Norwegian Meteorological Institute

The 4th International Symposium on Data Assimilation

23-27 February 2015
Conference location: RIKEN AICS, Kobe, Japan

Climatological Structure Functions in HARMONIE data assimilation

Jelena Bojarova *on behalf of the HIRLAM Team*

High Resolution Hirlam Limited Area Model + ALADIN = HARMONIE

The Basic Problem

An Attack:

*"HARMONIE DA with 3h RUC **does not help to improve** HARMONIE forecast. Why? Either the information content from previous observations is not captured by the system or the (unrealistic) small scale structures overwhelm the analysis increment already after 3 hours?"*

A disappointed DA scientists, Gert-Jan Marseille

A quick reaction:

*"In my view the problem is not related to small scale feature that the HARMONIE model cannot handle in the data assimilation, but related to systematic errors in the physics that make **data assimilation difficult or impossible**."*

A brave senior mathematician, Nils Gustafsson

In any case, the evidence is here :

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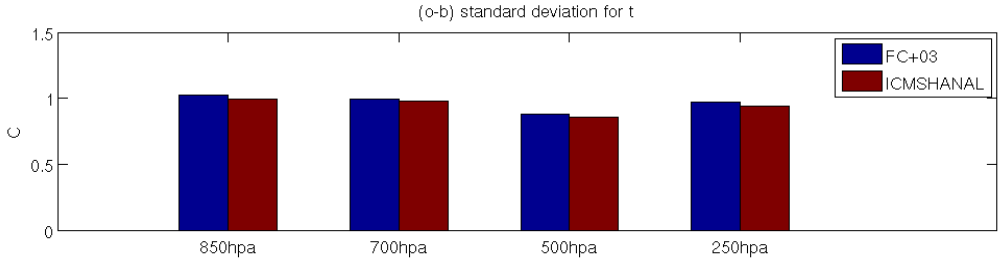

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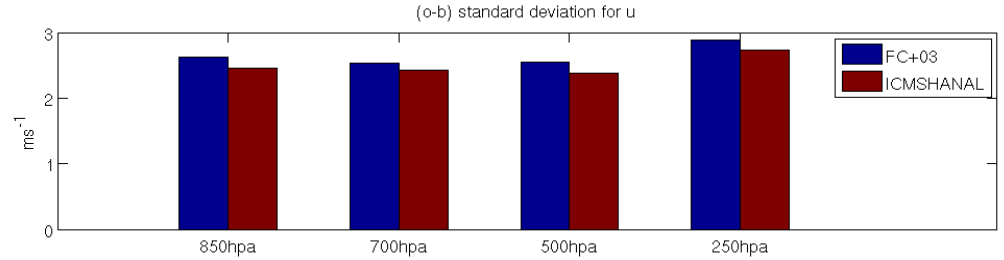

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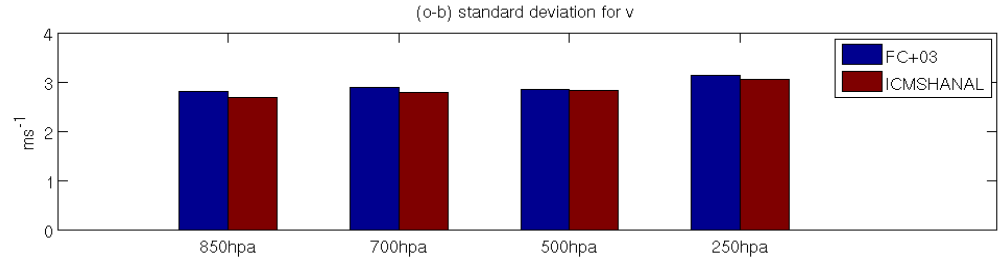


850hPa 700hPa 500hPa 250hPa

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)

The truth lies always somewhere in between, doesn't it ?...

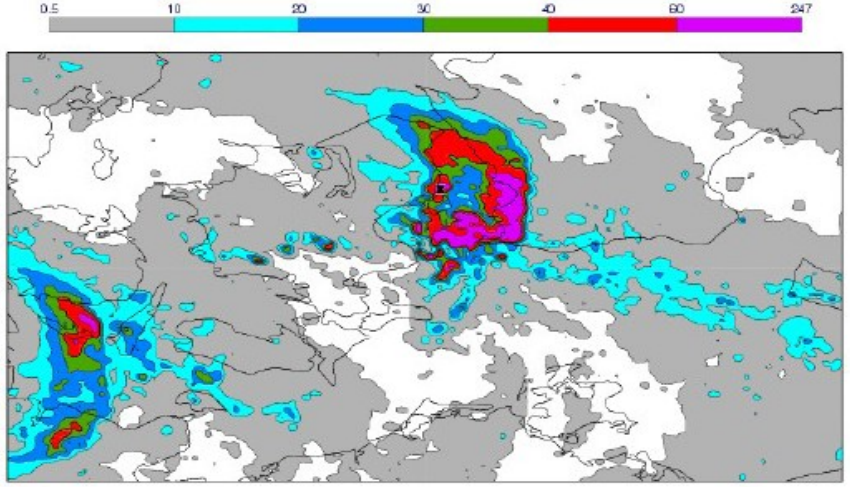
What is wrong essentially

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

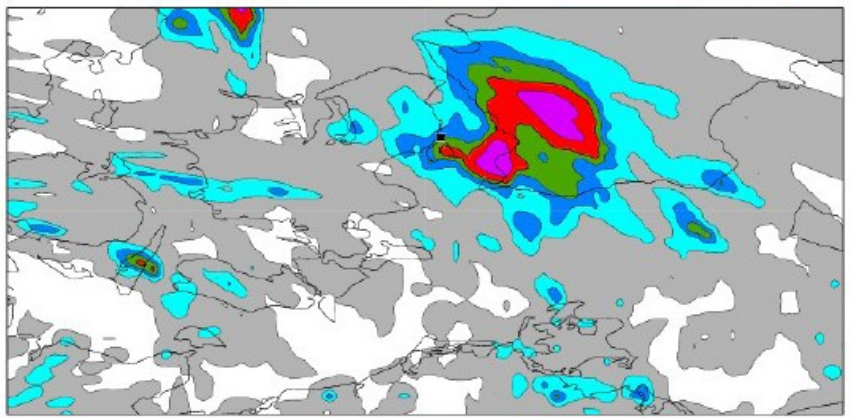
Verification of the HARMONIE A
2.5km forecasts for extreme we
event

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

Radar data 31.08 00UTC - 12UTC



HARMONIE AROME + 30h (MetCoOp)



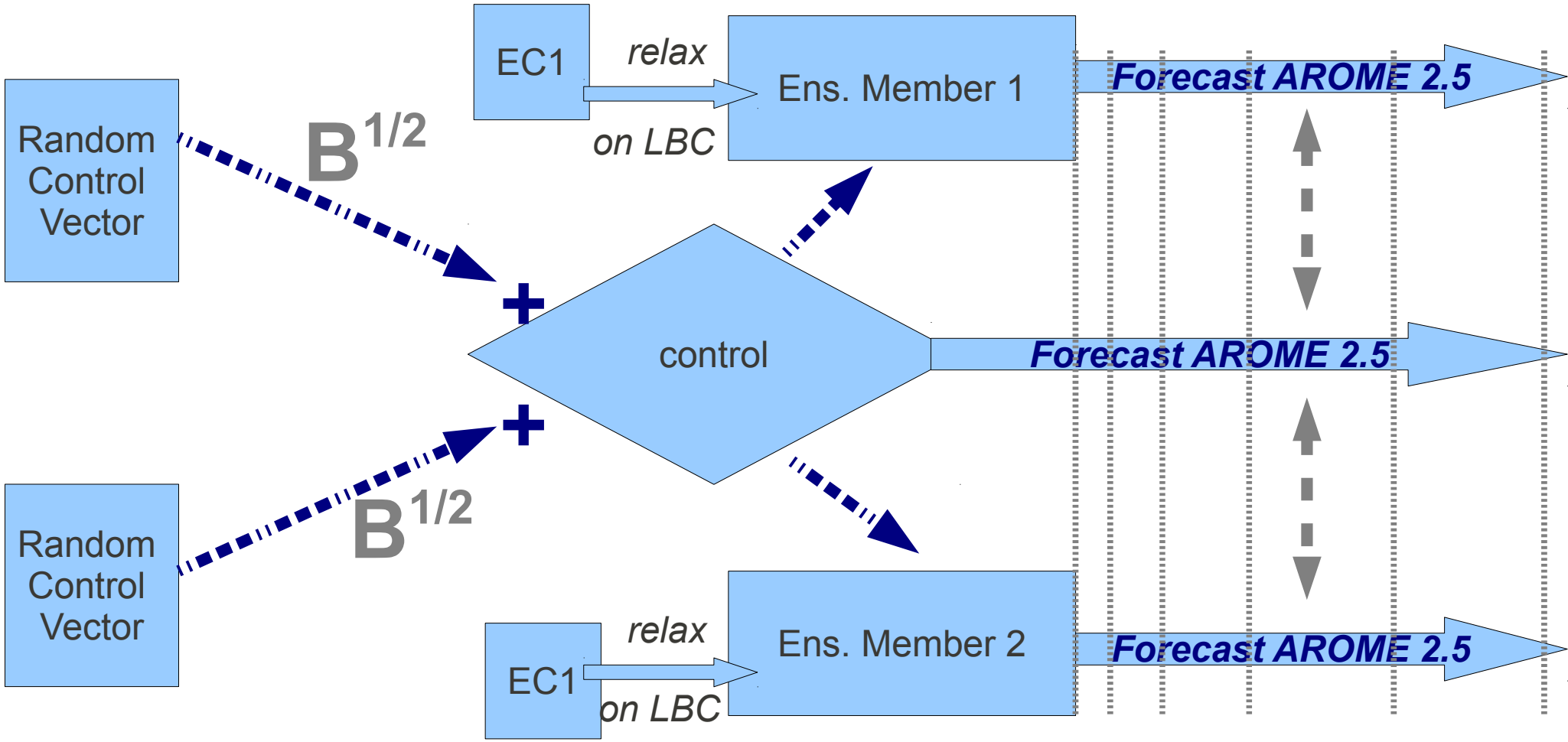
12 h accumulated rainfall

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);

