Tour d’horizon et assimilation de données à l’échelle convective

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Met Office @ Reading.

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2. a) Nowcasting & covariances d'erreurs de prévision à l'échelle kilométrique

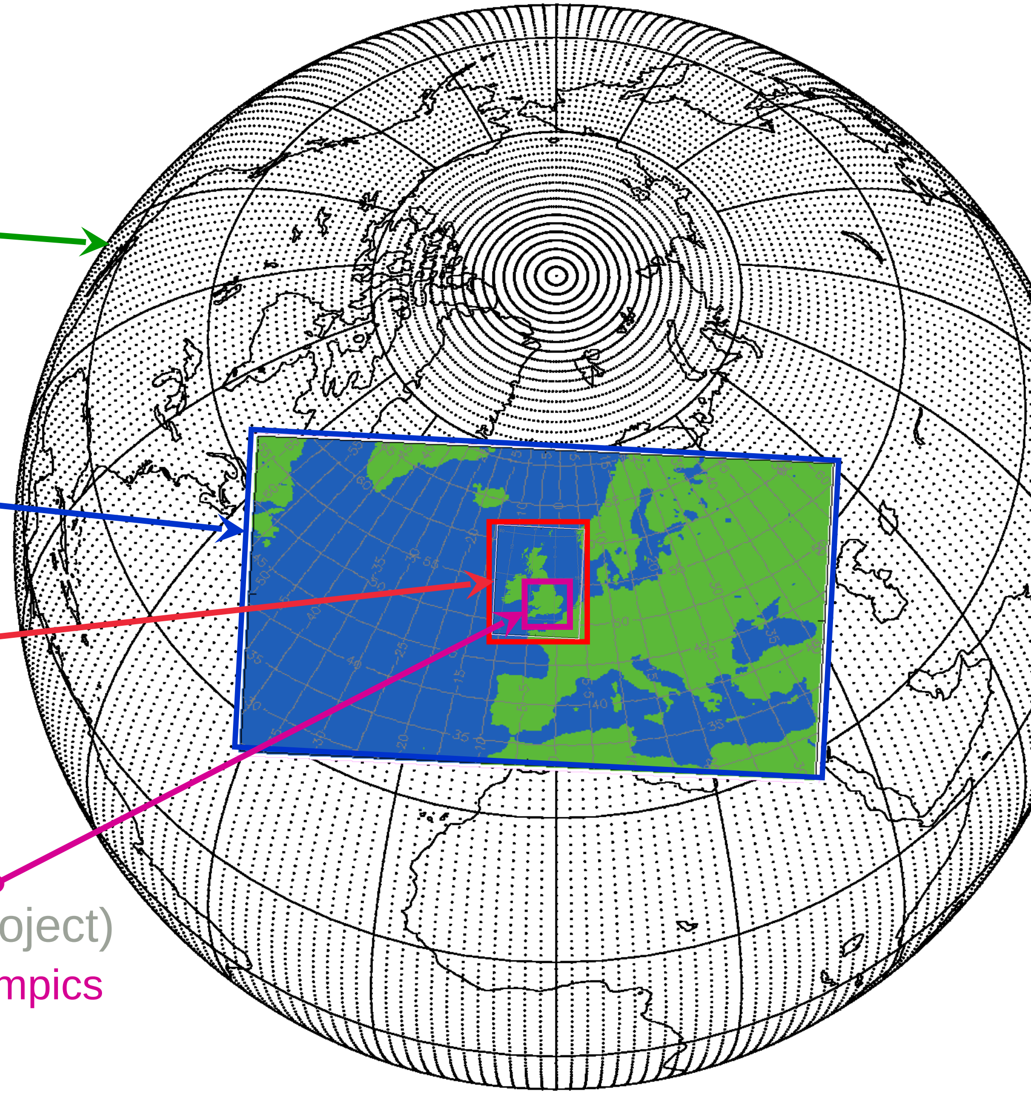
   b) Études des covariances d'erreurs de prévision en régions pluvieuses

1. Prévision d'ensemble à aire limitée : comment produire des perturbations aux conditions initiales cohérentes avec le SPE porteur ?

Où est le Met Office ?

Deterministic NWP Models

Met Office



Global

- 25-km 70 L (80-km top)
- 4DVAR (60-km inner-loop)
- 144 hour forecast - 00/12Z
- 60 hour forecast - 06/18Z

NAE (North Atlantic and Europe)

- 12-km 70 L (80-km top)
- 4DVAR (36-km inner-loop)
- 60 hour forecast - 4 times per day

UK4 & UKV

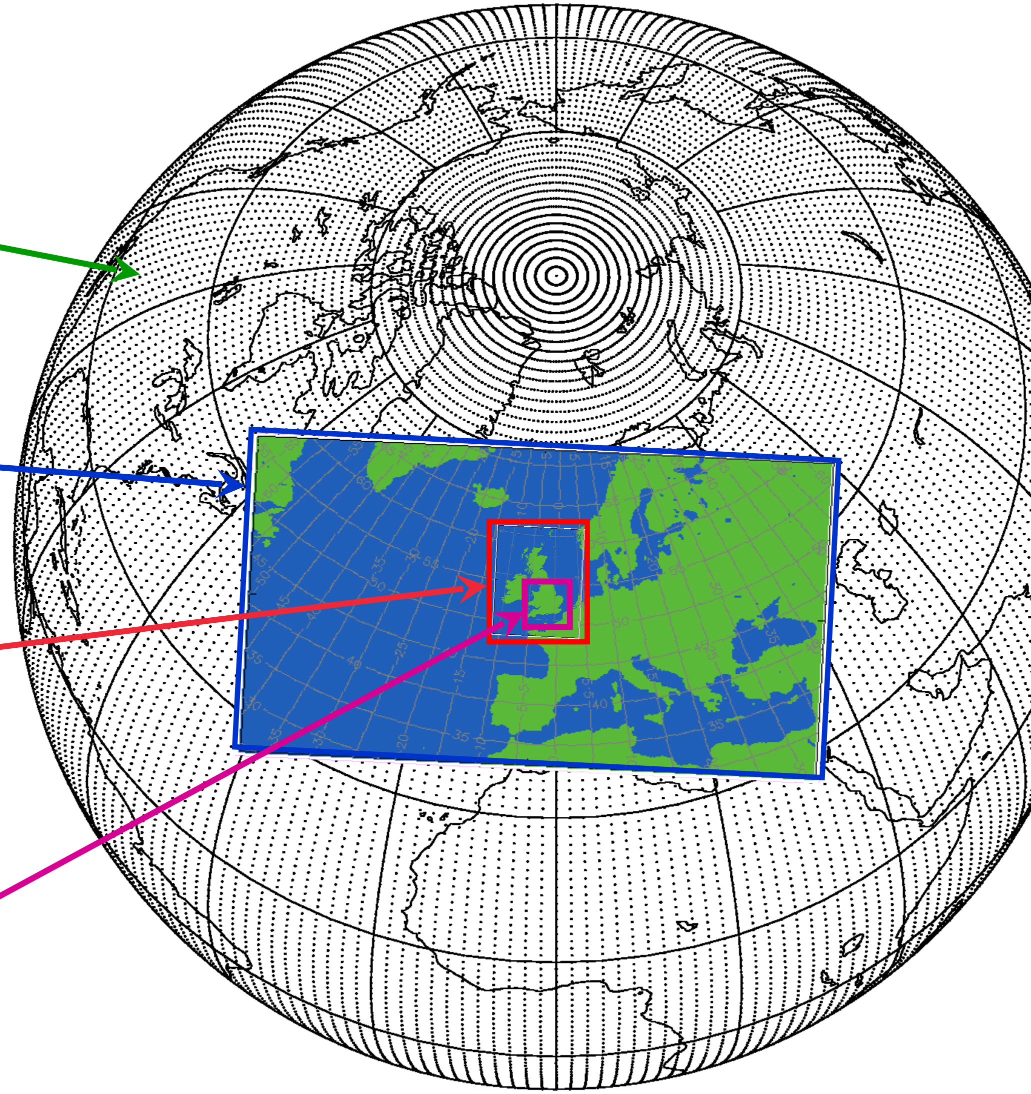
- 4/1.5-km 70 L (40-km top)
- 3DVAR
- 36 hour forecast - 4 times per day

NDP (Nowcasting Demonstration Project)

- In development for London's 2012 Olympics
- 1.5-km 70 L (40-km top)
- 4DVAR (3-km inner loop)
- 10 hour forecast - 24 times per day

Met Office Global and Regional EPS

Met Office



MOGREPS-G

- 24 member ETKF – 60 km
- 72 hour forecasts - 2 times per day (00/12Z)
- 15 day forecasts run @ ECMWF

MOGREPS-R (EU)

- Downscaled forecast pert. from global
- 24 member - 18-km
- 60 hour forecast - 2 times per day

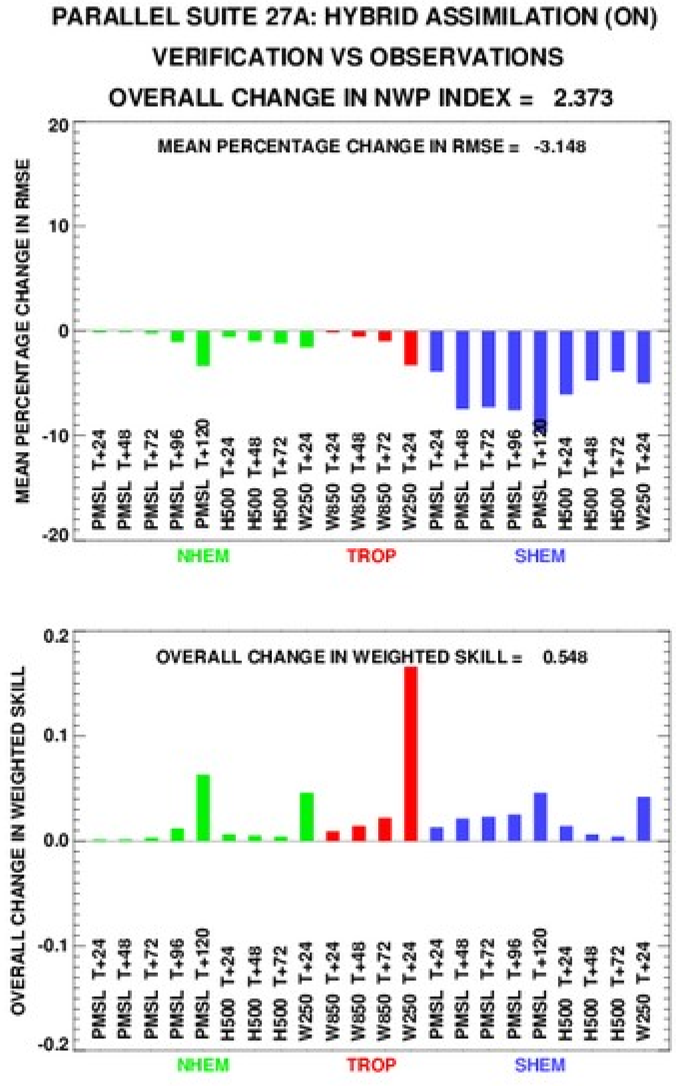
MOGREPS-UK

- In development – For 2012
- Downscaling of MOGREPS-R
- 12 member - 2.2-km
- 36 hour forecast - 4 times per day

1.5-km ETKF

- Research only
- 24 member ETKF - 1.5-km
- 1 hour forecast - 24 times per day

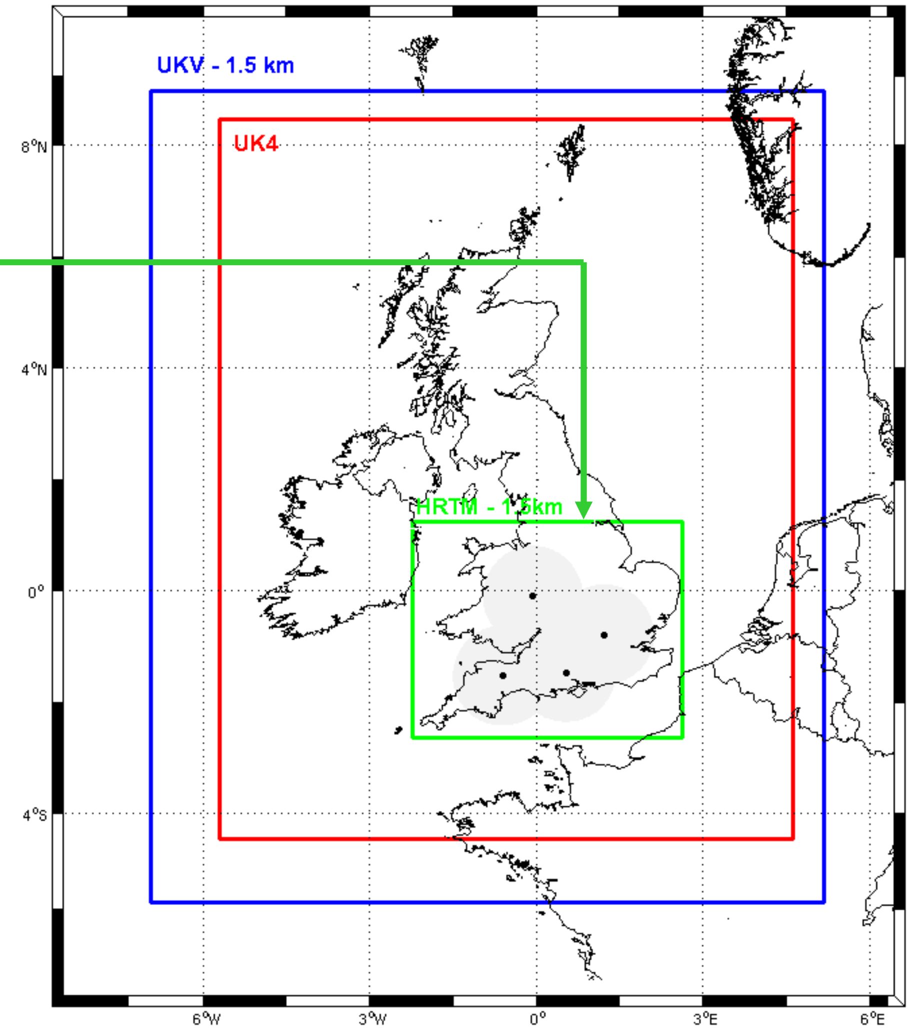
4DVAR hybride Global



Background error covariances for the nowcasting demonstration project

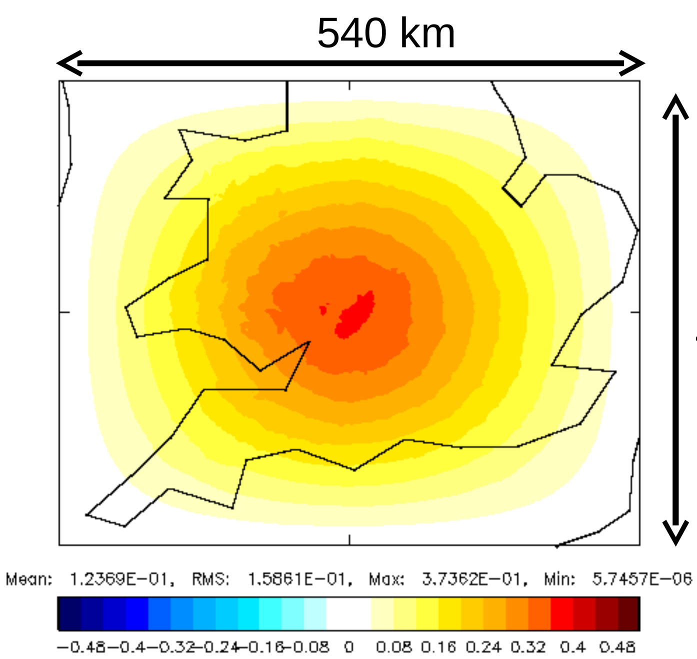
Nowcasting Demonstration Project

- 1.5 km NWP-based nowcasting system
- Southern UK only
- 4DVAR with Doppler winds
- Hourly cycling
- ~12 hour forecasts
- To be run in experimental mode during London's 2012 summer Olympics
- So far, all trials were made using UKV background error covariances



The elephant in the room

Response to the assimilation of a pseudo temperature at level 20 (~850 hPa)



theta at level 20 (~850 hPa)

Training data

- A set of 74 NMC 24h-12h (using same LBC) from UK4 model

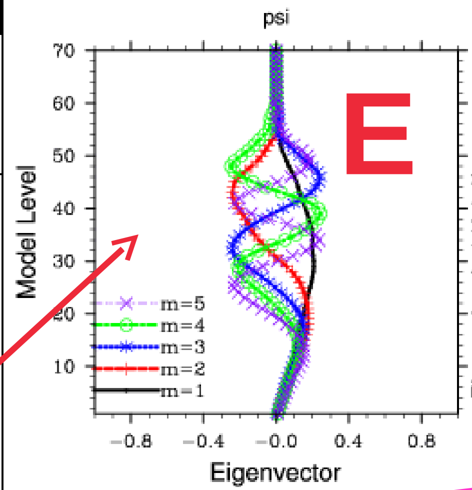
LAM covariance model

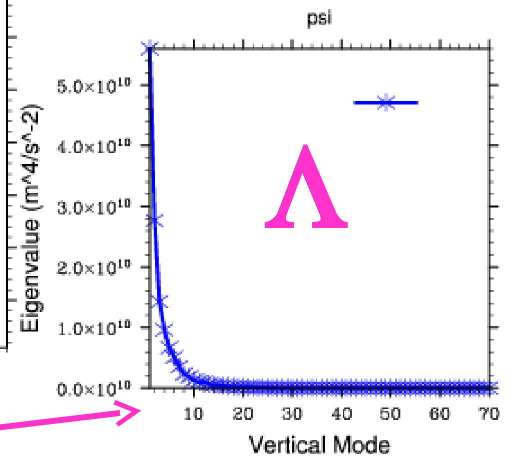
- Horizontal correlation modelled using adhoc lengthscales.
- Control variables : Same as in global and NAE
- Temperature increments obtained from P increments assuming hydrostatic balance
- No Ekman pumping, no coupling with humitidy, no coupling between latent heating and w …

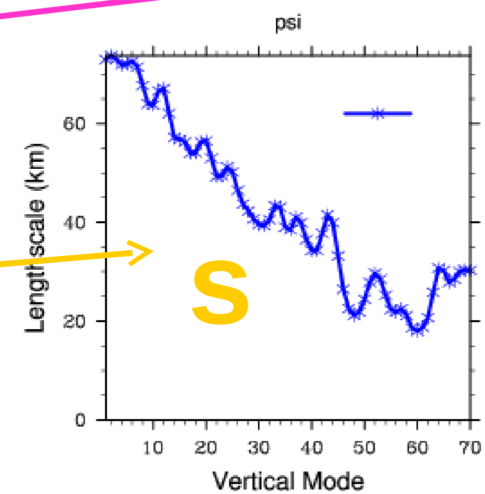
MetO VAR-LAM covariance model

Steps from model variable space to covariance model space

1	$\mathbf{x}'$	$u', v', \theta', \rho', p', q'$
2	Parameter transform $\mathbf{v}_p = \mathbf{T}_p \mathbf{x}'$	ψ', χ', p_u', r' $p_u' = p_h' - \mathbf{N} f(\psi')$ $\mathbf{N} = \langle f(\psi'), p_h' \rangle \langle p_h', p_h' \rangle^{-1}$
3	Vertical transform $\mathbf{T}_v$	auto covariances only $\mathbf{B}_v(i,j) = \mathbf{E} \Lambda \mathbf{E}^T$ $\mathbf{v}_p(i,j,k) \rightarrow \mathbf{v}_v(i,j,m)$
4	Horizontal transform $\mathbf{T}_h$	$\mathbf{B}_h(r) = \mathbf{B}_h(0)\left(1+\frac{r}{s}\right)e^{r/s}$





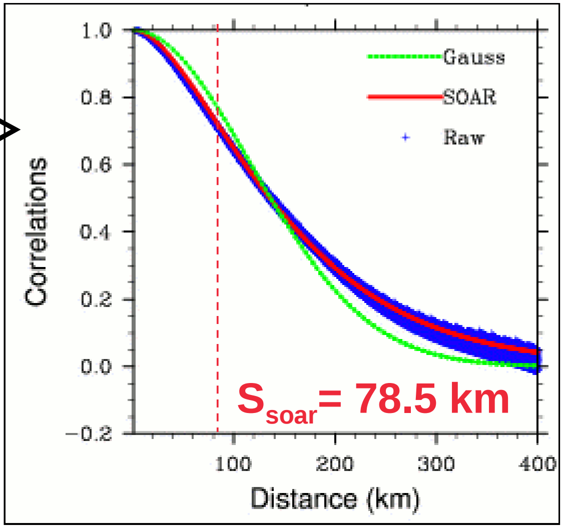


Gen_BE at the Met Office

(J.-F. Caron and Dale Barker)

Gen_BE is WRF's utility to compute background error covariances

- Clean and flexible conception: easy to test ideas
- Horizontal length scale in vertical mode space can be evaluated objectively.
- WRF covariance model similar to the UK MetO VAR (e.g. vertical transform first)
- Already a multi-model tool: used by NCAR (WRF) and KMA.



