Assimilation Of AMSU-B Radiances In The HIRLAM 3DVAR Analysis

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The HIRLAM Model

The HIRLAM programme, which started in 1985, develops and maintains a short-range weather forecasting system. Different versions of the HIRLAM model are used for operational forecasting at the participating institutes, namely: Finland, Sweden, Norway, Denmark, The Netherlands, Ireland and Spain.

The Experiment Setup

In this experiment, radiances from the humidity sounder AMSU-B were assimilated for one month, January 2005. AMSU-B has 5 channels. 2 window channels at 89 and 150 GHz, and 3 sounding channels in the water vapor absorption band at 183 GHz. NOAA16 data was used, downloaded from the MARS archive at ECMWF.

Forecast Model

The forecast model used in the experiment had the following characteristics:

- 33 km horizontal resolution
- 40 vertical levels, model top at 10hPa
- Semi-Lagrangian, semi-implicit dynamics
- Kain-Fritsch convection scheme
- Rash-Kristjansson stratiform physics scheme
- CBR turbulence parameterization
- ISBA surface scheme

Here, the boundaries were ECMWF analyses and applied every 6:th hour.

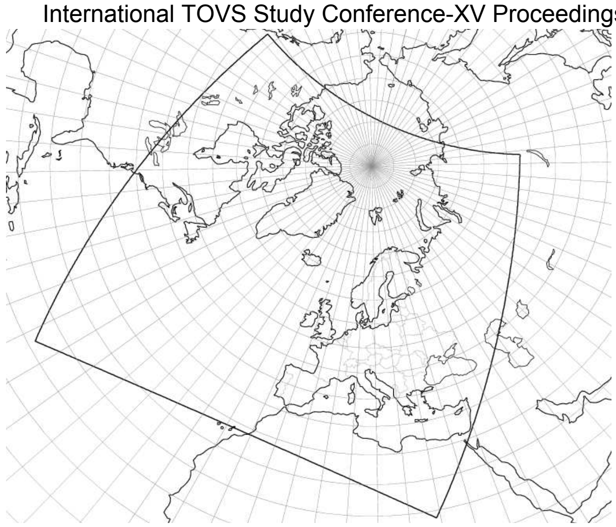

Figure 1: The model area

Analysis

- 3DVAR
- Background error structure functions based on analytical balance, described in (Gustafsson et al.,).
- FGAT (First Guess at Appropriate Time)
- 6h assimilation cycle
- REFERENCE: conventional observations+AMSU-A radiances
- EXPERIMENT: REFERENCE+ AMSU-B radiances from NOAA16 over sea

Bias Correction

The bias correction method follows (Harris and Kelly,), i.e. a linear regression scheme,

$$\delta T = p_0 + \sum_{j=1}^{N} c_j P_j \tag{1}$$

where δT is the correction term, p_0 a constant, P_j predictors and c_j coefficients that needs to be calculated from a reference data-set. Here, the following predictors were used:

- mean temperature between 1000-300hPa
- mean temperature between 200-50hPa
- square of the instrument scan-angle
- the instrument scan-angle

