NOAA Unique CrIS ATMS Processing System and Validation

Quanhua (Mark) Liu, Tony Reale, (Soundings EDR)
Chris Barnet,Antonia Gambacorta,Nick Nalli,
Xiaozhen Xiong,Chanyyi Tan,Flavio Iturbide-Sanchez,
Ralph Ferraro,Walter Wolf, and Mitch Goldberg

STAR/JPSS Annual Science Meeting
May 13, 2014

Outline

- Overview
  - Sounding product users and applications
  - Requirements
  - Teams
- NUCAPS Product Status
- NUCAPS Product Validation
  - Global products
  - Global validation against radiosondes
  - NUCAPS product validation during AERONET expedition
- Future Plans
- Summary

Sounding Product Users and Applications

- CLASS
- AWIPS-II
- FNMOC – Fleet Numerical Meteorology and Oceanography Center
- Nowcasting
- Direct broadcast
- Support SDR data monitoring, retrieval products and SDR have the same time, the same location, and the same footprint.
- Timely temperature and moisture profiles for the warning of severe weather (Mark DeMaria) , e.g. atmospheric stability condition for tropical storm. For tornado warning, retrieval products of higher spatial resolution (~ 10 km) is needed.
- Carbon products for climate studies
- Air quality monitoring: Trace gas CO, HNO_3, O_3, SO_2 profiling, a flag indicating the presence of dust and volcanic emissions.
- Trace gas product for NWP radiance assimilation on temperature, water vapor, and ozone.

JPSS Program Level-1 Requirements, v2.9, 6/27/2013

AVTP Applicable Conditions: 1. All Scenes (cloud-free, partly cloudy, cloudy)	
a. Horizontal Cell Size	
1. Nadir	50 km (1)
b. Vertical Reporting Interval	
1. Surface to 850 mb	20 mb
2. 850 mb to 300 mb	50 mb
3. 300 mb to 100 mb	25 mb
4. 100 mb to 10 mb	20 mb
5. 10 mb to 1.0 mb	2 mb
6. 1.0 mb to 0.5 mb	0.2 mb
c. Mapping Uncertainty, 3 Sigma	5 km
d. Measurement Uncertainty - Expressed as an error in layer average temperature	
1. Cloud-Free to Partly Cloudy, Surface to 300 mb over ocean (2)	1.6 K per 1 km Layer
2. Cloud-Free to Partly Cloudy, 300 mb to 30 mb (2)	1.5 K per 3 km layer
3. Cloud-Free to Partly Cloudy, 30 mb to 1 mb (2)	1.5 K per 5 km layer
4. Cloud-Free to Partly Cloudy, 1 mb to 0.5 mb (2)	3.5 K per 5 km layer
5. Cloudy, Surface to 700 mb (3)	2.5 K per 1 km layer
6. Cloudy, 700 mb to 300 mb (3)	1.5 K per 1 km layer
7. Cloudy, 300 mb to 30 mb (3)	1.5 K per 3 km layer
8. Cloudy, 30 mb to 1 mb (3)	1.5 K per 5 km layer
9. Cloudy, 1 mb to 0.5 mb (3)	3.5 K per 5 km layer

Infrared ozone profile:
globally, day and night
From surface to 30 hPa, same requirements on precision, accuracy, and uncertainty as UV ozone-NP.

AVMP Applicable Conditions: 1. All scenes (cloud-free, partly cloudy & cloudy)	
a. Horizontal Cell Size	
1. Nadir	50 km (1)
b. Vertical Reporting Interval	
1. Surface to 850 mb	20 mb
2. 850 mb to 100 mb	50 mb
c. Mapping Uncertainty, 3 Sigma	5 km
d. Measurement Uncertainty (expressed as a percent of average mixing ratio in 2 km layers)	
1. Cloud-Free to Partly Cloudy, Surface to 600 mb (2)	Greater of 20 % or 0.2 g kg^{-1}
2. Cloud-Free to Partly Cloudy, 600 mb to 300 mb (2)	Greater of 35 % or 0.1 g kg^{-1}
3. Cloud-Free to Partly Cloudy, 300 mb to 100 mb (2)	Greater of 35 % or 0.1 g kg^{-1}
4. Cloudy, Surface to 600 mb (3)	Greater of 20 % or 0.2 g kg^{-1}
5. Cloudy, 600 mb to 400 mb (3)	Greater of 40 % or 0.1 g kg^{-1}
6. Cloudy, 400 mb to 100 mb (3)	Greater of 40 % or 0.1 g kg^{-1}

~50 km at nadir,
all 9 CrIS FOVs are used to produce one FOR sounding,

	= 0%	Free
cloudiness	> 0% and <= 50%	Partly cloudy
	> 50%	Cloudy

Refresh: at least 90% of the global every 18 hours (monthly average)

