SEVIRI radiance assimilation at ECMWF

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Introduction

The European Centre for Medium-range Weather Forecasts (ECMWF) assimilates satellite data from a wide range of instruments using a 4D-Var analysis system (Courtier *et al.*, 1994). Humidity sensitive data are assimilated from HIRS, AMSU-B, AIRS and SSM/I on polar orbiting platforms, as well as from the GOES imager, MVIRI and SEVIRI instruments on a number of geostationary platforms (Thépaut, 2003). The most recent addition to this observing system is data from the SEVIRI water vapour sensitive channels flown on Meteosat-8 (Szyndel *et al.*, 2005). This satellite is the most recent in the Meteosat series and the first of the 4 Meteosat Second Generation (MSG) satellites (Schmetz *et al.*, 2002). These data, together with data from Met-5, GOES-9, GOES-10 and GOES-12, give total coverage of the tropics with fine temporal resolution.

Clear sky radiance products

Infrared radiance data from the MVIRI and SEVIRI instruments are cloud cleared and packaged as a 'clear sky radiance' (CSR) product by EUMETSAT (Köpken *et al.*, 2004). Similarly, GOES imager data are cloud cleared and packaged as a 'clear sky brightness temperature' (CSBT) product by CIMSS. The EUMETSAT product consists of the mean radiance for cloud free pixels in a 16 by 16 pixel square, along with indicators giving details of the amount of the segment free of cloud, the confidence in the cloud clearing and other similar measures. The CIMSS product is broadly similar, but considers a 17 by 11 rectangle of pixels. Both of these products are generated hourly. This frequency of data allows the ECMWF 4D-Var analysis to introduce wind increments as well as humidity and temperature increments.

SEVIRI CSR data

Meteosat-8 became operational on 29th January, 2004. The SEVIRI instrument has 8 infrared channels and 4 visible channels, including a high spatial resolution broad spectral response visible channel. The infrared channels have a 3 km resolution at nadir. This compares favourably with MVIRI's 2 infrared and 1 visible channel and infrared nadir spatial resolution of 5 km. The additional information gathered by SEVIRI allows a more advanced cloud clearing algorithm. Furthermore, the infrared channels carried by SEVIRI include two water vapour channels, increasing the vertical resolution of the instrument.

Initial comparisons of SEVIRI data from Met-8 and MVIRI data from Met-7, the operational back-up for Met-8, were favourable. Large biases are observed between MVIRI infrared channels on Met-7 and simulations of these data based on NWP models. These biases were much reduced in equivalent SEVIRI channels. The Met-7 MVIRI WV channel has a mean bias of 3.5K when compared to simulations from the ECMWF IFS background. The

equivalent figures for Met-8 SEVIRI in February 2004 were approximately -1.7K for the 6.2μm channel and 0.7K for the 7.3μm channel.

The SEVIRI channels do exhibit a diurnal cycle with respect to the ECMWF model which is not seen in the MVIRI instruments. This cycle has a peak-to-peak amplitude of about 0.4 K in both the SEVIRI water vapour channels. Figure 1 shows mean first guess and analysis departures for SEVIRI WV6.2 and WV7.3.
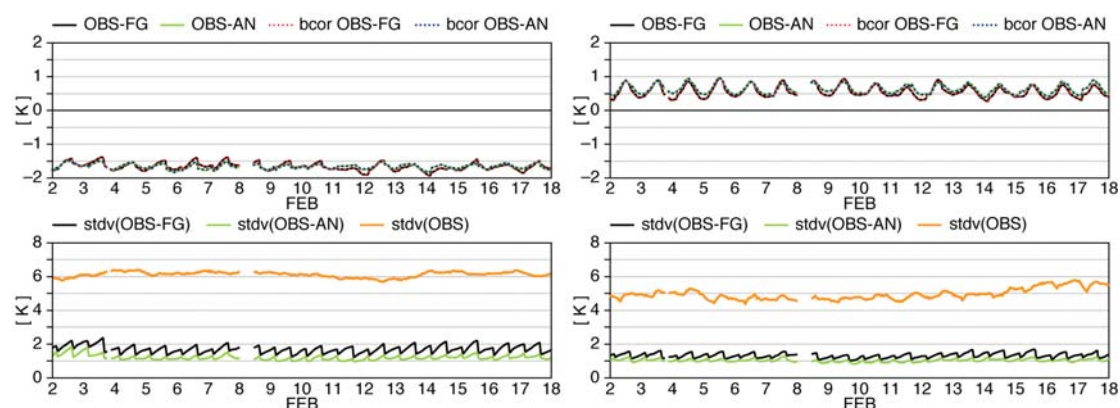

Figure 1: (Left) Mean observation departures and standard deviations for MET-8 WV6.2 channel summing over all data with cloud free fraction 0.7 or greater. (Right) as (Left) for MET-8 WV7.3 channel.

