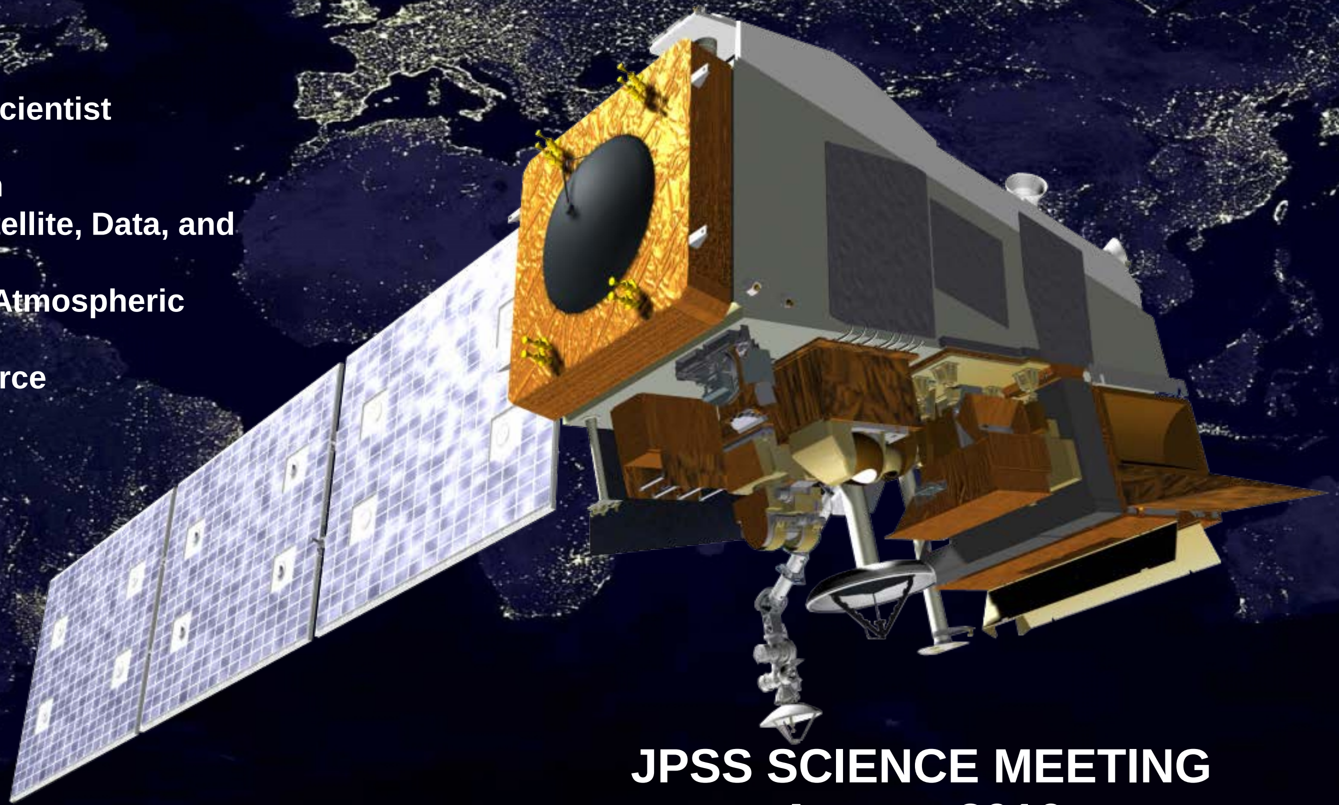
Joint Polar Satellite System (JPSS)

Soundings and Applications

Mitch Goldberg, Program Scientist

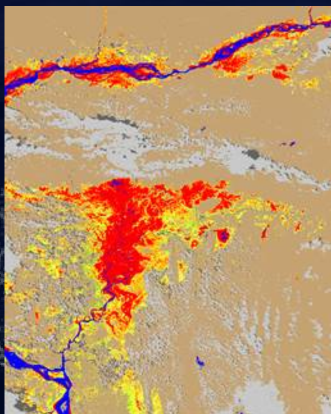
Joint Polar Satellite System
National Environmental Satellite, Data, and Information Service
U.S. National Oceanic and Atmospheric Administration
U.S. Department of Commerce



JPSS SCIENCE MEETING
August 2016

www.jpss.noaa.gov

From Photons to Applications to Decisions



Decisions

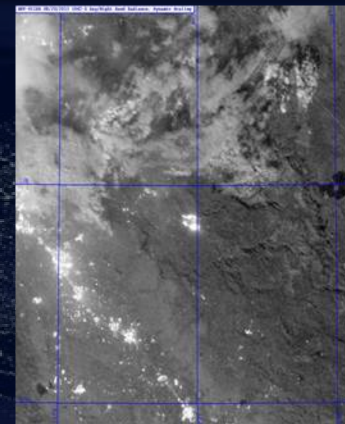
Warnings

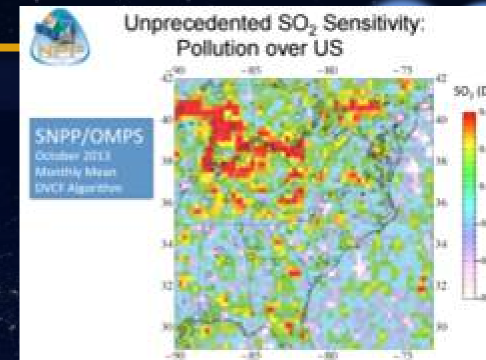
Impact Assessments

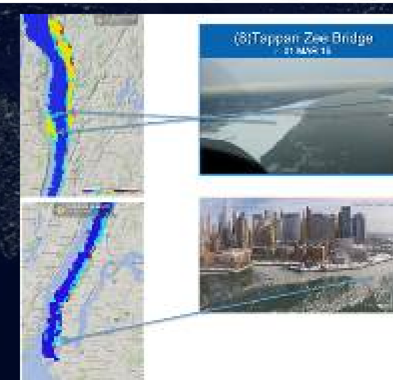
Specialty Forecasts – e.g., floods

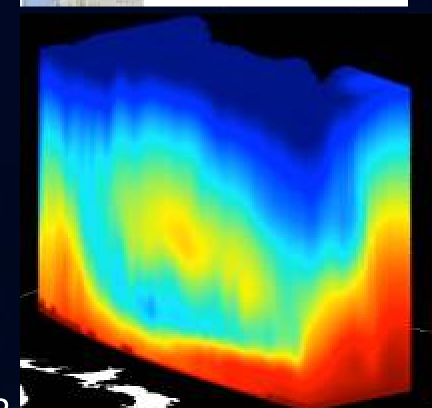
Weather Forecasts e.g., 3-5 days

Baseline of Robust and Accurate Observations









Addressing Needs Across NOAA

WEATHER READY NATION

1. Aviation Weather and Volcanic Ash
2. Fire Weather
3. Hydrology and Water Resources
4. Marine Weather and Coastal Events
5. Hurricane/Tropical Storms
6. Routine Weather
7. Severe Weather
8. Space Weather
9. Tsunami
10. Winter Weather
11. Environmental Modeling Prediction

National Weather Service

HEALTHY OCEANS

1. Ecosystem Monitoring, Assessment and Forecast
2. Fisheries Monitoring, Assessment and Forecast
3. Habitat Monitoring and Assessment
4. Protected Species Monitoring

National Marine Fisheries Service

RESILIENT COASTS

1. Coastal Water Quality
2. Marine Transportation
3. Planning and Management
4. Resilience to Coastal Hazards and Climate Change

National Ocean Service

CLIMATE

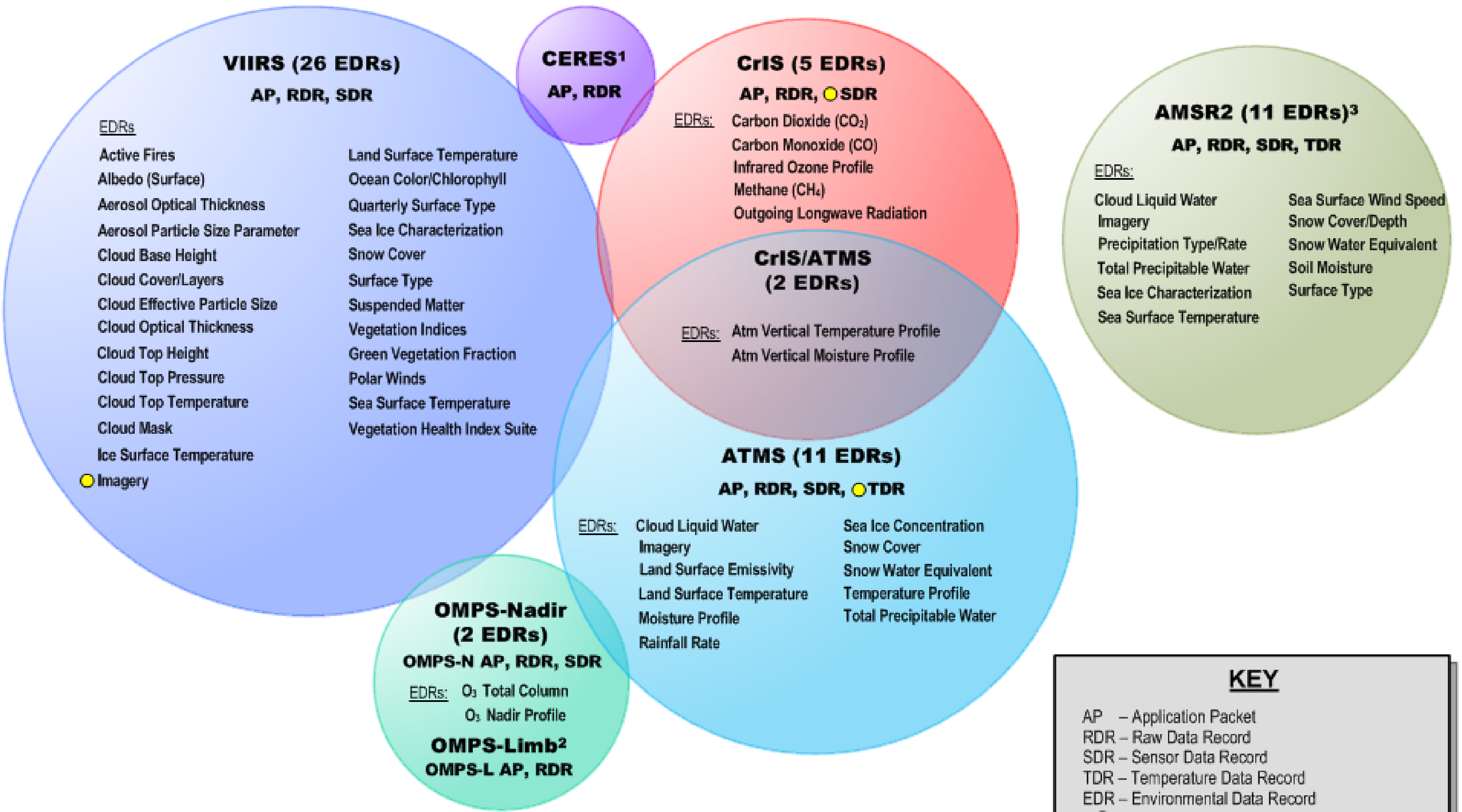
1. Assessments of Climate Changes and Its Impacts
2. Climate Mitigation and Adaptation Strategies
3. Climate Science and Improved Understanding
4. Climate Prediction and Projections

Office of Oceanic and Atmospheric Research

NOAA Mission Service Areas by Line Office

JPSS Program Data Products

JPSS Level 1 Requirements Document, v1.8



Notes:

[1]AP and RDR for the JPSS-2 Mission are contingent on NASA manifest of the Radiation Budget Instrument (RBI)

[2]Not applicable to JPSS-1; AP and RDR contingent on NASA manifest of OMPS-Limb on the JPSS-2 Mission

[3]All products dependent on the Global Change Observation Mission (GCOM) provided by the Japan Aerospace Exploration Agency

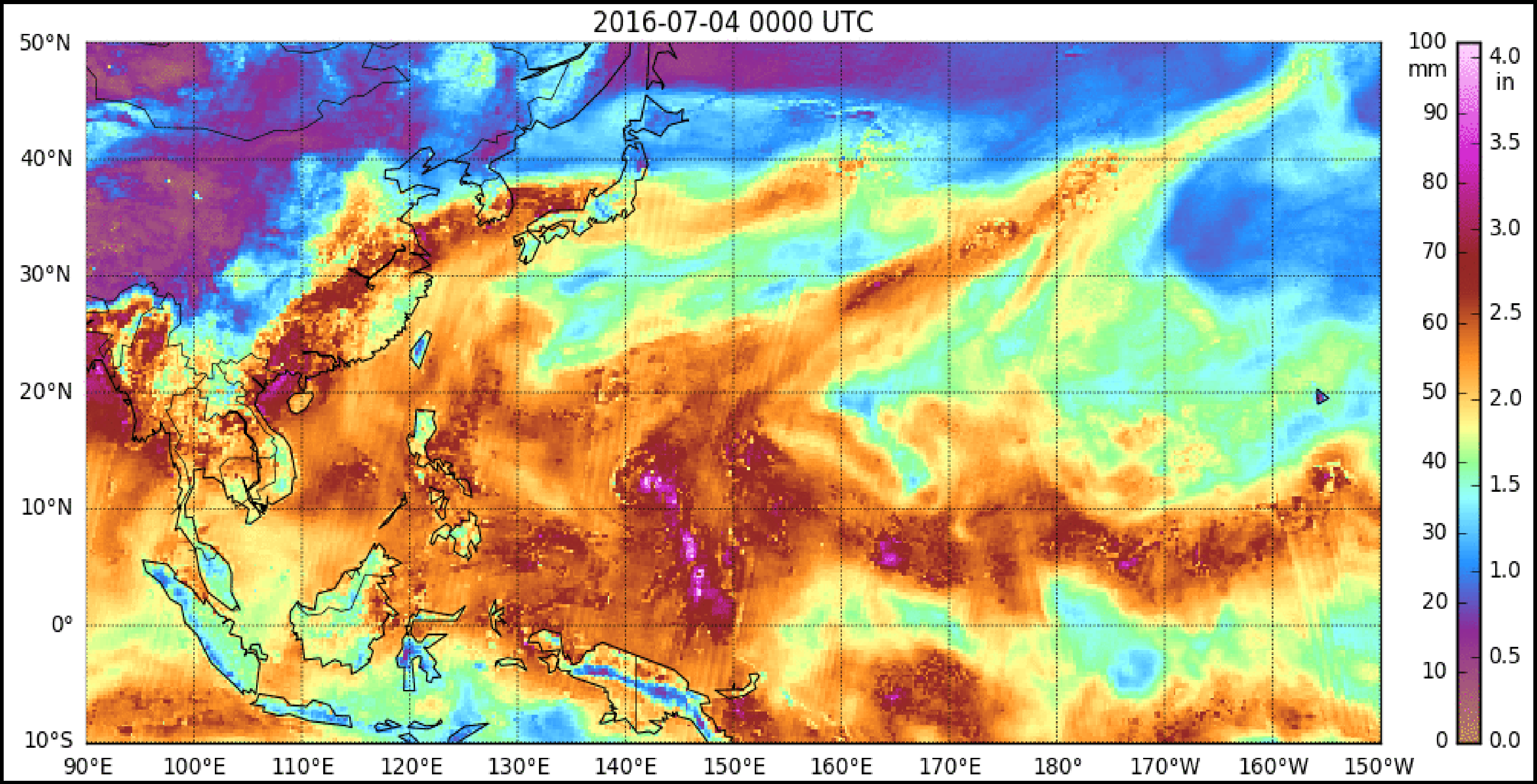
The JPSS Program includes Ground System Support for the Metop, DMSP, and GCOM missions

April 3, 2015

This chart is controlled by JPSS Program Systems Engineering

JPSS-P Rev C.1

Temporal merging of MIRS TPW from 5 microwave sounders including ATMS



Words of wisdom

Cal/Val and periodic assessments of performance, and understanding issues and addressing them continues to be important.

End of the day, it's the applications. But the applications will depend on the performance. Think about the applications, talk to the users, and talk to Program Science – where we can verify the priority and help with the coordination.

Comparative Results of AIRS/AMSU and CrIS/ATMS Retrievals Using a Scientifically Equivalent Retrieval Algorithm

Joel Susskind, Louis Kouvaris, and Lena Iredell
NASA GSFC
Earth Sciences Division - Atmospheres, Code 610AT

NOAA JPSS Meeting
College Park, MD

August 10, 2016

Objective

The AIRS Science Team Version 6 retrieval algorithm is currently producing high quality level-3 Climate Data Records (CDRs) from AIRS/AMSU which are critical for understanding climate processes. The AIRS Science Team is finalizing an improved Version-7 retrieval algorithm to reprocess all old and future AIRS data. AIRS CDRs should eventually cover the period September 2002 through at least 2020

CrIS/ATMS is the only scheduled follow on to AIRS/AMSU

The objective of this research is to prepare for generation of a long term CrIS/ATMS level-3 data using a finalized retrieval algorithm that is scientifically equivalent to AIRS/AMSU Version-7.

Success Metric

- Agreement of AIRS/AMSU and CrIS/ATMS monthly mean fields with each other, and even more importantly, agreement of interannual differences of monthly mean fields.

Background

Last year at this meeting, I presented results comparing AIRS/AMSU and CrIS/ATMS retrievals using Version-6.22. The CrIS/ATMS level-1b data used was generated by the IDPS. The ATMS level-1b data was brightness temperatures, T_B, resampled to the CrIS footprints. There is now a new source of CrIS/ATMS level-1 data generated by U. Wisc/JPL. The new ATMS level1-b data is antenna temperatures, T_A.

We continue to make improvements in our AIRS/AMSU retrieval methodology. The latest scientific version we use for both AIRS/AMSU and CrIS/ATMS is called Version-6.28, which now runs at JPL for both AIRS/AMSU and CrIS/ATMS. JPL plans to generate many months in common of AIRS Version-6.28 and CrIS Version-6.28 data products, or possibly products using further improved versions of each retrieval system, for comparison purposes. JPL CrIS/ATMS retrievals will use ATMS T_A's. The results we show today also use ATMS T_A's.

Major Improvements in Version-6.28 Over Version-6

Version-6.28 is very much like Version-6 with some modifications in details. The major improvements are listed below.

- AIRS Version-6.28 retrievals of $O_3(p)$ have improved considerably compared to AIRS Version-6, both with regard to accuracy and Quality Control (QC) methodology.
- AIRS Version-6.28 retrievals of *q(p)* have also improved considerably compared to Version-6, especially during the day.

Quality Control

Version-6.28 has QC flags for all parameters. Level-3 products include all cases passing climate QC (QC=0 or QC=1). All results presented today are for cases passing climate QC.

First guesses used in the retrieval

First guesses for *T(p)* and *q(p)* use Neural-Net methodology with coefficients trained once and for all early in the AIRS/AMSU and CrIS/ATMS missions. The $O_3(p)$ first guess is zonally averaged monthly mean climatology. All longitudinal $O_3(p)$ structure comes from the retrieval process.

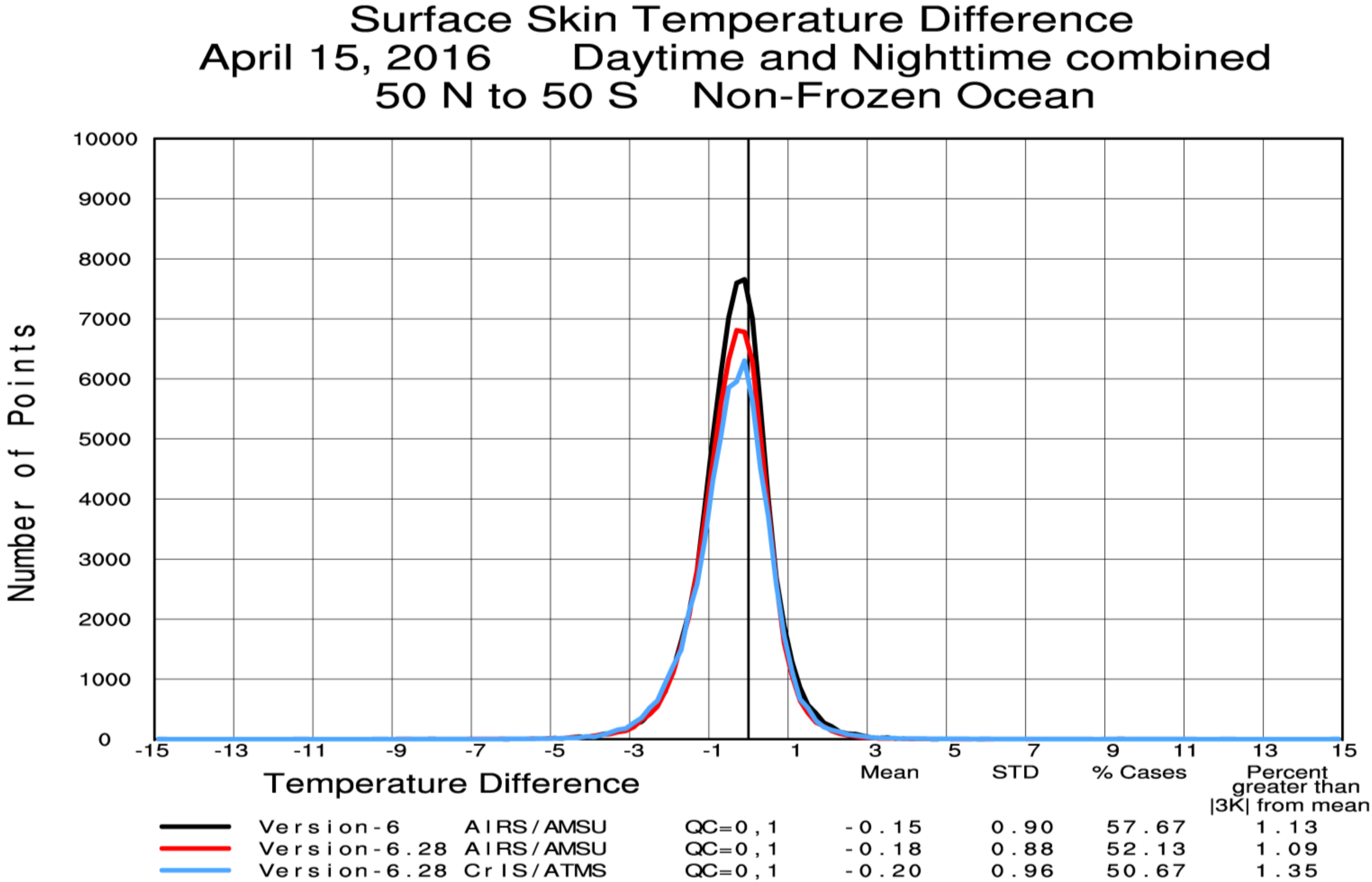
Comparison of AIRS Version-6, AIRS Verison-6.28, and CrIS Version-6.28 Results

The following results are shown for the single day, April 15, 2016. EOS Aqua and NPP orbits overlap closely on this day. This is important for comparison purposes to minimize time-of-day sampling differences.

We show Climate QC'd level-2 results for all experiments in terms of yields, RMS errors, and biases compared to ECMWF for $T(p)$, $q(p)$, and ocean surface skin temperature T_s.

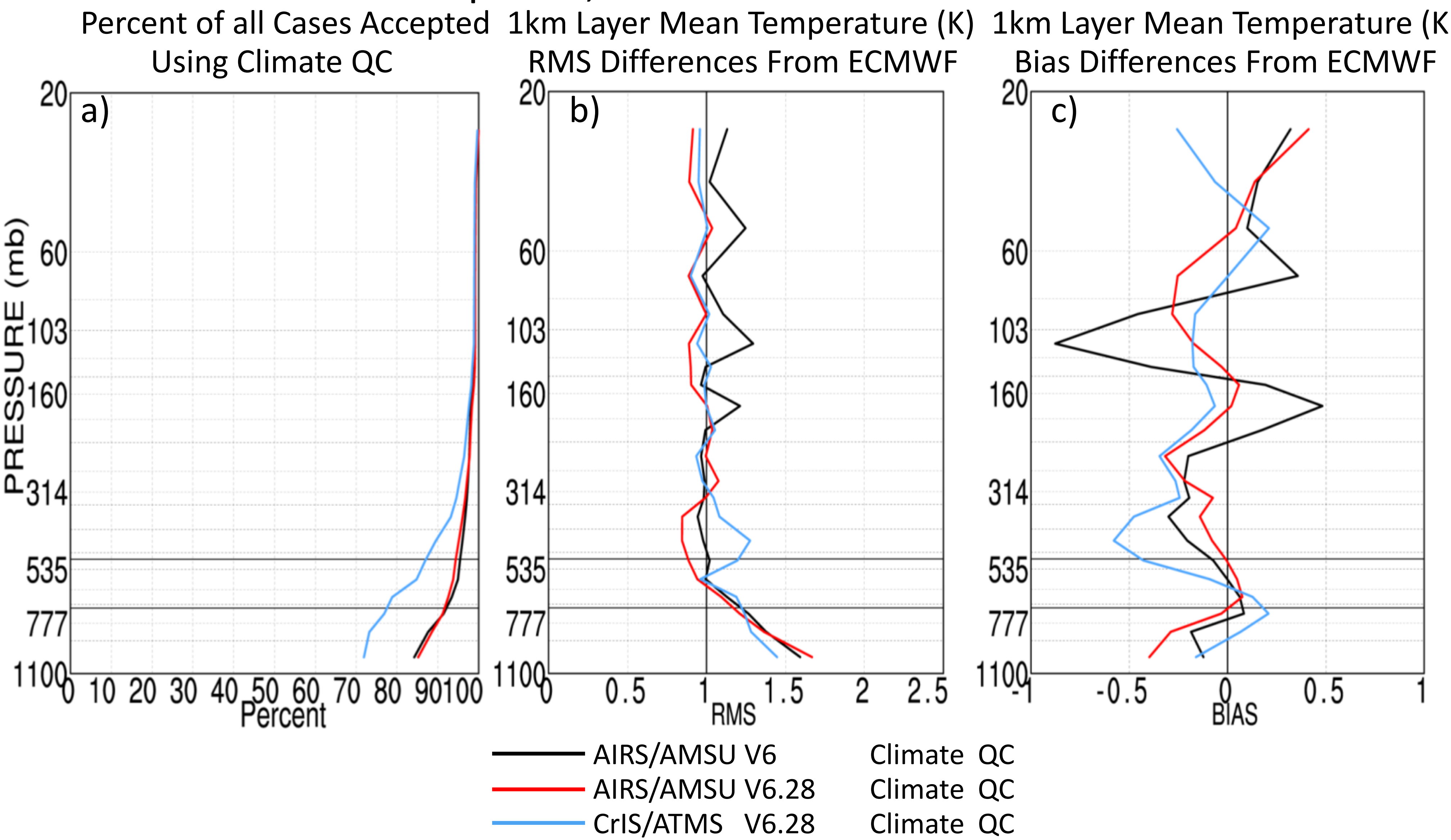
In addition, we show AIRS Version-6, AIRS Version-6.28, and CrIS/ATMS Version-6.28 level-3 gridded fields and compare them to measures of truth. AIRS and CrIS results using Version-6.28 are significantly improved compared to Version-6 for ozone products.

Finally, we compare level-3 fields of other select products of Version-6.28 AIRS and Version-6.28 CrIS which show good agreement with each other, especially over ocean.



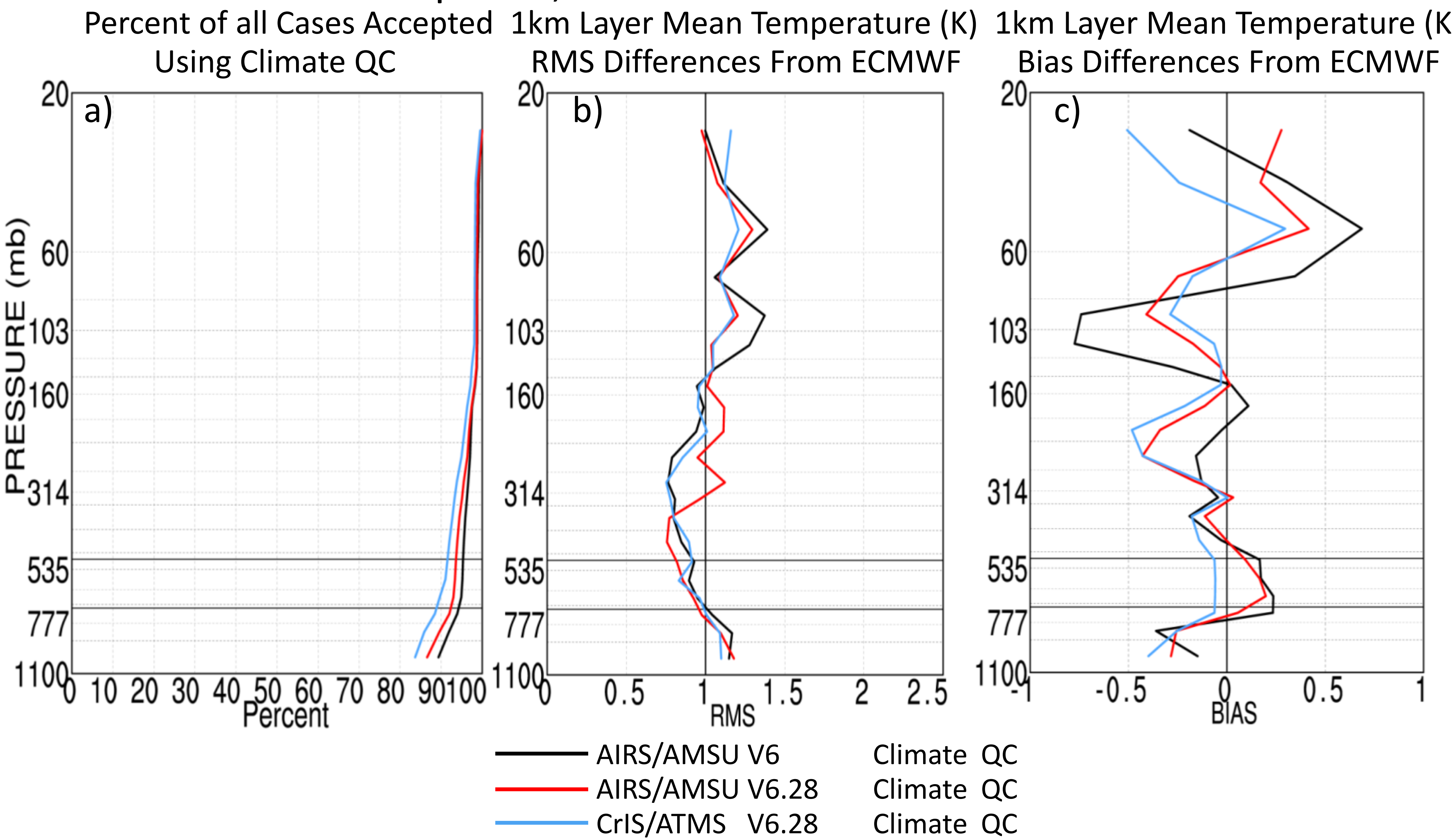
Counts of QC'd values as a function of errors of AIRS Version-6, AIRS Version-6.28 and CrIS Version-6.28 sea surface temperatures using Climate (QC=0,1) QC thresholds. All three sets of results are excellent and are of comparable quality with each other. CrIS SW spectral coverage truncated at 2550 cm^{-1} does not degrade ocean SST significantly.

April 15, 2016 Global Statistics



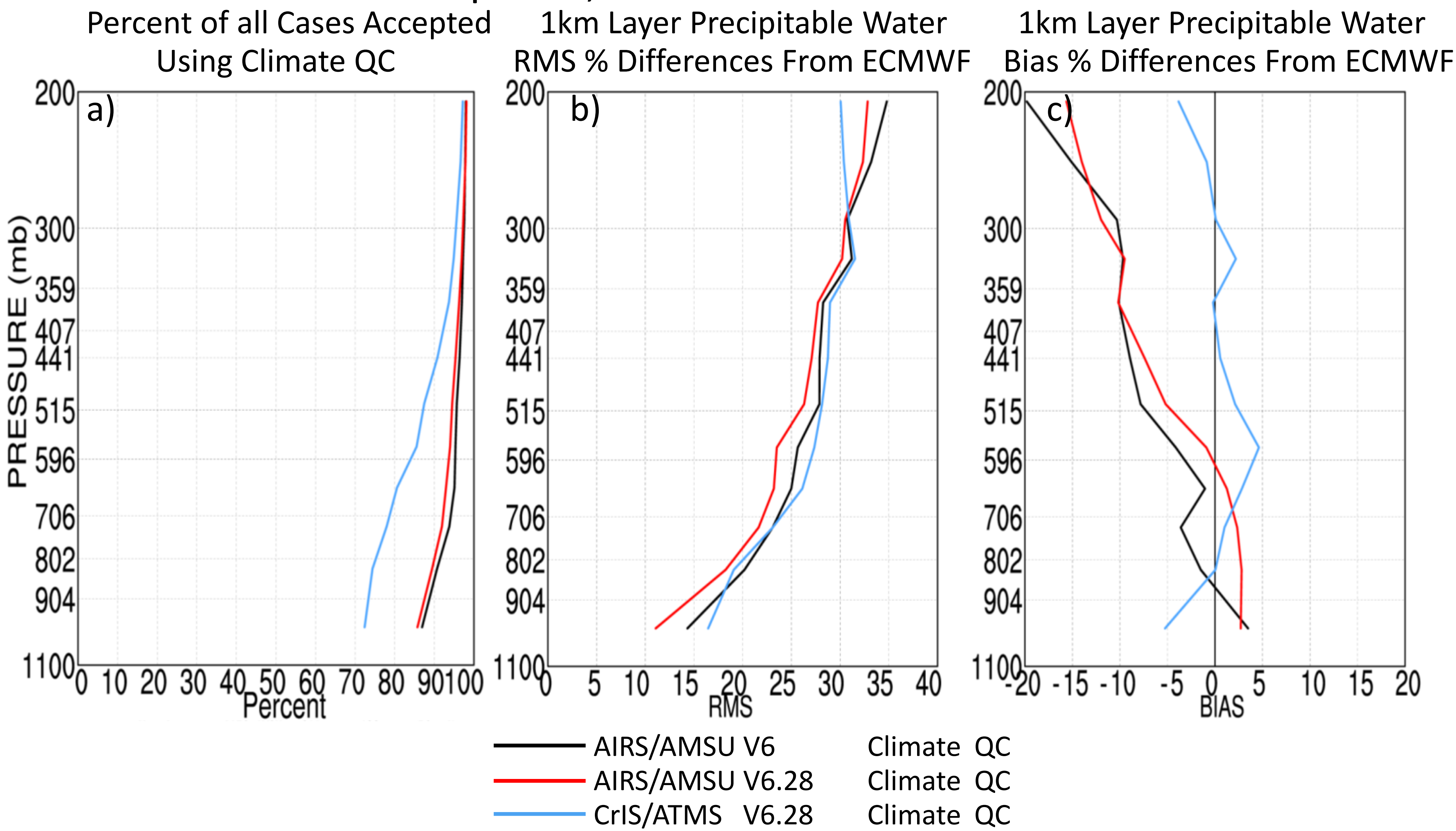
AIRS V6.28 and CrIS V6.28 1 km layer mean temperatures are both more accurate than AIRS V6 overall. CrIS V6.28 results with Climate QC has a lower yield, and somewhat larger errors, than AIRS V6.28, with a spurious positive bias at 700 mb and a negative bias at 500 mb.

April 15, 2016 50°N to 50°S Ocean

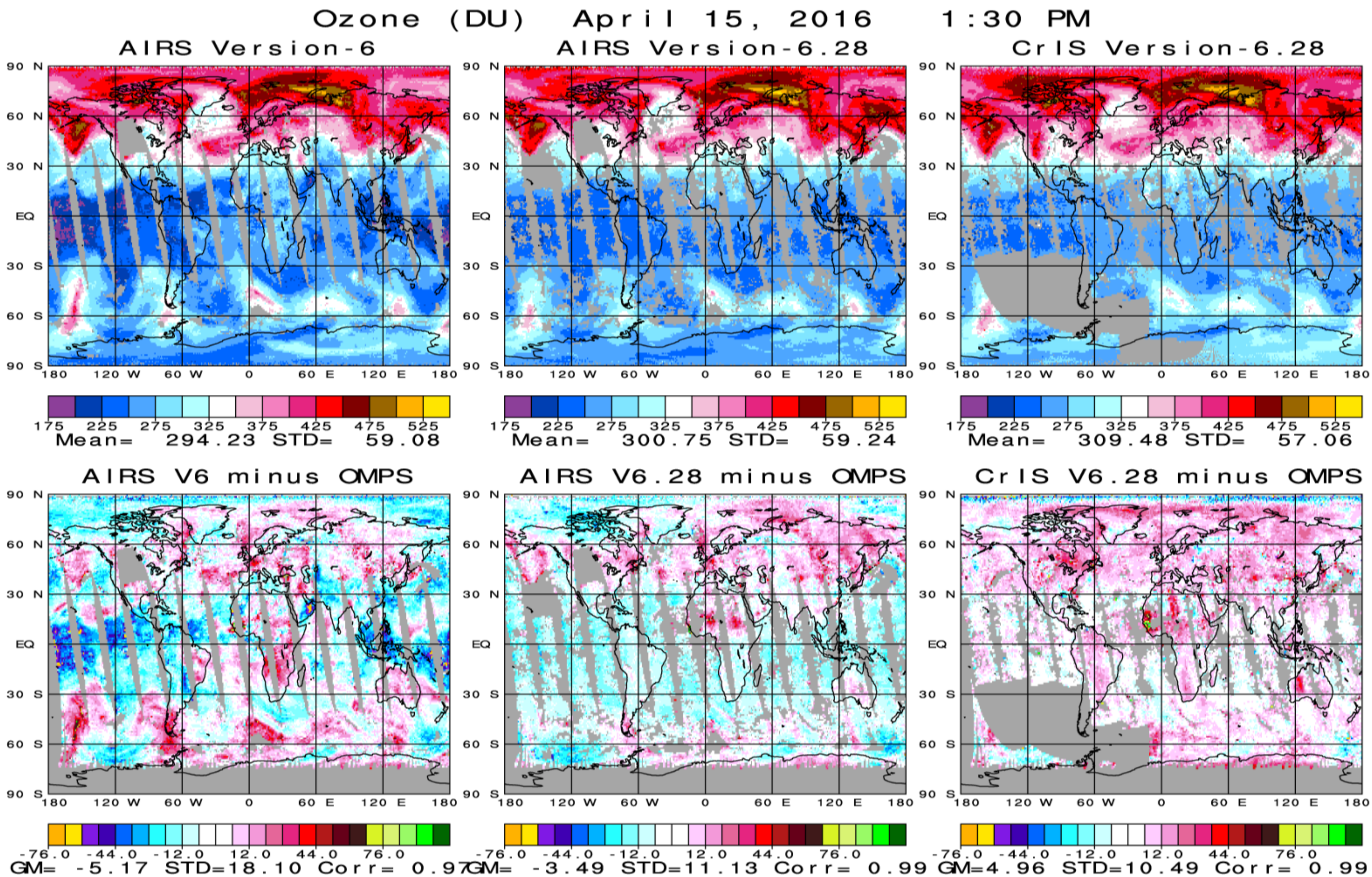


CrIS/ATMS statistics for *T(p)* are similar to those of AIRS/AMSU over mid-latitude ocean using Climate QC thresholds. Degradation of CrIS/ATMS retrievals compared to AIRS/AMSU occurs primarily over land.

