Annual Report 2010

European Centre for Medium-Range Weather Forecasts

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Foreword by the Director-General

The main event of 2010 was undoubtedly the entry into force of the amended Convention on 6 June. It concluded a process that started more than ten years ago when the ECMWF Council decided that it wanted to allow new States to join ECMWF. This period was divided in two almost equal phases. The first one was dedicated to defining the necessary changes and resulted in the unanimous adoption of the proposed changes at an extraordinary session of the Council in April 2005. During the second one it was necessary for all Member States to adopt these amendments, which, for most of them, required a decision by their Parliaments. By the end of 2010 two States had already officially applied to become ECMWF Member States.

Sadly 2010 was also marked by the death of ECMWF's first Director, Prof Aksel Wiin-Nielsen, on 26 April. Aksel was instrumental in setting ECMWF on track to become the world leader in global numerical weather prediction it has been ever since. He led the Centre from its creation in 1975 to 1981, and also served as President of the Council in 1987. It is remarkable that the basic organisation and the working practices he set up, based on strong interaction and cooperation between all teams, have remained almost unchanged.

ECMWF's core mission is to develop its global weather forecasting systems, run them operationally and distribute the results to its Member and Co-operating States. Throughout 2010, the Centre was able to enhance its worldwide reputation and maintain its leadership in global numerical weather prediction in the medium range.

The performance of the Centre's forecasting systems has improved steadily, thanks in particular to the implementation of two major new cycles of the Integrated Forecasting System which had positive impacts on the skill of the forecasts:

- The new cycle that became operational in January included an increase in horizontal resolution for the deterministic and the probabilistic forecasting systems. The resolution now reaches 16 km for the assimilation and the deterministic forecasting systems, and 32 km for the Ensemble Prediction System.
- Another new cycle was implemented in June. It introduced a new method for providing initial perturbations for the Ensemble Prediction System which improved the simulation of initial uncertainties, especially in the early forecast range and for the tropics.

The high scores for the ECMWF model confirmed that it performed consistently well in 2010. In addition, there was a notable achievement in February – the useful range of the deterministic forecasts for both the European region and the northern hemisphere exceeded ten days, which was a record monthly performance for the forecasting system.

ECMWF's strategy puts the early warning of severe weather events as one of its principal goals. Major severe weather events were well forecast in 2010. During summer the monthly forecast gave good early indications of the heavy rainfall in Pakistan and the extreme heat in Russia. Also the seasonal forecasting system was able to predict the extremely active Atlantic hurricane season and the cold spell in Europe in January. The storm Xynthia, which was one of the most damaging storms of the last decade hitting particularly the southwest of France in February, was well forecast. Overall the forecasting system upgrades in 2010 improved the ability to predict heavy precipitation events and the intensity of tropical cyclones.

The Centre's high-performance computing facility continued to provide a very reliable service. Following the Council's authorisation, a contract was signed in December for IBM's service contract to be extended by one year to mid-2014.

Through its core activity, ECMWF is contributing significantly to climate change studies that support the development of strategies to mitigate and adapt to climate change, although the Centre does not directly carry out climate simulations. The Centre's reanalyses are suitable for studies of long-term climate variability. A collaborative research project proposal, coordinated by ECMWF, has been selected for funding from the European Union's Seventh Framework Programme. The goal of ERA-CLIM is to prepare the input data and assimilation systems necessary for the production of a next-generation global atmospheric reanalysis that spans the entire 20th century.

Good progress was made regarding the collaborative project MACC (Monitoring Atmospheric Composition and Climate), which provides data that is important for understanding climate and validating and improving the models used to predict climate change. MACC is developing the central atmospheric monitoring component of Europe's GMES (Global Monitoring for Environment and Security) initiative. The project is funded under the European Union's Seventh Framework Programme and is being coordinated by ECMWF.

Statement by the President of the Council

ECMWF continued to monitor the energy efficiency of the site and particularly the data centre infrastructure. New and existing technologies to reduce energy consumption were evaluated in 2010. Various projects increased ECMWF's energy efficiency. These included the replacement of part of the Uninterruptible Power Supply system and most of the chillers used to provide cooling water for equipment. Actions were also taken to reduce energy use in the office buildings. Installation of some 'free cooling' for the ECMWF data centre is being studied, whereby the ambient (external) air is used to cool the air or water that provides the direct cooling to equipment in the data centre.

A major overhaul of ECMWF's financial framework was initiated. It culminated with the adoption of an extensively revised set of financial regulations by the Council in December. It will, in particular, make it possible for the Centre to implement the International Public Sector Accounting Standards (IPSAS) from 2012.

ECMWF recruits staff members from its Member States and Co-operating States, and consultants are recruited worldwide. At the end of 2010, 27 nationalities were represented at ECMWF. A key ingredient to the success of ECMWF is the high level of expertise and dedication of the staff. This has ensured that ECMWF continues to be at the forefront of applying the latest research and technological developments to meet the increasingly demanding needs of Member States.

Dominique Marbouty
Director-General of ECMWF

ECMWF plays a significant role in complementing the activities of national institutions in Member and Co-operating States, particularly meteorological and hydrological services. During my presidency in 2010, the Centre once again provided very good early forecasts of various severe weather events several days or even weeks ahead, thereby allowing early warnings to the public.

The amendments to the Convention of ECMWF entered into force on 6 June. This is a milestone in ECMWF's history as it allows an expansion of the scope of its activities and an enlargement of ECMWF's membership – the original Convention restricted ECMWF's membership to the founding 18 Member States. On 28 October and 6 December respectively, Iceland and Slovenia submitted formal applications to become ECMWF Member States. As a result, more delegates will be sitting around the Council table. The amended Convention will allow the Centre to run Third Party Activities that are in line with its purposes and objectives. Also it allows the establishment of Optional Programmes that contribute to ECMWF's purposes and objectives; these will provide an excellent means for executing activities in which not all Member States wish to be involved.

The number of States benefitting from ECMWF is also increasing via co-operation agreements. A co-operation agreement with Bulgaria entered into force on 12 July.

On 28 October, a co-operation agreement between Israel and ECMWF was signed and entered into force on the date of signature. This brought the number of States supporting ECMWF up to 33, with 18 Member States and 15 Co-operating States.

The ECMWF Council made a number of important decisions in 2010, one being the unanimous appointment of Prof Alan Thorpe as the next Director-General of the Centre at its 74th session on 7–8 December.

Prof Thorpe will take up his appointment from 1 July 2011 and he will succeed Mr Dominique Marbouty, ECMWF Director-General since 2004.

The ECMWF governing bodies have been very busy in 2010. In particular the Finance Committee had two extraordinary sessions over the summer. Also there was much activity associated with the Working Group on Long-term Building and Refurbishment Requirements and three subgroups of the Technical Advisory Committee.

It was a great pleasure for me to serve as President of the ECMWF Council. I am confident that ECMWF, in close collaboration with its Member and Co-operating States, will maintain its leading role in global numerical weather prediction and play a major part in supporting the activities of the international meteorological community. National meteorological services will continue to rely on the Centre to deliver high-standard products.

Finally, I would like to congratulate the whole team working at ECMWF on the remarkable progress made in a variety of areas during 2010.

Wolfgang Kusch,
President of Council

Key events of the year

11–15 January

The first General Assembly of MACC (Monitoring Atmospheric Composition and Climate) was held at ECMWF. The project's progress and plans for the coming year were reviewed.

26 January

A new cycle of the ECMWF forecasting and analysis system, Cy36r1, was introduced in operations. This cycle includes major increases in horizontal resolution for the deterministic and the probabilistic forecasting systems. The higher-resolution wind fields are better at representing features such as tropical storms, fronts and land/sea transitions; this translates into better wave forecasts.

February

ECMWF reached a landmark in the performance of its deterministic forecasting system during a month. For the first time ever, the headline measure of skill in February reached the forecast range of 10 days.

1 February

The India Meteorological Department was the first to sign a reduced maximum charge licence agreed by the Council in December 2009. The licence allows national hydro-meteorological services to use ECMWF products for non-commercial purposes such as the protection of life and property, research activities and educational use.

2–4 March

The User Interface Committee of the Group on Earth Observations (GEO) held its 14th meeting at ECMWF. Since the initiative was started in 2003, ECMWF has been a Participating Organization in GEO. Also the Scientific Advisory Team of the European Composite Observing System (EUCOS) met at ECMWF.

12 May

The ERA-CLIM project proposal, submitted to the European Commission in January, was selected for funding in the Seventh Framework environmental research programme. This three-year project will be coordinated by ECMWF. The goal of ERA-CLIM is to prepare the input data and assimilation systems necessary for the production of a next-generation global atmospheric reanalysis that spans the entire 20th century.

13 May

New products were made available on the website following Council's decision to extend the range of weather forecast products that are available freely and with no restrictions. The new products are from the ECMWF Ensemble Prediction System (EPS), which provides guidance on the day-to-day predictability of the atmosphere. This gives an important complement to the information that is already available from the deterministic forecast.

6 June

The amendments to the ECMWF Convention entered into force. This is a milestone in ECMWF's history as it allows an enlargement of ECMWF's membership and an expansion of the scope of its activities. To celebrate this event representatives from London-based embassies of Member States and Co-operating States were invited to ECMWF.

Subgroup and working group meetings

5 February	TAC Subgroup to Review the BC Project	*1st session*
17–18 February	Working Group on the Long-term Building and Refurbishment Requirements	*1st session*
15–16 April	TAC Subgroup on Verification Measures	*3rd session*
9–10 September	TAC Subgroup on 'Green Computing'	*1st session*
20–21 September	TAC Subgroup on Verification Measures	*4th session*
23–24 September	TAC Subgroup to Review the BC Project	*2nd session*
19–20 October	Working Group on the Long-term Building and Refurbishment Requirements	*2nd session*

22 June

A new cycle of the ECMWF forecasting and analysis system, Cy36r2, was implemented. This includes a new method for providing initial-time perturbations for the EPS. In the new cycle, differences between members from the Ensemble of Data Assimilations (EDA) are used.

24–25 June

Under the chairmanship of its President, Mr Wolfgang Kusch (Germany), the Council held its 73rd session at the ECMWF headquarters. Council made several major decisions (see page 62). In the evening of the first day of the Council session, the entry into force of the amended Convention was celebrated with all Council attendees and ECMWF staff.

12 July

The Centre received a 'Note Verbale' from the Bulgarian Embassy in London, informing the Centre that the internal procedures necessary for the entry into force of the co-operation agreement between the Republic of Bulgaria and ECMWF had been completed.

28 October

Mr Israel Katz, Israeli Minister of Transport and Road Safety, and Mr Dominique Marbouty, Director-General of ECMWF, signed a co-operation agreement. Dr Henia Berkovich, Director of the Israeli Meteorological Service, attended the ceremony at ECMWF's headquarters. The agreement entered into force on the date of signature. Israel became ECMWF's 15th Co-operating State.

9 November

A new model cycle was implemented in operations. Cy36r4 includes a new cloud parametrization scheme and new surface analysis schemes introduced for snow and soil moisture.

7–8 December

The Council's 74th session was held at ECMWF's headquarters under the chairmanship of its President, Mr Wolfgang Kusch (Germany). Some major decisions were made (see page 63).

19 December

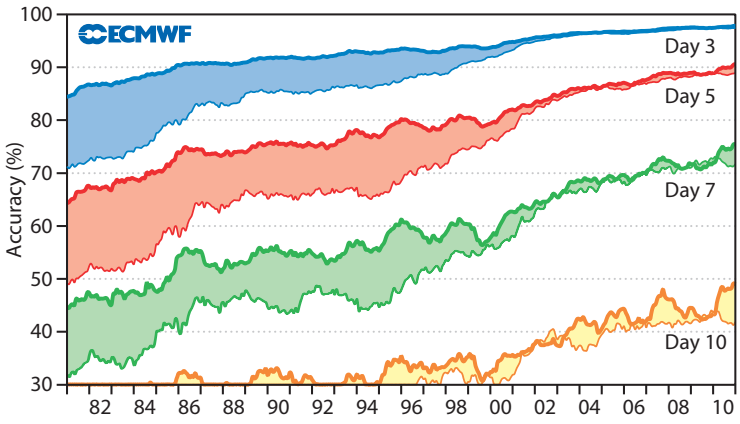
The process of migrating data from the old silos to the new automated tape libraries finished.

20 December

Following Council's authorisation, a contract was signed for a one-year extension to mid-2014 for IBM's service contract for the high-performance computing facility. The contract extension represents the same good value for money as achieved in the initial procurement.

Evolution of the forecasting system

ECMWF has a worldwide reputation for providing the most accurate medium-range, global weather forecasts. The wide-ranging programme of research and development at ECMWF continues to play a key role in the remarkable advancement of weather forecast skill and the use of satellite and in-situ observations of the atmosphere. Several upgrades to the forecasting system that enhance the atmospheric and marine forecasts have been made, including the horizontal resolution increase to 16 km (T1279) for the deterministic forecasts and 32/65 km (T639/T319) for the Ensemble Prediction System.



Improving accuracy of the ECMWF forecasts. *The increase in the verification scores for the northern and southern hemispheres shows that ECMWF forecasts have steadily improved with time, with the accuracy of the forecasts in the northern and southern hemispheres now being similar. The shaded areas highlight the differences in forecast accuracy between the hemispheres. The score used is the anomaly correlation of forecasts of 500 hPa height.*

Operational prediction system

The ECMWF forecasting system produces a wide range of global atmospheric and marine forecasts.

- Deterministic forecasts of the atmosphere and ocean waves to 10 days ahead, twice per day.
- Probabilistic forecasts of the atmosphere and ocean waves to 15 days ahead, twice per day.
- Monthly probabilistic forecasts of the atmosphere and ocean waves to 32 days ahead, once per week.
- Seasonal probabilistic forecasts of the atmosphere and ocean waves to 7 months ahead, once per month, with an extension to 13 months ahead every 3 months.

Initial conditions for these forecasts come from two separate data assimilation systems:

- An atmospheric data assimilation system employing four-dimensional variational analysis (4D-Var).
- An ocean data assimilation system based on the optimum interpolation (OI) technique.

There are additional atmospheric data assimilations run to initiate forecasts for the Optional Project entitled 'Boundary Conditions for Limited-Area Modelling'. These forecasts are used by many Member States and Co-operating States to run their own limited-area models.

Upgrades to the forecasting system in 2010

Major changes to the horizontal resolution of the deterministic model and Ensemble Prediction System (EPS) were made on 26 January 2010. Before operational implementation, the higher-resolution configurations of all components of the forecasting system were thoroughly tested. A substantial number of individual global forecast cases were examined to identify any numerical, dynamical or physical problems. Also, several periods of data assimilation and forecasts were studied to assess the impact of the increased resolution on objective scores, including those for weather parameters.

The implementation of the increased horizontal resolution has had a positive impact on the performance of the deterministic and ensemble forecasting systems. The higher-resolution wind fields are better at representing features such as tropical storms, fronts and land/sea transitions, which translates into better wave forecasts. In addition, tropical cyclone track and intensity forecasts are generally improved in the higher-resolution system.

On 22 June 2010 the Ensemble of Data Assimilations (EDA) was introduced into operations to provide additional initial perturbations for the EPS. This improved the simulation of initial uncertainties, especially in the early forecast range and over the tropics.

The new approach to the simulation of initial uncertainties provided clear improvements to the EPS spread, particularly in the first few days of the forecast and led to better, more reliable probabilistic forecasts.

The changes introduced on 9 November 2010 included a large number of improvements, including a new cloud scheme and new surface analyses for soil moisture and snow depth. The new snow-depth analysis resolves several of the issues that affected the snow analysis in the 2009/10 winter season. Also the revision of the stochastic schemes used to simulate model uncertainties in the EPS improved the correspondence between EPS spread and forecast accuracy.

Change in model resolution

The following changes were made to the horizontal resolution of the forecasting model on 26 January 2010.

- The resolution of the deterministic model was increased from 25 km (T799) to 16 km (T1279).
- The resolution of the Ensemble Prediction System was increased from 50 km (T399) to 32 km (T639) for the first 10 days of the forecast and from 80 km (T255) to 65 km (T319) thereafter.

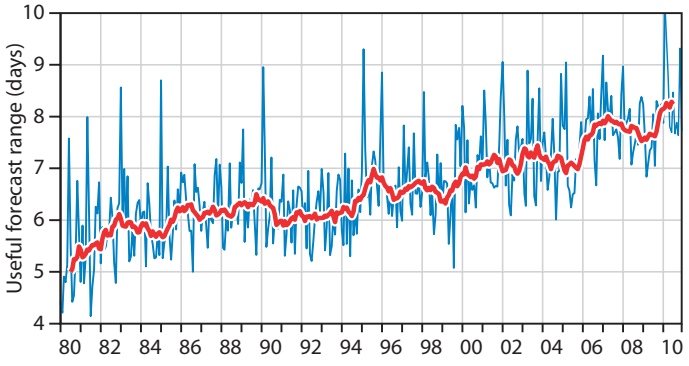
Performance of the deterministic forecasting system

Forecasts have improved steadily from 1980 as a result of improvements in the global observing system, more powerful computers, and advances in the science of ECMWF's data assimilation system and forecasting model. Seven-day forecasts in the northern hemisphere are now more accurate than the five-day forecasts were 25 years ago. Also there has been a marked improvement in the accuracy of the southern hemisphere predictions, mainly due to the use of satellite data. Overall, the forecasts in the northern and southern hemispheres now have a similar accuracy.

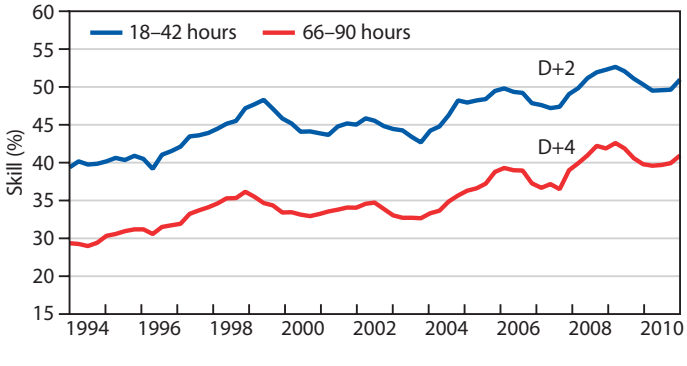
The skill of the deterministic forecast has been consistently good throughout 2010, with the useful range of the forecasts being around eight days for each month (except June for the northern hemisphere).

In February 2010 the useful range of the deterministic forecasts for both the European region and the northern hemisphere exceeded ten days; this was a record monthly performance for the forecasting system. The exceptional scores are partially a result of the large circulation anomalies in the 2009/10 winter.

The anomalies were associated with a strong negative phase of the North Atlantic Oscillation and Arctic Oscillation. Typically cold weather in northern Europe and more active weather systems and heavy rainfall affecting south-west Europe are linked with these patterns. The high scores for the ECMWF model confirm that it performed consistently well in predicting these anomalous weather conditions.



Record performance of the deterministic forecasting system. *The useful range of the deterministic forecasts for Europe reached its highest ever monthly value in February 2010. Overall the performance has been consistently good during 2010. The useful forecast range is determined by the time at which the anomaly correlation for 500 hPa height operational forecasts at 12 UTC reached 60%.*



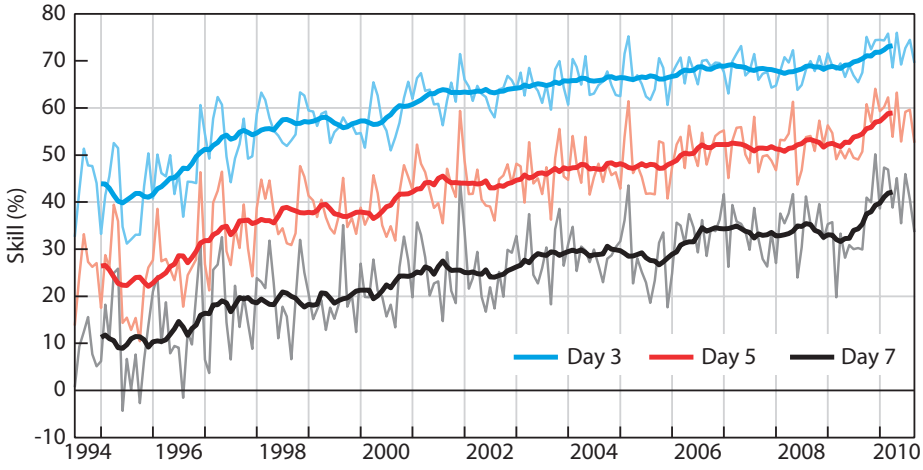
Skill of precipitation forecasts remains high. *The recent skill of the precipitation forecasts from the deterministic forecasting system is below the record levels achieved in 2008 but has remained consistently above the levels reached in previous years. The true skill scores for precipitation forecasts exceeding 10 mm per day are based on verification against observations from European weather stations. Curves show TSS for 24-hour accumulations for 18–42 hours and 66–90 hours from forecasts starting at 12 UTC. Scores are calculated over three-month seasons; curves show running average over four seasons to highlight long-term trend. Last point includes summer (June–August) 2010.*

Ensemble Prediction System and monthly forecasts

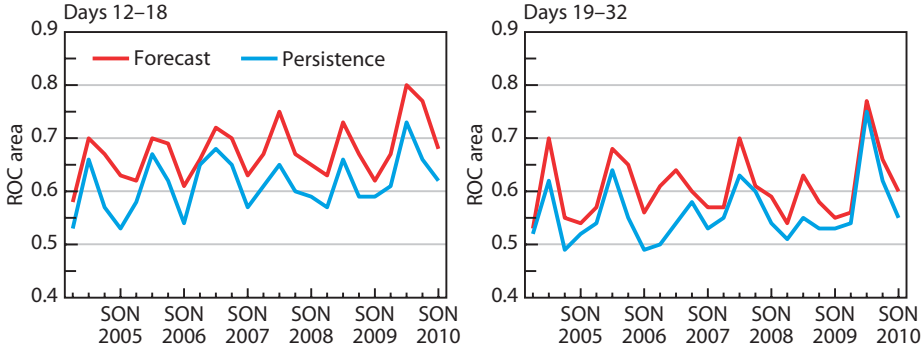
The Ensemble Prediction System (EPS) aims at quantifying the impact of uncertainties in initial conditions and the inability of models to fully represent complex atmospheric processes. Output from the EPS provides forecasters with a range of possible forecasts that can be used to estimate the probability of specific weather events occurring during the forecast period. The EPS has been a key element of ECMWF's operational forecasting system since 1992, and has been upgraded several times.

The exceptional performance of the EPS for winter 2009/10 was followed by the best ever summer scores. This consistent improved performance confirms the benefits of the recent upgrades of the EPS, including the resolution upgrade, revisions to model physics perturbations and introduction of additional initial perturbations based on the Ensemble of Data Assimilations (EDA).

Since March 2008, the monthly forecasting system and EPS have been merged, and extended-range forecasts spanning the monthly time range have been produced by EPS forecasts that are run every Thursday at 00 UTC. The monthly forecasts have continued to perform well. During summer 2010 the monthly forecast gave good early indications of the heavy rainfall in Pakistan and the extreme heat in Russia.



The skill scores of the EPS continue to improve. *The skill score is based on the ranked probability skill score for EPS forecasts of 850 hPa temperature for Europe. The monthly score and 12-month running mean are shown.*



The monthly forecasts outperform the persistence forecasts. *The score used represents the trade-off between hits and false alarms across a range of thresholds, with the higher the value the better. The results are based on the area under the Relative Operating Characteristic (ROC) curve for the probability that the 2-metre temperature will be in the upper third of the climate distribution. Scores are calculated for each three-month season since autumn (September–November) 2004 for all land points in the extratropical northern hemisphere. The red curve shows the score for the monthly forecasting system for forecast days 12–18 (7-day mean) and 19–32 (14-day mean). As a comparison, the blue curve shows the score for persistence of the preceding 7-day or 14-day period of the forecast.*

Overall view of ECMWF's Technical Advisory Committee, 6–9 October 2010

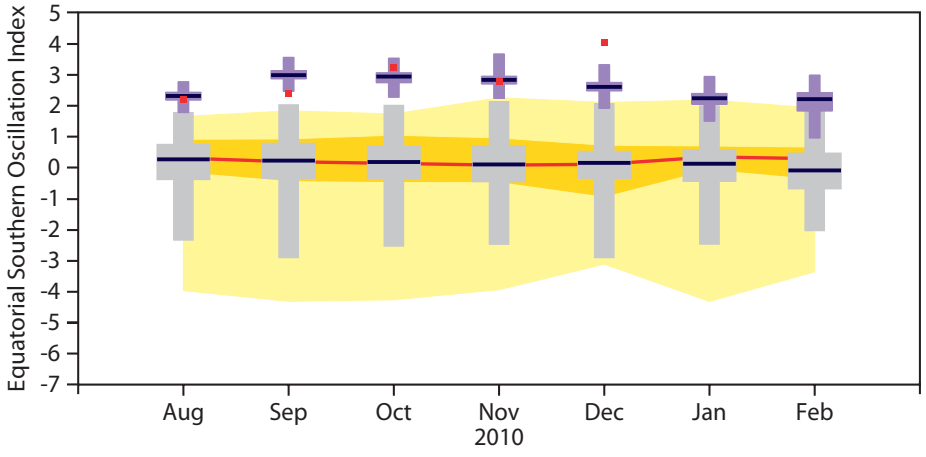
In regard to its overall view of the operational forecasting system the Committee:

i. congratulated ECMWF on the consistently good results from all its forecasting systems in the previous year, in particular for the outstanding forecasts produced in February, when scores for the northern hemisphere and Europe reached their highest level ever, and on maintaining its leading position in global weather forecasting;
ii. was encouraged by the clear positive impact from the introduction of the ensemble of data assimilations and by the promise shown by the new cloud microphysics;
iii. was encouraged to learn that monthly forecasts for temperature are beginning to show some evidence of skill out to week 3, in particular during high-impact episodes such as the recent extreme temperatures experienced in Europe this winter and Russia this summer;
iv. appreciated the continued positive trend shown in the verification of severe events;
v. noted that the skill of the ensemble prediction system, already high, continues to increase, both in absolute terms and in relation to other centres;
vi. welcomed the increased use of ensemble products in the Member States for input into downstream models and at longer time ranges;
vii. was pleased to note that the scores for ECMWF wave forecasts continue to improve and maintain their lead over other centres' forecasts;
viii. with respect to deterministic forecasts of weather parameters:
   - acknowledged that precipitation forecasts show some improvement at day 3–4 but there remains a tendency to overpredict light rain;
   - noted, with some concern, that the significant cold bias over Europe at night continued during the last winter and spring;
   - noted that the severity of the cold temperatures during the last winter had emphasised model problems with snow depth and density but was encouraged by the work which has been undertaken to improve the snow analysis and forecasts.

