The CrIMSS EDR algorithm:
Provisional Maturity and Beyond

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Questions/Comments/Suggestions – Please email to Murty.Divakarla@noaa.gov
CrIMSS EDR Product Assessment Steps

CrIMSS EDR Product Maturity Levels
Atmospheric Vertical Temperature Profiles (AVTP) ; Atmospheric Vertical Moisture Profiles (AVMP)

- Product Quality may not be optimal
- Incremental product improvements are still occurring
- Version control is in effect
- General research community is encouraged to participate in the QA and validation but need to be aware that product validation and QA are ongoing
- May be replaced in the archive when the validated product becomes available
- Ready for operational evaluation

Pre-Launch to Post-Launch
November 11, 2011, ATMS
February 24, 24, 2012
Divakarla et al., AMS-2012

CrIMSS EDR Beta Maturity (July 2012)
CrIMSS IDPS Version Emulation
Assessment with Matched ECMWF
Focus Days 02/25/2012; 05/15/2012

CrIMSS EDR Provisional Maturity (Jan 2013)
Optimization of CrIMSS EDR Algorithm
Baseline IDPS Version - MX5.3 (Past)
Current IDPS Version - MX6.3 (Current)
Upcoming IDPS Version – MX 7.1 (June 2013)
Off-line <-> ADL4.1 Synchronization -> DPE Assessment with Matched ECMWF/Dedicated RAOBs
Focus Days 05/15/2012; 09/20/2012; PMRF RAOBs

Stage 1, Stage 2, Stage 3 Validations (June 2013)
Dedicated RAOBs (ARM/CART)
Special Campaigns (AEROSE)
Global RAOB Network
Focus Day Data Sets

AVTP Product Example: 500 hPa Temp
May 15, 2012

AVMP Product Shown as Total Precipitable Water
May 15, 2012
Evaluation Scheme Implemented

1. **Global evaluation of CrIMSS EDR products (STAR)**
   - Focus Day matches of correlative data sets
     - 05/15/2012, 09/20/2012, 02/03/2013, 03/12/2013
     - with ECMWF model/forecast analysis fields
     - Aqua-AIRS EDR products

2. **Global RAOB collocations (STAR)**
   - Typically ~300 co-located matches for a given day (± 3 hours, 100 km radius)
   - Representative highly sampled geographic locations (RAOBs predominant in NH-Midlatitudes) and the instrument types used in the RAOB Ascents
   - Many Sources (STAR-AIRS/IASI Testbed -> NPROVS, NG Sounder SDR/RAOB matchup PGEs on NSIPS, NCEP/PREPBUFR)

3. **GPS Radio occultation profiles from the COSMIC Network (SSEC, Bob Knuteson)**
   - 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**
   - ARM/CART Sites (Dave Tobin, SSEC)
   - Campaigns of Opportunity (AEROSE, Nick Nallli)
   - Aerospace PMRF RAOBs (Andrew Mollner)
   - Some of these data sets have been acquired and currently undergoing analysis to generate best estimates as was done by David Tobin for the AIRS Validations
### Focus Day Correlative Data Sets

