

# **4D-Var**

# **HARMONIE Developments**

ALADIN/HIRLAM

21 th Workshop / All Staff meeting 2011

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Magnus Lindskog, Ole Vignes, Nils Gustafsson, Trygve Aspelien, Roger Randriamampianina, Mariano Hortal, Ulf Andrae, Per Dahlgren, Bernard Chapnik, Olivier Riviere, Claude Fischer, Gergely Boloni, Florian Meier, Benedikt Strajnar, Antonin Bucanek, Vanja Kovac



# Outline

- Introduction
- Brief History
- Recent developments
- Extended assimilation experiment
- Summary and Future plans

# Variational data assimilation

**Cost function:**

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

where

$$\delta x = x - x^b = (\delta u \quad \delta v \quad \delta T \quad \delta q \quad \delta \ln p_s)^T$$

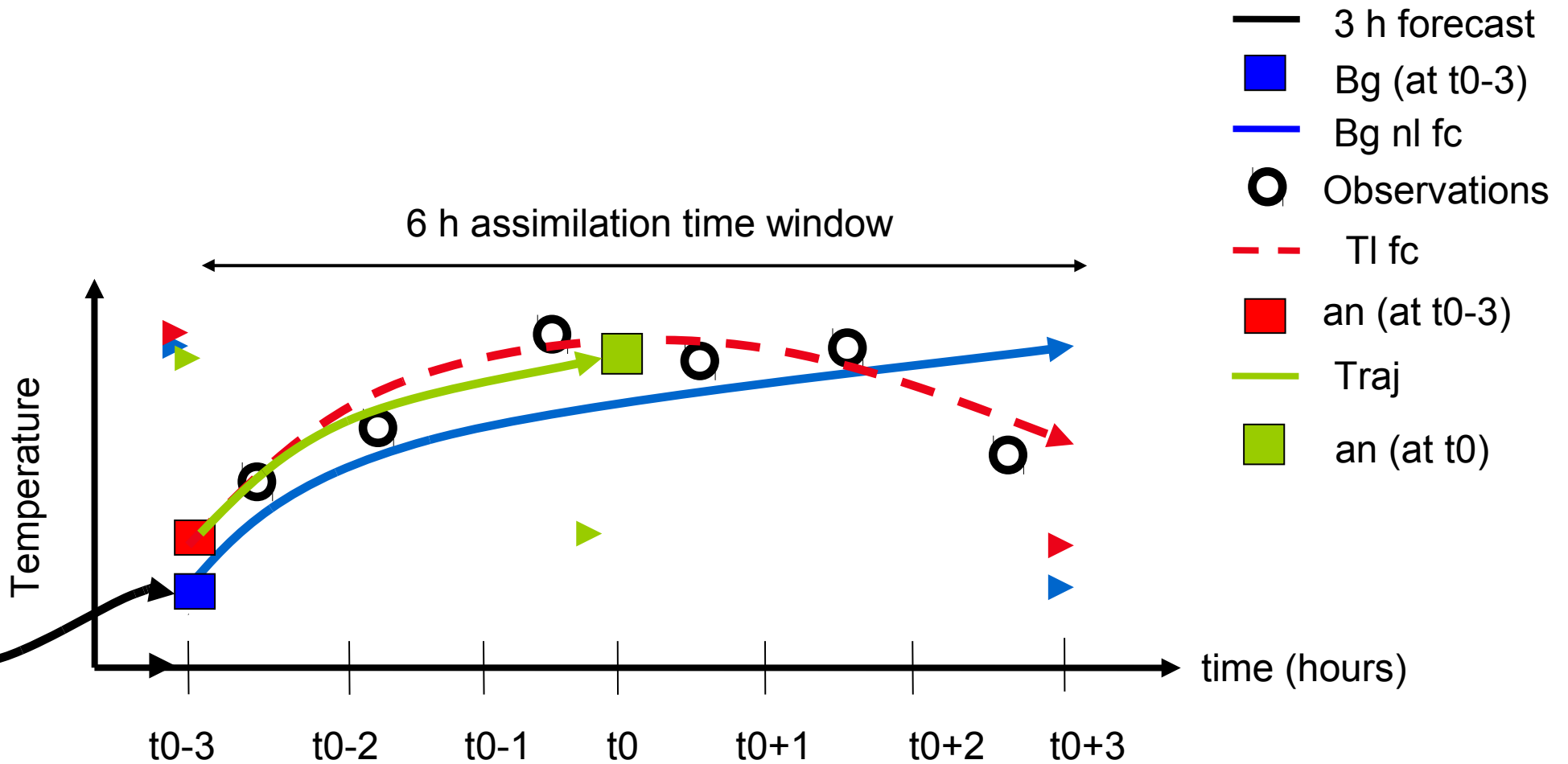
$x^b$  Background state

$B$  Background error covariances

$R$  Observation error covariances

$H, H_{tl}$  Observation operators

# HARMONIE 4D-Var Minimization



# Brief HARMONIE 4D-Var History

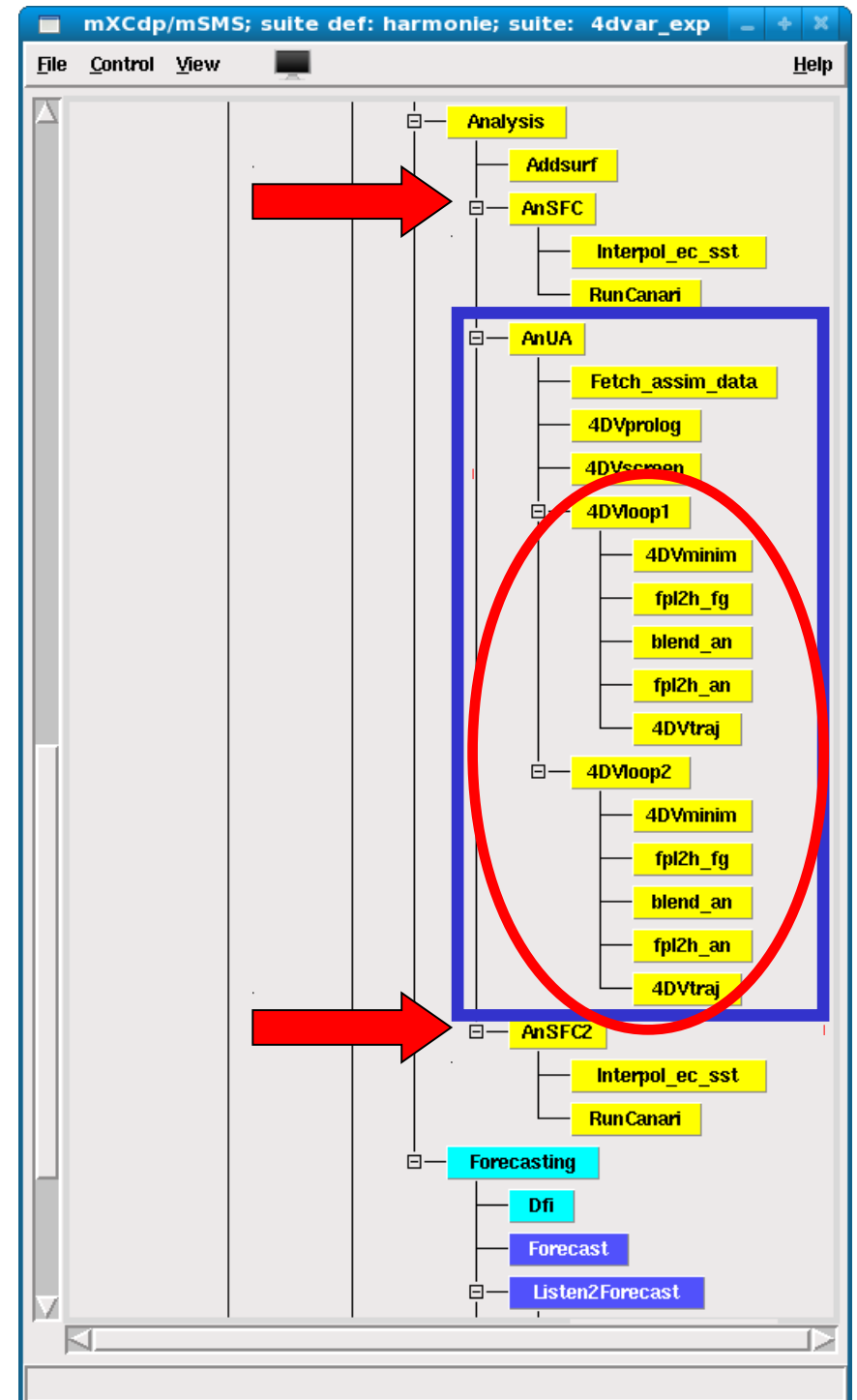
- Nils, Magnus and Ole visits Météo-France 8-12 Dec. 8-12, 2008, **to learn how Bernard Chapnik had set up first version of ALADIN 4D-Var** (in OLIVE system).
- First HARMONIE 4D-Var working week at met.no June 8-11, 2009 (Nils, Magnus, Ole, Trygve), during which **HARMONIE 4D-Var prototype is developed** (in mini-SMS control system).
- During second working week at met.no Sept. 7-11, 2009 (Nils, Magnus, Ole, Trygve). **First working version of HARMONIE 4D-Var is established.**
- Third working week at SMHI 30 Nov-4 Dec 2009, was devoted to **careful testing of the HARMONIE 4D-Var components. Planning for future developments** (multiple outer loop iterations, more advanced simplified physics). HIRLAM, Météo-France and LACE participants.
- Fourth working week at met.no 3-7 May, 2010 (Nils, Magnus, Ole, Trygve, Roger). **Work towards introduction of satellite data and phasing to cy 36.**
- Fifth working week at SMHI 22-26 November 2010. **Cleaning and various enhancements of HARMONIE 4D-Var.** HIRLAM and LACE (Météo-France in teleconference part).