Seasonal forecasts

During an El Niño or La Niña the changes in the temperature of the equatorial Pacific Ocean affect tropical rainfall and winds. These in turn cause changes in worldwide weather patterns. The seasonal forecasting system performed well in predicting the evolution of El Niño and La Niña during 2010. The peak of the El Niño at the end of 2009 was well represented, together with the atmospheric response over the Pacific region. However, the strong North Atlantic Oscillation pattern that dominated the European weather between December 2009 and February 2010 was not well captured until one month before the start of the event.

Forecasts initiated from February 2010 onwards gave a good indication of the impending La Niña event that became fully established in the autumn. This La Niña event has been exceptional in terms of the strength of the atmospheric response, as can be measured by the Equatorial Southern Oscillation Index (ESOI). The seasonal forecasts successfully predicted the extreme nature of the ESOI.



The seasonal forecast successfully predicted the extreme nature of the Equatorial Southern Oscillation Index (ESOI). *For each month in the seven-month range of the forecast started in August 2010, the plot shows three distributions. The forecast (purple boxes and whiskers), the model climatology derived from the hind-cast (grey boxes and whiskers) and the analysis covering the hind-cast period 1981–2005 (yellow and orange bands). For each distribution, the graph shows the median, the interval between the lower and upper terciles, and the interval between the 5th and 95th percentiles. Monthly verification data to end of 2010 is shown by red squares. ESOI is defined as the difference between the standardized monthly anomalies of sea level pressure averaged over an area of the eastern Pacific (80°W–130°W, 5°N–5°S) and over Indonesia (90°E–140°E, 5°N–5°S).*

Use of satellite observations

During 2010, ECMWF has continued its sustained effort to improve and extend the usage of satellite data. The main achievements were the improvement and extension of all-sky microwave radiance assimilation, successful use of radiances and Atmospheric Motion Vectors (AMV) from the GOES-13 and MTSAT-2 satellites, and improvement of the timeliness for the early delivery suite by the assimilation of MetOp-A and NOAA-19 microwave data from EARS (EUMETSAT Advanced Retransmission Service) and Pacific RARS (Pacific Regional ATOVS Retransmission Services).

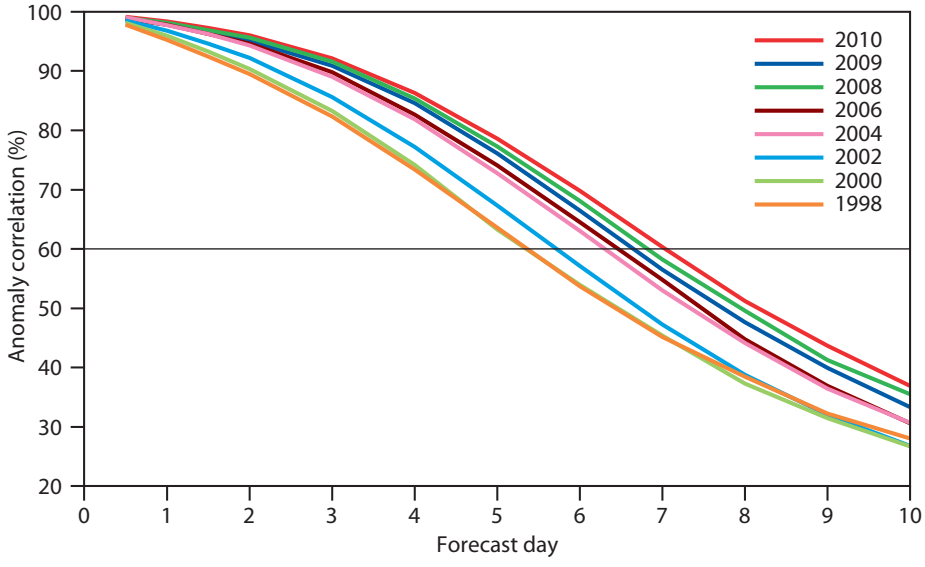
To prepare for further improvements of satellite data usage, ECMWF has implemented the passive monitoring of new data types: AVHRR winds from MetOp-A, winds from the Chinese satellites FY-2D and FY-2E, radiances from the MWTS and MWHS instruments onboard FY-3A, GPS radio occultations from the TERRA SAR X satellite, and ozone from the SBUV-2 instrument onboard NOAA-19.

Significant technical progress has been made towards the implementation of real-time processing, monitoring and assimilation of data from the SMOS (Soil Moisture and Ocean Salinity) satellite. The assimilation of these novel observations will potentially lead to a significant improvement in the analysis of the soil moisture.

As part of its operational activities, ECMWF responded quickly to a series of data quality and availability anomalies. Corrective actions were taken when appropriate.

Ocean wave forecasts

The ocean wave forecasting system continued to perform well. Over the past 12 years there have been large improvements in forecast skill of significant wave height. When verified against the analysis it is seen that in the northern hemisphere forecast skill has increased by two days. The same improvement is noted in the southern hemisphere, whilst in the tropics forecast skill has increased by three days.



Improving forecasts of significant wave height. *The verification results show that nowadays forecast skill in significant wave height is more than 7 days while 12 years ago skill was only just over 5 days. The skill is measured by the time the anomaly correlation remains greater than 60%.*

Early warning of severe weather

ECMWF forecasts are used by its Member States and Co-operating States to provide early warnings of severe weather to their customers, including civil protection agencies and the public. A number of ECMWF products, such as the Extreme Forecast Index, have been developed specifically to assist users in exploiting the information available from ECMWF's forecasting systems. ECMWF also provides access to a range of its products for Member States of the World Meteorological Organization. Major severe weather events, including the devastating floods in Pakistan in July and the extreme heat during the summer in Russia, were well forecast. Forecasting system upgrades improved the ability to predict the intensity of tropical cyclones and of heavy precipitation events.

ECMWF's strategy puts the early warning of severe weather as one of its principal goals. This is particularly important as severe weather is predicted to become more frequent and more intense in some parts of the world under climate change. ECMWF can contribute to the development of strategies to mitigate and adapt to climate change. In particular, ECMWF's emphasis on the provision of reliable predictions of severe weather can be seen as a key contribution to help society adapt to the dangers and threats associated with global warming.

The Extreme Forecast Index (EFI) was developed at ECMWF as a tool to provide general guidance on potential extreme events. By comparing the EPS distribution of a chosen weather parameter with the model's climatological distribution, the EFI indicates occasions when there is an increased risk of an extreme event occurring.

Two major severe weather events of 2010 were the devastating floods in Pakistan in July and the extreme heat during the summer in Russia. These were well forecast at both the medium and extended range by the EPS. Also the Atlantic hurricane season has been extremely active, as predicted by the seasonal forecasting system.

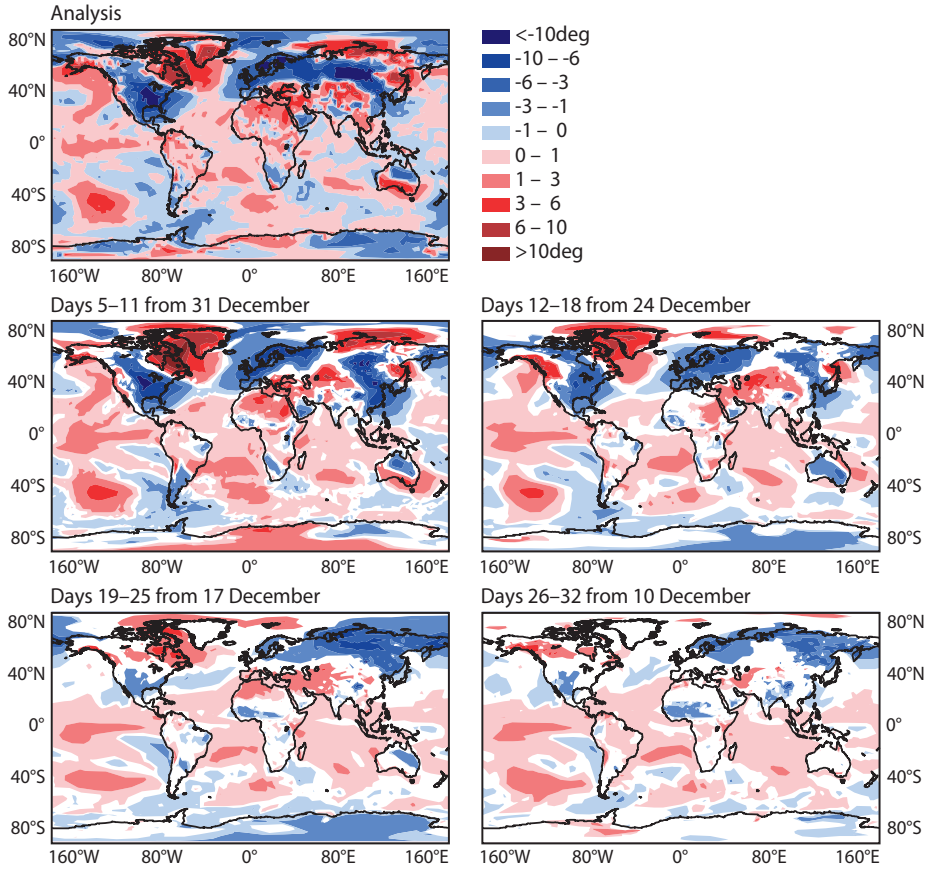
In Europe there was a cold period in January. The following month's storm Xynthia, one of the most damaging storms of the last decade, caused significant damage and loss of life. The development of Xynthia was forecast by both the deterministic and ensemble forecasting systems, and the EFI indicated the likely occurrence of strong winds and heavy rainfall.

Through the year there were a number of heavy precipitation events leading to damaging flash floods (e.g. the flash flooding in the Liguria region of Italy in October). Early warnings of these events were provided by the EFI. Similarly, the EFI gave early warning of strong winds (e.g. the exceptionally strong Bora winds in the Adriatic in March).

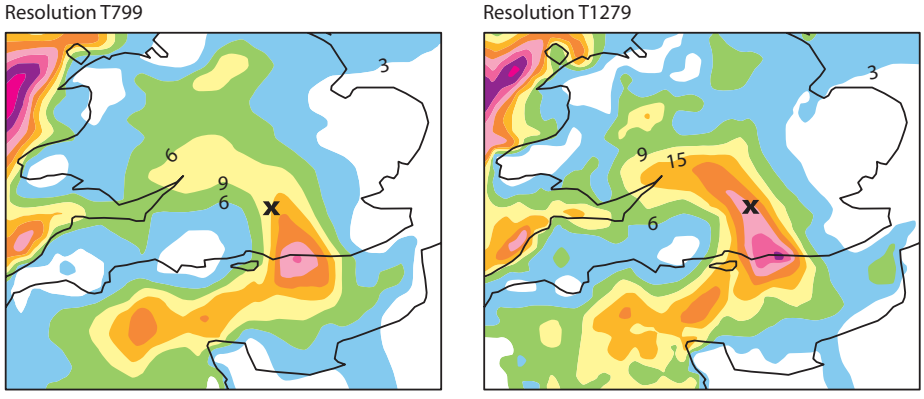
Cold period across northern and western Europe

In early January temperatures were substantially colder than normal across the whole of northern and western Europe. This was associated with a circulation pattern affecting the northern hemisphere: over East Asia, this period produced extreme snow (a 50-year record) for China (Beijing), Korea and then Japan. At the same time, Florida experienced its coldest temperatures for 50 years. This period was well predicted by the monthly forecast two weeks ahead with some indication of the large-scale hemispheric pattern also at longer lead times.

During the cold period, southern England was affected by exceptional snowfall. This was well forecast by the operational system. However, the forecast from the new higher-resolution system, which was in pre-operational testing at that time, provided a good example of the extra detail, especially on the intensity, that can be captured in the new system.



Monthly forecast predicted cold temperatures for Europe in January 2010. *The monthly forecast from mid-December indicated that parts of Europe would be colder than normal in the first week of January. This signal became more prominent with later runs of the monthly forecast. The top-left panel shows the analysed anomaly of 2-metre temperature (°C) for the week 4–10 January. The four lower panels show the monthly forecasts for that week made on 31, 24, 17 and 10 December.*



Forecast of exceptional snow over southern England. *Comparison of the precipitation totals (liquid water equivalent) shows that the new high-resolution model (16 km, T1279, bottom) provided more detail, particularly about intensity. Results are shown for the period 00 UTC on 5 January 2010 (T+0 h) to 09 UTC on 6 January 2010 (T+33 h). The cross marks ECMWF, where 27 cm of fresh snow was measured. This melted down to about 20 mm of rainfall equivalent, which is much closer to the high-resolution forecast (~18 mm).*

Examples of the early warning of exceptionally strong winds and heavy rainfall

Strong winds

On 10 March an exceptional, damaging strong wind event (Bora) affected countries along the eastern and northern Adriatic coasts. In Dolenje, western Slovenia, winds gusts to 133 km/h (more than 70 knots) were recorded. The EFI gave early indication of the event several days in advance. Wind speeds in excess of 110 km/h were forecast in the affected area.

Heavy rainfall

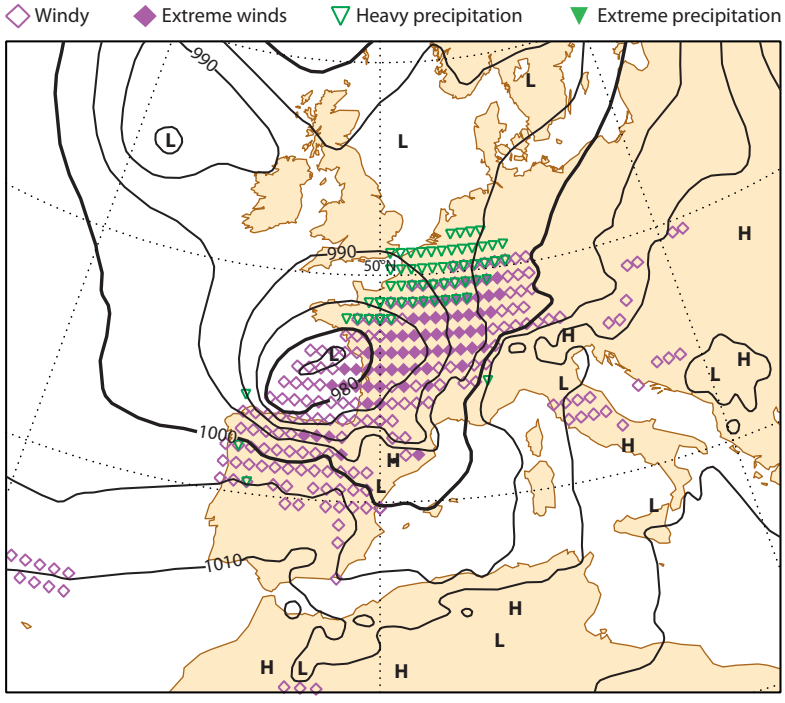
On 4 October there was heavy rainfall of up to 200 mm in 24 hours that caused flash floods and mudslides in the Liguria region of Italy. The EFI provided a consistent signal of localised extreme rainfall in the days leading up to the event.

Storm Xynthia

In February, storm Xynthia caused significant destruction across western Europe, along its path from Portugal through Spain and France to Germany. Over 70 people lost their life, and economic losses are estimated at several billion euros.

Xynthia originated from a sub-tropical low pressure system in the Atlantic on 27 February and developed into an intense storm during that day, striking Portugal and northern Spain. Xynthia reached the French Atlantic coast during the night of 27–28 February and the following day left a trail of damage caused by extreme winds and heavy rain. Also there was a storm surge along parts of the French coast.

The development of Xynthia was consistently forecast by both the deterministic forecasting system and the EPS several days in advance. The track of Xynthia was well forecast by the high-resolution model. In addition, the Extreme Forecast Index confirmed that strong winds and heavy rainfall were very likely, giving forecasters a high confidence in the predictions.

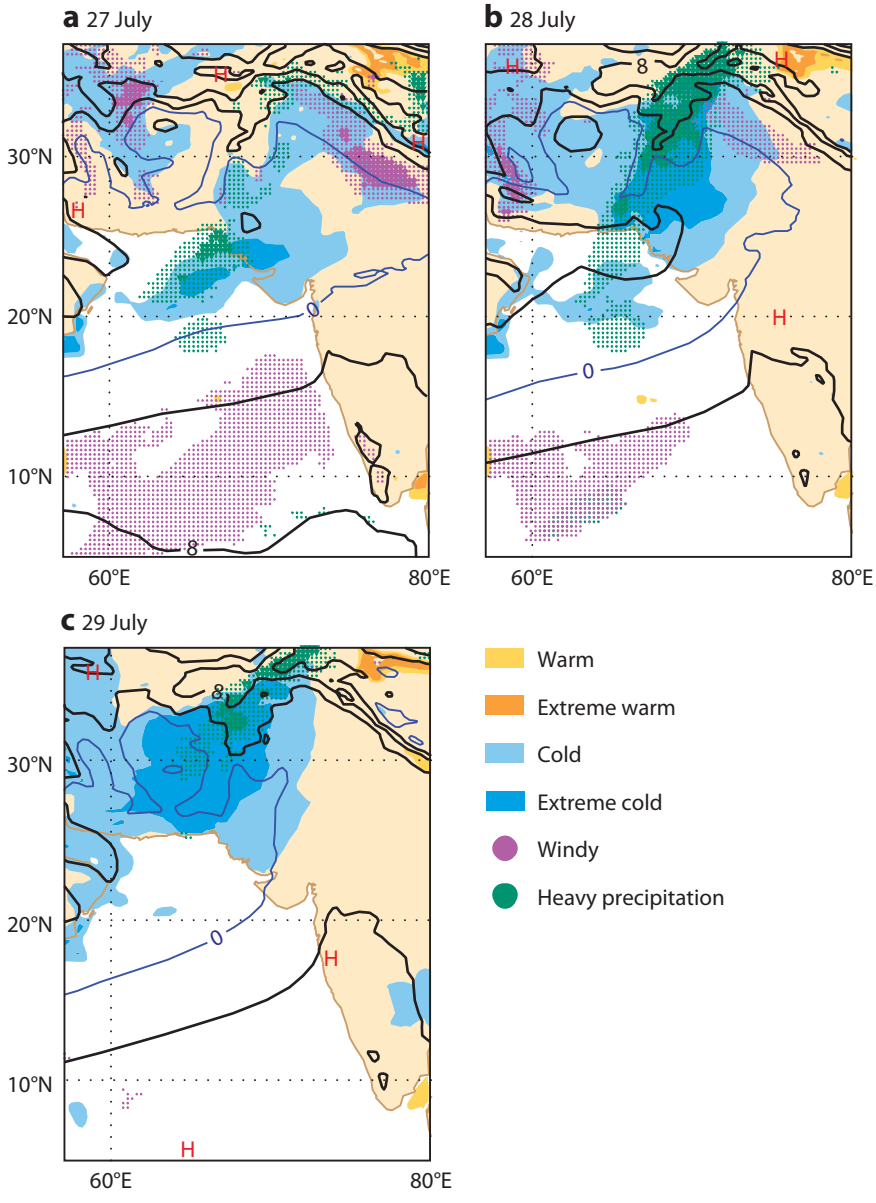


Early warning for winter storm Xynthia, February 2010. *The high-resolution deterministic model and EPS provided good forecasts of the track and likelihood of extreme weather. The forecasts were initialised at 00 UTC on 25 February. Contours show the sea-level pressure field for 00 UTC 28 February as forecast by the deterministic model. Coloured symbols show the locations of strong winds (purple symbols) and heavy rainfall (green symbols) given by the Extreme Forecast Index for 28 February. Filled-in symbols indicate greater risk of extreme events.*

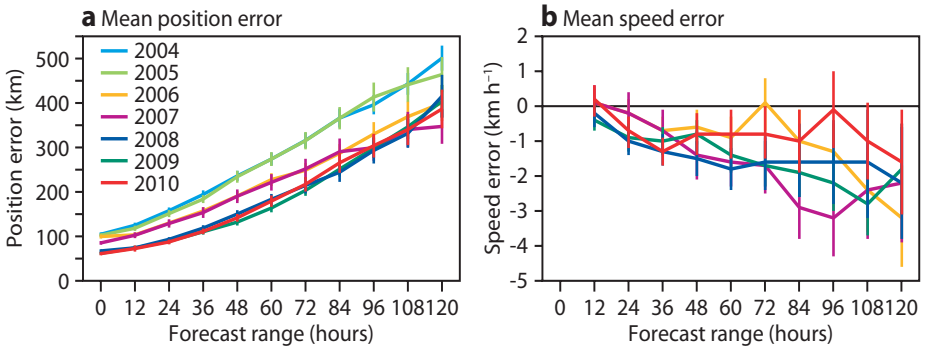
Flooding in Pakistan

In the summer of 2010 Pakistan suffered devastating flooding following extreme monsoon rainfall. The ECMWF forecasting systems (deterministic and ensemble) consistently predicted the exceptional rainfall in Pakistan at the end of July 2010. The monthly forecast picked up the anomalous nature of the rainfall well in advance.

Closer to the event, the Extreme Forecast Index gave a clear signal for exceptional precipitation at the extreme, high end of the climatological distribution. Also the EPS medium-range forecasts indicated significant probabilities of precipitation amounts higher than 200 mm in four days, while the high-resolution deterministic forecast indicated that the four-day total could be as high as 400 mm in some areas.



Warning of heavy precipitation in Pakistan and parts of India. *The Extreme Forecast Index (EFI) had a clear signal with values close to 1 (maximum risk) for precipitation well above climate values. The sequence of three plots showing the EFI values for Pakistan and neighbouring parts of India depicts the build-up of the heavy precipitation event from 27 to 29 July. Shown are the EFI categories for Pakistan and neighbouring India for three consecutive days: (a) 27 July, (b) 28 July and (c) 29 July 2010. EFI charts are available to the national hydrometeorological services of WMO Members via log-in access to the ECMWF website.*

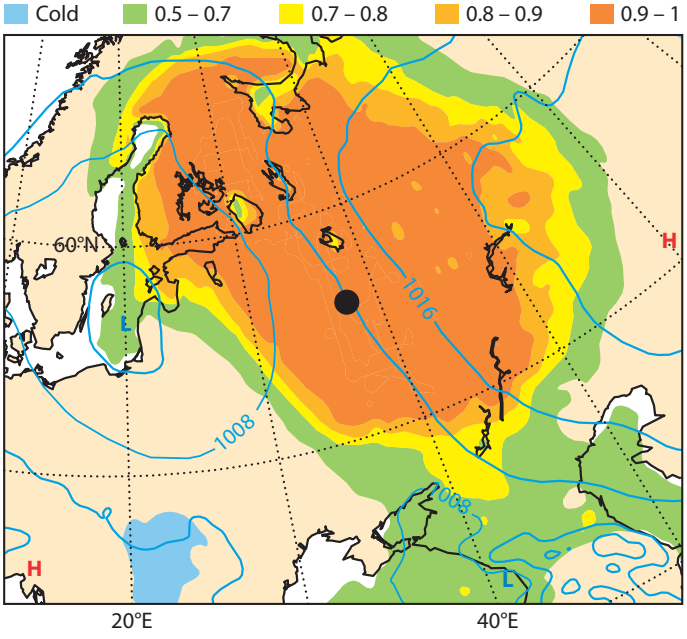


Steady improvement in the predictions of tropical cyclones. *There has been a steady improvement in the predictions of the position and speed of tropical cyclones. (a) The mean position error. (b) The mean speed error (negative values indicate that the forecast speed is too slow). The uncertainty in the scores in indicated by the 90% confidence interval; there are substantially fewer events at later forecast steps than earlier in the forecast and hence there will be greater uncertainty in the scores at the later ranges. Verification is against the observations reported in real time via the WMO Global Telecommunication System. Results are shown for 12-month periods ending on 31 December 2010.*

Heat wave in Russia

Summer 2010 was the hottest summer ever recorded in Russia. Droughts and wild fires reduced the wheat harvest by more than one third and acrid smog cost almost 5,000 lives. The ECMWF forecasting system performed well in indicating the heat wave up to three weeks in advance and consistently forecasting the high temperatures in the medium range.

The highest observed temperatures occurred during the last week of July and the first week of August when temperatures soared to record values of up to 39°C at Moscow Domodedovo airport and Moscow Observatory. The ECMWF ensemble forecast indicated a high likelihood of the extreme temperatures four days ahead.



