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
- 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

- Initial Analysis
- Perturbations
- Single-model products
- Statistics & plots
- Multi-model Products

ECMWF

- Perturbed Initial conditions
- Run Ensemble forecast
- MOGREPS-15 ensemble
- Combine Ensemble forecasts
- Multi-model Ensemble
- TIGGE archive
- ECMWF & NCEP ensembles

Product generation

Combine

Verification

Single-model Product generation

Multi-Model Product generation

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

3 variables:
- MSLP
- 2m Temp
- 500mb Height
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).

\[ P_{MM}(x) = \sum_{k=1}^{M} w_k p_k(\bar{x}_k, \sigma_k^2) \]

- \( w_k \): weight given to ensemble \( k \)
- \( p_k \): single model pdf
- \( \bar{x}_k \): ensemble mean
- \( \sigma_k^2 \): ensemble variance
- \( M \): number of single-model ensembles
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

THORPEX Multimodel Probability map for PMSL > 1020hPa
DT: 002 Thu 23/08/2007
VT: 122 Fri 31/08/2007 lead time 204h
(Ensemble Mean PMSL plotted as faint background)

Model weights in the multimodel (averaged over plot area)

- ECMWF: 33.33%
- NCEP: 33.33%
- Met Office: 33.33%

T+204
PMSL > 1020 hPa
Mean and spread with Equal Weights

T+156, PMSL

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.
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

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.
Mean and spread with Equal Weights

THORPEX Multimodel Mean and Spread for PMSL (hPa)

T+156, PMSL

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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)
The multi-model uses equal weights for each model.

(RMS errors, globally averaged over 40 days.)
Use a climatological mean, and globally average over 15 days of data.
Brier Skill Scores: Threshold = 90th percentile

Brier skill score

Reliability

Resolution

ROC
Forecasting High-impact weather
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 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)
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.
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.
The cyclone database objectively identifies fronts and cyclonic features in the extra-tropics.

DT: C0Z Fri 21/09/2007  VT: C0Z Mon 24/09/2007 lead time 72h
- 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

Mogreps-15 Probability map for 2m temp <5/>95th percentile, 12hr precip > 10mm, and 10m wind speed > 28kn
DT: 00Z Fri 21/09/2007 VT: 12Z Tue 25/09/2007 lead time 108h
(Ensemble mean PMSL overlain in contours)
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?

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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:
  - Reforecast
  - 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

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