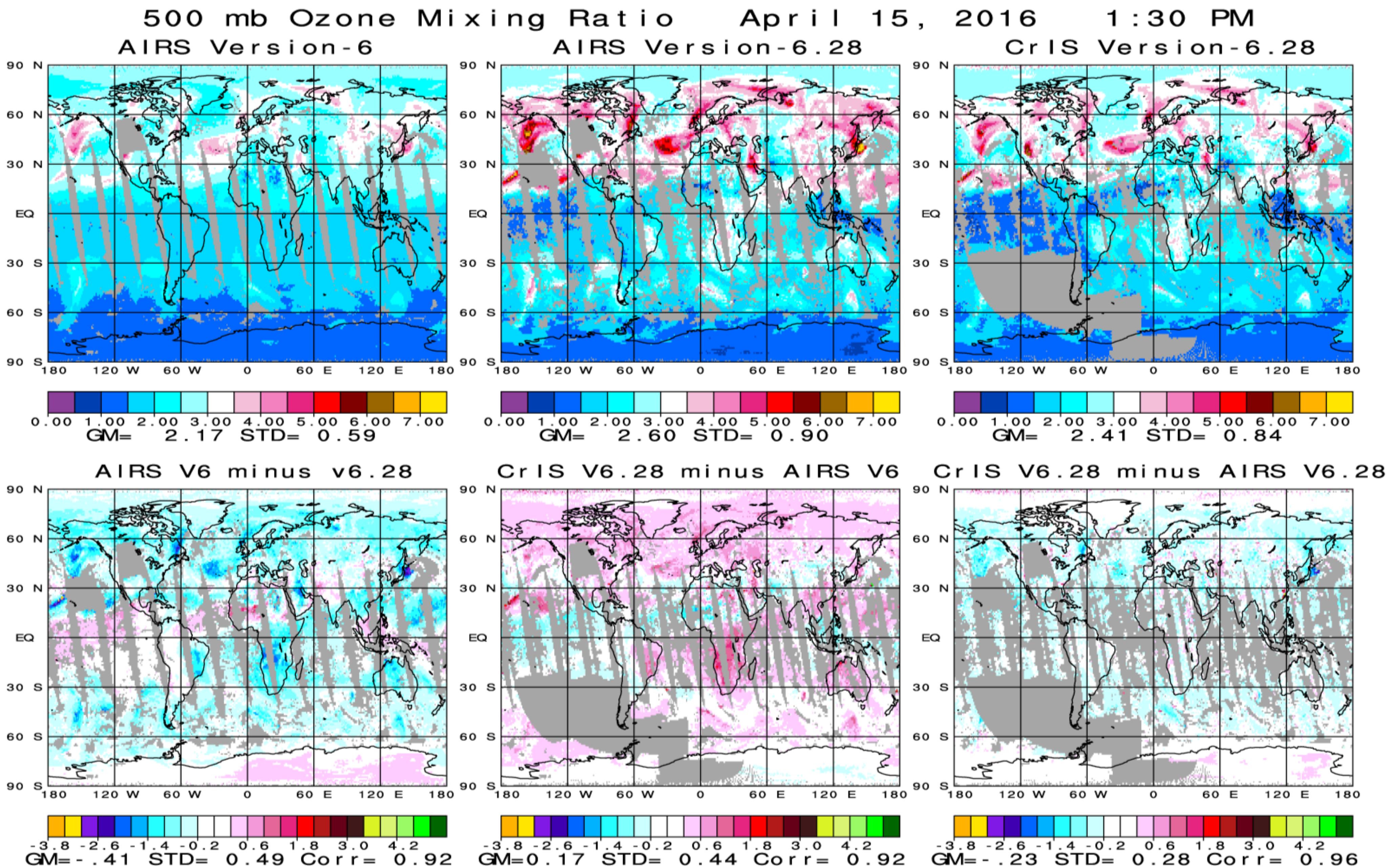
April 15, 2016 Global Statistics



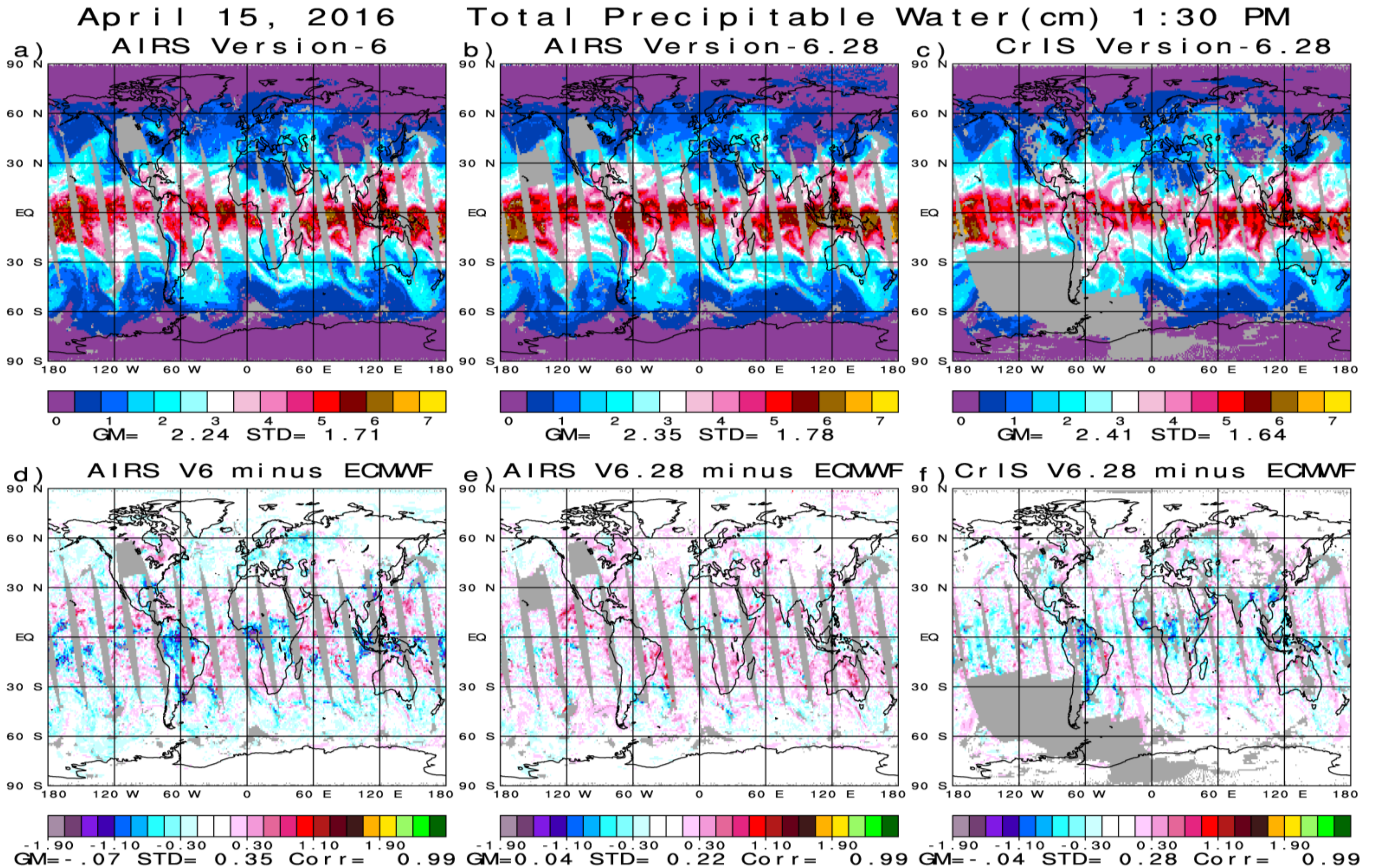
AIRS V6.28 1 km layer precipitable water results are superior to those of AIRS V6 with regard to both RMS errors and biases. The AIRS V6.28 dry bias above 500 mb has been alleviated by subsequent research. Global CrIS V-6.28 water vapor retrievals have comparable RMS errors to those of AIRS V6.



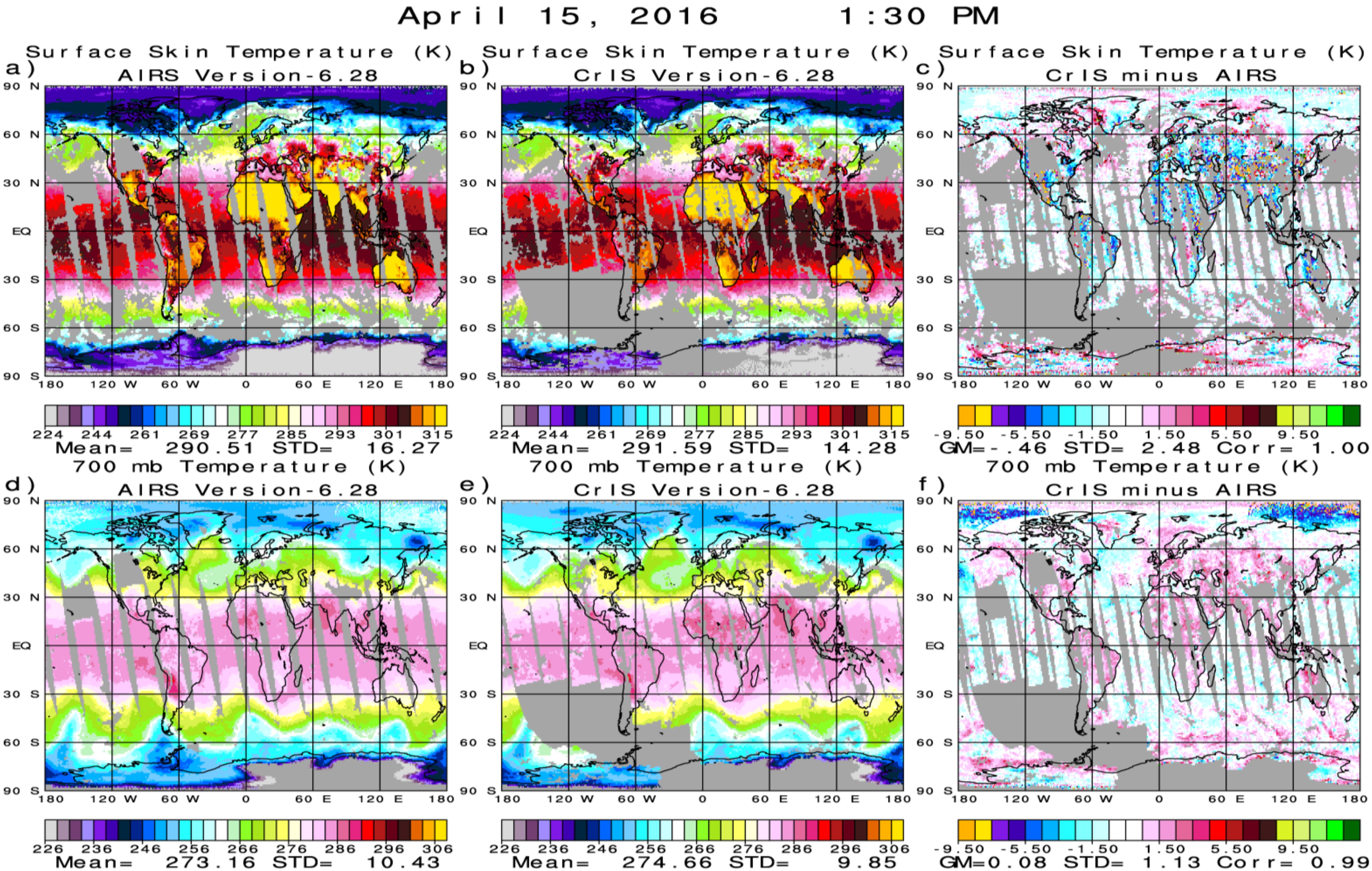
AIRS Version-6, AIRS Version-6.28, and CrIS Version-6.28 QC'd fields of total O_3 for ascending orbits on April 15, 2016, and their differences from OMPS. CrIS is missing parts of some orbits. AIRS V6.28 and CrIS V6.28 agree much better with OMPS than AIRS V6 with regard to both STD and spatial correlation. CrIS V6.28 statistics are comparable to AIRS V6.28.



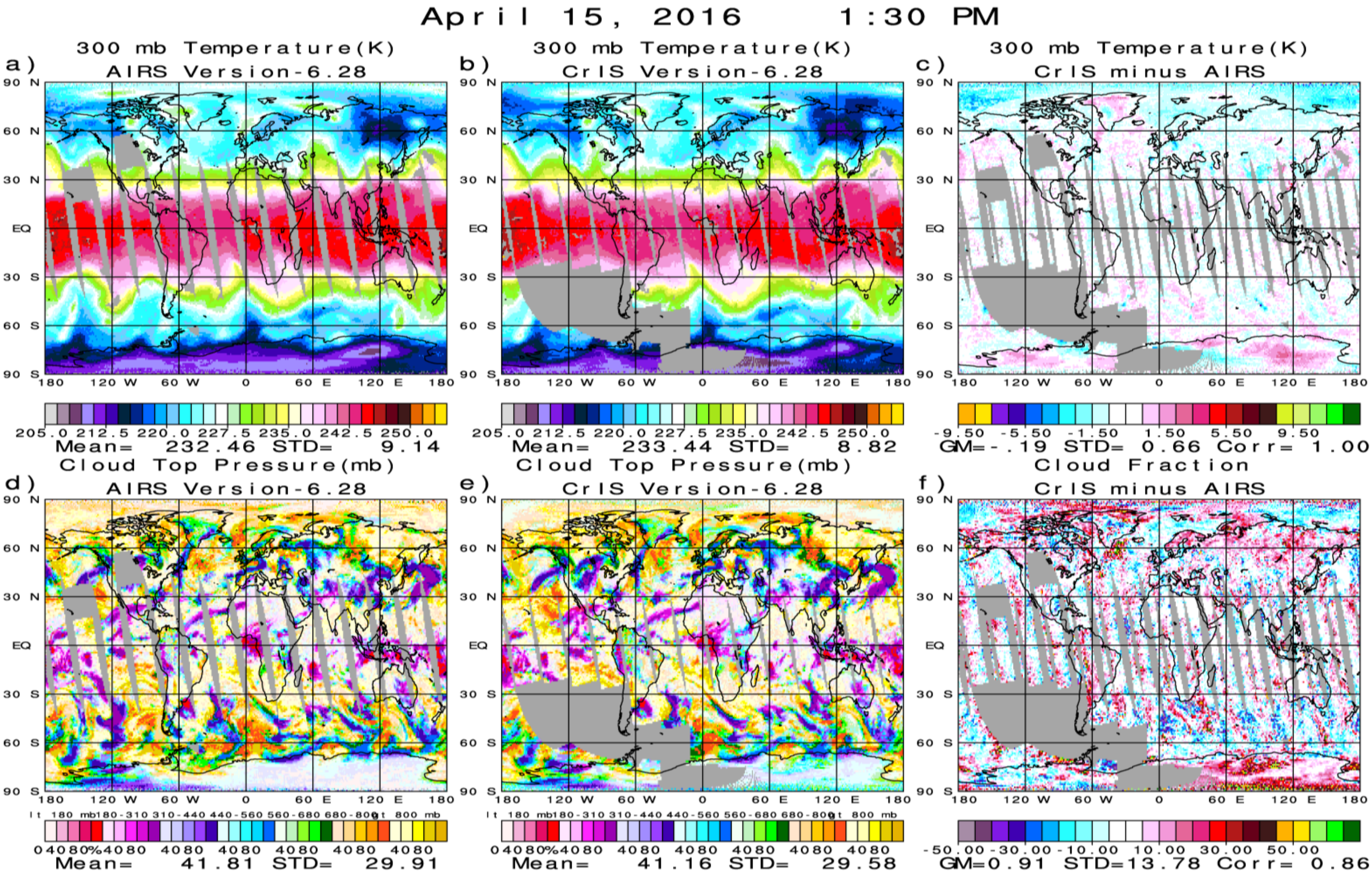
AIRS Version-6.28 and CrIS Version-6.28 QC'd fields of O_3 500 mb mixing ratio agree reasonably well with each other, and both show more pronounced spatial structure than what was found in AIRS Version-6.



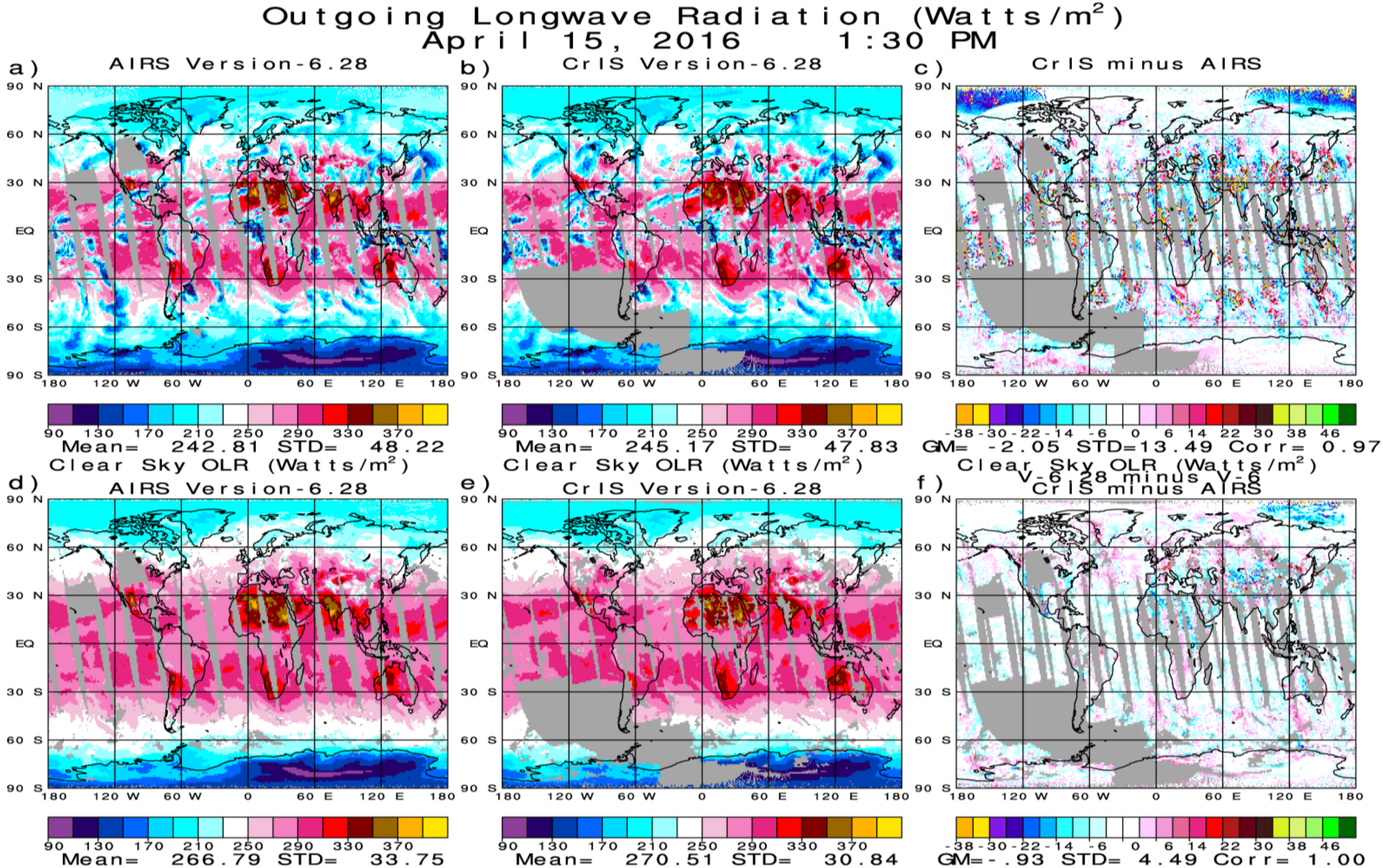
AIRS V6.28 W_{tot} is much more accurate than AIRS V6, especially in areas of high cloud cover.
CrIS V6.28 W_{tot} has intermediate accuracy.



AIRS and CrIS retrieved values of surface skin temperature and 700 mb temperature for ascending orbits on April 15, 2016 agree very well over the tropical oceans. There are some differences over land, especially at high latitudes. Cooler CrIS land skin temperatures result in spuriously warmer 700 mb temperatures.



AIRS and CrIS retrieved values of 300 mb temperatures agree very well with each other. Cloud fields show both cloud top pressure (color) and cloud fraction (intensity). Cloud parameter agreement over tropical ocean is excellent, but some differences occur at high latitudes.



Agreement of AIRS and CrIS OLR and OLR_{CLR} fields is excellent with regard to both global means and spatial correlations. Some of the differences in OLR are a result of imperfect alignment of EOS Aqua and NPP orbits.

Summary

We evaluated Version-6.28 AIRS and Version-6.28 CrIS products on a single day, April 15, 2016, and compared results to those derived using AIRS Version-6.

- AIRS and CrIS Version-6.28 $O_3(p)$ products are both superior to those of AIRS Version-6.
- All AIRS and CrIS products agree reasonably well with each other.
- CrIS Version-6.28 $T(p)$ and $q(p)$ results are poorer than AIRS over land, especially under very cloudy conditions.

Both AIRS and CrIS Version-6.28 now run at JPL. Our short term plans are to analyze many common months at JPL in the near future using Version-6.28 or a further improved algorithm to assess the compatibility of AIRS and CrIS monthly mean products and their interannual differences.

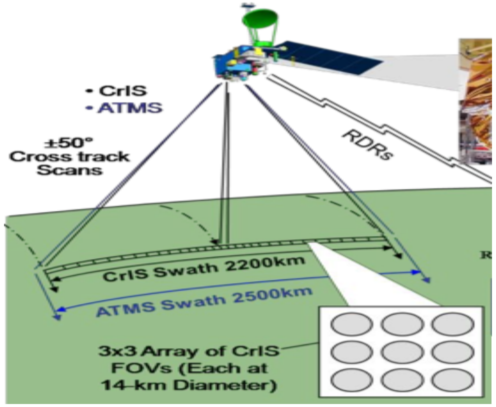
Updates to the calibration of both CrIS and ATMS are still being finalized. JPL plans, in collaboration with the Goddard DISC, to reprocess all AIRS/AMSU data using a still to be finalized Version-7 retrieval algorithm. Our goal is to have all recalibrated CrIS/ATMS data eventually reprocessed using Version-7 as well.

NASA

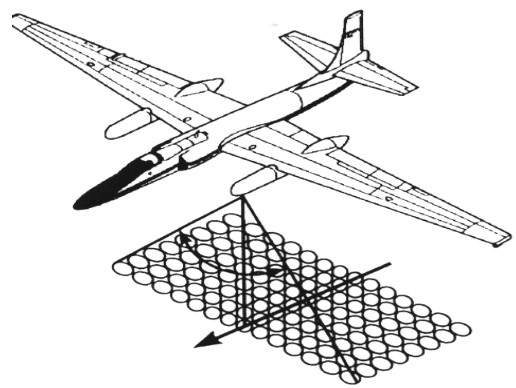
VALIDATION OF JPSS RELATED SOUNDING MEASUREMENTS- SUOMI NPP AND HS3 AIRBORNE FIELD CAMPAIGNS

W. Smith Sr.[1,3], A. Larar[2], H.Revercomb[1], J. Taylor[1], j. Tian[2], D. Tobin[1],
E. Weisz[1], R. Knuteson[1], X. Liu[2], D. Zhou[2,] M. Goldberg[4]
[1]University of Wisconsin – Madison, [2]NASA/LaRC, [3]NASA/SSAI, [4]NOAA/NESDIS

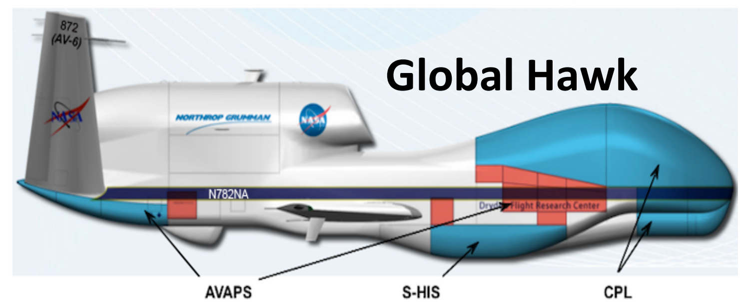
Suomi-NNP-1 & 2 CrIS Cal/Val

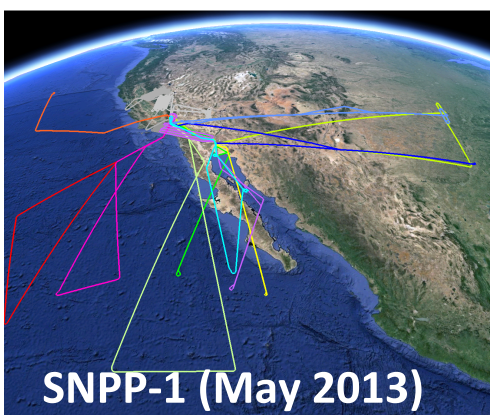


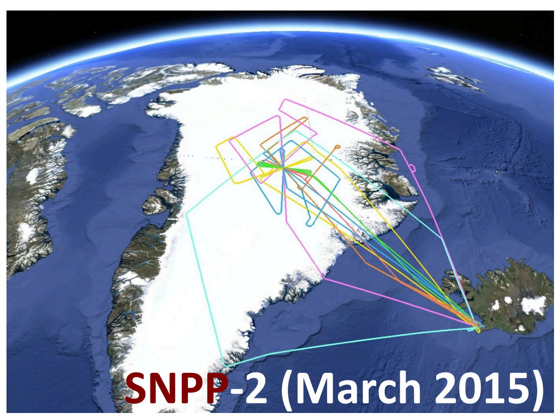
ER-2 NAST-I & S-HIS

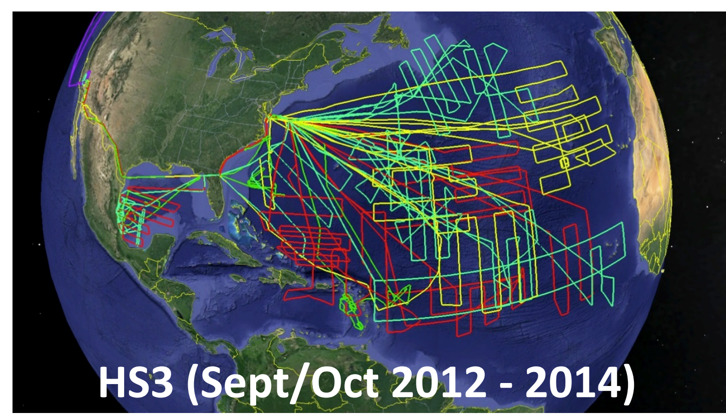


Hurricane and Severe Storm Sentinel (HS3)









“Dual-Regression” Retrieval Algorithm* Overview

Global clear soundings

Radiances (clear FM)

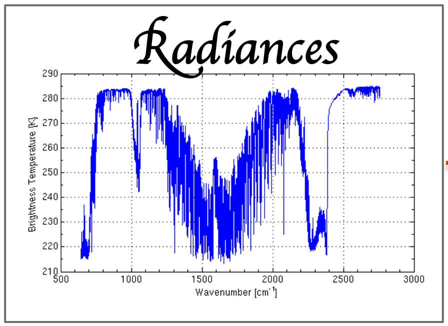
Clear-trained regression coefficients

Global cloudy soundings

Radiances (cloudy FM)
Cloud height classes

Cloud-trained regression coefficients

Theoretical Statistics

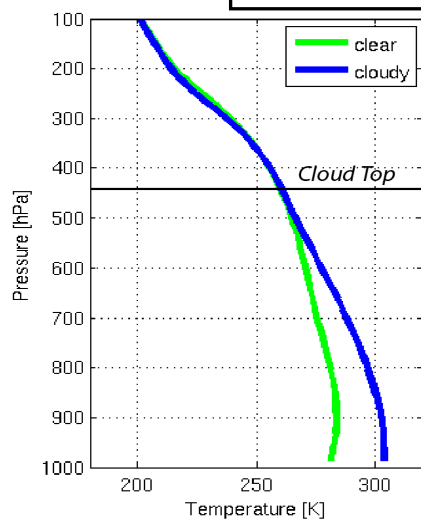


Radiance Observations

Clear-trained EOF regression retrieval

Cloud-trained EOF regression retrieval

Cloud Top Altitude
Level where $T_{cloudy} > T_{clear}$ for $p > p_{cld}$



Final Profile
Clear-trained above and cloud-trained Cloud Top

Temperature, Humidity and Ozone profiles, Surface and Cloud parameter at single FOV (0-2-km) resolution

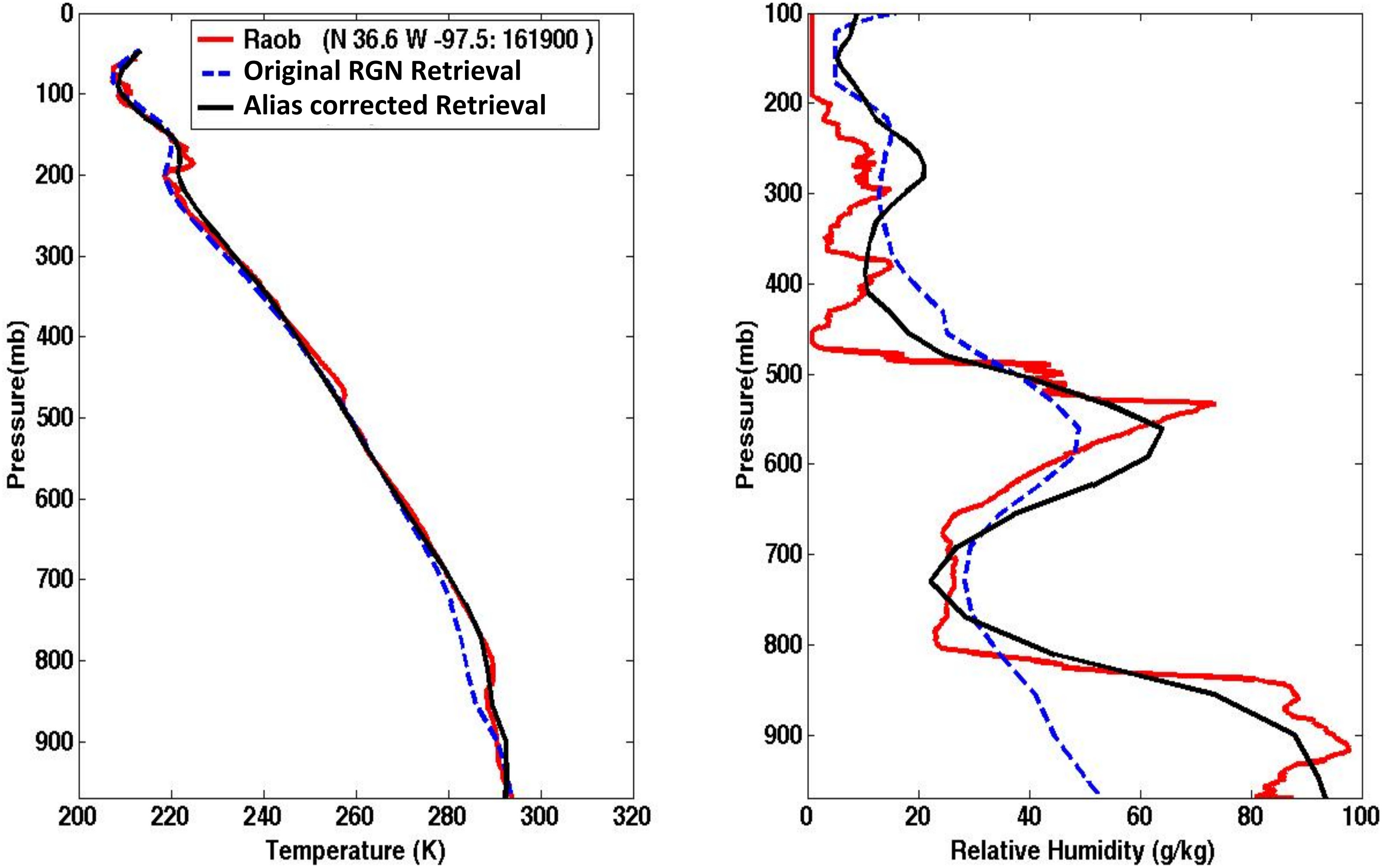
* Smith, W. L., E. Weisz, S. Kirev, D. K. Zhou, Z. Li, and E. E. Borbas (2012), Dual-Regression Retrieval Algorithm for Real-Time Processing of Satellite Ultraspectral Radiances. *J. Appl. Meteor. Clim., 51*, Issue 8, 1455-1476.

Physical Correction Using Forecast Model Profile

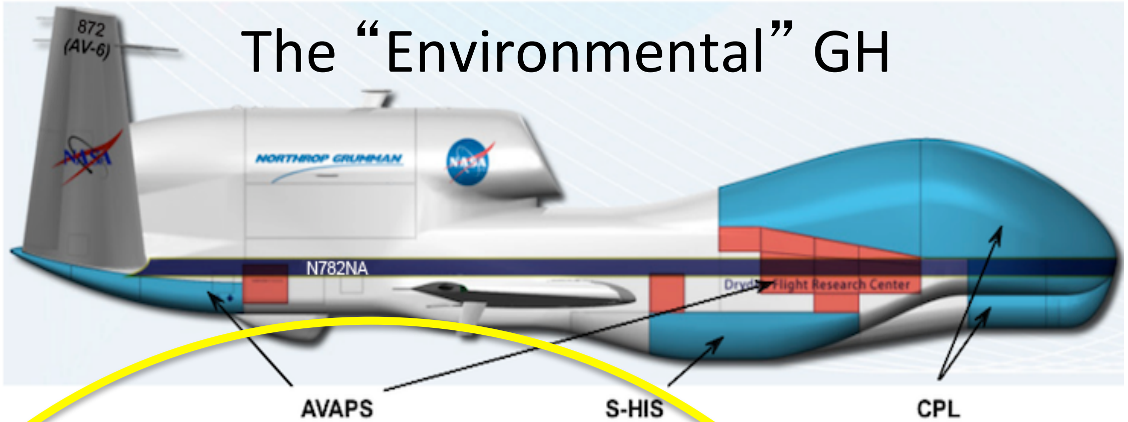
Problem: DR method uses a global statistical training data set. Imperfect skill, due to lack of vertical resolution in radiances leads to a vertical aliasing error.

Solution: Calculate radiance spectrum from forecast profile (FP) and perform DR retrieval using simulated forecast radiances.

Vertical Alias = Forecast Simulated Profile – Forecast Profile



The “Environmental” GH

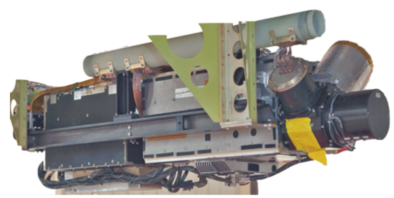


Airborne Vertical Atmospheric Profiling System (AVAPS)

89 Dropsondes / flight

Temperature, Pressure, wind, humidity vertical profiles

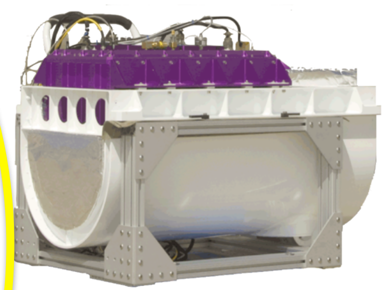
Scanning High Resolution Infrared Sounder (S-HIS)



Upwelling thermal radiation at high spectral resolution between 3.3 and 18 microns.

Temperature, water vapor vertical profiles

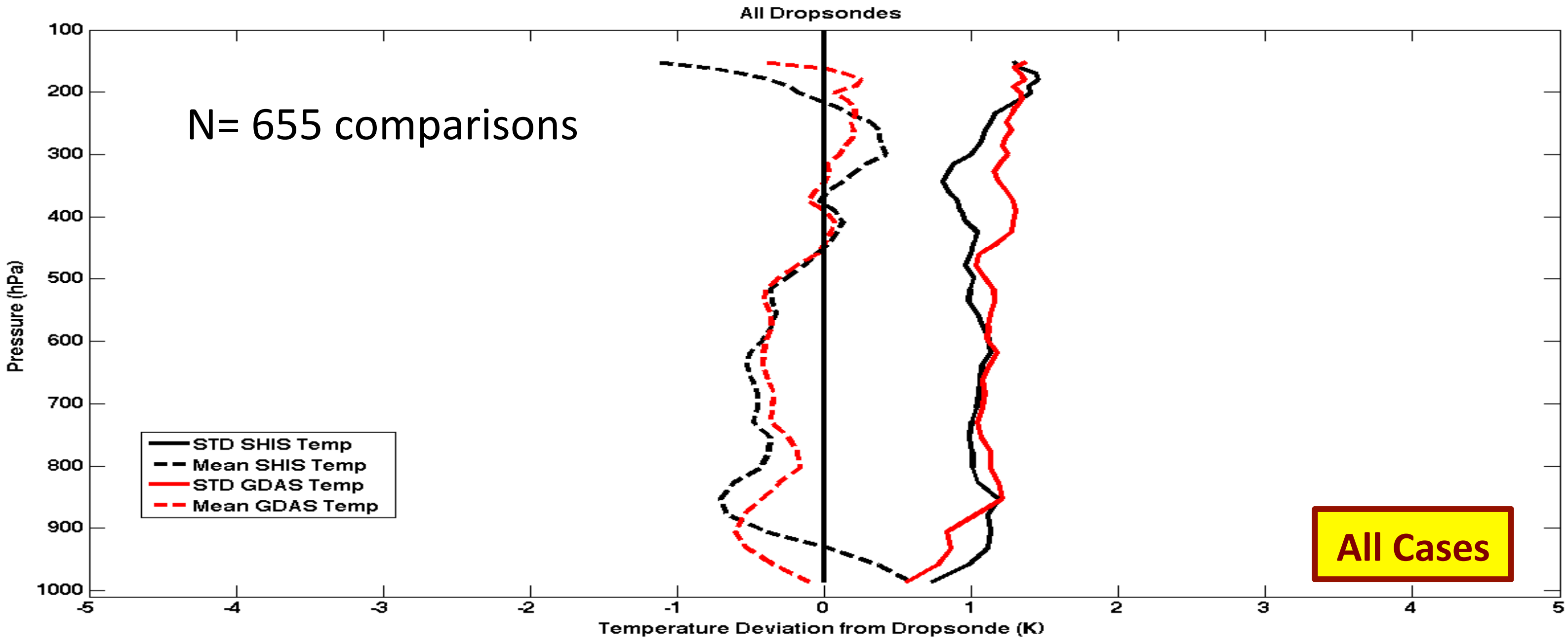
Cloud Physics Lidar (CPL)

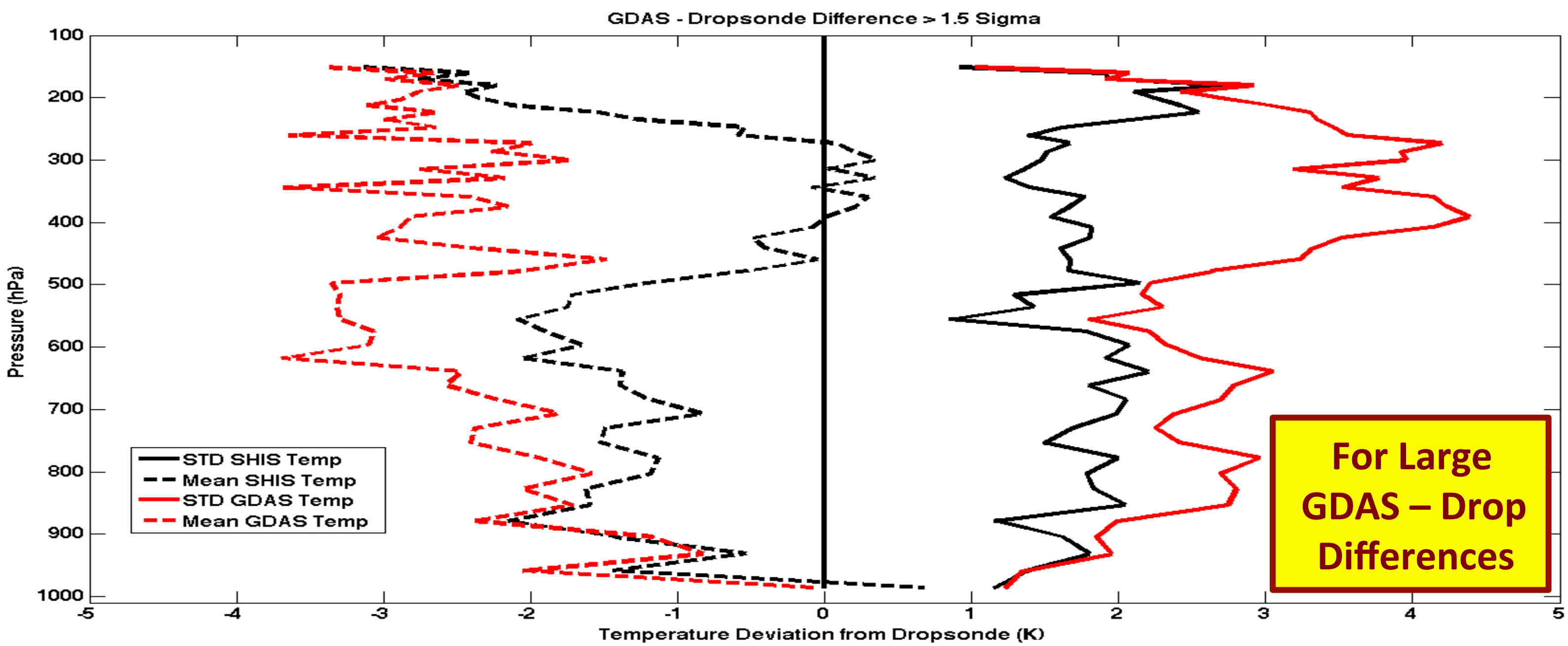


532/1064 nm Lidar Reflection

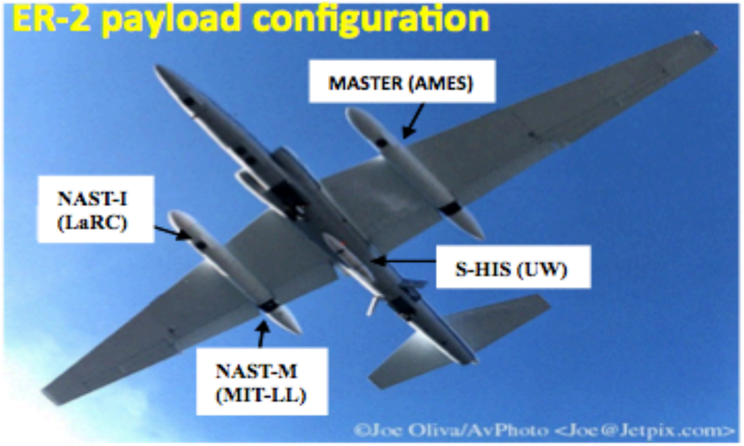
Cloud structure and depth

DA S-HIS Vs. Dropsonde Statistics (HS3-2014)





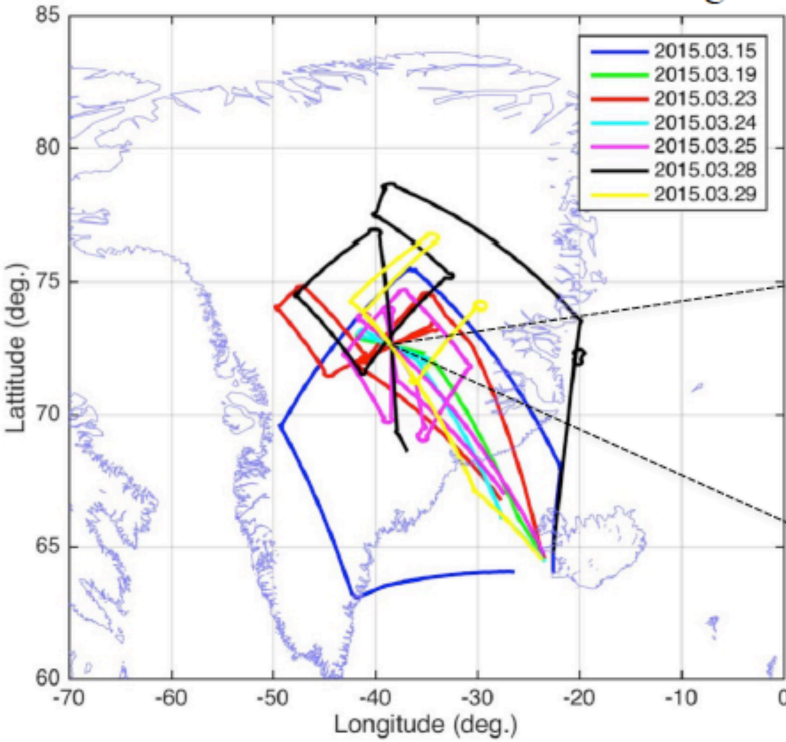
Second Suomi-NPP Calibration/Validation Experiment



ER-2 Mission Science Flights (over Greenland):

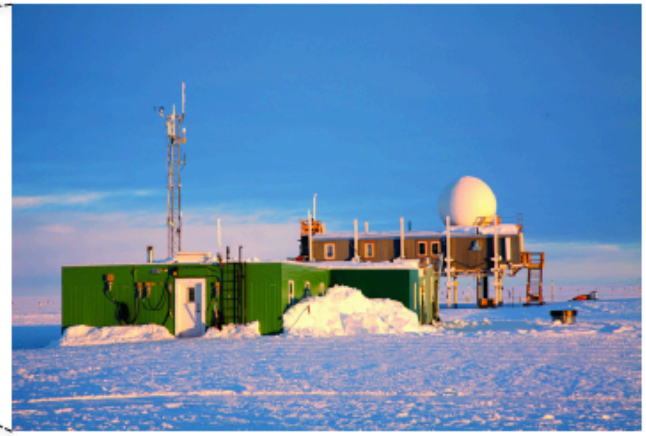
Date:	3/15/15	3/19/15	3/23/15	3/24/15	3/25/15	3/28/15	3/29/15
Duration (hrs.):	5.9	4.6	6.3	4.2	7.5	7.4	6.1
Summit Overpass:	0	4	2	2	4	2	2

Second Suomi NPP Cal/Val Science Flight Tracks



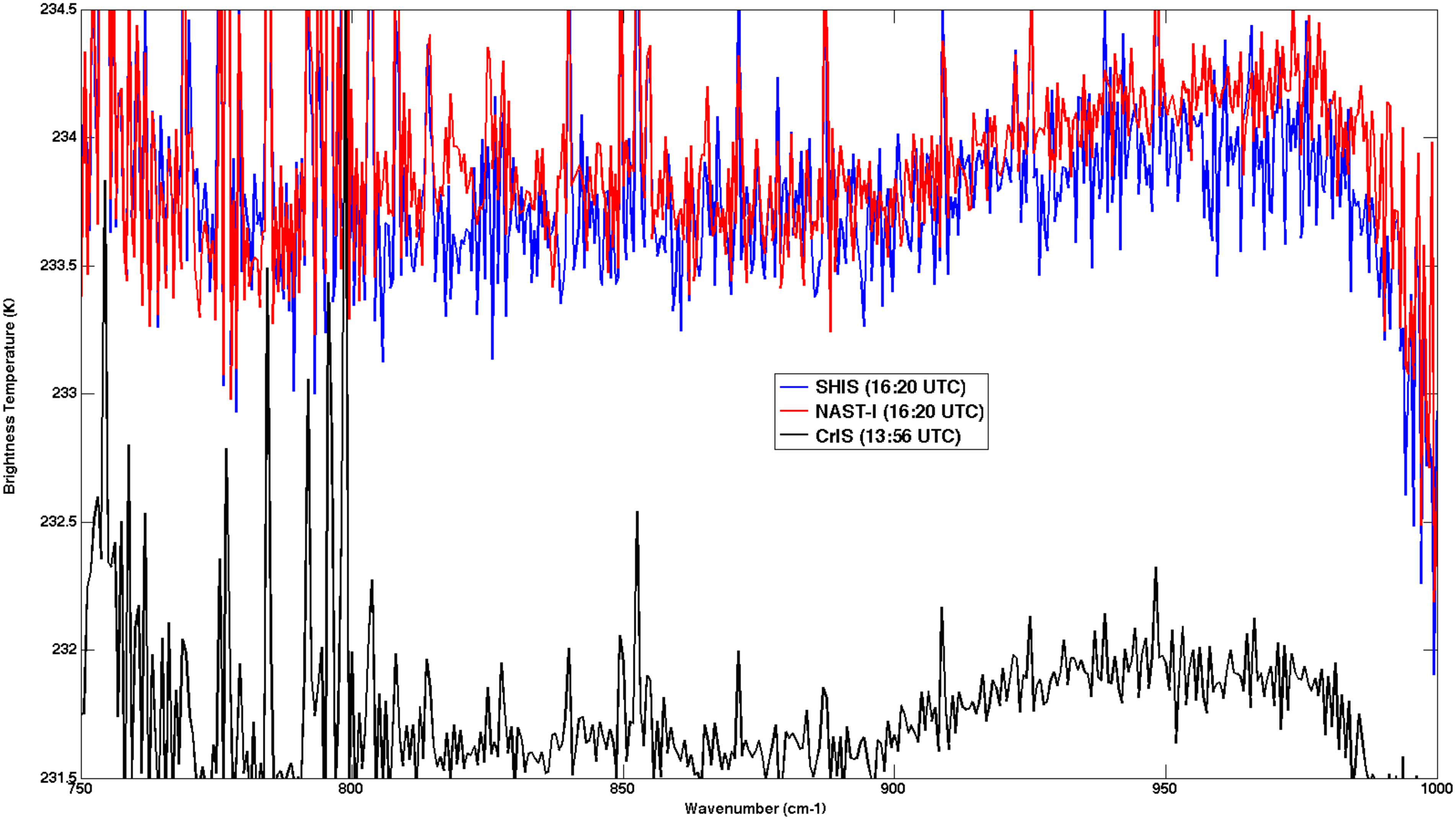
Ground Validation Site:

Summit Station (72°36′ North, 38°25′ West), a research platform at the summit of the Greenland ice sheet.