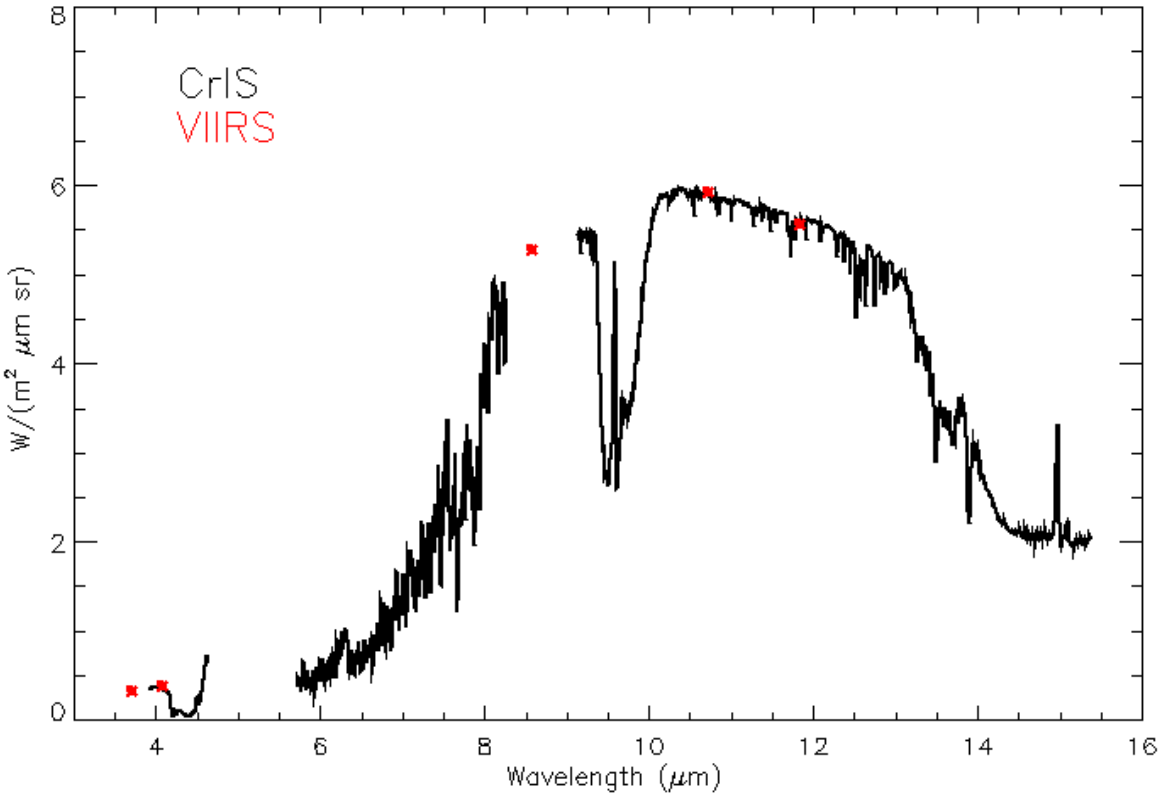
JPSS-1 Requirements

EDR Attribute	CO	CO_2	CH_4
Vertical Coverage	Total Column	Total Column	Total Column
Horizontal Resolution	100 km	100 km	100 km
Mapping Uncertainty, 3 sigma	25 km	25 km	25 km
Measurement Range	0 – 200 ppbv	300 – 500 ppmv	1100 – 2250 ppbv
Measurement Precision	35%	0.5% (2 ppmv)	1% (~20 ppbv)
Measurement Accuracy	±25%	±1% (4 ppmv)	±4% (~80 ppbv)
Refresh	24 h	24 h	24 h
Note			

Teams and Members

Lead for Activity	Organization	Task
Anthony Reale	NOAA/NESDIS/STAR	NPROVS and NPROVS+ operational RAOB comparisons
Quanhua (Mark) Liu	NOAA/NESDIS/STAR	A. Gambacorta (algorithm lead), N. Nalli (VALAR validation system), X. Xiong, C. Tan, F. Iturbide-Sanchez
Chris Barnet	STC	NOAA CrIS/ATMS EDRs in complex weather regimes
Xu Liu	NASA/LaRC	CrIS/ATMS EDR Assessment
Dave Tobin	SSEC, U. Wisconsin	ARM-RAOBS
James H. Mather	DOE Battelle Pacific Northwest National Laboratory	RAOBS, Validation

CrIS and ATMS SDR Data



SDR	Number of channels
ATMS	22, temperature/water vapor
CrIS	399 in total
window	24
temperature	87
water vapor	62
ozone	53
CO	27
N2O	24
HNO3	28
CH4	54
SO2	24
CO2	53

CrIS/ATMS SDR are used in the retrieval

NUCAPS Sounding Products Released at NOAA CLASS since April 8, 2014

- Atmospheric Vertical Temperature Profile
- Atmospheric Vertical Moisture Profile
- Infrared Ozone Profile

- (requirement: total column)
- Vertical CO Profile
- Vertical CO_2 Profile
- Vertical CH_4 Profile
- Outgoing Longwave Radiation (OLR)

- (new)
- Vertical HNO_3 Profile
- Vertical N_2O Profile
- Vertical SO_2 Profile
- A flag indicating the presence of dust and volcanic emissions
- Cloud-Cleared Radiances

- **Integrated Retrieval System for CrIS/ATMS, IASI/AMSU, and AIRS/AMSU**

NUCAPS Sounding Products Released at NOAA CLASS since April 8, 2014

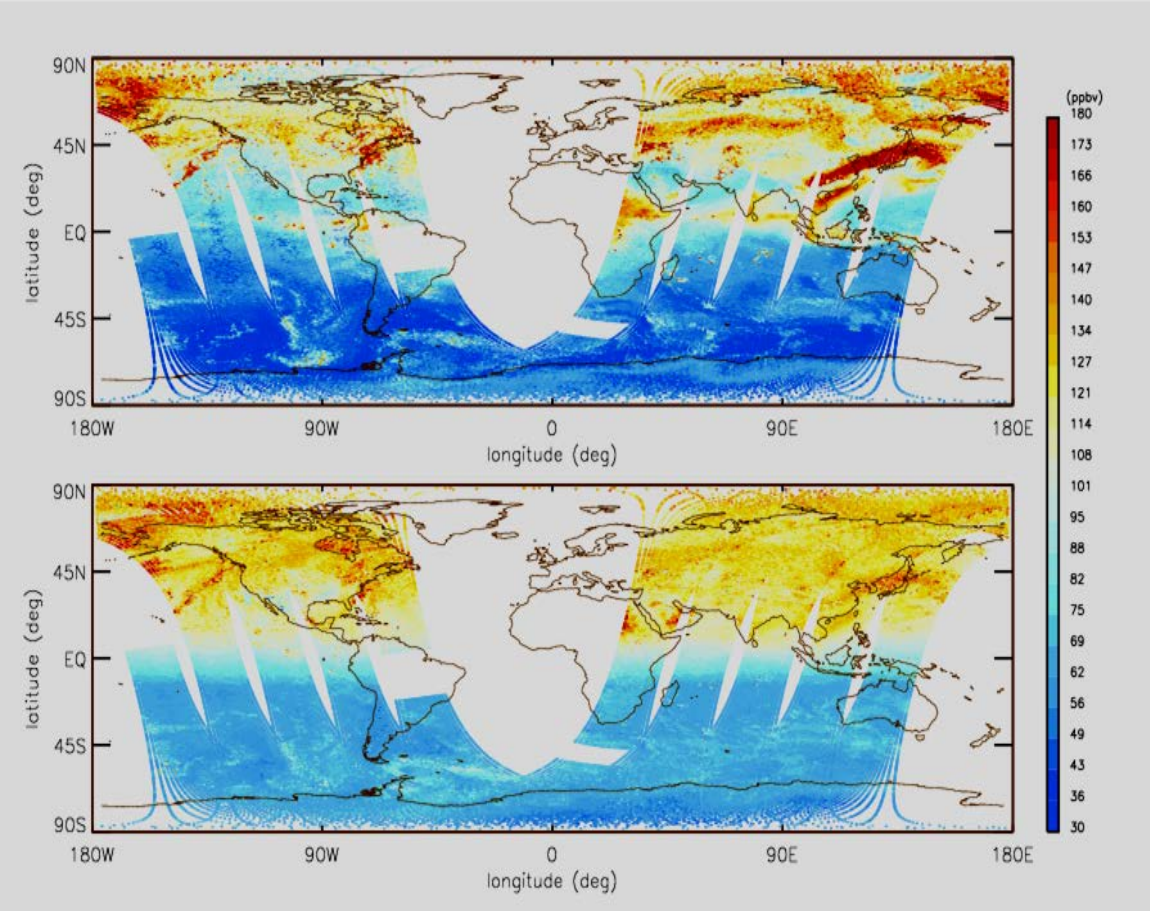
- Atmospheric Vertical Temperature Profile
- Atmospheric Vertical Moisture Profile
- Infrared Ozone Profile

