Radiometric requirements for a post-EPS microwave sounder

Abstract Planning for the next European Polar System (post-EPS) is underway and a microwave sounder will be an important component of the mission payloads. As part of an ESA-funded study, a number of observing system experiments (OSEs) were carried out at the Met Office and ECMWF. They aim at establishing the sensitivity of forecast accuracy to radiometric performance for a microwave sounding mission using AMSU-A data and noise degraded AMSU-A data. The results show measurable degradation in the impact of MWS data if the noise performance (NEΔT) of AMSU is degraded from 0.1 K to 0.2 K (for remapped data), with Southern Hemisphere forecast impacts reduced by ~10–15%.

W. Bell [1*], **S. English** [1], **S. Di Michele** [2], **P. Bauer** [2] and **J. Charlton** [3]

1 Met Office, FitzRoy Road, Exeter, UK (*W. Bell now at ECMWF)

2 ECMWF, Shinfield Park, Reading, UK

3 Sula, Wotton-under-Edge, UK

The process of defining the mission requirements for the next generation series of European meteorological polar orbiting satellites (post-European Polar System, or post-EPS), to operate post-2018, is underway. Microwave sounding data has in the past provided very significant benefit in NWP systems and recent observing system experiments have shown that microwave sounding data continues to provide significant benefit, even in the presence of advanced infrared sounders (AIRS and IASI), as shown in Figure 1. A microwave sounding instrument (MWS) will therefore be an important component of post-EPS.

The radiometric requirements for such a sounding mission have a significant bearing on the type of instrument chosen for the MWS. For example due to the longer integration times possible with cross-track radiometers NEΔTs are generally low, relative to conical scan geometries. Recent studies on the on-orbit performance of SSMIS have also shown that conical scanners can be more prone to complex systematic biases that limit their impact in NWP DA systems (*Kunkee (2008) and Bell (2008)*).

Radiometric requirements for temperature sounding channels are particularly stringent as background (i.e. T+6 hour forecast) fields are generally of very high quality in NWP models (HBH^T ~0.1 K for tropospheric sounding channels). Figure 2 shows the observation minus fist guess departures for AMSU channel 6 at 54.4 GHz. Measured radiances therefore need random noise performance (NEΔTs) and residual systematic biases below 0.3 K to improve analyses and forecasts.

This poster presents a set of observing system experiments (OSEs) carried out at the Met Office and ECMWF, funded by ESA, aimed at assessing the impact of degraded radiometric performance on forecast accuracy achieved by current global NWP models.

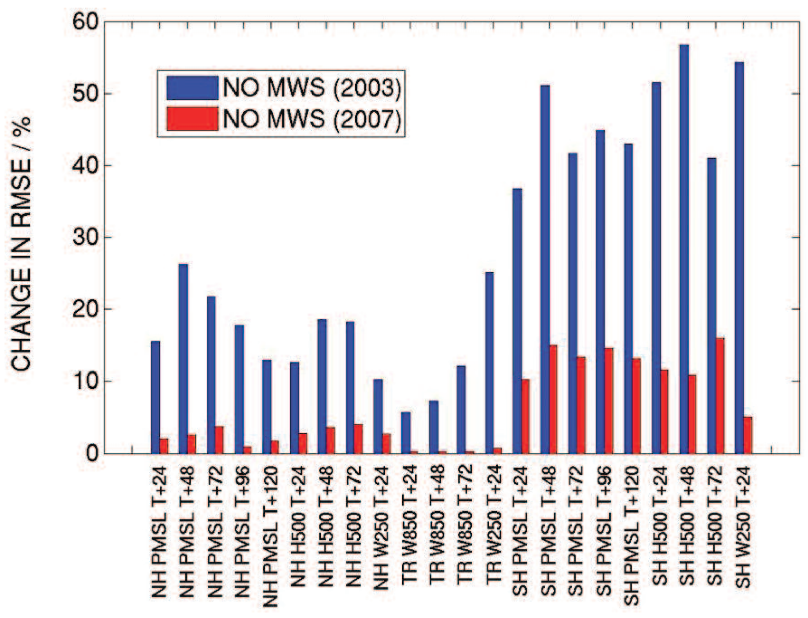

Figure 1 Data denial experiments in 2003 (blue) showing the impact of withdrawing all MWS sounding data. The 2007 experiment (red) is relative to a control which includes AIRS and IASI.

