

# Improved structure functions for 3D-VAR

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# Outline

- Introduction
- HIRVDA newly generated structure functions
- Assimilation experiments
- Potential problems
- Conclusions



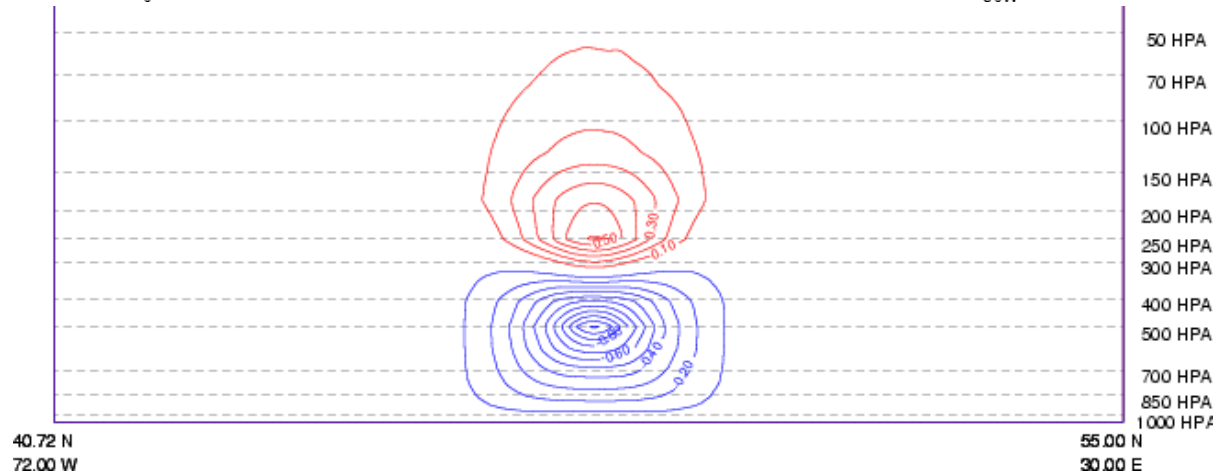
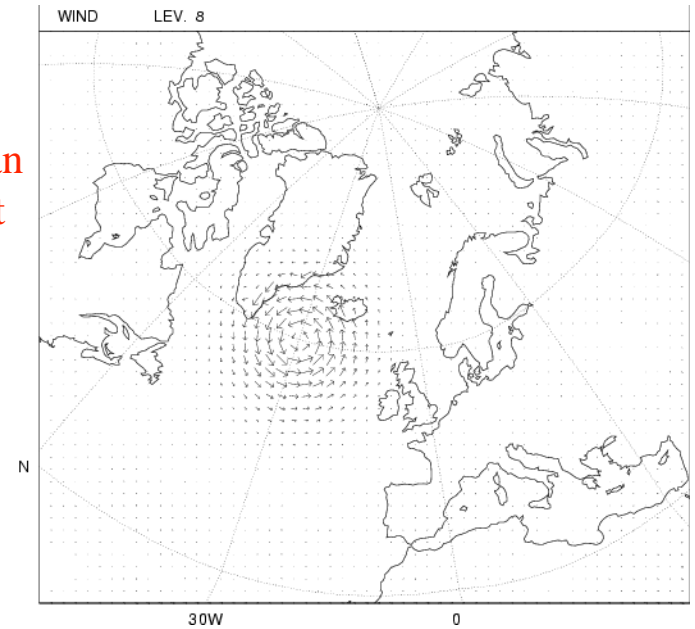
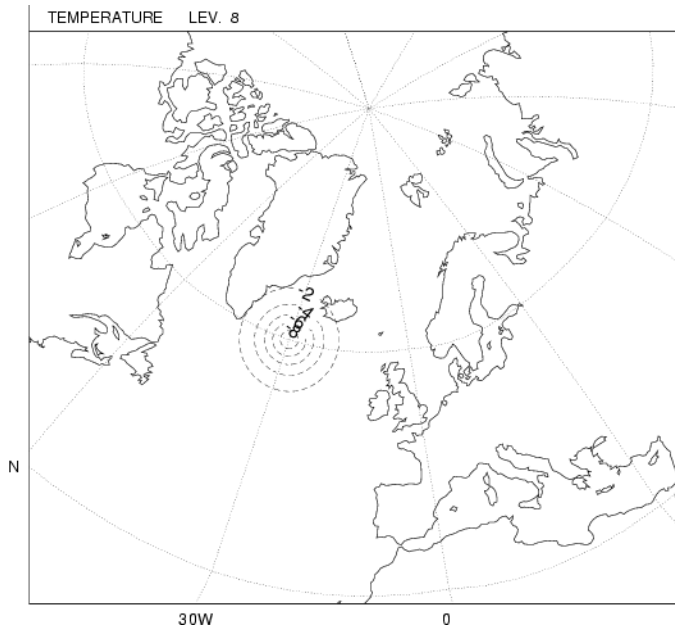
# Structure functions

$$J = J_b + J_o = \frac{1}{2} (x - x^B)^T B^{-1} (x - x^B) + \frac{1}{2} (Hx - y)^T R^{-1} (Hx - y)$$

