Norwegian Meteorological Institute

Upper-air data assimilation in HIRLAM Progress report

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29th ALADIN Workshop & HIRLAM All Staff Meeting 1-4/04/2019, Madrid, Spain

outline

- Operational upper air data assimilation (UA-DA) systems in HIRLAM

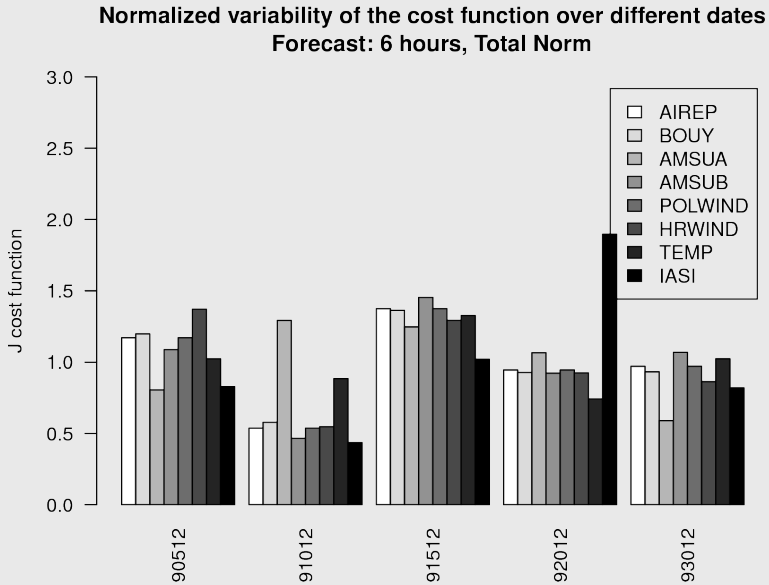
- Some development works related to UA-DA

- Local implementation

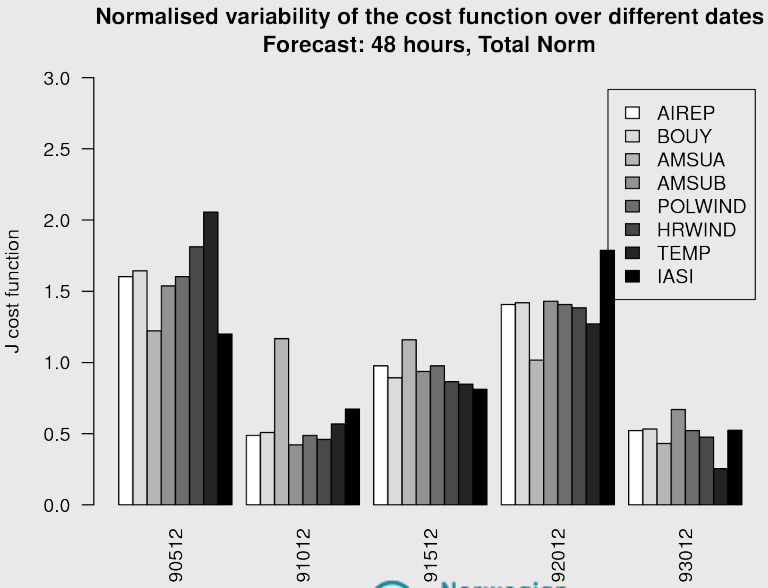
- Data assimilation meetings (training, working week and video)

Operational upper air data assimilation (UA-DA) systems

- **Assimilation scheme:** 3D-VAR;
- **Cycling Strategy:** 3 hourly;
- **Conventional observations:** SYNOP, SHIP, BUOY, AMDAR, AIREP, ACARS, ModeS EHS, Pilots, TEMP;
- **Satellite radiances:** AMSU-A, AMSU-B/MHS, ATMS, IASI;
- **Satellite retrievals:** Scatterometer, GNSS ZTD, GPS RO, (geo **and polar**)AMV;
- **Radar observations:** Reflectivity;
- **Bias correction scheme:** Variational (VarBC).



Experiment run with AROME-MetCoOp Sensitivity of the forecast model to different observations



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Highlight of the progress – towards improved tools and schemes

Bator for all observations (CY43): Bator is used to read all observations
(Eoin Whelan)

- Bator now default for processing of conventional (BUFR) observations
- Local and ECMWF BUFR catered for with a collection of *param* files
- Subroutines for “old” WMO templates maintained using *#ifdef OLDBUFR* (SYNOP/BUOY/AMDAR/TEMP)
- Code adapted to make full use of ECMWF *codetype* – “enhanced accounting”

- Data checks for RH calculations (Thanks Ulf Andrae)
- BATOR_DECODHDF5_BALT (from CY40) (Thanks Martin Ridal)
- Write surface pressure to ODB
  - SYNOP/SHIP/BUOY
  - Ps *vs* PMSL *vs* default pressure strategies maintained using namelist (SynopPsMethod)
  - Ps *vs* Z taken care of by LISTE_LOC

Cloud initialisation using SAF/NWC products

– Cloud initialisation: under test (**Erik Gregow**)

MetCoOp-Nowcasting (MNWC)

MNWC is running as pre-operational within MetCoOp

Run at every hour, at FMI Teho HPC

15-minutes cut-off time for observations

First-Guess fields from MEPS (both surface and upper-air)

Grib1 and Grib2 output hourly, surface output every 15-minute

Satellite (MSG) cloud-ingest is used to “adjust” the 3D-humidity

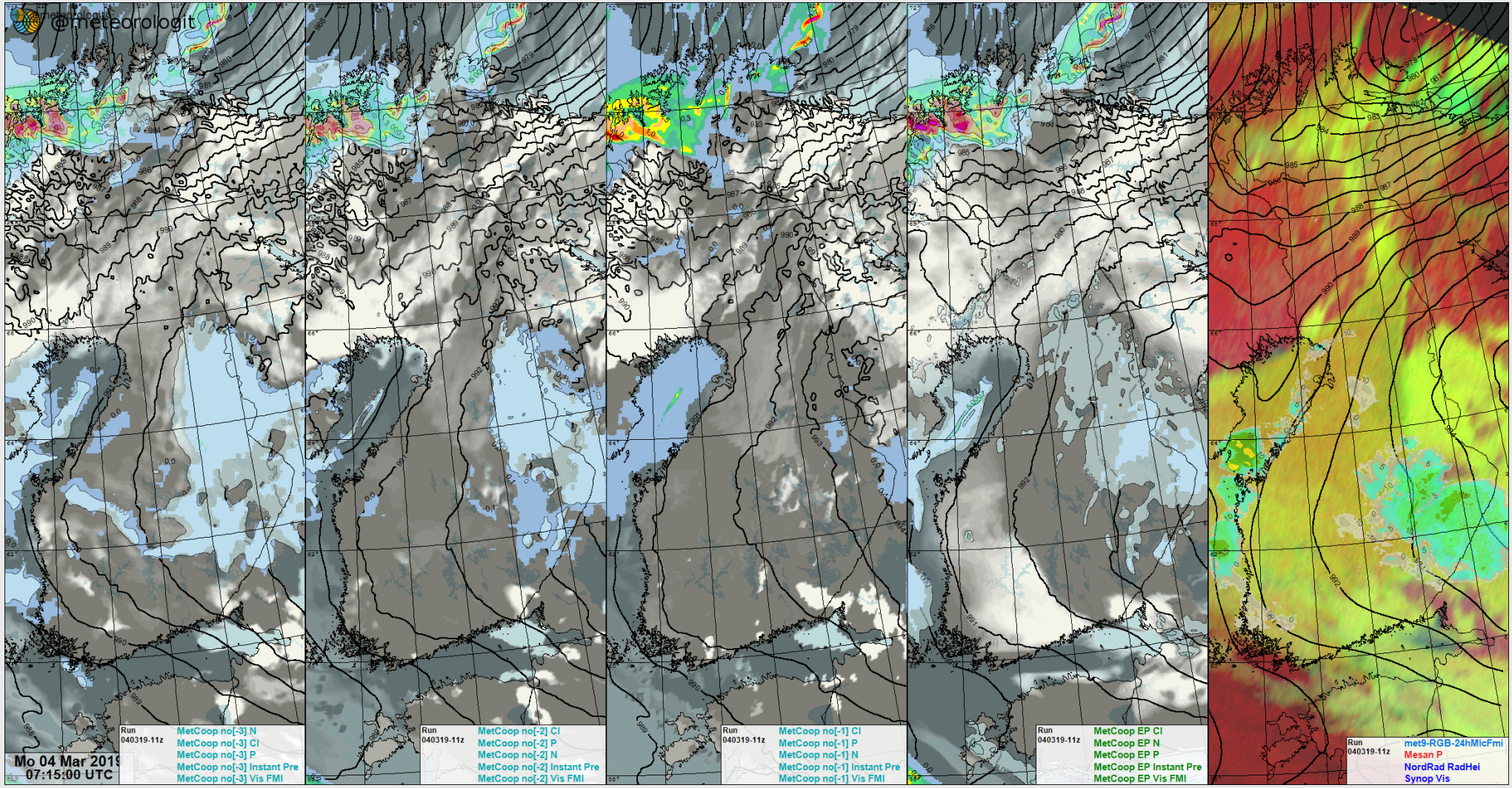
- Start to use in MNWC: 28 March 2019
- Not a traditional 3D-VAR
- First results are being evaluated
- Several developments in pipe-line

