



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



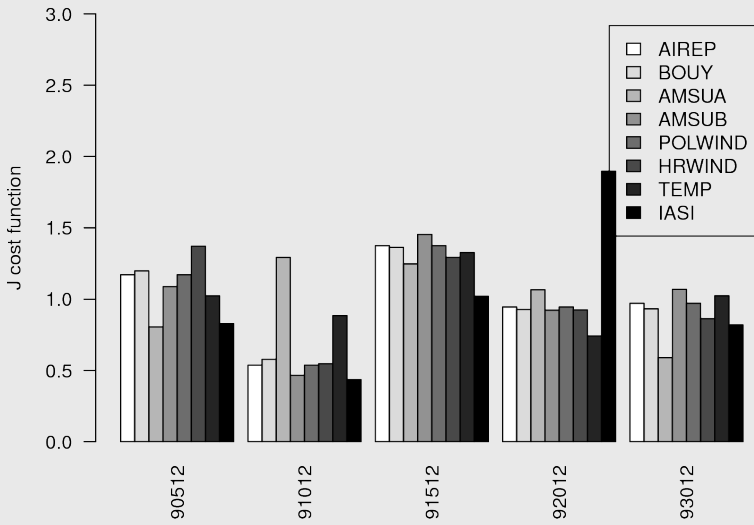
- Operational upper air data assimilation (UA-DA) systems in HIRLAM
- Some development works related to UA-DA
- Local implementation
- Data assimilation meetings (training, working week and video)

Operational upper air data assimilation (UA-DA) systems



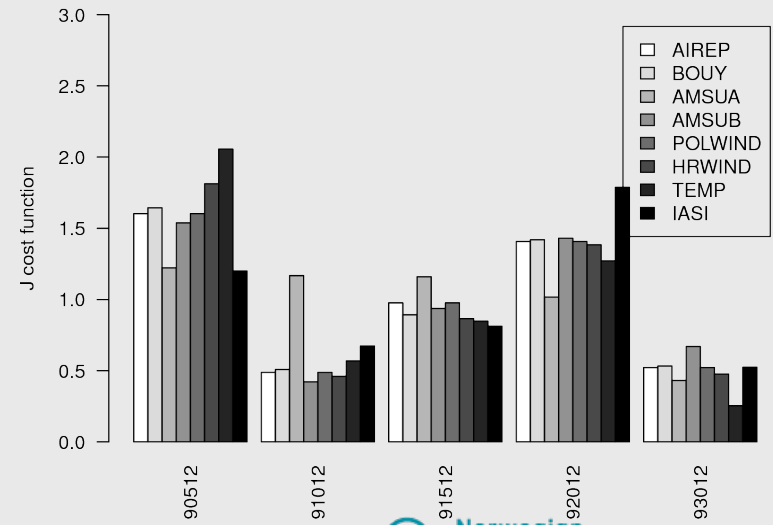
- **Assimilation scheme:** 3D-VAR;
- **Cycling Strategy:** 3 hourly;
- **Conventional observations:** SYNOP, SHIP, BUOY, AMDAR, AIREP, ACARS, ModeS EHS, Pilots, TEMP;
- **Satellite radiances:** AMSU-A, AMSU-B/MHS, ATMS, IASI;
- **Satellite retrievals:** Scatterometer, GNSS ZTD, GPS RO, (geo and polar)AMV;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

Normalized variability of the cost function over different dates
Forecast: 6 hours, Total Norm



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

Normalised variability of the cost function over different dates
Forecast: 48 hours, Total Norm



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

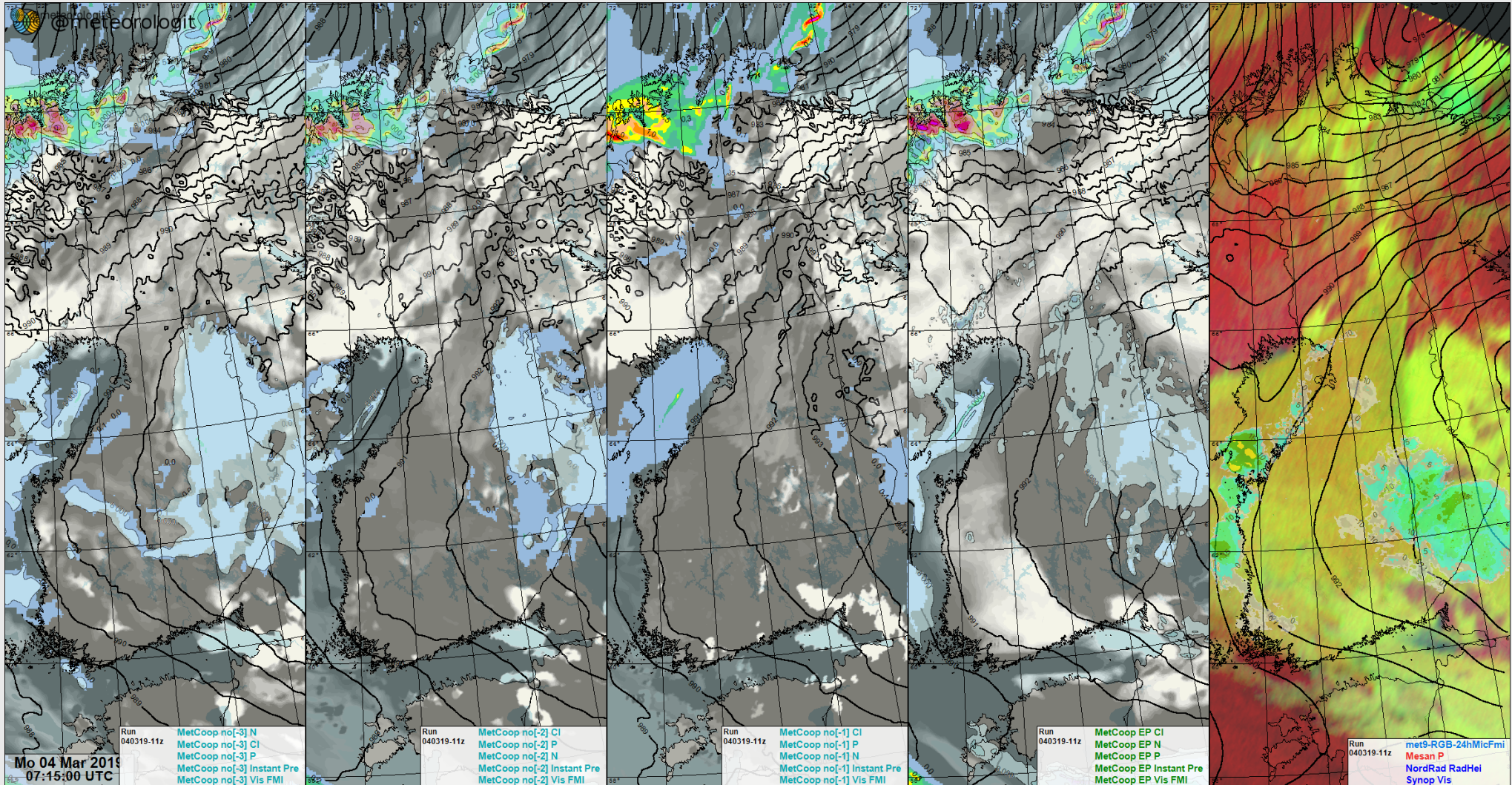
MNWC -2h

MNWC -1h

MNWC -0h

MEPS - recent

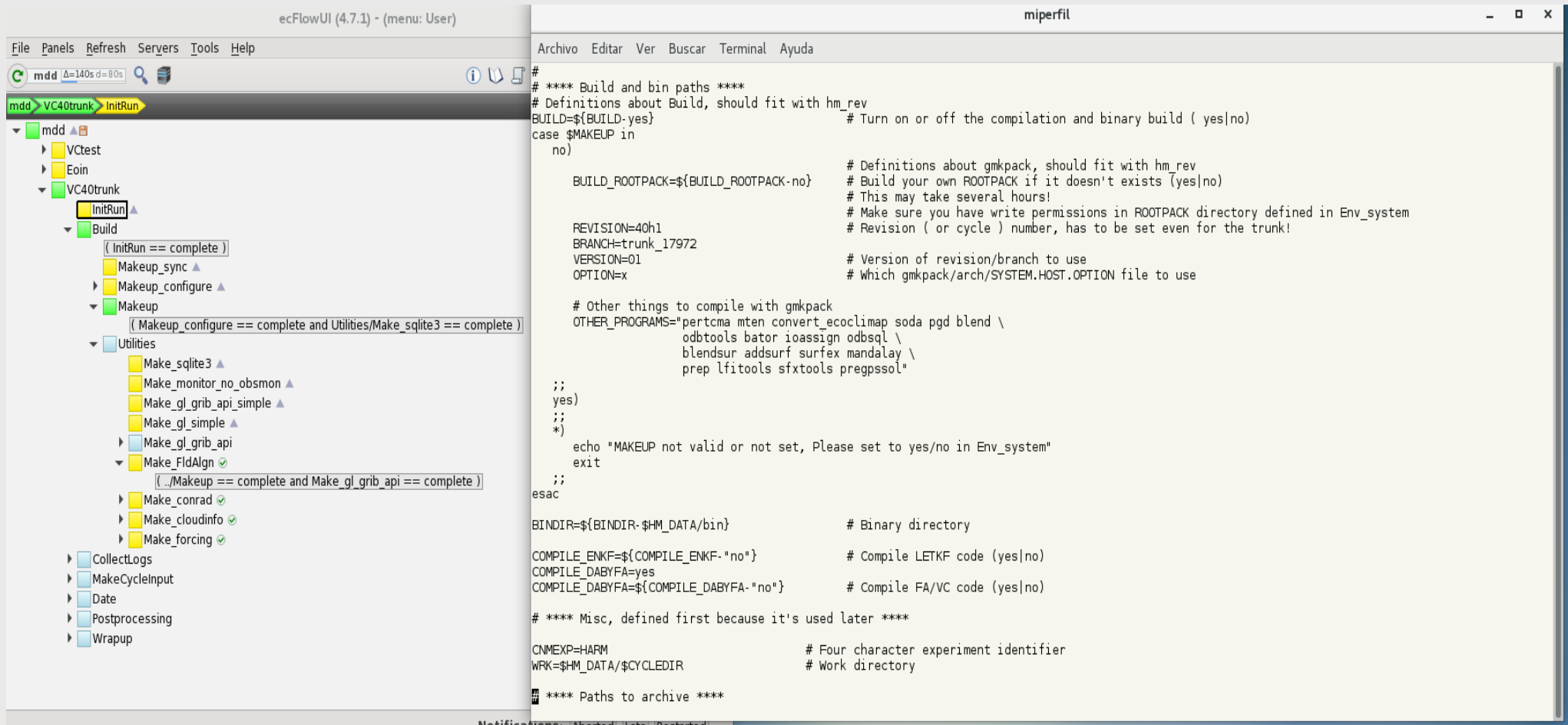
Satellite



MNWC and MEPS: Grey color – clouds, blue-red color – precipitation
Satellite: Yellow – low clouds, green-yellow precipitation