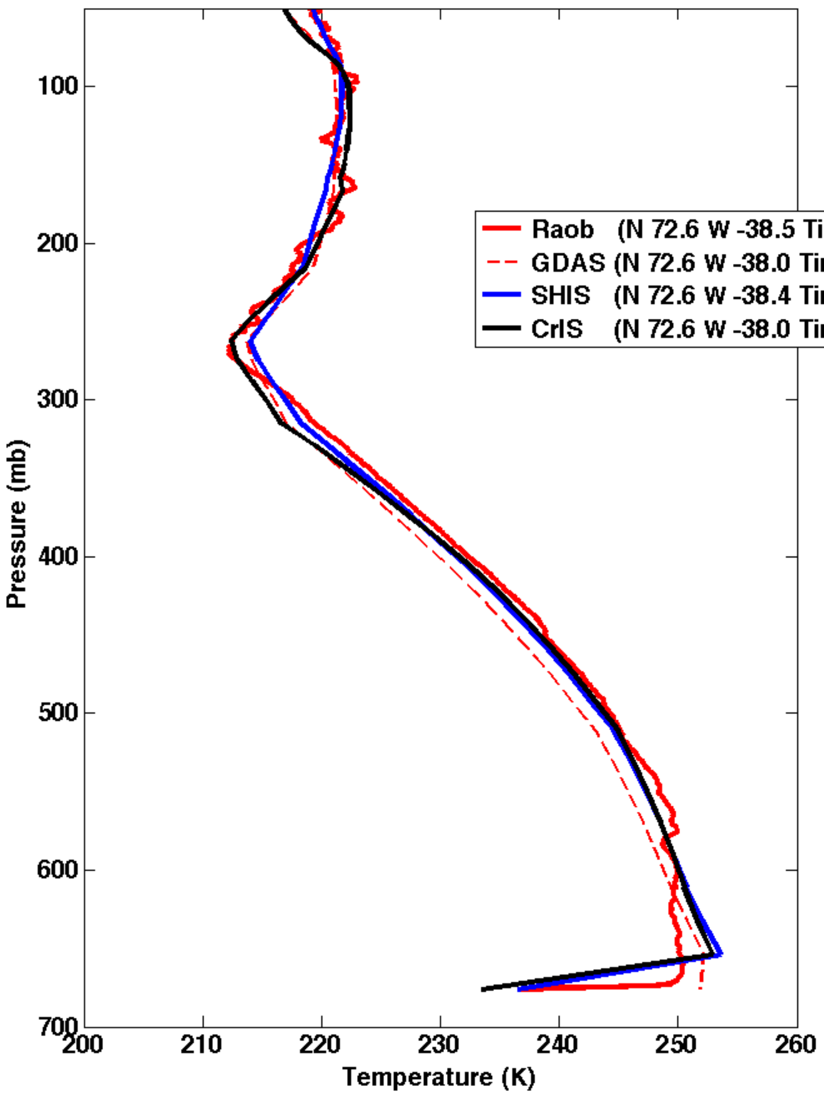


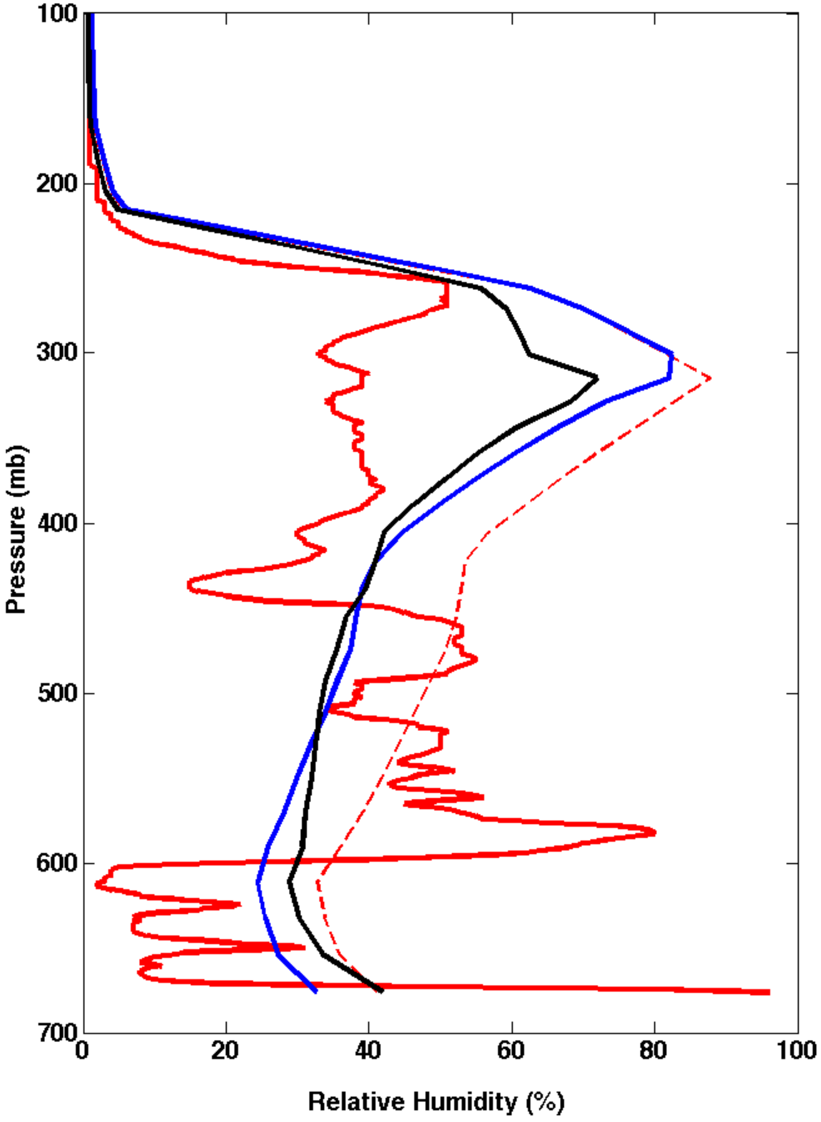
March 19, 2015 Radiance Comparison

Note: 3-Hr time difference between ER-2 and SNPP Radiance Observations

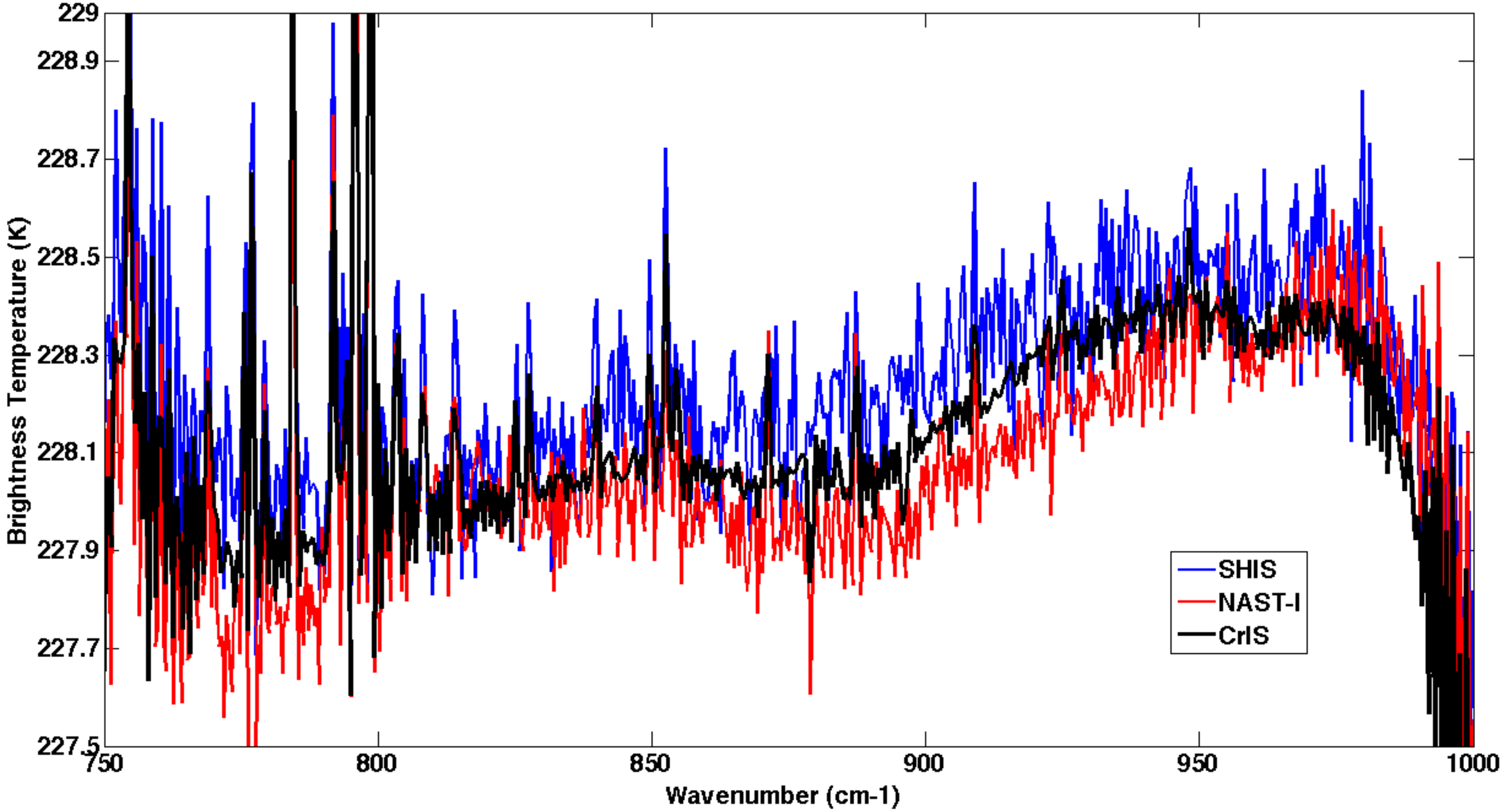


Raob Vs.SHIS & CrIS DR Retrieval Summit Greenland (March 19, 2015)



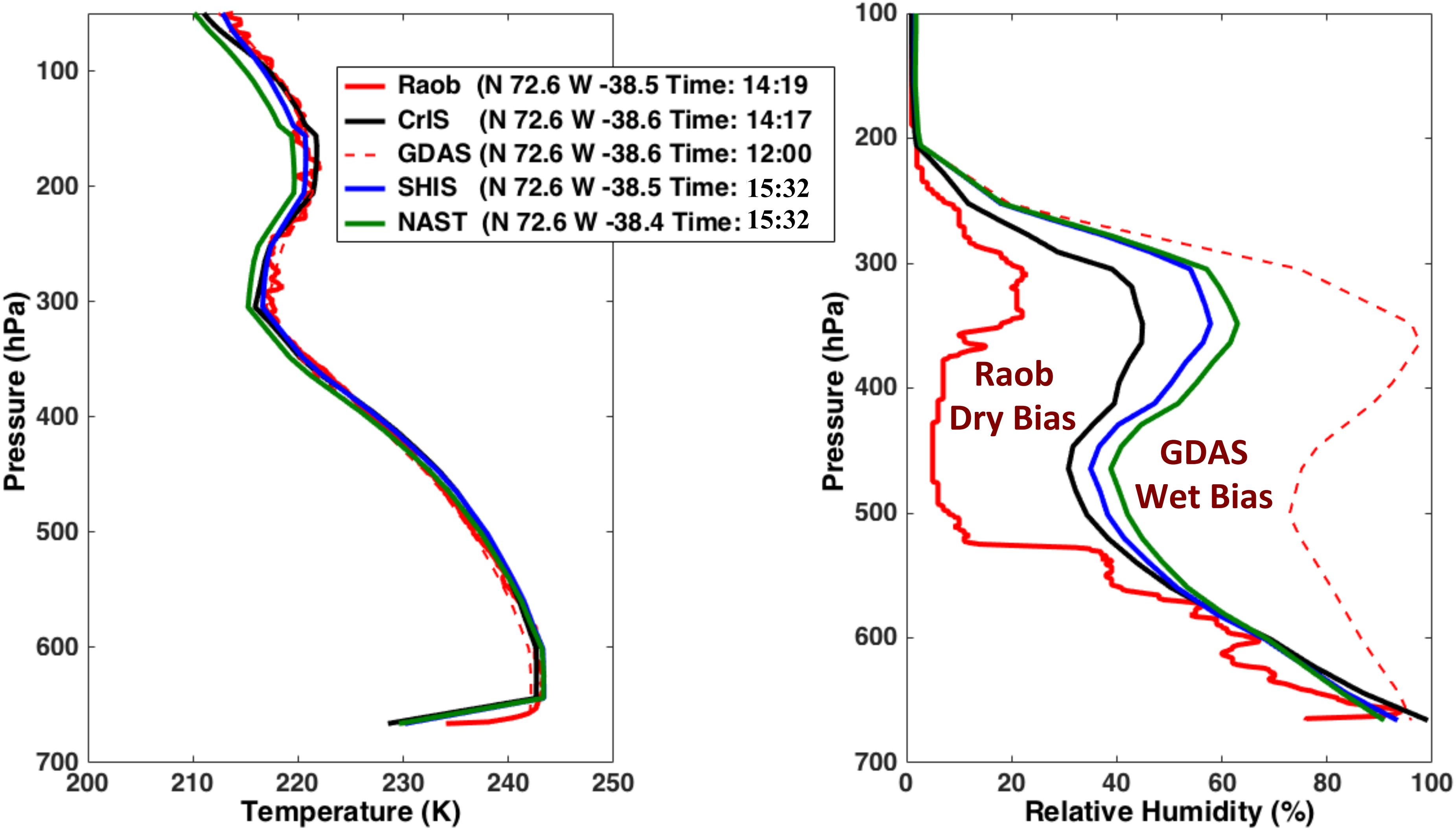


March 23, 2015 Radiance Comparison



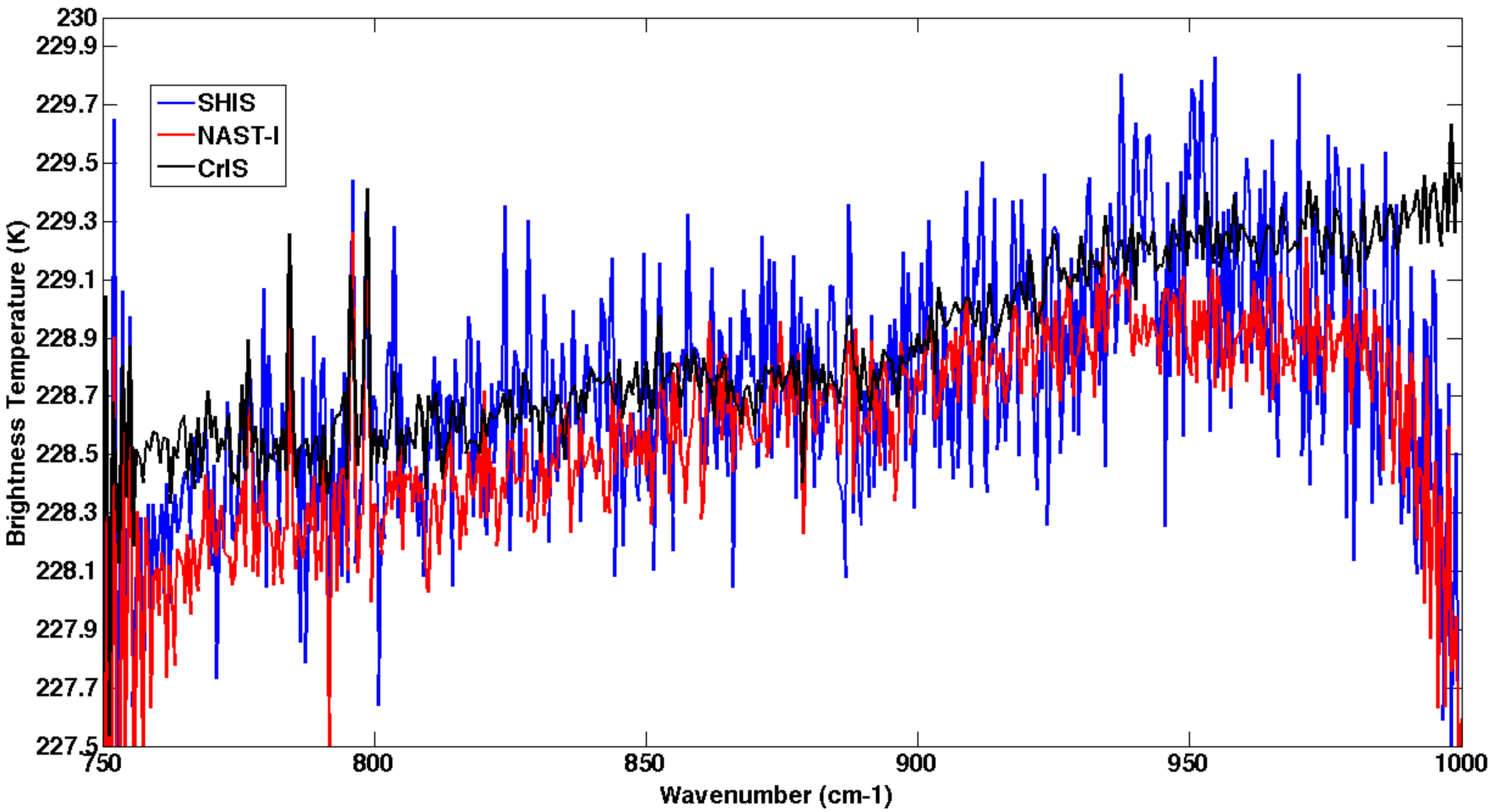
Radiosonde Vs. DR Retrievals*

Summit Greenland (March 23, 2015)

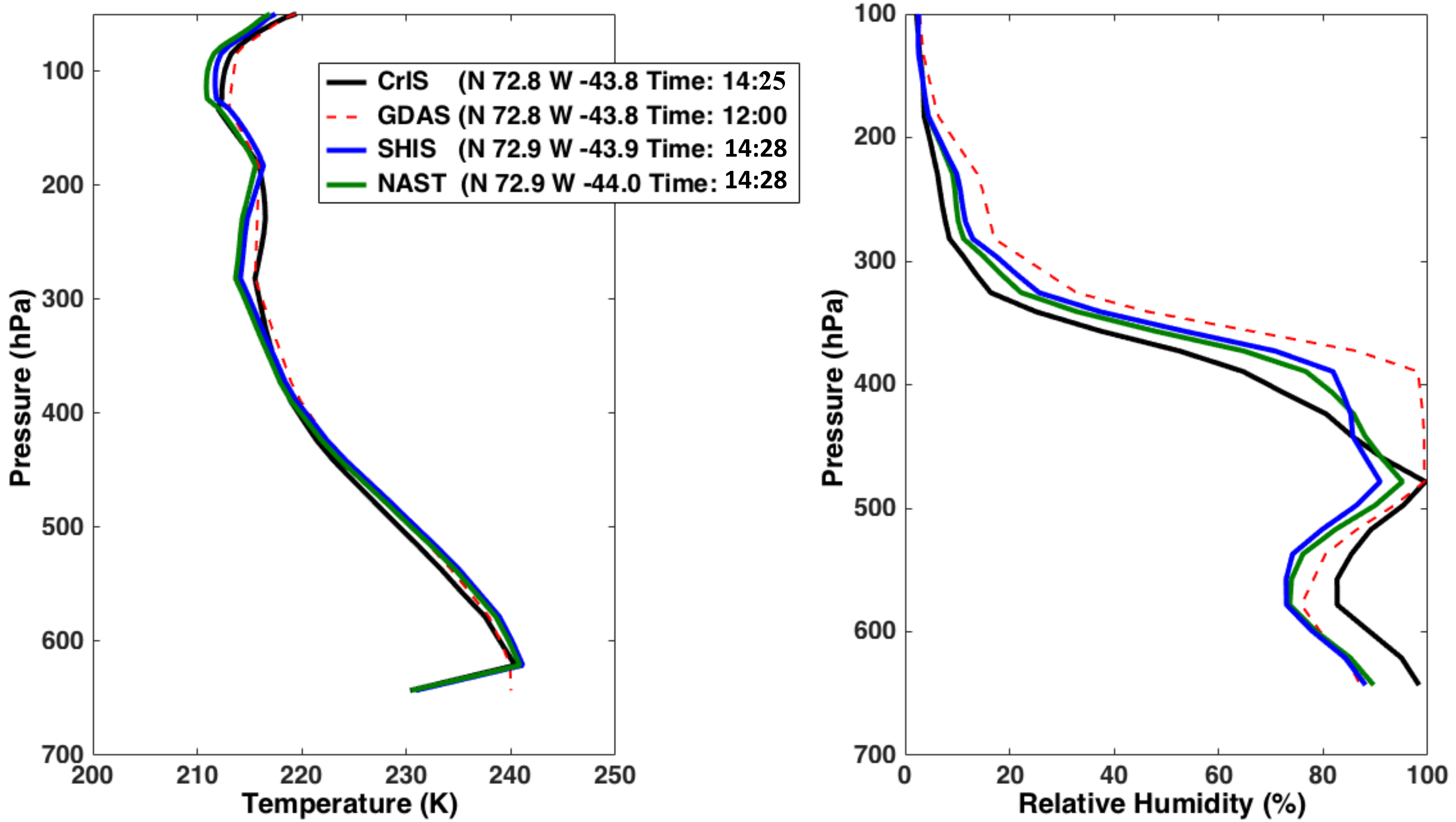


* 25-km Average Retrieval Closest to the Summit Radiosonde Location

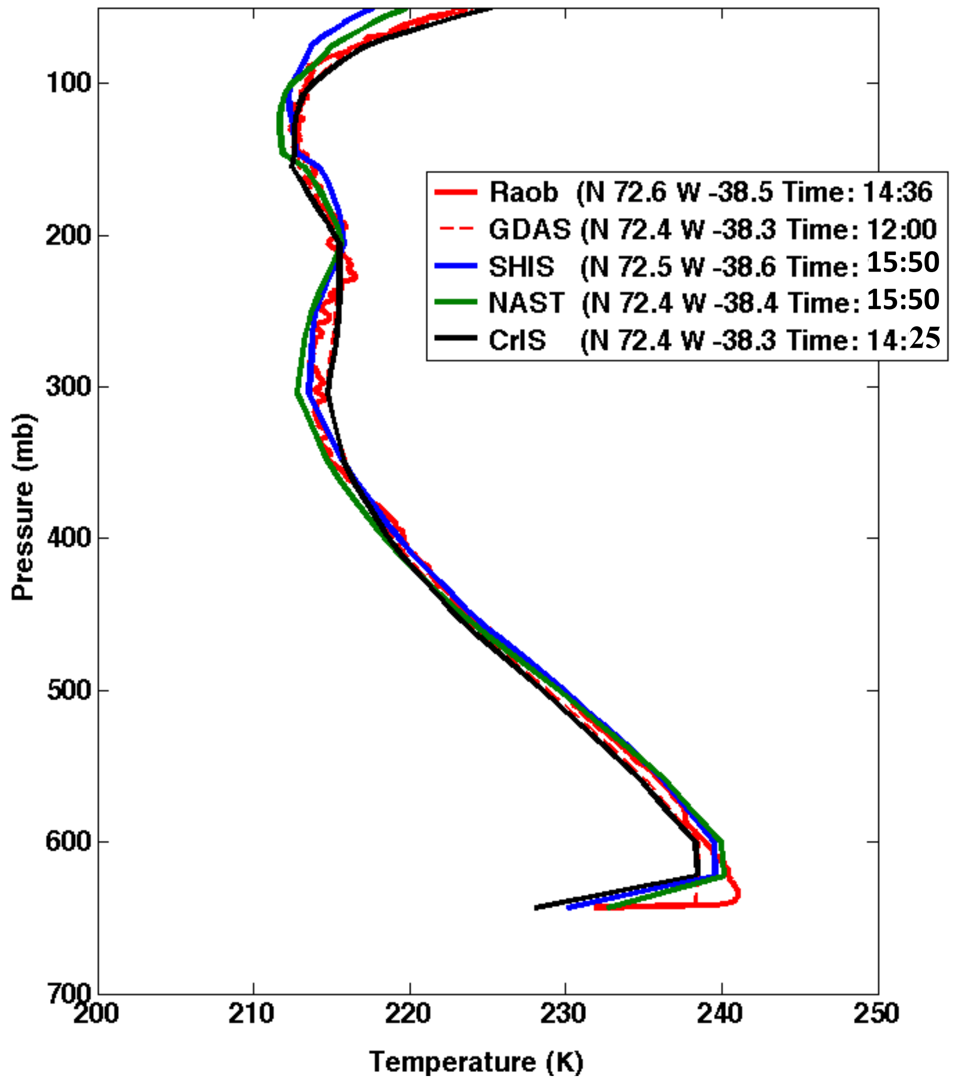
March 28, 2015 Radiance Comparison

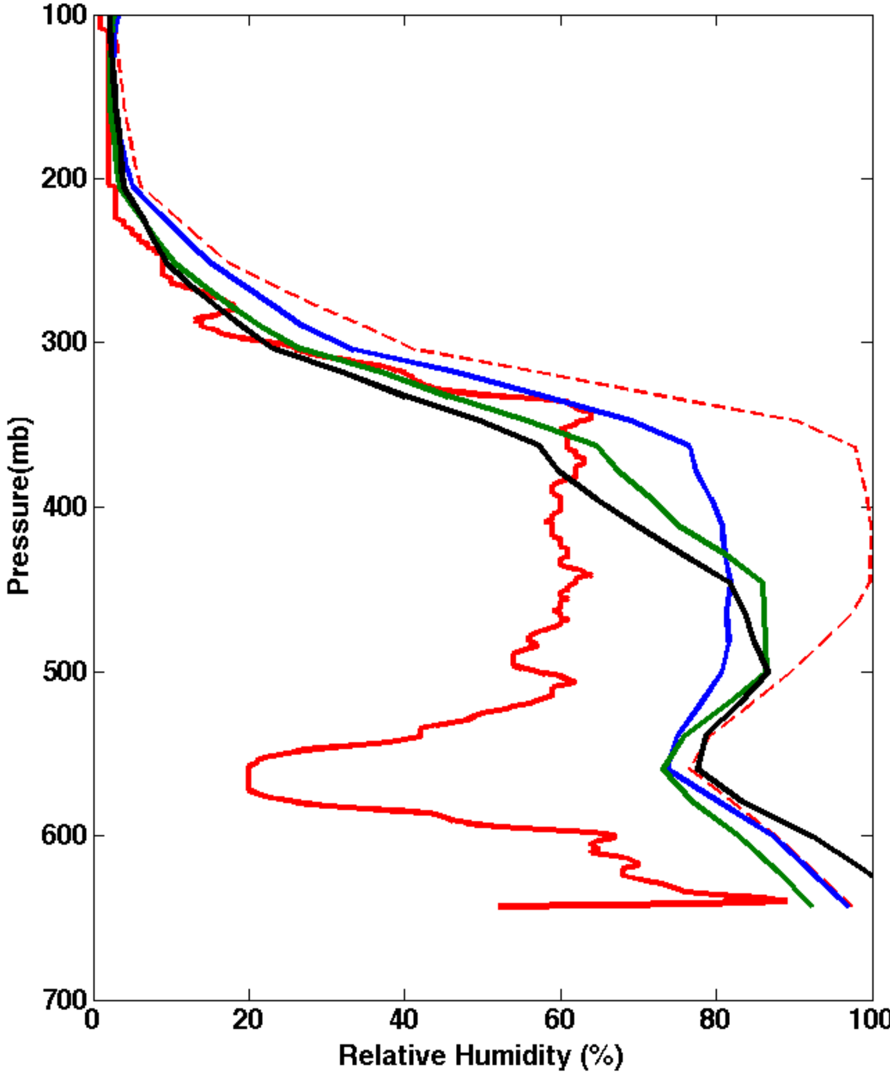


SHIS & NAST Vs. CrIS DR Retrieval Greenland (March 28, 2015)



Raob Vs.SHIS & NAST & CrIS DR Retrieval Summit Greenland (March 28, 2015)

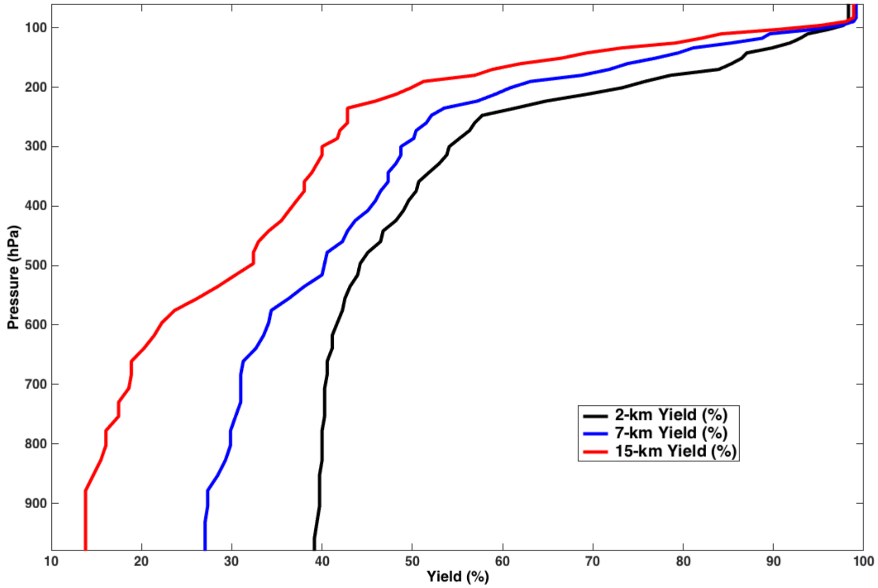




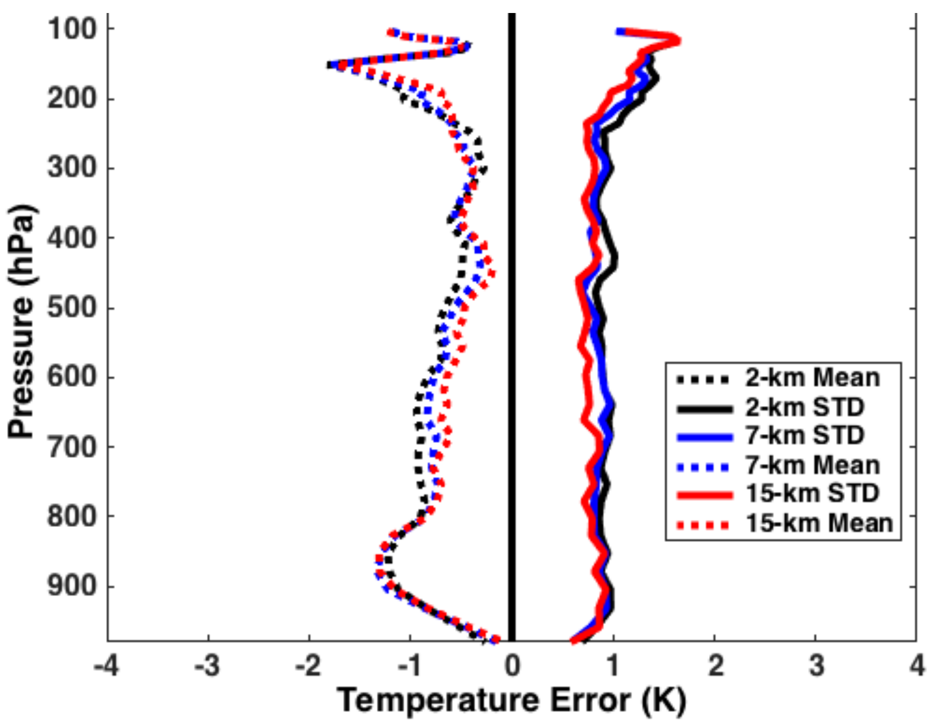
CrIS Sounding Dependence on FOV Size – Retrieval Yield and Accuracy

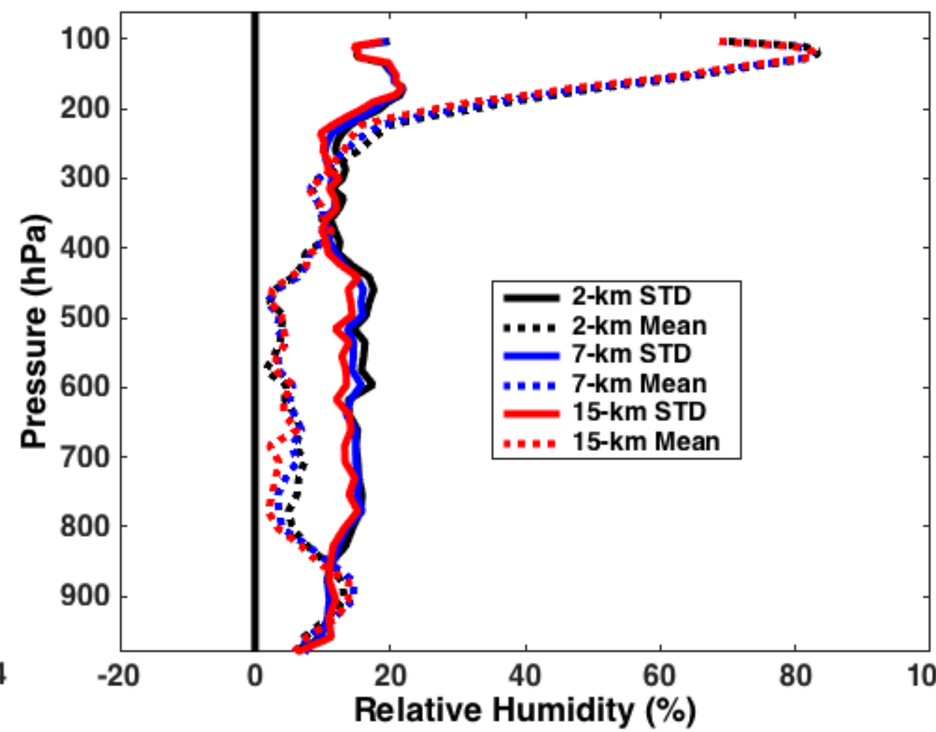
- **Future JPSS CrIS sounding yield can be greatly improved by reducing the Field-Of-View (FOV) size of the CrIS instrument.**
- **This improvement is demonstrated using NASA Global Hawk HS3 SHIS retrievals and simultaneous Dropsonde profiles.**
- **CrIS retrievals are created by averaging full resolution (1-2 km) SHIS retrievals over assumed CrIS FOV sizes (2-km, 7-km, 15-km).**
  - ***A single CrIS FOV sounding is considered to be missing below the highest cloud level of any SHIS retrieval being averaged, the profile in the clear air above the cloud is retained.***
  - ***The CrIS 50-km Field-of-Regard (FOR) average "CrIS" sounding is then formed and yield (%) and Mean and Random Error statistics are obtained by comparisons with simultaneous dropsonde profiles.***

Retrieval Accuracy and Yield Dependence on FOV Size



Results show that if the FOV density is increased with decreasing FOV size in order to maintain FOV contiguity, the FOR (e.g. 50-km area) sounding yield is greatly increased in cloudy sky conditions without increasing sounding noise level. This result is a result of the DR linear retrieval method which outputs clear-air retrievals above cloud-top level (i.e., all clear air radiance information within cloudy FOVs is used to obtain the average FOR profile).





