Use of geostationary and polar atmospheric motion vectors

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Introduction

One of the gaps identified in many studies of the present atmospheric observing system is the limited amount of upper-air wind observations (see for instance recent simulation studies on the positive impact on forecasts of adding wind data to the present observing system by *Riishojgaard et al, 2012* and *Garand et al 2013*). The planned Aeolus mission (*Stoffelen et al, 2005*) is expected to demonstrate use of spaceborne LIDAR for the purpose of filling part of this gap, but there are presently no plans for any operational follow-on. The only other presently available satellite based wind observation dataset is so-called Atmospheric Motion Vectors (AMVs), where the winds are indirectly derived from displacements in consecutive satellite images. However, these winds have earlier had problems of long latency, limited coverage, in particular at high latitudes, and quality problems, partly connected to height assignment. Applying these data for forecasting for Norwegian and Arctic areas has therefore not been so interesting up to now.

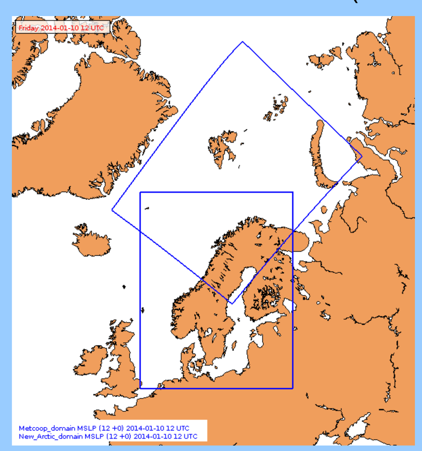
We have recently seen progress in international research which has lead to improved AMVs and new products from recent satellite programs. There are now products with better horizontal resolution and in addition novel AMV products from polar orbiting satellites which have increased the coverage at high latitudes dramatically. There has also been an evolution in the ground infrastructure and processing, giving a potential for faster delivery well suited for our purposes in regional weather prediction with rapid updating. There is reason to believe that there is a significant potential for benefit from assimilating these data in our regional numerical weather prediction (NWP) system for application both in rapid update cycling over a Nordic area and over an Arctic domain.

SAWIRA project gives a framework to assess the availability of the AMV data at MET Norway and also possibility for testing their use in our regional NWP models (AROME-MetCoOp and AROME-Arctic). The processing and assimilation of AMV data in this study follows the implementation work done at the Hungarian Meteorological Service (*Mile at al.*, 2015).

The AROME-Arctic and AROME-METCOOP test models

System setup: (Harmonie cycle 38h1.1)
Domain: 750x960 grid points; **Horizontal resolution:** 2.5 km; **Model level definition:** 65 level;
Non-hydrostatic dynamic; **Physical parametrisation:** AROME/mezo-NH; **Assimilation strategy:** 3-hourly cycling; **Lateral boundary conditions:** hourly ECMWF; **Surface data assimilation:** Optimum interpolation; **Upper-air data assimilation:** 3D-VAR

Used observations: Surface (SYNOP, DRIBU), Radiosondes, Aircraft, ATOVS (AMSU-A, AMSU-B/MHS) and IASI



Radiances assimilation:
– AMSU-A : Channels 5 -10;
– AMSU-B/MHS: Channels 3 - 5;
– IASI : 65 Active channels
38, 51, 63, 85, 87, 104, 109, 167, 173, 180, 185, 193, 199, 205, 207, 212, 224, 230, 236, 239, 242, 243, 249, 252, 265, 275, 294, 296, 306, 333, 337, 345, 352, 386, 389, 432, 2701, 2819, 2910, 2919, 2991, 2993, 3002, 3008, 3014, 3027, 3069, 3087, 3098, 3207, 3228, 3281, 3309, 3322, 3339, 3438, 3442, 3484, 3491, 3499, 3506, 3575, 3582, 3658, 4032