- (requirement: total column)
- Vertical CO Profile
- Vertical CO_2 Profile
- Vertical CH_4 Profile
- Outgoing Longwave Radiation (OLR)

- (new)
- Vertical HNO_3 Profile
- Vertical N_2O Profile
- Vertical SO_2 Profile
- A flag indicating the presence of dust and volcanic emissions
- Cloud-Cleared Radiances

- **Integrated Retrieval System for CrIS/ATMS, IASI/AMSU, and AIRS/AMSU**

CO High Spectral Resolution vs Operational Low Resolution Results



NUCAPS CO retrieval (~450 hPa)

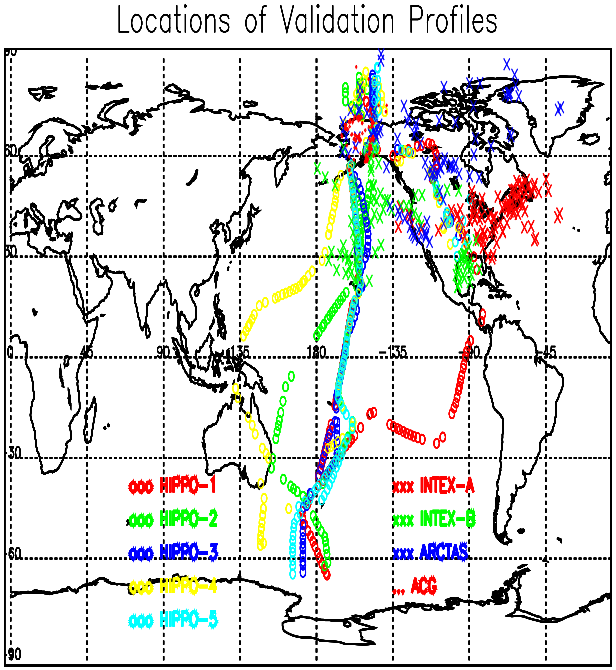
high

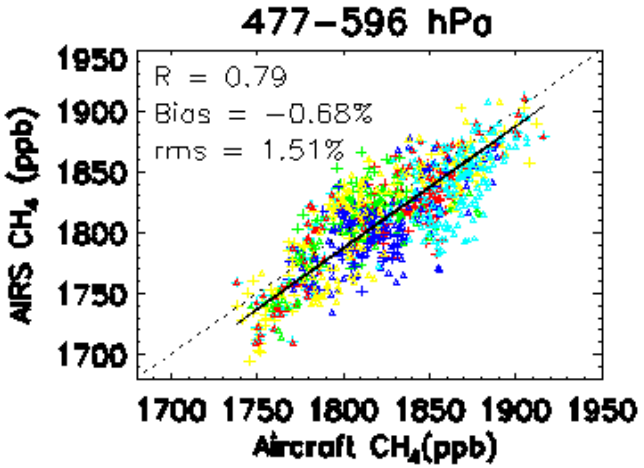
low

- The higher information content enables a larger departure from the a priori, hence the increased spatial variability observed in the high spectral resolution map (top left) compared to the low resolution (bottom left).
- A demonstration experiment in support for the need of high spectral resolution CrIS measurements.
- NUCAPS modular architecture has proven that there is no risk of disruption to the operational processing upon switching to high spectral sampling. (Ref. Gambacorta et al. 2013, IEEE Letters)