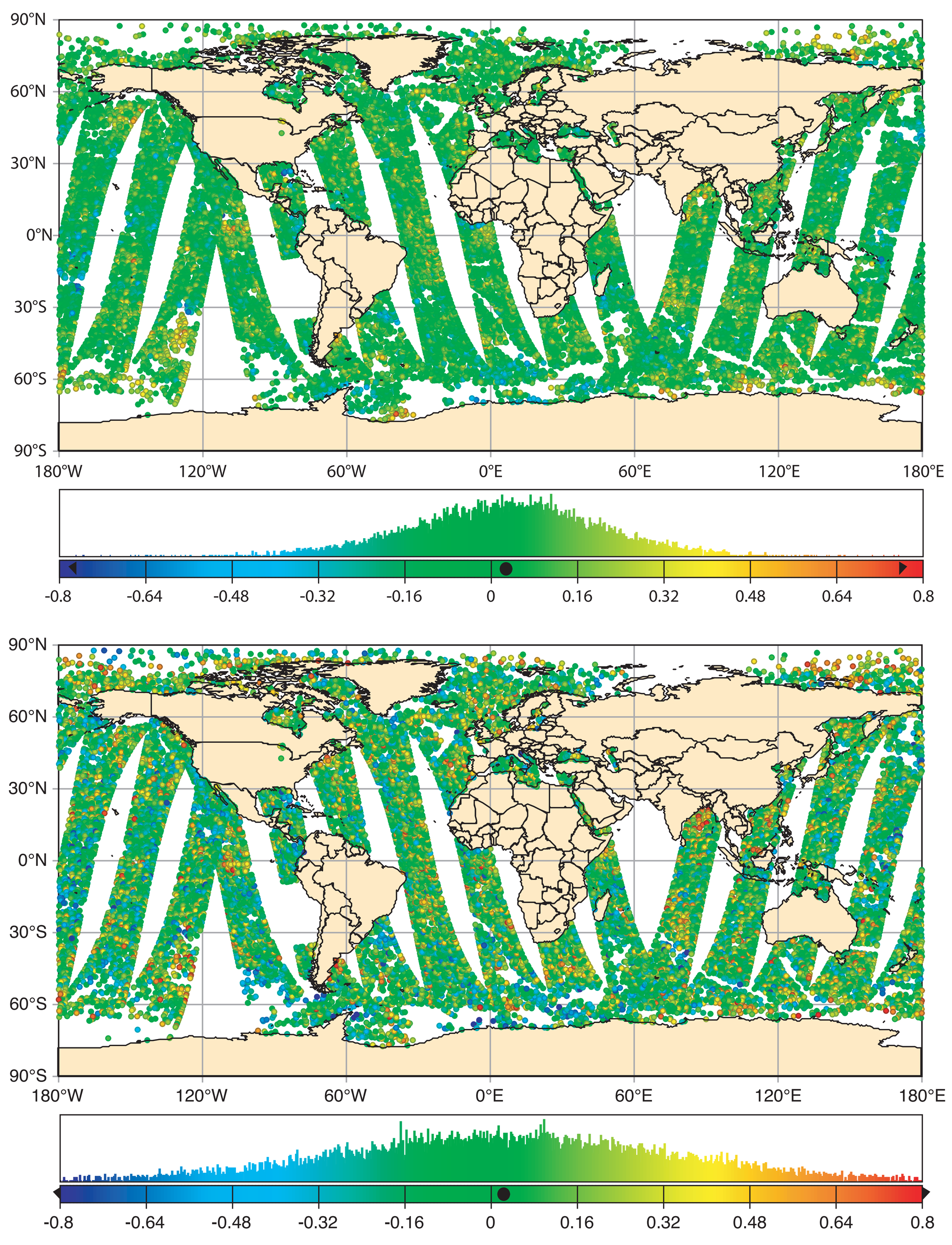

Figure 2 First guess departure field for (top) normal AMSU-A, and for noise degraded AMSU-A (bottom).

