Recent progress in HIRLAM upper-air data assimilation

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with contribution from HIRLAM colleagues

EWGLAM, 2019, Sofia, Bulgaria

outline

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

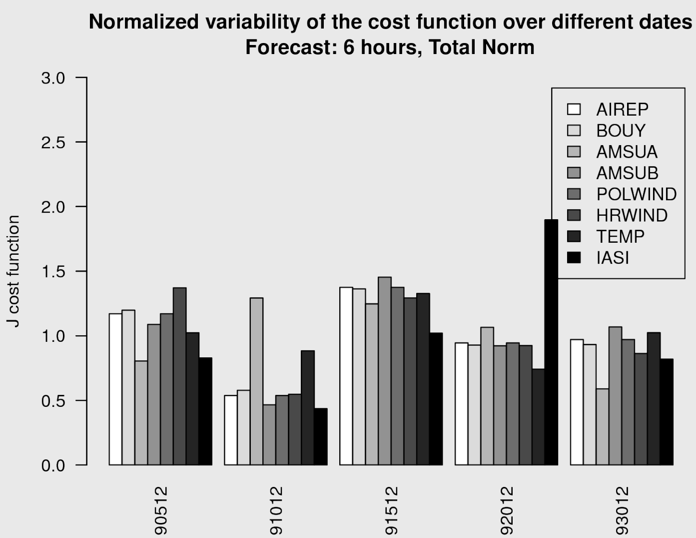
- Algorithmic development

- Improving the use of observations

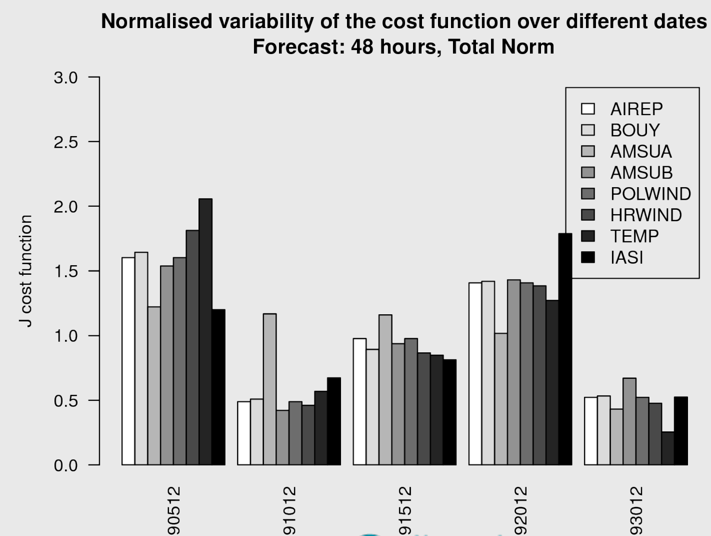
- Concluding remarks and further plan

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, AMV;
- **Radar observations:** Reflectivity;
- **Bias correction scheme:** Variational (VarBC)
- **Blacklisting of conventional observations:** IFS decision



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



Progress with 4D-Var

N Gustafsson, J Barkmeijer, M Lindskog, J Bojarova

Experiments:

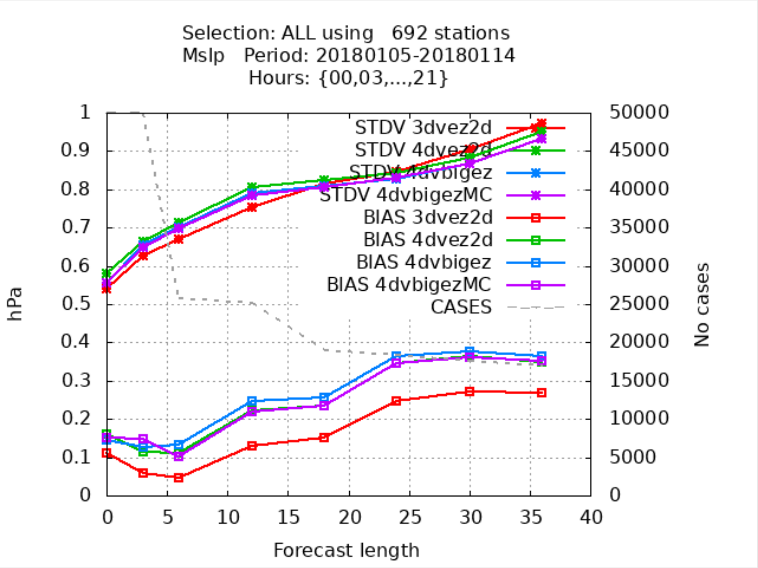
3dvez2d : 3D-Var, ez=11, LSM,
Redzone = 120 km

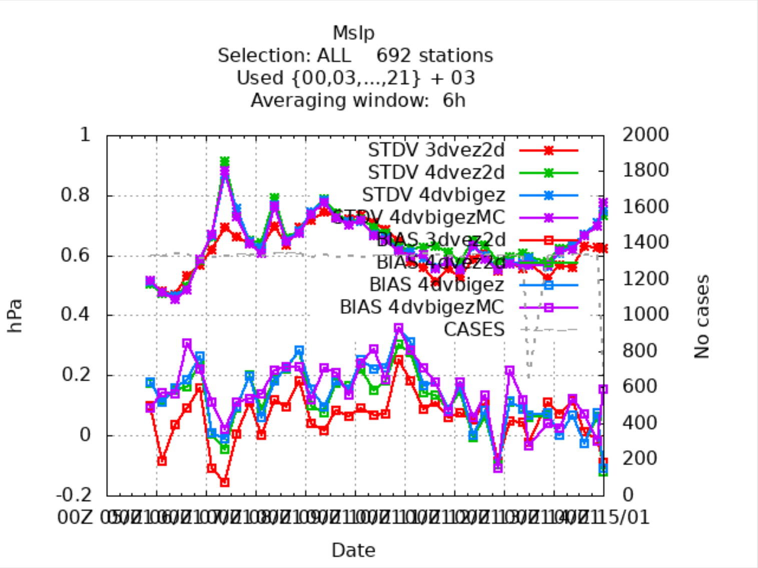
4dvex2d : 4D-Var, ez=23, no LSM,
6x, 3x increments
Redzone = 120 km

3dvnolsm : 3D-Var, ez=11, no LSM

4dvbigez : 4D-Var, ez=11 in model,
ez=191/131 in minim.
No LSM, 6x, 3x,
Redzone = 10 km

4dvbigezMC : as 4dvbigez but with
fresher LBCs in 03, 09 ….





