MOGREPS – Met Office Short-Range Ensemble Prediction System

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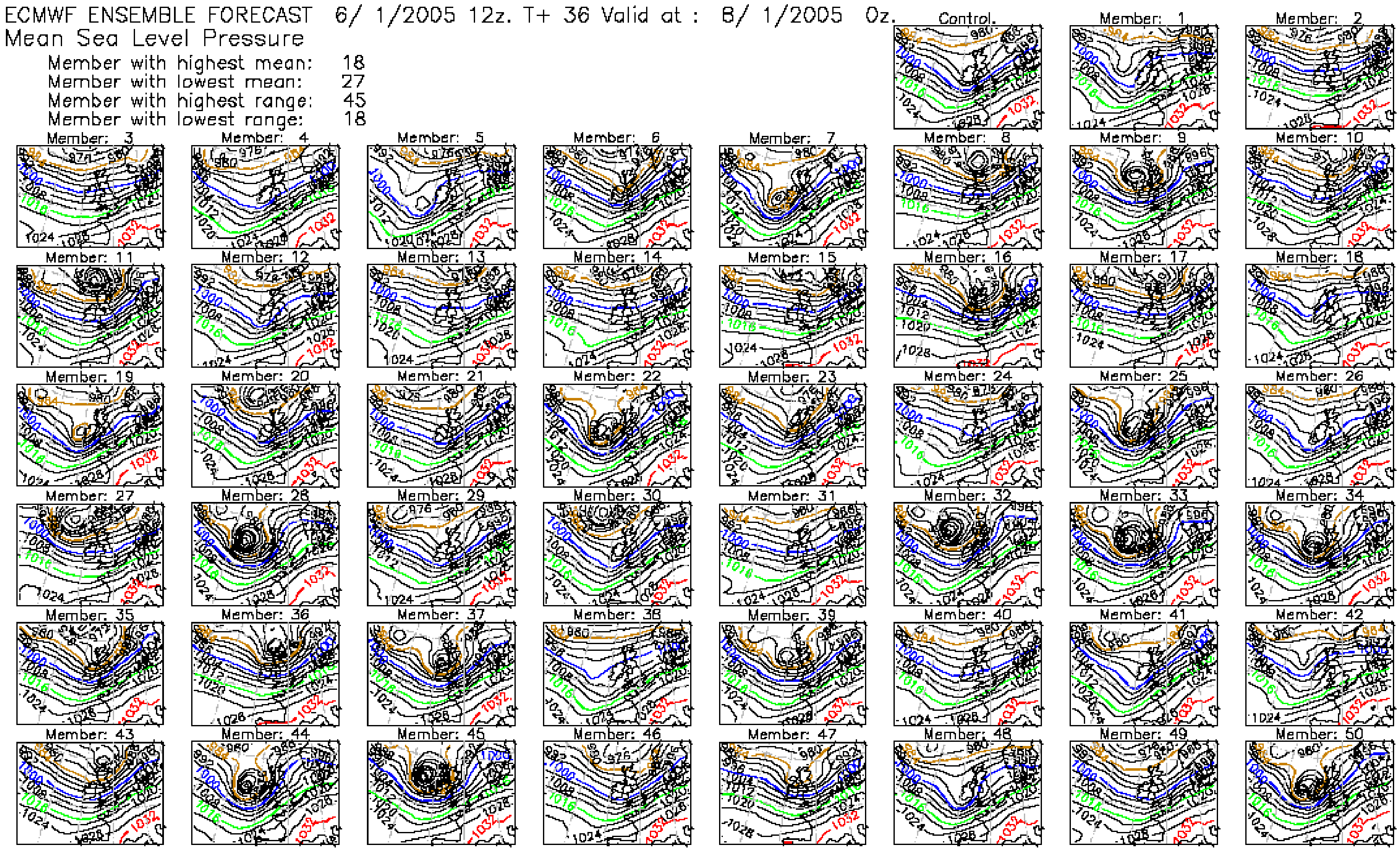
Ensemble Forecasting Group

Thanks also to: Dave Goddard, Ian Pearman, Clare Bysouth, Paul Maisey and many others!

Outline

- Motivation and strategy
- Products and feedback
- Initial condition perturbations
- Stochastic physics components
- Early verification results

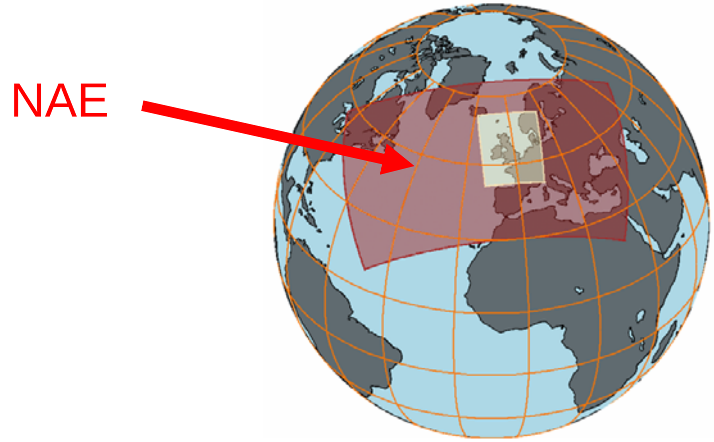
ECMWF Ensemble prediction System (EPS)



Carlisle storm, Jan 05, from ECMWF 51-member medium-range ensemble

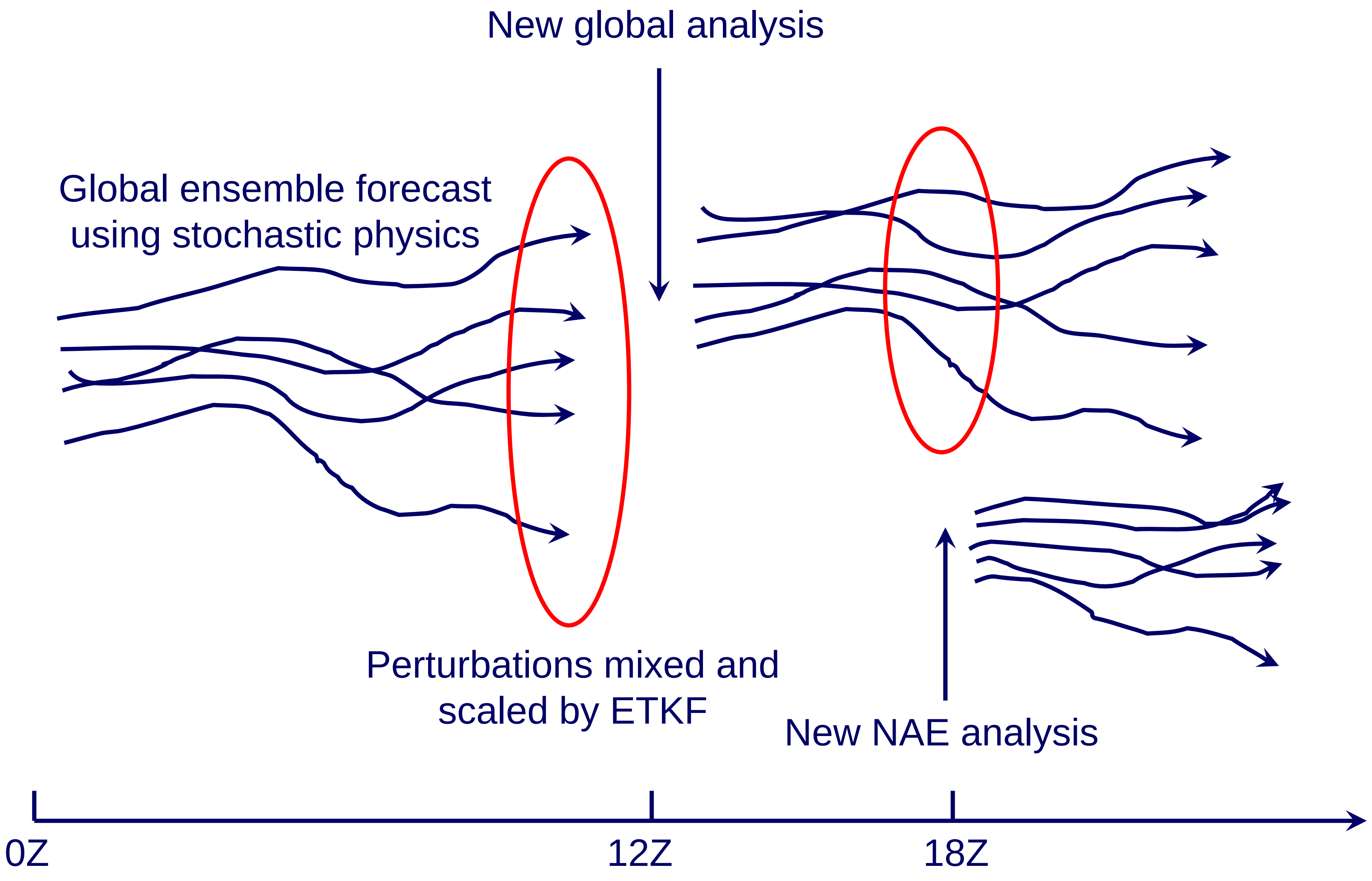
MOGREPS – The Met Office short-range Ensemble

- Ensemble designed for short-range
  - Regional ensemble over N. Atlantic and Europe (NAE)
  - Nested within global ensemble
  - ETKF perturbations
  - Stochastic physics
  - T+72 global, T+36 regional
  - Aim to assess uncertainty in short-range, eg.:
    - Rapid cyclogenesis
    - Local details (wind etc)
    - Precipitation
    - Fog and cloud



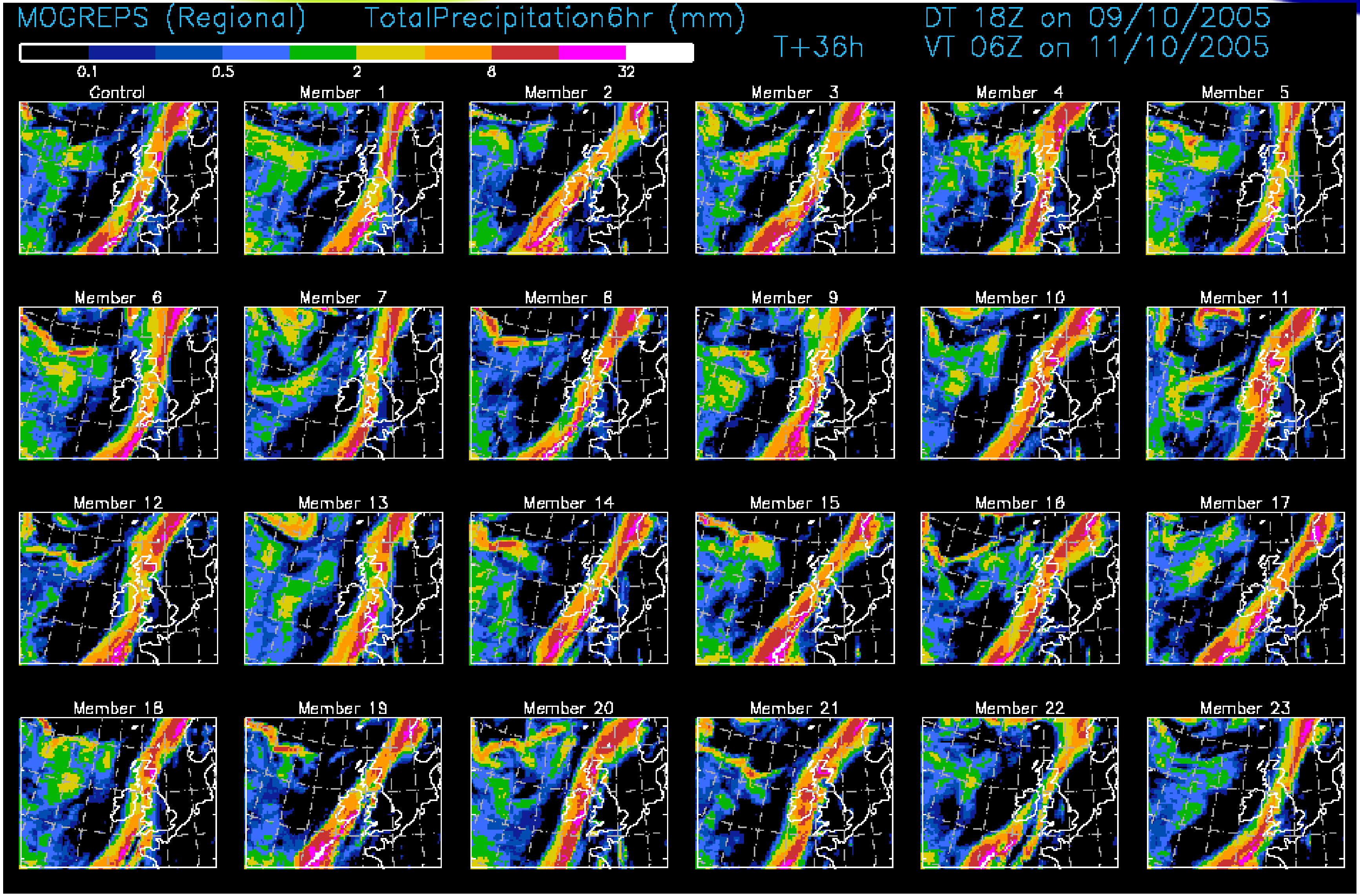
MOGREPS is on Operational Trial for 1 year from September 2005