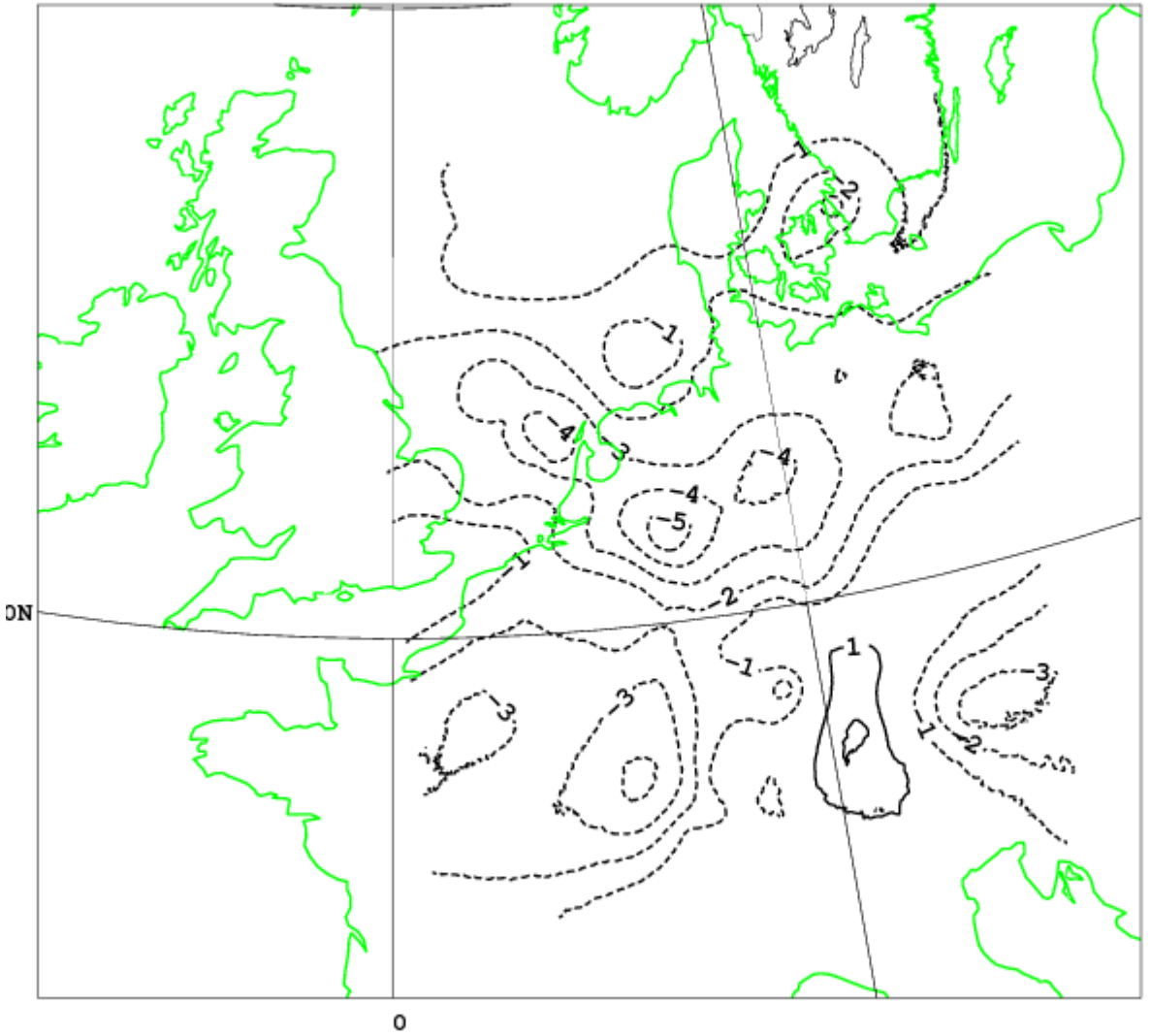
The quality of the short-term forecasts in the operational runs is not satisfactory : **coupling strategy and data assimilation to be blamed**

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



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

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

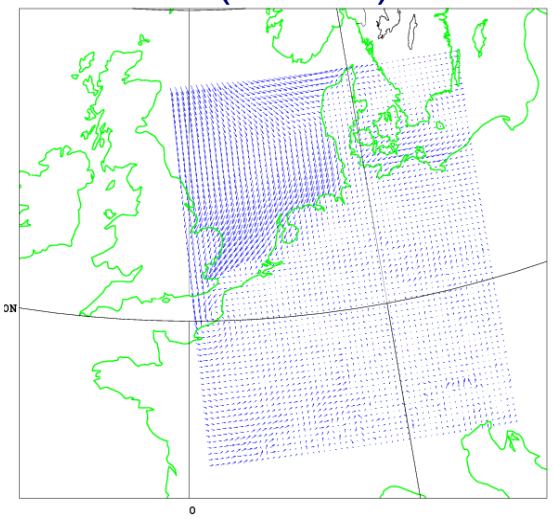


➔ Surface pressure is too high and we are not able to correct it...

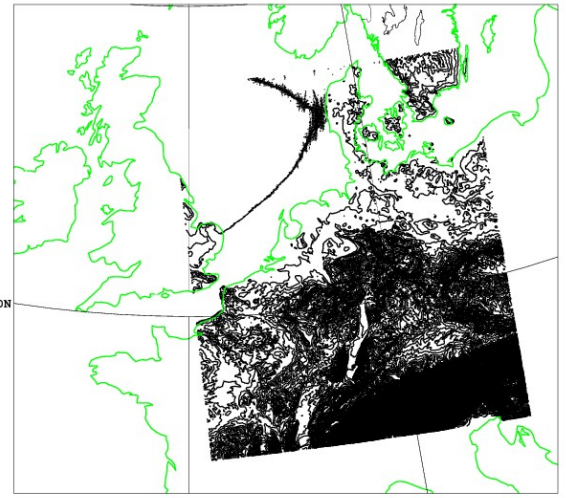
Evolution of two random perturbations with structure of B-matrix covariance

Forecast length: +00h

10-m wind (control)

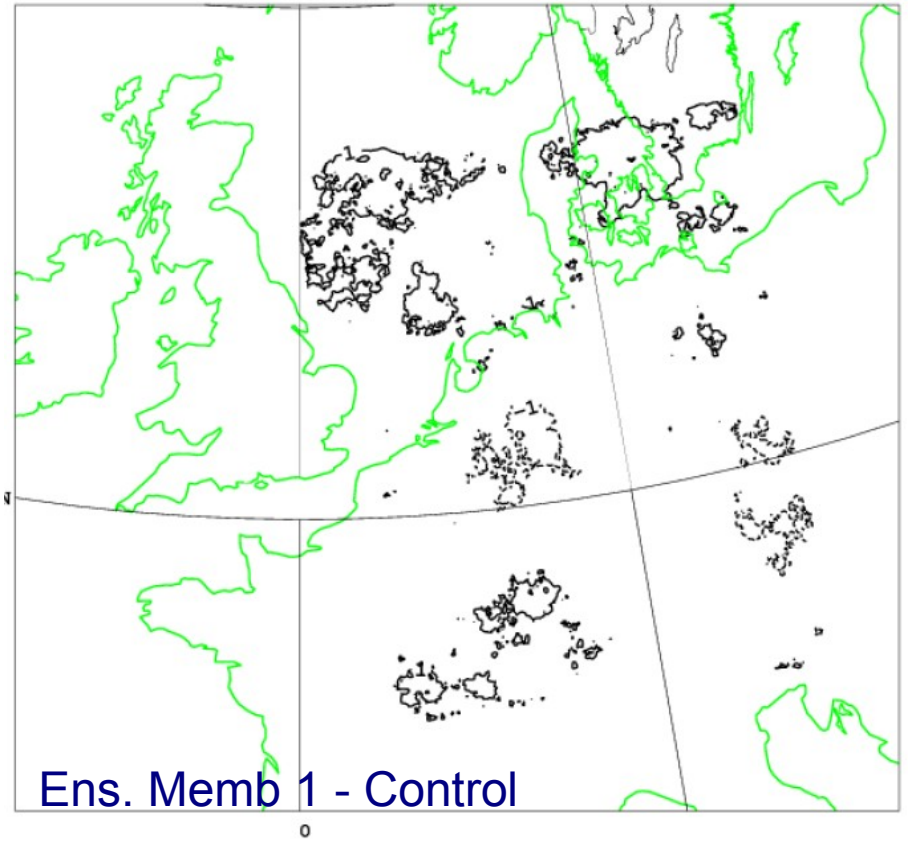


Surface pressure (control)

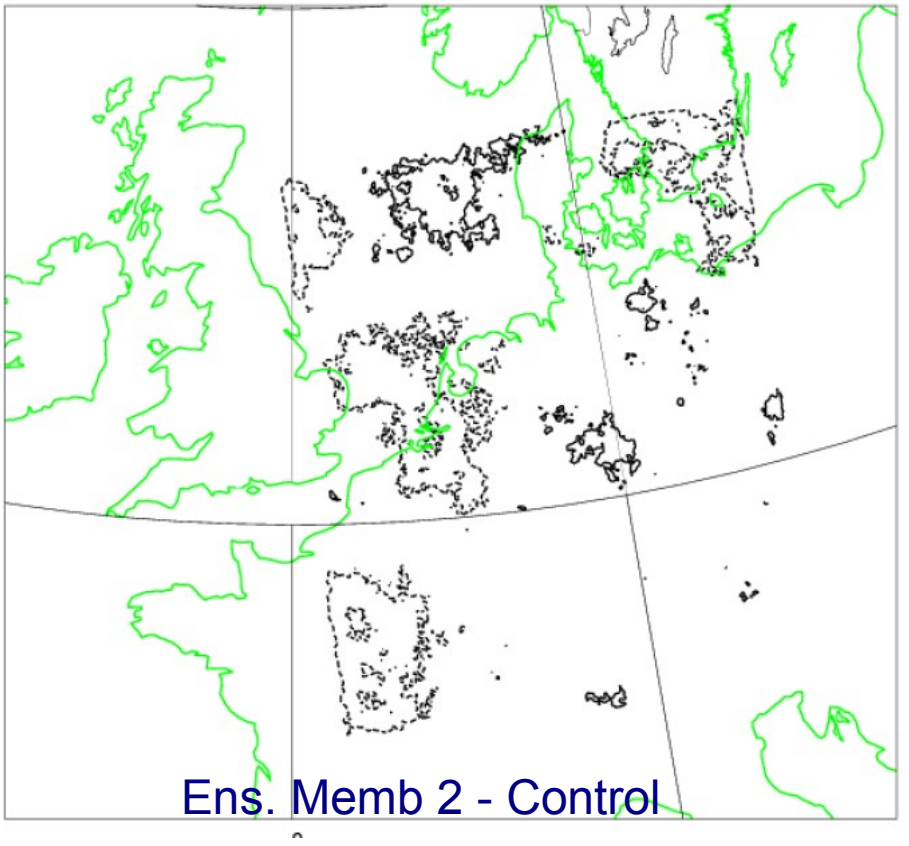


13 08 2012 03UTC

Surface pressure increment



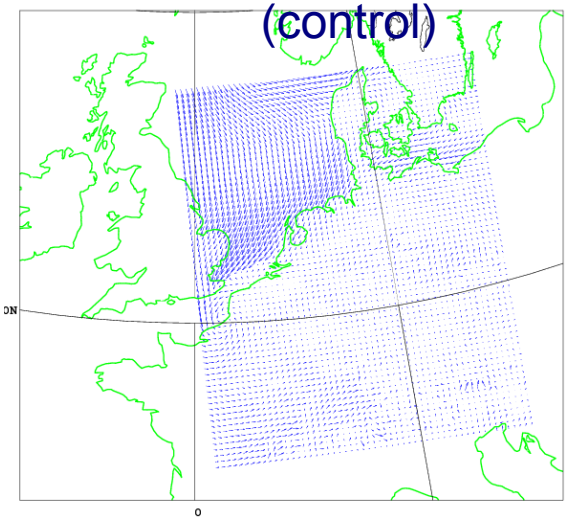
Ens. Memb 1 - Control



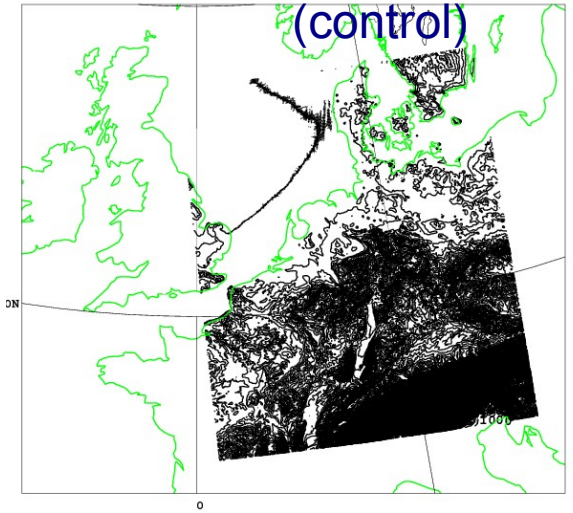
Ens. Memb 2 - Control

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

10-m wind (control)

