Validation of CrIMSS EDR Products with Matched ECMWF Analysis, RAOB Measurements, and IASI Retrievals

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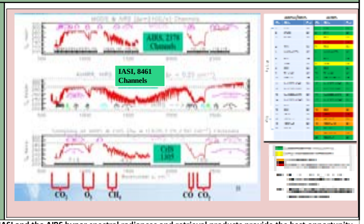
Abstract: **Atmospheric Vertical Temperature Profiles (AVTP), Atmospheric Vertical Moisture profiles (AVMP), and other Environmental Data Records (EDRs) retrieved by the Cross-track Infrared Sounder and Advanced Technology Microwave Sounder Suite (CrIMSS) EDR algorithm were evaluated using matched European Center for Medium-Range Weather Forecasts (ECMWF) analysis fields, radiosonde (RAOB) measurements, and independent retrieval products from Infrared Atmospheric Sounder Interferometer (IASI) observations. The proxy CrIS and ATMS Sensor Data Records (SDRs) needed to generate CrIMSS EDR products were derived for the "Focus Day," October 19, 2007, using IASI, Advanced Microwave Sounding Unit (AMSU), and Microwave Humidity Sounder (MHS) observations, respectively. Empirical bias tuning procedures were employed in the CrIMSS EDR algorithm to make the proxy SDRs consistent with the forward model used in the CrIMSS algorithm. The CrIMSS AVTP and AVMP products were evaluated for 42 granules of the focus day data set. Using the ECMWF/RAOB measurements as the truth, bias and RMS differences were computed for the CrIMSS and IASI EDR products. The results of the evaluation reveal that bias correction of forward model errors and sensor errors is critical to the CrIMSS algorithm performance. Evaluation of the 'infrared plus microwave' AVTP and AVMP retrievals reveals reasonable agreement with the ECMWF and IASI retrieval products. Further assessment of the CrIMSS EDRs with RAOBs and other correlative data sets is in progress to demonstrate launch-readiness.**

Hyper-spectral IR and MW Satellite Observations

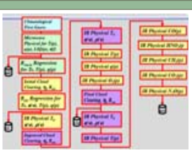
AIRS/IASI/AMSU-A/MHS Proxy-CrIS/ATMS



The IASI and the AIRS hyper-spectral radiances and retrieval products provide the best opportunity to generate and evaluate proxy CrIS SDRs and EDR products. The IASI and CrIS are Fourier Transform Spectrometers. Because IASI has higher spectral resolution and covers the full CrIS spectral range, the IASI SDRs offer an advantage in generating CrIS proxy SDRs. The AMSU-A and MHS instruments provide necessary data to generate ATMS proxy SDRs.

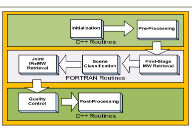
The IASI/AMSU-A/MHS and CrIS/ATMS (CrIMSS) Retrieval Algorithms

NOAA-STAR IASI- Operational System



- Developed During the Aqua Mission (Susskind et al., 2003)
- Expanded to Retrieve EDRs from IASI/AMUS-A/MHS SDRs - T(p), q(p), O3(p), and other trace gas products (Barnet et. al., 2009).
- Emerging as NOAA-Unique CrIS/ATMS Product System (NUCAPS)
- Identical Systems one for Research and the Other for Operations
  - Reprocessing options with algorithm upgrades.
  - Emulate various IASI/AIRS retrieval versions.

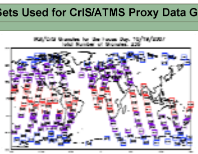
CrIMSS LaRC V1.5 Implementation at STAR (Kizer et al., 2010)



- Simultaneous Retrieval of T(p), q(p), O3(p),Tskin, Spectral Emissivities
- OSS-RTM
- Use of EOFs to Characterize and Measure Retrieved Parameters
- *a-priori Constraints* Derived from a Blended Training Data Set

Data Sets Used for CrIS/ATMS Proxy Data Generation

Focus-Day (IASI/AMSU-A/MHS Data Set (Barnet et al., 2010)



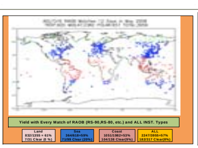
236 Granules of Matched Datasets for the 'Focus Day' 10/19/2007