# HARMONIE 4D-Var under mini-sms

- (old feature: low res ass incr.)
- Multiple outer loop iterations
- Surface analysis

## Other Recent Developments

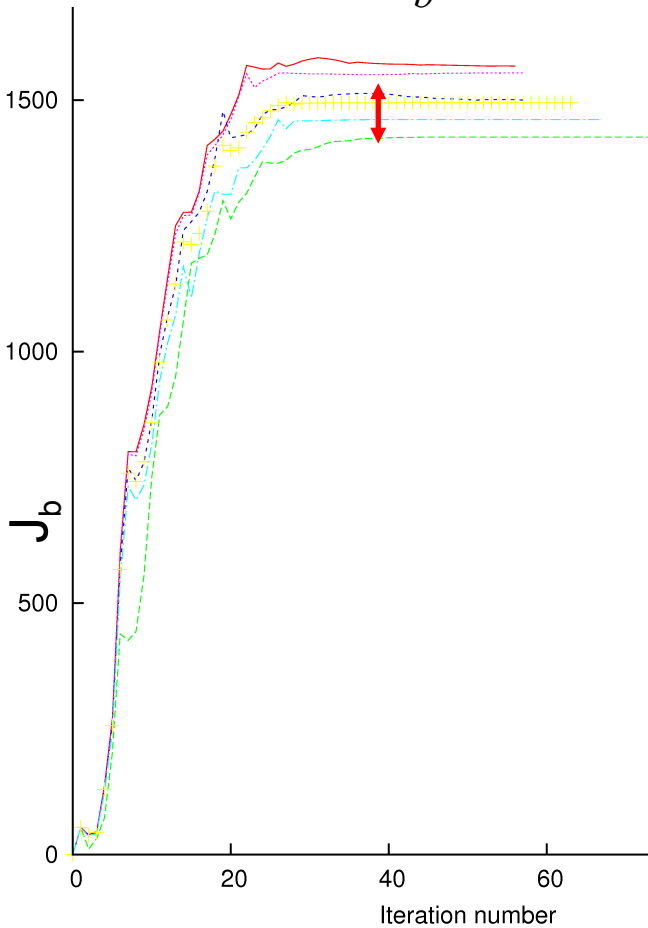
- Properly working Jc DFI
- Satellite observations included
- More advanced simplified physics
- 4D-Var with a wide extension zone