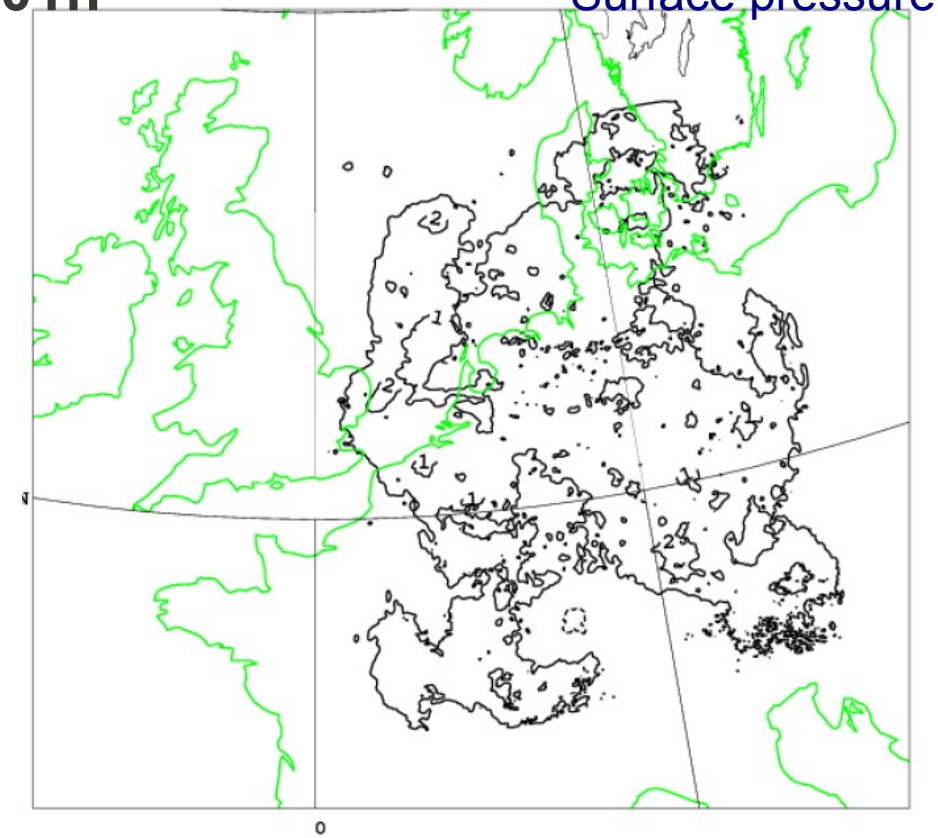


Surface pressure (control)

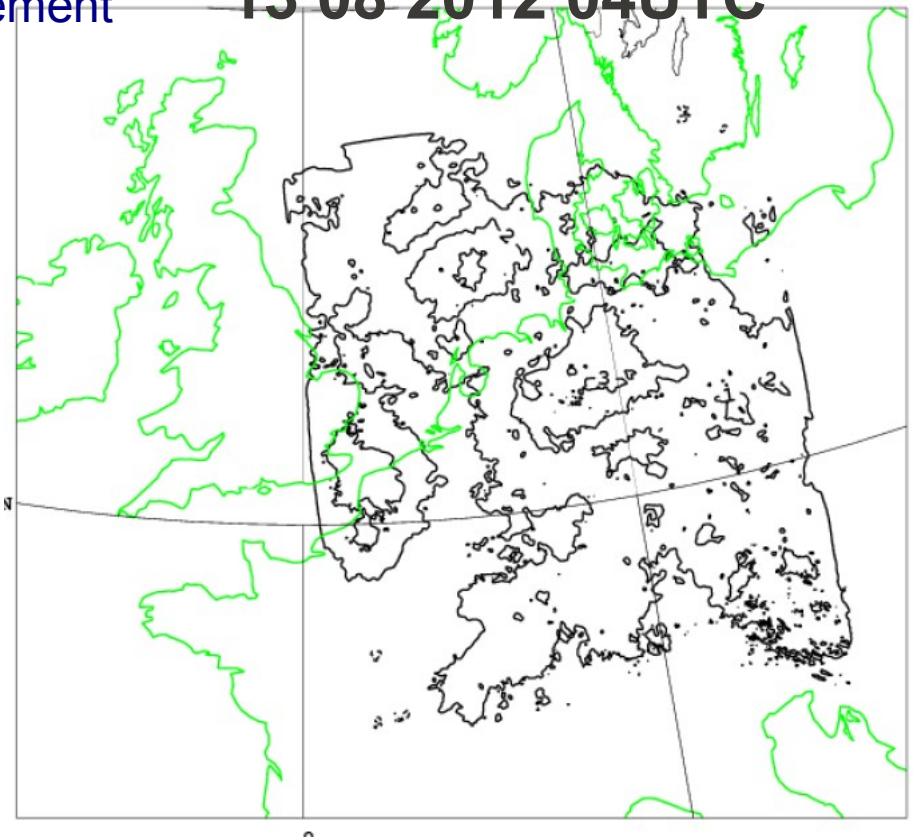


Forecast length: +01h

Surface pressure increment



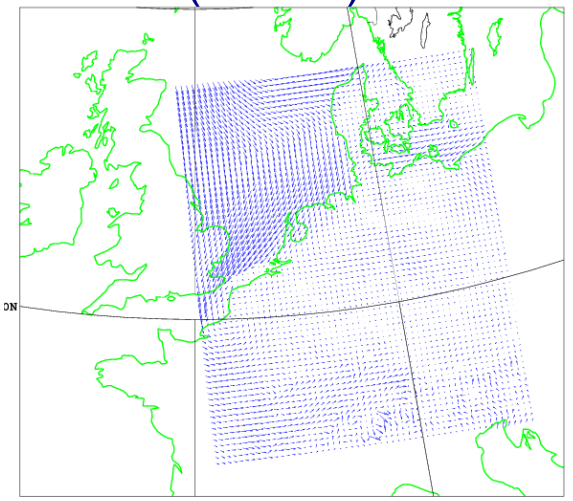
13 08 2012 04UTC



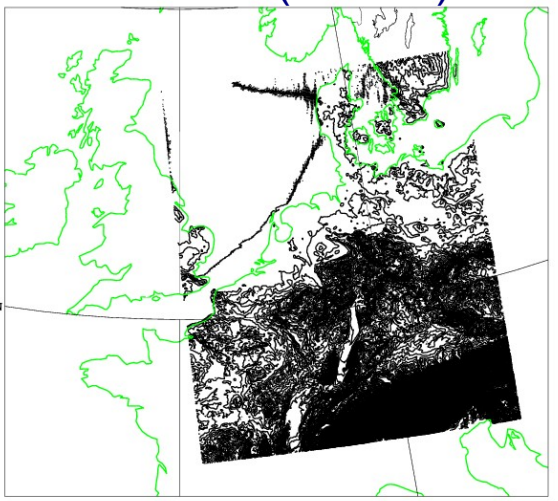
Evolution of two random perturbations with structure of B-matrix covariance

Forecast length: +05h

10-m wind (control)

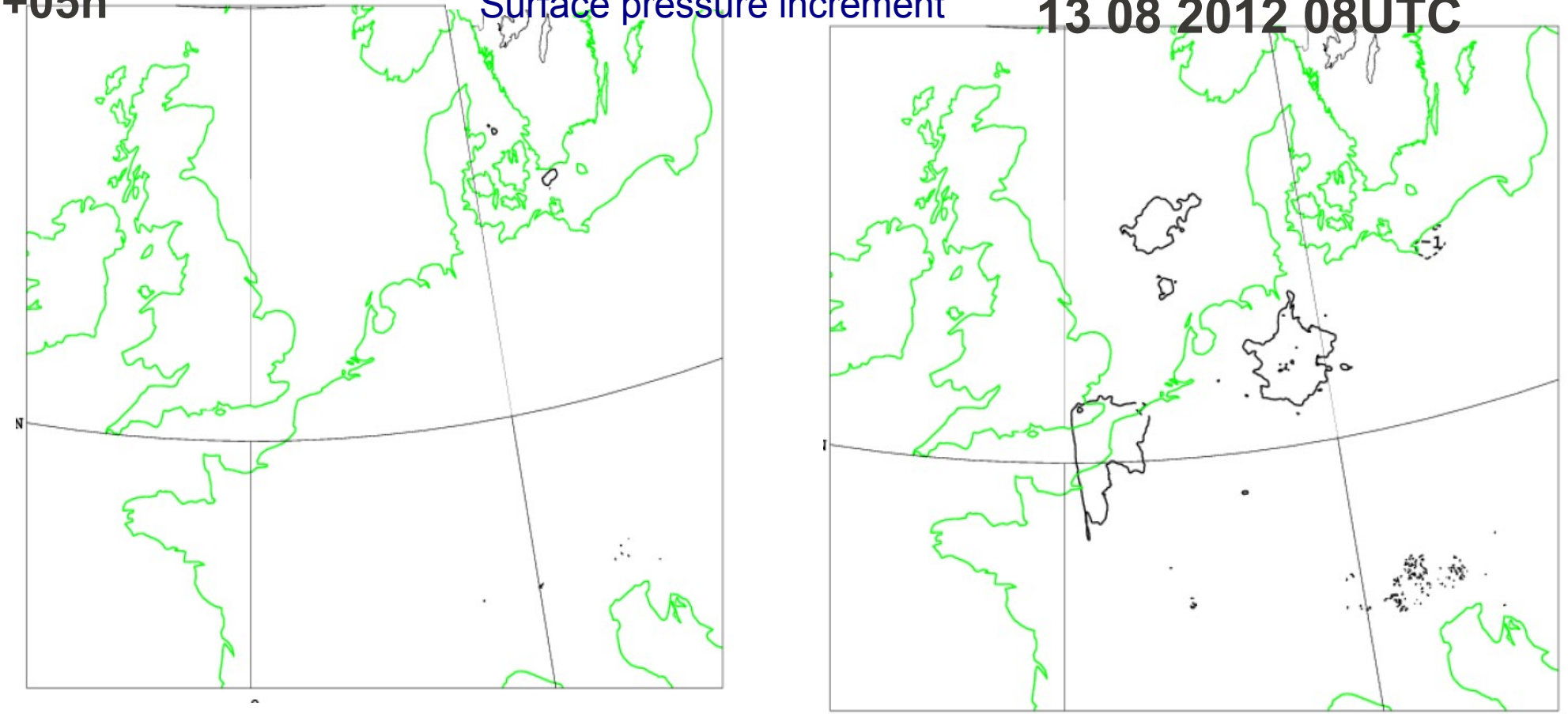


Surface pressure (control)