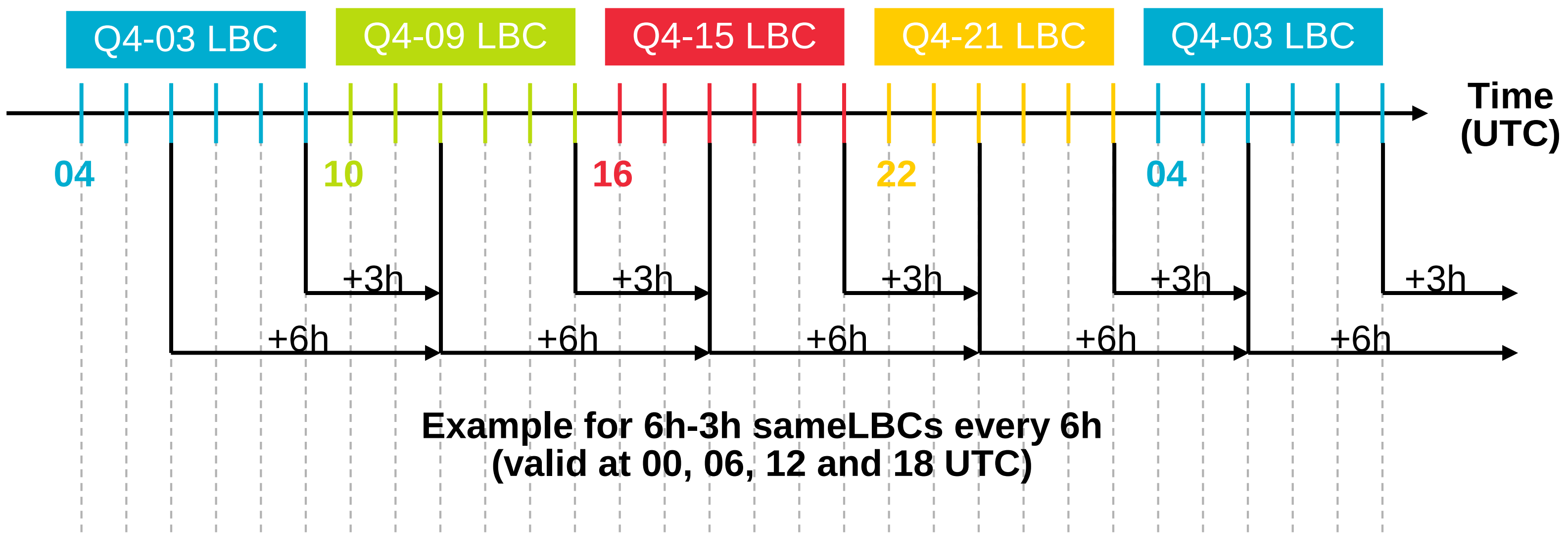
Objective #1: Adapt Gen_BE to provide the appropriate input to the actual VAR's covariance model in limited area mode (completed)

Objective #2: Use Gen_BE to conduct examinations of B at the convective scale (in progress)

Training data for the NDP

NMC method

- From a three week cycle of the hourly SUK 1.5km (16/03/10 to 06/04/10) in 3DVAR mode using the UKV Covstats
- Outputs from +1h to +6h, every 1h
- Possibility to compute lagged forecast differences with forecasts having the same LBCs or different LBCs



Example for 6h-3h sameLBCs every 6h (valid at 00, 06, 12 and 18 UTC)

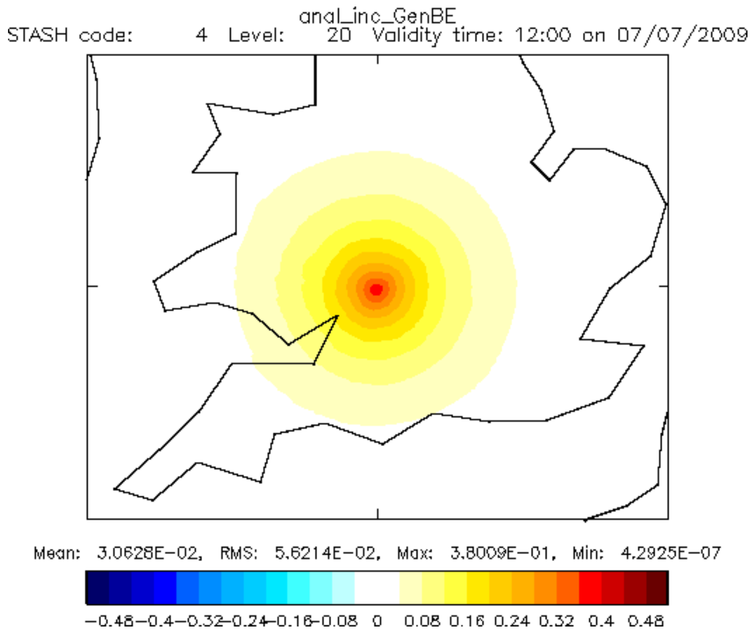
Single pseudo-obs experiments

http://www-nwp/~frfc/work/hrtm/1obs/gen_be1.html

Response to the assimilation of a pseudo temperature at level 20 (~850 hPa)

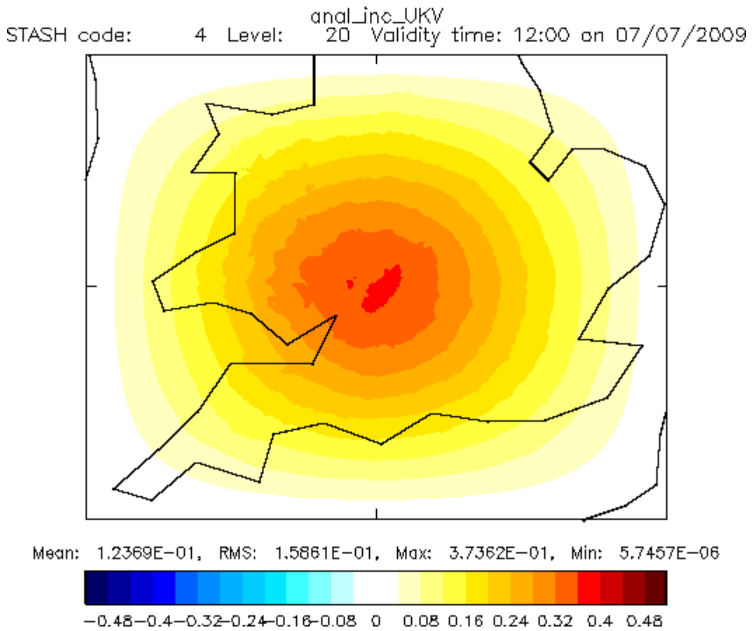
innovation = 2 K and observation error = 1 K

New CovStats



theta at level 20 (~850 hPa)

Old CovStats



theta at level 20 (~850 hPa)

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Response to the assimilation of a pseudo u-wind at level 20 (~850 hPa)

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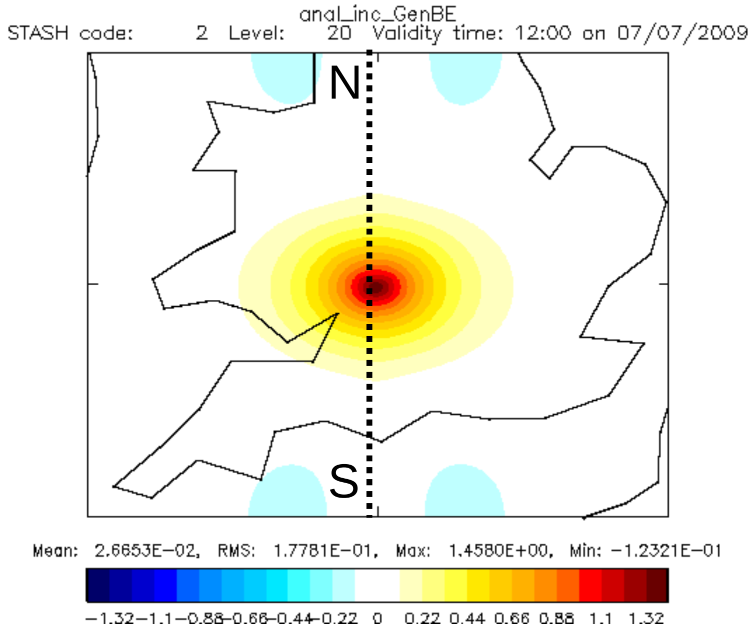
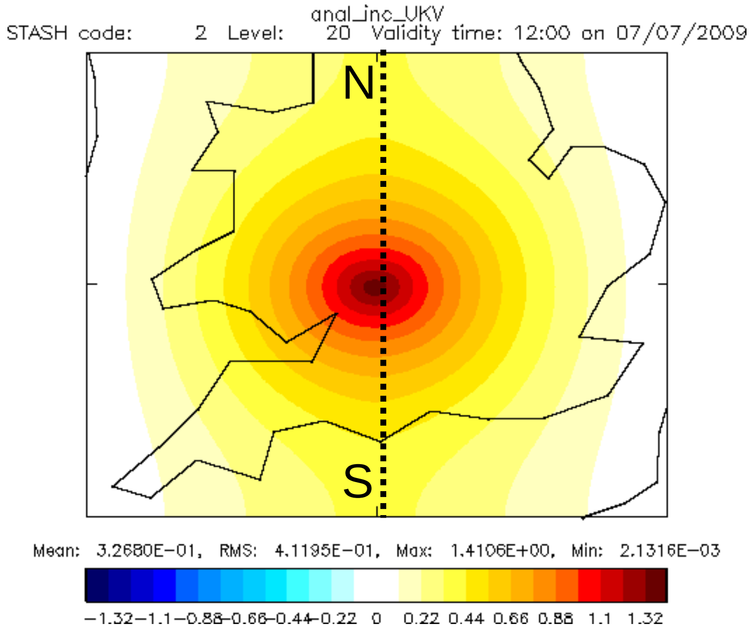


u-wind at level 20 (~850 hPa)

Old CovStats



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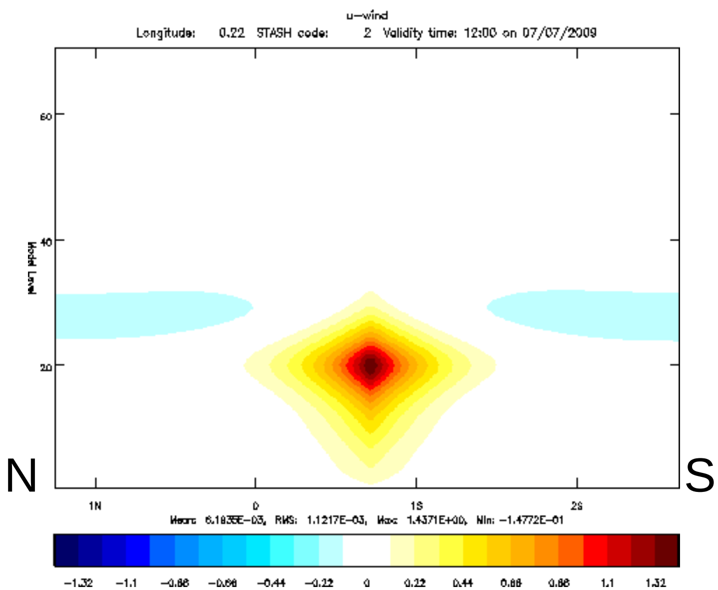
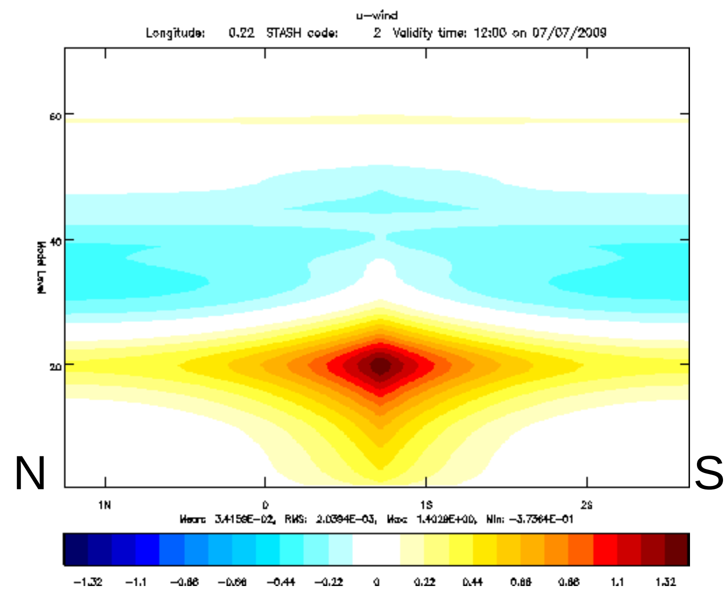


u-wind

Old CovStats



u-wind

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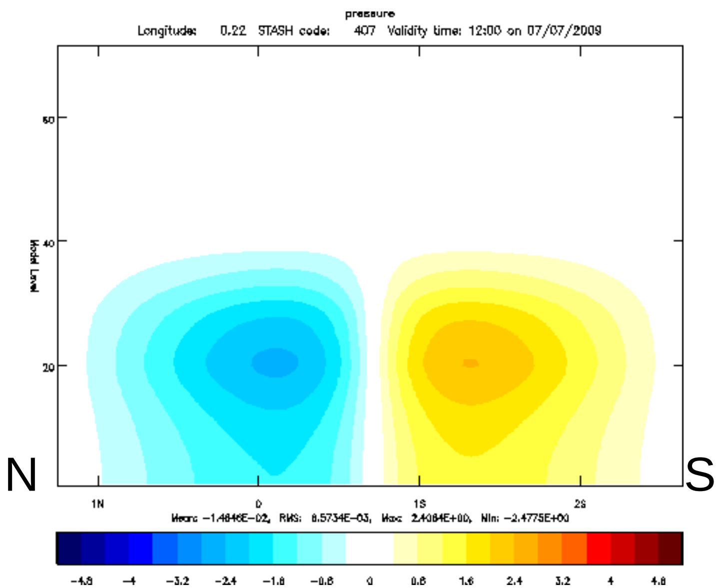
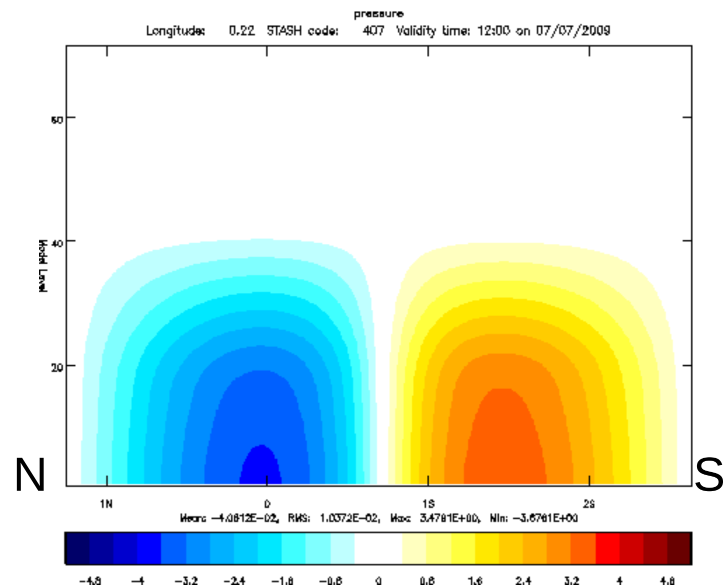