MOGREPS Operational System diagram

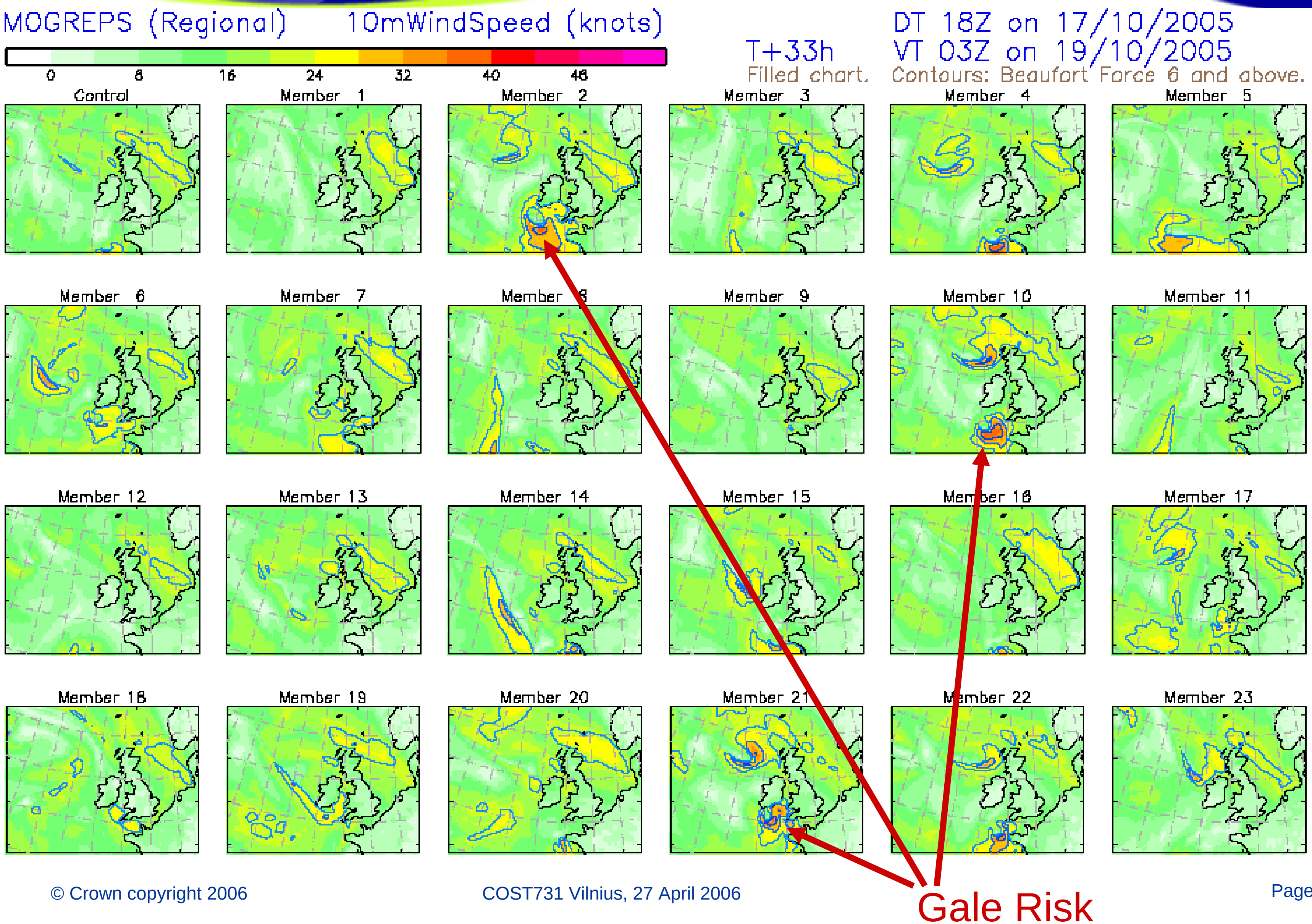


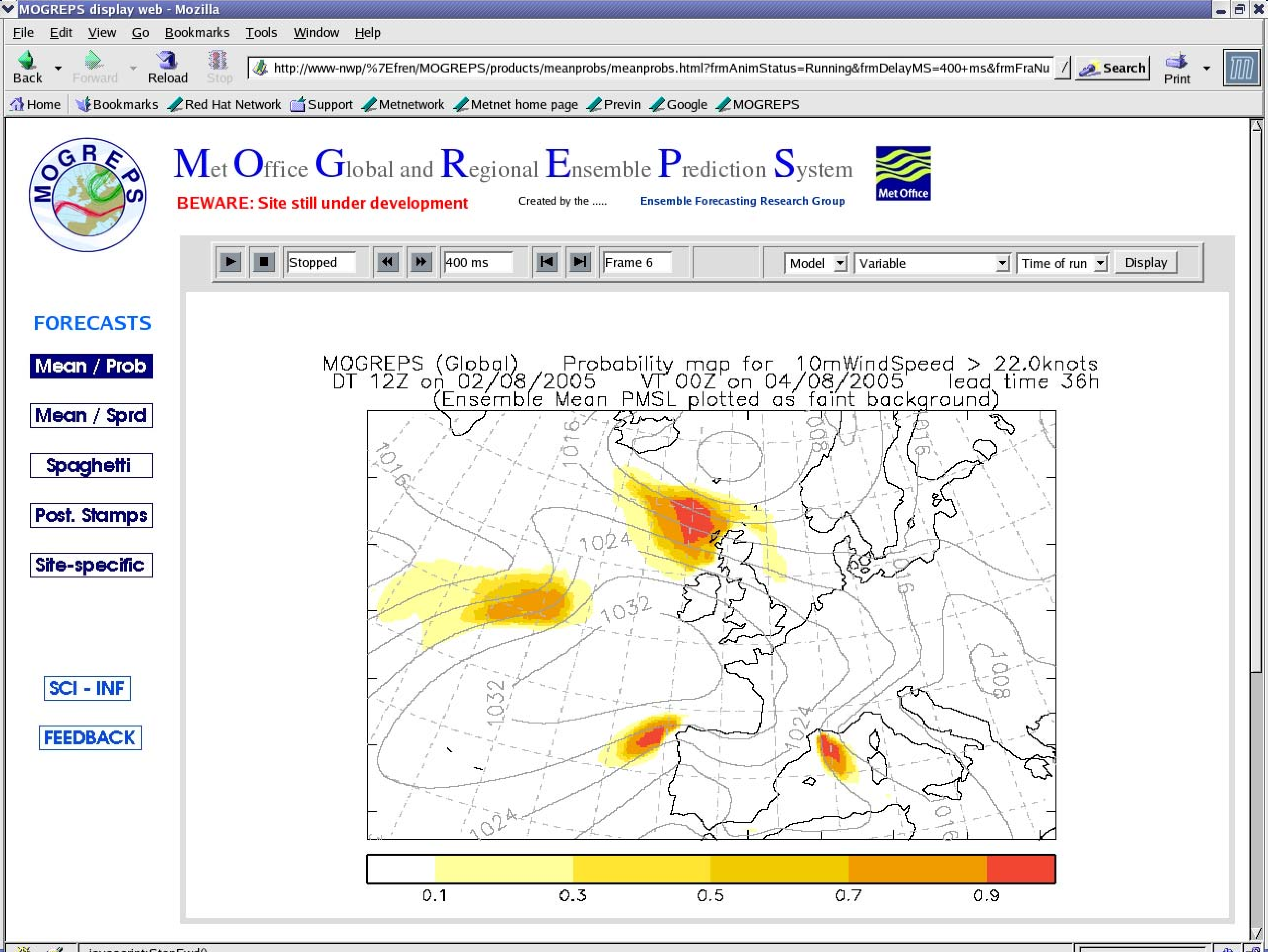
Product Examples

Example MOGREPS 36h Rainfall forecast

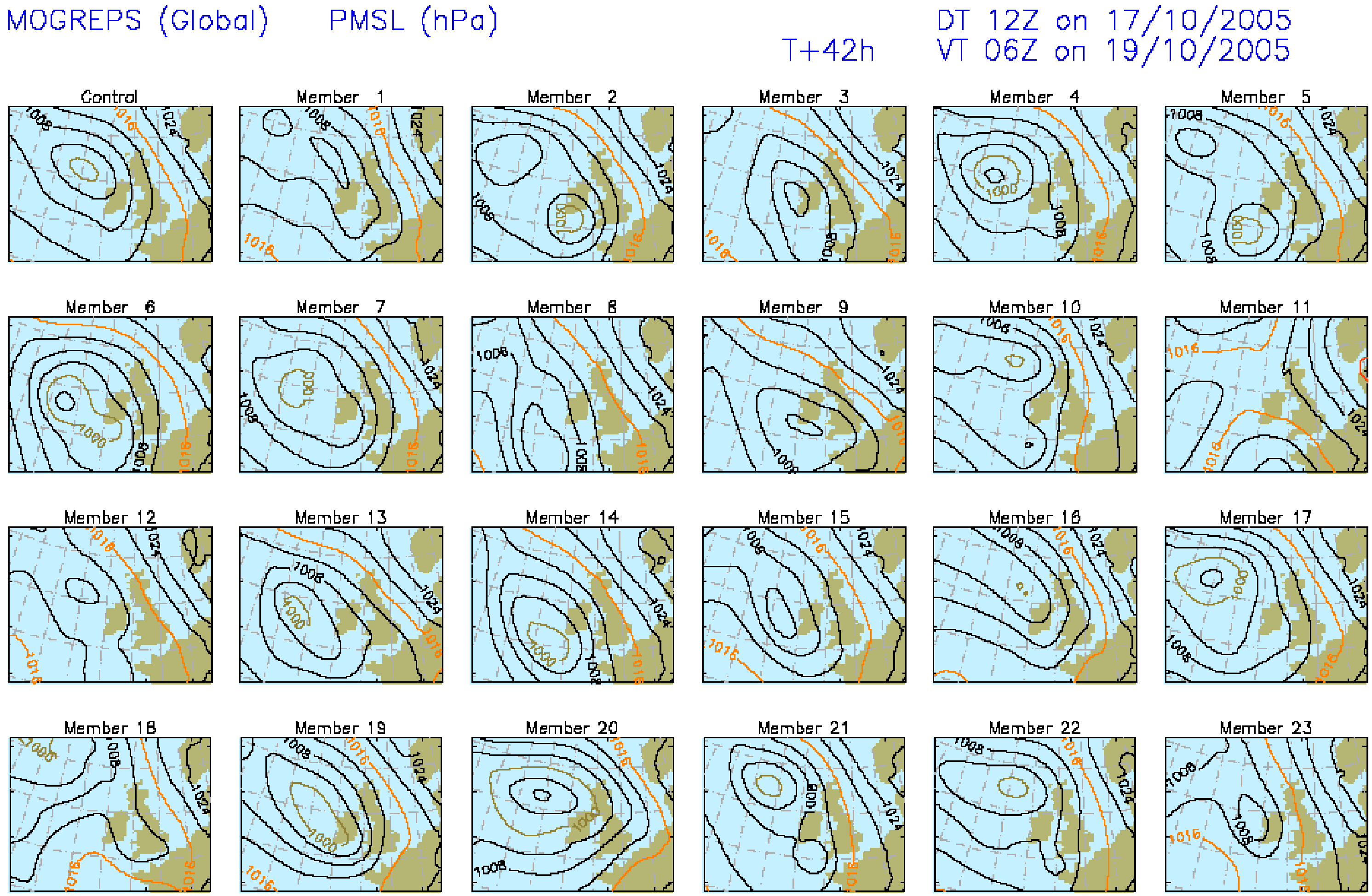


Example MOGREPS 33h 10m WS forecast



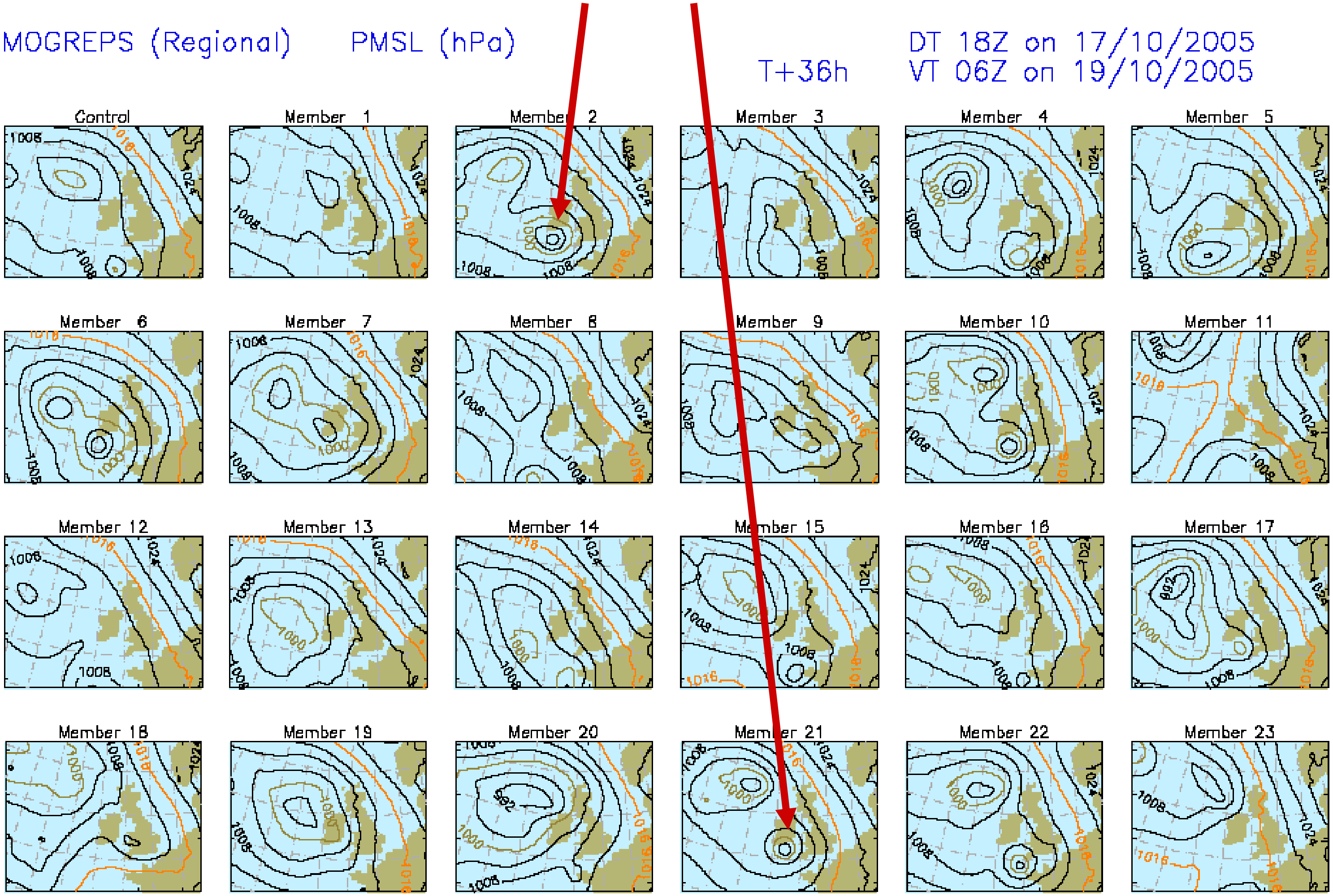

MOGREPS display web - Mozilla
File Edit View Go Bookmarks Tools Window Help
Back Forward Reload Stop
http://www-nwp/%7Efren/MOGREPS/products/meanprobs/meanprobs.html?frmAnimStatus=Running&frmDelayMS=400+ms&frmFraNu
Search
Print
Home Bookmarks Red Hat Network Support Metnetwork Metnet home page Previn Google MOGREPS
MOGREPS
Met Office Global and Regional Ensemble Prediction System
Met Office
BEWARE: Site still under development
Created by the .....
Ensemble Forecasting Research Group
Stopped
400 ms
Frame 6
Model
Variable
Time of run
Display
FORECASTS
Mean / Prob
Mean / Sprd
Spaghetti
Post. Stamps
Site-specific
SCI - INF
FEEDBACK
MOGREPS (Global) Probability map for 10mWindSpeed > 22.0knots
DT 12Z on 02/08/2005 VT 00Z on 04/08/2005 lead time 36h
(Ensemble Mean PMSL plotted as faint background)
1016
1024
1032
1008
0.1
0.3
0.5
0.7
0.9