One single T-obs. at  
500 hPa -1 K colder than  
background equivalent

Horizontal

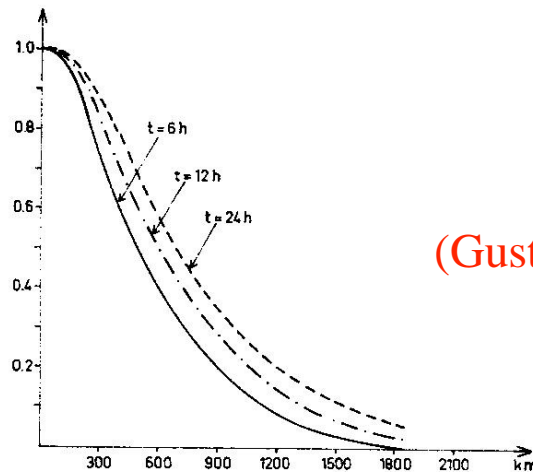
Vertical



# Generating structure functions

## The NMC-method

- Estimate error statistics from differences of forecasts valid at the same time (usually 48h-24h, but also 36h-12h).



(Gustafsson, PhD-Thesis)

*Fig. 1.* The autocorrelation for different time intervals.

## Ensemble assimilation

- Estimate error statistics from a number of 6 h (or 12h) forecasts with perturbed observations, boundaries, model physics....

# Design of Ensemble assimilation experiment

## Perturbed observations

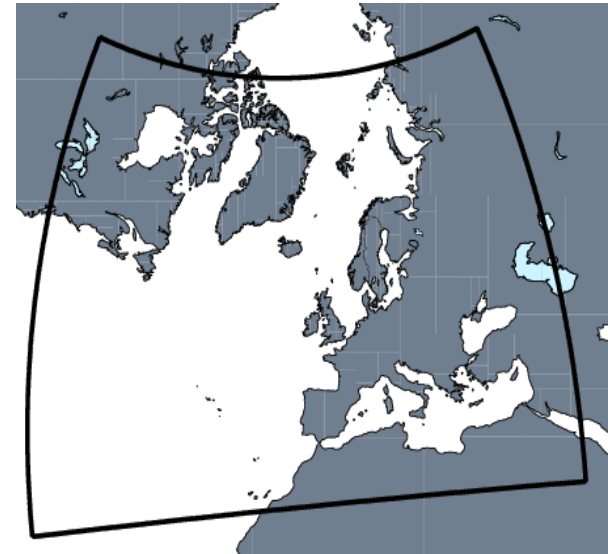
- All conventional obs. are perturbed randomly

## Perturbed boundaries

- Taken from a similar experiment at ECMWF

## Model setup

- HIRLAM ver. 6.3.6
- 22 km resolution, 40 vert. levels, RCR area
- 6h assimilation cycle, up to 24 hour forecasts from each analysis time
- October 2000 was run for 10 ensemble members



# Balances

Regardless of whether the NMC-method or ensemble assimilation is used .....

Described error correlations between different variables are dependent on the balance equations used within the assimilation. Two different balances may be applied: **Analytical balance** or **Statistical balance**.

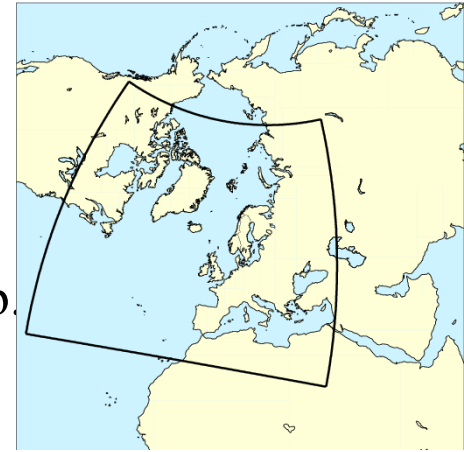
**Advantages statistical balance: Scale and latitude dependent geostrophy, boundary layer friction, moisture effects are represented**

(Loik Berre, *Mon Wea. Rev.*, March 2000)

# Generated structure functions

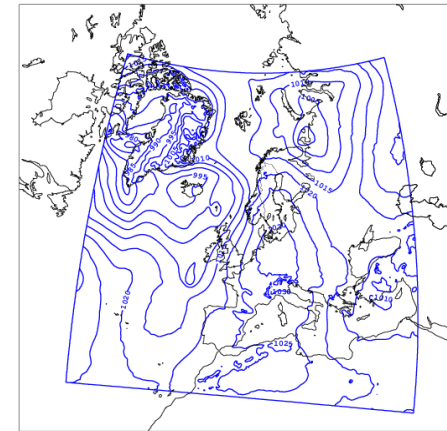
## HIRLAM 3D-Var reference (f3d):

- NMC-method applied on 3 winter months (Dec. 97-Feb. 98) of old SMHI operational forecast differences (48h-24h). 44 km horizontal resolution 31 vertical levels. Analytical balance.



