Of Chessboards and Ghosts –
Signatures of micro-vibrations from IASI monitoring in NWP?

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Abstract

IASI data has been extensively assimilated in Numerical Weather Prediction (NWP) systems, with significant positive forecast impact. NWP systems have also been used to monitor and further investigate the data, contributing to a detailed characterisation of the performance of the instrument. Here we present a specific analysis that points to a very small instrument error that appears to be correlated with the direction of the movement of IASI's corner cube mirror.

Spatial covariances of observation minus background departures have been calculated from a large sample of pairs of IASI observations. Displayed as a function of scan-line and scan-position difference between the observation pairs, the covariances show a peculiar chessboard-like pattern. The size of the pattern depends on the channel number, and can exceed 0.01 K^2 for some channels. The effect depends on which IASI pixel within the AMSU-A FOV is being considered, with pixels 1 and 2 showing the largest effect, whereas pixels 3 and 4 showing little to no effect. The effect has been observed in covariance statistics from ECMWF and the Met.Office.

The fact that spatial covariances of background errors are smooth suggests that the pattern originates from the IASI observations. The pattern appears to be correlated with the direction of the movement of the corner cube mirror of IASI. The current understanding is that it is an effect of micro-vibrations of IASI's beamsplitter, leading to so-called "ghost" features.

While the effect is small and therefore of no concern to the use of the data, the analysis highlights the power of NWP to provide detailed analyses of very small aspects of instrument performance.

Introduction

IASI data has been extensively assimilated in Numerical Weather Prediction (NWP) systems, with significant positive forecast impact (e.g., Collard and McNally, 2009). NWP systems have also been used to monitor and further investigate the data, contributing to a detailed characterisation of the performance of the instrument.

IASI monitoring in NWP

Monitoring of IASI data in NWP includes a comparison of observed brightness temperatures and corresponding values simulated from short-term forecasts. The difference between the two is called background departure. These background departures provide a comparison of the observations against a reference that has characteristics that are fairly stable (in time) and that includes information from all other observations used in the NWP system. Statistics on background departures are increasingly used to further characterise and explain the performance of satellite instruments (e.g., Bell et al. 2008, Geer et al. 2010).

A large sample of background departures were analysed here, as part of a wider study aimed at providing guidance for the specification of observation errors for IASI and other sounder radiances (Bormann et al., 2009). The sample was based on IASI radiances that were used in the assimilation system and for which all assimilated channels were diagnosed as cloud-free. Only data over sea were considered. Also, ECMWF assimilates only the first IASI pixel within an AMSU-A field of view (Figure 1).

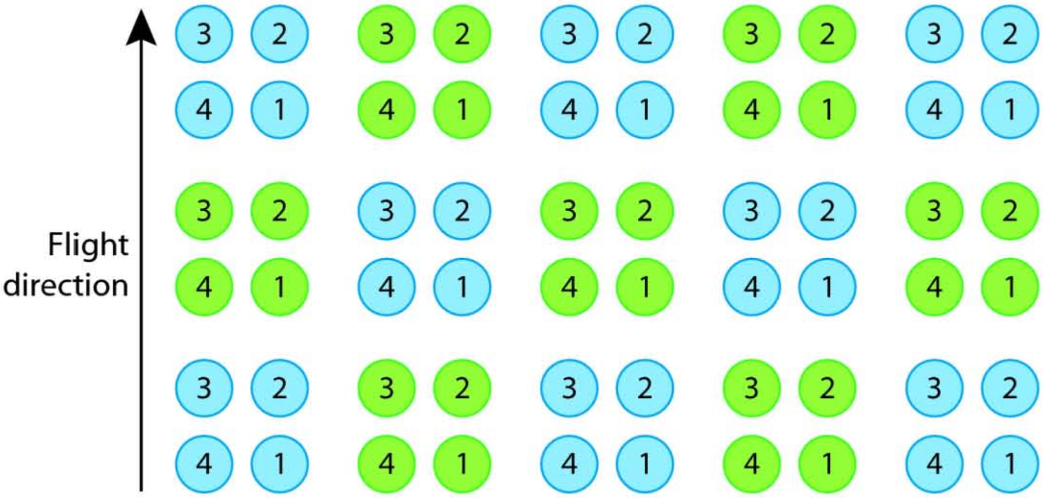

Figure 1: Simplified schematic of the IASI scan pattern, showing the pixel numbering for the four pixels within an AMSU-A field of view, relative to the flight direction. The colour coding corresponds to the alternating direction of the movement of IASI's corner cube mirror.

