EWGLAM, October 2011

Met Office data assimilation activities

Bruce Macpherson

Contents

This presentation covers the following areas

- flow dependent covariances
- humidity control variable
- Doppler radial winds
- road sensor data
- symmetric cloud observation errors
- high resolution assimilation impact
- observation sensitivity study
- plans

July 2011 Global Data Assimilation Upgrade Package (PS27)

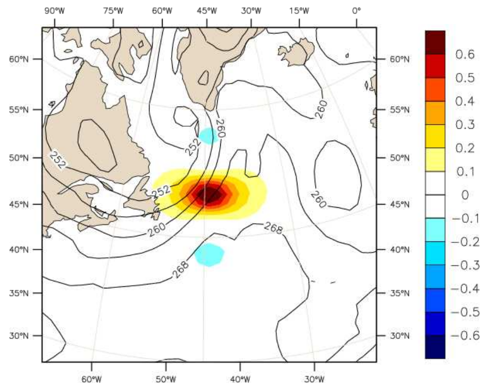
- Assimilation method
  - Hybrid 4D-VAR algorithm.
  - Moisture control variable: Replacing RH with scaled humidity variable
- Observation changes
  - Introduce METARS
  - GOES/Msat-7 clear-sky radiances, extra IASI (land)
  - Revisions to MSG clear-sky processing and GPSRO
  - Reduced spatial thinning (ATOVS/SSMIS/IASI/AIRS/aircraft)

Met Office

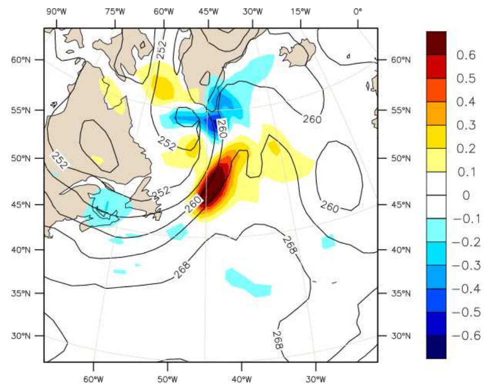
Hybrid data assimilation

- **Basic idea:** Use data from MOGREPS-G to improve the representation of background error covariances in global 4D-VAR:

u response to single u observation:

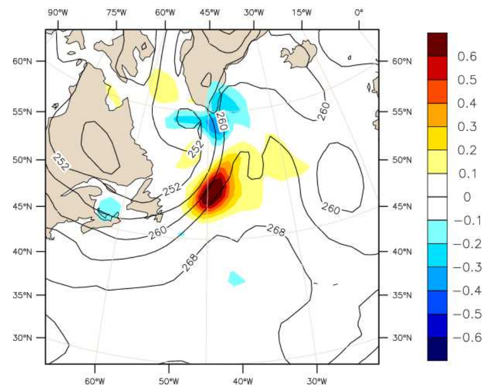


Climatological COV



MOGREPS COV

- MOGREPS is sensitive to the position of the front, and gives covariances that stretch the increment along the temperature contours.
- Ensemble currently too small to provide the full covariance, so we blend the MOGREPS covariances with the current climatological covariances; i.e., we use a **hybrid** system:



Hybrid COV

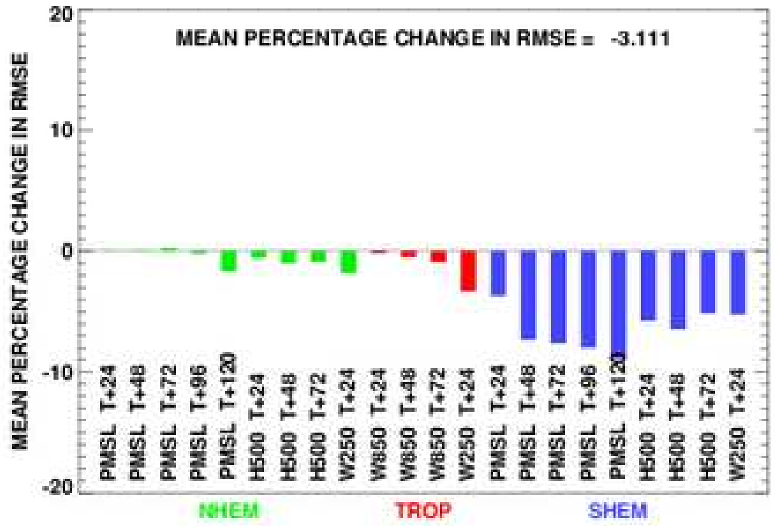
Adam Clayton

PS27 Global NWP Index Impact

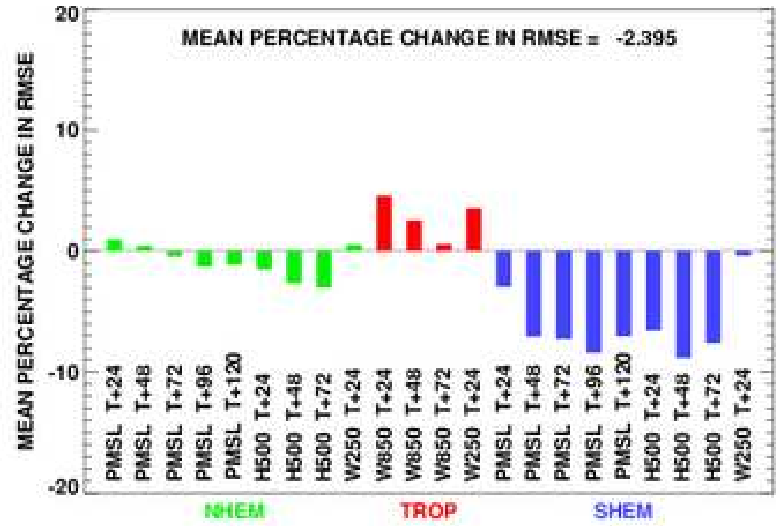
rms

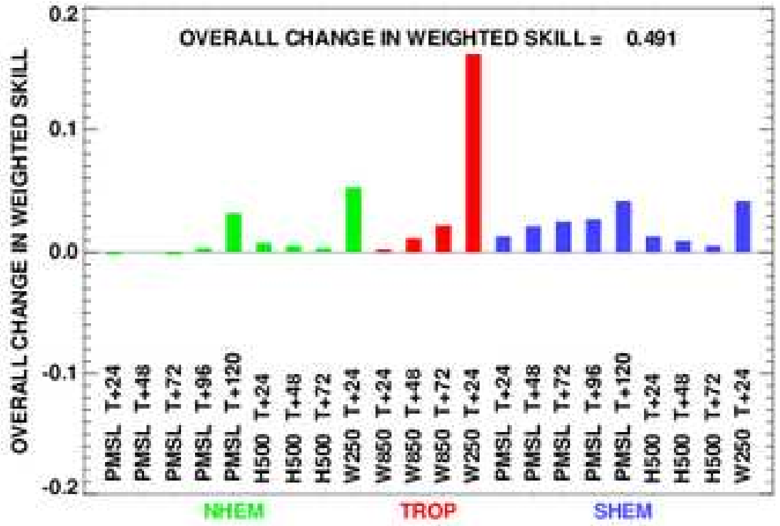
skill

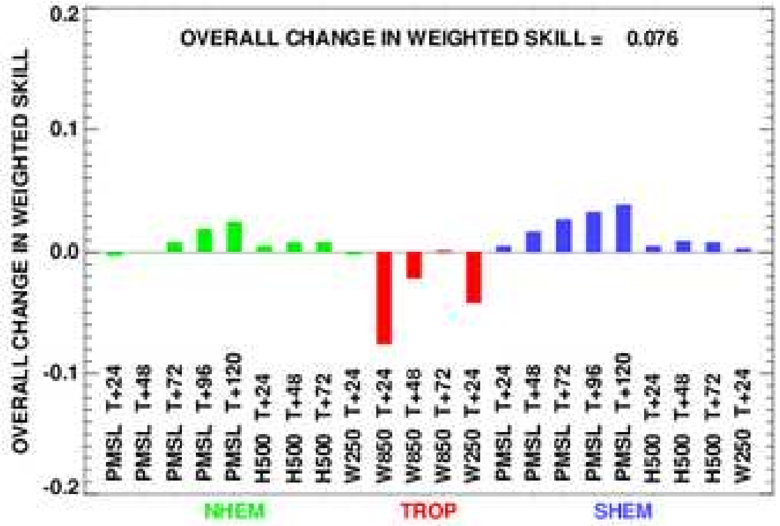
Impact Vs. Observations=+2.11



Impact Vs. Analyses=+0.67







- Biggest single reduction in overall global forecast error for many years.
- First time in memory that all parameters have reduced error vs obs. (usually a mix).