Assimilation trial

The effect of assimilation of the water vapour channel clear sky radiance data from SEVIRI on Met-8 was tested for the period between 2nd February 2004 and 2nd March 2004. In this trial the data were assimilated with an observation error of 2 K for both channels. The data were assimilated in place of the Meteosat-7 MVIRI WV channel data. The data were bias corrected following the method of Harris and Kelly (2001), using 1000 to 300 hPa thickness, 200 to 50 hPa thickness and total column water vapour as predictors. Data with more than 30% of a segment cloudy were rejected, as were data with a local satellite zenith angle of 60° or greater and data from a point over ground higher than 1.5 km. These quality controls are used to minimise the number of data with residual cloud or which are beyond the tested regime for the radiative transfer calculations used in assimilation. Our test was compared with an equivalent stream including MVIRI WV assimilation (henceforth called 'operations') and another stream with both MVIRI and SEVIRI blacklisted (hereafter 'control').

The analysis increment due to assimilation of these data shows an increased level of vertical structure when compared to the equivalent MVIRI increment. Figure 2(a) shows the difference between the first relative humidity analyses of the operations and the control stream; it therefore shows the relative humidity increments due to the MVIRI water vapour channel. Figure 2(b) shows the equivalent increments due to SEVIRI water vapour channel assimilation. It is clear from these increments that water vapour increments are stronger and have more structure in the SEVIRI assimilation. Increments to wind vectors are affected in a similar manner; increments are stronger and have more structure.
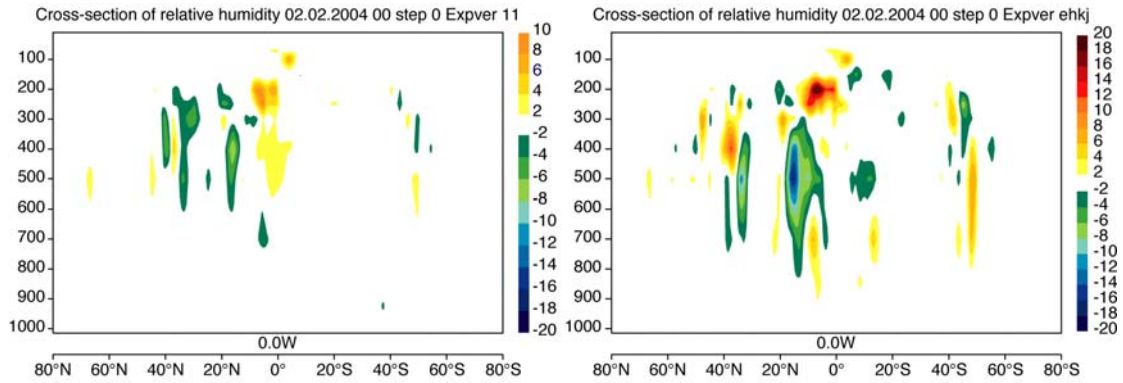
Figure 2: Cross-section of difference in relative humidity increment in percent for first analysis due to (Left) MET-7 WV channel assimilation and (Right) MET-8 WV6.2 and WV7.3 channels.

Forecast impact

The assimilation of SEVIRI water vapour radiance data improves the fit of radiosonde data; figure 3 shows that the biases of sonde humidity data against both the background and analysis are reduced in the area observed by Met-8. The fit of AMSU-B data in the same area is also improved; figure 4 shows the difference in standard deviation of first guess departure of AMSU-B channel 3 on NOAA-16 for the trial and control. The area observed by Met-8 is clearly visible, showing that the background is closer to AMSU-B in this area. A similar result is found for HIRS channel 12.
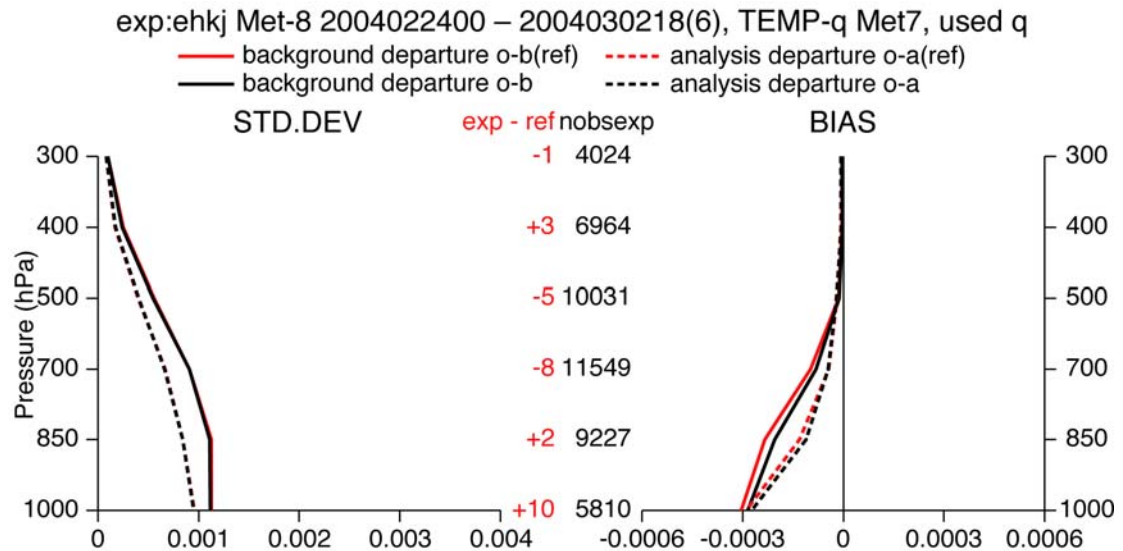