Global T+42 forecast for 06Z on 19/10/05



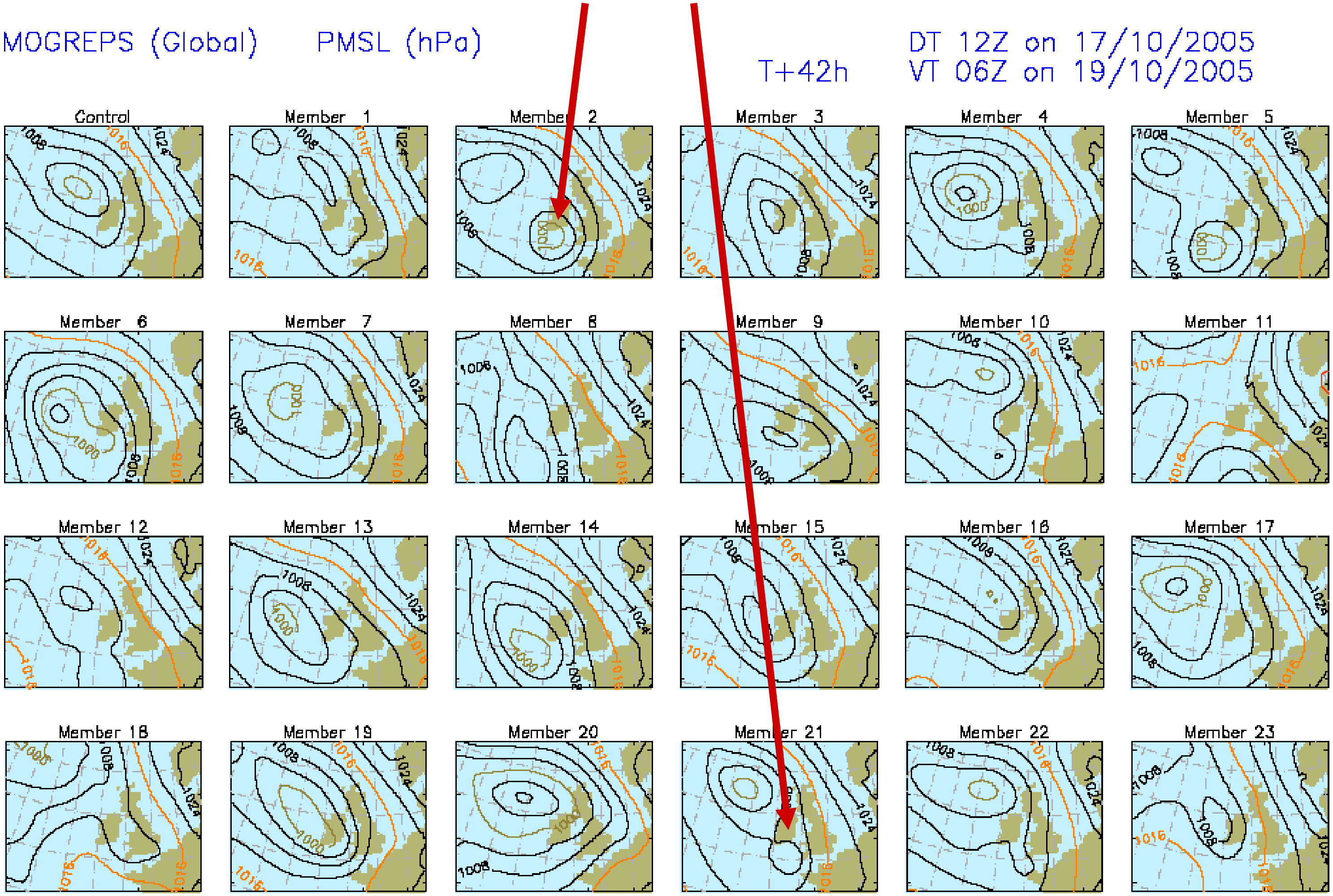
NAE T+36 forecast for 06Z on 19/10/05

Note extra detail and deeper lows in NAE



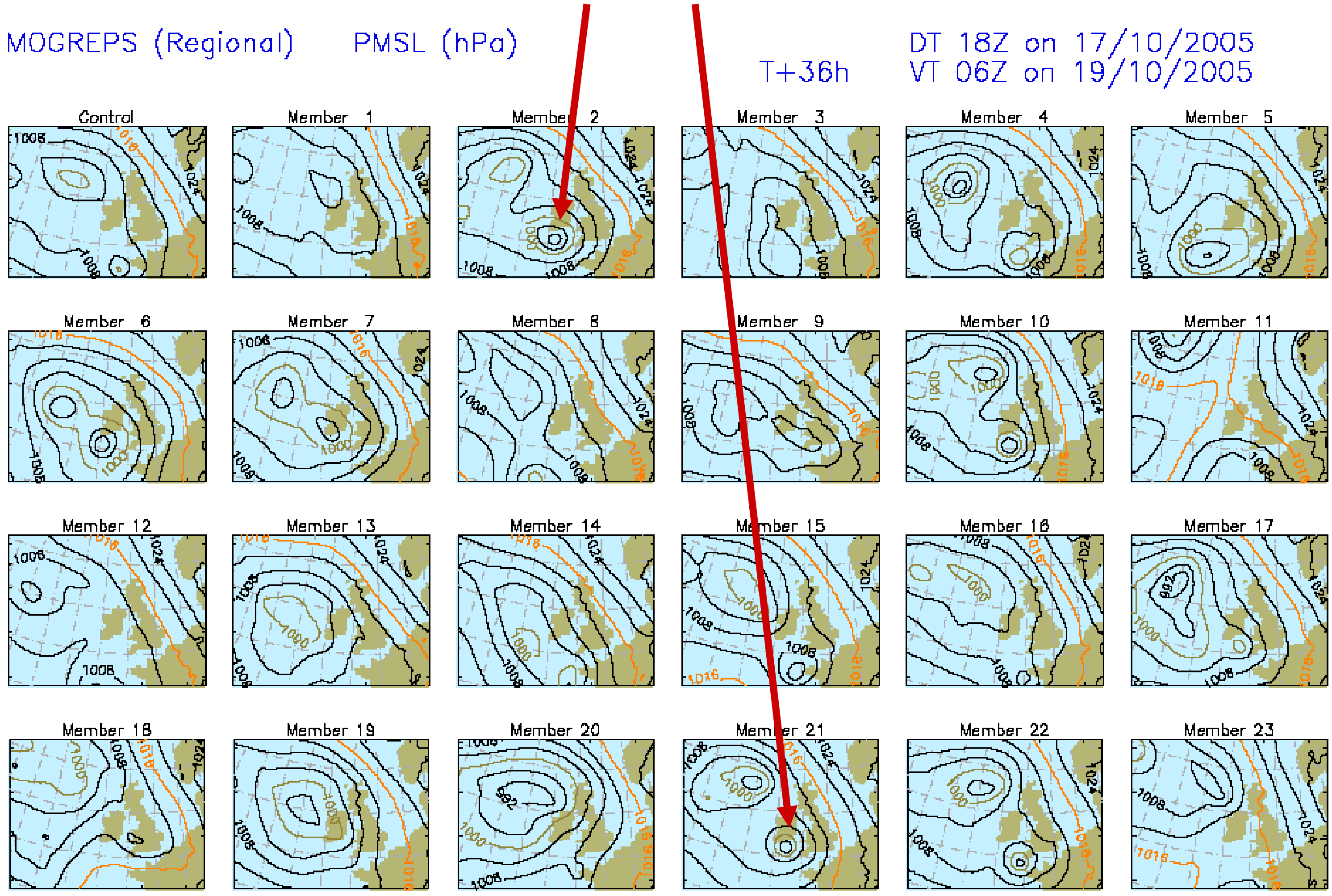
Global T+42 forecast for 06Z on 19/10/05

Note extra detail and deeper lows in NAE



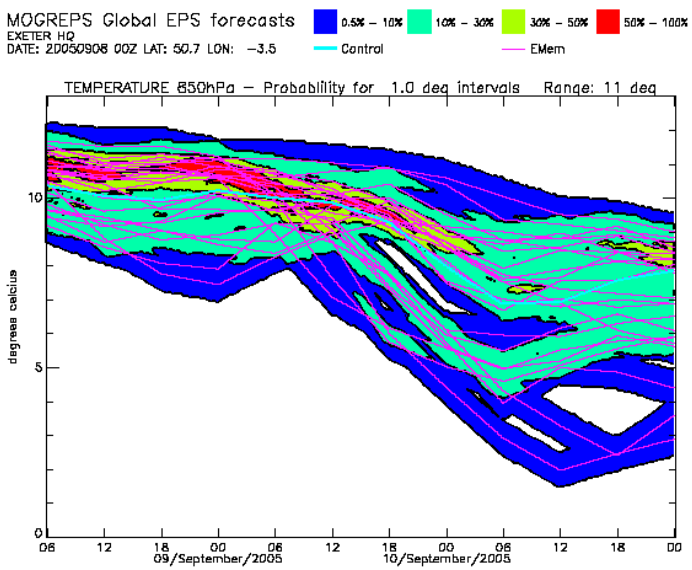
NAE T+36 forecast for 06Z on 19/10/05

Note extra detail and deeper lows in NAE

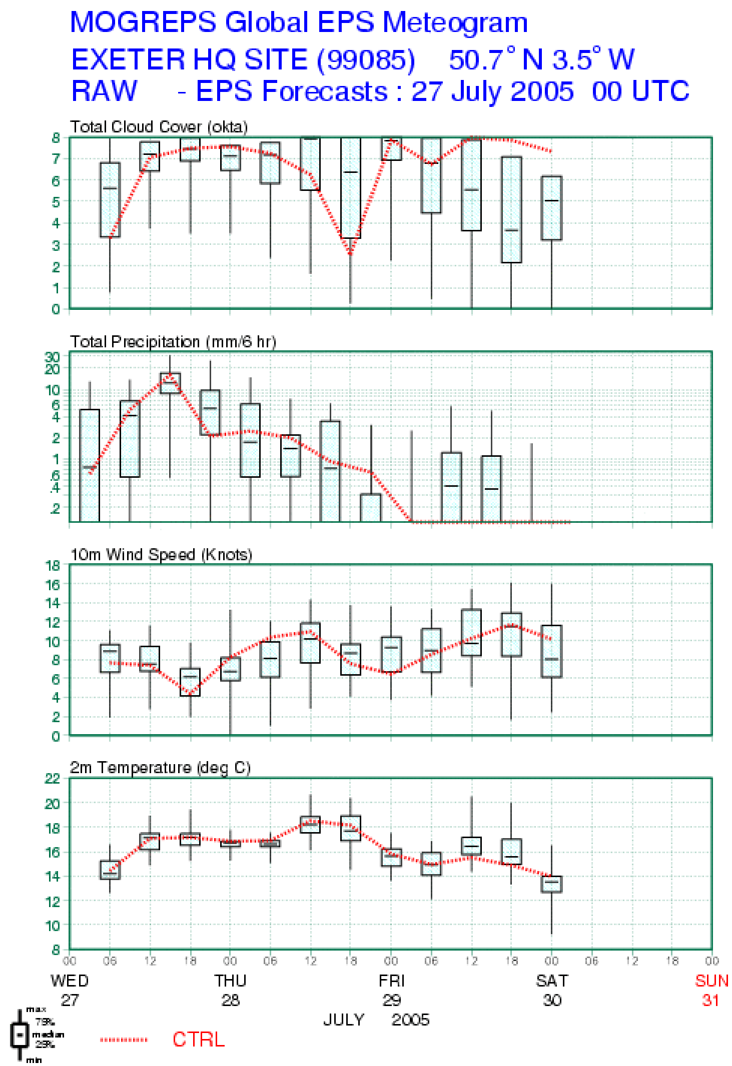


MOGREPS Site-specific forecasts

- EPS Meteogram
- MOGREPS Plume



- Kalman filter MOS is being implemented for MOGREPS forecasts



Feedback Quotes from Forecaster Trial

Positive

- probs for visibility were useful
- ensemble appears to give useful guidance on risk of fog and frost under anticyclone
- Modified towards deeper low off NW Scotland
- Prob field for 6hour > 0.3mm very good in highlighting areas at risk.

Negative

- Point probs too small - need areal probs.
- spread of mslp values in UK ridge seems a little too large

Initial Condition Pertubations - ETKF

Ensemble Transform Kalman Filter (ETKF)

- Simplified version of Ensemble Kalman Filter
  - Data assimilation scheme
- Do not try to update ensemble mean, only to chose appropriate perturbations
- Accounts for the observations in choosing a method for re-scaling the perturbations

- New analysis perturbations are transformed as

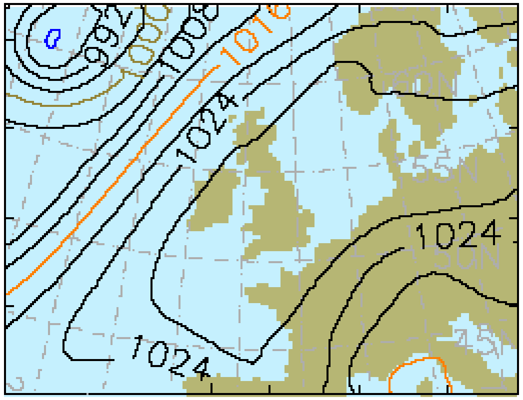
$$\mathbf{X}^a \qquad \mathbf{X}^f\mathbf{T}$$

- Perturbations are applied to U, V, T, P, q (no perturbations to q_{cl}, q_{cf}, SST or land-surface)

Bishop et al. (2001) MWR

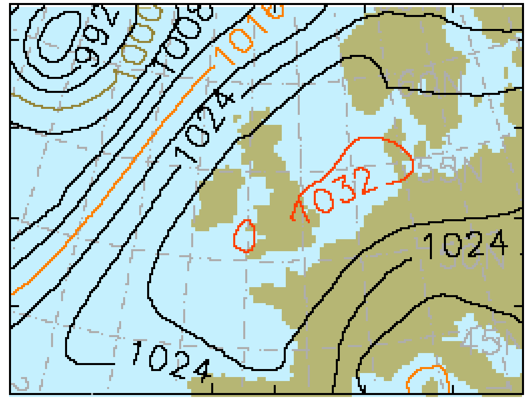
Error Breeding

(



T+12 perturbed forecast

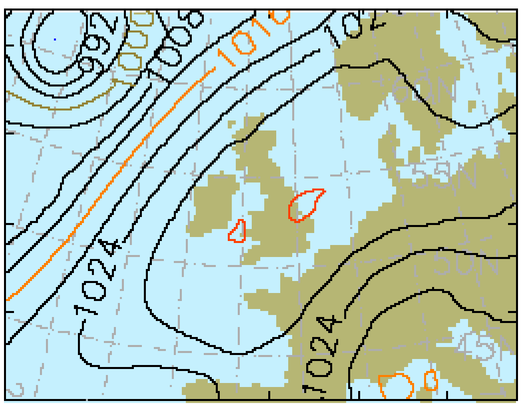
-



T+12 control forecast

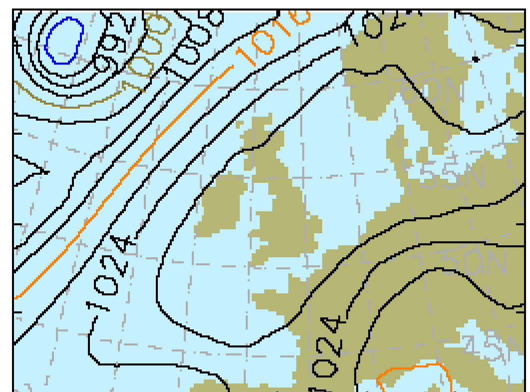
)*F

+



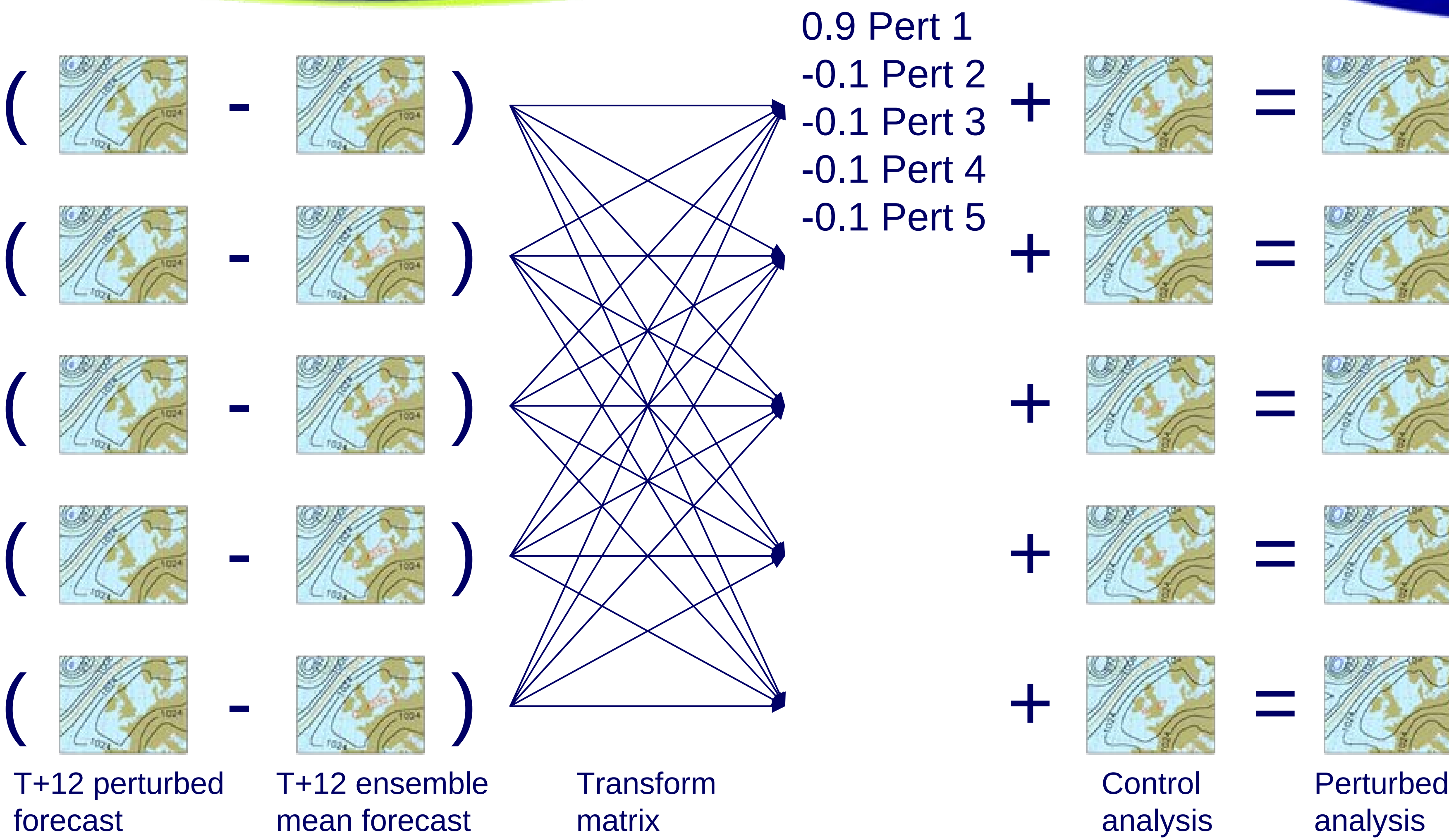
Control analysis

=



Perturbed analysis

Ensemble Transform Kalman Filter (ETKF)

