# ECMWF products to represent, quantify and communicate forecast uncertainty

## Using ECMWF's Forecasts, 2015

David Richardson

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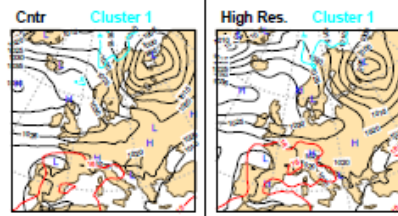
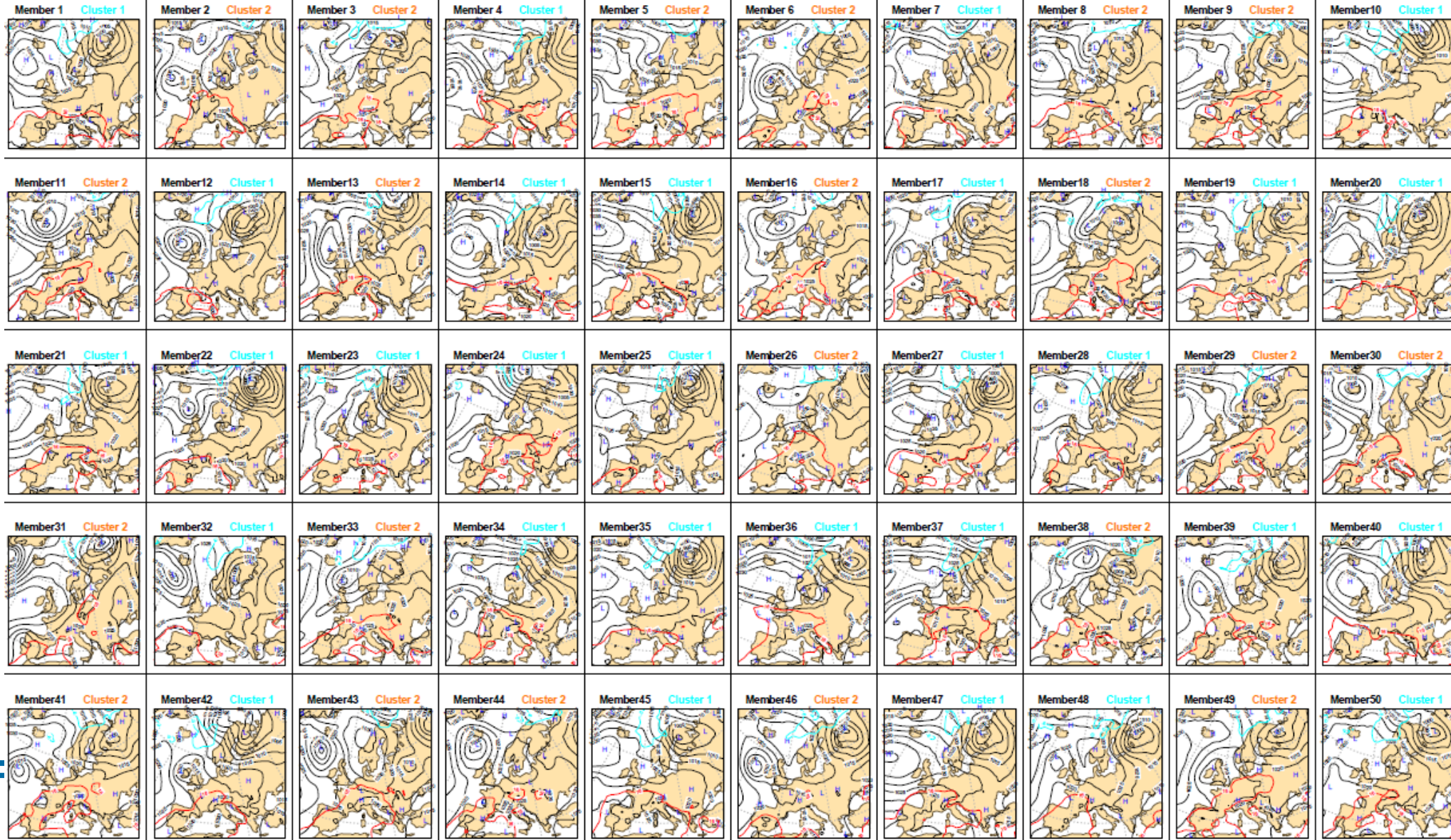David.Richardson@ecmwf.int

**ECMWF**

# ECMWF Forecasts

HRES

ENS control
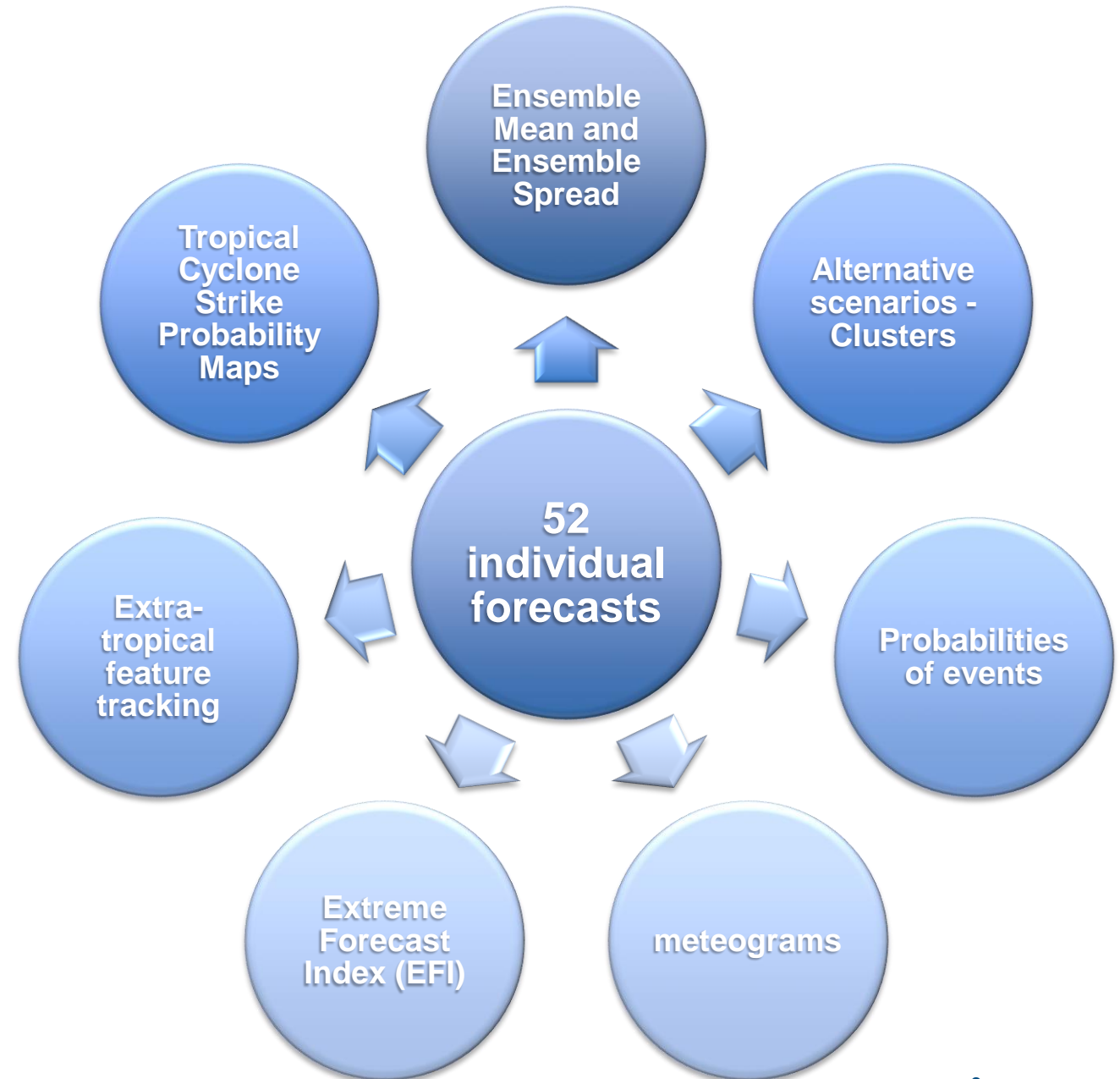
ENS perturbed members



ECMWF ENSEMBLE FORECASTS

Monday 01 June 2015 0000 UTC ECMWF forecast t+168 VT:Monday 08 June 2015 0000 UTC
MSLP (contour every 5hPa) Temperature at 850hPa (only -6 and 16 isolines are plotted)

# ECMWF forecast products

- Summarise information in HRES and ENS

- Represent uncertainty

- Broad-scale evolution out to 15 days

- Changes in weather regime

- Highlight potential for severe weather few days ahead

- Monthly and seasonal outlooks

- To assist operational forecasters (in Member States)

- Users generate their own tailored products for specific applications

**52 individual forecasts**

- Ensemble Mean and Ensemble Spread
- Alternative scenarios - Clusters
- Tropical Cyclone Strike Probability Maps
- Probabilities of events
- Extra-tropical feature tracking
- Extreme Forecast Index (EFI)
- meteograms

# Point forecasts: timeseries (meteogram)

HRES

Control

Summary of ENS
members

Nearest ENS model
(land) grid point

HRES interpolated to
ENS grid

No statistical correction
(except for 2m T height
adjustment)

Highest value of all members
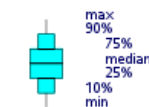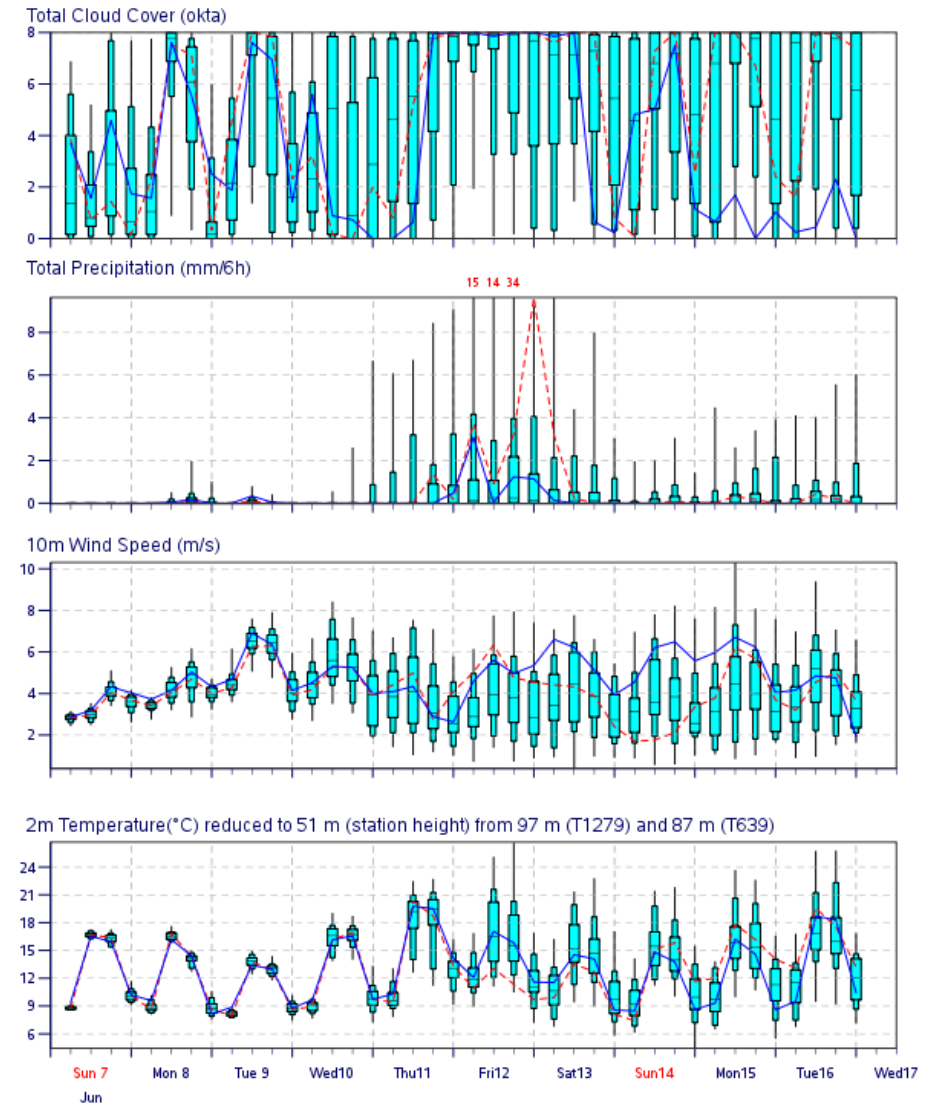
90th centile

75th centile

Median

25th centile

10th centile

Lowest value of all members



ENS Meteogram
Reading, United Kingdom 51.57°N 0.83°W (EPS land point) 51 m
High Resolution Forecast and ENS Distribution Sunday 7 June 2015 00 UTC

Total Cloud Cover (okta)

Total Precipitation (mm/6h)

10m Wind Speed (m/s)

2m Temperature(°C) reduced to 51 m (station height) from 97 m (T1279) and 87 m (T639)

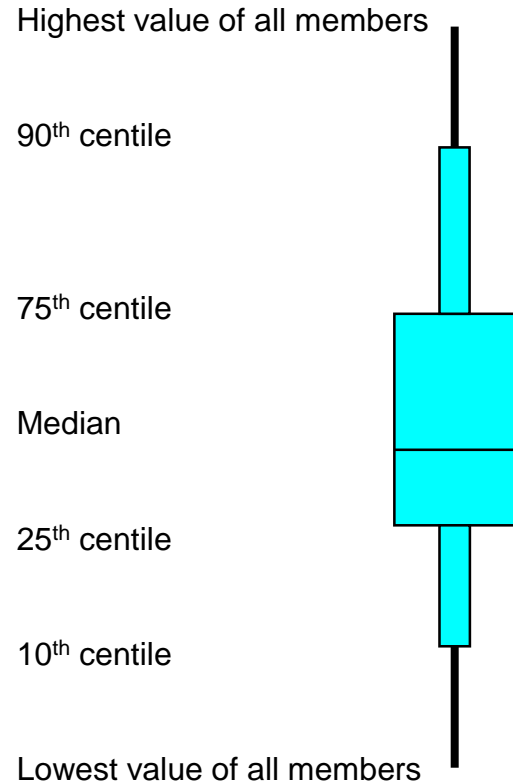ENS Control(31 km)    High Resolution (16 km)

# Point forecasts: timeseries (meteogram)

15-day meteogram

Summary of ENS members

Complement to the 10-day meteogram

Fields for days 1-10 interpolated to day 10-15 grid

Highest value of all members

90th centile

75th centile

Median

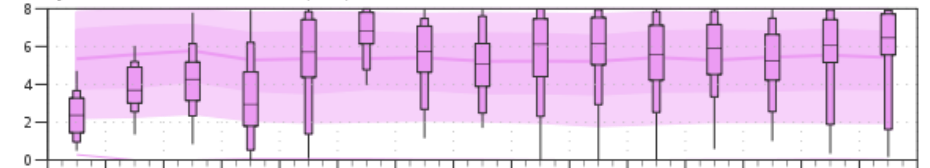25th centile
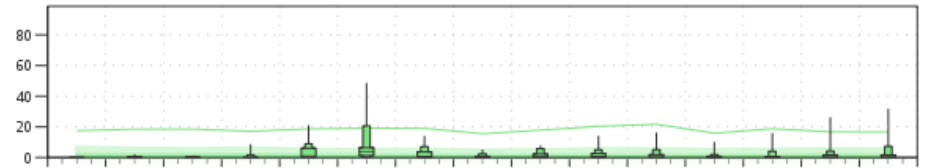
10th centile