Summary & Conclusions

- **Global Hawk S-HIS and dropsonde data have been used to validate the accuracy of the Dual Regression (DR) retrieval algorithm**
  - Temperature/humidity accuracy ≈ 1 K / 10 %
  - Errors much smaller than GDAS analysis errors when GDAS differs significantly from the dropsonde observations
- **Radiosonde observations and NASA ER-2 aircraft NAST-I and S-HIS observations utilized with the DR regression retrieval algorithm to validate SNPP CrIS sounding retrievals**
  - CrIS profile retrieval errors shown to be within the ≈ 1 K / 10% uncertainty of the DR retrieval error associated with airborne hyperspectral sounding retrievals and with radiosonde observations
- **If the FOV size of future CrIS instruments is reduced while maintaining FOV contiguity, the yield of sounding profiles can be greatly increased without sacrificing sounding accuracy**

Status of the NOAA Unique Combined Atmospheric Processing System (NUCAPS): algorithm upgrades and lessons learned after 5 years in orbit

Antonia Gambacorta (1), Chris Barnet (1), Nadia Smith (1), Jonathan Smith (1), Walter Wolf (2), Tom King (2), Michael Wilson (2), Letitia Suillard (2), Mark Liu (2), Tony Reale (2), Nick Nalli (2), Bomin San (2), Kexin Zhang (2), Changyi Tan (2), Flavio Iturbide-Sanchez (2), Xiaozhen Xiong (2), Mitch Goldberg (3)

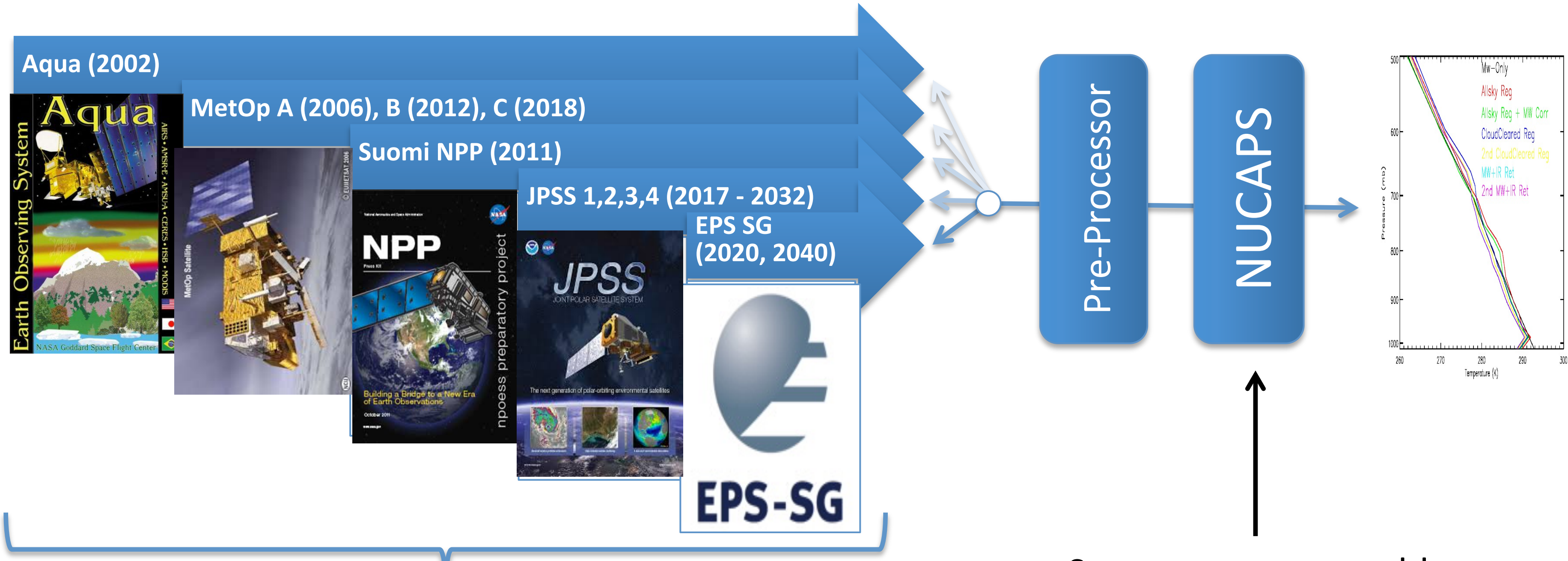
3rd JPSS Annual Meeting
August 10, 2016

1. Science and Technology Corporation, STC
2. NOAA NESDIS STAR
3. NOAA JPSS Project Scientist

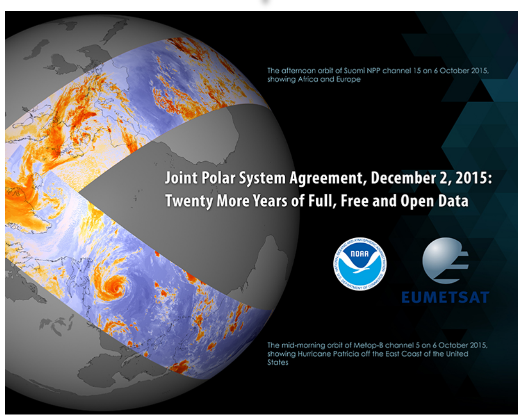
Introduction

- The **NOAA Unique Combined Atmospheric Processing System (NUCAPS)** is the NOAA operational algorithm to retrieve temperature, water vapor and trace gases from IR hyper spectral sounders (AIRS, CrIS, IASI) in combination with microwave (AMSU, MHS, ATMS) and visible (MODIS, AVHRR, VIIRS) instruments .
- NOAA/NESDIS/STAR has been operationally running NUCAPS since 2003 and distributing its products in near real time (~2 hour latency) to the science community through CLASS.
- On September 3rd 2014, NUCAPS passed stage 1 at the JPSS validation review.
- NUCAPS has been implemented in AWIPS-II.
- NUCAPS is now running on Univ. of Wisconsin's PEATE (Product Evaluation and Algorithm Test Element) test machine
- Full implementation of NUCAPS in the Community Satellite Processing Package (CSPP) was completed in Dec. 2014 and went operational in February 2015. Direct broadcast latency is ~ 0.5 hour.
- **Focus of this talk:** an overview of the status of the algorithm, lessons learned in the past years and the path forward.

The history of the NOAA Unique Combined Atmospheric Processing System (NUCAPS)



Same exact executable
Same underlying Spectroscopy
Same look up table methodology
for all platforms



Philosophy of NUCAPS

- **The challenge**: high computationally efficiency and sophisticated inversion methods to maximize utilization of large volumes of data for real time weather and long-term climate applications

- **Philosophy of NUCAPS**: developing a mathematically sound and globally applicable (land/ocean, day/night, all season, all sky, TOA-surface) retrieval product that can fully exploit all available satellite assets (infrared, microwave, visible). These are among the essential metrics defining a modern, physical and independent data record of atmospheric variables, suitable for both weather and climate applications.

What's unique about NUCAPS?

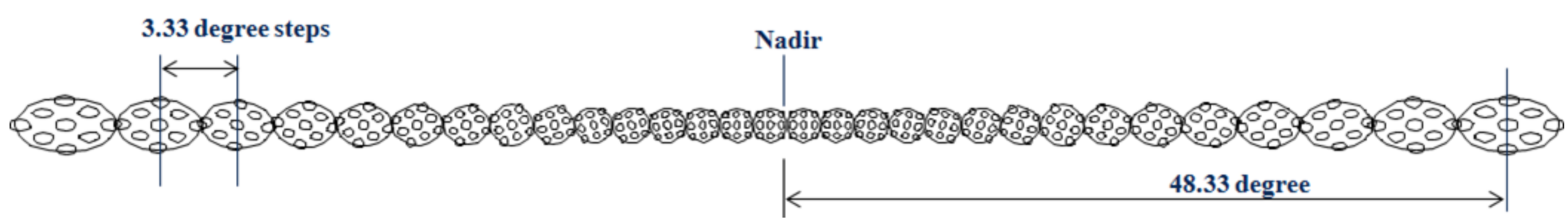
- **NOAA operational algorithm heritage of the AIRS Science Team code**, with additional unique components
- **Designed, from the beginning, to be product-centric** rather than sensor-centric (NPP Science Team priority recommendation)
  - AIRS/AMSU, IASI/AMSU/MHS, and CrIS/ATMS are processed with literally the same NUCAPS code.
  - Same underlying spectroscopy and look up table methodology
  - Instrument agnostic: specific items are file-driven, not hardwired
  - Extremely fast compared to other approaches (1 CPU for CrIS/ATMS)
  - Code is backward and forward (as much as possible) compatible.
  - Retrieval components are programmable via namelists (can quickly compare retrieval enhancements and/or methodologies).
  - Operational code is a "filtered" version of the science code.
  - Capable of processing CrIS full-resolution spectra (Gambacorta 2013 IEEE GRSL);
- **Uses an open framework** (NPP Science Team priority recommendation)
  - other researchers can link other algorithms for the core products and new algorithms for ancillary products (e.g., cloud microphysical products, trace gases, etc.).
- **Could add new products**
  - Ammonia, Formic Acid (HCOOH), and Peroxyacetyl Nitrate (PAN), etc.

What's unique about NUCAPS?

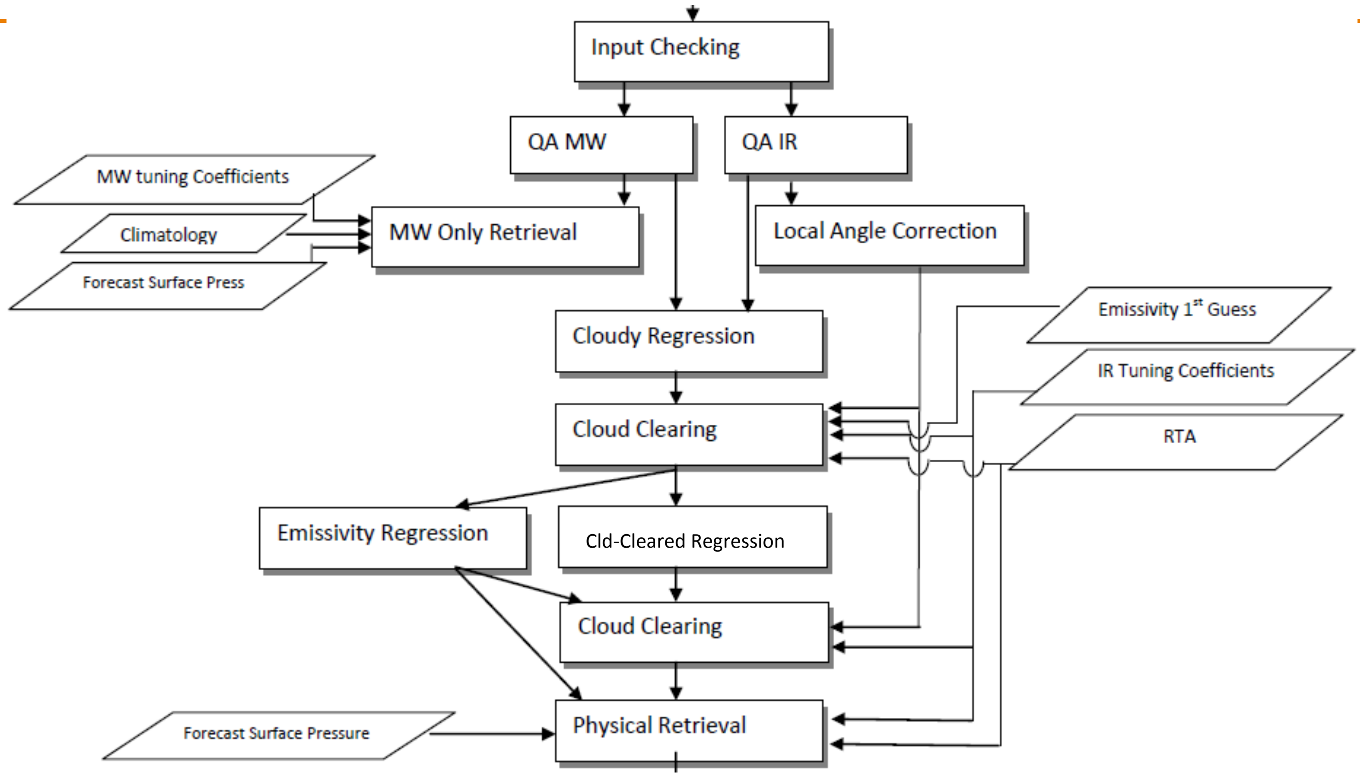
- **Designed to use all available sounding instruments.**
  - Microwave radiances used in microwave-only physical retrieval, "allsky" regression solution, "cloud cleared" regression and downstream physical T(p) and q(p) steps.
  - Visible radiances used to improve cloud clearing
- **Utilizes the high-information content of the hyper-spectral infrared – both radiances and physics.**
  - Climatological startup. Only ancillary information used is surface pressure from GFS model
  - Sequential physical algorithm allows for a robust and stable system with minimal geophysical a priori dependence
  - Utilizes forward model derivatives as spectral constraint to help stabilize the solution
  - Error from previous steps are mapped into an error estimate from interfering parameters
- **Utilizes cloud clearing**
  - Goal is to sound as close to the surface as possible
  - Sacrifices spatial resolution to achieve global coverage: no clear sky biases
  - Allows graceful degradation with decreased information content
  - Avoids ad hoc switches between clear sky only and cloudy sky single FOV algorithms

Goal of NUCAPS is to sound as close to the surface as possible

- We use a cluster of 9 infrared footprints to eliminate the effects of clouds
  - Cloud clearing sacrifices spatial resolution for coverage
  - Cloud clearing works in ~70% of cases (~225,000 / 324,000 per day)
  - Removes the difficulty of separating clouds from temperature and water vapor, typical of simultaneous cloudy retrievals
  - Works with complex cloud systems (multiple level of different cloud types).
  - Simple concept: a small number of parameters can remove cloud contamination from thousands of channels.
  - Does not require knowledge of cloud microphysics, nor cloud a priori.
  - Error introduced by cloud clearing is formally built into the measurement error covariance matrix and propagated through downstream retrieval error steps.



NUCAPS Flow Chart



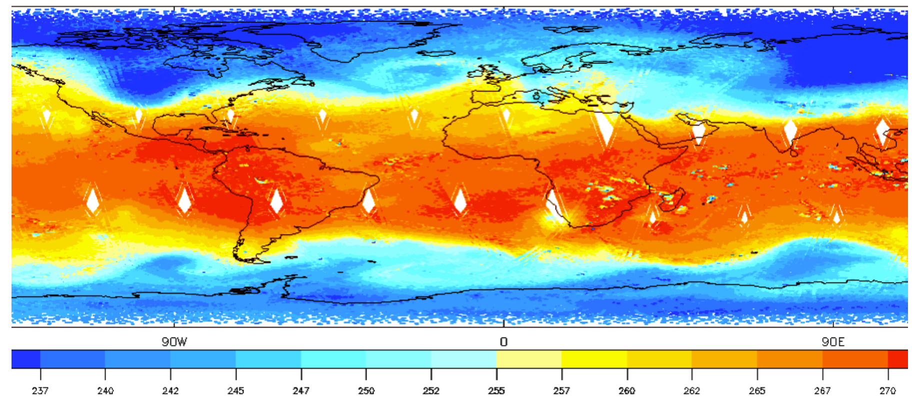
- **I. A microwave retrieval module** which computes Temperature, water vapor and cloud liquid water (Rosenkranz, 2000)
- **II. A fast eigenvector regression** retrieval that is trained against ECMWF and all sky radiances which computes temperature and water vapor (Goldberg et al., 2003)
- **III. A cloud clearing module** (Chahine, 1974)
- **IV. A second fast eigenvector regression** retrieval that is trained against ECMWF analysis and cloud cleared radiances
- **V. The final infrared physical retrieval** based on a regularized iterated least square minimization: temperature, water vapor, trace gases (O_3, CO, CH_4, CO_2, SO_2, HNO_3, N_2O) (Susskind, Barnet, Blaisdell, 2003)

NUCAPS operational retrieval products

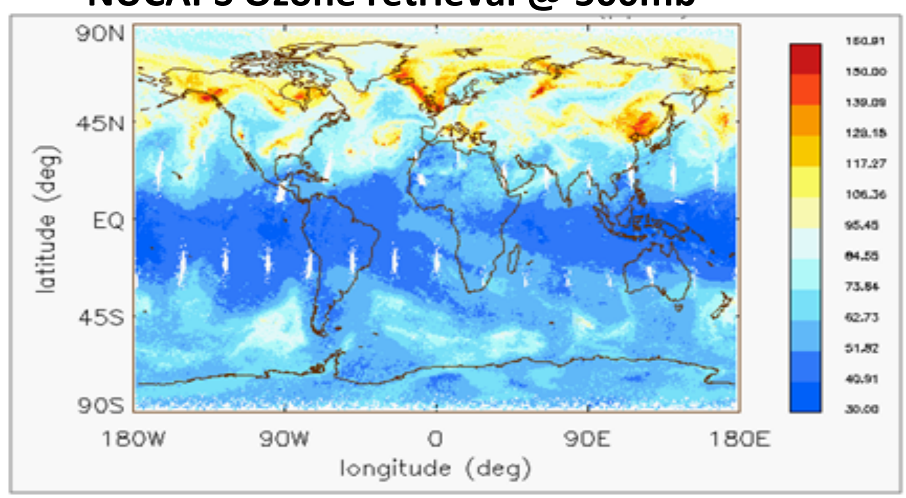
Retrieval Products

Cloud Cleared Radiances	**660-750 cm-1** **2200-2400 cm-1**
Cloud fraction and Top Pressure	**660-750 cm-1**
Surface temperature	**window**
Temperature	**660-750 cm-1** **2200-2400 cm-1**
Water Vapor	**780 – 1090 cm-1** **1200-1750 cm-1**
O3	**990 – 1070 cm-1**
CO	**2155 – 2220 cm-1**
CH4	**1220-1350 cm-1**
CO2	**660-760 cm-1**
N2O	**1290-1300cm-1** **2190-2240cm-1**
HNO3	**760-1320cm-1**
SO2	**1343-1383cm-1**

NUCAPS Temperature retrieval @ 500mb



NUCAPS Ozone retrieval @ 500mb

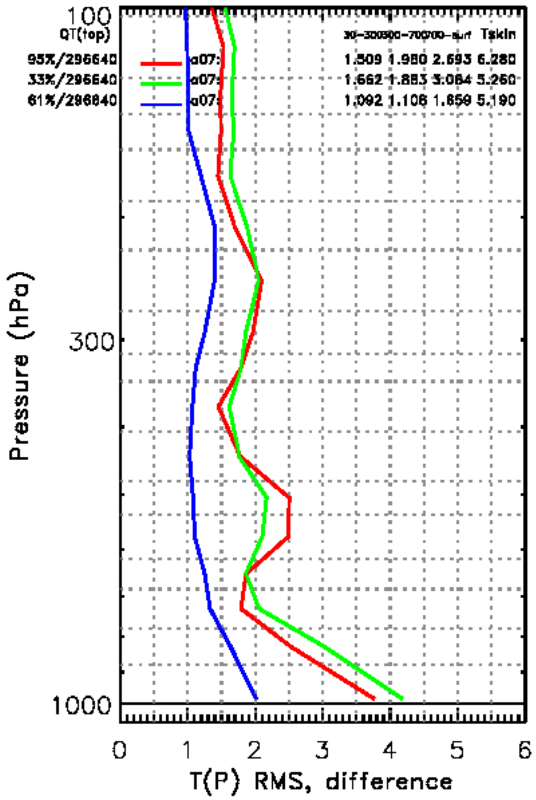


One year has gone by…

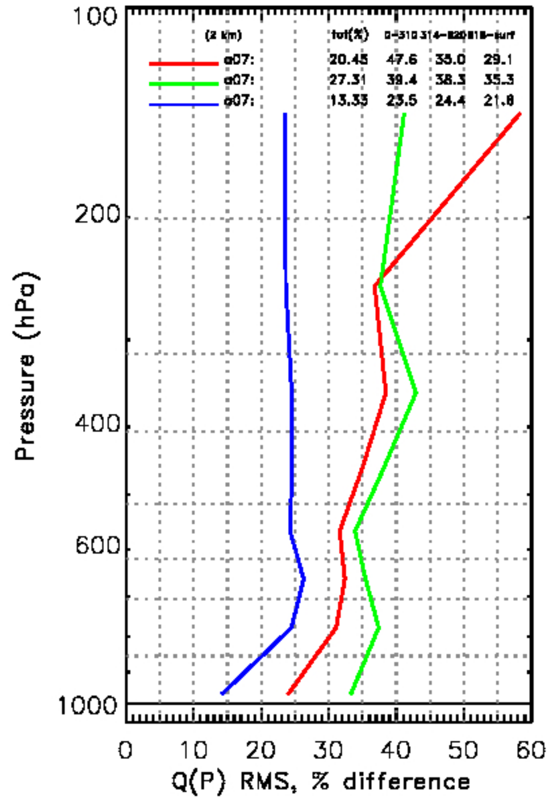
- A team effort between NOAA/STAR, NPP Science Team and NOAA JPSS:
  - A fully functional NUCAPS MW-only retrieval module, consistent across AMSU/MHS and ATMS
  - A fully functional NUCAPS in CrIS high resolution mode
    - NUCAPS Phase IV CDR held on February 4, 2016
    - NUCAPS high resolution first guess modules
    - NUCAPS high resolution channel selection
    - NUCAPS high resolution RTA model and bias correction
    - Delivery expected in late 2016.
  - A fully functional capability of NUCAPS in IR-only mode

Global RMS Performance of NUCAPS

Temperature RMS



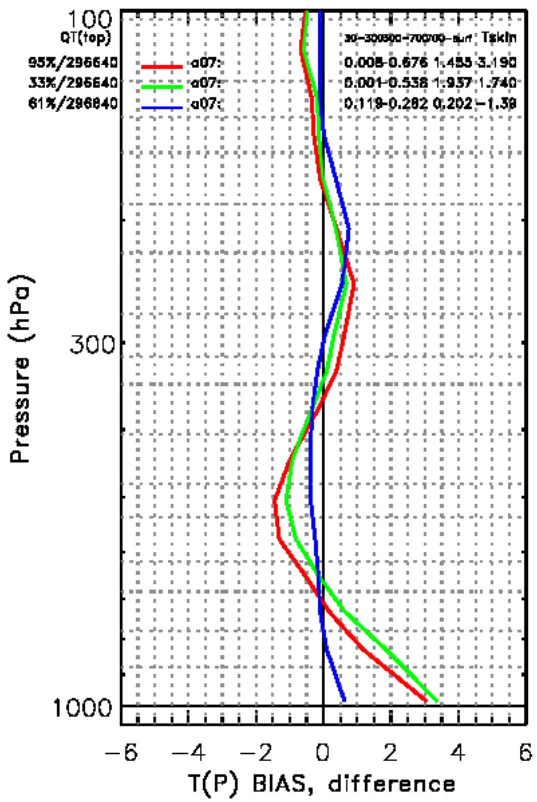
Water vapor RMS



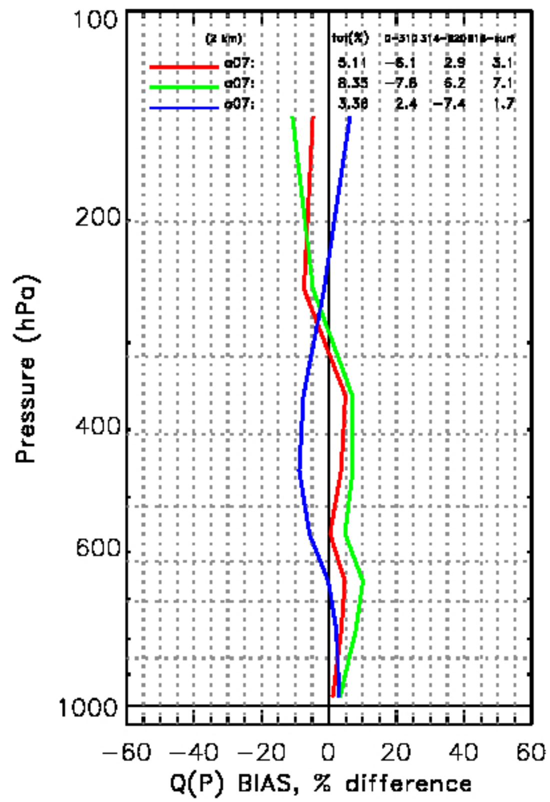
NUCAPS MW ONLY (95%) **NUCAPS MW+IR (70%)** **NUCAPS MW ONLY (rejected by IR, 30%)**

Global Performance (BIAS)

Temperature RMS



Water vapor RMS



NUCAPS MW ONLY (95%) **NUCAPS MW+IR (70%)** **NUCAPS MW ONLY (rejected by IR, 30%)**

A busy list of JPSS funded initiatives to demonstrate NUCAPS application capabilities

I. **Aviation Weather Testbed (AWT)**: Cold Air Aloft

II. **NUCAPS in AWIPS-II**: training & improvements

III. **Hazardous Weather Testbed (HWT)**: Convective Initiation

IV. **Hydrometeorology Testbed (HMT)**: Pacific field campaigns (2014, 2015 CalWater & 2016 ENRR)

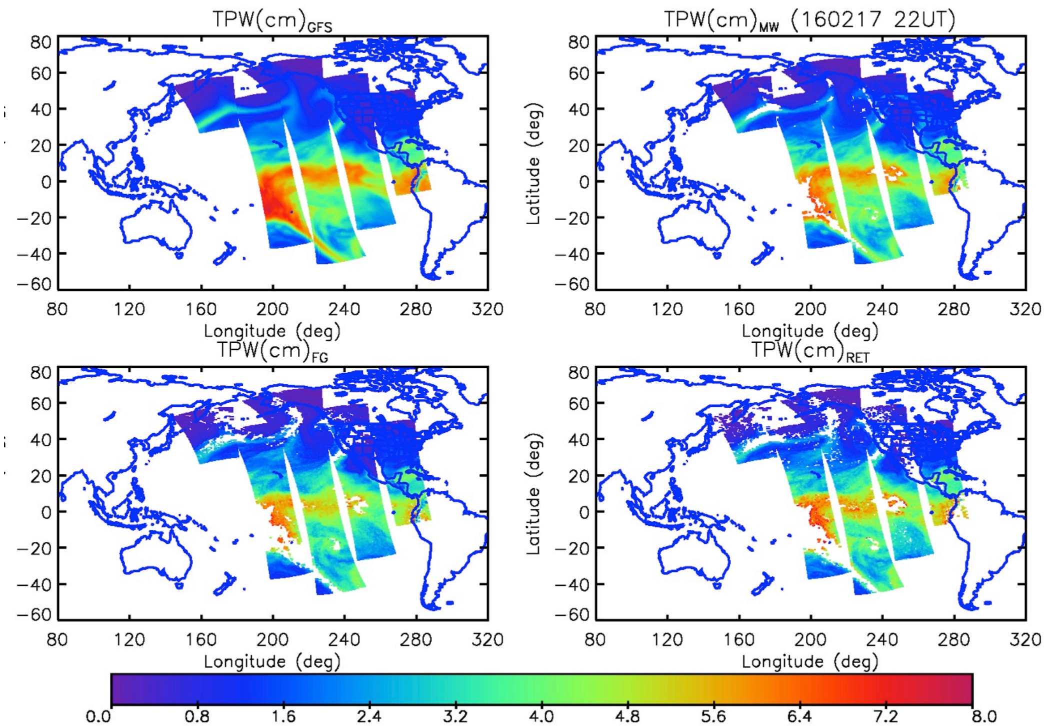
V. **Carbon Monoxide and Methane product evaluation** (NESDIS/STAR & OAR/ESRL/CSD)

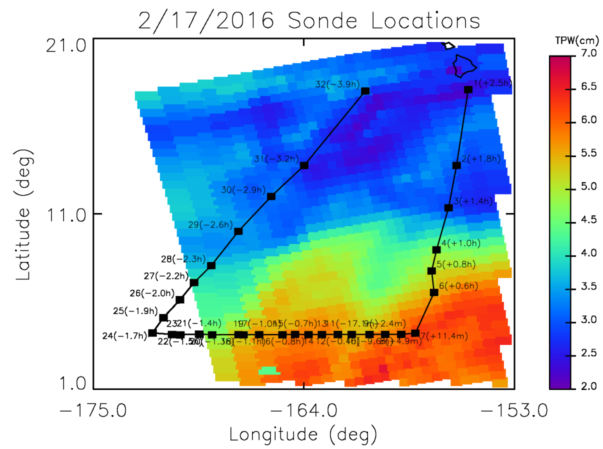
VI. **Use of NUCAPS Ozone in hurricane extratropical transition applications**

How can NUCAPS add value to the forecast of societally relevant weather events?

- Our goal is to demonstrate NUCAPS soundings capability in capturing high impact mesoscale phenomena over otherwise poorly sampled regions.
- NUCAPS implementation into CSPP direct broadcast enables unprecedented low latency data distribution, suitable for decision aid applications.
- Primary goal is to promote user applications.
- Intensive field campaign data are incredibly valuable for algorithm validation
  - Synergistic initiatives yield a large sample of in-situ data (~450 dropsondes and 175 radiosondes from CalWater-15 alone)
  - NUCAPS is a test-bed to study new methodologies

Assessing and improving NUCAPS sounding capability during high impact weather events: a test case from the 2016 El Nino Rapid Response Campaign



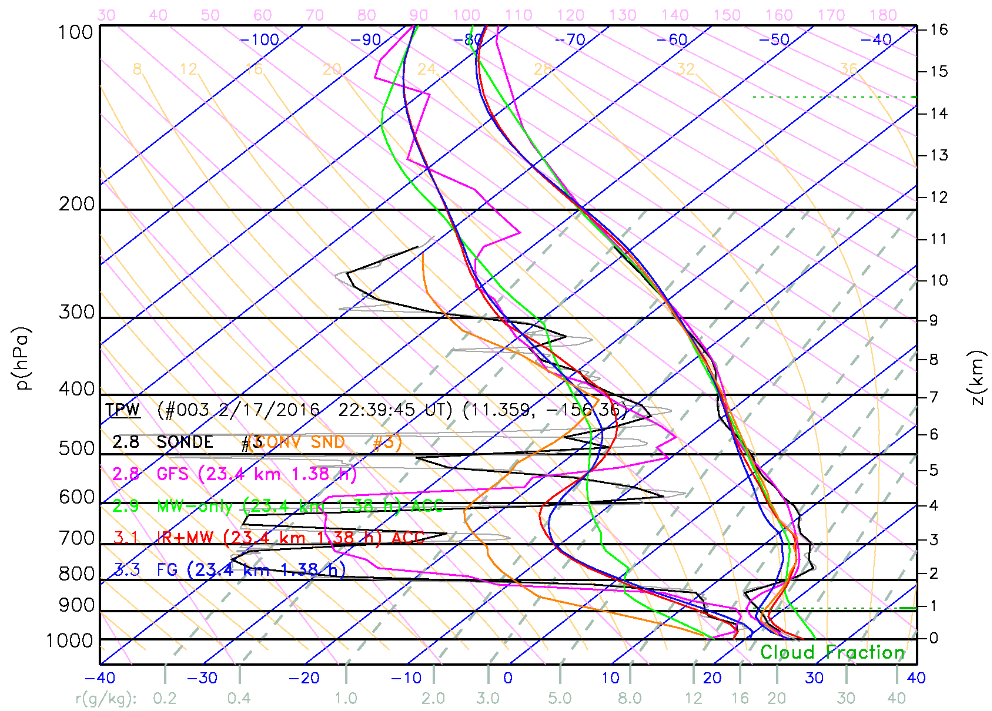


A close up figure over the flight path

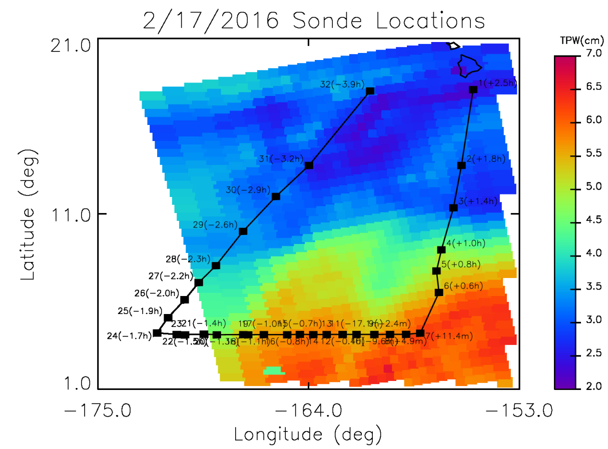
A snapshot of the full region

➤Satellite data can provide near real time (~0.5 hour), 3D context to a high impact weather event

El Nino Rapid Response Campaign
February 17, 2016

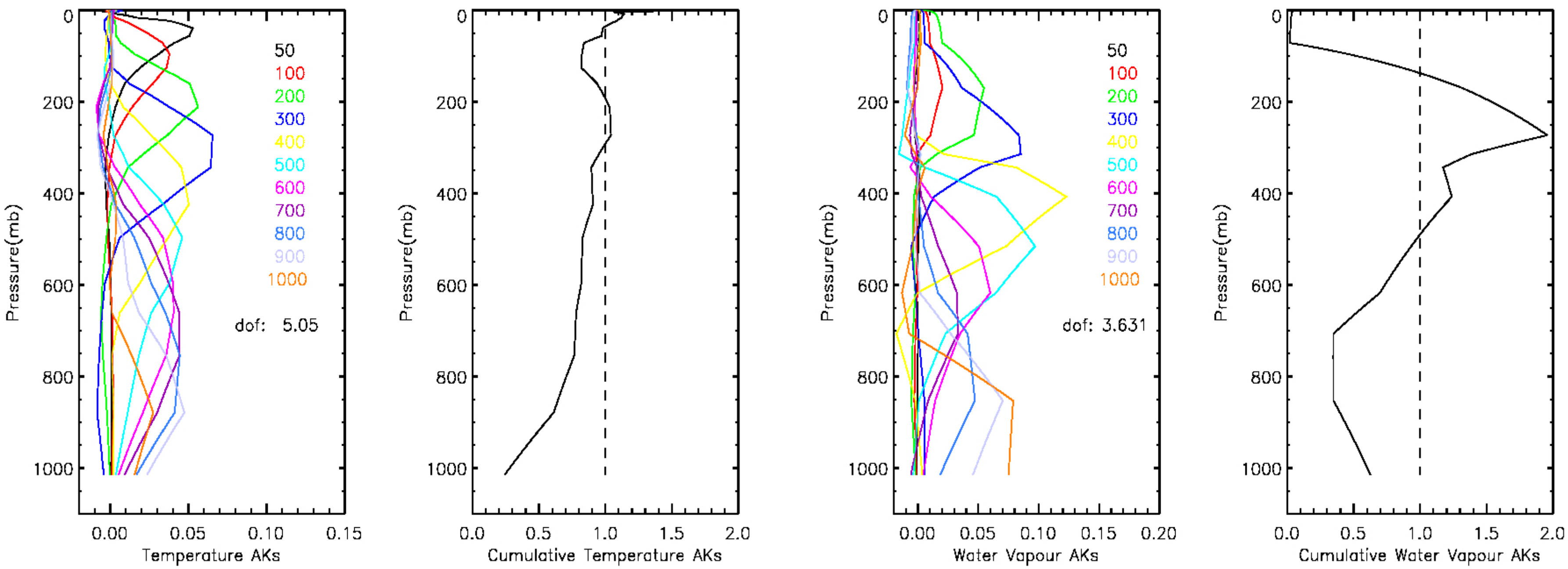


Orginal Sonde, AK-conv. Sonde, GFS, MW-only, MW+IR, FG



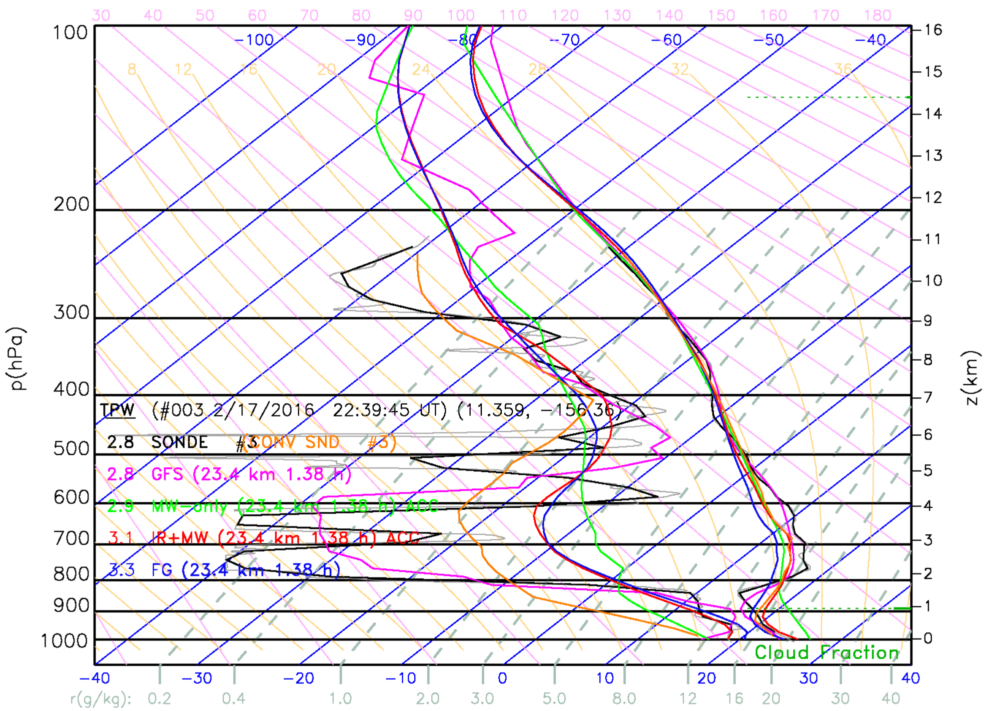
- We are building a diagnostic capability to assess NUCAPS performance under high impact weather events. This will enable a more intelligent use of NUCAPS products and ultimately serve to make improvements on the algorithm.

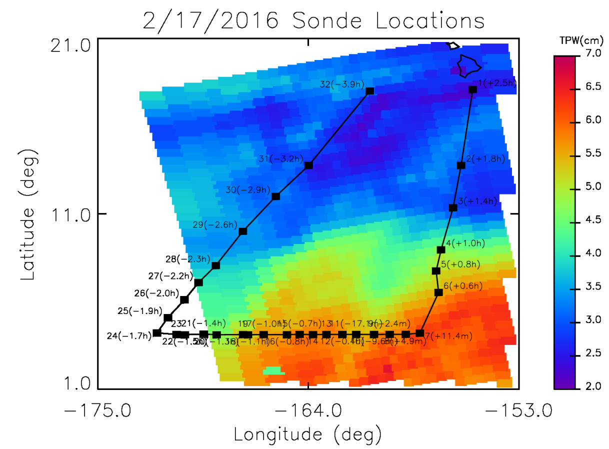
Vertical resolution, information content and departure from first guess as metrics to assess *and improve* retrieval performance



- Averaging Kernels provide insights on NUCAPS effective vertical resolution (broadness of the peaks), information content (magnitude of the peaks) and separation of the contributions to the solution originating from the measurement and from the a-priori.
- They represent a necessary tool for any characterization, validation and proper application of a retrieval product.

El Nino Rapid Response Campaign
February 17, 2016





- We are building a diagnostic capability to assess NUCAPS performance under high impact weather events. This will enable a more intelligent use of NUCAPS products and ultimately serve to make improvements on the algorithm.
- What's NUCAPS effective vertical resolution and how can we improve it?
- Where do we have and how can we improve information content?
- What are the sources of retrieval error at play?

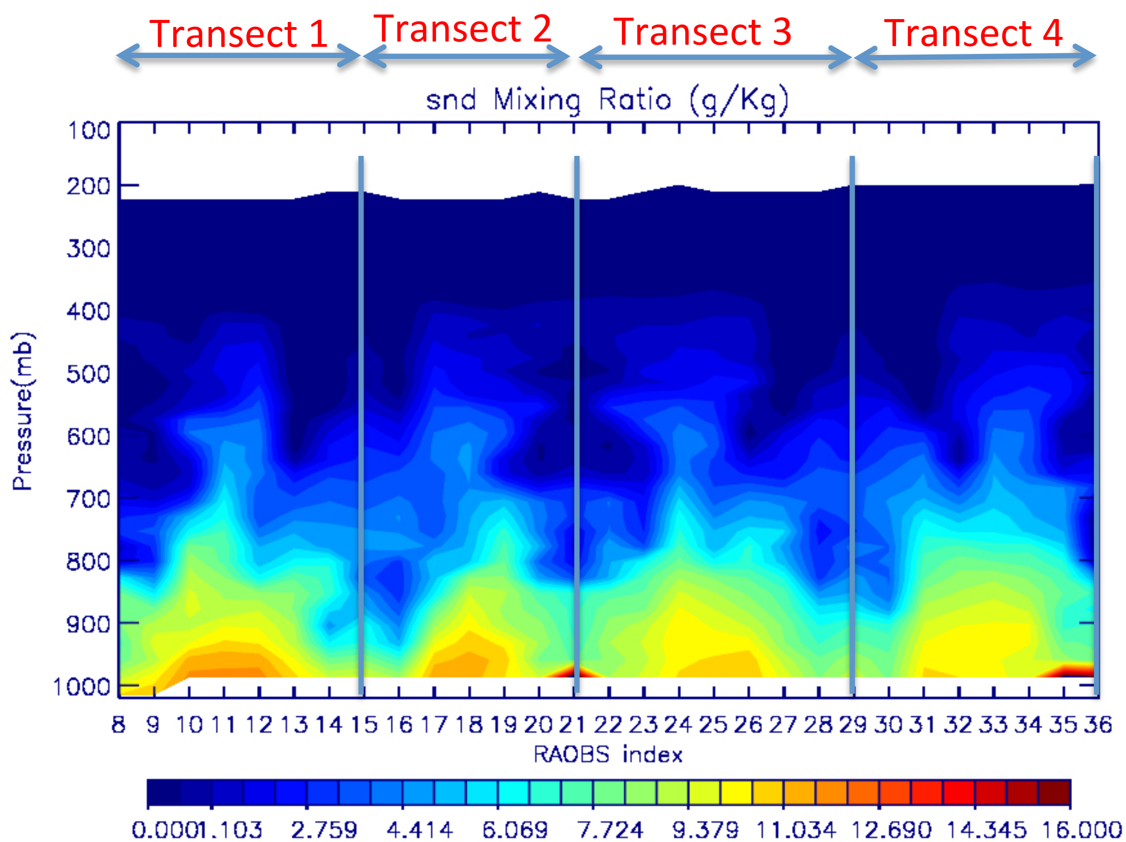
Channel selections, A priori, QCs, RTA, CCR, err prop., etc.

