Short-Range Ensemble Prediction Systems at the Met Office

MOGREPS – Met Office Global and Regional Ensemble Prediction System

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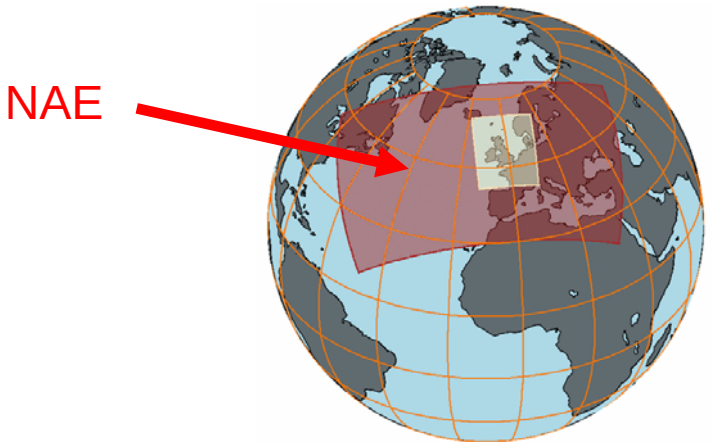
Ensemble Forecasting Research

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

MOGREPS – The new Met Office short-range EPS

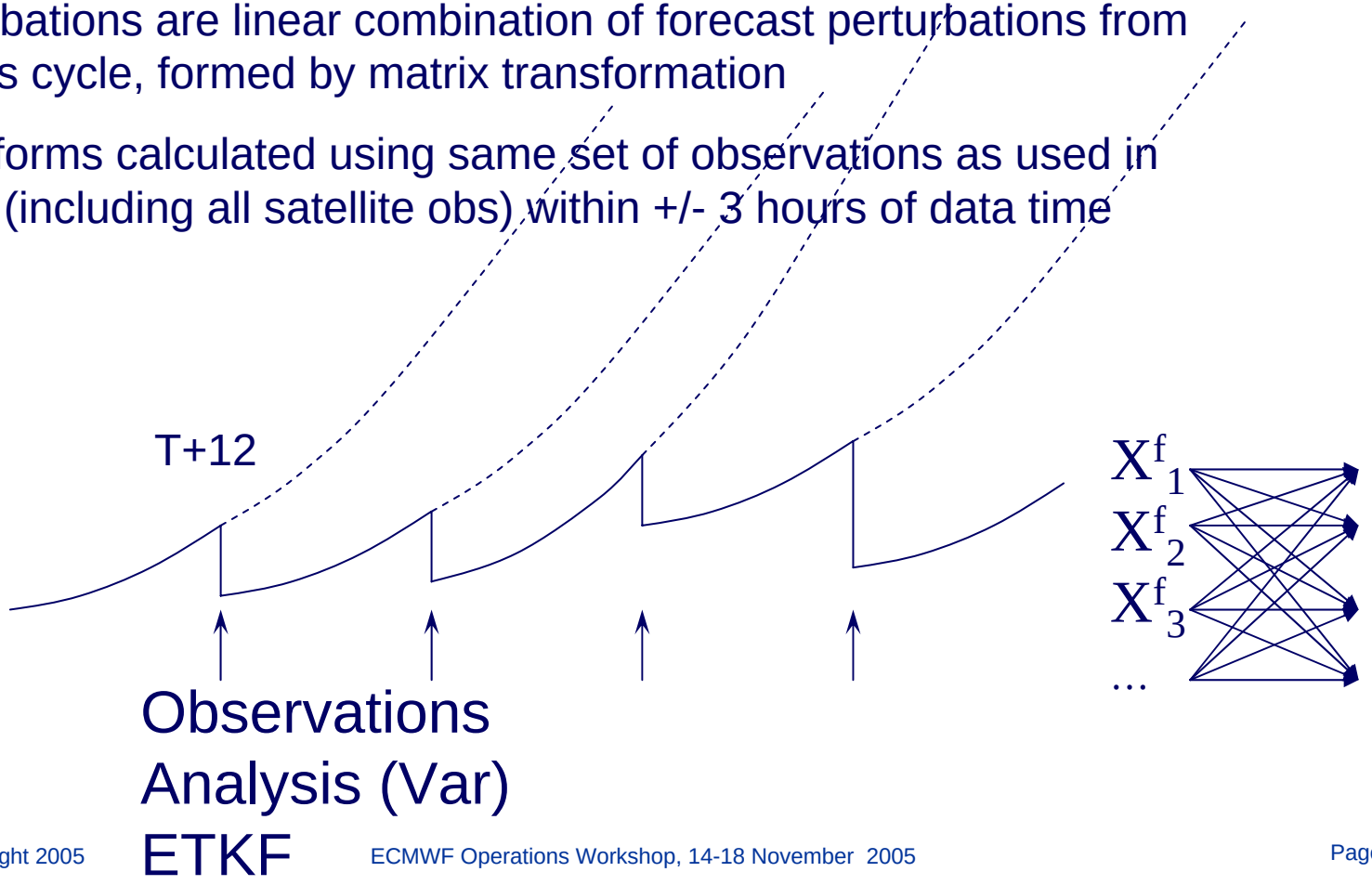
- Ensemble designed for short-range
  - Regional ensemble over N. Atlantic and Europe (NAE)
  - Nested within global ensemble
  - ETKF perturbations
  - Stochastic physics
  - T+72 global, T+36 regional
  - Aim to assess uncertainty in short-range, eg.:
    - Rapid cyclogenesis
    - Local details (wind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



MOGREPS is on Operational Trial for 1 year from September 2005

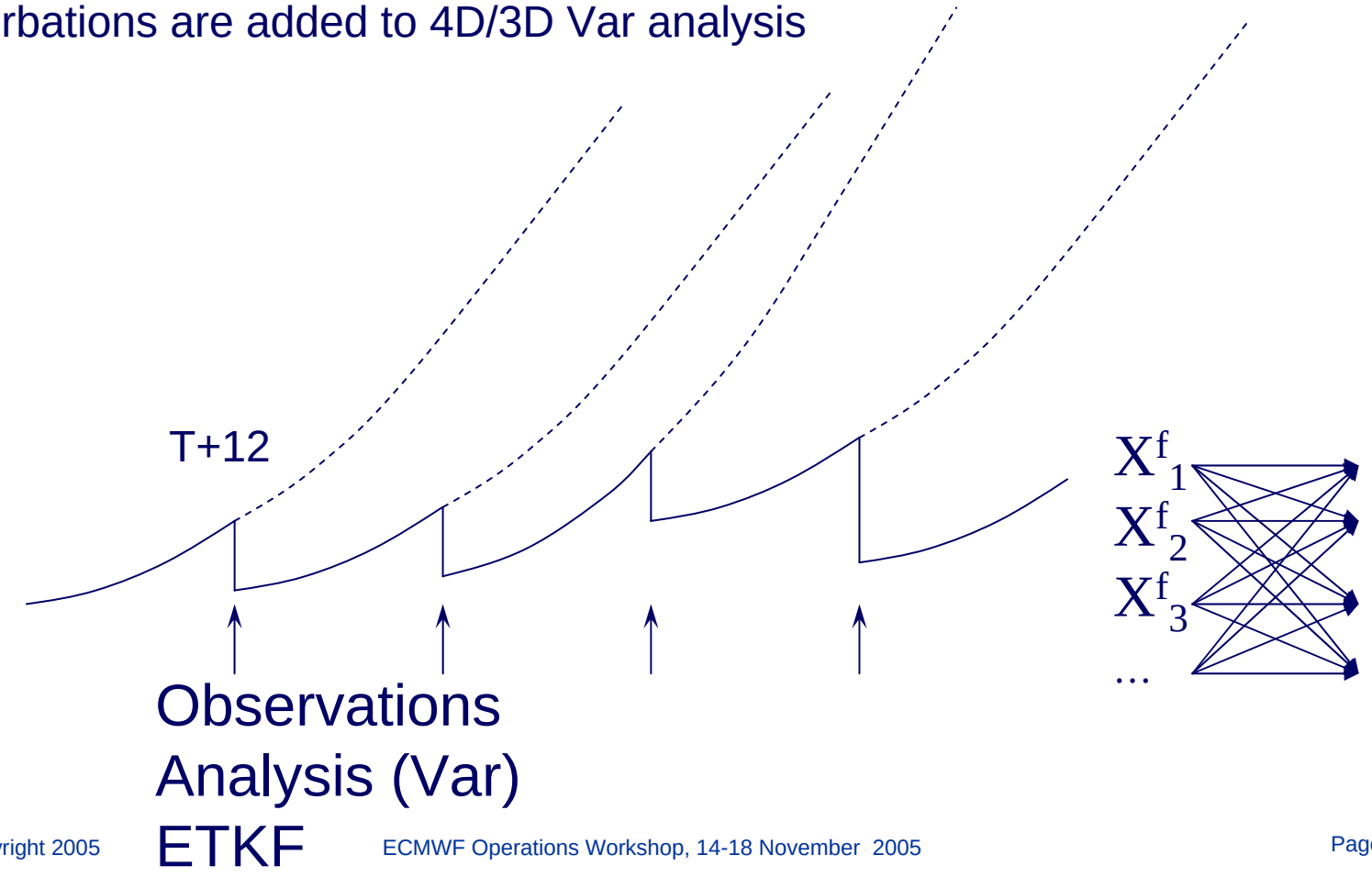
ETKF Initial Condition Perturbations

- ETKF – Simplified version of Ensemble Kalman Filter $\mathbf{X}^a = \mathbf{X}^f \mathbf{T}$
- ETKF similar to Error Breeding
  - Perturbations are linear combination of forecast perturbations from previous cycle, formed by matrix transformation
  - Transforms calculated using same set of observations as used in 4D-Var (including all satellite obs) within +/- 3 hours of data time



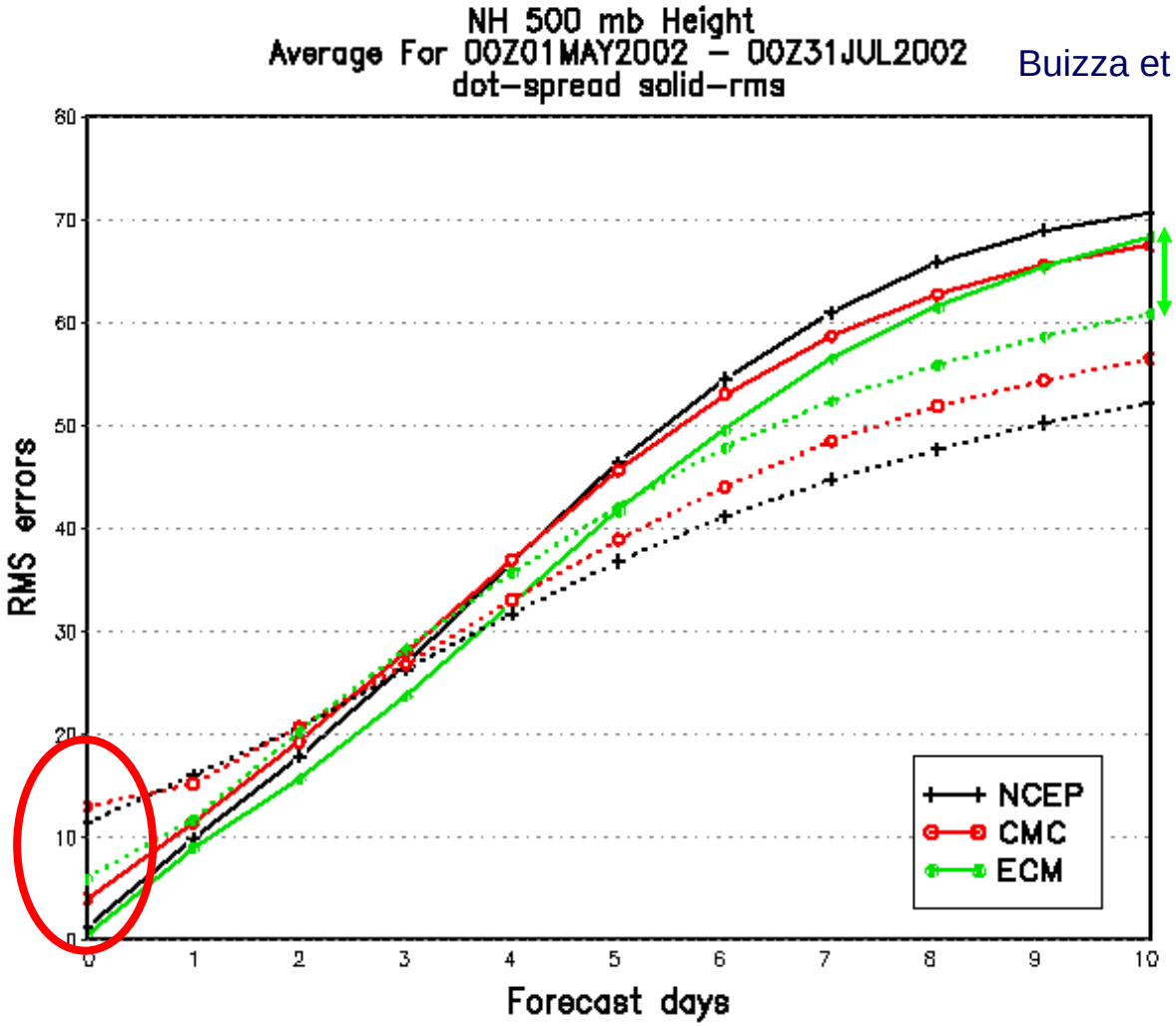
ETKF Initial Condition Perturbations

- ETKF – Simplified version of Ensemble Kalman Filter
  - Cannot update mean state – covariance information only
  - Perturbations are added to 4D/3D Var analysis



Stochastic physics

…. the quest to increase spread!



Buizza et al., MWR, 2004

All three systems are under-dispersive!!

Stochastic physics for the UM

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

- Stochastic Convective Vorticity (SCV)
  - Unresolved impact of organised convection (MCSs)
  - Not used in the higher resolution regional ensemble
- Random Parameters (RP)
  - Structural error due to approximations in parameterisation
- Stochastic Kinetic Energy Backscatter (SKEB)
  - Excess dissipation of energy at small scales
  - SKEB not yet implemented

Impact is propagated to next cycle through the ETKF

Stochastic schemes for the UM

The Random Parameters (Arribas, 2004)

- All parameterizations include a number of empirical-adjustable parameters and thresholds (with somewhat arbitrary values!)

- These parameters are treated as stochastic variables, and, each 3-h, their values are calculated using a first-order auto regression model:

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

- Same value at all grid points (i.e. spatial corr. = 1)

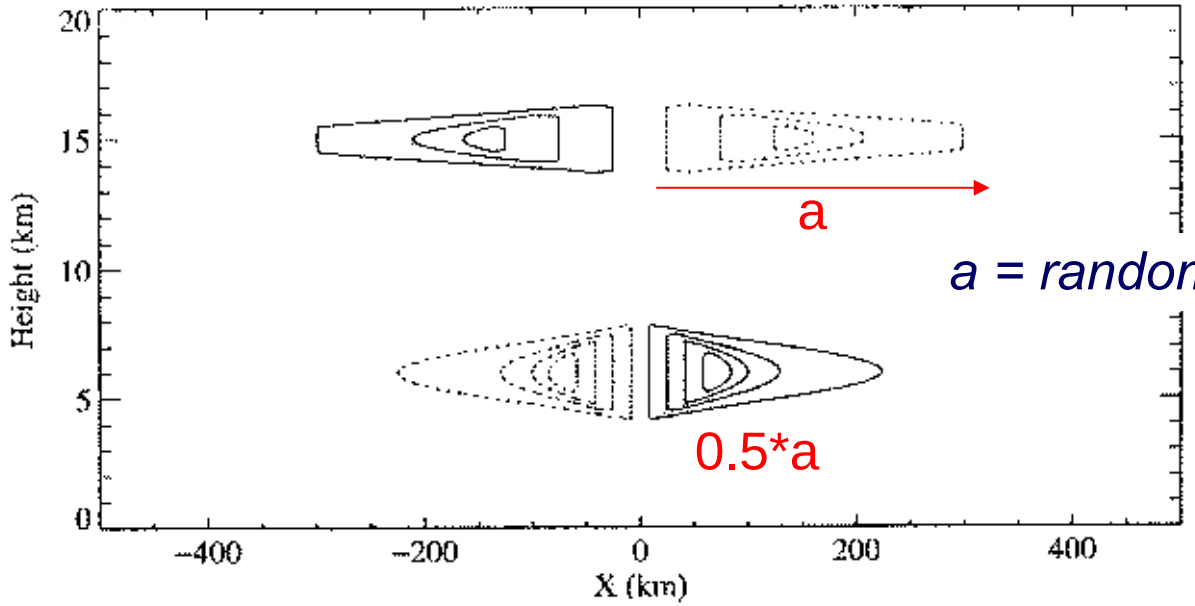
Stochastic scheme for the UM

The Random Parameters

Parameter	Scheme	min/std/Max
Entraiment rate	CONVECTION	2 / 3 / 5
Cape timescale	CONVECTION	30 / 30 / 120
Rhcrit	LRG. S. CLOUD	0.6 / 0.8 / 0.9
Cloud to rain (land)	LRG. S. CLOUD	1E-4/8E-4/1E-3
Cloud to rain (sea)	LRG. S. CLOUD	5E-5/2E-4/5E-4
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

