

Assimilation Of NOAA-19 Data – The Pinnacle Of ATOVS Data At ECMWF?

Niels Bormann

*European Centre for Medium-range Weather Forecasts (ECMWF),
Shinfield Park, Reading RG2 9AX, United Kingdom
Contact: n.bormann@ecmwf.int*

Abstract

For over a decade data from the ATOVS suite of instruments has provided important input to data assimilation systems for NWP. It continues to contribute substantially to today's forecast skill. Here we report on the early monitoring of NOAA-19 ATOVS data and initial assimilation trials before the operational assimilation. With data from six AMSU-A, four AMSU-B/MHS and three HIRS these experiments will make use of what is probably the largest number of ATOVS instruments we will ever have simultaneously in the ECMWF system.

Early monitoring showed that overall NOAA-19 data from the three instruments performed as expected, with First Guess departure statistics comparable to those from other instruments already used in the system.

Assimilation trials with adding NOAA-19 data as the sixth AMSU-A, the fourth AMSU-B/MHS and the third HIRS still show a small, but consistent positive forecast impact. This is remarkable, given the relatively large number of similar instruments already used in the system.

Since these experiments have been performed, some ATOVS instruments suffered problems or showed deteriorating performance, most notably the NOAA-19 MHS, but otherwise primarily older instruments such as the NOAA-16 AMSU-A or the NOAA-17 AMSU-B.

Introduction

For over a decade data from the ATOVS suite of instruments (e.g., Goodrum et al. 2009) has provided important input to data assimilation systems for NWP. It continues to contribute substantially to today's forecast skill (e.g., Kelly and Thépaut 2007).

Here we report on the early monitoring of NOAA-19 ATOVS data and initial assimilation trials before the operational assimilation. The satellite was launched on 6 February 2009 as the last satellite in the NOAA-series. It suffered some damage during manufacture, when the spacecraft fell on the floor while being turned, as some bolts holding the satellite had been removed. The satellite and instruments were subsequently refurbished and considered within specification.

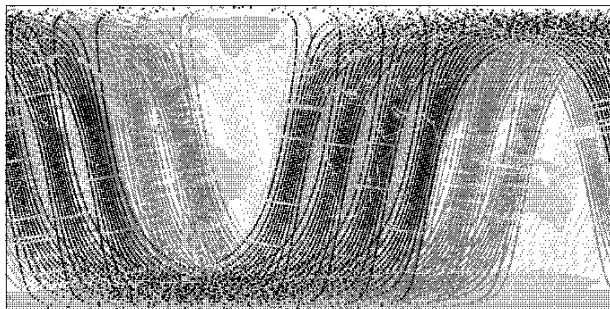
NOAA-19 takes over from NOAA-18 as NOAA's primary afternoon satellite, and it becomes the seventh satellite with some ATOVS instruments currently considered for assimilation at ECMWF (see Table 1 for the other satellites). Not all ATOVS instruments are available or considered fit for assimilation on all seven satellites (Table 1), and the resulting coverage for the three instruments considered during a 6-hour period is shown in Fig. 1. The Figure shows that there is considerable overlap for NOAA-19 with other satellites in the case of AMSU-A (esp. with NOAA-18 and Aqua), but for HIRS, NOAA-19 fills the gap left by the poorly performing HIRS instrument on the NOAA-18 satellite.

In the experiments presented here we make use of what is probably the largest number of ATOVS instruments we will ever have simultaneously in the ECMWF system.

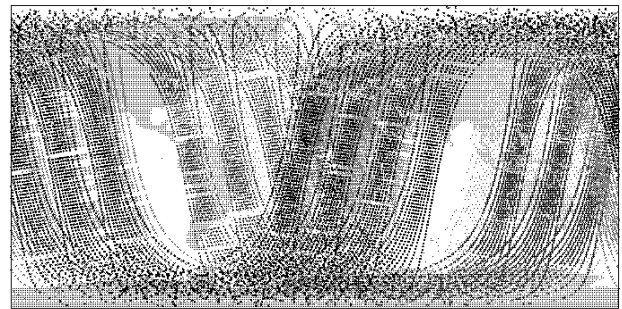
Table 1: Other ATOVS instruments used operationally in March/April/May 2009.

