The CrIS, IASI, and AIRS: A Perspective on Hyper Spectral Sounder Retrievals and Validation

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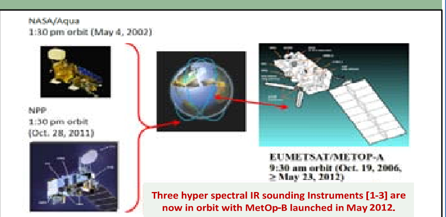
Abstract

The Cross-Track Infrared Sounder (CrIS), the Infrared Atmospheric Sounding Interferometer (IASI), and the Atmospheric Infrared Sounder (AIRS), on-board Suomi-NPP, MetOp, and Aqua respectively, provide high quality hyper-spectral infrared radiances to retrieve vertical profiles of temperature, moisture, trace gases, and other geophysical products. These infrared sounders are accompanied by microwave sounding instruments (ATMS for CrIS; AMSU-A and MHS for IASI; AMSU-A for AIRS), which enable the generation of these products in scenes with up to 80% cloud cover. The center for Satellite Applications and Research (STAR) at NOAA has been involved in the development and implementation of a variety of retrieval algorithms to process these instrument observations into sensor data records (SDRs) and geophysical products (Environmental Data Records, or EDRs). These EDR products are evaluated using in-situ measurements, model forecast analysis fields, and other correlative measurements to ensure products meet specifications. These validations also provide confidence on cloud-cleared radiances for future NWP assimilations and in the generation of climate-quality data sets. Evaluation of various retrieval algorithms against a common dataset also helps to optimize these algorithms for future product generation.

1. Hyper-Spectral Infrared (IR) Obs. from Polar Orbiting Satellites

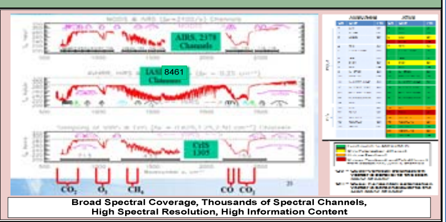
Aqua-AIRS; MetOp-IASI; S-NPP-CrIS



Three hyper spectral IR sounding Instruments [1-3] are now in orbit with MetOp-B launched in May 2012.

1.1 Hyper-Spectral IR and Accompanied Microwave (MW) Observations

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

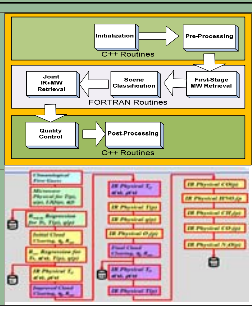


Broad Spectral Coverage, Thousands of Spectral Channels, High Spectral Resolution, High Information Content

2. Retrieval Algorithms to Generate EDR Products

CrIMSS EDR Algorithm [4, 5] (AER/NGAS/Raytheon/LaRC)

NOAA-AIRS/IASI/CrIS Heritage Algorithm [6]

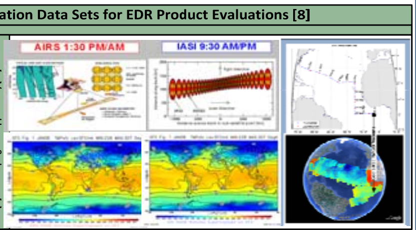


- Simultaneous Retrieval of T(p), q(p), O3(p),Tskin Spectral Emissivities
- 'MW-Only' Retrieval Followed by 'IR+MW' Retrieval
- OSS-RTM
- Use of EOFs to Characterize and Measure Retrieved Parameters

- Developed During the Aqua Mission [6]
- Expanded to Retrieve EDRs from IASI/AMUS-A/MHS SDRs - T(p), q(p), O3(p), and other trace gas products [7]
- 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.

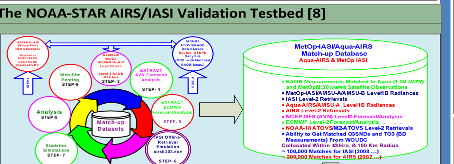
3. Validation Data Sets for EDR Product Evaluations [8]

The validation data sets include Focus-Day data Sets (ECMWF, NCEP-GFS Analysis Fields); global RAOB Collocations [8], dedicated RAOBs from ARM/CART Sites [9] and campaigns of opportunity [10].

