



# **Progress in development of HARMONIE 3D-Var and 4D-Var**

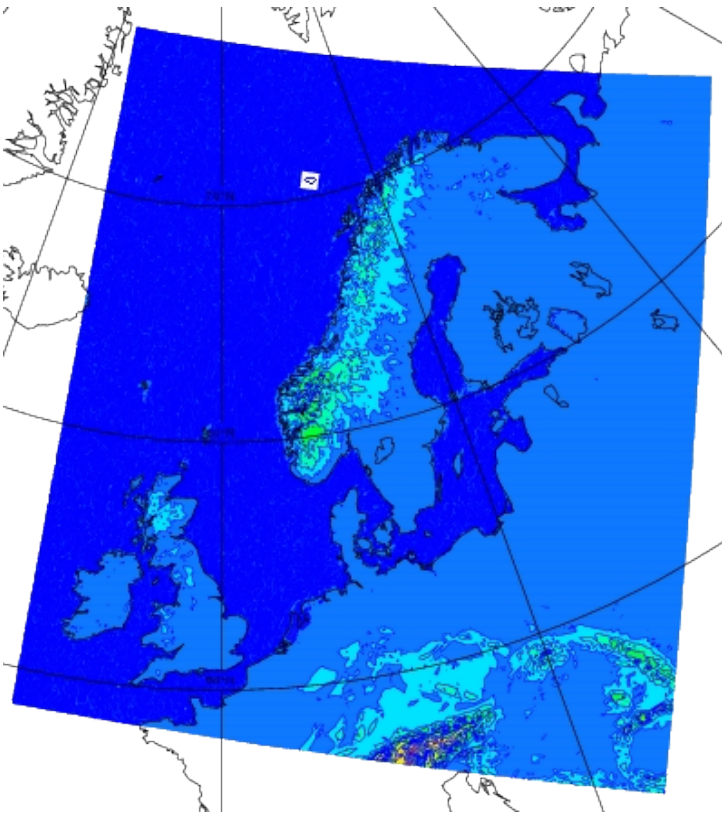
**Contributions from Magnus Lindskog,  
Roger Randriamampianina, Ulf Andrae,  
Ole Vignes, Carlos Geijo, ....**

**Collected and presented by Nils Gustafsson**

# High priority tasks during 2010

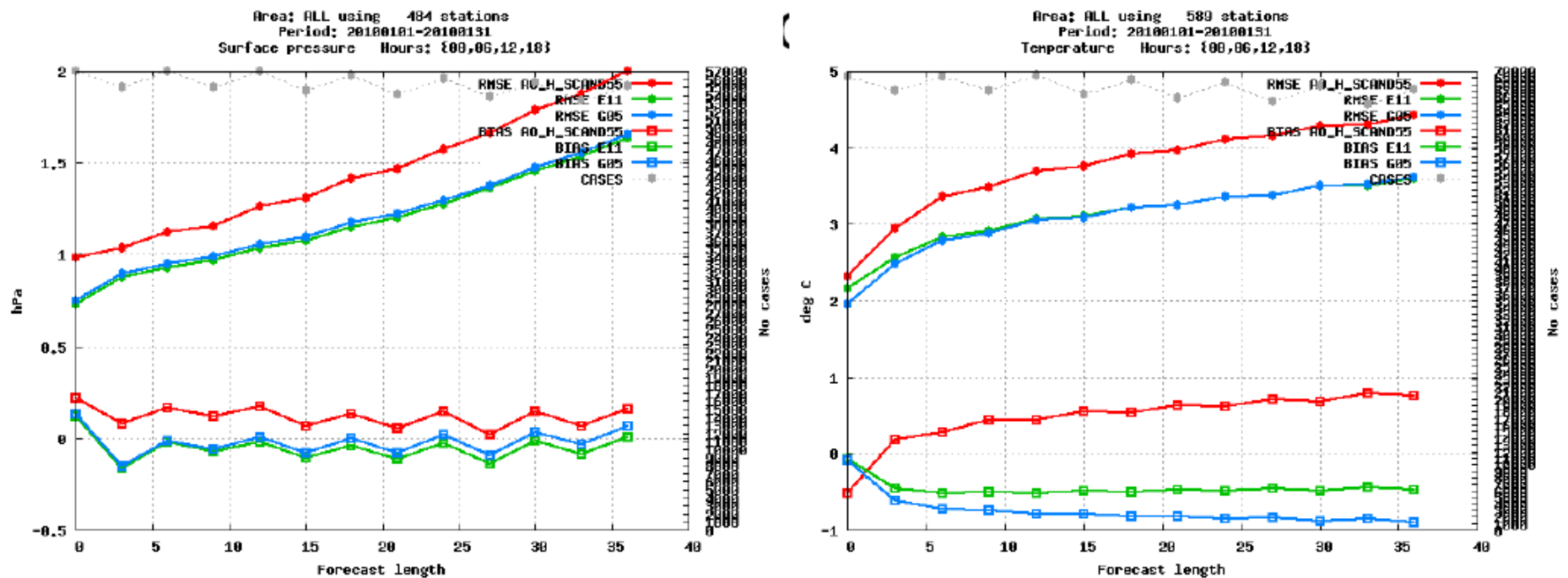
- 3D-Var: Installation of HARMONIE 3D-Var within the HIRLAM community
- 3D-Var: Background error statistics and large scale error constraint at mesoscale resolution
- (3-)4D-Var: A solution to the large extension problem
- Adjustment of 4D-Var to “simpler” ECMWF and HIRLAM algorithms; Improved 4D-Var physics
- Rapid update cycling
- Use of radar wind and reflectivity data

# Pre-operational tests at SMHI



- Cy35t1
- 5.5 km, 60 levels
- ALARO physics
- 3D-Var + CANARI
- B from downscaled ECMWF ensemble assim.
- ECMWF SST:s
- ECMWF LBC
- Incremental DFI

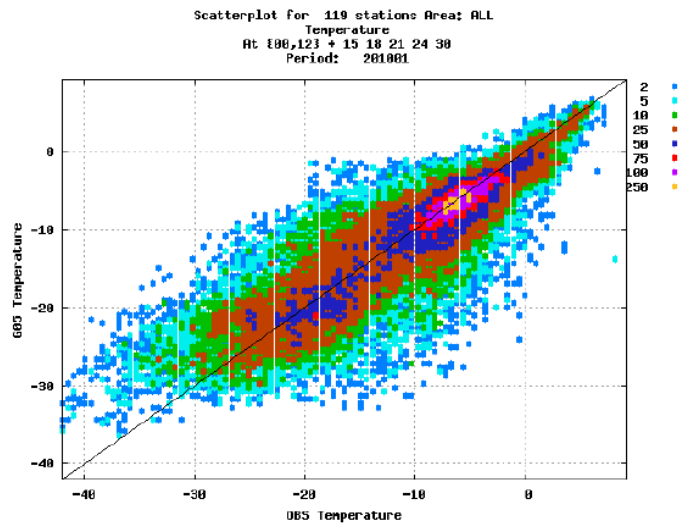
# Forecast verification scores - comparison with HIRLAM



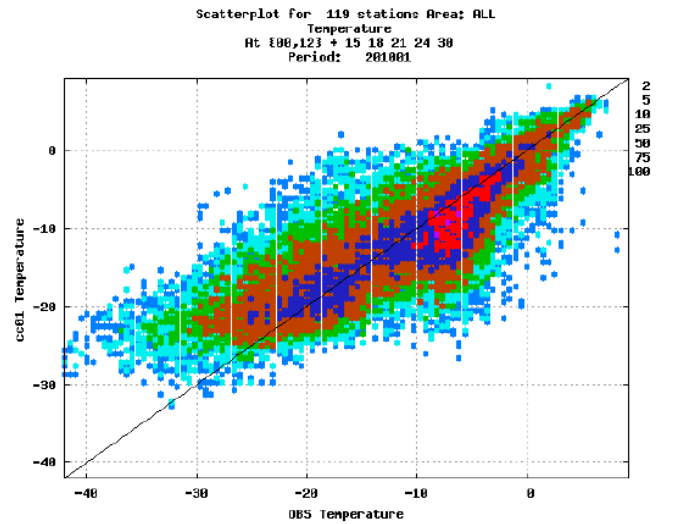
**Fig.2a:** Bias and RMS for January, 2010 as function of forecast length for ALARO (red), HIRLAM E11 (green) and HIRLAM G05 (blue). Left is for MSLP (unit: hPa) and right for 2 metre temperature (unit: K).