	AMSU-A	AMSU-B/MHS	HIRS
NOAA-15	yes (not ch 6, 11 14)	no	No
NOAA-16	yes	no	No
NOAA-17	Instrument failed	yes	Yes
NOAA-18	yes	yes	No
Aqua	yes (not ch 7)	n/a	n/a
METOP-A	yes (not ch 7)	yes	Yes

a) AMSU-A



b) AMSU-B/MHS



● METOP-A ● NOAA-15 ● NOAA-16 ● NOAA-17 ● NOAA-18 ● Aqua ● NOAA-19

c) HIRS

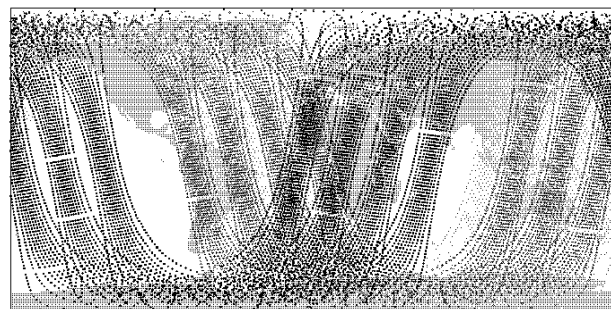


Figure 1: Sample coverage for ATOVS instruments, colour-coded by satellite, for the 6-hour period around 3 April 2009 0Z. For display purposes, not every available field of view is plotted.

Monitoring and cross-validation

Early monitoring in March/April 2009 showed that overall NOAA-19 data from the three instruments performed as expected, with First Guess departure statistics comparable to those from other instruments already used in the system (Figures 2-4). To produce these statistics, the new instruments were passively monitored in the ECMWF system, and the variational bias correction (Dee 2004) was used to establish bias corrections. Screening and data selection criteria as well as details on the bias correction models used for each instrument can be found in Bormann and Bauer (2010).

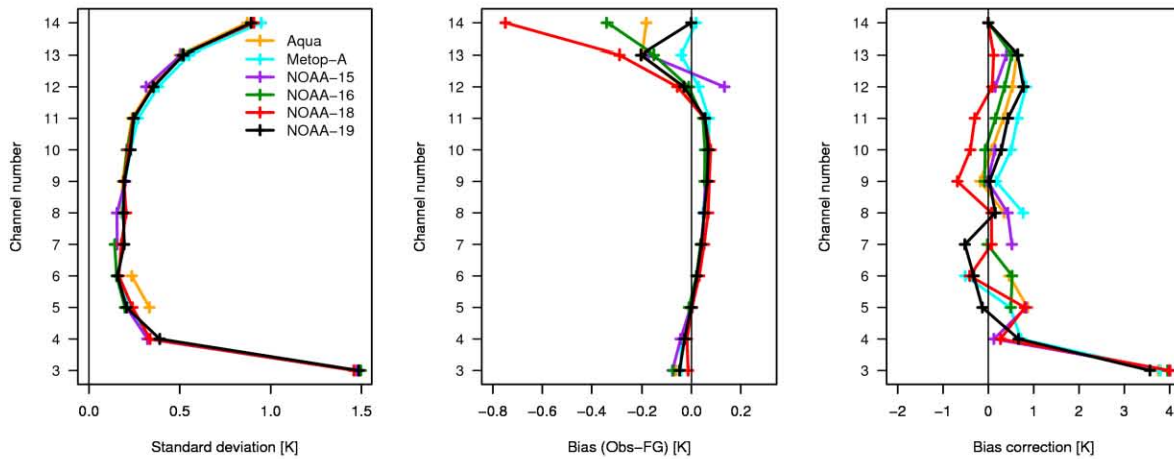


Figure 2: Global FG-departure statistics for AMSU-A over sea for the satellites considered in the ECMWF system, in terms of the standard deviation of FG-departures after bias correction (left), the mean residual observation-minus-FG bias after bias correction (middle), and the mean bias correction (right). For NOAA-19, statistics are based on passively monitored data after quality control, whereas for the other satellites statistics are shown for assimilated data or passive data that is used for quality control. Statistics are based on the 5-day period 21-25 April 2009 and they have been taken from the operational assimilation system.

