Assimilation of ATOVS data at SMHI, Sweden

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Abstract

Cloud cleared AMSU-A radiances over sea are operationally assimilated into the HIRLAM model analysis (3DVAR) at SMHI. Data is collected via EARS (Eumetsat ATOVS Retransmission Service) to gain data over the Atlantic, and statistical verification of forecasts show positive impact on temperature and MSLP.

The use of humidity soundings from AMSU-B over sea is on its way. We wish to describe how we do quality control, bias correction and deal with low peaking radiances affected by the ground. Results from the first assimilation experiments are planned to be ready for the meeting. Unfortunately, no impact study results

In the framework of the EC-sponsored project IOMASA we are investigating if AMSU-B can be used over the Arctic region. The first experiments are focused on how to identify radiances contaminated by clouds. Can the cloud mask with its cloud type information from the Ocean and Sea Ice (OSI) SAF be used for this purpose?

The HIRLAM model at SMHI

SMHI use HIRLAM (HIgh Resolution Limited Area Model) for operational forecasting. The model is setup with a 6h assimilation cycle and 48h forecasts are done at 00,06,12 and 18UTC. Boundaries are taken from ECMWF forecasts and applied at every 3:rd hour. The horizontal resolution is 22km and 40 vertical levels are used with the model top at 10hPa. Several dynamic schemes are available: eulerian, semi-lagrangian and spectral. At SMHI the semi-lagrangian semi-implicit dynamics is used.

Physics:

- Rasch-Kristjansson, stratiform

- Kain-Fritsch, convection

- CBR, turbulence

- ISBA, surface physics

Analysis:
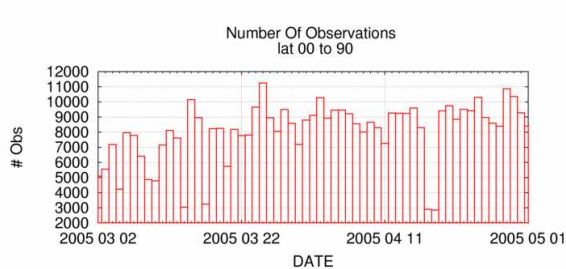
Figure 1: Operational HIRLAM domain at SMHI

Figure 2: Number of received AMSU-A observations per per day from NOAA16

- 3DVAR

- FGAT, First Guess at Appropriate Time

- Cut off time for observations is 2h

Operational Use Of ATOVS

ATOVS data is collected via the EUMETSAT ATOVS Retransmission Service (EARS), which gives us fast access to data. This is important due to our short cut-off time, 2h.

Cloud cleared, bias corrected AMSU-A radiances are directly assimilated into the operational model with RTTOV-7. Only CH5-10 are used, CH4 is not used because it peaks too low and our T_{skin} is not good enough. The remedy for this is to have T_{skin} in the control-vector and the tests with that is ongoing. CH11-14 are not used because they peak over the model top.

Several impact studies have been done during the development phase and a positive impact on especially T and MSLP has been shown, see e.g. (Amstrup,). Before we implemented AMSU-A operationally in the winter of 2004 we only did a short impact study of 2 weeks.
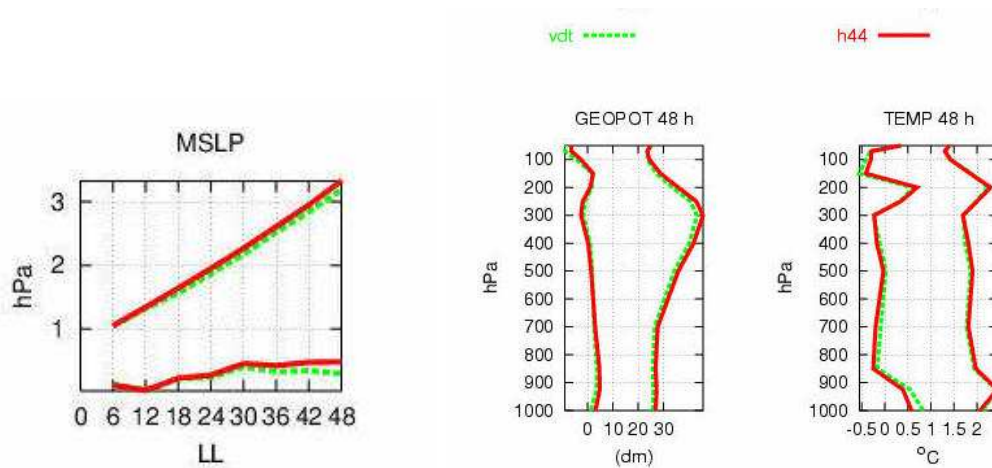
Figure 3: Verification from a 2 week period of Dec 2003. Plots show RMSE and bias. Red: reference, no AMSU-A is used Green: AMSU-A data is assimilated

Bias Correction Of AMSU-A

We perform bias correction of the AMSU-A radiances by linear regression with the following predictors:

- mean T 1000-300hPa

- mean T 200-50hPa

- surface T

- integrated water vapor content

- square of the observation zenith angle

- the observation zenith angle

The coefficients are static and calculated from a reference dataset, usually a couple of months. This gives about 200 000-400 000 observations. The coefficients are updated if the monitoring shows that it is necessary.

