Spatial Filtering and Resampling of Multi-Resolution Microwave Sounder Observations[1]

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Abstract

Spatially oversampled radiometric measurements of the Earth's surface and atmosphere can be reprocessed to optimize various performance metrics. These metrics include resolution, distortion, and effective antenna beam efficiency. In this paper, we explore several strategies for two-dimensional image processing for microwave sounder observations and assess the performance using several metrics. Simulated measurements of the Advanced Technology Microwave Sounder (ATMS, to be flown on the NPOESS Preparatory Project in 2011) are used in the evaluation. We examine both spatial filtering (a modification of the effective spatial resolution of the measurements) and resampling (a modification of the effective boresight of the composite footprint). Resampling performance is examined in the context of combined infrared and microwave sounding, where ATMS observations are resampled to align with those of the Cross-track Infrared Sounder (CrIS, also to be flown on NPP). We demonstrate that known mechanical misalignments can be corrected during image processing.

Background

CrIS and ATMS (together known as CrIMSS, the Cross-Track Infrared and Microwave Sounding Suite) will enable retrievals based on both microwave and infrared data. This requires ATMS brightness temperatures to be spatially filtered and resampled so the resolution and beam center alignment are matched to those of CrIS. We first consider various approaches, such as Backus-Gilbert optimization [2, 3], that can be used to carry out the necessary image processing, and we discuss performance metrics. One challenge of this work is that the CrIMSS instruments will be mounted to the NPP spacecraft such that their scan paths will have a (known) yaw misalignment of 0.917° (see Figure 1). An objective of this study was to assess the efficacy of software compensation that could be performed by adjusting the Backus-Gilbert coefficients used in the ATMS Sensor Data Record resampling algorithm.

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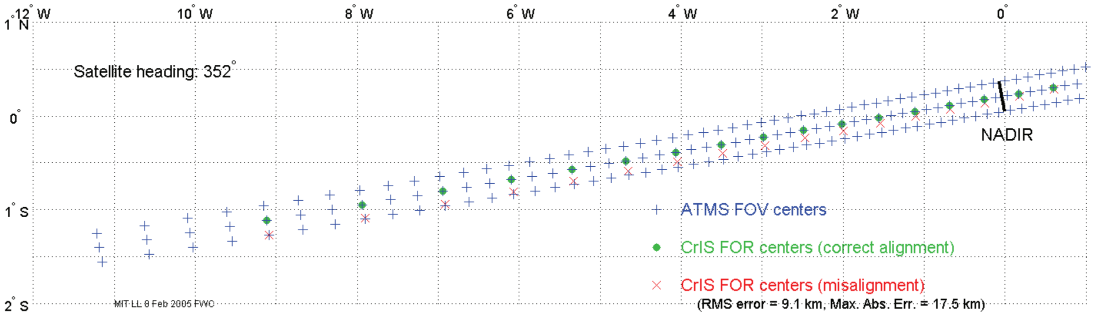
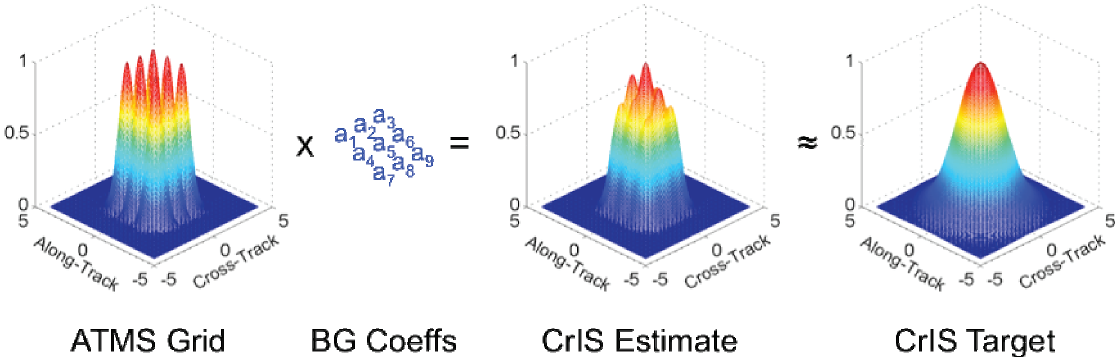


Figure 1. ATMS & CrIS scan patterns for mounting configuration planned for NPP

Methodology

The spatial filtering and resampling algorithm filters observed brightness temperatures in a way that is appropriate for the target resolution and beam center. This will be accomplished by computing weighted averages of brightness temperature measurements over a given region of support. The coefficients comprising the weighted average depend on the FOR and the resolution of the channel (see Figure 2).