# Problems with cold temperatures

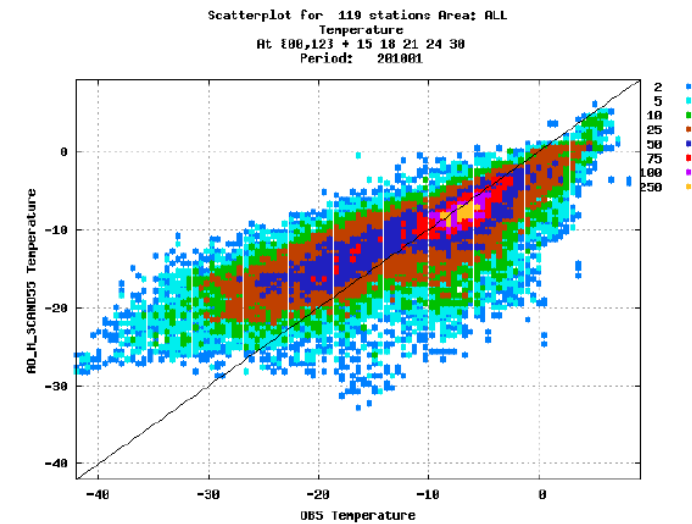
HIRLAM



AROME

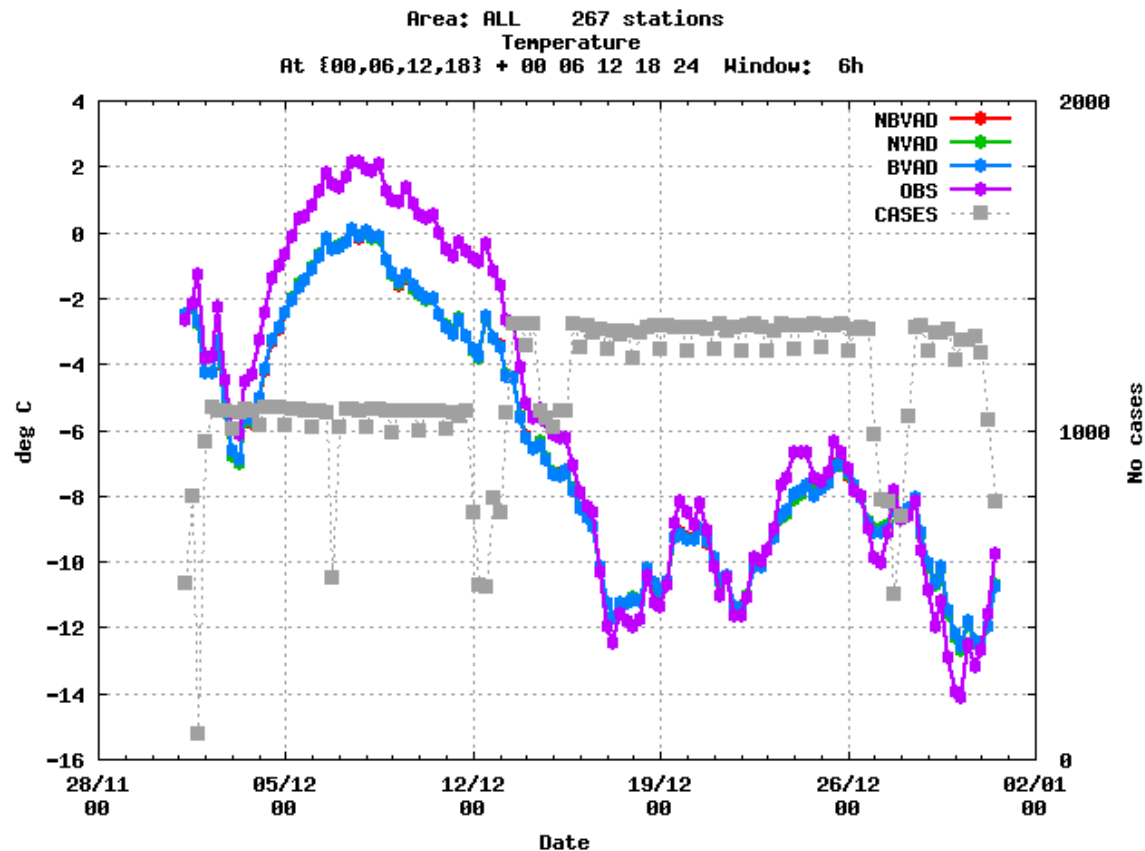


ALARO



**Fig.3:** T2m temperatures for (from left to right) HIRLAM, AROME and ALARO for January 2010.

# Met.no experiences (from a radar wind impact study by Roger)



# Tests at AEMET

- AEMET testing the HARMONIE 3D-Var on a CRAY SV2. Recently (April 2010) we have completed the installation of the 35h1.2 version at 11 km horizontal resolution and 60 levels.
- The results showed that forecasts verify somewhat worse than those initialized from interpolated HIRLAM 7.2 analyses.
- The testing mode was extended to the surface analysis (CANARI). The results indicated that the impact of the surface analyses is retained not long in the forecast. After a few hours of integration the verification parameters reach values similar to those from forecasts initialized with interpolated fields.

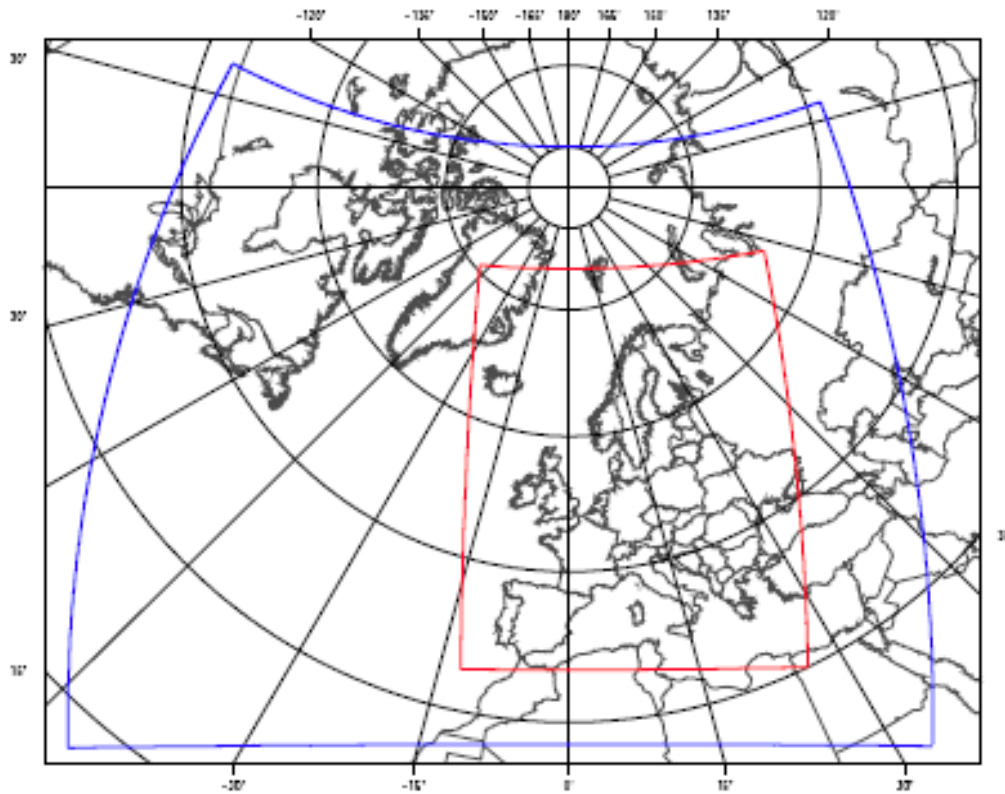
# Use of HARMONIE for EUCOS – comparison with HIRLAM

