Convective-Scale Data Assimilation

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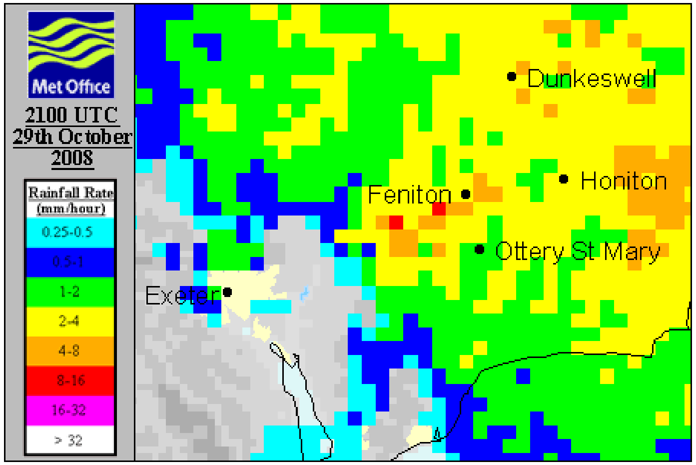
Luc Fillion (Environment Canada),
Kazuo Saito (JMA/MRI)

THORPEX/DAOS Working Group Meeting
20 September 2012, UW, Madison, Wisconsin, USA

Challenges For Convective-Scale DA

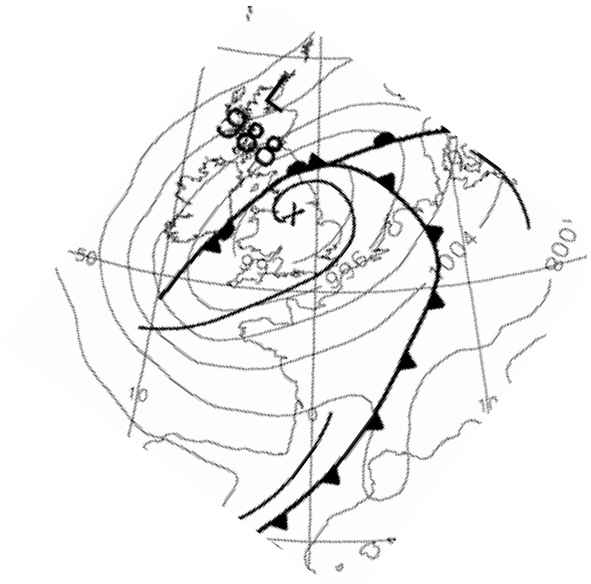
- Convection develops/evolves quickly.
- Good NWP model + model error estimate vital. >
- Rapid update and quick turnaround essential. >
- Many novel observation types available. >
- Highly nonlinear, complex error covariances. >
- Need to add value to global NWP. >
- Careful treatment of LBCs/large-scales required. >
- Predictability limit implies probabilistic approach.>



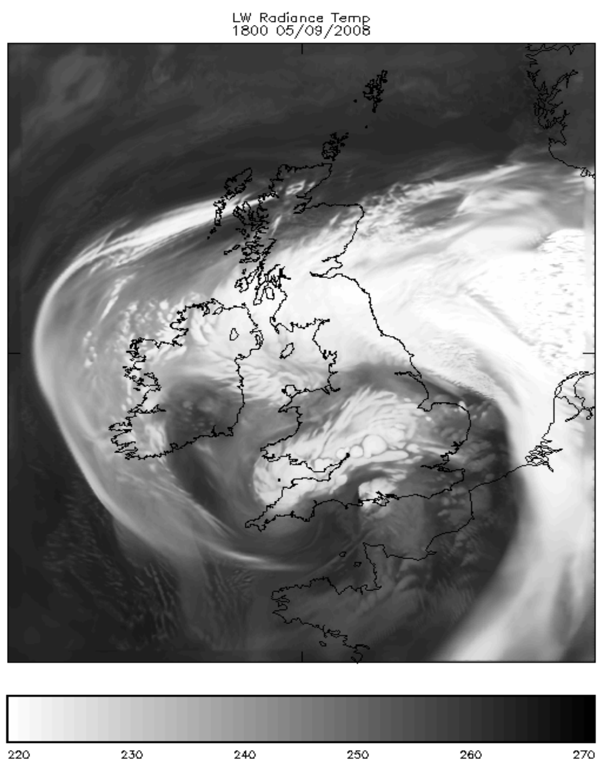
Convective-Scale NWP (UKV 1.5km)
The ‘Morpeth Flood’, 6 Sept 2008

- Prototype UK-V : 1.5 km L70
- No Data Assimilation
- Driven by 12 UTC 05 Sept 12 km Regional Model
- Starting from T+3 15 UTC Regional Model

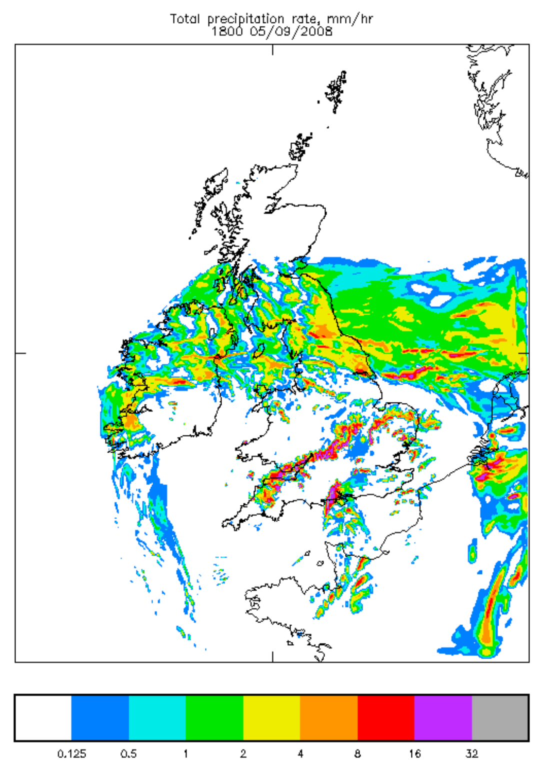
0600 UTC 6 Sept



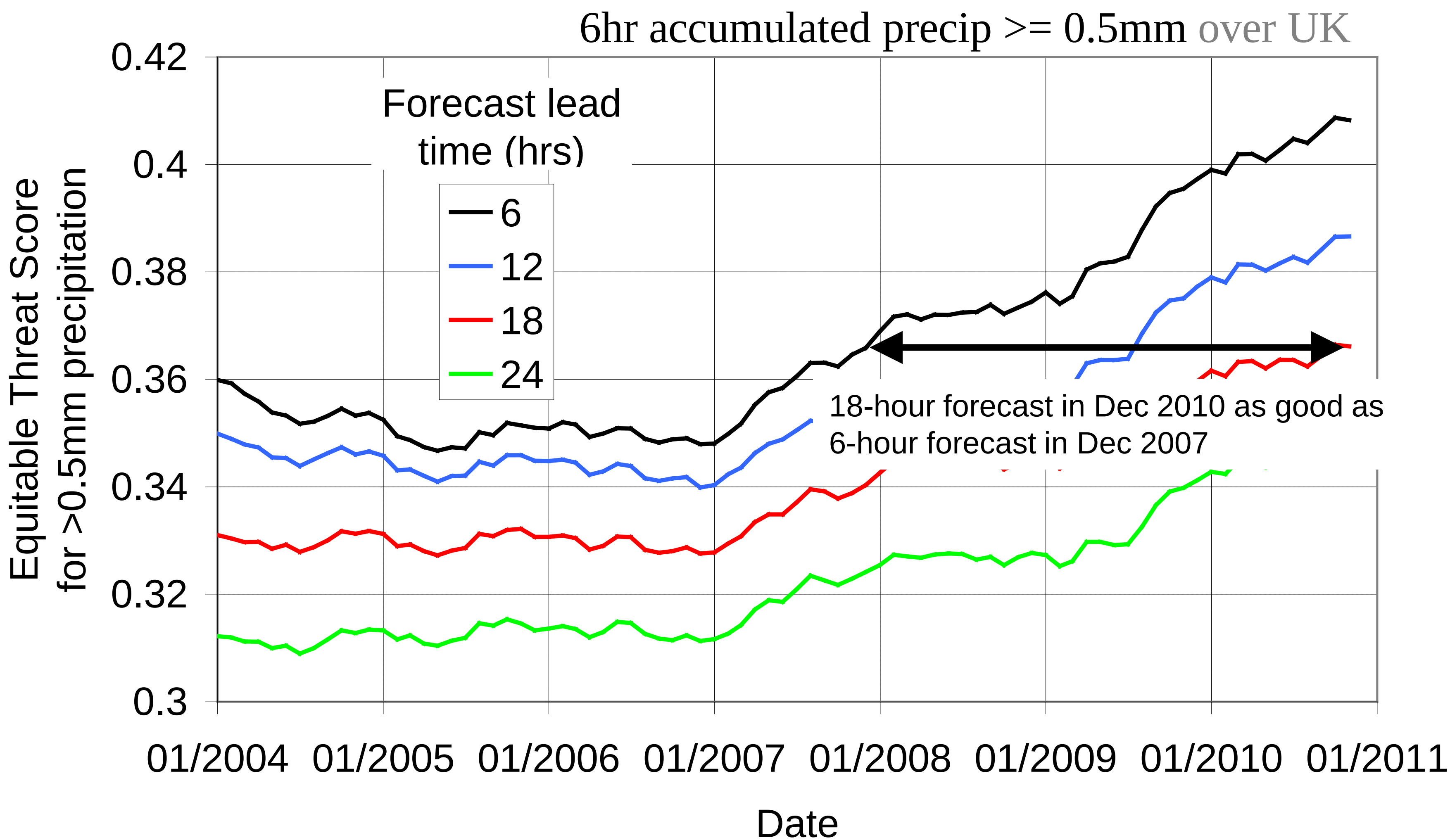
Model Simulated Imagery
18UTC 5 Sept => 15UTC 6 Sept