ATMS Grid

BG Coeffs

CrIS Estimate

CrIS Target

Figure 2. ATMS observations are linearly combined to approximate the CrIS target footprint

Backus-Gilbert theory was used to derive coefficients for filtering ATMS brightness temperatures to CrIS resolution and observation centers. Backus-Gilbert theory is a framework for determining the types of localized averages that can be computed from observations. In this study, the computations followed the procedure described in [3], and the antenna patterns of the measurements and the target antenna pattern were Gaussian-shaped functions. Other methods will also be considered, such as spatial frequency filtering techniques [1]. The resolution is the diameter of the full-width half maximum (FWHM) contour, i.e. the contour where the value of the antenna pattern (as a function of solid angle around the satellite) is half of the peak value.

Two sets of Backus-Gilbert coefficients were computed. One set is for the case in which the ATMS and CrIS scan paths are aligned, and the other is for the case representing the current alignment as planned for NPP, where the scan paths are offset by a yaw angle of approximately 0.917°.

Results and Conclusions

The Backus-Gilbert coefficients were calculated for all the fields of regard across the entire swatch using a variety of optimization metrics. Figure 3 shows example results near nadir (FOR #1) and at edge-of-scan (FOR #15). Signal-to-noise ratio and the target fit are two parameters that can be traded against one another. The solid curves in Figure 3 indicate the performance when SNR is optimized and when the match to the target pattern is optimized.

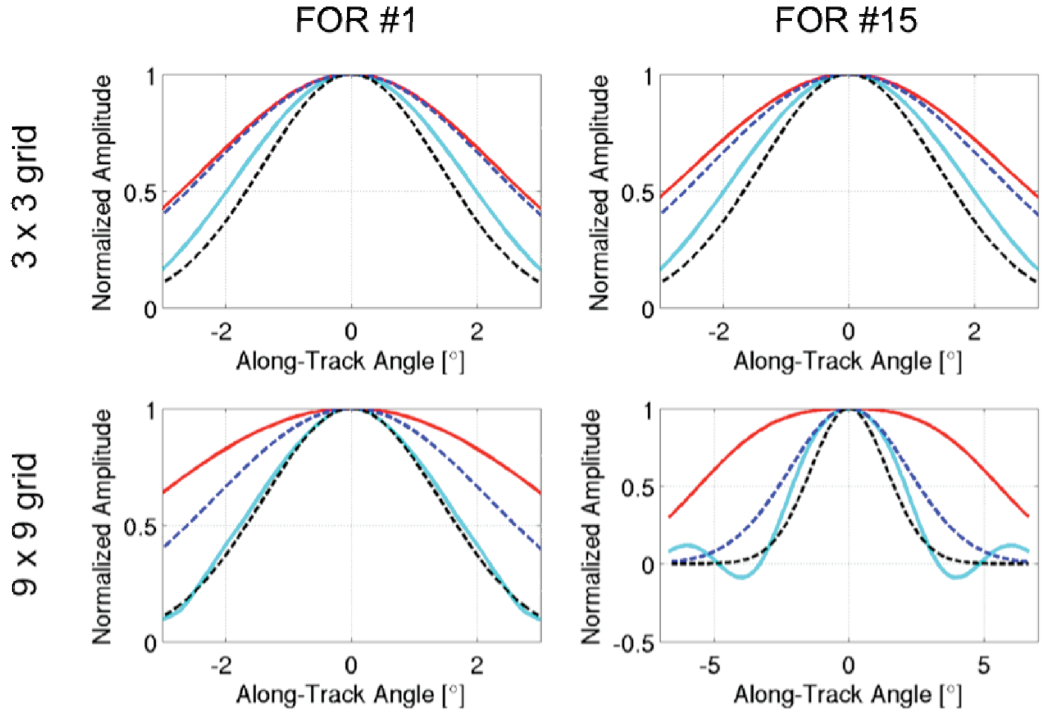


Figure 3. CrIS target pattern reconstructions for various optimization strategies. The blue dash curves indicate the native ATMS antenna patterns and the black curves indicate the CrIS target pattern. The red curve show the optimization results with best signal-to-noise ratio and the light blue curves show the optimization results with the best match to the target pattern.

The quality of the software compensation was compared with the "baseline case" of mechanically rotating the CrIS sensor by 0.917° in yaw to align the scan paths of CrIMSS. It was found that software compensation could correct the measured brightness temperatures to within 0.04 K RMS with respect to the baseline case, which would have a negligible effect on the CrIMSS Environmental Data Record quality.

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