The CrIMSS EDR Algorithm Assessment: Provisional Maturity and Beyond

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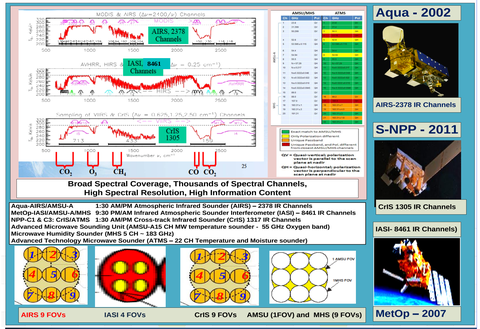
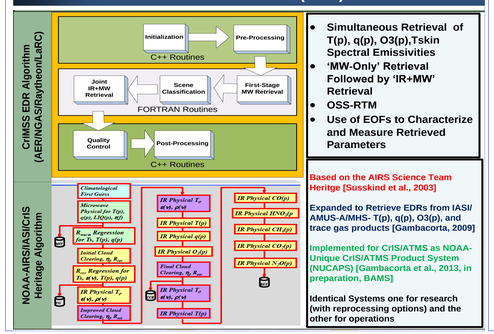
Abstract

The Cross-track Infrared Sounder (CrIS) and the Advanced Technology Microwave Sounder (ATMS) instruments aboard the Suomi National Polar-orbiting Partnership (S-NPP) satellite provide high quality hyper-spectral Infrared (IR) and Microwave (MW) observations to produce atmospheric vertical temperature, moisture, and pressure profiles (AVTP, AVMP and AVPP), and many other Environmental Data Records (EDRs). The official Cross-track Infrared and Microwave Sounder Suite (CrIMSS) EDR algorithm version MX8 is currently in operations. Prior to the operational implementation of MX7.1, emulations of MX7.1 were created and were used to evaluate AVTP and AVMP products with a variety of validation data sets to demonstrate provisional maturity. Based on the evaluations and recommendations made by the Joint Polar Satellite System (JPSS) provisional maturity assessment committee, the CrIMSS AVTP and AVMP products associated with the MX7.1 build were declared to be of provisional quality in January 2013. Following provisional maturity, the CrIMSS EDR algorithm team tested numerous optimizations to improve further the accuracy of AVTP and AVMP products. These include an improved precipitation detection algorithm, optimizations to ATMS and CrIS bias correction look-up tables (LUTs), snow and ice microwave emissivity representations, and use of external emissivity data bases to improve CrIS cloud-cleared radiances. This paper presents an assessment of the AVTP and AVMP products from the IDPS MX7.1 operations, and then shows the EDR performance enhancements achieved beyond MX7.1. The AVTP and AVMP product evaluations with dedicated radiosondes and ECMWF analysis data show that these optimizations have improved the AVTP and AVMP accuracies beyond what was observed with the MX7.1 operational version. Overall, yields have improved since launch to include approximately 90% of atmospheric profiles from the first stage 'MW-only' retrieval, and over 50% of profiles from the 2nd stage 'IR+MW' retrieval. These results reveal that the CrIMSS EDR algorithm has shown remarkable improvement within two years of operation closely meeting the AVTP and AVMP product requirements.

Hyper-Spectral IR and MW Sounding Instruments The CrIS, AIRS and IASI; AMSU-A/MHS and ATMS



Retrieval Algorithms for CrIS+AMTS (CrIMSS) Environmental Data Record (EDR) Products



- Simultaneous Retrieval of T(p), q(p), O3(p),Tskin Spectral Emissivities
- 'MW-Only' Retrieval Followed by 'IR+MW' Retrieval
- OSS-RTM
- Use of EOFs to Characterize and Measure Retrieved Parameters

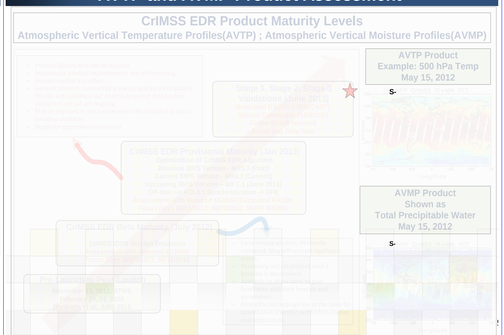
Based on the AIRS Science Team Heritge [Susskind et al., 2003]

