



*Meteorologisk
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Flow-dependent data assimilation in HIRLAM community

**HIRLAM/ALADIN ASM, Marrakesh,
Morocco
7-11 May 2012**

Jelena Bojarova

Structure of the presentation



1. **What to we have now:**

- a) Climatological variability of the forecast error covariance
- b) 4D-VAR scheme for HIRLAM and HARMONIE models .
- c) Hybrid ensemble variational data assimilation

2. **Where do we go**

What is the best way to generate ensemble :
ETKF/LETKF/EnsDA?

3. **What obstacles do we have on the road**

Ensemble is not reach enough

4. **Solution in the longer term perspective :**

Assimilation of structures



Powerful and flexible research tool
designed for synoptic scale systems

HIRLAM (High Resolution
Limited Area Model)

ECMWF IFS (Integrated
Forecasting System)

ALADIN (Aire Limitée Adaptation
Dynamique Développement InterNational)

The goal: move operational activities here
but is still under development

HARMONIE (*Hirlam Aladin*
Regional/Meso-scale Operational NWP In Europe)

But, HIRLAM should fall to sleep forever in peace !



What do we have now

Climatological variability of the background error covariance



A combination of different climatologies through the augmented control vector space

4D-Variational data assimilation with the climatological forecast error covariance



Assimilation of structures : warping technique to account for non-additive errors

Hybrid ensemble variational data assimilation



3D-VAR
4D-VAR



ETKF
LETKF
EnsDA



4D-Variational data assimilation

model	HIRLAM	HARMONIE ALARO	HARMONIE AROME
status	Advanced/ operational	Pre-operational implementation	Design and early implementation stage
comment	Assimilation of structures is under development	Decision about the feasibility of the scheme by the end of 2013	ECMWF physics/ Simplified Tangent linear ECMWF ph. p

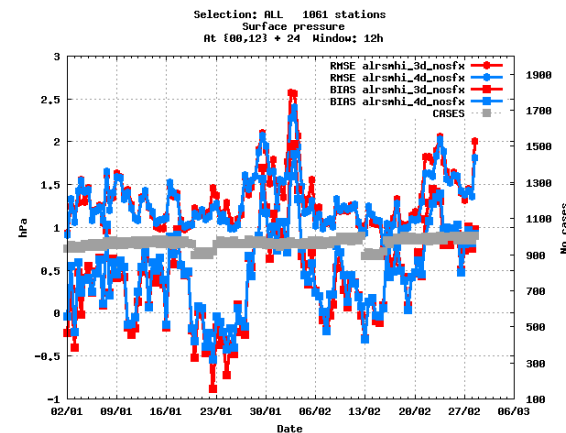
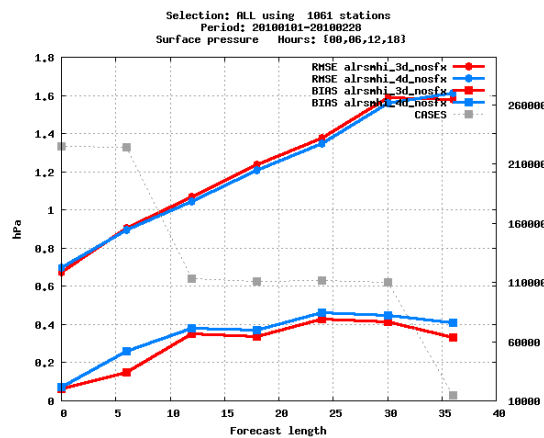
The latest progress with of the HARMONIE 4D-VAR



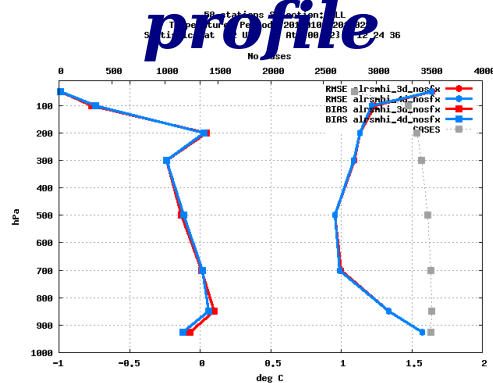
P_s
bias + rms

P_s
time series

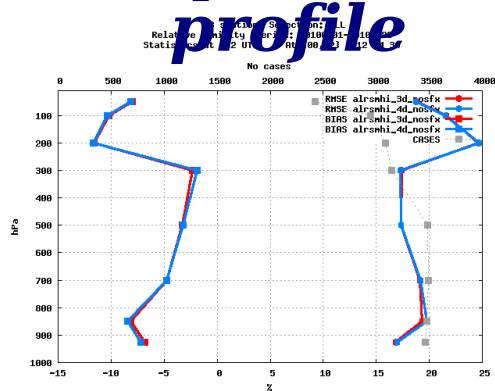
- **3D-Var** vs **4D-Var** (2 months)
- 1 Jan 2010-28 Feb 2010
- Swedish ALARO + “old surface”
- Conventional + AMSU-A
- model res. 5.5
- 4D-Var minimization 11 km



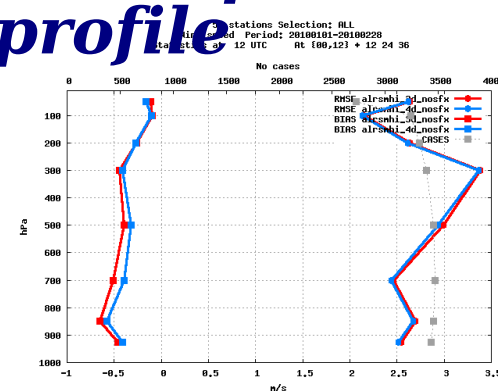
T
profile



q
profile



wind speed
profile



Hybrid Ensemble Variational Data Assimilation



model

HIRLAM

HARMONIE

ensemble techniques:

Lateral boundaries:
TEPS/ECEPS/random
Regional ETKF/EnsDA

Lateral boundaries
ECEPS/random
Regional LETKF/EnsDA

variational assimilation

3DVAR/4DVAR

3DVAR/RUC(3h)

status/plans

pre-operational
implementation

Ensemble generation:
EnsDA finalize August 2012
LETKF start fall 2012
Hybrid schem : estart fall 2012