AMV data: MPEF, HRW AMV and Polar AMVs

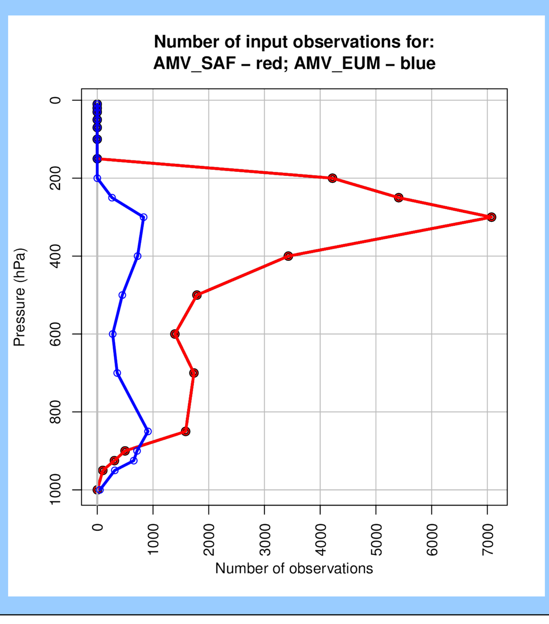
The experimental AROME-Arctic and AROME-Metcoop domains.

Access to AMV data at MET Norway

We checked the availability of the AMV data at MET Norway, which can be summarised the following ways:
– We receive the AMV data trough two sources: 1) the EUMETSAT data transmission system – EUMETCast and 2) the global telecommunication system – GTS.
– Almost all products are available through the EUMETCast, and with lower latency than those received through GTS.
– The latency of the EUMETSAT geostationary satellite based AMV received through EUMETCast is roughly 9 minutes, which is far less than our cut-off (time used to wait for the observations in operational regime) used in our rapid refresh and operational data assimilation systems (see more details below).
– We found quite big differences between the latency of the polar orbiting satellite based AMV (called also polar winds and will be referred as polar winds hereafter) depending on the production centre and the technique used in their production. For example, polar winds produced at EUMETSAT using triplet Metop B-A-B have lower and good enough latency (maximum 1 hour 10 minutes) compared to the triplet Metop A-B-A with maximum latency of 1 hour 53 minutes. Using our operational cut-off of 1 hour 45 minutes, the polar winds from triplet Metop B-A-B fits well and can be used in the operational AROME-Arctic. The only problem is that these data are not available for our early morning runs (00, 03, 06 UTC). The latency of the polar winds from TERRA satellite and produced in Tromsø (by the way stopped in 4th of September) is with minimum above 2 hours. So, we cannot use them with our "main assimilation cycles" – 00, 06, 12, 18 UTC. When these data are produced at EUMETSAT, the latency is also long, with minimum about 2 hours. Polar winds produced at EUMETSAT based on VIIRS data from NPP have also long latency with minimum above 2 hours. It's clear from these data that for our early morning runs, we need to find solution for faster production of the polar winds.

Producing the AMV data at MET Norway

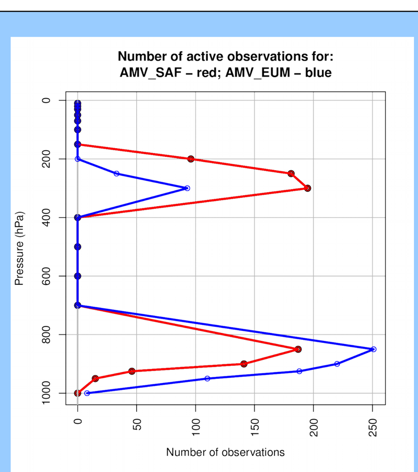
Several centres (Hungarian Meteorological Service and UK MetOffice) reported good experience of producing the AMV data locally. That is why we also implemented the satellite application facility for nowcasting (SAF-NWC) package at MET Norway to process the geostationary AMV. The implemented package uses the European centre for medium range weather forecasting (ECMWF) products as a priory information for the retrieval of wind data. One of the advantages of using the locally produced winds is the relatively high number of AMV compared to the ones produced at EUMETSAT (see Fig1, as used in our test runs).
As explained above, to access the polar winds within cut-off time, we need solution to produce these data locally. We seek retrieval packages that are able to process polar winds from polar orbiting satellites available in early morning over our area of interest. Such satellites can be NOAA-19 and NOAA-18 or their combination with other satellites (NPP) like the example of Metop A and B satellites.