**For CrIMSS EDR Evaluation**

<table>
<thead>
<tr>
<th>Focus Days</th>
<th>IDPS versions</th>
<th>Off-line Emulations</th>
<th>Correlative Data Sets</th>
</tr>
</thead>
</table>
| 05-15-2012      | MX5.3         | MX5.3, MX6.3, MX7.1, MX8.1 (upcoming)| ECMWF/GFS (NOAA-STAR)  
Aqua-AIRS V6 SDR/EDRs (JPL- NASA)  
IASI SDR/EDR Products (NOAA-STAR)  
NUCAPS SDR/EDR Products (NOAA-STAR)  
GPSRO Measurements (SSEC: Bob Knuteson) |
| 09-20-2012      | MX5.3         | MX5.3, MX6.3, MX7.1, MX8.1 (upcoming)| NPROVS  
Other sources: NCEP/PREPBUFR STAR-Matchups |
| 02-03-2013      | MX6.3         | MX5.3, MX6.3, MX7.1, MX8.1 (upcoming)| NPROVS  
Other sources: NCEP/PREPBUFR STAR-Matchups |
| 03-12-2013      | MX6.6         | MX5.3, MX6.3, MX7.1, MX8.1 (upcoming)| NPROVS  
Other sources: NCEP/PREPBUFR STAR-Matchups |
| Global RAOB Matches | MX6.3, MX6.6 | MX5.3, MX6.3, MX7.1, MX8.1 (upcoming)| NPROVS  
Other sources: NCEP/PREPBUFR STAR-Matchups |
| Dedicated RAOB Ascents | MX5.3, MX6.3 | MX5.3, MX6.3, MX7.1, MX8.1 (upcoming)| • Aerospace PMRF RAOBs Kauai, Hawaii, May-Sept, 2012 (Andrew Mollner)  
• ARM/CART Dedicated RAOBs (Lori Borg, Dave Tobin)  
• Special Campaigns of Opportunity (Nick Nalli) |

CrIMSS SDRs/EDRs for these focus days are available on STAR FTP Site

**Contact:** Changyi.Tan@noaa.gov and Murty.Divakarla@noaa.gov,
Realization of IDPS MX7.1

Series of ‘CrIMSS’ Algorithm telecons between STAR, NGAS, and LaRC from ‘pre-launch proxy’ era to ‘present time’.

-- Discussed results of investigations and fixes among all cal/val groups.

-- Decided which changes should become MX7.1.

Offline CrIMSS EDR, ADL, and G-ADA were all used synergistically to mimic current IDPS operations and generate code change requests (CCRs) and Algorithm Change Packages (ACPs) to realize MX7.1 Operational implementation (June 2013)

Degui Gu, Xia L Ma, and Denise Hagan, Northrop Grumman Aerospace Systems
Xu Liu and Susan Kizer, Langley Research Center
Murty Divakarla, Mike Wilson, C.D. Barnet, Xiaozhen Xiong and Changyi Tan, Flavio Iturbide, STAR, NOAA/NESDIS
Wael Ibrahim, Richard Cember, Raytheon

<table>
<thead>
<tr>
<th>MX6.3 Emulation (Operated Until Oct. 2012)</th>
<th>MX6.6 Emulation (Currently in Operations)</th>
</tr>
</thead>
<tbody>
<tr>
<td>New Climatology, Microwave Bias, and IR Bias LUTs</td>
<td>Fix indexing for non-LTE and ozone cases.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>MX7.1 Emulation (Expected OPS, June 2013)</th>
<th>Other Variations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fix bug to add RTM error to total radiance error.</td>
<td>Fix surface pressure in IDPS product.</td>
</tr>
<tr>
<td>Fix a bug that calls partly cloudy skies clear in fovsel.f</td>
<td>Turn off climatology stratification.</td>
</tr>
<tr>
<td>Loosen a constraint between skin temperature and air temperature for daytime land.</td>
<td>Alternative LUTs (IR-ATM-NOISE-LUT, IR-NOISE-LUT).</td>
</tr>
<tr>
<td>Change threshold for warm ocean vs. cold ocean.</td>
<td>Multiply devnoise by 1.8.</td>
</tr>
<tr>
<td>Loosen microwave chiq requirement for combined retrieval from 2 to 4.</td>
<td>Modifications to clear/partly cloudy/cloudy skies.</td>
</tr>
<tr>
<td>New IR-NOISE-LUT and New IR-ATM-NOISE-LUT</td>
<td></td>
</tr>
</tbody>
</table>
Yields for Three Versions of CrIMSS EDRs

