Monitoring and Assimilation of IASI Radiances at ECMWF

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Abstract

IASI radiances have been assimilated operationally at ECMWF since 12th June 2007. The initial configuration focussed exclusively on the use of the temperature sounding 15μm CO_2 band as this was expected to provide the greatest benefit (based on experience with AIRS). This resulted in positive impact on the forecast scores. The additional assimilation of channels from the IASI humidity band are described. Ten extra IASI humidity-sensitive channels are assimilated with an assumed observation error of 1.5K, these values being chosen on examining the impact on the analysis fit to other humidity measurements with different IASI humidity channel configurations. The weight given to these new IASI humidity observations is significantly greater than that for any other satellite instrument except for AIRS. While the impact of the observations on the analysis is to improve its agreement with independent data sources, the effect on the forecast scores for relative humidity, geopotential and vector wind is found to be neutral.

1. Introduction

The first of the IASI (Infrared Atmospheric Sounding Interferometer) series (Chalon *et al.*, 2001) was launched on the MetOp-A satellite on 19th October 2006. IASI is an infrared Fourier transform spectrometer and is the first such instrument to fly as part of an operational meteorological mission. A series of three MetOp missions make up the EUMETSAT Polar System (EPS) which will fly in the 09.30 (descending node) polar orbit as part of the International Joint Polar System (IJPS).

IASI measures the radiance emitted from the Earth in 8461 channels covering the spectral interval from 645–2760cm^{-1} at a resolution of 0.5cm^{-1} (apodised). The instrument scans through 60 scan positions up to 47° either side of nadir. At each scan position observations are made in a 2x2 array of fields of view each with a diameter 1.25°, corresponding to 12km at nadir.

High spectral-resolution infrared sounders such as IASI can provide information on the atmospheric state with a vertical resolution of the order of 1km (e.g., Prunet *et al.*, 1998; Collard, 1998) – far superior to other nadir sounding instruments. The vertical resolution is a result of high quality measurements made with a large number of channels with different, overlapping Jacobians.

IASI observations have been disseminated in near-real-time to selected NWP centres since February 2007 and were declared operational on 27th July 2007. All IASI data (i.e., 8461 channels and every field of view) are received at ECMWF via the EUMETCAST system.

The exploitation of IASI data at ECMWF has been based on the system used for the operational assimilation of radiances from the Atmospheric Infrared Sounder (AIRS) instrument since September 2003 (McNally *et al.*, 2006). AIRS (Aumann *et al.*, 2003), unlike IASI and future operational advanced infrared sounders such as CrIS, is a grating spectrometer rather than an interferometer but has similar spectral and spatial coverage and resolution to IASI. The experience with the operational use of AIRS data for the five years preceeding IASI has facilitated the efficient implementation of an operational system for assimilation of IASI observations as described in this paper.

In this paper the initial implementation of IASI data assimilation is reviewed and the introduction of IASI humidity data is discussed. The impact of the assimilation of these channels on the forecast fields is described and based on the results it is proposed to modify the use of both AIRS and IASI humidity channels in the ECMWF data assimilation system.

