Results from the MOGREPS Regional Ensemble – A comparison of downscaled global perturbations versus perturbations from the ETKF for the regional ensemble.

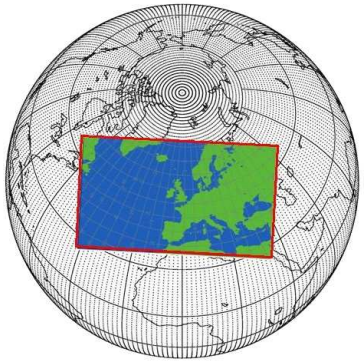
Neill Bowler and Sarah Beare - EWGLAM Madrid October 2008.

Contents

This presentation covers the following areas

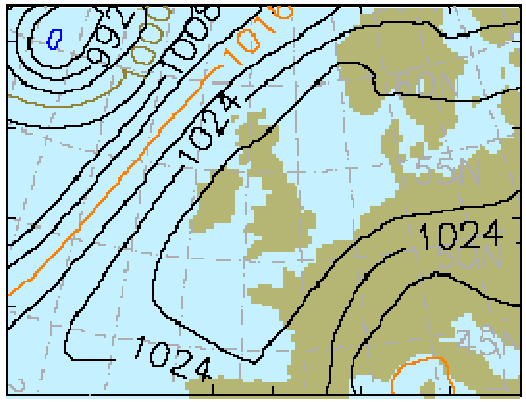
- Introduction to MOGREPS
- Experiment design
- Results
- Summary and conclusions

MOGREPS Overview



- Global Ensemble (N144L38 – T+72) run at 00Z and 12Z
- Regional Ensemble (24km,L38 – T+54) run at 06Z and 18Z
- 23 perturbed members + control
- ETKF Initial Conditions
- Representation of model error
- Routinely run since September 2005
- Now fully operational

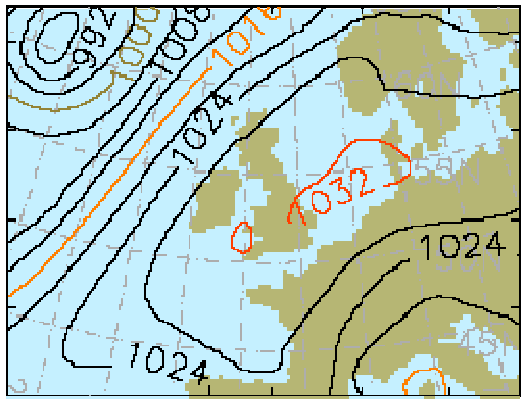
Global Perturbations



T+7 perturbed forecast

Reconfigured to 24km

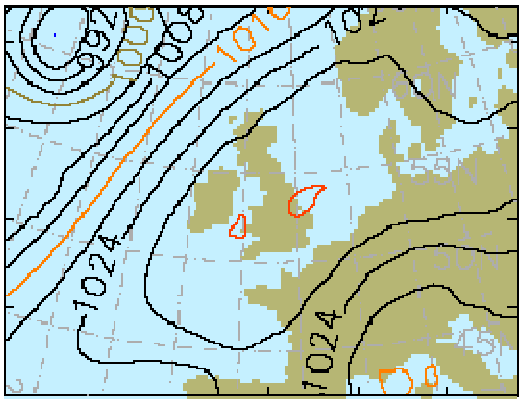
-



T+7 control forecast

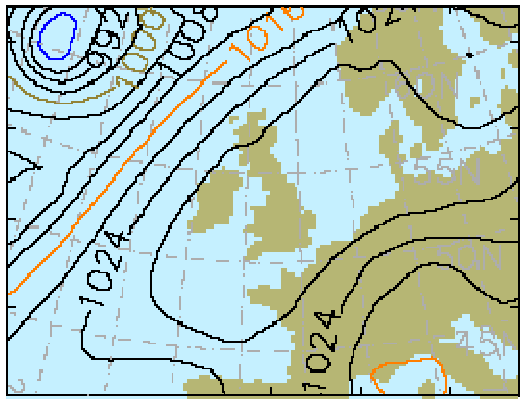
Reconfigured to 24km

+



Control analysis

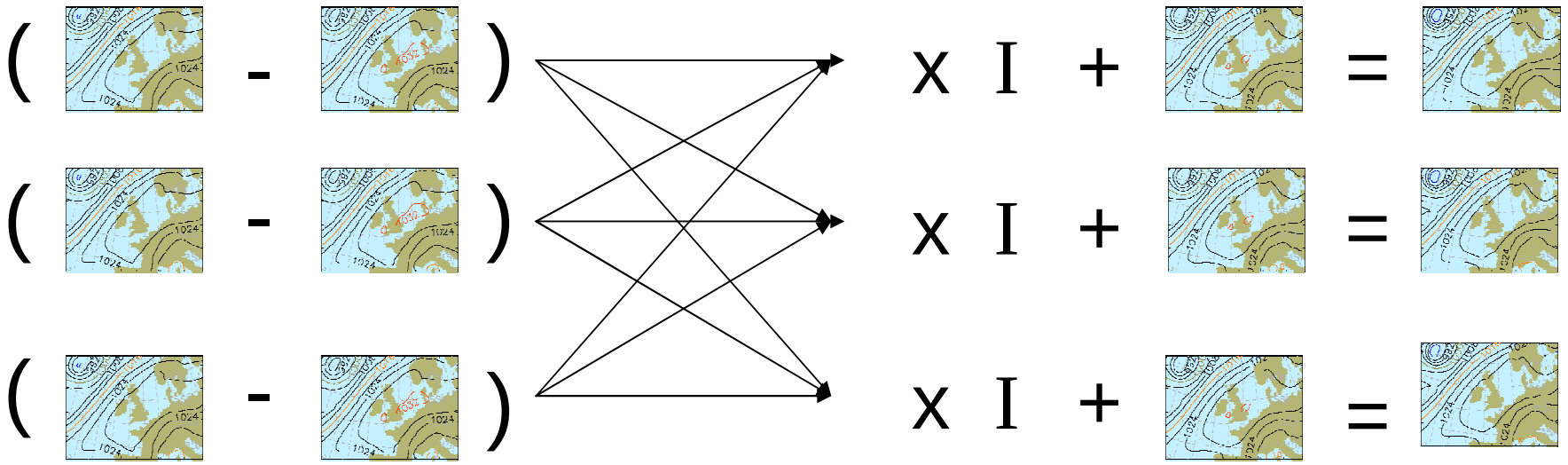
=



Perturbed analysis

Ensemble Transform Kalman Filter (ETKF)