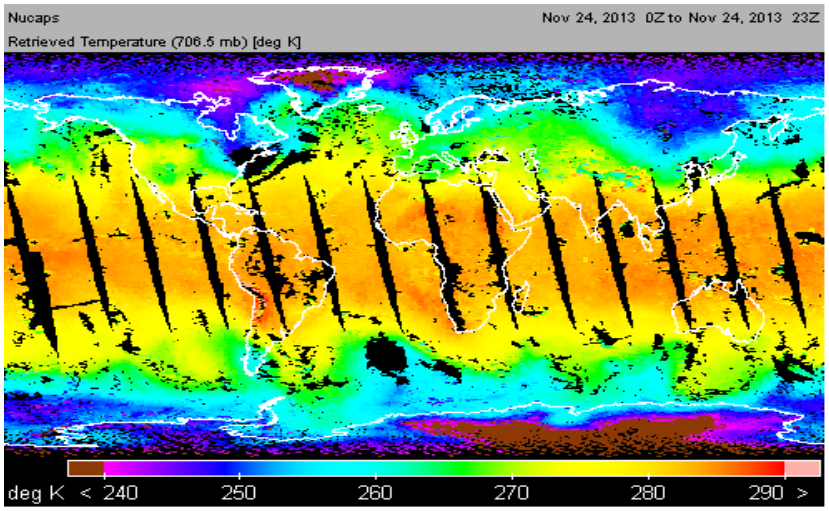
Current Status for Trace Gases

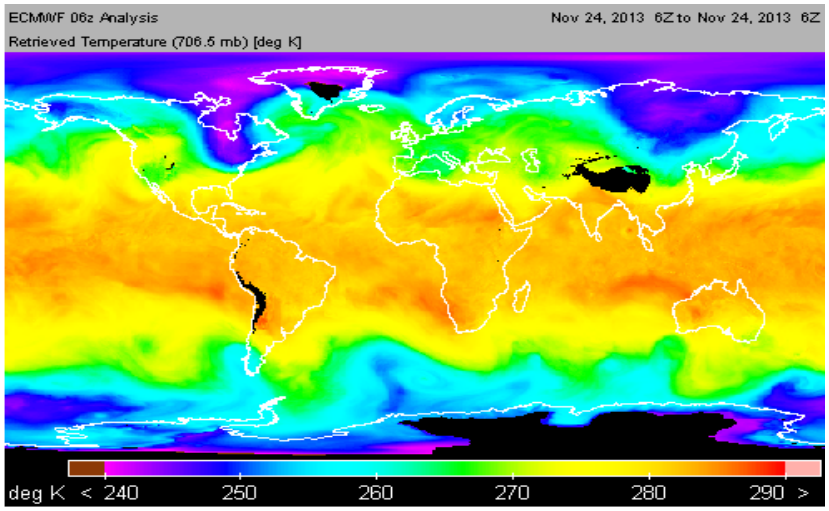
1. Started with Chris Barnet, STAR has been actively involved in CO_2, CO, CH_4, N_2O, HNO_3 and SO_2 retrievals using AIRS and IASI. Similar algorithm has been implemented in NUCAPS.
2. Dr.Xiaozhen Xiong took charge of the AIRS-v6 CH_4 product and its validation, and has published several papers (JGR,2008; ACP, 2009; Remote Sensing, 2010; JGR, 2011; GRL, 2013);
3. IASI CH_4 product has been validated with optimized QC (Xiong et al., 2013, AMT);
4. Significant improvement in N_2O retrieval using AIRS was recently made (Xiong et al, 2014, JGR, under revision).
5. Using AIRS and IASI to validate GOSAT (Japan) TIR CH_4 product since 2010 (MOU between STAR and NIES, Japan);

