

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

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## Abstract

Until recently (A)TOVS<sup>1</sup> data have mainly been (operationally) assimilated into global numerical weather models, but the study of their impact on a regional model is of great relevance for many weather services, especially if data can be made available with sufficiently short delay for operational use.

A study of the impact of adding NOAA16 and NOAA17 ATOVS AMSU<sup>2</sup>-A radiances to the DMI-HIRLAM<sup>3</sup> system is carried out. The analysis is performed with both locally received data from the two stations Smidsbjerg (Denmark) and Sdr. Strømfjord/Kangerlussuaq (Greenland), and with data from EARS<sup>4</sup>. The data used are from the temperature sounding channels (channels 4-10) from the AMSU-A instrument. A positive impact is observed in the winter time when using the satellite data, whereas the conclusion on summertime use of the data is less certain.

As a result of the assimilation experiments the satellite observations have been used operational at DMI since December 2002.

## DMI-HIRLAM

At DMI a local version of the HIRLAM is being used (Sass et al., 2002; Amstrup et al., 2003). The model is regional and nested with four different regions (see figure 1 for an illustration and table of the position and resolution for the various models). The largest model (DMI-HIRLAM-G) has lateral boundaries from ECMWF<sup>5</sup>, whereas the inner models have lateral boundaries from their surrounding HIRLAM model. The DMI-HIRLAM analysis and forecasting system consists of a 3 dimensional variational data analysis system (Gustafsson et al., 2001; Lindskog et al., 2001) with an assimilation window of 3 hours, and a forecast model with 40 levels reaching the 10 hPa pressure level - above this a climatological model is applied for data needed in the radiative transfer model. The HIRLAM partners are Denmark, Finland, Iceland, Ireland, Netherlands, Norway, Spain and Sweden.

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<sup>1</sup>(Advanced) TIROS Operational Vertical Sounder

<sup>2</sup>Advanced Microwave Sounding Unit

<sup>3</sup>Danish Meteorological Institute - High Resolution Limited Area Model

<sup>4</sup>EUMETSAT ATOVS Retransmission Service

<sup>5</sup>European Centre for Medium-Range Weather Forecasts

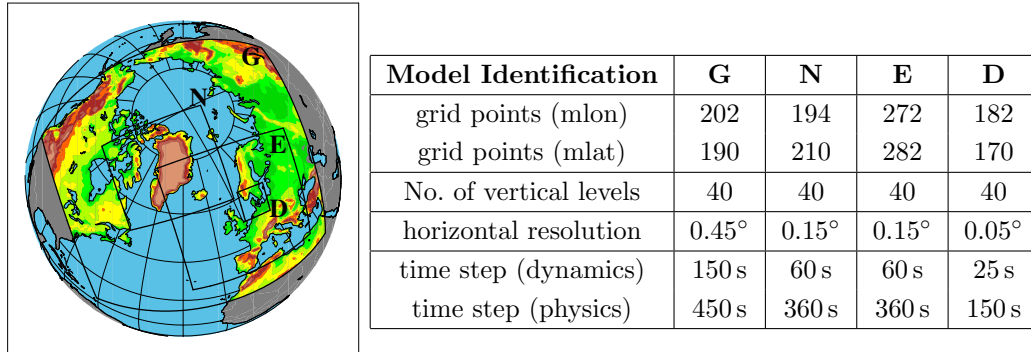


Figure 1: The DMI-HIRLAM regions, geographical coverage and resolution specifications.

## Data sources

Initially two sources of ATOVS AMSU-A data were available: the global dump from NOAA/NESDIS<sup>6</sup> and the locally received. Each data set has advantages and disadvantages. The global dumps have global coverage but arrive late (hours) after data recording, whereas the locally received data only have low coverage, but arrive within half an hour of data recording. In between the two sources one with high coverage and low time delay would be useful. This has been made available through EARS which uses the best of the two systems: locally received data from several stations are transmitted to EUMETSAT<sup>7</sup> from where they are retransmitted through an ordinary digital broadcasting channel to all end-users, ready to be received by relatively simple and cheap equipment. The total time from data recording to reception by the end-users is specified to be less than half an hour.