Model Precipitation Rate
18UTC 5 Sept => 15UTC 6 Sept



Improvements in UK Precipitation Forecasting at The Met Office

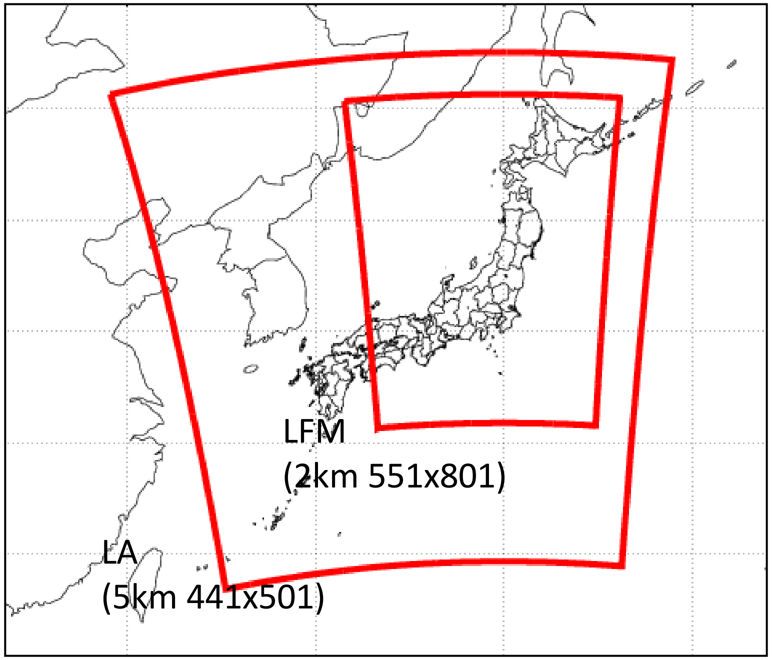


Bob Tubbs

JMA Local NWP System

- Operation has just started in Aug. 2012
- Objectives : Producing sophisticated disaster prevention and aviation weather information with high resolution NWP
- Systems
  - Forecast Model : Local Forecast Model (LFM) JMA Nonhydrostatic Model (JMA-NHM)
  - Data Assimilation System : Local Analysis (LA) 3DVar-system based on JMA-NHM (JNoVA-3Dvar)

Domains



Specifications

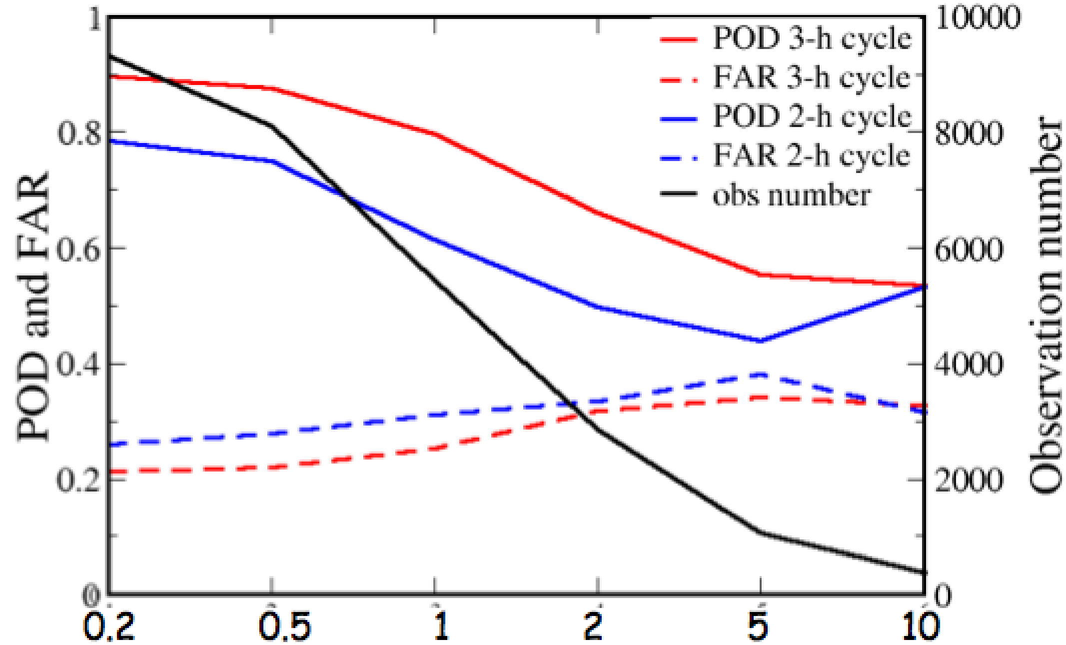
- Horizontal resolution ： 2km （LFM）
- Forecast term ： + 9hours (3 hourly)
- Boundary condition
  JMA Meso-Scale Model (MSM: dx=5km)

Kazuo Saito, JMA/MRI

AROME: Rapid Update Cycling Problems

- Experiments with 1, 2 and 3-h frequency continuous cycle during a 30-day-long period
  - 1-h cycle : forecast crashed after 2 days
  - 2-h cycle : poorer performance than 3-h cycle

Quantitative Precipitation Forecats scores for different thresholds for the total rain forecast between 0- and 12-h compared to rain-gauge measurements in November 2008

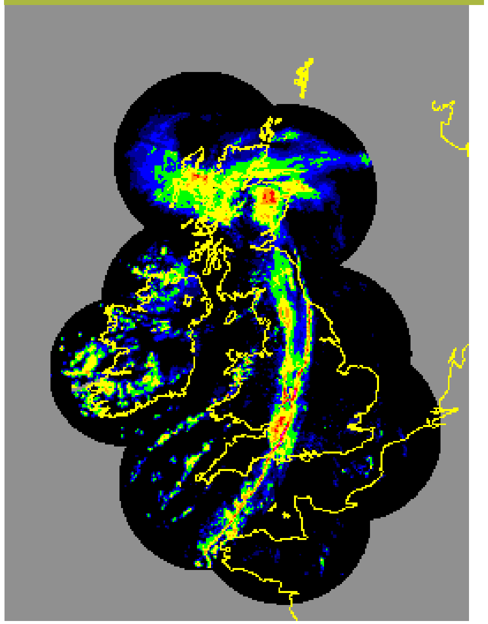


Brousseau (2009)