pressure

Old CovStats



pressure

Single pseudo-obs experiments

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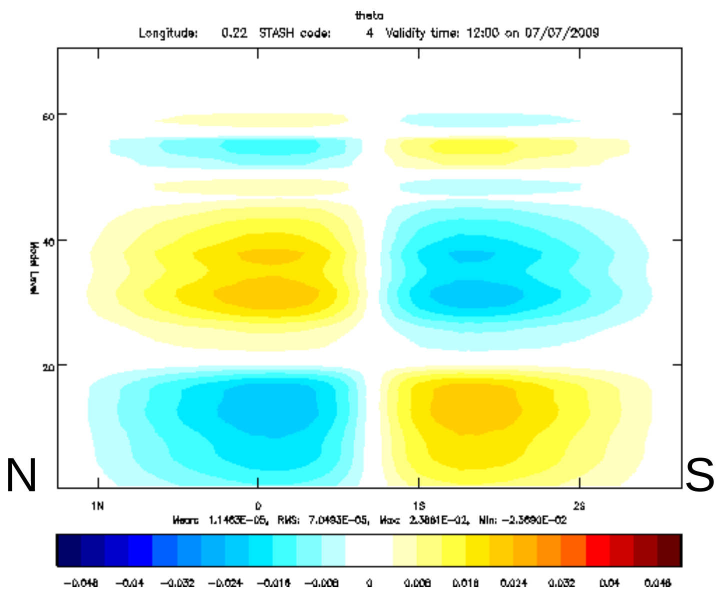
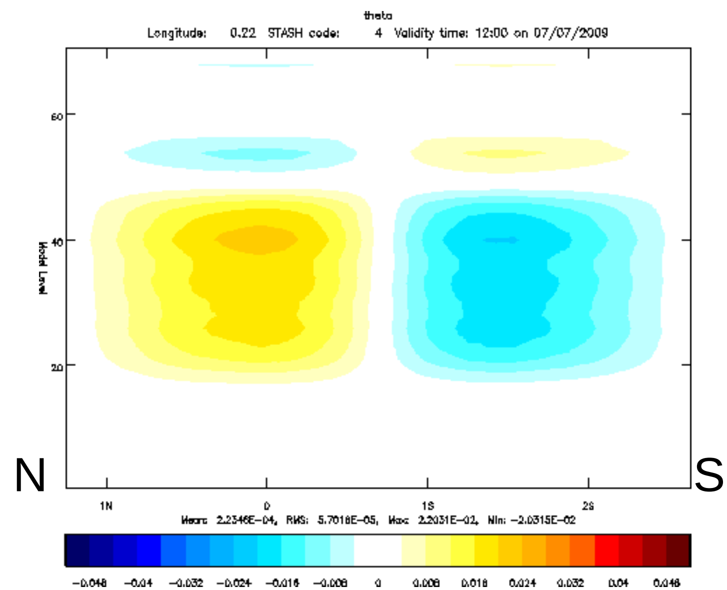


theta

Old CovStats

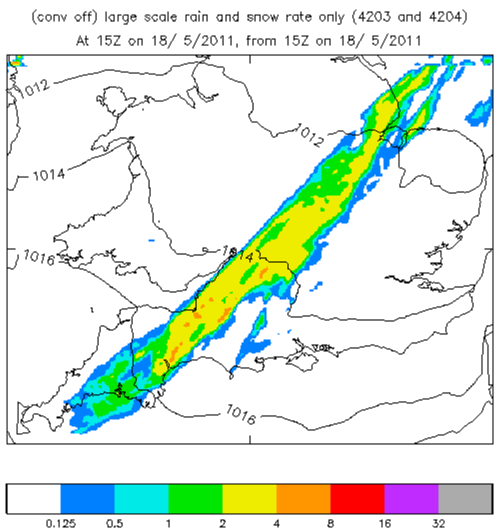


theta

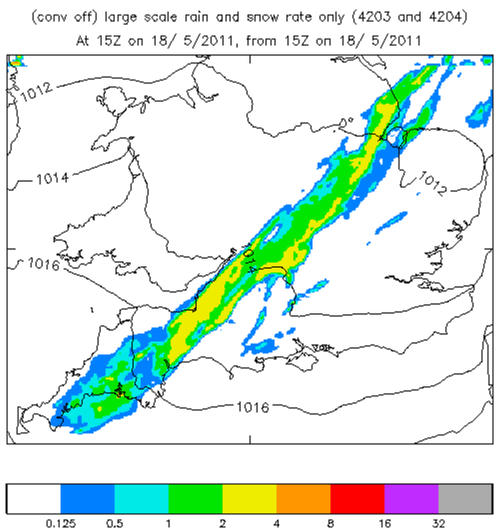
Forecast impact (from Zihong Li)

So far so good...

30-min forecasts from 4DVAR analyses

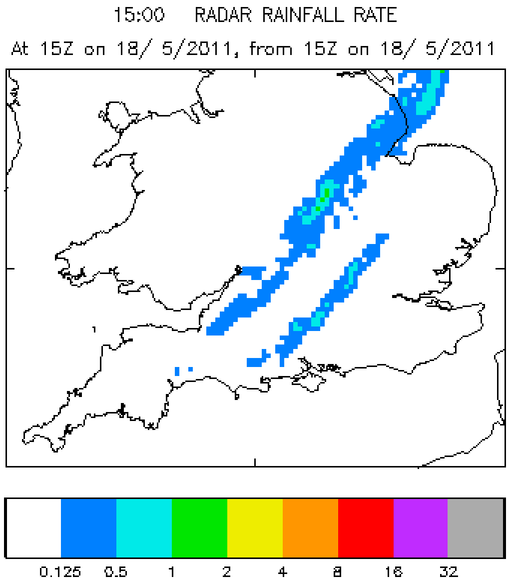


Old CovStats



New CovStats

Radar



Summary and future work

- Before: An elephant was in the room

  We were using inappropriate estimates of forecast errors in a covariance model developed for large scale DA using ad hoc horizontal length scales

- Now: An hippopotamus is in the room

  We are using more appropriate estimates of forecast errors in a covariance model developed for large scale DA using objective estimates of horizontal length scales

- Next

  Develop an appropriate covariance model for convective scale DA

Using Gen_BE to conduct examinations of B at the convective scale

B_{precip} vs. $B_{non\ precip}$

Intro

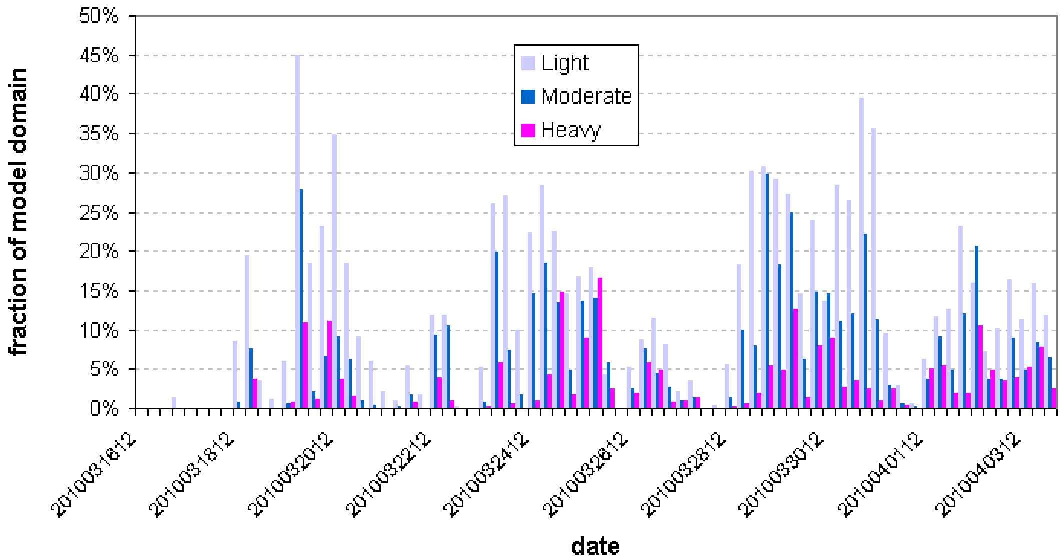
- Short-term precipitation forecast is the key objective in meso-γ scale forecasting & radar observations are the main component of the meso-γ scale observing system.
- Is **B** very different in precipitation areas ?
- How to take these differences into account in VAR without '**B** of the day' ?

Caron and Fillion, 2010	• (Linear) Balance decreases with precipitation intensity at synoptic and meso-β scales • Introduced the idea of deriving rain-dependent background error statistics. • Showed that statistical balance operators can be improved over precipitation areas by using only profiles from precipitation areas in training data.
Montmerle and Berre, 2010	• Compared $\mathbf{B}_{precip}$ vs $\mathbf{B}_{non\ precip}$ in summer convective regime at meso-γ scale and showed significant differences • Implemented rain-dependent **B** formulation in AROME 3DVAR
Michel et al, 2011 (in press)	• $\mathbf{B}_{precip\ +\ hydrometeors}$
Ménétrier and Montmerle, 2011 (submitted)	• $\mathbf{B}_{fog}$

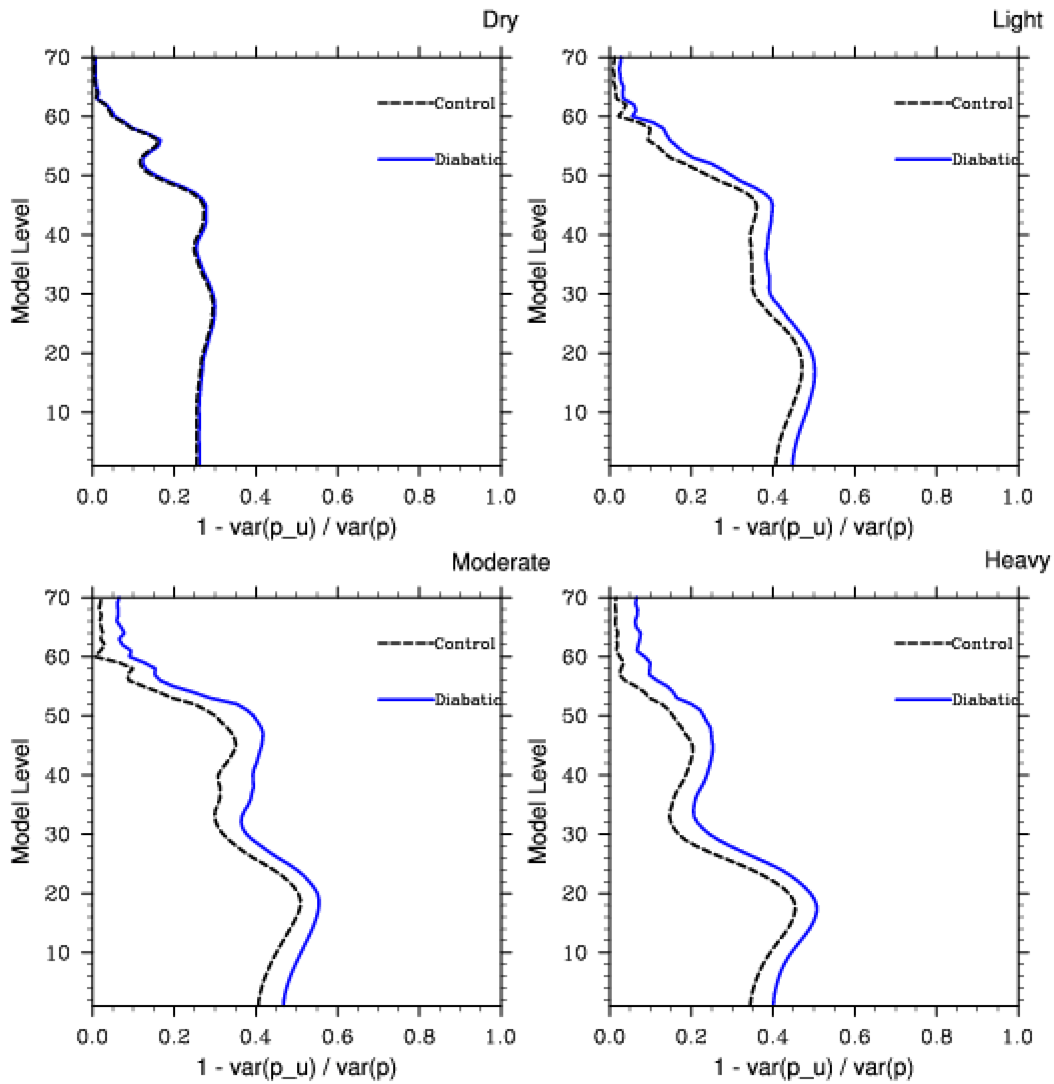
Definition of precipitations areas

Category	$P_M = \text{Max}(P_{6h}, P_{3h})$ (mm/h)	Fraction of **total** points (%)	Fraction of **precip** points (%)
Dry	$P_M < 0.1$	77.9	—
Light	$0.1 \leq P_M < 1.0$	12.6	56.9
Moderate	$1.0 \leq P_M < 2.75$	6.6	29.8
Heavy	$2.75 \leq P_M$	2.9	13.3

Time-series of precip categories in (NMC) training data



B_{precip} vs $B_{non-precip}$



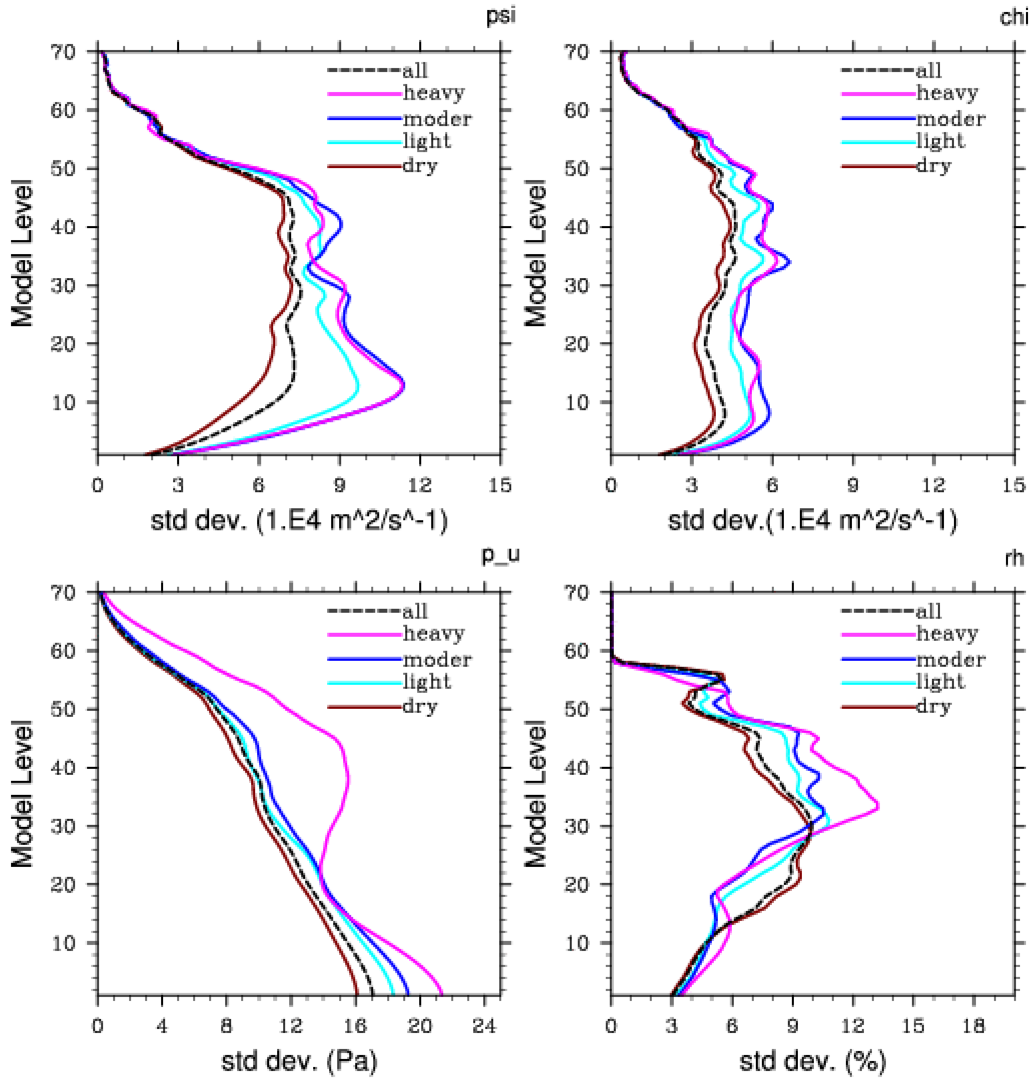
Explained pressure variance by the statistical balance operators

