Norwegian Meteorological Institute

The 25 th ALADIN HIRLAM All Staff Workshop

13- 16 April 2015
Conference location: Conventum centre, Helsingjør, Denmark

Some thoughts about predictability on meso-scales and HARMONIE data assimilation performance or...

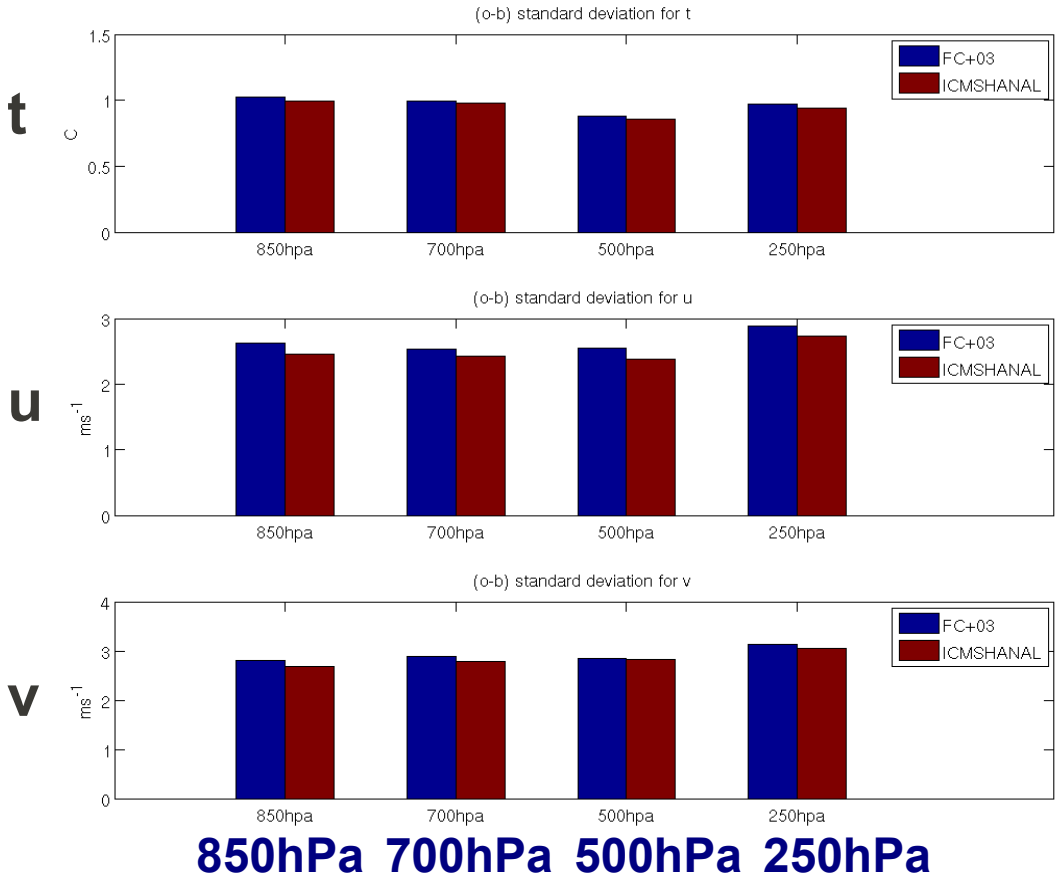
Uncertainty about Uncertainty

Jelena Bojarova *on behalf of the HIRLAM Team*

High Resolution Hirlam Limited Area Model + ALADIN = HARMONIE

We learn little from victory, much from defeat …

(Japanease Proverb)



850hPa 700hPa 500hPa 250hPa

Analysis error verified against AIREP observations

HARMONIE FC+3

HARMONIE FC+3 + LSM ECMWF

HARMONIE AROME 3DVAR 3hRUC
ECJAN domain;
800x800, 2.5km,
conventional + scatterometer winds
(from Gert-Jan Marseille)

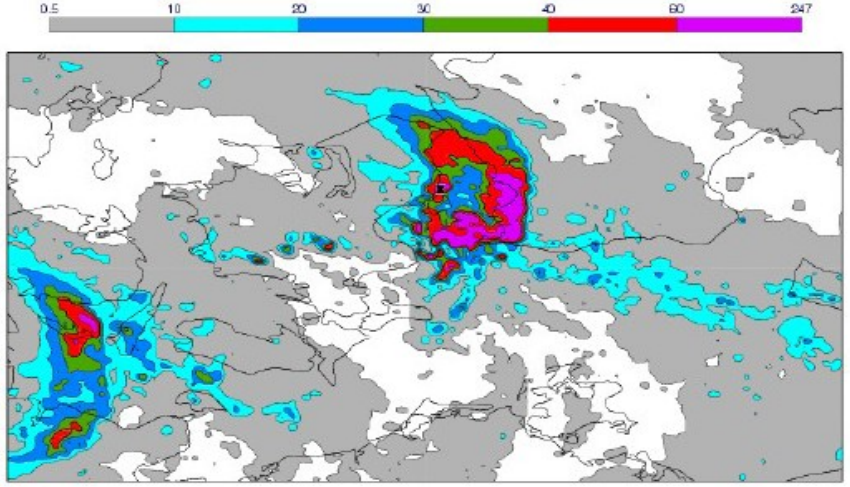
Whom to blame?...

→ 1) structure functions?
→ 2) unrealistic small scale structures?
→ 3) systematic errors (model biases) ?

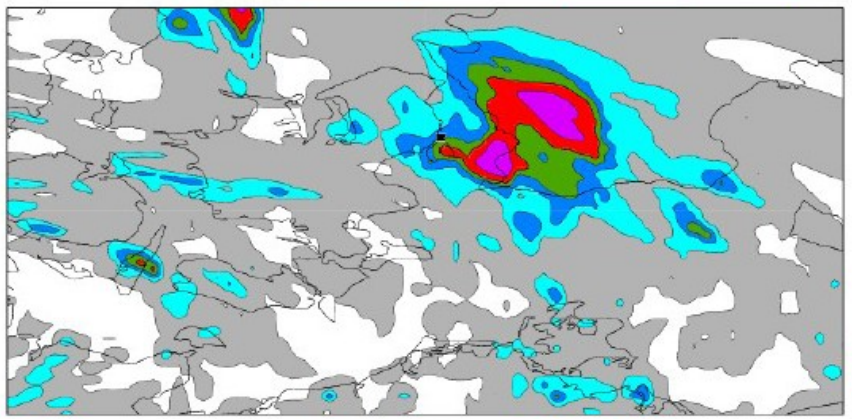
Verification of the HARMONIE A
2.5km forecasts for extreme we
event

(from Xiaohua Yang (DMI) &
Lisa Bengtsson et al (SMHI))

Radar data 31.08 00UTC - 12UTC



HARMONIE AROME + 30h (MetCoOp)



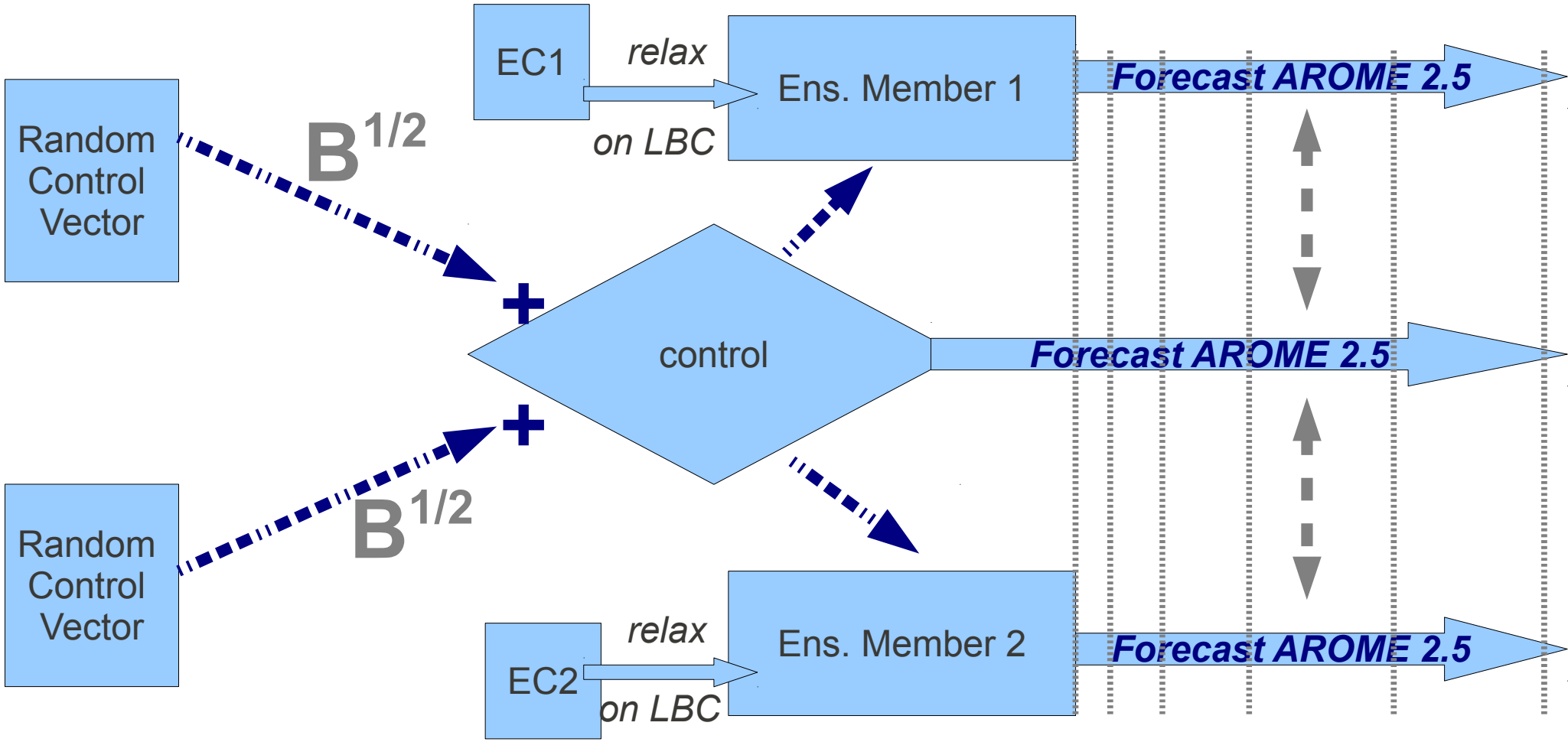
12 h accumulated rainfall

The HARMONIE AROME **is capable** in many cases to predict convective precipitation events (severe high impact weather events);

Stochastic nature of the convective phenomena should be taken into account both for verification and in post-processing (timing and location uncertainty);

