Introduction to ECMWF

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www.ecmwf.int

Outline

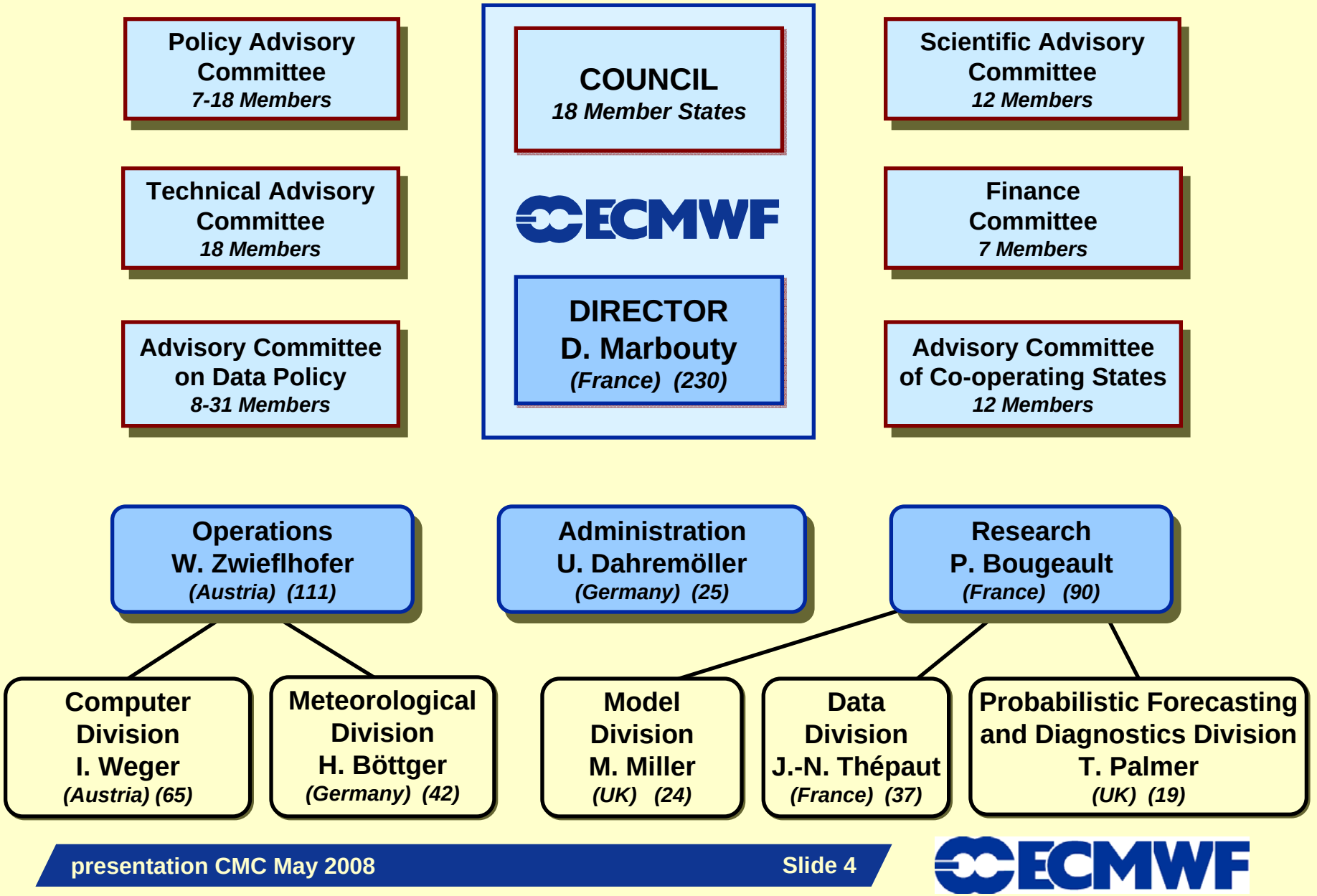
- **General introduction**
- **Developments**
- **Severe weather**
- **Outlook**

ECMWF

ECMWF Objectives

- **Operational forecasting up to 15 days ahead (including waves)**
- **R & D activities in forecast modelling**
- **Data archiving and related services**
- **Operational forecasts for the coming month and season**
- **Advanced NWP training**
- **Provision of supercomputer resources**
- **Assistance to WMO programmes**

Organisation of ECMWF



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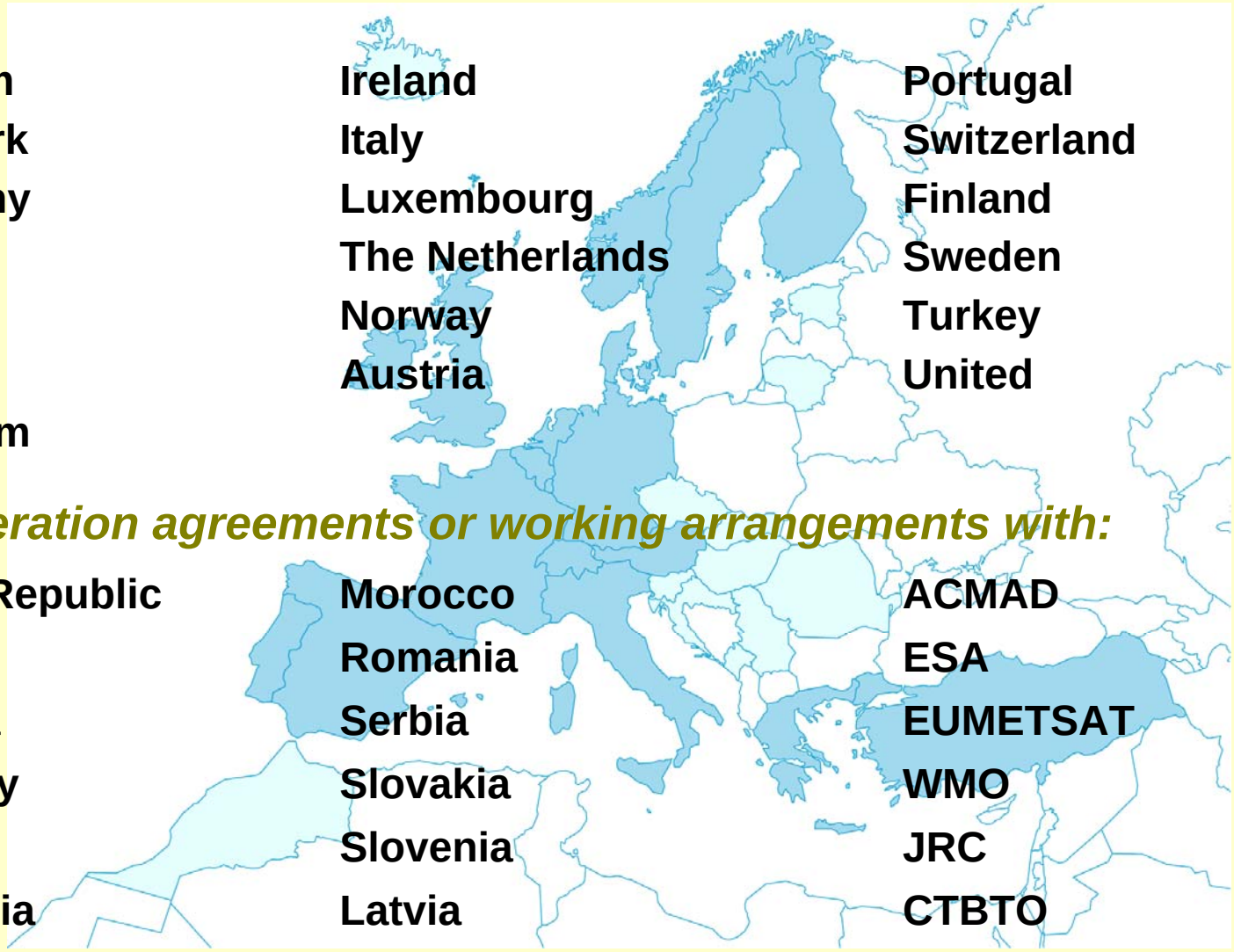
Supporting States and Co-operation

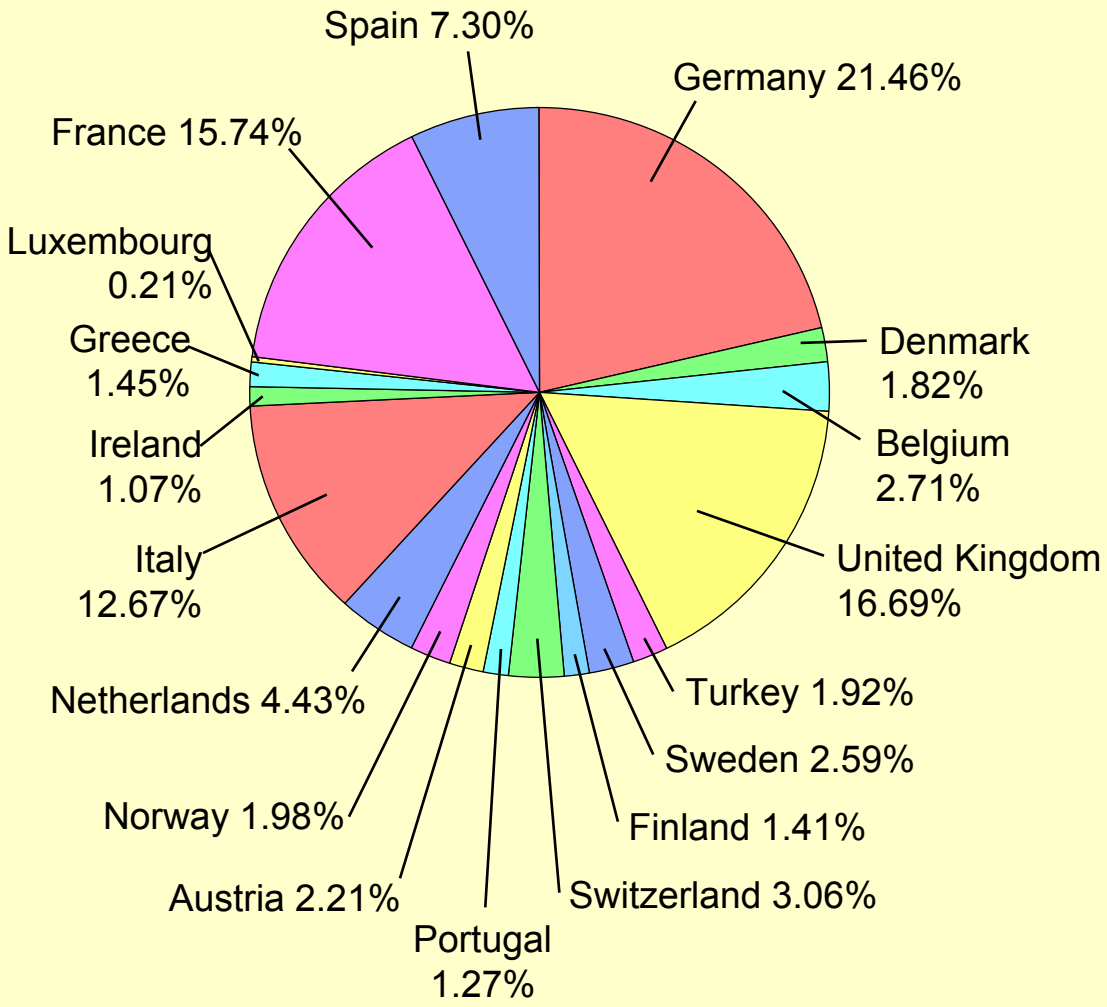


Belgium
Denmark
Germany
Spain
France
Greece
Kingdom
Ireland
Italy
Luxembourg
The Netherlands
Norway
Austria
Portugal
Switzerland
Finland
Sweden
Turkey
United

Co-operation agreements or working arrangements with:

Czech Republic
Croatia
Estonia
Hungary
Iceland
Lithuania
Montenegro
Morocco
Romania
Serbia
Slovakia
Slovenia
Latvia
ACMAD
ESA
EUMETSAT
WMO
JRC
CTBTO
CLRTAP

ECMWF Budget 2008

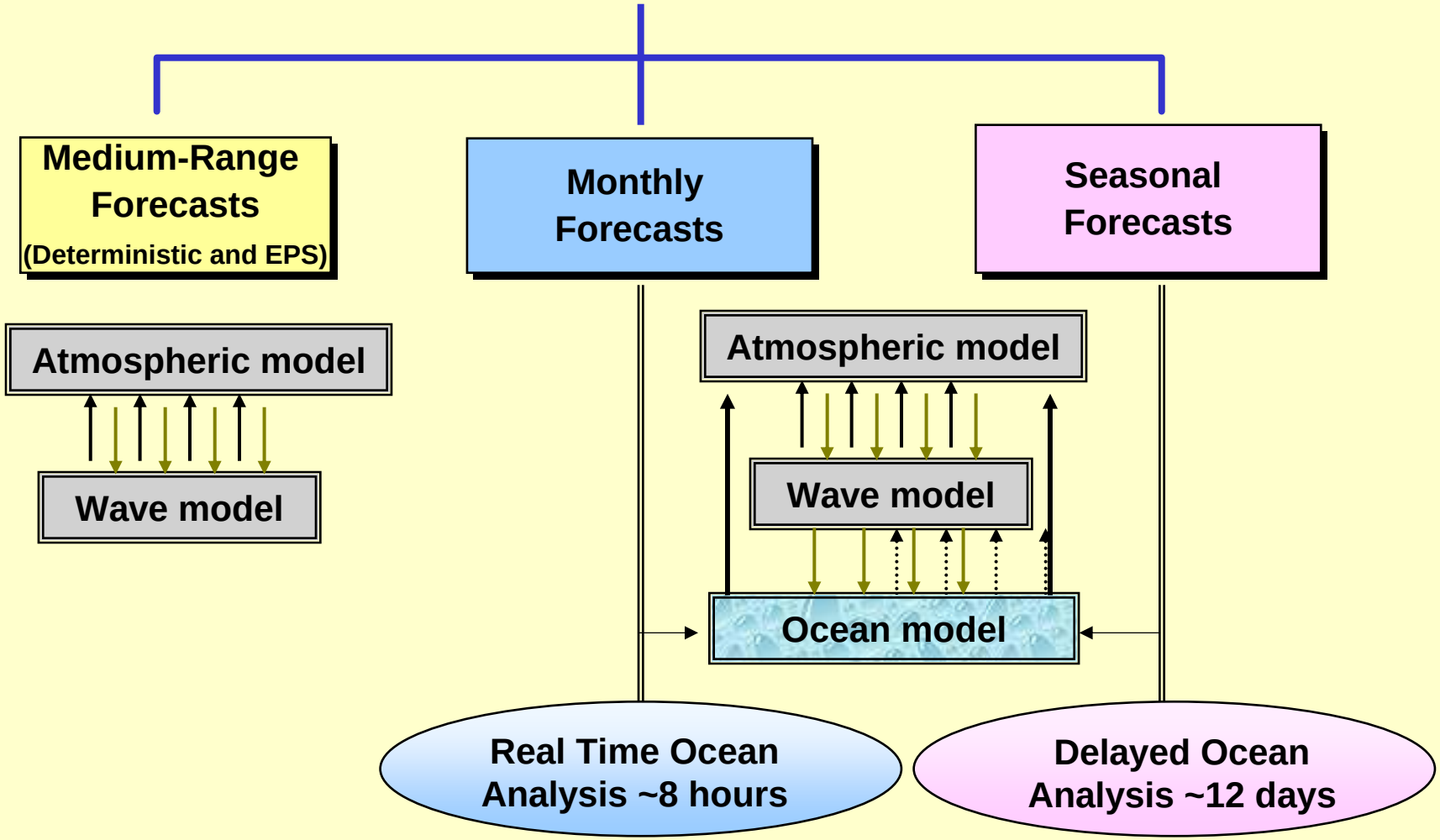


GNI Scale 2006–2008

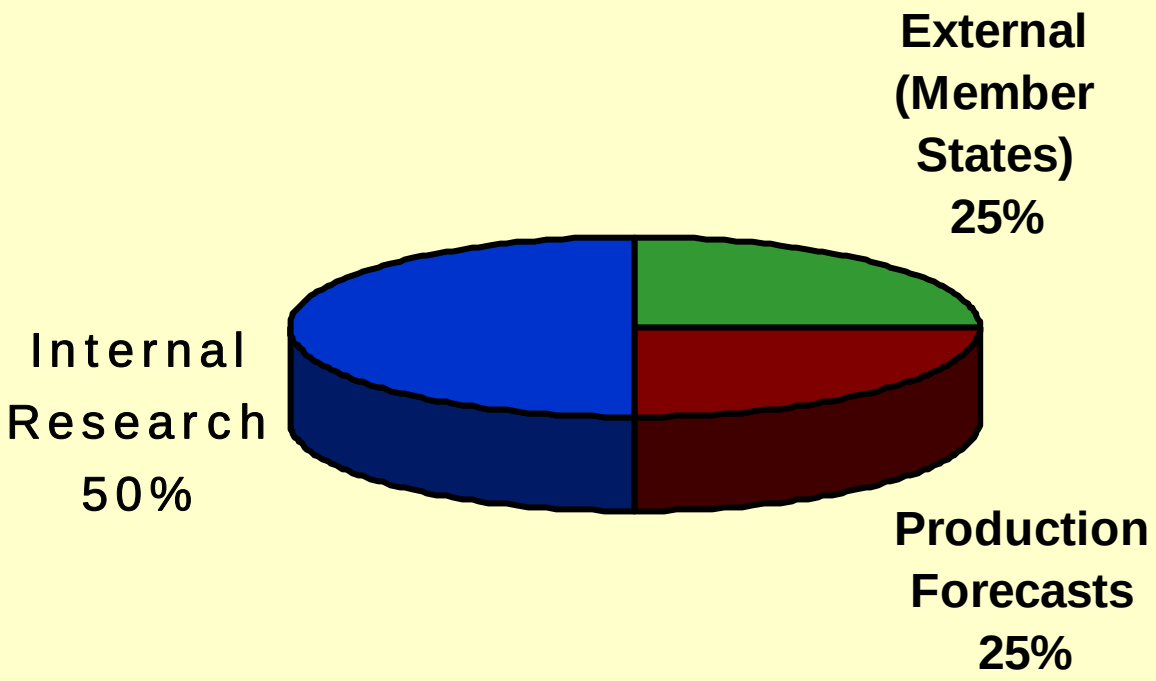
Main Revenue 2008	
Member States' contributions	£29,840,000
Co-operating States' contributions	£651,200
Other Revenue	£1,443,500
Total	**£31,934,700**

