An update on the Assimilation of ATMS data at ECMWF

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ABSTRACT

The Advanced Technology Microwave Sounder (ATMS) has been assimilated operationally at ECMWF since 26 September 2012, with a neutral to slightly positive impact on forecast scores. In this paper we present an update on the use of ATMS at ECMWF since it was first introduced into the ECMWF forecasting system.

Firstly, to compare the general forecast impact of ATMS to that of AMSU-A and MHS, we report on assimilation experiments in the context of a depleted observing system. Adding ATMS to a baseline system without polar satellite data results in a positive forecast impact that is comparable to that of one AMSU-A/MHS combination.

Secondly, we present results of a study to increase the data usage by introducing surface-sensitive data were over land and sea-ice. In order to add these data over land and sea-ice we used an approach that dynamically retrieves emissivity using window channel observations, similar to the one currently used for AMSU-A and MHS. It was found that introducing these new data improved the fit of AMSU-A and MHS observations to the background, thus improving short-range temperature and humidity forecasts.

1 Introduction

The Advanced Technology Microwave Sounder (ATMS) is the new microwave radiometer for temperature and humidity sounding flown on the Suomi-NPP (S-NPP) platform. It continues the AMSU-A and MHS heritage, providing temperature and humidity sounding information. A successful exploitation of the data are important for Numerical Weather Prediction.

ATMS has been assimilated operationally in the ECMWF system since 25 September 2012 (see [Bormann et al., 2013]). We use the data after averaging over 3 neighbouring scan positions and 3 scan lines to reduce the noise. Channels 6 - 15 and 18 - 22 are assimilated in clear conditions. Assimilation trials showed a neutral to positive forecast impact when ATMS was added in this way to the current ECMWF system, which already uses data from 5 AMSU-A and 3 MHS instruments. This is shown in figure 1, where positive values indicate a reduced root mean square forecast error with respect to the control. Comparisons between observations and short-term forecasts showed overall a good performance of the instrument, with some evidence of striping noise.

These results indicate that ATMS brings some benefit to the ECMWF forecasting system. However if we want to compare the performance of ATMS to that of AMSU-A and MHS we need to perform assimilation trials where we introduce firstly ATMS and secondly an AMSU-A/MHS combination into a depleted observing system which does not include AMSU-A and MHS. This is presented in section 2.

The initial implementation of ATMS was restricted to data over sea for surface-sensitive channels as the assimilation of surface-sensitive channels over land and sea-ice is more difficult. However since the ATMS data has been shown to have a positive impact on forecast scores when surface-sensitive channels were added over ocean we now want to extend the coverage to include surface-sensitive channels over land and sea-ice. Results of assimilation trials investigating this are shown in section 3.

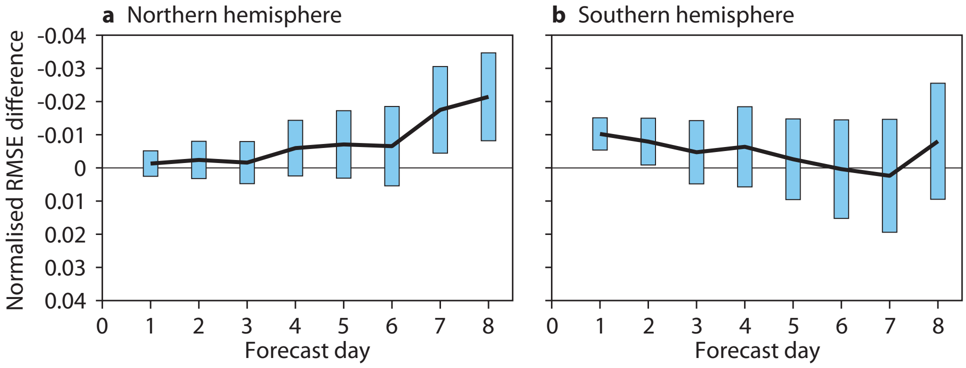

Figure 1: Normalised differences in the root mean square error of the 500 hPa geopotential for the Northern (left) and the Southern Hemisphere (right) as a function of forecast range from a total of 102 cases over the periods 15 December 2011 - 6 February 2012 and 28 June - 31 August 2012. The experiments have been conducted with ECMWFs assimilation system, at a spatial resolution of T51140km (with a final incremental analysis resolution of T255 80km). Error bars indicate 95 % confidence intervals.