Different approaches for the generation of ensembles of analyses perturbations



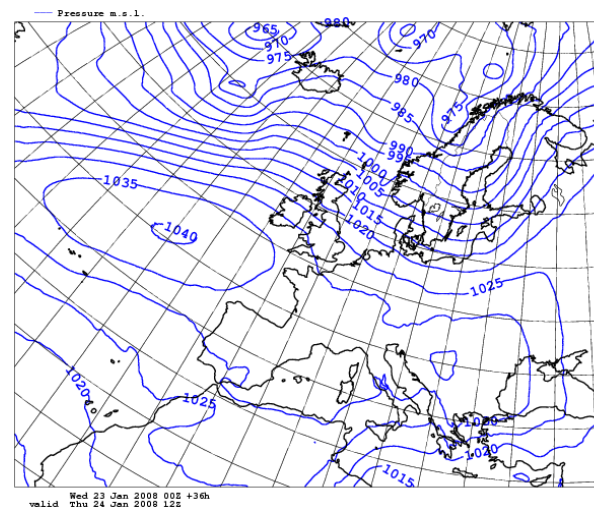
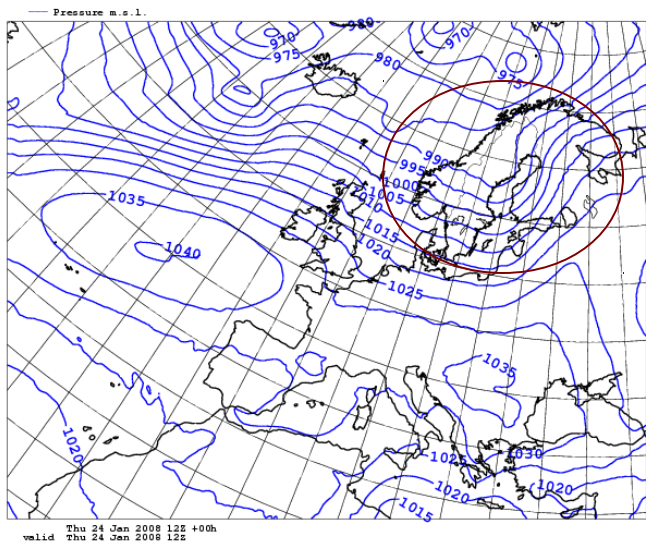
The EuroTEPS perturbations (based on global singular vector perturbations targeted to Europe with 48h optimization time (the time scale of baroclinic development); the evolved singular perturbations added in order to better capture the analysis error)

dynamics+observation network

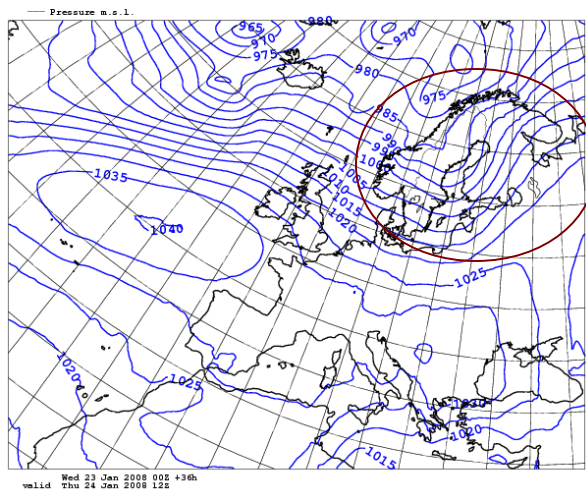
The ETKF rescaling perturbations (LAM perturbations with EuroTEPS boundaries based on the Generalized Breeding technique; perturbations are sampled deterministically taking into account both the dynamical instabilities and the density and the quality of the observation network)

observation network

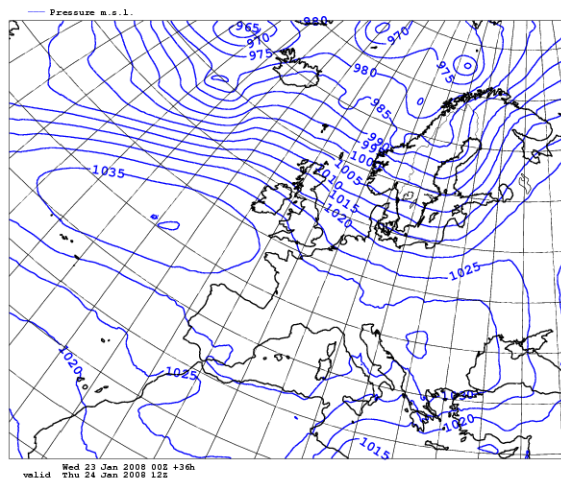
The EnsDA perturbations (LAM perturbations with EuroTEPS boundaries; stochastically simulate analysis error via observation perturbations techniques)



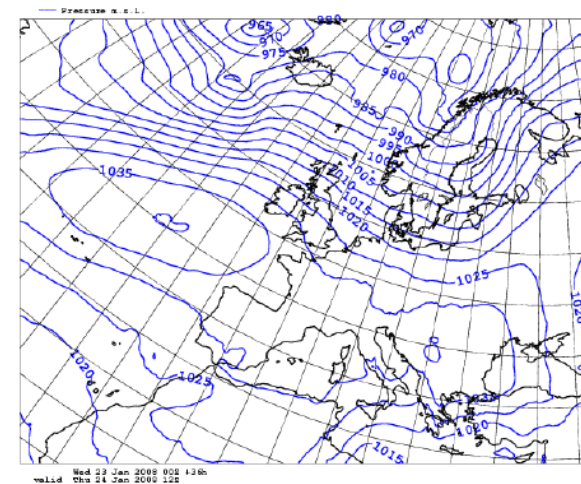
3DVAR



3DVAR+ETKF



3DVAR+EnsDA

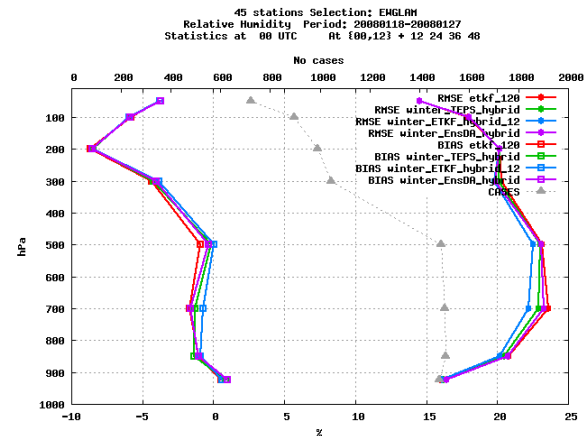
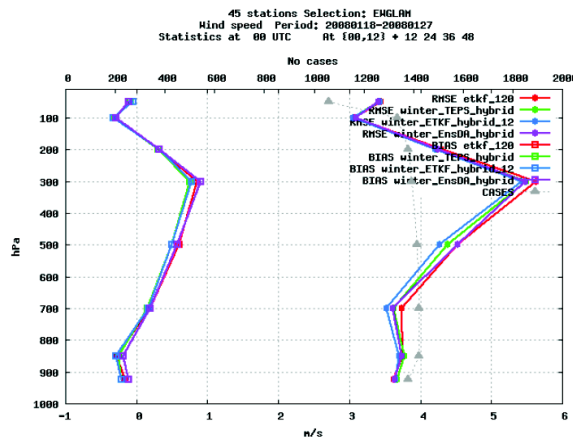
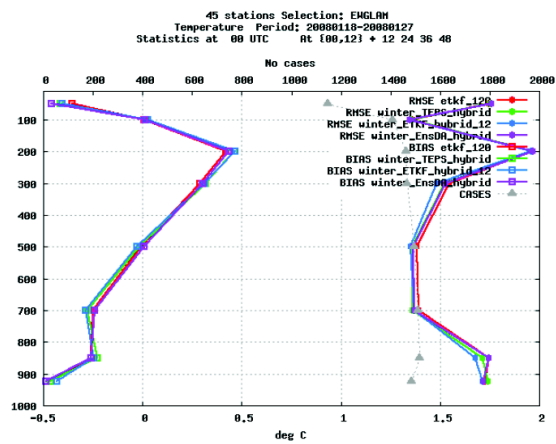