Results – Chessboards

Spatial covariances of the background departures have been calculated from pairs of IASI observations. Displayed as a function of scan-line and scan-position difference between the observation pairs, the covariances show a peculiar chessboard-like pattern (Figure 2, left).The size of the pattern depends on the channel number, and can exceed 0.01 K^2 for some channels (Figure 3). As can be seen, almost all channels show at least a hint of the pattern, but channels (734.75 cm^{-1}) and 3110 (1422.25 cm^{-1}) show it the most.

The same analysis has been repeated at the Met Office, with similar results (Figures 2, right and 4). The agreement in terms of spatial pattern and magnitude is remarkable. This rules out that the pattern is introduced through some ECMWF-specific processing. Instead, it suggests a small instrument or data-specific error.

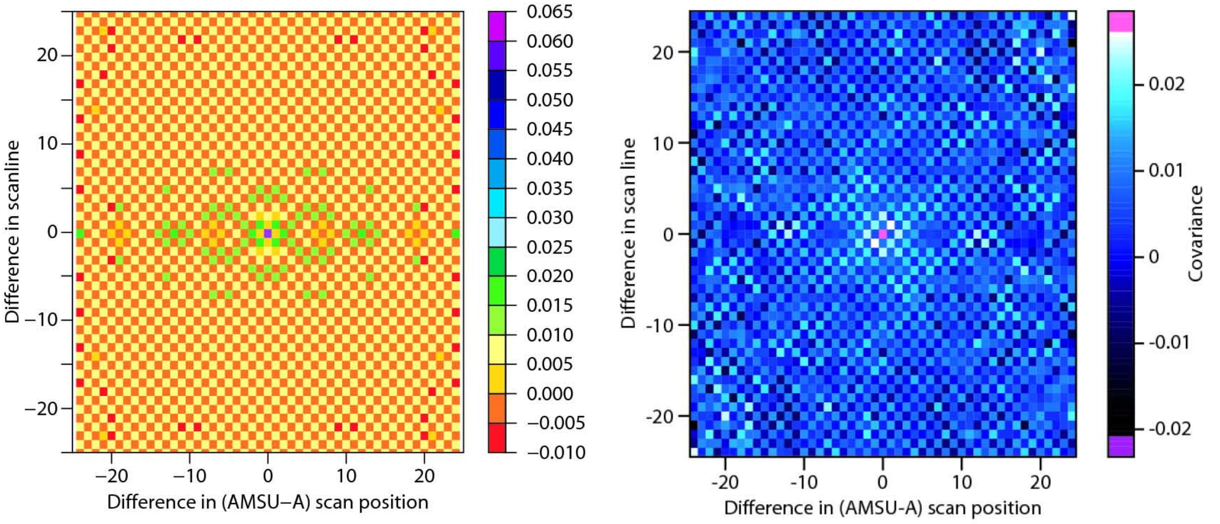

Figure 2: Spatial covariances of background departures for IASI channel 360 (734.75 cm^{-1}) as a function of difference in scan position and difference in scan line (using pixel 1 only). Channel 360 is one of those most affected. Left: Results for ECMWF statistics, covering the period 22 August – 11 September 2008. Right: Results from Met Office statistics, for 17/18 July 2008.