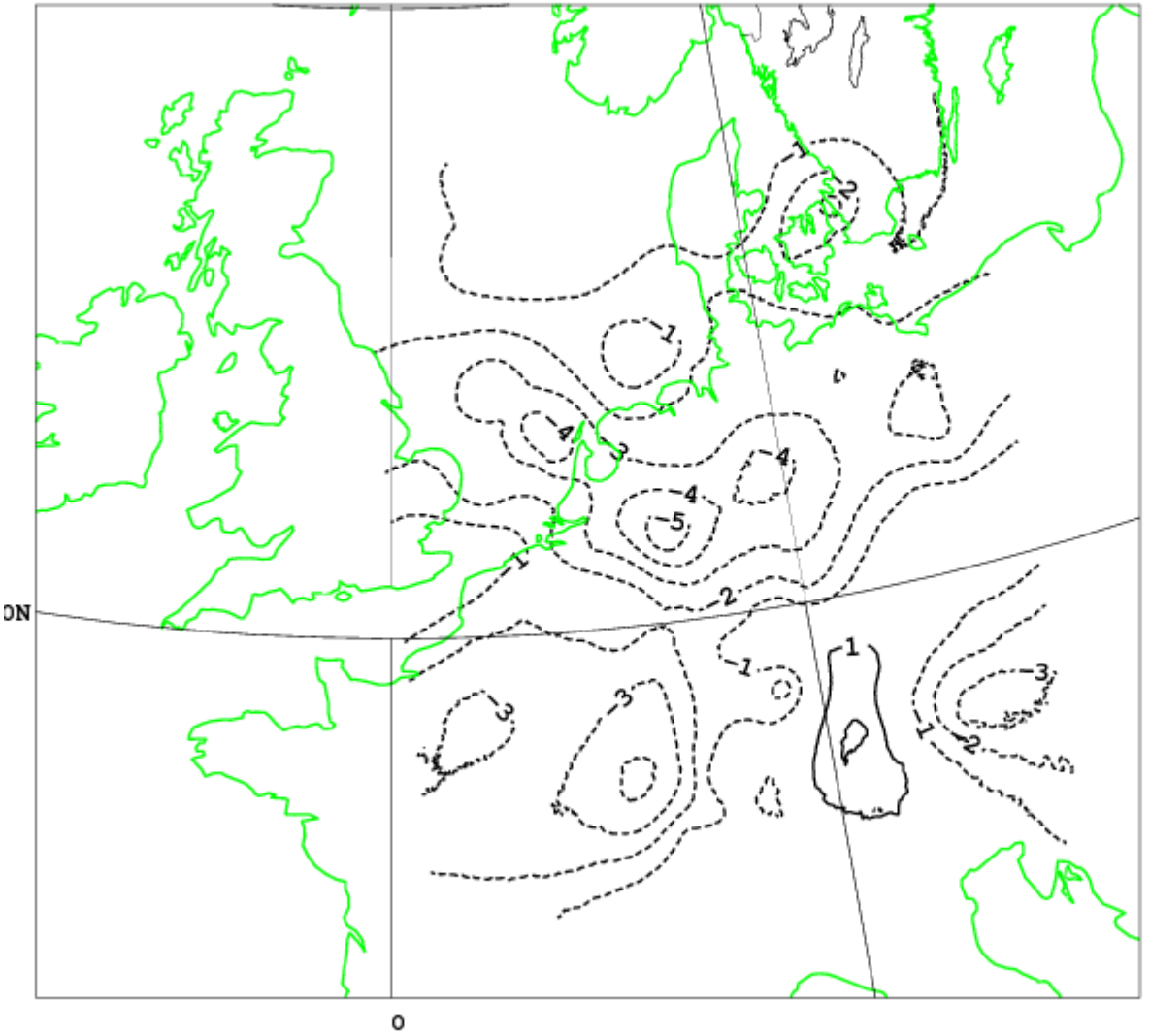
The quality of the short-term forecasts in the operational runs is not satisfactory : **coupling strategy and data assimilation to be blamed**

What to do ? => First of all, try to simulate and understand what happens (more exactly what goes wrong) during the data assimilation process in HARMONIE AROME 2.5



The Scheme: generation of perturbations with the structure of B-matrix covariance.

A typical (!) analysis increment in the experiment (12 – 25 August 2012)

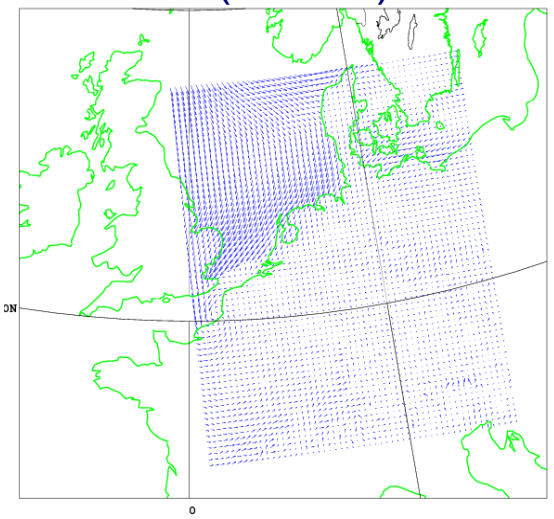


➔ Surface pressure is too high and we are not able to correct it...

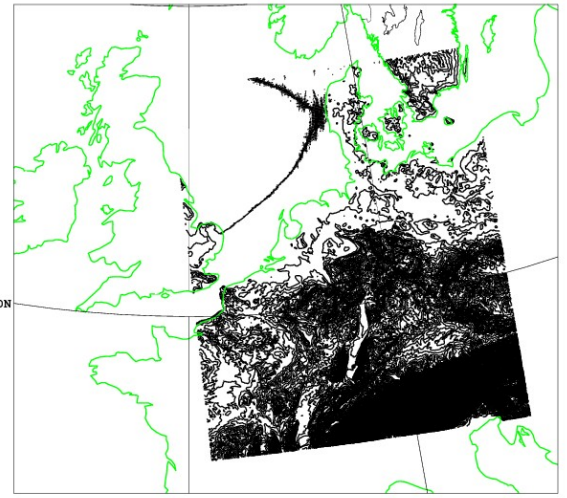
Evolution of two random perturbations with structure of B-matrix covariance

Forecast length: +00h

10-m wind (control)

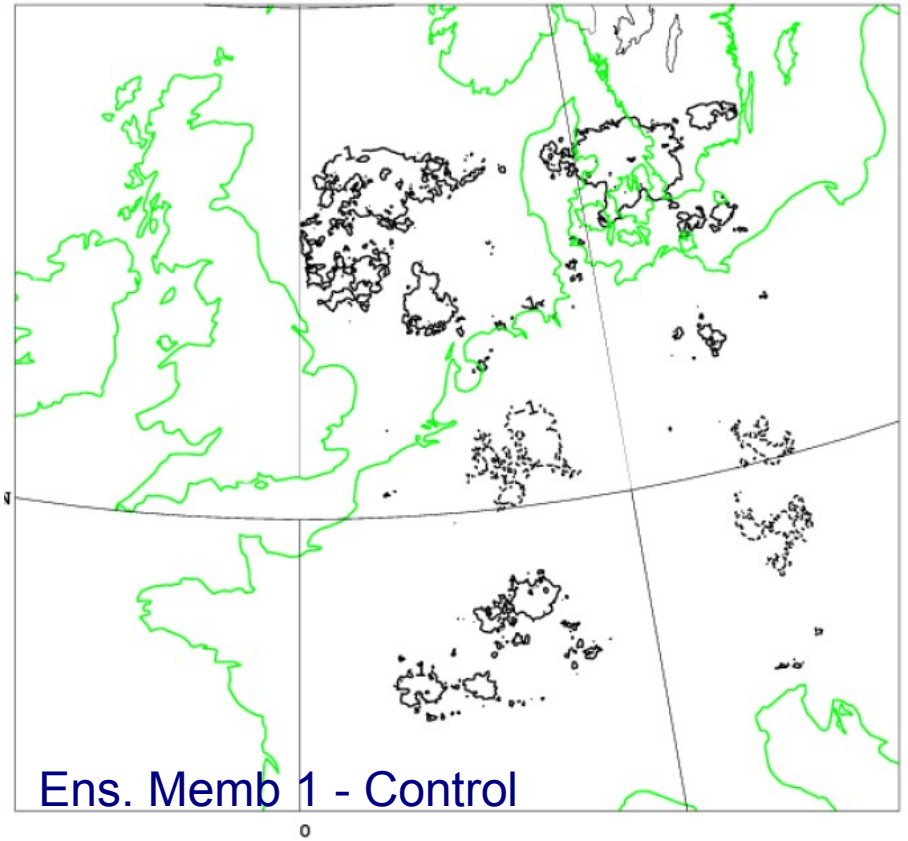


Surface pressure (control)

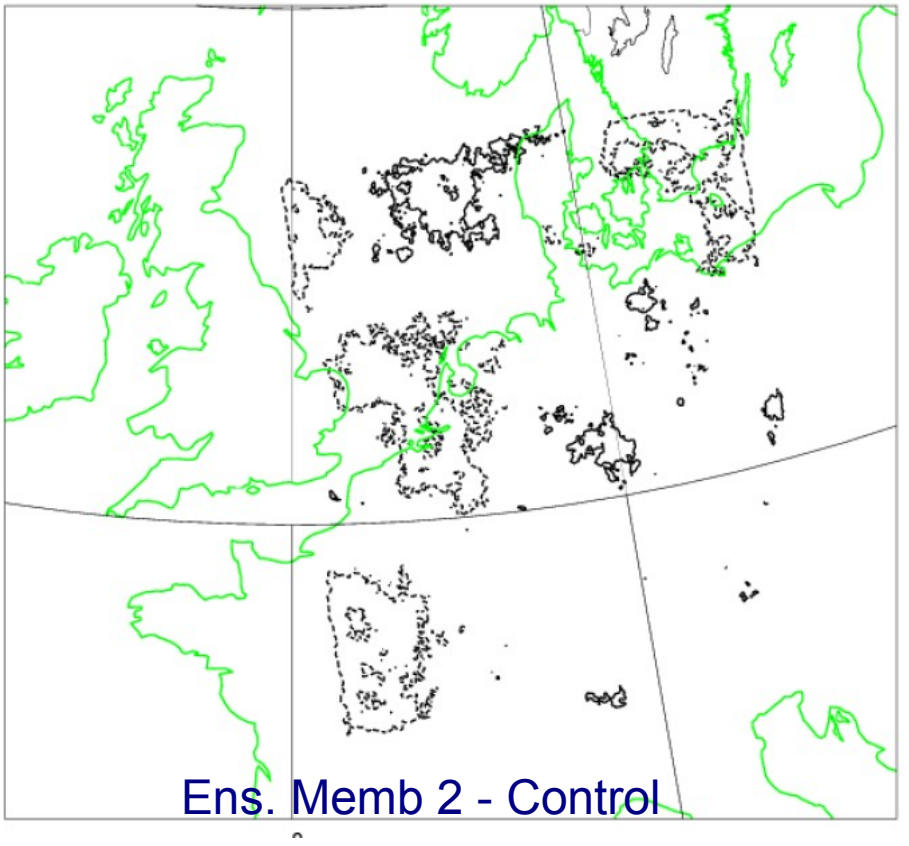


Surface pressure increment

13 06 2012 03UTC



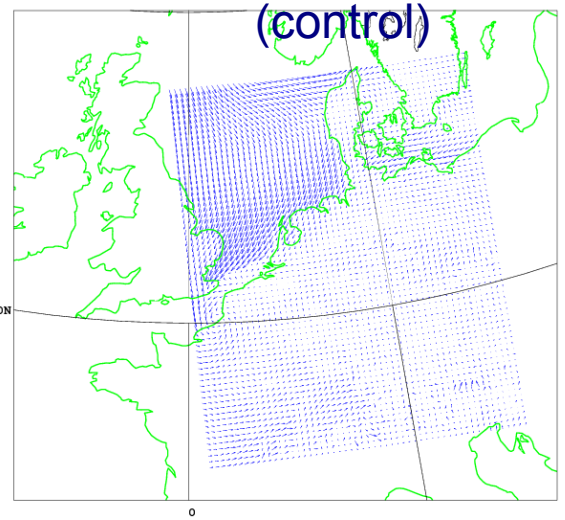
Ens. Memb 1 - Control



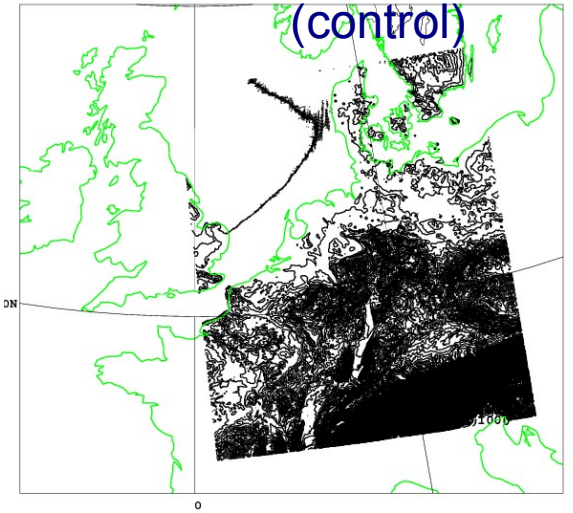
Ens. Memb 2 - Control

Evolution of two random perturbations with structure of B-matrix covariance

10-m wind (control)