Lowest value of all members



ENS Meteogram
Reading, United Kingdom 51.39°N 0.83°W (EPS land point) 51 m
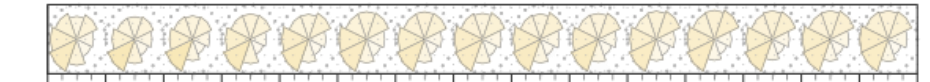Extended Range Forecast based on ENS distribution Sunday 7 June 2015 00 UTC

Daily mean of Total Cloud Cover (okta)
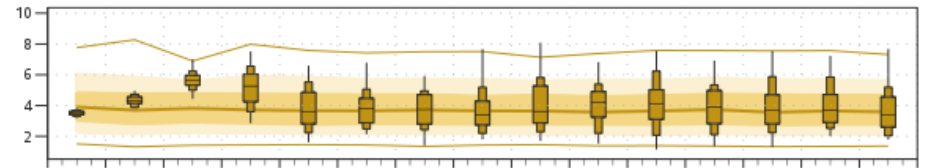
Total Precipitation (mm/24h)

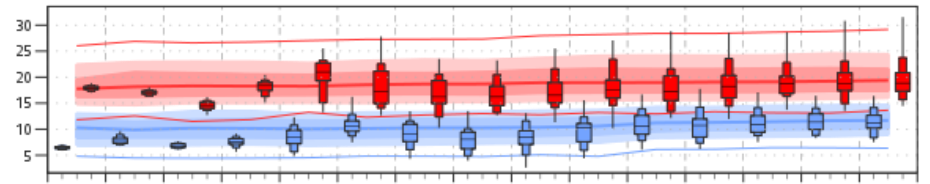M-Climate of the distribution of 10m Wind Direction
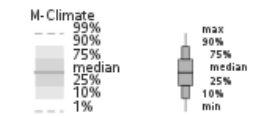
Daily Distribution of 10m Wind Direction
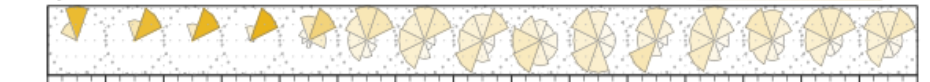
Daily mean of 10m Wind Speed (m/s)

2m min/max Temperature (°C) reduced to 51 m (station height) from 96 m (T319)

Sun 7  Mon 8  Tue 9  Wed10  Thu11  Fri12  Sat13  Sun14  Mon15  Tue16  Wed17  Thu18  Fri19  Sat20  Sun21
Jun
2015

M-Climate
99%
90%
75%
median
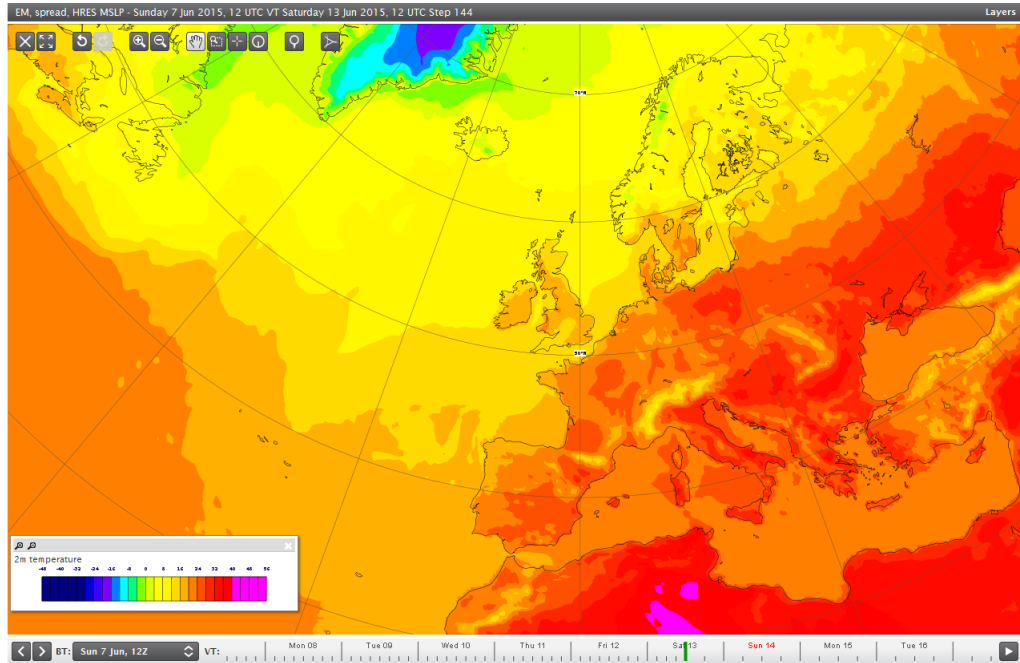25%
10%
1%

max
90%
75%
median
25%
10%
min

**M-Climate**: this stands for Model Climate. It is a function of lead time, date (+/-15days), and model version. It is derived by rerunning a 11 member ensemble over the last 20 years twice a week (1980 realisations). M-Climate is always from the same model version as the displayed ENS data.
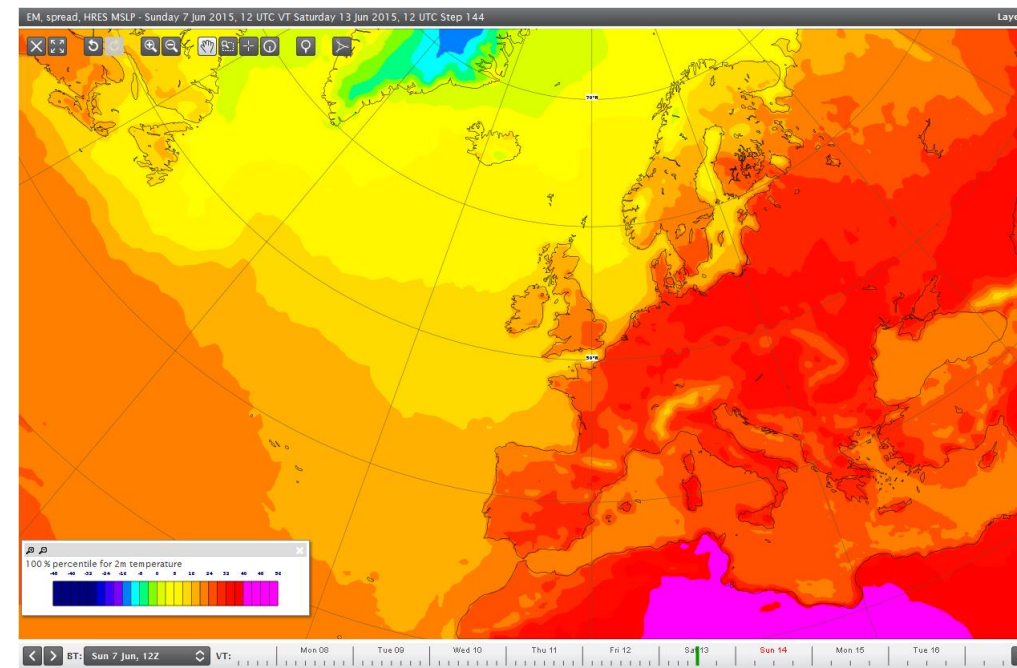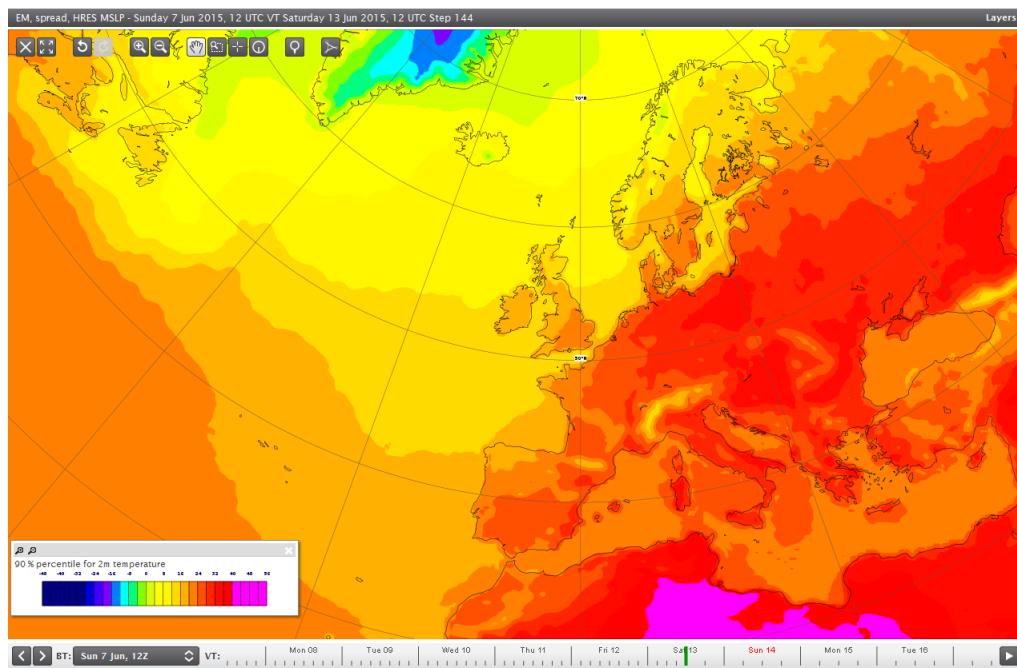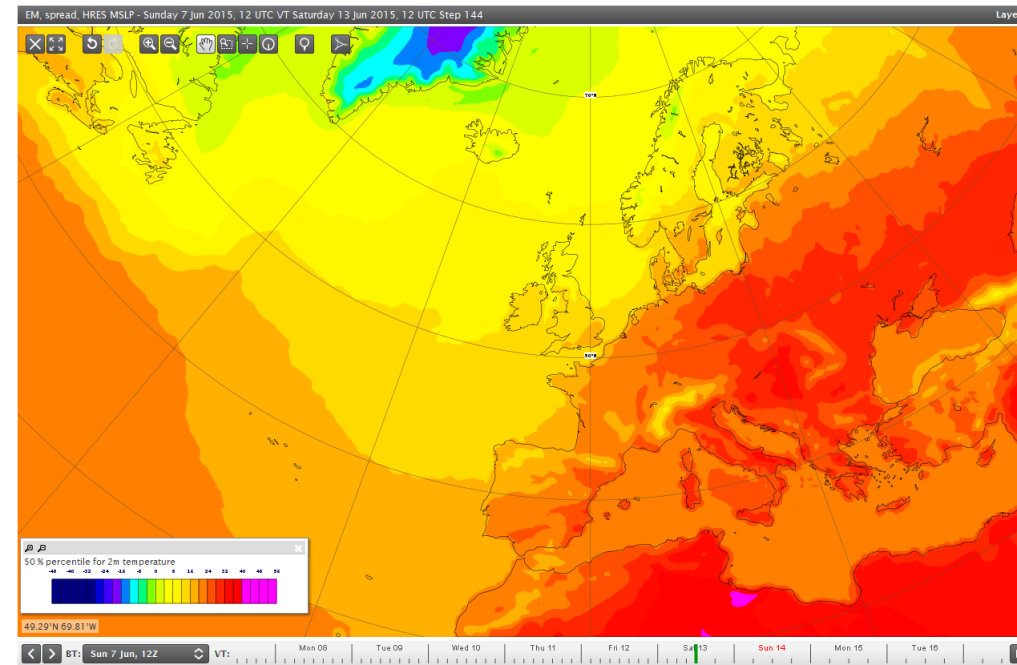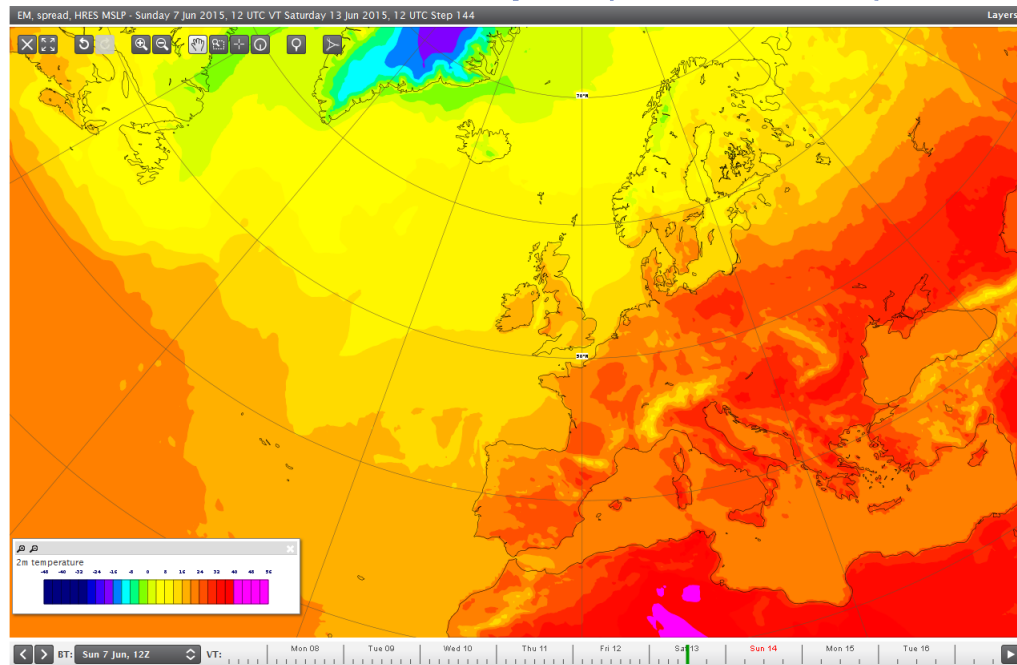
# Quantiles as maps (ecCharts)