<table>
<thead>
<tr>
<th>MX Version</th>
<th>Date</th>
<th>Combined Yield Percentage</th>
<th>MW-Only Percentage</th>
<th>Poor Yield</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MX5.3</td>
<td>May 15, 2012</td>
<td>4.76%</td>
<td>66.34%</td>
<td>28.90%</td>
</tr>
<tr>
<td></td>
<td>Sept. 20, 2012</td>
<td>4.15%</td>
<td>70.72%</td>
<td>25.14%</td>
</tr>
<tr>
<td></td>
<td>Feb. 3, 2013</td>
<td>3.37%</td>
<td>61.72%</td>
<td>34.91%</td>
</tr>
<tr>
<td></td>
<td>Mar 12, 2013</td>
<td>3.74%</td>
<td>61.89%</td>
<td>34.37%</td>
</tr>
<tr>
<td>MX6.3</td>
<td>May 15, 2012</td>
<td>22.09%</td>
<td>66.47%</td>
<td>11.44%</td>
</tr>
<tr>
<td></td>
<td>Sept. 20, 2012</td>
<td>20.17%</td>
<td>68.23%</td>
<td>11.60%</td>
</tr>
<tr>
<td></td>
<td>Feb. 3, 2013</td>
<td>19.86%</td>
<td>65.21%</td>
<td>14.94%</td>
</tr>
<tr>
<td></td>
<td>Mar 12, 2013</td>
<td>20.73%</td>
<td>65.91%</td>
<td>13.37%</td>
</tr>
<tr>
<td>MX7.1</td>
<td>May 15, 2012</td>
<td>47.36%</td>
<td>43.47%</td>
<td>9.17%</td>
</tr>
<tr>
<td></td>
<td>Sept. 20, 2012</td>
<td>47.62%</td>
<td>43.56%</td>
<td>8.82%</td>
</tr>
<tr>
<td></td>
<td>Feb. 3, 2013</td>
<td>47.73%</td>
<td>40.22%</td>
<td>12.05%</td>
</tr>
<tr>
<td></td>
<td>Mar 12, 2013</td>
<td>49.41%</td>
<td>39.84%</td>
<td>10.75%</td>
</tr>
</tbody>
</table>

- CrIMSS EDR algorithm reports 2\textsuperscript{nd} stage ‘IR+MW’ retrieval as the final product.
- If the 2\textsuperscript{nd} Stage fails to produce a better EDR Product, the 1\textsuperscript{st} MW-only Product is reported as final product.
- MX7.1 (IR+MW) yield and results of evaluations with ECMWF for different focus-day are very similar. Results presented in next set of slides are for the focus-day: 05/15/2012
CrIMSS EDRs - MW-only (1st Stage), IR+MW (2nd Stage), Aqua-AIRS Retrievals, and ECMWF Matches

- AVTP (850 hPa-surface) 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)

\( T(p) \text{ RET:25 478.0–535.2 hPa 2012/05/15 DESC CL2002_UPD} \)
CrIMSS Combined ‘IR+MW’ AVTP, AVMP RMS Differences wrt ECMWF
MX 5.3 (Day1), MX 6.3 (Present) and MX 7.1 (June 2013)
Data: Global (Focus Day: 05/15/2012)

CrIMSS MX7.1, MX6.3, MX5.3,

IDPS MX5.3 vs. ECMWF (05/15/2012)

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

Global ALL
N=318,600

T(p) RMS (K)

q(p) RMS (%)
CrIMSS Combined ‘IR+MW’ AVTP, AVMP MX7.1 RMS Differences wrt ECMWF
Global, Land, Sea, Coast, ALL (05/15/2012)

CrIMSS IR+MW
MX7.1

Global ALL
N=318,000
Yield:
ALL: 47%
Land: 47%
Sea: 47%
Coast(---): 43%

Difficulties over land cases are causing CrIMSS Global EDR stats exceeding the requirements at sfc-700 hPa (Improvements Planned are in Summary)
MX7.1 T(p), q(p) RMS Differences wrt ECMWF
Tropics, Midlat, Polar, Global