Stochastic schemes for the UM

The SCV component



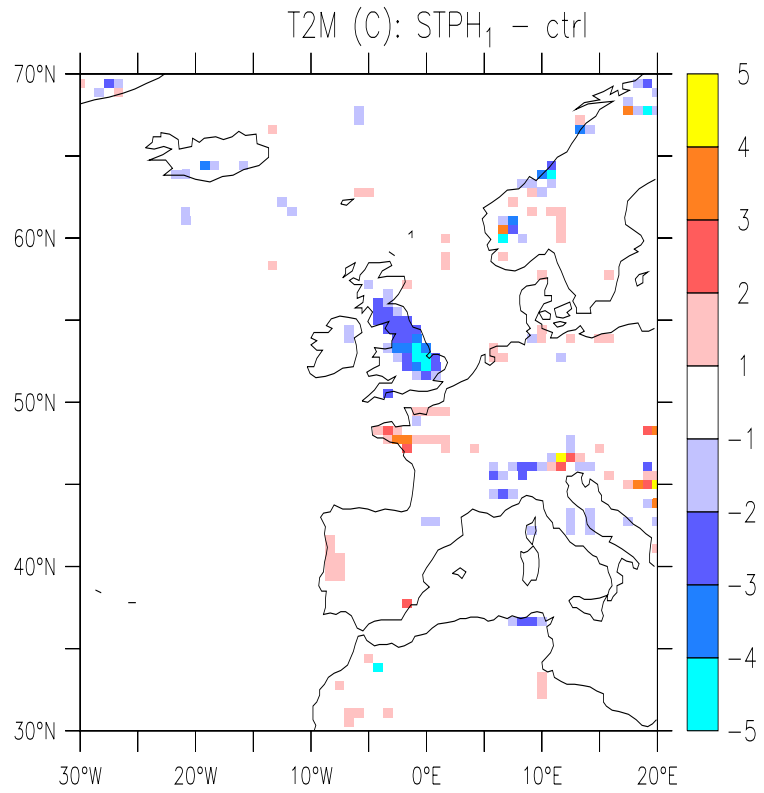
a = random f(CAPE)*

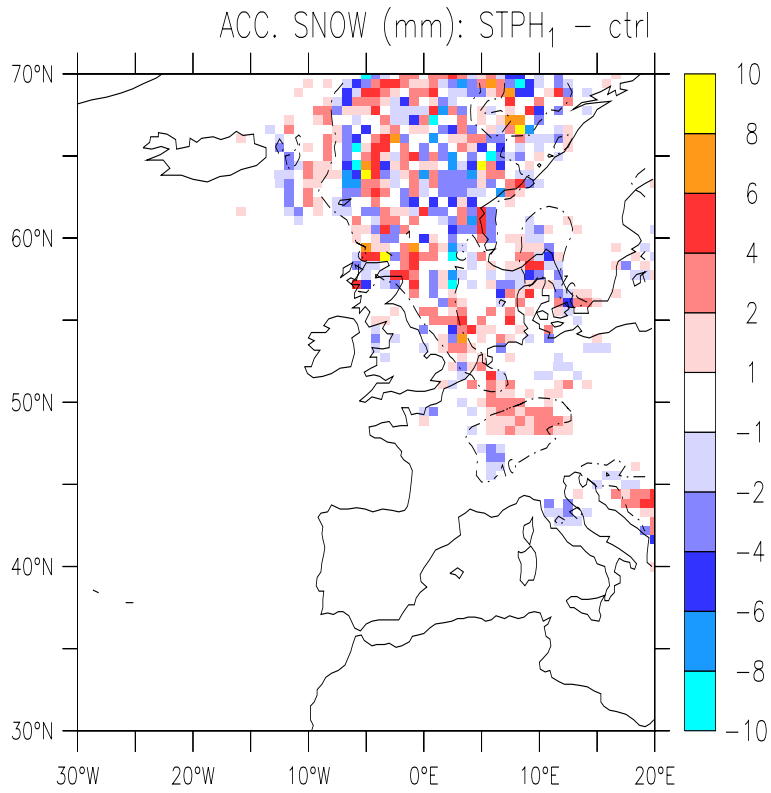
- In the SCV scheme the PV dipole is formed by two vortices which scales are determined by a randomised function

RP+SCV in MOGREPS

Covered in previous MOSAC – sample of impact

2004012700Z – T+72





Stochastic Kinetic Energy Backscatter

(Arribas and Shutts, 2005)

- **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.

- Each member of the ensemble is perturbed by a different realization of this backscatter forcing

SKEB

Backscatter forcing:

$$F_{\psi} = \frac{\alpha \cdot KE \cdot R(\lambda,\phi)\sqrt{D}}{\Delta\tau}$$

α.- Tunable amount of energy feedback

KE.- Kinetic Energy

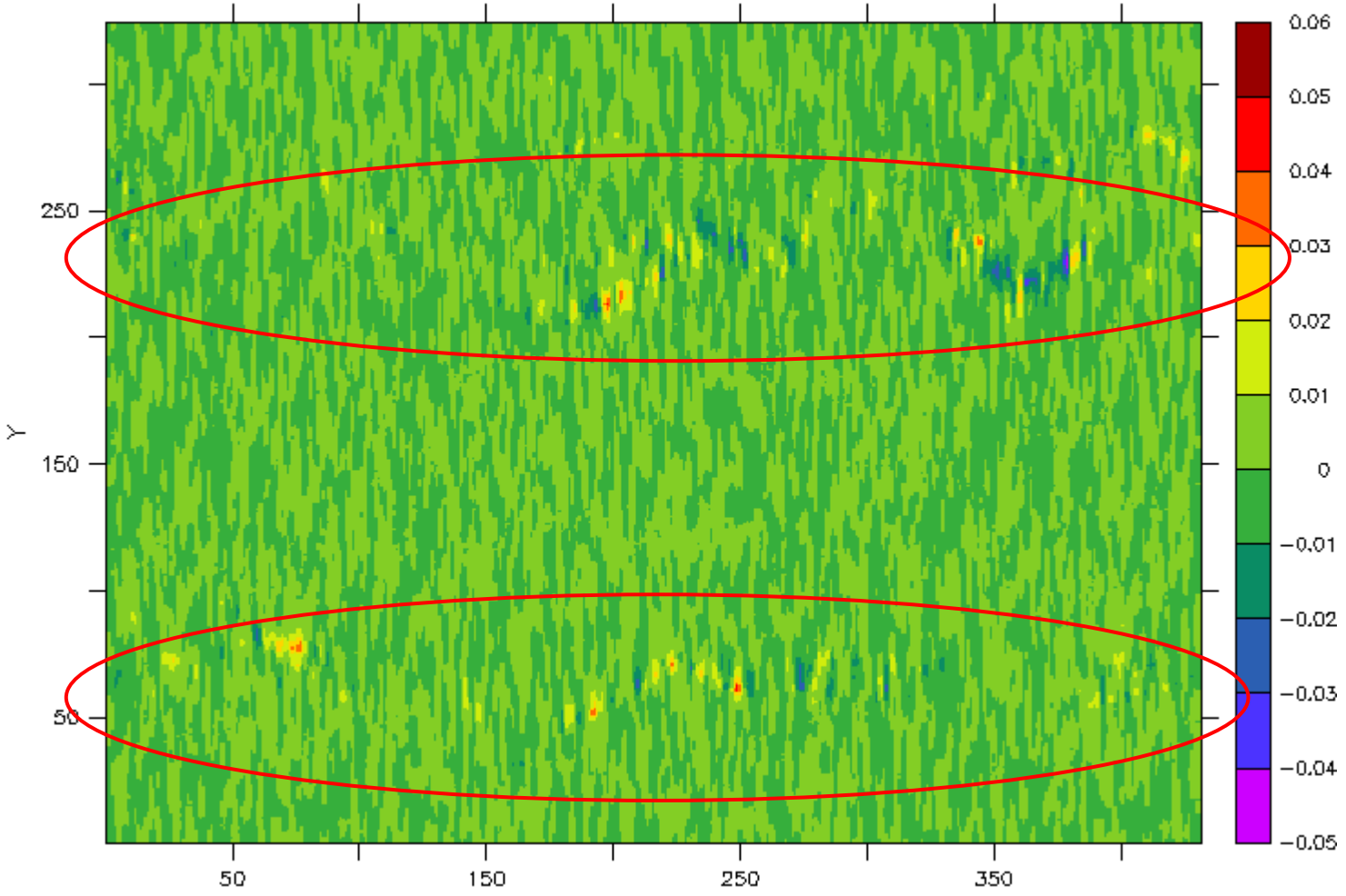
R.- Random field

D.- Dissipation rate

$\Delta\tau$.- Time-step

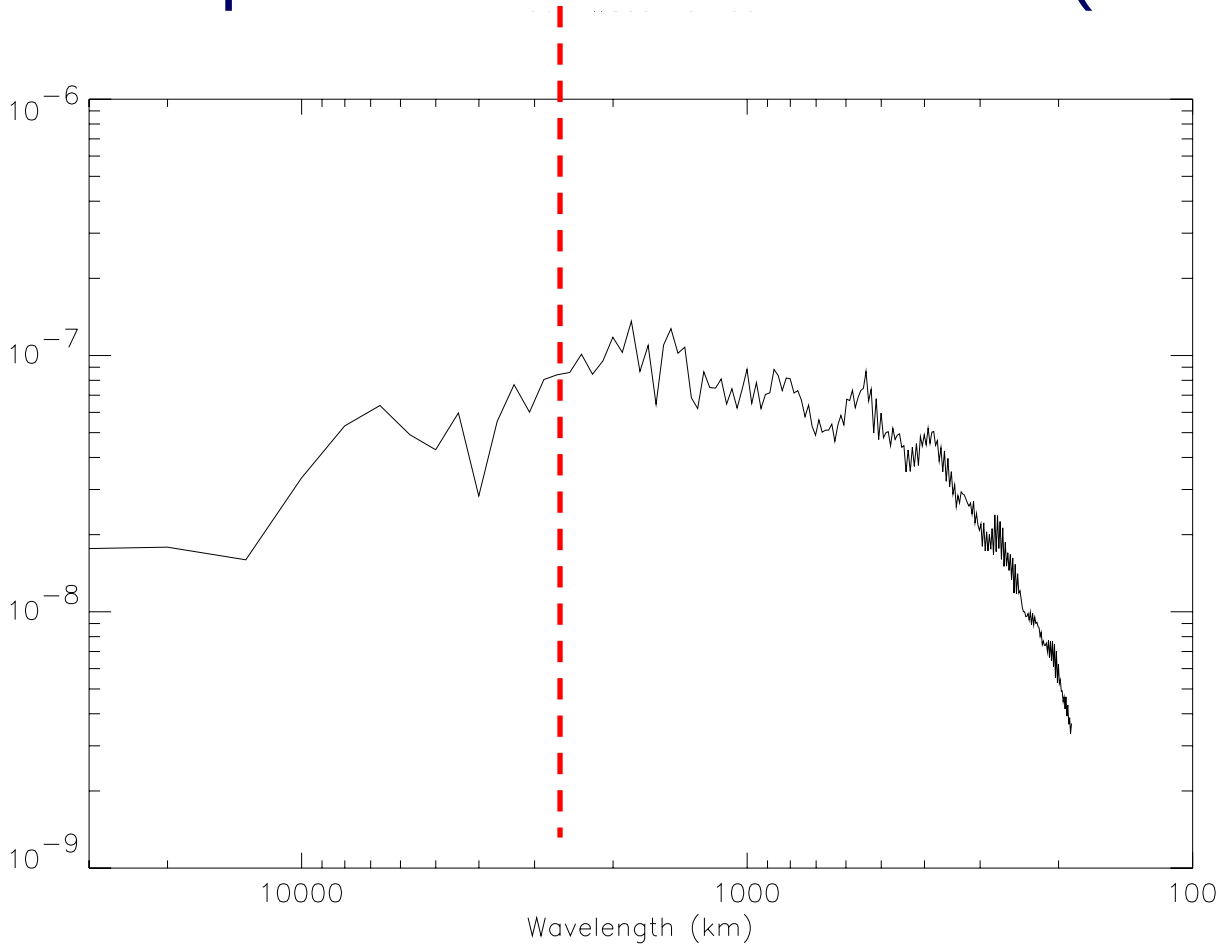
$R(\lambda,\phi) \longrightarrow$ 3D random pattern in which horizontal, vertical and temporal correlations can be imposed to reproduce CRM statistics

Aspect of the forcing: u incr. at 500 hPa



Spectra of the forcing **(KE at 500 hPa)**

– agrees with spectra from CRM studies (Shutts)

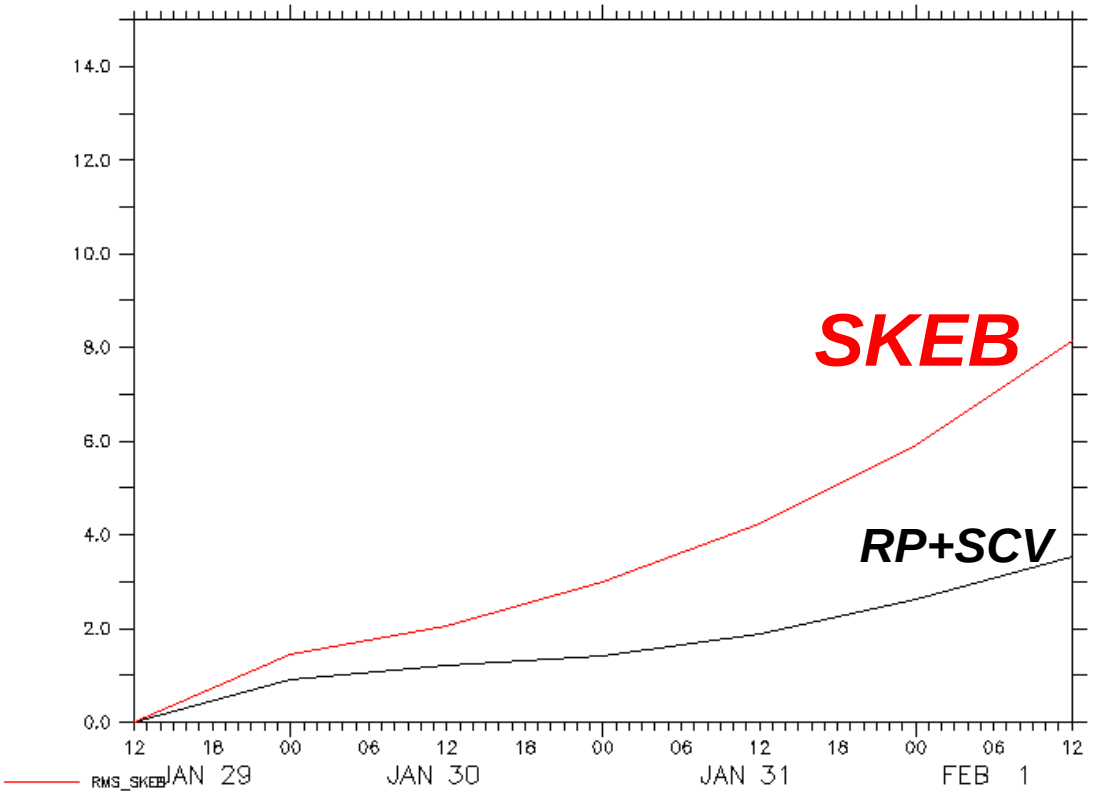


Preliminary results:

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

Increase in spread respect to an IC-only ensemble

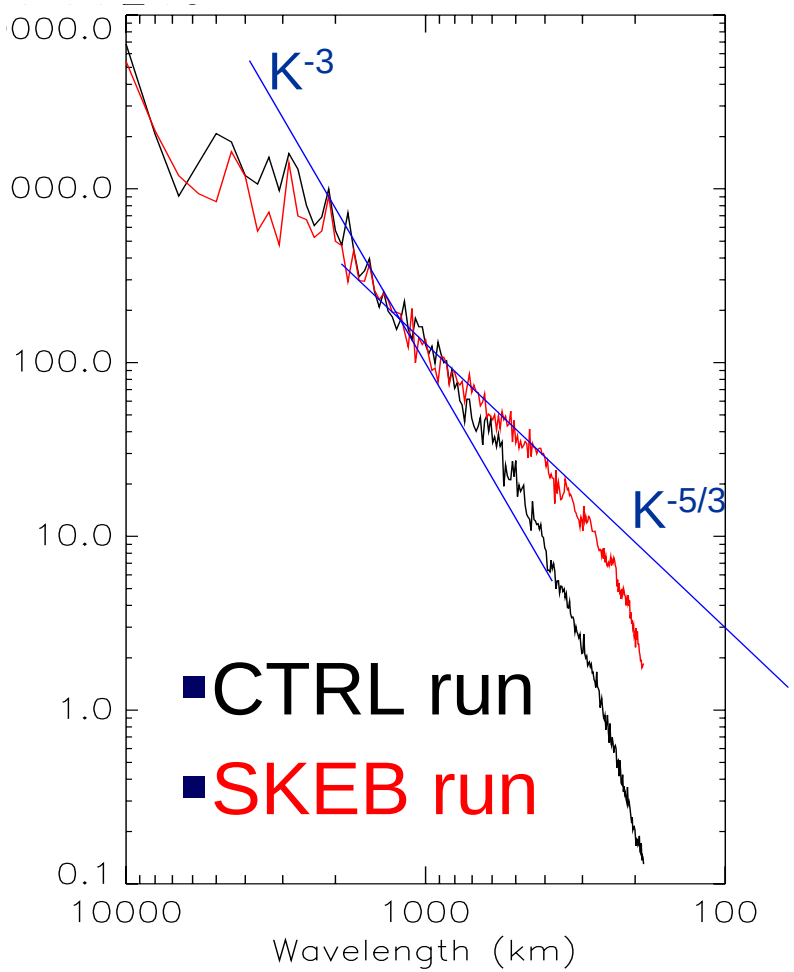
500 hPa geopotential height

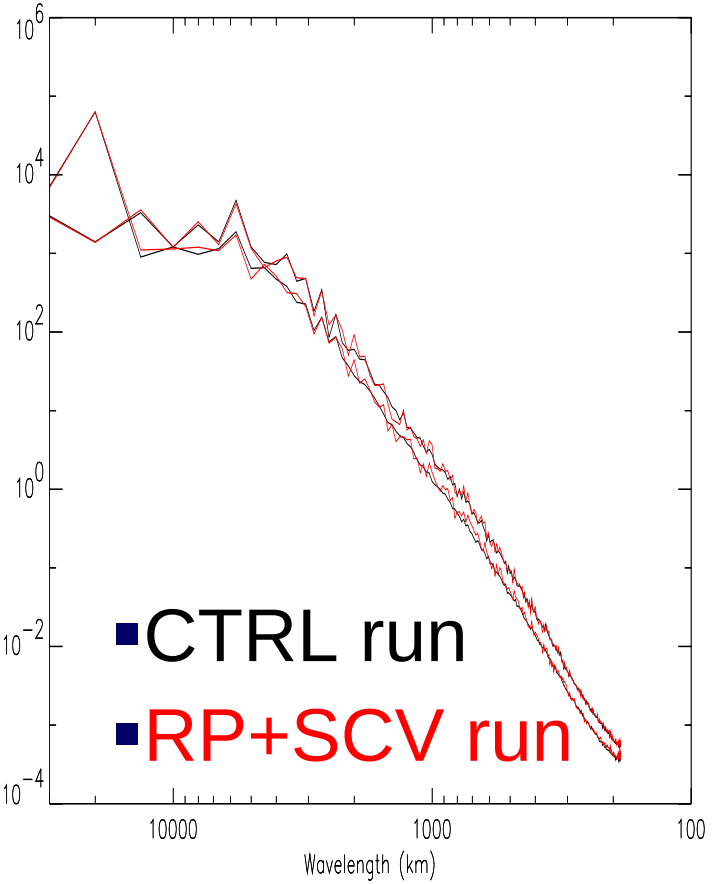


SKEB

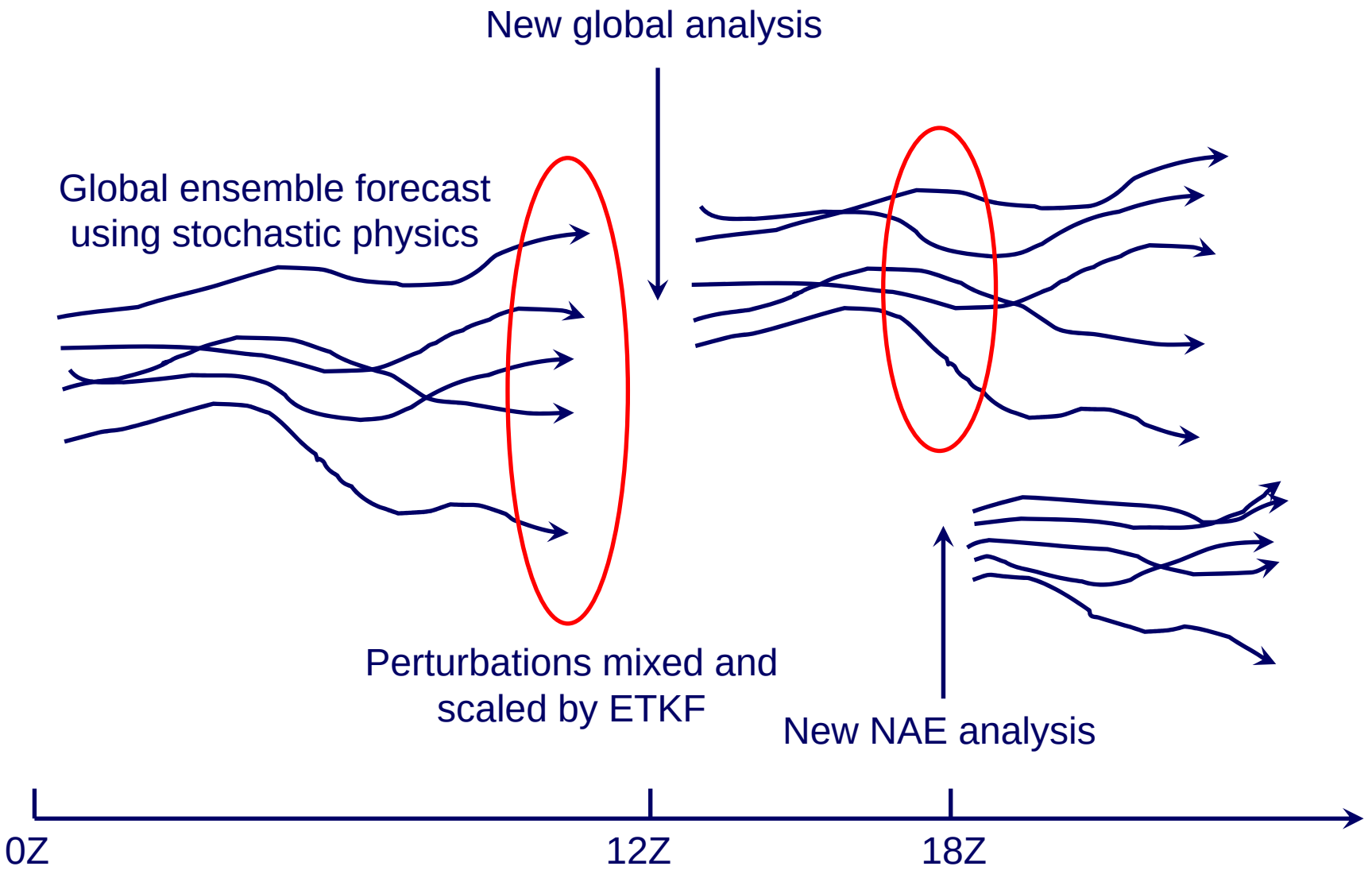
Preliminary results:

- Better representation of forecast spectra





MOGREPS Operational System diagram



MOGREPS display web - Mozilla

File Edit View Go Bookmarks Tools Window Help

Back Forward Reload Stop http://www-nwp/%7Efren/MOGREPS/products/spaghetti/spaghetti.html?frmAnimStatus=Running&frmDelayMS=400+ms&frmFraNum=I Search Print

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Met Office Global and Regional Ensemble Prediction System

BEWARE: Site still under development

Created by the ..... Ensemble Forecasting Research Group

Met Office

Stopped | 400 ms | Frame 9 | Model | Variable | Time of run | Display

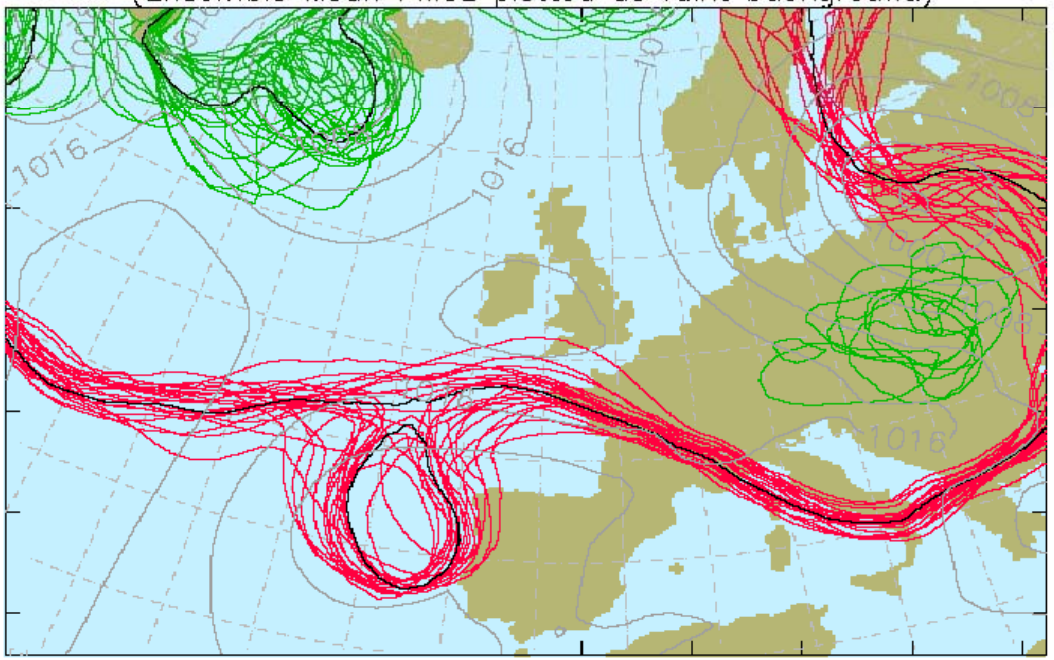
FORECASTS

- Mean / Prob
- Mean / Sprd
- Spaghetti
- Post. Stamps
- Site-specific

SCI - INF

FEEDBACK

MOGREPS (Global) Spaghetti chart for 1000–500hPaThickness
DT 00Z on 08/08/2005 VT 06Z on 10/08/2005 lead time 54h
510/528/546/564dam (Black lines represent Control member)
(Ensemble Mean PMSL plotted as faint background)



MOGREPS display web - Mozilla

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Met Office Global and Regional Ensemble Prediction System

BEWARE: Site still under development

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Met Office

Stopped | 400 ms | Frame 6 | Model | Variable | Time of run | Display

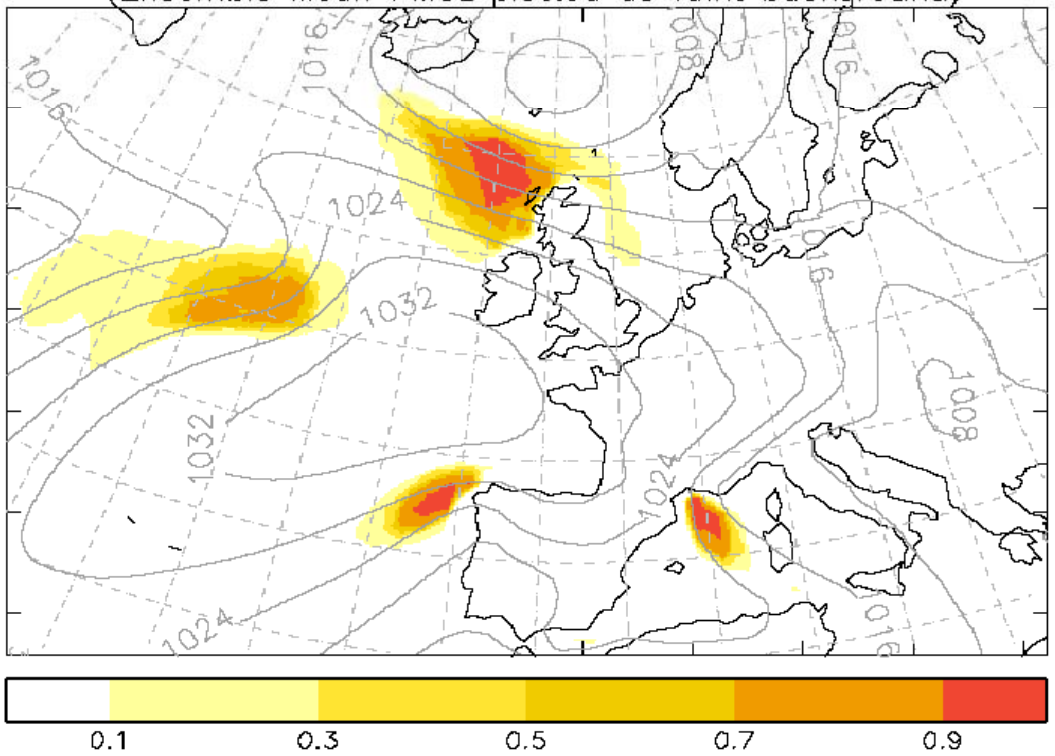
FORECASTS

- Mean / Prob
- Mean / Sprd
- Spaghetti
- Post. Stamps
- Site-specific

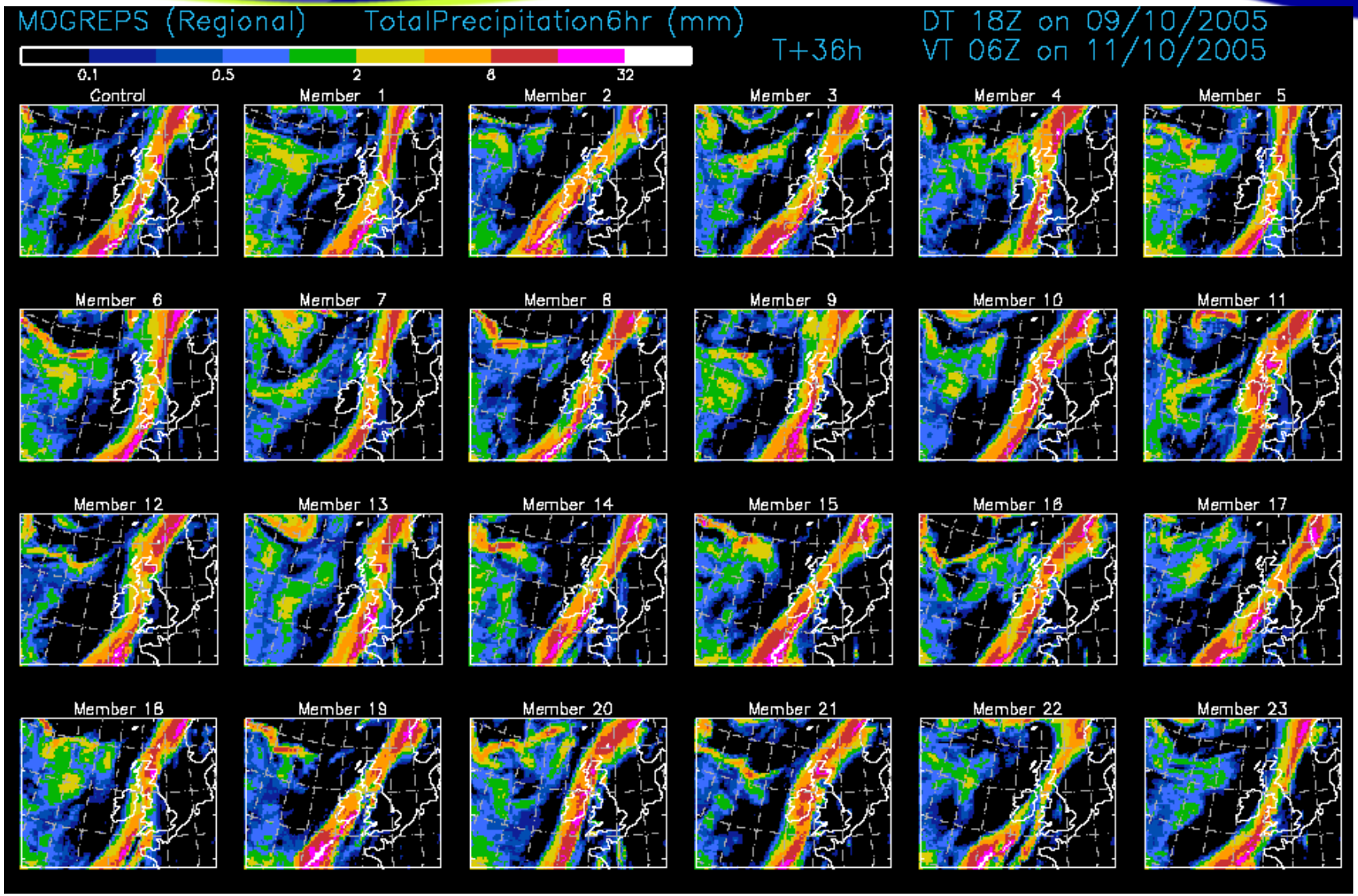
SCI - INF

FEEDBACK

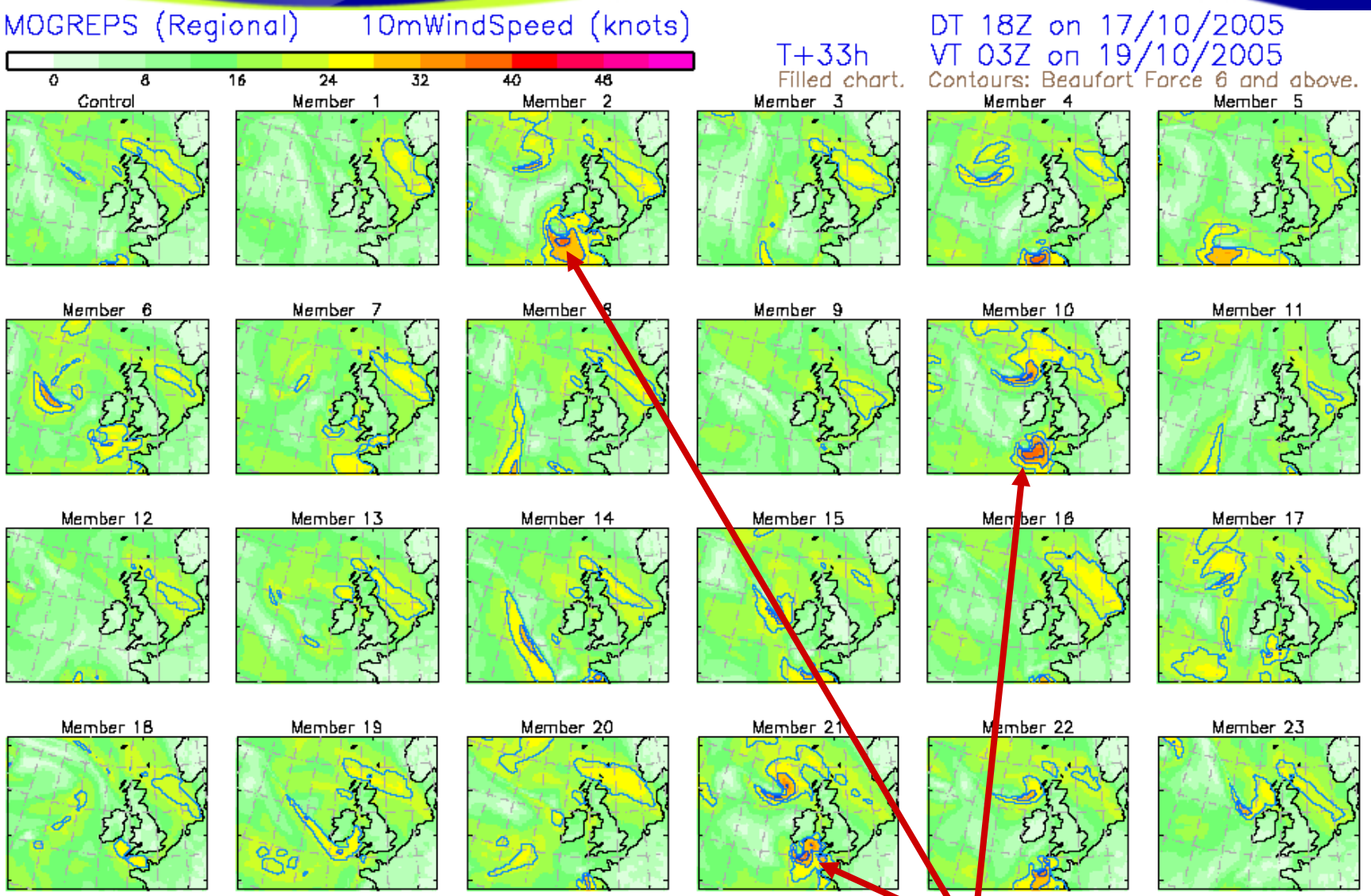
MOGREPS (Global) Probability map for 10mWindSpeed > 22.0knots
DT 12Z on 02/08/2005 VT 00Z on 04/08/2005 lead time 36h
(Ensemble Mean PMSL plotted as faint background)



