

# **4D-Var for HIRLAM & HARMONIE (progress, problems, plans)**

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# Status of 4D-Var in HIRLAM & HARMONIE

## HIRLAM for the synoptic scales:

- Incremental 3D-Var with FGAT OK
- SL TL & AD models OK
- Buizza physics OK
- Janiskova simplified physics OK
- Multi-incremental minimization OK
- Weak digital filter constraint OK
- VarQC (in inner loops) OK
- First operational version, Feb 2008
- LBC control works formally, OK late 2008?
- To be phased out operationally 2010-2012
- THE END OF HIRVDA

## HARMONIE for the mesoscale:

- Non-incremental 3D-Var with FGAT OK
- SL, TL & AD models OK
- Buizza physics OK
- Janiskova simplified physics early 2009?
- Multi-incremental minimization late 2008?
- Weak digital filter constraint late 2008?
- VarQc (in outer loops) early 2009?
- First operational version early 2010?
- LBC control, early 2009?
- To replace the synoptic scale HIRLAM (2010-2012)
- Simplified physics for the mesoscale
- Moisture balances
- Etc etc

# HIRLAM 4D-Var components:

- 3D-Var
- Tangent linear and adjoint of the semi-Lagrangian (SETTLS) spectral HIRLAM.
- Simplified physics packages: Buizza vertical diffusion and Meteo France (Janiskova) package (vertical diffusion, large-scale condensation and convection).
- Multi-incremental minimization (spectral or gridpoint HIRLAM in outer loops).
- Weak digital filter constraint.
- Control of lateral boundary conditions (not yet in the reference)
- .

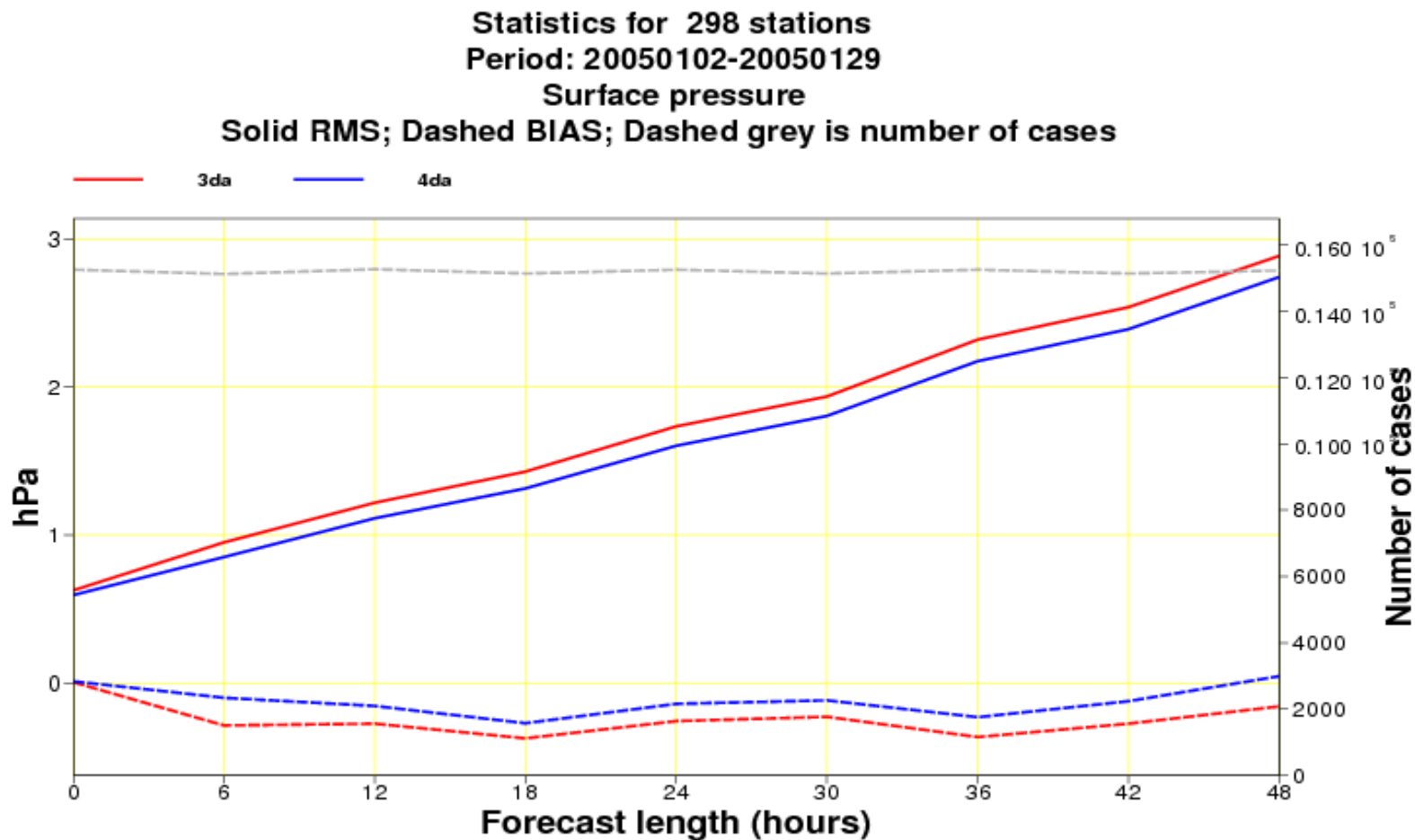
# Comparison tests 3D-Var – 4D-Var

- SMHI area, 22 km, 40 levels, HIRLAM 7.1.1, KF/RK, SMHI area, statistical balance background constraint, reference system background error statistics (scaling 0.9), no "large-scale mix", LINUX cluster, 4.5 months, operational SMHI observations and boundaries
- 3D-Var with FGAT, 40 km increments, quadratic grid, incremental digital filter initialization
- 4D-Var, 6h assimilation window, 60 km increment, linear grid, Meteo-France simplified physics (vertical diffusion only), weak digital filter constraint, no explicit initialization