The NWCSAF retrieval package (release edition v2013) was successfully implemented where the default HRW configurations were slightly modified in order to fit more to the DA system of AROME/Hungary. The main characteristics of the HRWproduct were the following:
- BUFR format for data assimilation: EUM
- Output filtering QI_THRESHOLD = 70%
- Channels to be used for AMV retrieval: HRVIS, VIS08, IR108, WV062, WV073
- Without using wind guess information WIND_GUESS = 0

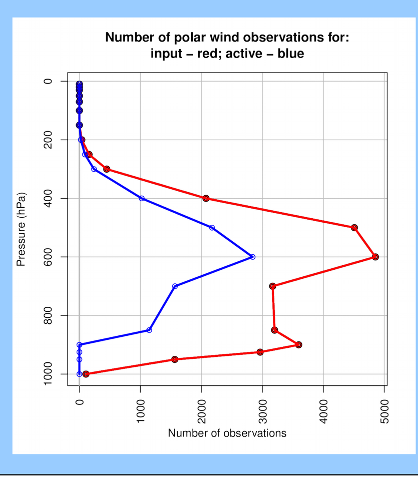
Testing AMV data at MET Norway

The following experiments were conducted:
AMV_EUM – experiment using geowind from EUMETSAT and tested in AROME-MetCoOp;
AMV_SAF – experiment using locally produced geowind and tested in AROME-MetCoOp;
AMV_2ME – experiment using polar winds and tested in AROME-Arctic;
AMV_NOW – reference experiment (no geowind) for the MetCoOp test runs;
AMV_ANO – reference experiment (no polar winds) for the Arctic test run.



The availability of AMV data – first experiments

	Locally produced geowinds (retrieval technique used)	Geowinds from EUMETSAT (retrieval technique used)	Polar winds (retrieval technique used)
00 UTC	WVCL1, WVCL2, IR3	WVMIX1, WVMIX2, IR3	IR
03 UTC	WVCL1, WVCL2, IR3	WVMIX1, WVMIX2, IR3	IR
06 UTC	WVCL1, WVCL2, IR3, VIS2, VIS3	WVMIX1, WVMIX2, IR3, VIS2, VIS3	IR
09 UTC	WVCL1, WVCL2, IR3, VIS2, VIS3	WVMIX1, WVMIX2, IR3, VIS2, VIS3	IR
12 UTC	WVCL1, WVCL2, IR3, VIS2, VIS3	WVMIX1, WVMIX2, IR3, VIS2, VIS3	IR
15 UTC	WVCL1, WVCL2, IR3, VIS2, VIS3	WVMIX1, WVMIX2, IR3, VIS2, VIS3	IR
18 UTC	WVCL1, WVCL2, IR3, VIS2	WVMIX1, WVMIX2, IR3, VIS2, VIS3	IR
21 UTC	WVCL1, WVCL2, IR3, VIS2	WVMIX1, WVMIX2, IR3	IR