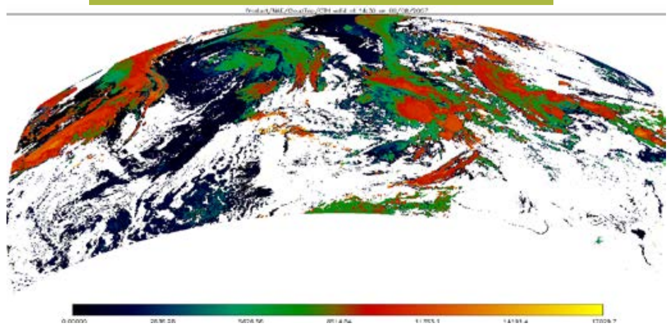
Met Office

Observations For Convective-Scale DA

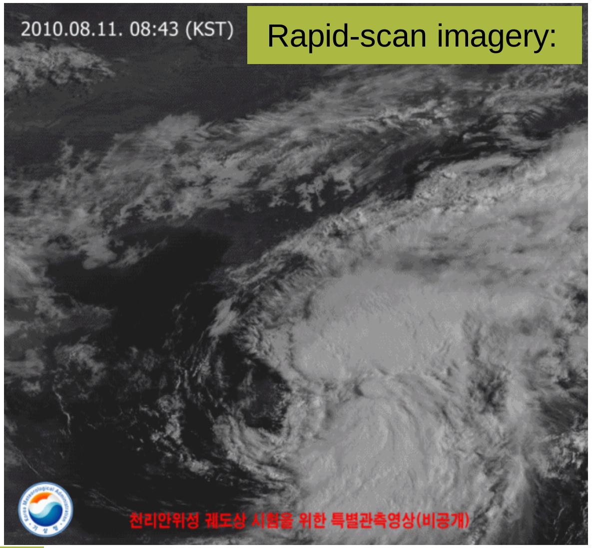
Radar (wind, reflectivity, etc)



SEVERI Cloud Top Height:

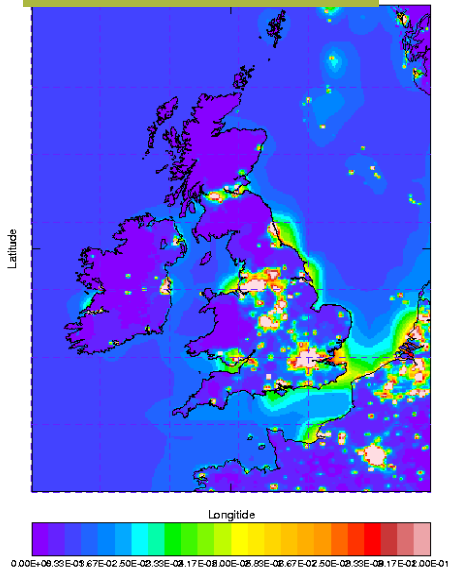


Rapid-scan imagery:

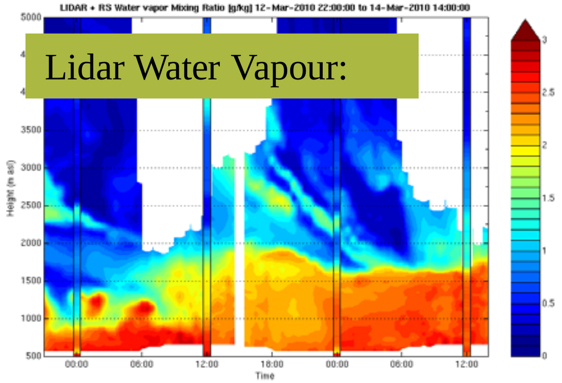


TAMDAR: T, u/v, RH, icing, turbulence:

Aerosol/visibility:



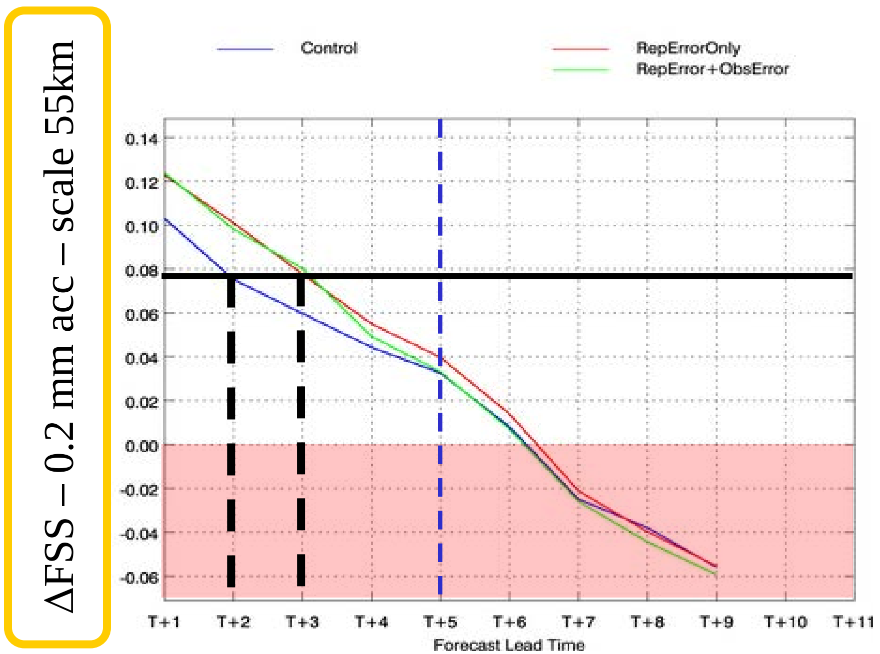
Lidar Water Vapour:



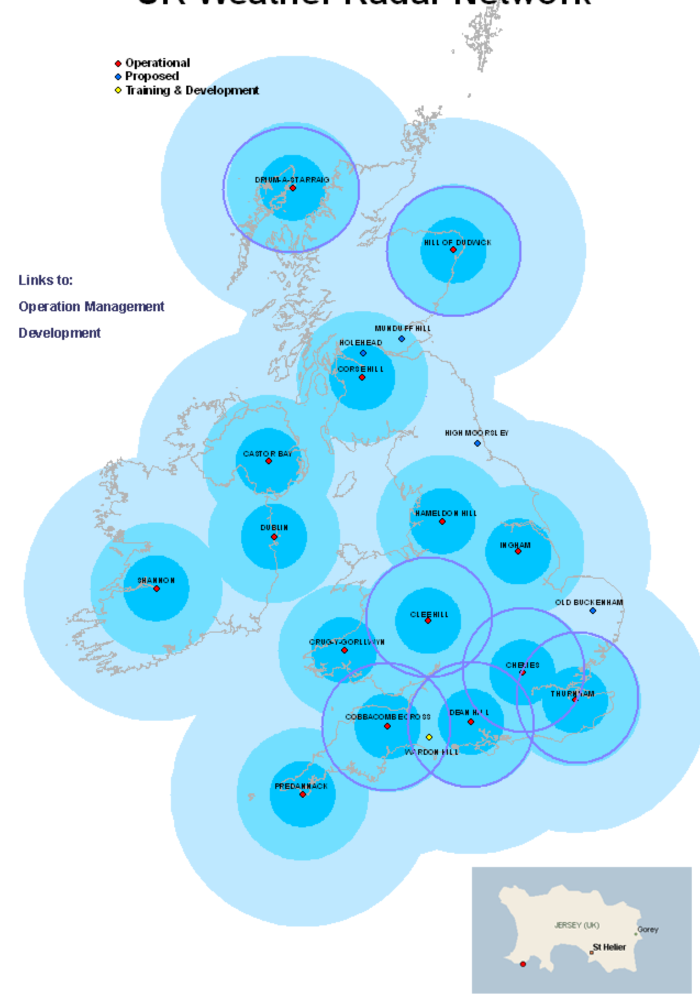
PV Cell (radiation):

Doppler Radial Wind Assimilation

- 6 radars providing radial winds for experiment
- Plans to upgrade whole network by 2013
- 1st assimilation in UKV: July 2011 (4 radars)