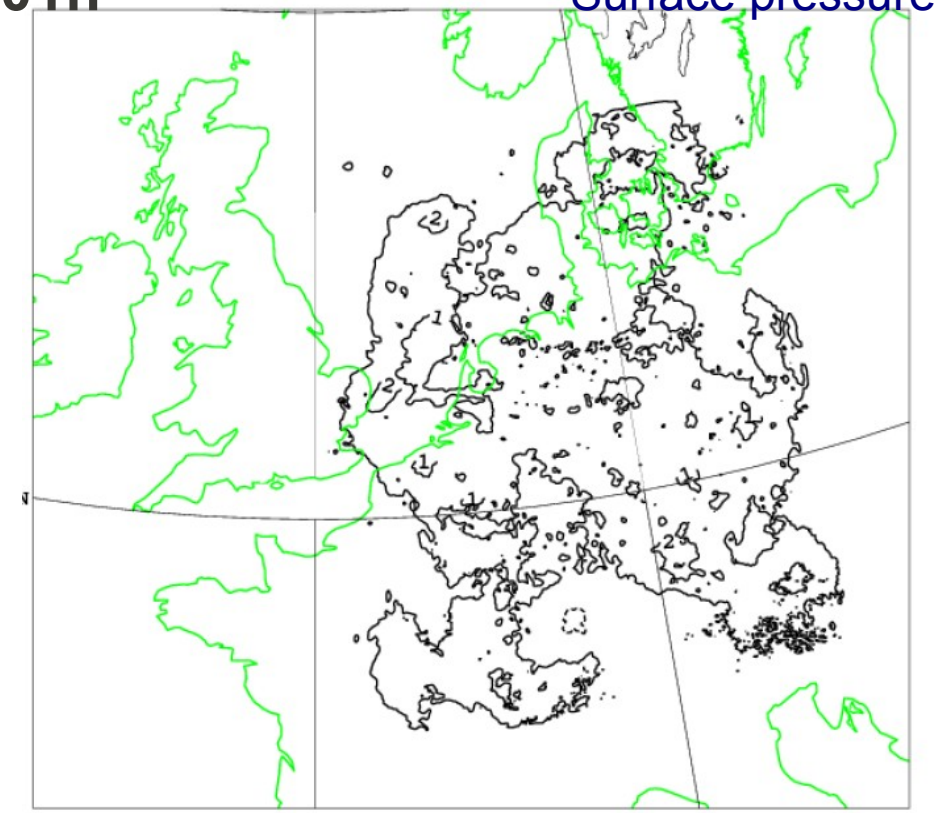
Surface pressure (control)



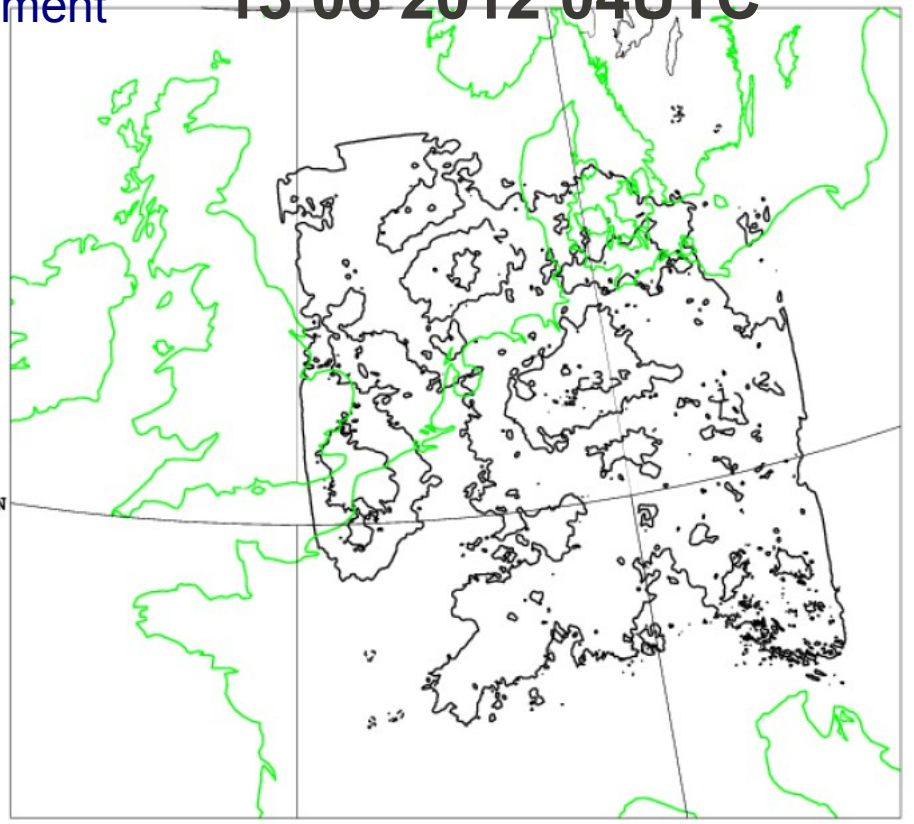
Forecast length: +01h

Surface pressure increment

13 06 2012 04UTC



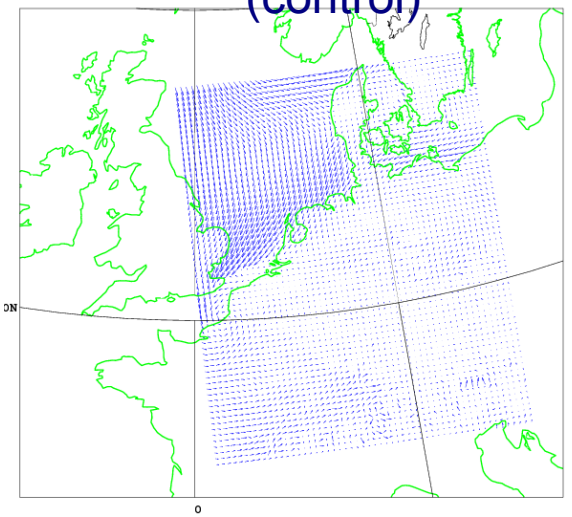
Ens. Memb 1 - Control



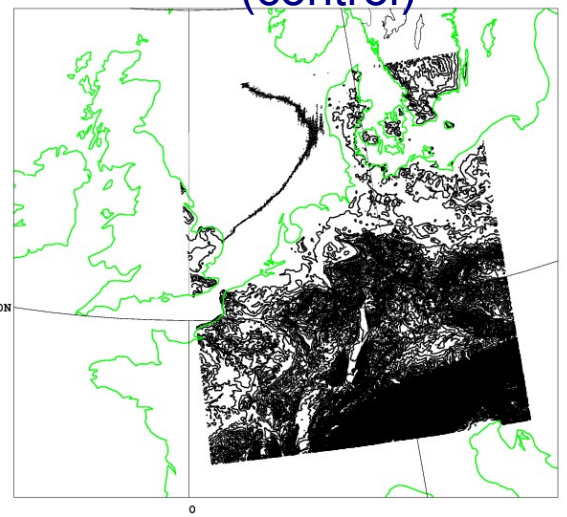
Ens. Memb 2 - Control

Evolution of two random perturbations with structure of B-matrix covariance

10-m wind (control)



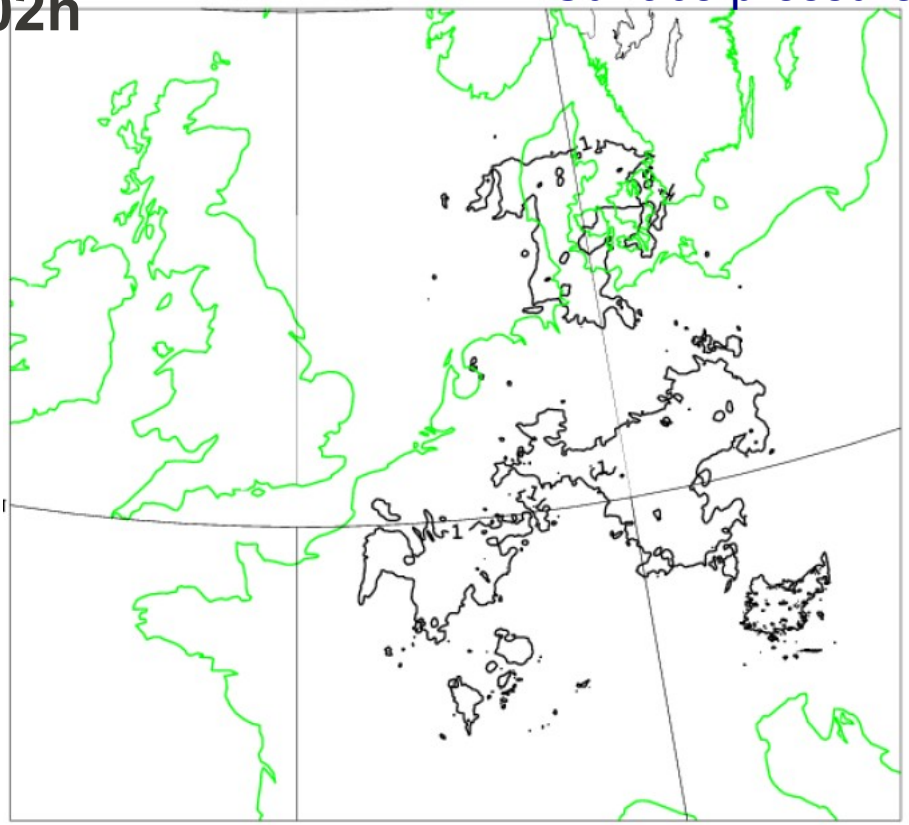
Surface pressure (control)