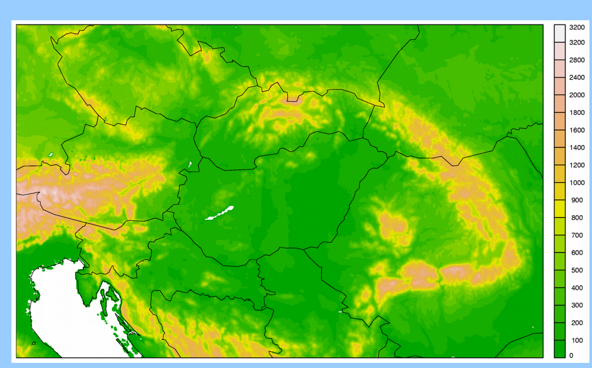


Concluding remarks

The geostationary satellites based AMV data are available at MET Norway with very reliable latency for both short-range and nowcasting (rapid refresh system) weather forecasting. We assess in this report access to kinds of products: 1) locally processed and 2) produced at EUMETSAT.
Regarding to the access to the polar satellite based AMV data, we found quite serious long latency of some of the products. But, we found that some of the Metop satellite based polar winds have acceptable latency suitable for our operational application. These data are mainly available for assimilation from 09 till 21 UTC. We, then, still miss data for early morning runs (00, 03, and most of the time for 06 UTC). Solution can be locally processing of NPP and NOAA-19 satellites observations. As discussed in Section 2, this is a complex solution and needs some time for its realisation. The CSPP package can be a good candidate as tool for locale processing of additional polar winds.
Concerning the assimilation and impact of the AMV data on the AROME-MetCoOp and AROME-Arctic models, the data are assimilable and have acceptable quality. Based on our earlier experience (*Randriamampianina, 2006*), some tuning work is needed to use more retrievals not only from the locally produced geowinds, but also for those processed at EUMETSAT. We need to check if further tuning is beneficial concerning the polar winds from both Metop satellites.
From the 10 days test runs, the impact of both geowind and polar winds is very promising. We are very glad to see that more polar winds are available at most of our assimilation time (from 09 to 21 UTC). This is very good news and the positive impact makes these data more attractive for us.

The AROME mesoscale model in Hungary

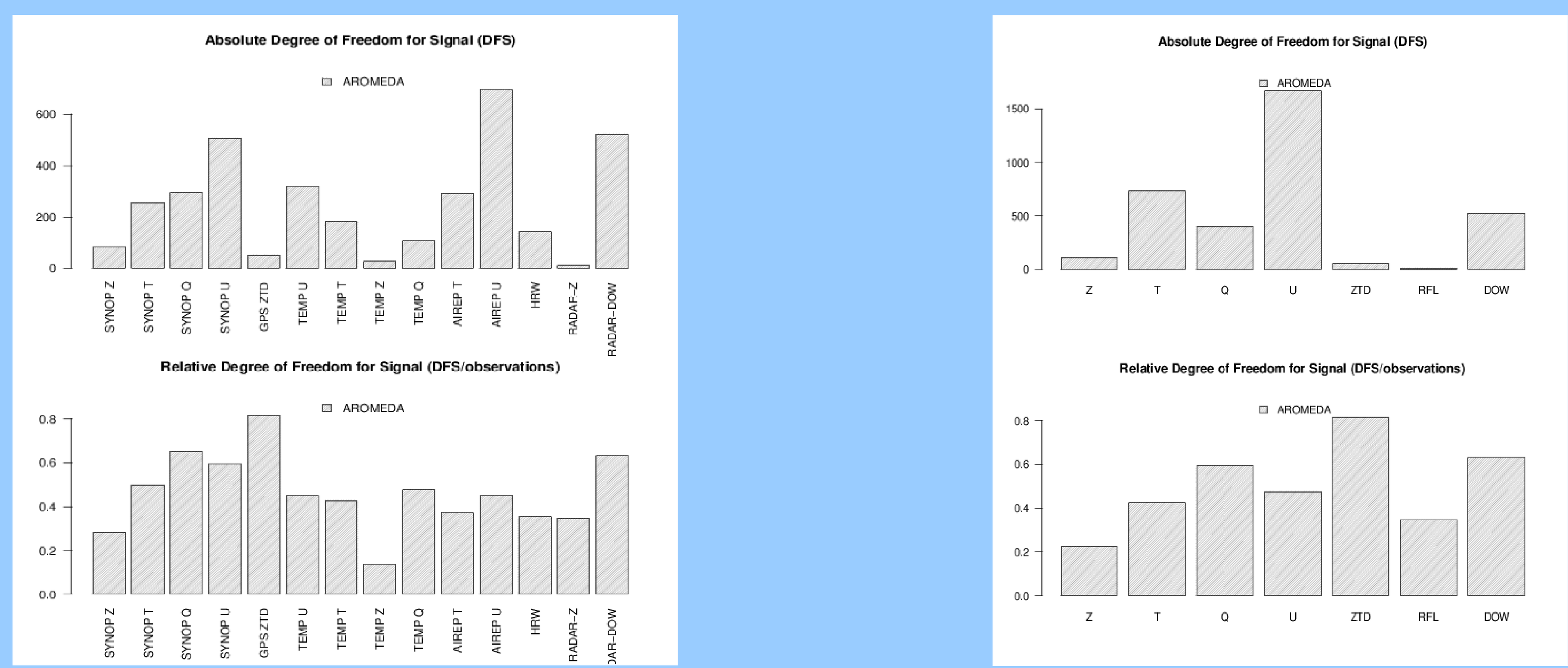
System setup: cycle 38t1_bf03
Domain: 500x320 grid points; **Horizontal resolution:** 2.5 km; **Model level definition:** 65 level;
Non-hydrostatic dynamic; **Physical parametrisation:** AROME/mezo-NH; **Assimilation strategy:** 3-hourly cycling; **Lateral boundary conditions:** hourly ECMWF; **Upper-air data assimilation:** 3D-VAR; Background error statistics computed as mean over 4 seasons.



