

Development of ECMWF's forecasting systems

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Outline

Development of ECMWF's forecasting systems

Three current forecasting system upgrades: 1) cy37r3, 2) Monthly FC on Monday, 3) Seasonal FC System 4

Recent FC performance in terms of the new "Headline Scores"

The current FC system configuration

Forecast products based on the EPS

Summary

Now is a busy time ...

➤ Pre-operational testing

- Technical implementation of updated libraries and scripts
- Thorough assessment of the forecast skill
- Adaptation of the web products
- Provision of test data via archive and real-time dissemination

➤ Three major system changes this autumn:

- 10 Oct/14 Nov: Monday run of the monthly system
- 8 November: Seasonal forecasting System 4
- 15 November: IFS cy37r3

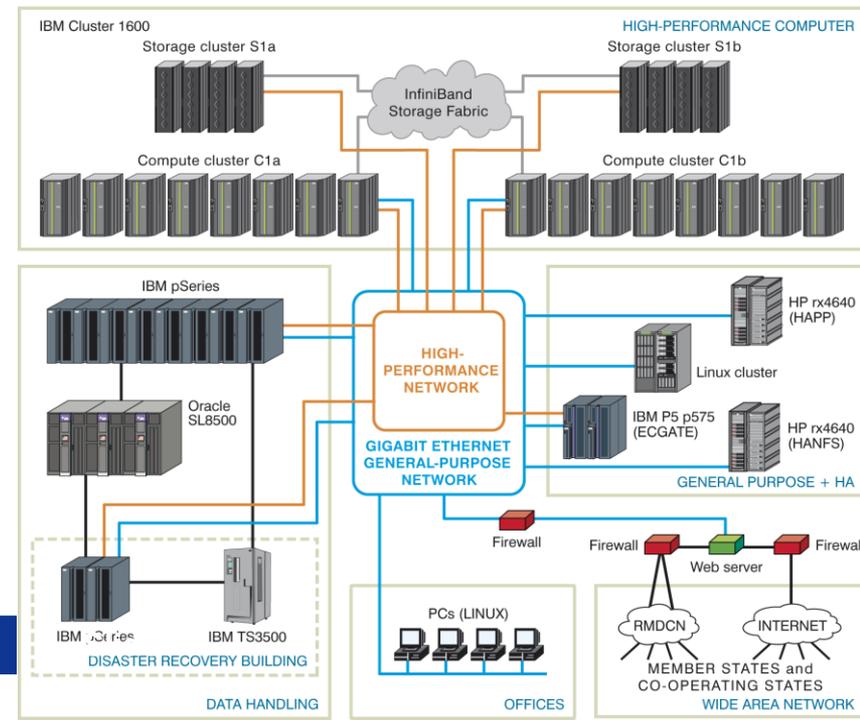
High-performance computing (HPC)

➤ Phase 1

- 2 POWER6 clusters, each with 272 nodes (32-core)
- Provides an excellent service

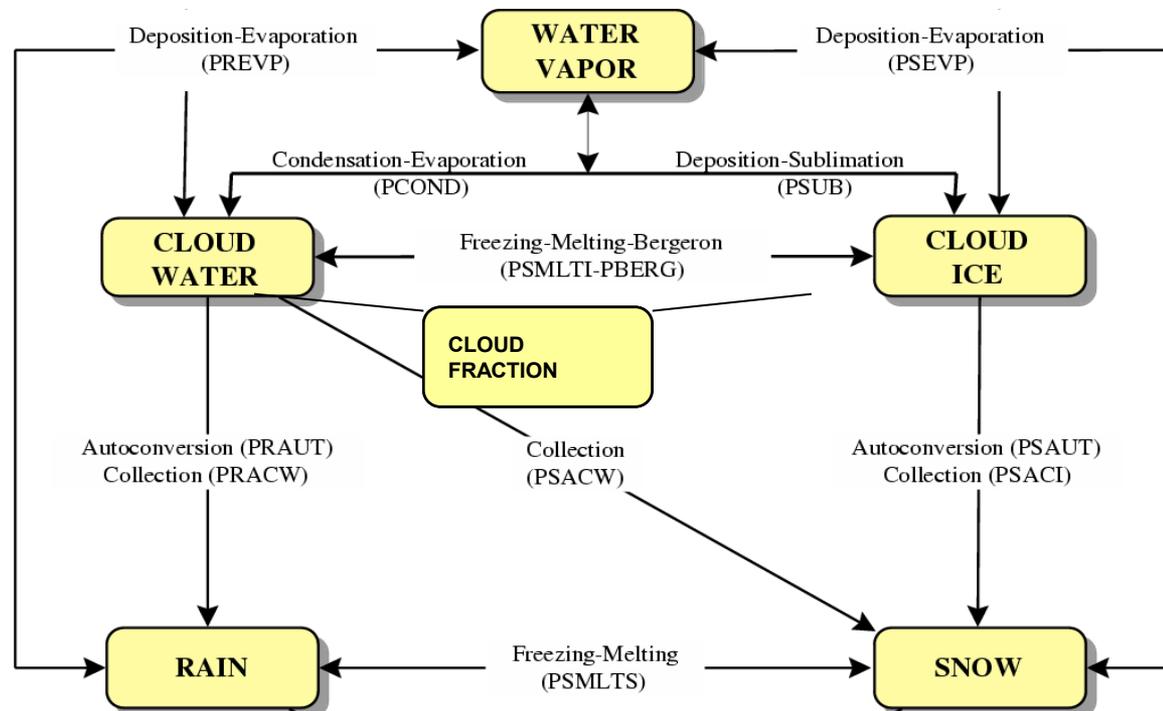
➤ Phase 2/3

- 2 POWER7 clusters, each with around 750 nodes (32-core)
- Floor strengthening and modification of the chilled water circuits have been completed
- Installation has started
- Will deliver 2.8x the performance



cycle 36r4

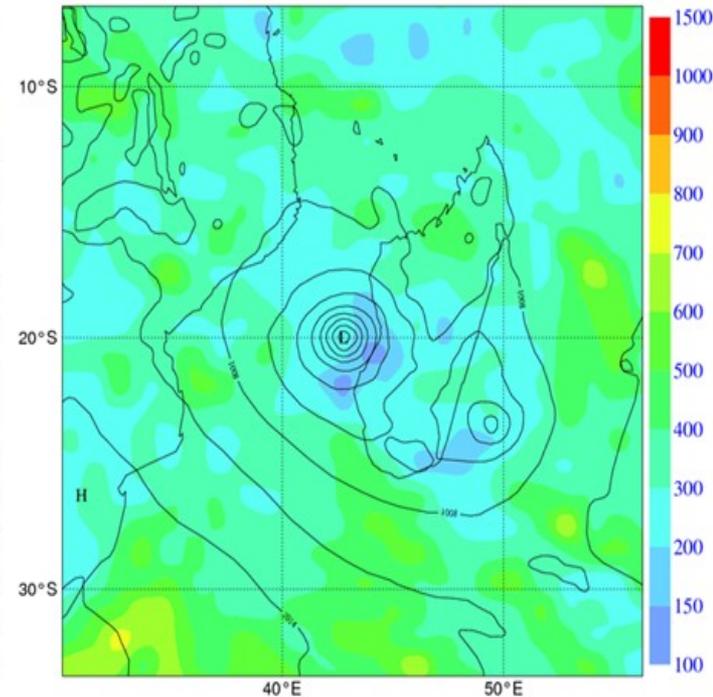
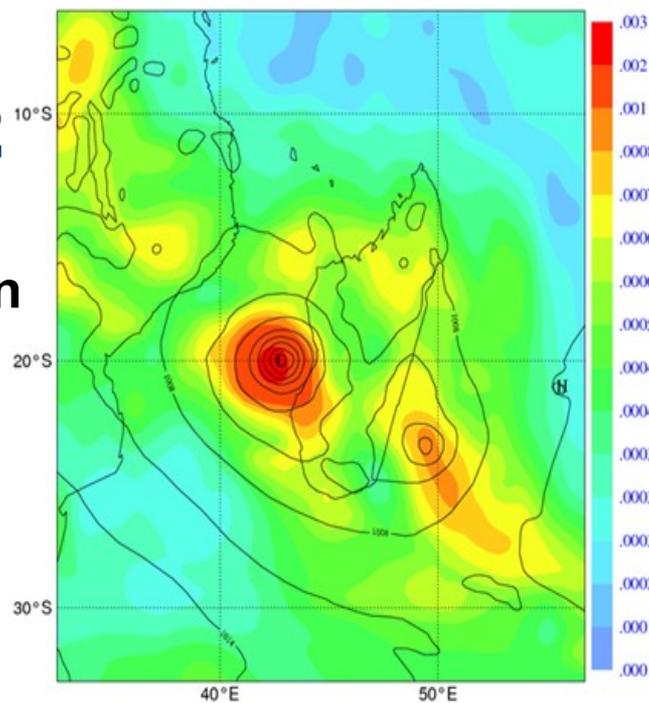
- Implemented in November 2010



- Five-species prognostic microphysics scheme
- All-sky improvements of microwave radiance assimilation
- New soil-moisture analysis scheme
- New snow analysis and the use of higher resolution NESDIS data
- Changes to the EPS perturbations (introduction of a spectral stochastic backscatter scheme)

cycle 37r2

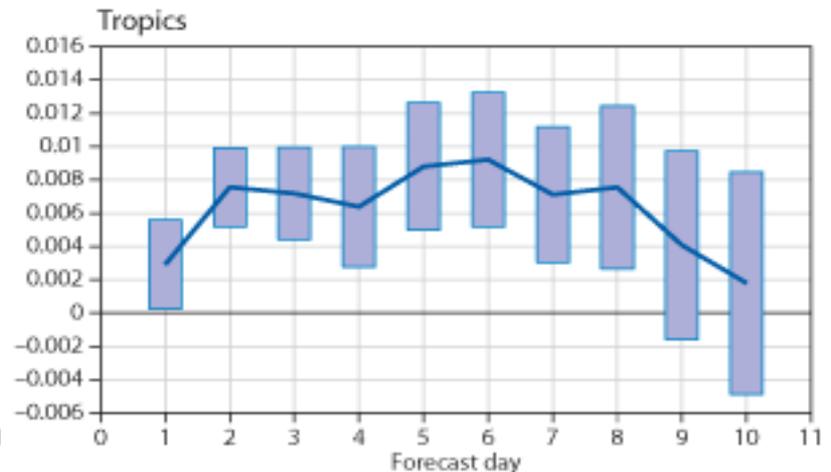
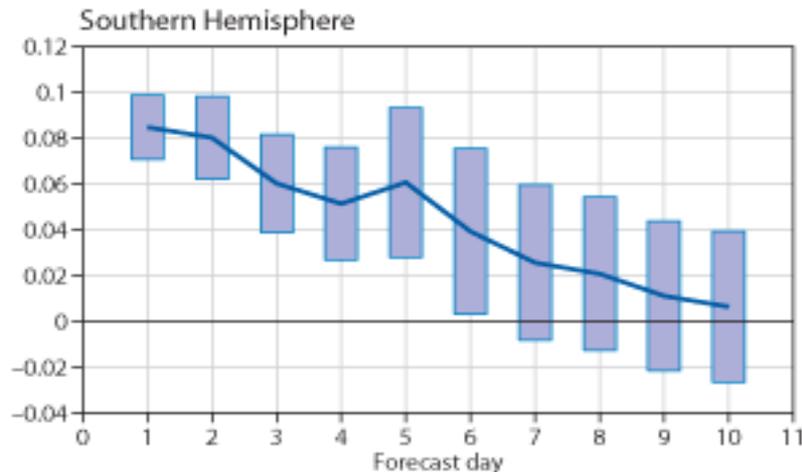
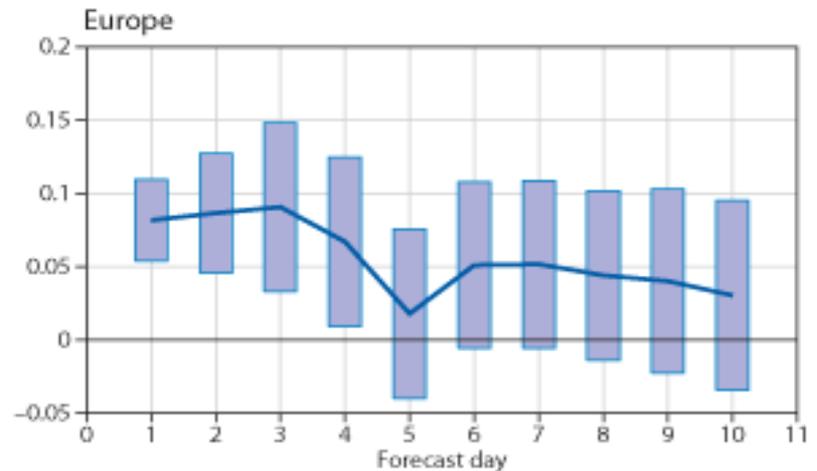
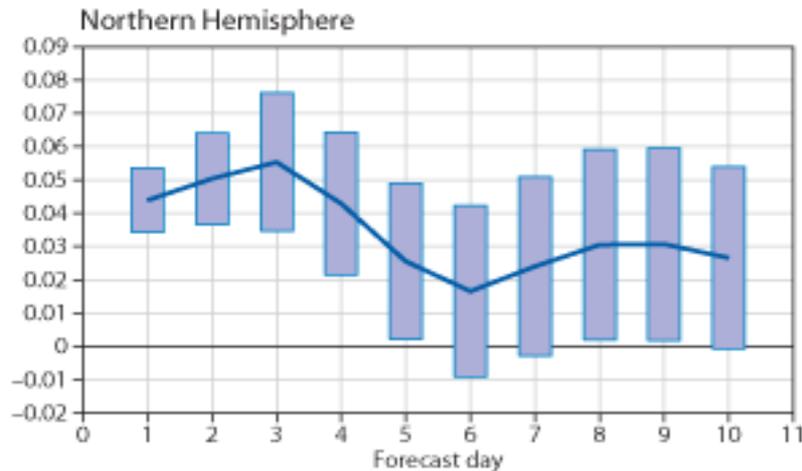
➤ Implemented in
May 2011



- Use of background error variances from the ensemble of data assimilations by the deterministic 4D-Var
- Improvements to the new cloud scheme
- Improvements to the assimilation of satellite data
- Model-level data in GRIB edition 2

CY37R2 (18 May 2011):

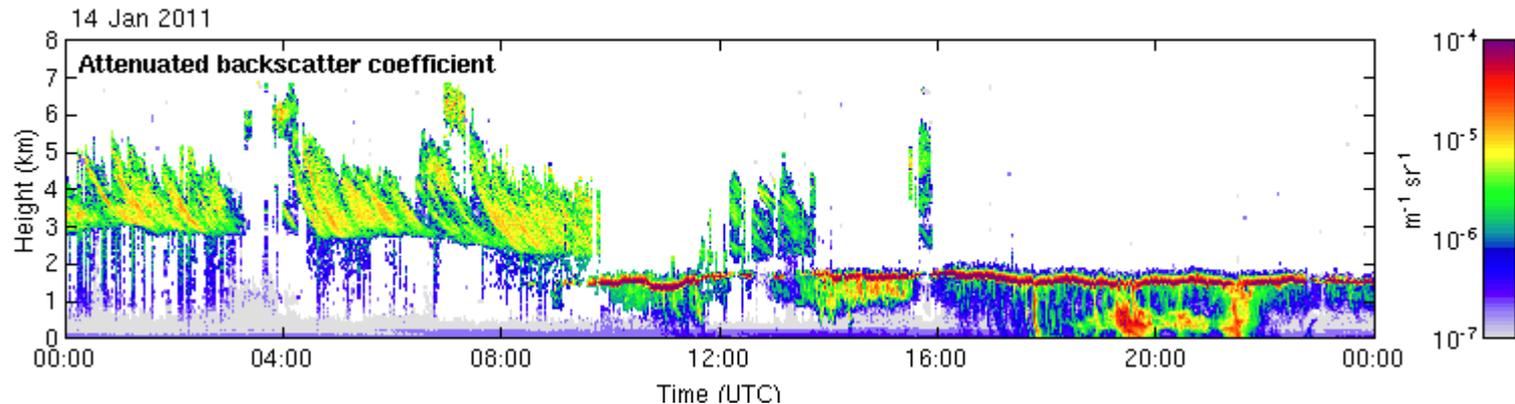
- ❑ Use of EDA Variances in 4D-Var
- ❑ Reduction of AMSU-A observation errors



WMO FM-92 GRIB edition 2 migration

- Replaced more than 1800 GRIBEX calls (IFS, MARS, product generation, emoslib, Metview, ...)
- 5 million model level fields are produced daily (in GRIB-2)
- Extensive testing:
 - More than two years of internal testing
 - Seven months of parallel e-suite runs, cross-checking every single field (7.5 TB per day)
 - Test data for Member States in MARS and through parallel dissemination
 - Ten days to finish one MARS test (12.5 million different fields, 0.5 million interpolations) - repeated for every software change
- Strong interaction with MS and other users during testing