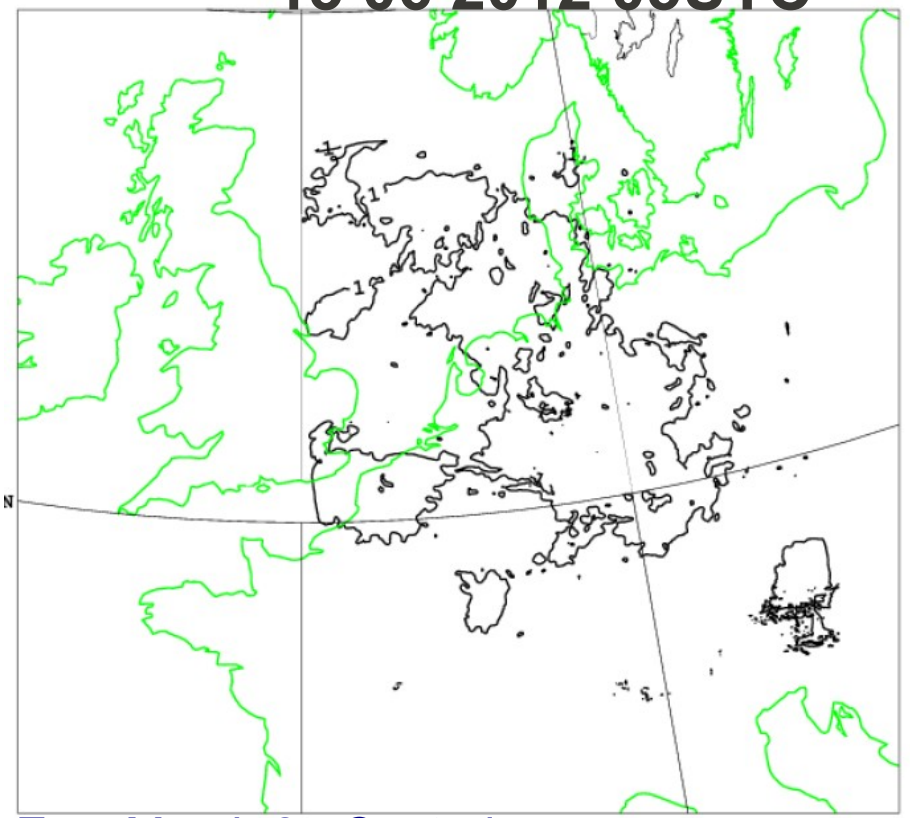
Forecast length: +02h

Surface pressure increment

13 06 2012 05UTC



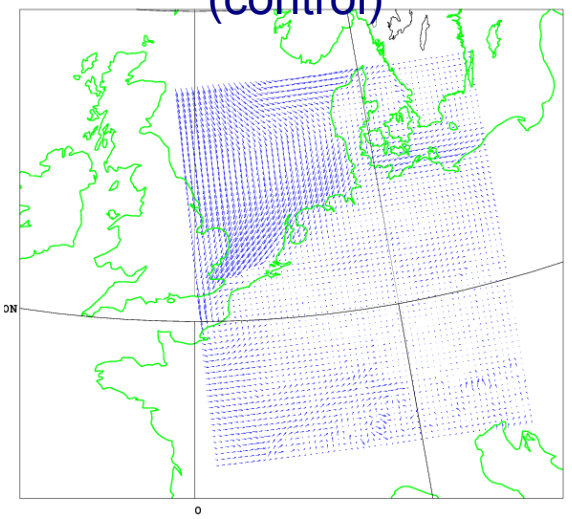
Ens. Memb 1 - Control



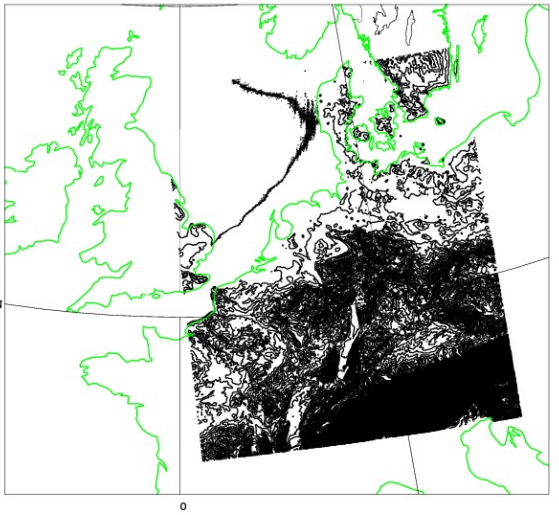
Ens. Memb 2 - Control

Evolution of two random perturbations with structure of B-matrix covariance

10-m wind (control)



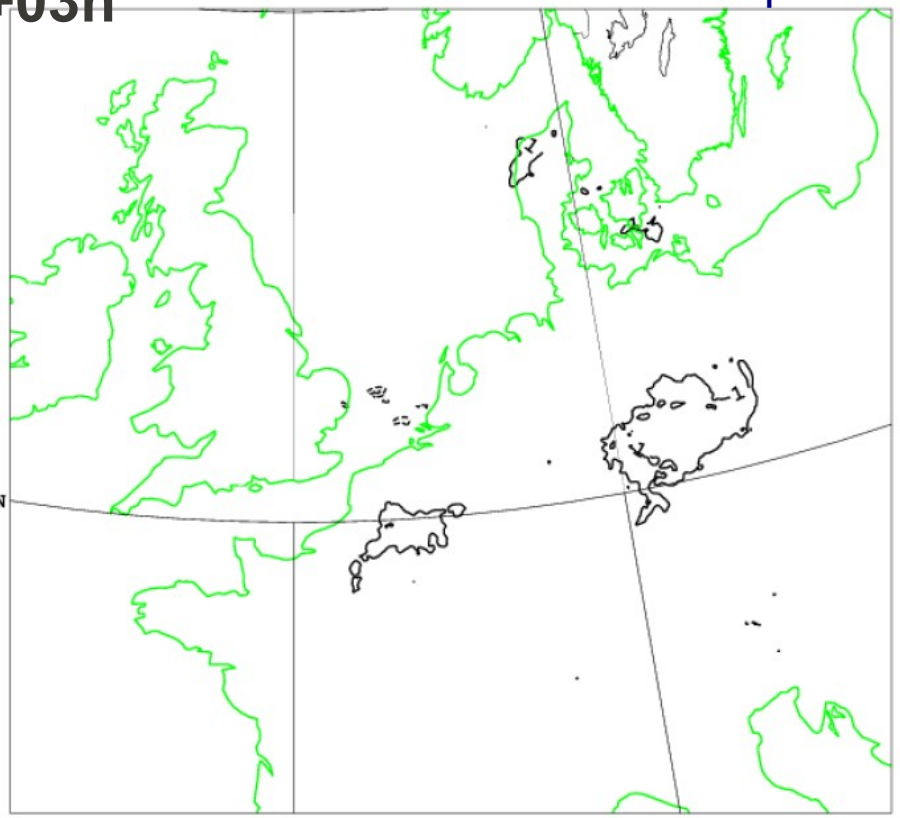
Surface pressure (control)



Forecast length: +03h

Surface pressure increment

13 06 2012 06UTC



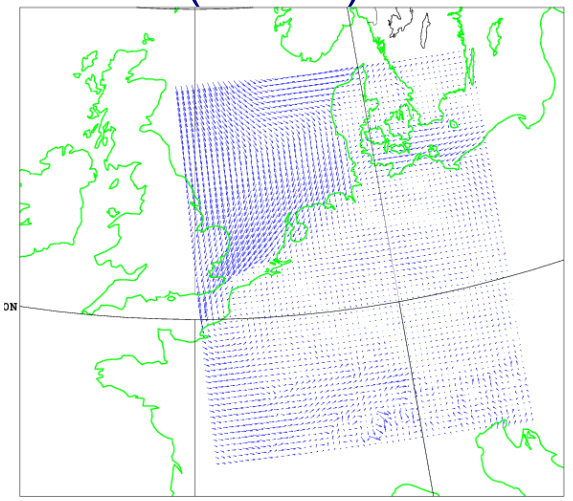
Ens. Memb 1 - Control

Ens. Memb 2 - Control

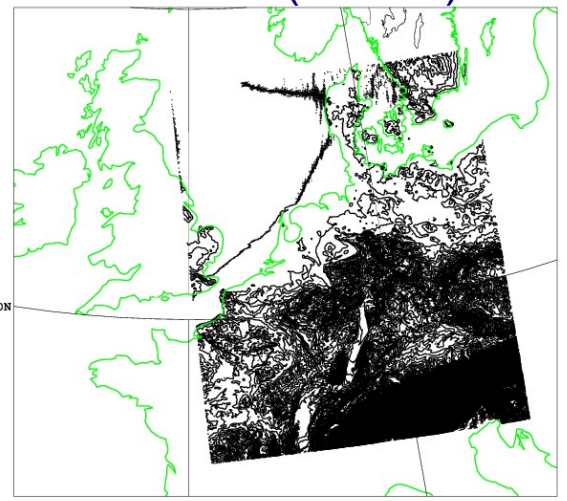
Evolution of two random perturbations with structure of B-matrix covariance

Forecast length: +05h

10-m wind (control)

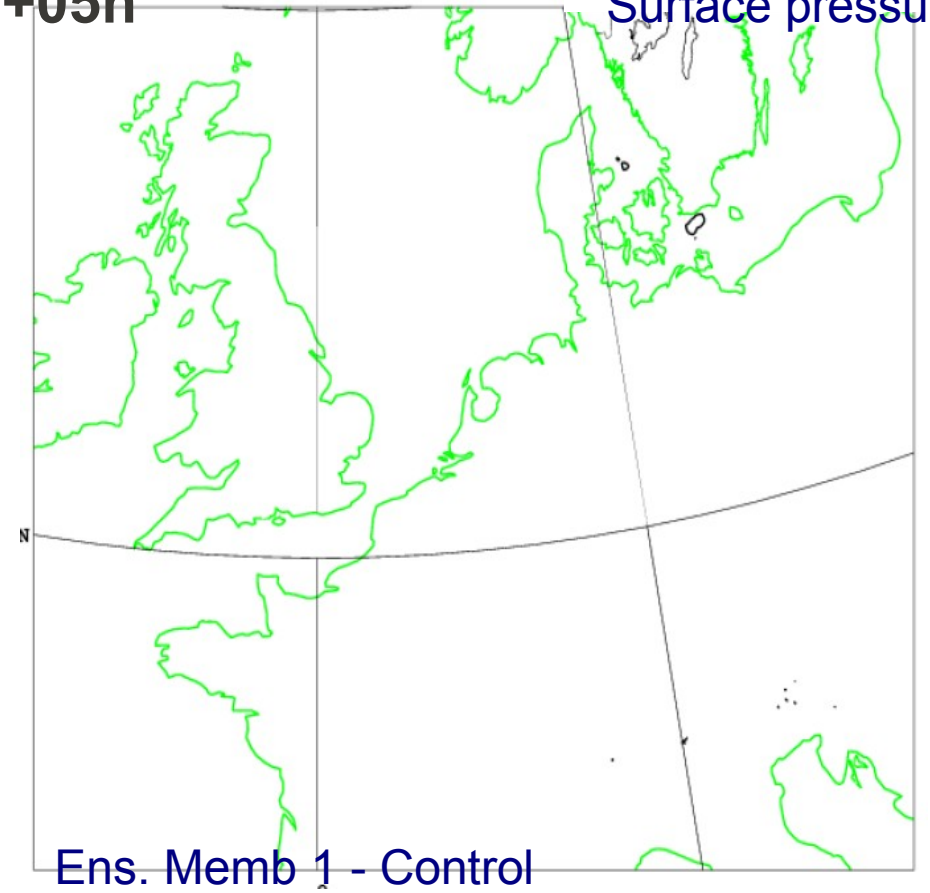


Surface pressure (control)