Example MOGREPS 36h Rainfall forecast

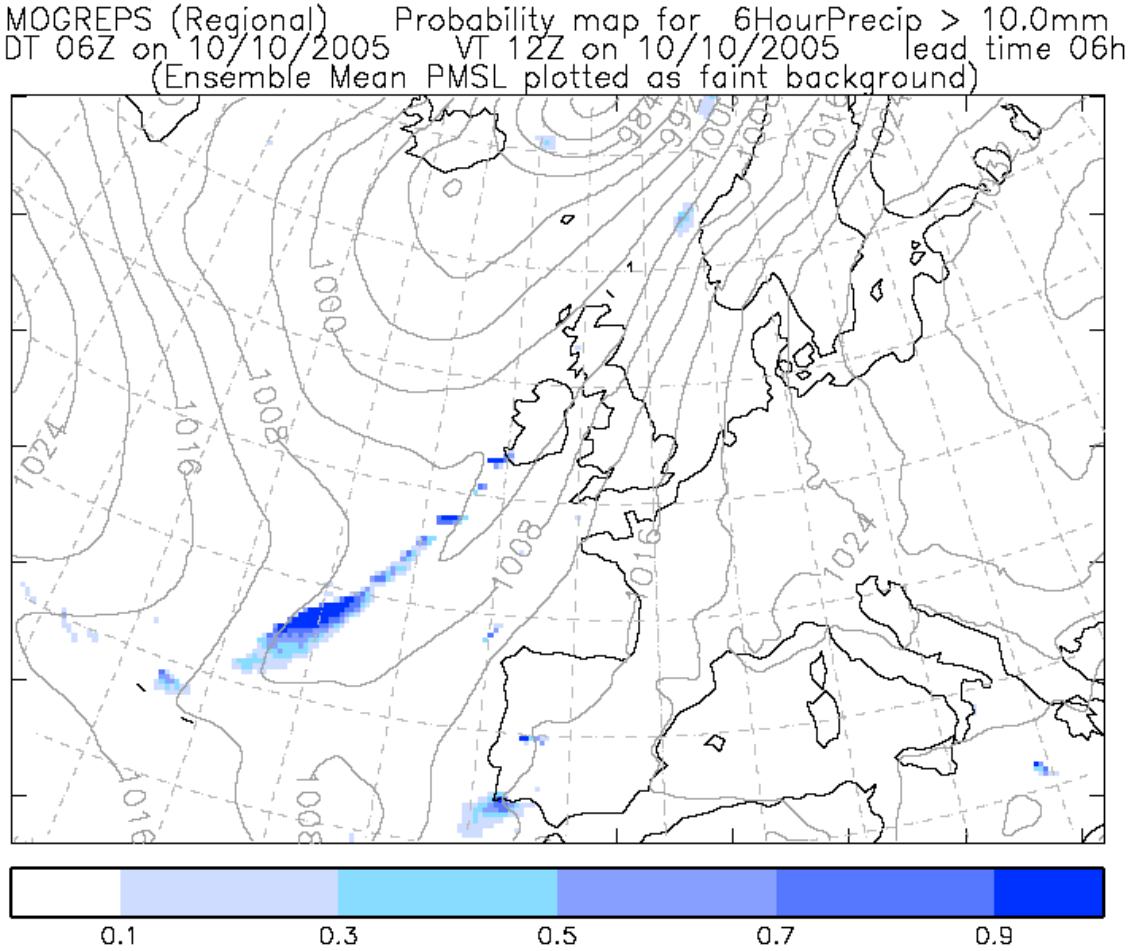


Example MOGREPS 33h 10m WS forecast



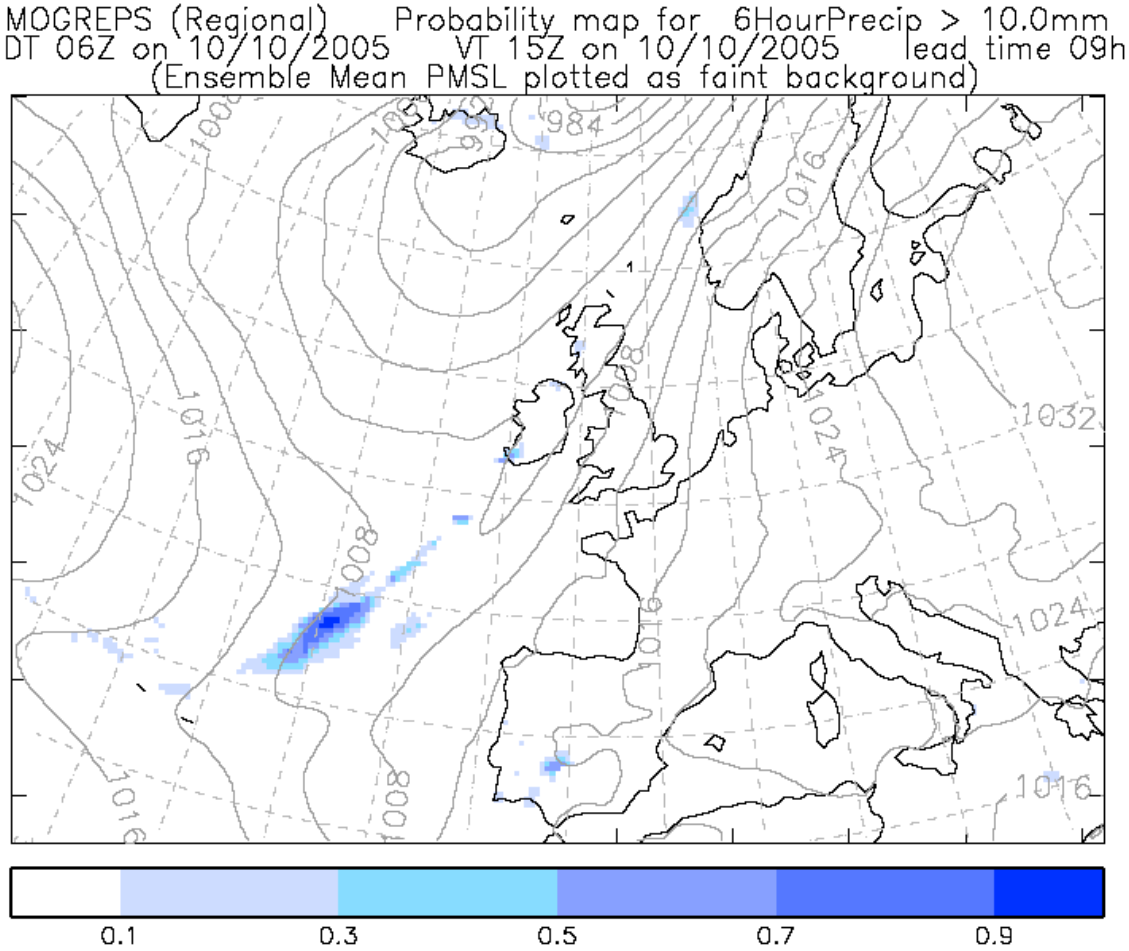
Probability of >10mm/6h T+06

Proportion of ensemble members gives estimate of probability



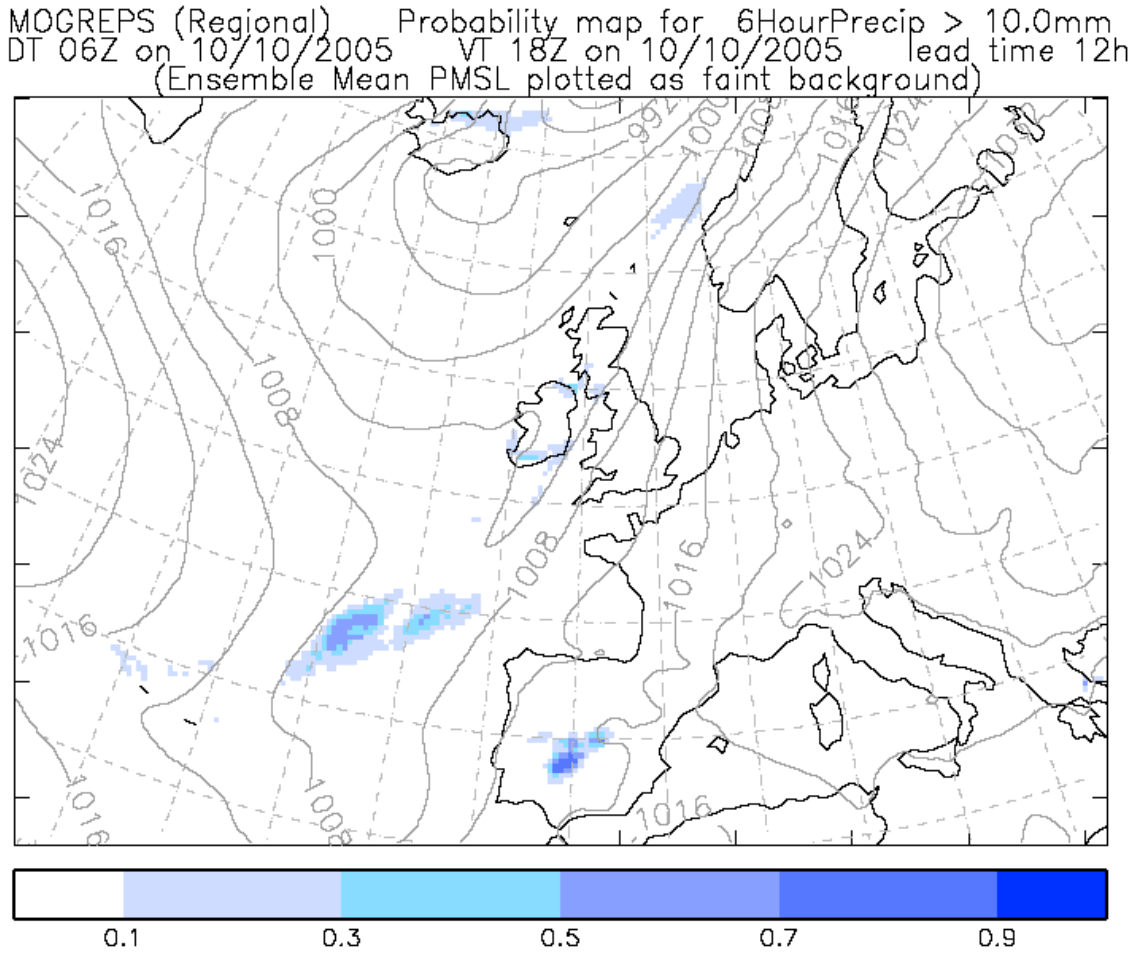
Probability of >10mm/6h T+09

Proportion of ensemble members gives estimate of probability



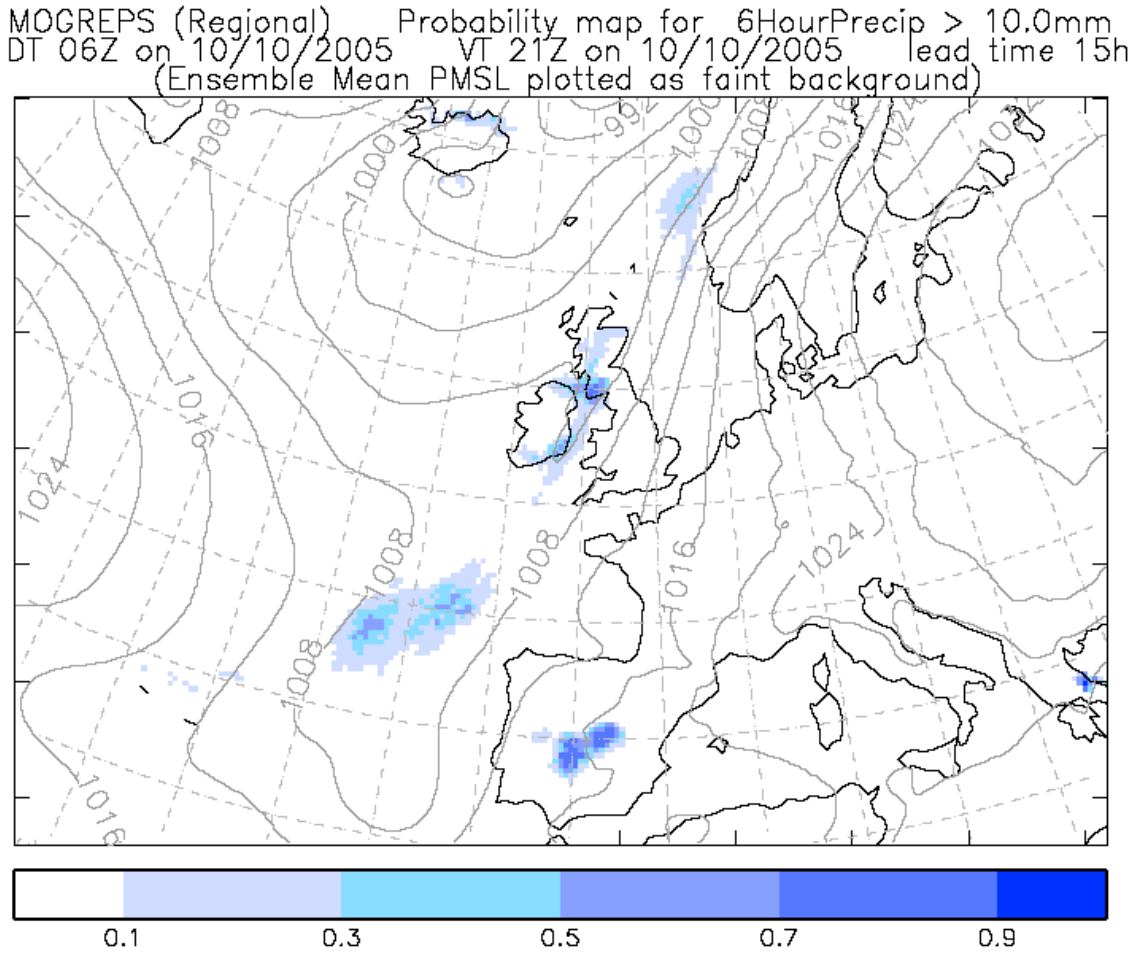
Probability of >10mm/6h T+12

Proportion of ensemble members gives estimate of probability



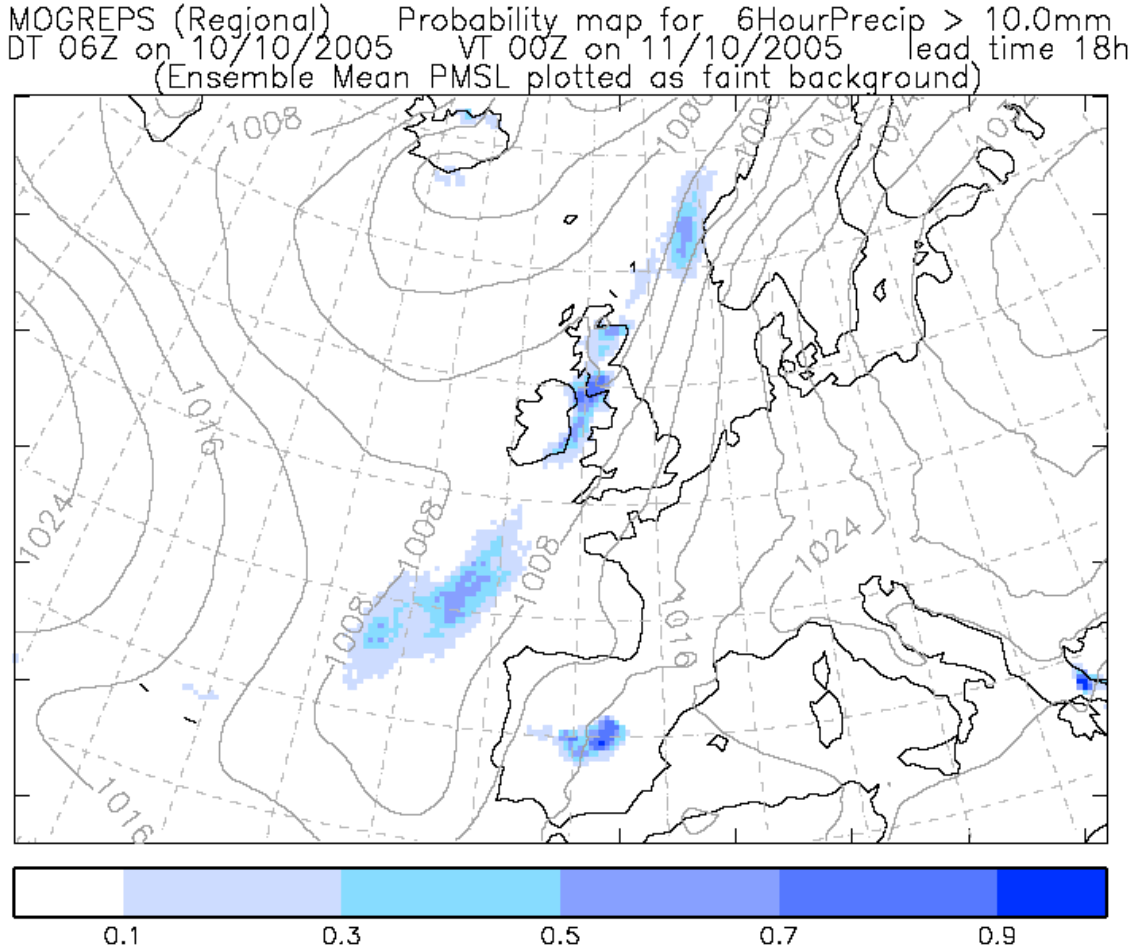
Probability of >10mm/6h T+15

Proportion of ensemble members gives estimate of probability