Cloud initialisation using SAF/NWC products

– Cloud initialisation: under test by **E. Gregow**

MNWC_preop: MSG-cloud ingest, case 04 March 2019, 07:15Z

MNWC -2h | MNWC -1h | MNWC -0h | MEPS - recent | Satellite



MNWC and MEPS: Grey color – clouds, blue-red color – precipitation

Satellite: Yellow – low clouds, green-yellow precipitation

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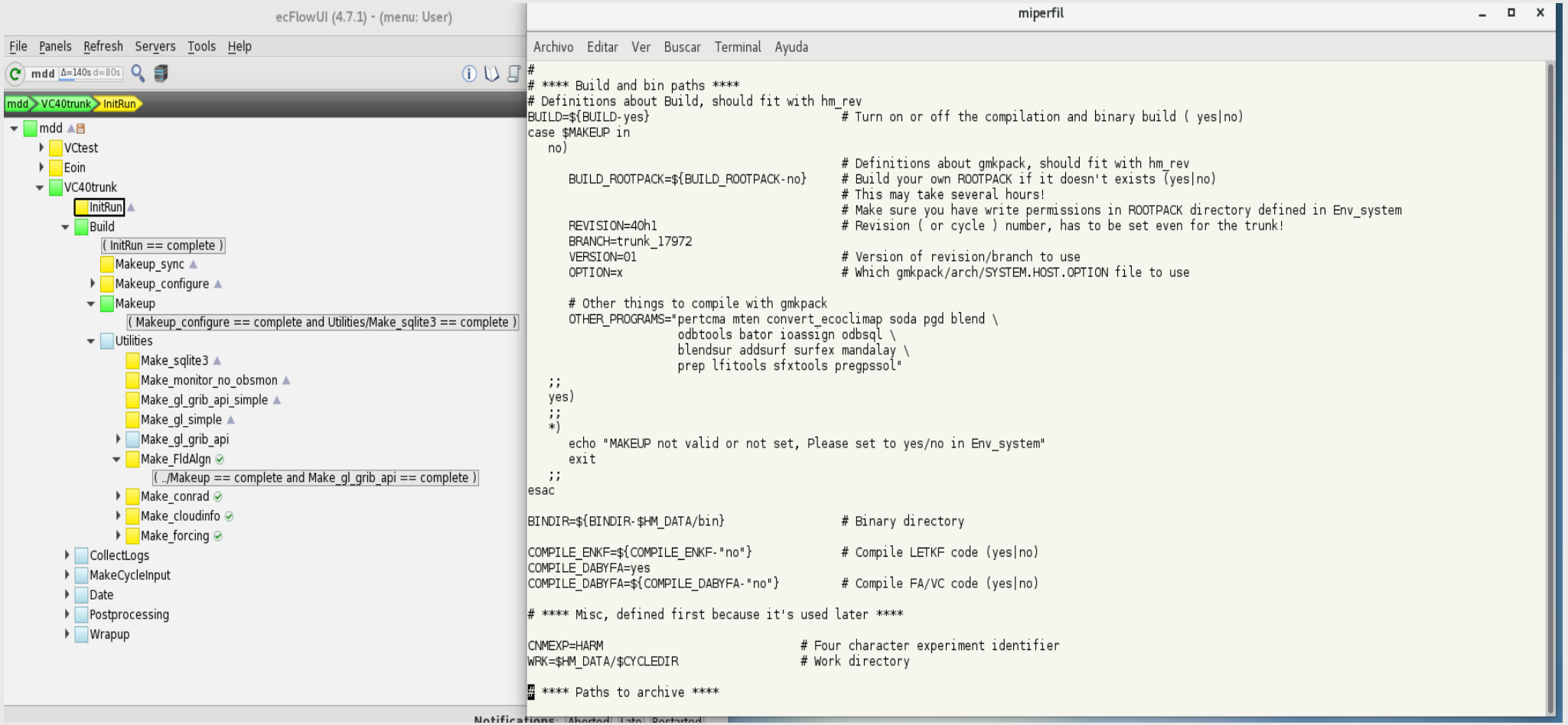
Highlight of the progress – initialisation

– Filed alignment (FA) and Variational constraint (VC) scheme are now in trunk: (**Carlos Geijo**)



Application of the FA with VC needs good description of the background errors.
=> Modelling of fow-dependent Covariances with Gaussian Integral approach is ongoing

Highlight of the progress – initialisation

– Incremental Analysis Update (IAU) implementation: (Jelena Bojarova)

Incremental Analysis Update

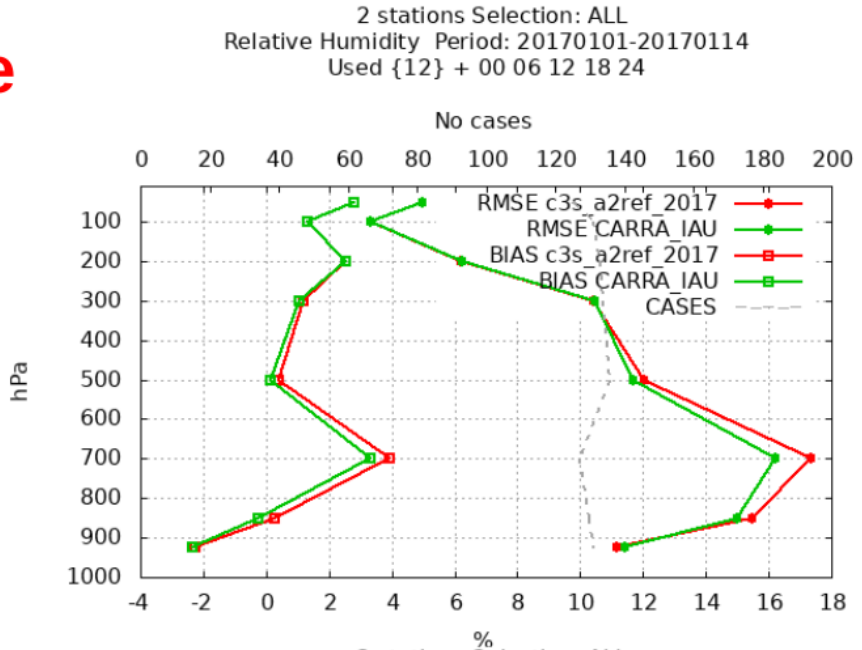
$$X^{t+1} = X^t + \Delta t * M\,(X^{t+\Delta t/2}) + \\ + \Delta t * L\,((X^{t+1} - X^t)/2 - X^{t+\Delta t/2,}) \\ + (X^a - X^b)/N_{steps}$$

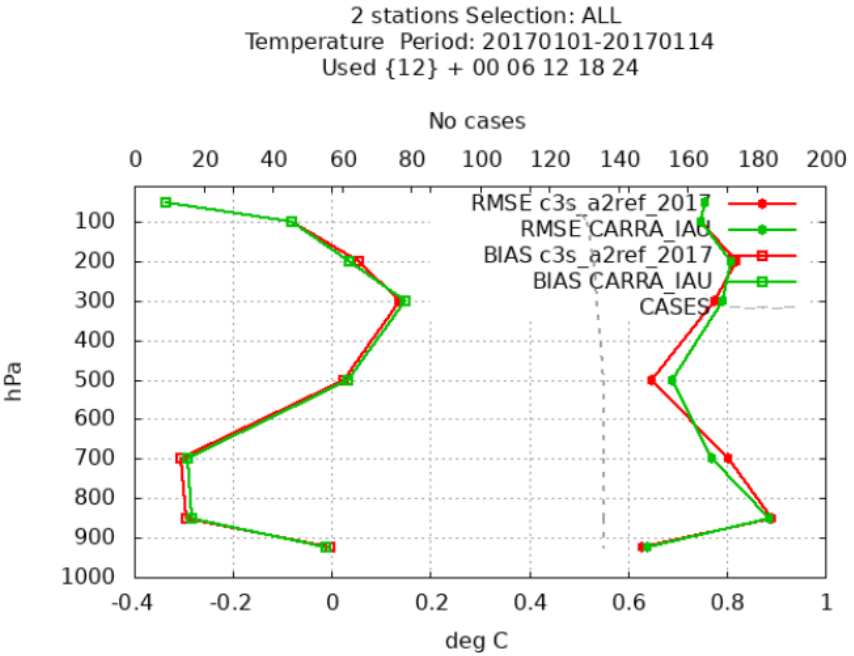
Variables : ($\ln p_s$, u,v,T_v,q);

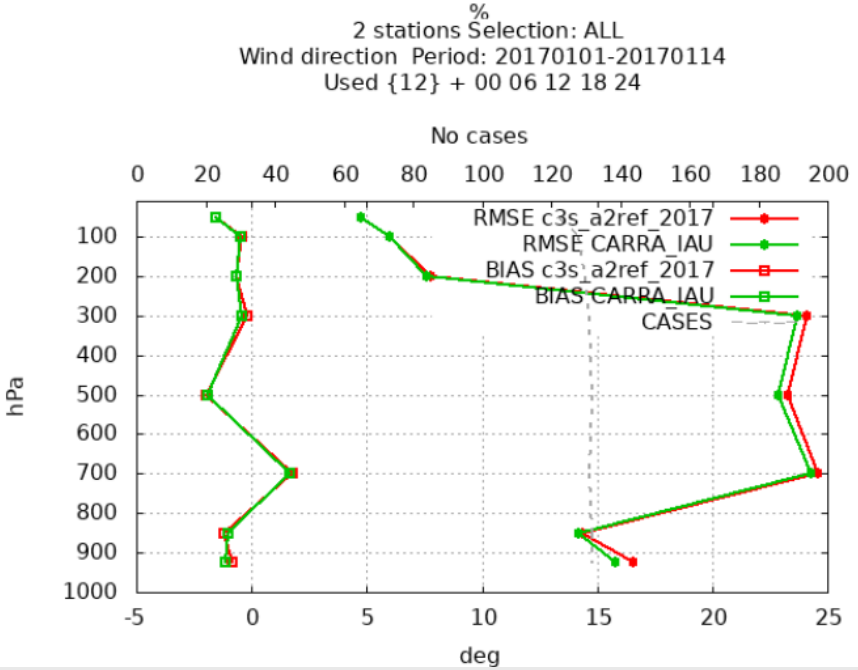
conv. obs.