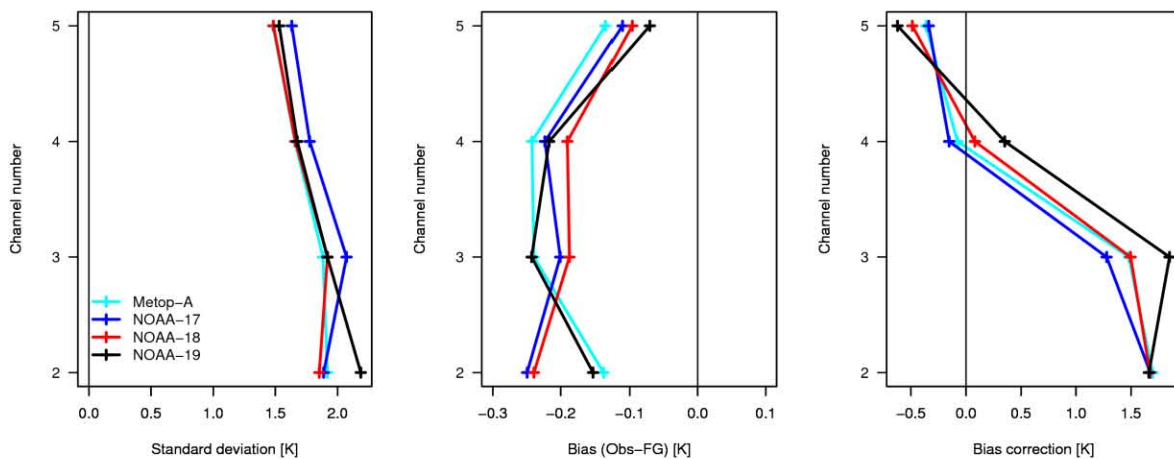


Figure 3: As Fig. 2, but for AMSU-B or MHS data.

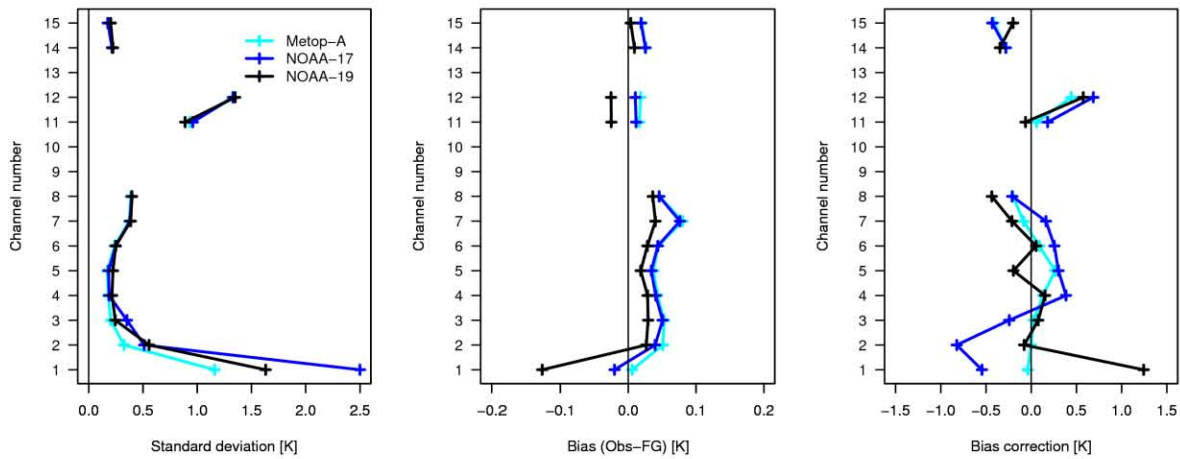


Figure 4: As Fig. 2, but for HIRS data.