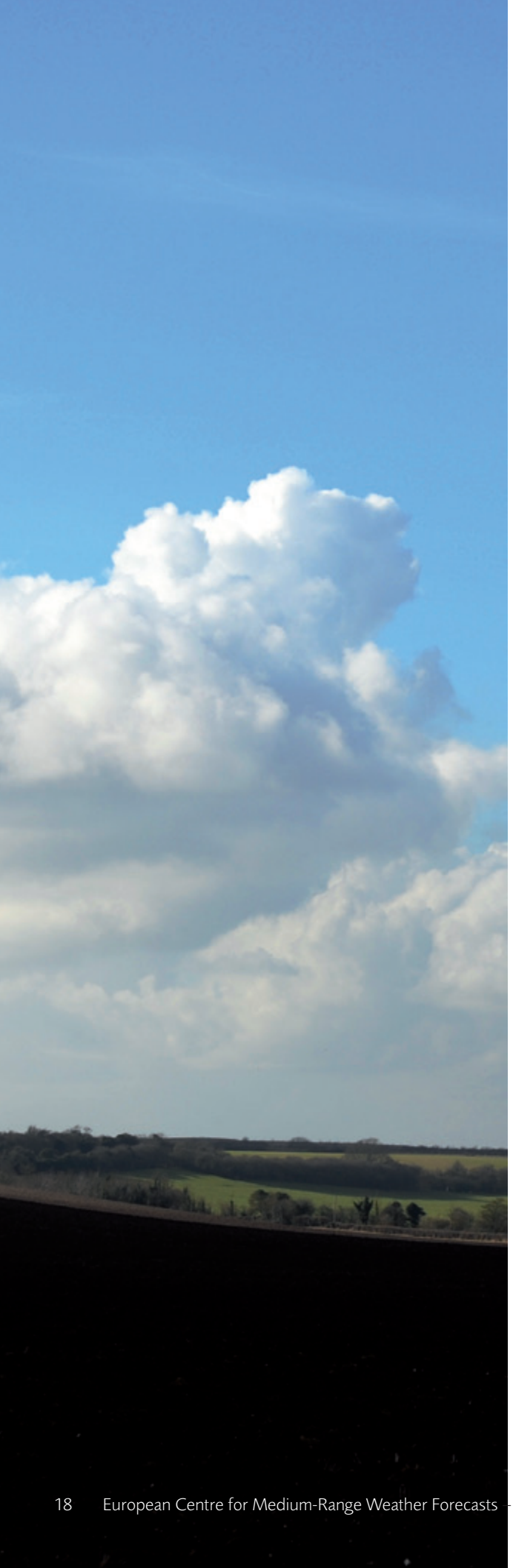
Warning of extreme temperatures in Russia. *There is an extensive area with high values of the Extreme Forecast Index (EFI) from the Ural Mountains to the western borders of Russia. The EFI for Moscow (black dot) is close to 1 (corresponding to the highest probability of temperatures above the climate maximum values) and a significant risk of extremely hot weather is also forecast for large parts of Finland. Shown is the four-day forecast of the EFI from 00 UTC on 25 July 2010.*

Tropical cyclone forecasts

Since April, the seasonal forecast predicted significantly enhanced activity for the 2010 Atlantic hurricane season, forecasting up to twice the average number of tropical storms. This is consistent with the forecast of the transition from El Niño to La Niña conditions: La Niña typically contributes to increased Atlantic hurricane activity by decreasing the vertical wind shear over the Caribbean Sea and tropical Atlantic Ocean.

After a slow start, the 2010 season has been extremely active: in total there were 19 named tropical storms (average 10) and 12 hurricanes (average 6).

Developments of the forecasting system have resulted in substantial improvements to the quality of tropical cyclone forecasts in recent years. For the last three years, the forecast has on average predicted the location of tropical cyclones three days ahead to within 200 km of the observed position. This compares with position errors of around 300 km in previous years. The model has a tendency to move the tropical cyclones more slowly than is observed, showing a speed bias of one km/hour on average. The increase in resolution in January 2010 significantly reduced the tropical cyclone intensity errors, continuing the improvements made in earlier model upgrades.



Research highlights

ECMWF has a wide-ranging programme of research and development directed at improving the quality and variety of forecast products for the medium range and beyond. The benefits of the research are seen in the steadily improving performance of the forecasts and the expanding range of operational products that maintain the status of ECMWF as the world's leading centre for operational global forecasting.

Ensemble of Data Assimilations

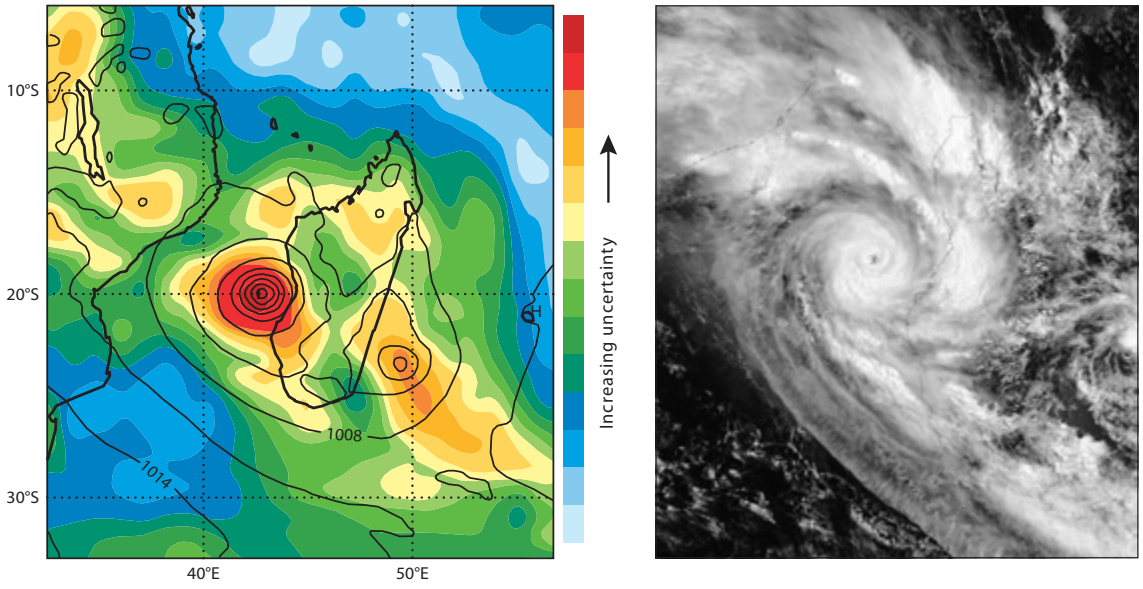
The implementation of the Ensemble of Data Assimilations (EDA) in the Integrated Forecasting System (IFS) took place on 22 June 2010. The EDA provides good estimates of the uncertainty in the atmospheric analysis, taking the density and accuracy of assimilated observations into account. The analysis uncertainty is the main source of forecast uncertainty from the initial time and into the medium range. The EDA will be further developed in the coming years and forms one of the cornerstones of ECMWF's long-term development strategy.

Since its implementation, EDA-based perturbations have been used to improve the initial perturbations for the Ensemble Prediction System (EPS). Another application of the EDA is to provide flow-dependent background error estimates for the deterministic 4D-Var assimilation system.

The EDA system consists of an ensemble of eleven independent, lower-resolution 4D-Var assimilations that differ by perturbing observations and sea-surface temperature fields according to their perceived accuracy: ten use perturbed observations and one uses observations that are unperturbed.

Model uncertainties are also simulated in the ten perturbed assimilations using the stochastic scheme operational since 1999 in the EPS. Analysis uncertainty estimates are difficult to obtain by other means and will provide very valuable guidance for forecasters about the quality of ECMWF's short-range forecasts.

Using EDA information in the deterministic assimilation system is expected to increase the forecast accuracy through a reduction of the analysis error, particularly in regions that contain quickly developing circulation structures such as tropical cyclones and mid-latitude storms.



The EDA provides information about short-range forecast uncertainty. *The 9-hour forecast of uncertainty in the surface pressure associated with the tropical cyclone Fanele close to the coast of Madagascar is evident. The results are based on a 20-member EDA valid at 09 UTC on 20 January 2009, with the mean sea-level pressure field (3 hPa contours) overlaid. Also shown is a satellite picture of Fanele.*

Improved ensemble predictions

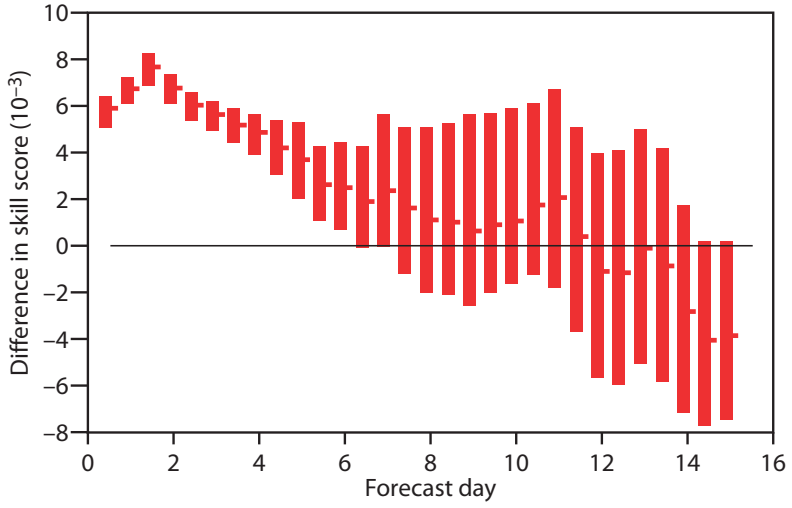
The simulation of initial uncertainties is one of the key aspects in ensemble prediction. Since the implementation of the first version of the ECMWF EPS in 1992, these uncertainties have been represented by initial-time and evolved singular vectors (SVs, i.e. perturbations characterised by the fastest growth). On 22 June the EDA-based perturbations replaced the evolved singular vectors. It has been demonstrated that the new EPS perturbations lead to a higher probabilistic forecast skill.

Following the June change, initial uncertainties are simulated using a combination of EDA-based perturbations and initial-time SVs. The former represent uncertainties that have been growing during the data assimilation cycles while the latter sample perturbation structures that will grow quickly over the first two days of the forecast. The new initial perturbations result in a smoother, more geographically well-balanced perturbation spread at initial time but almost the same spread structure after 24 hours of forecast time.

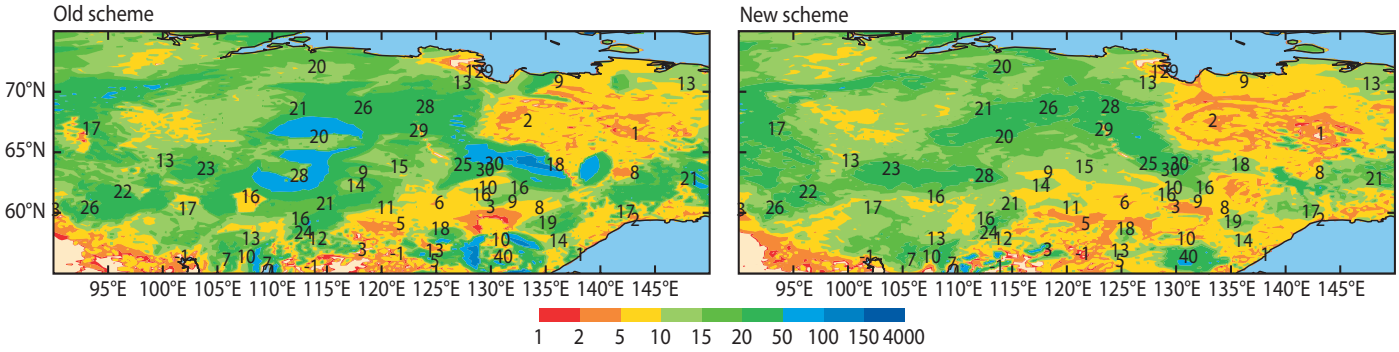
On 9 November 2010 the representation of initial uncertainties and model uncertainties in the EPS was revised. These changes improved substantially the effects of model uncertainties on the EPS, and further improved its reliability.

Verification statistics show that these changes improve the spread–skill relationship over the extratropics in the early forecast range, and over the tropics for the whole forecast range.

European limited-area ensemble prediction systems (e.g. COSMO-LEPS) that use EPS initial and boundary conditions are expected to benefit from the improvement. Probabilistic forecasts from the new EPS version have significantly higher skill in a statistical sense.



Positive impact of the EDA on the EPS scores. *The results show that the EDA has improved the skill of the EPS probability forecasts. Shown is the difference between the average skill of probability forecasts for the 850 hPa temperature over the northern hemisphere of the new and old versions of the EPS, measured by the Ranked Probability Skill Score (RPSS). Positive (negative) differences indicate that the skill of the new ensemble-mean is higher (lower). Red bars show the 5th–95th confidence interval. The average skill has been computed considering 88 EPS forecasts from 12 UTC on 5 October 2009 to 31 December 2009.*



Improved analysis of snow. *The new snow analysis makes better use of synoptic observations of snow-depth using optimum interpolation: it presents a smoother and more correct snow analysis without spurious disk-shaped patterns. The figure shows a comparison of snow depth analysis between the old (left) and new (right) schemes in northern Asia on 30 October 2010. Surface synoptic snow-depth measurements are reported in black on the figure.*

New snow analysis

The 2009/10 winter season in Europe highlighted the importance of a good quality snow analysis. Many areas experienced record snow conditions and cold spells.

Snow can directly affect the accuracy of temperature forecasts communicated to customers and users. Furthermore, the snow mass influences the evolution of soil moisture for up to several months after the snow melts.

Several changes were introduced in operations last winter to address the handling of snow density and the use of surface and satellite observations. In addition, there have been major developments to solve many of the remaining snow analysis issues.

A new improved snow analysis was implemented on 9 November and was used for winter 2010/11. It uses the optimum interpolation (OI) surface analysis scheme, which has been used for 2-metre temperature and humidity analyses for many years.

The higher-resolution (4 km) snow-cover product from NESDIS (National Environmental Satellite, Data, and Information Service) is used in the new snow analysis instead of the 24-km product. In particular, the 4-km NESDIS product provides better snow-cover definition in coastal areas.

For surface synoptic observations, quality control of snow-depth data and a station blacklist have been introduced. Detailed information on rejections of surface data is being generated and stored for subsequent inspection.

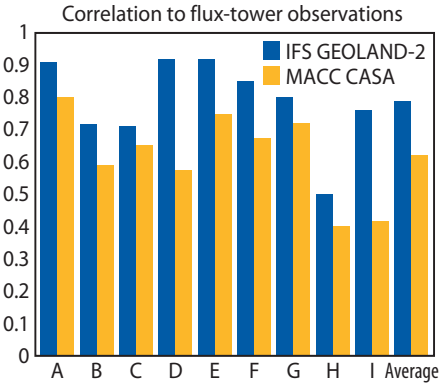
Improved use of satellite radiance data

The performance of the data assimilation system is very sensitive to the specification of the observation errors. In particular, the use of satellite data is strongly influenced by the estimated errors.

Characteristics of observation errors have been investigated for all satellite radiances used in the ECMWF system. Currently, observation errors for radiances are assumed to be uncorrelated in the assimilation system. However, this assumption is questionable because, for example, observation errors for radiances need to include the radiative transfer error which may be spatially or spectrally correlated. Neglecting these correlations or an otherwise poor specification of observation errors can lead to an over- or under-weighting of the radiances in the assimilation.

A study has been carried out to provide guidance for optimising the use of satellite data. It is found that interchannel or spatial error correlations are relatively small after bias correction for most microwave and longwave infrared temperature sounding channels that are not sensitive to the surface (e.g. for most AMSU-A channels currently used). In contrast, some interchannel or spatial error correlations are found for water vapour channels in the infrared or microwave, surface-sensitive channels, and short-wave infrared channels.

Work is now directed at using the findings to refine thinning scales or the observation error covariance specification in the assimilation. For instance, the statistics suggest that more weight can be put on AMSU-A radiances in the assimilation, either by using the data more densely or by lowering the assumed observation error, as error correlations appear to be small. Experiments with these adjustments indeed show a significant positive forecast impact. Consequently, a reduction of observation errors for AMSU-A is planned for operational implementation early 2011.



The new ECMWF land surface scheme performs better than the CASA product. *Shown is the correlation of modelled land carbon dioxide exchange produced by the CASA product (as used in the MACC project) and the new ECMWF land surface scheme (IFS GEOLAND-2) evaluated against flux-tower observations from nine sites.*

Land surface modelling

The Geoland-2 project, funded by the EU, is supporting the development of a third-generation land-surface scheme at ECMWF that includes vegetation phenology and natural land carbon dioxide exchange fully coupled with the energy and water cycles. This activity, started in March 2009, has already resulted in an upgrade of ECMWF's operational system in November 2010. The fixed leaf area index (LAI) was replaced by a monthly climatology based on MODIS satellite data gathered over a nine-year period. This vegetation climatology improves the representation of the seasonal phenological cycle and shows a positive impact on short-term temperature forecasts.

A more realistic representation of the vegetation cycle has been identified as a necessary step towards a scheme with a full coupling of the carbon, water and energy cycles.

A carbon-based evapotranspiration parametrization will be implemented in a future model cycle. This follows from the successful comparison to the so-called 'big-leaf' approach, used in the current operational system, evaluated against numerous field site experiments from the quality-controlled FLUXNET ground-based observing network (http://www.fluxnet.org).

The land carbon dioxide Net Ecosystem Exchange (NEE) fluxes produced by the meteorologically-forced simulations with the new land surface scheme show an improvement compared to the Carnagie Ames Standford Approach (CASA) product currently used by the MACC (Monitoring Atmospheric Composition and Climate) project as boundary conditions. These results are particularly relevant for the monitoring and prediction of atmospheric concentration of carbon dioxide where the land ecosystem represents a major natural sequestration mechanism.

Future research will focus on the representation of tropical forests and the impact of the modelled NEE will be evaluated in collaboration with the MACC project. Data assimilation activities foreseen in the second half of the Geoland-2 project will concentrate on the inclusion of near-real-time LAI information in the IFS land surface analysis.

Views of the Scientific Advisory Committee – October 2010

Extracts from the Report of the Chair of the Scientific Advisory Committee (SAC) to Council

The SAC was impressed by the significant progress in research made over the past year. Successful operational implementation of the 16 km deterministic model and the increased EPS resolution was a good start for the year 2010. The highlight was the implementation of the 10-member EDA system and its coupling to the generation of initial perturbations for the EPS system. The SAC noted with satisfaction that there is now a clearly increased coherence of research activities in data assimilation and ensemble prediction. The extensive experience gained over the years in ensemble prediction techniques has clearly benefitted the Centre's work on designing the new EDA system. The EDA will become an important tool in the ECMWF forecasting system. Considerable computing resources will be required for its development.

The operational performance of the deterministic and ensemble prediction systems has been excellent. The SAC congratulates the Centre for maintaining high levels of forecast skill in Europe and Northern Hemisphere over the past year. This achievement is a result of dedicated work over many years, and the operational implementations over the past 12 months are representative of the longer term efforts of the Centre. Timeliness of the product deliveries to the Member States has also been the best ever.

The SAC was pleased to note that the world-wide lead of the Centre has been maintained in the medium-range weather forecasting, now for over 30 years. The differences among forecast centres have become smaller in the recent years for the deterministic system. However, the Centre has maintained a substantial lead with the EPS.

The SAC was impressed by the achievements of the MACC project in assimilation and forecasting of atmospheric greenhouse gases, reactive gases, and particulate matter. Demand for these services is large, and increasing in the foreseeable future. The MACC activities are building the capacity to meet future challenges, and are very well in line with the Centre's new convention, which now includes Earth-system monitoring. A MACC-II application is under preparation. The SAC congratulated the Centre for its excellent coordination of the MACC project.

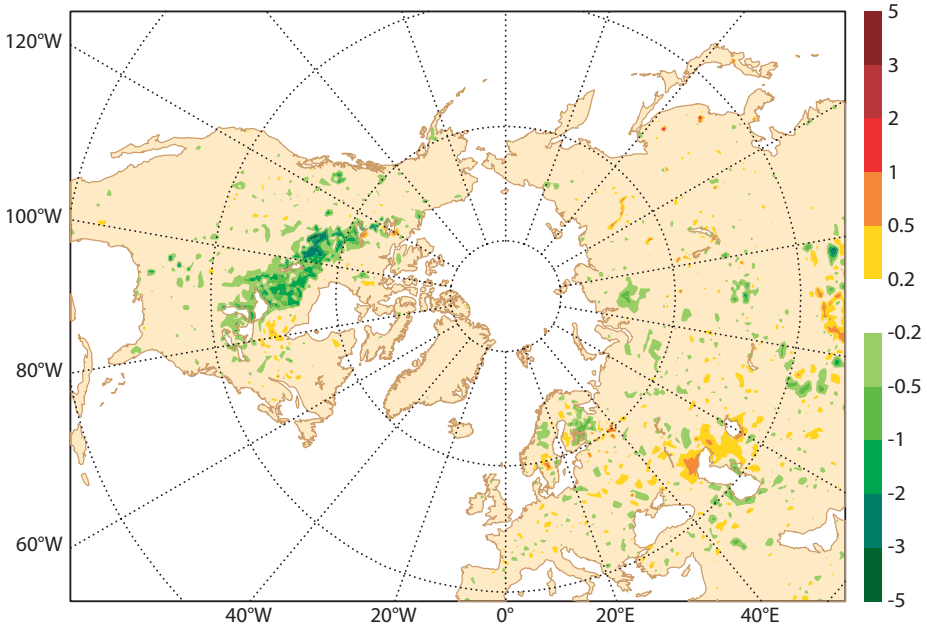
Lake model development

The Fresh-water Lake (FLake, http://lakemodel.net) model has been investigated for a possible future operational implementation. It is capable of predicting the vertical temperature structure and mixing conditions in lakes of various depths (between 5 and 50 metres) on time scales from a few hours to a few years.

The FLake model is highly suitable for NWP and climate modelling due to its low computational cost. It is based on a two-layer parametric representation of the time-evolving temperature profile and on the integral budgets of heat and kinetic energy. The structure of the stratified layer between the upper mixed-layer and the basin bottom, namely the lake thermocline, is described using the concept of self-similarity (assumed shape) of the temperature-depth curve.

The same concept is used to describe the temperature structure of the thermally active upper layer of bottom sediments and of the ice. The lake modelling activity in Europe has benefited from coordinated efforts under the SRNWP (Short Range Numerical Weather Prediction) consortium, which has established up-to-date lake datasets.

Deterministic forecasts and long climate-range integrations have been performed with the FLake model incorporated in the land surface parametrization of the IFS. The thermal inertia effect of lakes can clearly be seen in the results. This leads generally to a cooling in spring and a warming in autumn as expected, and an improvement to the 2-metre temperature forecasts in the proximity of northern hemisphere lake regions.



Using the FLake model improves the 2-metre temperature forecasts in the proximity of northern hemisphere lake regions. *Shown is the mean absolute error of the 2-metre temperature for two-day forecasts in spring 2008. Green colours indicate an improvement which is associated with a cooling.*

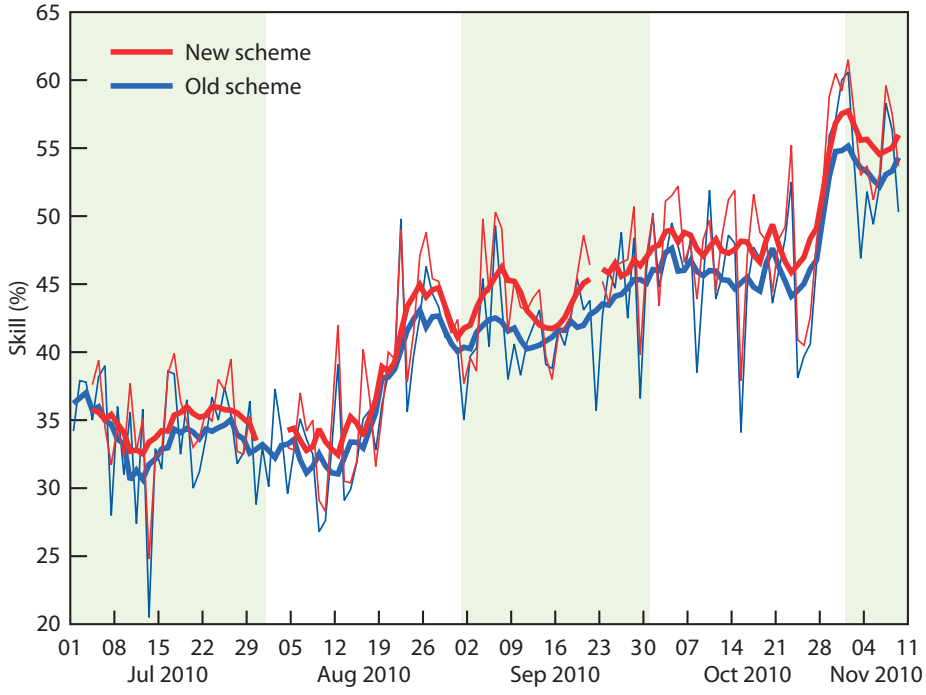
New cloud microphysics

A new cloud microphysics scheme was implemented in the operational model on 9 November 2010. The new scheme has significantly modified the cloud parametrization in terms of the number of prognostic variables, formulation of mixed-phase and precipitation processes, and numerical methods.