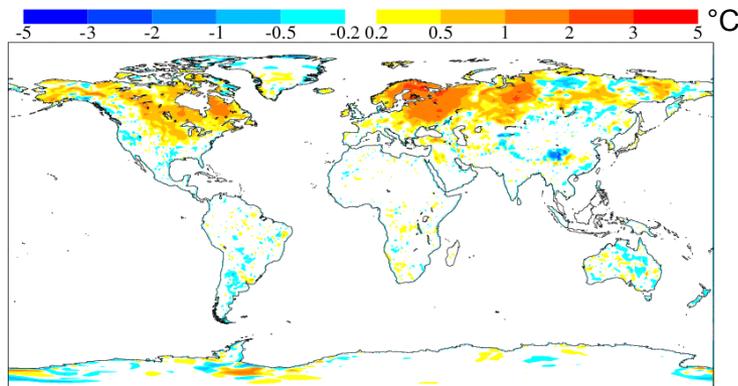
Cold bias over northern Europe



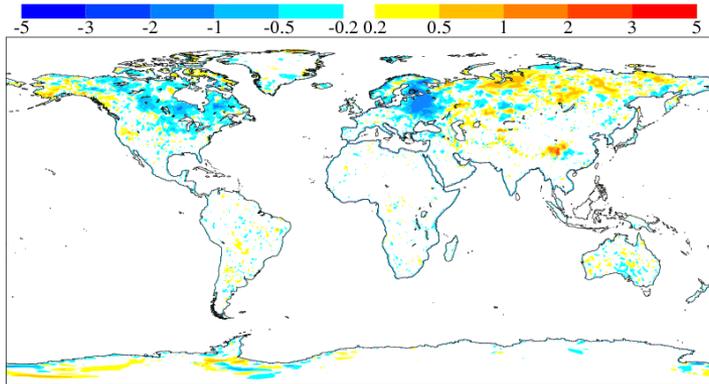
- Affected parts of northern Europe, especially during periods of very cold conditions in January 2011
- Linked with a lack of super-cooled water droplets in low clouds
- Model improvements have been developed for Cy37r3
- Cycle 37r3:
 - AMDAR T bias correction,
 - Revised surface roughness, reduced T2m diurnal cycle
 - Use of NEMO ocean model

Radiative impact on low-level temperature over land

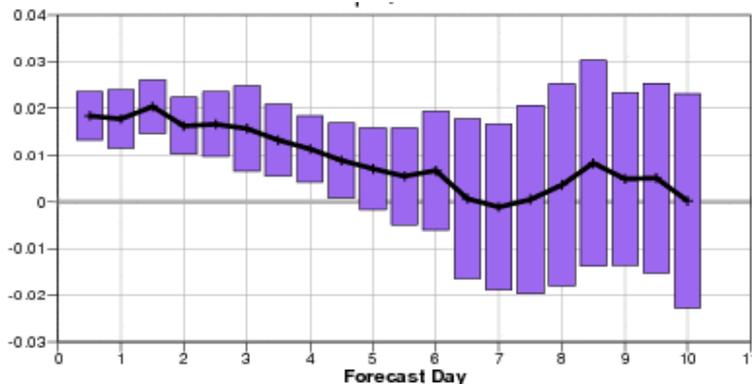
Mean T2m change
(72hr forecast for
Jan 2011) for Cy37r3
slw cloud changes



As above, but
change in mean
absolute error
(generally reduced)



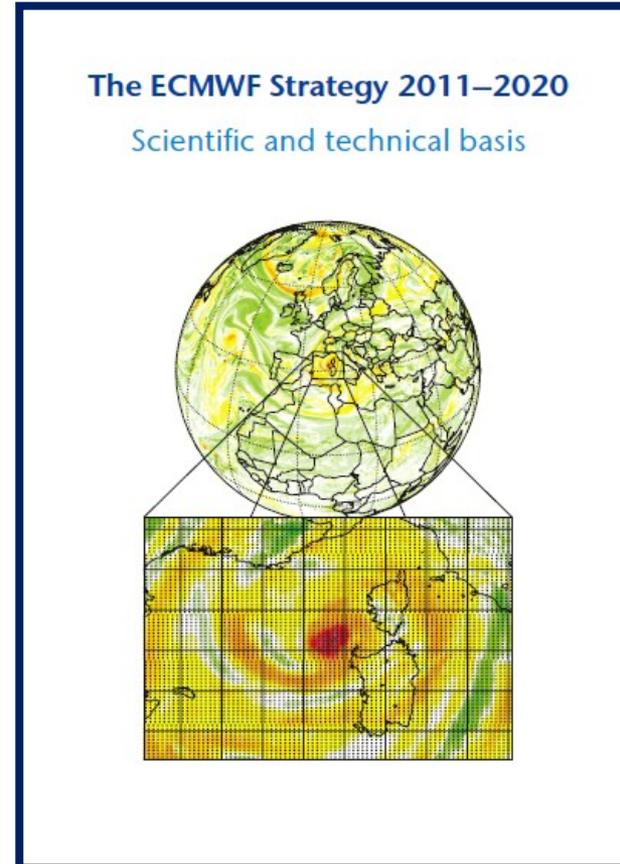
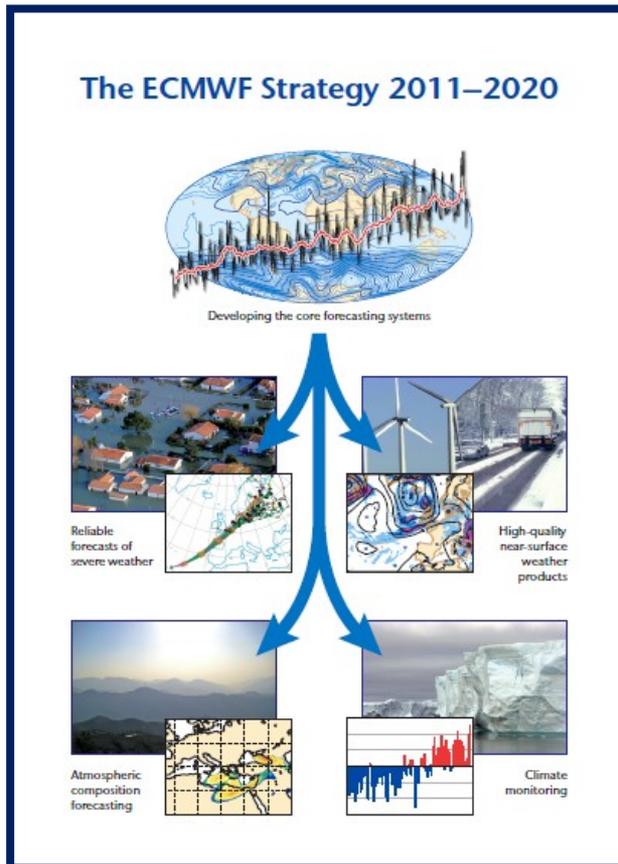
NH T1000 hPa
r.m.s.e for
Jan/Feb 2011
Control – Expt
(+ve is good)

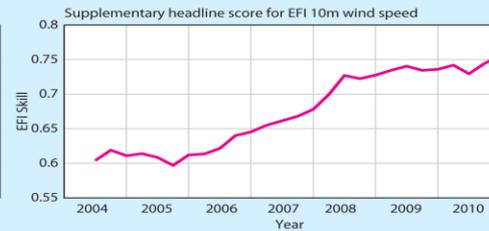
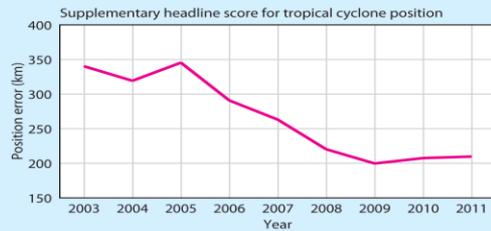
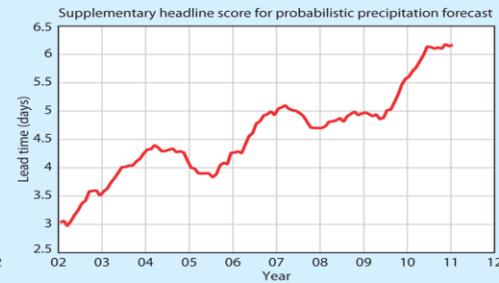
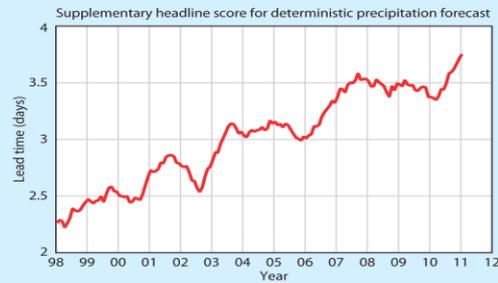
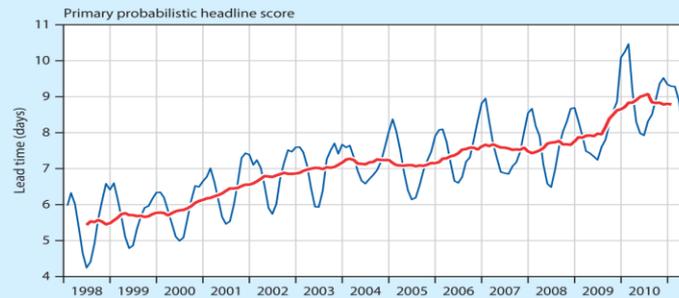
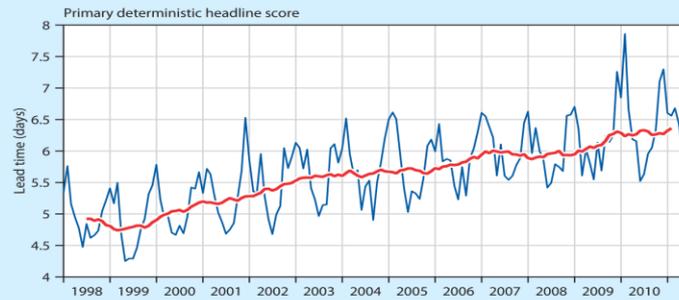


- Changes to representation of super-cooled liquid water in Cy37r3 positive impact.
- General increase in occurrence of super-cooled liquid water, particularly in weakly forced situations.
- Improved temperature bias and reduced errors in winter -time low cloud over land.
- Impacts clearly seen in NH and European T1000 scores.

ECMWF Strategy 2011-2020

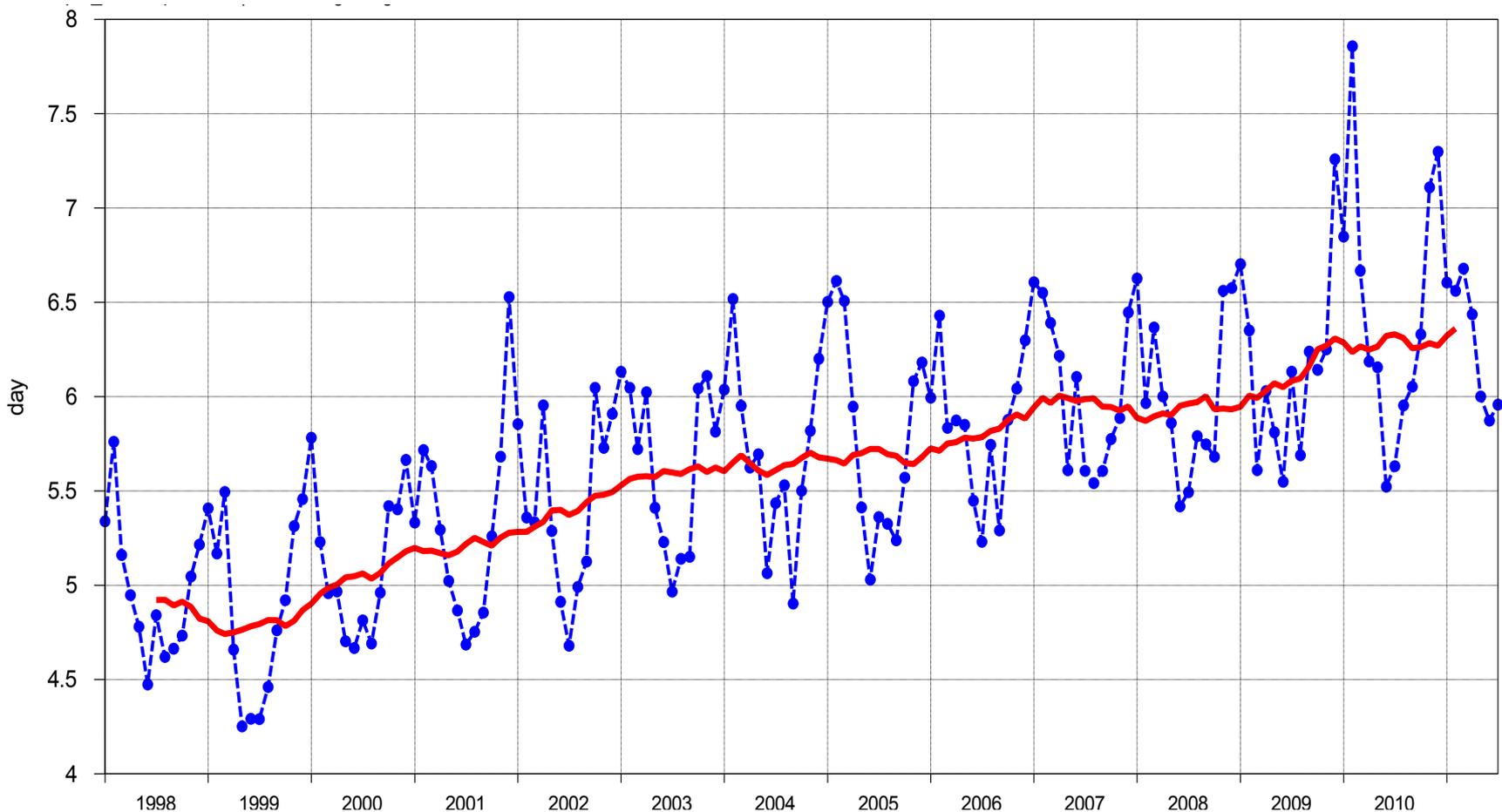
- Approved by Council in June 2011 (unanimously)
- Includes targets and a new set of headline measures





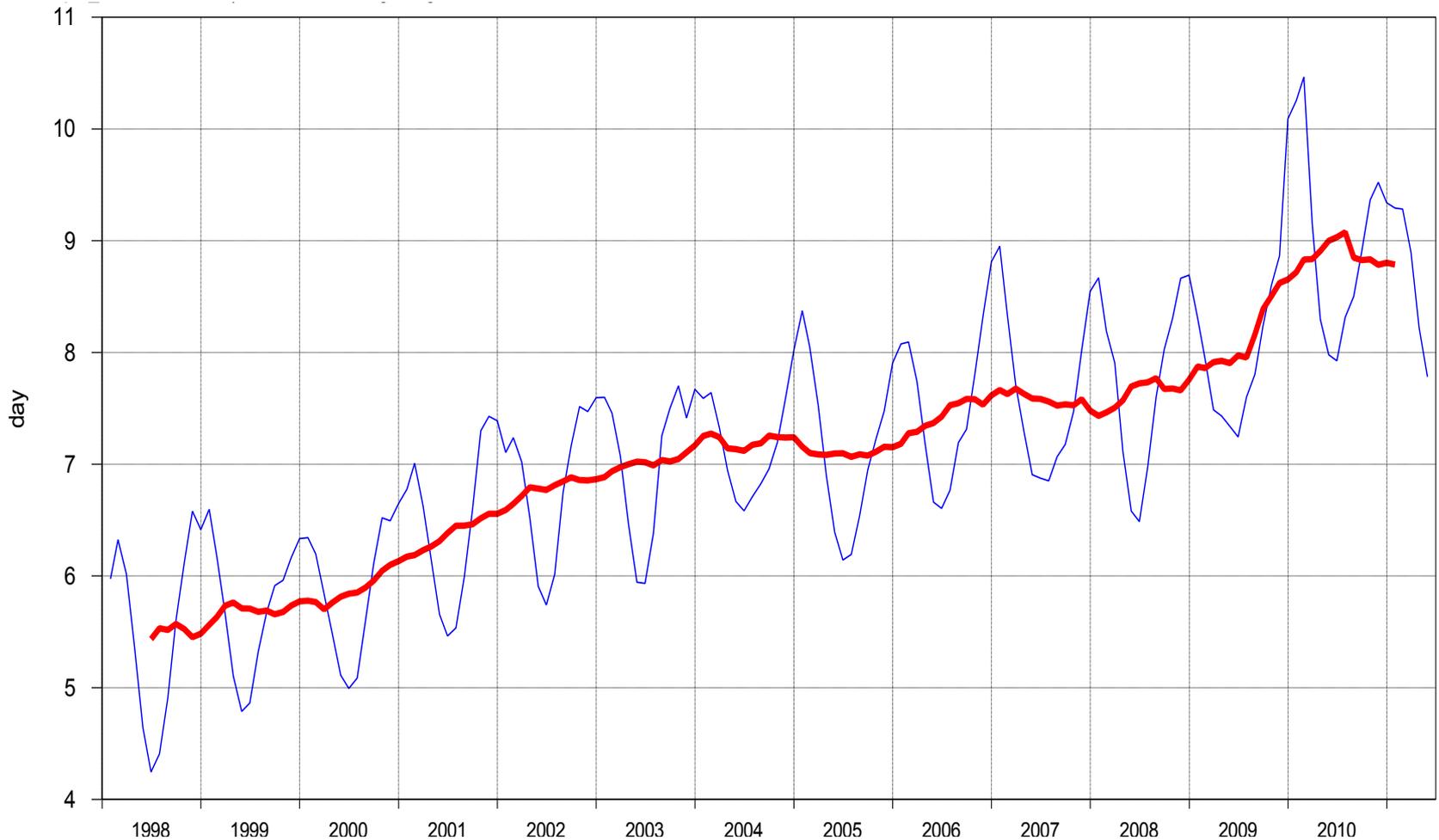
Primary headline score - deterministic

(Z500 ACC = **80%** for NH extra-tropics)