# Quantiles as maps (ecCharts)
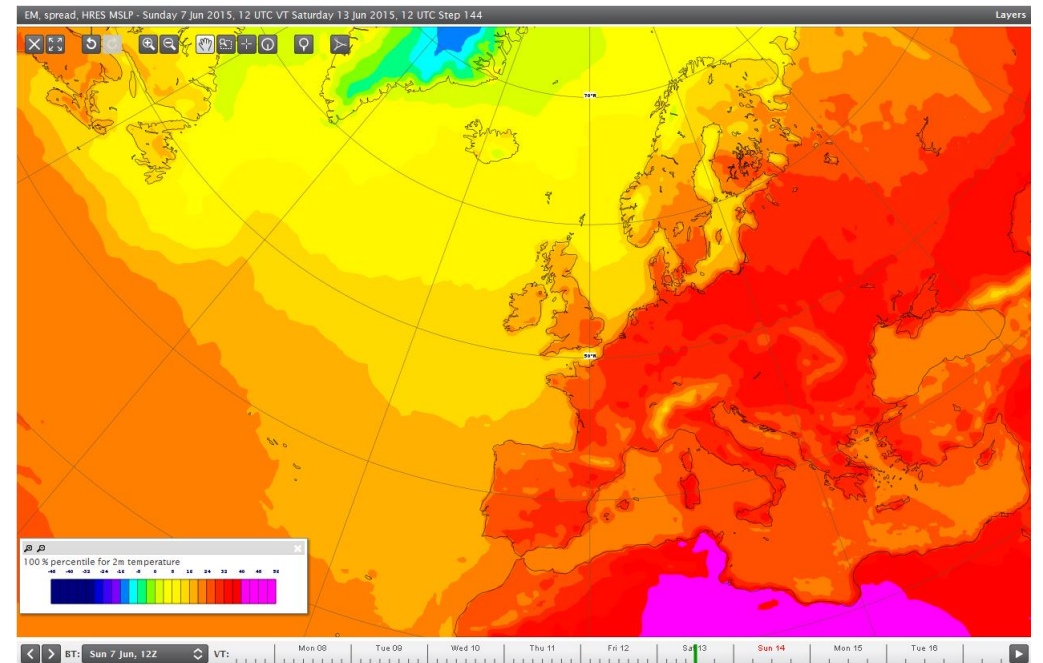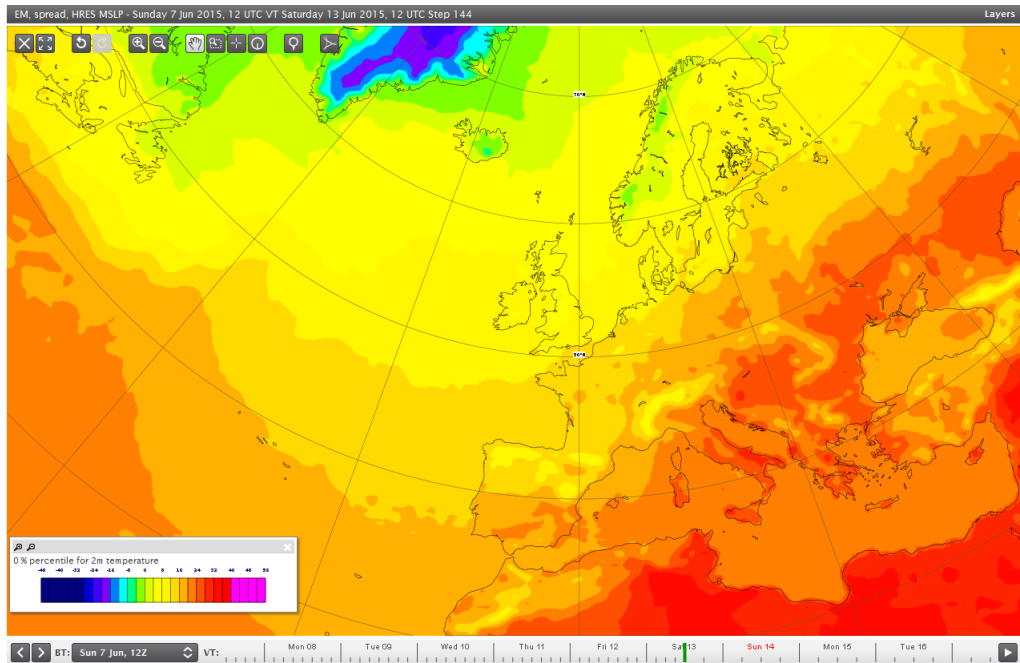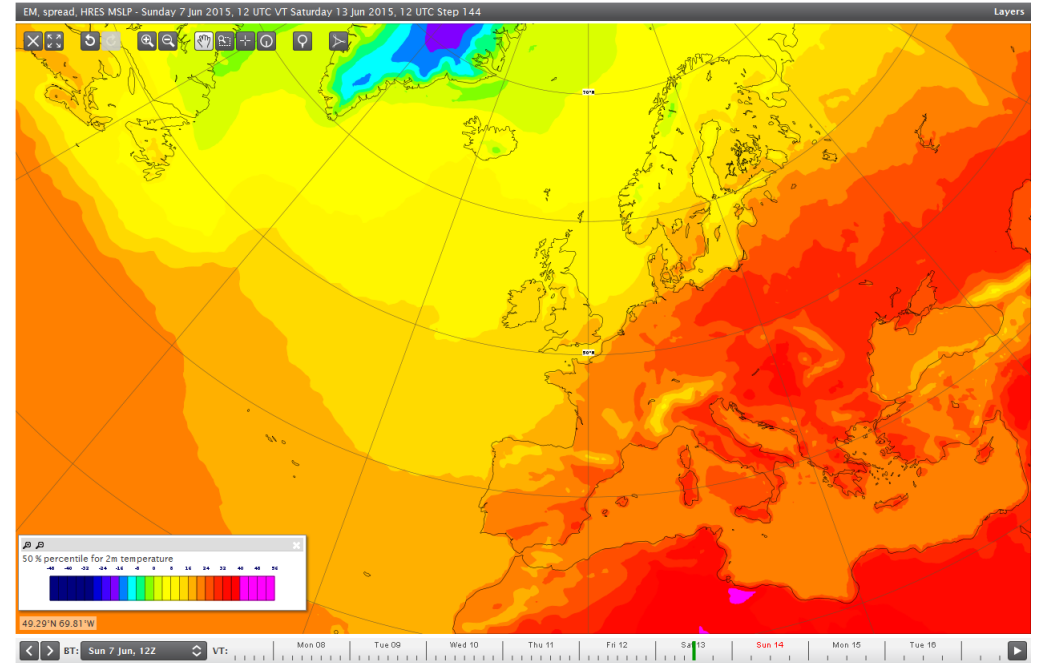


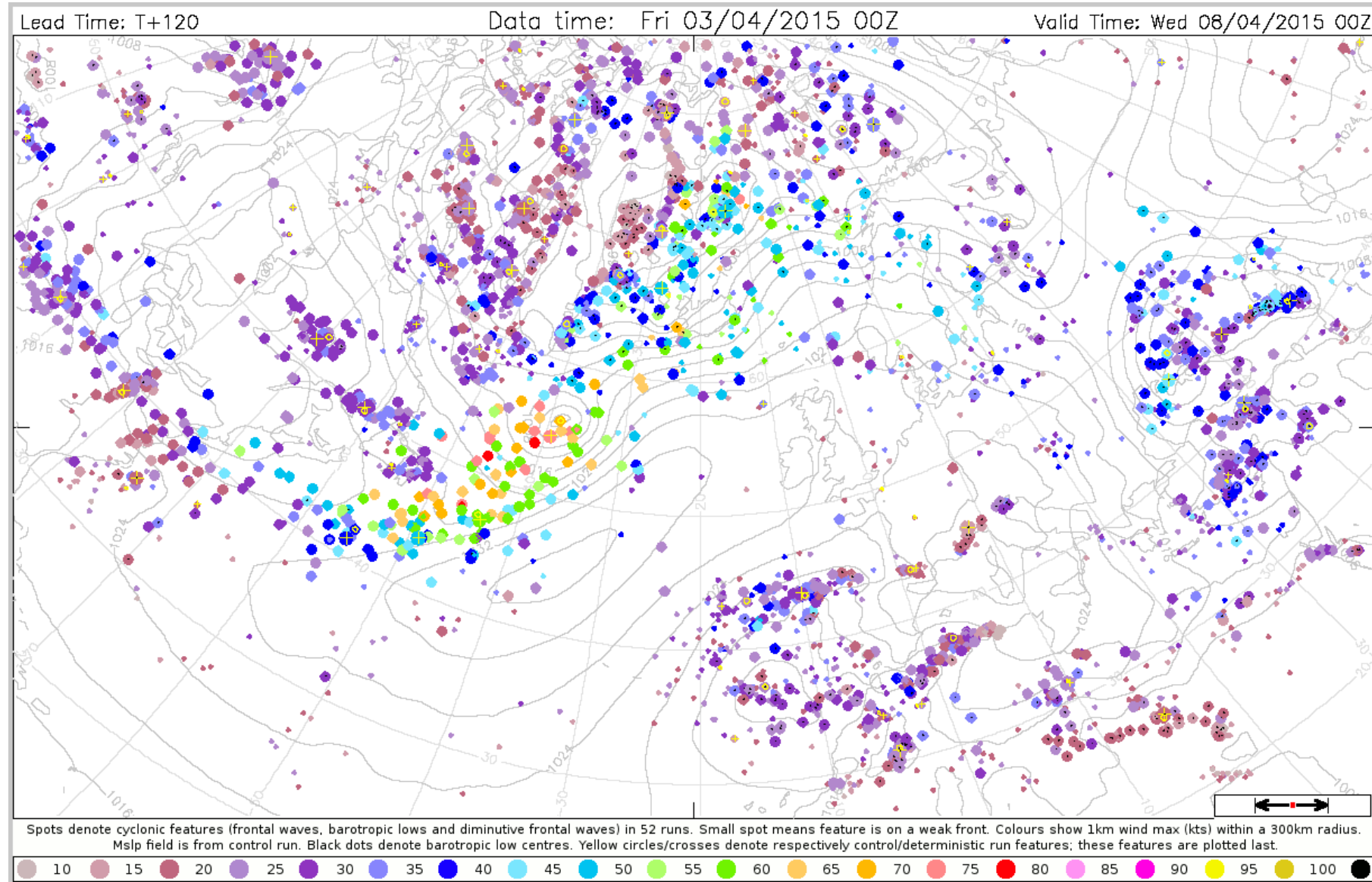ATHER FORECASTS

# Extra-tropical cyclonic feature tracking

Forecast cyclonic centres

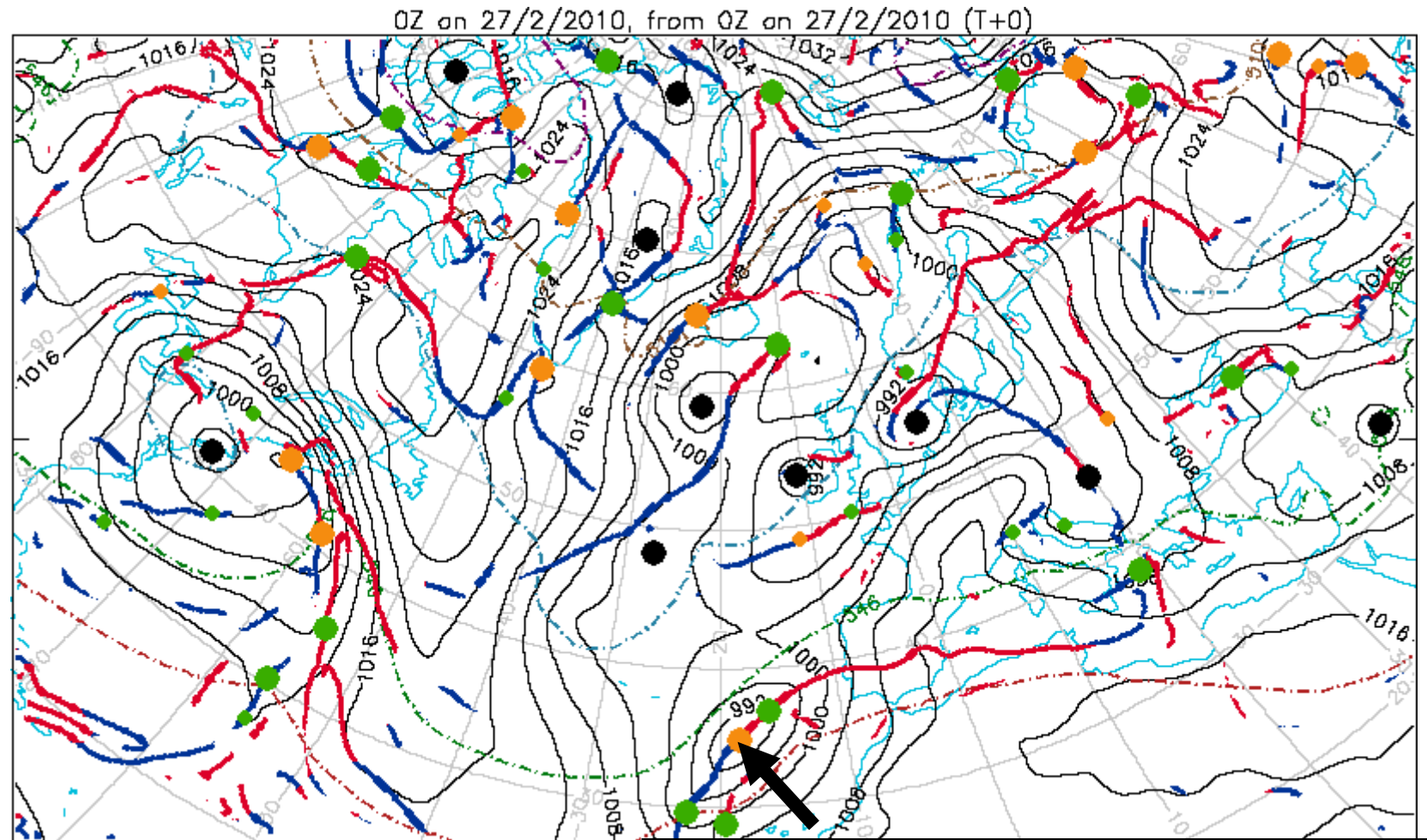HRES, control, ENS



Lead Time: T+120    Data time: Fri 03/04/2015 00Z    Valid Time: Wed 08/04/2015 00Z

Spots denote cyclonic features (frontal waves, barotropic lows and diminutive frontal waves) in 52 runs. Small spot means feature is on a weak front. Colours show 1km wind max (kts) within a 300km radius. Mslp field is from control run. Black dots denote barotropic low centres. Yellow circles/crosses denote respectively control/deterministic run features; these features are plotted last.

10  15  20  25  30  35  40  45  50  55  60  65  70  75  80  85  90  95  100

# Extra-tropical cyclonic feature tracking

Forecast cyclonic centres

HRES, control, ENS



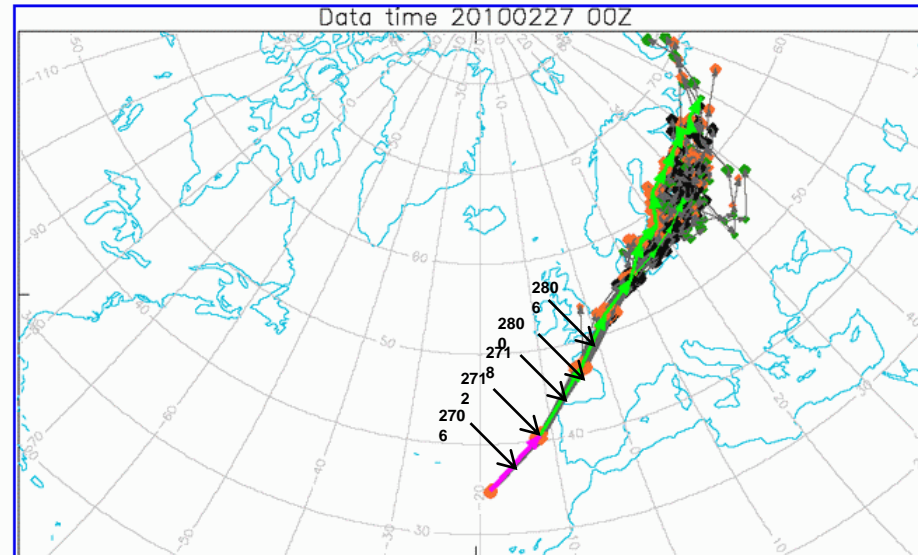0Z on 27/2/2010, from 0Z on 27/2/2010 (T+0)

User can click on any spot (= cyclonic feature) to see how that feature evolves in the forecast

