

Implementation of AMSU-A usage over sea-ice in DMI-HIRLAM

Jakob Grove-Rasmussen and Bjarne Amstrup

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



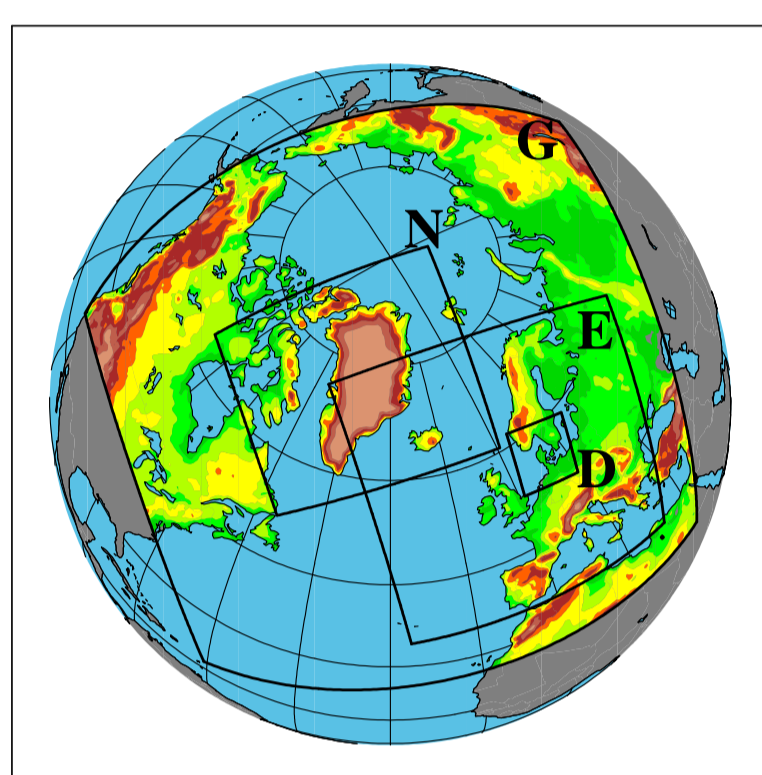
Introduction

The DMI-HIRLAM (High Resolution Limited Area Model) 3D-VAR (three dimensional variational) data assimilation and forecasting system (Gustafsson et al., 2001; Lindskog et al., 2001) has been modified to use ATOVS AMSU-A radiance data over sea-ice and land in addition to the operationally used data over oceans (Amstrup, 2003; Schyberg et al., 2003). The extended use of data requires calculation of new bias statistics for each surface type, and determination of proper error covariance matrices.

DMI-HIRLAM

The DMI-HIRLAM system is a 3 dimensional variational assimilation system covering. The present work has employed regions seen in figure 1, whereas the present operational system (since 14th June 2004) covers two regions: DMI-HIRLAM-T15 corresponding to G but in 0.15° resolution and DMI-HIRLAM-S05 covering northern Europe in 0.05° resolution. 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 surrounding model. All models have 40 vertical levels reaching 10 hPa, above which a climatological model is used.

In the operational DMI-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), NOAA15 and NOAA16 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: DMI-HIRLAM domains used in this experiment. See (Sass et al., 2002) for further details on the DMI-HIRLAM system.

The AMSU-A data used are received via both local equipment and via EARS (EUMETSAT ATOVS Retransmission Service).

Forward model and emissivity

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 up to 10 hPa the radiative transfer equation integration is using a climatological model above this height. Experiments are made with RTTOV8 - see poster by B. Amstrup.

Data is rejected over land and sea-ice, and a cloud clearing based on the total cloud liquid water content is made. The data are subsequently thinned to 0.9° for NOAA15 and NOAA16 data separately.

Each observation is categorized to be over either ocean, sea-ice or land based on the HIRLAM masking. In this experiment observations over land and sea-ice are assigned constant values of emissivity, respectively $\epsilon_{\text{land}} = 0.95$ and $\epsilon_{\text{sea-ice}} = 0.85$. These values are assigned based on previous works (e.g. (Hewison and English, 1999)), but should be handled with great care as the emissivity value changes with e.g. sea-ice type/age and land surface humidity. Only data over ocean and sea-ice is used in this experiment.

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. An early study (Schyberg et al., 2003) showed latitude dependency of the bias. 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 estimation scheme has been applied for the three surface types simultaneously giving a set of predictor coefficients for each satellite (NOAA-15 and NOAA-16), surface type and latitude band. A time-span of four months (June to September 2003) has been used. The coefficients have been determined for both the experiment values of emissivity and an additional test with $\epsilon_{\text{sea-ice}} = 0.90$ to test the system sensitivity. The change in emissivity only resulted in minor changes of the coefficients.

The observation error covariance matrix has been chosen diagonal with the same values for NOAA15 and NOAA16. Over oceans the values for channels 1-3 ("surface channels") are so large that effectively only channels 4-10 are used. Over sea-ice furthermore channels 4-6 are given low weight due to strong surface contamination - see table 1.