4D-Var and LBCs

Nils Gustafsson

3D-Var: The analysis is influenced by observations all the way to the Lbs and the analysis is used as the first LBC

4D-Var: The TL increment is relaxed to zero in the forward run and the AD (dJ/dx) is also relaxed to zero.
(+ forecast LBC in the middle of the window)

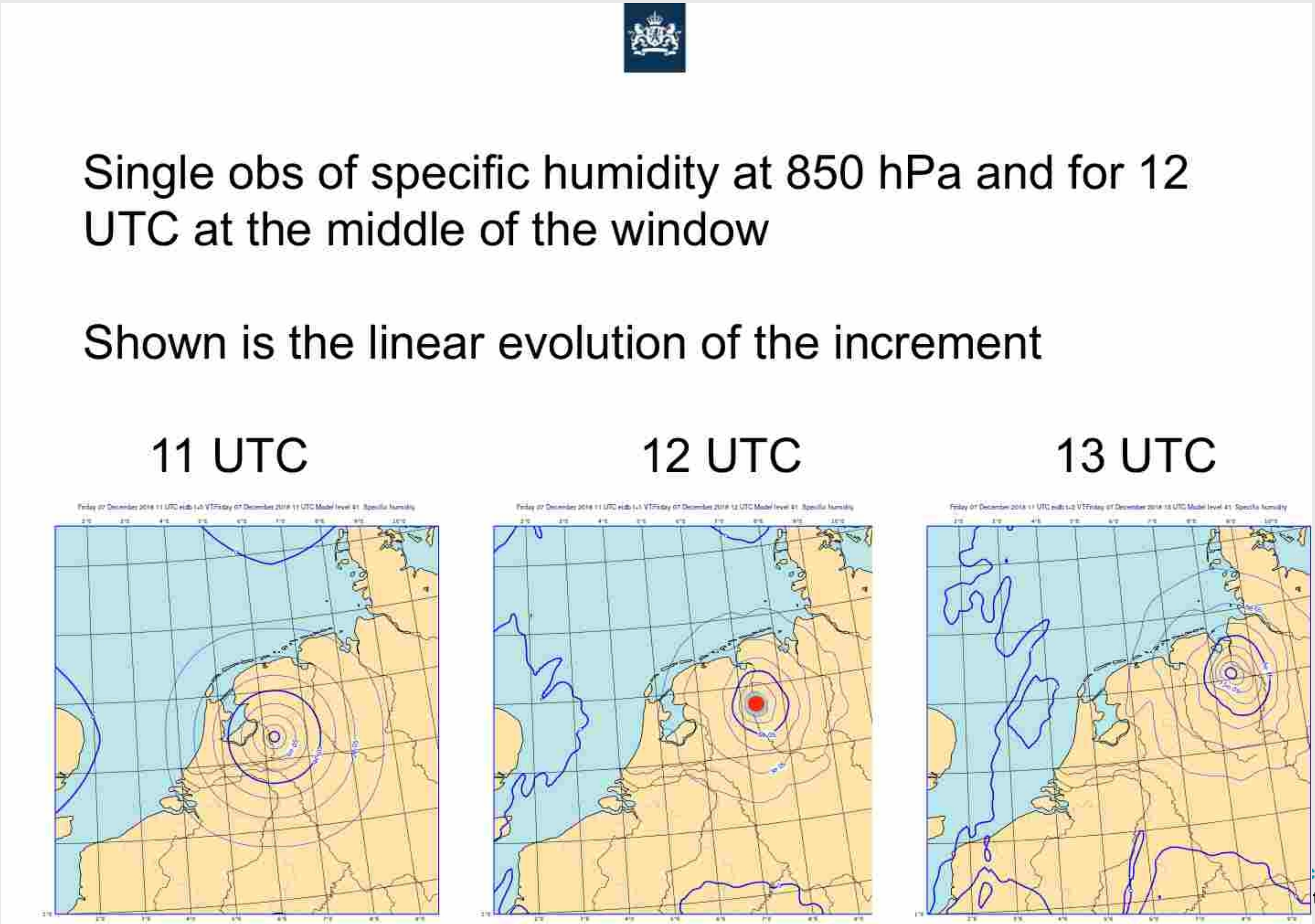
How to cure this?
(1) Use the increment at the start of the window (analysis increment) as first LBC (quite simple)

(2) Control LBCs at the end of the window (requires one more control vector)

Single observation in 4D-Var

R. Azad, N. Gustafsson, J. Barmeijer, M. Mile

Many tested the 4D-Var scheme with single observation. Expected behaviour was found: good evolution of the increment.



Other development on algorithm ...

LETKF (*P. Escriba*)**:** Further tuning of the scheme showed very promising results. Porting of the code to higher model version demands resources.

Hybrid and EnVar scheme (*J. Bojarova*)**:** Further testing and tuning of scheme is needed. Similarly, here as well we need to port the code to higher model version.

Estimation of the background error statistics (*J. Bojarova, X. Yang*)**:** Different techniques (downsc/EDA/Brand) were compared in frame of a reanalysis project (Copernicus Arctic Reanalysis project).

Accounting for large scale information(*J. Bojarova, M. Dahlbom*)**:** Spectral blending vs Jk.

