

ECMWF products and performance

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Thanks to:

**Meteorological Operations Section, Graphics Section,
Data Services, Jean Bidlot, Martin Leutbecher**

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 (80km beyond day 10) and 62 levels

Ocean wave forecasts

- Global forecast to ten days from 00 and 12 UTC at 40 km resolution
- European waters forecast to five days from 00 and 12 UTC at 25 km resolution
- 50 ensemble forecasts to fifteen days from 00 and 12 UTC at 100 km resolution

Monthly forecasts: Atmosphere-ocean coupled model

- Global forecasts to one month:
 - atmosphere:** 125 km resolution, 62 levels
 - ocean:** horizontally-varying resolution ($\frac{1}{3}^\circ$ to 1.4° lat x 1.4° lon), 29 levels

Seasonal forecasts: Atmosphere-ocean coupled model

- Global forecasts to seven months:
 - atmosphere:** 125 km resolution, 62 levels
 - ocean:** horizontally-varying resolution ($\frac{1}{3}^\circ$ to 1.4° lat x 1.4° lon), 29 levels

Main operational changes 2006-2007

➤ **1 February 2006 (cycle 30r1)**

- high-resolution forecast system

➤ **12 September 2006 (cycle 31r1)**

- Physics changes including cloud scheme, convective transports, orographic drag; revised assimilation of rain-affected radiances, variational bias correction of satellite radiances

➤ **28 November 2006**

- Dissemination of day 11-15 products from second leg of VarEPS
EPS control and two cal/val forecasts are run to 15 days

➤ **12 December 2006 (cycle 31r2)**

- Assimilation of new satellite data: MTSAT AMVs, GPS RO (CHAMP, GRACE, COSMIC)

Main operational changes 2006-2007

➤ 11 January 2007

- Operational assimilation of MetOp-A data (AMSU-A and MHS)

➤ 15 March 2007

- Seasonal forecast system 3

➤ 5 June 2007 (cycle 32r2)

- Improved moist physics and third inner loop in assimilation; new short-wave radiation

➤ 12 June 2007

- Assimilation of IASI and ASCAT data

➤ 6 November 2007 (cycle 32r3)

- Big changes to convection (major increase in tropical variability)
- New soil types (drier Sahel)
- Revised radiosonde bias correction
- Assimilation of AMSR-E, TMI, SSMIS window channels (clear sky), SBUV (N-17, N-18) and monitoring of OMI; increase of number of RO from COSMIC

Time series Acc=0.6 Europe

ECMWF FORECAST VERIFICATION 12UTC

500hPa GEOPOTENTIAL

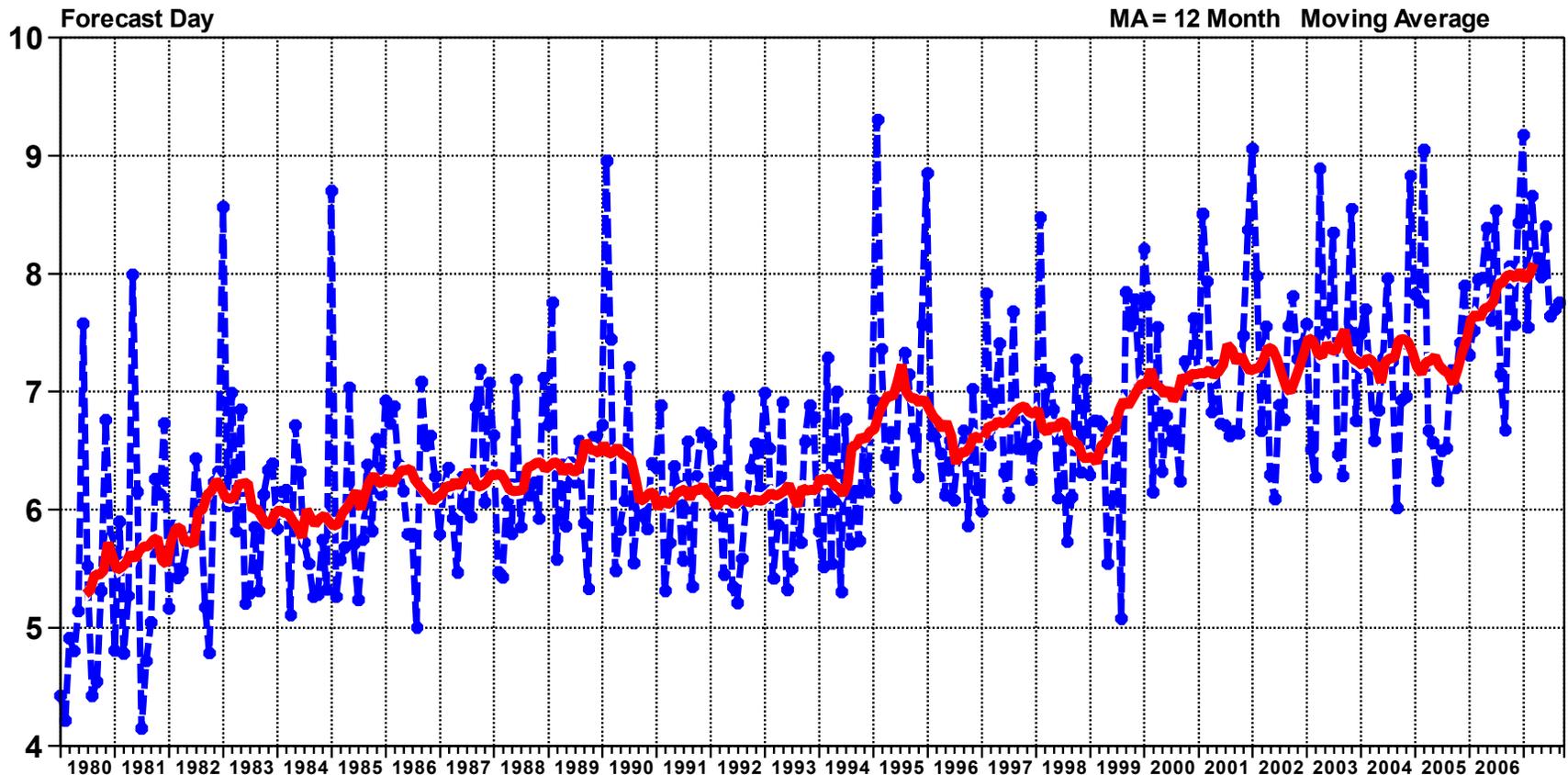
ANOMALY CORRELATION

FORECAST

EUROPE LAT 35.000 TO 75.000 LON -12.500 TO 42.500

—●— SCORE REACHES 60.00

— SCORE REACHES 60.00 MA



Time series Acc=0.6 N hemisphere ECMWF FORECAST VERIFICATION 12UTC

500hPa GEOPOTENTIAL

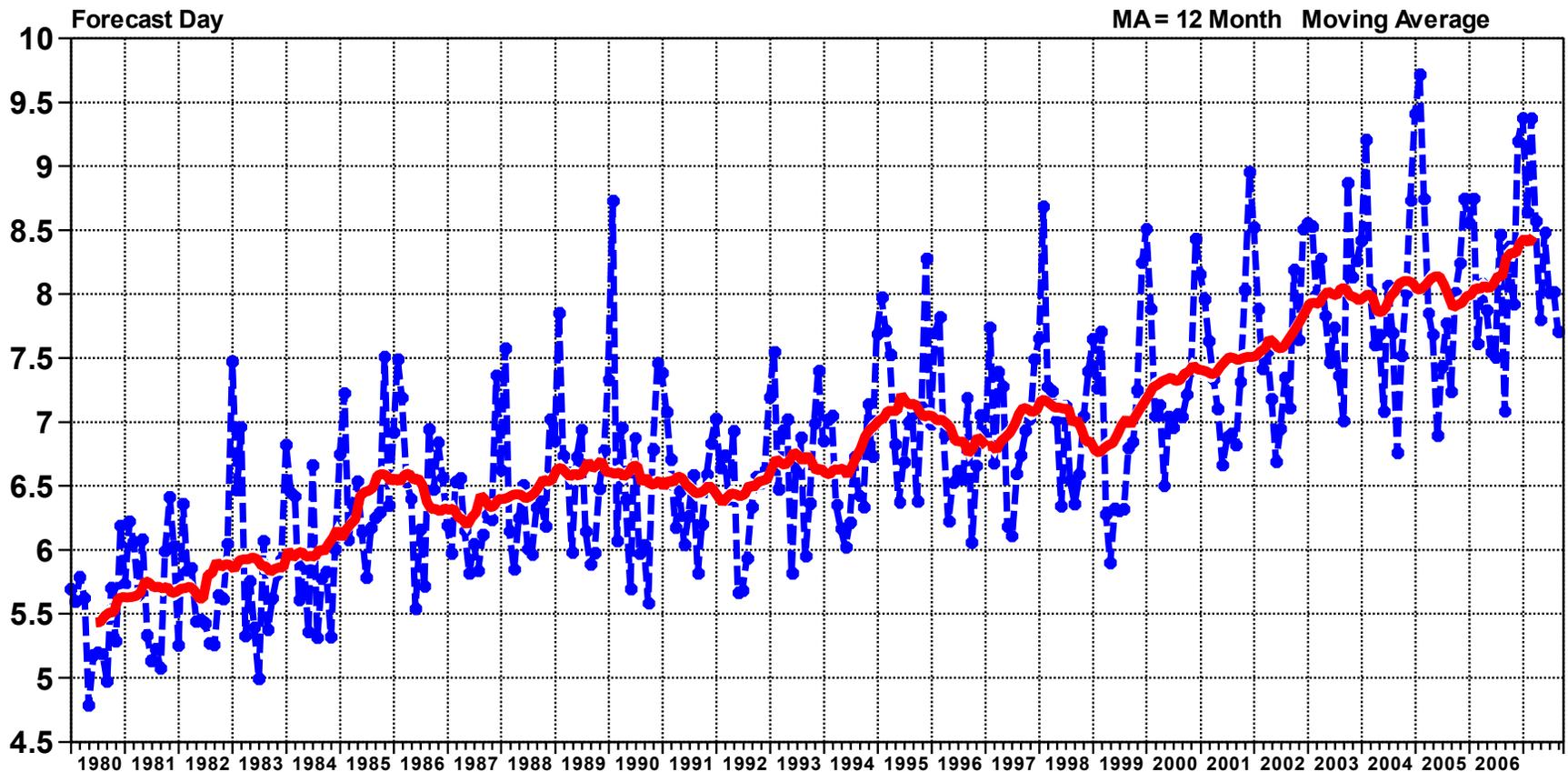
ANOMALY CORRELATION

FORECAST

N.HEM LAT 20.000 TO 90.000 LON -180.000 TO 180.000

—●— SCORE REACHES 60.00

— SCORE REACHES 60.00 MA



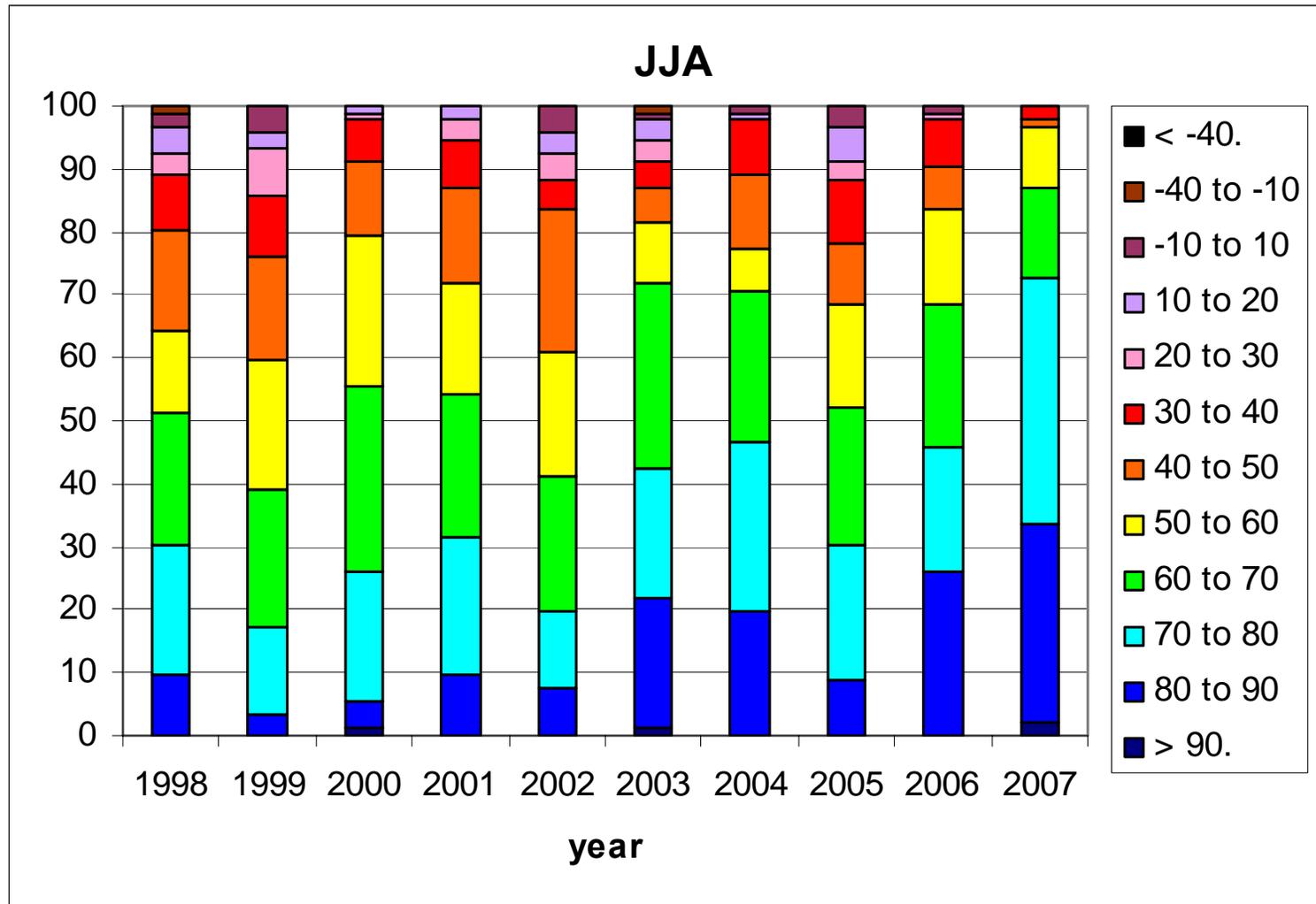


Figure 4: Cumulative distribution of Anomaly Correlation of the **Day 7 850hPa** temperature forecasts with verifying analyses over **Europe** in summer (JJA) since 1997-1998.

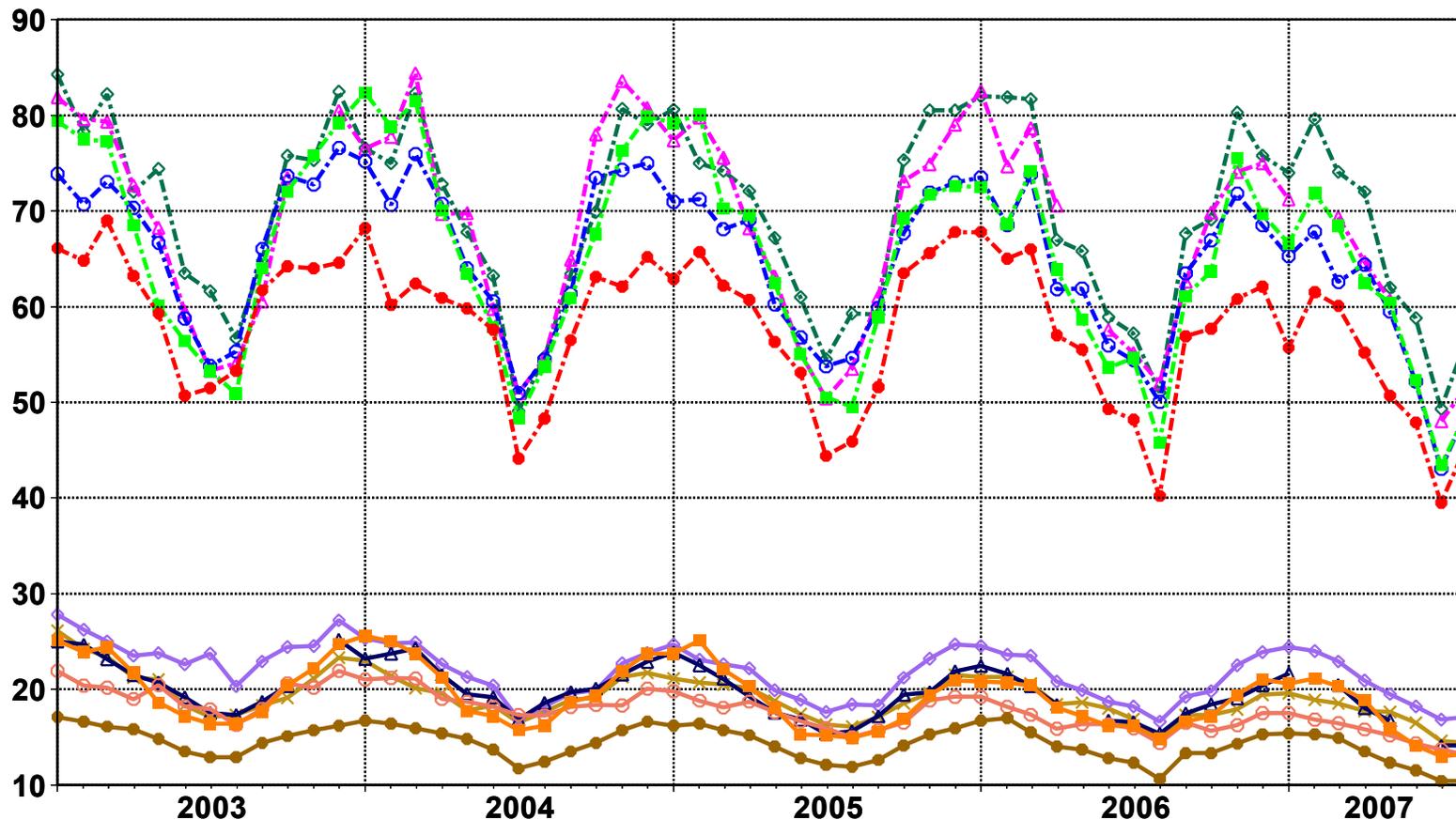
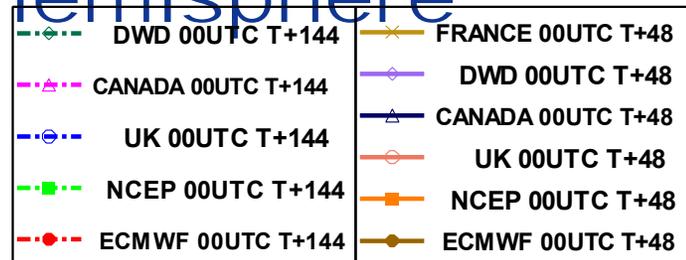
WMO scores Z500 N Hemisphere

VERIFICATION TO W.M.O. STANDARDS

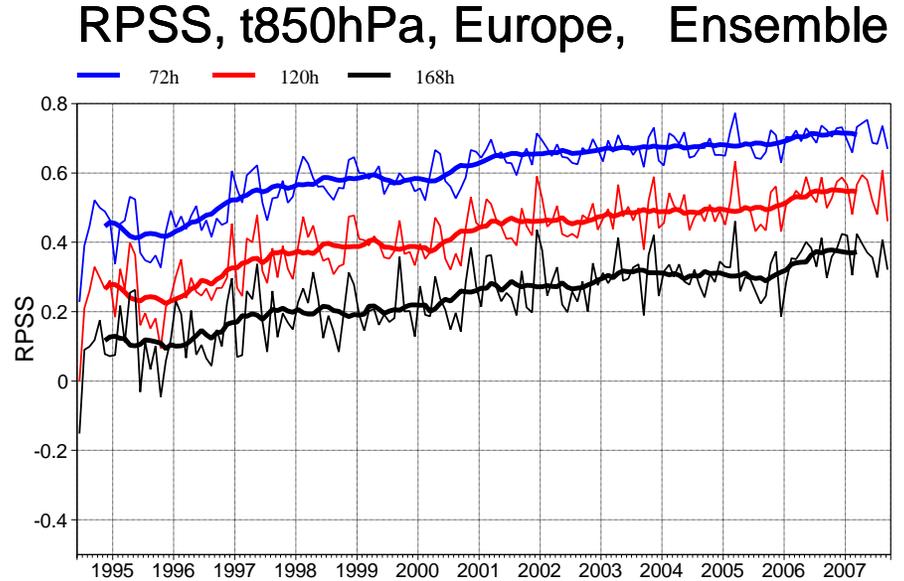
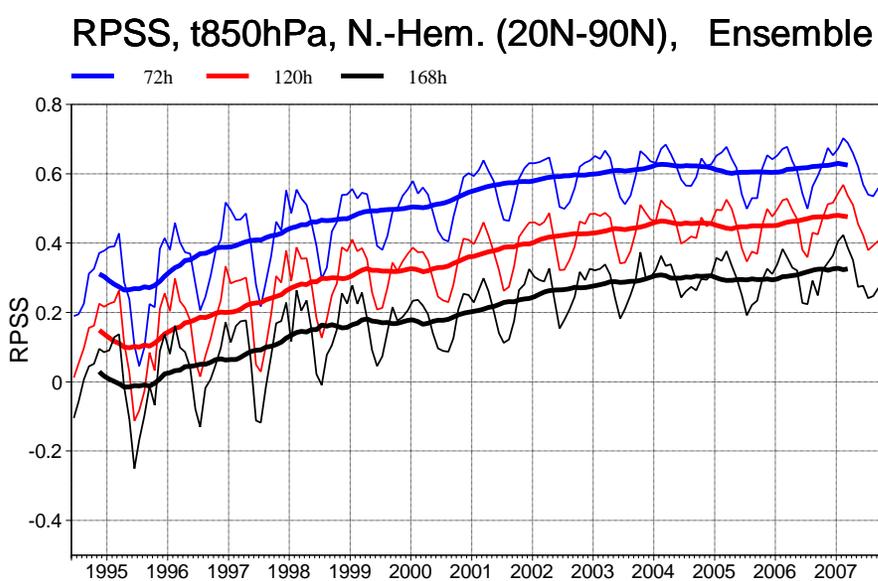
NORTHERN HEMISPHERE