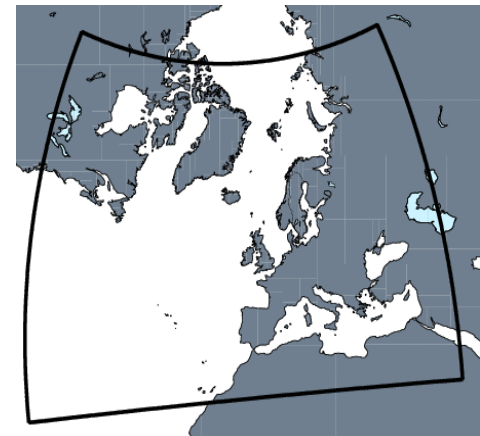
## New NMC based (sbq):

- NMC-method applied on 4 months (Aug.-Nov. 2004) of new SMHI operational forecast differences (36h-12h). 22 km horizontal resolution, 40 vertical levels. Statistical balance.



## New ensemble-based (sbe):

- Differences from 2 weeks of 6 h forecasts (18 -31 Oct. 2000) from ensemble assimilation experiment. 22 km horizontal resolution, 40 vertical levels. Statistical balance. 10 members + control  
co-1,1-2,2-3,.....,9-10,10-co =>  $14 \times 11 = 154$  cases



# Illustration structure functions

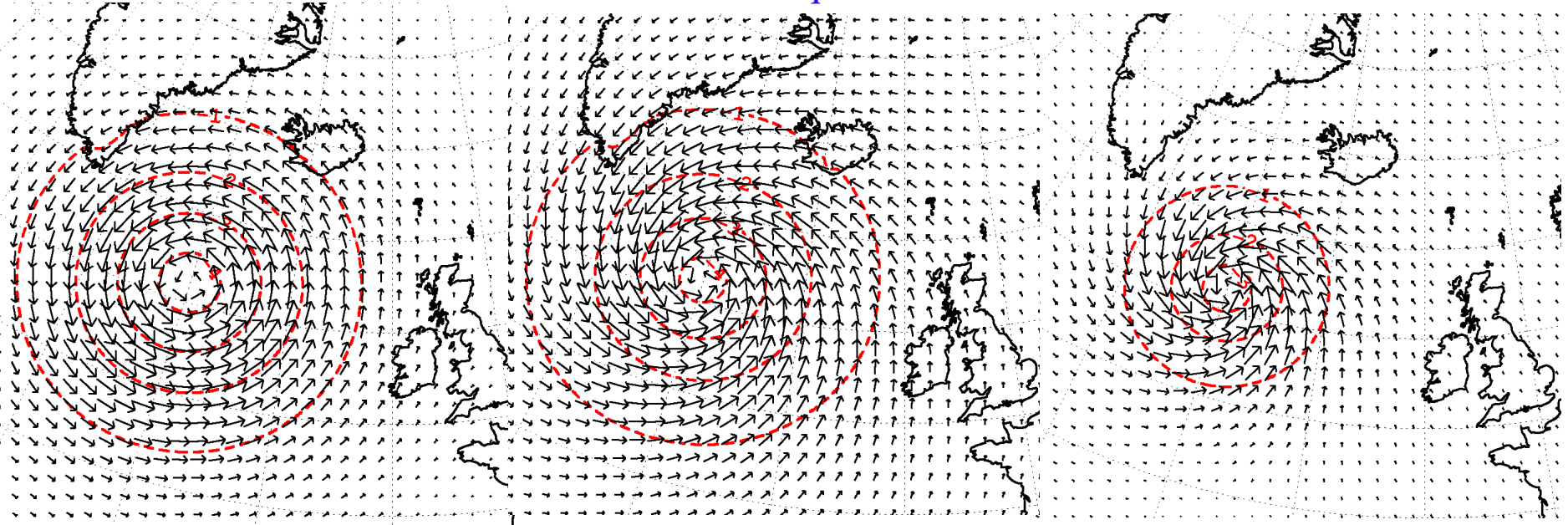
Impact of one single surface pressure observation 5 hPa less than the corresponding background equivalent (red: surface pressure, black: winds at lowest mod level)