Figure 3: Standard deviation and bias in first guess and analysis departures of radiosonde specific humidity data in the MET-8 observed area in the final week of the trial.
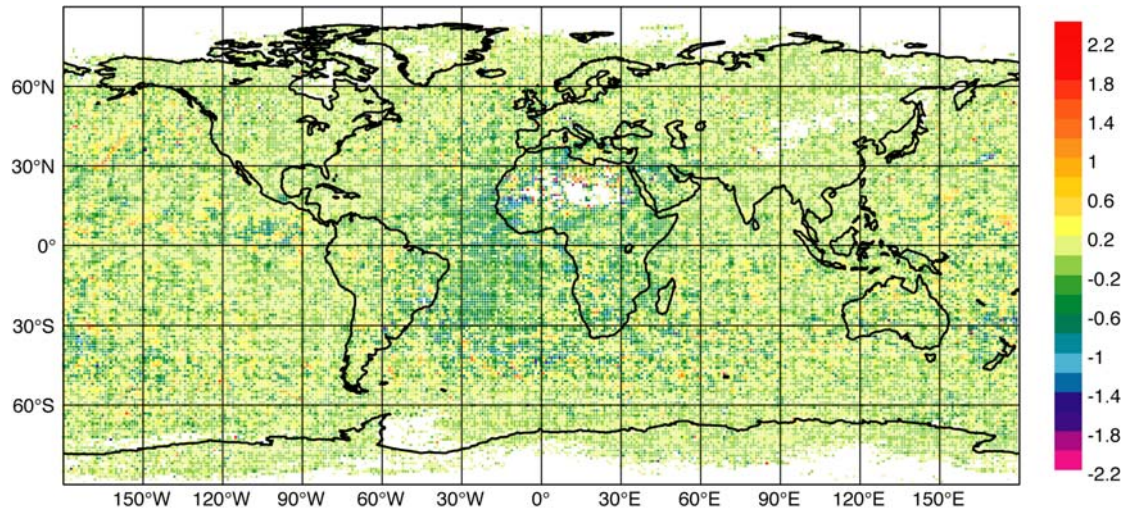
Figure 4: Difference in standard deviation of AMSU-B channel 3 first guess departure on NOAA-16 with and without SEVIRI water vapour channel assimilation. Greens and blues imply a better fit, yellows and reds a worse fit.

When RMS error in vector winds are studied, we find that winds, particularly at upper tropospheric levels, show a small but statistically significant improvement; table 1 shows the t-test significance of RMS error reduction. No indications were found that the RMS error grew when SEVIRI data are assimilated.

Forecast Range (Days)	2	3	4	5	6	7
1000 hPa, Tropics	-	-	-	95%?	99.5%?	99.8%?
850 hPa, Tropics	-?	-	90%	95%	98%?	99.5%?
500 hPa, Tropics	-	-	-	-	-	99%
300 hPa, Tropics	95%	99.5%	95%	95%	95%	98%

Table 1: t-test significance of impact on RMSE in vector wind of the trial versus the control run. All impacts are positive, [-] denotes no impact of 90% or greater. A question mark indicates that a significant correlation or anti-correlation between consecutive cases was detected.

The anomaly correlation of geopotential heights shows a small but statistically significant increase in skill for the northern hemisphere when SEVIRI data are assimilated. Table 2 shows the t-test significance of the change in anomaly correlation. Figure 5 shows the mean difference in score between the SEVIRI trial and control normalised by (100% - Mean Score). The error bars show the 90% confidence margin. These graphs show a clear increase in skill at the 4-6 day range in the northern hemisphere. The southern hemisphere appears neutral.