Liquid and ice cloud condensates are now determined by explicit microphysical processes rather than by a fixed function of temperature. This results in a wider variability of super-cooled liquid water occurrence and mixed phase cloud, as inferred from observations of different cloud regimes across the globe. Also precipitating rain and snow are now advected by the wind, particularly significant over mountainous areas for producing persistent downstream precipitation to the lee of the orography.

Many aspects of the model are systematically improved with the new scheme. For example, the total ice water path in the atmosphere that is now radiatively active shows good agreement with satellite estimates and the model errors in precipitation and radiation are both reduced compared with satellite-derived climatologies. Also deterministic forecast scores show positive impact in the northern hemisphere summer and a noticeably improved verification of precipitation against rain gauge observations.

Overall, this is a major change to the representation of moist physics and a significant milestone towards a more physically-based cloud and precipitation parametrization scheme in the operational model. Future developments will include an optimisation of the scheme in winter conditions and further refinements of physical processes.



New cloud microphysics scheme improves precipitation forecasts. *The time series of precipitation skill scores shows that there is a consistent improvement in the version of the model that includes the new microphysics scheme. The score is calculated for 24-hour precipitation accumulations for the two-day forecast valid at 00 UTC verified against observations from global surface synoptic stations; it is a combined measure of the skill for three precipitation categories (no precipitation, light and heavy). The operational model at the time (operational until 11 November 2010) is shown along with the version of the model with the new cloud microphysics scheme (operational from 12 November 2010). Thin lines correspond to daily values and the bold lines correspond to a running weekly average. The general increase in skill of both models from summer into autumn is part of the normal annual cycle in precipitation forecast skill. The skill is determined by (1-SEEPS), where SEEPS is the stable equitable error in probability space.*

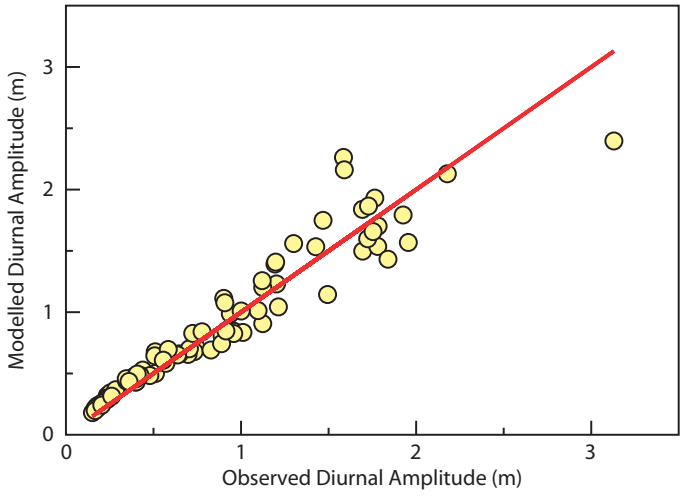
Ocean waves

Work has been carried out that should be regarded as a first step in the development of a tightly coupled atmosphere, ocean-wave, ocean circulation model.

The effects of wave breaking on mixing of heat and momentum in the upper ocean have been studied in order to assess the relevance of sea state information on vertical ocean transports. The mixed-layer scheme is based on a solution of the turbulent kinetic energy equation and combines effects of wave breaking, Langmuir turbulence, buoyancy and dissipation of turbulence. Owing to wave breaking it is found that there are large deviations from the usual law-of-the-wall near the ocean surface.

The model was applied to the three-month period of March until May 1995 at a location in the Arabian Sea when observations of wind speed, air-sea fluxes and sea-surface temperature were made by Woods Hole Oceanographic Institution. Sea state information was not measured and therefore was obtained from the ERA-Interim reanalysis.

The diurnal cycle of sea-surface temperature in the Arabian Sea can be quite profound, and the mixing process of momentum and heat plays an important role in the size of the amplitude of the diurnal cycle. It is found that the model is capable of giving a realistic representation of the diurnal cycle. In addition, it is found that, as expected, near the surface ocean mixing is largely determined by wave breaking.



Good agreement between simulated and observed diurnal amplitude in sea-surface temperature. *Results are from a location in the Arabian Sea for the three-month period starting from 1 March 1995. The amplitude of the diurnal cycle is well simulated by the mixed-layer model. However, when effects of wave breaking are excluded the model overestimates the amplitude to a large extent.*

Contribution to climate studies

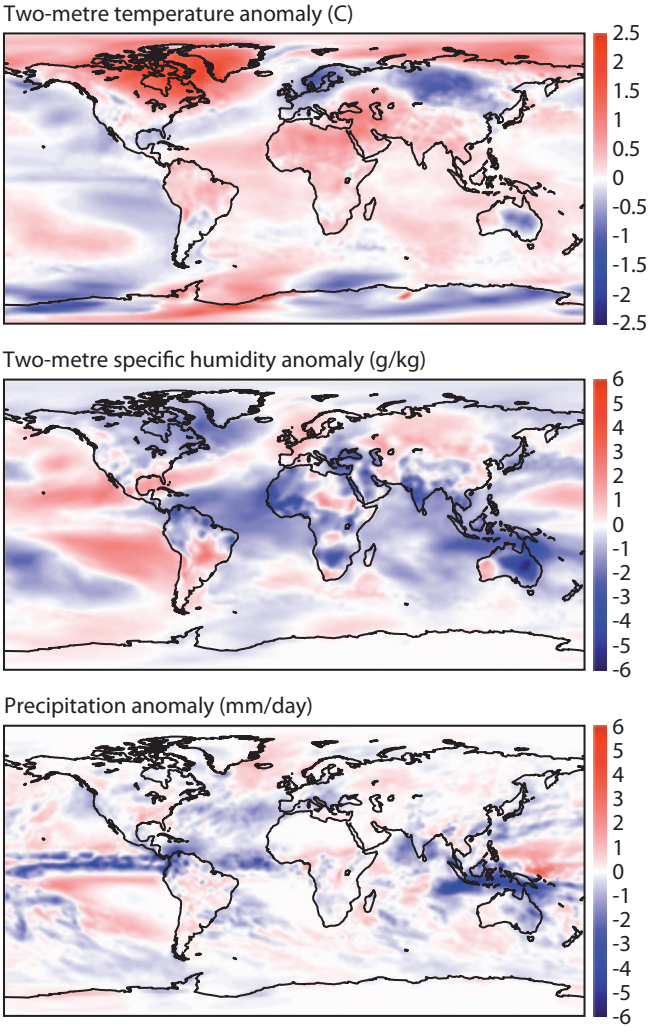
ECMWF's core mission is to develop its global weather forecasting system, run it operationally and distribute the results to its Member States. Through its core activity, ECMWF is contributing significantly to climate change studies although it does not directly carry out climate simulations.

Reanalysis

Reanalysis is the reprocessing of past observations with a modern data assimilation system. Since reanalyses are produced with fixed, modern versions of data assimilation systems used for NWP, they are more suitable than operational analyses for studies that require an observational record of the state of either the atmosphere or its underlying land and ocean surfaces.

In 2006 the ERA-Interim project was initiated in order to prepare for a new, more ambitious ECMWF reanalysis to succeed ERA-40, which covered the period 1957 to 2001. The ERA-Interim reanalysis covers the period from 1 January 1989 onwards, and continues to be extended forward in near-real time. An extension from 1979 to 1989 is currently in preparation.

Gridded data products include a large variety of 3-hourly surface parameters, describing weather as well as ocean-wave and land-surface conditions, and 6-hourly upper-air parameters covering the troposphere and stratosphere. Vertical integrals of atmospheric fluxes, various synoptic and daily monthly averages, and other derived fields have also been produced. Information about the current status of ERA-Interim production and availability of data on-line, along with near-real-time updates of various climate indicators derived from ERA-Interim data, can be found on the Internet at http://www.ecmwf.int/research/era.



ERA-Interim data can be used to assess changes in temperature, precipitation and humidity for the year 2010 relative to 1989–2009 averages. *Temperature changes reflect the exceptional warming experienced in 2010 over most land areas, especially at high latitudes in the northern hemisphere. In most places higher (lower) temperatures are associated with more (less) moisture; exceptions are Australia, Brazil, southern Africa, and Russia, which suffered a well-publicised dry heat wave during the summer of 2010. Very large positive anomalies in humidity and precipitation over most of Australia, consistent with a strong La Niña, caused extreme flooding in large parts of Queensland.*

ERA-Interim data is used by numerous scientists world-wide for many different purposes, both in research and for method development, and increasingly in the commercial sector (e.g. for assessing wind energy potential). The ECMWF public data server has now registered more than 5,000 distinct users of ERA-Interim data. A new public section of the ERA-Interim web pages dedicated to climate monitoring has been created, containing a selection of graphical products based on monthly data from ERA-Interim and ERA-40. User-selectable graphics show time series of global and regional averages of monthly-mean reanalysis data for a variety of climate indicators; these include directly analysed parameters, a large selection of model-generated parameters, and derived fluxes and large-scale circulation indices.

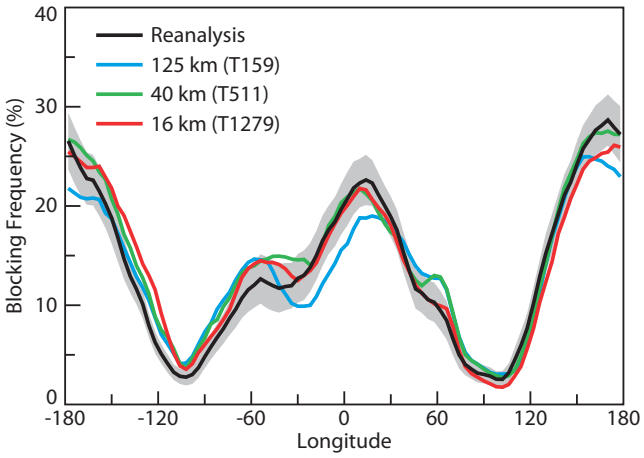
An advantage of using reanalysis for climate change assessment is that the data is provided with only a short time delay, and it presents a global and coherent view of many essential climate variables in a physically consistent framework. For example, ERA-Interim data can be used to monitor changes in near-surface temperature, humidity, and precipitation in near-real time and at all locations globally.

To help prepare for a new global atmospheric reanalysis spanning the entire 20th century, a collaborative research project proposal coordinated by ECMWF has been selected for funding from the European Union's Seventh Framework Programme. The three-year ERA-CLIM project, which starts in January 2011, will prepare the input data and assimilation systems necessary for the new reanalysis, which is planned to begin production in 2014.

A large part of the project resources will be dedicated to data recovery and reprocessing efforts by partner institutions in Europe and elsewhere. A specific focus will be put on upper-air observations made in the first half of the 20th century. Several pilot reanalyses will be delivered by ECMWF, including (i) a century-long, low-resolution reanalysis based on surface-observations only, (ii) a high-resolution, land-surface reanalysis for the same period, and (iii) a comprehensive reanalysis from 1979 to present at moderate-to-high resolution.

An important feature of ERA-CLIM is that all reanalysis data, including observation feedback information, will be made publicly available via ECMWF Data Services. The ERA-CLIM partner institutions are ECMWF, the UK Met Office, Météo-France, EUMETSAT, University of Vienna, University of Bern, University of Lisbon, Russian Research Institute for Hydrometeorological Information and the Chilean Meteorological Service.

Reanalysis activities have been complemented by other projects: the ERA-NCAS project funded by the NERC (National Environment Research Council) in the UK and the CMUG (Climate Model User Group) project funded by the ESA Climate Initiative. A contribution from CNRS (Centre National de la Recherche Scientifique) in France is aimed at improving the quality of atmospheric reanalysis data for ocean applications.



Increasing the horizontal resolution improves the climate of the ECMWF model in terms of the frequency of blocking. *These results show that increasing the horizontal resolution from 125 km though 40 km to 16 km leads to significant improvements in the simulated frequency of occurrence of Euro-Atlantic blocking events compared with the results from reanalysis. Shown is the frequency of occurrence of blocking days (for winters (December through March) of the period 1960–2007.*

Sensitivity of the ECMWF model climate to horizontal resolution

It is widely believed that increasing the resolution of weather and climate models to accurately resolve mesoscale phenomena in the atmosphere can dramatically improve the fidelity of the models in realistically simulating and predicting the large-scale flow of the atmosphere. One particularly important feature of the large-scale flow is blocking over the North Atlantic and Pacific Oceans. A faithful simulation of blocking characteristics gives additional confidence to the simulation of regional climate change, particularly over the European area.

Following the World Modelling Summit at ECMWF in May 2008, the US National Science Foundation (NSF) recognised the importance of this issue and a resource was made available that could be used to test the benefit of employing very high resolutions. The NSF offered the dedicated use of the Athena supercomputer over a period of six months from 1 October 2009 to 31 March 2010. Athena is a Cray XT-4 computer with 18,048 computational cores (ranked number 30 in the TOP500 list of supercomputers as of November 2009). The 'Athena Project' is an international collaboration including groups from Japan and the USA as well as ECMWF.

As part of the project ECMWF has been carrying out long atmosphere-only integrations covering the period 1960–2007 to investigate the impact of increased resolution on the climate of the ECMWF model, including severe and other high-impact weather events. Resolutions employed include 125 km (T159), 40 km (T511), 16 km (T1279) and 10 km (T2047, 1989–2007 only) with 91 levels in the vertical. Results show that increasing the resolution to 40 km and 16 km leads to significant improvements in the simulated frequency of occurrence of Euro-Atlantic blocking events, extratropical cyclone characteristics and near-surface winds in the tropical Pacific. Problems in simulating the Madden-Julian Oscillation remain, however, even at resolutions of 16 km and 10 km.

EC-Earth

ECMWF collaborates with the EC-Earth consortium, which is developing a new fully-coupled atmosphere-ocean-land-biosphere model that is usable from seasonal to decadal climate predictions and climate projections. The project is run by a consortium of scientists from Member States under the leadership of KNMI. It builds upon ECMWF's world-leading coupled model system to develop a climate model suitable for 'seamless' predictions across a wide range of time scales. ECMWF provides technical support to the project with a consultant fully supported by EC-Earth funding.

In 2010, a version of the EC-Earth model suitable for phase five of the Coupled Model Intercomparison Project (CMIP5) experimentation has been finalised. A number of multi-decadal simulations covering pre-industrial and 20th century conditions have been performed by the members of the consortium.

Projects concerned with decadal predictability

THOR (Thermohaline Overturning – at Risk?): establishes an operational system that will monitor and forecast the development of the North Atlantic thermohaline circulation on decadal time scales and assess its stability and the risk of a breakdown in a changing climate.

COMBINE (Comprehensive Modelling of the Earth System for Better Climate Prediction and Projection): advances Earth-system models for more accurate climate projections and for reduced uncertainty in the prediction of climate and climate change in the next decades.

VALOR (Value of the RAPID Array): assesses the value of the RAPID array of ocean observations at 26.5°N in the Atlantic for predictions of the Atlantic meridional overturning circulation and its impacts on climate.

Decadal forecast experiments

ECMWF is involved in three projects concerned with decadal predictability: THOR and COMBINE funded by the EU's Seventh Framework Programme, and VALOR funded by the UK's Natural Environment Research Council (NERC).

There are two key scientific questions to be addressed in the THOR project.

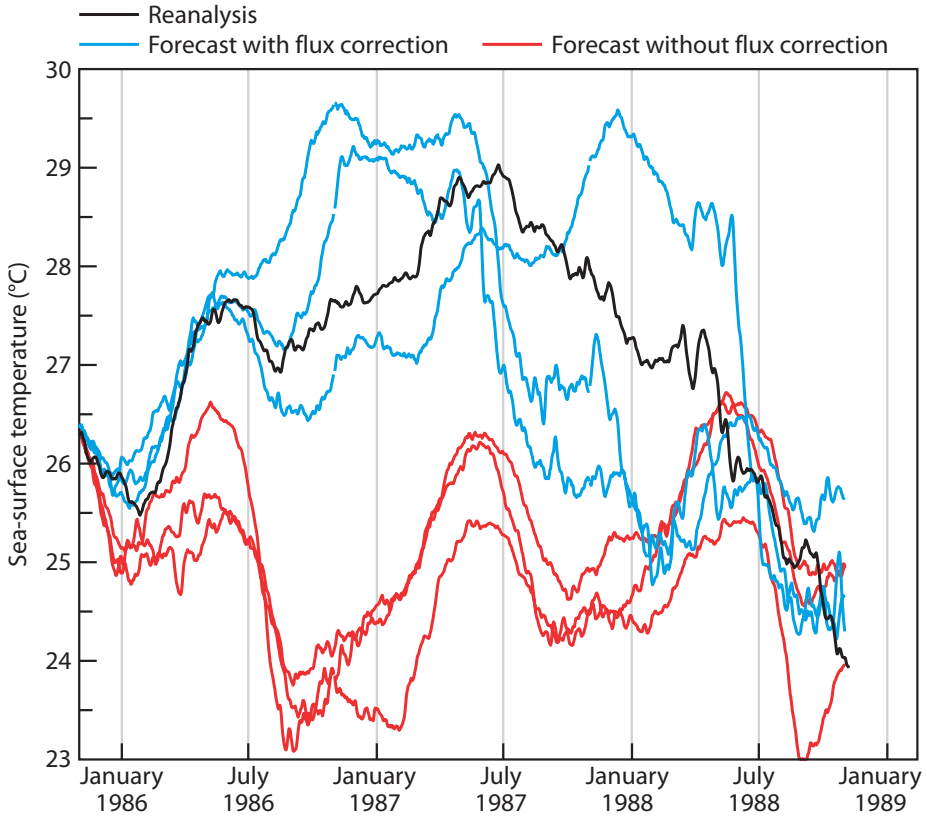
- To what extent is the thermohaline circulation predictable on the decadal timescale using realistic ocean-atmosphere initial conditions?
- What is the impact of such initial conditions relative to external forcing on the skill of thermohaline circulation predictions?

To address these issues, the coupled atmosphere-ocean forecasting system has been tested in multi-decadal integrations with different external forcing by greenhouse trace gases. The system consists of the IFS (Integrated Forecasting System) and NEMO (Nucleus for European Modelling of the Ocean). Two three-member ensemble hindcasts 25 years long were started once every ten years over the period 1965 to 1985 (i.e. in 1965, 1975 and 1985). The control integration includes the interannual evolution of global mean annual greenhouse gases, while in the second experiment the greenhouse gas concentration is kept constant at the actual values.

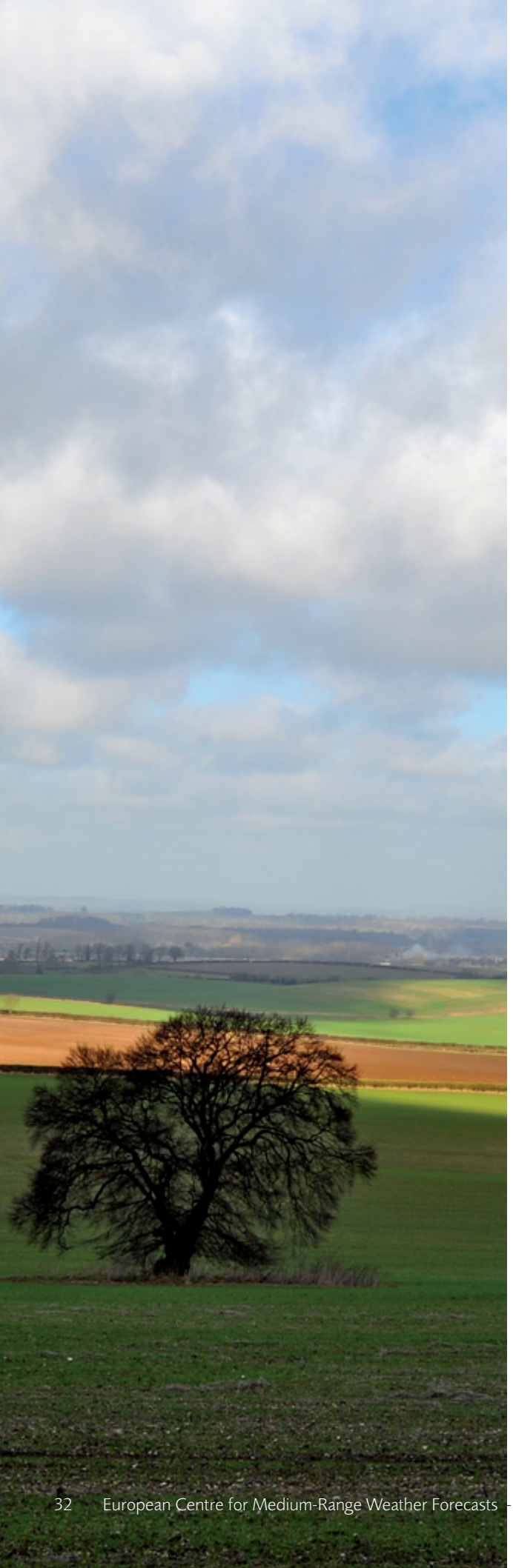
In COMBINE, different strategies for the initialisation of coupled decadal simulations are tested. The strategies currently under investigation are anomaly initialisation and flux correction. The aim of anomaly initialisation is to initialise the model by adding observed anomalies to the model climate. Using this strategy, the model drift is avoided by initialising the model in a biased state. On the other hand, the aim of using flux correction is to keep the state of the ocean model unbiased (i.e. close to the observed climatology).

The use of either momentum or heat flux correction or a combination of them is being investigated. The results using flux correction show that it is possible to remove most of the model drift in the tropical Pacific, which leads to an improved mean state. The modification of the mean state seems to largely improve the interannual variability for the El Niño/La Niña (variations in the temperature of the surface of the tropical eastern Pacific Ocean) and the Southern Oscillation (variations in surface pressure in the tropical western Pacific) compared with a non-flux corrected forecast. Early results also indicate an improved skill in forecasting El Niño events in the first two to three years. The correction in the mean state also seems to improve the precipitation pattern in the tropics.

The ECMWF contribution to VALOR is concerned with the impact of sea-ice variability on decadal variability and predictability in the North Atlantic region. In collaboration with the EC-Earth consortium, a two-level thermodynamic-dynamic sea-ice model (LIM-2) has been activated in the ECMWF version of NEMO. Experiments to evaluate the coupled model climatology, including sea-ice variability, are under way. Decadal ensemble simulations with interactive sea-ice will be performed during 2011.



Improved skill in forecasting El Niño events. *Use of heat and momentum flux correction improves the forecast of El Niño in the first two to three years of a decadal forecast. Shown is the sea-surface temperature for the Nino3.4 area of the Pacific (10°N–10°S, 120°W–170°W) for the ocean reanalysis along with one ensemble forecast consisting of three members with and without heat and momentum flux correction. The initial date for the forecasts is 1 November 1985.*



Monitoring the environment

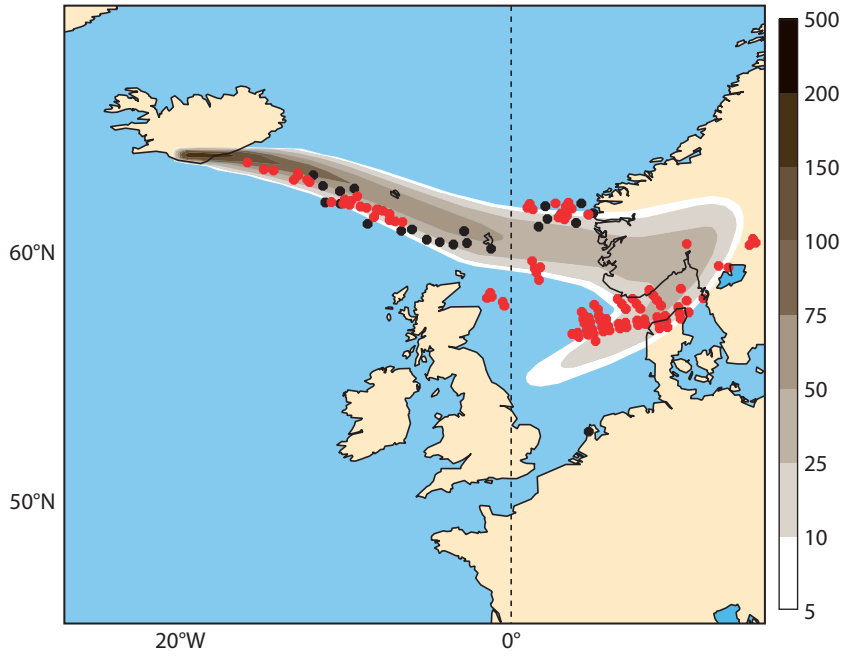
ECMWF contributes actively to the European GMES (Global Monitoring for Environment and Security) initiative, which aims to make environmental information more readily available to scientists, policy makers, industry and citizens. ECMWF's principal contribution is through its coordination and implementation of a sequence of collaborative projects undertaking the development and pilot operation of a core atmospheric environmental monitoring service.

MACC (Monitoring Atmospheric Composition and Climate; www.gmes-atmosphere.eu) uses the modelling and data assimilation approach of numerical weather prediction to monitor the composition of the Earth's atmosphere and predict air quality with a focus on Europe. It provides data that is important for understanding climate and validating and improving the models used to predict climate change. Information important for protecting health and for efficient use of solar power generation is also supplied.

MACC is the collaborative project that is currently developing the central atmospheric monitoring component of Europe's GMES (Global Monitoring for Environment and Security) initiative, and is funded under the European Union's Seventh Framework Programme. MACC is undertaken by a 45-member consortium. Eleven of the participants are national meteorological services from ECMWF Member and Co-operating States.

Aside from overall coordination of the project, ECMWF's main roles in MACC are as follows.