UK Weather Radar Network



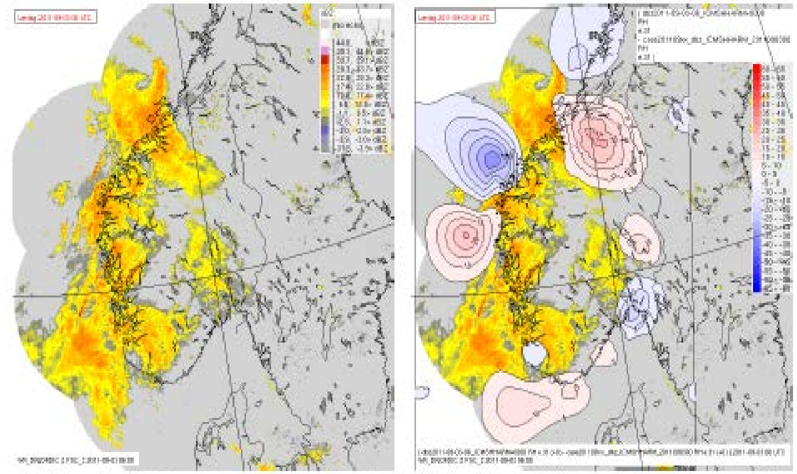
David Simonin

Assimilation of radar reflectivity data in HARMONIE (Jelena Bolarova, met.no)

Case Study in a non-optimal setup

(small domain + 6h update frequency)

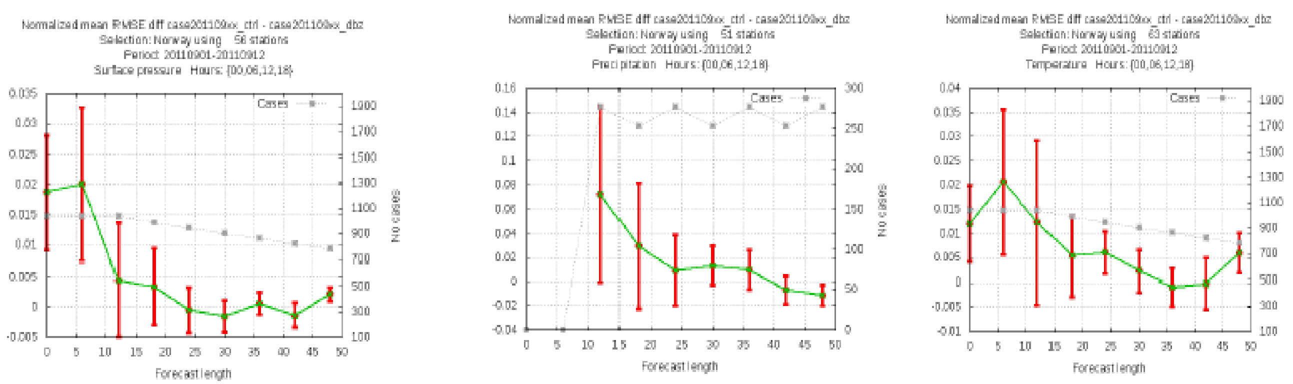
Positive impact on surface pressure, 12h accumulated precipitation and temperature scores for short forecast length



(a) Observed reflectivity at analysis time (Pseudo-CAPPI, *i.e.* reflectivity at about 500–700 m)

(b) Analysis minus first guess (model background) in relative humidity (RH) at model level 31

Figure 3.16: Analysis increments for HAR25EXP_RADAR. We can see that assimilation of radar reflectivity is increasing/decreasing relative humidity at appropriate places. Note that the pseudo-CAPPI plot does not reflect the full volume of observed reflectivity (which is used in the assimilation).



(a) Surface pressure (PS)

(b) Precipitation (12 h accumulated)

(d) Temperature

(*by Martin Sigurd Grønsleth and Roger Randriamampianina, met.no report*

Adaptive Mesh Transform

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

- Motivation: Introduce flow-dependence analysis response near strong temperature inversions in presence of stratocumulus clouds (no UKV ensemble so can't use hybrid method yet).

- Static adaptive mesh methods concentrate grid points where there is a rapid variation of the atmospheric field.

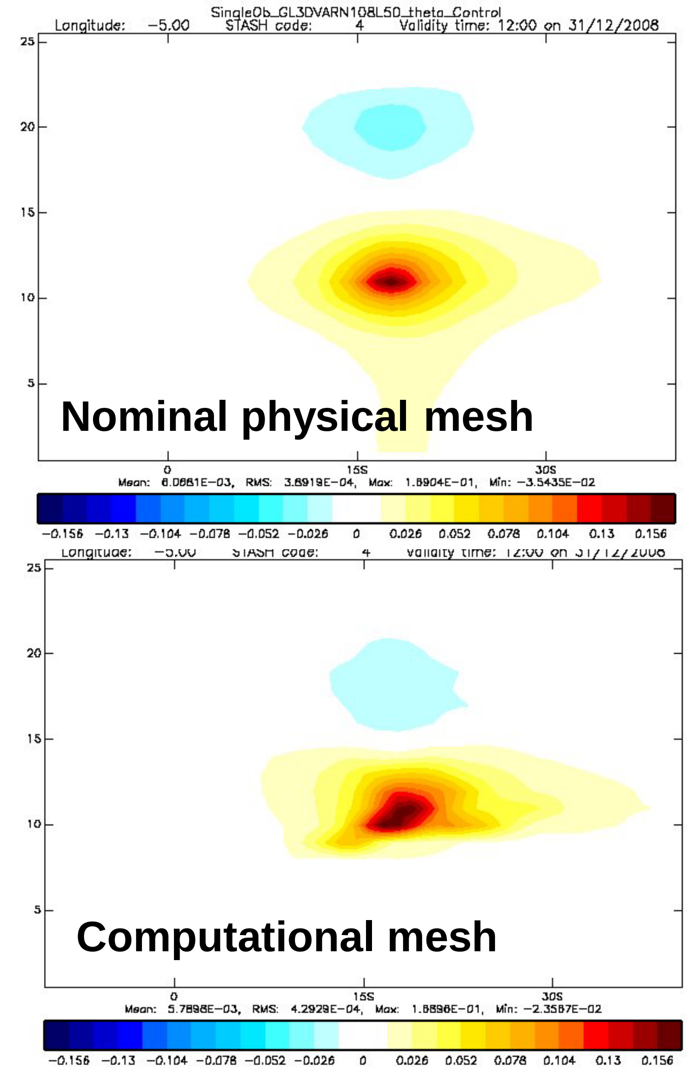
- Transformation from the physical grid to the computational grid is guided by a monitor function:

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

- Grid transformation introduced within VAR control variable transform:

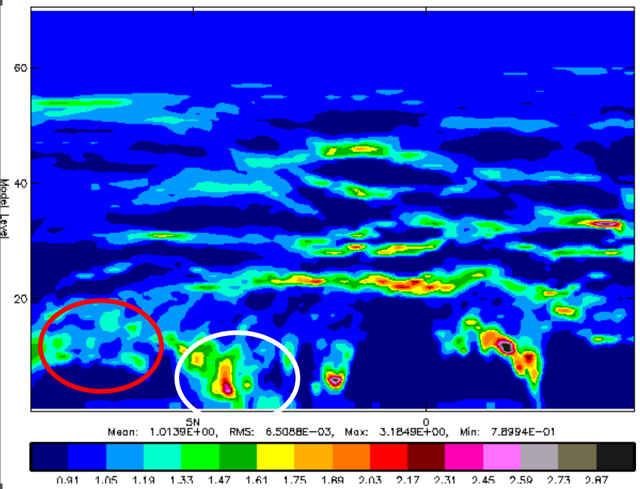
$$\delta\mathbf{x} = \mathbf{U}\mathbf{v} = \mathbf{U}_p \boxed{\mathbf{U}_a} \mathbf{U}_v \mathbf{U}_h \mathbf{v}$$

