DRAFT VERSION

Deconvolution and Translation Between High Spectral Resolution IR Sounders

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1 Introduction

Upwelling infrared radiation as measured by the AIRS, IASI, and CrIS sounders is a significant part of the long term climate record. We would like to treat this information as a single data set but the instruments have different spectral resolutions, channel response functions, and band spans. To address this problem we consider several channel radiance translations: IASI to CrIS, IASI to AIRS, CrIS to AIRS, and AIRS to CrIS.

Translation from AIRS to CrIS presents a special challenge because while CrIS and IASI are Michaelson interferometers with single response functions, AIRS is a grating spectrometer with a distinct response function for each channel. We take advantage of detailed knowledge of the AIRS spectral response functions (SRFs) to deconvolve AIRS channel radiances to a resolution enhanced intermediate representation.

The translations are validated by comparisons with calculated reference truth. For example to test the IASI to AIRS translation, we start with 49 fitting profiles spanning a significant range of atmospheric conditions. Upwelling radiance is calculated at a 0.0025 cm^{-1} grid with kcarta over a band spanning the AIRS and IASI response functions. “True AIRS” is calculated from this by convolving the kcarta radiances with tabulated AIRS SRFs, and “true IASI” by convolving kcarta radiances to the IASI instrument specs. IASI is translated to AIRS (we call this “IASI AIRS”) and this is compared with true AIRS.

This sort of validation assumes perfect knowledge of the AIRS and IASI instrument response functions and so gives only a lower bound on how well the translations can work in practice. But the better we know the response functions, the closer practical translations can approach these limits.

The conversions here are presented in order of their accuracy, with IASI to CrIS most accurate and CrIS to AIRS the least. As noted above AIRS to CrIS is a special case because of the non-interferometric nature of the deconvolution, and that section requires a more detailed presentation than the others.

2 IASI to CrIS

The CrIS user grid comprises three bands, LW 650 to 1095 cm^{-1}, MW 1210 to 1750 cm^{-1}, and SW 2155 to 2550 cm^{-1}. For the CrIS high resolution mode the channel spacing is 0.625 cm^{-1} for all three bands. The CrIS user ILS is a sinc function. The IASI user grid is a single band from 645 to 2760 cm^{-1} with a channel spacing of 0.5 cm^{-1}. The IASI user ILS is a modified Gaussian, as shown in figure 1, convolved with a sinc function.

IASI to CrIS is a relatively easy translation because IASI spans the CrIS bands and has a nominal (though strongly apodized) higher resolution. The main steps of the translation, for each CrIS band, are

- apply a bandpass filter to the IASI data to restrict it to a single CrIS band with a roughly 20 cm^{-1} rolloff outside the CrIS user grid, when possible. For the LW band we use a 5 cm^{-1} rolloff because IASI starts at 645 cm^{-1}.

- take the filtered radiances to an interferogram with an inverse Fourier transform

- apply the pointwise inverse of the IASI Gaussian over the IASI 1 cm OPD and truncate this to the 0.8 cm CrIS OPD.

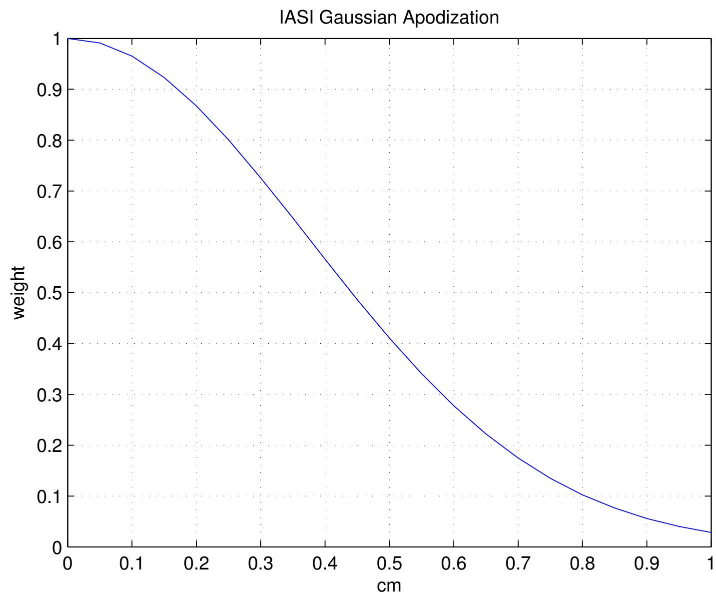

Figure 1: IASI truncated Gaussian apodization

- take the interferogram back to radiance at the CrIS 0.625 cm^{-1} channel spacing with a forward Fourier transform

Figure 2 shows the mean and standard deviation of IASI CrIS minus true CrIS over the 49 fitting profiles, for the CrIS LW band. The residual is greatest at the low end of the LW band. This may be due in part to the 5 cm^{-1} LW rolloff, as residuals near the band edges are larger with a smaller rolloff. The residual is reduced significantly if we apply Hamming apodization to the IASI CrIS and true CrIS radiances, as shown in figure 3.