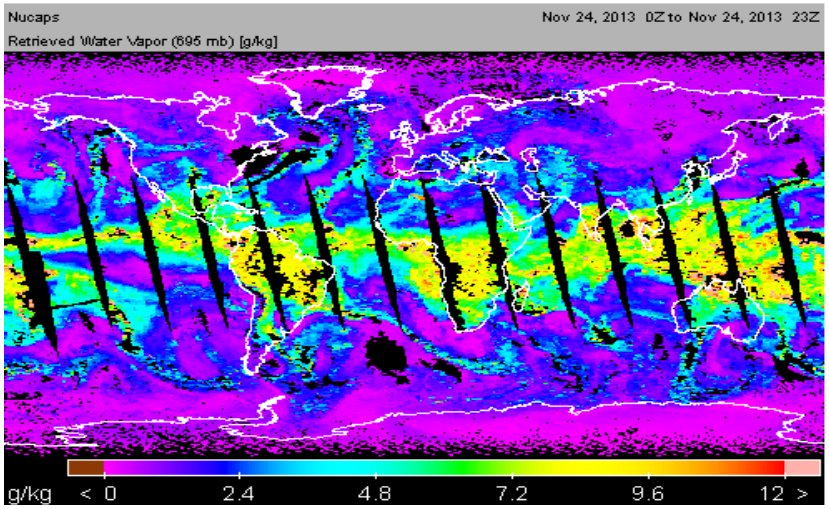


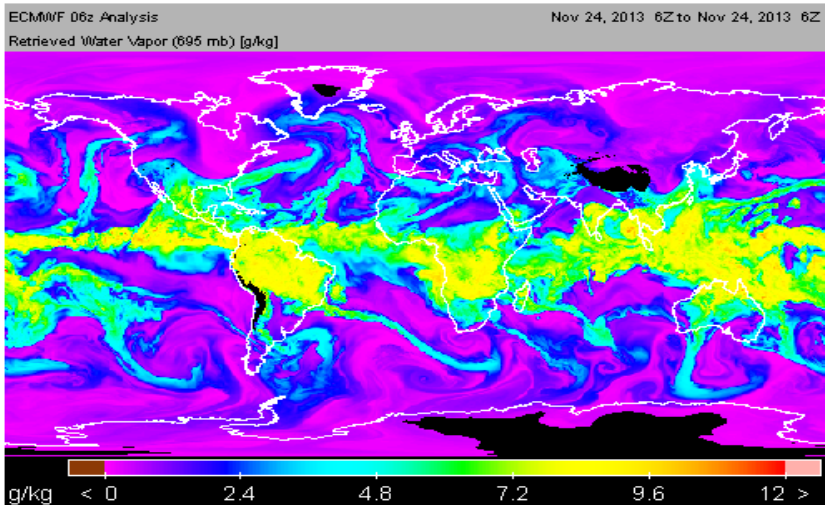


NUCAPS vs ECMWF, T and H_2O







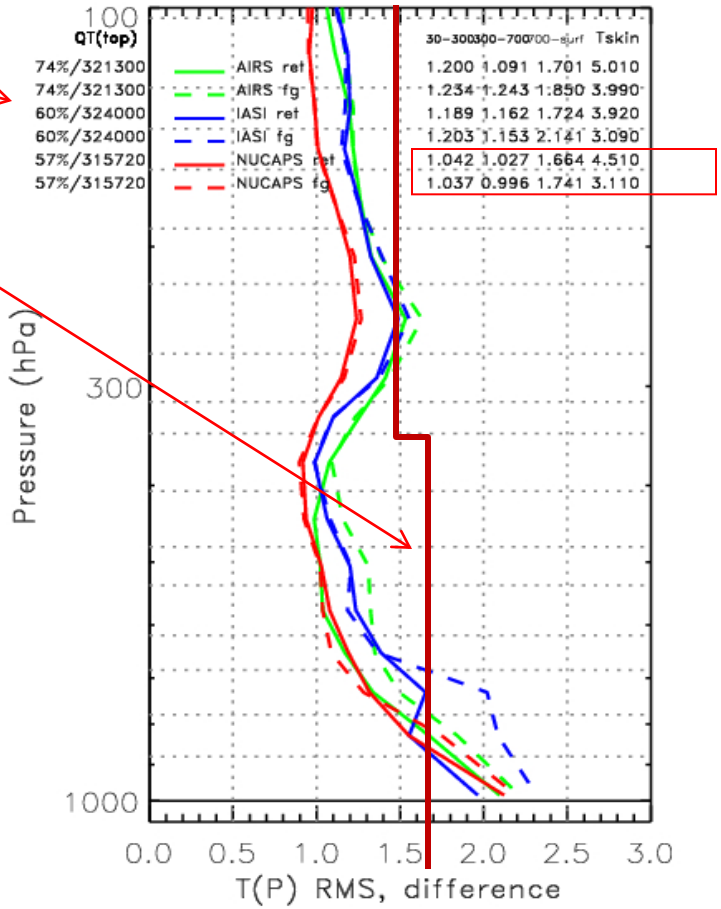


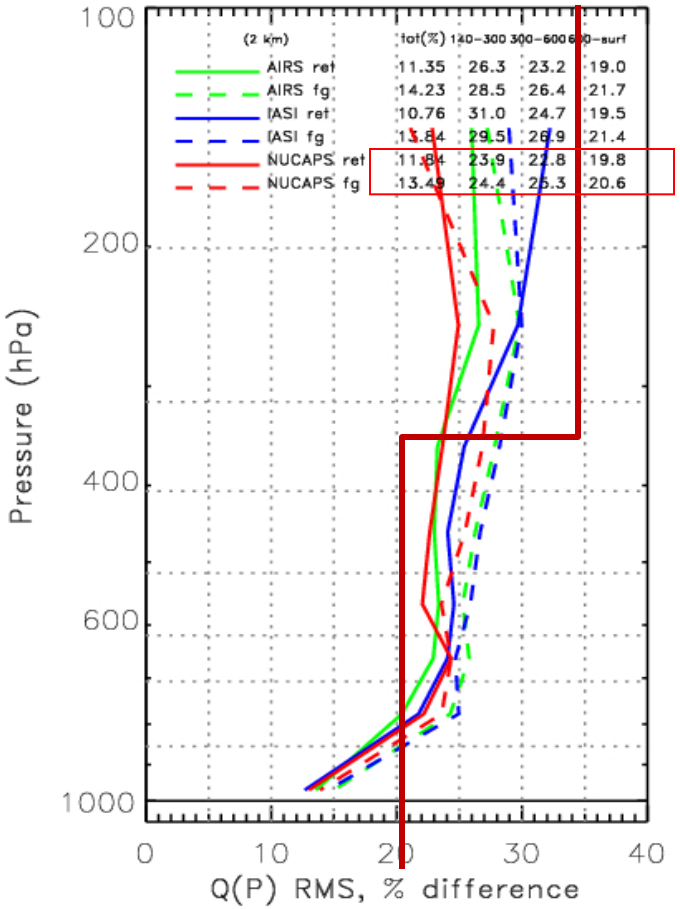
Black indicate where IR+MW and MW-only failed qc …