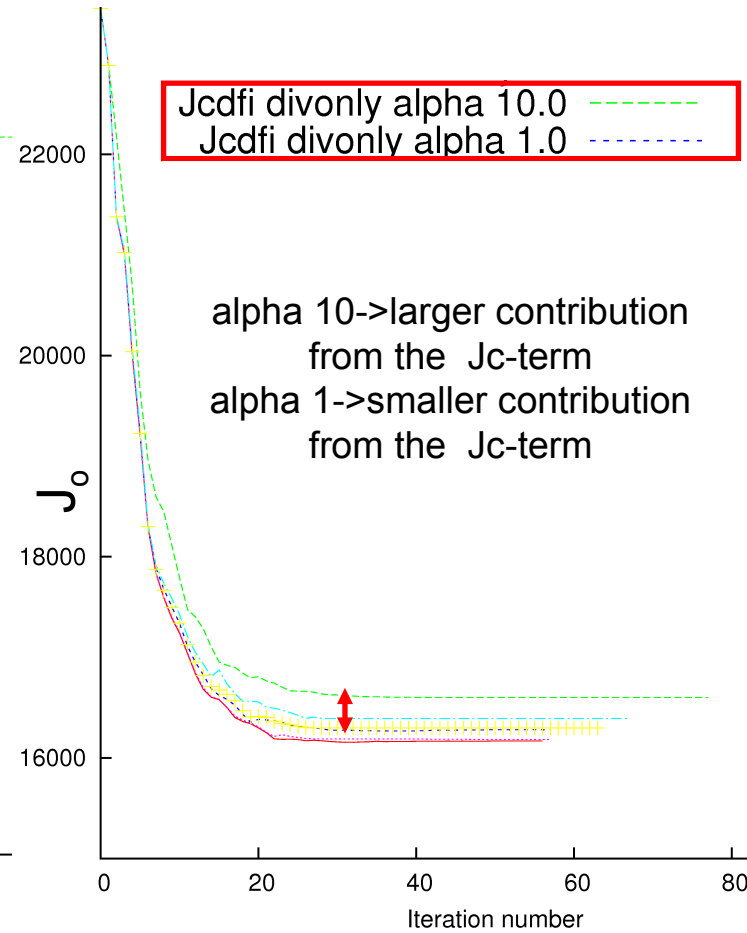
# Jc DFI

$$J = J_b + J_o + J_c$$

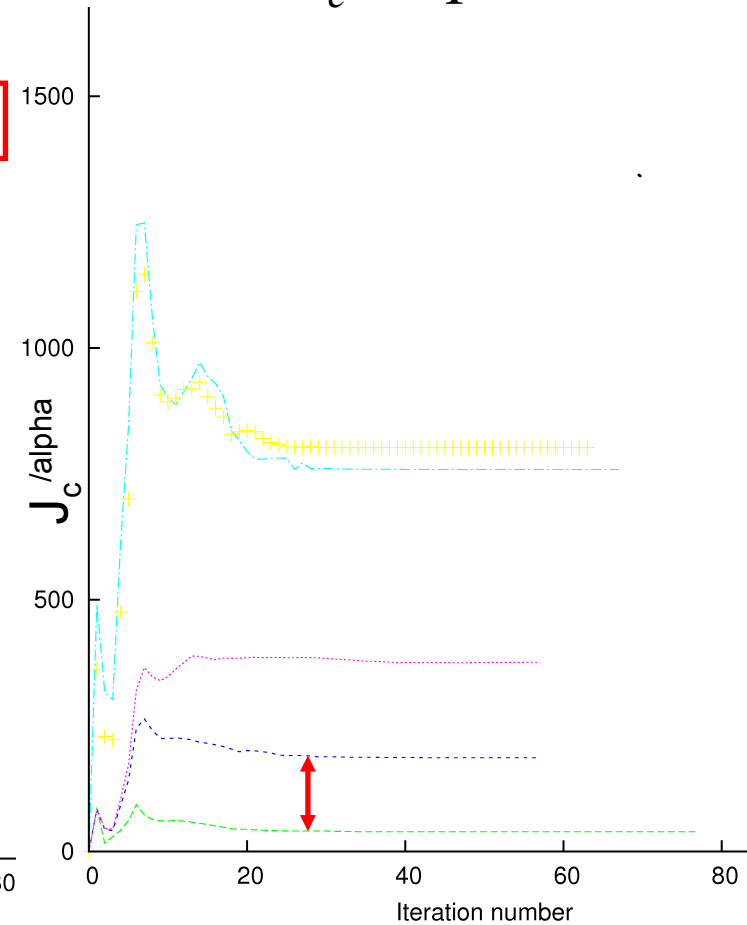
$J_b$



$J_o$



$J_c / \alpha$



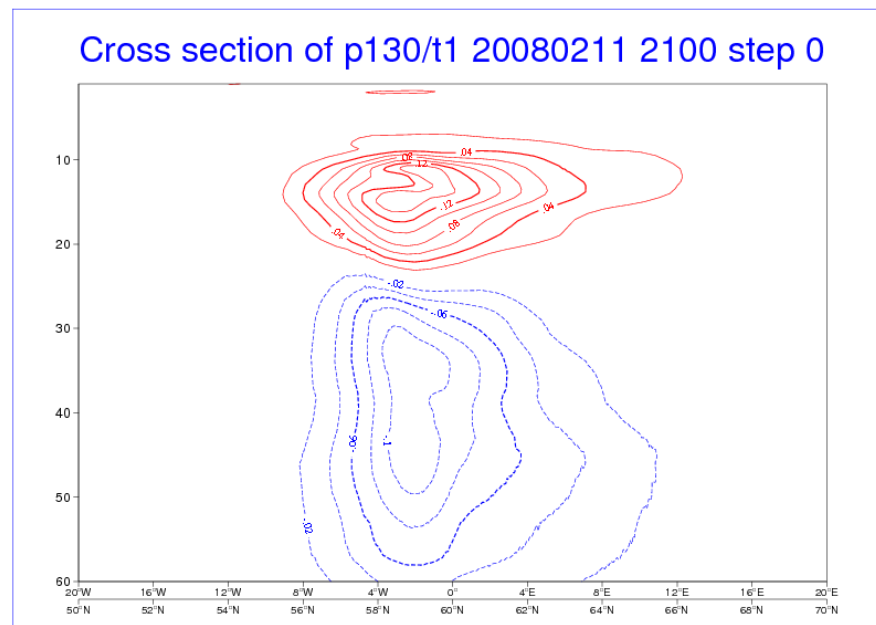
Larger alpha gives stronger filtering, smaller increments, worse fit to observations and less high frequency variations.

# Satellite data in HARMONIE 4D-Var

ATOVS (AMSU-A, AMSU-B, MHS), IASI, ASCAT, AMV

Impact of one single AMSU-A channel 7 observation in HARMONIE 4D-Var. Observation time at 20080212 12 UTC, 0 degree longitude, 60 degree latitude. Observed value 1 K warmer than corresponding background value.

Vertical cross section of temperature analysis increments (K) due to one single AMSU-A ch 7 observation.





# HARMONIE 4D-Var Simplified Physics

## Earlier simplified physics

- Only Buizza vertical diffusion (Buizza, ECMWF Tech. Mem. 192, 1993).