The operational AROME domain used at the Hungarian Meteorological Service.

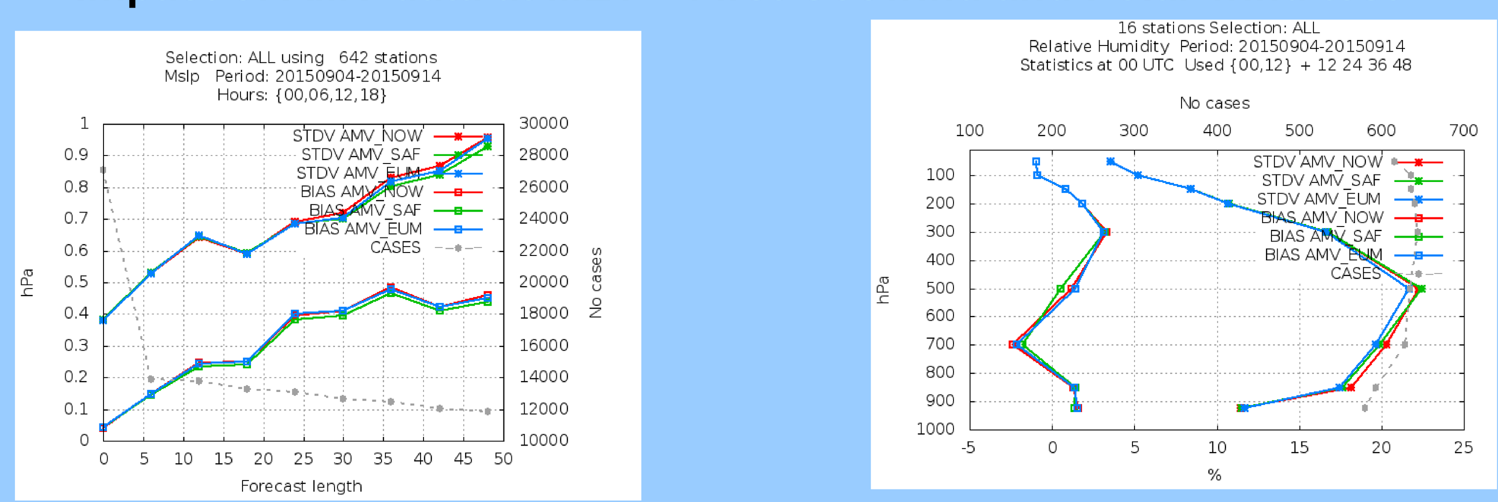
The use of observations and characteristics of the DA system
- Observations are downloaded from the OPLACE system (Operational Preprocessing for LACE)
- SYNOP (T, Rh, Z)
- SHIP (T, Rh, Z, u, v)
- TEMP (T, u, v, q)
- AMDAR (T, u, v) with 10 km thinning distance and 3 hours time-window
- AMV (MPEF and HRW AMV) data (u, v) (experimentally tested on the top of conventional observations)
- Web-based observation monitoring system

