PRE-LAUNCH PERFORMANCE VERIFICATION OF THE CRIMSS ATMOSPHERIC TEMPERATURE AND MOISTURE EDR RETRIEVAL ALGORITHM

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The Cross-track Infrared and Microwave Sounder Suite (CrIMSS) will be flying on the National Polar-orbiting Operational Environmental Satellite Systems (NPOESS). Atmospheric vertical temperature and moisture profiles are the two key Environmental Data Records (EDRs) to be measured by the CrIMSS. The retrieval algorithm for producing these two EDRs has been developed and verified following a rigorous pre-launch algorithm performance verification process using the Northrop Grumman Aerospace Systems (NGAS) Environmental product VErification and Remote Sensing Testbed (EVEREST). In this paper, we will present the methodology and test data used in our verification process as well as the current best estimates of the CrIMSS EDR algorithm's performance.

1. CrIMSS SENSORS

The atmospheric vertical temperature profile and moisture profile EDRs are defined as layer-averaged temperature and water vapor mass mixing ratio, respectively, within a 3-D cell at specified pressures above the surface. They are produced from the measurements of the Cross-track Infrared and Microwave Sounder Suite (CrIMSS), which consists of an infrared sounder and a microwave sounder. The EDRs will be produced over land and ocean under all weather conditions.

The infrared component of CrIMSS is the Cross-track Infrared Sounder (CrIS), a passive infrared Michelson interferometer. The instrument will measure radiances in three spectral bands from 650-2155cm^{-1}, with spectral resolutions of 0.625cm^{-1}, 1.25cm^{-1} and 2.5cm^{-1} in the long-wave, mid-wave and short-wave bands, respectively. The cross-track scan spans 49.395 degrees on either side of nadir and consists of a total of 30 earth view positions, or Fields of Regard (FOR). The CrIS focal plane has nine detectors (arranged as a 3x3 array), and simultaneously produces radiometric measurements over the 9 Fields of View (FOV) at each scan position. The FOV size is about 14km in diameter at nadir. The microwave component, the Advanced Technology Microwave Sounder (ATMS), is developed based on the heritage of the Advanced Microwave Sounder Unit (AMSU) and Microwave Humidity Sounder, and many of its spectral and spatial features closely resemble those of the heritage sensors. ATMS will be properly synchronized with CrIS, and its measurements will be re-sampled to match CrIS FOR locations in order to fully exploit the synergism between the two sensors. Combining ATMS and CrIS, CrIMSS will produce global measurements of temperature and moisture profiles with a high degree of accuracy at fine vertical and horizontal resolutions.

2. CrIMSS EDR RETRIEVAL ALGORITHM

The CrIMSS EDR retrieval algorithm was developed by Atmospheric Environmental Research, Inc. for NPOESS. Details of the design and implementation of the CrIMSS algorithm can be found in the CrIMSS EDR Algorithm Theoretical Basis Document[1]. It is an iterative physical retrieval algorithm that simultaneously estimates the geophysical states of both the atmosphere and the surface from the infrared and microwave radiances measurements. The algorithm combines a fast and accurate radiative transfer model, a constrained inversion model, and a heritage cloud-clearing algorithm to meet the EDR latency and accuracy requirements. The algorithm is normally executed in two distinctive stages to fully exploit the radiometric information contained in the microwave and infrared radiance data. In the first stage, retrievals are performed using only the ATMS data. Since the microwave sensor can "see" through the clouds, this step produces a reasonable estimate of the atmosphere and surface states, which is required to initiate the second stage processing and to estimate and compensate for the cloud contamination in the infrared radiance data (cloud-clearing). In the second stage, the inversion is performed combining both the microwave and infrared data on either a single CrIS FOV or a cluster of CrIS FOVs depending on the cloudiness of the scene.

In the CrIMSS algorithm, state vectors are projected onto a set of Empirical Orthogonal Functions (EOFs) to reduce the dimensionality of the inversion problem. The inversion is done in the EOF space and the retrieved EOF coefficients are then used to reconstruct the state vectors. This EOF transformation has the benefits of stabilizing the solution and reducing the computation time. The latter is particularly important for the algorithm to meet the stringent latency requirement for the operational data processing system.

As mentioned earlier, the second stage retrieval is done using the cloud-cleared radiance. Cloud clearing is a key component of the CrIMSS algorithm. It is adapted from the approach used by the AIRS retrieval algorithm [2], and has shown promising performance on our simulated test data.

3. CrIMSS ALGORITHM PERFORMANCE VERIFICATION

The algorithm was tested and verified using the end-to-end Environmental product VErification and Remote Sensing Testbed (EVEREST) developed by NGAS, which offers a suite of tools and models for simulating the environmental scenes, radiances, sensor effects, spacecraft and orbiting effects to evaluate the capability of future remote sensing systems.

The NGAS global test datasets consist of 12 days of global, day and night measurements. There is one dataset for each month to capture the seasonal variability of the environmental conditions. The data has been sparsely re-sampled to reduce data volume without compromising the spatial and temporal coverage. The re-sampling is done based on the NPOESS satellite orbital parameters and CrIMSS sensor scanning geometry. After re-sampling, each dataset corresponds to about 1/3 of an orbit's worth of full resolution data in data volume but covers the whole globe.