## Present simplified physics

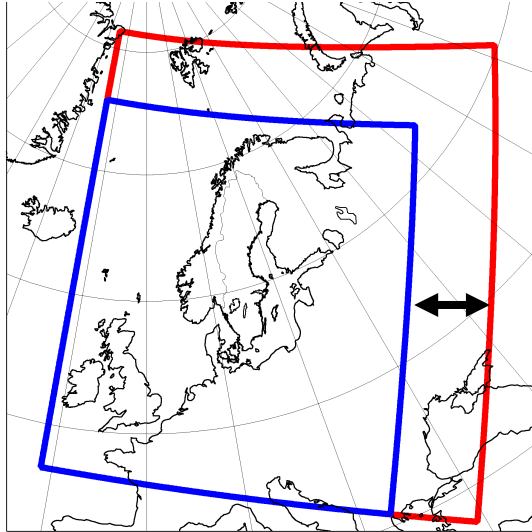
- Météo-France simplified physics (Janiskova *et al.*, MWR, 1999). Only Vertical diffusion and gravity wave drag applied at present (large scale condensation will be introduced and tested).

## Plans

- Introduction of ECMWF simplified physics in HARMONIE 4D-Var.

# Preparations for 4D-Var with wide extension zone

## Scandinavian domain with wide extension zone



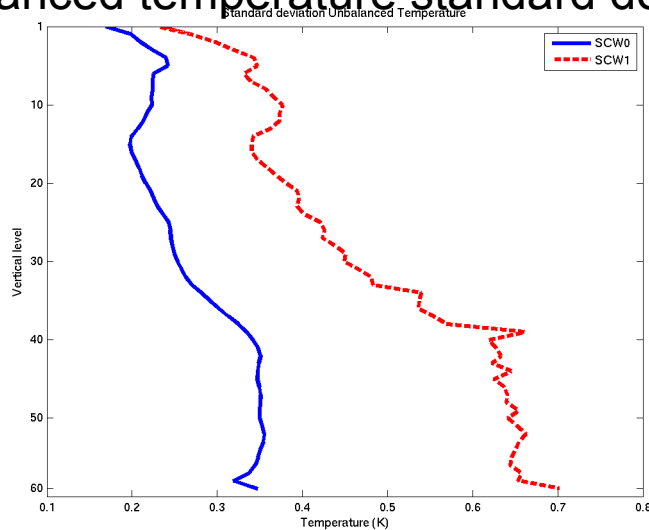
- Extended area

- Inner area

**Extension zone**

**63 gridpoints:~700 km**

## Unbalanced temperature standard deviations (K)



Inner area only, Extended area

- Ezone contributions excluded from background error statistics.
- All parts of 4D-Var has been run with extension zone calculations eliminated.