- 6 different upper air network scenarios were simulated with both HIRLAM and HARMONIE
- For a summer period 1 June – 15 July 2007 it was possible to compare:
  - HIRLAM at 11 km with 4D-Var
  - Non-hydrostatic HARMONIE with ALADIN physics at 4 km (LBCs from HIRLAM) with 3D-Var

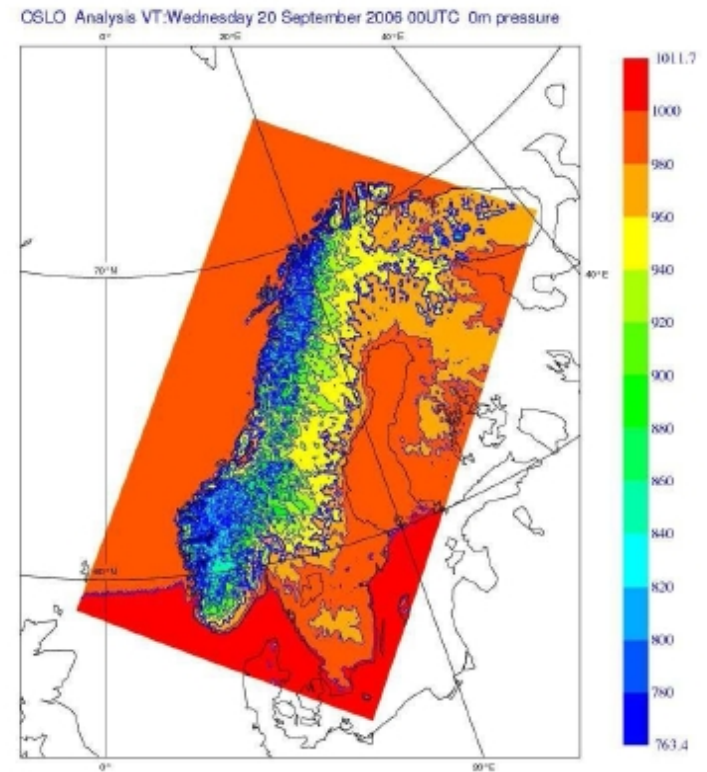
(Nils Gustafsson, Roger Randriamampianina, Sigurdur Thorsteinsson and John de Vries)