## Horizontal

f3d

sbq

sbe



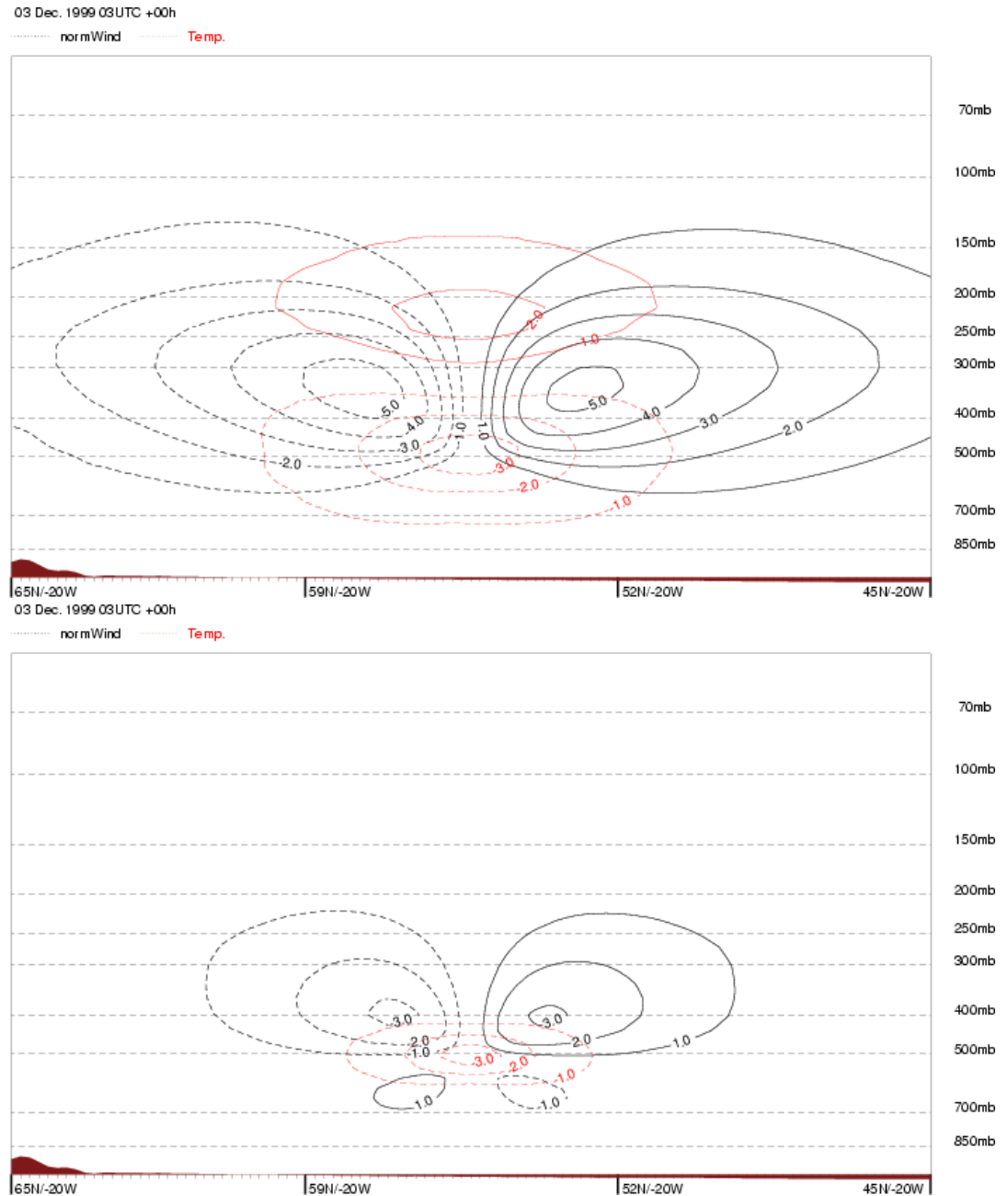


# Illustration structure functions

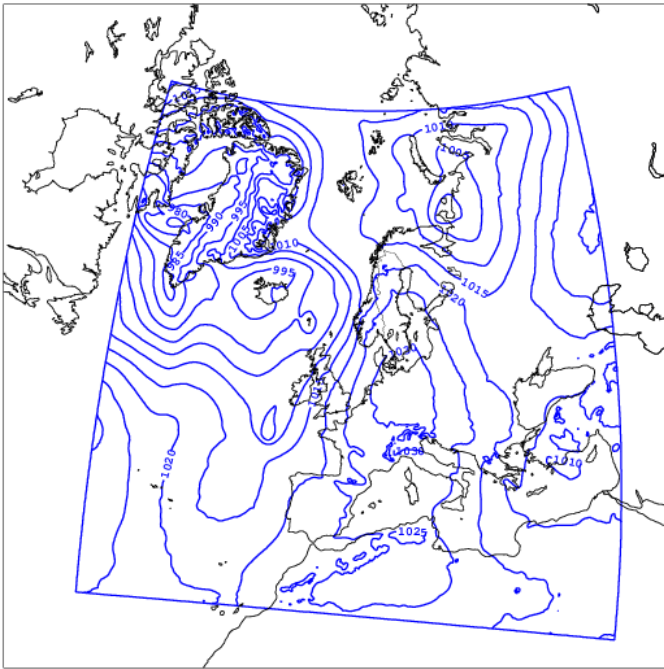
Vertical **sbq**

Impact of one single temperature  
observation at 500 hPa and 5 K  
less than the corresponding  
background equivalent (**red:**  
**temperature**, **black:** wind speeds).