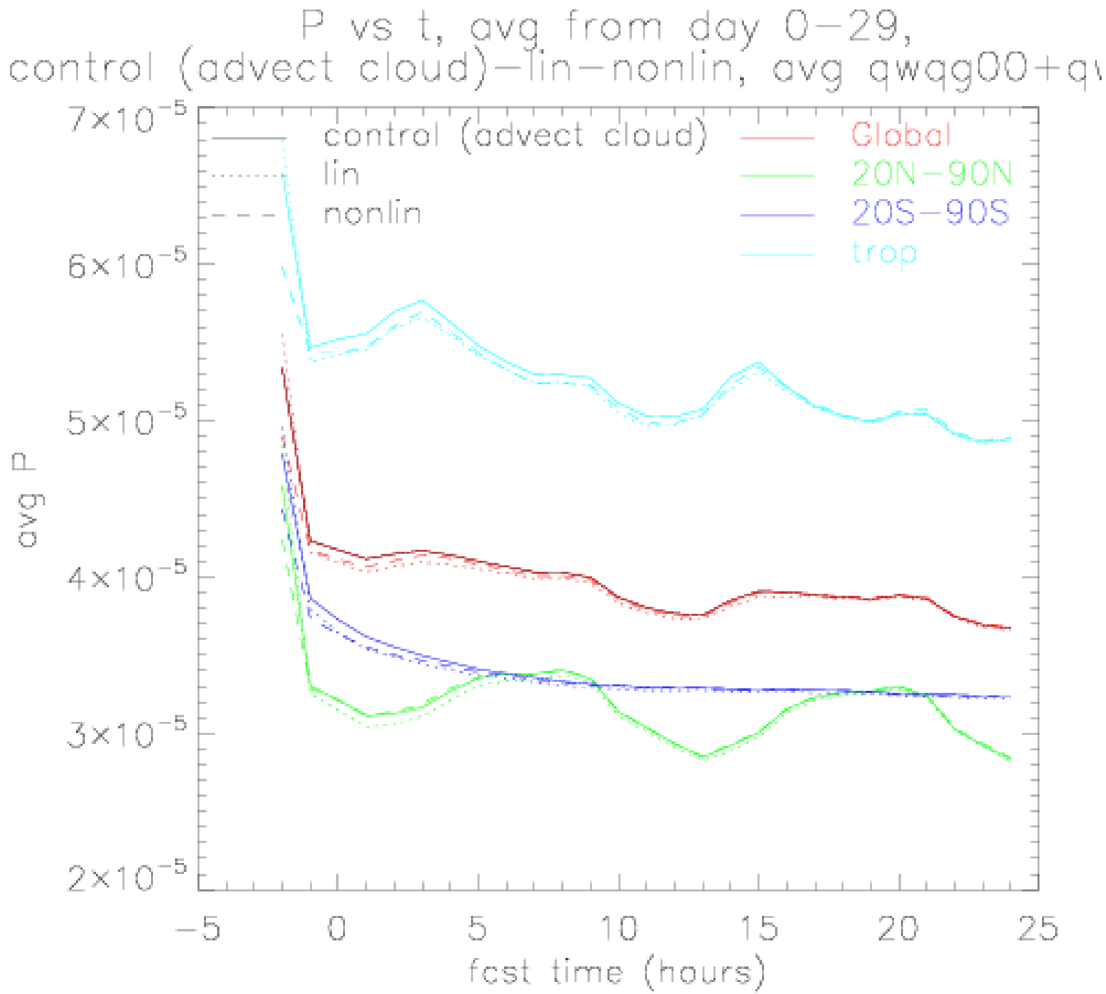
New Humidity Transform

- $$\mu = (q_T' - h c T')\, a / \mathrm{qsat}(\mathbf{b})$$

- q_T' increment of total q – including cloud
- T' temperature increment
- h=h(RH**b**) gives “balanced” q_T increment from T'
- a=a(RH**a**,RH**b**) is normalising factor so that $\sigma(\mu)\approx 1$ this reduces under/overshoots
  - h and a are derived from training data
- If a=a(RH**b**) then we have linear transform

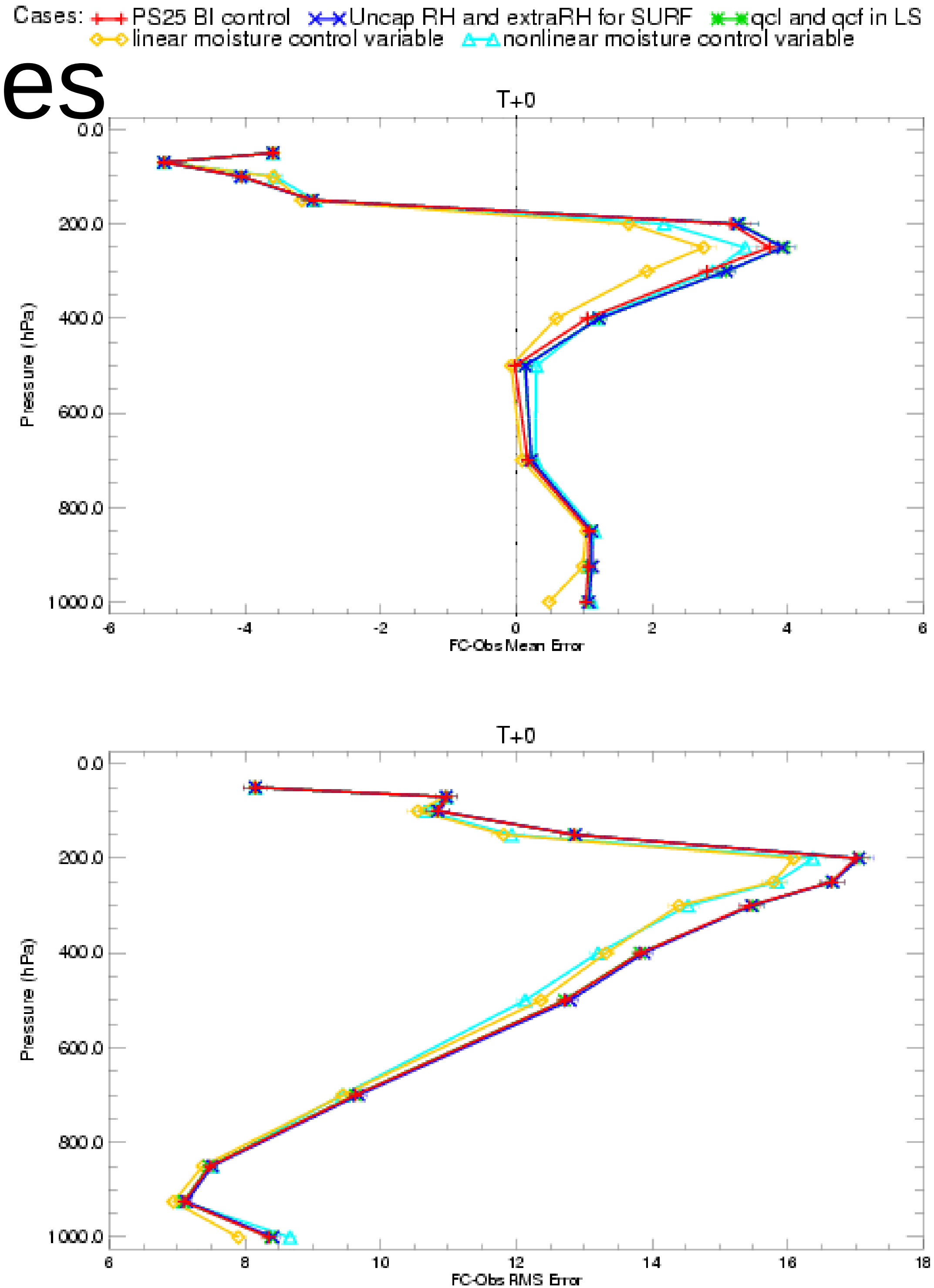
Precipitation spin-down

- Excessive ppn over first hour (esp. over oceans) then slower decline
- Nonlinear trial (dashed) reduces jump by ~40%



Bruce Ingleby

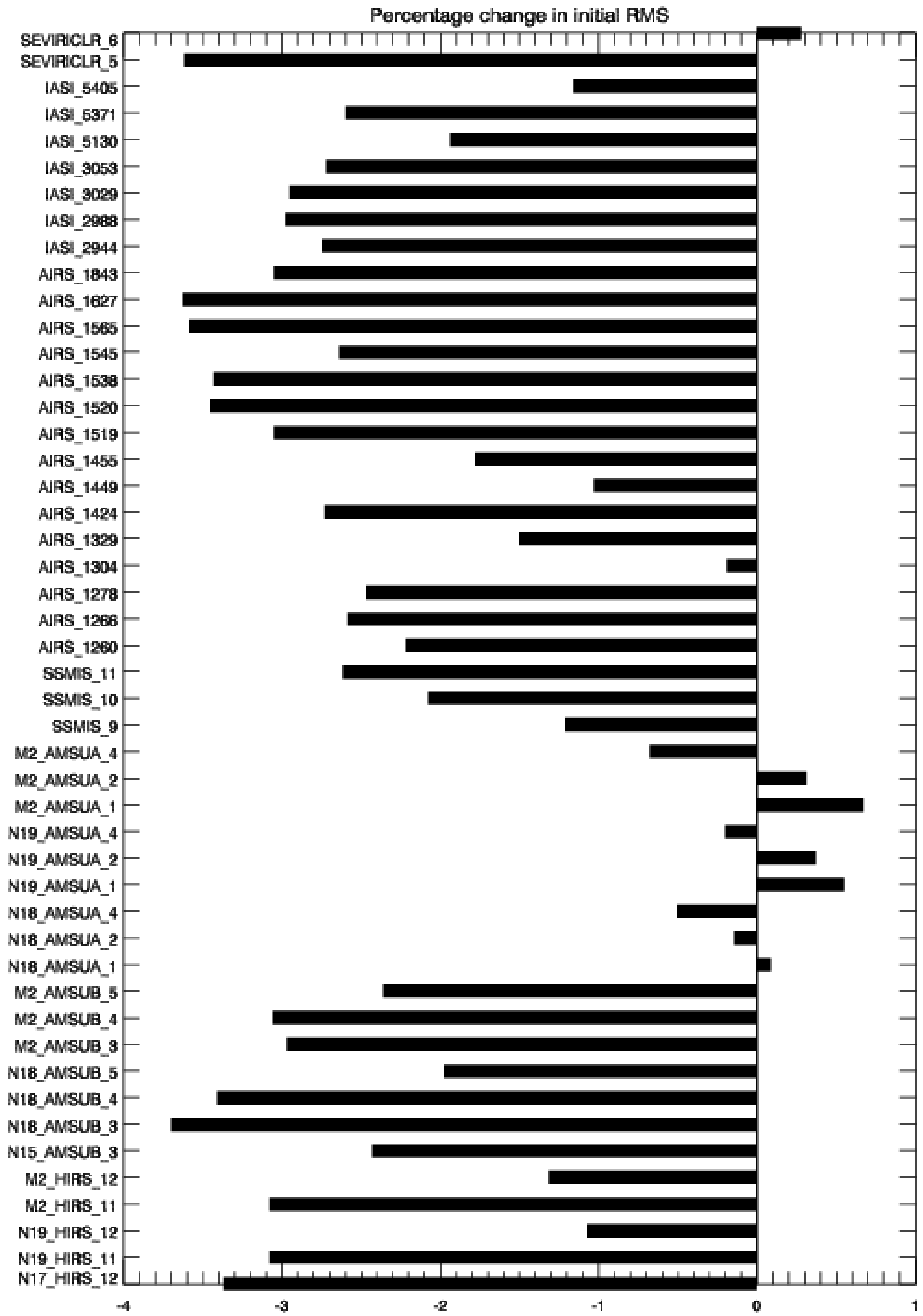
RH v Sondes 20-90°N



- T+0 mean fit:
- T+0 rms fit:
- largest diffs in upper-trop – better fit for trials there

% change in fit to humidity channels

- Fit to upper tropospheric humidity-sensitive channels improved by ~ 3% (large)
- Less improvement for channels that "see" the surface.



Adaptive Mesh Transform

(Piccolo & Cullen, 2011: Q. J. R. Met. Soc., 137, 631-640)

Met Office

❖ aims to change the vertical background-error correlations by moving the vertical levels to concentrate mesh points around temperature inversions.

