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USE OF RETRIEVED DATA IN THE HARMONIE-AROME DATA ASSIMILATION SYSTEM

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ABSTRACT

This paper describes the activities related to retrieved wind observations at the Norwegian meteorological institute (MET Norway). The activities include regional reanalysis, calibration and validation (CAL/VAL) and operational application. The reanalysis projects run under the umbrella of the Copernicus climate change service (C3S) for both Europe and the Arctic regional domains. The CAL/VAL project, financed by the Norwegian Research Council, deals with the Aeolus horizontal line-of-sight (HLOS) wind. At the Norwegian Meteorological Institute, both the geostationary and polar orbiting satellite based atmospheric motion vectors (AMV) and the scatterometer wind data were tested in our operational regional numerical weather prediction (NWP) models (MetCoOp and AROME-Arctic). The operational systems are based on the HARMONIE-AROME model. The scatteromer data were introduced into operational in both the systems already a while ago and the decision about the AMV data was taken for the AROME-Arctic and the realisation has started.
This paper describes as well, the result of the assessment of the availability of the AMV wind data at our institute, and the impact study preformed with both MetCoOp and AROME-Arctic models. The impact sturdy was done following the strict requirement on timeliness of observations for short-range and nowcasting operational applications. In the study, winds derived from polar orbiting and geostationary satellites were considered. While from polar orbiting satellites only data from Metop satellites (called hereafter as polar winds) were useful, from geostationary satellites both locally produced (called hereafter as high-resolution winds - HRW) and EUMETSAT produced (EUMW) winds were incorporated.
The polar winds showed clear and significant positive impact on the analyses and forecasts of the AROME-Arctic. While the locally produced HRW showed slightly better impact compared to that of EUMW, the combination of the polar wind and HRW have enhanced positive impact on analyses and forecasts of the MetCoOp models compared that of HRW only.

ACTIVITIES RELATED TO RETRIEVED WIND DATA

In 2017, we started two reanalysis projects in the frame of C3S. MET Norway is leading the Arctic (C3S_322_Lot2) and participate in the European (C3S_322_lot1) regional reanalysis. Compared to the earlier reanalysis projects, these systems will use satellite observations, including the AMVs. This will all the participating Institutes very interesting tasks and opportunity to extend the HARMONIE-AROME (Bengtsson et al., 2017) environment and ability. The European system will be run over the Euro-cordex-4, with the production starting the early 80’s until 2021. Figure 1. shows the domains of the Arctic regional reanalysis system, which starts from 1979 until 2021.
MET Norway is also involved in a CAL/VAL exercise aiming at accessing the quality of the Aeolus HLOS winds. The PRODEX project is financed by the Norwegian Research Council.