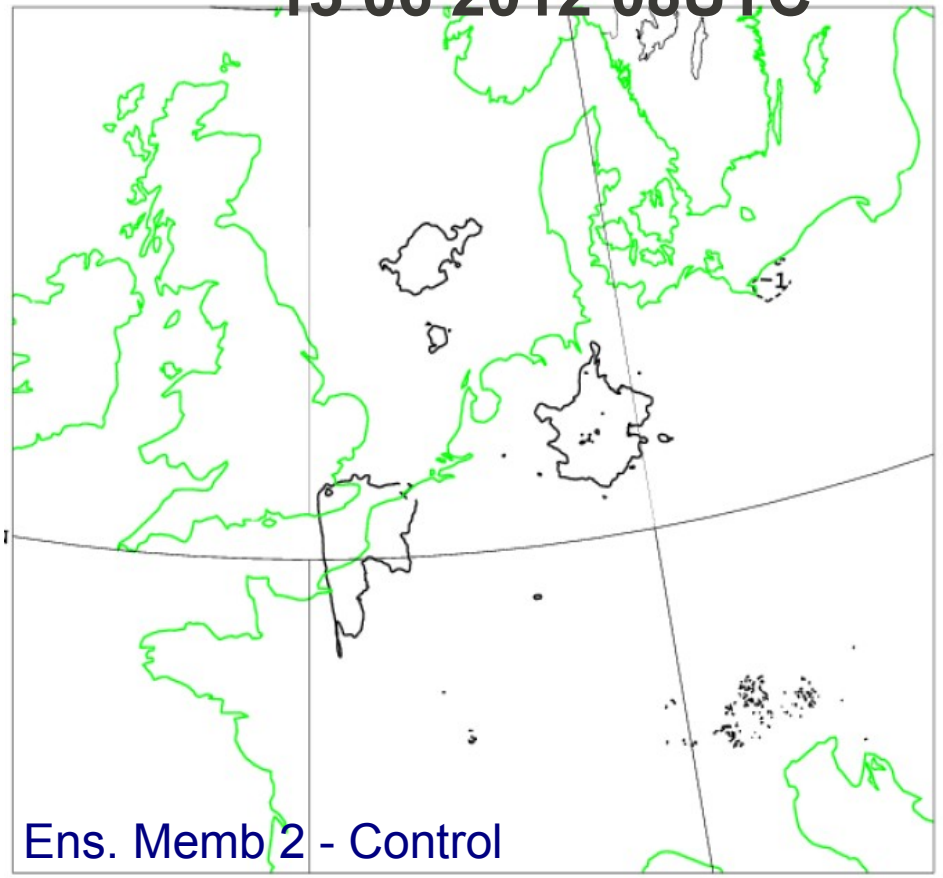


Surface pressure increment

13 06 2012 08UTC

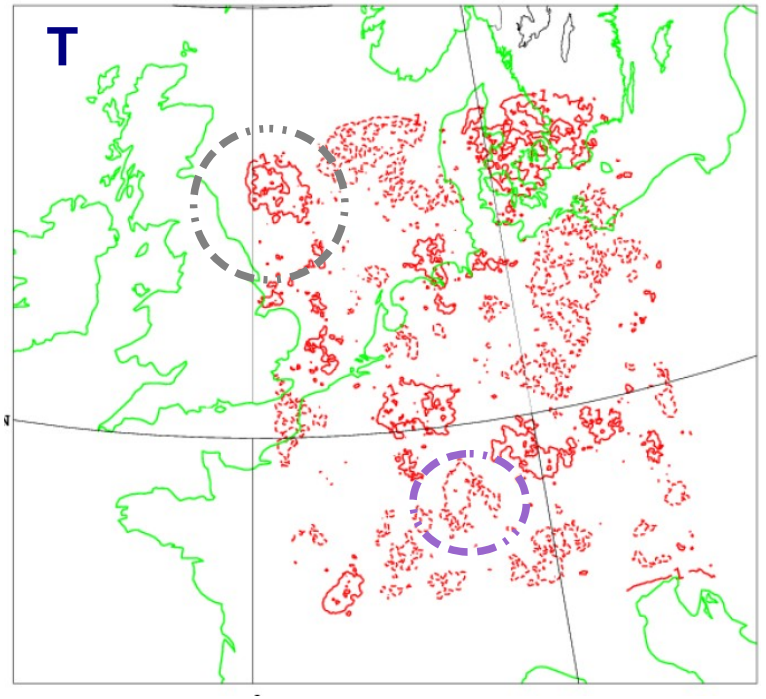


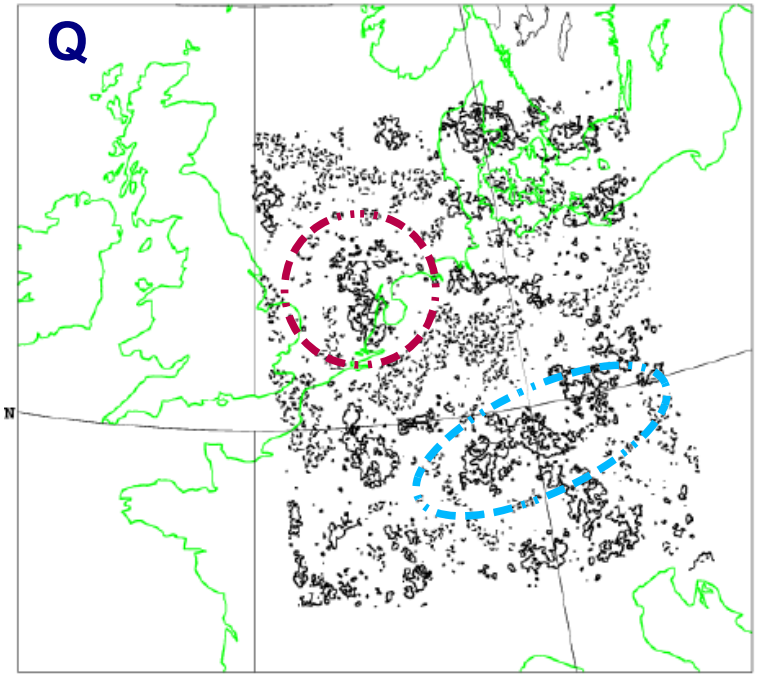
Ens. Memb 1 - Control



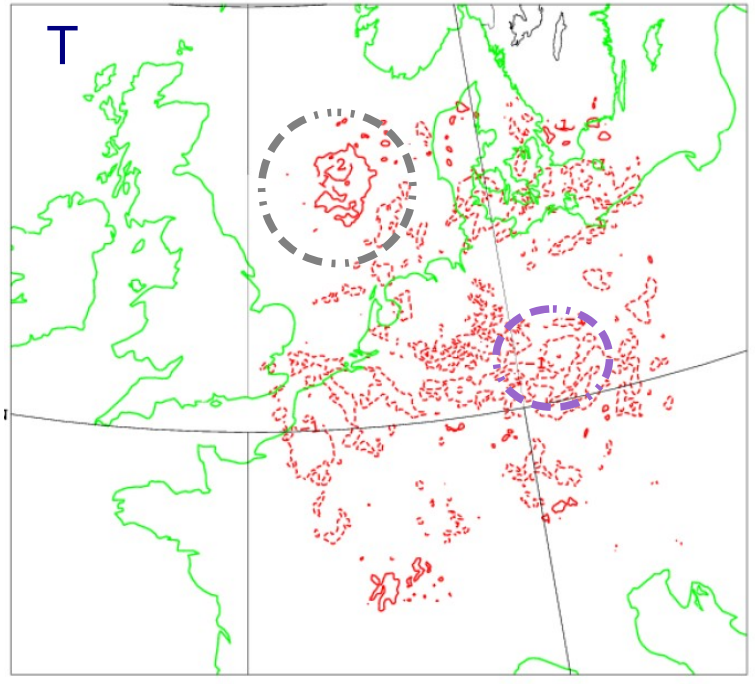
Ens. Memb 2 - Control

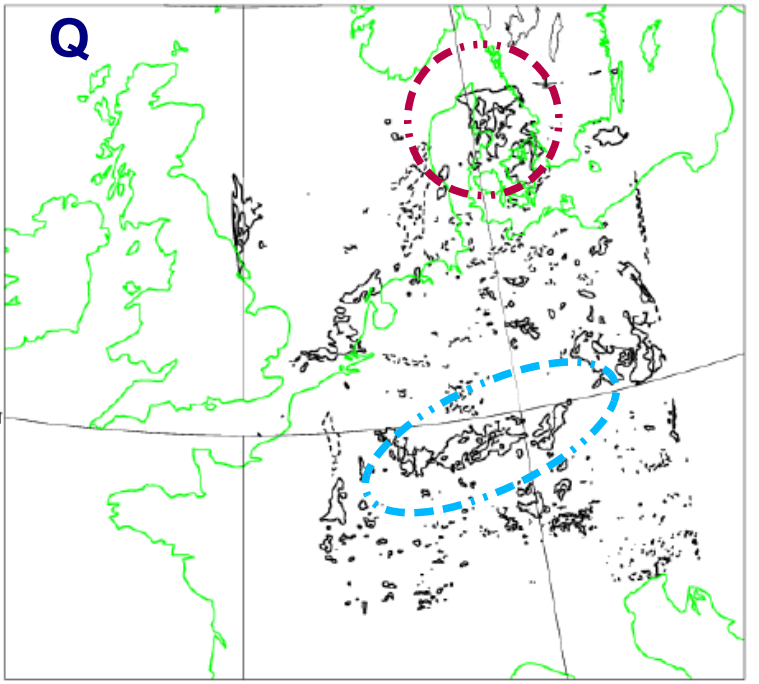
Evolution of perturbation with structure of B-matrix covariance





03 06 2012 03UTC
Forecast length +00h





03 06 2012 07UTC
Forecast length +04h

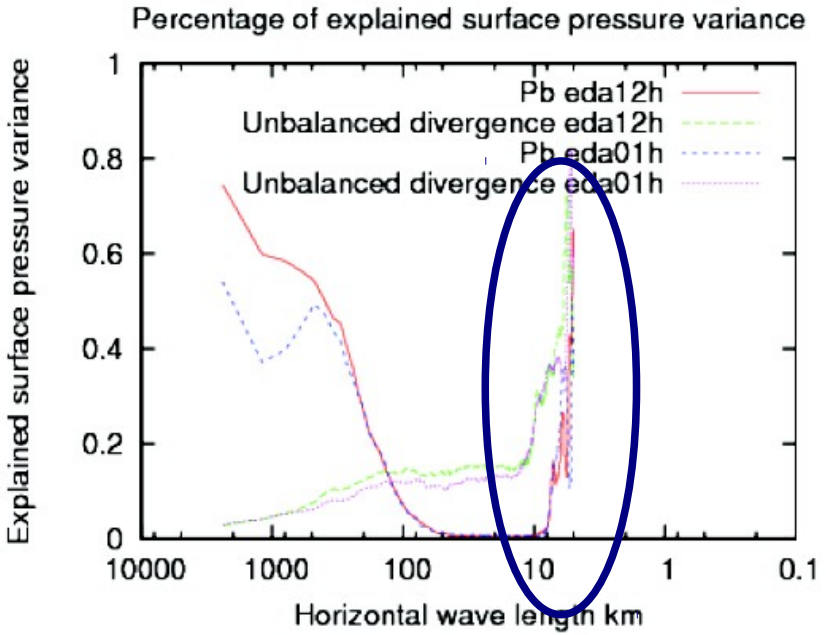
Why does the surface pressure increment escape?

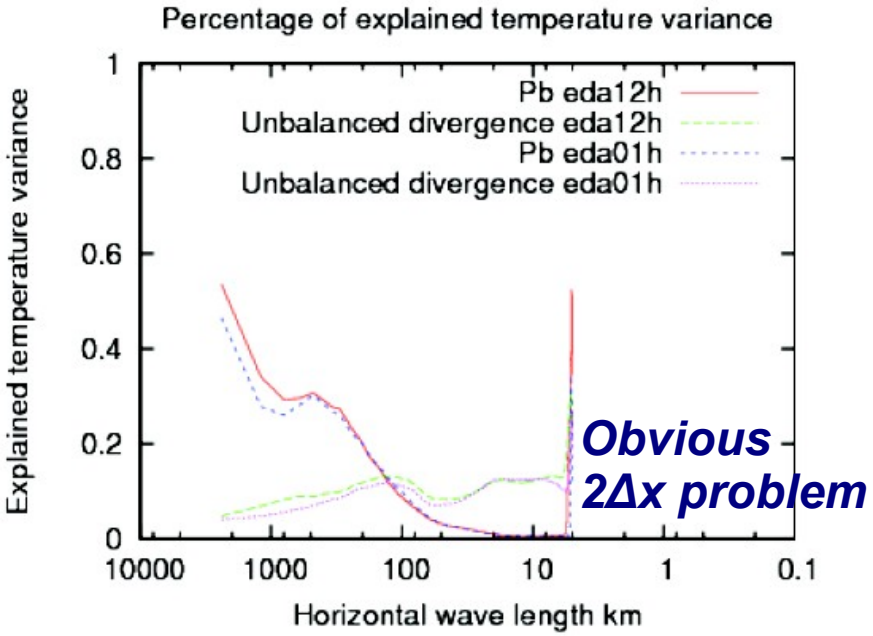
Surface pressure is an integrated quantity => if surface pressure increment escapes, some mis-balances in the model field must be present =>**How?**

➔Unbalance of non-hydrostatic part of the flow (pressure departure, vertical divergence) ?
➔ Inconsistent the GFL fields due to hydrostatic DA increment (liquid water, solid water, rain, snow, graupel) ?
➔Unrealistic non-physical structure functions?
➔Technical bug?