$$X^a = X^f T \Pi_n$$



T+12 perturbed forecast

T+12 ensemble mean forecast

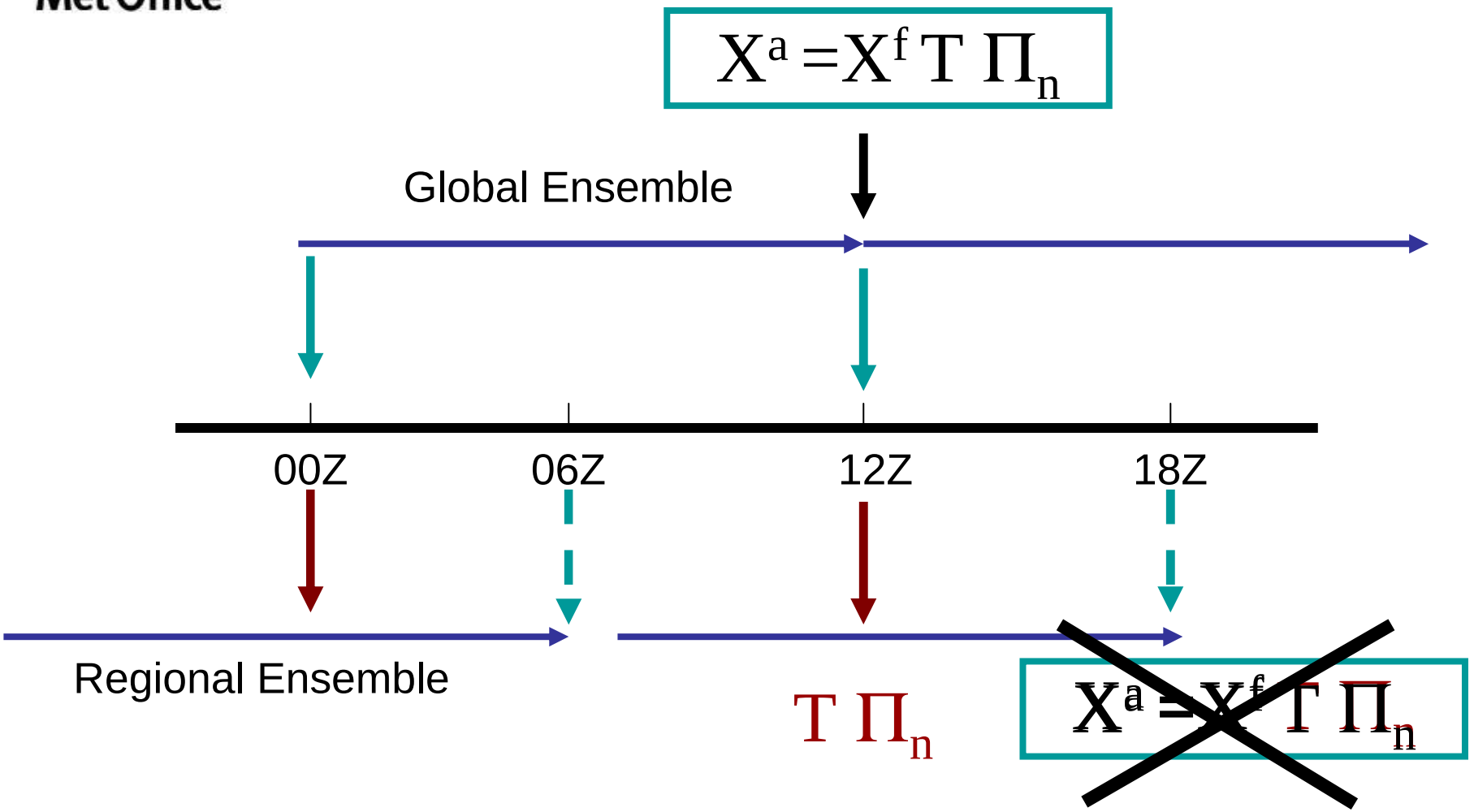
Transform matrix

Inflation factor

Control analysis

Perturbed analysis

ETKF Continued..



Experiment Design

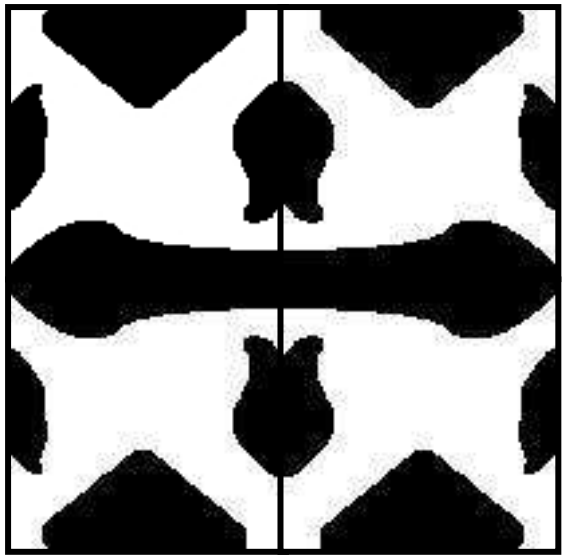
- 10 December 2006 – 13 January 2007
- One full forecast run per day at 18 UTC
- Both Global and Regional ensembles use UM vn6.1
- Identical 24km model versions and global LBCs used in each case.
- The ensemble using the regional ETKF was spun up for 1 week