3DVAR+TEPS

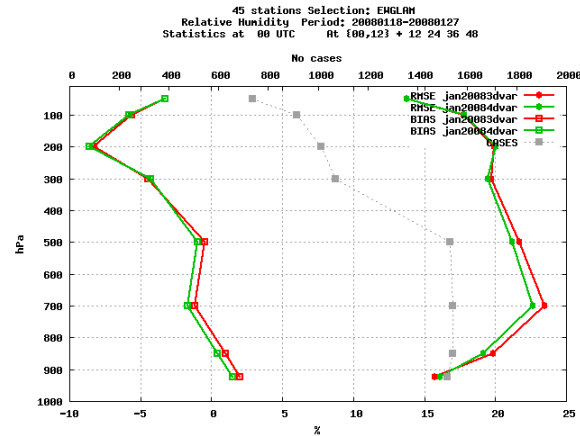
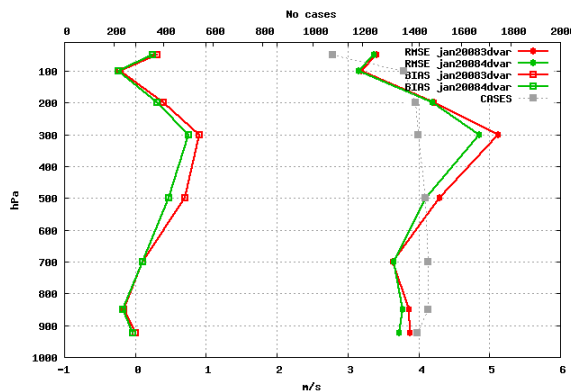
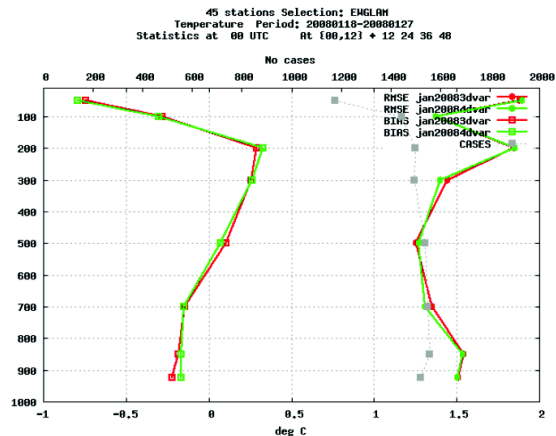
Verification scores : "winter case" 17Jan2008-27Jan2008 (too optimistic)



3D-Var versus hybrid approach (ETKF, EnsDA, TEPS)



3D-Var versus 4DVAR approach



Temp.

Wind speed

Rel. humid.

What is the best way to generate perturbations?



In our experiment the ETKF rescaling perturbations provided the best results

Why?

The ETKF rescaling perturbations contain more appropriate structures describing the short term (6h) background error growth

Deterministic sampling

EnsDA perturbations suffer from severe sampling noise for small size sample

Mature structures

Long optimization time for the SV underestimate dispersion for short time ranges



EDA

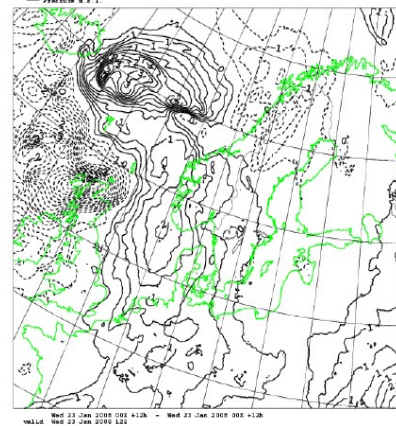
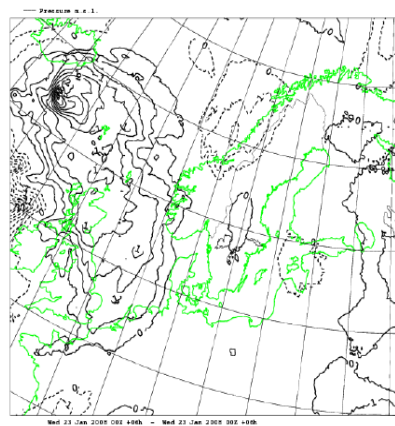
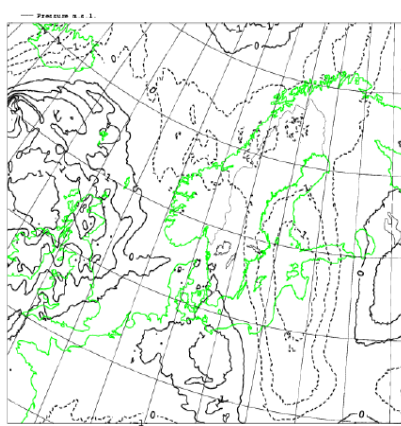
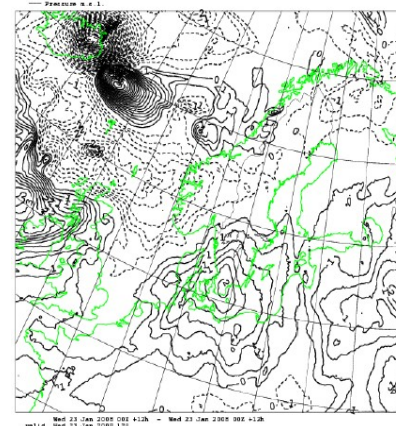
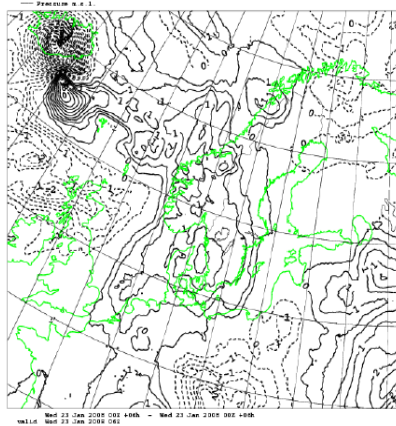
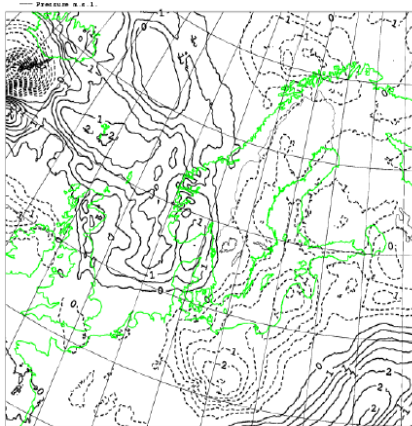
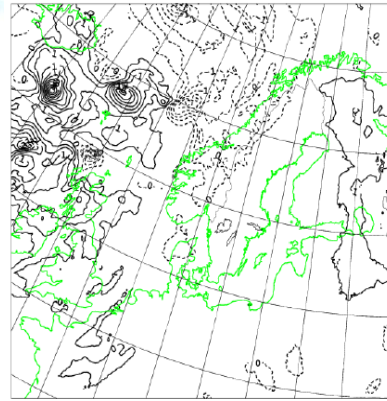
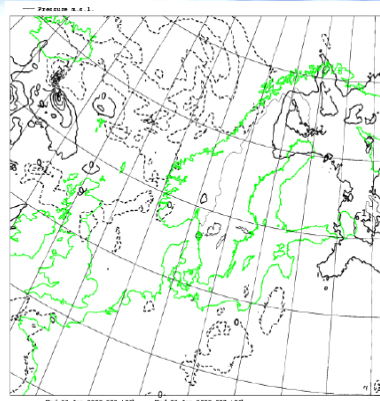
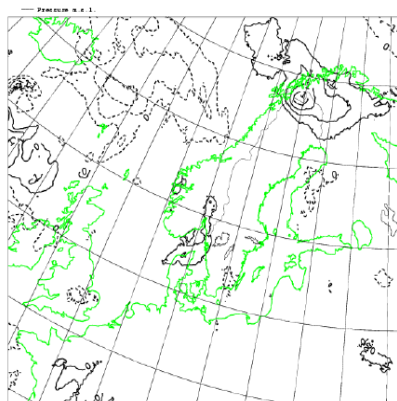
ETKF

