Medium-range Ensemble Forecasts at the Met Office

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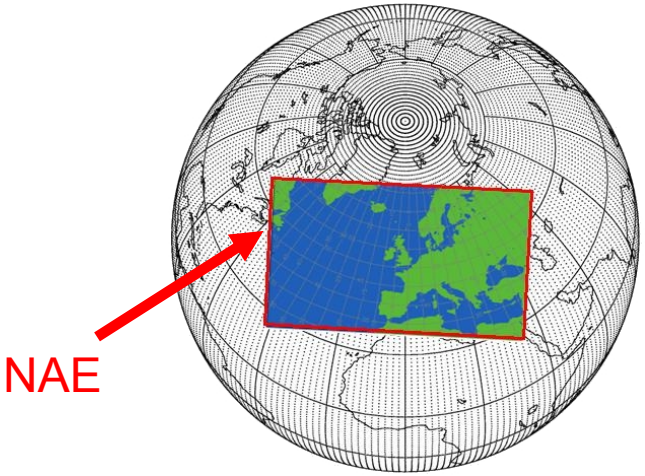
ECMWF workshop on Ensembles

Medium-range ensembles at Met Office

- MOGREPS-15 system - medium-range ensemble forecasts
- Multi-model ensembles
- Forecasting high-impact weather

Met Office Global and Regional EPS, MOGREPS

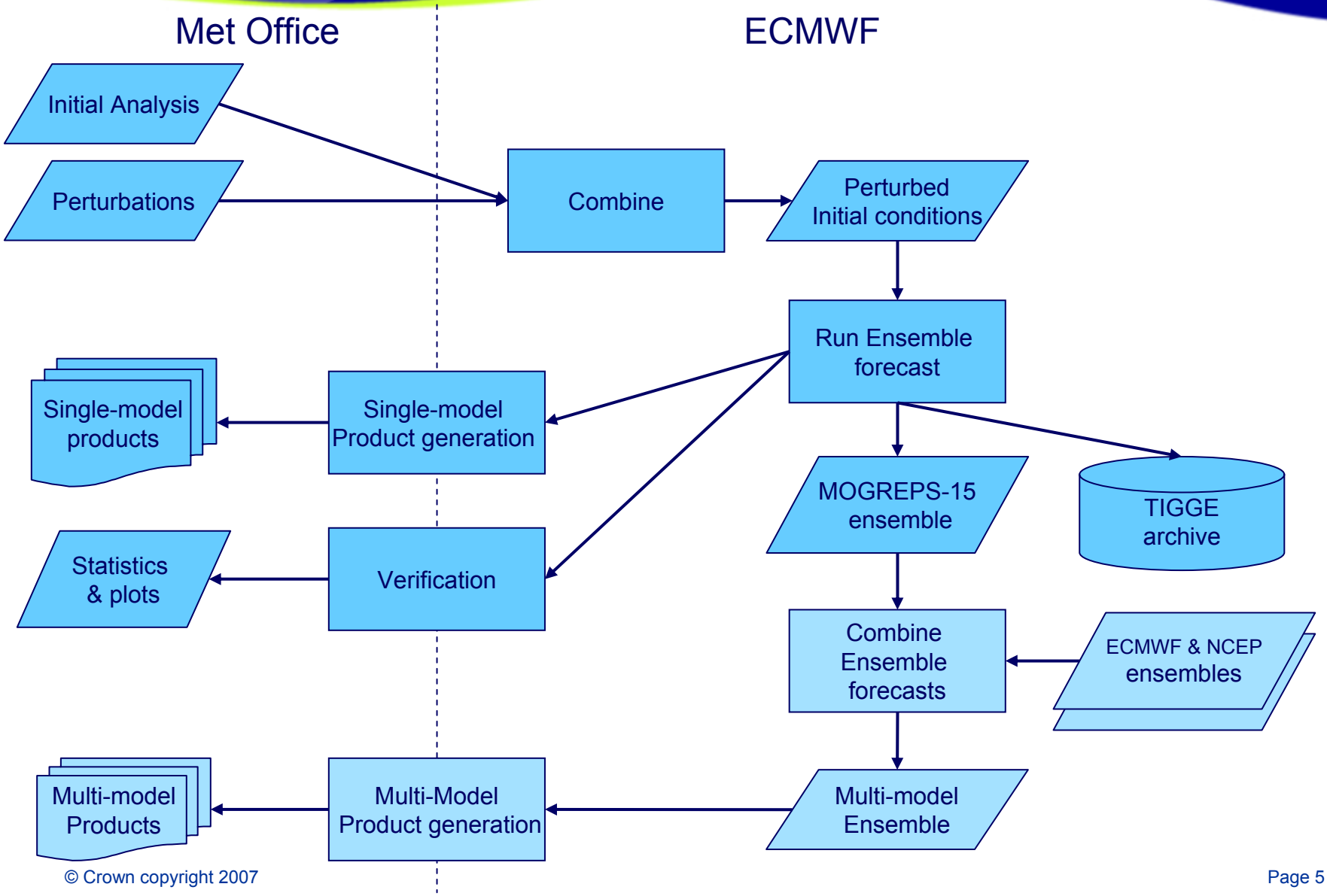
- Ensemble designed for short-range forecasting
  - Regional ensemble over N. Atlantic and Europe (NAE)
  - T+54
  - Aim to assess uncertainty in short-range, eg.:
    - Rapid cyclogenesis
    - Local details (wind etc)
    - Precipitation
    - Fog and cloud
  - Expected to be made fully operational March 2008
  - Nested within global ensemble
  - Local ETKF perturbations
  - Stochastic physics



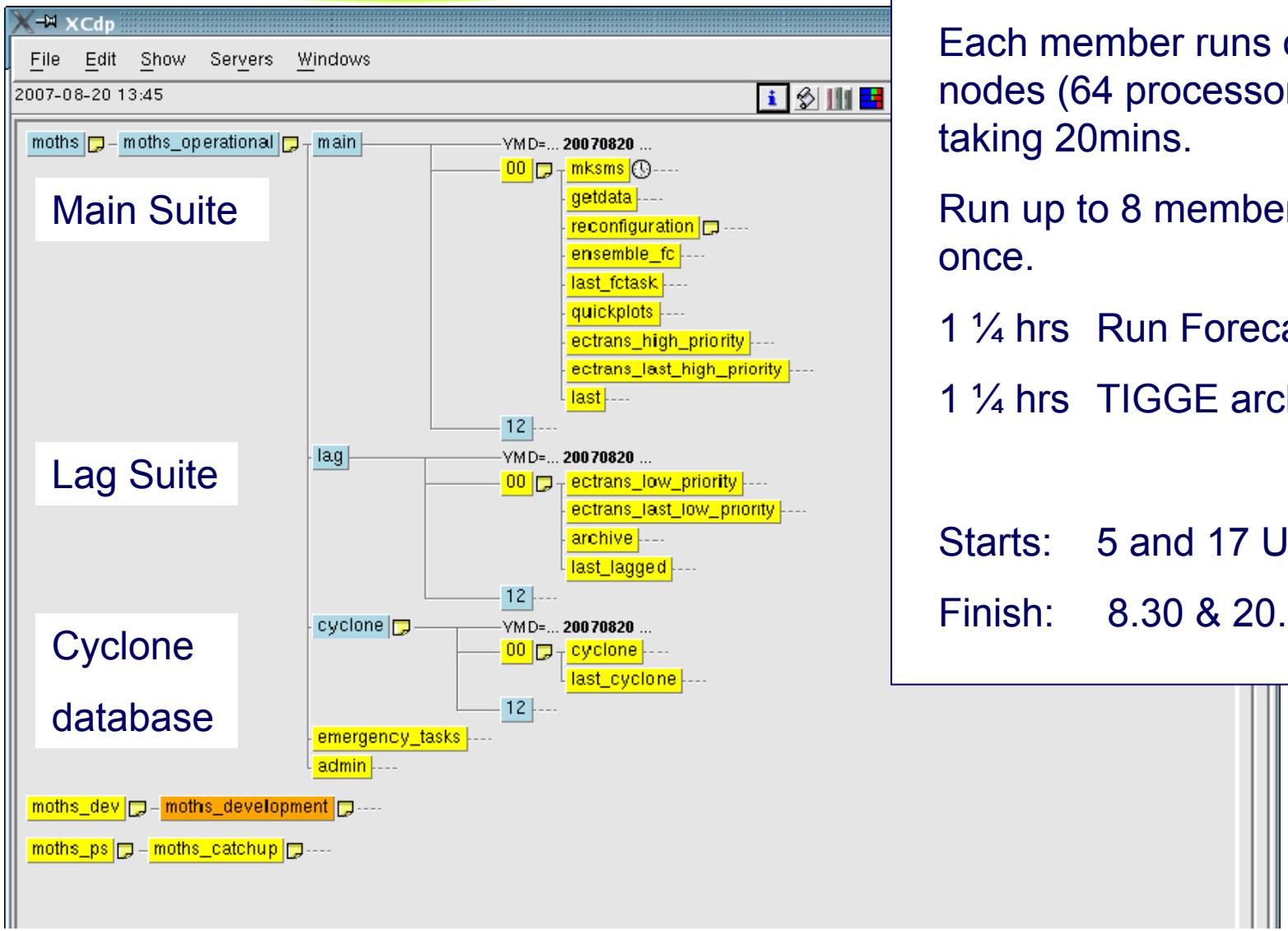
MOGREPS-15; 15-day ensemble forecasts

- Developed from MOGREPS short range ensemble system.
- Ensemble system is run at ECMWF, as a “time critical” suite.
- 24 members (control + 23 ETKF-based perturbations), run twice a day (0 and 12 UTC).
- Resolution: N144 (0.833° x 1.25°), 38 levels.
- Regular runs started late March 2006.
- Available from the TIGGE (THORPEX Interactive Grand Global Ensemble) database, from 1st October 2006.

Medium-range Ensemble Forecast system



Met Office THORPEX suite



Each member runs on 4 nodes (64 processors), taking 20mins.

Run up to 8 members at once.