Power Spectra

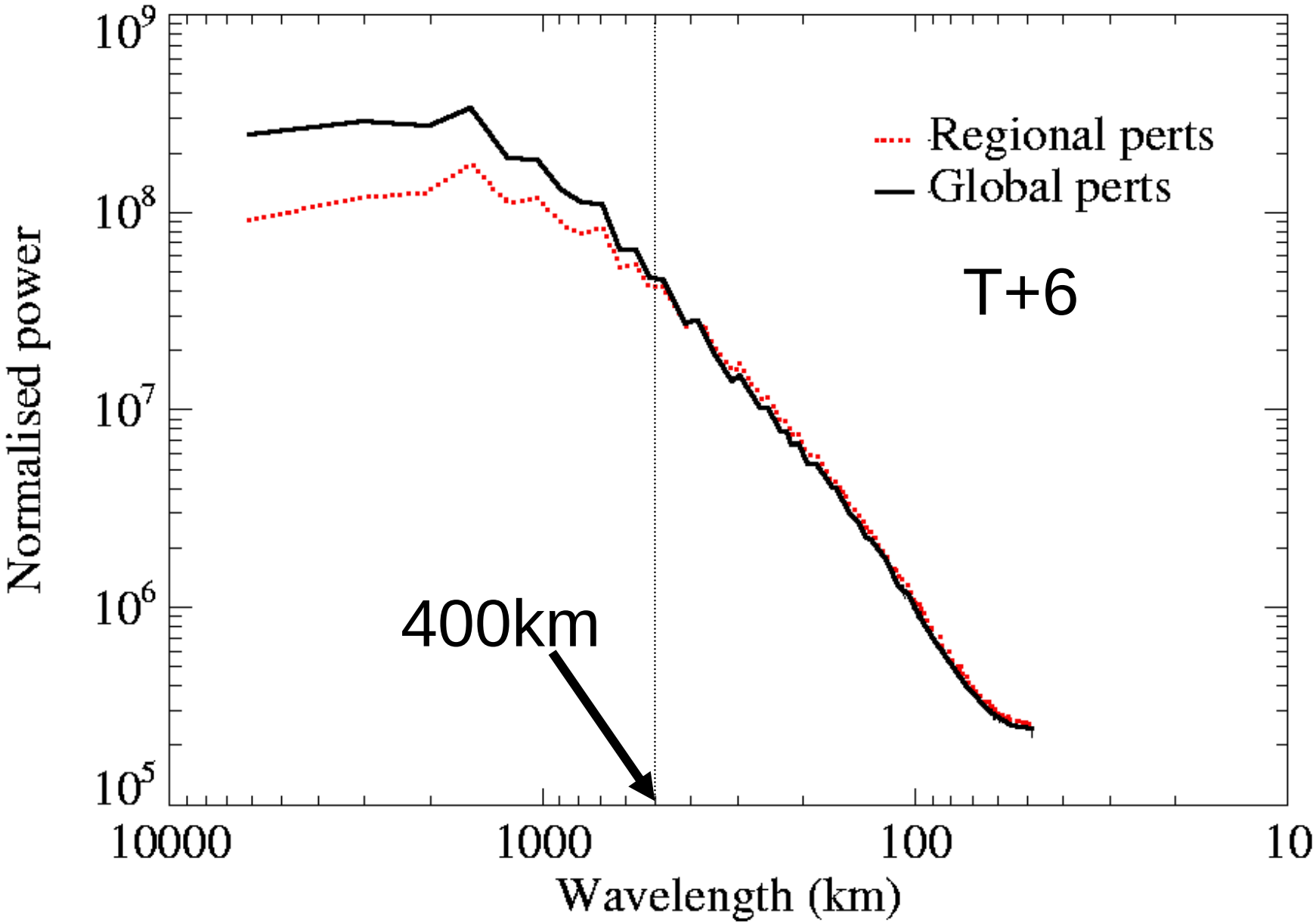
Mean Spectrum $= \sum_{j}^{Ndays} \sum_{i}^{Nmem} Spectrum(X_{i,j} - \overline{X}_{j})$

X = perturbed member forecast

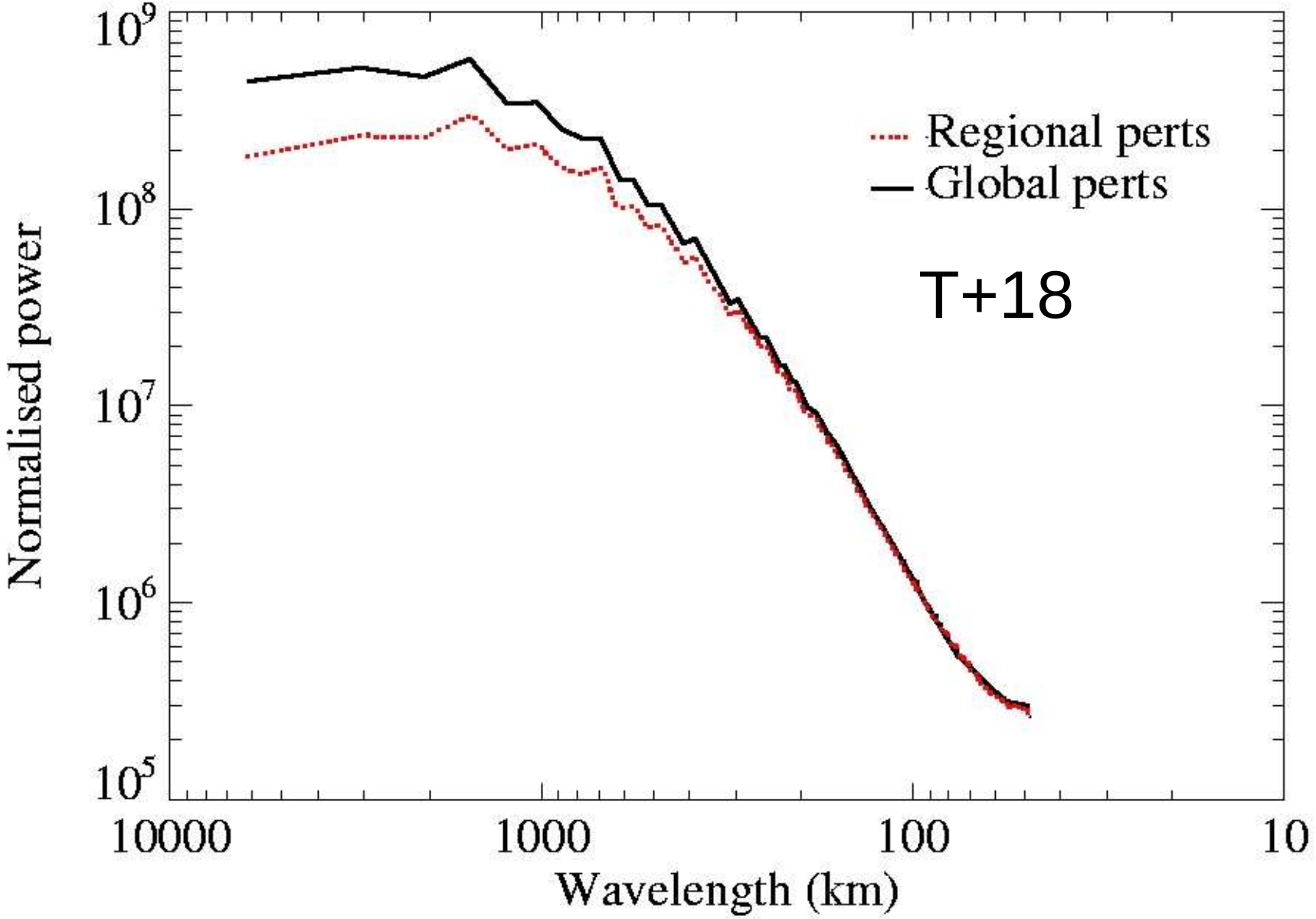
$\overline{X}$= Ens mean forecast



Power Spectrum of 850hPa Temperature



Power Spectrum of 850hPa Temperature



Verification Results

- RMS Spread and Error
- Spread Error Correlation
- Continuous ranked probability score