One small exception is channel 7 of AMSU-A which shows more rugged scan biases than commonly observed (Fig. 5). These biases also changed state during the early monitoring period, coincident with jumps in the mean space counts observed for this channel (Figures 5 and 6). The latter are thought to have been caused by the triggering of the temperature compensation circuit. Scan biases for other AMSU-A channels also show a somewhat more complex structure than what is typically encountered with other AMSU-As (Fig. 7). Scan-biases are corrected for in the ECMWF system as part of the variational bias correction, using a 3rd order polynomial in the scan-position. Due to the complex structure of the biases, this approach struggles to completely remove the observed scan biases. As a result, significant bias remains after bias correction, reaching values comparable to the standard deviation of the FG-departures for some channels for some scan-positions (esp., channels 7-10). For channels other than channel 7, the scan bias pattern are, however, stable in time, so improved bias correction with a different bias model would be feasible.

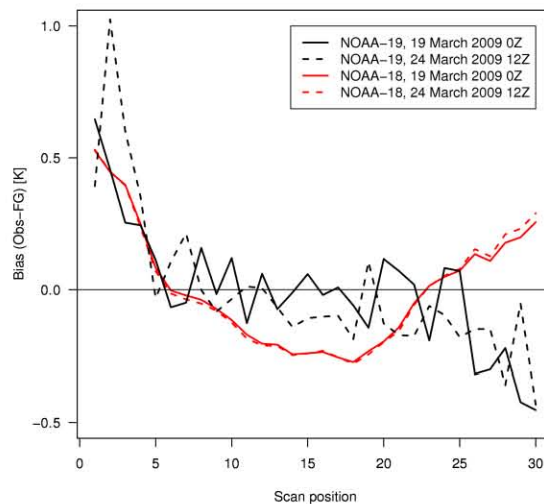


Figure 5: Scan bias (observation minus FG) for NOAA-19 (black) and NOAA-18 (red) AMSU-A channel 7 for different periods, taken from offline monitoring experiments. Only the mean bias has been subtracted. Solid lines show statistics for the period 18 March 2009 21 Z - 19 March 2009 9 Z, whereas dashed lines show statistics for the period 24 March 2009, 9 - 21 Z.

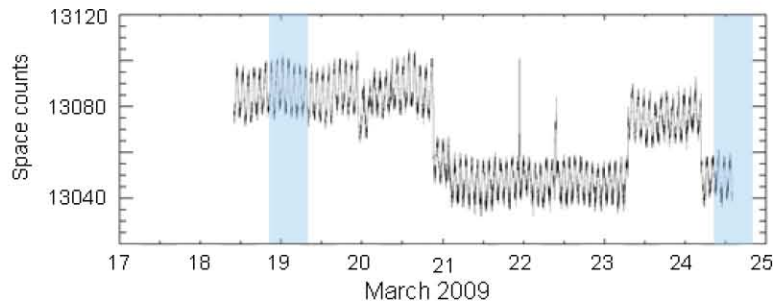


Figure 6: Time-series of the mean space counts for NOAA-19 AMSU-A channel 7 (courtesy of Nigel Atkinson, Met.Office). Periods used for comparison in Fig. 5 are marked in blue.