Highlight of the progress – initialisation

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



The image shows two windows from a development environment. The left window, titled 'ecFlowUI (4.7.1) - (menu: User)', displays a project tree for 'mdd'. The tree shows a 'VC40trunk' directory containing an 'InitRun' task, which is currently running. Below it, a 'Build' task is shown as complete. The right window, titled 'miperfil', displays a configuration file with various build options and definitions. The file includes comments and settings for build paths, gmkpack, revision, and other programs to compile.

```
#
# **** Build and bin paths ****
# Definitions about Build, should fit with hm_rev
BUILD=${BUILD:-yes} # Turn on or off the compilation and binary build ( yes/no)
case $MAKEUP in
no)
    BUILD_ROOTPACK=${BUILD_ROOTPACK:-no} # Definitions about gmkpack, should fit with hm_rev
    # Build your own ROOTPACK if it doesn't exists (yes/no)
    # This may take several hours!
    # Make sure you have write permissions in ROOTPACK directory defined in Env_system
    REVISION=40h1 # Revision ( or cycle ) number, has to be set even for the trunk!
    BRANCH=trunk_17972
    VERSION=01 # Version of revision/branch to use
    OPTION=x # Which gmkpack/arch/SYSTEM.HOST.OPTION file to use

# Other things to compile with gmkpack
OTHER_PROGRAMS="pertcma mten convert_ecoclmap soda pgd blend \
odbttools bator ioassign odbsql \
blendsurf addsurf surfex mandalay \
prep lfertools sfxttools prepssol"
;;
yes)
;;
*)
echo "MAKEUP not valid or not set, Please set to yes/no in Env_system"
exit
;;
esac

BINDIR=${BINDIR:-$HM_DATA/bin} # Binary directory

COMPILE_ENKF=${COMPILE_ENKF:-"no"} # Compile LETKF code (yes/no)
COMPILE_DABYFA=yes
COMPILE_DABYFA=${COMPILE_DABYFA:-"no"} # Compile FA/VC code (yes/no)

# **** Misc, defined first because it's used later ****

CNMEXP=HARM # Four character experiment identifier
WRK=$HM_DATA/$CYCLEDIR # Work directory

# **** Paths to archive ****
```

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

Highlight of the progress – initialisation

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

Incremental Analysis Update

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

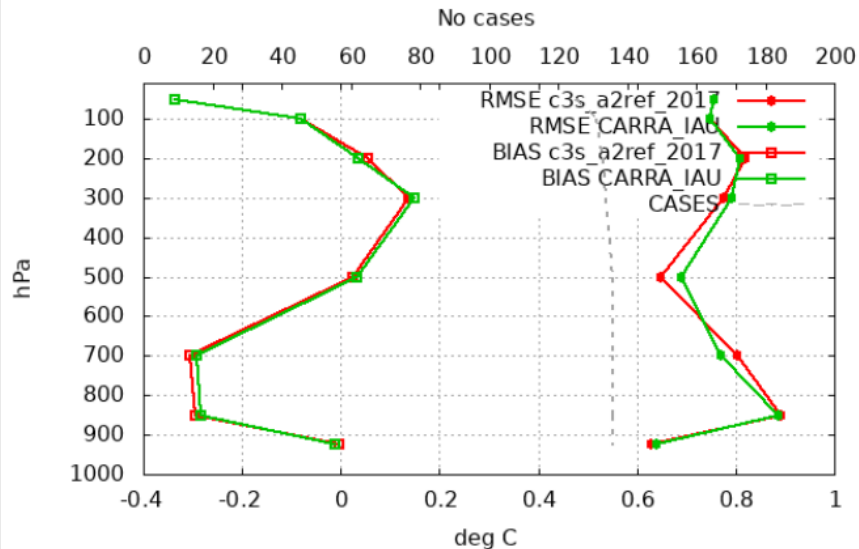
Variables : $(\ln p_s, u, v, T_v, q)$;

conv. obs.

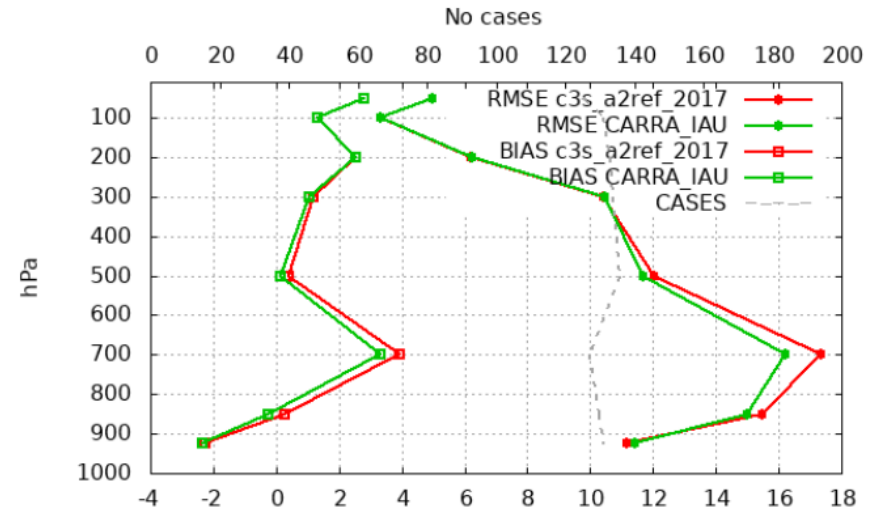
Non-centered 3h IAU

3h 3DVAR

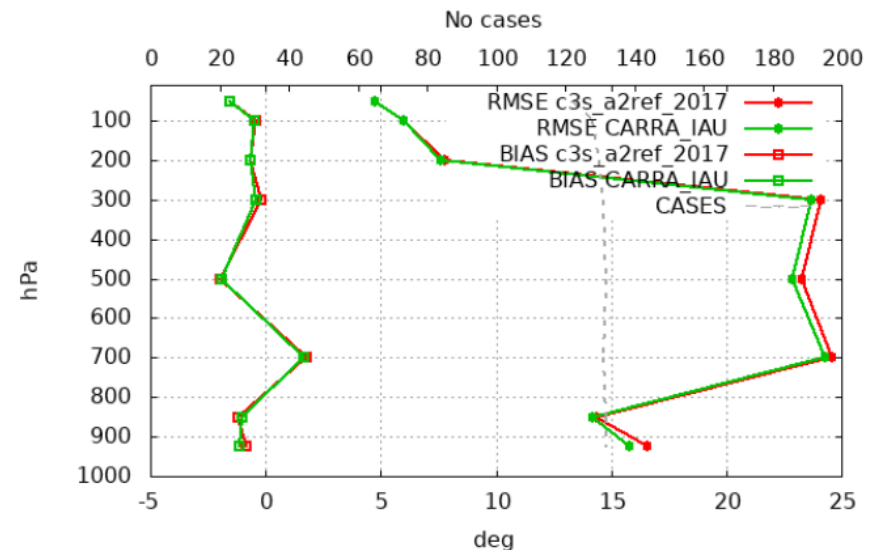
2 stations Selection: ALL
Temperature Period: 20170101-20170114
Used {12} + 00 06 12 18 24



2 stations Selection: ALL
Relative Humidity Period: 20170101-20170114
Used {12} + 00 06 12 18 24



2 stations Selection: ALL
Wind direction Period: 20170101-20170114
Used {12} + 00 06 12 18 24