The bias correction shows a bias reduction on $(\mathbf{y} - \mathbf{H}\mathbf{x}_b)$ statistics (not shown), but it is also very interesting and important to test whether it improves the quality of the data. We therefore did an impact study where AMSU-A data was assimilated without bias correction to see if the scores were affected, figure 4. The test showed, fortunately, that the scores got a bit worse if bias correction is not applied.

Assimilation Of AMSU-B Over Sea

AMSU-B is more difficult to use than AMSU-A due to its sensitivity to water vapor. First of all, we can conclude that the AMSU-B radiances are 'contaminated' by rain and cirrus (ice) clouds. At first we used a section of the AAPP code to spot these observations by applying the indexes in the routines PPASCAT and PPACIRR. These indexes require AMSU-A information mapped onto the AMSU-B field of view which makes it difficult to implement outside AAPP.
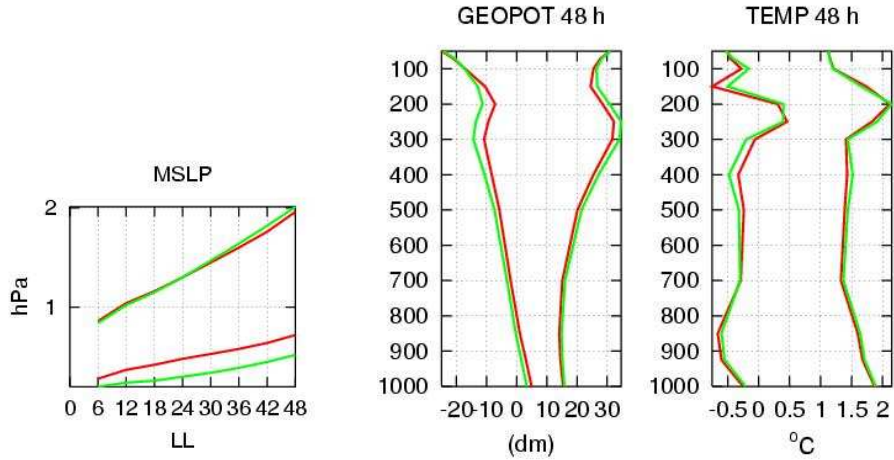
Figure 4: Verification from a period between 10:th Aug to 11:th Sep 2004. Red: reference, AMSU-A is assimilated Green: AMSU-A is assimilated without bias correction

Since we need to do all quality control of the data inside the analysis code, we now use a more crude index for the rain check instead, (from Bennartz):

$$T_{CH1}^{89GHz} - T_{CH2}^{150GHz} > -15 \Rightarrow reject \tag{1}$$

and hope that this removes most of the 'contaminated' observations and variational quality control can take care of the remaining ones. The AMSU-B observations are bias corrected the same way as AMSU-A. The difference is that the surface temperature and integrated water vapor are not used as predictors.

Since the AMSU-B response functions depends on water vapor amount they are not constant, figure 5. This gives at least two problems that needs to be addressed:

1. It can be a problem if the first guess field is not good enough. Then the jacobians are based on a linearization around response functions that are different from the truth. This can leed to convergence to a solution that is not the most optimal. It may therefore be helpful to setup the assimilation system to to use inner and outer loops with intermediate re-linearizations.

2. If the response functions sees the ground and we have a fixed T_{skin} that is not good enough it may also lead to convergence towards a solution that is not optimal. Our solution to this is to include T_{skin} in the control vector.