# Model domains for the EUCOS studies:

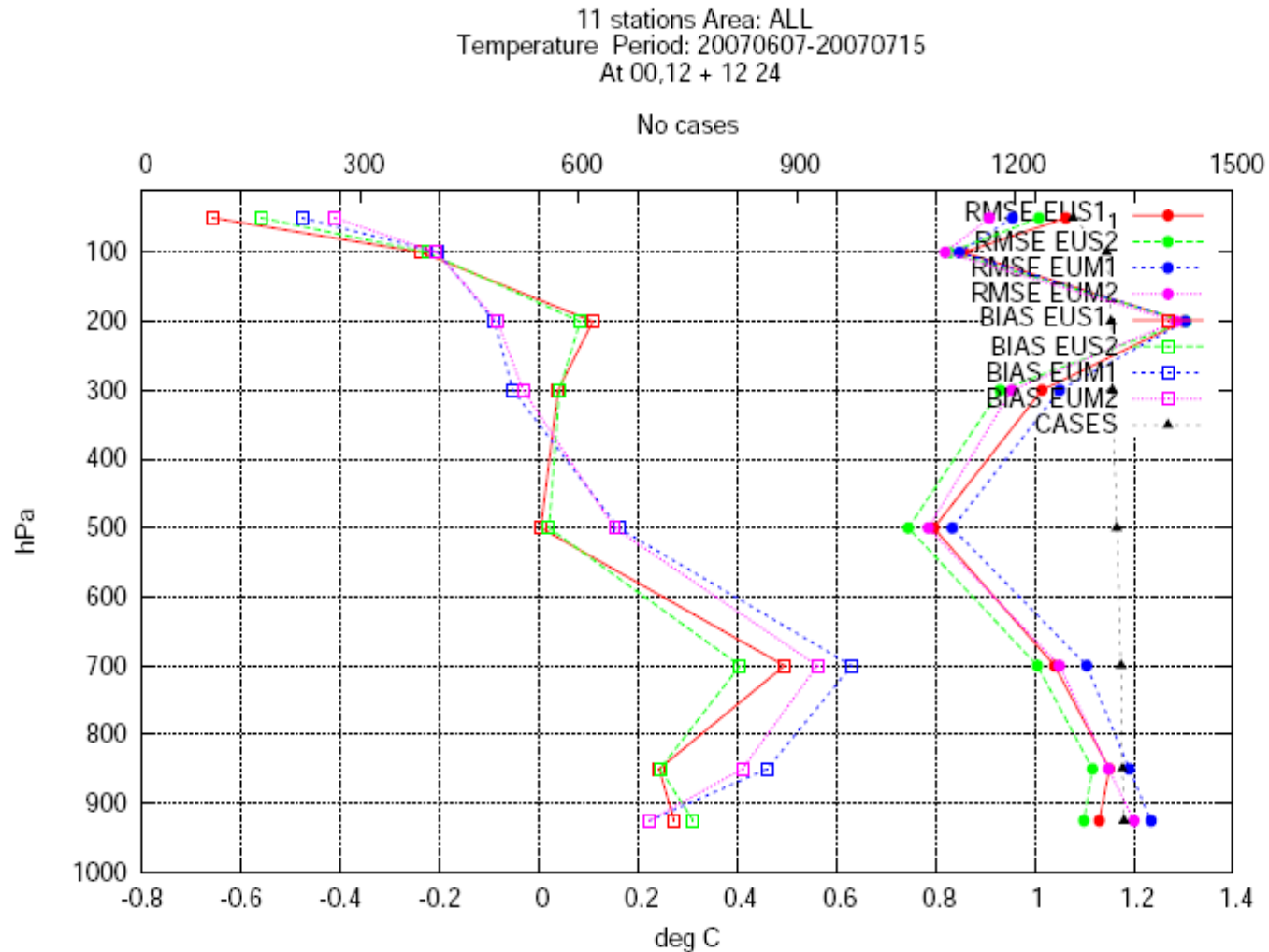


HIRLAM 17 km and 11 km

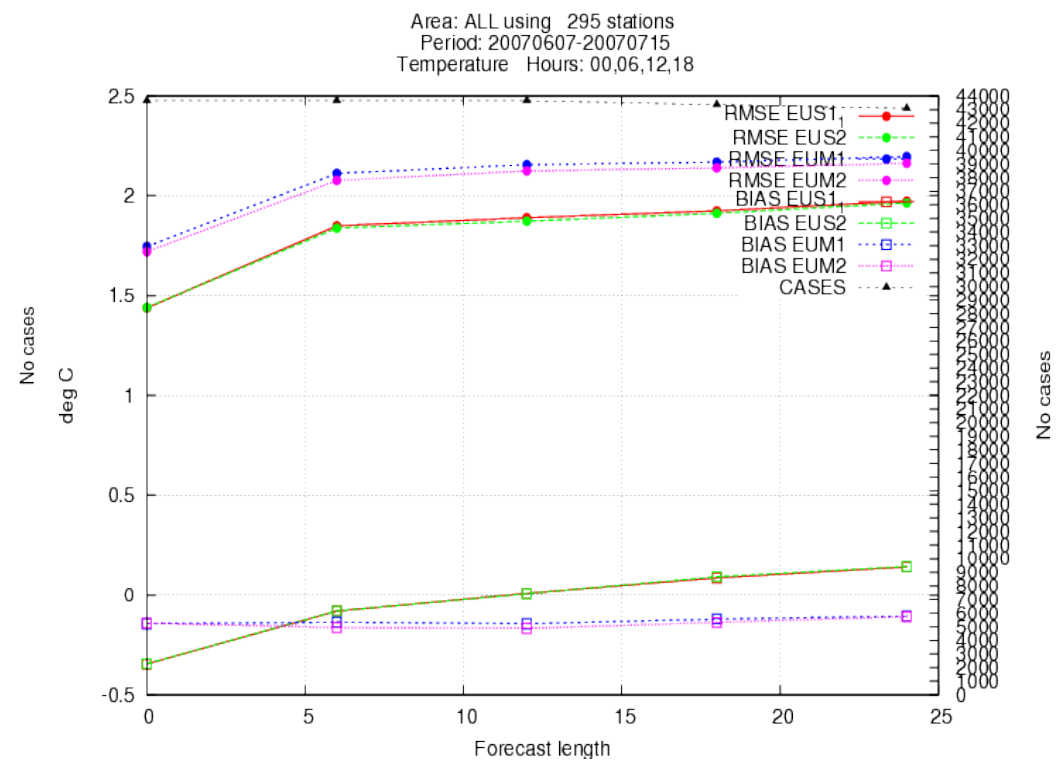
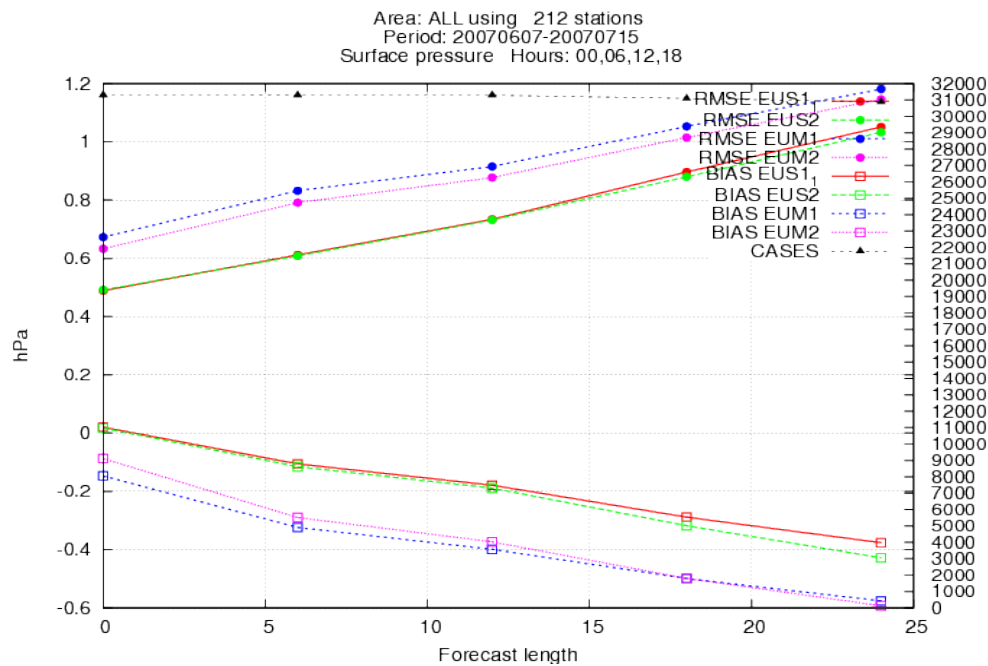


HARMONIE 4 km

# Verification of temperature profiles in the “best” and “worst” scenarios



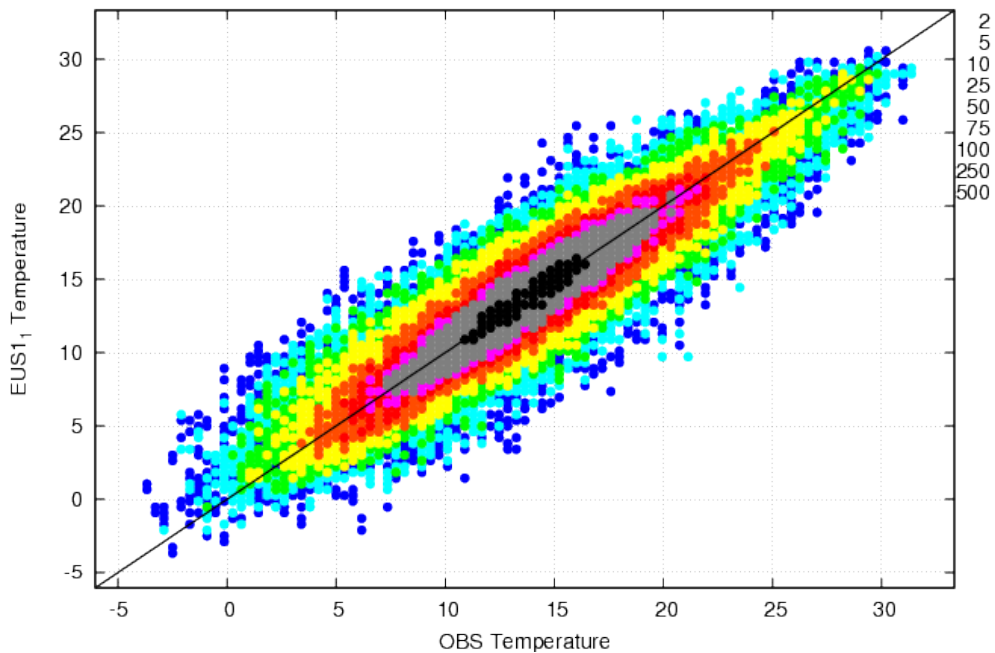
# Verification of surface pressure and 2 meter temperature in the “best” and the “worst” scenarios



# 2 meter temperature, scatter plots

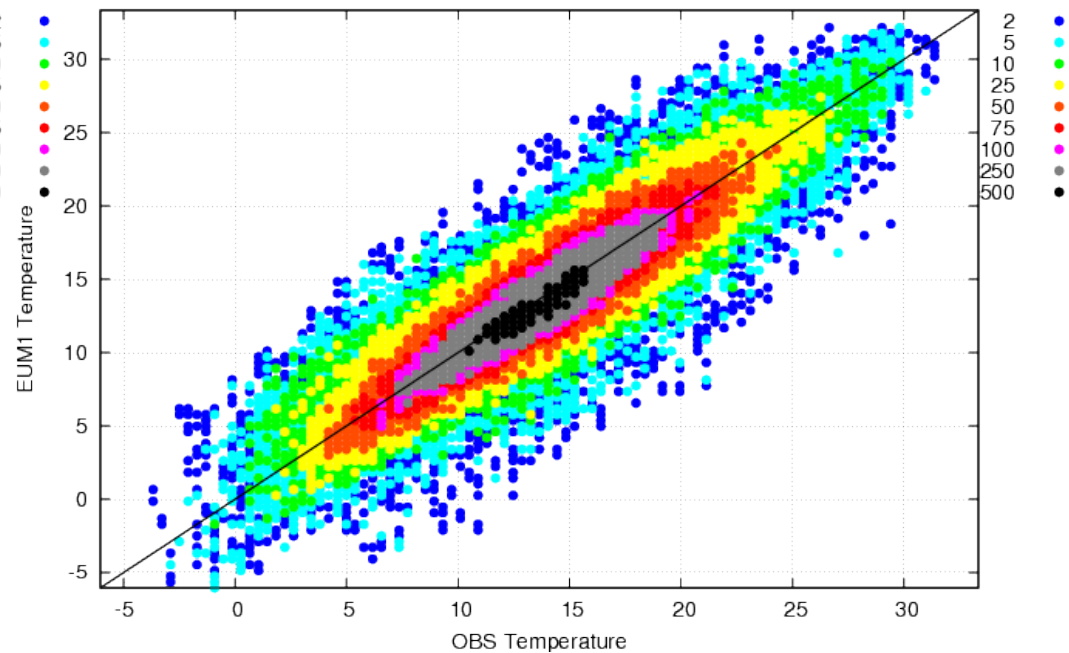
## HIRLAM

Scatterplot for 295 stations Area: ALL  
Temperature  
At 00,06,12,18 + 06 18  
Period: 20070607-20070715