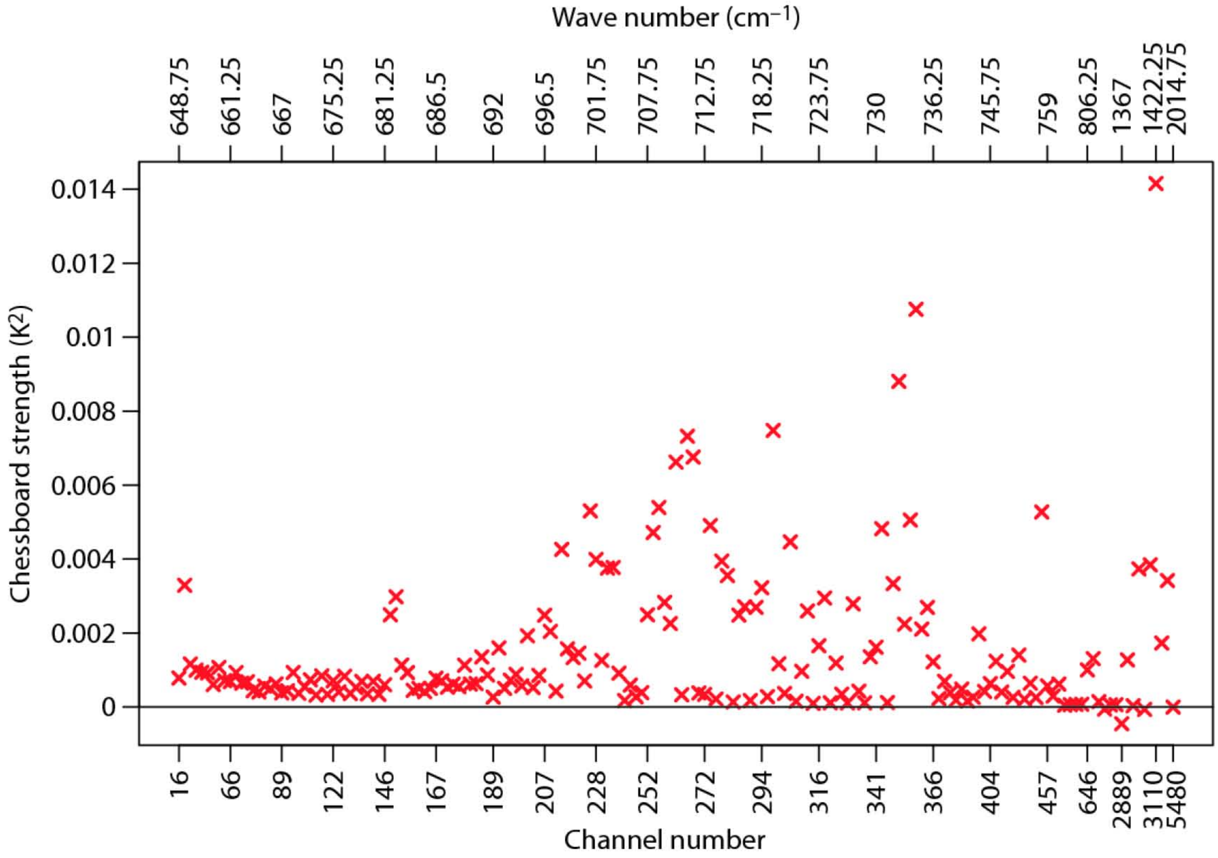

Figure 3: Strength of the chessboard pattern in the background departure covariances for the 175 IASI channels used in the ECMWF system [K^2], based on data from pixel 1 only. The strength has been calculated as the mean difference between the two populations given by the chessboard pattern of high and low background departure covariances (excluding values at zero separation).