VERIFICATION AGAINST ANALYSIS

500 hPa GEOPOTENTIAL HEIGHT RMSE (m)

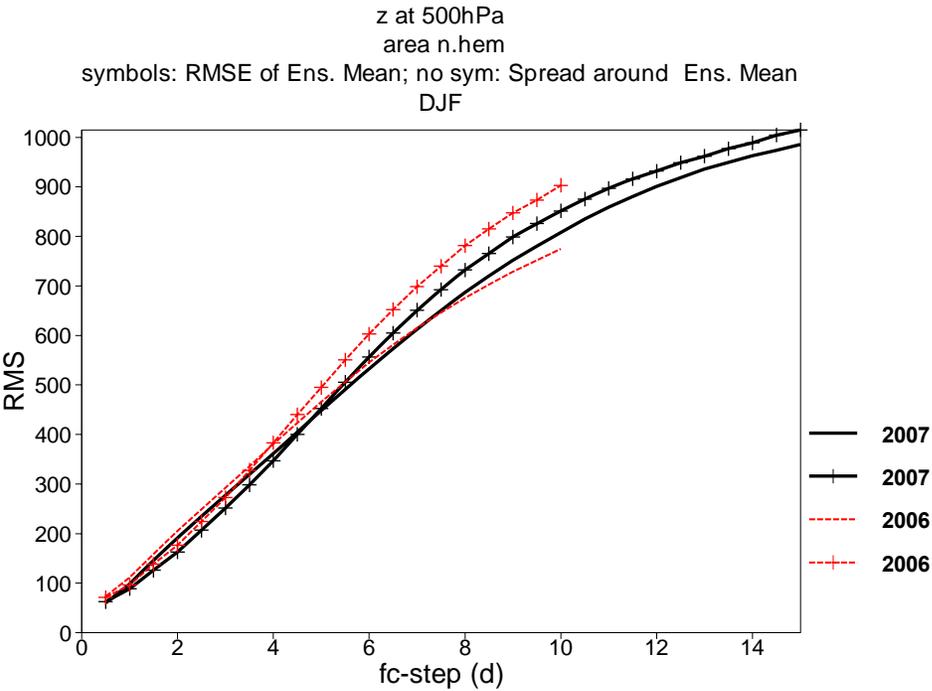


EPS performance – probability skill

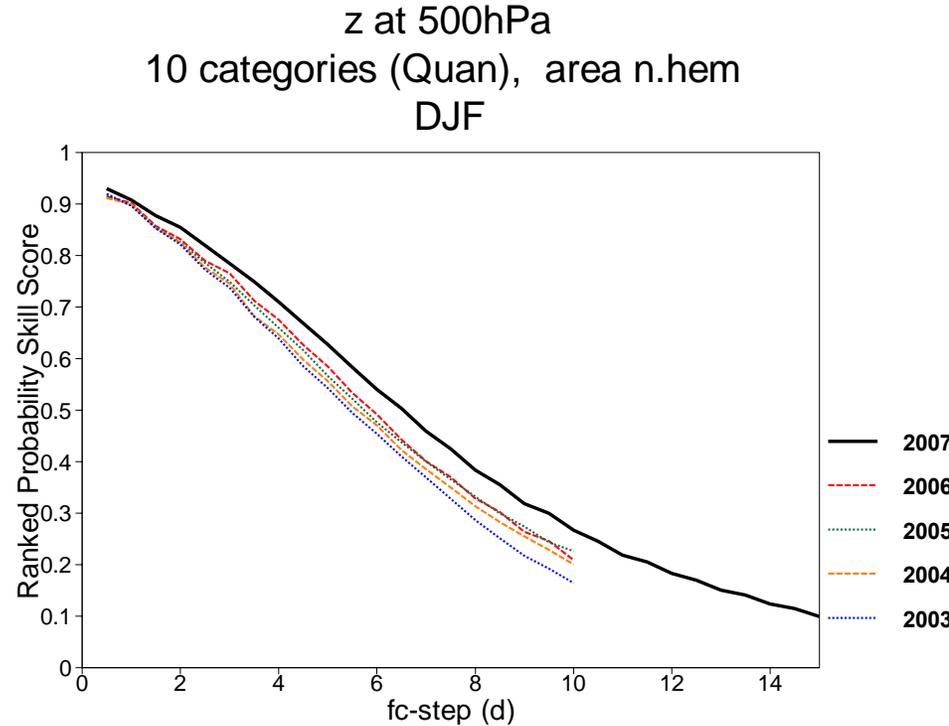


Monthly score and 12-month running mean (bold) of Ranked Probability Skill Score for EPS forecasts of 850 hPa temperature at day 3 (blue), 5 (red) and 7 (black) for the northern hemisphere extratropics (left) and Europe (right).

EPS performance – winter 2006-07



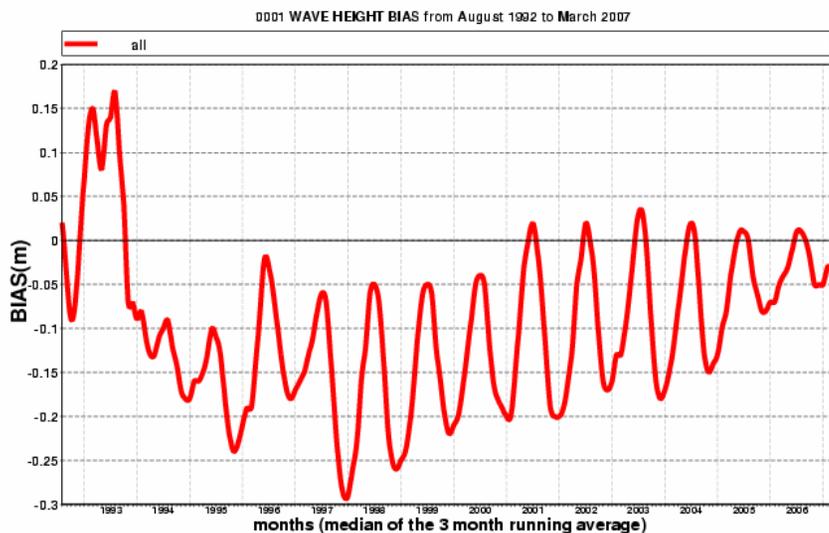
Ensemble spread (standard deviation) and root mean square error of ensemble-mean (lines with crosses) for 500 hPa height for winter 2006-07 (black) and 2005-06 (red) over NH



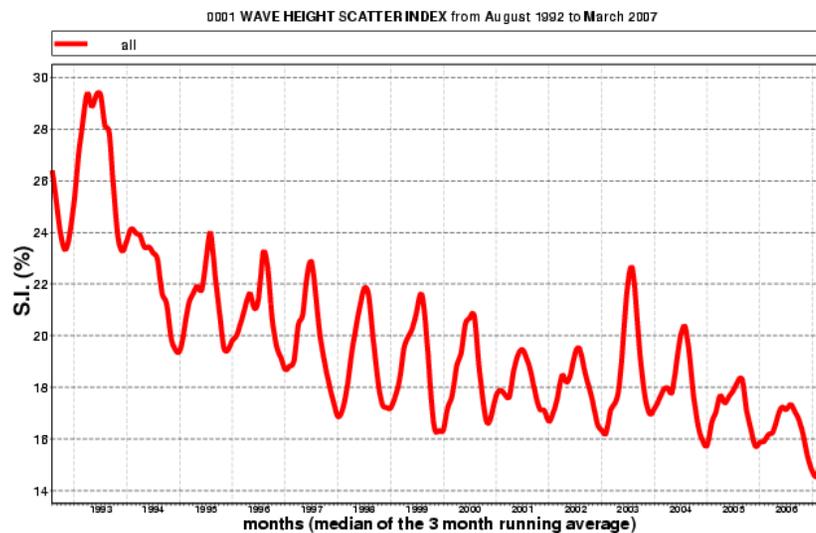
Ranked probability skill score for 500 hPa height, EPS forecasts for winter (December-January) over NH. The solid black line shows the skill from the VarEPS days 1-15 forecasts for winter 2006-07.

Ocean wave forecasts - verification

Analysed **wave height** against buoy measurements since August 1992.



Bias=Model-observations

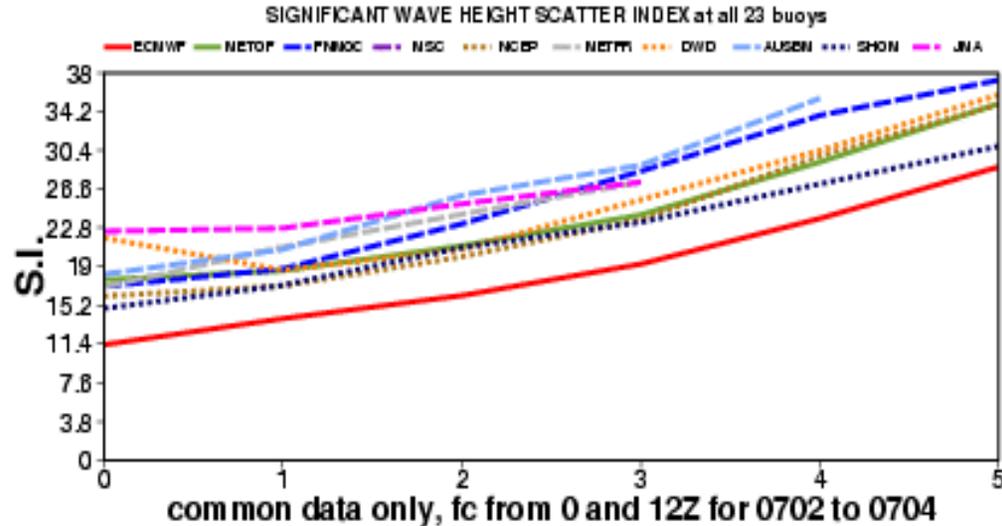


Scatter Index is the standard deviation of the difference normalised by the mean of the observations

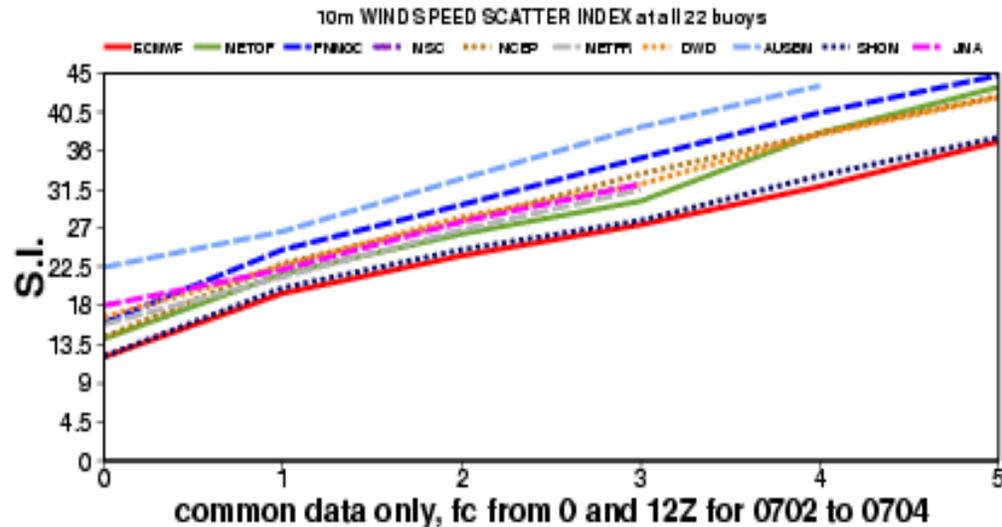
Waves – comparison to other centres

- Two new centres
 - JMA (magenta)
 - French Navy, SHOM (dark blue)
- SHOM use ECMWF winds (on a coarser grid) and a wave model that is a hybrid between ECMWF and US; with no wave data assimilation
- JMA have their own system.

Hs

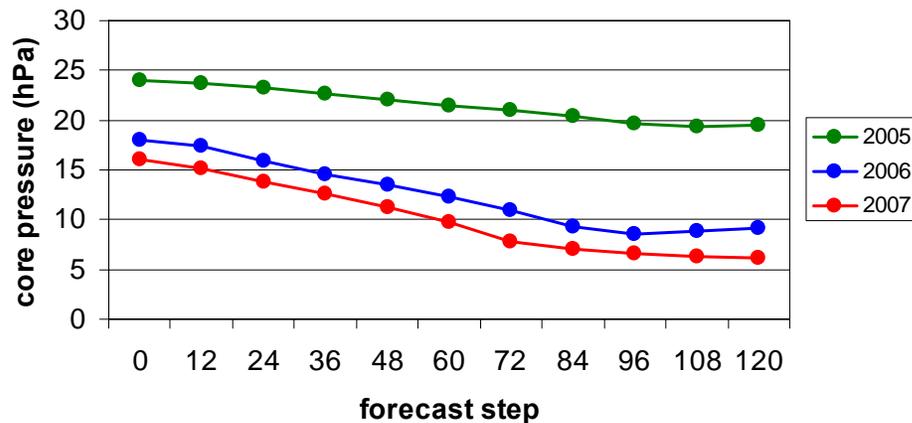


wind

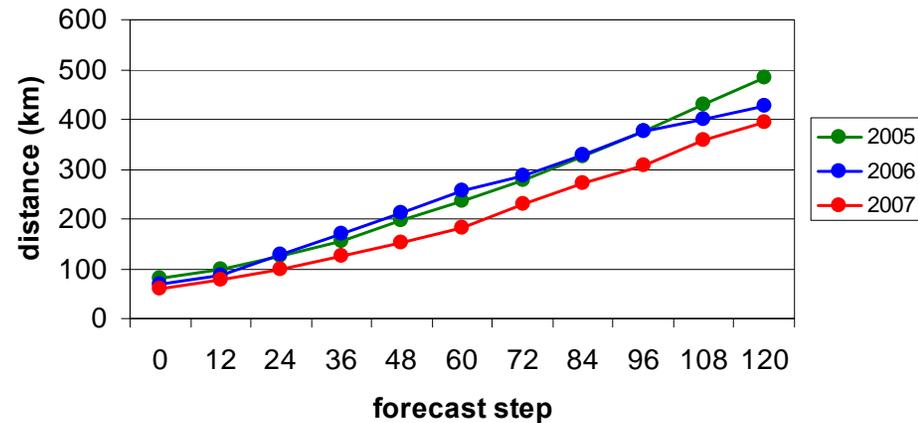


Tropical cyclone verification

Tropical Cyclone Intensity Error (mean of 365 days ending at 15 August)



Tropical Cyclone Position Error (mean of 365 days ending at 15 August)



Verification of tropical cyclone predictions from the operational deterministic forecast for three 12-month periods: August 2004 - August 2005 (green), August 2005 - August 2006 (blue) and August 2006 - August 2007 (red). Mean error in core pressure (left) and position (right).

Performance summary

- **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, well maintained out to Day 15**
- **Changes in the model physics (cy31r1, Sept 2006) gave improvements in weather parameters**
- **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**

Product development

➤ **Implemented (2006-2007)**

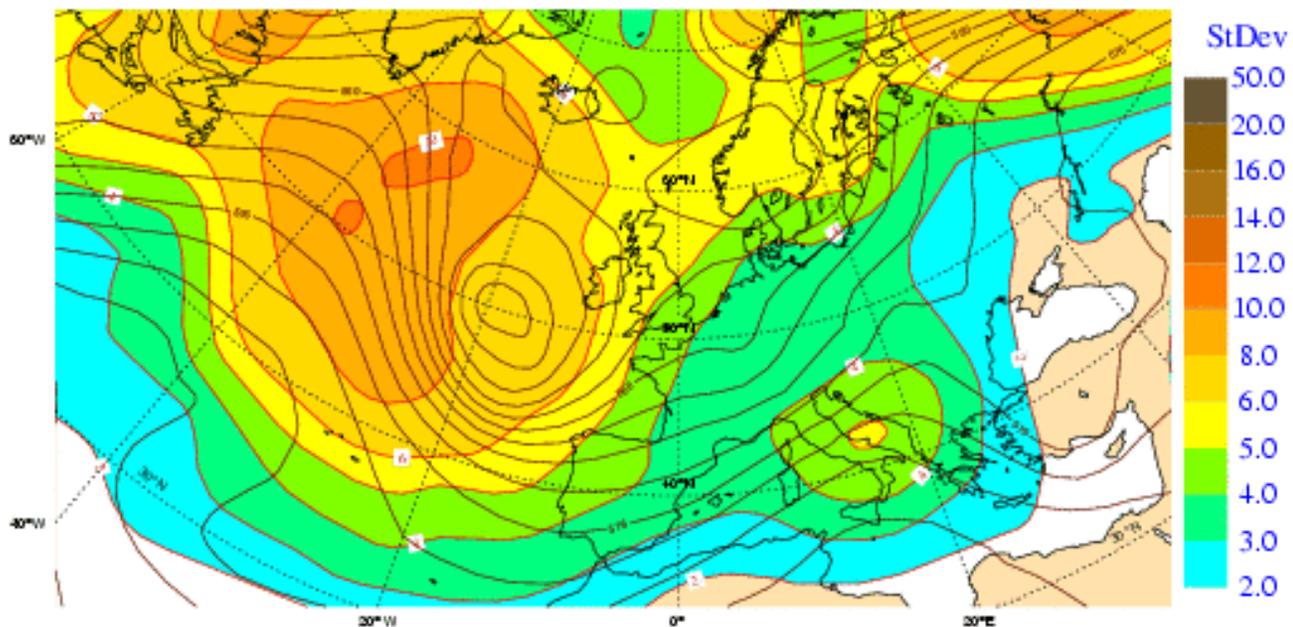
- Added 10th, 90th centile to EPSgrams
- Extended EPS products to day 15
- Added EPSgram with daily steps (Tmax, Tmin)
- Added probabilities for 5-day period D11-15 (based on existing products for D6-10)
- Ensemble mean and spread added to plots on web
- Wind direction added on 15-day EPSgram

➤ **In development**

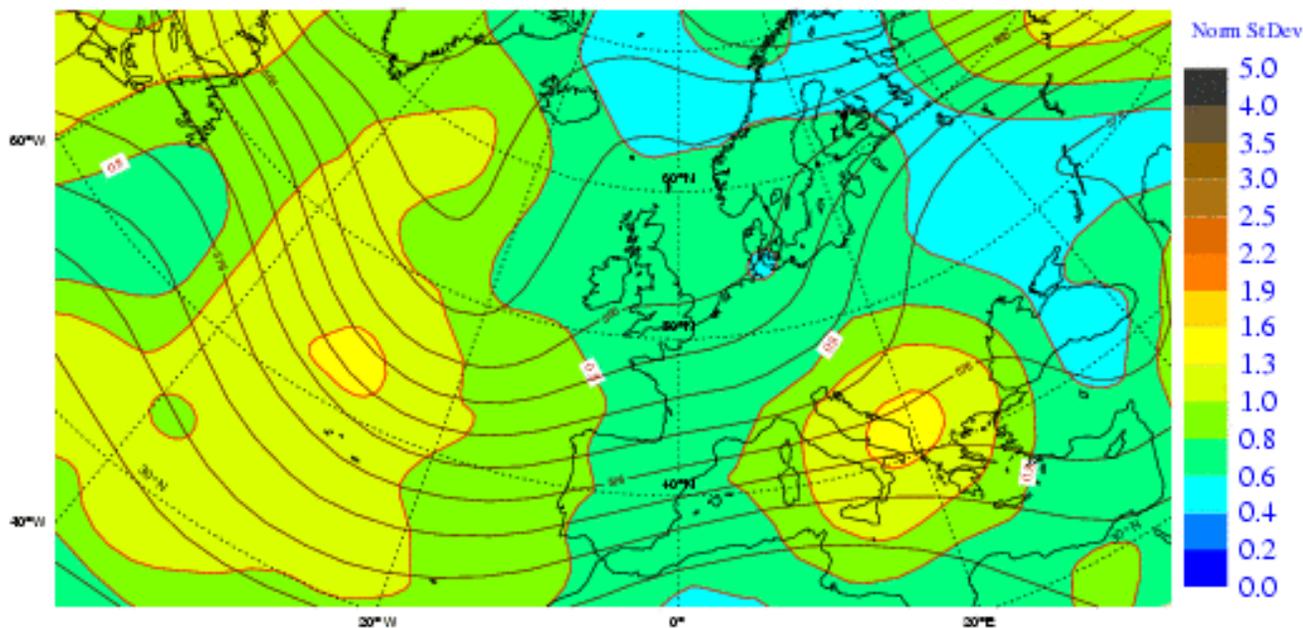
- Wave EPSgrams
- Revision of clustering
- Tracking of tropical cyclones developing during forecast
- Climate information on EPSgrams, EFI maps; probabilities to exceed quantiles of climate
- quantile maps
- Clickable EFI map (show EPS and climate distribution at point)
- Extend EFI beyond 5 days, using new EFI climate from VarEPS/monthly system

Ensemble mean and spread added to web plots

Monday 11 June 2007 00UTC ECMWF Forecast 14-168 VT: Monday 18 June 2007 00UTC
500hPa Geopotential (gdam) Deterministic Forecast and Standard Deviation (shaded)