Non-centered 3h IAU

3h 3DVAR

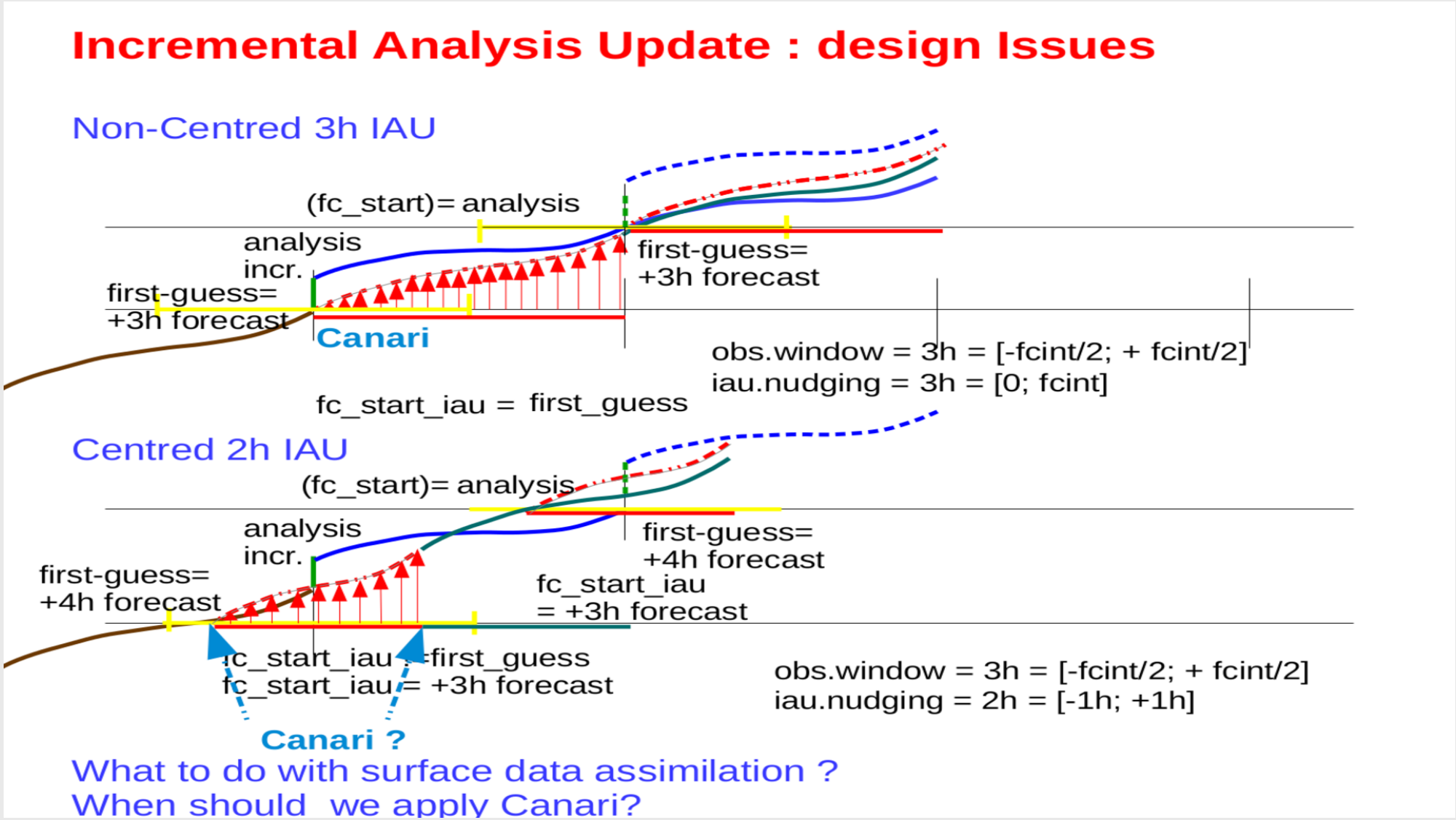






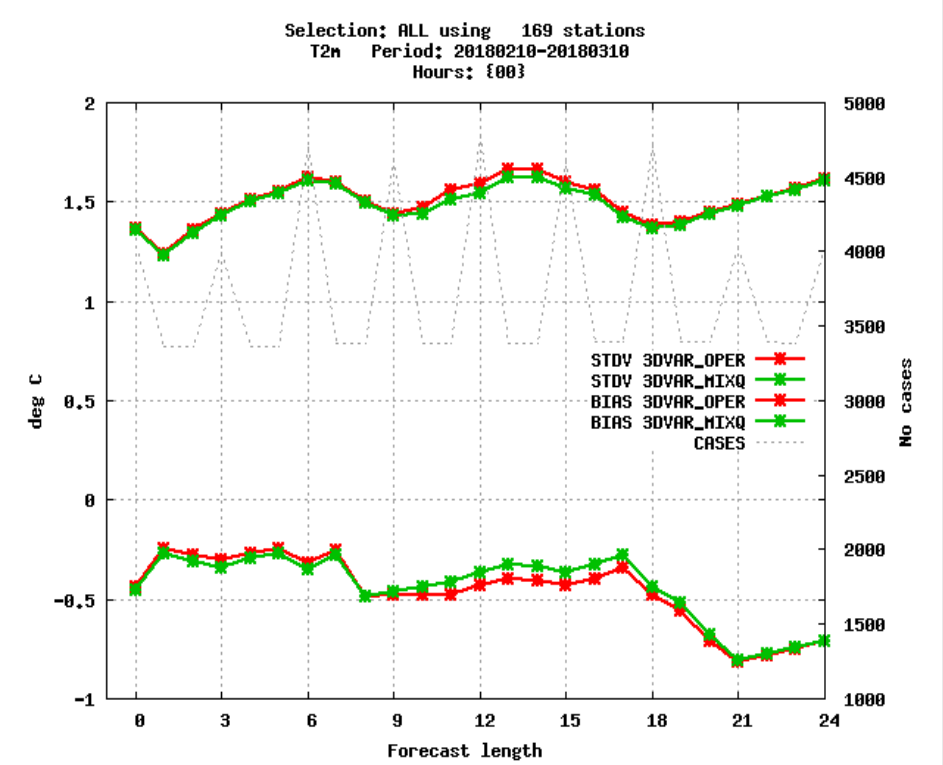
Highlight of the progress – initialisation

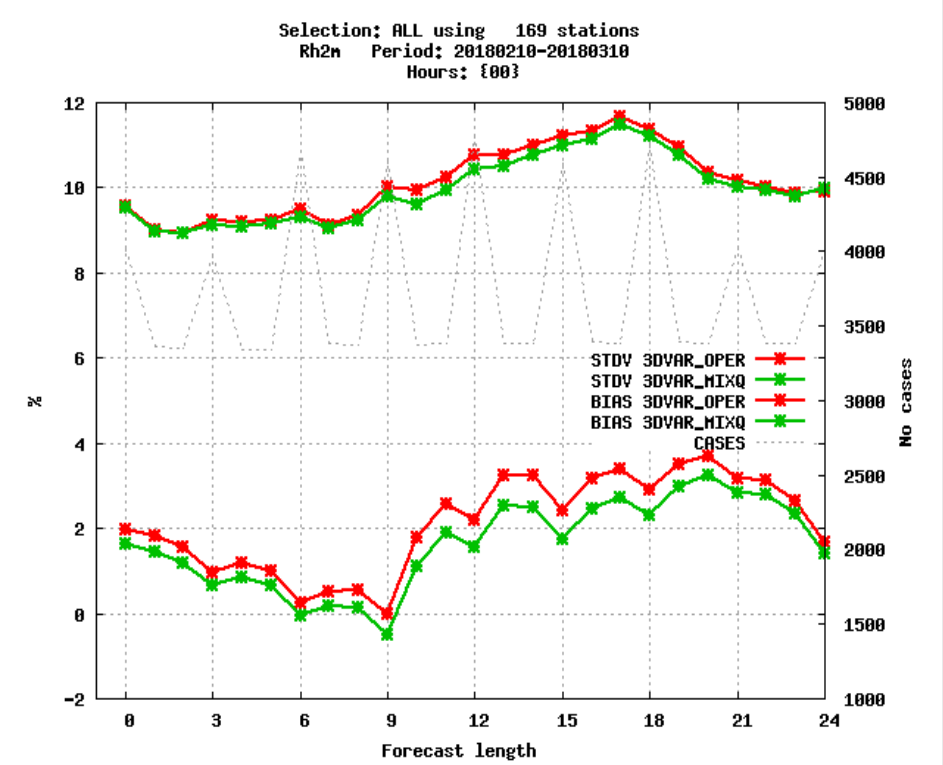
– Incremental Analysis Update (IAU) implementation:
(Jelena Bojarova)

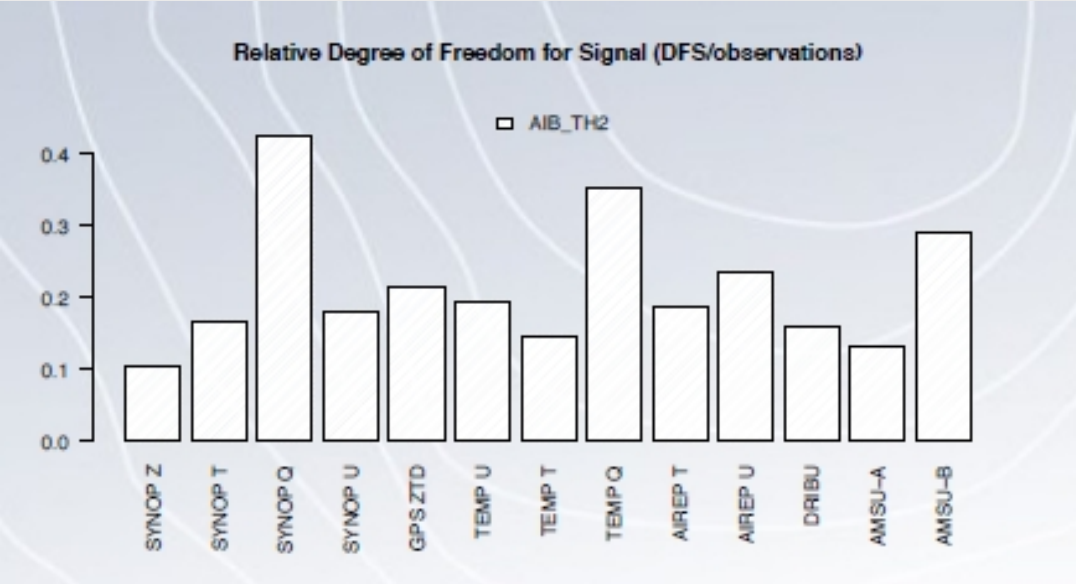


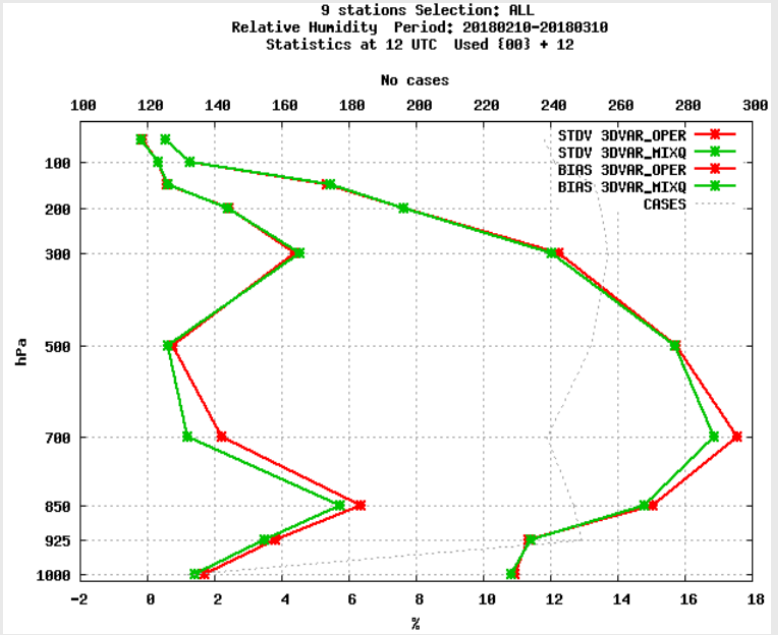
Highlight of the progress – initialisation

– Large scale mixing with Q (Pau Ecriba & Maria Diez)









Highlight of the progress – towards improved tools and schemes
== 4DVar ==

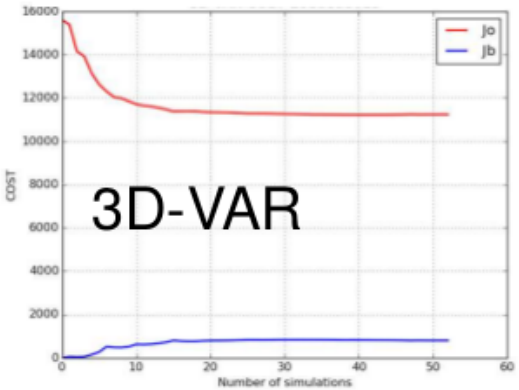
Progress with 4DVar scheme: (Magnus Lindskog)

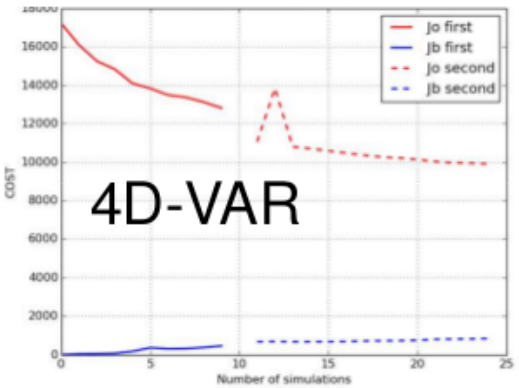
==> Testing the 4DVar scheme with the MetCoOp model and observations.