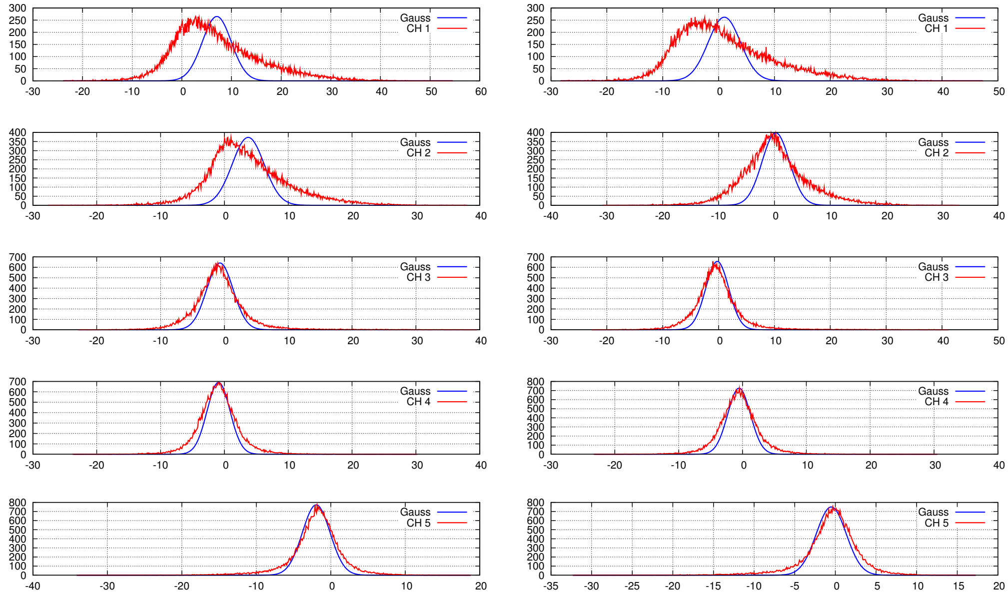

Figure 2: Left: distribution of innovation vectors for uncorrected observations. Right: the same, but for bias-corrected observations. y-axis: number of observations. x-axis: innovation-vectors, $(y - Hx_b)$ [K], 0.1K slots.

To calculate the coefficients, c_j, the model was run for December 2004 only computing 6h forecasts, i.e. the month prior to the experiment month, with AMSU-B in passive mode. The obtained innovation vectors were then used to calculate the coefficients.

Figure 2 shows the effect of the bias-correction for the experiment period, i.e. January 2005. It seems like channel 5 has the largest bias, and it is also clearly reduced after bias-correction. Channel 5 is the channel that peaks closest to the surface and it is likely that surface influences are the cause for the large bias.

Quality control

Rain and/or ice particles causes scattering that will influence the AMSU-B observations. If these scattering characteristics are not modeled accurately by the NWP and Radiative Transfer Model (RTTOV-7), observations influenced by scattering must be removed.

The difference between channel 1 and 2, 89GHz-150GHz, can act as a crude indicator of precipitation over sea. And that has also been used here, after some tuning the following limit was chosen: **Ch1-Ch2** $>$ **-15K** $\rightarrow$ **reject**

Observation errors

The error assigned to an observation, σ_o, also determines the weight the observation will have during the analysis. Ideally, this should be tuned with care to make sure that the error is larger than the noise-level in the measurements. And that the weight given to the observation is not significantly larger or smaller than other observation types.

The ratio between the background error and the observation error, σ_b/σ_o, is an indicator of how much weight an observation gets in the analysis. It is very important to realize that σ_b in this context must be expressed in observation space, called BGOS (BackGround errors in Observation Space)

	Approximated background error (BGOS)	Assigned observation error	Weight given in the analysis σ_b/σ_o
Ch 3	3.5K	2.0K	1.75
Ch 4	2.0K	2.0K	1.0
Ch 5	1.5K	2.0K	0.75

With an observation error of 2K we actually set different weight to each channel. Channel 5, which is the most likely to cause problems (due to ground influence), has been given the least weight.

Results

First of all, the forecasts were compared to measurements from synops and radiosondes. RMSE (Root Mean Square Error) and bias, or mean error, were computed compared to these measurements. RMSE can sometimes be misleading as a quality indicator for forecast performance if the model variability is different between the experiments. It is, however, unlikely that the model variability changes in data-assimilation experiments.

A humidity increment will, off course, change the humidity field. Due to the analytical balance used for deriving the background error structure functions, there is also a weak coupling between humidity and wind, see (Gustafsson et al.,). Figure 3 shows just that, i.e. the humidity and wind-field have changed at the analysis time. Changes in other variables may occur anyway. For example, when new observation information is added it may cause the variational quality control to behave different and accept data that was rejected before. Since no other changes are seen than in the humidity and wind-field it seems like nothing like that has happened. In fact, the logs from the analyses have been checked and there were no changes in the use of other observations between the experiments.

The differences seen at +00h are though vanished at +18h, figure 4. One probable explanation is that the initial humidity and wind changes were not in balance with the dynamics of the model. After some time, the mass field creates its own moisture and wind field, this is very probable in the extratropics where the windfield tend to adjust to the massfield.