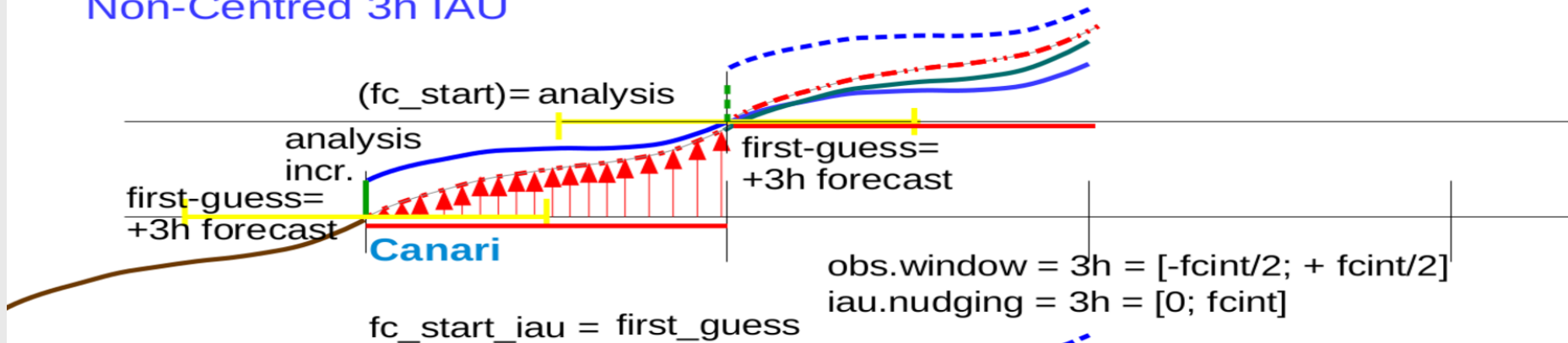


Highlight of the progress – initialisation

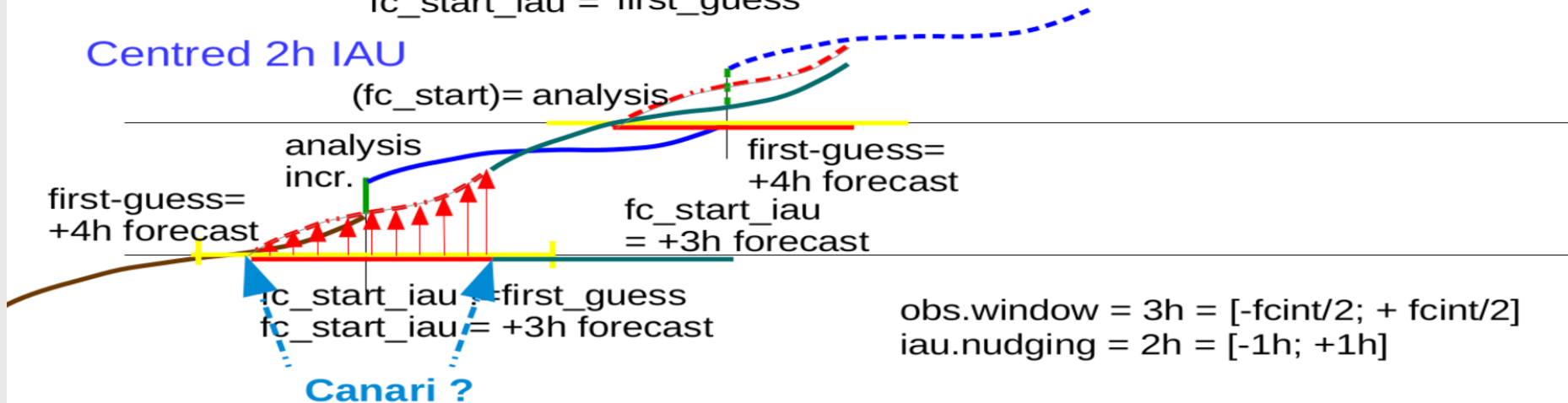
- Incremental Analysis Update (IAU) implementation:
(Jelena Bojarova)

Incremental Analysis Update : design Issues

Non-Centred 3h IAU



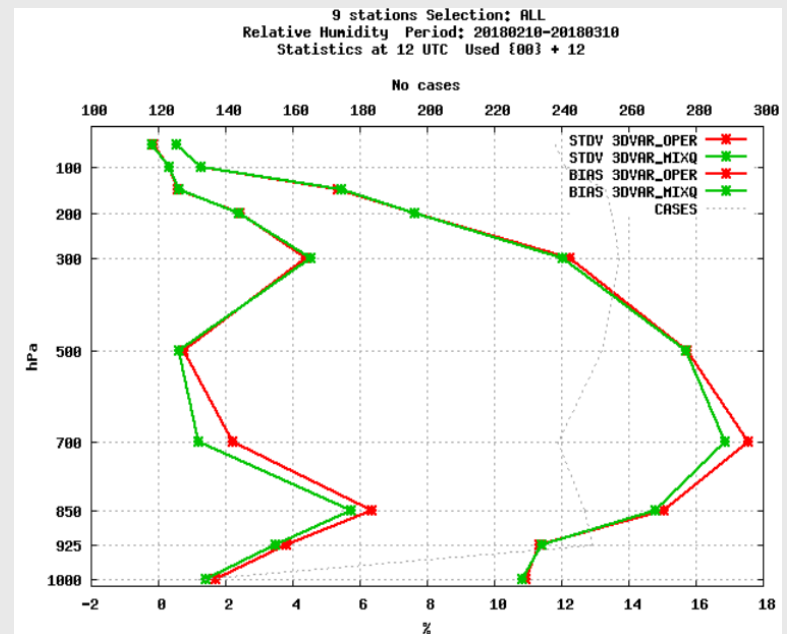
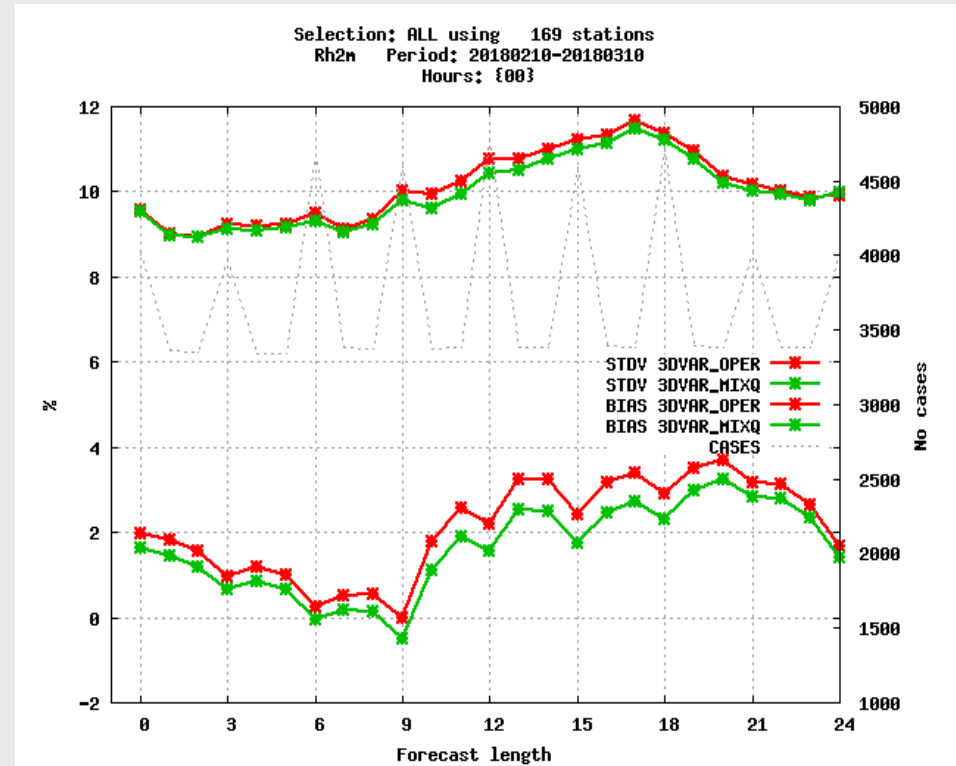
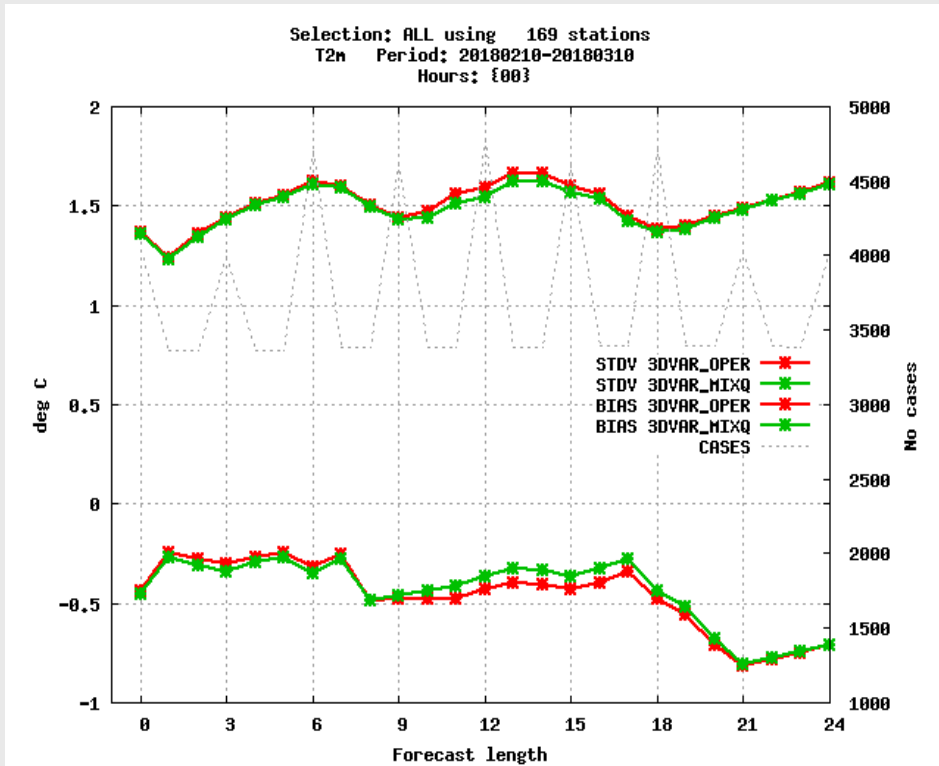
Centred 2h IAU



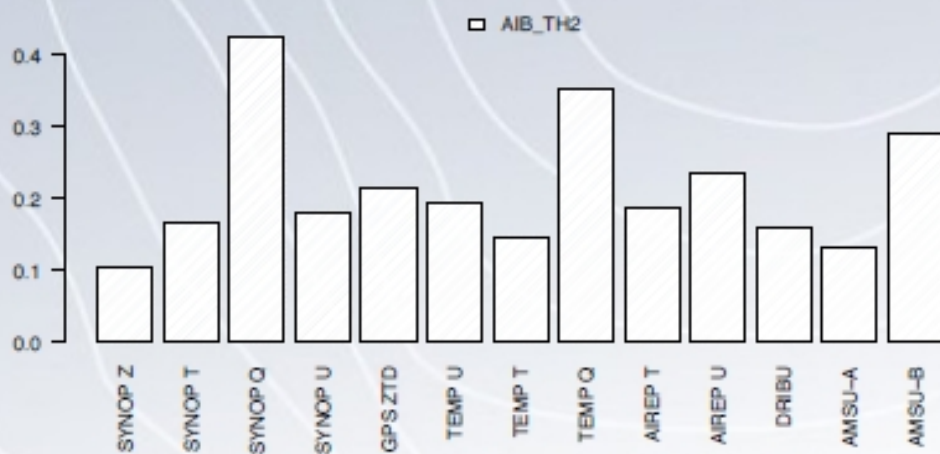
What to do with surface data assimilation ?
When should we apply Canari?