# Extended assimilation experiment

One-month parallel assimilation and forecast experiment for January 2010:  
(only conventional types of observations were utilized in the data assimilation)

- **3D-Var**
- **4D-Var**

(4D-Var: one outer loop, ass. incr. at half model resolution, no Jc-DFI, surface analysis applied after upper-air analysis)



Version: 36 h1.3 (with small mods)  
Area: Scandinavia (11 gp ezone)  
Model/Physics: ALADIN  
Hor. Res.: 11 km  
Number of vertical levels: 60  
Surface: ISBA-2L (not SURFEX)  
Surface DA: CANARI  
Initialization: IDFI  
Forecast length: 0-36 h

# Scores for verification against observations

(Surface pressure)

4D-Var

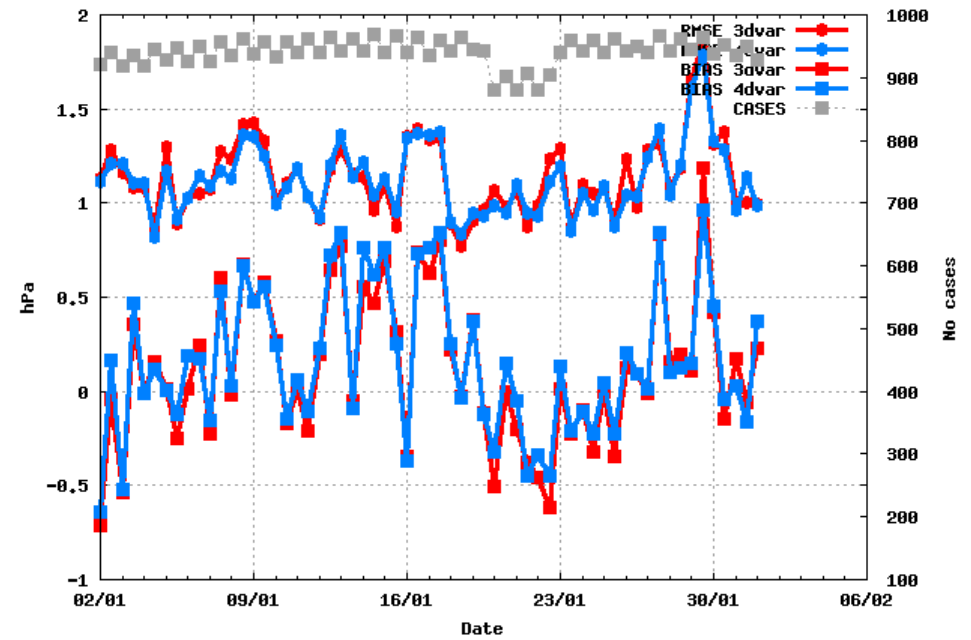
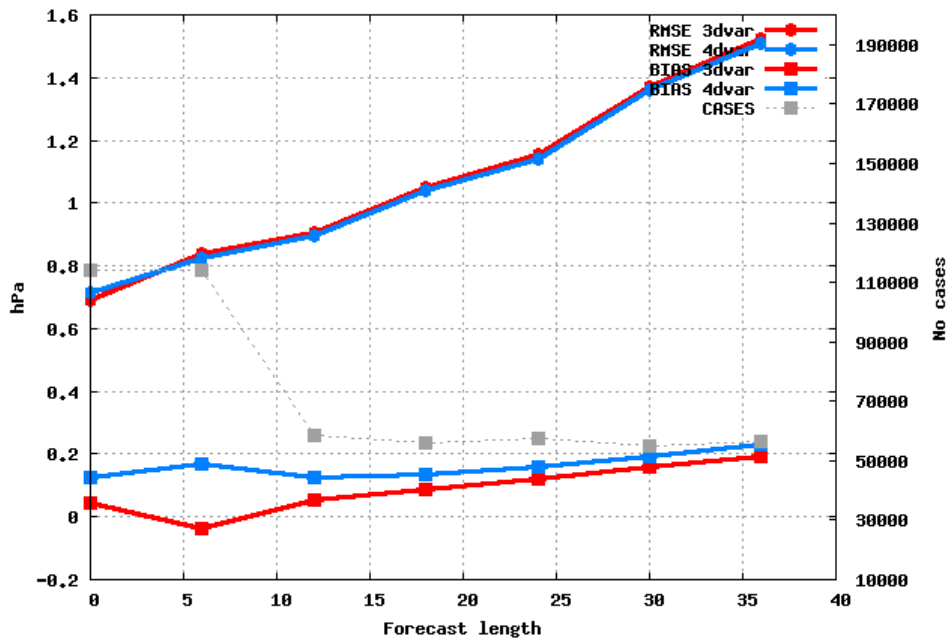
3D-Var