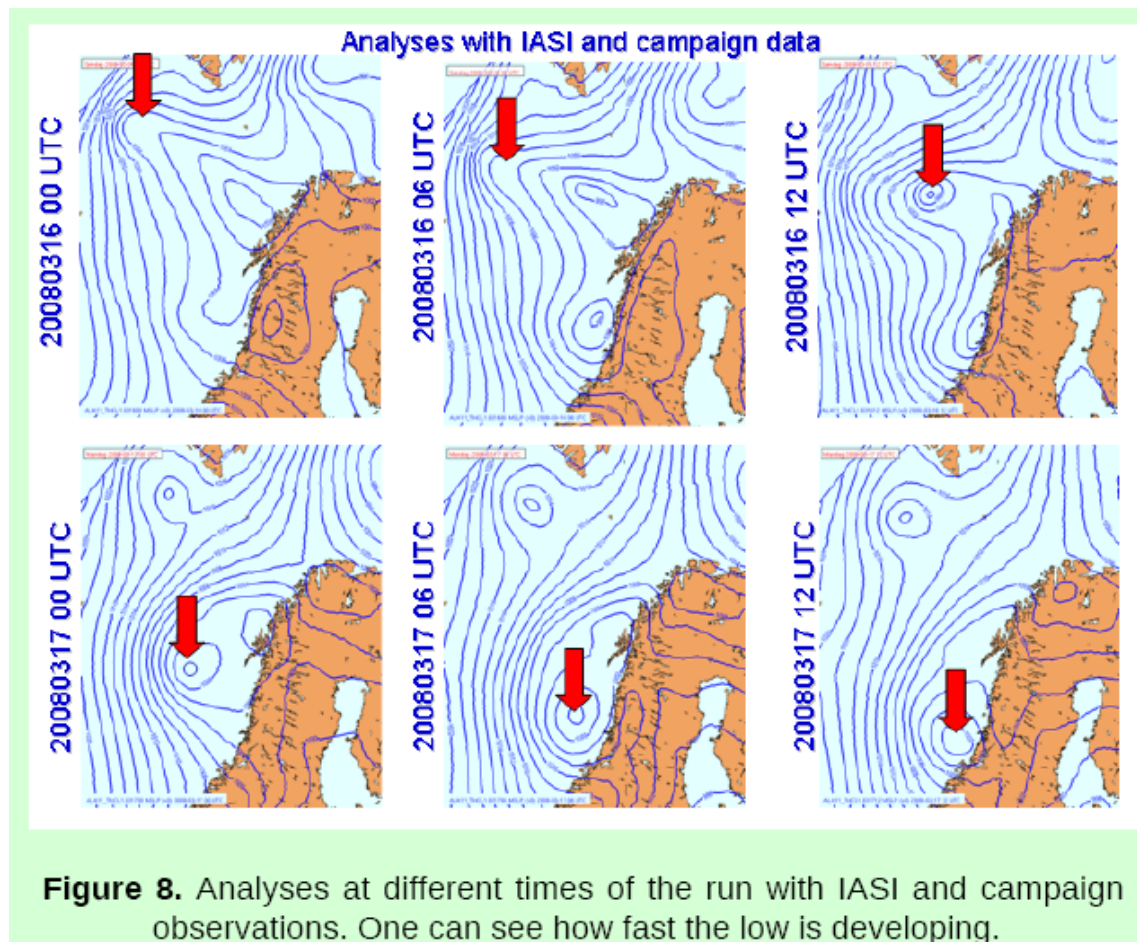


## HARMONIE

Scatterplot for 295 stations Area: ALL  
Temperature  
At 00,06,12,18 + 06 18  
Period: 20070607-20070715