# Extra-tropical cyclonic feature tracking

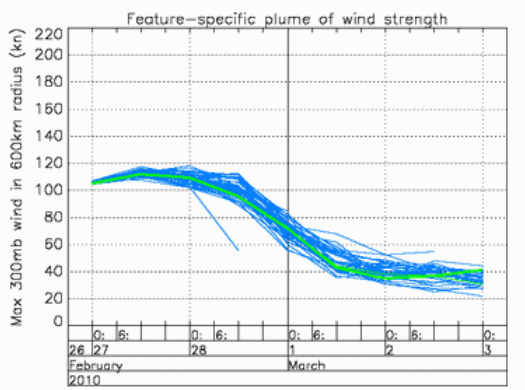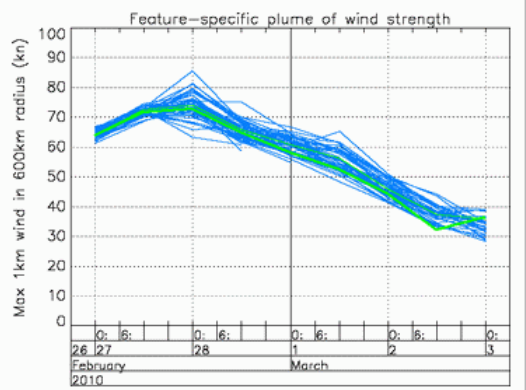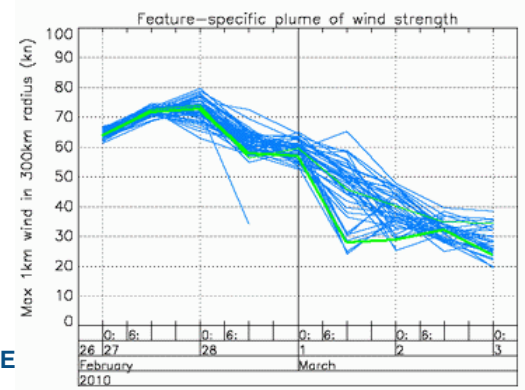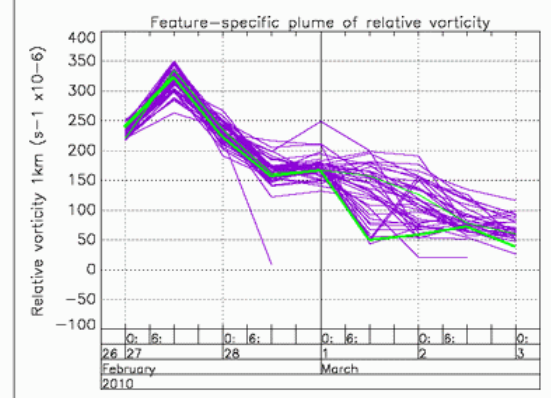Forecast cyclonic centres

HRES, control, ENS

# Tropical cyclones

Tracks of TCs
present at start of
forecast

HRES, control, ENS

# Tropical cyclone activity

All TCs including those that form during the forecast

Tracks will be available in BUFR

Test data soon available by ftp

Tropical Storm Strike Probability Start date:Sunday 08 March 2015 at 00 UTC
valid for 48hours from Thursday 12 March 2015 at 00 UTC to Saturday 14 March 2015 at 00 UTC
Probability of a Tropical Storm passing within 300km radius

| | | |
|---|---|---|
| 5-10 | 10-20 | 20-30 |
| 30-40 | 40-50 | 50-60 |
| 60-70 | 70-80 | 80-90 |
| >90% | | |
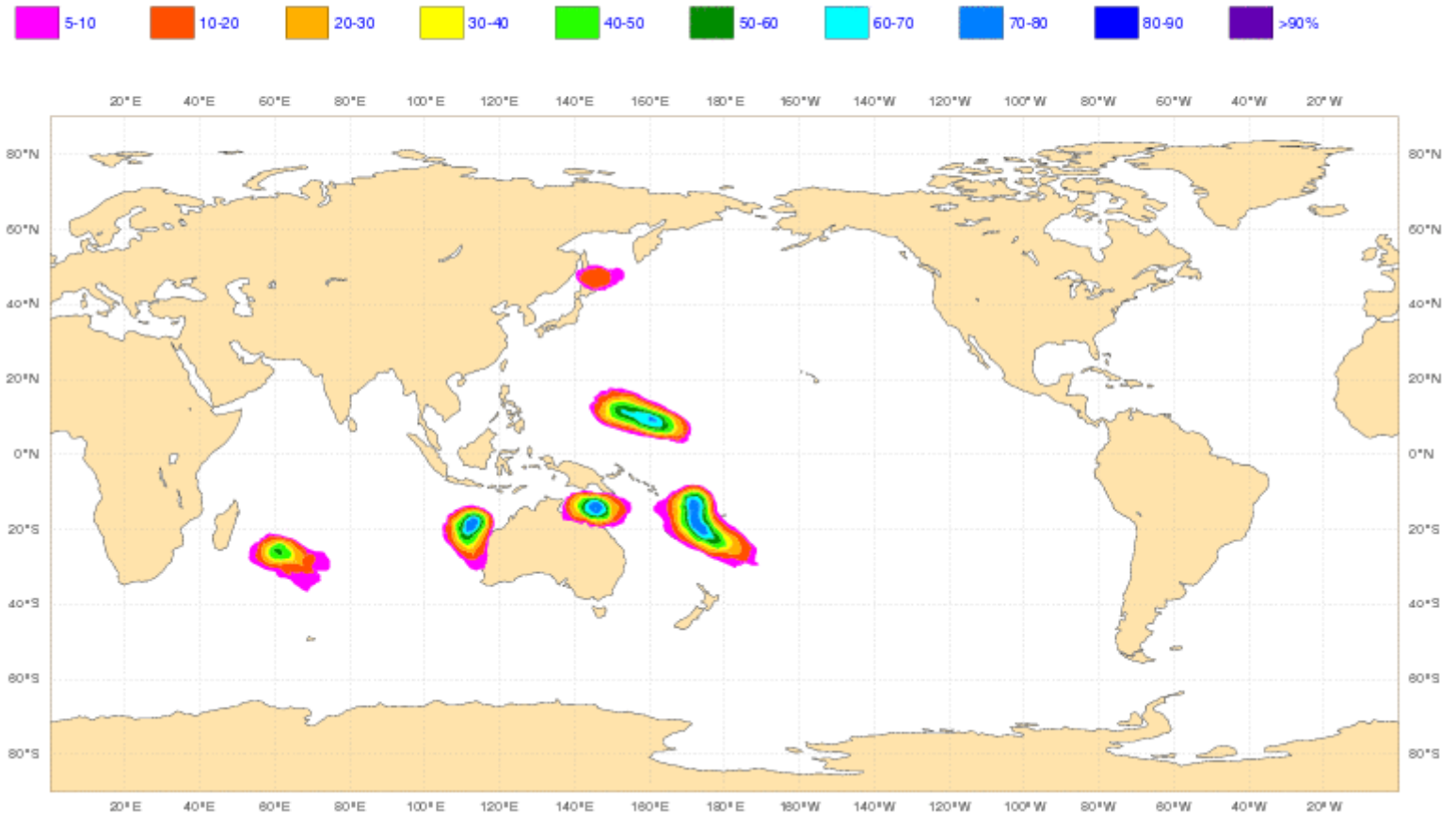
# Tropical cyclones – extended-range forecasts

All TCs including those that form during the forecast

Compare to model climate

Enhanced TC activity associated to active MJO



**ECMWF MONTHLY FORECASTS**
**FORECAST BASED 26/02/2015 00UTC**

Day 1   Day 5   Day 10   Day 15   Day 20   Analysis
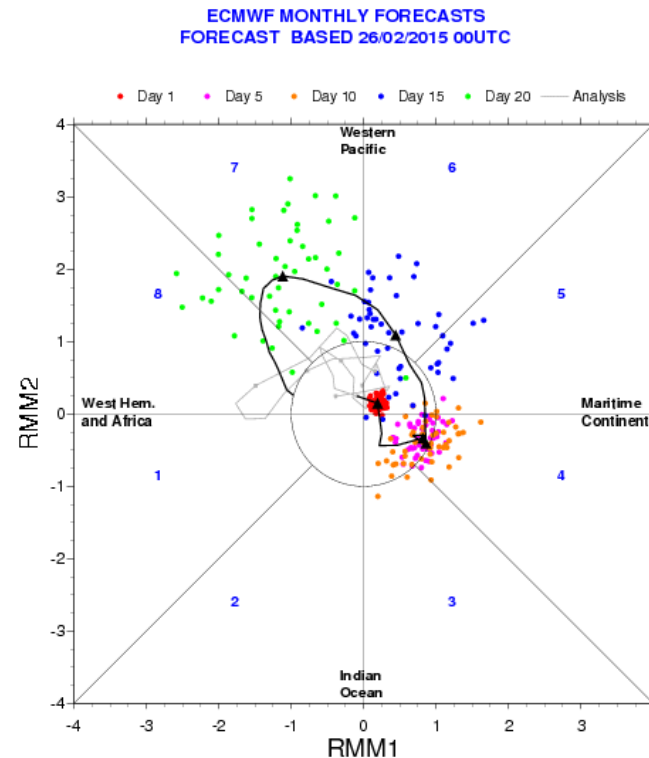


**ECMWF Monthly Forecast**
**Accumulated Cyclone Energy**
Forecast start reference is 26/02/2015
Ensemble size = 51, climate size = 100

DAY 12-18
09/03-15/03/2015
Climate = 1995-2014

Forecast Mean   Climate Mean

No Significant   Significant at 5%
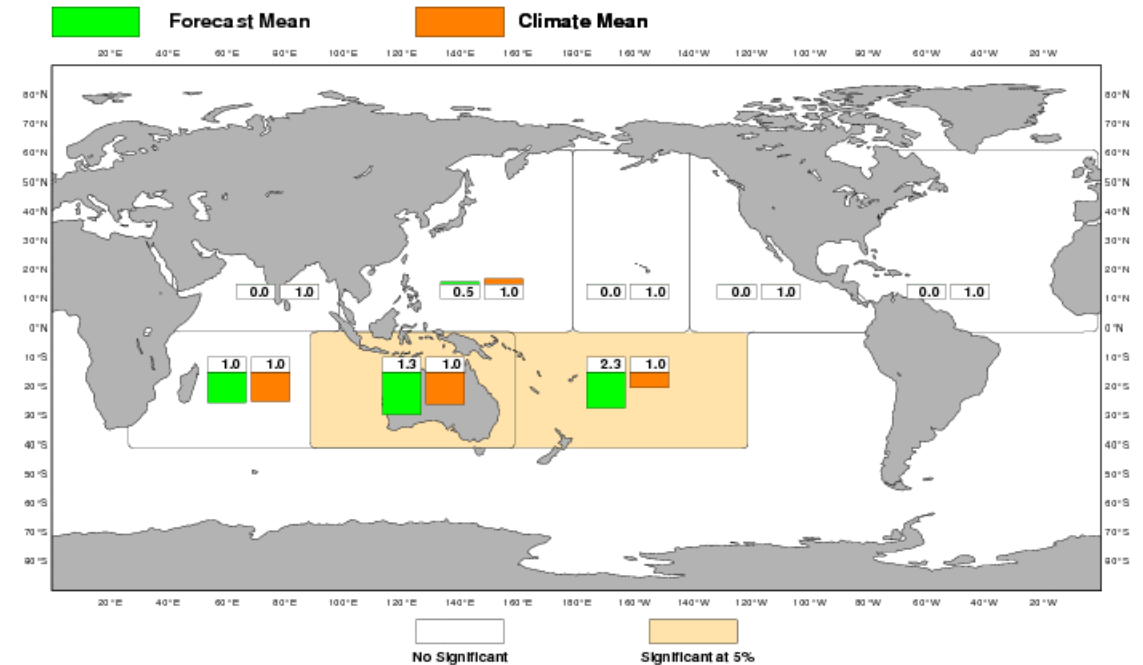
# Extreme forecast index (EFI)

Measures the distance between the ENS cumulative distribution and the model climate distribution

Ranges from –1 (all members break climate minimum records) to +1 (all beyond model climate records)

Indicates places where the ENS distribution is towards the extreme of the climate distribution





Cumulative Distribution Functions for 10m wind gust at 52.41°/4.89° VT: 28/10/2013 00UTC - 29/10/2013 00UTC
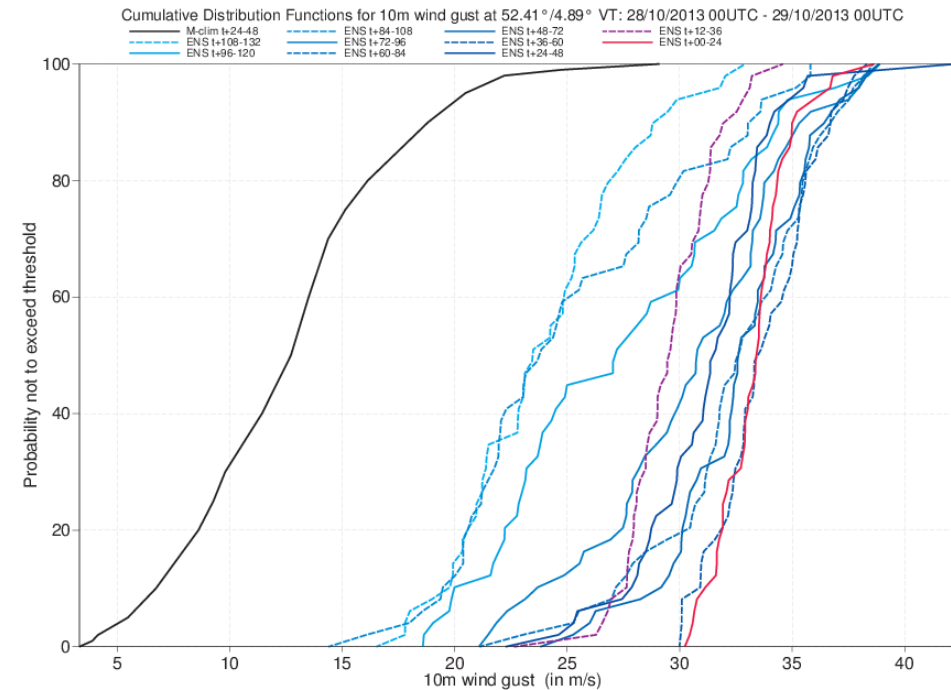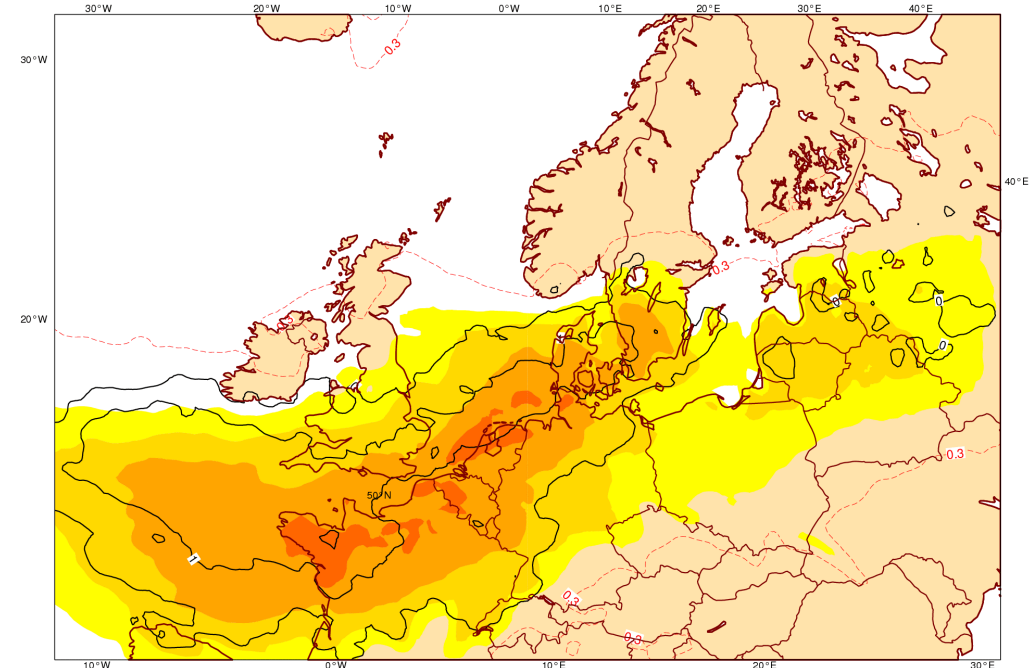
# New Longer Range products for the EFI