2. Initial Assimilation of IASI Radiances.

The initial configuration for the assimilation of IASI radiances is described in Collard and McNally (2008). This initial implementation uses 168 channels in the 15μm CO_2 band. Fields of view over land not used nor are channels affected by cloud. The density of channels chosen in the upper-troposphere/lower-stratosphere region is close to the maximum possible once channels with interfering species are omitted and adjacent channels are not used due to high correlations caused by apodisation (Collard, 2007). The distribution of the used channels is shown in Figure 1, where it can be seen that the density of channels used in IASI assimilation is much larger than that for AIRS. The impact of assimilating these channels is shown in Figure 2 where the forecasts are verified versus the operational analysis at the time which did not contain information from IASI. There is significant positive impact in the medium-range.
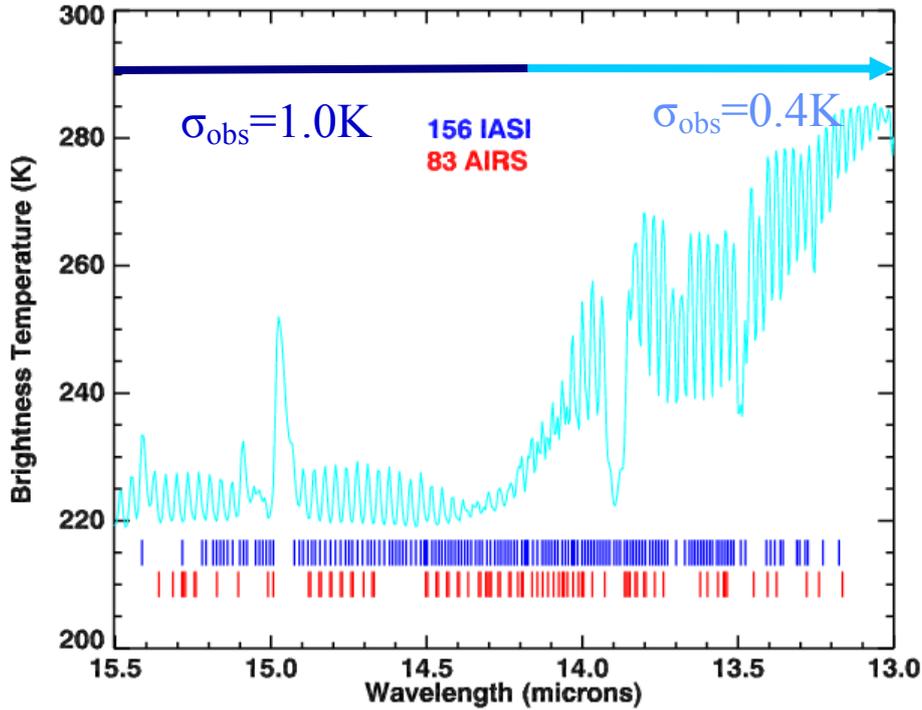
Figure 1: The 15μm CO_2 band of a typical IASI spectrum showing the positions of the channels actively used in AIRS and IASI assimilation. Also indicated are the observation errors assigned for both instruments.
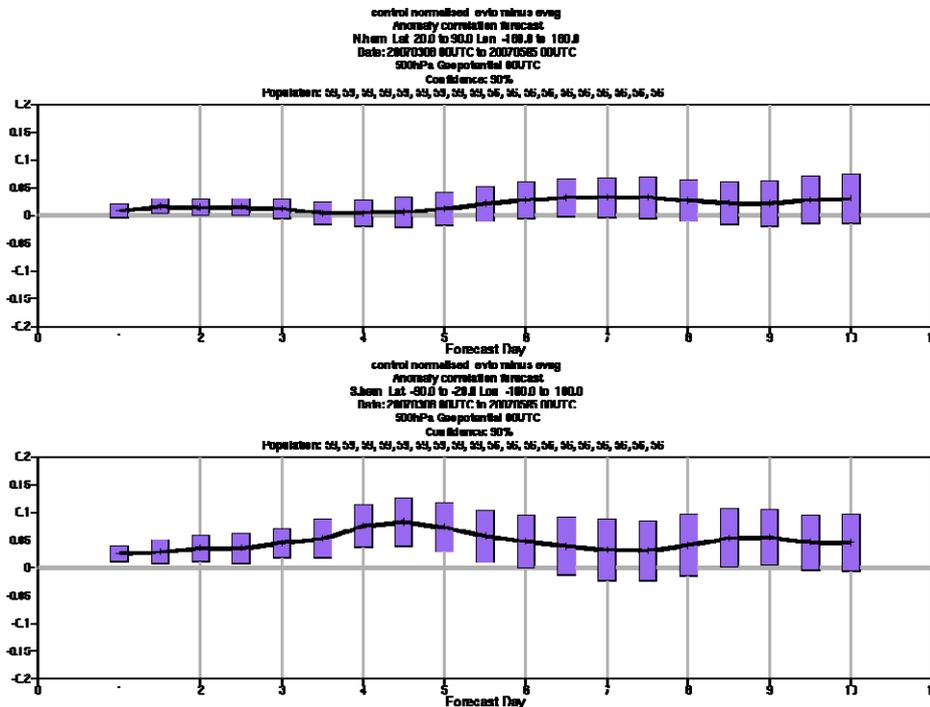

Figure 2: Change in anomaly correlation forecast scores on assimilating IASI radiances for northern (top) and southern (bottom) hemisphere geopotential at 500hPa. The scores are normalised by the control's forecast error and positive values indicate improvement on using IASI.

3. Addition of IASI Humidity Channels.

3.1. Cloud detection

AIRS and IASI use the McNally and Watts (2003) cloud detection scheme which is employed to identify channels which are unaffected by cloud. This algorithm works by taking the observed-minus-calculated brightness temperature differences (hereinafter also referred to as first guess departures) and looking for the signature of opacity that is not included in the clear-sky calculation (i.e. cloud or aerosol). To do this, the channels are first ordered according to their height in the atmosphere (with the highest channels first and the channels closest to the surface last) and then the resulting ranked brightness temperature departures are smoothed with a moving-average filter in order to reduce the effect of instrument noise. The level at which cloud no longer significantly affects the radiances is found by stepping through the channels in order of increasing height until the first-guess departure and local gradient fall below pre-determined thresholds. All channels below this point are marked as cloudy and all channels above as clear. The thresholds are set to conservative values to reduce the possibility of cloud-contaminated radiances being used.