❖ movement of the levels is guided by a scalar ***monitor function***, chosen to be a function of the *static stability* which strongly controls vertical mixing in the atmosphere and thus probably the vertical correlation structure of model variables.

❖ introduce the adaptive method within the Met Office VAR system as an extra transformation in the sequence of variable transformations used to simplify the background term of the cost function:

$$\delta\mathbf{x} = \mathbf{U}\boldsymbol{\chi} = \mathbf{U}_p \boxed{\mathbf{U}_a} \mathbf{U}_v \mathbf{U}_h \boldsymbol{\chi} \quad \text{and} \quad \mathbf{B} = \mathbf{U}\mathbf{U}^T$$

where $\mathbf{U}_a$ is the "adaptive mesh transform" which is placed between the parameter transform $\mathbf{U}_p$ and the vertical transform $\mathbf{U}_v$

Adaptive Grid Formulation

The first step of the $\mathbf{U}_a$ transform is to calculate a *monitor function* M (>0) in physical space z $\in$ [0,1]:

$$\int_0^1 M(z')dz' = 1$$

The second step is to generate the adaptive mesh in physical space by defining a computational coordinate $\zeta \in [0,1]$:

$$\varsigma(z) = \int_0^z M(z')dz'$$

The map from computational domain to physical domain is thus defined by the a unique one-dimensional map which connects intervals of a prescribed length.

Finally, the control variables χ which will be generated at points ζ by the vertical transform are then interpolated to the true levels z.

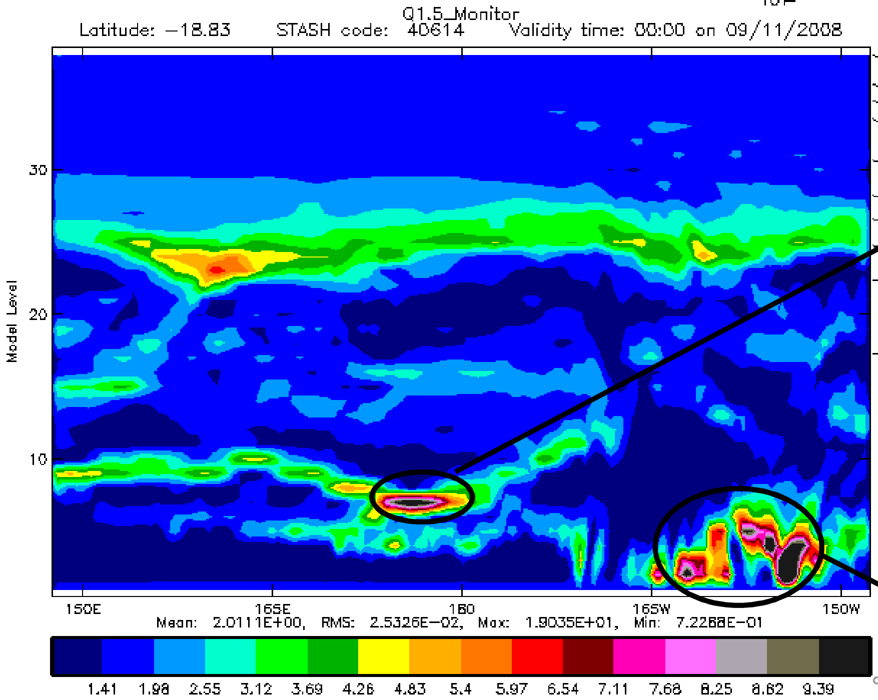
Choice of the Monitor Function

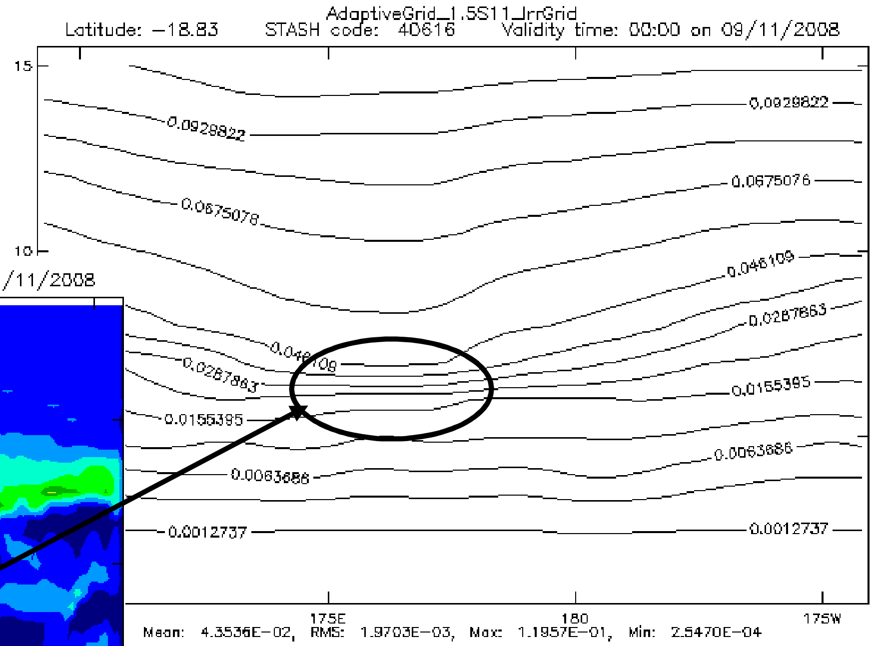
$$M = \sqrt{1 + c^2 (\partial\theta/\partial z)^2}$$

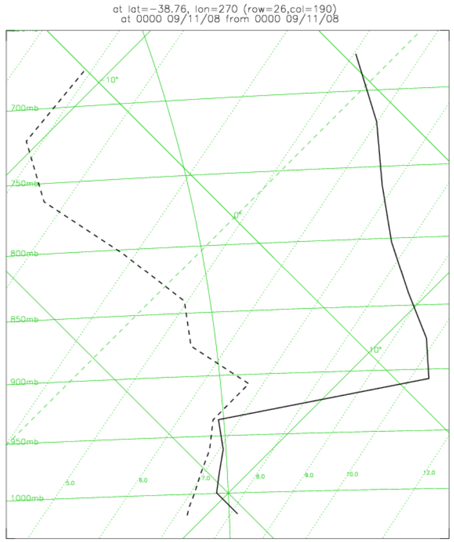
$M > 0$ and can be modulated by a scaling factor c.
If c = 0, the computational grid and the physical grid are the same.

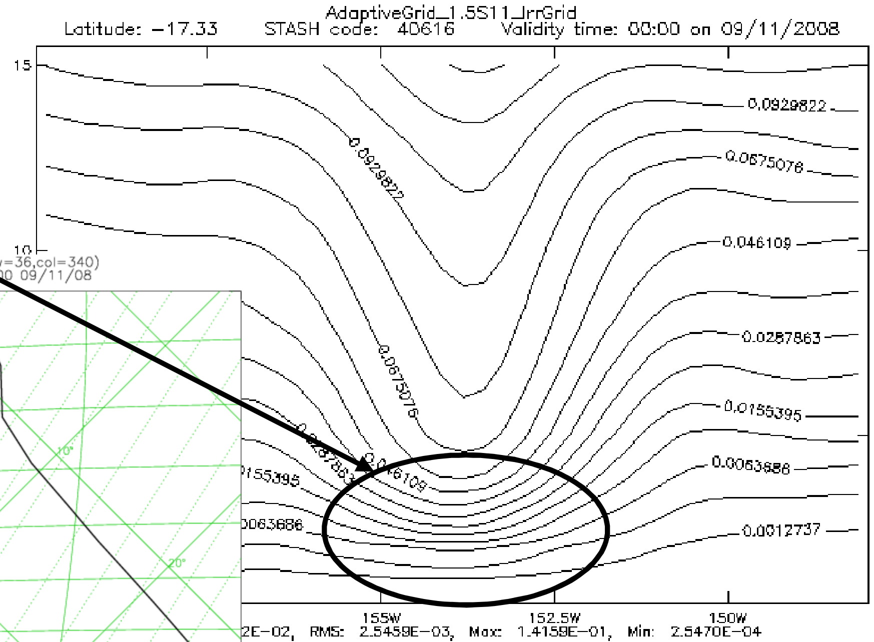
Since mesh points will be clustered where the monitor function is large, this choice of M will cluster mesh points in regions of large static stability.