1 ¼ hrs Run Forecasts

1 ¼ hrs TIGGE archiving

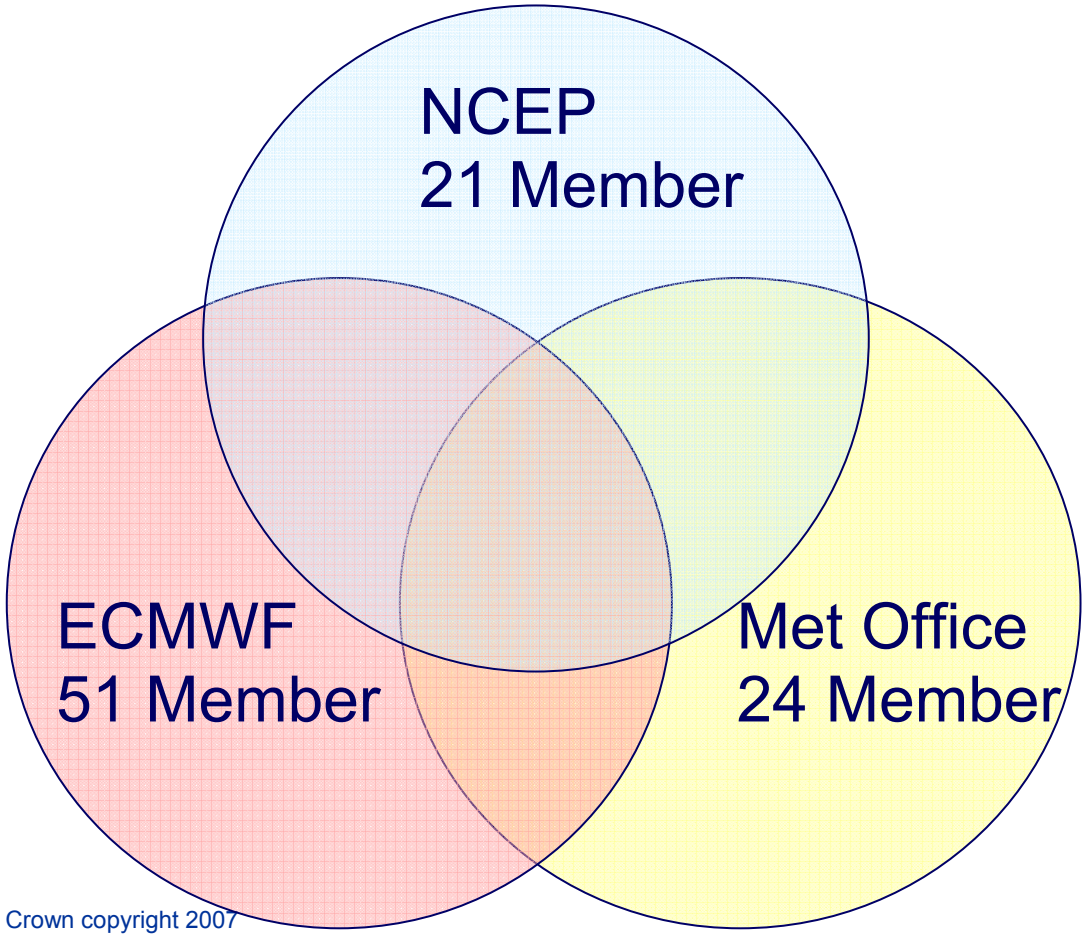
Starts: 5 and 17 UTC

Finish: 8.30 & 20.30 UTC.

Multi-model ensemble

Multi-Model Ensemble

Aim: To reduce forecast errors by combining and calibrating forecasts from different models.



3 variables:

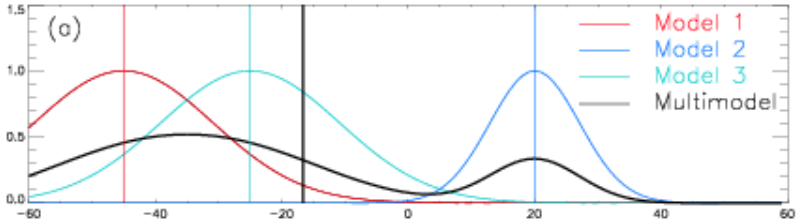
MSLP

2m Temp

500mb Height

Procedure

Raw Ensembles



From the law of total probability, the multi-model pdf is given by an average of the pdfs from the single-models (Raftery et al, 2005).

$$p_{MM}(x) = \sum_{k=1}^{M} w_k \, p_k(\overline{x}_k, \sigma_k^2)$$

w_k weight given to ensemble k

p_k single model pdf

$\overline{x}_k$ ensemble mean

σ_k^2 ensemble variance

M number of single-model ensembles

Calibration statistics

The bias and MSE are calculated using a moving-average of ensemble data at every grid point and lead time.

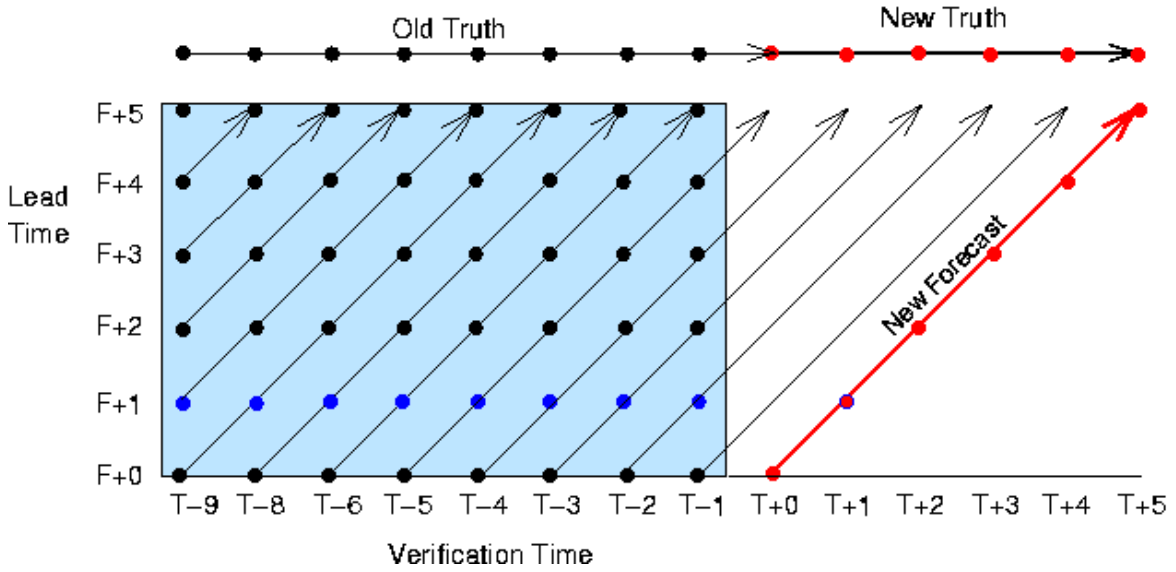
$$MSE_n = (1-\alpha)MSE_{n-1} + \alpha(x-y)^2$$

where x = forecast

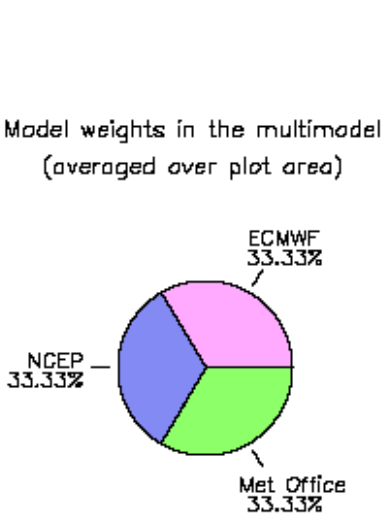
y = observation

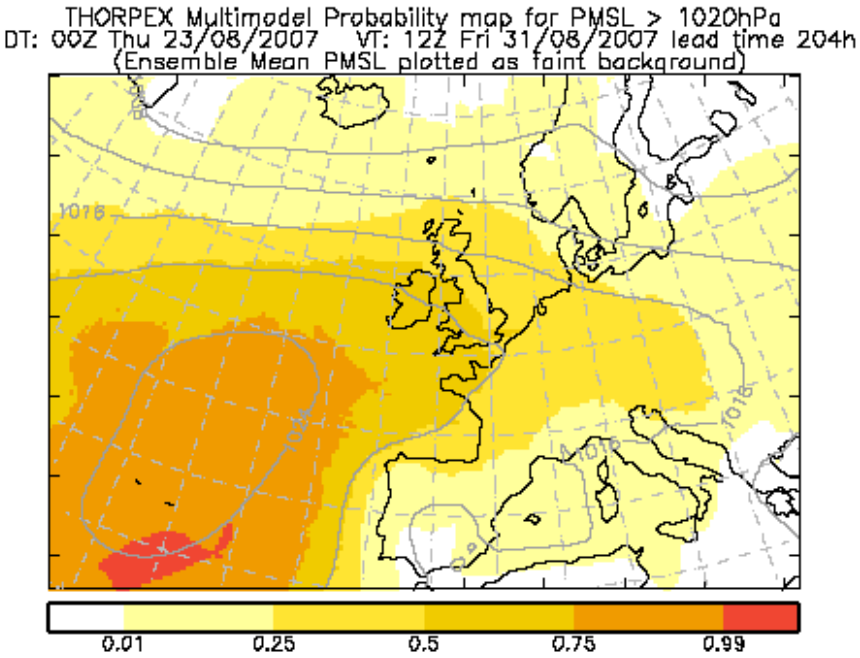
$w_k = N / MSE_k$

N=normalization



Multimodel products: Probability plot

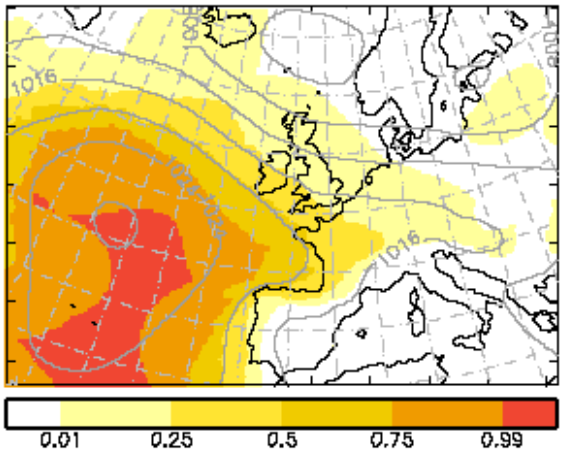




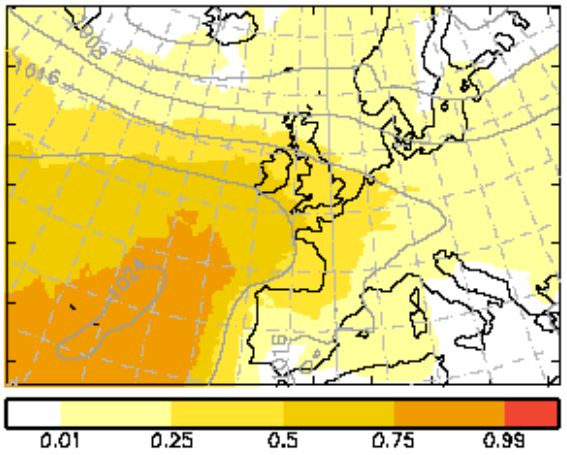
T+204

PMSL > 1020 hPa

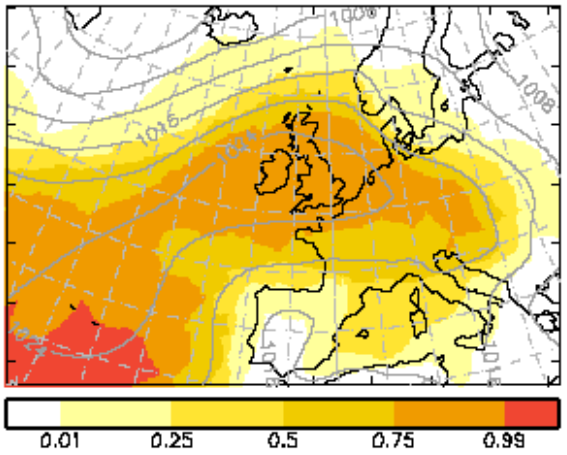
Met Office Ensemble (bias corrected)