Expanded to Retrieve EDRs from IASI/AMUS-A/MHS- T(p), q(p), O3(p), and trace gas products [Gambacorta, 2009]

Implemented for CrIS/ATMS as NOAA-Unique CrIS/ATMS Product System (NUCAPS) [Gambacorta et al., 2013, in preparation, BAMS]

Identical Systems one for research (with reprocessing options) and the other for operations

Operational CrIMSS EDR Algorithm AVTP and AVMP Product Assessment



CrIMSS AVTP and AVMP EDR Products Requirements & Validations

Stage-1: Product Validation performed using a small number of independent measurements obtained from selected locations and time periods and ground-truth/field program effort.

State 2: Product Validation performed over a widely distributed set of locations and time periods via several ground-truth and validation efforts.

Stage 3: Product Validation performed and uncertainties were well established via independent measurements made in a systematic and statistically robust

Atmospheric Vertical Temperature Profile (AVTP) Measurement Uncertainty – Layer Average Temperature Error	
PARAMETER	THRESHOLD
AVTPClear, surface to 300 mb	1.0 K / 1 km layer
AVTPClear, 300 to 30 mb	1.5 K / 1 km layer
AVTPClear, 30 mb to 1 mb	1.5 K / 1 km layer
AVTPClear, 1 mb to 0.5 mb	3.5 K / 1 km layer
AVTPCloudy , surface to 700 mb	**2.5 K / 1 km layer**
AVTPCloudy, 700 mb to 300 mb	1.5 K / 1 km layer
AVTPCloudy, 300 mb to 30 mb	1.5 K / 1 km layer
AVTPCloudy, 30 mb to 1 mb	1.5 K / 1 km layer
AVTPCloudy, 1 mb to 0.5 mb	3.5 K / 1 km layer

Atmospheric Vertical Moisture Profile (AVMP) Measurement Uncertainty – 2 km Layer Average Mixing Ratio % Error	
PARAMETER	THRESHOLD
AVMP Clear, surface to 600 mb	Greater of 20% or 0.2 g/kg / 2 km layer
AVMP Clear, 600 to 300 mb	Greater of 35% or 0.1 g/kg / 2 km layer
AVMP Clear, 300 to 100 mb	Greater of 35% or 0.1 g/kg / 2 km layer
AVMP Cloudy, surface to 600 mb	**Greater of 20% of 0.2 g/kg / 2 km layer**
AVMP Cloudy, 600 mb to 400 mb	Greater of 40% or 0.1 g/kg / 2 km layer
AVMP Cloudy, 400 mb to 100 mb	Greater of 40% or 0.1 g/kg / 2 km layer

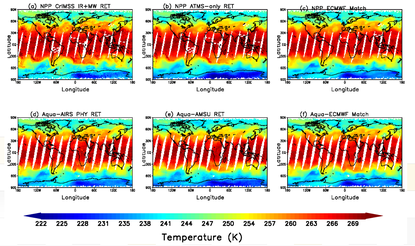
Source: JPSS Program L1RD Requirements, Preliminary, Version 4.7; NOAA/NESDIS, NASA; Nalli et al.,2013; Divakarla et al.,2014.

Evaluation Scheme for AVTP and AVMP Products Provisional Maturity to Stage 1-3 Validations

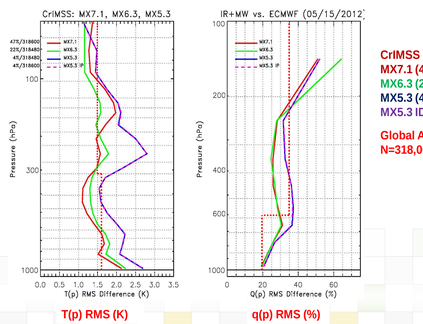
1. Global evaluation of CrIMSS AVTP and AVMP retrievals with 'Focus Day' correlative data sets
   - 05/15/2012, 09/20/2012, 02/03/2013, 03/12/2013 - 324,000 Matches/Day
   - ECMWF/GFS model/forecast analysis fields, Aqua-AIRS EDR products
   - These Data Sets are available on STAR FTP Site to down-load
2. Global RAOB collocations collected over a period of time
   - Typically ~300 co-located matches for a given day (± 3 hr, 100 km) Representative of highly sampled geographic locations (RAOBs predominant in NH-Midlatitudes) and instrument types (RS80 Predominant)
   - Many thousands of RAOB matches over a period of time.
3. GPS Radio occultation profiles from the COSMIC Network:
   - Global sampling and long-term stability of GPS RO makes it a good candidate as a validation reference.
   - ~ 200-300 matches/day
4. Dedicated Sondes – RS92 Matches collected over a period of time
   - ARM/CART Sites (TWP, SGP, NSA)
   - Campaigns of Opportunity (e.g. AEROSE)
   - Aerospace Pacific Missile Range Facility (PMRF), Hawaii.