Figures 4 and 5 show similar results for the unapodized radiances for the MW and SW bands. The residuals are very small. Unless otherwise noted, all CrIS spectra shown here are unapodized.

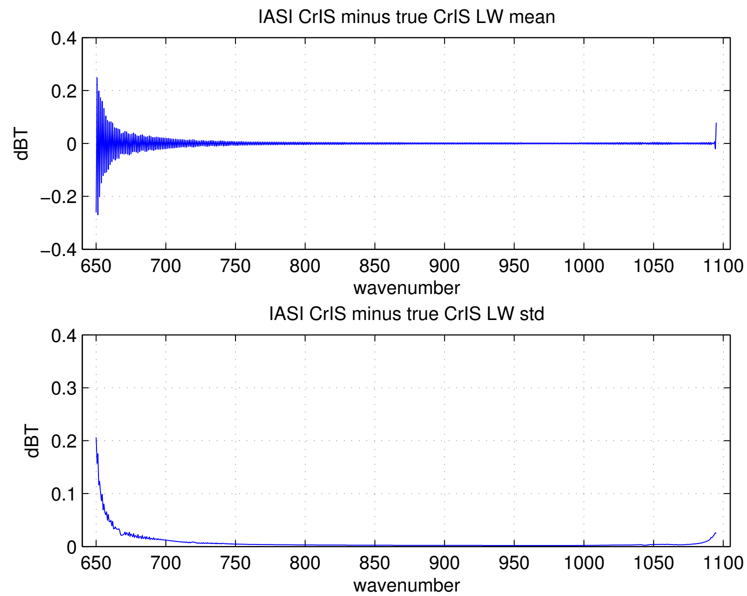

Figure 2: Mean and standard deviation of unapodized IASI CrIS minus true CrIS, for the CrIS LW band.

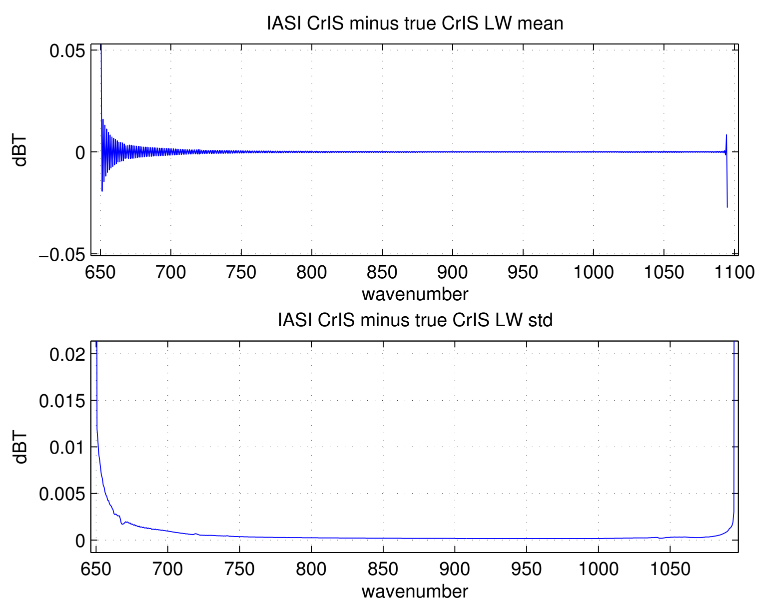

Figure 3: Mean and standard deviation of Hamming apodized IASI CrIS minus true CrIS, for the CrIS LW band.