The current operational configuration for AIRS at ECMWF employs a "in-band" configuration of cloud detection scheme which divides the spectrum into five bands and uses the first guess departures in each band to determine the clear channels therein. A feature of this scheme is that in the water band large humidity errors may be interpreted as clouds and such observations may be rejected accordingly. A more realistic distribution of first-guess departures in the humidity band can be obtained by using the Watts & McNally cloud detection scheme in the 15μm temperature sounding CO_2 band and using the cloud height derived there to infer clear channels in the humidity band (this method is hereinafter referred to as "cross-band cloud detection"). This approach has not been operationally implemented for AIRS before the present as the impact on forecast scores is negative unless the assumed 2.0K observation errors are inflated significantly.
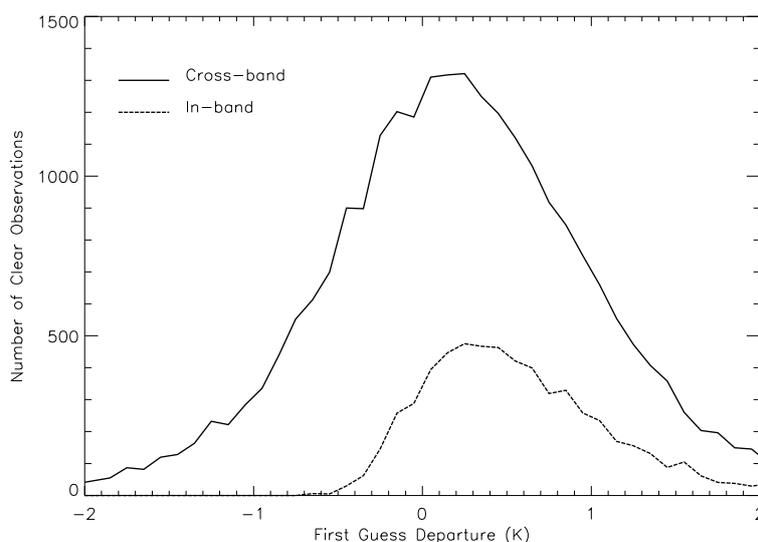

Figure 3: The histogram of the first guess departures for AIRS channel 1477 when using in-band and cross-band cloud detection.
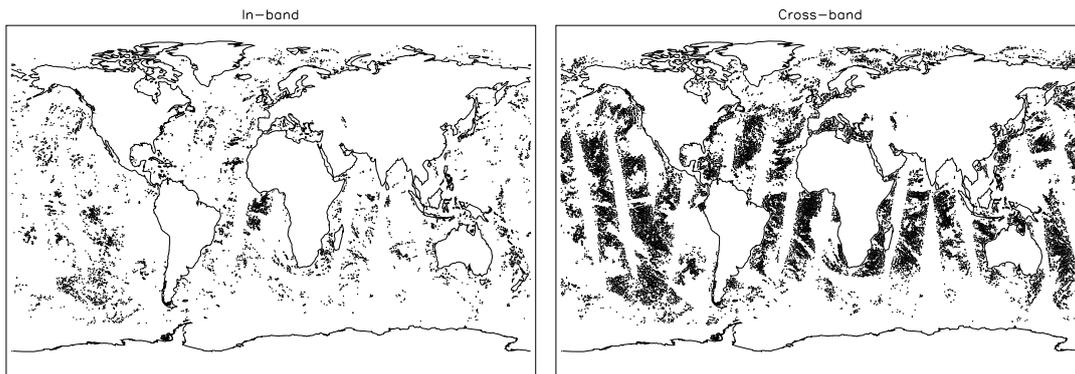
Figure 4: The distribution of clear fields of view for AIRS channels 1477 as determined by in-band (left) and cross-band (right) cloud detection configurations.

The difference between the "in-band" and "cross-band" configurations is illustrated in Figures 3 and 4. Here the distribution of clear observations and the histogram of observed-background brightness temperature differences are shown for AIRS channel 1477 (1345.31cm^{-1}; 7.433μm) which peaks around 600hPa. The cross-band scheme can be seen to provide a more symmetric probability distribution function (with a standard deviation more consistent with that expected from background model error) and far better global coverage. For these reasons, the cross-band configuration will be used for the active use of IASI humidity channels.

3. Channel selection and assumed observation errors.

To put the discussion of IASI observation errors into context, Figure 5 shows the mean and standard deviation of observed-background brightness temperature for all IASI channels in clear fields of view (the clear fields-of-view are determined by an independent test based on the homogeneity of the scene as seen by AVHRR channel 5 – an infrared window channel). It can be seen that the standard deviation in the 6.3μm humidity band (between 1350 and 2000cm^{-1}) is around 1.7K. Except for the highest peaking channels on the shorter wavelength side of the band (seen as positive spikes between between 1750 and 2000cm^{-1}), this signal is dominated by errors in the background humidity On the "longward" side of the band (1350 and 1600cm^{-1}), where the majority of the channels selected for monitoring are situated, instrument noise is in the 0.2K-0.5K range. The situation is very similar for AIRS except the shortwave side of the humidity band is missing and the instrument noise is slightly lower.

The current assumed observation error for AIRS humidity channels is 2.0K (with the in-band cloud detection reducing the total weight given to the band further). Experiments with the adjustment of this observation error have shown that the fit to other observations (see below for explanation of this in the context of IASI) is degraded if the observation error is reduced further.

For IASI, the decision has been made to implement a system using cross-band cloud detection and to derive reasonable values for the number of channels used and the assumed observation errors. Two channel configurations were tested. The first used