ECMWF Ensemble (bias corrected)



NCEP Ensemble (bias corrected)



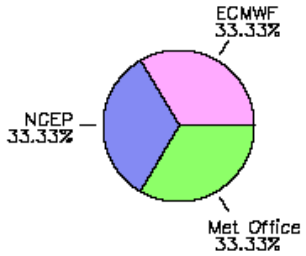
Mean and spread with Equal Weights

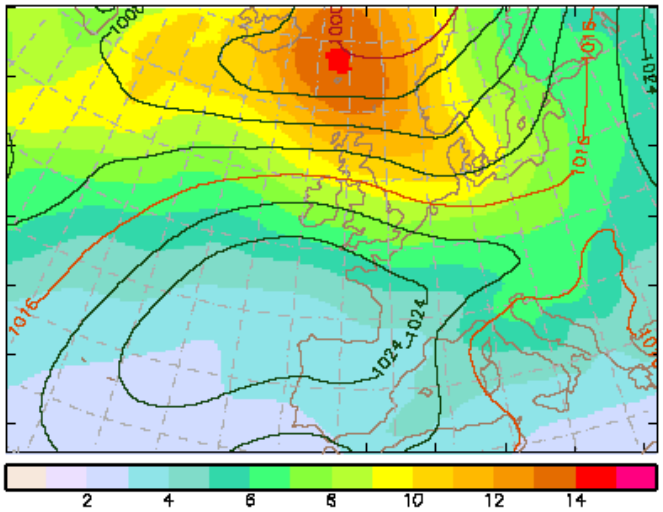
THORPEX Multimodel Mean and Spread for PMSL (hPa)

DT: 00Z Thu 25/10/2007 VT: 12Z Wed 31/10/2007 T+156h

T+156, PMSL

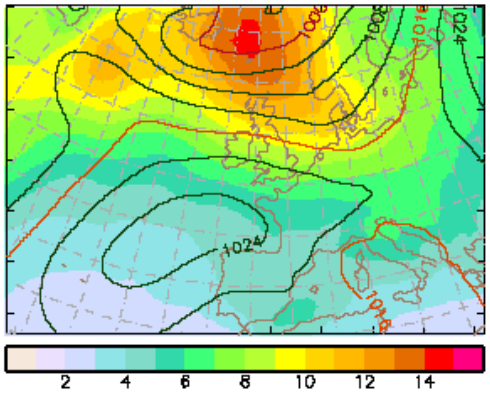
Model weights in the multimodel (averaged over plot area)





The spreads for the single–models (below) show the spread of all the members from the multimodel ensemble around the single–model mean. The spread gives an indication of the size of the uncertainty in the single model mean, and has a relatively large value if that model is not consistent with the multimodel mean.

Met Office Ensemble Mean (bias corrected)



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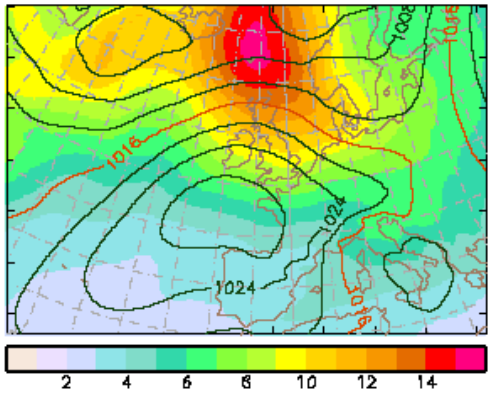

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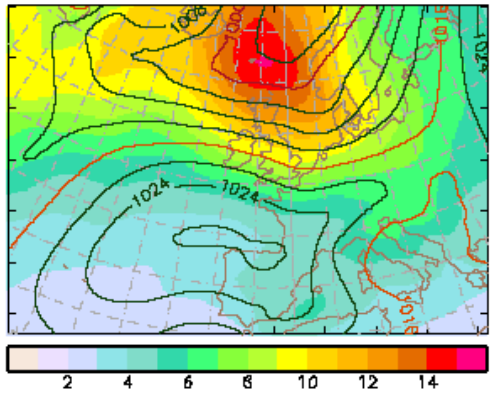
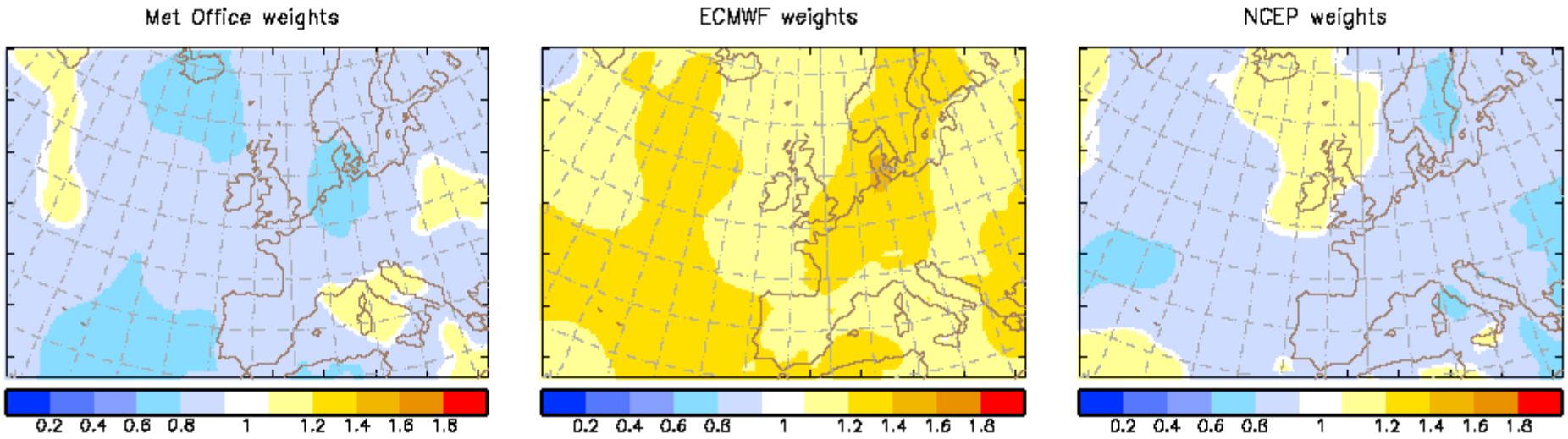


Model-dependent weights

Weights are calculated for every lead time, grid point and variable

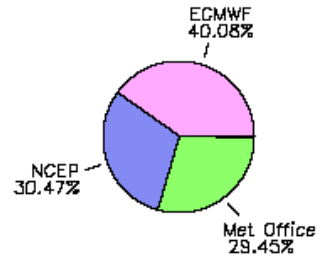
Weights are allowed to vary over time

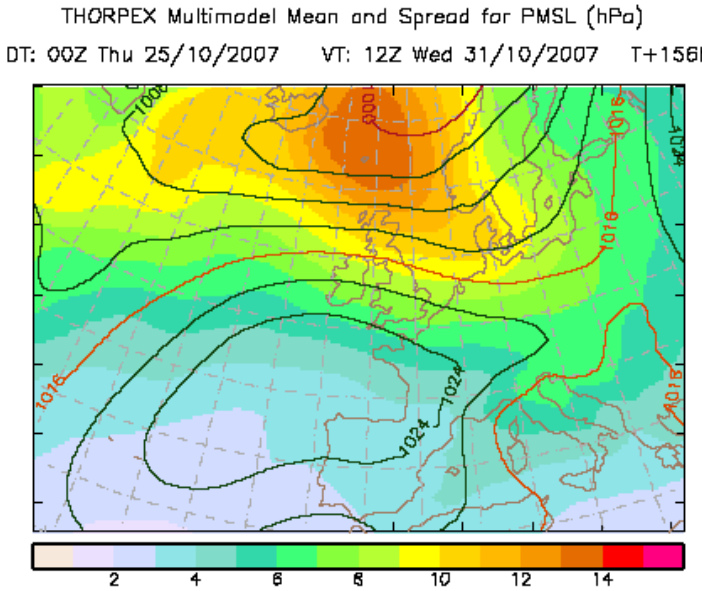
Weights are a function of the MSE of the bias corrected ensemble mean



PMSL, T+156

Men and spread with Model-dependent weights





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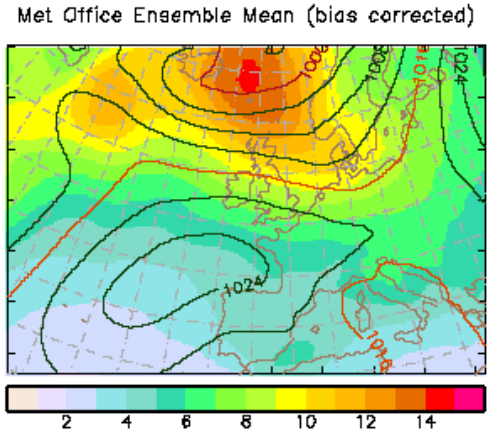

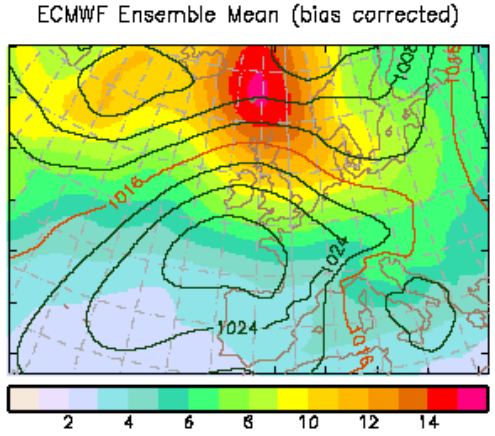

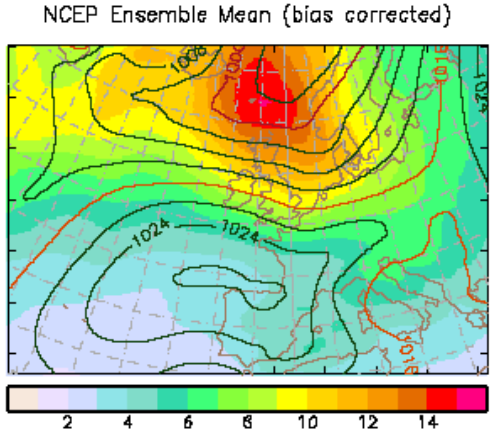

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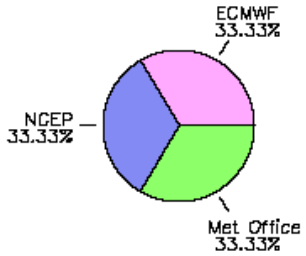