≅

Met Office

B_{precip} vs $B_{non\text{-}precip}$

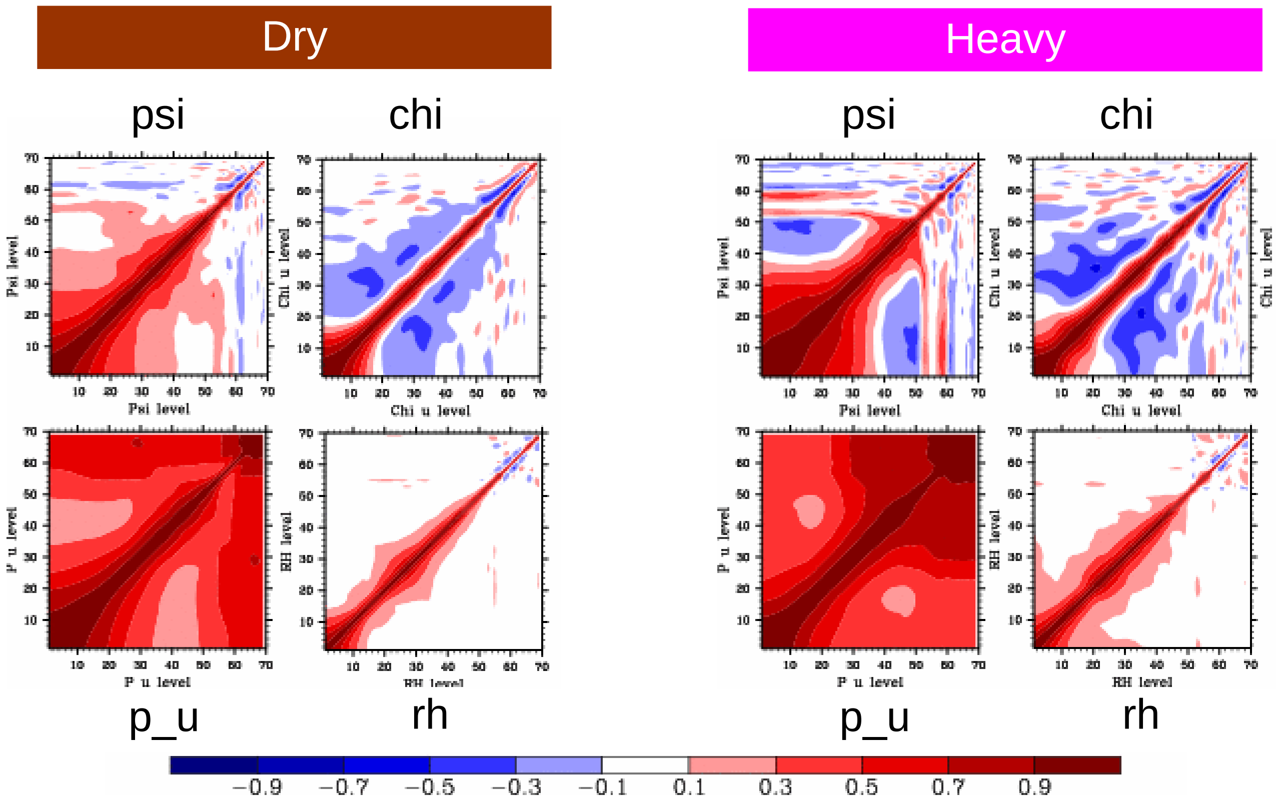
Standard deviation profiles



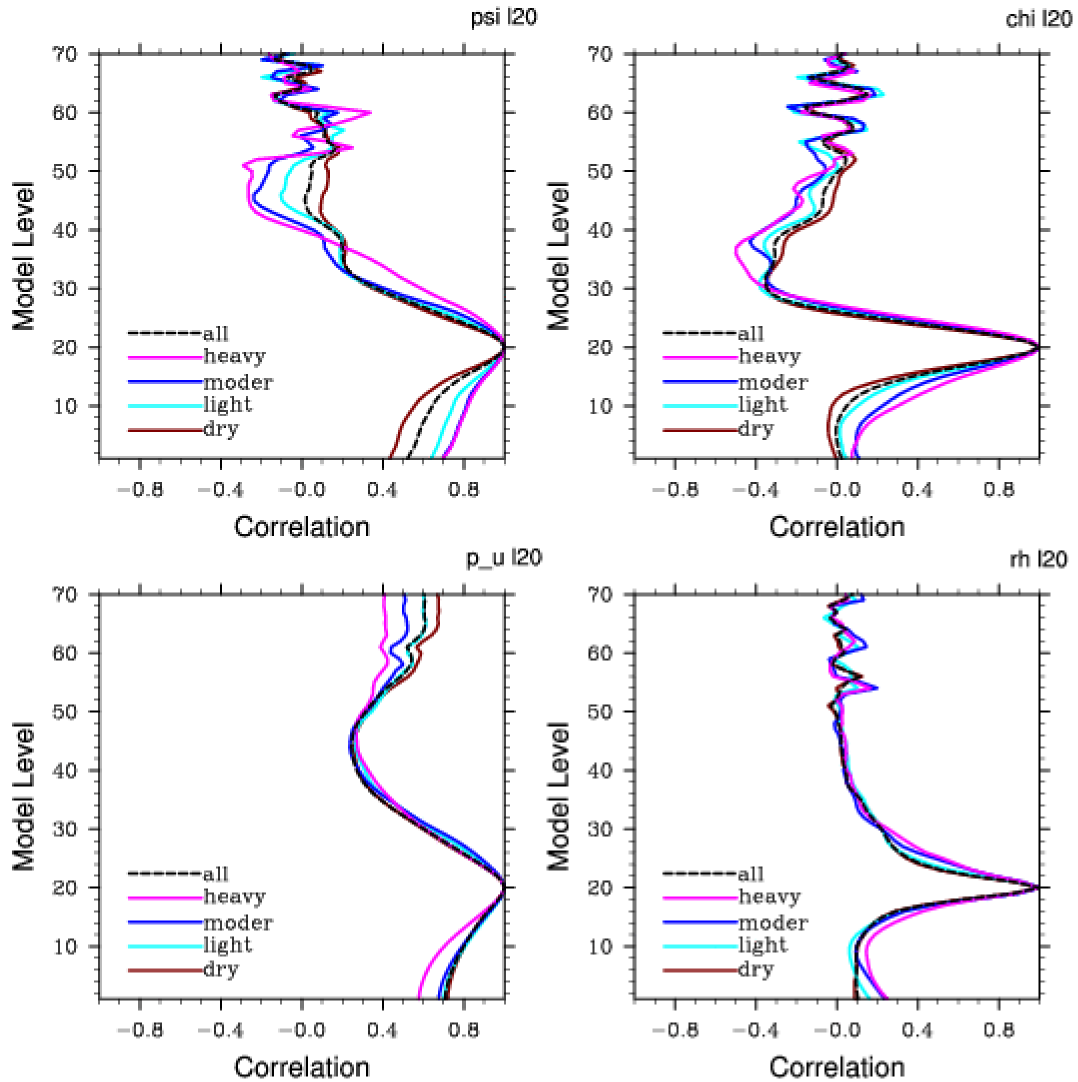
≅

B_{precip} vs $B_{non\text{-}precip}$

Vertical correlation matrices

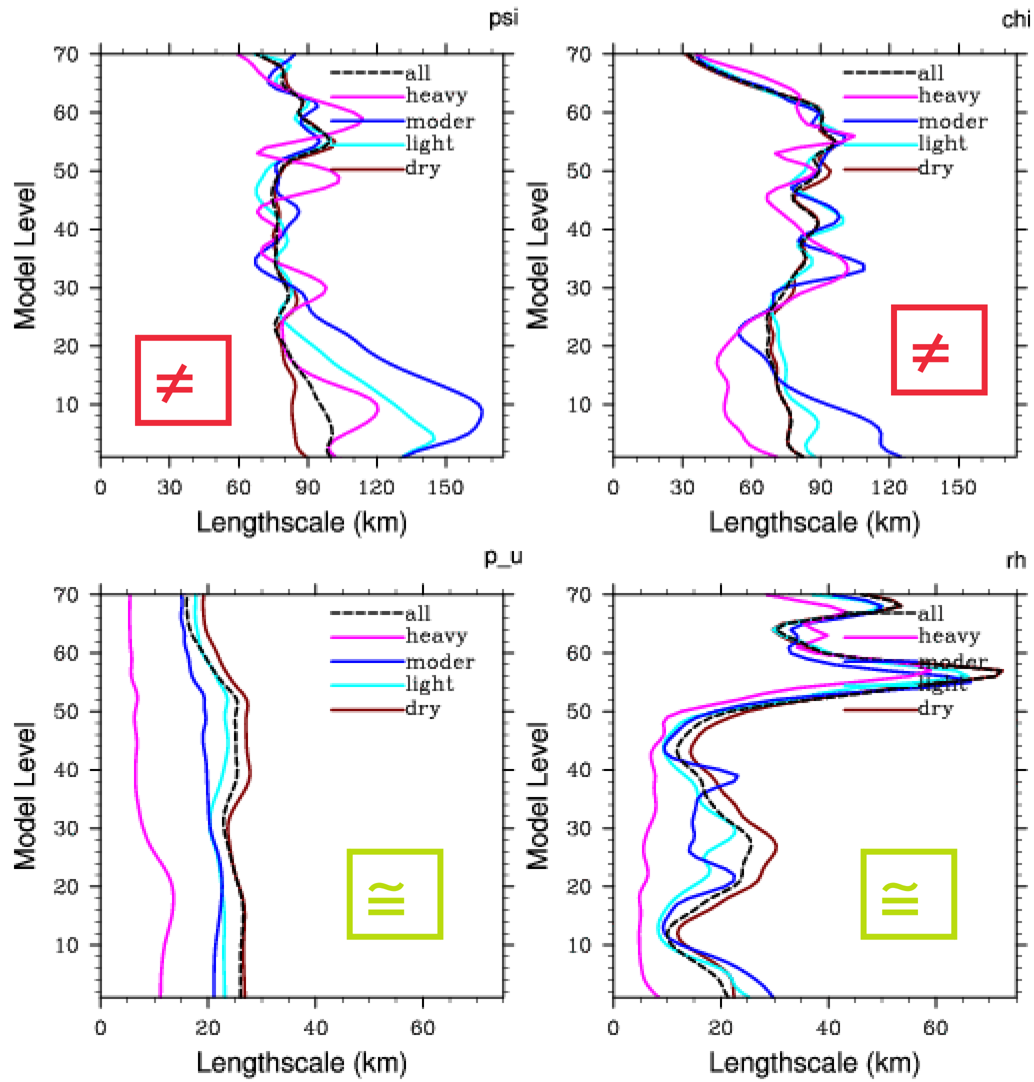


B_{precip} vs $B_{non\text{-}precip}$



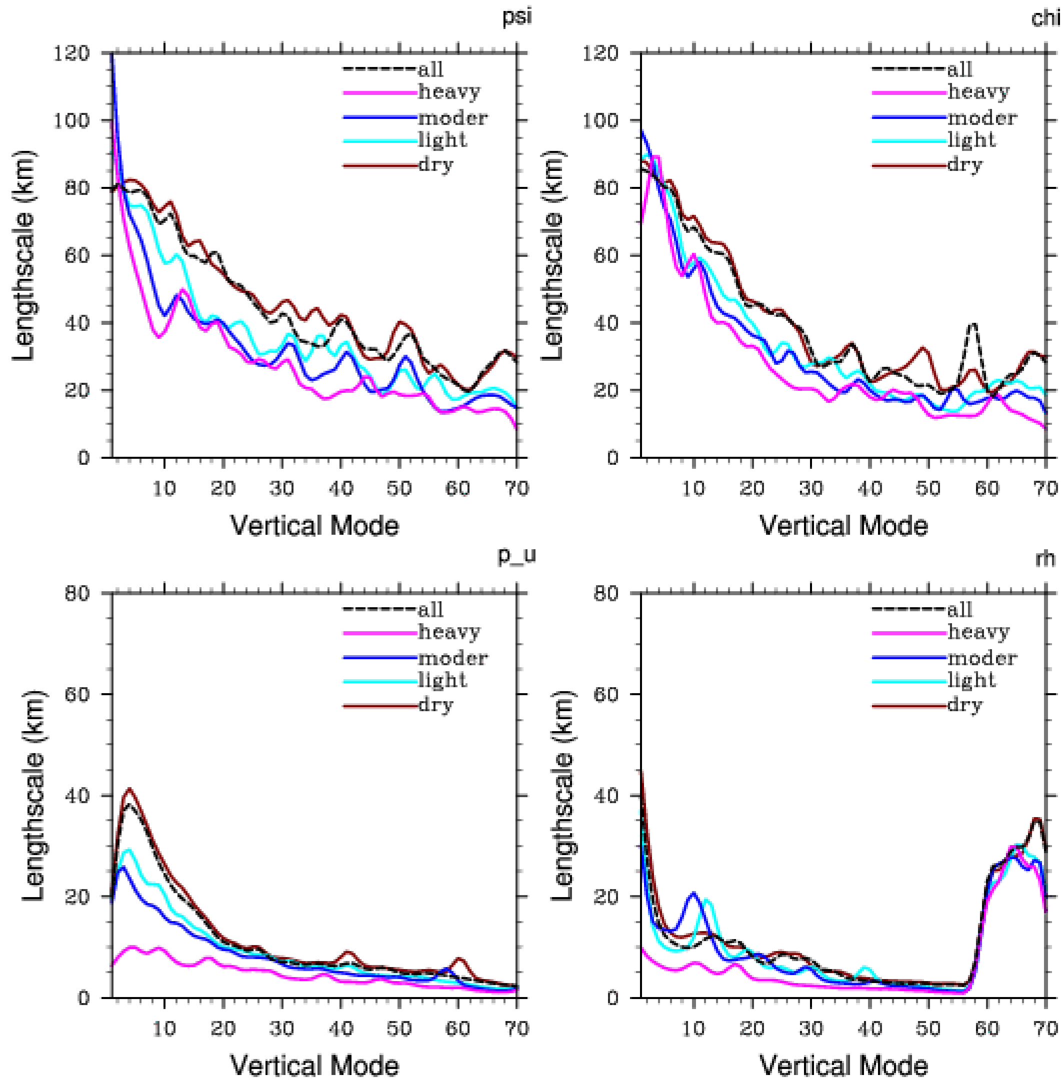
Vertical correlations with level 20 (~1.5 km)

B_{precip} vs $B_{non\text{-}precip}$



SOAR horizontal length scales on **model levels**

B_{precip} vs $B_{non\text{-}precip}$

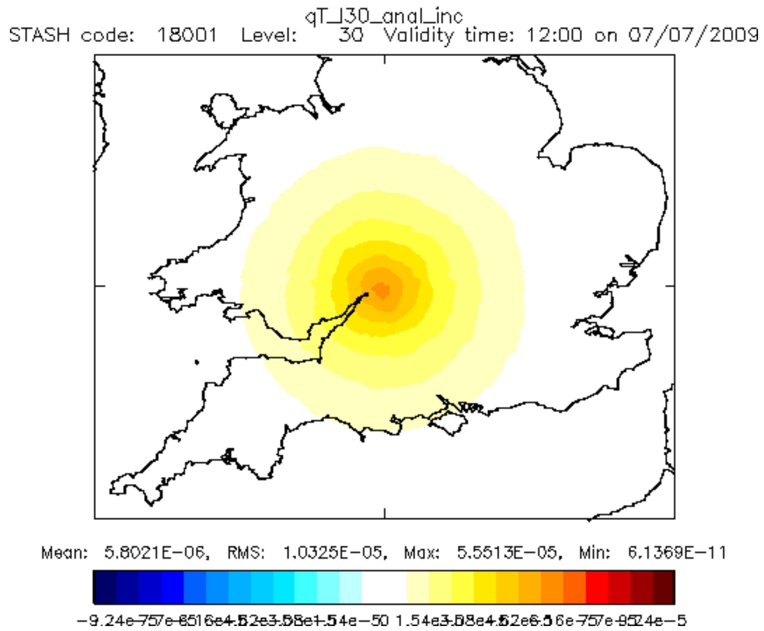


SOAR horizontal length scales in **vertical mode space**

Single pseudo-obs experiments

Response to the assimilation of a pseudo Humidity (q) at level 30 (~700 hPa)

B_dry

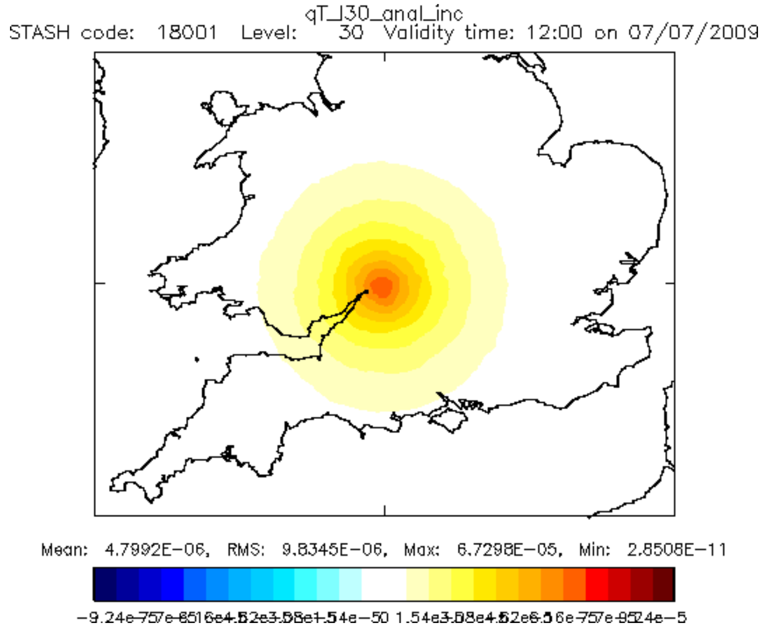


q at level 30 (~700 hPa)

Single pseudo-obs experiments

Response to the assimilation of a pseudo Humidity (q) at level 30 (~700 hPa)

B_light

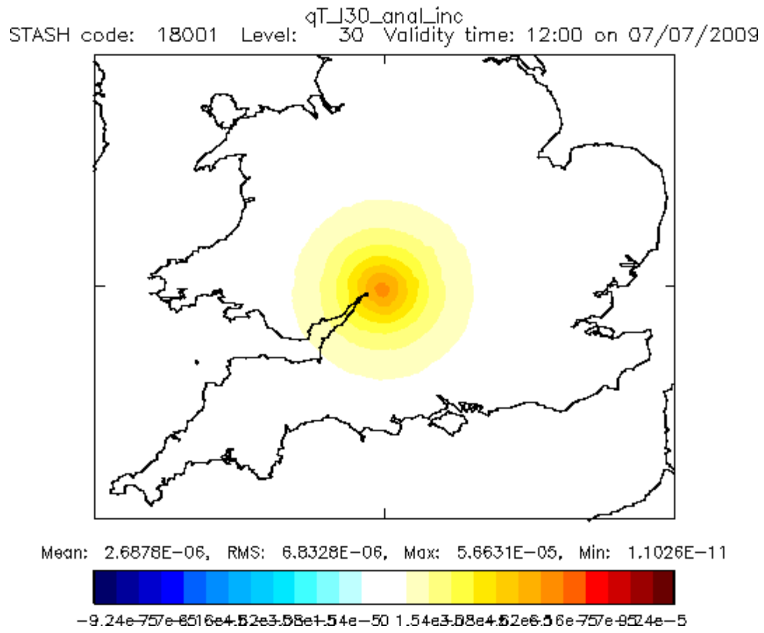


q at level 30 (~700 hPa)

Single pseudo-obs experiments

Response to the assimilation of a pseudo Humidity (q) at level 30 (~700 hPa)

B_moderate

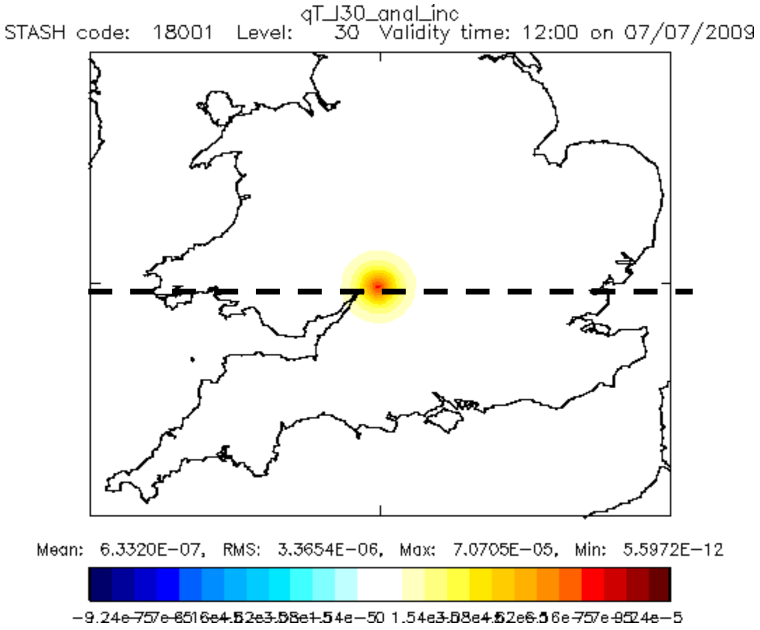


q at level 30 (~700 hPa)

