Observing system experiments on ATOVS orbit constellations

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The impact of ATOVS data on the performance of global numerical weather prediction (NWP) is evaluated through observing system experiments on different orbit constellations. This work aims to provide some references for planning future observing systems that involve ATOVS-like instruments, according to the CGMS' objectives to harmonise meteorological satellite mission parameters such as orbits.

Experiments

At the time of writing, there are seven polar-orbiting satellites present in the ECMWF system carrying one or more ATOVS instruments: the NOAA series, NASA's Aqua satellite and the European MetOp-A satellite. A set of experiments were run where ATOVS Microwave (MW) sounder data (AMSU-A and AMSU-B/MHS) from already-deployed instruments were added or denied as shown in Table 1. The NOAA-15 experiment uses a more homogeneous sampling with equally spaced orbits, whereas in the NOAA-19 experiment two orbits are very close to each other (Figure 1). Only AMSU-A has been tested as an additional instrument in the "three-satellite experiments", as there are not three satellites in the desired orbits carrying all functioning ATOVS instruments. Experiments were run from 14 April 2009 to 4 August 2009 within the ECMWF 4D-Var assimilation system at a T511 (40 km) resolution.

Experiment name	Satellite	MW sounders
"no-MW sounder experiment"	–	–
"two-satellite experiment"	NOAA-18	AMSU-A MHS
	MetOp-A	AMSU-A MHS
"NOAA-15 experiment"	NOAA-15	AMSU-A
	NOAA-18	AMSU-A MHS
	MetOp-A	AMSU-A MHS
"NOAA-19 experiment"	NOAA-18	AMSU-A MHS
	NOAA-19	AMSU-A
	MetOp-A	AMSU-A MHS
"all-satellite experiment"	NOAA-15	AMSU-A
	NOAA-16	AMSU-A (*until 22 June 2009*)
	NOAA-17	AMSU-B
	NOAA-18	AMSU-A MHS
	NOAA-19	AMSU-A MHS
	Aqua	AMSU-A
	MetOp-A	AMSU-A MHS

Table 1 ATOVS MW sounders available to the experiments.

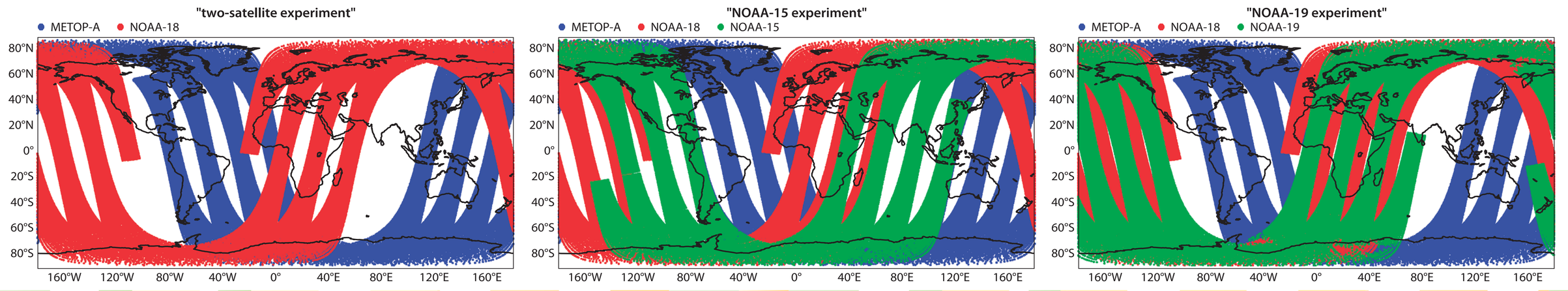

Figure 1 Sample coverage for used AMSU-A data in the "two-satellite experiment", the "NOAA- 15 experiment", and the "NOAA-19 experiment".

Results

Statistics of observation departures from NWP model estimates.

- Both NOAA-15 and NOAA-19 bring some improvement to the fit to temperature observations compared to the assimilation of data from just two satellites, as well as to the fit to AMSU-A data already present in the system (onboard of NOAA-18 and MetOp-A). The latter improvement is slightly greater in the "NOAA-15 experiment" than in the "NOAA-19 experiment" (Figure 2).
- Wind information can be gained through the assimilation of ATOVS MW sounders data in 4D-Var (Figure 3).
- When comparing the "NOAA-15 experiment" and the "NOAA-19 experiment", there are no relevant differences in the departure statistics of the radiosonde temperatures in favour of one experiment or the other, and the differences are marginal also for the aircraft temperatures and for radiosonde humidity observations.