Table 1: The values in the diagonal of the error covariance matrix for observations over ocean and sea-ice. All off-diagonal elements are 0.

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

Results

An assimilation experiment has been made in the DMI-HIRLAM system to visualize the impact of the added sea-ice data (land data is still in early testing).

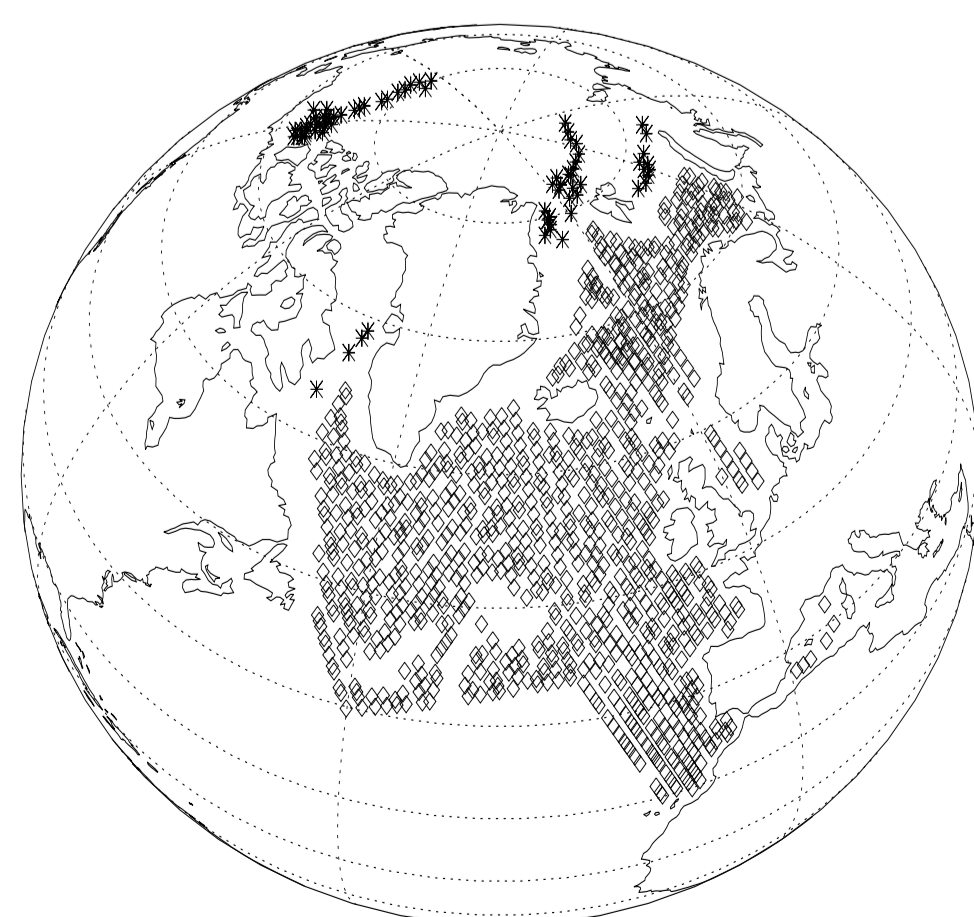


Figure 2: ATOVS AMSU-A data after removal and thinning of data points for January 8th 2005, 15:00 UTC. Diamonds are categorized as over ocean and stars over sea-ice.