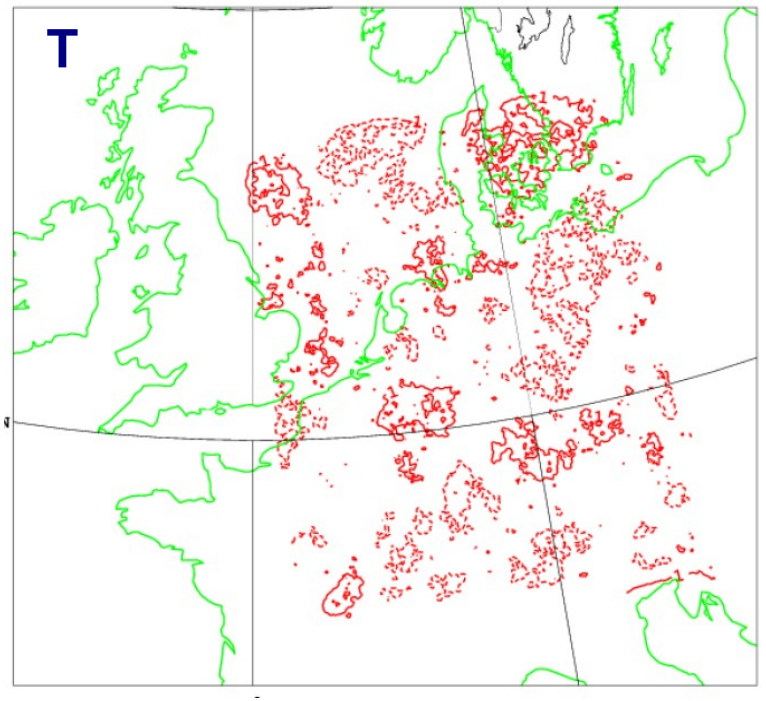


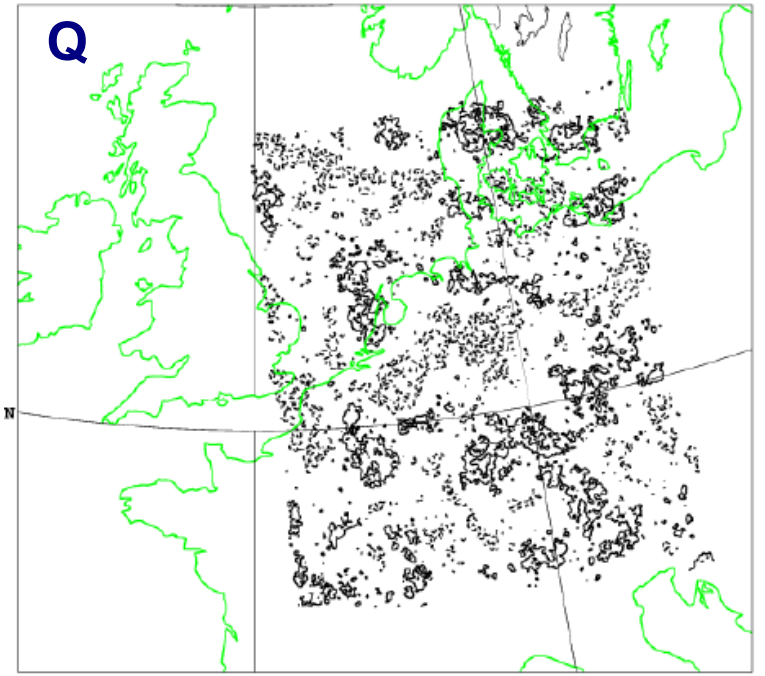
Surface pressure increment

13 08 2012 08UTC

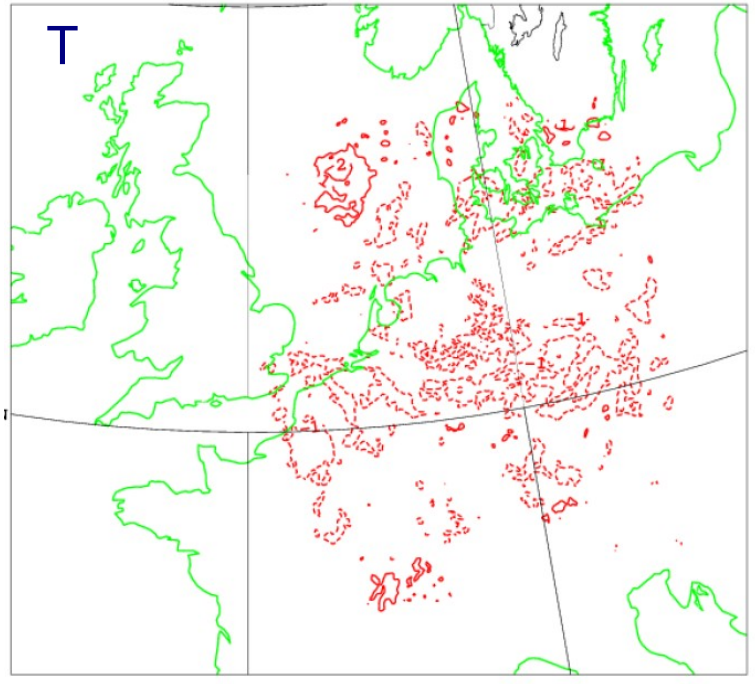


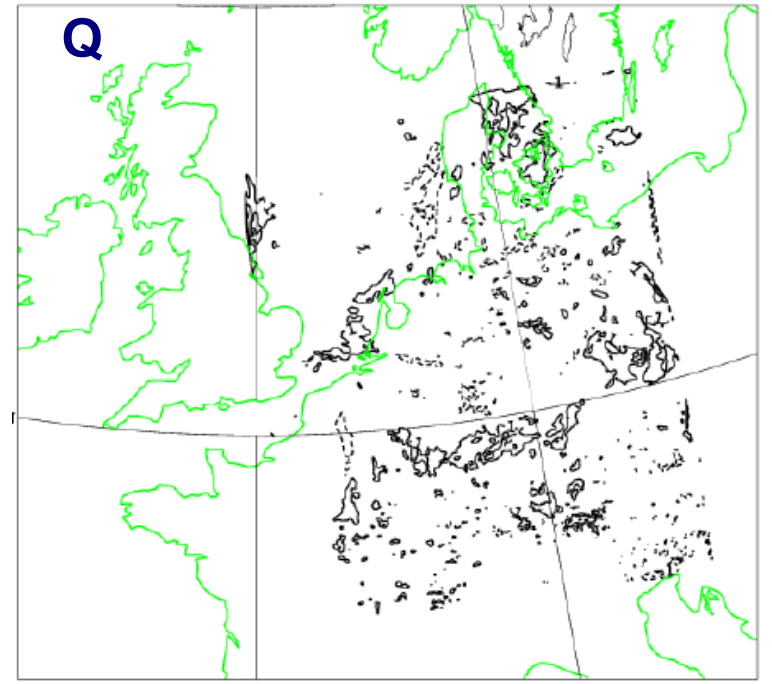
Evolution of perturbation with structure of B-matrix covariance





03 08 2012 03UTC
Forecast length +00h

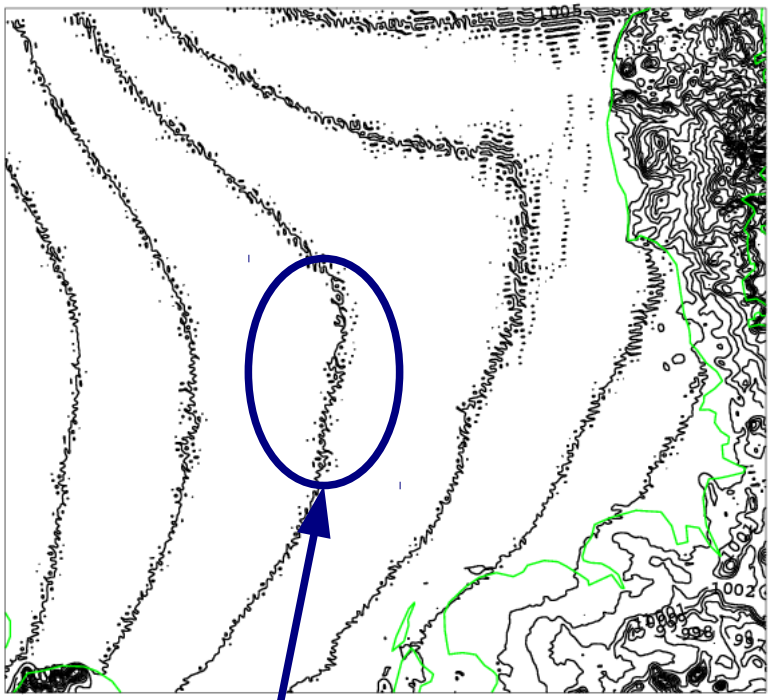




03 08 2012 07UTC
Forecast length +04h

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

Surface pressure

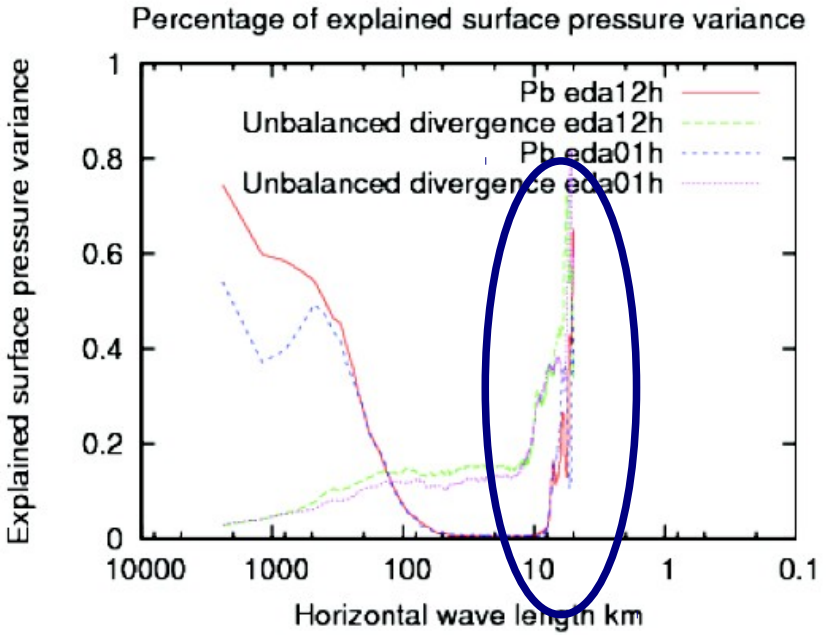


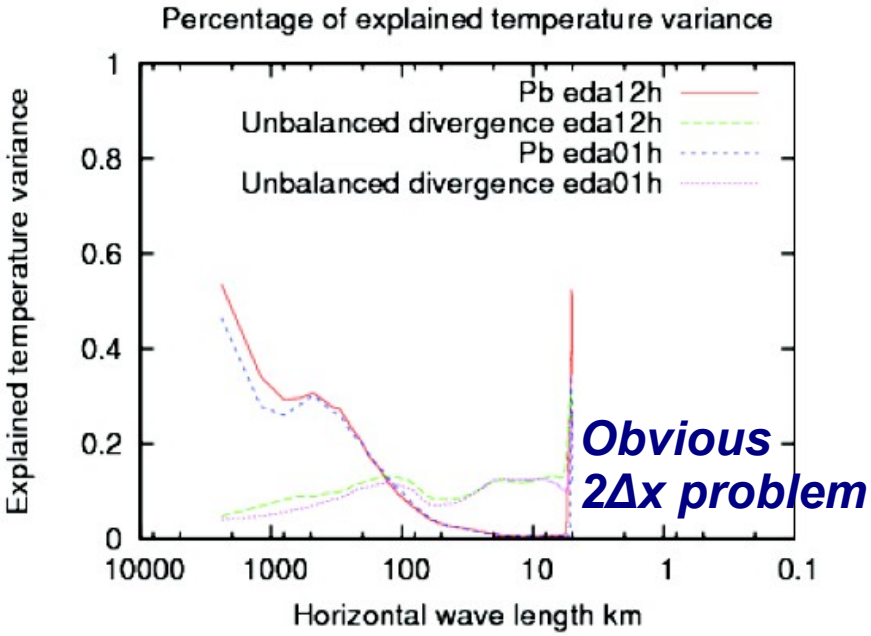
Or numerical truncation ?

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

➔ Physics-numerics interactions?
➔ 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) ?

What structure functions say





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

(from Nils Gustafsson SMHI)

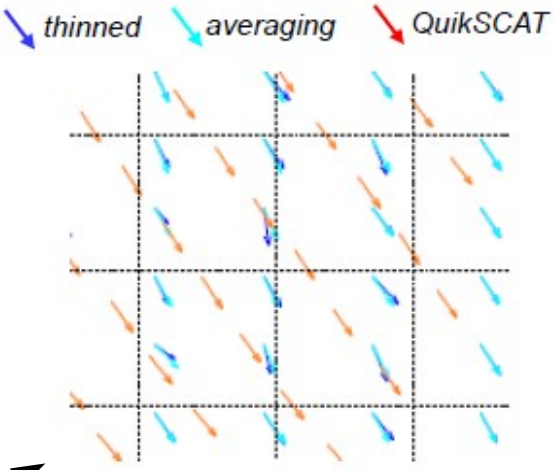
The preliminary results using **cubic grid truncation** (Mariano Hortal implementation) show encouraging results : **increased numerical stability of the scheme and longer time stepping in the semi-lagrangian forward propagation**. Processes are resolved in the grid-point space and smoothed in the spectral space.