Main Expenditure 2008	
Staff	£13,715,400
Leaving Allowances & Pensions	£2,573,700
Computer Expenditure	£11,948,300
Buildings	£2,790,000
Supplies	£907,300
Total	**£31,934,700**

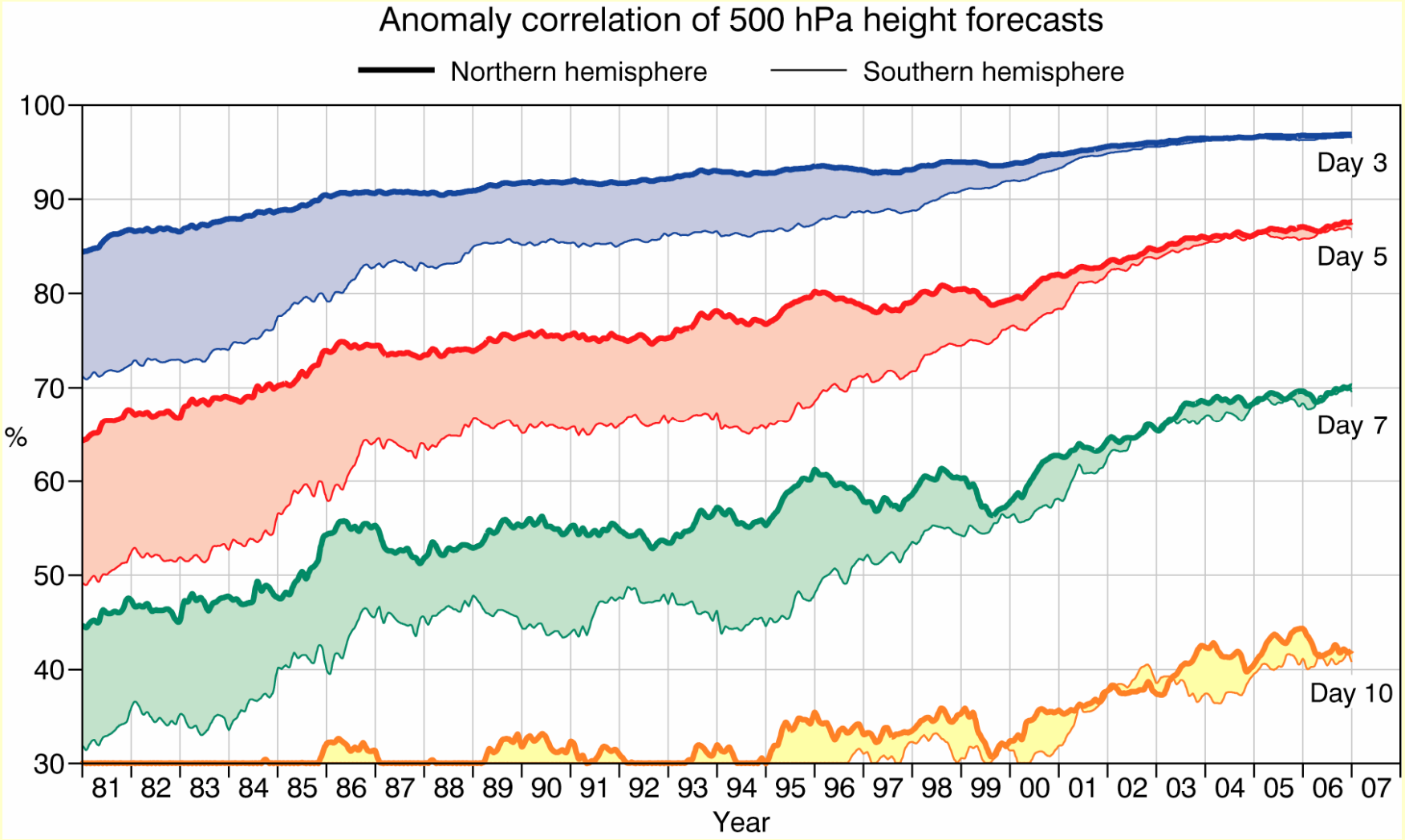
ECMWF forecasting systems



Allocation of HPC resources



Evolution of ECMWF scores comparison northern and southern hemispheres



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ECMWF – a few figures – 2008

- **Supported by:** **31 States**
- **Employees:** **220**
- **Age:** **33 years**
- **Budget:** **£32 million per annum**
  Contributions by Member States and Co-operating States £29.8 million per annum

Outline

- General introduction
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- Severe weather
- Outlook

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The operational forecasting system

- **High resolution deterministic forecast, twice per day:**
  25 km 91-level, to 10 days ahead
- **Ensemble forecast (EPS), twice daily:**
  50 members, 50/80 km 62-level, to 15 days ahead
- **Ocean waves, twice daily:**
  Global: 10 days ahead at 40 km
  European Waters: 5 days ahead at 25 km
  Ensemble: 15 days ahead at 100 km
- **Monthly forecast, once a week (coupled to ocean model)**
  50-members, 125 km 62 levels, to one month ahead
- **Seasonal forecast, once a month (coupled to ocean model)**
  50 members, 210 km 42 levels, to six months ahead
- **Boundary Conditions: short cut-off analyses based on 6-hourly 4D-Var initiating a forecast to 3 days, four times per day**

Forecasting system changes in 2007

- **Jan 07: Assimilation of AMSU-A and MHS from Metop-A**
- **Mar 07: Seasonal Forecasting System 3**
- **Jun 07: IFS Cycle 32r1**
  - Three-minimization version of 4D-Var (T95/T159/T255) with improved moist linear physics
  - New short-wave radiation scheme
- **Jun 07: Assimilation of IASI and ASCAT from Metop-A**
- **Nov 07: IFS Cycle 32r3**
  - Improved convection scheme
  - New soil hydrology scheme
  - Assimilation of AMSR-E, TMI, SSMIS window channels
  - Increase in number of radio occultation data from COSMIC

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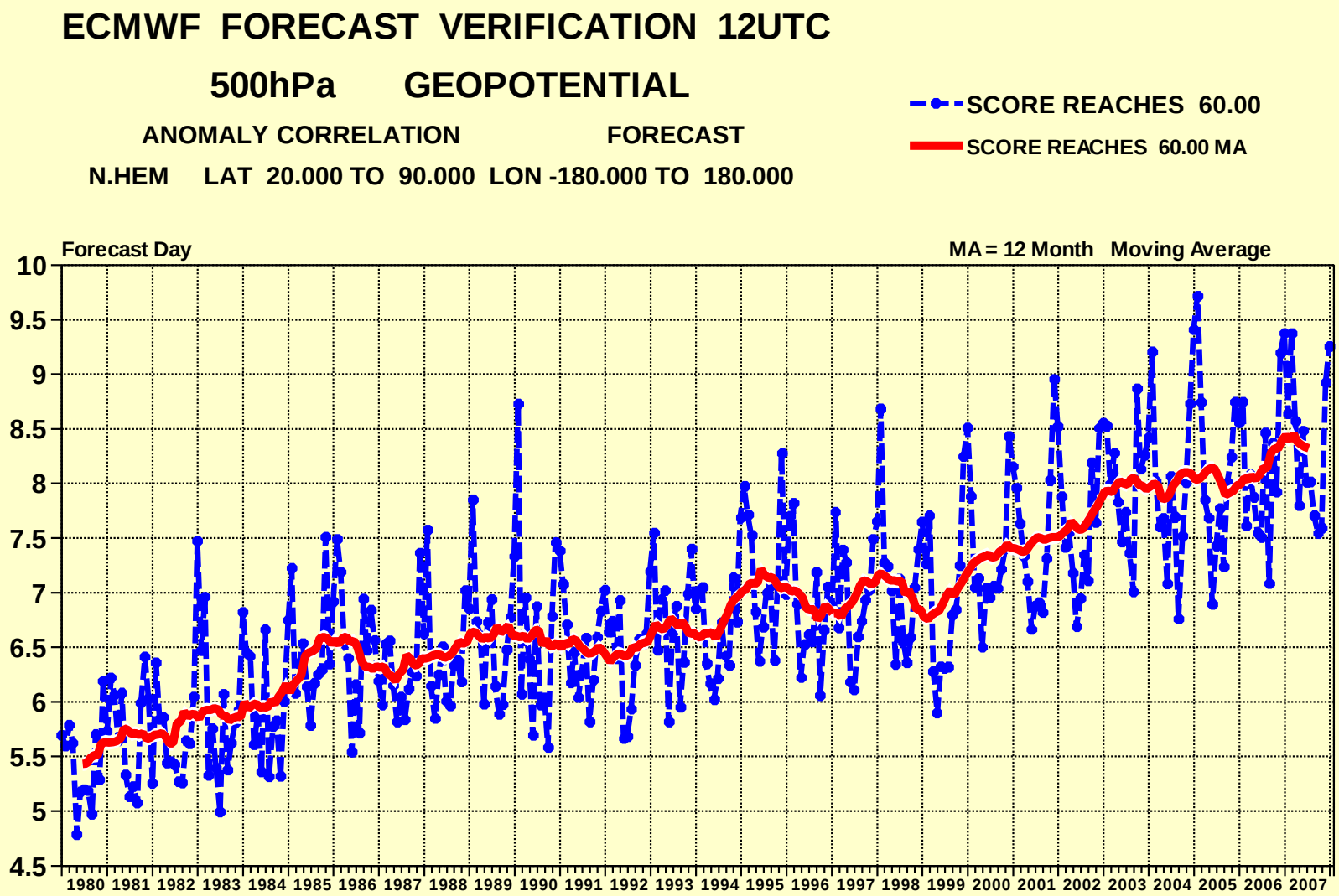
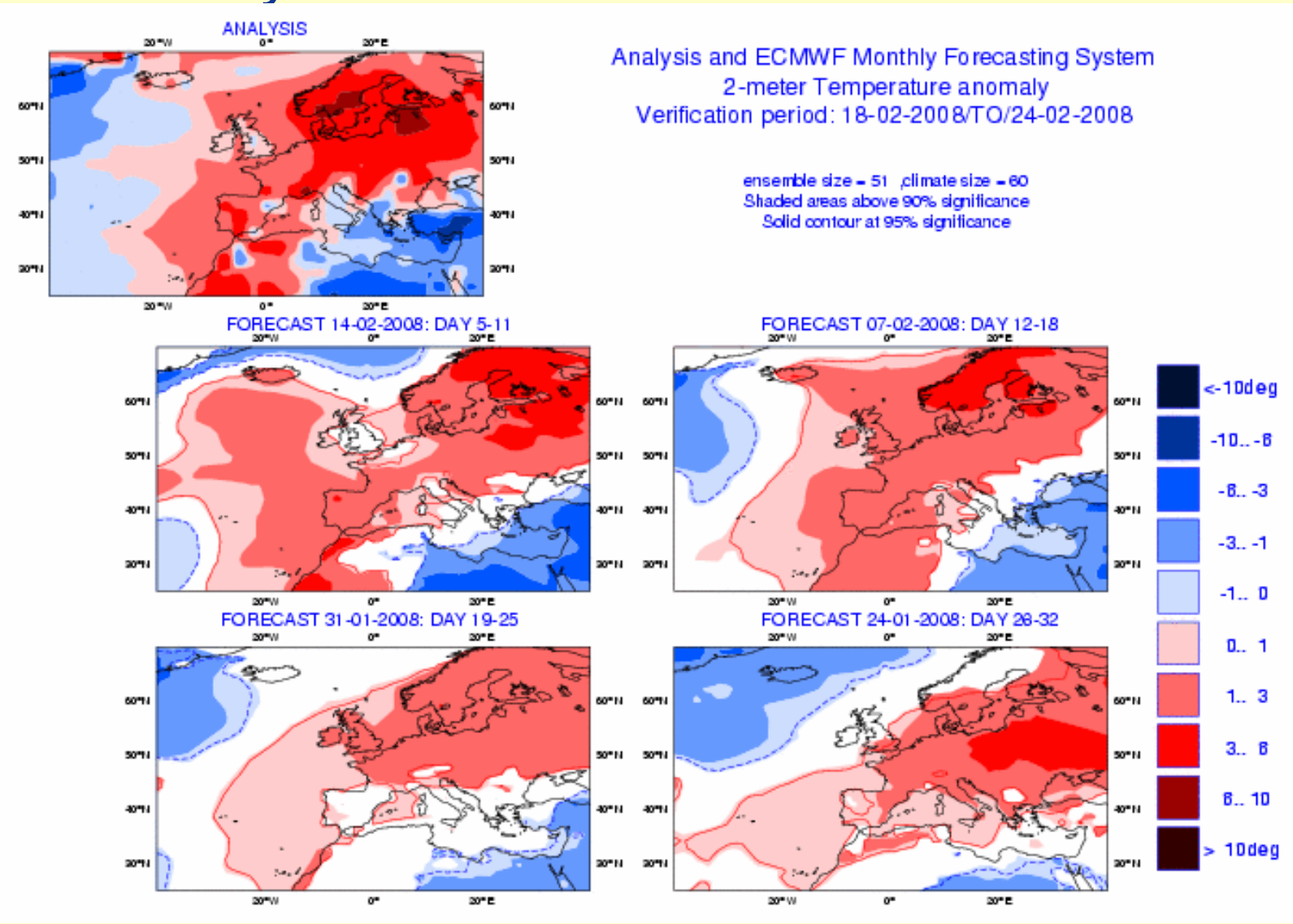
The ECMWF archive

- **The largest NWP archive worldwide**
- **Built since ECMWF operations started in 1979**
- **Holds more than 5 petabytes today**
- **6 terabytes added daily**
- **Contains:**
  - **All data used**
  - **All analyses**
  - **All forecasts**
  - **Reanalyses**
- **Fully accessible on-line to Member States users**

