ECMWF Feature article

from Newsletter Number 136 – Summer 2013

METEOROLOGY

New microwave and infrared data from the S-NPP satellite

www.ecmwf.int/en/about/news-centre/media-resources

doi:10.21957/vh0r17kv

This article appeared in the Meteorology section of ECMWF Newsletter No. 136 – Summer 2013, pp. 28–30.

New microwave and infrared data from the S-NPP satellite

Niels Bormann, Tony McNally

With the launch of the Suomi National Polar Partnership (S-NPP) satellite in October 2011 the USA made its first step into a new era of operational meteorological polar-orbiting satellites. The satellite carries a suite of new instruments, including a microwave radiometer, a hyperspectral infrared interferometer, and an ozone instrument; together these instruments are primarily aimed at providing temperature, humidity and ozone soundings. S-NNP is the successor of the extremely successful NOAA-series of satellites whose ATOVS data has been providing essential input to operational NWP systems for many years. Calibration and validation of the radiance data from S-NPP in the ECMWF system shows that the data is generally of good quality, and assimilation of the data leads to some improvements in forecast skill.

To assist the reader, Box A gives the full name of instruments referred to in this article.

ATMS

The Advanced Technology Microwave Sounder (ATMS) on S-NPP provides temperature and humidity sounding capabilities in the microwave part of the Earth's spectrum. ATMS continues the heritage of AMSU-A and MHS (similar to AMSU-B) which have been flown on the NOAA platforms as well as on the European MetOp satellites. The temperature sounder AMSU-A in particular has been established as one of the leading satellite instruments contributing to today's forecast skill. Microwave data is less affected than infrared data by the presence of clouds, therefore providing important information in these areas. Further ATMS-like instruments are planned for follow-on missions for S-NPP, and a successful exploitation of ATMS data for NWP is hence of paramount importance to maintain or improve forecast quality. Also, while currently five AMSU-A instruments are being assimilated, these are 4–15 years old and have a design lifetime of three years, so failure or instrument degradation of some of these instruments can be expected in the near future.

The temperature sounding channels of ATMS are similar to those of AMSU-A, but with important differences in the detailed channel specifications: ATMS samples the atmosphere more densely than AMSU-A and with a smaller footprint, but each individual ATMS measurement is less accurate than that of AMSU-A. By design, only a spatially-averaged version of the data achieves similar accuracies to the ones we are used to with AMSU-A. This aspect is very important for NWP, as errors in short-term forecasts from today's NWP systems are rather small (of the order of 0.1 K for tropospheric channels), such that the accuracy requirements for temperature-sounding radiances are rather high. In the following, we therefore consider only spatially-averaged ATMS data, obtained by averaging nine adjacent footprints. After averaging, the instrument noise for the tropospheric channels is expected to be around 0.15 K.

A

Instruments onboard the S-NPP satellite

- ATMS: Advanced Technology Microwave Sounder
- CrIS: Cross-track Infrared SounderOMPS: Ozone Mapping Profiler Suite

Instruments onboard other satellites

- AMSU-A: Advanced Microwave Sounding Unit-A (onboard NOAA-15–19, MetOp, and Aqua)
- AMSU-B: Advanced Microwave Sounding Unit-B (onboard NOAA-15 – 17)
- MHS: Microwave Humidity Sounder (onboard NOAA-18 – 19 and MetOp)
- HIRS: High-resolution Infrared Sounder (onboard NOAA and MetOp satellites)
- ATOVS: Advanced TIROS Operational Vertical Sounder: suite of AMSU-A, AMSU-B/MHS, HIRS instruments
- AIRS: Atmospheric Infrared Sounder (onboard Aqua)
- IASI: Infrared Atmospheric Sounding Interferometer (onboard MetOp)

 doi:10.21957/vh0r17kv

To assess the general quality of the ATMS data, we first compare brightness temperature observations unaffected by cloud to short-term forecast equivalents. Given the accuracy of the short-term forecast, this is a very stringent test, benefitting from the wealth of other observations assimilated in the ECMWF system. It allows significant instrument anomalies to be detected easily. Such comparisons are an integral part of the international calibration/validation of the data.

