 1 main scene + 0...3 secondary scenes
Now 2 / 4 / 8 ... 12 equal-sized scenes
Synchronized in time (optional)
Full functionality for each scene (sep. GUI)
CellView layout
Clients: move to 64 Bit systems (incl. JVM)
OS Win XP-64, Win 7, Linux

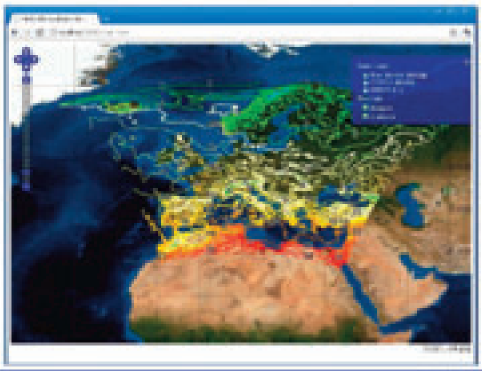

Deutscher Wetterdienst
GUI layout : multiple scenes
Top left: main scene
GUI for each scene
(exchange, fullscreen, load/store scene favorit etc.)


Deutscher Wetterdienst
GUI layout: CellView for nowcasting
Top left:
main map window
with locator
Bottom left:
cross section
window (active)
Right side:
12 sub-windows
with various Radar
[+ Satellite] data
(same location)


Deutscher Wetterdienst
Technical issues : GeoTIFF & GML export
Current scene may be exported as GeoTIFF or GML
(certain projections only) and results used / displayed
e.g. in GIS

Deutscher Wetterdienst

GML export example (visualized by WMS client)



Deutscher Wetterdienst

Recent Developments: Nowcasting Layer

- Data types:
  - NowcastMIX
  - CellMOS
  - RADVOR-OP (earlier in NWP layer)
- automatic update of model run
  - also (as available earlier) automatic update of time
  - model-run frequency 5 min … 15 min
- all visualization methods of grid data possible
  - Isoline, isoarea, pixel-related, filtering methods

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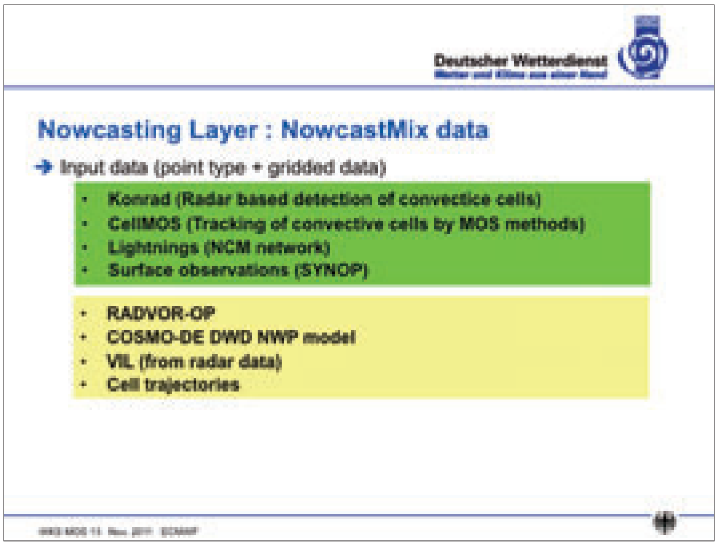
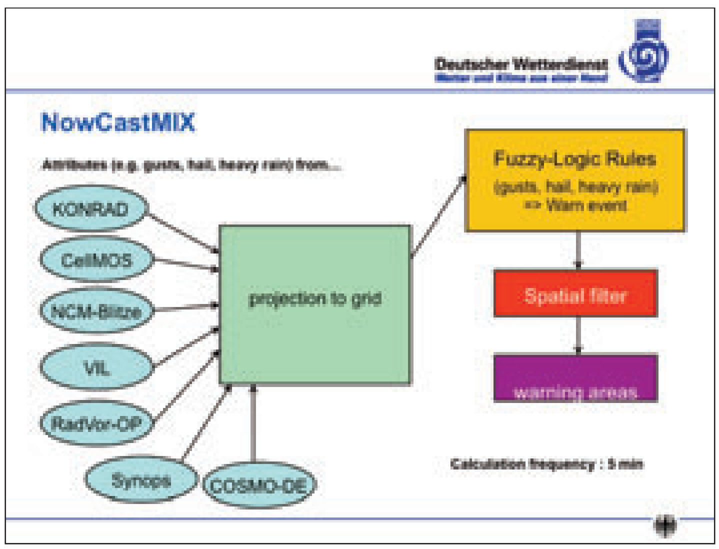
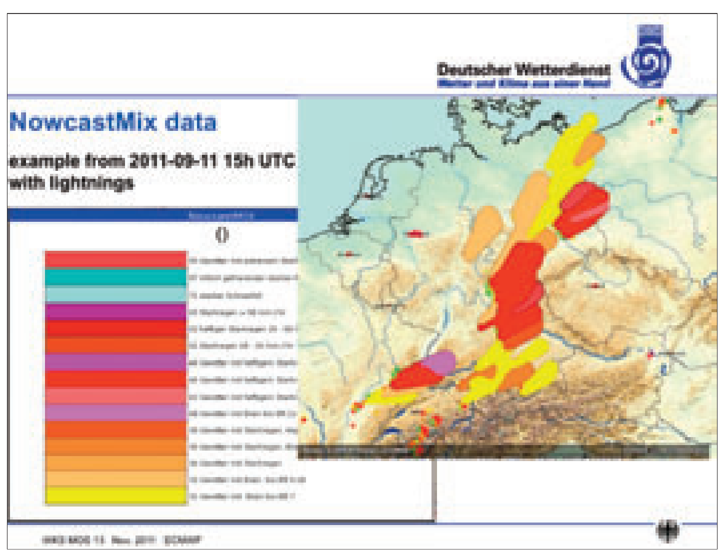
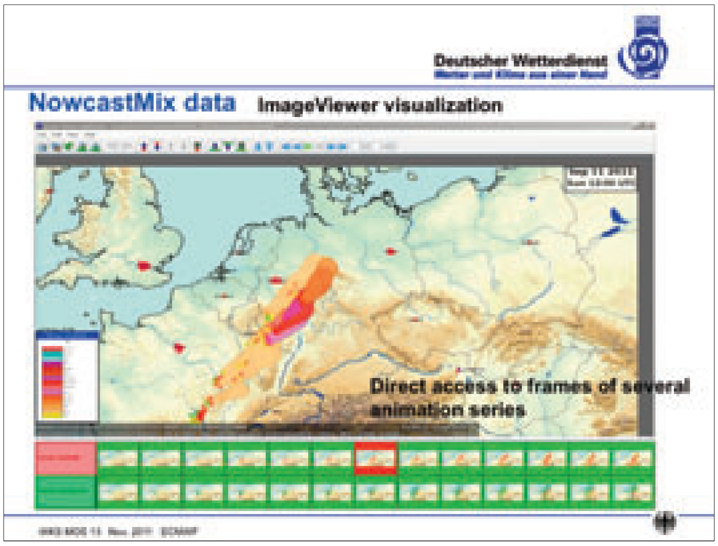
Nowcasting Layer : NowcastMix data

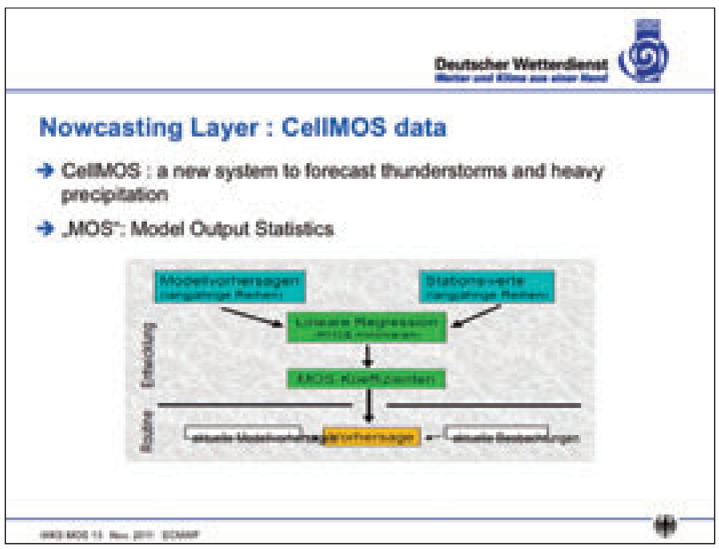
- Simulteaneous monitoring & analysis of several important types of input data in order to produce a unique value indicating the kind and severity of an expected weather event, depending on location
- Auto WARN: monitor several data types individually
- NowcastMIX: only one (per location) parameter is output
- Combined evaluation of relevant data
- Has meteorological „intelligence" through filtering and weighting
- Serves as AutoWARN input

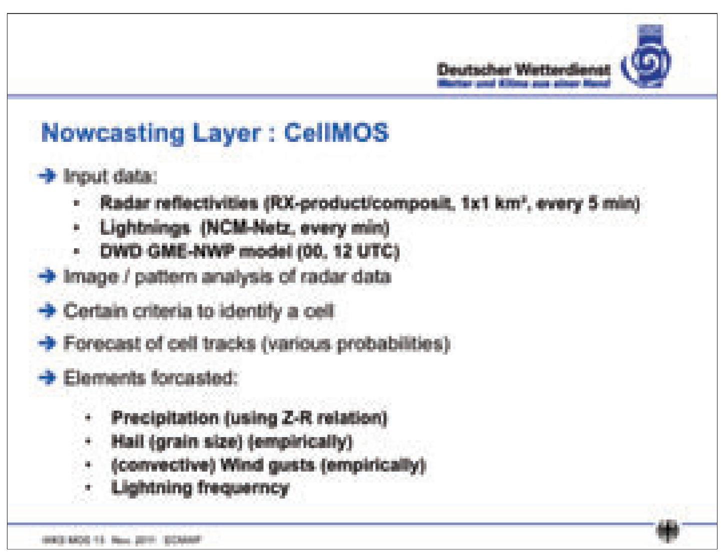

Deutscher Wetterdienst
Nowcasting Layer : NowcastMix data
➔ Input data (point type + gridded data)
• Konrad (Radar based detection of convectice cells)
• CellMOS (Tracking of convective cells by MOS methods)
• Lightnings (NCM network)
• Surface observations (SYNOP)
• RADVOR-OP
• COSMO-DE DWD NWP model
• VIL (from radar data)
• Cell trajectories

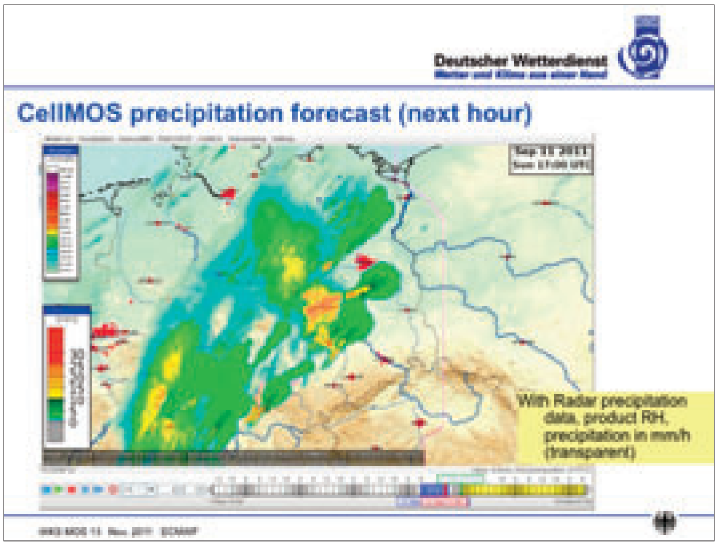

Deutscher Wetterdienst
NowCastMIX
Attributes (e.g. gusts, hail, heavy rain) from...
KONRAD
CellMOS
NCM-Blitze
VIL
RadVor-OP
Synops
COSMO-DE
projection to grid
Fuzzy-Logic Rules
(gusts, hail, heavy rain)
=> Warn event
Spatial filter
warning areas
Calculation frequency : 5 min

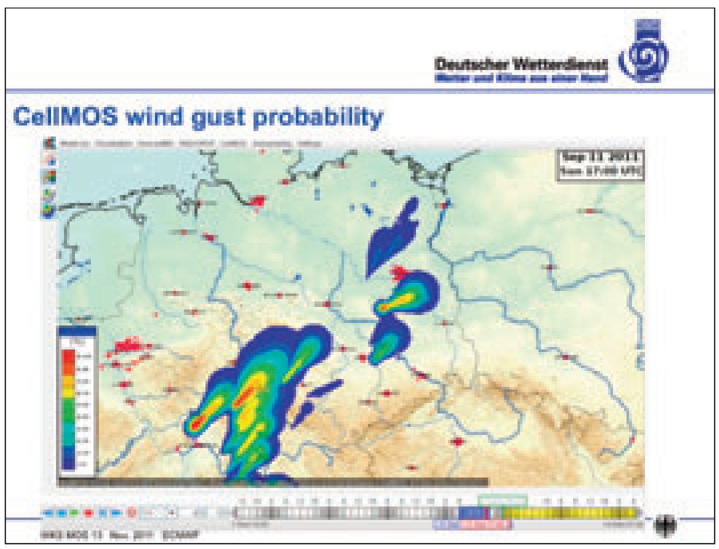

Deutscher Wetterdienst
NowcastMix data
example from 2011-09-11 15h UTC
with lightnings


Deutscher Wetterdienst
NowcastMix data
ImageViewer visualization
Direct access to frames of several animation series


Deutscher Wetterdienst
Nowcasting Layer : CellMOS data
CellMOS : a new system to forecast thunderstorms and heavy precipitation
„MOS": Model Output Statistics
Modellvorhersagen
Stationswerte
Lineare Regression
MOS-Koeffizienten
Entwicklung
Routine
Vorhersagen


Deutscher Wetterdienst
Nowcasting Layer : CellMOS
Input data:
Radar reflectivities (RX-product/composit, 1x1 km², every 5 min)
Lightnings (NCM-Netz, every min)
DWD GME-NWP model (00, 12 UTC)
Image / pattern analysis of radar data
Certain criteria to identify a cell
Forecast of cell tracks (various probabilities)
Elements forcasted:
Precipitation (using Z-R relation)
Hail (grain size) (empirically)
(convective) Wind gusts (empirically)
Lightning frequerncy





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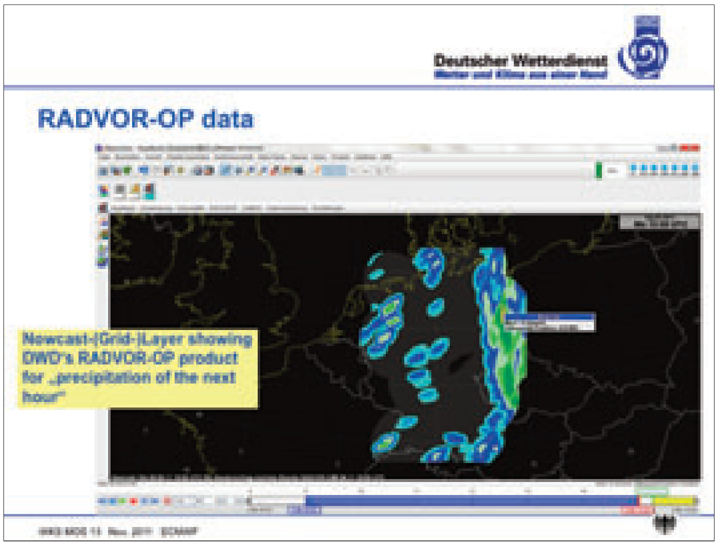
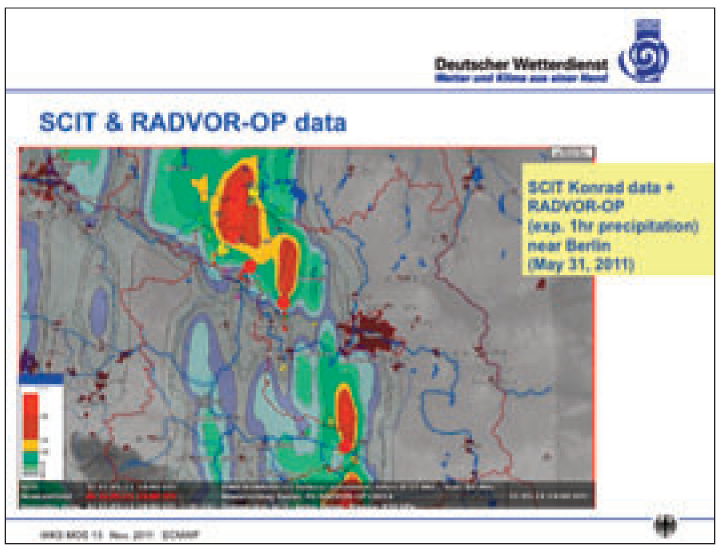
Nowcasting Layer : RADVOR-OP data

- ➔ Data provided by climatological / hydrological dept.
  - ➔ project Radolan
  - ➔ in NWP layer earlier
- ➔ Radar based forecast and analysis of precipitations
- ➔ Various products, also calibrated
- ➔ Forecast for ½ and 1 hour, available in steps of 5 & 15 min.





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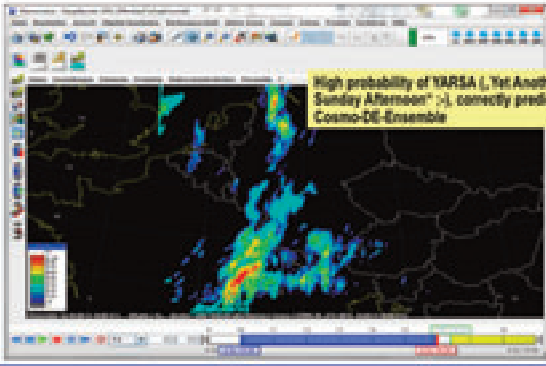
Ensemble Layer

- → Models
  - → COSMOS_DE_EPS
  - → COSMO-LEPS
  - → ECMWF_EPS
  - → PEPS

  → More visualization types for meteograms

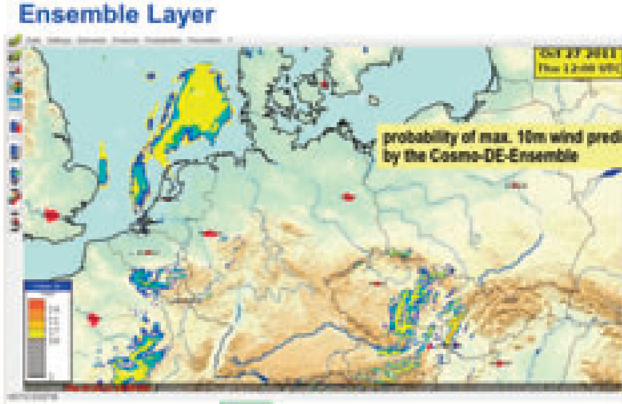
Deutscher Wetterdienst

Ensemble Layer



Deutscher Wetterdienst

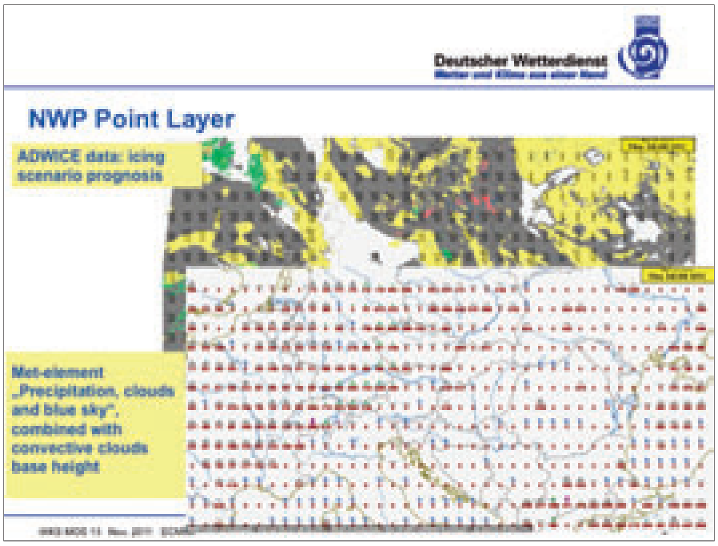
Ensemble Layer



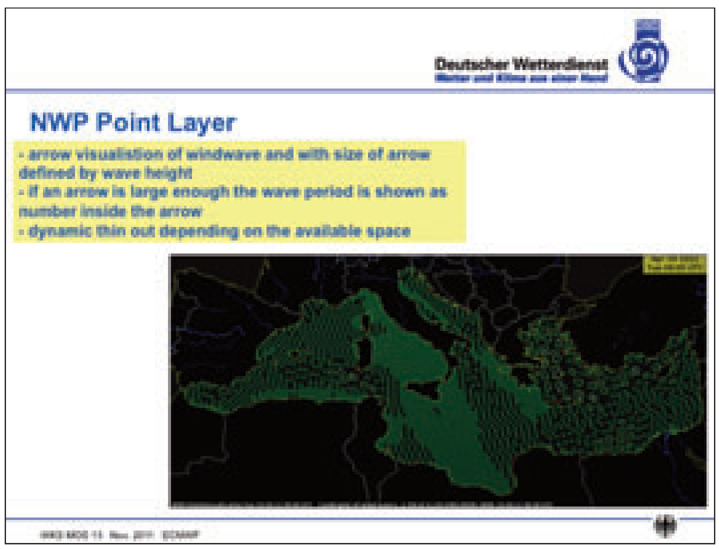
Deutscher Wetterdienst

Numerical Weather Forecast Point Layer

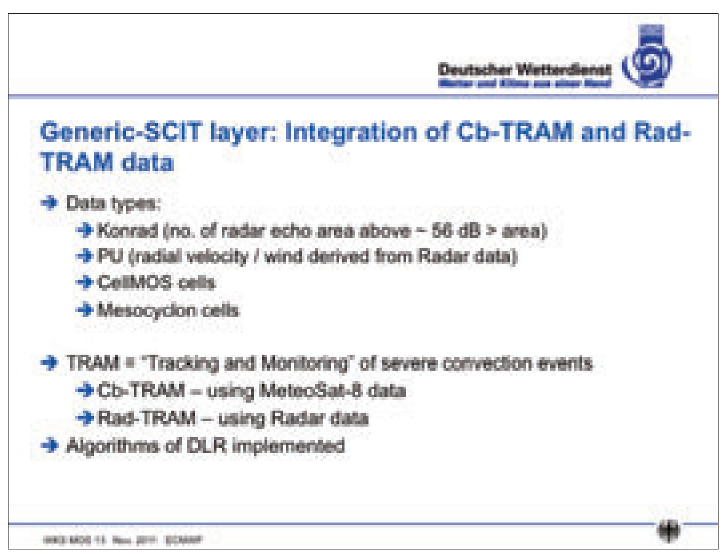
- ➔ Specialized combi plots for gridded model data
  - ➔ Visualization methods taken from point data layer
- ➔ Maps for aviation & maritime purposes
  - ➔ WAFC data
  - ➔ ADWICE data
  - ➔ Wave height models
  - ➔ Used also for batch products



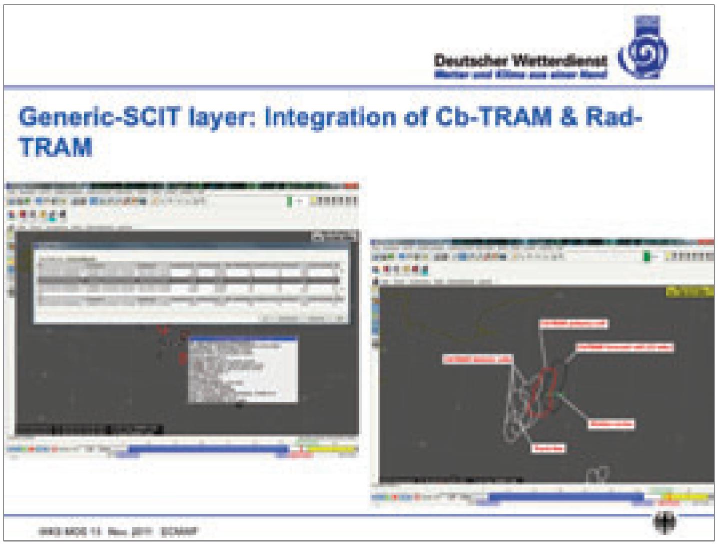
Deutscher Wetterdienst
NWP Point Layer
ADWICE data: icing scenario prognosis
Met-element „Precipitation, clouds and blue sky", combined with convective clouds base height

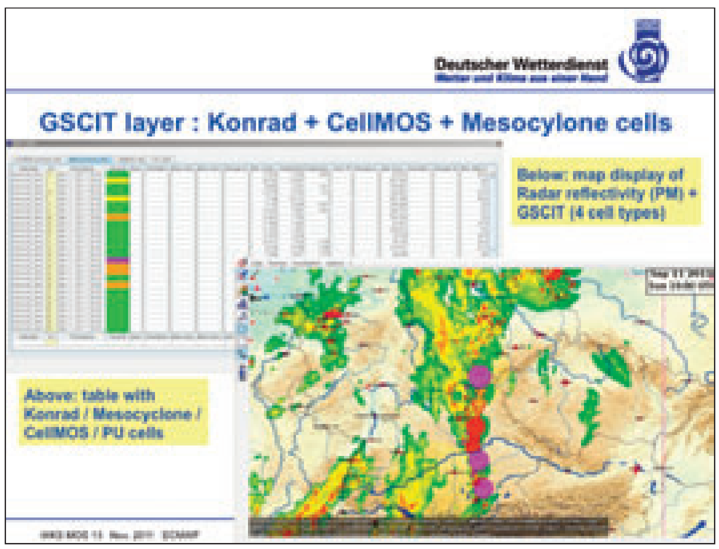


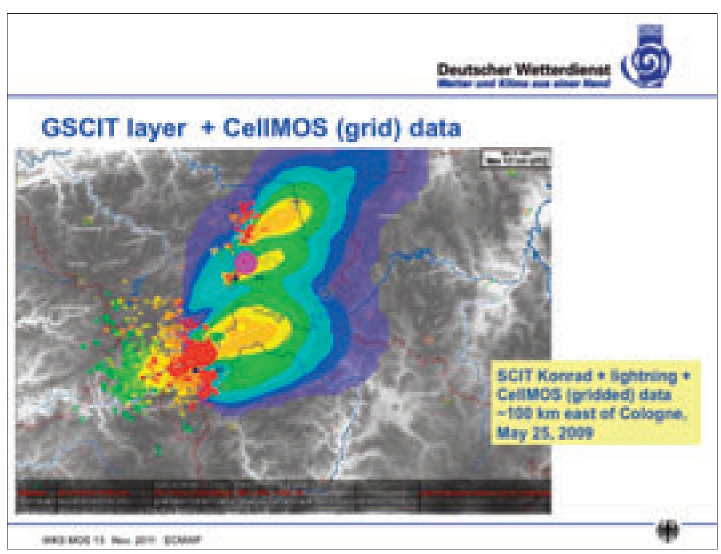
Deutscher Wetterdienst
NWP Point Layer
- arrow visualistion of windwave and with size of arrow defined by wave height
- if an arrow is large enough the wave period is shown as number inside the arrow
- dynamic thin out depending on the available space



Deutscher Wetterdienst
Generic-SCIT layer: Integration of Cb-TRAM and Rad-TRAM data
Data types:
Konrad (no. of radar echo area above ~ 56 dB > area)
PU (radial velocity / wind derived from Radar data)
CellMOS cells
Mesocyclon cells
TRAM = "Tracking and Monitoring" of severe convection events
Cb-TRAM – using MeteoSat-8 data
Rad-TRAM – using Radar data
Algorithms of DLR implemented


Deutscher Wetterdienst
Generic-SCIT layer: Integration of Cb-TRAM & Rad-TRAM


Deutscher Wetterdienst
GSCIT layer : Konrad + CellMOS + Mesocylone cells
Below: map display of Radar reflectivity (PM) + GSCIT (4 cell types)
Above: table with Konrad / Mesocyclone / CellMOS / PU cells


Deutscher Wetterdienst
GSCIT layer + CellMOS (grid) data
SCIT Konrad + lightning + CellMOS (gridded) data ~100 km east of Cologne, May 25, 2009

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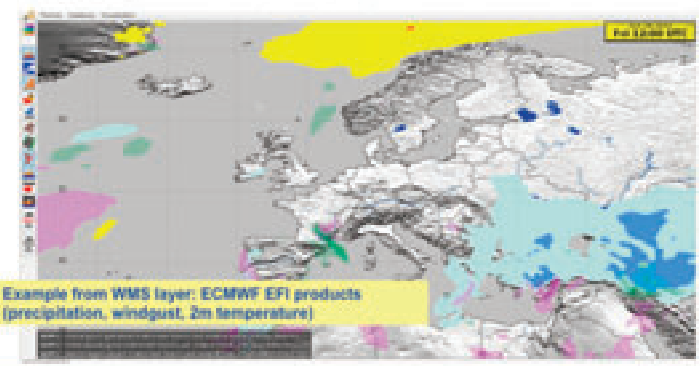
Wetter und Klima aus einer Hand

Web Map Service (WMS) Layer

- Legends available
- Selection of time-step and other feature via GUI
- Participation at ECMWF interoperabilty experiment
- see egows presentation

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

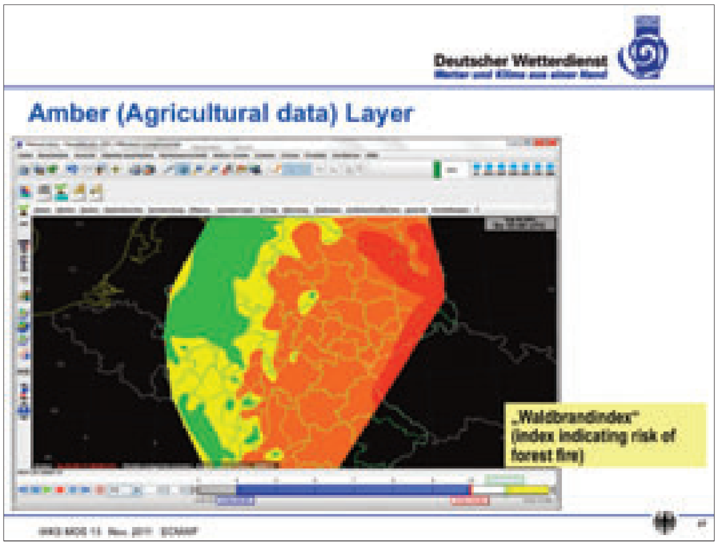
Web Map Service (WMS) Layer

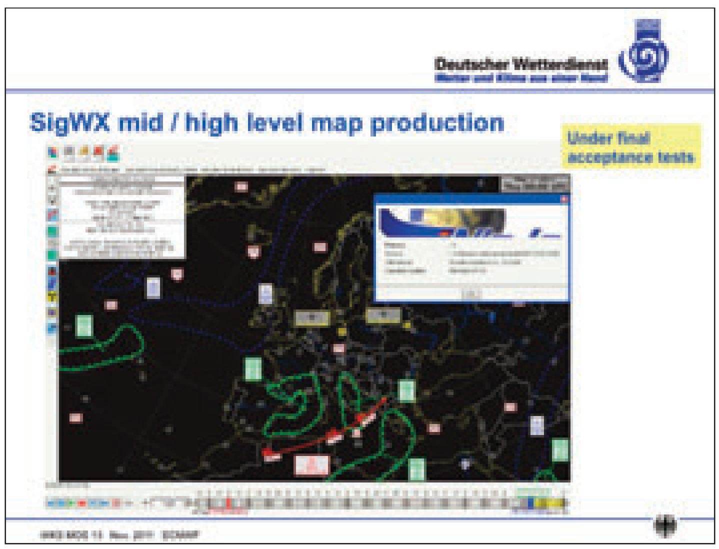


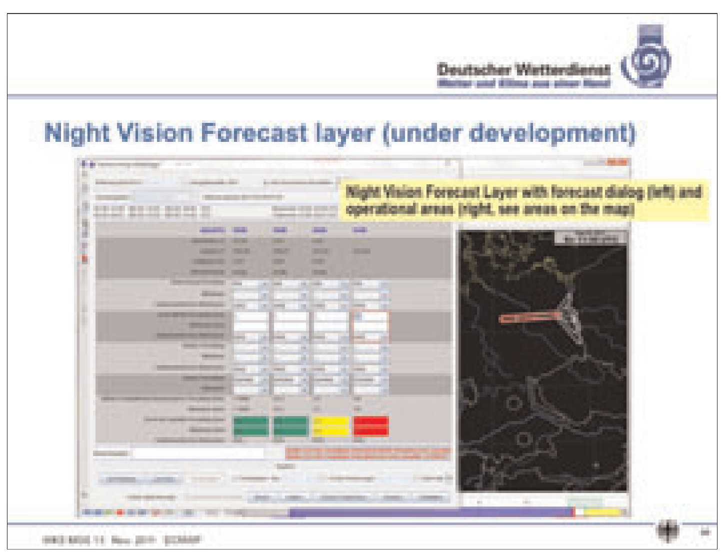
Deutscher Wetterdienst
Wetter und Klima aus einer Hand

Amber (Agricultural data) Layer

- Various data
  - Observations
  - Phenological data
  - Forecasts
- More climatological data to come


Deutscher Wetterdienst
Amber (Agricultural data) Layer
„Waldbrandindex"
(index indicating risk of forest fire)

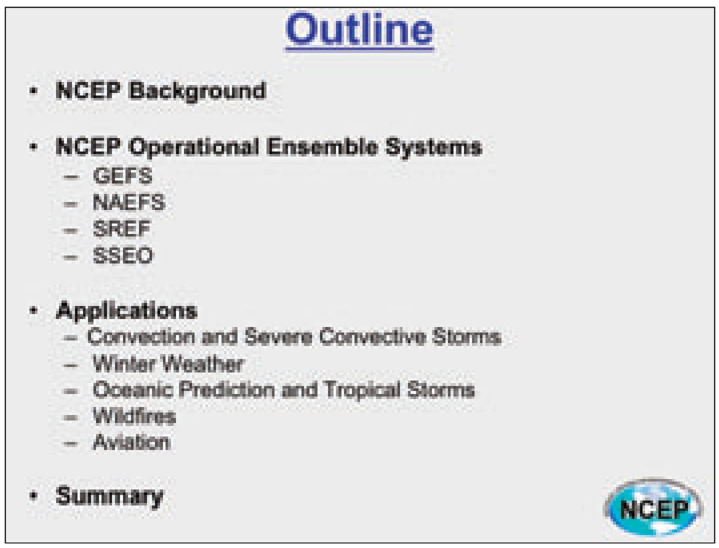

Deutscher Wetterdienst
SigWX mid / high level map production
Under final acceptance tests

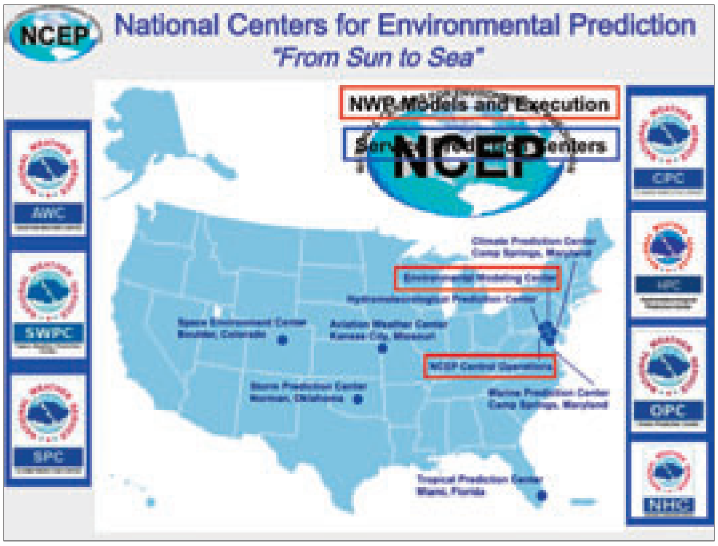

Deutscher Wetterdienst
Night Vision Forecast layer (under development)
Night Vision Forecast Layer with forecast dialog (left) and operational areas (right, see areas on the map)

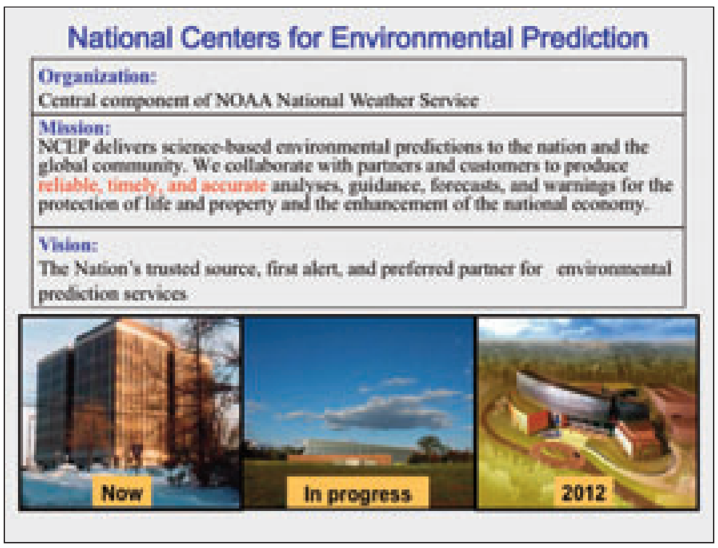
The NCEP application of ensemble information across multiple scales and user groups

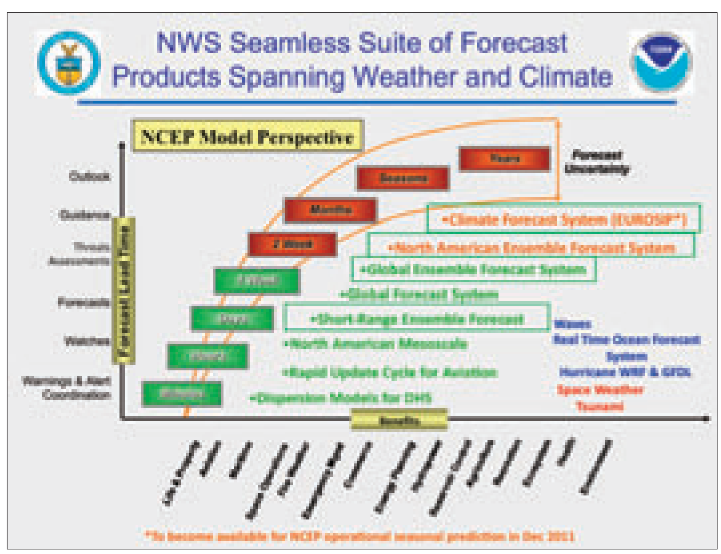
David Bright, NOAA/NWS/NCEP/Aviation Weather Center

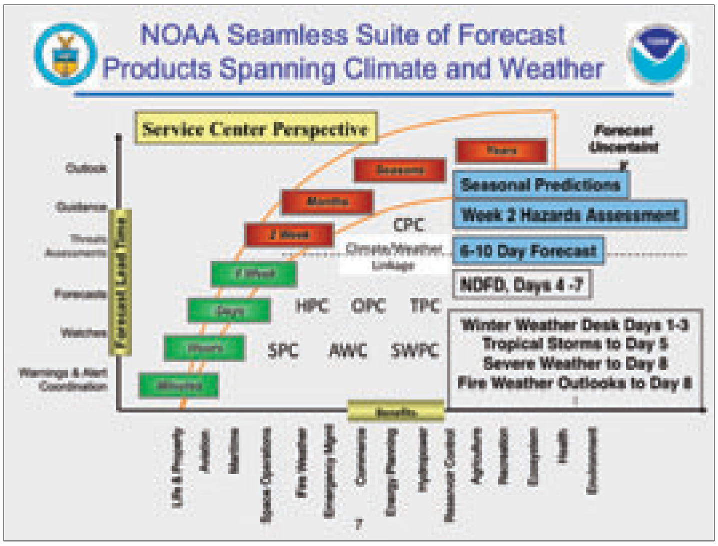
The National Centers for Environmental Prediction (NCEP) deliver global weather, water, climate, and space analyses, guidance, forecasts, and warnings. To accomplish the predictive mission of the service-based Centers, NCEP relies on ensemble guidance across a spectrum of temporal and spatial scales for a variety of customers and partners. Examples of the multi-disciplinary ensemble guidance used by forecasters in completing their operational mission will be shown. The ensemble-based guidance will demonstrate the ability of NCEP short and medium-range ensembles to increase forecaster confidence and enhance decision support capability to aviation, severe convection, excessive precipitation, hurricanes, and oceanic forecasting and warning services. NCEP regional ensembles are used primarily to support aviation planning, excessive precipitation and flooding, and severe convective storm forecasting, while medium-range global ensembles are employed for outlooks of heavy precipitation, winter storms, thunderstorms, tropical systems, and societal impacts up to a week in advance.

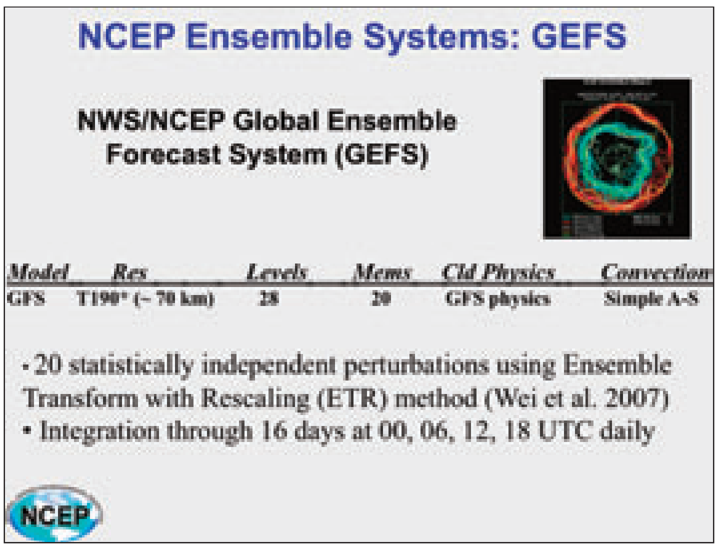


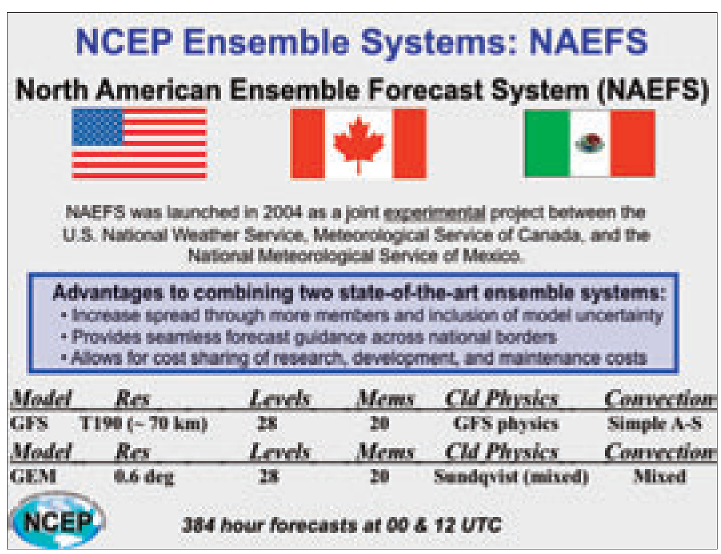

NCEP
National Centers for Environmental Prediction
"From Sun to Sea"
NWP Models and Execution
NCEP
AWC
SWPC
SPC
CPC
OPC
NHC

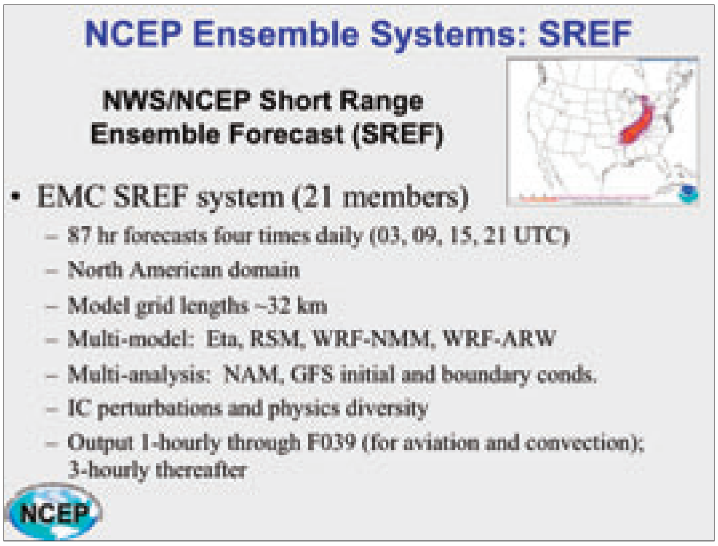

National Centers for Environmental Prediction
Organization:
Central component of NOAA National Weather Service
Mission:
NCEP delivers science-based environmental predictions to the nation and the global community. We collaborate with partners and customers to produce reliable, timely, and accurate analyses, guidance, forecasts, and warnings for the protection of life and property and the enhancement of the national economy.
Vision:
The Nation's trusted source, first alert, and preferred partner for environmental prediction services
Now
In progress
2012

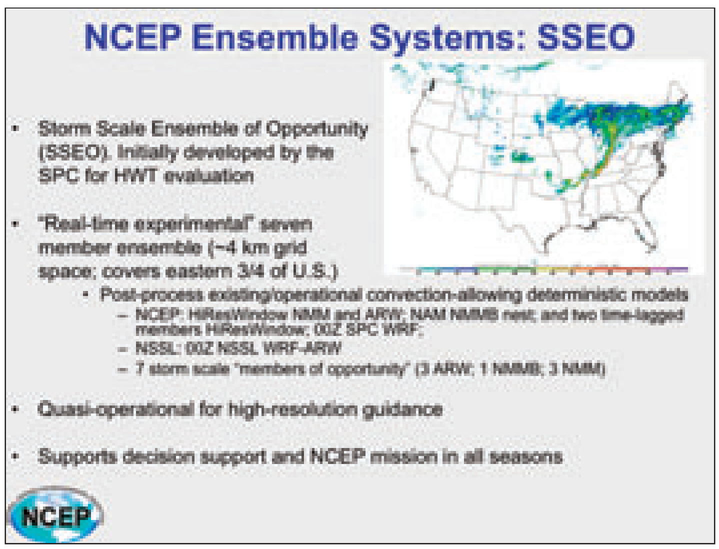

NWS Seamless Suite of Forecast
Products Spanning Weather and Climate
NCEP Model Perspective
Outlook
Guidance
Threats Assessments
Forecasts
Watches
Warnings & Alert Coordination
Forecast Lead Time
Years
Seasons
Months
2 Week
Forecast Uncertainty
•Climate Forecast System (EUROSIP*)
•North American Ensemble Forecast System
•Global Ensemble Forecast System
•Global Forecast System
•Short-Range Ensemble Forecast
•North American Mesoscale
•Rapid Update Cycle for Aviation
•Dispersion Models for DHS
Waves
Real Time Ocean Forecast System
Hurricane WRF & GFDL
Space Weather
Tsunami
Benefits
*To become available for NCEP operational seasonal prediction in Dec 2011

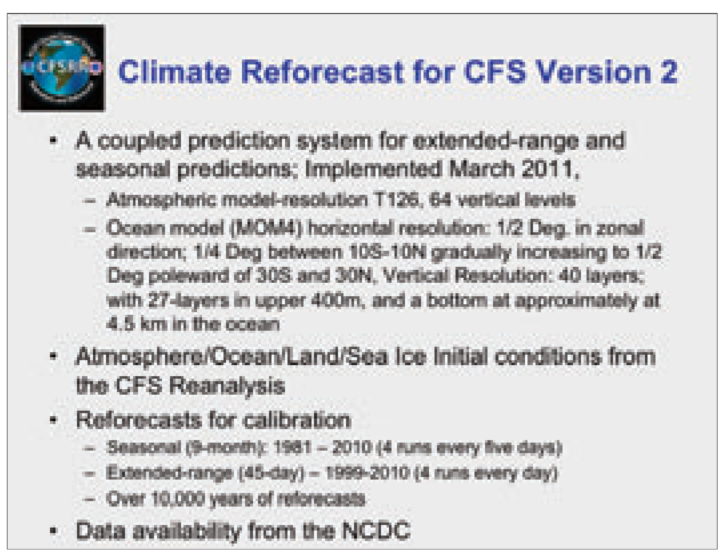

NOAA Seamless Suite of Forecast Products Spanning Climate and Weather
Service Center Perspective
Forecast Uncertainty
Seasonal Predictions
Week 2 Hazards Assessment
6-10 Day Forecast
NDFD, Days 4 -7
Winter Weather Desk Days 1-3
Tropical Storms to Day 5
Severe Weather to Day 8
Fire Weather Outlooks to Day 8
CPC
HPC OPC TPC
SPC AWC SWPC
Forecast Lead Time
Outlook
Guidance
Forecasts
Watches
Warnings & Alert Coordination

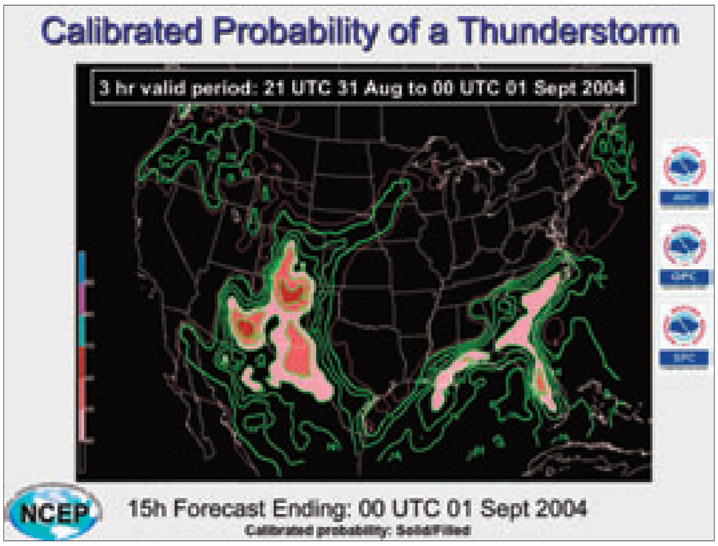

NCEP Ensemble Systems: GEFS
NWS/NCEP Global Ensemble Forecast System (GEFS)
Model Res Levels Mems Cld Physics Convection
GFS T190* (~ 70 km) 28 20 GFS physics Simple A-S
• 20 statistically independent perturbations using Ensemble Transform with Rescaling (ETR) method (Wei et al. 2007)
• Integration through 16 days at 00, 06, 12, 18 UTC daily
NCEP

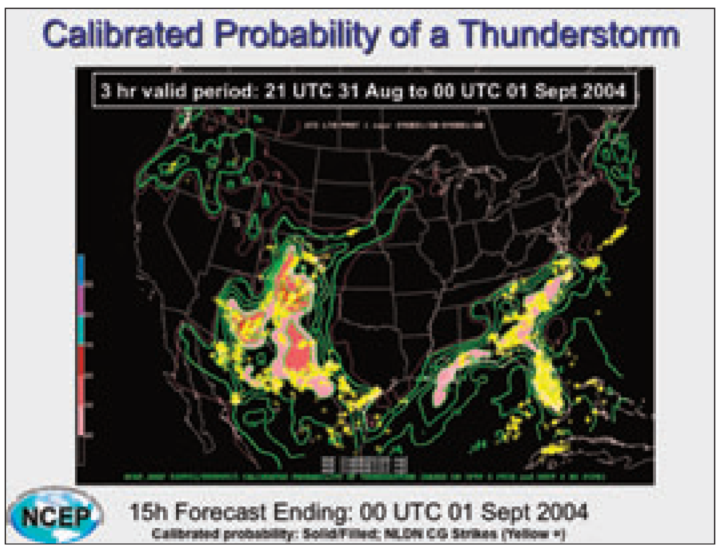

NCEP Ensemble Systems: NAEFS
North American Ensemble Forecast System (NAEFS)
NAEFS was launched in 2004 as a joint experimental project between the U.S. National Weather Service, Meteorological Service of Canada, and the National Meteorological Service of Mexico.
Advantages to combining two state-of-the-art ensemble systems:
• Increase spread through more members and inclusion of model uncertainty
• Provides seamless forecast guidance across national borders
• Allows for cost sharing of research, development, and maintenance costs
Model Res Levels Mems Cld Physics Convection
GFS T190 (~ 70 km) 28 20 GFS physics Simple A-S
Model Res Levels Mems Cld Physics Convection
GEM 0.6 deg 28 20 Sundqvist (mixed) Mixed
NCEP
384 hour forecasts at 00 & 12 UTC

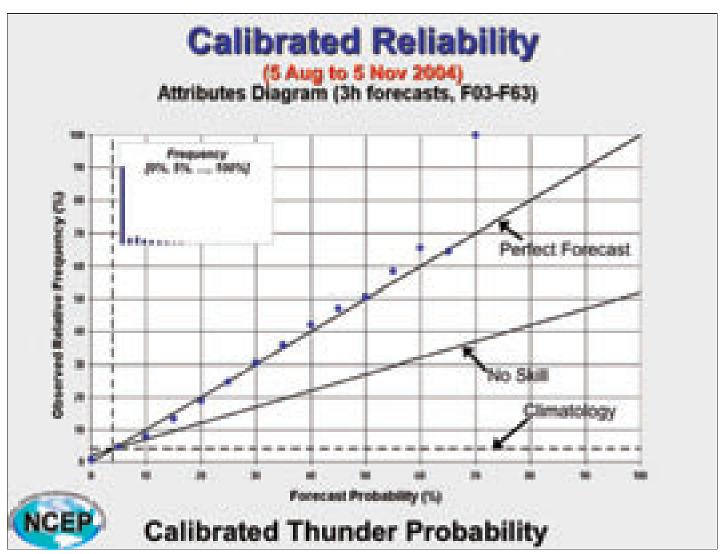

NCEP Ensemble Systems: SREF
NWS/NCEP Short Range Ensemble Forecast (SREF)
• EMC SREF system (21 members)
– 87 hr forecasts four times daily (03, 09, 15, 21 UTC)
– North American domain
– Model grid lengths ~32 km
– Multi-model: Eta, RSM, WRF-NMM, WRF-ARW
– Multi-analysis: NAM, GFS initial and boundary conds.
– IC perturbations and physics diversity
– Output 1-hourly through F039 (for aviation and convection); 3-hourly thereafter
NCEP

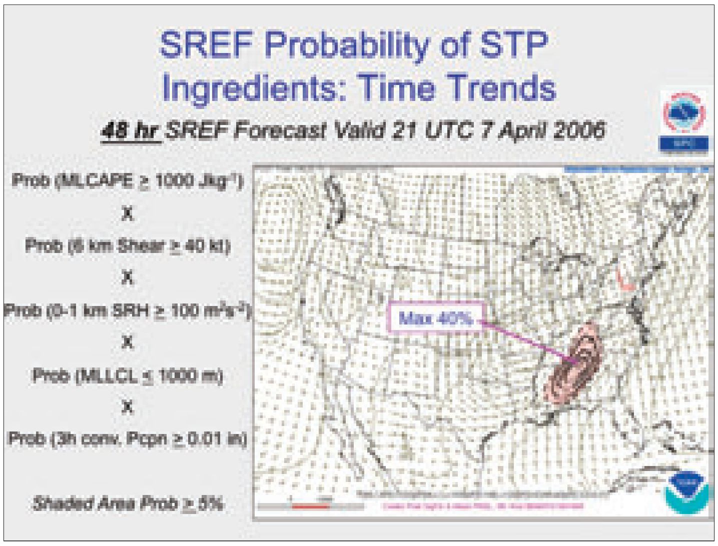

NCEP Ensemble Systems: SSEO
• Storm Scale Ensemble of Opportunity (SSEO). Initially developed by the SPC for HWT evaluation
• "Real-time experimental" seven member ensemble (~4 km grid space; covers eastern 3/4 of U.S.)
• Post-process existing/operational convection-allowing deterministic models
– NCEP: HiResWindow NMM and ARW; NAM NMMB nest; and two time-lagged members HiResWindow; 00Z SPC WRF;
– NSSL: 00Z NSSL WRF-ARW
– 7 storm scale "members of opportunity" (3 ARW; 1 NMMB; 3 NMM)
• Quasi-operational for high-resolution guidance
• Supports decision support and NCEP mission in all seasons
NCEP

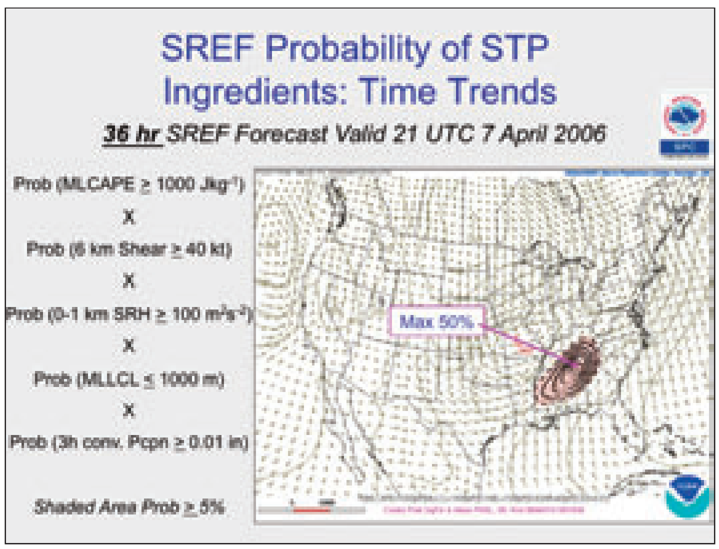

CFSRR
Climate Reforecast for CFS Version 2
• A coupled prediction system for extended-range and seasonal predictions; Implemented March 2011,
– Atmospheric model-resolution T126, 64 vertical levels
– Ocean model (MOM4) horizontal resolution: 1/2 Deg. in zonal direction; 1/4 Deg between 10S-10N gradually increasing to 1/2 Deg poleward of 30S and 30N, Vertical Resolution: 40 layers; with 27-layers in upper 400m, and a bottom at approximately at 4.5 km in the ocean
• Atmosphere/Ocean/Land/Sea Ice Initial conditions from the CFS Reanalysis
• Reforecasts for calibration
– Seasonal (9-month): 1981 – 2010 (4 runs every five days)
– Extended-range (45-day) – 1999-2010 (4 runs every day)
– Over 10,000 years of reforecasts
• Data availability from the NCDC

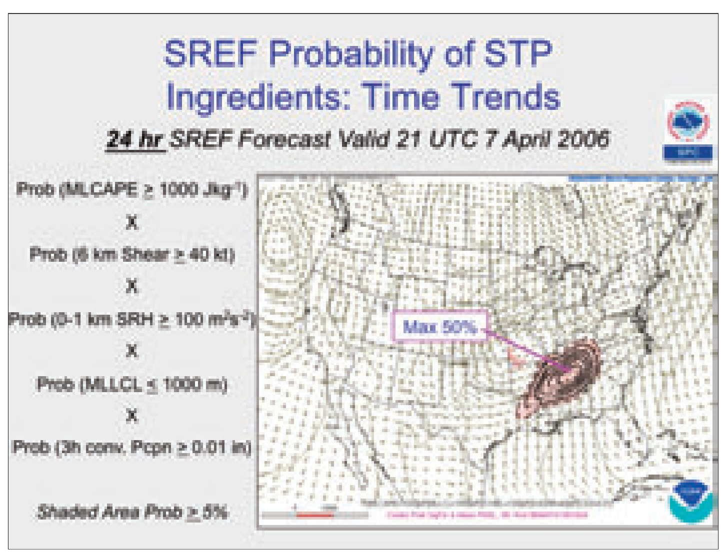

Calibrated Probability of a Thunderstorm
3 hr valid period: 21 UTC 31 Aug to 00 UTC 01 Sept 2004
NCEP
15h Forecast Ending: 00 UTC 01 Sept 2004
Calibrated probability: Solid/Filled

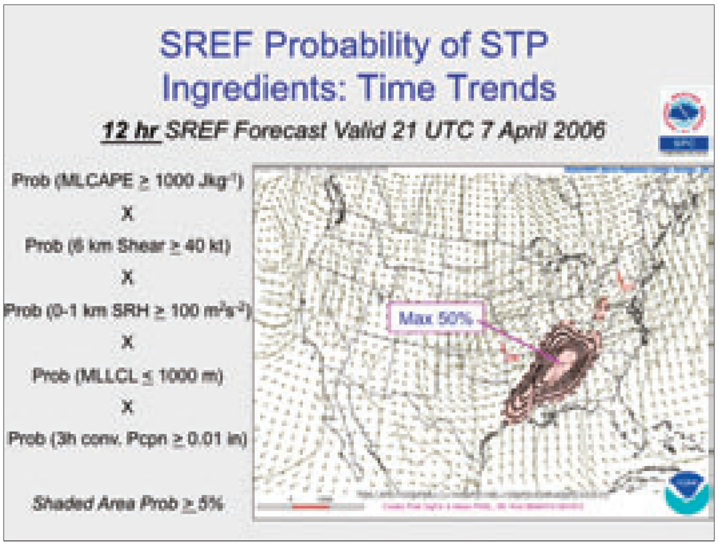

Calibrated Probability of a Thunderstorm
3 hr valid period: 21 UTC 31 Aug to 00 UTC 01 Sept 2004
NCEP
15h Forecast Ending: 00 UTC 01 Sept 2004
Calibrated probability: Solid/Filled; NLDN CG Strikes (Yellow +)

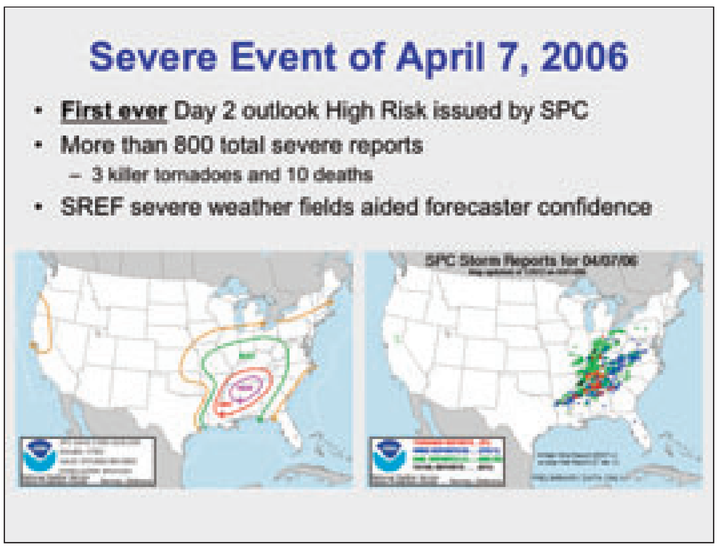

Calibrated Reliability
(5 Aug to 5 Nov 2004)
Attributes Diagram (3h forecasts, F03-F63)
Perfect Forecast
No Skill
Climatology
Forecast Probability (%)
NCEP
Calibrated Thunder Probability

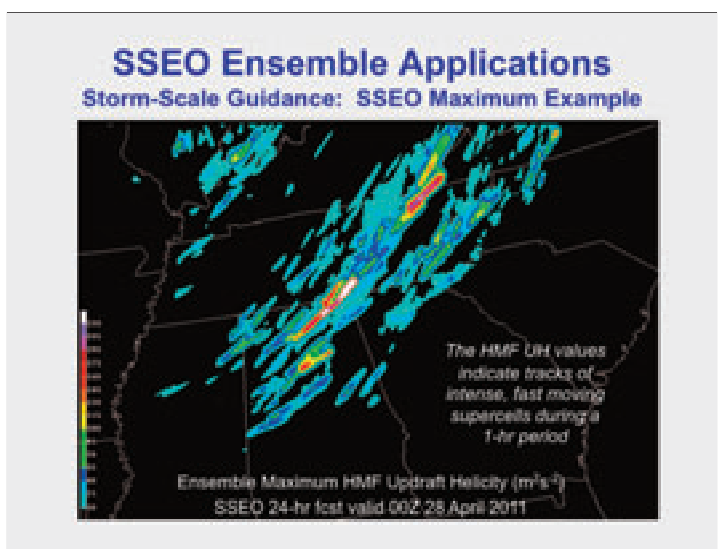

SREF Probability of STP
Ingredients: Time Trends
48 hr SREF Forecast Valid 21 UTC 7 April 2006
Prob (MLCAPE ≥ 1000 Jkg-1)
X
Prob (6 km Shear ≥ 40 kt)
X
Prob (0-1 km SRH ≥ 100 m2s-2)
X
Prob (MLLCL ≤ 1000 m)
X
Prob (3h conv. Pcpn ≥ 0.01 in)
Shaded Area Prob ≥ 5%
Max 40%

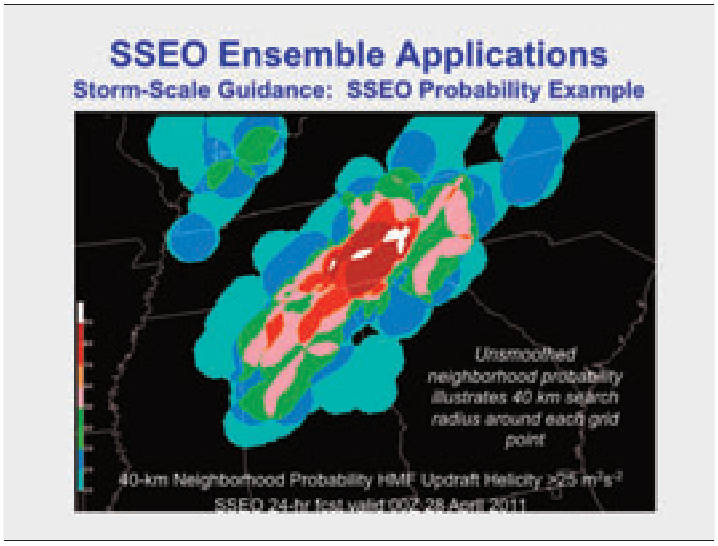

SREF Probability of STP
Ingredients: Time Trends
36 hr SREF Forecast Valid 21 UTC 7 April 2006
Prob (MLCAPE ≥ 1000 Jkg-1)
X
Prob (6 km Shear ≥ 40 kt)
X
Prob (0-1 km SRH ≥ 100 m2s-2)
X
Prob (MLLCL ≤ 1000 m)
X
Prob (3h conv. Pcpn ≥ 0.01 in)
Shaded Area Prob ≥ 5%
Max 50%

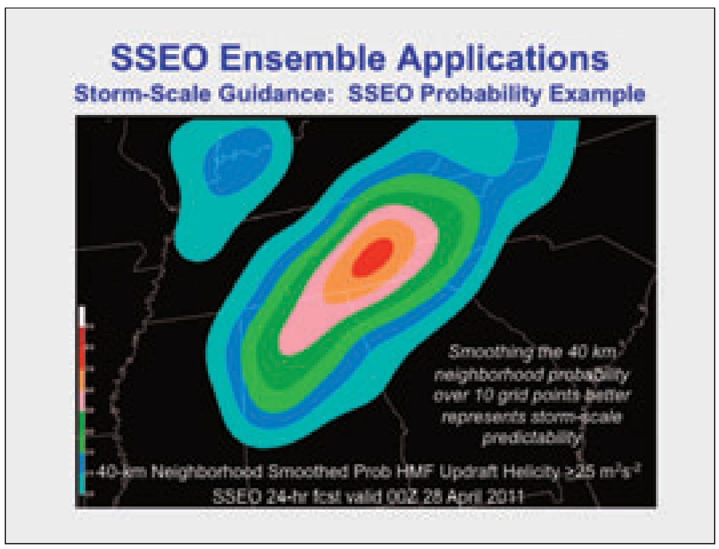

SREF Probability of STP
Ingredients: Time Trends
24 hr SREF Forecast Valid 21 UTC 7 April 2006
Prob (MLCAPE ≥ 1000 Jkg-1)
X
Prob (6 km Shear ≥ 40 kt)
X
Prob (0-1 km SRH ≥ 100 m2s-2)
X
Prob (MLLCL ≤ 1000 m)
X
Prob (3h conv. Pcpn ≥ 0.01 in)
Shaded Area Prob ≥ 5%
Max 50%

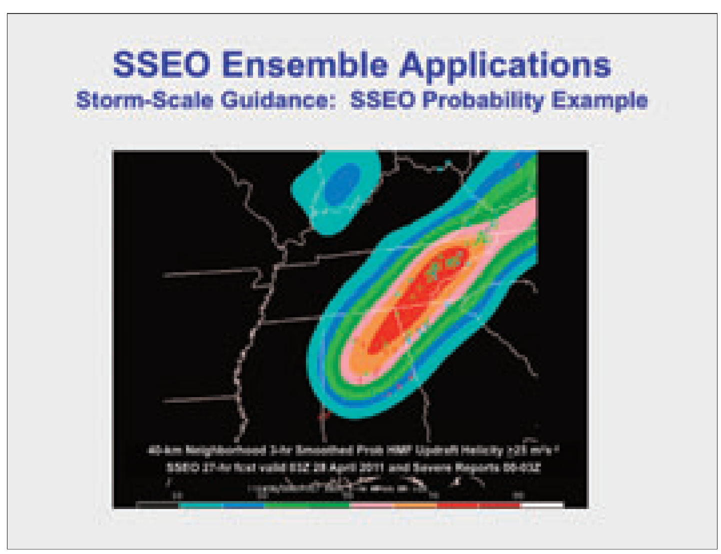

SREF Probability of STP Ingredients: Time Trends
12 hr SREF Forecast Valid 21 UTC 7 April 2006
Prob (MLCAPE ≥ 1000 Jkg⁻¹)
X
Prob (6 km Shear ≥ 40 kt)
X
Prob (0-1 km SRH ≥ 100 m²s⁻²)
X
Prob (MLLCL ≤ 1000 m)
X
Prob (3h conv. Pcpn ≥ 0.01 in)
Shaded Area Prob ≥ 5%
Max 50%

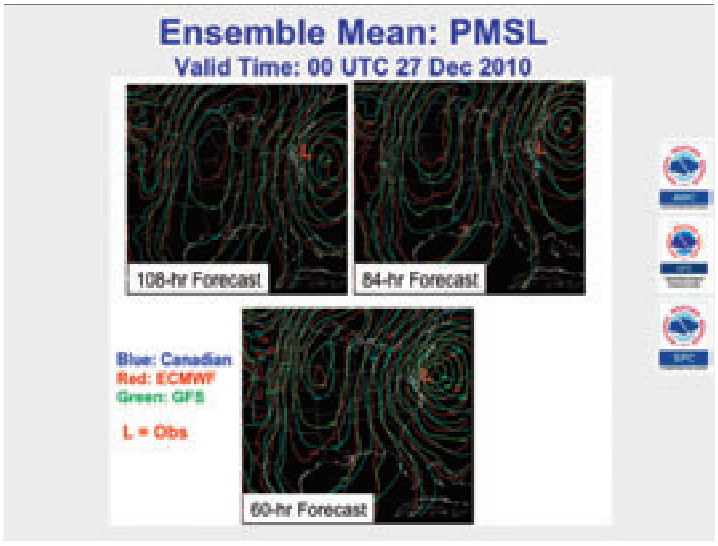

Severe Event of April 7, 2006
• First ever Day 2 outlook High Risk issued by SPC
• More than 800 total severe reports
– 3 killer tornadoes and 10 deaths
• SREF severe weather fields aided forecaster confidence
SPC Storm Reports for 04/07/06

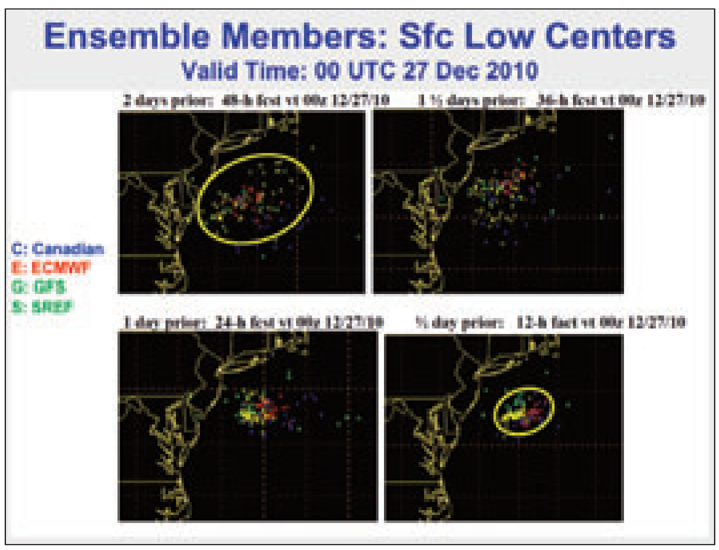

SSEO Ensemble Applications
Storm-Scale Guidance: SSEO Maximum Example
The HMF UH values indicate tracks of intense, fast moving supercells during a 1-hr period
Ensemble Maximum HMF Updraft Helicity (m²s⁻²)
SSEO 24-hr fcst valid 00Z 28 April 2011

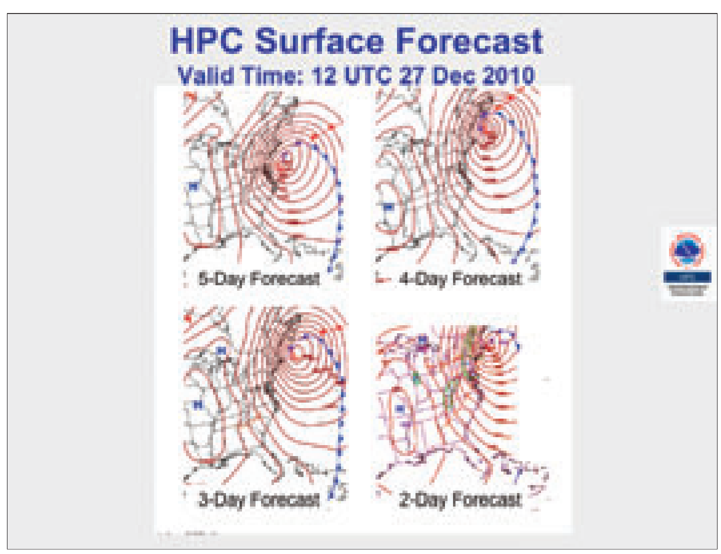

SSEO Ensemble Applications
Storm-Scale Guidance: SSEO Probability Example
Unsmoothed neighborhood probability illustrates 40 km search radius around each grid point
40-km Neighborhood Probability HMF Updraft Helicity >25 m²s⁻²
SSEO 24-hr fcst valid 00Z 28 April 2011

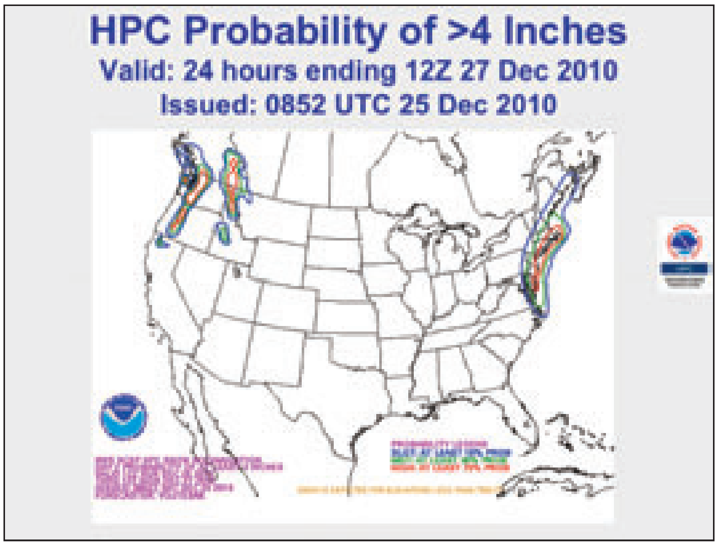

SSEO Ensemble Applications
Storm-Scale Guidance: SSEO Probability Example
Smoothing the 40 km neighborhood probability over 10 grid points better represents storm-scale predictability
40-km Neighborhood Smoothed Prob HMF Updraft Helicity >25 m²s⁻²
SSEO 24-hr fcst valid 00Z 28 April 2011

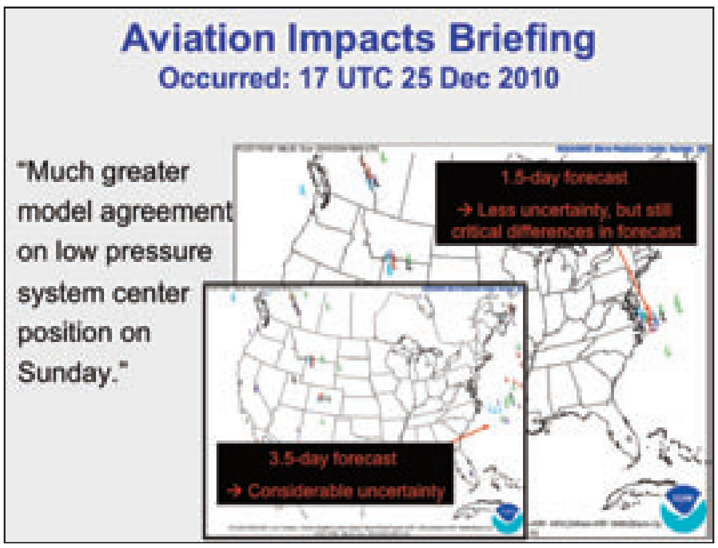

SSEO Ensemble Applications
Storm-Scale Guidance: SSEO Probability Example
40-km Neighborhood 3-hr Smoothed Prob HMF Updraft Helicity ≥25 m²s⁻²
SSEO 27-hr fcst valid 03Z 28 April 2011 and Severe Reports 00-03Z

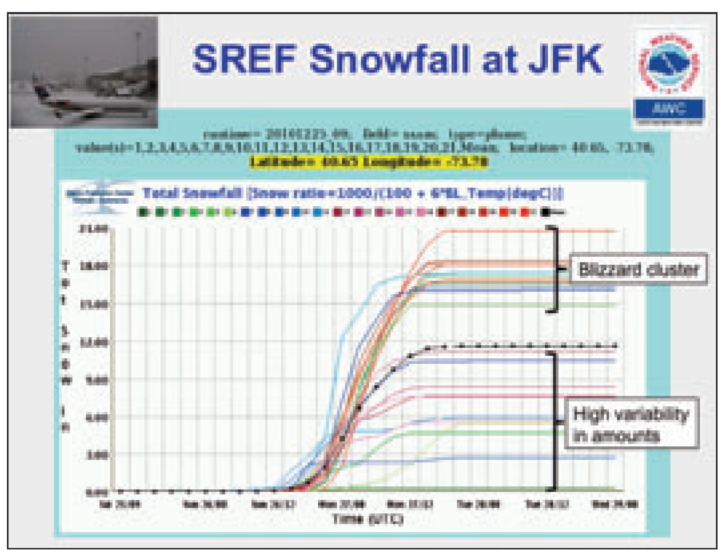

Ensemble Mean: PMSL
Valid Time: 00 UTC 27 Dec 2010
108-hr Forecast
84-hr Forecast
Blue: Canadian
Red: ECMWF
Green: GFS
L = Obs
60-hr Forecast


Ensemble Members: Sfc Low Centers
Valid Time: 00 UTC 27 Dec 2010
2 days prior: 48-h fcst vt 00z 12/27/10
1 ½ days prior: 36-h fcst vt 00z 12/27/10
C: Canadian
E: ECMWF
G: GFS
S: SREF
1 day prior: 24-h fcst vt 00z 12/27/10
½ day prior: 12-h fcst vt 00z 12/27/10

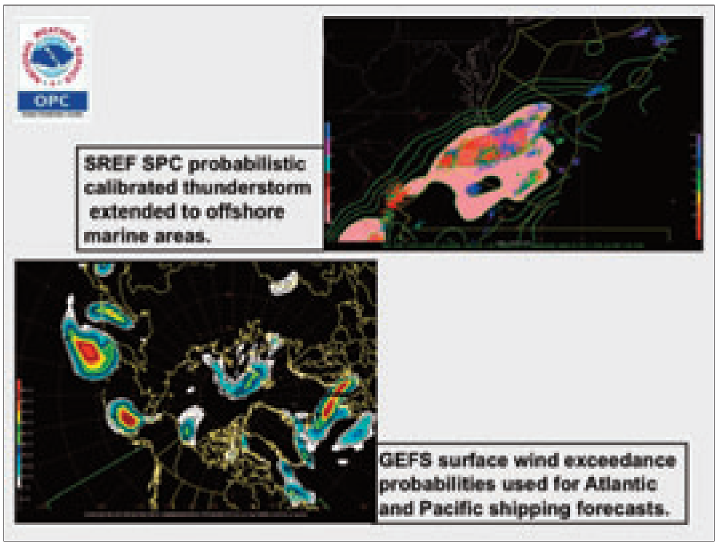

HPC Surface Forecast
Valid Time: 12 UTC 27 Dec 2010
5-Day Forecast
4-Day Forecast
3-Day Forecast
2-Day Forecast

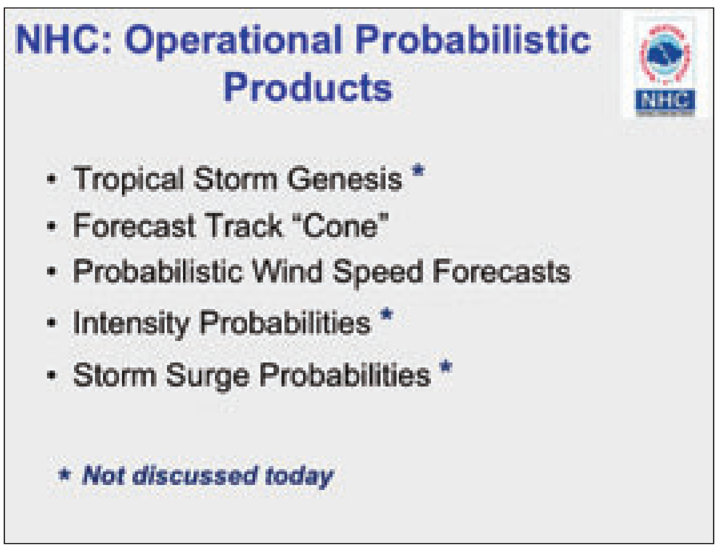

HPC Probability of >4 Inches
Valid: 24 hours ending 12Z 27 Dec 2010
Issued: 0852 UTC 25 Dec 2010

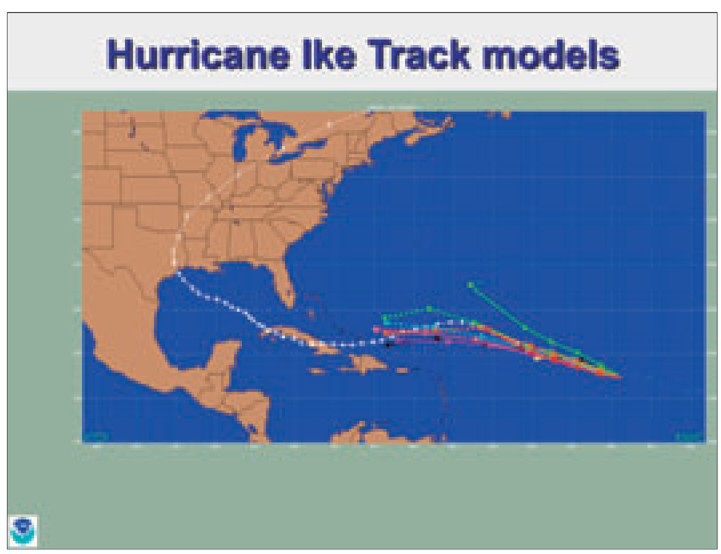

Aviation Impacts Briefing
Occurred: 17 UTC 25 Dec 2010
"Much greater model agreement on low pressure system center position on Sunday."
1.5-day forecast
→ Less uncertainty, but still critical differences in forecast
3.5-day forecast
→ Considerable uncertainty

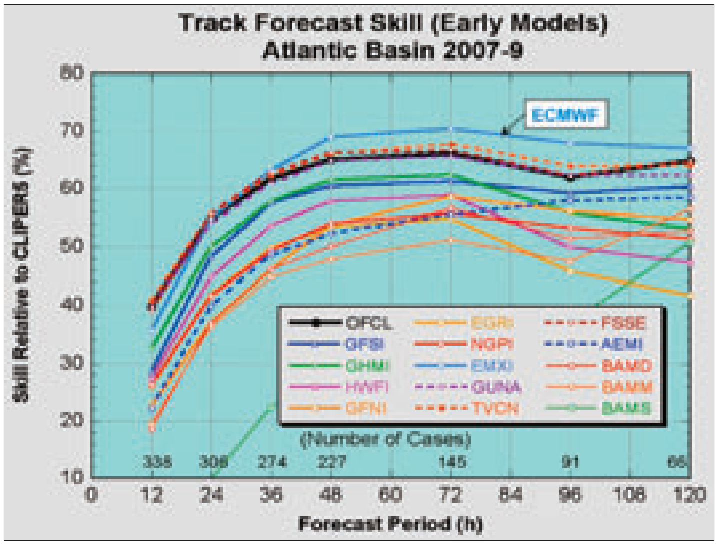

SREF Snowfall at JFK
Blizzard cluster
High variability in amounts
Time (UTC)

Ocean Prediction and Tropical Storms

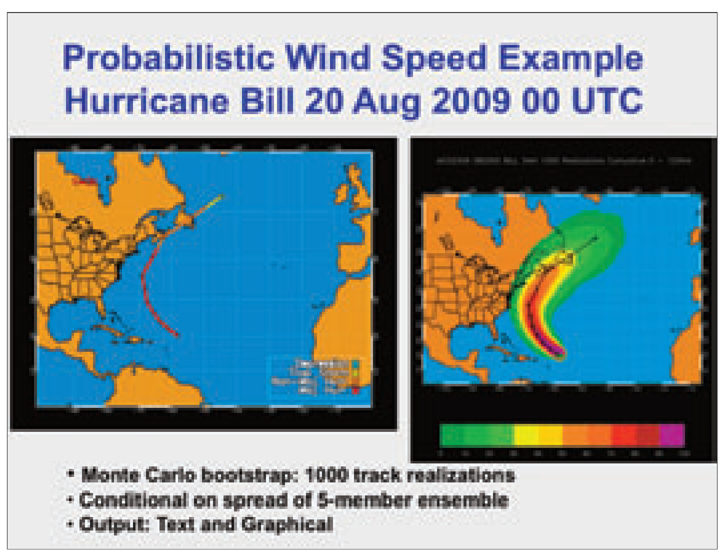


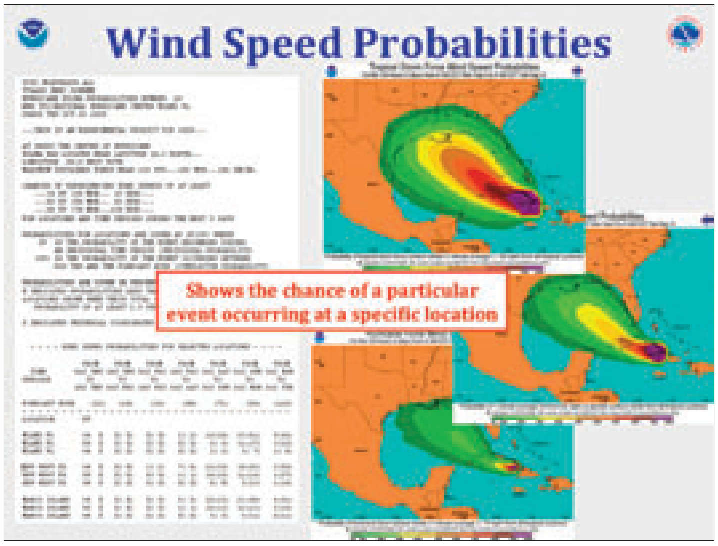




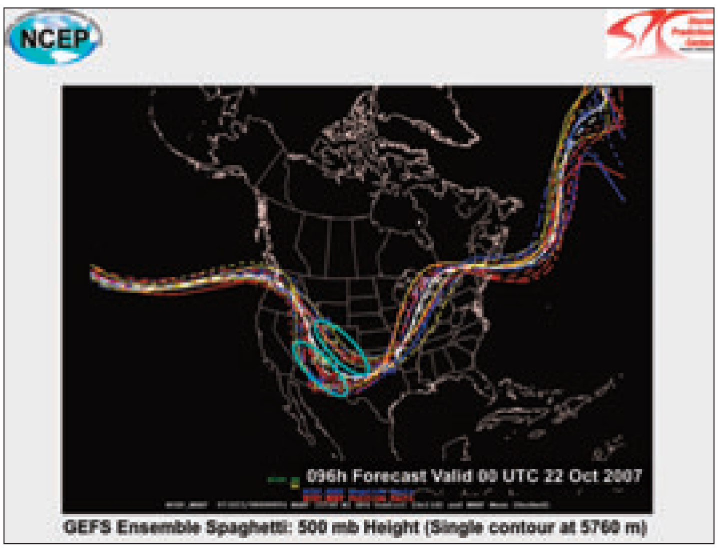

Track Forecast Skill (Early Models)
Atlantic Basin 2007-9
ECMWF
OFCL
GFSI
GHMI
HWFI
GFNI
EGRI
NGPI
EMXI
GUNA
TVCN
FSSE
AEMI
BAMD
BAMM
BAMS
(Number of Cases)
338 308 274 227 145 91 66
Skill Relative to CLIPER5 (%)
10 20 30 40 50 60 70 80
0 12 24 36 48 60 72 84 96 108 120
Forecast Period (h)

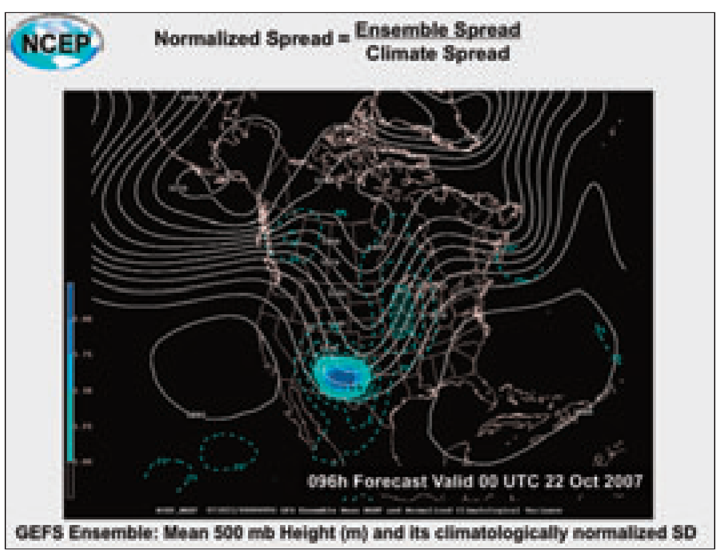

NHC Forecast Cone
•Probabilistic track of the center of the tropical cyclone.
•The size of the cone represents tropical cyclone position 67% of the time.