Highlight of the progress – initialisation

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



Relative Degree of Freedom for Signal (DFS/observations)



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

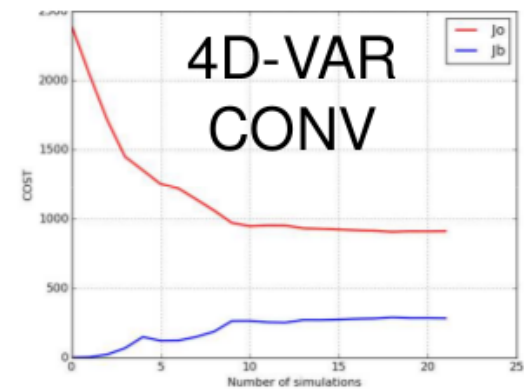
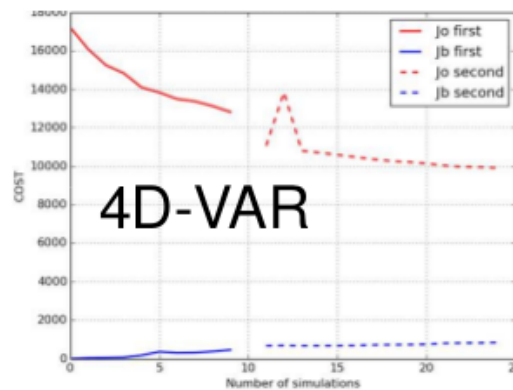
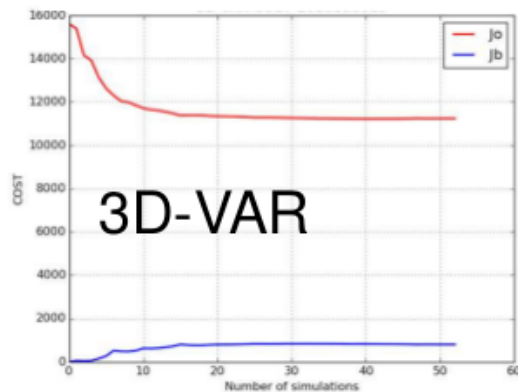
Progress with 4DVar scheme: (Magnus Lindskog)

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

Demonstration of functionality



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 ==

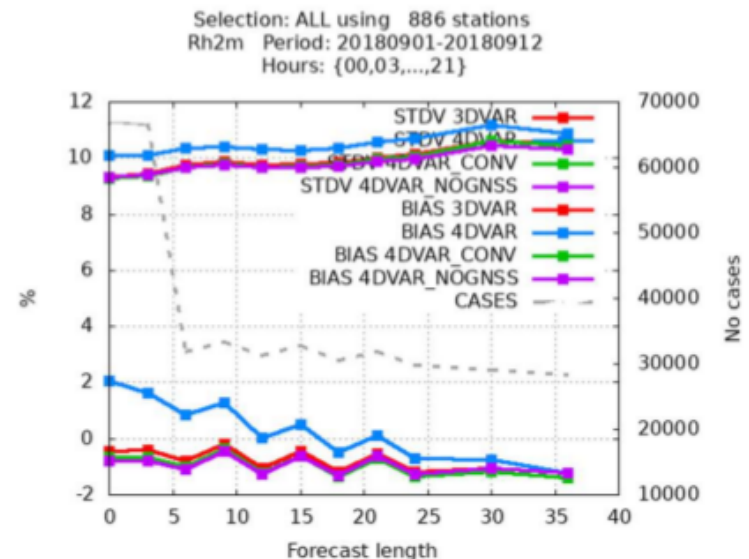
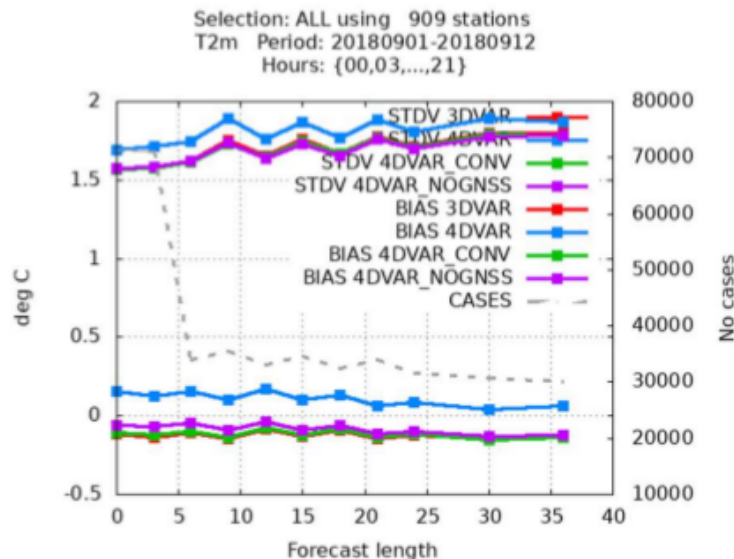
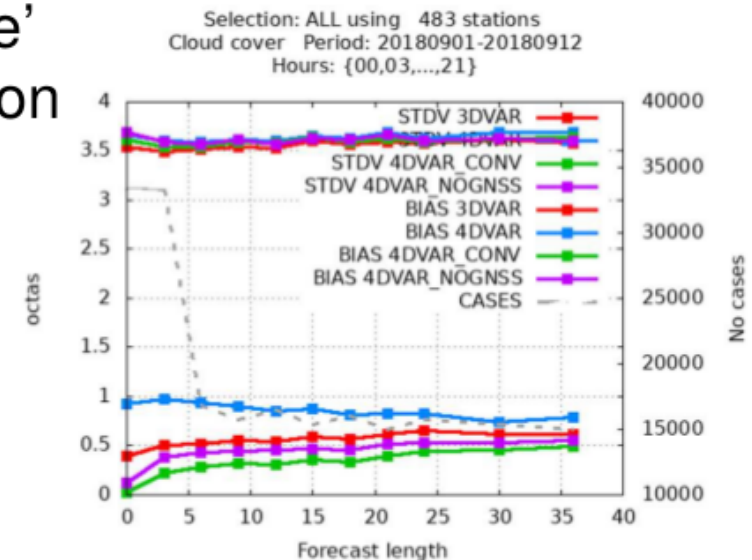
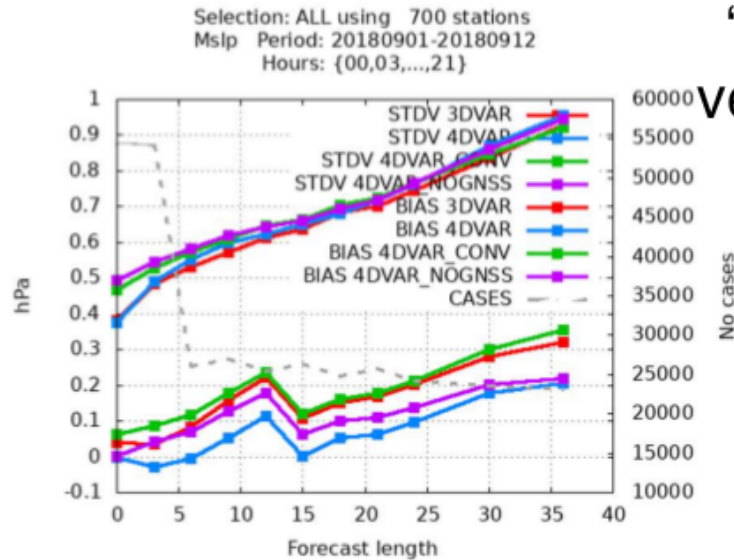
Progress with 4DVar scheme: (Magnus Lindskog)

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

Results



'Surface' verification



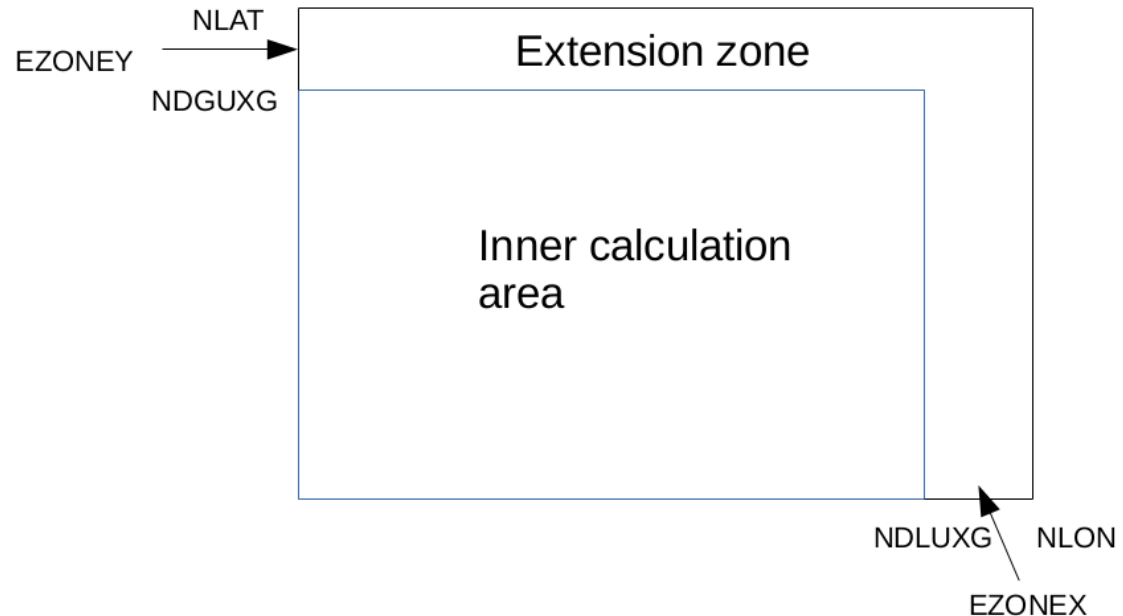
Highlight of the progress – towards improved tools and schemes

== 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.