Global ALL
N=318,000
Yield:
ALL: 47%
Tropics: 55%
Midlat: 46%
Polar: 41%

Difficulties over polar regions are affecting Global EDR stats
(see Improvements Planned in Summary)
**Global, Combined IR+MW, MW-Only**

**MX7.1 AVTP and AVMP RMS Differences wrt ECMWF**

Global ALL

N=318,000

Yield:

IR+MW: 47%

MW-only: 42%

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**CrIMSS IR+MW**

**CrIMSS MW-only**

**MX7.1**
MX7.1 AVTP and AVMP Biases wrt ECMWF
Global, Combined IR+MW, MW-Only

CrIMSS MX7.1, Combined IR+MW

<table>
<thead>
<tr>
<th>Pressure (hPa)</th>
<th>T(p) Bias (K)</th>
<th>q(p) Bias (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>475/318600</td>
<td>0.184 0.117 -0.168 -0.56</td>
<td>0.087 -0.184 0.080 0.340</td>
</tr>
<tr>
<td>425/318600</td>
<td>0.117 -0.168 -0.56</td>
<td>0.080 0.340</td>
</tr>
</tbody>
</table>

CrIMSS IR+MW
CrIMSS MW-only
MX7.1

Global ALL
N=318,000
Yield:
IR+MW: 47%
MW-only: 42%
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

N= 5,538
AIRS: 5% dashed
CrIMSS solid
Crimss vs. ECMWF; AIRS V6 vs. ECMWF
Using Matched AIRS-V6 and CrIMSS EDRs
Matched EDRs - Cloud-Cleared: Global Ocean and Ocean ±Lat60

T(p) RMS (K)

T(p) Bias

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
Comparison of CrIMSS AVTP bias and RMS difference relative coincident ECMWF and COSMIC GPS radio occultation data for the focus day 05/15/2012. The bias trend with altitudes observed between CrIMSS and COSMIC, and between the CrIMSS and ECMWF for the focus day complement each other thus making this data set viable source of independent verification. Evaluations with longer validation time period is in progress.
Identified and Tested Fixes - CrIMSS EDR Precipitation Flag
Expected to be in Operations November 2013
Slide Courtesy: Ralph Ferrao and Wenze Yang (AMS-2013)

(a) Current Precip Flag (05/15)
(b) Improved Precip Flag (05/15)

Improvements to CrIMSS EDR algorithm - Precipitation Flag. (a) Precipitation detection flag as depicted from the current CrIMSS EDR algorithm. (b) Updated precipitation flag using MSPPS ‘Day-2’ like algorithm. The updated algorithm shows increased rain occurrences in the ITCZ, and much more rain over land and compares well with MIRS and other MW-only systems.
## Intensive Cal/Val Dedicated RAOB Campaign(s)

More Details:
Lori Borg, Dave Tobin et al., Status of ARM Best Estimate:

<table>
<thead>
<tr>
<th>Location</th>
<th>Manus Island, Papua New Guinea</th>
<th>Ponca City, Oklahoma, USA</th>
<th>Barrow, Alaska, USA</th>
<th>Kauai, Hawaii, USA</th>
<th>Beltsville, Maryland, USA</th>
<th>Tropical North Atlantic Ocean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regime</td>
<td>Tropical Pacific Warm Pool, Island</td>
<td>Midlatitude Continent, Rural</td>
<td>Polar Continent</td>
<td>Tropical Pacific, Island</td>
<td>Midlatitude Continent, Urban</td>
<td>Tropical Atlantic, Ship</td>
</tr>
<tr>
<td>Planned $N$</td>
<td>90</td>
<td>180</td>
<td>180</td>
<td>40</td>
<td>—</td>
<td>≈ 60–120</td>
</tr>
<tr>
<td>Launched $n_1$</td>
<td>82</td>
<td>100</td>
<td>93</td>
<td>40</td>
<td>23</td>
<td>69</td>
</tr>
<tr>
<td>Launched $n_2$</td>
<td>—</td>
<td>96</td>
<td>90</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

### NPP CrIMSS EDR ICV Dedicated RAOB Sites

[Map of Dedicated RAOB Sites]
The Aerospace RAOB (Kauai, 22.05N, 159.78W, Hawaii)
Dedicated RAOB, ECMWF, CrIMSS Versions (MX5.3, MX6.3, MX7.0)
• The 1st stage MW-only retrievals get affected by the land fraction (ATMS surface sensitive channels), and the retrievals may not represent a ‘sea-only’ CrIMSS EDR as we anticipate.