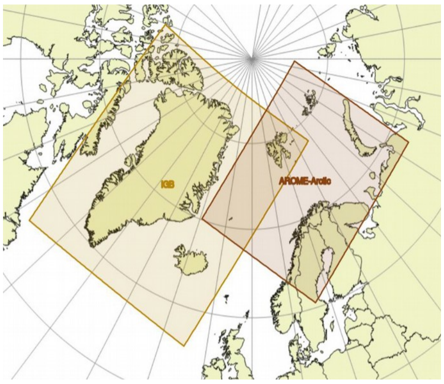


Figure1: **The domains of the C3S_322 lot2 Arctic regional reanalysis system.**

SHORT DESCRIPTION OF THE EXPERIMENTAL MODELS

The dimension of both the regional models MetCoOp and AROME-Arctic was the same at the time of this study: 750x960 grid points with 2.5 km horizontal resolution and with 65 vertical levels. Both use the HARMONIE-AROME physics (Bengtsson et al., 2017), 3D-Variational scheme (Brousseau et al. 2011, Mile et al. 2015) for upper-air fields (ex. winds, temperature, specific humidity and surface pressure), and optimun interpolation for the surface (ex. soil moisture content, skin temperature and snow depth) analyses. For the short-range system a 3-hour cycling and for the nowcasting a 1-hour non-cycling (known also as rapid-refresh - RR) of data assimilation and forecast was applied. In both short-range and nowcasting systems, conventional (ex. synop, ship, dribu, aircraft, radiosonde) and satellite radiances (AMSU-A, AMSU-B/MHS, IASI) and retrievals (AMV) were used. Note, that the operational MetCoOp and AROME-Arctic more observations. While the scatterometer ASCAT data is used by both the models, MetCoOp is using the ground-based GPS (GNSS ZTD) and radar reflectivity observations. For the sake of simplicity, the experiments performed forecasts up to 48 hours twice a day from 00 and 12 UTC, while in the operational systems produce 66 hours forecasts four times a day at 00, 06, 12, and 18 UTC. Both systems use the ECMWF analyses and forecasts as lateral boundary conditions. Figure 2 shows the domains of both systems.

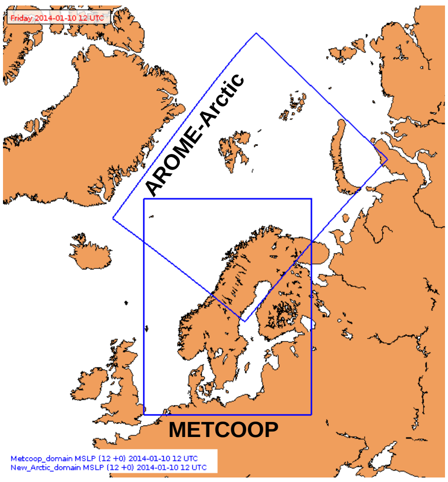


Figure 2: **The domain extension for the MetCoOp and the AROME-Arctic regional models.**

DESCRIPTION OF THE EXPERIMENTS

For the study with short-range system, the following experiments were performed:
The first series (period: 2015 September 1-30) covered the following combination:

Experiments done with MetCoOp configuration:

AMV_NoM: Experiment without AMV data – reference experiment;
AMV_EU1: Experiment with geowind from EUMETSAT (E-geowind);
AMV_SAF3: Experiment with locally produced HRW;
AMV_BSP: Experiment with HRW and polar winds;
AMV_TSB: Experiment all three available AMV data.

Experiment done with the AROME-Arctic configuration:

AMV_NoP: Experiment without AMV data – reference experiment;
AMV_2MP: Experiment with polar winds.

The second series (period: July 1-31) of experiments used the following combination:

Experiments done with MetCoOp configuration:

AMV_JNoM: Experiment without AMV data – reference experiment;
AMV_JBSP: Experiment with HRW and polar wind;

Experiment done with the AROME-Arctic configuration:

AMV_JNoP: Experiment without AMV data – reference experiment;
AMV_J2MP: Experiment with polar winds.

For the study with the nowcasting system, the following experiments were performed:
AMV_BRR: 3-hourly cycling experiment (using all available observations, including AMVs);
AMV_NNWC: RR without HRW;
AMV_NWC: RR with HRW.
AMV_ATO: RR without ATOVS radiances;

RESULTS

Sensitivity of the HARMONIE-AROME analysis system to the AMV data:
Using the above experiments, the degrees of freedom for signals (*Chapnik et al. 2006)* was computed following *Randriamampianina et al. (2011)* to evaluate the sensitivity of our system to the AMV data. Fig.3 shows, although relatively small amount of geostationary satellite based AMV data was assimilated, modest influence to the data assimilation system influencing the assimilation of other observations in the system (see arrows in Fig3).

Sensitivity of the HARMONIE-AROME forecasts to the AMV data:
To evaluate the sensitivity of the MetCoOp forecasts to the AMV data, a technique using the most total energy norms (MTEN) (*Storto and Randriamampianina, 2010*) differences was applied. One can see that both polar and HRW winds cause similar sensitivity to the MetCoOp forecast system.

Impact of the AMV data on analyses and forecasts in (3-hourly) cycled data assimilation system

Accounting for the availability of the polar, HRW and EUMW observations, the impact of the HRW and EUMW was evaluated using the MetCoOp model, while the impact of the polar winds was evaluated using both the regional models.