Monday 11 June 2007 00UTC ECMWF Forecast 14-168 VT: Monday 18 June 2007 00UTC
500hPa Geopotential (gdam) Ensemble Mean and Normalised Standard Deviation (shaded)



15-day EPSgram

➤ Daily values

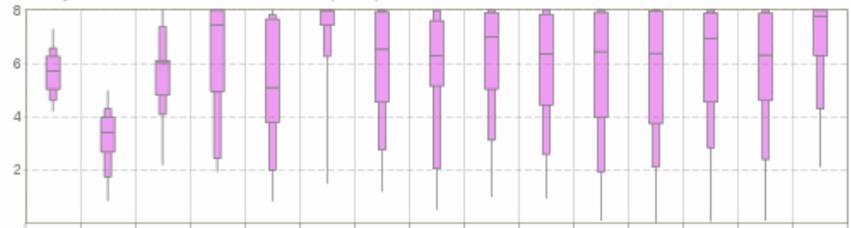
- 2m temp: max, min

➤ Wind direction added recently

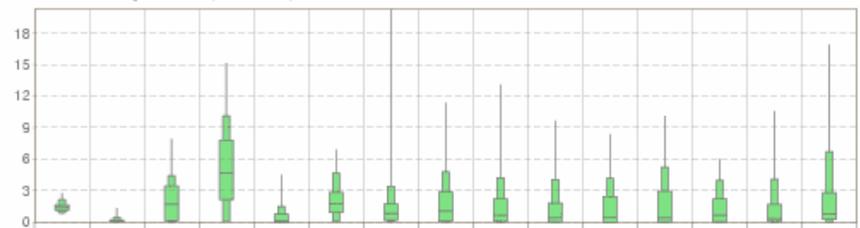
- Daily distribution of 10m wind direction (uses 00, 06, 12, 18 UTC)
- Size and shading of each octant both indicate fraction of members forecasting that direction
- To aid visualisation, each rose is scaled to the size of the most populated octant

EPS Meteogram
test(0 m) 64.21°N 16.5°E
Extended Range Forecast based on EPS Distribution Wednesday 31 October 2007 00 UTC

Daily mean of Total Cloud Cover (okta)



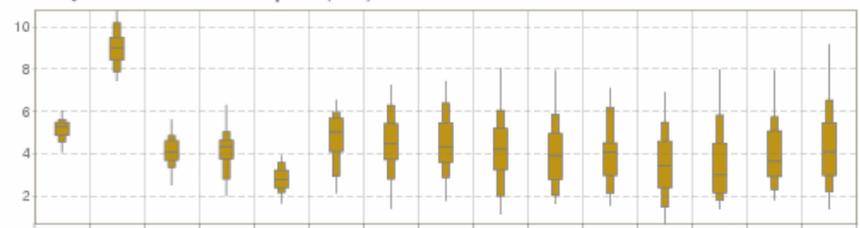
Total Precipitation (mm/24 h)



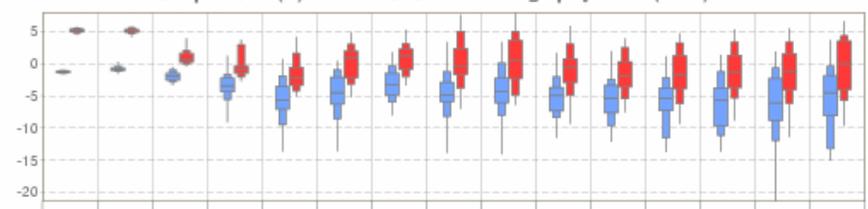
Daily distribution of 10m Wind Direction



Daily mean of 10m Wind Speed (m/s)



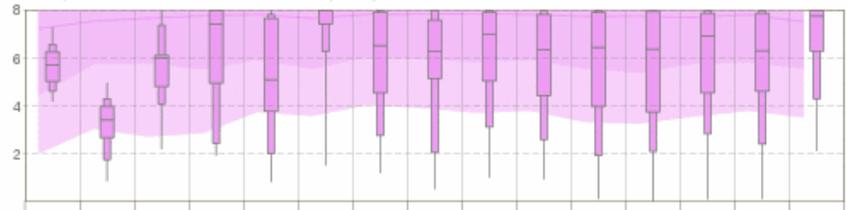
2m min/max temperature (C) reduced to the T511 orography 395m (T255)



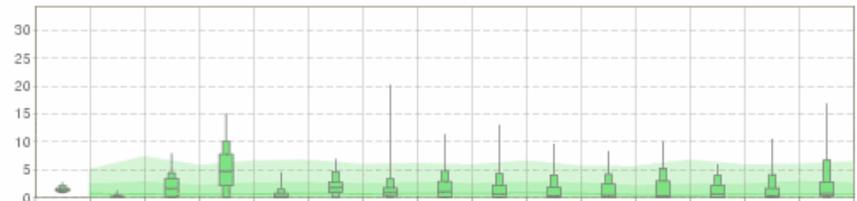
15-day EPSgram

- With climate information from new (test) EFI climate reforecast

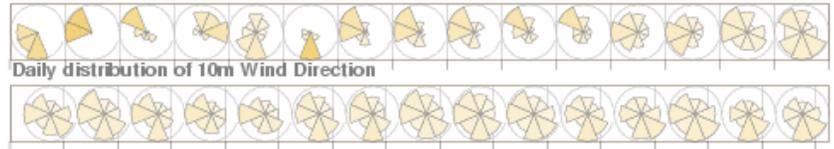
Daily mean of Total Cloud Cover (okta)



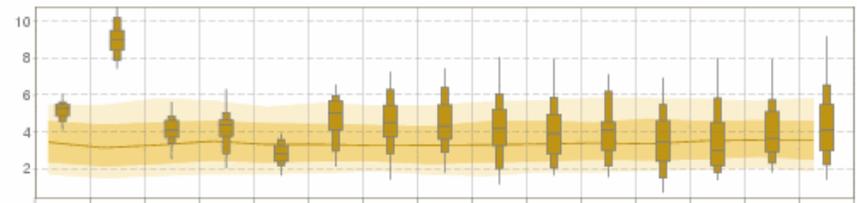
Total Precipitation (mm/24h)



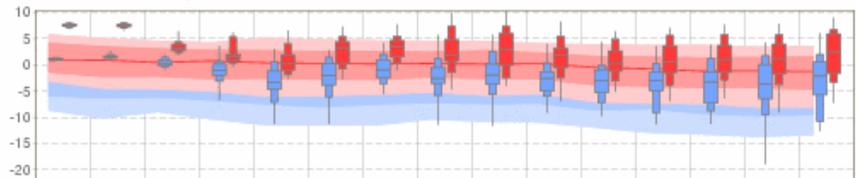
Daily distribution of 10m Wind Direction



Daily mean of 10m Wind Speed (m/s)



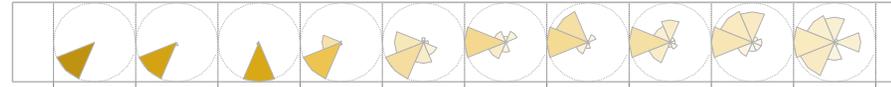
2m min/max temperature (C) reduced to station height 395m (T255)



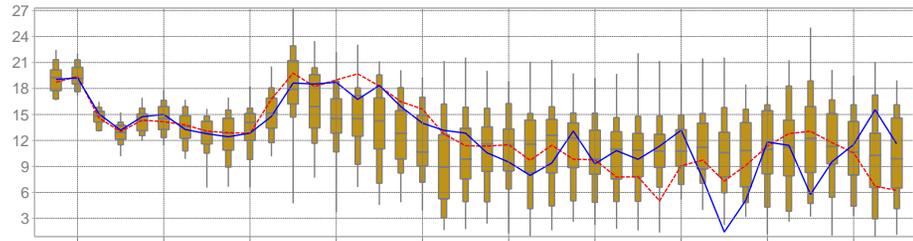
Wave Epsgram (prototype)

- 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
- 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

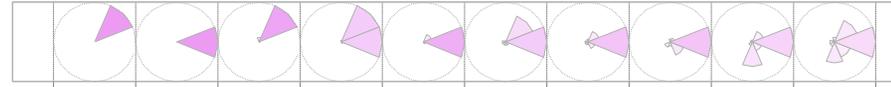
Distribution of 10m Wind Direction



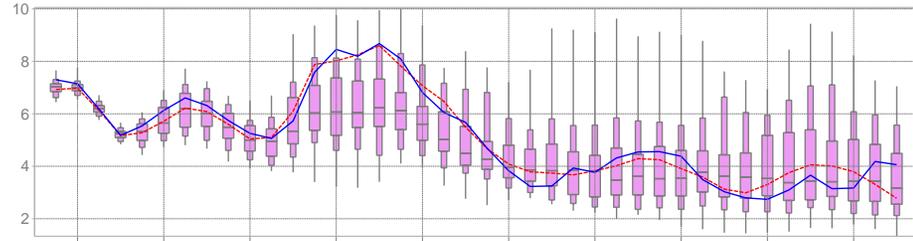
10m Wind Speed (m/s)



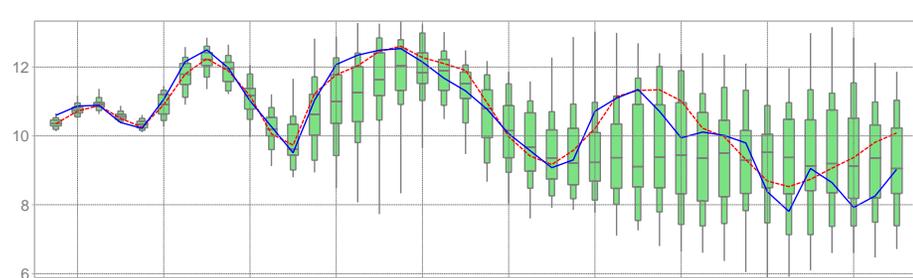
Mean wave direction (oceanographic convention)



Significant wave height (m)



Mean wave period (s)

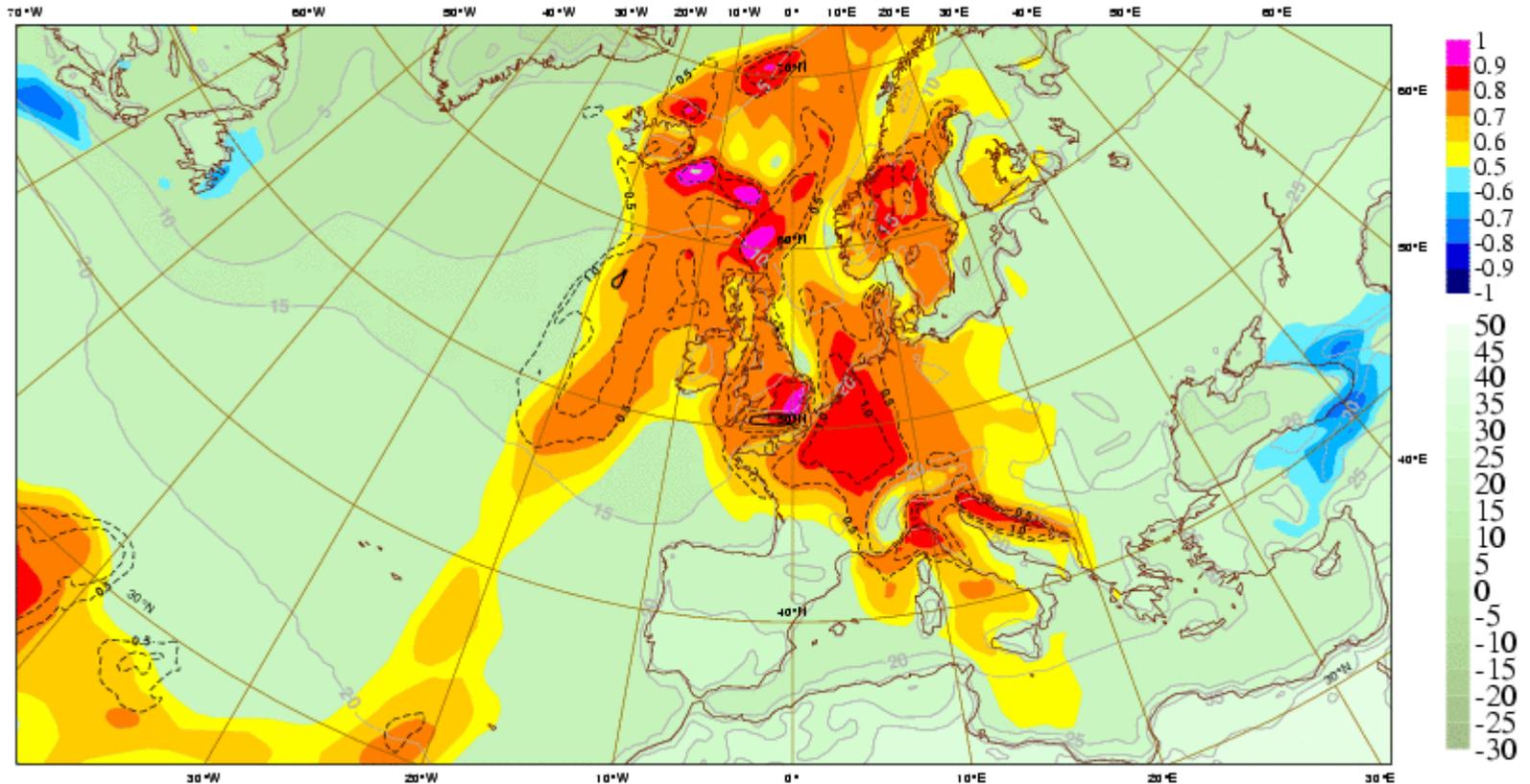


Mon 22 Tue 23 Wed 24 Thu 25 Fri 26 Sat 27 Sun 28 Mon 29 Tue 30 Wed 31 Thu 1
October 2007 November 2007

EFI – additional information on maps

Climate (99th percentile), SOT

Thursday 12 April 2007 00UTC @ECMWF Extreme forecast index t+048-072 VT: Saturday 14 April 2007 00UTC - Sunday 15 April 2007 00UTC



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)

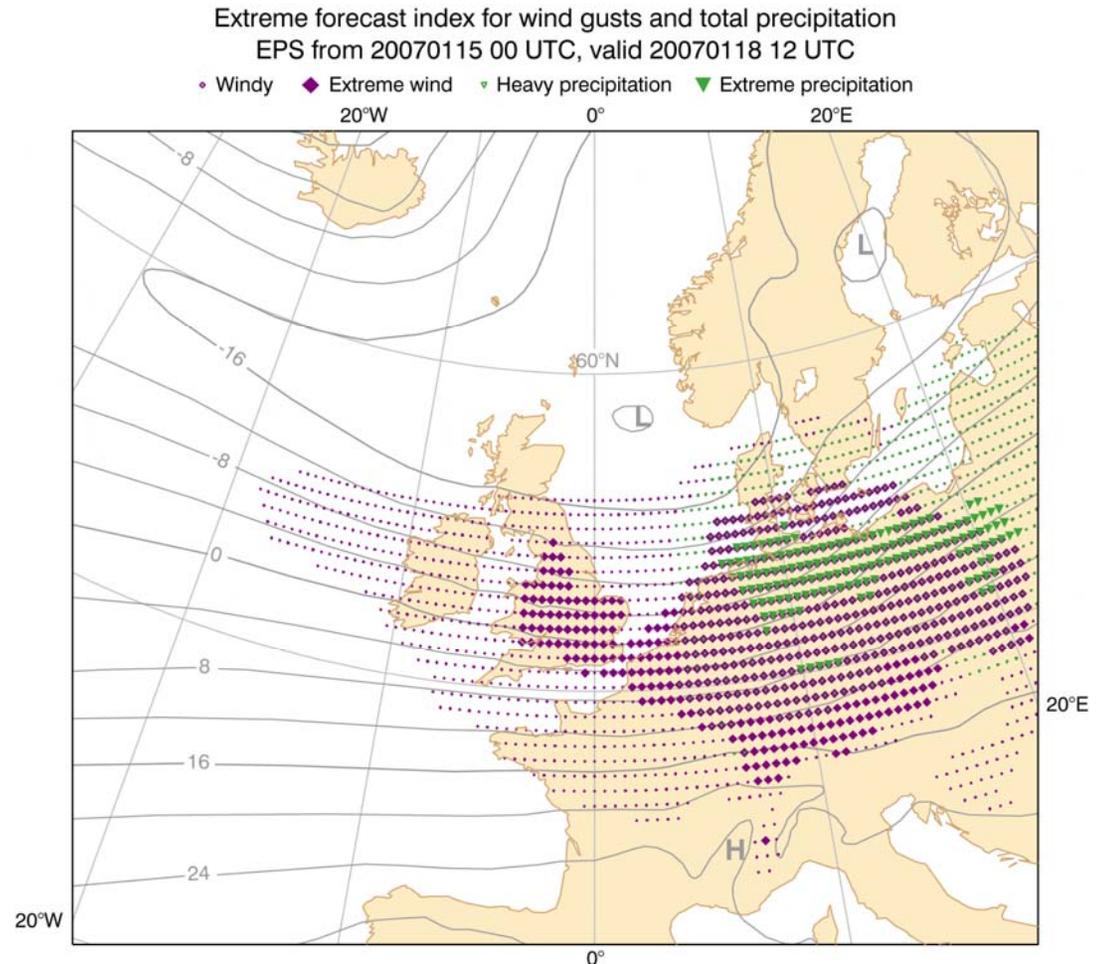


autobahn in Thuringia

Storm Kyrill: EFI early warning

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

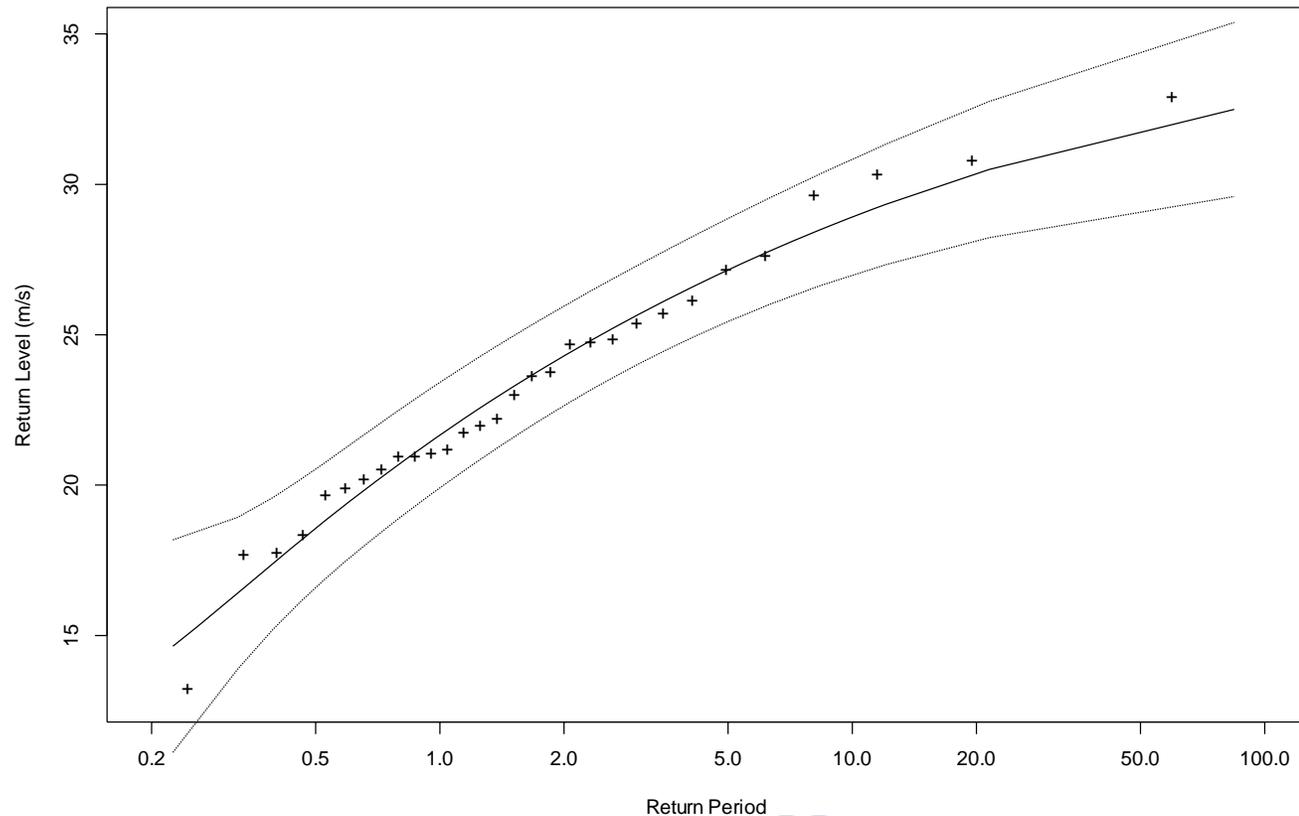


Return period and level

- **Model climate and extreme value distribution to predict return period**

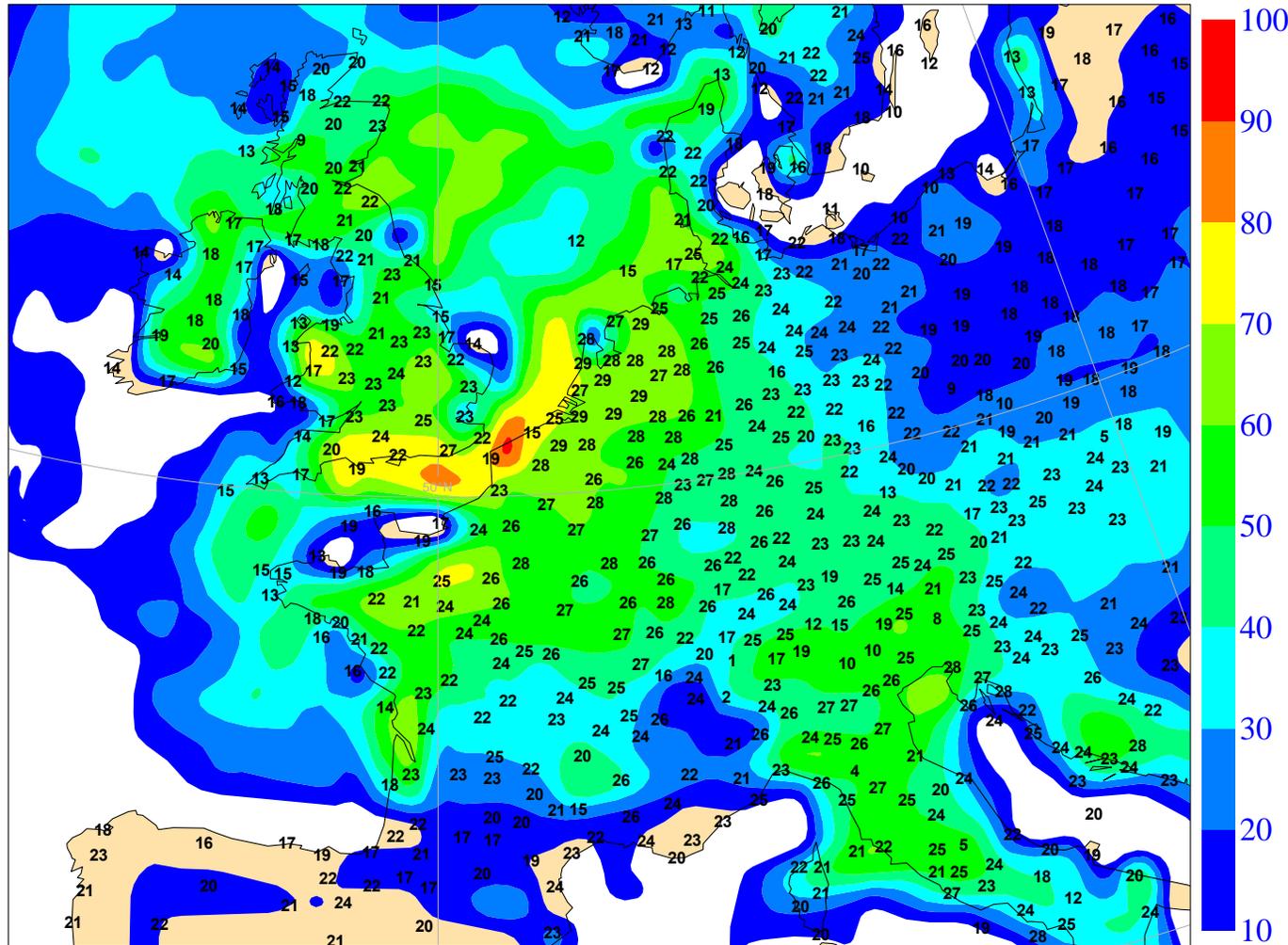
Forecast 15.01.07

- **40% members predicted 1 in 10 year event**
- **20% members predicted 1 in 20 year event**