At DMI two stations for locally reception are available, one in Kangerlussuaq/Sdr. Strømfjord (Greenland) and one at Smidsbjerg. They provide a good coverage for DMI-HIRLAM, but still more data could be used. With the EARS the coverage by the originally proposed 6 stations (of which one is the DMI station at Kangerlussuaq) is as seen in figure 2. The position of the receiver stations are such that a large fraction of DMI-HIRLAM is covered.

EARS has a structure which makes addition of further stations rather easy, and new stations have already been added. This would increase the geographical coverage without having to restructure the system unless the data volume increase above the present system limits.

## Data flow

Data are received via HRPT<sup>8</sup> and pre-processed through the AAPP<sup>9</sup> to level 1c which is geolocated and calibrated to radiances and brightness temperatures. The level 1c data is received

<sup>6</sup>National Oceanic and Atmospheric Administration/National Environmental Satellite, Data, and Information Service

<sup>7</sup>European organisation for the exploitation of METeorological SATellites

<sup>8</sup>High-Rate Picture Transmission

<sup>9</sup>ATOVS and AVHRR Processing Package, provided by EUMETSAT

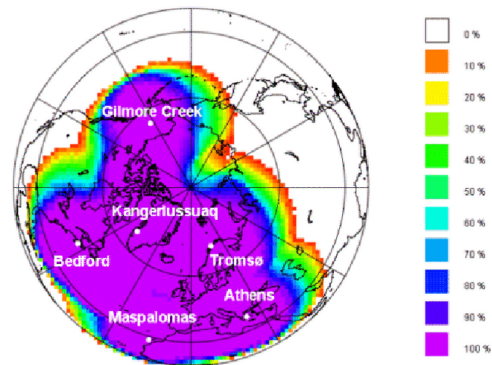


Figure 2: Percentage of observed data at a specific position being retransmitted through EARS. From <http://www.eumetsat.de/en/dps/atovs.html>.

either via local equipment or via EARS, and is encoded into BUFR<sup>10</sup> for the use in the DMI assimilation system.

### Forward model and data usage

The forward model presently used at DMI to calculate model derived brightness temperatures for ATOVS data is RTTOV7<sup>11</sup> developed in the Numerical Weather Prediction SAF<sup>12</sup> 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.

### Bias correction and error statistics

For bias-correction a Harris-Kelly (Harris and Kelly, 2001) scheme with 7 predictors from the background model (model first guess) is 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 7.5 months of data from 2003. This has decreased the bias slightly.

<sup>10</sup>Binary Universal Form for Representation, defined by World Meteorological Organization.

<sup>11</sup>Radiative Transfer model for TOVS, release 7

<sup>12</sup>Satellite Application Facility

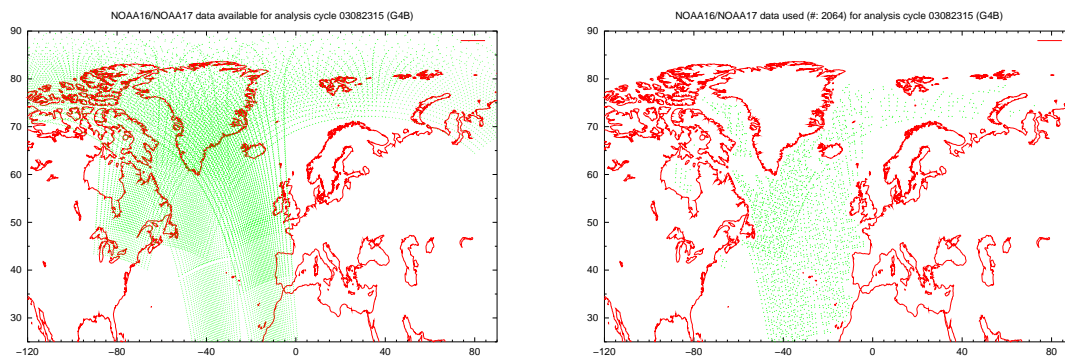


Figure 3: ATOVS AMSU-A data before (left) and after (right) removal and thinning of data points for August 23rd 2003, 15:00 UTC.