Nowcasting-related dev: From development to operational implementation and testing (MetCoOp and DMI).
R. Azad (MET Norway), *E. Gregow, D. Schönach* (FMI), *X. Yang* (DMI)

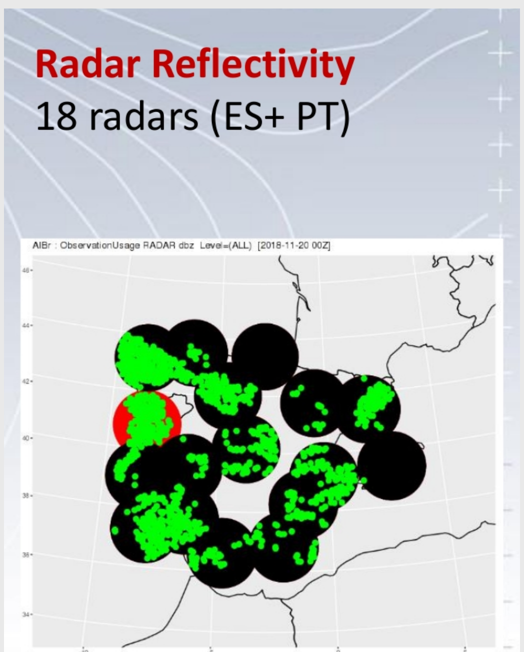
Use of more observations in operational DA

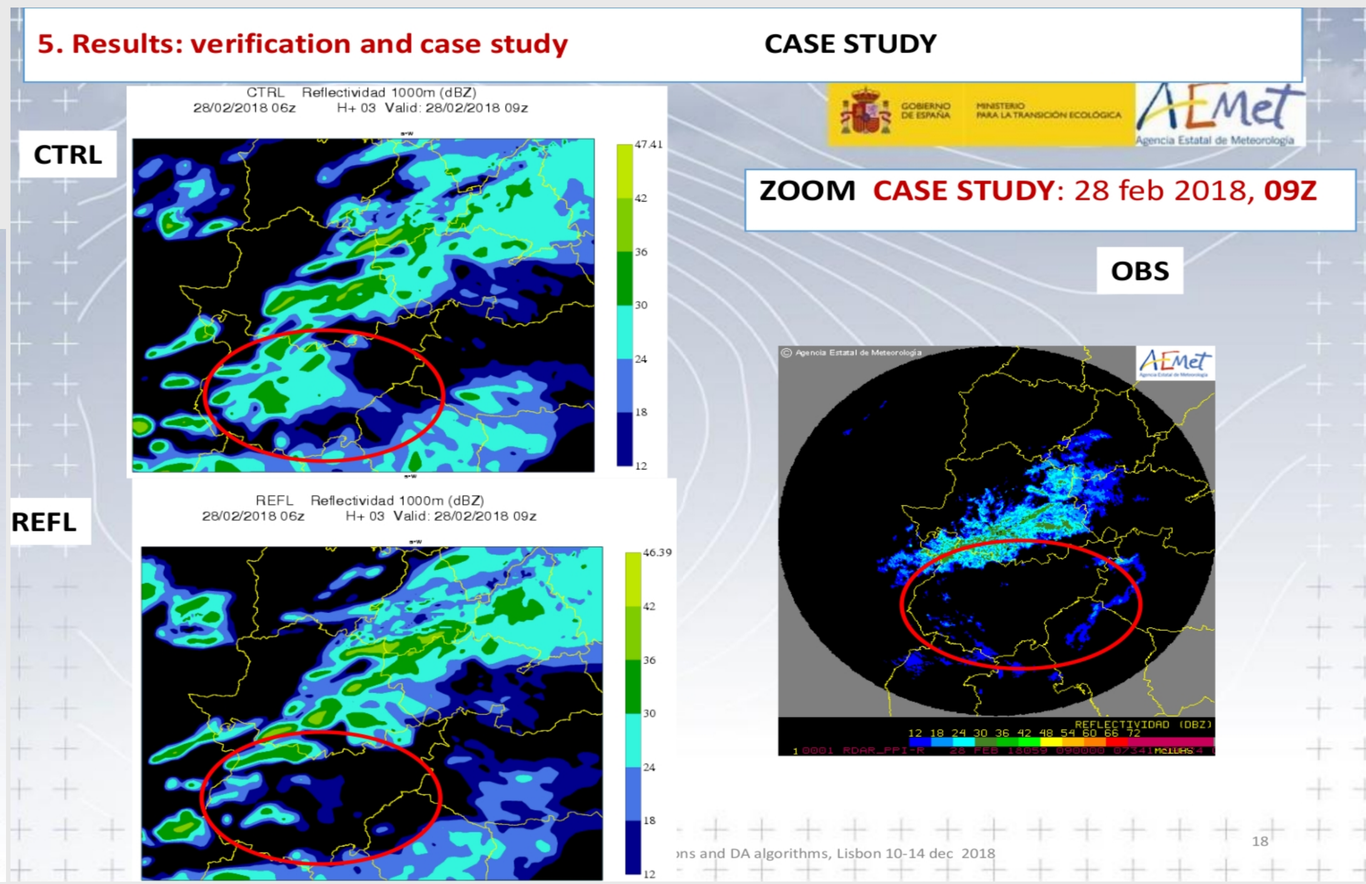
Observations added since last EWGLAM meeting:
– At Met Éireann (E Whelan): ASCAT, AMSU-A, MHS, IASI

– At KNMI:

– At AEMET (J Sanchez, M Diez): Radar RFL, RH2m and T2m

(J Sanchez & co.)





Alertness

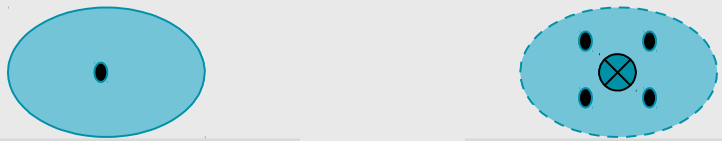
Better use of observations in DA

Implementation of supermodding technique for ASCAT

M Mile, PhD work

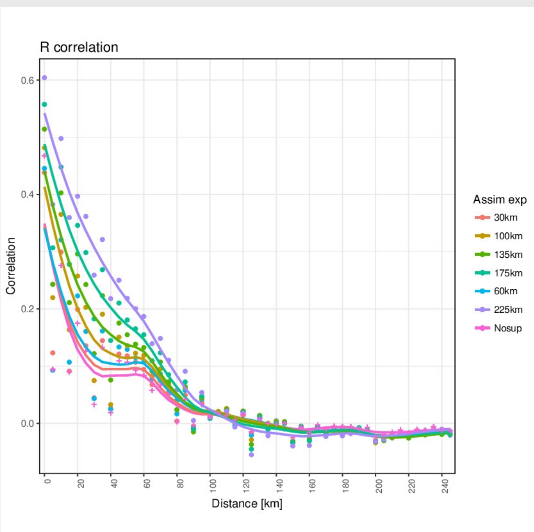
observation effective resolution < model effective resolution: superobbing