CrIS IASI AIRS (2012-05-15)
Global RMS Statistics vs ECMWF Analysis

QA Acceptance Yield

Vertical red bars indicate JPSS specification requirements

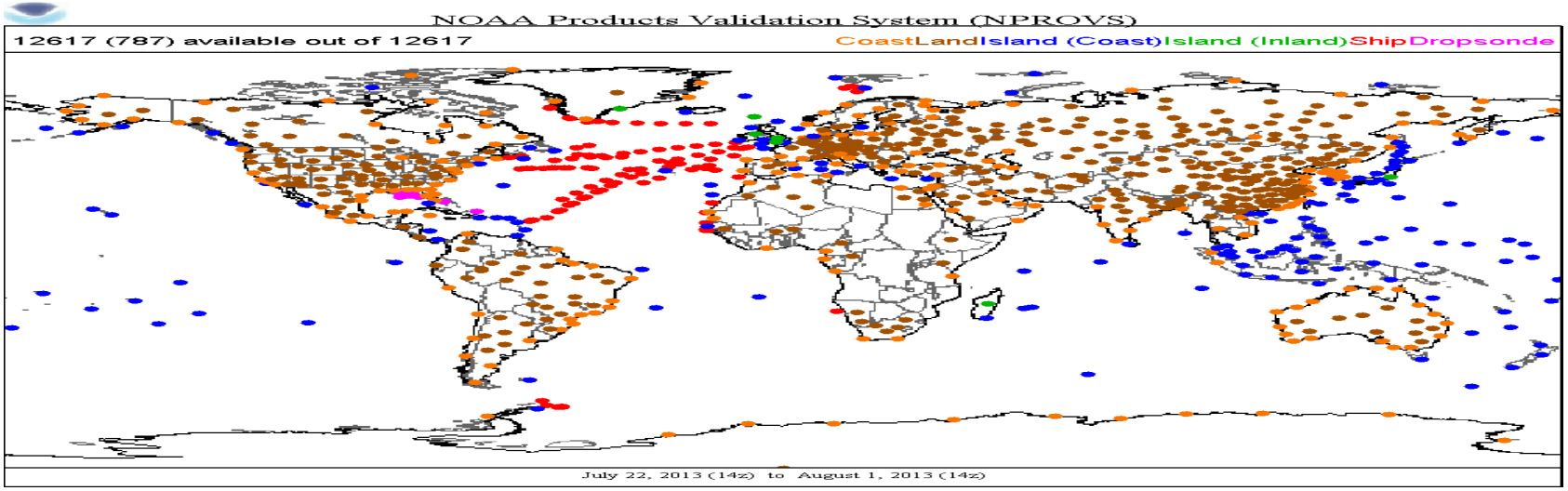




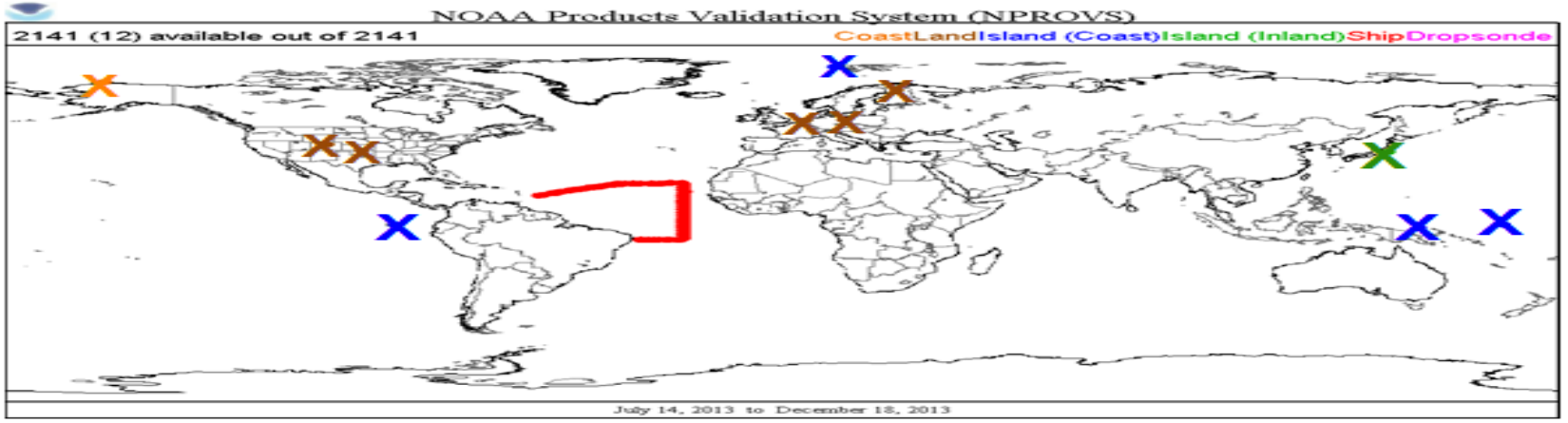
- Retrieval performance is stable and consistent across the three platforms.
- CrIS comparable to AIRS and IASI (10+ year maturity systems)
- Physical retrieval (solid) shows significant departure from first guess (dash line)

