Use and impact of ATOVS in the DMI-HIRLAM regional weather model

Jakob Grove-Rasmussen, Bjarne Amstrup and Kristian S. Mogensen

Danish Meteorological Institute, Lyngbyvej 100, DK-2100 København Ø.
Emails: jgr@dmi, bja@dmi.dk and ksm@dmi.dk

Introduction

The HIRLAM (HIgh Resolution Limited Area Model) 3D-VAR (three dimensional variational) data assimilation system (Gustafsson et al., 2001; Lindskog et al., 2001) has been used operationally at DMI since October 2001. A major reason for changing from the former OI (Optimum Interpolation) data assimilation system was to be able to make better use of satellite radiance data. At DMI experiments with use of locally received ATOVS AMSU-A data has been ongoing since 2001 (Amstrup, 2003; Schyberg et al., 2003). Based on this, use of locally received NOAA16 AMSU-A data (channels 1-10) was made operational December 2002, and use of locally received as well as EARS (EUMETSAT ATOVS Retransmission Service) NOAA16 and NOAA17 AMSU-A data (channels 1-10) has been operational since September 2nd 2003.

DMI-HIRLAM

The DMI-HIRLAM system is a 3 dimensional variational assimilation system covering four regions. The largest region is based on lateral boundaries from ECMWF (European Centre for Medium-Range Weather Forecasts), whereas the inner models are based on lateral boundary input from the sourrounding model. All models have 40 vertical levels reaching 10 hPa.

In the operational HIRLAM 3D-VAR system the following observation types (and observation quantities) are used: SYNOP (pressure), DRIBU (pressure), SHIP (pressure), TEMP (temperature, wind and specific humidity), PILOT (wind), AIREP (temperature and wind), NOAA16 and NOAA17 AMSU-A data (brightness temperature) and QuikScat data (surface wind).
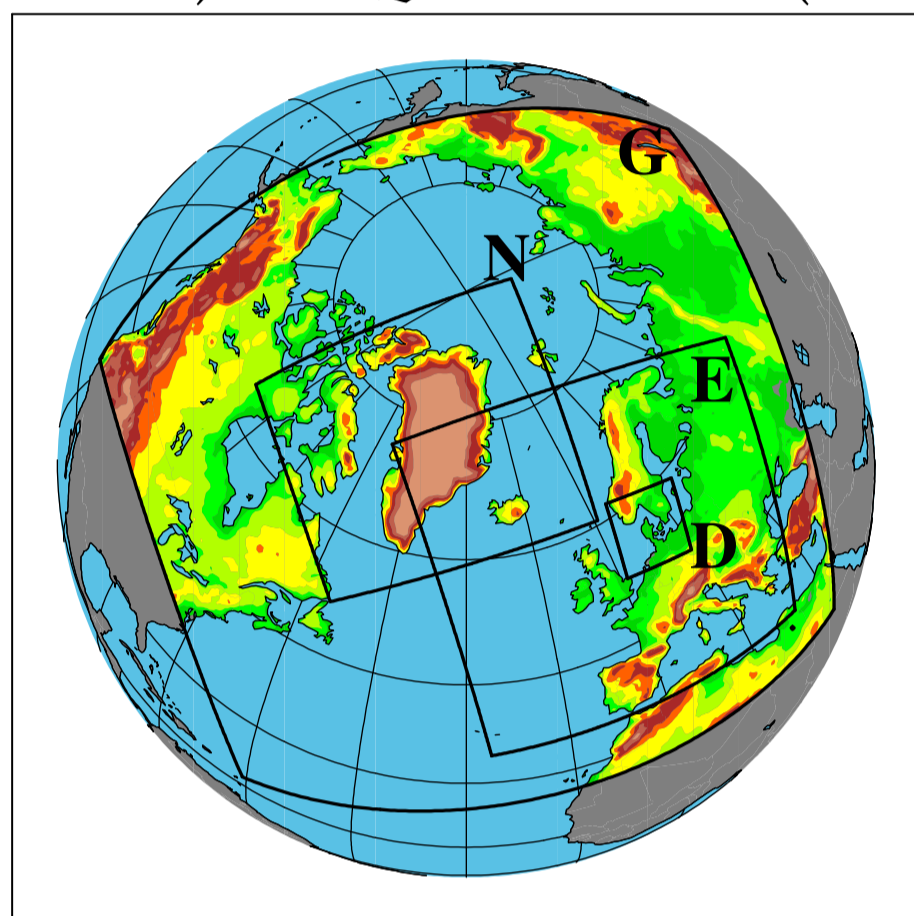
Model Identification	G	N	E	D
grid points (mlon)	202	194	272	182
grid points (mlat)	190	210	282	170
No. of vertical levels	40	40	40	40
horizontal resolution	0.45°	0.15°	0.15°	0.05°
time step (dynamics)	120 s	50 s	50 s	18 s
time step (physics)	360 s	400 s	300 s	216 s

Figure 1: Operational DMI-HIRLAM domains. See (Sass et al., 2002; Amstrup et al., 2003) for further details on the operational DMI-HIRLAM system.