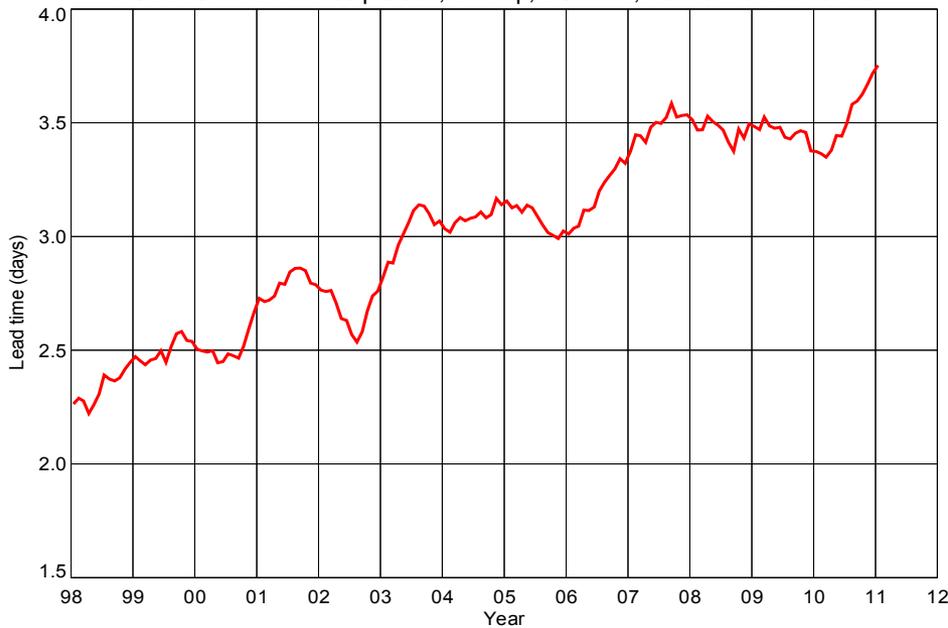
Primary headline score – EPS

(T850 CRPSS = **25%** for NH extratropics)

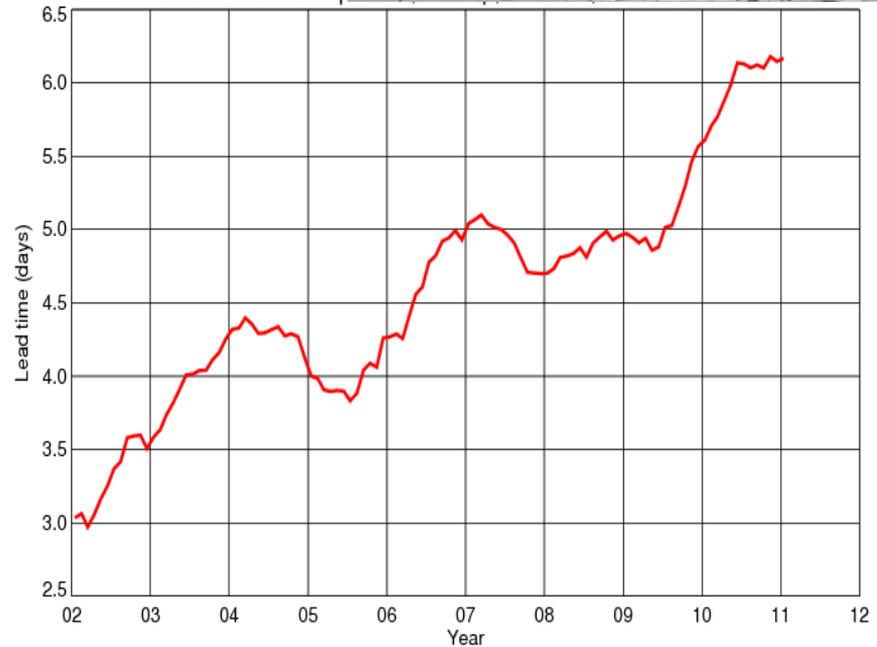


Supplementary scores – precipitation

1-SEEPS for 24-h Precipitation, ExTrop, ECMWF, 19970715-20110715

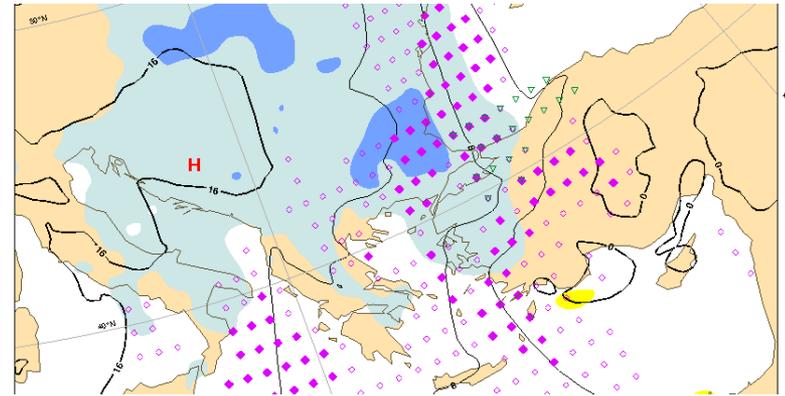
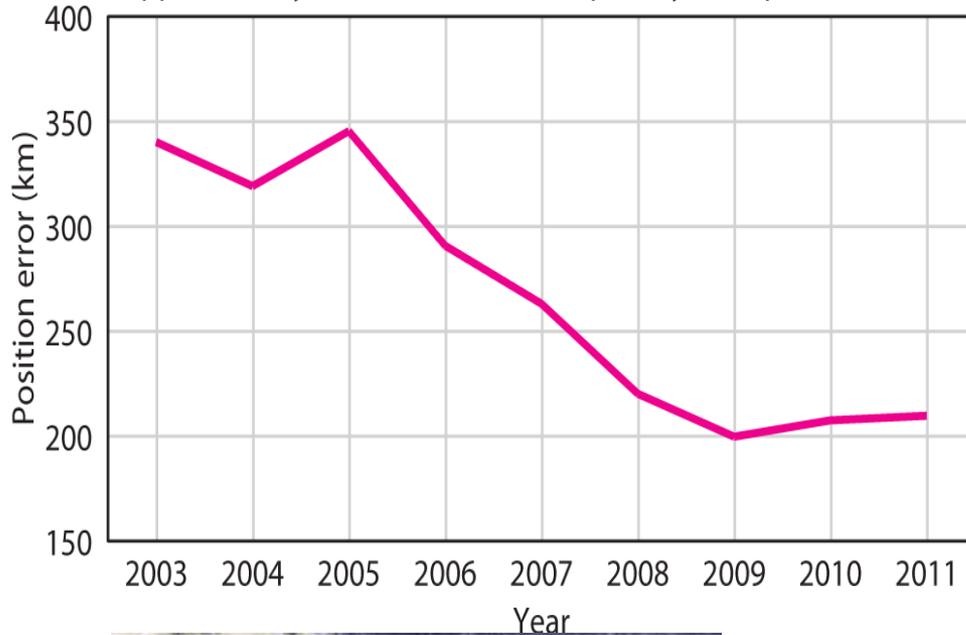


CRPSS for 24-h Precip

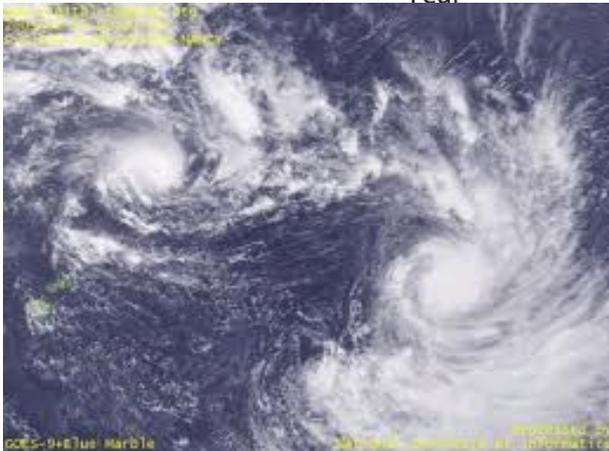
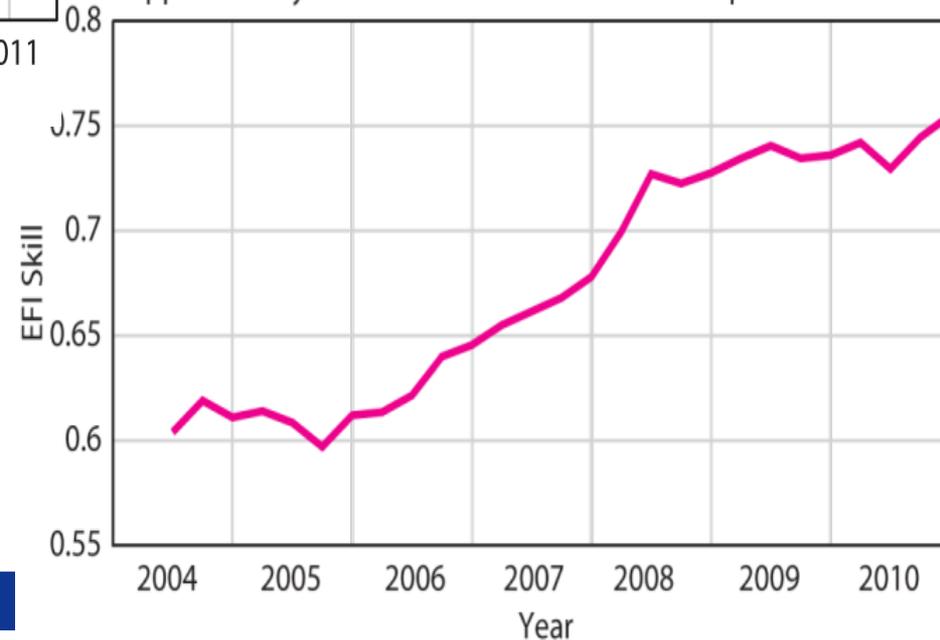


Supplementary scores – severe weather

Supplementary headline score for tropical cyclone position

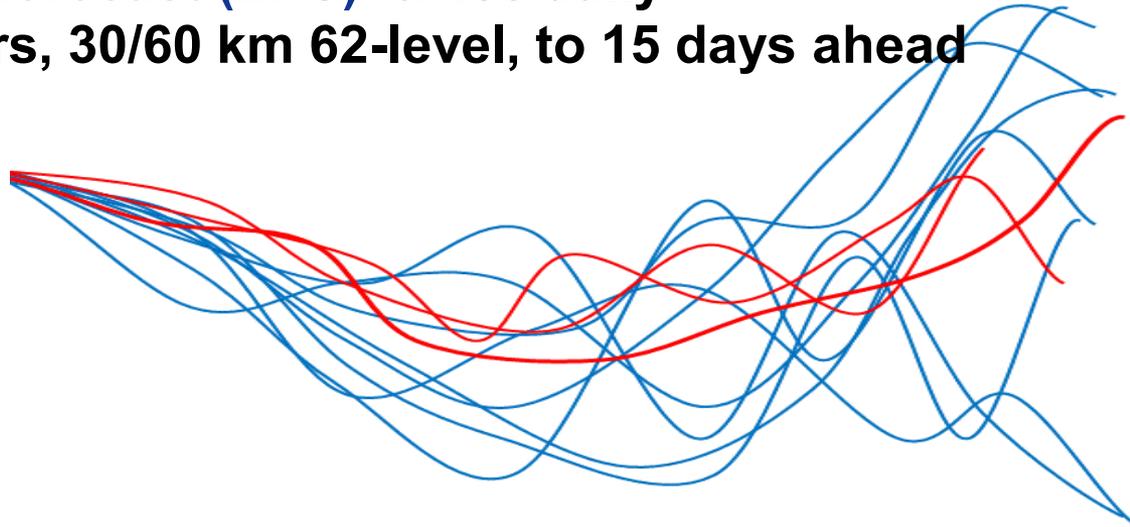


Supplementary headline score for EFI 10m wind speed



The operational forecasting system

- **High resolution deterministic forecast:** twice per day
16 km 91-level, to 10 days ahead
- **Ensemble forecast (EPS):** twice daily
51 members, 30/60 km 62-level, to 15 days ahead



- **Monthly forecast EPS extension:** twice a week (Mon/Thursdays)
51 members, 30/60 km 62 levels, to 1 month ahead
- **Seasonal forecast:** once a month (coupled to ocean model)
41 members, 125 km 62 levels, to 7 months ahead

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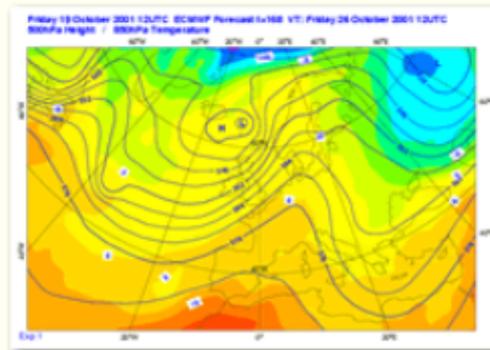
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The following forecasts are produced operationally at ECMWF:

Medium-range: global atmospheric model coupled to ocean wave model

- Forecasts to ten days from 00 and 12 UTC at 16 km resolution and 91 levels.
- 51-member ensemble forecasts to 15 days from 00 and 12 UTC at 31 km resolution to day 10 and 62 km to day 15 (32 on Thursdays) and 62 levels.
- Global Ocean forecasts to ten days from 00 and 12 UTC at 28 km resolution; European waters wave forecast to five days from 00 and 12 UTC at 10 km resolution.

Products: <http://www.ecmwf.int/products/forecasts/d/charts>

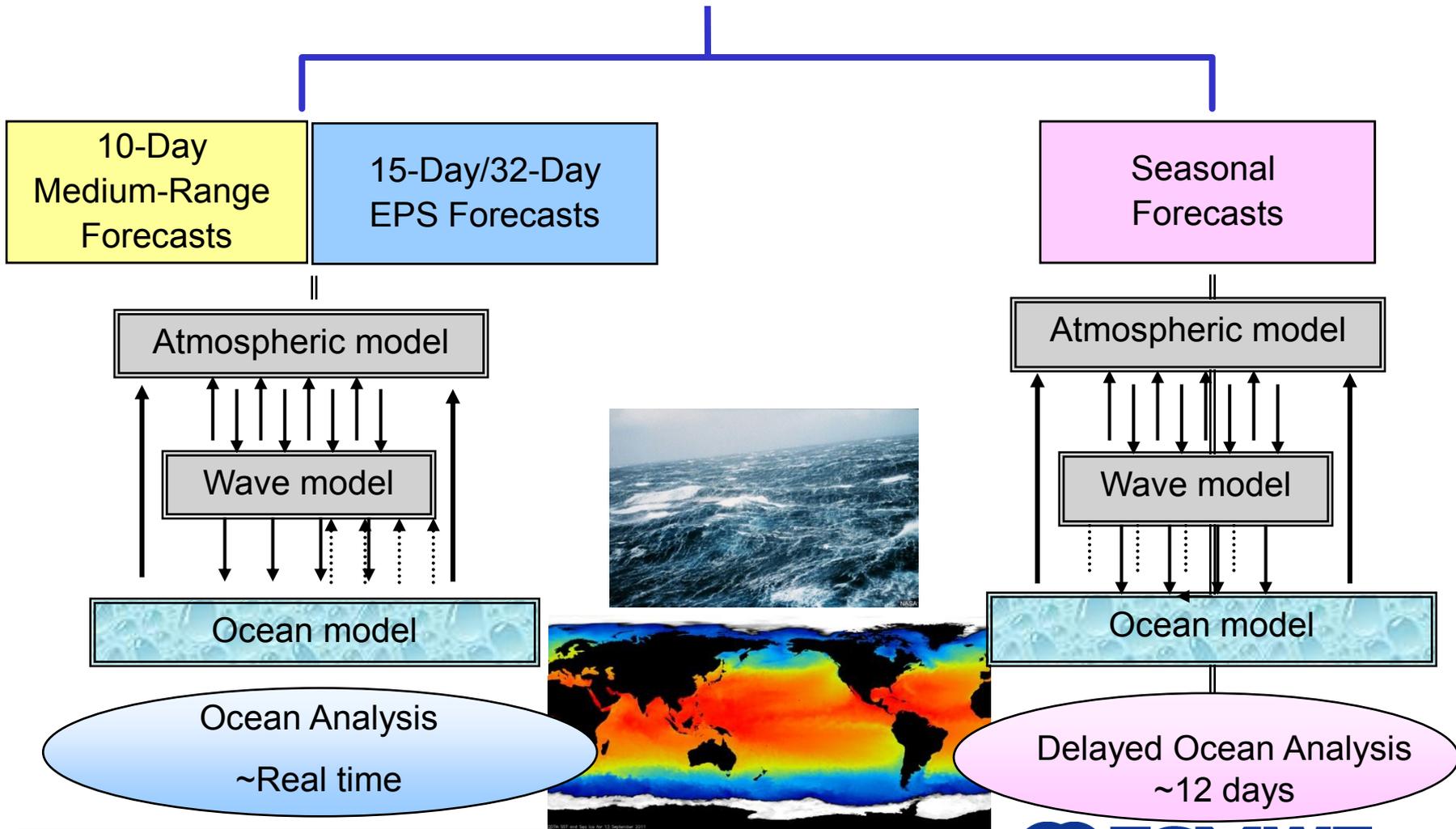
Documentation: (below for summary)

About (Users)