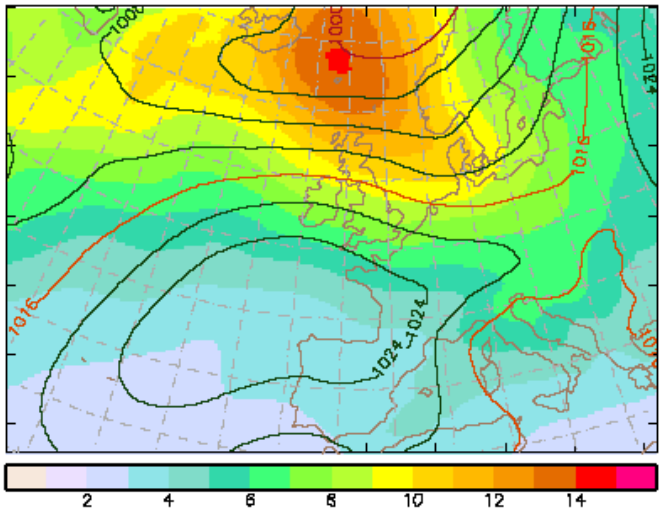

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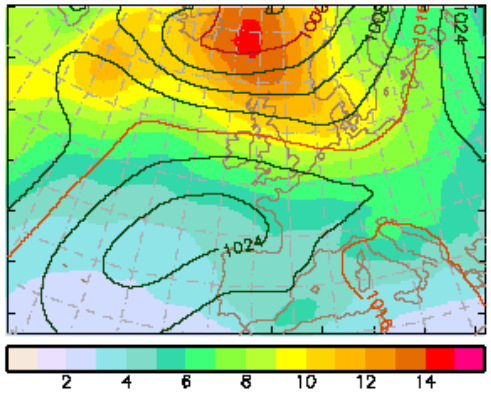

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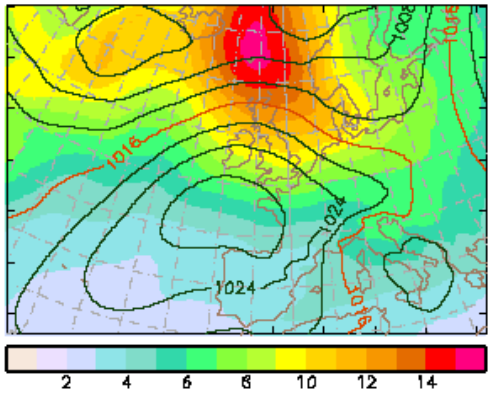
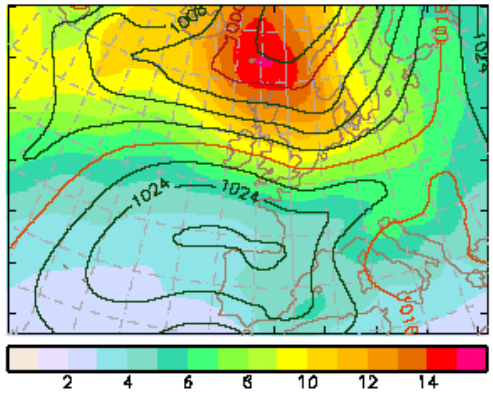
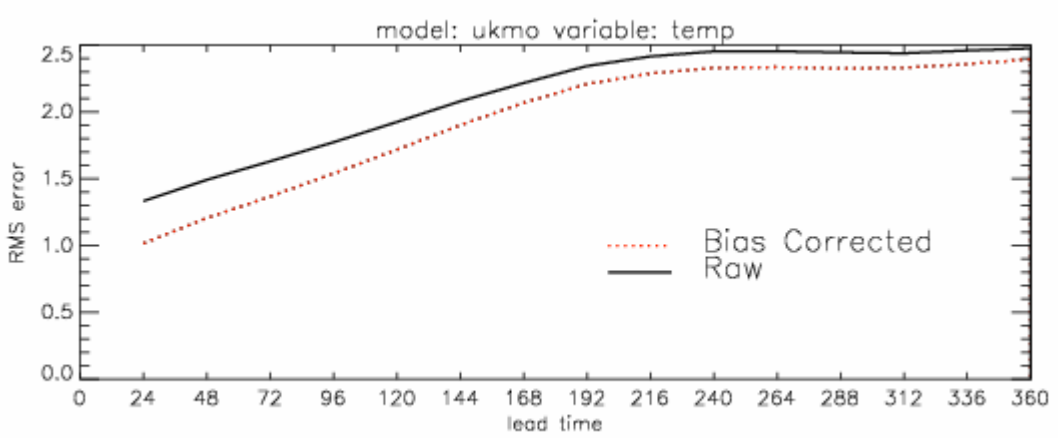


NCEP Ensemble Mean (bias corrected)

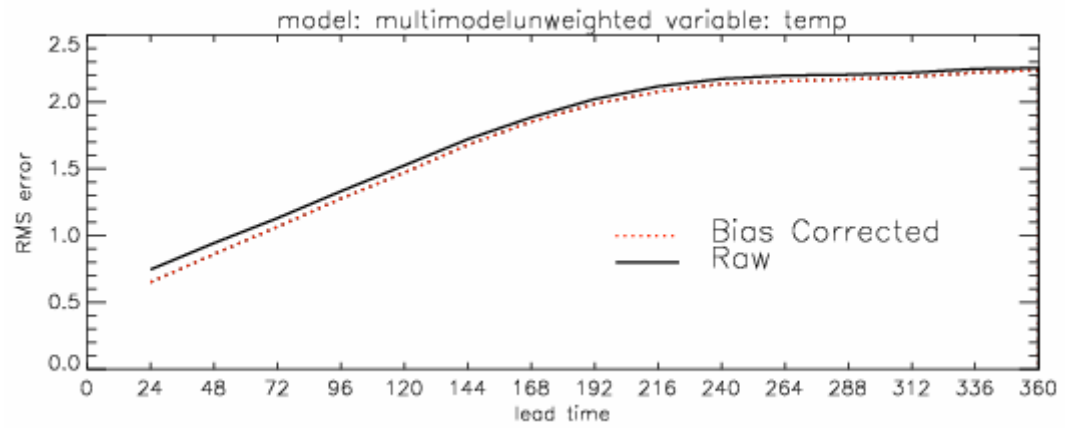


RMS errors: effect of bias correction

Effect on the single-model (Met Office) ensemble mean.



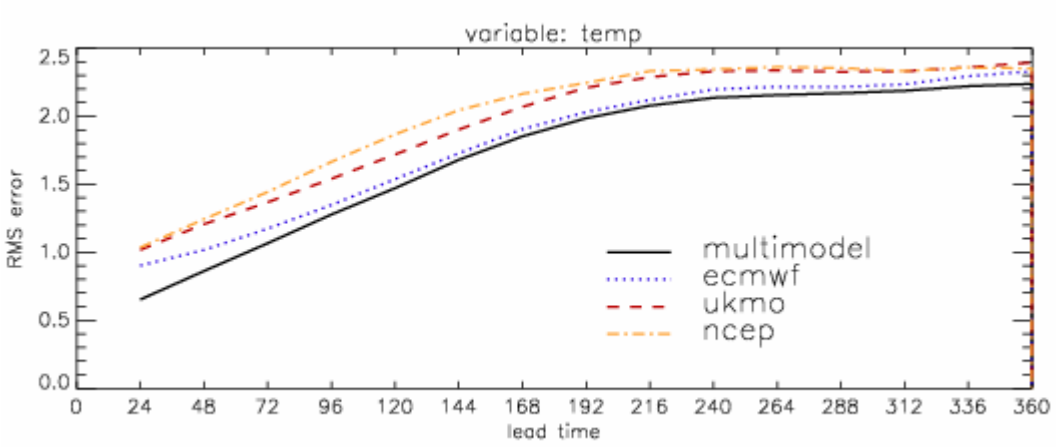
Effect on the multi-model ensemble mean.



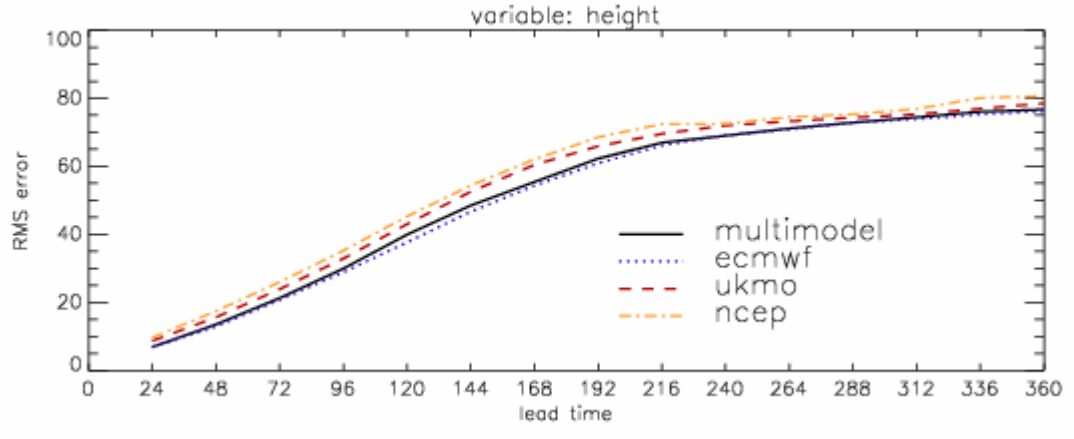
(RMS errors, globally averaged over 40 days, verified against a multi-model analysis)

RMS errors: effect of combination

Temperature



Height



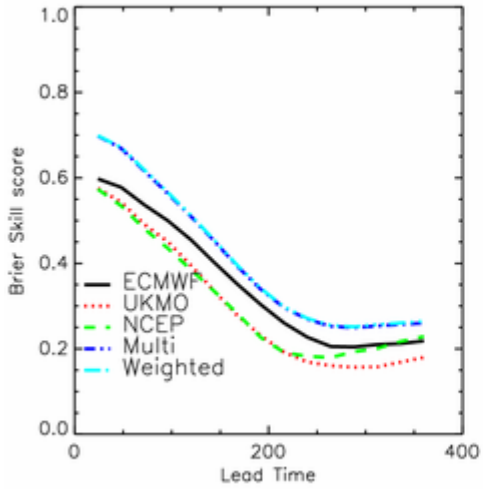
The multi-model uses equal weights for each model.