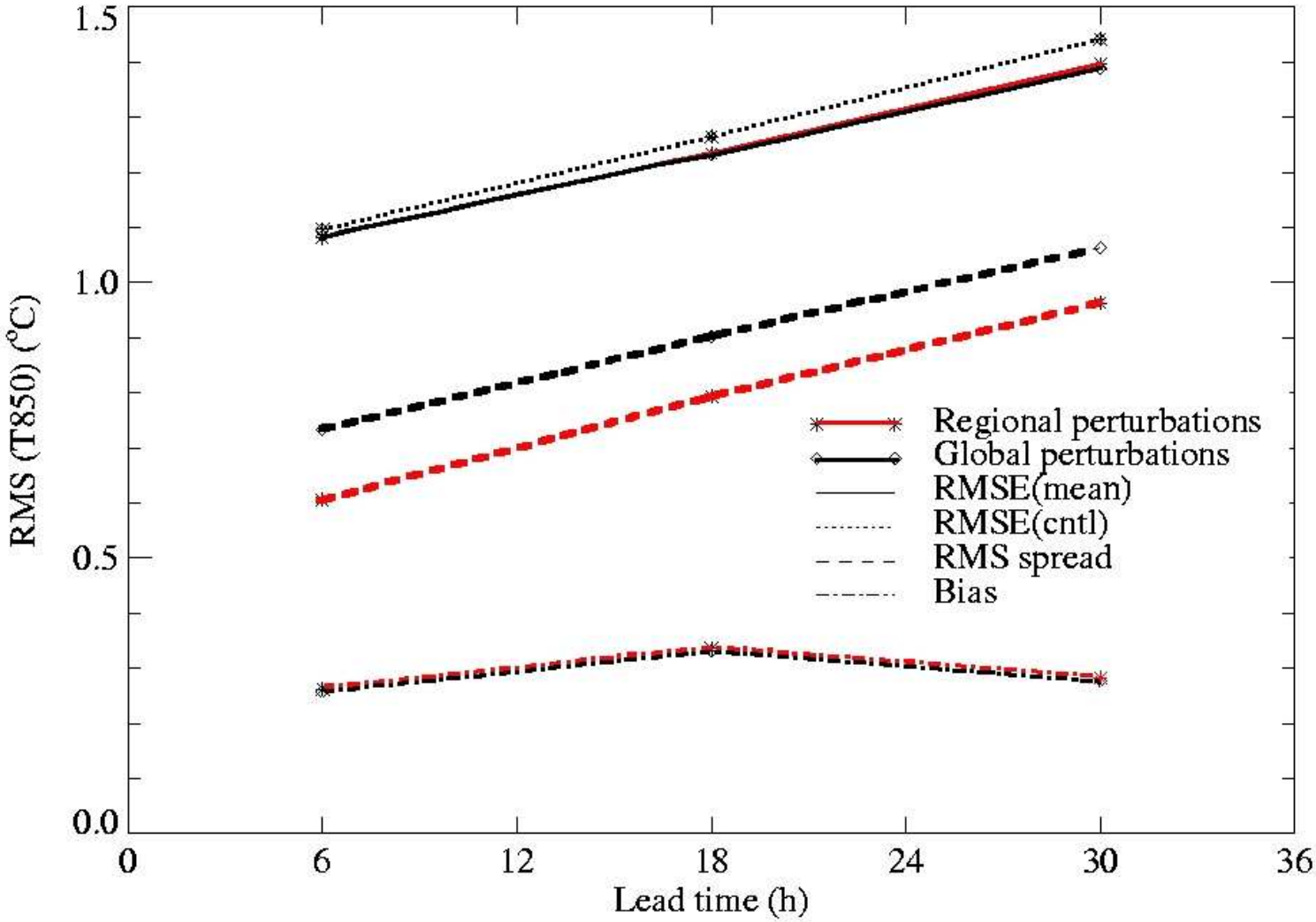
Accounting for Observation Errors

- $RMSE_c = \sqrt{RMSE^2 - ObsErr^2}$

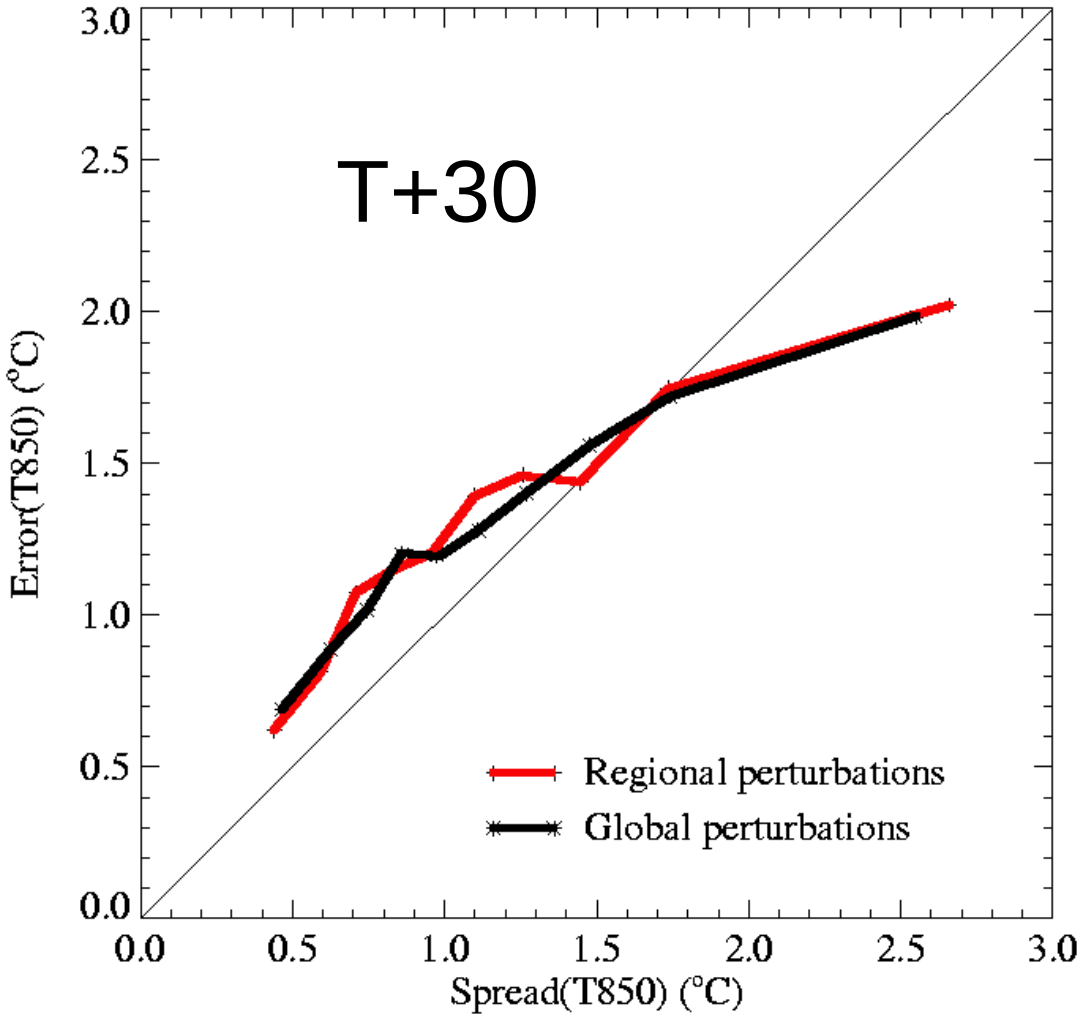
- Perturb each ensemble member by a random number drawn from Gaussian distribution.