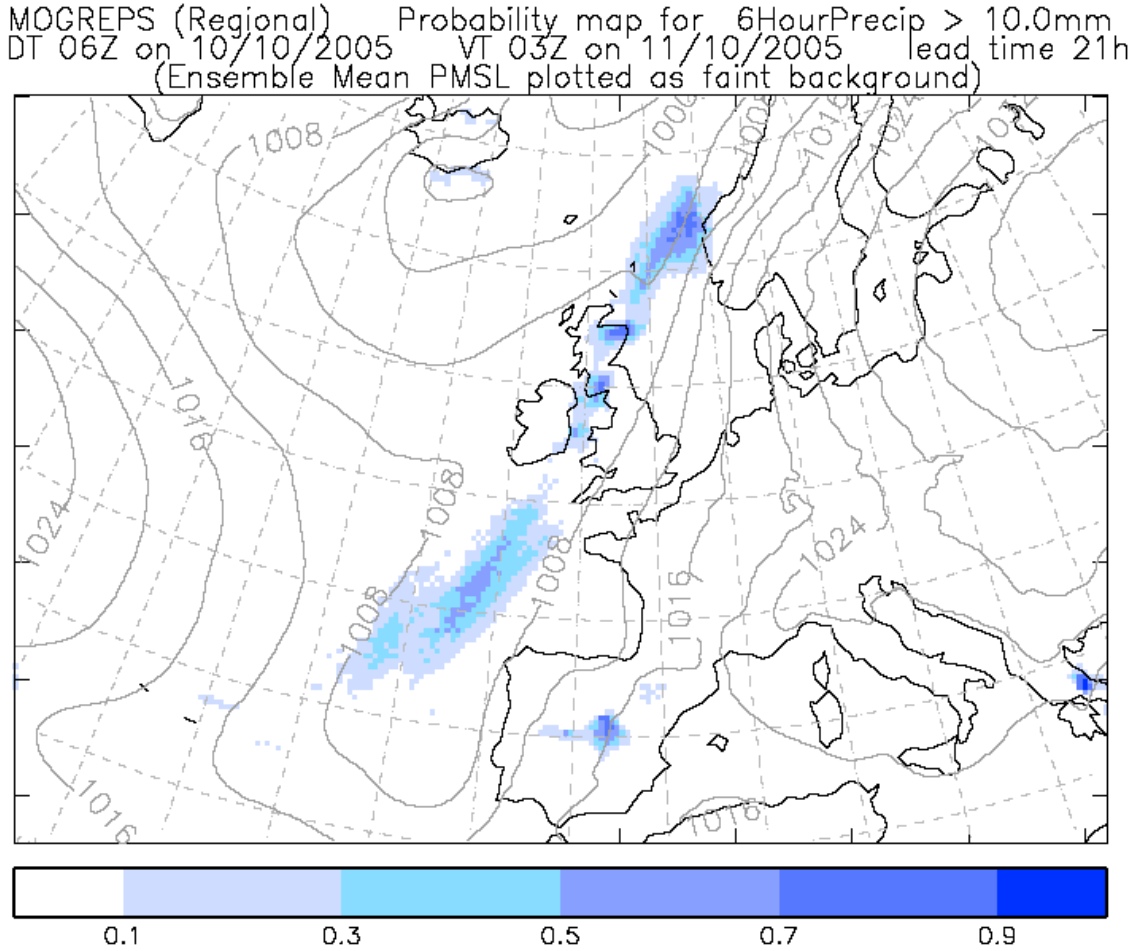
Probability of >10mm/6h T+18

Proportion of ensemble members gives estimate of probability



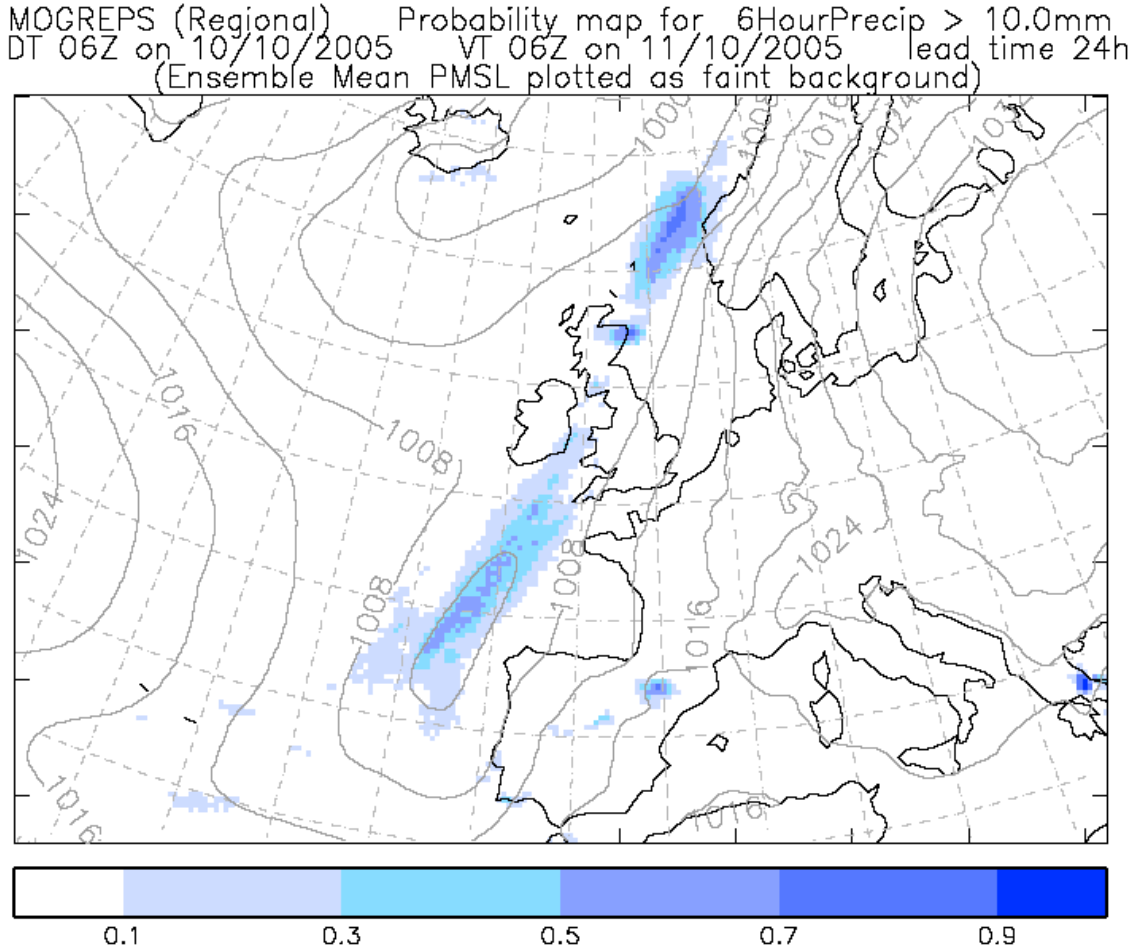
Probability of >10mm/6h T+21

Proportion of ensemble members gives estimate of probability



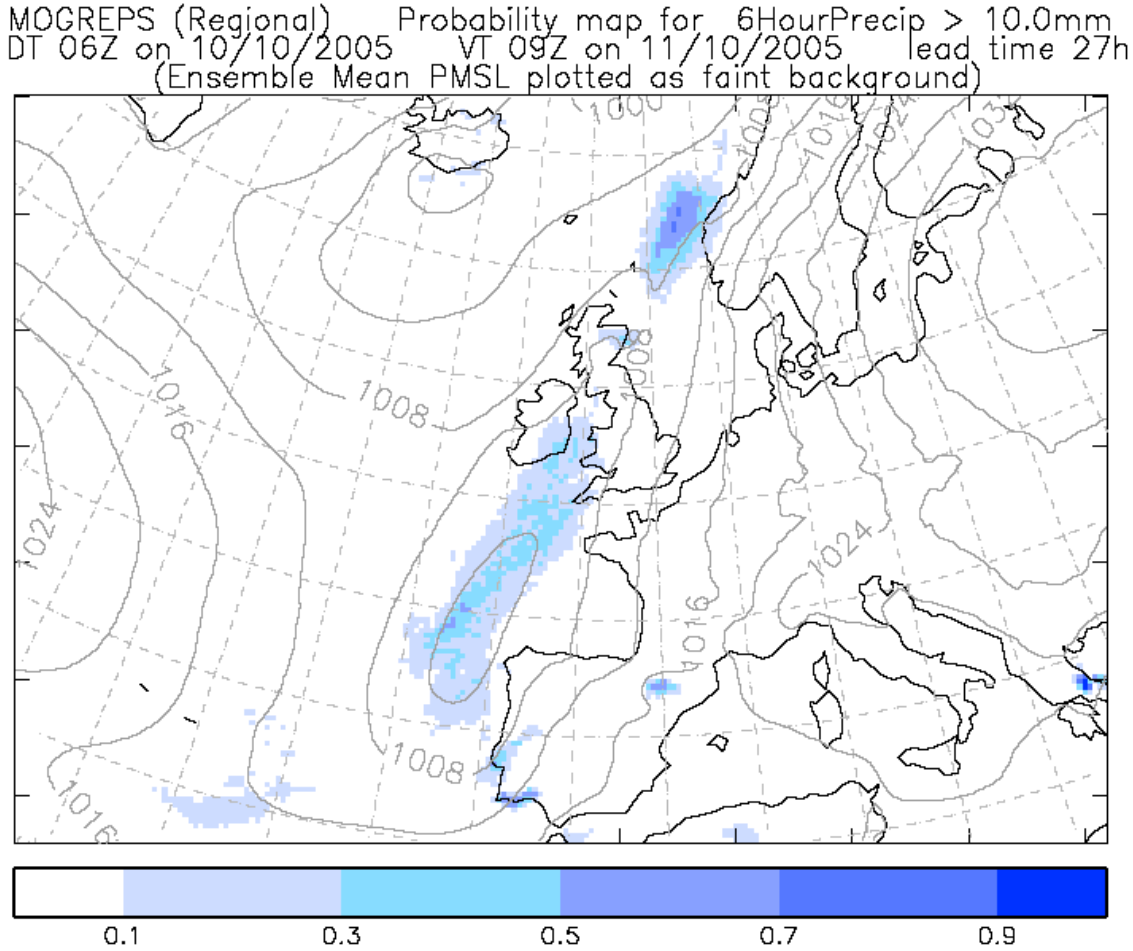
Probability of >10mm/6h T+24

Proportion of ensemble members gives estimate of probability



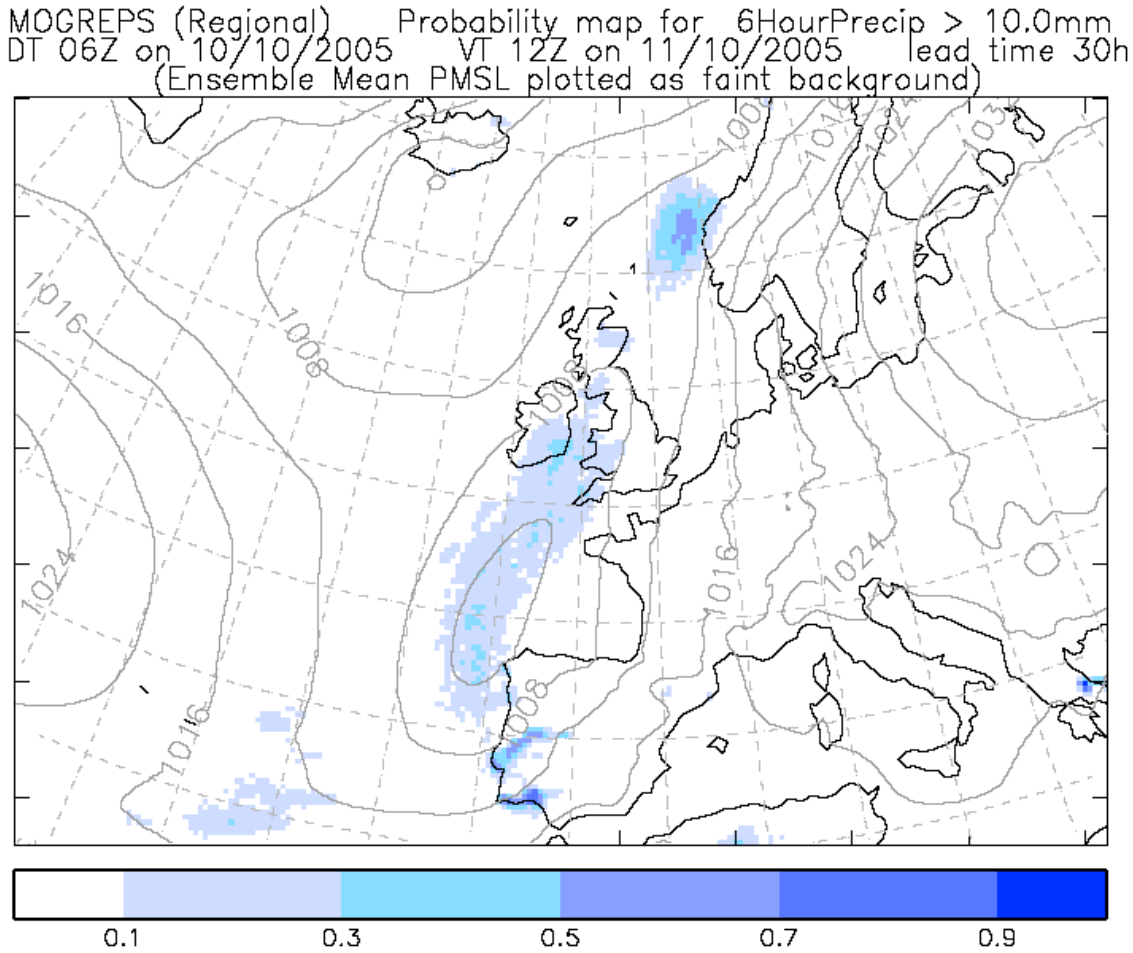
Probability of >10mm/6h T+27

Proportion of ensemble members gives estimate of probability



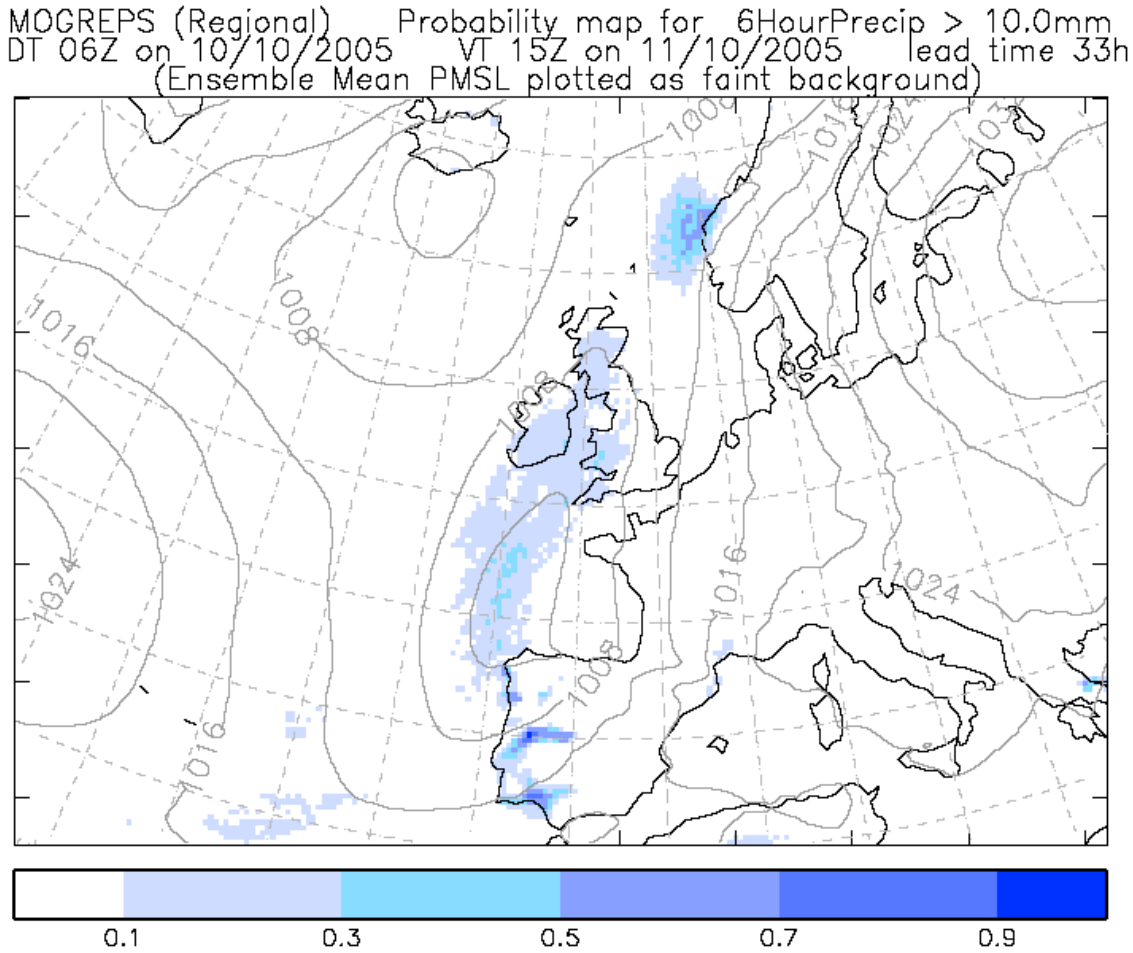
Probability of >10mm/6h T+30