Comparisons against short-term forecasts show that the ATMS data achieves an overall accuracy that is similar to or better than that of AMSU-A and MHS (Figure 1), and the instrument is well within specification. For the tropospheric channels (ATMS 6–9), ATMS performs clearly better than all the AMSU-A instruments currently assimilated; this is particularly good as some of these channels have already failed for the AMSU-A instruments currently in orbit. Another attractive feature of ATMS is that the scan biases vary very smoothly with scan position, even out to the outermost scan positions, for which AMSU-A tends to show complicated biases that make assimilation more difficult (Figure 2). Combined with the wider swath from ATMS, this means a significant gain in the number of observations that are considered for assimilation.

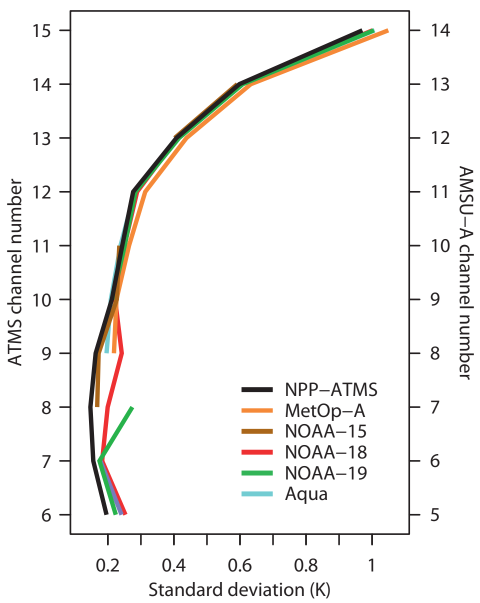

Figure 1 Performance of the ATMS instrument in comparison to AMSU-A: Standard deviations of first-guess departures for ATMS in comparison to AMSU-A instruments carried on Aqua and the NOAA satellites, and MHS on MetOp-A, all of which are currently assimilated in the ECMWF system.

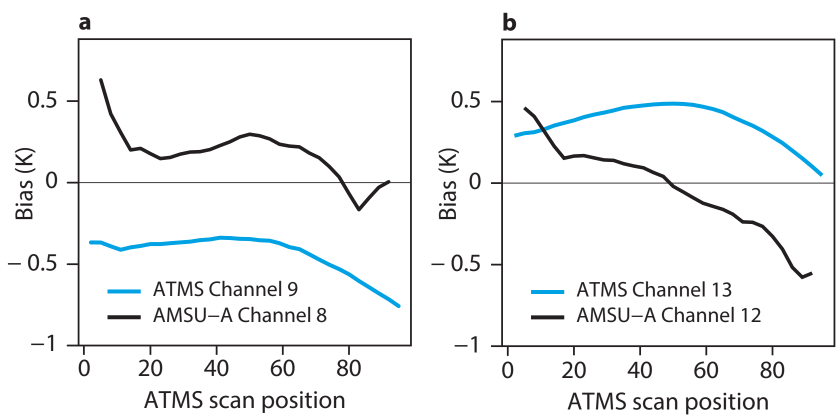

Figure 2 Comparison of scan biases for ATMS and AMSU-A: Mean differences between observed and simulated brightness temperatures as a function of scan position for (a) ATMS channels 9 and the equivalent channel 8 from AMSU-A onboard NOAA-18 and (b) ATMS channel 13 and the equivalent channel 12 from AMSU-A onboard NOAA-18.