We still do not understand what happens...

What do structure functions say...

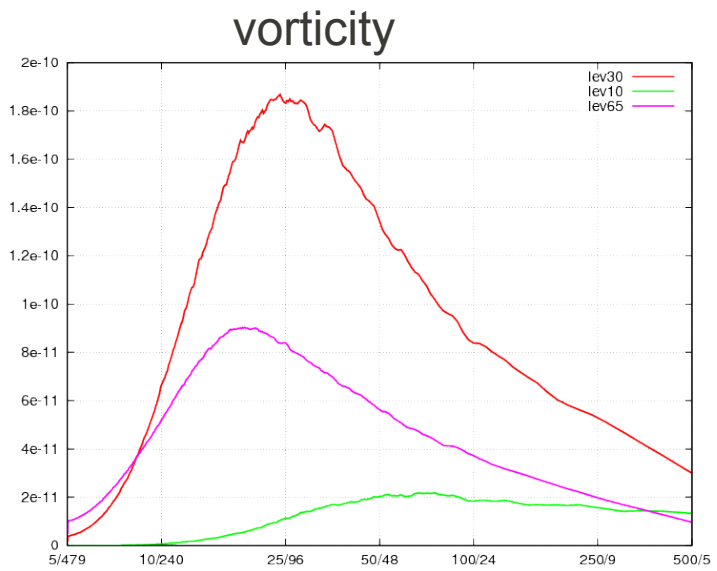


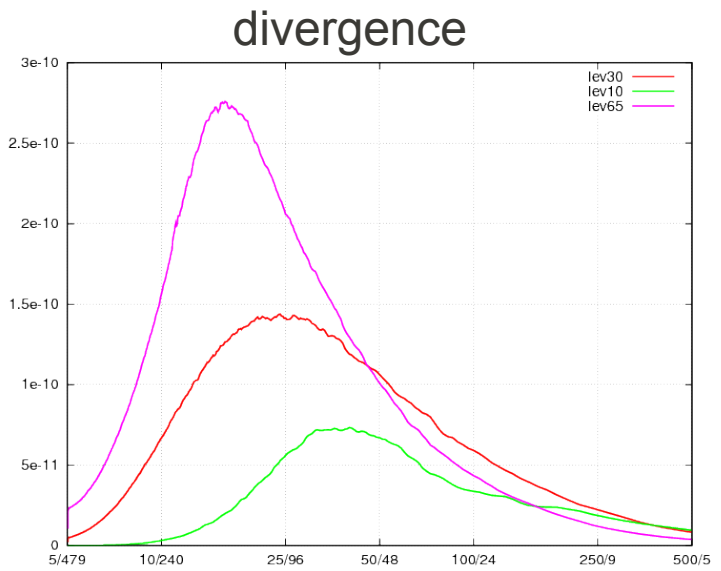


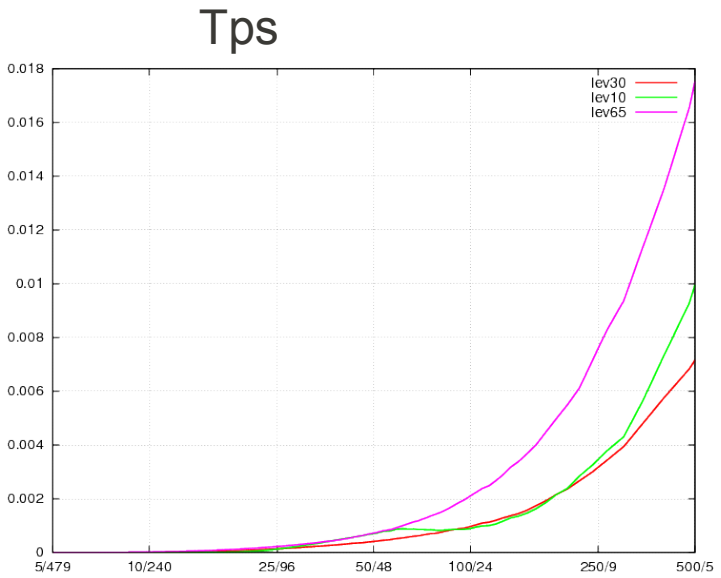
Aliasing of high-order terms on 2Δx, 3Δx, 4Δx, 5Δx waves

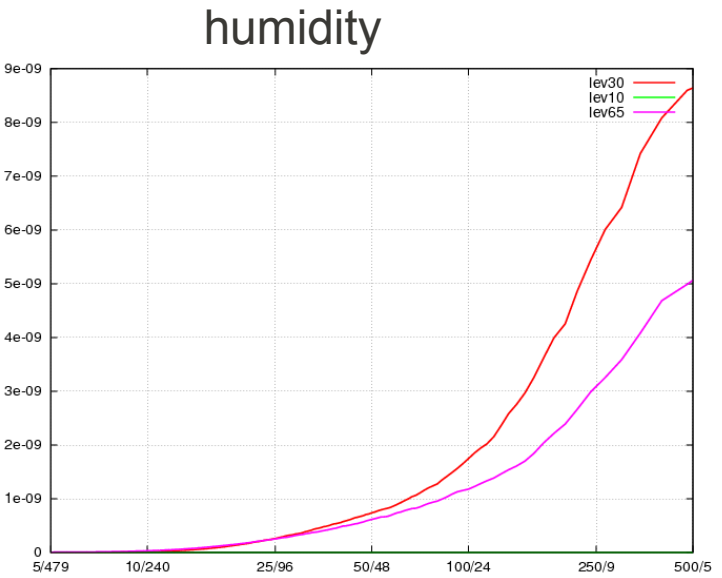
(from Nils Gustafsson SMHI)

The preliminary results using **cubic grid truncation** (Mariano Hortal implementation) show results encouraging further investigations : even with the current grid-point space resolution **numerical stability of the scheme is increased and longer time stepping in the semi-lagrangian forward propagation is allowed**. Processes are solved in the grid-point space and smoothed out in the spectral space.





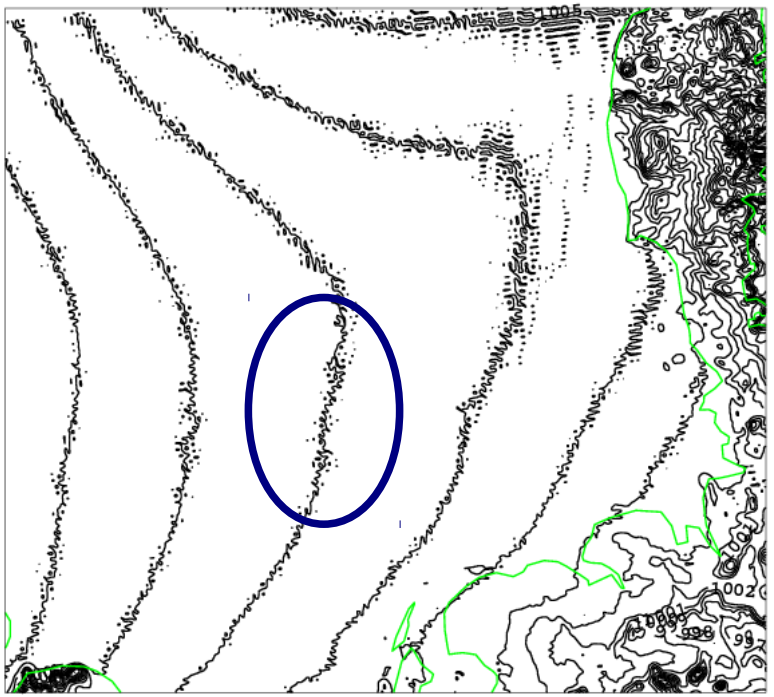




Structure functions (balanced part of the increment) contains very little energy on scales below 100 km =>Linear balance constraint **is not supported by the data on meso-scales**.. ***We must start to trust our data more and learn more from them...***

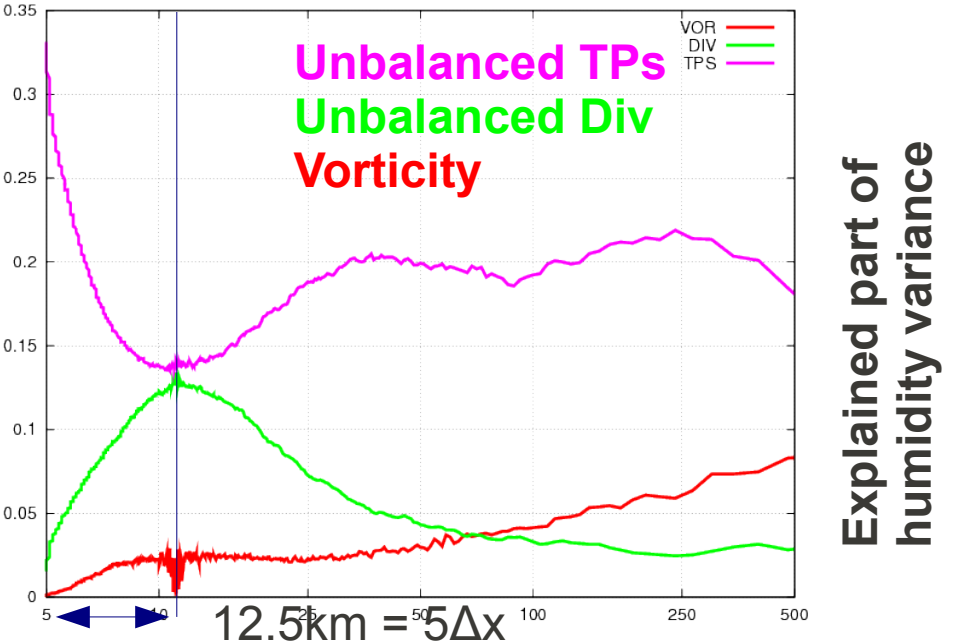
Small scales structure : noise or realistic small-scale variability?

Surface pressure



HARMONIE fields look very noisy. Transformation to the pressure levels, transformation to the physical quantities, change of resolution add small scale noise: **Why? =>**

- ➔ Physics-numerics interactions?
- ➔ Numerical truncation ?
- ➔ ....?

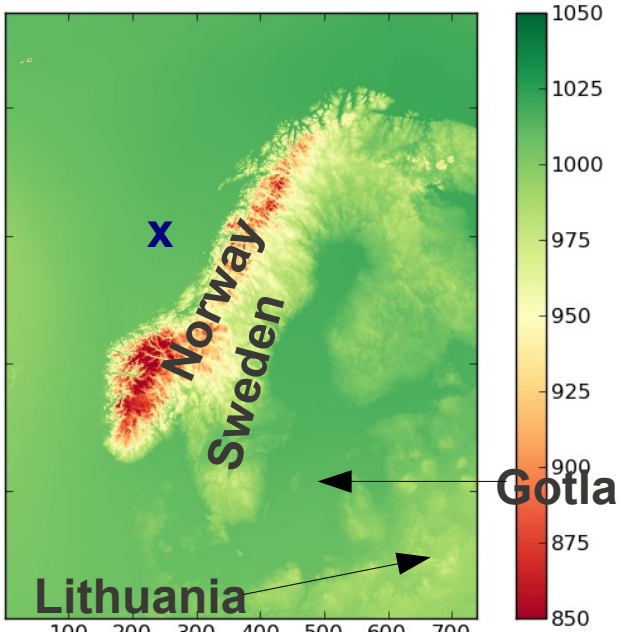


Processes represented on scales beyond 5Δx should be interpreted with care!