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 (see table 1). An example of the effect of bias correction for NOAA16 in the operational DMI-HIRLAM-G model is found in figure 6

Table 1: The values in the diagonal of the observation error covariance matrix. All off-diagonal elements are 0.

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 3 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 (especially in the south-western Atlantic) could be used in case of better ground station coverage.

Figure 4 shows results from observation verification using an EWGLAM<sup>13</sup> station list for an OSE<sup>14</sup> 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.

<sup>13</sup>European Working Group on Limited Area Model

<sup>14</sup>Observing System Experiment

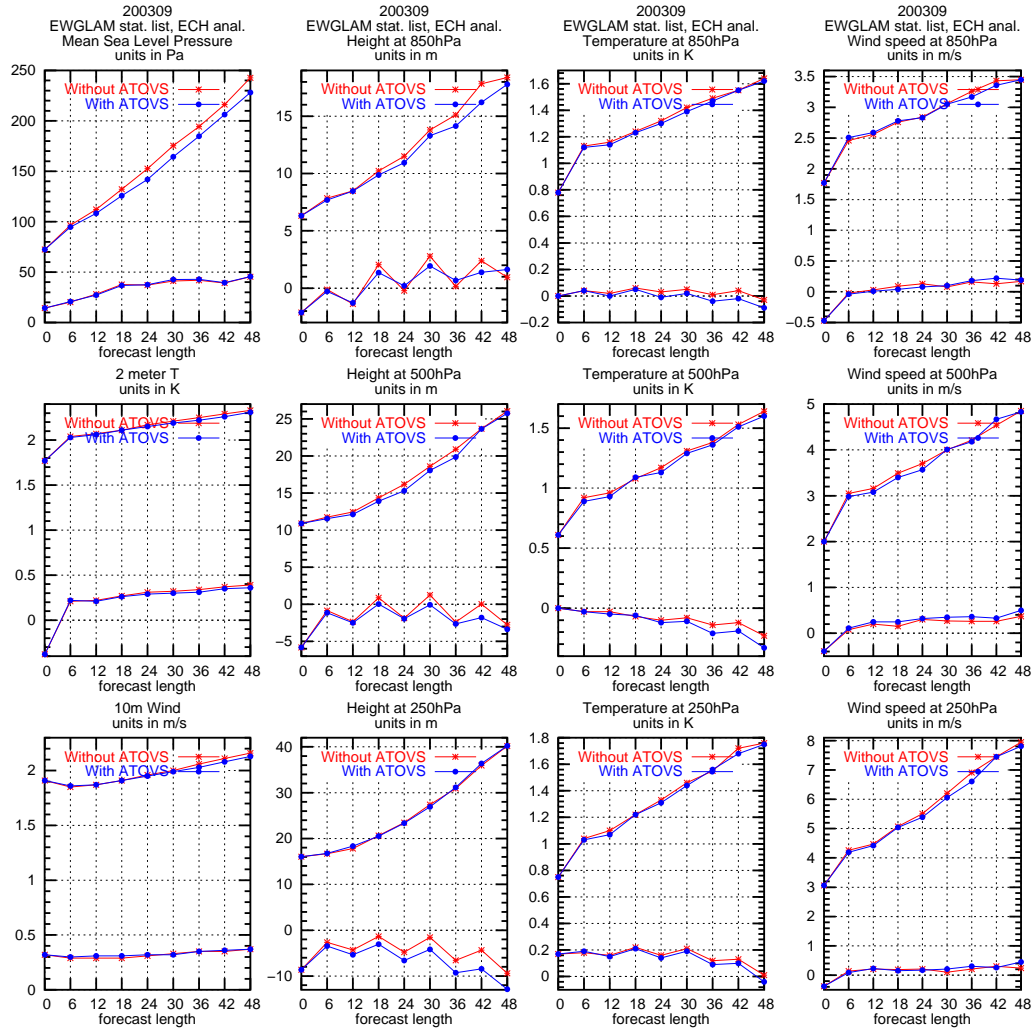


Figure 4: Observation verification (bias and rms, EWGLAM station list) results for September 2003 of surface parameters and geopotential height, temperature and wind for pressure levels specified in the plot. The OSE experiment was done with the DMI-HIRLAM-G model (see figure 1). The upper curves are rms and lower curves bias, red without ATOVS and blue with ATOVS.

## Conclusion and future work

ATOVS AMSU-A data have been assimilated into the regional DMI-HIRLAM model, with data from the two local receiver stations and 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 mean sea level pressure scores for a testrun in a June/July period 2002 using only NOAA16 data.

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.