- Acquire and pre-process the observations of atmospheric composition needed for data assimilation and validation of products.
- Lead development and operate a system for estimation of emissions from wildfires.
- Work with partners on the modelling of greenhouse gases, reactive gases and aerosols, and to develop global data assimilation for these variables.
- Operate the global system routinely for monitoring and forecasting purposes.
- Provide central web, data and validation services.

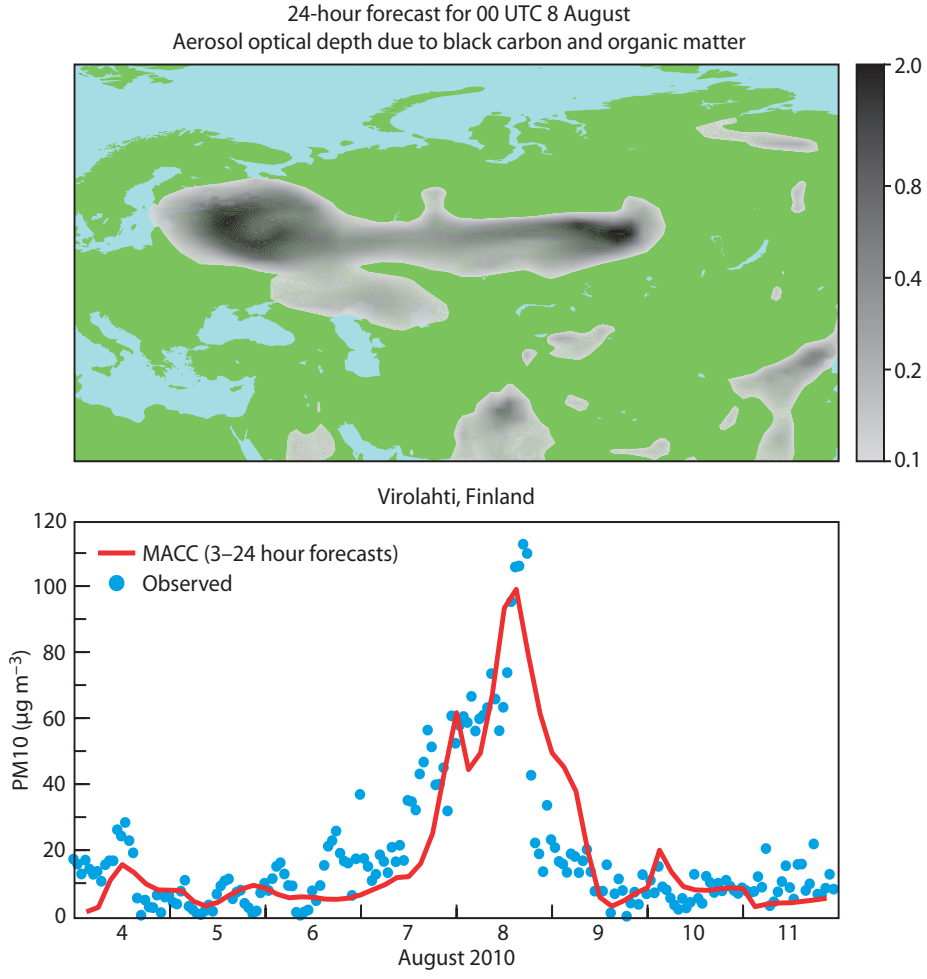


Trajectory of simulated aerosol injected by Eyjafjallajökull. *The map shows a 39-hour MACC forecast for 15 UTC on 15 April, depicting the trajectory of simulated aerosol injected steadily at 5 km height starting at 08 UTC on the previous day. The legend indicates only a relative magnitude of column aerosol tracer. The dots show where high-resolution infrared sounding data from the satellite-borne AIRS (black) and IASI (red) instruments were rejected by ECMWF's operational data assimilation due to excessive aerosol contamination during the period 09–21 UTC on 15 April. The MACC derived aerosol distribution could thus potentially have improved the operational use of satellite data if it had been included in the operational weather prediction system.*

During 2010 the regular running of the near-real-time global system was supplemented by a new stream running about six months behind real time, in particular to provide carbon dioxide and methane fields for improving estimates of surface sources and sinks. A global reanalysis for the period 2003 to 2010 was also started. Preparations began for an important move of the near-real-time system so that it runs under ECMWF's operational supervision.

Model development included substantial progress on incorporating chemistry and related modules into the Integrated Forecasting System (IFS) to eliminate the overheads of the current approach that involves coupling the IFS with global chemical transport models.

Special attention was paid to key events, most notably related to the plume from the eruption of Eyjafjallajökull in April and May and the fires in western Russia in July and August.



MACC forecast shows the spread of aerosols from wildfires in western Russia. *The map shows the net aerosol optical depth of black carbon and organic particulates in a 24-hour MACC forecast for 00 UTC on 8 August. The build-up of high values over eastern Finland is confirmed by the accompanying plot, which shows densities of PM10 – particulates with sizes up to 10 micron – as derived from successive 24-hour MACC forecasts and as measured at a ground station near Virolahti, close to the Finnish border with Russia.*

The volanic eruption of Eyjafjallajökull in Iceland caused major disruption to air transport in April 2010, and some disruption continued into May. Although responsibility for short-term forecasting advice for aviation lay with the London Volcanic Ash Advisory Centre for this event, plume forecasts were promptly set up using MACC's integrated global weather/composition forecasting system, as they were by several MACC partners operating regional transport models. The global forecasts were run daily to five days ahead and made available on the MACC website, attracting a considerable number of additional visitors to the site.

Persistent hot, dry weather conditions over western Russia in the summer of 2010 were accompanied by widespread wildfires in late July and August. Smoke from the fires was largely advected eastward, but anticyclonic circulation and transport over the Baltic and Nordic countries also occurred. Aerosol forecasts from MACC were able to simulate the spread of the smoke.

In the aerosol forecasts, a tendency of the model to underestimate values is corrected at short range by the assimilation of aerosol data from the MODIS instruments on NASA's Terra and Aqua satellites. The underestimation has been linked in turn to an underestimation of emissions due to an unusually large contribution from burning peat; this also manifests itself in an underestimation of carbon monoxide unless corrected by assimilation of observational data such as that derived from the IASI instrument on Europe's MetOp satellite. Aerosol forecasts in general have been improved recently by correction of an erroneously high rate of deposition of particles.

MACC provides:

- 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 service providers

Data and products

New forecast products are being developed in direct response to user requirements. Some are graphical products available via the ECMWF website and some are distributed to Member States. The efficient distribution of data and products produced by ECMWF is essential to support operational activities as well as research and development. By the end of 2010, ECMWF disseminated 10,000,000 analysis and forecast products per day to Member States and Co-operating States via its privately managed network and website, and to non-members via the WMO's Global Telecommunication System. The forecast performance is being monitored using a set of new headline scores that has been developed following detailed consultation with the Member States.

MARS and Data Services – facts and figures

In July 2010, the daily dissemination amounted to 13 million products with a volume of 900 gigabytes. In addition, ECMWF disseminated 38 gigabytes of monthly forecast products (once per week) and 32 gigabytes of seasonal forecast products (once per month).

There are 39 commercial destinations, of which 15 are maximum charge customers, as well as one NMHS for non-commercial use. Of the 39 commercial users, 26 hold a contract with a Member State that has delegated the data delivery to ECMWF.

There are more than 4,400 users registered for the ERA-Interim data server.

MARS has been upgraded to support the increase in data volumes archived and retrieved following the implementation of the higher-resolution forecasting system.

The product generation system has been enhanced to support the higher-resolution forecasting system, i.e. the T1279 deterministic forecast and the T639 EPS.

Progress has been made in the migration of ECMWF's applications to the new GRIB encoder/decoder software (GRIB API) which has been in use in operations since June 2010.

Web services

ECMWF's website is a major, easily accessible and much appreciated resource for the international meteorological and research communities. Users can access computer facilities and run experiments as well as accessing a wide range of information such as operational and research data, training material and data on Special Projects. The ECMWF web servers continued to provide a stable and reliable service.

The two-year project to re-engineer the Centre's web services is on track for operational implementation in summer 2011. Its primary goal is to provide for forecasters a significantly improved service (ecCharts) for accessing ECMWF's graphical forecast products. In addition, the ecCharts service will be supported as part of the operational provision of forecast products. Users will be able to visualise forecast products in ways that are more appropriate to them and perform actions such as changing forecast parameter accumulation and probability thresholds, and zooming and panning of maps. As a result, they will be able to customise products more specifically for their needs.

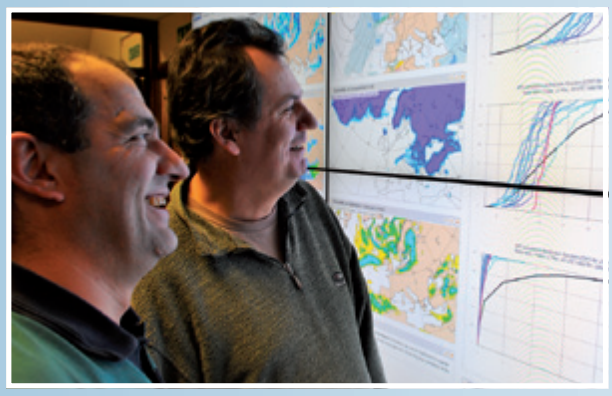
The ecCharts will provide access over the Internet using both web browsers and computer-to-computer standard 'web services'. The service has been designed to meet forecasters' needs and, as such, will be highly responsive (for interactive use), highly available (so it can be relied upon for operational use) and scalable (so new capacity can be added as required).

MARS and Data Services

The Meteorological Archival and Retrieval System (MARS) is the main repository of meteorological data at ECMWF. It contains operational and research data as well as data from Special Projects. MARS data is freely available to registered users in the Member States and Co-operating States. There has been an extension of MARS to support the archiving of new data, such as sea-surface height measurements from the JASON-2 satellite mission and output from the Ensemble of Data Assimilations (EDA), the ALADIN limited-area ensemble forecasting (LAEF) model and the new extended-area European Wave Model.

High-resolution products for WMO Members have been made available for downloading from the ECMWF data server. Also the WMO 'Essential' dataset, available via WMO's Global Telecommunication System, has been extended to include extra parameters and time steps, as well as ensemble mean and ensemble standard deviation.

In June 2010 the Council decided to remove the information cost for data from the ECMWF Catalogue of archived products. This will have important implications, for example, for the conditions of use of data from the data servers.



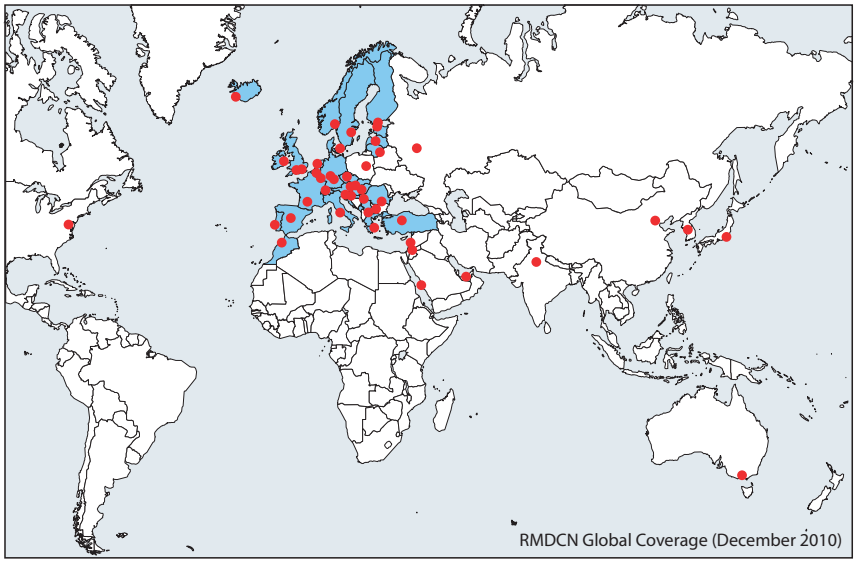
Regional Meteorological Data Communication Network

The Regional Meteorological Data Communication Network (RMDCN) provides a network infrastructure for the connections between ECMWF and its Member States and Co-operating States. In addition it has most of the connections for WMO Regional Association VI that are part of the WMO's Global Telecommunication System. Over time it has expanded to encompass other geographical areas with connections to North America, Asia and Australia. ECMWF manages the project and monitors the network on behalf of the connected user sites following an agreement with WMO.

The reliability of the network is very high, having achieved 100% monthly availability from January to November and 99.99% in December.

The Dynamic Multipoint Virtual Private Network (DMVPN) project, which provides a large-scale operational pilot service for a backup of the RMDCN over the Internet, was launched in 2010. The specific set-up for the RMDCN backup allows automatic failover of a failed RMDCN connection via dynamically established encrypted tunnels over the Internet. So far, six sites are part of this network: ECMWF and Sweden are acting as gateways (or 'hub sites') between the DMVPN network and the RMDCN, while Italy, Norway, Romania and Bulgaria have been set up as clients (or 'spoke sites').

While the RMDCN has been delivering a well-received operational service for a decade, paving the way to the 'next generation' of the RMDCN service started in 2010. In early 2010, ECMWF organised a technical workshop for the RMDCN community, covering network technologies suitable for a future RMDCN service. Following initial discussions within the WMO Task Team on the RMDCN and the ECMWF Technical Advisory Committee (TAC), agreement has been reached for the initiation of a procurement process for a new RMDCN. The plan envisages the definition of requirements during 2011 for the future provision of a managed data network for the RMDCN, taking into account the requirements of both the ECMWF dissemination system and the WMO Information System (WIS). The TAC has established a Subgroup to assist ECMWF in the definition of requirements, including their relationship to the use of the Internet, and to review the subsequent procurement process. The latter is envisaged to take place in 2012, with a possible migration to a follow-on network scheduled for mid-2013.



The RMDCN connects ECMWF and its Member States and Co-operating States. *The RMDCN is currently being used operationally by 44 national meteorological services, ECMWF, EUMETSAT (two sites) and one disaster recovery site for the Netherlands. The map shows the coverage of the RMDCN as at December 2010.*

The new clustering technique

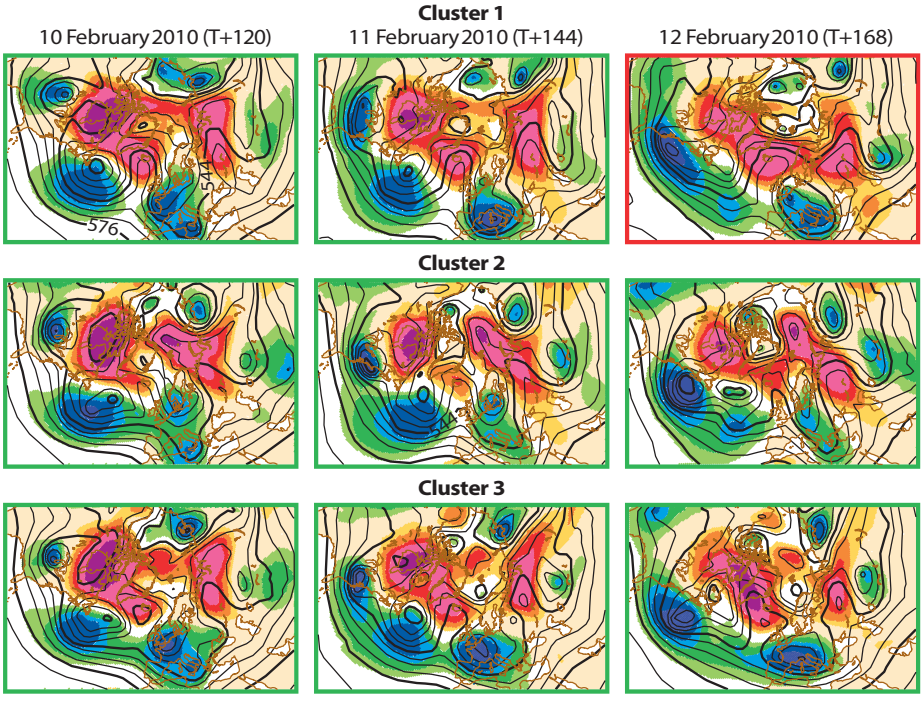
The clustering uses the 500 hPa geopotential forecast fields and is performed for four different time windows: 3–4, 5–7, 8–10 and 11–15 days. Between one and six clusters are produced, depending on the dispersion within the ensemble. The new system includes two components:

- A set of four fixed climatological regimes for each season, computed using 28 years of reanalysis data (ERA-Interim and ERA-40).
- A daily clustering of the forecast fields from the EPS, similar in principle to the current EPS clustering but using a different algorithm. The daily clustering determines weather scenarios, defined as the ensemble members closest to the centroid of each cluster.

Product development

The new clustering application for the EPS is now fully operational: products are available in dissemination, MARS and on the web. The new approach provides the user with:

- A set of weather scenarios that appropriately represent the ensemble distribution.
- An additional objective measure of the differences between scenarios in terms of large-scale flow (by using the attribution of each weather scenario to the climatological regimes).
- A flow-dependent assessment of forecast performance (under development).



New EPS clustering provides a set of weather scenarios and associates them with climatological regimes. *The panels show the cluster scenarios (representative members) for clusters 1 to 3 (rows) at forecast ranges 5, 6 and 7 days (columns). Here all three clusters at days 5 and 6 are associated with the negative North Atlantic Oscillation (NAO) pattern (green frame); at day 7, one of the clusters is closest to the Atlantic Blocking pattern (red frame). Each scenario is associated with one of four predefined large-scale climatological regimes. In this case there are three clusters for the 5–7 day range. Contours show the 500 hPa height field; shading indicates the anomaly (difference from the climatology) with positive shown in red and negative in blue. The EPS forecast is from 00 UTC on 5 February 2010.*

As well as providing users with more information, the new clustering tool is configurable and can be customized for different areas and variables as required.

In June 2010 the Ensemble Prediction System (EPS) was enhanced by the inclusion of initial perturbations generated from the Ensemble of Data Assimilations (EDA). Maps of the initial ensemble spread therefore provide some information about the analysis uncertainty. For that reason, the ensemble mean and spread maps on the ECMWF website were extended to include step 0; the normalised spread indicates regions where the analysis uncertainty is relatively high (or low) compared with the last 30 days.

Three new products were made available for dissemination from February 2010:

- Wind at 100 metres above ground level from the deterministic model and the EPS.
- Maximum and minimum temperature for 6-hour periods.
- Stokes drift representing ocean drift induced by surface waves, computed from the wave spectrum of the ocean wave model and important for the upper ocean transport.

Also the ocean wave products on the ECMWF website have been enhanced by the addition of significant wave height and mean wave period for the swell (low frequency) and wind-sea (high frequency) parts of the wave spectrum.

Graphics

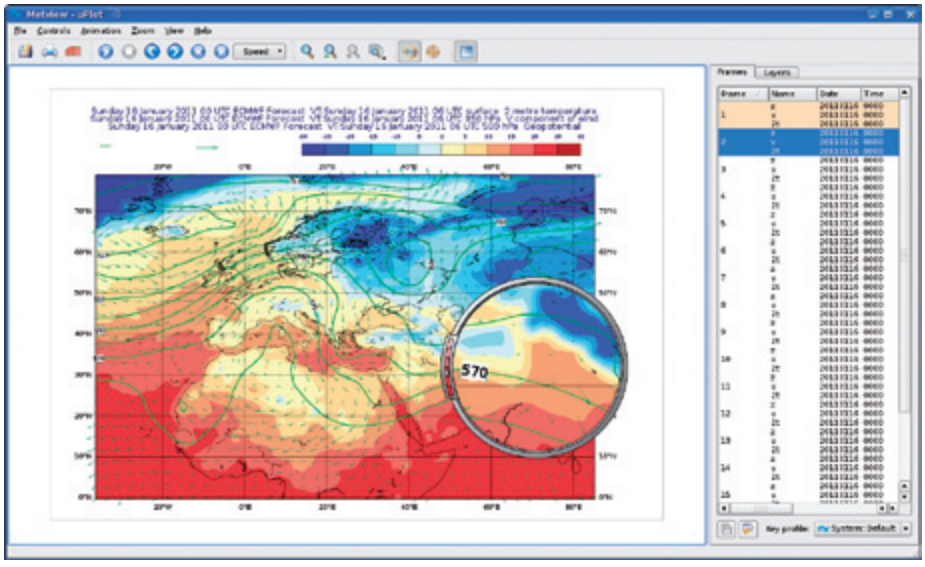
ECMWF's graphics library, Magics++, now offers improved performance and new features, such as a Python interface and advanced plotting of observations. There has been a growth in the number of internal and external users contributing to these Magics++ developments.

Magics++ provides the graphics for ecCharts, the new interactive web interface for forecasters. Work has been carried out to ensure the ambitious performance targets for ecCharts were met.

With the release of version 4 in September 2010 a new generation of ECMWF's Metview interactive workstation and batch system has been started.

Metview has been enhanced to cater for the increased amounts of data from the higher-resolution forecasting system and the larger volumes of satellite data used by the data assimilation system.

Metview 4 contains several new tools for the interactive examination and post-processing of observations, analysis feedback and forecast data. Building on the release of Metview 4, developments in the user interface and Macro (batch) language will give internal and external users more powerful access to ECMWF's products.



The new visualisation module of Metview 4 provides easier browsing, selecting and examining of data. *Icons at the top let the user interact with the display, while the menu on the right enables browsing through frames and layers. Users can easily browse and select data and examine the data value through the magnifier glass.*

Scores recommended by the Subgroup on Verification Measures

Primary headline scores

These address the synoptic-scale upper-air skill:

- Anomaly correlation of 500 hPa height of the deterministic forecast.
- Continuous ranked probability skill for 850 hPa temperature from the EPS forecast.

Supplementary scores

These are measures of forecast skill focusing on surface parameters and high-impact weather:

- Precipitation from the deterministic forecast.
- Precipitation from the EPS.
- Tropical cyclone position error.
- Extreme Forecast Index (EFI) for 10-metre wind.

Development of verification methods

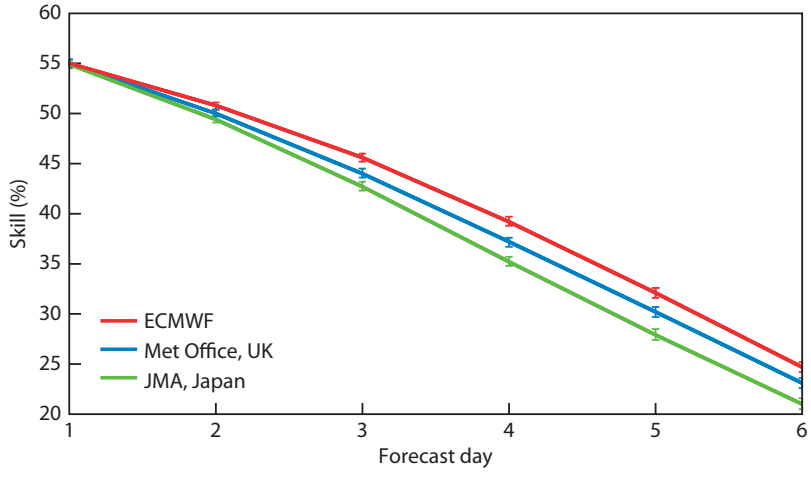
In 2009 the TAC established a Subgroup on Verification Measures that included 12 external participants (representatives from Member and Co-operating States and invited experts from EUMETNET and Exeter University) and ECMWF representatives. The Subgroup presented its final report to the TAC in October 2010.

The Subgroup reviewed the requirements for scores to monitor the long-term performance of the ECMWF forecasting systems and made recommendations on additional measures to complement the two current primary headline scores. The Subgroup concluded that precipitation accumulated over 24 hours, verified against surface observations from the WMO's Global Telecommunication System, best meets requirements for both the deterministic and ensemble medium-range forecasts. ECMWF has developed new precipitation verification procedures, based on the recommendations of the Subgroup.

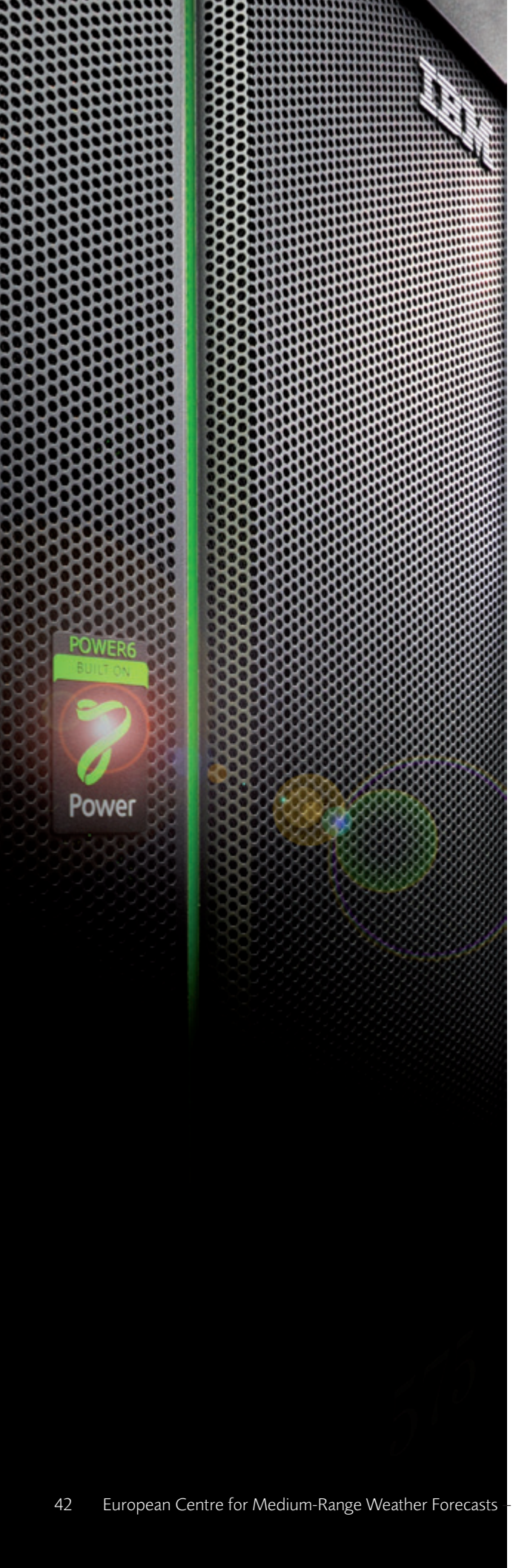
The Subgroup also considered the requirements for the verification of severe weather and reviewed the suitability of available verification measures. It concluded that no measure currently available satisfies all the requirements for the verification of such events. Consequently substantial fundamental research is still required to develop suitable scores for verifying deterministic and probabilistic forecasts of severe weather.