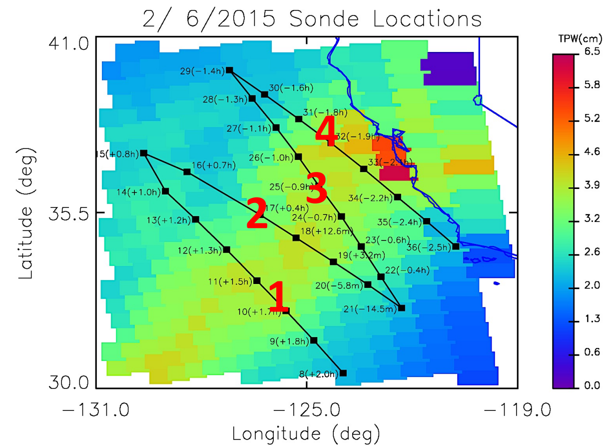
Summary & Future Work

- NUCAPS has demonstrated to meet user requirements
- NUCAPS Phase IV expected to become operational this Fall in preparation for J1.
- We now have ground truth and a diagnostic capability to assess NUCAPS performance under high impact weather events for user applications of societal importance.
- This new type of validation approach enables a more intelligent use of NUCAPS products, engages new users, promotes new users requirements, leads to improvements to the retrieval products, justifies transition to operations.

Backup slides

Radiosonde measurements from CalWater 2015 February 6th test case





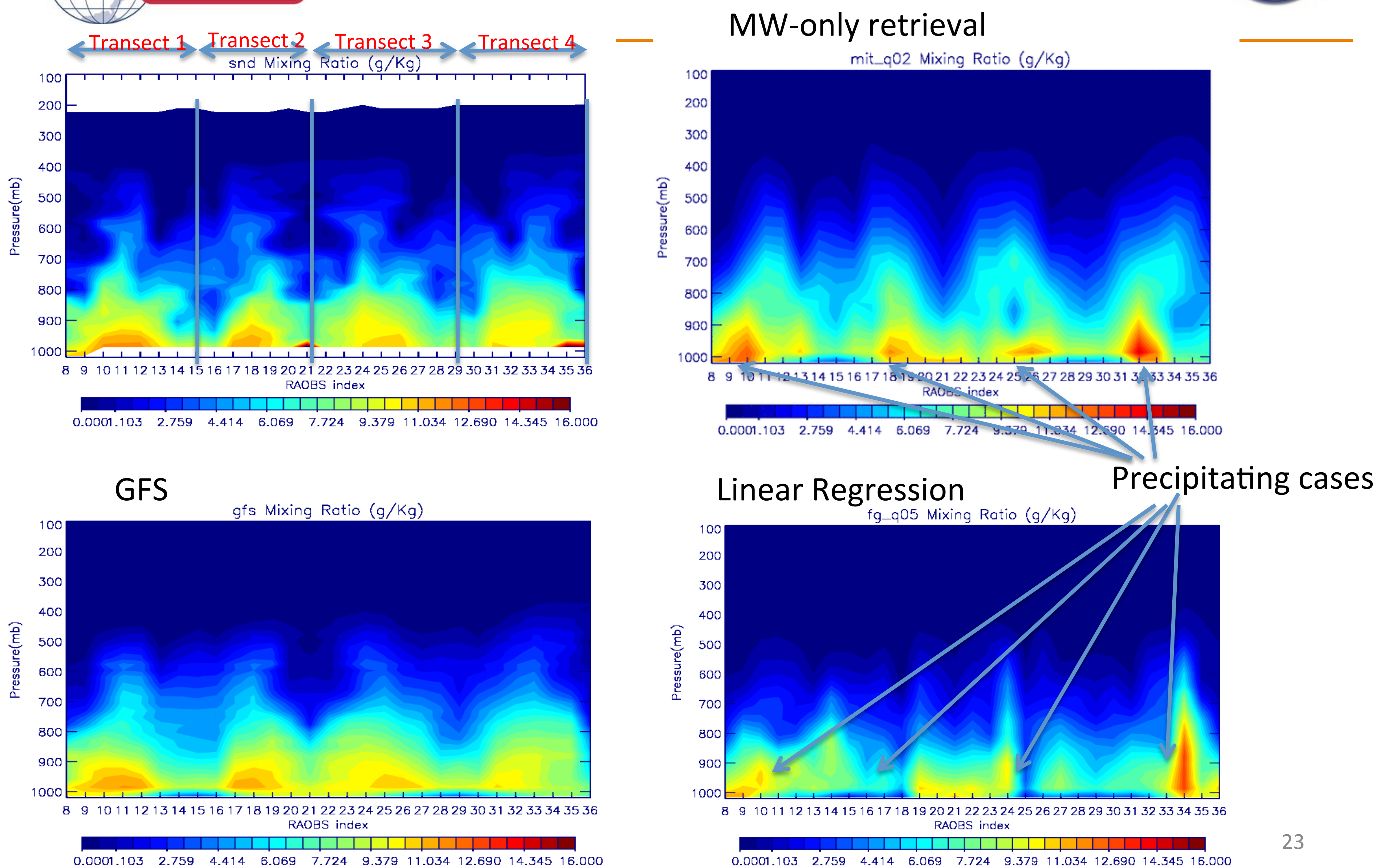
- ~ 4 hours flight with 4 transects across the river capturing pre, in and post river environment as the river quickly approaches the US West coast
- Good spatial and temporal matching with NPP (drop sonde location 19 is ~ 3.2 minutes ahead of over pass

Understanding the role of the a priori and first guess

- NUCAPS is currently using a statistical operator (linear regression) as a priori

Pro's	Con's
Does not require a radiative transfer model for training or application.	Training requires a large number of co-located "truth" scenes.
Application of eigenvector & regression coefficients is VERY fast and for hyper-spectral instruments it is very accurate.	The regression operator does not provide any diagnostics or physical interpretation of the answer it provides. It can introduce sub-resolved structures in the retrieval
Since real radiances are used the regression implicitly handles many instrument calibration (e.g., spectral offsets) issues. This is a huge advantage early in a mission.	The regression answer builds in correlations between geophysical parameters. For example, retrieved O_3 in biomass regions might really be a *measurement* of CO with a statistical correlation between CO and O_3.
Since clouds are identified as unique eigenvectors, a properly trained regression tends to "see through" clouds.	Very difficult to assess errors in a regression retrieval without the use of a physical interpretation.

Towards a more stable a-priori and first guess choice



Correct choice of a priori and first guess

We have started investigating three possible *a-priori:*

1) climatology built from a decade of ECMWF (this has already been constructed by the AIRS science team and will be tested)

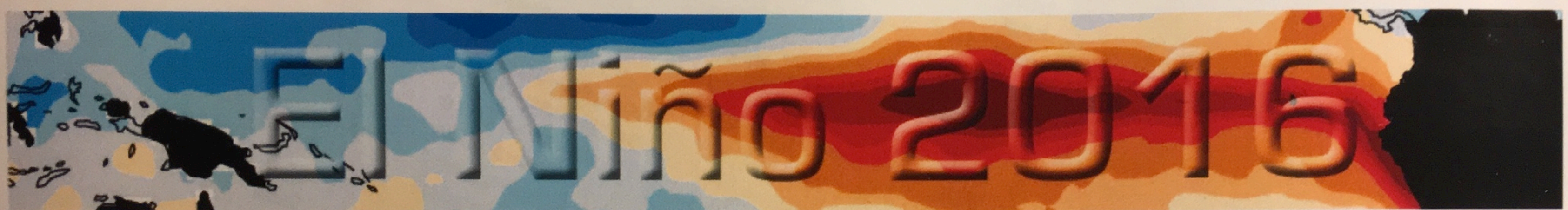
2) ERA-interim; NCEP reanalysis; MERRA.

3) microwave-only retrieval. For CrIS/ATMS this has the potential to be an exceptional *a-priori*. For AIRS/AMSU and IASI/AMSU/MHS it is unlikely that the AMSU information content is sufficient.

Note:

- the retrieval solution is derived on the assumption that both measurement and a priori error statistics are Gaussian. Gaussian behaviour in a priori and first guess statistics must be be verified.
- Need a statistically significant validation ensemble.

El Nino Rapid Response Initiative
January – March 2016

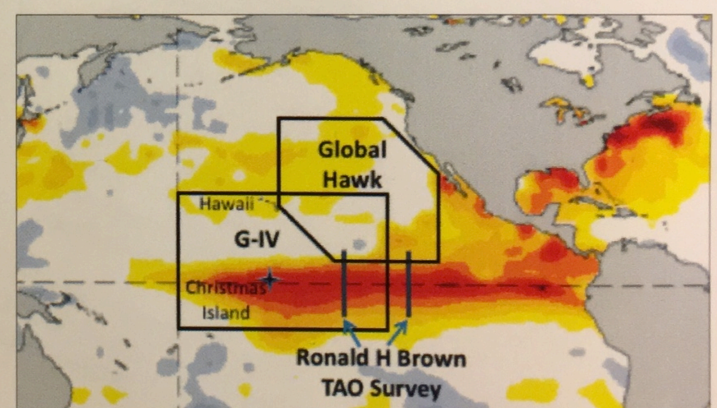


NOAA El Niño Rapid Response Field Campaign

January–March 2016

The current major El Niño presents an unprecedented scientific opportunity to accelerate advances in understanding and predictions of an extreme climate event and its impacts through research conducted *while the event is ongoing*.

- NOAA scientists are set to launch a land, sea, and airborne research effort to better **observe** and document the responses to the current strong El Niño.
- Intensive observations gathered in the tropical Pacific will provide a foundation to better **understand** how El Niño influences U.S. weather.
- The results will help scientists to better **predict** how climate phenomena like El Niño influence weather and climate extremes and their impacts.

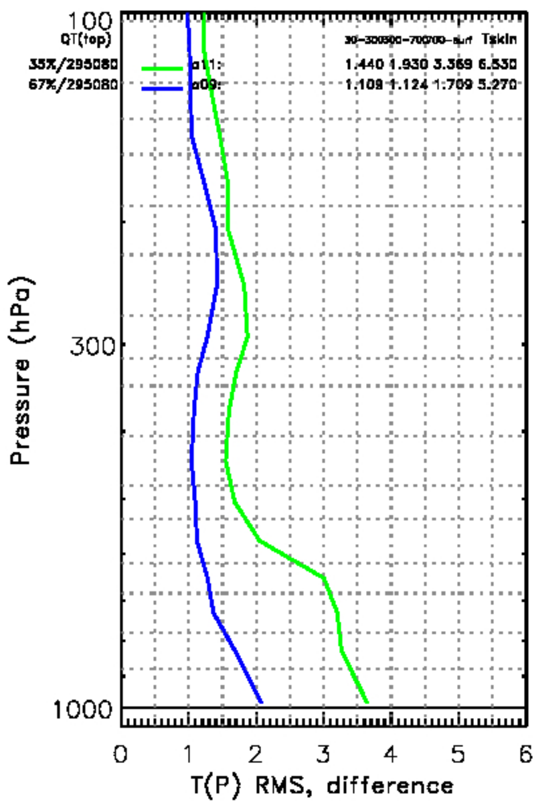


Simultaneous vs sequential OE approach

Simultaneous OE	Sequential OE
Solve all parameters simultaneously	Solve each state variable (*e.g.*, T(p)), separately.
Error covariance includes only instrument model.	Error covariance is computed for all *relevant* state variables that are held fixed in a given step. Retrieval error covariance is propagated between steps.
Each parameter is derived from all channels used (*e.g.*, can derive T(p) from CO2, H2O, O3, CO, … lines).	Each parameter is derived from the best channels for that parameter (*e.g.,* derive T(p) from CO2 lines, q(p) from H2O lines, etc.)
A-priori must be rather close to solution, since state variable interactions can de-stabilize the solution.	*A-priori* can be simple for hyperspectral.
This method has large state matrices (all parameters) and covariance matrices (all channels used). Inversion of these large matrices is computationally expensive.	State matrices are small (largest is 25 T(p) parameters) and covariance matrices of the channels subsets are quite small. Very fast algorithm. Encourages using more channels.

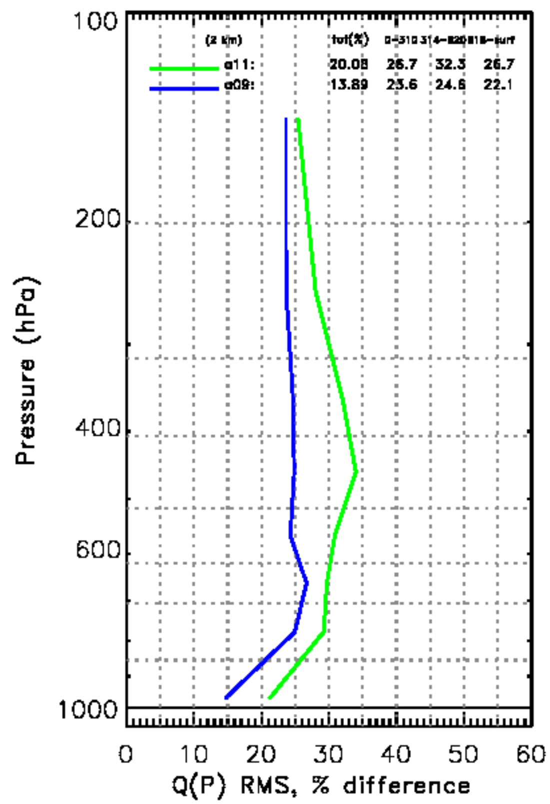
Global impact of losing MW-only sounding capability (2)

Temperature RMS



NUCAPS MW+IR (67%)

Water vapor RMS

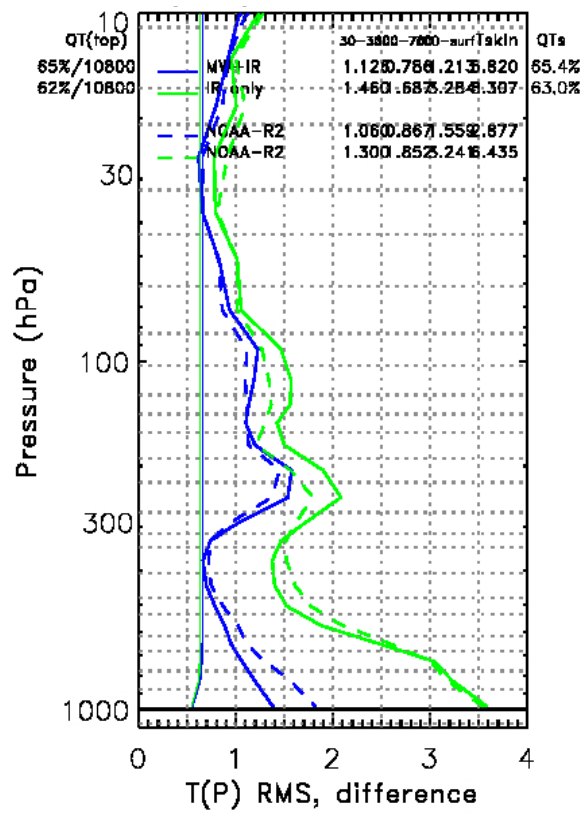


NUCAPS IR ONLY (35%)

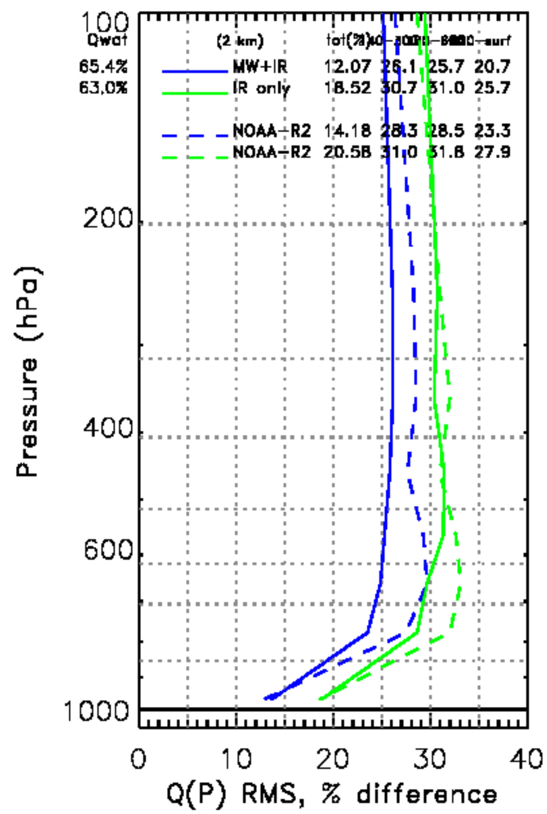
- Losing the MW instrument degrades the global retrieval performance of temperature (water vapor) rms statistics by ~2K (~5%) in the lower troposphere and 1.5K (7%) in the mid troposphere

Impact of losing MW-only sounding capability during extreme events: a case study from May 6, 2015 tornado event in Norman, OK (3)

Temperature RMS



Water vapor RMS

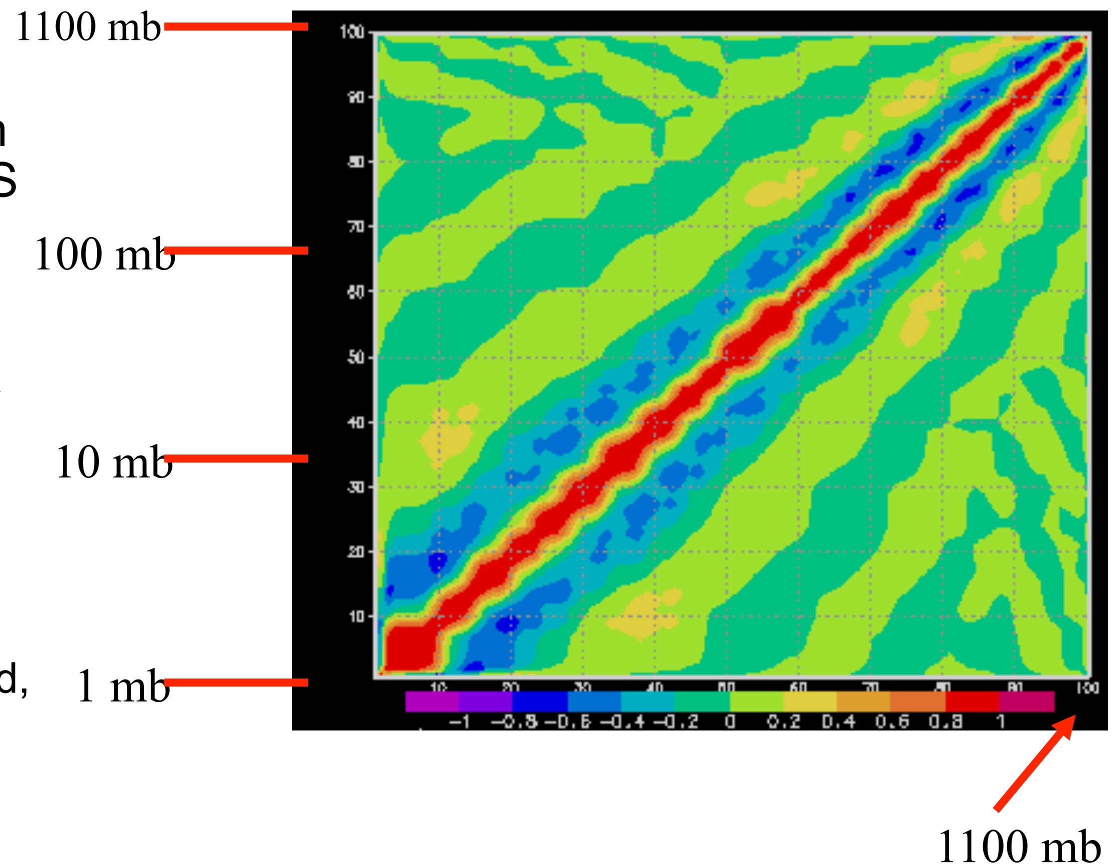


NUCAPS MW+IR (67%) **NUCAPS IR ONLY (62%)**

- Losing the MW instrument degrades the global retrieval performance of temperature (water vapor) rms statistics by ~2K (~5%) in the lower troposphere and 1.5K (7%) in the mid troposphere

Example of temperature retrieval error covariance

- An example of temperature retrieval correlation (minimum variance method) for the AIRS instrument
- Top of atmosphere radiances (TOA) are used to invert the radiative transfer equation for T(p).
- This results in a correlation that is a vertical oscillatory function.
  - TOA radiances are minimized, but
  - An error in one layer is compensated for in other layer(s).



Therefore, the use of retrieval products requires knowledge of retrieval "averaging kernels" and/or error *covariance* estimates.

30 YEARS 1986-2016

EUMETSAT

MTG-IRS: Update on level 1 and level 2 processing

Stephen Tjemkes, Stefano Gigli, Rolf Stuhlmann

Overview

- Current status Level 1 and Level 2 Processor
- Future activities
  - Level 1
  - Level 2
  - Test data
- Concerns about Level 2 processor

Status of Level 1

- The following tools to are getting in place
  - Instrument simulator: IRASS
    - Complete but simplified instrument simulator with limited level 1 processing capabilities
  - Level 1 reference processor
    - An implementation of the detailed Level 1 processing specifications, which are prepared for the IDPF-S procurement. Objective of the L1RP is to demonstrate the physical concepts, and prepare break point data for testing operational implementation of the specifications.

Level 1 Processing Specifications

- The detailed specifications are subject to peer review.
  - Release of documents to review panels on 29/08/2016
  - dispatch of Peer Review Report on 07/10/2016

Status of Level 2

- Programmatic:
  - ATBD v3.0 is still latest (available on web)
  - Soon start to prepare for detailed processing specs
- Science:
  - The Level 2 Validation and Demonstration Processor is implementation of the ATBD v3.0
  - Running autonomous and unsupervised since June 2016 on actual observations provided by IASI and CrIS

MTG-IRS NRT Demo Project

- Products are derived globally from IASI M01, selected regions IASI M02 and CrIS
- The products are delivered to participants of the MTG-IRS NRT demo project
  - Regular product (operational forecasters):
    - DWD, FMI, DMI, AEMET, COMET, KNMI, NHMS, TSMS, SSEC
  - Specialised product for data assimilation
    - KNMI, CETEMPS, ECMWF,
    - Univ. Hawaii expressed interest to receive the data as well.

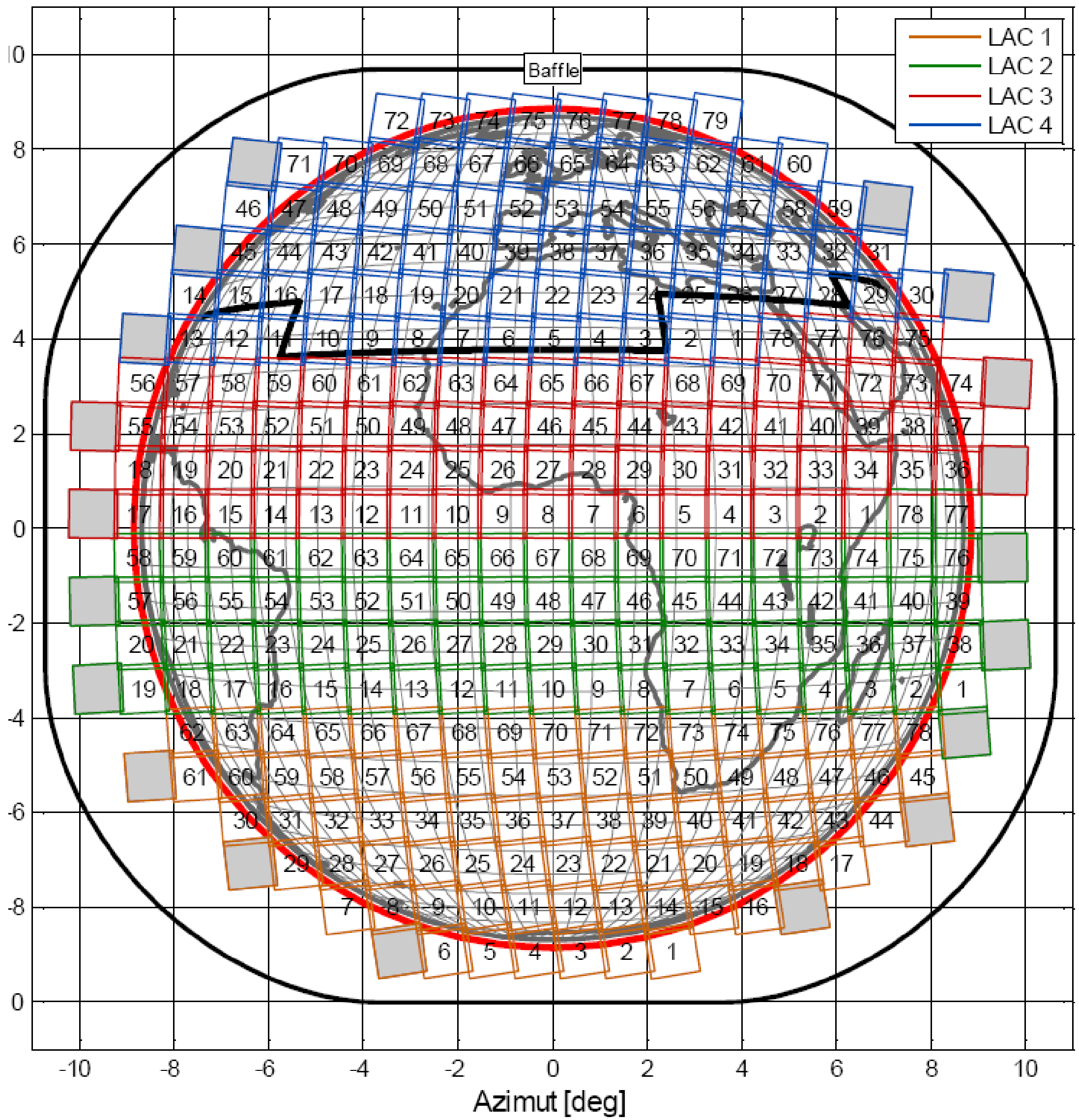
Current system (for completeness)

- Approximately 3000 channels (IASI), 800 channels (CrIS)
- SCE analysis based on IASI/CrIS measurements
- 1DVAR
  - Background: state and covariance from ensemble forecast by ECMWF
  - RTM: OSS (normal mode)
- Products for cloud free cases:
  - T(p), q(p), O3(p), Ts, emissivity
  - SPS (=T+q projected in feature space)

Level 1: Planned activities

- Consolidate the processing specs:
  - Harmonisation of response?
  - Order of calibration sequence,
  - Characterisation of the background radiation for radiometric calibration,

Illustration of Step and Stare of IRS



Planned activities: Level 2

- Investigate retrievals in feature space
  - Consider information matrix:

$$\hat{\mathrm{S}}_s = \mathrm{S}_\epsilon^{-1/2}\hat{\mathrm{K}}\mathrm{S}_a^{1/2}$$

  - Contains all information in the system. Extract the key components using SVD and use the eigenvectors to project observations and state into feature space
  - Apply the 1dvar in this space

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Retrievals in feature space

- Advantages is a significant reduction of the set of linear equations to solve
- Concentrate on the key features

Development (not for operations/day1)

- Add the capabilities to perform retrievals in presence of low or high level clouds
- Include the ILS in the state vector

Test Data

- Plan to generate a high spatial resolution test dataset
  - high resolution NWP
  - Limited regional and temporal coverage
- Investigate to produce a “operational” stream of synthetic IRS data to support users prior to launch

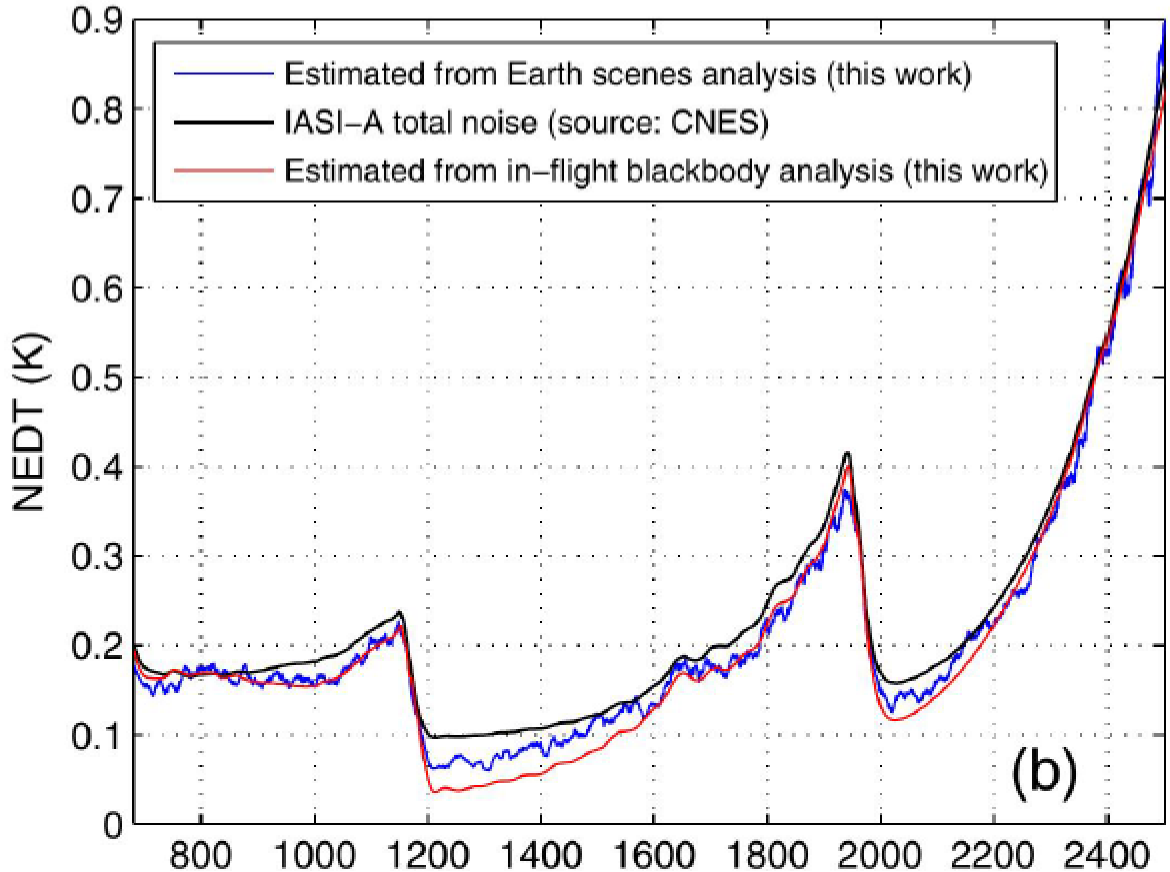
Current concerns

- Knowledge of the error covariance matrices
- method to derive observational error covariance exists
    - IASI (Serio et al 2015)
    - CrIS, pending

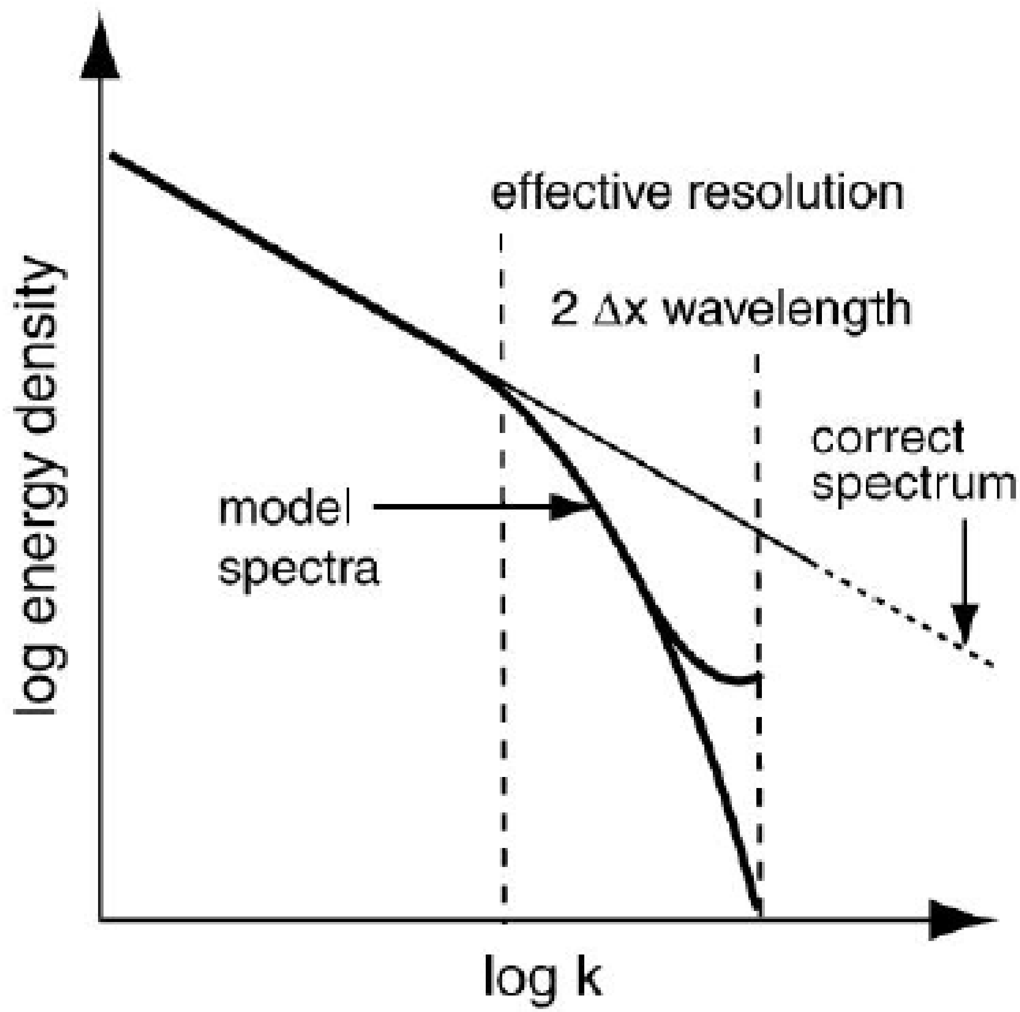
- Forward model errors are unknown
    - Missing a method to rigorously estimate this

- ECMWF background error covariance is likely too optimistic (representativeness error missing)

From Serio et al. 2015



From Skamarok (2004)



Contact

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Fast Radiative Transfer Model Development for Hyperspectral Sounders in the Presence of Clouds and Solar Radiation

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NOAA/STAR JPSS Annual Science Team Meeting
College Park, MD, August 8-12, 2016

Outline

- Motivation
  - Find an Efficient and Accurate Way to Calculate the Multiple Scattering of Solar Radiance by Cloud/Aerosol
- Main Results of This Work
  - Multi-Layer Clouds (Include One-Layer)
    - Dual Stream PCRTM-SOLAR
  - One-Layer Cloud (LUT for Faster Performance)
    - Parameterization/LUT
- Conclusion

Motivation

- Efficient radiative transfer (RT) simulation for cloudy-sky is essential for operational satellite data processing and climate OSSEs
- Our Previous Works:
  - PCRTM-IR model
    - Multi-layer multiple scattering of clouds included
    - Been used to perform single FOV cloudy sky retrieval successfully
  - PCRTM-Solar
    - Includes azimuthal dependency
    - Fast and accurate
- Current Work:
  - To further increase the simulation speed and reduce the computational burden

RT Computational Burden & Our Strategies to Reduce It

- The channel radiances measured by a sensor are the result of monochromatic radiances convolved with the instrument lineshape function:

$$R_i^{channel} = \frac{\sum_{k=1}^{N} R_k^{mono} \rho_k}{\sum_{k=1}^{N} \rho_k}$$

- LBL Model: over hundreds of thousands or millions of mono radiances have to be calculated accurately to get one channel radiance spectrum of a hyperspectral sensor.
- Our Methods to reduce the computational burden of multi-scattering of solar radiance by cloud particles:
  - **Regular PCRTM-SOLAR**: only **FEW HUNDREDS** of mono radiances are needed to be calculated accurately.
  - **Dual Stream PCRTM-SOLAR (multi-layer clouds, this work):** only **FEW TENS** of mono radiances are required to be calculated accurately.
  - **One-Layer Cloud PCRTM-SOLAR (1-layer cloud, this work):** **no need** to call multi-scattering solver.

Using PCA to Reduce Computational Burden

Instrument	Apodization	# of Channels	# of Mono
IASI	Gaussian	8461	753
AIRS	Airs Filter	2378	500
HR CrIS	Boxcar	2211	540
HR CrIS	Blackman	2211	374
HR CrIS	Hamming	2211	398
CrIS	Boxcar	1317	485
CrIS	Blackman	1317	369
CrIS	Hamming	1317	384
NASTI	Boxcar	8632	748
NASTI	Kaiser	8632	559
SHIS	Boxcar	4316	647
SHIS	Kaiser	4316	647

Using PCA to Reduce Computational Burden

- CLARREO Reflected Solar (RS) spectrum from 300 nm to 2.5 μm with 1 cm^{-1} resolution (29,311 channel frequencies).
- MODTRAN: need radiances at 259,029 mono frequencies
  - Real Example: qsub to CLARREO machine at NASA LaRC, 16-stream, one spectrum)
    - CPU TIME = 2 hours 39 minutes = 9540 s
- PCRTM-SOLAR: need radiances at only 1,359 mono frequencies for land surface (~ 190 times faster)
  - Real Example: qsub to CLARREO machine at NASA LaRC, 16-stream, one spectrum)
    - CPU TIME = 67.736237 (radiances at 1359 mono frequencies)
- PCRTM-SOLAR is able to treat multi-layer cloud/aerosol

0.3-2.5 μm	PCRTM-SOLAR	MODTRAN	SPEED UP
Ocean 1 cm^{-1}	958	259,029	270
Land 1 cm^{-1}	1,359	259,029	190
Ocean 8 nm	241	259,029	1075
Land 8 nm	263	259,029	985

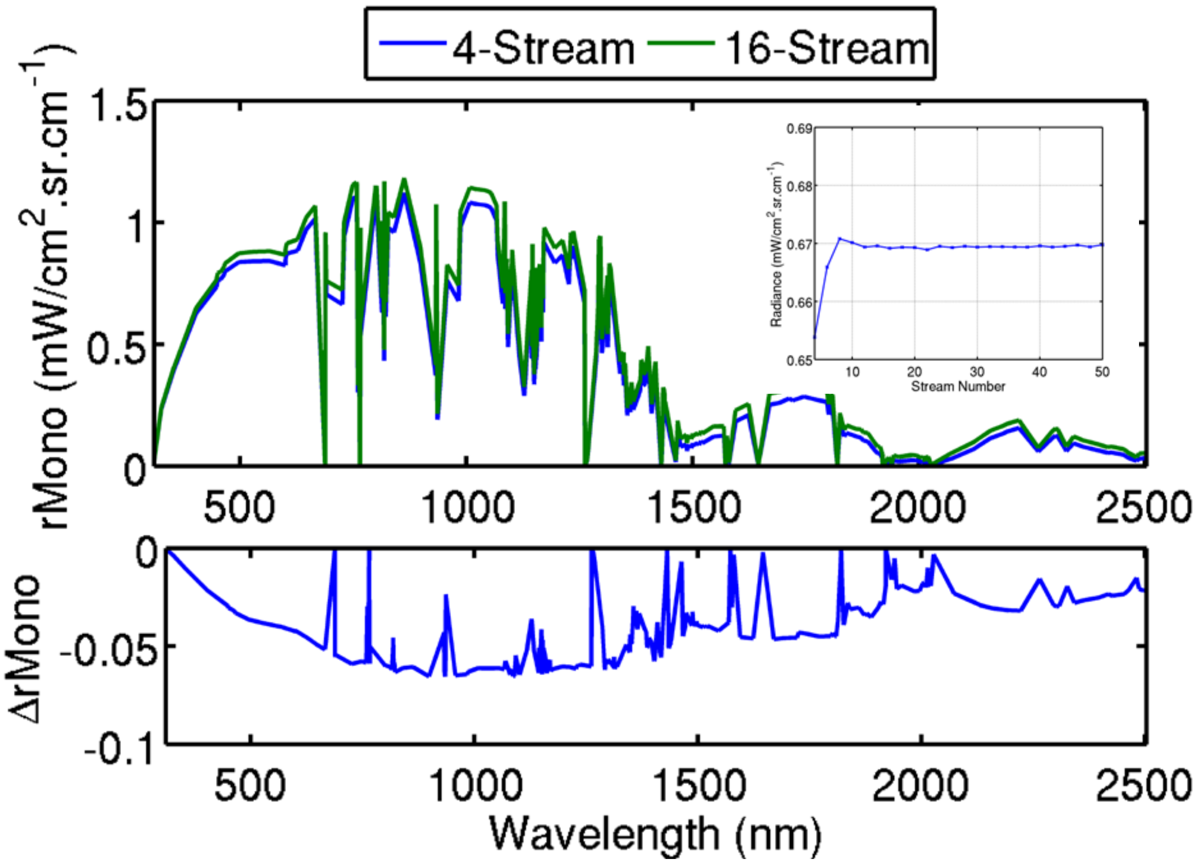
$$R^{chan}_{nch\times ns} = U_{nch\times npc} A_{npc\times nsmo} R^{mono}_{nsmo\times ns}$$

Methods to Solve Scattering Involved RT Equation

- Fast Approximate Methods:
  - Single Scattering Approximation
  - Two- and Four-Stream Approximation
  - Eddington and Delta-Eddington Approximation
- Slow Accurate Methods:
  - Discrete-Ordinate Method (if stream number big enough)
  - Adding-Doubling Method (if stream number big enough)
  - Successive Order of Scattering (if stream number big enough)
  - Monte-Carlo Method (if photon number is big enough)

Speed & Accuracy Dilemma to Solve RT Equation

- Speed and accuracy dilemma in DO/AD/SOS methods
  - The accuracy depends on stream number N. Larger N usually gives higher accuracy.
  - The computation time is approximately proportional to N^3.
- Do we have to compromise between accuracy and speed? (We want both!!!)