Analysis Increment for single q ob above Sc band

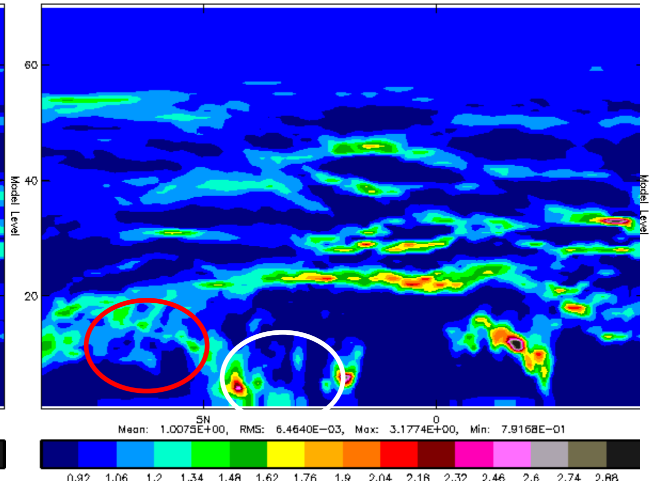


Iterative Calculation of Monitor Function

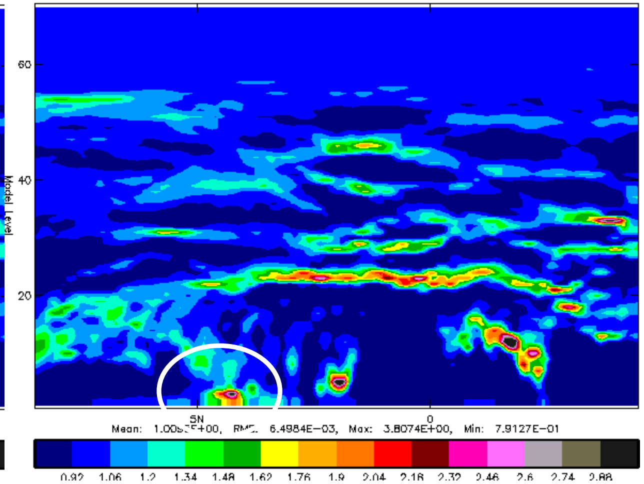
M (background-state - 3h forecast)



M (After 10 iteration 3D-Var)



M (After 2nd converged 3D-Var)

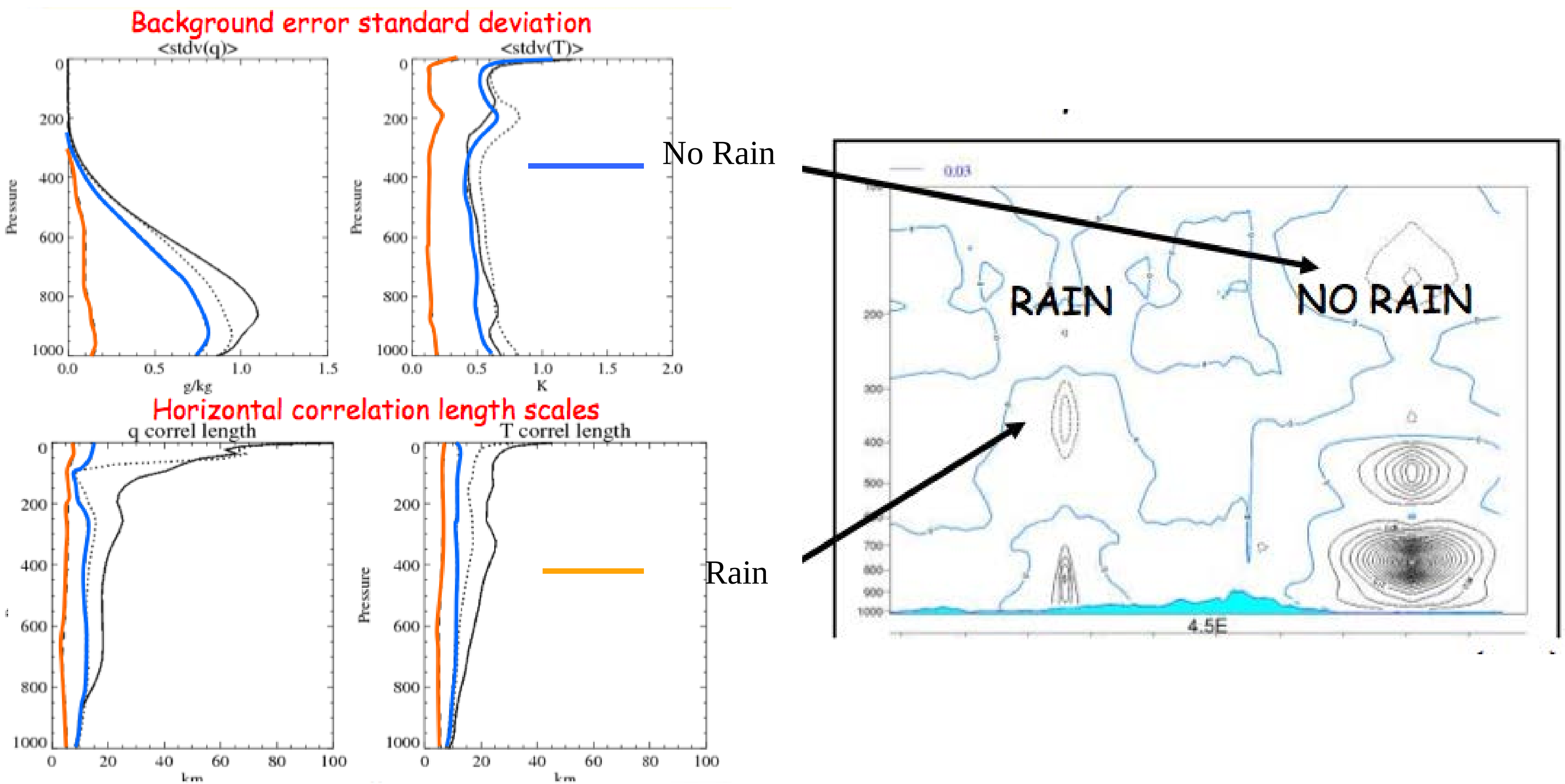


Adaptive vertical grid provides a small positive impact to the UK index:

Period	Vis	Precip	Cloud amount	Cloud base	Temp	Wind	Overall
23 Dec 2010 – 3 Jan 2011	-2.56%	5.48%	-1.05%	3.03%	0.22%	-0.04%	+0.25%
10 Aug 2010 - 20 Aug 2010	12.20%	0.00%	0.00%	4.17%	0.23%	0.10%	+0.55%

Partition of Error Covariance Between Different Regimes

Met Office



Brousseau (2009)

Surface DA : improved spatialisation tool

(MESCAN, EURO4M in collaboration with MF)

Introduction of more realistic correlation function in CANARI:

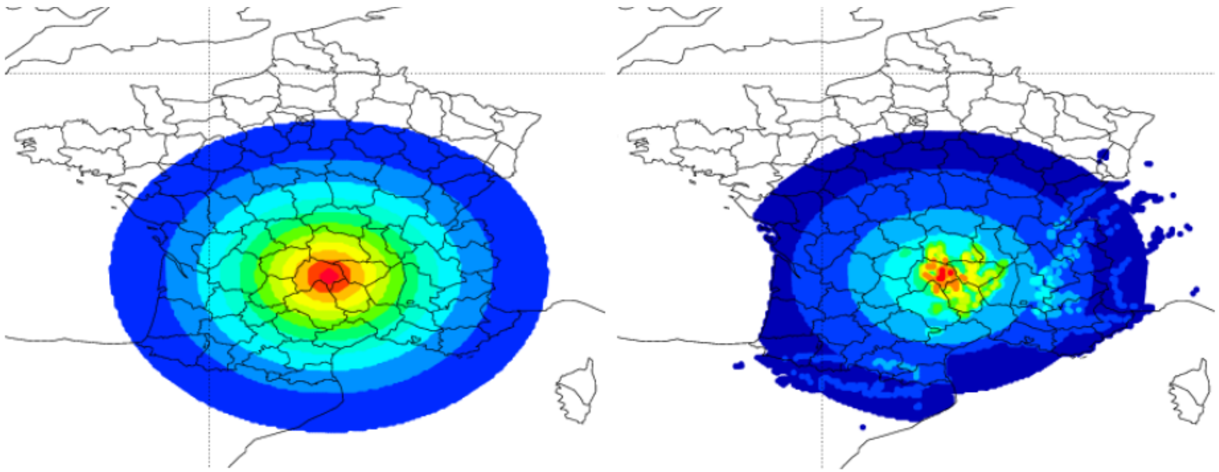
Old:

$$Corr_{CAN}(r) = e^{-0.5\frac{r}{d_1}}$$

New:

$$Corr_{MES}(r,d_p,d_z) = 0.5\left[e^{-\frac{r}{d_2}} + \left(1+\frac{2r}{d_2}\right)e^{-2\frac{r}{d_2}}\right]\cdot F_p(d_p)F_z(d_z)$$

after Häggmark et al, 2000, Tellus, 52A, 2-20.