The Subgroup emphasised that homogeneous Europe-wide datasets, based on institutional or national observational data, are needed (in near-real time) for the purposes of verification, in particular of heavy precipitation and strong winds.

Based on the Subgroups recommendations, ECMWF has continued to develop products and verification procedures for severe weather (including the Extreme Forecast Index (EFI), tropical cyclone genesis and tracks, and extra-tropical features) for both deterministic and probabilistic forecasts.



Comparison of precipitation forecast skill using the new verification score SEEPS.
The new verification score shows that ECMWF outperforms two other centres in terms of the skill of its precipitation forecasts. Shown is a skill measure based on the new verification score SEEPS (stable equitable error in probability space) developed as part of the work for the TAC Subgroup on Verification Measures. The skill measure (1-SEEPS) is computed over all available synoptic stations in the extratropics for forecasts from March to October 2010. Bars indicate 95% confidence intervals. At each observation location, the weather is partitioned into three categories: 'dry', 'light precipitation' and 'heavy precipitation'. The boundary between 'light' and 'heavy' is determined by the station climatology so that SEEPS assesses salient features of the local weather and accounts for climate differences between stations. The SEEPS score evaluates the performance of the forecast across all three categories.



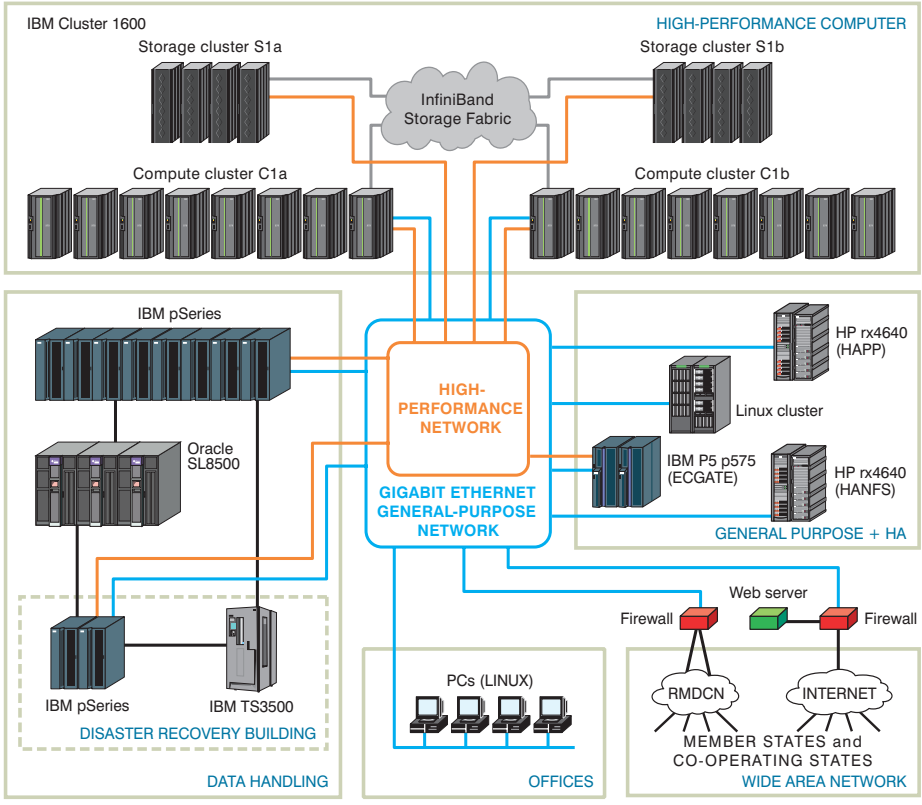
Computing

Running ECMWF's complex weather forecasting models to a relatively tight schedule requires extremely powerful computers and instant access to massive amounts of data. Central to the Centre's activities are its IBM supercomputers and its unique archive of meteorological data that has been collected over three decades and stored in the data handling system (DHS).

High-performance computing facility

ECMWF has a long history of high-performance computing (HPC) in a production environment for weather forecasting, going back to the installation of its first supercomputer in 1978. Over time, various architectures have been used, including CRAY vector shared-memory systems, Fujitsu VPP vector distributed-memory systems, and IBM scalar SMP clusters. From the beginning, ECMWF has ensured that its codes are portable. Also it has invested considerable resources in ensuring that they remain suitable for most prevailing HPC architectures, which has made it possible to migrate relatively easily from one type of system to another.

The current high-performance computing facility (HPCF) comprises two identical IBM POWER6 compute clusters, each with 272 32-core p6-575 servers, as well as two identical storage clusters, each of which holds about 0.6 petabytes of data.



Computer configuration as of December 2010. *The diagram shows how the major components, including the HPCF, are interconnected via the local area networks.*

HPCF – facts and figures

- 2 identical clusters
- 544 32-way p6-575 servers
- 17,408 SMT-2 cores
- 20 teraflops sustained performance
- 325 teraflops theoretical peak performance
- 38 terabytes of memory
- 6,048 disk drives (each 300 gigabytes)
- 1.2 petabytes of usable disk space

DHS – facts and figures

13 IBM pSeries servers
3 Oracle SL8500 automated tape libraries
151 Oracle T10000B tape drives
500 terabytes of usable disk space
Capacity: 28,000 tape cartridge slots
Data volume: 18.5 petabytes of primary data
Number of files: 80 million
Archive growth: 24 terabytes added every day
Disaster recovery system
IBM TS3584 automated tape libraries
10 LTO-3 & 10 LTO-5 tape drives
6 petabytes of backup data (secondary copy)

The HPCF continued to provide a good and reliable service to ECMWF's users. Its availability in 2010 has averaged 99.45%. About 200,000 parallel jobs and over a million serial jobs are processed per week. Many of the serial jobs perform ancillary tasks for the parallel jobs, such as archiving results to the data handling system. About 95% of the HPCF resources used are accounted for by the parallel jobs. In terms of billing units, Member States' users account for 13% of the overall use of the HPCF.

ECMWF's current HPCF is provided under a service contract with IBM. The current system, 'Phase 1' of the service contract, will be replaced by a POWER7 based 'Phase 2' system to be installed in 2011. In 2010 ECMWF concluded a one-year contract extension to mid-2014 that will give ECMWF a scientifically valuable increase in compute resources in mid-2012. The total number of nodes in Phase 2 will increase from around 1,000 to slightly over 1,500, giving more than 5 times the number of processor cores compared to the current systems and a total peak performance of approximately 1.5 petaflops.

The extension of the service contract is a good fit with ECMWF's research programme and the additional compute resources to be installed in mid-2012 will enable ECMWF to make faster progress in addressing the scalability issues within the ECMWF data assimilation system.

Data handling system (DHS)

Weather forecasting makes use of, and generates, very large volumes of data – observations, analyses and research experiments – that need to be stored for long periods. The data represents a valuable asset that is used by researchers in meteorological and environmental studies, and is also available for educational and commercial purposes.

For many years ECMWF has operated a dedicated data handling system (DHS) in which all ECMWF users can store and retrieve data needed to perform a wide variety of research and development activities. The high-performance storage system (HPSS) is the underlying data management system in which all of the data in the DHS resides. Users do not use HPSS directly, but access the data via one of two applications that have been developed by ECMWF.

- *Meteorological Archival and Retrieval System (MARS)*: a unique resource which allows research and operational staff to access and retrieve a wealth of meteorological data using a meteorological interface.
- *ECMWF Common File System (ECFS)*: a facility which allows users to store data that is not suitable for storing in MARS.

In early 2010 ECMWF installed a third automated tape library (ATL) as the second phase of a contract with Sun Microsystems Ltd. (now Oracle), adding on to the ATLs already installed in 2009. This system was fully accepted at the end of the year and eventually replaced the StorageTek tape silos that had held ECMWF's data archive over the last two decades. The quality of the new ATLs is excellent. It is hoped that the new libraries will last for as long as the old Sun StorageTek ATLs, which provided an excellent service for 21 years.

Starting from early 2010, all new data has been archived in the new system. Almost 13 petabytes of data, residing on approximately18,000 IBM 3592 tape cartridges, had to be migrated to the new system before the end of the year; this was a major exercise to be achieved without impacting unduly on the quality of service provided to the users of the DHS.

In February the migration of the existing MARS data from the old system to the new one began. Migration of ECFS data started at the end of March after the data management software that underpins MARS and ECFS was upgraded to a new version; the upgraded software allowed small files to be aggregated into large 'containers' before being copied to tape as a means of enhancing performance. This feature was especially useful for ECFS, which has 21 million files smaller than half a megabyte in size.

Framework for Member State time-critical applications

The 'Framework for Member State time-critical applications' comprises three options:

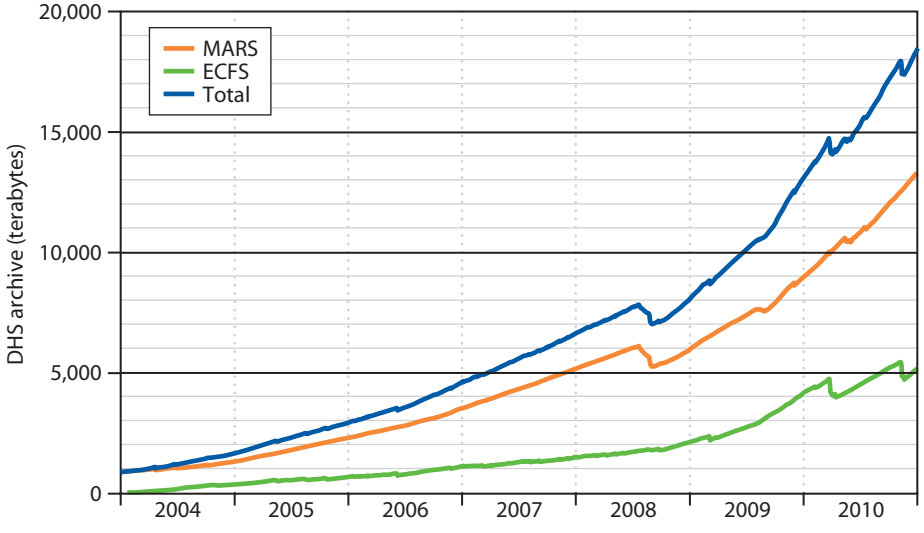
- ***Option 1***: Simple job submission monitored by ECMWF.
- ***Option 2***: Member State suites monitored by ECMWF.
- ***Option 3***: Member State suites managed by ECMWF.

Within this framework, Member States have been running the following main applications:

- TEPS/LAMEPS suite for Norway providing limited-area ensemble predictions and targeted ensemble predictions.
- A suite which prepares boundary files for the ALADIN NWP Project.
- A suite for 'on demand' data extraction of IFS boundary conditions that drive a dispersion model run at Météo-France.
- COSMO-LEPS suite providing limited-area ensemble predictions for the COSMO Consortium.
- MOGREPS15 suite providing ensemble predictions based on the Unified Model for the UK Met Office.

The migration of both MARS and ECFS data was successfully completed on schedule at the end of 2010 and the old ATL environment has been decommissioned since.

At the end of December 2010 the volume of primary data residing in the DHS was over 18.5 petabytes, which is equivalent to a stack of CDs almost 34 km in height, and would reach up to the middle of the stratosphere. Also over 6 petabytes of essential data is backed up in the disaster recovery system, housed in a small on-site building separate from the main computer building.



Growth of archive data from 2004 to the end of 2010. *Since 2004 the amount of data held in the archive has grown from about a petabyte (1,000 terabytes) to 18.5 petabytes at the end of 2010. This is an annual growth rate of 53%. The top line represents the total data in the archive, which is a sum of the middle line, MARS data and the bottom line ECFS data. The reduction in storage in mid-2008 is due to the removal of experimental data that was no longer required. During 2010, when archive data was migrated from the obsolete tape libraries to the new ones, some obsolete data was removed before the migration.*

User support

Significant efforts have been spent on providing a steadily increasing number of users from the Member States and Co-operating States with support and advice on the use of ECMWF's computing facilities. In particular, several Member State users have been assisted and advised in their use of the high-performance computing facility.

Considerable work has gone into the preparation of the service on the new ECGATE cluster of servers that is provided for use by Member States. Users were assisted in testing their applications on the new system before its introduction into service.

Since its introduction at the end of 2004, the framework for Member State time-critical applications has increasingly been used by Member States and Co-operating States for running applications at ECMWF. The teams responsible for the various time-critical applications were assisted in testing their applications in preparation for the implementation of the higher horizontal resolution in January 2010.

Green computing

High-performance computing (supercomputing) is central to the core functions of ECMWF. As such systems develop to provide greater computational power they will most likely require increasing amounts of electricity. ECMWF is keen to offset some of the increase in electricity usage by creating a more energy-efficient environment for the super-computer thereby reducing energy usage. As well as lowering the cost of operations, this will have the added benefit of reducing carbon emissions, thus making the supercomputer facility 'greener'.

Comparing the energy efficiency of data centres

The Power Usage Effectiveness (PUE) of a typical data centre is about 2, although there are data centres with PUEs exceeding 4. A PUE of 2 means that the data centre is using twice as much energy as that required just to power its IT equipment. New data centres are being constructed with the aim of consuming only 10% to 20% additional energy for the infrastructure corresponding to a PUE in the range 1.1 to 1.2, but those centres in the UK that were investigated as part of the study are generally only suitable for standard IT servers and not supercomputers. The assumption of equipment being in fixed, standard size racks is made, and that future equipment would also fit these racks. The cooling methods are designed for air-cooled equipment with a maximum heat output around 20 kW per rack, and the cooling methods used could not be modified to provide chilled water directly to cool equipment, such as supercomputer racks with a heat output exceeding 50 kW per rack.

ECMWF uses less than an additional 50% of energy for its infrastructure, on top of that used to power the IT equipment. The PUE of the computer building is about 1.45. This means that for every kilowatt of electricity used directly by the computer systems an additional 0.45 kW is attributed to the ancillary services, such as cooling and lights, and losses in the power distribution system. This low value reflects the importance that was attached to increasing energy efficiency during computer and infrastructure procurements in previous years, and is a good result for a building that is more than 30 years old.

Green computing at ECMWF

Given the need to minimise energy use, the Technical Advisory Committee Subgroup on Green Computing initiated a study to advise ECMWF on how to move towards an environmentally-friendly high-performance computing facility (HPCF), with particular focus on energy efficiency and low carbon footprint. In the future the power and cooling requirements of supercomputers may increase significantly and this will pose major engineering and budgetary challenges. The study looked at other large data centres and examined best practice for providing an energy-efficient infrastructure for supercomputers.

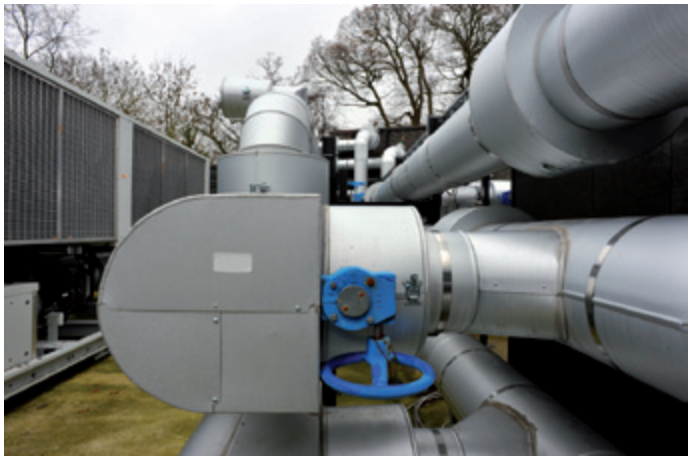
Energy consumption

The electricity used by a supercomputer of given computational power is fixed as far as the user is concerned. Manufacturers of supercomputer equipment have realised that they must limit the increase in electricity consumption of future hardware to be within electrical load limitations of major data centres and for running costs to be affordable. The infrastructure supporting a supercomputer consumes large amounts of electricity that contributes to the running costs of the data centre and to the carbon footprint. More than 95% of ECMWF's energy consumption is related to use of its HPCF, and so increasing the energy efficiency of the HPCF infrastructure will have a relatively large impact on ECMWF's total energy consumption.

To reduce the energy consumption in the data centre it is necessary to first know how much power each piece of equipment uses. This requires measurement of both the total energy use of the data centre and how this is divided amongst the components. To find out how much electricity each piece of equipment uses, ECMWF installed power meters around the site. Half-hourly readings are collected and central software logs all meter parameters: voltage, current, power factor, power and energy. The meters allow ECMWF to measure the electricity usage at power distribution unit level for computer equipment and at individual unit level for infrastructure such as chillers. Readings from the meters are recorded so that, over time, changes in the energy efficiency of the computer building can be assessed and quantified.

In a typical data centre the overall energy consumption is determined by the infrastructure, computer and other hardware, software, and how the system is managed. To compare the energy efficiency of one data centre with that of another there is a need for standard metrics. The measure that is used at ECMWF is the Power Usage Effectiveness (PUE); this measures the efficiency of the environment around the supercomputer. PUE is defined as the 'total power input to the data centre' divided by 'power input to computers'.

One of ECMWF's high-capacity UPS machines.



Part of ECMWF's chilled water system and chiller.

ECMWF Power Usage Effectiveness

ECMWF has been measuring its energy consumption since spring 2010 to calculate its PUE for the computer building. The power input to the computer building is calculated by subtracting the electricity consumed by the two office buildings and the conference building from the total electricity consumption for the site. This takes into account all losses within the main power distribution equipment (i.e. transformers and Uninterruptible Power Supply (UPS) systems). As the power input to the computers is known, the PUE can be determined.

ECMWF calculates PUE every 30 minutes from the half-hourly consumption data provided by its electricity supplier, and half-hourly data obtained from power metering equipment installed throughout the site. The intention is to build a rolling average over time to obtain the annual average for the computer building. Analysis of the data shows that the PUE of the computer building is about 1.45.

Reducing infrastructure energy consumption

Various projects have increased ECMWF's energy efficiency. These include replacement of part of the UPS system and most of the chillers used to provide cooling water for equipment. Actions have also been taken to reduce energy use in the office buildings.

On a typical data centre site the energy losses associated with power handling and distribution on-site are likely to be between 1% and about 10% of the site load. The type of UPS chosen will make most impact on the additional energy use.

ECMWF uses a rotary UPS to protect the site from loss of power due to loss of mains electricity. It works by using the incoming electrical supply to turn a flywheel that itself is connected to an integrated generator. If the National Grid supply is lost, the flywheel continues spinning and feeding energy into the electrical distribution system long enough for a diesel engine to cut-in and drive the generator. When power is flowing normally through the UPS from the National Grid, the UPS conditions the power supply (e.g. by removing transient spikes). These UPS machines are about 96% efficient. ECMWF has recently replaced its two oldest rotary UPS machines by two new, higher capacity machines. These are more efficient than the old ones due to advances in technology and control systems.

The centralised chilled-water systems at ECMWF use chillers incorporating Turbocor compressors. Over the last few years these new packaged air-cooled chillers have replaced old, relatively inefficient traditional chillers. Traditional screw or reciprocating compressor-based chillers are most efficient at full load, and the efficiency variation with ambient temperature is minimal. Turbocor-based chillers are designed to be more efficient at part load and at low ambient air temperatures.

The average annual efficiency for a Turbocor-based chiller is between 5.5 and 6.5, as opposed to being in the range 3 to 3.5 for a more traditional style chiller. This means that a Turbocor chiller uses half as much electricity as a conventional one to provide the same cooling. All chillers at ECMWF operate at less than full load because they are run in a redundant mode with spare capacity available, and they run continuously throughout the year as in most data centres. Consequently the saving to be made using Turbocor compressors is significant.

Efficiency of the chillers

One of the chilled-water circuits at ECMWF is driven by three Turbocor chillers. ECMWF switched off one of the three chillers to measure the effect on electricity consumption. It was found that two chillers operating at 90% of their maximum load use 12–15% more electricity than three chillers operating at about 60% of peak. This demonstrates the improved efficiency of Turbocor-type chillers at part load compared with conventional chillers which are more efficient at higher loads.

The ECMWF chilled-water system was designed with flow and return temperatures of 7°C and 14.5°C respectively. To reduce the amount of energy required for cooling of IT equipment, manufacturers are increasing the temperature at which the equipment can operate. This applies also to ECMWF's HPCF, where the temperature of the cooling water could be increased to 20°C. ECMWF has increased the temperature of the cooling water for one of the HPCF clusters from 7°C to 12°C. This has achieved a 13% saving in electricity use by the chillers. It was decided not to use water temperatures higher than this due to water flow capacity constraints and the need to allow a margin for the temperature of the chilled water to increase while remaining under control, in the event of chiller problems.

Use of 'free cooling'

There can be little doubt that the most efficient cooling method is the use of 'free cooling', which uses the ambient (external) air to cool the air or water that provides the direct cooling to equipment in the data centre. Installation of some free cooling for the ECMWF data centre is being studied. The main disadvantage of free cooling systems is that plant and equipment tends to be larger to take the maximum advantage of small temperature differences. This increases capital costs and space requirements but these costs will often be justified by life cycle cost analysis. The most important factor, however, is that free cooling systems will significantly reduce carbon emissions that would otherwise arise from the generation of electricity to drive mechanical cooling systems.

Office energy consumption and towards carbon neutrality

ECMWF set up an Energy Efficiency Working Group to examine and attempt to reduce the energy used in buildings other than the data centre. This Group made recommendations on the use of built-in passive infrared (PIR) sensors to control lighting in common areas, more efficient use of the central heating and chilled-water systems and more efficient use of desktops, such as using a blank screen saver to reduce electricity consumption.

As well as reducing the energy consumption on the site the Group investigated ways of working towards carbon neutrality. The strategies considered so far are:

- Purchase 'green' electricity through a conventional supplier.
- Invest in a supplier of renewables, 'earmarking' some of the renewable energy for use by ECMWF – the benefits being that the price can be negotiated explicitly (and thus is less susceptible to market variations) and the source can be identified.
- Generate electricity on-site using photovoltaic (solar) cells.
- Use ground water to provide some cooling for the data centre.

In the short term, the first option is being pursued. 'Green' tariffs are available from most large energy providers based on the premise that a proportion of the electricity supplied is generated from sustainable sources. At present the sustainable proportion is only in the order of 10%, although this is likely to increase over the next few years if government policy objectives are to be achieved. However, it is unlikely that a significantly higher proportion of grid-supplied energy will be produced from sustainable sources in the near future. The demand for green electricity exceeds the available supply. In 2010 green electricity was not available from ECMWF's supplier, but a proportion of the electricity supplied in 2011 will be from green sources.

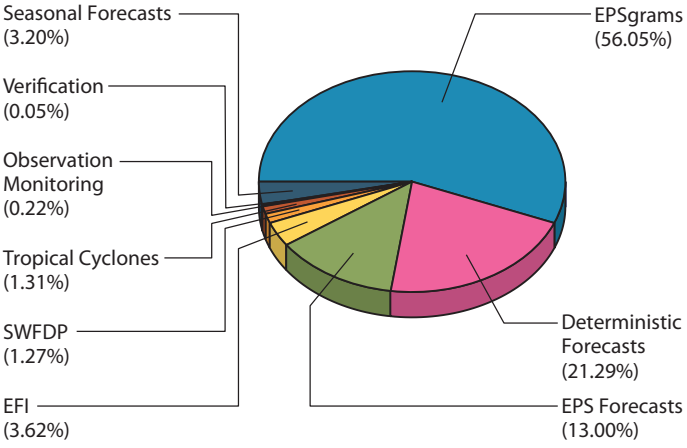
The second option has the potential for electricity price stability. However, this is a long-term option which requires further study.

The option to use photovoltaic cells to generate electricity has been shown to be uneconomic and impractical. Even if the whole of the data centre roof (the largest potentially suitable area on ECMWF's site) were used it would generate less than 1% of the required electricity and would have a payback period of 10 to 15 years under current assumptions about electricity costs and feed-in tariff. Use of ground water for cooling, the last of the options, is being investigated.

ECMWF will continue to monitor the energy efficiency of the site and particularly the data centre infrastructure. New and existing technologies to reduce energy consumption will be evaluated.

Cooperation

ECMWF pursues extensive scientific and technical collaboration, in particular with its Member States, with satellite agencies and with the European Commission. It participates in several programmes of the World Meteorological Organization (WMO) and contributes to climate monitoring in cooperation with the climate community.