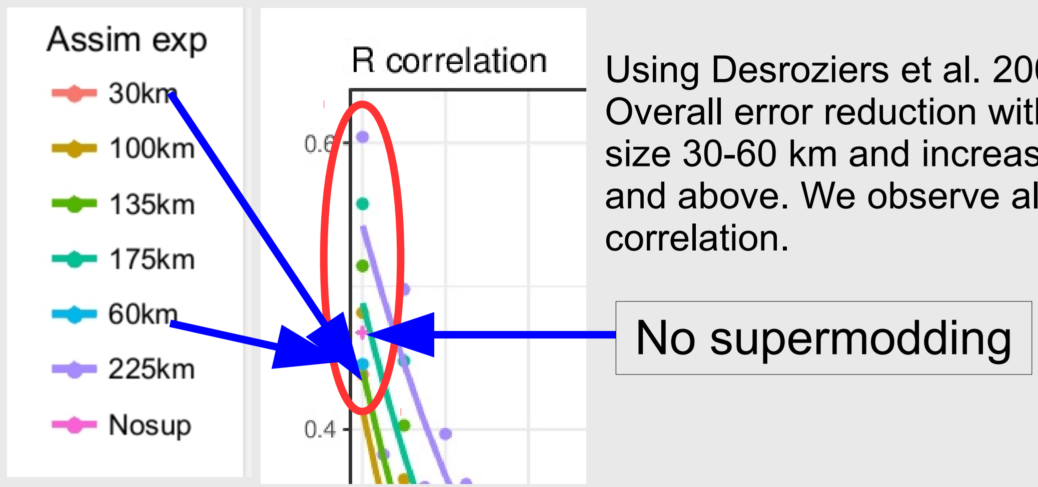
<u>observation effective resolution > model effective resolution: supermodding</u>



Observation space | Model space

– The task is to reduce the representativeness error in DA



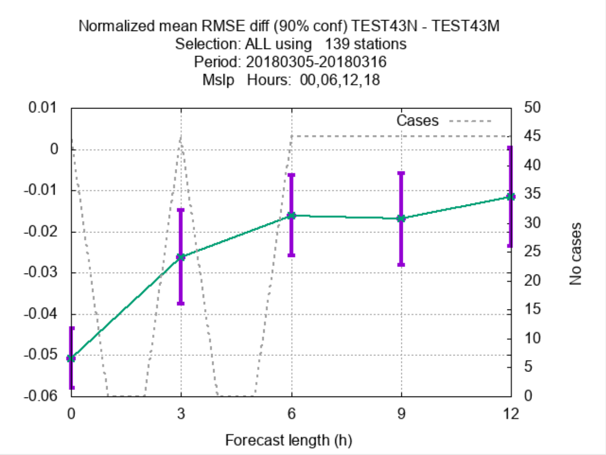


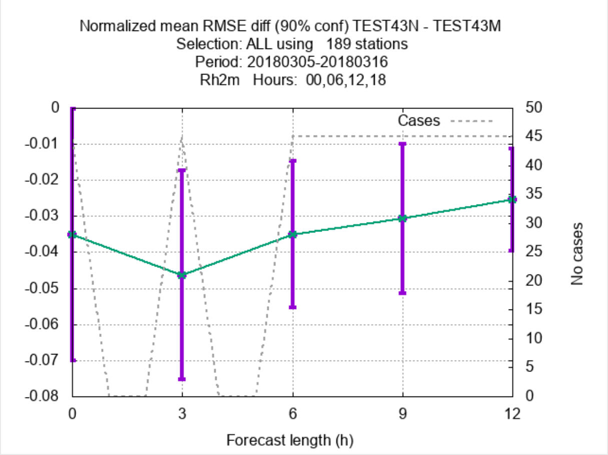
Using Desroziers et al. 2005:
Overall error reduction with supermodding size 30-60 km and increase from 100km and above. We observe also increase of correlation.

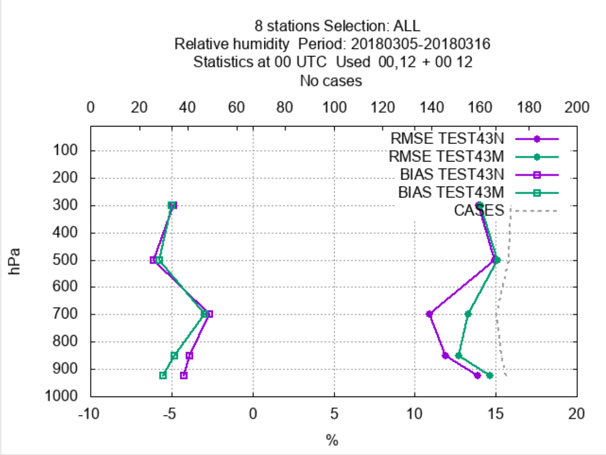
– Case study: Applying the supermodding technique in ASCAT DA improves the forecast of wind speed and direction.
Paper on this work will be submitted soon...

IFS blacklisting decision in Harmonie-Arome DA (CY43)

– In Harmonie DA, we use an old-dated blacklisting file from Meteo France.
– Versions of the IFS blacklisting decision were used in OSEs and reanalysis systems.
– We receive regularly the updated list of blacklisted conventional observations (stations IDs with bad parameters/instruments).
– The implementation is not one-by-one, because we kept the selection of active observations as for ARPEGE/ALADIN/AROME DA. So, mainly the adopted solution concerns only the blacklisting of conventional observations.







Error reduction: MSLP

RH2m

New blacklisting
Old blacklisting

Note the relatively short period.