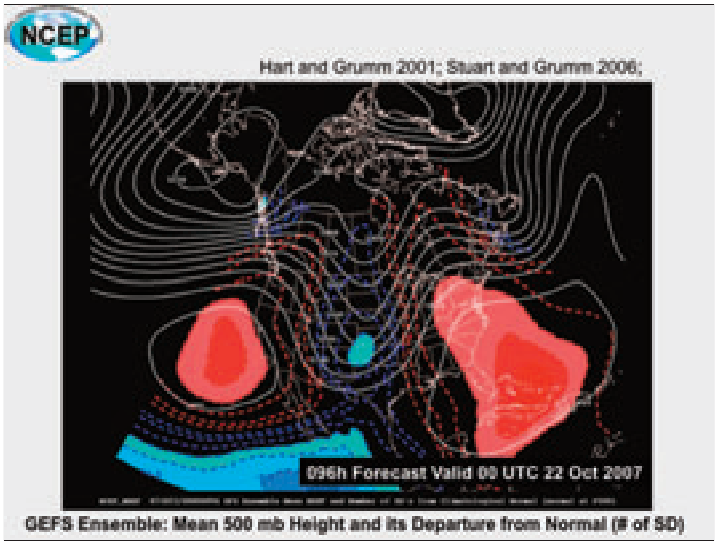

Probabilistic Wind Speed Example
Hurricane Bill 20 Aug 2009 00 UTC
• Monte Carlo bootstrap: 1000 track realizations
• Conditional on spread of 5-member ensemble
• Output: Text and Graphical

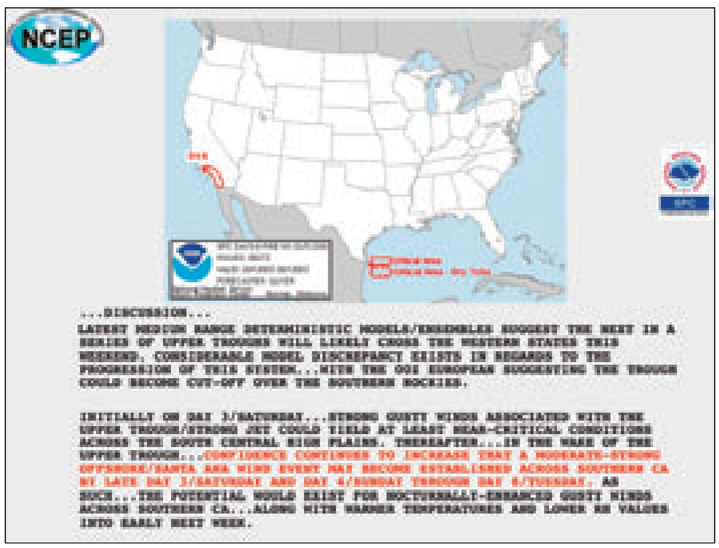

Wind Speed Probabilities
Shows the chance of a particular event occurring at a specific location

Wild fires

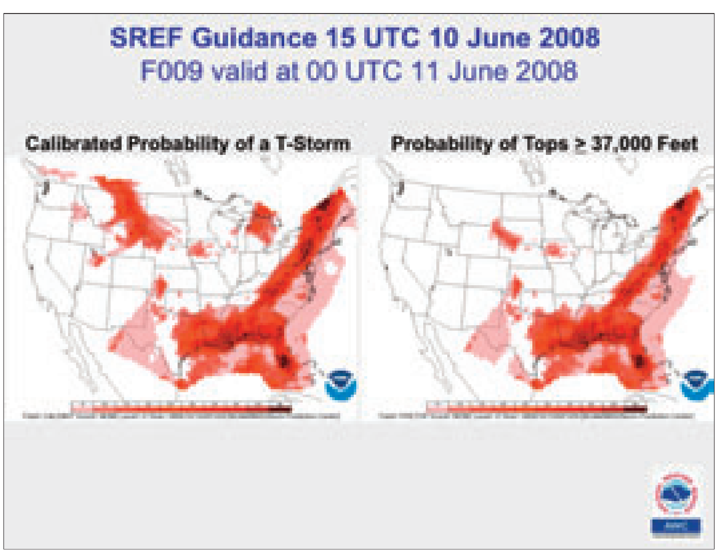

NCEP
096h Forecast Valid 00 UTC 22 Oct 2007
GEFS Ensemble Spaghetti: 500 mb Height (Single contour at 5760 m)

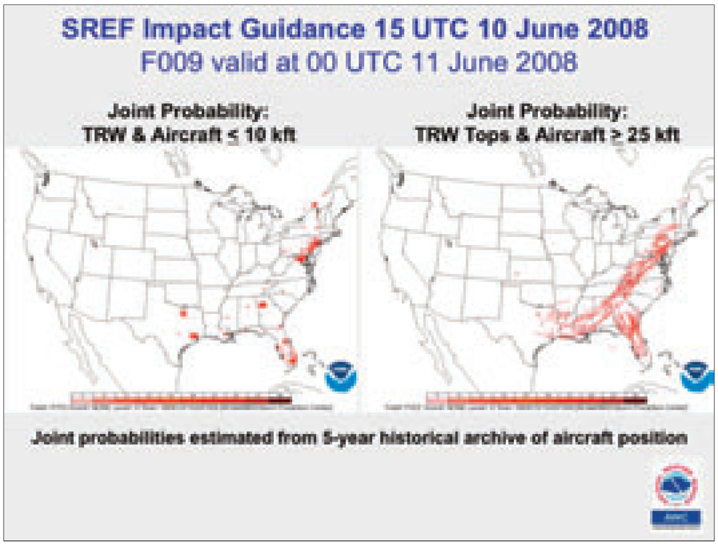

NCEP
Normalized Spread = Ensemble Spread / Climate Spread
096h Forecast Valid 00 UTC 22 Oct 2007
GEFS Ensemble: Mean 500 mb Height (m) and its climatologically normalized SD

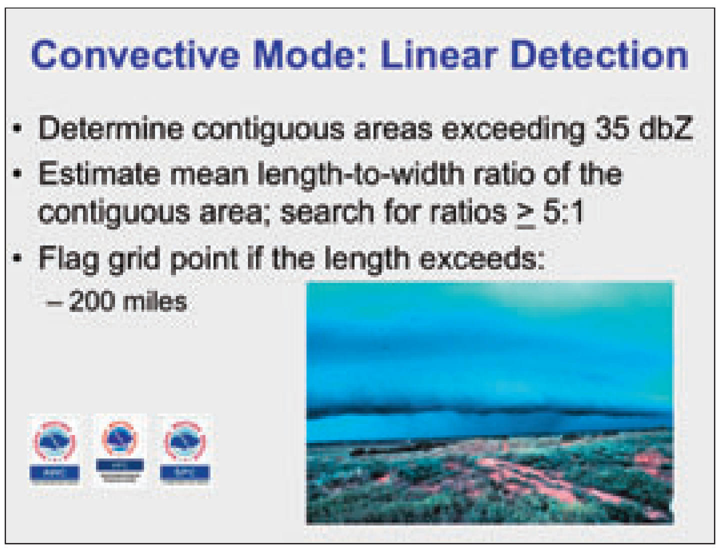


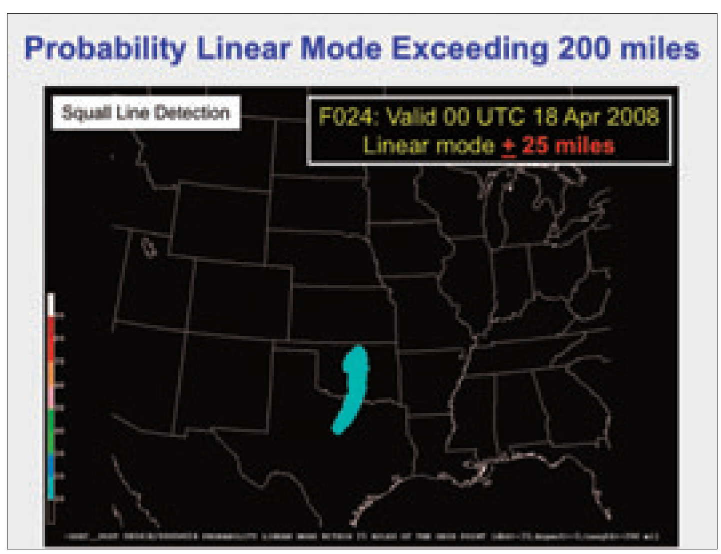


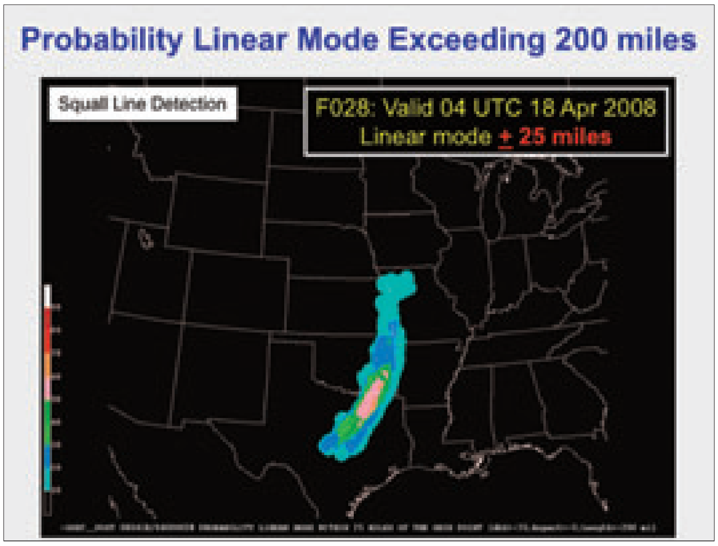
Aviation Weather

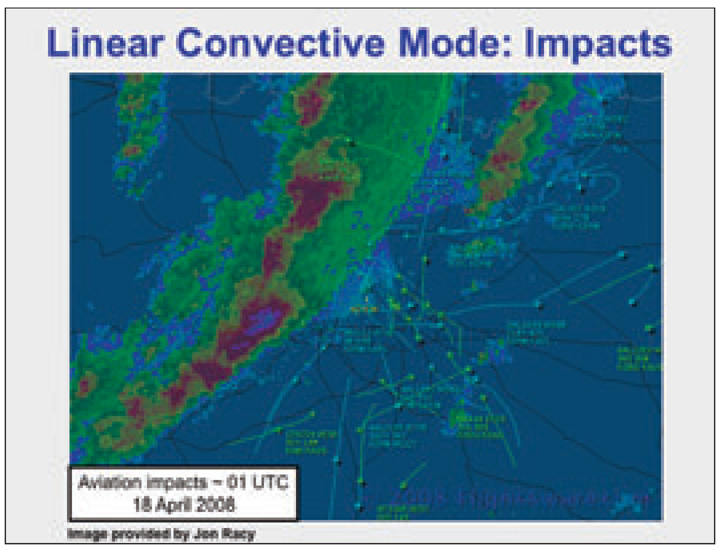


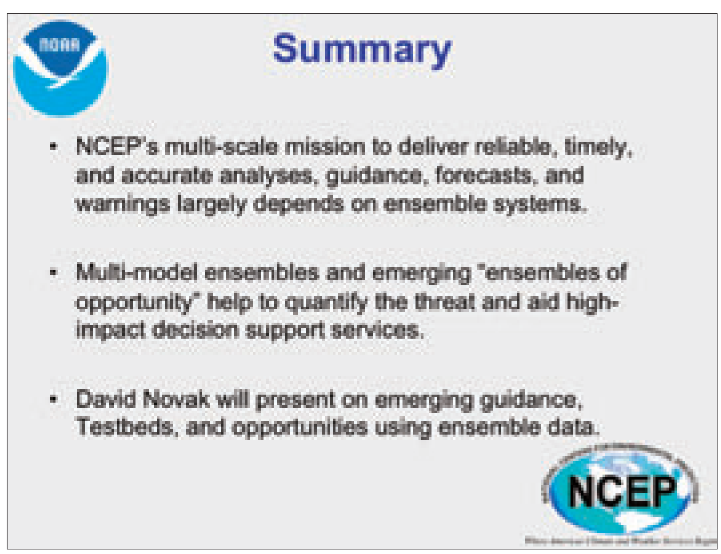

SREF Impact Guidance 15 UTC 10 June 2008
F009 valid at 00 UTC 11 June 2008
Joint Probability:
TRW & Aircraft ≤ 10 kft
Joint Probability:
TRW Tops & Aircraft ≥ 25 kft
Joint probabilities estimated from 5-year historical archive of aircraft position

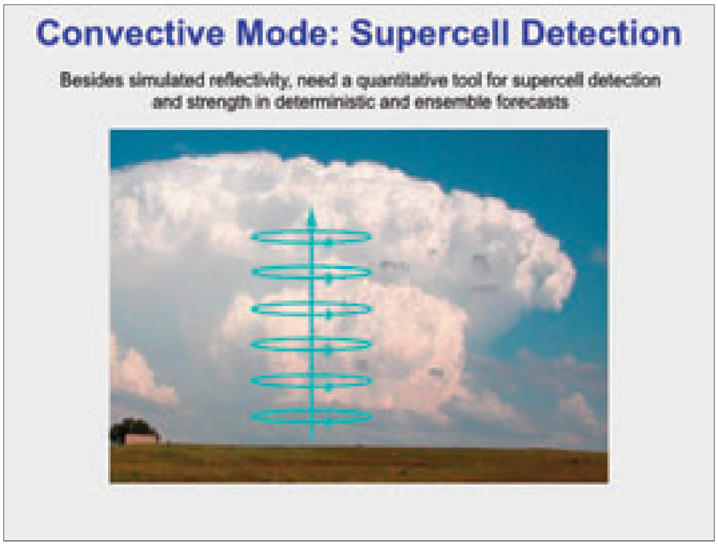

Convective Mode: Linear Detection
• Determine contiguous areas exceeding 35 dbZ
• Estimate mean length-to-width ratio of the contiguous area; search for ratios ≥ 5:1
• Flag grid point if the length exceeds:
– 200 miles

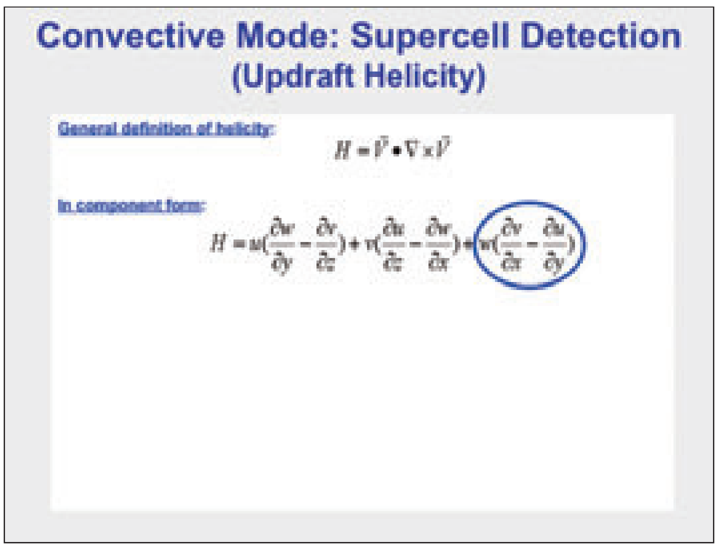

Probability Linear Mode Exceeding 200 miles
Squall Line Detection
F024: Valid 00 UTC 18 Apr 2008
Linear mode ± 25 miles

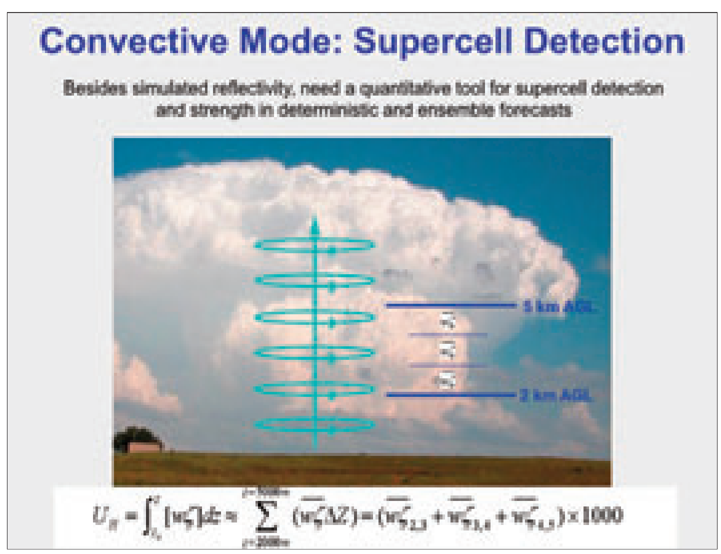

Probability Linear Mode Exceeding 200 miles
Squall Line Detection
F028: Valid 04 UTC 18 Apr 2008
Linear mode + 25 miles


Linear Convective Mode: Impacts
Aviation impacts ~ 01 UTC
18 April 2008
Image provided by Jon Racy


Summary
• NCEP's multi-scale mission to deliver reliable, timely, and accurate analyses, guidance, forecasts, and warnings largely depends on ensemble systems.
• Multi-model ensembles and emerging "ensembles of opportunity" help to quantify the threat and aid high-impact decision support services.
• David Novak will present on emerging guidance, Testbeds, and opportunities using ensemble data.
NCEP


Convective Mode: Supercell Detection
Besides simulated reflectivity, need a quantitative tool for supercell detection and strength in deterministic and ensemble forecasts

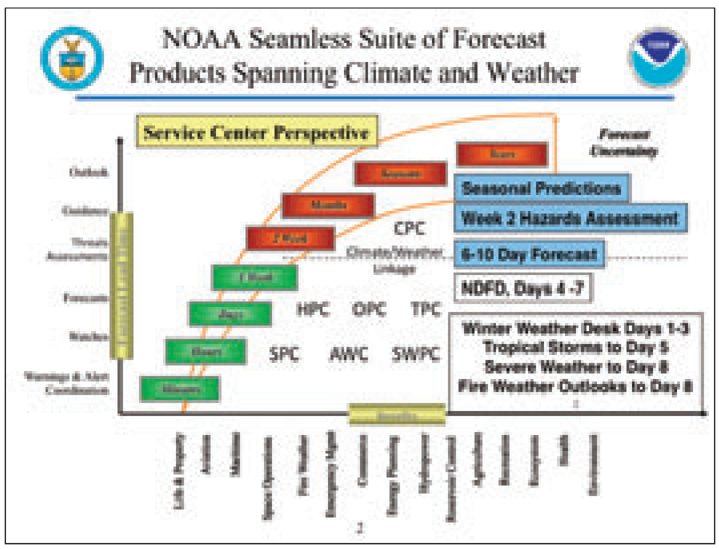

Convective Mode: Supercell Detection (Updraft Helicity)
General definition of helicity:
$H = \vec{V} \bullet \nabla \times \vec{V}$
In component form:
$H = u(\frac{\partial w}{\partial y} - \frac{\partial v}{\partial z}) + v(\frac{\partial u}{\partial z} - \frac{\partial w}{\partial x}) + w(\frac{\partial v}{\partial x} - \frac{\partial u}{\partial y})$

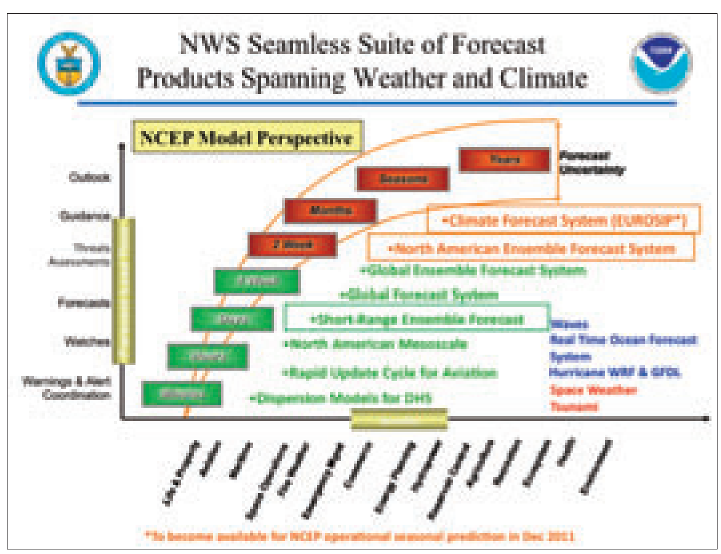

Convective Mode: Supercell Detection
Besides simulated reflectivity, need a quantitative tool for supercell detection and strength in deterministic and ensemble forecasts
5 km AGL
2 km AGL
$U_H = \int_{z_0}^{z_t} [w\zeta] dz \approx \sum_{z=2000m}^{z=5000m} (\overline{w\zeta}\Delta Z) = (\overline{w\zeta}_{2,3} + \overline{w\zeta}_{3,4} + \overline{w\zeta}_{4,5}) \times 1000$

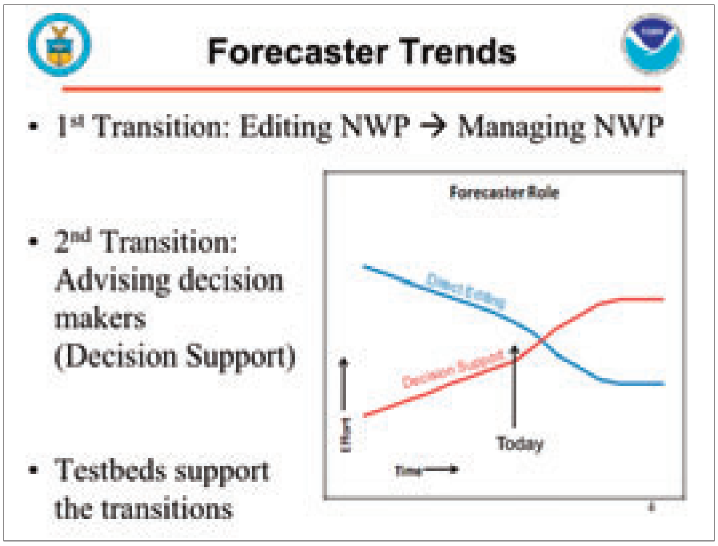
Emerging Trends in the Role of the Forecaster

David Novak, National Centers for Environmental Prediction/Hydrometeorological Prediction Center

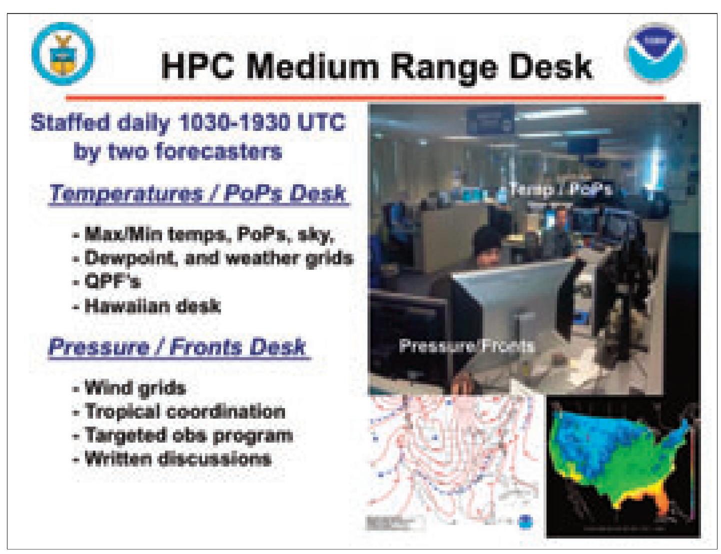
Three emerging trends in the role of the forecaster in the U.S. National Weather Service will be highlighted. The first trend is evolving the forecaster from labor-intensive manual forecast generation (forecaster-in-the-loop) to higher-level forecast decision making (forecaster-above-the-loop). The human application of subjective weights to objective model system output will be shown as one example of higher-level decision making. The second trend is the growing requirement for interpretive forecast services for public-sector decision makers, sometimes referred to as impact-based decision support. Increasingly the decision support requires quantification of forecaster confidence, in which ensemble systems are a major enabler. A third trend is the use of testbeds to foster the above forecast process changes. Examples from the NCEP suite of testbeds will be shown.

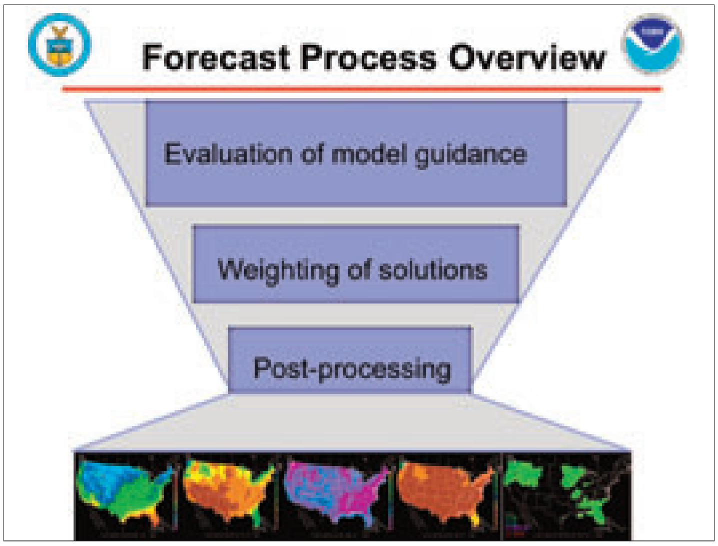


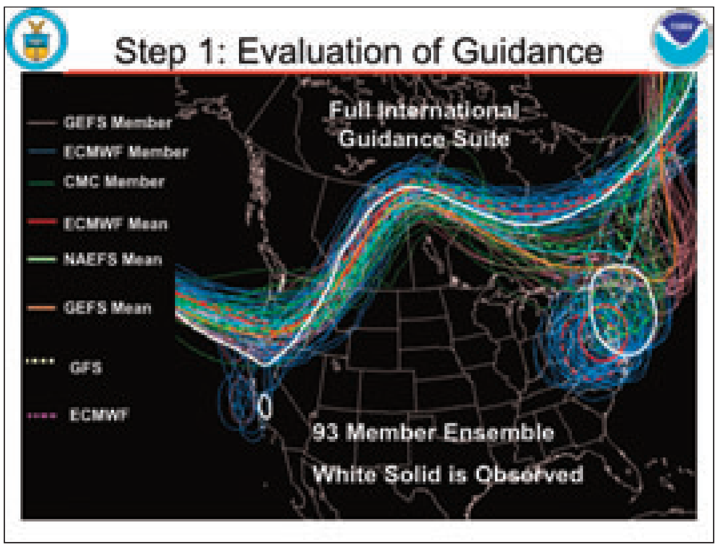


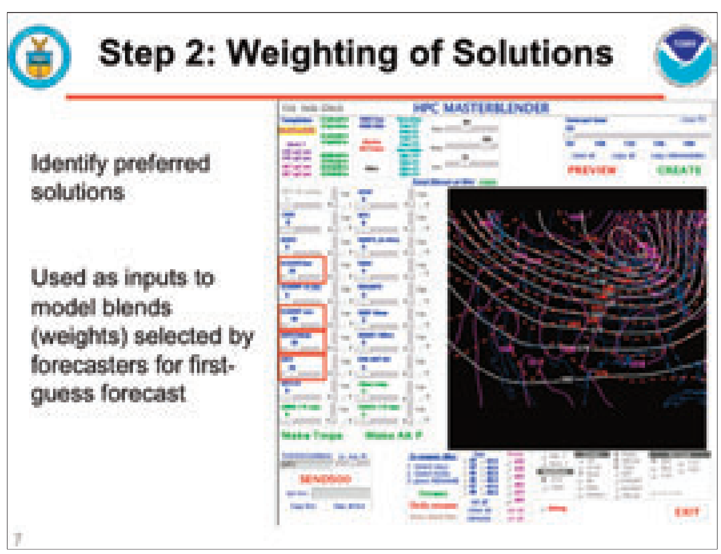

Forecaster Trends
• 1st Transition: Editing NWP → Managing NWP
• 2nd Transition: Advising decision makers (Decision Support)
• Testbeds support the transitions
Forecaster Role
Direct Editing
Decision Support
Today
Effort
Time
4

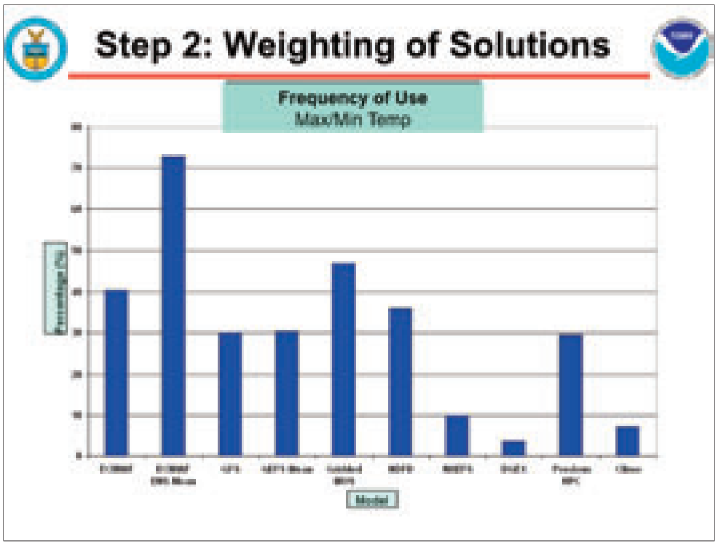

1st Transition
Forecaster Editing → Managing
Forecaster Role
Direct Editing
Decision Support
Effort
Time
5


HPC Medium Range Desk
Staffed daily 1030-1930 UTC by two forecasters
Temperatures / PoPs Desk
- Max/Min temps, PoPs, sky,
- Dewpoint, and weather grids
- QPF's
- Hawaiian desk
Pressure / Fronts Desk
- Wind grids
- Tropical coordination
- Targeted obs program
- Written discussions
Temp / PoPs
Pressure/Fronts

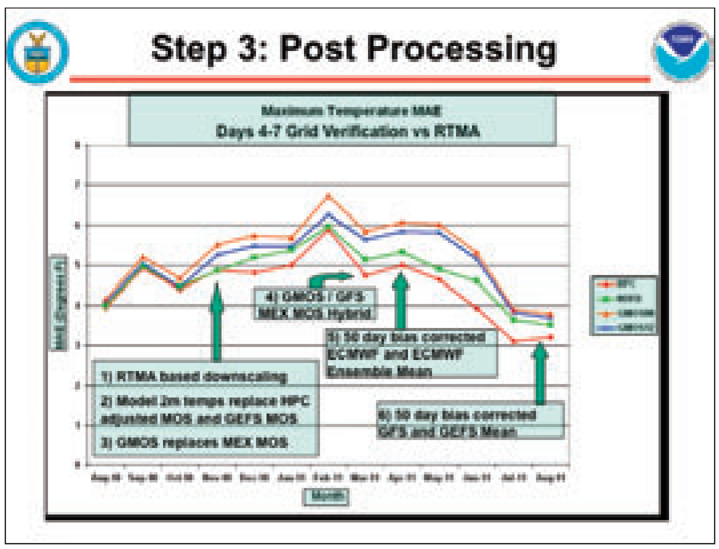

Forecast Process Overview
Evaluation of model guidance
Weighting of solutions
Post-processing


Step 1: Evaluation of Guidance
GEFS Member
ECMWF Member
CMC Member
ECMWF Mean
NAEFS Mean
GEFS Mean
GFS
ECMWF
Full International
Guidance Suite
93 Member Ensemble
White Solid is Observed

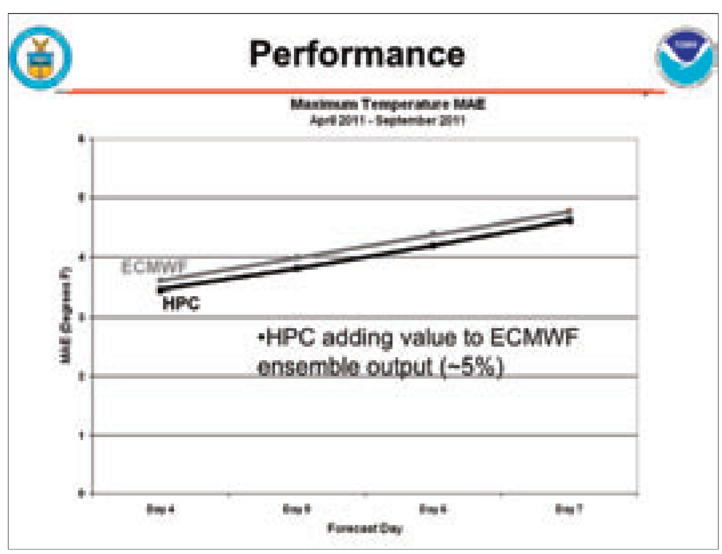

Step 2: Weighting of Solutions
Identify preferred solutions
Used as inputs to model blends (weights) selected by forecasters for first-guess forecast
HPC MASTERBLENDER



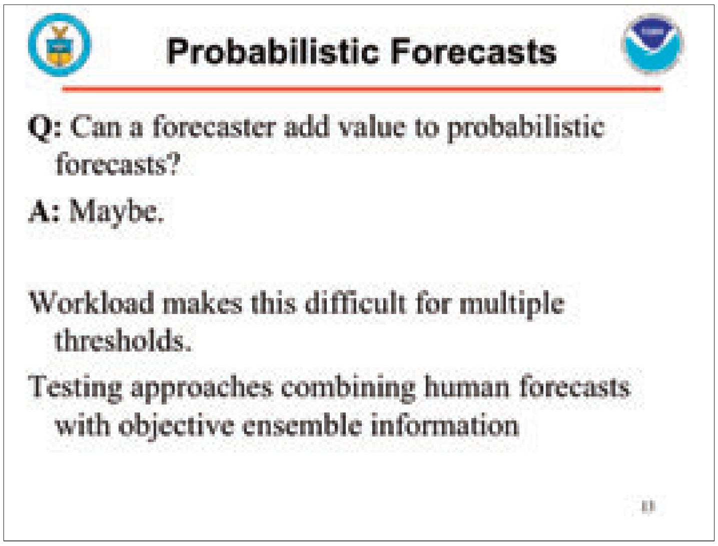
Step 2: Weighting of Solutions
Frequency of Use
Max/Min Temp
Model

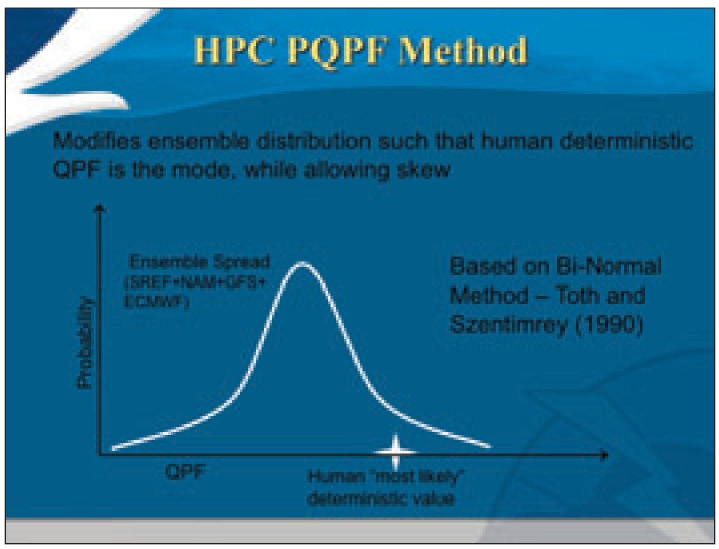


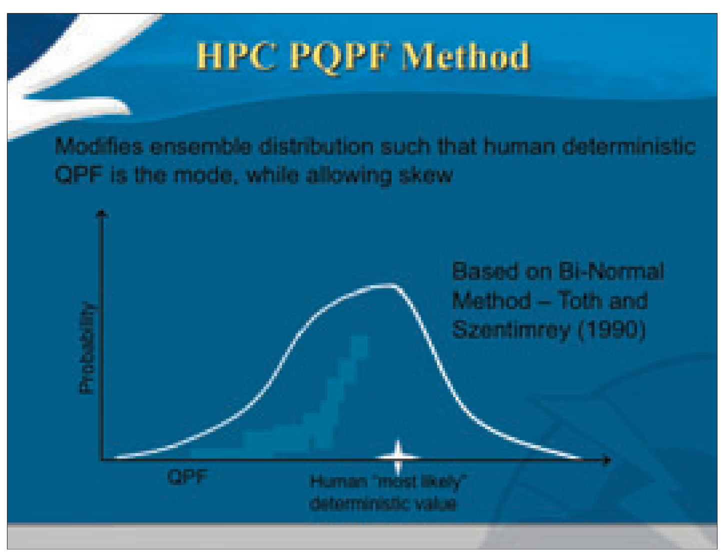
Step 3: Post Processing
Maximum Temperature MAE
Days 4-7 Grid Verification vs RTMA
4) GMOS / GFS MEX MOS Hybrid
5) 50 day bias corrected ECMWF and ECMWF Ensemble Mean
1) RTMA based downscaling
2) Model 2m temps replace HPC adjusted MOS and GEFS MOS
3) GMOS replaces MEX MOS
6) 50 day bias corrected GFS and GEFS Mean
Month



Performance
Maximum Temperature MAE
April 2011 - September 2011
ECMWF
HPC
•HPC adding value to ECMWF ensemble output (~5%)
Forecast Day


Probabilistic Forecasts
Q: Can a forecaster add value to probabilistic forecasts?
A: Maybe.
Workload makes this difficult for multiple thresholds.
Testing approaches combining human forecasts with objective ensemble information
13


HPC PQPF Method
Modifies ensemble distribution such that human deterministic QPF is the mode, while allowing skew
Ensemble Spread (SREF+NAM+GFS+ECMWF)
Probability
Based on Bi-Normal Method – Toth and Szentimrey (1990)
QPF
Human "most likely" deterministic value


HPC PQPF Method
Modifies ensemble distribution such that human deterministic QPF is the mode, while allowing skew
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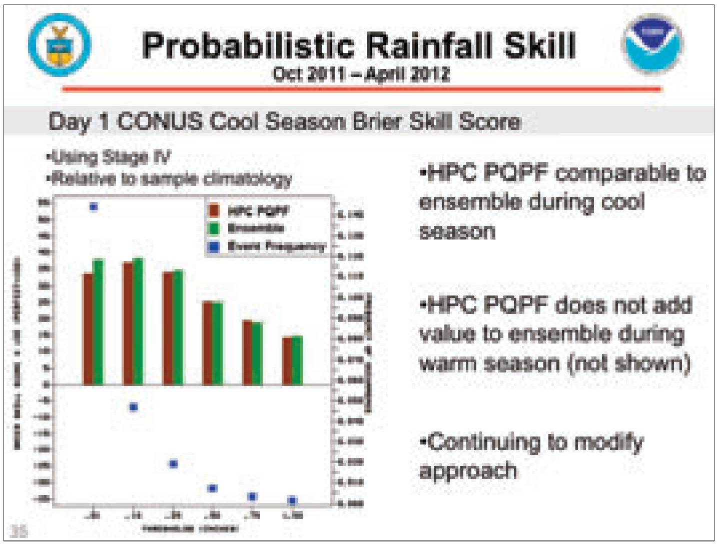
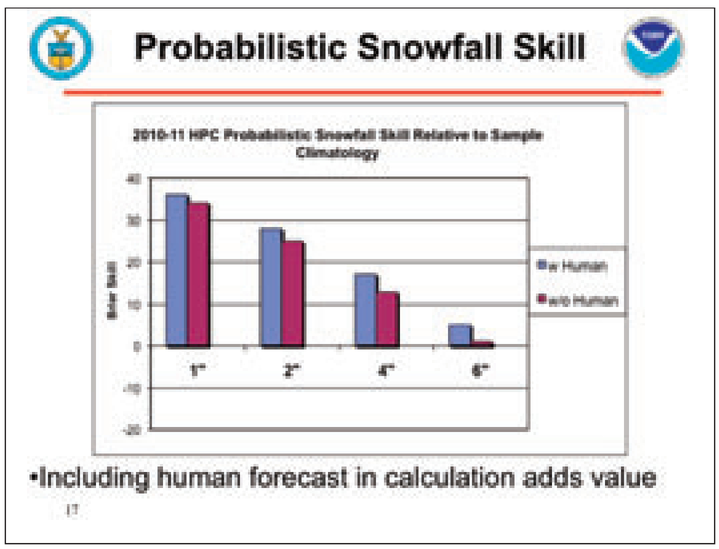

Probabilistic Rainfall Skill
Oct 2011 – April 2012
Day 1 CONUS Cool Season Brier Skill Score
•Using Stage IV
•Relative to sample climatology
HPC PQPF
Ensemble
Event Frequency
•HPC PQPF comparable to ensemble during cool season
•HPC PQPF does not add value to ensemble during warm season (not shown)
•Continuing to modify approach
35


Probabilistic Snowfall Skill
2010-11 HPC Probabilistic Snowfall Skill Relative to Sample Climatology
Brier Skill
40
30
20
10
0
-10
-20
1"
2"
4"
6"
w Human
w/o Human
•Including human forecast in calculation adds value
17

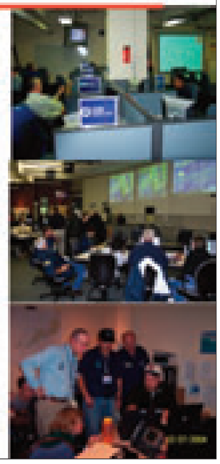

2nd Transition
Decision Support
18

Decision Support Services

Accurate and trusted weather information is just an *initial* requirement for saving lives and livelihoods

"The fact is, NWS services –principally direct interaction with decision makers–are in greater demand than at any time in our nearly 140-year history."

Jack Hayes, NWS Director 2008



Decision Support Services

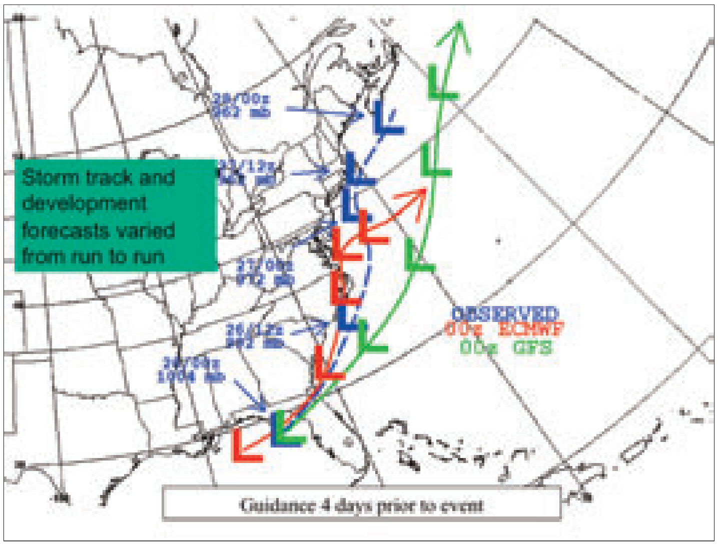
- Understand impact of forecasts on society
- Focus resources to provide decision assistance to core federal, state, and emergency partners

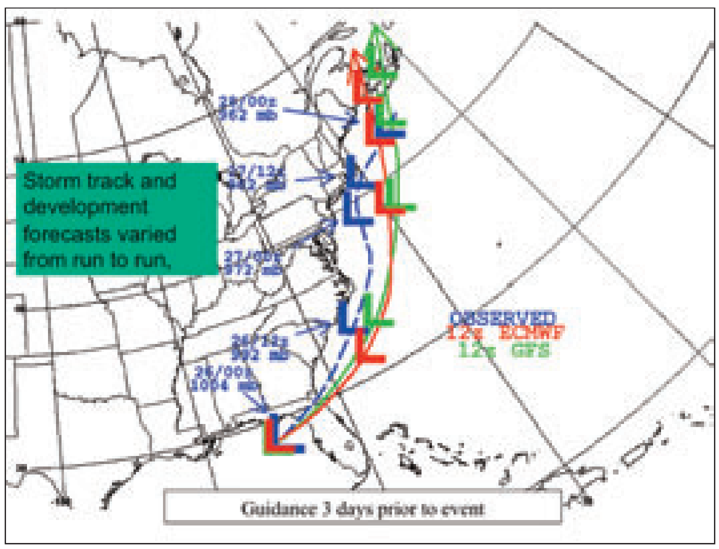
What Forecast Success Looks Like

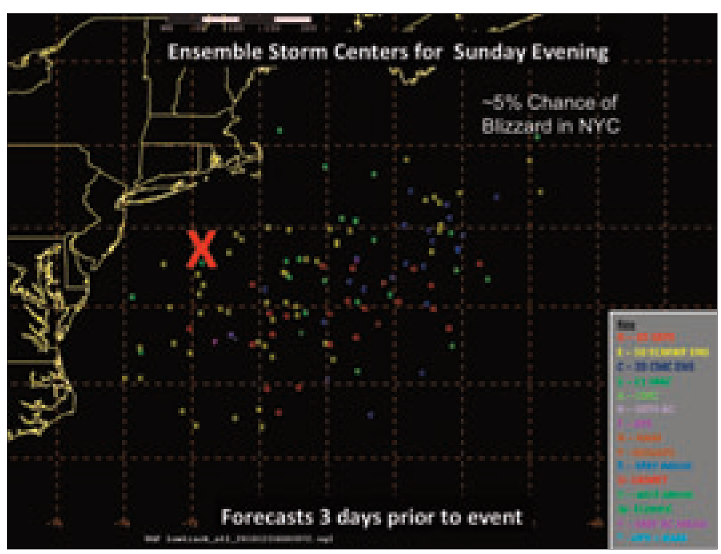
Accurate Forecast → Receive Forecast → Understand Forecast → Relate to Decision → React

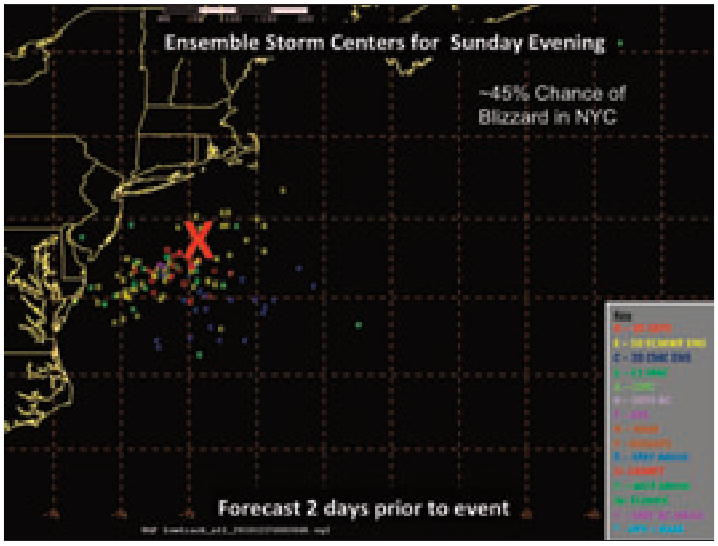
20

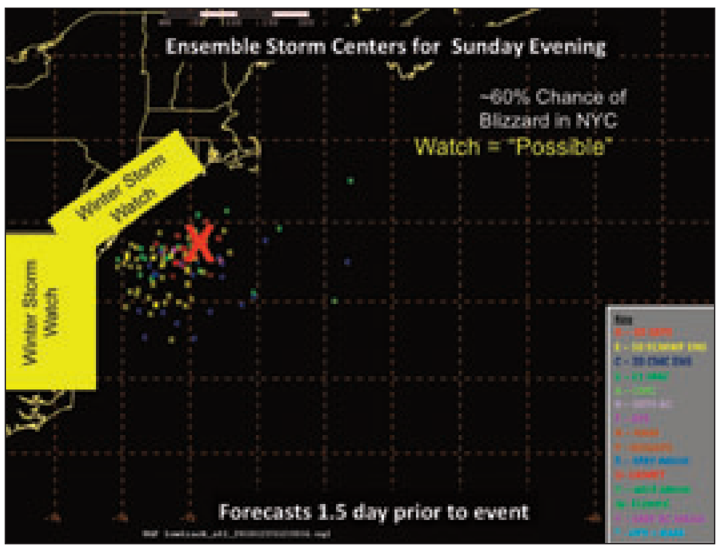
Post Christmas Storm

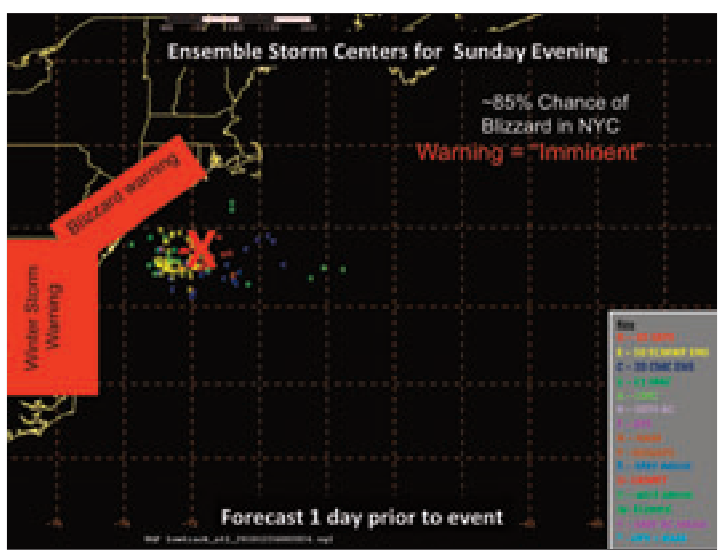

Storm track and development forecasts varied from run to run
28/00z 962 mb
27/00z 972 mb
26/12z 992 mb
26/00z 1004 mb
OBSERVED
00z ECMWF
00z GFS
Guidance 4 days prior to event


Storm track and development forecasts varied from run to run.
28/00z 962 mb
27/00z 972 mb
26/12z 992 mb
26/00z 1004 mb
OBSERVED
12z ECMWF
12z GFS
Guidance 3 days prior to event


Ensemble Storm Centers for Sunday Evening
~5% Chance of Blizzard in NYC
X
Forecasts 3 days prior to event

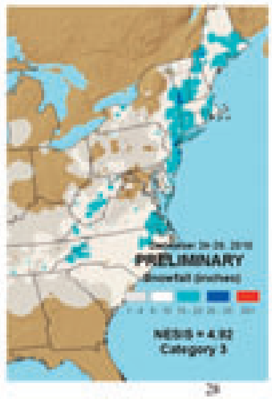

Ensemble Storm Centers for Sunday Evening
~45% Chance of
Blizzard in NYC
Forecast 2 days prior to event


Ensemble Storm Centers for Sunday Evening
~60% Chance of
Blizzard in NYC
Watch = "Possible"
Winter Storm
Watch
Winter Storm
Watch
Forecasts 1.5 day prior to event


Ensemble Storm Centers for Sunday Evening
~85% Chance of
Blizzard in NYC
Warning = "Imminent"
Blizzard warning
Winter Storm
Warning
Forecast 1 day prior to event

From a Forecast Perspective

- Potential for East Coast cyclone recognized days-week in advance
- Special efforts made to convey uncertainty related to track forecast
- Key transition December 24 – storm forecast along the coast with more certainty
  - NJ, NYC and New England would be main focus of blizzard conditions
- Warning lead times of 12-24 h



29

From a City Manger Perspective

Did not have necessary level of certainty before Christmas Day

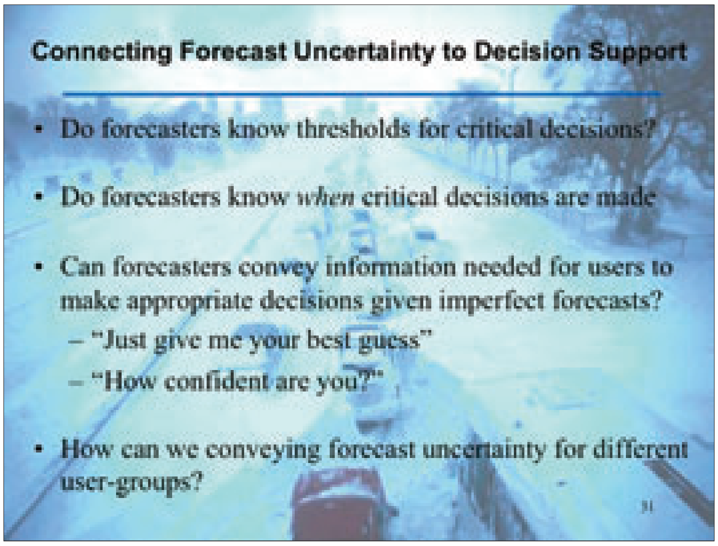
- NYC does not declare snow emergency
- Results in major gridlock within city
- City response under scrutiny

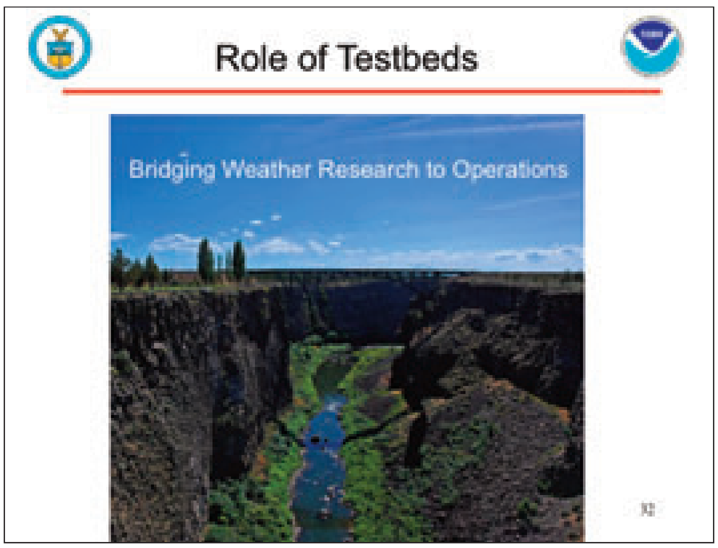
From a Aviation User Perspective

Conditioned to react on short lead time

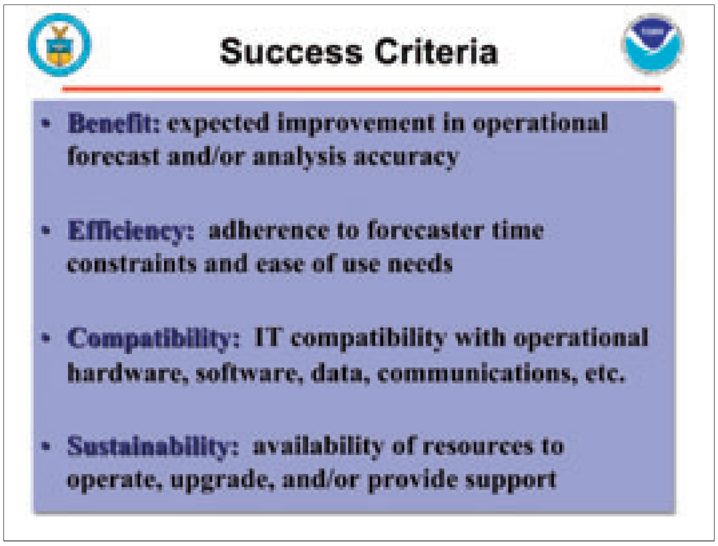
- Airlines/airports are prepared for crippling event
  - Cancel thousands of flights to mitigate impact on national and international flight operations
  - Fully recover in 3-4 days

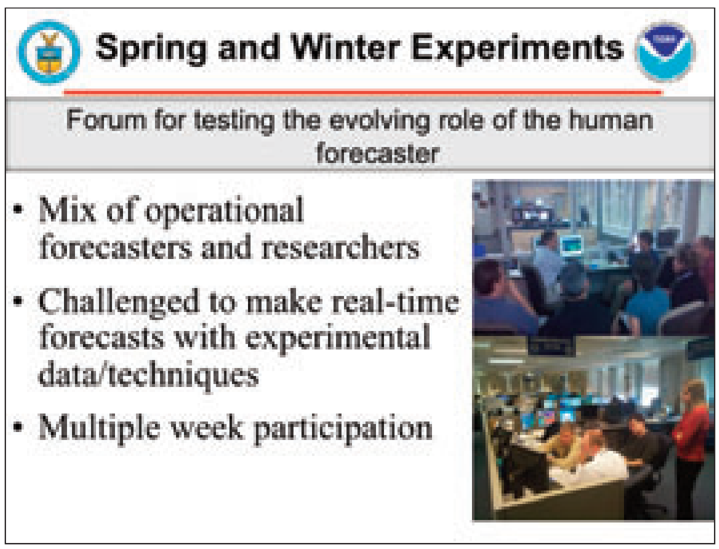
30

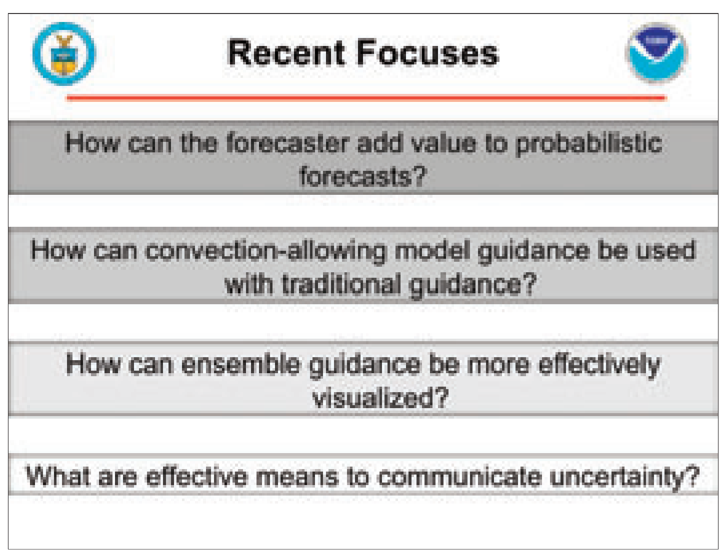

Connecting Forecast Uncertainty to Decision Support
• Do forecasters know thresholds for critical decisions?
• Do forecasters know *when* critical decisions are made
• Can forecasters convey information needed for users to make appropriate decisions given imperfect forecasts?
– "Just give me your best guess"
– "How confident are you?"
• How can we conveying forecast uncertainty for different user-groups?

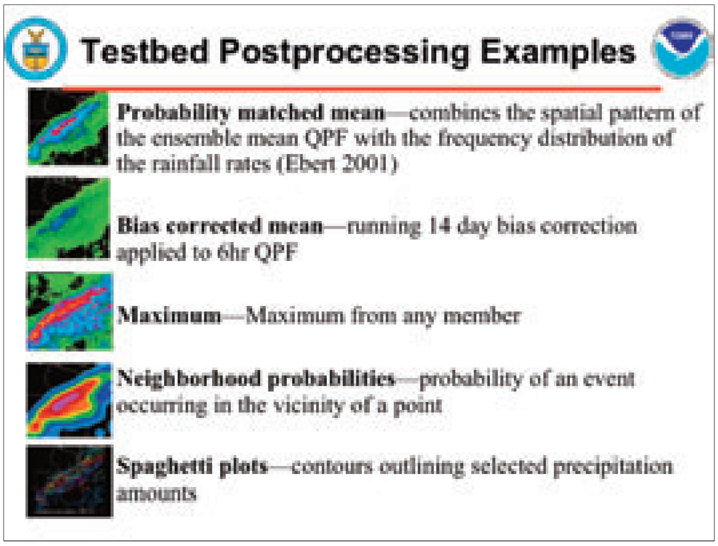

Role of Testbeds
Bridging Weather Research to Operations


NCEP Test Beds
"Does the new technique/model work?"
• EMC – Developmental Test Bed
• HPC – Hydrometeorological Test Bed
• AWC – Aviation Weather Test Bed
• SPC – Hazardous Weather Test Bed
• NHC – Joint Hurricane Test Bed
• CPC – Climate Test Bed
• OPC – Ocean Test Bed
• SPWC – Space Weather Test Bed

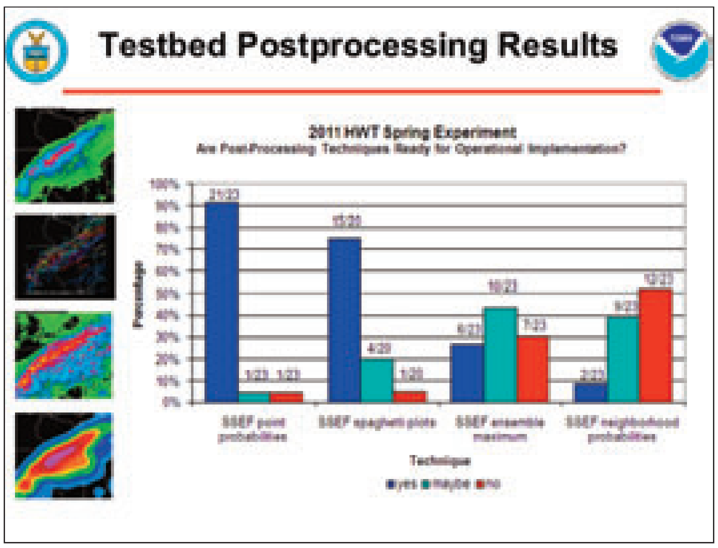

Success Criteria
• Benefit: expected improvement in operational forecast and/or analysis accuracy
• Efficiency: adherence to forecaster time constraints and ease of use needs
• Compatibility: IT compatibility with operational hardware, software, data, communications, etc.
• Sustainability: availability of resources to operate, upgrade, and/or provide support


Spring and Winter Experiments
Forum for testing the evolving role of the human forecaster
• Mix of operational forecasters and researchers
• Challenged to make real-time forecasts with experimental data/techniques
• Multiple week participation

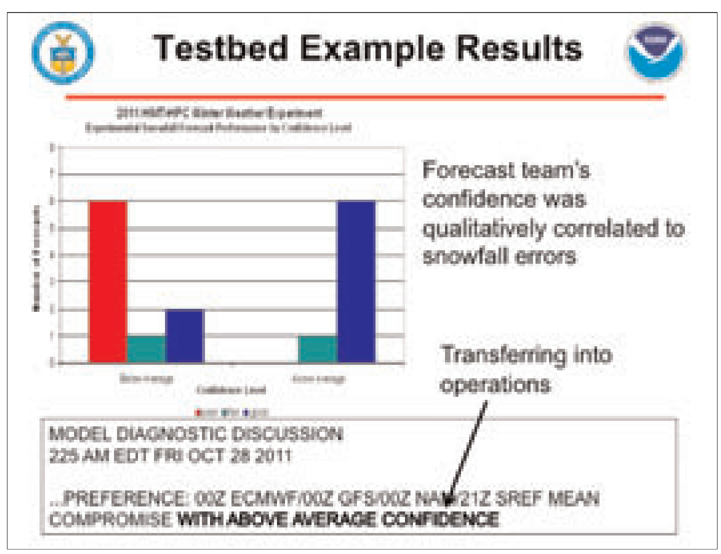

Recent Focuses
How can the forecaster add value to probabilistic forecasts?
How can convection-allowing model guidance be used with traditional guidance?
How can ensemble guidance be more effectively visualized?
What are effective means to communicate uncertainty?



Testbed Postprocessing Examples
Probability matched mean—combines the spatial pattern of the ensemble mean QPF with the frequency distribution of the rainfall rates (Ebert 2001)
Bias corrected mean—running 14 day bias correction applied to 6hr QPF
Maximum—Maximum from any member
Neighborhood probabilities—probability of an event occurring in the vicinity of a point
Spaghetti plots—contours outlining selected precipitation amounts



Testbed Postprocessing Results
2011 HWT Spring Experiment
Are Post-Processing Techniques Ready for Operational Implementation?
Percentage
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
21/23
1/23
1/23
15/20
4/20
1/20
6/23
10/23
7/23
2/23
9/23
12/23
SSEF point probabilities
SSEF spaghetti plots
SSEF ensemble maximum
SSEF neighborhood probabilities
Technique
yes
maybe
no



Testbed Example Results
Forecast team's confidence was qualitatively correlated to snowfall errors
Transferring into operations
MODEL DIAGNOSTIC DISCUSSION
225 AM EDT FRI OCT 28 2011
...PREFERENCE: 00Z ECMWF/00Z GFS/00Z NAM/21Z SREF MEAN COMPROMISE WITH ABOVE AVERAGE CONFIDENCE

Summary

Optimization of forecast resources via
- Transition to managing NWP
- Transition to focused decision support

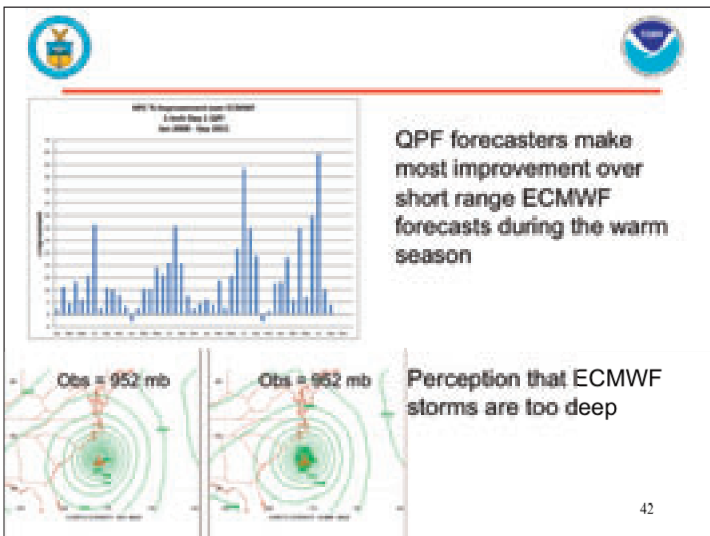
Allows:
- Extension of forecast through time
- Expansion of decision support services

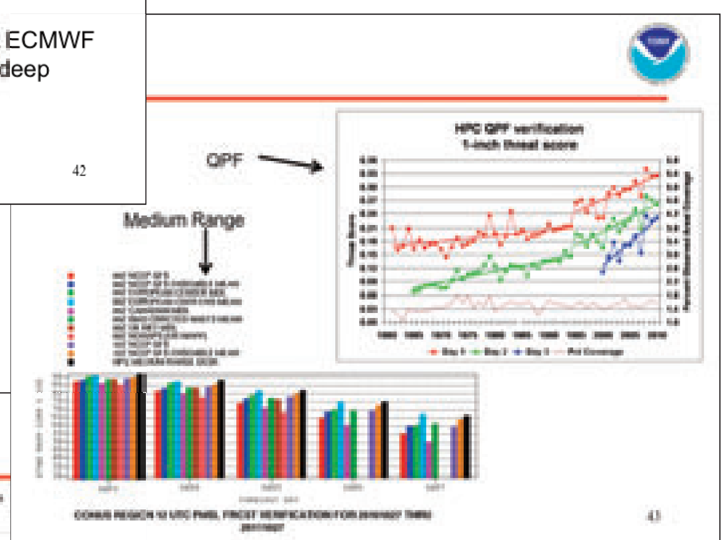
While maintaining accuracy

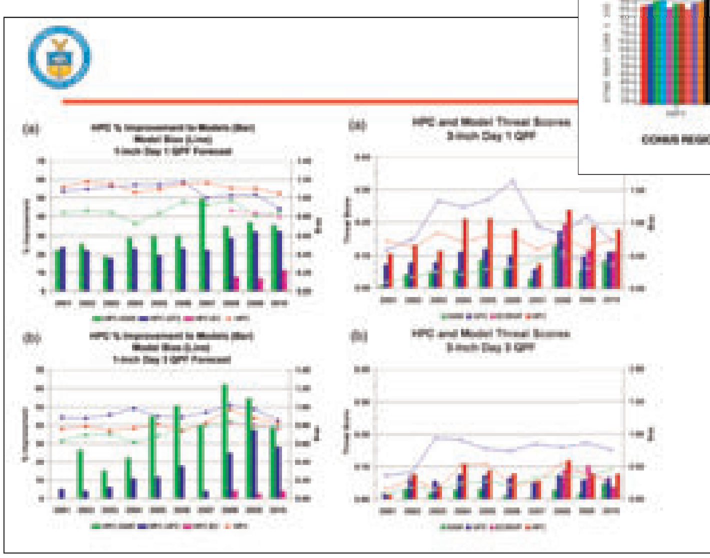
Ensemble guidance key part of transition

Testbeds supporting the transition

Backup





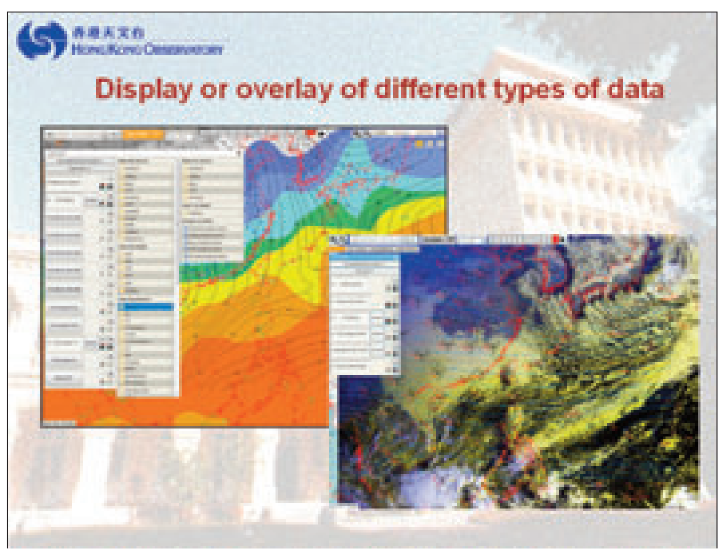


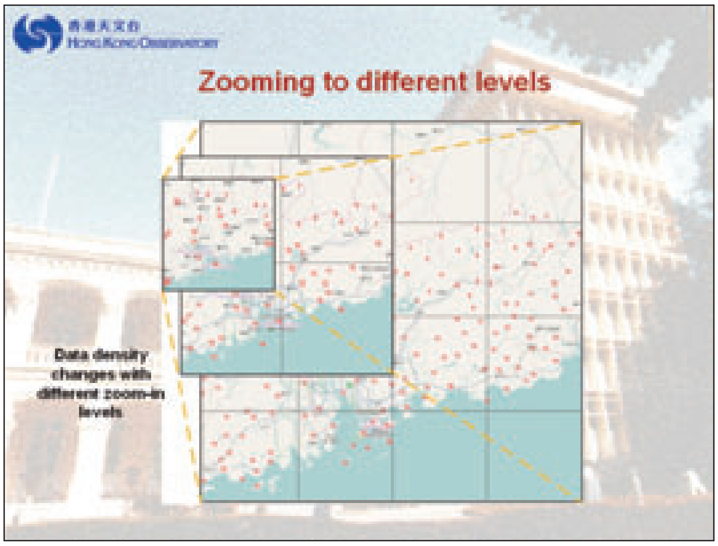
Application of NWP products and meteorological information processing system in Hong Kong

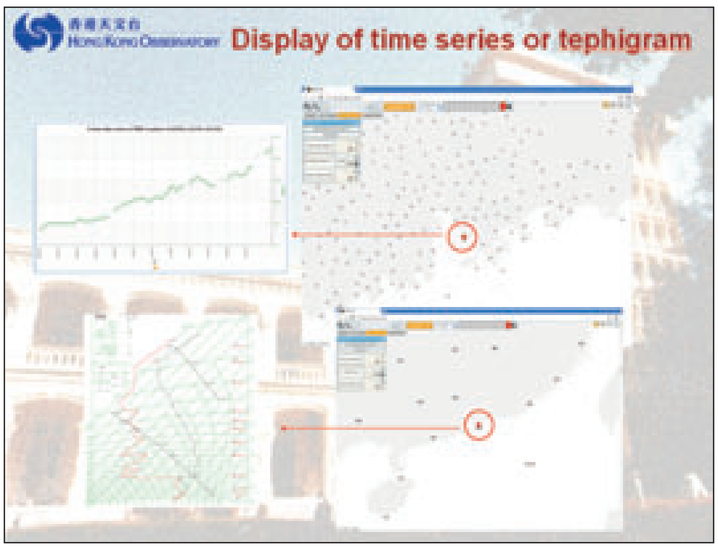
Li Yuet Sim, Hong Kong Obervatory

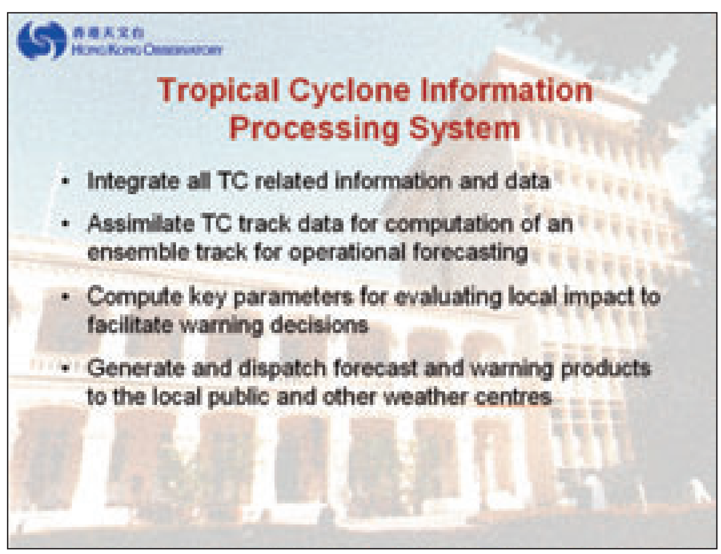
Abstract

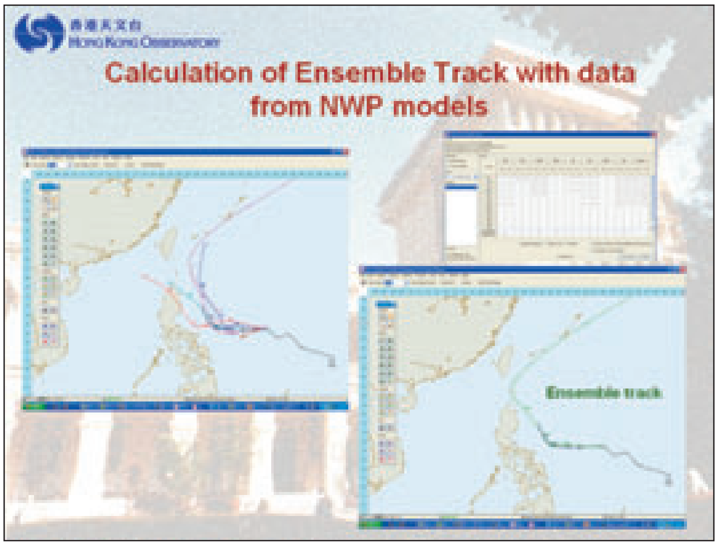
With the rapid increase in the spatial and temporal resolutions of NWP models in the recent years as well as the introduction of various new weather parameters, display of NWP forecasts simply on a two dimensional map might not be a way to make good use of the data. Functions, including zooming in/out, dynamic layering and on-the-fly display of time-series, cross-section or vertical profile, do facilitate forecasters to perform analysis in a more effective way. The Hong Kong Observatory (HKO) is now developing a GIS-based integrated meteorological information display system to display and overlay different types of data, including NWP data, observational data, and satellite/radar images enabling forecaster to better appreciate the weather situation. The Tropical Cyclone Information Processing System is another example of information processing system developed by HKO, the system can assimilate various types of tropical cyclone related data and evaluate potential impact on local weather.