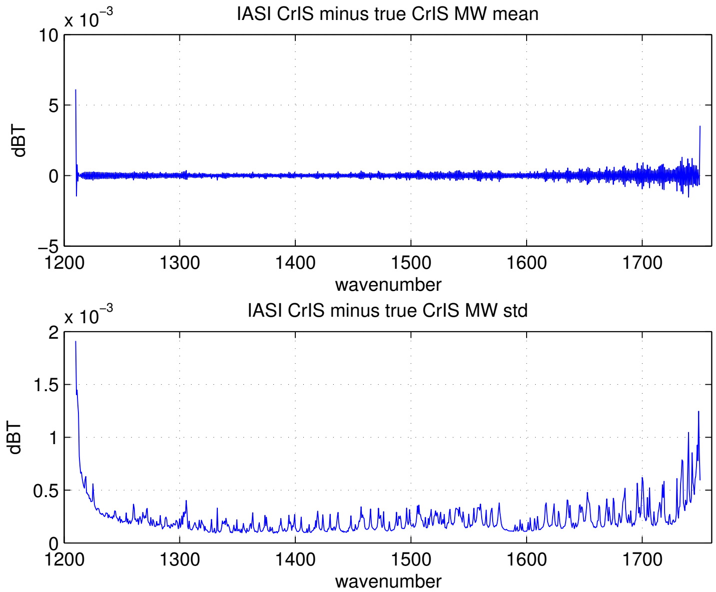

Figure 4: Mean and standard deviation of unapodized IASI CrIS minus true CrIS, for the CrIS MW band.

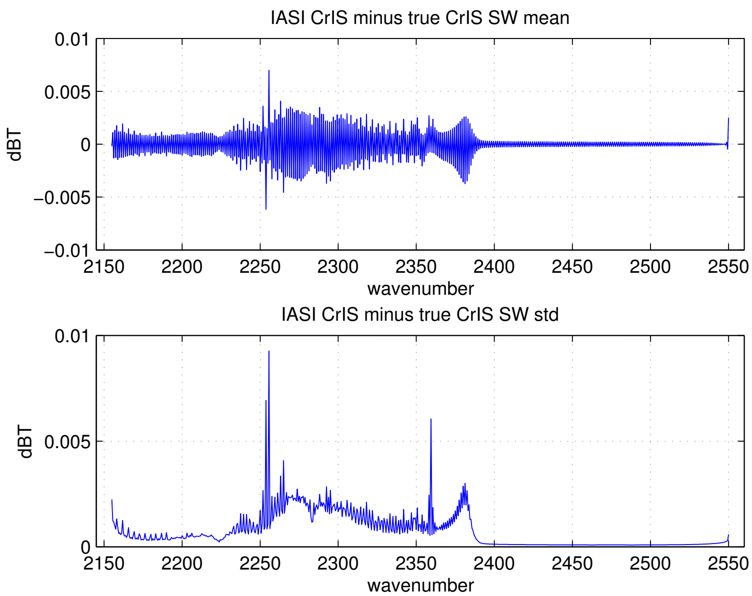

Figure 5: Mean and standard deviation of unapodized IASI CrIS minus true CrIS, for the CrIS SW band.

3 IASI to AIRS

AIRS L1b radiances are a set of channels between approximately 650 to 2650 cm^{-1} with the individual center frequencies and spectral response functions (SRFs) determined by the focal plane geometery. Channels are not uniformly spaced. AIRS L1c radiances are derived from the L1b, with improvements including filling the small gaps. The IASI to AIRS translation will work for either channel set, and is done as follows

- apply a bandpass filter to the IASI radiances to restrict them to the AIRS band span, with a 5 cm^{-1} rolloff
- deconvolve the filtered IASI radiances to a 0.1 cm^{-1} intermediate grid, the nominal resolution of the AIRS SRF tabulation. Aside from resolution and band spans, this exactly the same transform used for the IASI to CrIS translation
- convolve the 0.1 cm^{-1} intermediate representation with either the AIRS L1b or L1c SRFs

Figure 6 shows the first three AIRS SRFs and the bandpass filter wing. There is a tradeoff involved in the position of the bandpass wing—the deconvolution is better behaved with a broader wing, but we don't want to step on the wings of the AIRS SRFs.

Figure 7 shows true IASI, true AIRS, deconvolved IASI, and IASI AIRS. At this level of detail we mainly see the greater fine structure in the deconvolution. Figure 8 shows IASI AIRS minus true AIRS. The residual is larger than for the IASI to CrIS translation, but significantly better than the AIRS to CrIS or CrIS to AIRS translations.