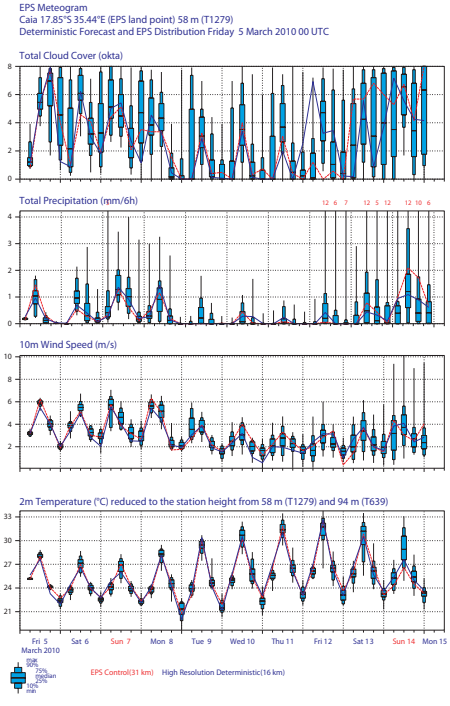
WMO Members access a wide variety of products from the ECMWF website. *The pie chart shows the proportional breakdown of WMO Members' access to ECMWF web products in May 2010 according to topic areas: EPSgrams, Deterministic Forecasts, EPS Forecasts, EFI (Extreme Forecast Index), SWFDP (WMO Severe Weather Forecast Demonstration Project), Tropical Cyclones, Observation Monitoring, Verification and Seasonal Forecasts.*

WMO

Following the Council's decision to increase the range of 'WMO Essential' products, ECMWF made these extra datasets available on WMO's Global Telecommunication System and on a data server. Charts of these extra 'essential' products have also been added to the ECMWF website. The new charts show the ensemble mean and ensemble standard deviation (spread) for 500 hPa geopotential, 850 hPa wind and temperature and mean sea-level pressure – they can be found at: http://www.ecmwf.int/products/forecasts/d/charts/medium/eps/

The first meeting of the WMO Co-ordination Group on Forecast Verification (CG-FV) was hosted at ECMWF from 24 to 26 November 2009. The meeting proposed the establishment of a Lead Centre for Deterministic NWP Verification (LC-DNV). At its 73rd session (June 2010) the Council agreed that ECMWF should respond positively to WMO's request for nominations to become the LC-DNV.

ECMWF is participating as a Global Centre in two subprojects that are part of the WMO Severe Weather Forecasting Demonstration Project (SWFDP); the subprojects are in southern Africa and the South Pacific islands. A range of graphical products is provided from ECMWF's high-resolution deterministic forecast and the EPS. Products are aimed at providing indications of the risk of severe weather. A new SWFDP is now being set up for east Africa; ECMWF will again support this initiative in its role as a Global Centre.



Example of an EPSgram provided to a WMO Member. *The EPSgram is for Caia, one of the ten locations for which ECMWF provides EPSgrams for Mozambique – one of the participants in the first WMO Severe Weather Forecast Demonstration Project (SWFDP) in southern Africa. The EPSgram starts on 5 March 2010.*

Group on Earth Observations (GEO)

GEO is leading a worldwide initiative to build a Global Earth Observation System of Systems (GEOSS) over the coming years. ECMWF has been a Participating Organization in GEO since the initiative was started in 2003. This has involved ECMWF contributing to the activities of the GEO User Interface Committee and the Science and Technology Committee.

ECMWF contributes to several tasks of the GEO 2009–2011 Work Plan in the societal benefit areas concerning weather, climate, health, energy, and water. Contributions are mainly based on reanalysis data, ECMWF's long-standing expertise in numerical weather prediction and in Observing System Experiments (OSEs), and activities associated with TIGGE.

Provision of real-time data

In addition to providing data to EUMETSAT and ESA, governed by co-operation agreements, ECMWF provides real-time data to space agencies and other satellite data producers on the condition that it receives observations for use in its forecasting system and that the use of ECMWF data is restricted to satellite data processing only (in particular calibration/validation).

ECMWF is currently providing real-time data to the following missions:

- NASA/GLDAS (since 2001)
- NASA/CLOUDSAT (since 2007)
- UCAR/COSMIC (since 2007)
- NASA/OCO (since 2008)
- NIES/GOSAT (since 2008)
- NOAA/NESDIS/NPOESS Preparatory Program (since 2009)
- ISRO/NRSC (since 2009)
- NCAR/MOPITT (since 2010)
- NASA-JPL/SMAP (since 2010)

Space agencies

The annual, bilateral meeting with EUMETSAT took place on 11 February. The use of EUMETSAT data, in particular from the MetOp satellite, was reviewed. Other items included the EUMETSAT fellowships, ECMWF's involvement in the satellite application facilities (SAFs) and the contributions of both organisations to the Group on Earth Observations (GEO) and Global Monitoring for Environment and Security (GMES). It is worth noting that EUMETSAT is a formal partner of the EU-funded reanalysis project, ERA-CLIM, led by ECMWF.

The annual, bilateral meeting with ESA took place on 5 March and allowed each organisation to present its plans. The collaboration on reanalysis and its role within the ESA Climate Change Initiative was consolidated. ECMWF also presented its technical and scientific preparation for the exploitation of the recently-launched Soil Mositure and Ocean Salinity (SMOS) Mission and the forthcoming Atmospheric Dynamics Mission (ADM). The interest and role of ECMWF in the monitoring of ESA future Sentinel satellites was also discussed.

EUMETNET

ECMWF contributes to the activities of the scientific advisory team of the EUMETNET Composite Observing System (EUCOS-SAT). The scientific advisory team, which met at ECMWF in March 2010, reviewed the European upper-air observation network that consists mainly of data from radiosondes and ascending and descending aircraft at the main airports. Based on the results from thorough investigations, the meeting recommended that, where such observations are within 100 km of each other within Europe, one observation location could be removed without degradation to the NWP forecast performance.

The impact of data from buoys drifting in the North Atlantic had been the subject of a specific study. The buoys were shown to be of significant benefit for the prediction of storm Klaus, which caused widespread damage across France and Spain in January 2009. Plans for further EUCOS-funded observing system impact studies were agreed (i.e. relative impact of the space-based and terrestrial data, and impact of targeted observations).

ECMWF has been a partner in the EUMETNET Short Range Numerical Weather Prediction (SRNWP) Interoperability Project since 2008. The three-year project combines efforts from the three European limited-area model (LAM) consortia and the European providers of lateral boundary conditions from global atmospheric models. The third project meeting was held at ECMWF in December 2010. ECMWF contributes to the project its experience in defining and encoding a common model dataset in GRIB edition 2 using ECMWF's software and providing a data server for sharing sample datasets and documentation from all participating partners.

EFAS hydrological forecast indicating the possibility of flooding in Central Europe. *The EFAS forecast issued on 12 May 2010 indicated the possible occurrence of high river levels in Central Europe. Thereafter a series of weather events caused devastating flooding across several Central European countries during May, June and August 2010. The red reporting points indicate where the forecast probability to exceed the EFAS high threshold (return period between 5 and 20 years) is greater than 10%. By the side of the reporting points are numbers denoting how many members exceed the high threshold from the ECMWF EPS (out of 51) and COSMO-LEPS (out of 16).*

Input to the EFAS

EFAS uses LISFLOOD – a GIS-based, distributed hydrological rainfall-runoff-routing model specifically designed to be used in large-scale catchments. The model is for all of Europe on a 5 km grid in different configurations:

- With an hourly time step, using deterministic high-resolution weather forecasts from either Deutscher Wetterdienst (DWD) or ECMWF.
- With a six-hourly time step using weather forecasts from COSMO-LEPS (the limited-area ensemble prediction system developed within the COSMO consortium).
- Daily time step using ECMWF EPS forecasts.

EFAS provides discharge forecasts for the main European river basins.

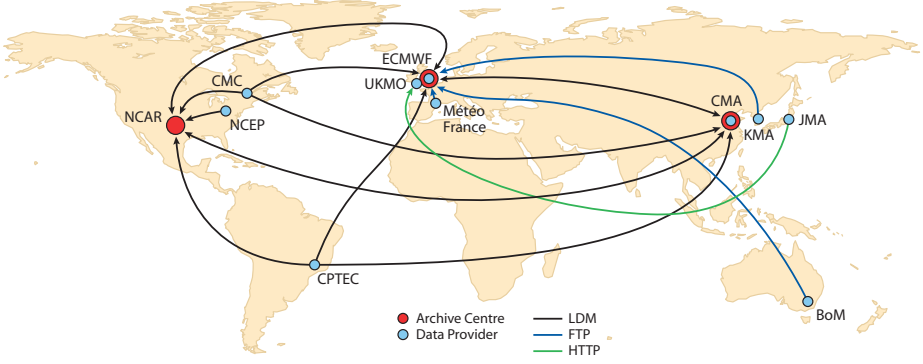
THORPEX/TIGGE

ECMWF has continued its involvement in the WMO World Weather Research Programme on THORPEX, called TIGGE (THORPEX Interactive Grand Global Ensemble), both as a contributor to the development and provision of the necessary infrastructure and as a data provider. The current service consists of feeding the TIGGE data repository with research and operational forecasts from various centres in near-real time. Tools to access this archive and to provide consistent data access have been further developed.

The TIGGE database is a key component of THORPEX, aimed at enhancing international collaboration between operational centres and academia on the development of ensemble prediction.

TIGGE allows scientists around the globe to access an archive of operational and research ensemble forecasts from a number of NWP centres. The TIGGE database now contains four years of global data from ensemble prediction systems and holds more than 388 terabytes (2.15 billion fields). There are more than 900 registered users of the TIGGE data portal.

The TIGGE website hosted by ECMWF has been extended to include more information on the research being undertaken using the TIGGE data and includes a list of references to publications that have used TIGGE data. More than 30 scientific papers, conference papers and other reports have been produced so far; almost half of these were published in 2010, indicating the use that is now being made of the TIGGE dataset.



TIGGE data exchange enhances international collaboration between operational centres and academia on the development of ensemble prediction. *There are ten producing centres and three archiving centres. Around 430 gigabytes of data (~1.6 million fields) are exchanged daily between several data providers and the three archive centres in near-real time. ECMWF uses the TIGGE archive to compare its own EPS with the other ensemble prediction systems.*

Joint Research Centre of the European Commission

The European Flood Alert System (EFAS) developed by the Joint Research Centre (JRC) of the European Commission at Ispra, Italy, provides early flood alerts on a pre-operational basis to national hydrological services.

ECMWF is working closely with JRC to evaluate EFAS performance and further improve the system. In a recent collaborative study, the performance of EFAS when driven by ECMWF single high-resolution forecasts was assessed over a period of ten years. EFAS river discharge forecasts were run in a hindcast mode every week for a period of ten years using the ECMWF weather forecasts available at the time, and evaluated for a total of 1,025 key river gauging stations across Europe. Results indicate that over the period of ten years, the skill of the EFAS forecasts has steadily increased based on the improvements in the quality of the operational meteorological forecast.

Following the signing of a one-year contract between JRC and ECMWF, work started in October 2010 to install a pre-operational version of EFAS at ECMWF. JRC has transferred all data and programs to ECMWF. In addition to the work on the pre-operational set-up of EFAS at ECMWF, the evaluation of bias-correction of rain and temperature based on the EPS re-forecast suite will be carried out.

Education and training, workshops and meetings

Scientists and computer specialists from Member States, Co-operating States and WMO Members participate in ECMWF's extensive education and training programme to enhance their understanding of NWP and the ECMWF computer facilities. In addition, workshops and meetings provide the opportunity for experts from around the world to get together to exchange ideas, discuss the latest research and debate future developments.

Number of attendees at the meteorological training courses in 2010. *There were 113 applicants, from 19 Member States and Co-operating States, for one or more modules of the meteorological courses. In addition there were 18 applicants from states and organisations with which ECMWF has a working agreement.*
MET OP: *Use and interpretation of ECMWF products.*
NWP NM: *Numerical methods, adiabatic formulation of models and ocean wave forecasting.*
NWP DA: *Data assimilation and use of satellite data.*
NWP PA: *Parametrization of subgrid physical processes.*
NWP PR: *Predictability, diagnostics and extended-range forecasting.*

	Met OP (I & II)	NWP NM	NWP DA	NWP PA	NWP PR
Member States/Co-operating States	78	18	26	49	18
Non-Member States	12	10	9	10	9
Total applications	90	28	35	59	27
Total attendees	54	28	35	38	18

Education and training

Use of computing facilities

Six independent modules of the course on 'Use of Computing Facilities' were run at ECMWF.

- GRIB API: Library and tools (23–26 February)
- Introduction for new users/MARS (1–5 March)
- Magics (8–9 March)
- Metview (10–12 March)
- Use of supercomputing resources (15–19 March)
- Introduction to SMS/XCdp (22–24 March)

A total of 49 participants from 18 Member States, Co-operating States and other organisations attended the various modules in 2010. In the context of the WMO Disaster Risk Reduction Programme, six participants from Albania, Bosnia and Herzegovina, and the former Yugoslav Republic of Macedonia attended the modules on Magics and Metview.

Material presented during the various modules is available on the ECMWF website.

Use and interpretation of ECMWF products

The objective of this course is to assist Member States and Co-operating States with advanced training in the use of operational products from the ECMWF forecasting system. It is directed towards those staff in the meteorological services who are (or will be) using ECMWF products either directly as forecasting staff, or in research and development work, and is aimed at maximising the benefits to users of the Centre's products. Courses were given from 1 to 5 February and 8 to 12 February.

As in previous years ECMWF organised an additional course for participants from WMO National Meteorological and Hydrological Services which are not from ECMWF Member States or Co-operating States. This took place from 11 to 15 October. There were 25 applications. WMO funding provided financial support for seven candidates (from Burkina Faso, Georgia, the former Yugoslav Republic of Macedonia, Philippines, Solomon Islands, Uganda and Vanuatu) who are participants in WMO Severe Weather Demonstration Projects. Three candidates (from Brazil and China) had their own funding. Additional places were available but these could not be filled because of lack of funding for travel.

Numerical Weather Prediction

ECMWF conducts an NWP training course each year. This is designed to provide meteorologists from Member States and Co-operating States with advanced training in NWP. The training course this year consisted of the following modules.

- Numerical methods, adiabatic formulation of models and ocean wave forecasting (12–16 April)
- Data assimilation and use of satellite data (5–14 May)
- Parametrization of subgrid physical processes (17–27 May)
- Predictability, diagnostics and extended-range forecasting (18–27 October)

The NWP PR module had to be re-scheduled since 90% of the participants were not able to travel to ECMWF due to the 'volcanic ash travel restrictions' in April. The module took place in October and most of the original candidates managed to attend.

ECMWF/JCSDA workshop. *Participants of the ECMWF/JCSDA Workshop on 'Assimilating satellite observations of clouds and precipitation into NWP models' hosted by ECMWF from 15 to 17 June 2010.*

Seminar and workshops

ECMWF/JCSDA Workshop on 'Assimilating satellite observations of clouds and precipitation into NWP models'

From 15 to 17 June a workshop organised by ECMWF and JCSDA (Joint Center for Satellite Data Assimilation) was hosted at ECMWF. Its aim was to review the current status of cloud/precipitation assimilation in NWP and produce recommendations for future research developments and collaboration. About 65 participants attended the workshop, representing most major NWP centres around the world as well as research institutes and universities.

The workshop sessions concentrated on issues related to cloud- and precipitation-affected observations, radiative transfer modelling, cloud and precipitation representation in numerical models, and problems of integrating such data in operational data assimilation systems. A novel approach to working group organisation was taken by running groups composed of experts in observation, modelling and data assimilation in parallel.

More details on the workshop and all presentations can be accessed at: www.ecmwf.int/newsevents/meetings/workshops/2010/Satellite_observations/index.html

Annual Seminar on 'Predictability in the European and Atlantic regions from days to years'

The seminar reviewed recent progress in predicting European–Atlantic variability on a variety of scales, with emphasis on the links between different regions and various components of the weather/climate system.

Some meetings hosted by ECMWF

- Bilateral meeting with EUMETSAT, 11 February
- Scientific Advisory Team of the EUMETNET Composite Observing System (EUCOS-SAT), 2–4 March
- GEO User Interface Committee, 2–4 March
- Bilateral Meeting with ESA, 5 March
- 21st Annual Meeting of the European Working Group on Operational Meteorological Workstations (EGOWS), 1–4 June
- 5th SAFEWIND Project Workshop, 28 September–1 October
- WMO Co-ordination Group on Forecast Verification (CG-FV), 24–26 November
- 3rd Meeting of the SRNWP Interoperability Project, 1–3 December

Some meetings organised by ECMWF

- First General Assembly of the MACC Project, 11–15 January
- Web Developers' Meeting, 1–2 February
- TAC Subgroup to Review the BC Project, 1st session, 5 February
- Working Group on the Long-term Building and Refurbishment Requirements, 17–18 February
- TAC Subgroup on Verification Measures, 3rd session, 15–16 April
- Forecast Products Users' Meeting, 9–11 June
- Meetings of Security Representatives and Computing Representatives, 14–17 June
- TAC Subgroup on Green Computing, 1st session, 9–10 September
- TAC Subgroup on Verification Measures, 4th session, 20–21 September
- TAC Subgroup to Review the BC Project, 2nd session, 23–24 September
- Working Group on Long-term Building and Refurbishment Requirements, 19–20 October

Some key recommendations from the workshop on 'Assimilating satellite observations of clouds and precipitation into NWP models'

- Data assimilation techniques should be adjusted to facilitate the usage of cloud information.
- Studies on critical analysis errors should be performed for the understanding of errors that drive forecast performance.
- Attention should be given to the fundamental model biases associated with the life cycle of cloud development and decay.
- Longer-term research should be invested in work on model error definition.
- Alternative assimilation techniques should be explored that are better suited to treat non-linear inversion problems.
- Model ensembles should pave the way towards hybrid methods that combine the advantages of ensemble techniques with 4D-Var.

Some key recommendations from the workshop on 'Non-hydrostatic modelling'

- Explore the use of explicit versus semi-implicit methods for the compressible Euler equations.
- Continue exploration of increased scalability and efficiency of the spectral transforms.
- Only consider abandoning the spectral approach if proven uncompetitive with gridpoint methods.
- Continue exploration of stability and efficiency of the semi-implicit algorithm.
- Carry out more research into the consistency between the non-hydrostatic dynamical core and the physical parametrization package.
- Consider organising a workshop specifically aimed at 'grey zone' problems.
- Maintain resources to continue investigations of the impact of the non-hydrostatic model on forecast skill.
- Maintain and strengthen existing links and establish new collaborations with users/developers of the non-hydrostatic IFS/ARPEGE system outside of ECMWF.
- Keep abreast of external developments concerning different approaches and, if circumstances dictate, move to develop/adopt a new core whilst recognising that this will require significant new resources.

14th Workshop on 'High-performance computing in meteorology'

The workshop took place from 1 to 5 November 2010 and was attended by over 100 participants from meteorological services, research institutions and computer vendors, coming from 18 different countries. The emphasis of this workshop was on running meteorological applications at sustained teraflops performance in a production environment, and in particular on the future scalability of NWP codes and the tools and development environments to facilitate this.

At the workshop there were 45 presentations covering a wide range of topics. Four of these talks were on the use of General Purpose Graphics Processing Units (GPGPUs) which are now being used as accelerators on the world's fastest supercomputers. It will be interesting to follow such developments at future workshops, with emphasis on whether these units can be successfully applied to numerical weather prediction or climate forecasting.

Presentations from this workshop can be found at:
www.ecmwf.int/newsevents/meetings/workshops/2010/high_performance_computing_14th/presentations/

Workshop on 'Non-hydrostatic modelling'

A three-day workshop on non-hydrostatic modelling was held at ECMWF from 8 to 10 November 2010. The workshop brought together about 35 leading experts in the field of non-hydrostatic modelling.

The workshop started with a series of 15 invited presentations on the status of and recent developments in non-hydrostatic modelling at major NWP centres and atmospheric research institutions from around the world.

In the second part of the workshop, the participants separated into three parallel working groups that made valuable recommendations and suggested potential avenues for ECMWF to explore. This guidance is timely as the Centre plans to upgrade its operational resolution to 10 km by about 2015, beyond which it is essential for the Centre to have an efficient, accurate and robust non-hydrostatic model.

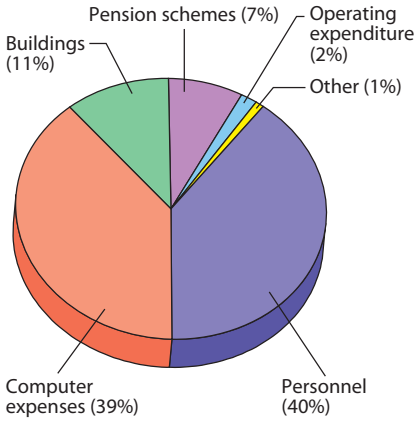
A full report will be published in the workshop proceedings, available by following the links at:
www.ecmwf.int/publications/

Administrative matters

To ensure that ECMWF can fulfil its strategic aims, it is necessary that appropriate facilities and funding are in place. In addition, the recruitment and retention of highly qualified and motivated staff, coupled with staff exchanges between ECMWF and its Member States, play a key role in maintaining ECMWF as the world leader in global medium-range weather forecasting.

Year	B-grades	A-grades
2006	50%	17%
2007	48%	17%
2008	50%	17%
2009	51%	17%
2010	49%	17%

Proportion of female staff employed by ECMWF during the period 2006–2010.



Expenditure in 2010 by category.

Personnel

ECMWF's Director-General, appointed by the Council, is responsible for implementing the organisation's objectives and oversees three departments: Operations, Research and Administration.

At the end of December 2010, ECMWF employed 161 staff members and 77 consultants. Furthermore, 33 contractors were working on the ECMWF site. During the year, 12 staff members were recruited, 4 staff members left the organisation and 2 staff members retired.

ECMWF recruits staff members from its Member States and Co-operating States, and consultants are recruited worldwide. Currently, 27 nationalities are represented at ECMWF.

A key ingredient to the success of ECMWF is the high level of expertise and dedication of the staff. This has ensured that ECMWF continues to be at the forefront of applying the latest research and technological developments to meet the increasingly demanding needs of Member States.

Employment

ECMWF operates an equal opportunities policy. Staff and consultants are recruited solely on the basis of their qualifications and experience, regardless of gender, nationality, marital status, race or religion.

The proportion of female staff employed at ECMWF as at the end of 2010 was 49% for B-grades and 17% for A-grades. The corresponding figures for 2009 were 51% and 17%.

During 2010, ECMWF issued a total of 33 vacancy notices (compared with 17 vacancy notices during the previous year), of which 19 were for staff positions and 14 for consultancy positions. Of the 33 vacancies, 20 have been completed. In total ECMWF received 899 applications, of which 696 (77%) were from male applicants and 203 (23%) from female applicants. Of the selected staff and consultants, 64% are male and 36% are female.

The work on the new computerised recruitment module within the NAVISION computer system is still in progress. Although the work has been delayed, it is envisaged that the new module will be implemented in the early part of 2011.

Finance

At its meeting in December 2009, the Council agreed that Member States' contributions to the budget for 2010 would increase by 3.12% over the budget for 2009.

ECMWF's budget for 2010 was £39,569,200. This included contributions from Member States and Co-operating States amounting to £37,564,800. The main expenditure was on staff and the high-performance computer (HPC) infrastructure.

The Centre is aiming to be compliant with International Public Sector Accounting Standards (IPSAS) by 2012. In order to ensure that this aim is met, ECMWF has set up an IPSAS Steering Committee to oversee the implementation of IPSAS. This committee has set up working groups to review specific aspects of IPSAS and make recommendations to ensure compliance with the standards. There are currently two working groups, one to review accounting for staff benefits and one to consider treatment of fixed assets.

Awards and appointments

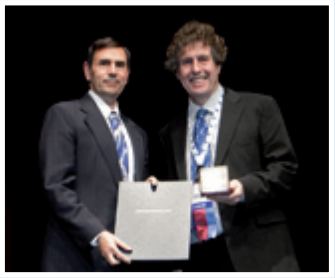
David Burridge, former Director of ECMWF, was awarded the European Meteorological Society silver medal for his outstanding leadership and scientific contributions in the field of numerical weather prediction.

Tim Palmer (Head of Probabilistic Forecasting and Diagnostics Division at ECMWF) was awarded the Carl-Gustaf Rossby Research Medal at the 90th Annual Meeting of the American Meteorological Society (AMS) in recognition of his outstanding contributions to the understanding of the structure or behaviour of the atmosphere. Also he became President of the UK's Royal Meteorological Society.

Florian Pappenberger (Predictability and Diagnostics Section) received the Outstanding Editor Award from the European Geosciences Union (EGU) in recognition of his excellent services as editor of 'Hydrology and Earth System Sciences'.

Bob Riddaway (Consultant) received the FitzRoy Prize from the Royal Meteorological Society for the contributions made to education and training.

Olaf Stiller (Consultant) was awarded the Buchan Prize from the Royal Meteorological Society for two papers published in its journals that are adjudged to contain the most important original contributions to meteorology.