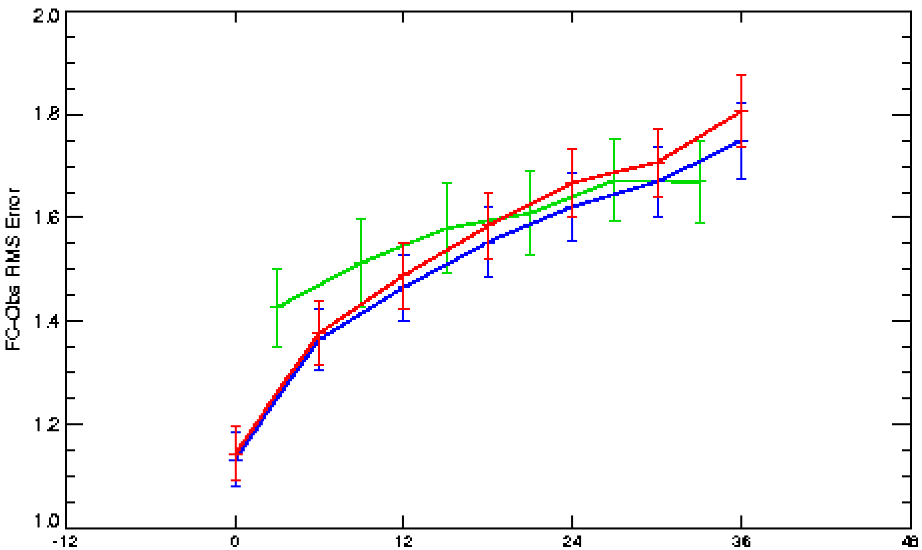
The new anisotropic correlation function creates more realistic analysis increments (right Figure) by accounting for height difference and land-sea mask.

by Tomas Landelius and Magnus Lindskog, SMHI

Convective-Scale (4km) DA – Why Bother ?

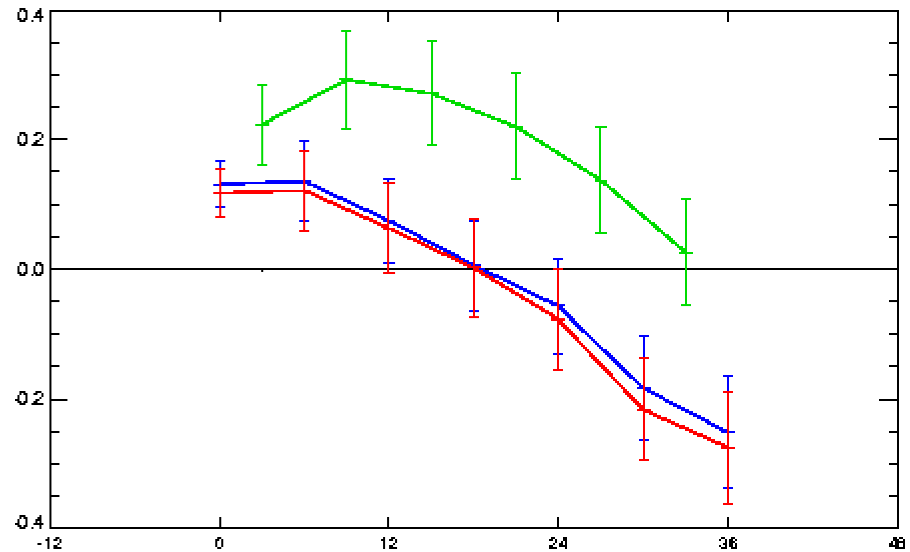
Impact of high resolution UK4 DA (20 days, winter 10-11)

T2m RMS error Vs Obs



fc time (hr)

T2m Mean error Vs Obs



fc time (hr)

UK4DA+NAE LBC

UK4DA+GL lbc

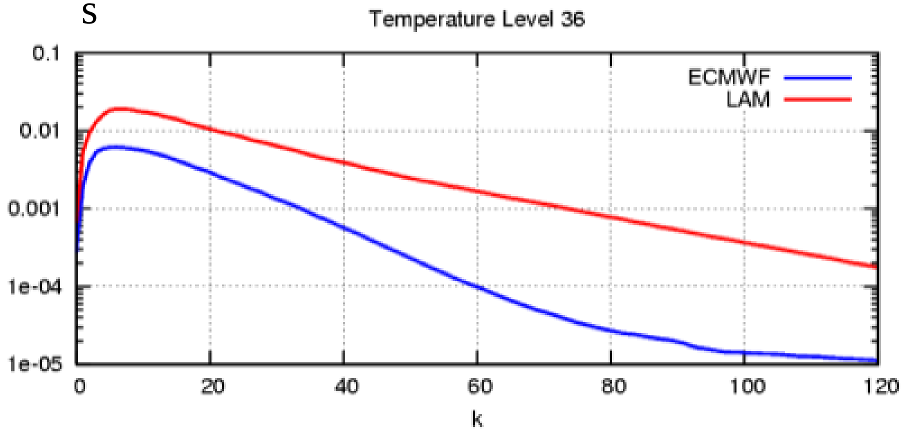
UK4 Downscaler (NoDA) +GL IC/lbc

Mark Weeks

Merging large/small scales

- Large-scale information from low-resolution model can be introduced to high-resolution DA system via a new term in the cost function:

Power Spectra For Low/High-Res errors
s



$$J_k = (\mathbf{d}_k + \mathbf{H}_2\delta\mathbf{x})^T \mathbf{V}^{-1} (\mathbf{d}_k + \mathbf{H}_2\delta\mathbf{x})$$
$$\mathbf{d}_k = \mathcal{H}_2(\mathbf{x}_b) - \mathcal{H}_1(\mathbf{x}_{ls})$$

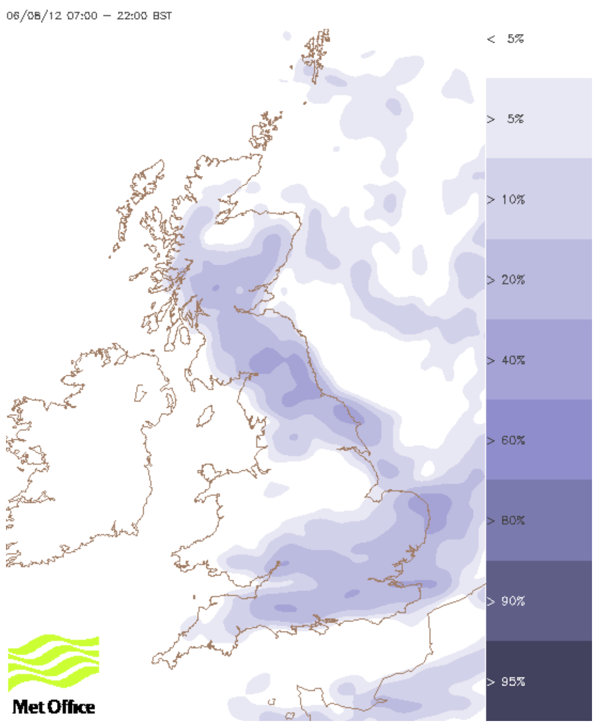
x_{ls}=ECMWF $+6h$ forecast
$\mathcal{H}_1$= Interpolate and truncate global field
x_b=HIRLAM first guess
$\mathcal{H}_2$= Truncate HIRLAM first guess
$\mathbf{H}_2$=Tangent linear of $\mathcal{H}_2$
$\mathbf{V}$=Error statistics for $\mathcal{H}_1(\mathbf{x}_{ls})$
$\delta\mathbf{x} = \mathbf{x} - \mathbf{x}_b$ increments in model space

- See Guidard V. and C. Fischer; 2008: Introducing the coupling information in a limited area variational assimilation *Quart. Jour. Roy. Meteor. Soc.*, ***134. 723-735*** and Lindskog (2008 EnKF workshop).