- To extend ECMWF guidance regarding severe/anomalous weather beyond day 10 new lead times were added to the EFI/SOT product suite at the end of May
- These are for: **Day 10-15**, and **Day 1-15**
- They are available for: **2m Temperature**, **Wind Speed** (not gust), **Total Precipitation**
- Because ensemble spreads increases with lead time, getting strong signals of extreme weather beyond day 10 is difficult and rare (example plots are shown below)
- Therefore EFI maps for Day 10-15 often look empty, especially for precipitation.
- So to provide some extra information regarding how the distribution compares with climatology we plot also contours for EFI values of +0.1 and -0.1



TEMP — Day 1, Day 10-15

PRECIPITATION — Day 1, Day 10-15
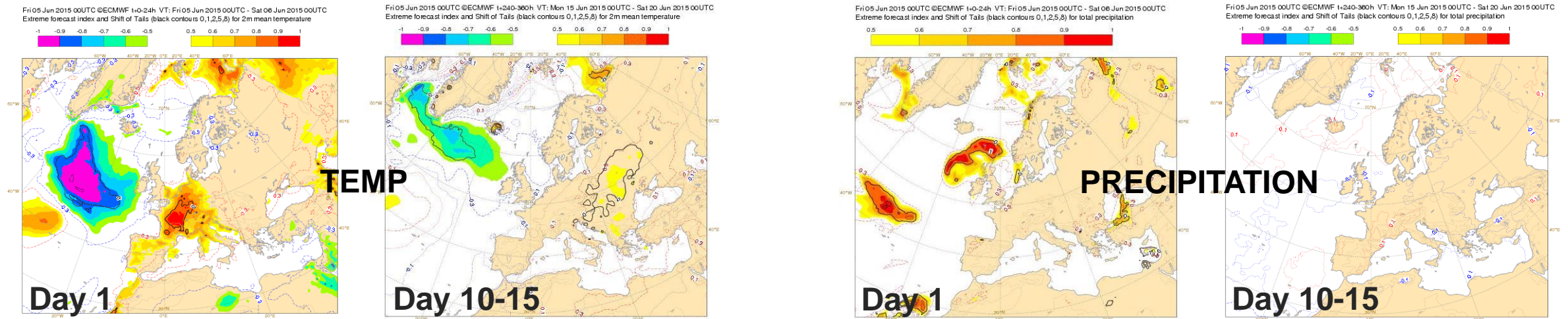
# EFI for severe convection

Based on CAPE and shear

More details in next Newsletter

Test this summer

From Ivan Tsonevsky



ECMWF  EUROPEAN CENTRE FOR MEDIUM-RANGE
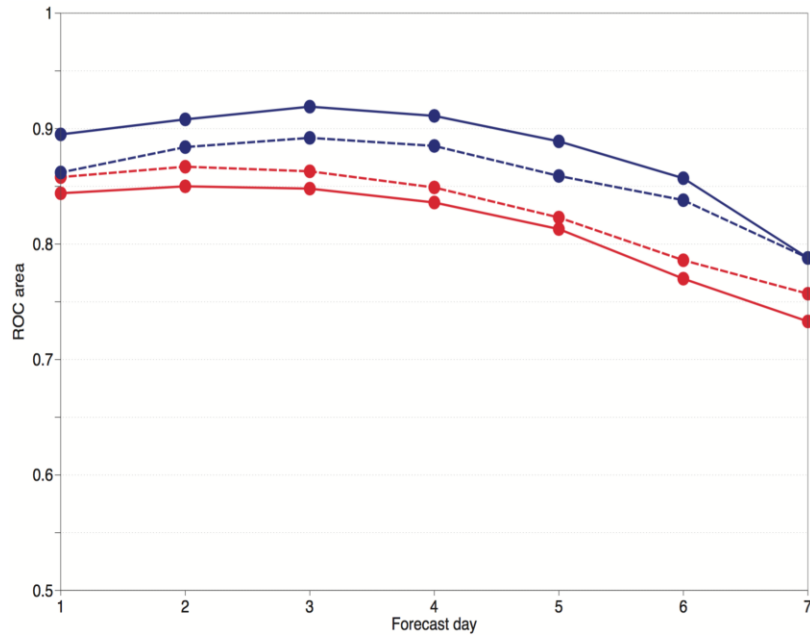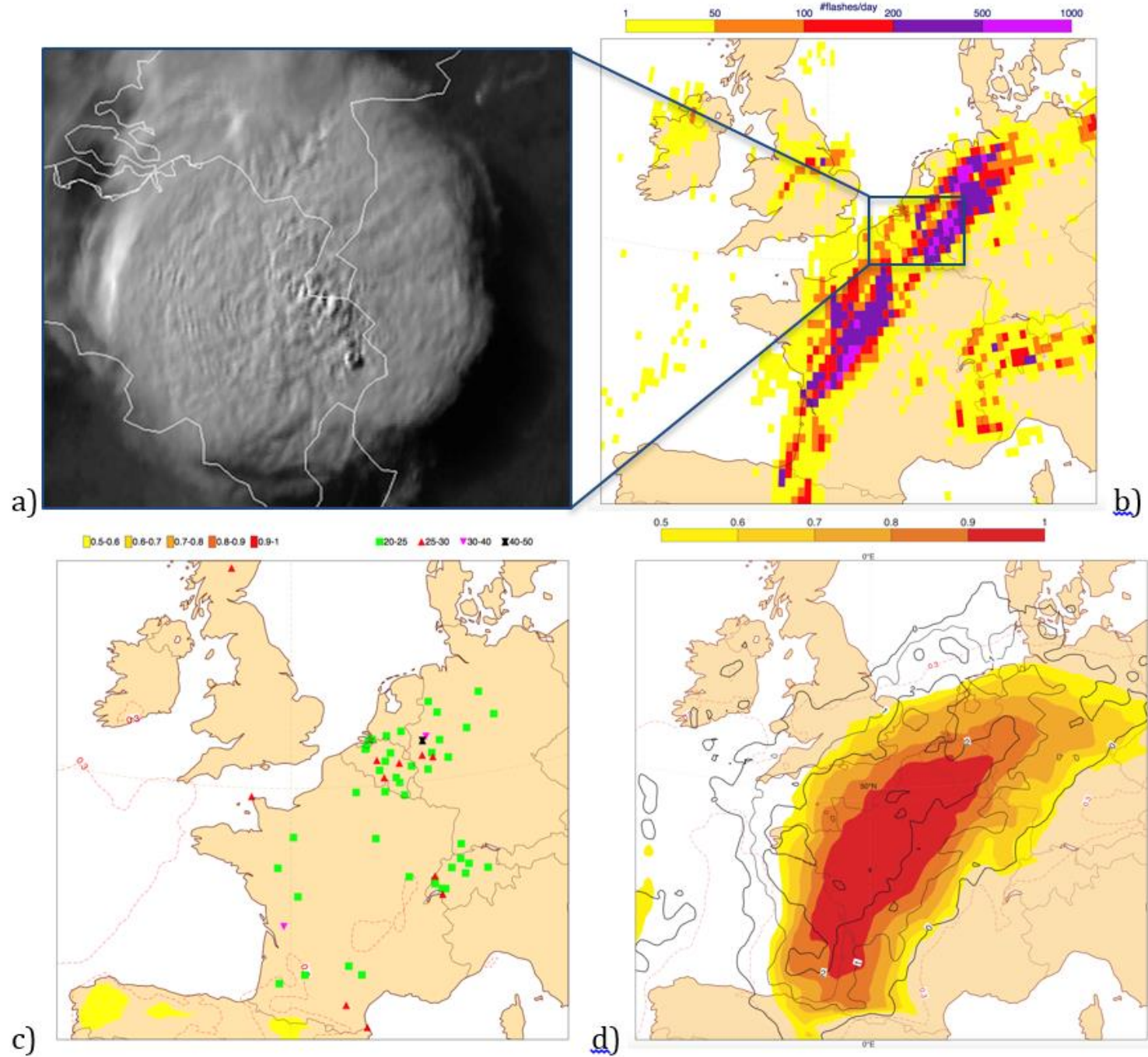
# Re-forecasts

- Provide model climates for the medium-range EFI/SOT and the extended-range (monthly) products

- Run with operational IFS version (for start dates from previous 20 years)

- Upgraded with cycle 41r1 (May 2015)

  - twice a week, for Mondays and Thursdays (instead of just Thursday).

  - size of each re-forecast ensemble increased from 5 to 11 members

  - forecast range extended to 46 days

| | Mon 18th May 2015 | Thu 21rd May 2015 | Mon 25th May 2015 | Thu 28 May 2015 | Mon 1June 2015 | Thu 4 June 2015 |
|---|---|---|---|---|---|---|
| | 22:00 ENS Extended | 22:00 ENS Extended | 22:00 ENS Extended | 22:00 ENS Extended | 22:00 ENS Extended | 22:00 ENS Extended |
| **NEW** Disseminated 3-4 days earlier twice a week BUT in the evening | 23:00 Re-forecasts 21 May 1995 - 21 May 2014 | 23:00 Re-forecasts 25 May 1995 - 25 May 2014 | 23:00 Re-forcasts 28 May 1995 - 28 May 2014 | 23:00 Re-forecasts 1 June1995 - 1 June 2014 | 23:00 Re-forecats 4 June 1995 - 4 June 2014 | 23:00 Re-forecats 8 June 1995 - 8 June 2014 |

# Re-forecasts

- model climate (M-climate) used for EFI and SOT

  - 9 re-forecast runs centred on the week of interest (5 weeks in total)

  - Sample size: 1980 values (11 members X 20 years X 9 start dates)

  - M-climate will be updated twice a week (every Monday and Thursday)

- model climate used for the monthly forecast

  - 3 re-forecast runs centred on the start date of forecast

  - Sample size: 660 values (11 members X 20 years X 3 start dates)

  - climate will be updated twice a week (every Monday and Thursday)
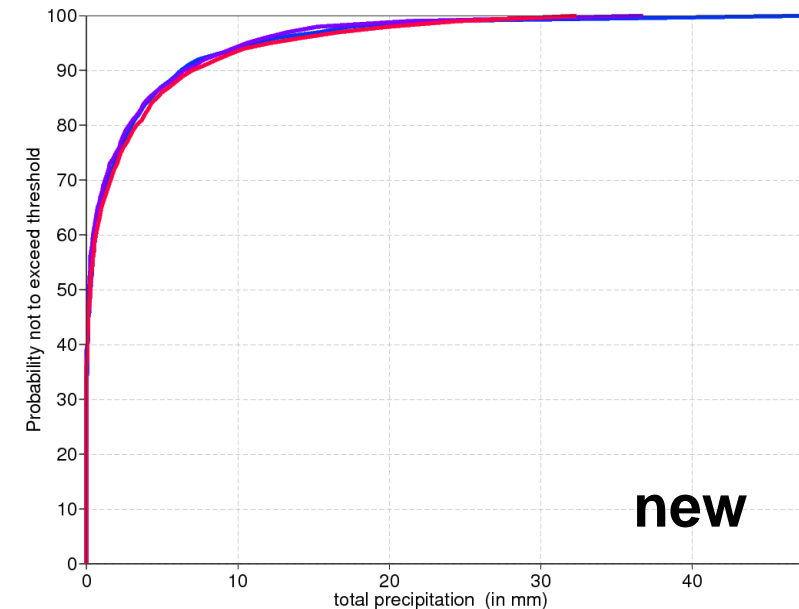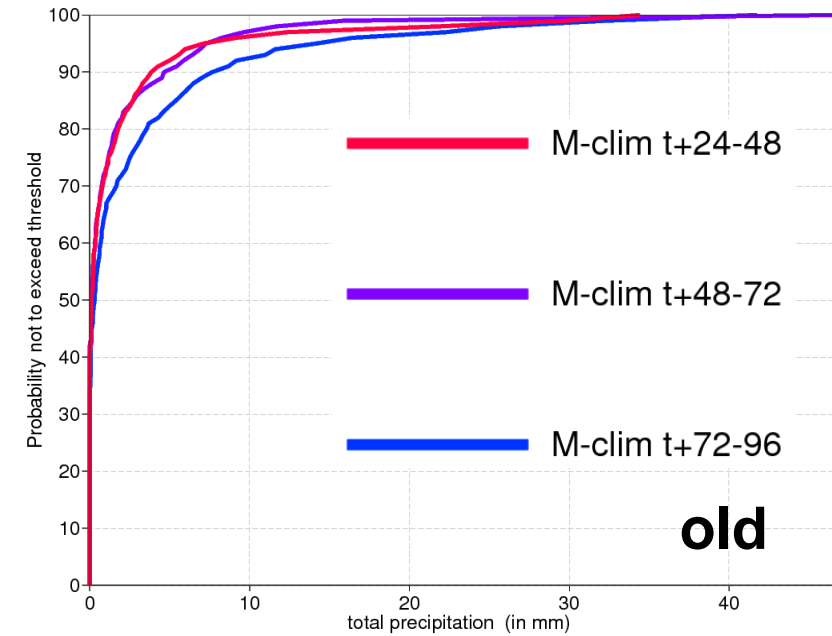
# Calibration of forecasts

- At ECMWF: medium-range forecast products generally not statistically post-processed

  - EFI is exception

- Study to demonstrate benefit of calibrating ENS (T Gneiting et al HITS, Heidelberg)

  - Combining HRES and ENS

- Surface parameters:

  – 2m T, 24-hour precip, 10m wind, total cloud

- Verification against global synoptic observations

- ECMWF forecasts Jan 2002 to Mar 2014

  – 52-member ensemble comprising HRES, CTRL and 50 perturbed members

- Tested range of methods - best results using ensemble model output statistics (EMOS)

# Calibration summary

- Calibration substantially improves probabilistic forecasts

- Greatest benefit from HRES, CTRL and ENS as one system

- Benefit of calibration is consistent over time
  - similar benefits expected in future

- Reforecast data gives equivalent results to traditional sliding window
  - enhanced re-forecast configuration should improve