Met Office OSEs

The global observing system in the post-EPS era is likely to include two advanced infrared sounders (of AIRS / IASI class) and therefore the Met Office OSEs employed a baseline configuration (NO-MWS) which included all observation types (including AIRS and IASI) used operationally but which withheld all microwave temperature and water vapour sounding channels (from N-16, -18, MetOp-A AMSU-A/-B and F-16 SSMIS).

The two test experiments introduced:

- Data from MetOp-A AMSU with nominal noise performance (NEΔT ~0.1 K for channels 5–9, as Met Office AMSU data are remapped to the HIRS grid).
- Data from MetOp-A AMSU with synthetic noise added, to achieve NEΔT ~0.2 K

The experiments were run over a 30-day period covering 24 May–24 June 2007. Figure 3 shows the impact of adding normal and noisy AMSU to the NO-MWS baseline, relative to a range of observation- and analysis-based verification measures. A single AMSU improves forecasts by 5–10% in the Southern Hemisphere. The impact is weaker, but still positive, in the Northern Hemisphere at ~2–3%. The impact of adding noise is to reduce the impact of the data by ~10%. This is shown more clearly in Figure 4, which shows the impact against a range (123) of verification measures in the NH, tropics and SH.

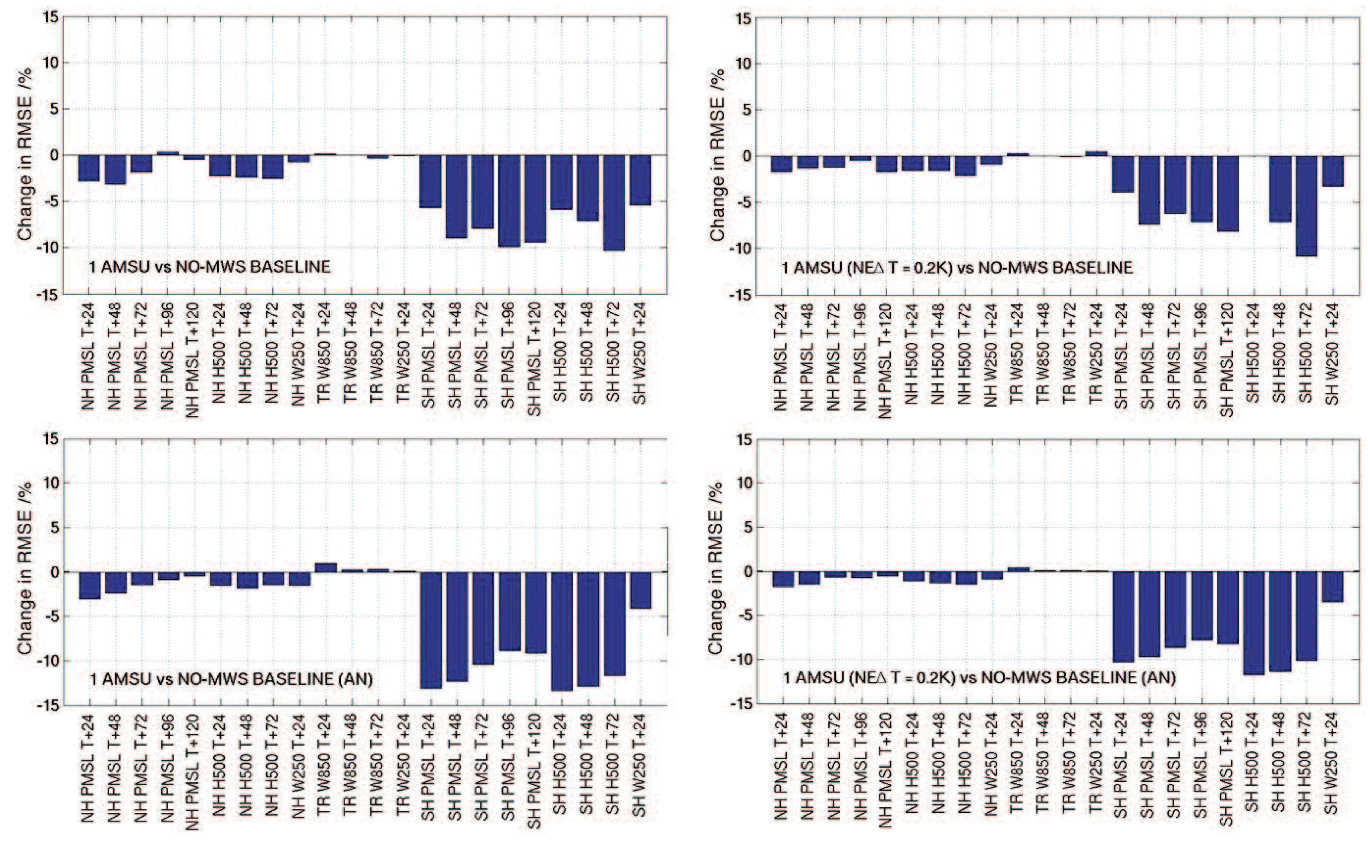

Figure 3 The impact of adding normal / noisy AMSU-A data to a NO MWS data baseline. Verification is derived relative to observations (top plots) and analysis (bottom plots).

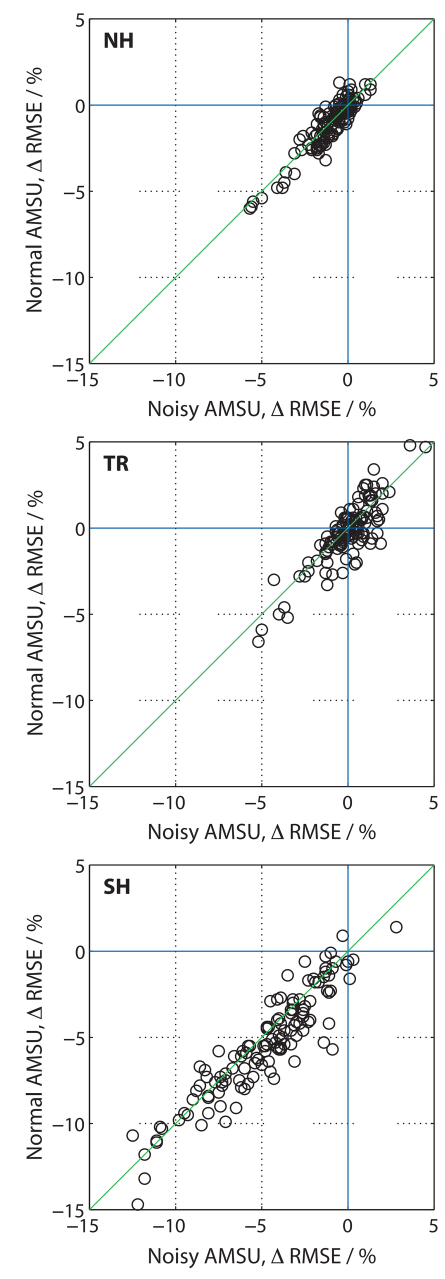

Figure 4 Impacts for an extended group of verification scores in NH, Tropics and SH for normal / noisy AMSU-A.