2 Assimilation experiments with a depleted observing system

2.1 Assimilation Trials

Assimilation trials were conducted with a depleted observing system as follows:

- Control: Baseline assimilation experiment in which no radiance data from polar-orbiting instruments were assimilated. Only conventional observations together with GPS radio occultation data, AMVs, and scatterometer winds were assimilated.
- AMSU-A/MHS: As Control, but with AMSU-A and MHS from NOAA-18 added.
- ATMS_Full: As Control, but with ATMS added.
- ATMS_AsAMSU: As ATMS_Full, but mimicking the AMSU-A/MHS use, i.e. only the equivalent scan-positions were assimilated as in the AMSU-A/MHS case, and the two additional humidity channels available from ATMS were also excluded.

The experiments cover the period 1 July 2012 - 31 August 2012, and otherwise use the same setup as the ones with the full observing system. Note that for AMSU-A we exclude the outermost 3 scan-positions on either side due to bias issues (9 for MHS), but for ATMS we do not find such a cautious approach necessary.

2.2 Results

Figure 2 compares the forecast impact of the ATMS and AMSU-A/MHS experiments against the control. Note that positive values indicate an improvement with respect to the control. It can be seen that in the absence of other radiance observations from polar-orbiting satellites, a single ATMS or a single AMSU-A/MHS combination have a very large positive forecast impact. Used in a similar way, ATMS and AMSU-A/MHS have a similar impact (compare AMSU-A/MHS - Control and ATMS_AsAMSU - Control). When the additional scan-positions and the two additional humidity channels for ATMS are used this does lead to some benefits for the days 1 and 2 forecasts, however, as shown by comparing ATMS_Full - Control and ATMS_AsAMSU - Control.

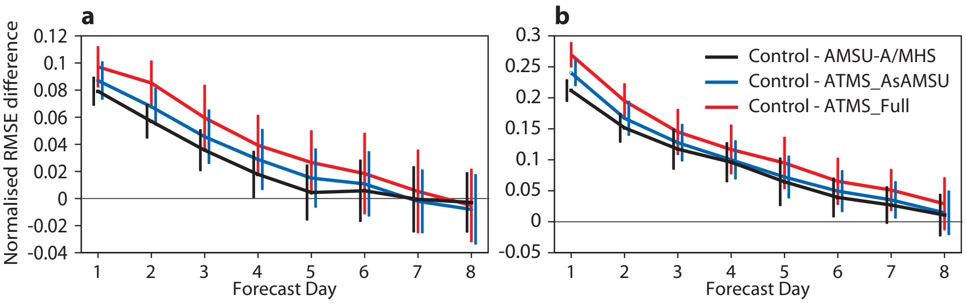

Figure 2: Normalised differences in the root mean squared forecast error as a function of forecast range (days) for the baseline experiments. The three lines indicate differences to the Control for the AMSU-A/MHS, ATMS_Full, and ATMS_AsAMSU experiments, respectively, as indicated in the legend. The vertical bars indicate 95% confidence intervals. Each experiment has been verified against the operational analysis, with a total of 62 cases. a) For the 500hPa geopotential over the Northern Hemisphere extra-tropics. b) As a), but for the Southern Hemisphere extra-tropics.

3 Use of data over land and sea-ice

3.1 Assimilation Trials

Experiments were carried out to include the assimilation of ATMS data over land and sea ice, as follows. Three sets of experiments were run:

- Control: the same as the operational 4D-VAR system at ECMWF, including data from 6 AMSU-A instruments, and 4 MHS instruments. ATMS is also used as in the current operational system.
- ATMS over land: As control but with ATMS humidity channels (18 - 22) and temperature surface-sensitive channels (6 - 8) actively assimilated over land.
- ATMS over land and sea-ice: As 'ATMS over land' with the additional temperature and humidity ATMS channels (6 - 8 and 18 - 22) also actively assimilated over sea-ice.

Note that the land emissivity and sea-ice emissivities were taken from a dynamic retrieval scheme, developed for AMSU-A and MHS ([Karbou et al., 2006], [Di Tomaso et al., 2013]), where the emissivity is calculated from the measured radiances of an ATMS window channel prior to the assimilation. We use emissivities retrieved from channel 3 for the temperature-sounding channels over land and sea-ice, and channel 16 emissivities for the humidity-sounding channels over land and channel 17 over sea-ice. A sink variable is used for the skin temperature, which is allowed to vary during the analysis with the background taken to be the model value and an applied background error of 5 K over land and 7.5 K over sea-ice, as for AMSU-A and MHS. In addition data are screened for cloud which is done over land and sea-ice by applying a first guess check on a window channel, combined with a scatter index check. The experiments were run in the 39R1 version of the ECMWF system at T511 resolution (40km) with 137 model levels in the vertical, and covered two periods: 1.5 months in January - February 2013 and 3.5 months in April - July 2013.