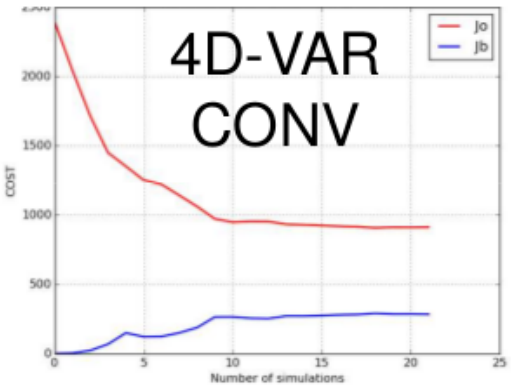
Demonstration of functionality

SMHI

20180907 18 UTC **COST FUNCTION** AND COMPARISON OF **NUMBER OF OBSERVATIONS** IN MINIMIZATION FOR SOME OBSERVATION TYPES







OBSTYPE	NUMOB 3D-VAR	NUMOB 4D-VAR
SYNOP Z	501	1091
AIREP T	817	507
ASCAT	222	222
RADAR	2195	12426
AMSUA	1100	1857
IASI	23900	50050
GNSS	8	201

Highlight of the progress – towards improved tools and schemes
== 4DVar ==

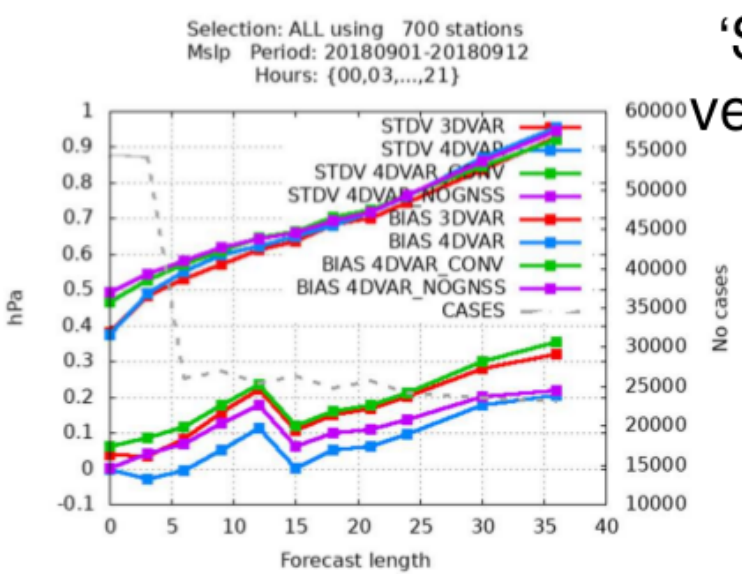
Progress with 4DVar scheme: (Magnus Lindskog)

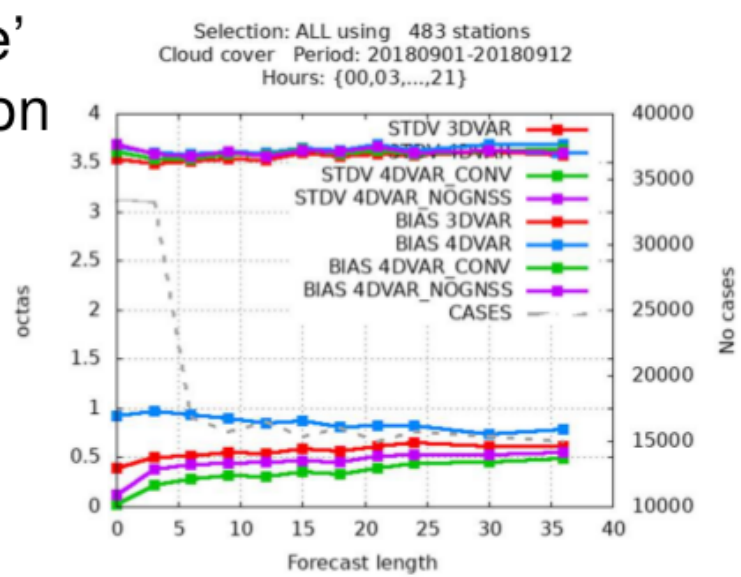
==> Testing the 4DVar scheme with the MetCoOp model and observations.

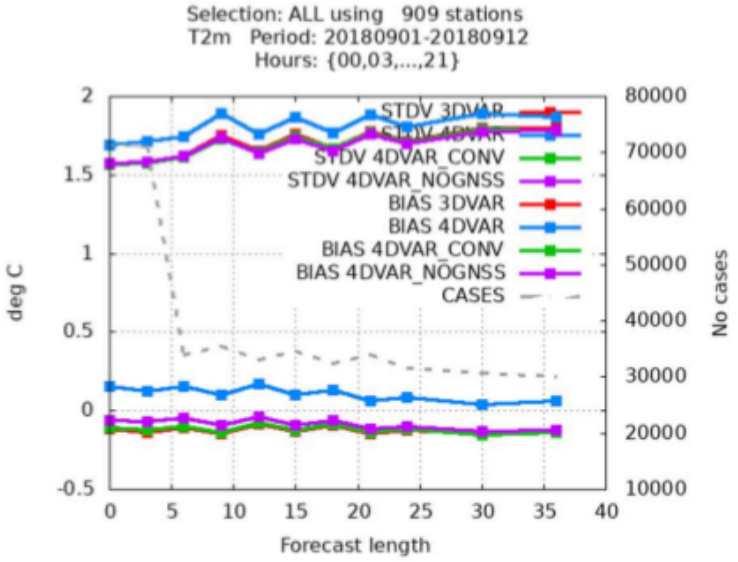
Results

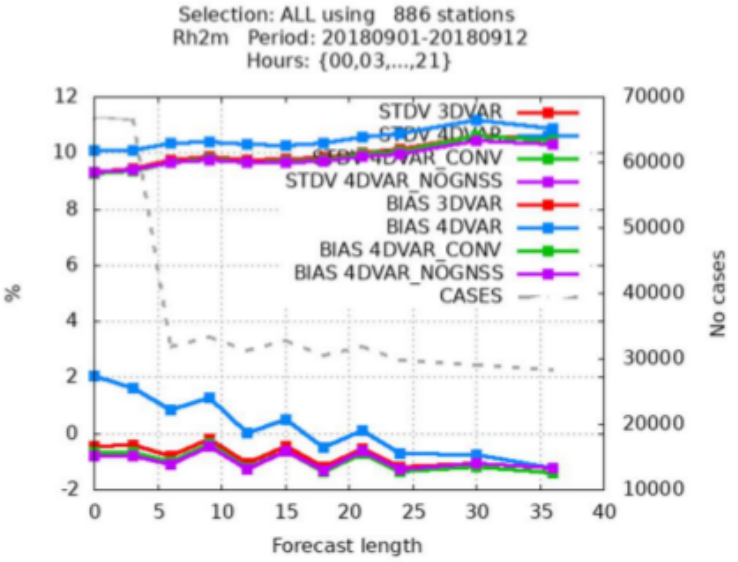
SMHI

‘Surface’ verification







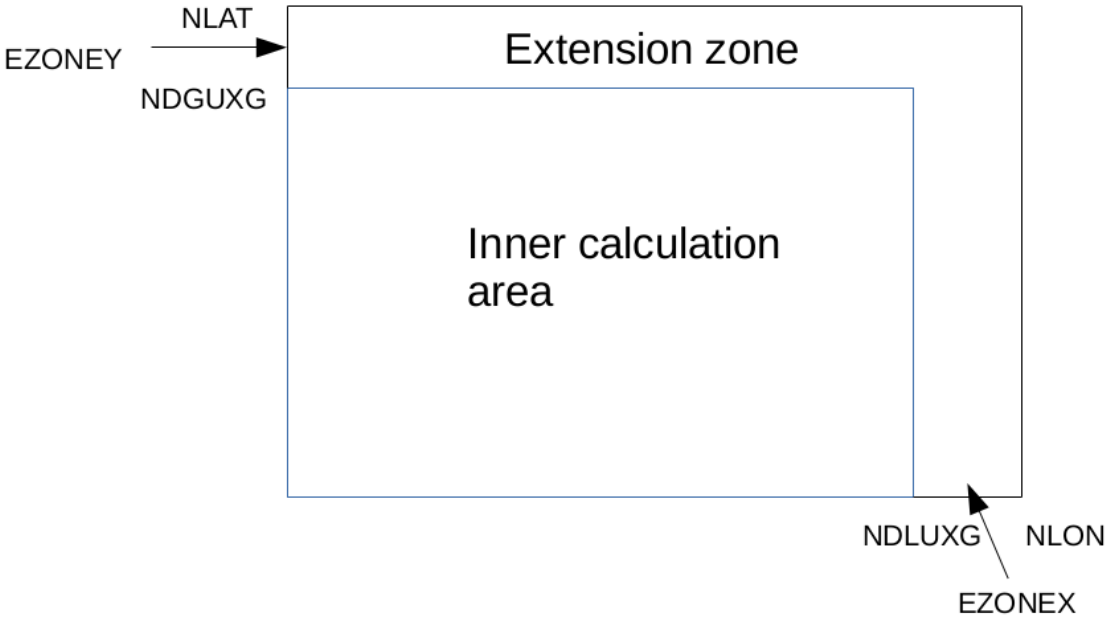


Highlight of the progress – towards improved tools and schemes
== 4DVar ==

Progress with 4DVar scheme: (Nils Gustafsson)

==> Testing the 4DVar scheme with different extension zones.

4D-Var and Extension zone (EZONE) in HARMONIE - issues



Area decomposition for MPI parallelization is over the NLON/NLAT domain => With a large EZONE, many processors will not carry out much meaningful job!

Two purposes of EZONE: (1) Bi-periodicity in the spectral model; (2) Representation of horizontal correlations for the data assimilation

For (1) a small EZONE (11 g.p.) is OK, but for (2) an EZONE with a width of 200-300 km is required.

So far, the same EZONE has mostly been used for (1) and (2).

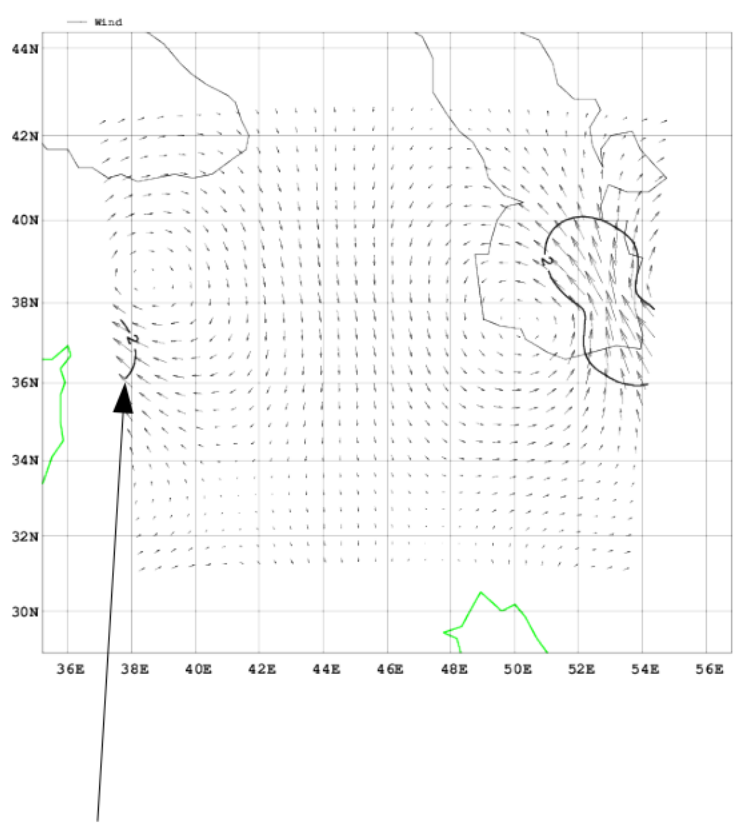
New strategy: Use different EZONE for the model and in the minimization for data assimilation.