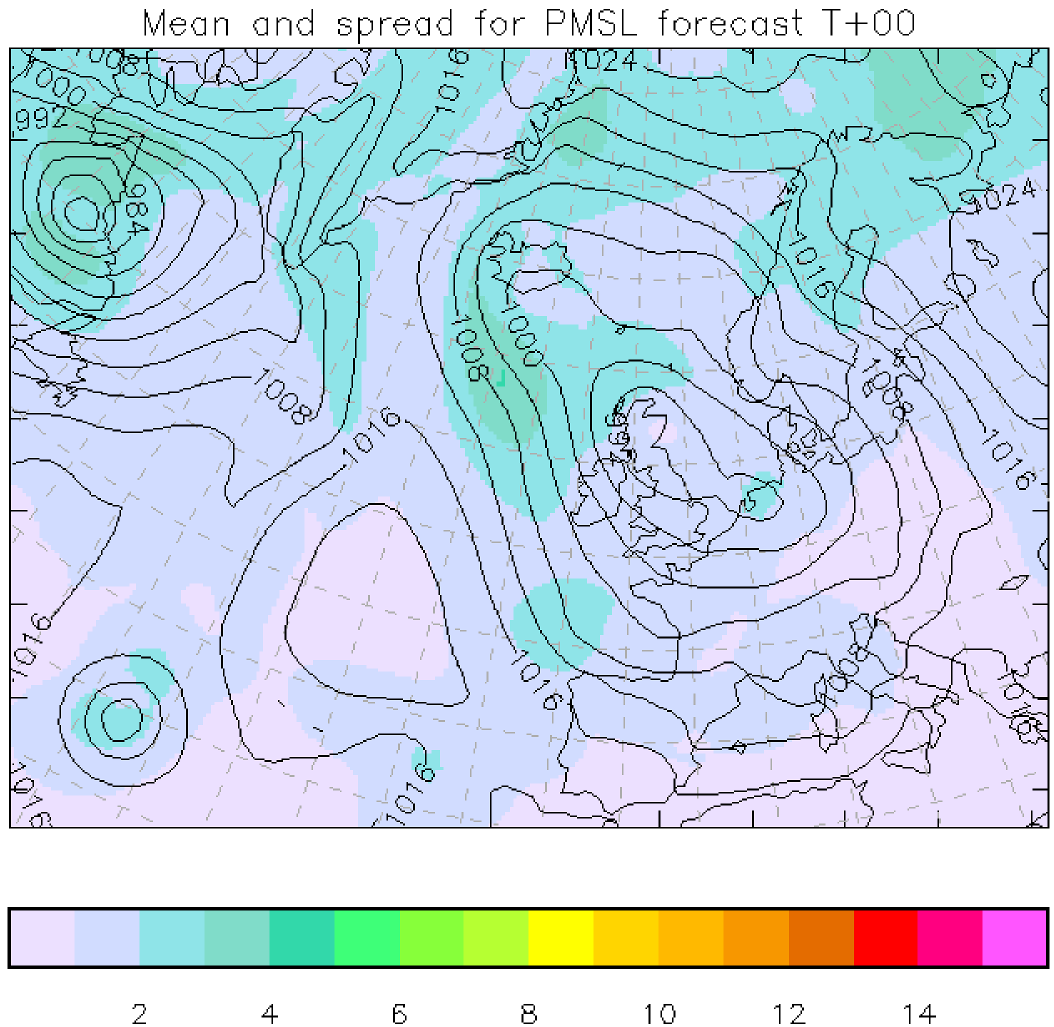


Why we chose the ETKF

- We have developed an ensemble for short-range forecasting (0-3 days) and EnKF quantifies the errors in the analysis
- ETKF is a computationally efficient way of updating ensemble perturbations
- Studies have shown that ETKF is superior to error breeding

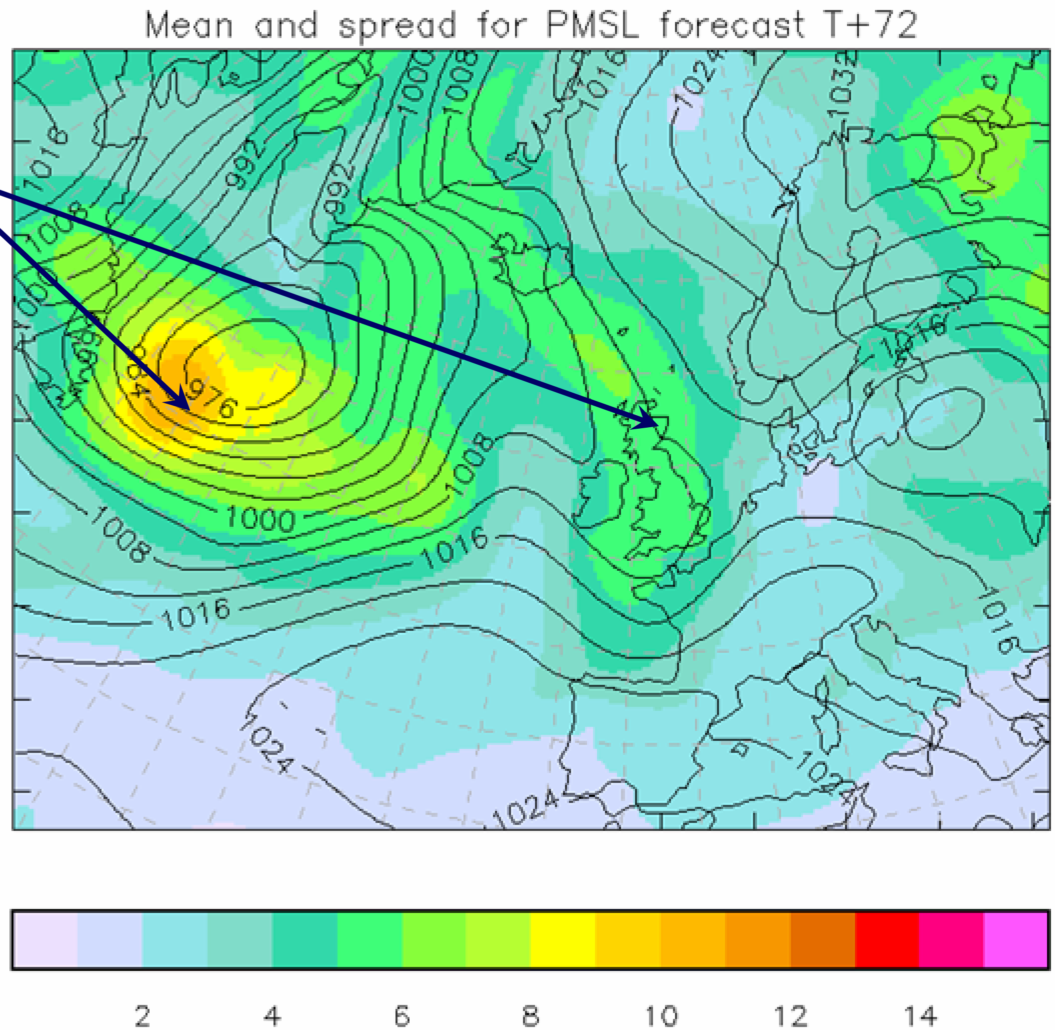
Perturbation structure

Perturbation Structures – Mean and spread PMSL

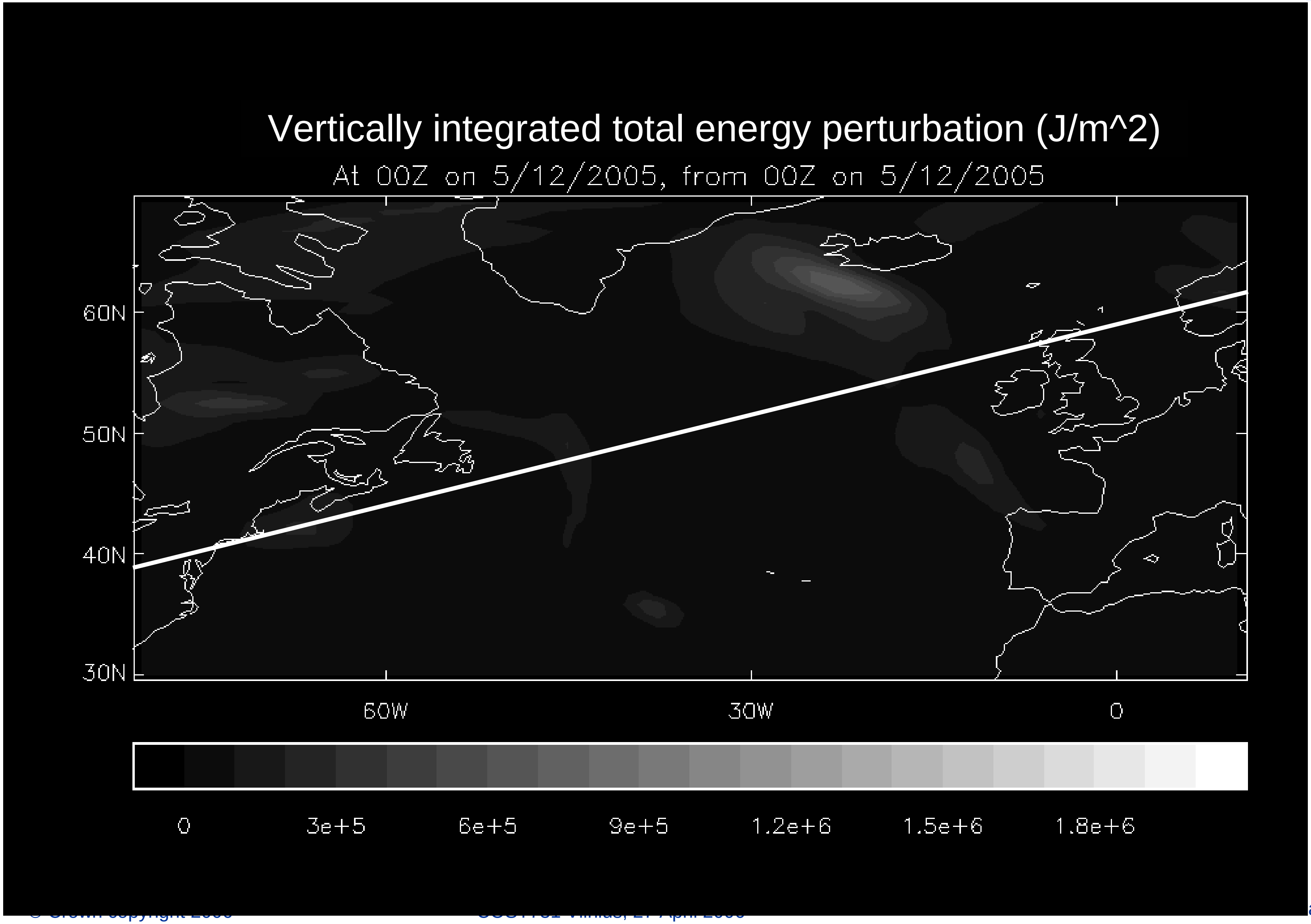


Perturbation Structures – Mean and spread PMSL

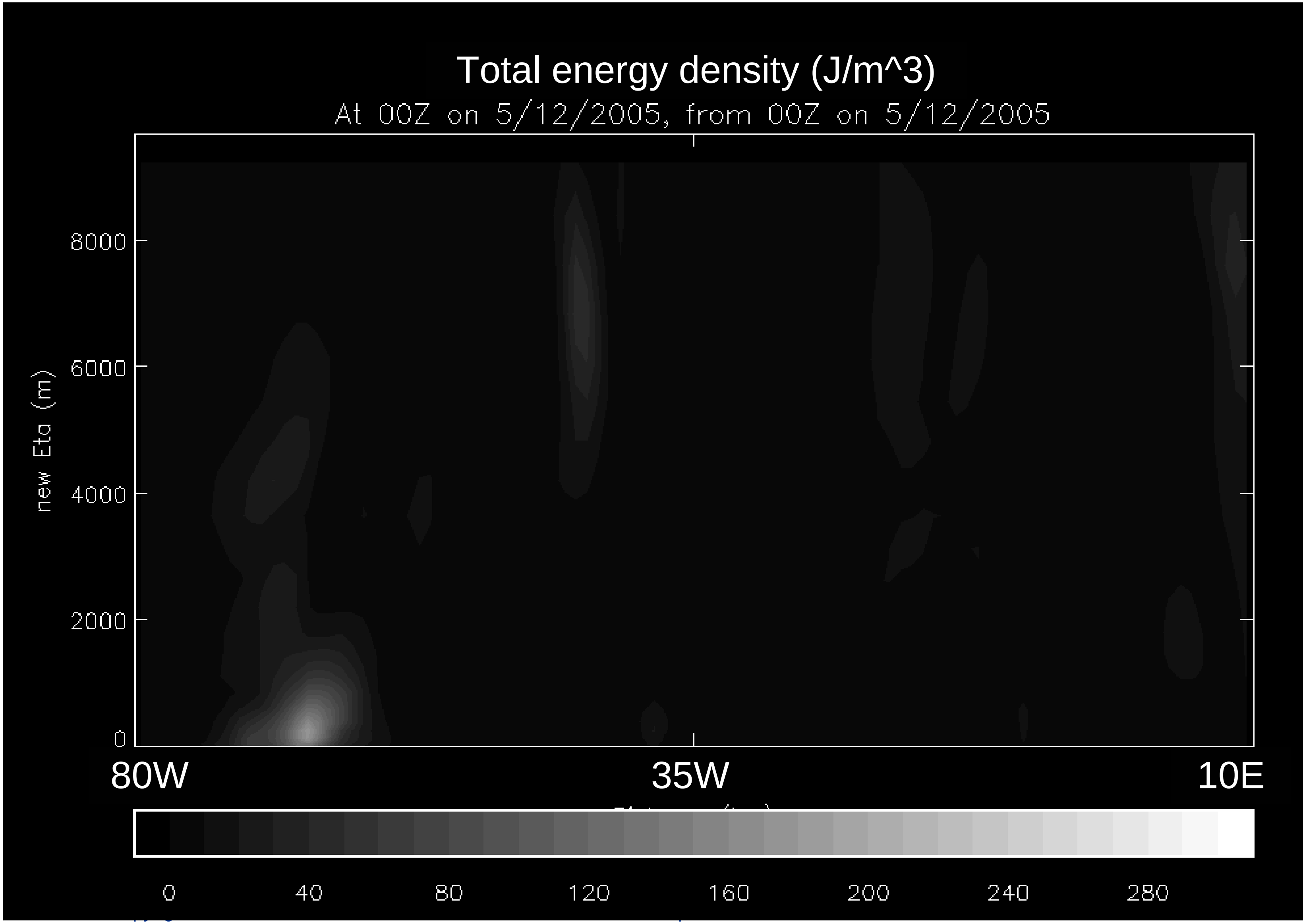
- Spread tends to be concentrated around fronts and sharp gradients
- Perturbation is non-zero everywhere (in contrast to SVs)



Vertically integrated total energy

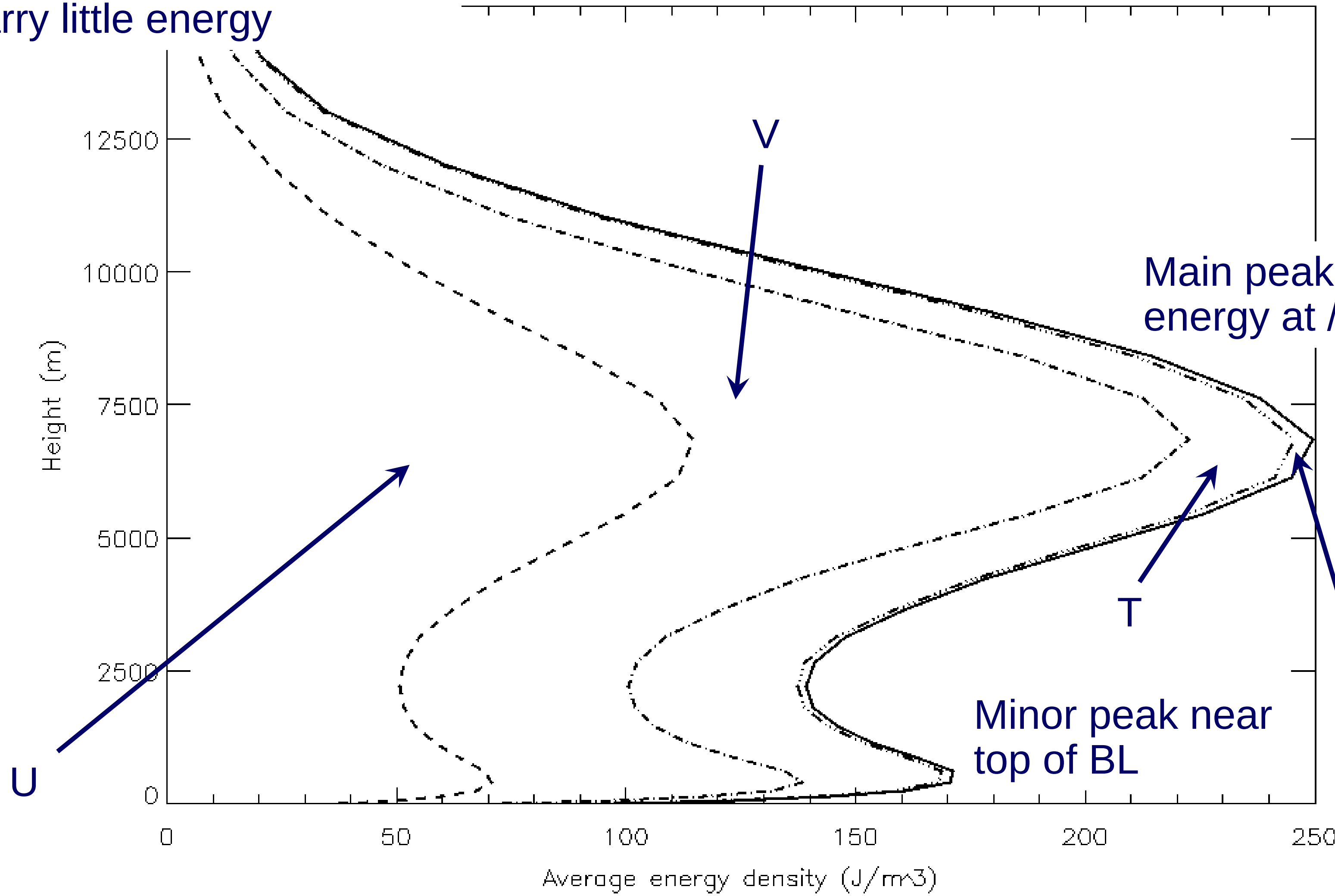


Total energy cross-section



Total Energy with height

Perturbations above 15km carry little energy



This, and following data, is calculated based on all ensemble members

Stochastic Physics

Stochastic physics in MOGREPS

MOGREPS employs three schemes to address different sources of model error:

- Random Parameters (RP)
  - Error due to approximations in parameterisation
- Stochastic Convective Vorticity (SCV)
  - Unresolved impact of organised convection (MCSs)
- Stochastic Kinetic Energy Backscatter (SKEB)
  - Excess dissipation of energy at small scales

Impact is propagated to next cycle through the ETKF

Stochastic scheme for the UM

The Random Parameters

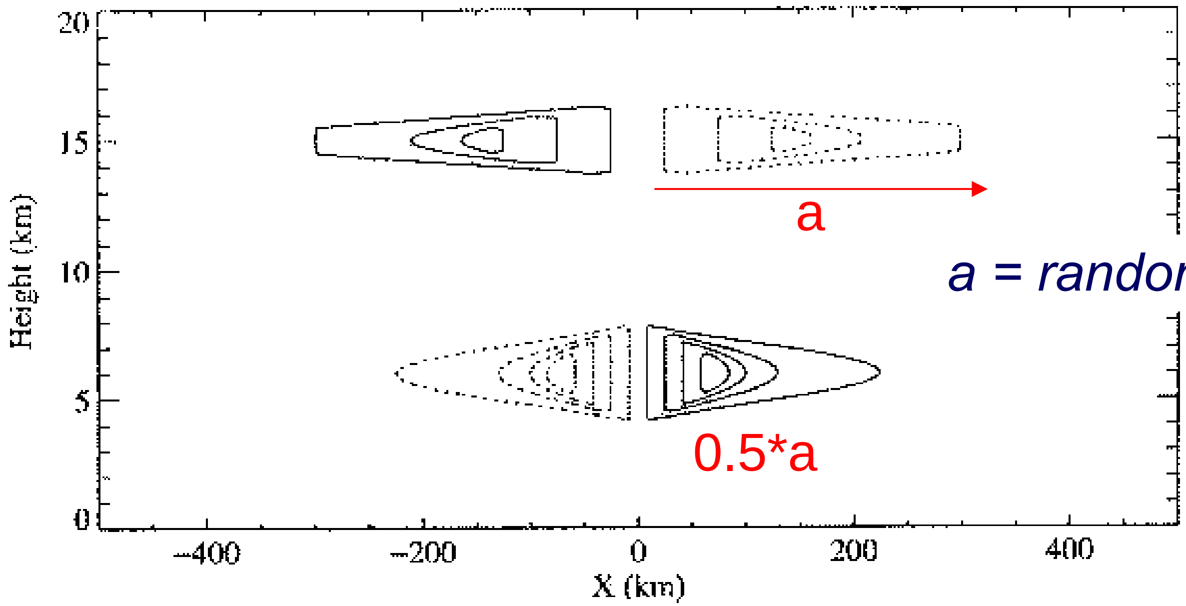
Parameter	Scheme	min/std/Max
Entrainment rate	CONVECTION	2 / 3 / 5
Cape timescale	CONVECTION	30 / 30 / 120
Rhcrit	LRG. S. CLOUD	0.6 / 0.8 / 0.9
Ice fall	LRG. S. CLOUD	17 / 25.2 / 33
Flux profile param.	BOUNDARY L.	5 / 10 / 20
Neutral mixing length	BOUNDARY L.	0.05 / 0.15 / 0.5
Gravity wave const.	GRAVITY W.D.	1E-4/7E-4/7.5E-4
Froude number	GRAVITY W.D.	2 / 2 / 4

These parameters are treated as stochastic variables:

$P_t = \mu + r(P_{t-1} - \mu) + \varepsilon$ with $r = 0.95$

Stochastic schemes for the UM

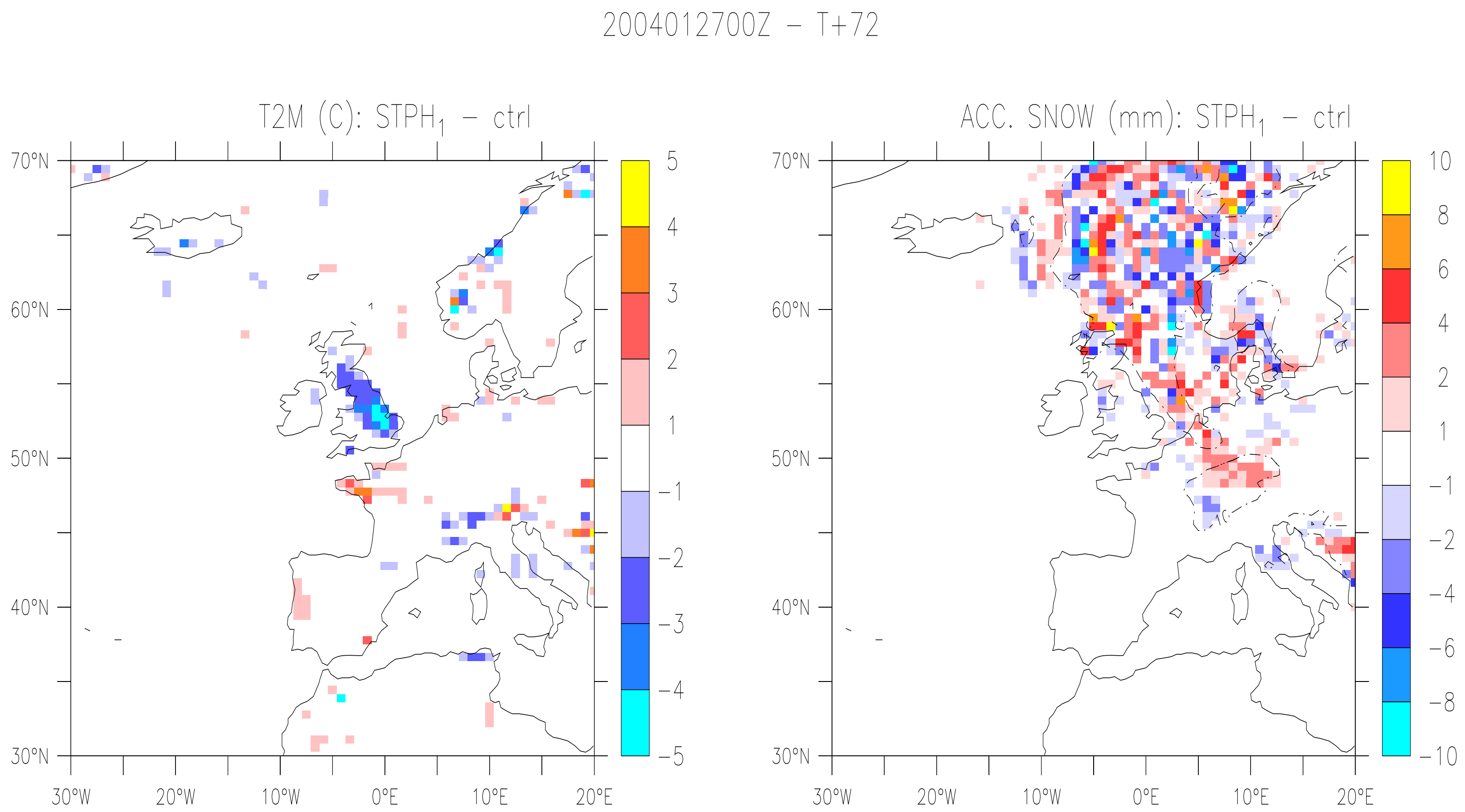
The SCV component (Gray and Shutts, 2002)



a = random f(CAPE)*

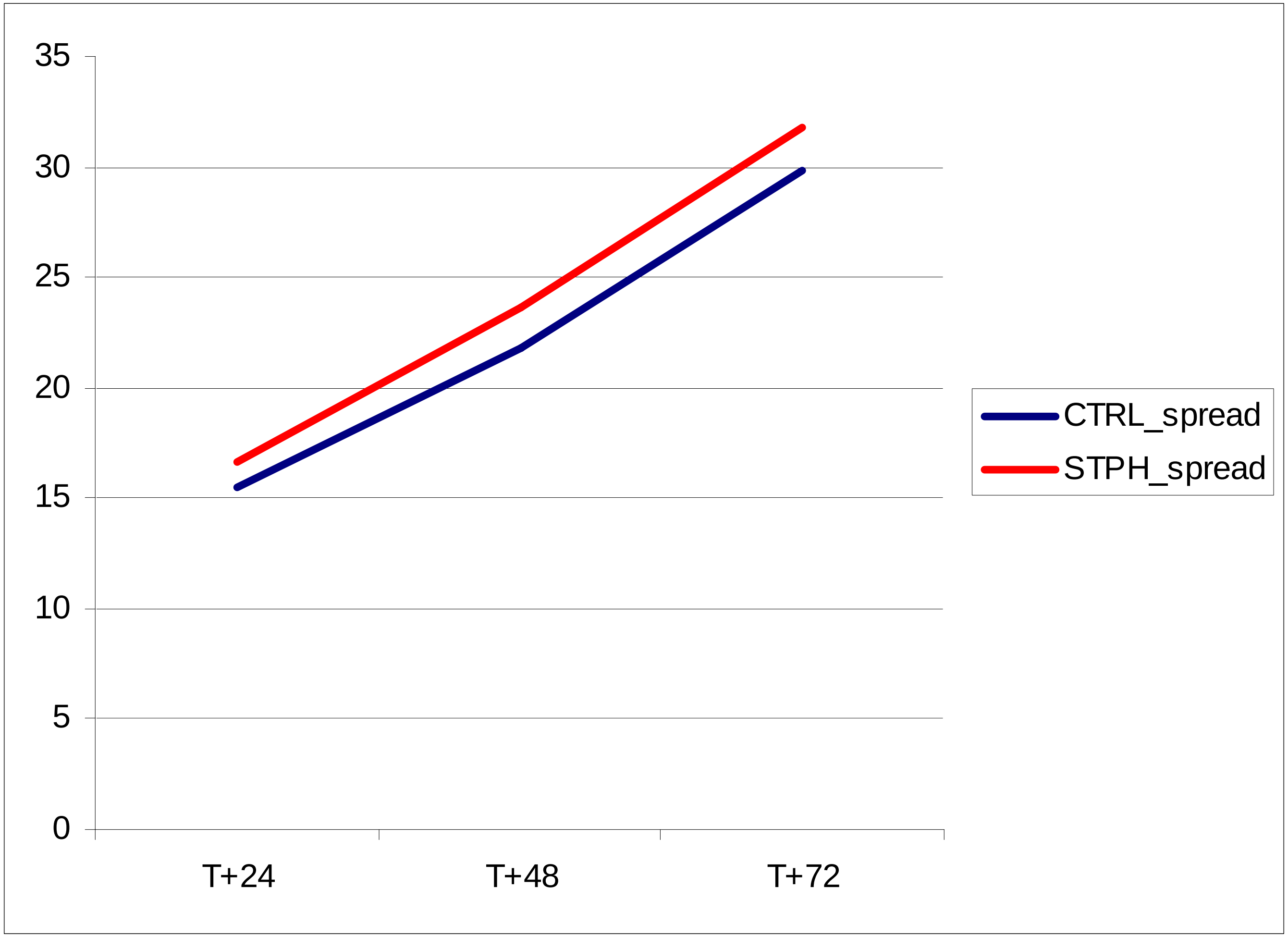
- In the SCV scheme the PV dipole is formed by two vortices which scales are determined by a randomised function

RP+SCV in MOGREPS



RP+SCV in MOGREPS

500 hPa Geopotential height



SKEB

Stochastic Kinetic Energy Backscatter (Arribas and Shutts)

- **Aim:** To backscatter (stochastically) into the forecast model some of the energy excessively dissipated by it at scales near the truncation limit.

  (similar to ECMWF's CASBS by Shutts)

- A total dissipation of 0.75 Wm-2 has been estimated from the Semi-lagrangian and Horizontal diffusion schemes.