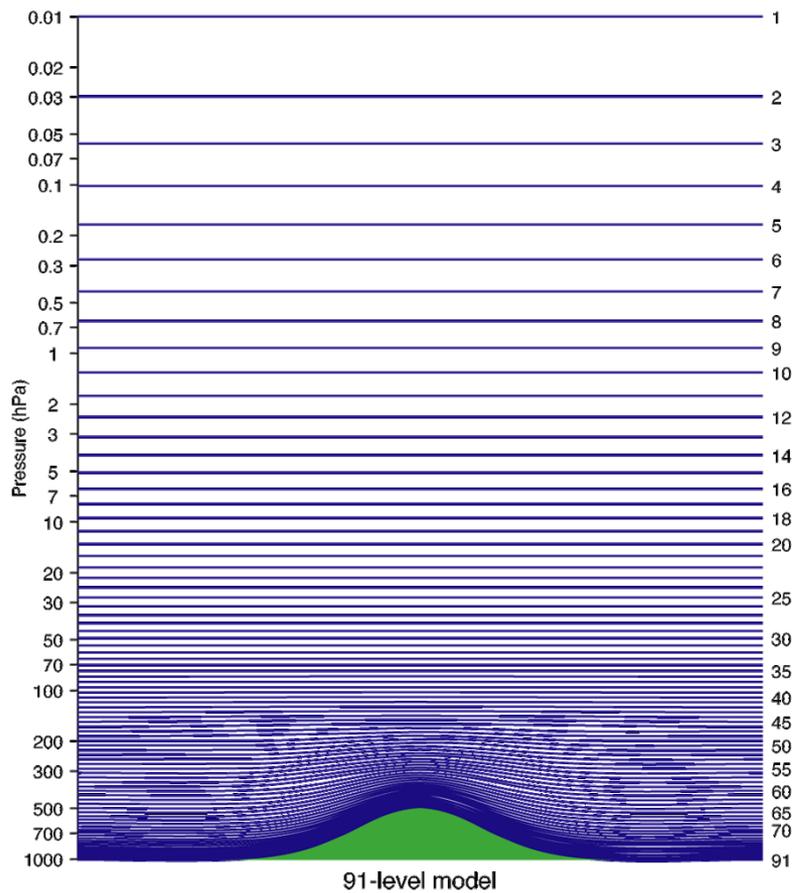
About (Procedural)

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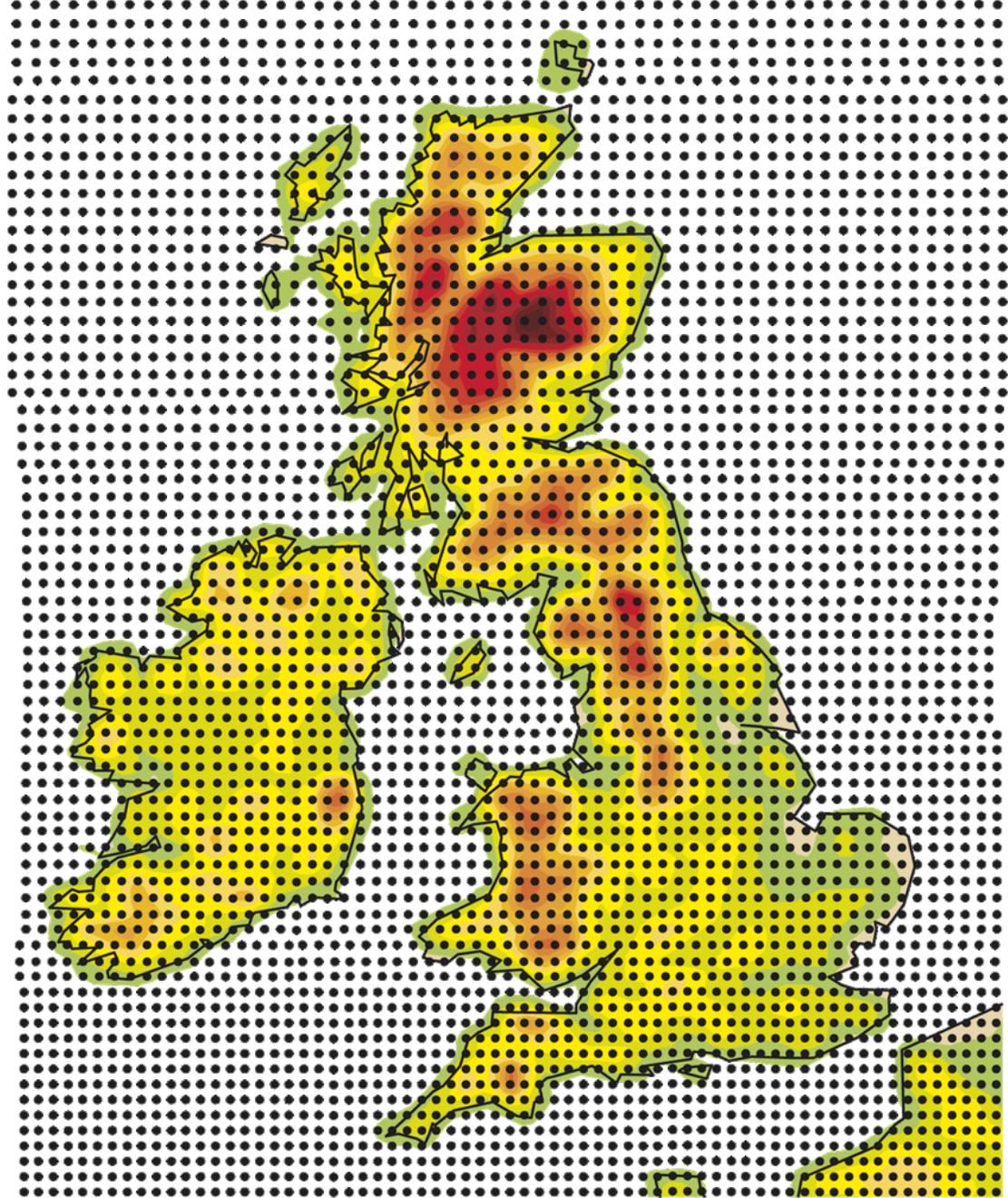
ECMWF forecasts from days to seasons



Global model with 16 km resolution and 91 levels



91-level model

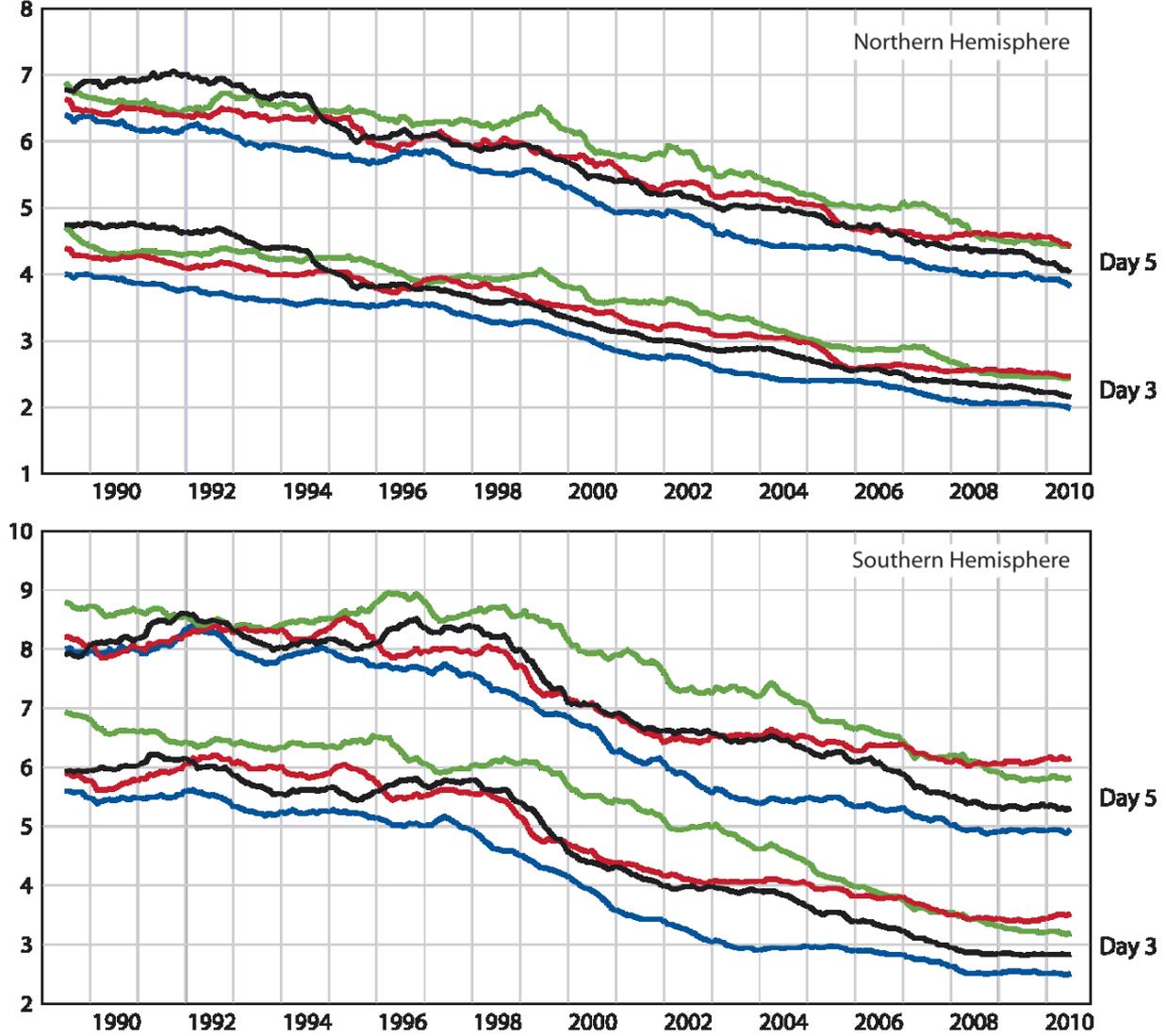


Evolution of forecast performance

ECMWF, Japan, UK and USA

RMS error (hPa) of forecasts of mean sea level pressure

— ECMWF — JAPAN — UK — USA



Why do we run an ensemble prediction system?

Basic idea:

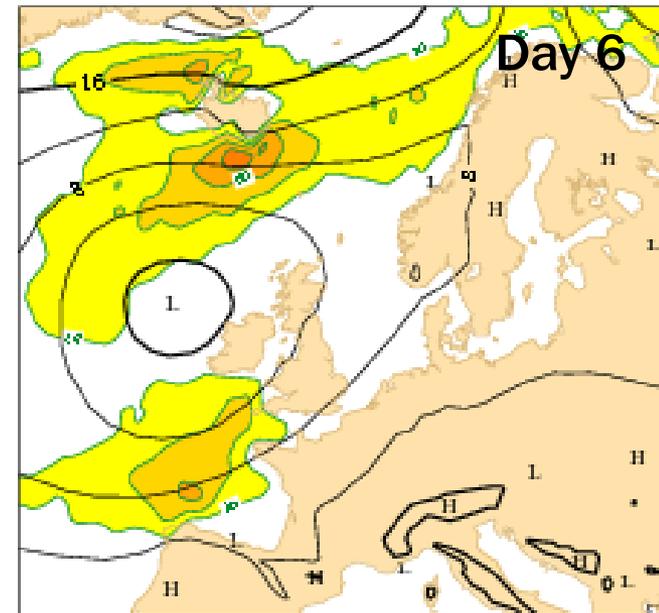
- Taking account of uncertainty
- Forecasting forecast skill

Forecasting benefits

- Assess uncertainty of today's forecast
- Provide alternative forecast scenarios
- Highlight the predictable (large-scale) component and the risk for a less likely but significant (small-scale) event

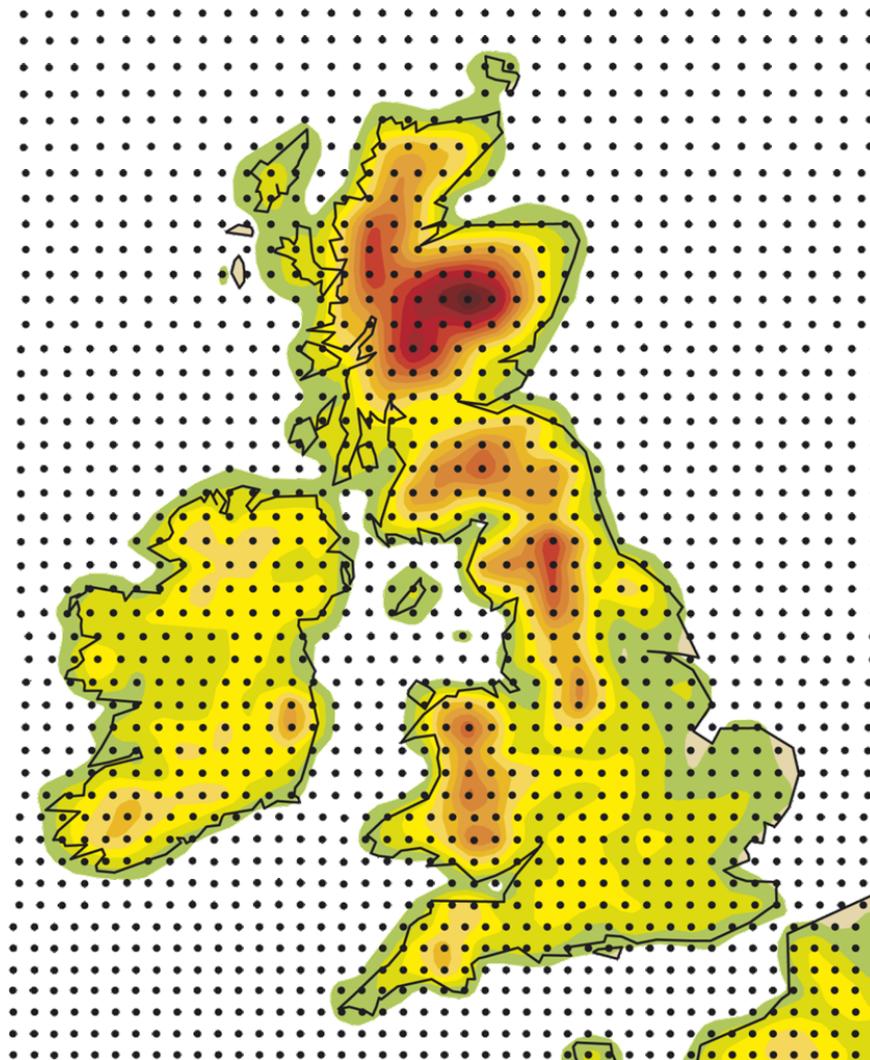
Continuing challenges

- Forecasting extreme events
- Extending the forecast range



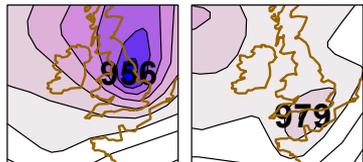
Model grid (32 km)

Multi-value forecast – the Ensemble Prediction System

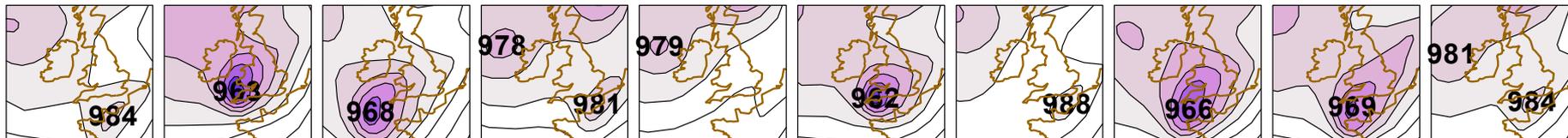


MSLP 66-h forecasts for 16-Oct-1987

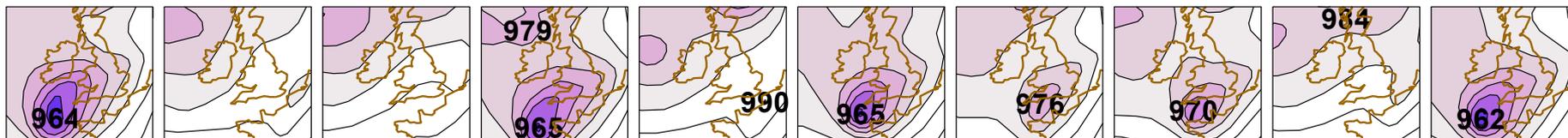
Multi-valued forecast, the EPS



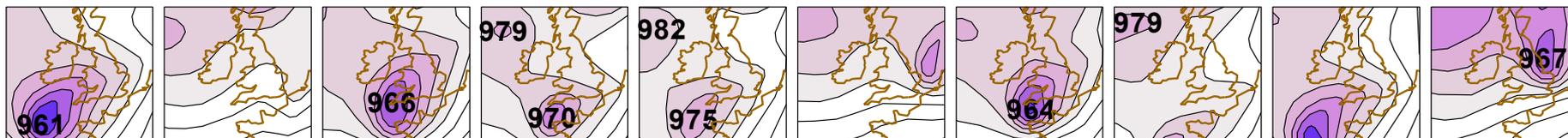
- mem no. 1 of 51 +66 h - mem no. 2 of 51 +66 h - mem no. 3 of 51 +66 h - mem no. 4 of 51 +66 h - mem no. 5 of 51 +66 h - mem no. 6 of 51 +66 h - mem no. 7 of 51 +66 h - mem no. 8 of 51 +66 h - mem no. 9 of 51 +66 h - mem no. 10 of 51 +66 h