Forecast Range (Days)	2	3	4	5	6	7
500 hPa, Tropics	-	90%	98%	98%	95%	-
500 hPa, Tropics	-	-	-	-?	-	-?
300 hPa, Tropics	-	90%	99%	99.5%	95%	-
300 hPa, Tropics	-	-	-	-	-	-

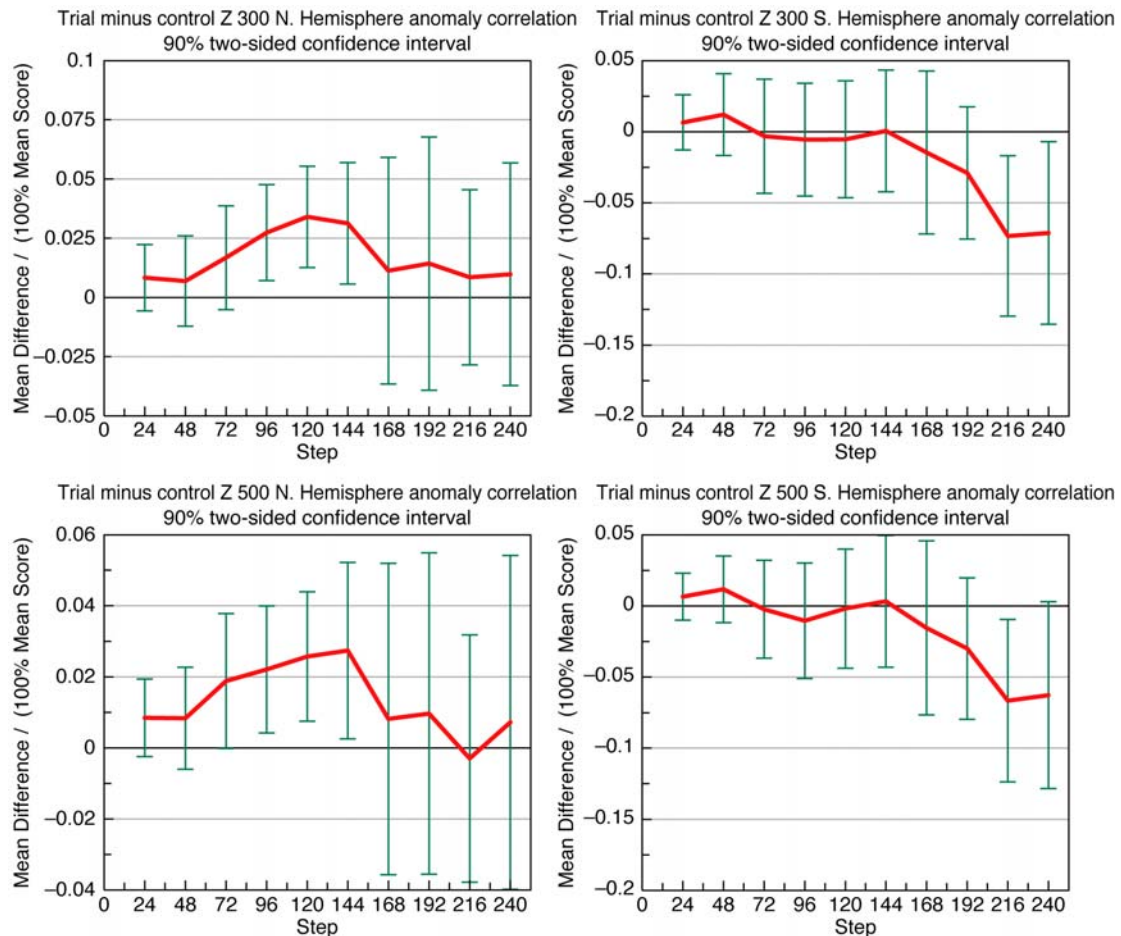Table 2: As table 1, but for height field anomaly correlations.

Figure 5: Difference between MET-8 assimilation and control anomaly correlation of height field forecasts. Line marks mean difference and error bars mark 90% confidence region adjusted for one-step autocorrelation.

Outlook

In summary the use of two infrared water vapour channels from geostationary orbit appear to improve the humidity analysis, as shown by the improvement in the fit to other humidity observations. This appears to improve the geopotential anomaly correlation in the northern hemisphere, as well as the vector winds in the tropics. Following this we hope to examine the impact that FY-2C and MTSAT-R imager humidity measurements have on the ECMWF analysis. We are also investigating the possibility of assimilating cloud affected radiances, following the work of Chevallier *et al.* (2004).

References

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