## Summary of forecast scores

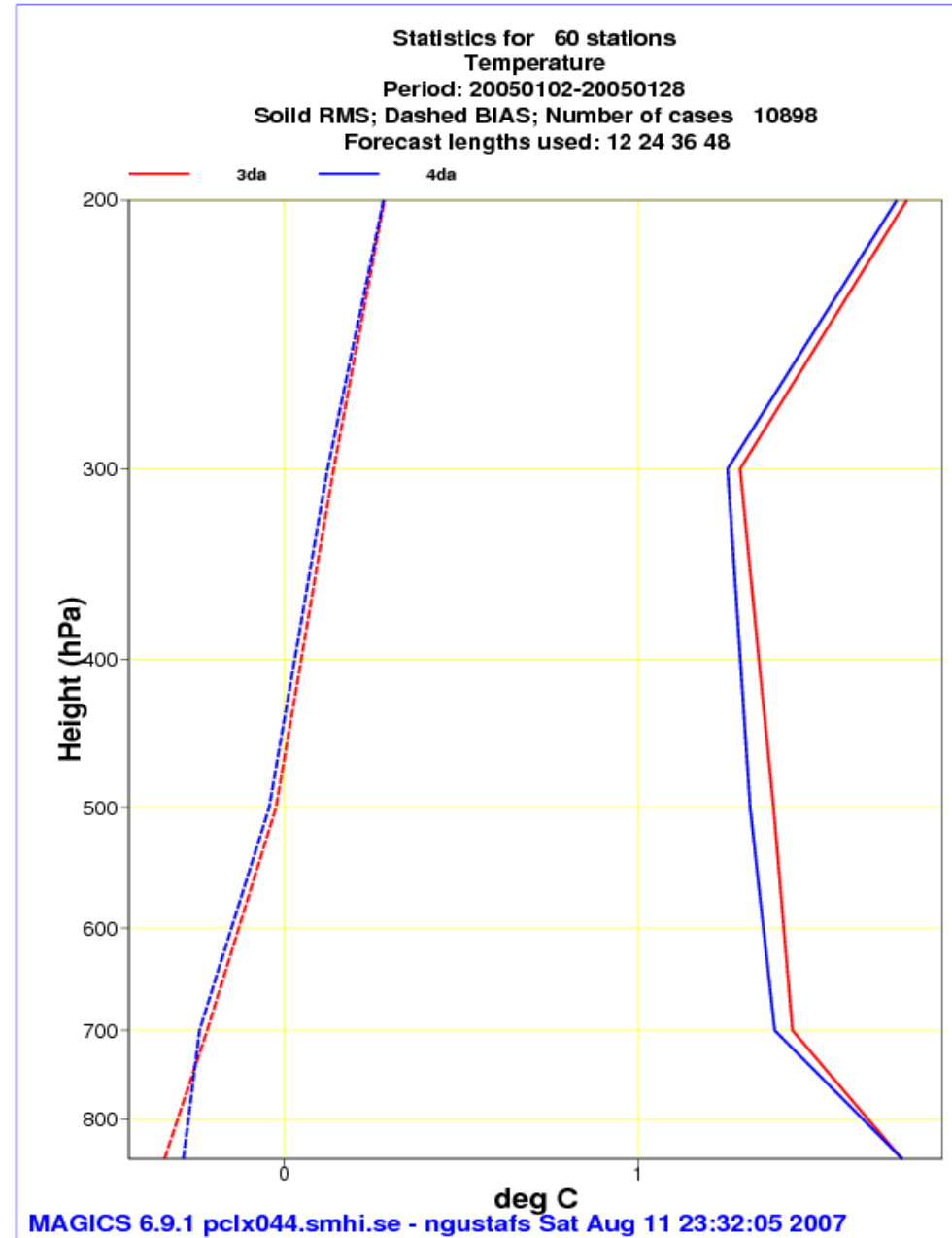
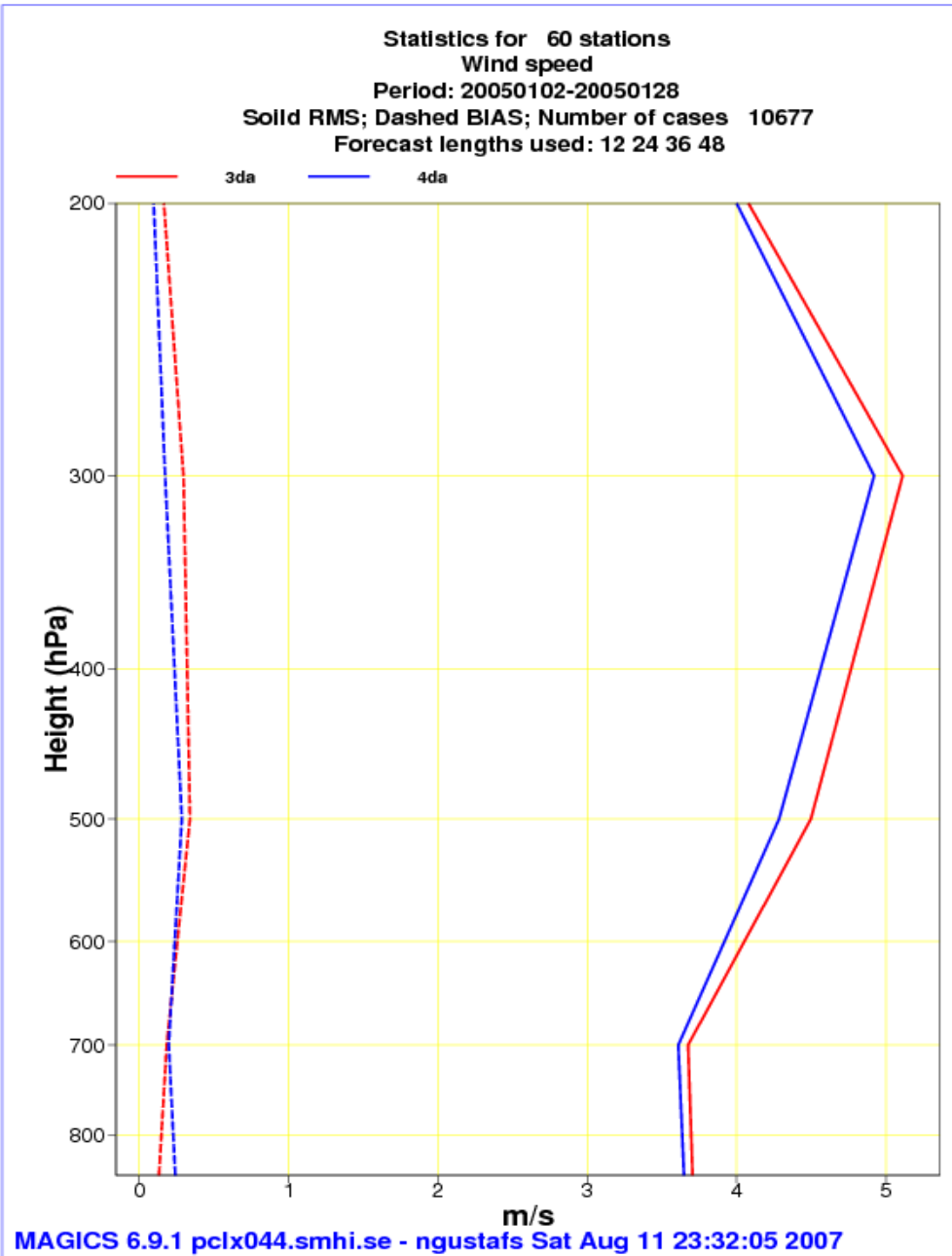
Period	Surface pressure	Upper air
April 2004	Neutral	Positive impact of 4D-Var
Jan 2005	Positive impact of 4D-Var	Positive impact of 4D-Var
June 2005	Neutral	Positive impact of 4D-Var
Jan 2006 (11 days)	Positive impact of 4D-Var	Small positive impact of 4D-Var
Jan 2007	Positive impact of 4D-Var	Small negative impact of 4D-Var on 300 and 200 hPa heights

# 3D-Var <-> 4D-Var , surface pressure forecast verification scores



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# 3D-Var versus 4D-Var; upper air wind and temperature forecast verification scores