Time series Acc=0.6 N hemisphere



Monthly forecast

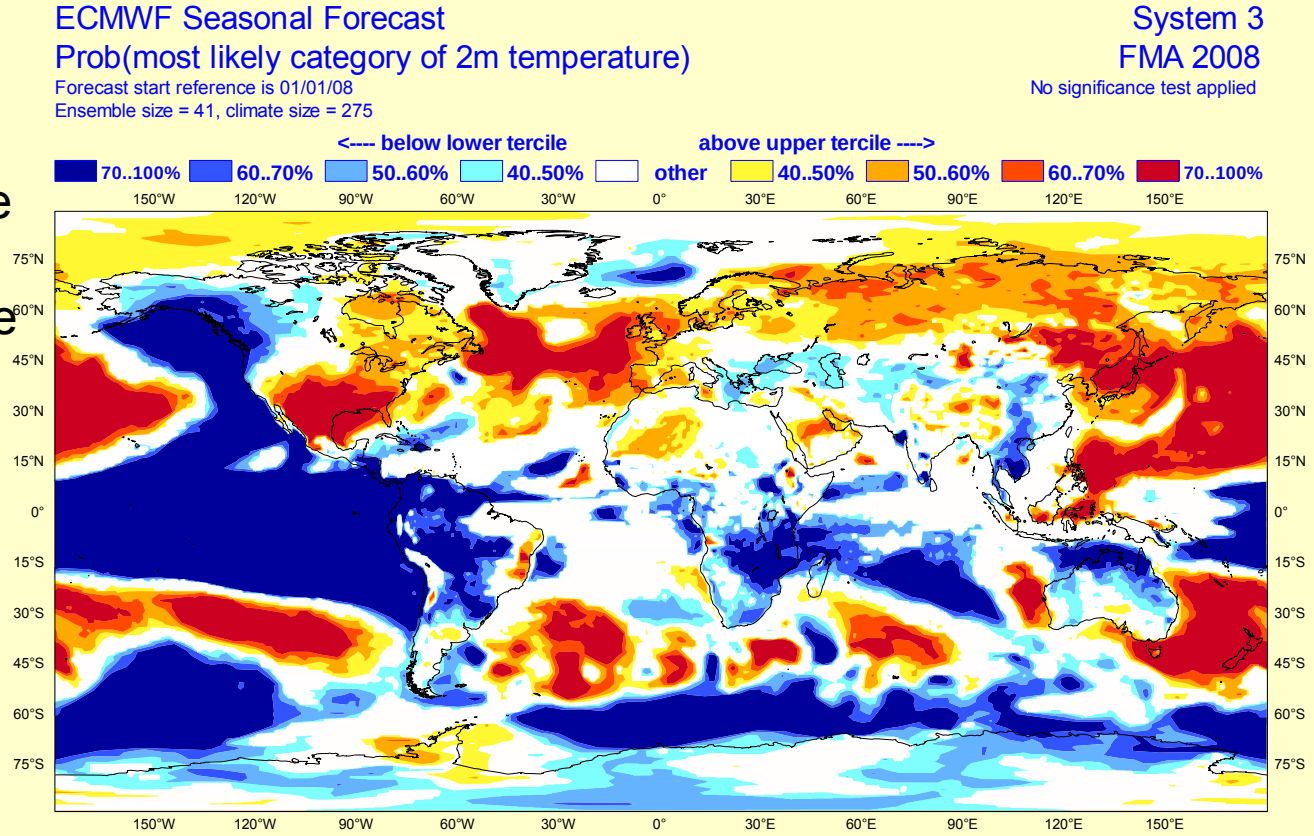


Seasonal forecast charts :

- Spatial maps representing the seasonal forecast in terms of model probabilities stratified by terciles

Parameters:

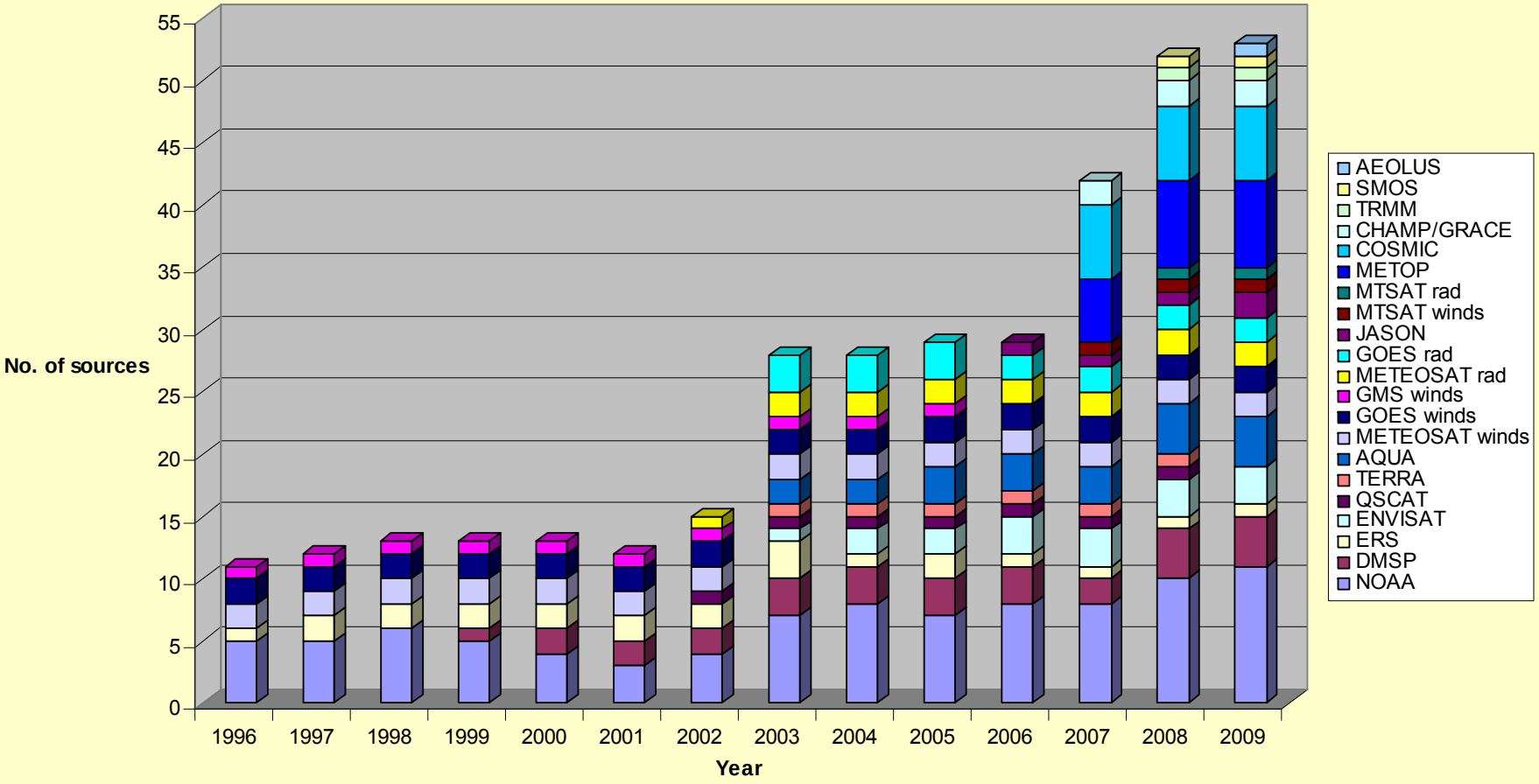
2m Temperature
Mean sea level pressure
Precipitation
Sea surface temperature
850 hPa temperature
500 hPa geopotential



Forecast issue date: 15/01/2008

Forecast is made available on the 15th of each month.

Satellite observing system



By mid-2007 we used data from 41 different satellite sources (instruments), expected to increase to ~50 until 2009.

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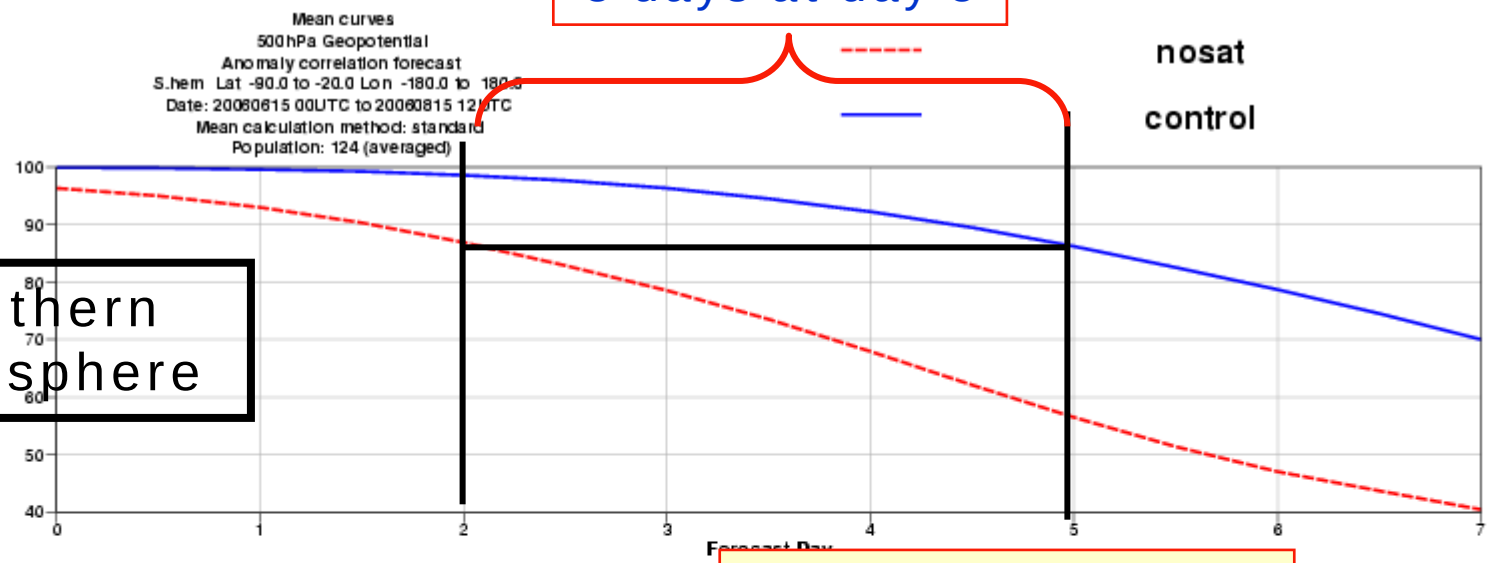
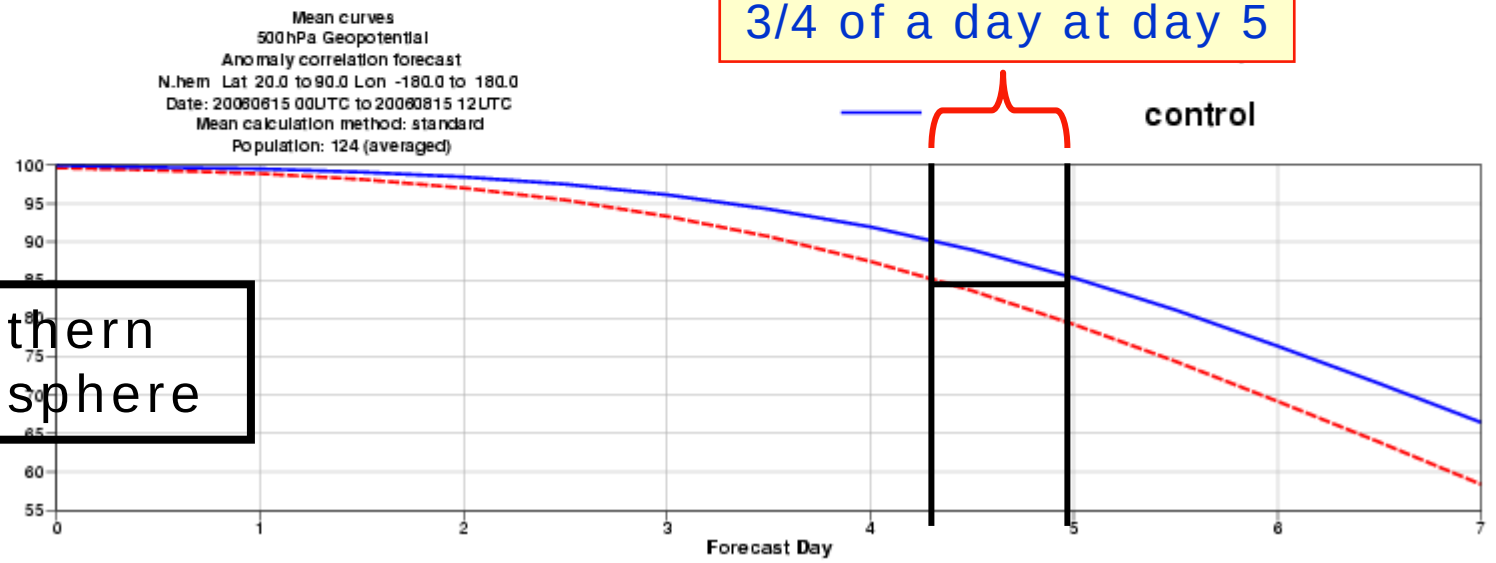
Impact of satellites on the forecast skill

3 days at day 5



Southern Hemisphere

3/4 of a day at day 5



Northern Hemisphere

Performance summary (1)

- **Overall high level of performance, general increase in skill over past year**
- **Further reduction of poor forecasts**
- **EPS skill consistently high and increasing, both over NH and Europe**
- **Benefit from resolution increase in early 2006**
- **Improved spread/skill relationship, maintained out to Day 15**
- **Changes in the model physics (cy31r1, Sept 2006) gave improvements in weather parameters**

Performance summary (2)

- **Improved ocean wave analysis following use of JASON altimeter data**
- **Standard inter-comparison of wave forecasts gives excellent results for ECMWF**
- **More realistic (deeper) tropical cyclones with higher resolution and better signal detection**
- **Improved extended range forecasts, in particular days 12-18**
- **Tropical SST and precipitation forecasts benefit from introduction of Seasonal System 3**

HPC procurement for 2009-2012

- **ECMWF's governing body (Council) approved in December 06 an increase in the budget for HPC**
- **Invitation to Tender was issued with a closing date of 1 Jun 07**
- **Bids received were evaluated over the summer months**
- **ECMWF's selection was approved by Council in December 07**

Outcome of the HPC procurement

- **IBM was selected to provide the service until 1H2013**
- **Two identical clusters**
- **Phase 1 (to be installed during second half of 2008)**
  - **Performance improvement of x5 over the existing system**
  - **Based on POWER6 technology**
  - **Peak performance of each cluster will be around 145 teraflops**
- **Phase 2 (to be installed during first half of 2011)**
  - **Further performance improvement of x2**
  - **Phase 1 will be replaced by future POWER technology**

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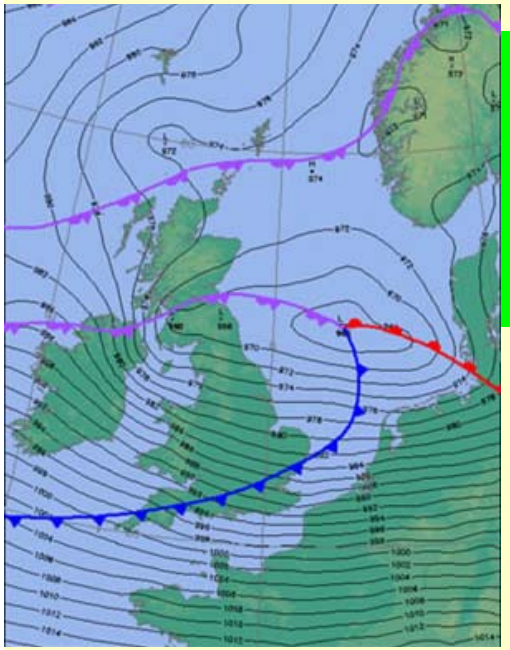
Successful warnings of extreme weather events in 2007



18th January 2007

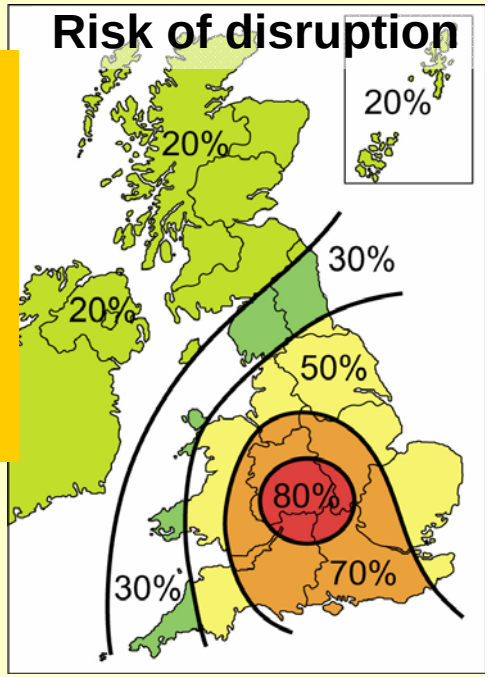
Severe wind storm in Wales & southern England

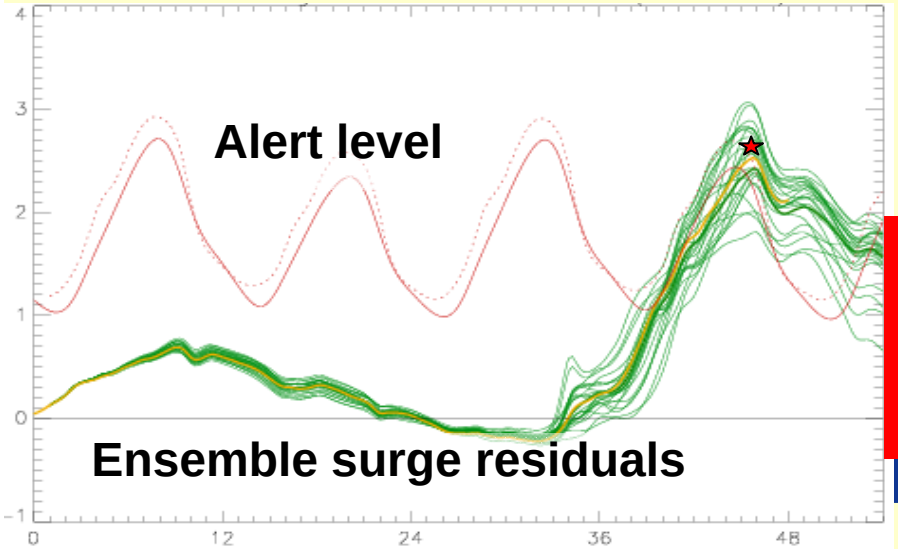
Pres

20th July 2007

Severe flooding in lower Severn valley

Precise warnings issued 24 hours in advance





9th November 2007

East coast storm surge

First warning given on 5th

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Severe weather: storm Kyrill 18 January 2007