Scales for the deterministic analysis update

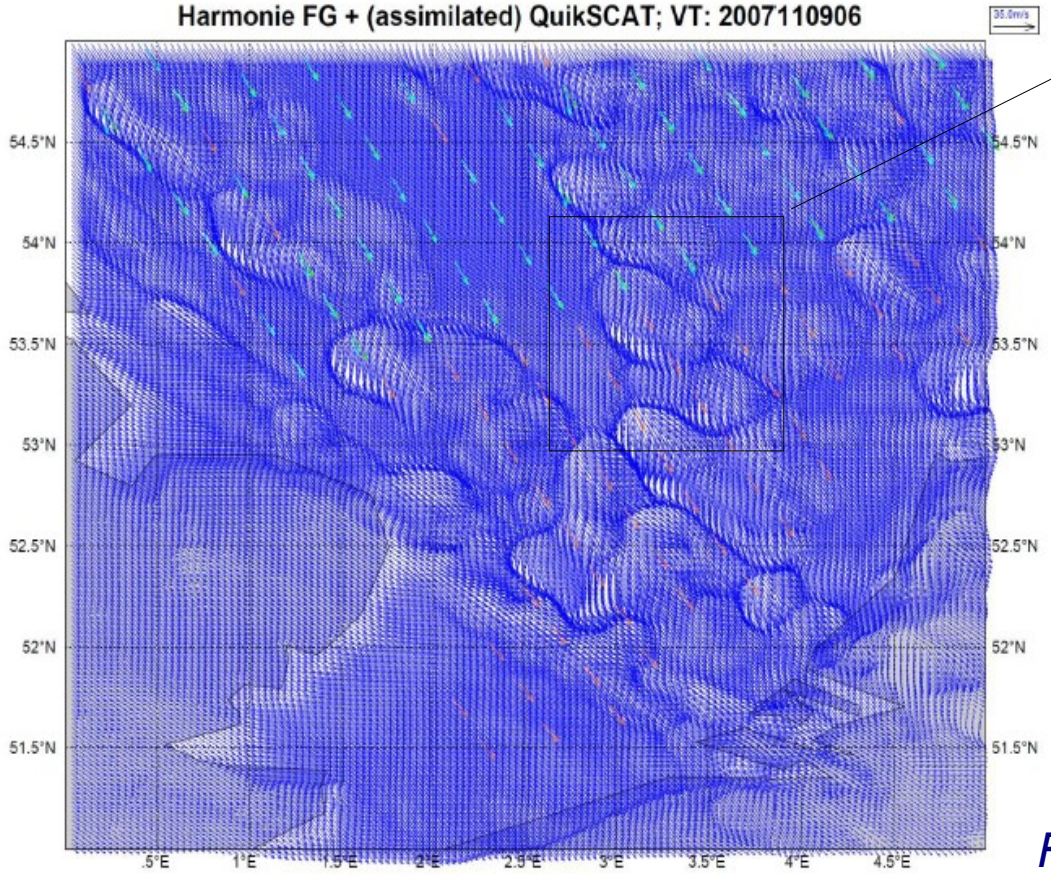
→ Averaged HARMONIE fields compare well with observations;

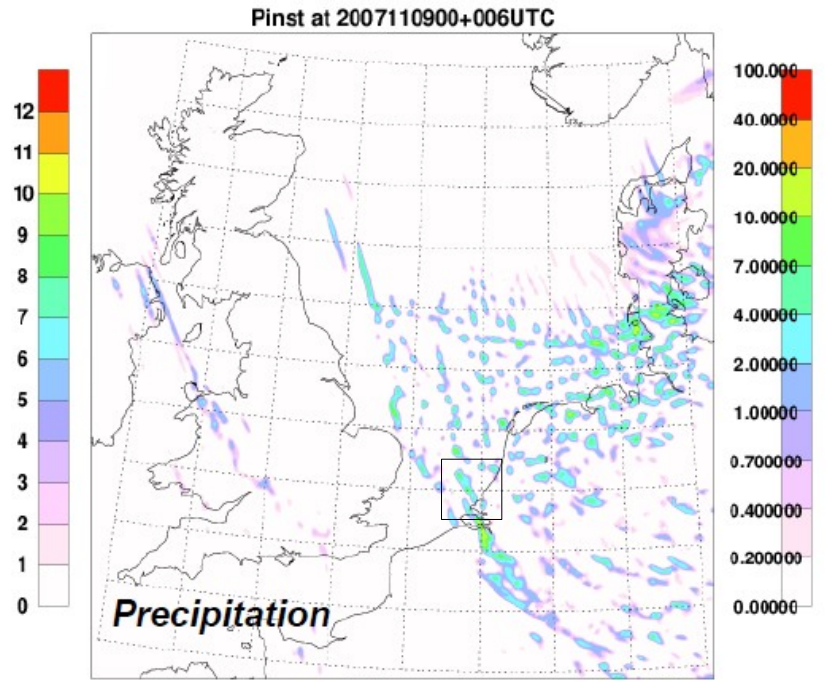
→ **HARMONIE AROME 2.5** small scales structures are probably realistic, **but are they real**?

→ Nature and NWP model <=> two realisations of a stochastic process; **What are the meaningful scales for deterministic analysis update?**



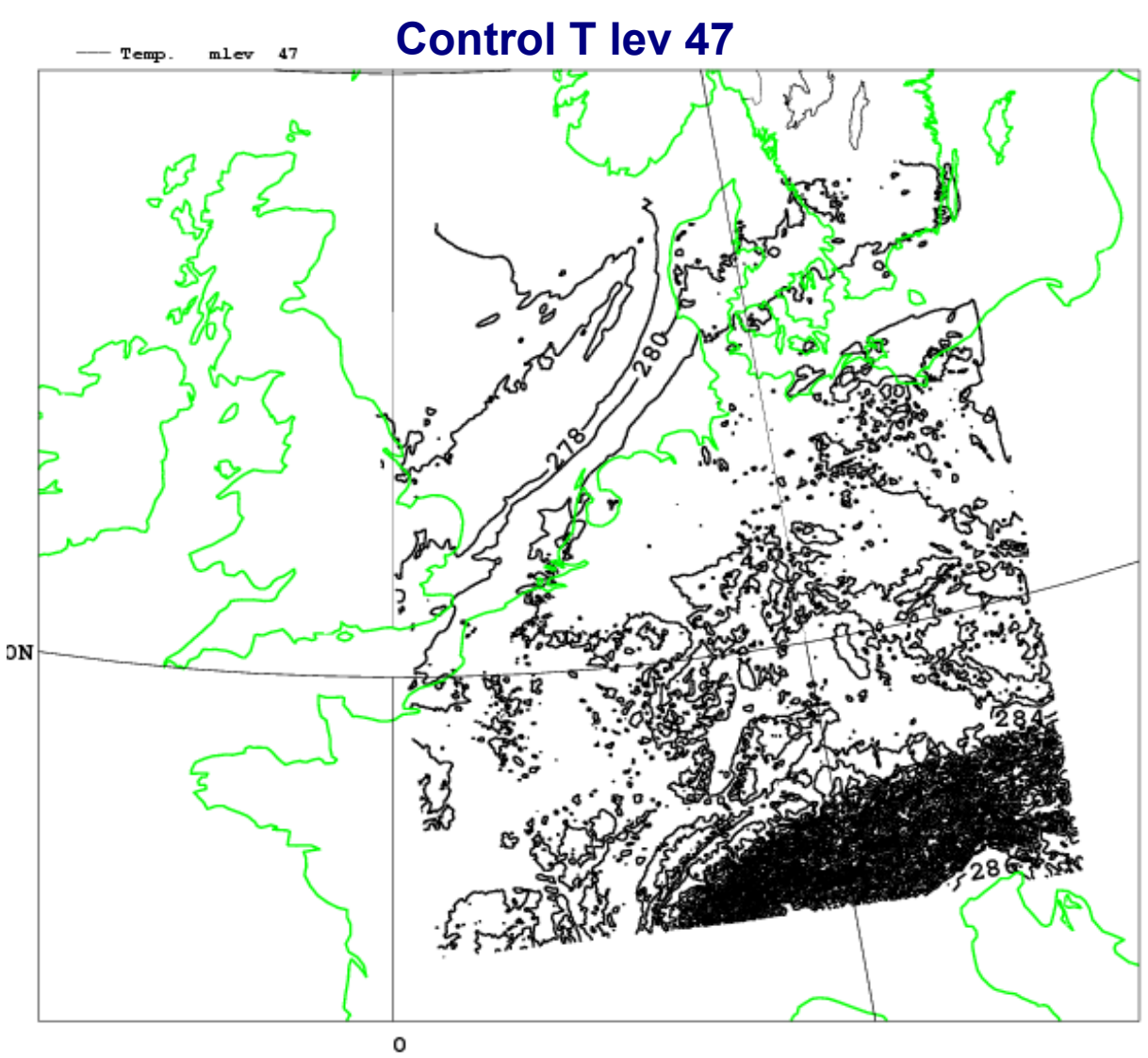
QuickSat footprint is about 50km^2

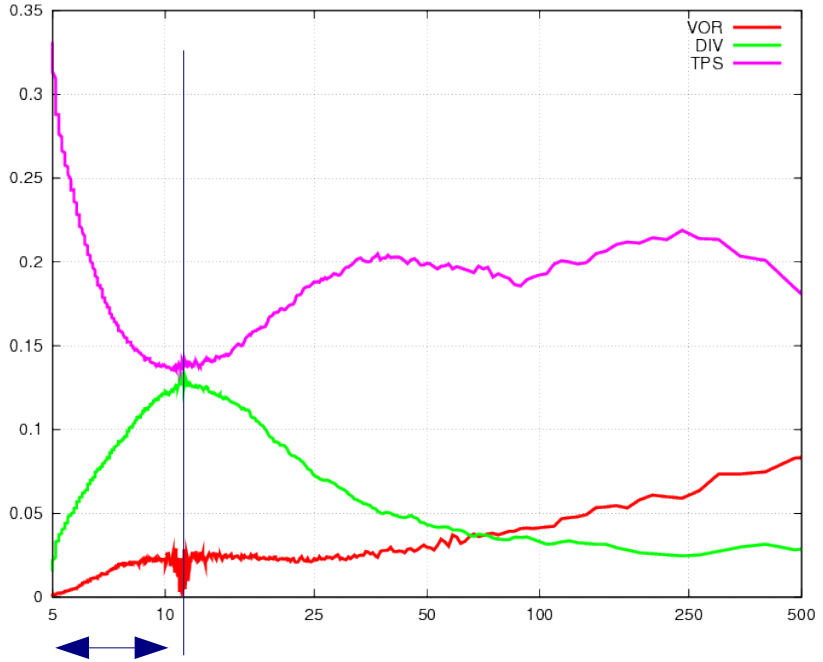




From Gert-Jan Marseille & Wim de Rooy (KNMI)

Despite of small scale noise HARMONIE AROME is able to model realistically processes on meso-scales!