SVs

+00h

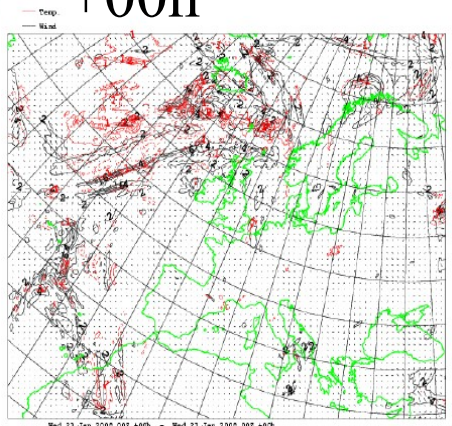
+06h

+12h

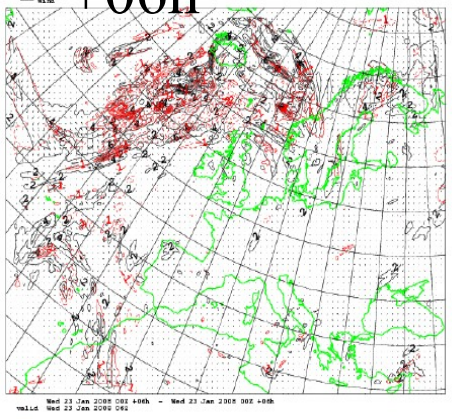


PMSL perturbation (member 5), 23 Jan 2008 00 UTC

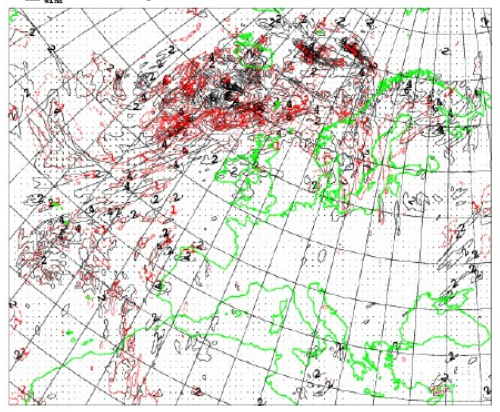
+00h



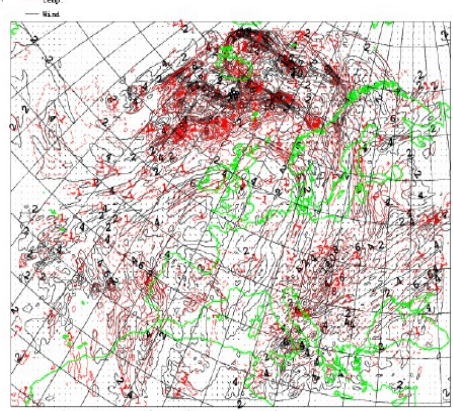
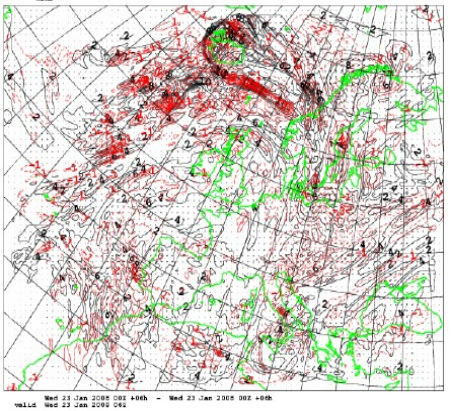
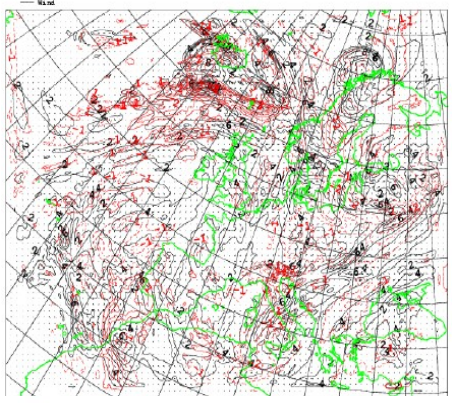
+06h



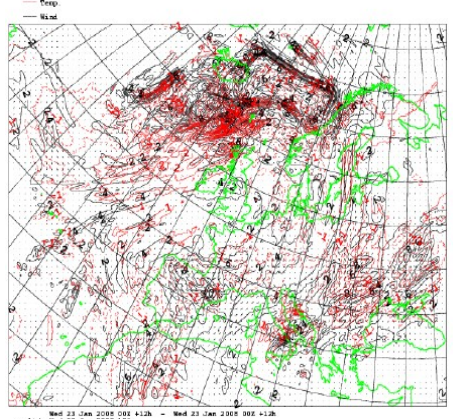
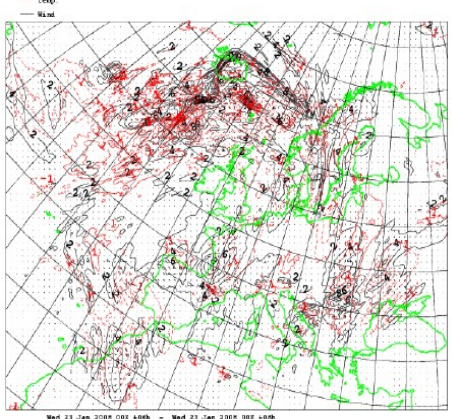
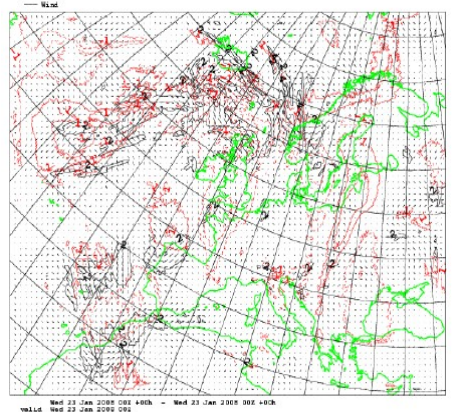
+012h