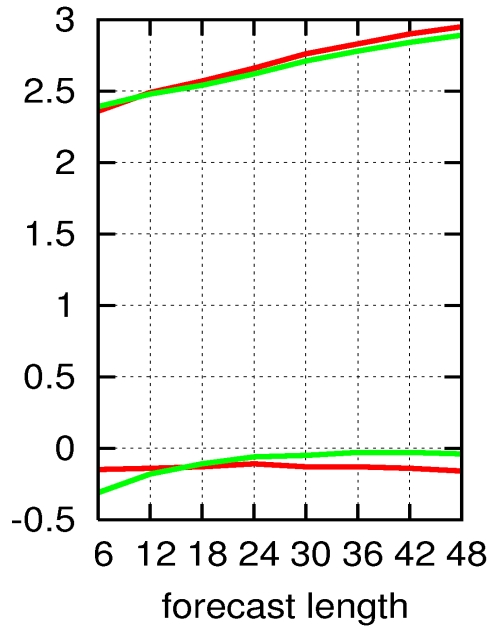
# Operationalization of 4D-Var

- SMHI pre-operational tests show positive impact of 4D-Var in comparison with 3D-Var
- Improved parallel scaling is needed: (a) openMP within nodes & MPI between nodes; (b) Message passing for SL advection "on demand"; (c) Some reductions of the number of FFT:s
- Included as default in HIRLAM 7.2 (early 2008)
- **OPERATIONAL AT SMHI (22 km area) IN FEBRUARY 2008 !!**

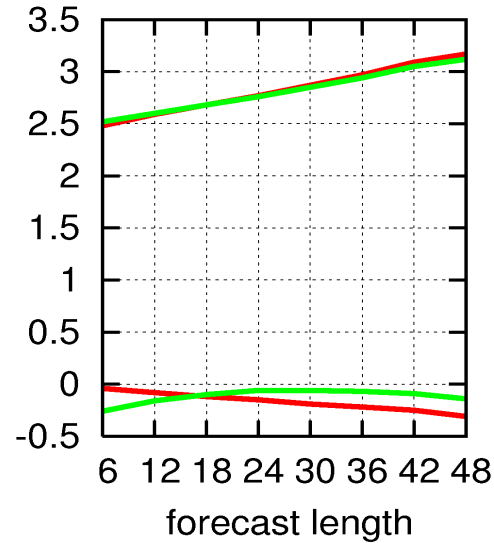


# SMHI 22km pre-operational verification

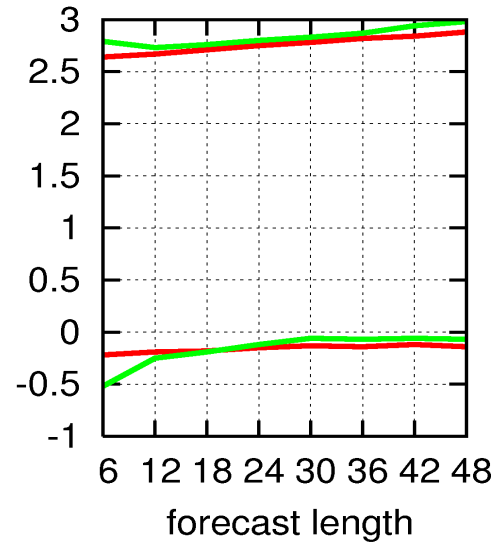
Temperature 4-29jan-2008



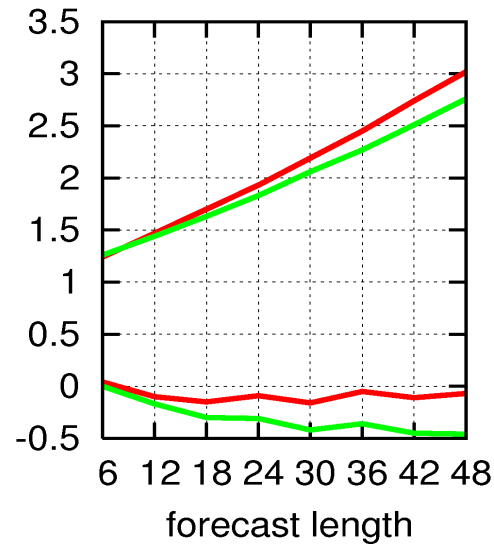
Dew point



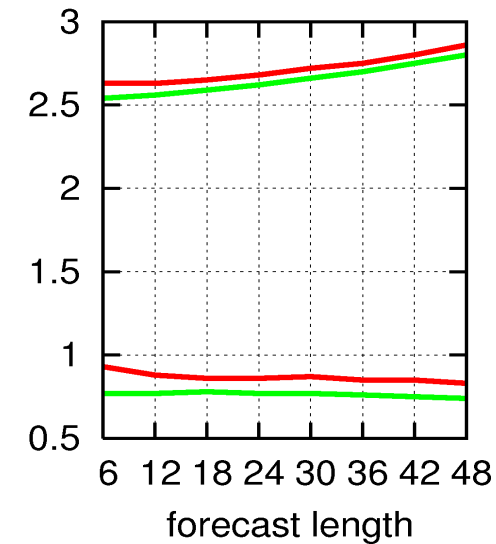
Cloudiness octas



Mean sea level pressure



10-m wind m/s



C22.3DV —  
C22.4DV —

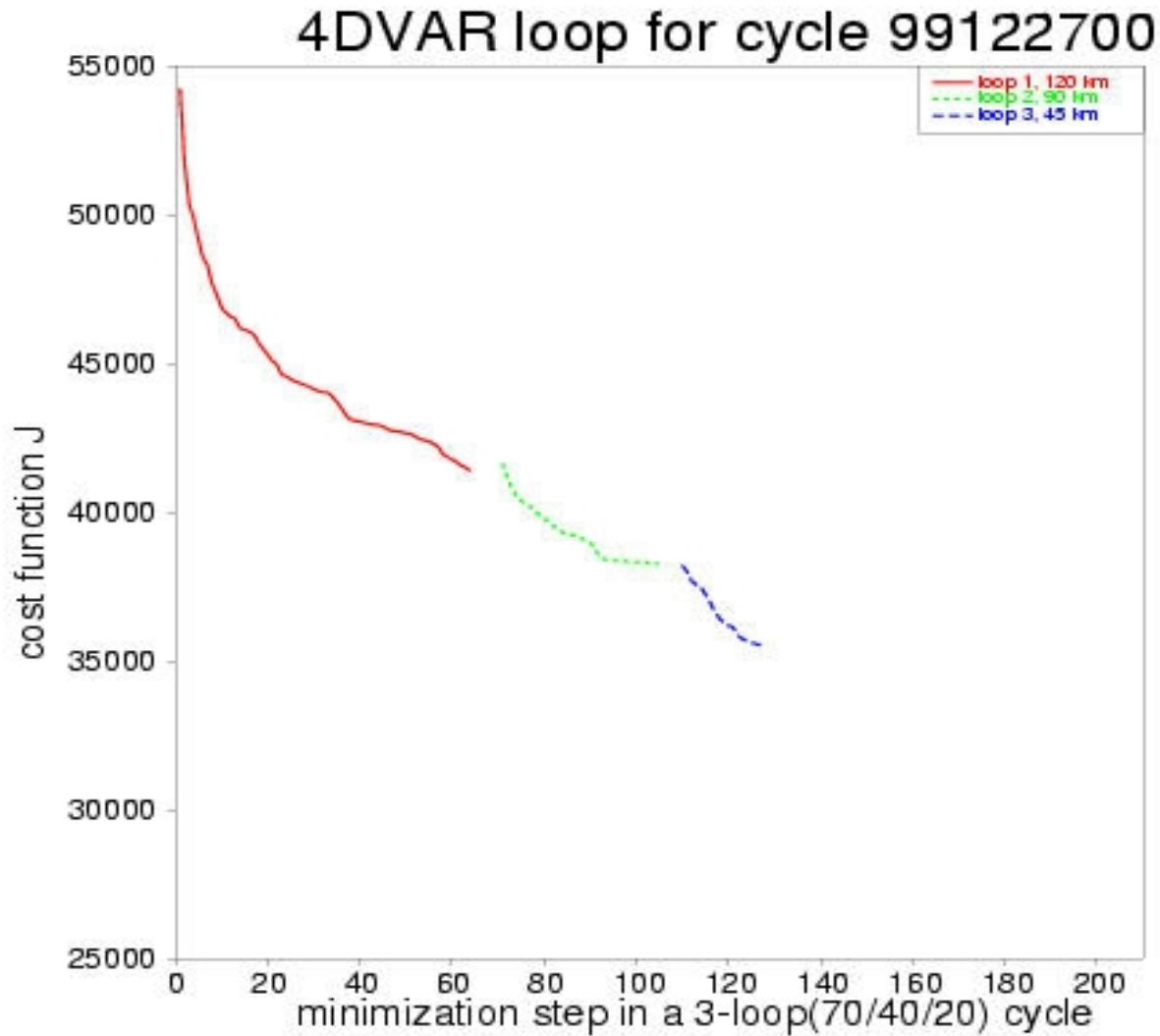
# **What can we expect to achieve with the HIRLAM data assimilation before it will be phased out?**