Proportion of ensemble members gives estimate of probability



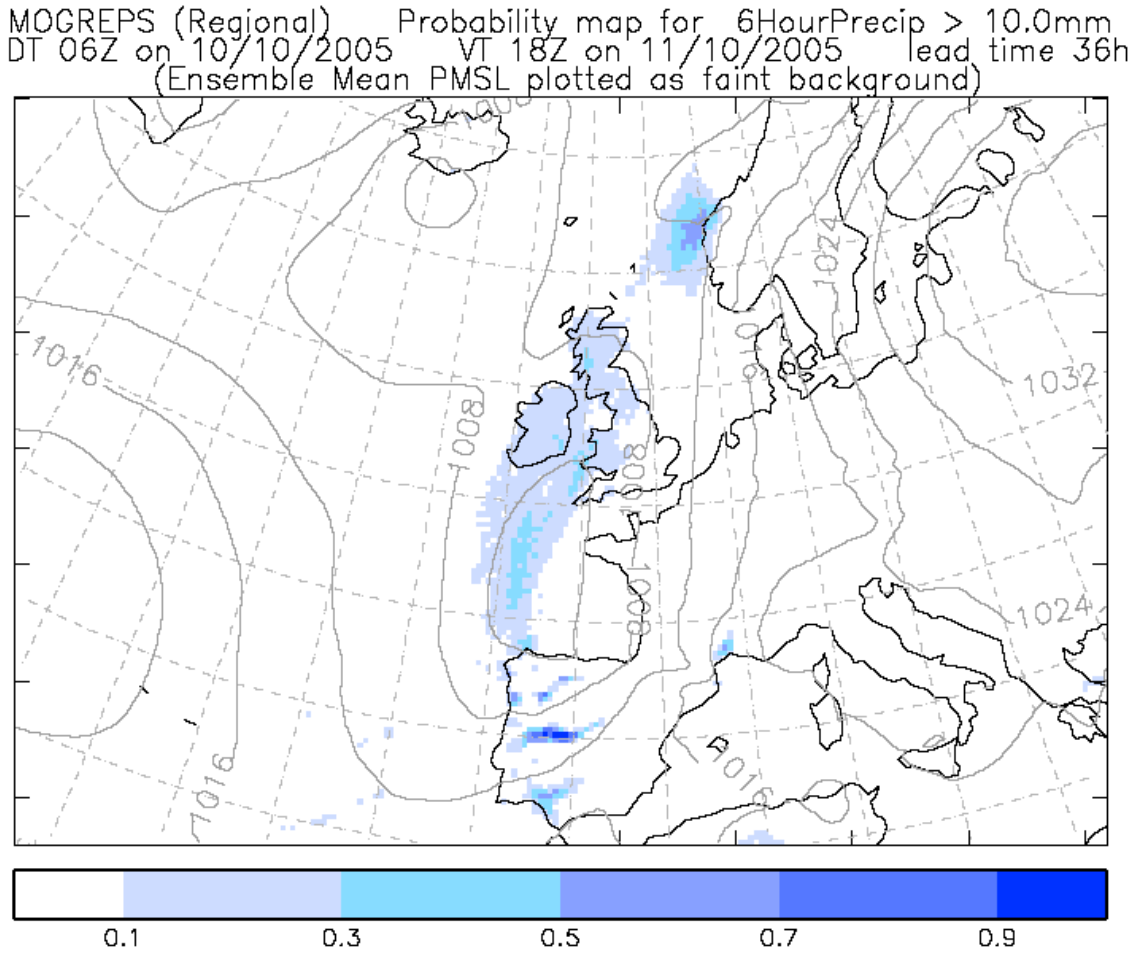
Probability of >10mm/6h T+33

Proportion of ensemble members gives estimate of probability

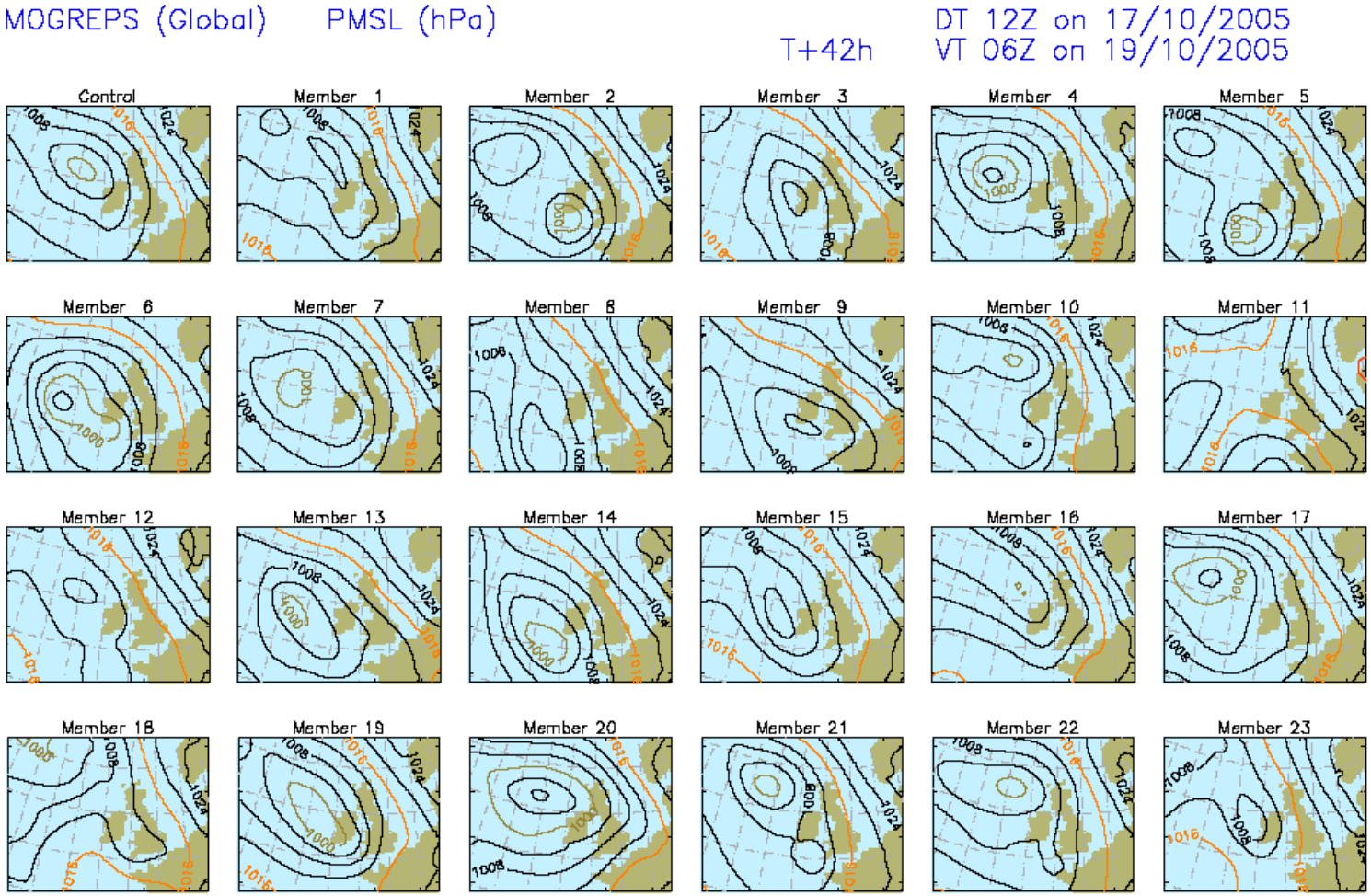


Probability of >10mm/6h T+36

Proportion of ensemble members gives estimate of probability

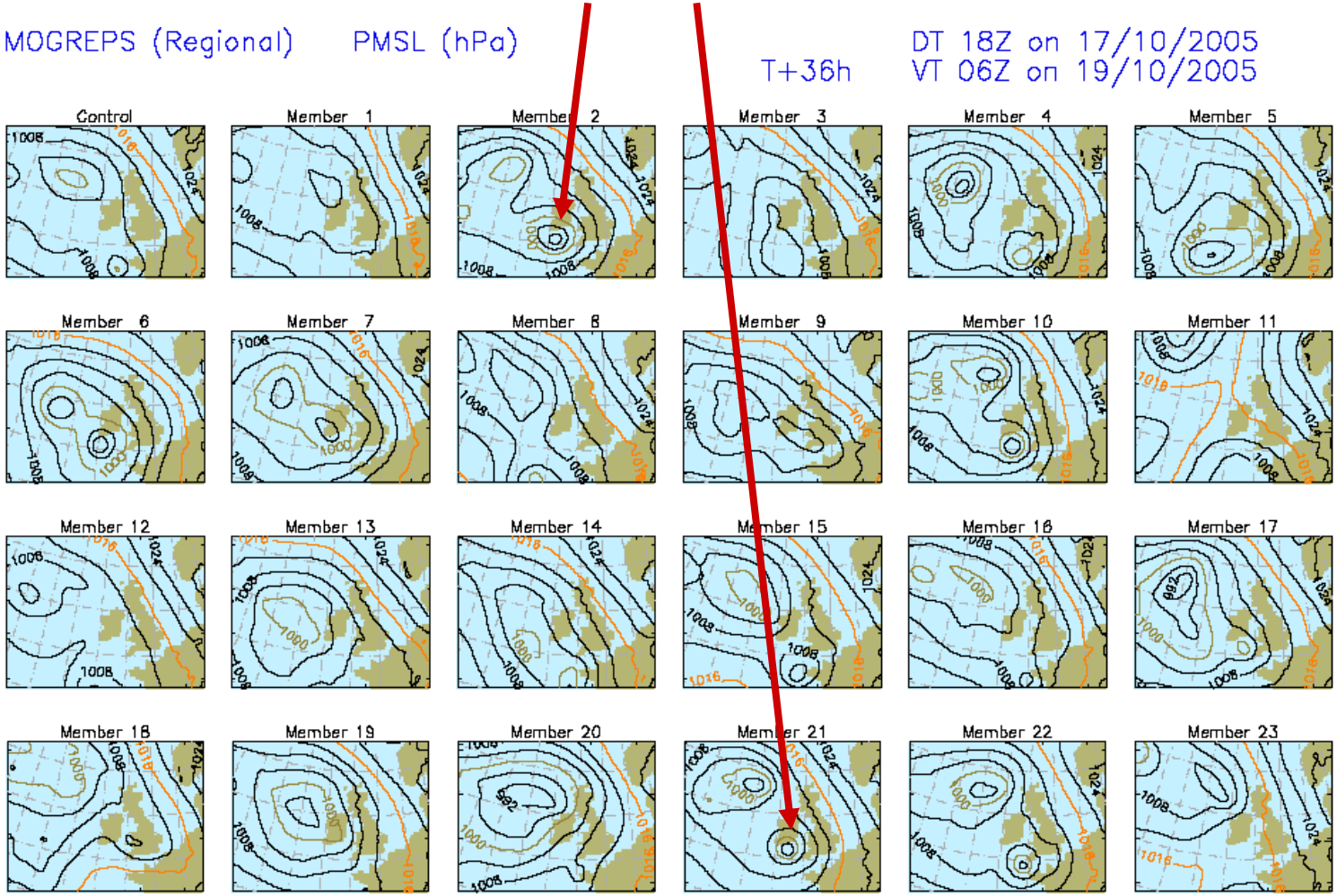


Global T+42 forecast for 06Z on 19/10/05



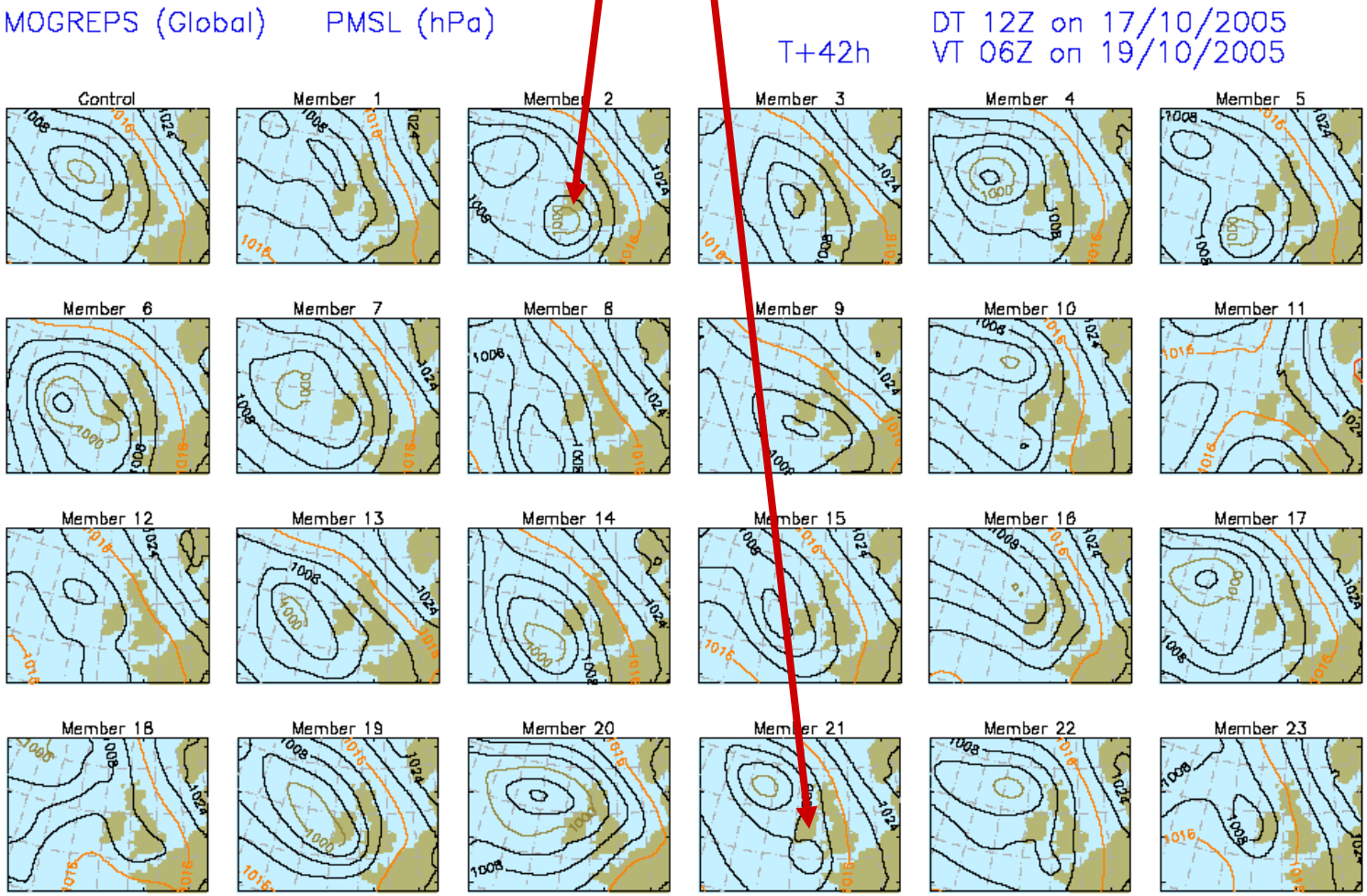
NAE T+36 forecast for 06Z on 19/10/05

Note extra detail and deeper lows in NAE



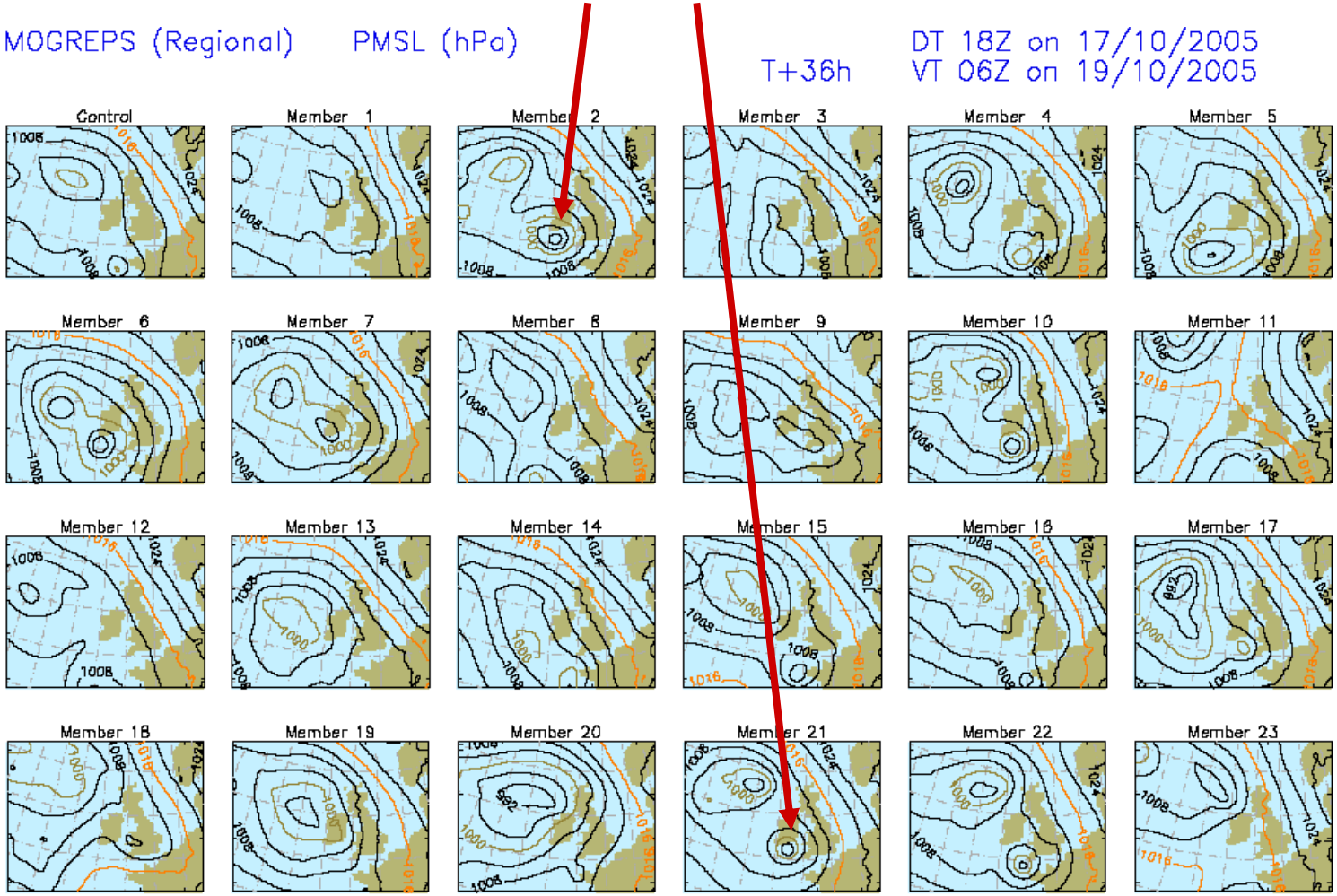
Global T+42 forecast for 06Z on 19/10/05