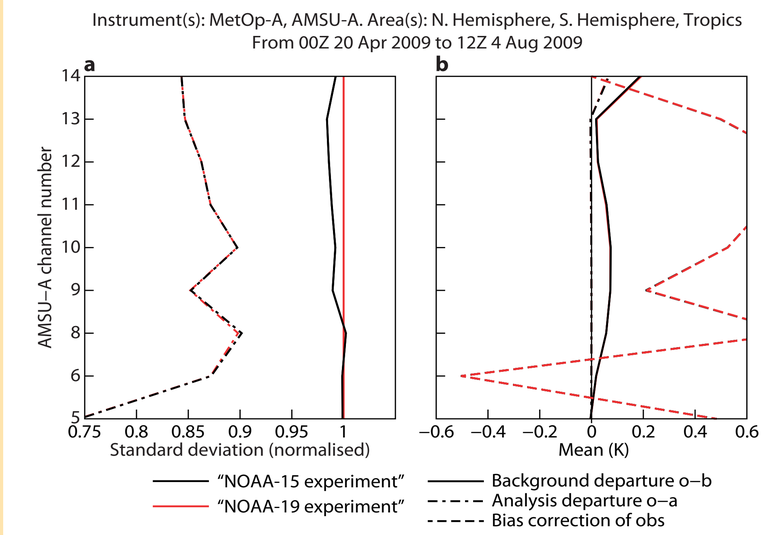

Figure 2 MetOp-A brightness temperature departure statistics for the "NOAA-15 experiment" (black) and the "NOAA-19 experiment" (red). Standard deviations have been normalised to the "NOAA-19 experiment".

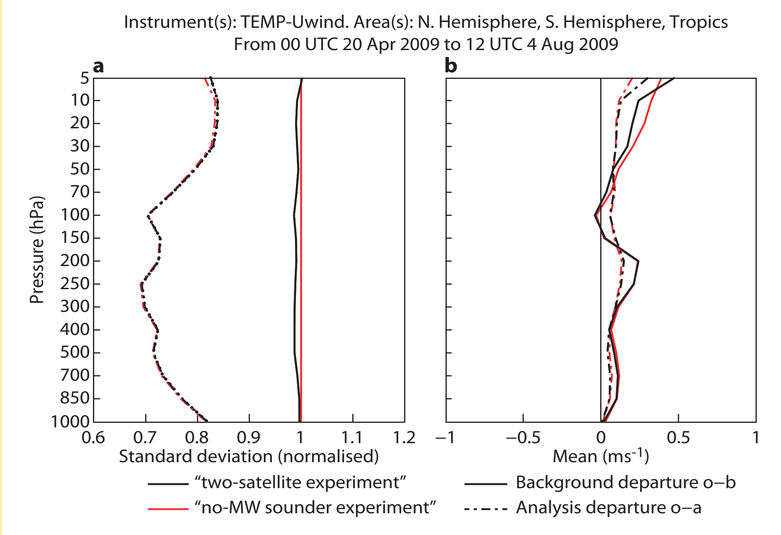

Figure 3 Radiosonde winds departure statistics for the "two-satellite experiment" (black) and the "no-MW sounder experiment" (red). Standard deviations have been normalised to the "no-MW sounder experiment".

Forecast impact

- The assimilation of AMSU-A and AMSU-B/MHS data from two satellites has a very strong positive impact on the forecast of the geopotential. The full system still outperforms the two or three satellite systems in the Southern Hemisphere (Figure 4).
- When averaged over the extra-Tropics the impact for the forecast of the geopotential of the "NOAA-15 experiment" versus the "NOAA-19 experiment" is neutral to slightly positive. For the forecast of the temperature the impact of the "NOAA-15 experiment" versus "NOAA-19 experiment" is also quite neutral, with a slightly positive impact in the Southern Hemisphere that appears statistically significant at the 95% level about the 5-day forecast at 1000 hPa and 850 hPa (Figure 5).