- 4D-Var with several outer loops and improved moist physics
- Control of lateral boundary conditions in 4D-Var
- A new moisture control variable (talk by Thorsteinsson)
- Large scale mix via Jk cost function term
- Background and large scale error statistics based on EnsAss
- Tuning of screening and VarQC (talk by Lindskog)
- Use of several new types of observations. (AMSU over land and ice, scatterometer winds, MODIS winds, GPS, radar winds, better sea ice and SST, IASI?) - Comprehensive Impact Studies
- Large scale mix

Most development efforts should be finished during 2008!

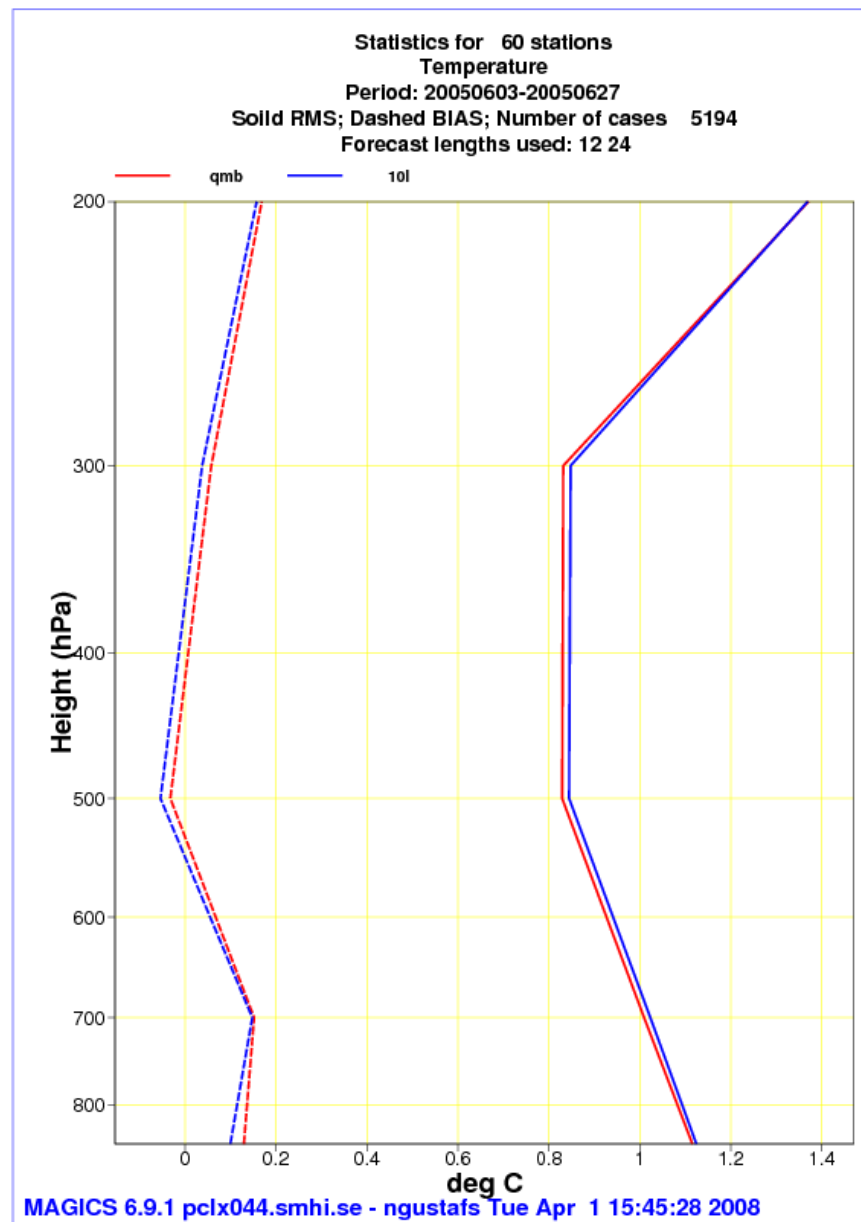
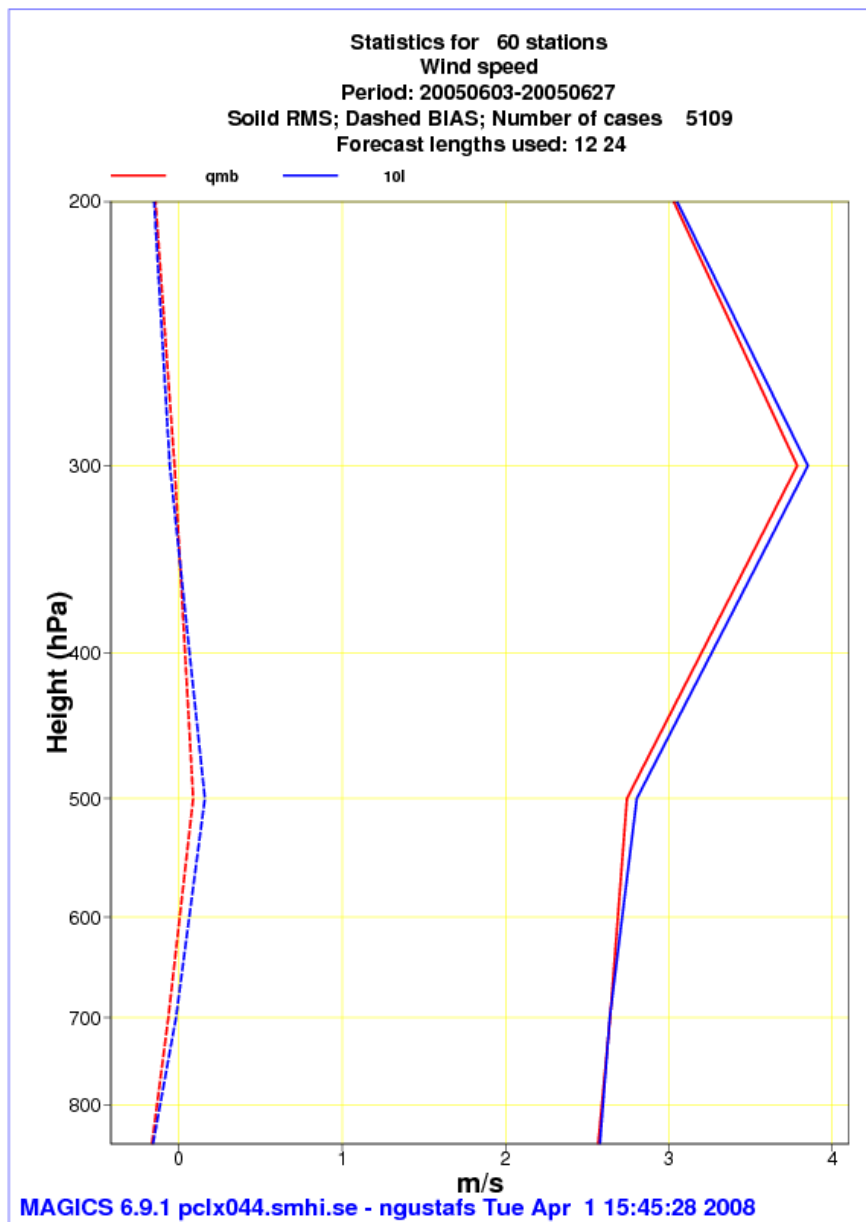
**A synoptic scale HARMONIE should be comparable!!**