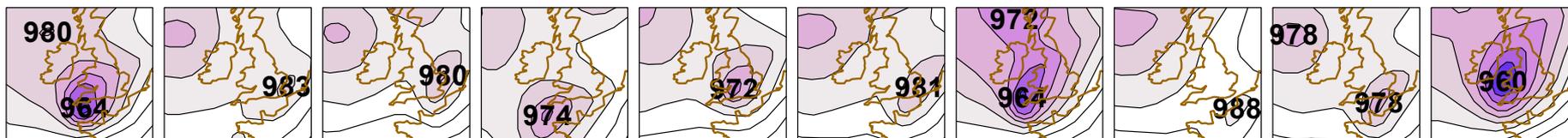
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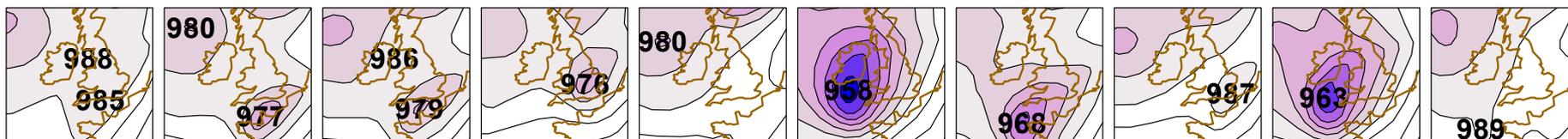
- mem no. 21 of 51 +66 h - mem no. 22 of 51 +66 h - mem no. 23 of 51 +66 h - mem no. 24 of 51 +66 h - mem no. 25 of 51 +66 h - mem no. 26 of 51 +66 h - mem no. 27 of 51 +66 h - mem no. 28 of 51 +66 h - mem no. 29 of 51 +66 h - mem no. 30 of 51 +66 h



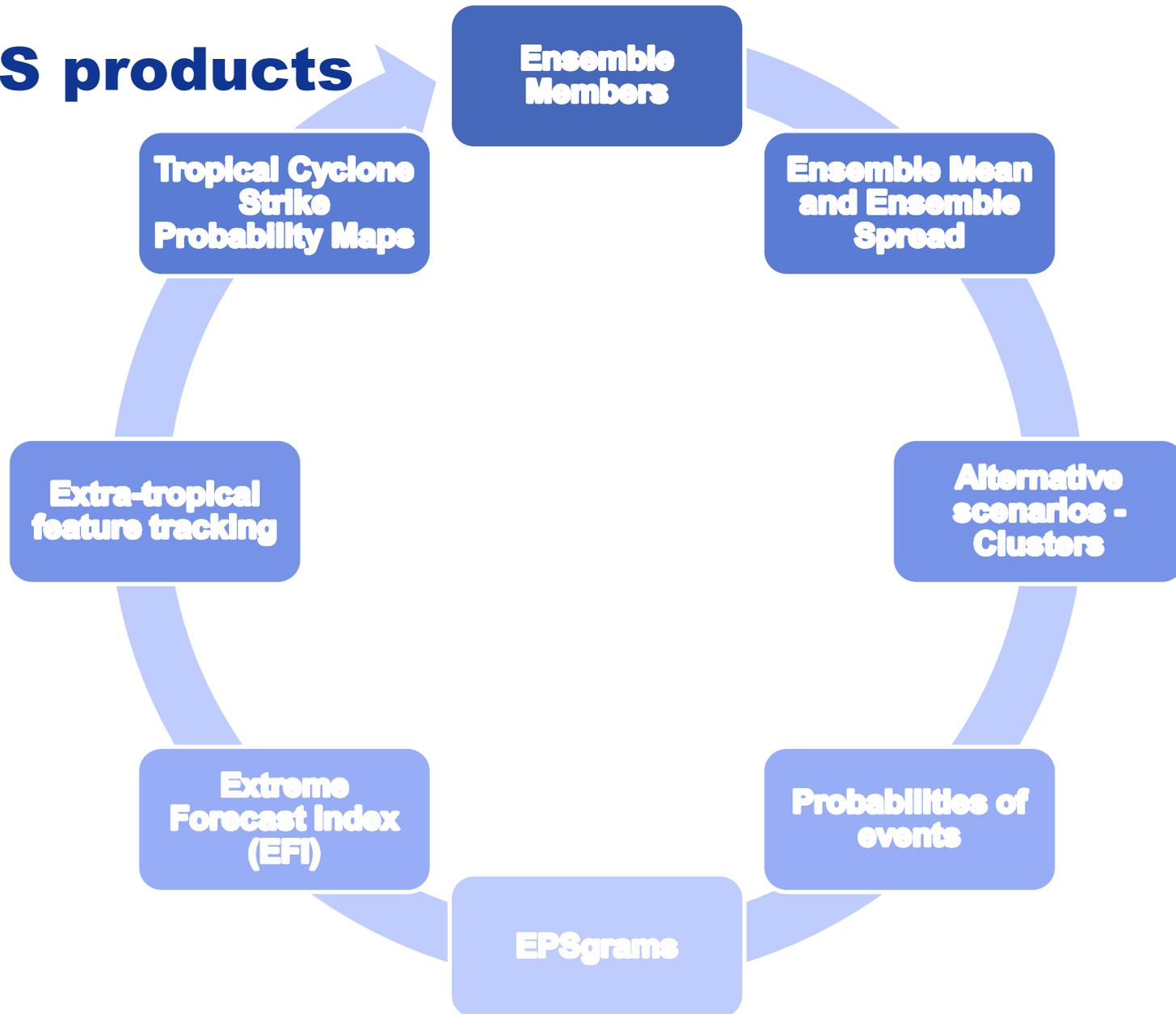
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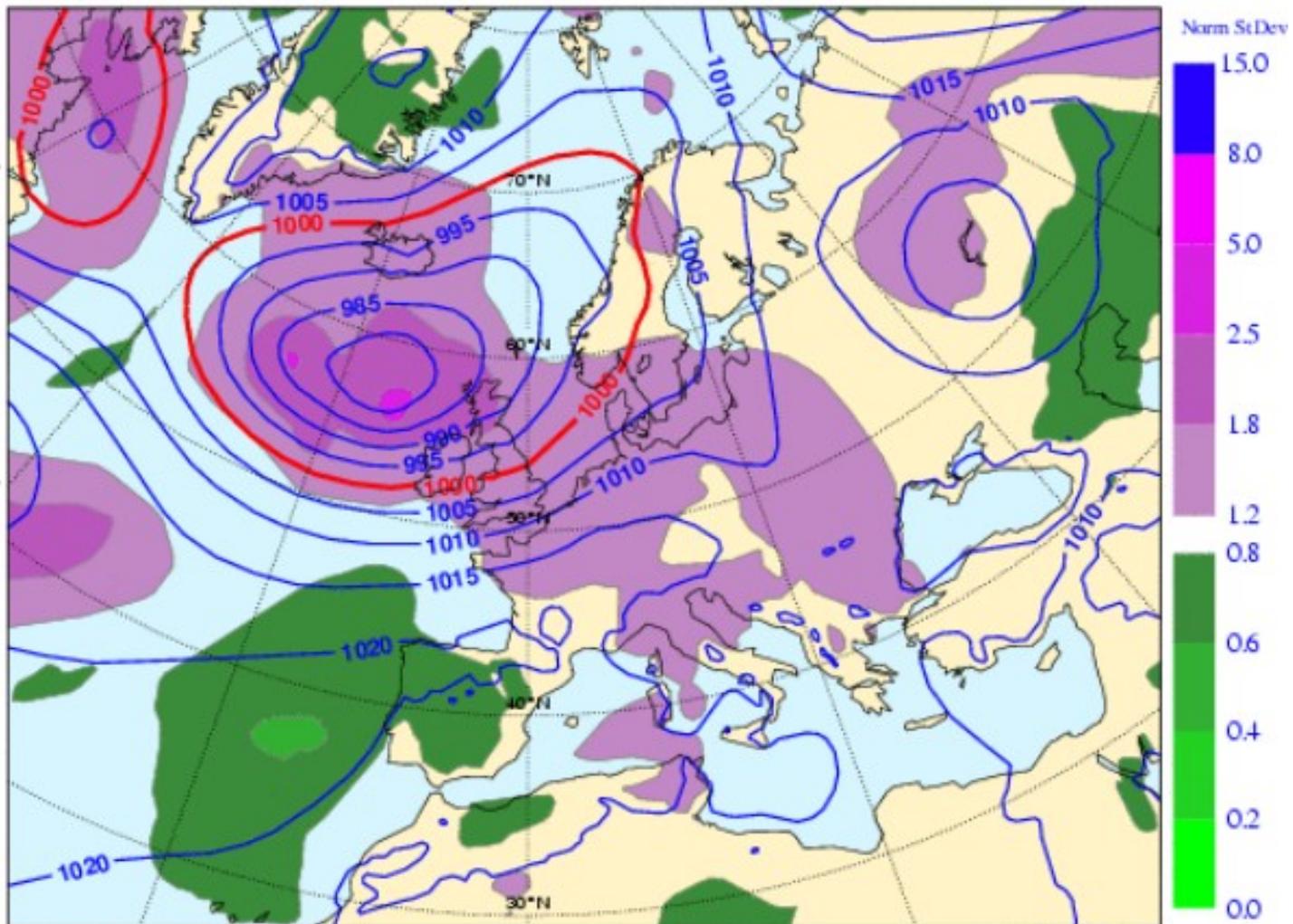
- mem no. 41 of 51 +66 h - mem no. 42 of 51 +66 h - mem no. 43 of 51 +66 h - mem no. 44 of 51 +66 h - mem no. 45 of 51 +66 h - mem no. 46 of 51 +66 h - mem no. 47 of 51 +66 h - mem no. 48 of 51 +66 h - mem no. 49 of 51 +66 h - mem no. 50 of 51 +66 h



EPS products

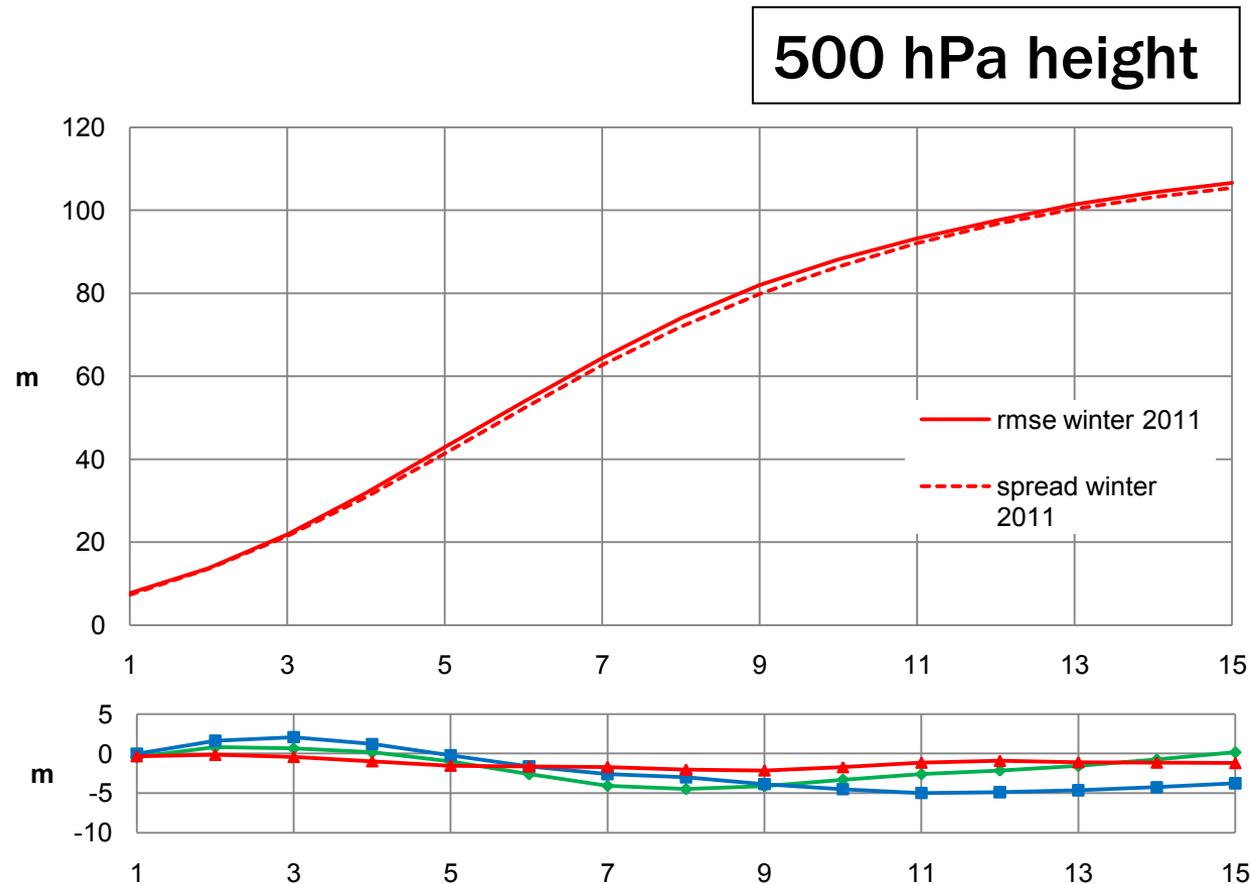


Ensemble mean and ensemble spread 5-day fc for Monday 12 Sept (ex-Katiaia)



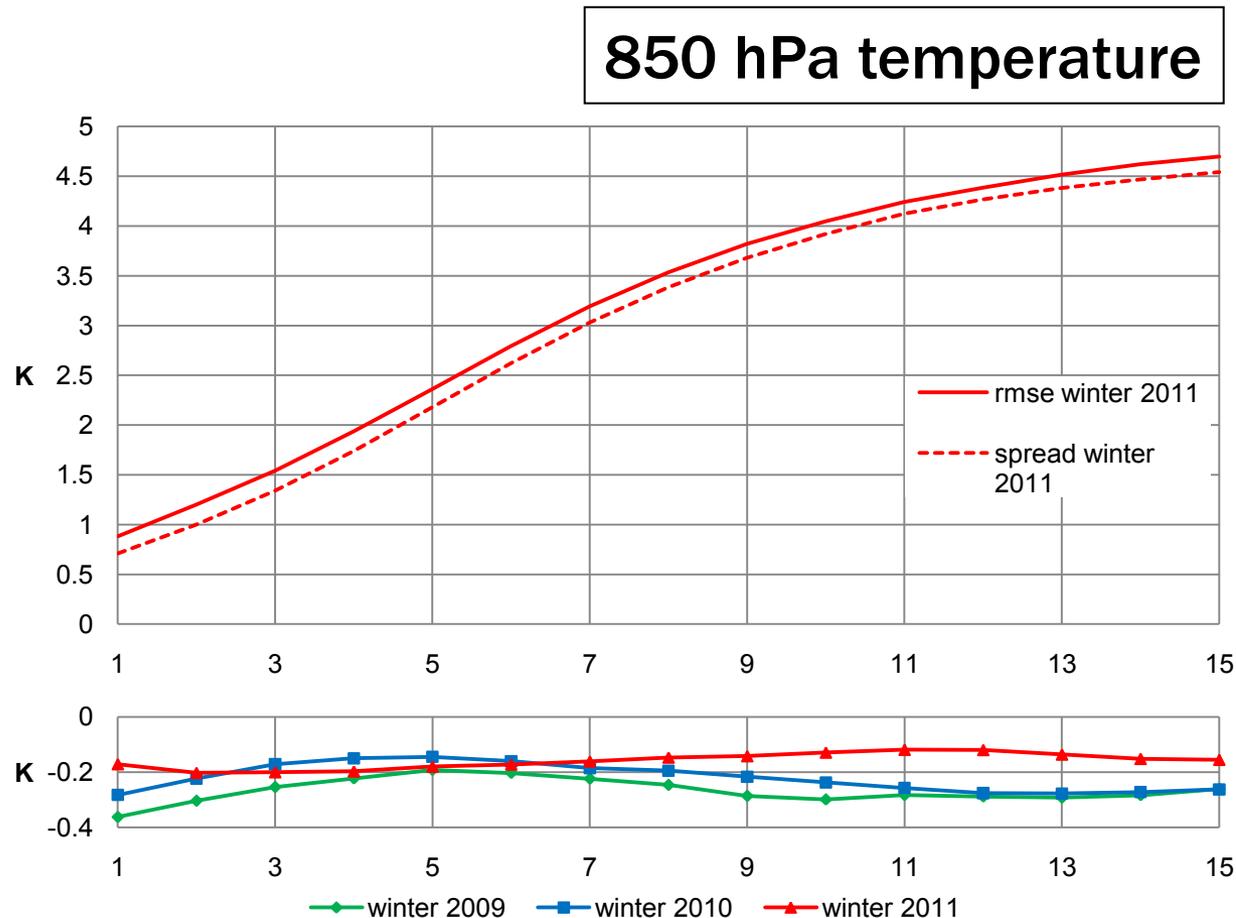
Are the EPS probabilities well calibrated