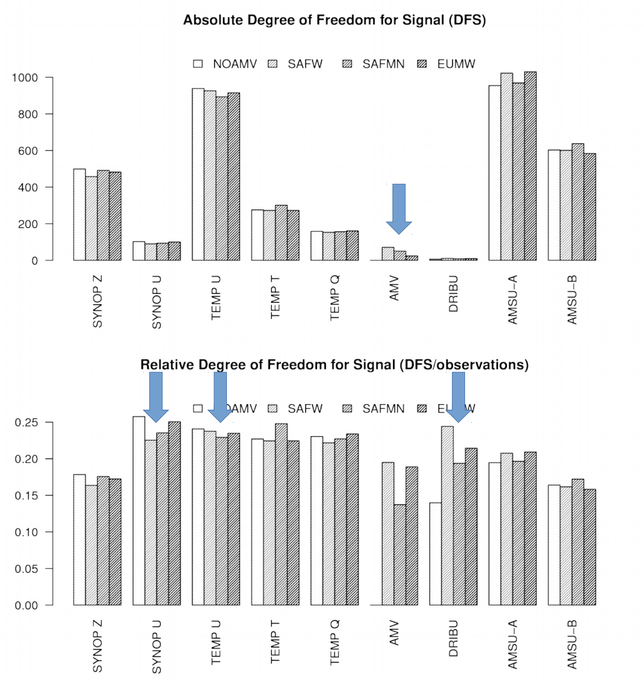


Figure 3: **Absolute and relative DFS averaged from different assimilation times. NOAMV is a system without AMV; SAFW and SAFMN are systems using tuned HRW data; and EUMW is the system using AMV winds produced at EUMETSAT.**

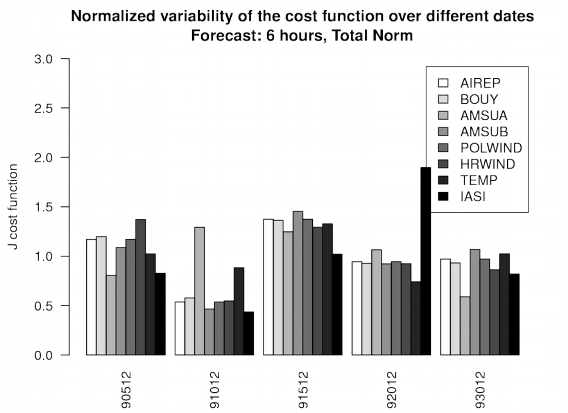


Figure 4. **The estimated normalised cost function showing the moist total energy norm loss in the forecast model when losing different observations from the analysis system. This shows how sensitive the model forecast to these observations. The observations from white to dark black is AIREP, BOUY, AMSUA, AMSUB, POLWIND, HRW, TEMP; and IASI. The horizontal label is showing month, day and hour. For ex. 90512 means 5th of September 12 UTC.**

Impact of polar winds on analyses and forecasts of the AROME-Arctic:
Figure 5 shows that the impact polar winds is positive up to 24 hours forecast for relative humidity and it lasts even longer for wind and geopotential fields.