Single pseudo-obs experiments

Response to the assimilation of a pseudo Humidity (q) at level 30 (~700 hPa)

B_heavy

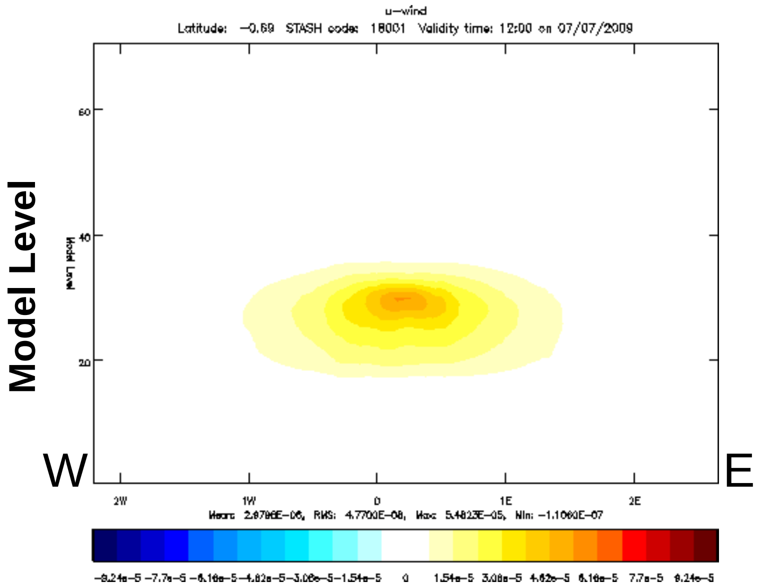


q at level 30 (~700 hPa)

Single pseudo-obs experiments

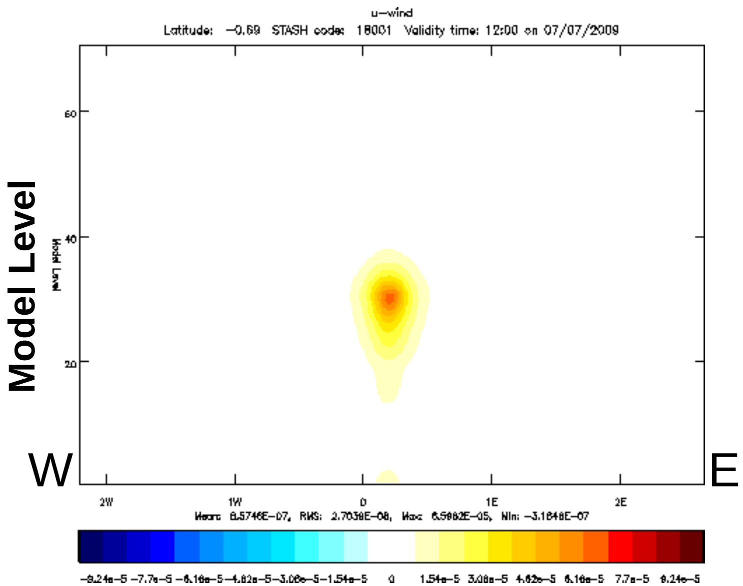
Response to the assimilation of a pseudo Humidity (q) at level 30 (~700 hPa)

B_dry



q

B_heavy



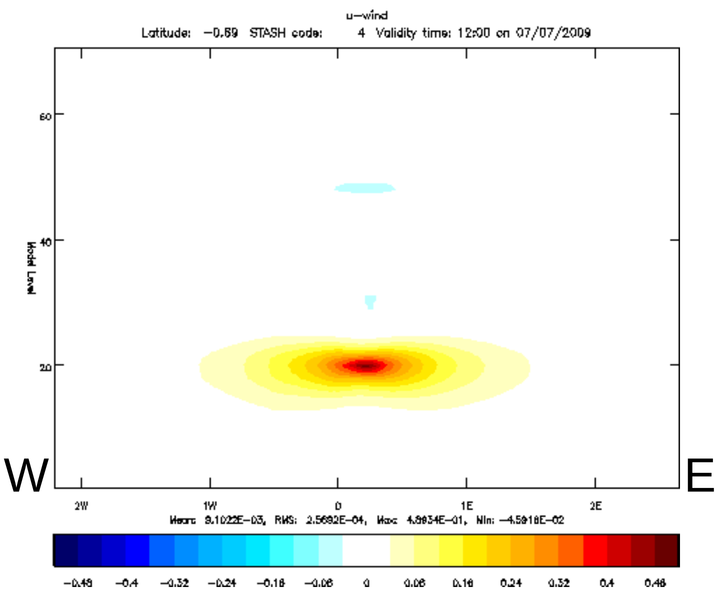
q

Single pseudo-obs experiments

Response to the assimilation of a pseudo Temperature at level 20 (~850 hPa)

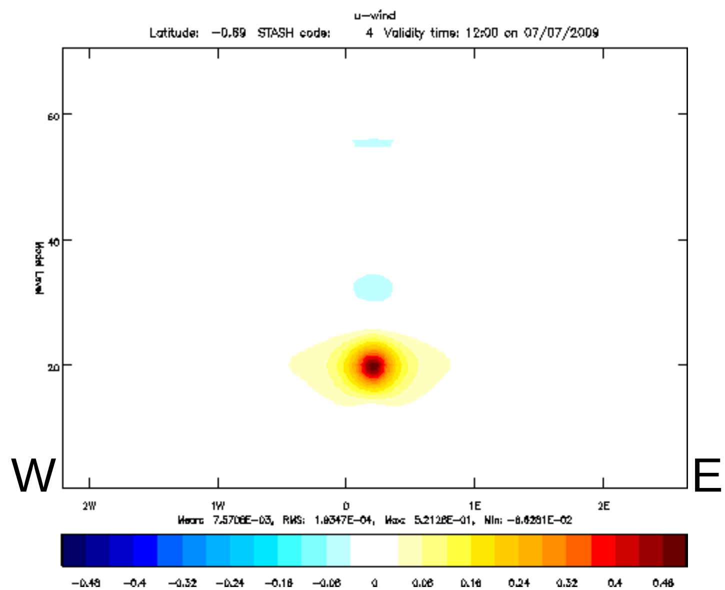
innovation = 2 K and observation error = 1 K

B_dry



Potential temperature

B_heavy



Potential temperature

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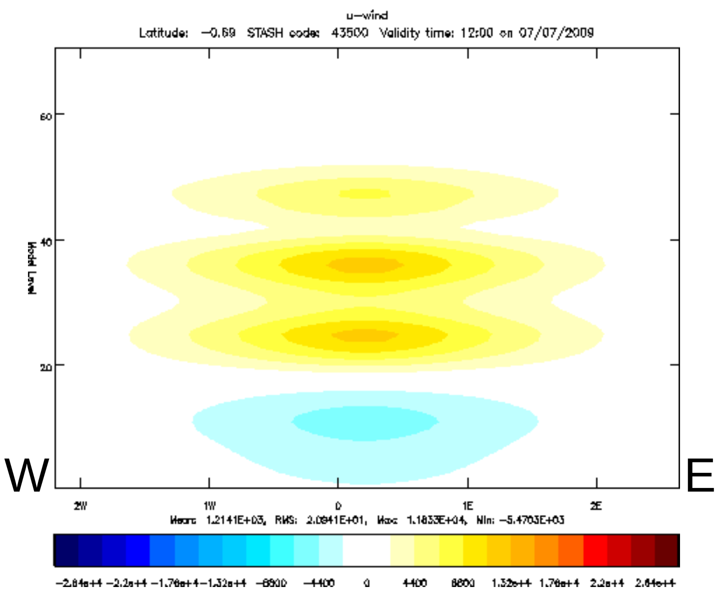
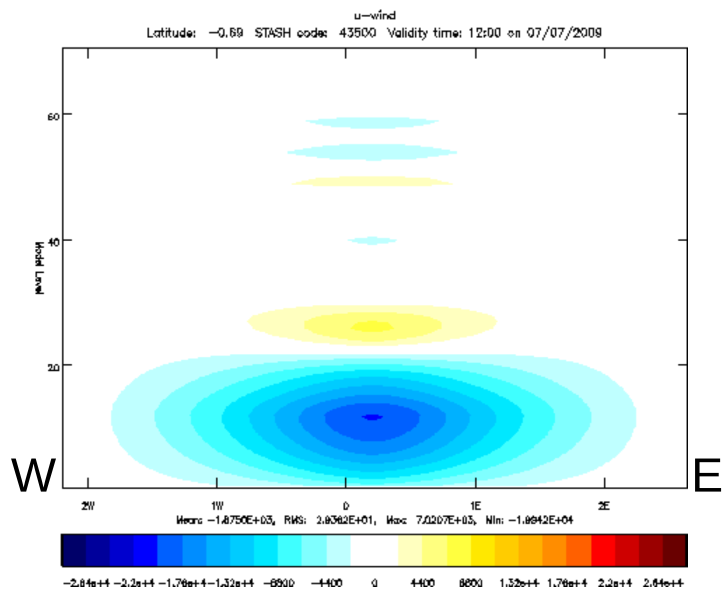


Stream function (ψ)

B_heavy



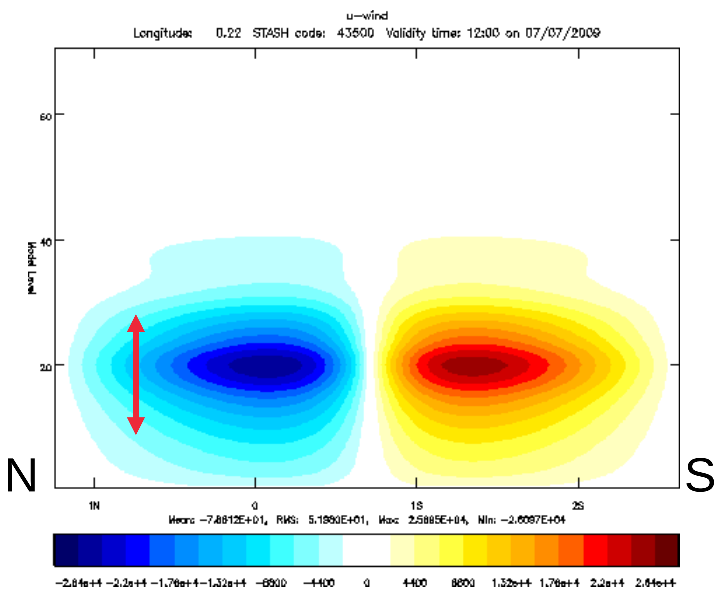
Stream function (ψ)

Single pseudo-obs experiments

Response to the assimilation of a pseudo u-wind at level 20 (~850 hPa)

innovation = 2 m/s and observation error = 1 m/s

B_dry



Stream function (ψ)

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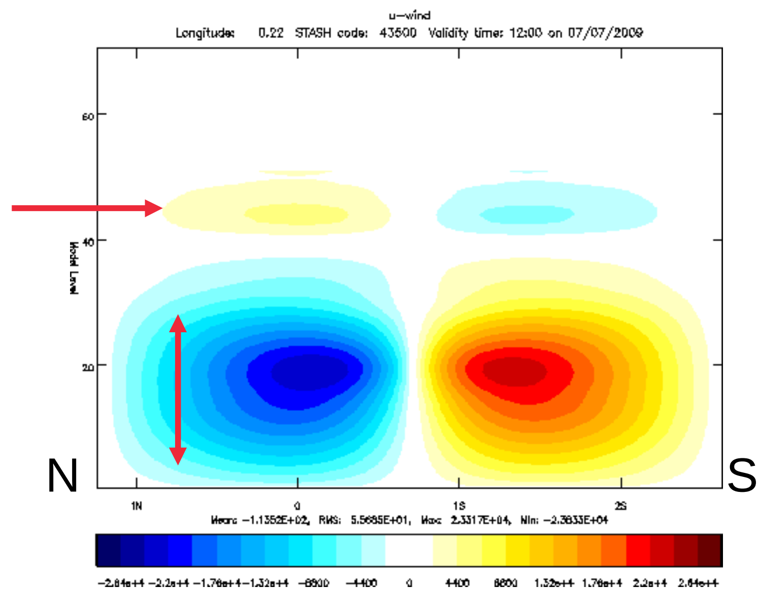

Stream function (ψ)

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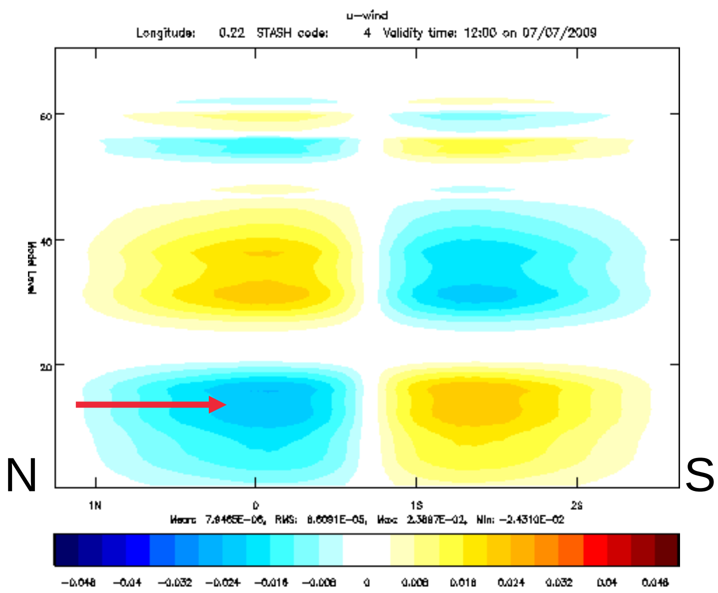
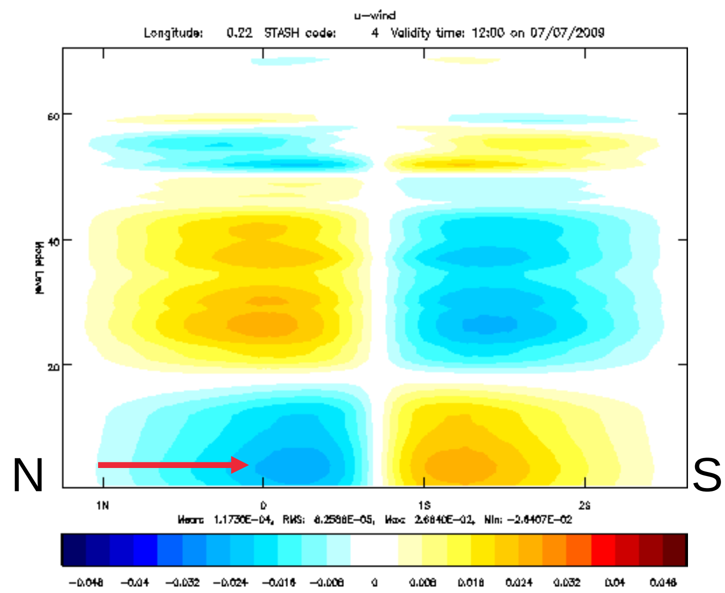


Potential temperature

B_heavy



Potential temperature

Summary and future work

- Statistical balance operators can also be improved over precipitation areas at meso-γ scale by using only precipitation profiles in training data.
- Background error covariance exhibit significant differences in precipitation areas compared to dry areas, most differences are proportional with precipitation intensity.

  In precipitation areas, we found that…

  - Variances are increased.
  - Vertical correlations are either broader or similar.
  - Horizontal length scales for mass fields are smaller. For wind fields: unexpected larger correlations in the low levels.

- Next Steps

  - Test different control variables (e.g. vorticity, divergence).
  - Investigate cross-covariances (e.g. humidity and divergence).
  - Implement B_{precip} approach in a 1DVAR for the retrieval of T and q from radar reflectivities.

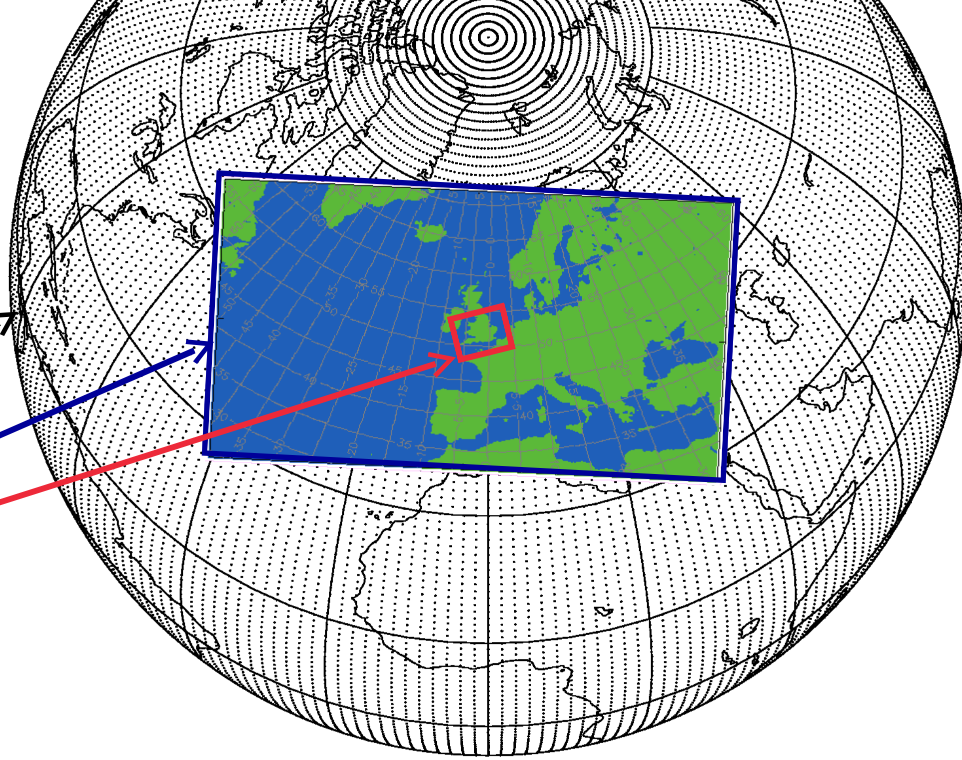
How to optimally treat large scale information in limited area EnDA/EPS ?