12.5km = 5Δx

Part of humidity variance explained from
Unbalanced Temperature
Unbalanced Divergence
Vorticity

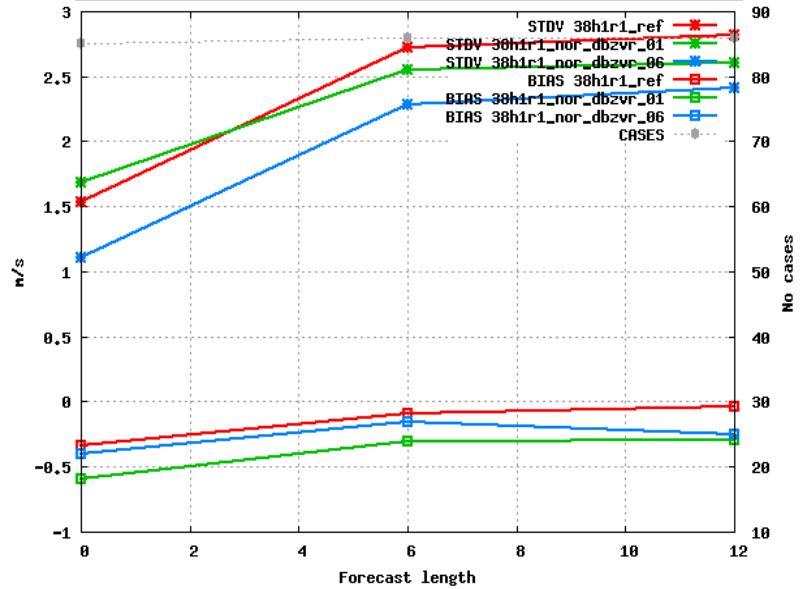
Processes on scales below 12-15 km should be interpreted with care ! (Resolved convection : AROME 500m?)

Impact of the climatological background error statistics

Assimilation of radar data
(summer experiment)

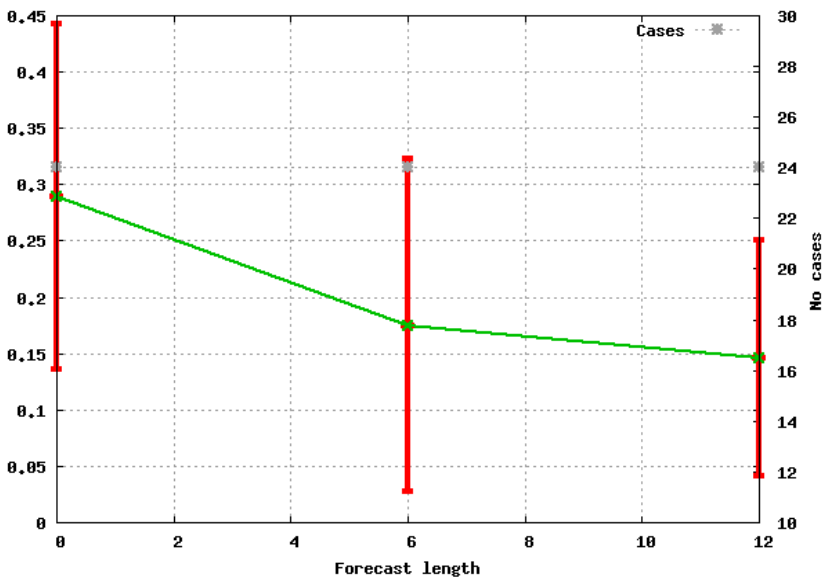
Verification against
Radiosonde wind at 925hPa (~750m)

RMSE and BIAS



Default model
Default model + radar
New model statistics + radar

Difference (95% confidence)



from Malte Müller (RapidWind, MET Norway)

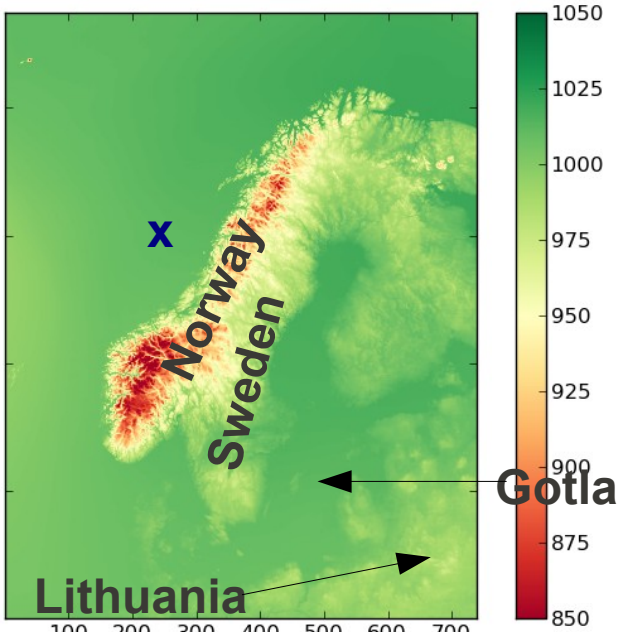
New model statistics:

Observing network (with radar data/without radar data) perturbed on convective scales + varying physics parameterization + 12h model integration

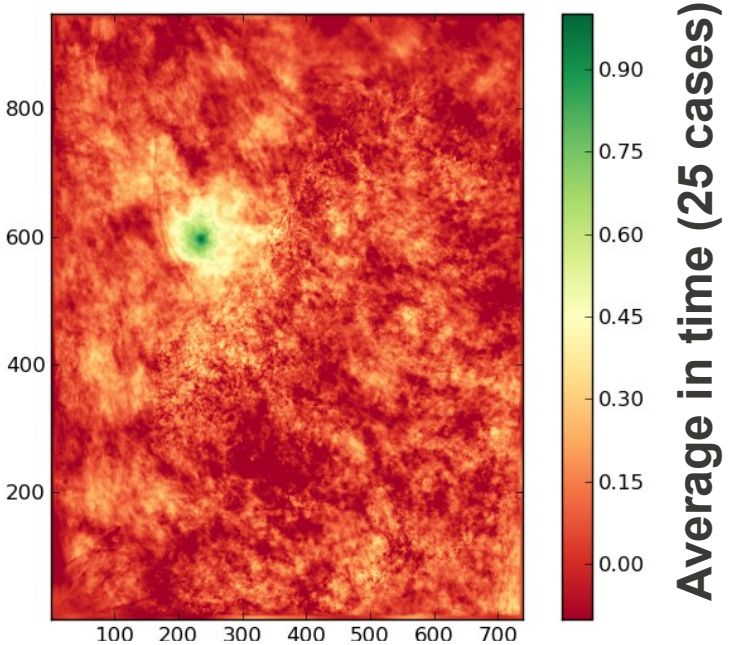
Climatological structure functions

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

Surface pressure (MetCoOp domain)



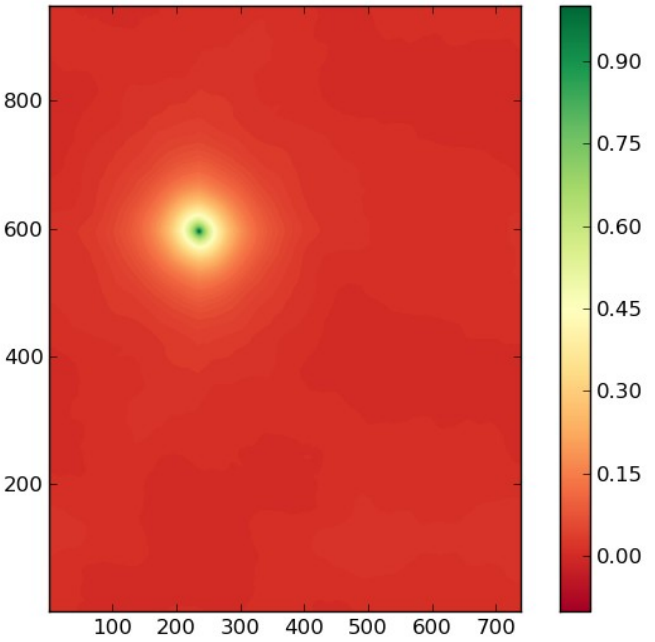
Correlations to a single reference point x= (235,595)



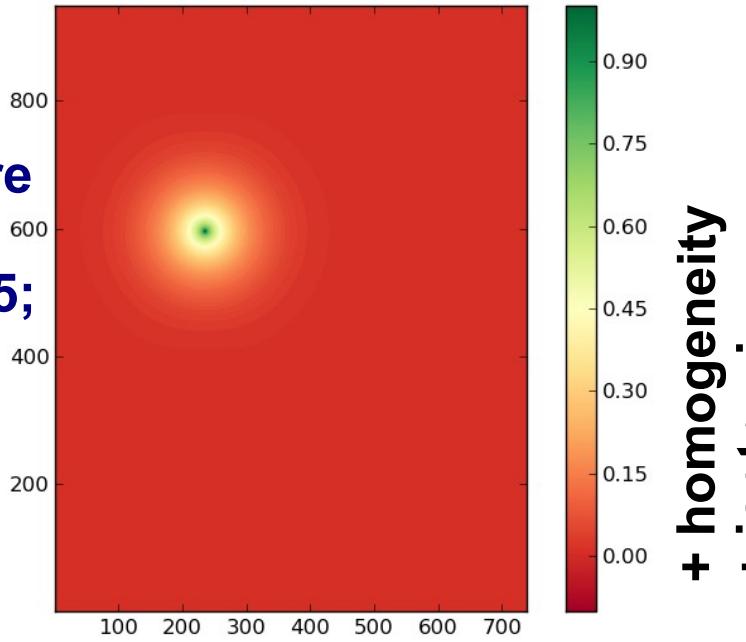
Average in time (25 cases)

(from Nils Gustafsson, SMHI)

+ homogeneity



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

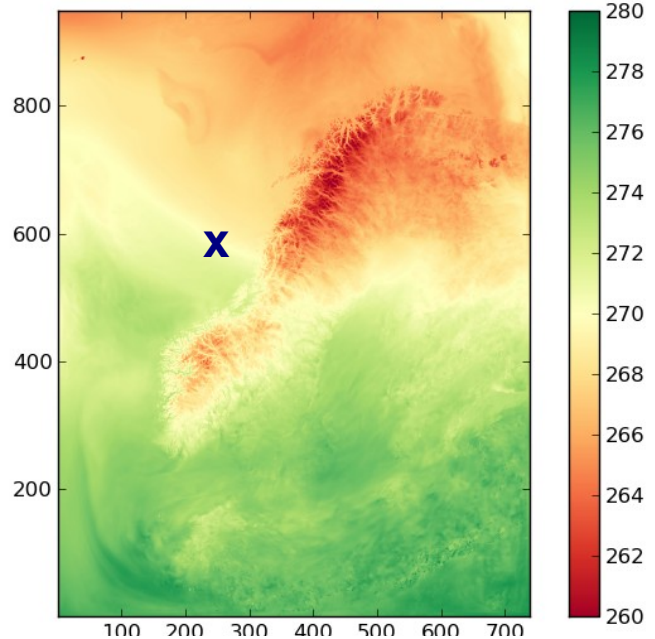


+ homogeneity
+ isotropi

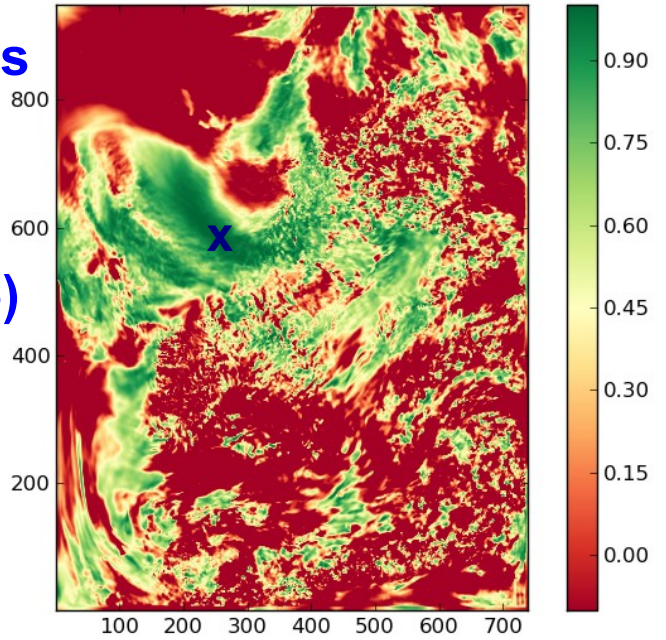
Climatological structure functions

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

Temperature (control)
(12 08 2008)