# Benefit of calibration

Mean CRPS over whole verification period for raw and post-processed ensemble for forecast lead times of one to ten days for European stations. 95% confidence intervals
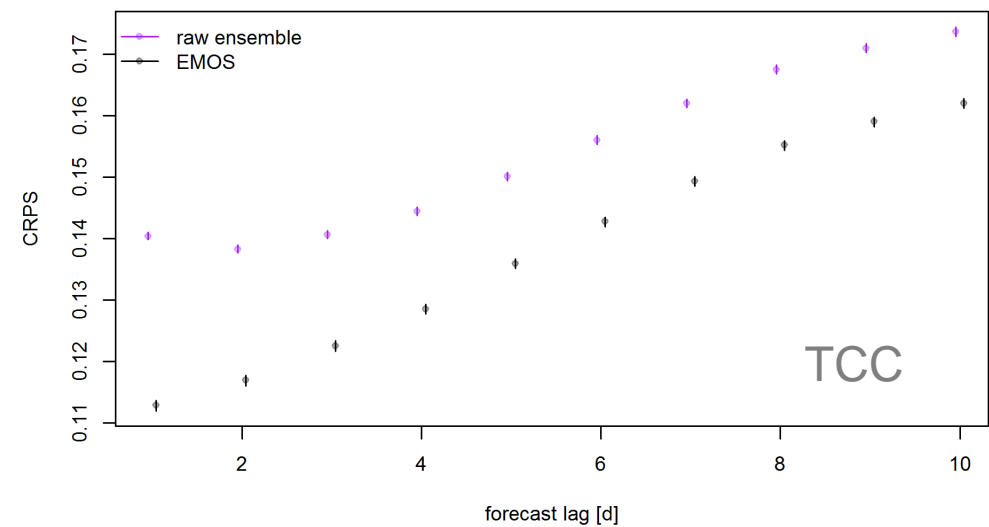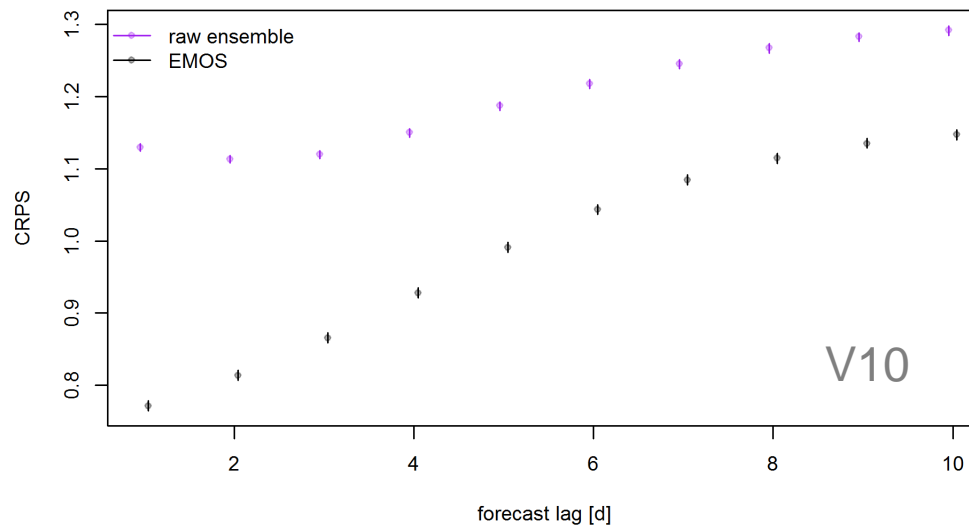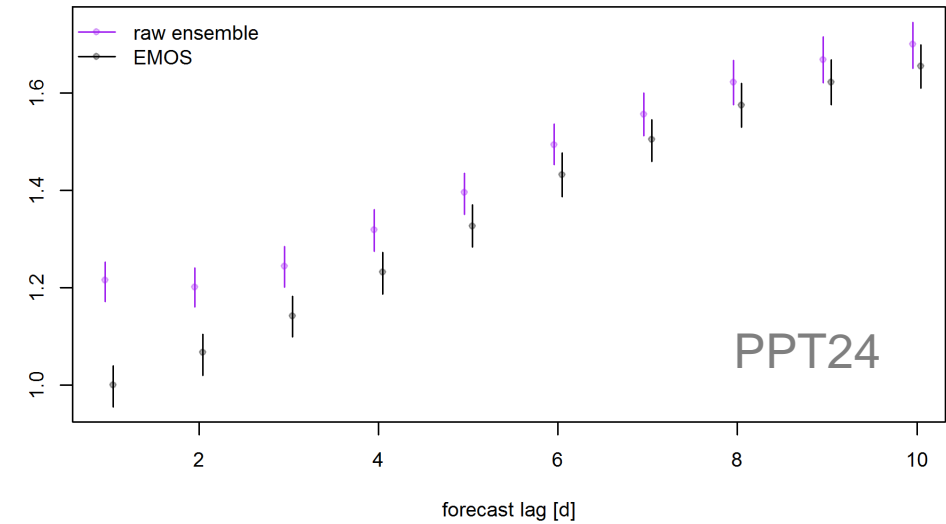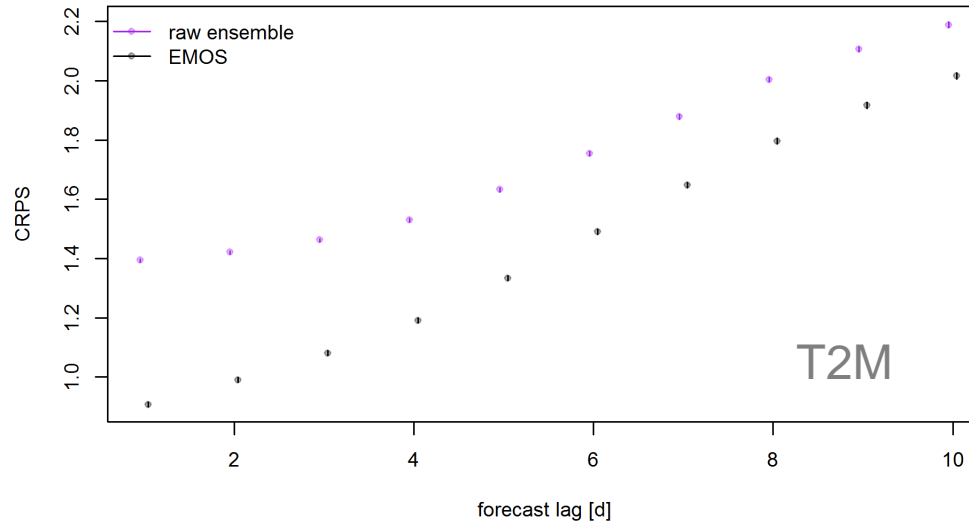
# Weights for HRES

Weights assigned to HRES

(equivalent number of ENS members)

Mean over all stations

2m Temperature

From Stephan Hemri, HITS



Mean weight of HRES

# Weights for HRES

Weights assigned to HRES

(equivalent number of ENS members)

Mean over all stations

2m Temperature

From Stephan Hemri, HITS



Mean weight of HRES
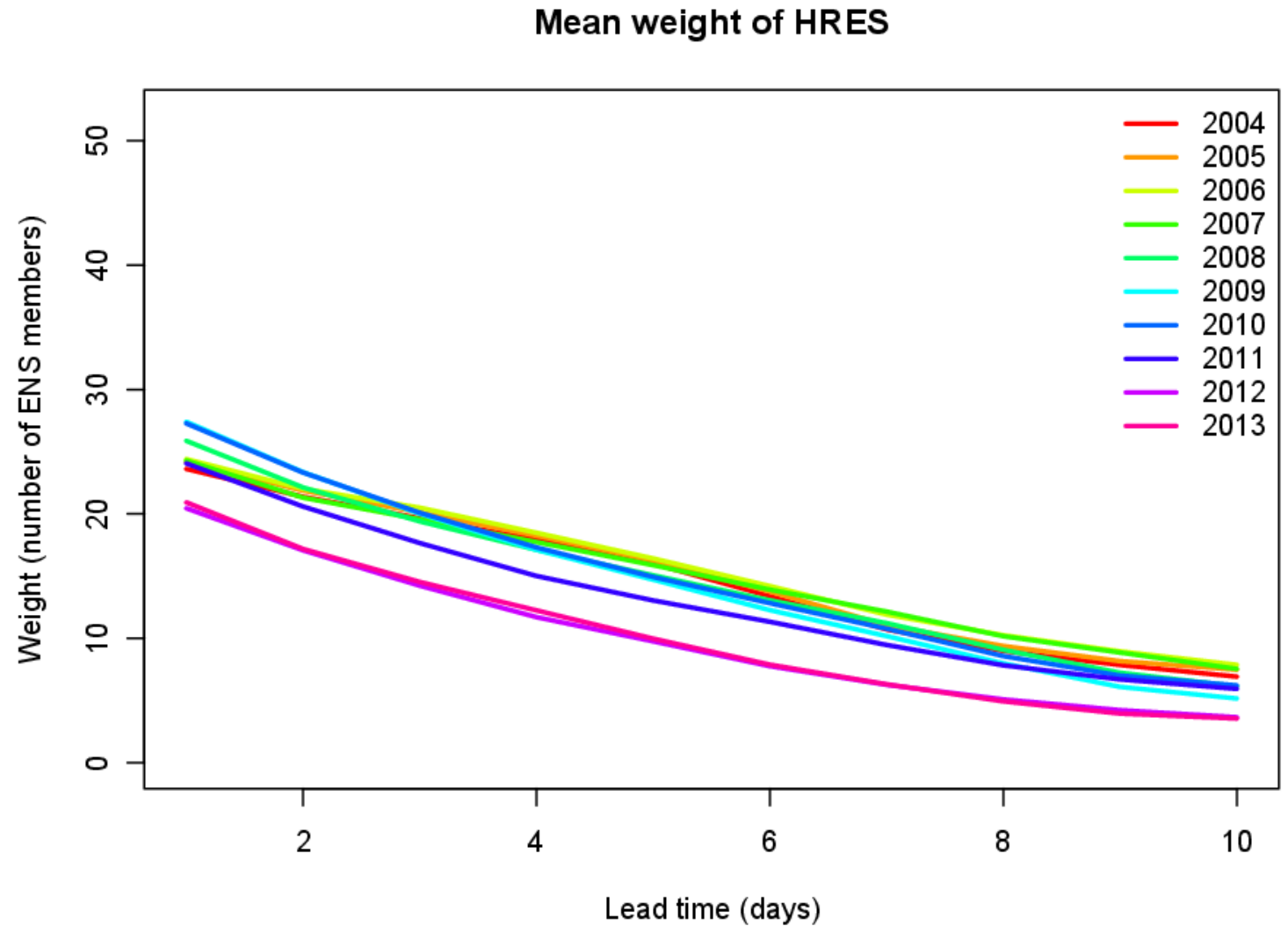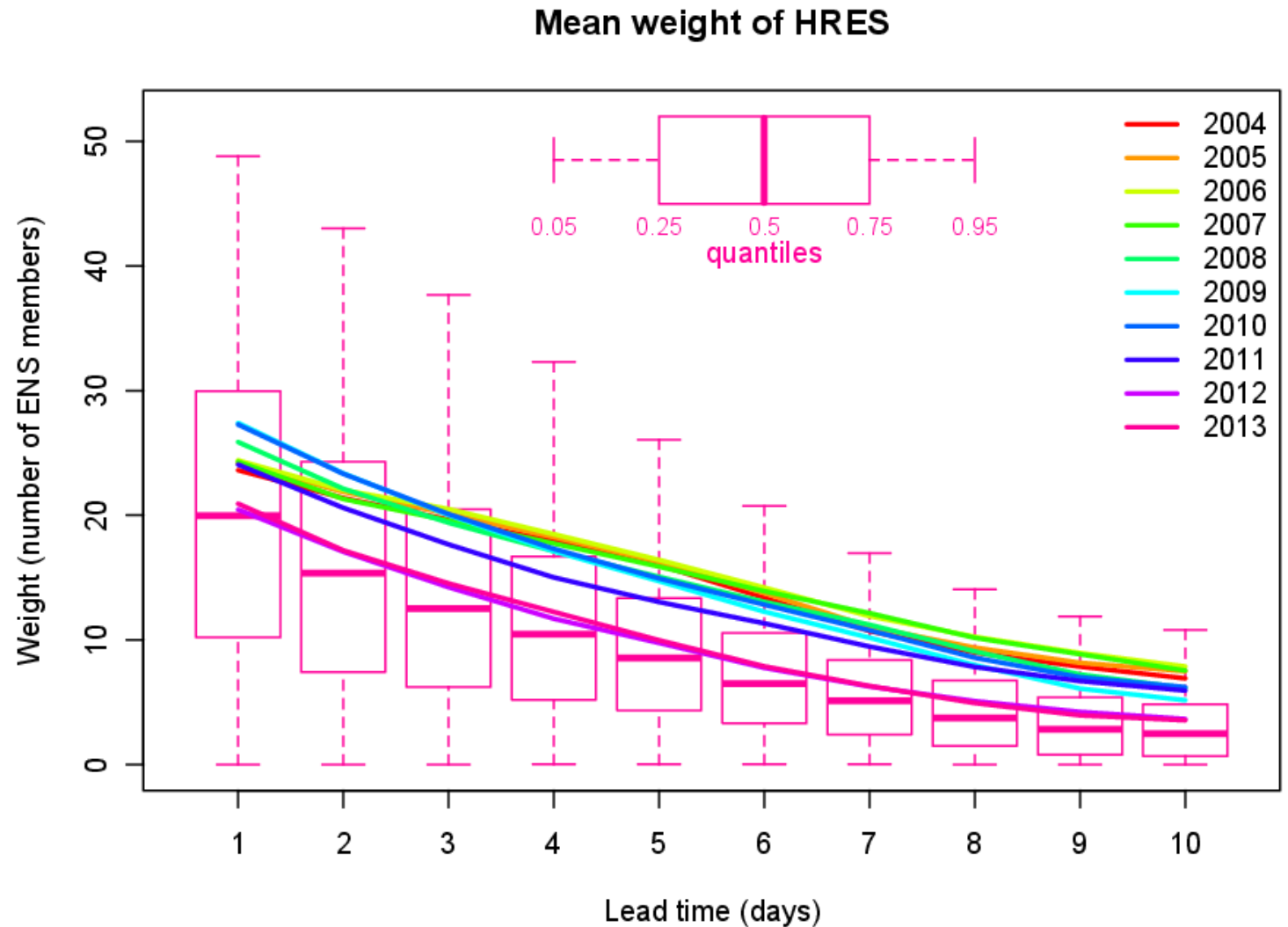
# Weights for HRES

Weights assigned to HRES

(equivalent number of ENS members)

Mean over all stations

10m wind speed

From Stephan Hemri, HITS
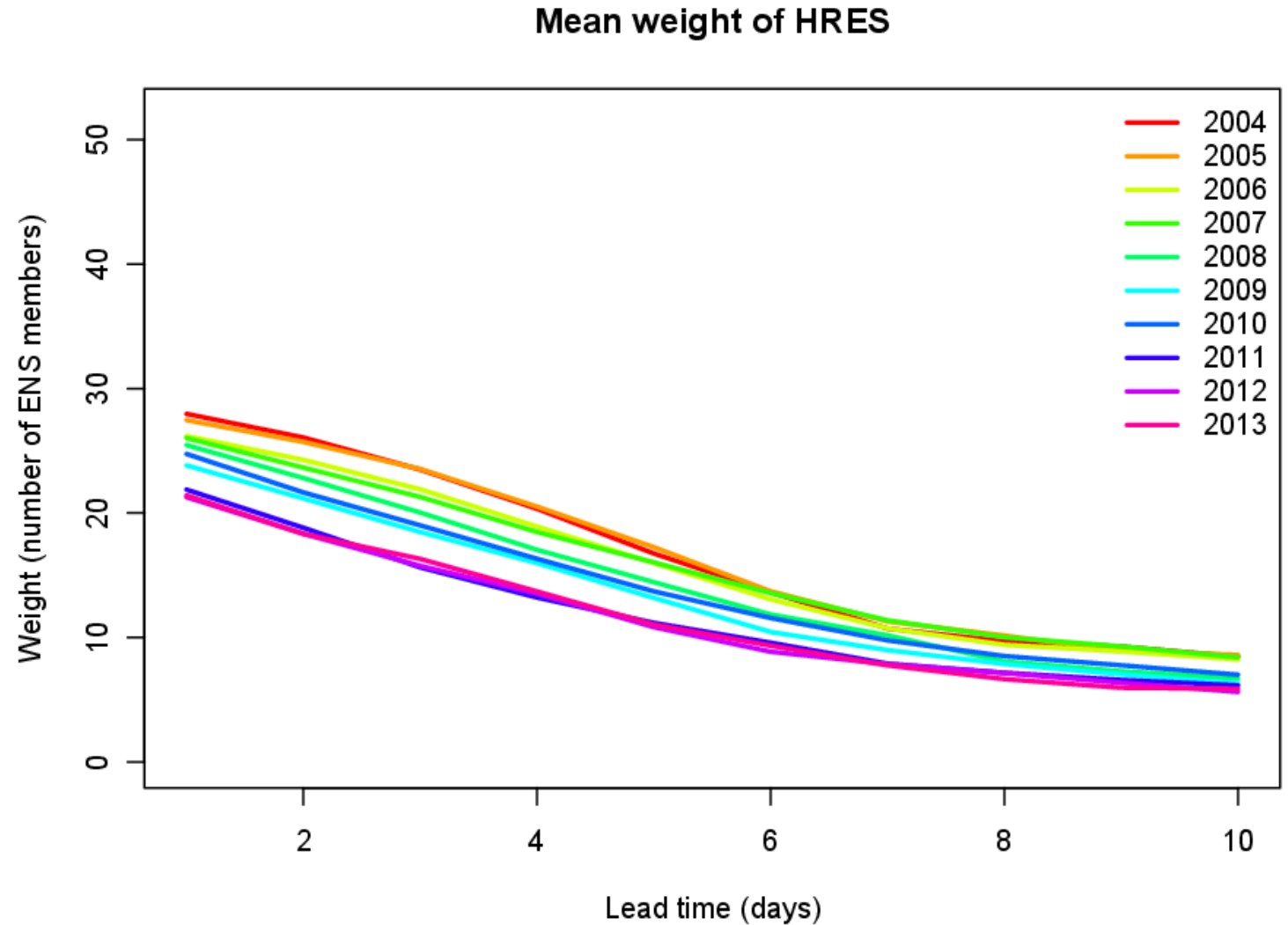


Mean weight of HRES

# Weights for HRES

Weights assigned to HRES

(equivalent number of ENS members)