  $X \sim N(\text{mean} = 0, \text{variance} = ObsErr^2)$

RMS Spread and Error T850

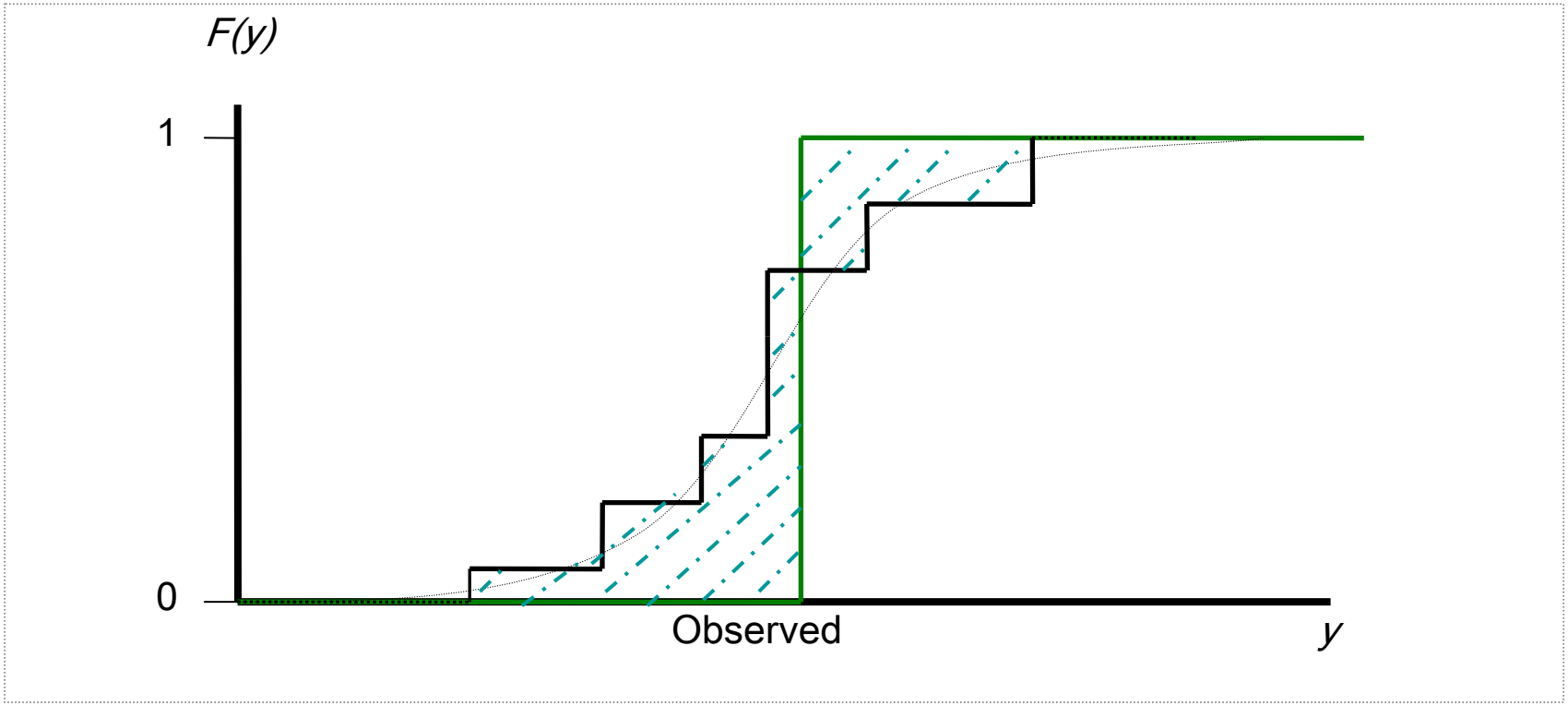


Spread Error Correlation T850

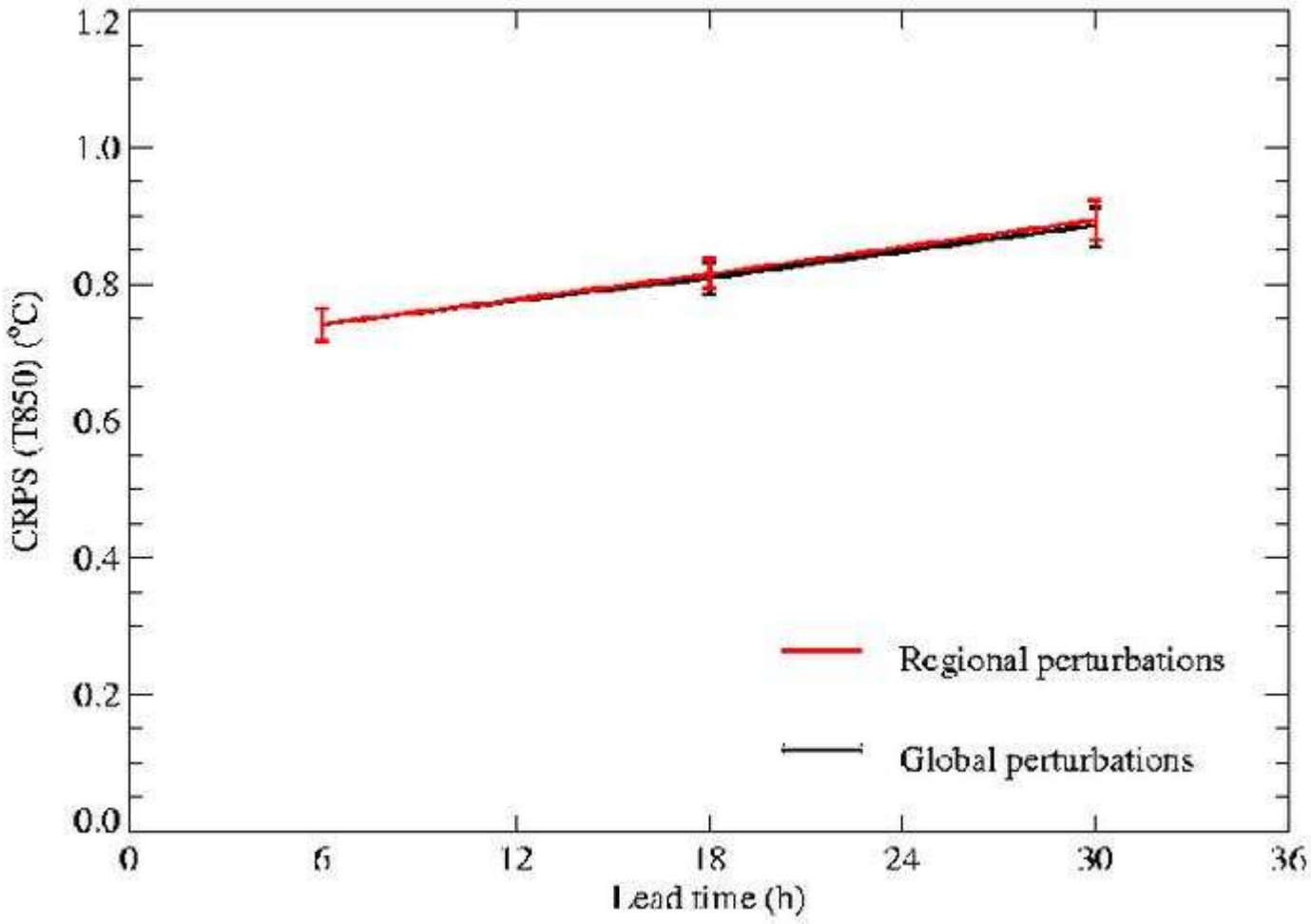


Continuous Ranked Probability Score

$$CRPS = \int_{-\infty}^{\infty} \left[F(y) - H_o(y) \right]^2 dy$$



850hPa Temperature
Continuous Ranked Probability Score



CRPS Differences (raw data)

Variable	T+6h	T+18h	T+30h
T 1.5m	0.09%	-0.11%	**-0.35%**
10m WS	-0.06%	**-0.19%**	**-0.53%**
PMSL	**2.21%**	**1.70%**	**0.89%**
6h Precip	**-3.03%**	**-3.43%**	**-3.27%**
T850	-0.51%	**-0.58%**	**-1.49%**
T500	**0.95%**	0.54%	-0.15%
T250	0.42%	**0.72%**	-0.28%
WS850	**-0.75%**	-0.11%	**-0.83%**
WS500	0.72%	0.01%	0.41%
WS250	**1.00%**	**1.46%**	0.13%