Highlight of the progress – towards improved tools and schemes
== 4DVar ==

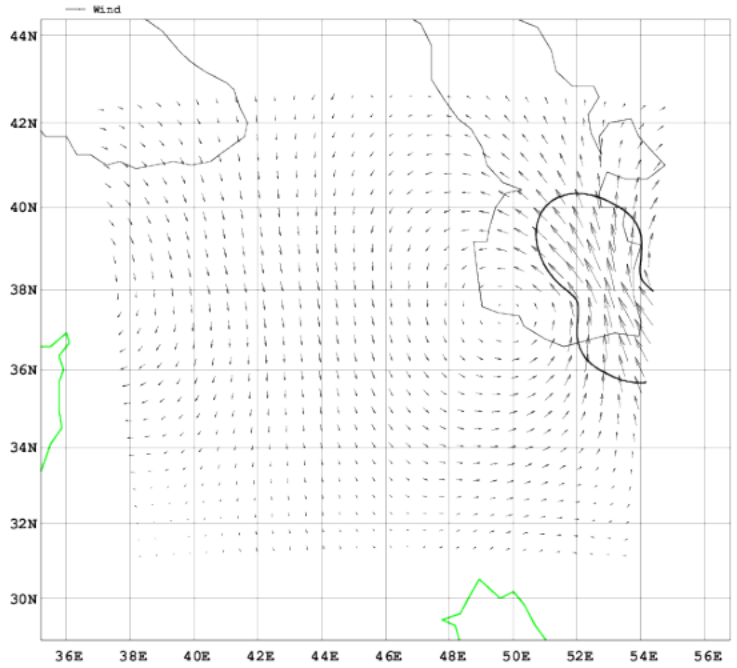
Progress with 4DVar scheme: (Nils Gustafsson)

==> Testing the 4DVar scheme with different extension zones.

Example of single simulated observation experimemt over Iran



Periodicity due to too small extension zone (28 km, applied operationally)!



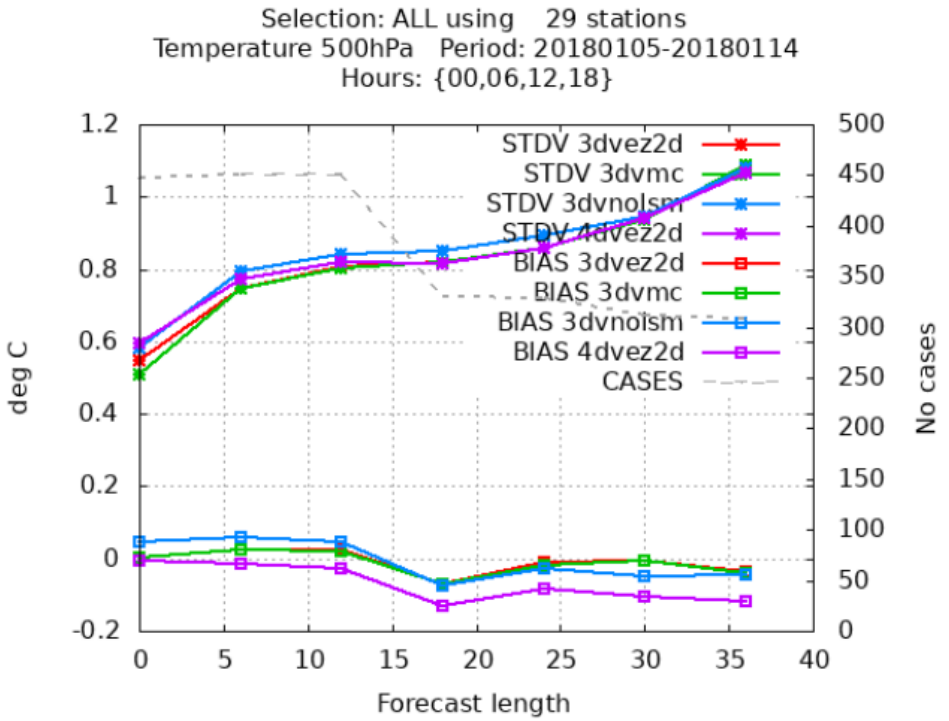
With increased width of the extension zone (300 km)

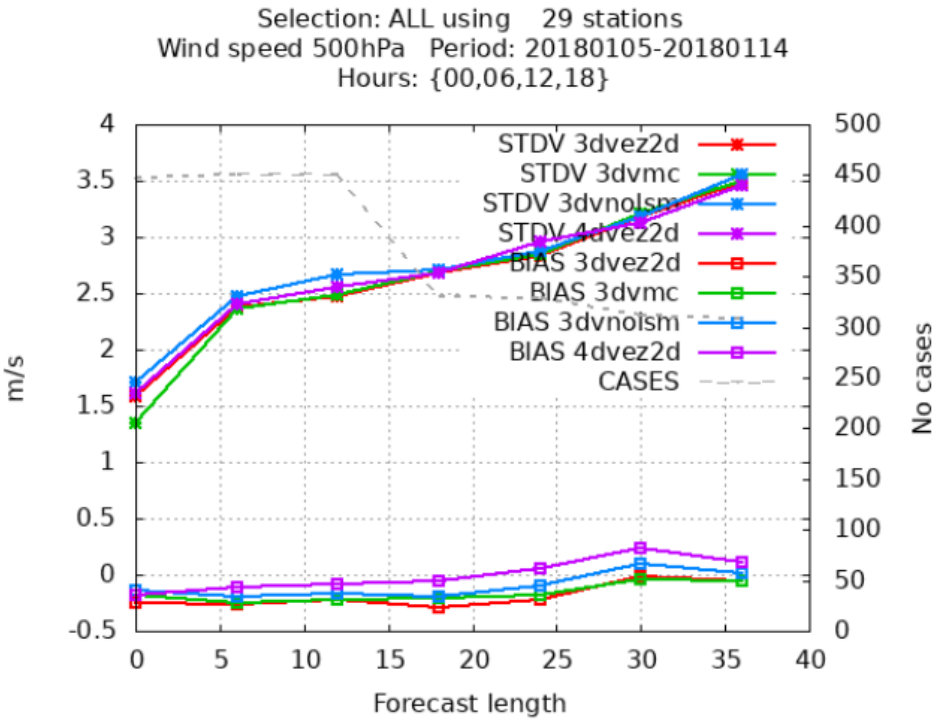
Highlight of the progress – towards improved tools and schemes
== 4DVar ==

Progress with 4DVar scheme: (Nils Gustafsson)

==> Testing the 4DVar scheme with different extension zones.

500 hPa temperature and wind speed



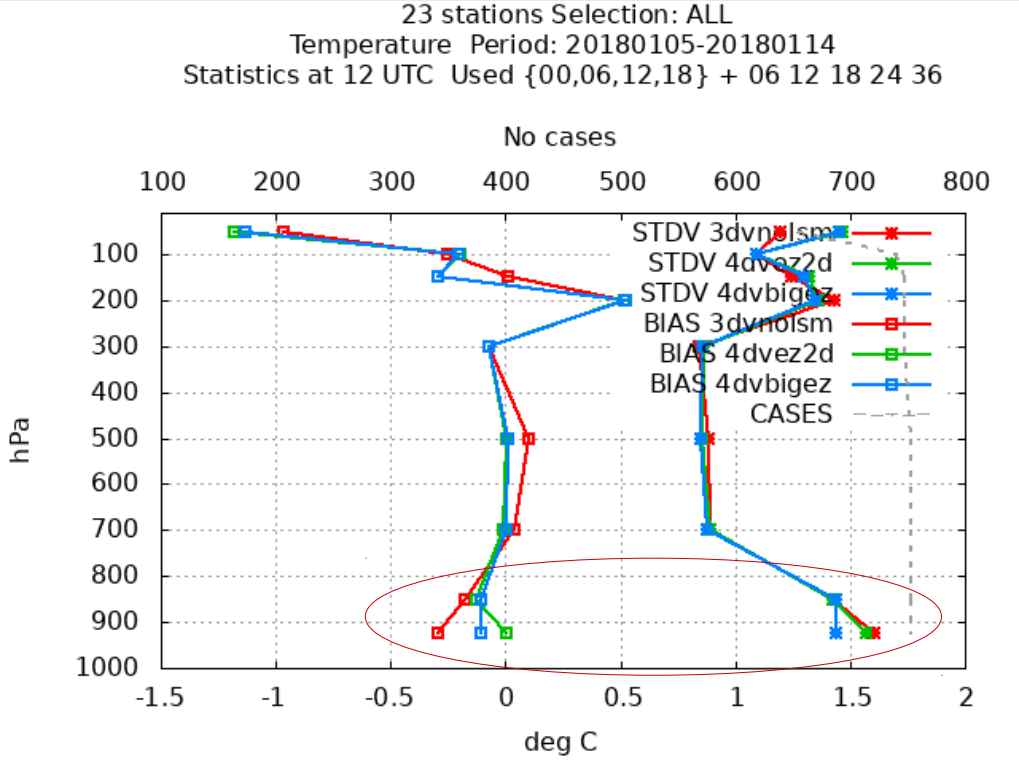


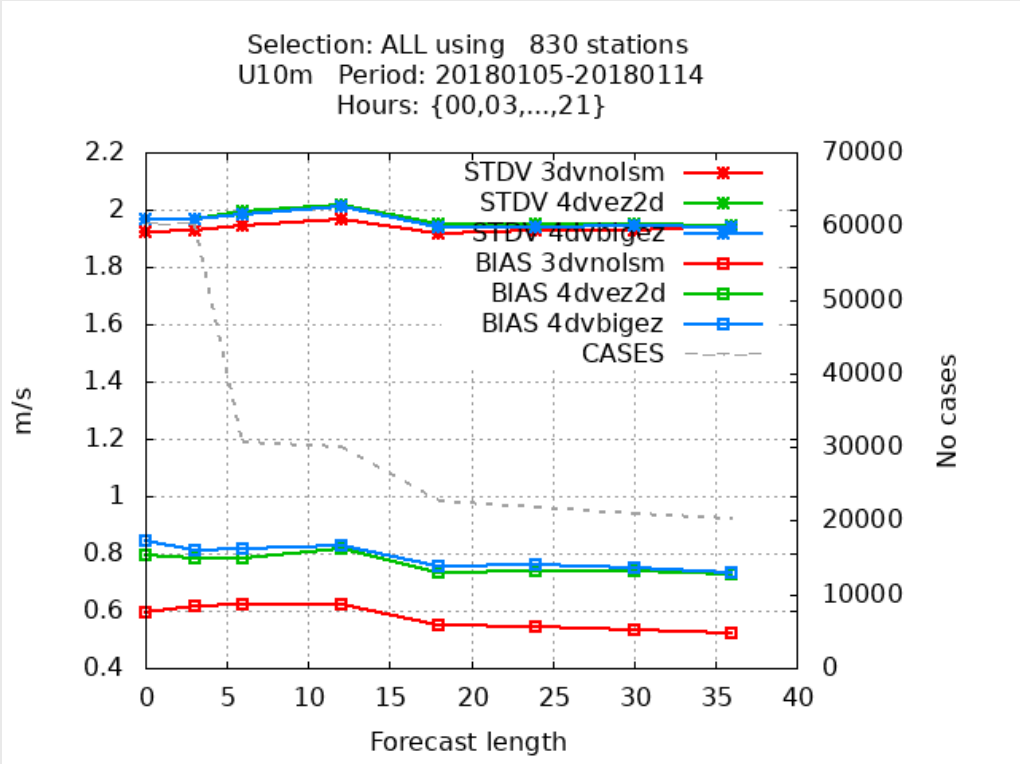
- Effects of large extension zone mainly at analysis time
- Encouraging results of 4D-Var without LSM compared to 3D-Var without LSM

Highlight of the progress – towards improved tools and schemes
== 4DVar ==

Progress with 4DVar scheme: (Nils Gustafsson)

==> Testing the 4DVar scheme with different extension zones.