Experiments

First of all we have done a single obs experiment with AMSU-B to verify that the information is treated correctly by the analysis. One thing that is interesting to see is how the information from AMSU-B is distributed in the vertical. If an integrated quantity is used, then the observation itself does not contain any information about the vertical distribution. It is then the background error statistics that totally determines the increments. Figure 6 shows that by using raw radiances some extra information can be added about the vertical distribution.
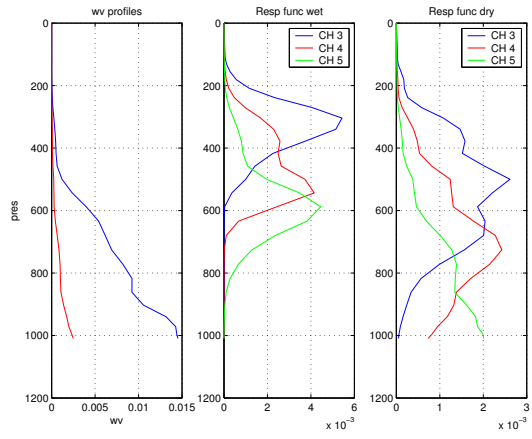
Figure 5: The response functions for CH3-5 for two different cases. One dry and one wet.
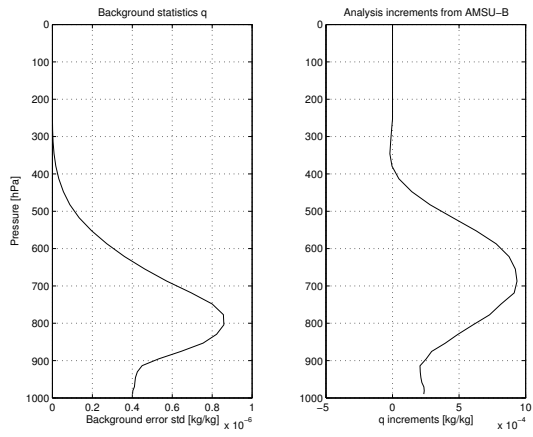

Figure 6: Right: A profile showing the q increments from AMSU-B at the observation point. Left: The background error standard deviation for q
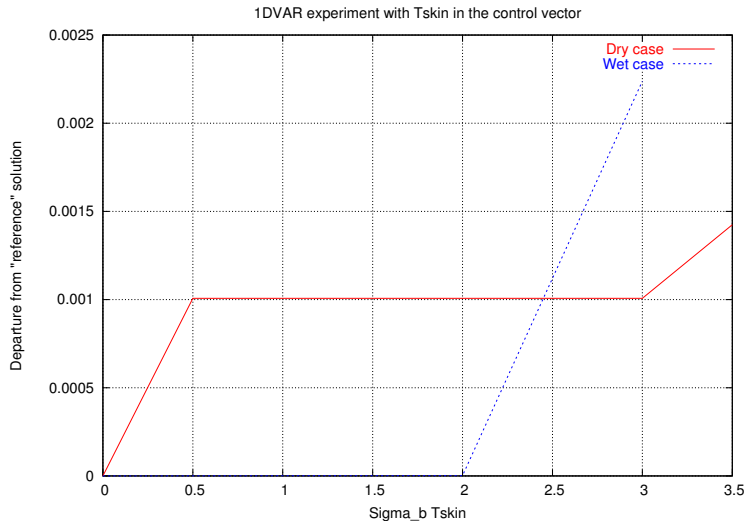
Figure 7: 1DVAR experiment with T_{skin} in the control vector. Several analyses are done with different σ_b for T_{skin}. σ_b=0 means that T_{skin} is not allowed to vary during the minimization, and the solution for that case is the 'reference solution'. As σ_b is increased, T_{skin} is allowed to be adjusted.

We have also done some experiments with T_{skin} in the control vector with a 1DVAR system. To set T_{skin} 'free' a σ_b value needs to be assigned. Figure 7 shows the result of an experiment with different σ_b. If it is dry and the ground is seen, the analysis converge to another solution if T_{skin} is allowed to vary. The final cost function value was also a bit smaller for this solution. If it is wet, the ground does not influence influence the analysis, which is what one could expect. If σ_b is too big, the T_{skin} gradient will dominate the jacobian which is unphysical. This is probably what happens when $\sigma_b > 2$ in figure 7.

Assimilation Of AMSU-B Over Ice

In the framework of the EC-sponsored project IOMASA we are investigating how AMSU-B can be used over the Arctic region. If we want to use raw radiances it is necessary to do some cloud screening, as we do over sea. A simple index with the window channels can not be used however, and therefore some other information about clouds must be found. We have done some preliminary tests with an AVHRR cloud mask from the OSI-SAF.

In the first step we determined which cloud types that indicate contaminated observations. This was done by comparing a cloud screened data set over open water with matching OSI-SAF cloud type data. We then used those cloud types to screen a data set over ice.

Figures 8 and 9 shows $(\mathbf{y} - \mathbf{Hx}_b)$ statistics for AMSU-B over ice. As input to RTTOV-7 a value of 0.75 was chosen for ϵ_{surf}, taken from a figure in (Selbach,). T_{skin} was taken from the NWP model. The data sample is from March and June of 2004, the two periods where merged to get a sample that was as big as possible. From the figures, it seems like the cloud screened statistics are narrower and more gaussian than the 'raw' statistics. Even if the cloud mask looks promising for this data set, it will need some more testing, especially for a winter period.