Closer inspection, however, reveals a small anomaly in the data which is not present for AMSU-A. Maps of differences between observations and short-term forecasts show a scanline-dependent striping (Figure 3). While the effect is very small, such signatures are clearly not visible for AMSU-A data. Further investigations by the calibration/validation team indicate that this feature is likely due so-called 1/f-noise of an amplifier used in the instrument. The instrument nevertheless still performs within specification, but it is unlikely that this error can be corrected through advanced processing of the data. For the assimilation of the data this means that a proportion of the error in the observations is correlated spatially and between channels. Such error correlations are usually neglected in the assimilation, and this feature of ATMS means that the data should not receive quite as much weight in the analysis as AMSU-A. However, given the excellent performance of the instrument otherwise, this was not considered a show-stopper.

Added to the suite of operationally assimilated observations, ATMS shows a neutral to positive forecast impact in the ECMWF system, with particularly positive impact for the short-range over the southern hemisphere (Figure 4). This is an excellent result, given that the system already assimilates data from five AMSU-A and three MHS instruments, with some of these in orbits very similar to that of S-NPP. It highlights that benefits are still to be gained with additional observations, and that ATMS is clearly a capable complement to today's global observing system.

ATMS data has been assimilated operationally in the ECMWF system since 25 September 2012.

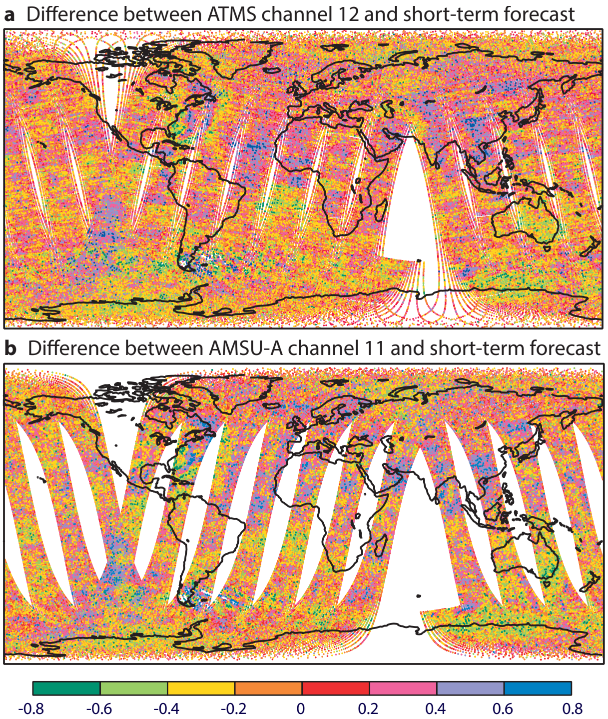

Figure 3 Cross-track striping feature in ATMS data: (a) Map of differences between observations and short-term forecast equivalents for ATMS channel 12 for the 6-hour period around 00 UTC on 2 July 2012. (b) As (a), but for the equivalent channel 11 from AMSU-A onboard NOAA-19.

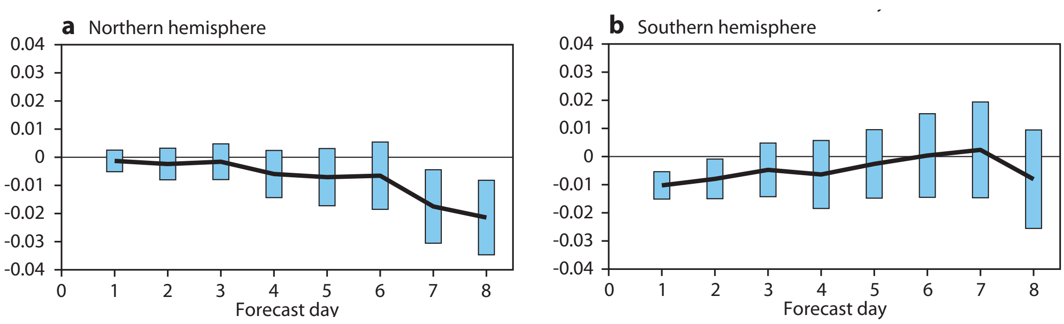

Figure 4 Positive impact from adding ATMS data to the assimilation: Normalised differences in the root-mean-square error (RMSE) of the 500 hPa geopotential for (a) the northern and (b) the southern hemispheres as a function of forecast range from a total of 102 cases from December 2011 to February 2012 and July to August 2012. Error bars indicate 95% confidence intervals.