- Strategy and Goal of This Work:
  - Multi-Layer Clouds:
    - Simulate thousands of mono radiances with both fast approximate methods and slow accurate methods
    - Find the relationship so that we may use the fast radiances to reconstruct the accurate radiances
    - Goals:
      - To quickly obtain highly accurate radiance spectrum by calculating few hundreds mono radiances with the fast approximation methods and few tens mono radiances with the slow accurate methods (Dual Stream PCRTM-SOLAR)
  - One-Layer Cloud:
    - Parameterize the 1-layer cloud results for operational application.

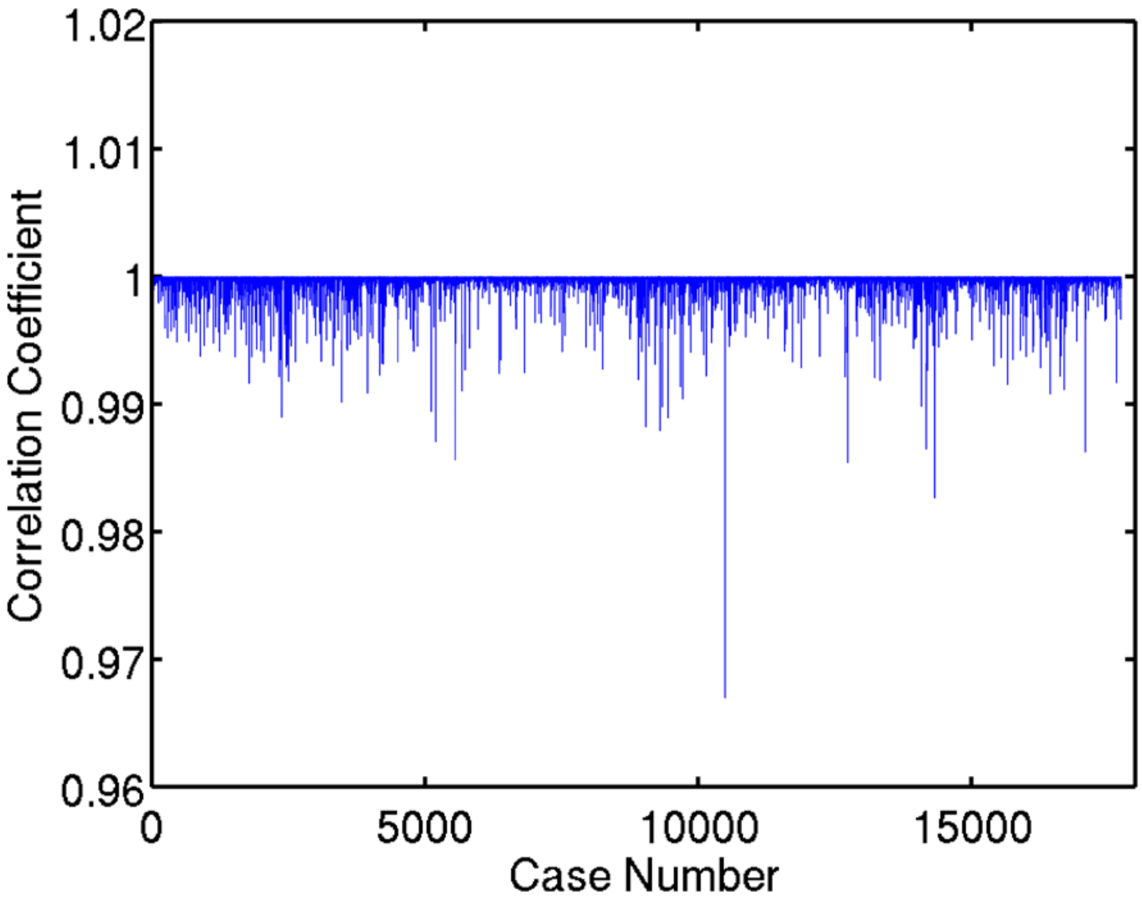
Dual Stream PCRTM-SOLAR: 4-Stream to N-Stream

- What we need:
  - Speed: 2-stream or 4-stream
  - Accuracy: N-stream (N >> 2)
- The link between 4-stream and N-stream (CLARREO: land surface, 1 cm^{-1} resolution case):

$$r_{Nstr}^{1359} = r_{4str}^{1359} + (r_{Nstr}^{1359} - r_{4str}^{1359}) = r_{4str}^{1359} + \Delta r^{1359}$$

They are highly related!

Correlation between mono radiances obtained from 4-stream and 16-stream DO method



Dual Stream PCRTM-SOLAR: 4-Stream to N-Stream

- Training the small difference:

$$\Delta r^{1359} = B^{1359\times M} \cdot \Delta r^{M}$$

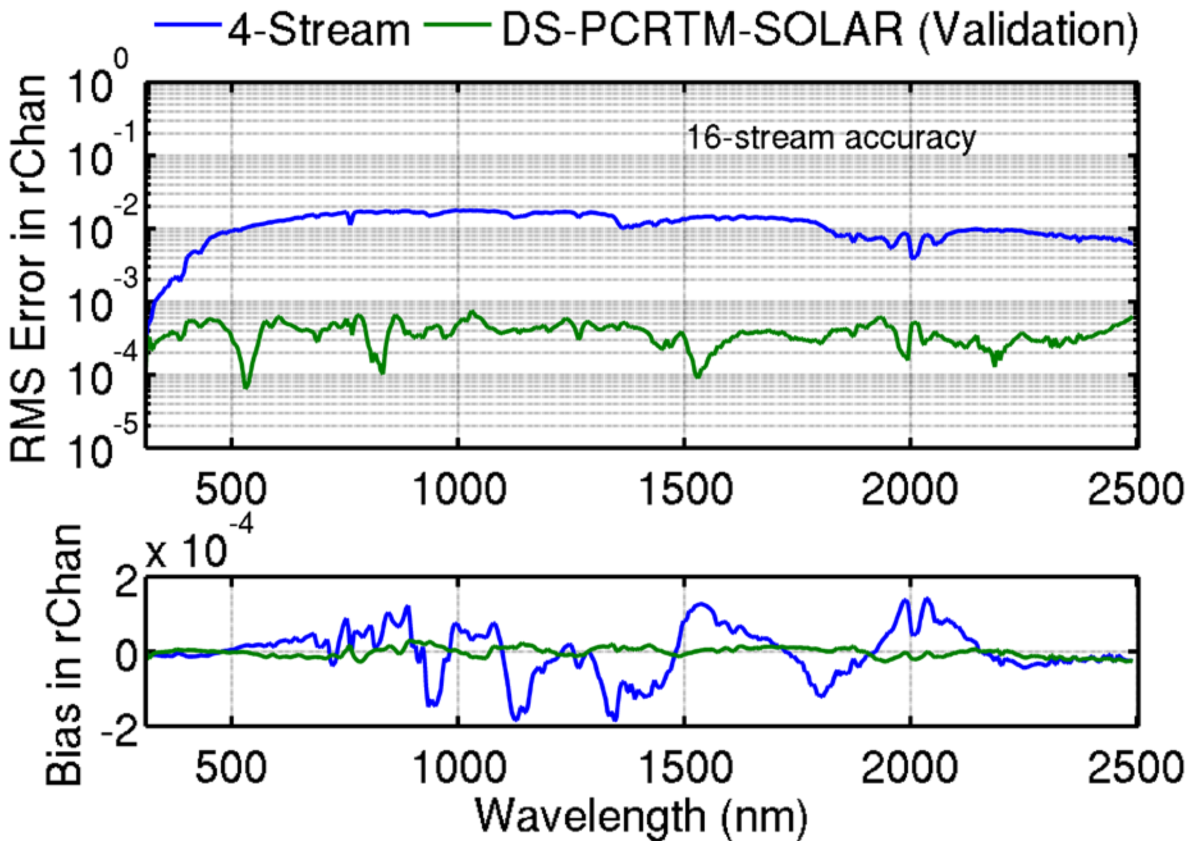
With M << 1359.

- The obtained radiance with N-stream accuracy is thus given by:

$$r_{Nstr}^{1359} = r_{4str}^{1359} + B^{1359\times M} \cdot \Delta r^{M} = r_{4str}^{1359} + B^{1359\times M} \cdot (r_{Nstr}^{M} - r_{4str}^{M})$$

- **Don't need N-stream calculation at all 1359 frequencies;**
- **Need N-stream calculation at M frequencies among the 1359 frequencies. (M << 1359)**
- **Need 4-stream calculation at all 1359 frequencies.**

RMS Errors of Dual Stream PCRTM-SOLAR



Dual Stream PCRTM-SOLAR: 4-Stream to N-Stream

- Estimated speed using the new strategy:

$$\text{time ratio} = \frac{\text{time for N-stream (all 1359 frequencies)}}{\text{time for 4-stream (all 1359 frequencies)} + \text{time for N-stream } (M \ll 1359 \text{ frequencies})}$$

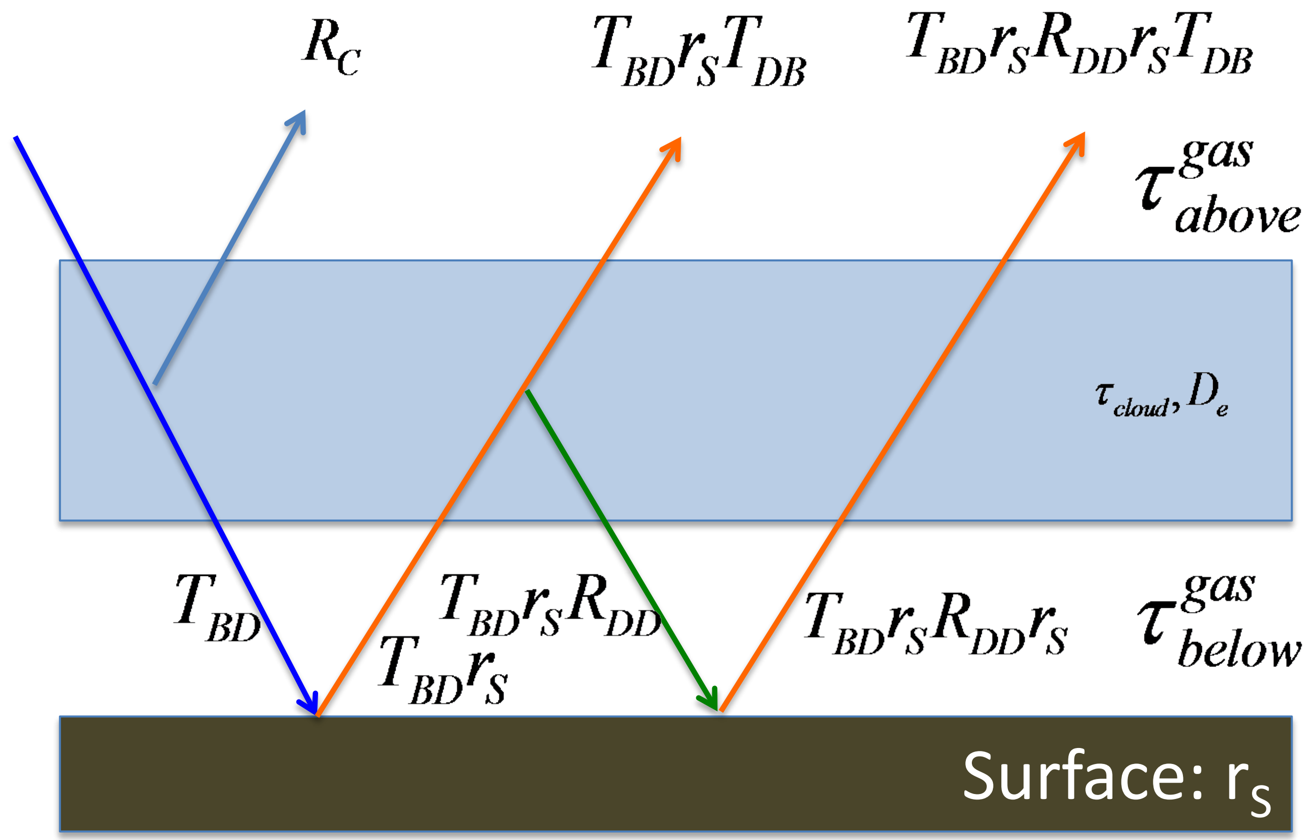
For 16-stream accuracy: N = 16

Method	Number of frequencies	Speed Up
MODTRAN	259,029	1
Regular PCRTM-SOLAR	1359	190
Dual Stream PCRTM-SOLAR	1359 (4 stream) + 35 (16 stream)	4560

M = 35

The dual stream PCRTM-SOLAR may complete one spectrum (29,311 channels) calculation in ~ 3 seconds, rather than ~ 3 hours (MODTRAN).

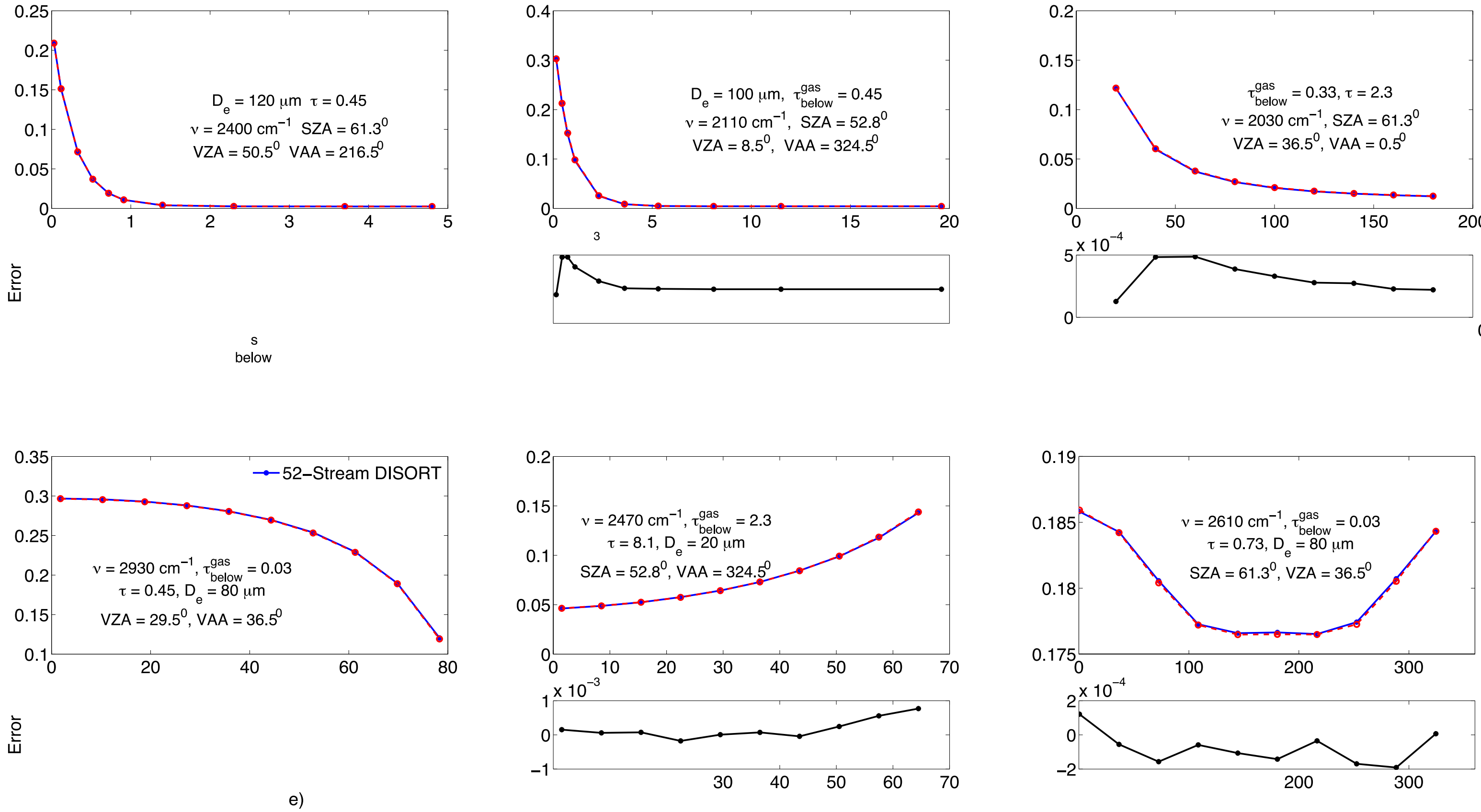
1-Layer Cloud PCRTM-SOLAR: Principal



$$R = \left(R_C + \frac{r_S T_{BD} T_{DB}}{1 - r_S R_{DD}} \right) e^{-\frac{\tau_{gas}^{above}}{\mu_0} - \frac{\tau_{gas}^{above}}{\mu}}$$

Dual Stream PCRTM-SOLAR

1-Layer Cloud PCRTM-SOLAR: Error



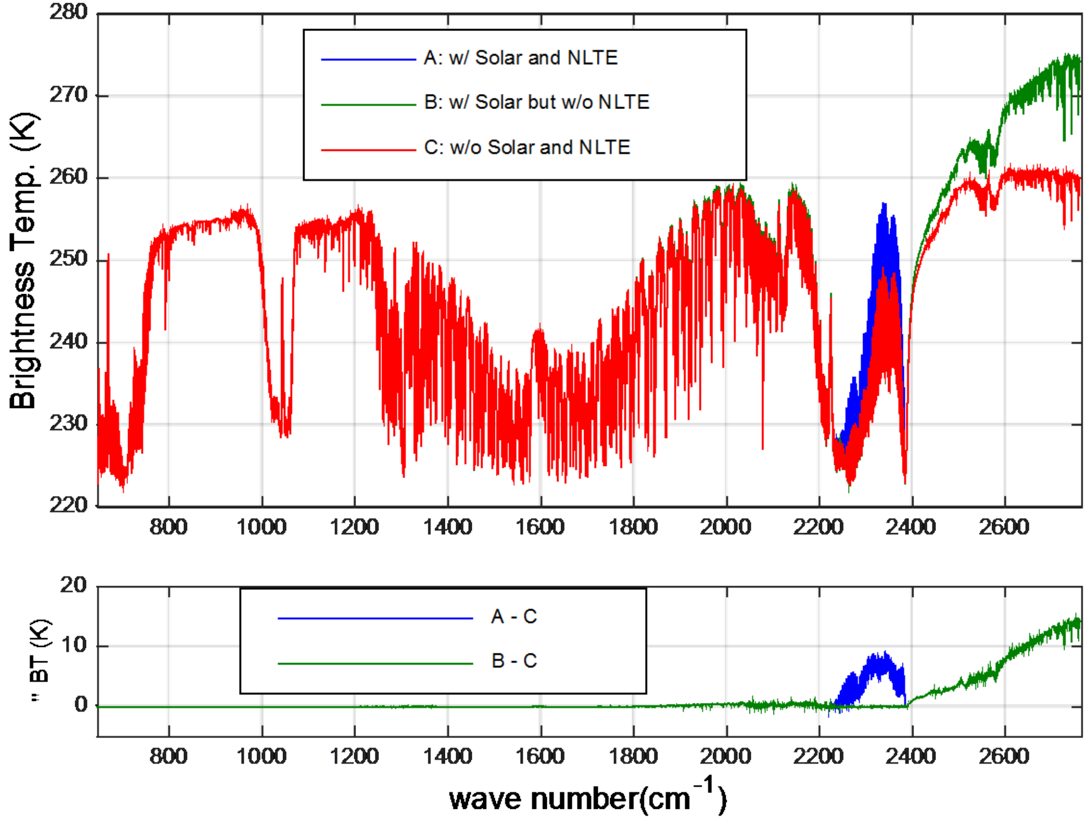
1-Layer Cloud PCRTM-SOLAR: Speed

- Example Satellite Sensor: IASI 0.25 cm^{-1} Spectral Resolution Full Channel Set
  - PCRTM_SOLAR: 4.89 ms/run
    - 1000 runs with the following parameters:

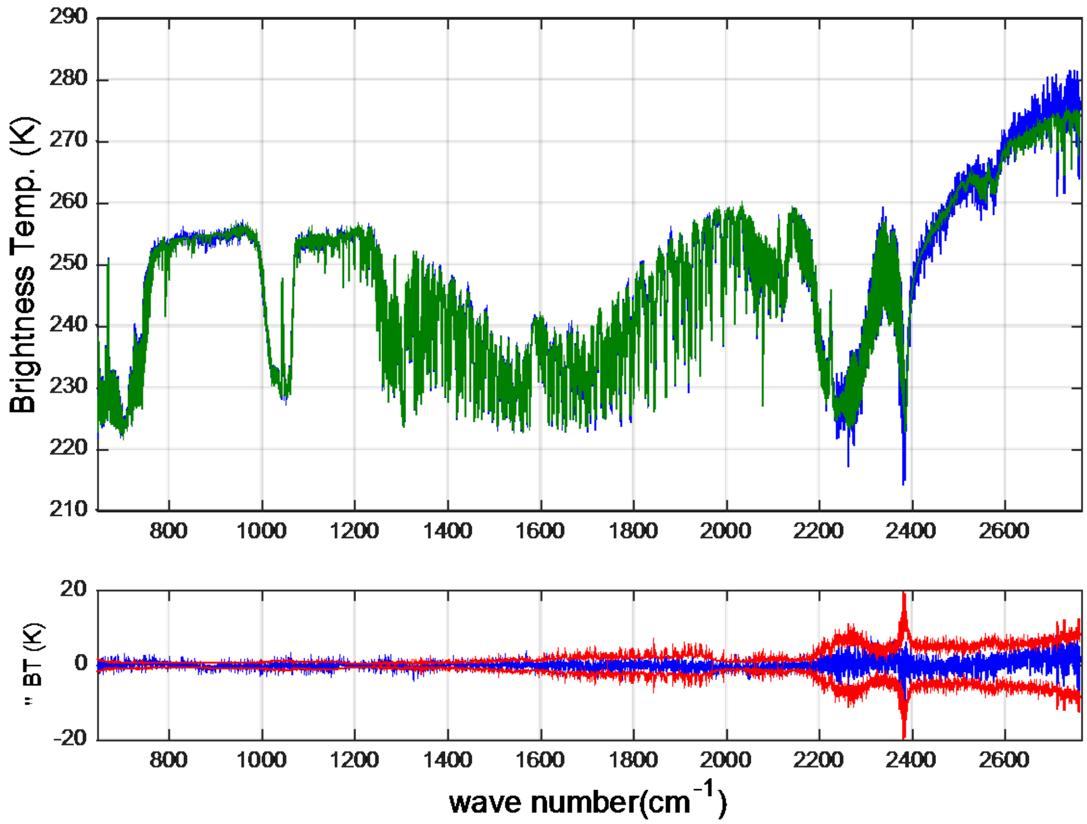
      SZA = 10^0, VZA = 60^0, VAA = 72.5^0, 439 mono frequencies, τ_{above} changes with wavenumber, τ_{below} changes with wavenumber, τ_{cloud} = 1.025, De = 48 μm, Rs = 0.02
  - PCRTM_IR: 20.86 ms/run
    - 1000 runs with the following parameters:

      VZA = 60^0, 735 mono frequencies, τ_{above} changes with wavenumber, τ_{below} changes with wavenumber, τ_{cloud} = 1.025, De = 48 μm, Rs = 0.02
  - PCRTM_SOLAR is a little bit faster than PCRTM_IR.
    - Integrate PCRTM_SOLAR to PCRTM will NOT influence the computation speed of PCRTM greatly.

1-Layer Cloud PCRTM-SOLAR: Solar Contribution to the Brightness Temperature



1-Layer Cloud PCRTM-SOLAR: Compare to IASI Measured Data



Conclusion

- A fast and accurate dual stream PCRTM-SOLAR model has been developed to simulate the TOA radiances for multi-layer clouds sky with solar radiation.
- A superfast one-layer cloud PCRTM-SOLAR model has been developed for operational usage.
- The RMS error for both models are normally less than 10^{-3}.
- Dual stream PCRTM-SOLAR needs about 3 s to simulate the whole TOA RS spectrum (300 to 2500 nm, 29,311 channels) with 16-stream accuracy.
- One-layer cloud PCRTM-SOLAR needs about 5 ms to simulate the solar contribution (1800-2760 cm^{-1}, 3841 channels) to the IASI spectrum (645-2760 cm^{-1}, 8461 channels).

Backup

R. Bennartz, T. Greenwald, "current problems in scattering radiative transfer modelling for data assimilatio," Q.J.R. Meteorol. Soc. 137: 1952-1962 (2011)

Table I. Comparison of normalized CPU time (seconds per instrument channel) for the RTTOV v10 and CRTM v2.0.2 for each instrument separated into time spent in the radiative transfer solver and total overall time. For details see text.

	HIRS-4 (s/chan)	AMSU-A (s/chan)	MHS (s/chan)
RTTOV solver	0.755	1.18	1.21
RTTOV total	4.42	4.24	5.44
CRTM 2-strm solver	57.0	55.8	75.7
CRTM 2-strm total	107	132	163
CRTM 4-strm solver	106	91.2	118
CRTM 4-strm total	160	176	215

NOAA Unique Combined Atmospheric Processing System (SNPP NUCAPS) Products and Validation

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2016 STAR JPSS Annual Meeting
College Park, Maryland, USA
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- **SNPP Sounder EDR Validation Dataset collection**
  - **NOAA AEROSE:** V. R. Morris, E. Joseph, M. Oyola, E. Roper (HU/NCAS); P. J. Minnett (UM/RSMAS); D. Wolfe (NOAA/ESRL); J. W. Smith (STC, NRC)
    - AEROSE works in collaboration with the NOAA PIRATA Northeast Extension (PNE) project (R. Lumpkin, G. Foltz and C. Schmid), and is supported by the NOAA Educational Partnership Program (EPP) grant NA17AE1625, NOAA grant NA17AE1623, JPSS and STAR
  - **U.S. DOE Atmospheric Radiation Measurement (ARM) program dedicated RAOBs**
    - L. Borg, D. Tobin (UW/CIMSS)
    - D. Holdridge and J. Mather (ARM Climate Research Facility)
  - **CalWater:** R. Spackman (STC); R. Leung (PNNL); C. Fairall, J. Intrieri (NOAA)
  - **ACAPEX:** N. Hickmon, M. Ritsche, A. Haruta, and the ARM Mobile Facility 2 (AMF2)
  - **PMRF Site:** A. K. Mollner, J. E. Wessel (Aerospace)
  - **BCCSO Site:** R. Sakai, B. Demoz, M. Oyola (HU/NCAS)
  - **GRUAN Lead Center:** Ruud Dirksen
  - **NASA Sounder Science Team:** T. Pagano, E. Fetzer (NASA/JPL)

- **SNPP sounder validation effort (past and present)**: M. Pettey, C. Brown, A.K. Sharma, W. W. Wolf, X. Xiong, M. Divakarla, E. Maddy (STAR); L. Borg, D. Tobin, R. O. Knuteson and M. Feltz (UW/CIMSS)

Outline

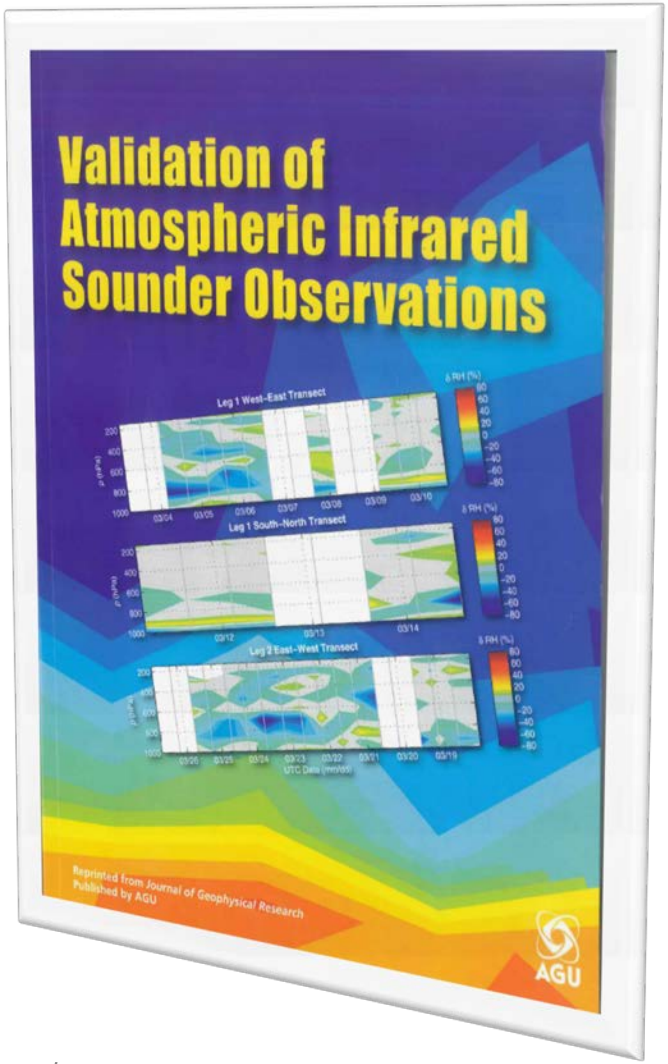
- **JPSS Sounder EDR Cal/Val Overview**
  - JPSS Level 1 Requirements
  - Validation Hierarchy
  - JPSS SNPP Validation Tools
    - STAR Validation Archive (VALAR)
    - NOAA Products Validation System (NPROVS/NPROVS+)
  - NUCAPS Algorithm
    - Operational – v1.5
      - Nominal resolution CrIS
    - Experimental – v1.8.1
      - Full resolution CrIS
- **NUCAPS Evaluation**
  - v1.5 (operational)
    - Global Focus Day
    - Dedicated/Reference RAOB ensemble
  - v1.8.1 (full-res CrIS)
    - Global Focus Day comparison
    - 2015 AEROSE campaign dedicated RAOB case
- **Summary and Future Work**
  - SNPP ICV and LTM

SNPP NUCAPS Products and Validation

JPSS SOUNDER EDR CAL/VAL OVERVIEW

Sounder EDR Validation

- **Validation** is "the process of ascribing uncertainties to… radiances and retrieved quantities through comparison with correlative observations" (*Fetzer et al.,* 2003).
  - EDR validation supports monitoring of SDRs and cloud-cleared radiances
  - EDR validation enables development/improvement of algorithms



SNPP/JPSS Program Cal/Val

- **JPSS Cal/Val Phases**
  - Pre-Launch
  - Early Orbit Checkout (EOC)
  - **Intensive Cal/Val (ICV)**
    - Validation of EDRs against multiple correlative datasets
  - **Long-Term Monitoring (LTM)**
    - Routine characterization of all EDR products and long-term demonstration of performance

- In accordance with the JPSS phased schedule, the **SNPP CrIS/ATMS EDR Cal/Val Plan** was devised to ensure the EDR would meet the mission **Level 1 requirements** (*Barnet,* 2009)

- **EDR validation methodology** based upon AIRS and IASI (*Nalli et al.,* 2013, *JGR Special Section on SNPP Cal/Val*)
  - Classification of various approaches into a "Validation Methodology Hierarchy"

- The **J-1 CrIS/ATMS EDR Cal/Val Plan** was drafted during Jul–Aug 2015 and v1.0 was submitted on 20 August 2015; the revised draft v1.1 was submitted on 31 December 2015

JPSS Specification Performance Requirements
CrIS/ATMS AVTP/AVMP EDR Uncertainty

CrIS/ATMS Atmospheric Vertical Temperature Profile (AVTP) Measurement Uncertainty – Layer Average Temperature Error		
PARAMETER	**THRESHOLD**	**OBJECTIVE**
AVTP, Cloud fraction < 50%, surface to 300 hPa	1.6 K / 1-km layer	0.5 K / 1-km layer
AVTP, Cloud fraction < 50%, 300–30 hPa	1.5 K / 3-km layer	0.5 K / 3-km layer
AVTP, Cloud fraction < 50%, 30–1 hPa	1.5 K / 5-km layer	0.5 K / 5-km layer
AVTP, Cloud fraction < 50%, 1–0.5 hPa	3.5 K / 5-km layer	0.5 K / 5-km layer
AVTP, Cloud fraction ≥ 50%, surface to 700 hPa	2.5 K / 1-km layer	0.5 K / 1-km layer
AVTP, Cloud fraction ≥ 50%, 700–300 hPa	1.5 K / 1-km layer	0.5 K / 1-km layer
AVTP, Cloud fraction ≥ 50%, 300–30 hPa	1.5 K / 3-km layer	0.5 K / 3-km layer
AVTP, Cloud fraction ≥ 50%, 30–1 hPa	1.5 K / 5-km layer	0.5 K / 5-km layer
AVTP, Cloud fraction ≥ 50%, 1–0.5 hPa	3.5 K/ 5-km layer	0.5 K/ 5-km layer

"Clear to Partly-Cloudy"
(Cloud Fraction < 50%)
↕
IR retrieval

"Cloudy"
(Cloud Fraction >= 50%)
↕
MW-only retrieval

CrIS/ATMS Atmospheric Vertical Moisture Profile (AVMP) Measurement Uncertainty – 2-km Layer Average Mixing Ratio % Error		
PARAMETER	**THRESHOLD**	**OBJECTIVE**
AVMP, Cloud fraction < 50%, surface to 600 hPa	Greater of 20% or 0.2 g·kg^{-1} / 2-km layer	10%
AVMP, Cloud fraction < 50%, 600–300 hPa	Greater of 35% or 0.1 g·kg^{-1} / 2-km layer	10%
AVMP, Cloud fraction < 50%, 300–100 hPa	Greater of 35% or 0.1 g·kg^{-1} / 2-km layer	10%
AVMP, Cloud fraction ≥ 50%, surface to 600 hPa	Greater of 20% of 0.2 g·kg^{-1} / 2-km layer	10%
AVMP, Cloud fraction ≥ 50%, 600–400 hPa	Greater of 40% or 0.1 g·kg^{-1} / 2-km layer	10%
AVMP, Cloud fraction ≥ 50%, 400–100 hPa	Greater of 40% or 0.1 g·kg^{-1} / 2-km layer	NS

Global requirements defined for lower and upper atmosphere subdivided into 1-km and 2-km layers for AVTP and AVMP, respectively.

Source: (L1RD, 2014, pp. 41, 43)

Validation Methodology Hierarchy

(e.g., *Nalli et al., JGR Special Section,* 2013)

1. **Numerical Model (e.g., ECMWF, NCEP/GFS) Global *Comparisons***
   - Large, truly global samples acquired from Focus Days
   - Useful for sanity checks, bias tuning and regression
   - Limitation: *Not* independent truth data

2. **Satellite Sounder EDR (e.g., AIRS, ATOVS, COSMIC) *Intercomparisons***
   - Global samples acquired from Focus Days (e.g., AIRS)
   - Consistency checks; merits of different retrieval algorithms
   - Limitation: Similar error characteristics; must take rigorous account of averaging kernels of both systems (e.g., *Rodgers and Connor,* 2003)

3. **Conventional RAOB Matchup *Assessments***
   - WMO/GTS operational sondes launched ~2/day for NWP
   - Representation of global zones, long-term monitoring
   - Large samples after a couple months (e.g., *Divakarla et al.,* 2006; *Reale et al.* 2012)
   - Limitations:
     - Skewed distribution toward NH-continents
     - Mismatch errors, potentially systematic at individual sites
     - Non-uniform, less-accurate and poorly characterized radiosondes
     - RAOBs assimilated , by definition, into numerical models

4. **Dedicated/Reference RAOB Matchup *Assessments***
   - *Dedicated* for the purpose of satellite validation
     - Known measurement uncertainty and optimal accuracy
     - Minimal mismatch errors
     - Atmospheric state "best estimates" or "merged soundings"
   - Reference sondes: CFH, **GRUAN** corrected RS92/RS41
     - Traceable measurement
     - Uncertainty estimates
   - Limitation: Small sample sizes and limited geographic coverage
   - E.g., **ARM sites** (e.g., *Tobin et al.,* 2006), **AEROSE**, **CalWater/ACAPEX ,** BCCSO, PMRF

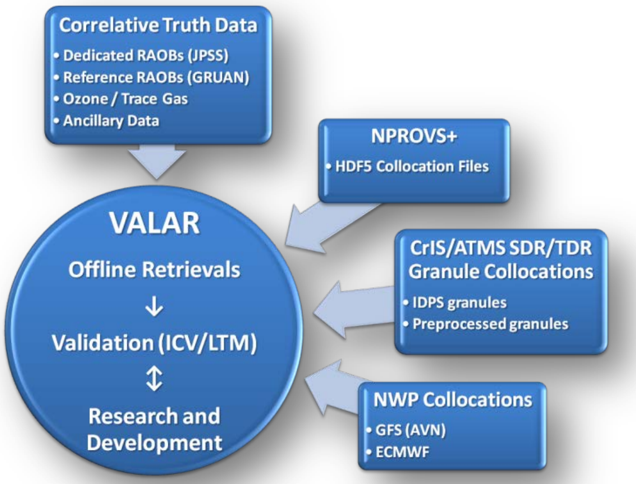
5. **Intensive Field Campaign *Dissections***
   - Include dedicated RAOBs, some *not* assimilated into NWP models
   - Include ancillary datasets (e.g., ozonesondes, lidar, M-AERI, MWR, sunphotometer, etc.)
   - Ideally include funded aircraft campaign using IR sounder (e.g., NAST-I, S-HIS)
   - Detailed performance specification; state specification; SDR cal/val; case studies
   - E.g., **SNAP, SNPP-1,-2, AEROSE, CalWater/ACAPEX**, JAIVEX, WAVES, AWEX-G, EAQUATE

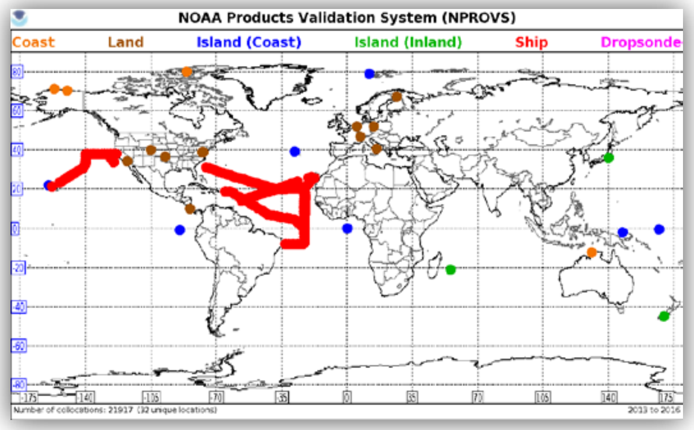
JPSS SNPP Validation Tools

- **STAR Validation Archive (VALAR)**
  - Low-level research data archive designed to meet needs of Cal/Val Plan
  - Dedicated/reference and intensive campaign RAOBs
  - SDR/TDR granule-based collocations ("stamps") within 500 km radius acquired off SCDR (past 90 days) or CLASS (older than 90 days)
  - Trace Gas EDR validation
  - Offline retrievals / retrospective reprocessing
  - MATLAB and IDL statistical codes and visualization software tools for monitoring
  - Rigorous coarse-layer (1-km, 2-km) product performance measures based on statistical metrics corresponding to Level 1 Requirements detailed in *Nalli et al.* (2013)

- **NOAA Products Validation System (NPROVS)** (*Reale et al.*, 2012)
  - Conventional RAOBs (NPROVS+ dedicated/reference), "single closest FOR" collocations
  - HDF5-formatted Collocation Files facilitates GRUAN RAOB matchups within VALAR
  - NRT monitoring capability
  - Satellite EDR intercomparison capability
  - Java based graphical user interface tools for monitoring
    - Profile Display (PDISP)
    - NPROVS Archive Summary (NARCS)

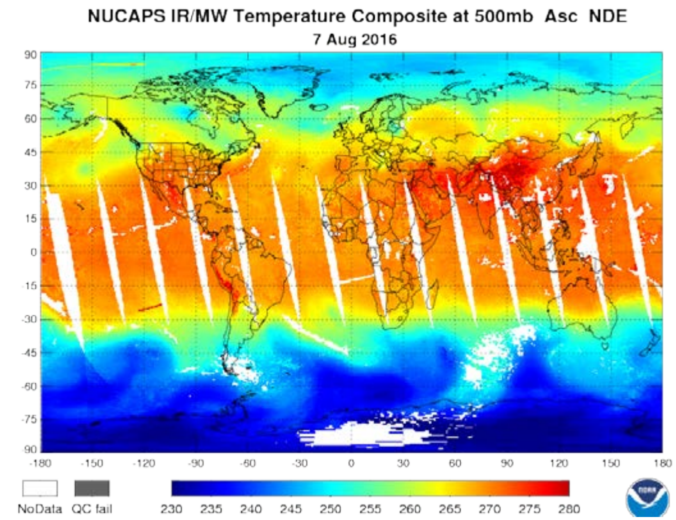
VALAR Concept and Objectives



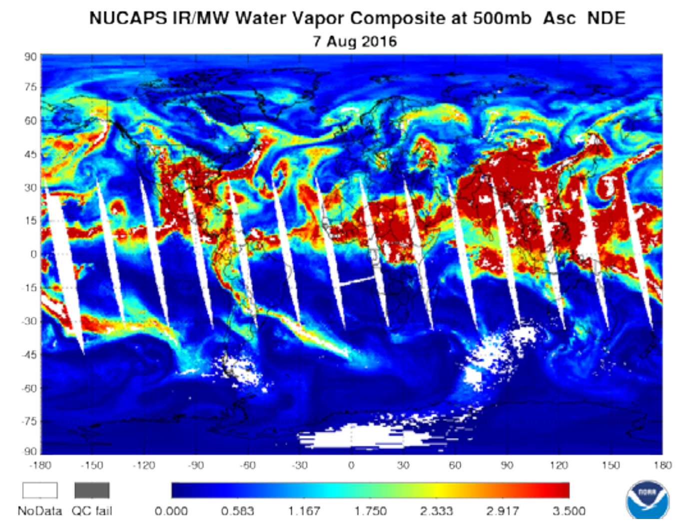


NOAA Unique Combined Atmospheric Processing System (NUCAPS) Algorithm (1/2)