Thanks to: Neill Bowler, Mike Cullen, Stefano Migliorini, Sue Ballard and many others…

Met Office

Introduction

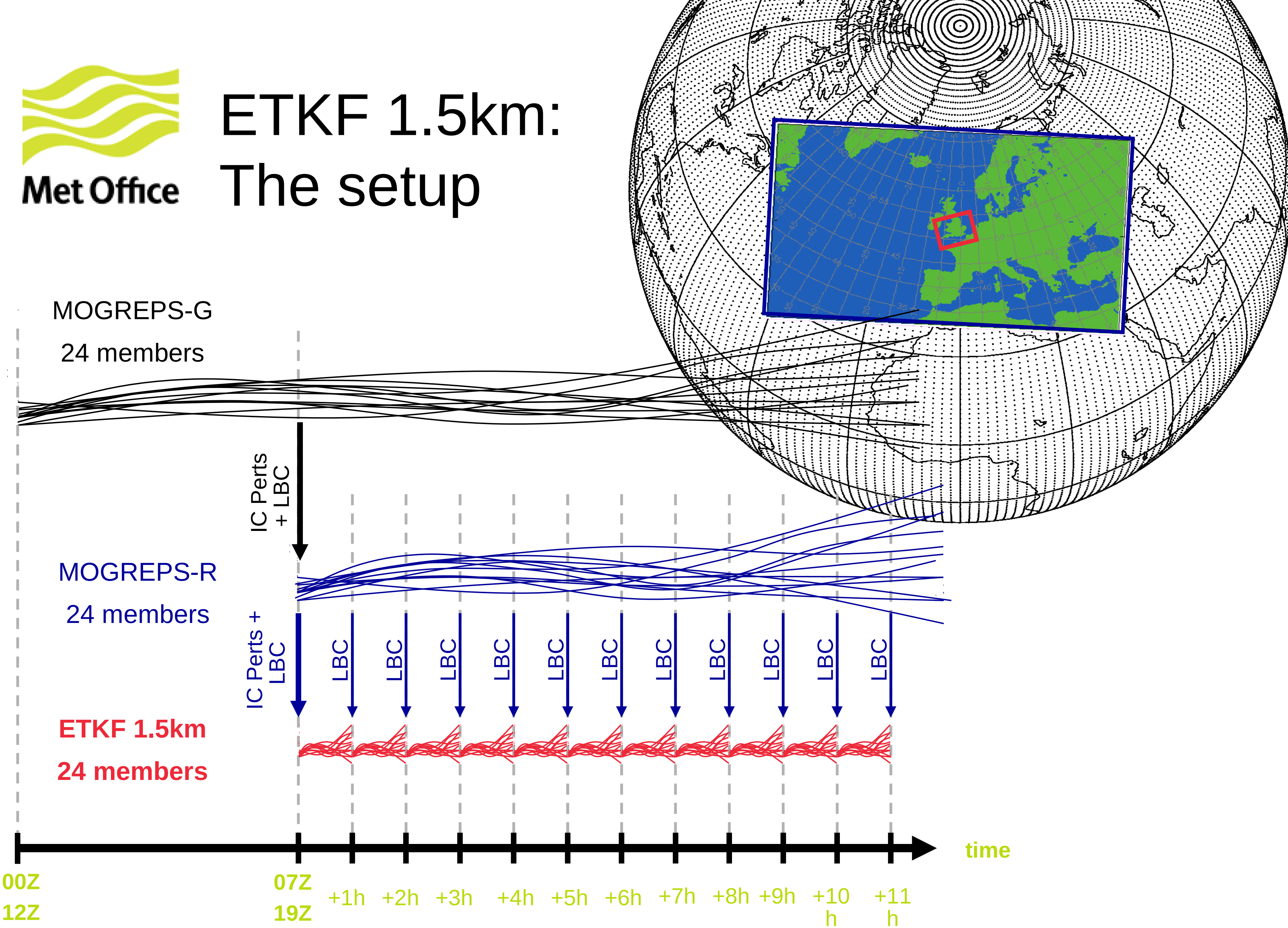
- MOGREPS-G (60 km) - operational
- MOGREPS-R (18 km) - operational
- SUK ETKF (1.5 km) - research



Purpose of this convective-permitting EPS

- Examine 1-h forecast error covariances for the benefit of a NWP-based nowcasting system in development (Bannister et al., 2011,Tellus)
- Predictability studies of very short-term weather events (Migliorini et al., 2011, Tellus)
- Test hybrid VAR DA at convective scale

ETKF 1.5km: The setup



ETKF ???

niveau de complexité

N prévisions + obs + erreurs d'obs

EnKF

N analyses

(Analyse moyenne + N perturbations d'analyse)

N prévisions + position & erreurs des obs

ETKF

N perturbations d'analyse

$$\mathbf{X}'_a = \mathbf{X}'_f \mathbf{T}$$

T : Combine (linéairement) les perturbations et réduit l'amplitude en fonction de la position des obs et de leurs erreurs

N prévisions

Breeding

N perturbations d'analyse

$$\mathbf{X}'_a = c\mathbf{X}'_f$$

$c \leq 1$: Peut varier à l'horizontale. Constant à la verticale et pour toutes les variables

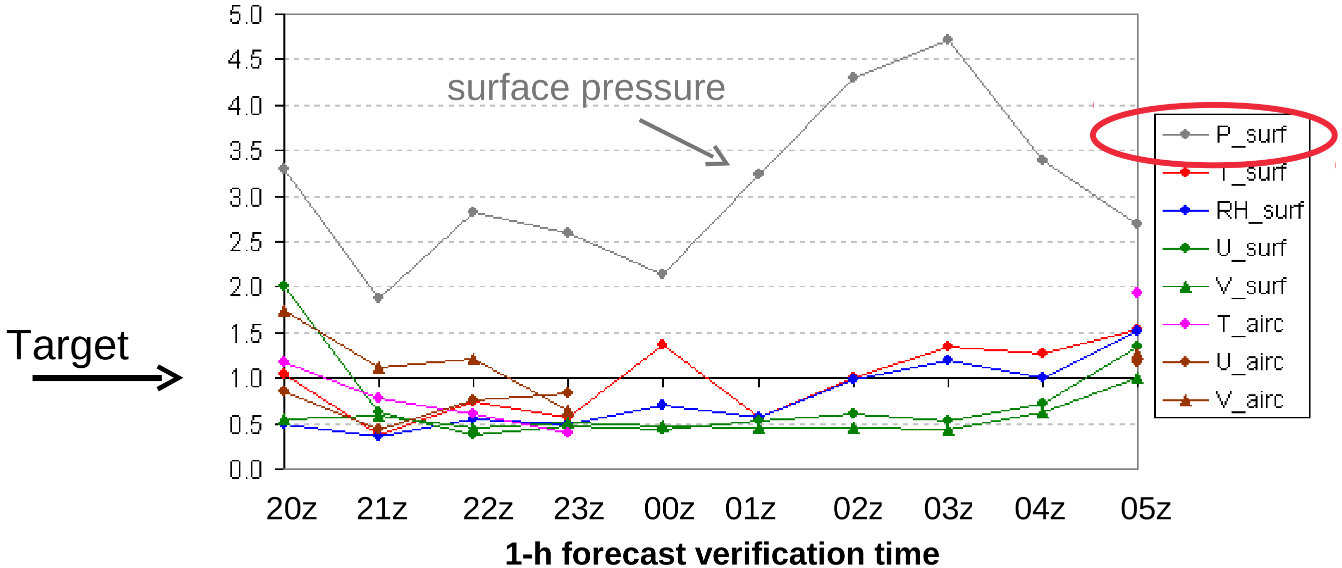
ETKF et Breeeding dépendent d'un système d'assimilation pour générer l'analyse de controle (l'analyse qui sera perturbée par les N jeux de perturbations)

ETKF 1.5km

Performance assessments

- 3 case studies so far (each case = 11 consecutive 1-h cycle of 1-h forecast only)
- Give satisfactory results except for surface pressure

Ratio: RMSS / RMSE (obs errors removed from MSE)

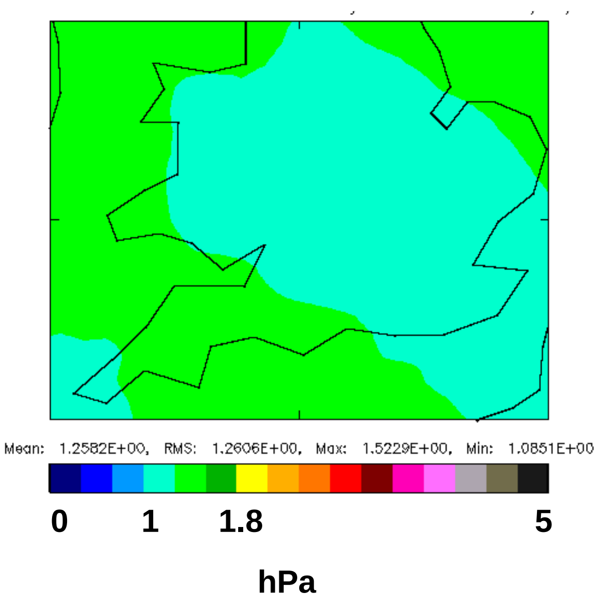


from 20Z 04 Dec to 05Z 05 Dec 2009

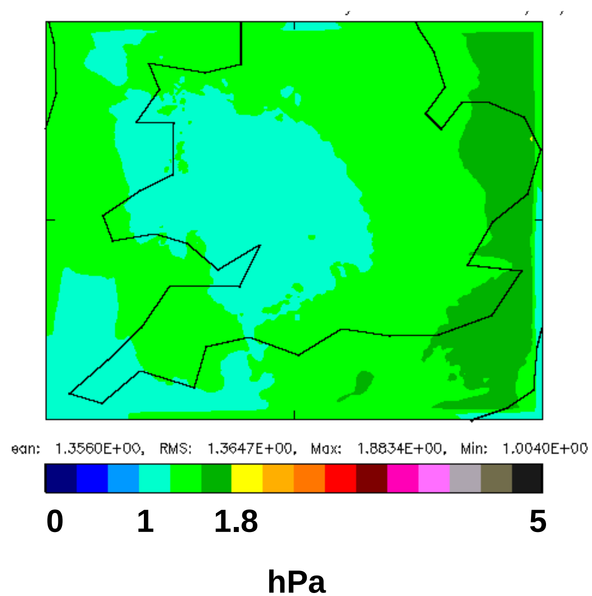
Overestimation of p_{surf} spread

- Most of the overspread in p_{surf} was found to be attributed to an overestimation in the spread of p_{surf} by MOGREPS-R.
- However p_{surf} spread is increased in the 1.5km ETKF vs MOGREPS-R

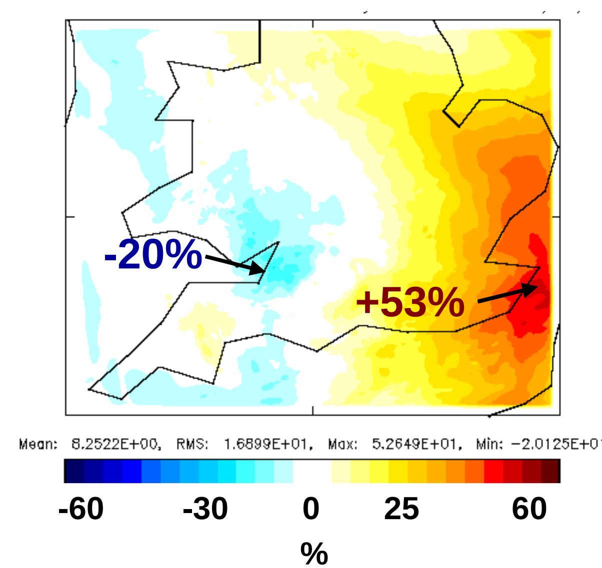
MOGREPS-R : 12h fcst



ETKF 1.5km : 1-h fcst



Relative difference (%)



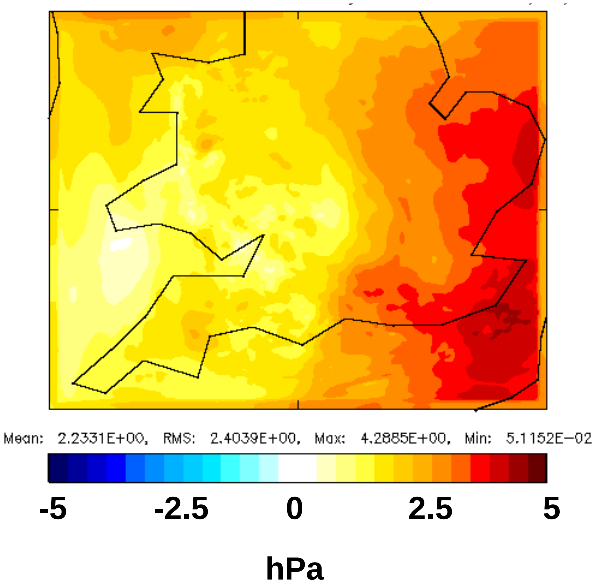
Domain average = +9.1%

fields valid at 06z 05/12/2009

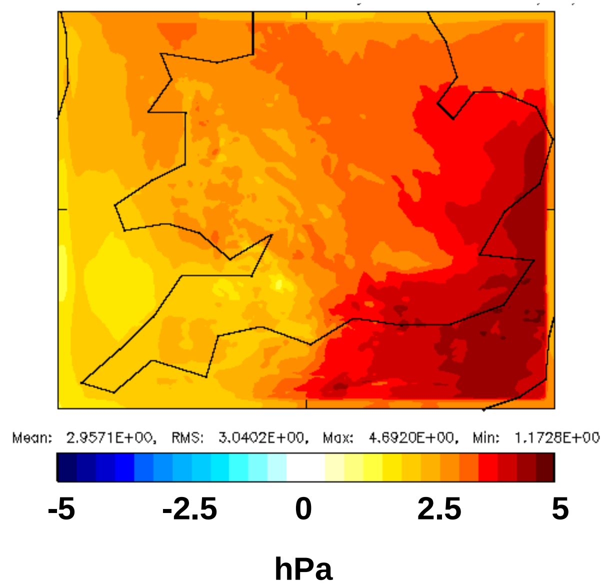
Overestimation of p_{surf} spread

- Why the p_{surf} spread is increased in the 1.5km ETKF ?

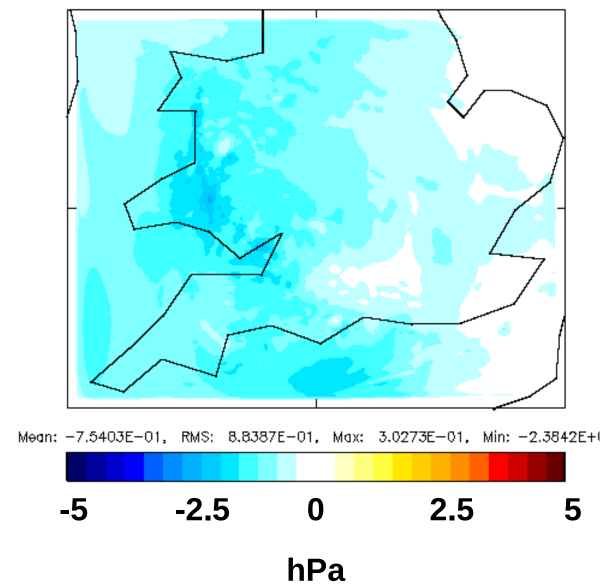
1-h p_{surf} perturbations for member #8



Contribution from LBC perturbations only



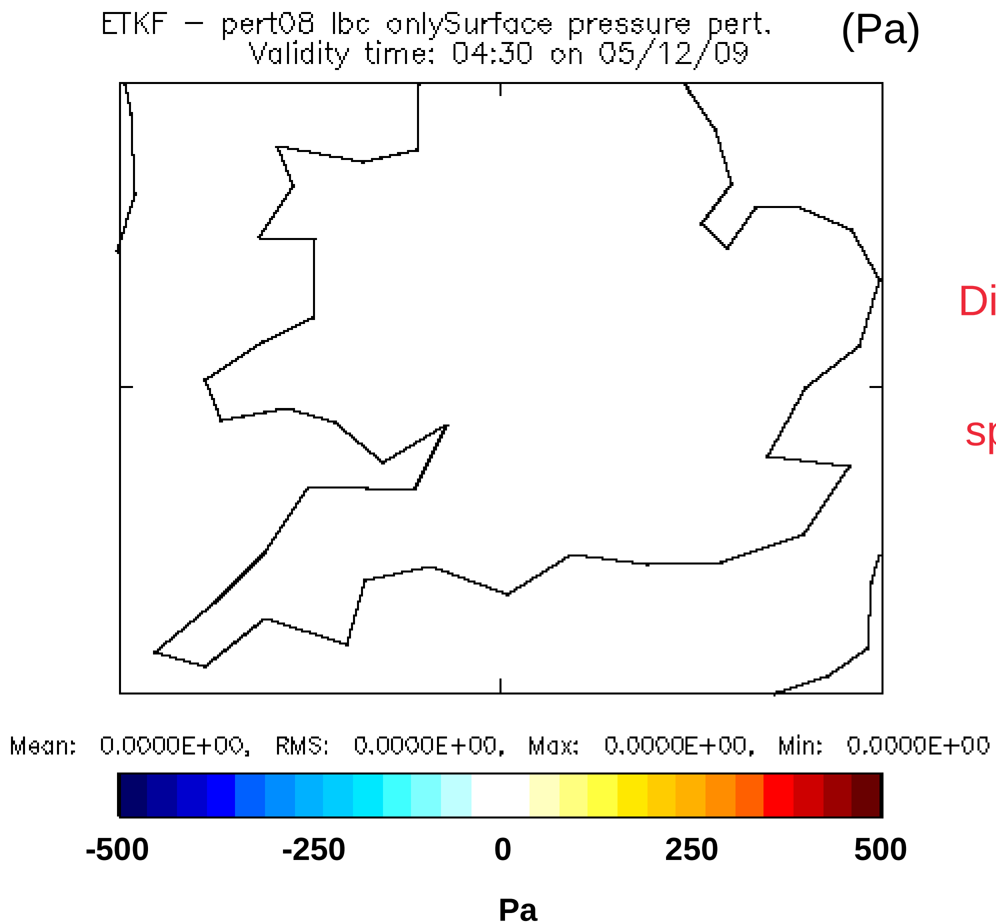
Contribution from IC perturbations only



1h forecast valid at 06z 05/12/2009

Overestimation of p_{surf} spread

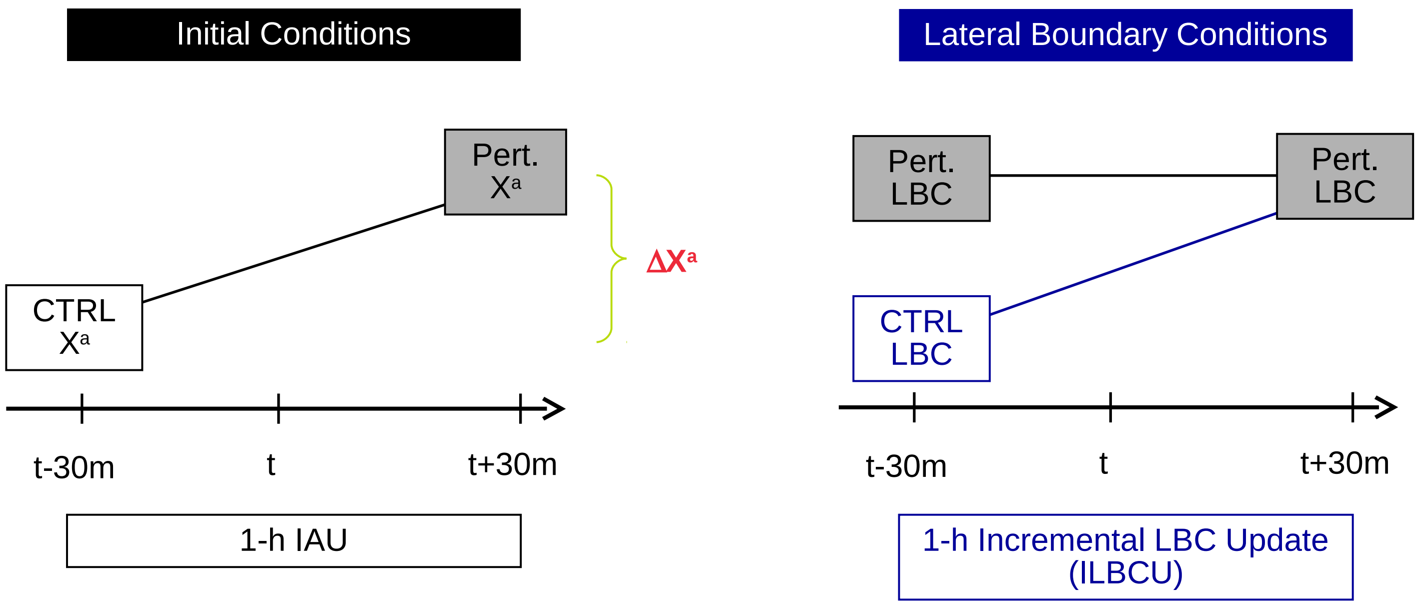
- Consequence of perturbing only the LBC



Discontinuities between IC and LBC can introduce significant spurious perturbations.