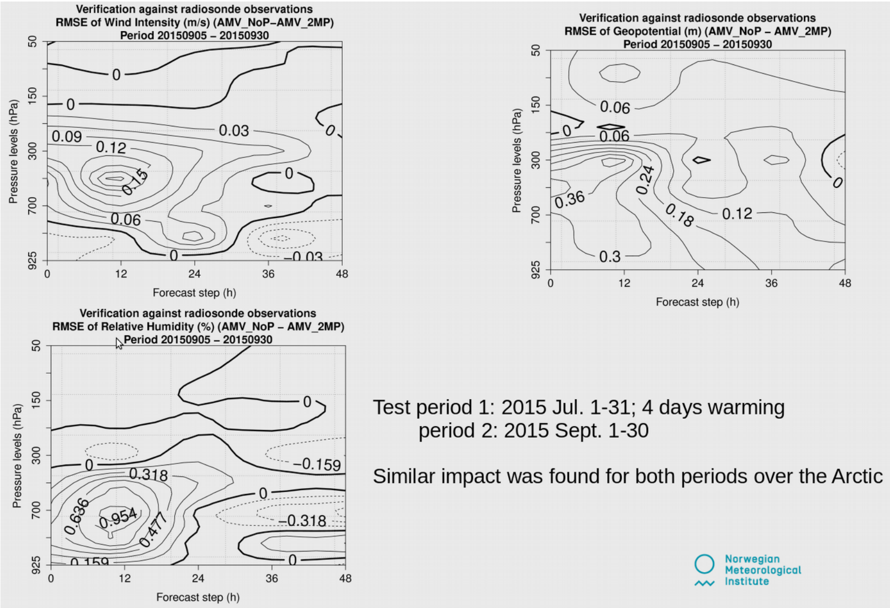


Figure 5: **the impact of polar winds on the AROME-Arctic analyses and forecasts.**

Impact of the individual wind data on the analyses and forecasts of the MetCoOp model:

Figure 6 shows the impact of the individual AMV on analyses and forecasts of the MetCoOp model.

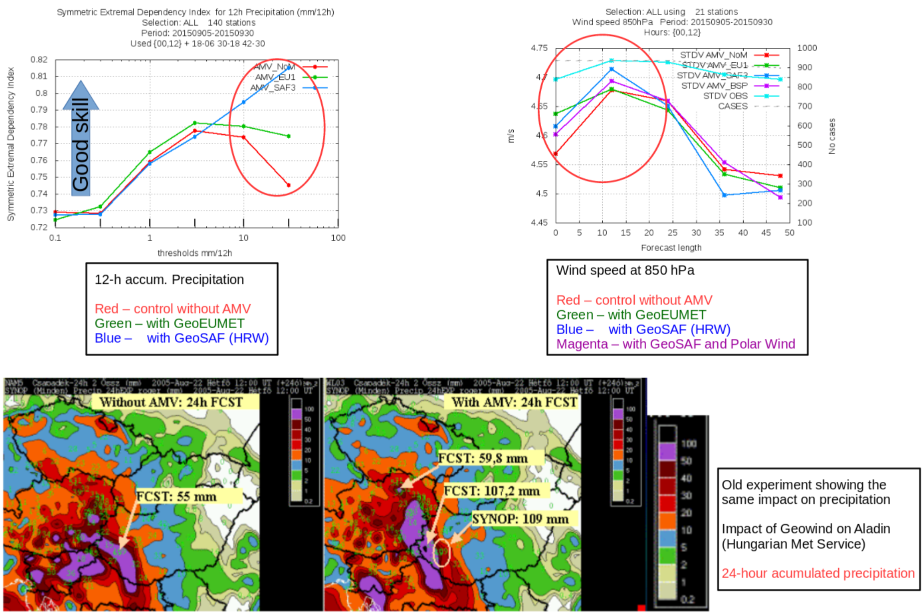
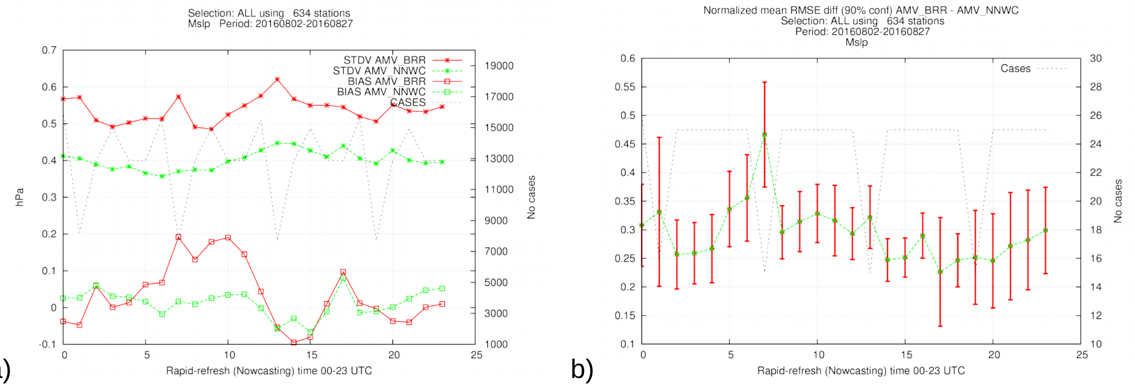


Figure 6: Impact of the individual wind data showing similar impact of the geostationary based AMV on large precipitation events. All AMV data have positive impact on the low level wind (850hPa).