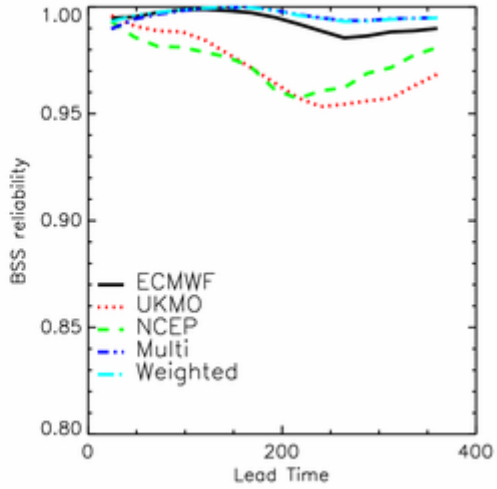
(RMS errors, globally averaged over 40 days.)

Brier Skill Scores: Threshold=mean

Use a climatological mean, and globally average over 15 days of data.

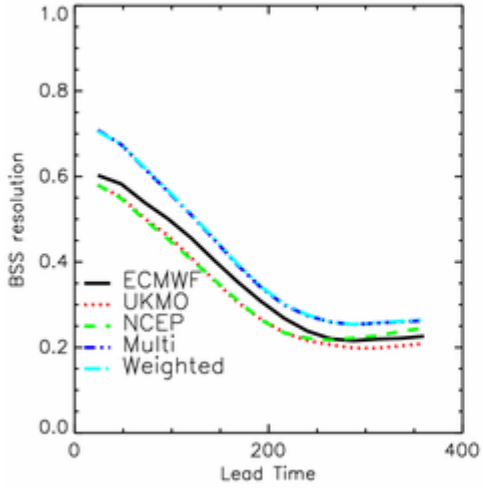
Brier Skill Score

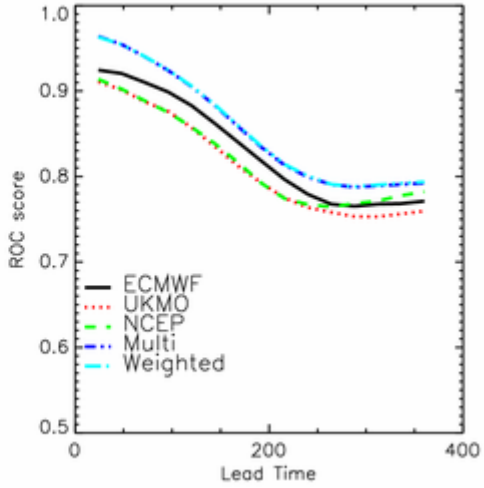




Reliability

Resolution

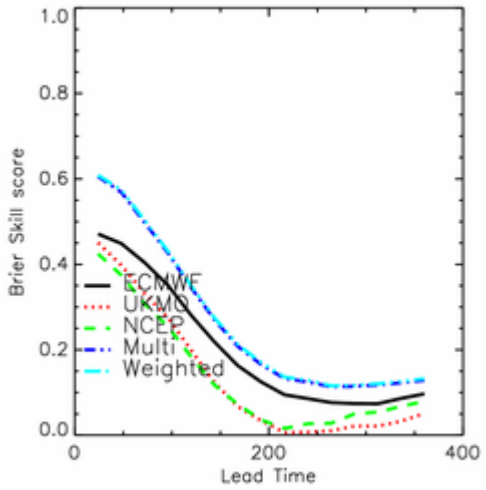


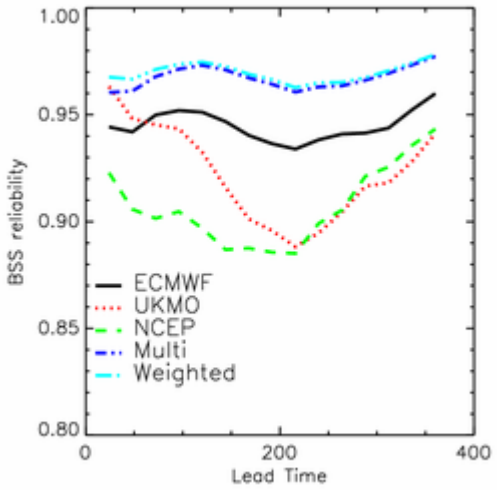


ROC

Brier Skill Scores: Threshold =90th percentile

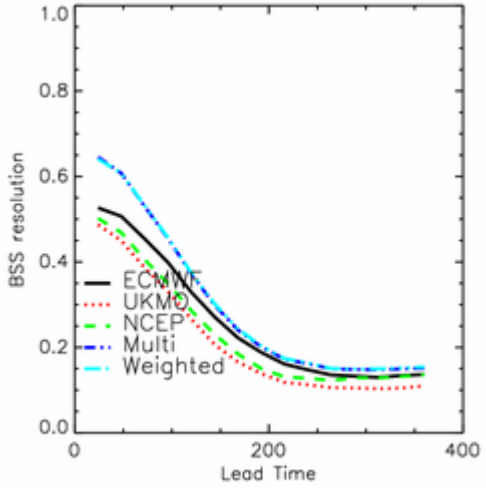
Brier skill score

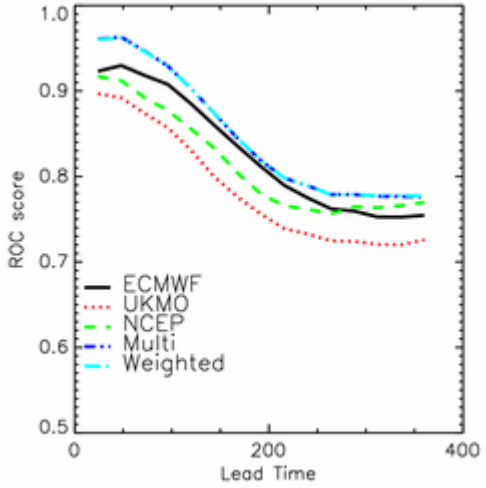




Reliability

Resolution



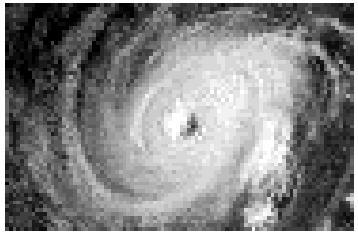


ROC

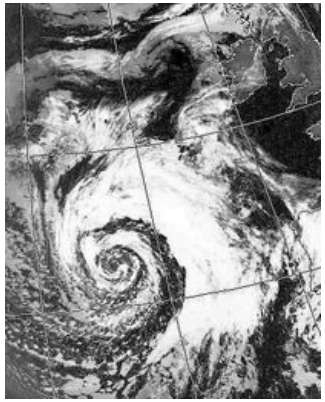
Forecasting
High-impact weather

Feature-based diagnostics from MOGREPS-15

- Almost all high-impact weather is feature-related e.g. extra-tropical cyclones leading to strong winds/heavy rain in the UK
- Numerical models often do not explicitly represent the severe weather parameters, especially in lower resolution ensembles
- They can however represent the features causing the high-impact weather
- For high-impact weather prediction, focus on post-processing ensemble data through automated identification and tracking of synoptic features
- Analysis of feature tracks and attributes allows evaluation of the potential for high-impact weather