3.2 Results

The background departures of used data were similar for ATMS and AMSU-A or MHS for equivalent channels as shown in Figures 3 and 4, confirming that the dynamic emissivity retrieval combined with cloud-screening works as well for ATMS as it does for AMSU-A and MHS.

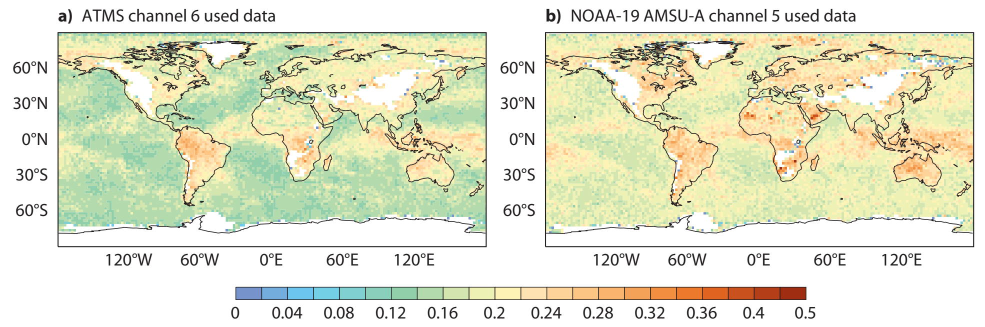

Figure 3: Standard deviation of background departures for a) ATMS channel 6 used data and b) NOAA-19 AMSU-A channel 5 used data for the ATMS over land and sea-ice experiment. These channels are equivalent and are the lowest peaking actively assimilated temperature channels with the highest surface-sensitivity. NOAA-19 and Suomi-NPP satellites have similar afternoon equatorial crossing times.

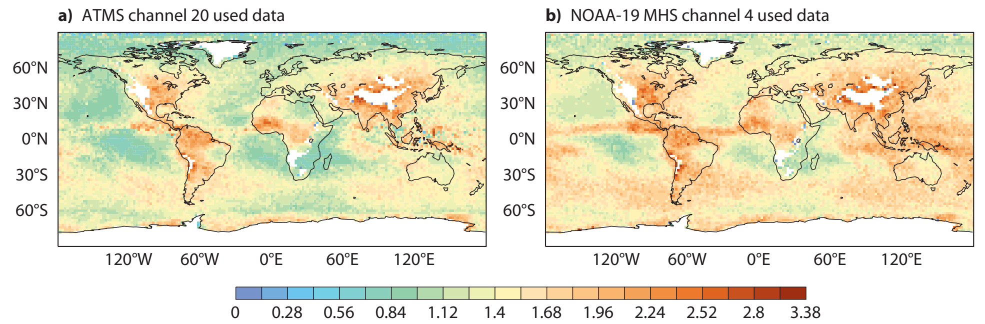

Figure 4: Standard deviation of background departures for a) ATMS channel 20 used data and b) NOAA-19 MHS channel 4 used data for the ATMS over land and sea-ice experiment. These channels are equivalent and are the lowest peaking humidity channels which are assimilated over sea-ice (channel 5 MHS and 18 ATMS are assimilated over land but not sea-ice).

Forecast scores were neutral overall for the introduction of ATMS over land, as shown in Figure 5 (red line) for 500hPa geopotential height for example. Note that in this figure negative values indicate an improvement with respect to the control. There was a reduction in the standard deviation of background departures for AMSU-A and MHS, which is shown in figure 6. This indicates that the new ATMS data introduced over land has improved the 12-hour temperature and humidity forecasts. For the introduction over land and sea-ice there was also a mainly neutral impact on forecast scores, and a reduction in the standard deviation of background departures for AMSU-A and MHS, shown in figures 5 and 6 respectively (black lines). However there was some degradation in the forecast scores for day 1 and 2 temperature over the Southern hemisphere extra-tropics. It is not clear why we see this degradation. It may simply be that adding more data has made the analysis more variable and so not degraded the forecast but rather changed the analysis. This is further supported by the fact that forecast scores verified against the operational analysis do not show this signature and the standard deviation of background departures were unchanged for AMSU-A in this area. Also the background fit to observations improved when this data was introduced.