- **Severe winter storm Kyrill caused extensive damage across Europe on 18 January 2007**
- **Major disruption to travel across many areas (road, rail, air)**
- **Widespread power outages**
- **Destruction of many forest areas**
- **Damage to buildings**
- **Estimated € 5-7 bn insurance losses**

Many DB train services cancelled (Photo Spiegel.de)

autobahn in Thuringia

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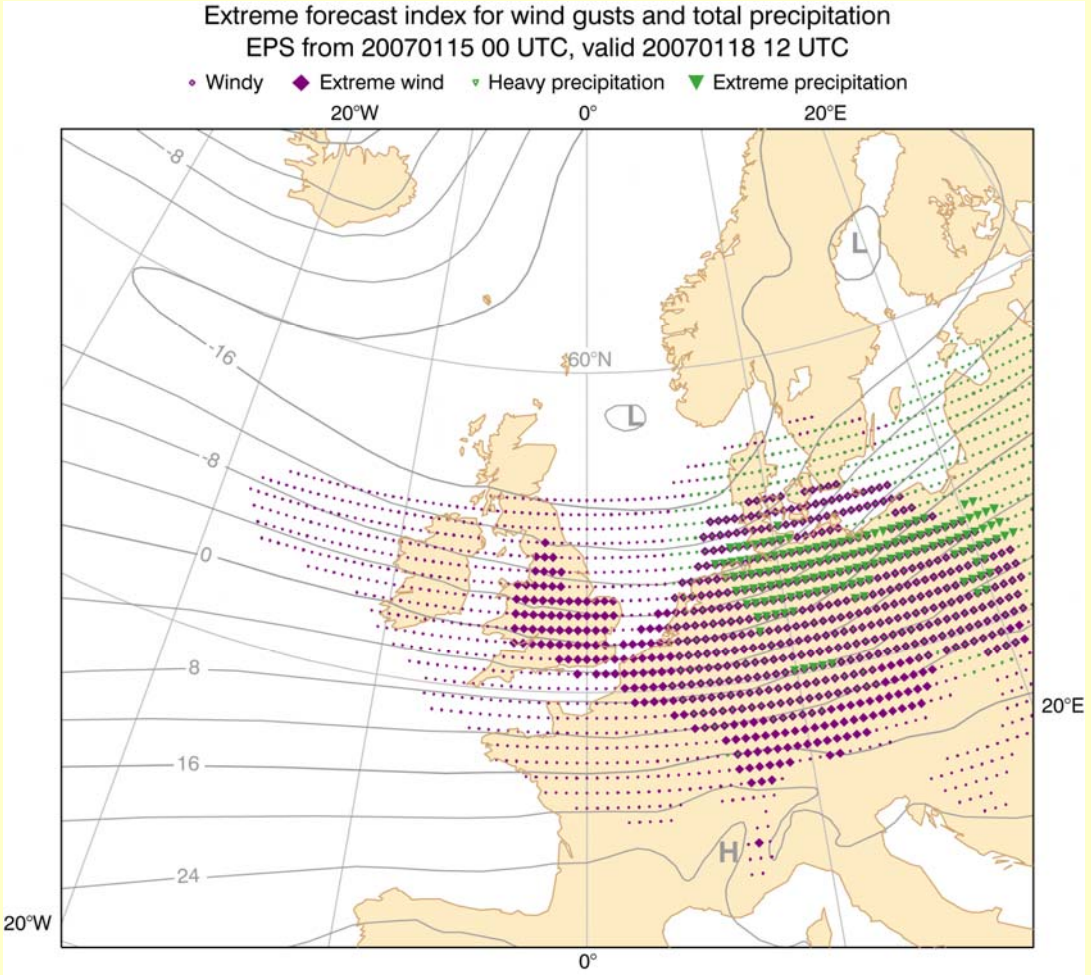
Storm Kyrill: early warning from ECMWF Ensemble Prediction System

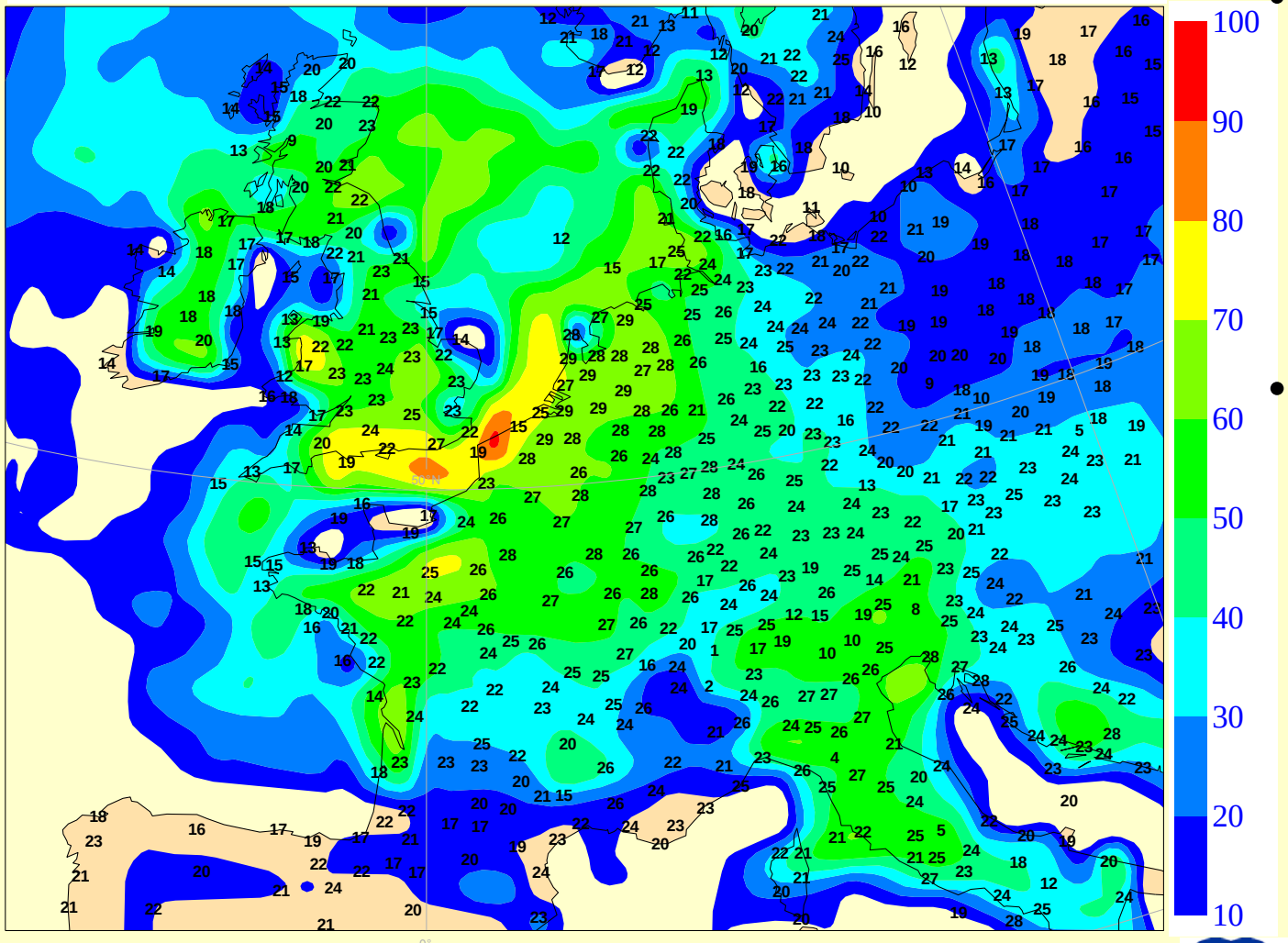
Severe winter storm (Kyrill) affected many areas, crossing from the UK into northern Germany on 18th January

Extreme forecast index (EFI) for widespread extreme winds from the EPS forecast of 00 UTC 15th January



Heat wave April 2007

Observed 2m temperature maxima on 15th April, and D+11 probabilities to exceed the 95th percentile



- **Exceptional warm temperature on 15 April 2007 (26-30° C)**
- **D11 probability forecast compared with observations**

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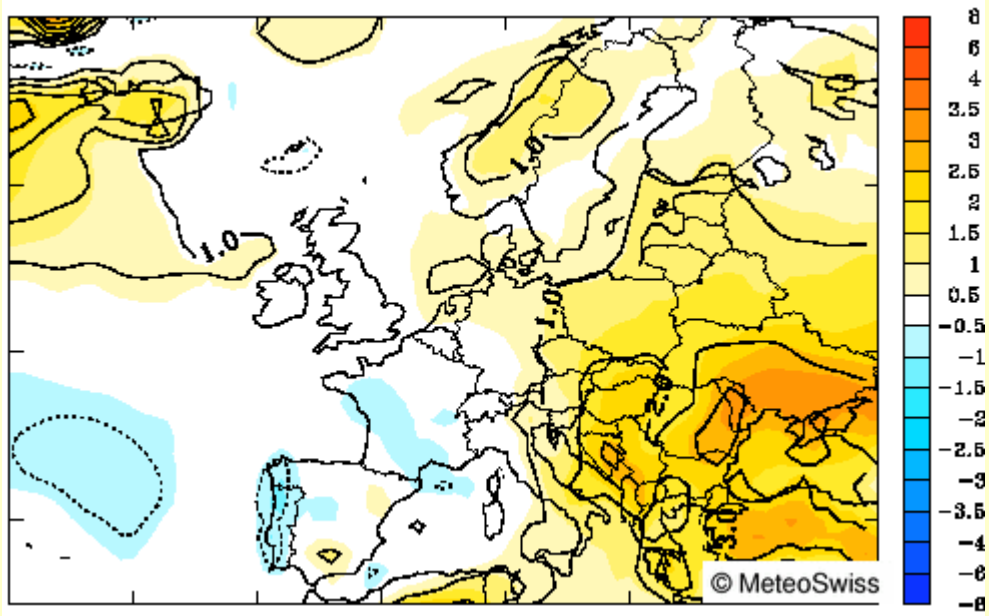
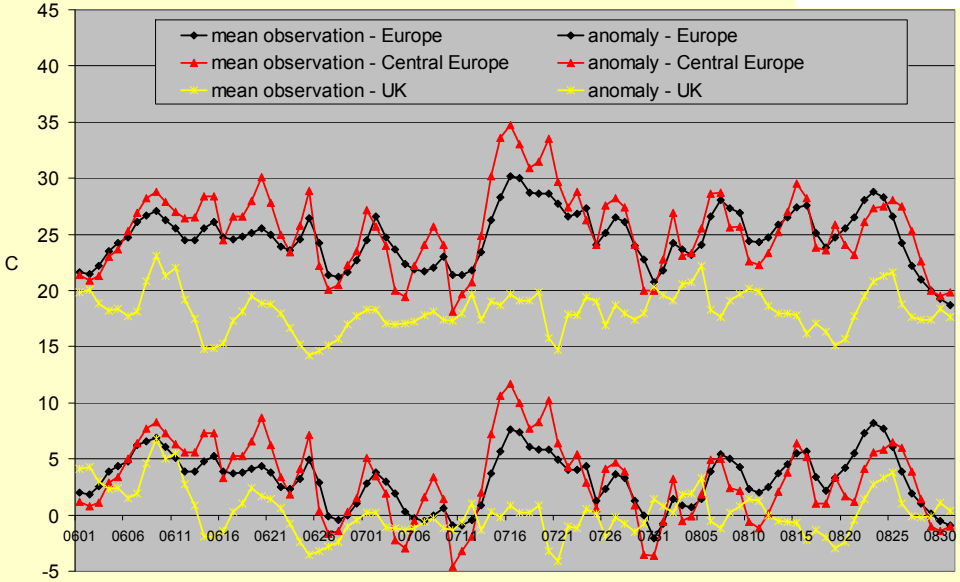
Heat wave South-east Europe 15-20 July





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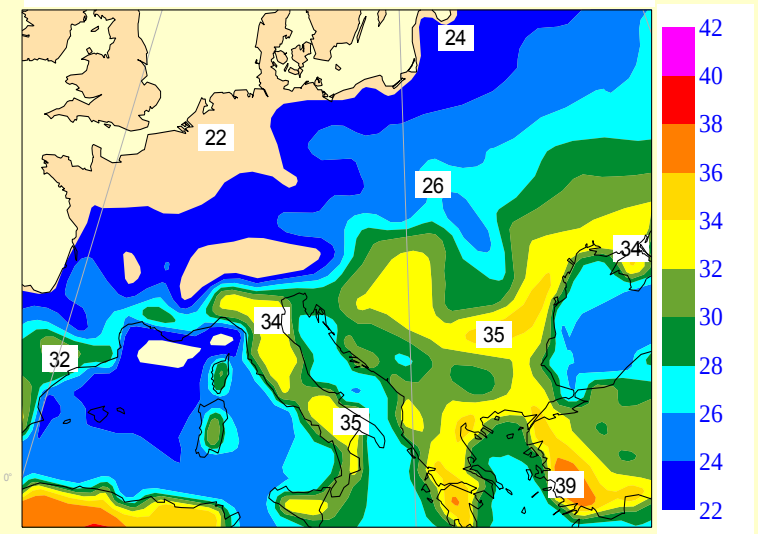
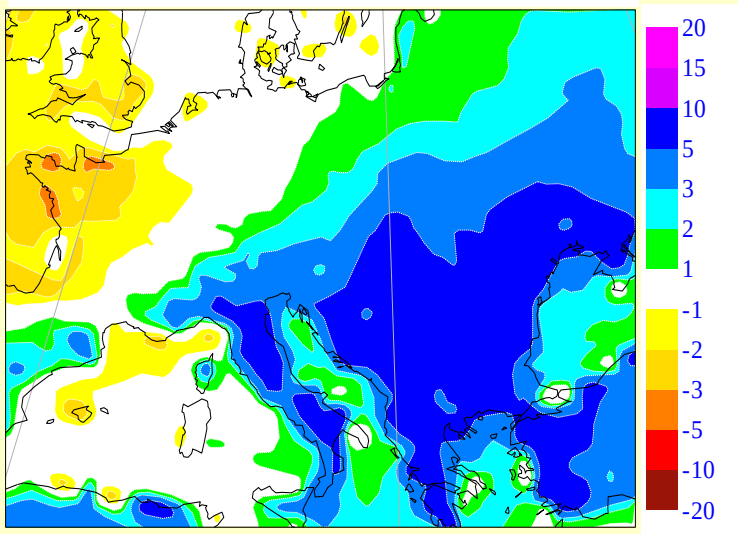
EPS Day-15 forecast for 20th of July: compl. fig. 18