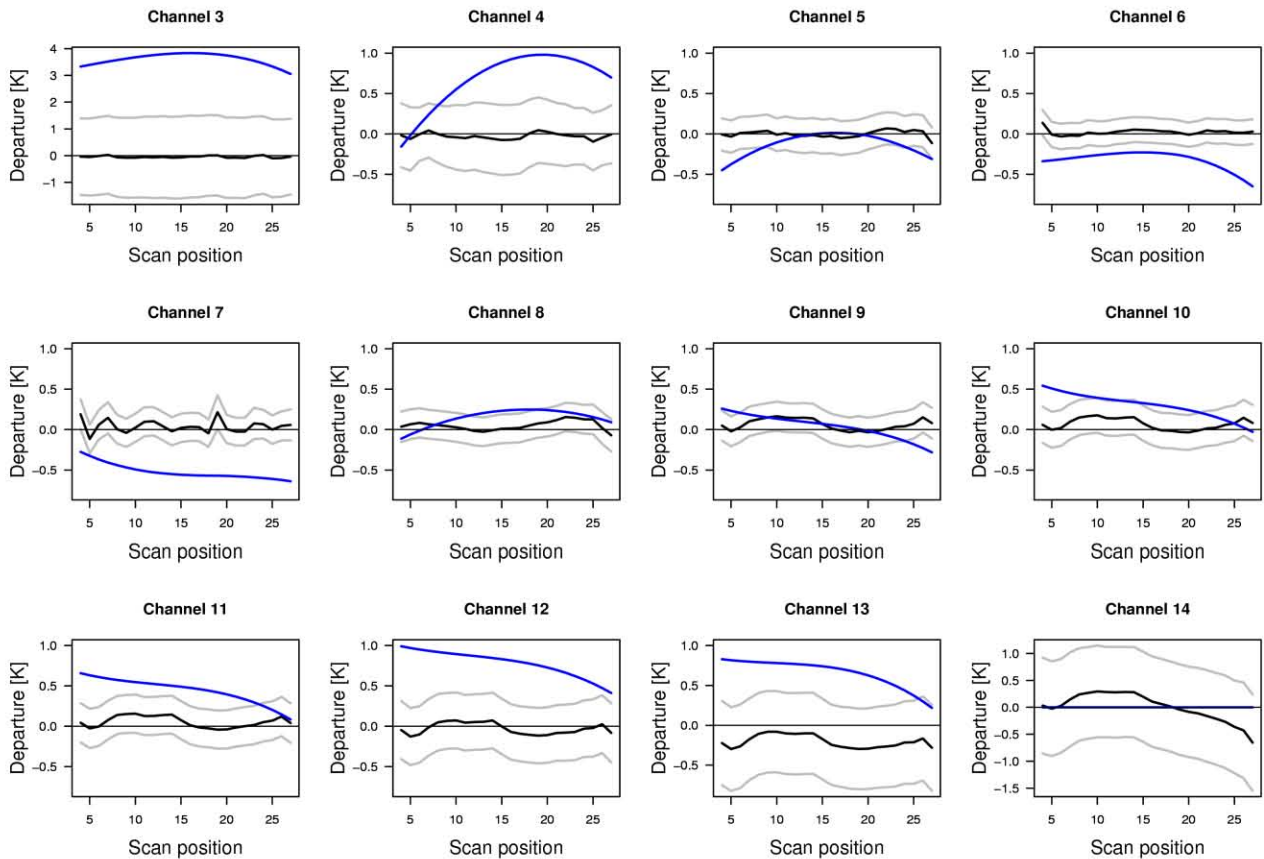


Figure 7: FG departure statistics as a function of scan position for NOAA-19 AMSU-A. Statistics are based on 5-days of data (21-25 April 2009), over sea, after quality control. Black indicates the mean departure after bias correction, with the grey lines indicating plus/minus one standard deviation. Blue is the mean bias correction.

Also, NOAA-19 MHS initially required somewhat larger bias corrections for most channels compared to other AMSU-B/MHS instruments (Fig. 4). This was mitigated after an update of the antenna pattern correction (Jörg Ackermann 2009, pers. communication), which brought the bias corrections more in-line with those for other instruments.

Assimilation

Assimilation trials were performed in which NOAA-19 data from the three ATOVS instruments were added as the sixth AMSU-A, the fourth AMSU-B/MHS and the third HIRS (see Table 1 for the other ATOVS instruments assimilated in these experiments). The experiments used a model resolution of

T255 (~80 km), an incremental analysis resolution of T159 (~125 km) and covered the period 28 March - 26 May 2009. Coefficients for the variational bias correction for the new sensors were spun up for four days prior to the experimentation period.

The forecast impact of NOAA-19 ATOVS data is neutral to slightly positive for geopotential, wind, and relative humidity (e.g., Fig. 8). When averaged over the Northern Hemisphere, the improvements for geopotential are statistically significant at the 90 % level for most forecast ranges.