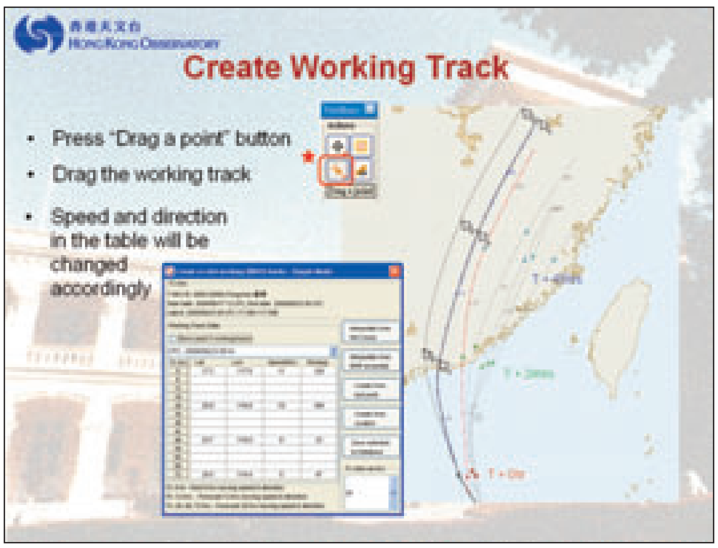


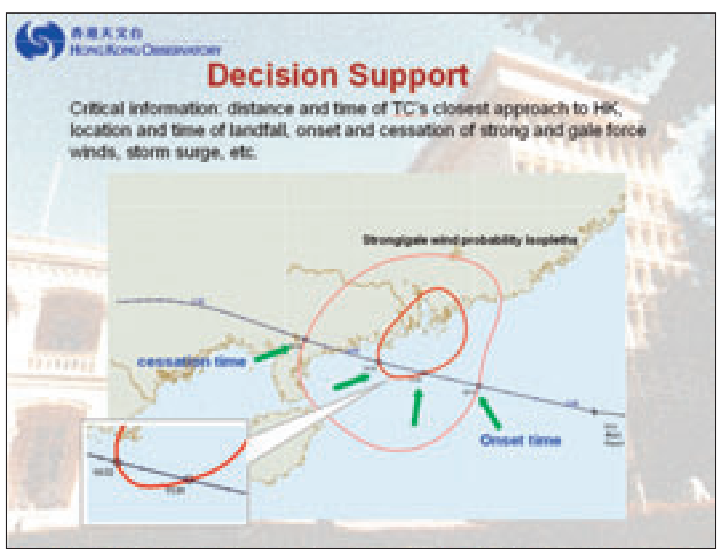

Zooming to different levels
Data density changes with different zoom-in levels


Display of time series or tephigram


Tropical Cyclone Information Processing System
• Integrate all TC related information and data
• Assimilate TC track data for computation of an ensemble track for operational forecasting
• Compute key parameters for evaluating local impact to facilitate warning decisions
• Generate and dispatch forecast and warning products to the local public and other weather centres


Hong Kong Observatory
Calculation of Ensemble Track with data from NWP models
Ensemble track


Hong Kong Observatory
Create Working Track
Press "Drag a point" button
Drag the working track
Speed and direction in the table will be changed accordingly


Hong Kong Observatory
Decision Support
Critical information: distance and time of TC's closest approach to HK, location and time of landfall, onset and cessation of strong and gale force winds, storm surge, etc.
Strong/gale wind probability isopleths
cessation time
Onset time

香港天文台
HONG KONG OBSERVATORY
Generation of Forecast Bulletins and Warning Products for the Public
Tropical Cyclone Warning for Shipping

The new ECMWF seasonal forecasting system 4

Laura Ferranti, ECMWF

Introduction

Following a line of research and development in extended-range predictions which has spanned almost three decades, a new seasonal forecast system (System 4) has been implemeted in November 2011.

ECMWF has been at the forefront of dynamical extended range forecasting since the mid 1980's, when experimentation on ensemble forecasting for the monthly time scale was started (Molteni et al. 1986, Brankovi? et al. 1990). Research on predictability on seasonal time scale in the early 1990's (e.g. Palmer and Anderson 1994) led to the implementation of the first ECMWF seasonal forecast system based on a global ocean-atmosphere coupled model in 1997, and a successful forecast of the 1997-98 El Niño (Stockdale et al. 1998). This first coupled system (referred to as System-1) was followed by System-2 in 2001 and the currently operational (at the time of writing) System-3 in March 2007 (Anderson et al. 2007; Stockdale et al. 2011).

All three ECMWF seasonal forecast systems so far have used the Hamburg Ocean Primitive Equation model (HOPE; Wolff et al 1997) as the ocean component, initialised through an optimum-interpolation (OI) ocean data assimilation scheme which was substantially improved in the transition from System-2 to System-3 (Balmaseda et al. 2008). Although System-3 proved to be a well balanced and skillful system, especially in its predictions of the ENSO phenomenon (Stockdale et al. 2011), the HOPE-OI system was considered obsolete, and it was clear that further progress would have been difficult to achieve until a new ocean model and ocean data assimilation scheme, with potential for future developments, were introduced.

The new ECMWF seasonal forecast System-4 benefits from the transition to the NEMO/NEMOVAR ocean components. NEMO (Nucleus for European Modelling of the Ocean, Madec 2008) ocean model is developed by a consortium of French and British institutions, and a variational ocean data assimilation system (NEMOVAR) is developed through a collaboration between ECMWF and research institutes in France and UK.

In addition System 4 benefits from progress achieved in a number of other areas, such as:

- The availability of a state-of-the-art re-analysis (ERA-Interim) to provide forcing fluxes for the ocean and initial conditions for the atmosphere;
- a recent cycle of the Integrated Forecasting System (IFS) with improved simulation of tropical intra-seasonal variability and reduced biases in the extratropical regions;
- higher horizontal and vertical resolution, with a better representation of stratospheric processes and forcings
- a set of re-forecasts spanning a 30-year period with a larger ensemble size than in System-3 (15 vs 11 members);
- a larger ensemble size in the operational system (51 vs 41 members), matching the size of themedium-range and monthly ensembles;
- a more accurate initialization of land-surface variables;
- a more sophisticated simulation of model-generated uncertainties, and a simple representation of sea-ice uncertainty through relaxation to alternative sea-ice conditions.

This paper describes the various components of System-4 and presents some results about model biases and predictive skill derived from an analyses of the 30-year re-forecast set.

The seasonal forecast System-4

NEMO (Nucleus for European Modelling of the Ocean, Madec 2008) is a state-of-the-art modelling framework for oceanographic research, operational oceanography, seasonal forecasts and climate studies (for more information see http://www.nemo-ocean.eu/). System 4 uses NEMO version v3.0, with some local modifications (dynamic memory, more flexible output, surface flux forcing, closure of fresh water budget). The grid configuration adopts the ORCA1 grid, which has a horizontal resolution of approx. 1 degree (with equatorial refinement), and 42 levels in the vertical, 18 of which are in the upper 200m. The configuration has been provided by the National Oceanographic Centre (NOC) in Southampton (http://www.noc.soton.ac.uk/nemo/). The horizontal resolution is similar to the one used in the current HOPE model, but the resolution in the vertical is increased, especially in the mid-deep ocean (from 29 in HOPE to 42 in NEMO). NEMOVAR is a multi incremental and multivariate variational data assimilation system for the NEMO ocean model. It is based on the variational data assimilation system OPAVAR, and it has been further developed within a collaborative project with ECMWF, the Met Office and CE FACS.

The atmospheric component of the S4 forecast system is the IFS Cycle 36r4. This model version was introduced for operational medium-range forecasting on the 9th of November 2010, at the time when System 4 configuration was being finalised. Care was taken to define a cost-effective configuration that would provide users with a large enough hindcast dataset, a larger ensemble size, and a better, higher-resolution coupled system.

System	Atmospheric Model cycle	Horizontal resolution	Vertical resolution	Ensem-ble size	Re-fore-cast years	Re-forecast members
S3	31R1	~120Km	L62 Top:5hPa	41	25 years 1981-2005	11
S4	36R4	~80Km	L91 Top:.01hPa	51	30 years 1981-2010	15

The ensembles for each forecast or re-forecast are generated by using an ensemble of initial conditions and by the use of stochastic physics. The ocean analyses are provided as a 5 member ensemble. The ensemble of analyses is driven by sampling uncertainty in winds and in deep ocean initial conditions, and sub-sampling observation coverage. The ocean analyses are then augmented by applying SST perturbations (as many as needed), with an associated sub-surface temperature signal. The ocean initial conditions thus represent the main uncertainties in the ocean state. For the atmosphere, the operational EPS machinery is used to calculate singular vectors and targeted singular sectors in the tropics, using 36r4 operational settings. The perturbations applied to the upper air fields are somewhat simplified compared to the full EPS system since the uncertainties estimated by the Ensemble Data Assimilation system are not used.

Every seasonal forecast model suffers from bias - the climate of the model forecasts differs to a greater or lesser extent from the observed climate. Since variations in the predicted seasonal distributions are often small, this bias needs to be taken into account, and must be estimated from a previous set of model integrations. Also, it is vital that users know the skill of a seasonal forecasting system if they are to make proper use of it, and again this requires a set of forecasts from earlier dates.

The re-forecasts for S4 are made starting on the 1st of every month for the years 1981-2010. The ensemble size is 15 members (increased from 11 in S3 to provide more reliable statistics). The data from these forecasts is available to users of the real-time forecast data, to allow them to calibrate their own real-time forecast products.

The real-time seasonal forecasts consist of a 51 member ensemble, as in the medium-range and monthly EPS. The ensemble is constructed by combining the 5-member ensemble ocean analysis with SST perturbations and the activation of stochastic physics. The forecasts have an initial date of the 1st of each month, and run for 7 months. Forecast data and products are released at 12Z UTC on the 8th of the month.

Skill measures and systematic errors

The quality of a seasonal prediction system is ultimately measured by the quality of its forecasts. However, the accuracy of the model's mean state is a necessary test of its quality, which is relevant both to the likely performance in forecast mode and to understanding any issues and problems regarding the model formulation. Figure 1 shows SST bias from the early range of the forecasts verifying in DJF for S4 and S3. Several features can be highlighted: S4 has a better annual cycle of SST at higher latitudes and in particular a reduced warm bias in the Southern Ocean. On the other hand, S4 has a more pronounced "cold tongue" bias in the equatorial Pacific. Further analysis (not shown) shows that S4 has a much improved seasonal cycle in the far eastern Pacific and in the equatorial Atlantic.

The improvements in physical parametrizations introduced between cycles 31r1 (S3) and 36r4 (S4) have a stronger impact on the reduction of biases when looking at purely atmospheric fields (not shown).

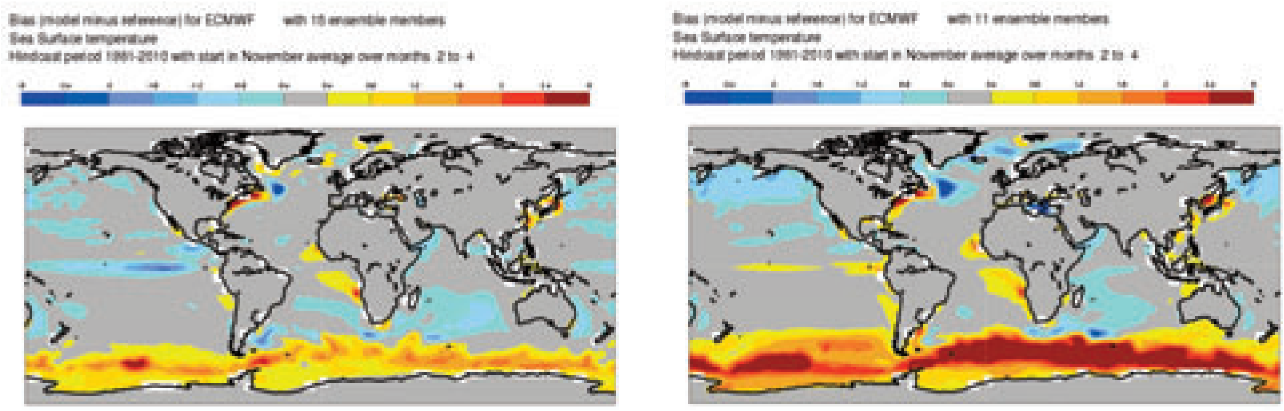


Figure 1 SST bias in DJF (from November start dates), for S4 (left) and S3 (right).

Although (as seen above) large reductions in model bias are present in many areas, S4 suffers from a cold drift in the equatorial SSTs over the Pacific. This bias has a progressively larger impact on long lead times (~ 1year) and on parameters which are strongly sensitive to the mean SST. In addition cycle 36r4 has a tendency to over-estimation of SST amplitude in the east Pacific. The over estimation is seasonally varying, and reaches its maximum for lead times of a few months verifying during the boreal spring. For the purpose of producing forecasts of "Nino SST" indices (one of the major seasonal forecast products), the forecast anomalies are scaled appropriately. While the mean of the SST forecasts is already corrected by the process of bias removal, this approach involves the additional step of correcting the variance of the model output to match the observed variance.

For a final perspective, the performance of S4 and S3 against the other EUROSIP models, from the Met Office and Météo-France is shown. The Met Office now calculates their re-forecasts only in near real time. We use their most recent version for which a year of data exists, which is the version that ran from late 2009 to almost the end of 2010. For this version, the re-forecast period available covers the 14 years 1989-2002. Re-forecast data is available for 11 months, and Figure 2 shows MSSS (Mean Square Skill Score against climatology) in the El Nino 3.4 region (5N-5S 120-170W)for S4, S3 and the other European models for these dates. Since the Met Office model has a similar over-activity to S4, it is processed in the same way (ie with variance scaling), which improves the MSSS. The Meteo-France and S3 models are underactive, and do not have their variance scaled. The ECMWF S4 forecast system maintains a substantial lead over the other two systems in NINO3.4, and extends its lead to substantial levels in NINO3 (not shown). In NINO4, the slight deterioration means that it is now only marginally ahead of Meteo-France for this period, although it is significantly ahead of the Met Office (not shown).

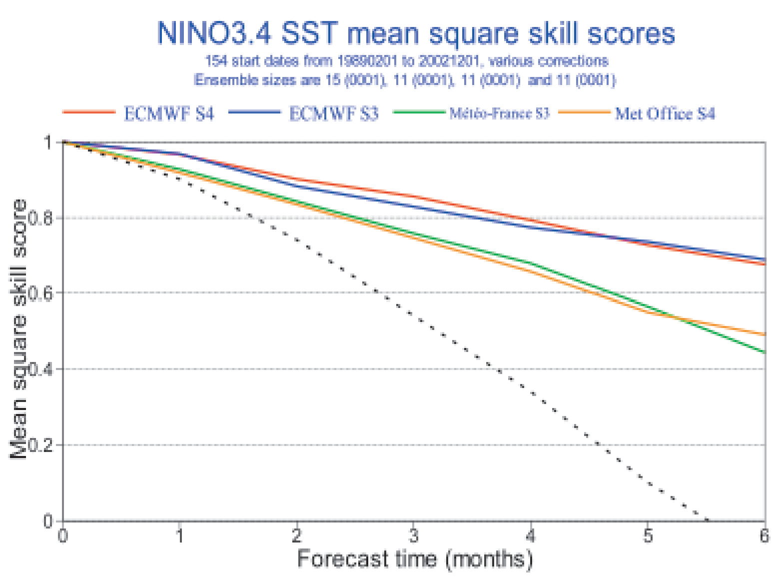


Figure 2 MSSS for S4 (red), S3 (blue), Meteo-France (green) and Met Office (orange), for the years 1989-2002, for NINO3, NINO3.4 and NINO4. Scores for persistence are in black.

Results show that S4 offers coherent performance gains over S3. In the tropics, where the sampling error is much smaller, the lead is sufficient to be seen in almost every skill map (not shown). Temperature related fields in the NH also show a consistent lead, although NH geopotential fields have a smaller advantage over S3. The gains in Anomaly Correlation skill seen by S4 are mirrored by improvements in probabilistic skill scores. Figure 3 shows reliability diagrams calculated from S3 (left) and S4 (right), in this case for 2m temperature exceeding the upper tercile in JJA for points in Europe, predicted from 1st May. The decomposition of the Brier Skill Score shows that S4 has both higher reliability and higher resolution than S3. The increase of reliability is mainly due to the effect of a larger ensemble size in System 4 re-forecast comparing with System 3 (see table). According to corresponding plots, this is true for many other regions and quantities, confirming the overall superiority of S4 over S3 as a probabilistic forecasting system.

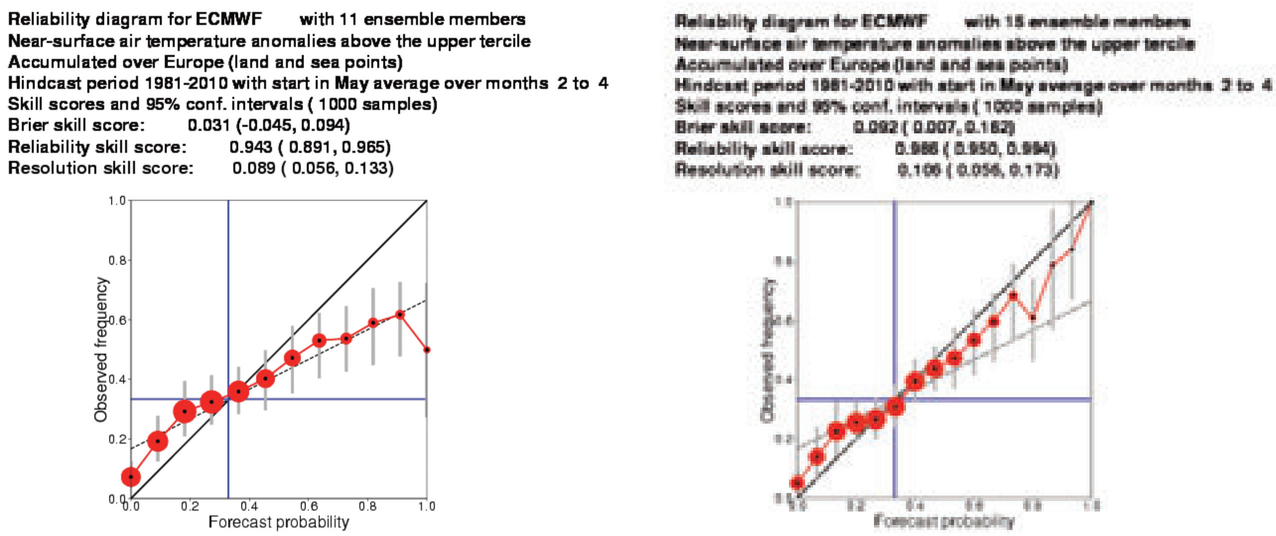


Figure 3 Reliability diagrams for JJA 2m temperature over Europe in the upper tercile category, for S3 (left) and S4 (right).

System 4 has been developed with the goals of improving those aspects where S3 was deficient, and posing the foundations for future progress in ocean and sea-ice modelling. As with any new operational systems, not every change is for the better. System 4 suffers from a stronger cold bias in tropical Pacific SST than S3, and this is reflected in a lack of improvement in West Pacific scores and too large variability in ENSO SST indices.

With respect to S3 (and to seasonal systems from most other operational centres), S4 has the advantage of providing a 30-year reforecast set initialised from, and verified against, a single state-of-the-art re-analysis for both the atmosphere (ERA-interim) and the ocean (the NEMOVAR based ORA-S4). Progress in physical parametrizations has led to substantial bias reductions in extratropical regions, and more realistic tropical intra-seasonal variability. Increased horizontal and vertical resolution has been introduced with the goal of providing a better representation of regional and/or extreme anomalies.

Some of the notable results include:

- very high levels of skill for ENSO forecasts, with further progress on the anomaly correlation of ENSO indices in most areas and seasons;
- more reliable predictions for extratropical regions, which improve on S3 in terms of both deterministic and probabilistic scores.

Please note that the above report is based on the ECMWF technical memoranda N.656: " The new ECMWF seasonal forecast system (System 4)" by Molteni et al. available at
http://www.ecmwf.int/publications/library/do/references/list/14

Customized Daily to Seasonal Predictions for the Energy Sector Using ECMWF Forecasts

James I. Belanger and Violeta E. Toma, School of Earth and Atmospheric Sciences,
Georgia Institute of Technology

1. Introduction

Climate Forecast Applications Network (CFAN) is a joint-venturelab company whose purpose is to transfer Georgia Tech's weather and climate research into daily operations and decision support services. We provide forecasts for a variety of high impact weather variables and phenomena including heat waves, cold air outbreaks, tropical cyclones, flooding, etc. These products are used to support energy trading, economic development, risk management, disaster mitigation and long-range asset planning. Many of these specialized forecasts would not be possible without ECMWF's suite of forecast and hindcast products.

CFAN has adopted a hierarchical forecasting philosophy using the full suite of ECMWF products including the ECMWF Variable Ensemble Prediction System (VarEPS), ECMWF Monthly Forecast System, and ECMWF Seasonal Forecast System. Many of the value-added components are introduced during statistical rendering and post-processing. Some of the statistical tools that are employed include model hindcast calibration and simple linear or more sophisticated MOS bias correction. To calibrate ensemble spread relative to observations, we employ quantile-to-quantile correction, which is a non-linear method to train the quantiles of the forecast distribution to the distribution of observations. This process forces the shape of the forecast distribution to become equivalent to the observed distribution and is an important step to ensure that the model's ensemble forecasts appropriately capture the frequency of high impact

extreme events. Other statistical tools are also used and these include: exploiting the temporal separation among ECMWF products through clustering higher-resolution, more frequent shortterm products to lower-resolution, long-term forecasts. Clustering provides a means to increase the forecast resolution at longer time scales by using a subset of ensembles, instead of relying on the mean of the full ensemble set.

2. CFAN Forecast Products

a. 15-Day Temperature Forecasts

Using the ECMWF VarEPS as well as the model's hindcast climatology, CFAN has developed MOS forecasts for 105 U.S. cities important for energy trading. The forecasts are conveyed in two formats. The first is a simple tabular product that provides a deterministic forecast for the daily maximum and minimum temperature over the next two weeks. Color shading is used to indicate how anomalous the forecast temperatures are relative to the observed climatology for a particular location over the last 30 years. The second format emphasizes the confidence or uncertainty in the forecast by conveying the daily forecast maximum and minimum temperature using interpercentile temperature plumes. Feedback from various endusers including energy traders suggests this format is very useful at conveying forecast uncertainty relative to deterministic tabular format. These users are also well equipped to make trading decisions with this probabilistic information. The primary reason why CFAN relies so heavily on the ECMWF product suite is their performance relative to other available modeling products such as from NCEP. Generally, the ECMWF deterministic outperforms the Global Forecast System (GFS) at all forecast lead-times especially in regions with the largest population density such as the Mid-Atlantic and Northeast. In addition, CFAN's MOS temperature forecasts provide significant value-added benefits to our end users, as they outperform both the ECMWF ensemble mean and the GFS at extended leadtimes.

b. North Atlantic Tropical Cyclone Forecasts

A second product that CFAN has developed which incorporates the ECMWF VarEPS and Monthly EPS is tropical cyclone forecasting in the North Atlantic. CFAN has developed a tailored dashboard product to key users in the energy sector who need as much lead-time as possible regarding the potential formation, movement, and maximum intensity of TCs moving into the Gulf of Mexico. CFAN's product is unique in the industry as it provides probabilistic TC genesis, track, and intensity forecasts for systems that have not formed but have reached at least a moderate probability (30%+) of formation.

CFAN also provides several value-added benefits with this tropical cyclone product on top of what the ECMWF VarEPS already provides. Although the ECMWF model provides superior track forecasts when compared to other global and regional models especially at extended leadtimes, the ECMWF VarEPS does suffer from track and intensity underdispersion. Resulting from this issue are forecast probabilities that are often overconfident relative to observations. Therefore, to calibrate the probabilistic track forecasts, CFAN utilizes the model's hindcast runs to determine the historical track error distribution of the VarEPS. From this dataset, a Monte Carlo resampling strategy is used to generate synthetic forecast tracks, which are used in the construction of the final track probabilities.

While the ECMWF VarEPS track forecasts are slightly underdispersive, systematic model biases in the VarEPS intensity forecasts preclude them from reliably being used in an operational setting. Therefore, significant statistical post-processing is utilized to develop reliable probabilistic intensity forecasts. After correcting for initial intensity errors between the model initialized intensity and observations, quantile-to-quantile look up tables are generated and updated weekly with the most recent hindcast run. These tables are used to calibrate the ensemble maximum intensities, which significantly increases the forecast ensemble spread and allows the end product to become more reliable and useful for our end users.

c. Monthly Temperature Forecasts

Using the ECMWF monthly forecasting system and its hindcast climatology, CFAN has developed probabilistic heat wave forecasts for 7 U.S. cities that are the most representative for energy trading decisions in the U.S. The temporal evolution of the extreme temperature probabilities is estimated using an extreme value approach. A theoretical generalized extreme value distribution is fitted to the hindcast climatology and the heat wave probability is then estimated based on the number of ensemble members above the upper quartile of the theoretical distribution. In addition, similar to the 15-days MOS product, interpercentile temperature anomaly plumes are used to convey the uncertainty associated with the monthly forecast. Results show that, the method underforecasts the observed frequency of heat wave occurrence. However, extreme events forecasts, which are the most important for our end users, are generally more reliable. Anomaly correlations between the observations and forecasts show statistically significant correlations for forecast lead-time of 10-17 days. Hoverer, the results are based on a short verification period of 2011 and a more extensive analysis is currently planned.

d. Seasonal Temperature Forecasts

CFAN also provides a seasonal outlook for surface air temperatures in the U.S. using the ECMWF seasonal prediction system and a simple multi-linear regression model based on observed predictors. To improve the predictability associated with mid-latitude teleconnection regimes (e.g. NAO, AO, PNA, etc.) out to 45 days, an ensemble clustering technique is implemented. We have experimented with clustering the ECMWF seasonal system based upon the initial validation (1-14 days) period of observed analyses with individual ensemble members. Results show that the distribution of temperature anomalies at forecast lead-times beyond the first month may be better captured by selecting the top five high predictable ensemble members rather than using the mean of the full set of ensembles.

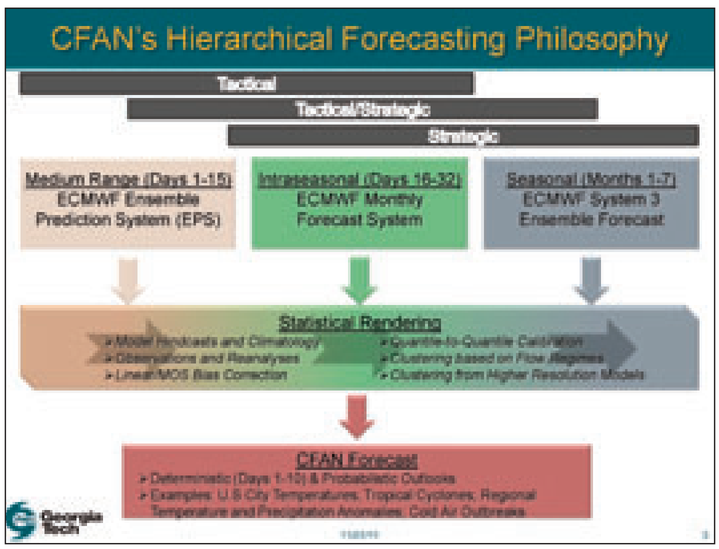
Additionally, for the winter period, the usefulness of a statistically-based regression forecast is also considered. Recent research shows that fall Arctic sea ice extent together with snow cover over Eurasia influences the surface air temperature distribution at lower latitudes over the Northern Hemisphere. Our analysis shows that the statistical model in comparison to the ECMWF seasonal forecast's ensemble mean better-represented observed U.S. temperatures anomalies for winter 2010-2011. However, neither the ensemble mean nor the statistical model captured the magnitude of December 2011-January 2012 temperature anomalies over the U.S.

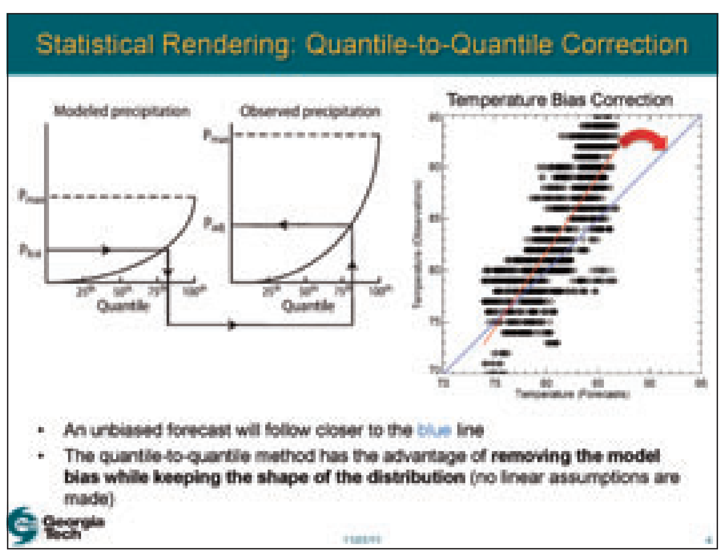
3. Conclusions and Recommendations

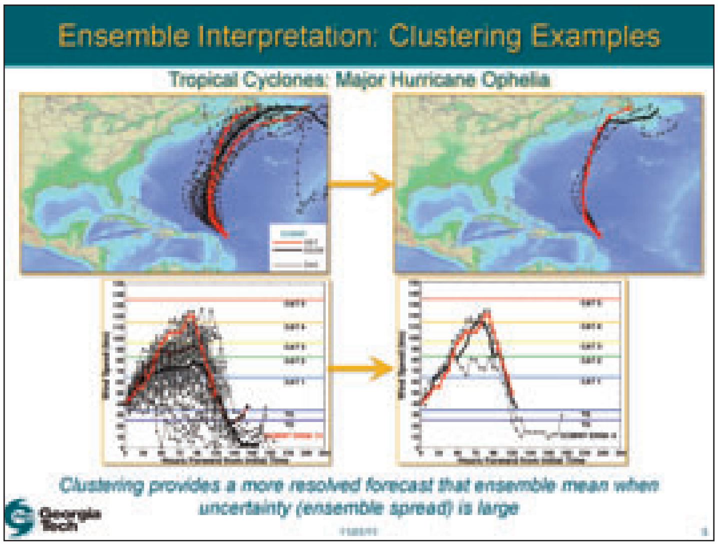
CFAN has relied on ECMWF's suite of forecast products since 2007 to provide customized daily to seasonal forecasts for a variety of clients in the energy sector. Our experience and analyses confirm that most of the ECMWF forecasts have better skill when compared to similar products produced from other global centers.

Many of our statistical post-processing tools take advantage of the ECMWF's hindcasts to understand how the model's forecast climate compares with observations. This product has provided an important tool to ensure that customized well-calibrated products for a local area may be produced for our end-users. We are hopeful that ECMWF may someday expand their hindcast suite to include a larger ensemble size or more frequent hindcast updates. In addition, we recommend that ECMWF consider releasing derived time series of the Madden-Julian Oscillation (MJO) index by ensemble member from the Monthly Forecast System, as this index is very useful in helping users quantify the uncertainty associated with the MJO and its propagation across the tropics.

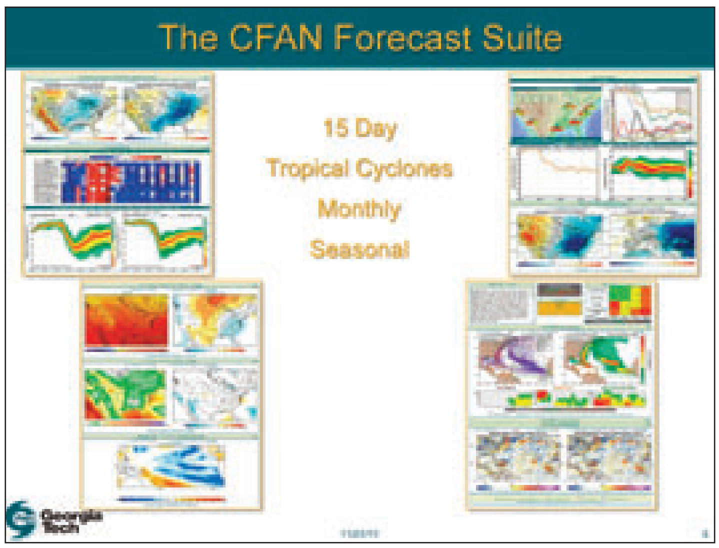

Who Is CFAN?
MISSION
Apply Georgia Tech's cutting-edge weather and climate research to provide forecasting and decision support for risk management
• GT Enterprise Innovation Institute VentureLab Company
• Our Products and Services
➢ Forecasting high impact extreme events on daily to seasonal time scales to support decision making
➢ Variables include temperature, wind, tropical cyclones, floods, precipitation, hydrology, snowpack
➢ Support energy trading, economic development, risk management, disaster mitigation, regional stability, long-range asset planning
Would not be possible without ECMWF's forecast and hindcast products!
Georgia Tech


CFAN's Hierarchical Forecasting Philosophy
Tactical
Tactical/Strategic
Strategic
Medium Range (Days 1-15)
ECMWF Ensemble Prediction System (EPS)
Intraseasonal (Days 16-32)
ECMWF Monthly Forecast System
Seasonal (Months 1-7)
ECMWF System 3 Ensemble Forecast
Statistical Rendering
➢Model Hindcasts and Climatology
➢Observations and Reanalyses
➢Linear/MOS Bias Correction
➢Quantile-to-Quantile Calibration
➢Clustering based on Flow Regimes
➢Clustering from Higher Resolution Models
CFAN Forecast
➢Deterministic (Days 1-10) & Probabilistic Outlooks
➢Examples: U.S City Temperatures, Tropical Cyclones, Regional Temperature and Precipitation Anomalies, Cold Air Outbreaks
Georgia Tech

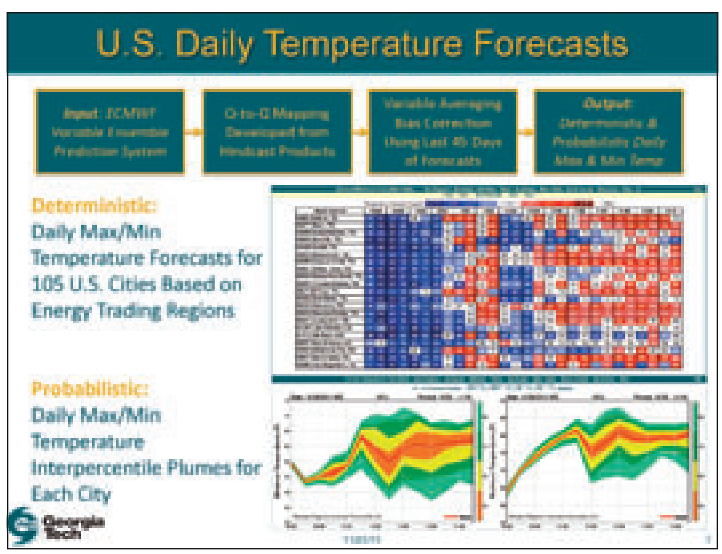

Statistical Rendering: Quantile-to-Quantile Correction
Modeled precipitation
Observed precipitation
Quantile
Quantile
Temperature Bias Correction
• An unbiased forecast will follow closer to the blue line
• The quantile-to-quantile method has the advantage of removing the model bias while keeping the shape of the distribution (no linear assumptions are made)
Georgia Tech



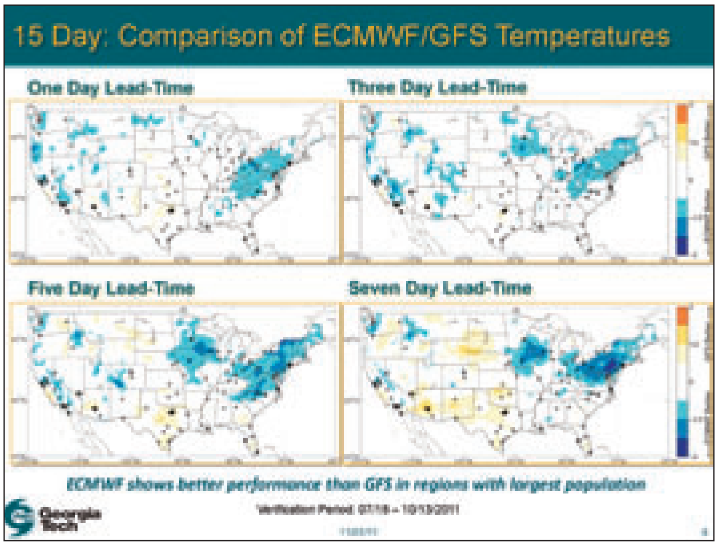
Ensemble Interpretation: Clustering Examples
Tropical Cyclones: Major Hurricane Ophelia
Clustering provides a more resolved forecast that ensemble mean when uncertainty (ensemble spread) is large
Georgia Tech



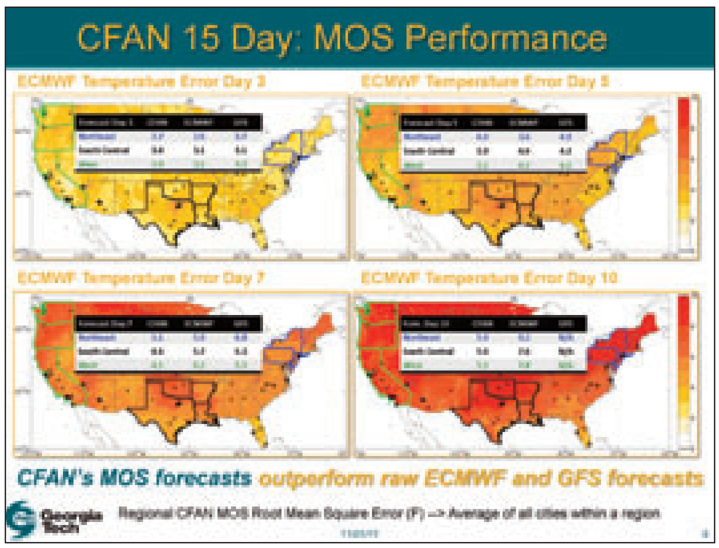
The CFAN Forecast Suite
15 Day
Tropical Cyclones
Monthly
Seasonal
Georgia Tech



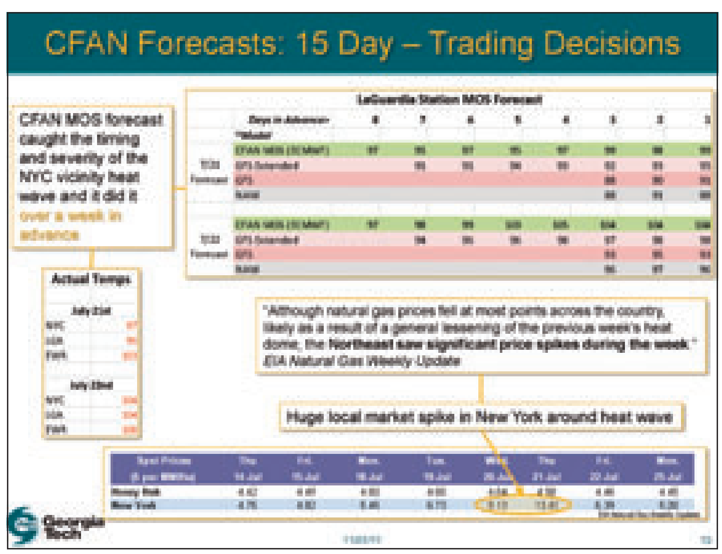
U.S. Daily Temperature Forecasts
Input: ECMWF Variable Ensemble Prediction System
Q-to-Q Mapping Developed from Hindcast Products
Variable Averaging Bias Correction Using Last 45 Days of Forecasts
Output: Deterministic & Probabilistic Daily Max & Min Temp
Deterministic:
Daily Max/Min Temperature Forecasts for 105 U.S. Cities Based on Energy Trading Regions
Probabilistic:
Daily Max/Min Temperature Interpercentile Plumes for Each City
Georgia Tech



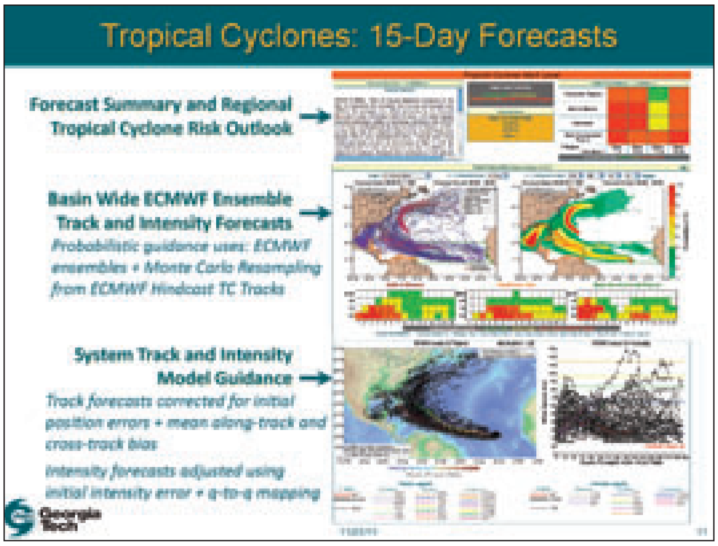
15 Day: Comparison of ECMWF/GFS Temperatures
One Day Lead-Time
Three Day Lead-Time
Five Day Lead-Time
Seven Day Lead-Time
ECMWF shows better performance than GFS in regions with largest population
Verification Period: 07/18 – 10/13/2011
Georgia Tech



CFAN 15 Day: MOS Performance
ECMWF Temperature Error Day 3
ECMWF Temperature Error Day 5
ECMWF Temperature Error Day 7
ECMWF Temperature Error Day 10
CFAN's MOS forecasts outperform raw ECMWF and GFS forecasts
Georgia Tech
Regional CFAN MOS Root Mean Square Error (F) --> Average of all cities within a region



CFAN Forecasts: 15 Day – Trading Decisions
LaGuardia Station MOS Forecast
CFAN MOS forecast caught the timing and severity of the NYC vicinity heat wave and it did it over a week in advance
Actual Temps
"Although natural gas prices fell at most points across the country, likely as a result of a general lessening of the previous week's heat dome, the Northeast saw significant price spikes during the week."
EIA Natural Gas Weekly Update
Huge local market spike in New York around heat wave
Georgia Tech



Tropical Cyclones: Forecast Skill of Regional Outlooks

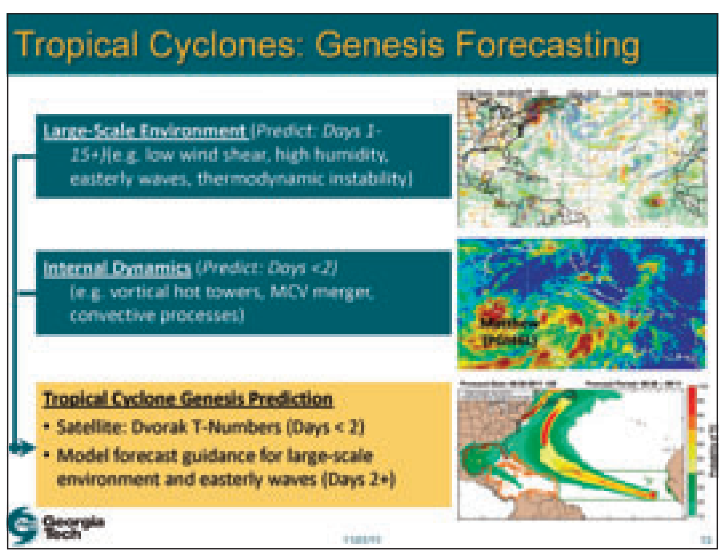
Brier Skill Scores 2008-2011

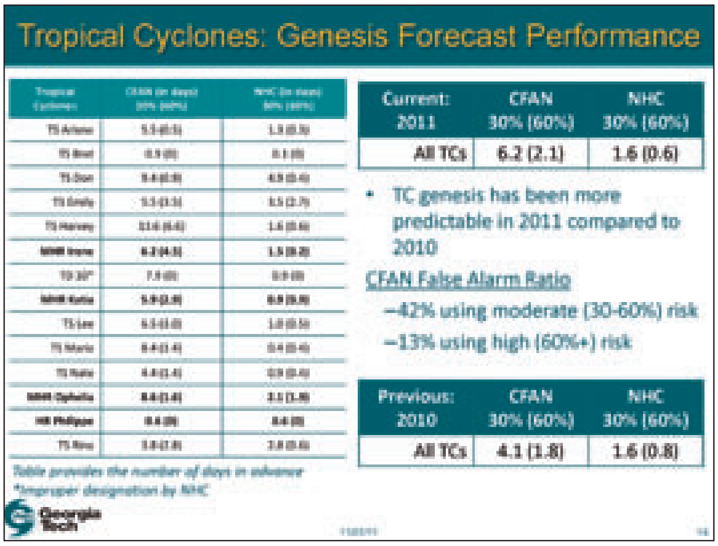
Regions	Days 1-5	Days 6-10	Days 11-15
Production Region	**0.45 (0.47)**	**0.27 (0.14)**	0.08 (0.05)
Gulf of Mexico	**0.56 (0.39)**	**0.19 (0.19)**	-0.06 (0.03)
Caribbean	**0.55 (0.42)**	**0.25 (0.21)**	-0.10 (-0.09)
Main Develop. Region	**0.52 (0.38)**	**0.14 (0.22)**	-0.20 (-0.12)
All Regions	0.52 (0.42)	0.21 (0.19)	-0.07 (0.03)

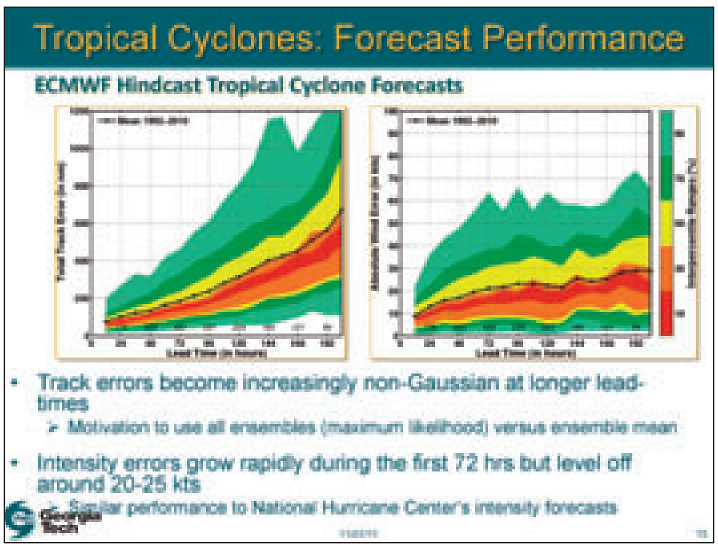
Format: CFAN (ECMWF); **Statistically Significant Values at 90% level**
Note: Values > 0 Forecast Skillful Relative to Climatology

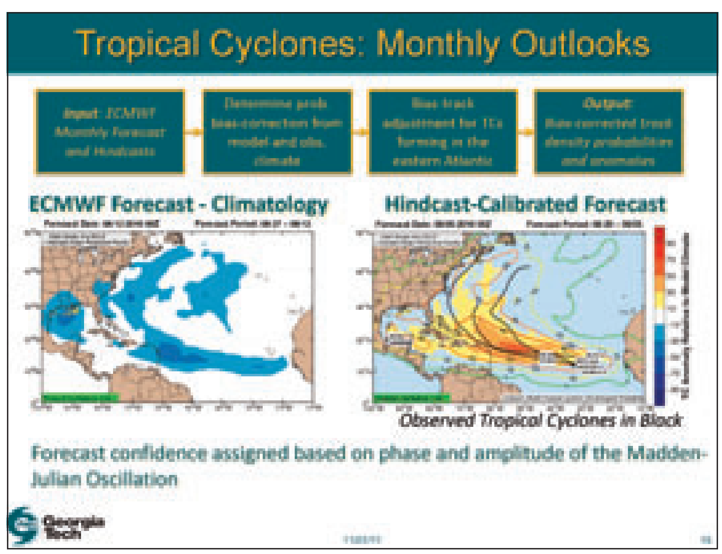
- CFAN has *outperformed ECMWF and climatology during the past four years for a majority of regions during Days 1-10.*
- CFAN performance relative to ECMWF is attributed to appropriately identifying periods of higher (lower) than normal predictability while accounting for systematic model tendencies/errors

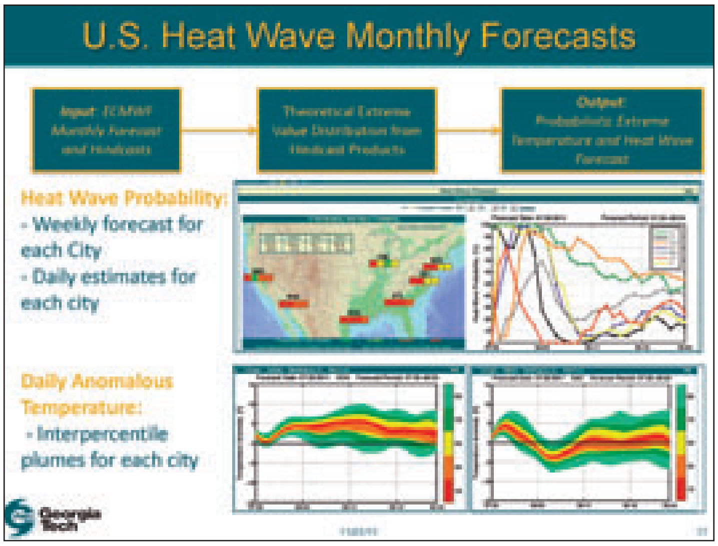
Georgia Tech

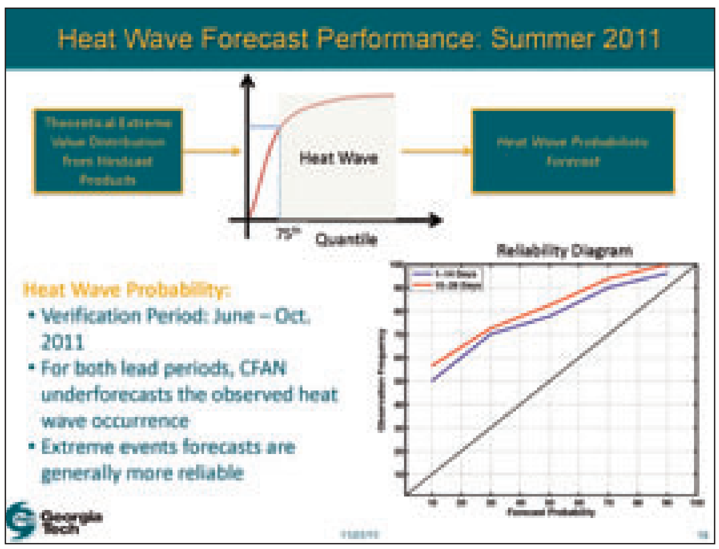


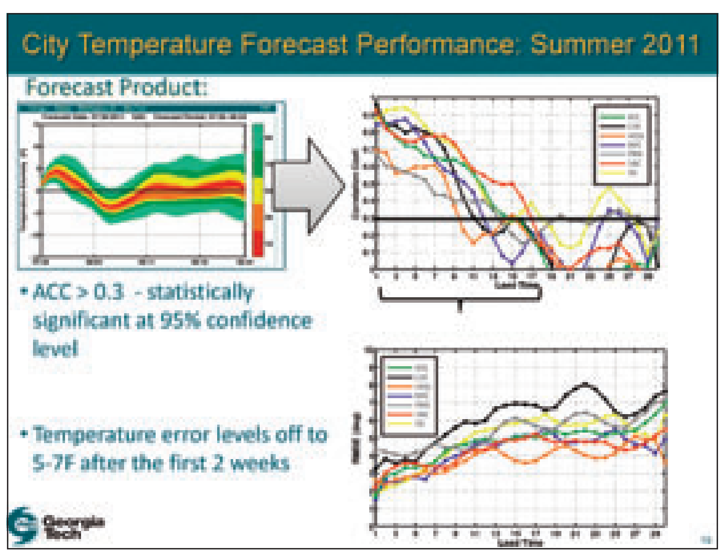

Tropical Cyclones: Genesis Forecast Performance
Current: 2011
CFAN 30% (60%)
NHC 30% (60%)
All TCs
6.2 (2.1)
1.6 (0.6)
TC genesis has been more predictable in 2011 compared to 2010
CFAN False Alarm Ratio
–42% using moderate (30-60%) risk
–13% using high (60%+) risk
Previous: 2010
CFAN 30% (60%)
NHC 30% (60%)
All TCs
4.1 (1.8)
1.6 (0.8)
Table provides the number of days in advance
*Improper designation by NHC
Georgia Tech

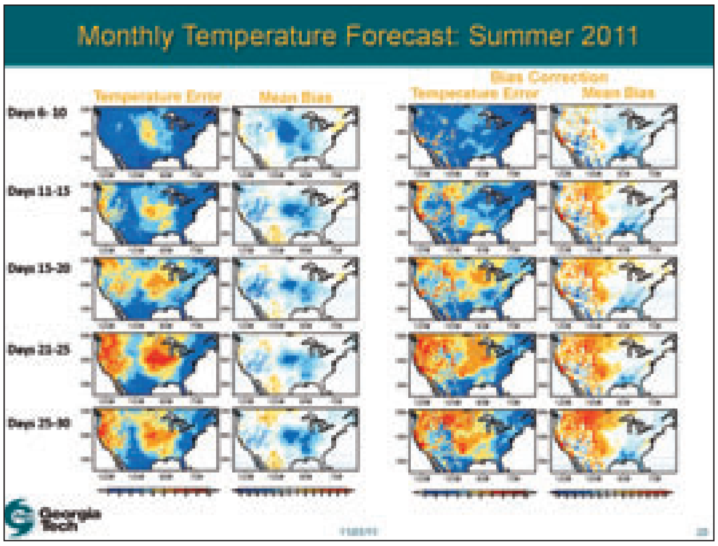

Tropical Cyclones: Forecast Performance
ECMWF Hindcast Tropical Cyclone Forecasts
Track errors become increasingly non-Gaussian at longer lead-times
Motivation to use all ensembles (maximum likelihood) versus ensemble mean
Intensity errors grow rapidly during the first 72 hrs but level off around 20-25 kts
Similar performance to National Hurricane Center's intensity forecasts
Georgia Tech

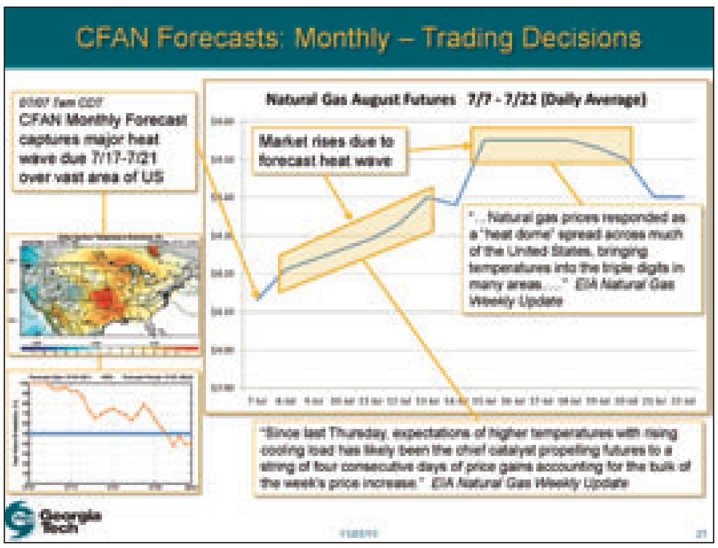

Tropical Cyclones: Monthly Outlooks
ECMWF Forecast - Climatology
Hindcast-Calibrated Forecast
Observed Tropical Cyclones in Black
Forecast confidence assigned based on phase and amplitude of the Madden-Julian Oscillation
Georgia Tech

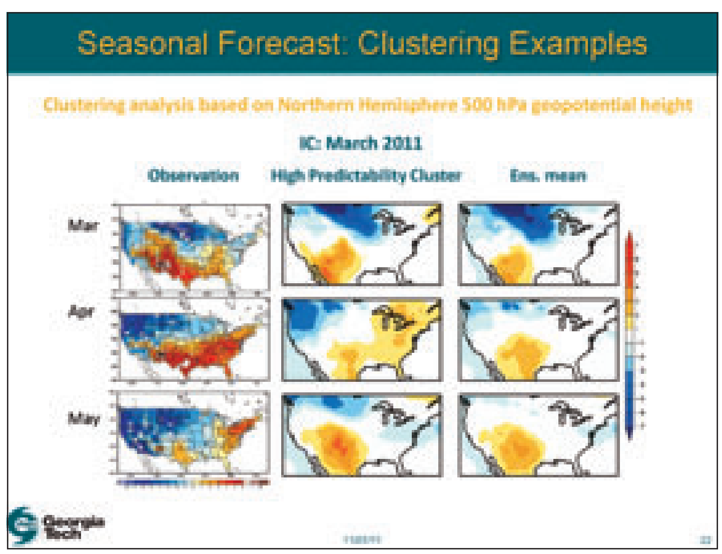

U.S. Heat Wave Monthly Forecasts
Input: ECMWF Monthly Forecast and Hindcasts
Theoretical Extreme Value Distribution from Hindcast Products
Output: Probabilistic Extreme Temperature and Heat Wave Forecast
Heat Wave Probability:
- Weekly forecast for each City
- Daily estimates for each city
Daily Anomalous Temperature:
- Interpercentile plumes for each city
Georgia Tech

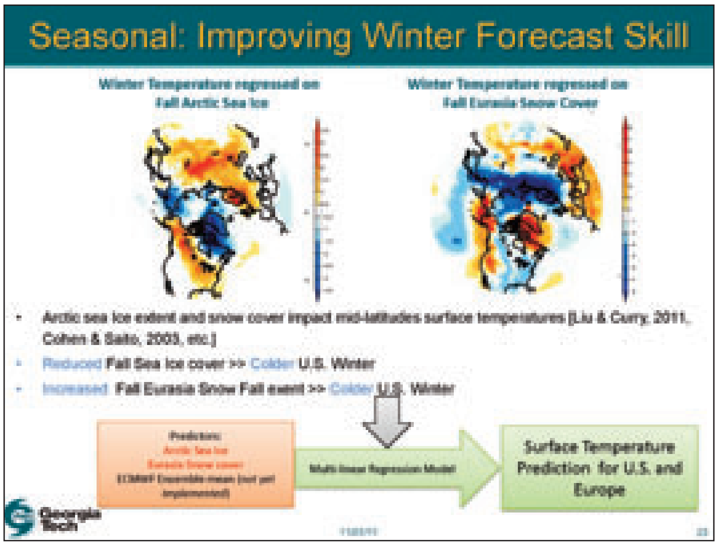

Heat Wave Forecast Performance: Summer 2011
Theoretical Extreme Value Distribution from Hindcast Products
Heat Wave
75th
Quantile
Heat Wave Probability Forecast
Reliability Diagram
Heat Wave Probability:
• Verification Period: June – Oct. 2011
• For both lead periods, CFAN underforecasts the observed heat wave occurrence
• Extreme events forecasts are generally more reliable
Georgia Tech

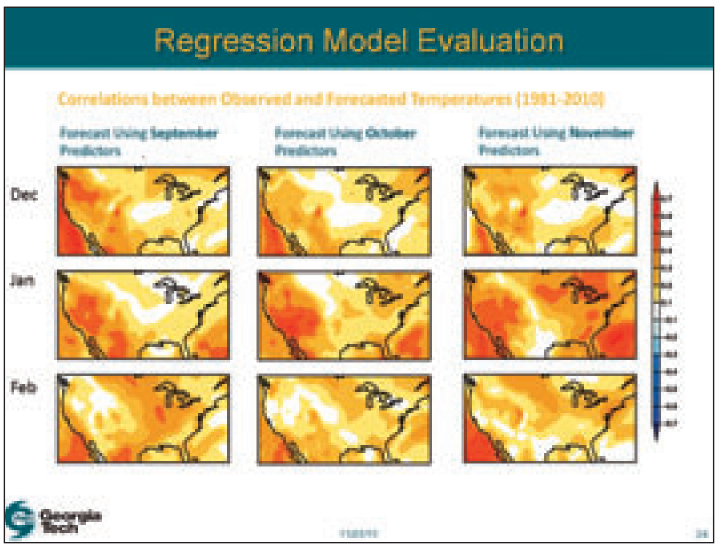

City Temperature Forecast Performance: Summer 2011
Forecast Product:
• ACC > 0.3 - statistically significant at 95% confidence level
• Temperature error levels off to 5-7F after the first 2 weeks
Georgia Tech

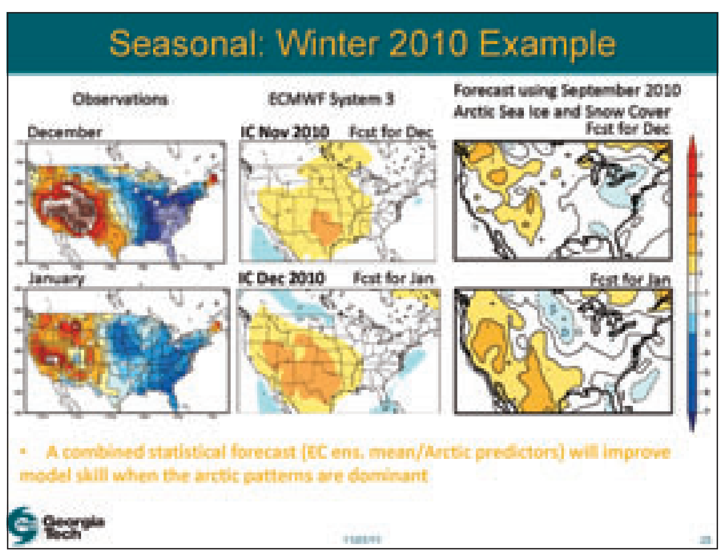

Monthly Temperature Forecast: Summer 2011
Temperature Error
Mean Bias
Bias Correction
Temperature Error
Mean Bias
Days 6-10
Days 11-15
Days 15-20
Days 21-25
Days 25-30
Georgia Tech

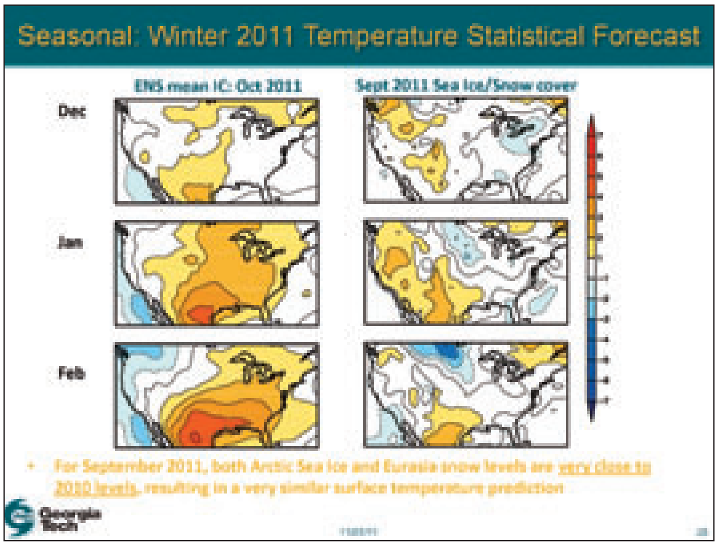

CFAN Forecasts: Monthly – Trading Decisions
07/07 7am CDT
CFAN Monthly Forecast captures major heat wave due 7/17-7/21 over vast area of US
Natural Gas August Futures 7/7 - 7/22 (Daily Average)
Market rises due to forecast heat wave
"…Natural gas prices responded as a "heat dome" spread across much of the United States, bringing temperatures into the triple digits in many areas…." EIA Natural Gas Weekly Update
"Since last Thursday, expectations of higher temperatures with rising cooling load has likely been the chief catalyst propelling futures to a string of four consecutive days of price gains accounting for the bulk of the week's price increase." EIA Natural Gas Weekly Update
Georgia Tech


Seasonal Forecast: Clustering Examples
Clustering analysis based on Northern Hemisphere 500 hPa geopotential height
IC: March 2011
Observation
High Predictability Cluster
Ens. mean
Mar
Apr
May
Georgia Tech

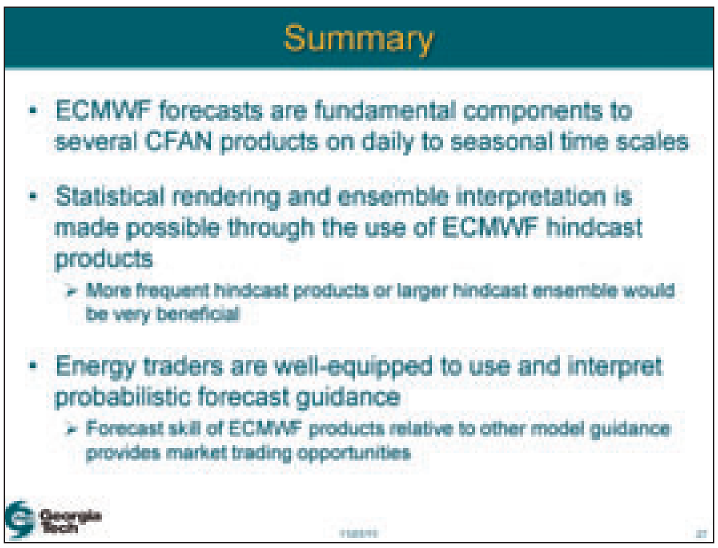

Seasonal: Improving Winter Forecast Skill
Winter Temperature regressed on Fall Arctic Sea Ice
Winter Temperature regressed on Fall Eurasia Snow Cover
• Arctic sea ice extent and snow cover impact mid-latitudes surface temperatures [Liu & Curry, 2011, Cohen & Saito, 2003, etc.]
• Reduced Fall Sea ice cover >> Colder U.S. Winter
• Increased Fall Eurasia Snow Fall event >> Colder U.S. Winter
Predictors:
Arctic Sea Ice
Eurasia Snow cover
ECMWF Ensemble mean (not yet implemented)
Multi-linear Regression Model
Surface Temperature Prediction for U.S. and Europe
Georgia Tech


Regression Model Evaluation
Correlations between Observed and Forecasted Temperatures (1981-2010)
Forecast Using September Predictors
Forecast Using October Predictors
Forecast Using November Predictors
Dec
Jan
Feb
Georgia Tech


Seasonal: Winter 2010 Example
Observations
ECMWF System 3
Forecast using September 2010 Arctic Sea Ice and Snow Cover
December
IC Nov 2010
Fcst for Dec
Fcst for Dec
January
IC Dec 2010
Fcst for Jan
Fcst for Jan
• A combined statistical forecast (EC ens. mean/Arctic predictors) will improve model skill when the arctic patterns are dominant
Georgia Tech



Seasonal: Winter 2011 Temperature Statistical Forecast
ENS mean IC: Oct 2011
Sept 2011 Sea Ice/Snow cover
Dec
Jan
Feb
For September 2011, both Arctic Sea Ice and Eurasia snow levels are very close to 2010 levels, resulting in a very similar surface temperature prediction
Georgia Tech



Summary
• ECMWF forecasts are fundamental components to several CFAN products on daily to seasonal time scales
• Statistical rendering and ensemble interpretation is made possible through the use of ECMWF hindcast products
➢ More frequent hindcast products or larger hindcast ensemble would be very beneficial
• Energy traders are well-equipped to use and interpret probabilistic forecast guidance
➢ Forecast skill of ECMWF products relative to other model guidance provides market trading opportunities
Georgia Tech

Presentation: GRIB data handling with SKY at Deutscher Wetterdienst

Harald Lemmin, Data Management Unit, Dept. Systems and Operations, Business Area Technical Infrastructure and Operations

SKY System components

SKY is a Java based software to store and retrieve mass data. It consists of client, import-server and server components. The Java client can be used by command line client or GUI client or by Java/C/Fortran api and provides read, export, delete, store, archive and unarchive request. The Java import server is a client that automatically stores data implementing a file based workflow. The server is a Java server program that separates meta data and binary data. The meta data is stored in an SQL database, the binary data in an online file system or in a tape archive. The binary data is moved transparently between online file system and tape archive.

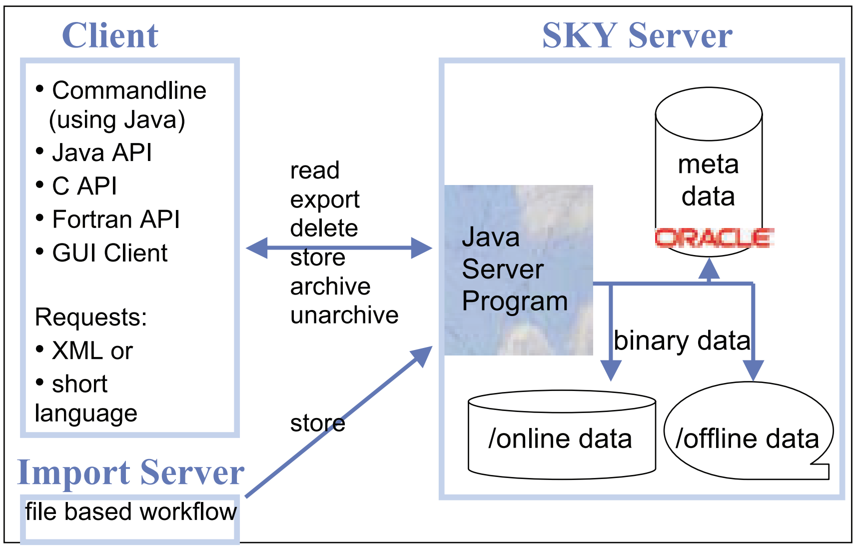


Figure 1 SKY system components

NWP data flow using SKY (Summer 2012)

As of today the observational data as well as satellite and radar data is already store in a SKY server called cirrus. By Summer 2012 all model data will be migrated from CSOBANK to SKY systems, too.

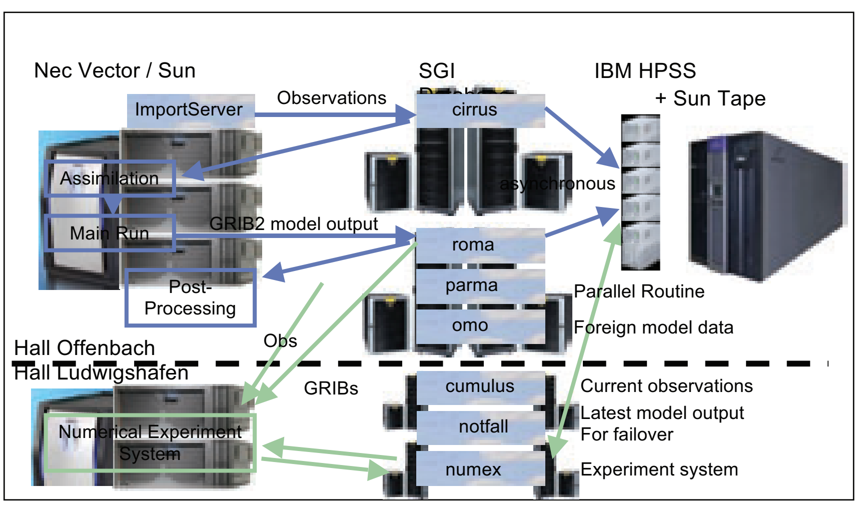


Figure 2 NWP data flow using SKY by summer 2012

Data Migration CSOBANK -> SKY

The migration from CSOBANK to SKY is a pure meta data migration. SKY unifies the GRIB1 and GRIB2 meta data by converting GRIB1 meta data to GRIB2.

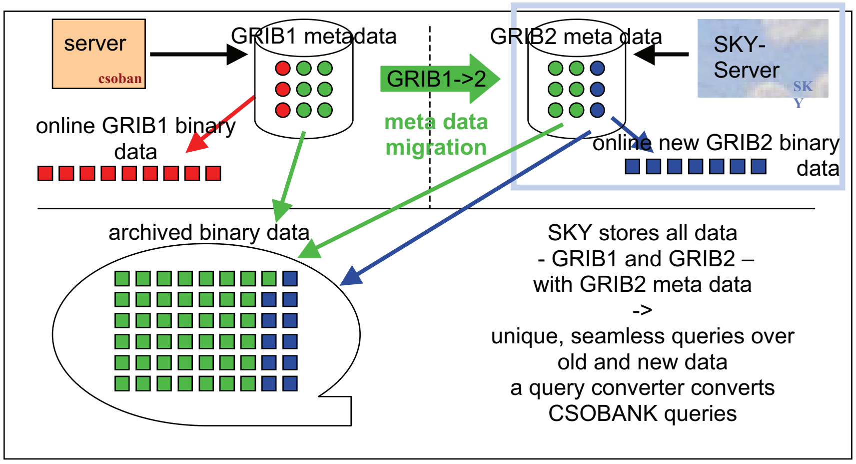


Figure 3 Data migration CSOBANK -> SKY

The meta data conversion is defined by ECMWF grib_api configuration files and complex GRIB1 to GRIB2 conversion rules. Grib_api could not be used directy, because SKY is implemented in Java. SKY also supports grib_api element short names for parameter selection.

ECMWF grib_api will be used widely at Deutscher Wetterdienst by forecasting and postprocessing routines when the GRIB2 migration is finished.

Hierarchial storage management (HSS)

Standard methods of hierarchical storage management are not used so far at Deutscher Wetterdienst, because the total amount of today db server online storage is 760 TB and no HPC vendor offered this functionality during invitation to tender so far. Additionally for the sake of production stability it has been decided not to combine db and (tape) archive server as the archive server is not as stable as the db server is.

Thus the SKY HSM functionality had to be developed to bridge between database servers with SKY server and online storages and archive server front end to tape robot archive system with a real HSM of 480 TB (today: HPSS with 4 mover and 3 virtual file system server).

SKY archives a storage container if it has been closed using HPSS parallel ftp (pftp). The storage container is still online.

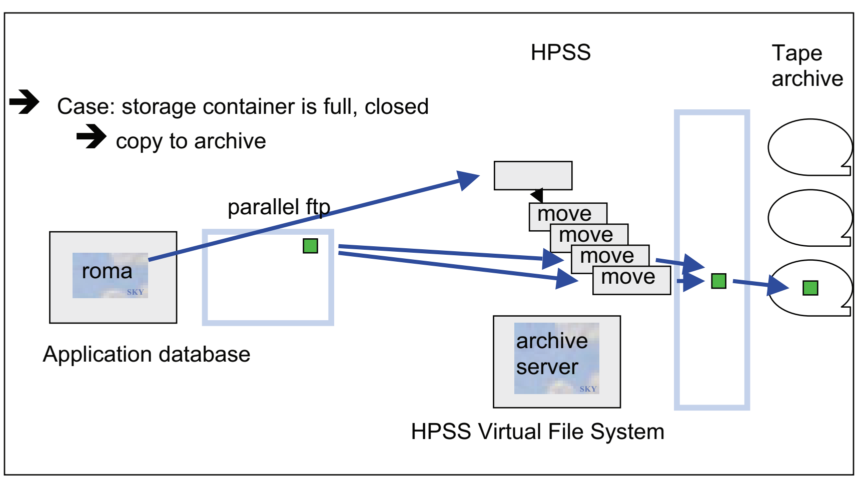


Figure 4 SKY HSS Logic: archive

If the online space gets scarce and the file is not used heavily enough, the online file will be deleted

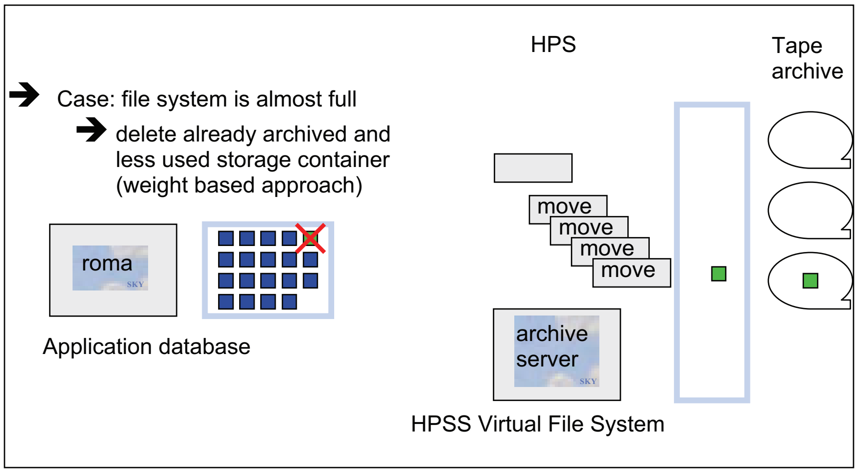


Figure 5 SKY HSS Logic: delete

If a file that is not online is to be read, the SKY server issues an request to the SKY archive server process, running on an HPSS virtual file system node. The SKY archive server collects the read result from the HPSS virtual file system and returns the result.

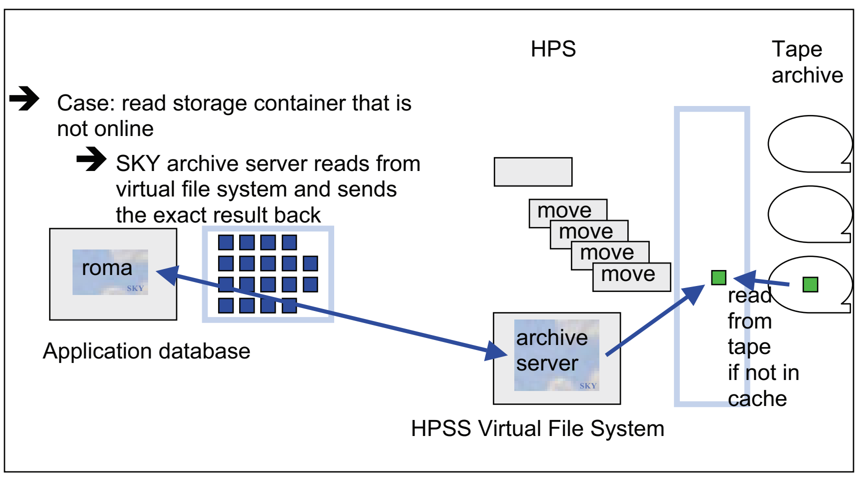


Figure 6 SKY HSS Logic: partial read

If the file again is used more often than other online files, the file is copied back to the online file system using HPSS parallel ftp.

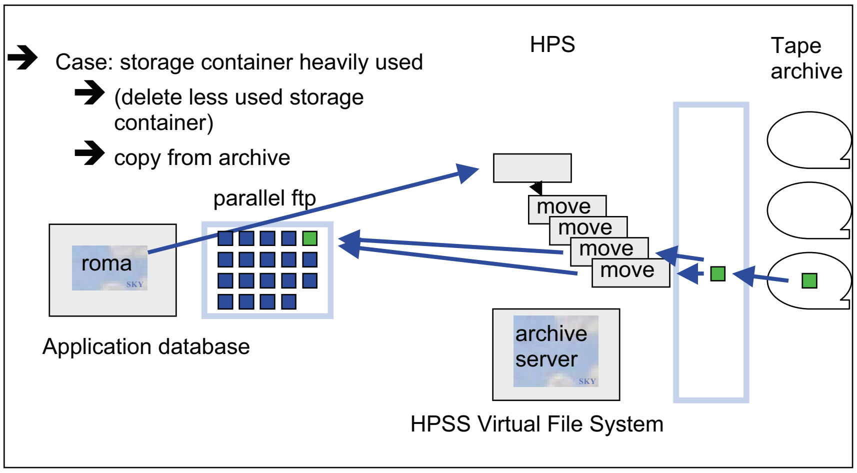


Figure 7 SKY HSS Logic: unarchive

Update of backup system

The backup system has to be updated constantly to minimize switch over time and keep up to the tight model schedule. If a storage container (4 GB) is full or if the data set (ensemble member, forecast step) is closed, the meta data and binary data of this storage container is copied to the backup systems.

If the backup system becomes the primary system, the backup system feeds the main system.

Spatial Data Architecture for Meteorological Operational Management in Romania

Gheorghe Stancalie, Florinela Georgescu, Vasile Craciunescu and Elena Toma, National Meteorological Administration, Bucharest, Romania

1. Introduction

The main goal of the European Directive 2007/2/EC as regards interoperability of spatial data sets and services (INSPIRE) is to achieve interoperability, harmonization across spatial data themes and benefit from the endeavors of users' and producers' communities [1]. The international standards are integrated into the concepts and definitions of the meteorological elements of spatial data themes are listed in the INSPIRE Directive; annex III ("Atmospheric conditions" and "Meteorological geographical features") [2].

In Romania the INSPIRE Directive implementation started in 2010 by a Governmental Ordinance establishing the National Spatial Data Infrastructure (INIS), which allow the implementation of the interoperable framework for the management of meteorological information able to contribute to rounding off a national spatial data infrastructure (SDI).

The Romanian National Integrated Meteorological System (SIMIN) is a complex observation system, with networks for: 159 weather stations, vertical sounder data, lightning detection actinometrical observations, upper-air soundings, radar and satellite data.

2. The visualization system

The Romanian meteorological service uses the neX_REAP visualization system (Next Generation Real-Time Environmental Application Program, prepared by Harris Corporation, Government Communication Systems Division (GCSD) for Lockheed Martin Overseas Corporation (LMOC), for the Romanian National Integrated Meteorological System (SIMIN).