Data flow

The AMSU-A data used are received via HRPT (High-Rate Picture Transmission) which have been processed by AAPP (ATOVS and AVHRR Processing Package, provided via EUMETSAT) to level 1c. The level 1c data are either received via local equipment or via EARS. The level 1c data are processed into BUFR code which is used in the 3D-VAR analysis system. The analysis system consists of observation preprocessing, screening of observations and minimization of a cost function.

Forward model and data usage

The forward model presently used at DMI to calculate model derived brightness temperatures for ATOVS data is RTTOV7 (Radiative Transfer model for TOVS, release 7) developed in the Numerical Weather Prediction SAF (Satellite Application Facility) project setup by EUMETSAT. As DMI-HIRLAM reach only 10 hPa the radiative transfer equation integration is using a climatological model above this height.

Data is presently rejected over land and ice, and a cloud clearing based on the total cloud liquid water content is made since the effect of precipitable particles is not modelled in the radiative transfer model. The data are subsequently thinned to 0.9° for NOAA16 and NOAA17 data separately.

Data sources

Three data sources are available for the assimilation system: distribution via NOAA/NESDIS, locally received and received through EARS. The first source is received too late for use in the regional model. The second source is having a limited coverage, determined by the location of the stations (in our case at Kangerlussuaq (Greenland) and Smidsbjerg (Denmark)). The third source (EARS) has a coverage determined by the amount of connected receiver stations and delivers data within 30 minutes (see www.eumetsat.de/en/dps/atovs.html). In the operational DMI-HIRLAM system both locally received and EARS data are used.

Bias-correction and error statistics.

For bias-correction 7 predictors from the background model (model first guess) are used: **1)** a constant displacement, **2)** thickness between 1000 hPa and 300 hPa, **3)** thickness between 200 hPa and 50 hPa, **4)** the surface temperature, **5)** the integrated water vapor content per area from the surface up to the top of the atmosphere, **6)** the square of the observation zenith angle and **7)** the observation zenith angle. The examination that was done for NOAA16 data (Schyberg et al., 2003) showed that the scatter of the difference between observed and modelled brightness temperature varied significantly as a function of latitude. Accordingly, there are separate bias-correction coefficients for three latitude bands: **1)** up to 50°N, **2)** between 50°N and 65°N, and **3)** north of 65°N. The bias-correction coefficients used operationally at DMI for the NOAA17 data were originally based on passive runs from October 19th to November 12th 2002. For NOAA16 data the bias-correction coefficients were based on data from the full month of April 2002. New bias estimates are based on 271 days of data from 2003. This has decreased the bias slightly.

The observation error covariance matrix has been chosen diagonal with the same values for NOAA16 and NOAA17. The values for channels 1-3 ("surface channels") are so large that effectively only channels 4-10 are used:

channel	1	2	3	4	5	6	7	8	9	10
error (K^2)	900	900	900	90	0.35	0.35	0.35	0.35	0.70	1.40