Each Granule Contains 22 or 23 Scan Lines of

- CrIS/ATMS Proxy SDRs
- IASI/AMSU-A/MHS SDRs
- CrIMSS EDR products
- IASI EDR Products from NOAA IASI Operations (NUCAPS)
- NCEP-GFS Analysis Fields
- ECMWF Analysis Fields

FTP Site to Download Files ftp://ftp2.orbit.nesdis.noaa.gov/smcd/tking/IPO_REL_V1.0

RAOB Matched Data Sets (Divakarla et al., 2010a)



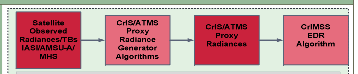
Radisonde Measurements and other Correlative Data Sets (May 1-12, 2008)

The Data Set Contains

- CrIS/ATMS Proxy SDRs
- IASI/AMSU-A/MHS SDRs
- IASI EDR Products from NOAA IASI Operations (NUCAPS)
- NCEP-GFS Analysis Fields
- ECMWF Analysis Fields
- Global RAOB Measurements

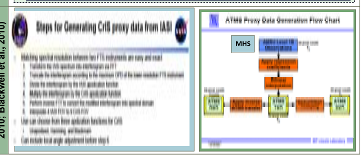
Proxy Data Generation Algorithms for CrIMSS EDR Retrievals

Concept of Proxy Data Generation



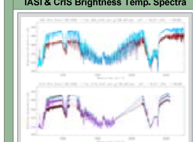
- Real Observations, Real Scenes (Atmosphere, Surface, Cloud), Sub-Pixel Variability
- Test Robustness of the Operational Code for Different QCs
- Check CrIMSS EDR Performance With Retrievals from Other Algorithms, and the Truth
- Truth is not known perfectly as like real data
- RTA Differences: Proxy Data Generation (e.g. ATMS LBL) vs. EDR Alg. RTA (OSS)

CrIS/ATMS Proxy Data Algorithms (Xu Liu and Kizer, 2010; Blackwell et al., 2010)



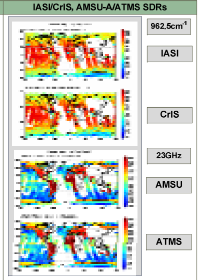
Evaluation of CrIS/ATMS Proxy SDRs (Divakarla et al., 2010b)

IASI & CrIS Brightness Temp. Spectra

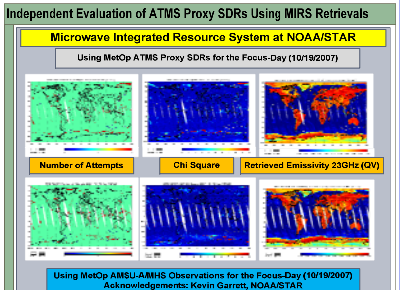


IASI observed brightness temperature spectra (top) and the corresponding CrIS proxy brightness temperature spectra (bottom). The IASI instrument has 8461 IR channels spanning the IR spectrum 645-2760 cm-1. The instrument has 4 fields of view (FOVs) for each Field of Regard (FOR) and the radiances are Gaussian apodized (top figure). The CrIS instrument has a total of 1315 IR channels in 3 bands covering longwave (655-1095 cm^{-1}), midwave (1210-1750 cm^{-1}), and shortwave (2155-2550 cm^{-1}) channels with spectral gaps between the bands. The instrument has 9 FOVs for each FOR and the radiances are Hamming apodized.

IASI/CrIS, AMSU-A/ATMS SDRs



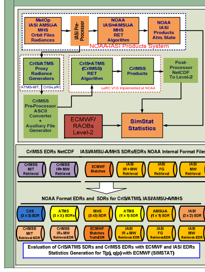
Independent Evaluation of ATMS Proxy SDRs Using MIRS Retrievals