## After ITSC13

After the unfortunate breakdown of AMSU-A on NOAA17 we were encouraged to implement use of NOAA15 data in the DMI-HIRLAM system. The NOAA15 data are received rather sparse at DMI, and hence the effort on their implementation has previously not been large. The implementation including preparation of new bias estimators was done by the end of November 2003. Subsequently, an impact study was done with the DMI-HIRLAM-G version for five weeks from the end of October to the end of November 2003. Three runs were made: one without use of NOAA AMSU-A data, one including NOAA16 AMSU-A data and finally a run including both NOAA15 and NOAA16 AMSU-A data. The results from an observation verification using the EWGLAM station list is shown in figure 5. For these measure, there is in general a clear positive impact from using the AMSU-A data. The impact from additional NOAA15 AMSU-A data compared to using only NOAA16 AMSU-A data is rather small except for somewhat better root mean square scores for mean sea level pressure, which appears to be the most sensitive parameter to adding AMSU-A data to the data assimilation system.

The bias and RMS for NOAA16 AMSU-A channels 2 to 10 for mid November to mid December 2003 are plotted in figure 6. The bias and RMS of most of the channels is significantly decreased, the bias to close to 0 K.

The bias estimate is based on 5 months of data from June to November 2003, made available to DMI from SMHI<sup>15</sup>.

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<sup>15</sup>Swedish Meteorological and Hydrological Institute