EPS mean, 2m max temp, VT:20070720, t+360

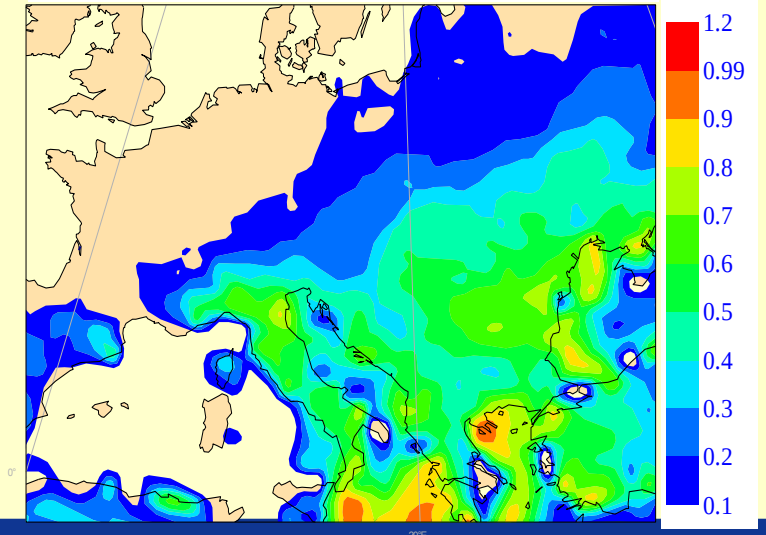


EPS anomaly, 2m max temp, VT:20070720, t+360

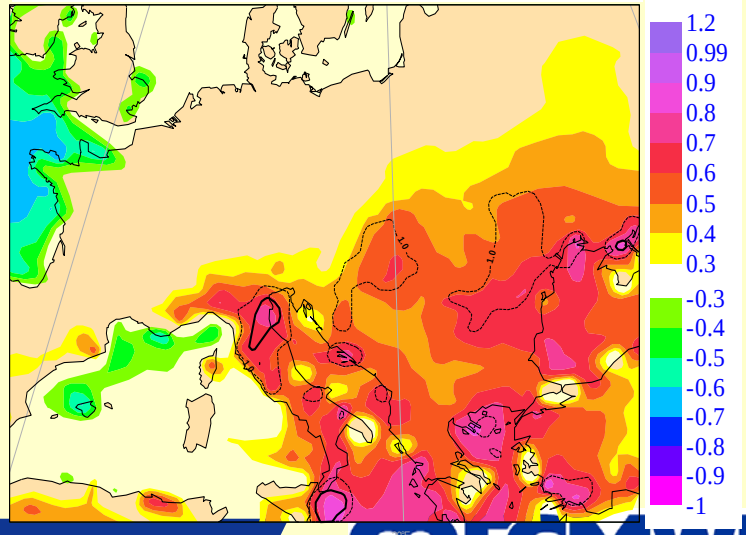


D15

EPS prob, 2m max temp gt Q95, VT:20070720, t+360



EFI, 2m max temp, VT:20070720, t+360



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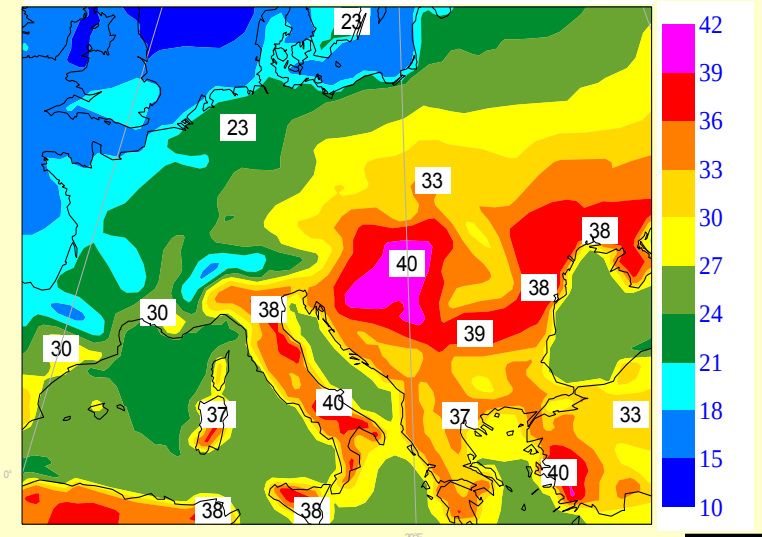
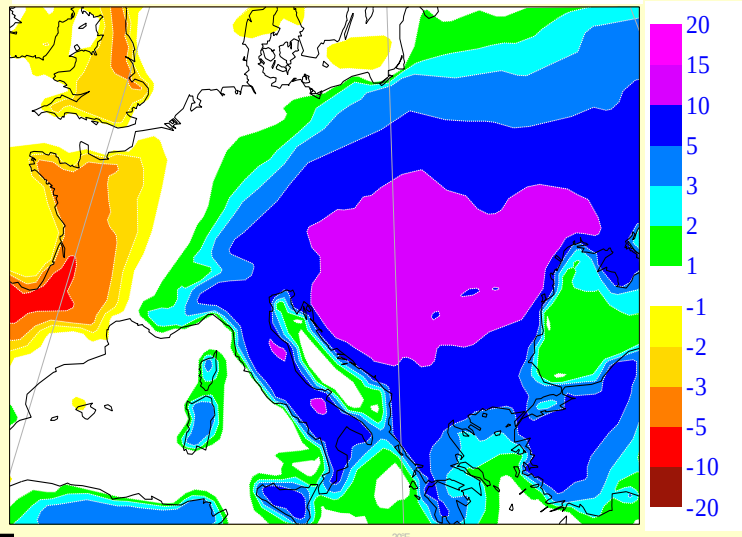
EPS Day-5 forecast for 20th of July

EPS mean, 2m max temp, VT:20070720, t+120

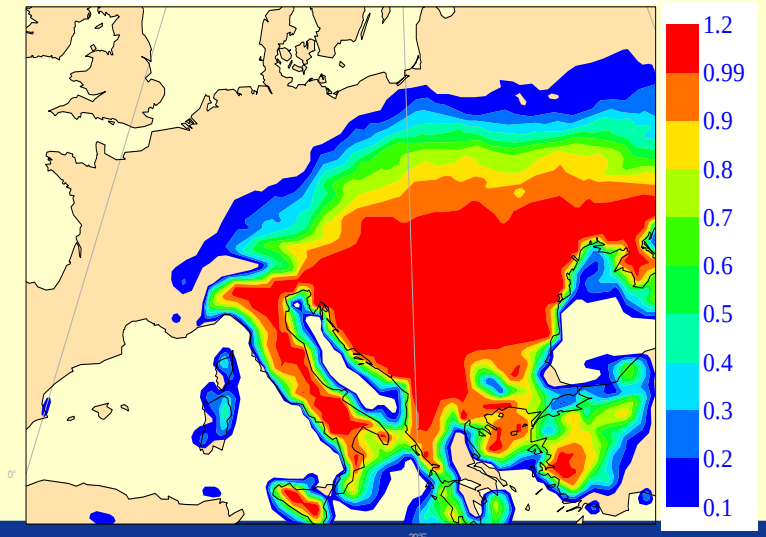


EPS anomaly, 2m max temp, VT:20070720, t+120

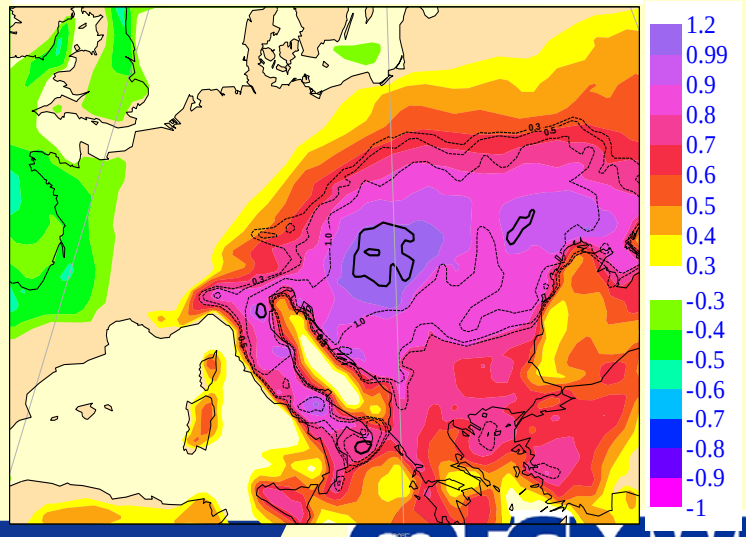


D5

EPS prob, 2m max temp gt Q95, VT:20070720, t+120



EFI, 2m max temp, VT:20070720, t+120



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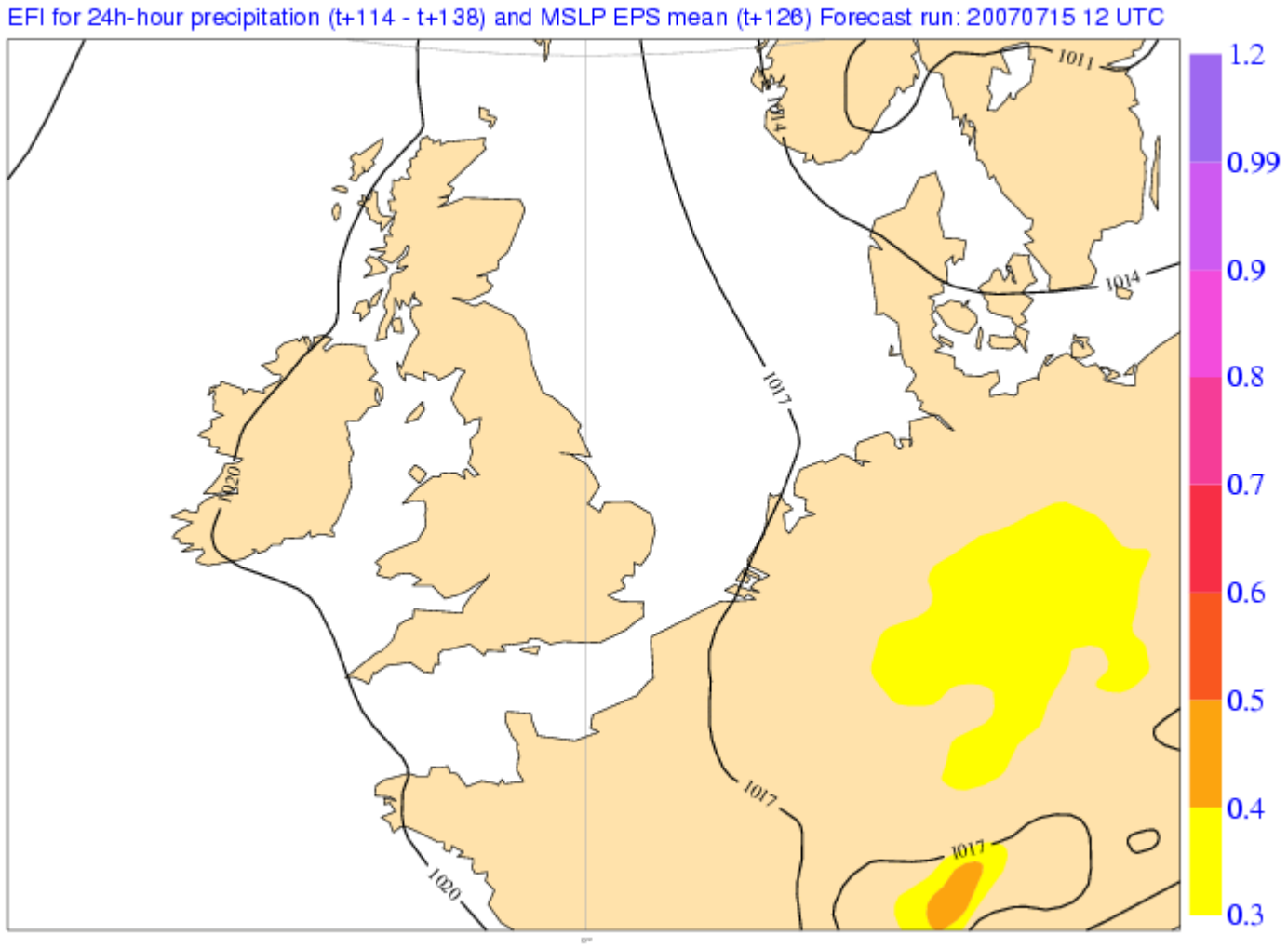
July 2007: Flooding over southern UK

- **June and July were record wet months in England & Wales**
- **Extreme precipitation on 20 July caused widespread flooding in southern England**

ECMWF

EFI (for 24-hour precip, 06-06) and EPS mean (for MSLP) for July 20, every 12 hour run starting 15 July 12.00



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ECMWF

Major milestones for 2008

- **Enhancements to the IFS**
  - **Prepare for the resolution upgrade to 16 km in late 2009**
  - **New soil moisture assimilation**
  - **Use of flow dependent information from Ensemble Data Assimilation**
  - **Validate a non-hydrostatic core for IFS**
- **Install the new HPC system**
- **Progress with the verification of severe weather events**

Summary of the strategy for ECMWF 2006 – 2015 (1/3)

A strategy for ECMWF for the period 2006 to 2015 was adopted unanimously by the ECMWF Council in December 2005.

In summary:

Principal Goal

- **The principal goal of ECMWF in the coming ten years will be to maintain the current, rapid rate of improvement of its global, medium-range weather forecasting products, with particular effort on early warnings of severe weather events**

Summary of the strategy for ECMWF 2006 – 2015 (2/3)

- **Complementary goals:**
  - **To improve the quality and scope of monthly and seasonal-to-interannual forecasts**
  - **To enhance support to Member States national forecasting activities by providing suitable boundary conditions for limited-area models**
  - **To deliver real-time analyses and forecasts of atmospheric composition**
  - **To carry out climate monitoring through regular re-analyses of the Earth-system**
  - **To contribute towards the optimization of the Global Observing System.**

Thank you for your attention

www.ecmwf.int

ECMWF Products – GTS Dissemination

- **Resolution**

  2.5° x 2.5° (12 areas: hemispheres truly global, tropical belt)

- **Parameters**

  Global: MSL pressure 850 hPa temperature 500 hPa geopotential
  850, 700, 500, 200 hPa winds 850, 700 Relative Humidity

  Tropics: 700 hPa vorticity 700 hPa divergence

- **Validity**

  Global: Analysis, 24, 48, 72, 96, 120, 144, 168 hour forecasts
  Tropics: Analysis, 24, 48, 72, 96, 120, 144 hour forecasts

- **Frequency**

  Twice per day, based on 00 and 12 UTC data

- **Format**

  FM92-Ext GRIB

ECMWF Forecast Products

Atmosphere global forecasts

- **Forecast to ten days from 00 and 12 UTC at 25 km resolution and 91 levels**
- **50 ensemble forecasts to fifteen days from 00 and 12 UTC at 50 km resolution**

Ocean wave forecasts

- **Global forecast to ten days from 00 and 12 UTC at 50 km resolution**
- **European waters forecast to five days from 00 and 12 UTC at 25 km resolution**

Monthly forecasts: Atmosphere-ocean coupled model

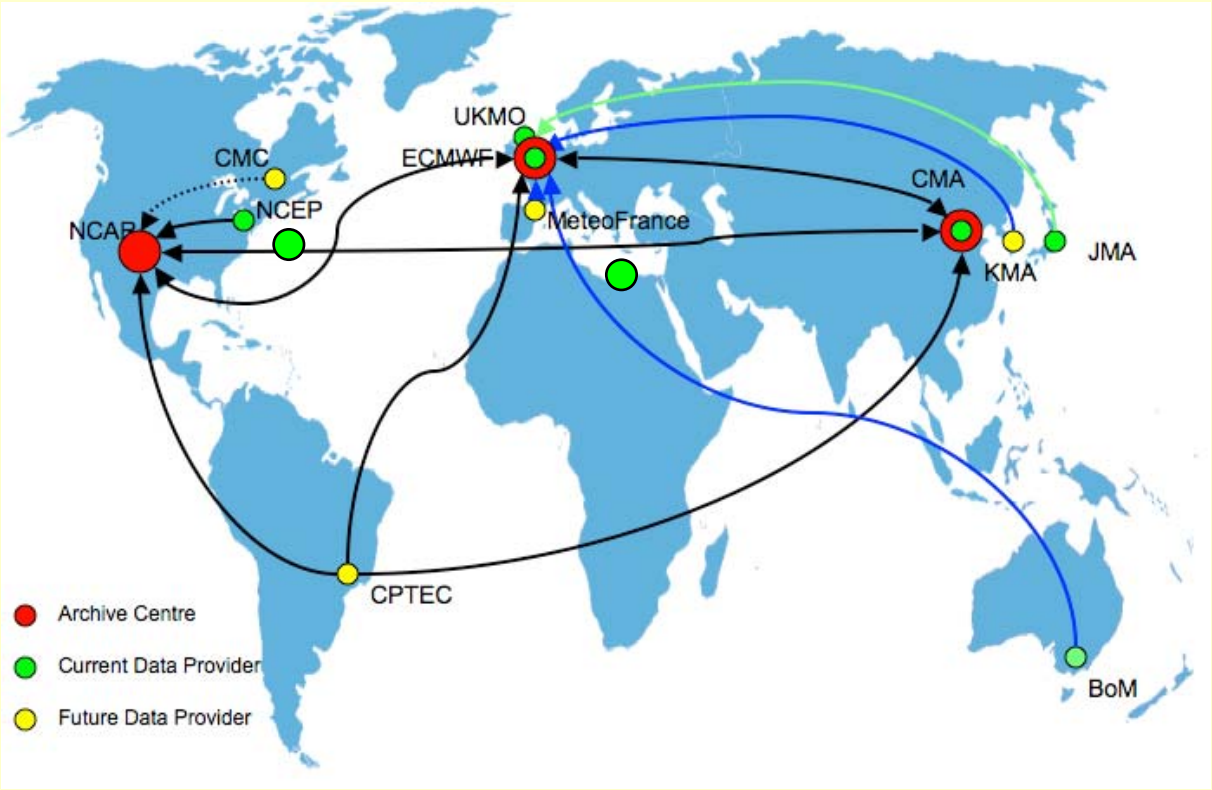
- **Global forecasts to one month:**
  atmosphere: 1.125° resolution, 62 levels
  ocean: horizontally-varying resolution ($\frac{1}{3}$° to 1°), 9 levels

Seasonal forecasts: Atmosphere-ocean coupled model

- **Global forecasts to six months:**
  atmosphere: 1.8° resolution, 40 levels
  ocean: horizontally-varying resolution ($\frac{1}{3}$° to 1°), 9 levels

TIGGE

THORPEX Interactive Grand Global Ensemble



Data is available for the research community
Near real time (48 hours delay), growing by 1.5 million fields/day