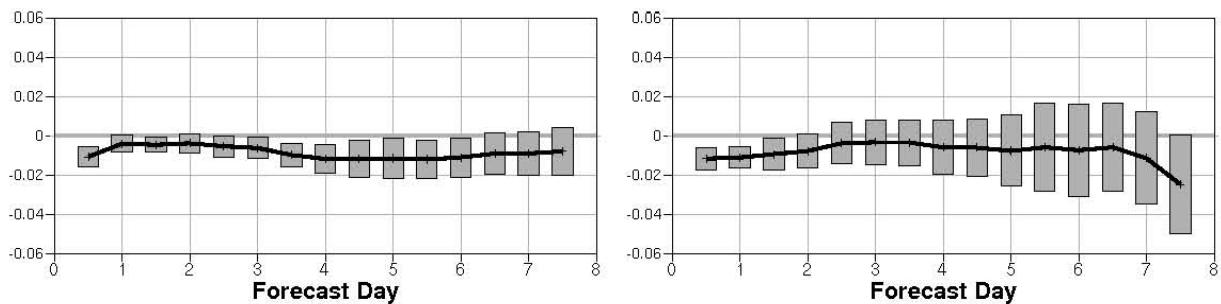


Figure 8: Forecast impact of NOAA-19 data: Normalised differences in the root mean squared forecast error between the NOAA-19 experiment and the control for the 0 Z forecast of the 500 hPa geopotential for the Northern Hemisphere (left) and the Southern Hemisphere (right). Verification is against the own analysis, and the period is 28 March - 18 May 2009 (52 cases). Error bars indicate 90 % significance intervals from a t-test.

Conclusions

The main conclusions from this study are:

- During the early monitoring phase, NOAA-19 data showed characteristics against the model First Guess that are overall in-line with data from similar instruments.
- In assimilation trials, NOAA-19 ATOVS data give a small positive forecast impact over the Northern Hemisphere when added as sixth AMSU-A, fourth AMSU-B/MHS, and third HIRS instrument. This is remarkable, given the many similar instruments already present in the system and the proximity of the NOAA-19 data to the already assimilated NOAA-18 or Aqua data.

NOAA-19 ATOVS data have been assimilated operationally at ECMWF since 2 June 2009.

Epilogue

Since these experiments have been performed, some ATOVS instruments suffered problems or showed deteriorating performance. NOAA-16 AMSU-A was excluded from the assimilation on 22 June 2009 as it showed re-occurring episodes of degradation in the instrument noise; similarly, NOAA-17 AMSU-B was excluded on 22 December 2009 after instrument problems. Most notably, NOAA-19 MHS was not assimilated operationally between 4 August 2009 and 17 March 2010 after noise problems in channels 3 and 4; channels 4 and 5 were re-introduced after the noise in channel 4 improved. Also, NOAA-19 AMSU-A channel 8 has too large noise since late December 2009 and has been excluded from the assimilation. Similarly, Aqua AMSU-A channel 5 was excluded from

operations on 29 April 2010 after noticeable degradation. At the time of writing, the number of operationally assimilated ATOVS instruments is down to 5 AMSU-As, 3 AMSU-B/MHSs, and 3 HIRS instruments.

Acknowledgements

The help of Nigel Atkinson (Met.Office), Martin Suttie, Milan Dragosavac, John Hodgkinson, and Ioannis Mallas in obtaining the NOAA-19 data is gratefully acknowledged. Brett Candy, Nigel Atkinson (both Met.Office) and Fuzhong Weng (NOAA/NESDIS) provided valuable feedback on the data quality.

References

Bormann, N. and P. Bauer, 2010: Estimates of spatial and inter-channel observation-error characteristics for current sounder radiances for numerical weather prediction. I: Methods and application to ATOVS data. Q.J.R.Meteorol.Soc., 136, in press.

Dee, D., 2004: Variational bias correction of radiance data in the ECMWF system. In Proceedings of the ECMWF workshop on assimilation of high spectral resolution sounders in NWP, ECMWF, Reading, UK., 97-112.

Goodrum, G., K. Kidwell, and W. Winston, 2009: NOAA KLM User's Guide with NOAA-N, -N-Prime supplement. NOAA, [available from: <http://www2.nedc.noaa.gov/docs/klm/cover.htm>, accessed: 17 August 2009].

Kelly, G. and J.-N. Thépaut, 2007: Evaluation of the impact of the space component of the Global Observing System through Observing System Experiments. Final Report SOW EUM.MET.SOW. 04.0290. [available from: <http://www.ecmwf.int/publications/library/do/references/list/203>]

International TOVS Study Conference, 17th, ITSC-17, Monterey, CA, 14-20 April 2010.
Madison, WI, University of Wisconsin-Madison, Space Science and Engineering Center,
Cooperative Institute for Meteorological Satellite Studies, 2011.