ECMWF OSEs

A set of OSEs were run at ECMWF for the same period. In a first reference experiment only conventional observations and atmospheric motion vectors were included in the assimilated observations. In a second experiment, a single AMSU-A (NOAA-18) was added to the 'poor' reference system, therefore allowing the evaluation of the (positive) impact of the new instrument. A third assimilation experiment differed from the previous only in having synthetic noise added to the AMSU-A observations. A fourth experiment was run with the full observing system as a control, i.e. to evaluate the forecast errors of previous experiments as differences from the corresponding control analysis.

The effect of the increased noise levels on the forecast scores is shown in Figures 5 and 6. Here, the RMS errors are normalized to those of the reference, and plotted as function of the forecast range. Black curves are for the experiment where original AMSU-A observations are assimilated, while red ones are for the experiment with augmented instrument noise. Vertical bars along each curve indicate 90% confidence intervals. Figure 5 shows the forecast error for geopotential height at four pressure levels (from top to bottom), separately for the Southern Hemisphere (left panels), Tropics (central panels) and Northern Hemisphere (right panels). In the Southern Hemisphere, a degradation of the forecast skill of ~15% is evident from Day 1 to Day 4 at all pressure levels. In the Tropics and in the Northern Hemisphere the degradation is smaller and well within the confidence bars, but still evident. Normalized rms forecast errors are reported in Figure 6 for the mean surface level pressure. Again, in SH, where AMSU-A data are more important for an accurate analysis, the degradation at Days 1 to 4 ranges from 14% to 20%.