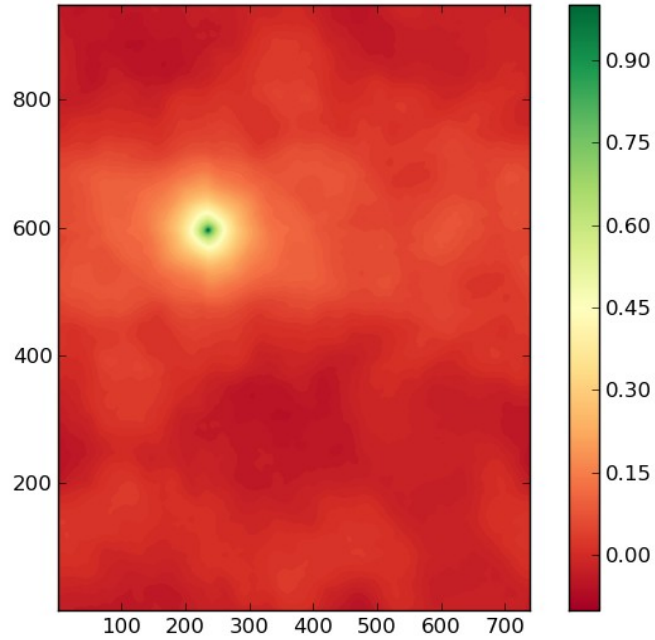


Correlations to a single reference point x= (235,595)

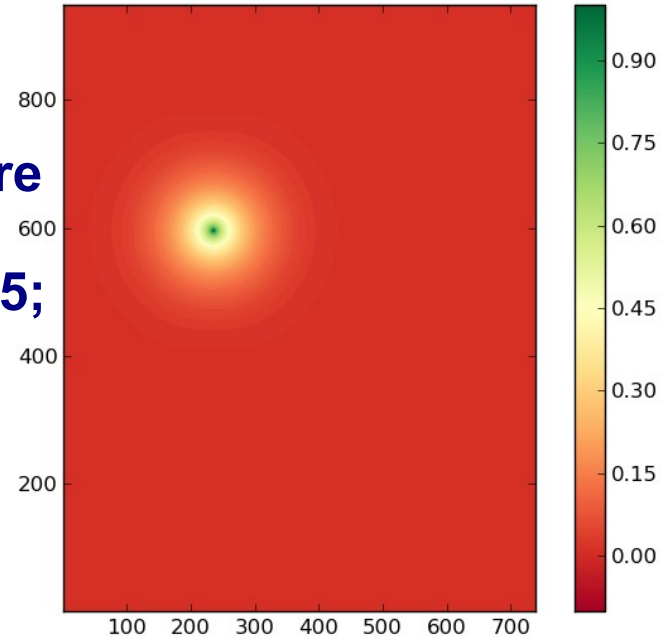


Single case

+ homogeneity



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

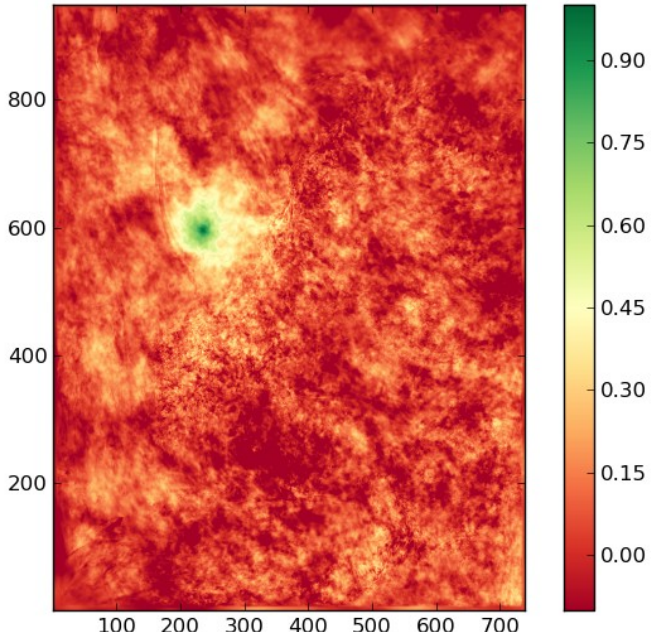


+ homogeneity
+ isotropy

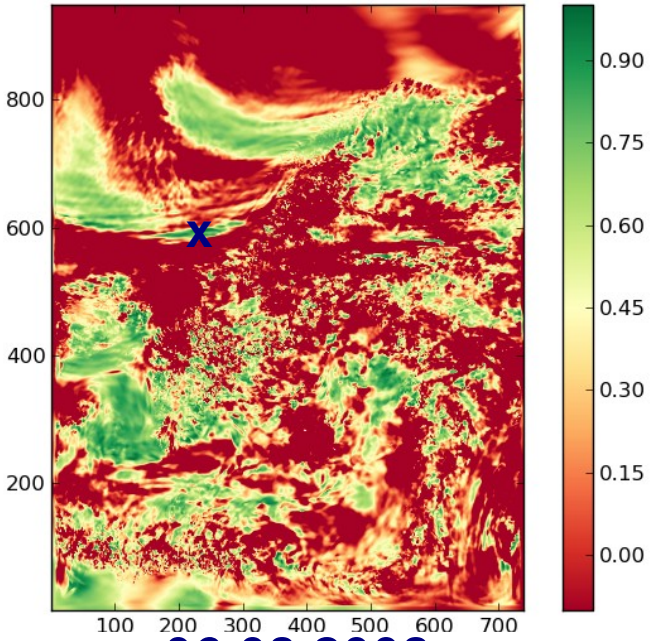
Climatological structure functions

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

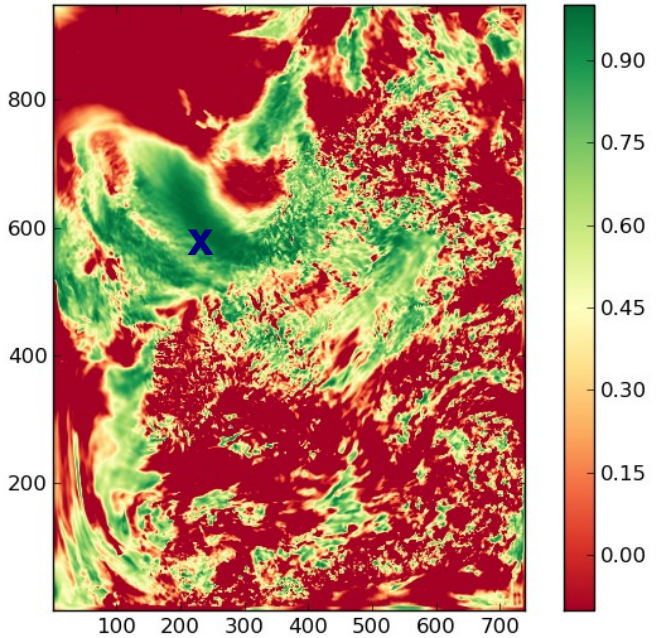
Average in time (25 cases)



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

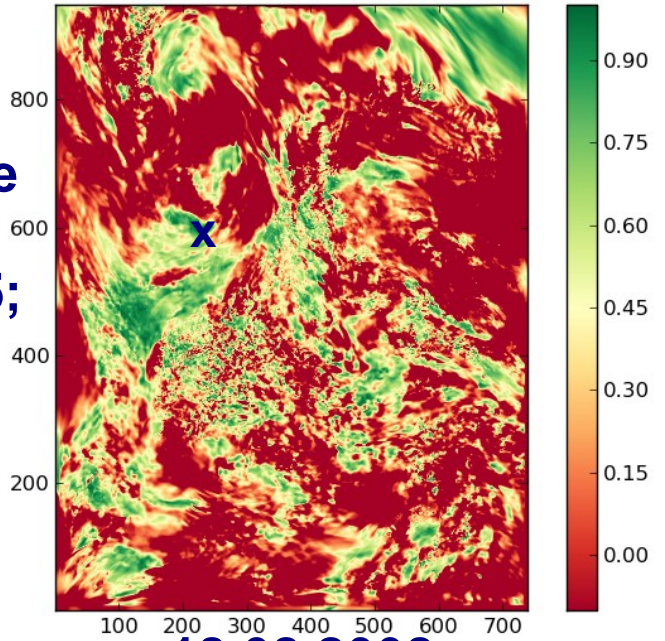


06 08 2008



12 08 2008

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



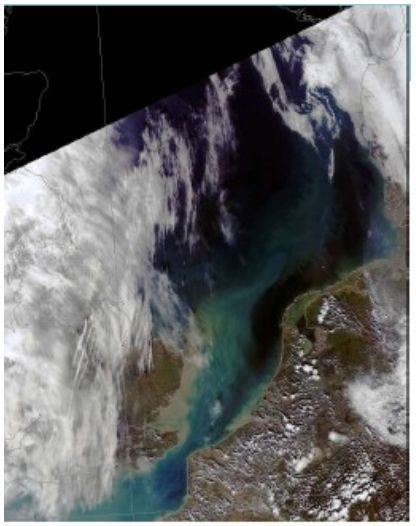
18 08 2008

Allow flow-depenency, Avoid homogeneity & isotropi

HARMONIE AROME 4DVAR Prototype

From Jan Barkmeyer & Sibbo var der Veen (KNMI)
Magnus Lindskog (SMHI)

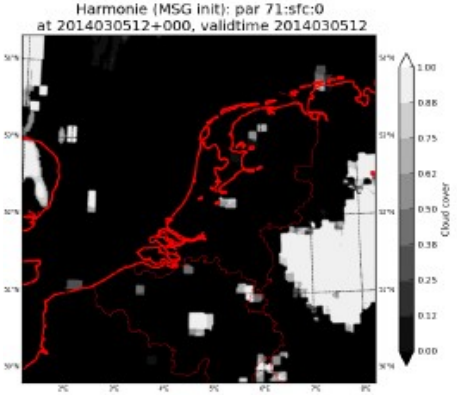
Satellite image



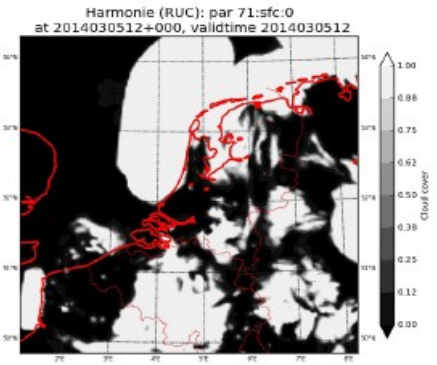
Flow-dependent structure functions even with a very crude TL/AD model helps!