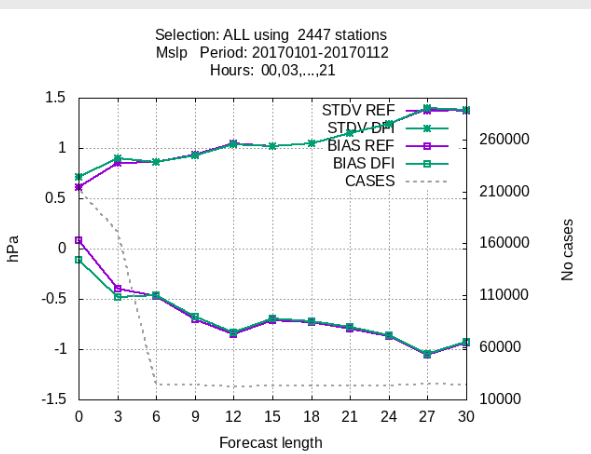
Norwegian Meteorological Institute

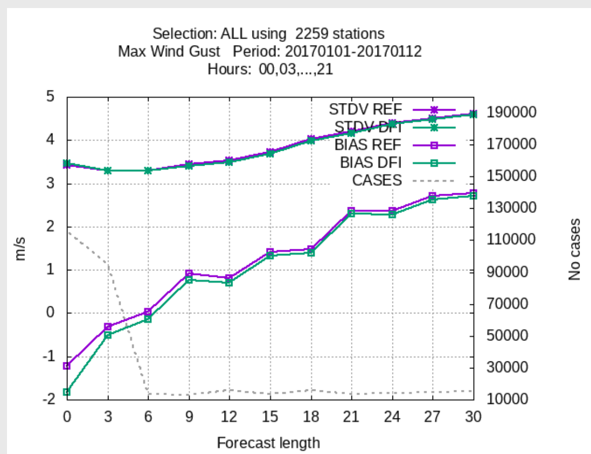
Maybe interesting for you

– At MET Norway we will start the implementation of All-sky radiance assimilation soon.
– Assimilate surface pressure instead of geopotential (0 m).
– Per Dahlgren tested the DFI approach in Precise (Aladin 5.5 km) system
– Radiance assimilation: The RT coeffs were updated to use 54 levels (microwave) and 101 levels for IASI
– Implementation of MHWS-2 (FY satellite series) radiance in MetCoOp
– In CY43 we have the ODB_IO_METHOD=4 instead of ODB_IO_METHOD=1

Potential for cooperation

– High-resolution radiosonde assimilation (both ascent and descent data)
– AMDAR Humidity assimilation
– SAPP package



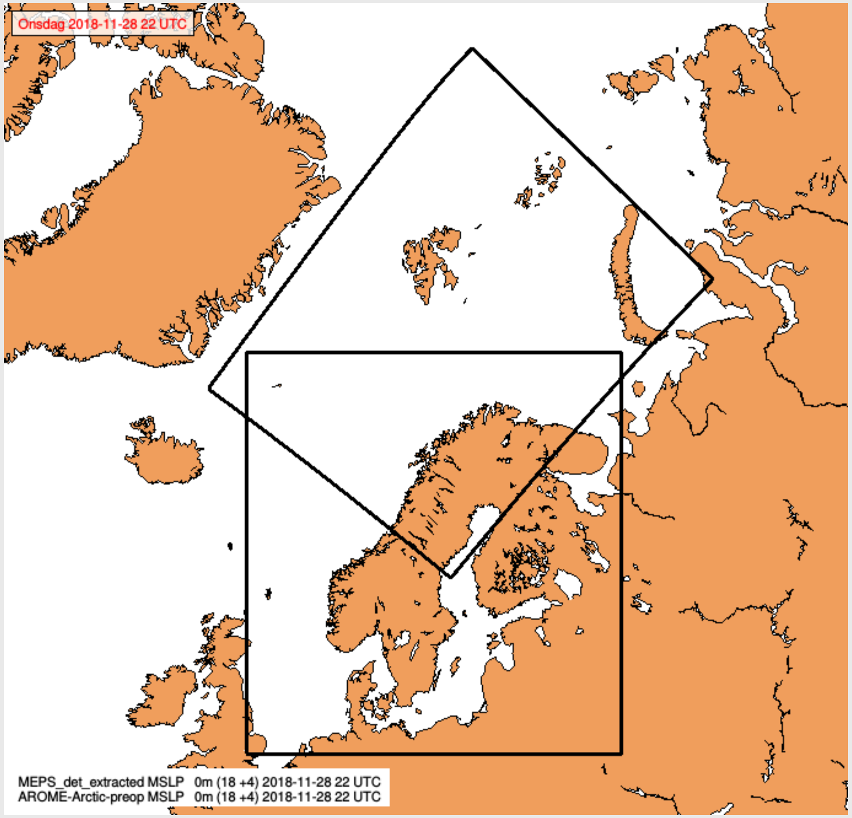


DFI in Aladin 5.5 km

Alertness

Relative impact of observations in LAM

In frame of the Alertness project we studied the impact of Arctic observations in AROME- Arctic model



System setup: (Harmonie cycle 40h1.1.1)

-- AROME-Arctic
-- Model level definition: 65 level
-- Horizontal resolution 2.5 km
-- Non-hydrostatic dynamic
-- Physical parametrization: Harmonie-AROME
-- Data assimilation: 3D-VAR
OI for surface
-- 3-hourly cycling
-- Lateral boundary conditions: ECMWF
-- Observations: Conventional, satellite
-- Satellite: AMSU-A, MHS, IASI, Scatterometer (L2), AMV
-- Blacklist of conventional observations: IFS decision

-- Large scale information taken into account using spectral mixing between first-guess and LBC

OSE experiments in Alertness

Alertness **task 2.5:** In frame of the **APPLICATE** project ECMWF is running OSE experiments and sharing with us the results to be used as lateral boundary conditions (LBCs).
They performed two series of OSE: with global and Arctic (lat >= 60) observations denial.