Heat wave April 2007

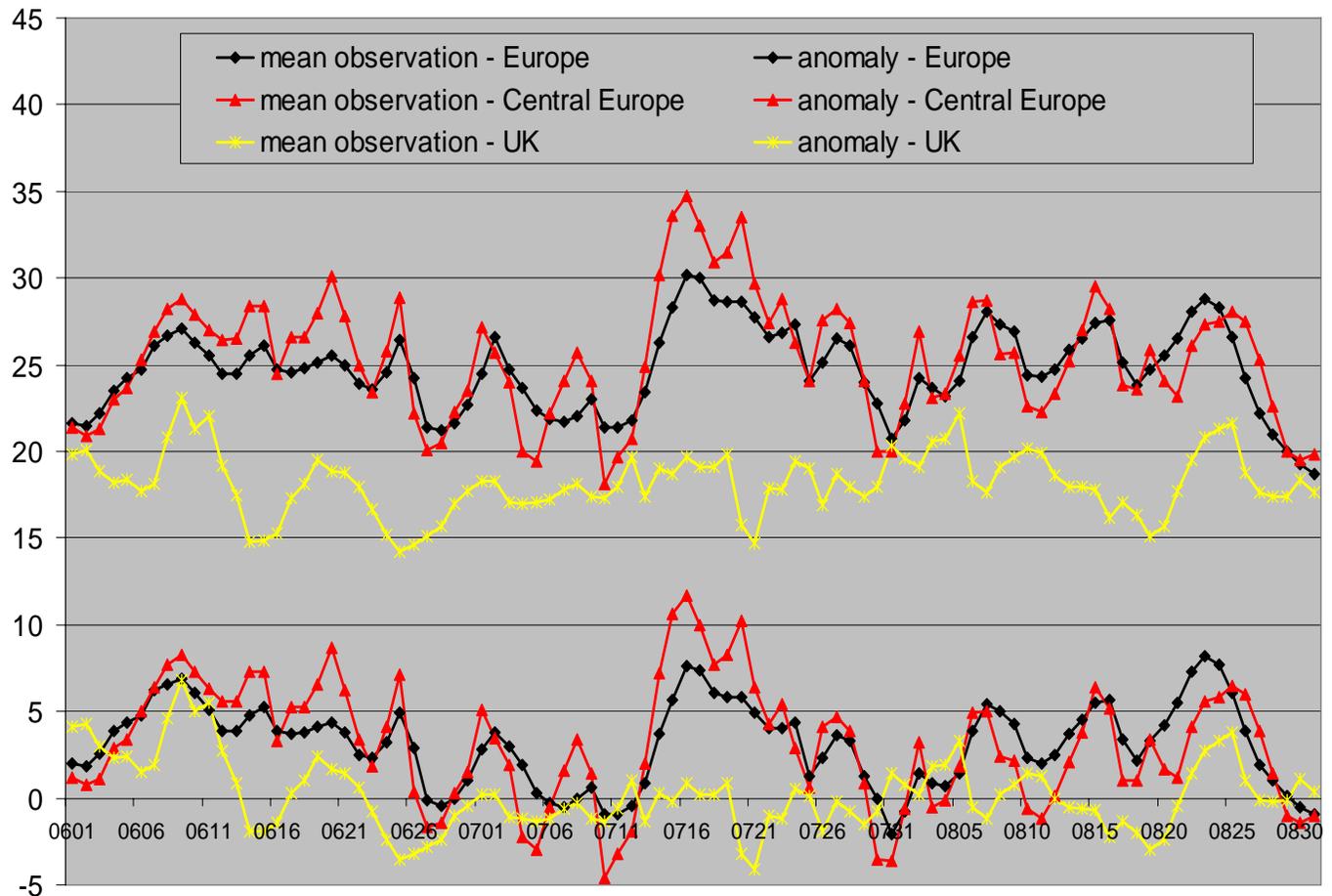
Observed 2m temperature maxima on 15th April, and D+11 probabilities to exceed the 95th percentile



- **Exceptional warm temperature on 15 April 2007 (26-30° C)**
- **D11 probability forecast compared with observations**
- **Probability of exceeding 95th centile of model climate**

Central Europe heat wave July 2007

Daily 2m maximum temperature anomalies summer 2007



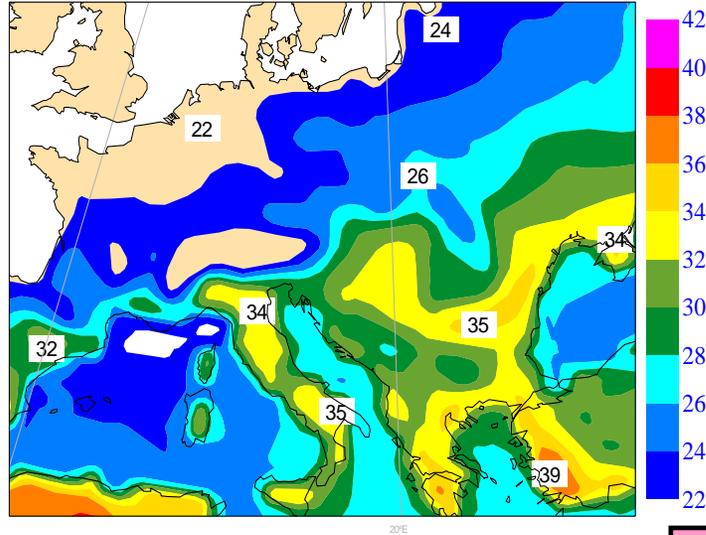
Extreme temperatures 15-20 July, over 40°C in many places

Forest fires, loss of crops, fatalities from heat stress

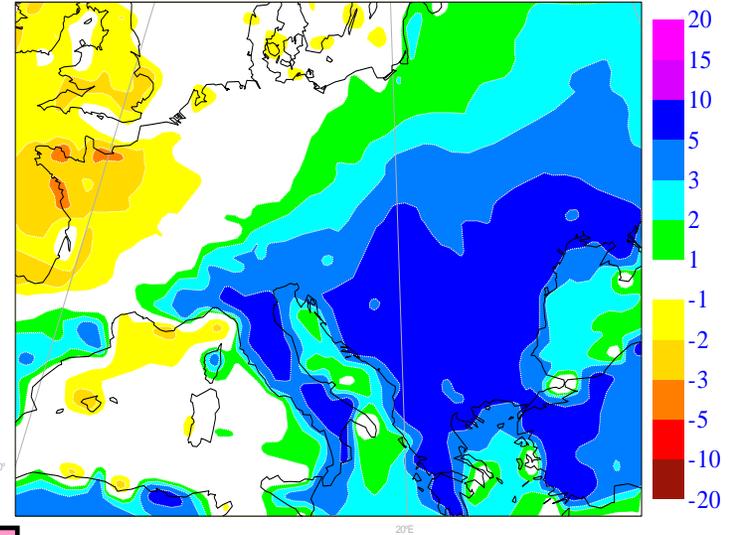
Strong signal in 15 day forecast

EPS Day-15 forecast for 20th of July

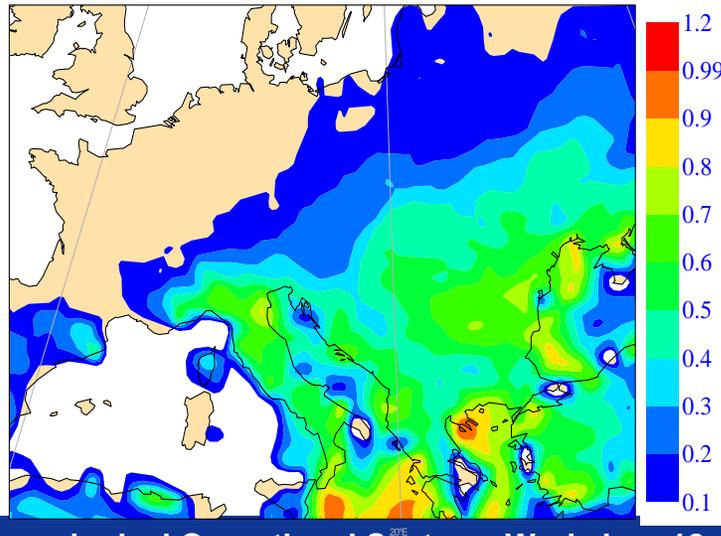
EPS mean, 2m max temp, VT:20070720, t+360



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

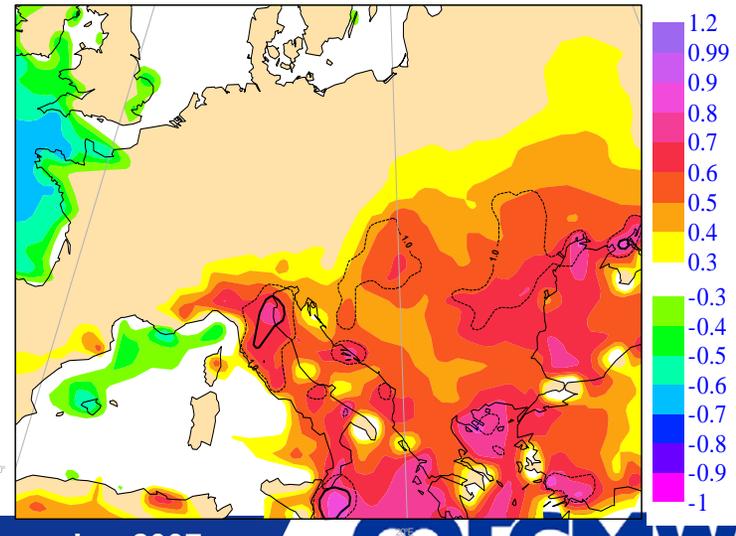


EPS prob, 2m max temp gt Q95, VT:20070720, t+360



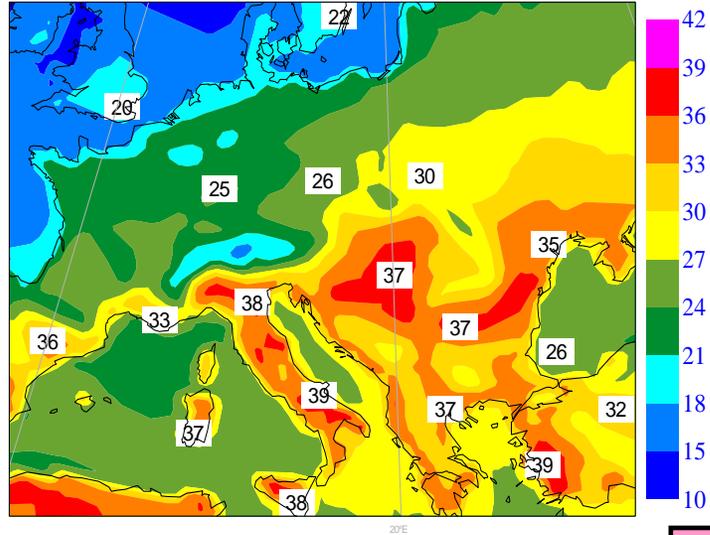
D15

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

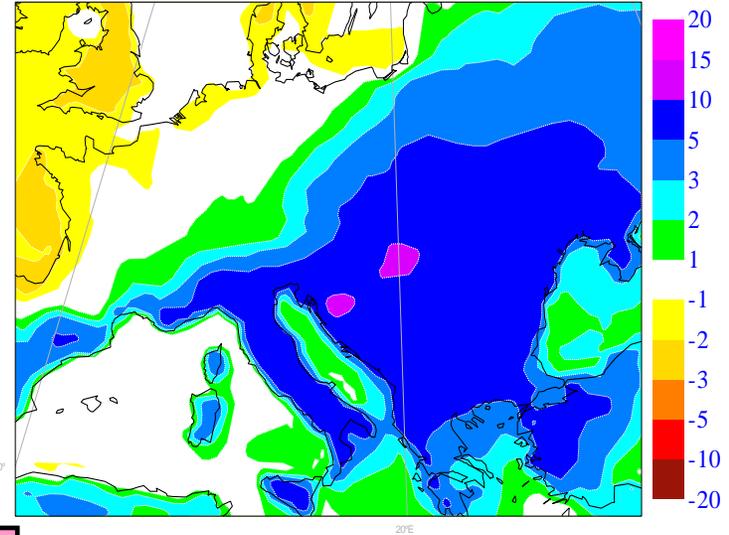


EPS Day-10 forecast for 20th of July

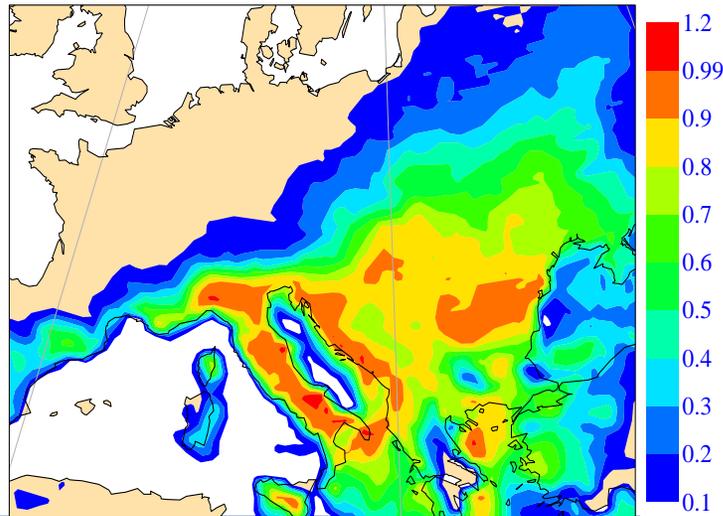
EPS mean, 2m max temp, VT:20070720, t+240



EPS anomaly, 2m max temp, VT:20070720, t+240

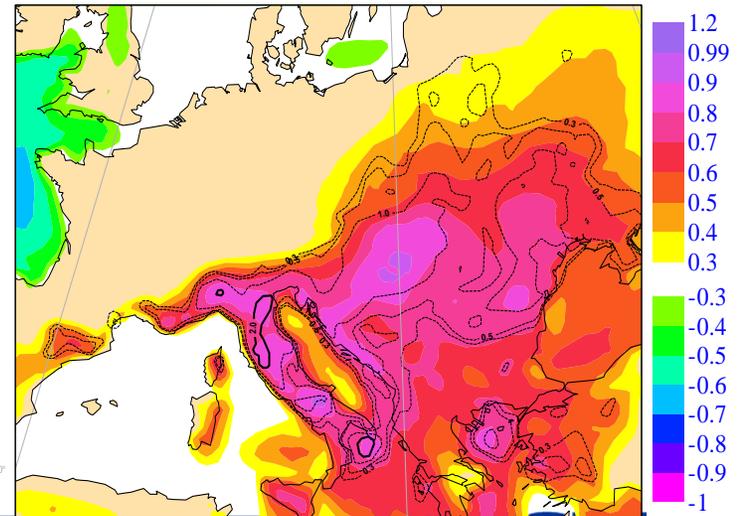


EPS prob, 2m max temp gt Q95, VT:20070720, t+240



D10

EFI, 2m max temp, VT:20070720, t+240



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**

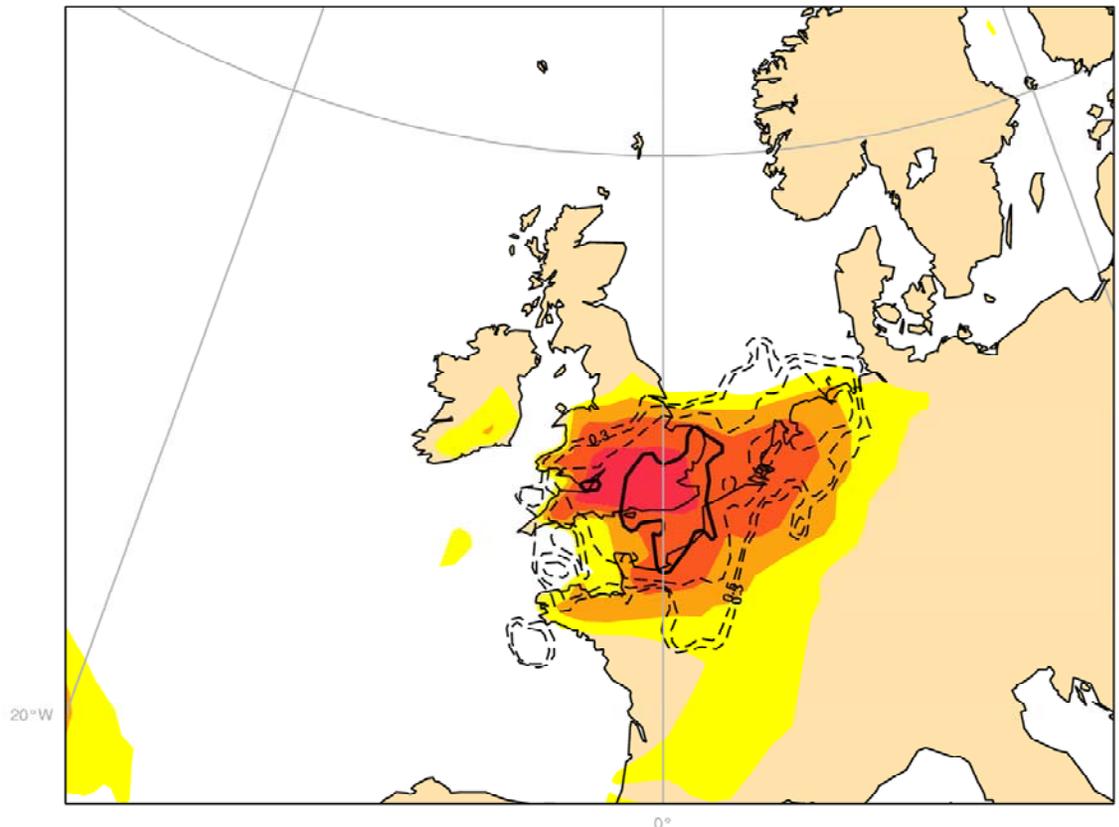


Severe rainfall and flooding over southern UK 20 July 2007

**Extreme forecast index for 24-hour total precipitation
EPS from 20070718 00 UTC, valid 20070720 (00-24 UTC)**

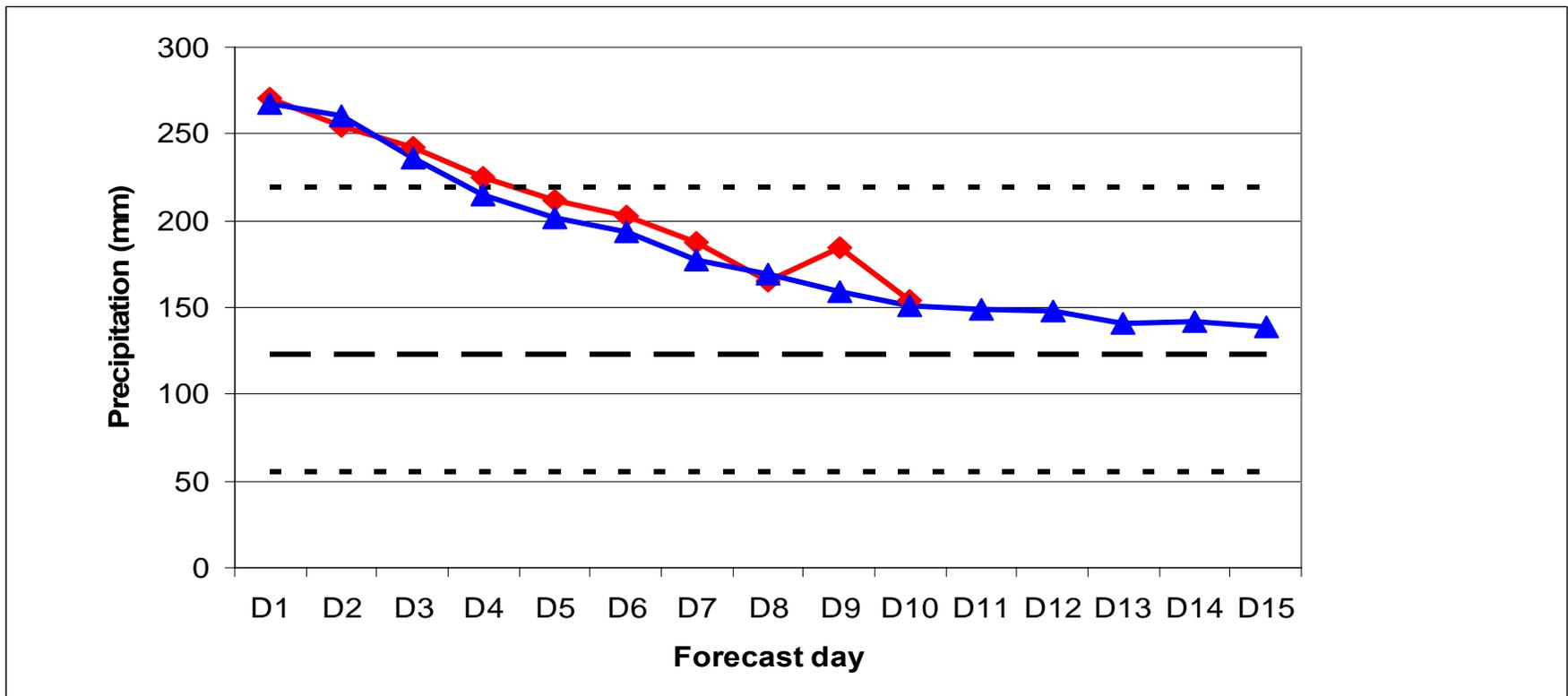
**Heavy rainfall over southern
UK on 20 July 2007.**