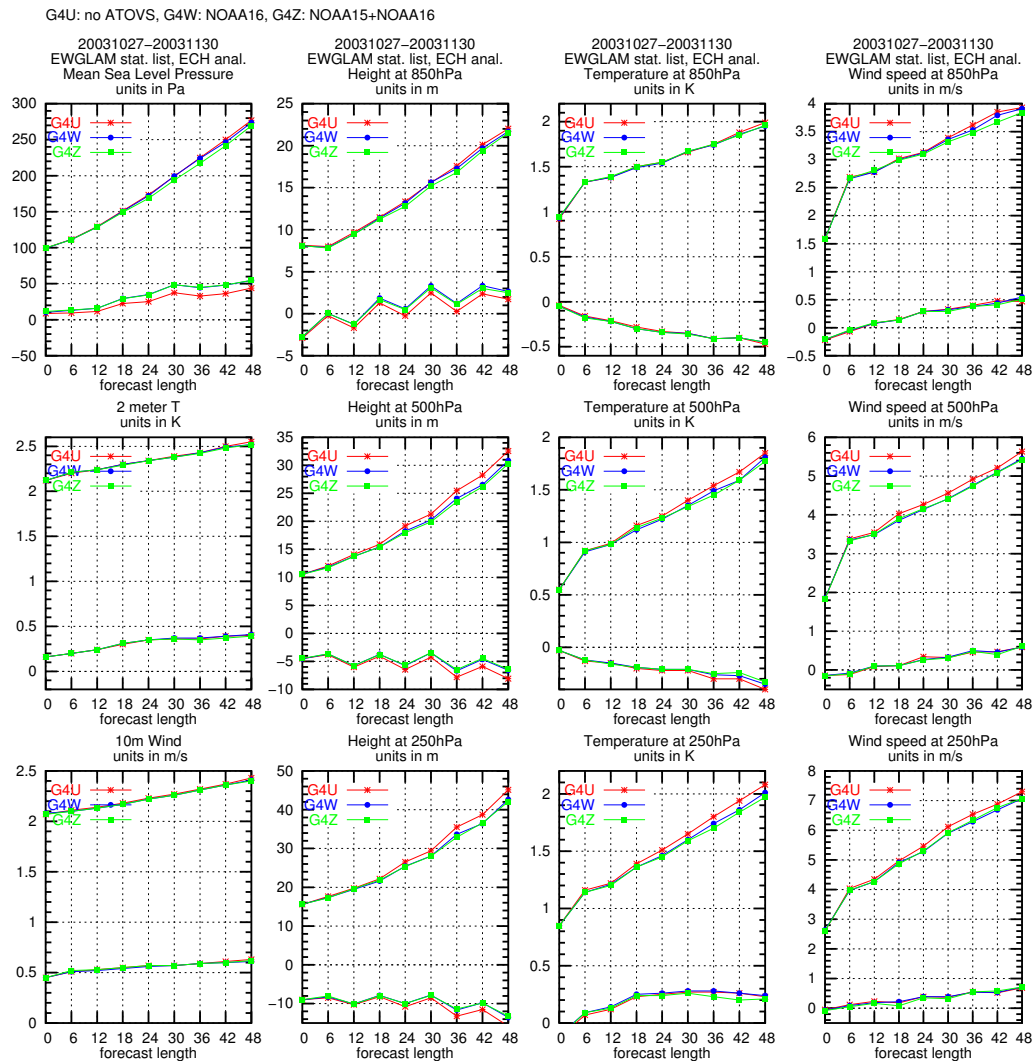


Figure 5: Impact of adding NOAA15 ATOVS AMSU-A to NOAA16 ATOVS AMSU-A. The red curves with crosses are without any ATOVS, blue curves with filled circles with only NOAA16 ATOVS AMSU-A, and the green curves with filled squares with both NOAA15 and NOAA16 ATOVS AMSU-A. The curves are based on data from October 27th to November 30th 2003.

## References

- Amstrup, B. (2003). Impact of NOAA16 and NOAA17 ATOVS AMSU-A radiance data in the DMI-HIRLAM 3D-VAR analysis and forecast system - January and February 2003. Scientific Report 03-06, Danish Meteorological Institute. <http://www.dmi.dk/f+u/publikation/vidrap/2003/Sr03-06.pdf>.
- 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. Technical Report 03-20, Danish Meteorological Institute. <http://www.dmi.dk/f+u/publikation/tekrap/2003/Tr03-20.pdf>.

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.
- Harris, B. and Kelly, G. (2001). A satellite radiance-bias correction scheme for data assimilation. *Q.J.R. Meteorol. Soc.*, 127:1453–1468.
- 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. Technical Report 02-5, Danish Meteorological Institute. <http://www.dmi.dk/f+u/publikation/tekrap/2002/Tr02-05.pdf>.
- Schyberg, H., Landelius, T., Thorsteinsson, S., Tveter, F., Vignes, O., Amstrup, B., Gustafsson, N., Järvinen, H., and Lindskog, M. (2003). Assimilation of ATOVS data in the HIRLAM 3D-VAR System. Technical Report 60, HIRLAM. <http://hirlam.knmi.nl/open/publications/TechReports/TR60.pdf>.