# Convergence of the multi-incremental minimization



(X. Yang)

**qmb = 2 outer loops; 1ol = 1 outer loop**



# CIS goal (dream) – Atlantic scale part

By 1 July 2008 we will have introduced the following new types of observations into full operational use within the HIRLAM RCR run at FMI:

AMSU-A radiances over land and sea ice surfaces

AMSU-B radiances over sea surfaces

Seawinds scatterometer data

AMV-GEO

AMV-MODIS

OSI/SAF SST and SIC, NAR SST and ECMWF SIC data

These data will enter the FMI RCR data assimilation runs through an agreed upon unique data stream that can easily be used operationally also by the other NWP centers participating in HIRLAM .



# **HARMONIE – Mesoscale data assimilation**

## **Initial considerations**

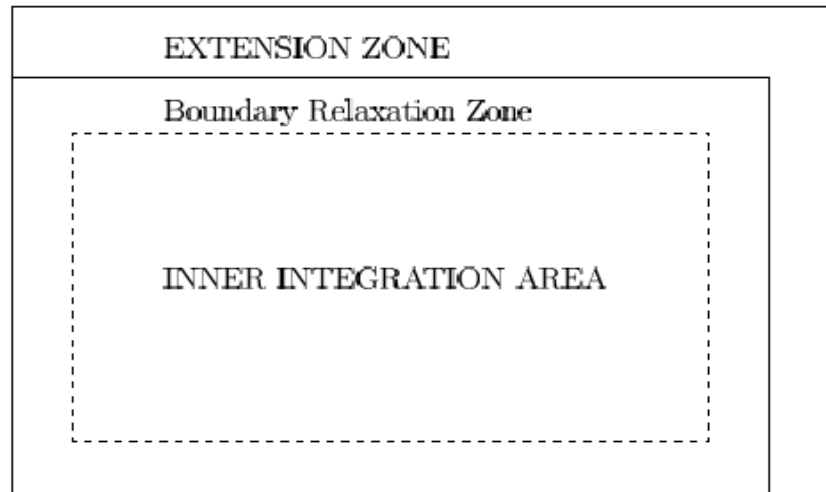
- Common data assimilation for HIRLAM and ALADIN
- Continue with variational data assimilation – challenges with most likely substantial return of investments
- Utilize information from ensembles
- Increase knowledge about (moist) balances at the mesoscale
- More emphasis on surface and soil assimilation

# List of actions to obtain code convergence

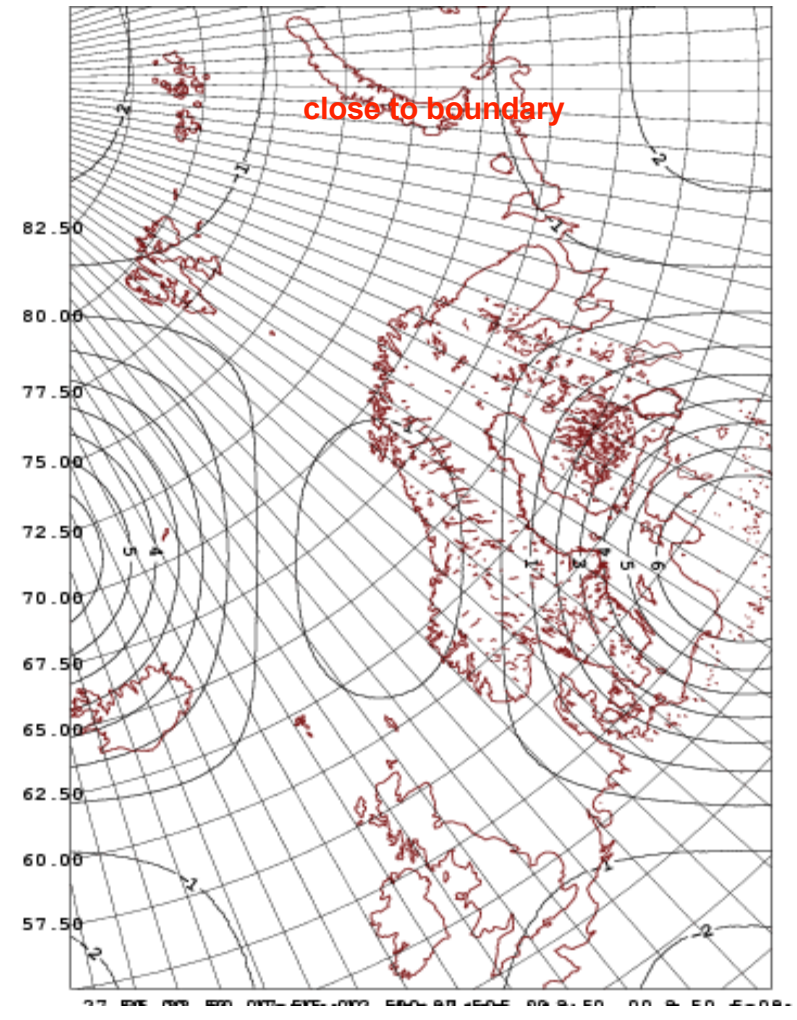
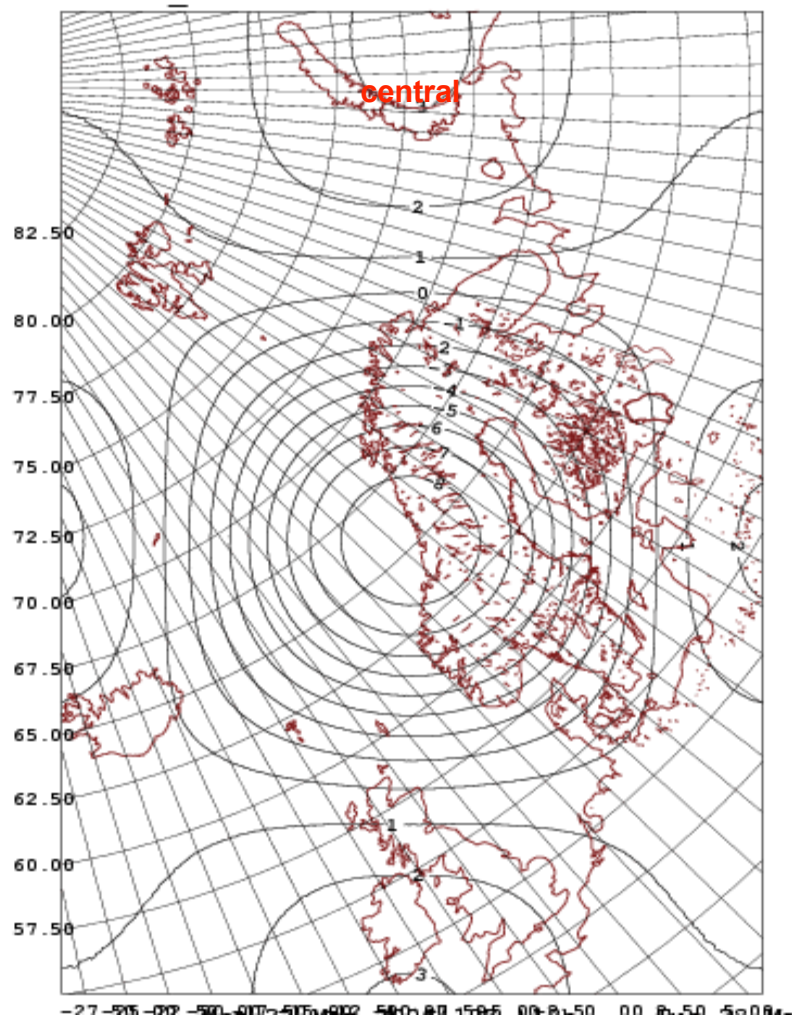
- Installation and testing of ALADIN 3D-VAR within the HIRLAM (talk by Randriamampianinia)
- Possible adaptation of the extension zone treatment in ALADIN (needed for efficiency of 4D-VAR, late 2008)
- Observation operator recoding and convergence (documentation done and some actions initiated)
- Insertion of ALADIN 3D-VAR (and CANARI) into the HARMONIE script system (almost completed)
- Comparison and validation of ALADIN and HIRLAM 3D-VAR for synoptic scales (started).
- Coding of ALADIN semi-Lagrangian TL and AD models (done)
- ALADIN sensitivity tests etc. (partly done)
- Basic ALADIN 4D-Var in OLIVE (autumn 2008)
- Basic HARMONIE 4D-VAR in mini-SMS (autumn 2008)