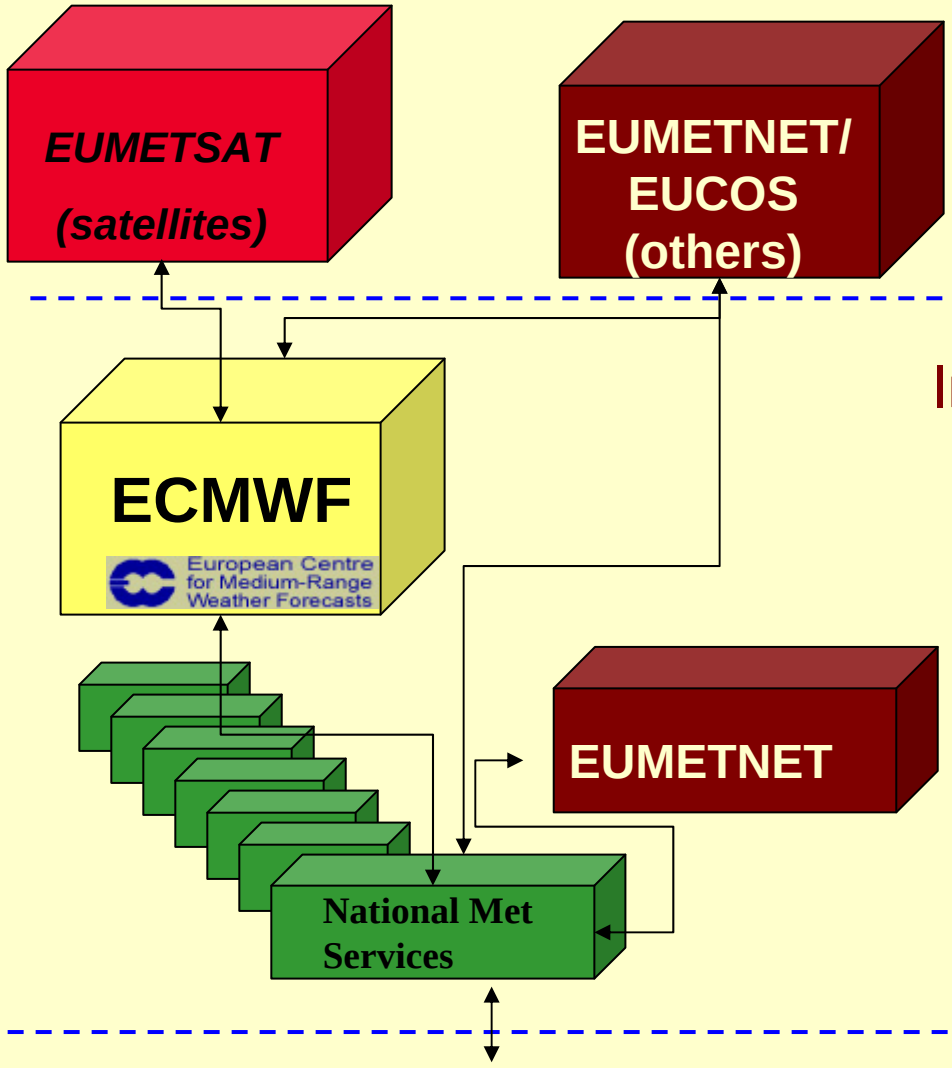
Reasons for ECMWF success

- **European:**
  - **Good working environment**
  - **attract best European scientists**
- **Small and focused:**
  - **Numerical Weather Prediction (NWP) only**
- **Dual: research + operation**
  - **Operation-driven research**
  - **Operation serving research**
- **Data assimilation: 4D-Var**
  - **Use of satellite data**
- **Contact with the research community**

RMDCN

- **Regional Meteorological Data Communication Network**
- **RMDCN is a Managed Data Network connecting most National Meteorological Services (NMS) within WMO Region VI. Recently NMS's outside Region VI were connected.**
- **The infrastructure is provided by EQUANT, while the network itself is managed and monitored by ECMWF.**
- **The network is currently based on Frame Relay technology and uses TCP/IP as its transport protocol. The network relies on a complex IP routing configuration utilising the BGP (Border Gateway Protocol) and OSPF (Open Shortest Path First) protocols.**
- **RMDCN will migrate from the Frame Relay protocol to MPLS (Multi Protocol Label Switching) over the next year.**

ECMWF: a component of the EMI



Shared and coordinated observation systems and related services

Information Systems and services

- **Analyses, forecasts and support to decision making climate monitoring**
- **Archiving and reanalysis**
- **Methods, tools and know-how**
- **Web, push and pull services.**

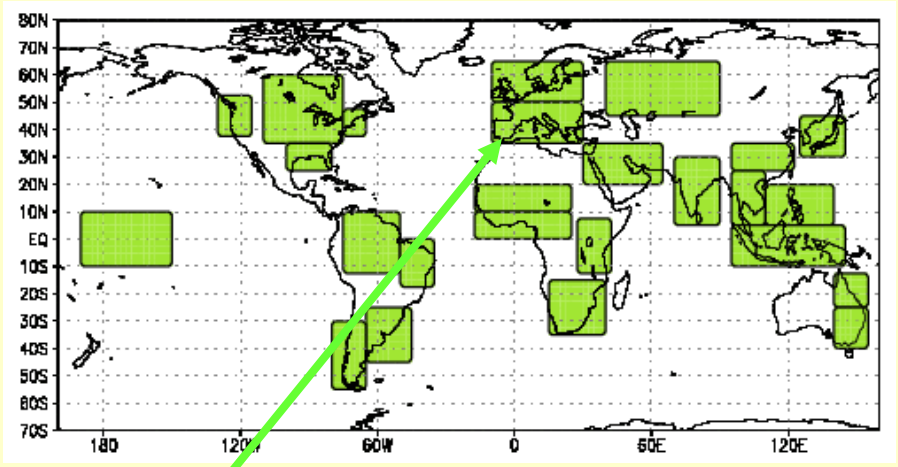
Selected ECMWF Contributions to Climate monitoring - 1

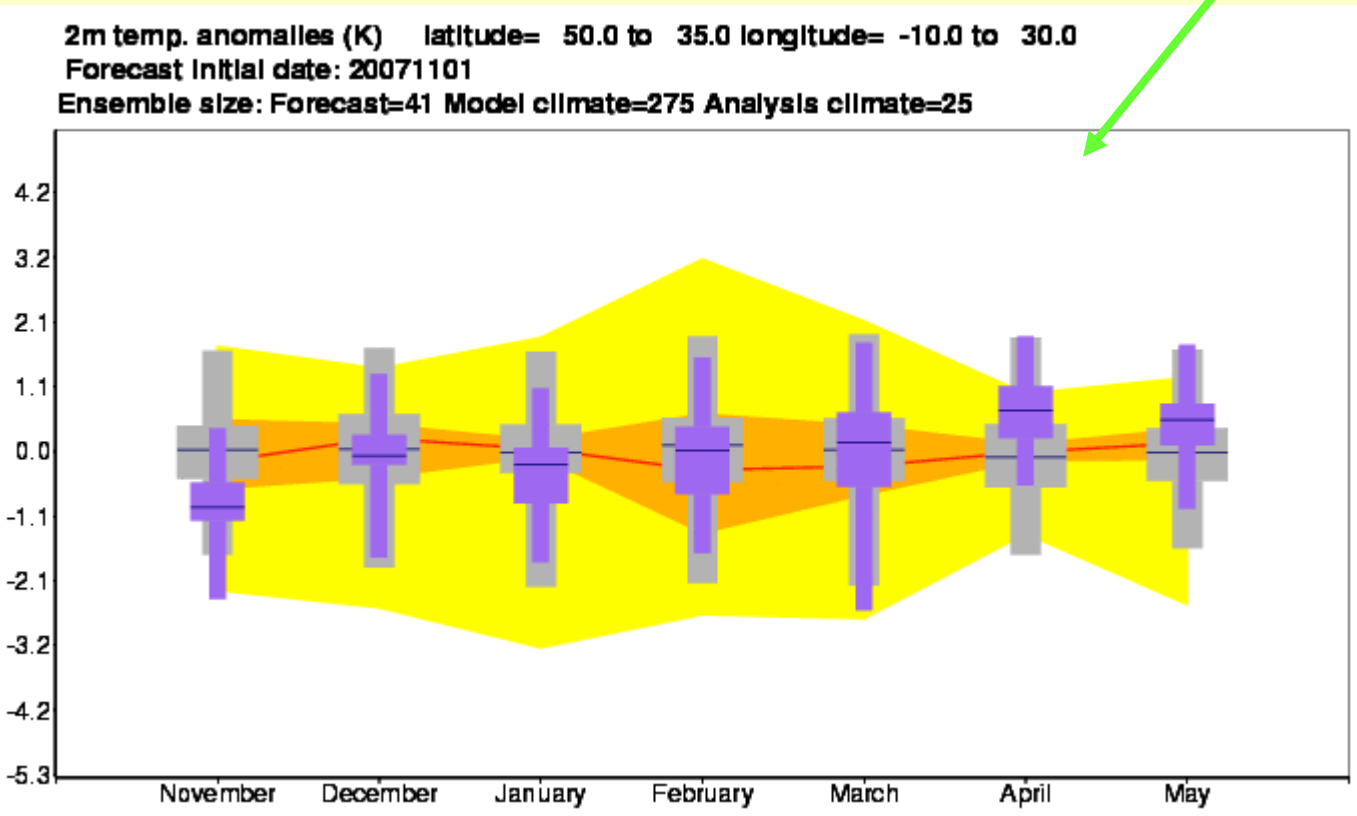
- **Re-analyses of weather and climate fluctuations of the last 50-70 years**
  - **Re-analyses are long series of atmospheric states obtained by re-processing the whole archive of observations with the most recent forecasting system**
  - **Re-analyses have been proven able to depict the fluctuations of the global climate over the past 50-70 years in a more complete and accurate way than any other method**
  - **Re-analyses are used by a large number of scientists throughout the world (6,000 users of ERA-40)**

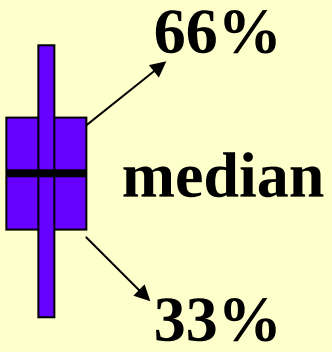
Selected ECMWF Contributions to Climate monitoring - 2

- **Monitoring the variations in the composition of the atmosphere**
  - **ECMWF develops an operational system to monitor the atmospheric composition in the GEMS project (EU GMES/FP6, with several partners, including MPI and FZJ from Germany)**
  - **Fluctuations of CO2 and other greenhouse gases – retrieval of surface sources and sinks of CO2**
  - **Fluctuations of ozone, aerosols, and other quantities of importance for global atmospheric chemistry**

Climagrams





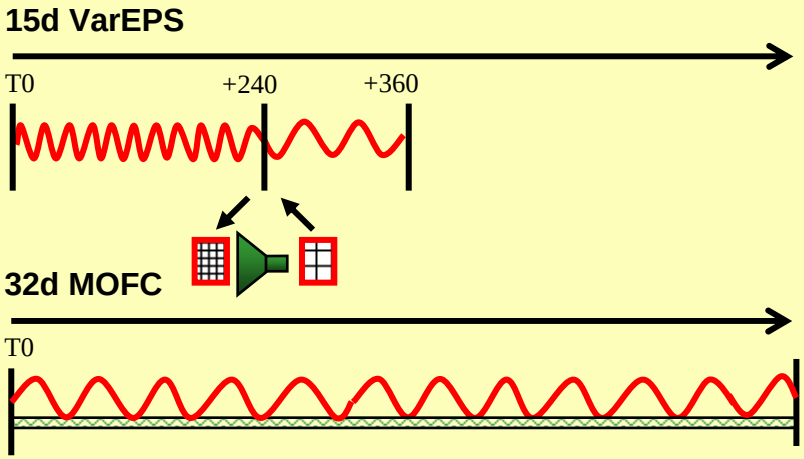


ECMWF

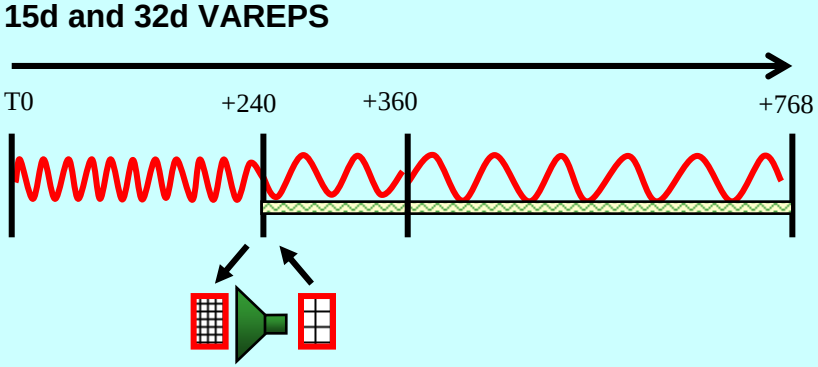
The 32-day unified VarEPS (March 08)

The 15d VarEPS and the 32d monthly ensemble systems will be unified

- **Twice-a-day (at 00 and 12 UTC):**
  - **-d 0-10: T_L399L62 uncoupled**
  - **-d 10-15: T_L255L62 uncoupled**
- **Once a week:**
  - **-d 0-32: T_L159L62 coupled**

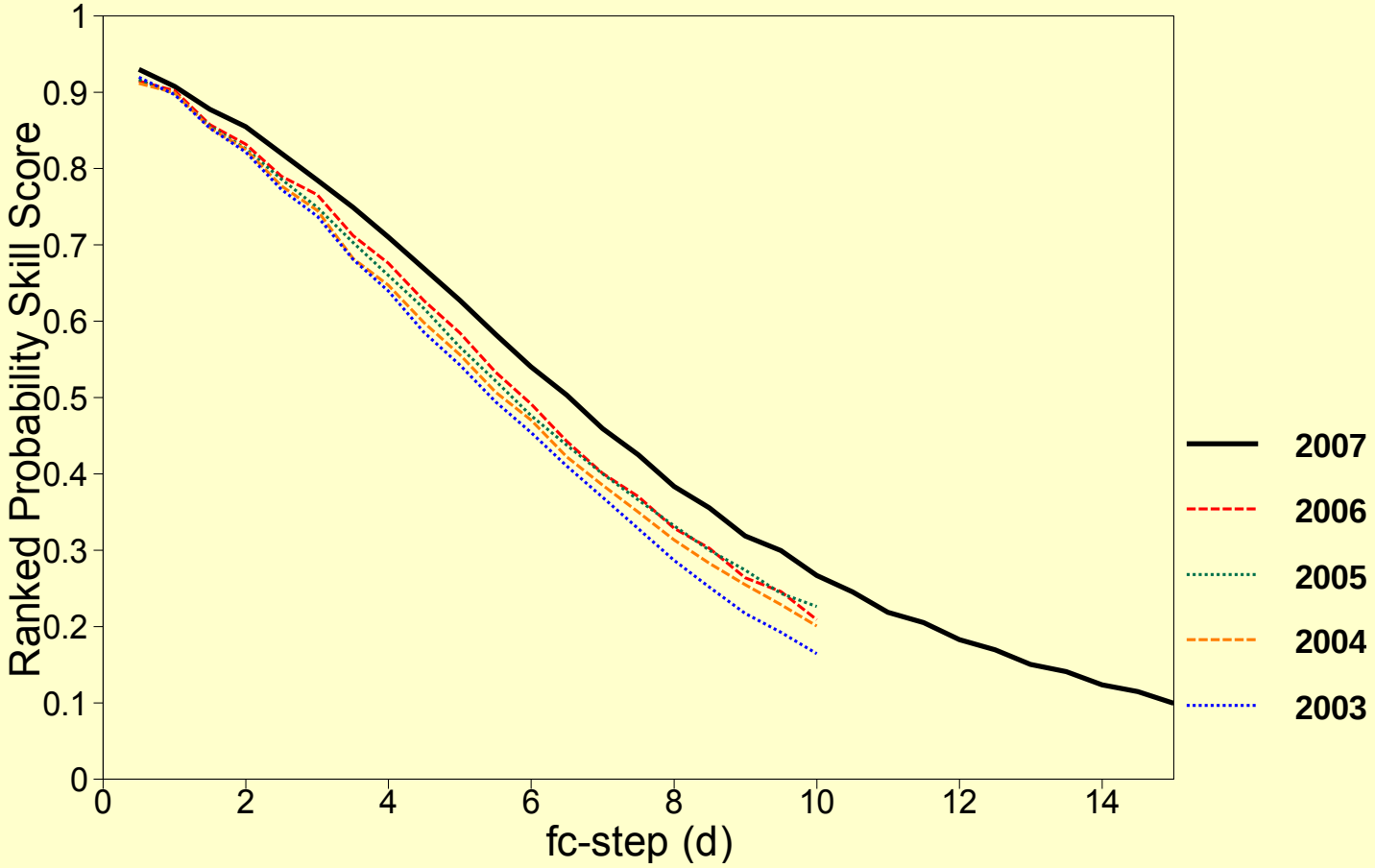


- **Twice-a-day (at 00 and 12 UTC):**
  - **-d 0-10: T_L399L62 uncoupled**
  - **-d 10-15: T_L255L62 (coupled at 00)**
- **Once a week:**
  - **-d 0-10: T_L399L62 uncoupled**
  - **-d 10-32: T_L255L62 coupled**