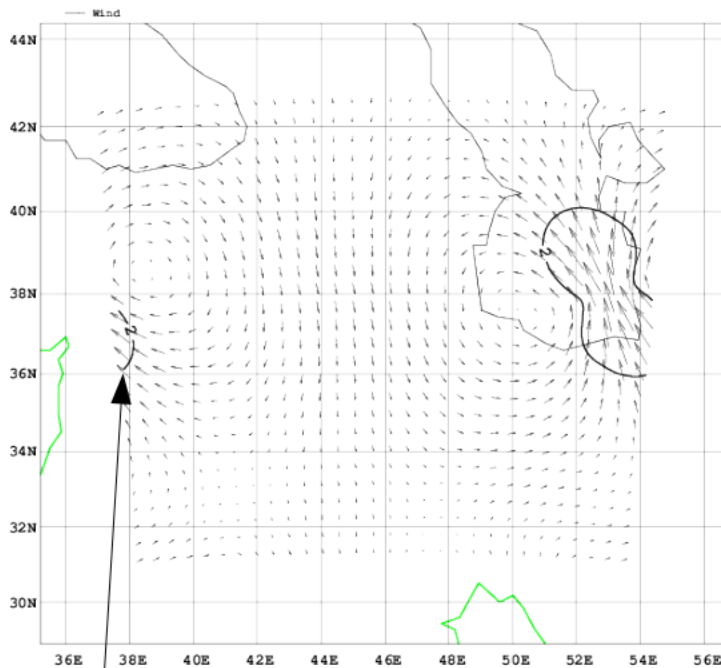
Highlight of the progress – towards improved tools and schemes

== 4DVar ==

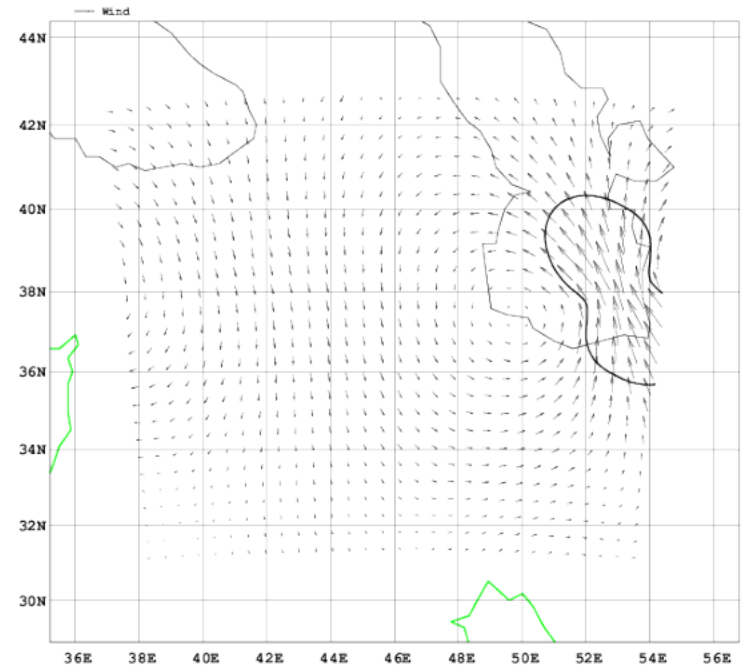
Progress with 4DVar scheme: (Nils Gustafsson)

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

Example of single simulated observation experiment over Iran



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



With increased width of the extension zone (300 km)

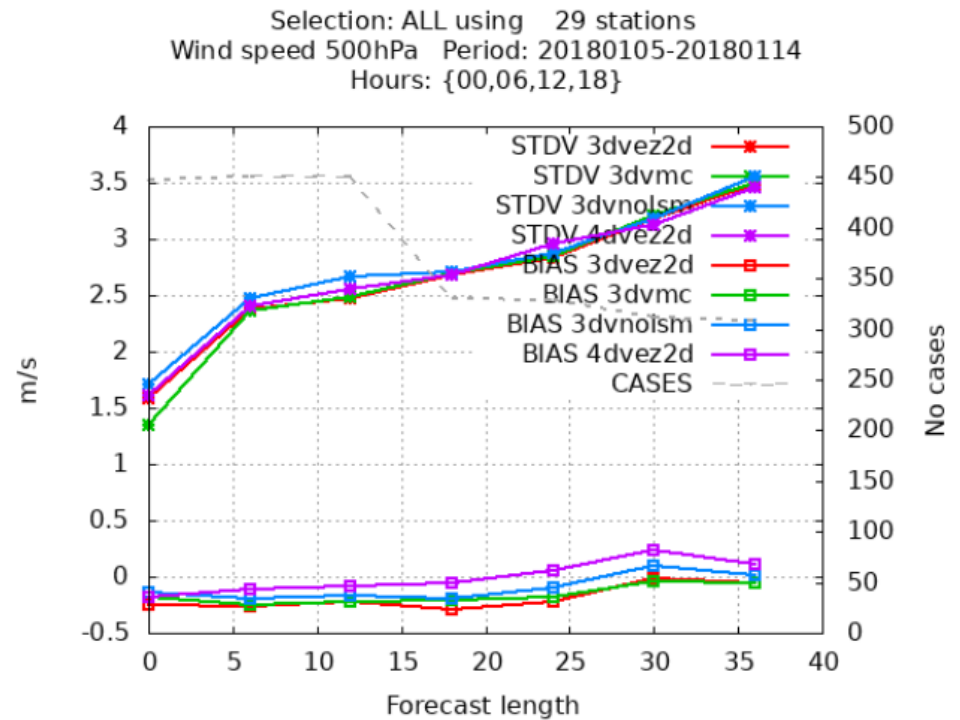
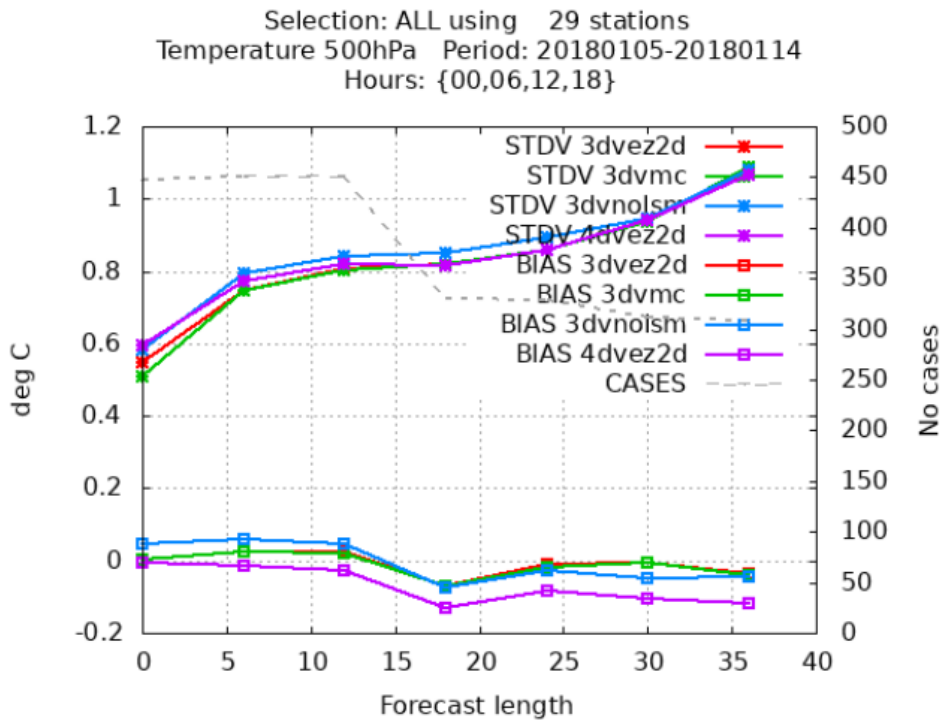
Highlight of the progress – towards improved tools and schemes

== 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

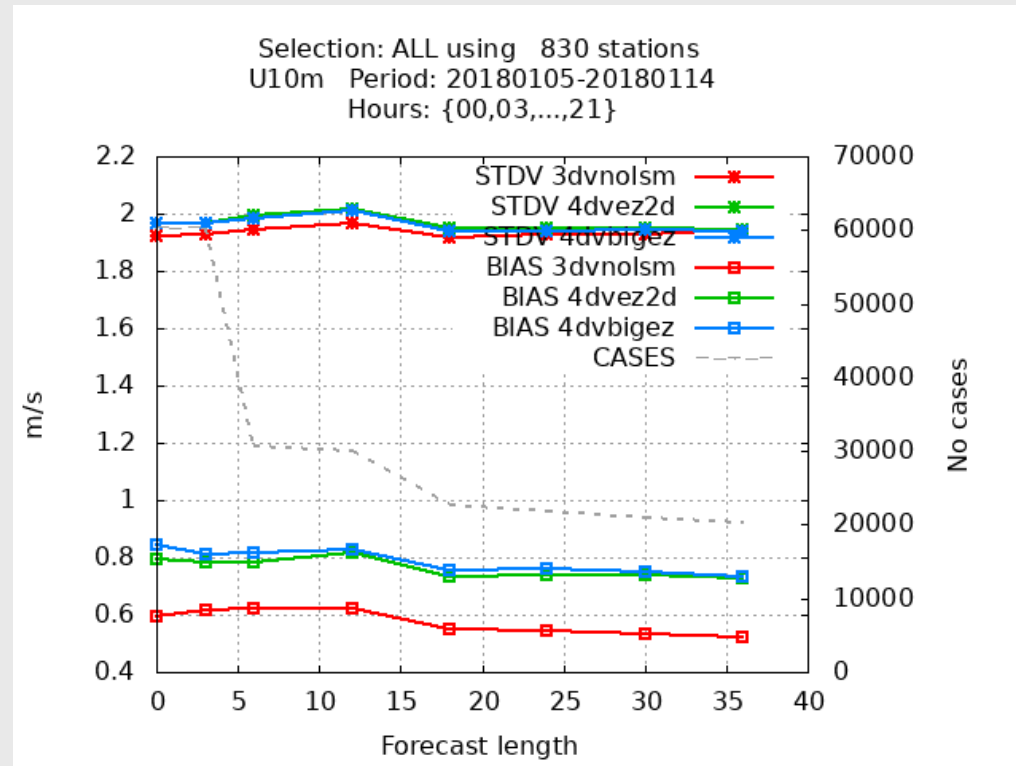
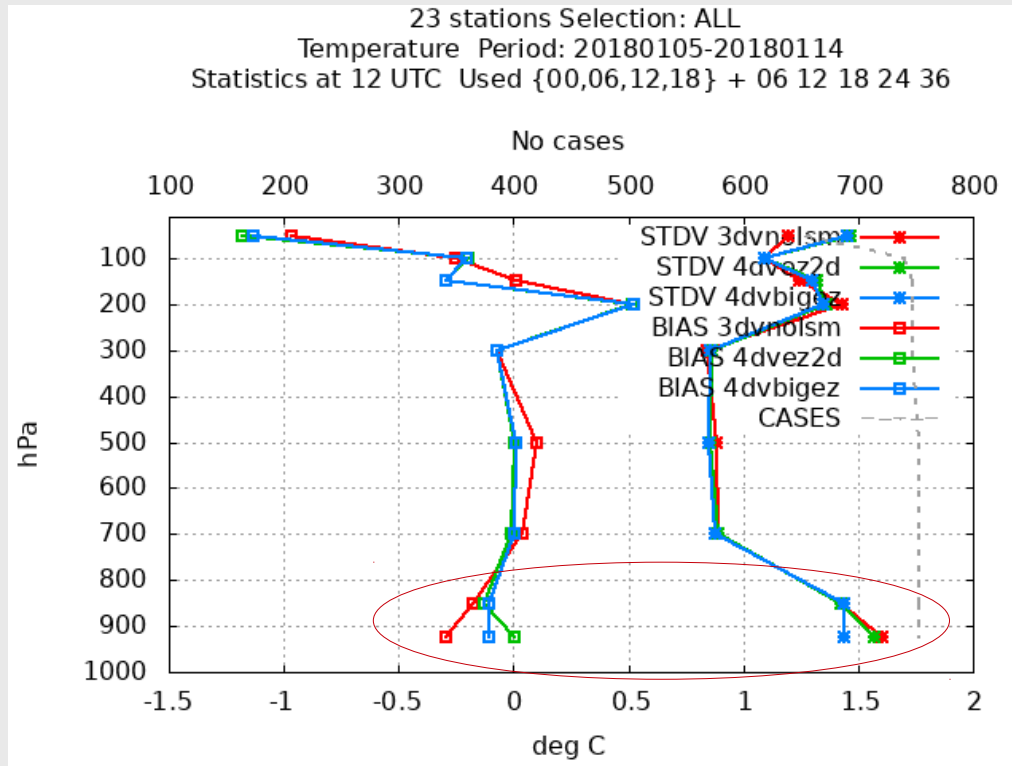