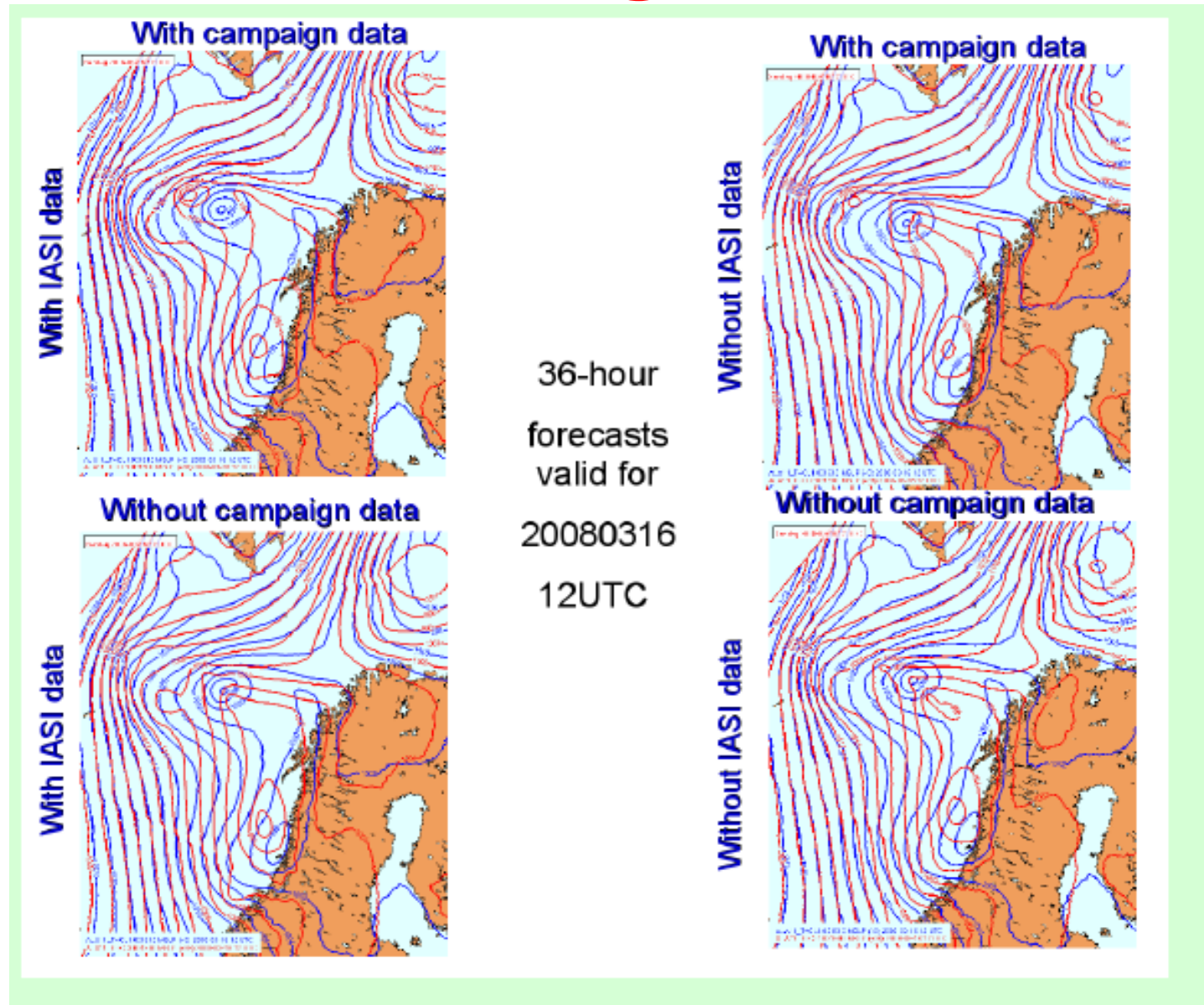


# IPY study: IASI and polar lows (Roger R.)





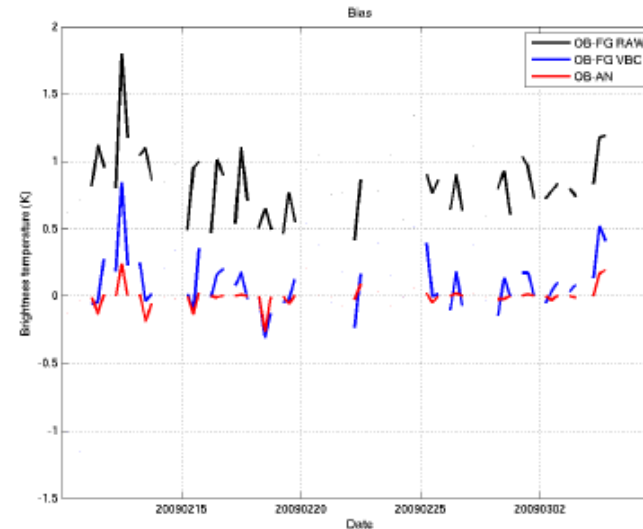
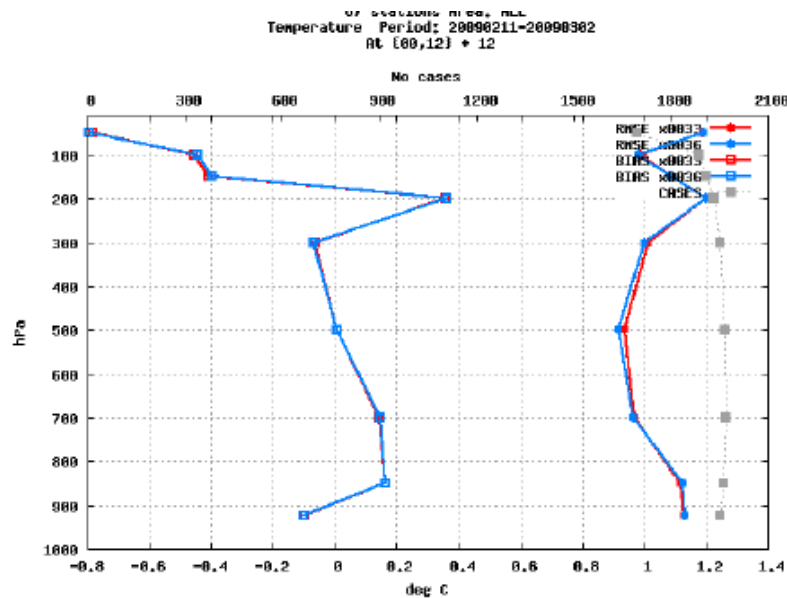
# Improved forecasts with IASI and campaign data



# AMSU impact study (Magnus L.)

Verification of  
temperature profiles

Efficiency of  
variational bias  
correction



**Fig.4:** Temperature forecast verification scores (unit: K) for the period 20090211 to 20090302 (left). Bias and RMS as function of vertical level for CRL (red) and SAT (blue). To the right the time-series of AMSU-A channel 10 departures (unit: K) from NOAA 16 are shown for the same period. for the period. Black curve is for raw observation minus background, blue curve is for bias corrected observation minus background and red curve for bias corrected observation minus analysis.

# Large extension zone test (Magnus L.)

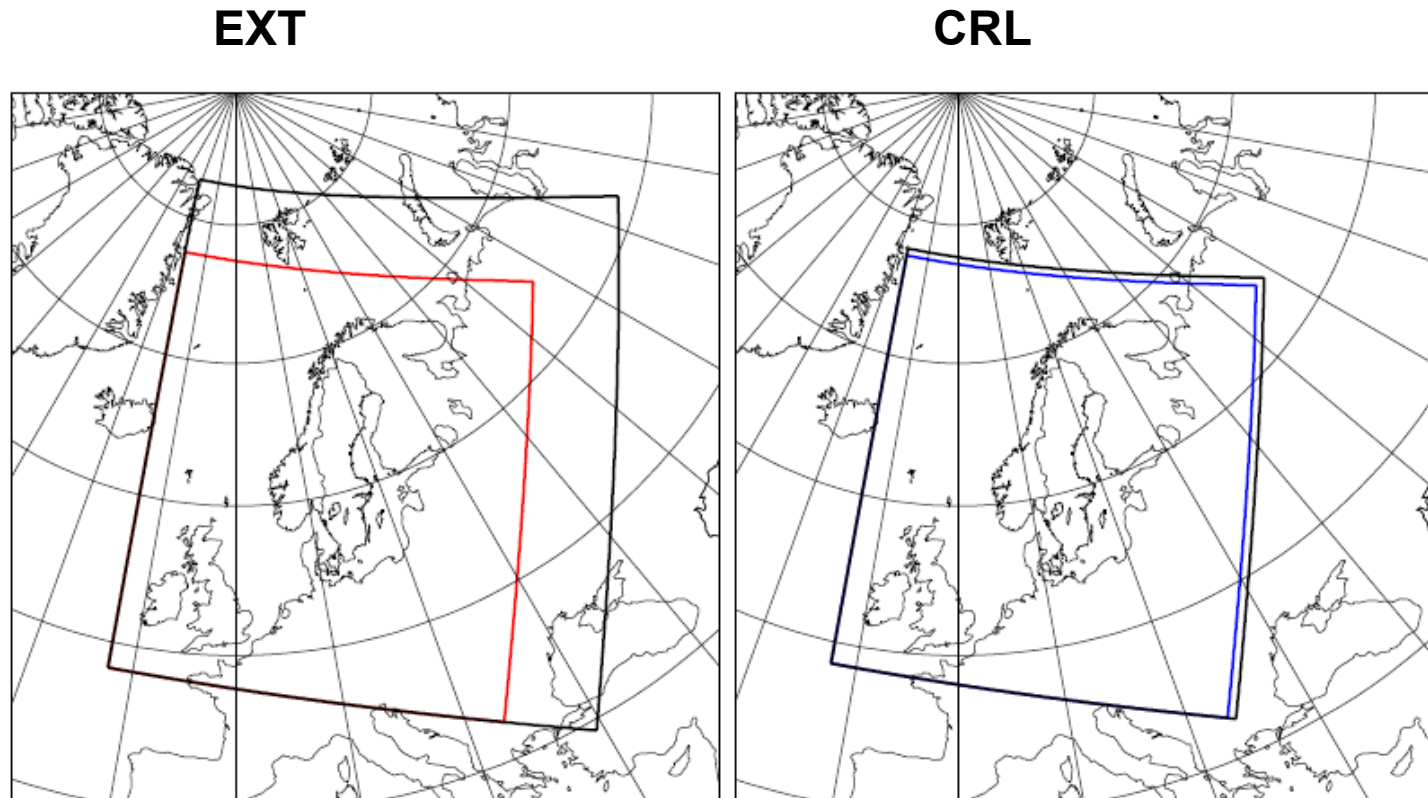
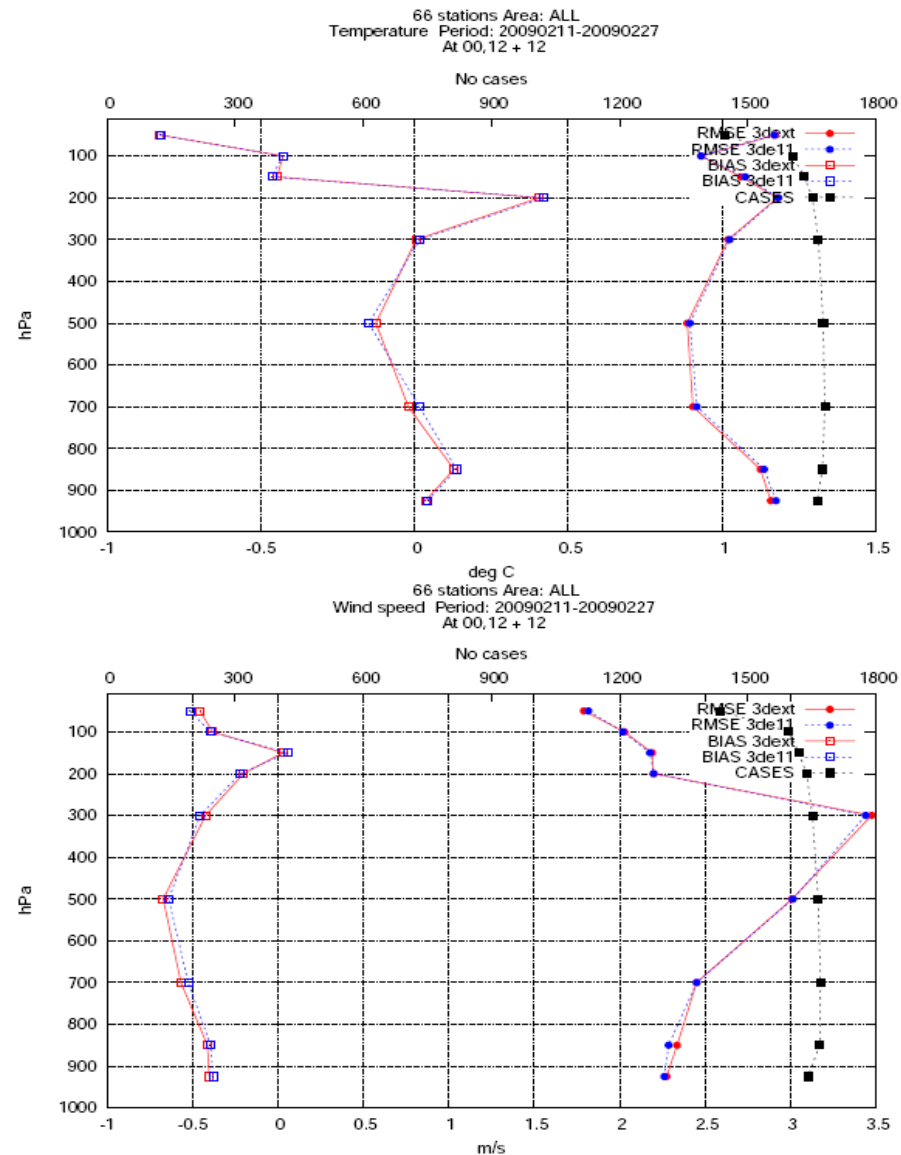