Results

An assimilation experiment has been made in the DMI-HIRLAM system to visualize the impact of the added data.
Figure 2 shows the amount of data before and after screening for land, ice and cloud contamination, and thinning for August 23rd 2003, 15:00 UTC. Due to summer data are used far to the north. More data (in the south-western Atlantic) could be used in case of better ground station coverage.
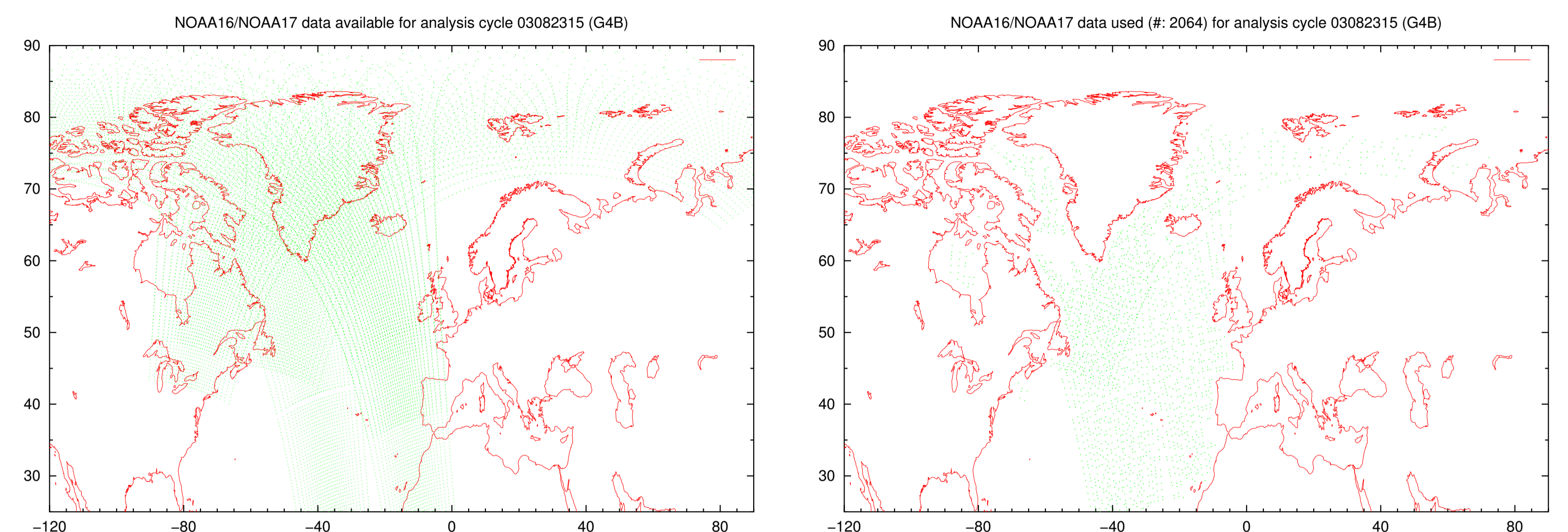

Figure 2: ATOVS AMSU-A data before (left) and after (right) removal and thinning of data points for August 23rd 2003, 15:00 UTC.
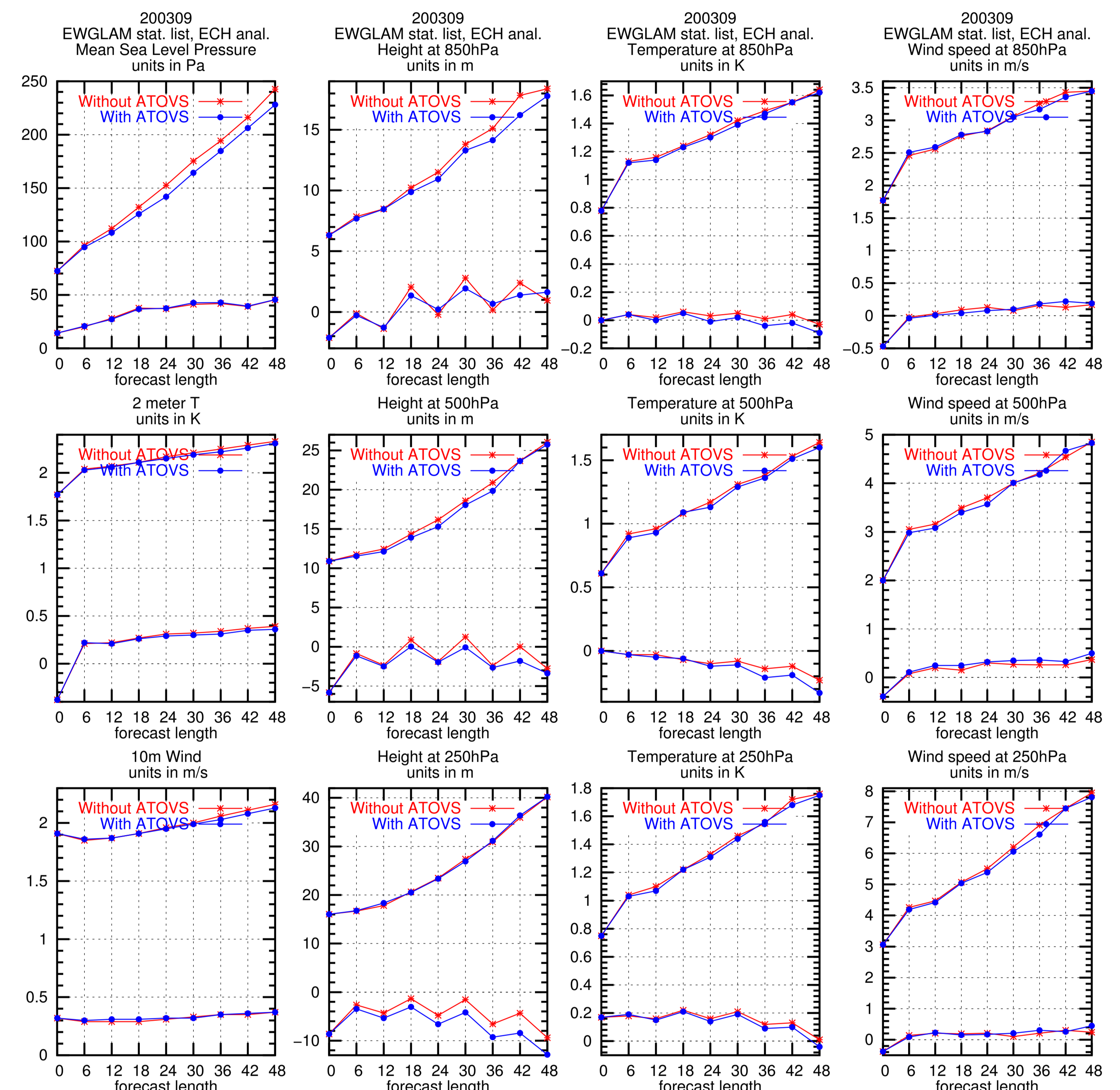