$$F \qquad \frac{KE\ \ R(\ \ ,\ \ )}{}$$

α.- Tunable amount of energy feedback

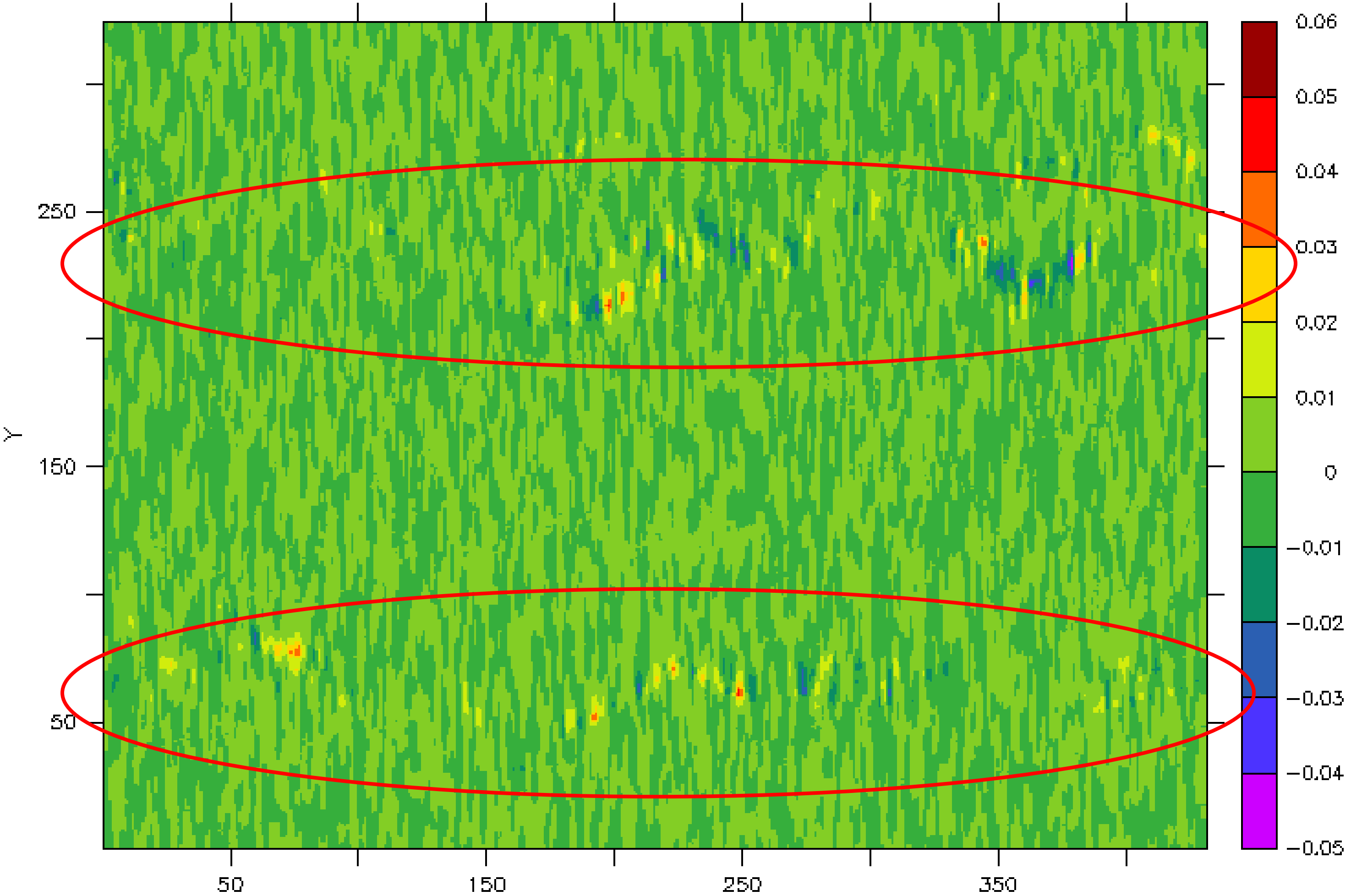
KE.- Kinetic Energy

R.- Random field

.- Time-step

SKEB

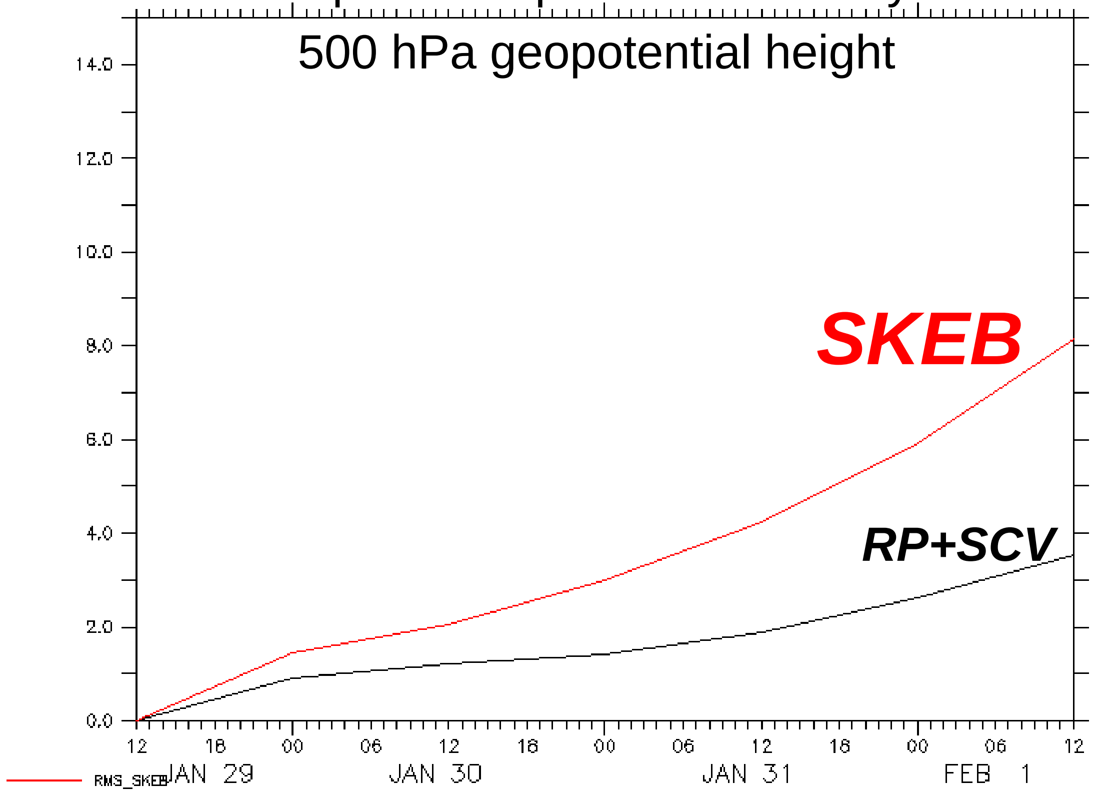
KE modulation: u incr. at 500 hPa



SKEB. Preliminary results

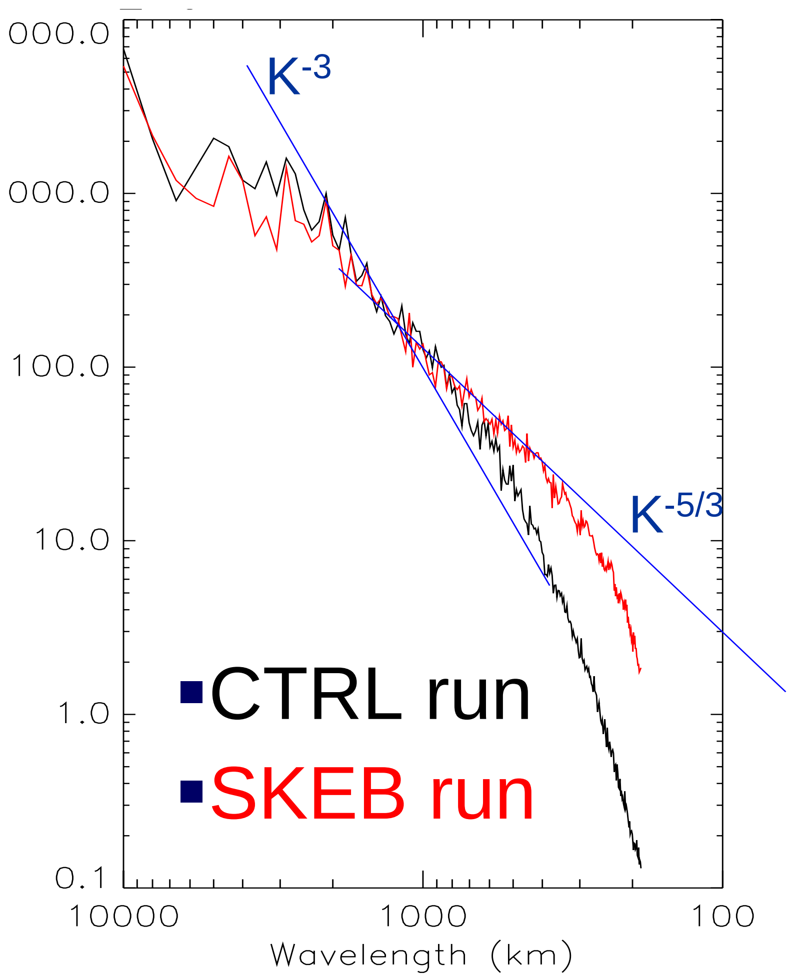
- Positive increase in spread (comparable to that seen at ECMWF)

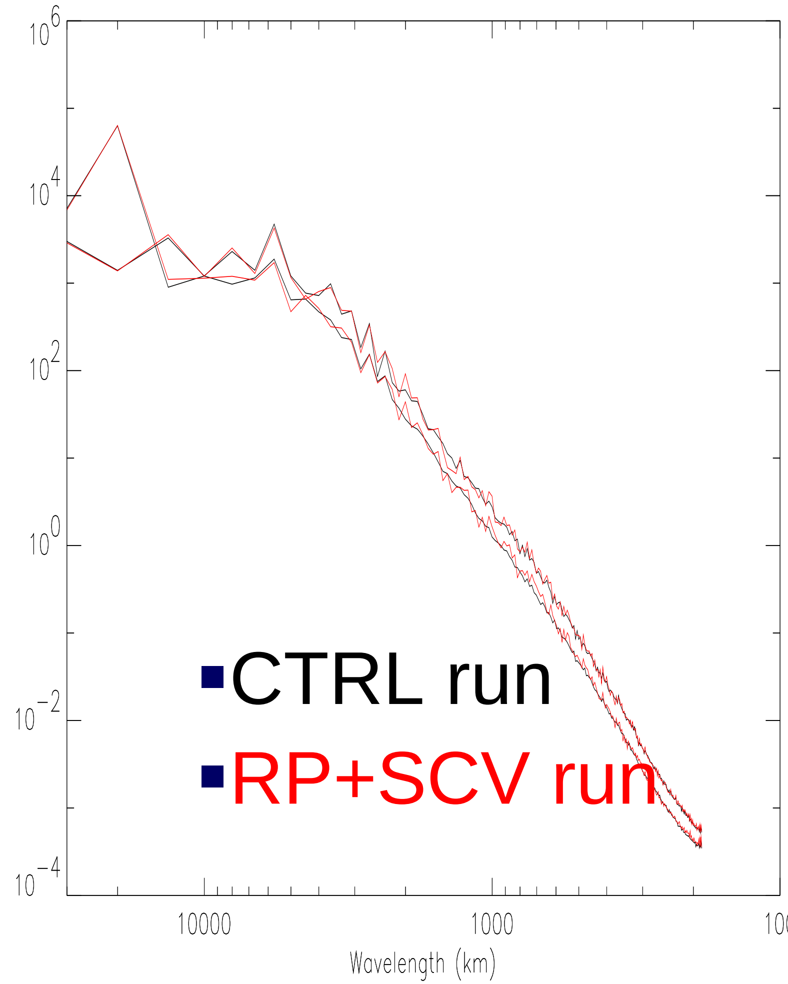
Increase in spread respect to an IC-only ensemble



SKEB. Preliminary results

- Better representation of forecast spectra





Verification

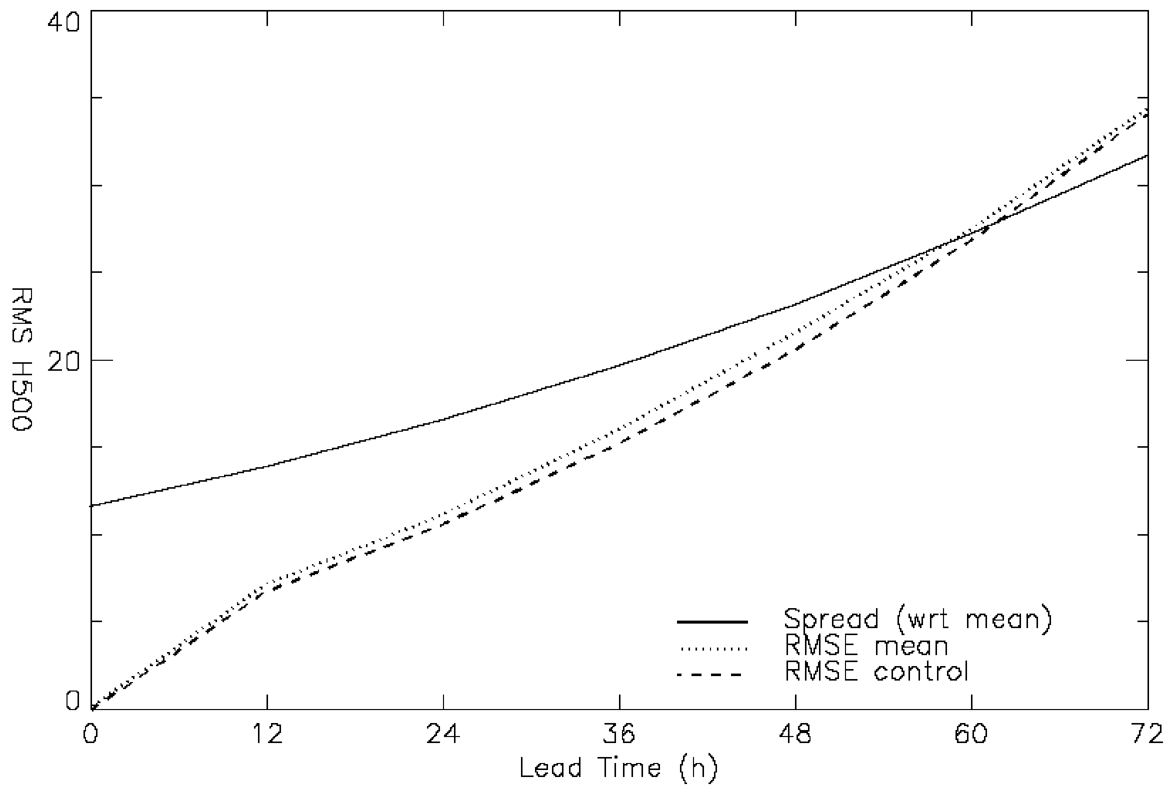
Verification

- Verification to date is very basic
- Verification performed over NAE area for forecasts from global ensemble
- Performed (except where stated) against analysis
- For 111 cycles between 17/10/05 and 9/1/06

500hPa height – spread and RMSE

- Spread growth is slower than error growth
  - SKEB should improve this
- Spread optimised by variable inflation factor against observations in *u, v, T* and *RH* at T+12
  - Appears too large because verified against analysis

Spread and RMSE for 500hPa GPH



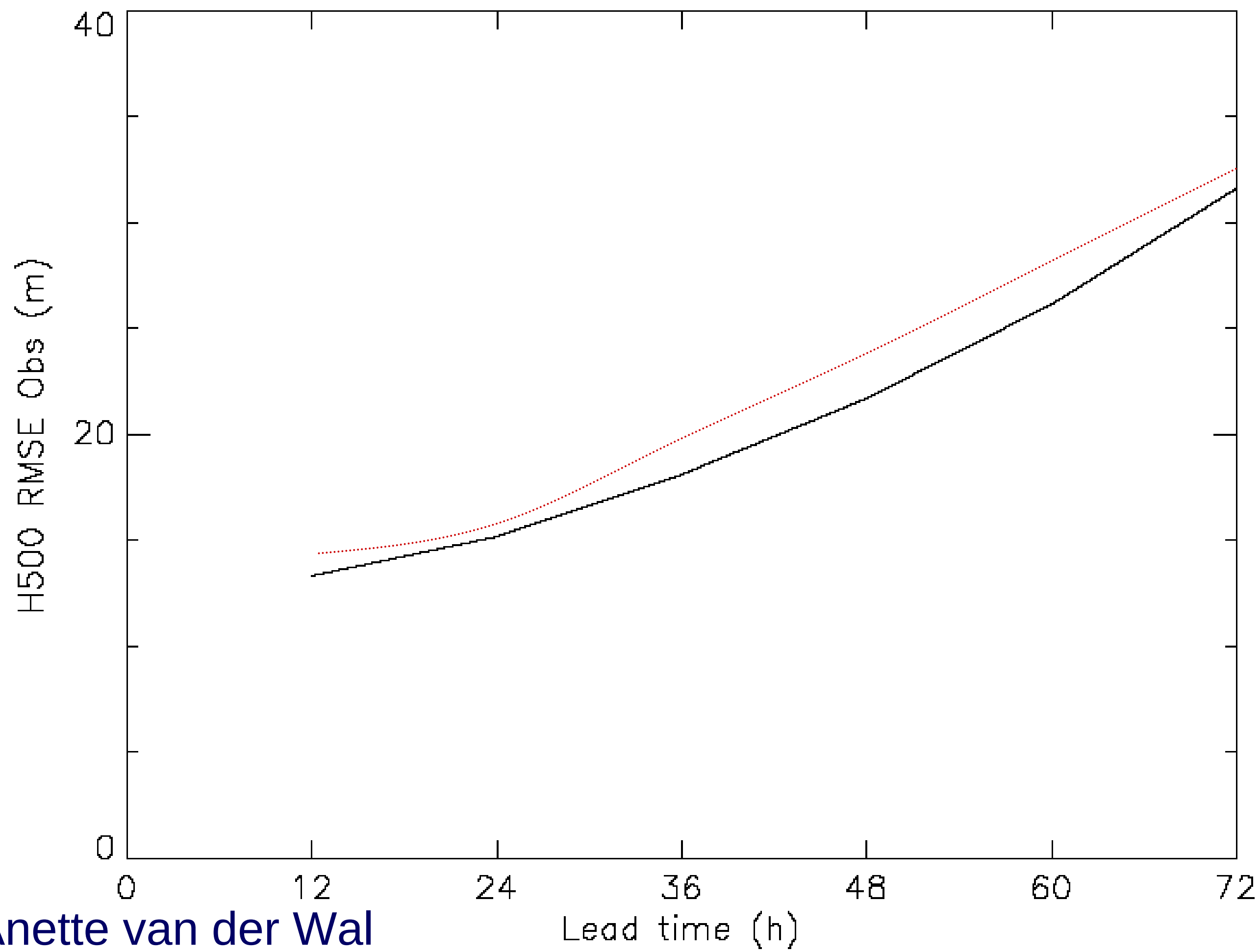
500hPa height – RMSE (part 2)

- Verification of 500hPa GPH forecasts against radio-sonde obs

- Verified over different region (NH), and for different forecasts (Nov Dec 2005) to other verification