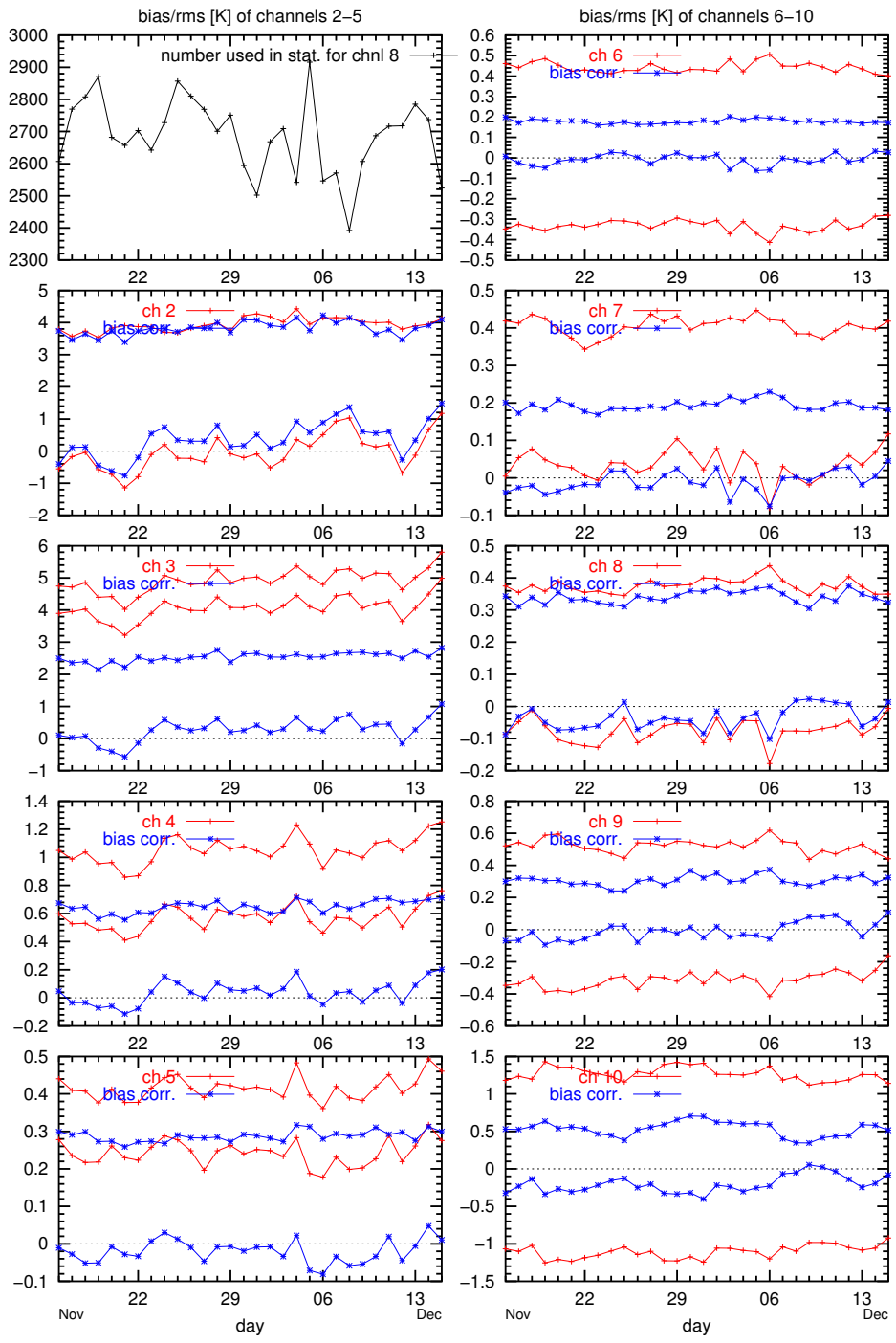


Figure 6: Bias and RMS (in brightness temperature Kelvin) for NOAA16 for November 15th to December 15th 2003 for channels 2 to 10. Uncorrected data in red and bias corrected in blue for the DMI-HIRLAM-G analysis. In the the top right panel the number of datapoints used is plotted. Notice the changing scale on the bias and RMS axis.