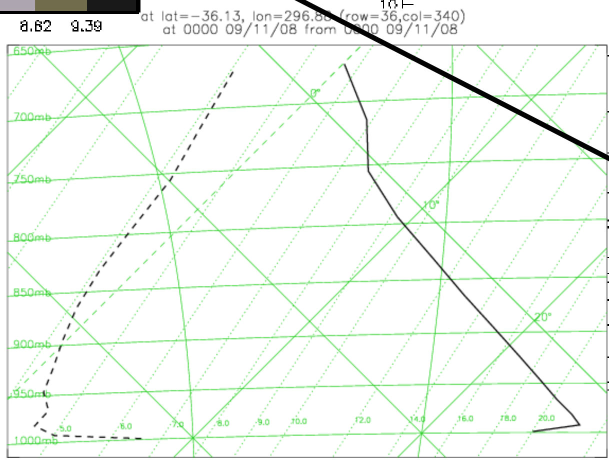
Monitor Function and Adaptive Grid





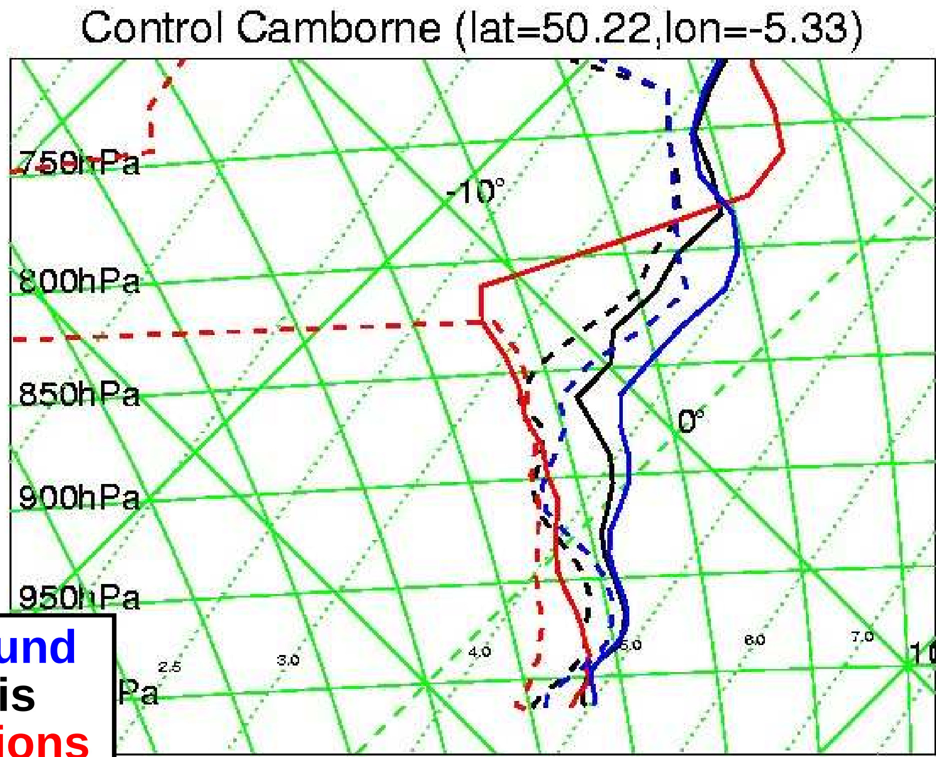




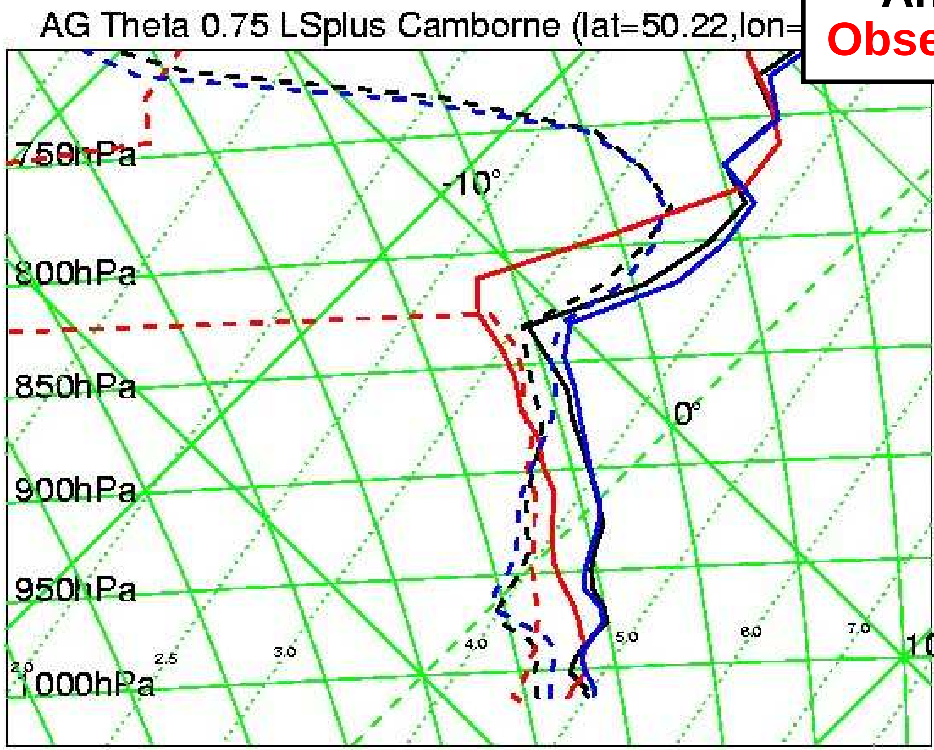


3 Jan 2011 00z: Camborne

The monitor function is based on the background state: if the inversion is not present, the vertical grid does not change.



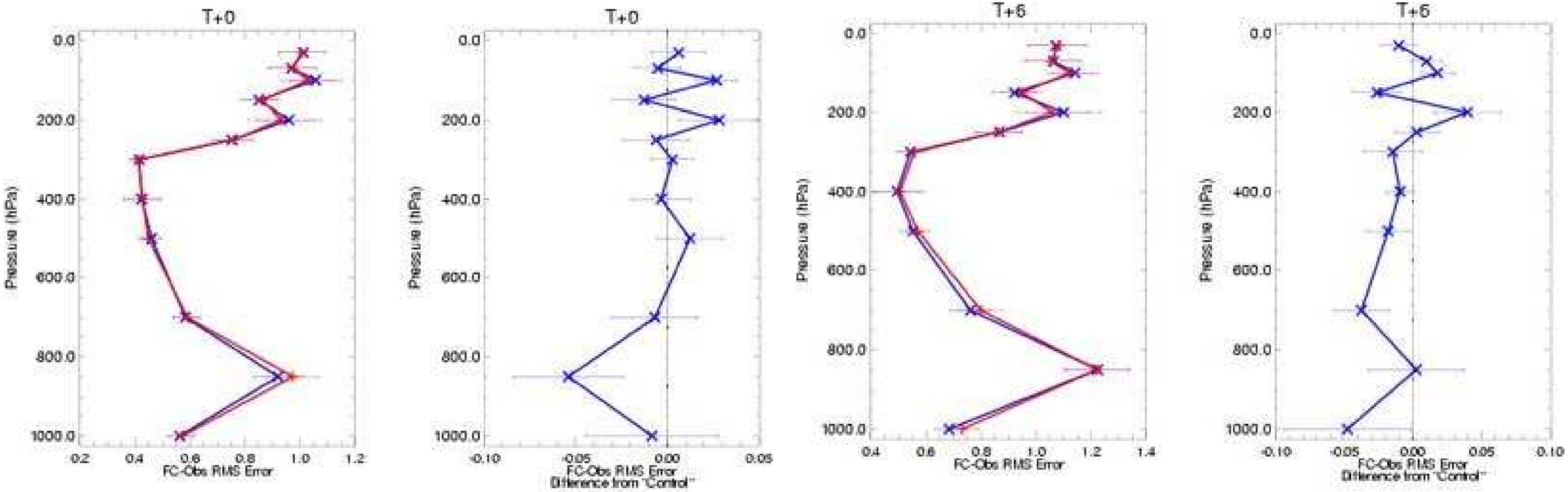
Background
Analysis
Observations



When the monitor function is based on an updated background-state using the observation's information in the minimisation process, the analysis has a clearer inversion.

Analysis vs Sonde Observations

Temperature RMS error over the winter period



Results from the full coupled analysis/forecast system:

➢ small improvement of temperature RMS error versus sonde profiles in the lower atmosphere for both winter and summer cases up to T+ 6h

➢ (also slight improvement for cloud base height and T2m)

Doppler radial winds

6 radars currently providing radial winds

(plans to upgrade whole network by 2013)