Highlight of the progress – towards improved tools and schemes

== 4DVar ==

Progress with 4DVar scheme: (Nils Gustafsson)

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



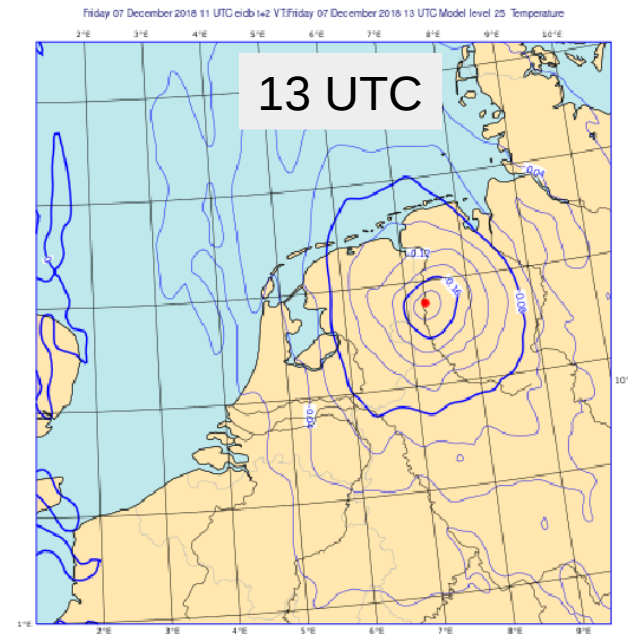
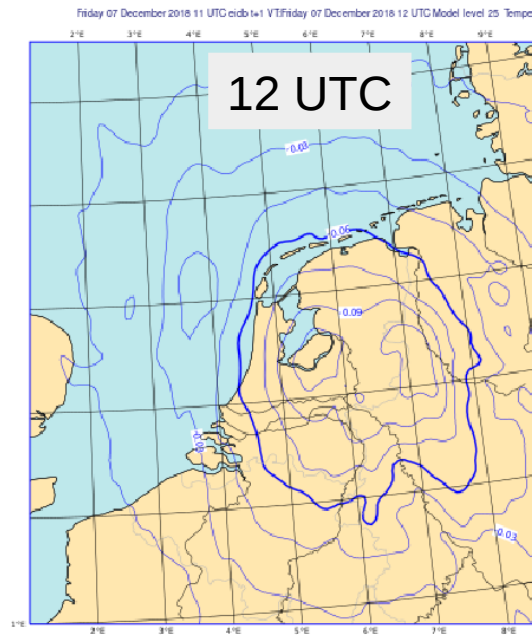
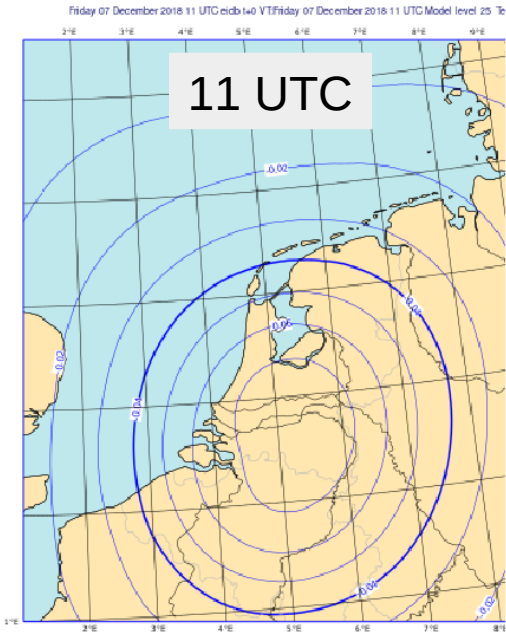
3dvnolsm – 3DVar without large scale mixing
4dvez2d – 4DVar with small extension zone
4dvbiggez – 4DVar with large extension zone

Highlight of the progress – towards improved tools and schemes

== 4DVar ==

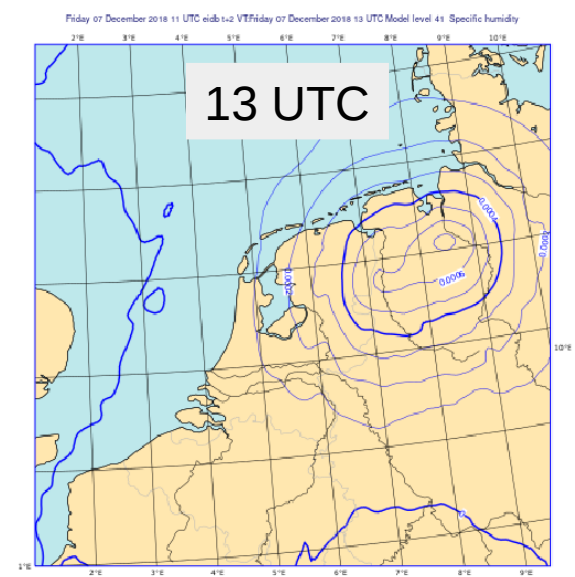
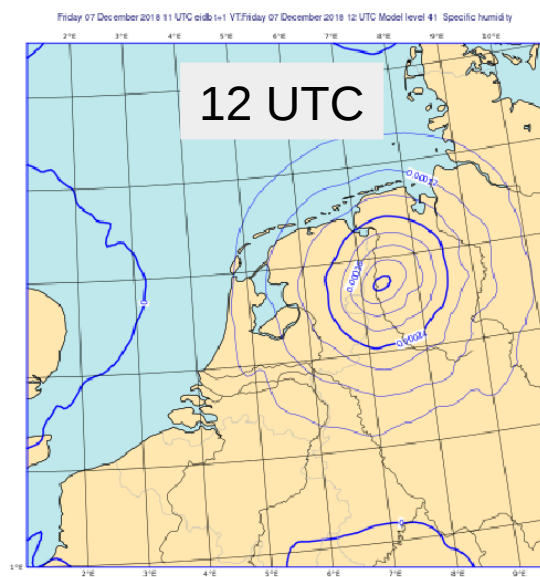
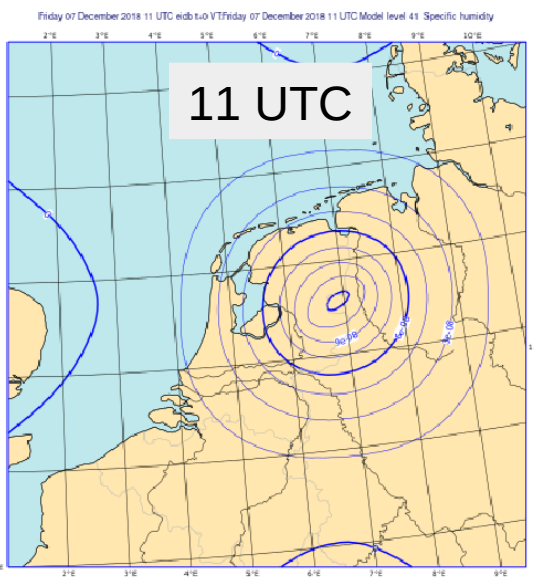
Progress with 4DVar scheme: (Jan Barkmeijer & Siebren de Haan)

==> Single observation with 4DVar scheme.



Obs at
13 UTC

At 500 hPa



Obs at
12 UTC

At 850 hPa

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. Gustafsson¹, J. Bojarova², and O. Vignes²

$$J(\delta \mathbf{x}_{\text{var}}, \boldsymbol{\alpha}) = \beta_{\text{var}} J_{\text{var}}(\delta \mathbf{x}_{\text{var}}) + \beta_{\text{ens}} J_{\text{ens}}(\boldsymbol{\alpha}) + J_0 \quad (6)$$