EDA



ETKF



SVs

u,v,T perturbation 500hPa (member 5) 23 Jan 2008 00 UTC



Problems experienced

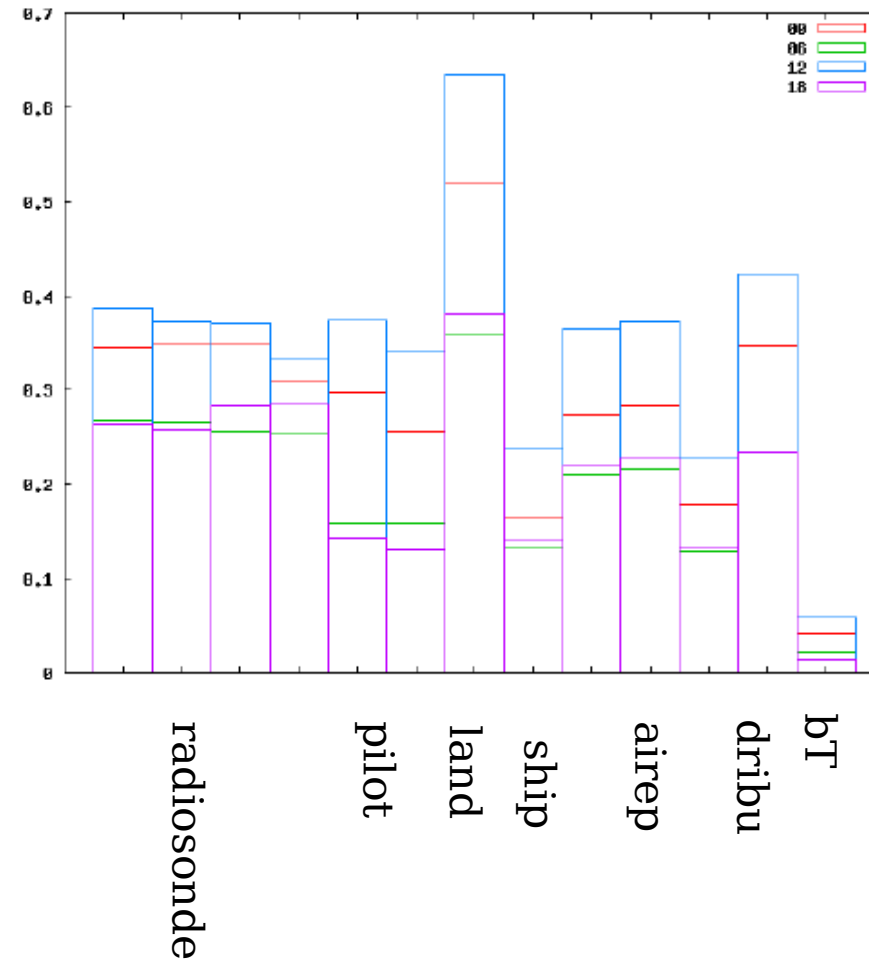
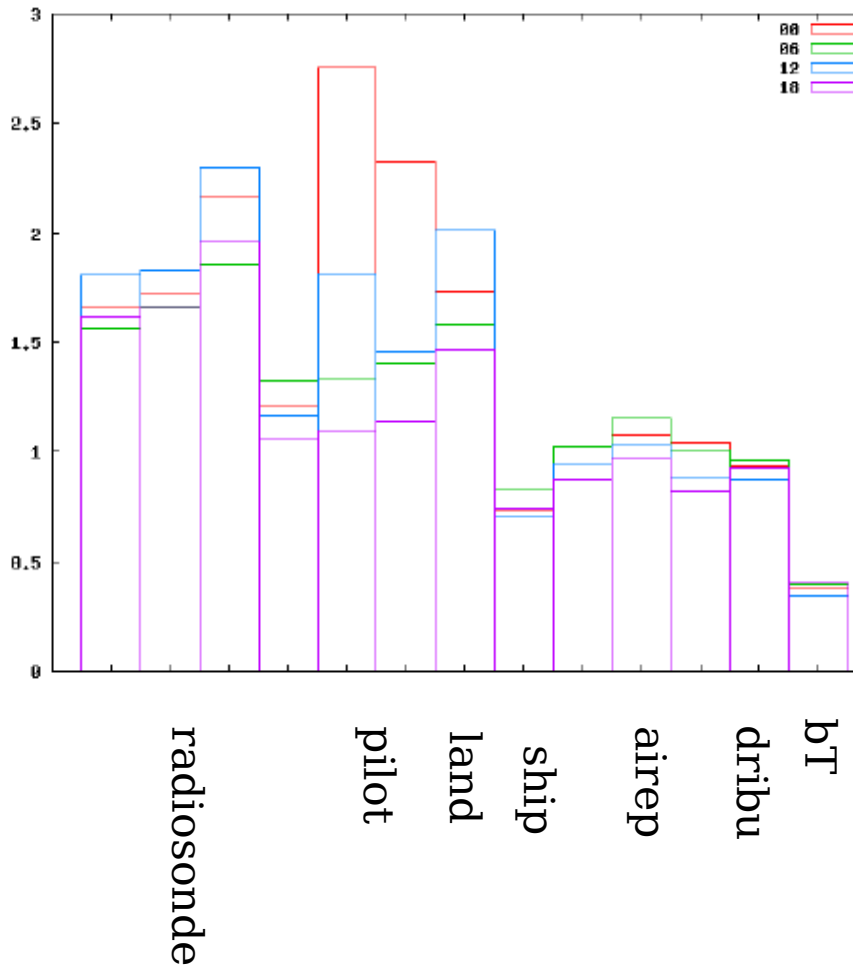
- ✓ Weak improvement using the hybrid scheme over 3DVAR-FGAT. 3DVAR-FGAT is a powerful scheme
- ✓ Negligible improvements using the hybrid scheme over the 4DVAR. At the beginning of the assimilation window +3h forecast ensemble is not mature enough
- ✓ The performance of the ETKF and EnsDA severely depend on how well the assimilation system is tuned. The 4DVAR scheme outperforms hybrid using the current operational setup of the background and observation error statistics

Relative squared innovation variance versus relative spread



$$d_i^2 := \sum_{j=1}^P \left(\frac{y_j - \mathcal{H}_j(x_i^b)}{\sigma_{\sigma_{\sigma_j}}^b} \right)^2 \propto \alpha_i \sum_{n=1}^{N-1} \lambda_{ni}^{N-1} + p$$

