Current status and future plans for the use of AIRS and IASI data at the Met Office


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At the Met Office we are now assimilating the AIRS Warmest Field of View (AIRSWF) dataset in both the Global and North Atlantic and European (NAE) numerical weather prediction models. Current work is focussed on improving the coverage of assimilated observations, to include observations over land and channels whose weighting functions peak above cloud. Preparations for assimilation of IASI data are progressing well; the status of the project will be discussed and plans for monitoring the early data presented.

**Status of AIRS processing**

AIRS Warmest Field of View (AIRSWF) data have been assimilated operationally in the Met Office Global forecast model since March 2006 and in the North Atlantic and European (NAE) model since 26th September 2006 (Candy and English 2006).

For the Global model, we receive a maximum of 81,000 observations for each six-hour assimilation cycle which are reduced to around 3,000 for assimilation in 4D-Var, through rejection of cloudy observations and those over land, and by thinning. For night-time observations, 57 channels are assimilated and 45 are used for day-time observations. AIRSWF has demonstrated similar impact to the central field of view dataset, delivering improvements to a no-AIRS system of up to 2% of RMS error in PMSL and 500hPa height across most forecast ranges. Met Office trials have also shown that the assimilation of AIRS gives valuable information for tropical cyclone prediction.

A measure of the impact of AIRS on the humidity field can be seen in the improvement to the model fit to SSM/I Total Column Water Vapour (TCWV) retrievals (which are not currently assimilated). During a recent AIRSWF vs no AIRS intercomparison NWP trial, an improvement in RMS fit to SSM/I TCWV of approximately 10% was observed throughout the trial period apart from a period of around 36 hours following an AIRS data outage (Figure 1).

Given that AIRS flies only on EOS-Aqua, data coverage in the NAE model is highly variable between cycles, but is aided by timely data delivery. A maximum of around 1000 observations can be assimilated in any one cycle. Impact in the NAE is measured on a different set of variables from the global model including visibility and total cloud amount (see explanation in Candy and English 2006). AIRS assimilation tests showed neutral impact. However, the same improvements in the fit to SSM/I TCWV retrievals were seen in the NAE, including the worsening of fit following the data outage, giving us confidence that AIRS is improving the humidity field.
Fig. 1: Improvement in Global model RMS fit to SSM/I TCWV retrievals during AIRSWF vs No-AIRS trial. Note period where the fit worsens following an AIRS outage.

**Plans for assimilation of IASI data**

Preparations for IASI data are now well advanced, with the baseline for assimilation matching current AIRS data usage of clear observations over sea. Clear scenes will be identified using the cloud detection method developed by English et al. (1999). We will store 300 channels from across the spectrum. These channels have been chosen by the method presented in Collard and Matricardi (2005). The intention is to use the majority of these channels for assimilation, leaving out the channels in the 10μm ozone band, and shortwave channels where the observation is affected by non-LTE effects and reflected solar radiation.

We are expecting to advance our use of AIRS data in the next twelve months (see below) and any developments will be incorporated into IASI processing as soon as possible.

**Future directions in IR sounding – Increasing data usage**

We are currently aiming to increase the quantity of AIRS data assimilated. Work is focussed in two main areas: using data over land and sea-ice, and using observations in cloudy areas. The strategy in for the use of observations over land is to use channels which peak high enough that their brightness temperatures are unaffected by the surface beneath them. Tests have been cautious, using only channels peaking above 400hPa, resulting in eight channels accepted for assimilation. The work is still at an early stage and the next step is to ensure that we can correctly screen out cloudy observations over land. The use of AIRS data in cloudy areas over the sea is presented in Pavelin and English (2006).
Future directions in IR sounding – Principal Component 1D-Var

One way in which we could exploit significantly more information from Advanced IR sounders would be to process the observations in principal component (PC) form. PCs remap a dataset into a new coordinate space defined by vectors (the PCs themselves) which represent the variability of the dataset in orthogonal directions. If a set of eigenvectors is calculated from several thousand full IASI spectra, the first PCs will contain most of the real information in the dataset and the lower order PCs will represent what would be noise to a data assimilation system. Applying these eigenvectors to each incoming IASI observation would enable the compression of thousands of channels into just a few hundred PCs, containing more information about the state of the atmosphere than a similar number of selected channels.