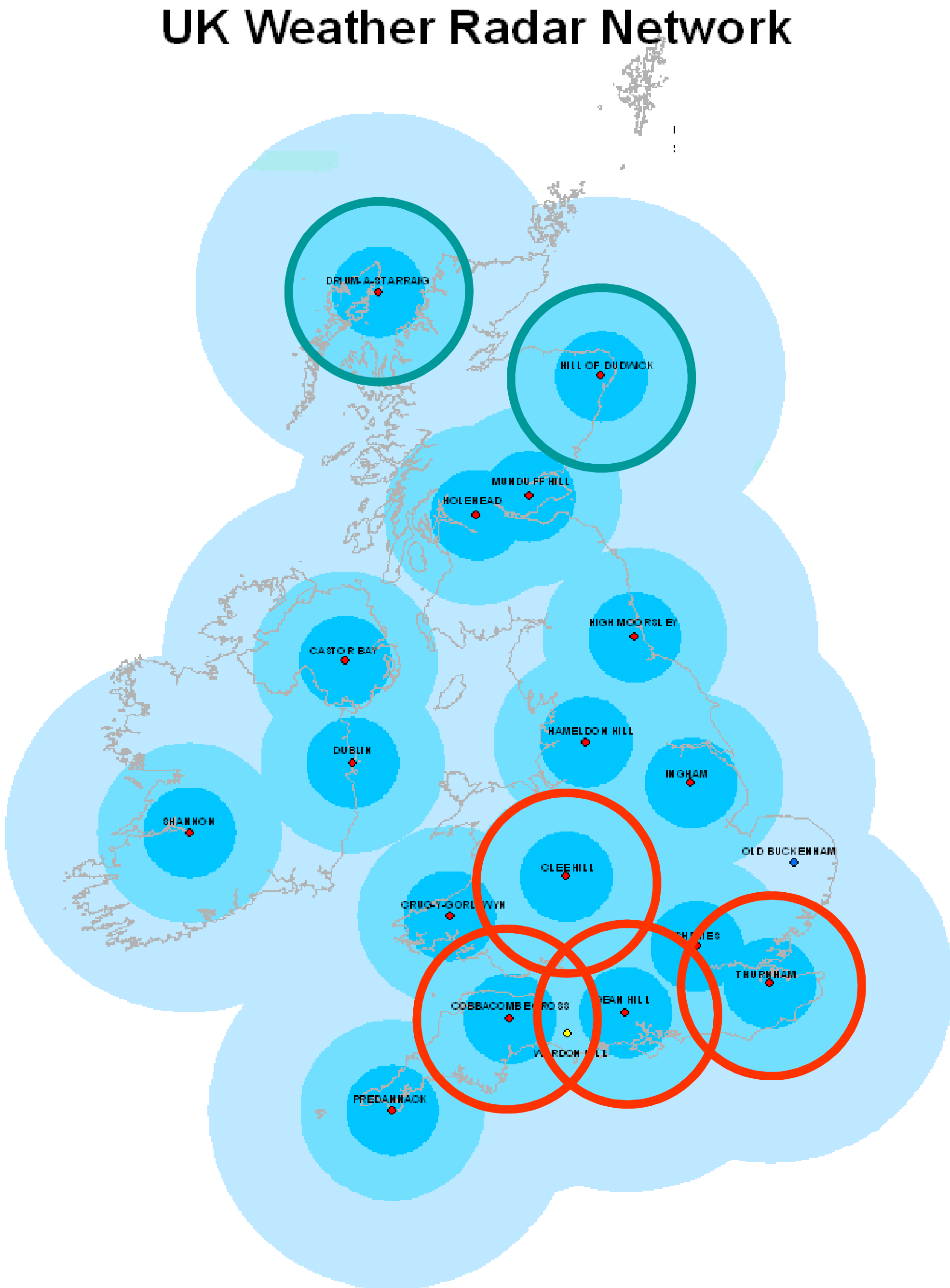
4 assimilated operationally so far

100 km radius

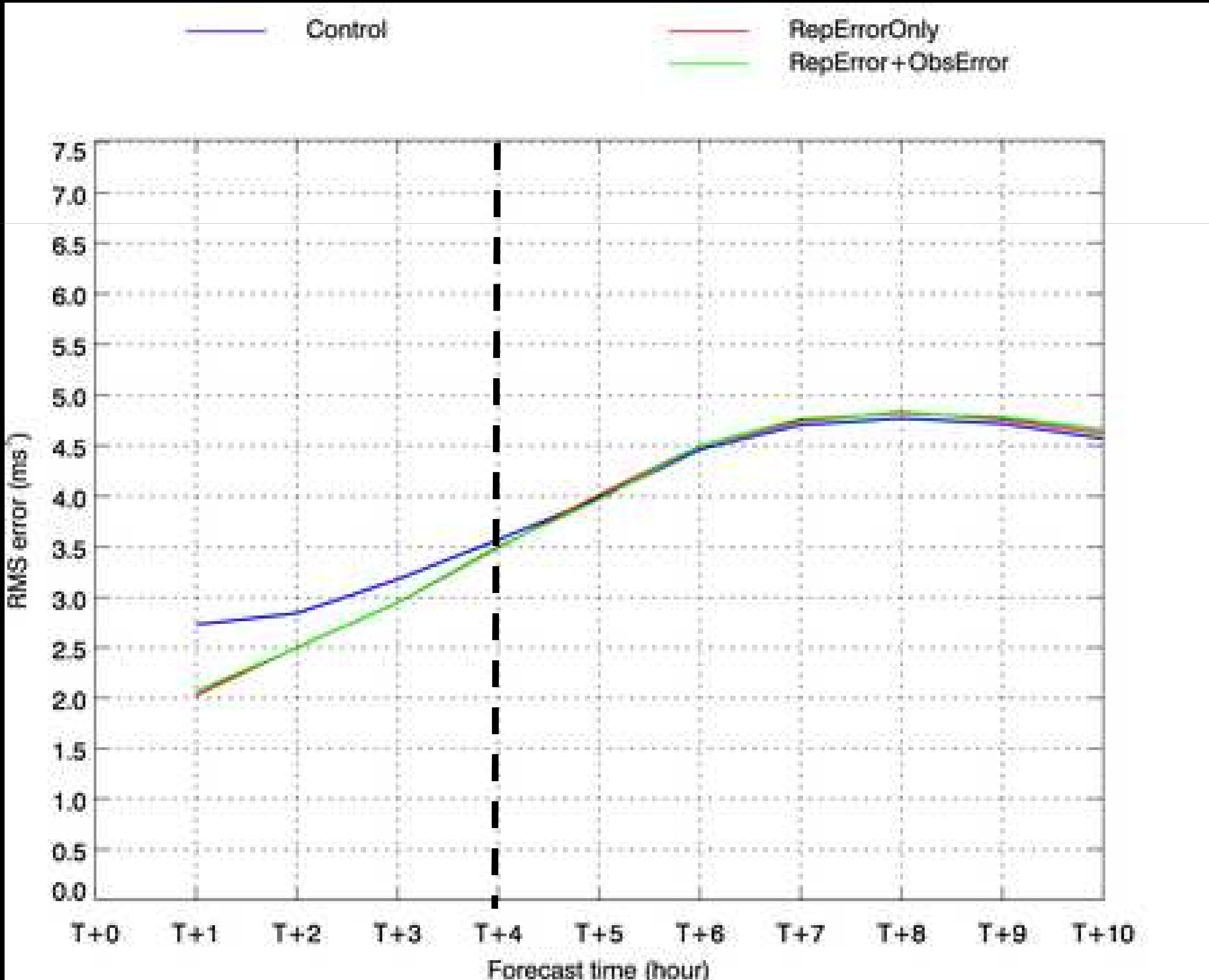
elevations between 1° and 9°

1° azimuthal 600 m radial

every 5 minutes



RMSE against Doppler Wind

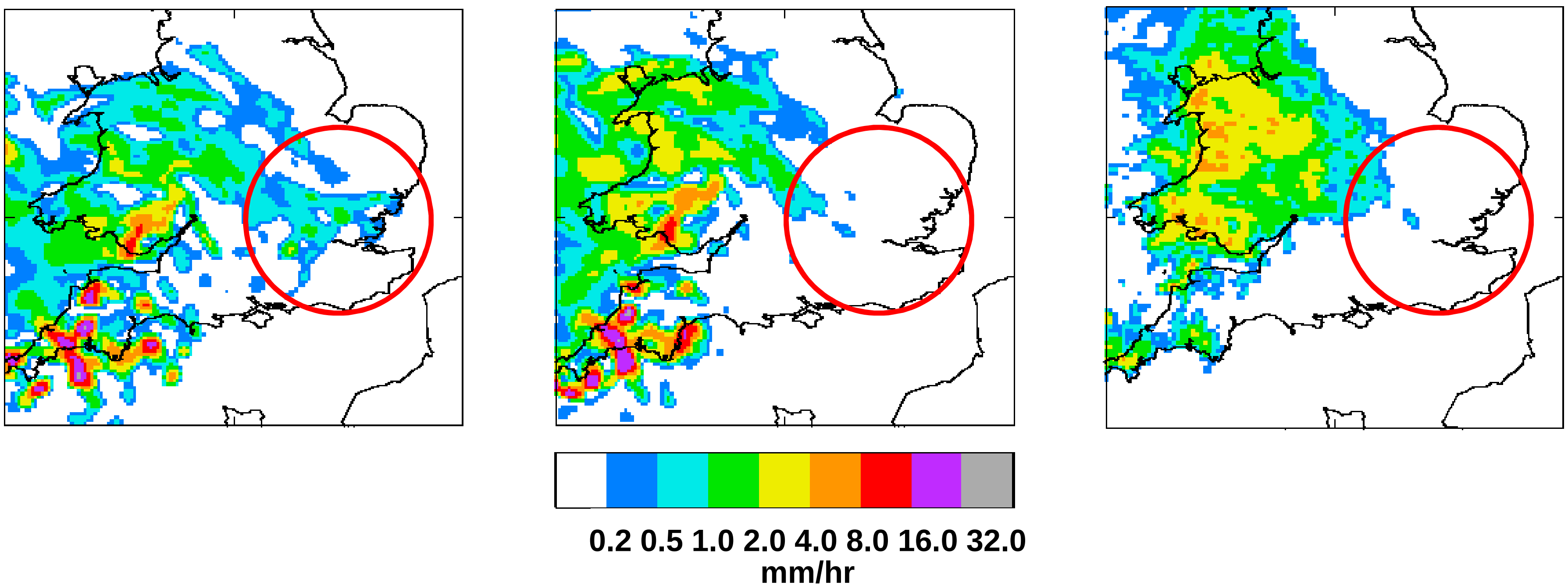


David Simonin

Individual case where rainfall location is seen to be improved

T+4

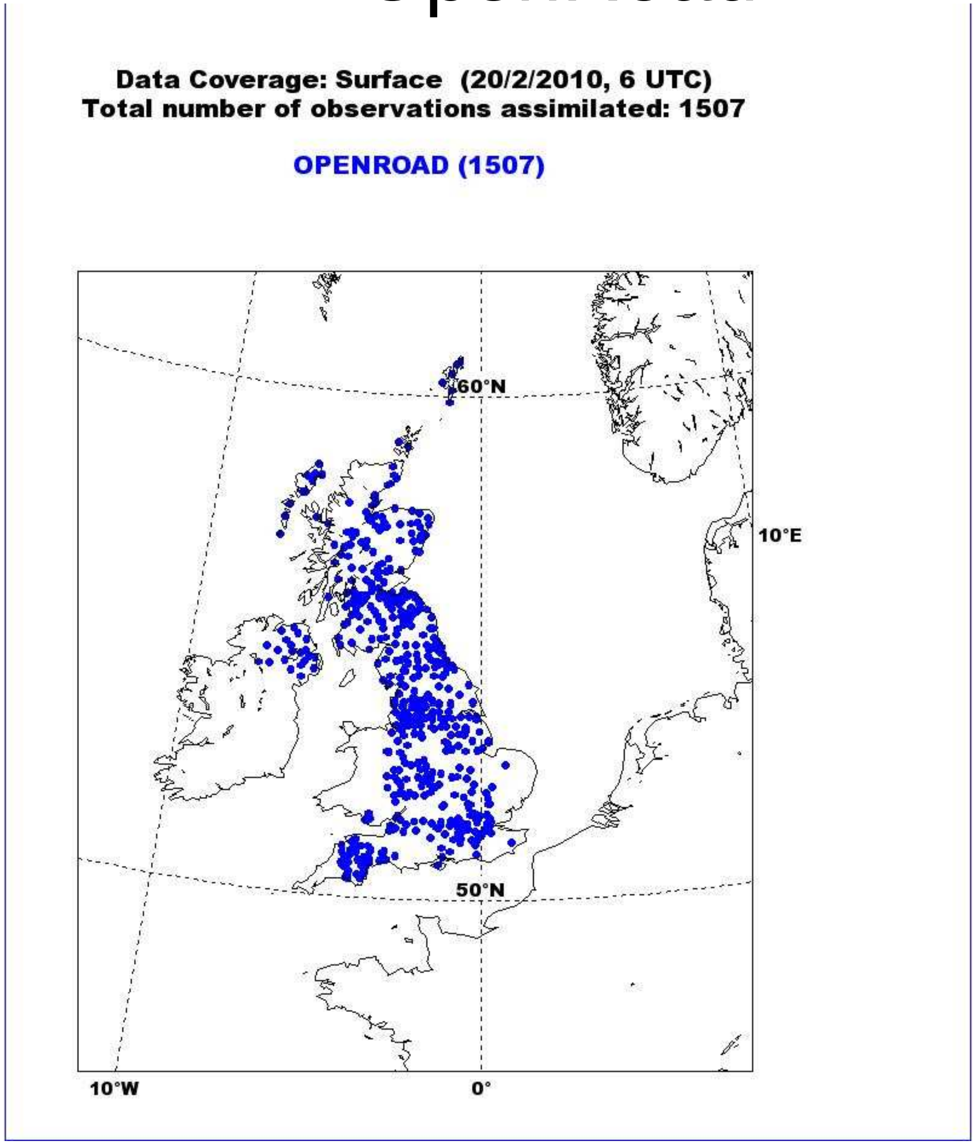
Control Trial Radar



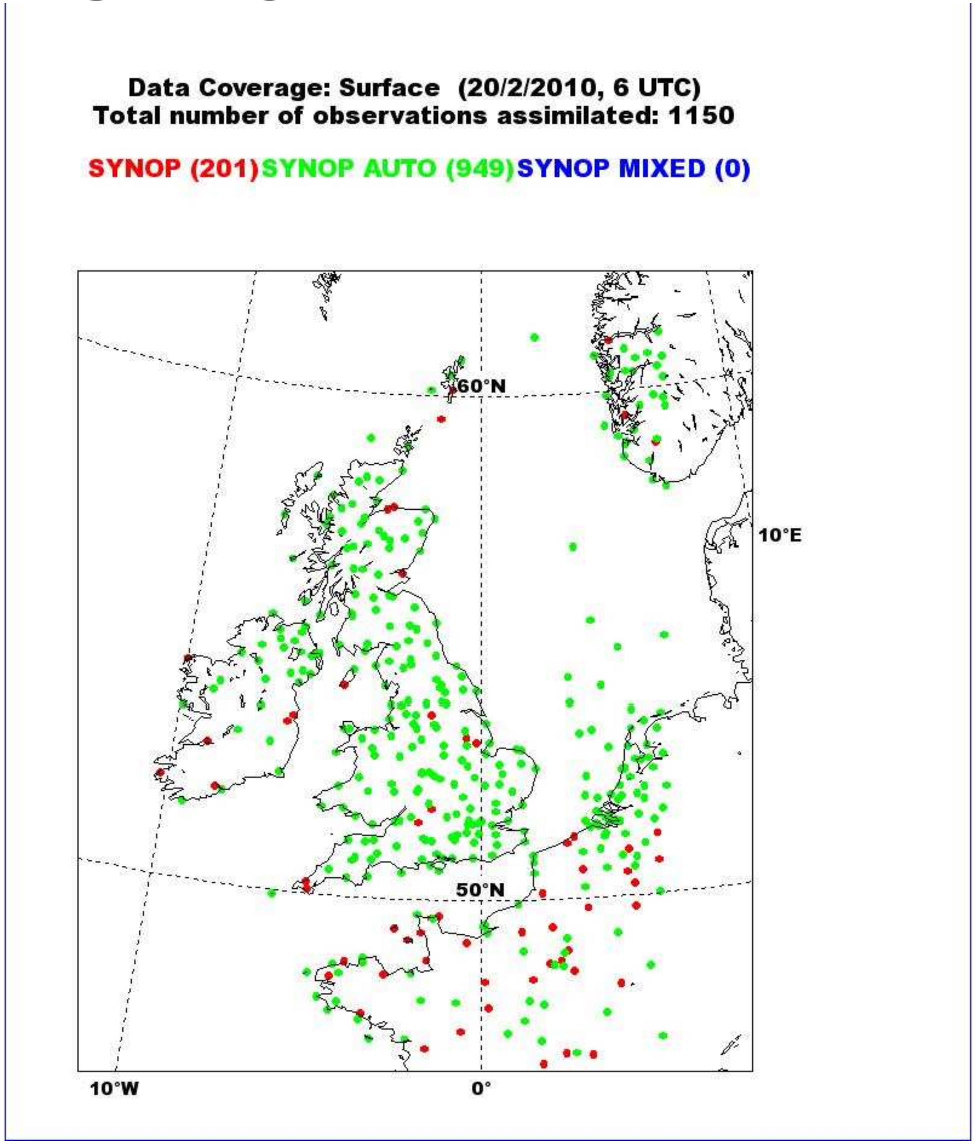
Helen Buttery

Roadside sensor network

OpenRoad



SYNOP



Gareth Dow