Z500	**0.89%**	0.35%	-0.42%

Positive = regional perturbations better

Negative = global perturbations better

Red/blue = statistically significant results at 5% level

CRPS Differences (calibrated data)

Variable	T+6h	T+18h	T+30h
T 1.5m	0.10%	0.05%	-0.23%
10m WS	-0.17%	**-0.40%**	**-0.36%**
PMSL	**0.55%**	**-0.49%**	**-0.76%**
6h Precip	-0.68%	**-0.77%**	**-1.13%**
T850	-0.20%	-0.13%	**-1.10%**
T500	0.06%	-0.27%	**-1.00%**
T250	0.49%	0.52%	-0.31%
WS850	**-0.70%**	-0.07%	**-1.04%**
WS500	0.51%	-0.46%	0.10%
WS250	0.44 %	**1.06%**	-0.20%
Z500	**0.59%**	-0.41%	**-1.09%**

Positive = regional perturbations better

Negative = global perturbations better

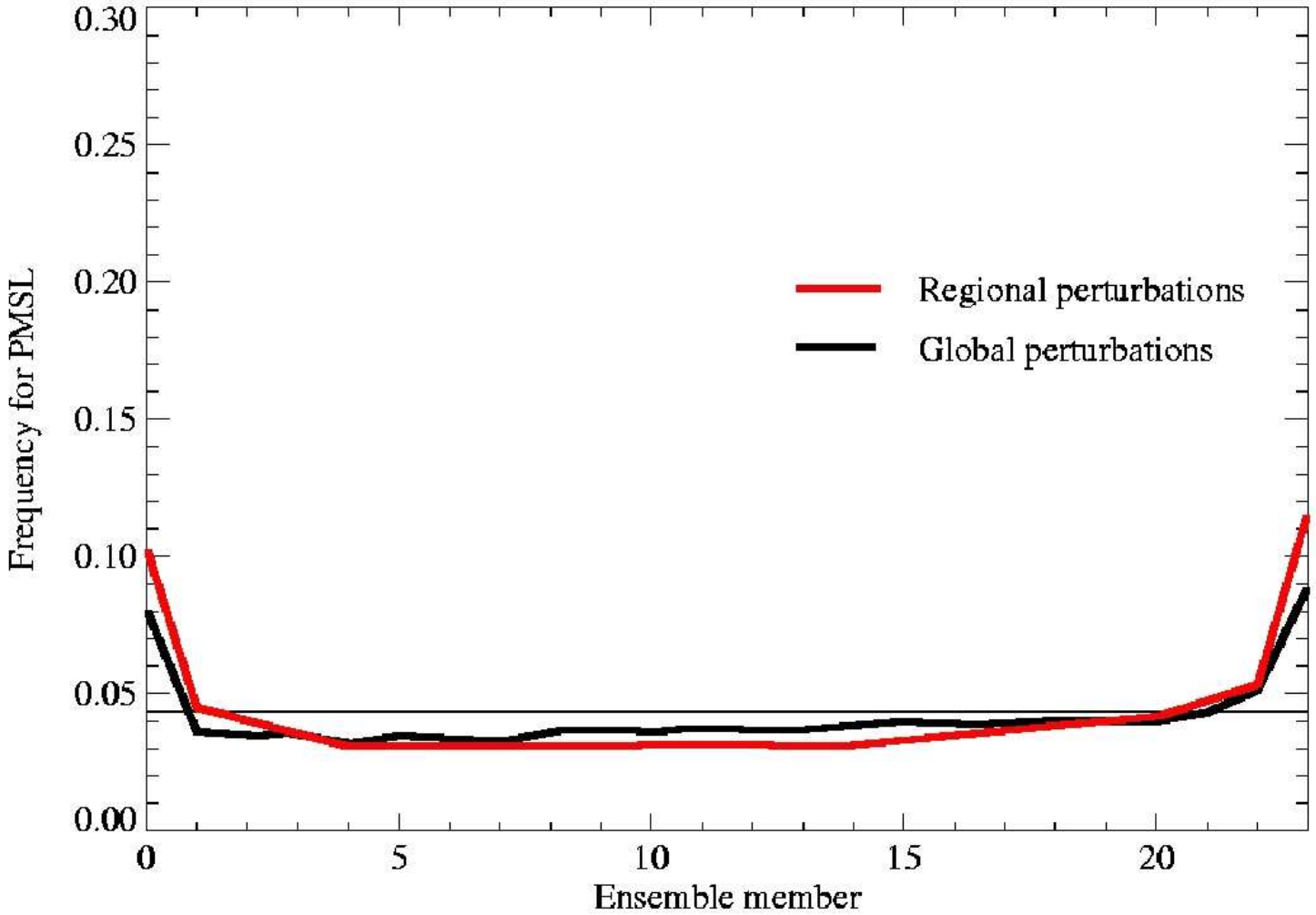
Red/blue = statistically significant results at 5% level