- Values are very similar to spread of ensemble

RMSE for 500hPa GPH

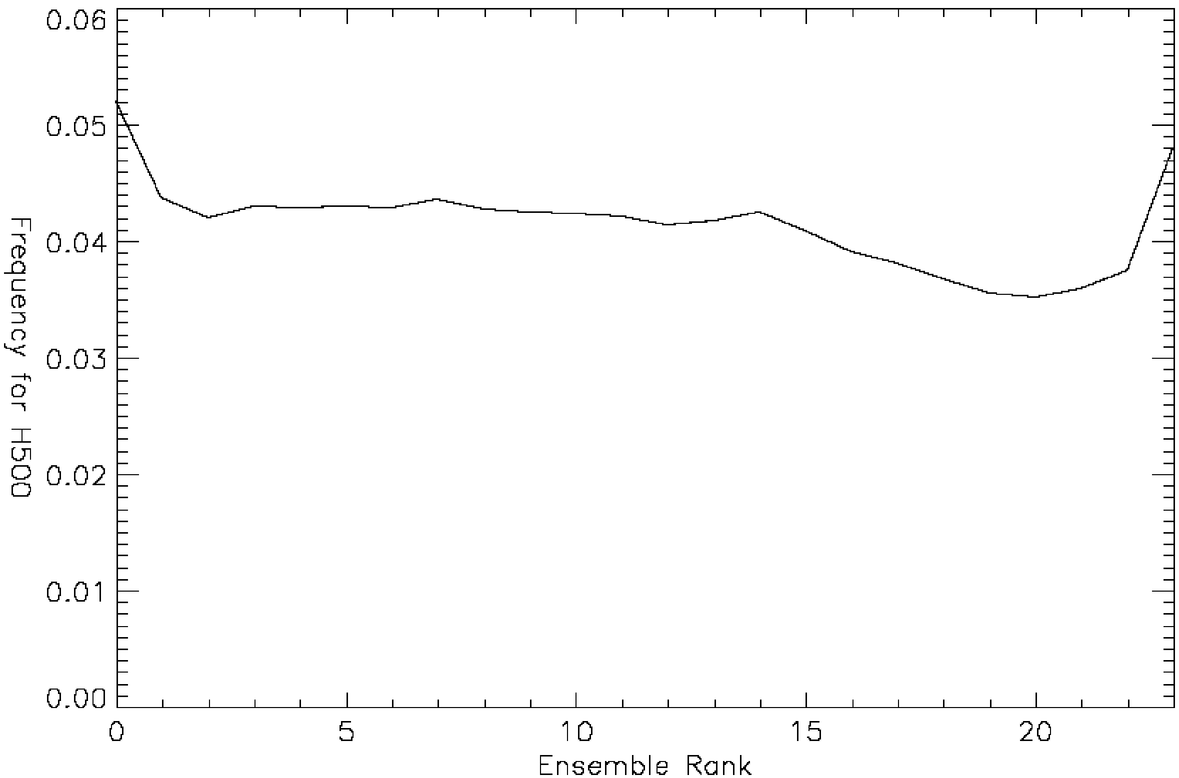


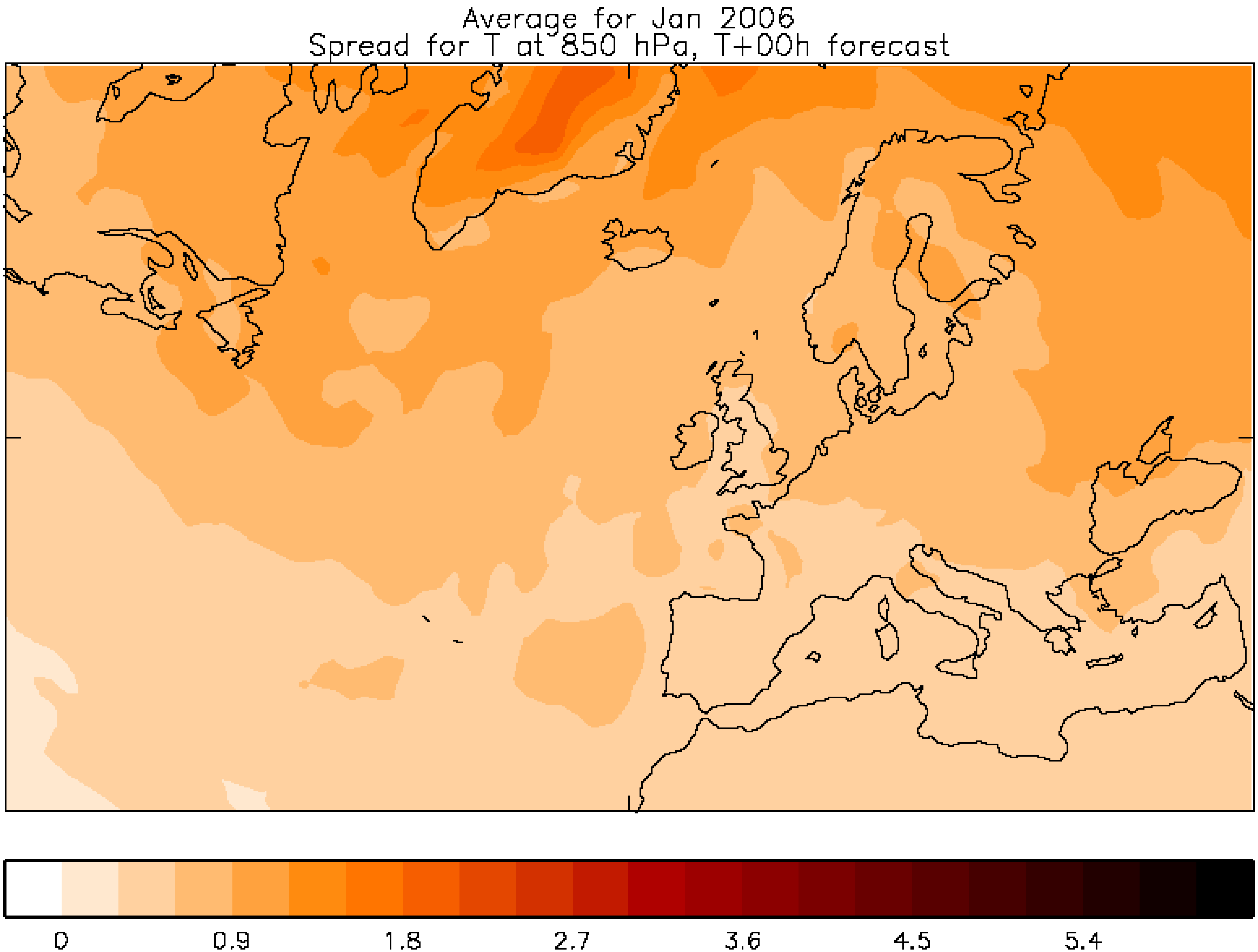
- Data courtesy of Anette van der Wal

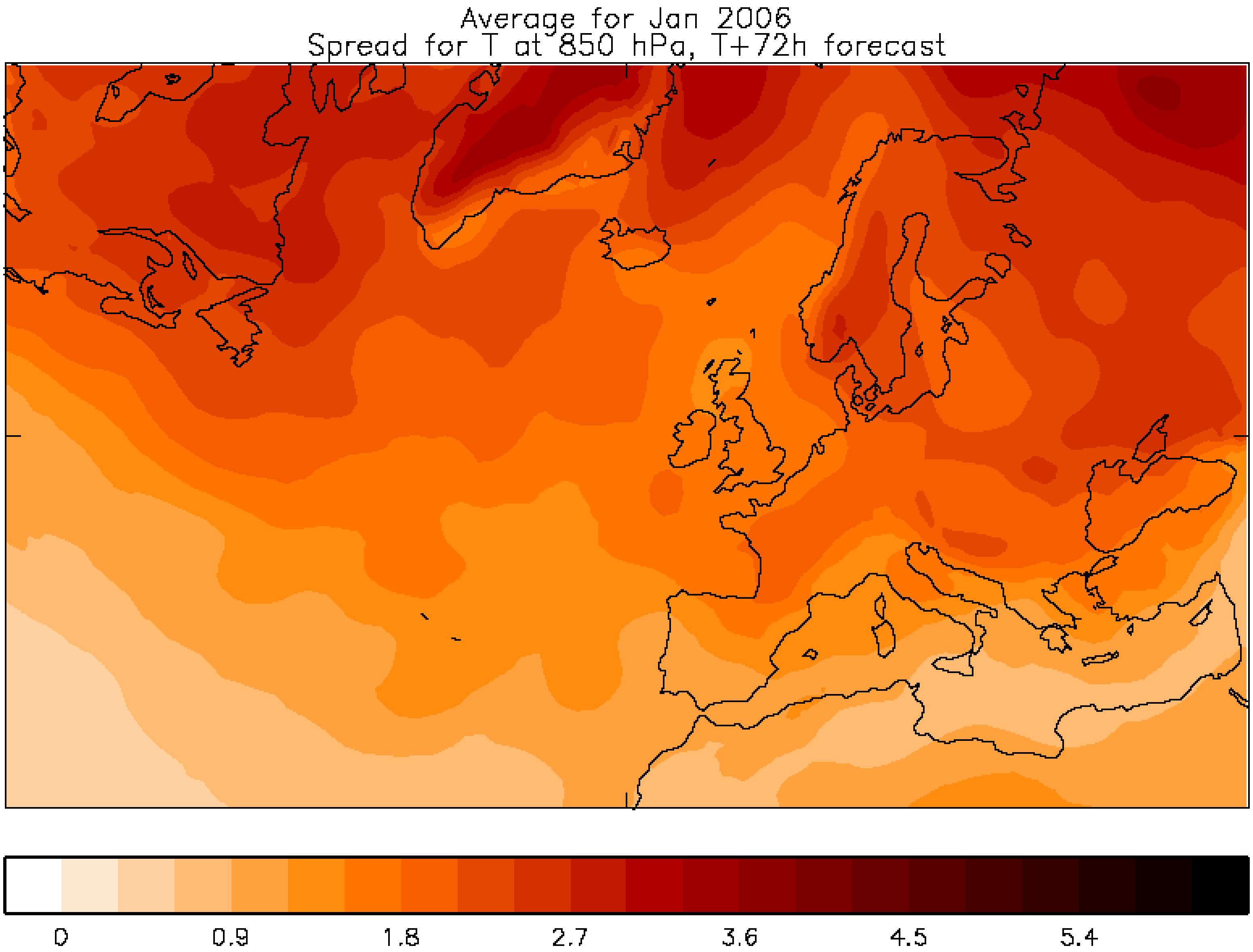
500hPa height – rank histogram

- Rank histogram is encouragingly flat
  - Close to ideal
- Suggests that ETKF perturbations are representative of genuine analysis errors
- This performance seems much improved on ECMWF ensemble

Rank Histogram at T+72 for 500hPa GPH




Average for Jan 2006
Spread for T at 850 hPa, T+00h forecast
0
0.9
1.8
2.7
3.6
4.5
5.4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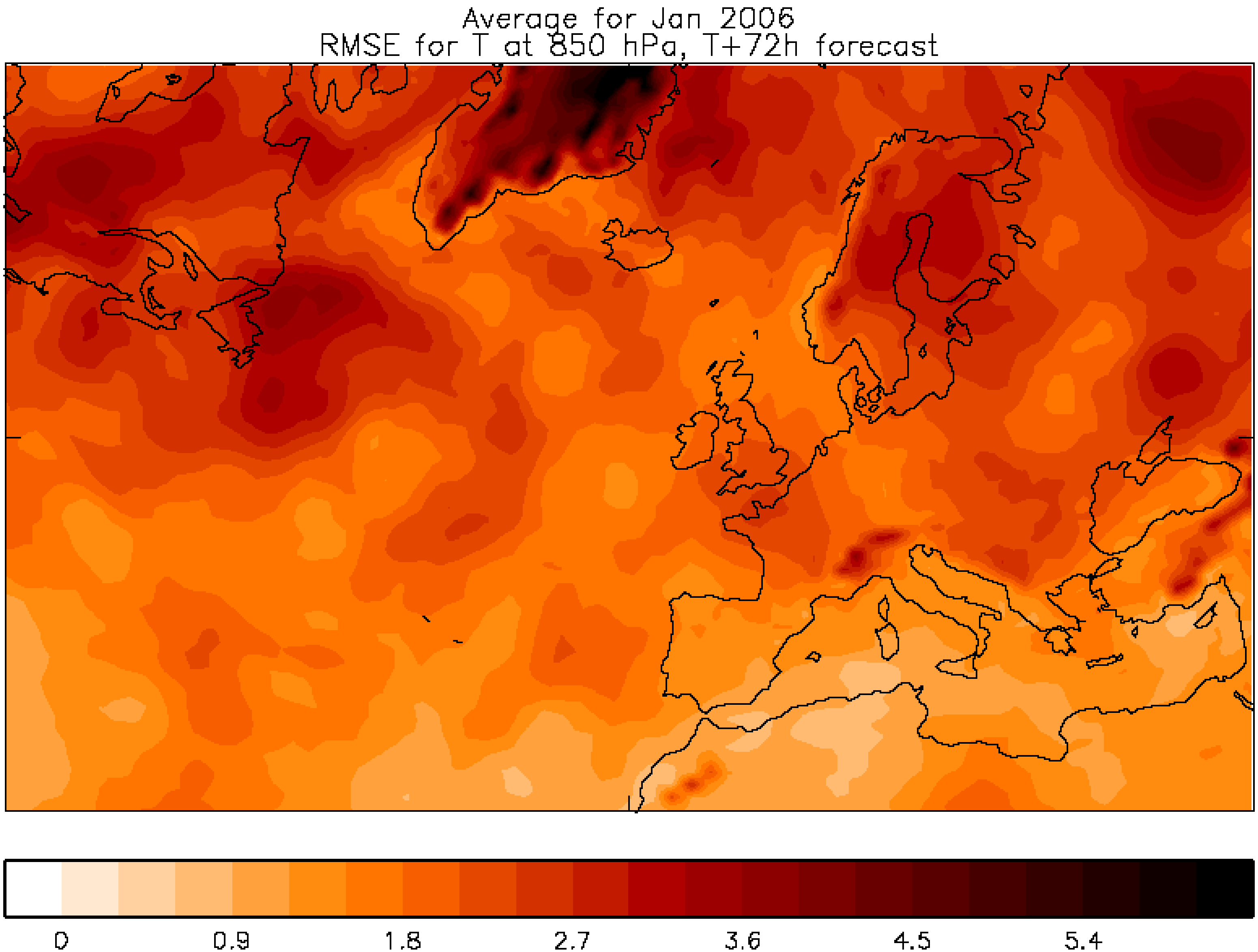
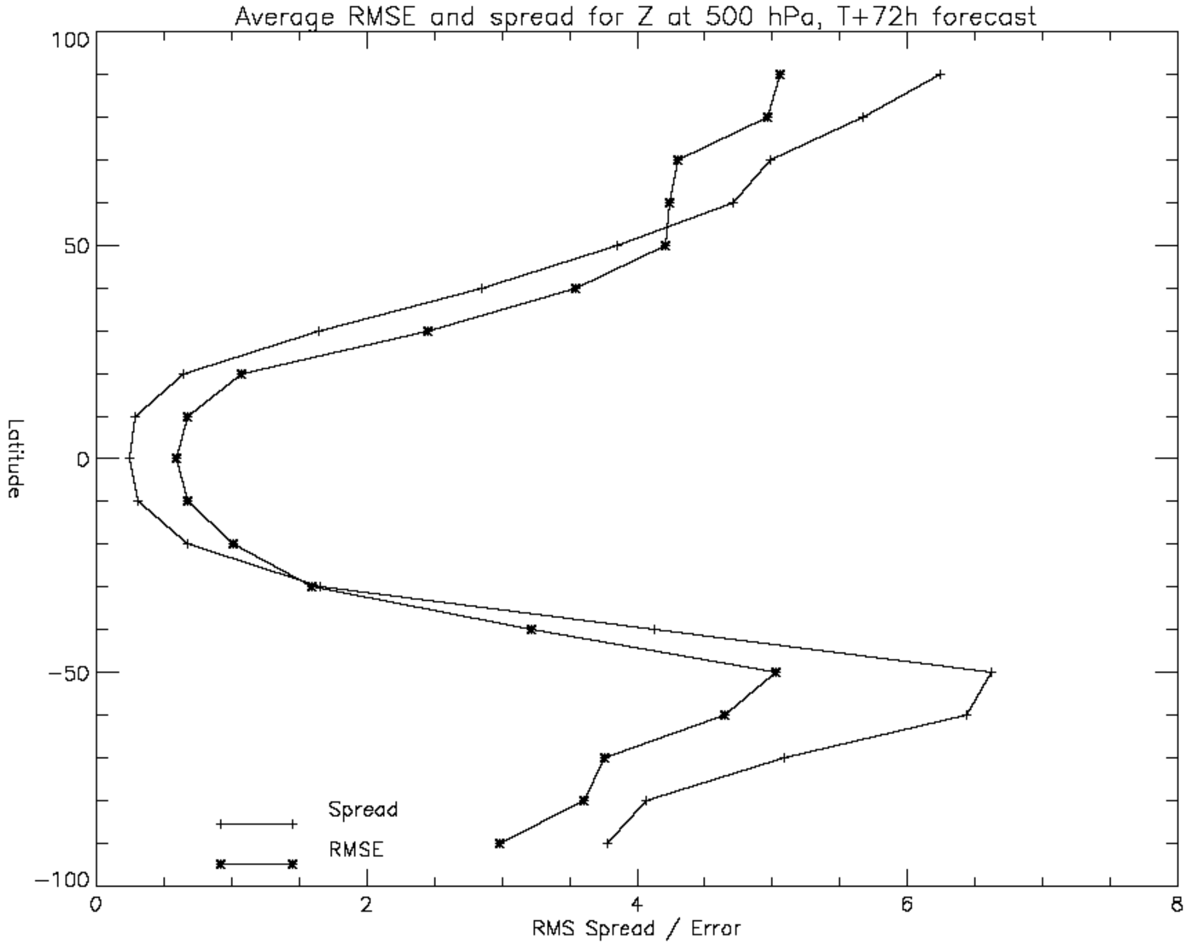
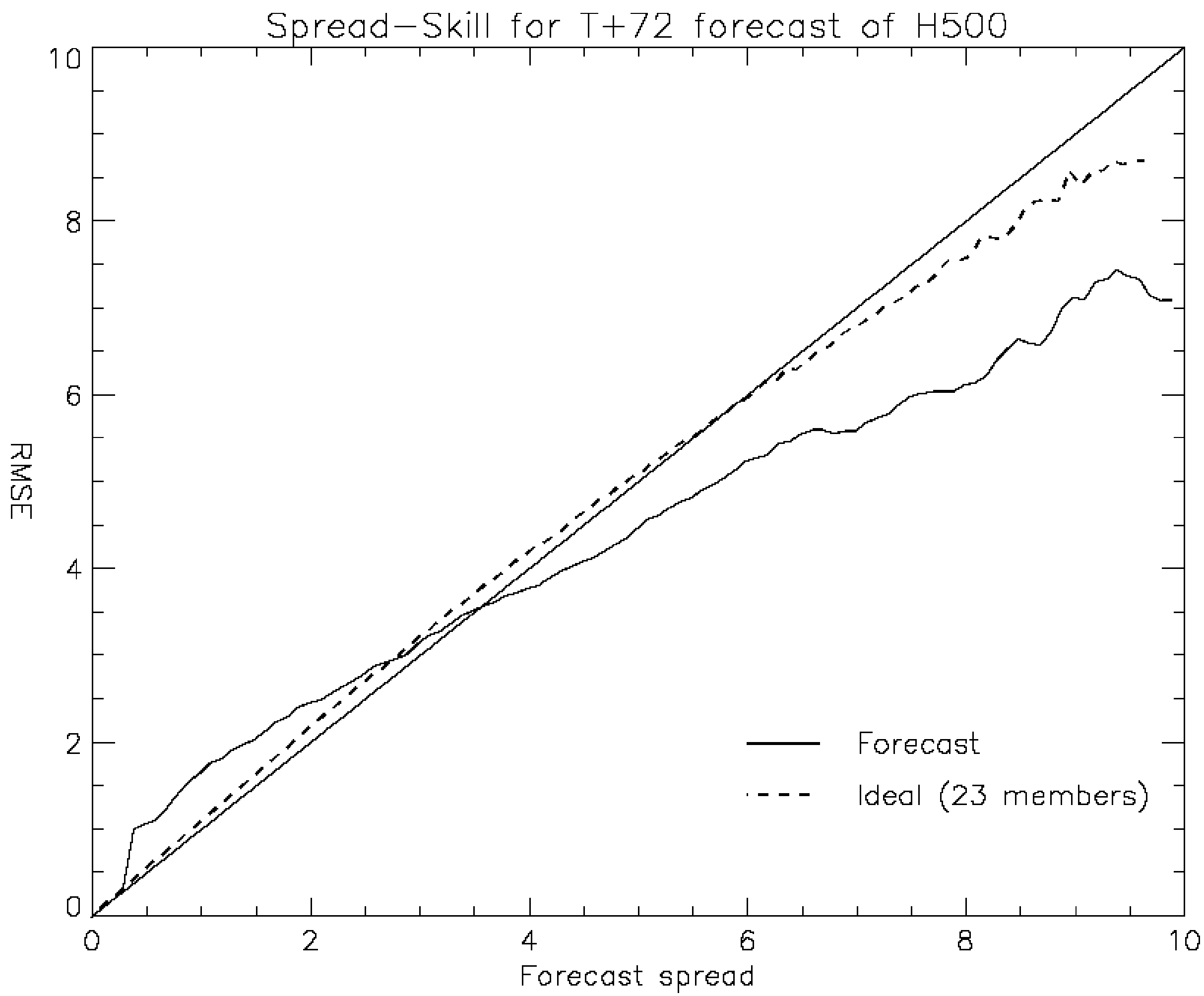