Sources of discontinuities at the LB (1)

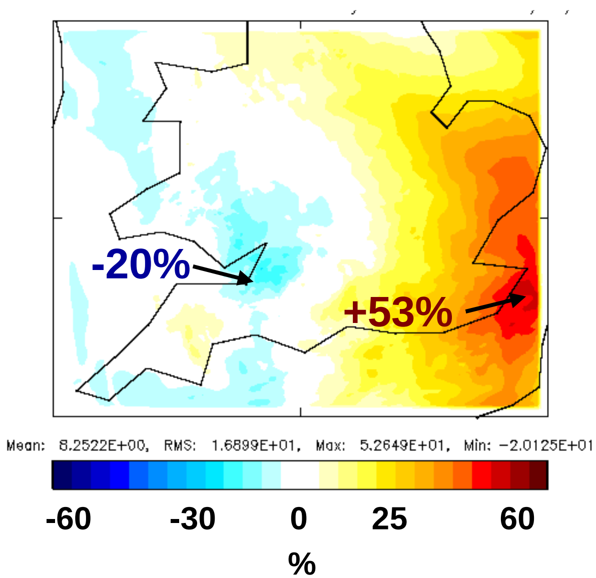
- The Incremental Analysis Update (IAU, i.e., how we add the IC perturbations)



Sources of discontinuities at the LB (1)

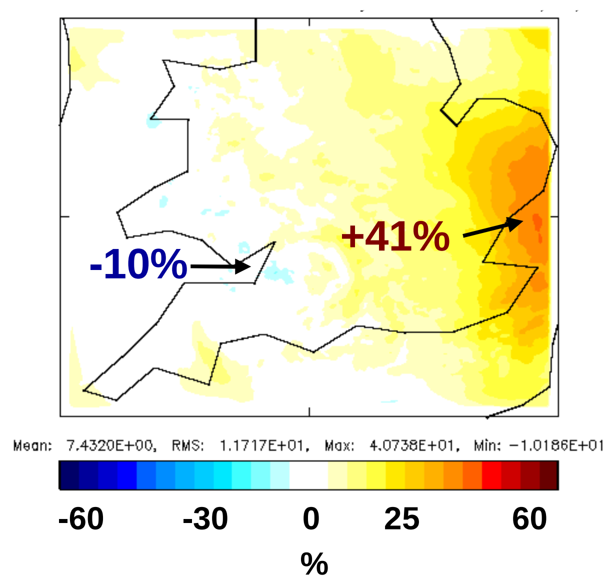
- Relative difference in p_{surf} spread : 1.5km ETKF vs. MOGREPS-R

IAU only



Domain average = +9.1%

IAU + ILBCU

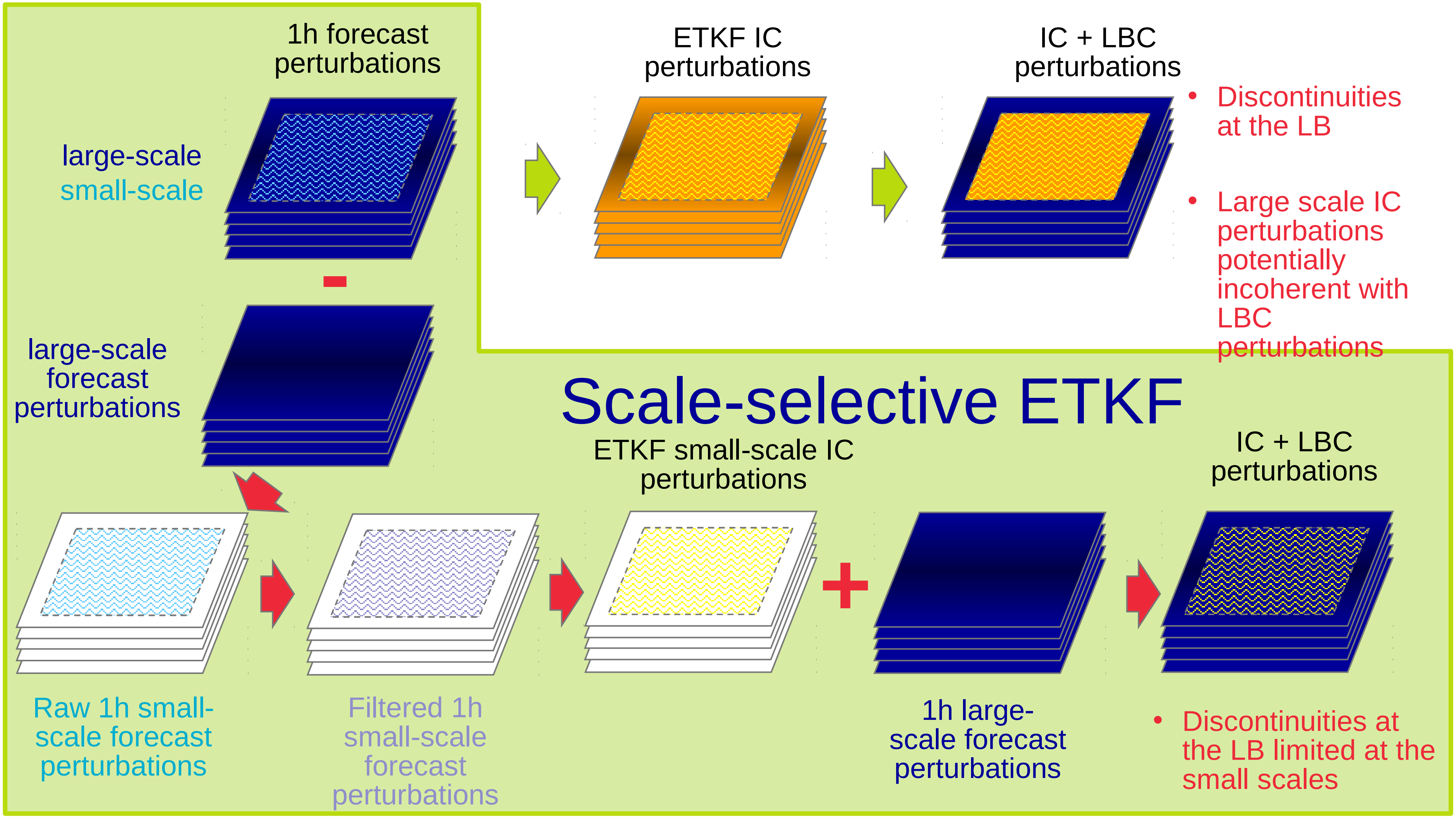


Domain average = +8.1%

Other sources of discontinuities between IC and the LBC must be present

1h forecast valid at 06z 05/12/2009

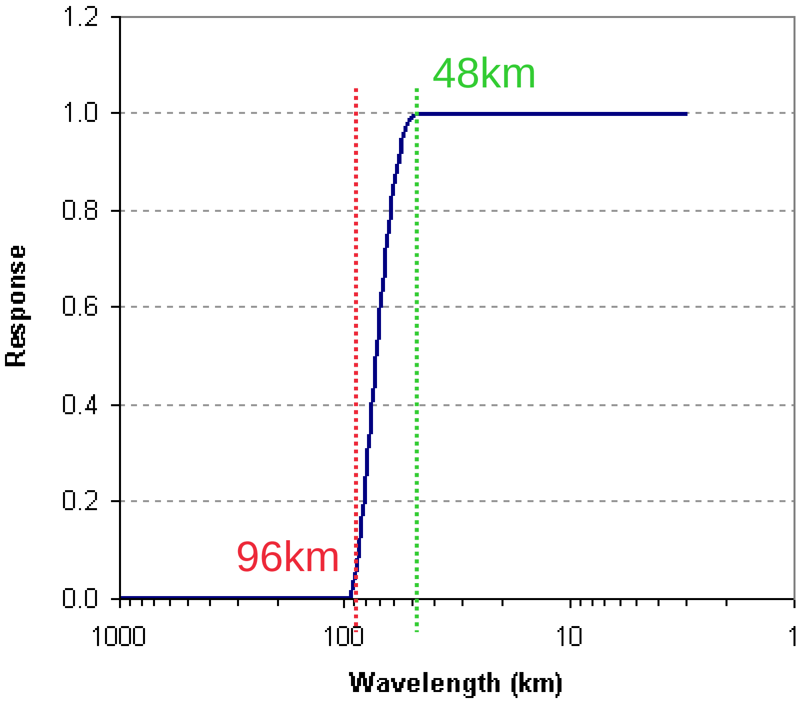
Sources of discontinuities at the LB (2)



- Discontinuities at the LB
- Large scale IC perturbations potentially incoherent with LBC perturbations

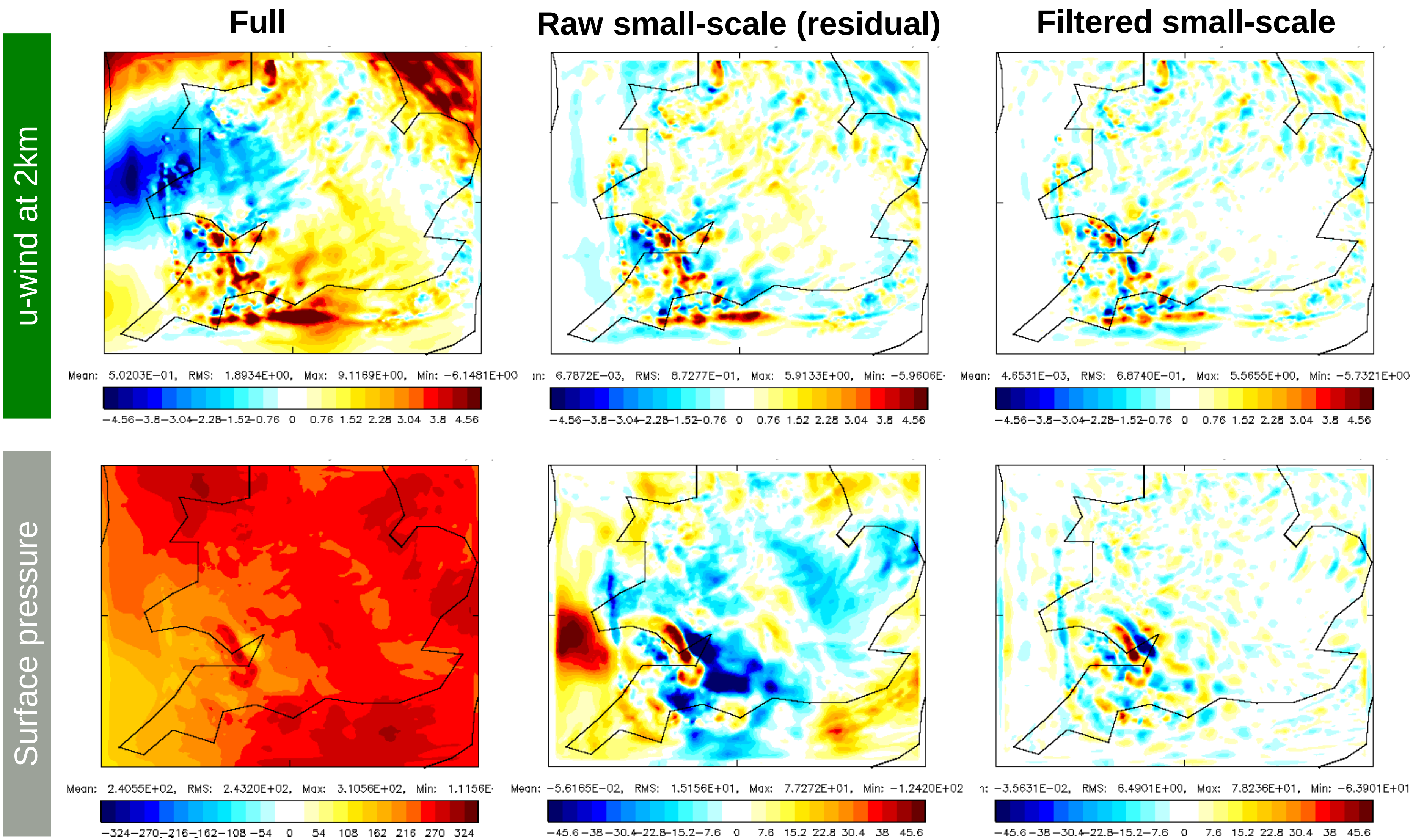
- Discontinuities at the LB limited at the small scales

Filtering



1.2
1.0
0.8
0.6
0.4
0.2
0.0
Response
48km
96km
1000
100
10
1
Wavelength (km)

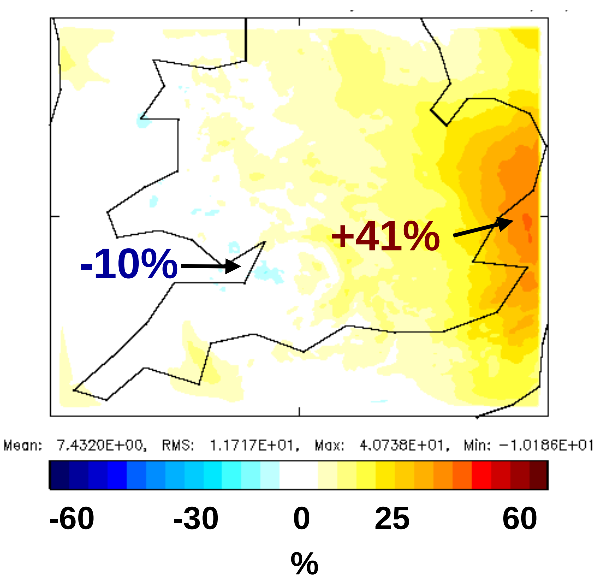
1-h forecast perturbations



Scale-selective ETKF

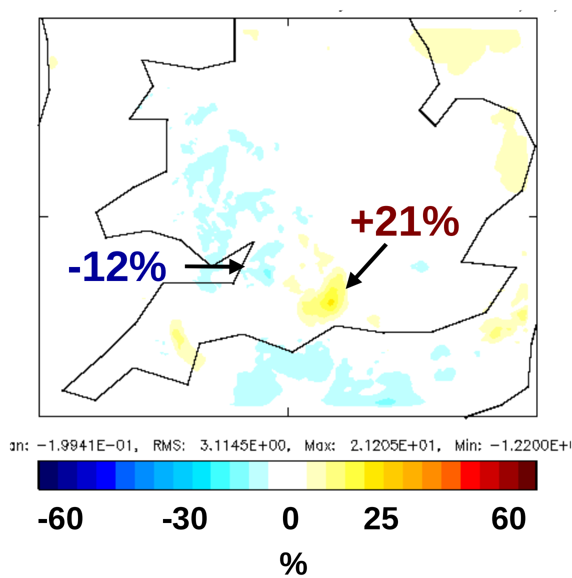
- Relative difference in p_{surf} spread : 1.5km EPS vs. MOGREPS-R