The spread \leftrightarrow skill relationship



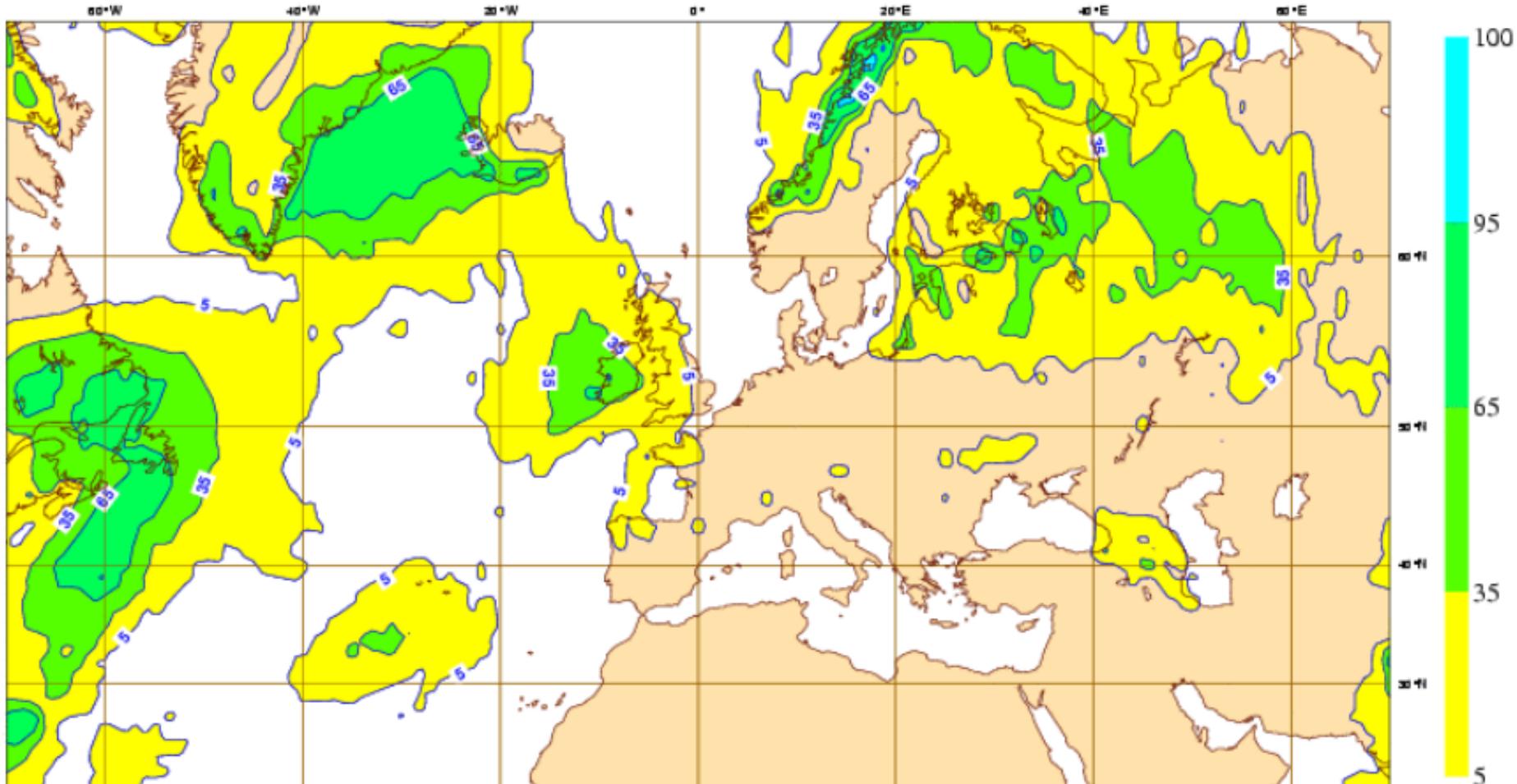
Are the EPS probabilities well calibrated

The spread \leftrightarrow skill relationship



Probabilities of events

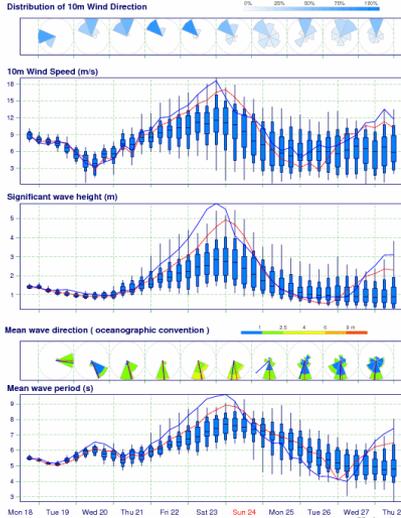
24h precip > 5 mm, 4-day forecast for today



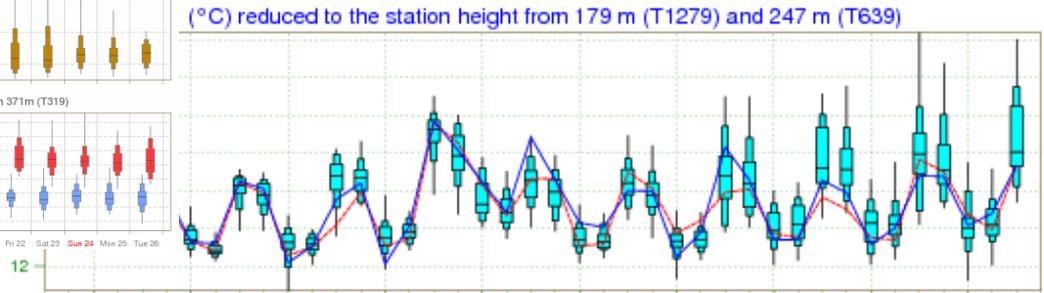
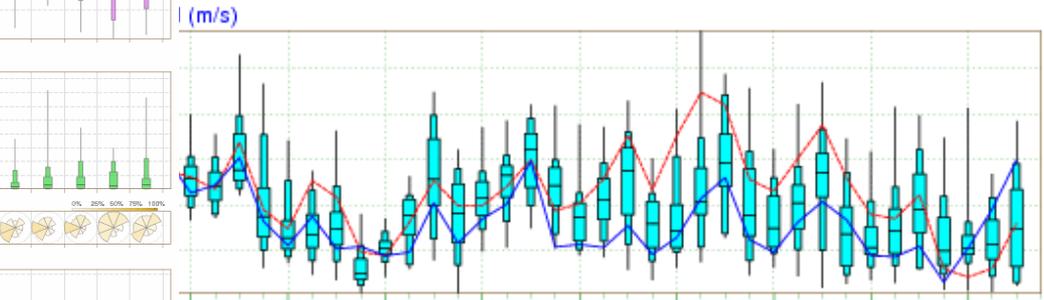
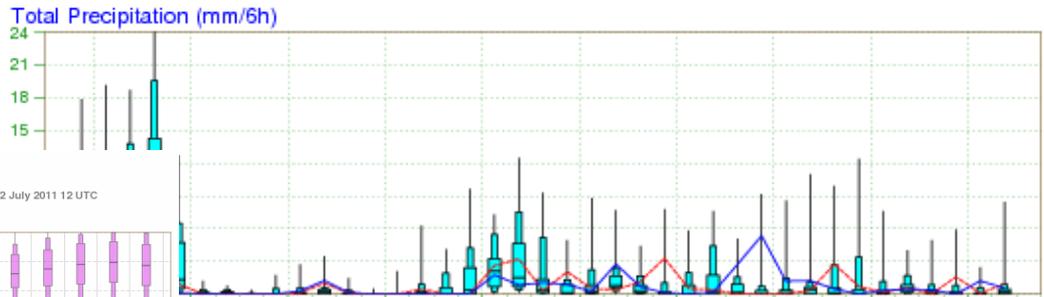
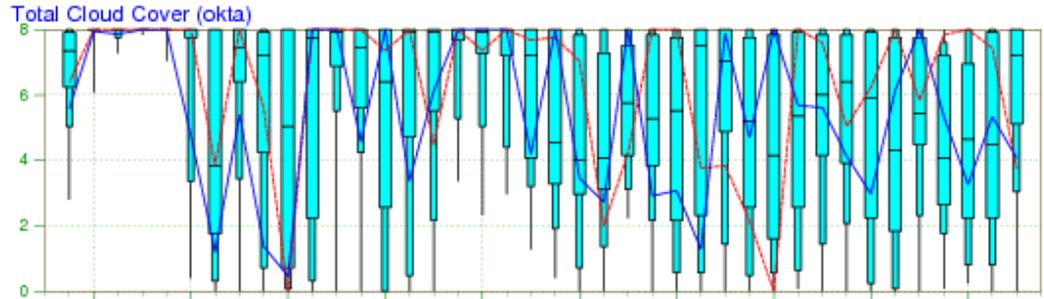
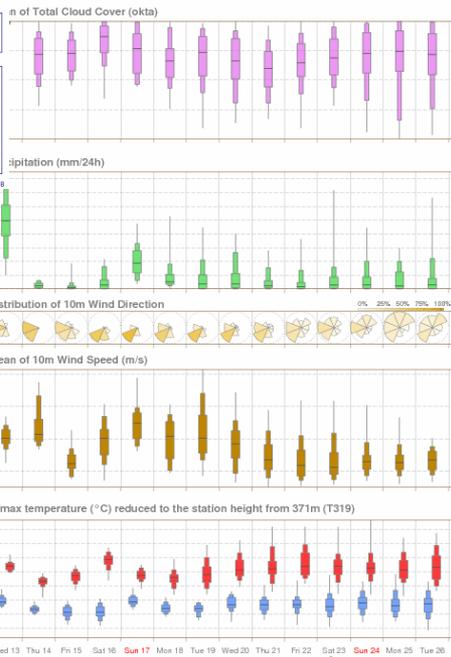
EPSgrams

EPS Meteorogram
 Strassbourg 48.48°N 7.6°E (EPS land point) 141 m
 Deterministic Forecast and EPS Distribution Tuesday 12 July 2011 12 UTC

Wave Epsgram
 55.22°N 2.81°E (EPS sea point)
 Deterministic Forecast and EPS Distribution Monday 18 July 2011 12 UTC



ogram
 48.58°N 8°E (EPS land point) 141 m
 Range Forecast based on EPS Distribution Tuesday 12 July 2011 12 UTC



Tue 12 Wed 13 Thu 14 Fri 15 Sat 16 Sun 17 Mon 18 Tue 19 Wed 20 Thu 21 Fri 22
 July 2011

Extreme forecast index (EFI)

20 Aug 2011

Is computed for temperature, precipitation, wind speed and wind gusts

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

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

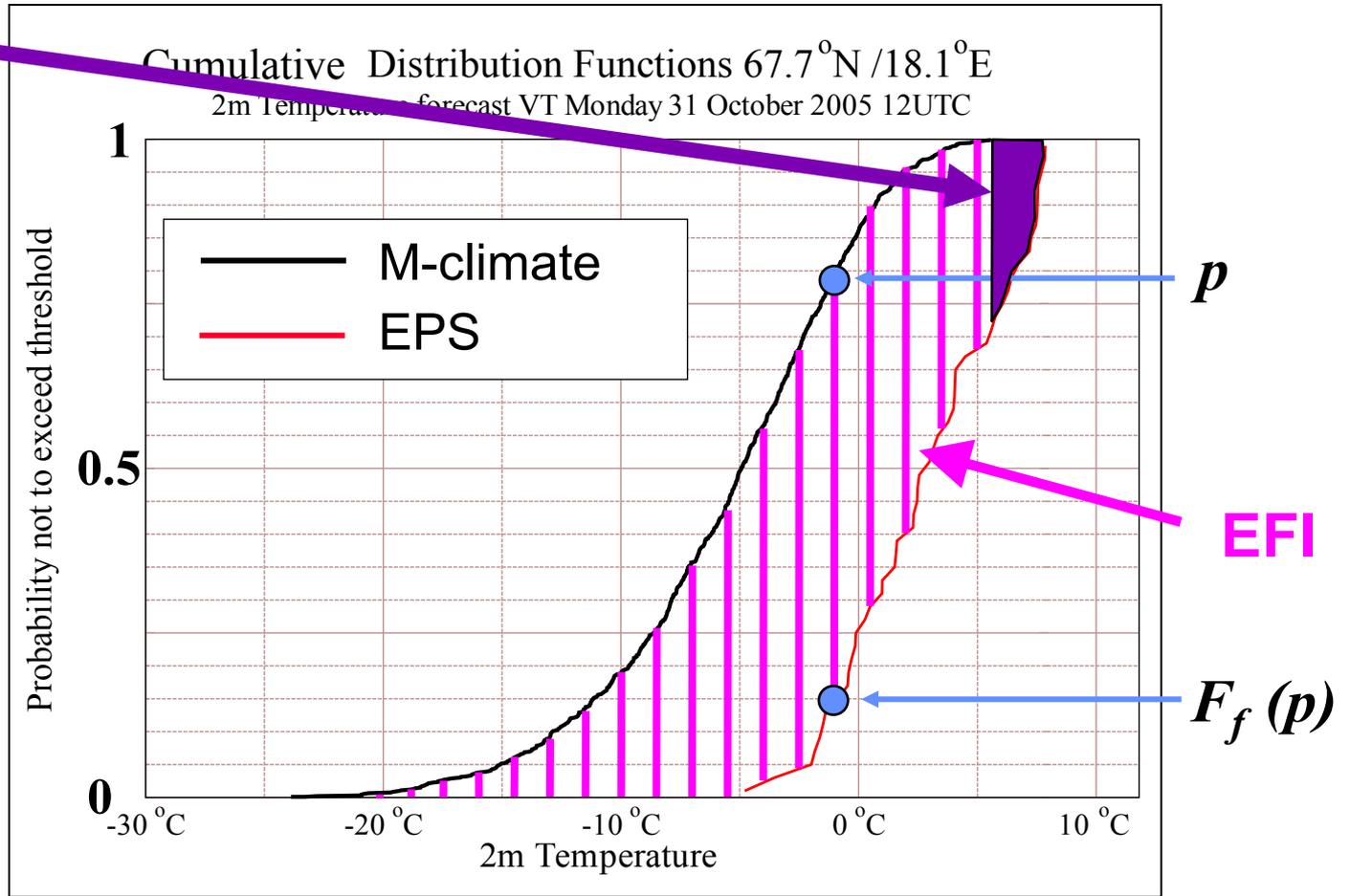
Indicates places where the EPS distribution is towards the extreme of the climate distribution

extreme cold cold warm extreme warm wind extreme wind precip extreme precip

$$EFI_{AD} = \frac{2}{\pi} \int_0^1 \left(\frac{p - F_f(p)}{p(1-p)} \right) dp$$

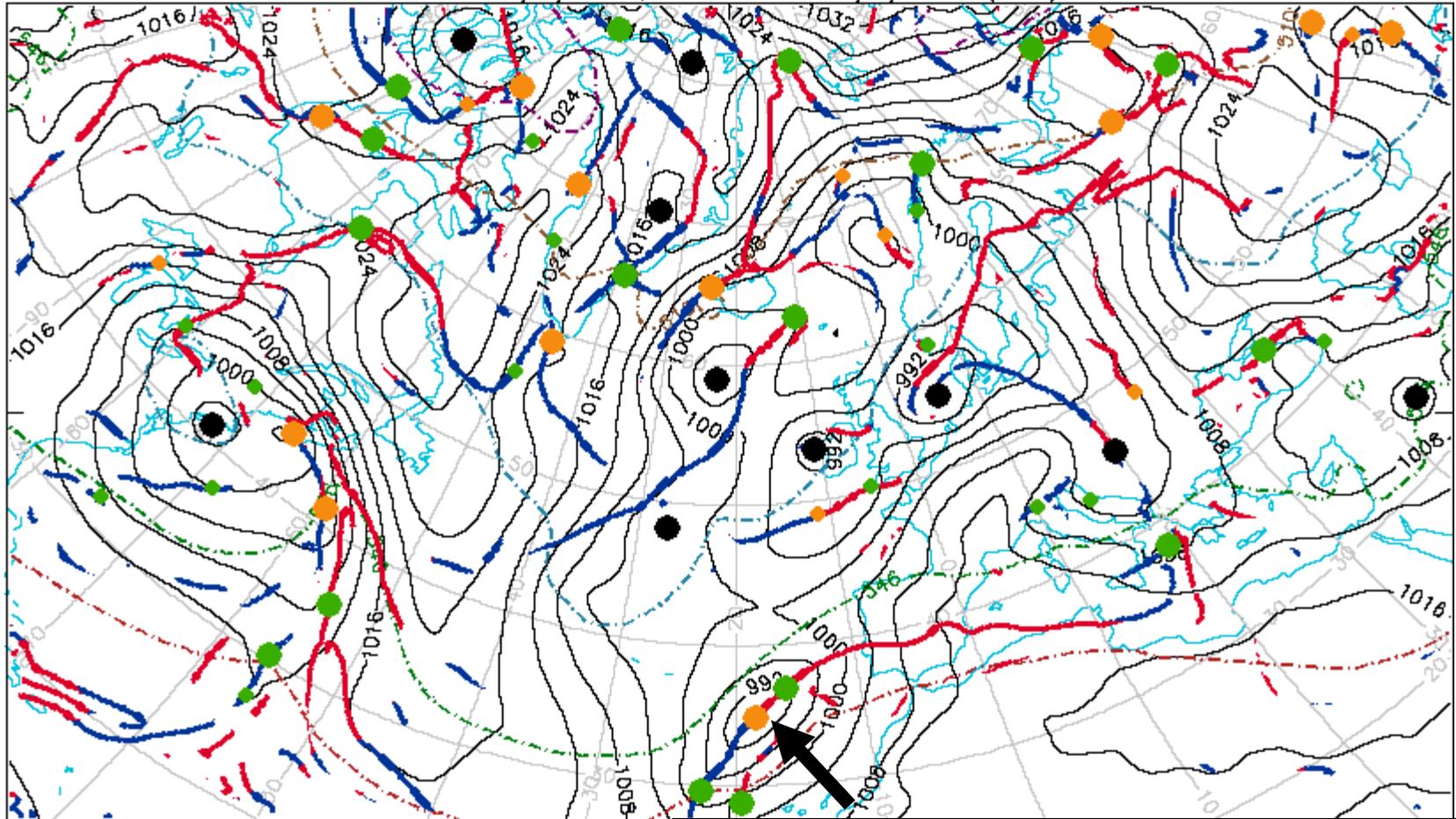
Represented by pink lines below
 More weight to extremes of M-climate