Mean over all stations

24-hour precipitation

From Stephan Hemri, HITS



Mean weight of HRES
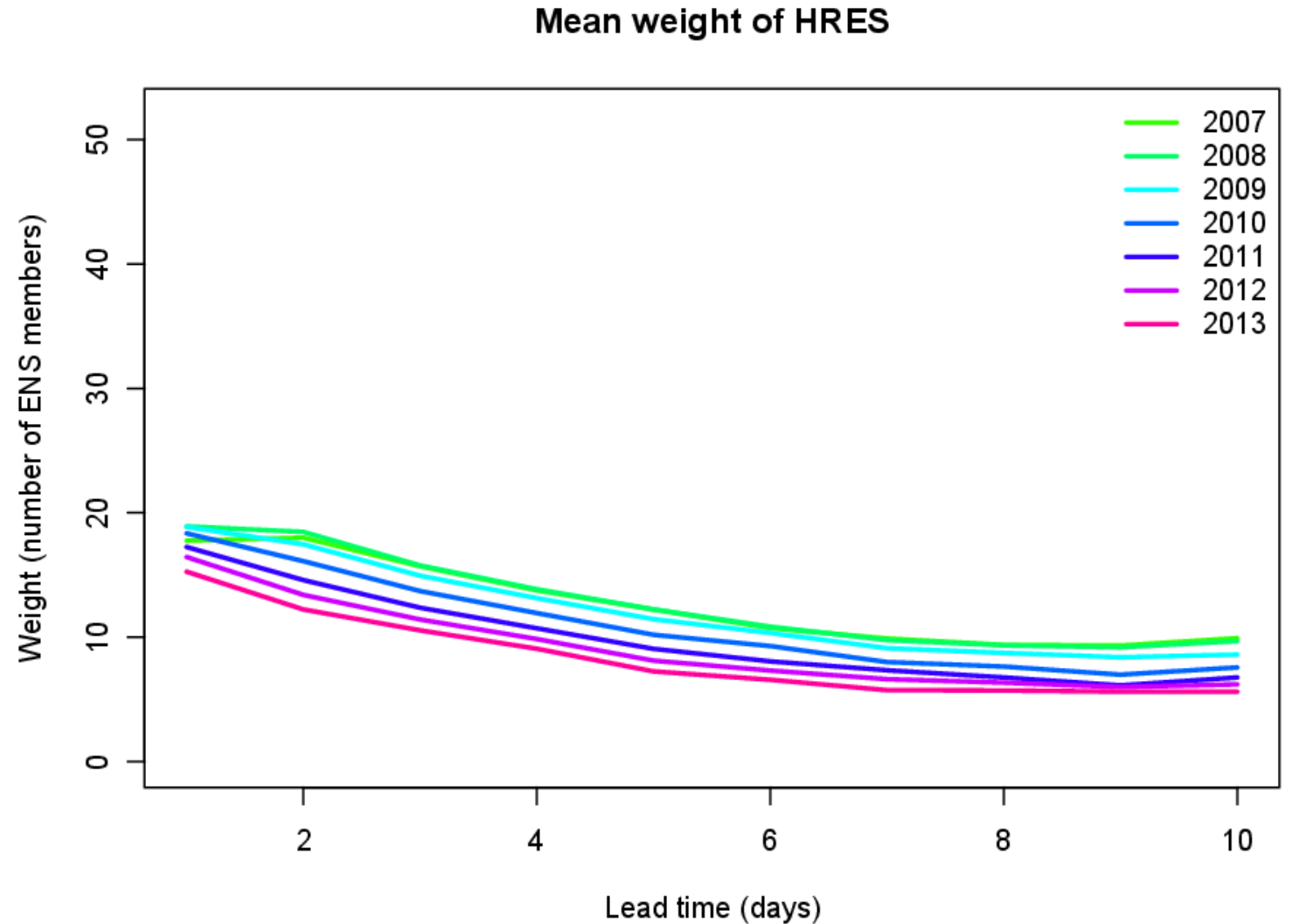
# ecCharts

- Display HRES and ENS together

- Customisation:
  - Show/hide, add/remove layers
  - Probability thresholds, percentiles

- Will test combining HRES and ENS
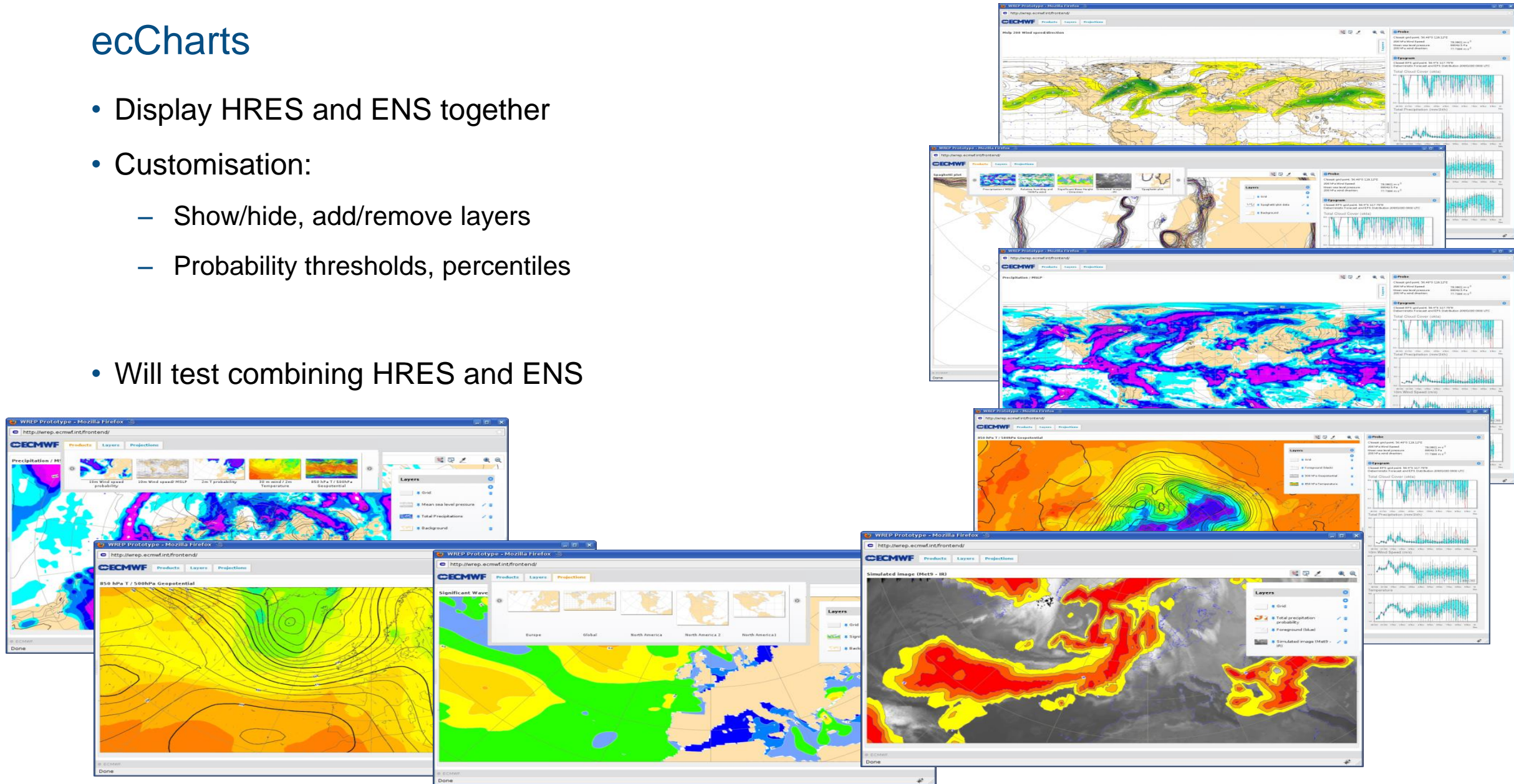
# Combined HRES and ENS

Weight assigned to HRES?

equivalent number of ENS members

Bimodal distribution?

From Mark Rodwell



Total Precipitation (mm/6h)
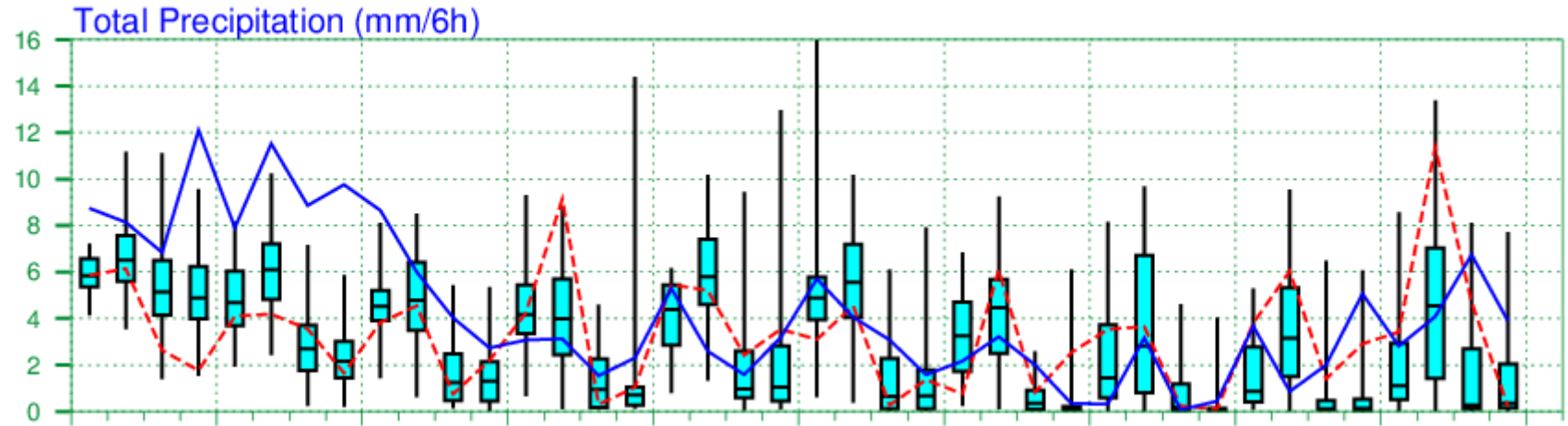
Total Precipitation (mm/day) Combined Probability Distributions
Optimized for the critical event the precipitation exceeds 1 mmday$^{-1}$
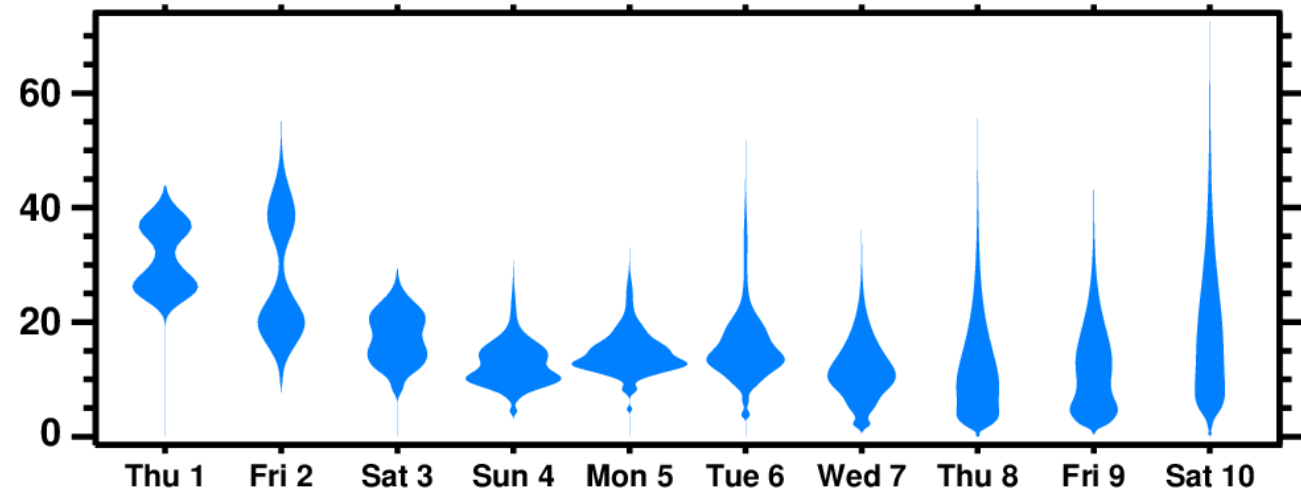
|  | Thu 1 | Fri 2 | Sat 3 | Sun 4 | Mon 5 | Tue 6 | Wed 7 | Thu 8 | Fri 9 | Sat 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Prob > 1 mm/day | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 94 | 98 | 94 |
| Brier Skill Score | 33 | 34 | 31 | 26 | 19 | 12 | 7 | 2 | 0 | 0 |

# New model output parameters

cycle 41r1 (May 2015) includes

- Precipitation type (including freezing rain
- Precipitation rate
- Visibility

ECMWF    EUROPEAN CENTRE FOR MEDIUM-RANGE WEATHER FORECASTS

Metres

0    100    200    300    400    500    1000    1500    2000    3000    5000    10000    30000    100000
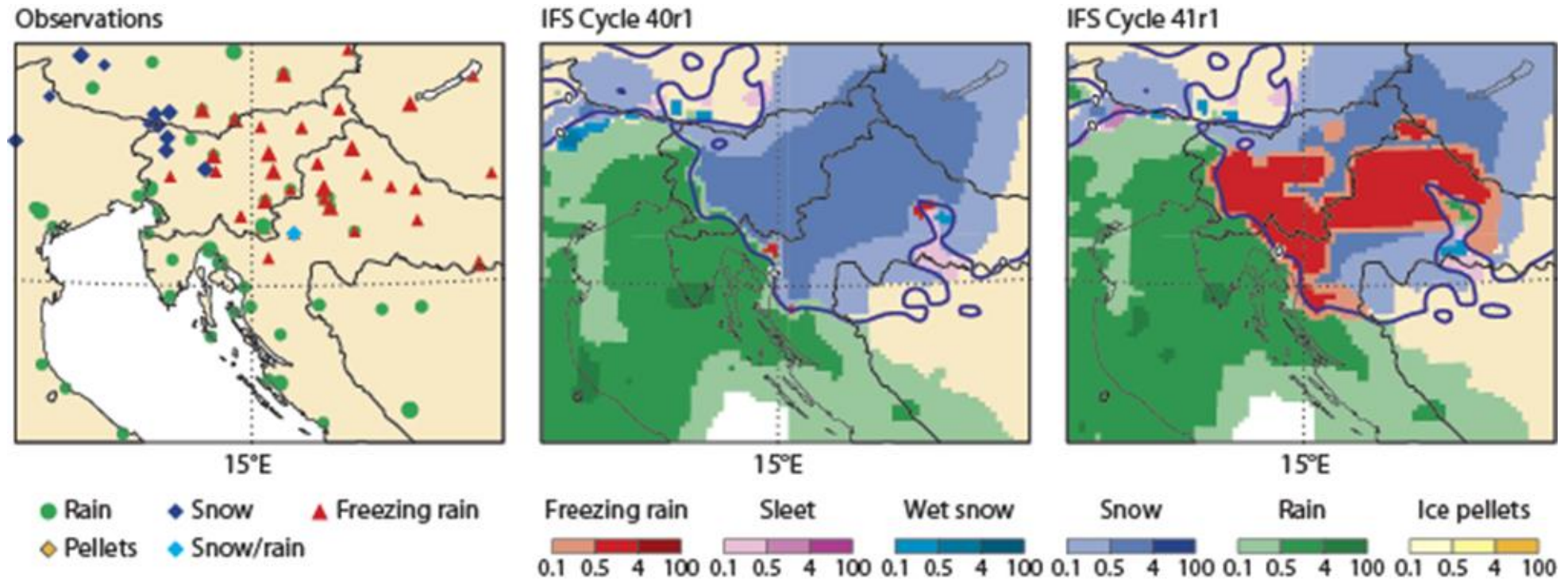
Tuesday 25 November 2014 00 UTC ecmf h+3 VT:Tuesday 25 November 2014 03 UTC surface  Mean sea level pressure
Tuesday 25 November 2014 00 UTC ecmf h+3 VT:Tuesday 25 November 2014 03 UTC surface  Visibility