Scenarios: **(1)Global control LBC1** **(2)Global Arctic denial LBC2** **(3)Global denial LBC3** **4) LAM control** **(5) LAM denial**

<u>Relative impact of observations:</u>
Case 1: LBC1 + (4) vs LBC1 + (5) => impact of obs in LAM
Case 2: LBC1 + (5) vs LBC2/LBC3+ (5) => impact of obs through LBC in LAM
Case 3: **Global** vs **Arctic** denial => impact of non-Arctic observations in Arctic (LAM)NWP

BUT: LBC1 + (4) vs LBC2/LBC3 + (5) shows the real impact of observations

Global study: Bormann et al. 2019; Arctic study: Lawrence et al. 2019

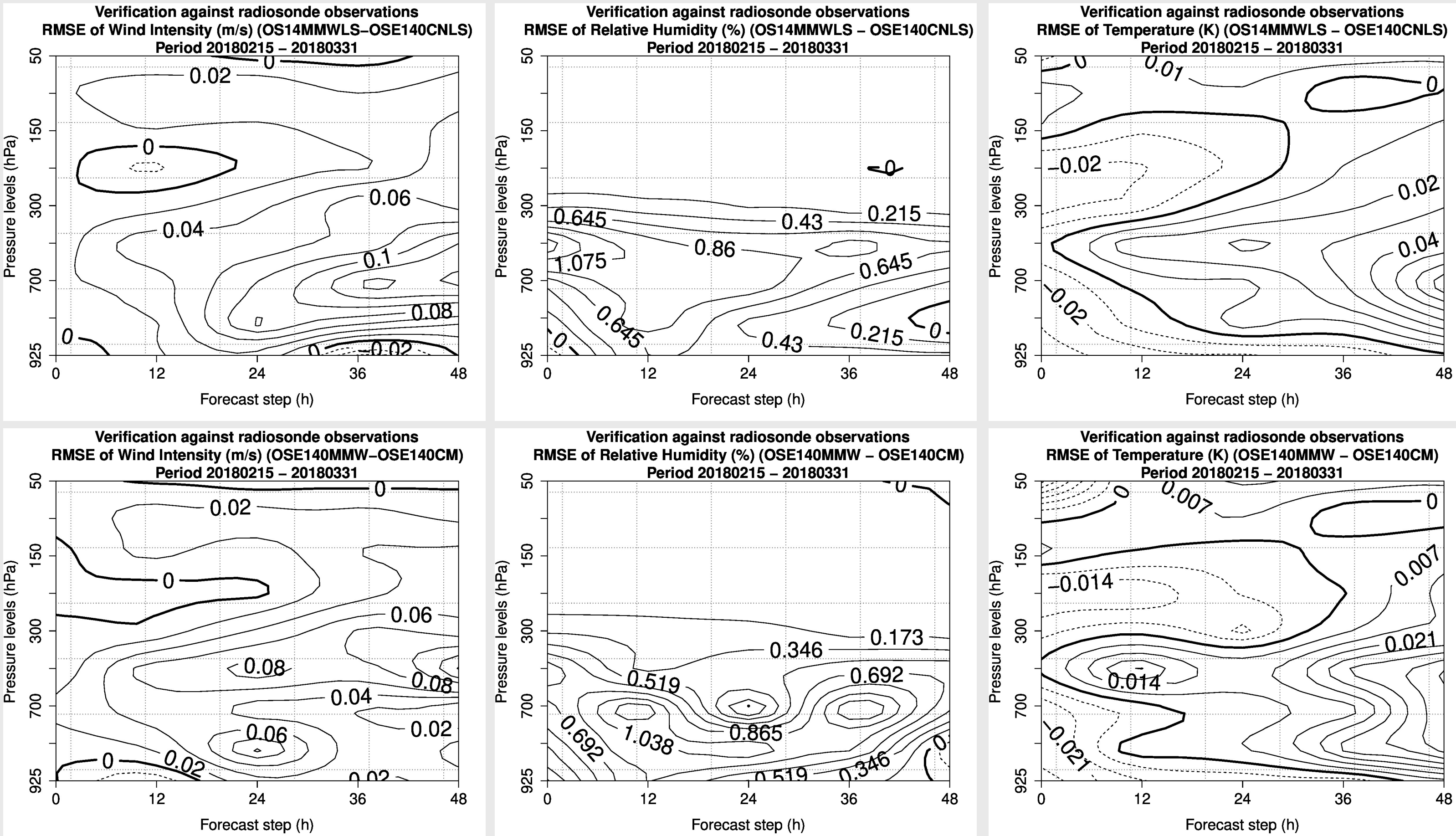
LBCs and the performed experiments

Observations	impact through LAM DA	impact through LBC	real impact	impact of non-Arctic observation
All microwave satellite radiances	yes	yes	yes	yes
All microwave temperature sensitive radiances	yes	yes	yes	
All microwave humidity sensitive radiances	yes	yes	yes	
All infrared satellite radiances	yes	yes	yes	
All atmospheric motion vectors (AMV)	yes			
All conventional observations	yes	yes	yes	
All radiosonde observations	yes	yes	yes	
All surface pressure observations	yes			
All SOP1 observations	yes			

Underlined "yes" means checked for both SOP periods

LBC2: Arctic denial experiments	LBC3: Global denial experiments
All microwave satellite radiances	All microwave satellite radiances
All microwave temperature sensitive radiances	
All microwave humidity sensitive radiances	
All infrared satellite radiances	All infrared satellite radiances
All atmospheric motion vectors (AMV)	
All conventional observations	All conventional observations
All radiosonde observations	
All surface pressure observations	
All SOP1 observations	

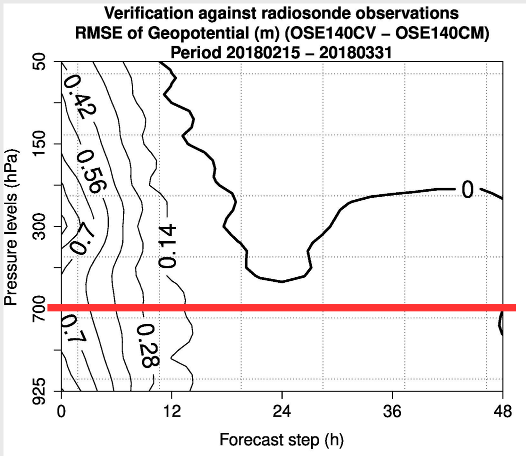
Real impact of microwave radiances in system with and without large scale mixing