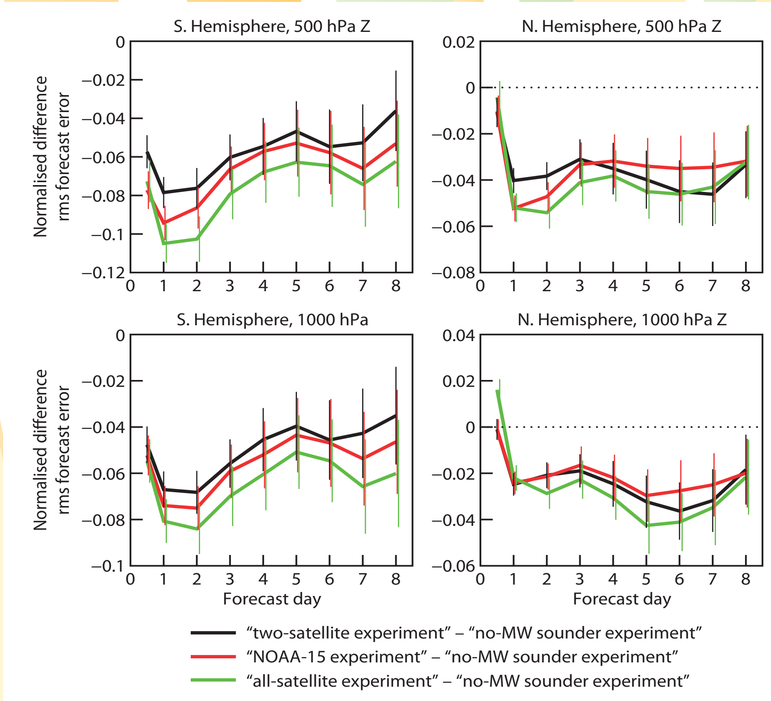

Figure 4 Normalised differences in the root-mean-square forecast error between the "two-satellite experiment" and the "no-MW sounder experiment" (black), between the "NOAA-15 experiment" and the "no-MW sounder experiment" (red), and between the "all-satellite experiment" and the "no-MW sounder experiment" (green) for the 0Z forecast of the 500 hPa and 1000 hPa geopotential. Verification is against the experiment own-analysis and the sample size is 107. Negative values indicate that the "two-", "NOAA-15", and "all-satellite experiment" have smaller RMS errors than the "no-MW sounder experiment".

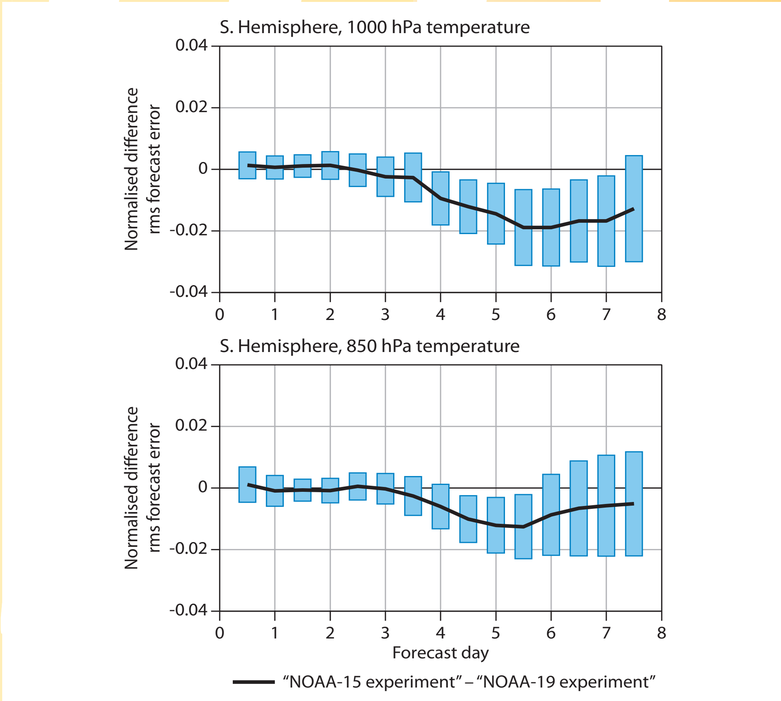

Figure 5 Normalised differences in the root-mean-square forecast error between the "NOAA-15 experiment" and the "NOAA-19 experiment" for the 0Z forecast of the 1000 hPa and 850 hPa temperature for the Southern Hemisphere. Verification is against the operational analysis and the sample size is 107. Negative values indicate that the "NOAA-15 experiment" has smaller RMS errors than the "NOAA-19 experiment".

Conclusions

- The assimilation of AMSU-A observations from a third satellite has a positive forecast impact in the Southern Hemisphere in comparison to the use of just two AMSU-A instruments, and there is a clear advantage in assimilating all available ATOVS data. The latter shows that the benefit of ATOVS data is not saturated yet with a three-satellite configuration.
- ATOVS microwave sounder data from three satellites providing a greater temporal sampling (i.e. MetOp-A, NOAA-18 and NOAA-15) have a slightly larger positive forecast impact in the Southern Hemisphere than data from three satellites having a less optimal coverage (i.e. MetOp-A, NOAA-18 and NOAA-19).
- Departures of MetOp-A AMSU-A observations from the NWP model estimates of the atmospheric state show some benefits from assimilating observations from NOAA-15 rather than NOAA-19 in addition to the a.m. and p.m. satellites (MetOp-A and NOAA-18), providing a further indication of an improved short-term forecast in the constellation of more evenly-spaced orbits.

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