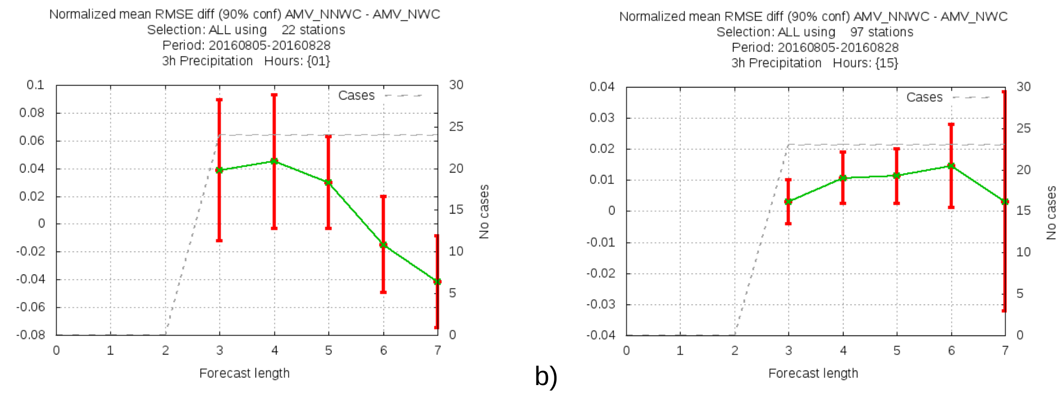
Impact of the AMV data on the rapid-refresh nowcasting system:
Figure 7 shows the accuracy of the rapid-refresh compared to the 3-hour cycling system.



a) b)

Figure 7: **Standard deviation and bias of the modelled mean sea level pressure (MSLP) from 3-hourly cycling (red) and RR (green). (a) is showing the nowcasting (analysis) error in comparison against observations, and (b) is showing the respective significance test of the normalised root-mean-square error (RMSE).**

The impact of the HRW was evaluated in the RR system. Figure 8 shows the impact of the HRW on the nowcasting (RR) 3 hours accumulated precipitation amount. A moderate promising positive impact is observed.



a) b)

Figure 8: **Significance test of the normalised root-mean-square error (RMSE) for 3-hourly accumulated precipitation for two nowcasting times: 01 (a) and 15 (b) UTC.**

CONCLUDING REMARKS

Through DFS computation, AMV data influence the analysis system so that the surface observations show slightly less relative influence. The sensitivity of the model to the AMV data is slightly higher than that of the other observing systems used the analysis in case of non-stationary or intense weather phenomena.

At MET Norway, we have now few projects dealing with different retrieved wind data. The ASCAT data was shown to have slightly positive impact on the analyses and forecasts of the Harmonie-Arome. Geostationary AMV have moderate positive rather than neutral impact on MetCoOp upper-air analyses and forecasts. The impact on the intense precipitation is clearly positive. The impact of the polar winds on the analyses and forecasts of the AROME-Arctic is clearly positive for both surface and upper-air fields. Using the polar winds together with the HRW significantly improved the accuracy of the analyses and forecasts of the MetCoOp model for both surface and upper-air levels. Using all the three available wind data sets together did not provide further clear improvement. For example this was seen in loss of accuracy in forecasts of precipitation. This probably indicates a redundancy problem with geostationary AMV (HRW and EUMW) data in the assimilation system.

Taking into account the timeliness of the geostationary and polar winds, the geostationary winds (HRW) was tested in the 1-hourly non cycling rapid-refresh (RR) system, where comparable impact as on the 3-hourly cycling DA was found. Positive impact on forecasts of precipitation and cloudiness was observed.

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