doi:10.21957/vh0r17kv

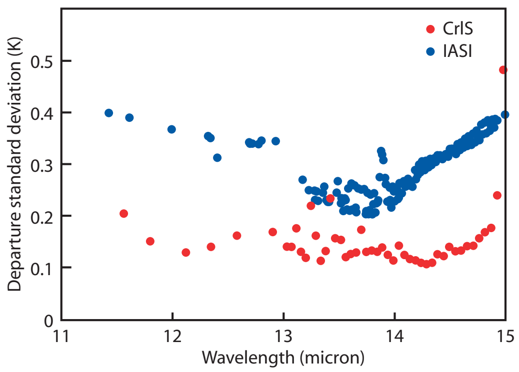

Figure 5 Performance of the CrIS compared to IASI: Standard deviations of radiance departures for CrIS and IASI for the long-wave region of the infrared spectrum. Statistics are evaluated over one month (August 2012).

CrIS

The Cross-track Infrared Sounder (CrIS) is a Fourier transform spectrometer that measures atmospheric infrared radiation in 1,305 spectral channels. These cover three wavelength regions: long-wave (9.14–15.38 microns), mid-wave (5.71–8.26 microns) and short-wave infrared (3.92–4.64 microns). CrIS provides information on atmospheric temperature, humidity and chemical composition. On the ground a typical CrIS pixel has a diameter of 14 km, and 30 Earth views consisting of a 3×3 array of CrIS pixels make up a single scan line across the 2,200 km swath. The CrIS is the contribution of the USA to operational hyper-spectral infrared sounding with the European contribution being the IASI instrument onboard the MetOp satellites.

As with ATMS, the quality of the CrIS observations has been evaluated by comparison with radiances computed from the ECMWF short-range forecast. Statistics for CrIS evaluated over a one month period are shown in Figure 5 where, for comparison purposes, the equivalent statistics for IASI are also displayed. It can instantly be seen that departure standard deviations are significantly lower for CrIS (typically a factor of two compared to IASI) indicating that the observations have a very low radiometric noise. Of course the comparison is not a fair one as IASI measures radiation with a much finer spectral resolution (8,463 spectral intervals compared to the 1,305 of CrIS), but the results do confirm that the CrIS radiance observations are of extremely high quality.

Assimilation experiments have been run where CrIS data is used in a very similar manner to IASI and AIRS data. Initially a very modest set of just 65 channels has been actively assimilated – taking into account that S-NPP sits in an almost identical orbital plane to the Aqua satellite and that 165 channels are already assimilated from AIRS. With observation errors set to the same values currently used for IASI (arguably conservative given the much lower noise levels) the impact of CrIS was rather neutral with some very slight positive impact. However, any attempts to increase the weight given to the CrIS radiances in the analysis by reducing observation errors closer to levels consistent with the departure statistics produces significantly worse results. Similarly, attempts to increase the number of channels assimilated results in degraded analyses and forecasts.

Research continues to understand the factors that are currently limiting the impact of CrIS. The most likely candidate is the presence of inter-channel error correlations that are not currently modelled in the ECMWF analysis. While the noise levels in the data are very low, certain processing of the observed spectra by the data provider correlates the error in one channel with its neighbours (through a process known as apodisation). Also, as noise levels in the observations are so low, correlated contributions from other sources (such as radiative transfer model error and errors of representativeness) become more significant in the overall radiance error. Experiments where these correlations are estimated and explicitly taken into account are in progress.

Interaction with space agencies

The experience with S-NPP highlights again the fruitful role that ECMWF plays during the calibration and validation phase for new satellite data. The feedback provided is not only important for the instruments under evaluation, but also helps to shape future satellite missions. We will continue our strong links with satellite agencies which are vital in this respect.