The Fog over sea problem is significantly reduced with HARMONIE AROME 4DVAR assimilation

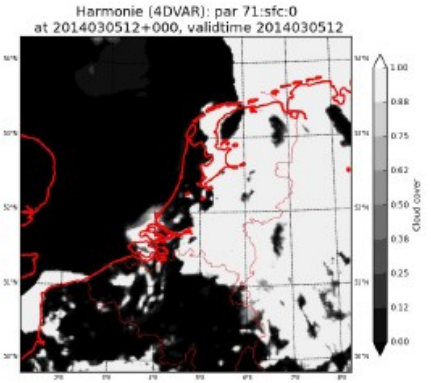
Cloud mask initialisation



HarRUC



Har4DV



➔**More on AROME 4DVAR : see Pierre Brousseau presentation**

Flow-dependent structure functions

Analysis increment from SSOE :

58° N, 15° W; 500hPa
5 hours into assimilation window
du =10m/s; dv = 5m/s

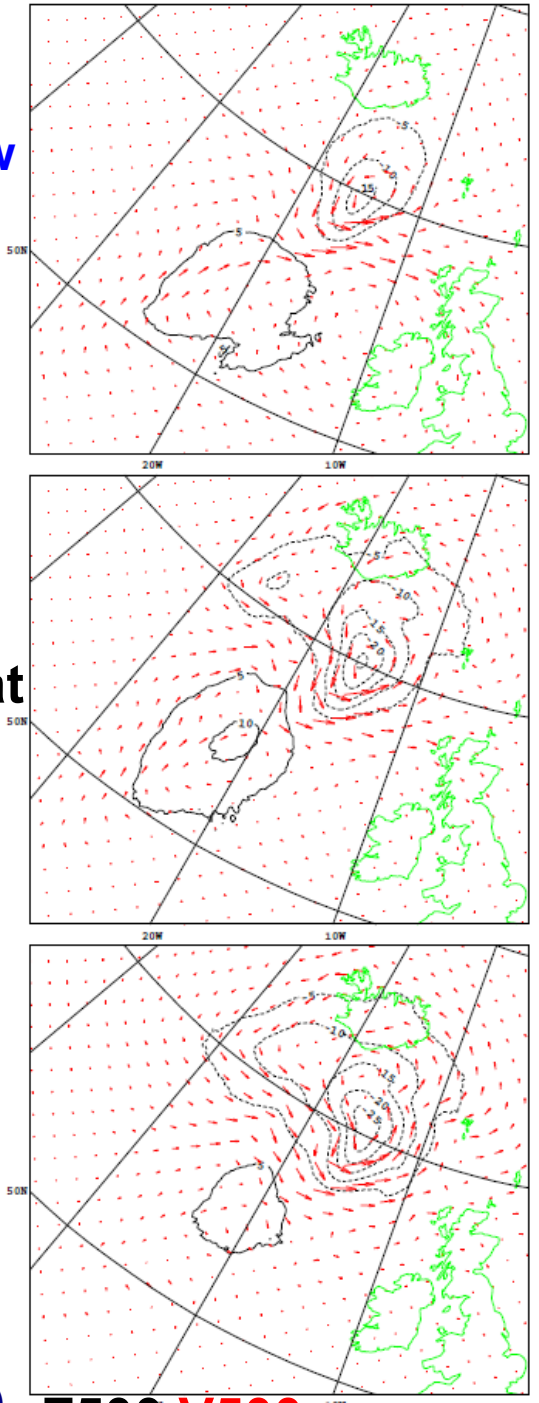
4D-Var :=> **TL model**

4D-Var Hybrid :=> **Ensemble constraint at initial time + TL model**

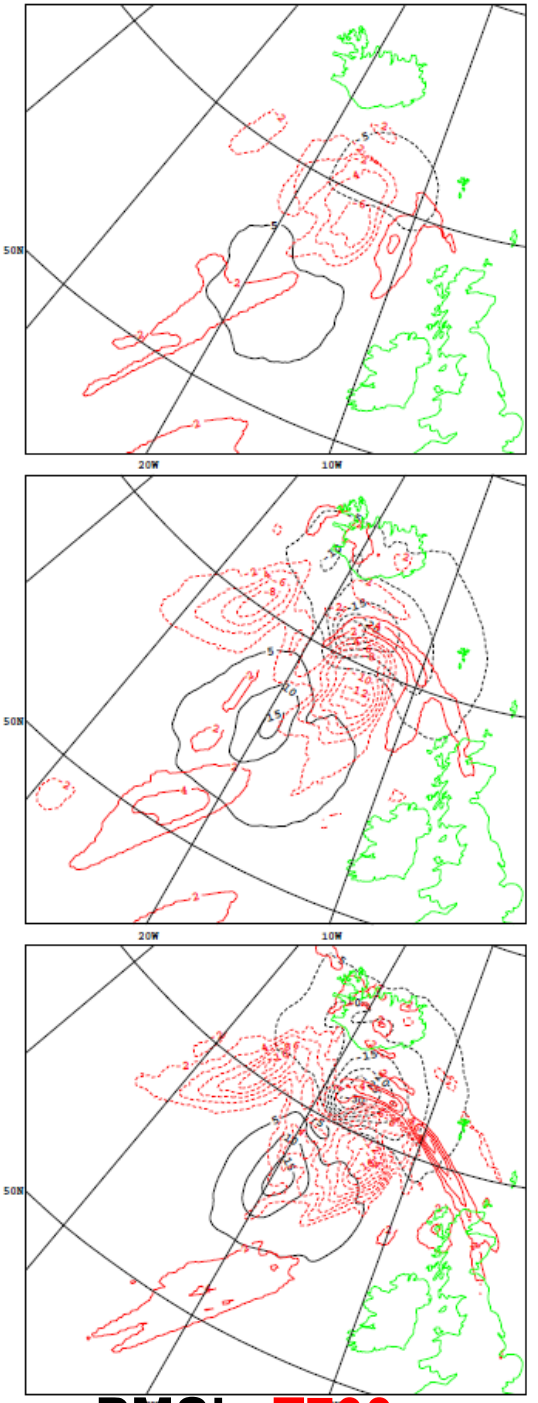
4D-En-Var

=> **Ensemble constraint at initial time + 4-D ensemble evolution**

(from Gustafsson&Bojarova, 2014)



Z500, V500



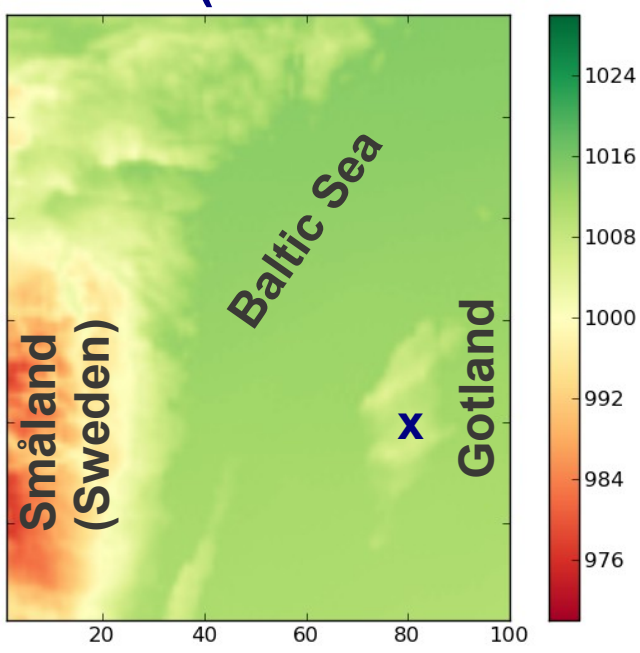
PMSL, T700

Use ensembles in DA!!

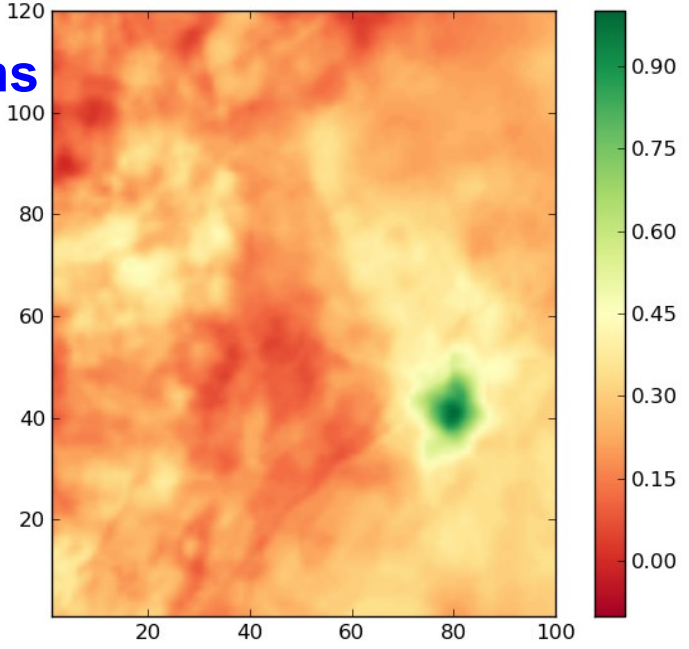
Climatological structure functions

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

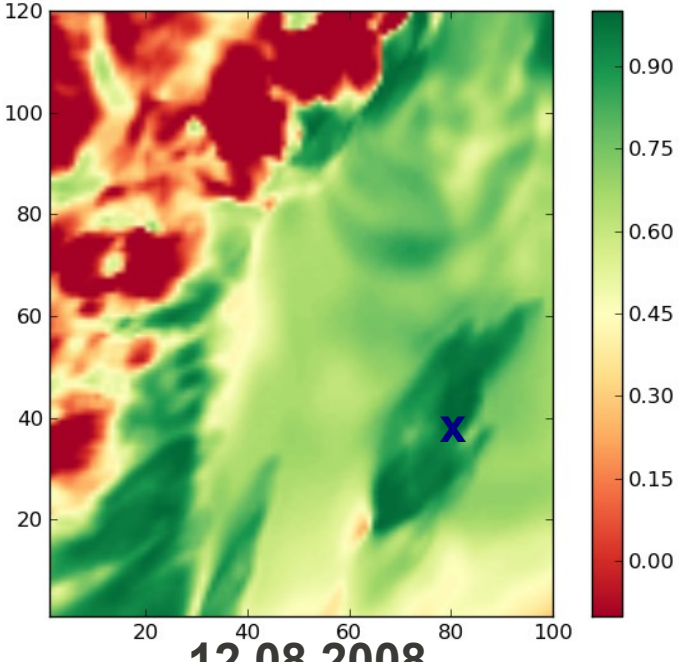
Surface pressure (zoom over Gotland)



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

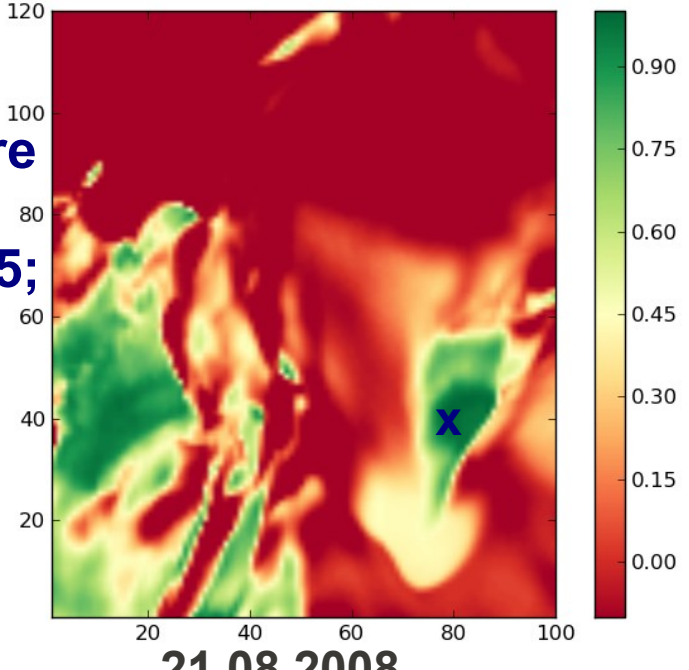


Average in time (25 cases)



12 08 2008

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



21 08 2008

Big potential of HarmonEPS ensemble for convective scale phenomena (surface &PBL)

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! More high resolution observations.

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

➔More on EnVar : **see Thibaut Montmerle presentation**

Keep Going ...

everything will be okay
in the end ...

if it's not okay,
it's not the end

Unknown

Thank You for your attention!