The neX_REAP visualization system is able to provide an easy, powerful way to analyze, forecast, and uses weather data. The major operational functions are: weather data receiving, collecting and organizing; weather data analysis; preparation of weather warnings and advisories; development of professional meteorologist briefings, displays and printouts (weather products), clear, graphical and helpful distribution of weather products for private pilots, maritime operators, commercial planners and others who need understandable, user-friendly weather information; weather product archiving (saving files).

The neX_REAP system consists of a menu-driven graphical user interface which uses point-and-click interaction. This system provides a window environment with an interactive screen interface.

The various menus on the menu bar enable the user to: performing save, print and send options; overlaying information; requesting alphanumeric data; viewing XY Diagrams; initiating and controlling animation loops; initiating and controlling product sequences; requesting products from specific times, and controlling the image size or viewing areas.

2.1 *Functional Description*

The neX_REAP system is comprised of Commercial Off-The-Shelf (COTS), Non-Developmental Item (NDI) hardware, and Harris developed software items. The system receives processes and disseminates satellite imagery, radar, alpha-numeric, and high resolution, graphical weather products for display.

2.2 *Software Architecture*

The neX_REAP software typically utilizes a server and workstation configuration to receive weather information from external sources that can then be processed, stored, displayed or printed. The application provides a windows NT compatible graphical user interface (GUI), to provide a user-friendly, multiple window environment for the display and animation of graphical weather products to multiple users.

The Communications Computer Software Configuration Item (CSCI) is responsible for handling (ingesting, receiving, transmitting, etc.) all of the neX_REAP external communications. This CSCI notifies the Decode/DB CSCI when data arrives and transmits requests for new data from the Display CSCI.

The Decode/DB CSCI is responsible for decoding and storing data, as well as site control (retention), product generation, alarm/alerts and archival. Decoded and pre-generated products are made available for display at the Meteorologist's Workstation and Briefing Terminals. This CSCI also handles A/N requests from the Briefing Terminals.

2.3 Briefing Terminal CSCI

The Briefing Terminal CSCI utilizes the neX_REAP software to manage the viewing and manipulating of alphanumeric and graphical weather products. This CSCI also interfaces with the Decode/DB CSCI to provides the downloading of weather products. The Display CSCI provides workstation system control, acquisition control, product manipulation and word processing for the meteorologists. This CSCI can also save products for transmission to the Briefing Terminals.

The Current products options is the main tool used by users to display a product in a PWC (Product Control Window). Typical products are satellite imagery, radar imagery, geographical maps, and other meteorological data.

2.4 Constraints and limitations

Theactual neX_REAP visualization system can not be implemented on a new computing platform, the actual platform being morally and physically surpassed. Some settings are hard coded in, which implies the impossibility to use facilities for changing a numerical model domain (e.g. the freezing level, vertical sections and upper-air polls prognostic).

The new data in standard WMO formats BUFR, CREX, GRIB2, (for international operational exchange by the GTS) are not supported;

There are also some limitations related to change of colors to zoom and unzoom, printing (resolution maps, and product quality printed format), etc.

3. Spatial data architecture for meteorological operational management in Romania

The main goal of this new approach is to the initiate and develops an interoperable framework for the management of the available observation and forecasting meteorological geo-information, able to contribute to rounding off a national spatial data infrastructure (SDI), in conformity with the provisions of the European Directive INSPRE.

The spatial data architecture for meteorological operational management includes: the design an online system "GEOMET", based on open source applications, allowing the management of meteorological data in a geospatial context as well as the implementation of the data cataloguing component using the GeoNetwork Open source application.

3.1 The online system "GEOMET"

This system will be effectively achieved through developing a webmapping client based on the open source OpenLayers library. The application implements the most relevant international standards concerning the description of the geographic information: ISO 19139 (GI — Metadata — XML schema implementation), FDGC (Federal Geographic Data Committee) and the Dublin core (Dublin Core Metadata Initiative) [3].

The application's architecture is compatible with OGC (Open Geospatial Consortium) standards regarding the Geospatial Portal Reference Architecture and the CSW (Catalogue Service for Web).

The implementation of the data cataloguing component will be based on the GeoNetwork Open source application, which is a standard web application for the management of geospatial information and the reference application for implementing the specification regarding the interrogation and retrieval of information coming from the web (CSW) catalogues. Geonetwork supplies a complex metadata editor as well as advanced search functions for the data indexed on the basis of metadata, using descriptive and spatial criteria.

3.2 The functionality of GEOMET

The online system GEOMET is able to search geospatial data in local or distributed catalogues, to download and upload geospatial datasets.

GEOMET includes an interactive webmapping application which allows combining geospatial layers using the WMS (Web Mapping Service) standard. This application can also be used for introducing the spatial data search criteria.

Other important functions of the online system are related to the online generation of maps and reports and their export in a PDF format, programming CSW-compatible sampling sessions of metadata from the distributed servers, synchronizing the metadata among the distributed catalogues, managing the users and user groups and defining policies for accessing data by user levels.

The cataloguing application supplies two interfaces for searching the indexed data:

- Simple (implicit) that allows the search following key words and / or the geographic location.
- Advanced, which supplies multiple search criteria including spatial ones, key words, temporal criteria, etc.

3.3 Metadata introduction and sampling

The cataloguing application supplies two possibilities for introducing metadata: using the online editor (selecting one of the three templates: ISO, FDGC or DC) and importing XML metadata created with an external editor. The metadata introduction and sampling is based on the unique universal identifier (uuid) concept. Each metadata set created with Geonetwork, or with a CSW – compatible editor has such an indicator associated.

Updating the metadata, from a network sampling nodes network is performed such that only those metadata sets are downloaded that have undergone modifications between the moment now and the last updating. Propagation takes place from node to node and the metadata sampled until a certain moment by one node can also be transmitted to other nodes, without the need of those nodes to access the parent node.

4. Application for heavy rain and related transboundary flood management

A Web-based Information System for Trans-boundary Flood Management (FLOODSAT), based on satellite data and GIS technology (fig.1), was already implemented in the Romania. The main functions of the FLOODSAT are: acquisition, storage, analysis and interpretation of data; preparation for a rapid data access; updating the information; elaboration of thematic documents; generation of value-added information; distribution of the derived products to end-users.

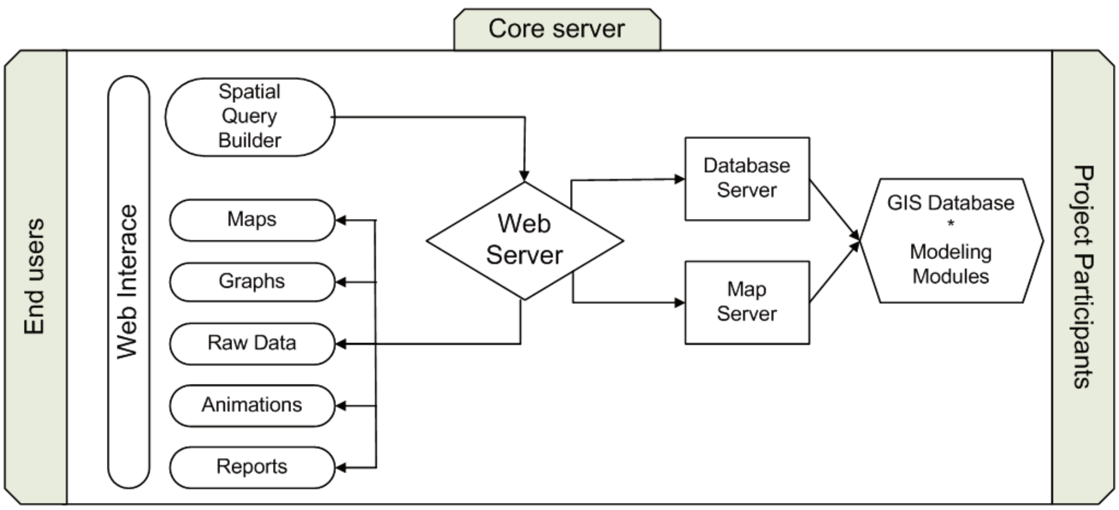


Figure 1 The FLOODSAT online system

The GIS and satellite–derived data configured for web uses, is based on a three-tiered components:

- a spatial data server that can efficiently communicate with a Web server and is able of sending and receiving requests for different types of data from a Web browser environment;
- a mapping file format that can be embedded into a Web page;
- a Web-based application in which maps can be viewed and queried by an end-user/client via a Web browser.

The typical products managed by the on-line system FLOODSAT are: numerical weather forecastings and warnings, hydrological/hydraulical model outputs, satellite-derived products, radar-derived products, geographical maps, and other meteorological data.

The data registered into the system is published through standard compliant services and can be accessed by users via a web or desktop client.

The end-users can access the system using a simple Web browser (like Internet Explorer or Mozilla Firefox) to display, query, analyze and retrieve information.

An important result concerns the improvement of the interoperability between institutions, through the development of a set of specifications that support interoperable services and incorporated in a technical guidelines document. End-users interested in hydro-meteorological hazards thematic applications will be able to share and integrate data in standard format that can be transformed into useful information.

5. Challenges and conclusions

In Romania already exists a reliable infrastructure for the operational management and dissemination of the meteorological data and products in the framework of the National Integrated Meteorological System (SIMIN).

In Romania a "modus operandi" with different end-users, for the extreme meteorological and hydrological phenomena generated disasters has been already established; a good example of cooperation work between the existing actors from different Romanian institutions was done during the recent big floods (2005, 2009 and 2010).

A Web-based Information System for Trans-boundary Flood Management (FLOODSAT), based on satellite data and GIS technology, was implemented in the Romania. The data registered into the system is published through standard compliant services and can be accessed by users via a web or desktop client.

The Romanian Meteorological Administration started some actions in order to develop and implement an interoperable framework for the management of meteorological information. This effort will contribute to carrying out a national spatial data infrastructure (SDI), in conformity with the provisions of the European Directive INSPRE.

The main goal is to achieve interoperability, harmonization across spatial data themes and benefit from the endeavours of users' and producers' communities.

In the near future a great concern is dealing with the implementation of the online system – GEOMET - based on open source applications, allowing the management of meteorological data in a geospatial context.

This new system will improve the capabilities of operational evaluation, mapping and analysis of meteorological and hydrological hazardous phenomena and the environment changes detection.

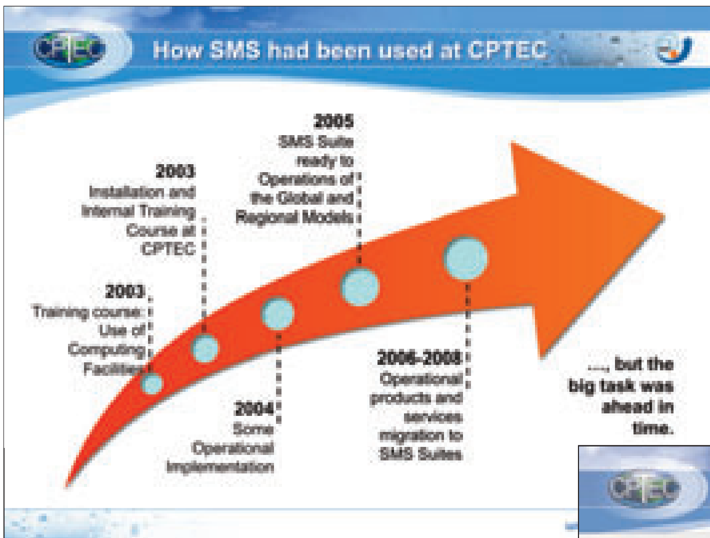
References

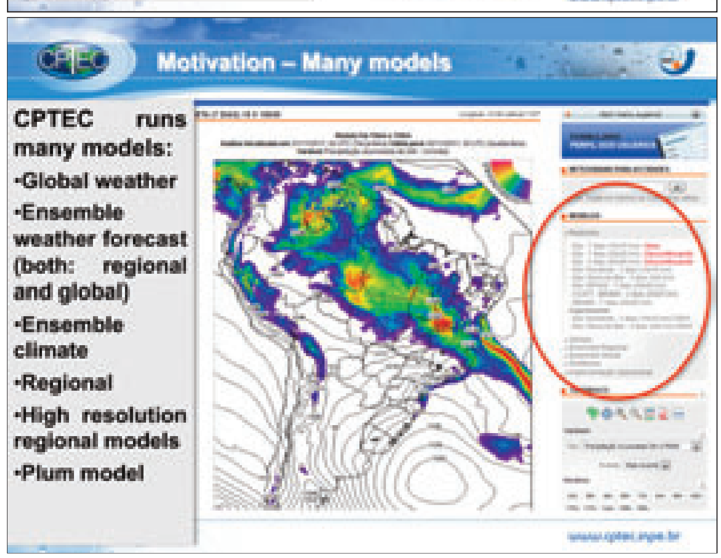
1. Directive 2007/2/EC of the European Parliament and of the Council of 14 March 2007 establishing an Infrastructure for Spatial Information in the European Community (INSPIRE) 14.03.2007 (http://inspire.jrc.ec.europa.eu/).
2. INSPIRE Metadata Regulation 03.12.2008 (http://eur-lex.europa.eu/LexUriServ/).
3. Standards guide ISO/TC 211 Geographic Information /Geomatics, 2009. (http://www.isotc211.org/Outreach/ISO_TC_211_Standards_Guide.pdf).

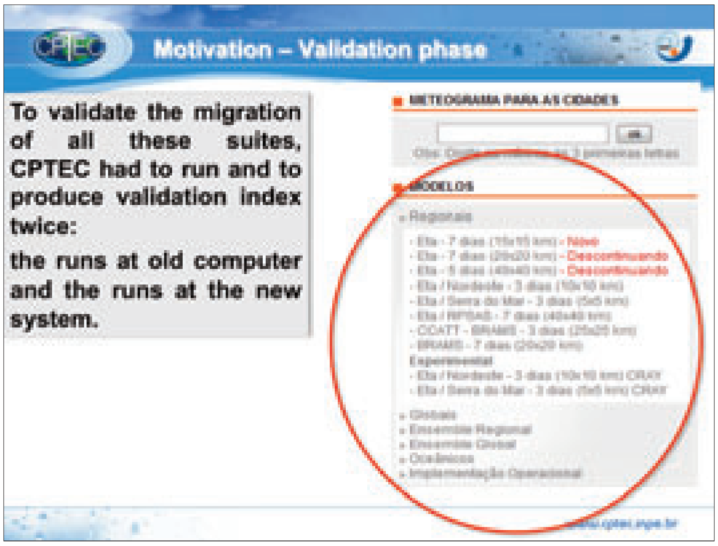
The use of SMS at CPTEC's suites alongside the supercomputer's replacement

José Aravéquia, CPTEC/INPE

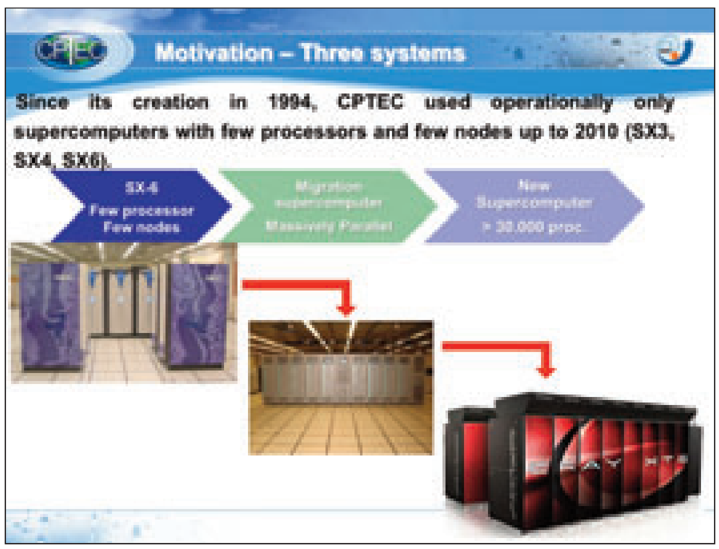
The CPTEC operational suites include global and regional for climate and weather models prediction. CPTEC also runs higher resolution models to the Serra do Mar and to Northeast Brazil regions. Since 2003 CPTEC has work with SMS to manage and operate all that model suites, as well as many weather and climate products that CPTEC provides thru its internet web site. In the last year CPTEC move their operational model suites to a new supercomputer that different from the older one, it is a massively parallel computer. To assure that their models work and to know their skills in the new supercomputer the use of SMS were indispensable. In this work we present how the SMS have helped CPTEC to manage and to implement all their operational model and products into its new supercomputer system.



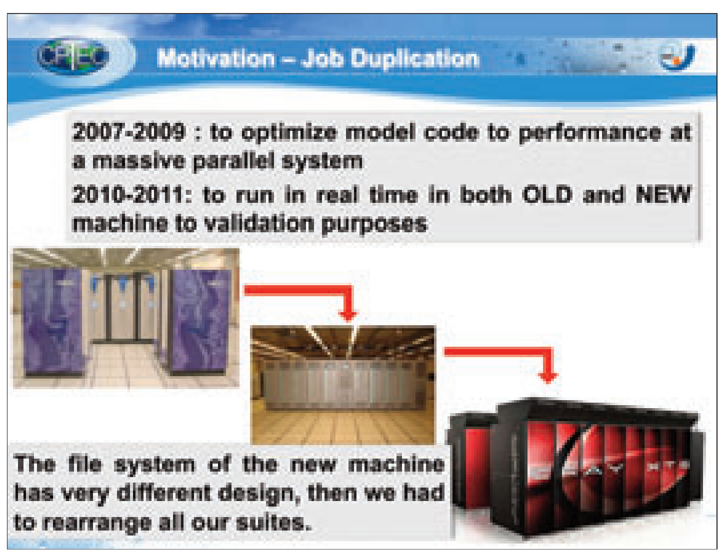




Motivation – Validation phase
To validate the migration of all these suites, CPTEC had to run and to produce validation index twice:
the runs at old computer and the runs at the new system.
METEOGRAMA PARA AS CIDADES
MODELOS

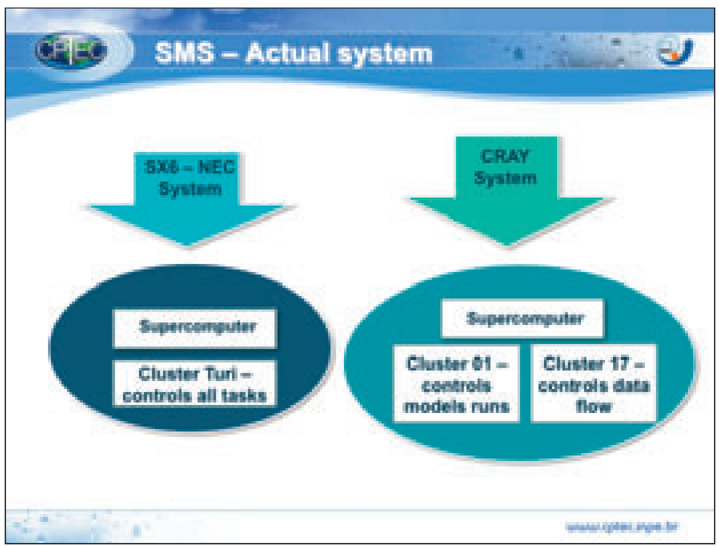


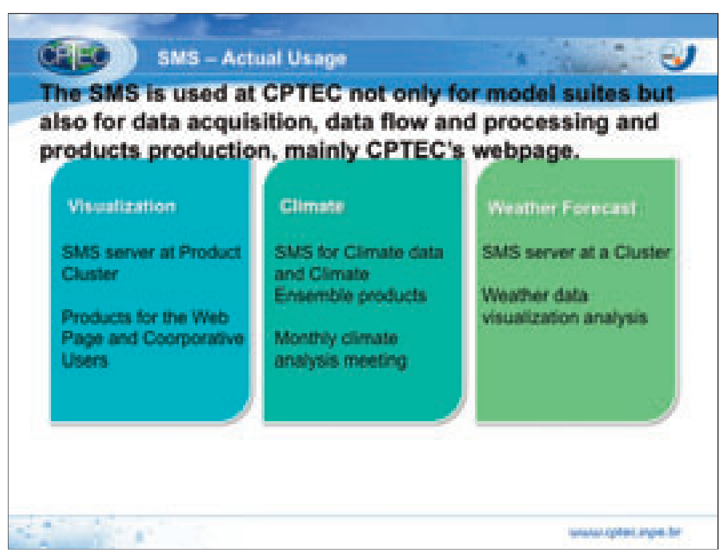
Motivation – Three systems
Since its creation in 1994, CPTEC used operationally only supercomputers with few processors and few nodes up to 2010 (SX3, SX4, SX6).
SX-6
Few processor
Few nodes
Migration
supercomputer
Massively Parallel
New
Supercomputer
> 30,000 proc.

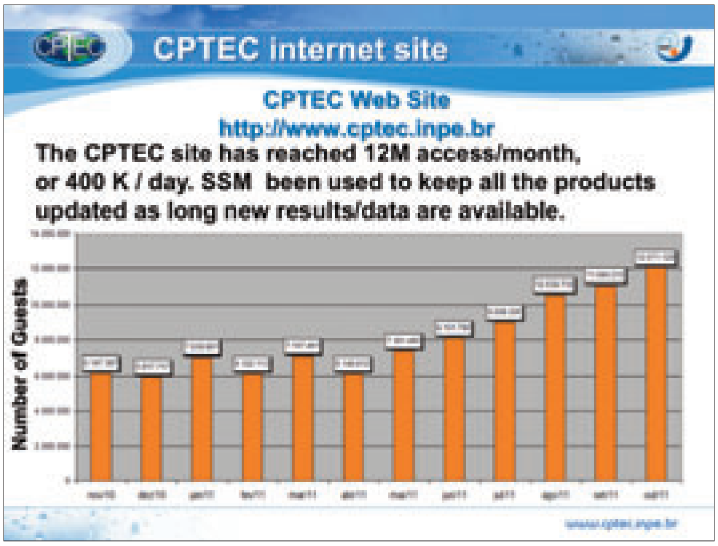


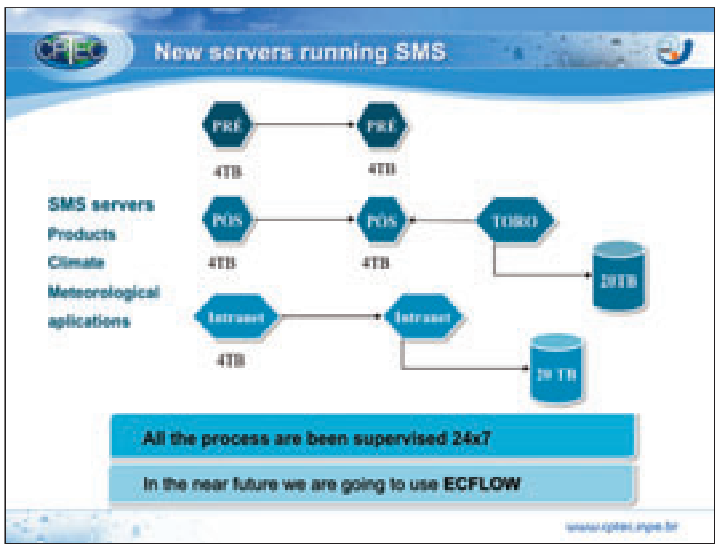
Motivation – Job Duplication
2007-2009 : to optimize model code to performance at a massive parallel system
2010-2011: to run in real time in both OLD and NEW machine to validation purposes
The file system of the new machine has very different design, then we had to rearrange all our suites.

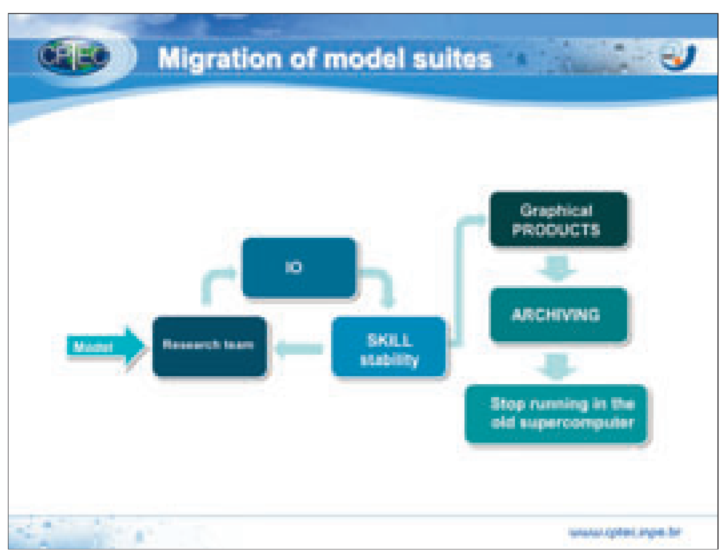

The Operational Implementation Group adopted SMS as its standard tool
The Goal : Integrate research results into an operational suite to be used in the Operational Division
Steps
Research
Experimental
Production
Research
Results Evaluation
HPC Analysis
METOP
Stability and Skill
Operational Implementation
OP

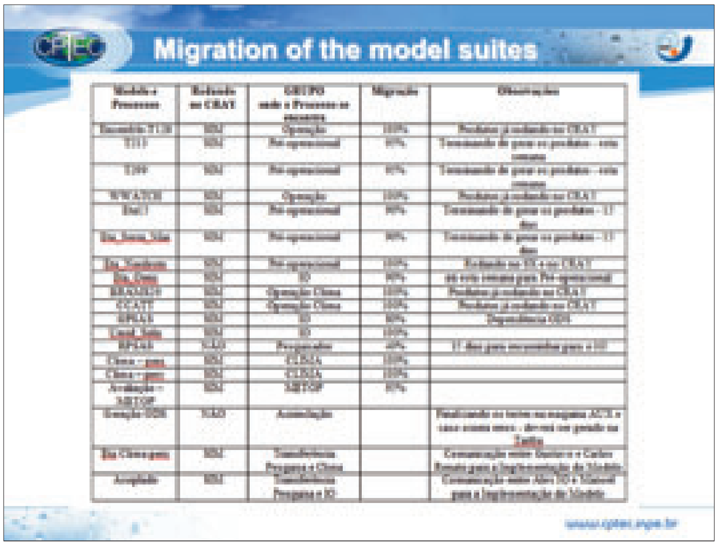

SMS – Actual system
SX6 – NEC System
CRAY System
Supercomputer
Cluster Turi – controls all tasks
Supercomputer
Cluster 01 – controls models runs
Cluster 17 – controls data flow

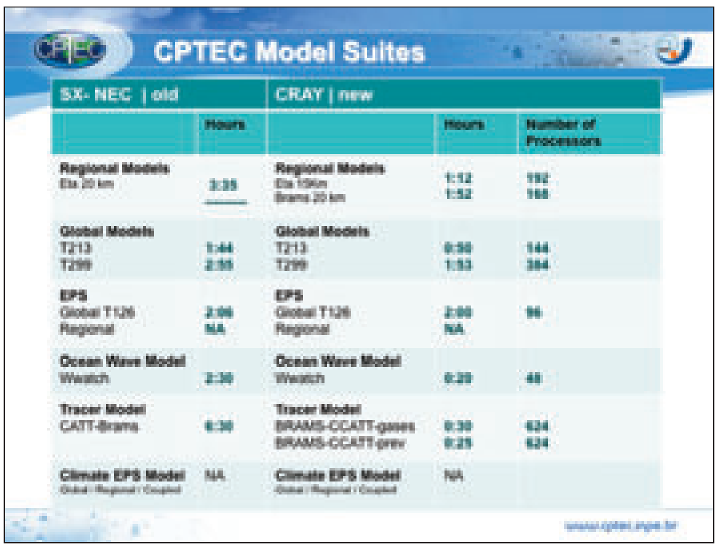

SMS – Actual Usage
The SMS is used at CPTEC not only for model suites but also for data acquisition, data flow and processing and products production, mainly CPTEC's webpage.
Visualization
SMS server at Product Cluster
Products for the Web Page and Coorporative Users
Climate
SMS for Climate data and Climate Ensemble products
Monthly climate analysis meeting
Weather Forecast
SMS server at a Cluster
Weather data visualization analysis

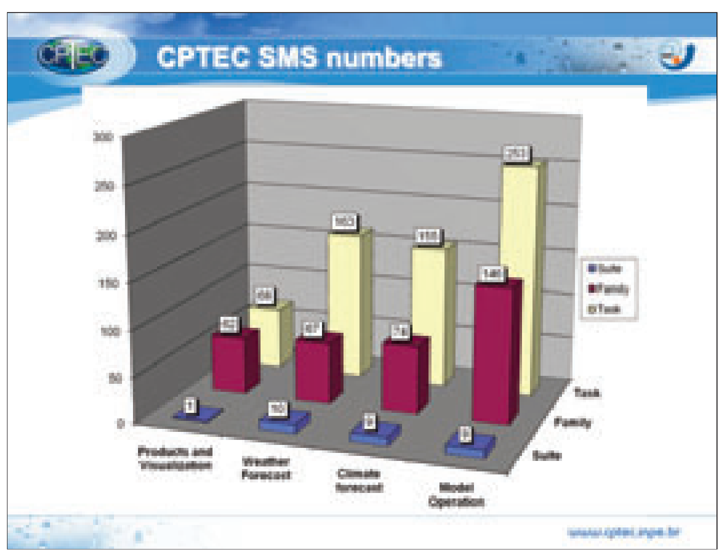

CPTEC internet site
CPTEC Web Site
http://www.cptec.inpe.br
The CPTEC site has reached 12M access/month,
or 400 K / day. SSM been used to keep all the products
updated as long new results/data are available.
Number of Guests
www.cptec.inpe.br

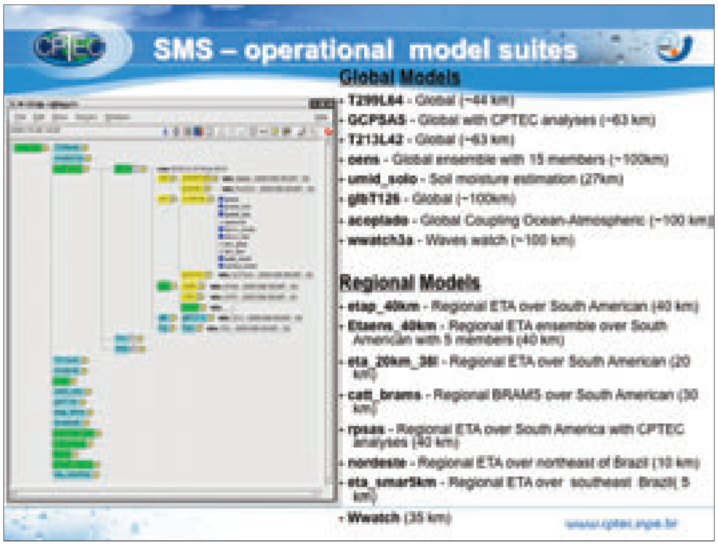

New servers running SMS
PRE
PRE
4TB
4TB
SMS servers
Products
Climate
Meteorological
aplications
POS
POS
TORO
4TB
4TB
20TB
Intranet
Intranet
4TB
20 TB
All the process are been supervised 24x7
In the near future we are going to use ECFLOW
www.cptec.inpe.br


Migration of model suites
Graphical
PRODUCTS
IO
ARCHIVING
Model
Research team
SKILL
stability
Stop running in the
old supercomputer
www.cptec.inpe.br

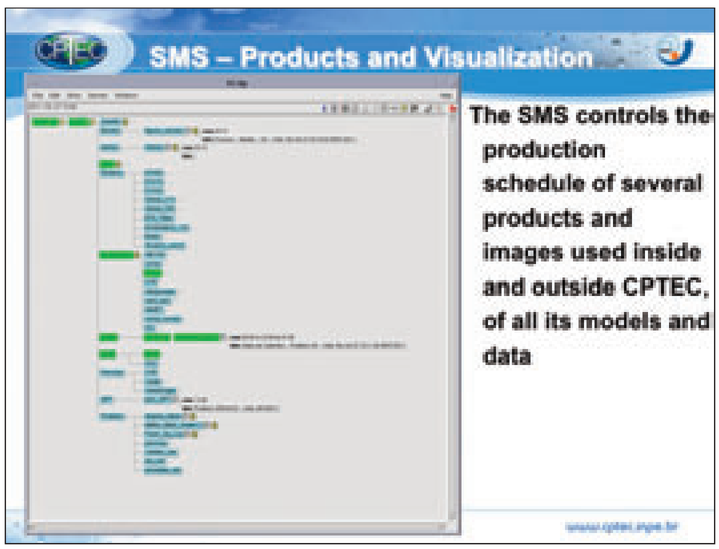

Migration of the model suites
www.cptec.inpe.br


CPTEC Model Suites
SX- NEC | old
CRAY | new
Hours
Hours
Number of Processors
Regional Models
Eta 20 km
Regional Models
Eta 10Km
Brams 20 km
1:12
1:52
192
168
Global Models
T213
T299
1:44
2:55
Global Models
T213
T299
0:50
1:53
144
384
EPS
Global T126
Regional
NA
EPS
Global T126
Regional
2:00
NA
96
Ocean Wave Model
Wwatch
2:30
Ocean Wave Model
Wwatch
0:20
48
Tracer Model
CATT-Brams
6:30
Tracer Model
BRAMS-CCATT-gases
BRAMS-CCATT-prev
0:30
0:25
624
624
Climate EPS Model
Global / Regional / Coupled
NA
Climate EPS Model
Global / Regional / Coupled
NA
www.cptec.inpe.br

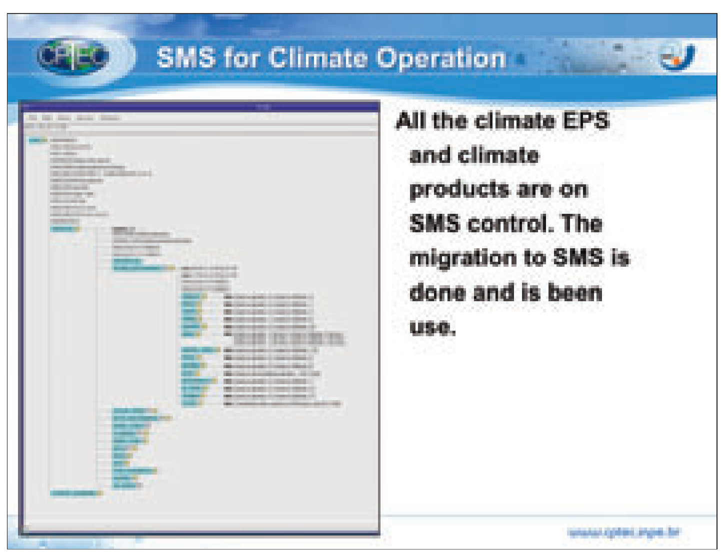

CPTEC SMS numbers
300
250
200
150
100
50
0
Products and Visualization
Weather Forecast
Climate forecast
Model Operation
Task
Family
Suite
Suite
Family
Task
www.cptec.inpe.br



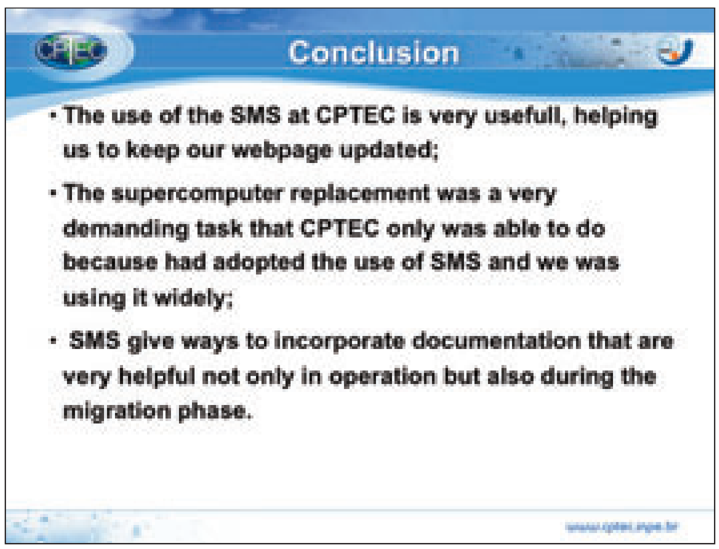
SMS – operational model suites
Global Models
- T299L64 - Global (~44 km)
- GCPSAS - Global with CPTEC analyses (~63 km)
- T213L42 - Global (~63 km)
- oens - Global ensemble with 15 members (~100km)
- umid_solo - Soil moisture estimation (27km)
- glbT126 - Global (~100km)
- acoplado - Global Coupling Ocean-Atmospheric (~100 km)
- wwatch3a - Waves watch (~100 km)
Regional Models
- etap_40km - Regional ETA over South American (40 km)
- Etaens_40km - Regional ETA ensemble over South American with 5 members (40 km)
- eta_20km_38l - Regional ETA over South American (20 km)
- catt_brams - Regional BRAMS over South American (30 km)
- rpsas - Regional ETA over South America with CPTEC analyses (40 km)
- nordeste - Regional ETA over northeast of Brazil (10 km)
- eta_smar5km - Regional ETA over southeast Brazil(5 km)
- Wwatch (35 km)
www.cptec.inpe.br



SMS – Products and Visualization
The SMS controls the production schedule of several products and images used inside and outside CPTEC, of all its models and data
www.cptec.inpe.br



SMS for Climate Operation
All the climate EPS and climate products are on SMS control. The migration to SMS is done and is been use.
www.cptec.inpe.br



References

http://www.ecmwf.int/publications/manuals/sms

Acknowledgements

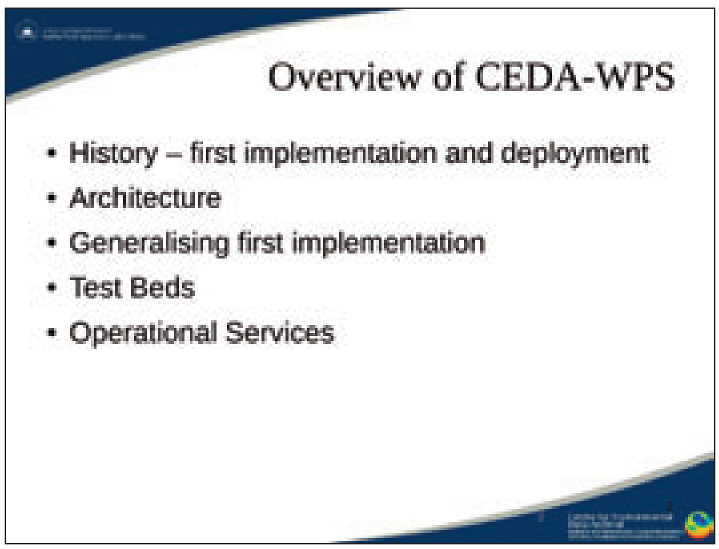
Visualisation Team, Implementation Team and many others from CPTEC that are developing their suites using SMS.

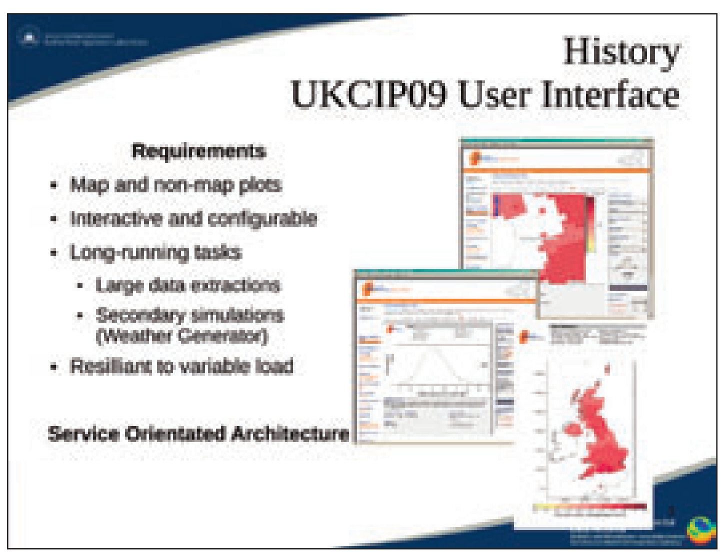
ECMWF that has provided the SMS software and training course.

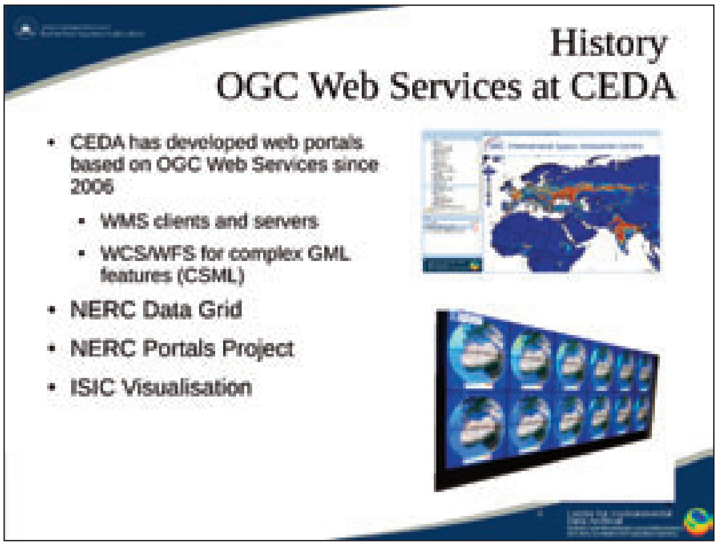
The CEDA web processing service for rapid deployment of earth system data services

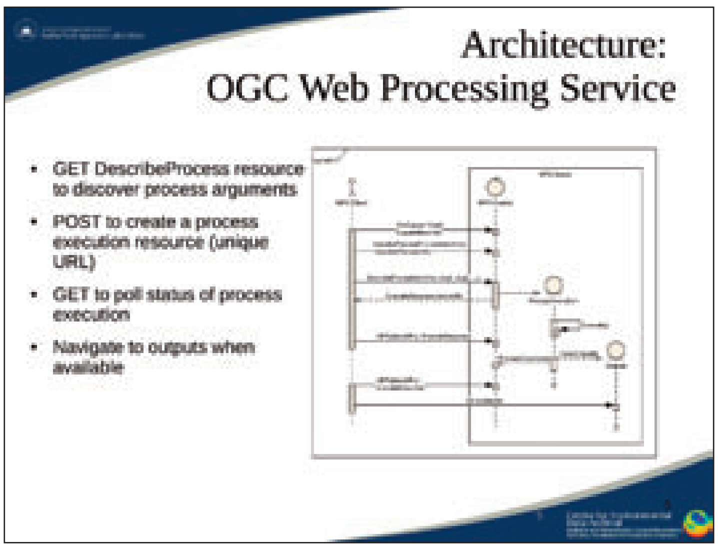
Stephen Pascoe, Science and Tecchnology Facilities Council, Rutehrford Appleton Laboratory

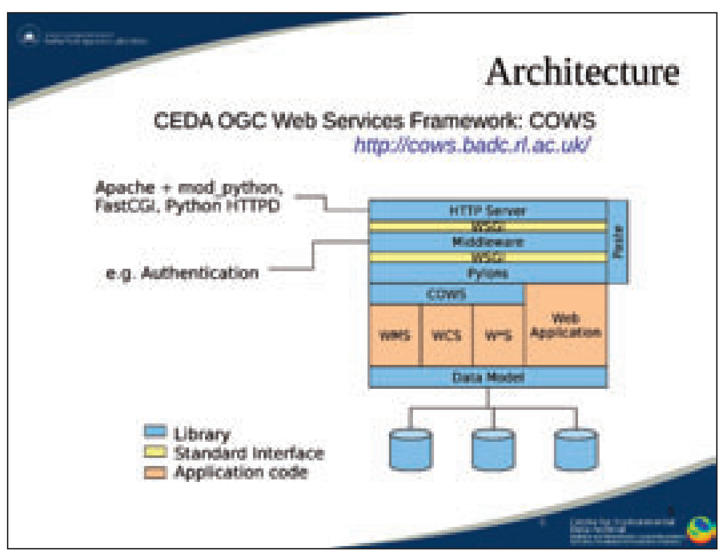
The CEDA Web Processing Service is a web service container that enables deployment of data services as WPS "processes" without building a bespoke interface each time. In this presentation we survey CEDA-WPS's features and architecture and how it has been applied to operational services at the Centre of Data Archival (CEDA) and projects including MashMyData and ExArch. Initially developed as a backend for the UKCIP09 user interface, CEDA-WPS has been generalised to provide a diverse set of extract, plot and analysis services at CEDA. It has used Open Geospatial Consortium WPS standard as a guide whilst putting usability, scalability and operational features centre stage. The result is a system that extends WPS where required whilst not attempting to implement optional WPS features that have little utility for our target community. CEDA-WPS provides an operational MIDAS station data extract service as well as test-beds for our work on delegated security, service chaining and OPeNDAP integration.

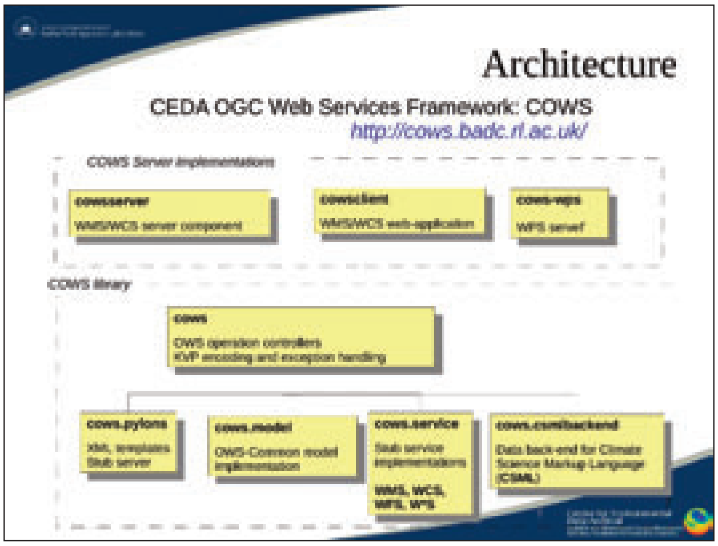


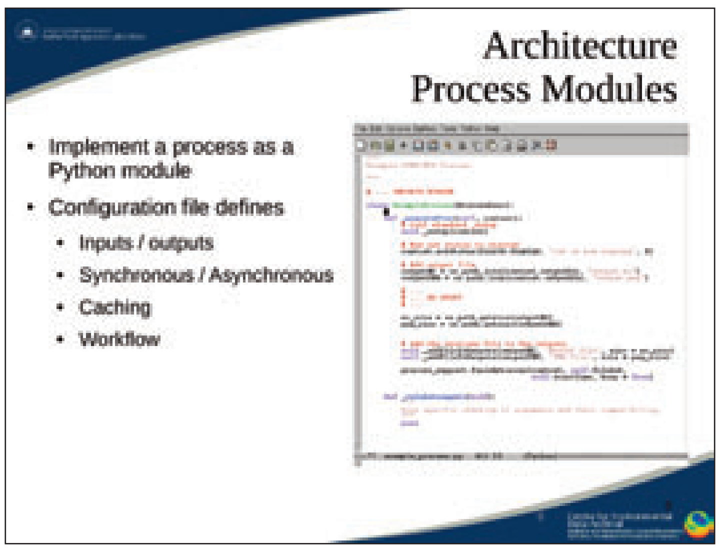


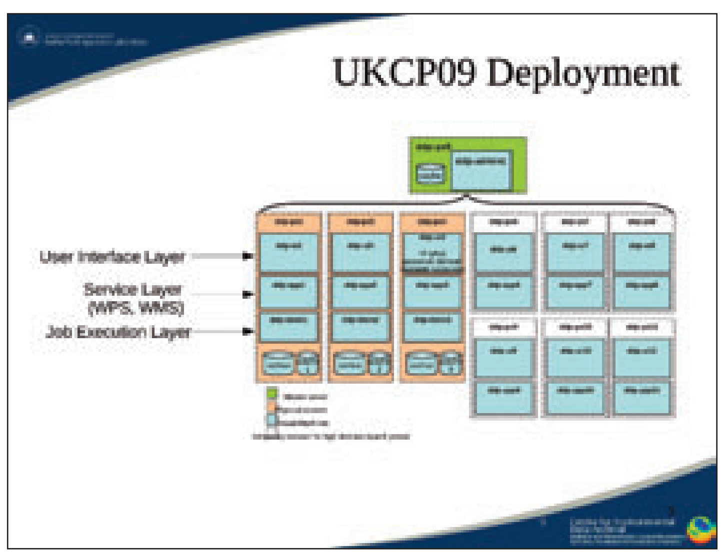

History
OGC Web Services at CEDA
CEDA has developed web portals based on OGC Web Services since 2006
WMS clients and servers
WCS/WFS for complex GML features (CSML)
NERC Data Grid
NERC Portals Project
ISIC Visualisation

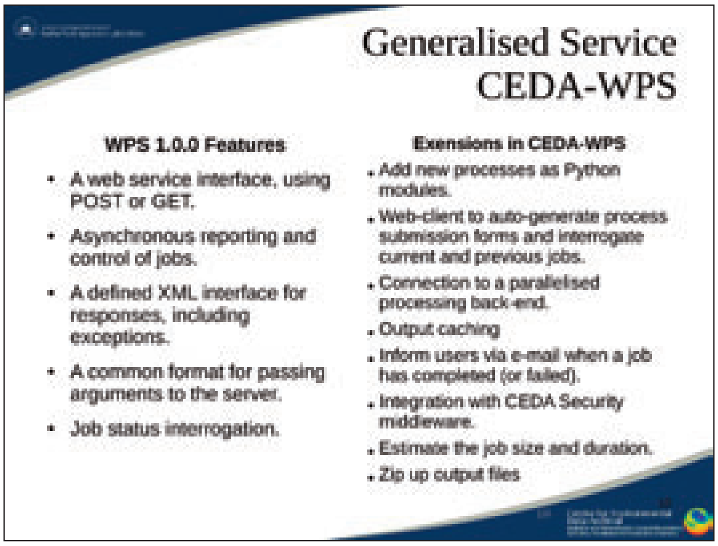

Architecture:
OGC Web Processing Service
GET DescribeProcess resource to discover process arguments
POST to create a process execution resource (unique URL)
GET to poll status of process execution
Navigate to outputs when available

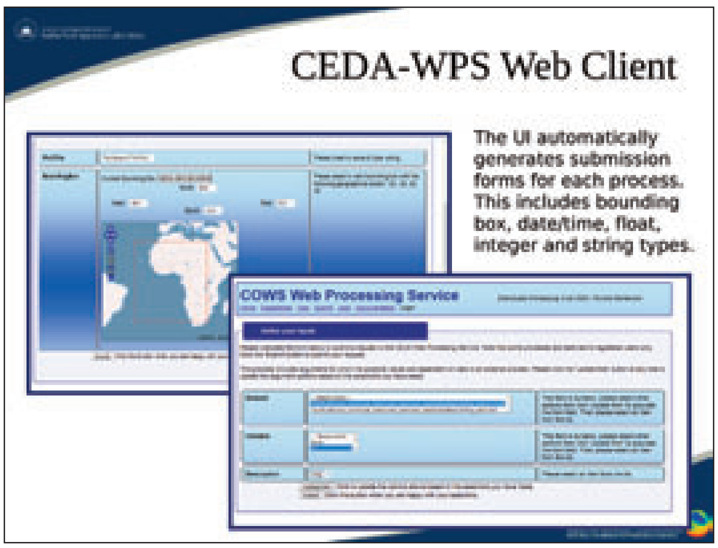

Architecture
CEDA OGC Web Services Framework: COWS
http://cows.badc.rl.ac.uk/
Apache + mod_python, FastCGI, Python HTTPD
e.g. Authentication
HTTP Server
WSGI
Middleware
WSGI
Pylons
Paste
COWS
WMS
WCS
WFS
Web Application
Data Model
Library
Standard Interface
Application code

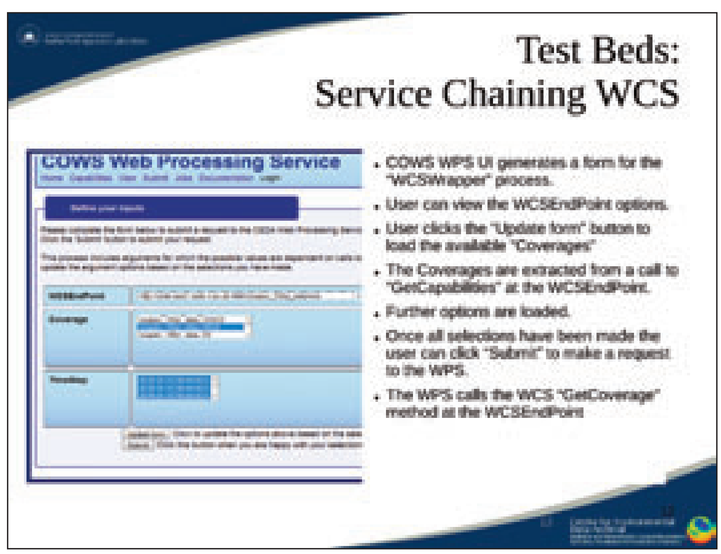

Architecture
CEDA OGC Web Services Framework: COWS
http://cows.badc.rl.ac.uk/
COWS Server implementations
cowsserver
WMS/WCS server component
cowsclient
WMS/WCS web-application
cows-wps
WPS server
COWS library
cows
OWS operation controllers
KVP encoding and exception handling
cows.pylons
Xlink, templates
Stub server
cows.model
OWS-Common model implementation
cows.service
Stub service implementations
WMS, WCS, WFS, WPS
cows.csmlbackend
Data back-end for Climate Science Markup Language (CSML)

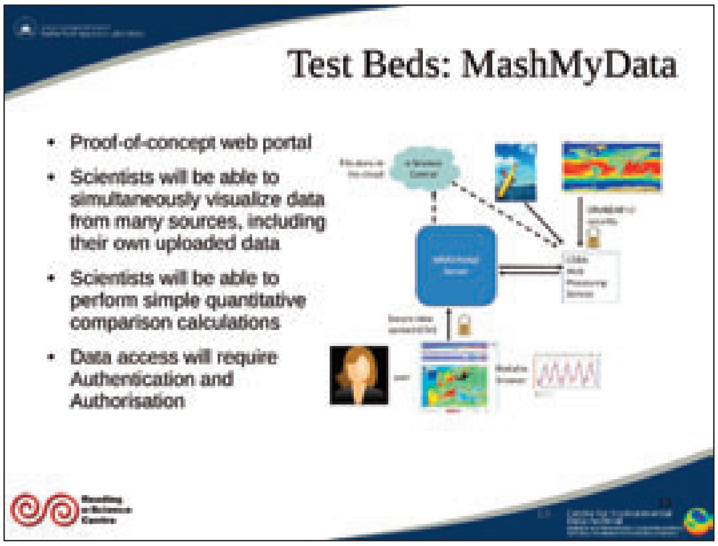

Architecture
Process Modules
• Implement a process as a Python module
• Configuration file defines
• Inputs / outputs
• Synchronous / Asynchronous
• Caching
• Workflow

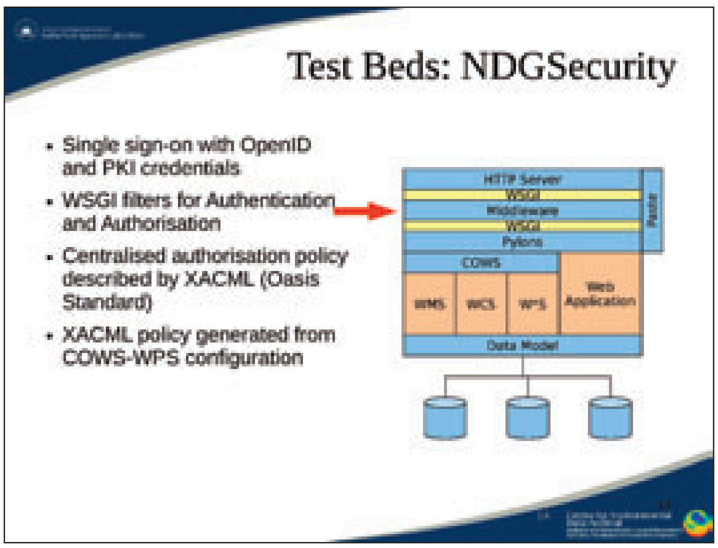

UKCP09 Deployment
User Interface Layer
Service Layer
(WPS, WMS)
Job Execution Layer

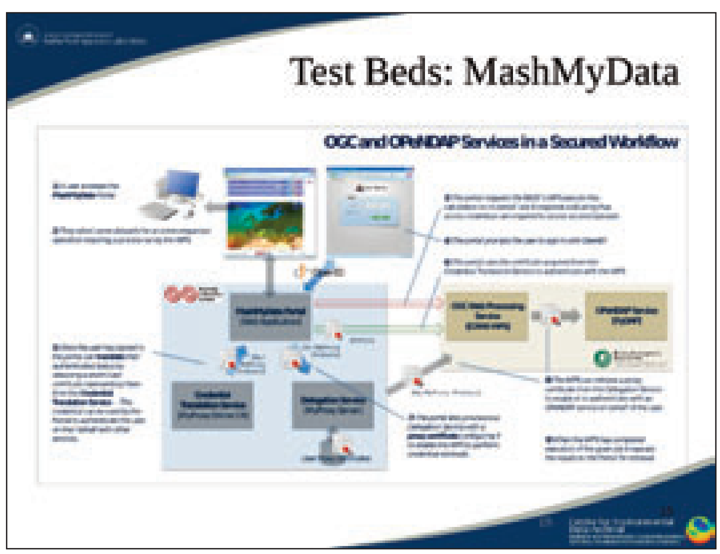

Generalised Service
CEDA-WPS
WPS 1.0.0 Features
A web service interface, using POST or GET.
Asynchronous reporting and control of jobs.
A defined XML interface for responses, including exceptions.
A common format for passing arguments to the server.
Job status interrogation.
Exensions in CEDA-WPS
Add new processes as Python modules.
Web-client to auto-generate process submission forms and interrogate current and previous jobs.
Connection to a parallelised processing back-end.
Output caching
Inform users via e-mail when a job has completed (or failed).
Integration with CEDA Security middleware.
Estimate the job size and duration.
Zip up output files


CEDA-WPS Web Client
The UI automatically generates submission forms for each process. This includes bounding box, date/time, float, integer and string types.
COWS Web Processing Service


Test Beds:
Service Chaining WCS
COWS Web Processing Service
COWS WPS UI generates a form for the "WCSWrapper" process.
User can view the WCSEndPoint options.
User clicks the "Update form" button to load the available "Coverages"
The Coverages are extracted from a call to "GetCapabilities" at the WCSEndPoint.
Further options are loaded.
Once all selections have been made the user can click "Submit" to make a request to the WPS.
The WPS calls the WCS "GetCoverage" method at the WCSEndPoint

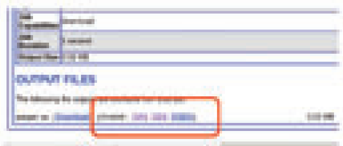

Test Beds: MashMyData
• Proof-of-concept web portal
• Scientists will be able to simultaneously visualize data from many sources, including their own uploaded data
• Scientists will be able to perform simple quantitative comparison calculations
• Data access will require Authentication and Authorisation


Test Beds: NDGSecurity
• Single sign-on with OpenID and PKI credentials
• WSGI filters for Authentication and Authorisation
• Centralised authorisation policy described by XACML (Oasis Standard)
• XACML policy generated from COWS-WPS configuration
HTTP Server
WSGI
Middleware
WSGI
Pylons
Paste
COWS
WMS
WCS
WPS
Web Application
Data Model


Test Beds: MashMyData
OGC and OPeNDAP Services in a Secured Workflow

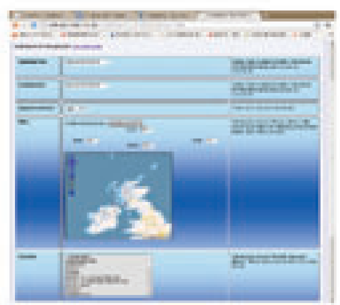
Test Beds: OPeNDAP

- WPS NetCDF Outputs available over OpeNDAP
- Implemented via an embedded PyDap server
- Interrogate NetCDF Metadata and Subset outputs
- Secured with NDGSecurity



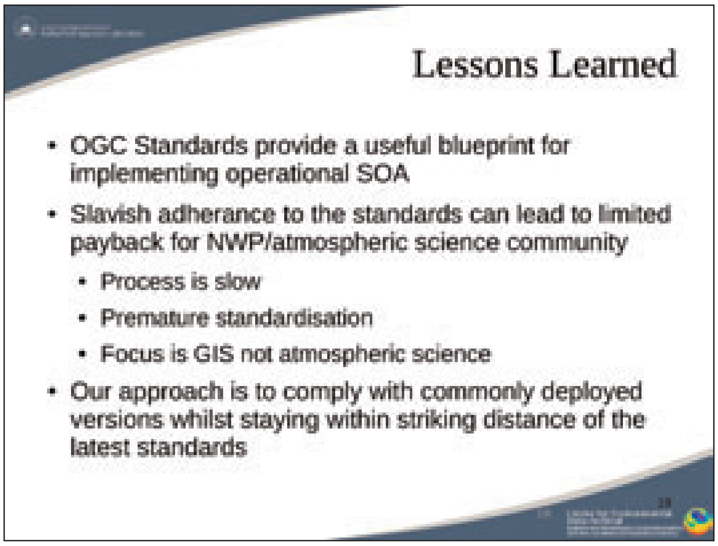
Operational Service MIDAS

- New Service at BADC (beta)
- UK Met Office MIDAS database
- Land surface observations data from the Met Office station network
- daily and hourly weather measurements
- Extract by UK county of bounding box
- CSV output



Future

- CDO Operators available as WPS Processes (ExArch Project)
- Run WPS Processes on the CMIP5 Archive
- Porting process execution backend to other schedulers (TORQUE)
- Improved WPS-1.0.0 compliance


Lessons Learned
• OGC Standards provide a useful blueprint for implementing operational SOA
• Slavish adherance to the standards can lead to limited payback for NWP/atmospheric science community
• Process is slow
• Premature standardisation
• Focus is GIS not atmospheric science
• Our approach is to comply with commonly deployed versions whilst staying within striking distance of the latest standards

Towards operational GMES atmosphere services: MACC/MACC-II global production at ECMWF

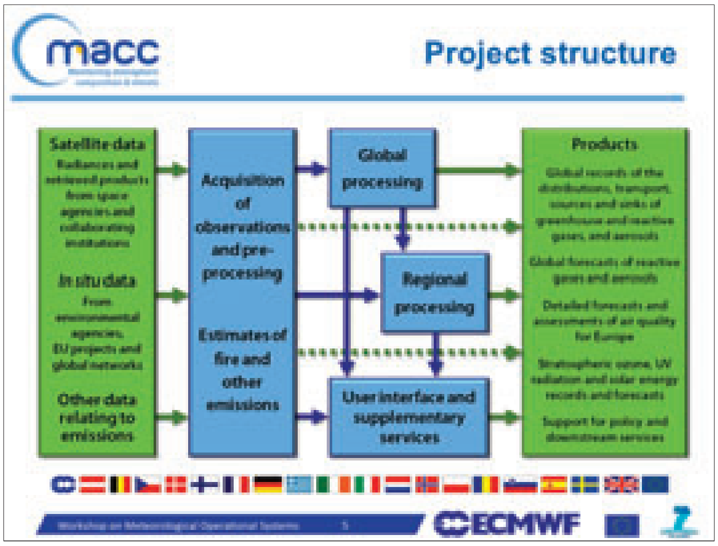
Richard Engelen, ECMWF

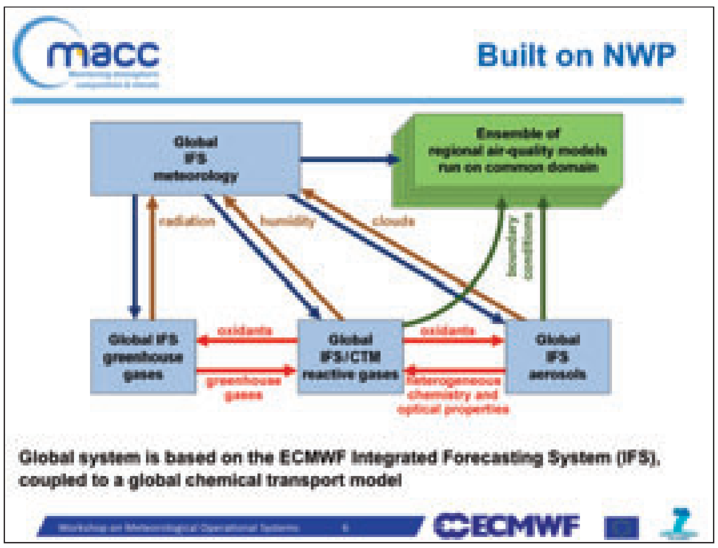
The Monitoring Atmospheric Composition and Climate (MACC) project is the current pre-operational atmospheric service of the European GMES programme. MACC provides data records on atmospheric composition for recent years, data for monitoring present conditions and forecasts of the distribution of key constituents for a few days ahead. ECMWF coordinates the project and is also responsible for providing a large part of the global component of MACC. Currently, MACC is making the transition from a research system to a pre-operational system.

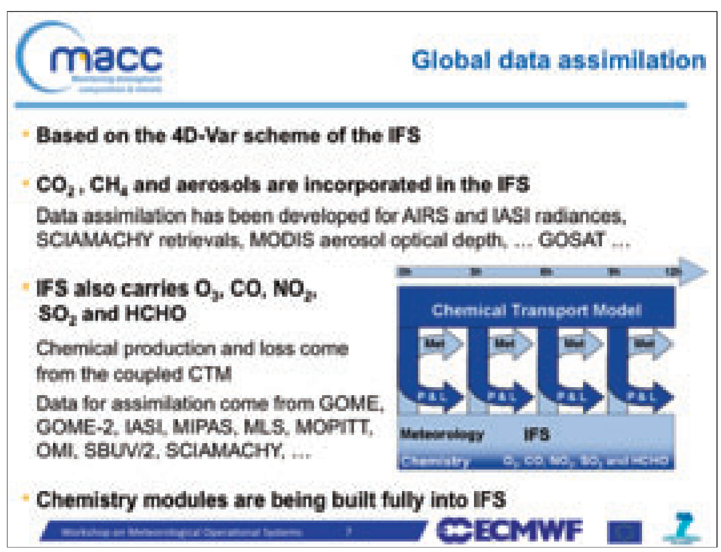
The MACC global assimilation and forecasting system is an extension of the ECMWF Integrated Forecasting System (IFS). Five main chemical species (O3, CO, NOx, SO2, and HCHO) have been added to the IFS model, which can be coupled to a Chemistry Transport Model (CTM) to account for the full chemistry. An aerosol model has been included in the IFS as well providing the capability to simulate sea-salt, dust, organic matter, black carbon, and sulphate aerosols. Daily 4-day forecasts are now available using existing, adapted, and new means of visualization. The underlying data is routinely provided to a growing set of users dealing with long-range transport of atmospheric pollutants, air quality, solar energy, scientific observational campaigns, etcetera.

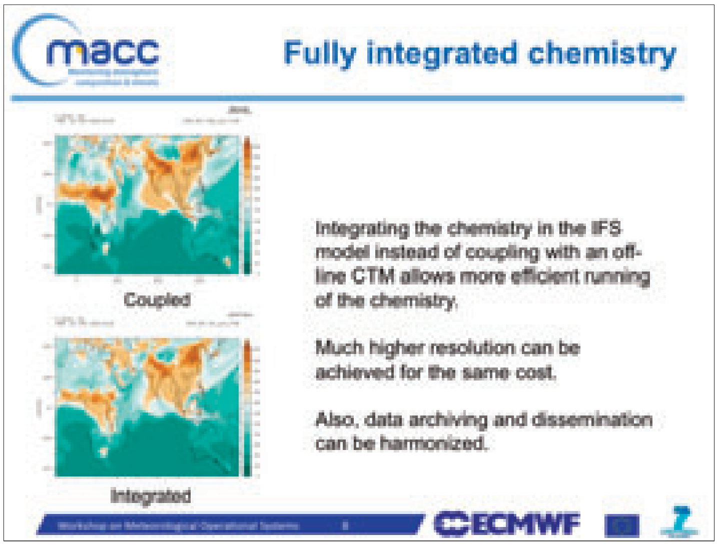
MACC also provides output from a reanalysis on atmospheric composition for the period 2003 – 2010, which includes some of the greenhouse gases (CO2 and CH4) in addition to the chemical species and aerosols. This data set is made available on a web data server in GRIB and Netcdf format.

Finally, MACC interacts with its users to adapt its services to make them more user-friendly. For instance, many users in the field of atmospheric environmental monitoring are not used to the GRIB format and also have no access to the ECMWF MARS archive. Having different formats, such as Netcdf, available on an ftp site or data server greatly enhances the ease-of-use of the data sets provided.

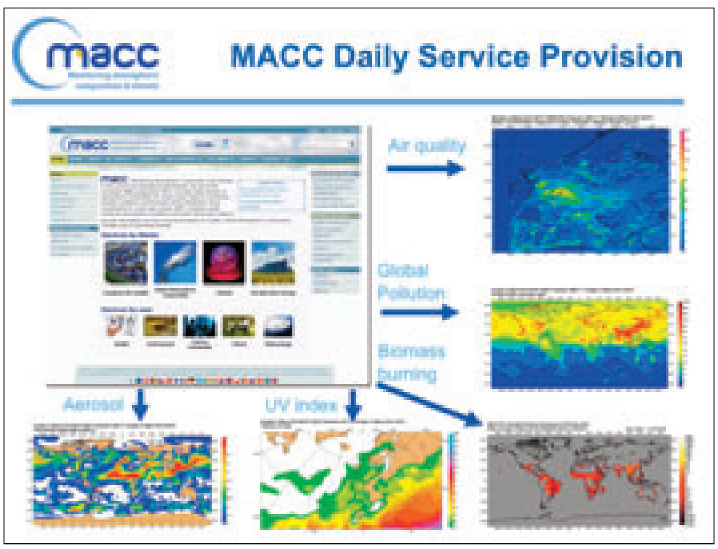

macc
Project structure
Satellite data
Radiances and retrieved products from space agencies and collaborating institutions
In situ data
From environmental agencies, EU projects and global networks
Other data relating to emissions
Acquisition of observations and pre-processing
Estimates of fire and other emissions
Global processing
Regional processing
User interface and supplementary services
Products
Global records of the distributions, transport, sources and sinks of greenhouse and reactive gases, and aerosols
Global forecasts of reactive gases and aerosols
Detailed forecasts and assessments of air quality for Europe
Stratospheric ozone, UV radiation and solar energy records and forecasts
Support for policy and downstream services
ECMWF

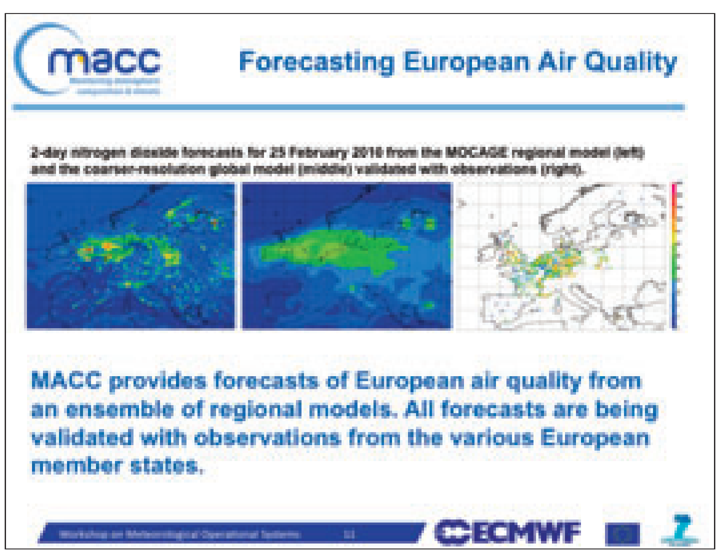

macc
Built on NWP
Global IFS meteorology
Ensemble of regional air-quality models run on common domain
radiation
humidity
clouds
boundary conditions
Global IFS greenhouse gases
Global IFS/CTM reactive gases
Global IFS aerosols
oxidants
oxidants
greenhouse gases
heterogeneous chemistry and optical properties
Global system is based on the ECMWF Integrated Forecasting System (IFS), coupled to a global chemical transport model
ECMWF

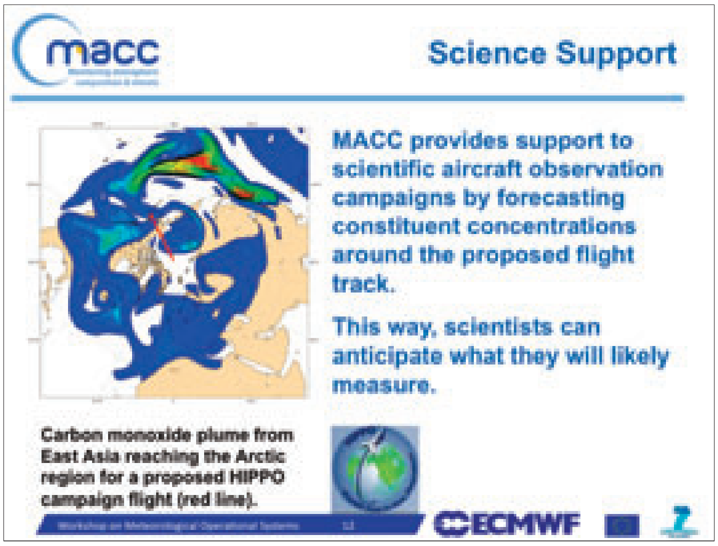

macc
Global data assimilation
Based on the 4D-Var scheme of the IFS
CO2, CH4 and aerosols are incorporated in the IFS
Data assimilation has been developed for AIRS and IASI radiances, SCIAMACHY retrievals, MODIS aerosol optical depth, … GOSAT …
IFS also carries O3, CO, NO2, SO2 and HCHO
Chemical production and loss come from the coupled CTM
Data for assimilation come from GOME, GOME-2, IASI, MIPAS, MLS, MOPITT, OMI, SBUV/2, SCIAMACHY, …
Chemical Transport Model
Met
P&L
Meteorology
IFS
Chemistry
Chemistry modules are being built fully into IFS
ECMWF

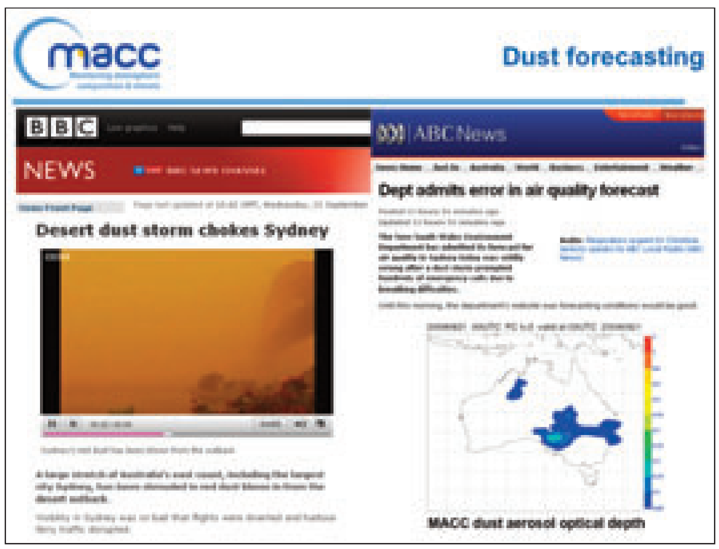


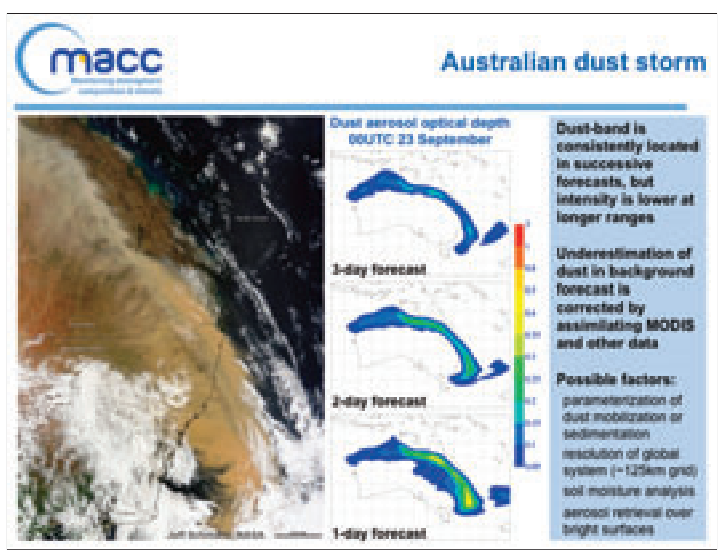
MACC products

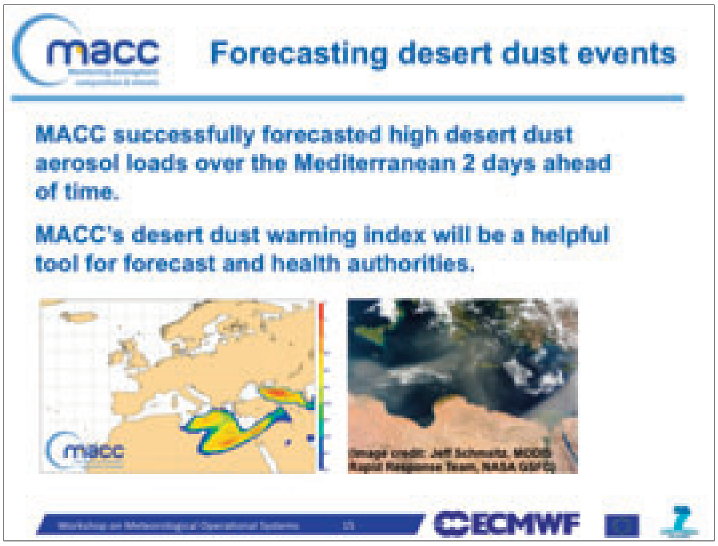


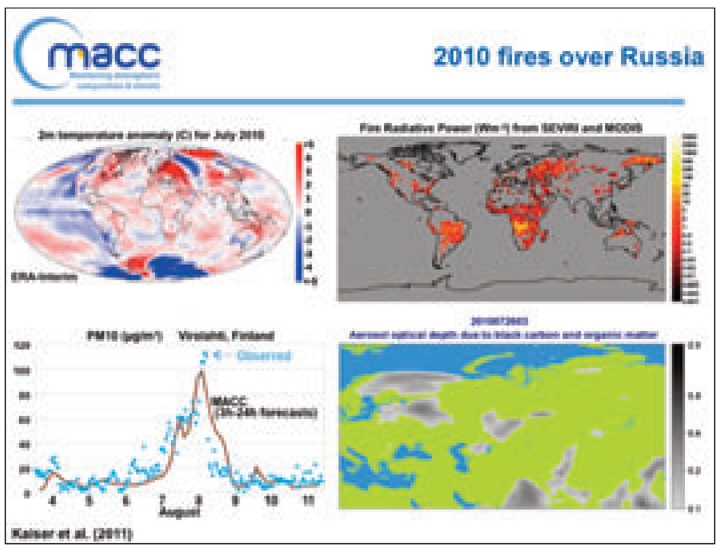


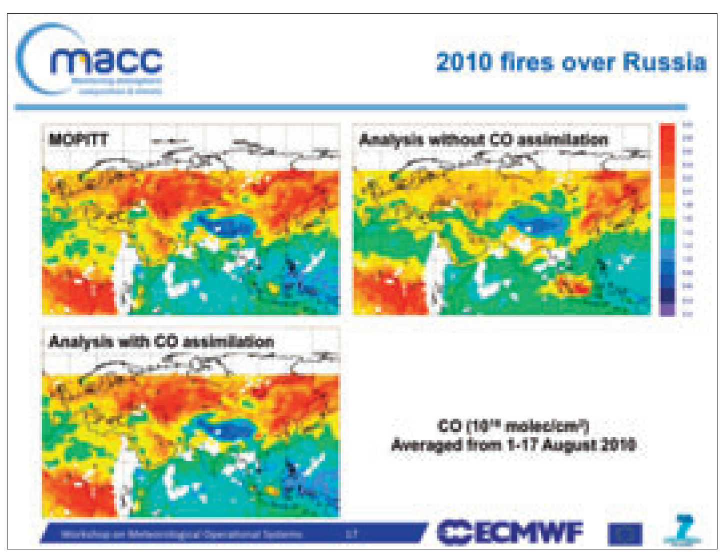

macc
Science Support
MACC provides support to scientific aircraft observation campaigns by forecasting constituent concentrations around the proposed flight track.
This way, scientists can anticipate what they will likely measure.
Carbon monoxide plume from East Asia reaching the Arctic region for a proposed HIPPO campaign flight (red line).
ECMWF

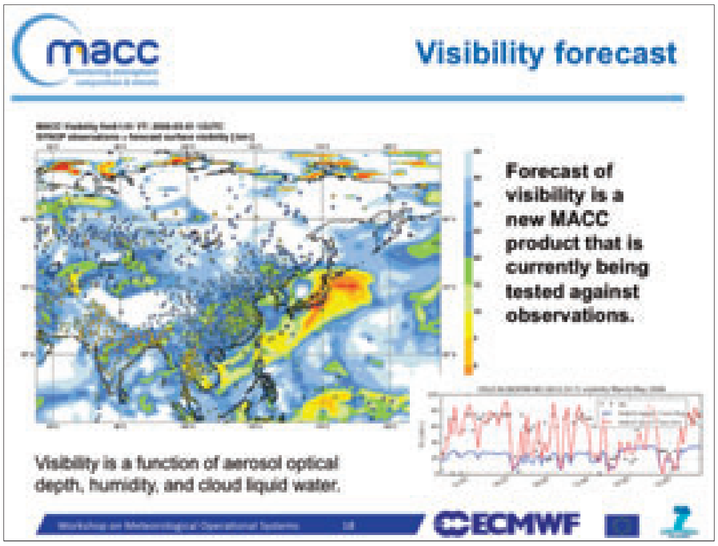

macc
Dust forecasting
BBC
NEWS
Desert dust storm chokes Sydney
ABC News
Dept admits error in air quality forecast
MACC dust aerosol optical depth


macc
Australian dust storm
Dust aerosol optical depth
00UTC 23 September
3-day forecast
2-day forecast
1-day forecast
Dust-band is consistently located in successive forecasts, but intensity is lower at longer ranges
Underestimation of dust in background forecast is corrected by assimilating MODIS and other data
Possible factors:
parameterization of dust mobilization or sedimentation
resolution of global system (~125km grid)
soil moisture analysis
aerosol retrieval over bright surfaces

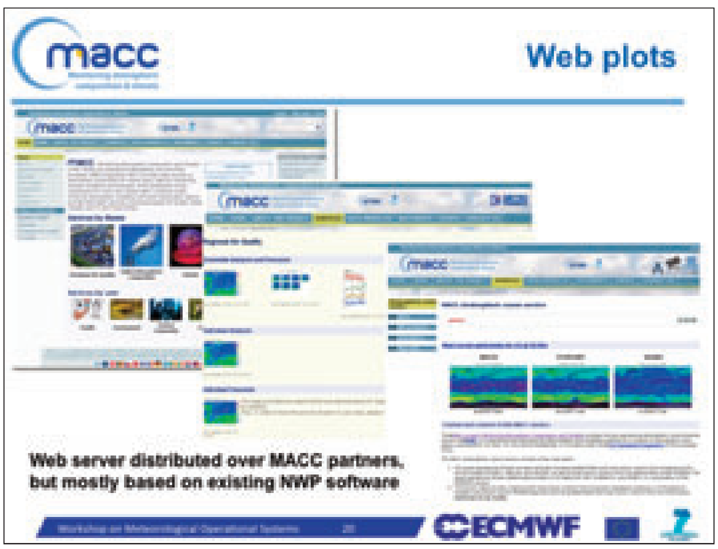

macc
Forecasting desert dust events
MACC successfully forecasted high desert dust aerosol loads over the Mediterranean 2 days ahead of time.
MACC's desert dust warning index will be a helpful tool for forecast and health authorities.
Image credit: Jeff Schmaltz, MODIS Rapid Response Team, NASA GSFC
ECMWF

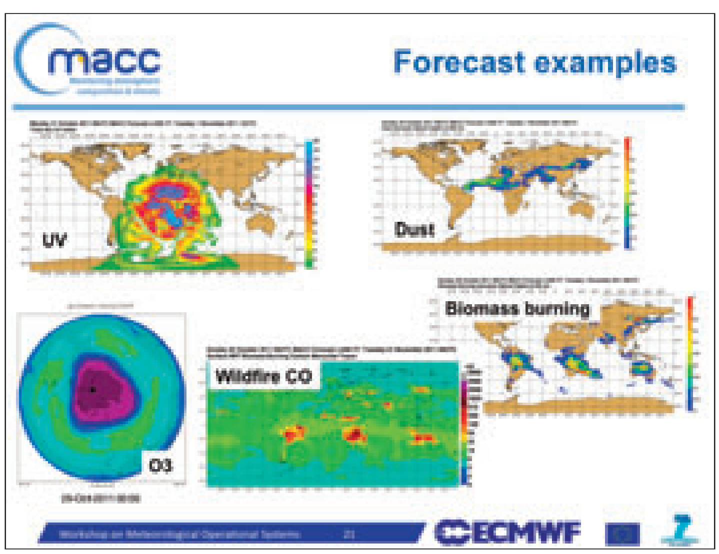

macc
2010 fires over Russia
2m temperature anomaly (C) for July 2010
ERA-Interim
Fire Radiative Power (Wm⁻²) from SEVIRI and MODIS
PM10 (µg/m³) Virolahti, Finland
Observed
MACC (3h-24h forecasts)
August
Aerosol optical depth due to black carbon and organic matter
Kaiser et al. (2011)

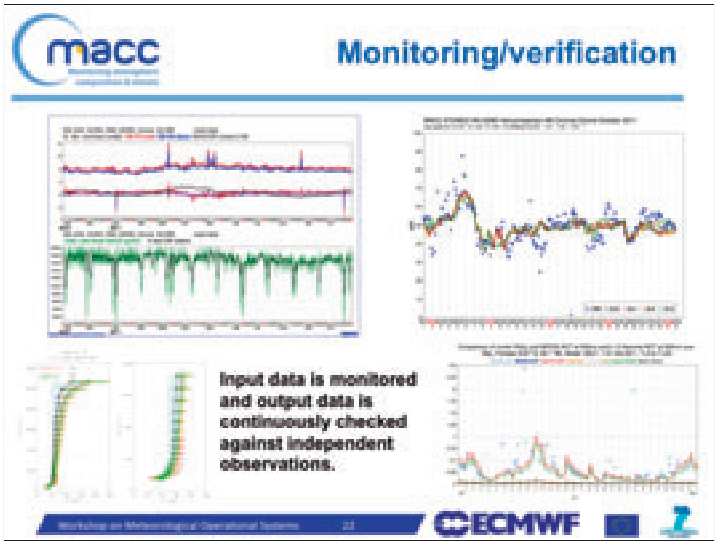

macc
2010 fires over Russia
MOPITT
Analysis without CO assimilation
Analysis with CO assimilation
Averaged from 1-17 August 2010
ECMWF

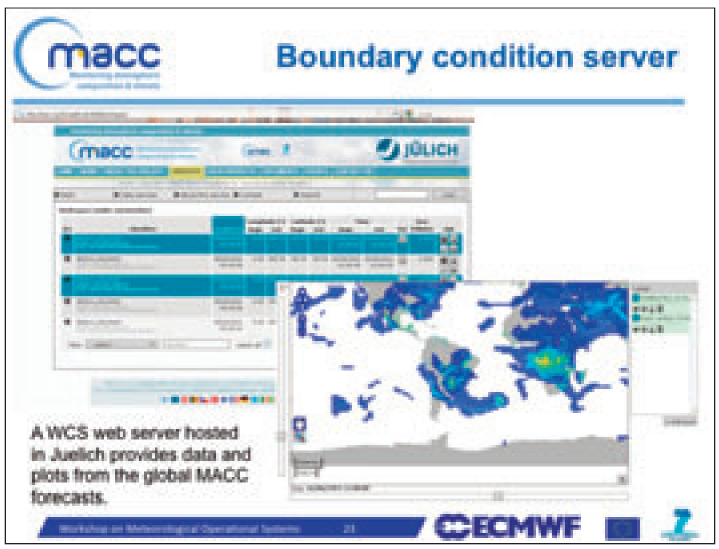


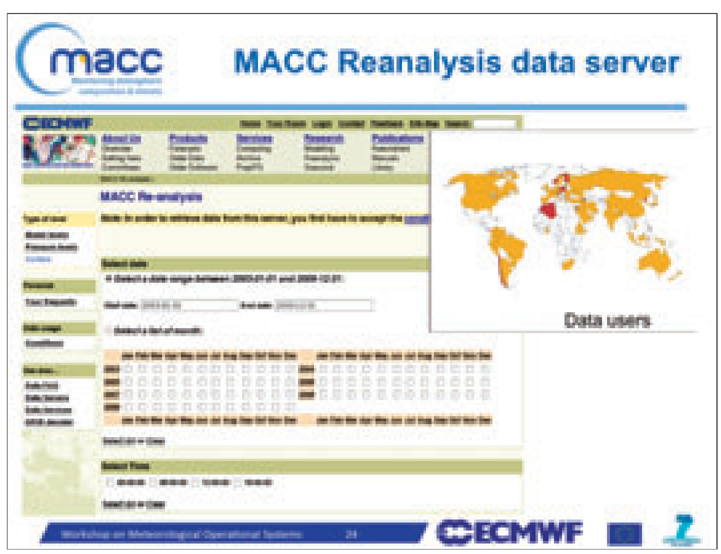
Data provision

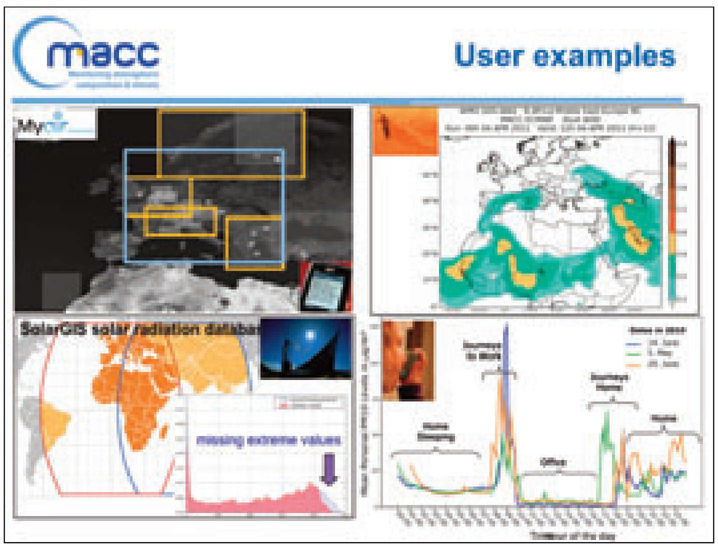





macc
Monitoring/verification
Input data is monitored and output data is continuously checked against independent observations.
ECMWF


macc
Boundary condition server
JÜLICH
A WCS web server hosted in Juelich provides data and plots from the global MACC forecasts.
ECMWF


macc
MACC Reanalysis data server
MACC Re-analysis
Data users
ECMWF



Data dissemination

- MARS and ECFS access for member states and MACC partners
- FTP server for daily forecasts on model grid
- Boundary condition WCS server
- ECMWF data server for Reanalysis
- Daily provision of many web plots

- Many users are not used to GRIB format
  - NetCDF format
  - Support with GRIB decoding
  - New ways…?