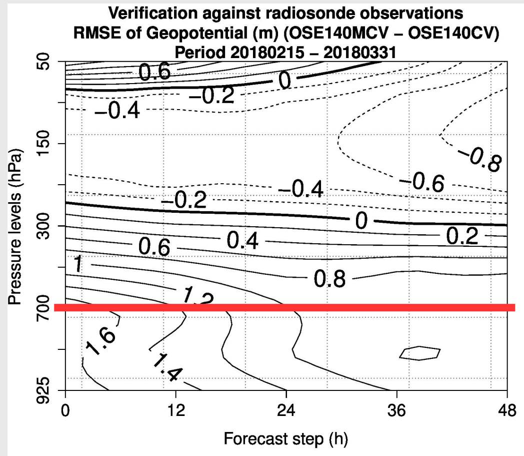


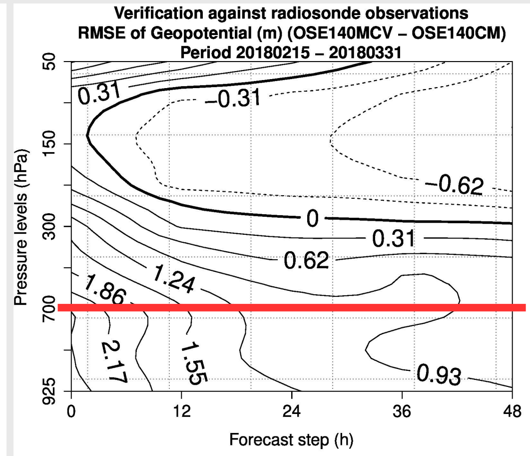
without

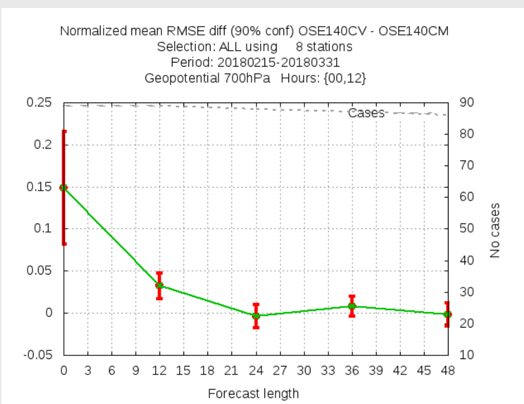
with

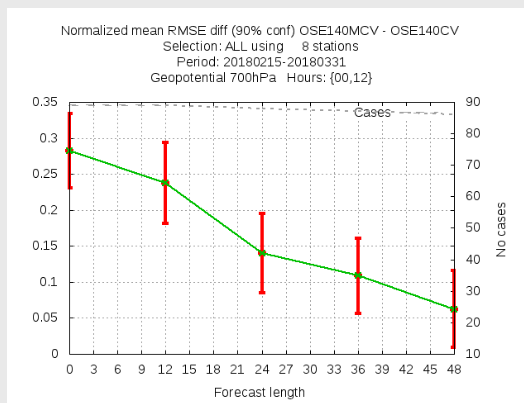
Relative impact of conventional obs. on AROME-Arctic forecasts in a system with large scale mixing