**sbe**



# 3D-Var Assimilation Experiment



*Three parallel runs:*

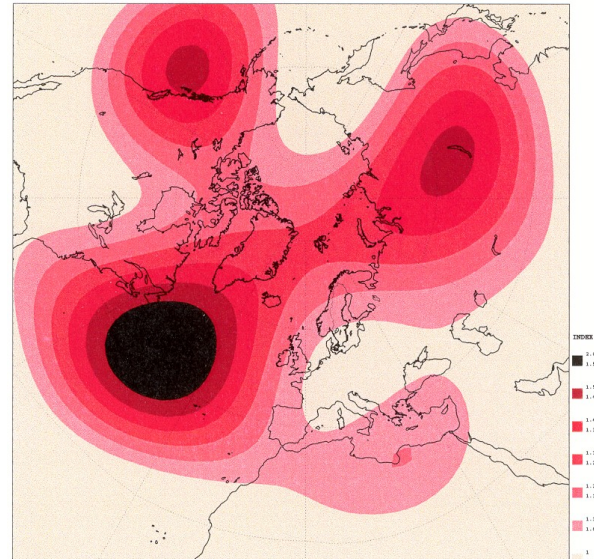
*(1) Reference structure functions (f3d), (2) NMC-method and statistical balance (sbq), (3) Ensemble assimilation and statistical balance (sbe)*

*Analyses and forecasts up to 48 h*

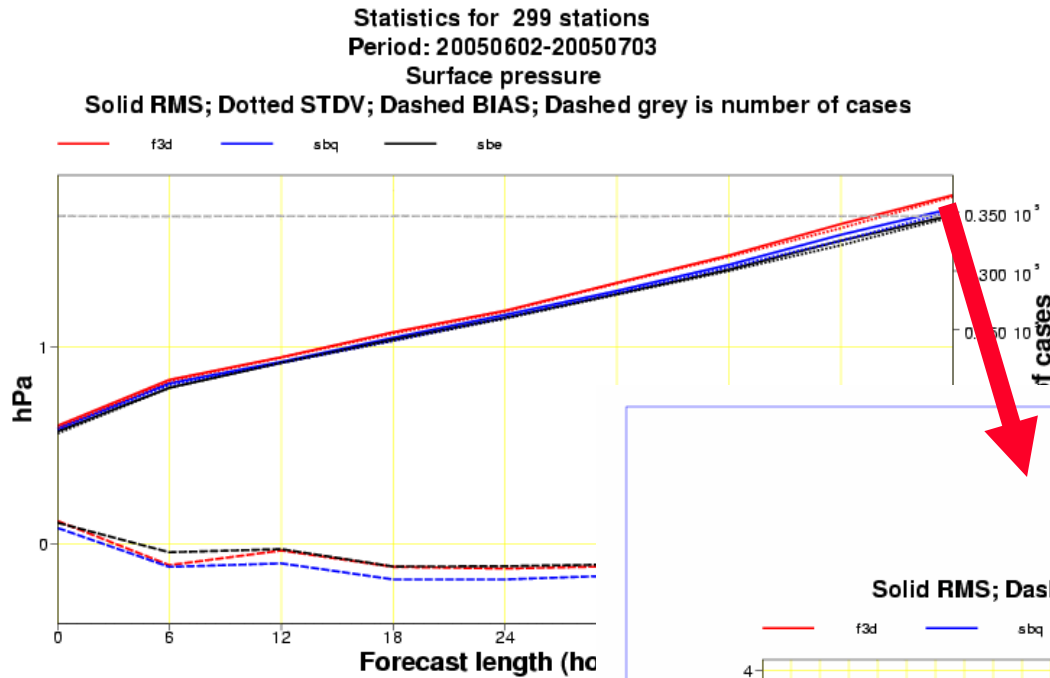
*4 times a day for 1 June -5 July, 2005*