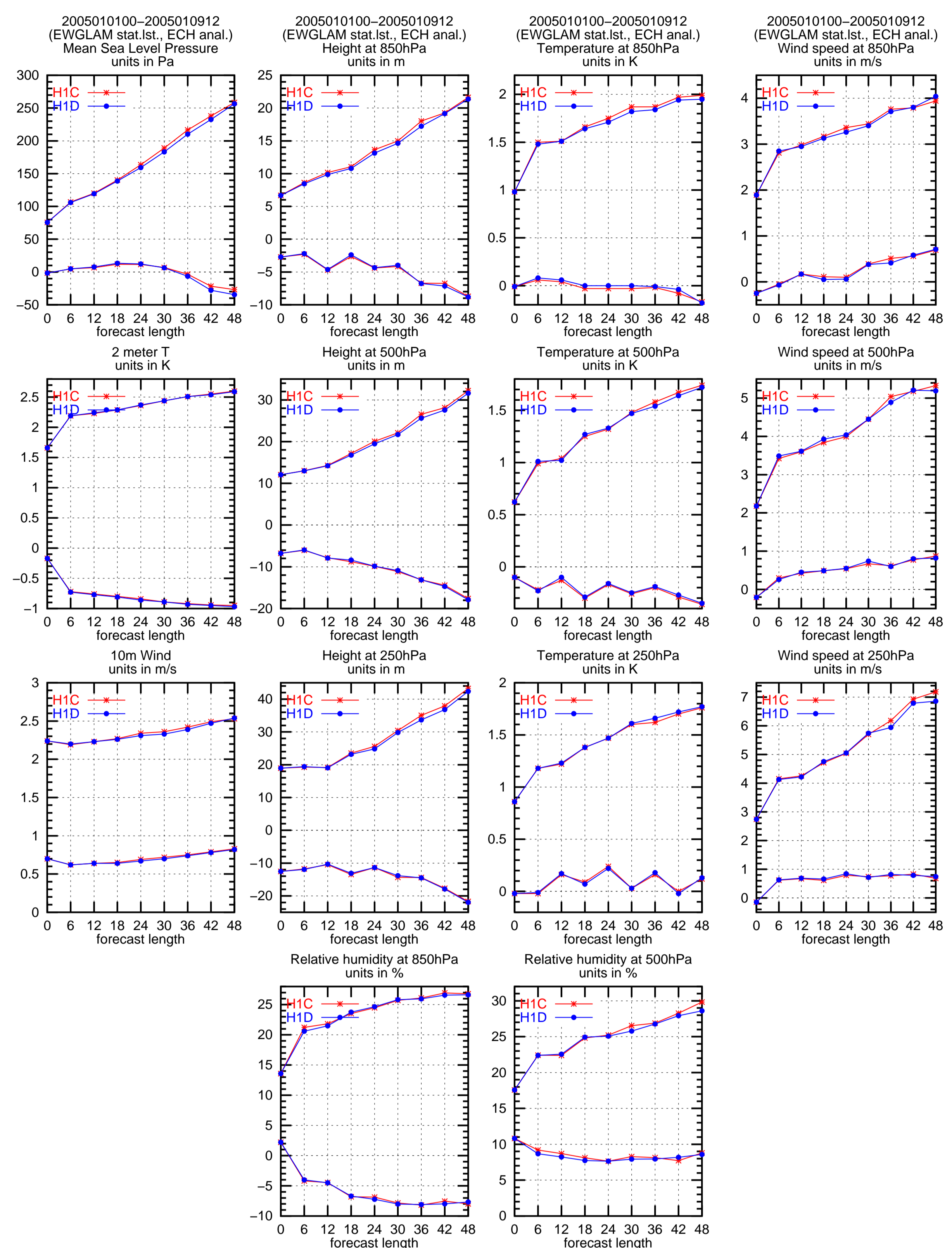


Figure 3: Observation verification (bias and rms, EWGLAM station list) results for beginning of January 2005 of surface parameters and geopotential height, temperature and wind for pressure levels specified in the plot. The OSE experiment was done with the DMI-HIRLAM-G model (see figure 1). The upper curves are rms and lower curves bias, red with observations over ocean and blue with additional observations over sea-ice.

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 January 2005.

The addition of sea-ice data to the original ocean data has a slight positive impact, especially at MSLP and geopotential height at 850 hPa. As virtually no observations have been added at these low heights the reason for the positive impact is the integrated effect close to the surface of the observations at a few hundred hPa.

A further increase of the positive impact is expected when expanding the amount of data used in the bias estimation to cover more winter season

See (Amstrup, 2003) for further results from an OSE impact study for January and February 2003.

In addition to the four month bias estimate, an estimate is made for each of the four months individually allowing for evaluation of the temporal stability of the bias estimates. It is found that only few channels show signs of systematic temporal variations, whereas the majority are either constant or show large variations. The time span is rather short for such a temporal evaluation, but still the analysis gives an indication of the stability.

Conclusion and future work

The assimilation system is stable for variation of the emissivities, but still some work needs to be done for the optimal emissivity values to be determined. Optimally the emissivity should be determined based on AMSU-A window channels, or with the emissivity being a free parameter. Only a weak dependency on emissivity is expected as all the channels with weighting function reaching the ground are given very low weight (see Table 1).

The temporal variation of the bias predictors is in general rather small, but a large constant displacement is derived, especially for the lower channels.

The land surface mask is to be refined to contain only land and no border zones as it is at present, where some sea-ice and ocean is included. This reduce the amount of data available as all border zones should be ignored, but the observations over land becomes a more homogeneous sample.

By using sea-ice data extra information is gained especially in the Greenland area. The amount of data is depending on season and hence a more stable information increase is expected from land-data usage.

The observation assimilation experiment using additional sea-ice data show a slight positive impact, which we expect to be recalculating the bias statistics to cover more winter season.

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.
- Gustafsson, N., Berre, L., Hörnquist, S., Huang, X.-Y., Lindskog, M., Navasqués, 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.
- Hewison, T. and English, S. (1999). Airborne retrievals of snow and ice surface emissivity at millimeter wavelengths. *IEEE Trans. on Geoscience and Remote Sensing*, 37(4):1871–1879.
- Lindskog, M., Gustafsson, N., Navasqués, 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.