BIAS/RMS as function of  
forecast range

BIAS/RMS time series of  
+24 h forecasts

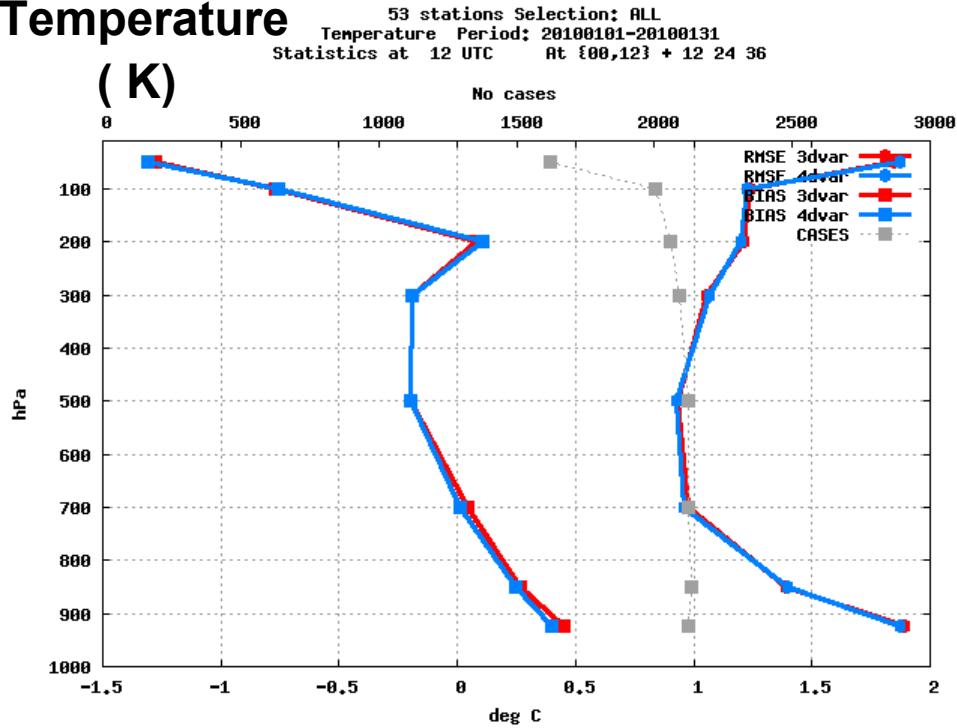
Selection: ALL using 992 stations  
Period: 20100101-20100131  
Surface pressure Hours: {00,06,12,18}

Selection: ALL 992 stations  
Surface pressure  
At {00,12} + 24 Window: 12h



# Temperature

( K )