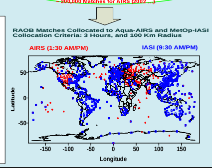


3.1 The NOAA-STAR AIRS/IASI Validation Testbed [8]

A Prototype planned to adapt for CrIMSS EDR versions (MX5.3, MX6.6, MX7.1) [5] and NOAA Unique CrIS/ATMS (NUCAPS) [7] retrieval validations

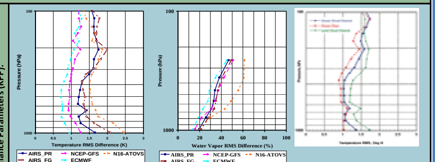

IASI/AMSU-A/B (Binary Files) from Operations
Matched to FIXED RAOB LOCATIONS (0,6,12,18 GMT)
STEP 1
Generate MetOp IASI/AMSU-A/B Level1B and Level-2 RAOB Matches
STEP- 3
IASI-M2 ATOVS/RAOB Down-Loads
Source: OSDPD Daily File (OBS. with Matched RAOB Meas.)
STEP 2
Web-Site Posting
STEP-9
EXTRACT AVN Forecast/ Analysis
STEP- 4
Analysis
STEP-8
Match-up Datasets
EXTRACT ECMWF Forecast/Analysis
STEP- 5
Statistics Simstat.exe
STEP- 7
IASI Offline-Retrieval Emulation airsb103.exe
STEP- 6
MetOp-IASI/Aqua-AIRS Match-up Database
Aqua-AIRS & MetOp IASI
RAOB Measurements Matched to Aqua (1:30 AM/PM) and MetOp(9:30 AM/PM) Satellite Observations
MetOp-IASI/AMSU-A/AMSU-B Level1B Radiances
IASI Level-2 Retrievals
Aqua-AIRS/AMSU-A Level1B Radiances
AIRS Level-2 Retrievals
NCEP-GFS (AVN) Level2-Forecast/Analysis
ECMWF Level-2 Forecast/Analysis
NOAA-18 ATOVS/M2-ATOVS Level-2 Retrievals
Ability to Get Matched O3SNDs and TO3 (BD Measurements) From WOUDC
Collocated Within ±3 Hrs. & 100 Km Radius
~100,000 Matches for IASI (2008 ...)
~200,000 Matches for AIRS (2002 ...)

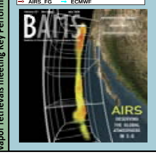
The nature of sun-synchronous Aqua/MetOp satellites with their ascending and descnding orbits crossing the equator at (1:30PM/AM), and 9:30 AM/PM, coupled with collocation criteria of ±3 hours provide matchups with skewed distributions. The Aqua-AIRS selects samples predominantly over the Europe and the West Coast of the United States. The MetOp IASI predominanty selects samples over the Eastern part of the United States, Eastern Asia as shown in the Map.



4. AIRS (V4) Validations for Key Performance Parameters [8,9,11]

The AIRS/IASI/CrIS algorithm validation Testbed and the validation data sets developed by STAR have helped to assess AIRS temperature and water vapor retrievals meeting Key Performance Parameters (KPP).





Validation of Aqua-AIRS Retrieval Products with Global Global RAOB network collocations [8,11]

Sample Size (N)=89,278; NH (90N-20N) 84% ; Tropics (23N-23S) – 8% SH (20S-90S) – 8%

Stages of Validation

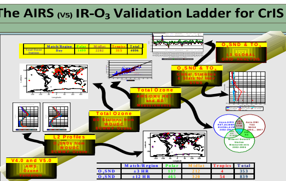
Stage 1: Product Validation performed using a small number of independent measurements obtained from selected locations and time periods and ground-truth/field program effort.

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

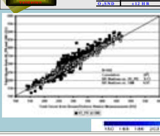
Stage 3: Product Validation performed and uncertainties were well established via independent measurements made in a systematic and statistically robust way that represents global conditions.

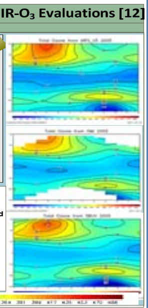
4.1. The AIRS (vs) IR-O_3 Validation Ladder for CrIS IR-O_3 Evaluations [12]

Procedures used in AIRS Ozone validations are being adapted for CrIS IR Ozone validations, and in the generation of CrIS/OMPS Blended Products



Match/Region	Polar	Midlat	Tropics	Total
±3 HR	137	212	4	353
±12 HR	465	320	54	839