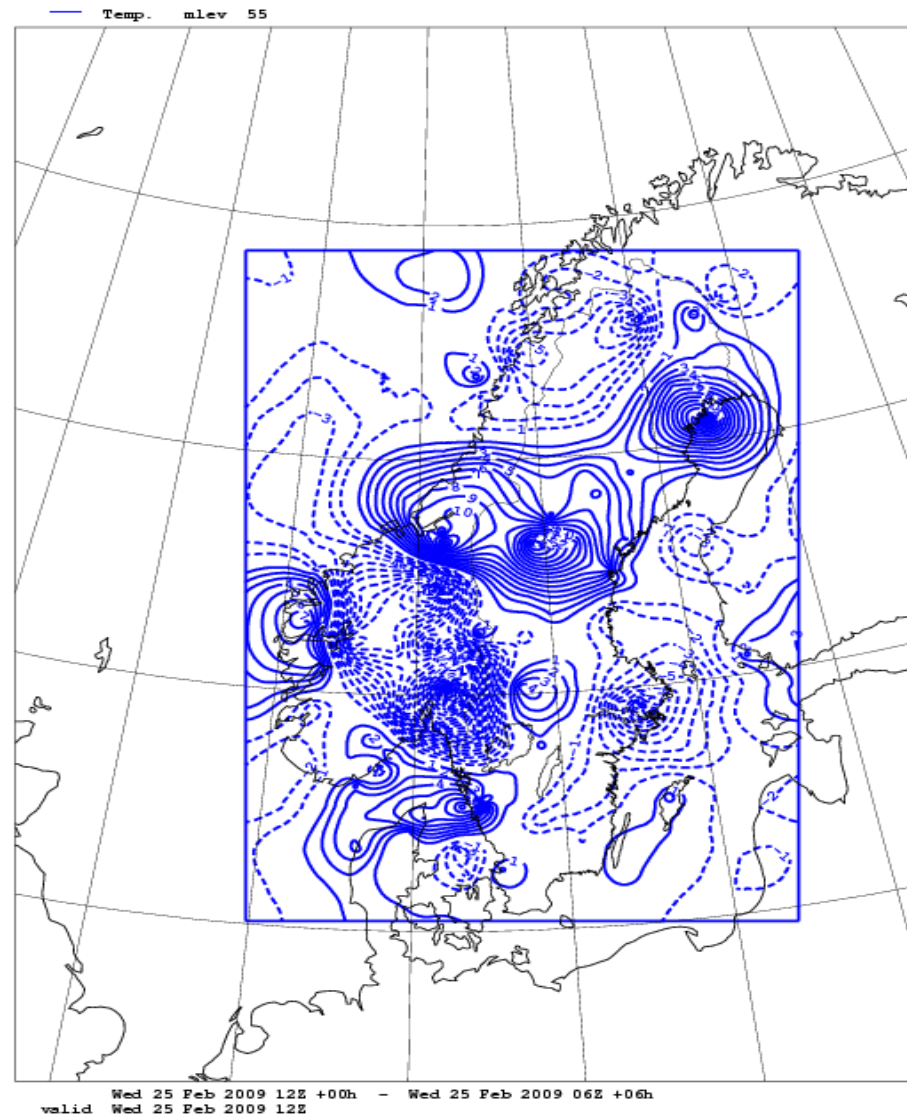
Figure 1: Scandinavian domain for EXT (left, red: inner area and black: extended area) and CRL (right, blue: inner area and black: extended area).



# Verification of temperature and wind profiles with large and small extension zone



# Example of assimilation increments from first AROME 3D-Var run (Magnus L. and Ulf A.)



# **Ensemble assimilation to generate background error statistics (Roger L. and Magnus L.)**

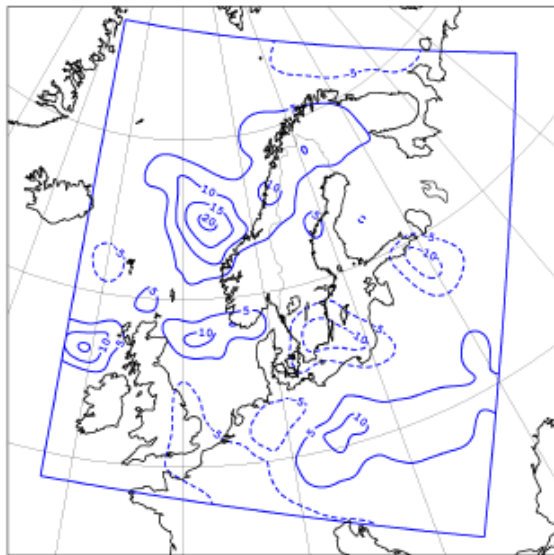
- So far, most work has been based on downscaling of global ensembles
- Software for assimilation based on perturbation of observations and use of global ensembles on the lateral boundaries has been prepared