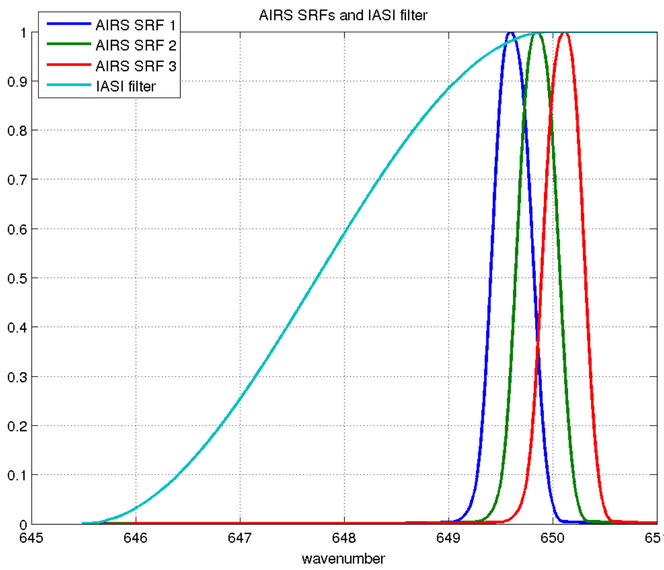

Figure 6: The first three AIRS SRFs and the bandpass filter wing

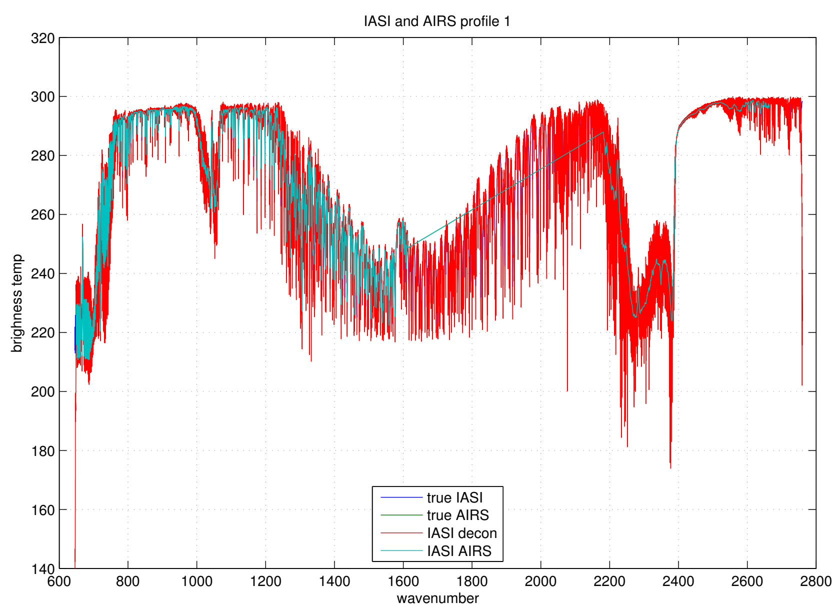

Figure 7: true IASI, true AIRS, deconvolved IASI, and IASI AIRS

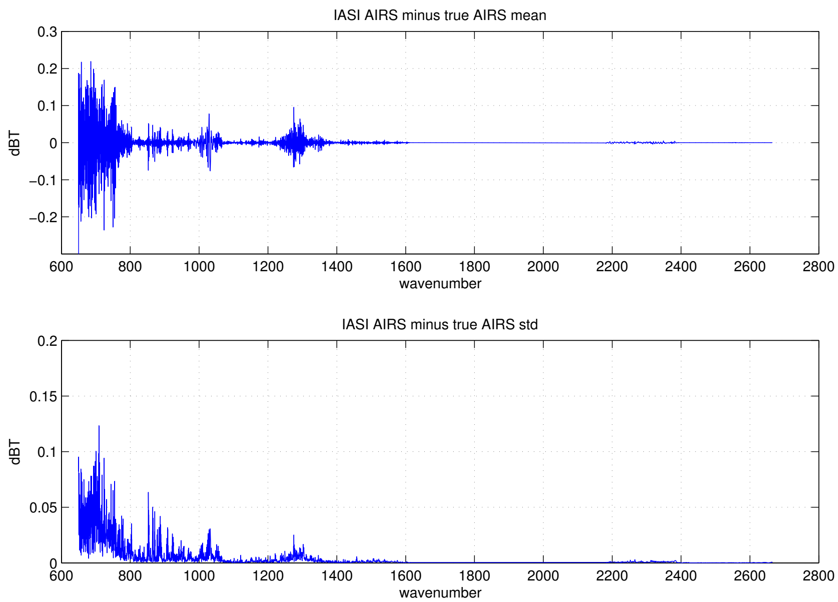

Figure 8: Mean and standard deviation of IASI AIRS minus true AIRS

4 AIRS to CrIS

5 CrIS to AIRS