# The extension zone problem in ALDIN 3-4 D-Var

- Double periodic variations through area extension, needed for FFT:s in the model and to represent horizontal correlations in the assimilation
- **Conflict:** Small extension zone in the model (economy) and large in the assimilation (correlation->0.)
- **Proposed solution:** Two different extension zones - will take some effort (4 months) to code in IFS



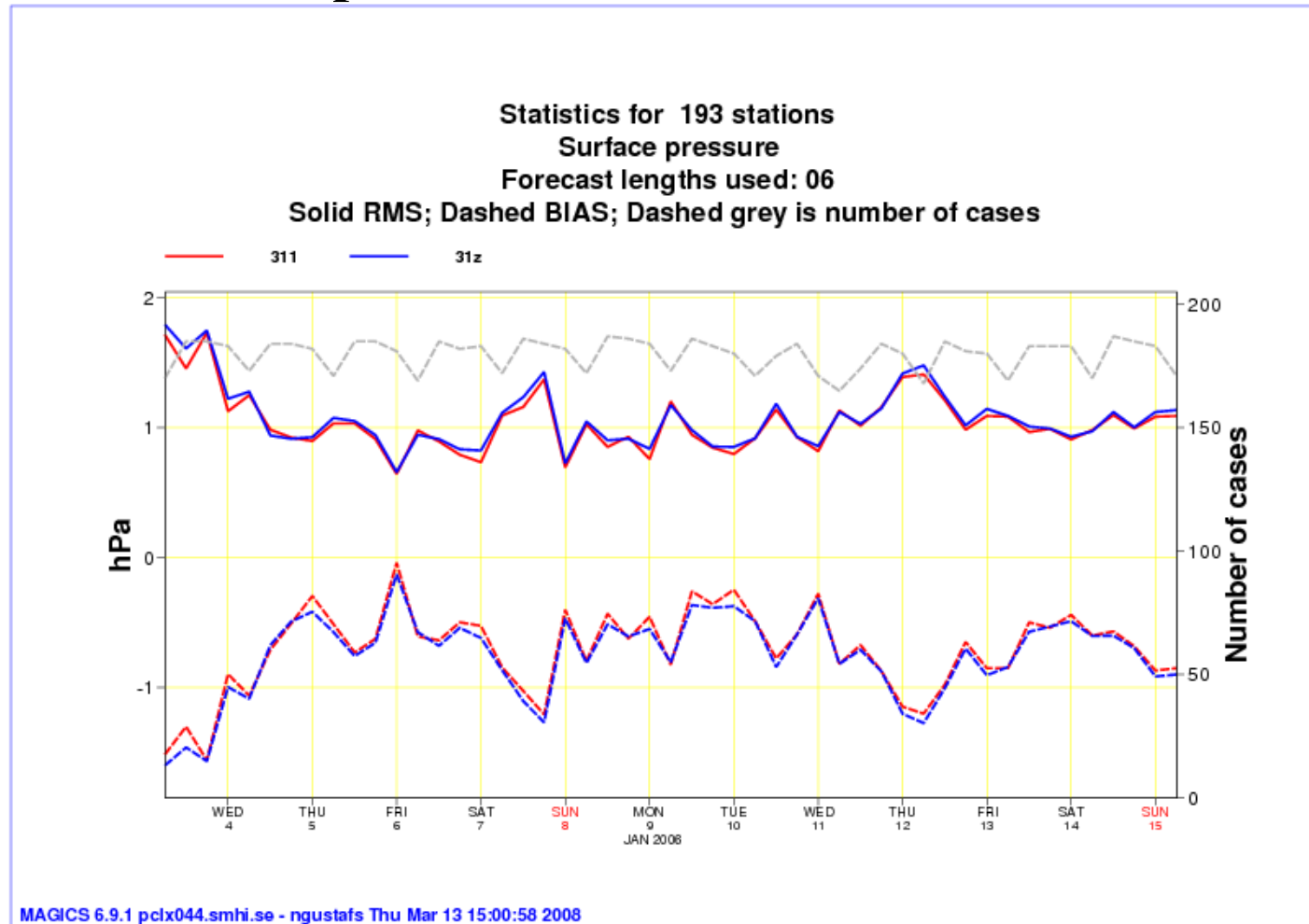
# Norwegian Domain and single observation experiments