- **Operational algorithm**
  - Unified Sounder Science Team (AIRS/IASI/CrIS) retrieval algorithm (*Susskind, Barnet and Blaisdell,* IEEE 2003; *Gambacorta et al.,* 2014)
  - Global non-precipitating conditions
  - Atmospheric Vertical Temperature , Moisture Profiles (**AVTP**, **AVMP**)
  - Trace gases (**O_3, CO, CO_2, CH_4**)
    - See presentation in **Session 11 Trace Gases** on Thursday
  - Validated Maturity for AVTP/AVMP, Sep 2014
- **Users**
  - **Weather Forecast Offices (AWIPS)**
    - Nowcasting / severe weather
    - Alaska (cold core)
  - NOAA/CPC (OLR)
  - NOAA/ARL (IR ozone, trace gases)
  - TOAST (IR ozone)
  - Basic and applied science research (e.g., *Pagano et al.,* 2014)
    - Via NOAA Data Centers (e.g., CLASS)
    - Universities, peer-reviewed pubs



NUCAPS AVTP



NUCAPS AVMP

Long Term Monitoring

http://www.star.nesdis.noaa.gov/jpss/EDRs/products_Soundings.php
http://www.ospo.noaa.gov/Products/atmosphere/soundings/nucaps/index.html

NOAA Unique Combined Atmospheric Processing System (NUCAPS) Algorithm (2/2)

- **NUCAPS Offline Code Versioning**
  - **Version 1.5**
    - **Current operational system**
    - Runs on **nominal CrIS spectral resolution** data
  - **Version 1.8.1**
    - **Offline experimental** algorithm
    - Runs on **CrIS full spectral resolution** data
    - Uses conventional regression algorithm for the IR/MW first guess (as opposed to MW retrieval as in v1.7 full-res)
    - Upgrades
      - Updated IR radiative transfer algorithm (RTA) bias correction coefficients (based on the best combination resulted after testing the use of several atmospheric states and trace gaseous profiles)
      - IR emissivity threshold decreased from 1.05 to 1.0 in the `temp_cris.nl` namelist.
      - Replaced the Taylor expansion to the Exponential formula in the `fasttau_co2.F` program.
      - Updated MW bias correction (as in v1.6)
      - Updated MW RTA model error coefficients (as in v1.6)
      - Removal of MW channel 16 (as in v1.6)

SNPP NUCAPS Products and Validation

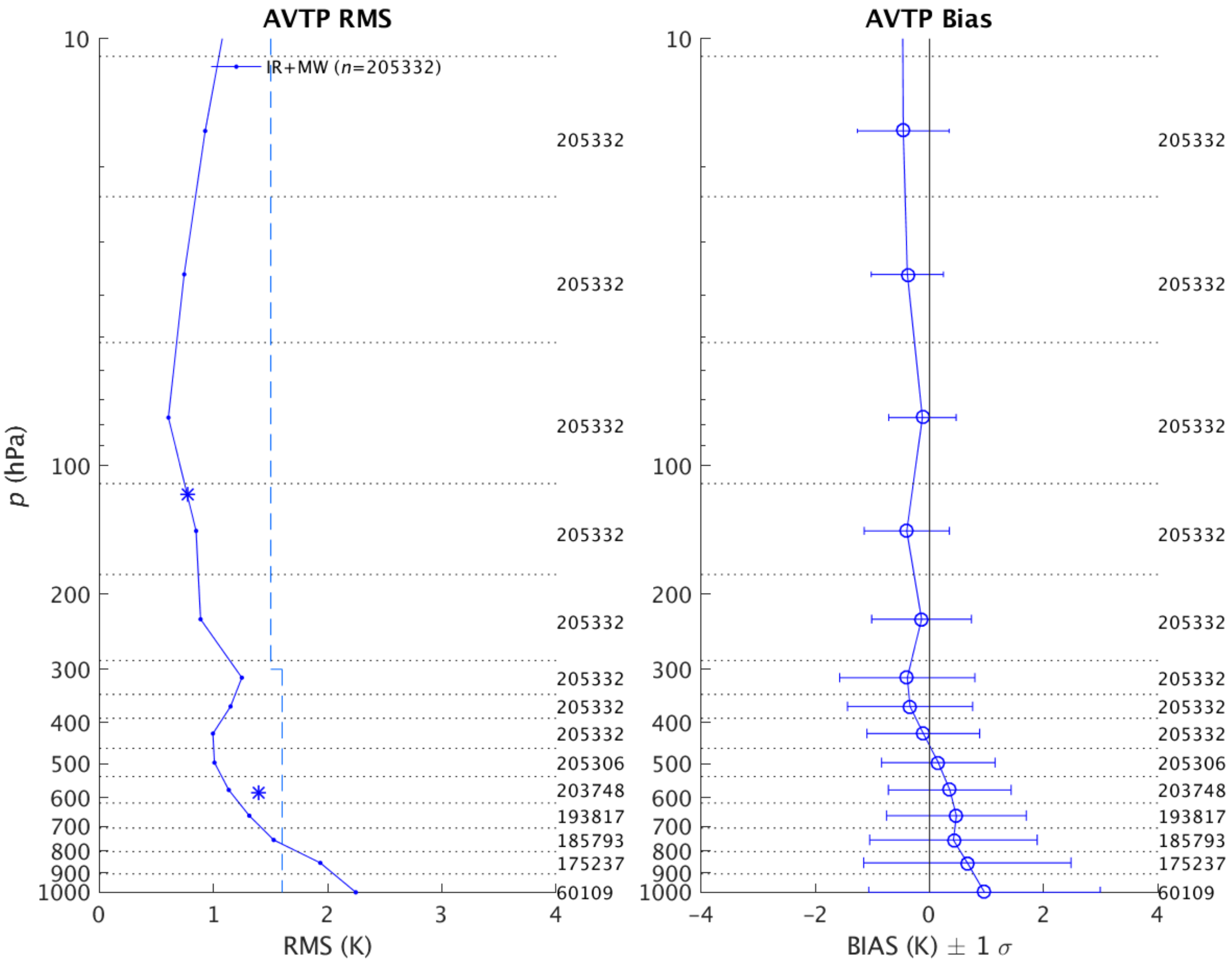
NUCAPS EDR EVALUATION: V1.5, NOMINAL CRIS RESOLUTION

NUCAPS Offline (v1.5) AVTP Coarse-Layer Statistics (1/2) Global Focus Day 17-Feb-2015

AVTP Versus ECMWF

*** "Broad-Layer" Stats (Per JPSS Level 1 Requirements)**

IR+MW Yield = 63.4%

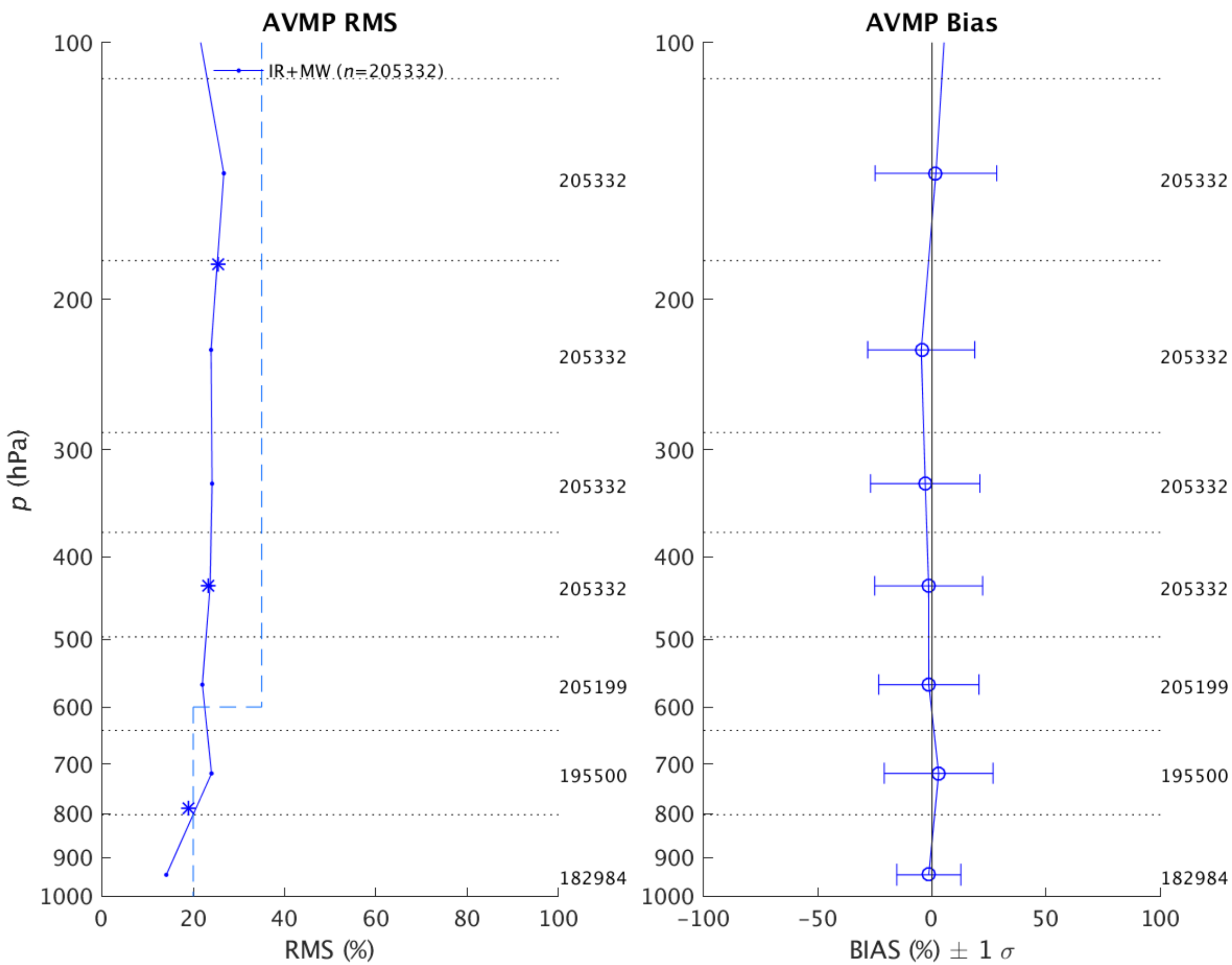


NUCAPS Offline (v1.5) AVMP Coarse-Layer Statistics (2/2)
Global Focus Day 17-Feb-2015

IR+MW Yield = 63.4%

AVMP Versus ECMWF

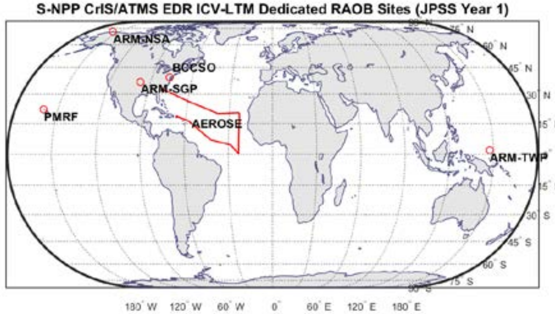
*** "Broad-Layer" Stats (Per JPSS Level 1 Requirements)**



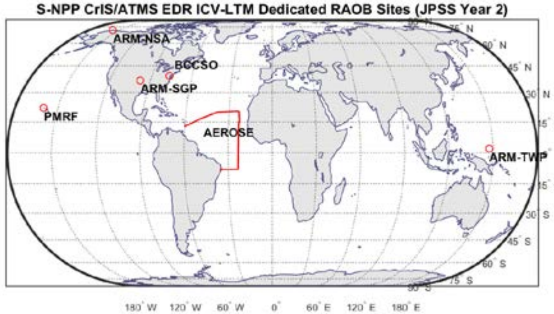
JPSS SNPP Dedicated and Reference RAOBs

JPSS SNPP Dedicated Years 1–2 (2012–2014)

S-NPP CrIS/ATMS EDR ICV-LTM Dedicated RAOB Sites (JPSS Year 1)

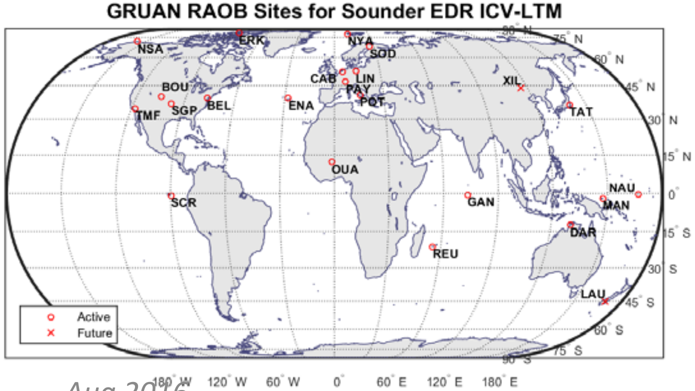


S-NPP CrIS/ATMS EDR ICV-LTM Dedicated RAOB Sites (JPSS Year 2)



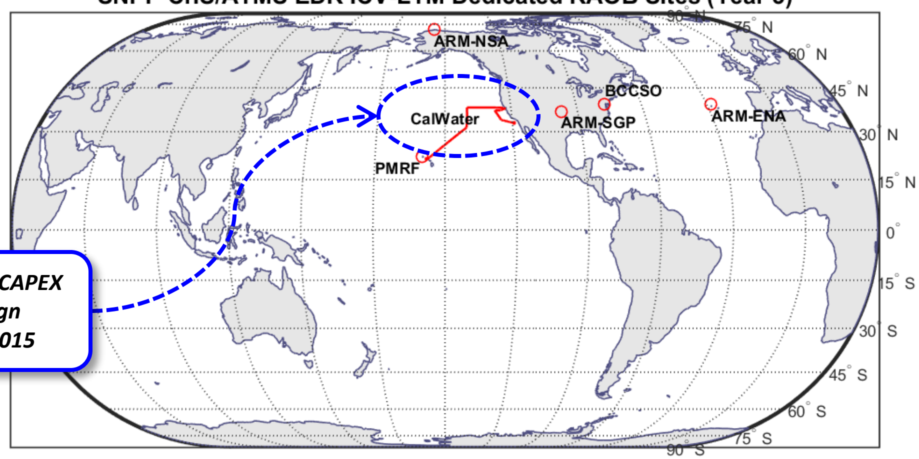
GRUAN Reference Sites

GRUAN RAOB Sites for Sounder EDR ICV-LTM



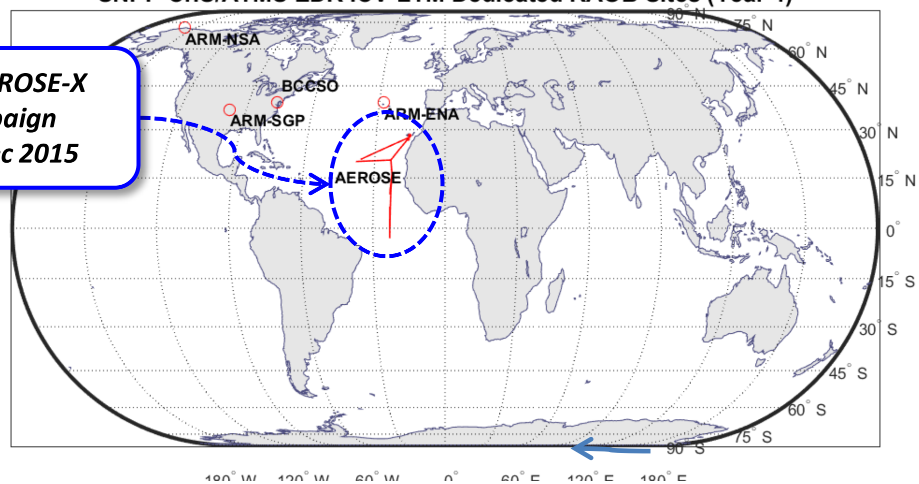
JPSS SNPP Dedicated Years 3–4 (2014-2016)

SNPP CrIS/ATMS EDR ICV-LTM Dedicated RAOB Sites (Year 3)



CalWater/ACAPEX Campaign Jan-Feb 2015

SNPP CrIS/ATMS EDR ICV-LTM Dedicated RAOB Sites (Year 4)

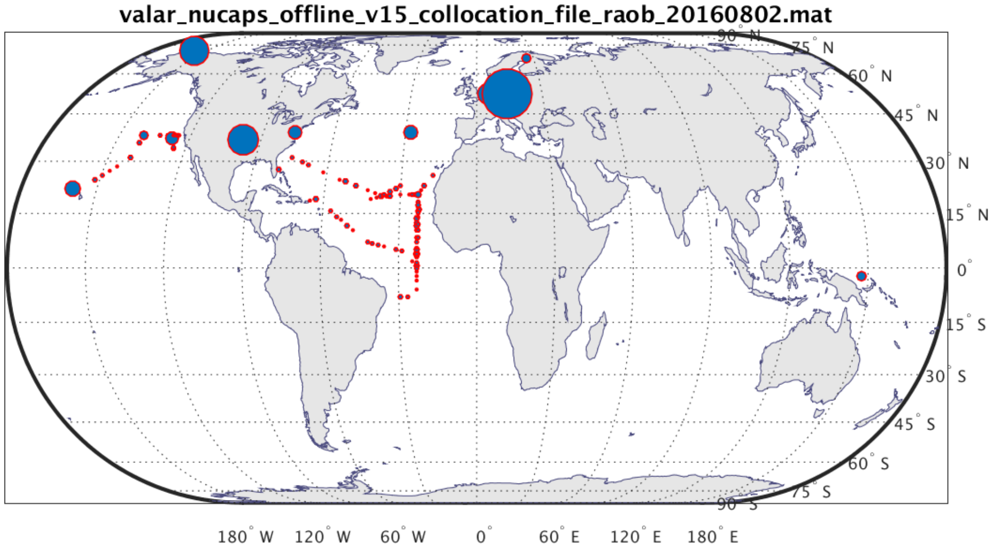


PNE/AEROSE-X Campaign Nov-Dec 2015

VALAR/NPROVS+ Dedicated/Reference RAOB-FOR Collocation Sample

VALAR Geographic Histogram

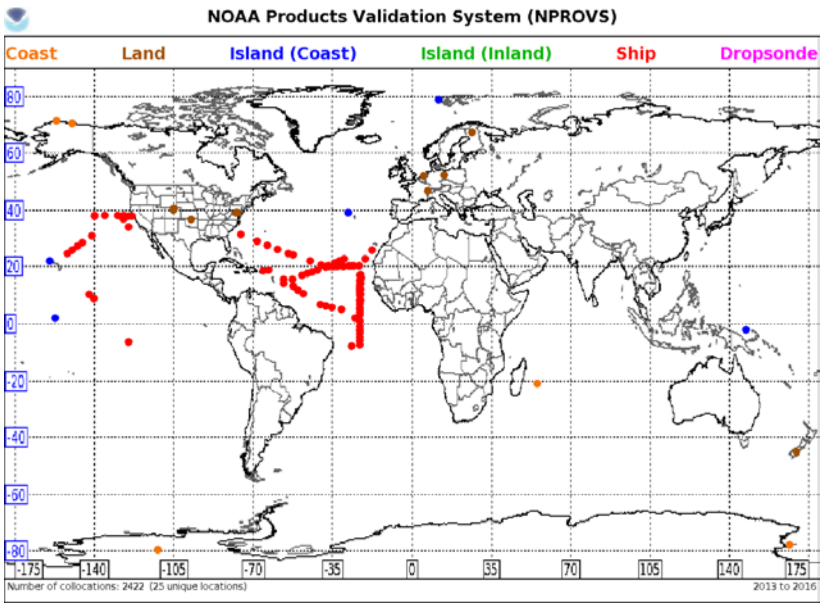
FOR Collocation Criteria: δx ≤ 50 km, −75 < δt < 0 min



VALAR map projection is equal-area.

NPROVS+ Collocation Map

FOR Collocation Criteria: Single Closest, −75 < δt < 0 min



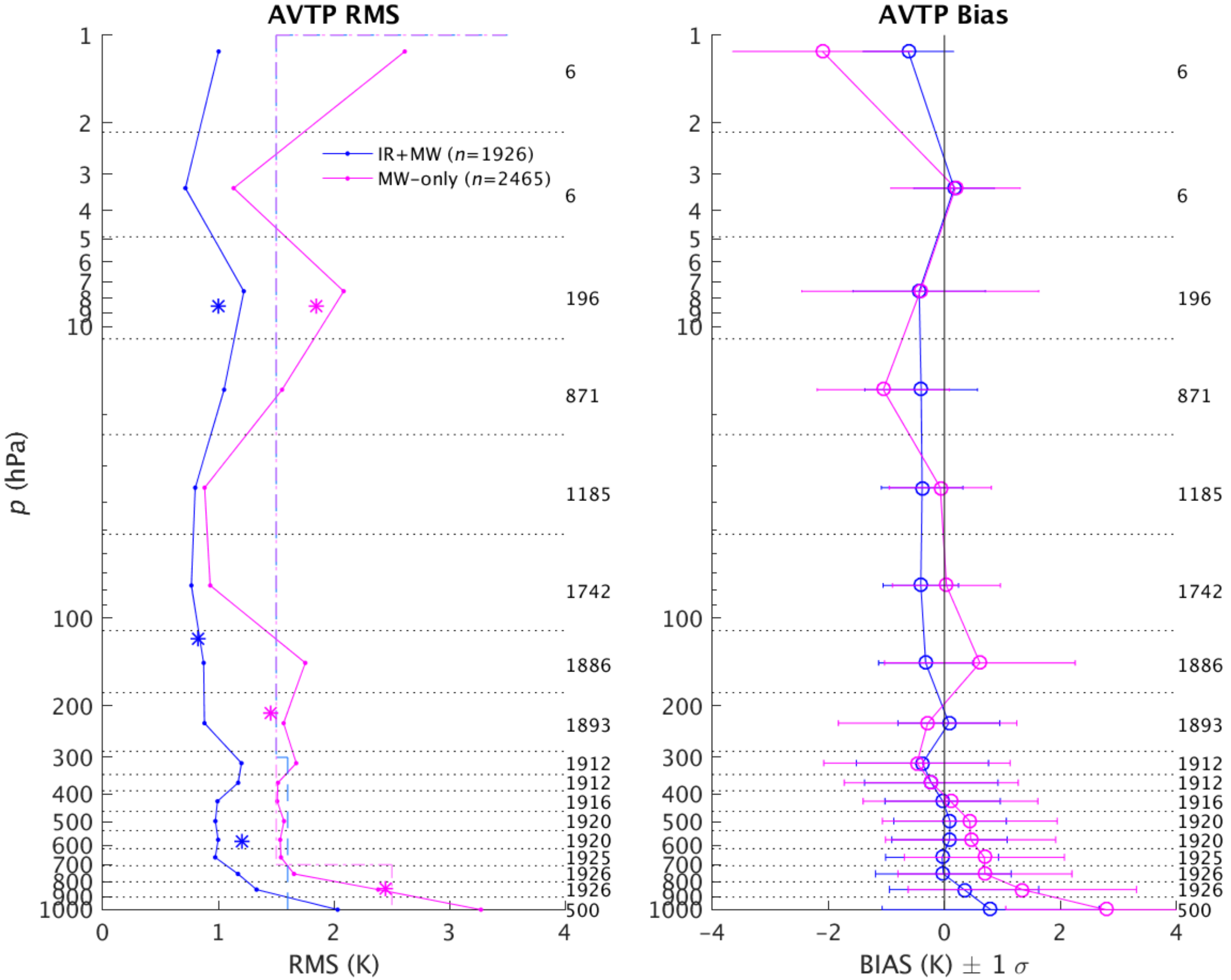
NUCAPS Offline (v1.5) AVTP Coarse-Layer Statistics
VALAR Dedicated/Reference RAOB Collocation Sample

AVTP Versus RAOB

**** Broad-Layer Stats (Per JPSS Level 1 Requirements)**

IR+MW
MW-Only

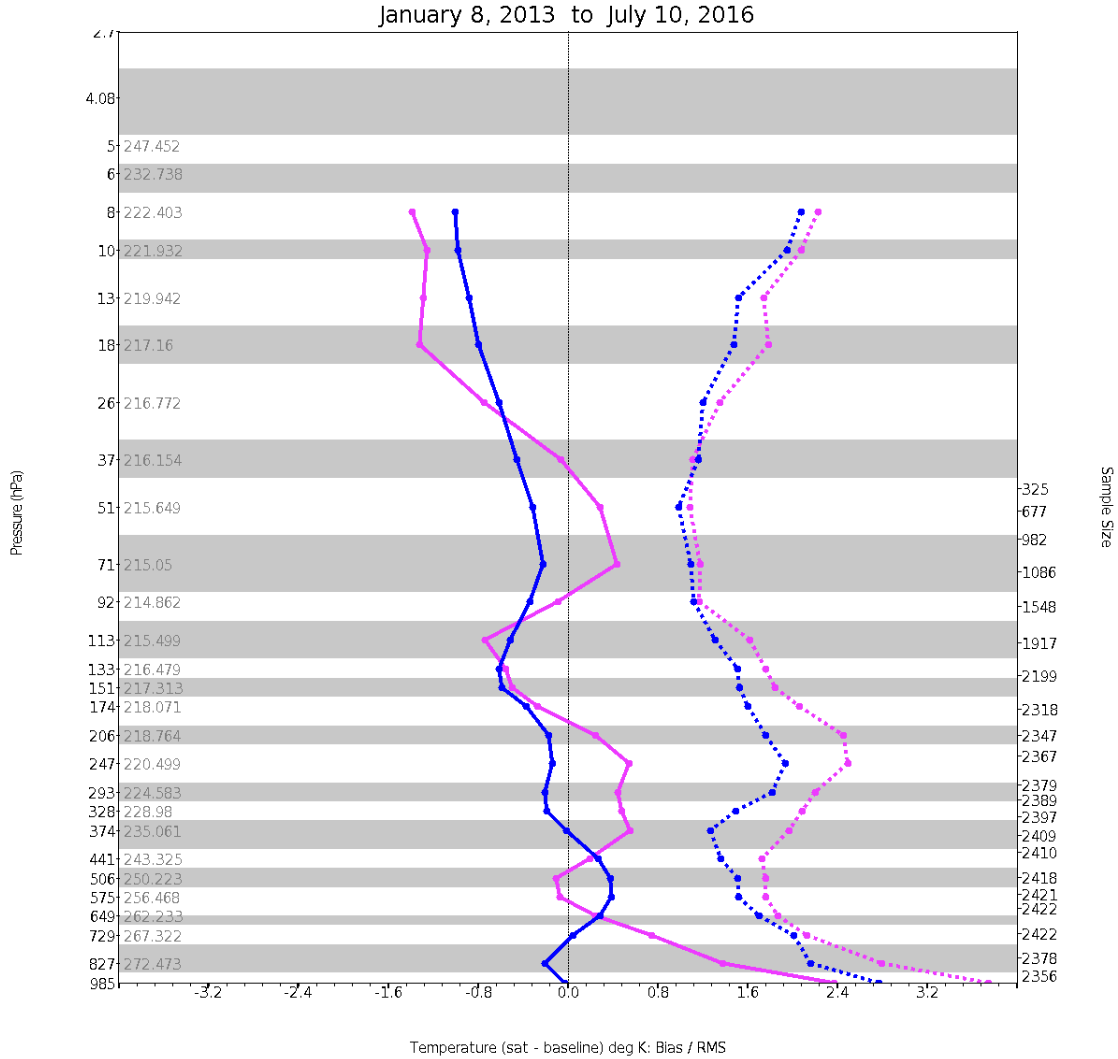
IR+MW Yield = 63.3%



NUCAPS Operational AVTP Coarse-Layer Statistics
NPROVS+ Dedicated/Reference RAOB Collocation Sample

AVTP Versus RAOB

IR+MW
MW-Only



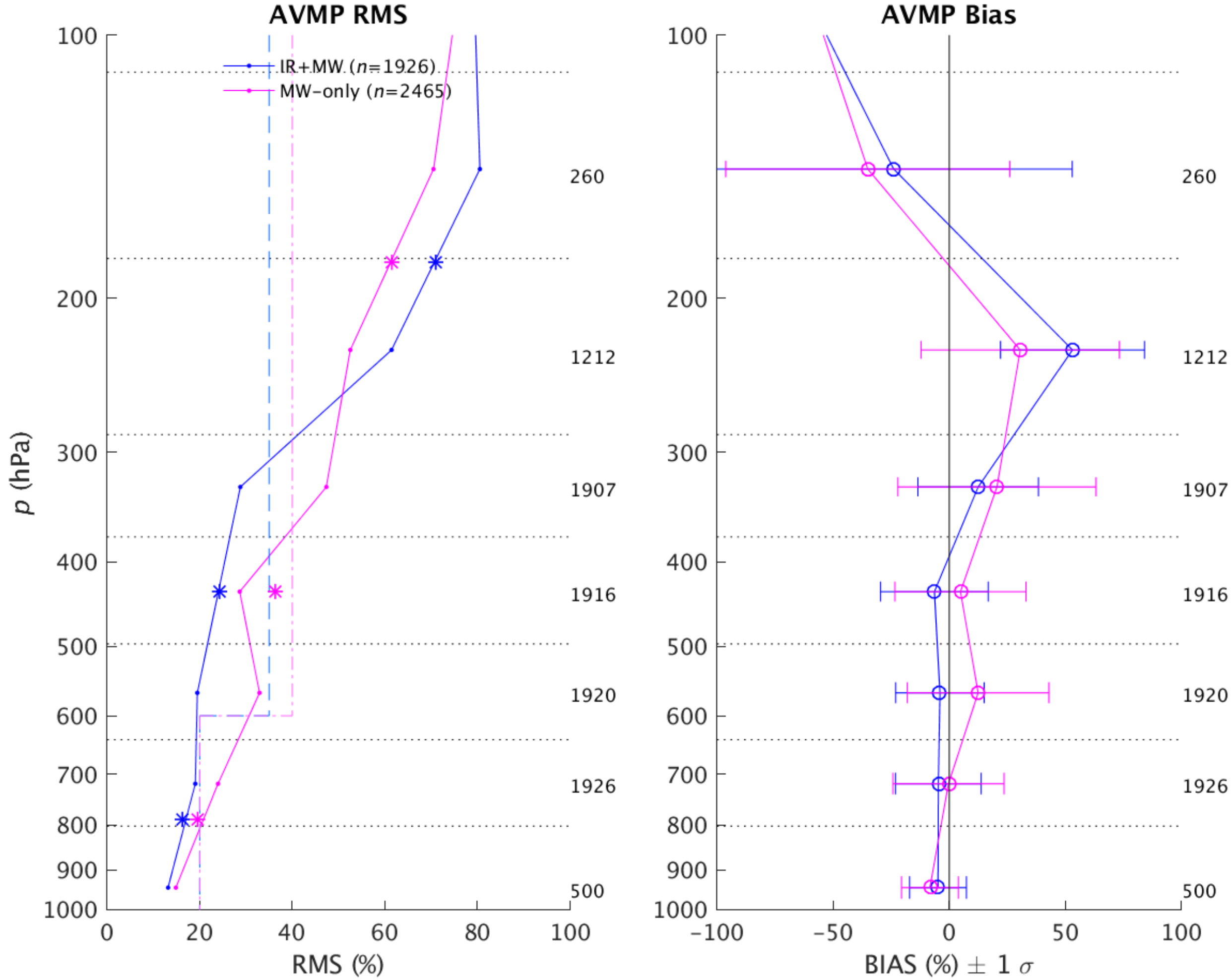
NUCAPS Offline (v1.5) AVMP Coarse-Layer Statistics
VALAR Dedicated/Reference RAOB Collocation Sample

AVMP Versus RAOB

** Broad Layer Stats (Per JPSS Level 1 Requirements)

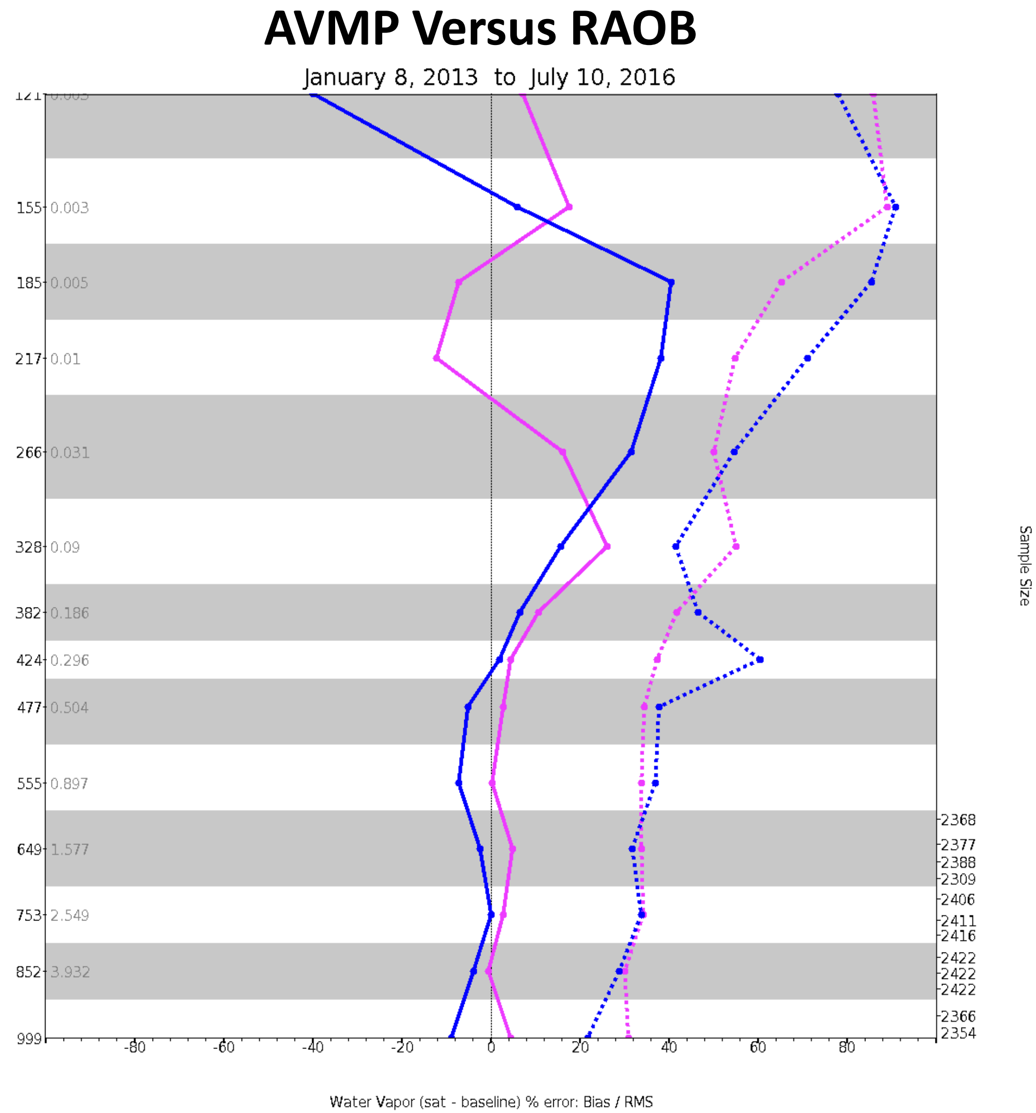
IR+MW
MW-Only

IR+MW Yield
= 63.3%



NUCAPS Operational AVMP Coarse-Layer Statistics
NPROVS+ Dedicated/Reference RAOB Collocation Sample

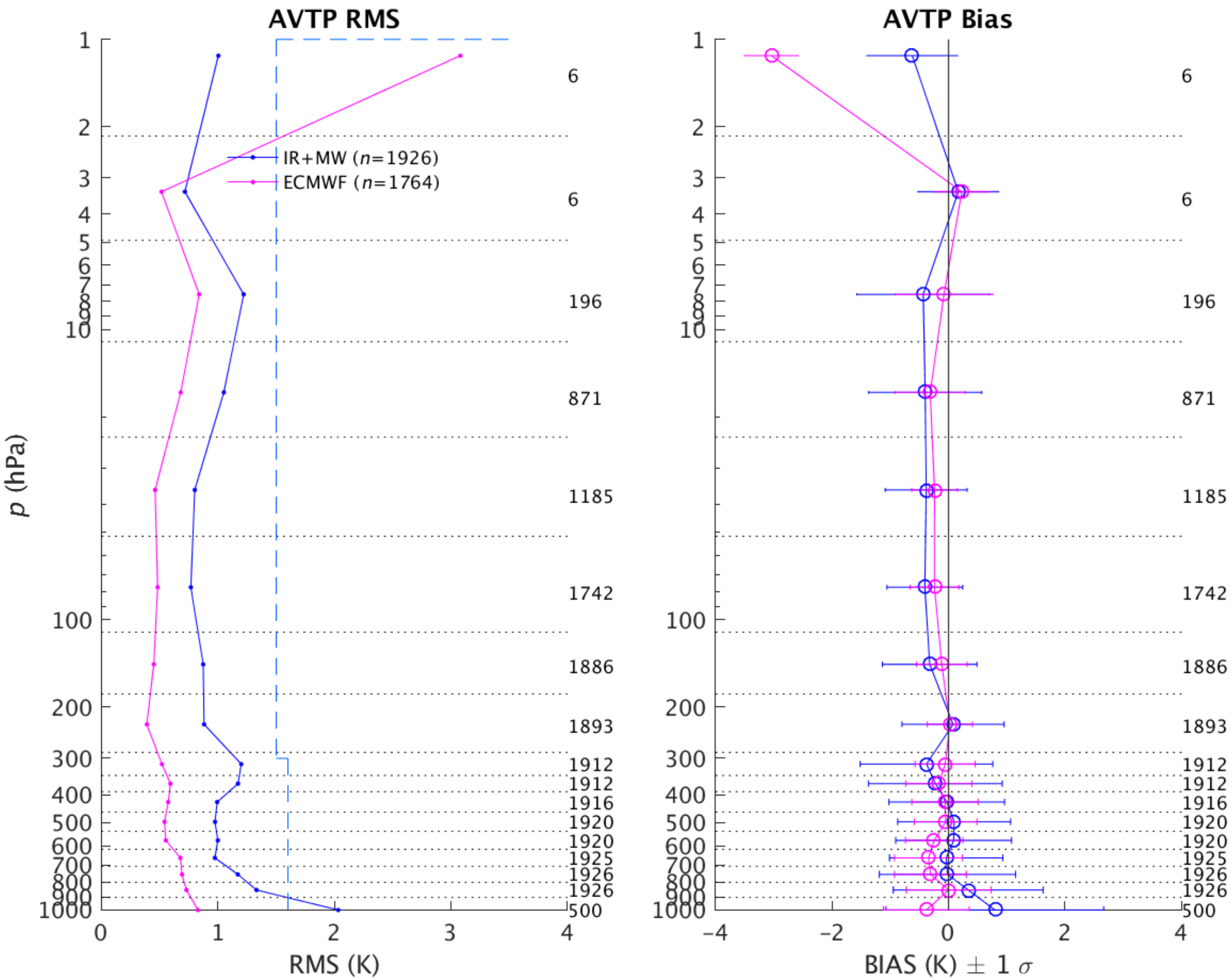
IR+MW
MW-Only



NUCAPS Offline (v1.5) AVTP and ECMWF Coarse-Layer Statistics VALAR Dedicated/Reference RAOB Collocation Sample

IR+MW AVTP and ECMWF Versus RAOB

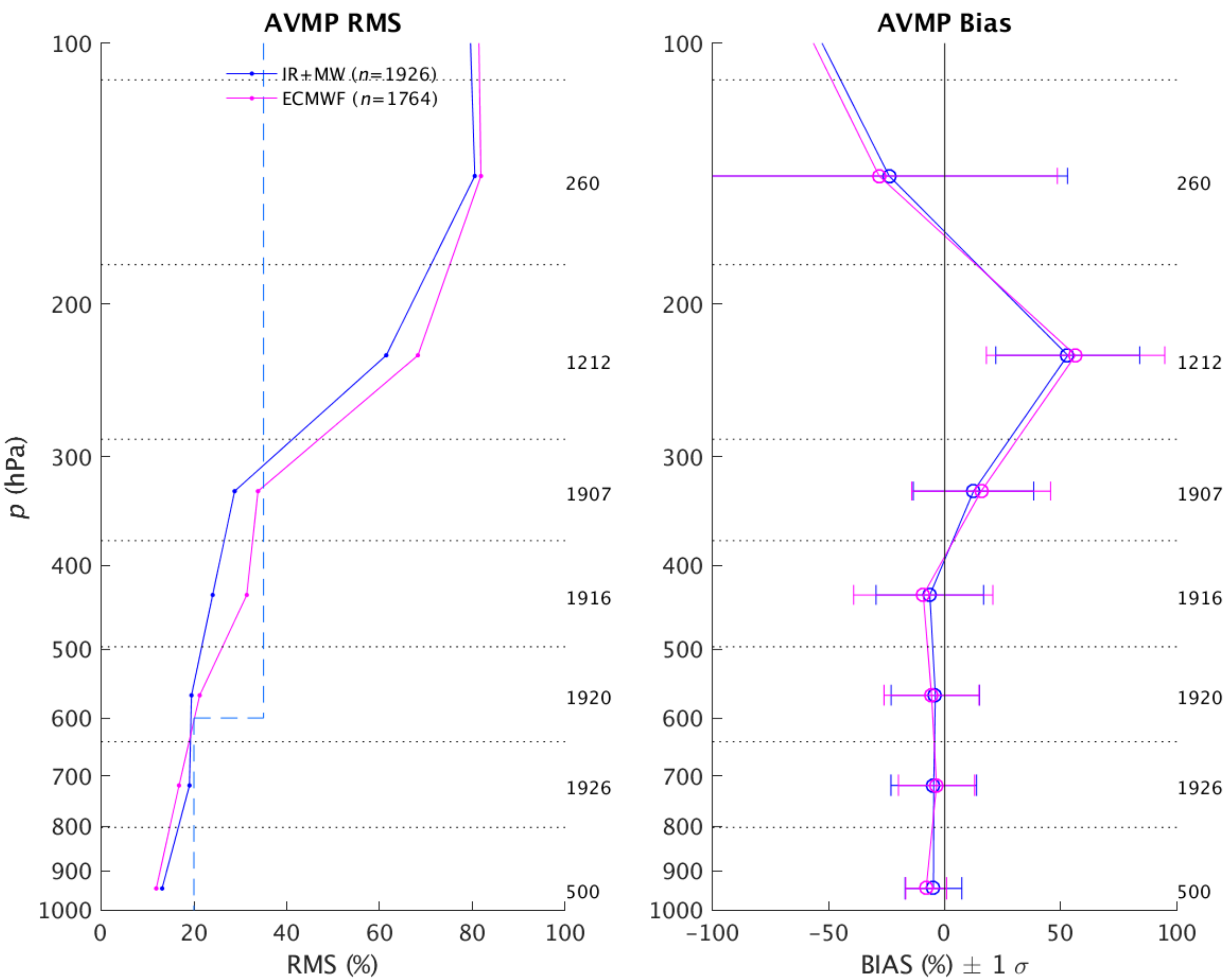
IR+MW Yield = 63.3%



NUCAPS Offline (v1.5) AVMP and ECMWF Coarse-Layer Statistics VALAR Dedicated/Reference RAOB Collocation Sample