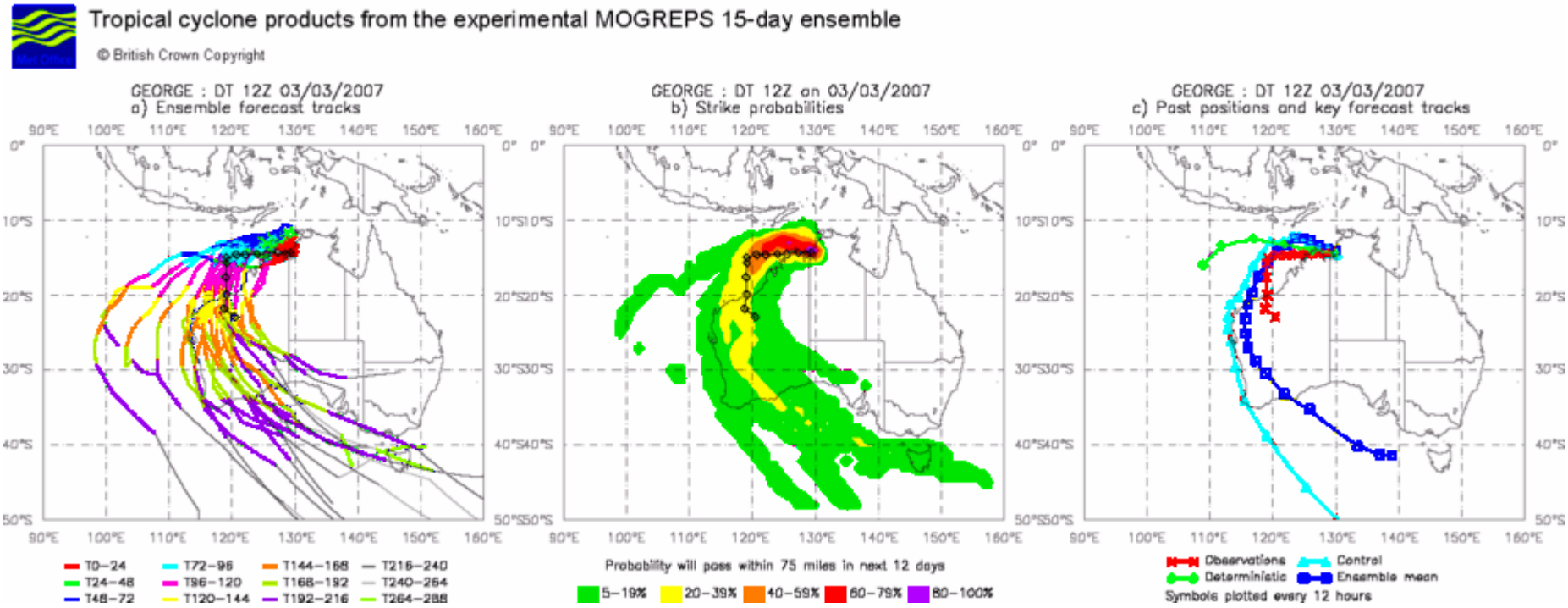
Tropical cyclones



Extra-tropical cyclones

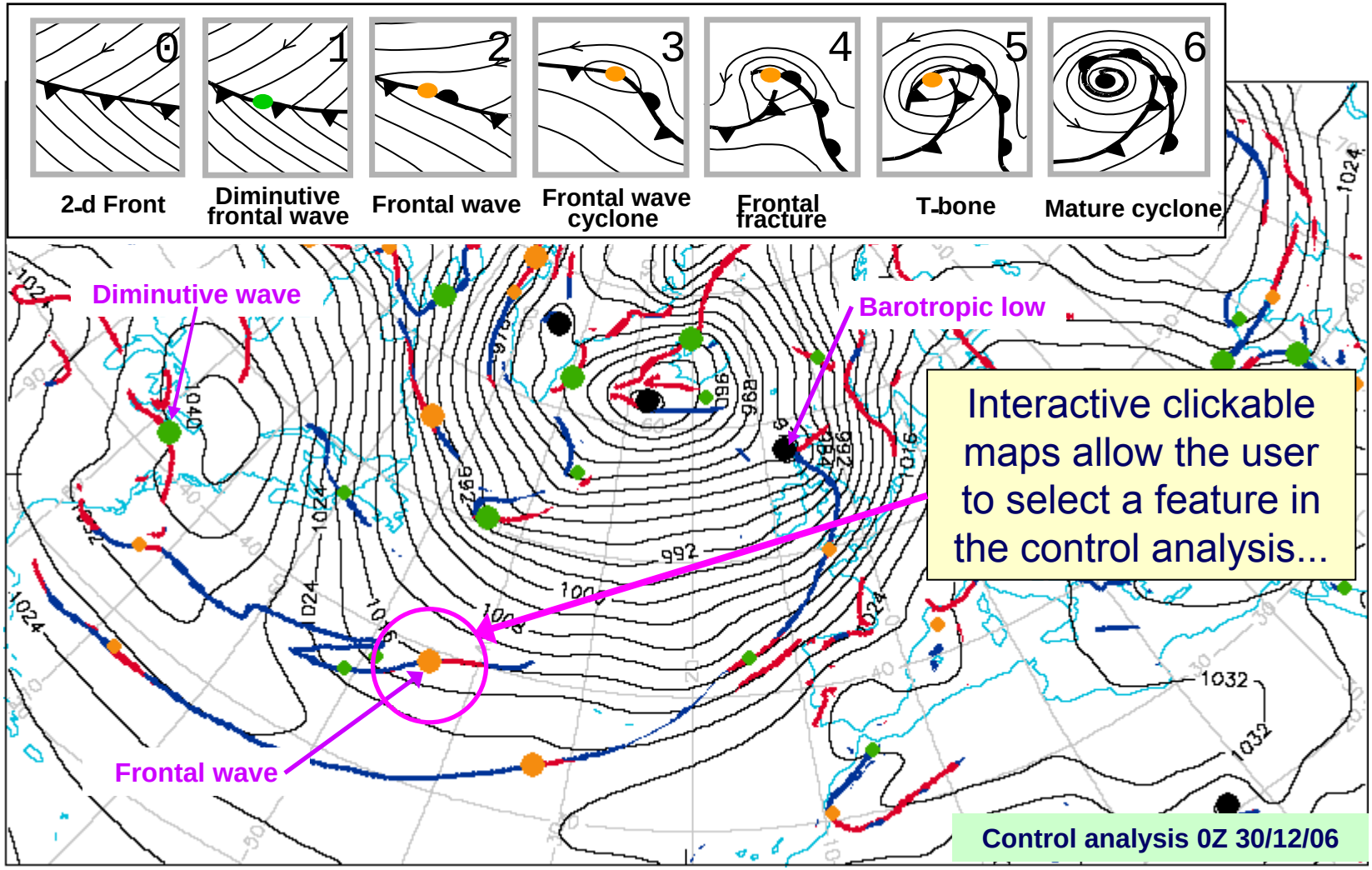
Tropical cyclone ensemble charts

- Tropical cyclones are identified and tracked using 850hPa relative vorticity maxima
- Identifies new storms out to T+144
- Cyclone George: Landfall near Port Headland, winds 195km/hr, 3 deaths



- Mean reduction in forecast errors for ensemble mean compared to deterministic:
- Similar up to T+72 • 12% at T+96 • 23% at T+120 (7 months data)

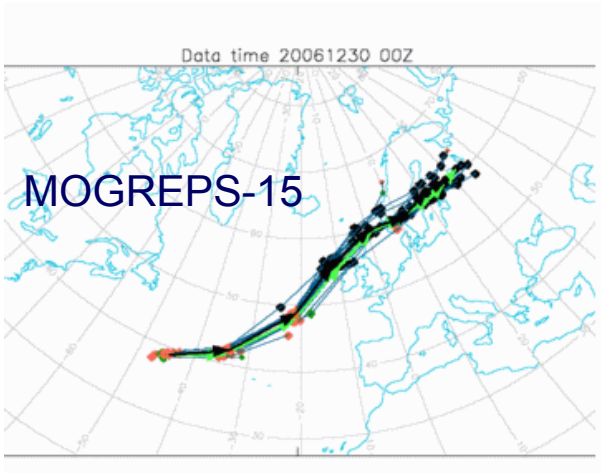
Cyclone database & New Year's Eve storm

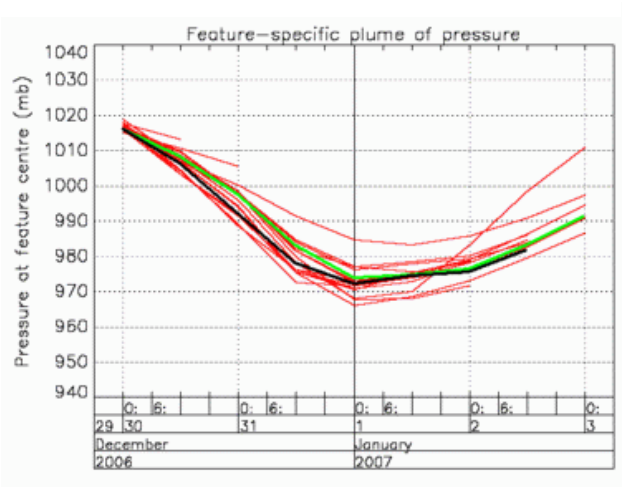


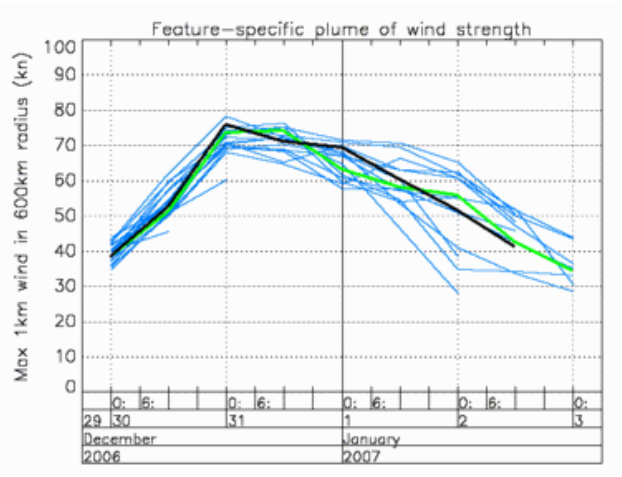
- Tracking scheme uses a combination of forward and backward tracking. It uses extrapolation and 500hPa steering wind to estimate positions, and matches features based on separation distance, type and thickness

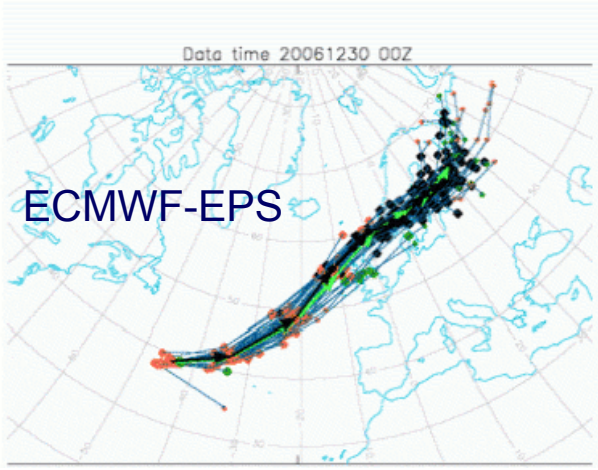
Cyclone database: 31/12/2006 example

- Clicking on a feature brings up feature-specific tracks from each ensemble member and matching plumes of intensity measures to identify the potential for high-impact weather