At +48h, however, we see a small positive impact on upper level temperature, geopotential and wind, figure 5. The initial changes in the humidity and wind-fields seems to have spread to the mass field in 48 hours, possibly via the precipitation. A mean value of the difference in total 6h precipitation for +18h forecasts show a difference in the precipiation pattern, figure 6. One may speculate that this is what has happened.

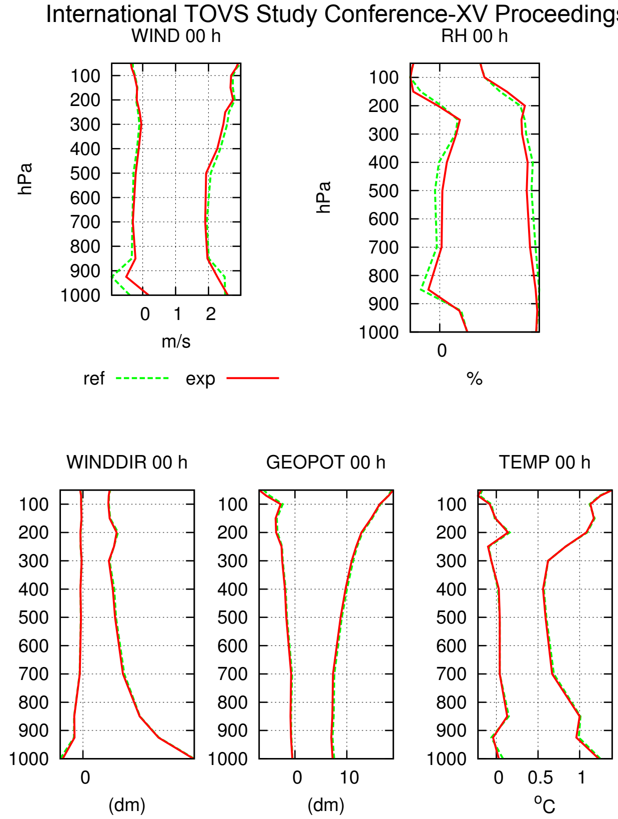

Figure 3: Verification against radio-sondes at +00h

Summary

Rain cleared radiances over sea from the noaa16 AMSU-B instrument has been assimilated into the HIRLAM model analysis, which is 3DVAR. The biases were corrected using a Harris and Kelly scheme with 4 predictors, and the statistics showed that the biases were reduced using this method.

Observation errors were set using background errors in observation space, BGOS. The ratio between σ_b and σ_o was used as an indicator to how much weight each channel gets in the assimilation. Channel 5 was given the least weight because it peaks closest to the surface, which may cause problems.

The impact on the model performance showed reduced RMSE values for humidity and wind on very short forecast ranges, +00h to +06h. Between +06h and +36h, no differences could be found compared to observations. However, there were differences in the precipitation pattern mainly over the Atlantic. On +36h up to +48h forecasts a small positive impact on temperature and geopotential RMSE could be seen.