CrIMSS AVTP - MW-only (1st Stage), IR+MW (2nd Stage), Aqua-AIRS Retrievals, and ECMWF Matches

- AVTP (500hPa) temperature product for May 15, 2012
  - CrIMSS IR+MW (upper left) and MW-only (upper middle)
  - AIRS IR+MW (lower left) and AMSU-only (lower middle)
  - Co-located ECMWF for CrIS (upper right) and AIRS (lower right)



CrIMSS 'IR+MW' AVTP, AVMP RMS Difference wrt ECMWF MX 5.3 (Day1), MX 6.3, and MX 7.1 (from June 2013) Data: Global (Focus Day: 05/15/2012)

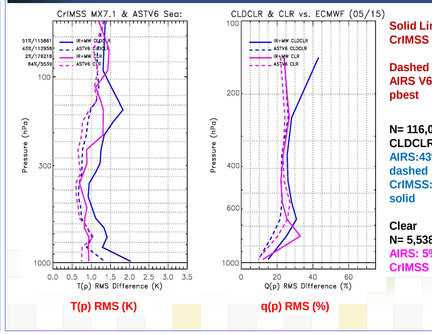


CrIMSS 'IR+MW'
MX7.1 (47%)
MX6.3 (22%)
MX5.3 (4%)
MX5.3 IDPS (4%)

Global ALL N=318,000

T(p) RMS (K) q(p) RMS (%)

CrIMSS vs. ECMWF; AIRS V6 vs. ECMWF Matched EDRs - Global Ocean – Cloud-Cleared, and Cloud-free



Solid Lines
CrIMSS IR+MW

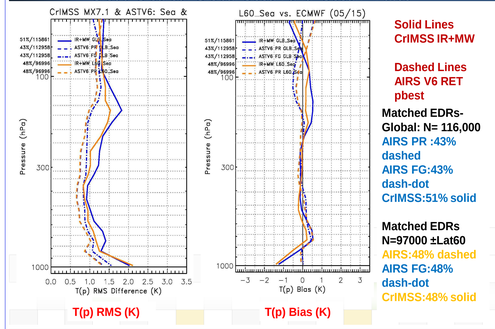
Dashed Lines
AIRS V6 RET pbest

N= 116,000 - CLDCLR
AIRS:43% dashed
CrIMSS:51% solid

Clear
N= 5,538
AIRS: 5% dashed
CrIMSS solid

T(p) RMS (K) q(p) RMS (%)

CrIMSS vs. ECMWF; AIRS V6 vs. ECMWF Using Matched AIRS-V6 and CrIMSS EDRs Cloud-Cleared: Global Ocean and Ocean ±Lat60



Solid Lines
CrIMSS IR+MW

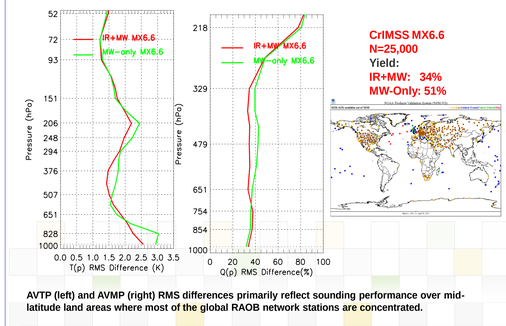
Dashed Lines
AIRS V6 RET pbest

Matched EDRs-Global: N= 116,000
AIRS PR :43% dashed
AIRS FG:43% dash-dot
CrIMSS:51% solid

Matched EDRs N=97000 ±Lat60
AIRS:48% dashed
AIRS FG:48% dash-dot
CrIMSS:48% solid

T(p) RMS (K) T(p) Bias (K)