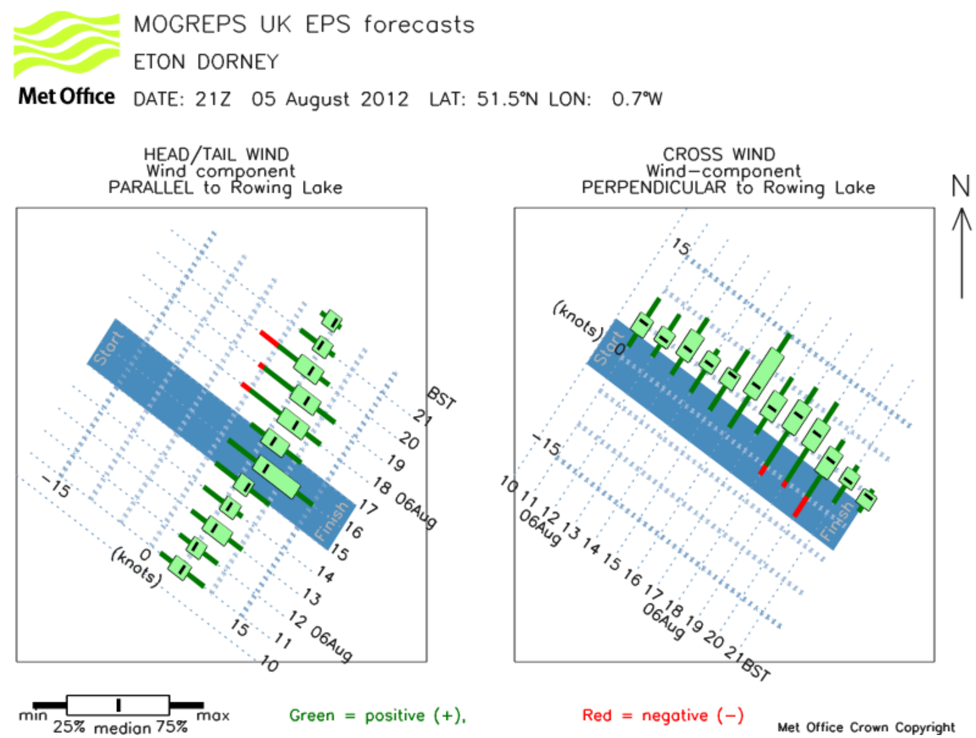
2.2km Convective-Scale Ensemble Showcase for London 2012 Olympics

6 August 2012

Probability Of Torrential Rain (>16mm):



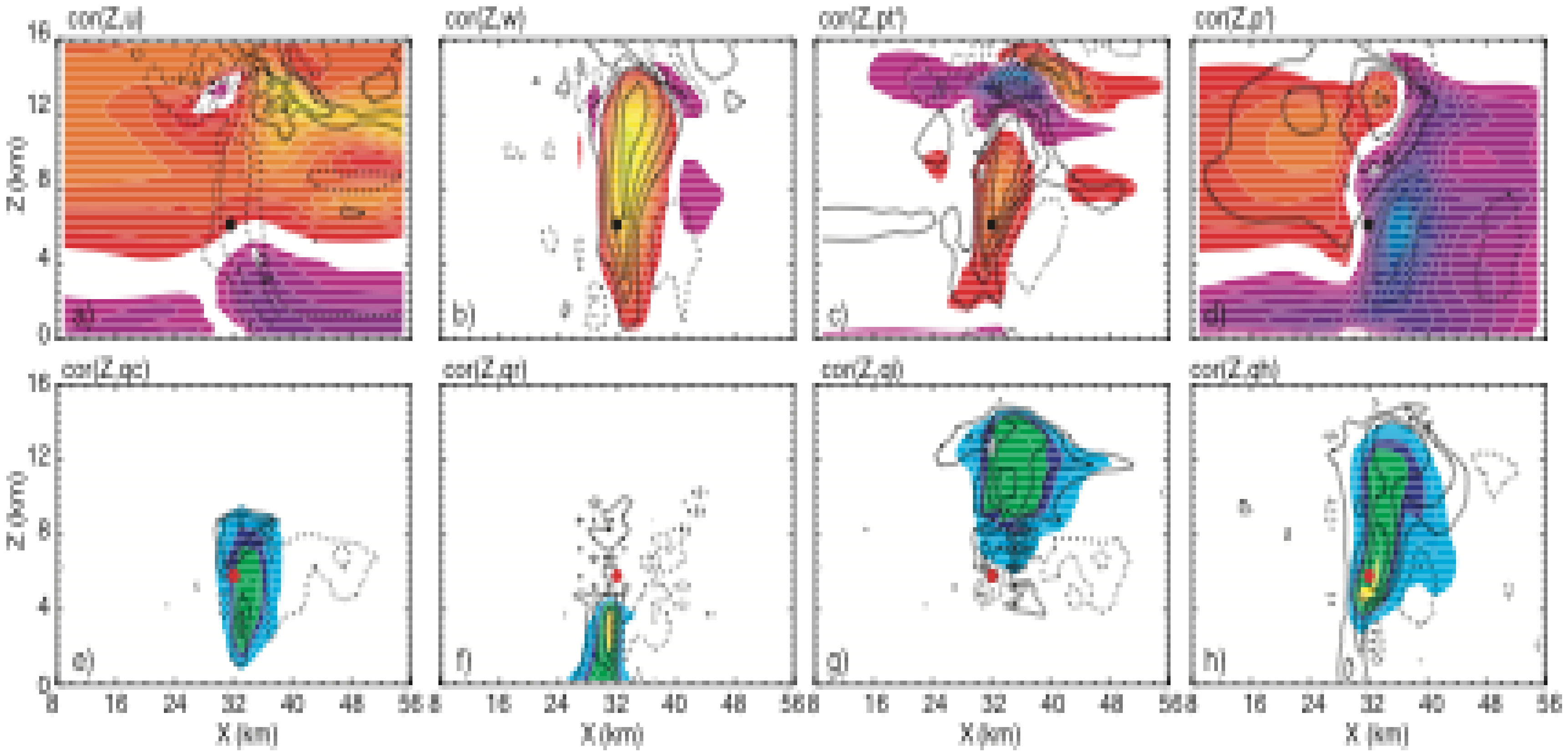
Wind Probabilities at Eton Dorney (Rowing):