ECMWF

The WMO Severe Weather Forecast Demonstration Project

David Richardson (ECMWF), Peter Chen (WMO)

1. Introduction

National Meteorological Hydrological Services (NMHSs) play a key role in the production and delivery of authoritative weather warnings to users, including the general public, disaster managers, civil protection authorities, and specialists in important societal sectors (e.g. transportation). In recent years a variety of NWP products have been developed to assist NMHS forecasters in the prediction of severe weather. Increasingly such products are based on the output of ensemble prediction systems (EPS). However, many low-capacity NMHSs in developing and least developed countries have limited experience with and access to the wide range of detailed NWP forecast information that is available (in principle) from such advanced forecasting systems.

The aim of the WMO Severe Weather Forecasting Demonstration Project (SWFDP) is to enable NMHSs in developing and least developed countries to implement and maintain reliable and effective routine forecasting and severe weather warning programmes through enhanced use of NWP products and delivery of timely and authoritative forecasts and early warnings, thereby contributing to reducing the risk of disasters from natural hazards. This will be achieved through cooperative work between global NWP producing centres, regional specialist centres and NMHSs.

The goals of the SWFDP are:

- to improve the ability of NMHSs to forecast severe weather events;
- to improve the lead time of alerting of theses events;
- to improve interaction of NMHSs with users, including Disaster Management and Civil Protection Authorities (DMCPA), media, and user communities in the various socio-economic sectors (e.g. agriculture, fisheries, etc.), both before and during events;
- to identify gaps and areas for improvements;
- to improve the skill of products from Global Centres through feedback from NMHSs.

The SWFDPs are implemented through a "Cascading Forecasting" process:

- Global NWP centres provide a range of NWP products, including EPS-based products, provided for the region of interest
- Regional centres interpret information received from global NWP centres, prepare daily guidance products (out to day 5) for NMHSs, run limited-area models to provide detailed shorter-range products, maintain RSMC Web site, liaise with the participating NMHSs;
- NMHSs issue alerts, advisories, severe weather warnings; liaise with Disaster Management, and contribute feedback and evaluation of the project;
- NMHSs have access to all products provided by the Global and Regional Centres, and maintain responsibility and authority over national warnings and services.

This approach proved to be very successful in the first SWFDP project in southern Africa. The project began in 2006 with the South African Weather Service acting as the Regional Centre, supporting 4 additional NMHSs. After an initial period, the project was extended to cover 16 countries southern Africa. There are now five regional SWFDPs:

- Southern Africa (ongoing; 16 countries; RSMC Pretoria)
- South Pacific Islands (ongoing; 9 Island States; RSMC Wellington)
- Southeast Asia (ongoing, 4 countries; Hanoi)
- Eastern Africa (ongoing, 6 countries; Nairobi)
- Bay of Bengal (in development, 6 countries; New Delhi)

2. ECMWF contribution to the SWFDPs

ECMWF has played an active role since the beginning of the SWFDP by participating as a Global Centre. The Met Office, NCEP and more recently also JMA (Japan), CMA (China) and KMA (Korea) also contribute to SWFDP as Global Centres.

ECMWF provides a range of products from both the deterministic forecasts and the Ensemble Prediction System (EPS), focusing on early warning for severe weather. These are provided as graphical products, mainly as charts focused on the region of interest for the SWFDP. The products are accessible via the ECMWF web site, on a password-protected page. Based on the requirements for the SWFDPs, these products include

- probabilities of precipitation and winds exceeding given thresholds
- extreme forecast index (EFI); identifies locations where the ensemble is substantially far from the model climate, indicating potential severe event
- tropical cyclone tracks and strike probability maps
- site-specific forecasts for surface weather parameters (EPSgrams) for specified locations (up to 10 stations for each participating country)

All products are updated twice a day with forecasts from 00 and 12 UTC; an archive of the previous 7 days will also be provided to assist in evaluation, an important aspect of the SWFDPs.

A comprehensive guide to the use of ECMWF products is available on the ECMWF web site. The guide includes descriptions of all products that are available to the participants of the SWFDPs.

http://www.ecmwf.int/products/forecasts/guide/

The guide also includes a useful introduction to ensemble forecasting as well as details about the ECMWF forecasting system.

ECMWF runs an annual training course on the Use and Interpretation of ECMWF Forecast Products for forecasters from WMO Member States. The purpose of the course is to train forecasters in the use and understanding of ECMWF products, especially those that may not be familiar, such as the probabilities from the Ensemble Prediction System (EPS), the EPSgrams, Extreme Forecast Index, and tropical cyclone strike probabilities.

Applicants from WMO Member Countries are not charged course fees for this course. In addition, a limited amount of funding is available (provided by WMO) to support travel and subsistence. In recent years a number of participants from the SWFDPs in southern Africa, eastern Africa and SW Pacific have benefited from participating in this course. Further information is provided on the ECMWF web site:

http://www.ecmwf.int/newsevents/training/

3. Benefits and success of the SWFDP

The SWFDP has been found to provide a practical and beneficial platform for the preparation and dissemination of multi-hazard, early warnings. Evaluation from the first SWFDP, in southern Africa has shown the following key benefits:

- Improved forecasting of severe weather
  - Very positive impact, increased skill and confidence
  - Probabilistic products found to be very significant and helpful
- Improved lead time of warnings
  - Significant for advisories & warnings issued
- Improved interaction between NMHSs and DMCPAs
  - relations with media and disaster management organizations were developed and improved in some countries
  - in other countries, assistance is still needed to develop improved working relations

The evaluation also identified a number of areas for improvement:

- Predicting convective weather (strong winds/gusts, heavy precipitation)
- Shortage of surface observations
- Getting feedback from users (media, DMCPAs)
- Feedback to the Global NWP Centres to evaluate and help improve their products needs to be better defined
- More effort on verification is needed

4. Training

Training of the forecasters in the NMHSs is essential to the success of the SWFDP. Forecasters in the participating countries have a wide range of educational background and skills. In general they do not have much experience of the range of products that are provided by the Global Centres, especially products based on the EPS, and they are not used to dealing with the objective uncertainty information that these systems can routinely provide. Each SWFDP has implemented training as an integral component of the project. This includes:

- Annual joint forecasting and Public Weather Service training targeted for SWFDP needs
- In-Country touring training team-of-2 (South Pacific Islands)
- SWFDP participants in WMO-associated training courses (e.g. ECMWF, DWD, Verification Methods Workshop)
- Specialised training on Severe weather
- Specialised training on Probabilistic forecasting
- Shortage of surface observations

Using ECMWF Products in Support of Mobile Weather Alert Pilot Project over Lake Victoria in Uganda

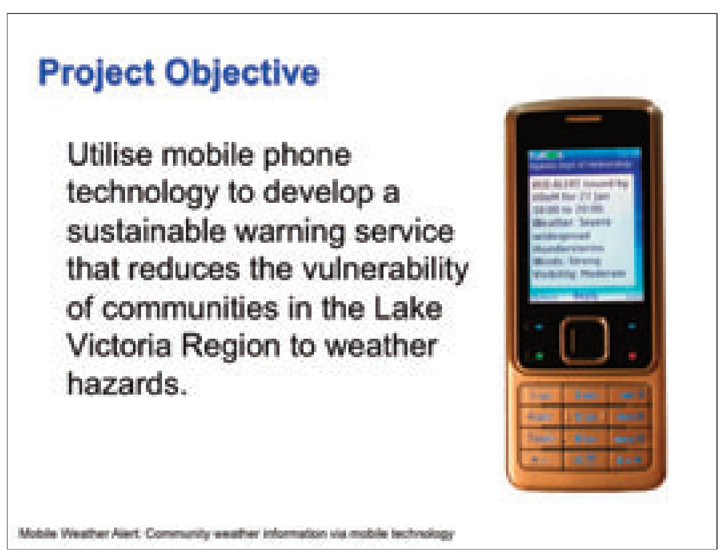
Khalid Y. Muwembe, Senior Meteorologist, Uganda Meteorological Department, MSc Student at University of Reading (Current). Email: khalid.muwembe@meteo-uganda.net Tel. 07551737500

Abstract

The frequent recurrence of weather related hazards over Lake Victoria underlined the need of Uganda Meteorological Department to provide tailored weather information and real-time warnings to fishermen so as to avert large scale disasters related to weather extremes. Working with the World Meteorological Organisation (WMO) under the Severe Weather demonstration Project, a pilot was designed specifically for Lake Victoria (Uganda) with a major objective to utilise mobile phone technology to develop a sustainable warning service on weather hazards that reduces the vulnerability of communities in the Lake Victoria Region.

In supporting our pilot project, MWO intended to overturn the growing technological gap in weather forecasting between developed and developing countries through capacity building and providing NMHS access to weather products from Global Weather Centres. Currently ECMWF products are critical to the accuracy of our weather forecasts.

Finally the success criteria of our Mobile Weather Alert service is to ensure that lives and property of fishermen are protected in a cost effective manner, with increased reach, enhanced trust and integrity of our weather information and real-time warnings



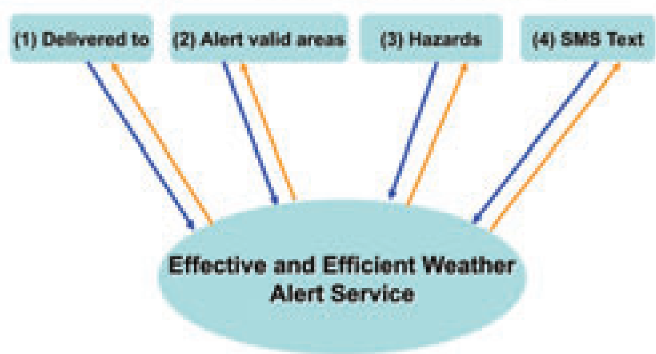
Mission – outcomes sought

- To safeguard life and property of the fishing community and other users of Lake Victoria by providing an effective, efficient and tailor made weather alert service, 24x7 for social-economic development.

Lake Victoria users includes

- Fishermen and other communities over Lake
- Ferry and other water transport operators
- Port Authority and Law Enforcement organisations
- Tourists

Specific requirements for the Mobile Weather Alerts are;



Specific requirements for the Mobile Weather Alerts are;

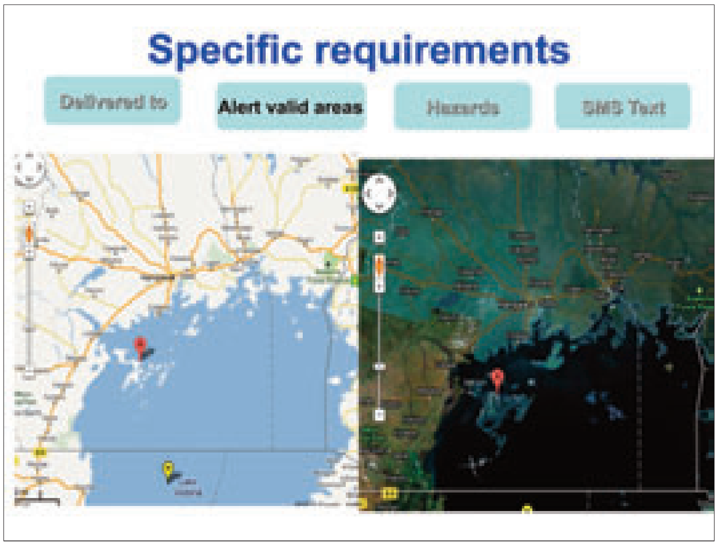
Delivered to | Alert valid areas | Hazards | SMS Text

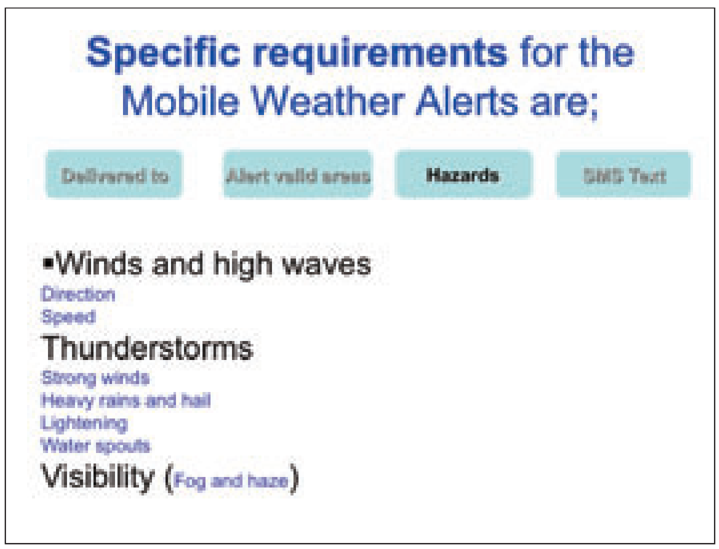
Currently Delivered to;

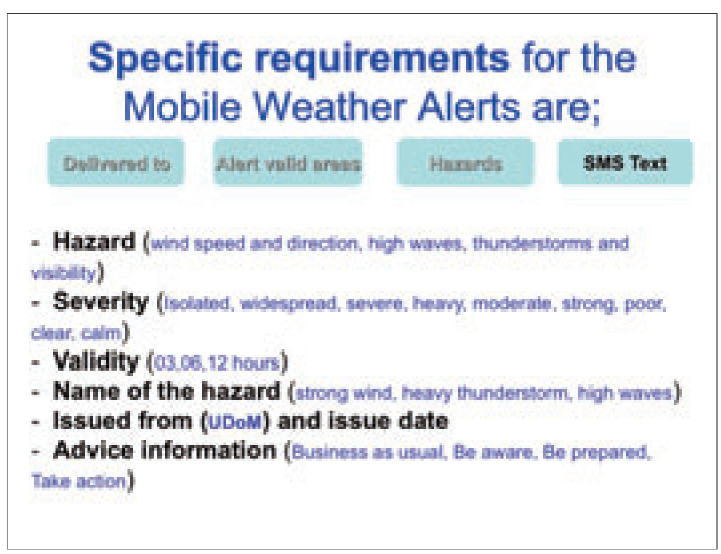
- Fishermen
- Radio stations currently only to Radio SSESE
- National Lake Rescue Institute (NLRI)

Potential Future Users

- Ferry and other water transport operators
- Police and UPDF Marines
- Department of Disaster (OPM)
- National Environment Management Authority (NEMA)


Specific requirements
Delivered to
Alert valid areas
Hazards
SMS Text


Specific requirements for the Mobile Weather Alerts are;
Delivered to
Alert valid areas
Hazards
SMS Text
▪Winds and high waves
Direction
Speed
Thunderstorms
Strong winds
Heavy rains and hail
Lightening
Water spouts
Visibility (Fog and haze)


Specific requirements for the Mobile Weather Alerts are;
Delivered to
Alert valid areas
Hazards
SMS Text
- Hazard (wind speed and direction, high waves, thunderstorms and visibility)
- Severity (Isolated, widespread, severe, heavy, moderate, strong, poor, clear, calm)
- Validity (03,06,12 hours)
- Name of the hazard (strong wind, heavy thunderstorm, high waves)
- Issued from (UDoM) and issue date
- Advice information (Business as usual, Be aware, Be prepared, Take action)

Main Forecast Tools

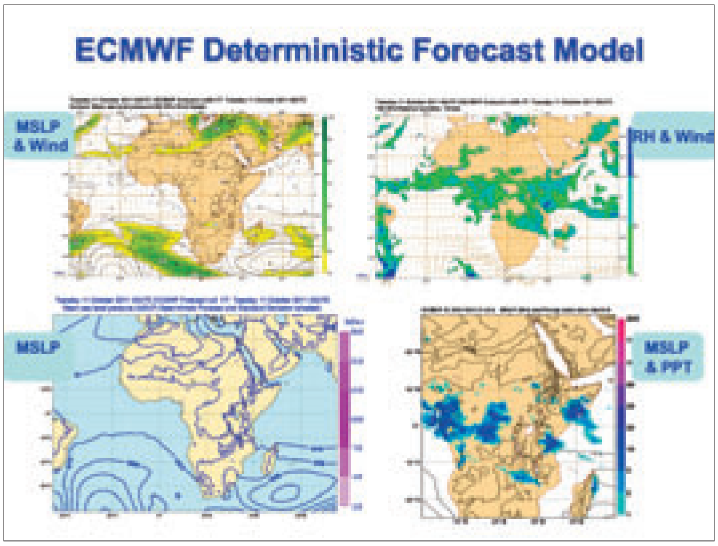
- Station and Satellite observations
- Analysis of wind flow patterns
- Model predictions from specialized forecast centres.
- Climatology and experience
- Feedback from information users

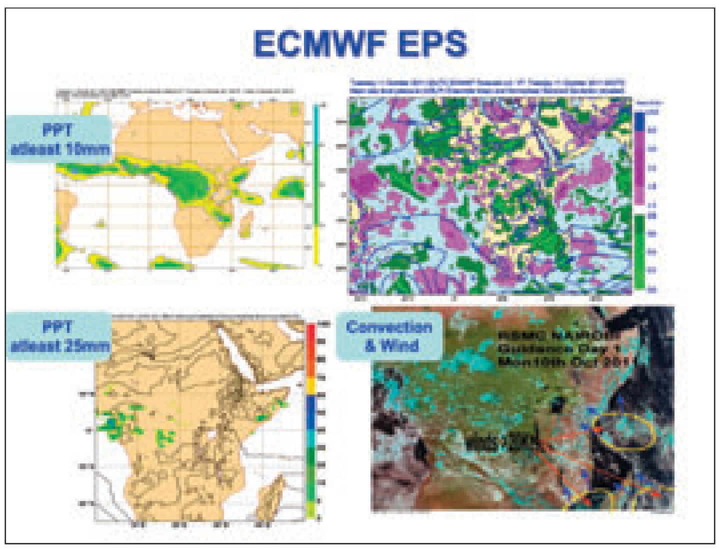
Model Prediction from World Centre

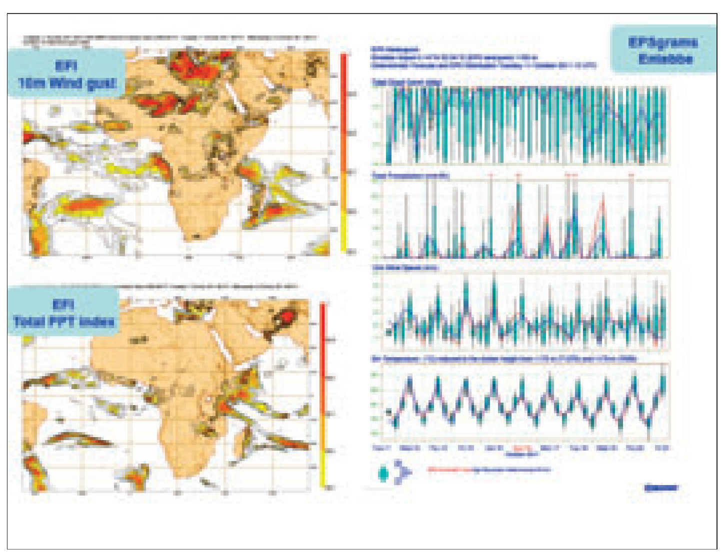
- UK Met Office: Africa LAM
- UK Met Office Lake Victoria Forecast
- ECMWF Products
- NCEP CPC Model Forecasts for Africa
- Guidance forecasts RSMC for Eastern Africa

Specific Reference to ECMWF Products

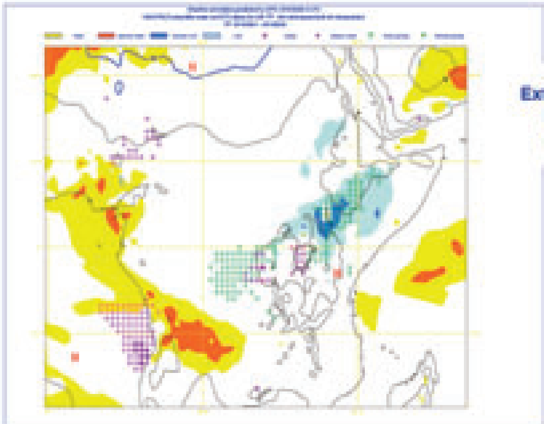
- Deterministic forecast: Analysis for Pressure and winds
- Probability forecast for precipitation
- Ensemble Prediction System (EPS) for MSLP and Humidity
- EFI for Wind, Wind gusts and PPT
- EPSgram


ECMWF Deterministic Forecast Model
MSLP & Wind
RH & Wind
MSLP
MSLP & PPT


ECMWF EPS
PPT atleast 10mm
PPT atleast 25mm
Convection & Wind

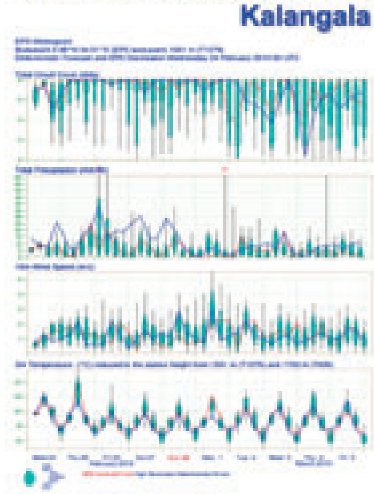

EFI 10m Wind gust
EFI Total PPT index
EPSgrams Entebbe

Useful Product not available to WMO Members



Extreme Forecast Index for All Parameters

Special Request: Additional EPSgram over Kalangala



Other issues considered

- Available daily, 24x7
- Forecast colour risk based on Hazard Matrix and Daily assessment
- Forecast advice available by phone to NMC on 0414320920/321403
- Alert validity should be flexible
- Alert amendable (Correction, update, amendment, cancellation)

Other issues cont…

- Post event analysis, verification and evaluation completed daily by 1500 UTC and filed in 'Mobile Weather Alert Pilot' folder
- Daily assessment also filed in 'Mobile Weather Alert Pilot' folder by 1500 UTC.
- User feedback is also important in improving the forecasts and alerts issued.

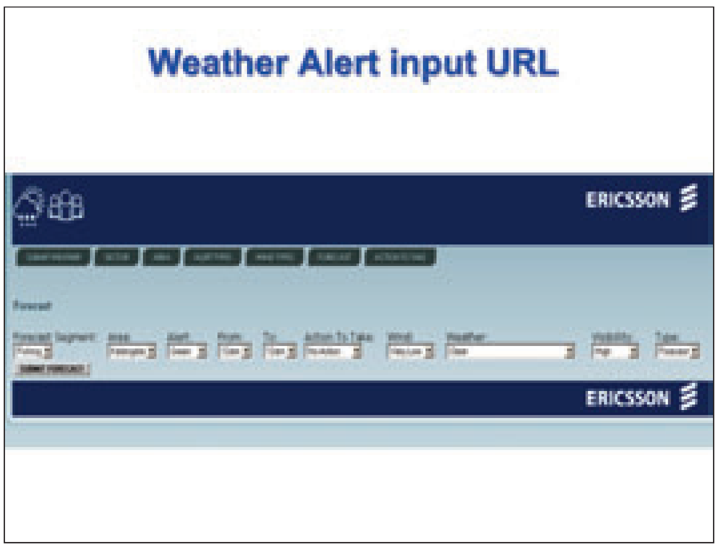
DoM Success Criteria

- Lives are saved and property protected in a cost effective manner
- Increased reach and enhanced trust and integrity
- Alerts should be timely i.e. received by users within 3 hours of issue, on time, in full
- Alert seen as a success if lead times of more than 3 hours is achieved and satellite/observations validates hazard.
- Alert seen as a success if fishermen take proportionate and appropriate actions based on the SMS text advice.
- The alert issued will be validated by a targeted questionnaire (email, letter, phone?) issued no more than 36 hours after alert issue.

Colour codes: Meaning and implications

Colour coding	Green	Yellow	Orange	Red
Hazard thresholds				
Mean Wind	0 – 5 KT	6 – 10 KT	11 – 20 KT	Over 20 KT
Wind gusts	5 – 10 KT	11 – 20 KT	21 – 30 KT	Over 30 KT
Thunderstorms	Light	Moderate	Strong	Severe
Visibility	> 1Km	500 – 1000m	100 – 500m	< 50m
Response Level	Appropriate individual response under BAU.	Some multi-agency response but mostly BAU.	Multi-agency response needed.	Multi-agency Strategic response needed, mutual aid necessary perhaps national co-ordination.
Implications for users of Lake Victoria	Business as Usual (BAU)	Forecast weather may lead to hazardous conditions. Be aware	Weather conditions are likely to lead to hazardous conditions. Be prepared should the situation worsen	Weather conditions will lead to life threatening conditions on the Lake. Take action.
Public Advice	Nil	Be Aware	Be Prepared	Take Action

Green Alert	**No alert**: No hazardous weather expected. Take normal precautions.	
Yellow Alert	**Be aware:** There might be changes in the weather. Be watchful and look out for signs of storm such as clouds, wind gusts, higher waves.	
Amber Alert	**Be prepared:** The weather is likely to change. Consider moving to safer areas and be prepared to take necessary actions.	
Red Alert	**Take action:** The weather will change soon. Take the necessary actions to get to a safe area.	



JMA's Coupled Ensemble Prediction System for seasonal forecast

Akira Ito, Japan Meteorological Agency

Abstract

JMA introduced the atmosphere-ocean Coupled General Circulation Model (CGCM) for seasonal forecasting in February 2010. Before bringing it into operational use, JMA carried out a hindcast involving numerical prediction experiments for a wide range of past cases to assess the skill of the model. The results indicated that the CGCM's introduction would improve forecast performance, especially with longer lead times and over the tropical region, in relation to that of the previous AGCM system.

JMA's Climate Prediction Division is responsible for the operation of the Ensemble Prediction System (EPS) using the CGCM and for domestic seasonal forecasting services. A characteristic point of these forecasting activities is JMA forecasters' use of a wide variety of prediction maps in addition to the statistical results and verifications of the massive hindcast carried out by JMA.

The level of skill in JMA's weekly/monthly predictions has gradually increased over the past decade. However, it is widely recognized that the exploration of using climate uncertainty information remains a long-term area to be addressed. Against this background, JMA has started joint research with agricultural organizations to promote the use of second-week temperature forecasts. JMA's temperature guidance is converted into user-friendly agricultural information and provided to users via the Internet. The information is also interactively modified based on user feedback. The results of this joint research are expected to act as a prototype of a successful case benefiting from the use of climate information.

1. JMA's operational seasonal forecast system

JMA introduced the use of the atmosphere-ocean coupled General Circulation Model in the ENSO forecasting service in 1999. In 2003, a two-tier dynamical ensemble prediction system was also introduced in long-range forecasting services. Through a major upgrade of the CGCM in 2008, JMA finally introduced this coupled system for long-range forecasting in February 2010. The current operational system for seasonal forecasts is detailed in Table 1.

AGCM	TL95 (180 km), 40 levels (up to 0.4 hPa)
OGCM	1.0˚ lon. ? 0.3 – 1.0˚ lat., 50 levels
Coupler	Every hour Adjustment for thermal and momentum fluxes
Initial conditions	JRA-25/JCDAS, MOVE/MRI-COM-G
Ensemble method	Combination of BGM and LAF
Ensemble size	51 members from six different initial dates

Table 1 JMA's current operational system for seasonal forecasts

2. Comparison of previous and current system performance

Before bringing the CGCM into operational use, JMA carried out a hindcast involving numerical prediction experiments for a wide range of past cases to assess the skill of the model. The details of the hindcast are as follows:

Period: 1979 – 2008

Initial date: around the end of every month

Integration time: 210 days

Member size: 10

Figure 1 indicates that the CGCM's introduction improves forecast performance, in relation to that of the previous AGCM system. Moreover, as a result of enhanced precipitation forecasting, an improvement is also seen in the Western North Pacific Monsoon (WNPM) index (Wang et al., 2001) associated with the Pacific-Japan (PJ) pattern (Nitta, 1987), which is a kind of teleconnection (see Figure 2). It is well known that this index is a major factor for predicting the summer climate over Japan. It is expected that the major improvement of the WNPM index will lead to breakthroughs for the summer outlook over Japan and East Asia.

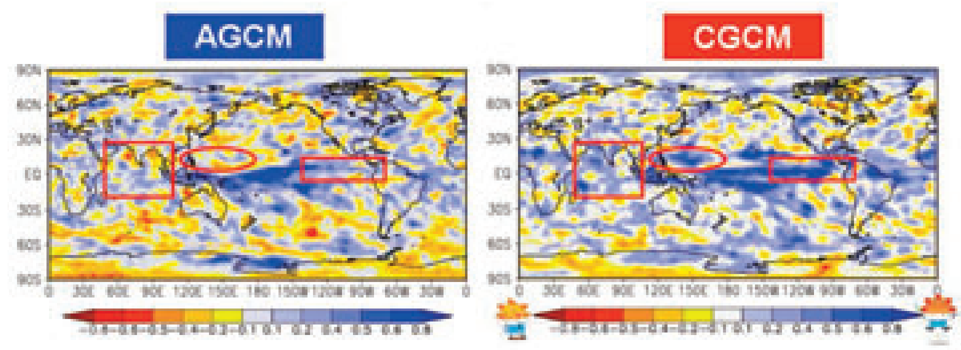


Figure 1 Anomaly correlation fields for precipitation in summer (1984 – 2005)

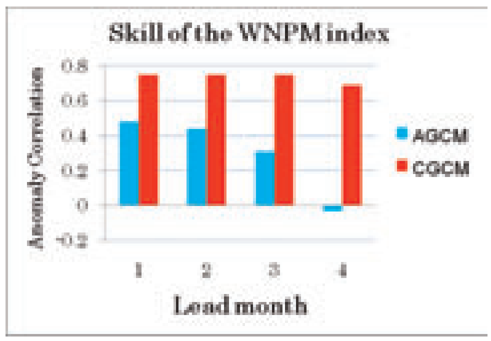


Figure 2 Skill of the WNPM index in JJA: the Western North Pacific Monsoon index, defined as U850 (100°E – 130°E, 5°N – 15°N) – U850 (110°E – 140°E, 20°N – 30°N). (Wang et al., 2001)

3. JMA's forecasting activities and outlook for summer 2011

JMA's Climate Prediction Division is responsible for the operation of the Ensemble Prediction System (EPS) using the CGCM and for domestic forecasting services. The series of operational forecasting activities is shown in Figure 3.

A characteristic point of these forecasting activities is JMA forecasters' use of a wide range of prediction maps in addition to the statistical results and verifications of the massive hindcast carried out by JMA (Figure 4).

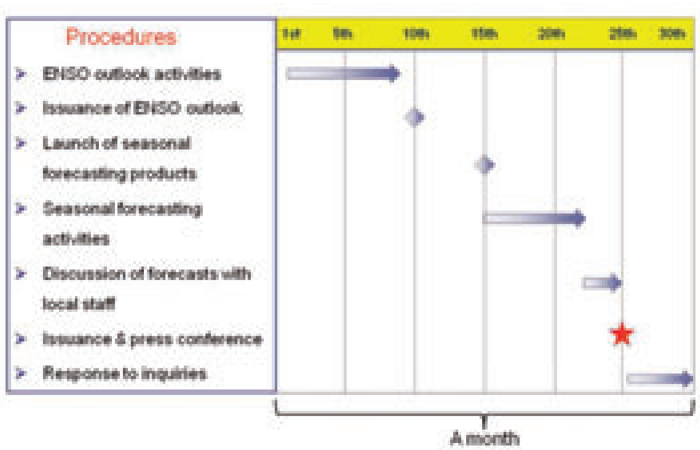


Figure 3 Schedule for seasonal forecasting activities and ENSO outlook activities

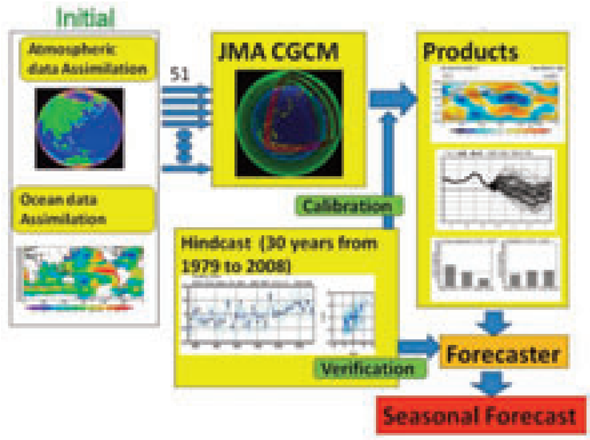


Figure 4 Combination of seasonal EPS and forecasting activities

4. Use of climate information in agriculture

It is widely recognized that the exploration of using climate uncertainty information remains a long-term area to be addressed. Against this background, JMA has started joint research with the National Agricultural Research Center for Tohoku Region (NARCT) to promote the use of second-week temperature forecasts (Figure 5).

First, NARCT produced climate normal data over 1-km mesh areas for the Tohoku region. Then, using a simple downscaling method for JMA's second-week temperature guidance, production of predicted temperature fields in 1-km meshes was introduced. NARCT converts the values to create user-friendly information such as figures to support pesticide application and growth management, and these products are made widely available to farmers and other agricultural organizations via the Internet. A high number of web accesses is seen in July and August, when rice crops are more likely to be affected by extreme temperature events.

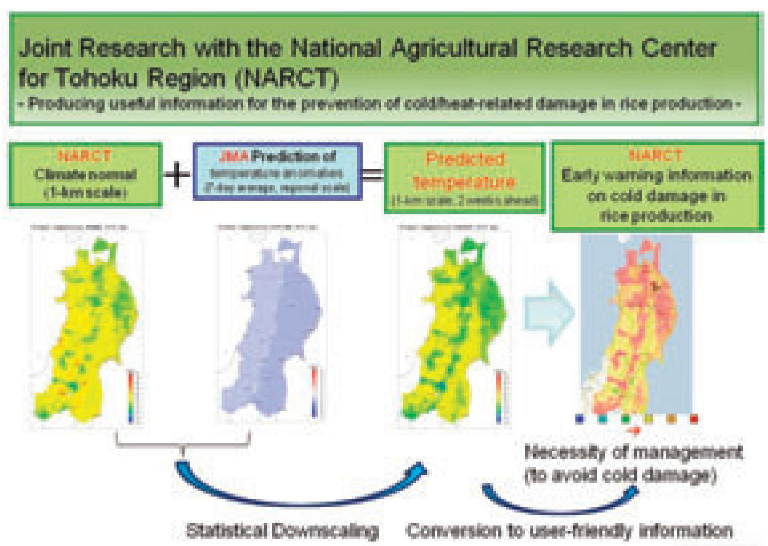


Figure 5 Joint research with NARCT

Figure 6 shows a flowchart of cooperation among JMA, NARCT and users.

JMA provides operational second-week temperature guidance with a certain level of skill based on hindcast for NARCT. Conversely, NARCT provides information on agriculture and user needs. This information can be obtained by users via the Internet and e-mail, and is interactively modified based on user feedback. The results of this research are expected to act as a prototype of a successful case benefiting from the use of climate information.

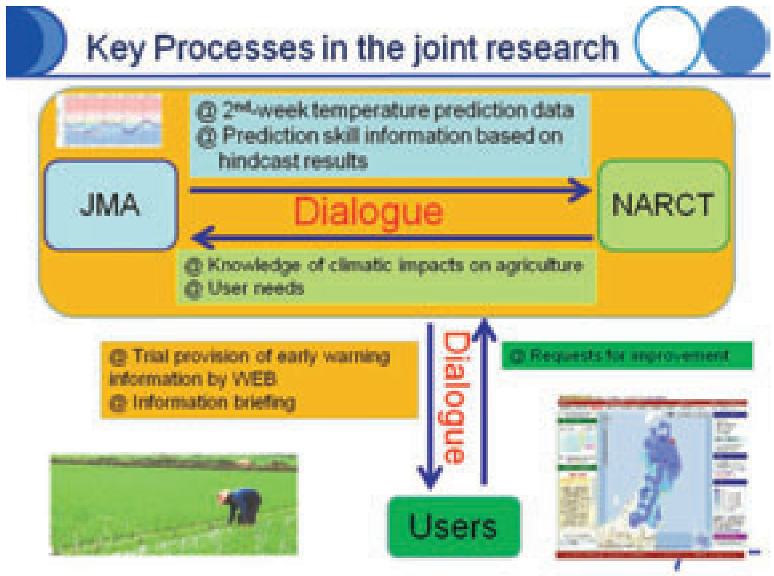


Figure 6 Key processes in the joint research

Acknowledgments

The author would like to thank the members of CPD/JMA involved.

Particular thanks go to Shuhei Maeda, Yuhei Takaya and Masayuki Hirai.

References

Nitta, T., 1987: Convective activities in the tropical western Pacific and their impact on the Northern Hemisphere summer circulation. *Journal of the Meteorological Society of Japan*, **65**, 373 – 390.

Wang, B., R. Wu, and **K. –M. Lau**, 2001: Interannual variability of the Asian summer monsoon: Contrasts between the Indian and Western North Pacific-East Asian monsoons. *J. Climate*, **14**, 4073 – 4090.

Extended Weather Forecast and Seasonal Climate Prediction at INPE-CPTEC

Paulo Nobre[1]

With an increasing number of extreme events occurring over Brazil over time, extended weather and seasonal climate prediction became a must for a country with continental proportions like Brazil. CPTEC innovated in numerical weather prediction and climate science in Brazil: With 15 years of experience in developing Numerical Weather Prediction (NWP), Numerical Seasonal Climate Prediction (NCP), Air Quality Prediction, and Regional Climate Change models, CPTEC has become the largest Meteorological Center in South America.

CPTEC's routine extended weather and climate forecasting activities consist of producing twice daily predictions up to 30 days through the use of the Center's own suite of global atmospheric(Cavalcanti et al. 2002), regional Eta atmospheric (Chou et al. 2005), and global coupled ocean-atmosphere (CGCM) (Nobre et al. 2012) models. Also air quality predictions are made routinely with Brams model (Freitas et al. 2009). CPTEC's NWP models resolutions have increased from 200 Km - 28 sigma levels in 1994 for the AGCM, to 20 Km - 96 levels in 2011. For the regional Eta model, the spatial resolution varied from 40 Km, 38 levels in 1994 to 5 Km and 50 levels in 2011 over South America and portions of the neighboring Pacific and Atlantic oceans. The supercomputer power in the Center also grew, from a mono processed 3.2 Gflops pick performance/60 Gbyes storage vectorial NEC SX3 machine in 1994 to today's 30K processors, 15 Tflops sustained/100 Pbytes storage massive parallel Cray XT6 machine.

In terms of NWP forecast skill, CPTEC has gained two days of predictions above the 60% correct forecast during the last 15 years, going from 5 to 7 days for 500 hPa geopotential height over South America. Comparison among the NWP models run at CPTEC revealed the coupled ocean-atmosphere model with the highest forecast skill (with NCEP analysis for the atmospheric initial conditions) up to 30 days extended weather predictions, while CPTEC's AGCM initialized with the Center's own "GPSAS" analysis shows the lowest forecast skill, for the same variable and area.

Yet, when the whole of Southern and Northern Hemispheres of the Earth are considered, then stagnation on the increase of CPTEC's AGCM NWP forecast skill is documented during the last few years. This is also the case for the comparison with a number of other operational meteorological centers around the world; presently CPTEC's AGCM forecast skill score is the lowest.

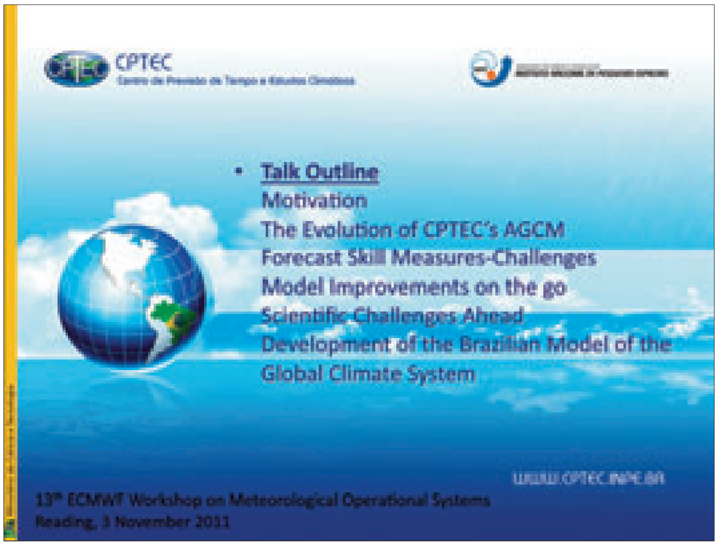
In terms of NCP over South America, a comparison among CPTEC, MétéoFrance, ECMWF, and the UKMO was done. Once again, CPTEC's model came last; with the UKMO and ECMWF's forecast skill score the best.

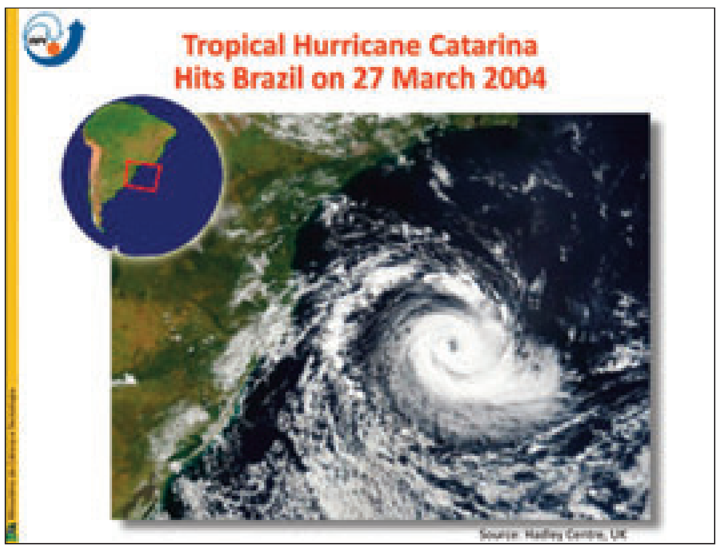
Some of the reasons for such poor performance of CPTEC's NWP and NCP were discussed, and actions being taken at the Center presented. Among them are the new data assimilation scheme (LETKF) and improvements on model physics (radiation and clouds schemes) and dynamics (e.g. atmospheric moisture transport treated as a tracer) being implemented on the AGCM.

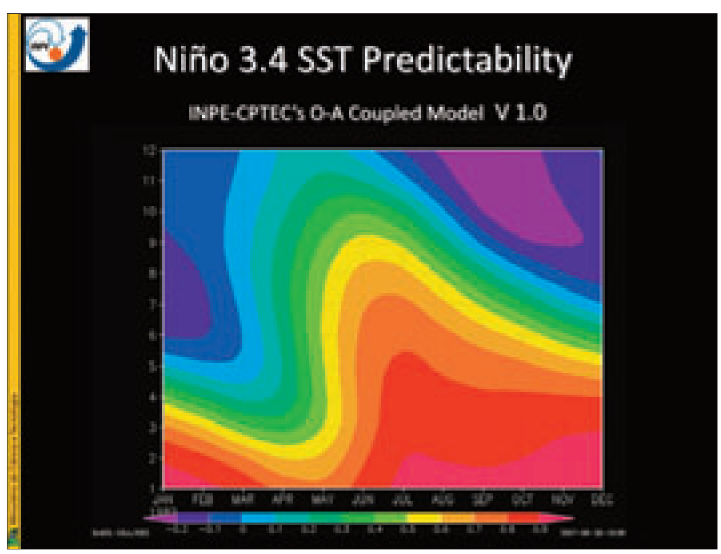
Also, INPE operates NOAA polar-orbiting satellites data reception, which covers a wide region over South America and the Atlantic Ocean. The ATOVS local data from NOAA satellites are acquired in real-time via the satellite's digital High Resolution Picture Transmission (HRPT) broadcast, then it is processed using AAPP scheme, and transmitted to Regional ATOVS Retransmission Services (RARS).

In terms of future developments, CPTEC is a central partner of the development of the Brazilian Model of the Global Climate System, contributing with the newest version of its AGCM (not documented in the score skill figures presented) and in the future with its atmospheric chemistry model. The MBSCG also incorporates GFDL's MOM4p1 ocean model and NCAR's IBIS continental surface model.

[1]Filiation: National Institute for Space Research – INPE, Center for Weather Forecasting and Climate Studies – CPTEC. Rodovia Presidente Dutra, Km 40, Cachoeira Paulista, SP 12630-000, BRAZIL. E-mail: paulo.nobre@cptec.inpe.br


CPTEC
Centro de Previsão de Tempo e Estudos Climáticos
• Talk Outline
Motivation
The Evolution of CPTEC's AGCM
Forecast Skill Measures-Challenges
Model Improvements on the go
Scientific Challenges Ahead
Development of the Brazilian Model of the Global Climate System
WWW.CPTEC.INPE.BR
13th ECMWF Workshop on Meteorological Operational Systems
Reading, 3 November 2011

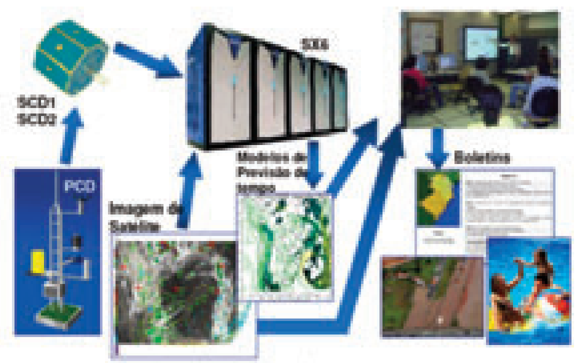

Tropical Hurricane Catarina
Hits Brazil on 27 March 2004
Source: Hadley Centre, UK


Niño 3.4 SST Predictability
INPE-CPTEC's O-A Coupled Model V 1.0
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC

CPTEC innovated in NWP and Climate Science in Brazil

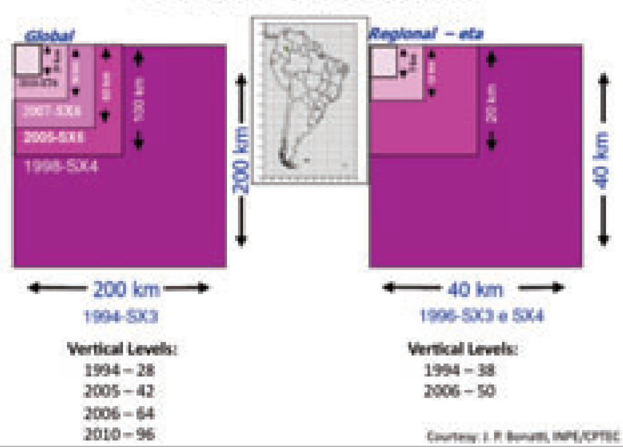
15 years of experience in developing Numerical Weather Prediction (NWP), Numerical Seasonal Climate Prediction (NSCP), Regional Climate Change Modeling, Air Quality Prediction at CPTEC, and climate modeling in general.

CPTEC's Numerical Weather Forecasting System

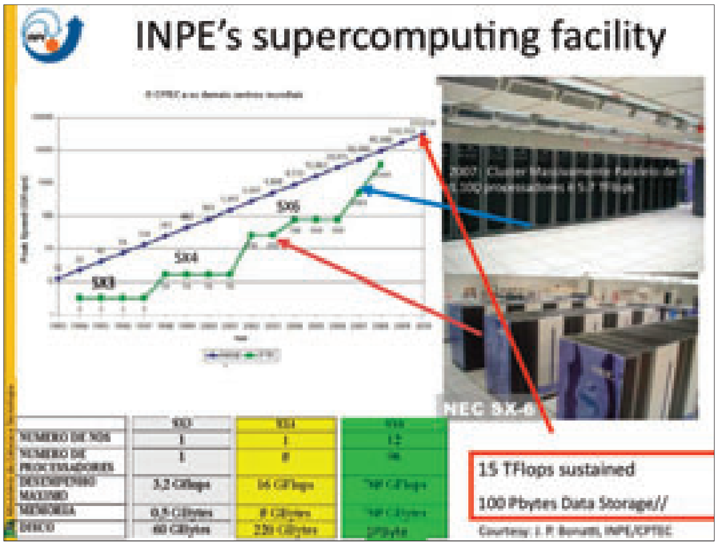


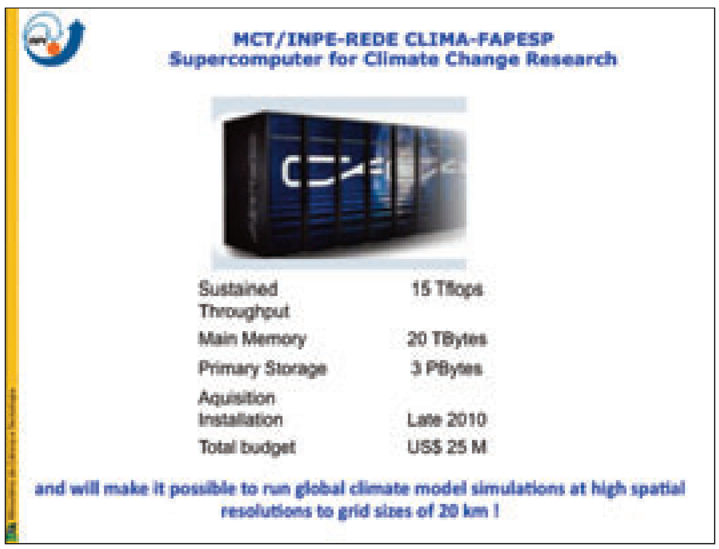
Coordinator: Dr. J. P. Bonatti

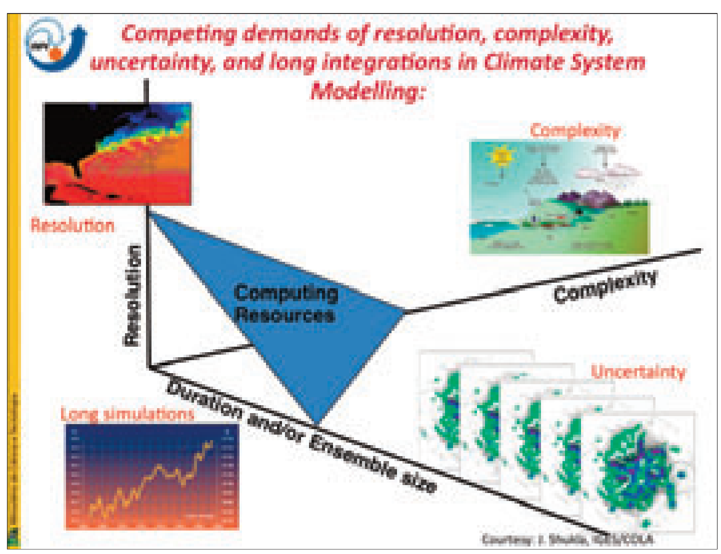
CPTE's Atmospheric Models: Evolution of Resolution

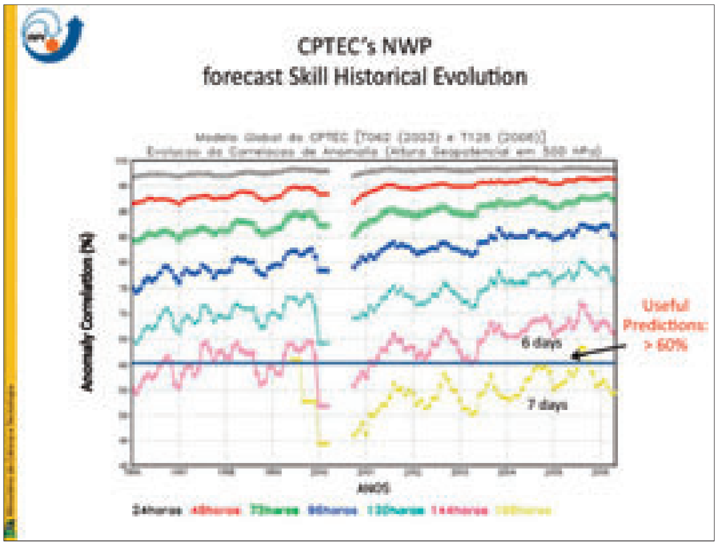


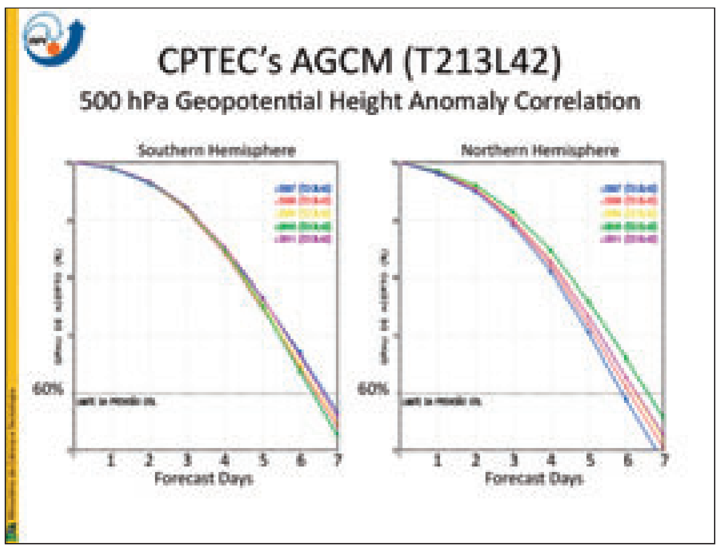
Courtesy: J. P. Bonatti, INPE/CPTEC

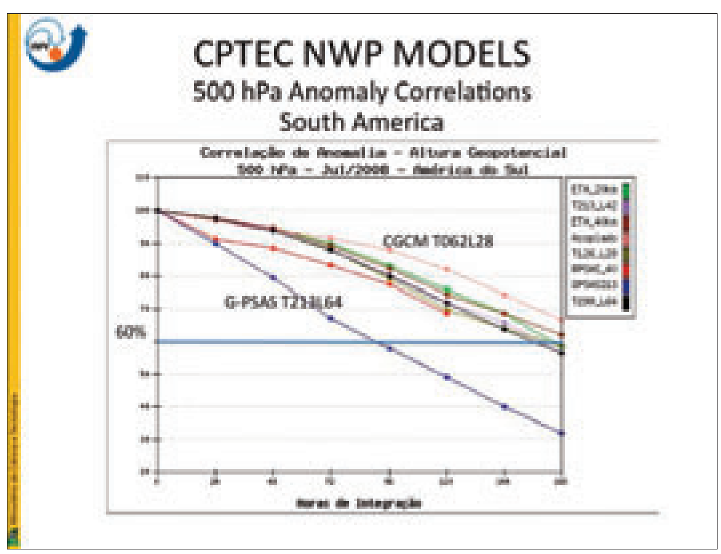

INPE's supercomputing facility
SX3
SX4
SX6
NEC SX-6
15 TFlops sustained
100 Pbytes Data Storage//
Courtesy: J. P. Bonatti, INPE/CPTEC

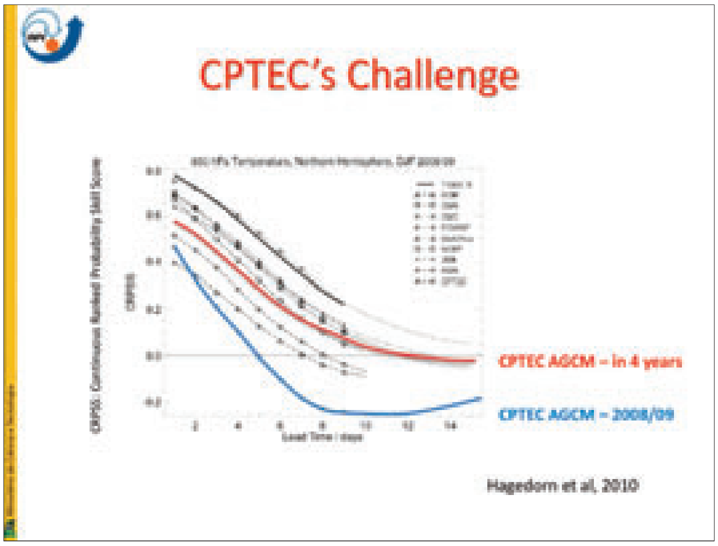

MCT/INPE-REDE CLIMA-FAPESP
Supercomputer for Climate Change Research
Sustained Throughput 15 Tflops
Main Memory 20 TBytes
Primary Storage 3 PBytes
Aquisition Installation Late 2010
Total budget US$ 25 M
and will make it possible to run global climate model simulations at high spatial resolutions to grid sizes of 20 km !

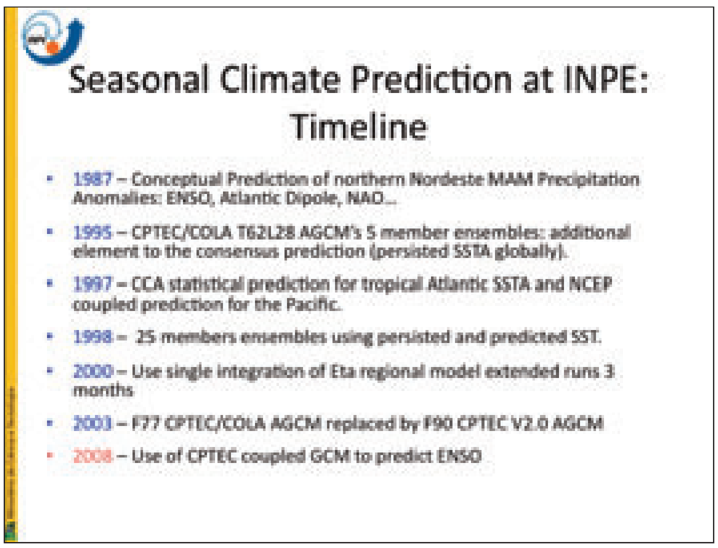

Competing demands of resolution, complexity, uncertainty, and long integrations in Climate System Modelling:
Resolution
Complexity
Uncertainty
Long simulations
Computing Resources
Resolution
Complexity
Duration and/or Ensemble size

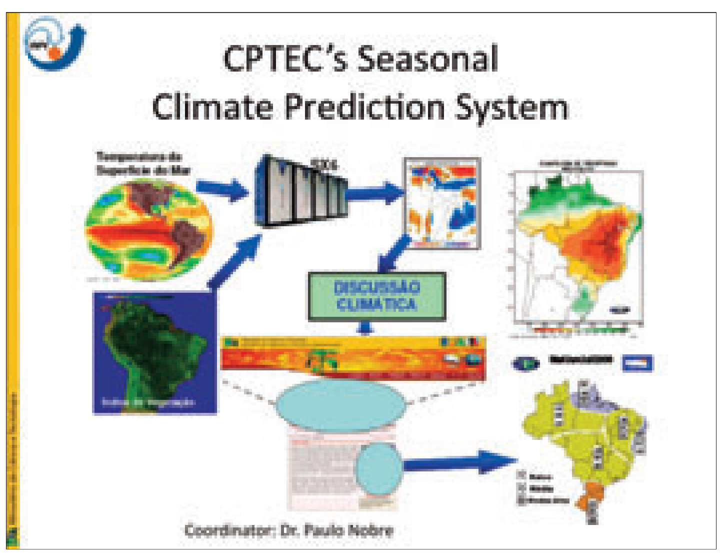

CPTEC's NWP
forecast Skill Historical Evolution
Anomaly Correlation (%)
Useful Predictions: > 60%
6 days
7 days
ANOS


CPTEC's AGCM (T213L42)
500 hPa Geopotential Height Anomaly Correlation
Southern Hemisphere
Northern Hemisphere
60%
60%
Forecast Days
Forecast Days

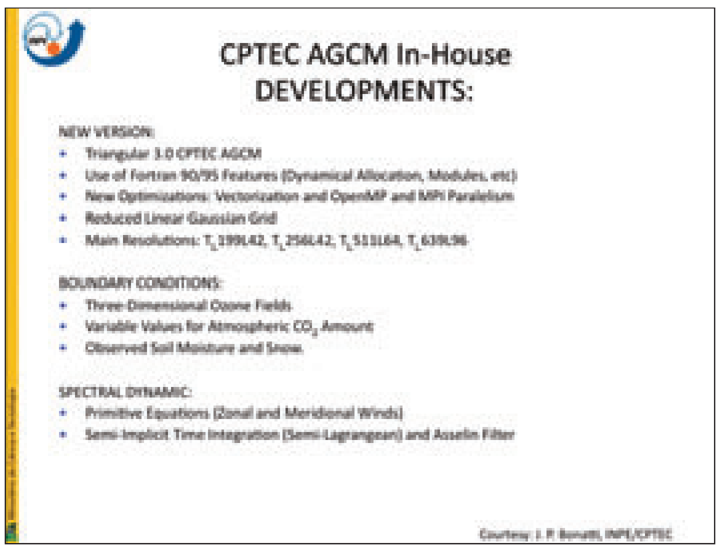

CPTEC NWP MODELS
500 hPa Anomaly Correlations
South America
CGCM T062L28
G-PSAS T213L64
60%


CPTEC's Challenge
CRPSS: Continuous Ranked Probability Skill Score
Lead Time / days
CPTEC AGCM – in 4 years
CPTEC AGCM – 2008/09
Hagedorn et al, 2010

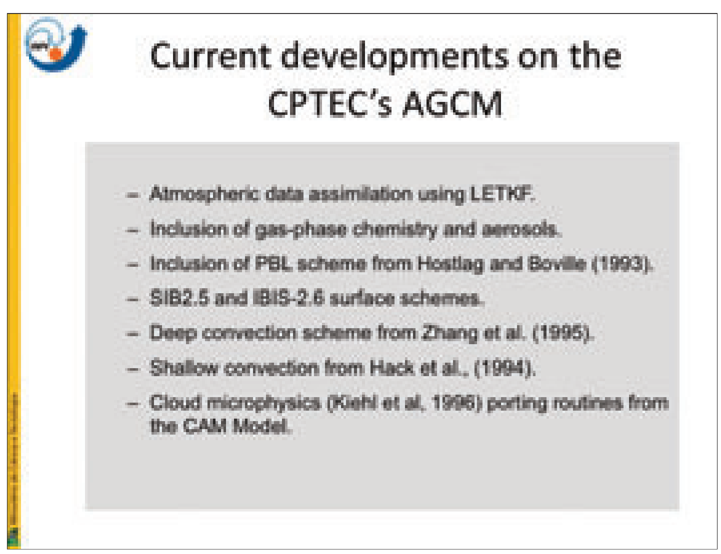

Seasonal Climate Prediction at INPE: Timeline
1987 – Conceptual Prediction of northern Nordeste MAM Precipitation Anomalies: ENSO, Atlantic Dipole, NAO...
1995 – CPTEC/COLA T62L28 AGCM's 5 member ensembles: additional element to the consensus prediction (persisted SSTA globally).
1997 – CCA statistical prediction for tropical Atlantic SSTA and NCEP coupled prediction for the Pacific.
1998 – 25 members ensembles using persisted and predicted SST.
2000 – Use single integration of Eta regional model extended runs 3 months
2003 – F77 CPTEC/COLA AGCM replaced by F90 CPTEC V2.0 AGCM
2008 – Use of CPTEC coupled GCM to predict ENSO


CPTEC's Seasonal Climate Prediction System
Temperatura da Superfície do Mar
SX6
DISCUSSÃO CLIMÁTICA
Coordinator: Dr. Paulo Nobre

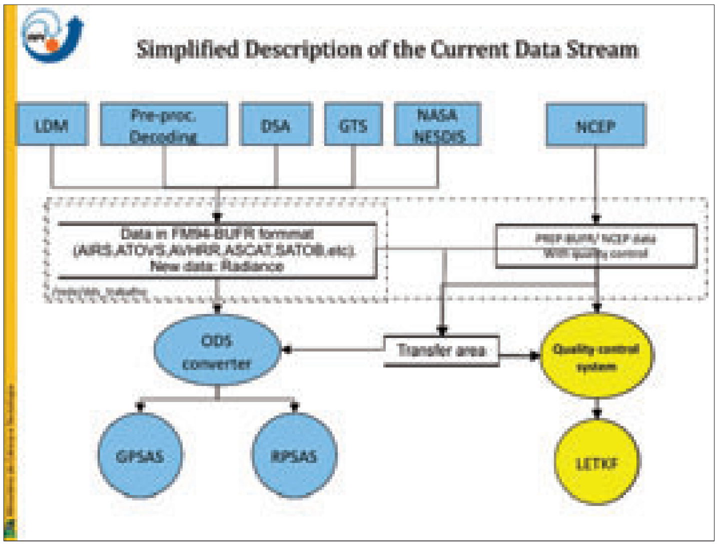
COUPLED O-A SEASONAL FCST
ROC SKILL SCORES
AVERAGED OVER BRAZIL
Data Source: Eurobrisa; This figure: Paulo Nobre; 02MAR2011

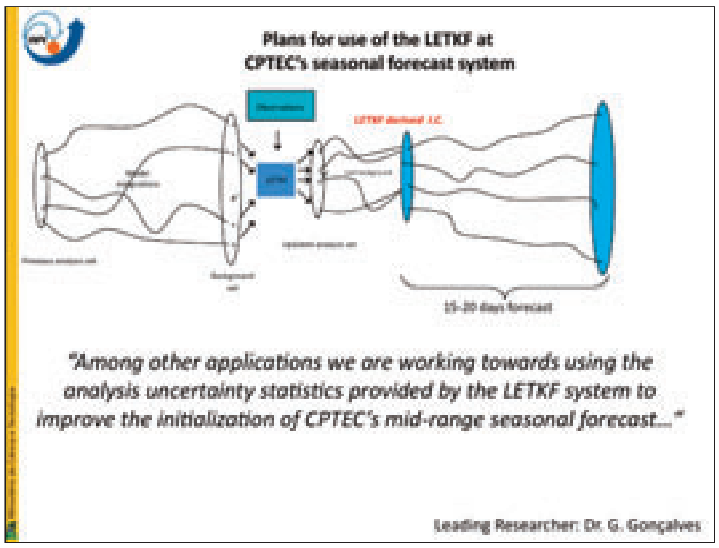


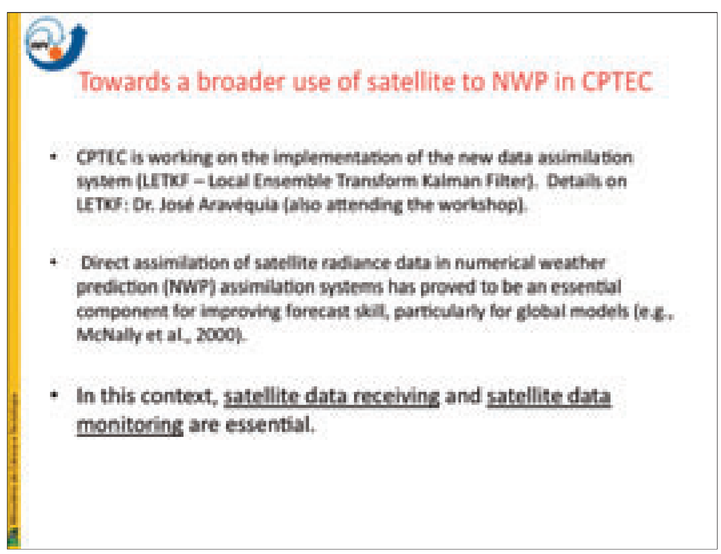
CPTEC AGCM In-House
DEVELOPMENTS:
NEW VERSION:
Triangular 3.0 CPTEC AGCM
Use of Fortran 90/95 Features (Dynamical Allocation, Modules, etc)
New Optimizations: Vectorization and OpenMP and MPI Paralelism
Reduced Linear Gaussian Grid
Main Resolutions: T_L199L42, T_L256L42, T_L511L64, T_L639L96
BOUNDARY CONDITIONS:
Three-Dimensional Ozone Fields
Variable Values for Atmospheric CO_2 Amount
Observed Soil Moisture and Snow.
SPECTRAL DYNAMIC:
Primitive Equations (Zonal and Meridional Winds)
Semi-Implicit Time Integration (Semi-Lagrangean) and Asselin Filter
Courtesy: J. P. Bonatti, INPE/CPTEC

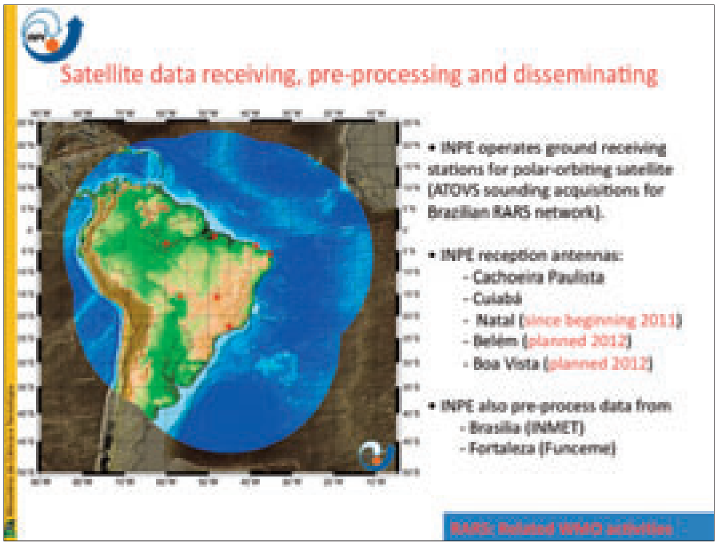


Current developments on the
CPTEC's AGCM
– Atmospheric data assimilation using LETKF.
– Inclusion of gas-phase chemistry and aerosols.
– Inclusion of PBL scheme from Hostlag and Boville (1993).
– SIB2.5 and IBIS-2.6 surface schemes.
– Deep convection scheme from Zhang et al. (1995).
– Shallow convection from Hack et al., (1994).
– Cloud microphysics (Kiehl et al, 1996) porting routines from the CAM Model.


Simplified Description of the Current Data Stream
LDM
Pre-proc. Decoding
DSA
GTS
NASA NESDIS
NCEP
Data in FM94-BUFR formmat
(AIRS,ATOVS,AVHRR,ASCAT,SATOB,etc).
New data: Radiance
ODS converter
Transfer area
Quality control system
GPSAS
RPSAS
LETKF

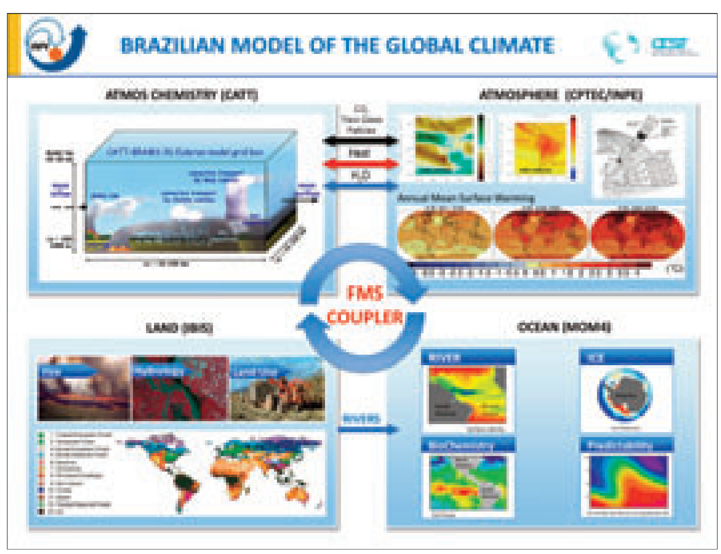

Plans for use of the LETKF at
CPTEC's seasonal forecast system
15-20 days forecast
"Among other applications we are working towards using the analysis uncertainty statistics provided by the LETKF system to improve the initialization of CPTEC's mid-range seasonal forecast..."
Leading Researcher: Dr. G. Gonçalves


Towards a broader use of satellite to NWP in CPTEC
• CPTEC is working on the implementation of the new data assimilation system (LETKF – Local Ensemble Transform Kalman Filter). Details on LETKF: Dr. José Aravéquia (also attending the workshop).
• Direct assimilation of satellite radiance data in numerical weather prediction (NWP) assimilation systems has proved to be an essential component for improving forecast skill, particularly for global models (e.g., McNally et al., 2000).
• In this context, satellite data receiving and satellite data monitoring are essential.



Scientific Challenges Ahead

- Summer rainfall over Southeastern South America – The South Atlantic Convergence Zone
- Systematic errors of Coupled Ocean-Atmosphere GCMs over the equatorial Atlantic
- The role of the Amazon Forest hydrology on global climate



Acknowledgements

Presentation developed with contributions from: E. Giarolla, M. Malagutti, S. Costa, J. P. Bonatti, G. Gonçalves, R. G. de Moura, C. Coelho, S. Freitas, C. Cunningham, S. Nilo.

References:

Cavalcanti, I. F. A., and **Coauthors**, 2002: Global climatological features in a simulation using CPTEC/COLA AGCM. *J. Climate*, **15**, 2965-2988.

Chou, S. C., J. Bustamante, and **J. L. Gomes**, 2005: Evaluation of Eta model seasonal precipitation forecasts over South America. *Nonlinear Processes in Geophysics*, **12**, 537-555.

Freitas, S. R., and **Coauthors**, 2009: The Coupled Aerosol and Tracer Transport model to the Brazilian developments on the Regional Atmospheric Modeling System (CATT-BRAMS) Part 1: Model description and evaluation. *Atmospheric Chemistry and Physics*, **9**, 2843-2861.

Nobre, P., R. A. F. De Almeida, and **M. Malagutti**, 2012: Coupled ocean-atmosphere variations over the South Atlantic ocean. *J. Climate*, accepted.

GLOSEA4 – the Met Office's new integrated monthly/seasonal forecast system

Tim Hewson. Met Office, Exeter.

Model structure

GLOSEA4 (GLObal SEAsonal Forecast System Version 4) is the Met Office's 'extended range' forecasting system, designed to deliver numerical model forecasts on monthly and seasonal timescales. The system is based around an 85 level coupled model (from "HadGEM3", a Hadley Centre climate model) and forms part of the Met Office's 'Unified Model' suite. Horizontal resolution is about 1˚ in the atmosphere, and 0.3 to 1˚ in the ocean. For a complete description see *Arribas et al* (2011); only a brief overview is provided below.