EDR Validation against RAOB

N P R O V S

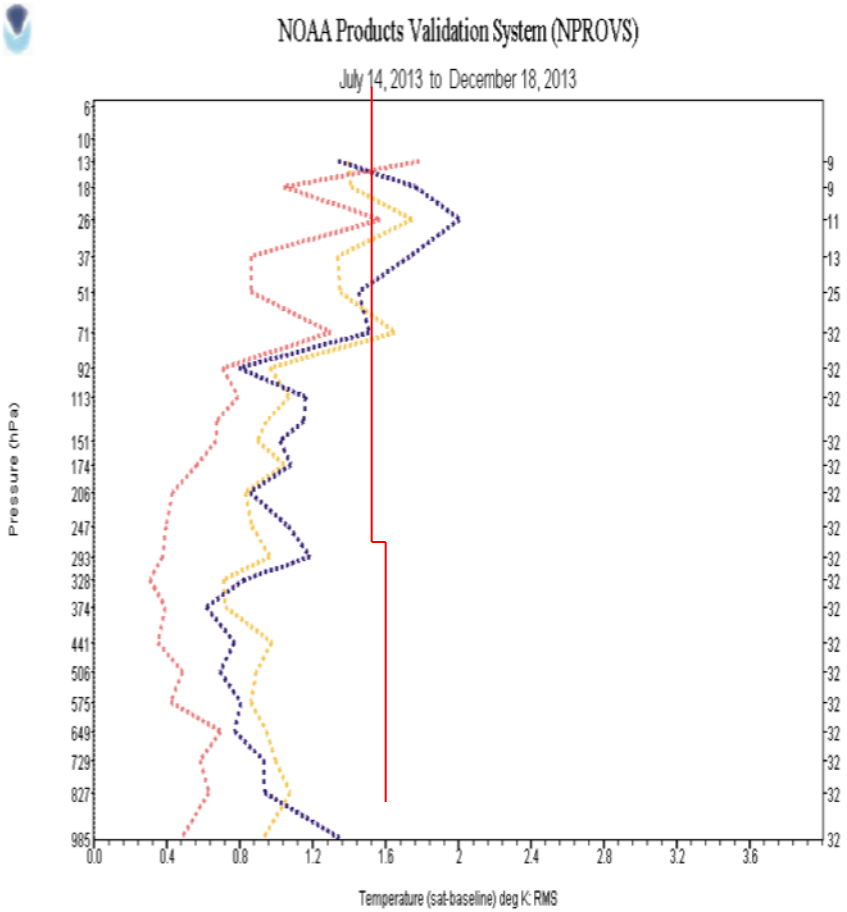


NPROVS+



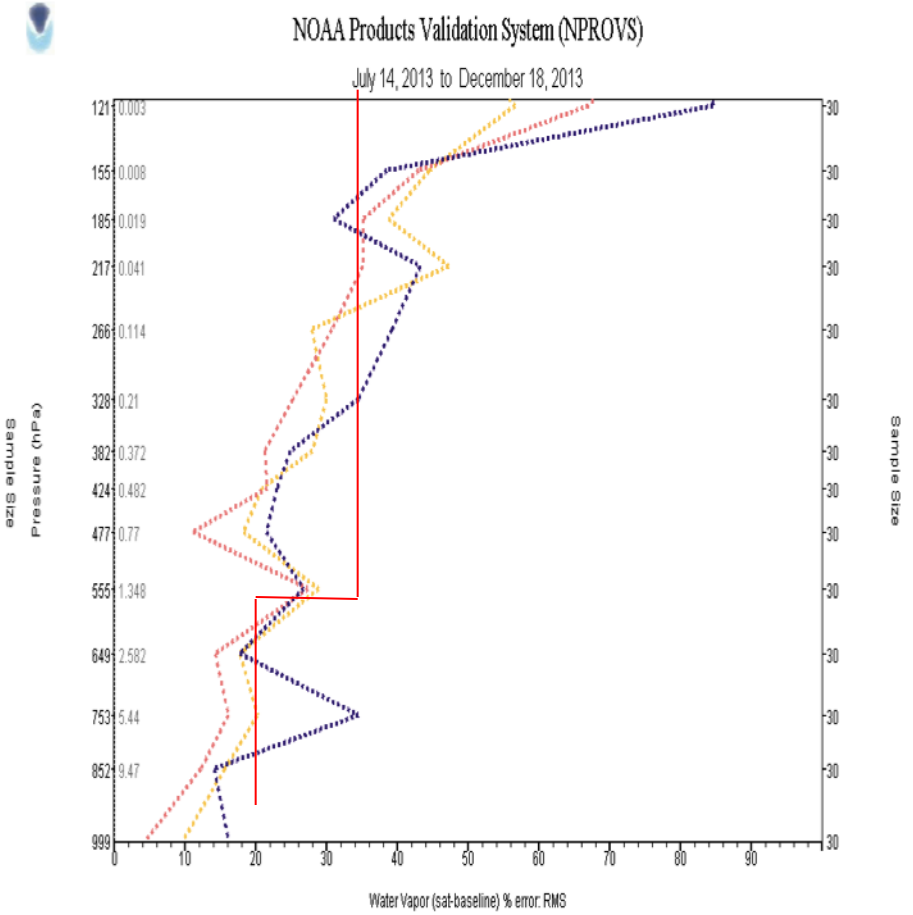
2050 collocations (350 Dedicated, 1700 GRUAN) … 5mos

NPROVS and NPROVS+ EDR Validation Results



Baseline: REFERENCE SONDE GRUAN RAOB

CRIMSS NPP Infrared (IP) ECMWF ANALYSIS NUCAPS NPP TEST



Baseline: REFERENCE SONDE GRUAN RAOB

CRIMSS NPP Infrared (IP) ECMWF ANALYSIS NUCAPS NPP TEST

IR + MW Pass QC … AEROSE only

Progress on the NUCAPS Microwave-Only Retrieval Improvement

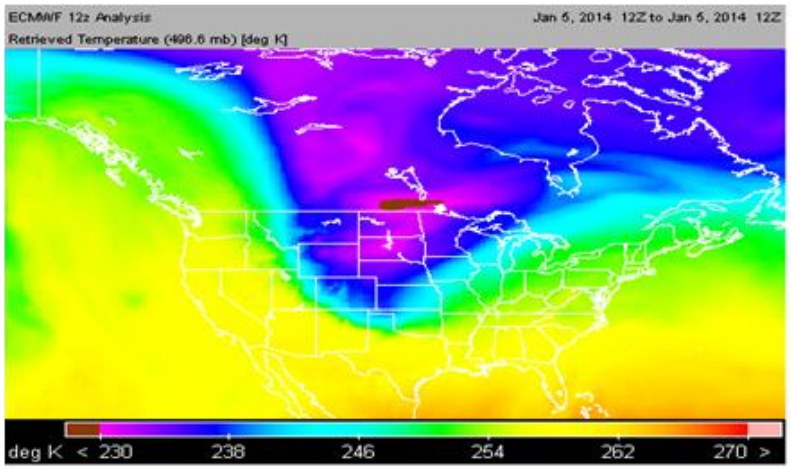
1) NUCAPS MW-only retrieval has a problem over polar-vortex area.

2) The NUCAPS MW-only physical retrieval result hasn't been used in IR+MW retrieval.

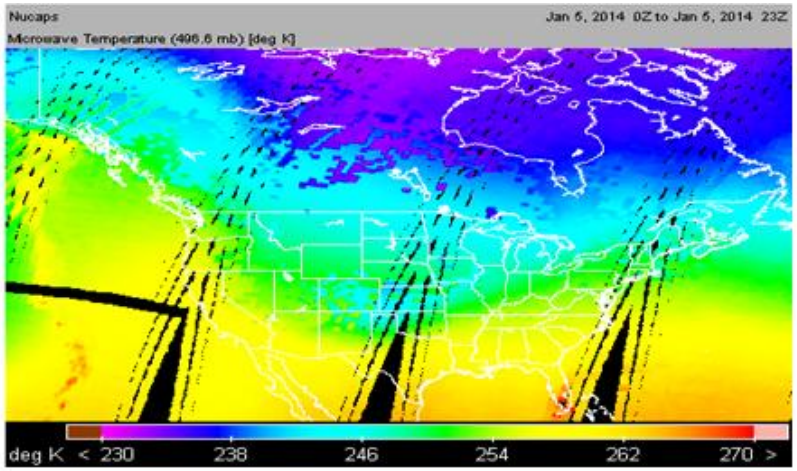
3) Revise MW-only retrieval algorithm.

4) Pass MW-only physical retrieval results to IR+MW retrieval.