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

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

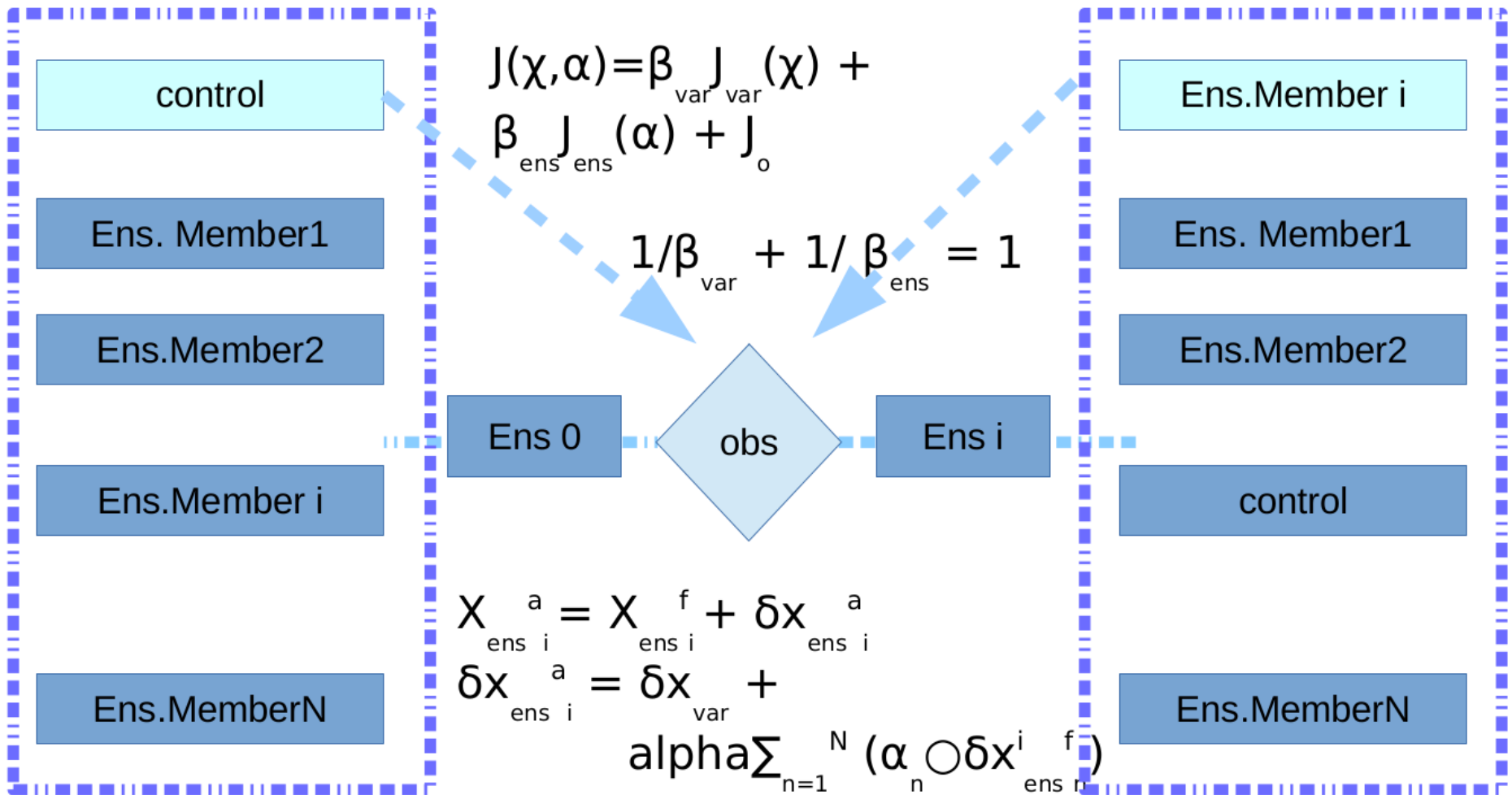
$$\mathbf{B}_{\text{ens}} = \mathbf{A} \circ \mathbf{B}_{\text{raw-ens}}$$

Ensemble : 10 members of BRAND perturbations

Localisation : spectrum of unbalanced surface pressure

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

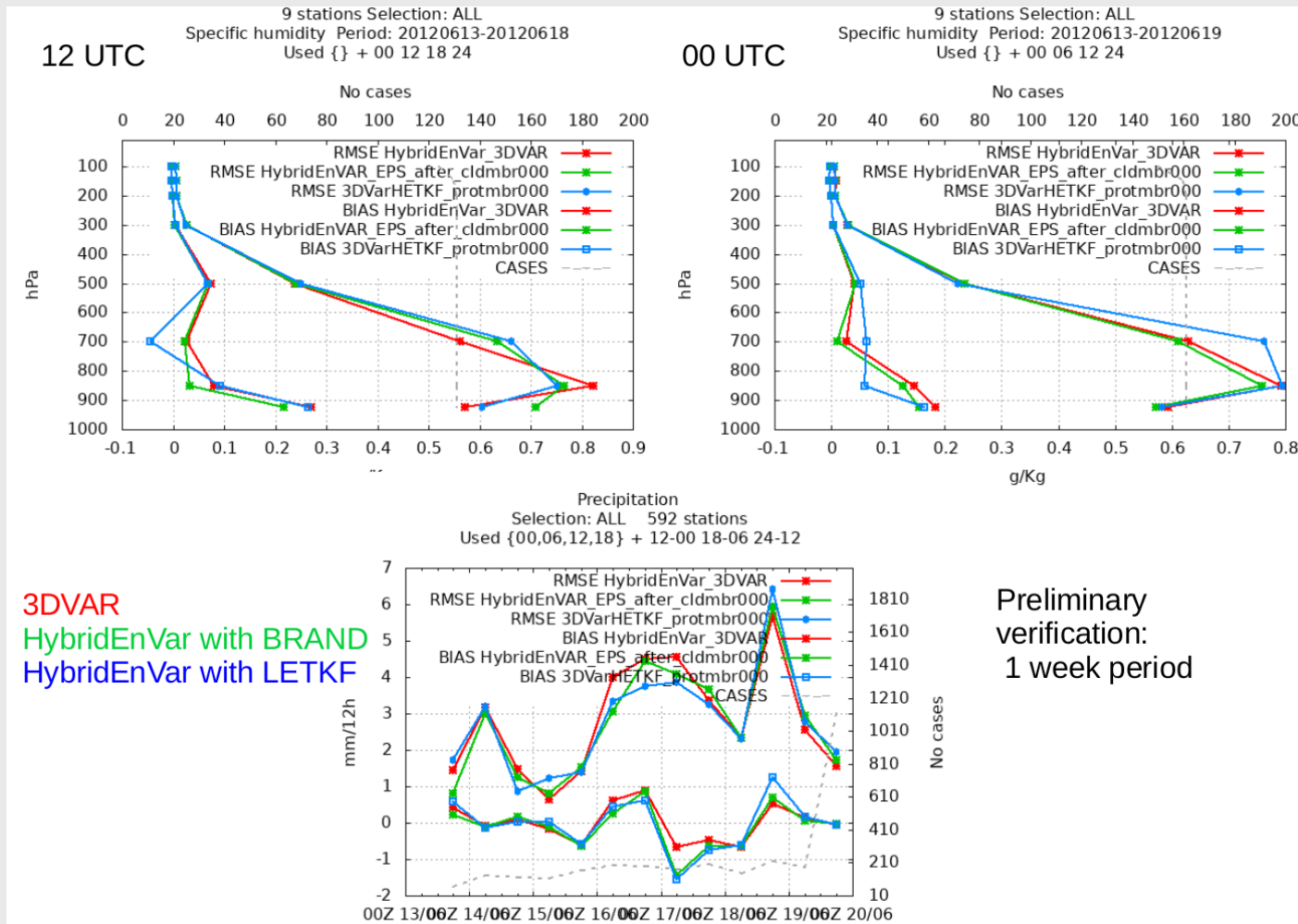
Ensemble of Data Assimilation runs without perturbing observations N+1 Hybrid EnVAR runs



$X_{\text{ens}}^{0,f}$

$X_{\text{ens}}^{i,f}$

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



3DVAR
 HybridEnVar with BRAND
 HybridEnVar with LETKF

Preliminary
 verification:
 1 week period

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)

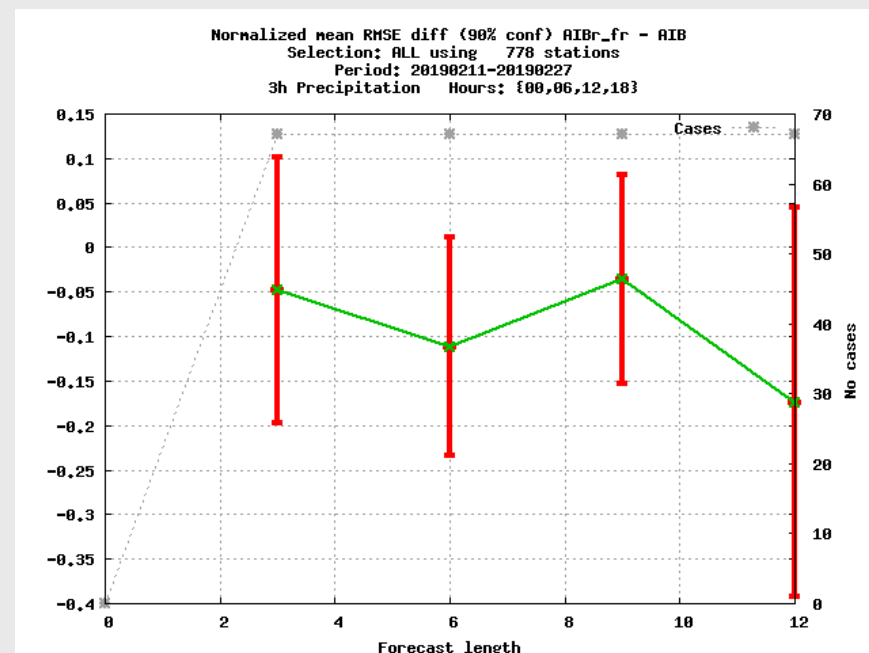
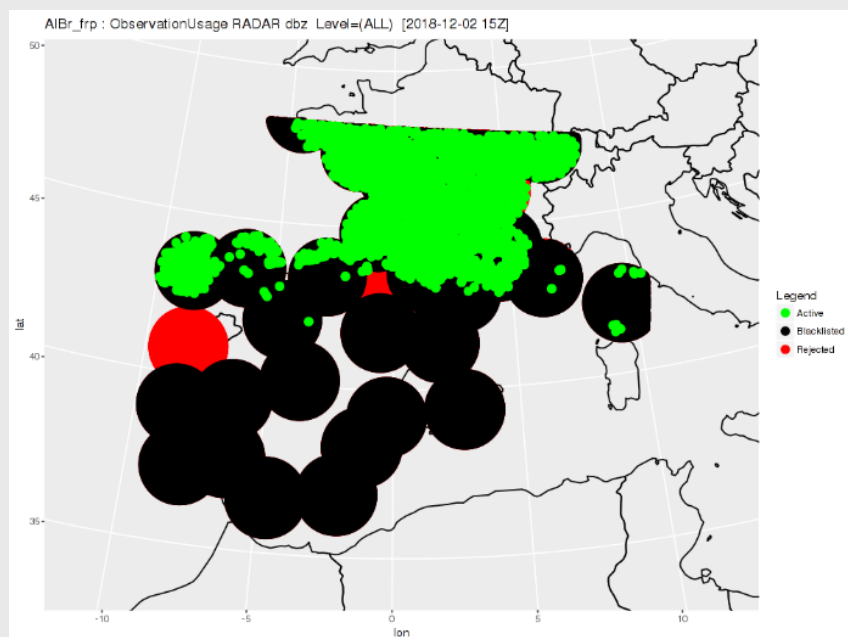
PERIOD of study: 11 feb - 3 march 2019 ...