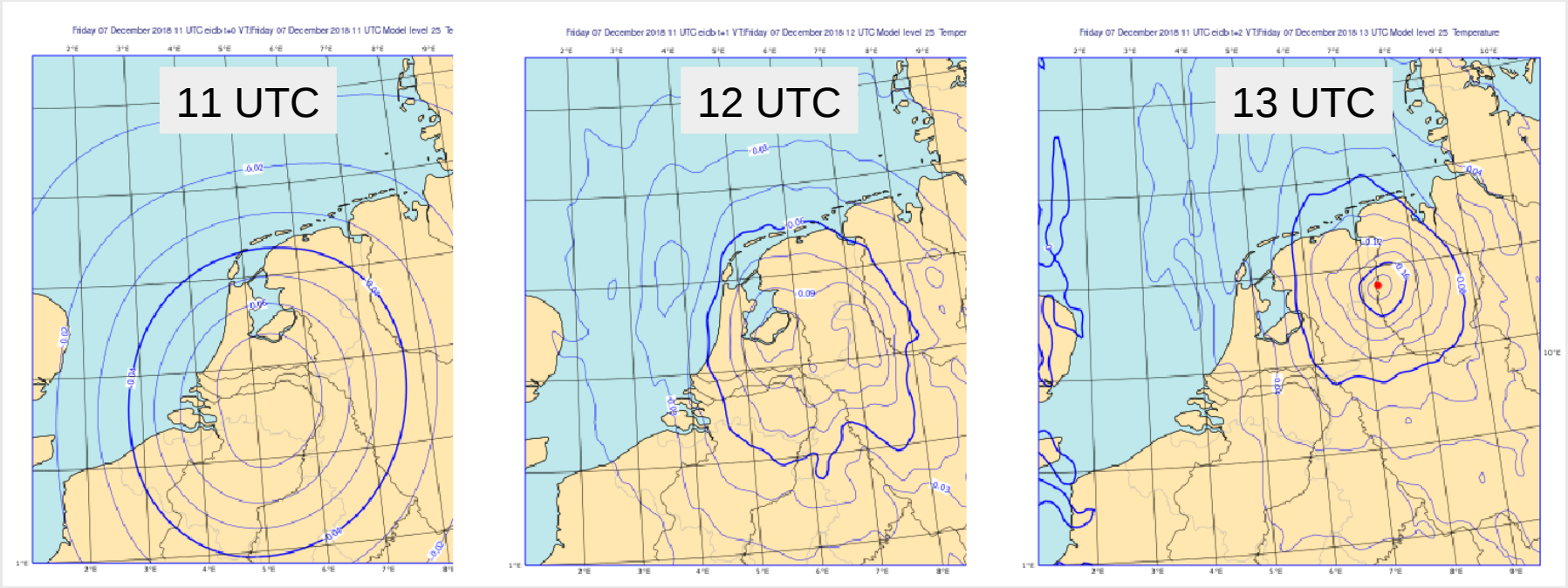


3dvnolsm – 3DVar without large scale mixing
4dvez2d – 4DVar with small extension zone
4dvbigez – 4DVar with large extension zone

Highlight of the progress – towards improved tools and schemes
== 4DVar ==

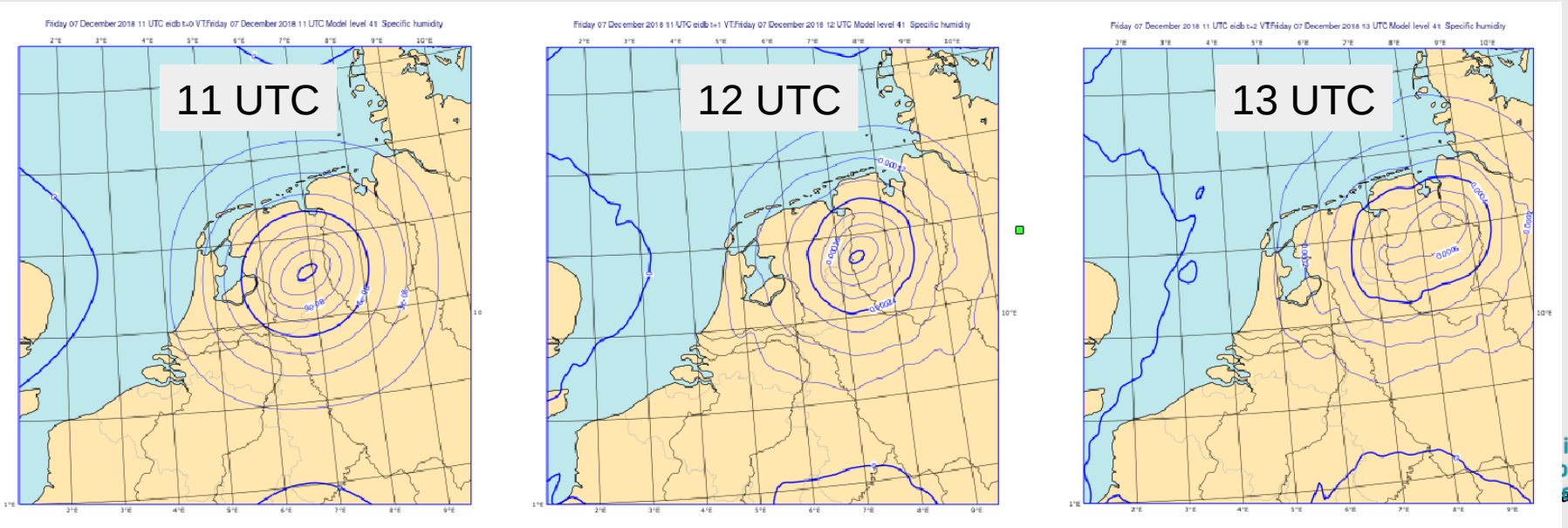
Progress with 4DVar scheme: (Jan Barkmeijer & Siebren de Haan)

==> Single observation with 4DVar scheme.



Obs at
13 UTC

At 500 hPa



Obs at
12 UTC

At 850 hPa

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logical
l Institute

Highlight of the progress – towards improved tools and schemes
== LETKF ==
(Pau Eescriba & Jelena Bojarova)

==> See Pau’s presentation !

Highlight of the progress – towards improved tools and schemes
== EnVar ==
(Jelena Bojarova)

HARMONIE Hybrid Ensemble Variational framework :

Implementation as in

A hybrid variational ensemble data assimilation for the HIgh Resolution Limited Area Model (HIRLAM)

N. Gustafsson[1], J. Bojarova[2], and O. Vignes[2]

$$J(\delta \boldsymbol{x}_{\mathrm{var}}, \boldsymbol{\alpha}) = \beta_{\mathrm{var}} J_{\mathrm{var}}(\delta \boldsymbol{x}_{\mathrm{var}}) + \beta_{\mathrm{ens}} J_{\mathrm{ens}}(\boldsymbol{\alpha}) + J_{\mathrm{o}} \qquad (6)$$

$$\frac{1}{\beta_{\mathrm{var}}} + \frac{1}{\beta_{\mathrm{ens}}} = 1.$$

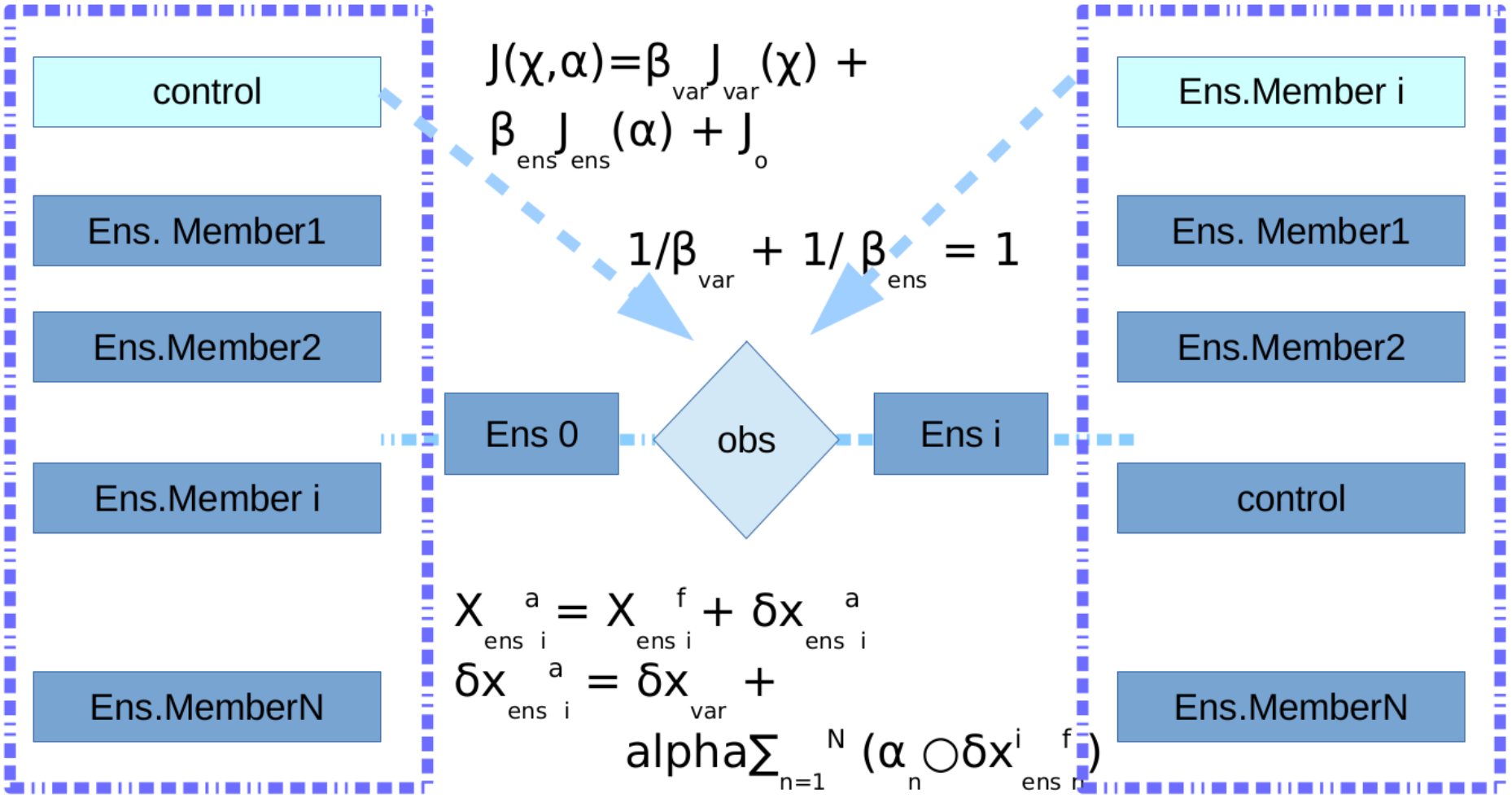
$$J_{\mathrm{ens}} = \frac{1}{2} \boldsymbol{\alpha}^T \mathbf{A}^{-1} \boldsymbol{\alpha}$$

$$\mathbf{B}_{\mathrm{ens}} = \mathbf{A} \circ \mathbf{B}_{\mathrm{raw\text{-}ens}}$$