**Extreme Forecast Index (EFI)
gives good indication of area
of exceptional precipitation in
72-hour forecast. Shading
shows EFI (higher values
indicate more extreme
events). Contours show the
complementary Shift of Tails
(SOT) index.**



Extreme UK precipitation in June-July 2007

Total precipitation over England and Wales during June-July 2007. The curves show the total rainfall accumulated over all forecasts verifying during June and July for each 24-hour forecast period from the deterministic T799 (red) and EPS ensemble mean (blue). The climatological range of the model forecasts is shown using the 30-year set of one-day forecasts used to generate the EFI climatology. The minimum, maximum (dotted) and mean (dashed) totals are shown.



Severe weather: storm Britta 1 November 2006

- **An intense low pressure system brought a persistent northerly flow over the North Sea, bringing high waves and a strong storm surge causing damage to shipping and flooding in coastal areas.**
- **Extreme waves and exceptional winds were recorded off Germany's North Sea coast.**
- **Hamburg authorities closed floodgates to prevent more damage.**
- **The EFI gave an early warning of strong winds and waves four days before the event in both the North Sea and the Baltic.**



Flooding in Hamburg (Photo Spiegel.de)

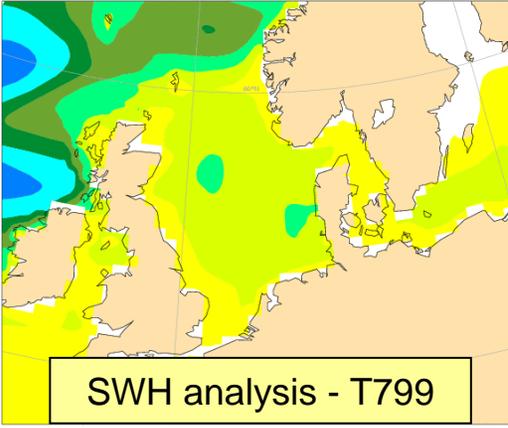


Dredger stranded in Wilhemshaven

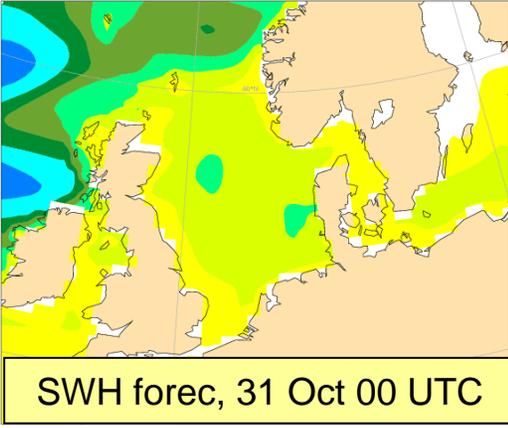
Significant Wave height and MSLP

31 October - 1 November 2006, every 6 hour

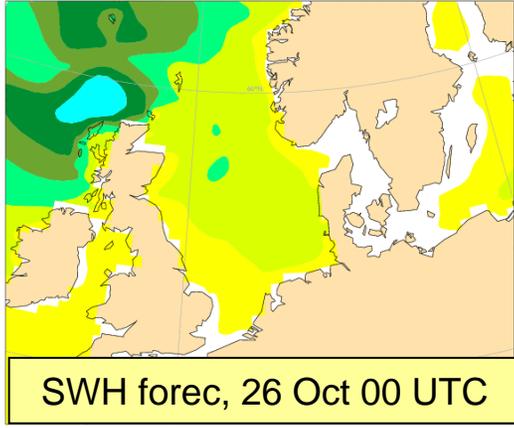
ECMWF Analysis VT: Tuesday 31 October 2006 00UTC Surface: significant wave height



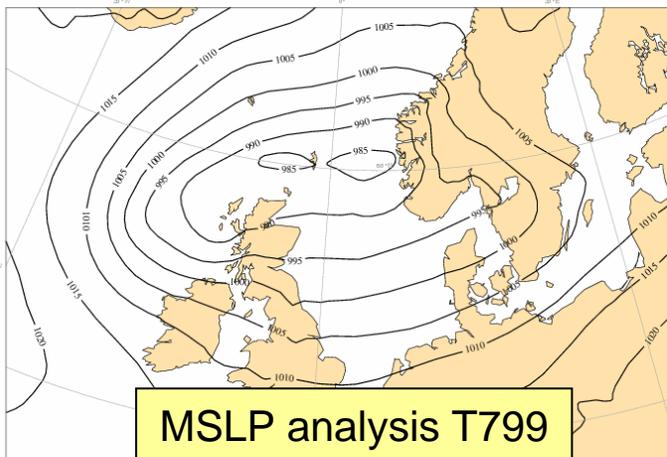
Tuesday 31 October 2006 00UTC ECMWF Forecast +0 VT: Tuesday 31 October 2006 00UTC Surface: significant wave height



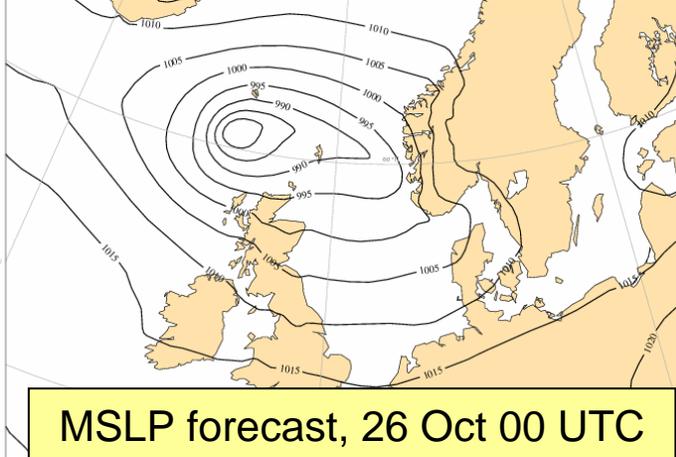
Thursday 26 October 2006 00UTC ECMWF Forecast +120 VT: Tuesday 31 October 2006 00UTC Surface: significant wave height



ECMWF Analysis VT: Tuesday 31 October 2006 00UTC Surface: Mean sea level pressure



Thursday 26 October 2006 00UTC ECMWF Forecast +120 VT: Tuesday 31 October 2006 00UTC Surface: mean sea level pressure



- Fast moving deep low with persistent and very strong northerly flow
- High waves, also close to the shores, peak of the event is 00-06 UTC on 1 Nov
- D+6 T799 forecast was really good forecasting the situation and the wave heights

Severe weather: large swell reaching la Réunion

- **Large waves reached La Reunion during the day on May 12th, 2007.**
- **Averaged wave heights of the order of 2-4m were observed during the day, increasing to 5-6m at night time (local time).**
- **Some largest waves, up to 10-11m, were reported.**
- **Two fishermen were lost at sea.**
- **Coastal flooding and severe damages were reported on the west and south coasts.**



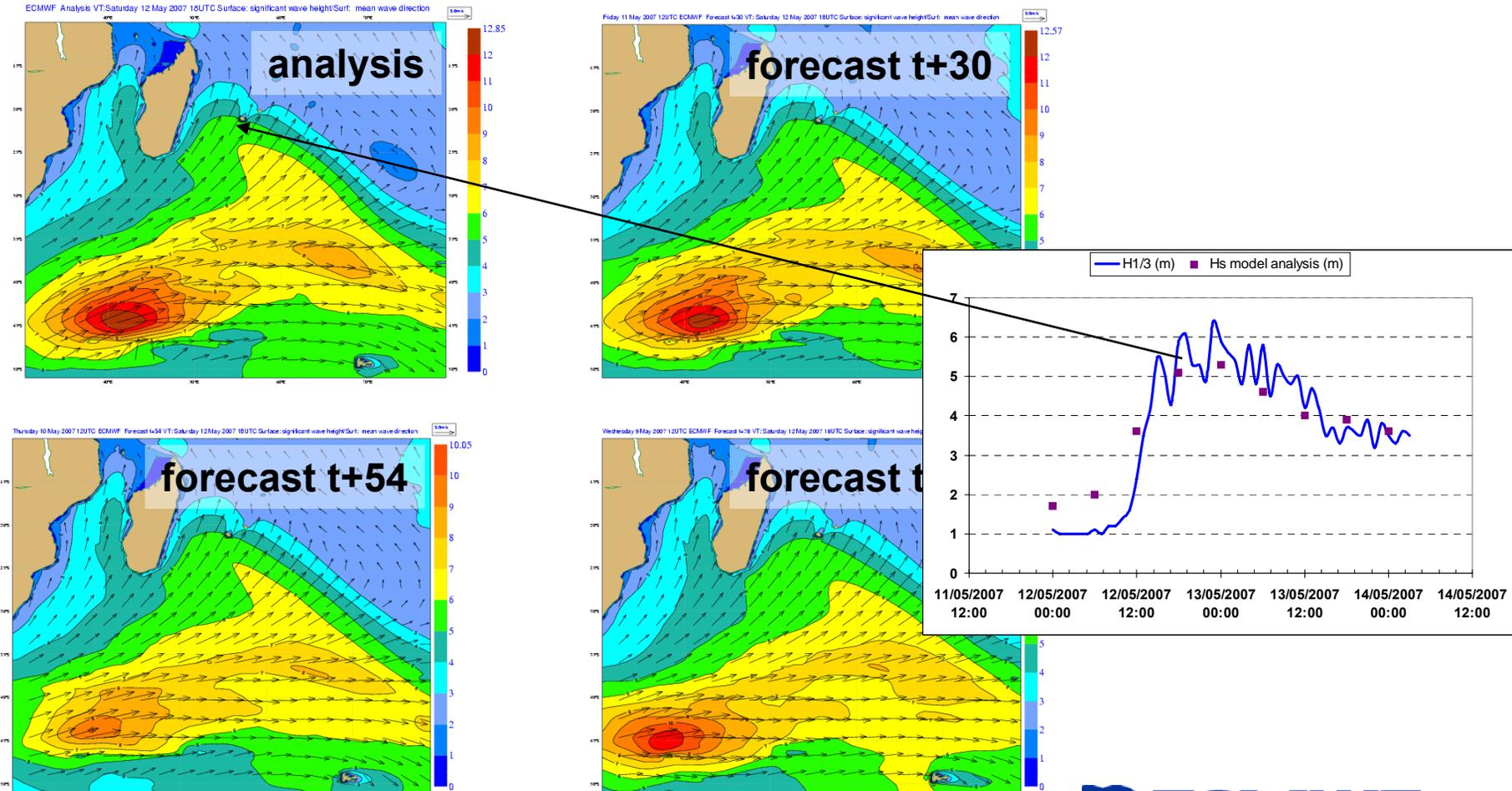
Photo courtesy of CLICANOO



Remains of a fishing boat destroyed by high waves (AFP photo).

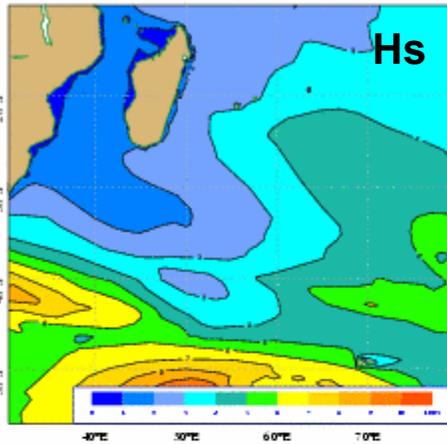
Severe weather - large swell at la Réunion

Significant wave height and mean propagation direction valid on May 12, 18UTC. The model has nicely predicted significant wave height in excess of 5m in the evening of the 12th. Combined with long period, it can generate quite a long wave runup on the coast.

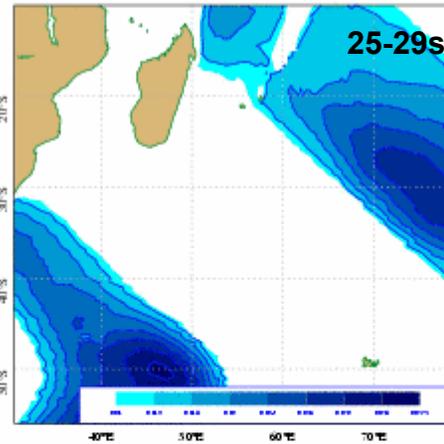


Large swell reaching Ia Réunion: the model

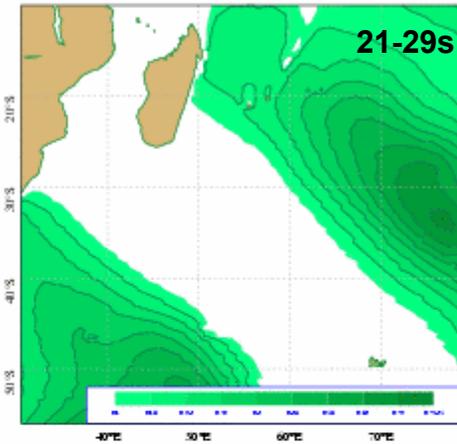
ECMWF Analysis V1 Thursday 10 May 2007 00UTC Surface significant wave height
Significant wave height (m)



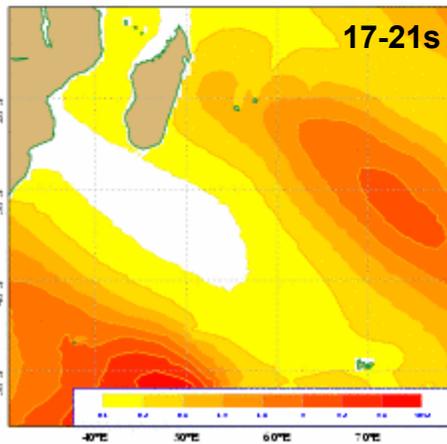
Wave energy (in terms of wave height) for waves
with periods between 25 and 29 sec. (1000 to 13000 m wavelength)



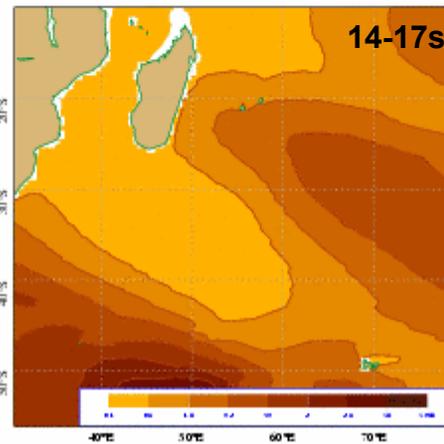
Wave energy (in terms of wave height) for waves
with periods between 21 and 25 sec. (700 to 1000 m wavelength)



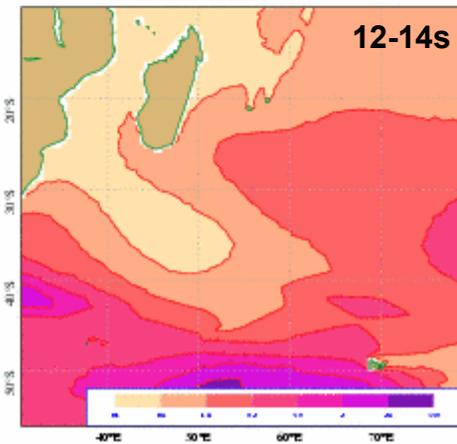
Wave energy (in terms of wave height) for waves
with periods between 17 and 21 sec. (450 to 700 m wavelength)



Wave energy (in terms of wave height) for waves
with periods between 14 and 17 sec. (300 to 450 m wavelength)



Wave energy (in terms of wave height) for waves
with periods between 12 and 14 sec. (225 to 300 m wavelength)