# Test of two different extension zones in HIRLAM 11km 3d-Var

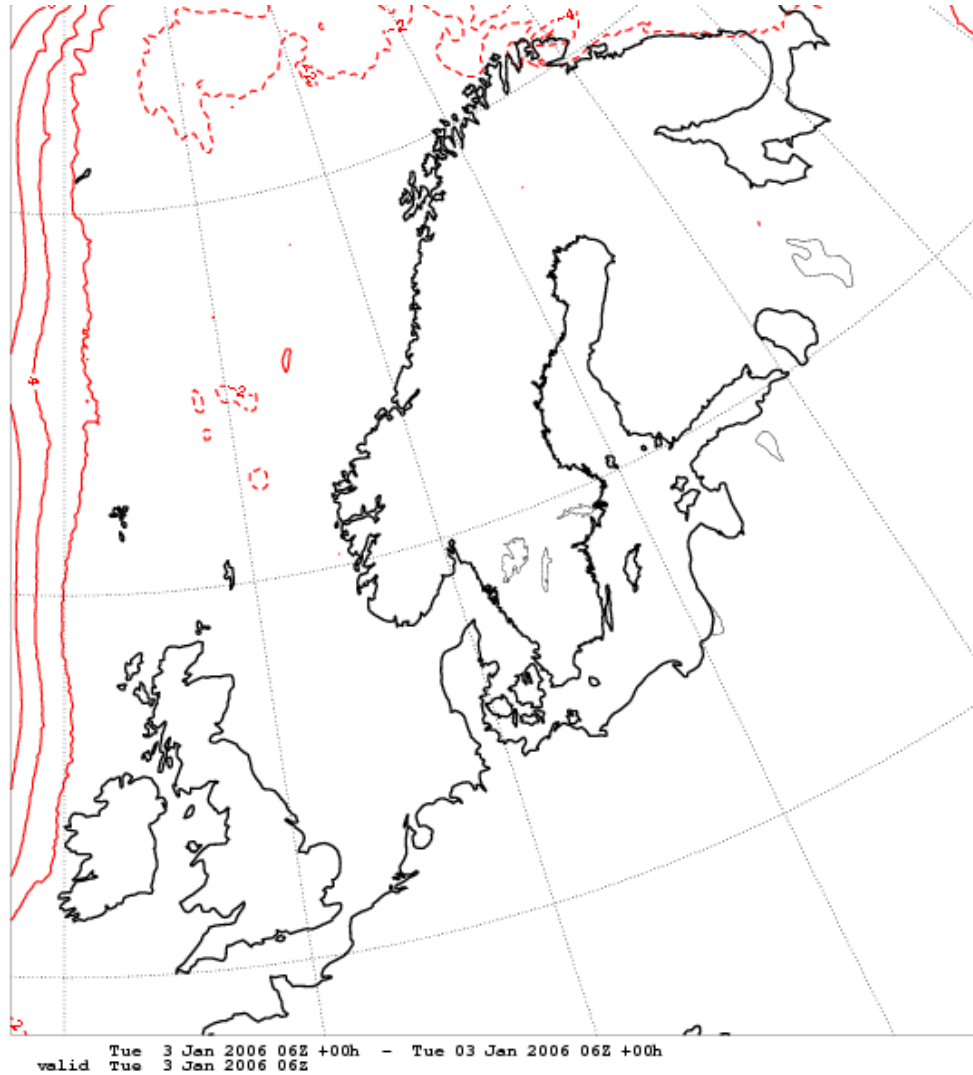
**311 large/operational (1200km); 31z small (140km)**