In Summary

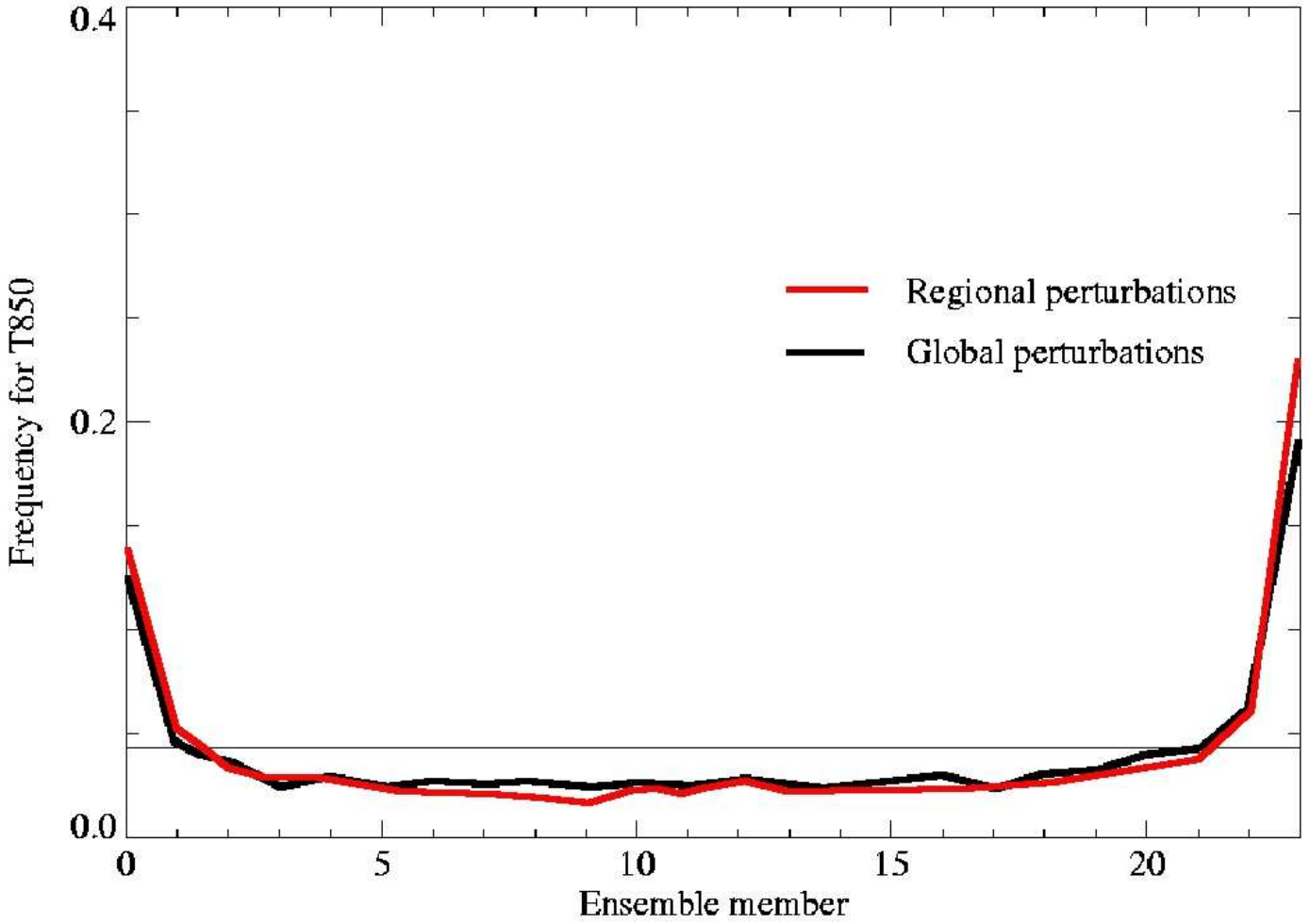
- ETKF perturbations for the regional ensemble contain more power on scales < 400 km, for up to 12hr into the forecast.
- Differences in spread observed in the two ensembles.
- RMSE of ensemble mean forecast for global perturbations lower than RMSE of regional ETKF perturbations.
- The performance of the two ensembles are very similar with higher skill observed when the perturbations are derived from the global ensemble.
- Improving on “dynamical downscaling” with explicit regional ensemble IC perturbations could be difficult.
- Implications for the MOGREPS-R ensemble.

Questions and Answers

Rank Histogram PMSL



Rank Histogram T850



Bias Correction and calibration

- Step one

Perturbed Fc – Mean error (Bias) of Ens Mean Fc

- Step two

Recalculate RMS spread about the ensemble mean

- Step three

Adjust the spread to match the RMSE of the ensemble mean forecast.

Regional ETKF v Global ETKF

- Global ETKF uses localisation, transform matrix calculated using T+12 forecasts and applied to perturbations valid at T+12.
- No localisation applied to regional ETKF
- Transform matrix and inflation factor calculated using observations centred around 00Z (12Z) for a 06Z (18Z) run of the regional ensemble, i.e., T+6 forecast.
- Transform matrix applied to the T+12 perturbations valid at 06 or 18Z.
- Offset assumes the non linearities of small perturbations are negligible
- Inflation factor calculated using radiosonde observations only.

Continuous Ranked Probability Score

- Overall measure – compares the ensemble and observation distributions.
- CRPS ≡ the Brier Score integrated over all possible thresholds.

or

- CRPS ≡ the Ranked Probability Score with infinitely small bin sizes.