Average for Jan 2006
RMSE for T at 850 hPa, T+72h forecast
0
0.9
1.8
2.7
3.6
4.5
5.4

Average spread with latitude 500hPa height



- Inflation factor chosen to get correct spread over extra-tropics
- Due to growth rate of perturbations, spread too large nearer poles

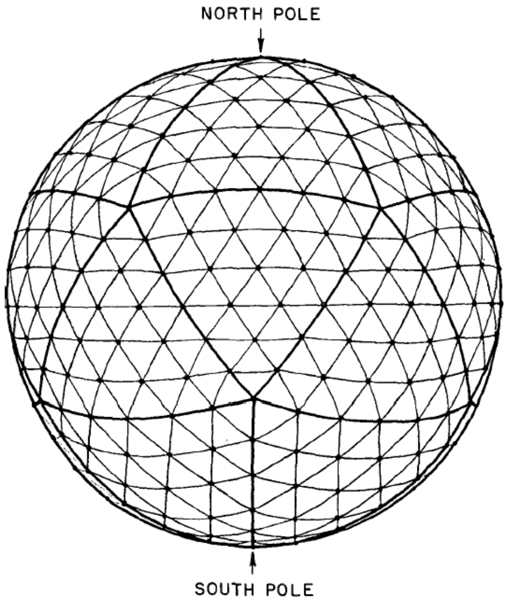
Spread – skill relationship



- Good relationship between spread and RMSE
- Note that perfect ensemble (with 23 members) would not lie on diagonal

Local ETKF

- Calculate the ETKF transform matrix, only using observations within a certain radius of a given "localisation centre"
- Interpolate transform matrix between localisation centres

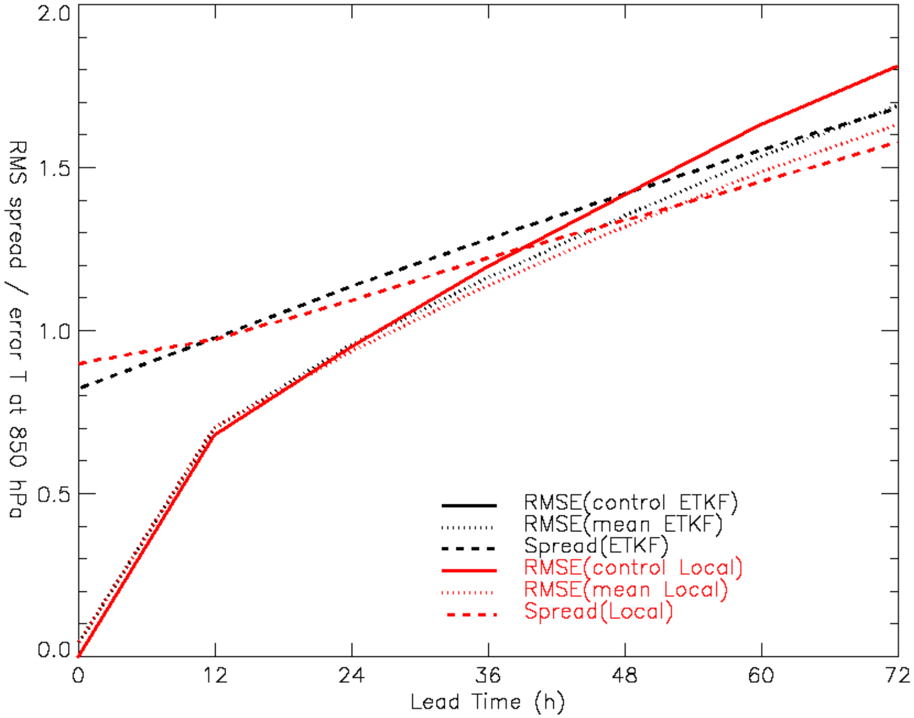


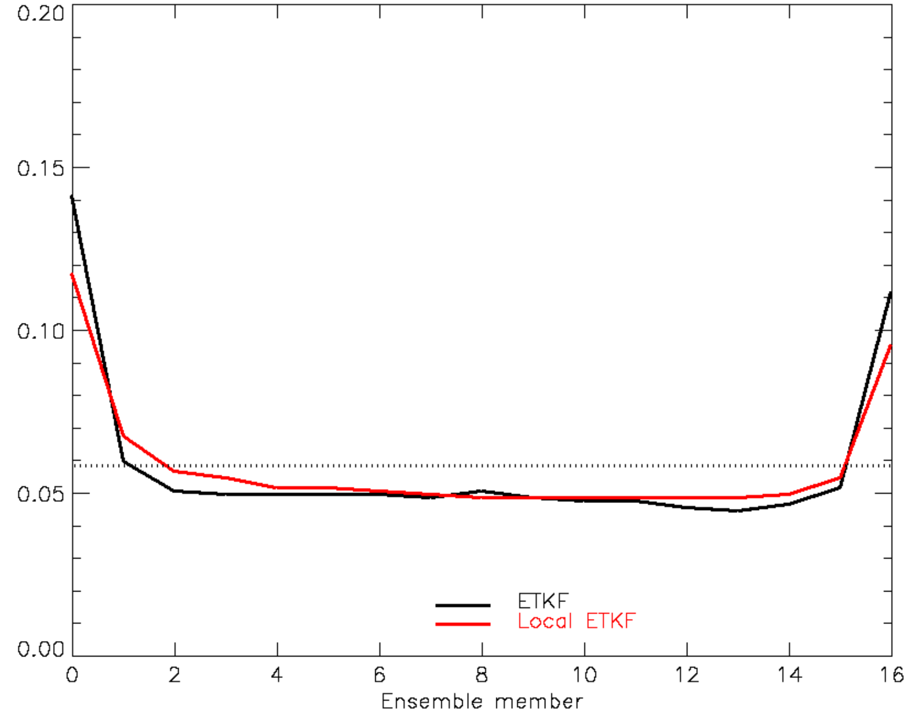
- Similar idea to LEKF developed at Maryland

- Warning: Inflation factors can be troublesome

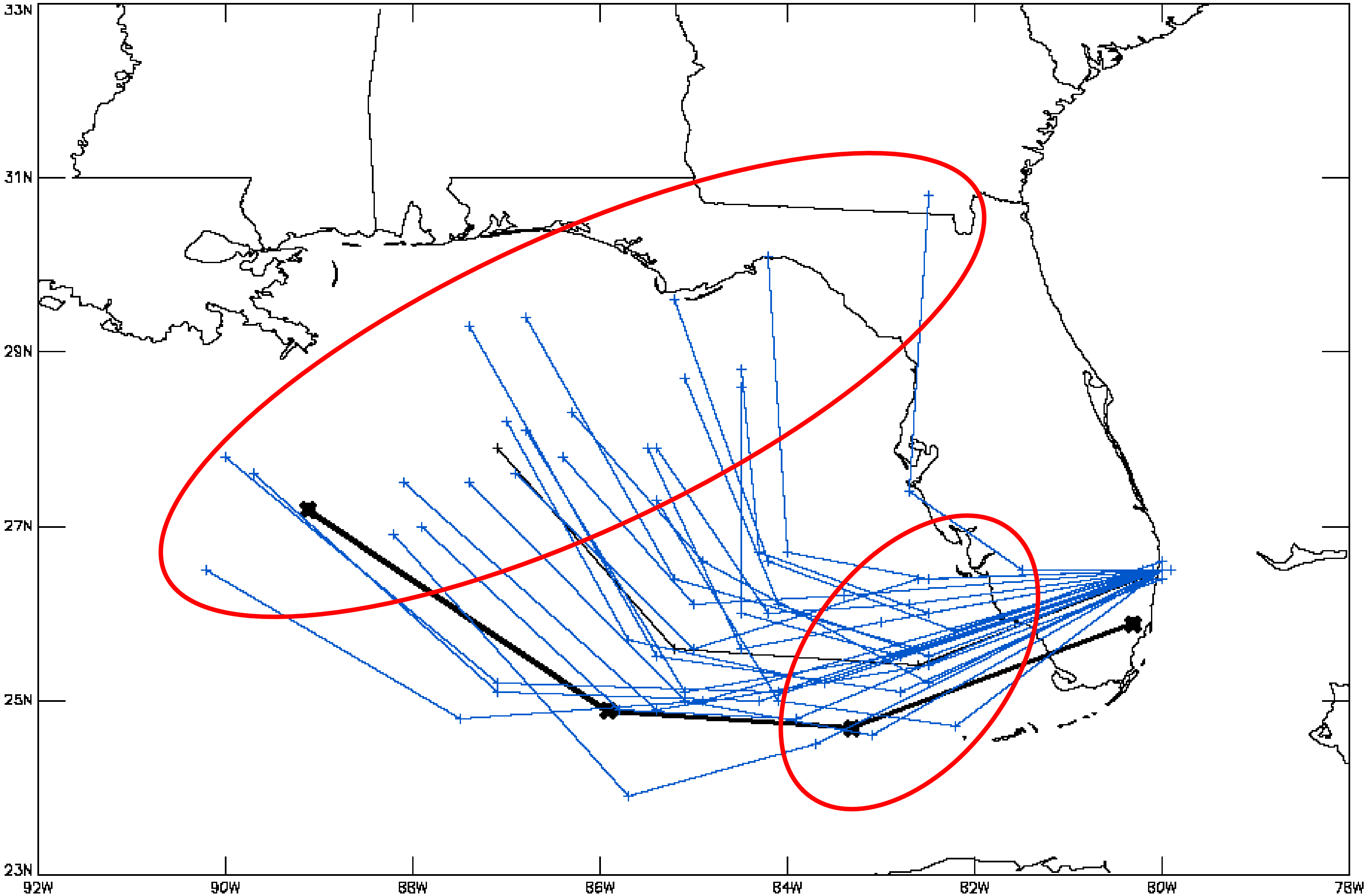
Local ETKF performance

- Reduces spread in higher extra-tropics, and increases spread near tropics
- Rank histograms improve, even when spread is reduced

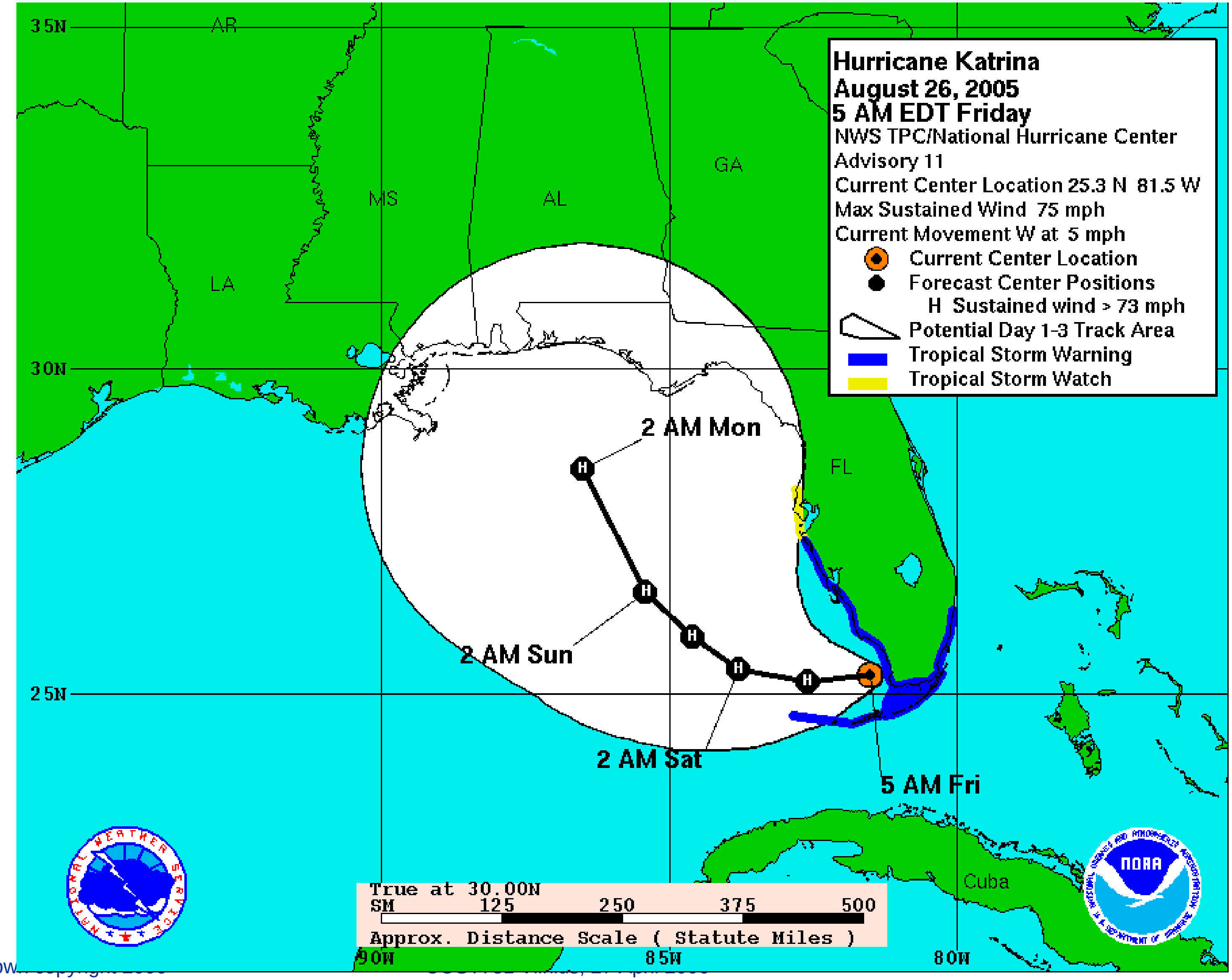




Katrina – MOGREPS forecasts



Katrina – NHC warning



MOGREPS Status

- MOGREPS started operational trials in September
  - Trials scheduled to run for 12 months
  - Objective verification and forecaster assessment
  - So far, performance has been good
- Further science upgrades planned
  - SKEB
  - Local ETKF and Regional perturbations for NAE
- MOGREPS cannot yet be used operationally
  - Could be operational later in 2006/07 subject to satisfactory performance in trial

Any questions?