## Effect on +6h surface pressure forecasts

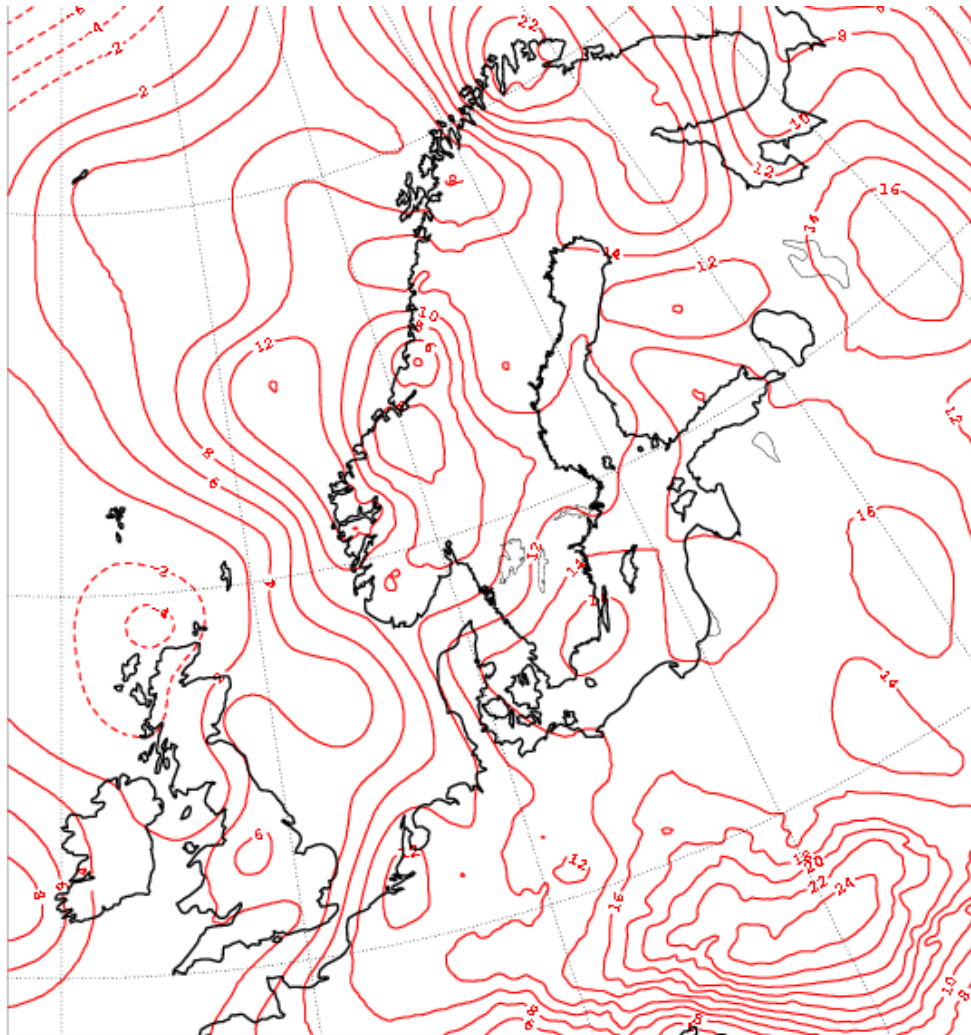




# Differences between surface pressure analyses - small and large extension zone

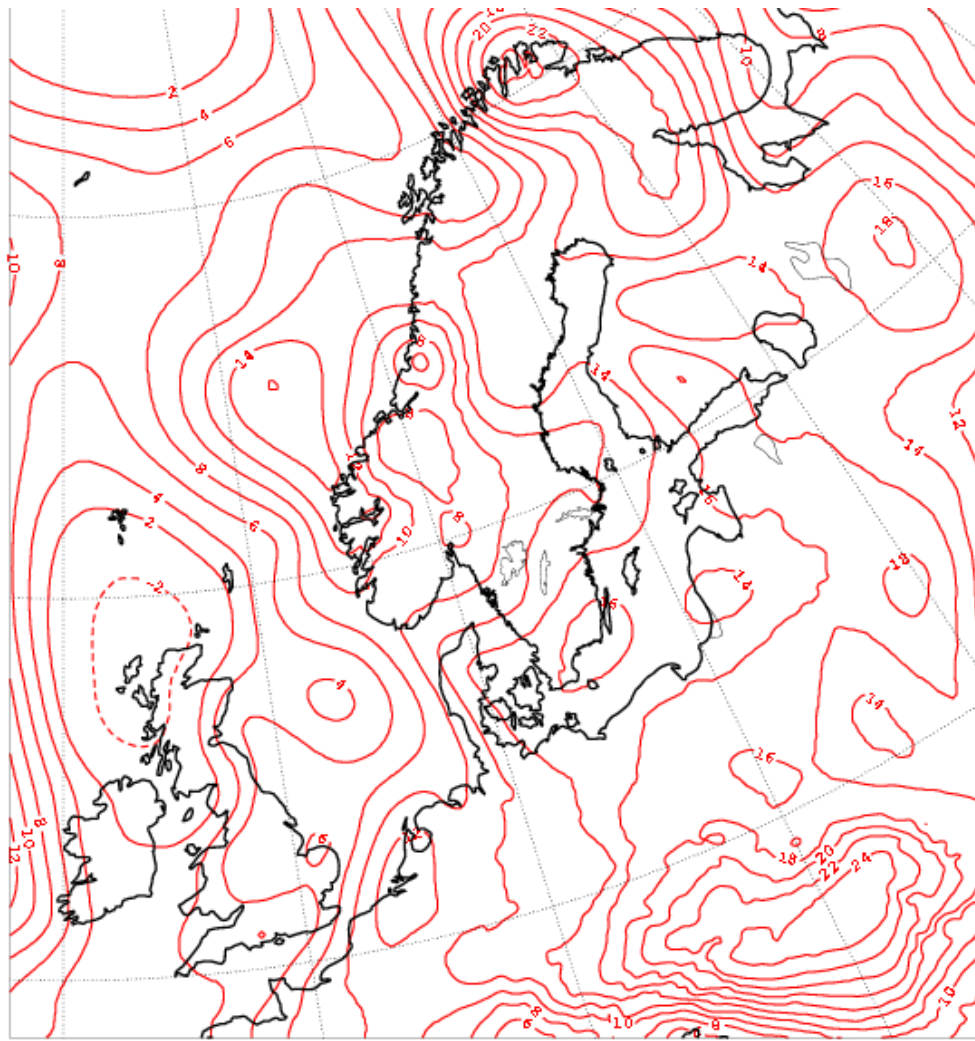


# Analysis increment with large extension zone



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valid Tue 3 Jan 2006 06Z

# Analysis increment with small extension zone

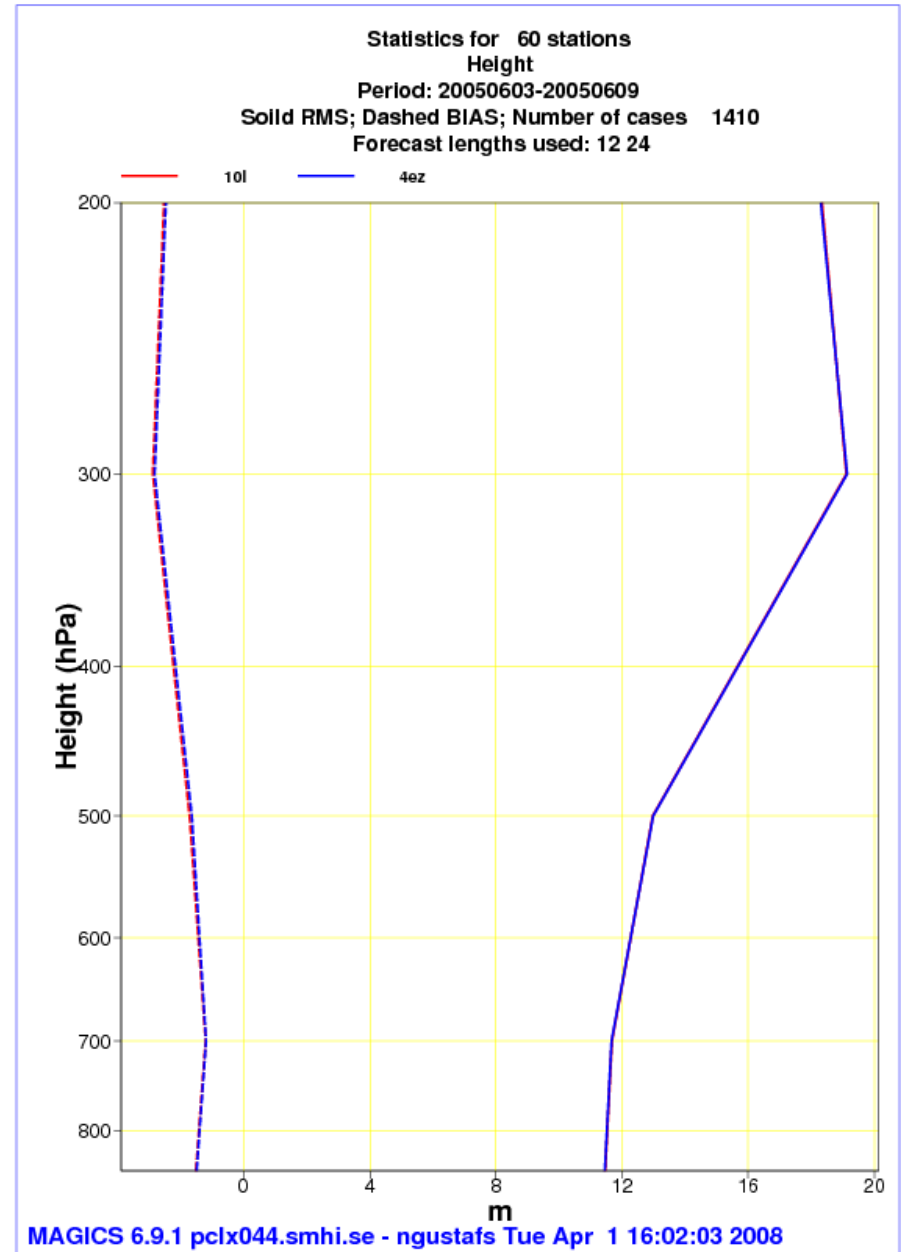


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# Test in HIRLAM 4D-Var (22 km, 40 levels) of the extension zone idea for HARMONIE 4D-Var

**1ol = large extension zone  
(1200 km)**

**4ez = large in Jb (1200 km);  
small in TL/AD models (500  
km)**



# **HARMONIE 4D-Var – Joint research efforts**

- Wavelet representation in Jb (ongoing)
- Moisture heterogeneities (ongoing)
- Balances
- Use of ensembles for sigma\_b (ongoing)
- Use of ensembles for spatial correlations
- Balances including moisture
- Simplified physics
- Moisture control
- Radar data (ongoing)
- Satellite data (ongoing)
- GPS data



# Summary



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**= HARMONIE !**