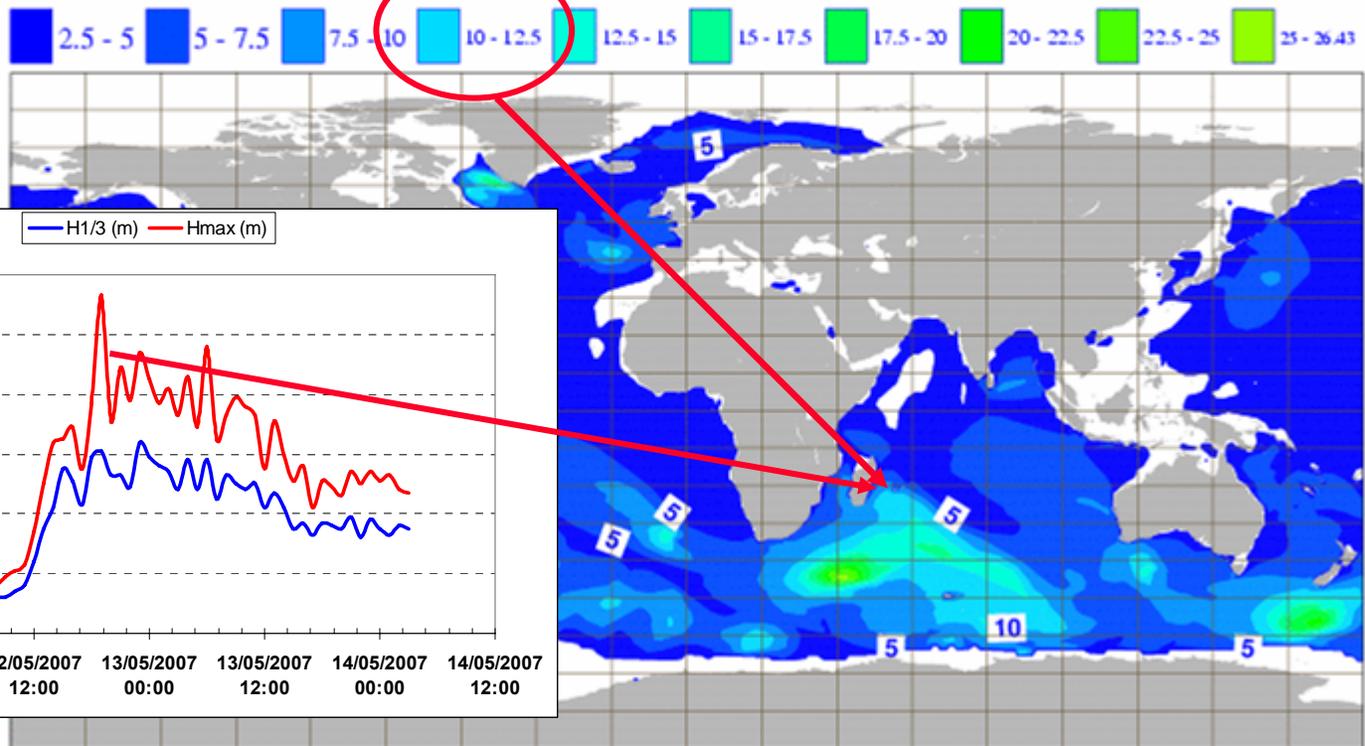


Large swell reaching la Réunion: the model

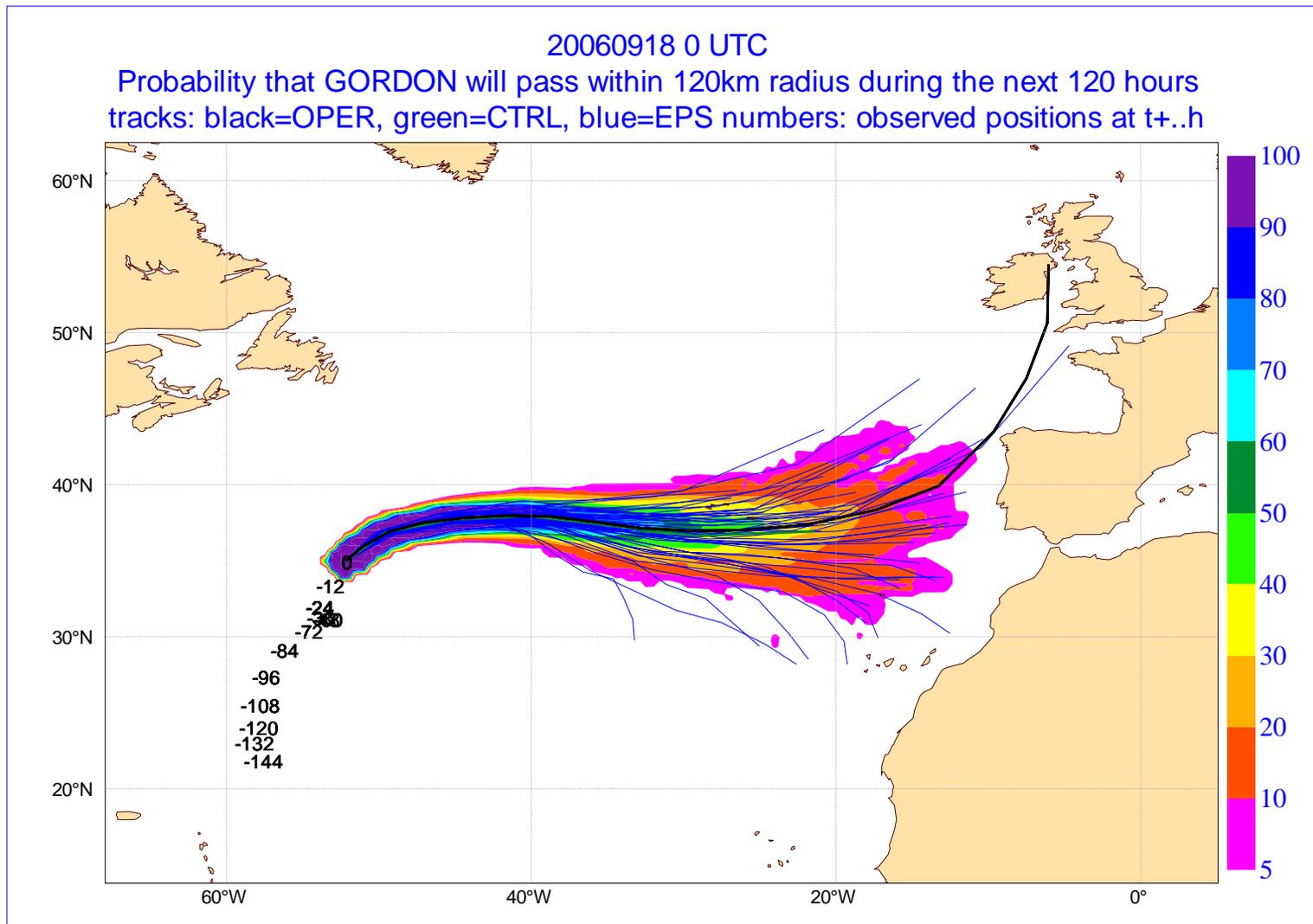
A new parameter is being developed. Namely the maximum wave height that can be expected within a certain time window (here 3 hours).

New parameter: Maximum wave height on May 12, 18UTC

HS_MAX AN on 2007051218 STEP=00



Tropical cyclones - hurricane Gordon



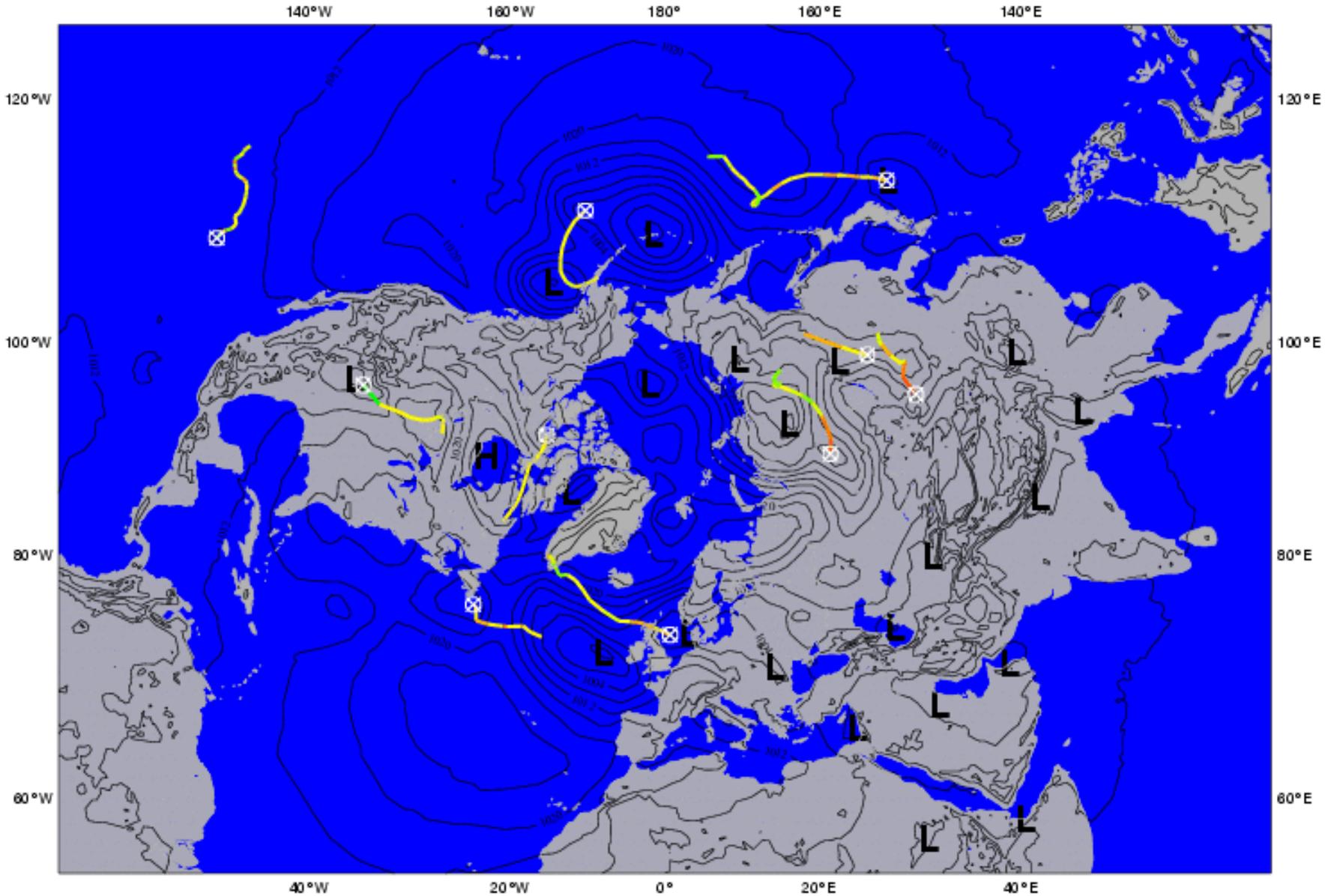
June 2007: Tropical cyclone Gonu

- **Strongest TC on record in the Arabian Sea**
- **Oman evacuated 20,000 people prior to its arrival**
- **Nevertheless, there were 50 fatalities in Oman**
- **Well predicted by 1/3 EPS members 8 days in advance**