ECMWF Temperature @496 hPa

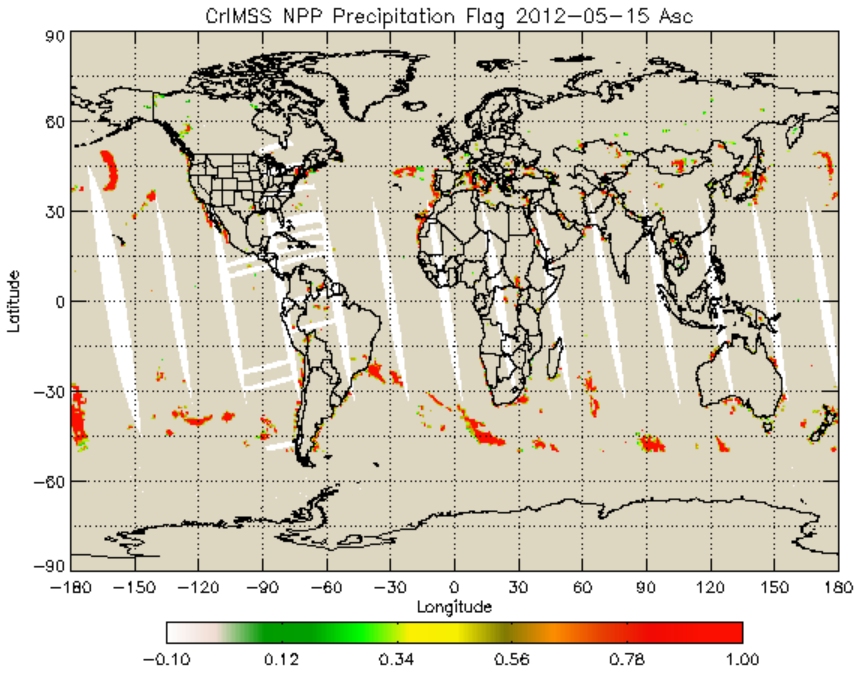


NUCAPS Temperature @496 hPa

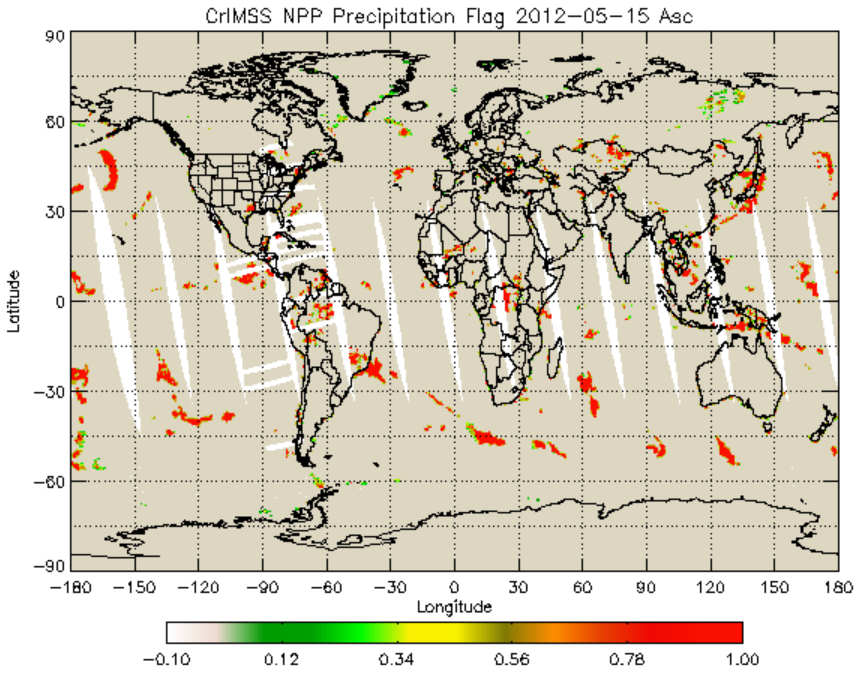


CrIMSS Precipitation Detection Algorithm for Ocean/Land Surfaces

- The new CrIMSS precipitation algorithm has improved the detection of precipitation and provided the confident rain flag to users.
- The new algorithm has not been implemented into IDPS.
- We will investigate the new algorithm for NUCAPS.
- Wenze Yang, Flavio Iturbide-Sanchez, Ralph Ferraro, Murty Divakarla, and Tony Reale, “Evaluation and Improvement of the S-NPP CrIMSS Rain Flag”. AMS 2014.



old



new

Session 5d: Soundings Breakout Session (Conf. Room 2552/2553)

Co-Chairs: Mark Liu/Tony Reale

Tomorrow
10:20 – 17:00

1120 - 1140	*Validation of CrIS Dual Regression Sounding Products during the Airborne Suomi-NPP Cal/Val Campaign*	Bill Smith	CMISS UW and Hampton University
1140 - 1200	*Analysis of CrIS/ATMS sounding data with an AIRS Version 6-like retrieval algorithm*	Joel Susskind	NASA/GSFC
1200 - 1330	*Lunch*		
1330 - 1350	*Status of the NOAA Hyper Spectral Infrared + Microwave Retrieval Algorithm*	Antonia Gambacorta	STAR
1350 - 1410	*Recent analysis of the NOAA CrIS/ATMS EDRs in complex weather regimes*	Chris Barnet	STC
1410 - 1430	*What can we learn from 11 years of AIRS observations?*	Eric Fetzer	NASA/JPL
1430 - 1450	*Single Field of View ATMS/CrIS Sounding Products Under All Sky Condition*	Xu Liu	NASA/LaRC
1450 - 1510	*MiRS Science Improvements and Sounding Product Performance for S-NPP/ATMS*	Christopher Grassotti/Jerry Zhan	STAR
1510 - 1530	*Break*		
1530 - 1550	*Updates on NUCAPS Operational Products and Services*	Awdhesh Sharma	NOAA/OSPO
1550 - 1610	*The NOAA PROducts Validation System and Plus*	Tony Reale, Bomin Sun	STAR
1610 - 1630	*Applications using Satellite Sounder Products at the NASA SPoRT Center*	Emily Berndt	NASA/SPoRT
1630 - 1650	*Validation of NUCAPS Operational Retrieval Products*	Nick Nalli	STAR
1650 - 1710	*GPS Units in the Pacific Region*	Bill Ward	NWS /PRH/ESSD
1710 - 1730	*The need for atmospheric chemistry products from CrIS*	Monika Kopacz	NOAA Climate Program Office

Future Plans

- MW-only retrieval (i.e. retrieval under cloudy condition) wasn't required for NUCAPS originally. It's the JPSS requirement.
- Revise Microwave Physical Retrieval for NUCAPS.
- Using MW Retrievals as the First Guess for IR Retrieval (Cloudiness < 50).
- NPROVS and NPROVS+ for Validations of NUCAPS and Uncertainty Estimation.
- Carbon Products (CO_2, CO, and CH_4), J1 new requirements, no F14 funding, scheduled in 2015.
- CrIS full spectral resolution retrieval.
- Integrated Sounding System for CrIS/ATMS, IASI/AMSU, and AIRS/AMSU

Summary

- Our validations showed that NUCAPS IR+MW sounding products meet threshold performance in general.
- MW only sounding product has problems that will be fixed.
- NUCAPS generates trace gas products, but they need to be evaluated and improved.
- A concern about information content over used.
- Integrated Sounding System for CrIS/ATMS, IASI/AMU, and AIRS/AMSU.