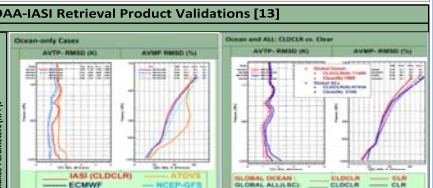


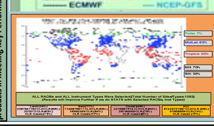


Qualitative and quantitative assessment performed for AIRS Ozone can be implemented for IASI, CrIS, and other satellite systems that have close orbital times (NASA-Aqua, NASA-Aura, NOAA Afternoon satellite series, and other A-Train satellites) and have instruments to measure ozone and other geo-physical parameters [12]

5. NOAA-IASI Retrieval Product Validations [13]

The AIRS/IASI/CrIS Algorithm validation testbed and the validation data sets developed by STAR have helped to evaluate NOAA-IASI retrieval products in meeting Key Performance Parameters (KPP).





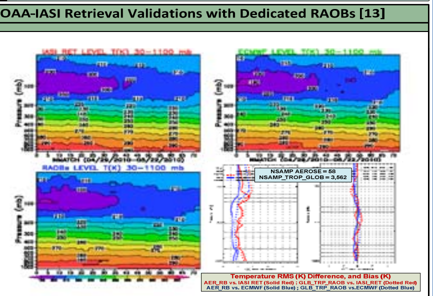
Plots of statistics for different regions and stratifications (tropics, mid-latitudes, polar; ocean, land; day and night are available at http://www.star.nesdis.noaa.gov/smcd/spb/iosspdt/iosspdt.php

We are in the process of updating the website with statistics for many years of collocations.

Details of evaluation were also presented and are available at: http://www.opticsinfobase.org/abstract.cfm?URI=HISE-2011-JWA25 [13]

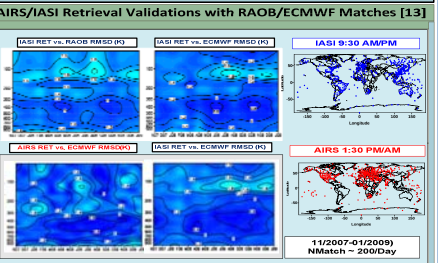
5.1 NOAA-IASI Retrieval Validations with Dedicated RAOBs [13]

NOAA- AEROSE-2010 IASI-TRET vs. ECMWF vs. AEROSE-RAOBs



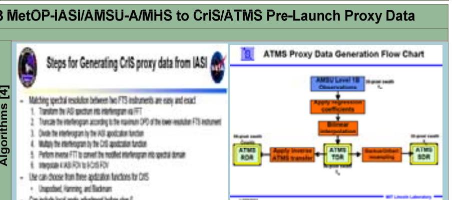
Temperature RMS (K) Difference, and Bias (K)

5.2 AIRS/IASI Retrieval Validations with RAOB/ECMWF Matches [13]



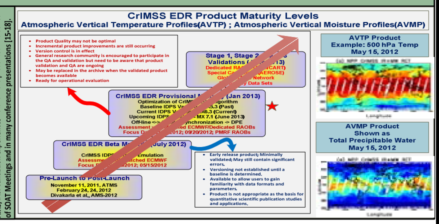
5.3 MetOP-IASI/AMSU-A/MHS to CrIS/ATMS Pre-Launch Proxy Data

Proxy Data Generation Algorithms [4]



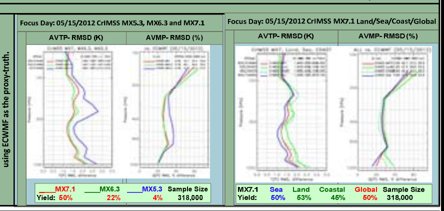
6. Suomi NPP- CrIMSS (CrIS+ATMS) Product Assessment Steps [14-18]

Plans for CrIMSS EDR product validations were initiated during S-NPP pre-launch phase [14] taking leverage from NOAA/STAR AIRS/IASI validation experience and were presented in a series of SOAT Meetings and in many conference presentations [15-18].