*(hirlam.6.4.0, 6 h assimilation cycle, ECMWF forecasts as lateral boundaries)*

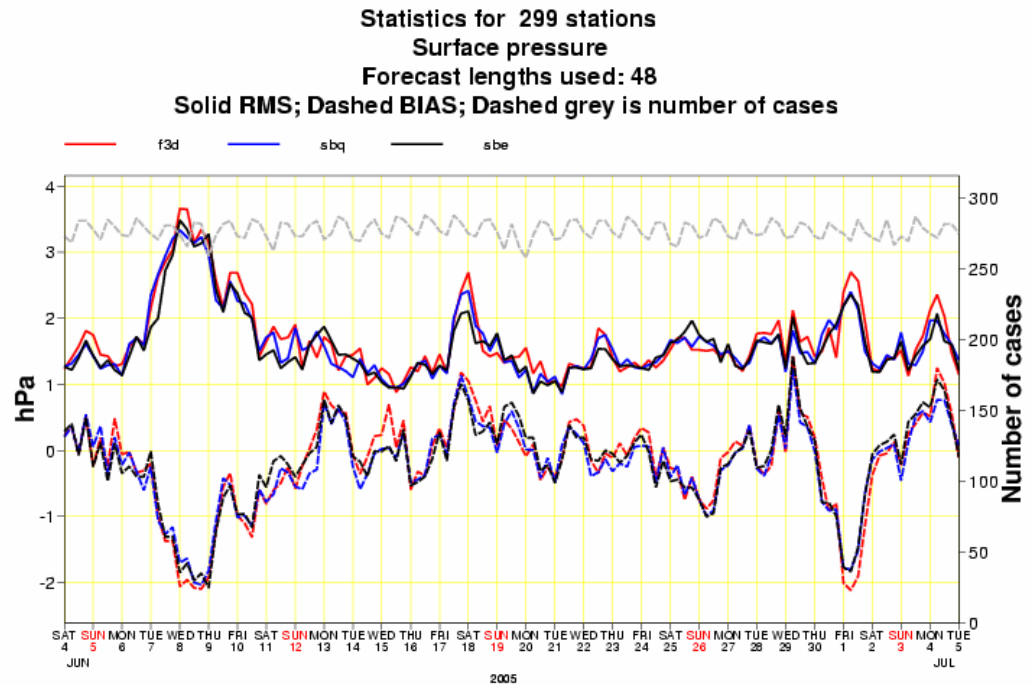
In *sbq* and *sbe*, climatological index field used for representation of horizontal sigma variations.



# Scores for verification against observations (Surface pressure)



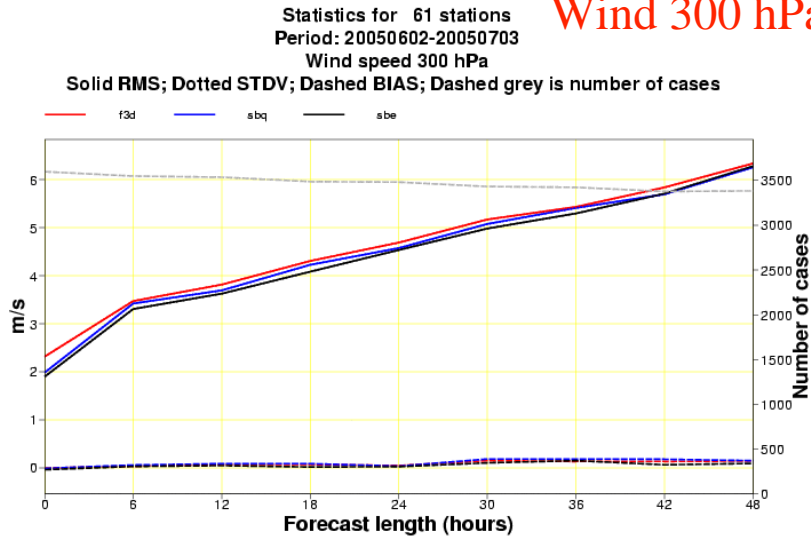
MAGICS 6.9.1 pclx041.smhi.se - ngustats Mon Mar 13 09:20:17 2006



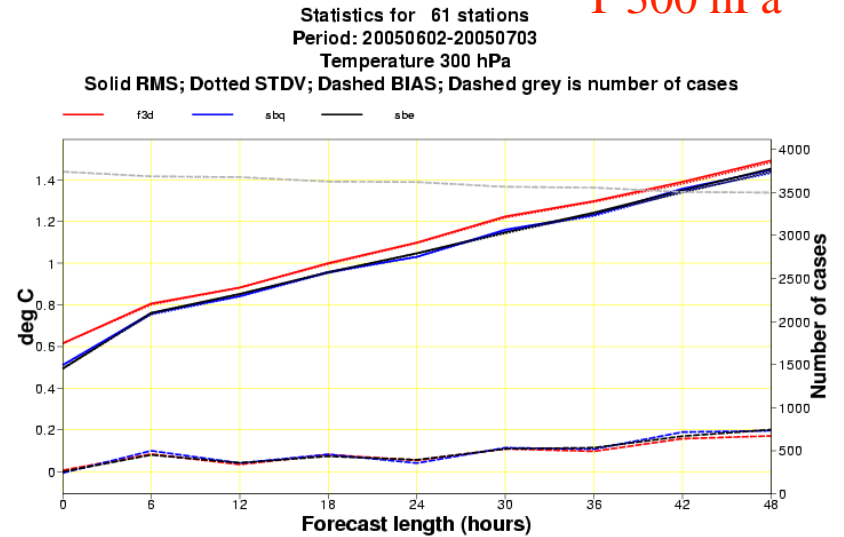
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# Scores for verification against observations (upper level)