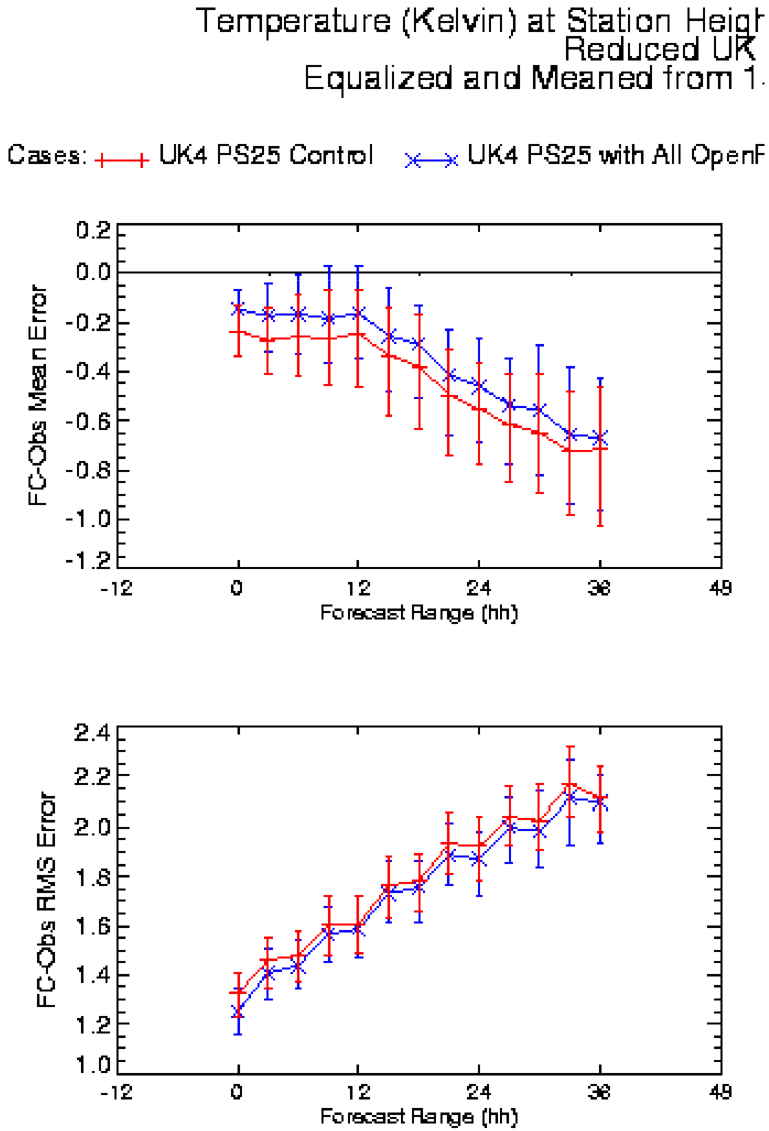
Roadside sensor network impact

Mean T2m error

control

test

Rms T2m error



(2nd half of Dec 2010)

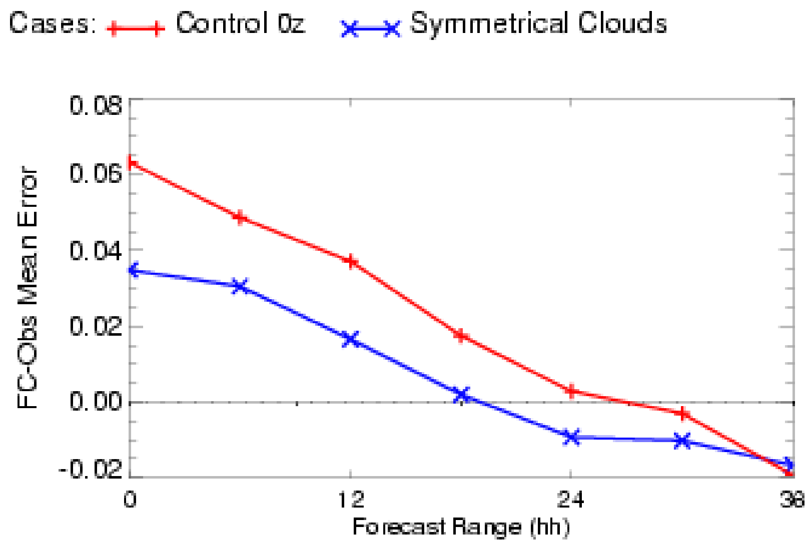
Gareth Dow

Symmetric Cloud Observation Errors

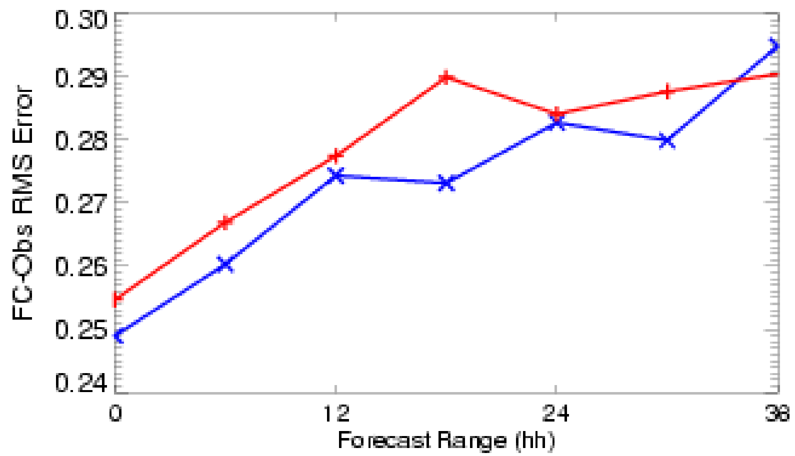
- $\varepsilon_{ob} = \mathrm{fn}\{ (CF_{ob} + CF_b)/2 \}$
- $\varepsilon_{ob} = 0.55$ when $CF_{ob} = CF_b = 0$
- $\varepsilon_{ob} = 0.25$ when $CF_{ob} = CF_b = 1$.
- Previously ε_{ob} was $\mathrm{fn}(CF_{ob})$ only, which tended to result in too much cloud