CrIMSS EDR Product Maturity Levels
Atmospheric Vertical Temperature Profiles(AVTP) ; Atmospheric Vertical Moisture Profiles(AVMP)
CrIMSS EDR Provisional
Stage 1, Stage 2
CrIMSS EDR Beta
Pre-Launch to Post-Launch
November 15, 2011, ATMS
February 24, 2012
Divakarla et al., AMS-2012
AVTP Product
Example: 500 hPa Temp
May 15, 2012
AVMP Product
Shown as
Total Precipitable Water
May 15, 2012

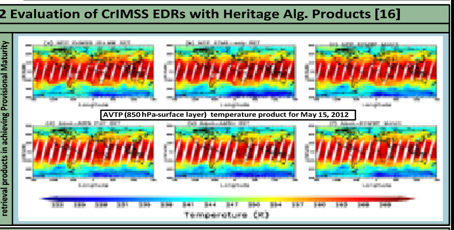
6.1 CrIMSS AVTP and AVMP Evaluations - Provisional Maturity

CrIMSS Retrieved Atmospheric Vertical Temperature and Moisture Profiles (AVTP, AVMP) were evaluated using ECMWF as the proxy-truth.



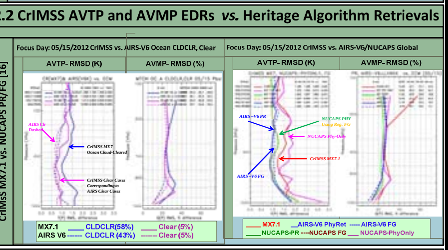
6.2 Evaluation of CrIMSS EDRs with Heritage Alg. Products [16]

CrIMSS EDR products were evaluated with Aqua-AIRS retrieval products in achieving Provisional Maturity



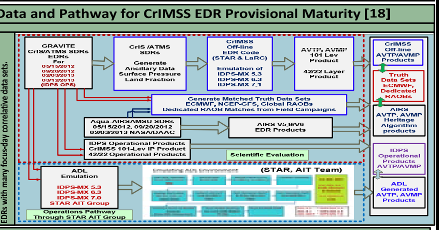
6.2.2 CrIMSS AVTP and AVMP EDRs *vs.* Heritage Algorithm Retrievals

CrIMSS MX7.1 EDRs vs. AIRS V6 PR/FG CrIMSS MX7.1 vs. NUCAPS PR/FG [16]



6.3 Data and Pathway for CrIMSS EDR Provisional Maturity [18]

The CrIMSS EDR Provisional Maturity assessment was achieved through an evaluation of CrIMSS operational EDRs with focus-day correlative data sets.


GRAVITE CrIMSS TMS SDRs EDRs For 05/15/2012 09/20/2012 02/03/2013 03/12/2013 (IDPS OPS)
CrIS /ATMS SDRs
Generate Ancillary Data Surface Pressure Land Fraction
CrIMSS Off-line EDR Code (STAR & LaRC)
Emulation of IDPS-MX 5.3 IDPS-MX 6.3 IDPS-MX 7.1
AVTP, AVMP 101 Lev Product
42/22 Layer Product
Generate Matched Truth Data Sets ECMWF, NCEP-GFS, Global RAOBs Dedicated RAOB Matches from Field Campaigns
Aqua-AIRS/AMSU SDRs 05/15/2012, 09/20/2012 02/03/2013 NASA/DAAC
AIRS V5.9/V6 EDR Products
IDPS Operational Products CrIMSS 101-Lev IP Product 42/22 Operational Products
Scientific Evaluation
ADL Emulation
IDPS-MX 5.3
IDPS-MX 6.3
IDPS-MX 7.0
STAR AIT Group
(STAR, AIT Team)
Operations Pathway Through STAR AIT Group
CrIMSS Off-line AVTP/AVMP Products
Truth Data Sets ECMWF, Dedicated RAOBs
AIRS AVTP, AVMP Heritage Algorithm products
IDPS Operational Products AVTP/AVMP
ADL Generated AVTP, AVMP Products

Summary

- NOAA/STAR has been involved with hyper-spectral retrieval algorithm development and validation starting with Aqua-AIRS, MetOp-IASI, and continuing with S-NPP CrIMSS.
- The experience gained through the development of AIRS and IASI validation testbed systems has helped to
  - Evaluate CrIMSS EDR products with 'truth' data sets and 'heritage' algorithm products leading to Beta Maturity and Provisional Maturity.
  - Define a Pathway for IDPS operational implementations through Discrepancy Reports and Code Change Requests to realize MX7.1, and future builds.
  - Provide correlative data sets to evaluate CrIMSS EDR products from "pre-launch proxy" to "post-launch".
  - Coordinate CrIMSS EDR algorithm improvements beyond Provisional Maturity through research in collaboration with NASA-LaRC, NGAS, and Raytheon.
  - Define a hierarchy of validation data sets to evaluate CrIMSS retrieval products leading to Provisional Maturity and moving towards Stage 1-3 validations.

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