Note extra detail and deeper lows in NAE



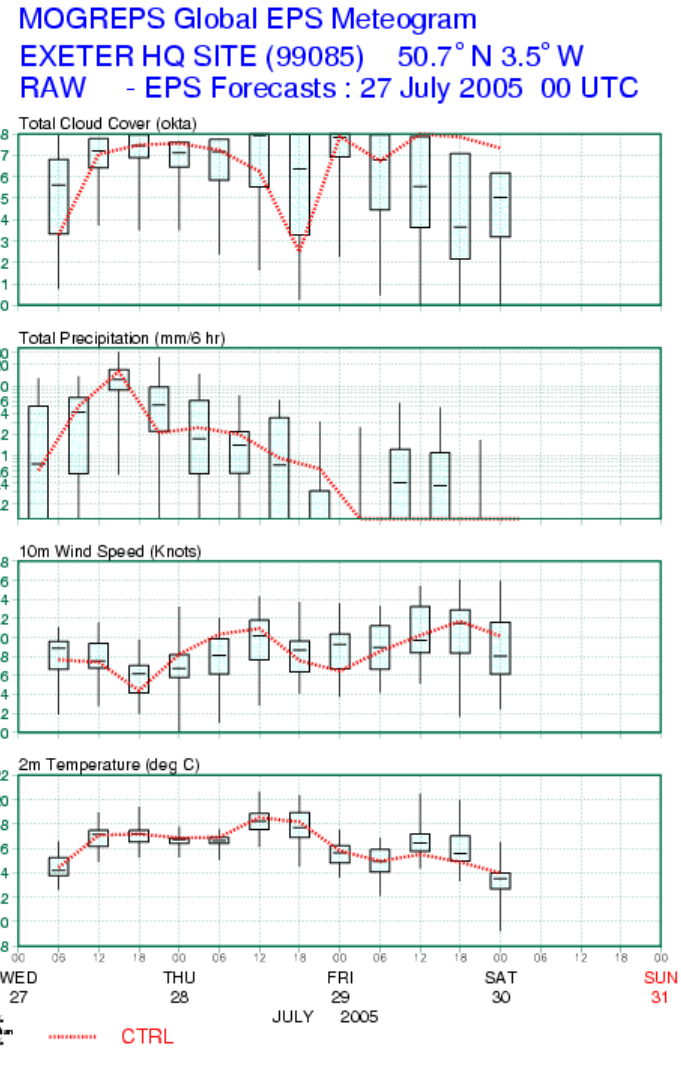
NAE T+36 forecast for 06Z on 19/10/05

Note extra detail and deeper lows in NAE

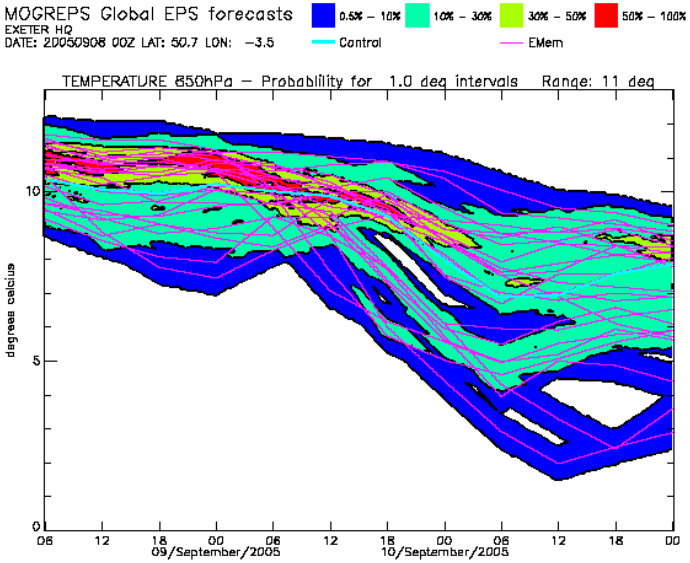


MOGREPS Site-specific forecasts

- EPS Meteogram



- MOGREPS Plume



- Kalman filter MOS is being implemented for MOGREPS forecasts

Site-specific Probabilistic Wind-rose

Key for wind direction & speed on windrose only:

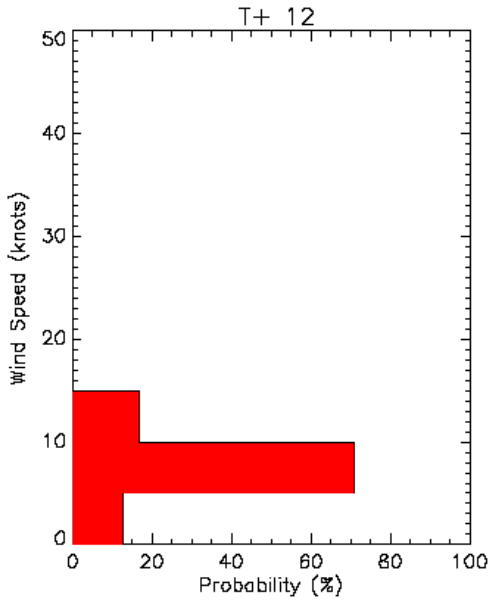
30 degree sectors (000–030, 030–060,...,330–360)
innermost circle only for wind direction

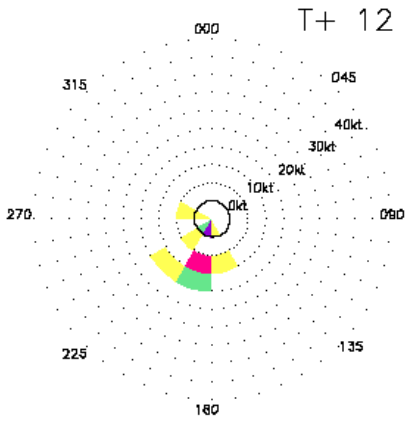
outer circles are divided into 5 knot bands, with wind speed increasing outwards
(eg. 0–5kt,5–10kt,10–15kt,15–20kt)

1% to 10% probability =		50% to 60% probability =	
10% to 20% probability =		60% to 70% probability =	
20% to 30% probability =		70% to 80% probability =	
30% to 40% probability =		80% to 90% probability =	
40% to 50% probability =		90% to 100% probability =	

NO COLOUR KEY FOR BAR CHART

GL_ENS 2005090800 Station: 99085

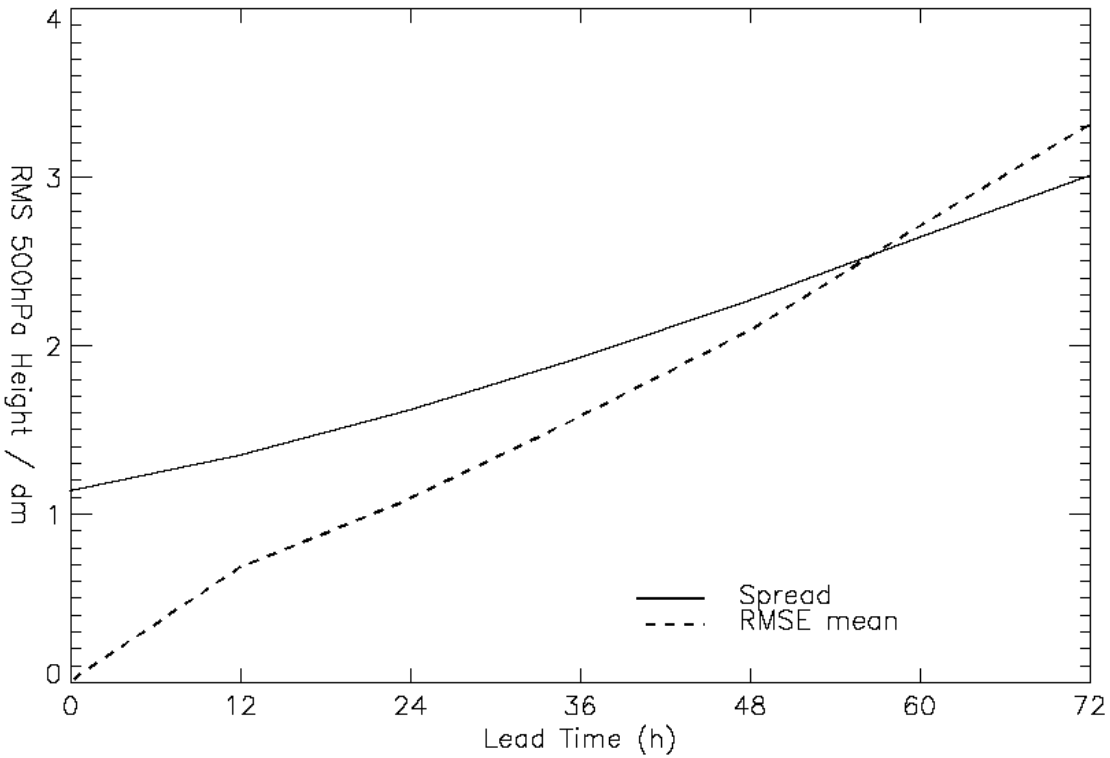




Global MOGREPS Performance

- 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

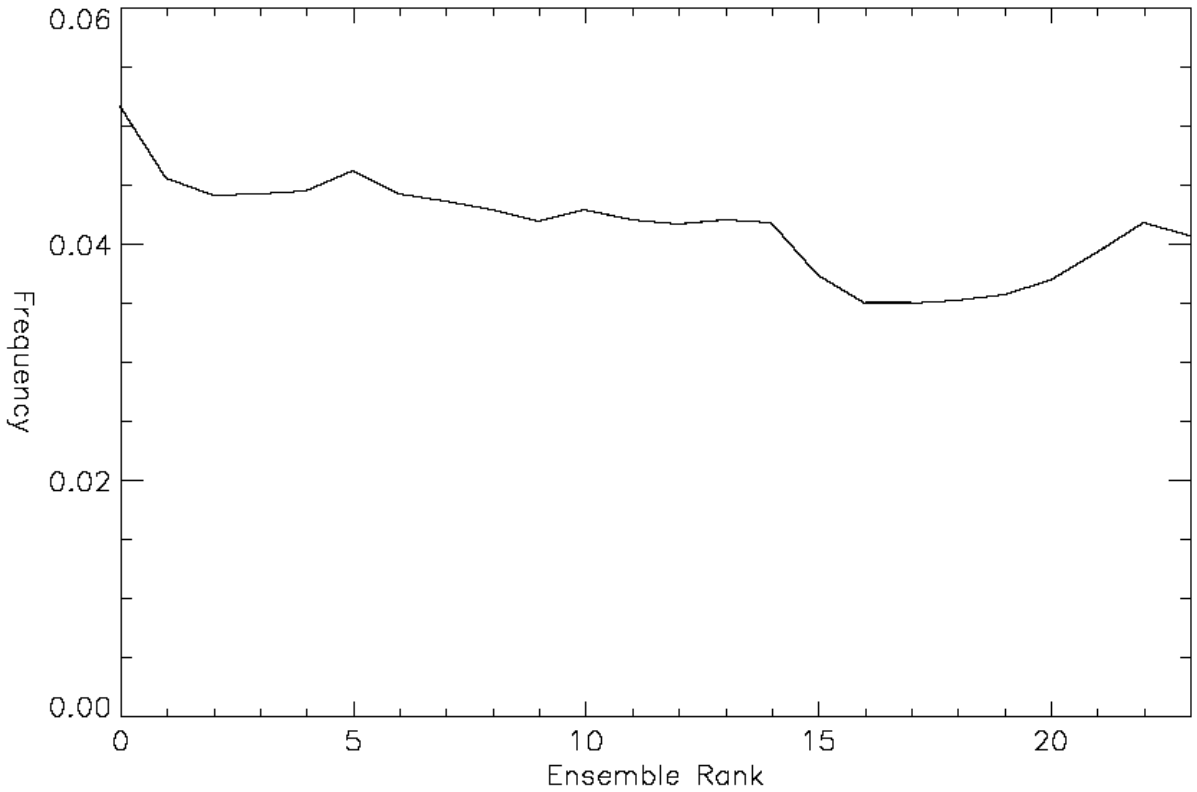
Spread and RMSE for 500hPa GPH



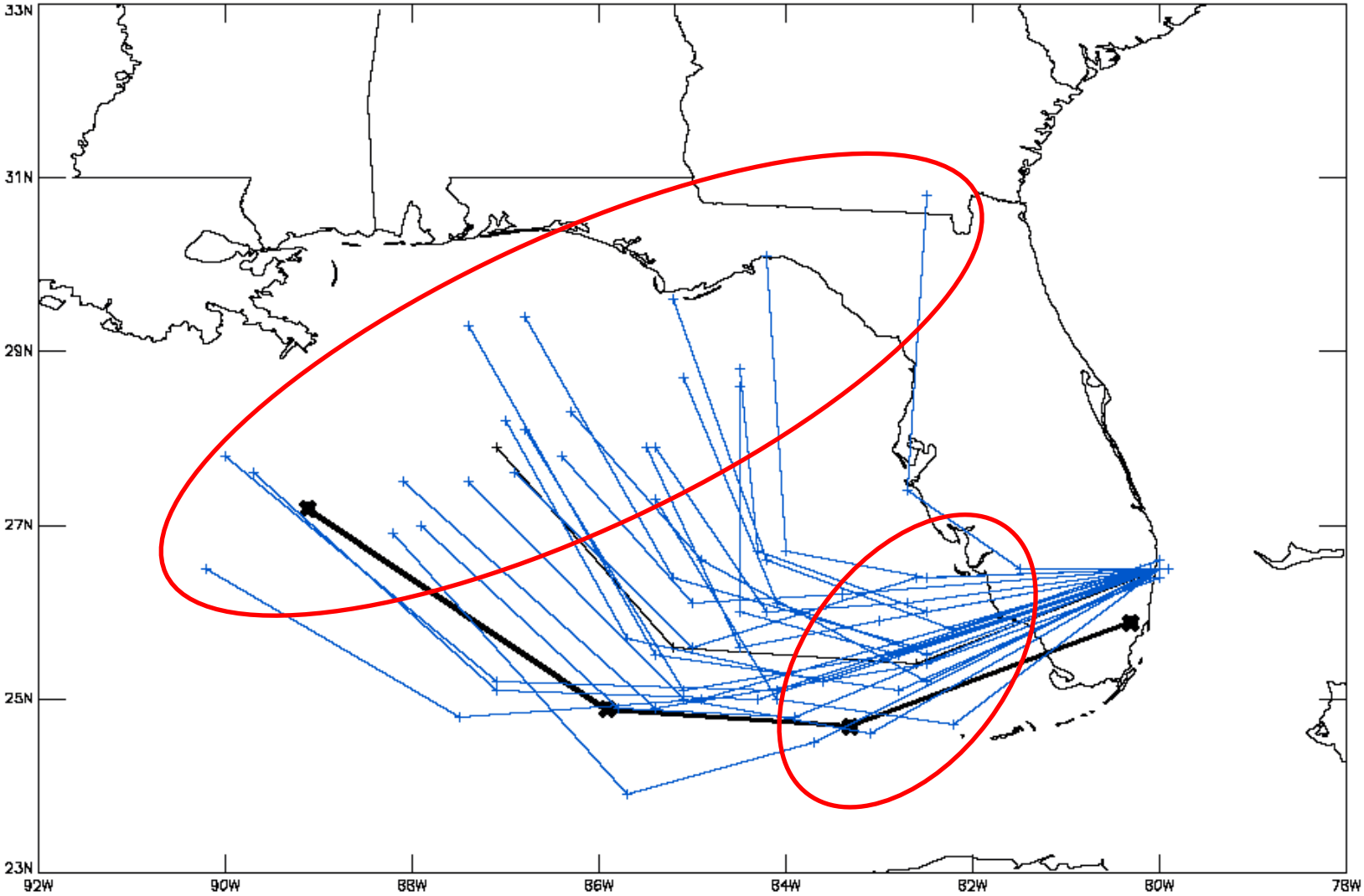
Global MOGREPS Performance

- Rank histogram is encouragingly flat
  - Close to ideal
- Suggests that ETKF perturbations are representative of genuine analysis errors
- RH for shorter lead-times is peaked in middle
  - Suggests overspread, but…
  - Probably due to verifying against analyses