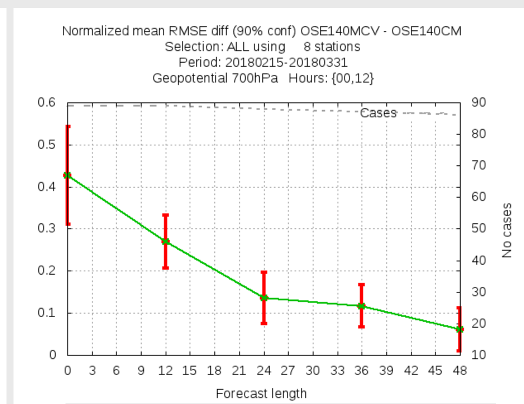












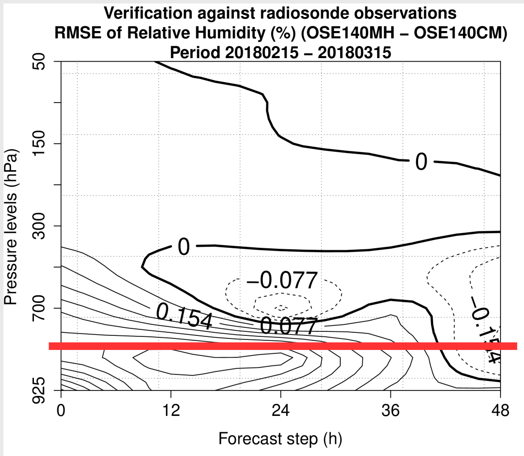
Impact through local DA

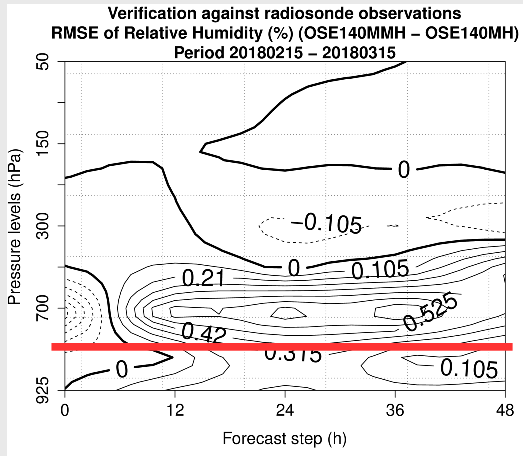
Impact through LBC

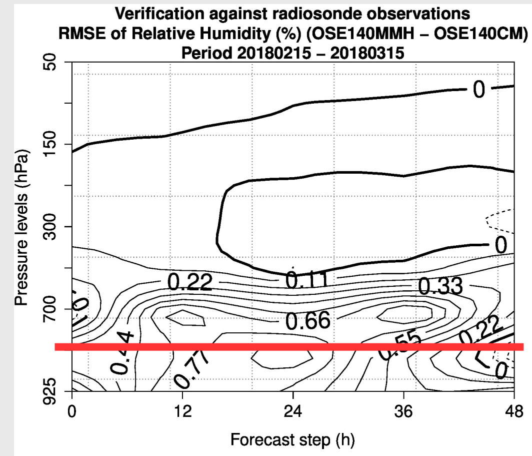
Real impact

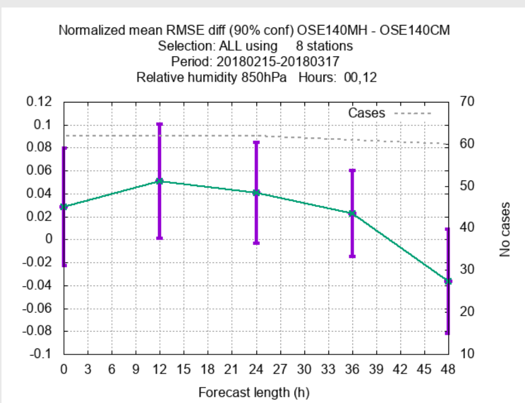
Geopotentia

Relative impact of microwave humidity sensitive radiance on AROME-Arctic forecasts in a system with large scale mixing

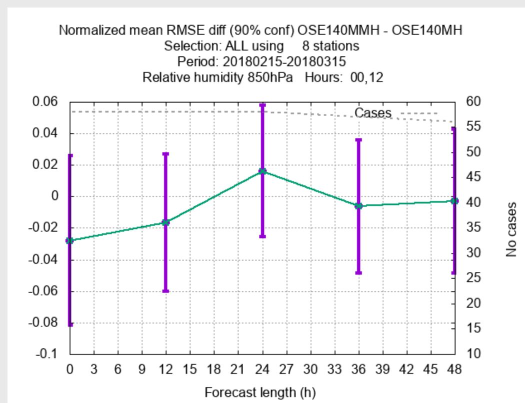




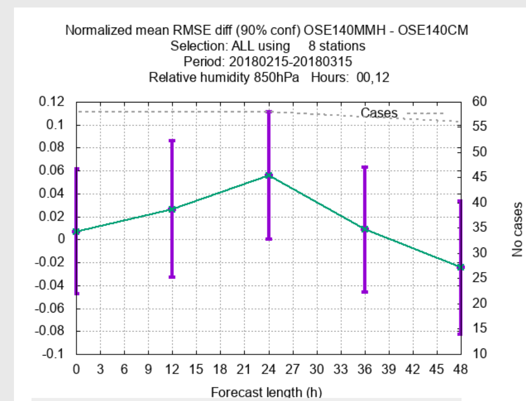




Impact through local DA



Impact through LBC



Real impact

Order of importance

Upper-air forecast

Observations are lost in both global and regional models

SOP1			
Temperature	Wind speed	Relative humidity	Geopotential height
All conventional IR, MW	All conventional IR MW	All conventional MW IR	All conventional IR, MW

Observations are lost in regional model

SOP1			
Temperature	Wind speed	Relative humidity	Geopotential height
All conventional IR, MW AMV	All conventional IR Up. Tr: AMV MW Lo. Tr: MW AMV	All conventional AMV, MW IR	All conventional Up. Tr: AMV, IR (d2) MW Lo. Tr.: MW AMV, IR (d1)
SOP2			
All conventional IR, MW, AMV	All conventional IR AMV MW	All conventional AMV, MW IR	All conventional AMV IR, MW

Many to say about the results, but as example …

Surface parameters: using both 00 and 12 UTC runs during SOP1 period

Surface pressure		2m temperature		
Day-1	Day-2	0 - 12 hours	12 - 24 hours	Day-2
MCV CV, PS RS, MW,MMW, MRS AMV IR, MIR,MT S1N	MCV MRS AMV MIR IR, MMW, S1N RS, CV MW MT, MH	MCV CV PS MRS RS MW, MMW IR, MIR, S1N MT, MH AMV	MCV CV MRS PS, MW, MMW IR, MIR RS, S1N AMV MT, MH	MCV, CV MRS, MW IR, S1N MIR, RS, PS MMW, AMV MT, MH

2m relative humidity		2m Specific humidity	
Day-1	Day-2	Day-1	Day-2
MH MMW, MW MRS, RS MT IR. MIR S1N, AMV MCV CV PS	MRS, MT MH, MIR, MCV MW MMW IR, S1N, RS, AMV CV PS	MCV CV MRS MMW, MW, MH, RS MT, S1N, AMV MIR, IR, PS	MCV CV MRS, MIR MW, MT, RS, AMV, PS, IR, S1N MH MMW

10m Wind speed			Total cloud cover		
0 - 12 hours	12 - 24 hours	Day-2	0 - 12 hours	12 - 24 hours	Day-2
MCV CV RS, MRS MT, MH AMV, S1N, MMW IR, MIR PS, MW	MCV MT MH MW, MMW MIR, CV, RS, MRS AMV S1N, IR PS	MT, MH, MMW MW, MCV, AMV MIR, RS S1N, PS, IR MRS, CV	MCV CV PS, RS, MH, MT MRS, MW MMW, AMV MIR S1N IR	MCV MMW MRS, AMV MT, RS IR MIR MH, MW S1N, CV, PS	MCV MMW MRS, AMV MW, MT, S1N CV, PS MH, IR, MIR, RS

LAM DA is import to get accurate forecasts of surface wind speed ...

Concluding remarks and outlook

– Continue the local implementation of more observations. This depends on the willingness of the local team, but needs also help from experts. So, it's common task…

– I hope to have 4D-VAR in operational soon

– The Harmonie-Arome is already an ensemble system. I hope to have it tuned to use the different recently (or planned) developed DA elements (nowcasting, LETKF and hybrid EnVar schemes)

– ….

Thank you