At each data location, the atmospheric and surface properties that may have impacted the CrIMSS radiances are defined based on information extracted from various databases and models. Best efforts have been made to make the state parameters self-consistent and realistic. The atmospheric attributes came from sources including NCEP AVN reanalysis (temperature, moisture, ozone, and cloud water profiles), UARS climatology database (upper atmosphere moisture and ozone profiles) and CIRA-86 climatology database (upper atmosphere temperature profiles). Cloud top and fraction data were simulated using the Northrop Grumman Information Technology's Cloud Scene Simulation Model with input from NCEP cloud liquid water profiles. Surface properties such as temperature and emissivities were simulated using information from NCEP fields (temperature, wind speeds) and a surface material composition database provided by Photon Research Associates.

The CrIMSS radiative transfer models were used to compute the infrared and microwave radiances corresponding to the state vectors that will be measured by the CrIS and ATMS sensors respectively. A detailed sensor model was used to simulate CrIS sensor effects, including sensor noise, jitter-induced noise, spectral and radiometric uncertainties, and band co-registration errors.

Training of the CrIMSS algorithm includes both the derivation of EOFs and specification of *a priori* and the associated covariance matrices. Beacuse the retrieval algorithm's performance will be affected to a certain degree by our imperfect knowledge about the EOFs and *a priori*, we decided to train the CrIMSS retrieval algorithm using a dataset different than our test datasets to avoid overestimating the performance. For this purpose, NGAS has compiled a large, diversified training dataset which also draws upon other well known data sources including the ECMWF diverse dataset [3], the NOAA88 radiosonde dataset, the ASTER and the UCSB emissivity libraries, and ocean/land microwave emissivity models [4][5]. Using the EOFs and *a priori* derived from these diverse databases and models, we expect the CrIMSS retrieval algorithm to be less dependent on the individual databases and models and less susceptible to their limitations.

4. CrIMSS EDR PERFORMANCE ASSESSMENT RESULTS

Figure 1 shows the current best estimates of the CrIMSS EDR quality performance under difference conditions: clear ocean (blue), clear land (green), partly cloudy ocean (red), partly clear land (cyan) and cloudy (magenta). The dash lines in Figure 1 represent the NPOESS system specifications. Based on the simulated test data, both the moisture and temperature profile EDRs meet the requirement specifications with good margin.

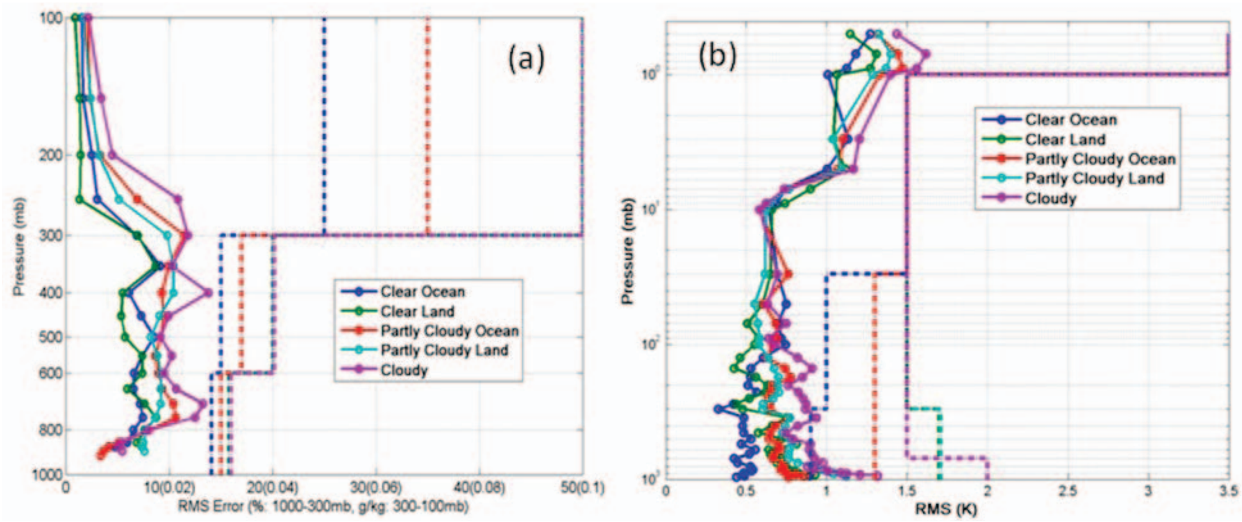

Figure 1. Estimated uncertainty of the atmospheric moisture profile (a) and temperature profile (b) EDRs. Dashed lines are NPOESS requirements.

It should be pointed out that the synthetic test data is limited by a number of factors including errors in the models, certain simplifications in the environmental conditions, and uncertainties in modeling actual sensor performance. As a result, the true performance of the CrIMSS EDR product quality could somewhat differ from the above estimates derived from the synthetic test data. The algorithm will continue to be tested and verified with additional data including those converted from other sensors (e.g. the Atmospheric Infrared Sounder (AIRS)) before launch. We also anticipate some enhancement to the retrieval algorithm and tuning to the algorithm look-up tables after launch to achieve the desired EDR quality performance.

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