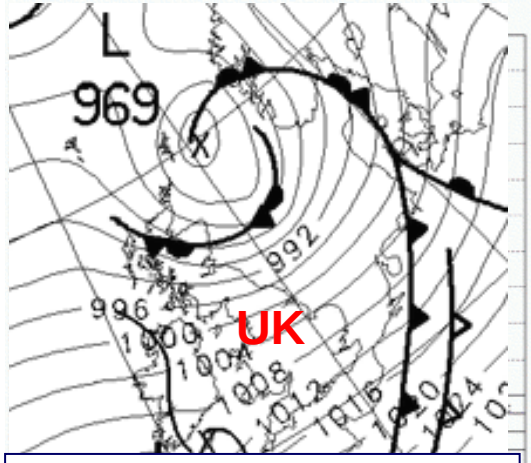








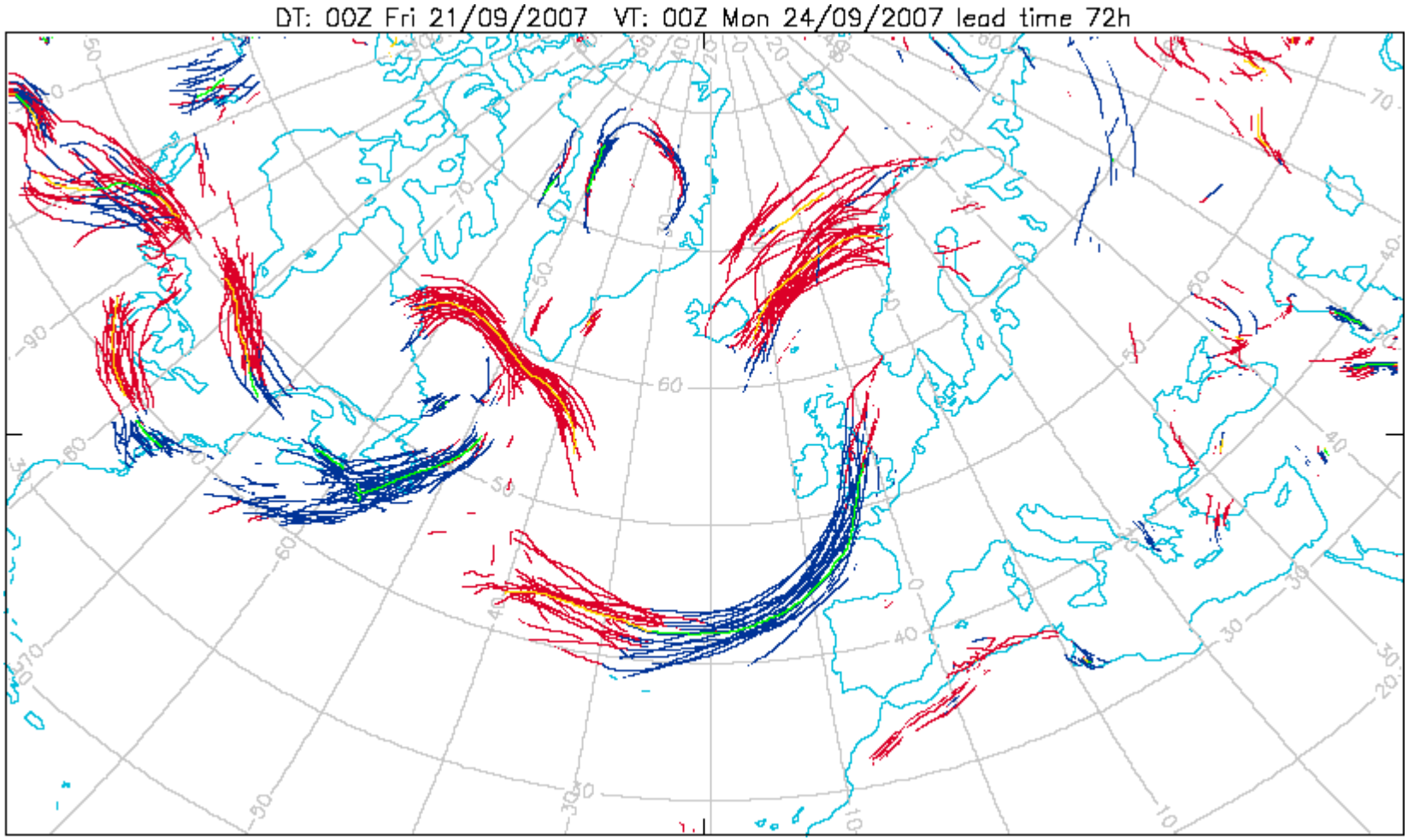
This storm tracked across Scotland, with gusts up to 100mph, leading to the high-profile cancellation of New Year's Eve celebrations and loss of power to 1000s of homes



Analysis 00Z 01/01/2007

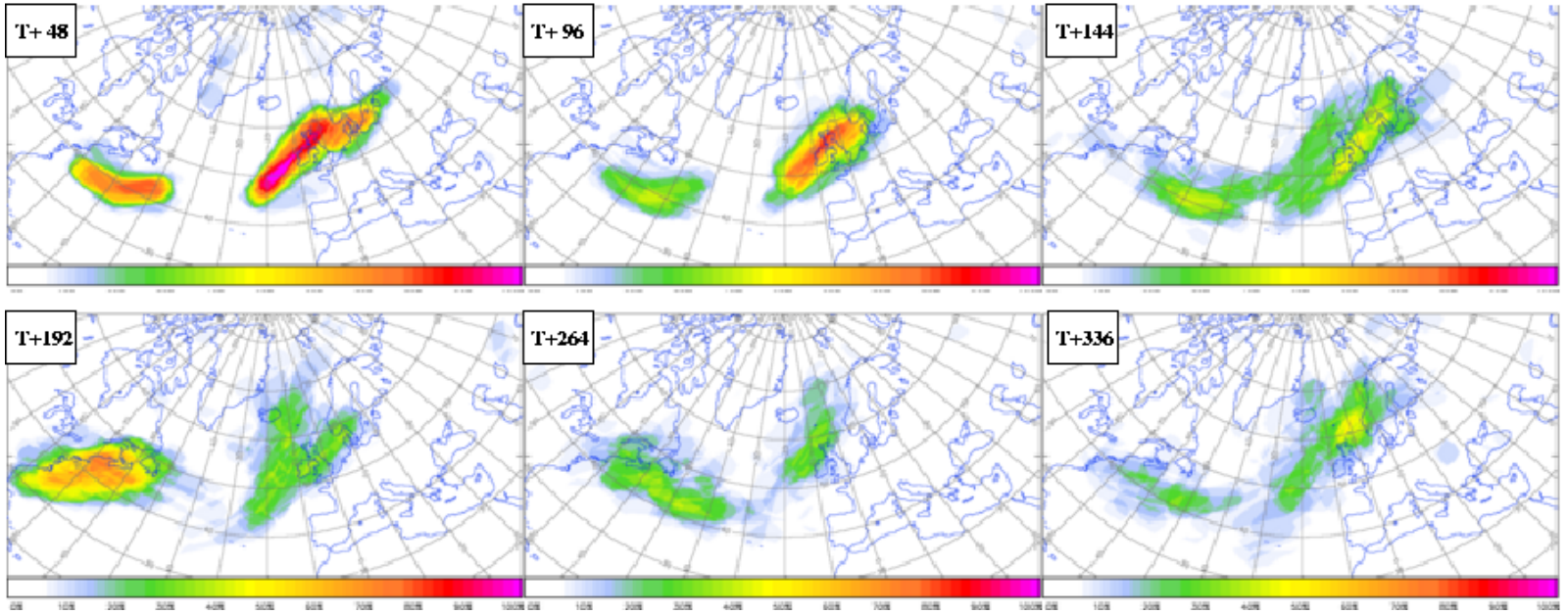
Cyclone database: Spaghetti plot of objective fronts

- The cyclone database objectively identifies fronts and cyclonic features in the extra-tropics