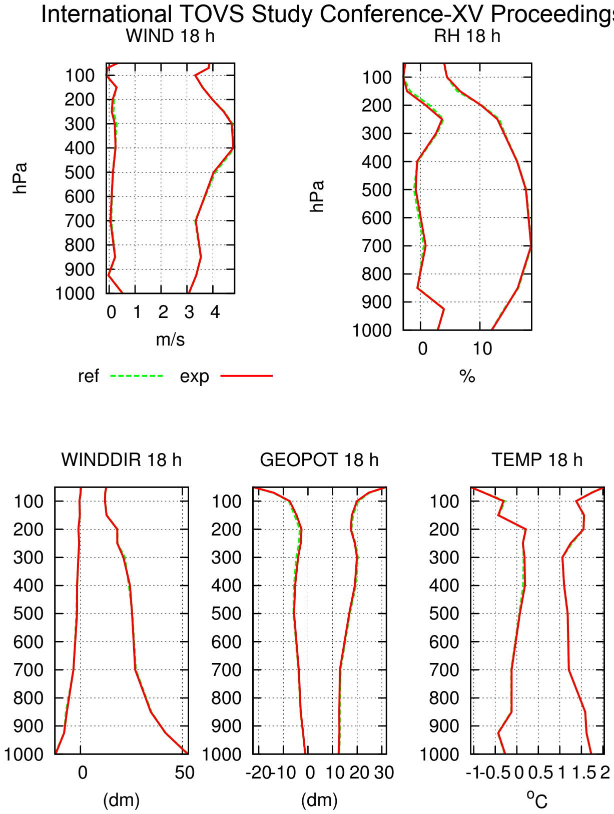

Figure 4: Verification against radio-sondes at +18h

References

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Harris, B. and Kelly, G. A satellite bias correction scheme for data assimilation. *Quaterly Journal of the Royal Meteorological Society*, 127:1453–1468.

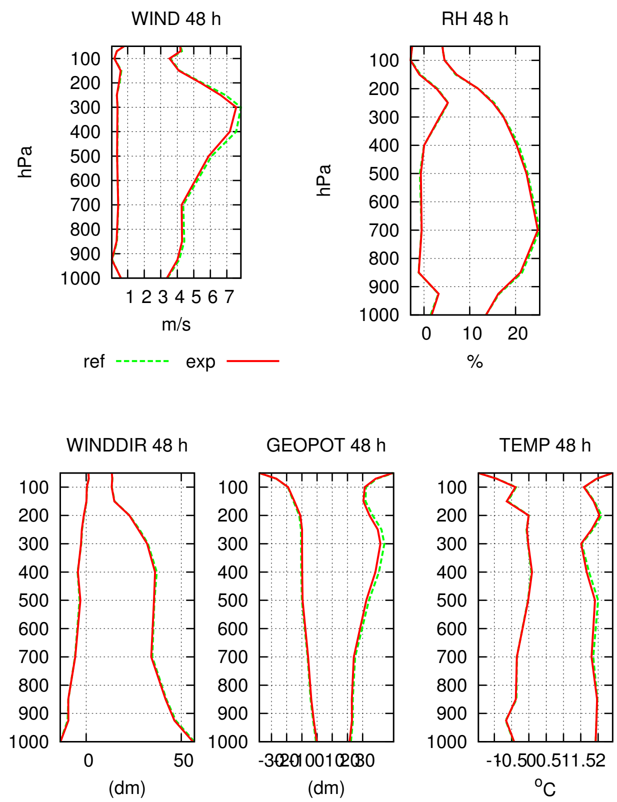

Figure 5: Verification against radio-sondes at +48h

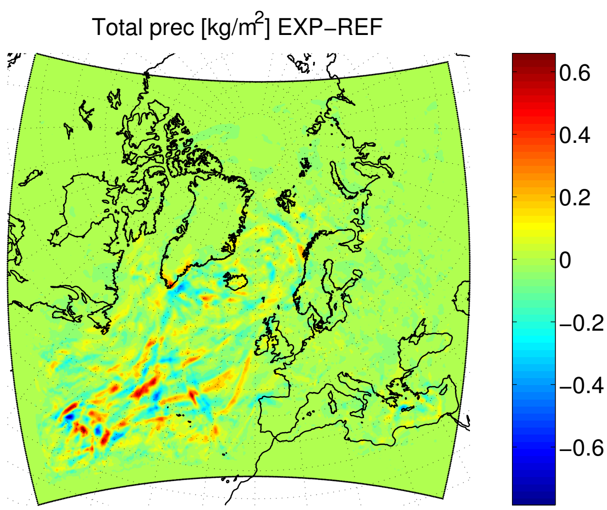

Figure 6: Mean difference between EXP and REF for +18h forecasted 6h precipitation. The mean is calculated over the whole experiment period, i.e. January 2005.

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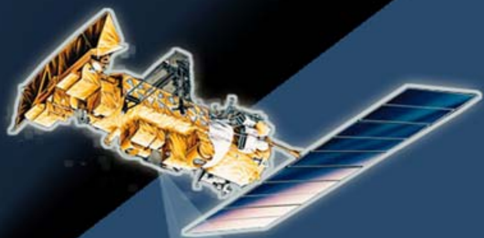

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