1.5km ETKF



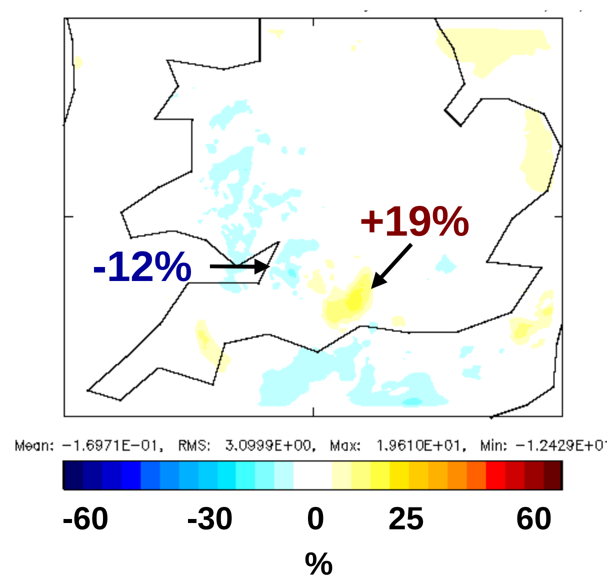
Domain average = +8.1%

Scale-selective 1.5km ETKF



= -0.2%

Downscaled perturbations from MOGREPS-R

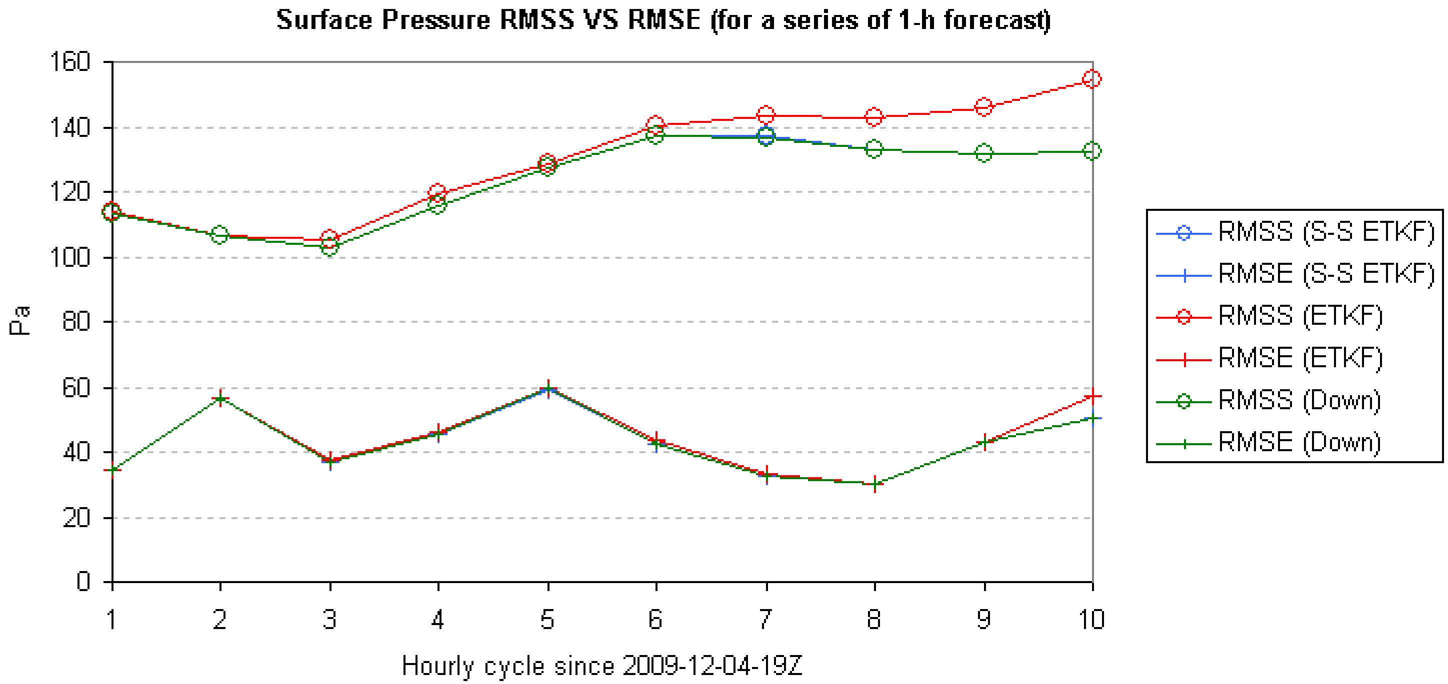


= -0.2%

1h forecast valid at 06z 05/12/2009

Scale-selective ETKF

- 1-h p_{surf} spread vs RMSE* in observation space

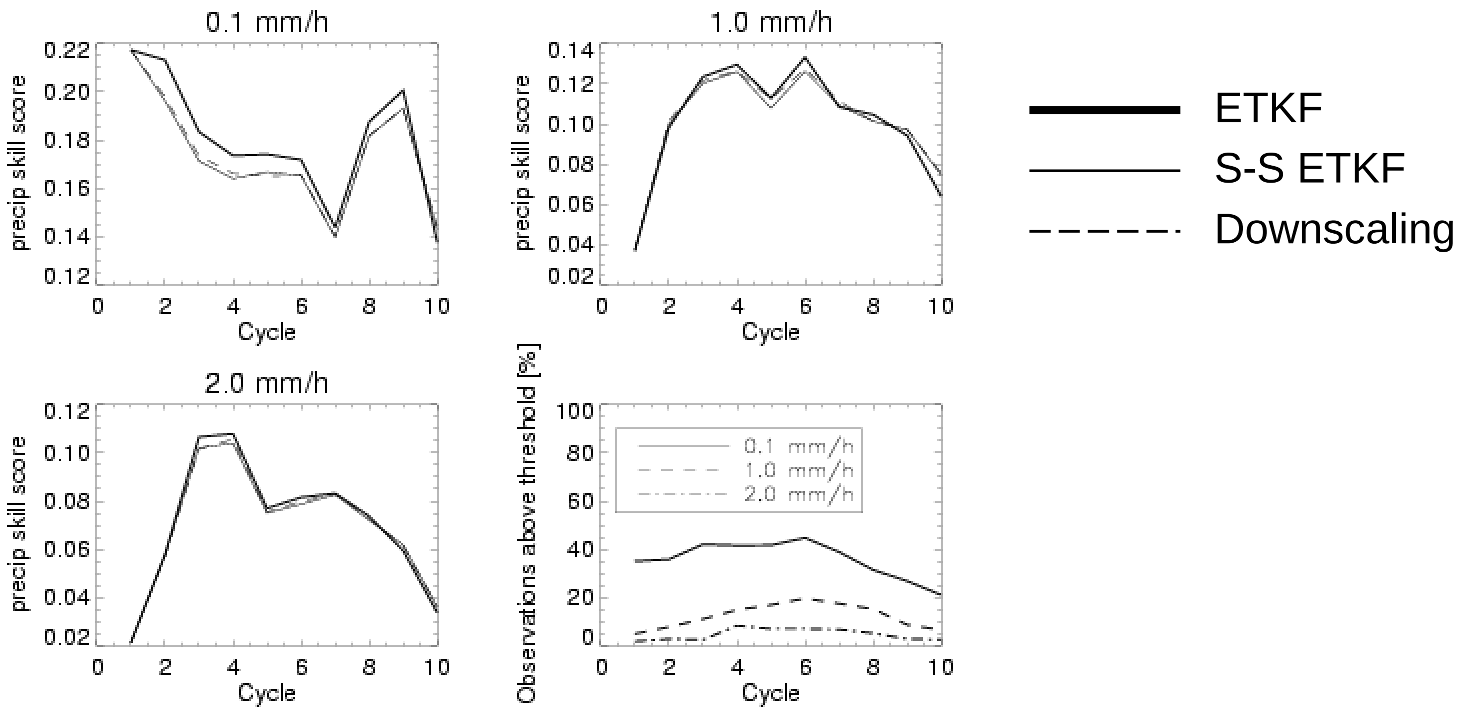


* The observation error was removed from the MSE

Scale-selective ETKF

- Verification of 1-h precipitation rate – Brier Score

A lower value is a better EPS forecast



Summary and discussion

- The current ETKF approach for limited area generates discontinuity between IC and LBC perturbations

  This is likely to be true for all current limited area EnDA approach

- In our small domain, discontinuities were found to introduce significant spurious perturbations in the pressure field.

  This is likely to be less important in larger domains.

- Results from the scale-selective ETKF suggest that preventing discontinuities at the resolved scales of the driving EPS can remove these spurious perturbations.
- Scale-selective ETKF improves slightly some other variables w.r.t. to the ETKF but… so far no clear benefit was found with respect to downscaled perturbations.

Summary and discussion

The experiment conducted here is far from being optimal…

- Large scales = scales resolved by the driving EPS

  Where to set the line between large-scale and small-scale ?

- The continuity of the spectra of the resulting IC perturbations was not inspected.
- No localization was applied on the small scale forecast perturbations
- An arbitrary fixed inflation factor was applied on the small scale IC perturbations

  Designing a variable inflation factor will not be trivial

- 1-h IAU was used. Probably too long for the small scale perturbations.

My main concern with the scale-selective ETKF

- The small scale IC perturbations are constructed without the knowledge of the large scale perturbations

  The small scale IC perturbations could potentially be incoherent with the large scale component.

Questions

VAR covariance model: MetO vs. EC

Steps from model variable space to covariance model space

Step	Met Office		EC	
1	$\mathbf{x}'$	$u', v', \theta', \rho', p', q'$	$\mathbf{x}'$	u', v', T', p_s', q'
2	Parameter transform $\mathbf{v}_p = \mathbf{T}_p \mathbf{x}'$	Global and LAM ψ', χ', p_u', r' $p_u' = p_h' - \mathbf{F}\, f(\psi)$	Parameter transform $\mathbf{v}_p = \mathbf{T}_p \mathbf{x}'$	$\psi', \chi_u', T_u', p_{s_u}', q'$ Global $(T_u', p_{s_u}') = (T', p_s') - \mathbf{F}\, f(\psi)$ $\chi_u' = \psi - \mathbf{G}\psi$ $\psi', \chi', T', p_s', q'$ LAM
3	Vertical transform $\mathbf{T}_v$	auto covariances only $\mathbf{B}_v(i,j) = \mathbf{E}\Lambda\mathbf{E}^T$ $\mathbf{v}_p(i,j,k) \rightarrow \mathbf{v}_v(i,j,m)$	Horizontal transform $\mathbf{T}_h$	$\mathbf{v}_p(i,j,k) \rightarrow \mathbf{v}_h(l,n,k)$
4	Horizontal transform $\mathbf{T}_h$	$\mathbf{B}_h(r) = \mathbf{B}_h(0)\left(1+\frac{r}{s}\right)e^{r/s}$ LAM $\mathbf{v}_v(i,j,m) \rightarrow \mathbf{v}_h(l,n,m)$ Global	Vertical transform $\mathbf{T}_v$	$\mathbf{B}_v(l,n)$ Global: auto covariances LAM: auto and cross covariances

Outline

- Description of a 1.5 km ETKF-based limited area EPS for research purpose
- Issues related to discontinuities at the large scale between IC and LBC perturbations

  * In this presentation the term “large scale” will refer to the scales resolved by the parent (or driving) EPS

- How to improve the representation of the large scale IC perturbations ? Some results using a scale-selective ETKF

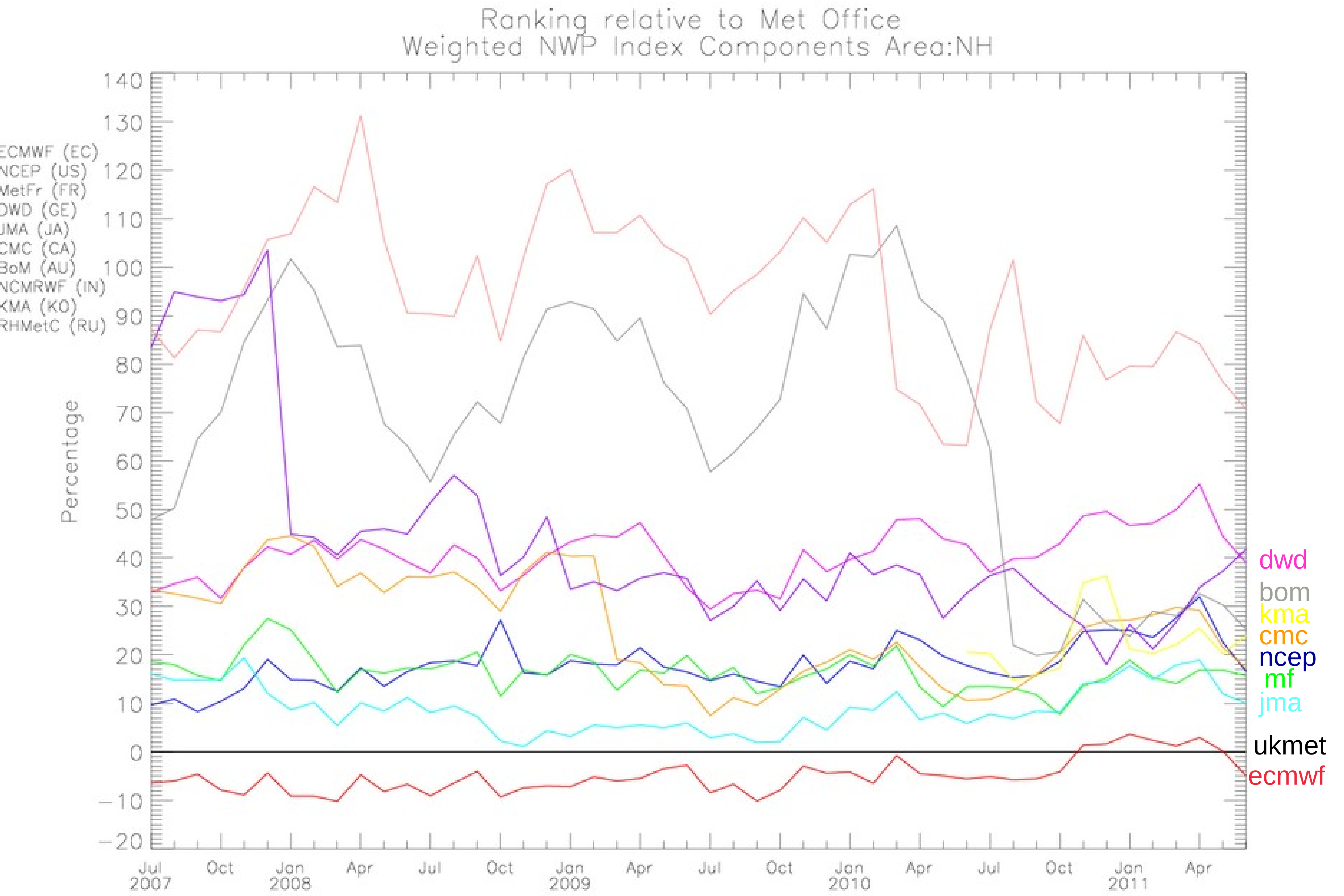
ETKF 1.5km: The setup

- Control analysis from 3DVAR SUK 1.5km 1-h cycle with cloud and latent heat nudging and UK 4km LBC
- IC perturbations* are produced by the ETKF using +1h forecast perturbations in observation space for all the assimilated observations in 3DVAR
  - Surface obs, Aircrafts
  - Radio-sondes
  - GPS, radiances
  - + *Radar derived surface rain rate (not assimilated in VAR)*

For more info see Sefano Migliorini's poster

- No localizations
- Variable inflation factor derived from surface obs (u, v, T) and aircraft data (u ,v, T)
- No representation of model errors
- LBC taken from MOGREPS-R (24km version)

* for the first cycle IC perturbations are taken from MOGREPS-G as in MOGREPS-R


Ranking relative to Met Office
Weighted NWP Index Components Area:NH
ECMWF (EC)
NCEP (US)
MetFr (FR)
DWD (GE)
JMA (JA)
CMC (CA)
BoM (AU)
NCMRWF (IN)
KMA (KO)
RHMetC (RU)
Percentage
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
−10
−20
Jul 2007
Oct
Jan 2008
Apr
Jul
Oct
Jan 2009
Apr
Jul
Oct
Jan 2010
Apr
Jul
Oct
Jan 2011
Apr
dwd
bom
kma
cmc
ncep
mf
jma
ukmet
ecmwf

Ce que les Britanniques pensent du Met Office ?

guardian.co.uk | The Observer

News | Sport | Comment | Culture | Business | Money | Life & style

News › UK news › Met Office

Met Office forecasts storm warnings over its accuracy

They are among the most respected, scientific and accurate forecasters in the world. Yet to the British public they are a joke. Tim Adams visits the Met Office's HQ in Exeter to meet the people for whom the outlook is always gloomy

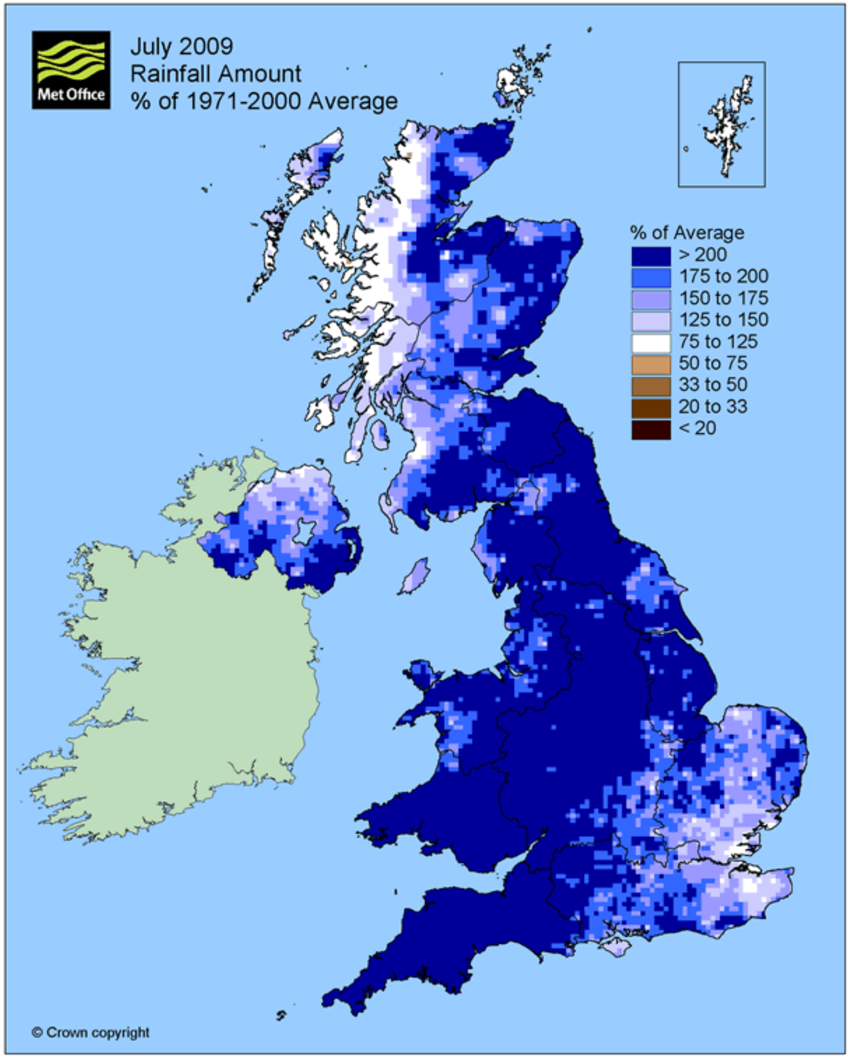
Tim Adams
The Observer, Sunday 21 February 2010
Article history

Ah! les prévisions saisonnières … (1)

Avril 2009

« The coming summer is 'odds on for a barbecue summer' »

Juillet 2009 >



Ah! les prévisions saisonnières … (2)

Octobre 2009 :

« Winter temperature are likely to be near or above average»

Janvier 2010 >