Figure 3: Observation verification (bias and rms, EWGLAM station list) results for September 2003 of surface parameters and geopotential height, temperature and wind for pressure levels specified in the plot. The OSE experiment was done with the DMI-HIRLAM-G model (see figure 1). The upper curves are rms and lower curves bias, red without ATOVS and blue with ATOVS.

Figure 3 shows results from observation verification using an EWGLAM (European Working Group on Limited Area Model) station list for an OSE (Observing System Experiment) experiment in September 2003. The rms-scores are slightly better for most variables for the run including AMSU-A data and the impact from using AMSU-A data is positive. See (Amstrup, 2003) for further results from an OSE impact study for January and February 2003. Similar experiments in the winter season gives a more consistent positive impact.

Conclusion and future work

ATOVS AMSU-A data have been assimilated into the regional DMI-HIRLAM model, with data coming from both two local receiver stations and coming from the EUMETSAT Retransmission Service.

Use of NOAA16 and NOAA17 ATOVS AMSU-A data has a positive impact in the DMI-HIRLAM limited area models based on standard observation verification scores, in particular in the winter season. In the summer season, the impact is largest on mslp scores (not shown).

New bias estimators have not improved the forecasts dramatically, but a slight improvement is found in particular in mean sea level pressure for a testrun in a June/July period.

Plans are in the future to make use of data points also over ice (especially relevant for the Greenland region) and land, either by applying an emissivity scheme or by using only channels not reaching the surface. Furthermore the upper boundary for DMI-HIRLAM should be changed from the present climatological model to data from ECMWF, and the processing should be prepared for AMSU-B and other available sounder instruments.

References

Amstrup, B. (2003). Impact of NOAA16 and NOAA17 ATOVS AMSU-A radiance data in the DMI-HIRLAM 3D-VAR analysis and forecasting system — january and february 2003. DMI scientific report 03-06, Danish Meteorological Institute.

Amstrup, B., Mogensen, K. S., Nielsen, N. W., Huess, V., and Nielsen, J. W. (2003). Results from DMI-HIRLAM pre-operational tests prior to the upgrade in December 2002. DMI technical report 03-20, Danish Meteorological Institute.

Gustafsson, N., Berre, L., Hörnquist, S., Huang, X.-Y., Lindskog, M., Navascués, B., Mogensen, K. S., and Thorsteinsson, S. (2001). Three-dimensional variational data assimilation for a limited area model. Part I: General formulation and the background error constraint. *Tellus*, 53A:425–446.

Lindskog, M., Gustafsson, N., Navascués, B., Mogensen, K. S., Huang, X.-Y., Yang, X., Andræ, U., Berre, L., Thorsteinsson, S., and Rantakokko, J. (2001). Three-dimensional variational data assimilation for a limited area model. Part II: Observation handling and assimilation experiments. *Tellus*, 53A:447–468.

Sass, B. H., Nielsen, N. W., Jørgensen, J. U., Amstrup, B., Kmit, M., and Mogensen, K. S. (2002). The operational DMI-HIRLAM system - 2002 version. DMI technical report 02-05, Danish Meteorological Institute.

Schyberg, H., Landelius, T., Thorsteinsson, S., Tveter, F. T., Vignes, O., Amstrup, B., Gustafsson, N., Järvinen, H., and Lindskog, M. (2003). Assimilation of ATOVS data in the HIRLAM 3D-VAR system. *HIRLAM Technical Report*, 60.