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**

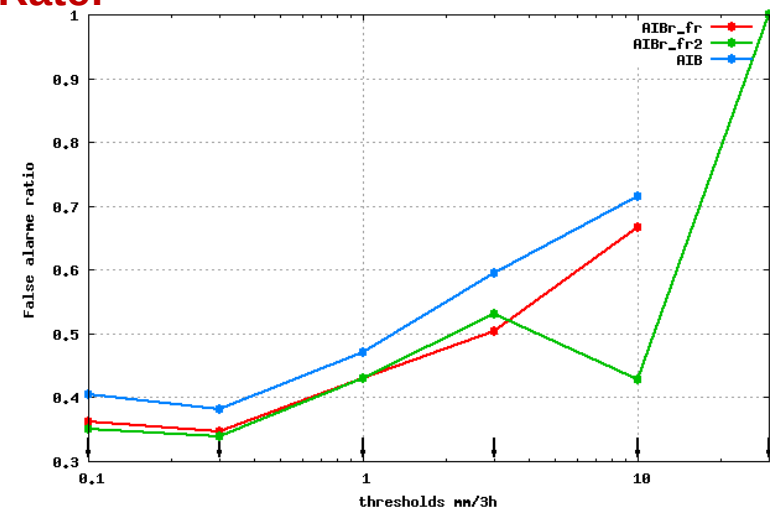
CTRL

REFL

REFL2

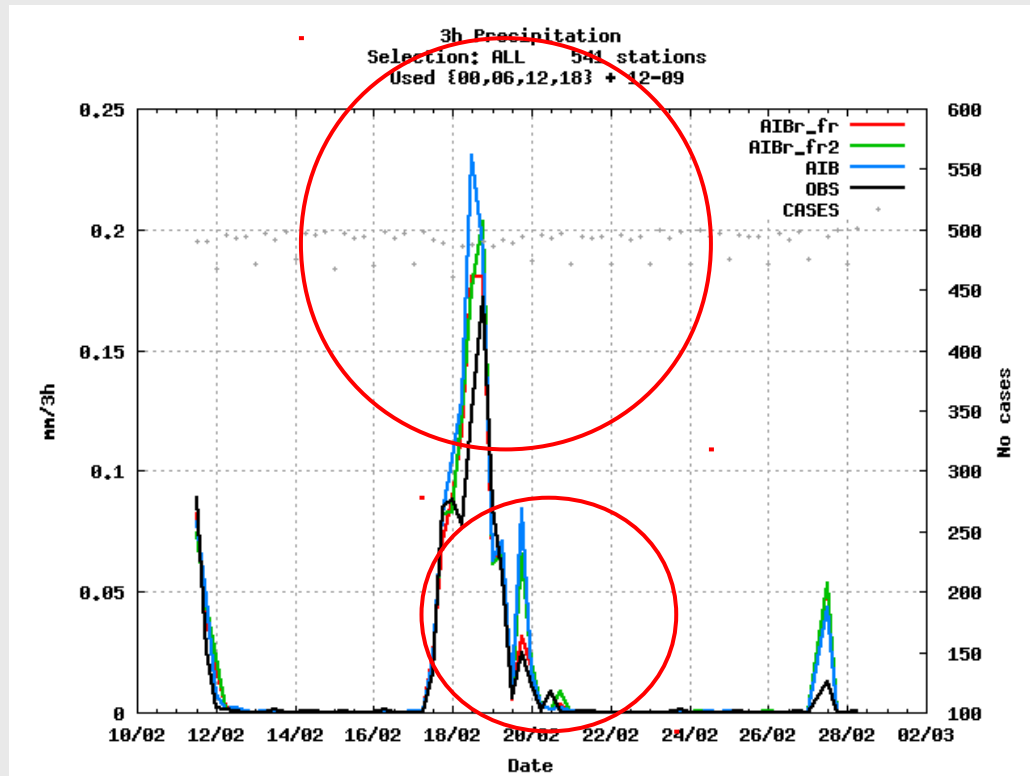
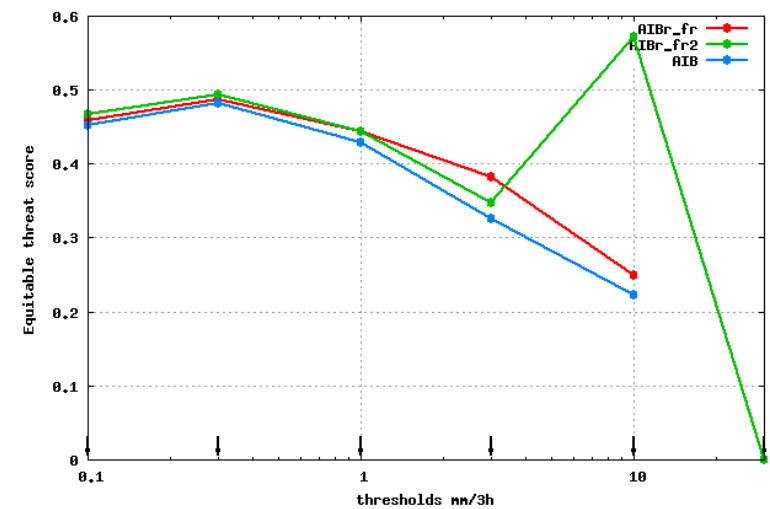
False Alarm Rate:

False alarm ratio for 3h Precipitation (mm/3h)
 Selection: ALL 796 stations
 Period: 20190211-20190227
 Used {00,06,12,18} + 03-00 06-03 09-06 12-09



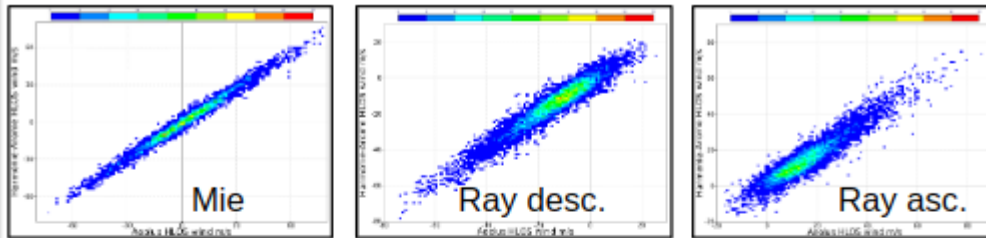
ETS:

Equitable threat score for 3h Precipitation (mm/3h)
 Selection: ALL 796 stations
 Period: 20190211-20190227
 Used {00,06,12,18} + 03-00 06-03 09-06 12-09

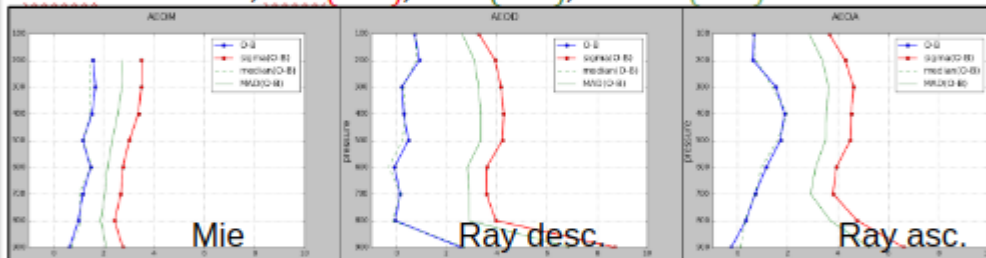


Highlight of the progress – New observation == Aeolus HLOS in CY43 == (Roohollah Azad)

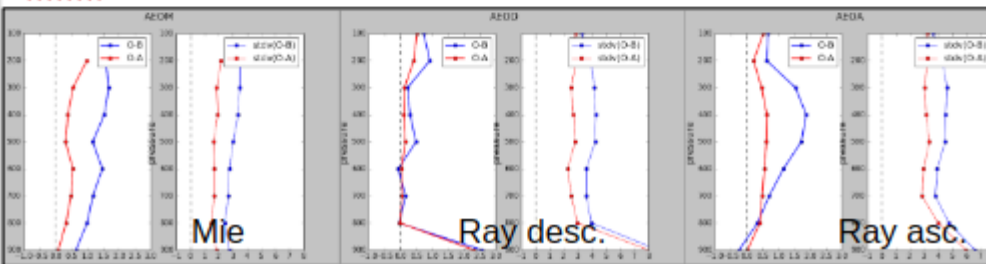
Model HLOS wind vs Aeolus HLOS wind



HLOS wind O-B, stdv(O-B), MAD(O-B), median(O-B)



HLOS wind O-B and O-A



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)

Case studies with Arome-Arctic
SOP1 period
Ongoing

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

Determine optimal
supermodding size

Study
representativeness
error

Experimental setup
(supermodding vs.
thinning)



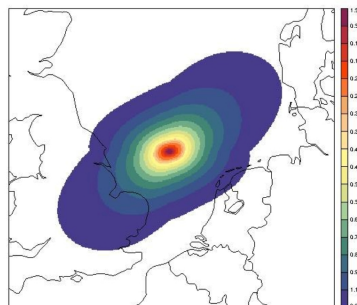
Flexible solutions using the supermodding or the old obs operator is implemented.
Multiple satellites can be assimilated with different approaches if needed.

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

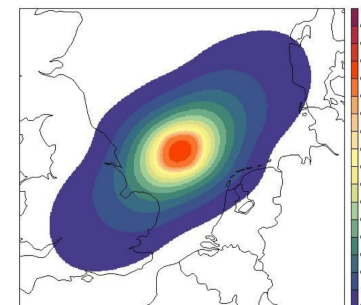
Alertness

**Single ASCAT
3D-Var
increments
(Wind V-
component)**

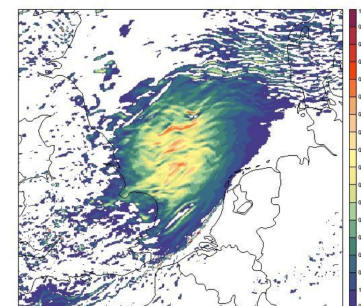
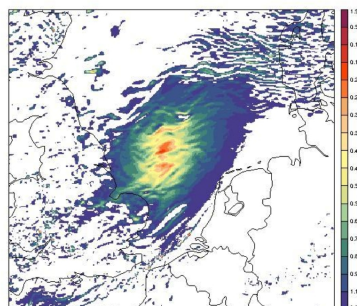
10 km supermodding size



100km supermodding size



**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