The way the forecast ensemble is created differs from many other systems in that instead of perturbing initial conditions at a given start time the member differences are mainly generated by using different start times, although there is also a stochastic physics component. In practice four members are run every day; two run for two months, the other two for six months. All runs (accumulated across many days) provide input to the nominal 'monthly forecast', whilst the six month runs feed the seasonal forecast. In late 2011 only the seasonal component had 'operational' status, but during 2012 the monthly component will be made operational too.

Hindcasts are essentially run at the same time as the forecast. This strategy ensures that forecasts and hindcasts are compatible and always from the same model version; it also allows model version upgrades to be made frequently and effortlessly, whenever they are deemed appropriate. The downside of this strategy is that it is computationally expensive, which in turn means that the hindcast dataset length is relatively short, at 14 years. Hindcast initialisation of the atmosphere and land surface comes from ERA-interim; for oceans and sea ice it comes from the Met Office seasonal 'ocean data assimilation' (ODA) analyses. There are four fixed hindcast start dates every month – 1st, 9th, 17th and 25th, with 3 members per year per start date. Bias correction for forecasts is based on the hindcasts, and is, in the usual way, a function of start date, lead time and location. Biases to be aware of include sea surface temperature (SST) in the important El Niño / La Niña region, as Fig. 1 shows. Note however that when bias is subtracted there is skill in SST predictions for this area, and that other forecasting systems do have similar characteristics. There are also some large SST biases in the extra-tropics. The negative anomaly south of Greenland, for example, is believed to be relevant for blocking – experimentation has shown that reducing the bias here, by using a very high resolution ocean model, can dramatically improve blocking climatology in climate runs (*Scaife et al*, 2011).

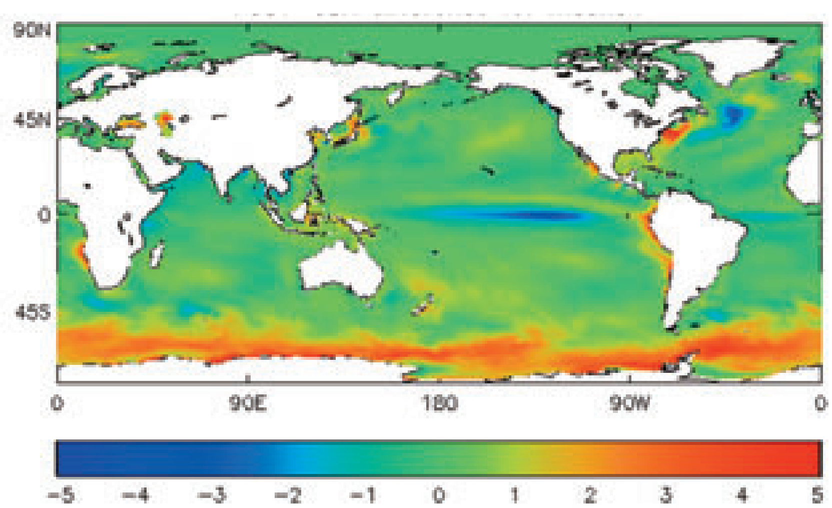


Figure 1 Sea surface temperature bias (˚C) in GLOSEA4 hindcasts. Valid month is January, for hindcasts begun in November.

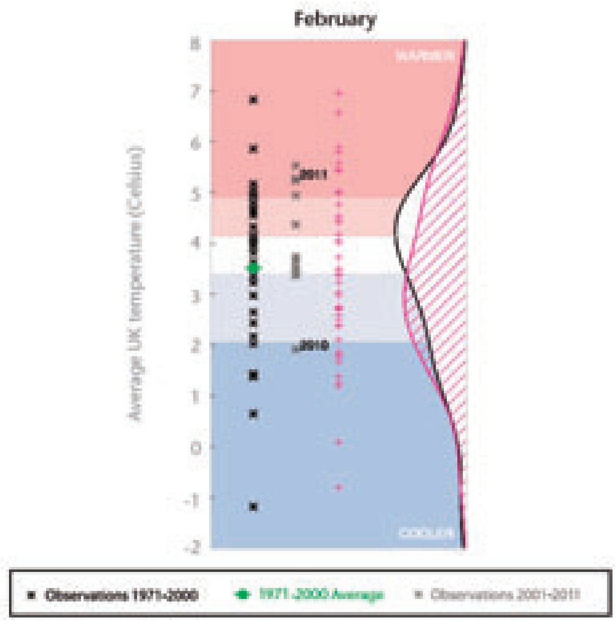


Figure 2 Part of the Met Office 3-month Outlook, showing the UK temperature forecast for February 2012 (pink crosses) alongside climatology. Curves show forecast and climatological (1971-2000) probability density functions (pdfs) in pink and black respectively, as derived from the points to the left. The Outlook includes a text component to highlight key messages and explain this and other graphs.

One feature of GLOSEA4 is its initialiased and coupled sea ice. In a 'warming world' in particular this should bring benefits compared to models that use climatological sea ice cover. To some extent however this is work in progress, with one current problem being excessive summer ice melt. This stems in part from problems with the ice thickness initialisation, which in turn partly relates to a lack of observations.

Customers and products

The Met Office is one of a number of Global Producing Centres (GPC) of long range forecasts designated by WMO. As such it provides real-time web-based probabilistic predictions of weather parameters on seasonal timescales across the globe, from GLOSEA4, as well as related skill information. Internally, products also allow users to see the degree to which forecast signals have changed in the recent days and weeks – an important consideration for a system which bases its perturbation method around using different forecast start times.

A number of customer groups are increasingly using products informed by GLOSEA4 output. Notably, forecasts are routinely provided to parts of Africa, where drought is an ever-present threat. For the West African monsoon GLOSEA4 forecasts represent reasonably well the general characteristics, notably the summer-time latitudinal migration, and also the inter-annual variability in onset time, with hindcasts tending to beat climatology. This skill stems in part from correctly capturing the variability in Gulf of Guinea SST. In the extra-tropics too, whilst skill levels are typically lower, there have been some notable 'successes'. The relatively blocked winters of 2009/10 and 20010/11 in northwest Europe were foreseen some time in advance. Figure 3 shows a winter forecast example comparing GLOSEA4 and ECMWF, from a September start time. Although not of sufficient magnitude the negative North Atlantic Oscillation (NAO-) signal in the GLOSEA4 forecast did 'verify'. Later forecasts, from October and November, retained this signal.

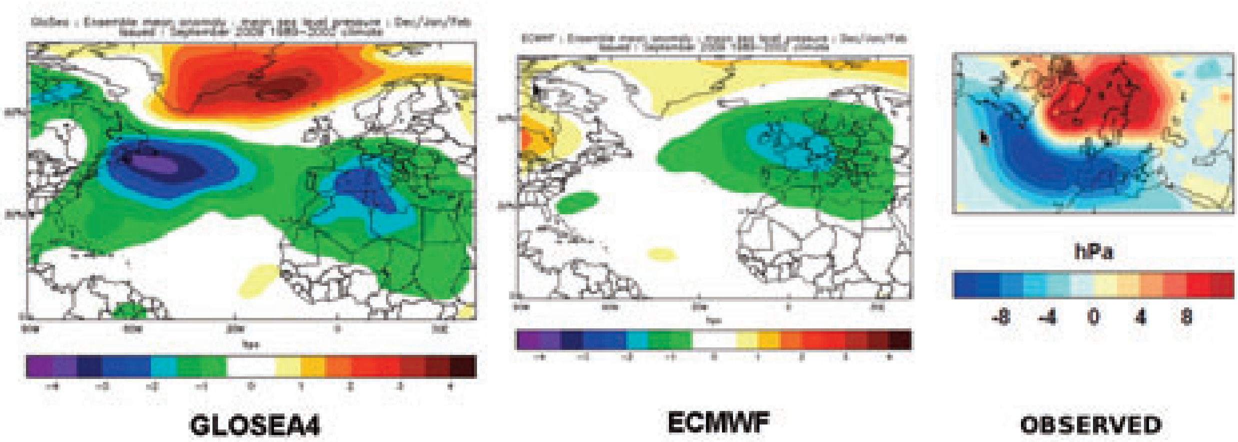


Figure 3 Operational forecasts of bias-corrected mean sea level pressure anomaly (hPa) for the December-January-February period (winter of 2009/10), from a September 2009 start time, from GLOSEA4 (left) and ECMWF (middle), and with validating analysis data on the right.

Late in 2011 the Met Office began issuing, on a monthly basis, a new format "3-month Outlook" for the UK to government customers. The starting point for this is a set of GLOSEA4 forecast points of bias-corrected temperature and precipitation for the UK, which are then subject to expert modification according to data from other models and techniques, and according to knowledge of skill characteristics. Key features of this product are (i) conveying output entirely in a probabilistic format, using crosses on graphs to represent every (expert-modified) ensemble member outcome, and (ii) placing the forecast in a climatological context, as an aid understanding. An example of a UK temperature forecast for February 2012 (created on 25th January) can be seen on Fig. 2. For a full 3-month Outlook see http://www.metoffice.gov.uk/publicsector/contingency-planners.

References

Arribas, A., M. Glover, A. Maidens, K. Peterson, M. Gordon, C. MacLachlan, R. Graham, D. Fereday, J. Camp, A.A. Scaife, P. Xavier, A. McLean, A. Colman, S. Cusack, 2011: The GloSea4 ensemble prediction system for seasonal forecasting. *Mon. Wea. Rev.* **139**. 1891-1910

Scaife, A. A., D. Copsey, C. Gordon, C. Harris, T. Hinton, S. Keeley, A. O'Neill, M. Roberts, and **K. Williams**. 2011. Improved Atlantic winter blocking in a climate model, *Geophys. Res. Lett.*, **38**.

Ensemble applications: The TIGGE archive and the multi-disciplinary GEOWOW project

David Richardson, Baudouin Raoult (ECMWF)

1. The THORPEX Interactive Grand Global Ensemble (TIGGE)

THORPEX is a 10-year international research and development programme to accelerate improvements in the accuracy of one-day to two-week high impact weather forecasts

for the benefit of society, the economy and the environment. THORPEX establishes an organizational framework that addresses weather research and forecast problems whose solutions will be accelerated through international collaboration among academic institutions, operational forecast centres and users of forecast products. THORPEX is a major component of the WMO World Weather Research Programme (WWRP); more information is available on the THORPEX web site: www.wmo.int/thorpex/

TIGGE, the THORPEX Interactive Grand Global Ensemble, is a key component of THORPEX. The TIGGE archive consists of ensemble forecast data from ten global NWP centres, starting from October 2006, which has been made available for scientific research. TIGGE has become a focal point for a range of research projects, including research on ensemble forecasting, predictability and the development of products to improve the prediction of severe weather.

The TIGGE archive is replicated in three identical databases, one in Europe (at ECMWF), one in America (NCAR) and one in Asia (at the China Meteorological Agency, CMA). These databases are fed in near real-time from the outputs of global ensemble prediction systems (EPS) run several times a day in operational numerical weather prediction centres in Australia, Brazil, Canada, China, France, Japan, Korea, the UK, and the USA and at ECMWF. Around 500 GB (~1.6 million global meteorological fields) are now exchanged daily between ten Data Providers and three Archive Centres in near-real-time. The TIGGE database now contains global EPS data from all ten Data Providers, and holds more than 620 TBytes of data (over 3 billion global meteorological fields).

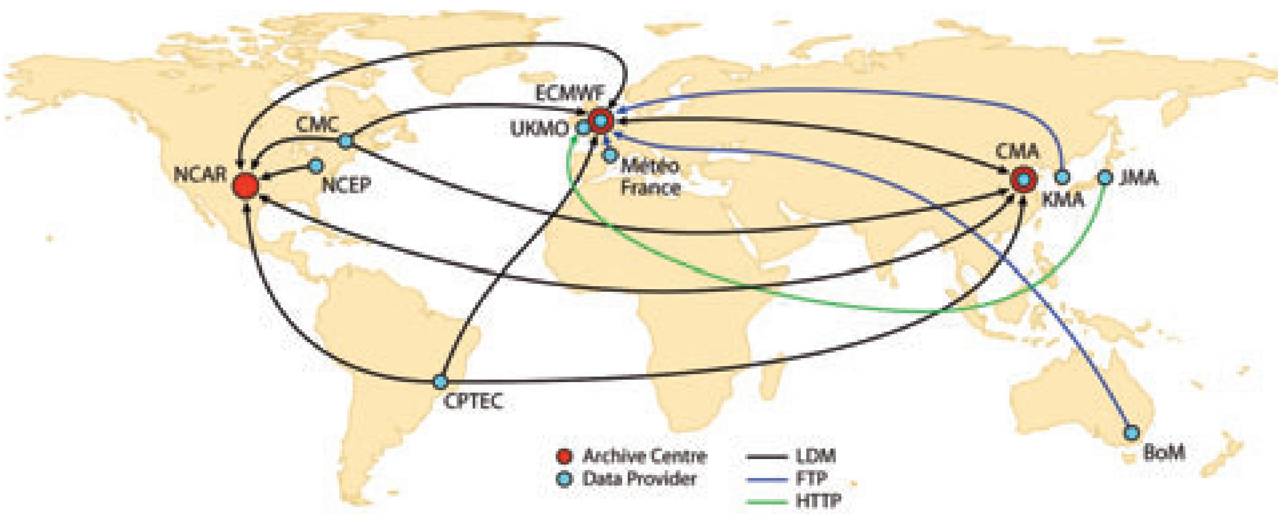


Figure 1 TIGGE data providers and archive centres.

Around 1600 users have registered with the TIGGE data portal at ECMWF, of which a third are active, generating up to 20,000 requests per month.

For the TIGGE project to succeed, it was paramount that the content of the database was as homogeneous as possible. The more consistent the archive, the easier it is to develop applications. Major features of the TIGGE archive are:

- All data are archived at native resolution (on native grid when possible)
- Data are interpolated on any limited-area lat-lon grid defined by the user just before download
- Field names, definitions, units, accumulation times, etc. are fully standardized
- Data gaps are continuously monitored and every effort is made to repair them quickly
- All data are provided in the WMO standard GRIB2 format

There are two methods for users to access the TIGGE data archive at ECMWF. The first is a web based interface that allows users to select data from a catalogue. This interface is publicly accessible: a user simply has to agree to the TIGGE terms and conditions before they are granted access to it.

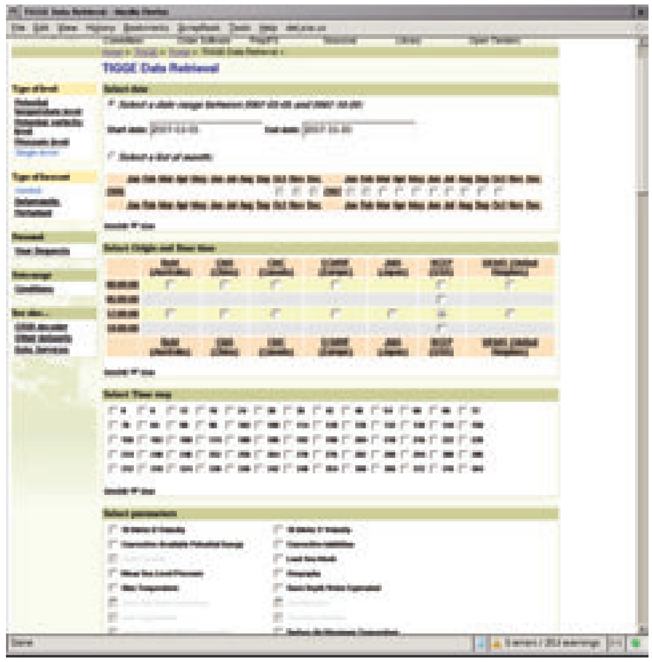


Figure 2 Selection of fields on the TIGGE data portal.

a **b** **c**

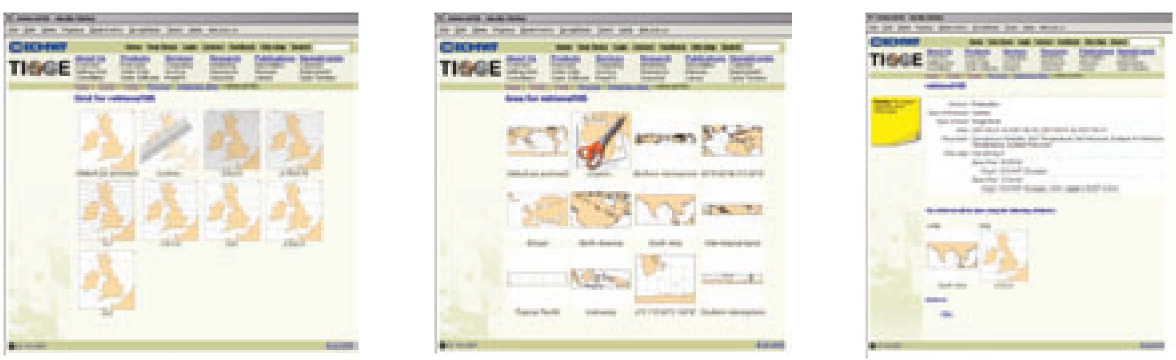


Figure 3 Web pages illustrating the selection of data in terms of (a) the grid and (b) the area and (c) the amount.

The second access method is a JSON/REST based web service. After agreement of the terms and conditions, the user is provided with a key that must be provided with all invocations of the web service. Examples on how to use the REST interface are provided in Perl and Python.

To date, over 40 research papers have been published using TIGGE data. They address a wide range of research areas, including calibration of EPS, combination of multi-models and research related to the development of probabilistic forecasts. Other topics addressed using date from the TIGGE archive include:

- skill of MJO forecasts (*Matsuedo and Endo* 2011)
- regime transitions (*Frame and Methven* 2011)
- propagation of extra-tropical cyclones (*Froude*, 2010)
- comparison of TC track forecasts (*Hamill* 2011)
- evolution of perturbation structure (*Kipling et. al.*, 2011)

An up-to-date list of TIGGE-related publications can be found on the TIGGE web site *http://tigge.ecmwf.int/references.html*

2. GEOWOW

The Group on Earth Observations (GEO) initiated the Global Earth Observation System of Systems (GEOSS). GEOWOW (GEOSS interoperability for Weather, Ocean and Water) is a project funded under the European Union Framework Programme (FP7) that will make a significant European contribution to GEOSS by improving the overall quality of the current GEOSS Common Infrastructure (GCI), addressing access to data, usability and interoperability. GEOWOW is a 3-year project that began in September 2011. The project is led by ESA and partners are ESA, Terradue, JRC, CNR, ECMWF, BfG, UNESCO, University Bonn, 52° North, KISTERS, UK Met Office, Météo-France, Karlsruhe Institute of Technology, INPE (Brazil), University of Tokyo.

GEOWOW's main challenge is to improve Earth observation data discovery, accessibility and exploitability, and to evolve GEOSS in terms of interoperability, standardization and functionality. It will propose and validate a distributed architectural model federating Earth observation and other Earth Science data holdings. GEOWOW will put this model forward as the European contribution to the GEOSS Common Infrastructure (GCI) and its evolution toward a wider GEOSS architecture. GEOWOW covers three of the GEO Societal Benefit Areas (SBA): Weather, Ocean and Water, and there is a particular focus on supporting multi-disciplinary interoperability across these 3 SBAs:

- Develop a multi-disciplinary framework for data exploration, access and use
- Provide a semantic framework for discovery and evaluation
- Demonstrate integration of multi-scale and multi-environmental and social models

The Water and Ocean components of GEOWOW will provide global freshwater fluxes (river runoff into the oceans) and ocean ecosystem observations.

More information about GEOWOW can be found on the project web site *www.geowow.eu*

3. Weather component of GEOWOW

The weather component of GEOWOW is aimed at improving access to and use of the TIGGE data, which has been designated as one of the key weather components of the GEOSS.

GEOWOW will significantly enhance the content and accessibility of the TIGGE archive at ECMWF for the wider user community by:

- Addition of European limited areas ensemble system (EPS-LAMs), to the ECMWF archive
- Creation of time-series datasets at selected locations (e.g. SYNOP or TEMP stations)
- Provision of TIGGE data in NetCDF format, in order to reach a wider community
- Registration of TIGGE data in GEO Common Infrastructure (GCI)

GEOWOW will review and document TIGGE data quality, with focus on the most important weather parameters for high-impact weather features such heavy rain and strong winds. This will include consideration of model biases and calibration and combination techniques.

GEOWOW will promote the wider use of TIGGE data for research across a range of GEO Societal Benefit Areas and show how the TIGGE archive can be used to develop ensemble products for different applications. GEOWOW will demonstrate the potential use of such ensemble products, with a focus on severe weather, in close liaison with the WMO Severe Weather Forecast Demonstration Project (SWFDP). Where feasible, this will be extended to include multidisciplinary use across different GEO Societal Benefit Areas.

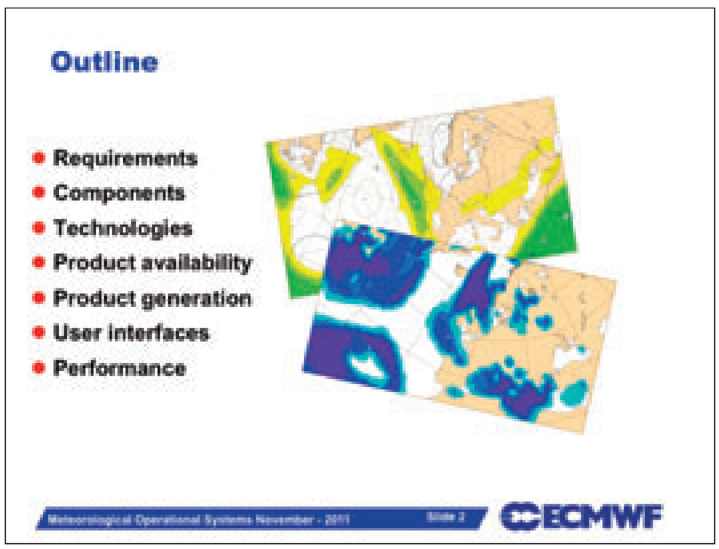
ECMWF, the Met Office, Météo-France and Karlsruhe Institute of Technology are partners in the Weather component of GEOWOW.

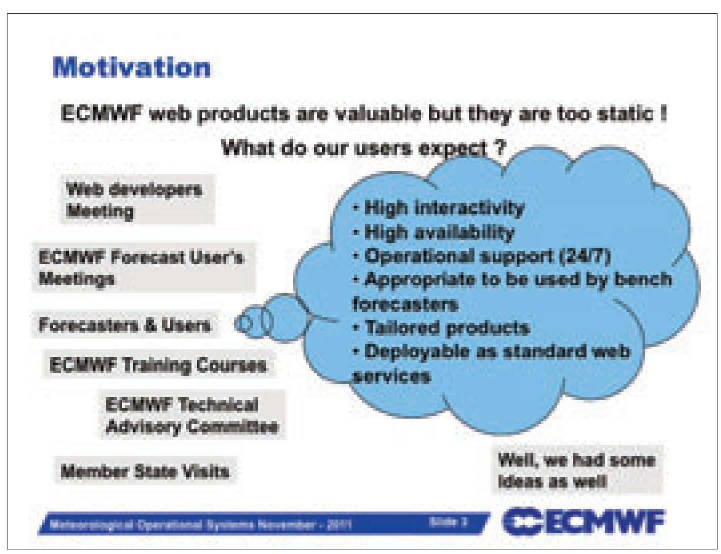
ecCharts

Cihan Sahin, ECMWF

ecCharts is a web based service that can be used to explore and visualise ECMWF graphical forecast products. It was designed to provide a highly interactive, highly available, operationally supported service to forecasters of the ECMWF Member States and Co-operating States. The project was driven by requirements to provide the forecasters with enhanced access to ECMWF products for their official duties. Built upon a Service Oriented Architecture, the application allows users to create customized graphical products on demand and to interact directly with the plots by performing actions such as zooming and panning. Products are also provided via Open Geospatial Consortium (OGC) web map services

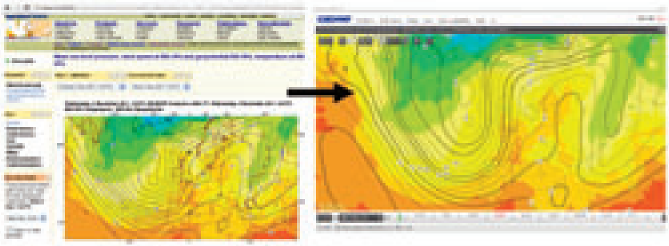
(WMS) so they can be integrated into the users' own client application. Recent Developments and plans for the COSMO-LEPS system





ecCharts

ecCharts is a highly interactive, highly available, operationally supported web based service to explore and visualise ECMWF graphical forecast products. It allows tailored product development and can be deployed as standard web services to be used by other software packages.



Current web products → *ecCharts*

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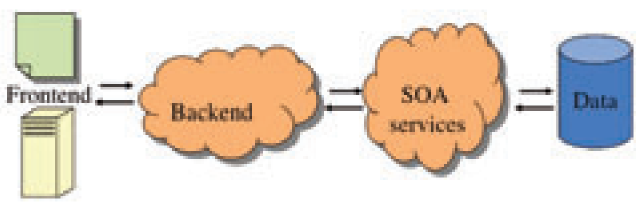
ecCharts components



Highly available end-to-end service is achieved;

- **Load balancing**
- **Distributed architecture**
- **Virtualization**
- **Service Oriented Architecture (SOA)**

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ecCharts components - II

- **Frontend – Web based user interface (UI)**
- **Backend – Load balanced web application services to handle incoming requests. Also manages Web Map Service (WMS) requests, product meta-data and user preferences.**
- **Service Oriented architecture (SOA) – Orchestrates the graphical product generation.**
- **Data storage – Highly available that holds the necessary meteorological data**
- **Secondary components**
  - Meta-data and non-GRIB data services
  - Distributed object caching
  - Request logging and monitoring services

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Service Oriented Architecture

- A "service" is a single purpose program that can be invoked over a network. There are several instances of each service running on many machines.
- Services are invoked in a given chain ("orchestration") to create a product (ie. "retrieve ->compute->plot")
- SOA advantages;
  - Resilience
  - Scalability and maintainability
  - Load balancing
  - Heterogeneous hardware
  - Legacy code encapsulation

The cost comes on troubleshooting, debugging gets harder!

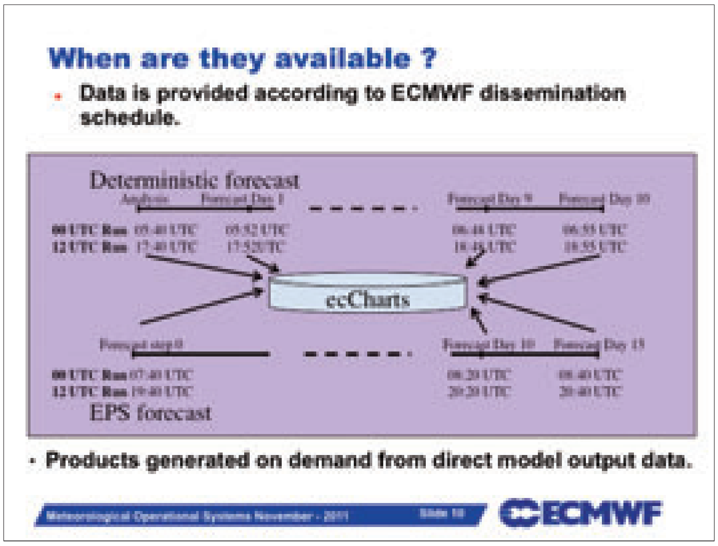
Technologies used

- Frontend : JQuery & AJAX based web application
- Backend : Django web framework
- Catalogue of products & User preferences: MongoDB collections of JSON documents
- Distributed Object Caching: Memcached
- SOA components : Bespoke python based framework (with twisted)
- SOA services: mostly in Python and C.
- Plot and plot metadata generation : Magics++
- Metview like macro for complex products (e.g. Spaghetti plots)
- Data : From MARS (Retrieve to ingest on ecCharts data clusters)
- Data cluster : Data replicated on standard unix file system.
- Data access: Based on MARS language
- Data related operations : GRIB API

What is in ecCharts ?

- High resolution deterministic and Ensemble Prediction System (EPS) model output (atmospheric & wave model)

- Point extracted data (for a given latitude/longitude)
  - Time series from all available parameters
  - EPS meteograms for a selected parameter set
- EPS derived data
  - Probabilities, percentiles, EFI, mean, spread …
- Coastlines, country borders , rivers


When are they available ?
Data is provided according to ECMWF dissemination schedule.
Deterministic forecast
Analysis
Forecast Day 1
Forecast Day 9
Forecast Day 10
00 UTC Run 05:40 UTC 05:52 UTC 06:48 UTC 06:55 UTC
12 UTC Run 17:40 UTC 17:52 UTC 18:48 UTC 18:55 UTC
ecCharts
Forecast step 0
Forecast Day 10
Forecast Day 15
00 UTC Run 07:40 UTC 08:20 UTC 08:40 UTC
12 UTC Run 19:40 UTC 20:20 UTC 20:40 UTC
EPS forecast
Products generated on demand from direct model output data.
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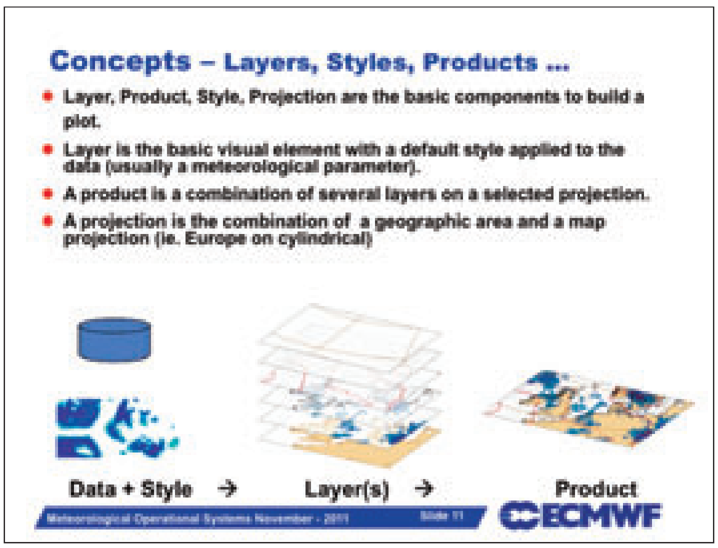
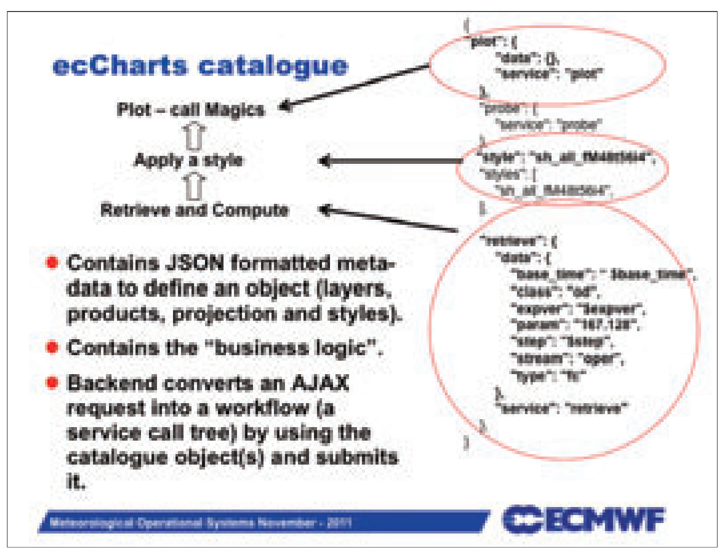
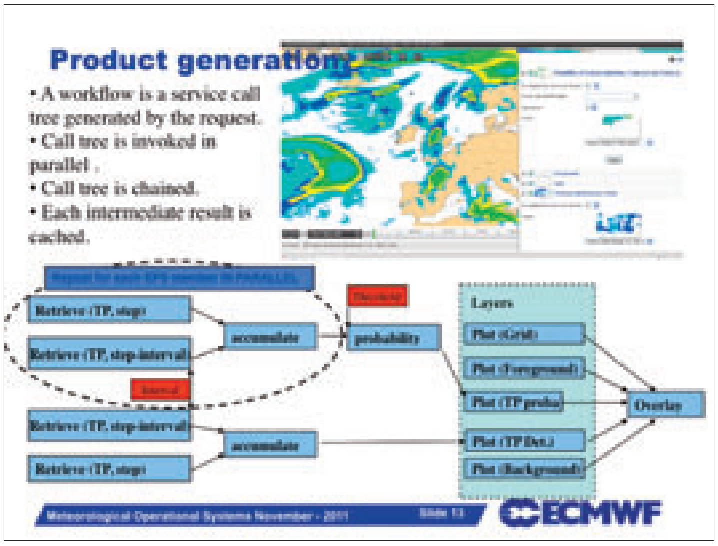
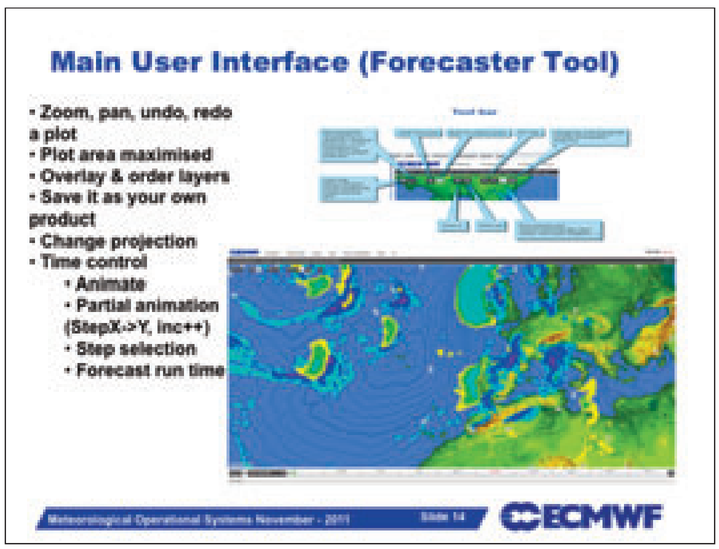
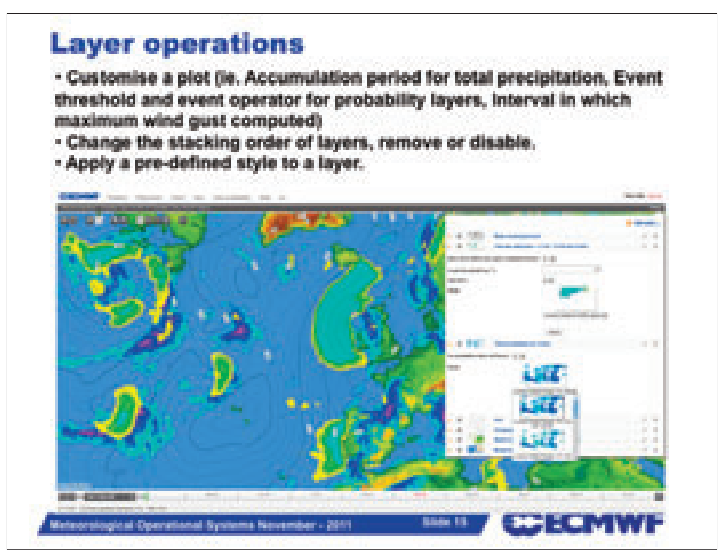
ECMWF


Concepts – Layers, Styles, Products ...
Layer, Product, Style, Projection are the basic components to build a plot.
Layer is the basic visual element with a default style applied to the data (usually a meteorological parameter).
A product is a combination of several layers on a selected projection.
A projection is the combination of a geographic area and a map projection (ie. Europe on cylindrical)
Data + Style →
Layer(s) →
Product
Meteorological Operational Systems November - 2011
Slide 11
ECMWF


ecCharts catalogue
Plot – call Magics
Apply a style
Retrieve and Compute
Contains JSON formatted meta-data to define an object (layers, products, projection and styles).
Contains the "business logic".
Backend converts an AJAX request into a workflow (a service call tree) by using the catalogue object(s) and submits it.
"plot": {
"data": {},
"service": "plot"
"probe": {
"service": "probe"
"retrieve": {
"data": {
"class": "od",
"param": "167.128",
"stream": "oper",
"type": "fc"
"service": "retrieve"
Meteorological Operational Systems November - 2011
ECMWF


Product generation
• A workflow is a service call tree generated by the request.
• Call tree is invoked in parallel .
• Call tree is chained.
• Each intermediate result is cached.
Retrieve (TP, step)
Retrieve (TP, step-interval)
Interval
accumulate
Threshold
probability
Retrieve (TP, step-interval)
Retrieve (TP, step)
accumulate
Layers
Plot (Grid)
Plot (Foreground)
Plot (TP proba)
Plot (TP Det.)
Plot (Background)
Overlay
Meteorological Operational Systems November - 2011
Slide 13
ECMWF


Main User Interface (Forecaster Tool)
• Zoom, pan, undo, redo a plot
• Plot area maximised
• Overlay & order layers
• Save it as your own product
• Change projection
• Time control
• Animate
• Partial animation (StepX->Y, inc++)
• Step selection
• Forecast run time
Meteorological Operational Systems November - 2011
Slide 14
ECMWF

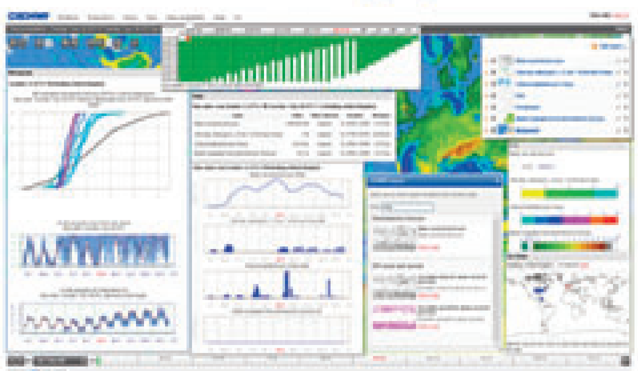

Layer operations
• Customise a plot (ie. Accumulation period for total precipitation, Event threshold and event operator for probability layers, Interval in which maximum wind gust computed)
• Change the stacking order of layers, remove or disable.
• Apply a pre-defined style to a layer.
Meteorological Operational Systems November - 2011
Slide 15
ECMWF

Data exploration tools

- They provide point (latitude/longitude) extracted information.
- Time series are available for all the layers in ecCharts and displays the values of the layers on a selected position.
- EPS Meteograms are only available for a relatively small subset of parameters (Same parameters as in current web Epsgram pages)

Meteorological Operational Systems November - 2011 Slide 16

Forecaster tool in a single picture



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Dashboard interface

- Organise multiple charts and epsgrams in te same "page". Basic elements are called widgets.
  - A chart widget is used to display a product either from ECMWF pre-defined set or your saved products.
  - EPS meteograms widgets (10 days, 15 days, EFI/CDF)
  - Control widget to apply collective actions for the charts on the same page ie. All charts in a tab animate simultaneously.
- User can create many tabs each containing many widgets.

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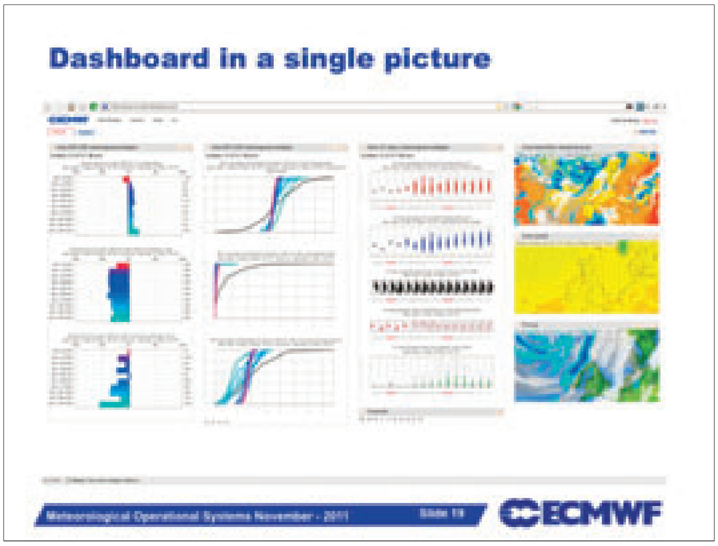
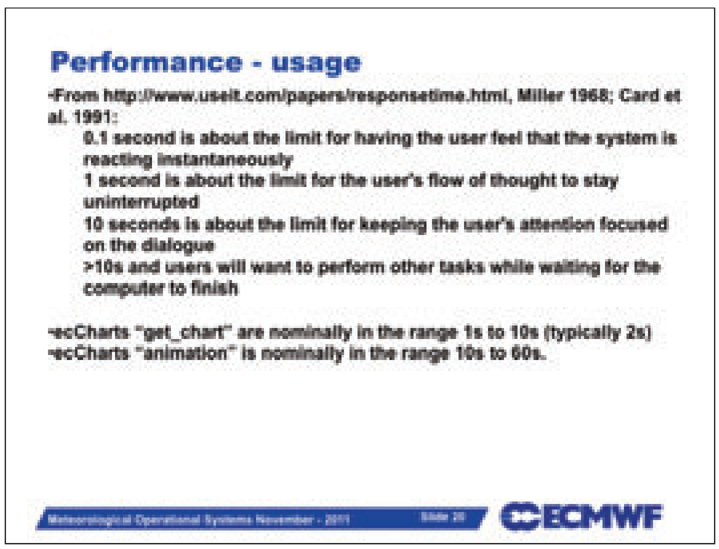
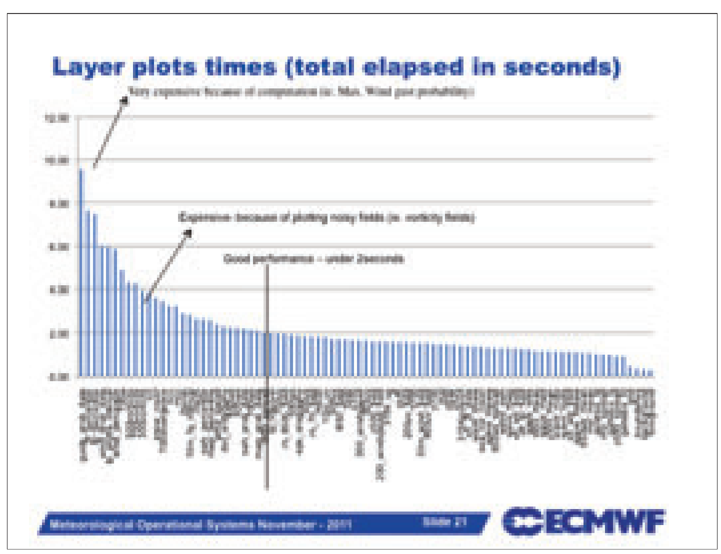
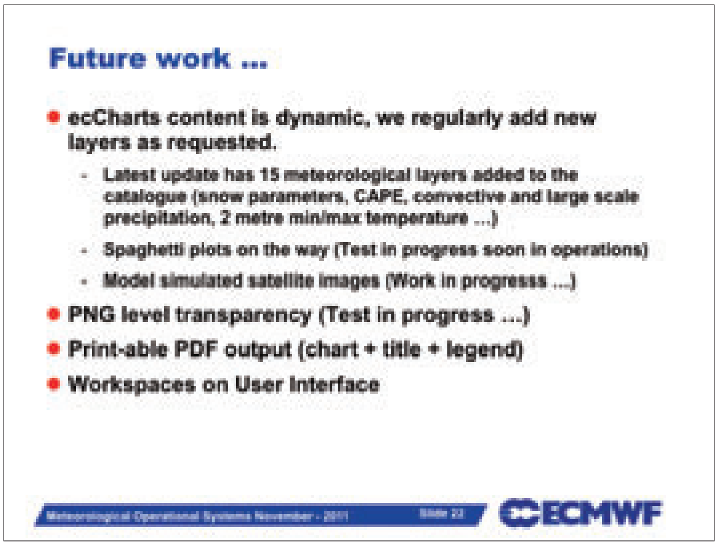

Dashboard in a single picture
Meteorological Operational Systems November - 2011
Slide 19
ECMWF


Performance - usage
•From http://www.useit.com/papers/responsetime.html, Miller 1968; Card et al. 1991:
0.1 second is about the limit for having the user feel that the system is reacting instantaneously
1 second is about the limit for the user's flow of thought to stay uninterrupted
10 seconds is about the limit for keeping the user's attention focused on the dialogue
>10s and users will want to perform other tasks while waiting for the computer to finish
•ecCharts "get_chart" are nominally in the range 1s to 10s (typically 2s)
•ecCharts "animation" is nominally in the range 10s to 60s.
Meteorological Operational Systems November - 2011
Slide 20
ECMWF


Layer plots times (total elapsed in seconds)
Good performance – under 2seconds
Meteorological Operational Systems November - 2011
Slide 21
ECMWF


Future work …
ecCharts content is dynamic, we regularly add new layers as requested.
- Latest update has 15 meteorological layers added to the catalogue (snow parameters, CAPE, convective and large scale precipitation, 2 metre min/max temperature …)
- Spaghetti plots on the way (Test in progress soon in operations)
- Model simulated satellite images (Work in progresss …)
PNG level transparency (Test in progress …)
Print-able PDF output (chart + title + legend)
Workspaces on User Interface
Meteorological Operational Systems November - 2011
Slide 22
ECMWF

Recent developments and plans for the COSMO-LEPS system.

Andrea Montani, C. Marsigli, T. Paccagnella (ARPA-SIMC)

In this work, we test different approaches to initialise the soil fields of COSMO-LEPS, the Limited-area Ensemble Prediction System developed by ARPA-SIMC in the framework of the COnsortium for Small-scale MOdelling.

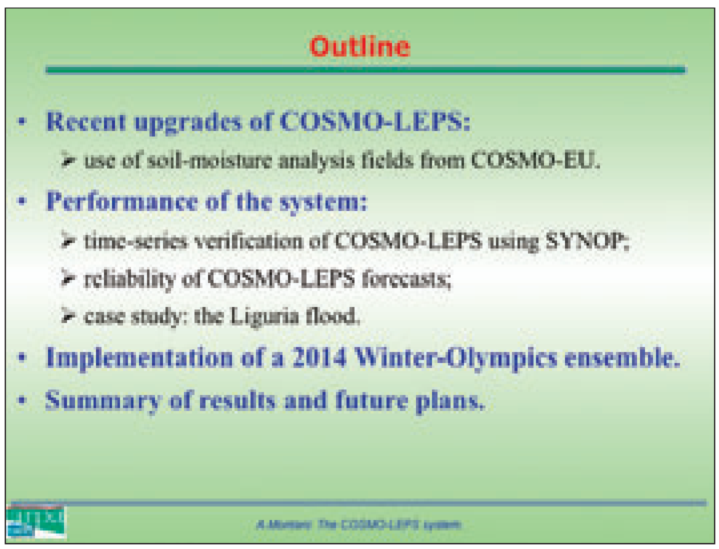
We investigate the impact of the different initialisations on the quality of short-range forecasts provided by the system during winter and spring 2011. The performance of COSMO-LEPS is studied for the prediction of near-surface variables, including 2-metre temperature,

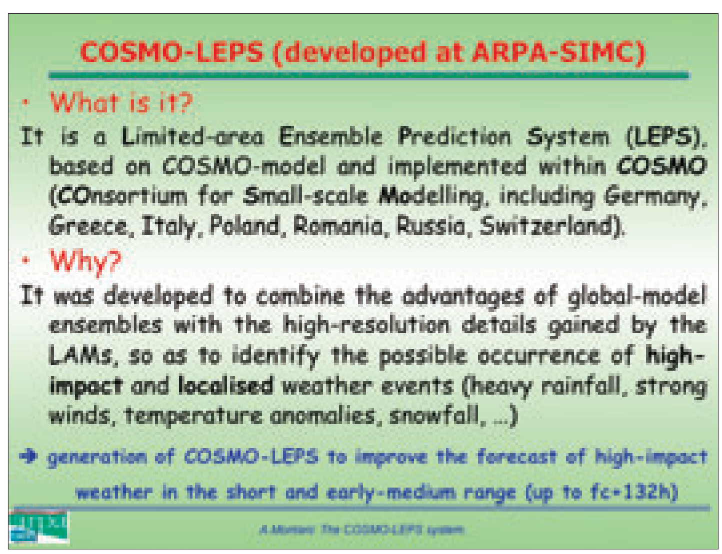
2-metre dew-point temperature and total precipitation.

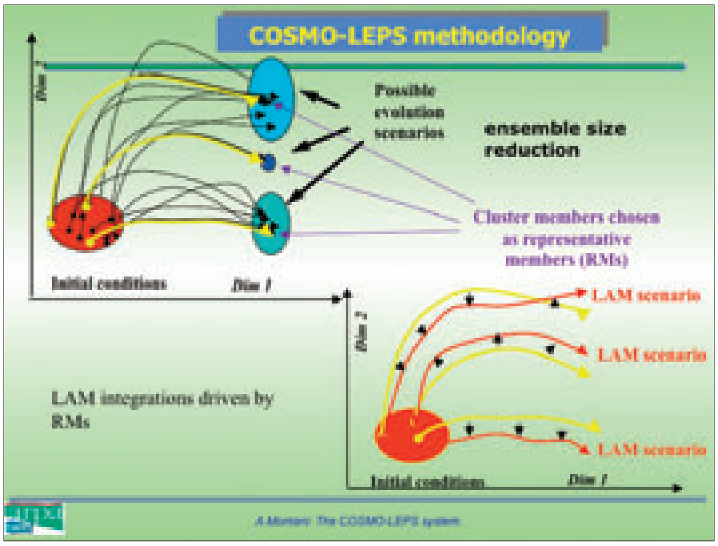
The skill of COSMO-LEPS for the probabilistic prediction of precipitation is also assessed in terms of time-series scores from 2002 onwards, by selecting a fixed number of SYNOP stations and comparing direct observations against short and early-medium-range forecasts.

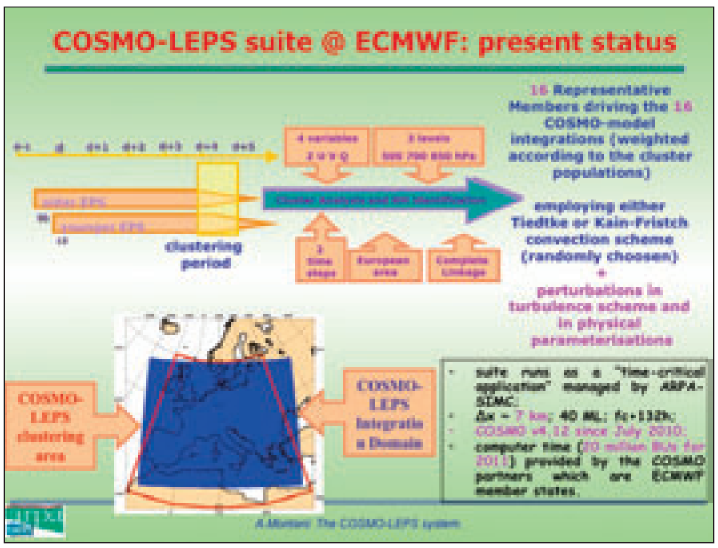
In addition to that, the spread/skill relation of COSMO-LEPS upper-air variables is studied for a few seasons and the results are related to the recent modifications of ECMWF EPS.

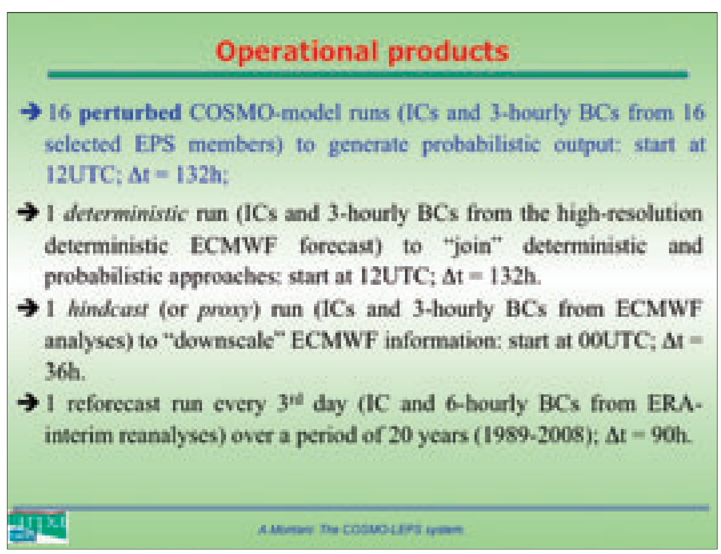
Finally, the main stream of development for COSMO-LEPS system are discussed with future possible upgrades and methodology modifications.






COSMO-LEPS methodology
Dim 2
Possible evolution scenarios
ensemble size reduction
Cluster members chosen as representative members (RMs)
Initial conditions
Dim 1
LAM scenario
LAM scenario
LAM integrations driven by RMs
Dim 2
LAM scenario
Initial conditions
Dim 1
A.Montani: The COSMO-LEPS system

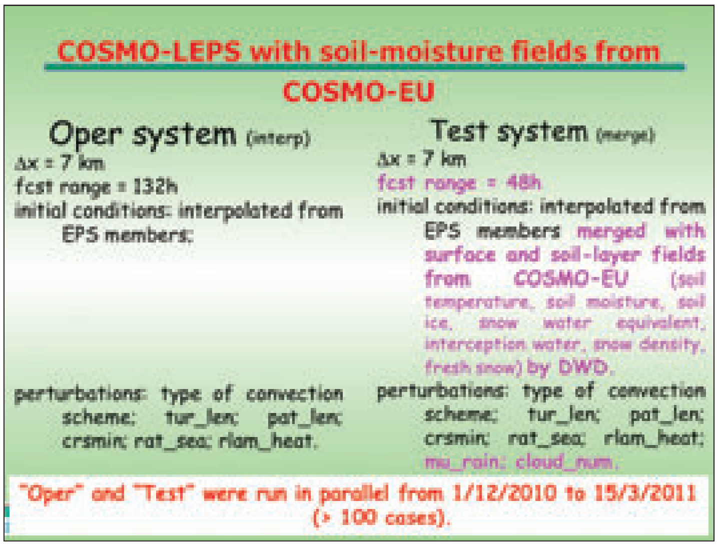

COSMO-LEPS suite @ ECMWF: present status
16 Representative Members driving the 16 COSMO-model integrations (weighted according to the cluster populations)
employing either Tiedtke or Kain-Fritsch convection scheme (randomly choosen)
+
perturbations in turbulence scheme and in physical parameterisations
4 variables
Z U V Q
3 levels
500 700 850 hPa
clustering period
European area
Complete Linkage
COSMO-LEPS clustering area
COSMO-LEPS Integration Domain
suite runs as a "time-critical application" managed by ARPA-SIMC;
Δx ~ 7 km; 40 ML; fc+132h;
COSMO v4.12 since July 2010;
computer time (20 million BUs for 2011) provided by the COSMO partners which are ECMWF member states.
A.Montani: The COSMO-LEPS system

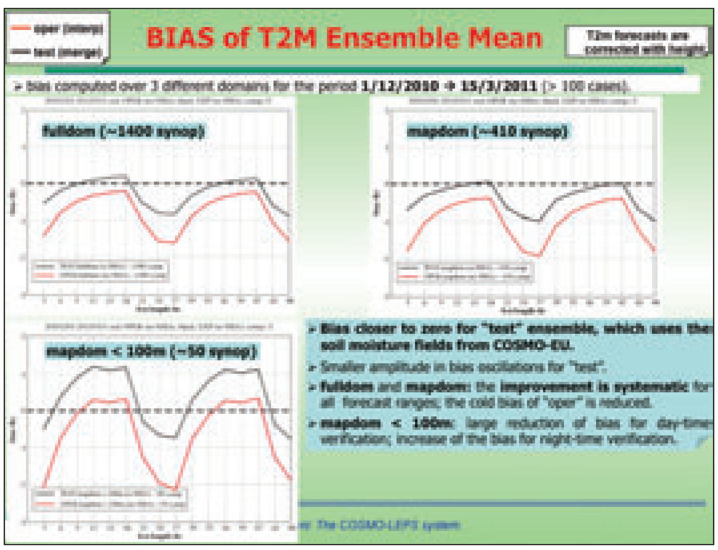

Operational products
➔ 16 perturbed COSMO-model runs (ICs and 3-hourly BCs from 16 selected EPS members) to generate probabilistic output: start at 12UTC; Δt = 132h;
➔ 1 *deterministic* run (ICs and 3-hourly BCs from the high-resolution deterministic ECMWF forecast) to "join" deterministic and probabilistic approaches: start at 12UTC; Δt = 132h.
➔ 1 *hindcast* (or *proxy*) run (ICs and 3-hourly BCs from ECMWF analyses) to "downscale" ECMWF information: start at 00UTC; Δt = 36h.
➔ 1 reforecast run every 3rd day (IC and 6-hourly BCs from ERA-interim reanalyses) over a period of 20 years (1989-2008); Δt = 90h.
A.Montani: The COSMO-LEPS system

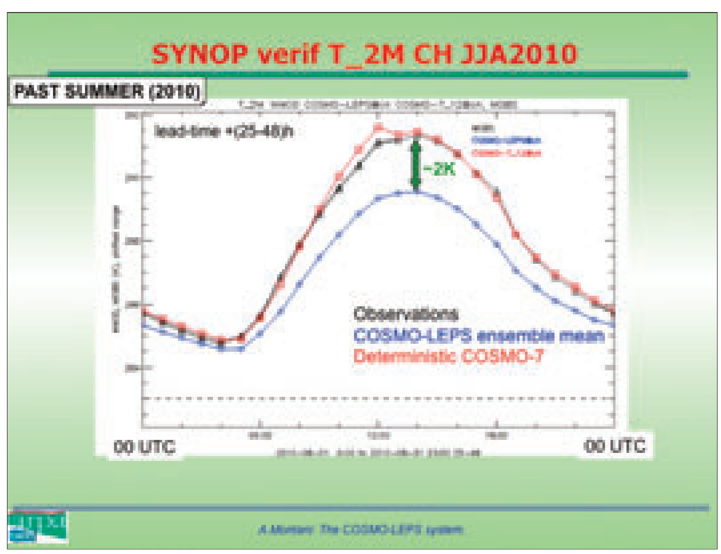
Outline

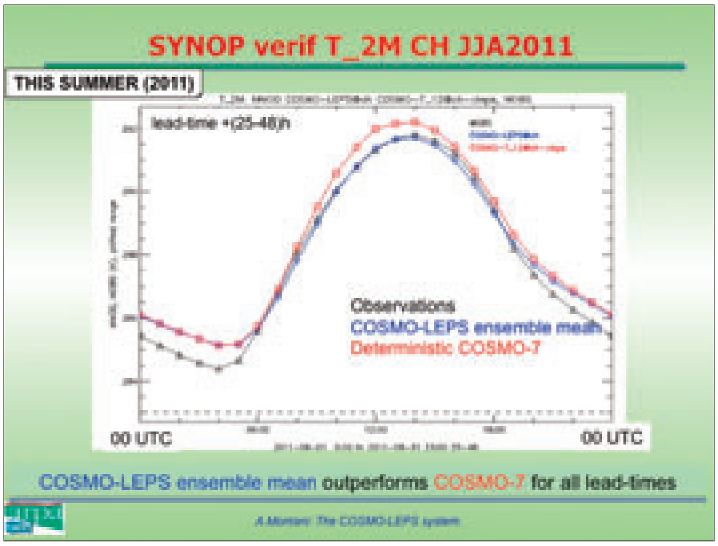
Recent upgrades of COSMO-LEPS:

- Use of soil-moisture analysis fields from COSMO-EU



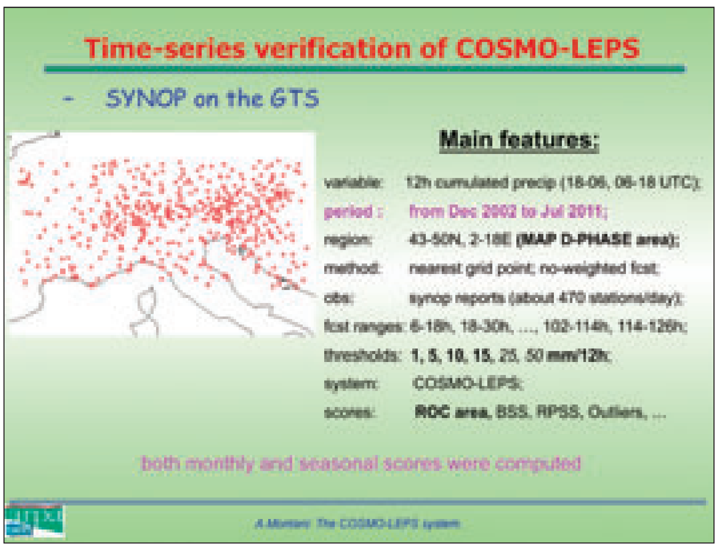


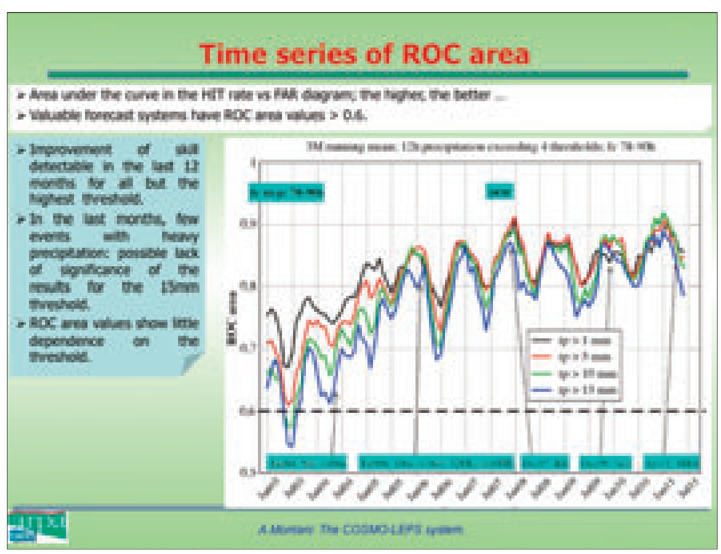




Performance of the system:

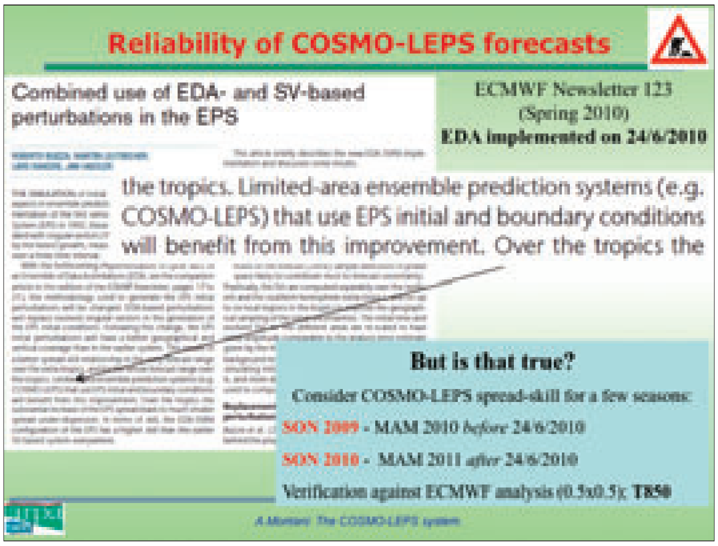
- Time-series verification of COSMO-LEPS using SYNOP;

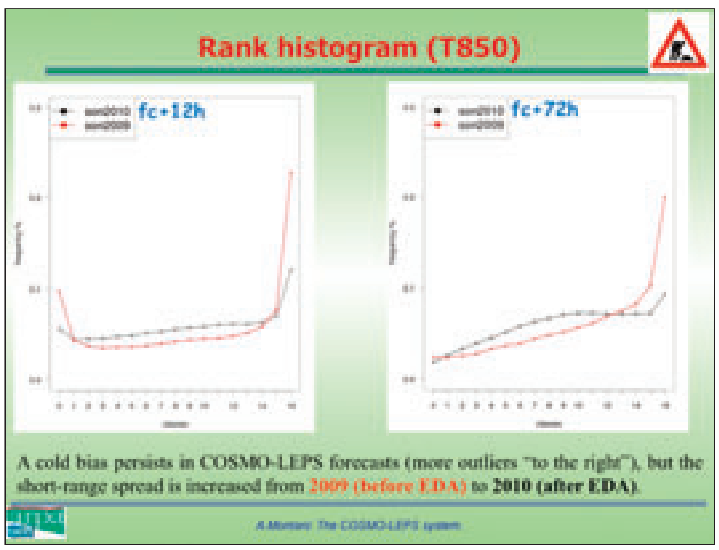


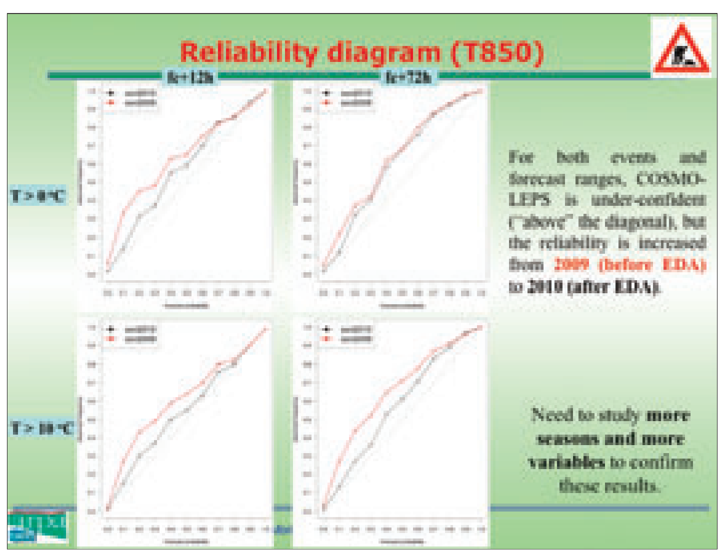


Performance of the system:

- Reliability of COSMO-LEPS forecasts.

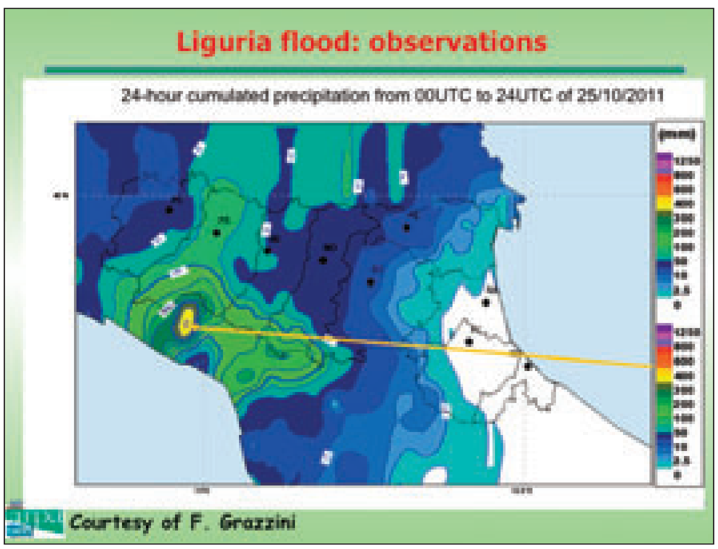


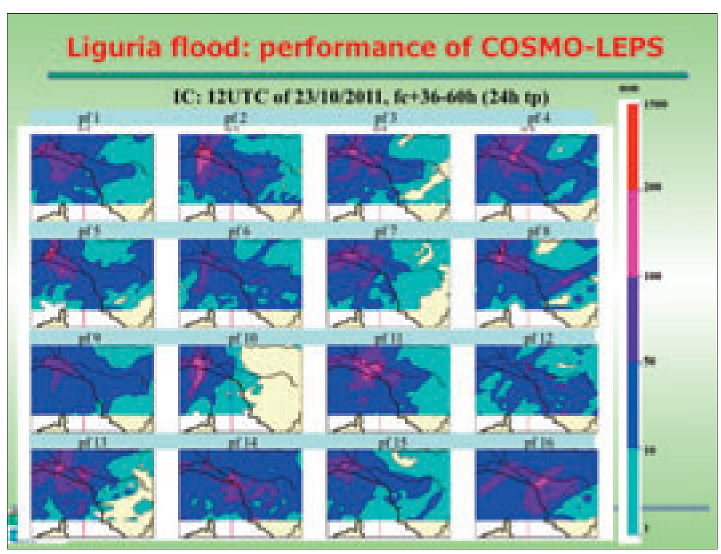


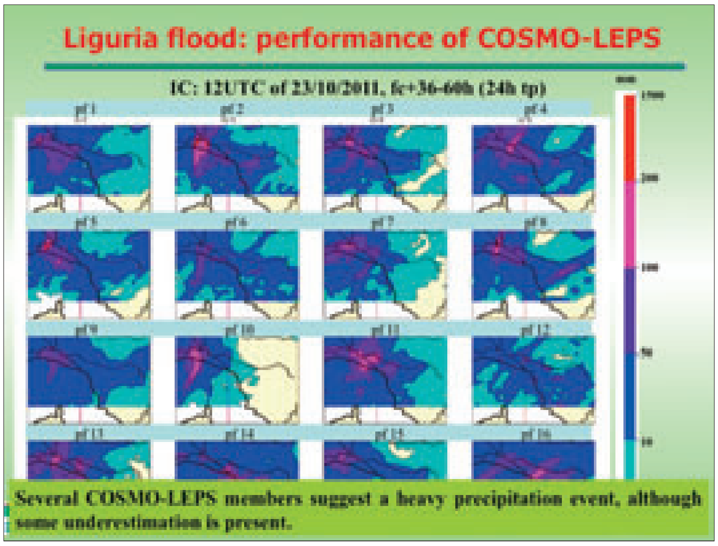


Performance of the system:

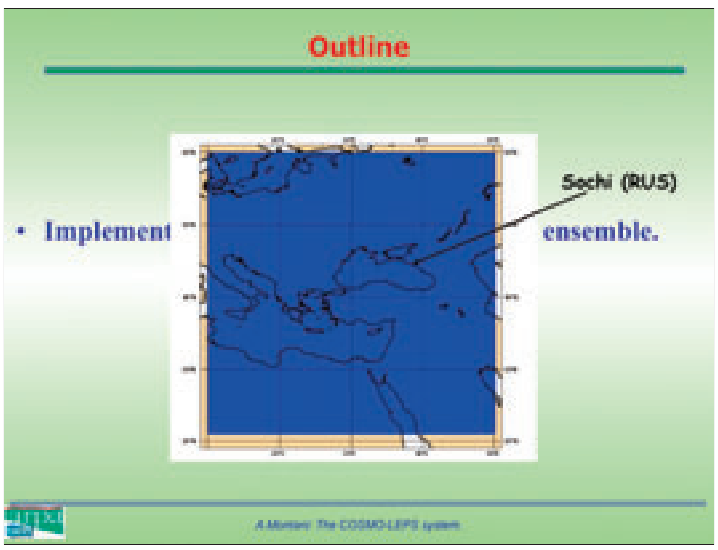
- Case study: the Liguria flood.

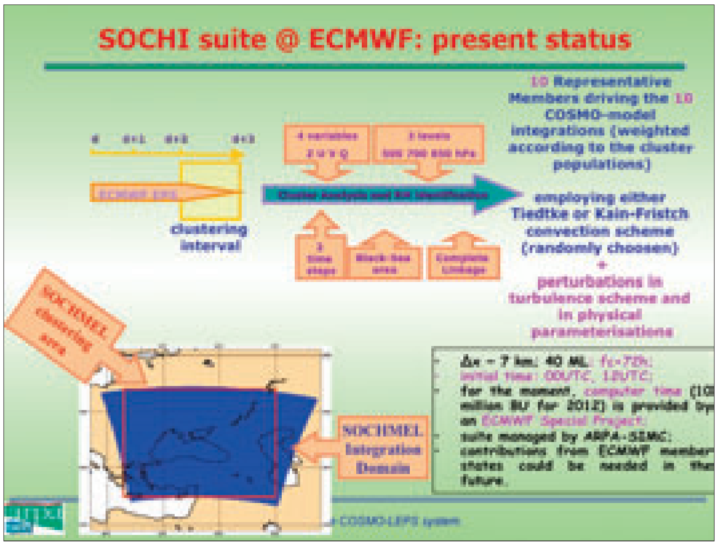






Implementation of 2014 Winter-Olympics ensemble.





Summary of results

11 April 2011: operational implementation of the soil-merge

- This should guarantee lower bias and mae for both T2M and TD2M in short range COSMO-LEPS forecasts.

Performance of the system

- ECMWF EPS changed substantially in the last months (introduction of EDA-based perturbations) and it is hard to disentangle improvements related to COSMO-LEPS upgrades from those due to better boundaries; nevertheless:
  - time-series scores indicate higher values of ROC area for the probabilistic prediction of 12-h precipitation.
  - lower outliers and higher reliability for T850.

SOCHi-targeted Mesoscale EnsembLe system

- The system can run "on demand".
- Develop a first prototype (inclusive of post-processing and dissemination) by December 2011.

A.Montani: The COSMO-LEPS system

Future plans

- Due to the increasing use and interest in COSMO-LEPS products, **COSMO-LEPS** will be implemented **also at 00UTC** by the end of the year.
- Test modifications to the clustering methodology: consider shorter forecast ranges for clustering intervals and/or select the Representative Members from only one EPS.
- Develop soil perturbations.
- Disseminate calibrated products over specific regions.
- COSMO-LEPS for TIGGE-LAM (GRIB2 encoding).
- LAMEPS_BC project → consider possible modifications to COSMO-LEPS suite.
- Carry on collaboration within research project (e.g. EFAS, SAFEWIND, IMPRINTS, NURC, ...).

A.Montani: The COSMO-LEPS system

BC-EPS – Generating boundary values for the COSMO-DE-EPS

Helmut P. Frank, Deutscher Wetterdienst

1 Introduction – COSMO-DE-EPS

Since April 20070 Deutscher Wetterdienst, DWD, is running the convection permitting limited area model COSMO-DE (*Baldauf et al.*, 2011) in operational production. COSMO-DE provides guidance for severe weather warnings especially in convective situtations during summer. It covers Germany and most of the Alpes (Figure 1) with a mesh size of 2.8 km. COSMO-DE makes 8 forecasts per day to 21 hours.

However, the predictability of small scale events is only short. In order to quantify uncertainties of the prediction DWD is developing the short range convection permitting ensemble prediction system COSMO-DE-EPS. Like the deterministic model COSMO-DEEPS is run 8 times per day to 21 hours. Presently, it consists of 20 members each running a slightly different COSMO-DE. Pre-operational production started in December 2010. In full production it shall have 40 members. Differences between members are generated using different values for some tuning constants in the physics parameterizations of the model (Gebhardt et al., 2011), from different initial conditions (*Peralta et al.*, 2012), or from different boundary conditions. BC-EPS is the suite which generates different boundary data for the members of the COSMO-DE-EPS.

In BC-EPS data from global models is used as initial and boundary data for a COSMOmodel with a mesh width of 7 km. Data from these COSMO runs is used as boundary data for the COSMO-DE members. Because of limited computing resources at DWD the suite is run at ECMWF. Hence, the file transfer of the results from ECMWF to DWD is a critical part of the suite.

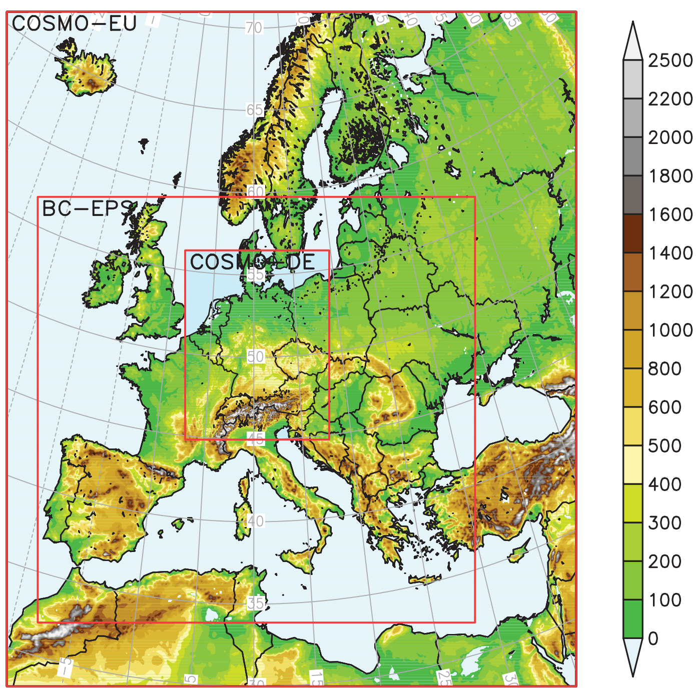


Figure 1 BC-EPS domain surrouding the COSMO-DE domain plus the domain of the Europe model COSMOEU for comparison.

	IFS (ECMWF)	GME (DWD)	GFS (NCEP)	GSM (JMA)	COSMO-EU (DWD)
Resolution Levels Grid points per level	0.125 deg 73 (of 91) 480 x 230 = 110400	30 km 60 13829	0.5 deg 21 (of 26 plevels) 211 x 121 = 25531	0.25 deg 50	7 km 9 soil levels 421 x 241 = 101461 511 x 415
transfer with	local dissemination	ecaccess	wget	wget	ecaccess
Size per run [MB] to 39 h Transfer time [s] Available (Ini. +hh:mm)	1403 13 +06.00	222 280 +02.55	79 300 +03.50	165 (jpeg) 950 +04.15	14 40 +02.50

Table 1 Data taken by BC-EPS from the global models and from COSMO-EU. Some information on the data transfer to ECMWF. The last line shows the delay between the initial time of global model forecasts and the time when the data is available at ECMWF.

2 How does BC-EPS work?

2.1 BC-EPS domain

Figure 1 shows the domain of the BC-EPS runs. It has 511°—415 grid points with a mesh width of 7 km and 40 levels. The mesh width and the levels are the same as the Europe model COSMO-EU of DWD. It is the same domain as for COSMO-LEPS and COSMO-SREPS which makes it easy to exchange data with these two projects.

2.2 Global model data

BC-EPS uses data from the global models GME of DWD, IFS of ECMWF, GSM of NCEP (National Center of Environmental Prediction, USA), and GSM of Japan Meteorological Agency, JMA (see Table 1). The following atmospheric fields are interpolated: Horizontal wind components, U and V, temperature, T, specific water vapor, QV, cloud water, QC, and surface pressure, PS. GME and IFS also provide cloud ice, QI.

Soil temperature and humidity, and surface data like snow fields are taken from the operational COSMO-EU of DWD as the BC-EPS domain is an exact subset of the COSMOEU domain.

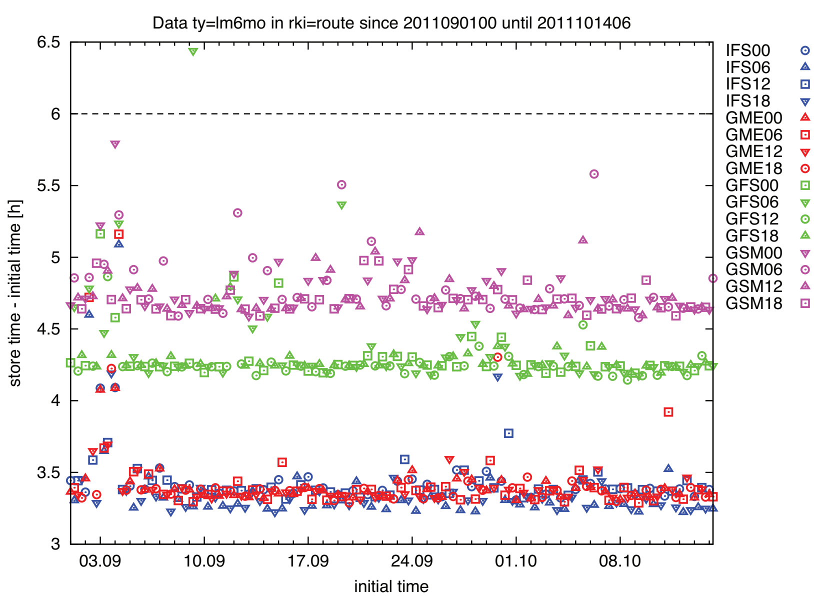


Figure 2 Difference between initial time and storage time in the DWD data base of the 27 hours foreacst of the BC-EPS runs. Different colors and symbols show data originating from the different global models IFS, GME, GFS, GSM and the 4 initial times 00, 06, 12, 18 UTC.

2.3 Data transfer and execution times

Table 1 lists how the data is transfered to ECMWF. IFS data is provided by local dissemination. During tests it took approximately one hour to extract the data from MARS because the data is needed on a fine regular grid.

DWD data is fetched with ecaccess. Only the grid points which are needed for interpolation or boundary conditions are transfered. This reduces the amount of data considerably. However, all model levels are taken.

Transfer of GFS data is fast because the resolution is least. Note that the data is available only on pressure levels.

GSM data is fetched from an http-server at JMA. The amount of data is much higher than for GFS, and the transfer rate is lower. The data is provided in compressed GRIB2 format. It has to be decompressed for the interpolation program int2lm.

DWD data is available less than 3 hours after the initial time of the model runs, GFS data approximately 3 hours and 50 minutes, and GSMdata 4 hours and 15 minutes after the initial time. ECMWF uses a long data cut-off. Therefore, the data is available approximately 6 hours after the initial time. In addition there are only 2 IFS runs per day at 00 and 12 UTC.

Transfering the initial data to ECMWF takes from less than aminute to approximately 15 minutes. The interpolation program int2lm takes 30 to 90 seconds depending on the amount of input data. Running COSMO on the BC-EPS domain to 39 hours with 192 processors takes 20 minutes. It does not make sense to speed it up further because the transfer of the GRIB data to DWD takes approximately 22 to 31 minutes for one run, and the transfer starts as soon as the first GRIB file has been produced.

The boundary GRIB data for COSMO-DE-EPS is transfered to DWD with ecaccess. Presently, 7.7 Gbyte of data are transmitted in 81 files to DWD per run. This makes a total of 124 Gbyte per day. The average transfer rate is 2.26Mbytes/s. For some big files it reaches 13.5 Mbytes/s.

3 Operational set up

Being a short range ensemble system it is very critical that the forecasts start as soon as possible. The deterministic COSMO-DE model finishes its 21 hour forecasts one hour after initial real time. For such short cut-offs it takes boundary data from a older COSMO-EU forecast 3 hours earlier. Similarly, the COSMO-DE-EPS uses boundary data from older BCEPS runs. It turns out that 6 hour old boundary data is possible as can be seen in Figure 2.