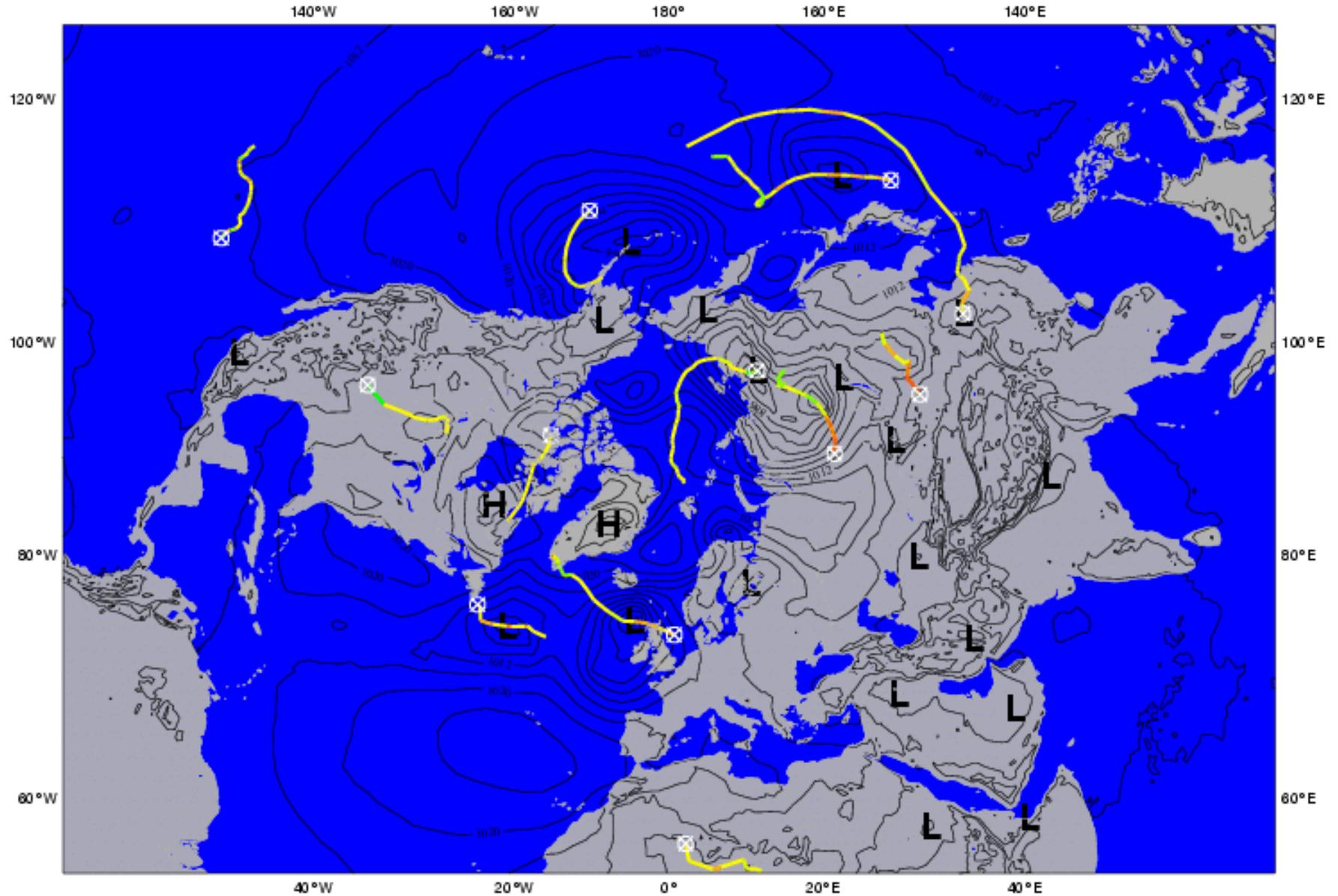
Cyclone Tracks

Basedate: 20070530 12UTC **t + 0h**



Cyclone Tracks

Basedate: 20070530 12UTC **t + 24h**



Cyclone Tracks

Basedate: 20070530 12UTC **t + 48h**

140°W 160°W 180° 160°E 140°E

120°W

120°E

100°W

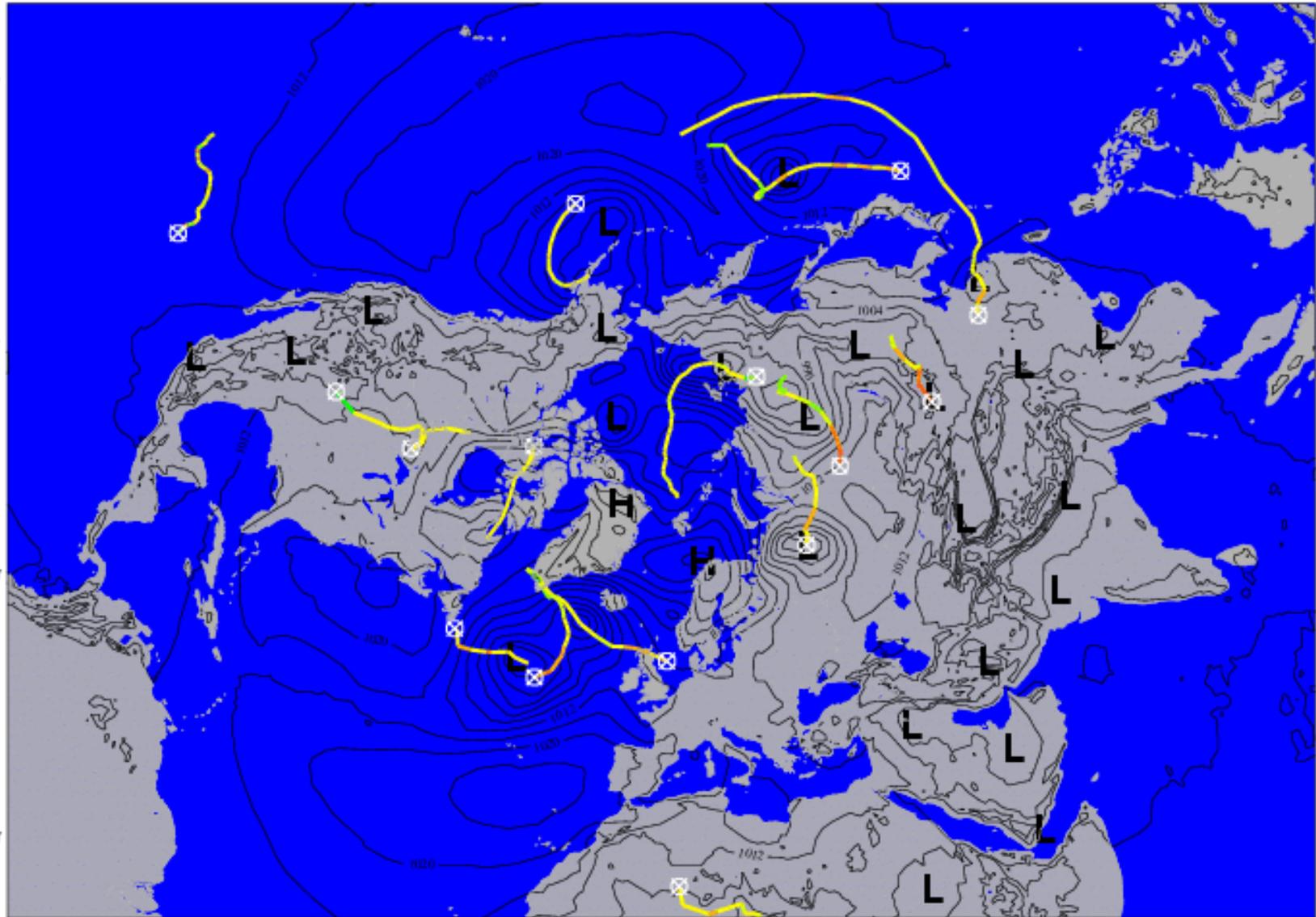
100°E

80°W

80°E

60°W

60°E



40°W

20°W

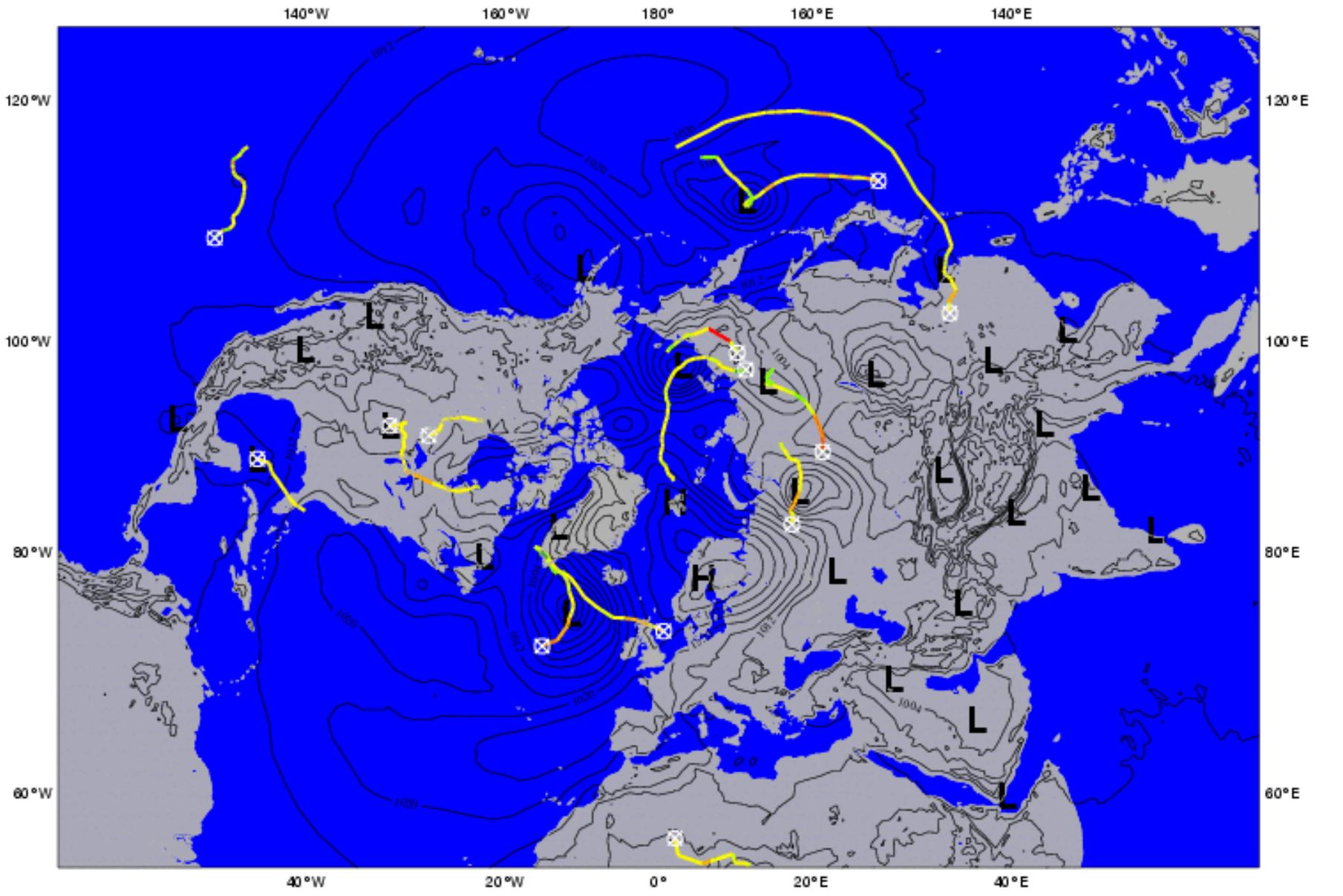
0°

20°E

40°E

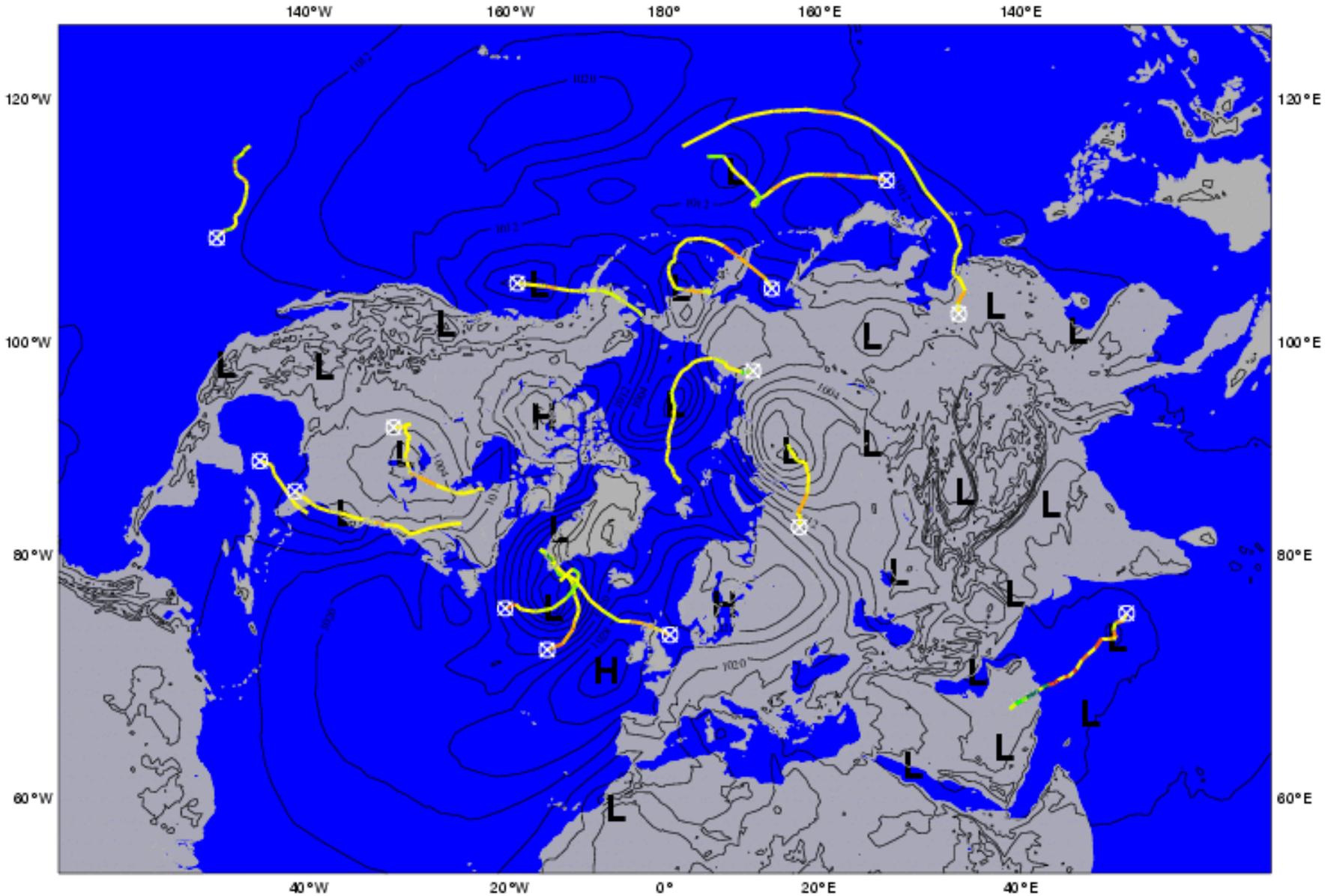
Cyclone Tracks

Basedate: 20070530 12UTC **t + 72h**



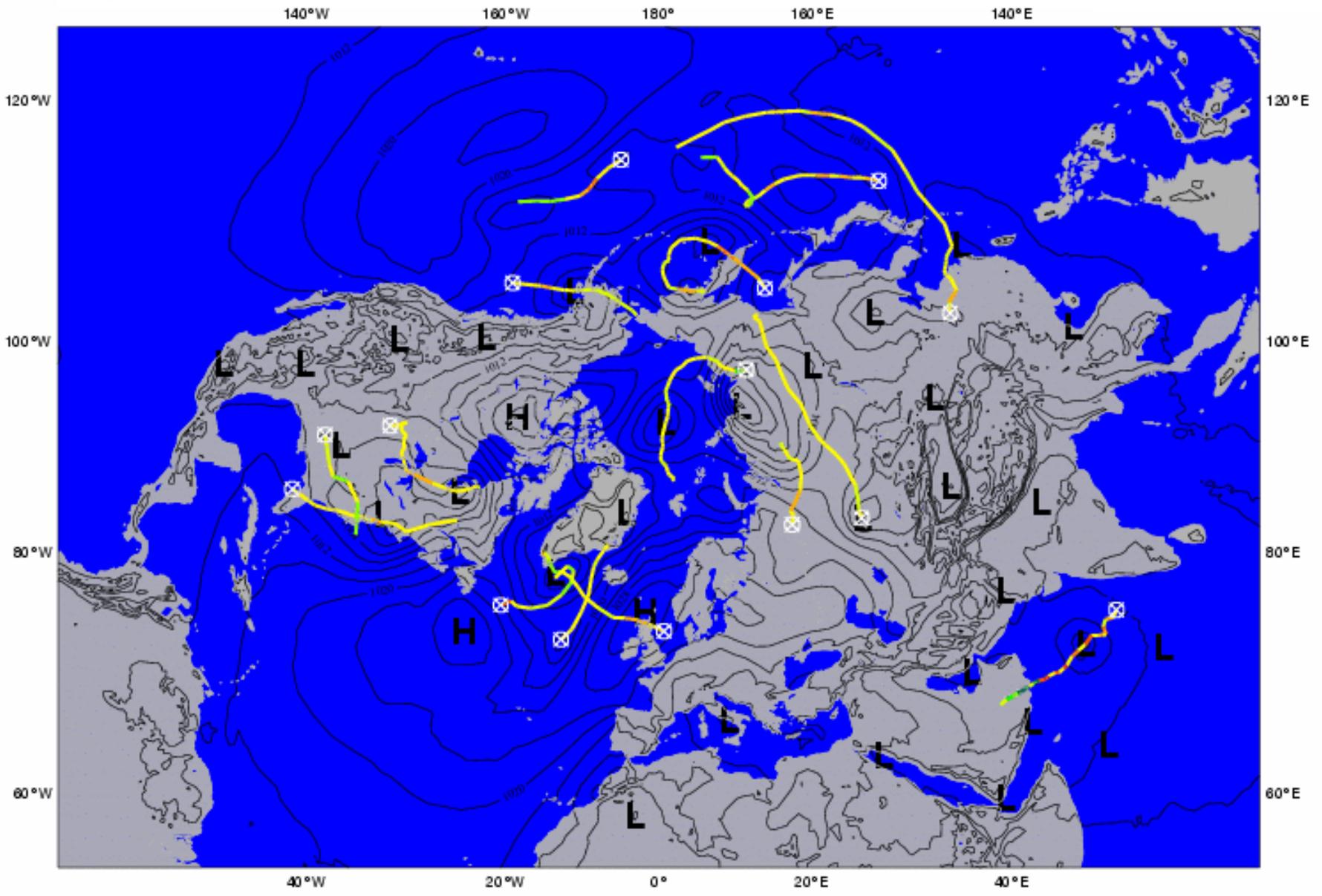
Cyclone Tracks

Basedate: 20070530 12UTC **t + 120h**



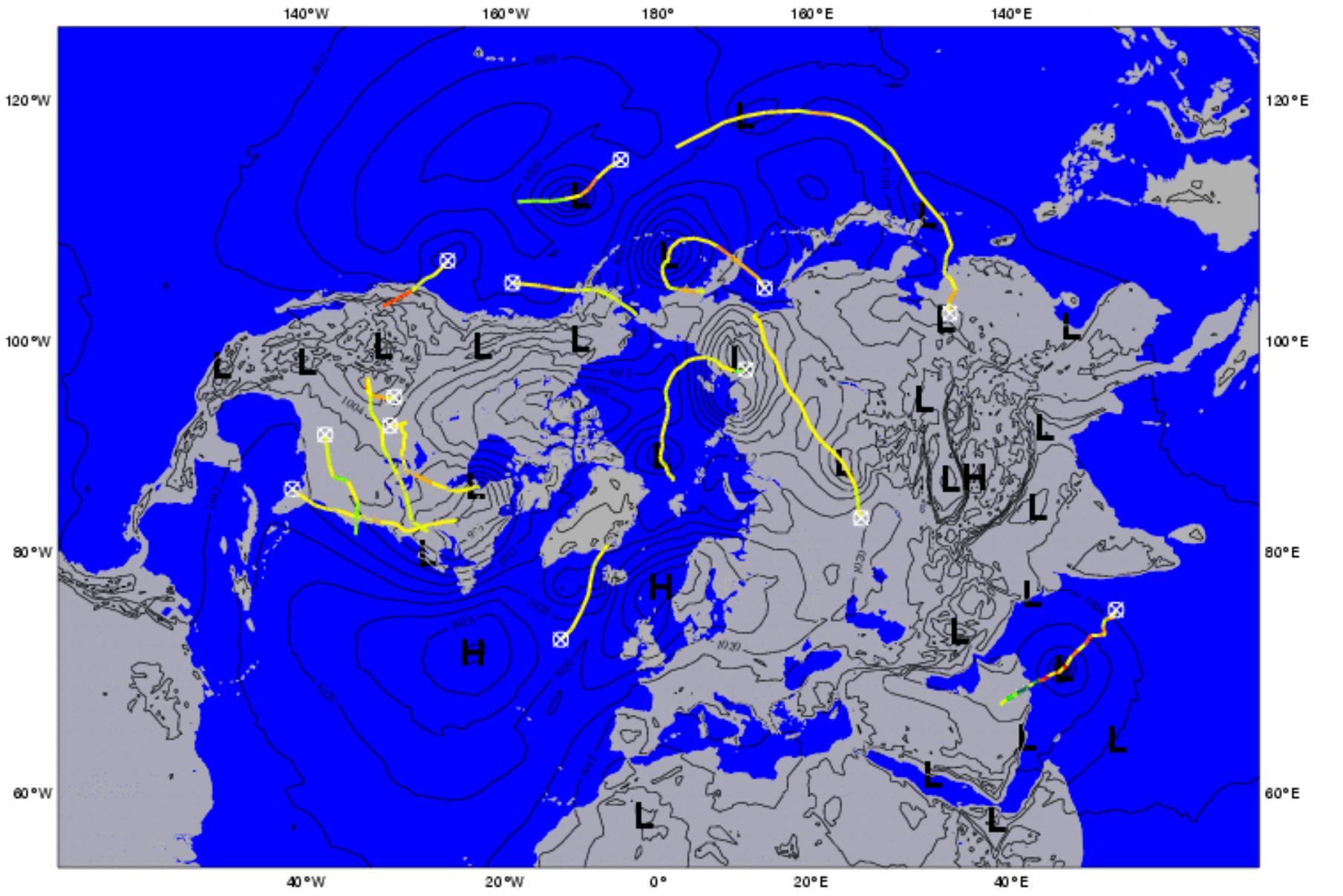
Cyclone Tracks

Basedate: 20070530 12UTC **t + 144h**



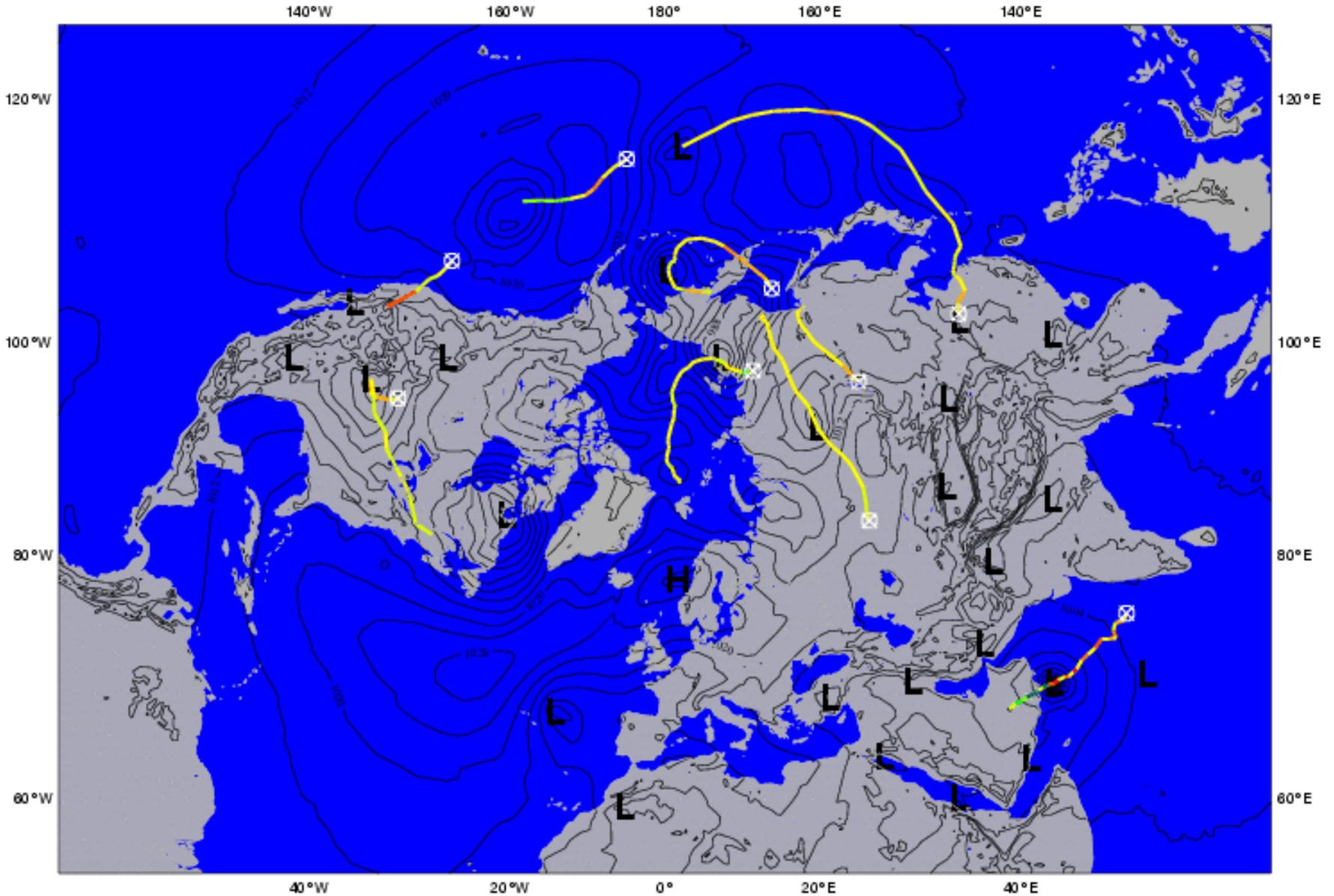
Cyclone Tracks

Basedate: 20070530 12UTC **t + 168h**



Cyclone Tracks

Basedate: 20070530 12UTC **t + 192h**



Cyclone Tracks

Basedate: 20070530 12UTC **t + 216h**

140°W 160°W 180° 160°E 140°E

120°W

120°E

100°W

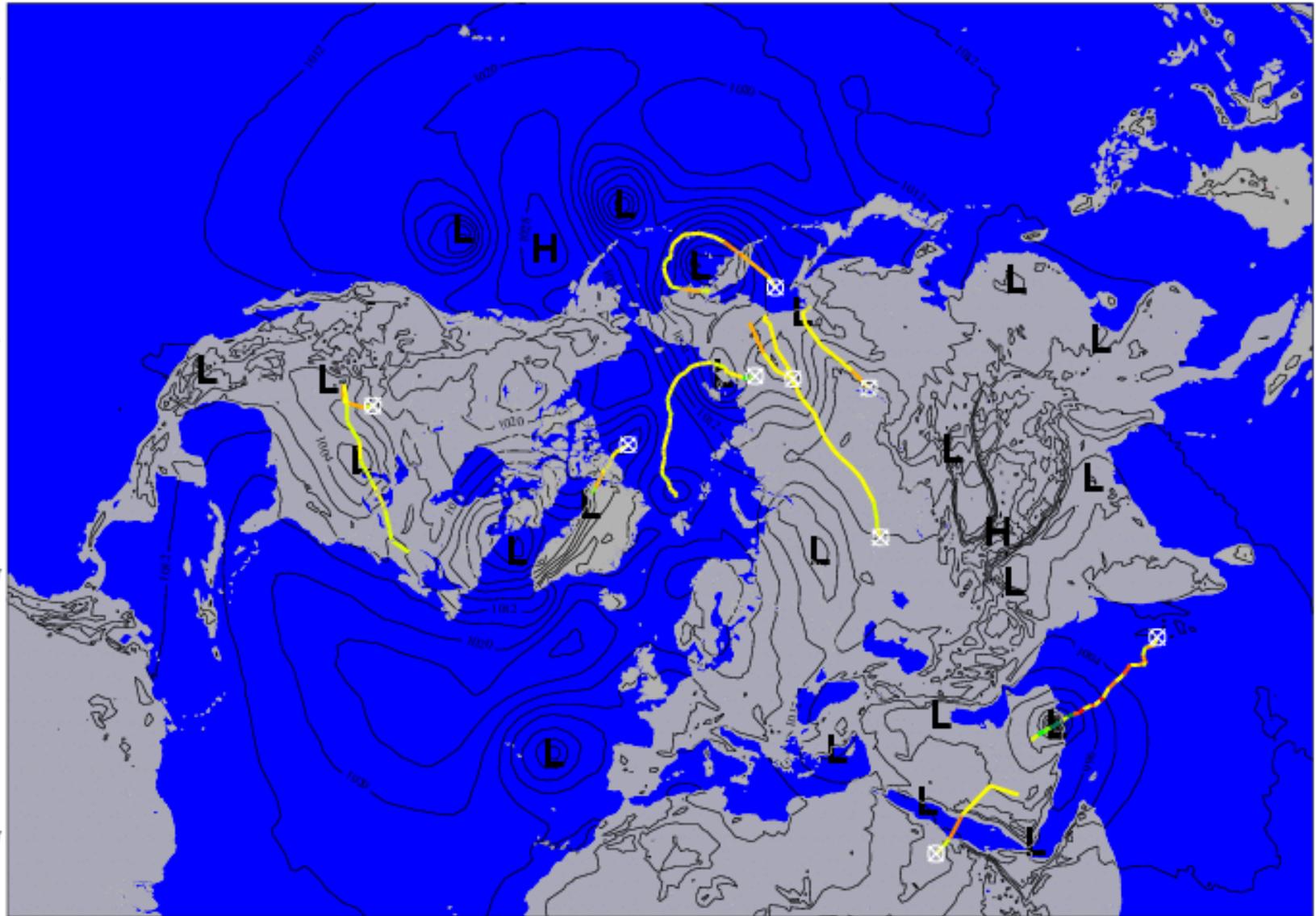
100°E

80°W

80°E

60°W

60°E



40°W

20°W

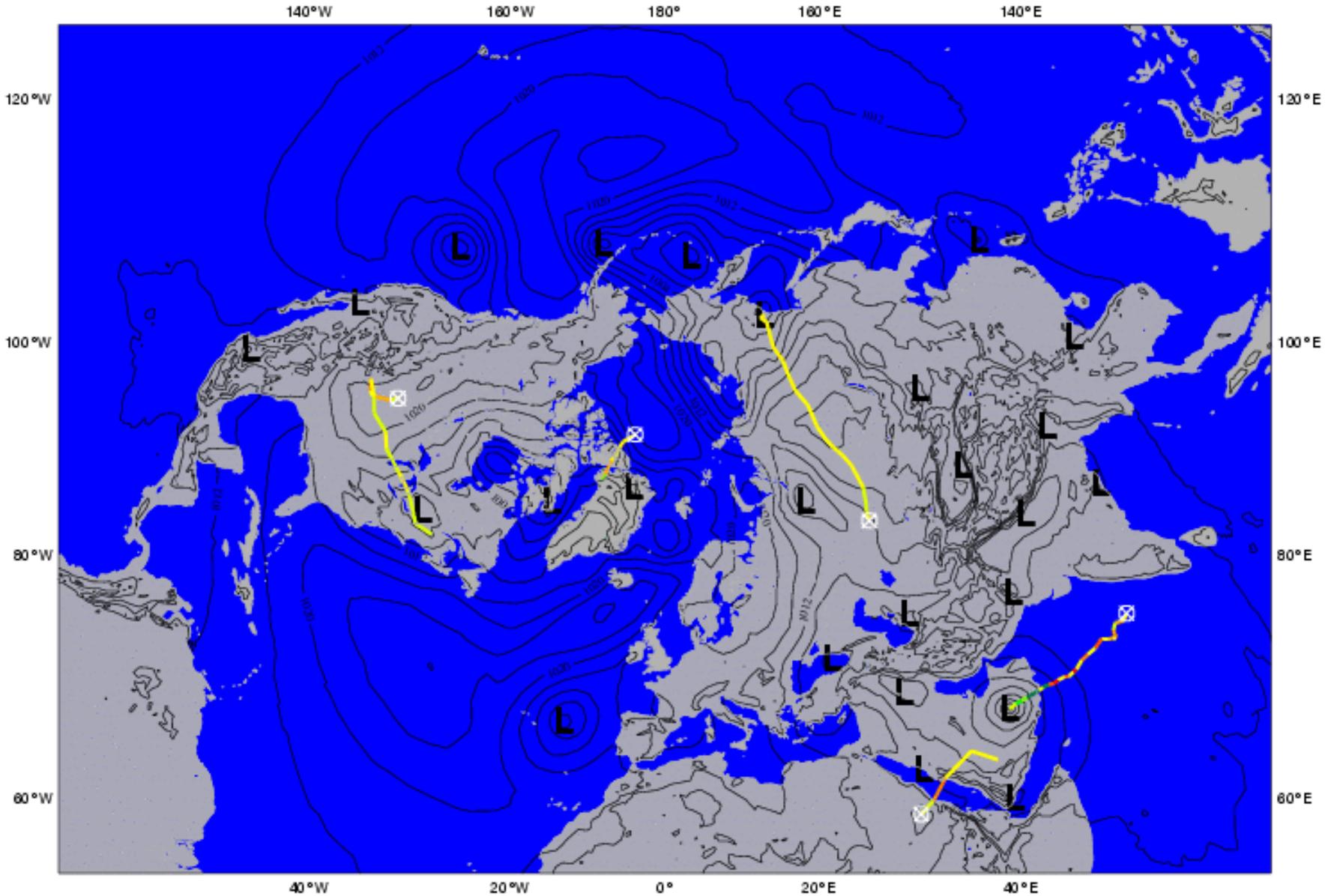
0°

20°E

40°E

Cyclone Tracks

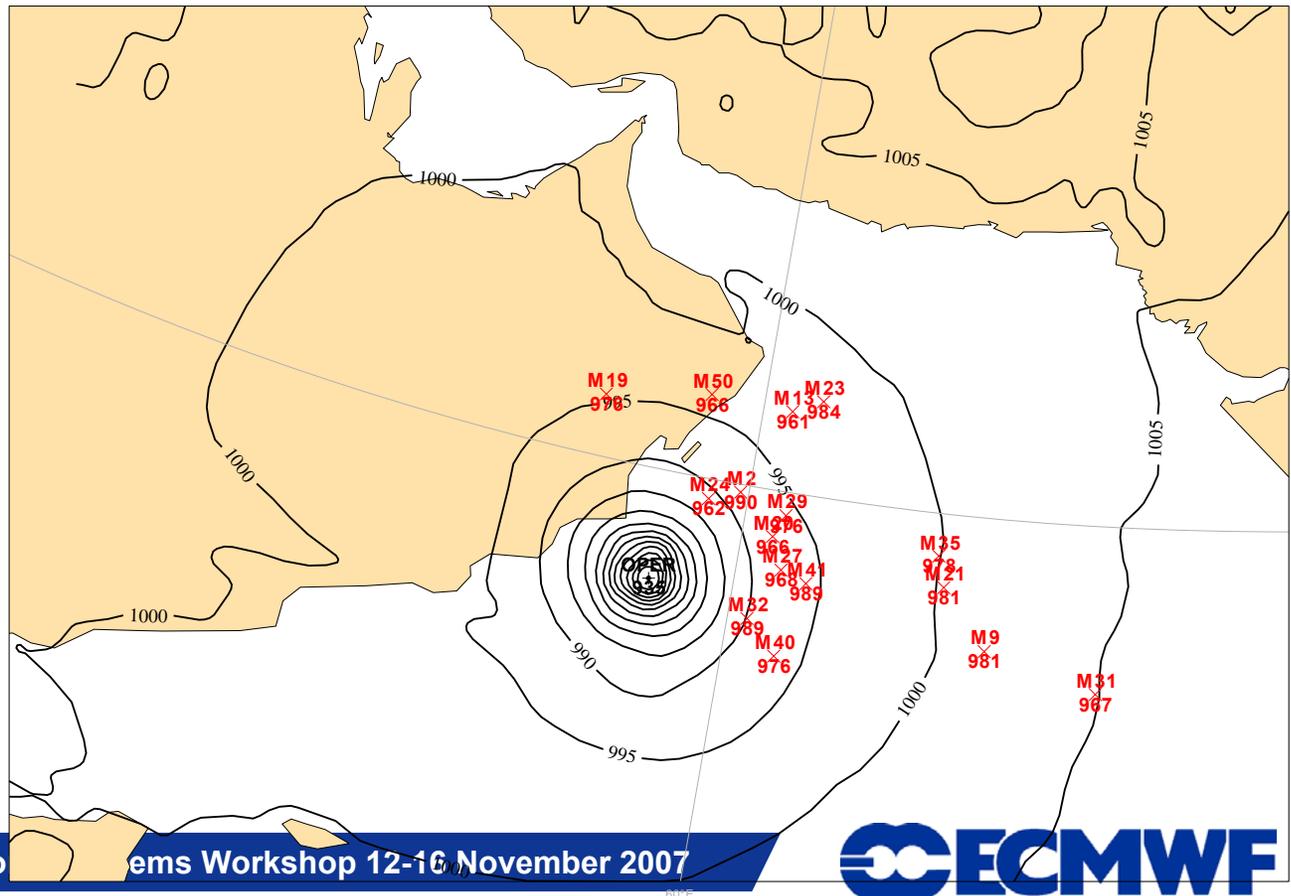
Basedate: 20070530 12UTC **t + 240h**



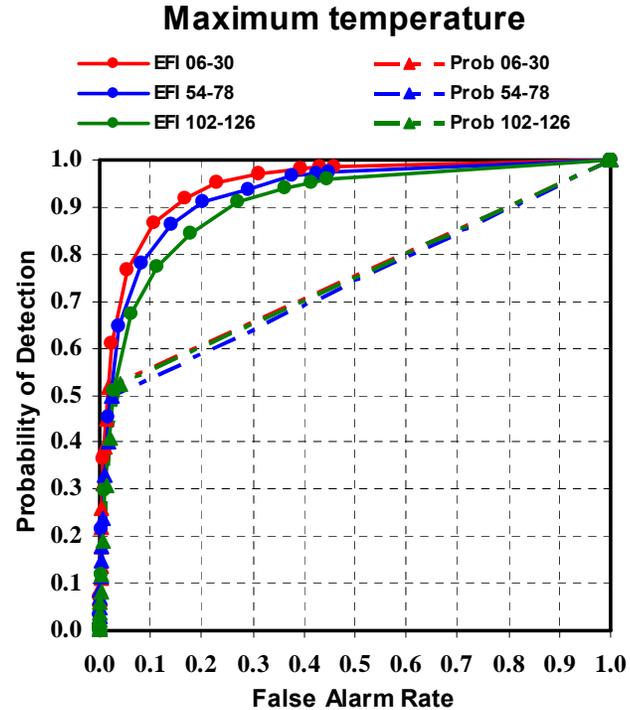
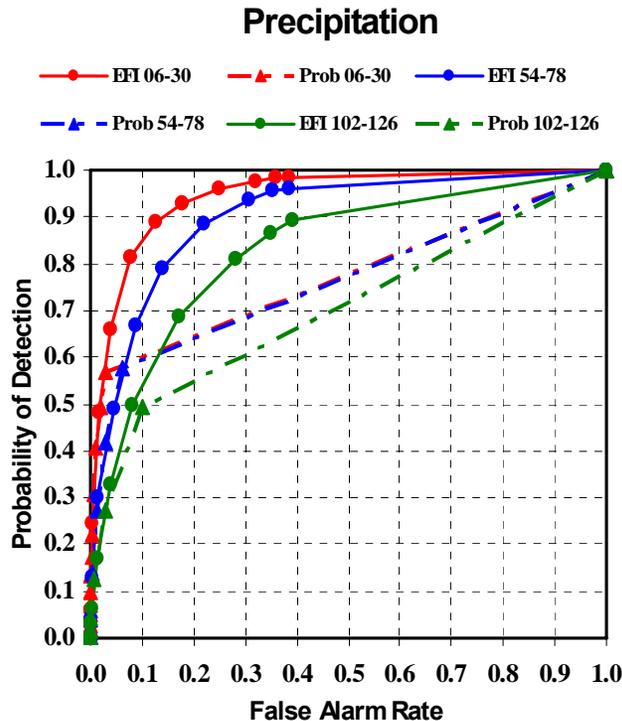
Tropical cyclone Gonu

TC predicted by approx 1/3 of EPS members (8-day forecast)

Observed intensity of Tropical Cyclone compared with the following forecasts:
Operational (black), All EPS members (red)
Forecast based on: 2007-05-30 at 00UTC, VT: 2007-06-07 06UTC (+198h)



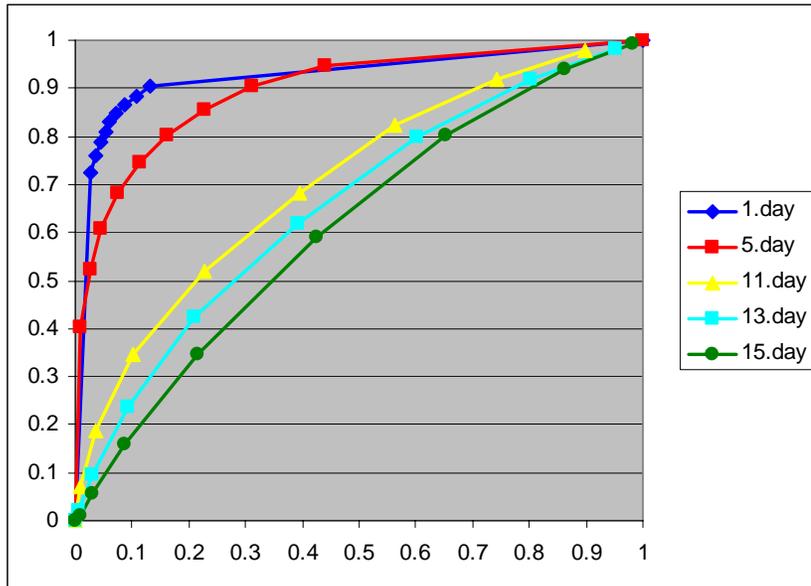
Extreme Forecast Index (EFI) verification



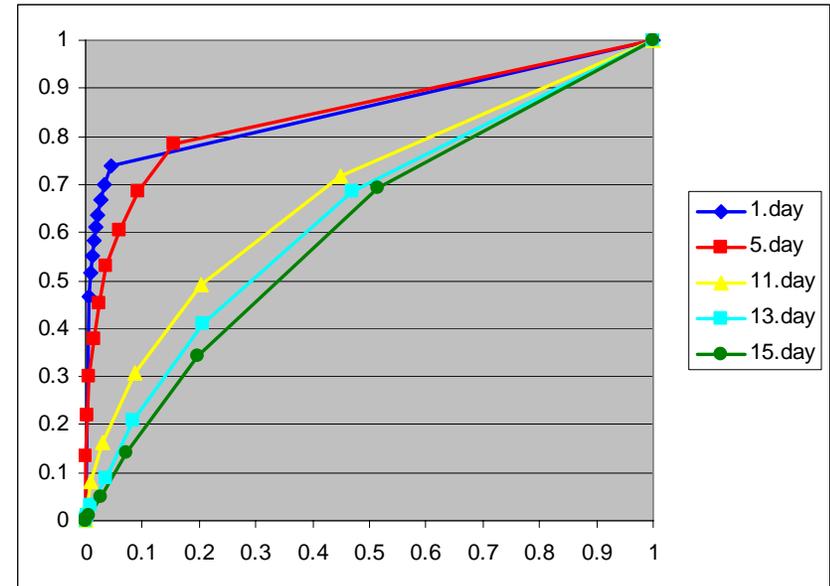
ROC verification of daily rainfall and maximum temperature exceeding the 99.5% threshold of the EUMETNET/ECSN station climatology. The performance using different thresholds of the EFI (solid lines) is compared to that using EPS probabilities of the event (dashed lines). Each colour is for a different forecast range: day 1 (red), day 3 (blue), day 5 (green). Sample contains all events over the period July 2005 to May 2006.