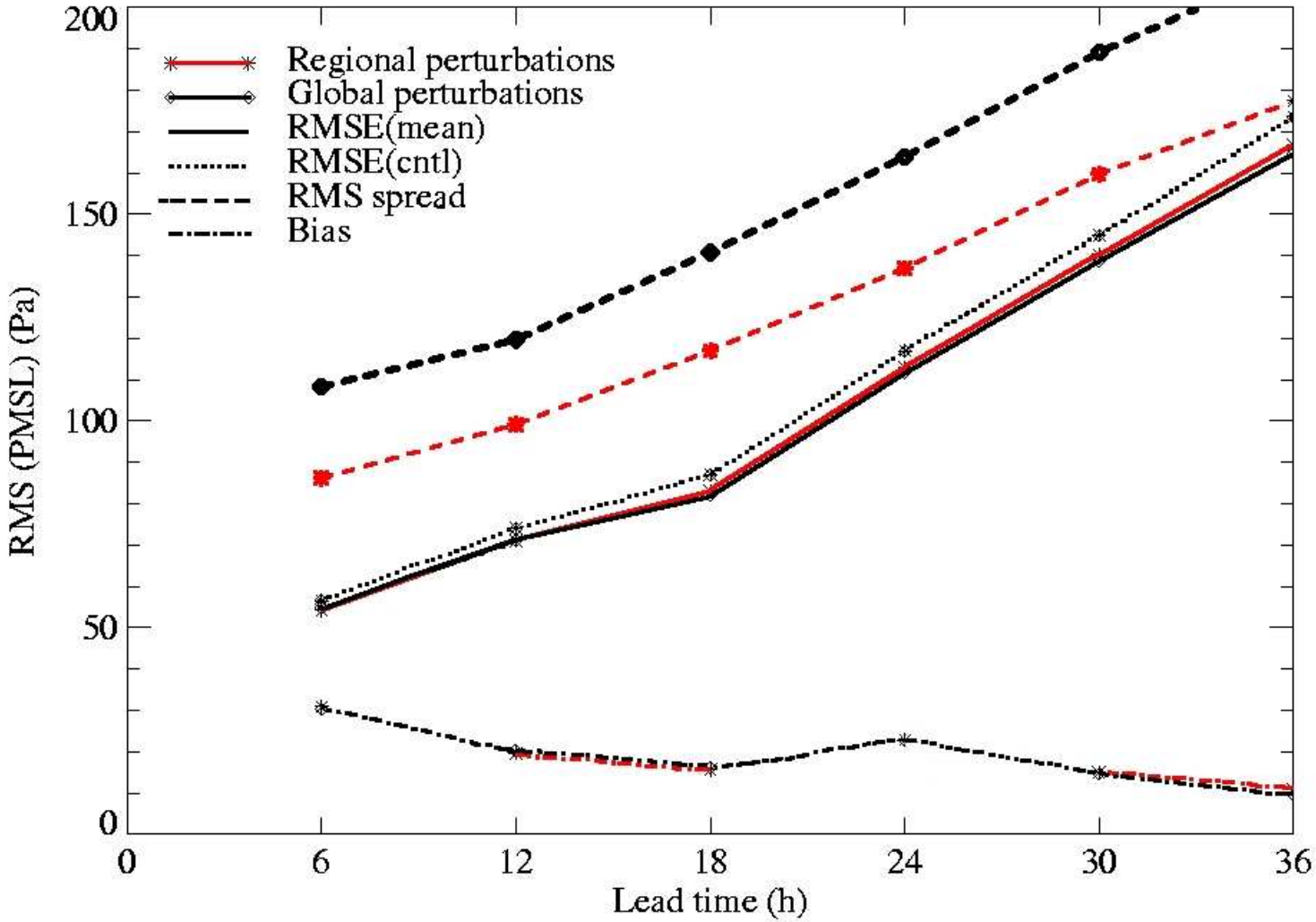
or

- CRPS ≡ Mean Absolute Error (in the deterministic case)
- Takes the unit of the variable calculated, smaller the better.

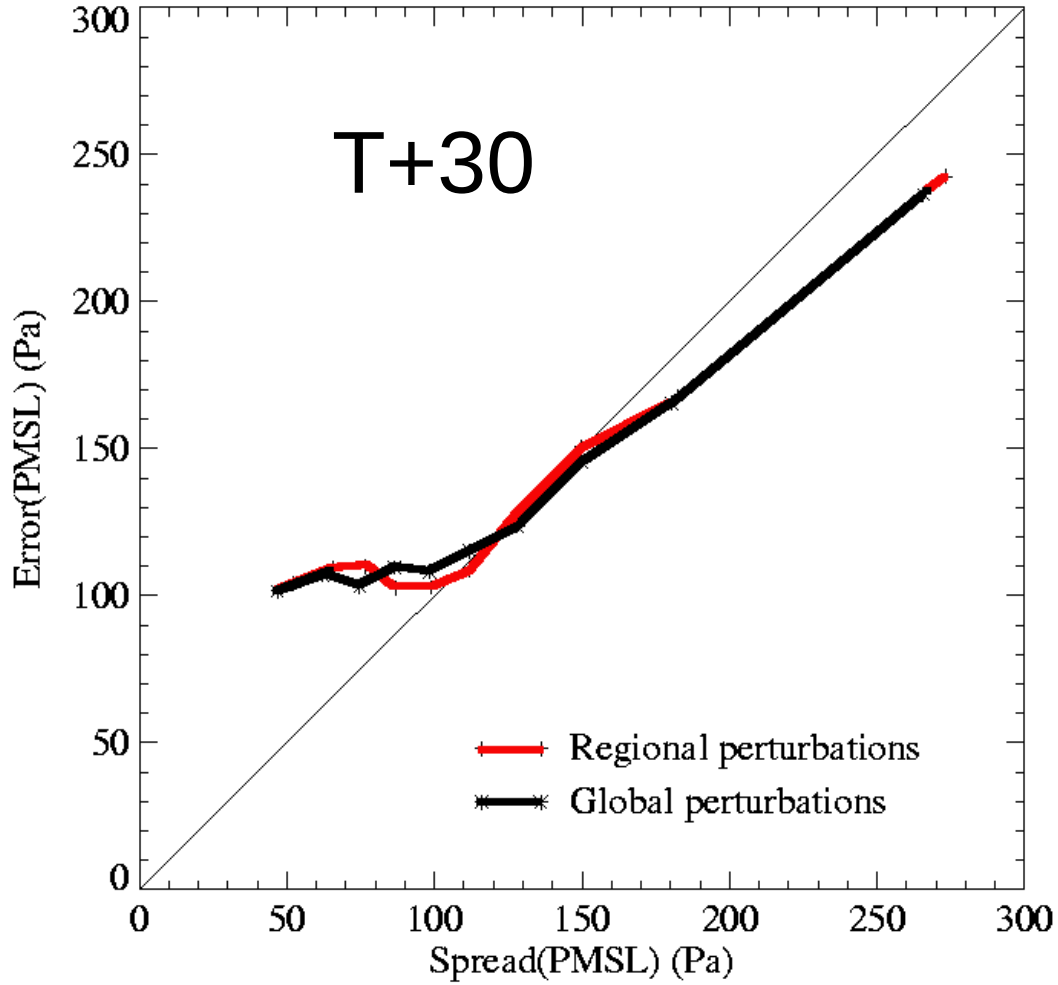
Bootstrap re-sampling

- Each day in record is treated separately
- Assumes no correlation in errors between days but that errors between stations are perfectly correlated.
- Because both ensembles are subject to the same weather, the difference in the CRPS may be more robust than the score itself.

RMS Spread and Error - PMSL



Spread Error Correlation PMSL



References

Bowler and Mylne (2008)

ETKF Perturbations for a regional ensemble prediction system.

Submitted to Quart. J. Roy. Meteor. Soc.

Continuous Ranked Probability Score PMSL