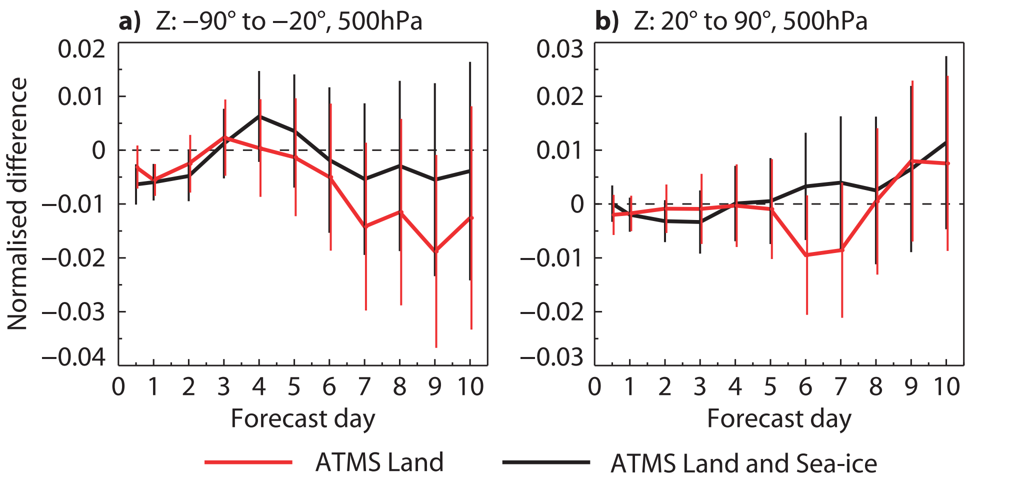

Figure 5: Normalised differences in the root mean squared forecast error as a function of forecast range (days) for the ATMS over land and ATMS over land and sea-ice experiments. The red and black lines indicate differences to the Control for the ATMS over land and ATMS over land and sea-ice experiments respectively. The vertical bars indicate 95% confidence intervals. Each experiment has been verified against the own analysis, and values are for the summer and winter experiments combined which is a total period of 4.5 months with a total of 127 - 147 cases. a) For the 500hPa geopotential over the Southern Hemisphere extra-tropics. b) As a), but for the Northern Hemisphere extra-tropics.

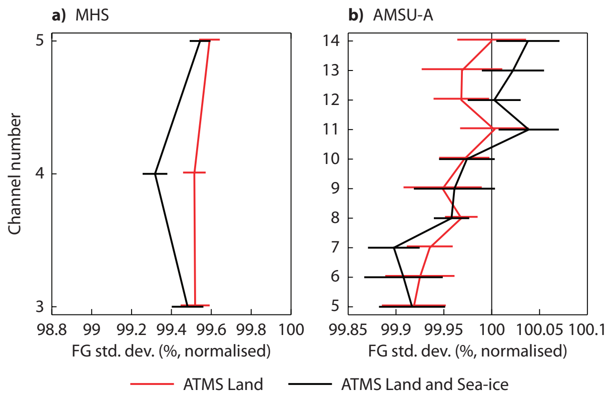

Figure 6: Normalised difference in the standard deviation of background departures between the experiments and the control for a) MHS and b) AMSU-A. Values are for used data averaged globally and over all satellites and for the summer and winter periods combined and are shown per channel (y axis). The red line shows values for the ATMS over land experiments minus the control and the black line indicates the ATMS over land and sea-ice results minus the control. Values are normalised to the control so that a shift left indicates a reduction. The vertical bars indicate 95% confidence intervals.

4 Conclusions

In this paper firstly we presented work done to assess the impact of ATMS data compared to AMSU-A and MHS in the ECMWF assimilation system. Experiments with a depleted observing system highlighted that ATMS performs overall in a comparable way to AMSU-A/MHS. When the additional scan positions and the two extra humidity sounding channels for ATMS were used then the ATMS instrument improved the day 1 and 2 forecast scores more than the equivalent AMSU-A/MHS combination.

Secondly we presented results of assimilation trials for the addition of ATMS channels 6 - 9 and 18 - 22 over land and sea-ice. We saw that ATMS background departures over land and sea-ice were comparable to those of AMSU-A and MHS (used data). For ATMS over land there was a decreased standard deviation of background departures for MHS and AMSU-A and a neutral change in forecast scores. We concluded that the use of additional ATMS data over land improves the short-range temperature and humidity forecasts, as indicated in the reduction of background departures for AMSU-A and MHS. However introducing data over sea-ice produced a more mixed result: the standard deviation of background departures for AMSU-A and MHS were reduced but there was some degradation in the day 1 and 2 temperature forecasts over the Southern hemisphere extra-tropics.

The assimilation of surface-sensitive ATMS data over land will be included in the next update of ECMWF's operational assimilation system, to be implemented in the second half of 2014.

Acknowledgements

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References

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