ROC for maximum temperature, spring 2007

Probability for the 67th percentile



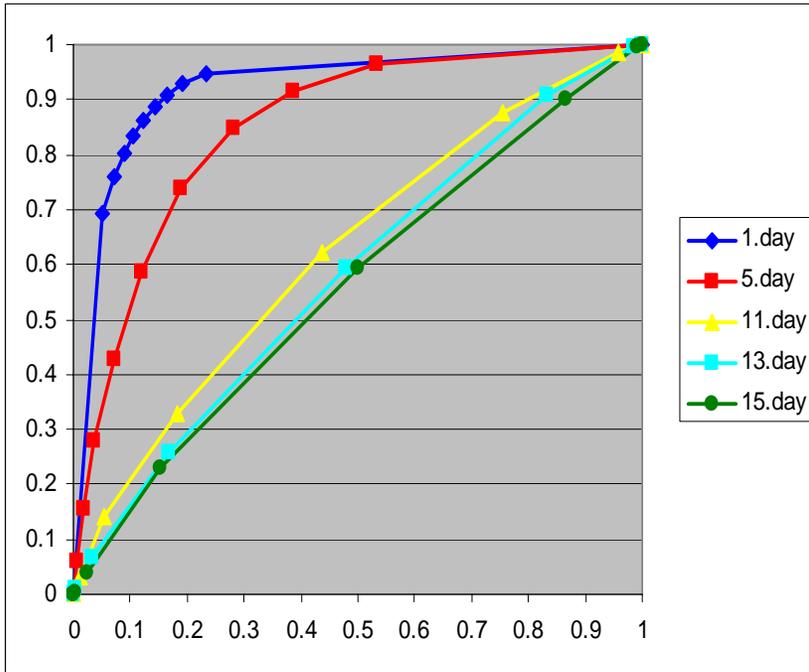
Probability for the 90th percentile



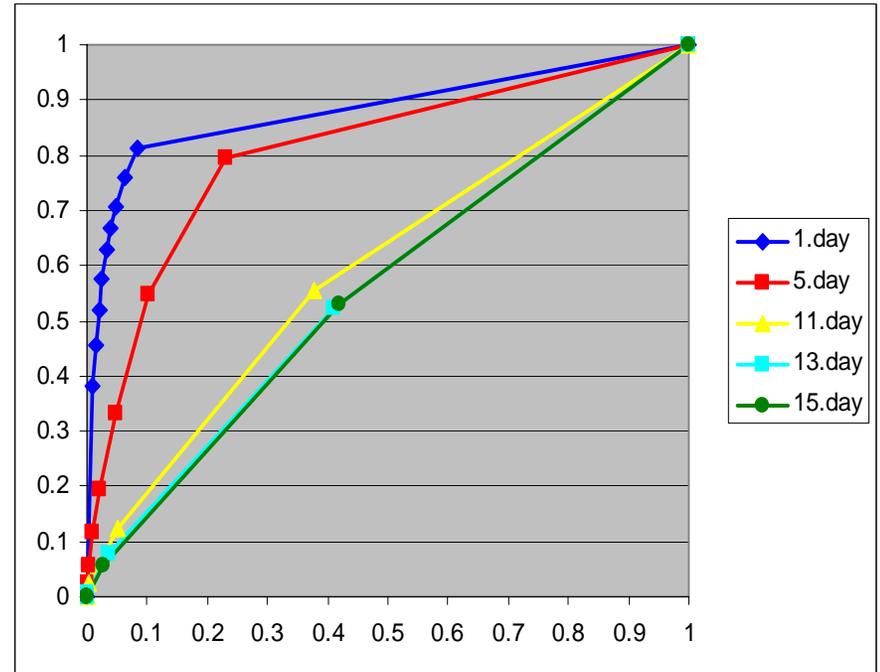
Verification of EPS forecasts of maximum temperature over Europe in spring 2007. Verification against SYNOP observations, forecast relative to EFI climatology

ROC for precipitation, spring 2007

Probability for the 67th percentile



Probability for the 90th percentile

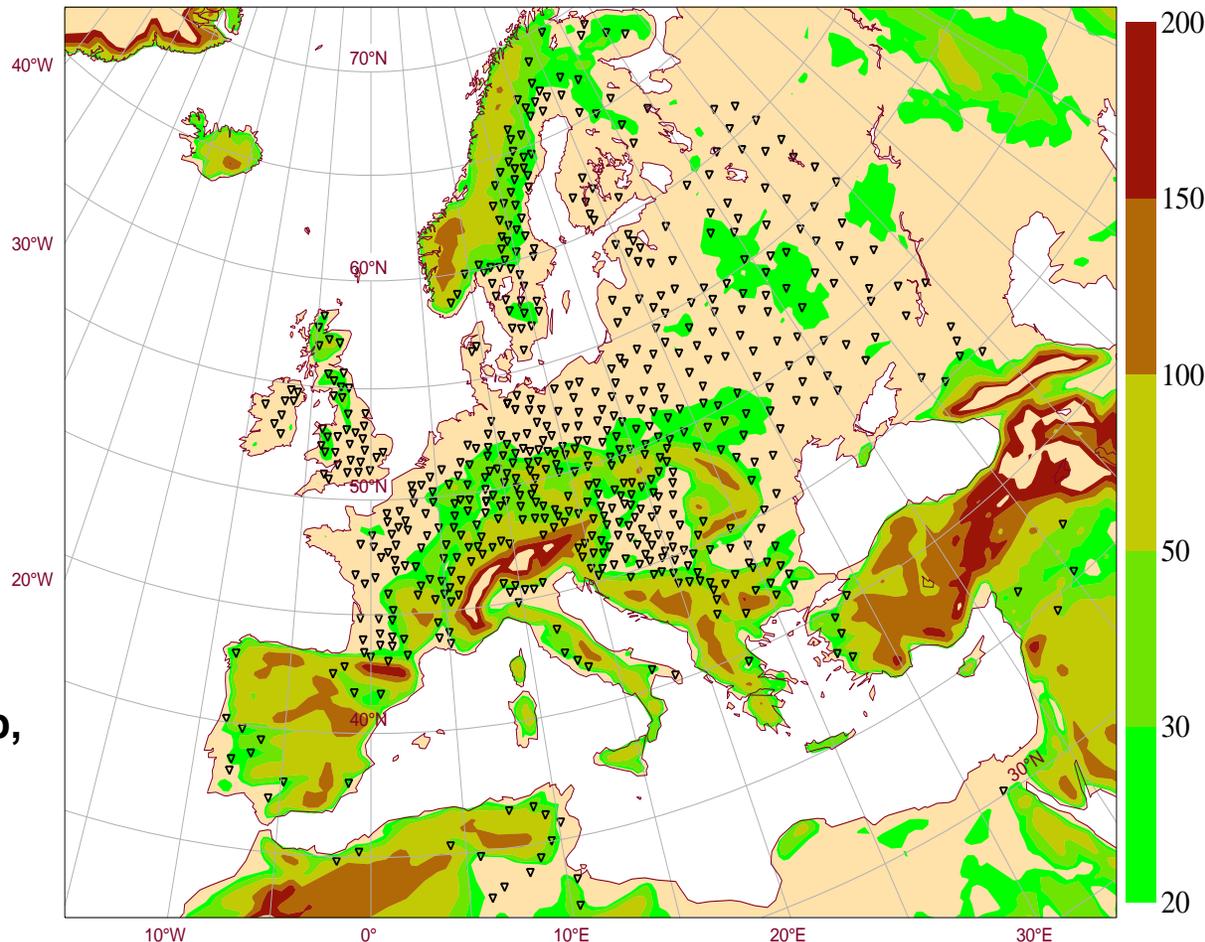


Verification of EPS forecasts of precipitation over Europe in spring 2007. Verification against SYNOP observations, forecast relative to EFI climatology

Verification against SYNOP observations

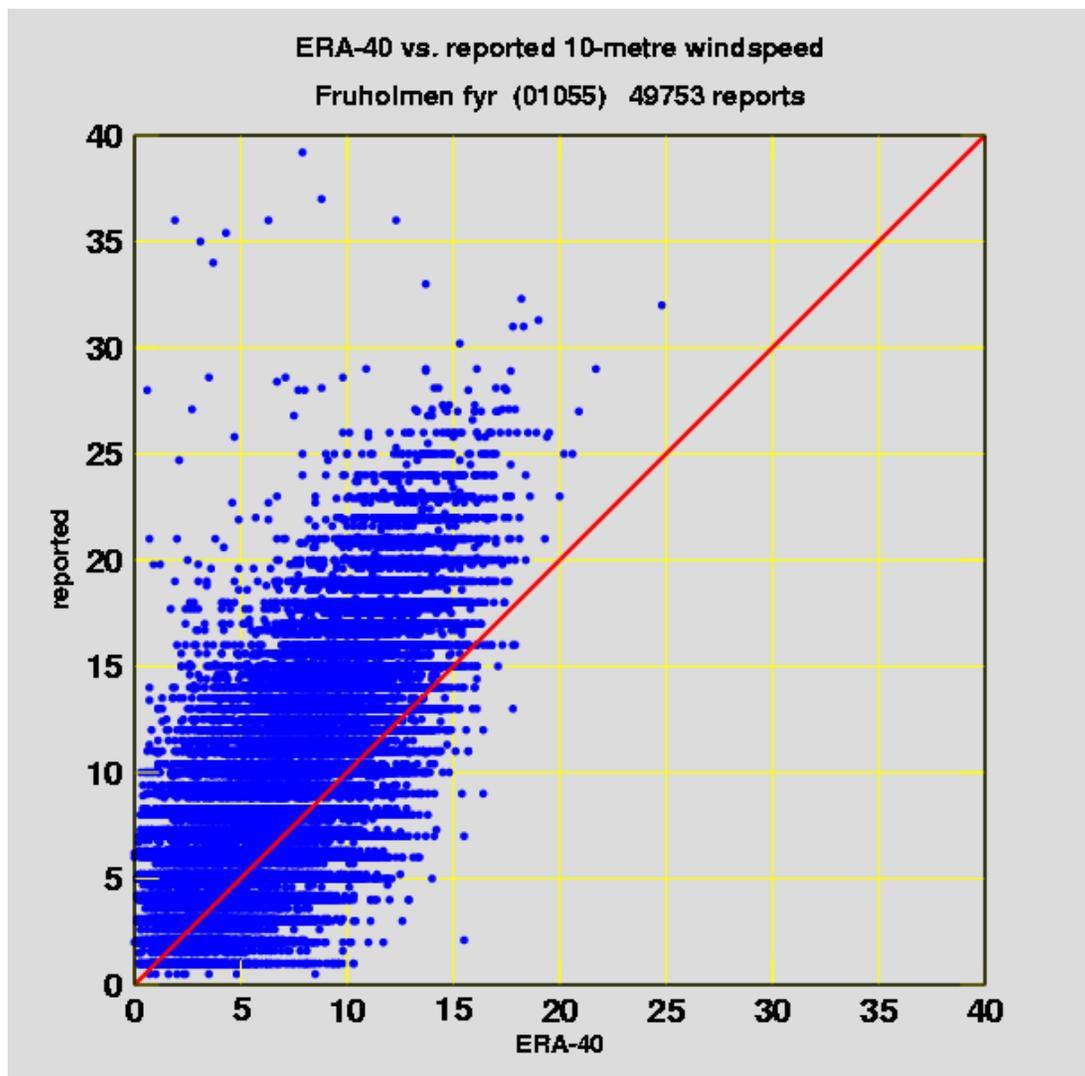
- **Inhomogeneous sample**
 - orography check (<500 m)
 - Exclude coastal areas
 - Altogether ~ 600 stations
- **The climate was taken as the “EFI” climatology throughout the 15-day forecast period (always the short range EPS control re-forecast 1971-2000)**
- **Parameters used in 15-day EPSgram – 24h max, min temp, total precip, wind**

Selected SYNOP stations with the T799 orography height



Model and observations

- **Model gridbox values are not directly comparable to point observations**
- **Post-processing or downscaling needed**



Per Kalberg, SMHI

Working Group – use and interpretation Severe or high-impact weather events

- **What products will help users in providing early warnings of severe events?**
- **What should we expect from the forecasting system at 3 days, 1 week, 1 month, 1 season?**
- **How important is post-processing/calibration of model data?**
- **How can we verify early warnings of severe weather?**
 - **Extreme/rare events**
 - **Sample size**
 - **Observations - how do we know what happened?**
 - **Extrapolate from moderate events**
 - **What scores to use**
- **How should case studies be used (consider false alarms and missed events)?**