Acknowledgements: Kevin Garrett, NOAA/STAR

Processes Implemented at NOAA/STAR

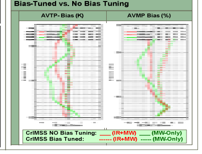
EDR Generation from CrIMSS and NUCAPS


Post-Processor NetCDF To Level-2
ECMWF RAOBs Level-2
SimStat Statistics
CrIMSS EDRs NetCDF
IASI/AMSU-A/MHS SDRs/EDRs NOAA Internal Format Files
NOAA Format EDRs and SDRs for CrIS/ATMS IASI/AMSU-A/MHS
CrIMSS MIT Retrieval-EDR
CrIMSS IR+MW Retrieval-EDR
ECMWF Matches Truth-EDR
IASI IR+MW Retrieval-EDR
IASI FG Retrieval-EDR
IASI MW Retrieval-EDR
Evaluation of CrIS/ATMS SDRs and CrIMSS EDRs with ECMWF and IASI EDRs
Statistics Generation for T(p), q(p) with ECMWF (SIMSTAT)

Bias Tuning Procedure (NGAS)

Earlier attempts (Divakarla et al., 2010a) on the evaluation of Proxy ATMS SDRs and EDRs retrieved using the CrIMSS EDR algorithm revealed the need for an empirical bias-tuning component in the CrIMSS algorithm. Accordingly, bias-tuning procedures were developed by NGAS and CrIMSS EDR products were generated for 46 granules (D.Gu et al., 2011).

Bias-Tuned vs. No Bias Tuning



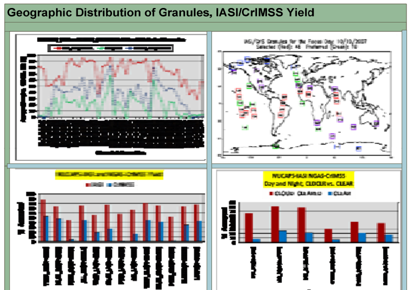
Evaluation of CrIMSS EDRs with ECMWF and IASI EDRs

Criteria and Statistical Metrics

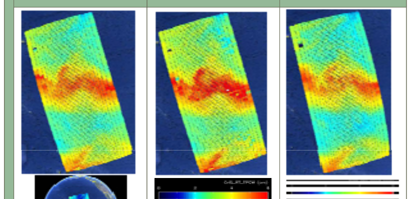
The NOAA/STAR IASI System employs the AIRS Science Team approach (Susskind et al., 2003) with enhancements to generate IASI EDRs (Barnet et al., 2010). In addition, the IASI system uses real SDR observations in contrast to proxy SDRs used by the CrIMSS algorithm. Thus, the whole intent of this validation exercise is to address any issues with the CrIMSS algorithm/EDRs for a possible fix so as to make the CrIMSS algorithm launch-ready. The CrIMSS EDR algorithm reports products for the first stage 'MW-only', and second stage 'IR+MW' retrievals with quality check (QC) flags that indicate matching of 'MW-only' radiances or 'IR+MW' radiances, respectively. CrIMSS QC flags stratify the scene as clear, partly-cloudy or cloudy. However, these QC flags require further optimization. Hence, we have used the IASI cloud-cleared, 'clear' accept/reject criteria as well as CrIMSS quality flag information to stratify the statistics into 'MW-only' and 'IR+MW' stage retrievals.

The ECMWF/RAOB measurements were taken as the truth and bias and Root Mean Squared (RMS) differences between the truth and CrIMSS AVTP and AVMP products were computed for (a) IR+MW reported retrievals, and for (b) 'MW-only' retrievals. Statistics for the IASI operational products were also computed for the same ensemble for the final IASI physical retrieval and the 'Microwave-only' retrievals that correspond to (a) and (b), respectively. The IASI EDRs were used as a baseline to measure CrIMSS EDR performance, since they are based on the source radiances used to derive proxy SDRs. Temperature statistics were derived for 1 km layers for 1000 hPa to 0.01 hPa. For water vapor, statistics were computed for column densities converted to integrated column water in 2-km layers from the surface to 100 hPa. The water vapor bias is computed as a percentage of the reference (ECMWF or RAOB) water vapor amount in the layer (100 x (CrIS – REF)/REF). The percent error for each 2-km layer was computed by weighting the standard deviation with the reference water vapor amount in the layer. In addition to the statistics generation, in-depth qualitative analysis of CrIMSS EDR products was performed using the ECMWF and IASI SDRs for a selected set of granules.