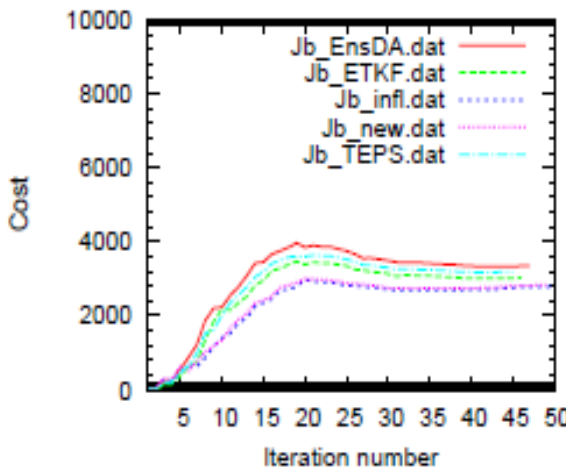
$$\text{trace}(B_{\text{ense}}^f) = \frac{1}{P} \sum_{j=1}^P \frac{\text{Var}(\mathcal{H}_j(d\mathcal{X}^f))}{\sigma_{\sigma_{\sigma_j}}^2}$$



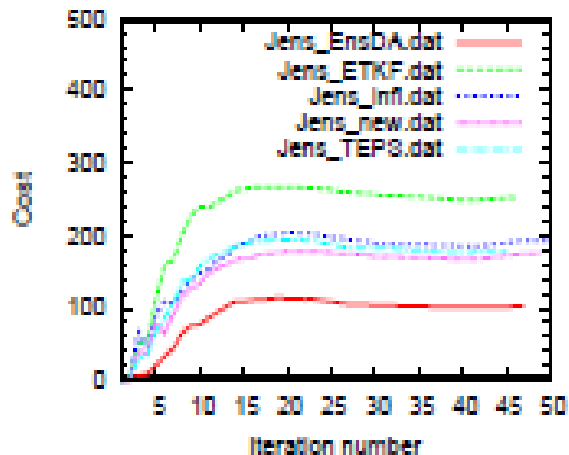
What obstacles do we have on the road



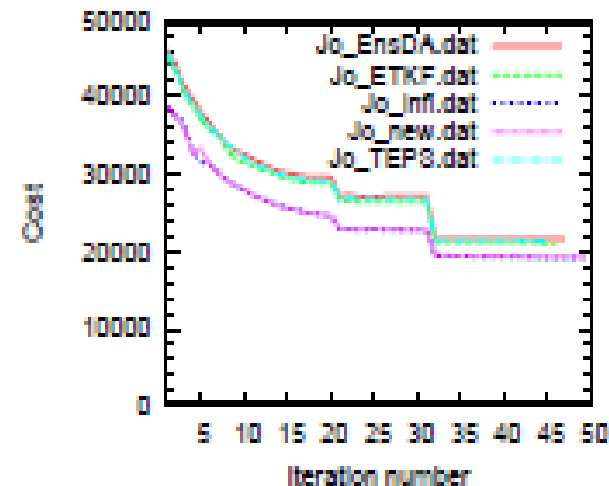
Jb



Jens



Jo



Diagnostics of the cost function minimization

Structures are not rich enough on smaller scales !

Larger ensemble size : lag ensemble ?

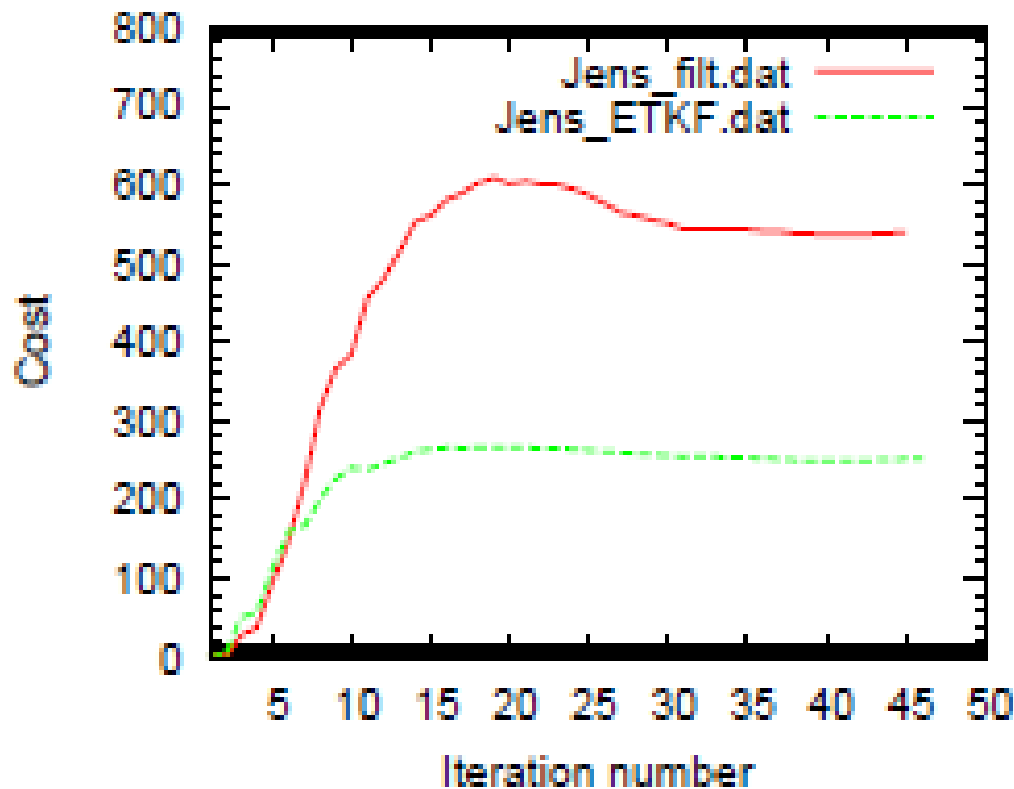
Small scale perturbations: model error ?

High resolution : dense observation network?