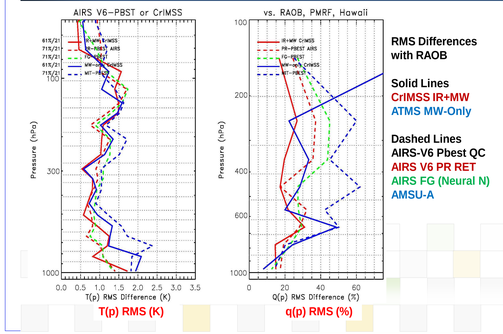
Evaluation with Global RAOB Matches (NPROVS)



CrIMSS MX6.6
N=25,000
Yield:
IR+MW: 34%
MW-Only: 51%

AVTP (left) and AVMP (right) RMS differences primarily reflect sounding performance over mid-latitude land areas where most of the global RAOB network stations are concentrated.

PMRF, Kauai, Hawaii (22.05°N, 159.78°W) Matches CrIMSS vs. RAOB; AIRS-V6 Pbest vs. RAOB



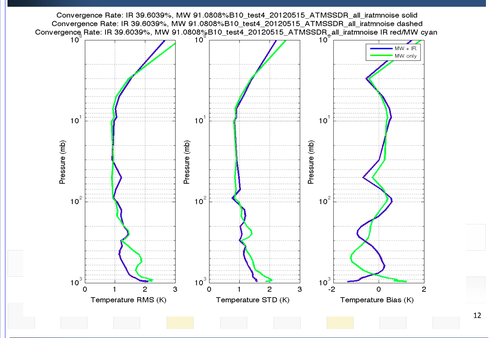
RMS Differences with RAOB

Solid Lines
CrIMSS IR+MW
ATMS MW-Only

Dashed Lines
AIRS-V6 Pbest QC
AIRS V6 PR RET
AIRS FG (Neural N)
AMSU-A

T(p) RMS (K) q(p) RMS (%)

CrIMSS EDR Improvements Beyond MX 7.1



Results and Discussion

1. The CrIMSS EDR algorithm is a baseline operational product utilizing physical only approach available to user community.
2. The Algorithm has been in operations for only 18 months, and with very minor changes to the code and LUT updates from the pre-launch version, the algorithm has shown a remarkably improved performance.
3. The global yield of the algorithm is about 91%. The combined 'IR+MW' EDR product performance (yield ~47-50%) and the MW-only only product performance with a (remainder yield of 43%) are meeting the AVTP and AVMP Global requirements for most of the atmosphere.
4. The algorithm is performing as expected for different categories (land, sea, and coast), and different regimes (tropics, midlatitudes, high-latitudes). A slightly larger global RMS difference exceeding the requirement at sfc-700 hPa is due to larger RMS differences over the land cases, and polar regions impacting the global RMS difference. Temperature RMS differences with ECMWF are very close to reaching the requirements. Water vapor retrievals may require a little more algorithm optimization. Proposed improvements are expected to improve the performance.

Results and Discussion

5. Evaluations with PMRF dedicated RAOBs, ECMWF and Aqua-AIRS retrievals
   - For low cloud amounts, and cloud-free samples the CrIMSS EDR algorithm appears to be very robust and the performance is very much similar to the AIRS-V6 heritage algorithm. In fact the CrIMSS AVMP retrievals show better promise for mid-to-upper troposphere water vapor compared to AIRS-V6 pbest retrievals.
   - The AVTP and AVMP RMS differences with RAOBs and ECMWF are very similar. The dedicated RAOB matches are not assimilated into global NWP models. Despite that, the retrievals (CrIMSS as well as AIRS) tend to agree better with ECMWF indicating that ECMWF analysis fields are robust for an evaluation over data sparse open oceans.
   - Evaluation with dedicated RAOBs and ECMWF analysis fields supports all the conclusions discussed using 'Focus-Day' CrIMSS EDR evaluations with ECMWF.
6. The AIRS-V6 physical retrieval is marginally better than the first guess neural network regression solution. The difference between AST-V6 and the CrIMSS EDR is that the CrIMSS EDR is 'physical-only' and does not incorporate any knowledge of ECMWF with in the retrieval. The larger RMS difference between the CrIMSS EDRs and the AST-V6 could be due to either a poorly optimized CrIMSS EDR retrieval or the ability of the neural network first guess to emulate the ECMWF statistics.

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