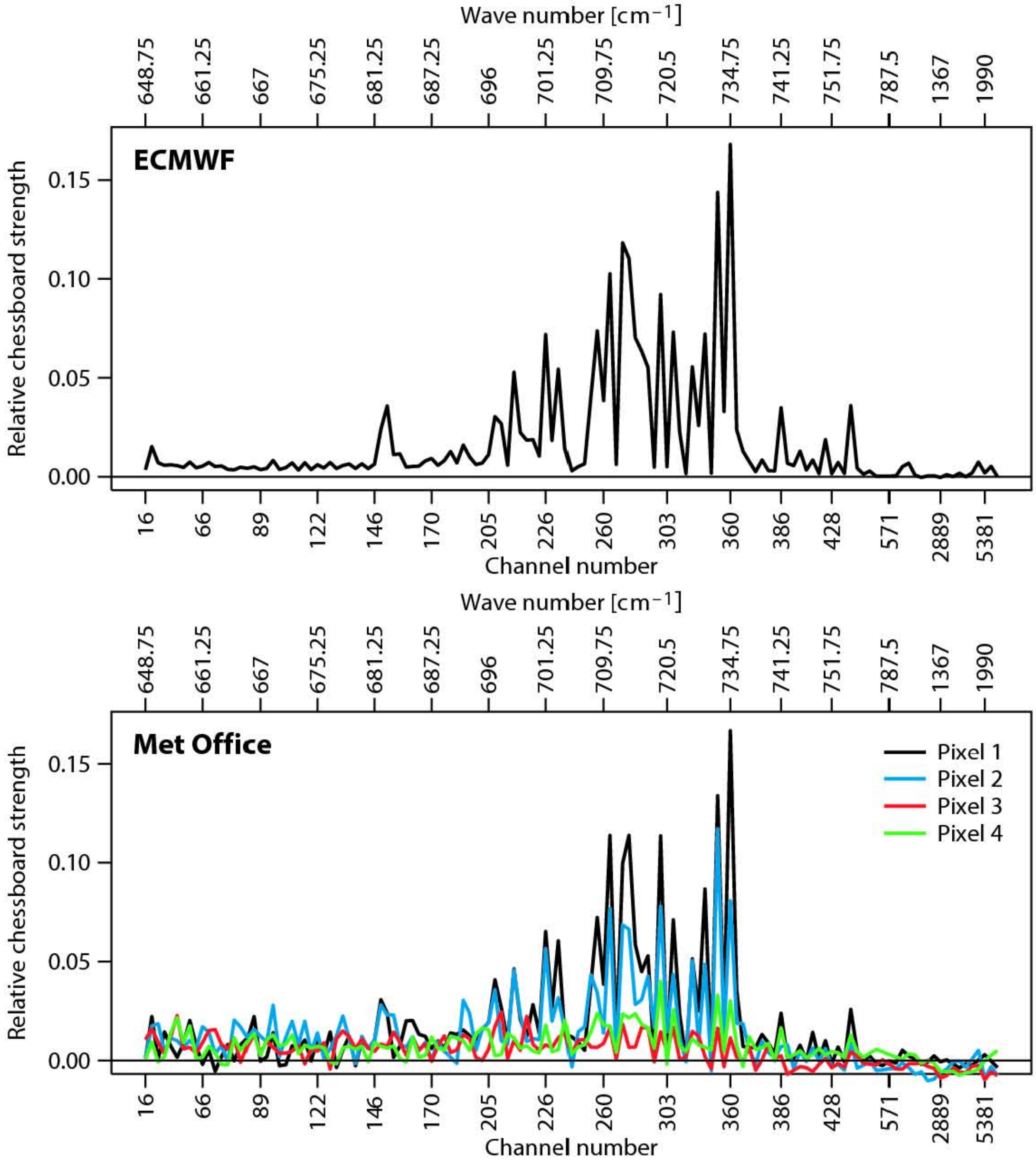

Figure 4: As Figure 3, but relative to the variance of the background departures for the 135 channels for which data were available from both the ECMWF (upper) and the Met Office (lower) system. For the ECMWF system, statistics are shown for data from pixel 1 only, whereas for the Met Office system, the four colours show statistics calculated separately for the 4 IASI pixels within an AMSU-A field of view. See Figure 1 for the pixel numbering.

The Met Office results can also be produced for other pixels within an AMSU-A field of view, as the Met Office does not restrict the assimilation of IASI data to the same pixel within an AMSU-A field of view as done in the ECMWF system (instead, the most homogeneous pixel is used, as determined by AVHRR). Results for the other pixels show that pixels 1 and 2 exhibit the largest effect, whereas pixels 3 and 4 show little to no effect (Figure 4).

Discussion – Ghosts?

The consistency of the pattern from two different assimilation systems suggests that it originates from the IASI observations. Also, spatial covariances of model background errors are smooth spatially, providing another argument that the pattern comes from the IASI observations rather than the background. The pattern suggests a small error in IASI observations that appears to be correlated with the direction of the movement of the corner cube mirror of IASI (see Fig. 1).

The current understanding is that the pattern is caused by micro-vibrations of IASI's beam splitter. These lead to minuscule variations of the optical path and hence the spectral characteristics, and these appear as pseudo-noise ("ghosts") in the spectrum (Blumstein and Pequignot, 2009, personal communication). The finding that pixels 1 and 2 show the largest effect whereas pixels 3 and 4 show little effect is consistent with this: pixels 3 and 4 project onto the bottom of the beam-splitter where the beam-splitter is attached to the optical bench, so that the effect of the vibrations is smaller.

The effect is very small compared to the instrument noise and therefore of no concern to the use of the data. Pseudo-noise as described above is also an expected effect for instruments like IASI, and the current findings appear within specifications (Fiedler, 2009, personal communication).

Our analysis highlights the power of NWP to provide detailed analyses of very small aspects of instrument performance.

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