Geographic Distribution of Granules, IASI/CrIMSS Yield

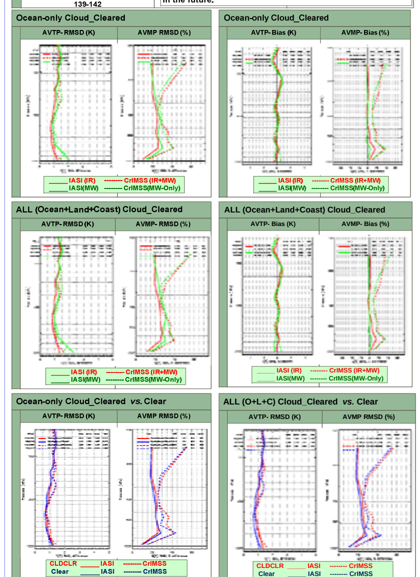


Retrieved Total Precipitable Water (cm) – Granules 139-142.



Location of Granules 139-142

The Google-Earth Pro interface used to display CrIMSS/IASI EDRs offers a very powerful method to evaluate EDRs qualitatively at the retrieval Field of Regard (FOR) resolution. Many retrieval products can be cross-checked with this interface and has a potential for many real-time applications in the future.



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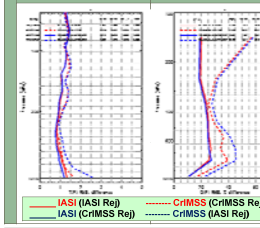
ALL (O+L+C) Cloud_Cleared: IASI & CrIMSS QC Flags



This figure shows the CrIMSS EDR performance when IASI retrieval 'Accepted/Rejected' flag (Yield: 78%) is applied on CrIMSS EDRs, and CrIMSS 'IR+MW' stage QC flag (Yield: 43%) is applied on IASI EDRs. This indicates that CrIMSS 'IR+MW' flag is comparable to the corresponding IASI QC flag. On the other hand when the IASI QC flag is applied onto CrIMSS EDRs, the statistics for CrIMSS look reasonably good with a slight degradation probably due to many 'MW-Only' retrievals. This suggests that the CrIMSS 'IR+MW' stage QC flag is very stringent, and possibly some of the partially-cloudy CrIMSS retrievals designated as 'MW-Only' stage retrievals can be added to the CrIMSS 'IR+MW' stage retrievals.

Results and Discussion

1. **Proxy Data is of Good Quality:** The CrIS proxy SDRs are a direct transformation of IASI EDRs. The ATMS proxy SDRs are of good quality for most of the globe except for high latitude regions (>70° latitudes) and over the sea/ice boundaries.
2. **Bias-tuning is Critical for CrIMSS Retrieval Performance:** Bias tuning procedures implemented in the CrIMSS algorithm improves CrIMSS EDR performance substantially. This needs to be tested on an independent data set (RAOBs).
3. **EDR Performance:** The CrIMSS algorithm shows reasonable ability for a launch-ready performance. Lower yields of CrIMSS EDR algorithm over polar granules and land cases is probably due to the limitations imposed by the proxy SDRs and needs to be verified. We anticipate that the new ATMS proxy SDRs and other enhancements (improved bias tuning, optimization of noise) will improve further, the agreement between CrIMSS EDRs and the truth data sets.

Future Work

1. **RAOB Matched Proxy Data sets:** We are working on radiosonde (RAOB) matched proxy data sets and other correlative measurements for further testing of the CrIMSS EDR performance.
2. **The IR and MW Emissivity Verification:** A detailed verification of the retrieved emissivities at the MW and IR hinge points over land and ocean using physical models and utilizing a compilation of Global Data Assimilation System (GDAD) and ECMWF fields is planned.
3. **Post-Launch Exercises with Pre-Launch Proxy SDRs:** Proxy SDRs for the Focus Day (10/19/2007) are in use for many post-launch exercises. Refinements to the bias-tuning procedures and optimization of CrIS noise are in progress at NGAS, LaRC and at NOAA. Interested users can down-load the data from NOAA FTP website and are welcome to participate in Telecon meetings.

References

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