IFS boundary data is even older because it is available even later. The 06 UTC BC-EPS run takes data from the 00 UTC IFS run, and the 12 UTC run again takes 06 UTC IFS forecast data because of the long cut-off of IFS. These off-sets are already subtracted in Figure 2.

The whole data flow from the global models to the usage as boundary data for COSMO-DE-EPS members is illustrated in Figure 3. As it can be seen COSMO-DE-EPS uses boundary data originally coming from 6 to 9 hour old forecasts of the global models GME, GFS, and GSM, and from 12 to 21 hour old IFS forecasts.

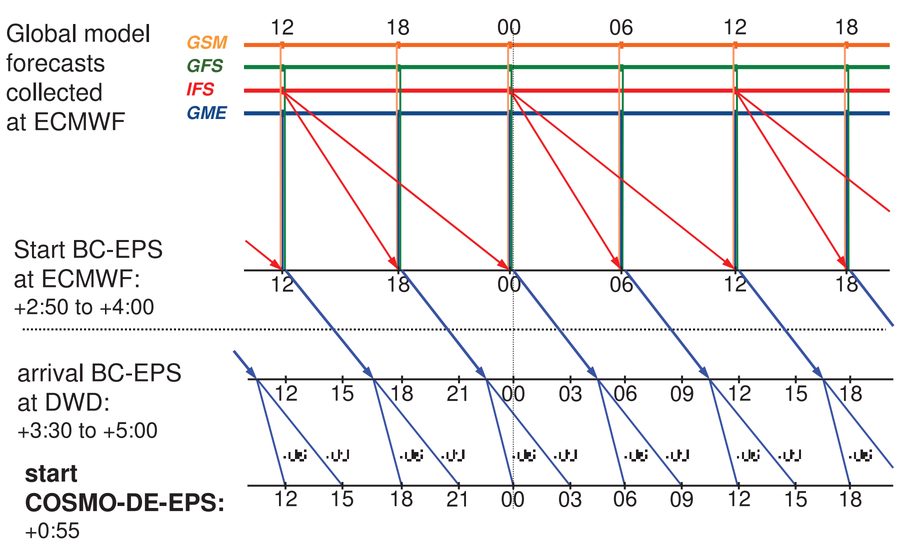


Figure 3 Illustration of the data flow from the global models GME, IFS, GFS, GSM to boundary data of COSMO-DE-EPS.

The suite is run at ECMWF as a time-critical application monitored by ECMWF staff. This has two major advantages. In case of maintenance or problems on super computer c1a it will run on the other computer c1b. And the jobs are allowed to run in privileged job classes. This is very important because in normal job classes the jobs sometimes had to wait over an hour before they were started. Then, some data arrived too late at DWD.

4 Example

As an example Figure 4 shows the 6 hours forecasts from 13 October 2011 at 00 UTC of relative humidity at 700 hPa and mean sea level pressure. The small differences in the position of the tongue of humid air introduce additional spread in the forecast of the COSMO-DEEPS. *Gebhardt et al.* (2011) showed that larger scale spread comes from different boundary data, whereas small scale spread is the result of perturbations of the model physics.

5 Summary

In BC-EPS the model COSMO is run using initial and boundary data from the 4 global models IFS, GME, GFS, and GSM to generate boundary data for the convection permitting short range ensemble system COSMO-DE-EPS. It runs at ECMWF as time-critical application monitored by ECMWF staff. Data arrives at DWD less than 5 hours after the initial time. Most of the time the data transfer is reliable. However, there were rare interruptions of the transmission for several hours for unknown causes. This needs further monitoring.

COSMO-DE-EPS is planned to become operational at DWD in 2012.

6 Acknowledgements

First of all DWD has to thank ECMWF, NCEP, and JMA for providing us with data from their global models. The author thanks ECMWF's user support, especially Carsten Maaß, for the help in setting up the suite. At the start Chiara Marsigli from ARPA-SIMC gave a lot of advice from her experience with COSMO-SREPS. At DWD Ulrich Schättler, Thomas Hanisch, and Kai-Thorsten Wirt were involved writing programs, scripts, and in the data transfer. For more information on COSMO-DE-EPS contact Susanne Theis (Susanne.Theis@dwd.de) and Christoph Gebhardt (Christoph.Gebhardt@dwd.de).

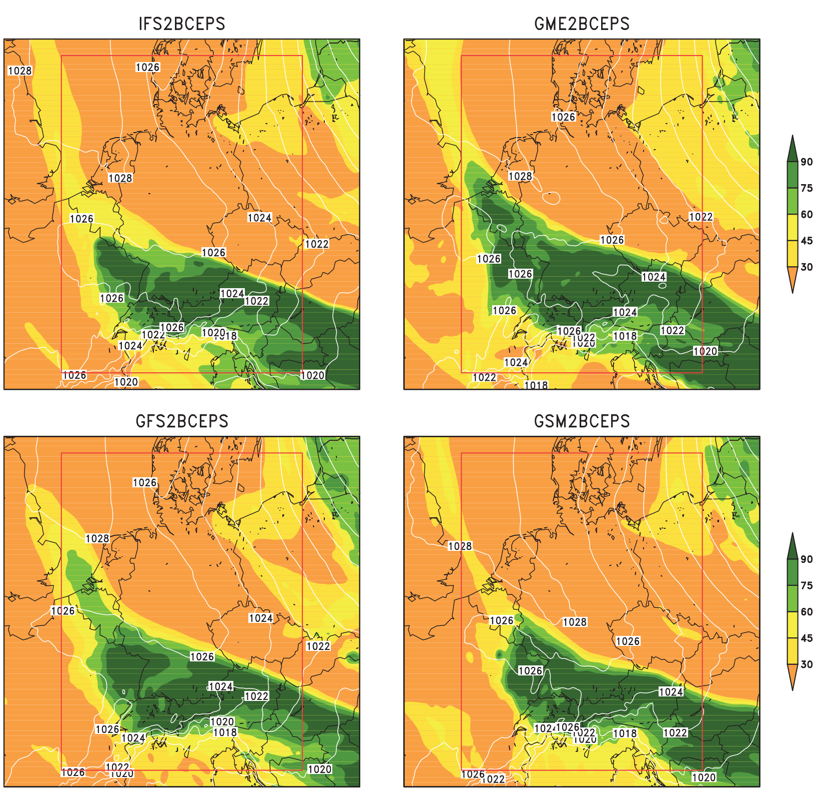


Figure 4 6 hour forecast of relative humidity at 700 hPa (colors, in %) and mean sea level pressure (contours, in hPa) of the 4 BC-EPS runs initialized at 2011-10-13 at 00 UTC. The red frame show the COSMO-DE domain.

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C. Gebhardt, S. E. Theis, M. Paulat, and **Z. Ben Bouallègue**. Uncertainties in cosmo-de precipitation forecasts introduced by model perturbations and variation of lateral boundaries. *Atmos. Res.*, **100**:168–177, 2011.

C. Peralta, Z. Ben Bouallègue, S. E. Theis, C. Gebhardt, and **M. Buchhold**. Accounting for initial condition uncertainties in cosmo-de-eps. submitted to *J. Geophy. Res.*, 2012.

Making Information Accessible – WMO Information System

Dr Steve Foreman, World Meteorological Organization, sforeman@wmo.int

WMO Information System and the Global Cryosphere Watch

Introduction

Since the 1960s, the World Meteorological Organization's (WMO's) Global Telecommunications System has served the operational meteorological community well, delivering crucial observations and products reliably in near real time. The very factors that contribute to this reliability make it difficult for users outside the operational meteorology community to exploit the GTS: it is difficult for such users to find out that information exists, to discover how to access the information, to receive information if they are not connected to the private GTS network, to read the data in specialised formats, or to make their own information available to the operational community and others. The WMO Information System (WIS) is being created to resolve these issues, and the first operational centres were approved in May 2011.

Aims of WIS and how they will be achieved

The aims of WIS are simple:

- to increase the visibility of data created by the WMO community
- to broaden the access to data
- making WMO data more accessible to more communities
- allowing WMO Members to make use of data from other communities
- to simplify data use.

These aims have to be met if meteorology, water and climate sciences are to meet the demands being placed on them. Operational weather forecasting needs a wider variety of information than before, seeking observations from communities that are on the border between operations and research, such ozone observations. The Global Framework for Climate Services will lead to a need for more systematic exchange of climate information, and application areas, such as Health, are seeing the benefits from combining weather and climate information in their decision making processes to reduce costs and to save lives. WIS will make it easier to meet these challenges.

What is WIS?

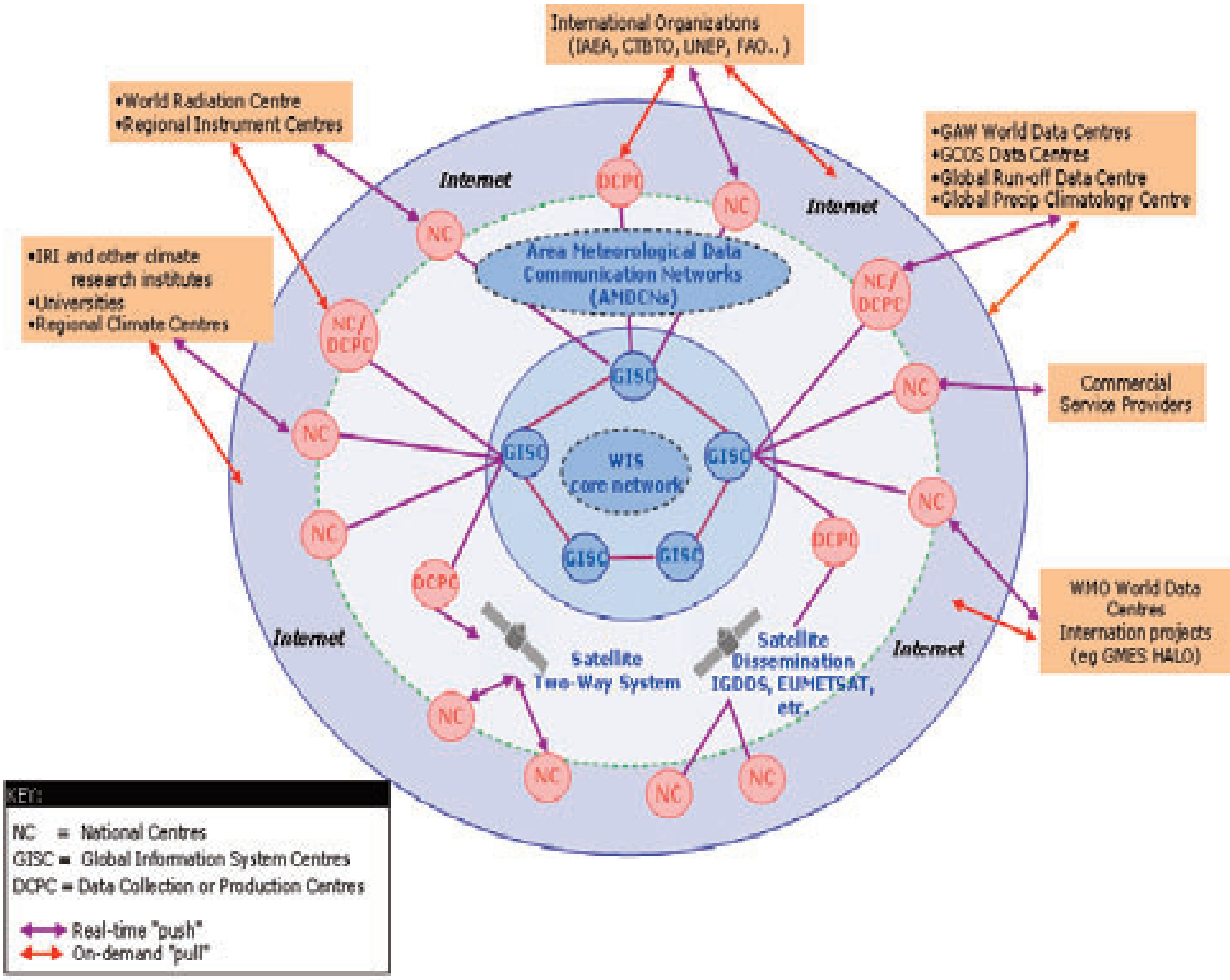
WIS is intended to build on the success of the GTS, and is taking an evolutionary approach, adding new access and telecommunications technologies to those of the GTS while allowing existing GTS users to maintain an unbroken service. For those organizations already on the GTS, the WIS offers an opportunity to simplify their operations, but only if they wish. For those that have had difficulty in connecting to the GTS for technical or financial reasons, the WIS offers alternative approaches to the routine exchange of information.

The WIS Specifications (in the Manual on WIS[1]) give the technical and procedural constraints that centres operating as information providers within WIS have to meet, and the Guide to the WIS[2] provides and guidance on how the WIS should operate.

The WIS is implemented at three types of information providing centre.

- GISCs (Global Information System Centres) hold the metadata catalogues, ensure that the regularly required information is passed rapidly and reliably around the world, and act as a conduit between the other types of centre and the rest of the world,
- DCPCs (Data Collection or Production Centres) are those with a specialist role; this may be in creating numerical products (such as ECMWF[3]), collecting observations (such as EUMETSAT[4]), or channelling information to the GISCs (the current Regional Telecommunications Hub role), or providing support for particular Programmes (such as the Arctic Data Centre[5]).
- NCs (National Centres) are centres that have a national responsibility; the National Meteorological Service will provide an NC, for example, but there may be others (such as an oceanographic centre). NCs will usually provide the main interface between national users and the WIS.

[1] Manual on WIS: *http://www.wmo.int/pages/prog/www/WIS/documents/Manual-on-WIS-en.pdf*
[2] Guide to WIS: *http://www.wmo.int/pages/prog/www/WIS/documents/Guide-to-WIS-en.pdf*
[3] More information about ECMWF's DCPC is at: *http://dcpc.ecmwf.int/geonetwork* (registration is required).
[4] More information about EUMETSAT's DCPC is at *http://dcpc.eumetsat.int*
[5] The Arctic Data Centre is operated by Met.No and is a WIS DCPC: *http://arcticdata.met.no/*



How will data users interact with the WIS?

At the heart of the WIS, and the major difference between the WIS and the GTS, is the metadata catalogue. This contains a description of all the information and services that WMO Members wish to make available through the WIS. The metadata will allow users to discover that information exists, and tell them how they can access it. The metadata catalogue will be synchronised between all the GISCs.

The GISCs will present the metadata catalogue to users is ways that allow them to search for metadata and, when they have discovered datasets that meet their requirements, will provide information on how to obtain the information. For information that is regularly exchanged around the world, it will be possible for users to download the current data immediately (if they are authorised to receive the data), or to request that the information is delivered to them when it becomes available (through a subscription service). In other cases, the metadata record may contain information on how to request the information or link to a request service, for example at a DCPC.

Data owners are responsible for creating the metadata records for their own data. The metadata records that are being used to initialise the metadata catalogue are being generated automatically from the information held about data exchanged on the GTS. Although technically correct, this is not often helpful to those outside the operational meteorology community. For WIS to be successful, data owners need to take care in crafting their metadata so that it is easily recognised and understood by the user communities for their metadata. Those datasets with the “best” metadata are those that are most likely to be used.

Providing data to the WIS

One of the objectives of the WIS is to increase the amount of information available for exchange. This means that the methods of providing data have to be more flexible than for the GTS, but there also have to be constraints on who is able to insert what types of information, otherwise it would not be possible to meet the quality or performance objectives for the WIS.

The route for inserting information into WIS is through a National Centre or Data Collection or Production Centre. Whereas for the GTS this would usually involve having dedicated telecommunications networks, the arrangements for WIS will be more flexible. The actual arrangement will depend on the particular NC or DCPC and the arrangements agreed by the sponsoring WMO Programme, but centres have already implemented ways of accepting information by email from authorised addresses, transfer using authenticated ftp to a server at the NC or DCPC, and upload using a web site.

A prime need of WIS is for information to be understandable by a broad user community. This means that the format of data exchanged by the WIS has to be publicly available and agreed by the Programme sponsoring the data collection. In addition to the Traditional Alphanumeric Codes and the Table Driven Code Forms (GRIB and BUFR) exchanged on the GTS, the Commission for Basic Systems has already agreed that NetCDF will be a major data format used in the WIS, and is looking towards the exchange of information in XML. To facilitate translation between formats, CBS will be using the concept of a "data model" as it evolves its data representations. If a WMO Programme has sponsored a data representation it may be used in WIS, but data contributors are encouraged to limit the variety of formats used to reduce the workload on data users. IPET-DRC is the team that develops the WMO data representations; although within CBS, from which the majority of its members have been drawn in the past, it is an Inter-Programme Expert Team and has a responsibility, within the resources available to it, for meeting the needs of all WMO Programmes, especially for changes to the Table Driven Code Forms.

The final requirement for data producers is to provide one or more metadata records describing the data set that they are providing. A key point is that the metadata describes a dataset, not individual data records, and that it only for discovery, access and retrieval purposes. More detailed metadata (for example about instrument characteristics or observing practices) are from a WIS perspective a dataset in their own right. Data that are provided in real time are normally considered as an (unfinished) dataset, but it is conceivable that in other cases a dataset could contain a single observation. The objective of the WIS metadata is to allow users, who are probably not experts in the same field as the originator, to discover the existence of information and to form an initial judgement on whether it is relevant to what they are trying to achieve. Writing good metadata contains an element of making sure that the technical details are right, but the most important aspect is ensuring that the keywords and descriptions are meaningful to a broad readership.

Status of the WIS

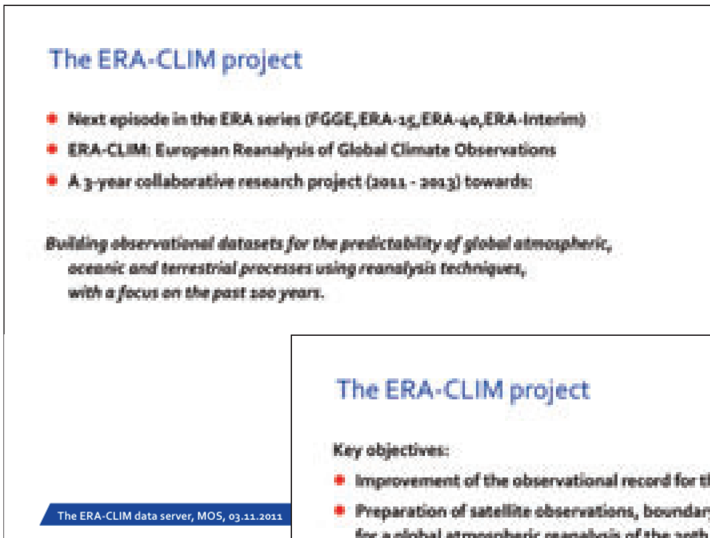
WIS is formally operational, with twp GISCs (Germany and Japan) having declared their status as operational. Others (China, France and the United Kingdom) are in pre-operational running. The start-up WIS metadata catalogue will be ready by 2012, at which stage the WIS will start to deliver its benefits, but these will be limited until metadata are published for datasets that are not already on the GTS and the start-up GTS metadata are updated by the data providers to make the data more comprehensible to non-operational users.

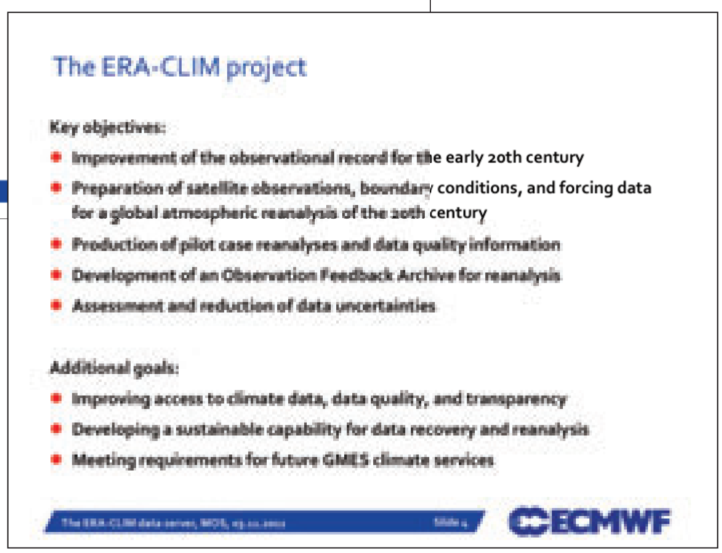
So, the technical facilities are there. WIS now needs the data and metadata – which relies on the whole WMO community to participate.

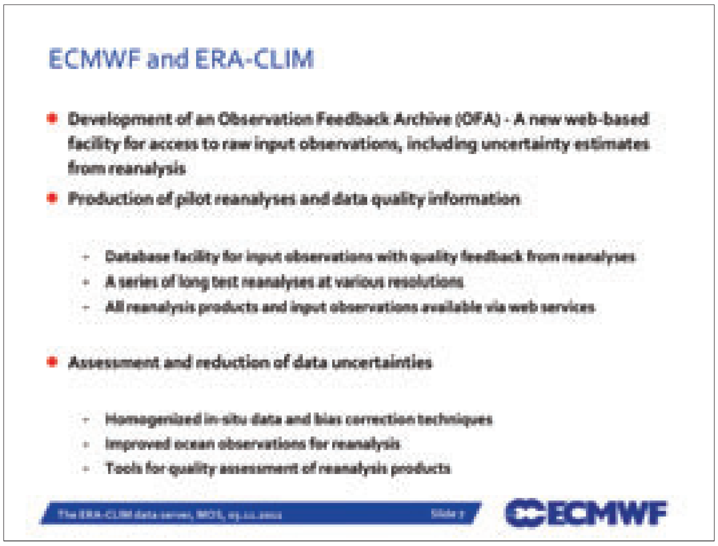
The ERA-CLIM data server

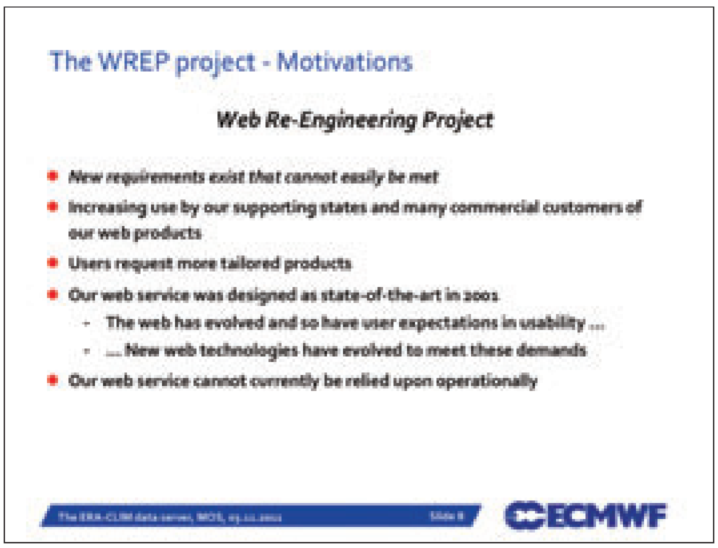
Cristian Codorean, ECMWF

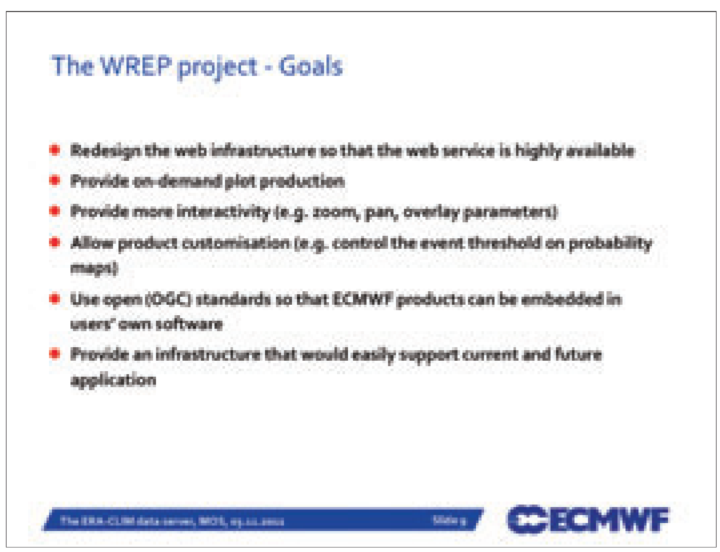
Over the past two years, ECMWF has been investing resources into building a new and modern web infrastructure in the context of the Web Re-Engineering Project (WREP) . While this effort was started mainly for the ecCharts project (on-demand creation of plots), now that the infrastructure is more mature, web applications hosted by the old web infrastructure can be ported to the new infrastructure. This presentation will be talking about such web applications being ported to the new infrastructure, with a focus on the porting of the webmars application and of the web data servers available for different projects like TIGGE, DEMETER, ERA and YOTC. In the context of the ERA-CLIM project, new developments allowed by the new web infrastructure will also be presented.



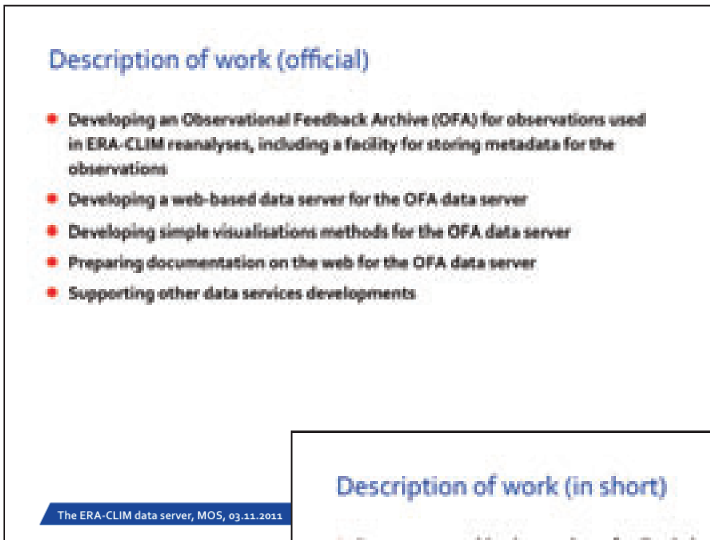


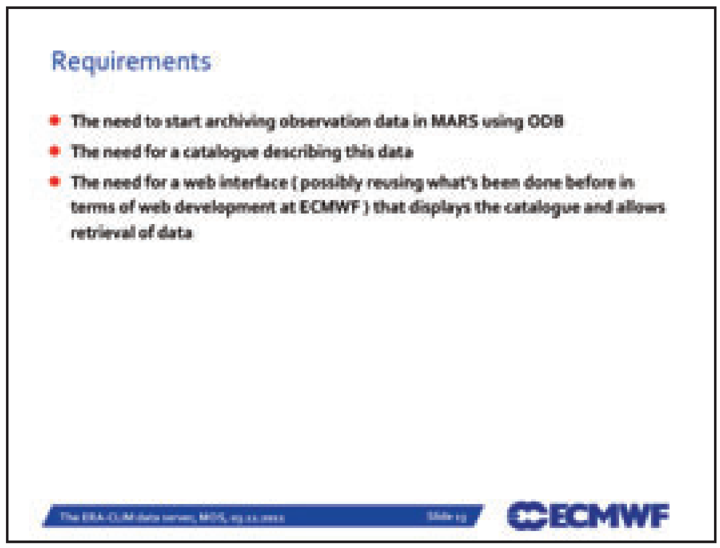

ECMWF and ERA-CLIM
Development of an Observation Feedback Archive (OFA) - A new web-based facility for access to raw input observations, including uncertainty estimates from reanalysis
Production of pilot reanalyses and data quality information
Database facility for input observations with quality feedback from reanalyses
A series of long test reanalyses at various resolutions
All reanalysis products and input observations available via web services
Assessment and reduction of data uncertainties
Homogenized in-situ data and bias correction techniques
Improved ocean observations for reanalysis
Tools for quality assessment of reanalysis products
ECMWF


The WREP project - Motivations
Web Re-Engineering Project
New requirements exist that cannot easily be met
Increasing use by our supporting states and many commercial customers of our web products
Users request more tailored products
Our web service was designed as state-of-the-art in 2001
The web has evolved and so have user expectations in usability ...
.... New web technologies have evolved to meet these demands
Our web service cannot currently be relied upon operationally
ECMWF

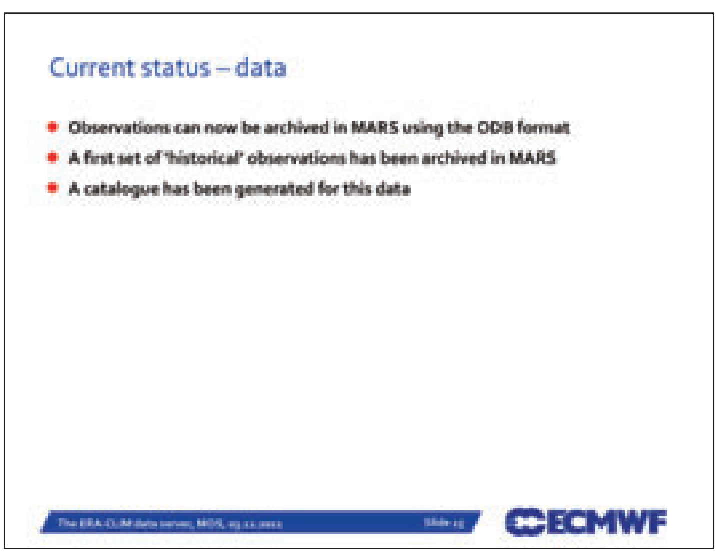

The WREP project - Goals
Redesign the web infrastructure so that the web service is highly available
Provide on-demand plot production
Provide more interactivity (e.g. zoom, pan, overlay parameters)
Allow product customisation (e.g. control the event threshold on probability maps)
Use open (OGC) standards so that ECMWF products can be embedded in users' own software
Provide an infrastructure that would easily support current and future application
ECMWF

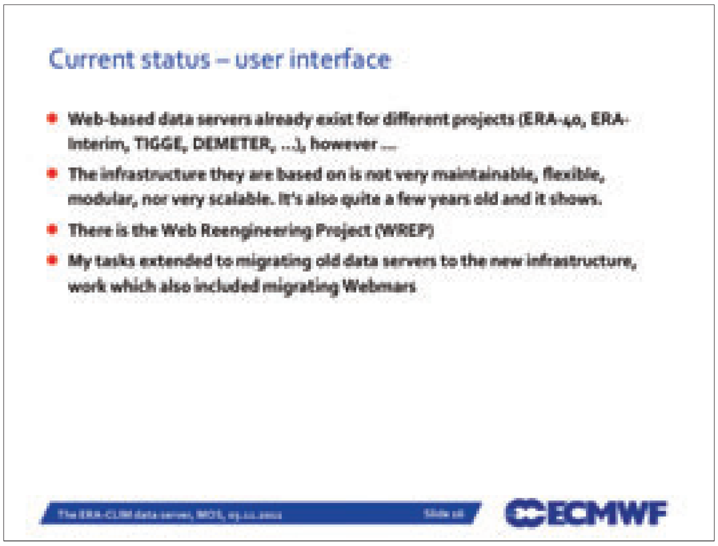
My role



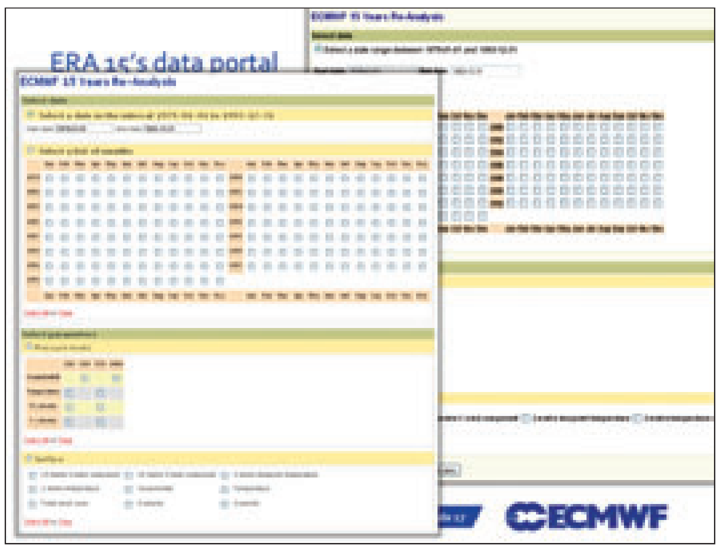


The work so far

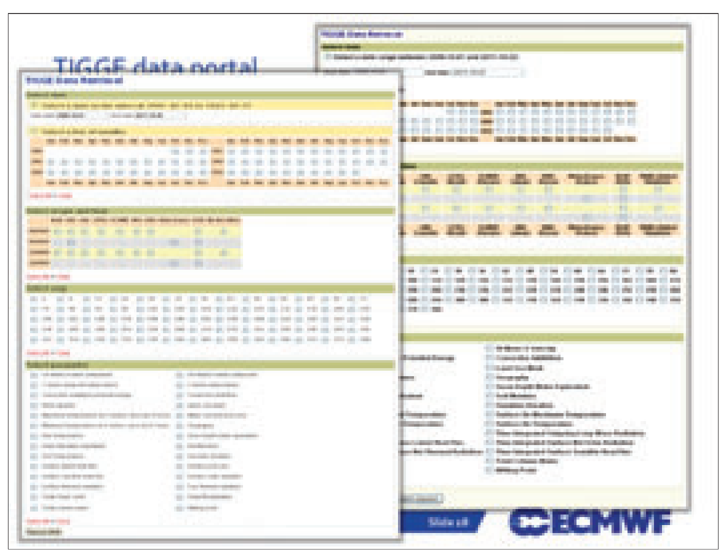




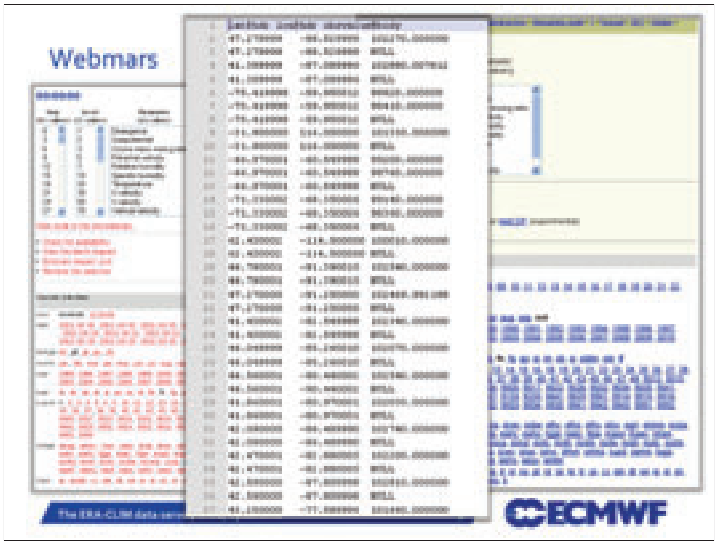
Current status – user interface
Web-based data servers already exist for different projects (ERA-40, ERA-Interim, TIGGE, DEMETER, …), however …
The infrastructure they are based on is not very maintainable, flexible, modular, nor very scalable. It's also quite a few years old and it shows.
There is the Web Reengineering Project (WREP)
My tasks extended to migrating old data servers to the new infrastructure, work which also included migrating Webmars
ECMWF

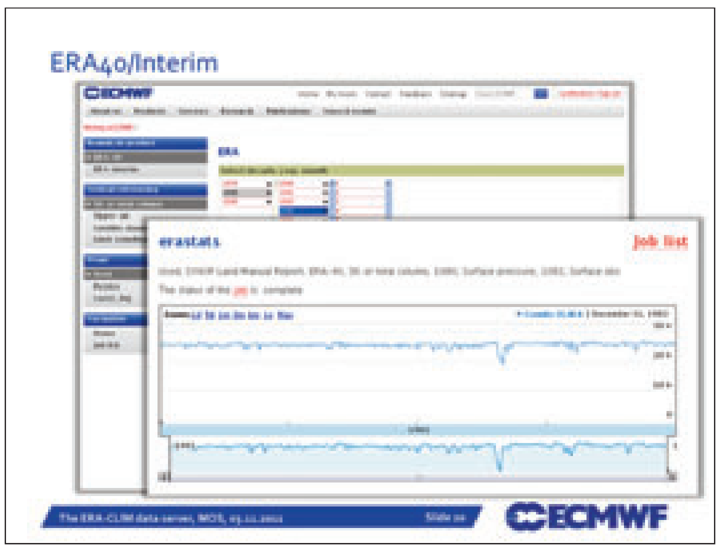


ERA 15's data portal
ECMWF 15 Years Re-Analysis
ECMWF



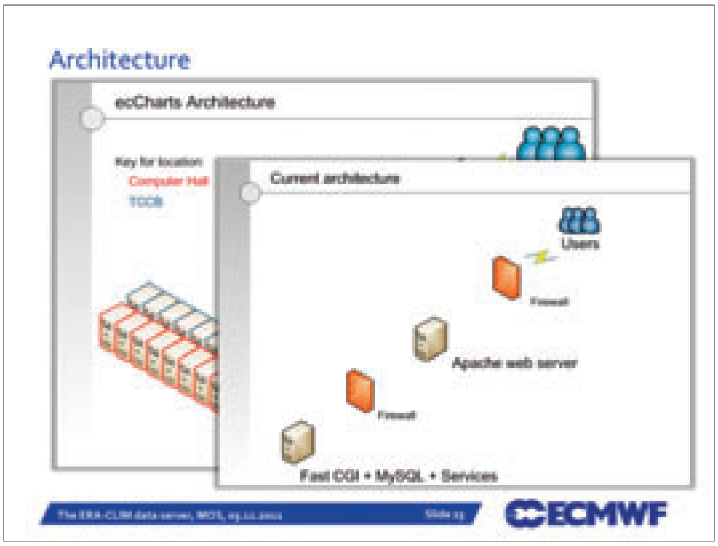
TIGGE data portal
TIGGE Data Retrieval
ECMWF

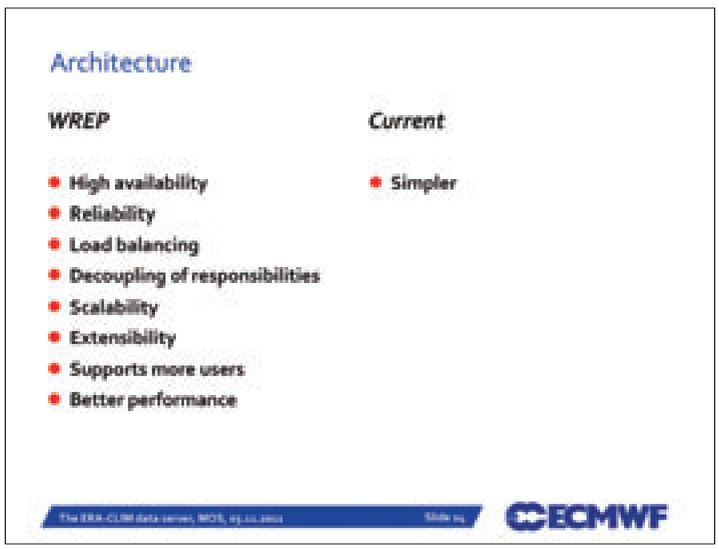

Webmars

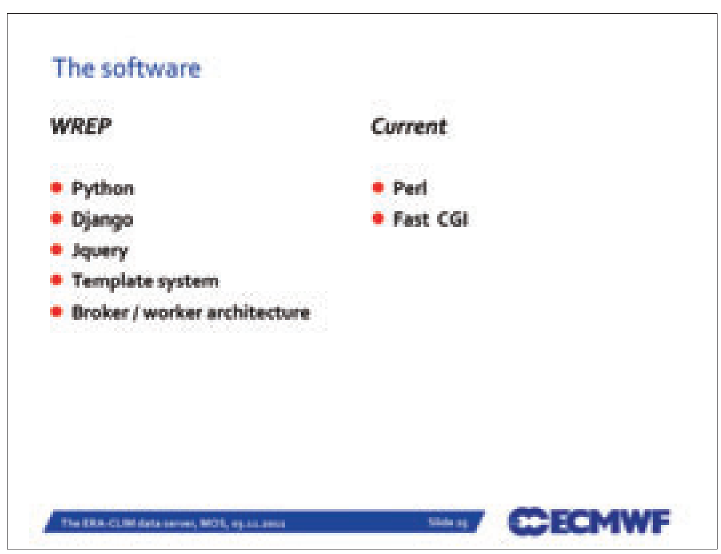

ERA40/Interim
erastats
Job list

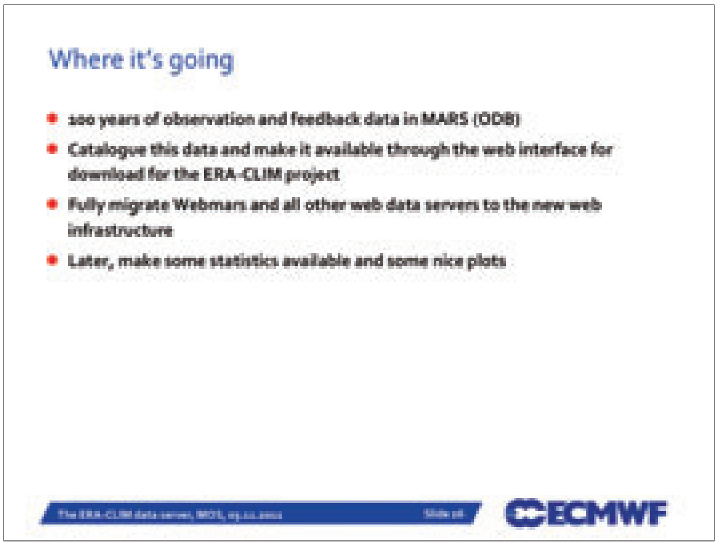

ISPD (International Surface Pressure Databank)
ISPD v2.2

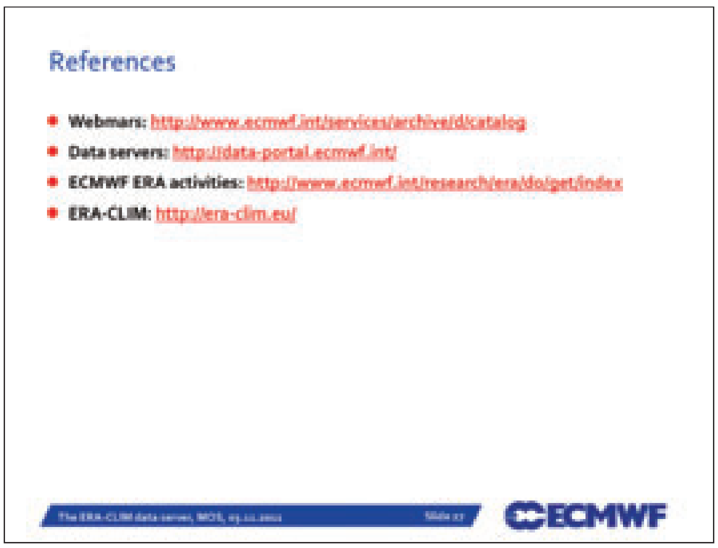
There is more to it than meets the eye








Where it's going
100 years of observation and feedback data in MARS (ODB)
Catalogue this data and make it available through the web interface for download for the ERA-CLIM project
Fully migrate Webmars and all other web data servers to the new web infrastructure
Later, make some statistics available and some nice plots
ECMWF


References
Webmars: http://www.ecmwf.int/services/archive/d/catalog
Data servers: http://data-portal.ecmwf.int/
ECMWF ERA activities: http://www.ecmwf.int/research/era/do/get/index
ERA-CLIM: http://era-clim.eu/
ECMWF

The work of the MetOcean Domain working group of the OGC

Marie-Francoise Voidrot, Météo-France

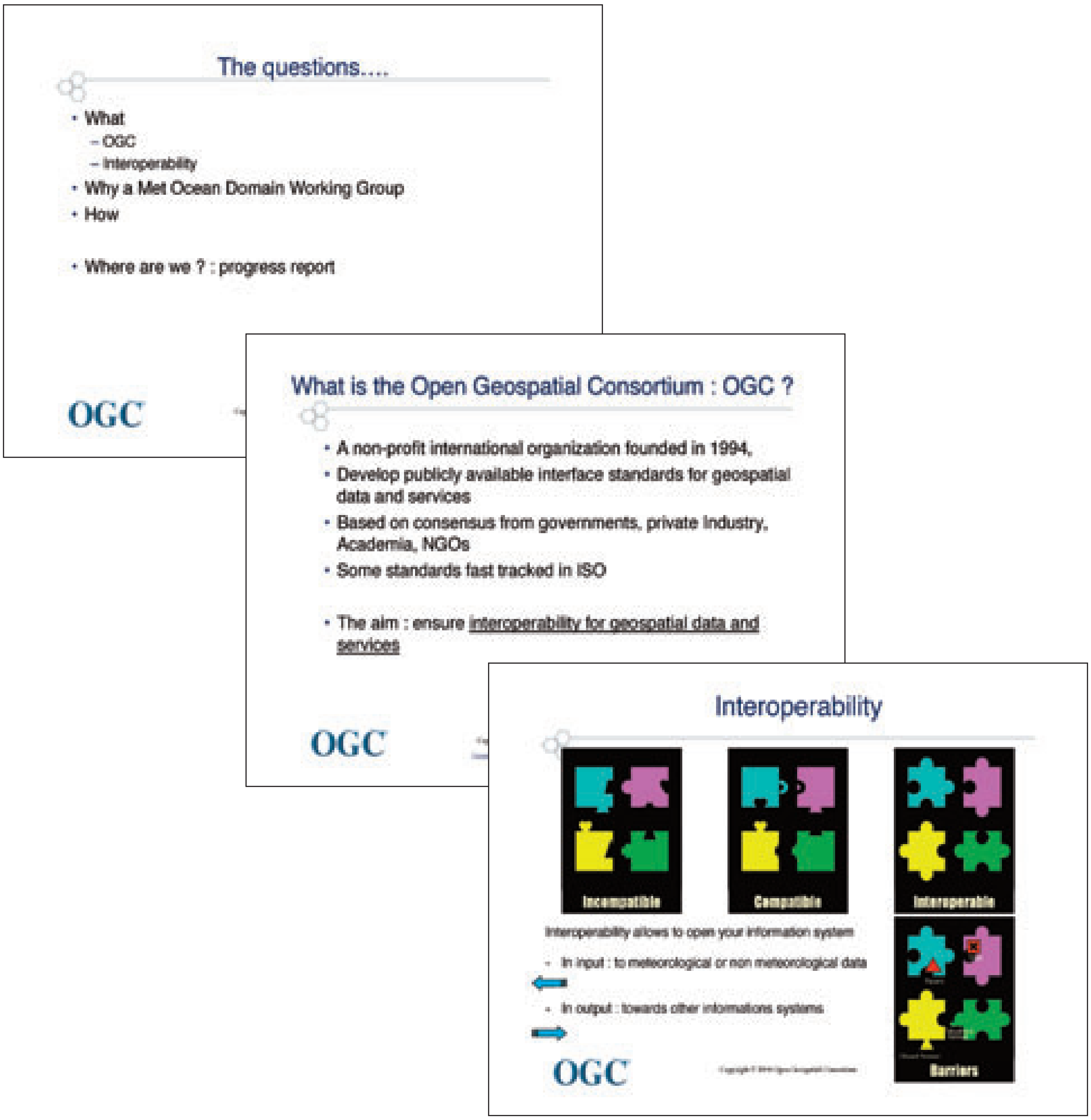
OGC is an international, consensus based, non-profit organisation which aim is to drive the development of open standards for geospatial information and location services to ensure interoperability.

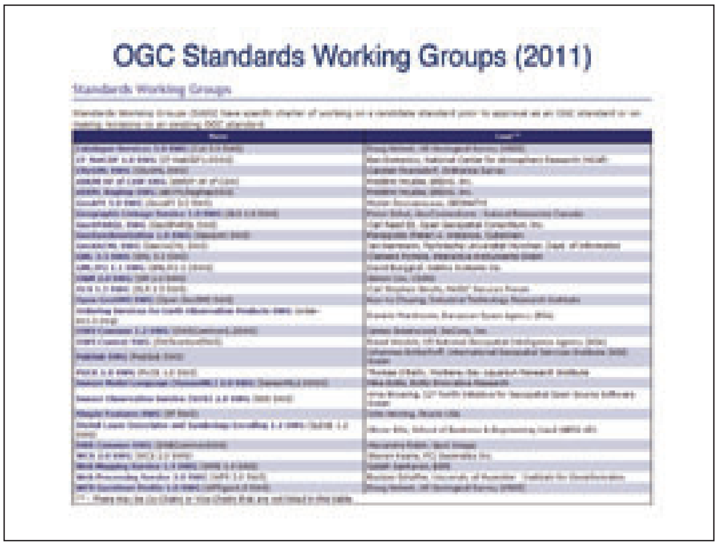
It's activities are organised through two types of Working Groups : "Standard" WGs (SWG), which work on specifications, and "Domain" WGs (DWG) with emphasis on technologies, areas, or fields and outreach.

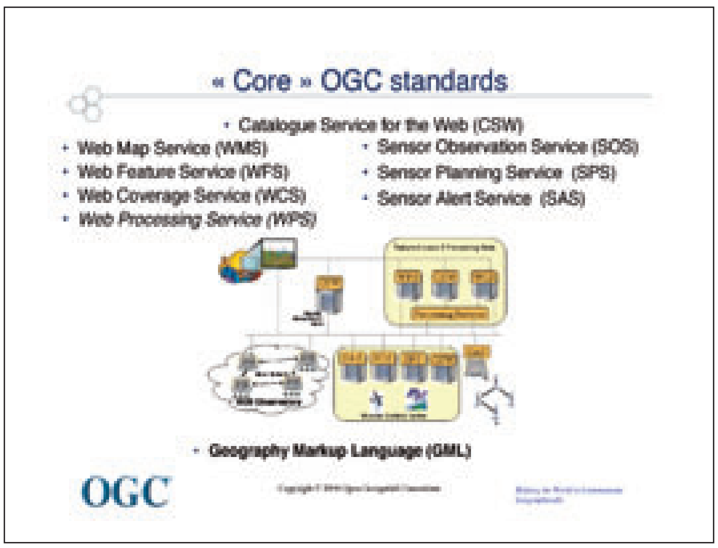
A recommendation of the Workshop on the Use of GIS/OGC Standards in Meteorology held in ECMWF in November 2008 was that to achieve real interoperability between meteorological systems, especially operational systems, the meteorological community should create a Meteorology domain Working Group within OGC and encourage a Memorandum of Understanding between OGC and WMO.

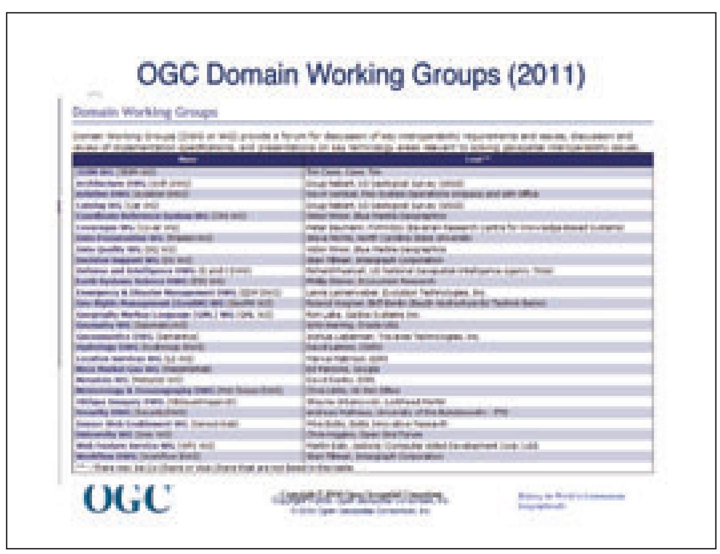
This working group has been created in April 2009 and a MoU between WMO and OGC signed up end of 2009.

This presentation will present the working process, and a progress report of the ongoing works.




OGC Standards Working Groups (2011)
Standards Working Groups


« Core » OGC standards
Catalogue Service for the Web (CSW)
Web Map Service (WMS)
Web Feature Service (WFS)
Web Coverage Service (WCS)
Web Processing Service (WPS)
Sensor Observation Service (SOS)
Sensor Planning Service (SPS)
Sensor Alert Service (SAS)
Geography Markup Language (GML)
OGC


OGC Domain Working Groups (2011)
Domain Working Groups
OGC

Why

1. INSPIRE recommends to use ISO or OGC standards
2. After some WS implementations in Met services, it appeared clearly that these implementations present a very high risk to be **non interoperable**

IF

we don't agree on best practices recommendations

OGC

Met Ocean Domain Working Group

- 2007 : proposal from the ECMWF MOS workshop to do a workshop on the use of GIS/OGC standards in Met
- 2008 : GIS/OGC standards in Met workshop recommended to create a Met Ocean DWG within OGC
- 2009 :
  - **April :** Creation of the Met Ocean Domain Working Group within OGC, rapidly extended to Oceanography

    A public email list open to everyone (OGC member or not) set up : https://lists.opengeospatial.org/mailman/listinfo/meteo.dwg

    A twiki space set up : http://external.opengis.org/twiki_public/bin/view/MeteoDWG/WebHome
  - **December :** MoU between OGC and WMO

OGC

Met Ocean Domain Working Group

- 2010/2011 : Works

1. Communication towards OGC Standard Working Groups
2. Communication towards the Met Ocean Community
3. Modelling activities
4. WMS best practices
5. Interoperability experiments (« *to test solutions in reality* »)

OGC

1-Communication towards OGC SWG

- Identify
  - what can be solved by Best Practices
  - what requires a standard evolution
- Check our understanding of the standards and benefit from OGC experts background
- Make future releases of the standards fit more naturally our needs
  - specific multi-dimensional meteorological visualisations presented to the WMS SWG : spatial and temporal cross sections, tephigrams, spectral wave diagrams, hodographs…
  - Specific plottings presented to SLD/SE SWG
  - …

OGC

WMO / Met Ocean DWG main Interests

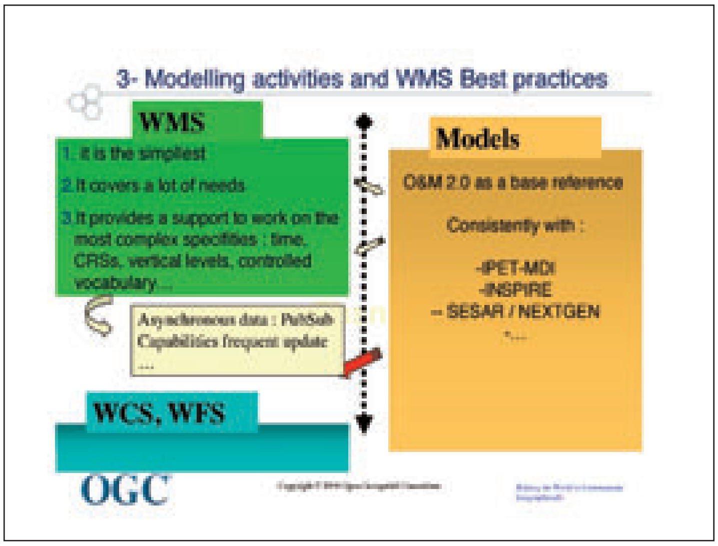
- WMS – Currently Proactive
  - Time – proposals now documented
  - Elevation
  - Map Projections
  - SLD/SE – Aviation SigWx and standard WMO Plots Use Cases
  - Tiling – WMTS now a separate standard – jigsaw edges
- Conceptual Modelling - Currently Proactive
  - WXXM
  - GML3.2.1, KML2.2
- WCS/WFS – Currently Reactive
  - 4D, CRS,
  - payload formats,
  - vector vs raster
- CSW – compatibility with ISO23950, OpenSearch - Currently Reactive
- O&M, SWE increasing in importance - Currently Passive

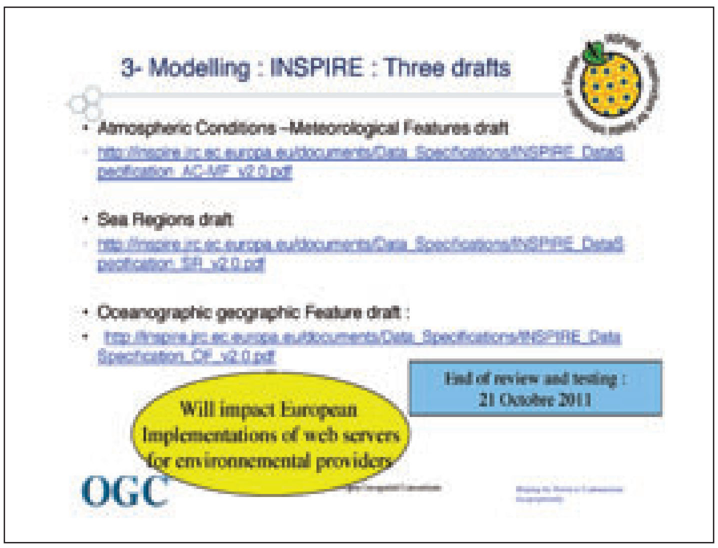
OGC

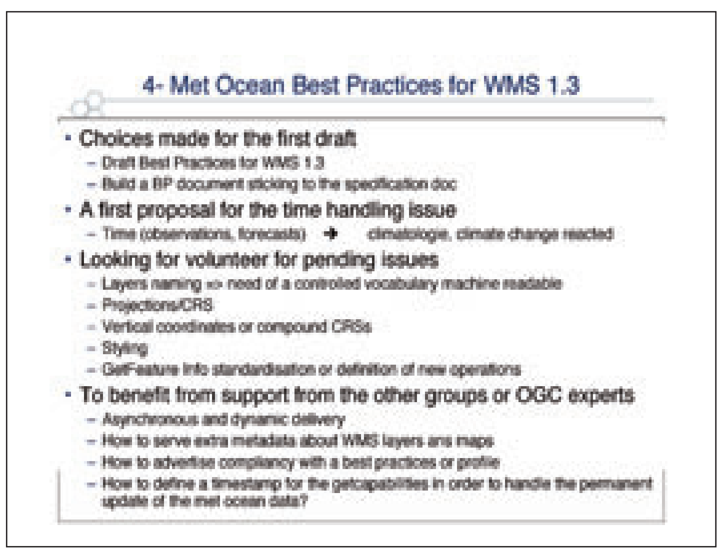
2- Communication towards the Met Ocean community

- In workshops (ECMWF, EGOWS, GIS/OGC standards in met….)
- Via the twiki,
- Via the email list,
- Via the teleconferences

OGC


3- Modelling activities and WMS Best practices
WMS
1. it is the simplest
2. It covers a lot of needs
3. It provides a support to work on the most complex specifities : time, CRSs, vertical levels, controlled vocabulary…
Asynchronous data : PubSub
Capabilities frequent update
…
WCS, WFS
Models
O&M 2.0 as a base reference
Consistently with :
-IPET-MDI
-INSPIRE
– SESAR / NEXTGEN
-…
OGC


3- Modelling : INSPIRE : Three drafts
• Atmospheric Conditions –Meteorological Features draft
http://inspire.jrc.ec.europa.eu/documents/Data_Specifications/INSPIRE_DataSpecification_AC-MF_v2.0.pdf
• Sea Regions draft
http://inspire.jrc.ec.europa.eu/documents/Data_Specifications/INSPIRE_DataSpecification_SR_v2.0.pdf
• Oceanographic geographic Feature draft :
• http://inspire.jrc.ec.europa.eu/documents/Data_Specifications/INSPIRE_DataSpecification_OF_v2.0.pdf
End of review and testing :
21 Octobre 2011
Will impact European Implementations of web servers for environnemental providers
OGC


4- Met Ocean Best Practices for WMS 1.3
• Choices made for the first draft
– Draft Best Practices for WMS 1.3
– Build a BP document sticking to the specification doc
• A first proposal for the time handling issue
– Time (observations, forecasts) ➔ climatologie, climate change reacted
• Looking for volunteer for pending issues
– Layers naming => need of a controlled vocabulary machine readable
– Projections/CRS
– Vertical coordinates or compound CRSs
– Styling
– GetFeature Info standardisation or definition of new operations
• To benefit from support from the other groups or OGC experts
– Asynchronous and dynamic delivery
– How to serve extra metadata about WMS layers ans maps
– How to advertise compliancy with a best practices or profile
– How to define a timestamp for the getcapabilities in order to handle the permanent update of the met ocean data?

5- Interoperability Experiments

- To check the proposals for the Best Practices,
- To check the performances
- To identify new issues
- To validate implementations
- To facilitate the learning curve on the standards and the existing implementations

OGC

Egows I.E Report

6 WMS servers
4 WMS clients specialised in meteorology
2 general purpose clients

Tested servers:	Tested clients:
DWD / Ninjo IBL /Visual Weather, Meteo-France /Synopsis ECMWF / ecChart Dresden UCAR/motherlode	*Specialised in Meteorology* IBL/Visual Weather KNMI Agaduc ECMWF / Metview Meteo-France / Synergie *General purpose :* gvSIG Gaia

Which tests

1- Free tries
2- Validate the responses to the requests
3- Test a real use case defined by forecasters
4- Test the TU Dresden server serving WMS Climate Change products

Feedbacks

Participants would like to make it more often : maybe remotely at predefined dates

Fasten the learning curve,

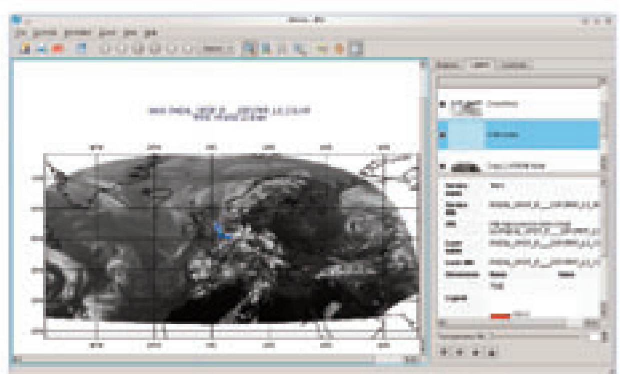
Helps validate implementations, identify issues for BP

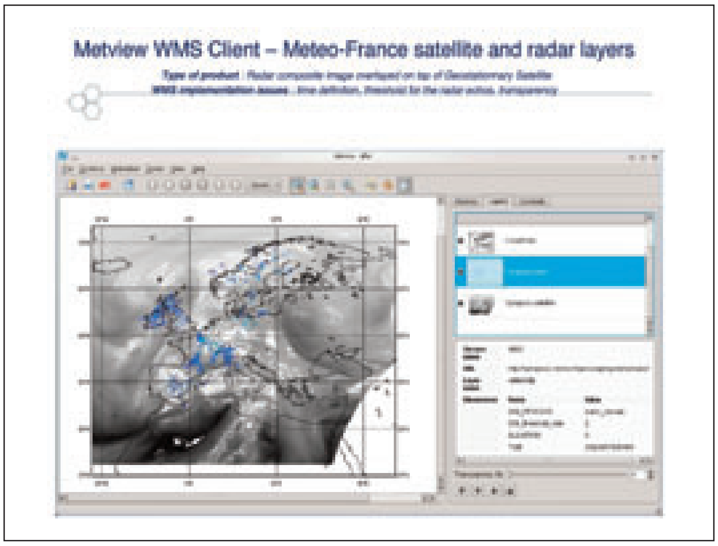
OGC

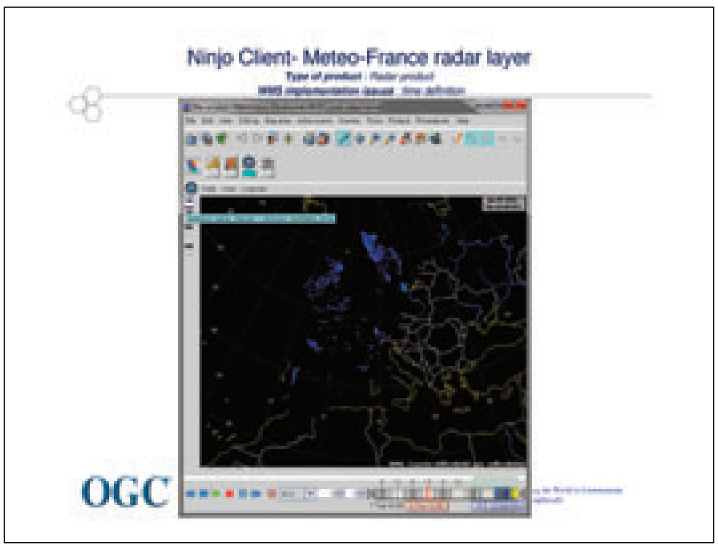
Metview WMS Client – KNMI satellite and radar layers

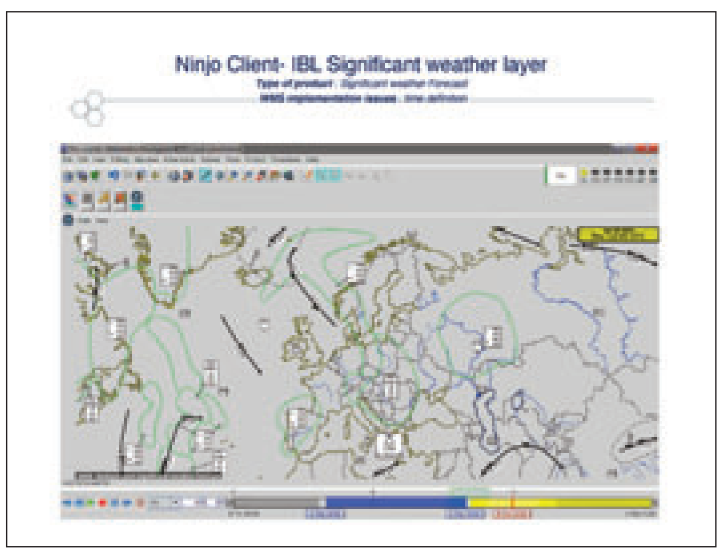
Type of product *: Radar composite image overlayed on top of Geostationary Satellite*

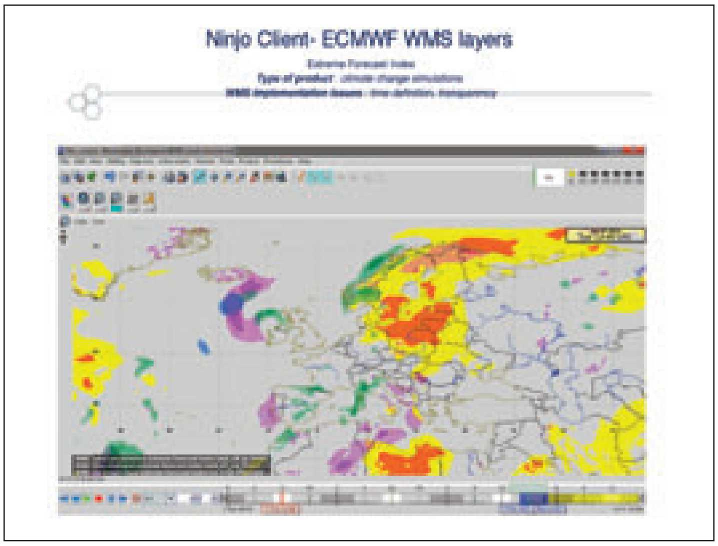
WMS implementation issues *: time definition, transparency*



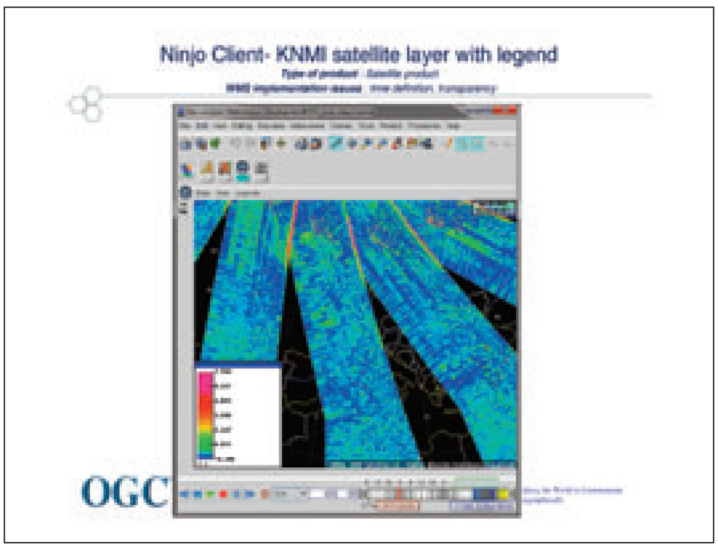

Metview WMS Client – Meteo-France satellite and radar layers
Type of product : Radar composite image overlayed on top of Geostationary Satellite
WMS implementation issues : time definition, threshold for the radar echos, transparency


Ninjo Client- Meteo-France radar layer
Type of product : Radar product
WMS implementation issues : time definition
OGC

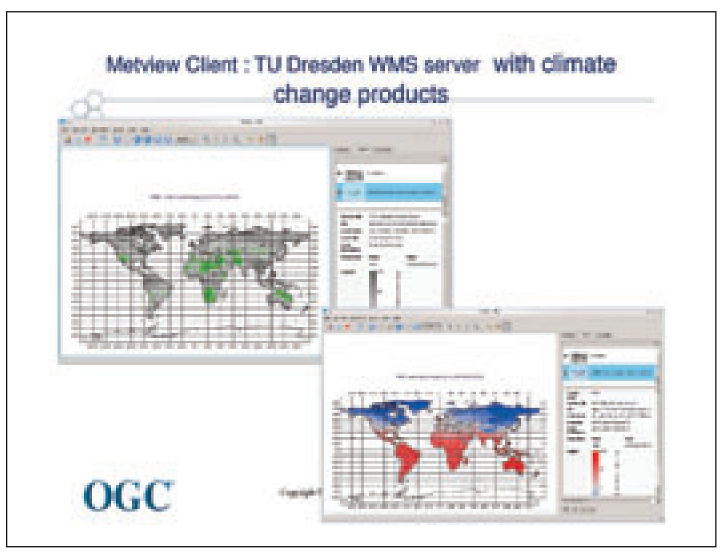

Ninjo Client- IBL Significant weather layer
Type of product : Significant weather Forecast
WMS implementation issues : time definition



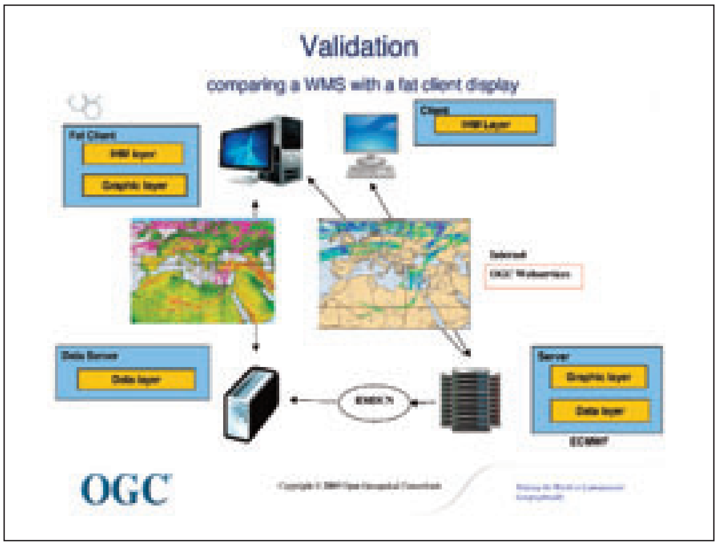
Ninjo Client- ECMWF WMS layers

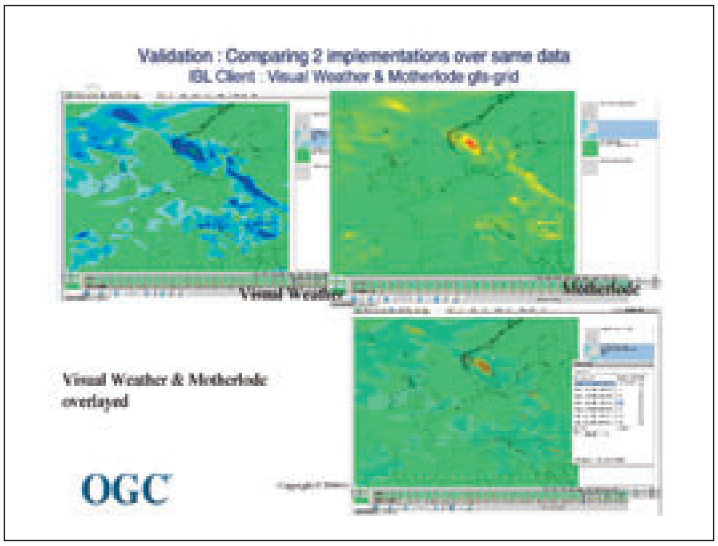


Ninjo Client- KNMI satellite layer with legend
OGC



Metview Client : TU Dresden WMS server with climate change products
OGC



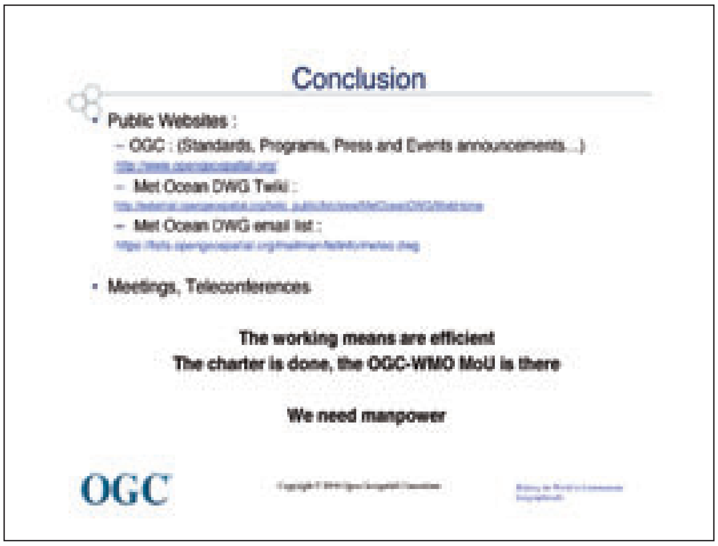


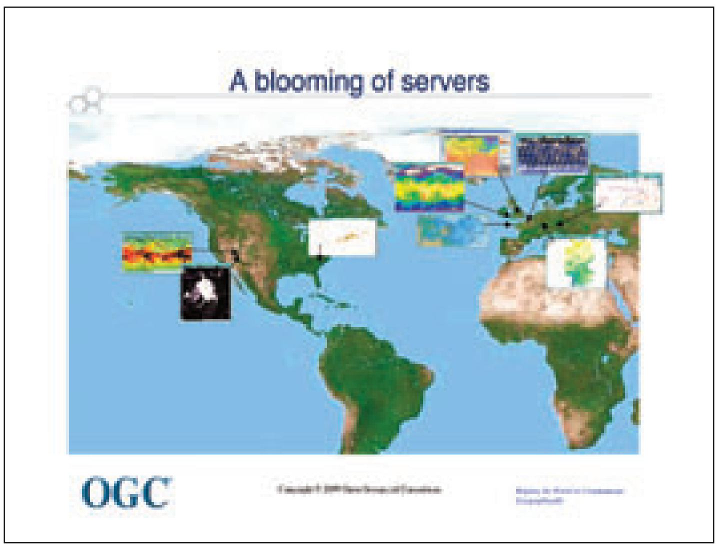
Roadmap

Next steps

- Met Ocean DWG telecon: check the twiki
- Next OGC Technical Comittee in Brussels, End November 2011 : a new best practices wording for the time handling, then vertical levels, ...
- A 4th Workshop on the use of GIS/OGC Standards in Meteorology maybe in NOAA Washington next spring (to be confirmed)
- More Experiments

OGC


Conclusion
Public Websites :
– OGC : (Standards, Programs, Press and Events announcements…)
– Met Ocean DWG Twiki :
– Met Ocean DWG email list :
Meetings, Teleconferences
The working means are efficient
The charter is done, the OGC-WMO MoU is there
We need manpower
OGC


A blooming of servers
OGC


PAST
Having some servers and clients available has taken time
Now :
We are in a growing dynamic
The group isn't enough robust still:
Volunteers always welcome
FUTURE
OGC

Metview 4 – Bringing OGC services to the desktop

Sándor Kertész, Meteorological Visualisation Section, ECMWF

Introduction

Metview is a meteorological workstation developed at ECMWF. It provides a complete working environment for both the operational and research meteorologist and is capable of performing powerful data access, processing and visualisation. Metview 4, the latest version of the software, was designed to support and access web services based on the standards of the Open Geospatial Consortium (OGC). These standards allow serving and retrieving geospatial data over the web. They have become increasingly popular over the last decade since they can offer an easy way for organisations within different domains to share geospatial information and thus enhance interoperability. This presentation briefly describes the development within Metview 4 to support OGC standards.

Web Map Service

OGC's Web Map Service (WMS) standard focuses on the generation and retrieval of geo-referenced map images over the web. A key concept of WMS is that of a layer representing a basic unit of geographical information that a WMS client can request as a map image from a WMS server. A client can send at least two types of requests to the server: a GetCapabilities request, to acquire information about the available layers, and a GetMap request, to generate a map image for a particular layer using a specified geographic co-ordinate reference system and graphical style.

WMS client in Metview 4

Client-Server architectures, such as used in WMS, fit very well into the service-oriented design of Metview. The Metview WMS client, whose icon can be seen in Figure 1, was designed as a standard Metview module to provide an easy and powerful way to incorporate WMS map images into the Metview environment. The client offers a high-level user interface to build and perform the GetMap request. Also it is able to send the resulting map images to Metview's Display Window, which can overlay them with other sources of data.

Figure 1 The icon representing the WMS client in Metview 4.

The WMS icon editor resembles a web browser as it can be seen in Figure 2. Once the WMS server's URL is typed in at the top of the interface, the client runs the GetCapabilities request and populate the user interface with the resulting list of layers and their meta-data. Users can easily browse and preview the available map image layers and automatically generate the GetMap request. Manual editing of all the request parameters are also possible by switching into a plain editor mode (Figure 3).

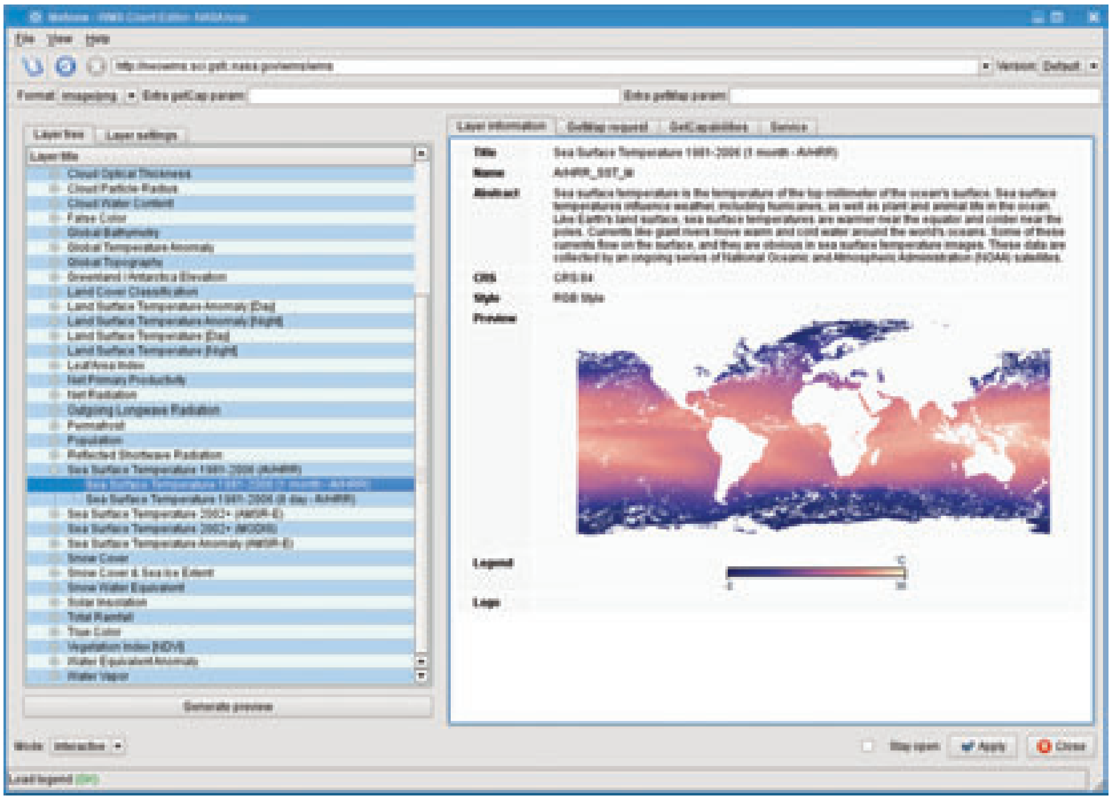


Figure 2 The WMS client's user interface connected to NASA's NEO (Earth Observation) server. The left hand side of the interface features the list of the available map layers, while on the right hand side the properties and a preview of the selected layer can be seen.

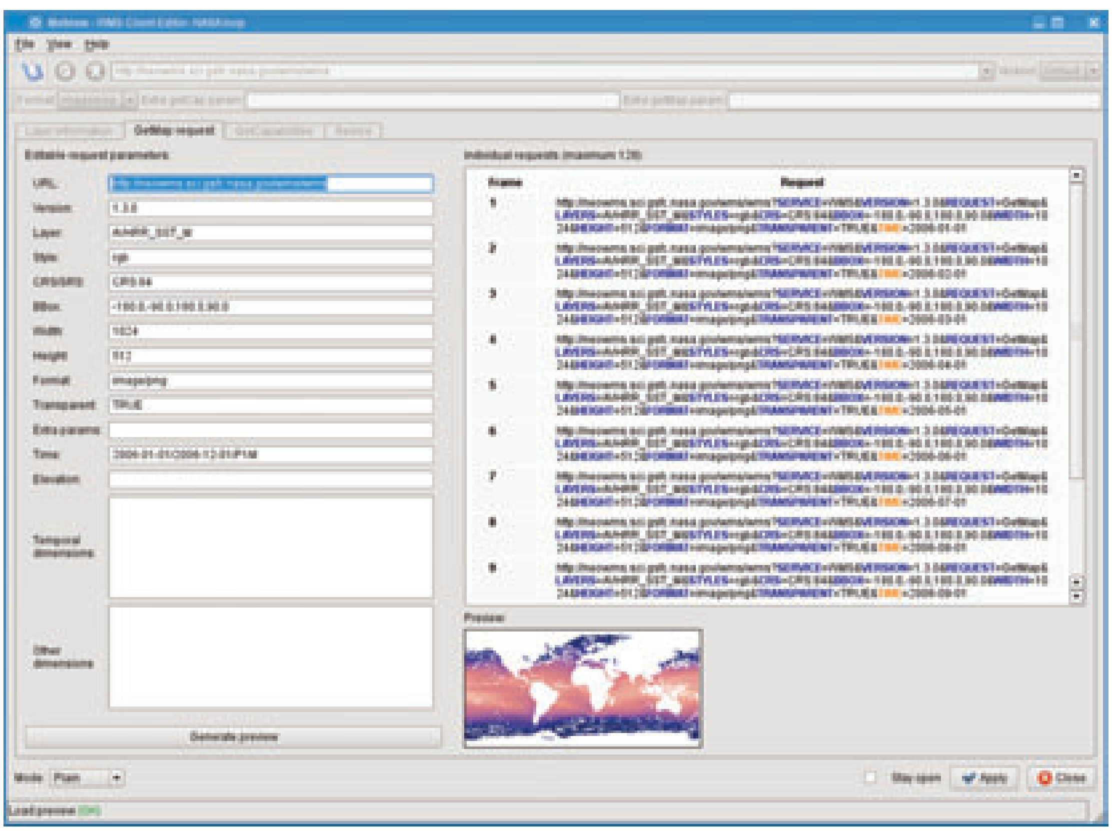


Figure 3 The WMS client's user interface in plain mode allowing the manual editing of the GetMap request.