• The Aerospace Corporation (POI: Andrew Mollner) supported launching of 40 RS-92 from the Pacific Missile Range Facility (PMRF), Barking Sands, Hawaii during May-September 2012. We are currently evaluating CrIMSS EDRs vs. matched RAOBs.
The AIRS/IASI Validation Testbed
Using Global RAOB/ECMWF/GFS Matchups → S-NPP
Divakara et. al., JGR-2006; 2008; HISE-2011a,b

NOAA STAR In-house Capability with Reprocessing Options
Adaptable to S-NPP Validations with Global RAOBs from NPROVS and other Sources
NOAA Products Validation System (NPROVS)

Contact: Tony.Reale@noaa.gov (JTECH, 2011)

Centralized Radiosonde and Collocation Processing

6-hour

NASA-EOS-Aqua AIRS

COSMIC (UCAR)

DMSP F-16 MIRS

NOAA-18: ATOVS MIRS

NOAA-19: ATOVS MIRS

GRAVITE / IPO

NPP EDR PROXY

(dropsonde) Radiosonde NWP

GOES (12,13 ...R)

MetOp: ATOVS MIRS IASI (NOAA) IASI (EU)

Collocated radiosonde and multiple satellite products dataset

April 2008 ...

Single Closest
MX7.1 to MX8 (in Operations – Nov. 2013)
Pathway Beyond MX8

• MX7.1 to MX8 Changes include the following:
  • DR 3193: Fixes a small error in the noise threshold. This is used to determine whether a scene is variable enough for cloud clearing.
  • DR 7116: The noise amplification factor is reported as fill when it is not used.
  • DR 7119: Makes definitions of clear, partly cloudy, and cloudy consistent with the ATBD.
  • DR 7197: Fixes a bug in the quality flags for overcast skies and failed 2nd-stage runs.

• MX8 and Beyond – On-Going Improvements with Off-line EDR algorithm for implementation into Operations
  – New surface emissivity maps will improve the first guess.
  – Additional hinge points will improve resolution in ozone-sensitive spectra
  – A new, improved precipitation algorithm will replace the primitive model in the EDR.
  – Fixes for overcast skies will remove unrealistic ozone profiles (currently flagged as bad, but should not be present at all).
Summary

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 (reminder 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.

5. The precipitation detection routines in the current operational version have issues with false positives and false negatives. Analysis performed with improved precipitation detection are expected to produce improved EDR performance.

6. Further improvements planned for various LUTs such as ATMS and CrIS bias corrections, emissivity improvements for the MW and IR land surface are expected to produce better EDR performance. Details on planned improvements and Discrepancy Report Discussions are available on STAR Website under CrIMSS EDR Algorithm Telecons.

7. Focus-Day SDR/EDR products are available on NOAA/STAR FTP site

8. The CrIMSS EDR team will be happy to select any future focus-day in concurrence with AIRS Science Team for inter-comparison of Aqua-AIRS V6 and CrIMSS EDR evaluations using a common ensemble of matched EDR products, ECMWF and other truth data sets.

9. Questions/Comments/Queries – Email To: Murty.Divakarla@noaa.gov
CrIMSS EDR Algorithm Evaluations, Improvements and Validation Plans
Series of Telecon Presentations on STAR FTP Site

- Emissivity Databases (SSEC, LaRC)
- CrIMSS Planned Improvements
- Status of ARM Best Estimate Product (Lori Borg et al.)
Backup Slides

• Thank You for your Attention