Sensitivity of the AROME/Hungary analysis system to observations

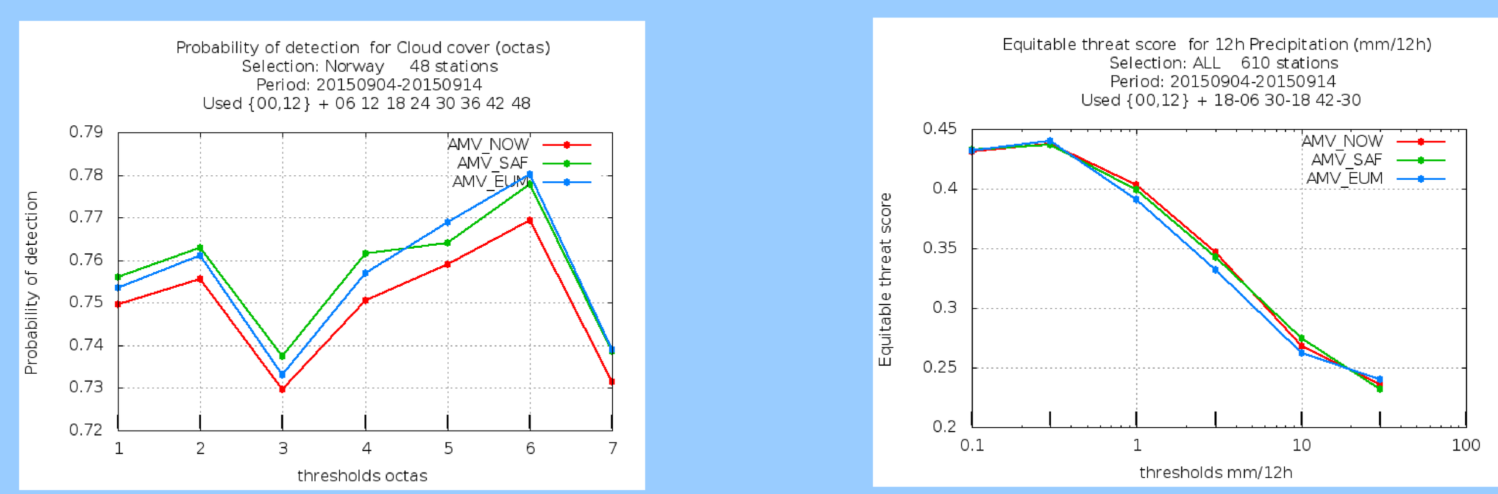


The absolute (on the top) and relative (on the bottom) DFS for AROME/Hungary DA system. Figures on the left are for each observed parameters by the different observation types and figures on the right are for parameters gathered regardless the observation types.

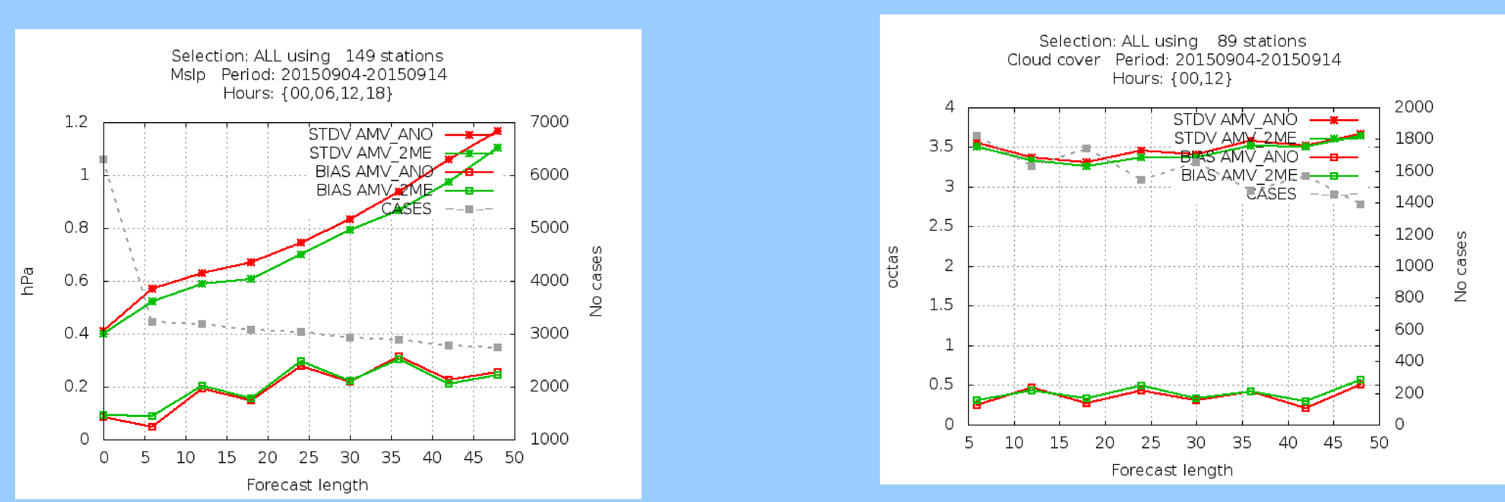
Impact of AMV data at MET – First Geowind and Polar wind test