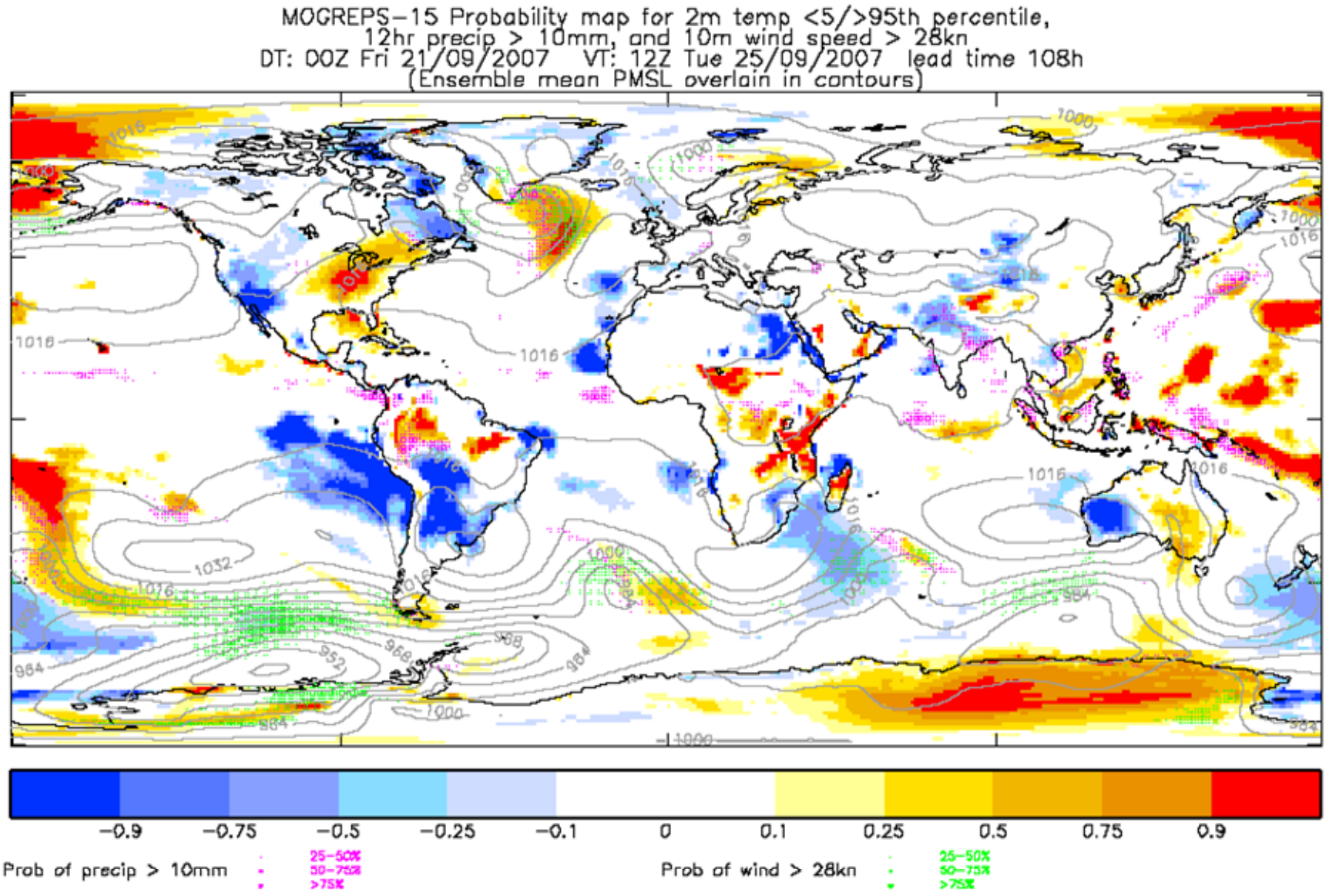


Strike probability plots

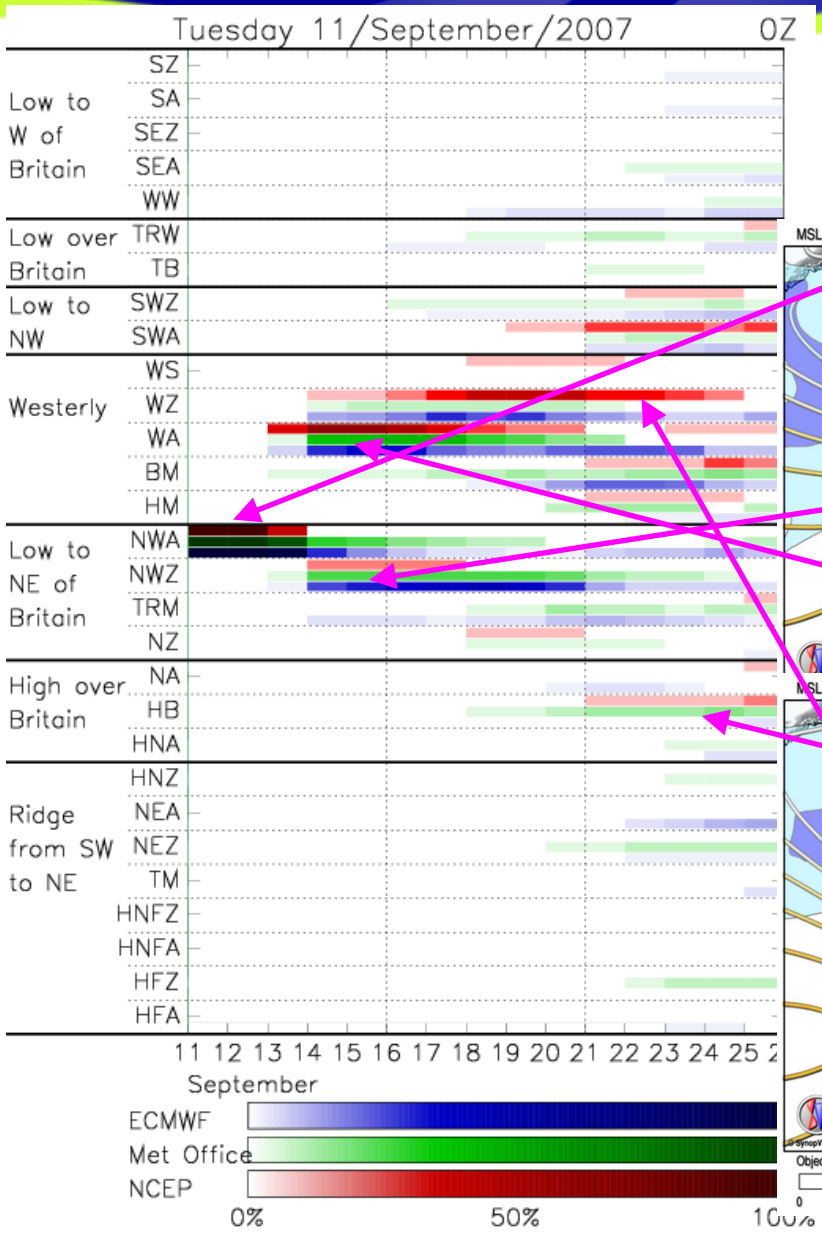
- At longer lead times, the uncertainty in tracking individual features increases (they may well not exist in the initial analysis).
- The strike probability plots give a broader indication of risk of storms, based on cyclone database data.
- Plots show number of MOGREPS-15 ensemble members with potential for surface gusts> 60 kt in each 24-hour period.

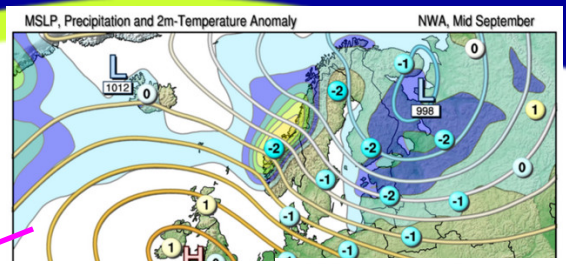


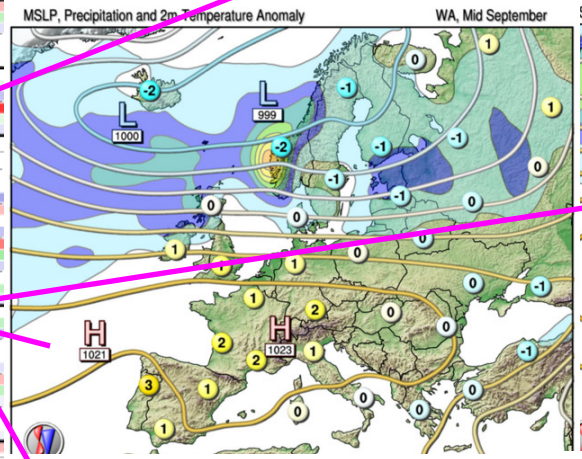
Combined high-impact weather risk map

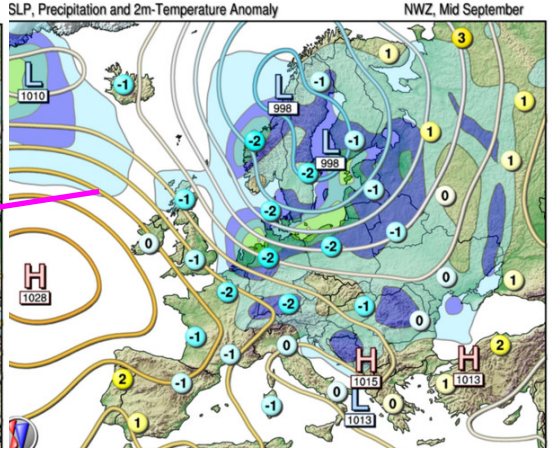


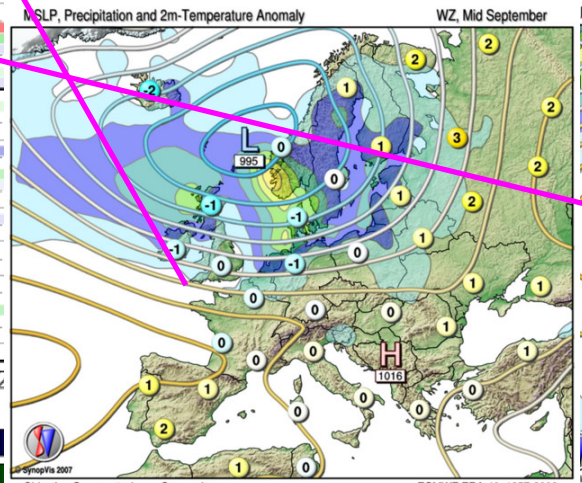
Regime-based diagnostics: Grosswetterlagen

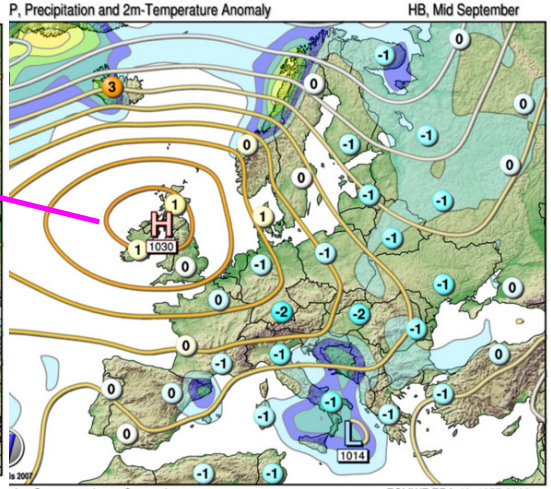












Summary

- For the last year and a half the Met Office has been running an experimental medium-range ensemble (MOGREPS-15) using UK member state allocation at ECMWF.
- A key emphasis of our research programme is the development of methods for combining MOGREPS-15 with other forecasts (ECMWF VAREPS, NCEP) in a multi-model ensemble.
- We are also developing a range of tools to highlight the risk of high-impact weather forecast by ensemble prediction systems.
  - Probabilities of exceeding high-impact thresholds
  - Feature-based cyclone diagnostics
  - Tropical cyclone tracks
  - Regime-based diagnostics (GWL)

Any Questions?

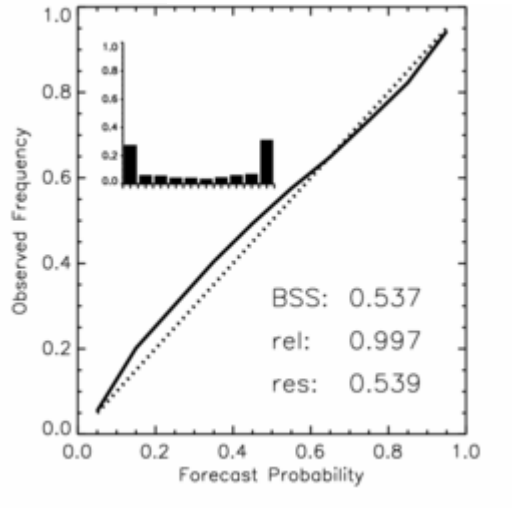
Acknowledgements: With thanks to Ensemble Forecast team, Nick Savage, Tim Hewson, Julian Heming, Paul James, Paul Dando, Martin Leutbecher & ECMWF

Future plans

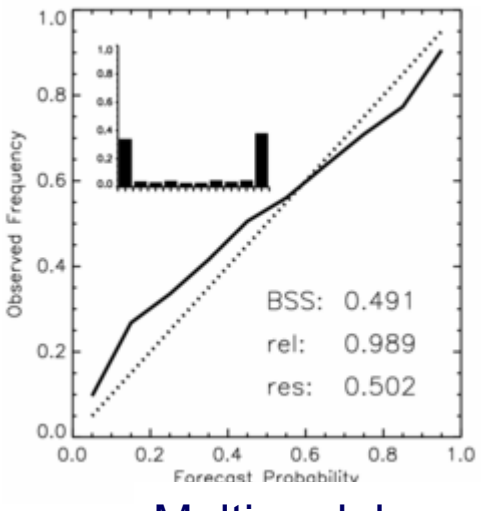
- Continue contributing ensemble forecasts to TIGGE
- Refine multi-model ensemble
  - e.g. Variance inflation
- Improve model resolution as computer resources allow
  - 38 → 70 levels
  - 90 → 60 km
- Possible implementation of:
  - Reforecasts
  - Coupled ocean model
- Expand high-impact products
  - e.g. Cyclone database in N Pacific for T-PARC
- Contribute to development of THORPEX Global Interactive Forecast System (GIFS)

Reliability Diagrams

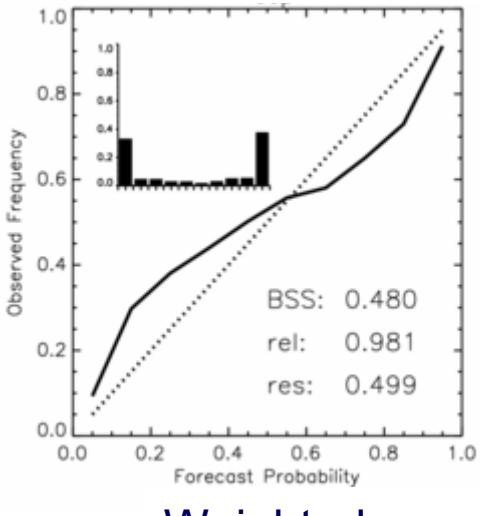
ECMWF



Met Office

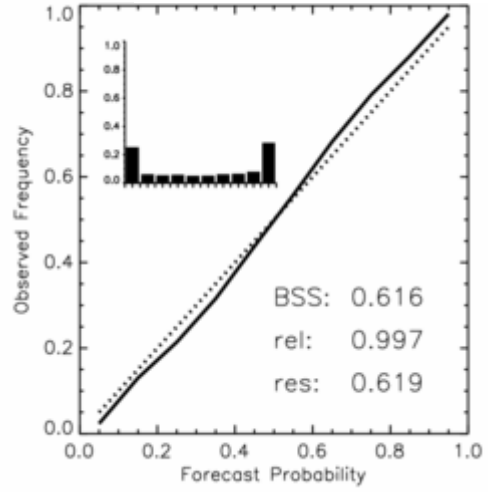


NCEP



- Lead time of 72 hours
- Threshold: Temperature greater than the climatological mean
- Globally averaged over 15 days.

Multimodel



Weighted