What obstacles do we have on the road



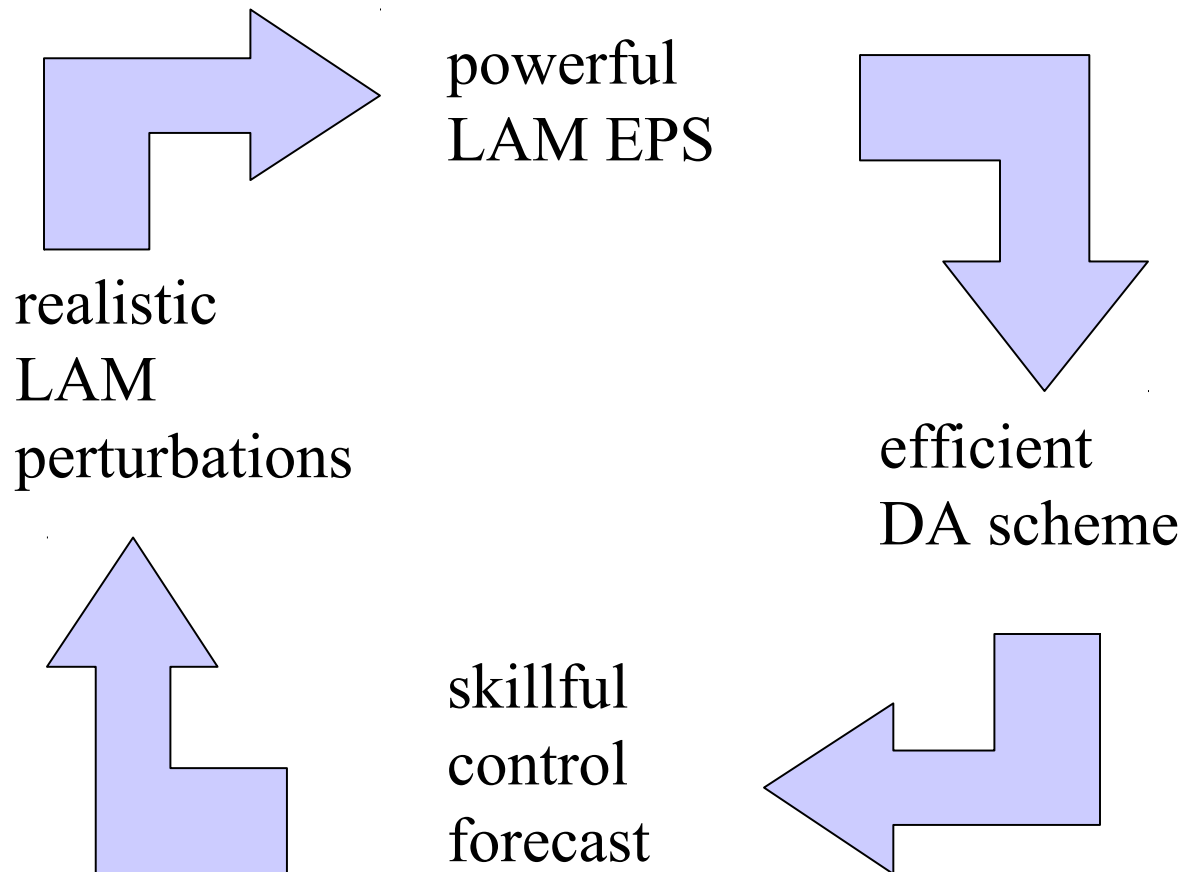
Jens



Diagnostics of the cost function minimization

Shorter auto-correlation scales for localisation do not help to extract useful information on short scale in analysis

Solution for long term perspective



Transversary issue: interaction of
initialisation/dynamics/physics/model error

Solution for long term perspective



The theoretical basis of the variational data assimilation is violated in presence of the systematic bias and the flow-dependent representativity error

This is the common situation assimilation remote sensing observations

Assimilate structures instead of point observations

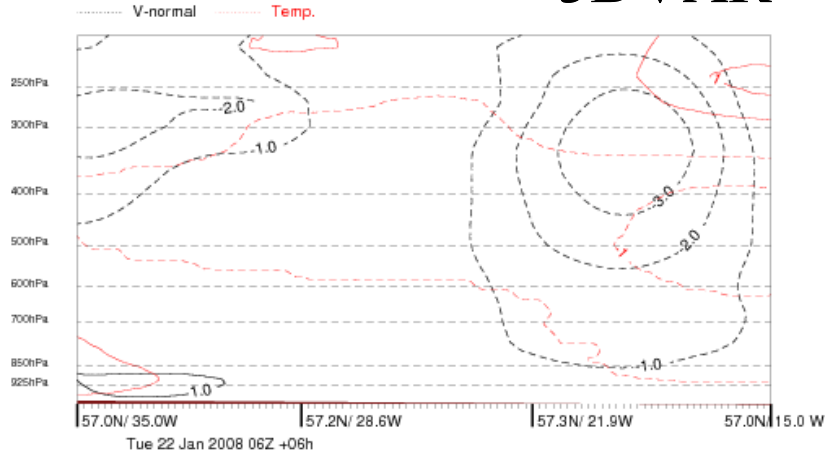
Which ensemble generation technique is the best one ?



Vertical cross-section of analysis increment

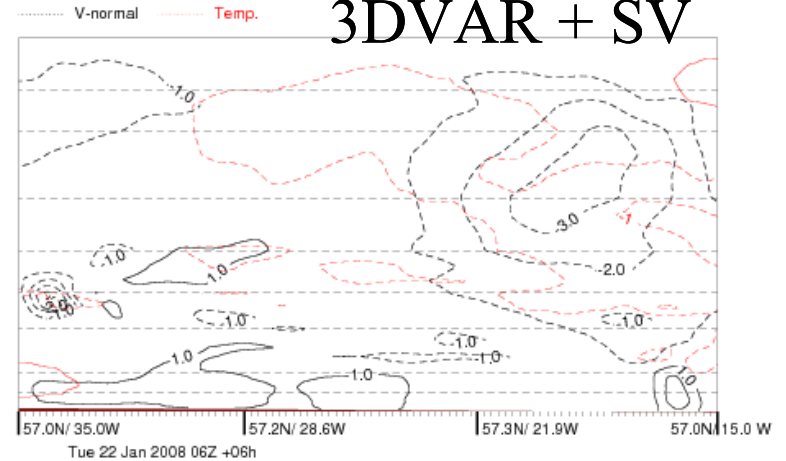
22 Jan. 2008 12UTC + 0h valid time: 22 Jan. 2008 12UTC

3DVAR



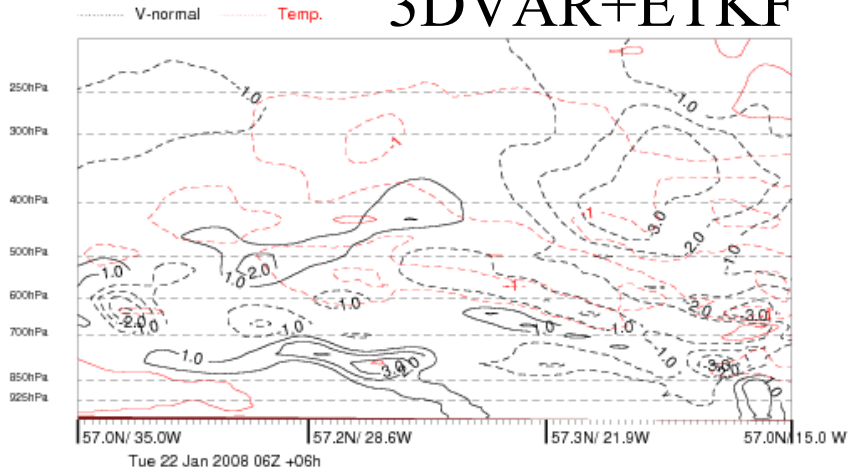
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3DVAR + SV



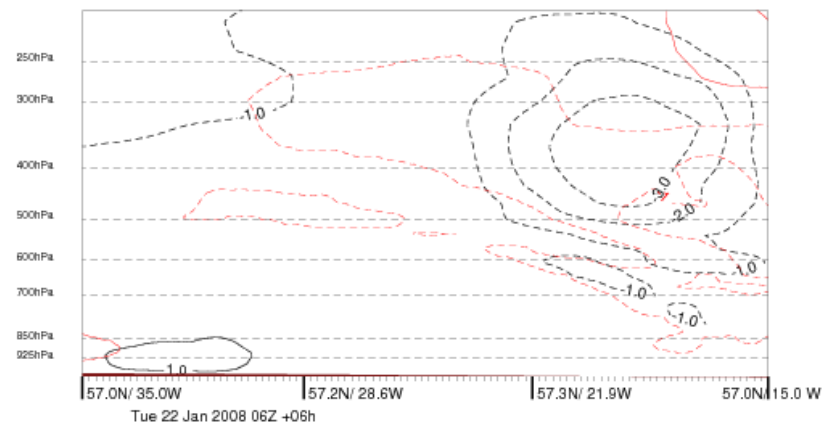
22 Jan. 2008 12UTC + 0h valid time: 22 Jan. 2008 12UTC