High pressure

Low pressure

03UTC
25 Nov 2015

**Visibility** is a new model parameter

- Introduced on 12 May (41R1)

- Bug fix (droplet size) will be introduced before end of June
- Example (left) is with this fix
- Shows Obs & 3h HRES forecast
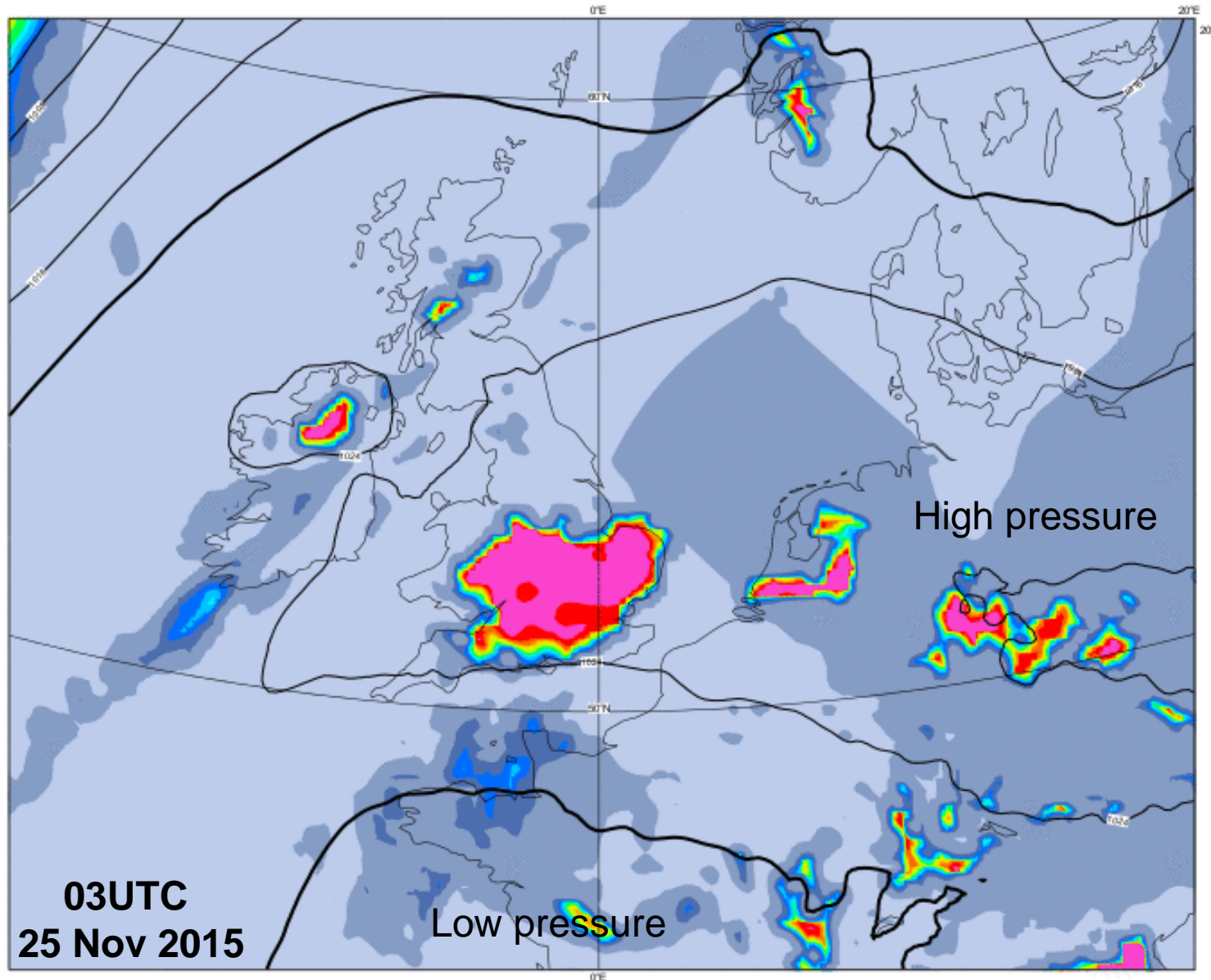- Bright colours are fog

- Agreement quite good generally
- But will be worse at longer leads

- In fog situations in particular visibility is intrinsically very difficult to forecast
- For example aerosol emissions and the physics/chemistry of droplet interaction with aerosols, of varying concentrations, are both important but are not used

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**Visibility** is a new model parameter

- Example shows how visibility evolves in HRES at 1h intervals, T+0 to T+12, 00-12UTC (Nov 25 2014). MSLP also shown.

- **3 factors are illustrated**:

- **Fog formation**, synoptically reasonable, focussed on anticyclonic light wind regions
- **Reduction in ppn**, e.g. with cyclone moving N from France
- **Background climatology**, e.g. causes straight lines in N Sea

- Other analysis suggests that instances of dense hill fog may be substantially underestimated

# Summary

- Medium-range: set of 52 forecasts

- Represent uncertainty

- Broad-scale evolution out to 15 days

- Changes in weather regimes

- Potential for severe weather few days ahead

- Calibration
  - Weights for HRES
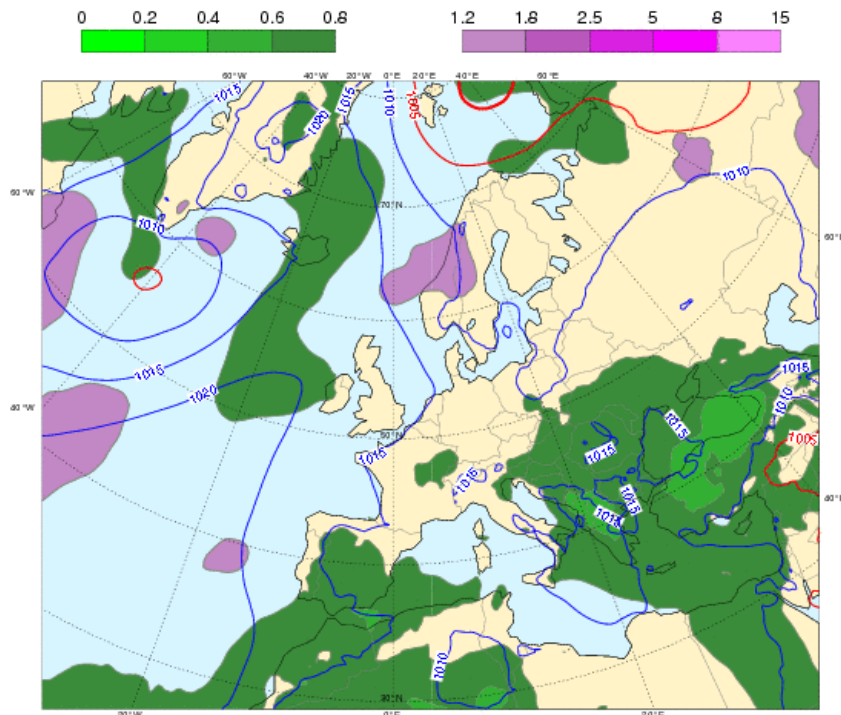
- New model output parameters

- What else do you need?
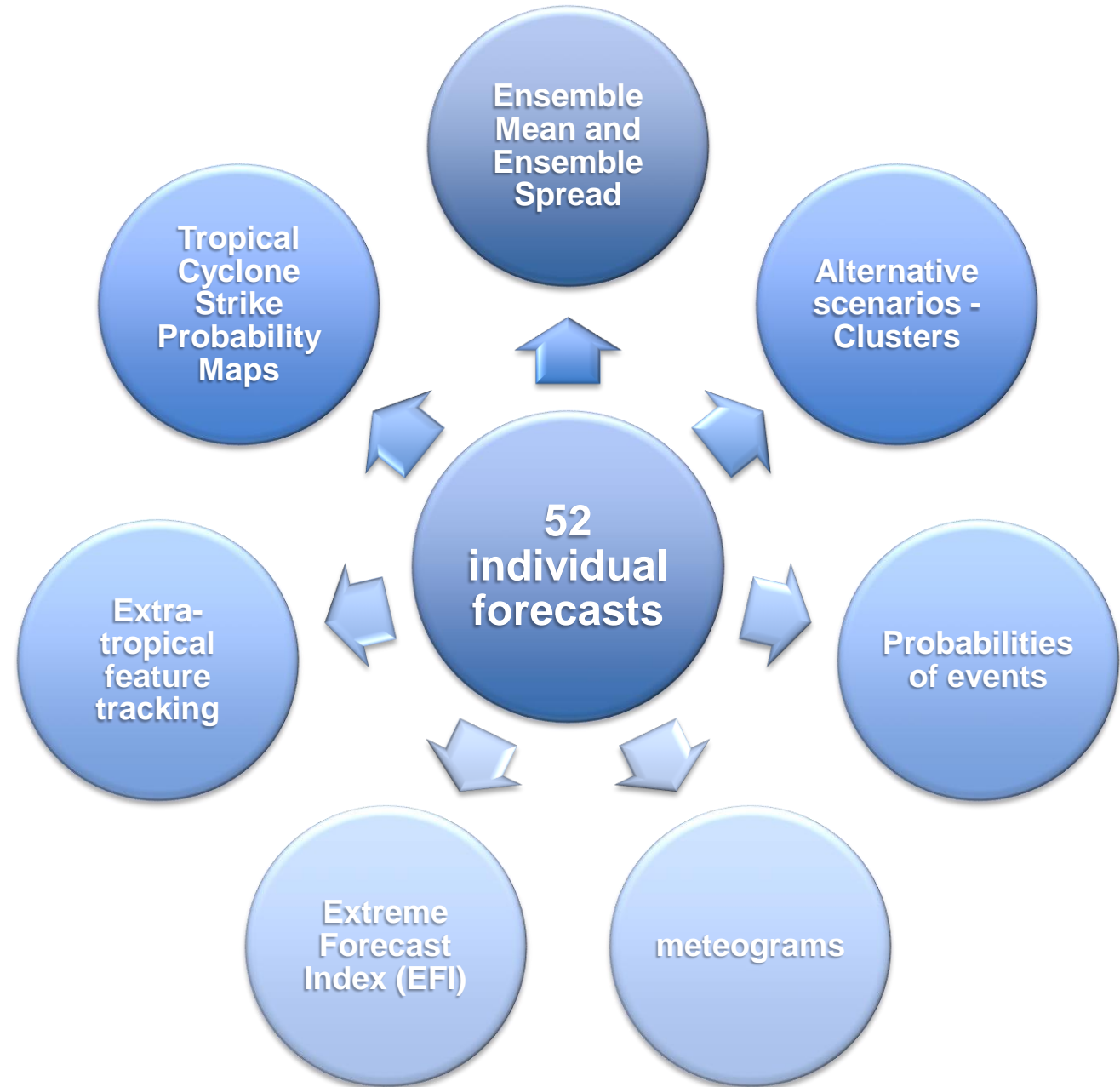
# Ensemble mean and spread

- Currently only few ensemble mean and spread pre-computed for medium-range

  - T500, T850; Z500, Z1000; wind speed 850; MSLP

- Would more pre-computed EM and spread be useful (save having to retrieve all members)?
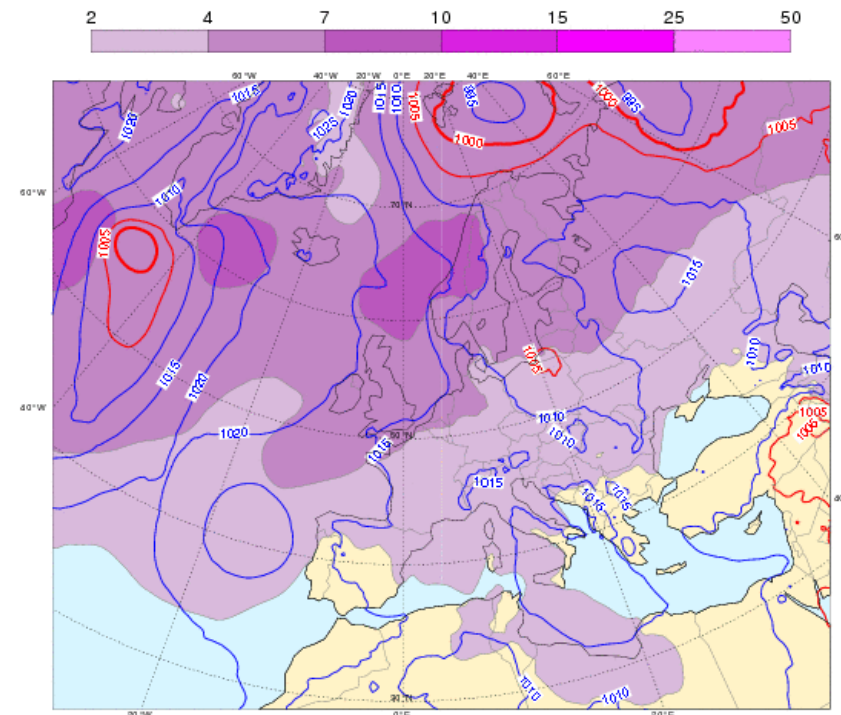
- What about quantiles?

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    – Does not necessarily save you time (dissemination  schedule)

**Dissemination schedule (for ENS)**

| 12 UTC based Forecast time | Time available | 00 UTC based Forecast time | Time available |
|---|---|---|---|
| Forecast step 0 | 19:40 | Forecast step 0 | 07:40 |
| Forecast Day 10 | 20:20 | Forecast Day 10 | 08:20 |
| Forecast Day 15 | 20:40 | Forecast Day 15 | 08:40 |
| Derived products 0 to D+10 | 20:21 | Derived products 0 to D+10 | 08:21 |
| Derived products D+10 to D+15 | 20:40 | Derived products D+10 to D+15 | 08:40 |

# Ensemble mean and spread, quantiles – will these be useful for you?

- Surface

  - 10m wind (speed, gust) ; 100m wind speed

  - 2m temperature (T, Tmax, Tmin)

  - Precip (total, convective, stratiform, snow)

  - Cloud (total, H,M,L)

  - CAPE

  - Waves (mean period, SWH)

  - Solar radiation (total, direct)

- Ensemble mean, standard deviation

- Quantiles (0, 10, 25, 50, 75, 90, 100)

- Time-steps (6-hourly, 24-hourly)


- Upper-air fields?