Ensemble : 10 members of BRAND perturbations
Localisation : spectrum of unbalanced surface pressure

Highlight of the progress – towards improved tools and schemes
== EnVar ==
(Jelena Bojarova)

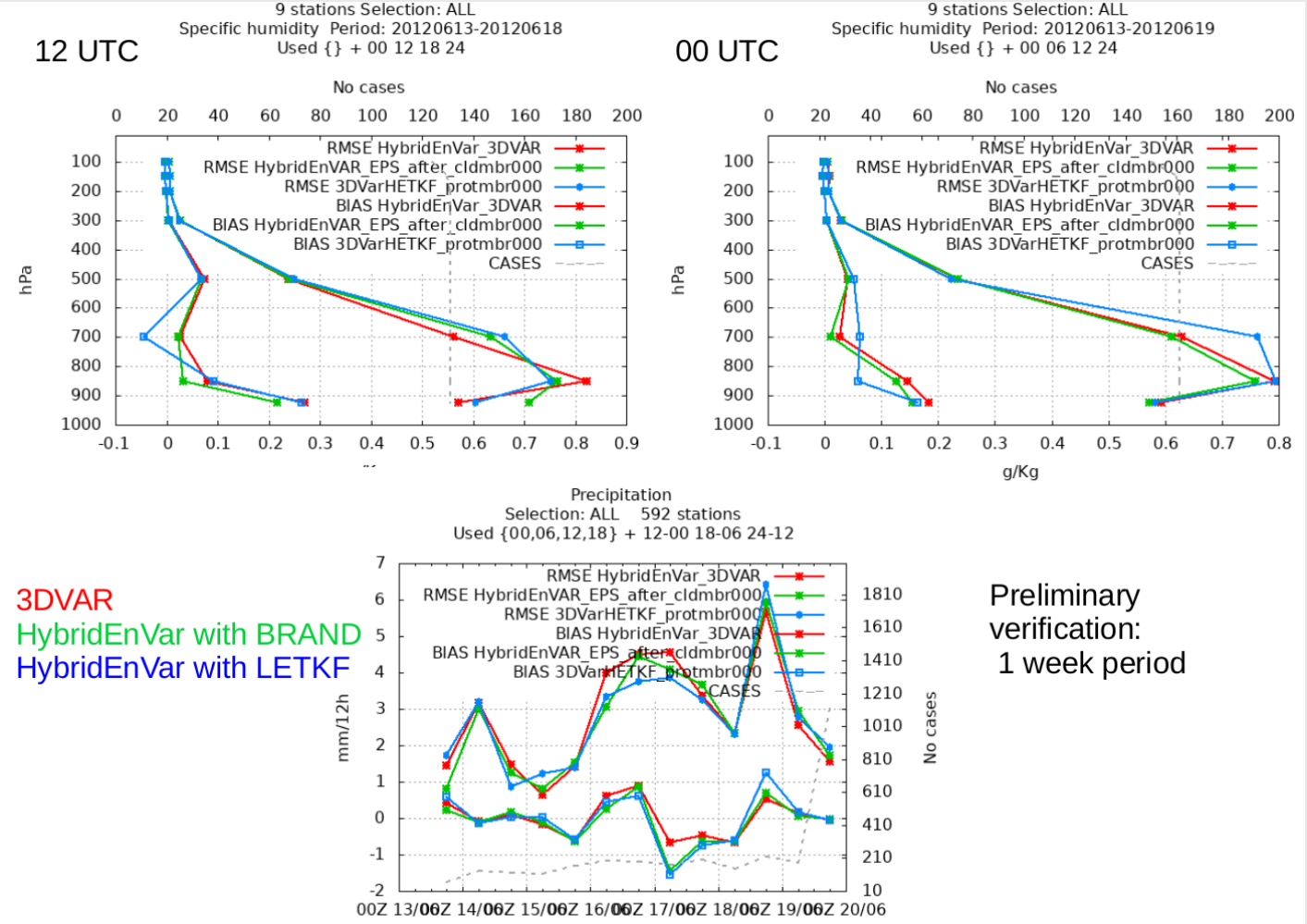
Ensemble of Data Assimilation runs without perturbing observations
N+1 Hybrid EnVAR runs



$X^{0,f}_{ens}$

$X^{i,f}_{ens}$

Highlight of the progress – towards improved tools and schemes
== EnVar ==
(Jelena Bojarova)



Promising results from the tested EnVar approaches was found pointing to large variance where more uncertainty is expected like for example at frontal lines

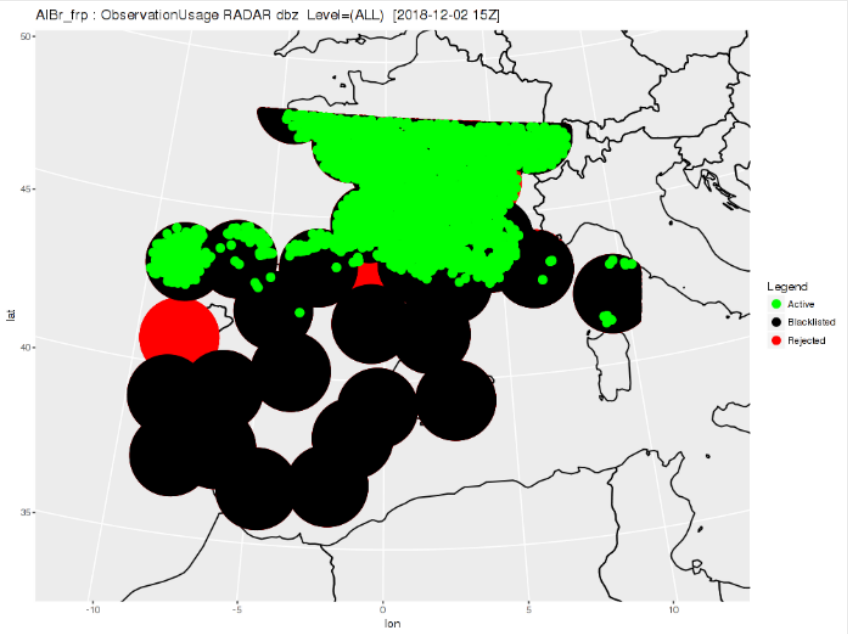
Highlight of the progress –local implementation of operational obs
== Radar Refl ==
(Jana Sánchez, Beatriz Navascués, Javier Calvo, Joan Campins)

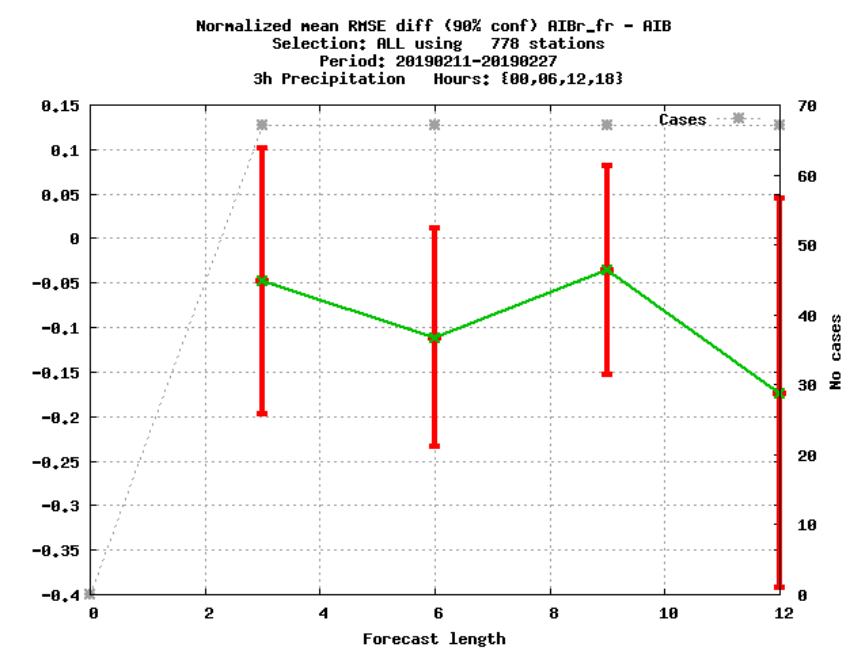
PERIOD of study: 11 feb - 3 march 2019 …
2 parallel experiments Cy40h11 at Nimbus: 3DVar, 3h cycle

1) AIB **(CTRL)**: **operational** (CONTROL) , NO radar
3DVar: conv, **GNSS ZTD,** ATOVS

2a) **AIBr_fr**: obs like CTRL + radar refl **(radars ES, PT,FR)** from BALTRAD
obs conv**, new GNSS ZTD (so=20,mm), new** ATOVS

2b) **AIBr_fr2:** obs like CTRL + radar refl **(radars ES, PT,FR)** from BALTRAD
obs conv**, new GNSS ZTD (so=30mm) , new** ATOVS





Non significant positive impact on short-range forecasts of precipitation

Highlight of the progress –local implementation of operational obs
== Radar Refl ==
(Jana Sánchez, Beatriz Navascués, Javier Calvo, Joan Campins)