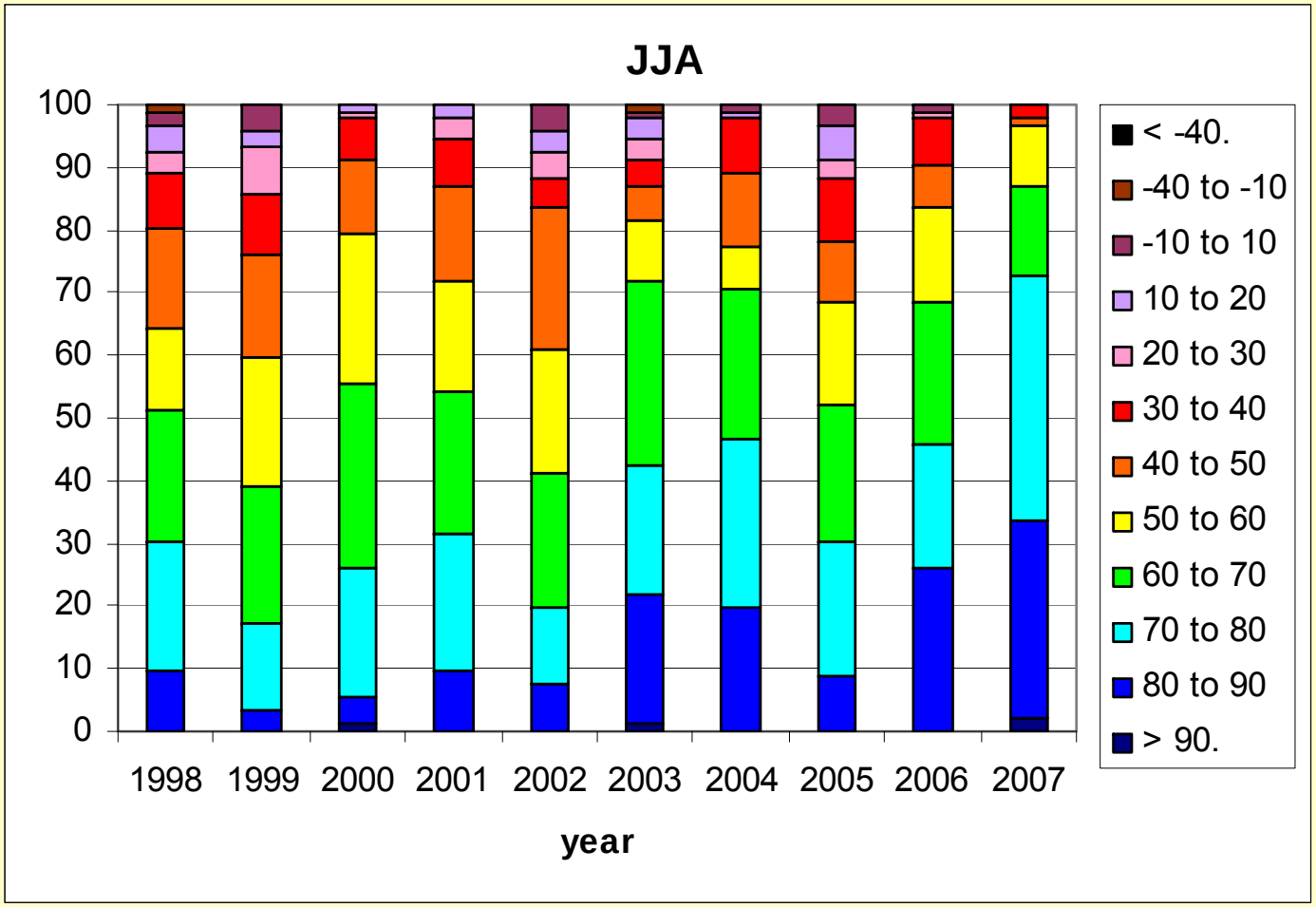
ECMWF

EPS performance – winter 2006-07



Ranked probability skill score for 500 hPa height, EPS forecasts for winter (December-January) over NH. The solid black line shows the skill from the VarEPS days 1-15 forecasts for winter 2006-07

Summer performance (850hPa)



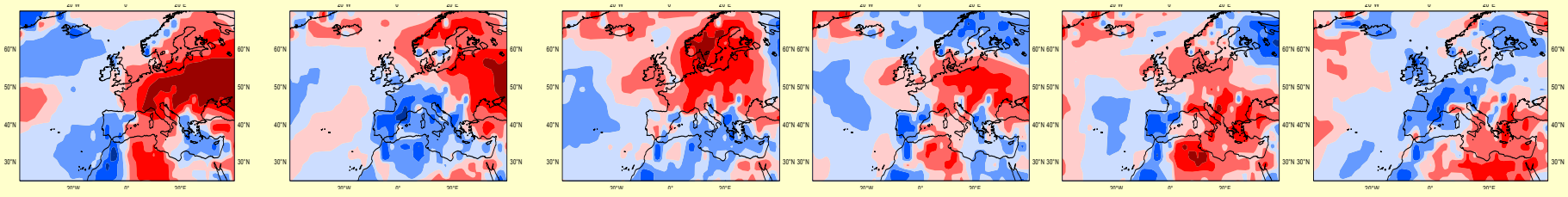
Cumulative distribution of Anomaly Correlation of the Day 7 850hPa temperature forecasts with verifying analyses over Europe in summer (JJA) since 1997-1998.

ECMWF

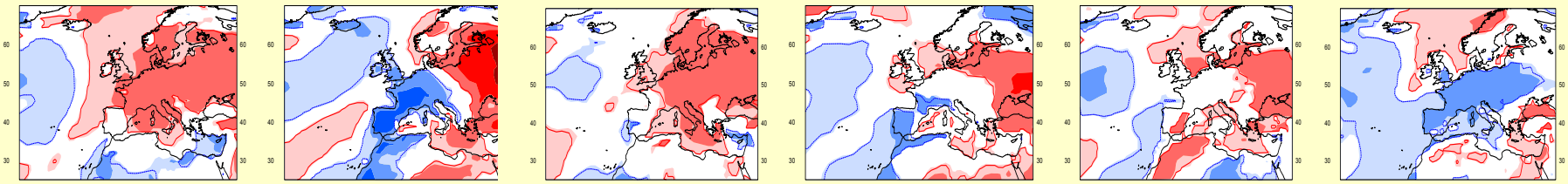
2m Temperature anomalies over EUROPE

Analysis

21/05-27/05 | 28/05-03/06 | 4/06-10/06 | 11/06-17/06 | 18/06-24/06 | 25/06-01/07



Day 12-18 Monthly Forecast



ECMWF

Product development (implemented)

- **Added 10th, 90th centile to EPSgrams**
- **Extended EPS products to day 15**
- **Added EPSgram with daily steps (Tmax, Tmin)**
- **Added probabilities for 5-day period D11-15 (based on existing products for D6-10)**
- **Ensemble mean and spread added to plots on web**
- **Wind direction added on 15-day EPSgram**
- **Added new wave EPSgram**

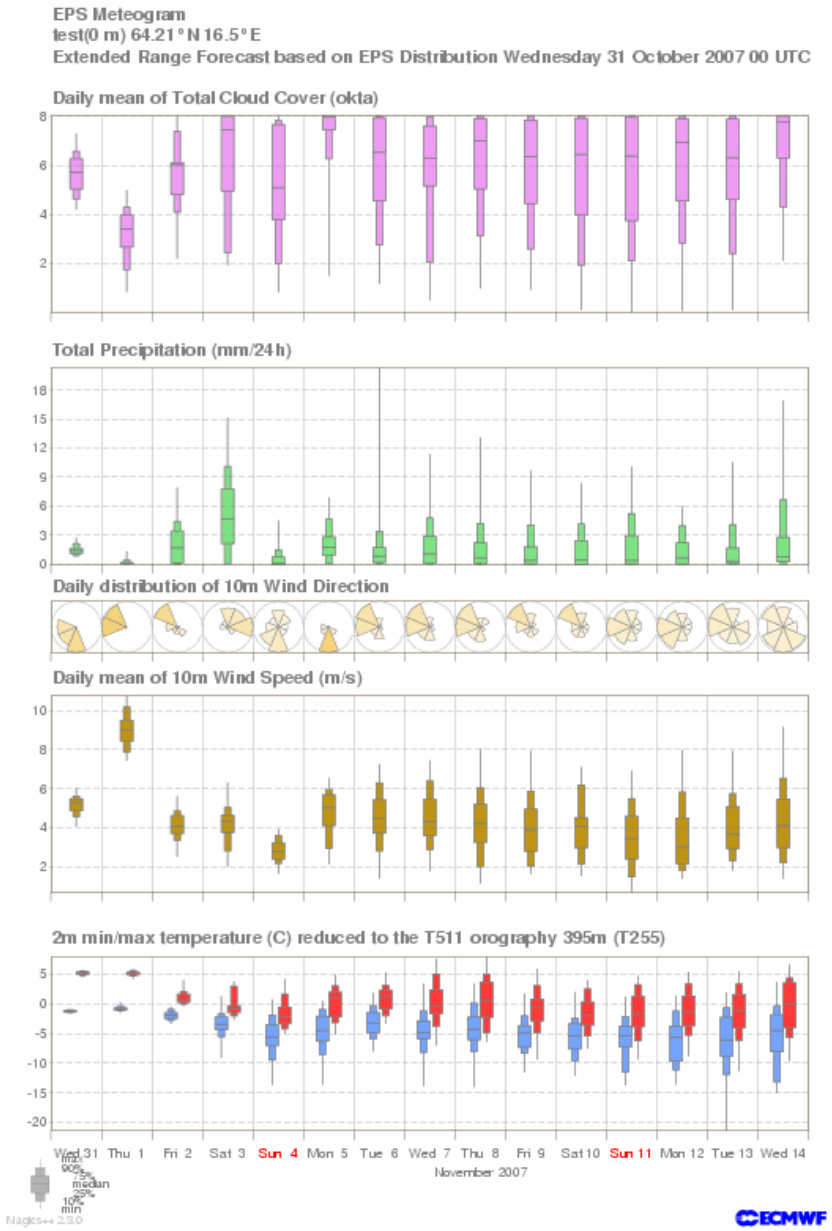
15-day EPSgram

Daily values

- 2m temp: max, min

Wind direction added recently

- Daily distribution of 10m wind direction (uses 00, 06, 12, 18 UTC)
- Size and shading of each octant both indicate fraction of members forecasting that direction
- To aid visualisation, each rose is scaled to the size of the most populated octant



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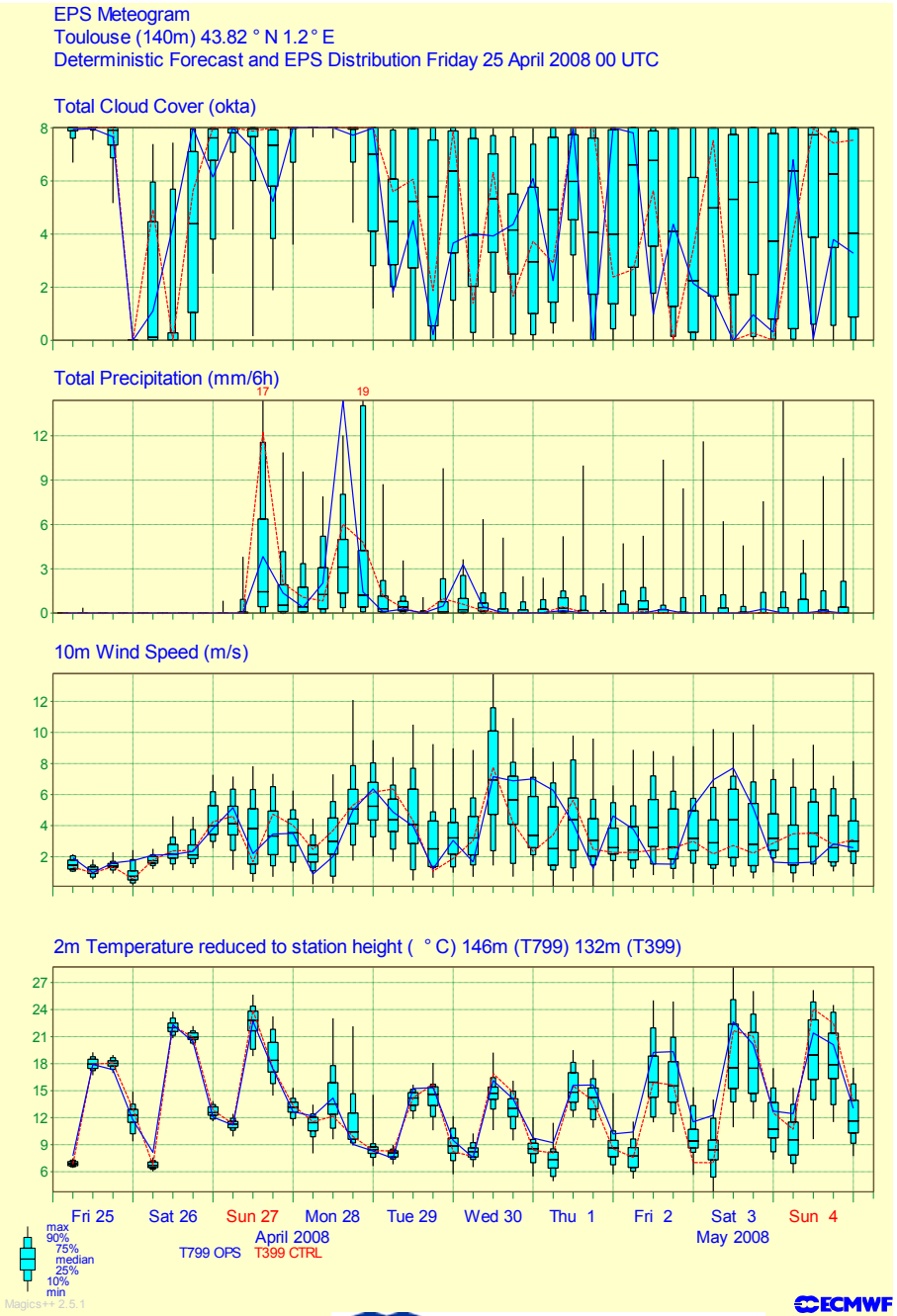
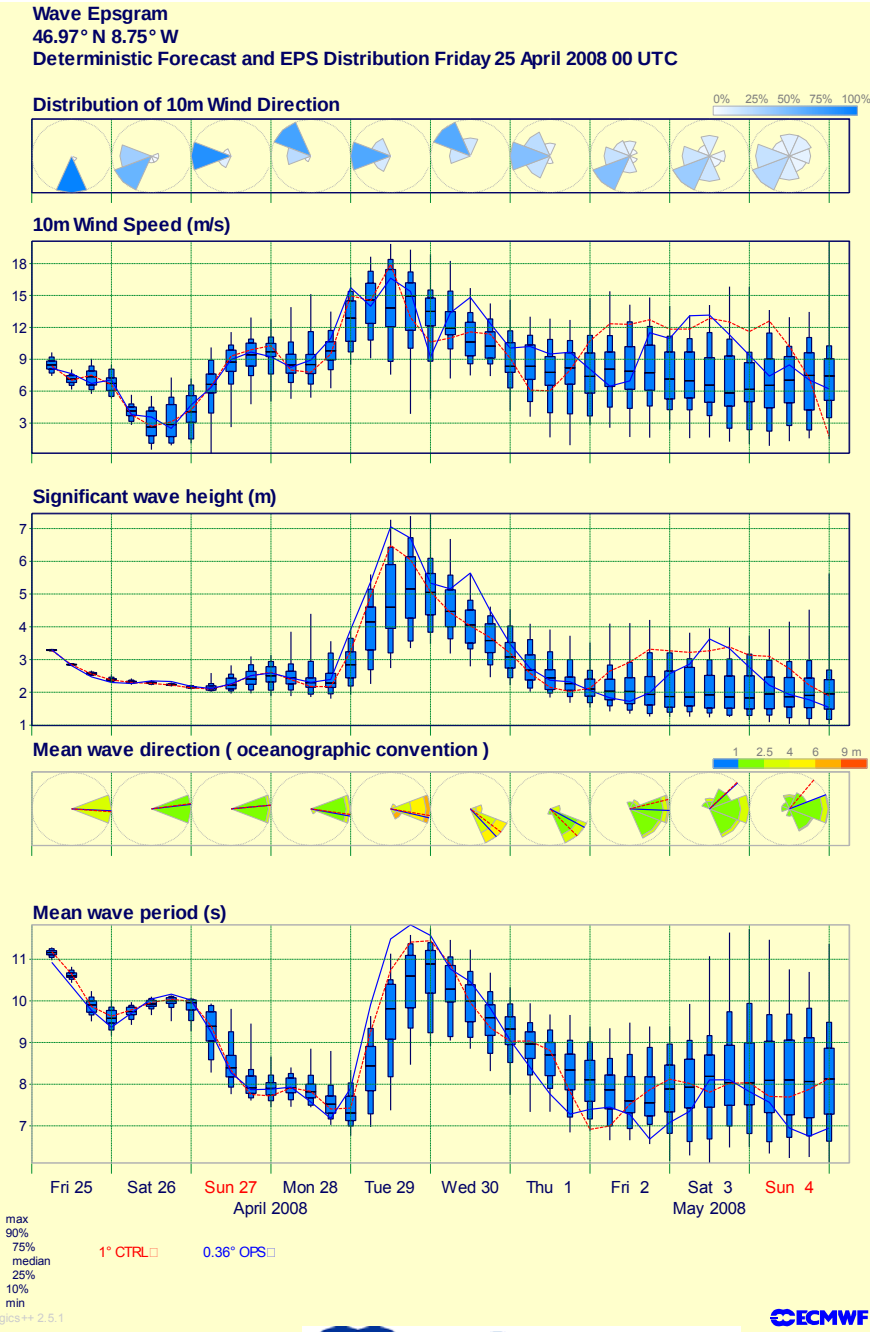
10-day EPSgram