The main barrier to the use of PCs to date has been limited availability of forward models and inverse code. However, PC radiative transfer is now maturing, with models such as PCRTM (Liu et al. 2006) being developed. A new PC radiative transfer model – the Havemann Taylor Fast Radiative Transfer Code (HT-FRTC) (Havemann, 2006) – is being developed at the Met Office for use in a PC-based experimental 1D-Var. This code, which has a similar methodology to PCRTM, has been designed with the flexibility to forward model both satellite and aircraft upward and downward-looking observations. The model is valid between 3 and 16.5μm, with spectral resolution currently set to 0.5cm\(^{-1}\) (it is possible to simulate a much higher resolution, perhaps to 0.0025cm\(^{-1}\)). The model is fast – although accurate timings have not been attempted, it is at a minimum comparable to RTTOV at this spectral resolution (there is a trade-off between resolution and processing time) – and displays accuracy of better than 0.01K across much of the spectrum, relative to the ‘slow’ model on which it is based (Figure 2). The slow model incorporates the K-Carta database (Strow et al. 1998).

Fig. 2: Standard deviation of brightness temperature differences between HT-FRTC and slow model for simulations of 100 independent profiles.
The PC 1D-Var will allow retrieval of temperature and water vapour profiles, surface temperature and spectrally resolved emissivity. It will be used in satellite calibration-validation activities and in scientific studies with aircraft observations. Importantly, it will allow testing of Jacobians from a PC radiative transfer model within a variational analysis framework, which should greatly enhance our understanding of the viability of principal component observations in operational assimilation.

**Monitoring early IASI data quality**

Experience with instruments such as SSMIS have shown the importance of careful monitoring of early data. Bell et al. (2005) show how instrument biases were identified by examination of time-series of observed minus forward modelled values. Pre-processing of the data to remove the effects of solar intrusions into the warm calibration load and thermal emission from the main reflector has significantly improved the data quality and SSMIS observations are now assimilated operationally at the Met Office (Candy et al. 2006).

IASI is a completely different type of instrument from SSMIS and we do not expect it to suffer from the same instrument design issues. However, it is still important to understand the characteristics of any new observation type before attempting assimilation. One of the best tools for increasing our understanding is comparing observations with forward modelled NWP background (O-B) values. With this in mind, it is useful to consider what we may expect from IASI data in such a comparison study.

Within the context of variational analysis, we can calculate what we expect the standard deviation in O-B to be by projecting the expected random error in the background into brightness temperature space and adding the expected random component of instrument and forward model error. This is done by calculating the quantity $H B H^T + R$ averaged over many profiles (where $H$ is the forward model Jacobian, $B$ is the background error covariance matrix and $R$ is the observation plus forward model error covariance matrix). This calculation has been performed for IASI, using RTTOV8 to generate $H$ for 43 levels of temperature, 26 levels of water vapour, skin temperature and 2m temperature and humidity. The $R$ matrix (Collard, pers. comm.) was diagonal and consisted of IASI FM2 noise data from optical vacuum tests added to an estimate of forward model noise. The $B$ matrix used was the Met Office operational 1D-Var background error covariance matrix.

Since the $B$ matrix was defined, there have been significant changes to the operational forecast model (for example, moving from pressure levels to height levels; increasing from 38 levels to 50 levels) which mean that $B$ is no longer fully representative of errors in the global model. In order to correct for this, the $H B H^T + R$ analysis was first carried out for the 324 AIRSWF channel set. The root mean square errors in AIRS O-B for the Global model were used to calculate a set of factors to adjust $B$ so that the calculated standard deviations were in line with the real O-B statistics (Figure 3a). The humidity variances were scaled by 0.25, the temperature variances by 0.16 and the skin and 2m temperature elements by 0.1225. The diagonal of the new $B$ matrix is shown in Figure 4. The shortwave channels still do not show agreement which could be a result of a bias being introduced because our assimilation of the short-wave channels is night-time only.
Fig 3: (a) Comparison between calculated expected standard deviation of O-B for 324 AIRSWF channels with true RMS error in O-B and assumed instrument plus forward model error (R). (b) Calculated expected standard deviation of O-B for 300 IASI channels and assumed instrument plus forward model error.
Using the adjusted $B$ matrix, the expected standard deviations of O-B departure were calculated for the 300 selected IASI channels and are shown in Figure 3b. As we would expect, the errors across the spectrum are similar to those calculated for AIRS, although slightly higher in the water vapour bands and Band 3 where the instrument noise for IASI is higher. Crucially for our early data monitoring, these results suggest that we should be fitting channels in the 14μm CO$_2$ band, where the background errors are lowest, to within 0.4K – this spectral region will be an important area to concentrate on in the first stages of data monitoring.

![Fig. 4: Diagonal elements of the $B$ matrix used to calculate expected standard deviations in O-B for IASI.](image)

**Routine IASI monitoring**

The Met Office intends to make routine IASI monitoring plots available on the external web, as is currently done for AIRS and ATOVS. We have been working with ECMWF, CNES and EUMETSAT to produce a recommendation for monitoring (Auligné et al. 2006) which will encourage NWP centres to produce similar monitoring plots to allow easy comparisons between different centres. This should aid in detection of instrument issues which can be fed back to the data providers.
References


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