Tim Palmer receiving an award from the AMS. *Presentation of the Carl-Gustaf Rossby Research Medal by Tom Karl (AMS President, left). Photograph: Jenni Girtman/Atlanta Event Photography; photograph provided courtesy of AMS.*

Working Group on the long-term building and refurbishment requirements

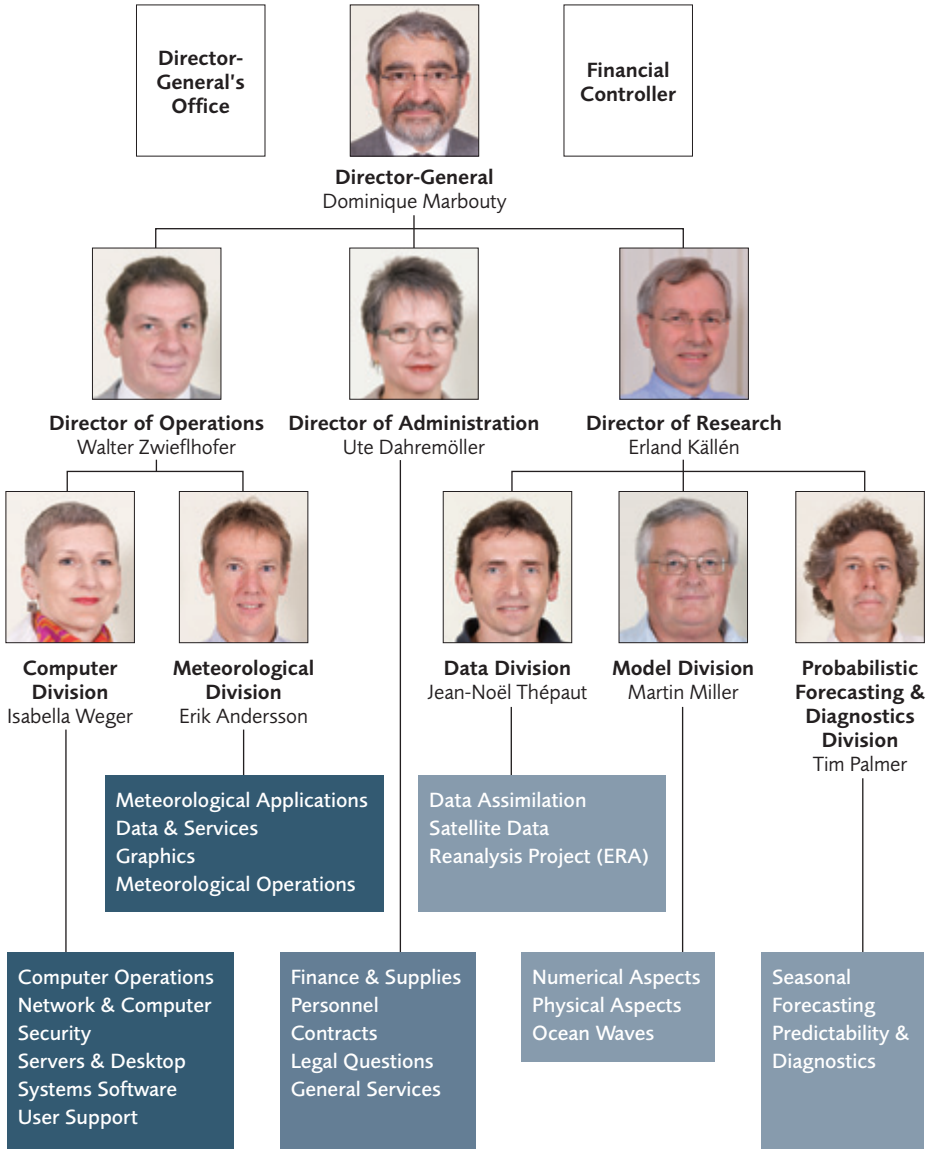
In December 2009 the Council established a working group with open participation to be chaired by Mr Detlev Frömming (Germany). Its remit is to draw up recommendations, including first cost estimates and timelines, for a comprehensive building and refurbishment plan for ECMWF. In doing this, the Working Group is expected to:

- analyse ECMWF's conference centre requirements, with special emphasis on the need to accommodate an increasing number of Member States;
- analyse the requirements for additional facilities;
- analyse the actual and foreseeable refurbishment requirements for the old office building;
- take into account the ongoing discussions in the Technical Advisory Committee on 'Green Computing'.

In 2010 the Working Group met twice: 17–18 February and 19–20 October.

As a first step, it agreed on the content of a detailed option and feasibility study.

The Centre's organisation on 31 December 2010



Prof Aksel Wiin-Nielsen

Prof Aksel Wiin-Nielsen, the first Director at ECMWF, sadly passed away on Monday, 26 April 2010. He was instrumental in the Centre's success.

A Danish national, Prof Wiin-Nielsen was ECMWF's first Director from 1 January 1974 to 31 December 1979. He put ECMWF on track to become a world leader in global numerical weather prediction. On leaving ECMWF, Prof Wiin-Nielsen became WMO Secretary-General in 1980, and then Director of the Danish Meteorological Institute (DMI) in 1984. In that function, Prof Wiin-Nielsen returned to ECMWF to attend sessions of the ECMWF Council, representing Denmark. He served as President of the ECMWF Council in 1987. He became Professor of Physics at the University of Copenhagen in 1987, and continued his research interests well after his retirement in 1995. During his long career Prof Wiin-Nielsen received many international awards.

Amendments to the Convention

The amendments to the Convention of ECMWF entered into force on 6 June 2010. This was a milestone in ECMWF's history as it allows an enlargement of ECMWF's membership and an expansion of the scope of its activities.

The original Convention restricted ECMWF's membership to the founding 18 Member States. The amended Convention enables more States to join ECMWF as full Member States. Following the entry into force of the amended Convention, requests for full membership were received from several Co-operating States. Negotiations on accession agreements started with these States.

Furthermore, the amended Convention enlarges ECMWF's mission to cover the monitoring of the Earth system. It allows the Centre to run Third Party Activities that are in line with its purposes and objectives, and also to establish Optional Programmes that contribute to the ECMWF objectives; these will provide an excellent means to execute activities in which not all Member States wish to be involved.

Co-operation agreements

During 2010, the co-operation agreements with Bulgaria and Israel entered into force, respectively on 12 July and 28 October. To date, co-operation agreements have been signed with Bulgaria, Croatia, Czech Republic, Estonia, Iceland, Israel, Hungary, Latvia, Lithuania, Montenegro, Morocco, Romania, Serbia, Slovakia and Slovenia.

Appendices

ECMWF's Member States and Co-operating States

Member States

Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

Co-operating States

Bulgaria, Croatia, Czech Republic, Estonia, Hungary, Iceland, Israel, Latvia, Lithuania, Montenegro, Morocco, Romania, Serbia, Slovakia and Slovenia.
Co-operating States have full access to ECMWF real-time products, archive data, software tools, as well as access to ECMWF training facilities.

Co-operation agreements

ECMWF has co-operation agreements with the following organisations:

- World Meteorological Organization (WMO)
- European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT)
- African Centre of Meteorological Applications for Development (ACMAD)
- ALADIN (Météo-France)
- Joint Research Centre (JRC) of the European Commission
- Preparatory Commission for the Comprehensive Nuclear Test-Ban Treaty Organization (CTBTO)
- Executive Body of the Convention on Long-range Transboundary Air Pollution (CLRTAP)
- European Space Agency (ESA)
- European Union (on the Development and Testing Phase of the European Flood Alert System)

The Council

As ECMWF's governing body, and comprising representatives from each Member State, the Council adopts measures that implement the Convention. Its responsibilities include admission of new members, authorising the Director-General to negotiate and conclude co-operation agreements, determining the annual budget and the scale of financial contributions of the Member States, adopting the Financial Regulations and the Staff Regulations, and pursuing the Centre's long-term strategy and programme of activities.

President:
Wolfgang Kusch (Germany)

Vice-President:
73rd session
Daniel Keuerleber-Burk (Switzerland),
74th session
François Jacq (France)

The 73rd and 74th sessions of Council took place on 24–25 June and 7–8 December 2010.

ECMWF Council 73rd session

The main results of this session were as follows.

Third Party Activities and Optional Programmes

The Council unanimously adopted the procedures for approving and implementing Third Party Activities and Optional Programmes now possible under the amended Convention.

Co-operation

The Council unanimously authorised the Director-General to negotiate and conclude a one-year extension of the current co-operation agreement with the Joint Research Centre (JRC) on the development and testing of the European Flood Alert System (EFAS) to cover a project fully funded by the Monitoring and Information Centre (MIC) of the European Commission.

GMES (Global Monitoring for Environment and Security)

The Council unanimously adopted the ECMWF strategy regarding GMES.

- The main involvement of ECMWF in GMES will remain in the atmosphere core services where it intends to continue to play both the role of coordinator and main player.
- ECMWF intends to continue to be a partner in land and emergency response core services where its role will be defined by the agreed scope of the core services.
- Reanalysis is recognised as a crucial input for climate monitoring and, therefore, it is expected that the GMES Climate Services will be the right framework for a European sustained reanalysis activity. ECMWF is willing to continue coordinating European efforts in reanalysis.
- ECMWF is prepared to coordinate the GMES Marine Core Services "if requested by the oceanographic community and by the GMES governing bodies".
- The main task of ECMWF will be to prepare with the European Commission and Member States an appropriate framework for its contribution to the implementation of sustained GMES core services from 2014 at the latest.

WMO

The Council unanimously:

- Authorised the continuation of ECMWF's ongoing support for WMO's severe weather forecast demonstration projects (SWFDP) as a Global Centre.
- Approved ECMWF's plan to respond positively to WMO's request at the forthcoming Commission for Basic Systems (CBS) for nomination as Lead Centre for Deterministic NWP Verification.
- Authorised the continued provision of deterministic and ensemble tropical cyclone track information in real time, for research use only, in support of THORPEX and other WMO-led research activities.

ECMWF Council 74th session

The main results of this session were as follows.

Appointment of a new Director-General

The Council unanimously approved the appointment of Prof Alan Thorpe as the new ECMWF Director-General from 1 July 2011.

New Co-operating and Member States

The Council unanimously authorised the Director-General to conclude co-operation agreements with the former Yugoslav Republic of Macedonia and with Bosnia and Herzegovina. Also the Council unanimously agreed to vote by correspondence on Iceland's and Slovenia's applications for full membership early in 2011.

Computer facility

The Council unanimously authorised the Director-General to conclude a one-year extension to mid-2014 for IBM's service contract for the high-performance computing facility (HPCF), based on the current money stream. The extension will give ECMWF a scientifically valuable increase in compute resources in mid-2012. This will enable ECMWF to make faster progress in addressing the scalability issues within the ECMWF data assimilation system. It represents the same good value for money as achieved in the initial procurement.

Four-year programme of activities

The Council unanimously adopted a four-year programme of activities for the years 2011–2014.

Member State	Attendees
Austria	Michael Staudinger
Belgium	Henri Malcorps An Neukermans
Denmark	Peter Aakjaer Leif Laursen
Finland	Juhani Damski Mikko Alestalo
France	François Jacq Alain Ratier
Germany	Franz Berger Detlev Frömming
Greece	Loukas Asimakis Theagenis Charantonis
Ireland	Liam Campbell
Italy	Mario Ali Costante de Simone Federico Cinquepalmi Sergio Pasquini
The Netherlands	Frits Brouwer
Norway	Jens Sunde Øystein Hov Roar Skålin
Portugal	Adérito Vicente Serrão
Spain	Ricardo García-Herrera
Sweden	Lena Häll Eriksson Ilmar Karro
Switzerland	Daniel Keuerleber-Burk Alex Rubli Peter Binder
Turkey	Ali Karatas Fatïh Büyükkasabbaşi
United Kingdom	John Hirst Alan Dickinson Mark Hodkinson
Co-operating State	
Estonia	Aarne Männik
Hungary	Ildiko Dobi Wantuch
Iceland	Theodor Hervarsson Halldor Petursson Arni Snorasson
Slovenia	Klemen Bergant

Policy Advisory Committee (PAC)

The PAC provides the Council with opinions and recommendations on any matters concerning ECMWF policy submitted to it by the Council, especially those arising out of the Centre's four-year programme of activities and long-term strategy.

Chair:
Alain Ratier (France)
Vice-Chair:
Petteri Taalas (Finland)

The 29th and 30th sessions of the PAC took place on 28–29 April and 18–19 October 2010.

Member State	Attendees
Austria	Michael Staudinger
Finland	Mikko Alestalo
France	Alain Ratier
Germany	Franz Berger
	Detlev Frömming
Greece	Aglaia Vrachnou
Italy	Massimo Capaldo
	Costante de Simone
The Netherlands	Piet de Wildt
Spain	Manuel Palomares
	José Luis Camacho
Sweden	Ilmar Karro
Switzerland	Alex Rubli
United Kingdom	Mike Gray
	Mark Hodkinson

Finance Committee (FC)

The FC provides the Council with opinions and recommendations on all financial and administrative matters submitted to the Council and exercises the financial powers delegated to it by the Council.

Chair:
Monika Köhler (Austria)
Vice-Chair:
Sergio Pasquini (Italy)

The 84th, 85th, 86th and 87th sessions of the FC took place on 27–28 April, 14–15 July, 16–17 September and 11–13 October 2010.

Member State	Attendees
Finland	Marko Viljanen
(also representing Denmark, Ireland, Norway and Sweden)	
France	Véronique Martin
Germany	Detlev Frömming
	Leander Jamin
Italy	Sergio Pasquini
	Antonio Bartolini
The Netherlands	Piet de Wildt
	Jupp de Bel
(also representing Austria, Belgium, Luxembourg and Switzerland)	
Portugal	Paulo Sousa
	Ana Raquel Ribeiro
(also representing Spain, Greece and Turkey)	
United Kingdom	Paul Mundy
	Mark Hodkinson
	Nicholas Jobling
	Melissa Welsh
Observers	
Austria	Monika Köhler
Belgium	Alain Heynen
Spain	Manuel Palomares

Scientific Advisory Committee (SAC)

The SAC provides the Council with opinions and recommendations on the draft programme of activities of the Centre drawn up by the Director-General and on any other matters submitted to it by the Council. SAC members are appointed in their personal capacity and are selected from among the scientists of the Member States.

Chair:
Heikki Järvinen
Vice-Chair:
François Bouttier

The 39th session of the SAC took place on 4–6 October 2010.

Attendees
Jan Barkmeijer
François Bouttier
John Eyre
Heikki Järvinen
Piero Lionello
Ernesto Rodriguez-Camino
Julia Slingo
Michael Tjernström
Robert Vautard
Observers
Dieter Klaes (EUMETSAT)
Ghassem Asrar (WMO)

Technical Advisory Committee (TAC)

The TAC provides the Council with advice on the technical and operational aspects of the Centre, including the communications network, computer system, operational activities directly affecting Member States, and technical aspects of the four-year programme of activities.

Chair:
Alan Dickinson (UK)
Vice-Chair:
Bernard Strauss (France)

The 42nd session of the TAC took place on 6–8 October 2010.

Member State	Attendees
Austria	Georg Kaindl
Belgium	Daniel Gellens
Denmark	Carsten Simonsen
Finland	Juhani Damski
	Kimmo Aaltonen
France	Bernard Strauss
	Matteo Dell'Acqua
Germany	Dieter Schröder
Greece	Emmanuel Lekkas
Ireland	Paul Halton
Italy	Massimo Ferri
The Netherlands	Toon Moene
Norway	Jens Sunde
	Roar Skålin
Spain	Eduardo Monreal
Sweden	Michael Hansson
	Håkan Borg
Switzerland	Stefan Sandmeier
	Eugen Müller
United Kingdom	Alan Dickinson
	Alan Radford
	Nick Grahame
Co-operating State	
Croatia	Čedo Brankovič
Czech Republic	Alena Trojakova
Hungary	Istvan Ihász
Iceland	Halldor Bjornsson
Slovakia	Jozef Vivoda

Advisory Committee for Data Policy (ACDP)

The ACDP provides the Council with opinions and recommendations on matters concerning ECMWF Data Policy and its implementation.

Chair:
Colin Cuthbert (UK)
Vice-Chair:
Klaus Haderlein (Germany)

The 11th session of the ACDP took place on 3–4 June 2010.

Member State	Attendees
Austria	Monika Köhler
Denmark	Søren E. Olufsen
Finland	Lea Leskinen
France	Philippe Santoni
Germany	Klaus Haderlein
Greece	Aglaia Vrachnou
Ireland	Joseph Bourke
Italy	Paolo Capizzi
Norway	Lillian Svendsen
Spain	Francisco Pascual
Sweden	Marcus Flarup
Turkey	Enver Erbaş
Co-operating State	
Latvia	Inita Stikute
Slovakia	Vladimir Pastircak

Advisory Committee of Co-operating States (ACCS)

The ACCS provides the Council with opinions and recommendations on the Centre's programme of activities, and on any matter submitted to it by the Council.

Chair:
Ivan Čačić (Croatia)
Vice-Chair:
László Bozó (Hungary)

The 16th session of the ACCS took place on 14 October 2010.

Co-operating State	Attendees
Bulgaria	Georgi Kortchev
Croatia	Ivan Čačić
	Čedo Brankovič
Estonia	Aarne Männik
Hungary	László Bozó
Serbia	Milan Dacić
Slovakia	Martin Benko
Slovenia	Jožef Roškar
Observer	
Israel	Henia Berkovich

Externally funded projects and services

Project Acronym	Project Description	Funding Agency	ECMWF role	Dates		ECMWF Budget (€)
				From	To	
ADM/AEOLUS	Development and production of aeolus wind data products	ESA	Subcontractor	01/10/04	30/06/12	1,220,511
AMV study	Using model-simulations to improve AMV characterisation	EUMETSAT	Contractor	01/11/10	20/02/12	129,961
ARM	Model validation studies	US DOE	Contractor	01/08/10	31/07/13	$530,015
BOSS4GMES	Building Operational Sustainable Services for GMES	EC	Contractor	01/12/06	31/01/10	149,997
CMUG	Climate Modelling User Group	ESA	Subcontractor	06/04/10	05/04/13	384,244
Combine	Comprehensive Modelling of the Earth system for better climate prediction and projection	EC	Contractor	01/05/09	30/04/13	296,200
DEISA2	Distributed European infrastructure for supercomputing applications 2	EC	Contractor	01/05/08	30/04/11	480,000
Dewfora	Improved Drought Early Warning and FORecasting to strengthen preparedness and adaptation to droughts in Africa	EC	Beneficiary	01/01/11	31/12/13	255,420
EC-EARTH	EC-Earth support at ECMWF	KNMI	Contractor	01/12/10	30/11/11	105,000
EFAS	Transfer of EFAS to operational service	JRC	Contractor	01/11/10	31/10/11	274,997
ENVISAT II	Technical support for global validation of ENVISAT data products	ESA	Contractor	01/08/08	31/12/10	689,325
EPS IASI	Support of ECMWF to EPS/IASI phase 5	EUMETSAT	Contractor	01/01/10	31/12/11	£273,758
ERA	ERA	NCAS/NERC	Subcontractor	01/09/07	31/08/11	221,090
ERS validation II	Technical support for global validation of wind and wave products (ERS II)	ESA	Contractor	01/07/08	30/06/10	£239,997
EUCOS	Space-terrestrial Observation System Experiments 2010-2011	DWD	Contractor	18/06/10	31/08/11	123,800
EUMETSAT fellowships	Fellowships	EUMETSAT	Contractor	Ongoing		190,000/yr
Geoland2	Towards an operational GMES Land Monitoring Core Service	EC	Contractor	01/09/08	31/08/12	485,119
Glowasis	A collaborative project aimed at pre-validation of a GMES Global Water Scarcity Information System	EC	Beneficiary	01/01/11	31/12/12	272,368
GRAS-SAF	The continuous development and operations phase of a EUMETSAT Satellite Application Facility on GRAS meteorology	EUMETSAT	Subcontractor	01/03/07	29/02/12	610,000
H-SAF	Satellite Application Facility on support to operational hydrology and water management	EUMETSAT	Subcontractor	01/09/05	31/08/10	220,000
KultuRisk	Knowledge-based approach to develop a cULTUre of Risk prevention	EC	Beneficiary	01/01/11	31/12/13	167,610
MACC	Monitoring Atmospheric Composition and Climate	EC	Coordinator	01/06/09	31/10/11	3,642,898
met.no consultant	Secondment of 1 consultant to ECMWF	met.no	Contractor	06/09/10	05/09/12	216,000
MyOcean	Development and pre-operational validation of upgraded GMES Marine Core Services and capabilities	EC	Beneficiary	01/01/09	31/03/12	65,000
NWP SAF CDOP	Development and Implementation of certain activities within a EUMETSAT Satellite Application Facility on numerical weather prediction	EUMETSAT	Subcontractor	01/03/07	28/02/12	988,510
NWP study	Study on the Impact of fututre developments of the space-based observing system on Numerical Weather Prediction	EUMETSAT	Contractor	01/08/09	31/08/10	119,410
ODB	Maintenance and support of the Observations Database Software	UK MetOffice	Contractor	01/06/10	31/05/12	200,000
Post EPS	Refinement of spectral and radiometric requirements for a Post-EPS Microwave imaging mission	EUMETSAT	Contractor	01/07/09	31/12/10	149,979
QuARL	Quantitative Assessment of the Operational Value of Space-Borne Radar and Lidar Measurements of Cloud and Aerosol Profiles	ESA	Contractor	01/09/08	30/08/10	499,373
QWeCi	Quantifying Weather and Climate Impacts on Health in Developing Countries	EC	Beneficiary	01/02/10	31/07/13	£249,480
SAFEWIND	Multi-scale data assimilation, advanced wind modeling and forecasting with emphasis to extreme weather situations for a secure large-scale wind power integration	EC	Beneficiary	01/09/08	31/07/12	£416,000
SMOS DA	Study methods and techniques to best assimilate SMOS data into ECMWF's operational numerical weather forecasting system	ESA	Contractor	01/10/10	31/01/13	279,088
THOR	Thermohaline Overturning - at Risk?	EC	Beneficiary	01/12/08	30/11/12	392,000
VALOR	Value of the Rapid array for climate prediction	NERC	Subcontractor	01/04/09	31/12/11	£136,300

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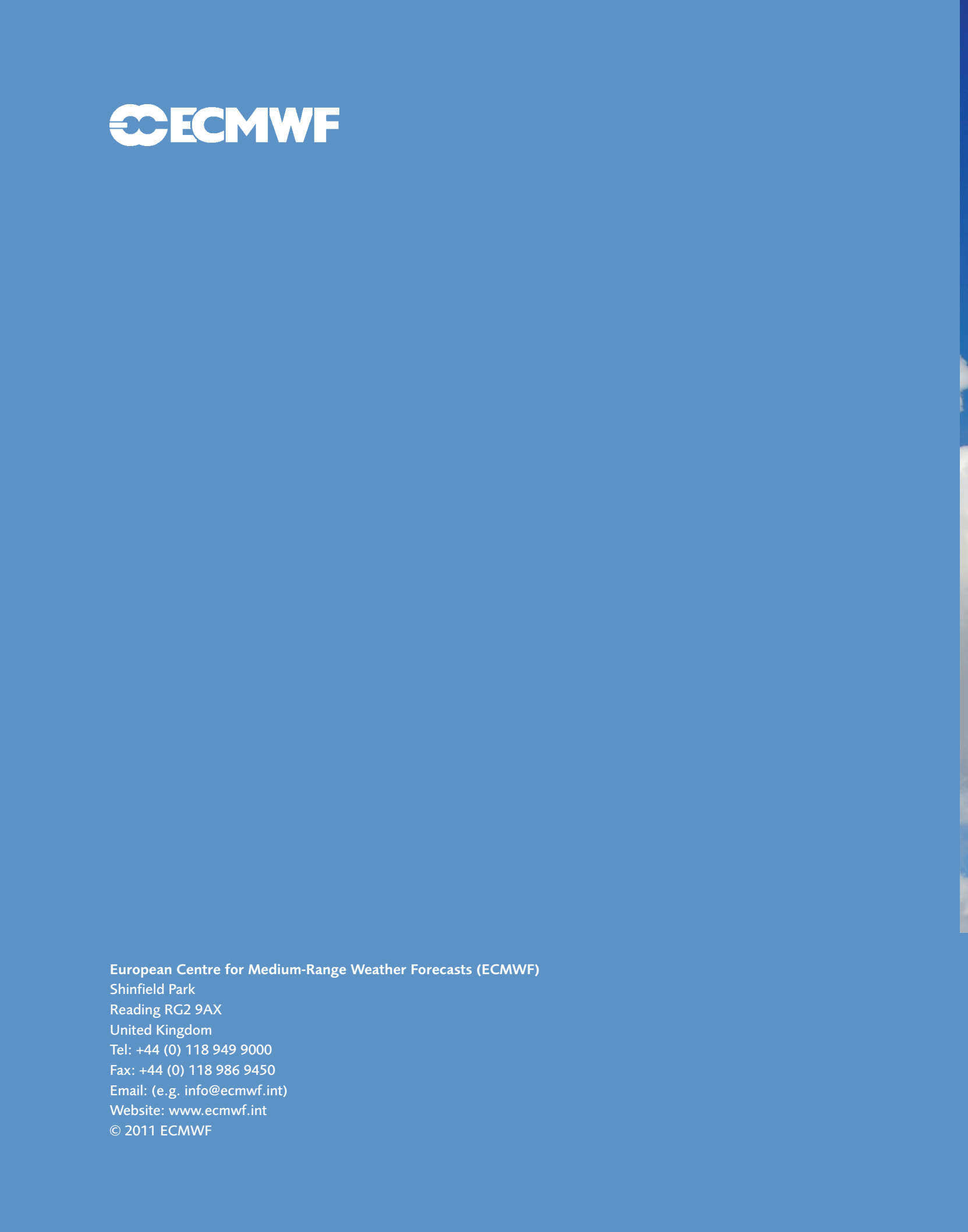

European Centre for Medium-Range Weather Forecasts (ECMWF)
Shinfield Park
Reading RG2 9AX
United Kingdom
Tel: +44 (0) 118 949 9000
Fax: +44 (0) 118 986 9450
Email: (e.g. info@ecmwf.int)
Website: www.ecmwf.int