EFI takes no direct account of these most extreme EPS members

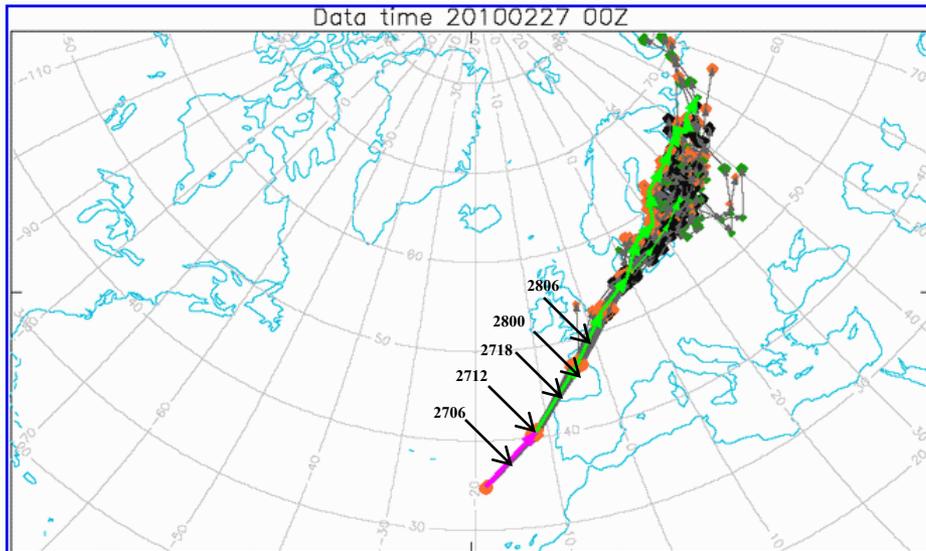


Extra-tropical feature tracking: Xynthia

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

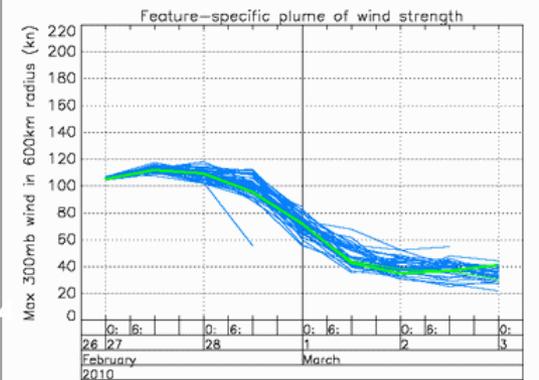
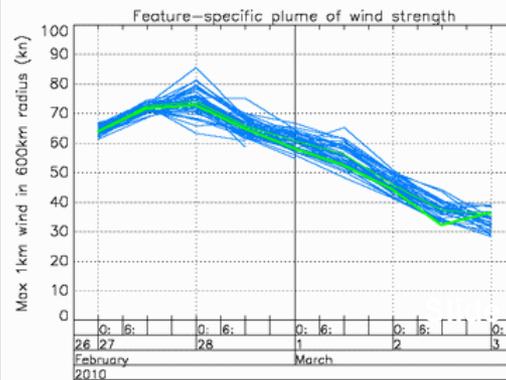
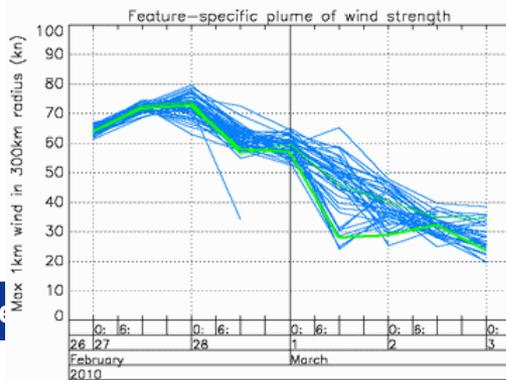
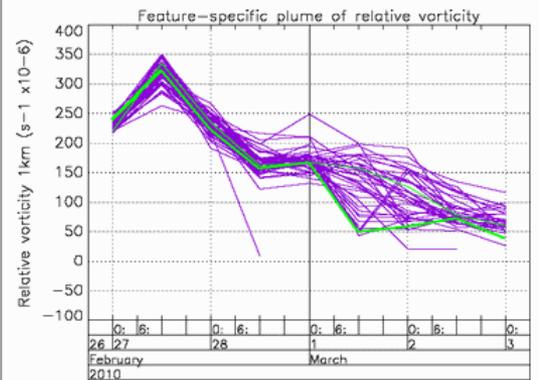
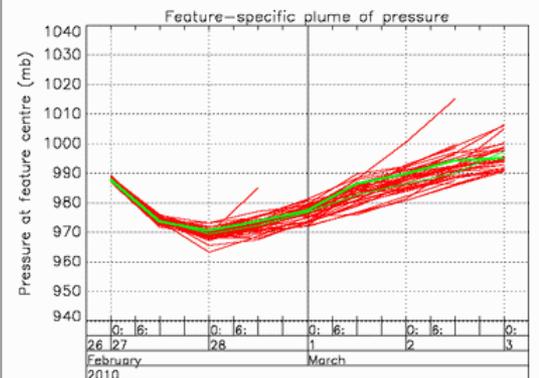


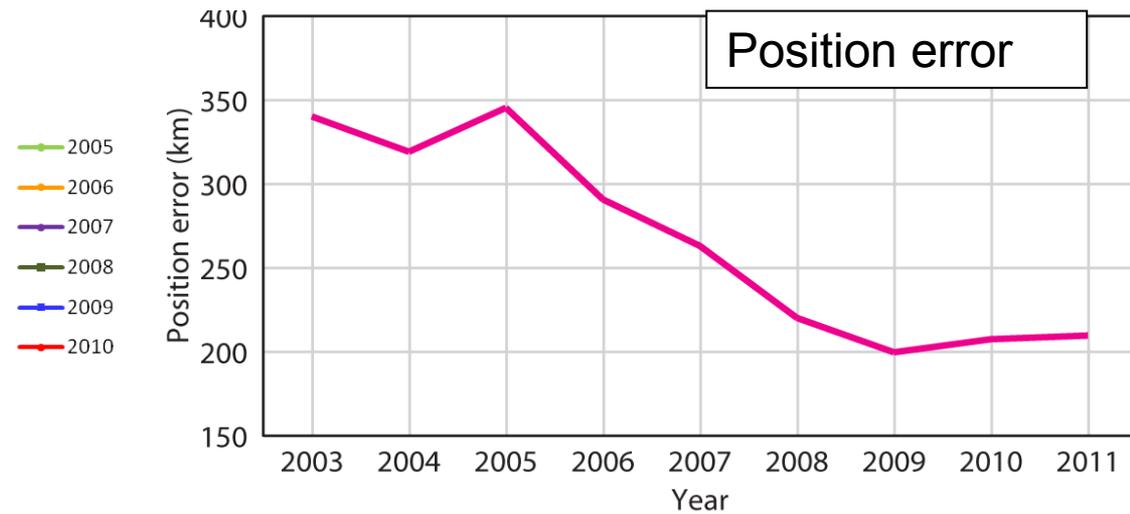
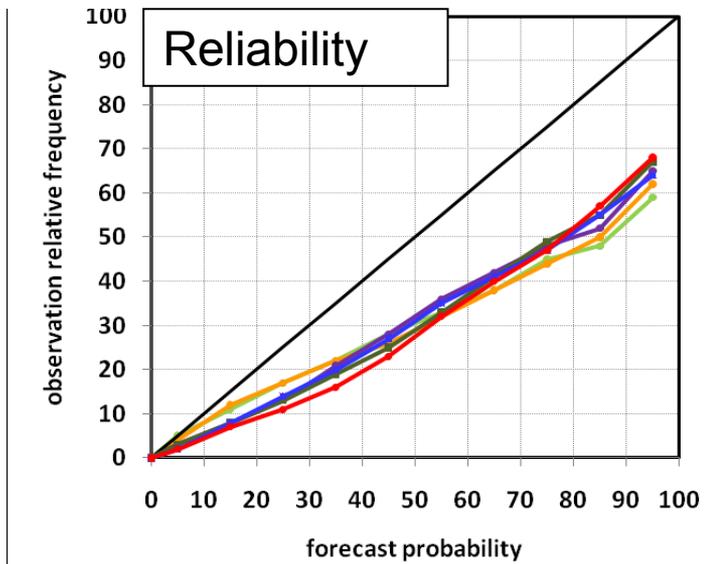
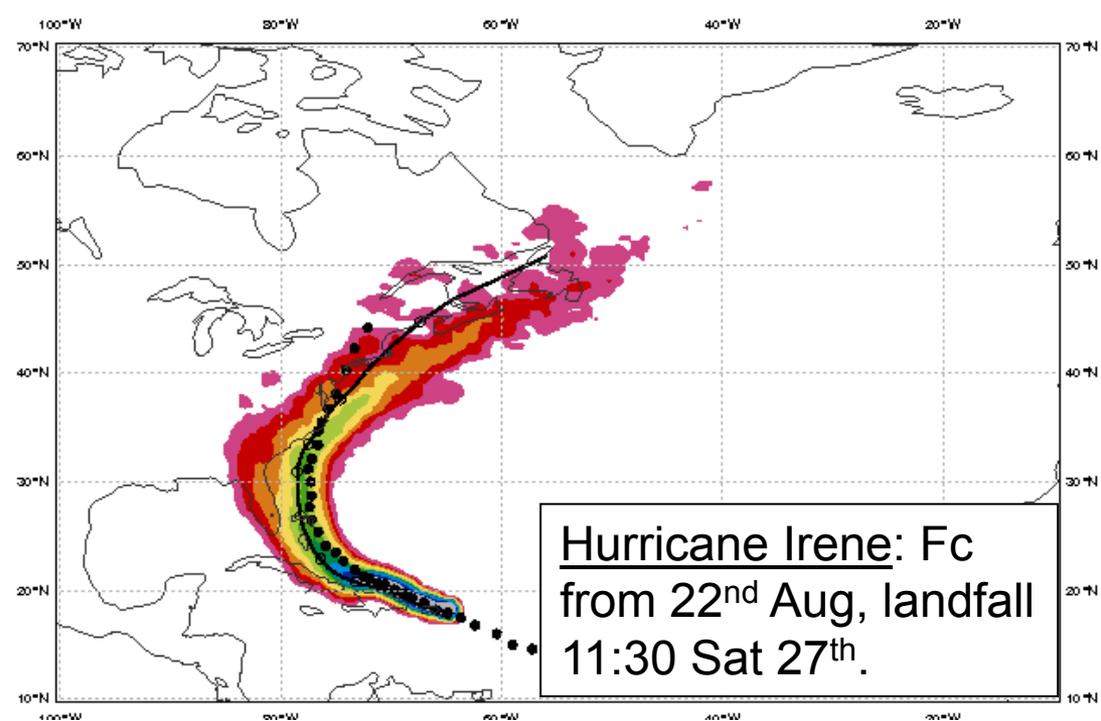
User can click on any spot (= cyclonic feature) to see how that feature evolves in the EPS



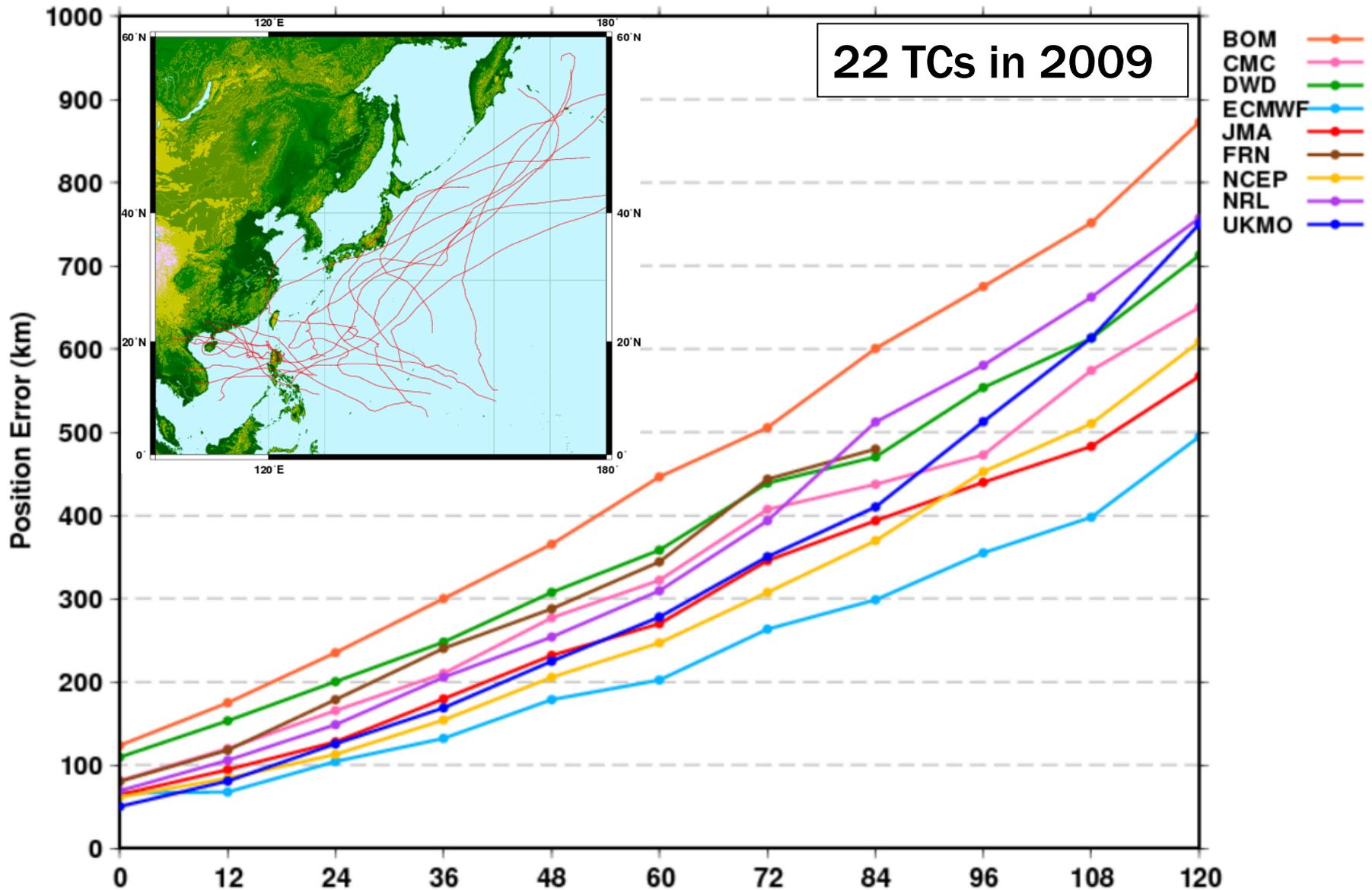
Percentage of members in track, and a list of the member numbers:

T+ 0: 100%	Det. 0,1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,50
T+ 12: 100%	Det. 0,1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,50
T+ 24: 100%	Det. 0,1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,50
T+ 36: 100%	Det. 0,1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,50
T+ 48: 94%	Det. 0,1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,17,18,19,20,21,22,23,25,28,27,28,29,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,50
T+ 60: 78%	Det. 0,1,3,4,5,6,7,8,9,11,12,14,15,17,18,19,21,25,26,27,28,29,31,32,34,35,36,37,38,39,40,41,42,43,44,45,47,48,49,50
T+ 72: 76%	Det. 0,1,3,4,5,6,7,8,9,11,12,14,15,17,18,19,21,25,26,27,28,29,31,32,34,35,36,37,38,39,41,42,43,44,45,47,48,49,50
T+ 84: 73%	Det. 0,1,3,4,5,6,7,8,9,11,12,14,17,18,19,21,25,26,27,28,31,32,34,35,36,37,38,39,41,42,43,44,45,47,48,49,50
T+ 96: 61%	Det. 0,1,3,4,5,6,7,8,9,12,14,17,18,19,21,25,28,31,32,34,35,36,37,38,39,42,43,44,45,47,48,50