If we want to assimilate these radiances we have the same problem as over sea: if it is dry the surface will be seen, with the difference that ϵ_{surf} will also be important. The plan is therefore to have both T_{skin} and ϵ_{surf} in the control vector over ice.
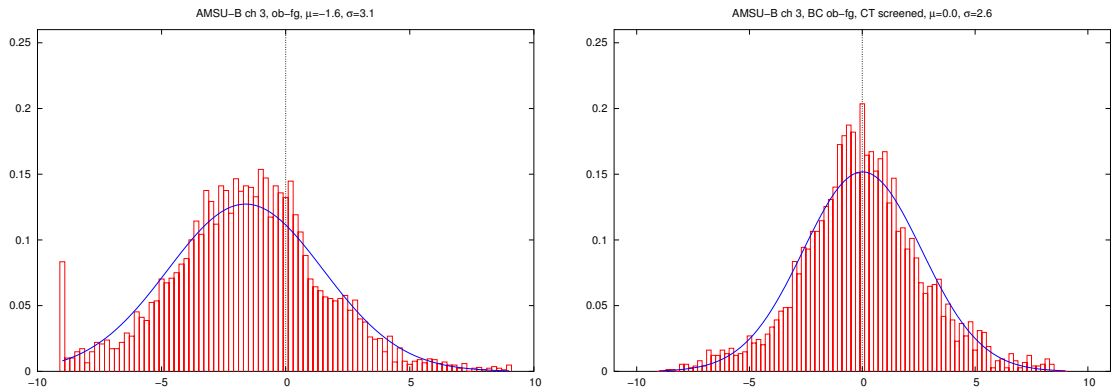
AMSU–B ch 3, ob–fg, μ=−1.6, σ=3.1

AMSU–B ch 3, BC ob–fg, CT screened, μ=0.0, σ=2.6

Figure 8: $(\mathbf{y} - \mathbf{Hx}_b)$ statistics for AMSU-B CH3 over ice. Left: Data that has not been screened for clouds. Right: Data has been screened for clouds with the OSI-SAF cloud mask. Blue curve is a fitted Gaussian.

AMSU–B ch 5, ob–fg, μ=−1.0, σ=2.4

AMSU–B ch 5, BC ob–fg, CT screened, μ=−0.2, σ=2.0

Figure 9: $(\mathbf{y} - \mathbf{Hx}_b)$ statistics for AMSU-B CH5 over ice. Left: Data that has not been screened for clouds. Right: Data has been screened for clouds with the OSI-SAF cloud mask. Blue curve is a fitted Gaussian.
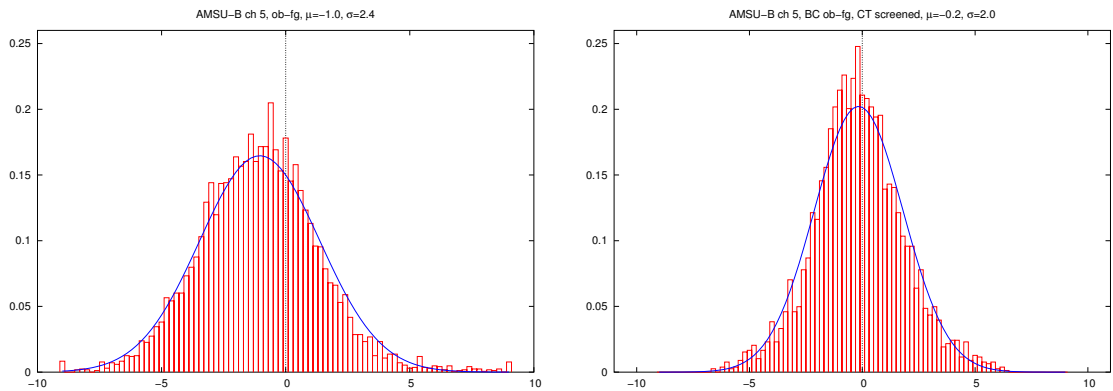
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Amstrup, B. Impact of noaa16 and noaa17 atovs amsu-a radiance data in the dmi-hirlam 3d-var analysis and forecasting system -january and february 2003. *DMI Scientific Report.*

Selbach, N. Determination of total water vapor and surface emissivity of sea ice at 89 ghz, 157 ghz and 183 ghz in the arctic winter. *Dissertation im Fachbereich Physik/Elektrotechnik der Universitt Bremen, 2003.*