Once the GetMap request is defined it can be run and visualised by right-clicking on the icon and selecting visualise from the context menu. Then the WMS map image appears in Metview's Display Window and can now be overlaid with other Metview charts (Figure 4). The meta-data associated with the WMS map image is displayed in the Layers tab on the right hand side of the Display Window.

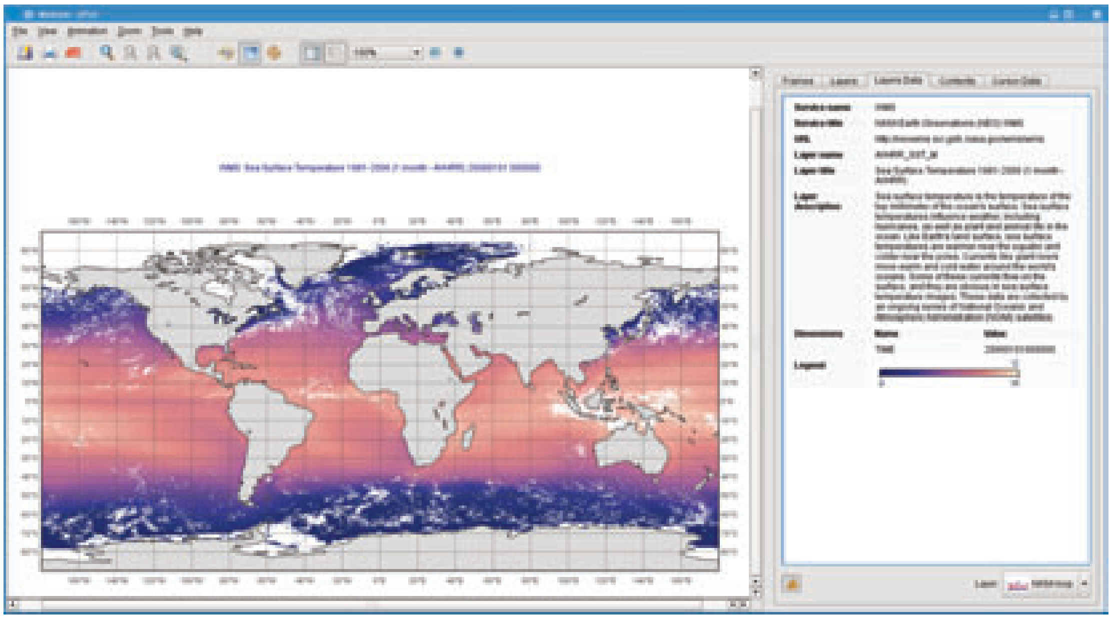


Figure 4 The WMS map image visualised in Metview 4, based on the GetMap request shown in Figure 3.

Metview users will find a tutorial that goes into more detail how to use the WMS client on the Metview documentation web page at

http://www.ecmwf.int/publications/manuals/metview/documentation.html

OGC MetOcean Domain Working Group

To support the meteorological community in adopting the OGC standards, the MetOcean Domain Working Group was established within the OGC. ECMWF is an active participant of this working group and the Metview WMS client has been extensively used to contribute to the group's work. In this context, tests with various servers were made whose outcome is documented at the MetOcean DWG webpage at

http://external.opengis.org/twiki_public/MetOceanDWG/MetocWMS_WMS_IE_Retex

Ongoing work

Work on Metview's WMS client is still ongoing with a special focus on the support for various geographical co-ordinate reference systems and the caching and tiling of the WMS images. Parallel to this work a client for OGC's Web Coverage Service is under development to access remote services providing gridded data via this standard.

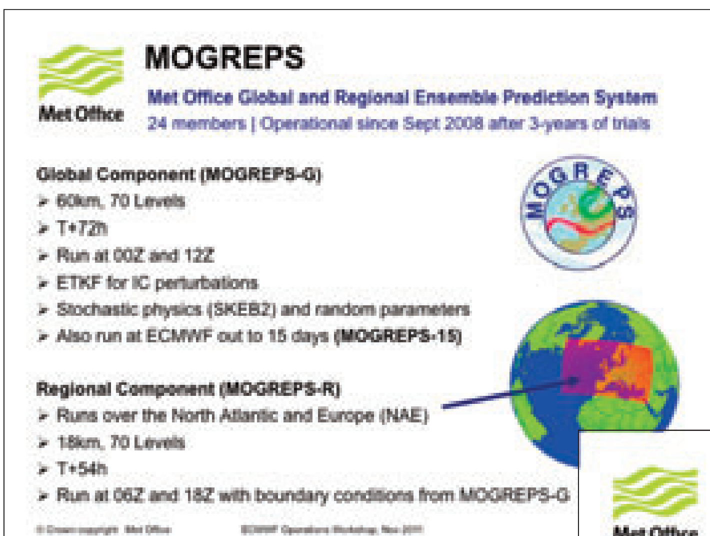
Ensemble applications and integration with deterministic post-processing

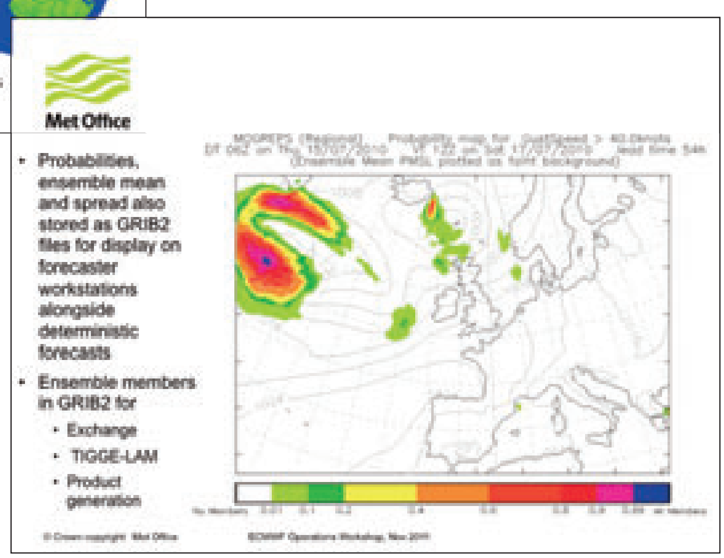
Ken Mylne, Met Office

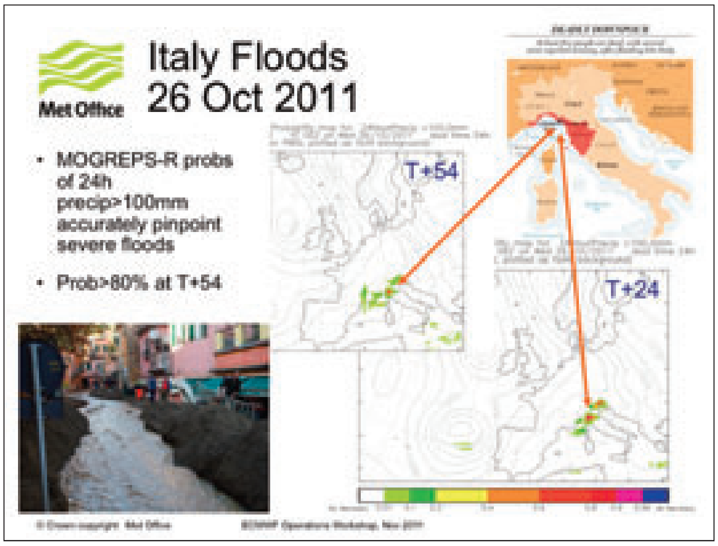
Forecasters have used ensemble forecasts for many years now to help inform their assessment of likely outcomes and risks of high impact events. Since the introduction of the ECMWF EPS in 1992, access to ensemble forecasts has grown steadily and forecasters at the Met Office now have access to a wide range of forecast products from the Met Office's MOGREPS short and medium-range ensembles as well as the EPS. This presentation will highlight some examples of applying ensembles to specific high-impact events, particularly propagating the meteorological uncertainty into impacts on related environmental impacts.

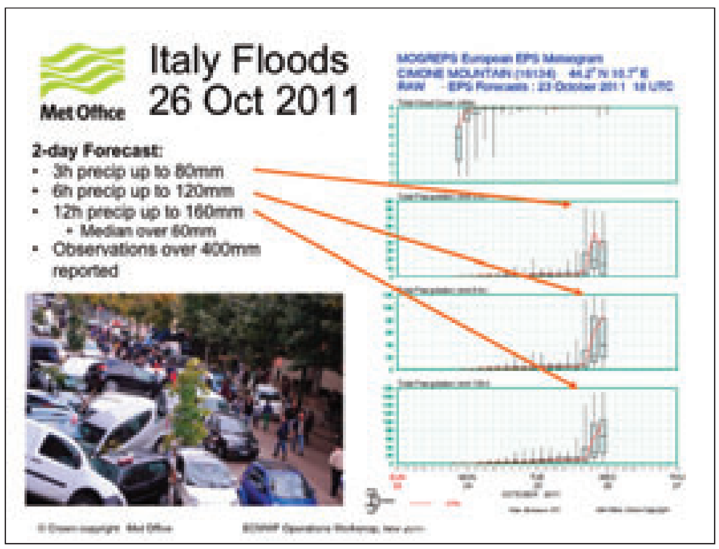
The MOGREPS ensembles are used to drive a storm surge ensemble for prediction of coastal flooding risk around the UK. Products from this system will be illustrated. Verification shows that the ensemble provides useful flow-dependent information above what could be obtained by simple dressing of the deterministic surge forecast. The use of the ECMWF EPS for estimating uncertainty in volcanic ash dispersion for aviation will also be shown. An important difference here is that, while the storm surge uncertainty is almost entirely due to uncertainty in the atmospheric forcing, the volcanic ash uncertainty is dominated by uncertainty in the volcanic source term.

Despite the above examples and the long history of operational ensemble prediction, use of ensembles is frequently still considered an add-on to the "operational" deterministic NWP. Much of the reason for this has been that ensemble post-processing has developed in parallel with deterministic post-processing, rather than being fully integrated, as forecaster workstations have been unable to support the ensemble forecast data other than via web browsers. Recent work at the Met Office, however, has started to integrate ensemble data more fully. Site-specific temperature forecasts for 10000 locations worldwide now combine a central best-estimate temperature with an uncertainty range based on the ensemble, and at lead-times above 5 days the central estimate is based on the ensemble mean, all bias-corrected using a Kalman filter for sites where observations are available. These forecasts are being further upgraded to provide a full set of percentile values allowing generation of full probabilistic forecasts for a large set of weather variables. Gridded fields of ensemble forecast data are also now being generated on the same high resolution grids as deterministic forecasts, and these will soon be ingested into the new SWIFT forecaster workstations, allowing forecasters to overlay ensemble fields with observations and other models in forecast production tools. These capabilities will allow the new convective-scale ensemble planned for introduction in 2012 to be immediately integrated and assessed on an equal basis with other NWP data.





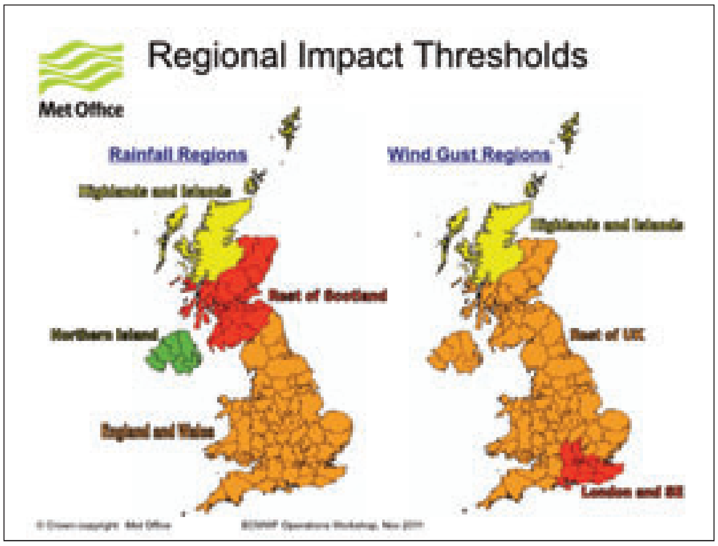


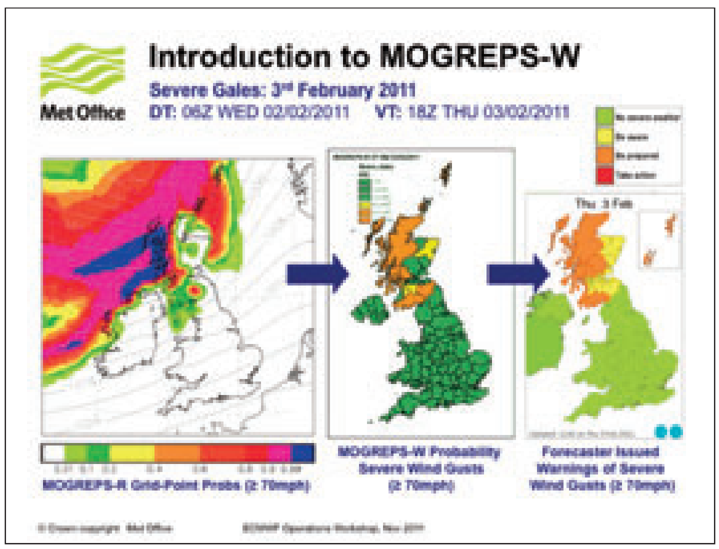


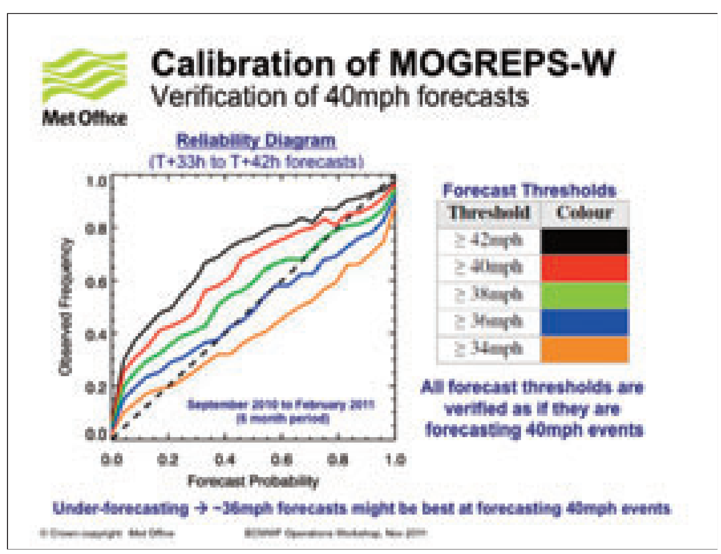
MORGREPS-W

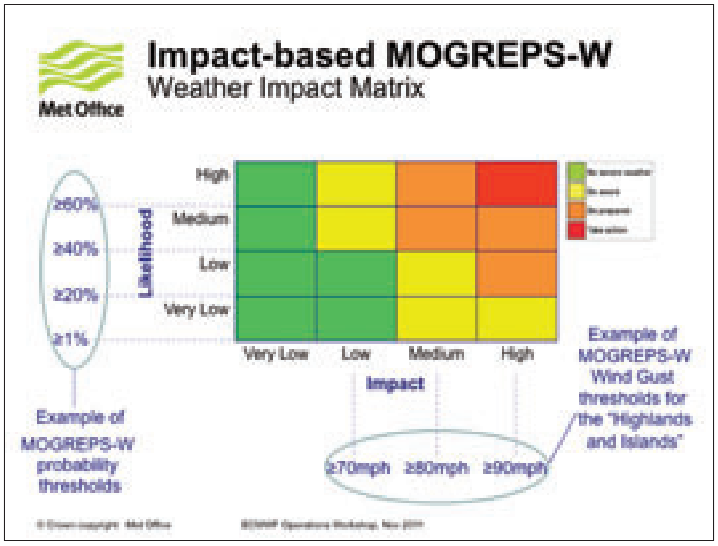
First-guess Severe Weather Warnings for NSWWS

Estimating Impact – a Risk tool

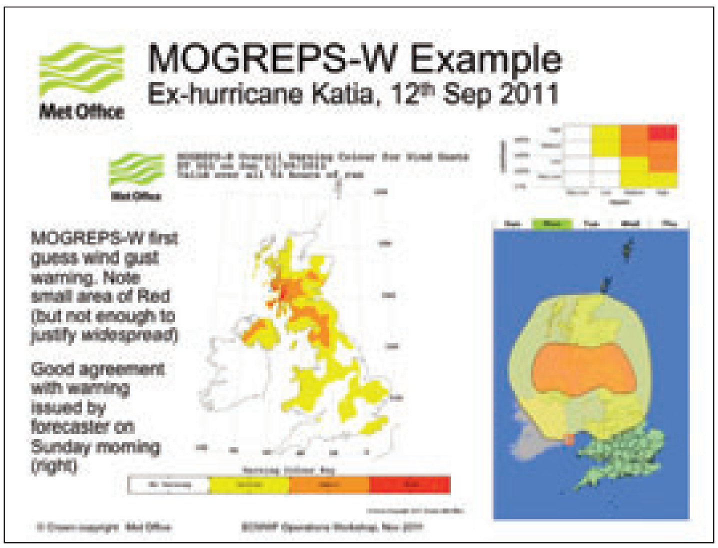

Regional Impact Thresholds
Met Office
Rainfall Regions
Wind Gust Regions
Highlands and Islands
East of Scotland
Northern Ireland
England and Wales
Highlands and Islands
Rest of UK
London and SE


Introduction to MOGREPS-W
Met Office
Severe Gales: 3rd February 2011
DT: 06Z WED 02/02/2011 VT: 18Z THU 03/02/2011
MOGREPS-R Grid-Point Probs (≥ 70mph)
MOGREPS-W Probability Severe Wind Gusts (≥ 70mph)
Forecaster Issued Warnings of Severe Wind Gusts (≥ 70mph)

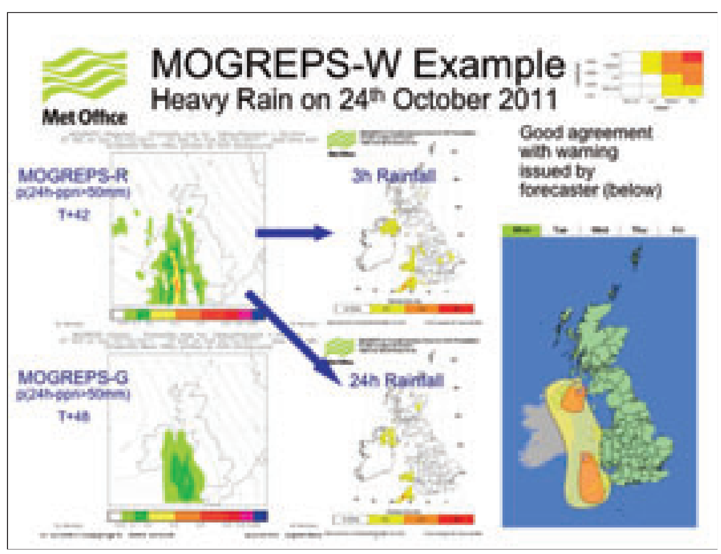

Calibration of MOGREPS-W
Verification of 40mph forecasts
Met Office
Reliability Diagram
(T+33h to T+42h forecasts)
Observed Frequency
Forecast Probability
September 2010 to February 2011 (6 month period)
Forecast Thresholds
Threshold
Colour
≥ 42mph
≥ 40mph
≥ 38mph
≥ 36mph
≥ 34mph
All forecast thresholds are verified as if they are forecasting 40mph events
Under-forecasting → ~36mph forecasts might be best at forecasting 40mph events



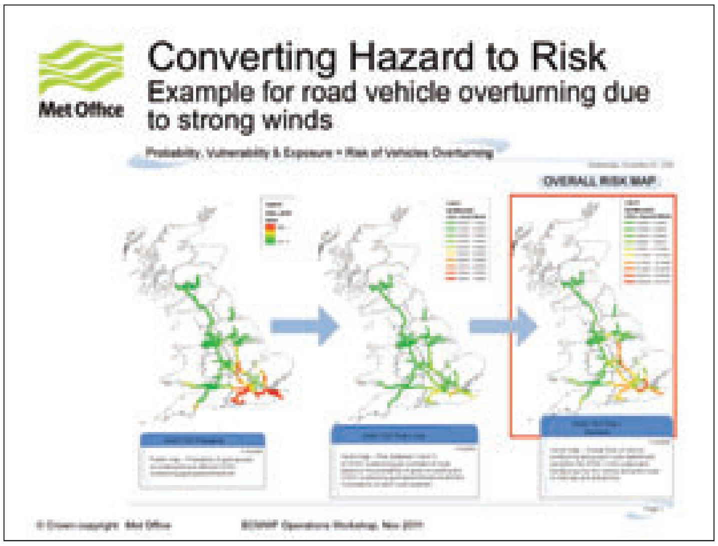
Impact-based MOGREPS-W
Weather Impact Matrix
Met Office
High
Medium
Low
Very Low
Likelihood
≥60%
≥40%
≥20%
≥1%
Very Low
Low
Medium
High
Impact
Example of MOGREPS-W probability thresholds
≥70mph
≥80mph
≥90mph
Example of MOGREPS-W Wind Gust thresholds for the "Highlands and Islands"



MOGREPS-W Example
Ex-hurricane Katia, 12th Sep 2011
Met Office
MOGREPS-W first guess wind gust warning. Note small area of Red (but not enough to justify widespread)
Good agreement with warning issued by forecaster on Sunday morning (right)



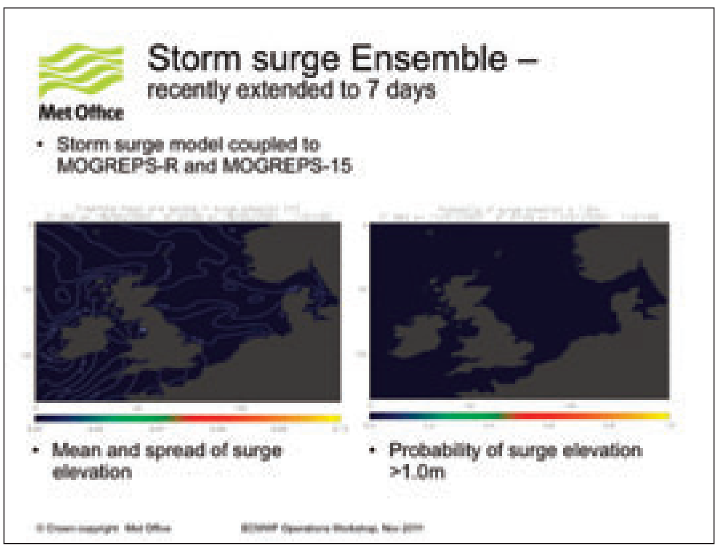
MOGREPS-W Example
Heavy Rain on 24th October 2011
Met Office
MOGREPS-R
p(24h-ppn>50mm)
T+42
MOGREPS-G
p(24h-ppn>50mm)
T+48
3h Rainfall
24h Rainfall
Good agreement with warning issued by forecaster (below)

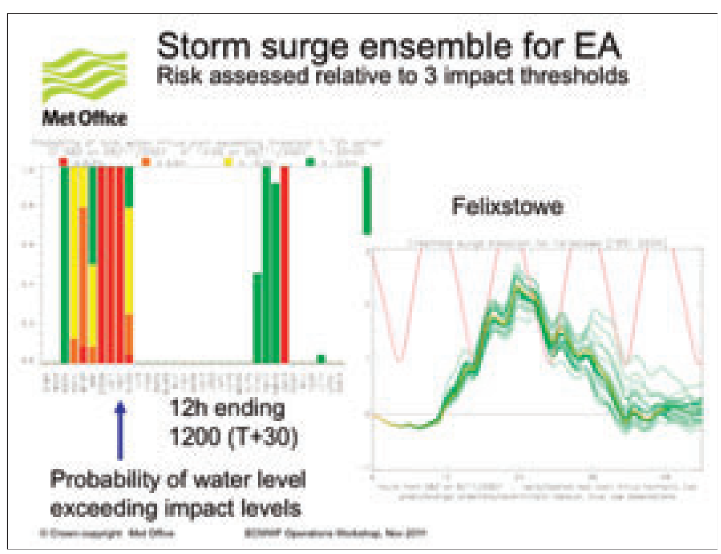


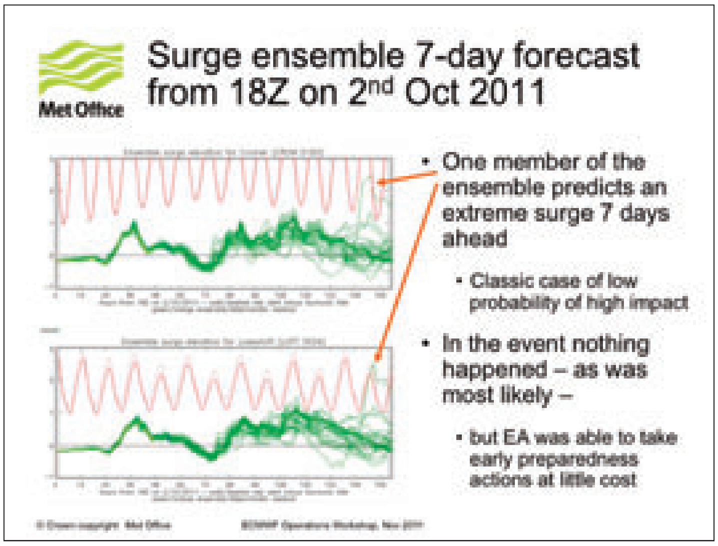
Storm surge ensemble

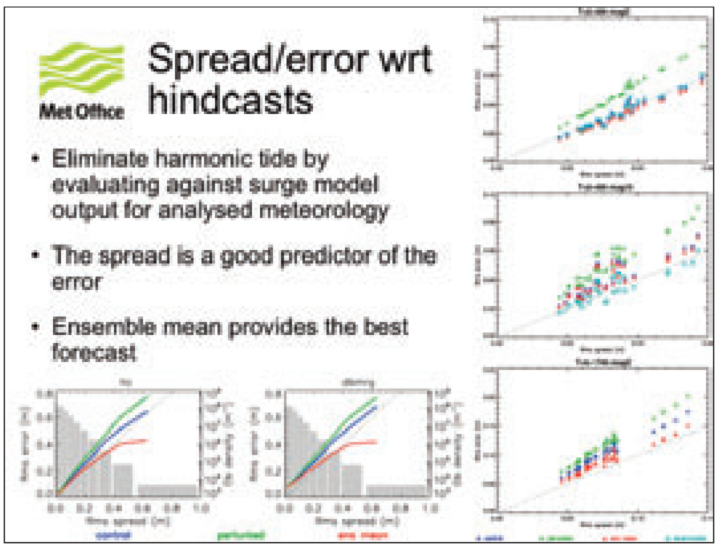
Coupling a surge model to MORGREPS-

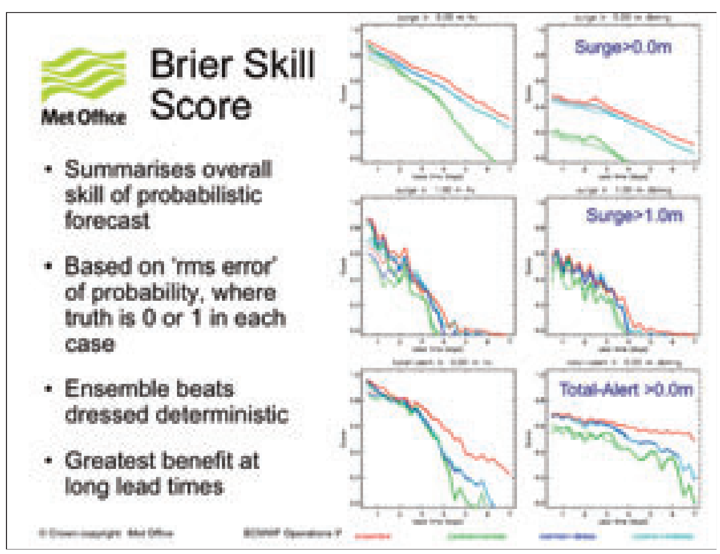
In support of coastal flood forecasting by the Environment Agency

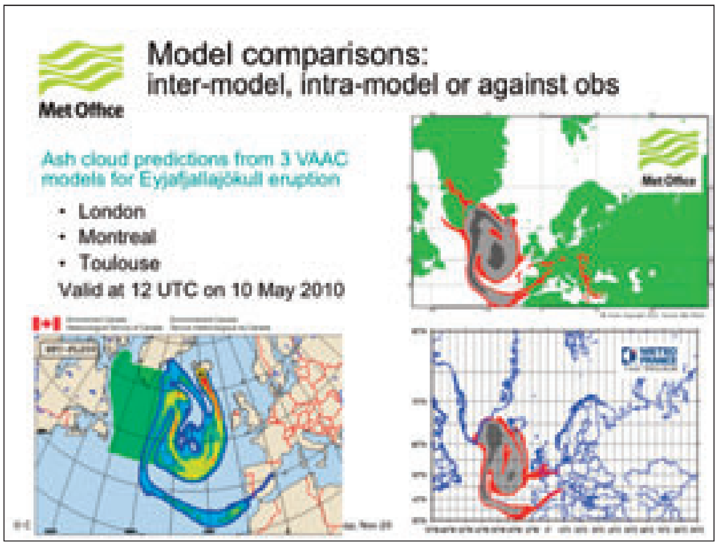


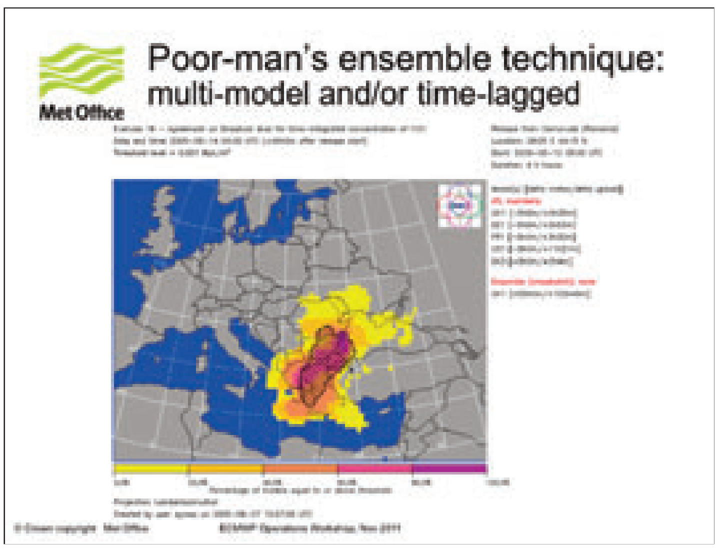


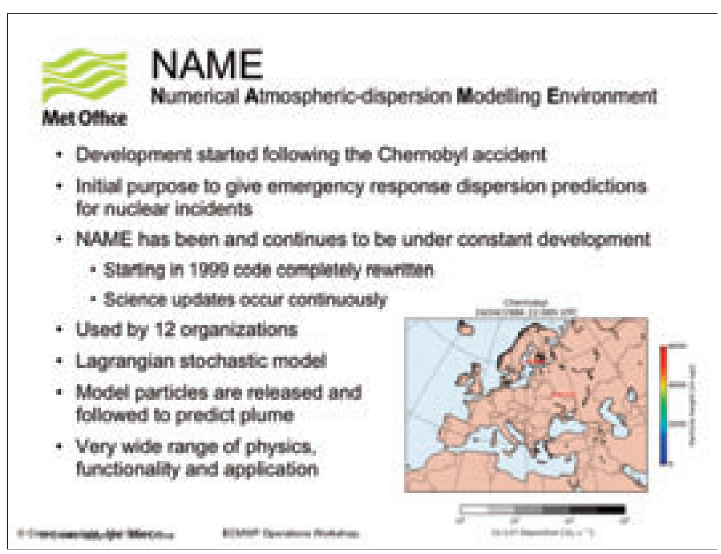

Met Office
Surge ensemble 7-day forecast from 18Z on 2nd Oct 2011
• One member of the ensemble predicts an extreme surge 7 days ahead
• Classic case of low probability of high impact
• In the event nothing happened – as was most likely –
• but EA was able to take early preparedness actions at little cost

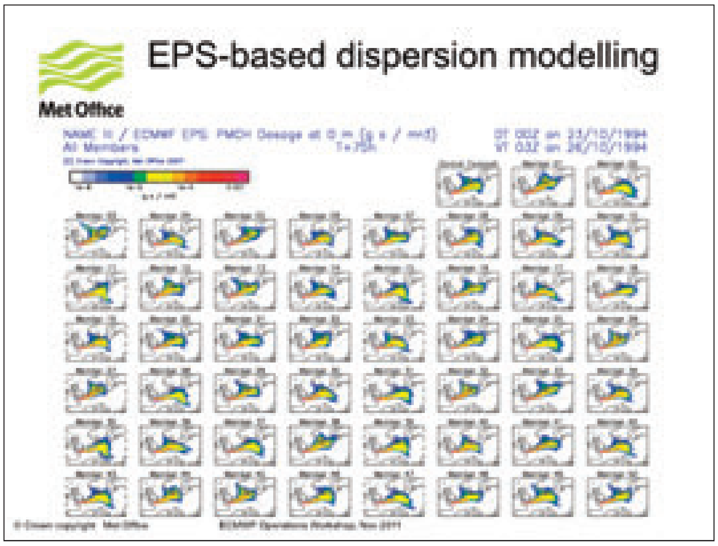

Met Office
Spread/error wrt hindcasts
• Eliminate harmonic tide by evaluating against surge model output for analysed meteorology
• The spread is a good predictor of the error
• Ensemble mean provides the best forecast

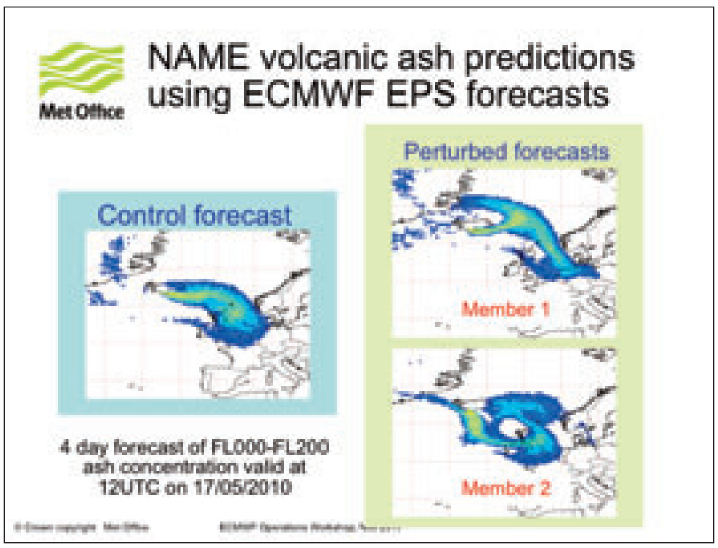

Met Office
Brier Skill Score
• Summarises overall skill of probabilistic forecast
• Based on 'rms error' of probability, where truth is 0 or 1 in each case
• Ensemble beats dressed deterministic
• Greatest benefit at long lead times
Surge>0.0m
Surge>1.0m
Total-Alert >0.0m

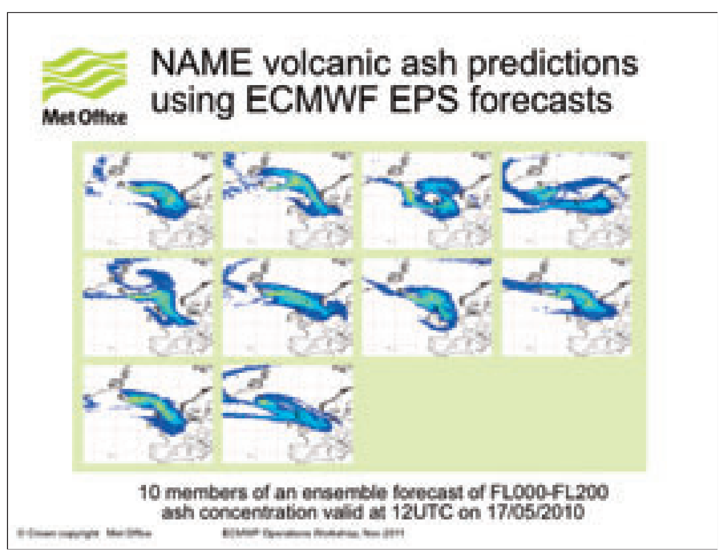

Model comparisons:
inter-model, intra-model or against obs
Met Office
Ash cloud predictions from 3 VAAC models for Eyjafjallajökull eruption
• London
• Montreal
• Toulouse
Valid at 12 UTC on 10 May 2010
Met Office

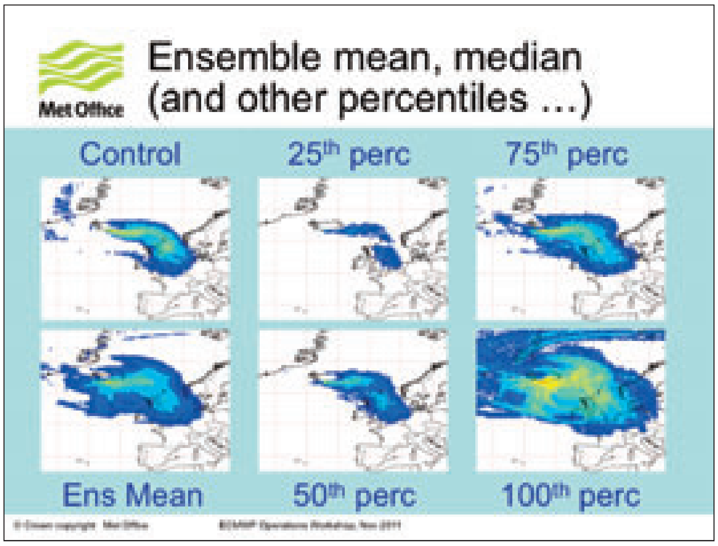

Poor-man's ensemble technique:
multi-model and/or time-lagged
Met Office

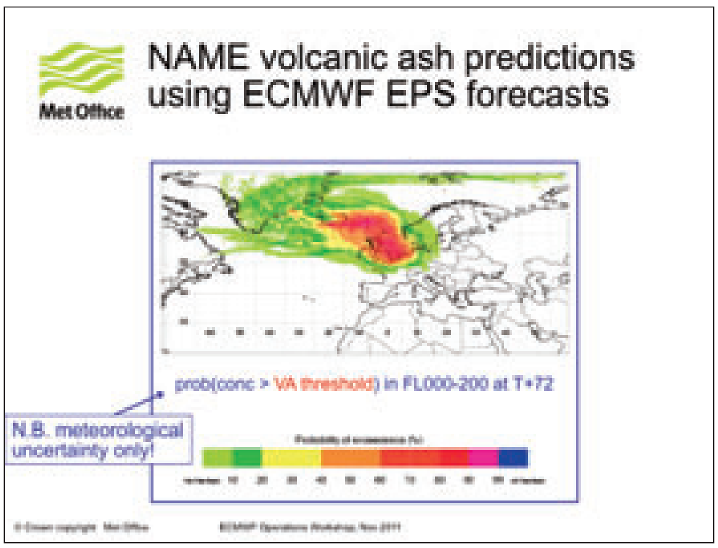

NAME
Numerical Atmospheric-dispersion Modelling Environment
Met Office
• Development started following the Chernobyl accident
• Initial purpose to give emergency response dispersion predictions for nuclear incidents
• NAME has been and continues to be under constant development
• Starting in 1999 code completely rewritten
• Science updates occur continuously
• Used by 12 organizations
• Lagrangian stochastic model
• Model particles are released and followed to predict plume
• Very wide range of physics, functionality and application

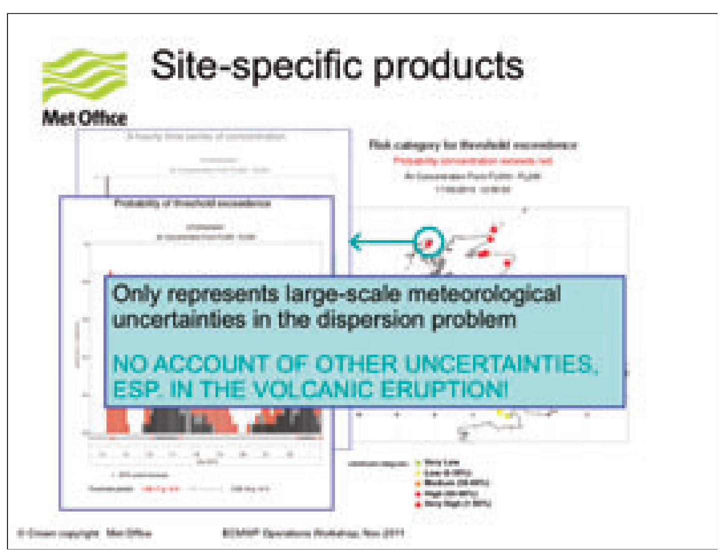

Met Office
EPS-based dispersion modelling

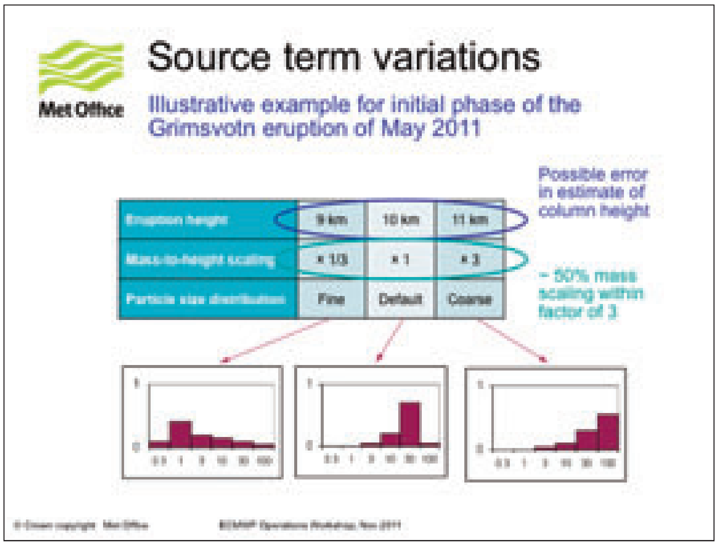

Met Office
NAME volcanic ash predictions using ECMWF EPS forecasts
Control forecast
Perturbed forecasts
Member 1
Member 2
4 day forecast of FL000-FL200 ash concentration valid at 12UTC on 17/05/2010

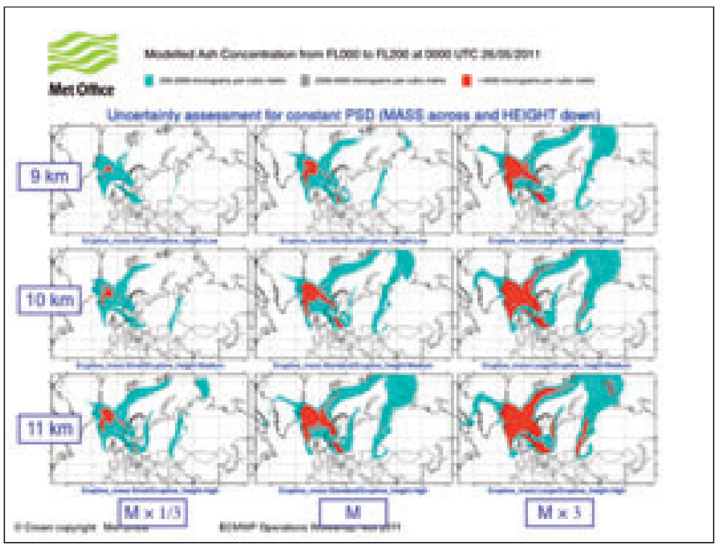

Met Office
NAME volcanic ash predictions using ECMWF EPS forecasts
10 members of an ensemble forecast of FL000-FL200 ash concentration valid at 12UTC on 17/05/2010

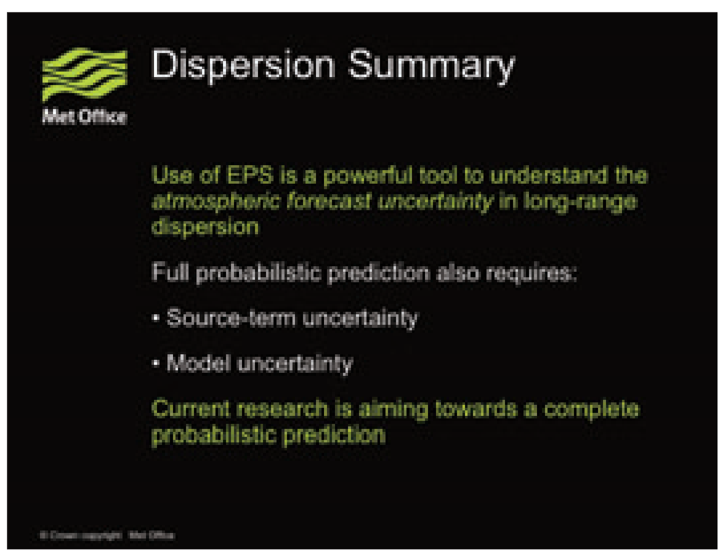

Met Office
Ensemble mean, median
(and other percentiles …)
Control
25th perc
75th perc
Ens Mean
50th perc
100th perc


Met Office
NAME volcanic ash predictions
using ECMWF EPS forecasts
prob(conc > VA threshold) in FL000-200 at T+72
N.B. meteorological
uncertainty only!

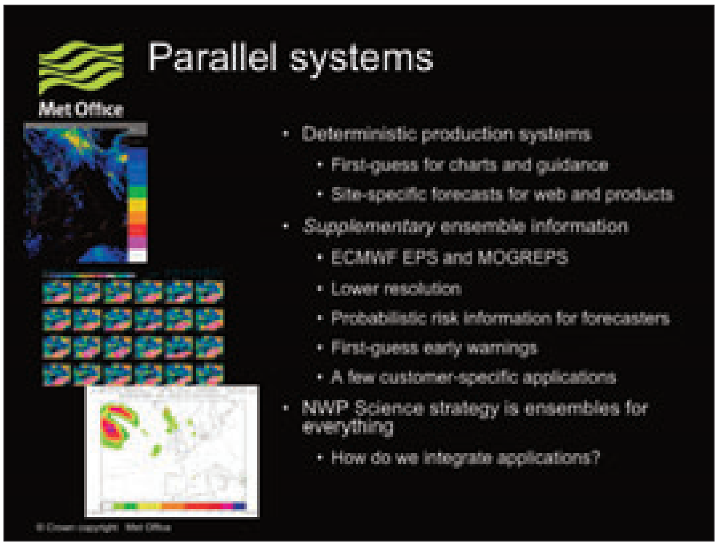

Met Office
Site-specific products
Only represents large-scale meteorological
uncertainties in the dispersion problem
NO ACCOUNT OF OTHER UNCERTAINTIES,
ESP. IN THE VOLCANIC ERUPTION!


Met Office
Source term variations
Illustrative example for initial phase of the Grimsvotn eruption of May 2011
Possible error in estimate of column height
Eruption height
9 km
10 km
11 km
Mass-to-height scaling
× 1/3
× 1
× 3
~ 50% mass scaling within factor of 3
Particle size distribution
Fine
Default
Coarse

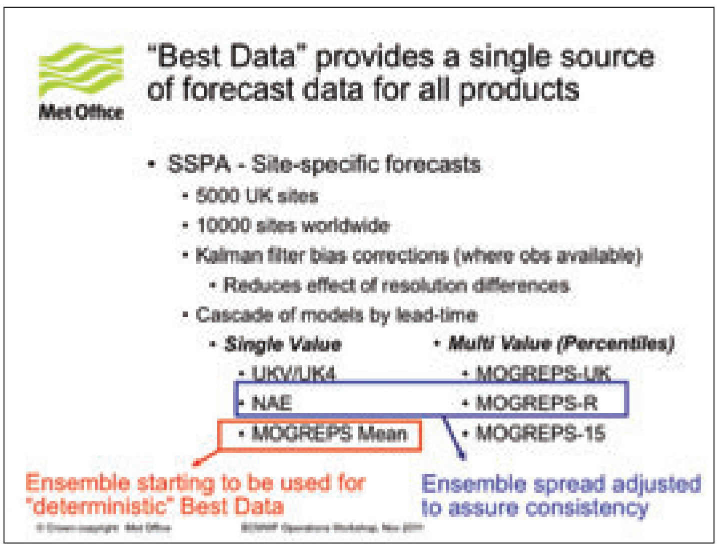

Met Office
Modelled Ash Concentration from FL000 to FL200 at 0000 UTC 26/05/2011
Uncertainty assessment for constant PSD (MASS across and HEIGHT down)
9 km
10 km
11 km
M × 1/3
M
M × 3

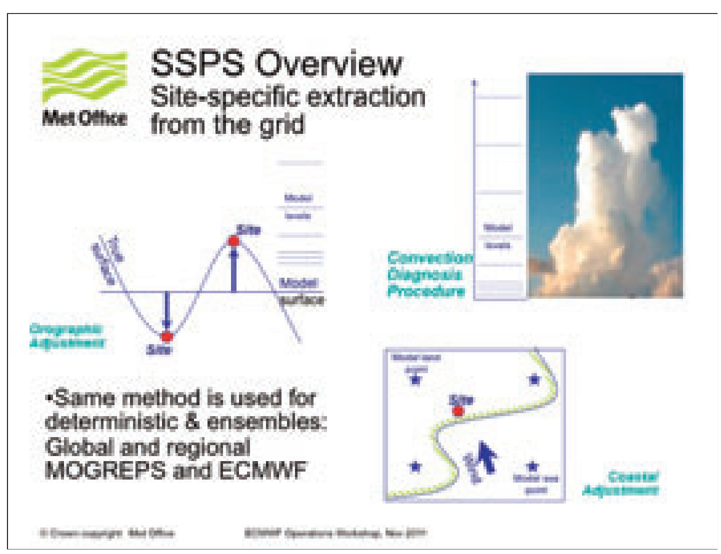

Met Office
Dispersion Summary
Use of EPS is a powerful tool to understand the atmospheric forecast uncertainty in long-range dispersion
Full probabilistic prediction also requires:
• Source-term uncertainty
• Model uncertainty
Current research is aiming towards a complete probabilistic prediction

Integrating Post-Processing of Ensemble and Deterministic NWP



Site-specific forecasts





Best Data Blending

Continuous updating of best deterministic

To start – 15 days out

- BestData(T+360) = MOGREPS-15(T+360) Mean

12 hours later

- BestData(T+348) = 0.5*MOGREPS-15(T+348) Mean + 0.5*BestData(T+360)

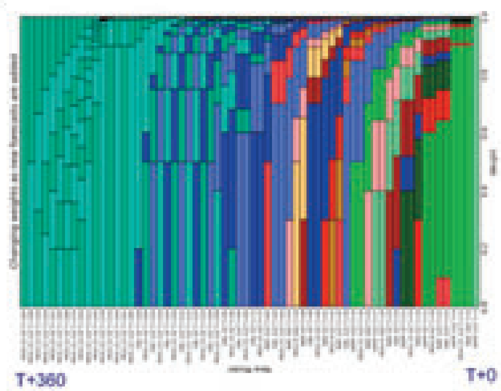
Current BestData = a * latest forecast + (1-a)* previous BestData

- 'a' varies with lead time and model combination

- At shorter range blend in:
  - MOGREPS-R
  - Higher resolution deterministic models including UKV
  - Nowcasts
- Coming soon – ECMWF data included in blend!

 ECMWF Operations Workshop, Nov 2011

Complex sets of weights by lead-time



T+360 T+0

 ECMWF Operations Workshop, Nov 2011

Ensemble Best-Data Stored as Percentiles

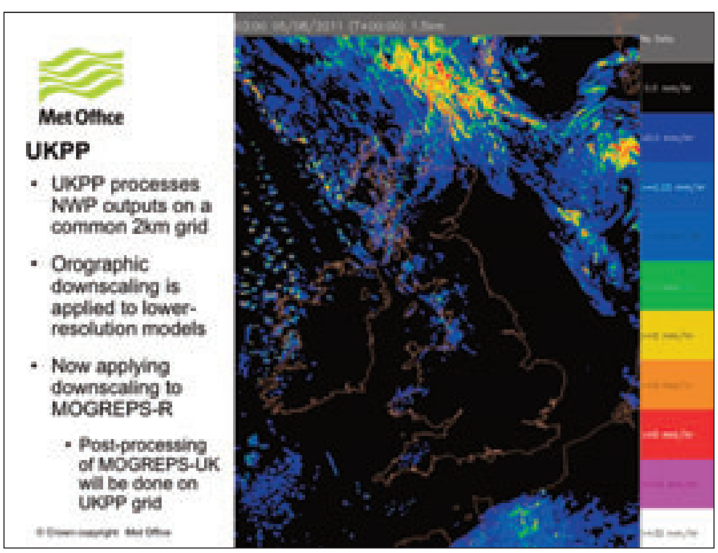
%	Min	5%	10%	20%	25%	30%	40%	50%	60%	70%	75%	80%	90%	95%	Max
T	-3.1	-2.9	-2.8	-2.3	-1.8	-1.7	-1.6	-0.7	-0.4	0.0	0.1	0.9	1.5	2.5	4.6

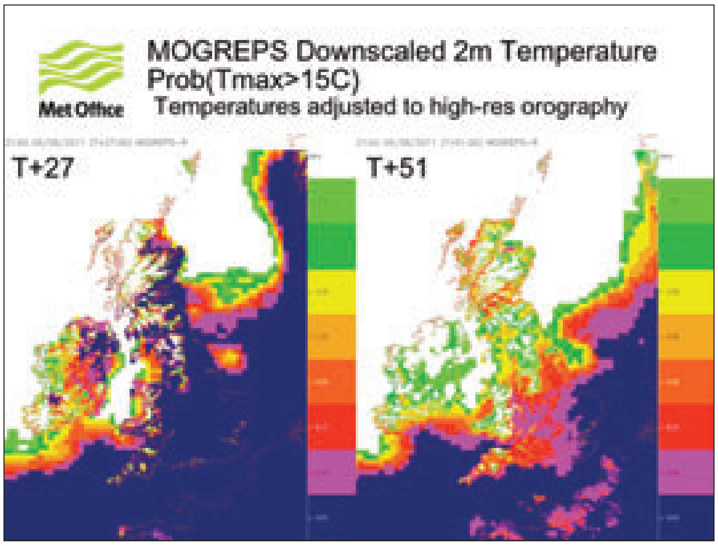
- Allows interpolation of probability for any threshold
- Independent of ensemble size or combination of data sources
- Using blend of multiple sources including hi-res deterministic models ensures consistency of:
  - Most probable
  - Uncertainty measures

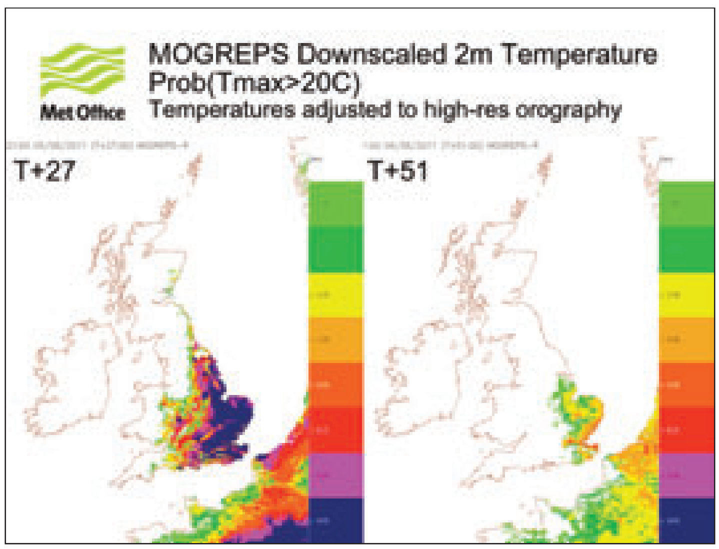
 ECMWF Operations Workshop, Nov 2011

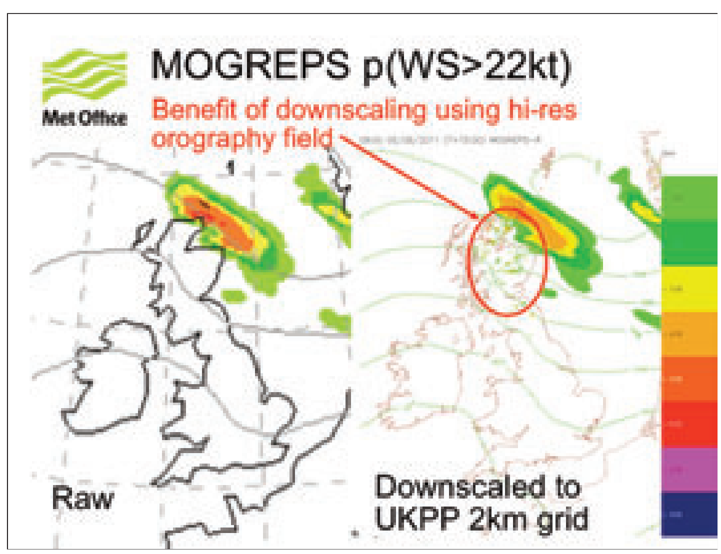
Integrating Gridded Data

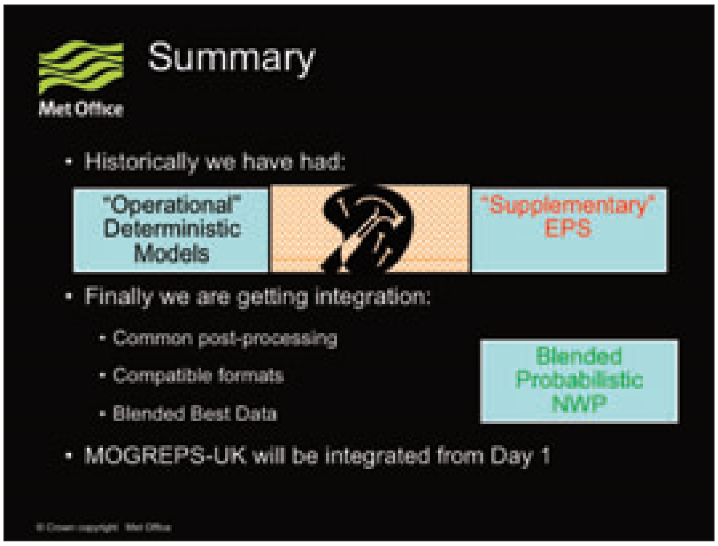
UK Post-processing (UKPP)

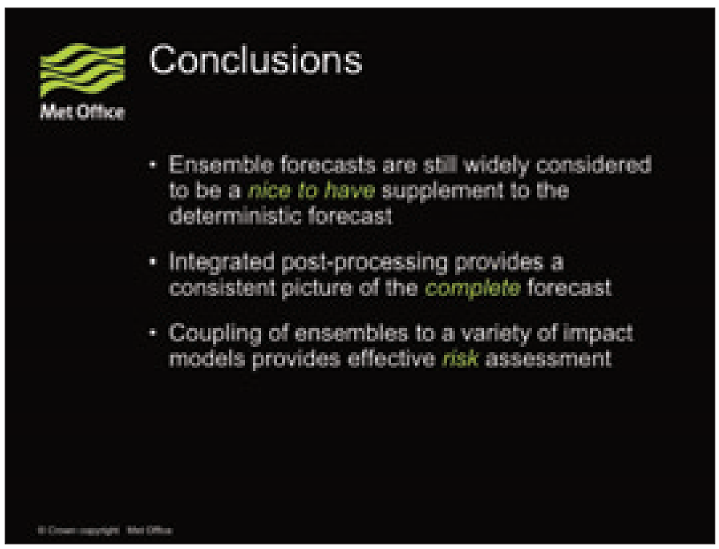



MOGREPS Downscaled 2m Temperature
Prob(Tmax>15C)
Temperatures adjusted to high-res orography
T+27
T+51


MOGREPS Downscaled 2m Temperature
Prob(Tmax>20C)
Temperatures adjusted to high-res orography
T+27
T+51


MOGREPS p(WS>22kt)
Benefit of downscaling using hi-res orography field
Raw
Downscaled to UKPP 2km grid


Met Office
Summary
• Historically we have had:
"Operational" Deterministic Models
"Supplementary" EPS
• Finally we are getting integration:
• Common post-processing
• Compatible formats
• Blended Best Data
Blended Probabilistic NWP
• MOGREPS-UK will be integrated from Day 1


Met Office
Conclusions
• Ensemble forecasts are still widely considered to be a *nice to have* supplement to the deterministic forecast
• Integrated post-processing provides a consistent picture of the *complete* forecast
• Coupling of ensembles to a variety of impact models provides effective *risk* assessment

Developments towards multi-model based forecast product generation

Ervin Zsótér, Hungarian Meteorological Service

1 Introduction

The development of the forecast product generation system at short and medium range has been a long term project at the Hungarian Meteorological Service (OMSZ). The latest development phase includes the introduction of the multi-model concept where the unified gridded forecast database – lying in the core of the system – can be initialised from a weighted combination of deterministic and/or ensemble numerical models used operationally at the meteorological service. The advantage of the new system is that the forecasters are able to control the forecasts through their choice of model blending at the database initialisation and also through a graphical forecast editor used for modifying the forecast fields. The different ranges of forecast end products are then generated from a unified source approved by the forecasters. In the following we introduce the current status of the developments.

2 Operational forecast production at present

The forecast product generation at short and medium range was designed on the basis of the unified gridded forecast database (FOCUS) which is meant to be a unified source of forecast information serving all kinds of forecast products. At present this goal is reached only to a certain extent as beside FOCUS we have two other forecast databases in operations – the simplified coded forecasts and the media database (see the brown boxes in Figure 1). The current system is therefore a segmented one containing potentially inconsistent pieces of forecast information and the NWP input and the contribution of the forecasters varies from database to database significantly. In the current set-up the forecasters have to endure duplicated manual work in trying to correct forecast inconsistencies arising from the different databases with different data formats.

The simplified coded forecasts are data file products containing all main weather parameters like temperature, cloud cover, wind, precipitation type and amount for areas in Hungary and locations worldwide. The forecasts are valid for 12- or 24-hour periods. The files are produced by the forecasters (only for Hungarian regions up to D+7) and also generated based on different NWP models and used for generating forecast texts, different commercial products and also used in verification applications.

The media database contains simple forecast summaries for specific locations in Hungary and worldwide. It covers daily forecasts up to D+7 with only the weather parameters of weather type, minimum and maximum temperature, and wind. It is initialised with the combination of the raw deterministic ECMWF model data and the simplified coded forecasts prepared by the forecasters for some Hungarian regions. A screenshot of the application for manual modification of the database is in Figure 2. This type of forecast data is used mainly in products for media, e.g. television, newspapers and the web.

The FOCUS database has already been in use for many years in conjunction with the graphical forecast editor. The FOCUS is a NetCDF database with currently 10 km horizontal resolution over a large Hungarian region and a 1-hour temporal resolution up to D+15. Currently the initialisation is done mainly based on the deterministic ECMWF model data with replacing the temperature by the ensemble mean beyond T+96 hours and with an option to use the in-house limited are model ALADIN for short range up to T+48 hours for all parameters. It includes all main categorical weather parameters with some supplementary probabilities. The forecast data is extracted directly from the FOCUS grid without any further corrections for hundreds of forecast products.

The graphical forecast editor (GFE or grid editor) currently in operations at the Hungarian Meteorological Service originates from the system used by the US National Weather Service. The forecasters currently modify only a subset of the important parameters namely the temperature and cloudiness. A screenshot of the grid editor can be seen in Figure 3.

3 Main characteristics of the new FOCUS system

The forecast production system is planned to be entirely based on the FOCUS database where the forecasters should control the forecast outputs at only one place simply by applying changes on the grid fields with the grid editor. The reason why FOCUS could not yet fulfil its potential is that it is only partially modified by the forecasters and therefore the data cannot be used comprehensively for all applications. The main weakness of the system was its complexity which makes the grid editing process very time consuming. One of the reasons is that the weather type variable (describing mist/fog, precipitation/no-precipitation, rain/snow/sleet, etc.) is defined with too much detail. The other one is that the system could only be initialised by deterministic models, which then provided some unpredictable details in the forecast fields especially for precipitation and cloudiness which was hard to be removed. The reconfiguration of the system affected these two areas.

Firstly some of the weather parameters were redefined, especially the ones related to weather type. In the new parameter scheme the core parameter is the "significant weather type" which summarises the main weather features (includes all precipitation types, 3-value visibility, 5-value cloud cover and only two wind categories).This variable is used exclusively in relation to the grid editing, and it is the first parameter to be edited. By setting the significant weather type, the forecasters can guarantee that the synthesis of the weather surely agrees with their own conception (the other way would to modify the ingredient weather parameters and build the weather type automatedly after grid editing). Modification of other parameters is done with consistency checks to the significant weather type.

Secondly we introduced the use of multi-model ensembles in the initialisation of the FOCUS. The database can now be initialised by the available deterministic models, ensemble models (including e.g. EPS clusters), lagged version of the models or any of the weighted multi-model combination of these model versions. The forecasters can decide on the FOCUS harmonisation by selecting the "best model guess", i.e. the available models are blended into a consensus for grid editing. Default multi-model combinations are also prepared to help the forecasters in making their decision. The processing of multi-model data actually guarantees that only the more predictable details will appear in the grid editor making the editing process easier for the forecasters.

4 FOCUS data processing and product generation

In the new FOCUS system all models are converted to a unified (currently 10 km) horizontal grid with a 1-hour forecast frequency at initialisation. If necessary we do up-scaling by computing a simple areal average, while at temporal interpolation the model's original post-processed interval's forecast values are preserved. Forecast data merging in time is done at FOCUS harmonisation over a ±3-hour interval which is done when data from different models or differently blended multi-models are merged. Consistency is checked between temperature and precipitation phase parameters and corrections are made in the precipitation phase (temperature remains fixed) if necessary.

A very important part of the new FOCUS project is the automated generation of forecast products. Forecast data for end products is derived exclusively from the gridded hourly FOCUS database which is the grid edited version of the FOCUS-harmonised data controlled by the forecasters. Based on the hourly gridded FOCUS files, forecasts for 6-, 12-, 18- and 24-hour periods are generated without any further human intervention. These interval forecasts are derived for grid points, locations and also regions. The schematic of the FOCUS data flow from NWP to products can be seen in Figure 4.

The generation of forecast data for locations requires further attention because of the potential inconsistency between the station height and the model orography, and also the land-sea mask problem. Currently we apply a simple correction scheme where the forecast of the "best grid point" is corrected based on the lower tropospheric temperature profile from the model, and in parallel also precipitation type parameters are adapted to the modified temperature if necessary.

Apart from the important role played in the forecast product generation, the FOCUS files are also useful operational tools for the forecasters. They provide a standardised platform for comparing numerical models as the parameter structure and the resolution (spatial and temporal) are the same in all FOCUS files and in addition to this the post-processed indices are also determined by the same algorithms from every model.

5 FOCUS parameters

Where it is meaningful the parameter values are defined with the weighted multi-model mean in the FOCUS (for cloudiness, wind, temperature and precipitation amount). The weighted mean is computed at initialisation of the hourly FOCUS when grid point values are defined, at computing the period value as a mean over the period, and also when computing the areal mean of grid points for regional or location forecasts (a small circular area represents a location if no station height temperature correction needs to be done).?

For weather events (precipitation, thunderstorm, etc.) the mean value should not be used, instead we determine the outcome based on the value distribution (range/bin/type). This is done at initialisation of the hourly FOCUS grid point values by counting each forecast member (with a weight) in the distribution. Besides, at derivation of the FOCUS-product files the period forecast values are determined by counting each hourly step in the period and the region values by counting each grid point in the area.

For precipitation we use about 40 categories in total comprising of the appropriate mixtures of three occurrence categories based on the precipitation probabilities (no precipitation, less likely precipitation, precipitation), seven precipitation phases (snow, freesing rain, rain, ice pellets and different mixtures), three precipitation intensities (drizzle, normal, shower) and finally three different thunderstorm intensity categories. The precipitation categories are determined based on the model's snow fraction of total precipitation, an in-house snow probability index, the convective/large-scale precipitation rate, an in-house developed empirical thunderstorm probability, and the lower tropospheric temperature pseudo temp of the model?.

For weather types two parameters are used. The significant weather type is designed specifically for helping the consistent grid editing (see earlier), while the extended weather type is used in the end products and it comes as a more complex combination of cloud cover, precipitation types and amount, visibility, wind speed, etc. An example of the significant weather type with all available models and the multi-model can be seen in Figure 5.

6 Preliminary verification results

We have performed some preliminary verification of the models we process in the new FOCUS system. One default multi-model combination of the available seven numerical models was compared with the performances of the single models. At short range the models were given equal weights, while beyond T+48 hours variable weights were assigned to the available two ECMWF (deterministic and ensemble) and the GFS forecasts (having the relative weight of the ECMWF ensemble increasing with the forecast range).

We used the SFC-based verification method which assesses the model performance on the larger scales and on the 12-hour time scale regardless of the original model resolution. This is done by having the forecast fields up-scaled to a fixed set of 13 Hungarian subareas each in the range of 10000 km2, and to the 12-hour periods of day time (06-18 UTC) and night time (18-06 UTC). Therefore the areas over a 12-hour period are always represented by mean/occurrence/min/max forecast and observed values. Verification was done against SYNOP observations (~100 stations including ~15 manned stations with visual observations). The basic continuous and categorical scores (ME, RMSE and contingency table scores) were determined for the most recent 3-month period, for the 00 UTC runs. A percentage score was also computed as a summary score by combining the performance of the four main parameters – temperature, precipitation, wind and cloudiness.

As an example figure 6 shows the percentage summary scores for day times and night times from D+1 to D+10 with all available input numerical models, the multi-model and the persistence. As one would expect, the best single models are the ECMWF models, especially the ensemble. The multi-model combination of the available seven models (at medium range only three models) seems to be showing a slight improvement over the ECMWF ensemble at short range, while for longer ranges no systematic difference can be seen. Although the verification period of three months is relatively short, we can already conclude that the multi-model combination appears to be a competitive alternative to any single model even with the simplest weighting strategy.

7 Summary and plans

A rather fundamental change of the forecast production is being carried out at the Hungarian Meteorological Service. The main goal of this project is to increase the efficiency in practical utilisation of the huge amount of NWP data we are dealing with in operational forecasting (help the forecaster as much as possible). The core element of the new system is the reconfigured FOCUS database with unified, gridded forecast data, where all forecast product data is served from this database.

The system is highly automated and human intervention is possible only at two important stages in the data flow from raw NWP data to products, at FOCUS initialisation and grid editing. The grid editing is still an important possibility, but it had to be simplified and now the focus is on the “weather outcome”. The role of the forecasters is therefore being shifted with the arrival of the new system as more emphasis is put on evaluation of the weather situation and decision making about the “best guess” for the forecast production.

A very important attribute of the new system is that multi-models with higher overall skills can be processed into traditional/categorical forecasts and therefore utilised in a very practical way. The multi model combination helps the forecasters by providing forecasts with the more predictable details, which makes the grid editing simpler. The preliminary results showed that the overall skill of the forecasts could be increased by combining all available models especially at short range. This could be achieved by applying equal weights using all models regardless of the actual skill of the models for the different parameters. A more sophisticated, model skill related combination of the models promises some further potential improvements.

By using the framework of the new system it is relatively easy to implement new ways of combining models, clusterings, representative members, etc. into the forecast production chain. We plan to extend the FOCUS database with detailed probabilistic information in the very near future. The best guess value, finalised by the forecaster, will be complemented with quantile information originating from the ensemble distribution. Comprehensive verification package is also planned as an integral part for monitoring each part of the system, including all stages of the production, along with the performance of the forecasters.

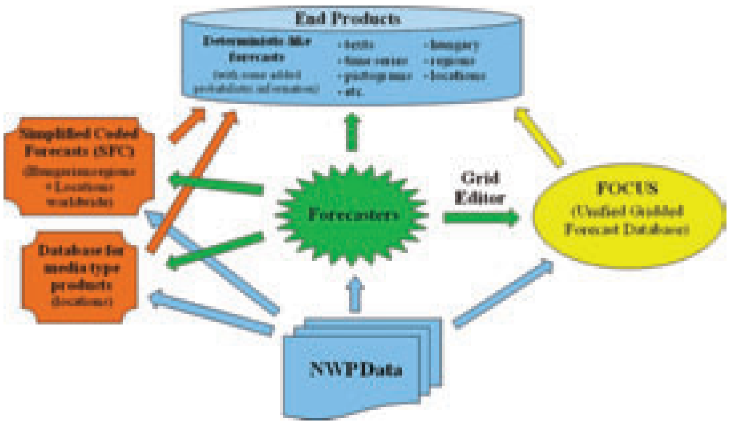


Figure 1 Schematic of the present forecast production at short- and medium-range at the Hungarian Meteorological Service with the three forecast databases (FOCUS, SFC and Media), the contribution of the forecasters and the data flow.

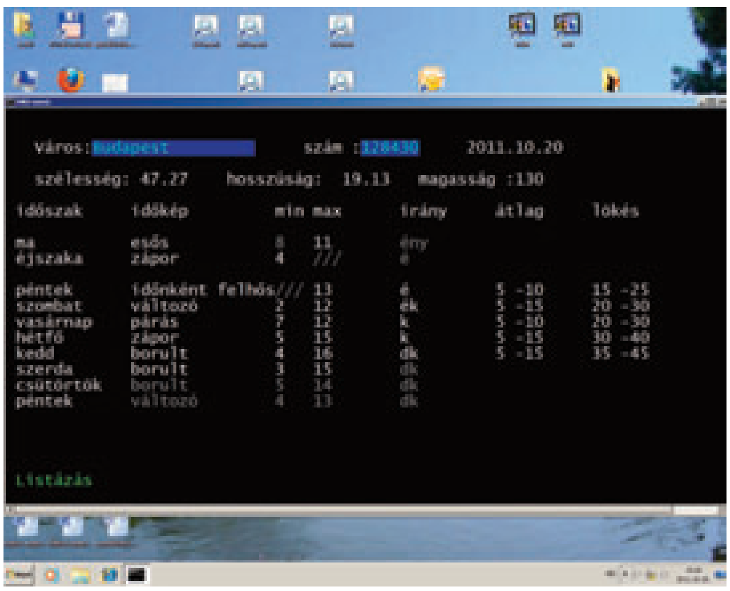


Figure 2 Screenshot of the application for modifying the media database by the forecasters.

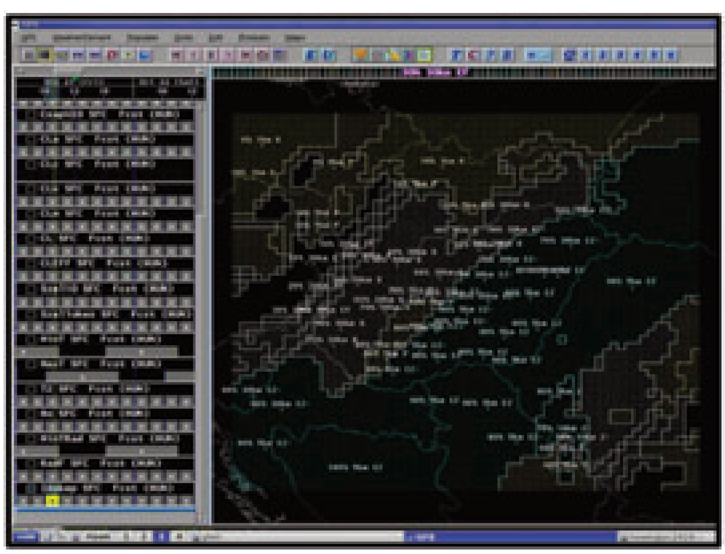


Figure 3 Screenshot of the Graphical Forecast Editor used to modify forecast fields by the forecasters.

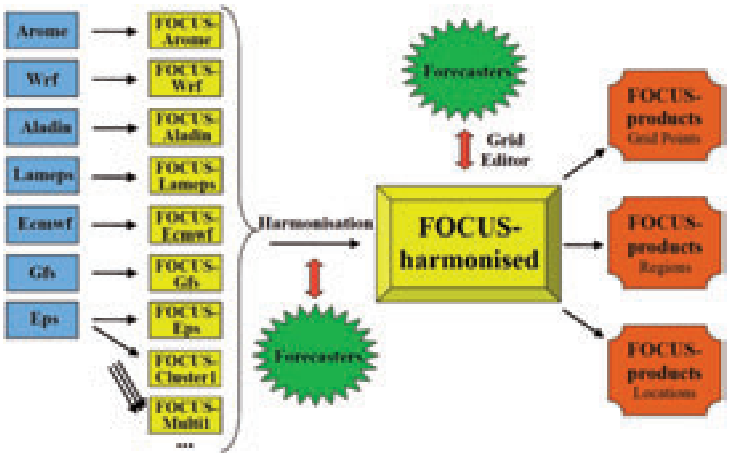


Figure 4 Schematic of the new forecast production at short and medium range at the Hungarian Meteorological Service. The raw NWP models are with blue, the FOCUS files with yellow and the product files with brown colours. The forecasters' contribution in the system is also highlighted by green.

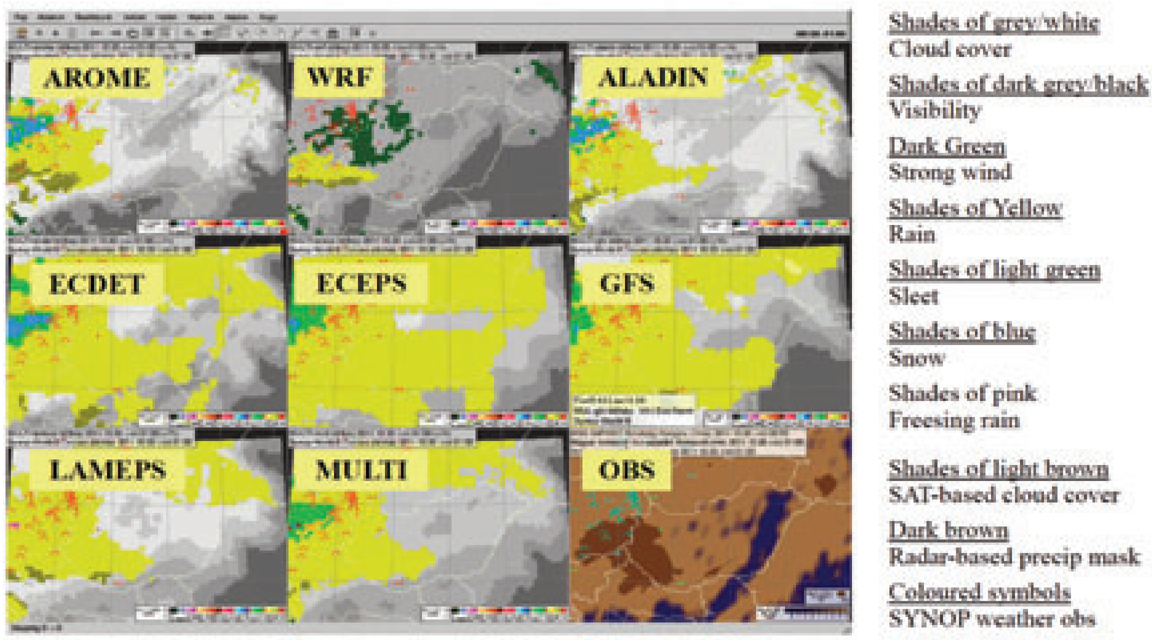


Figure 5 Screenshot of the FOCUS system with the significant weather type parameter (the colour shading) including all seven input NWP models and the multi-model combination. The observations are also plotted in the bottom right corner. All subplots are complemented by the SYNOP present weather symbols.

a) Day time (06-18 UTC)

b) Night time (18-06 UTC)

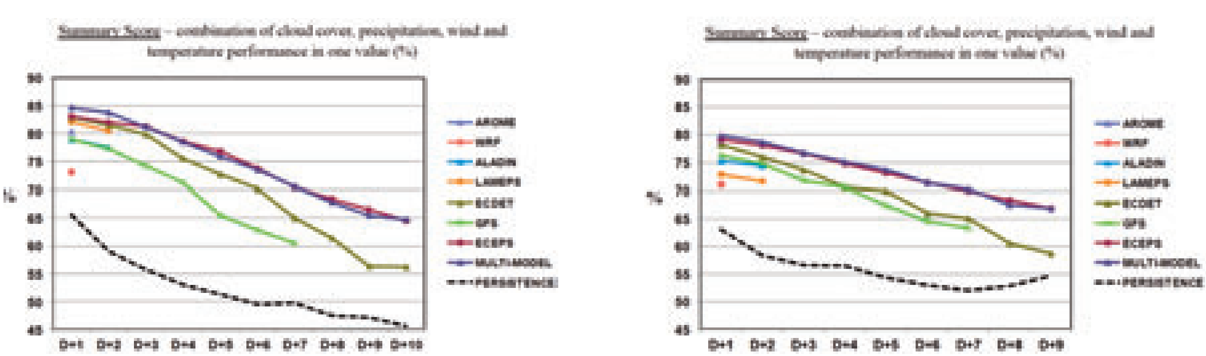


Figure 6 Percentage summary score performance of seven input numerical models, the multi-model and the persistence in the FOCUS system for July-September, always for the 12-hour forecast periods of day times (a) and night times (b) for D+1 to D+10. For more details please consult the text.