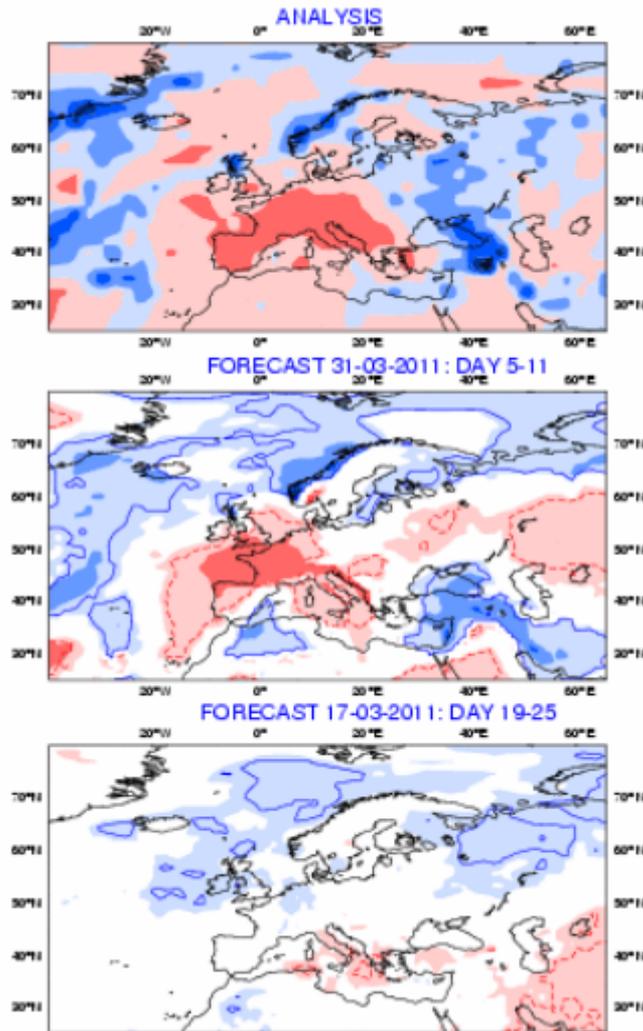




Tropical Cyclone position error

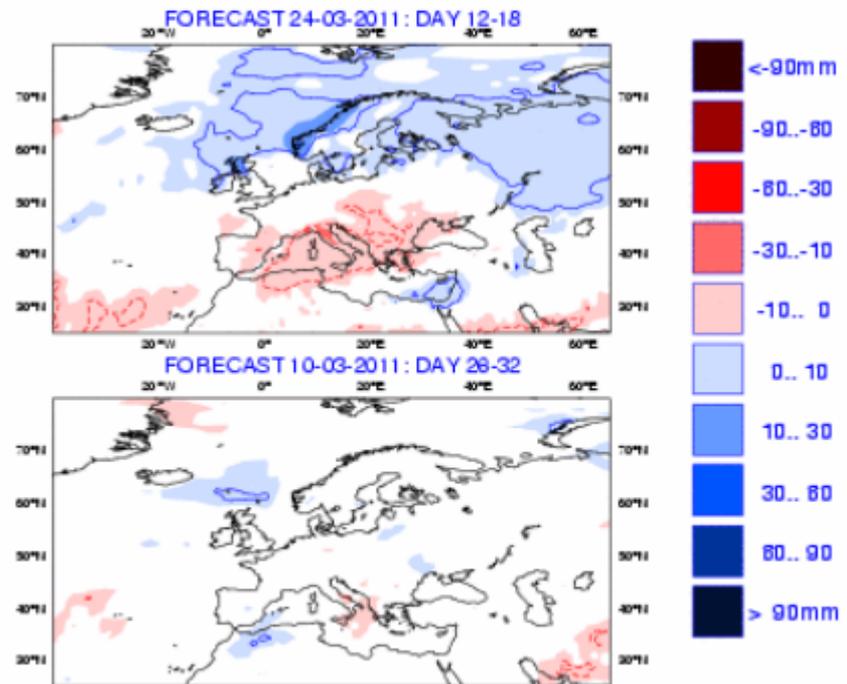


Monthly forecasts – weekly T anomalies



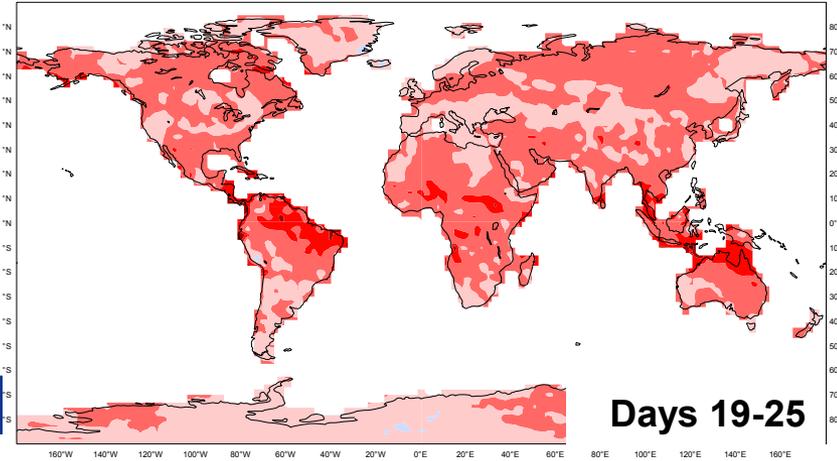
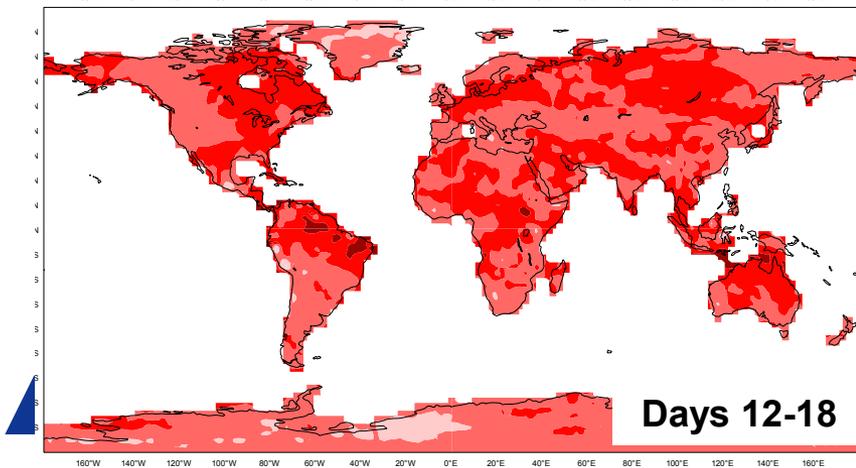
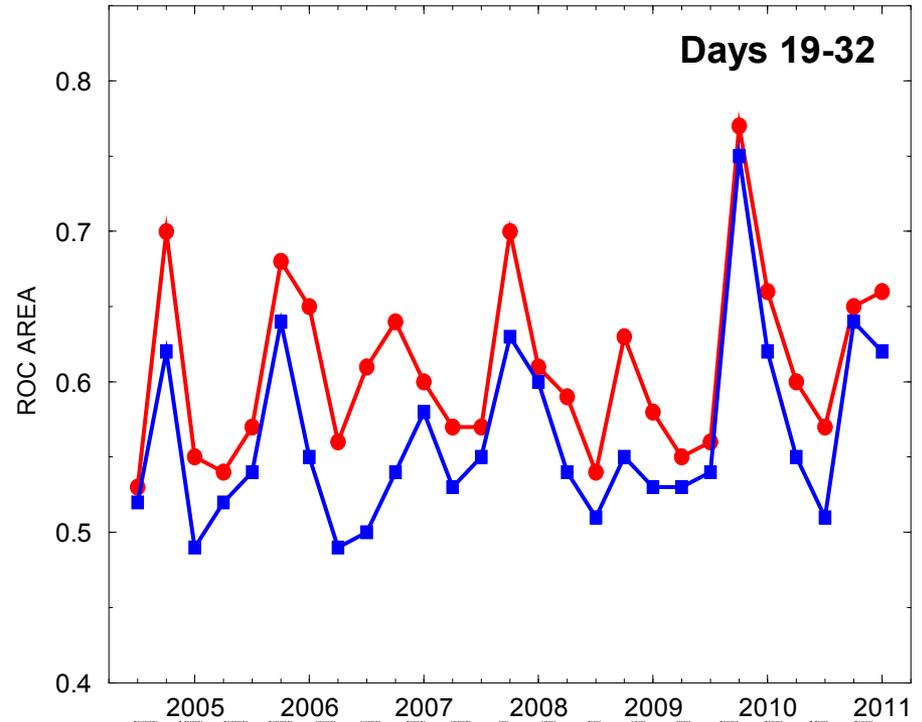
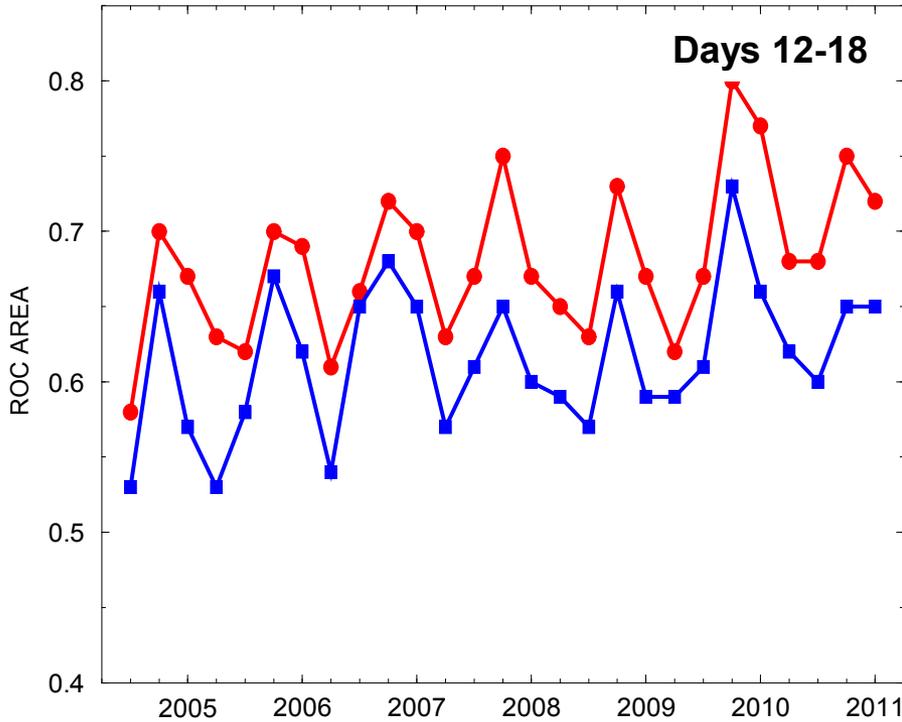
Analysis and ECMWF EPS-Monthly Forecasting System
 Precipitation anomaly
 Verification period: 04-04-2011/TO/10-04-2011

ensemble size = 51 , climate size = 90
 Shaded areas significant at 10% level
 Contours at 1% level



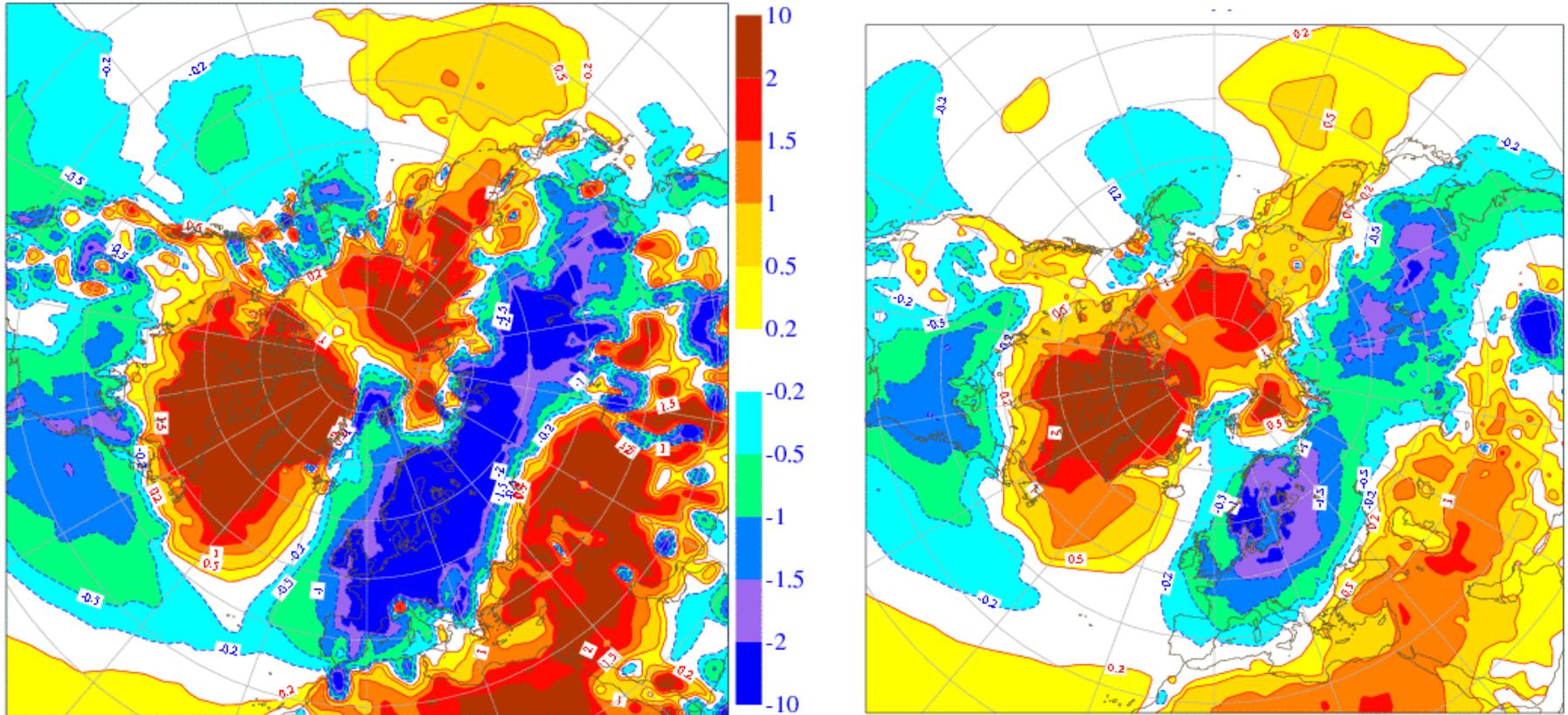
Monthly forecasts – verification (T2m)

skill in terms of weekly means



Monthly forecasts – verification

prediction of cold spells in Europe (October – March)



Summary

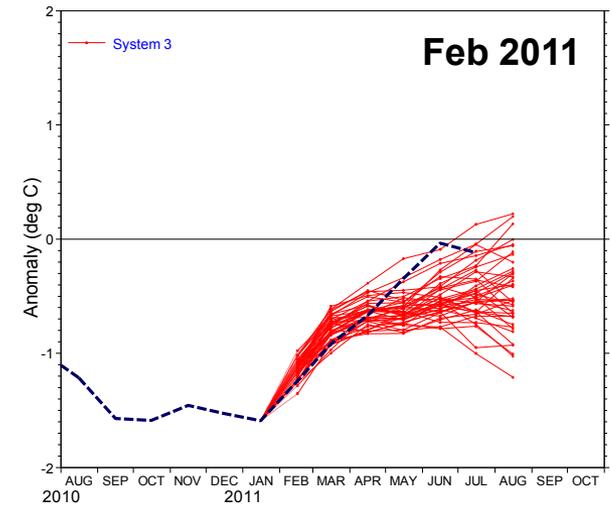
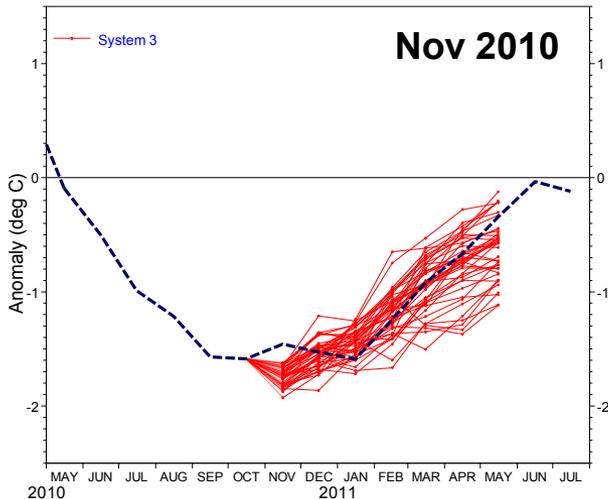
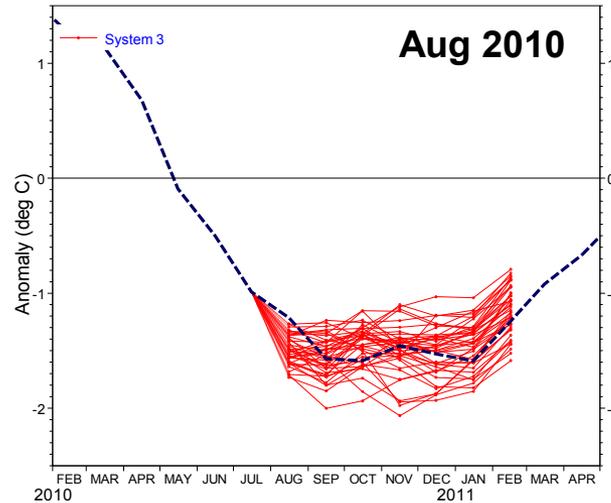
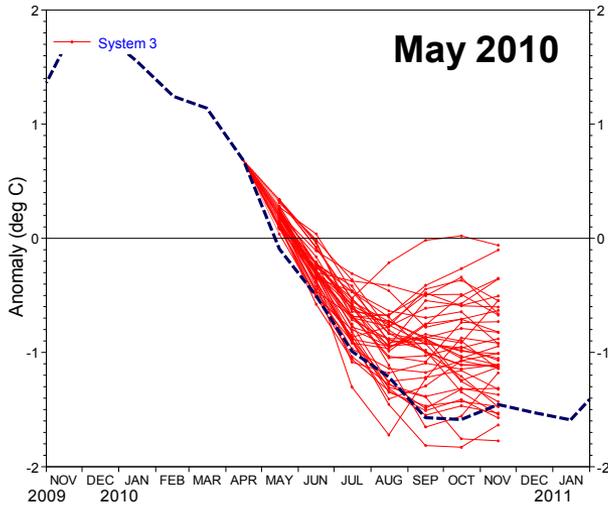
- ECMWF forecasts are used extensively to provide early warnings of severe weather and ocean waves
- ECMWF focuses its development effort on assisting our users in this work by
 - improving models,
 - using latest satellite data,
 - increasing resolution,
 - introducing products specifically for severe / extreme weather -
New comprehensive Users Guide published 2011
- Three current upgrades:
 - Monday run of the Monthly forecasting system
 - Seasonal forecasting System 4
 - IFS cycle 37r3

Main development areas for the next few years

- 140 levels - 2012
- 10 km resolution – 2015
- 20th century reanalysis – 2015
- MACC project - CO₂, carbon, atmospheric composition, aerosol, ...
- Increasing parallelism of codes and applications

- Explore new technologies and standards to make forecast products easily accessible to a widening user community – MOS13

Seasonal forecasts sea surface temperature, tropical Pacific



Seasonal forecasts – verification

Accumulated cyclone energy

1 June forecast for the July-December season