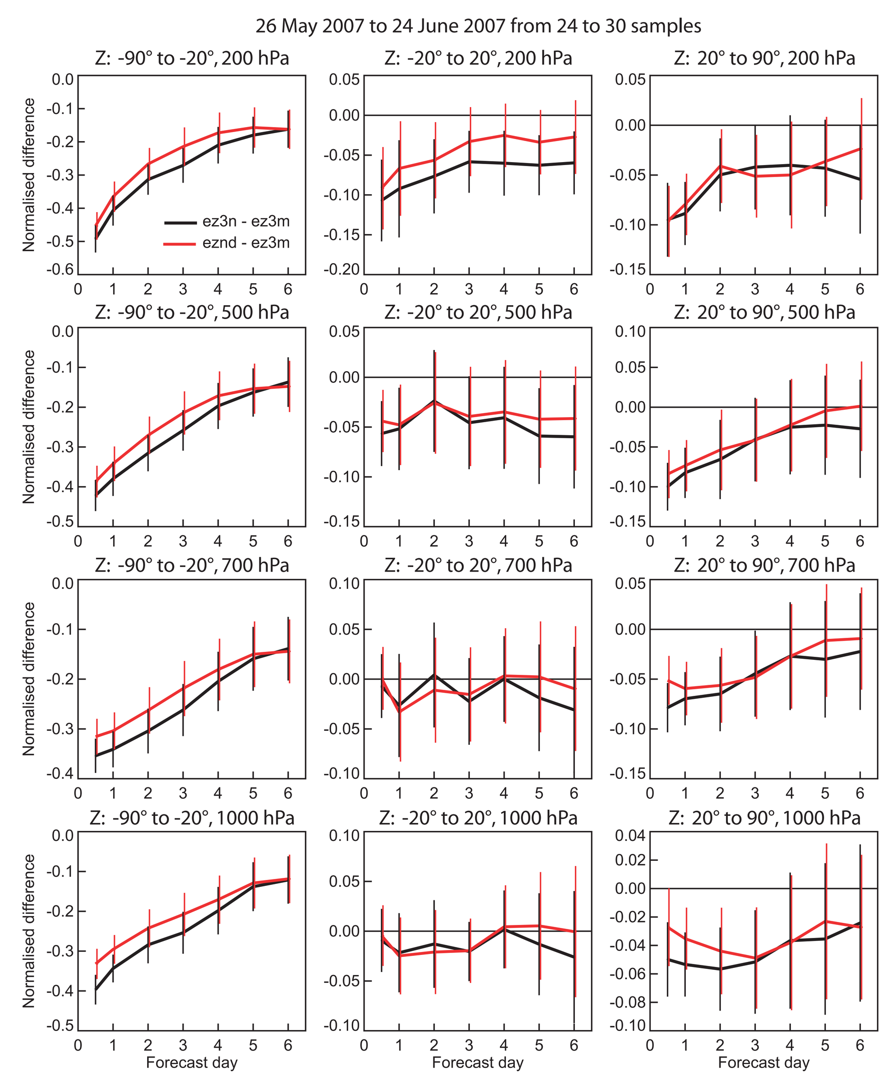

Figure 5 Impacts of normal (black) and noisy (red) AMSU-A data on geopotential height forecasts, relative to an observation 'poor' baseline experiment.

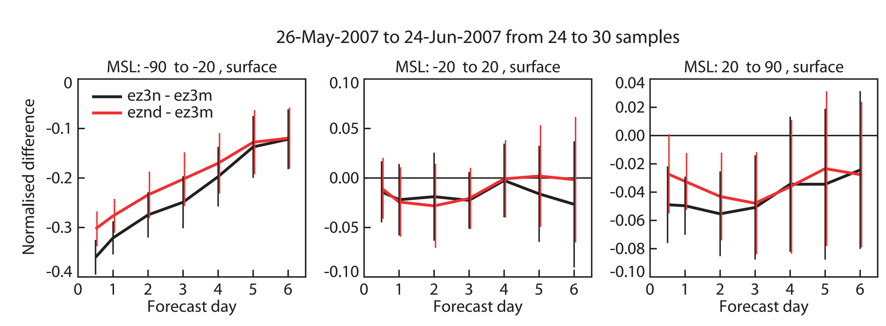

Figure 6 Impacts of normal (black) and noisy (red) AMSU-A data on mean sea level pressure forecasts, relative to an observation 'poor' baseline experiment.

Conclusions

The OSEs reported here show that there is a measurable and significant reduction in forecast improvements (10–15% for SH forecasts) provided by a single AMSU if the noise performance of the instrument is degraded to 0.2 K. The consistency of the independent tests at the Met Office and ECMWF suggests the sensitivities derived are robust.

The results reported here are relative to a baseline configuration which represents the most realistic simulation of the post-EPS observing system that can be achieved at present. Nevertheless, there are likely to be developments in NWP systems between now and 2018 that influence the significance of these results, including:

- The development of more intelligent averaging and thinning schemes
- More optimal use of MWS and IR data over land and sea
- More widespread use of MWS and IR data in cloudy and precipitating regions
- More optimal observation and background error definition, improved bias correction and quality control of data.

References

D.B. Kunkee et al., Special Sensor Microwave Imager Sounder (SSMIS) Radiometric Calibration Anomalies – Part I: Identification and Characterisation, *IEEE Transactions on Geoscience and Remote Sensing*, **46**, No. 4, April 2008.

W. Bell at al., The Assimilation of SSMIS Radiances in Numerical Weather Prediction Models, *IEEE Transactions on Geoscience and Remote Sensing*, **46**, No. 4, April 2008.

Acknowledgements

This work was carried out under the ESA-funded study 'Optimisation of the oxygen and water vapour sounding channels' spectral and radiometric requirements for cross-track and conically scanning radiometers' (ESTEC Contract No. 20711/07/NL/HE).

The authors would like to thank Tony McNally, Alan Geer, Niels Bormann, Lars Isaksen, and Jean-Noël Thépaut of ECMWF for their help at various points in the project.

Post-EPS planning process

http://www.eumetsat.int/Home/Main/What_We_Do/Satellites/Future_Satellites/Post-EPS/index.htm