Symmetric Cloud Errors
Sc Period – October 2010
Cloud Verification

mean cloud
fraction error

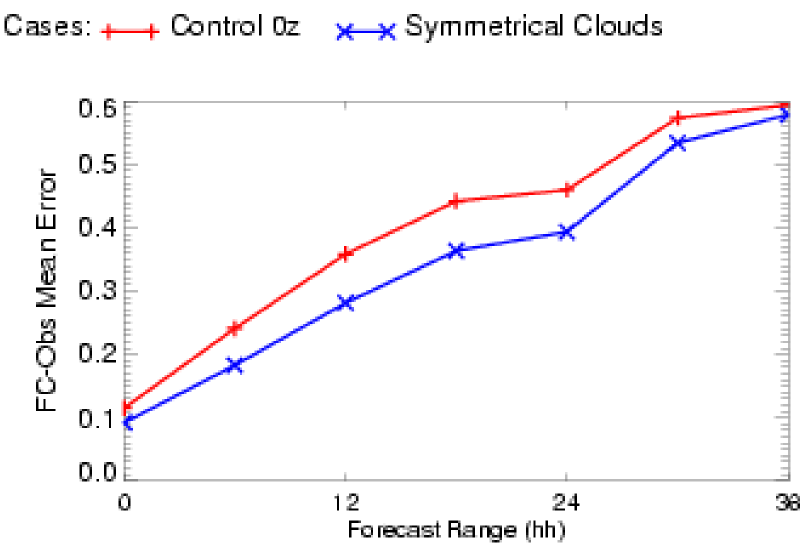


rms cloud
fraction error

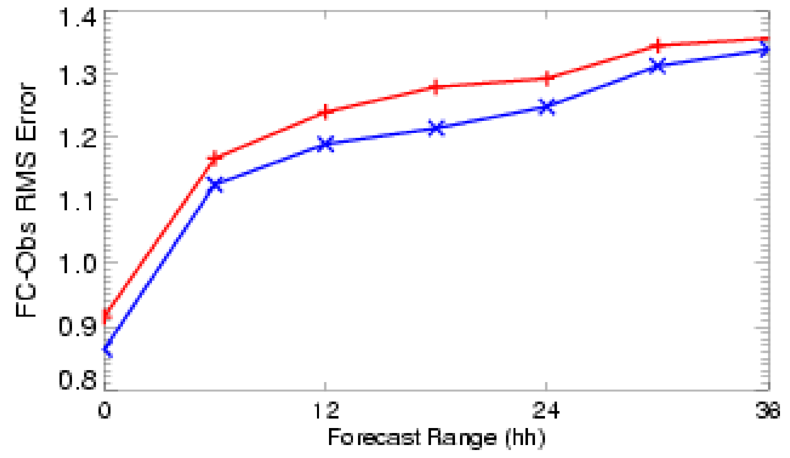


Symmetric Cloud Errors Sc Period – October 2010
T2m Verification

mean T2m error

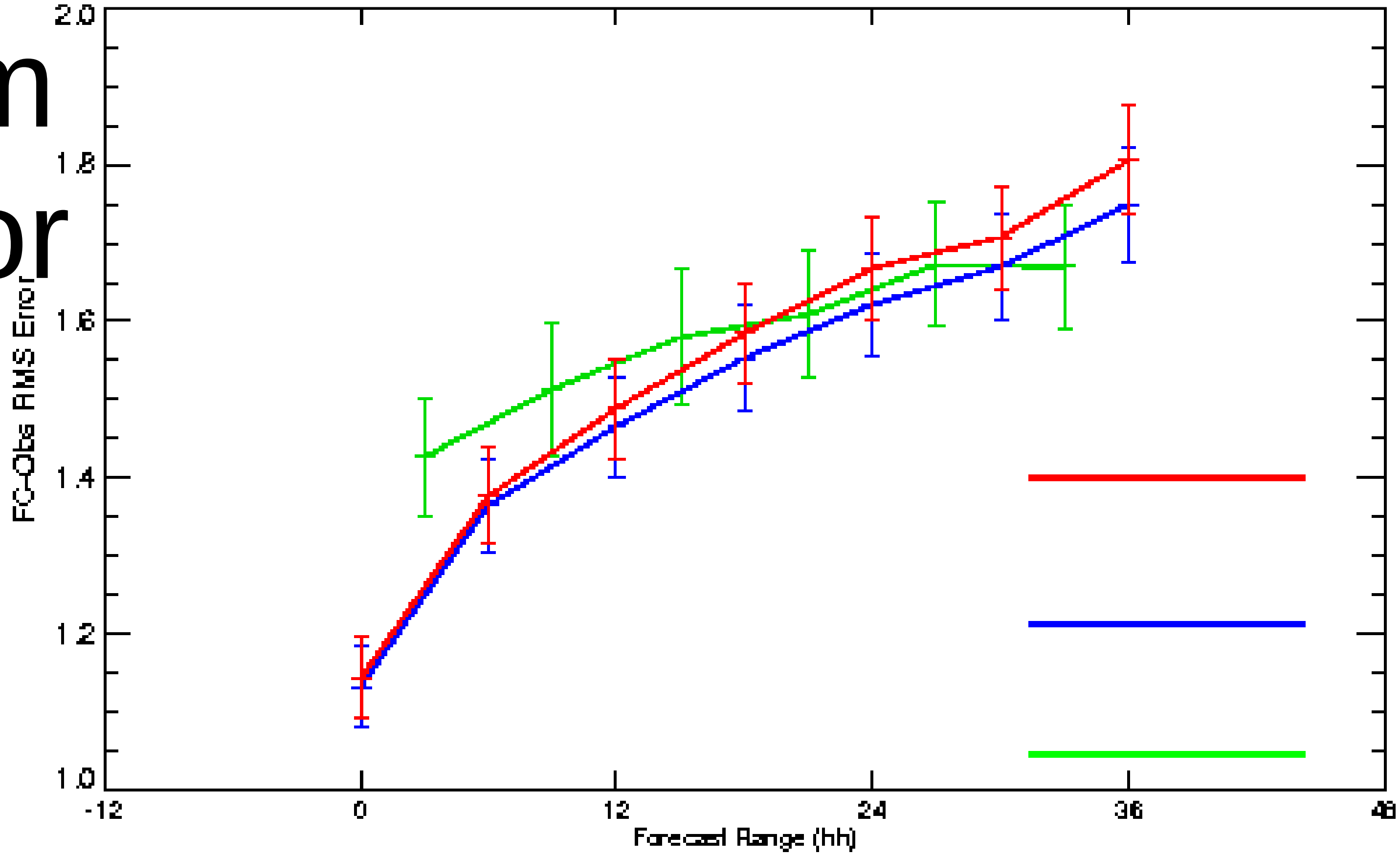


rms T2m error



Impact of high resolution assimilation in UK4 model

Rms T2m error



20 days, winter 10-11

CTRL

GL lbc

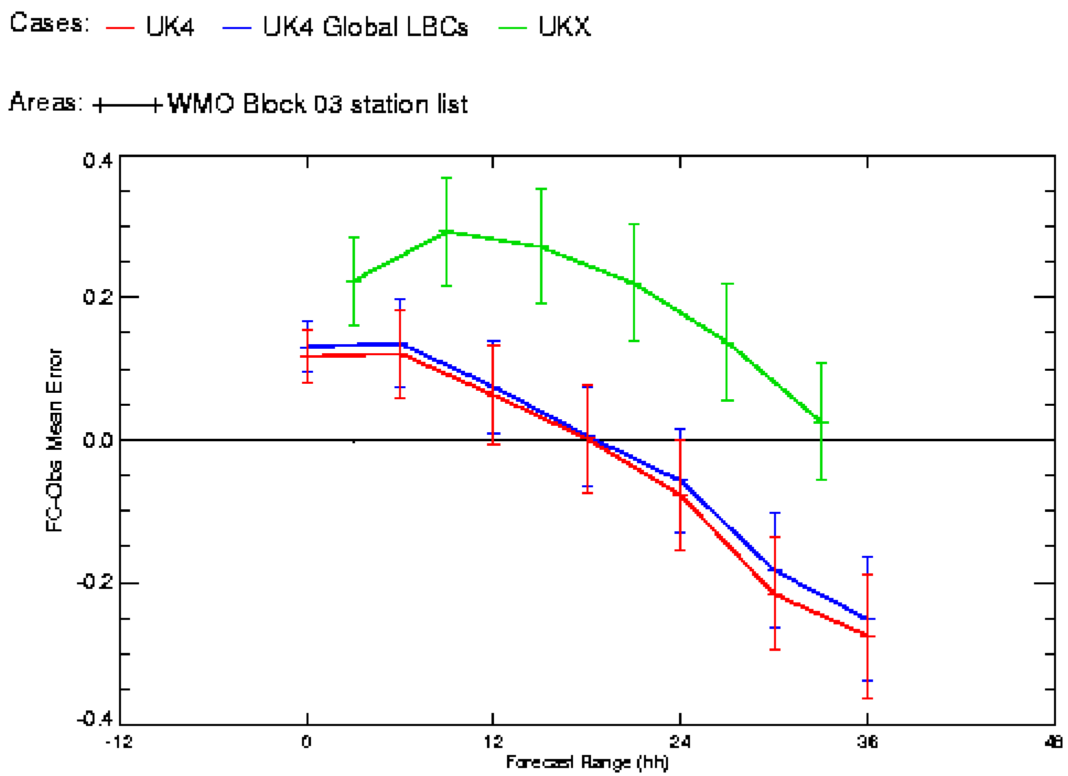
GL lbc + GL t-3 analysis

fc time (hr)

Mark Weeks

Impact of high resolution assimilation

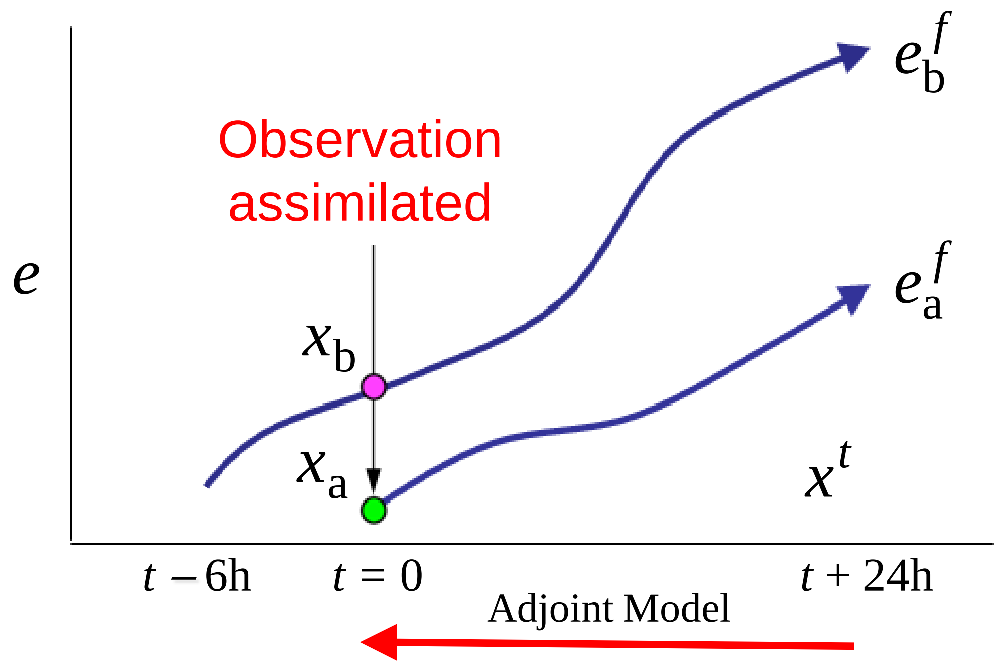
mean T2m error



Mark Weeks

Forecast Sensitivity to Observations (FSO)