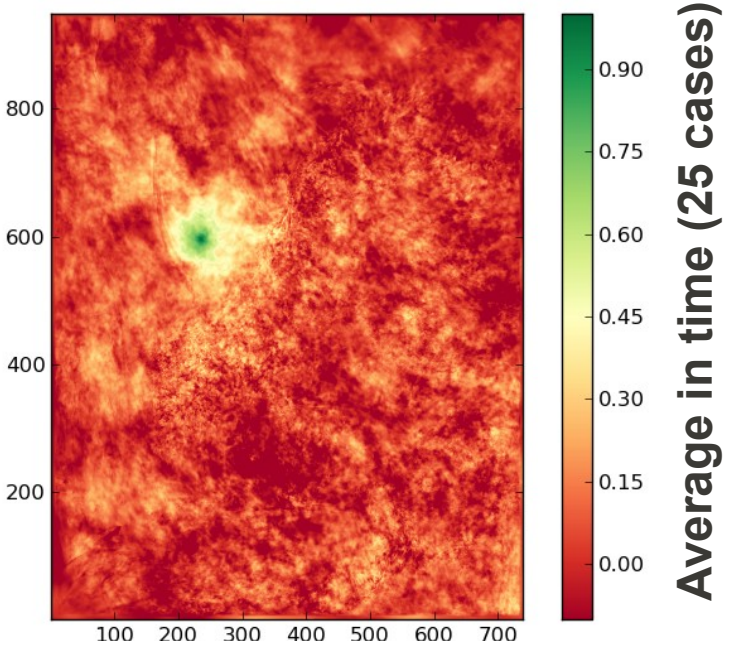
Climatological structure functions

(6 EDA based HarmonEPS perturbations; 06UTC +12h)

Surface pressure (MetCoOp domain)



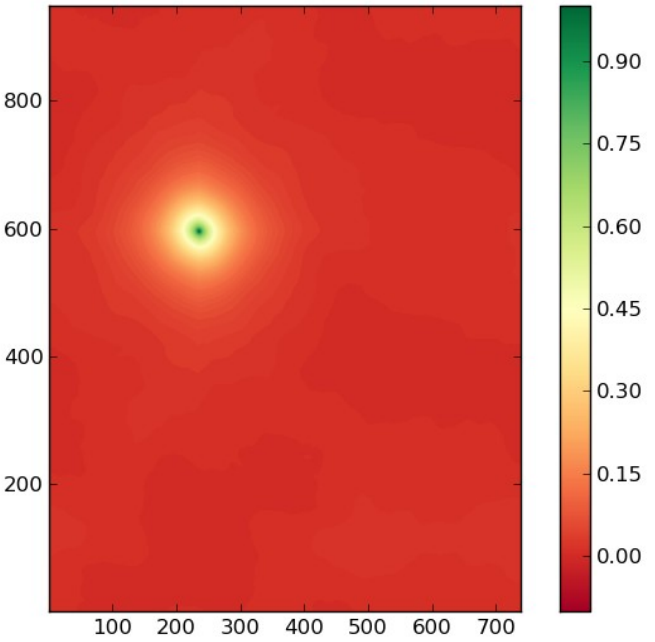
Correlations to a single reference point x= (235,595)



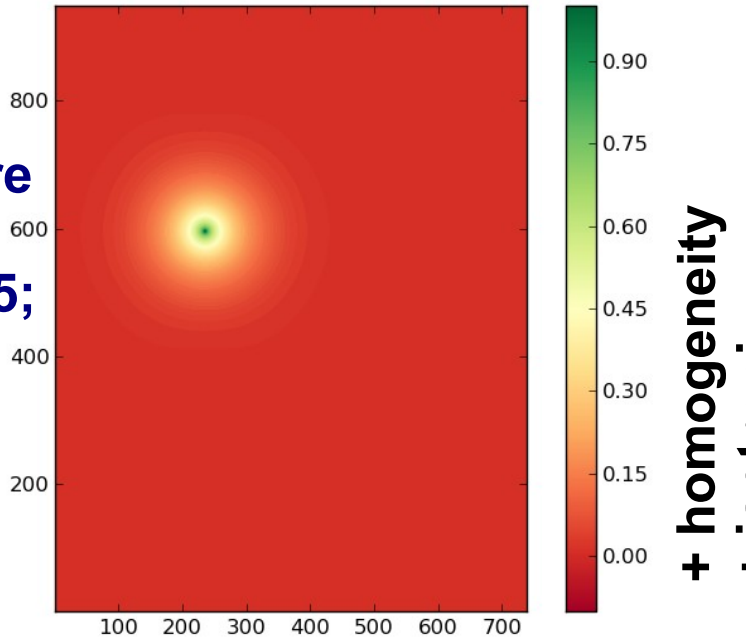
Average in time (25 cases)

(from Nils Gustafsson, SMHI)

+ homogeneity



Temperature ≈ 500hPa (AROME 2.5; 65 vert.l)

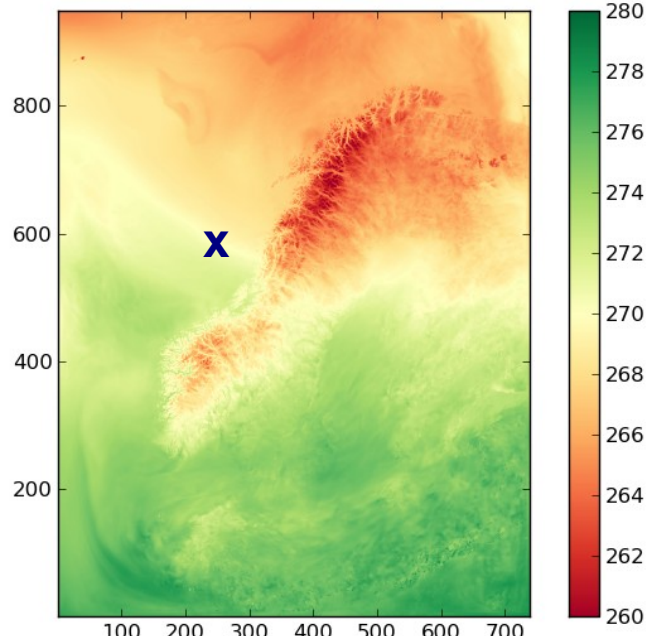


+ homogeneity
+ isotropi

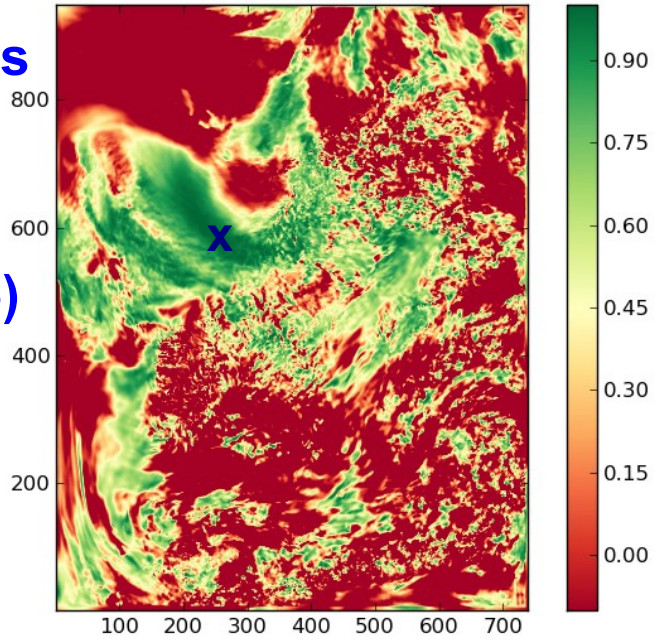
Climatological structure functions

(6 EDA based HarmonEPS perturbations; 06UTC + 12h)

Temperature (control)
(12 08 2008)

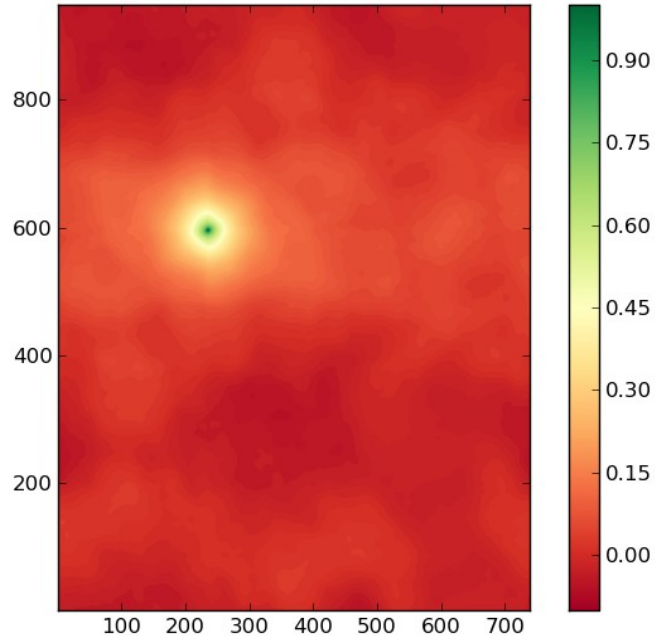


Correlations to a single reference point x= (235,595)

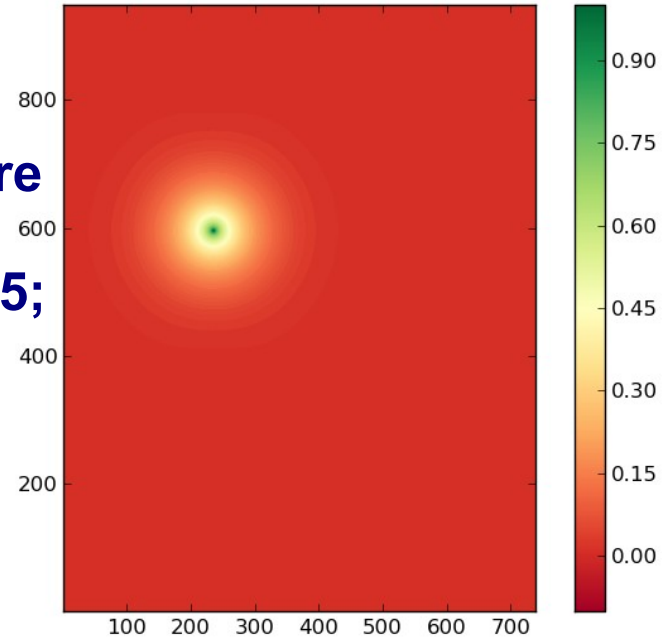


Single case

+ homogeneity



Temperature ≈ 500hPa (AROME 2.5; 65 vert.l)

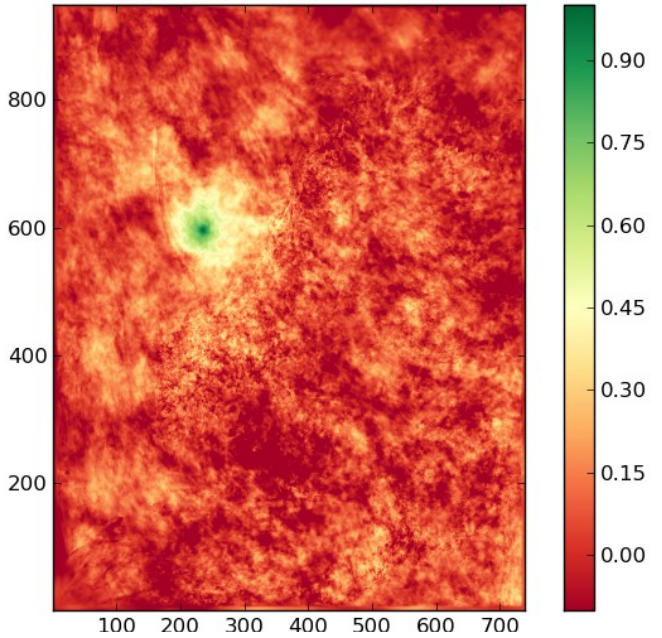


+ homogeneity
+ isotropy

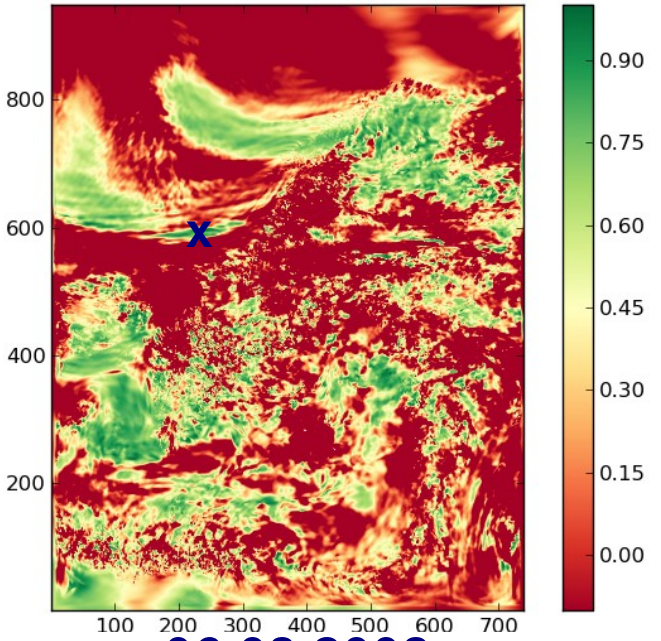
Climatological structure functions

(6 EDA based HarmonEPS perturbations; 06UTC + 12h)