- Availability of CS-scale EPS opens the door to CS-scale data assimilation

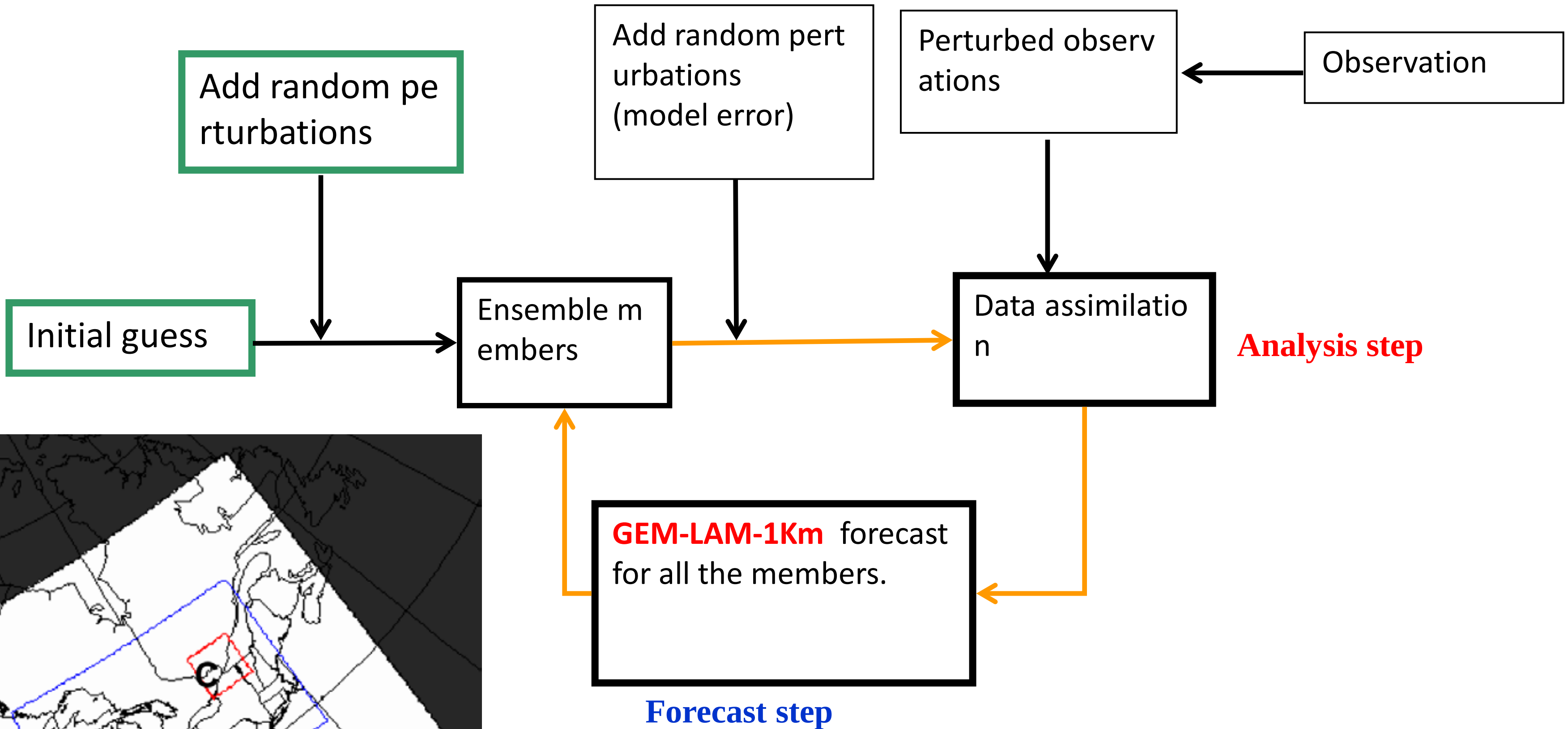
Error Correlations With Single Reflectivity Ob

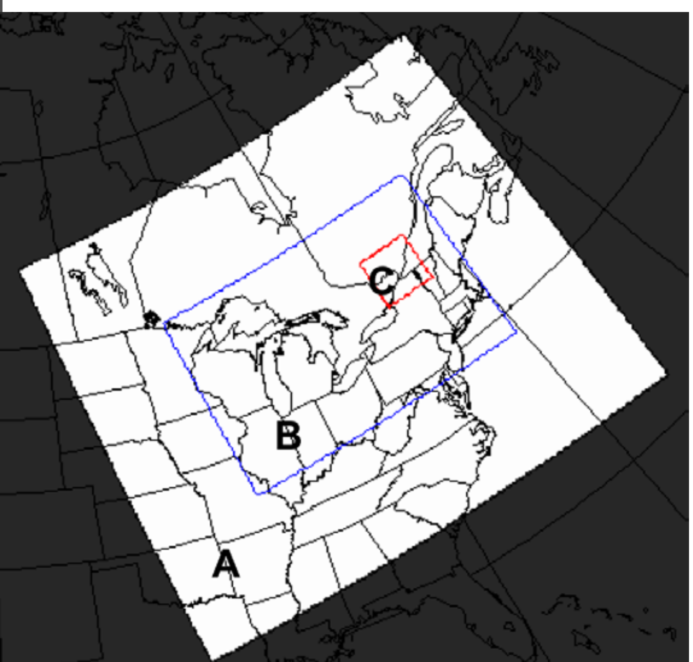
Shading : Full Fields **Line Contours : Error Correlations**



Tong and Zue (2005)

Canadian High Resolution Ensemble Kalman Filter System (HR-EnKF)





A: LAM15
B: LAM2p5
C: LAM1 300x300 (MTL region)

Luc Fillion, EC

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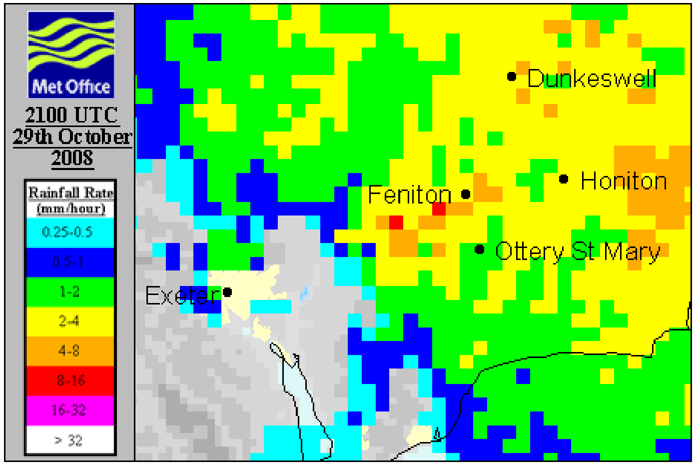
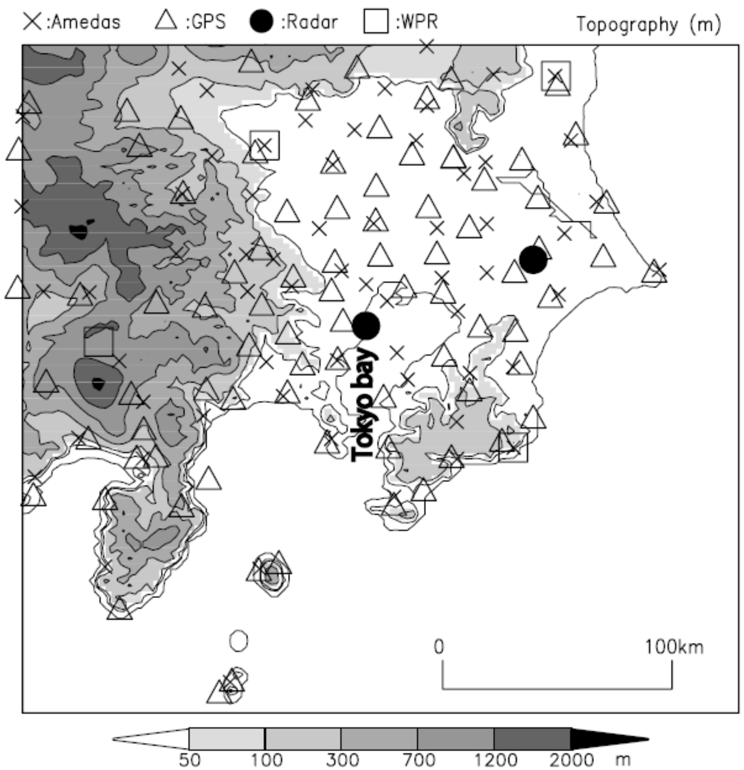


Met Office

Thank You!

JMA: Cloud resolving 4DVAR with cloud microphysics

(Kawabata et al., 2011; *Mon. Wea. Rev.)*



Kessler warm rain process was implemented in LT/ADJ models.

4DVAR assimilation of

- Doppler Radar's Radial Winds
- Radar Reflectivity
- GPS precipitable water vapor
- Surface observations (wind, temperature)

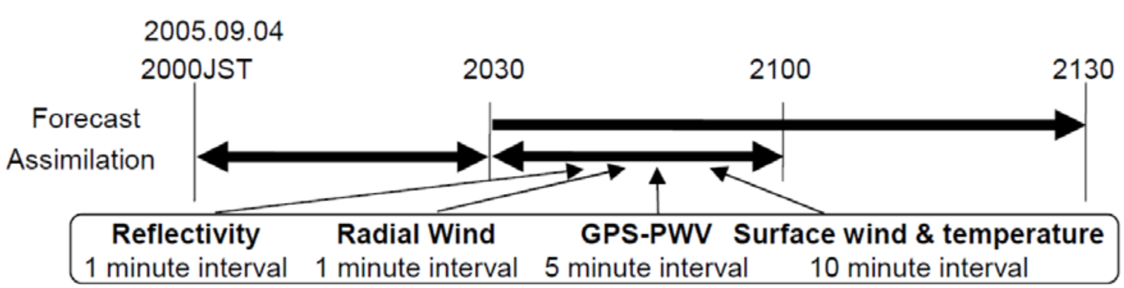


FIG. 9. Schematic diagram of assimilation experiment.