Energy-weighted forecast error norms



Observation impact is quantified as the difference in forecast error norm

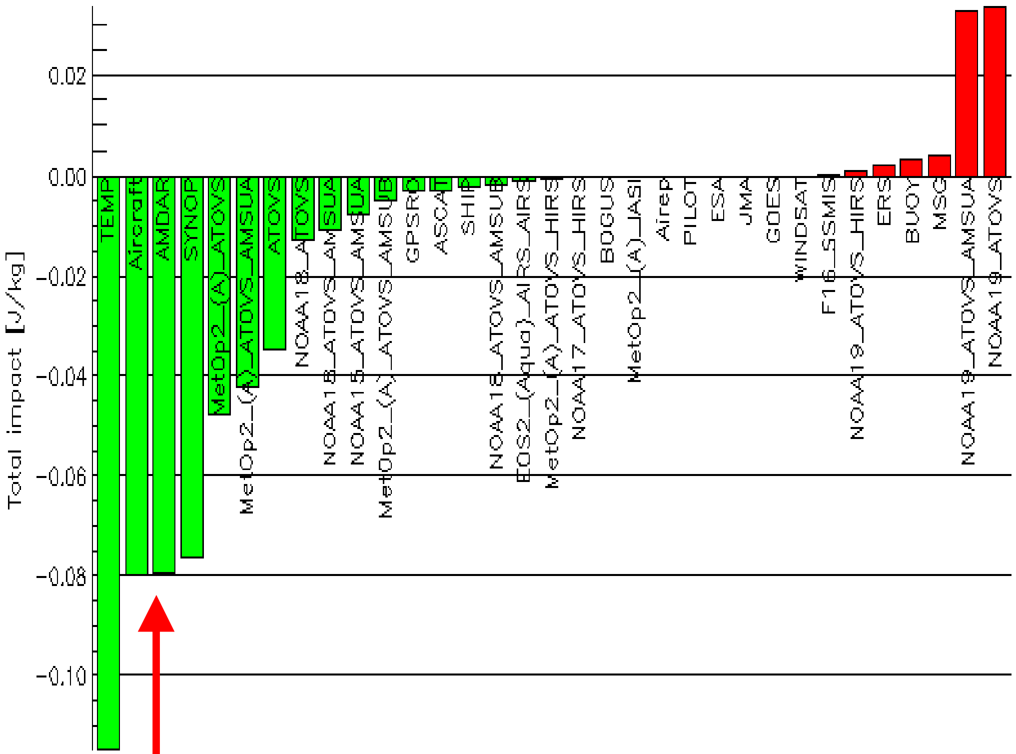
$$\delta e = e_a^f - e_b^f$$

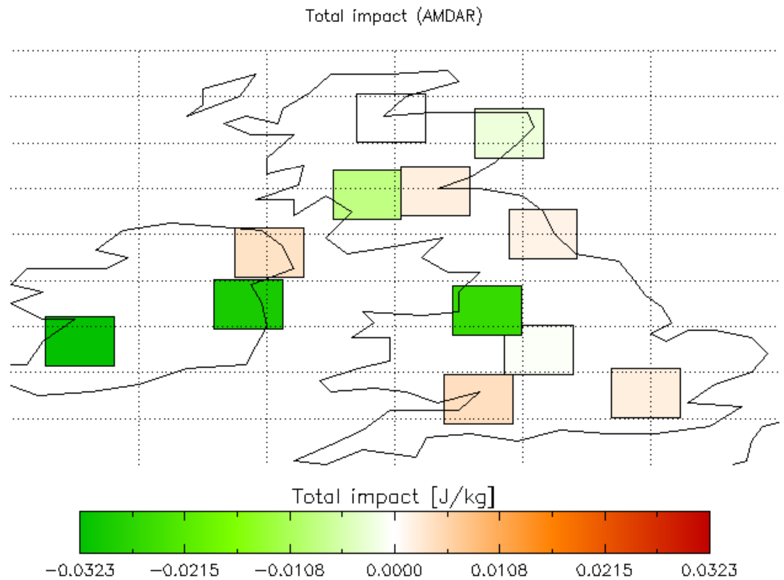
Adjoint of NWP model/DA system used to derive analysis/observation sensitivity.

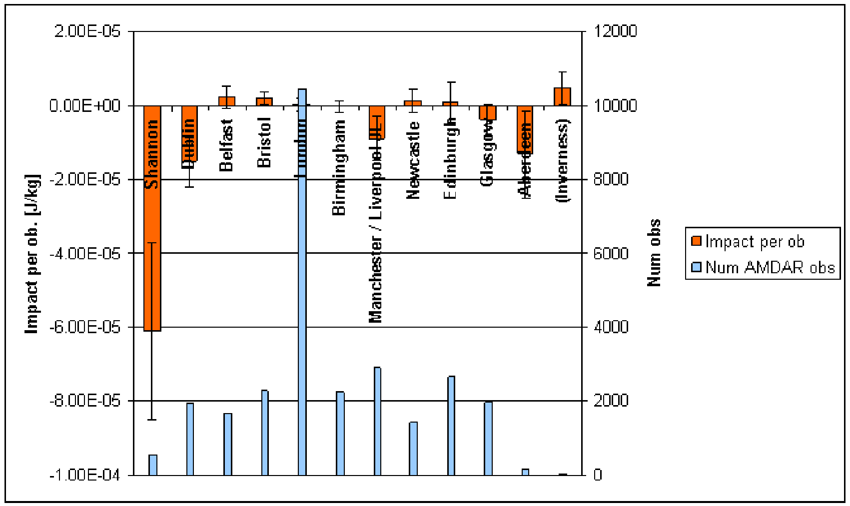
- FSO technique can estimate individual contribution of **every** observation.
- Reduces need for expensive data denial experiments.
- Assists optimal design of observation networks.

FSO Example Study: EasyJet AMDARs

3rd November – 13th December 2010 Global Model T+24 Forecast Impact Study







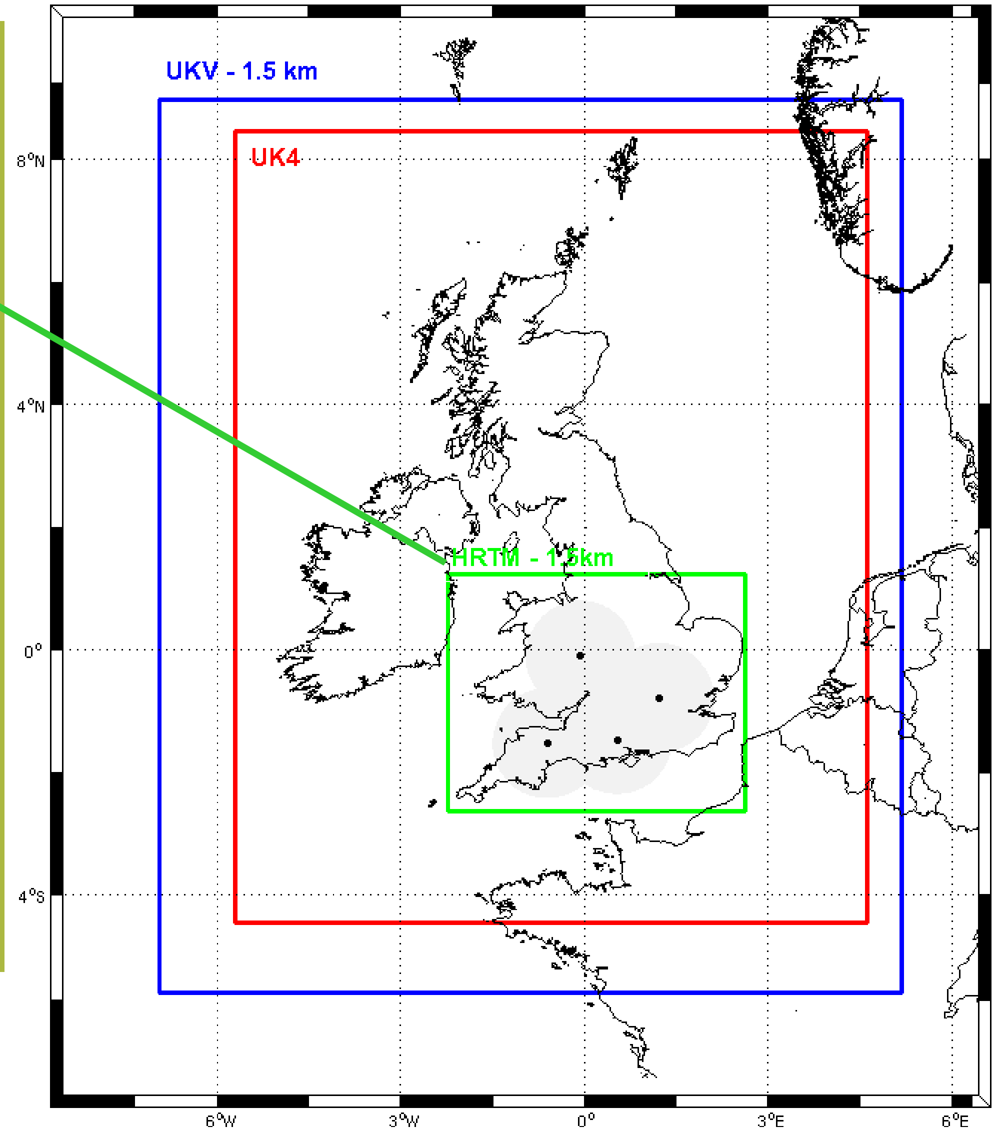
- AMDAR impact #2 after TEMP

- Significant regional variation in impact.

Richard Marriott

Nowcasting Demonstration Project

- 1.5 km NWP-based nowcasting system
- Southern UK only
- Hourly cycling, ~12 hr forecasts
- To be run in experimental mode during London's summer Olympics in 2012
- 3/4DVAR with Doppler winds/ reflectivities.



Sue Ballard

Future plans for UK assimilation

Met Office

- add large scale analysis increments from driving model whenever lateral boundary forcing is updated
- focus analysis increments on smaller horizontal scales
- replace MOPS cloud with separate assimilation of surface cloud obs and satellite cloud top
- expand network of Doppler radars
- assimilation of reflectivity (indirect / direct)
- SEVIRI radiances (clear and cloudy, sea and land)
- high resolution AMV's

Questions?