# Scores for verification against observations

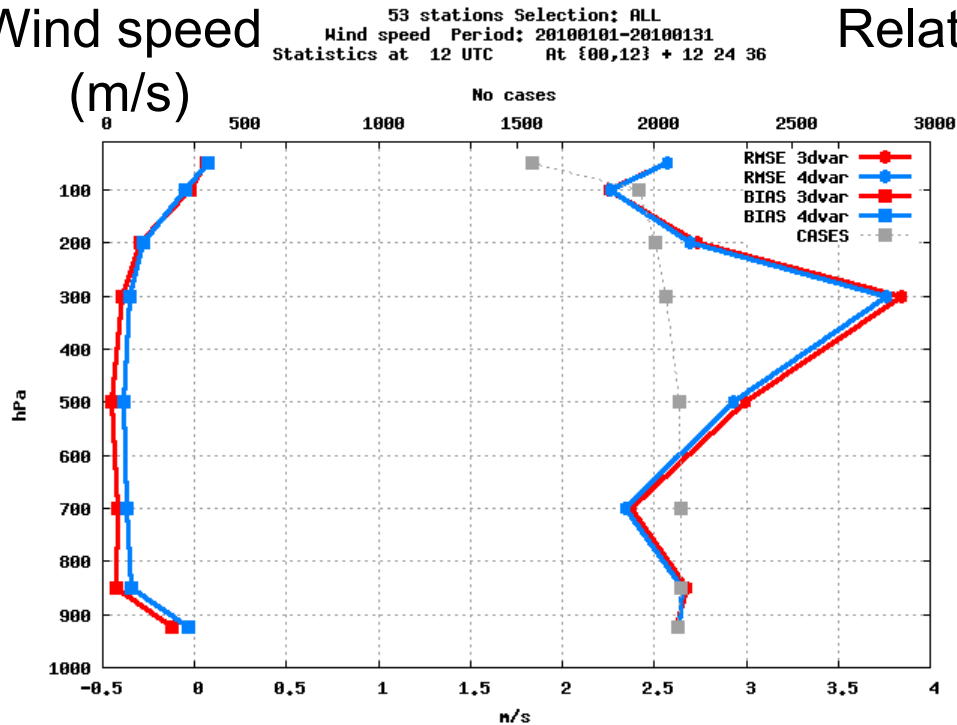
BIAS/RMS averaged over +12, +24, +36 h forecasts as function of vertical level

4D-Var

3D-Var

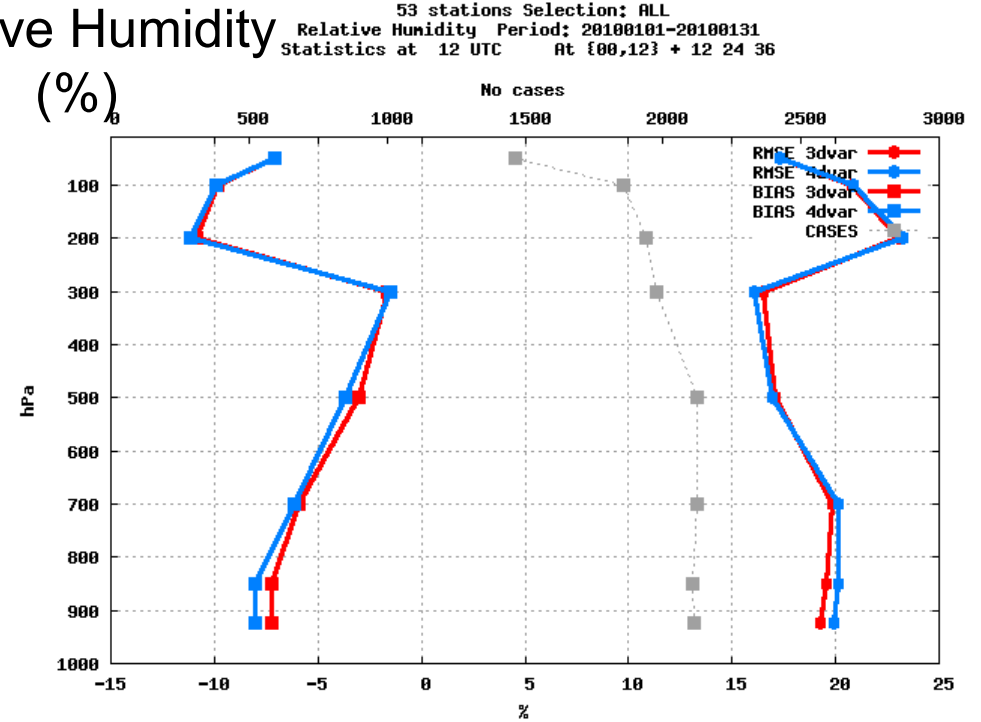
# Wind speed

(m/s)



# Relative Humidity

(%)



# Summary and Future Plans

- The functionality of fundamental HARMONIE 4D-Var components has been demonstrated.
- A one-month parallel experiment indicates a quality of 4D-Var comparable with 3D-Var, at present.
- Further extended assimilation experiments with ALARO/ALADIN at 5-11 kms horizontal resolution and including also satellite data are planned.
- Continued adjustments and evaluations of some recent 4D-Var enhancements are needed.
- ECMWF simplified physics will be introduced in HARMONIE 4D-Var.
- Adopt HARMONIE 4D-Var to AROME and to horizontal model res. ~1-3 kms (length of assimilation time window, simplified physics, multiple outer loop iterations, radar obs., ..., ..).