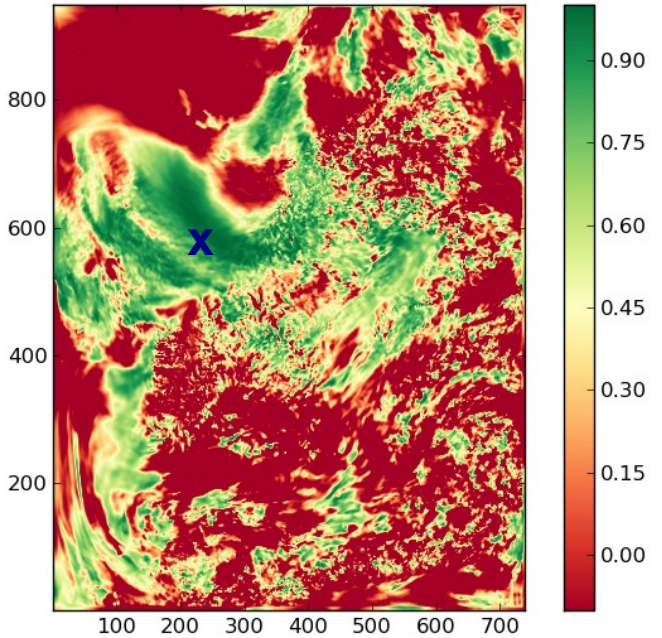
Average in time (25 cases)



Correlations to a single reference point x= (235,595)

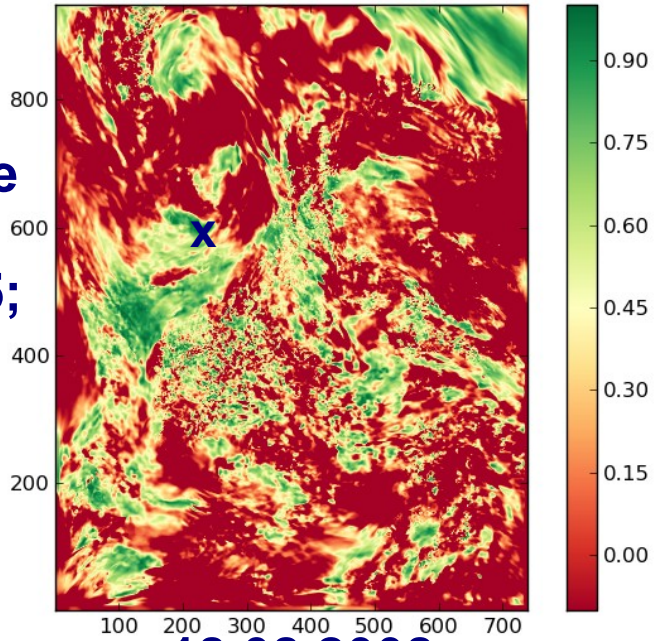


06 08 2008



12 08 2008

Temperature ≈ 500hPa (AROME 2.5; 65 vert.l)



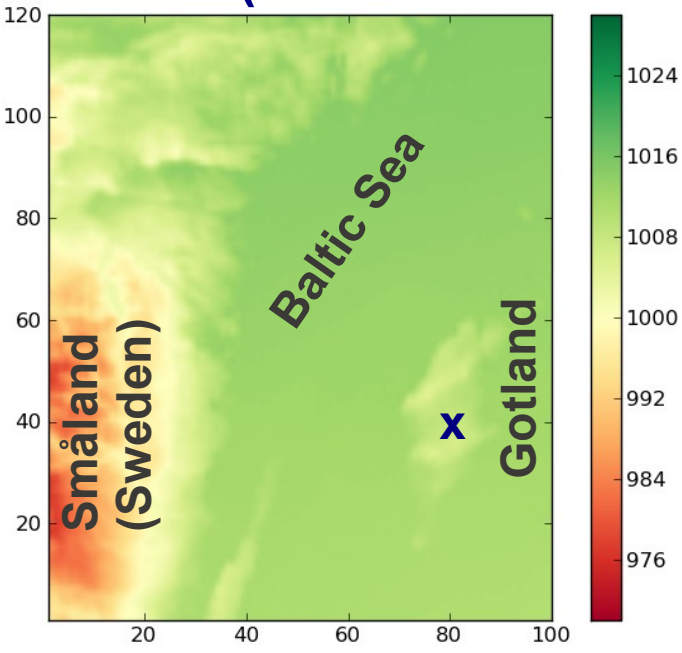
18 08 2008

Allow flow-depenency, Avoid homogeneity & isotropi

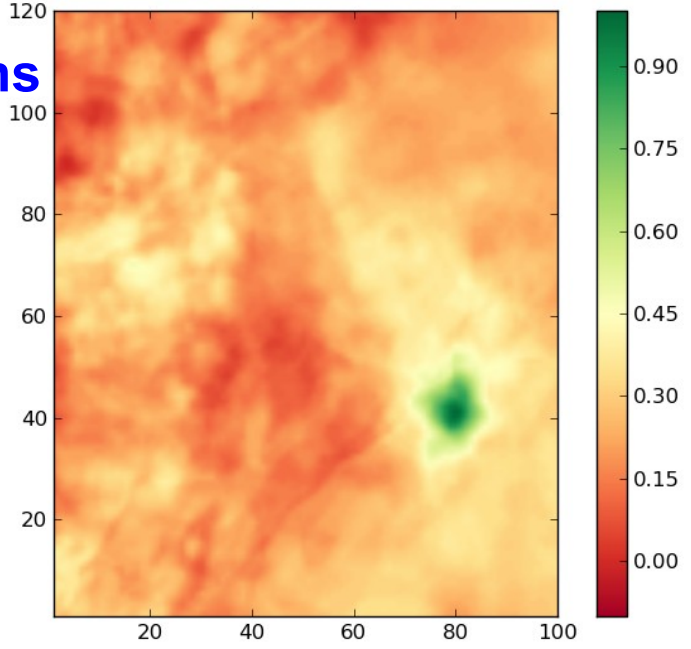
Climatological structure functions

(6 EDA based HarmonEPS perturbations; 06UTC + 12h)

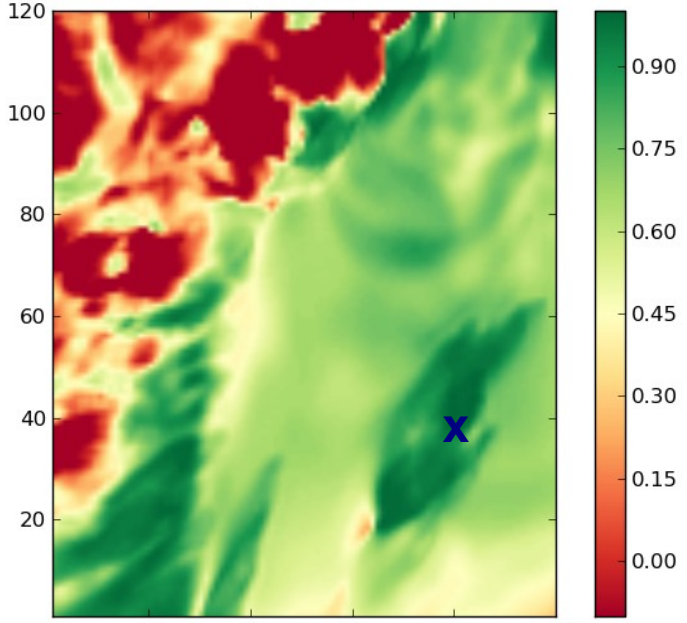
Surface pressure (zoom over Gotland)



Correlations to a single reference point x= (80,40)



Average in time (25 cases)



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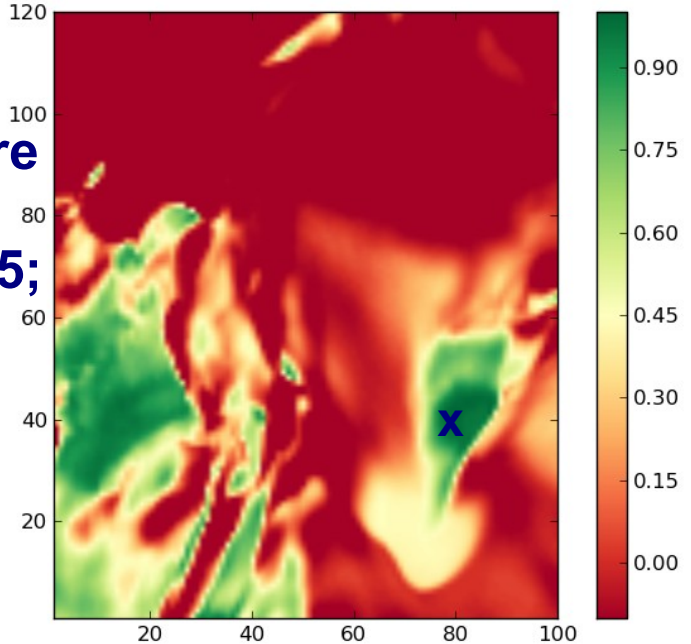
Temperature level 62 (AROME 2.5; 65 vert.l)



21 08 2008

How to extract the signal ?

Even a small size HARMONIE ensemble contains **clear response to orographic conditions** because the orography is a not stochastic process in itself => Strong potential of HARMONIE ensemble representing convective scale phenomena, ***in particular those induced by surface and PBL!*** ,

I). Wrong large scale environment => useless meso-scale data assimilation.
Constrain large scale environment

II). Avoid averaging and relax homogeneity and isotropy assumptions
Allow flow-dependency

III). Sample uncertainty and filter out noise. Localisation on a prescribed scale is harmful for data assimilation => **Try scale-dependent localisation** (Mark Buehner approach)

Two-dimensional surface analysis might be a feasible environment to develop this scheme

What can we learn from this experiment:

1) **We cannot come much further forward without flow-dependent structure functions!=>** homogeneity and isotropy assumption about the forecast error statistics do not hold for the convective scale phenomena;

2) **Small scales structures and noise is a dangerous combination** => Go for "cubic grid" truncations, possibly low-resolution orography; We need to rethink about initialisation on convective scales

3) **Near linear regime of development is valid for certain phenomena up to 3-4h because the advection seems to dominate** => hope for 4DVAR HARMONIE! Development of advanced data assimilation scheme requires a common system.

4) **Ensembles have big potential for data assimilation on convective scales (processes driven by surface and PBL conditions)** => Go for Ensemble Variational techniques using convection permitting ensembles. Allow scale-dependent localisation!

There is no elevator to the success

YOU WILL HAVE TO TAKE THE STAIRS!