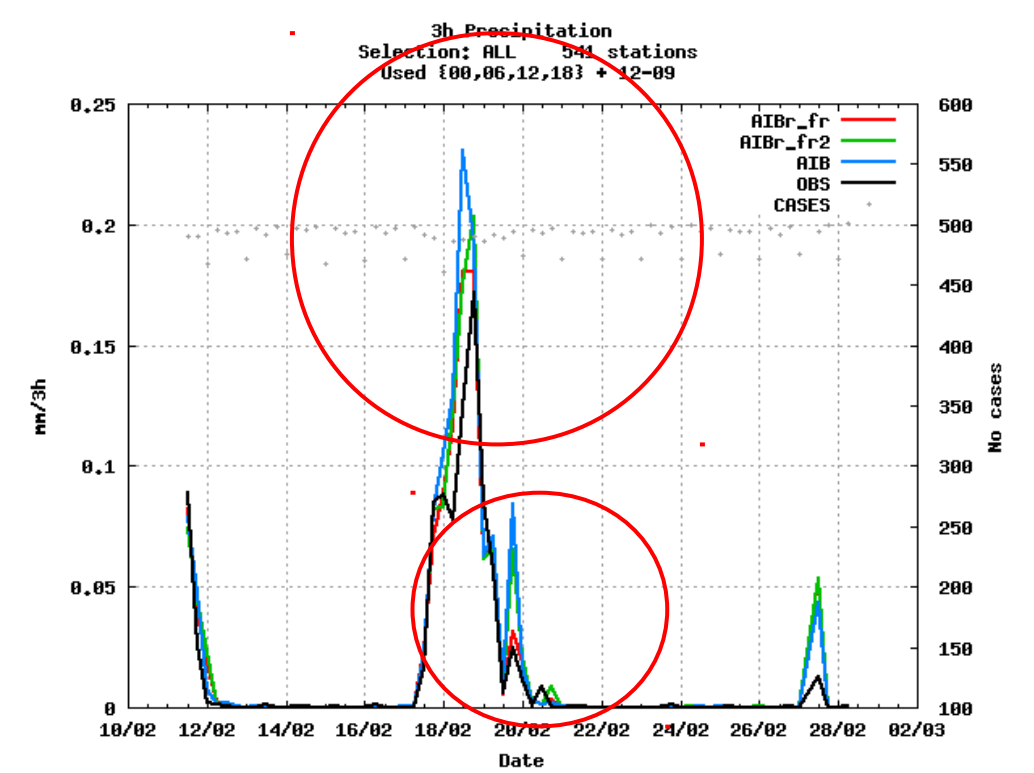
3h acc pcp (H+3):

Assimilating radar reflectivity leads to **decrease the FALSE ALARM RATE of pcp**

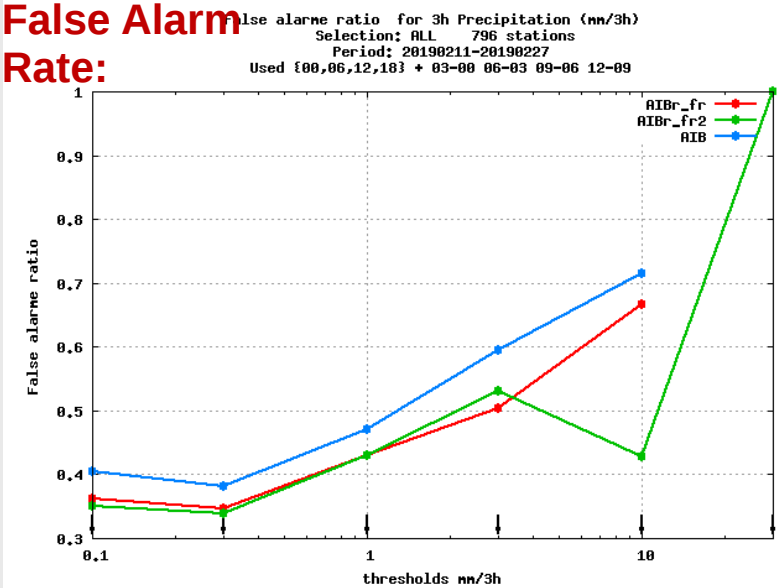
CTRL

REFL

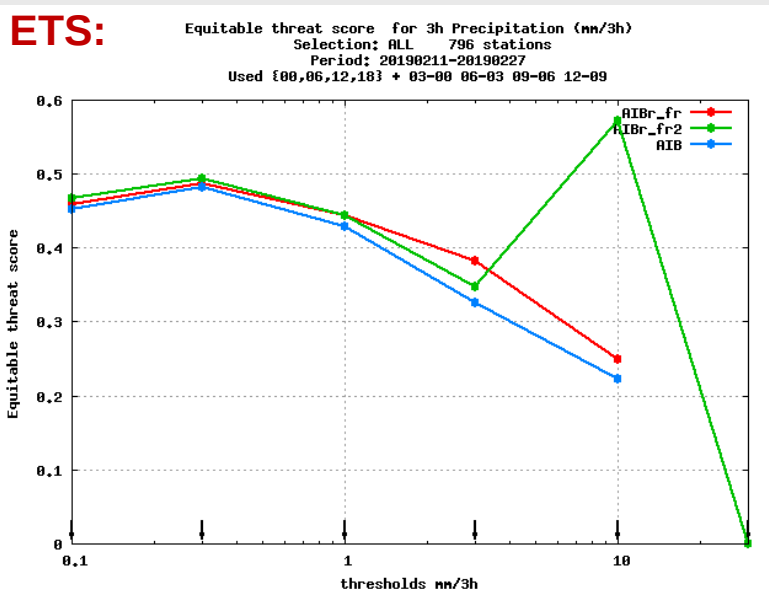
REFL2



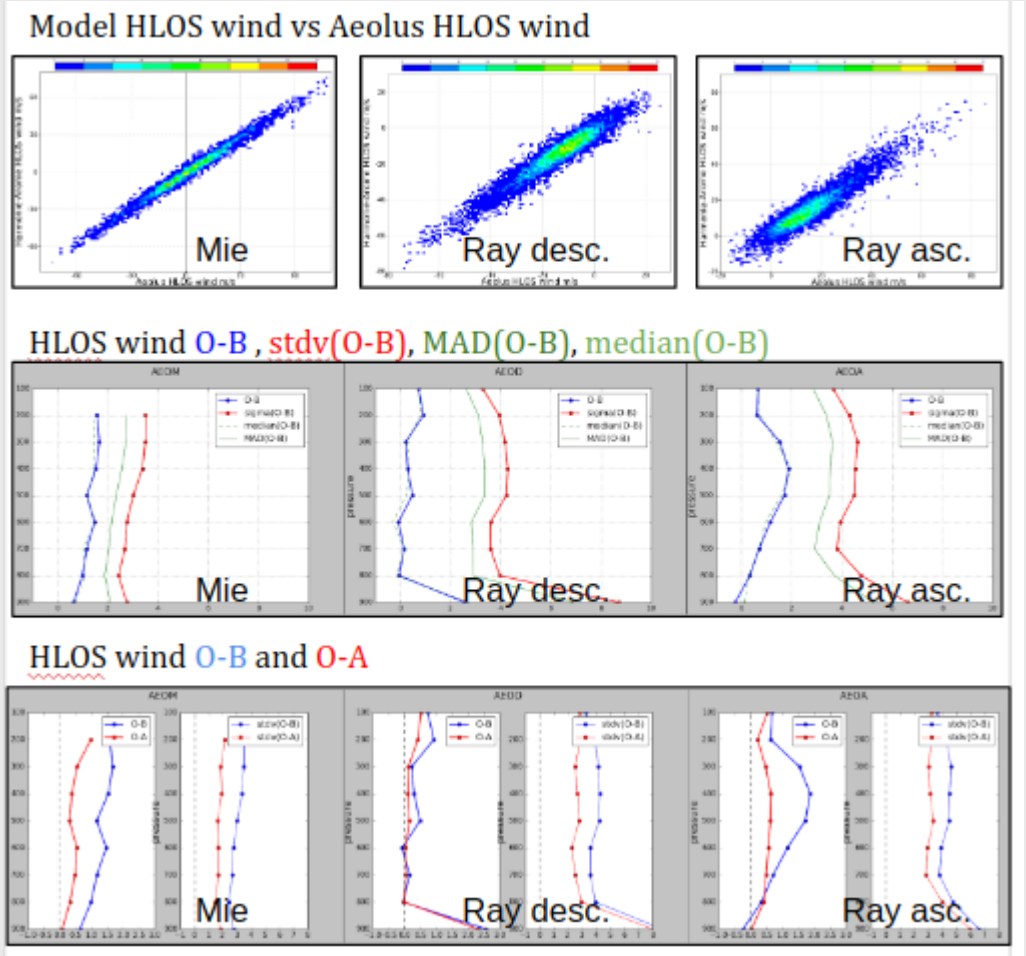
False Alarm Rate:



ETS:



Highlight of the progress – New observation
== Aeolus HLOS in CY43 ==
(Roohollah Azad)



See more about this implementation
Roohollah's poster

Highlight of the progress – New observation operator
== Supermodding ==
(Máté Mile)

Multi satellite implementation for scatterometer (ASCAT, OSCAT, QSCAT)
Gert-Jan will investigate it further

Supermodding implementation with **3D-Var** for scatterometer (ASCAT)

Supermodding implementation with **4D-Var** for scatterometer (ASCAT)

Computation of robust **O-G**; **O-A** statistics
Ongoing

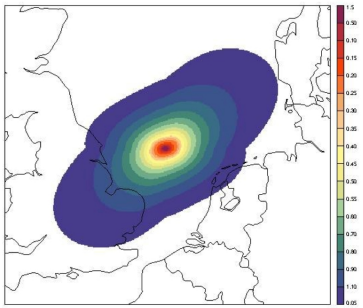
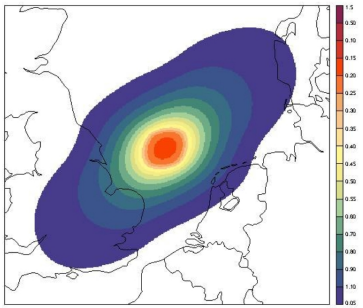
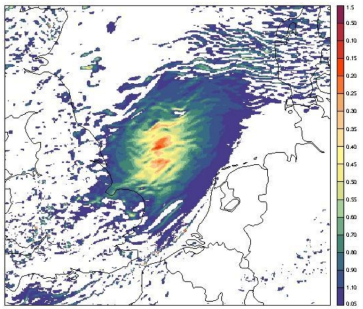
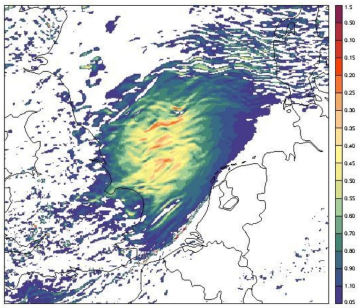
- Determine optimal supermodding size
- Study representativeness error
- Experimental setup (supermodding vs. thinning)

Case studies with Arome-Arctic SOP1 period
Ongoing

Flexible solutions using the supermodding or the old obs operator is implemented.
Multiple satellites can be assimilated with different approaches if needed.

Highlight of the progress – New observation operator
== Supermodding ==
(Máté Mile)

Alertness

	10 km supermodding size	100km supermodding size
Single ASCAT 3D-Var increments (Wind V-component)		
Single ASCAT 4D-Var increments (Wind V-component)		

If happy with Scatterometer implementation, start with other observations

Data assimilation meetings

- **Data assimilation training** (Budapest, 11-15 February 2019)
  - For starters and new comers.

- **Meeting on nowcasting systems** (back to back)

- **Meeting on reanalysis systems** (back to back)

- **Working weeks** (minimum once per year each)
  - On the use of observations
  - On algorithmic issues

- **Video meetings** (two series per year)
  - The use of conventional observations and COPE
  - Radar data (pre-)processing
  - Retrievals (observations)
  - Algorithmic issues: 3DVar, 4DVar, ETKF, etc…
  - Radiance data assimilation

Wiki page: https://hirlam.org/trac/wiki/Meetings/Data_assimilation
https://hirlam.org/trac/wiki/HarmonieSystemDocumentation/TrainingCourses

Thank you