3DVAR+ETKF



22 Jan. 2008 12UTC + 0h valid time: 22 Jan. 2008 12UTC

3DVAR+EDA



LAM EPS perturbations



flow dependent cross-correlations between model state variables

Errors-of-the-day variance

Combine climatological forecast error covariance with online estimate of the forecast error covariance from LAM EPS perturbations

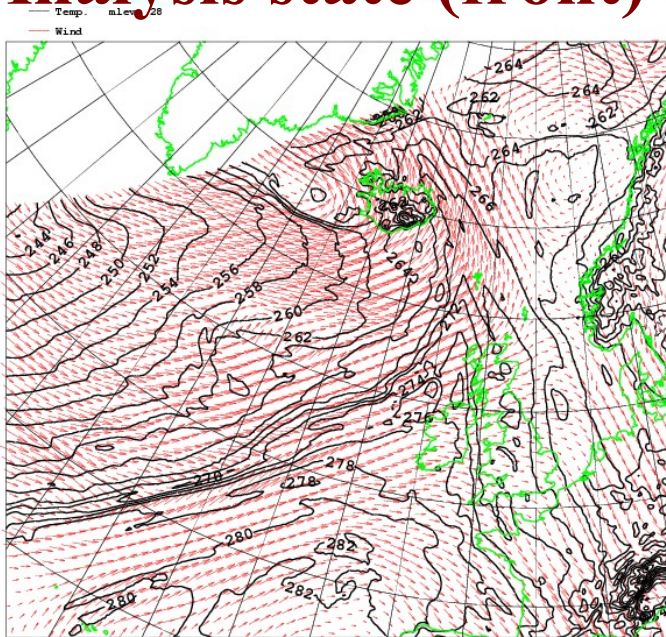
hybrid ensemble variational data assimilation

parameteric modelling of forecast error covariance in wavelts space

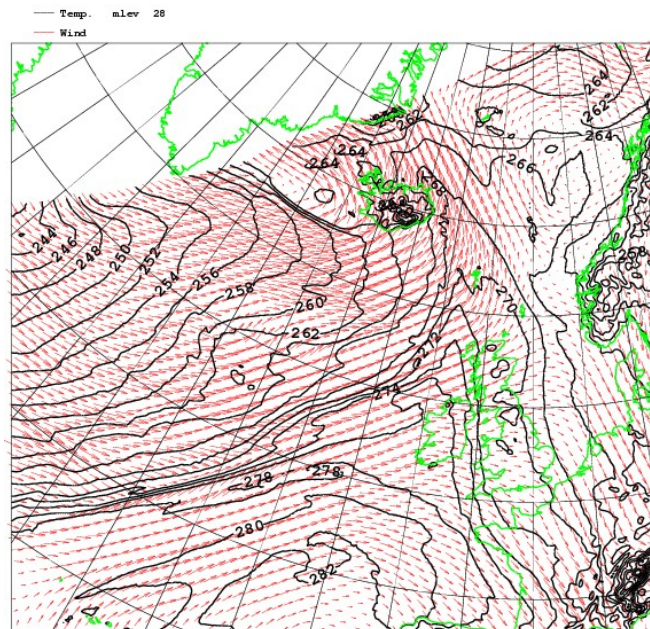
Analysis state (front) 700 hPa 22 Jan 2008 12 UTC



3DVAR



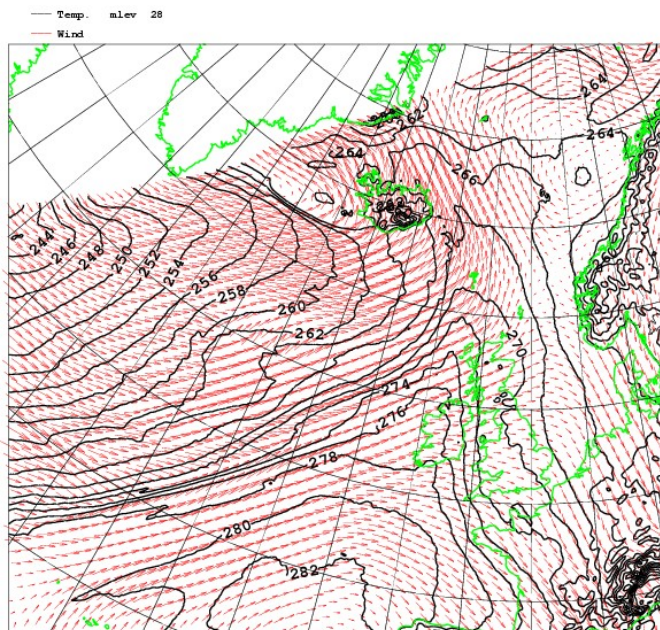
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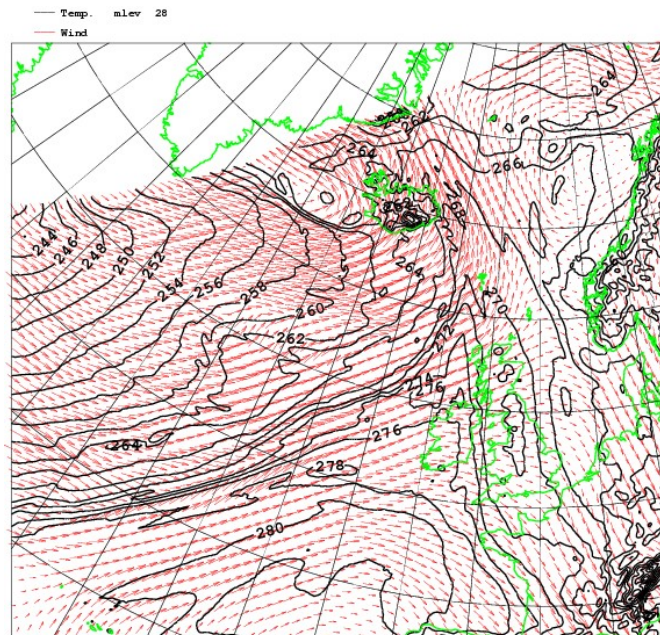
Tue 22 Jan 2008 12Z +00h
valid Tue 22 Jan 2008 12Z

3DVAR + TEPS

3DVAR + ETKF



Tue 22 Jan 2008 12Z +00h
valid Tue 22 Jan 2008 12Z



Tue 22 Jan 2008 12Z +00h
valid Tue 22 Jan 2008 12Z

3DVAR + EnSDA

Analysis increment (front) 700 hPa 22 Jan 2008 12 UTC