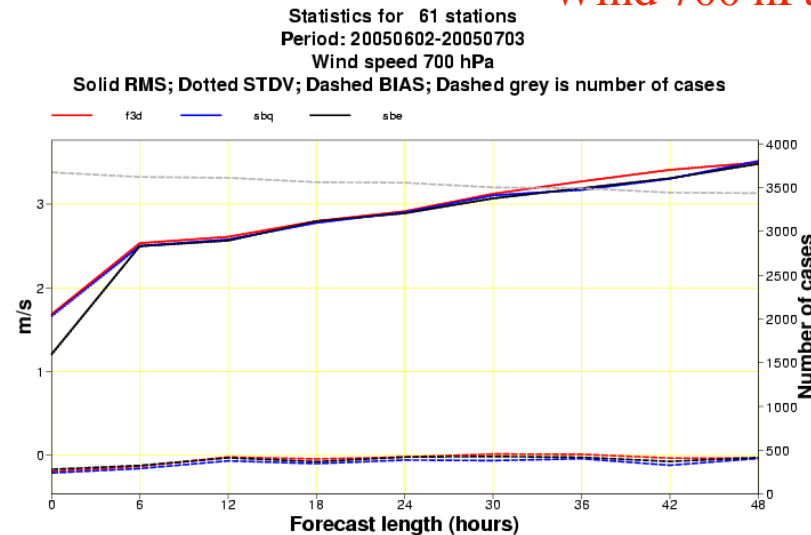
## Wind 300 hPa



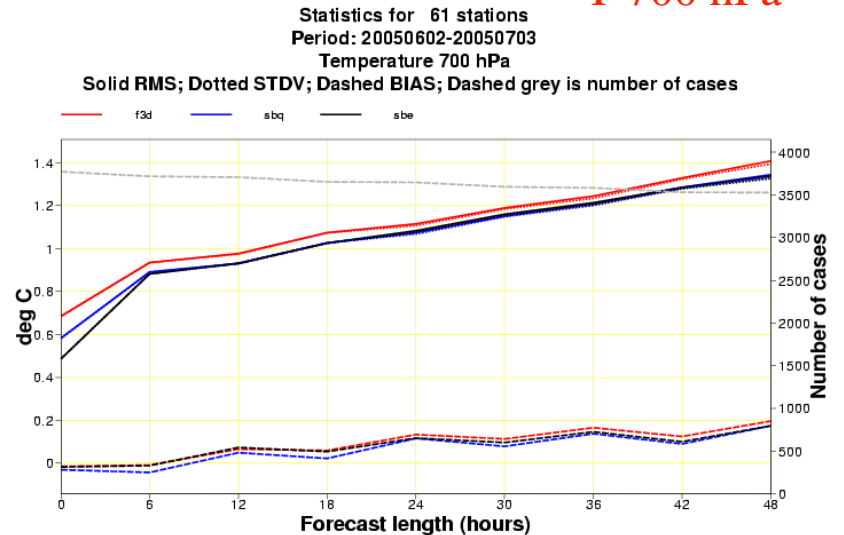
## T 300 hPa



## Wind 700 hPa

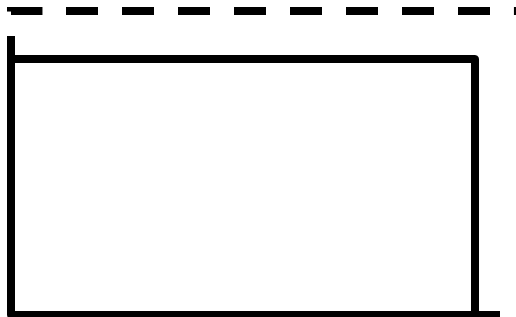
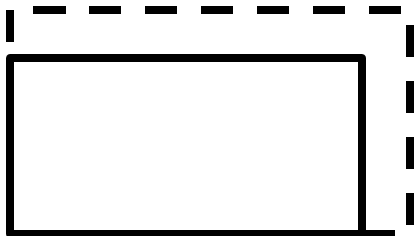
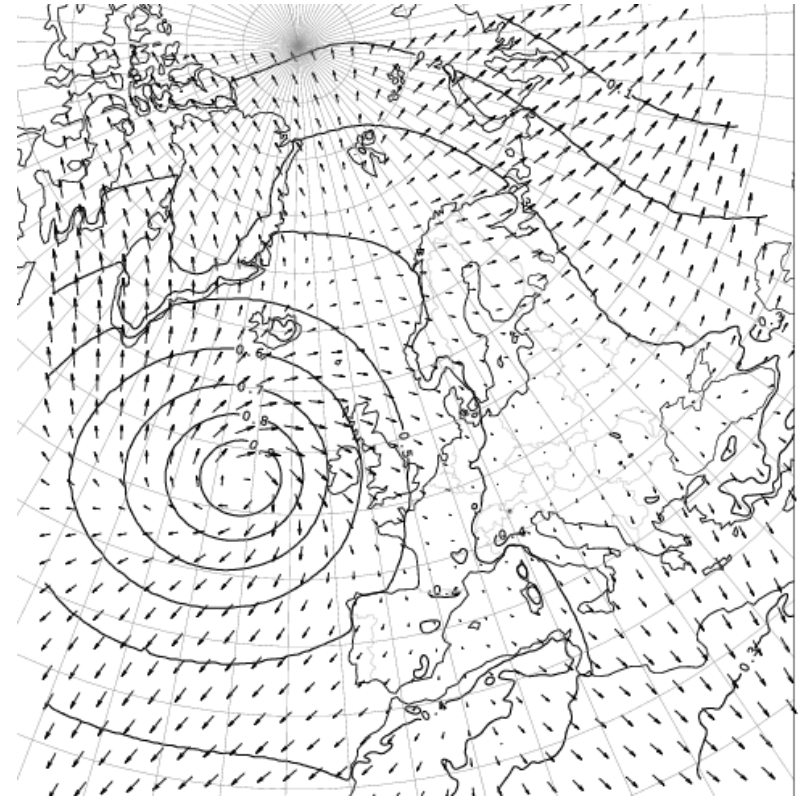
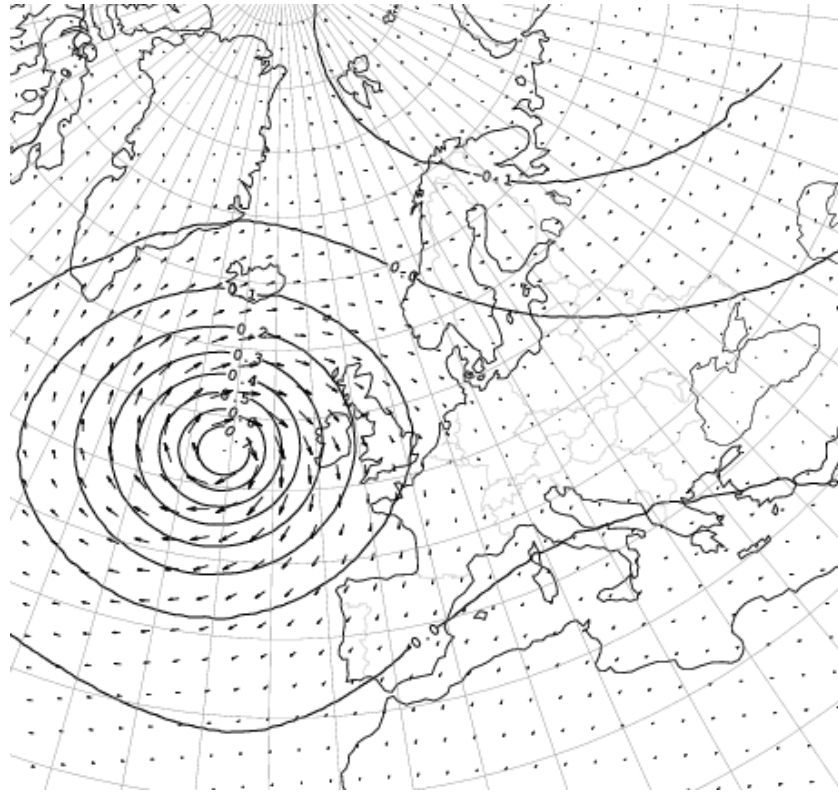


## T 700 hPa

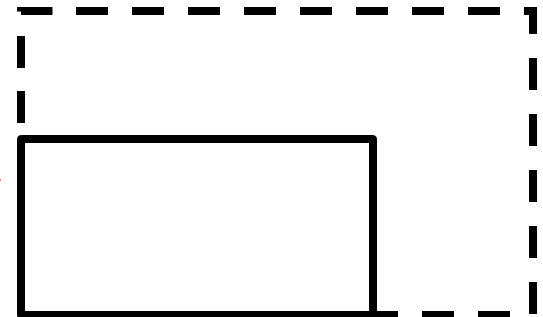


## Potential problems

Impact of one single surface pressure observation 1 hPa larger than the corresponding background equivalent (surface pressure and winds at lowest mod level)



OR



# Conclusions

- New structure functions have been generated for HIRVDA, using a statistical balance.
- Positive impact in assimilation experiment.
- Look at individual synoptical cases.
- One should take care when using structure functions based on statistical balance generated on a domain (smaller) different from the one used in assimilation.