- **Revision of precipitation scale**
  - **Current: scale set by maximum 6h precip of any member**
  - **New: scale adjusted to better show general distribution of precip in EPS. Maxima shown above chart**



Wave EPSgram (prototype)

- **6-hourly values for 10m wind speed, significant wave height and mean wave period sea grid points of the T255 model**
- **10m wind direction and wave direction are shown for 12 UTC, following the meteorological and oceanographic conventions respectively**
- **Wave direction – size of each octant indicated number of members; colours within each octant show distribution of significant wave height**



ECMWF

European Centre for Medium-Range Weather Forecasts

Background

1967 European Council of Ministers propose co-operation in science and technology (COST)

1969 Expert group in meteorology propose 'European Meteorological Computing Centre'

1971 Report on 'EMCC' : Net benefit of £100m per annum at 1971 prices

Establishment

1975 ECMWF convention in force

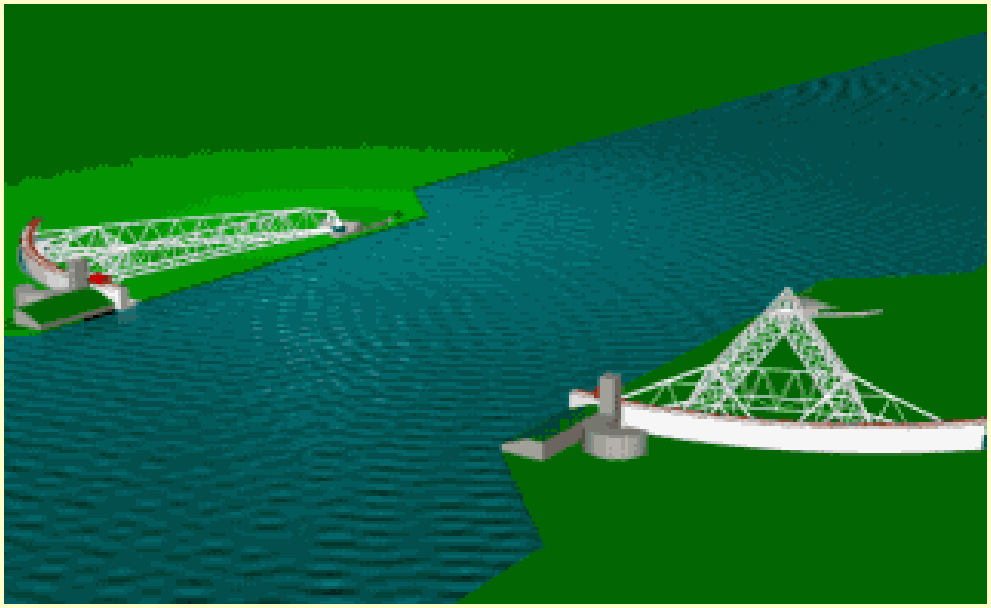
1978 Headquarters building completed

Start of operational activities

1978 Installation of first computer system

1979 Start of operations

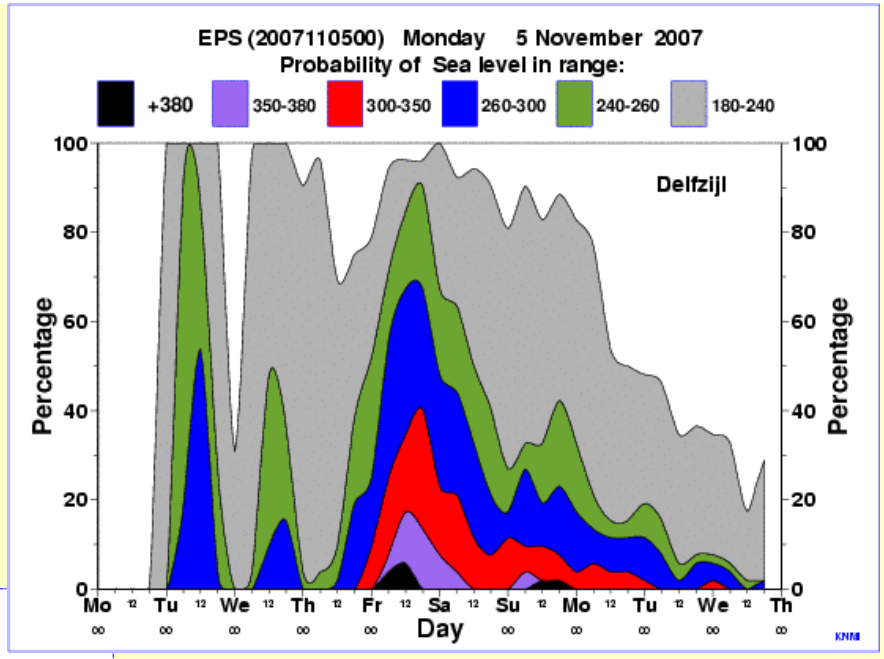
Storm-surge in the North sea
Friday 9 November

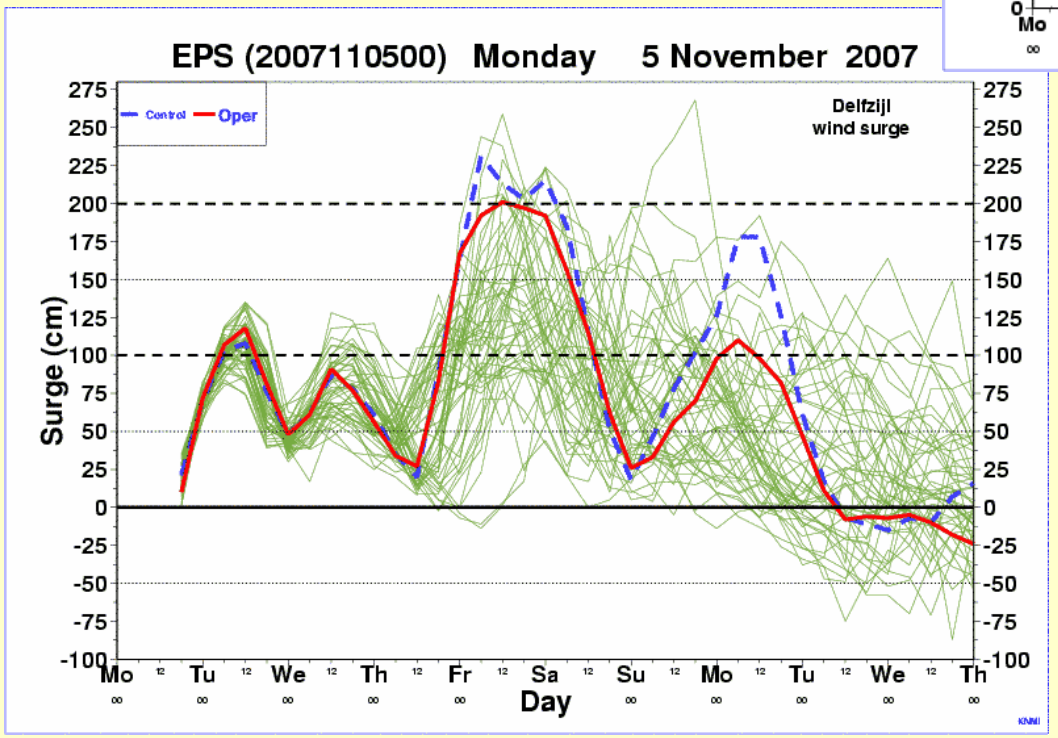


- **Barrier protecting Rotterdam closed for the first time ever**

ECMWF

Forecasts by KNMI on Monday 5 for Vlissingen



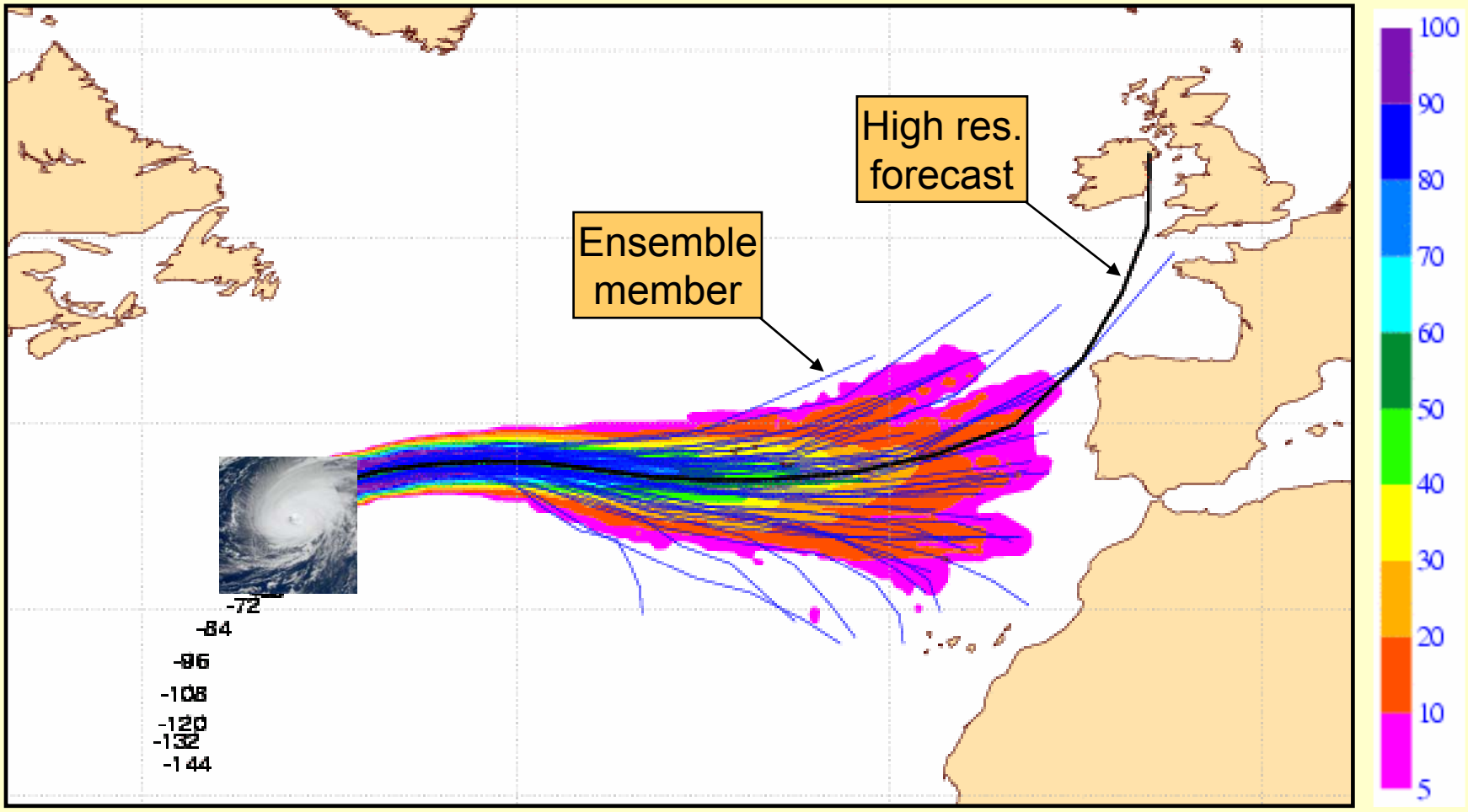


- **Storm-surge model using EPS**
- **Surge reached 367**
- **Minister was visiting KNMI on Monday**

ECMWF

Predictions for track of storm “Gordon”

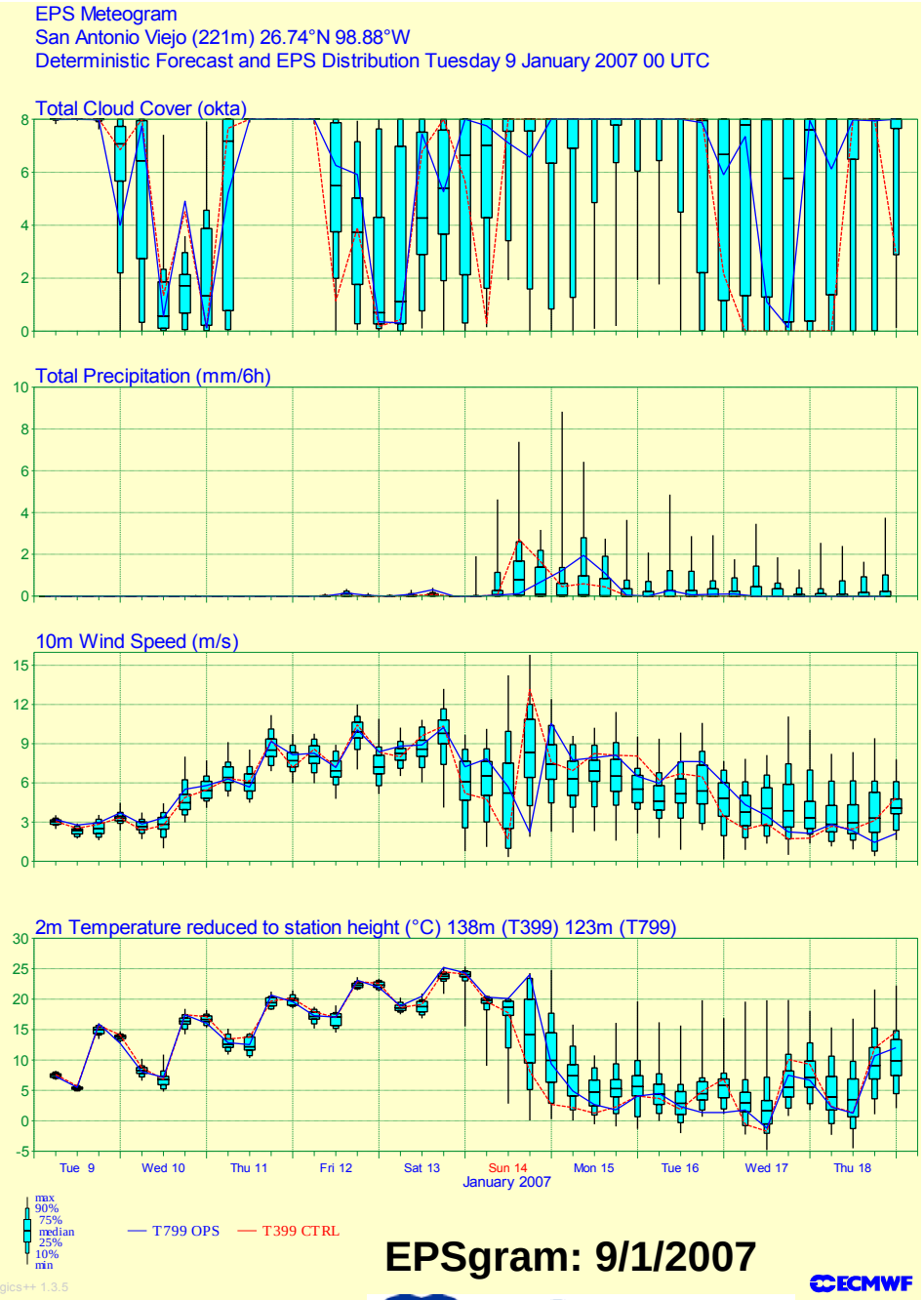
From 00UTC Monday 18 September 2006



Shading: Probability that Gordon would pass within 120km

Cold air outbreak

- AMS meeting January 14th-18th 2007 San Antonio Texas



EPSgram: 9/1/2007

ECMWF