# HARMONIE 4D-Var

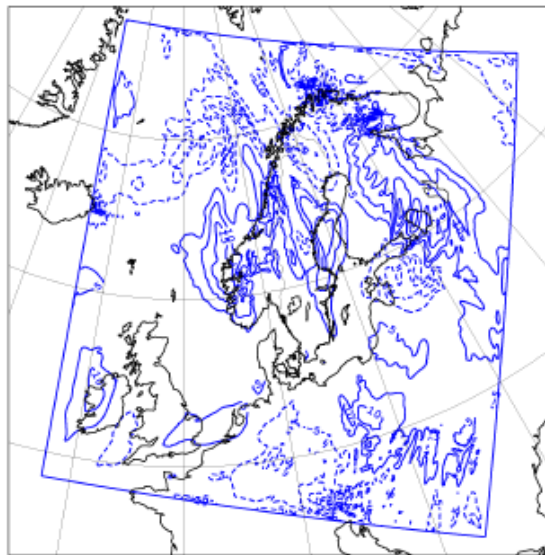
- A first version of HARMONIE 4D-Var has been prepared, mainly during 3 “working weeks”
- One of these of these working weeks in Dec. 2009 was with participation of ALADIN staff
- We now have a “running” HARMONIE 4D-Var including
  - Multi-incremental minimization
  - Weak digital filter constraint
  - Very simple 4D-Var physics (Buizza)

# Comparison of 4D-Var and 3D-Var assimilation increments

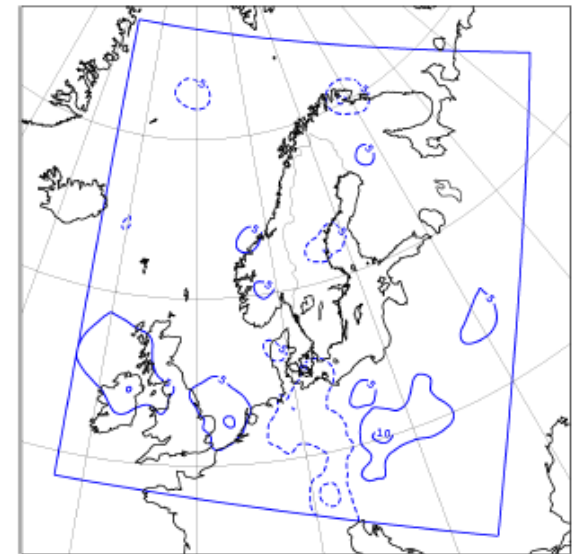
4D-Var start of window



4D-Var middle of window



3D-Var



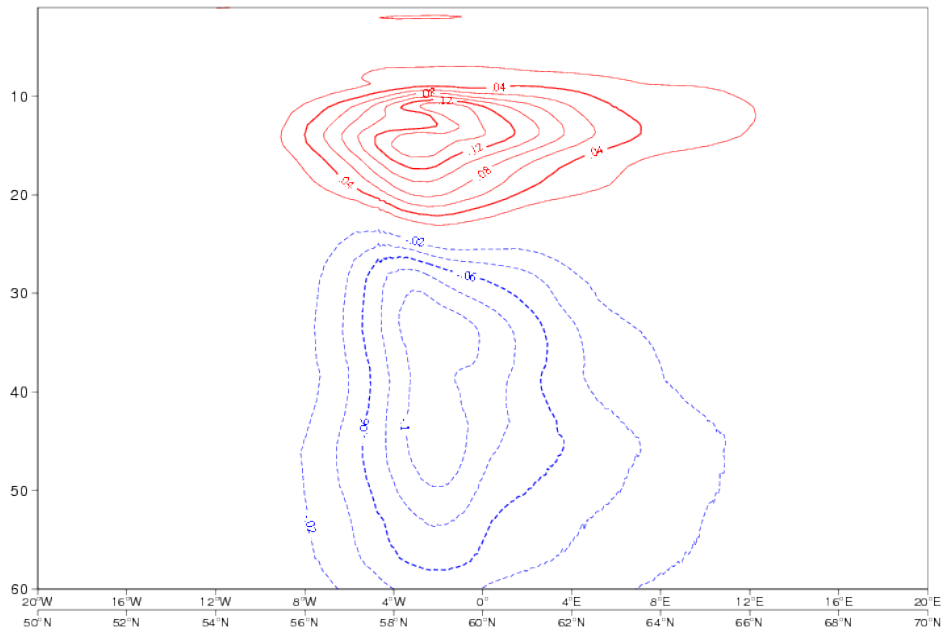
**Fig.5:** 200 hPa temperature assimilation increments (unit: K times 10) for the assimilation cycle 20090220 06 UTC. Left: 4D-Var increments at the beginning of the assimilation time window (03 UTC). Middle: 4D-Var increments propagated to the centre of the assimilation time window (06 UTC). Right: 3D-Var increments.

# AMSU-A channel 10 single obs experiment with 4D-Var

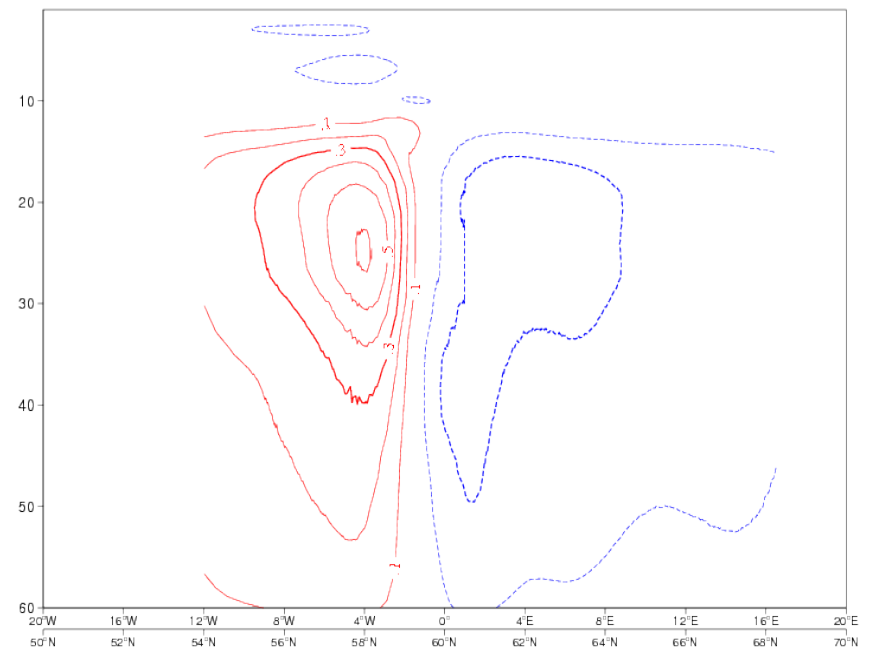
## Temperature

## Wind

Cross section of p130/t1 20080211 2100 step 0



Cross section of p131/t1 20080211 2100 step 0



# Next HARMONIE 4D-Var working week 3 – 7 May at met.no

- Will be devoted to testing and validation, example of tasks:
  - Clean and validate code developments for multi-incremental 4D-Var
  - Evaluate the functionality of Jc-dfi and removal of multiple dfi:s
  - Test different more informative minimizer.
  - Evaluate simplified physics (presently Buizza) and introduce new, as proposed and partially prepared by Olivier during last ww.
  - External Jbstat converter from one area to another
  - Start up extended exp with 3d-var vs 4dvar and case studies.
  - Start to develop 4d-var with larger extension zone.
  - Further generalisation of 4dvar namelists

# Summary

- HARMONIE 3D-Var has been installed at several HIRLAM member institutes – pre-operational at SMHI
- 3D-Var (and surface assimilation with CANARI + OI-Main) works technically, also for AROME on the mesoscale
- Problems with forecast quality => emphasis on validation for the remainder of HIRLAM A
- A basic 4D-Var exists
- No (Few) activities so far on rapid update cycles