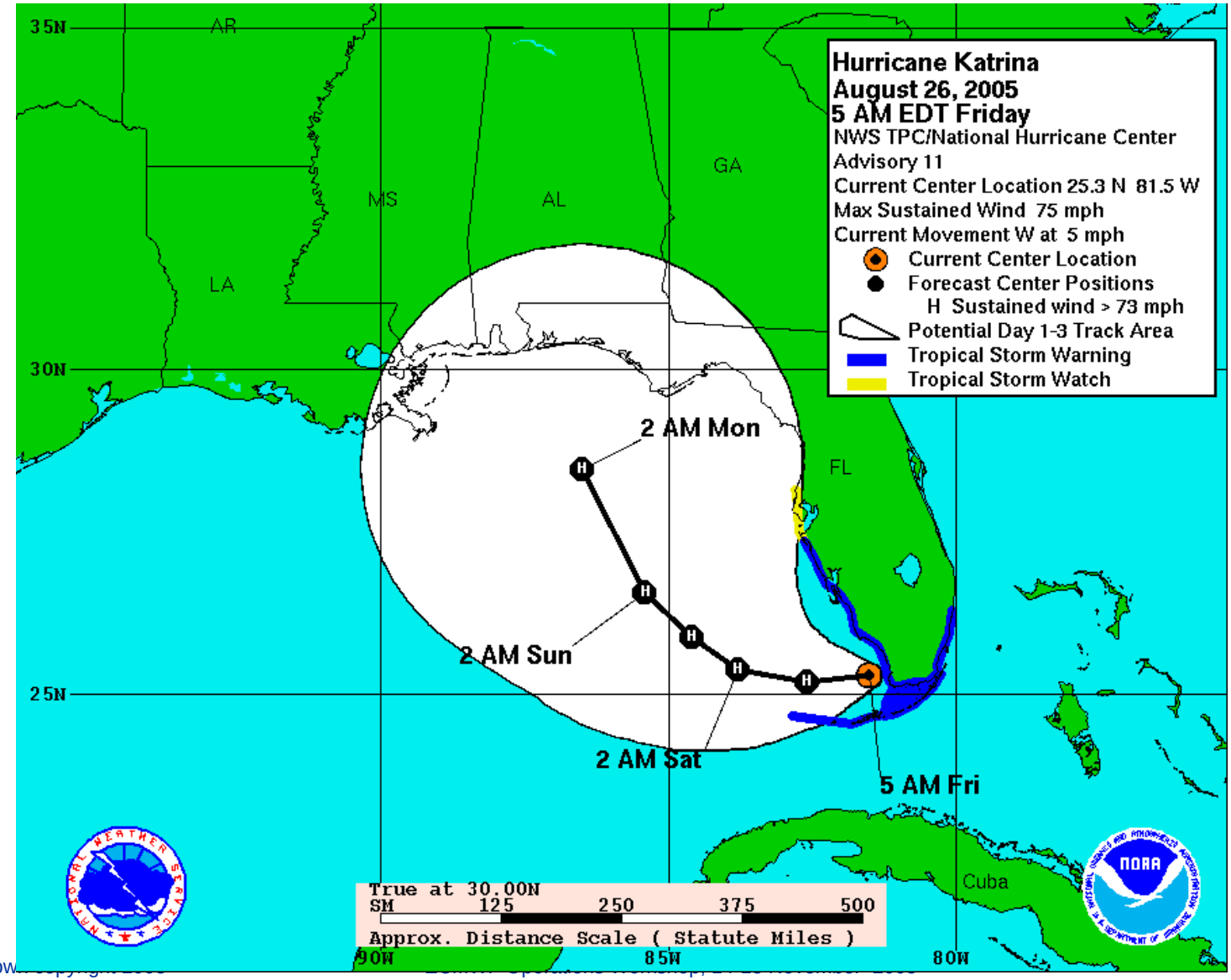
Rank Histogram at T+72 for 500hPa GPH



Katrina – from “operational” system



Katrina – NHC warning



Verification and Assessment

- Verification to date is very basic
- Verification is being implemented within the Area-based Verification system (ABV) and Site-specific Verification system (SBV)

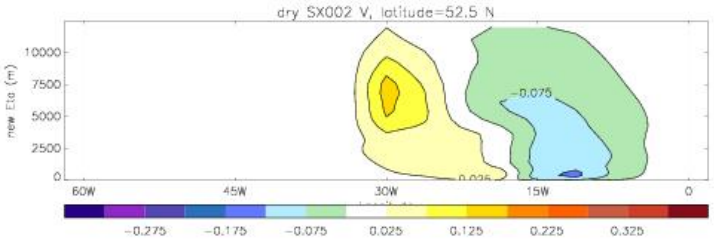
- Daily assessment is being carried out by Ops Centre forecasters and research staff
  - Fixed sets of questions
  - Initial forecaster response is enthusiastic and very positive

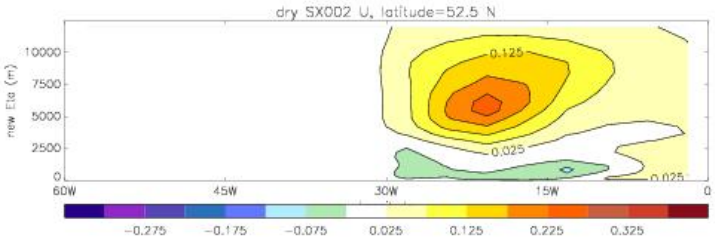
Singular Vector Research

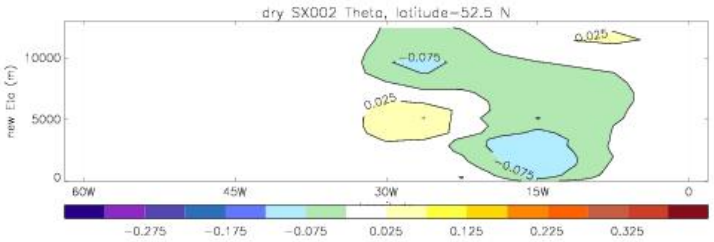
- ETKF is believed to be well-suited to short-range ensemble, but…
  - Singular vectors perform very well at ECMWF
  - Coutinho and Hoskins showed benefit of moist SVs with shorter optimisation time
- Following idea of Hoskins to use a very small SV-perturbed ensemble to assess possible extreme deviations from ensemble mean
  - Capability to calculate dry or moist SVs from DA team
  - Future possibility that forecasters could choose a target area around a feature of concern

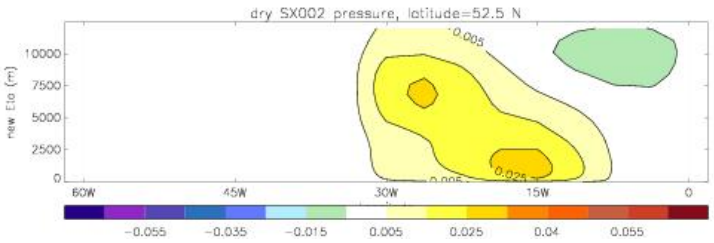
Singular Vector at final time (T+24)

Dry

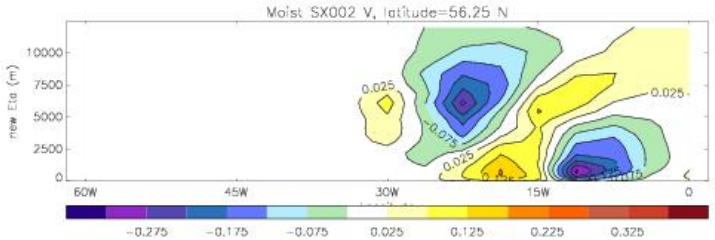


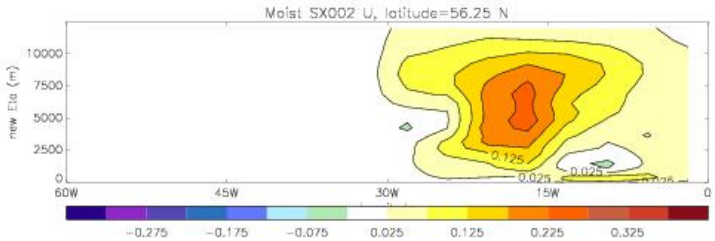


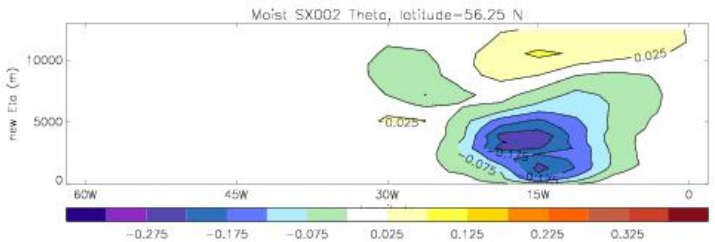


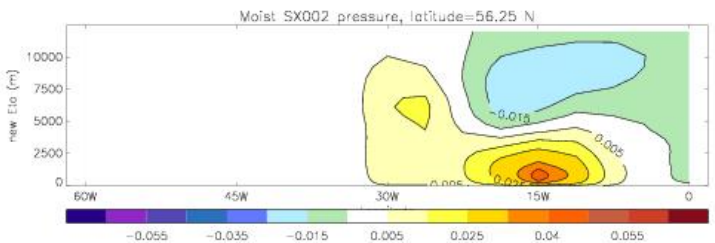


Moist

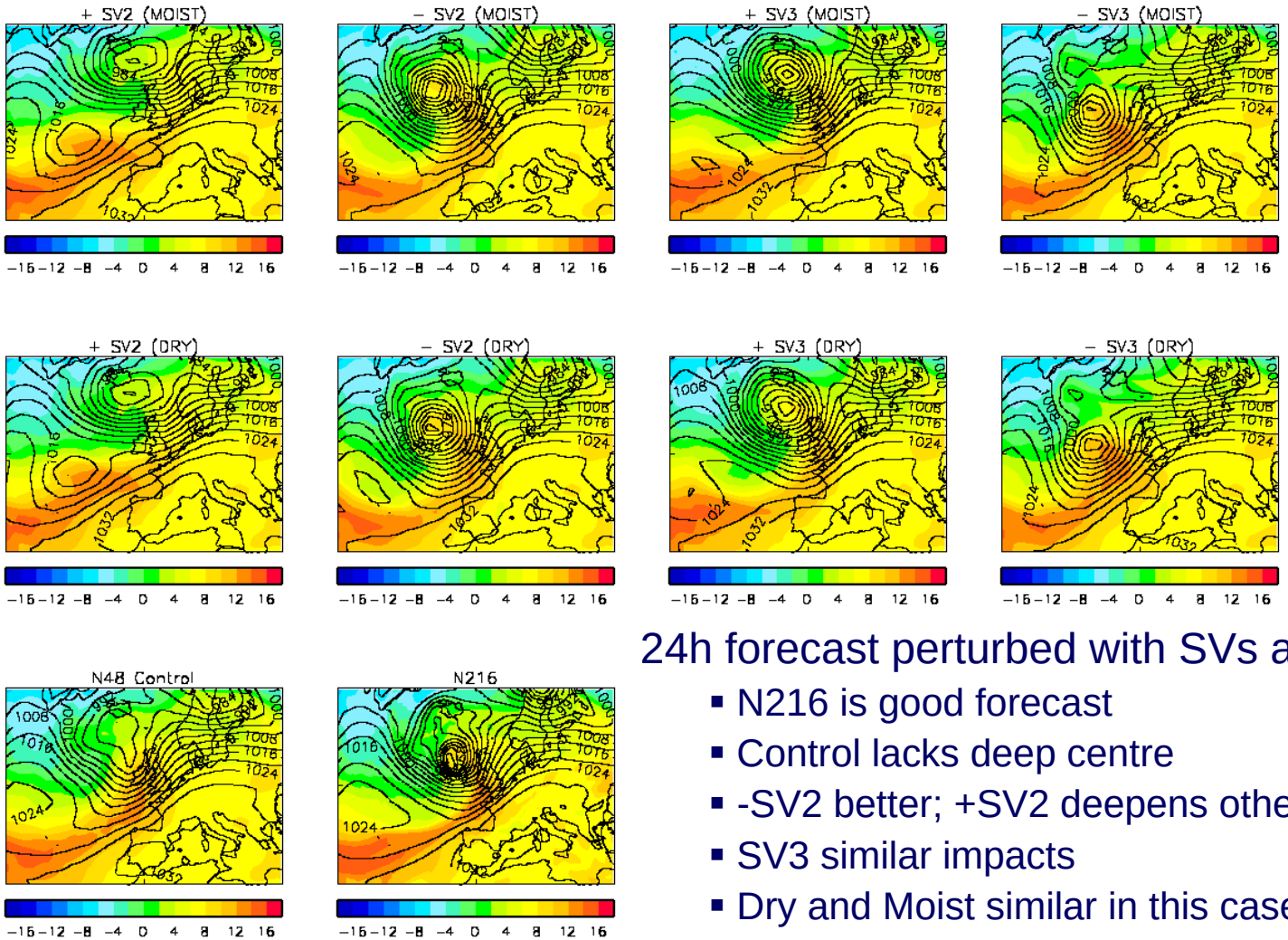








First SV perturbed forecast (N48 resolution)

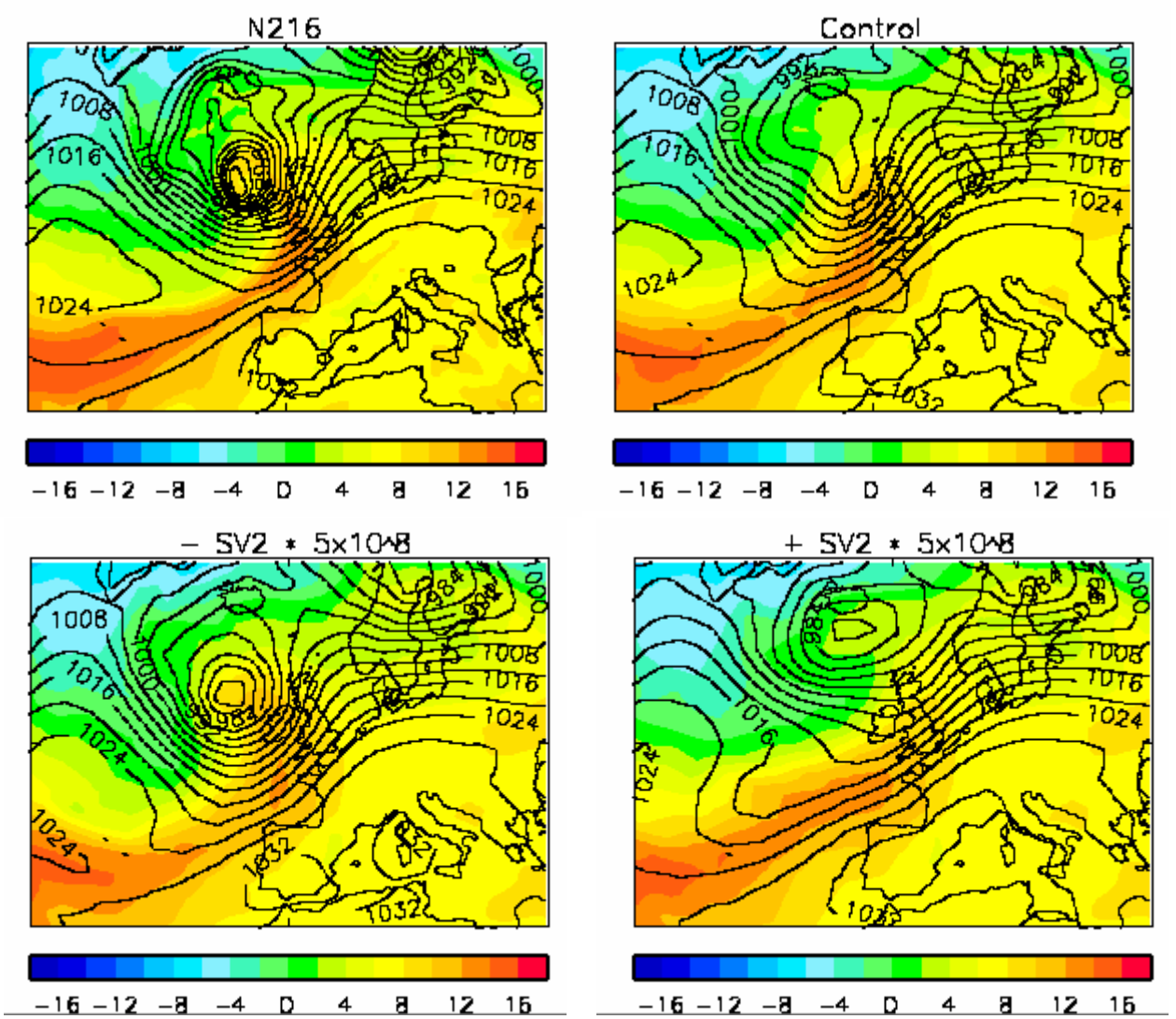


24h forecast perturbed with SVs at N48

- N216 is good forecast
- Control lacks deep centre
- -SV2 better; +SV2 deepens other centre
- SV3 similar impacts
- Dry and Moist similar in this case

First SV perturbed forecast (N48 resolution)

- Early 24h forecast perturbed with dry SV at N48
  - N216 is good forecast
  - Control lacks deep centre
  - -SV2 much better
  - +SV2 deepens other low centre



MOGREPS Status

- MOGREPS started operational trials in September
  - Trials scheduled to run for 12 months
  - Objective verification and forecaster assessment
- Further science upgrades planned
  - SKEB
  - Local ETKF and Regional perturbations for NAE
- Global MOGREPS being implemented at ECMWF to run to 15 days for THORPEX/TIGGE
  - Initial conditions supplied from Exeter
- MOGREPS cannot yet be used operationally
  - Could be operational later in 2006/07 subject to satisfactory performance in trial

Any questions?