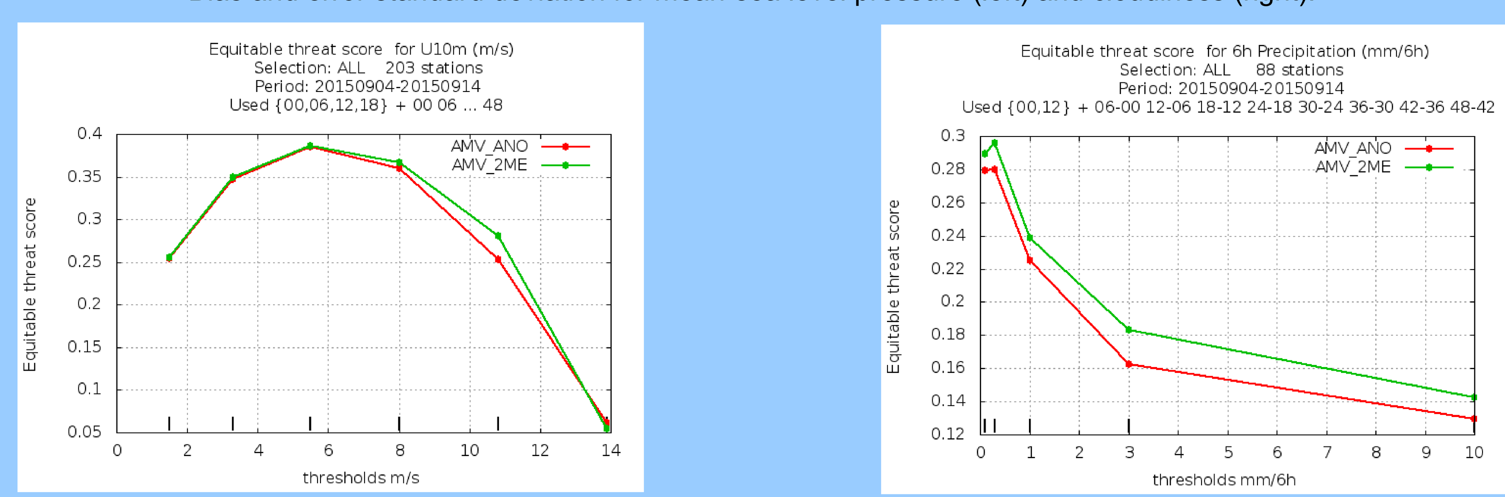
Bias and error standard deviation for mean-sea level pressure (left) and relative humidity profiles (right).



Skill scores showing the impact of geowind data on the forecast of cloudiness (left) and 12-hour accumulated precipitation (right). One can see that both geowind data provide higher probability of detection for cloud cover. The geowind data have neutral rather than slightly negative impact on 12-hour accumulated precipitation.



Bias and error standard deviation for mean-sea level pressure (left) and cloudiness (right).



Equitable thread score (ETS) for 10m wind (left) and 6-hour accumulated precipitation (right). Note, in this score the higher the better.