IR+MW AVMP and ECMWF Versus RAOB

IR+MW Yield = 63.3%



SNPP NUCAPS Products and Validation

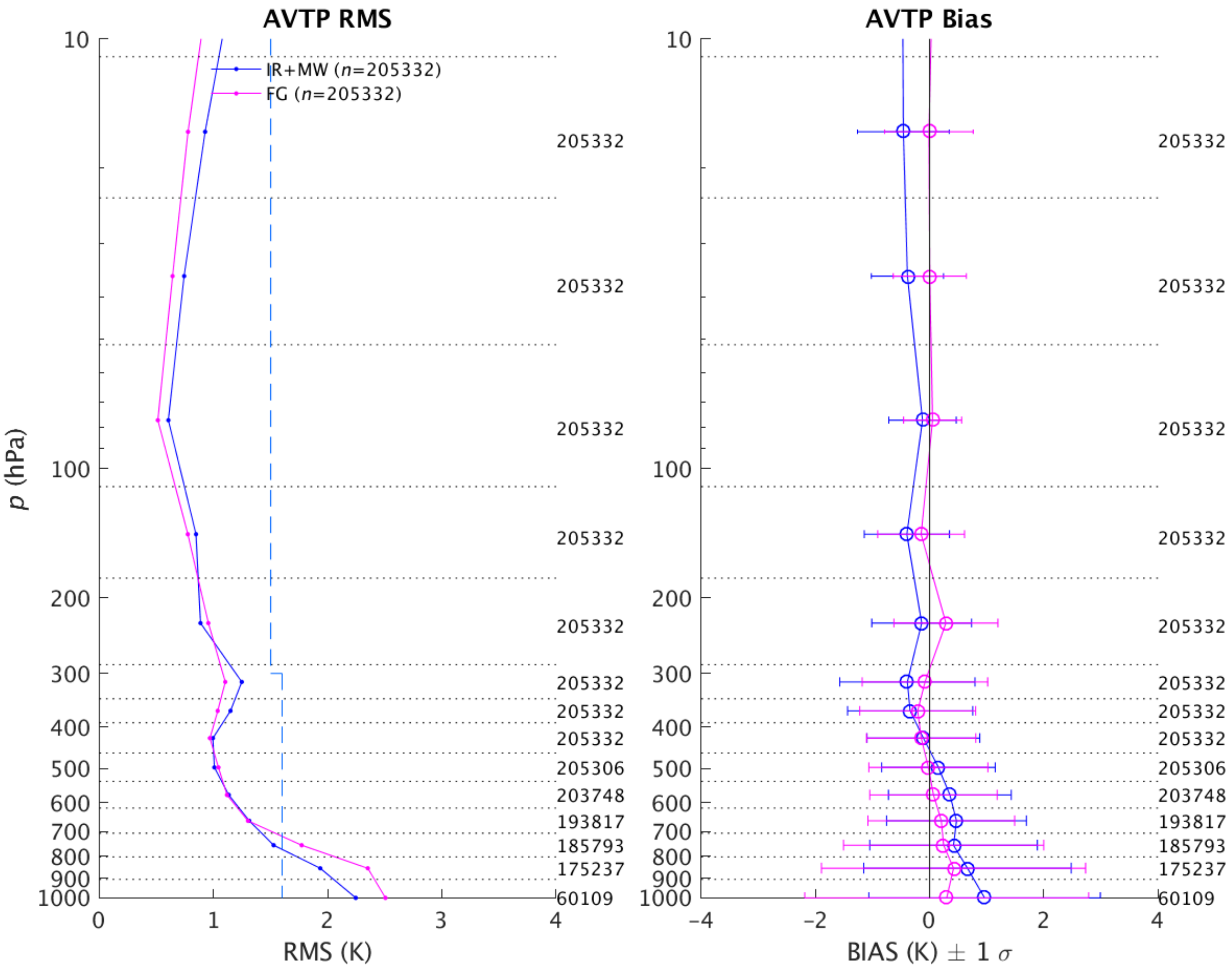
NUCAPS EDR EVALUATION: V1.8.1, FULL RESOLUTION CRIS

NUCAPS Offline (v1.5) AVTP Coarse-Layer Statistics
Global Focus Day 17-Feb-2015

AVTP Versus ECMWF

IR+MW
First Guess

NUCAPS v1.5
Yield = 63.4%

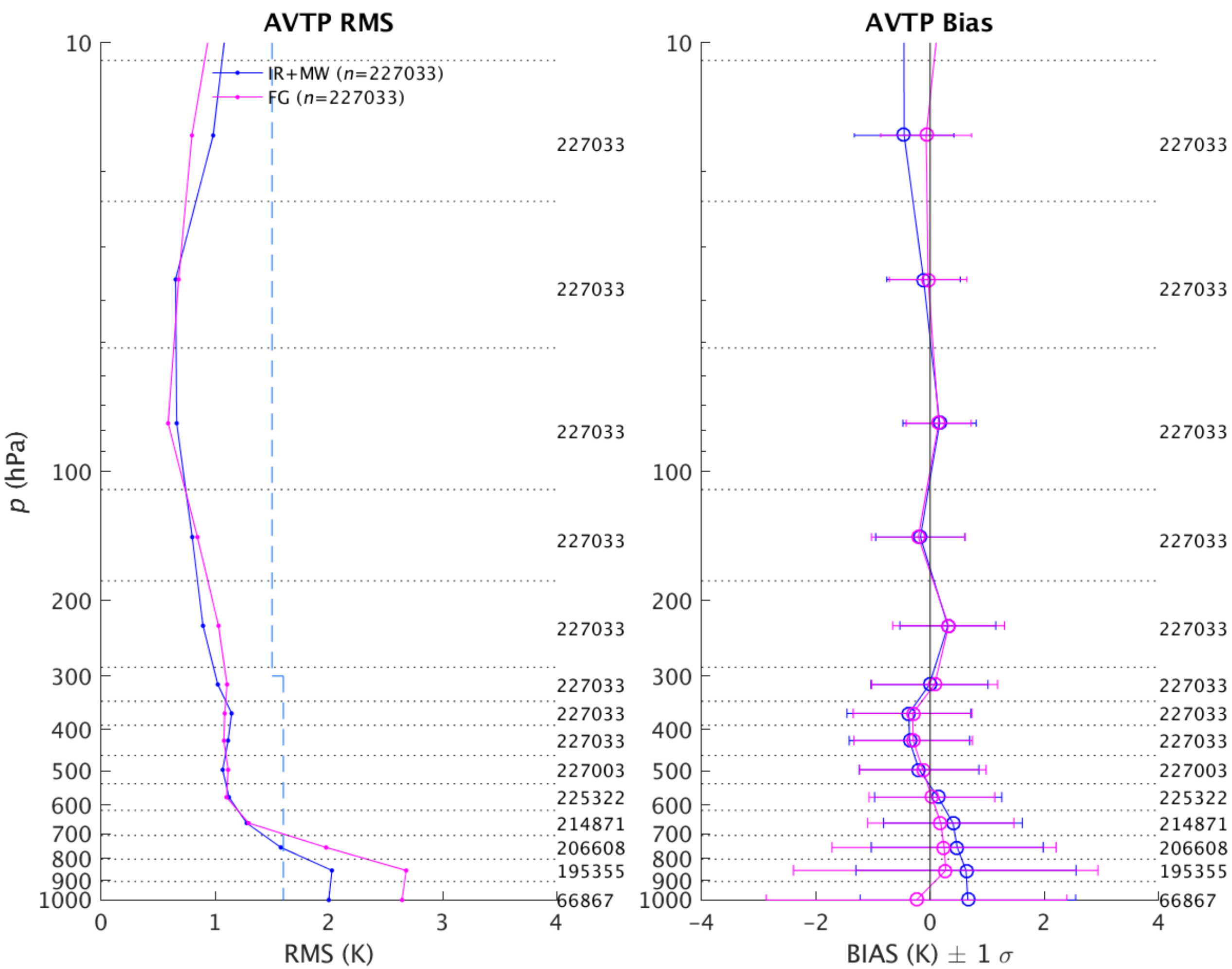


NUCAPS Offline (v1.8.1) AVTP Coarse-Layer Statistics
Global Focus Day 17-Feb-2015

IR+MW
First Guess

NUCAPS v1.8.1
Yield = 70.1%

AVTP Versus ECMWF

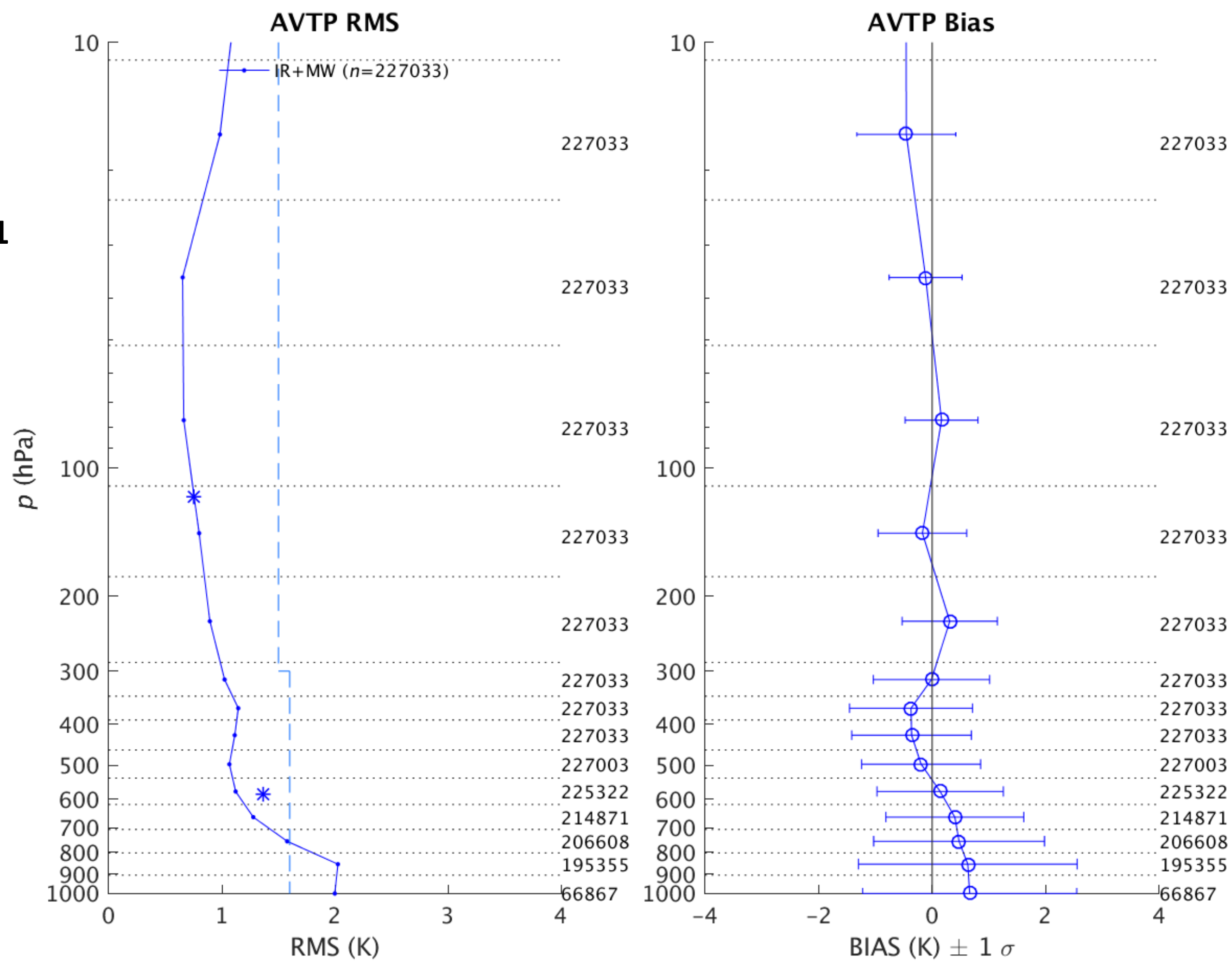


NUCAPS Offline (v1.8.1) AVTP Coarse-Layer Statistics Global Focus Day 17-Feb-2015

AVTP Versus ECMWF

* "Broad-Layer" Stats (Per JPSS Level 1 Requirements)

NUCAPS v1.8.1
Yield = 70.1%



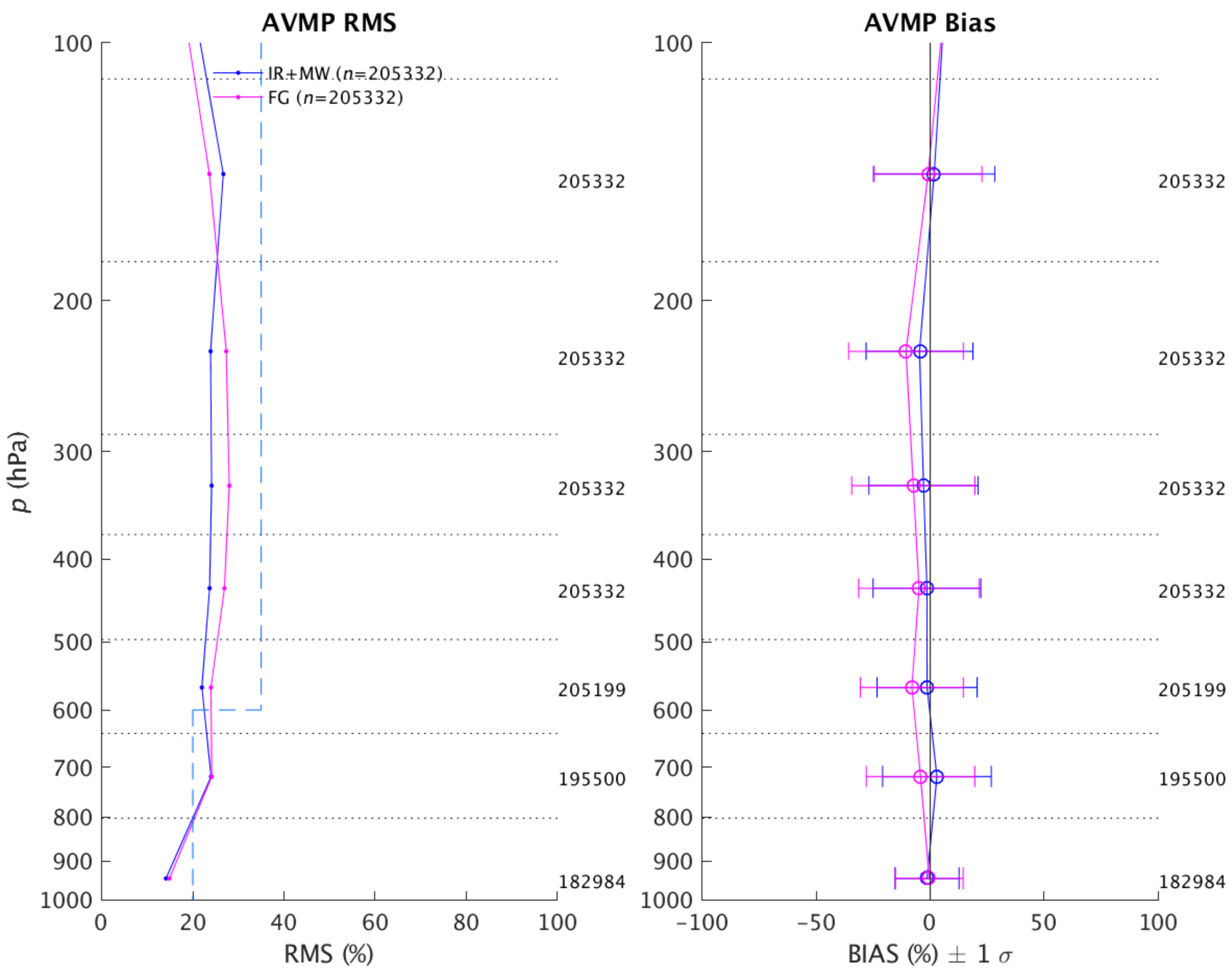
NUCAPS Offline (v1.5) AVMP Coarse-Layer Statistics Global Focus Day 17-Feb-2015

AVMP Versus ECMWF

IR+MW

First Guess

NUCAPS v1.5
Yield = 63.4%



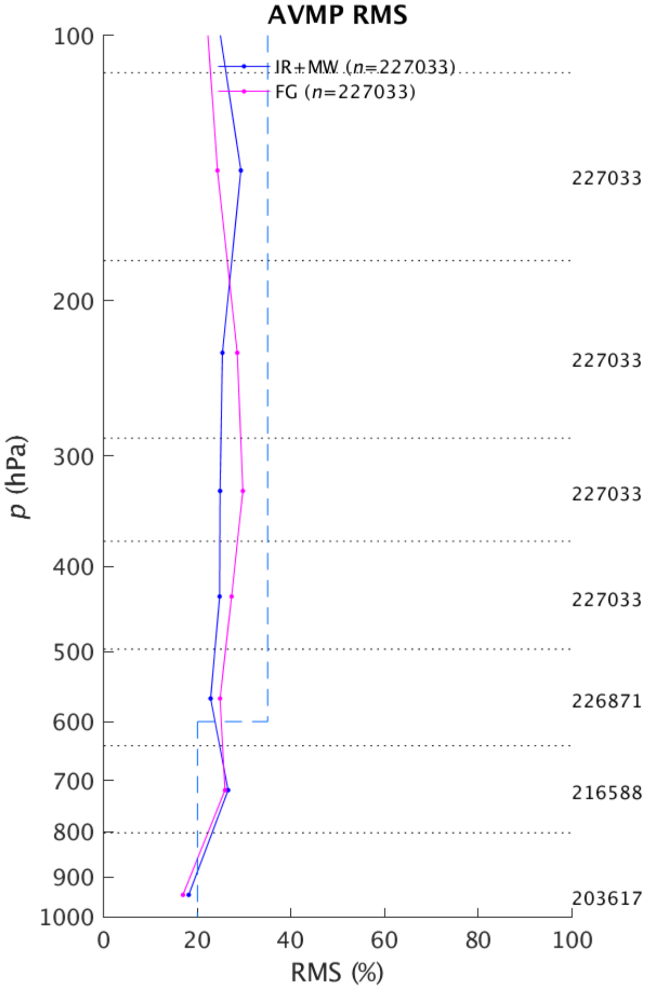
NUCAPS Offline (v1.8.1) AVMP Coarse-Layer Statistics Global Focus Day 17-Feb-2015

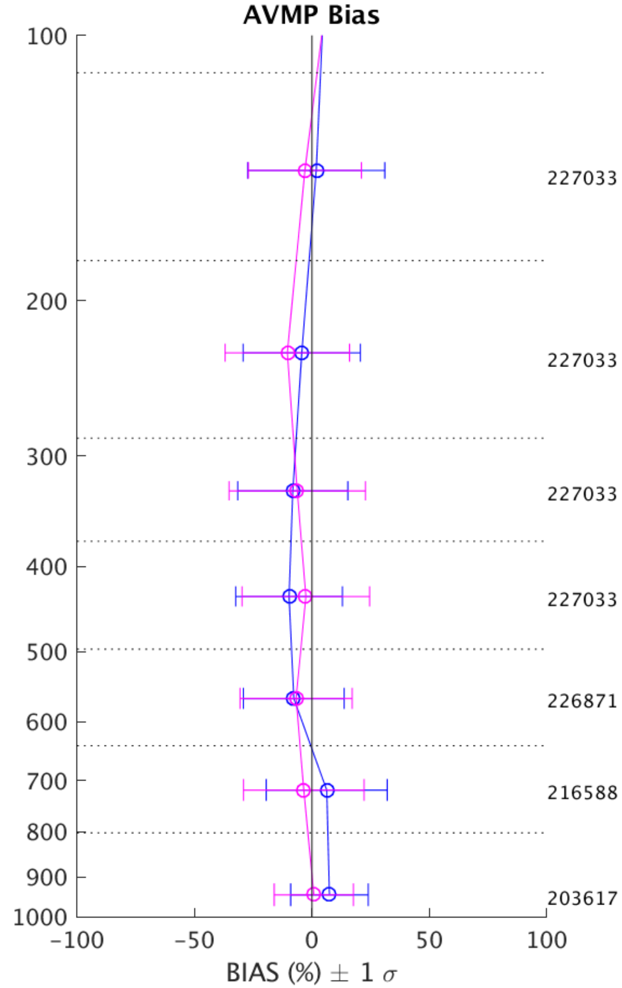
AVMP Versus ECMWF

IR+MW

First Guess

NUCAPS v1.8.1
Yield = 70.1%



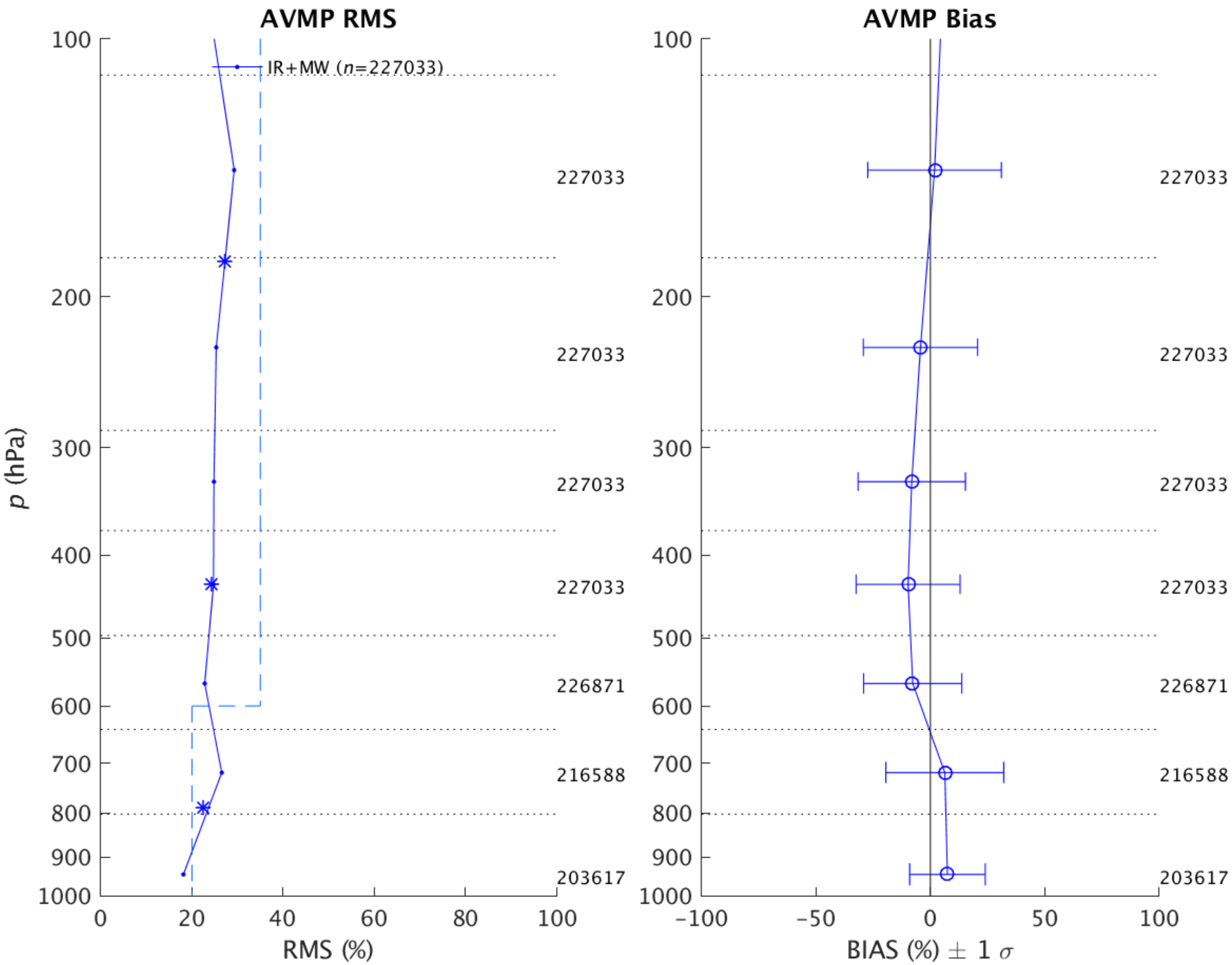


NUCAPS Offline (v1.8.1) AVMP Coarse-Layer Statistics Global Focus Day 17-Feb-2015

AVMP Versus ECMWF

*** "Broad-Layer" Stats (Per JPSS Level 1 Requirements)**

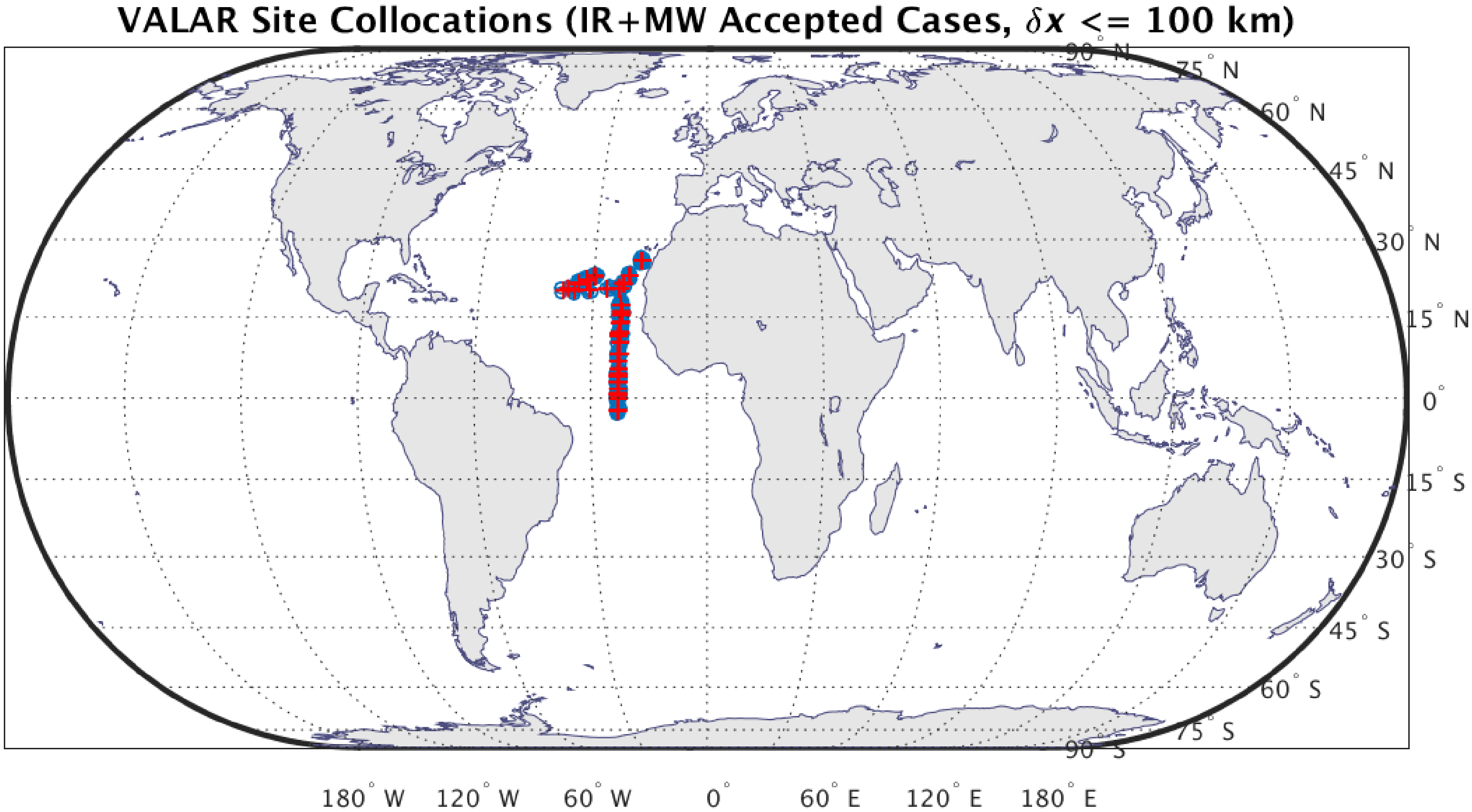
NUCAPS v1.8.1
Yield = 70.1%



NUCAPS v1.8.1 versus v1.5
Nov-Dec 2015 AEROSE Campaign (JPSS Year-4)

VALAR Collocation Map – AEROSE 2015

FOR Collocation Criteria: $\delta x \leq 100$ km, $-75 < \delta t < 0$ min

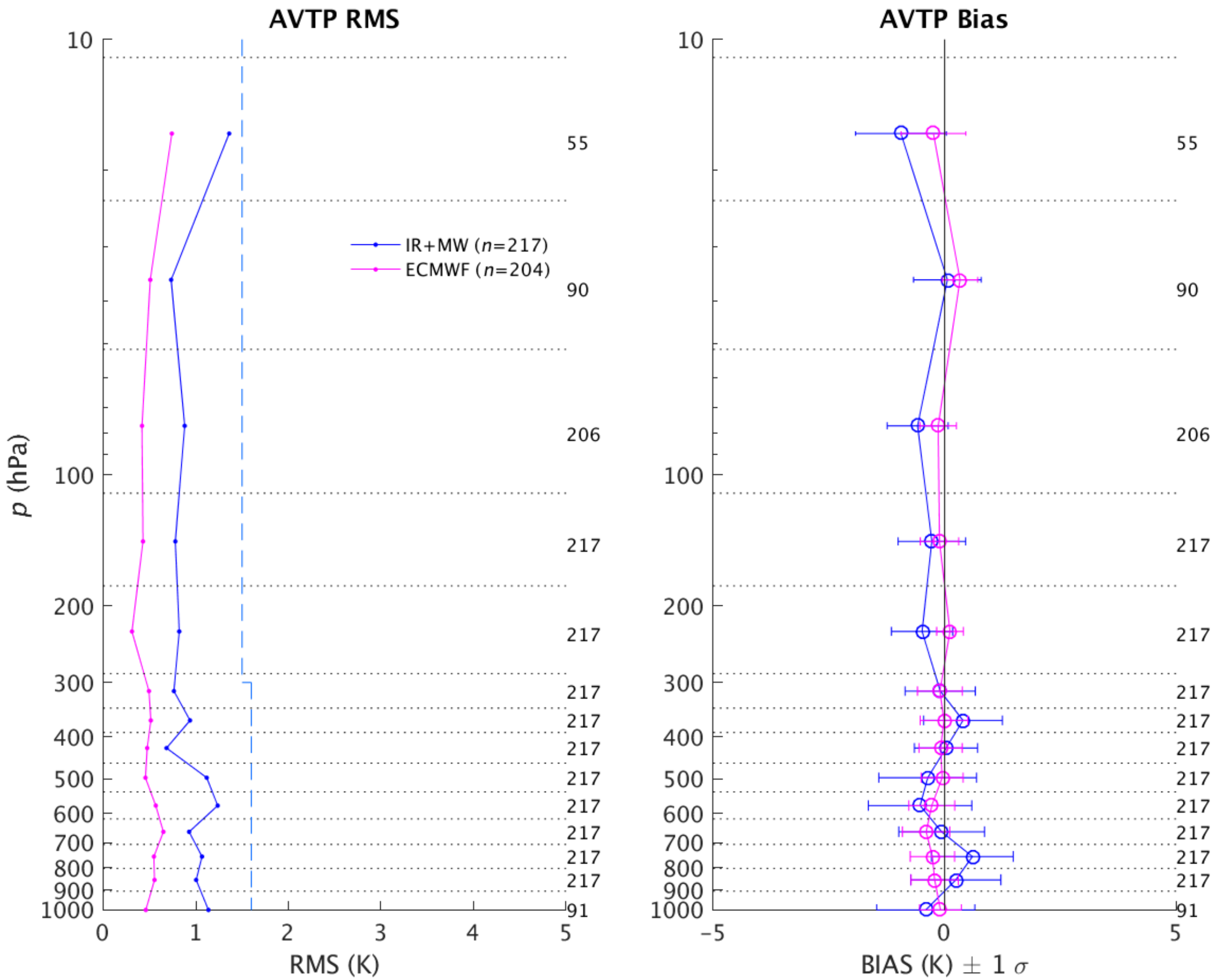


NUCAPS Offline (v1.5) AVTP Coarse-Layer Statistics
Nov-Dec 2015 AEROSE Campaign (JPSS Year-4)

AVTP Versus Dedicated RAOB

IR+MW
ECMWF

IR+MW Yield = 75.7%

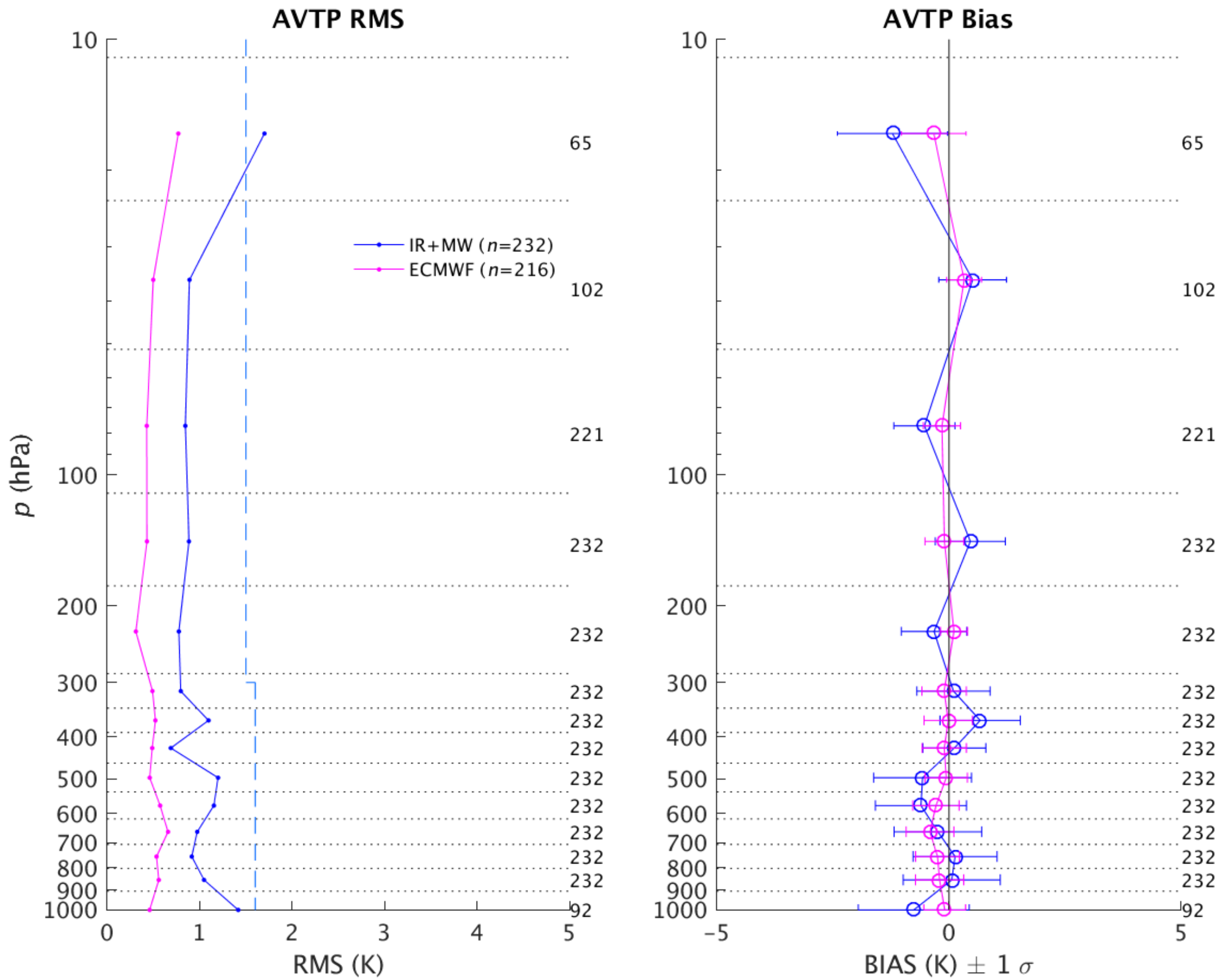


NUCAPS Offline (v1.8.1) AVTP Coarse-Layer Statistics
Nov-Dec 2015 AEROSE Campaign (JPSS Year-4)

AVTP Versus Dedicated RAOB

IR+MW
ECMWF

IR+MW Yield = 85.0%



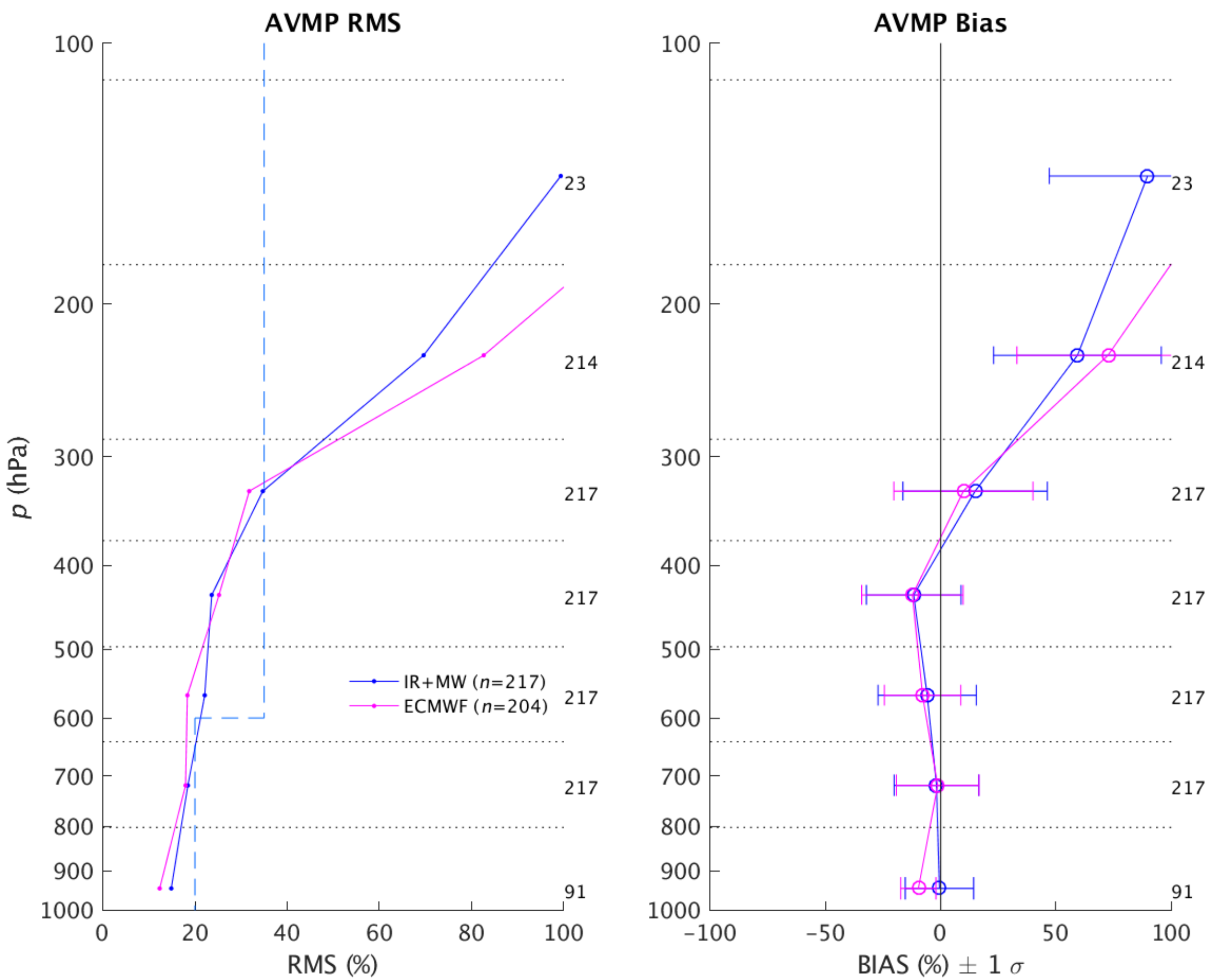
NUCAPS Offline (v1.5) AVMP Coarse-Layer Statistics
Nov-Dec 2015 AEROSE Campaign (JPSS Year-4)

AVMP Versus Dedicated RAOB

IR+MW

ECMWF

IR+MW Yield = 75.7%

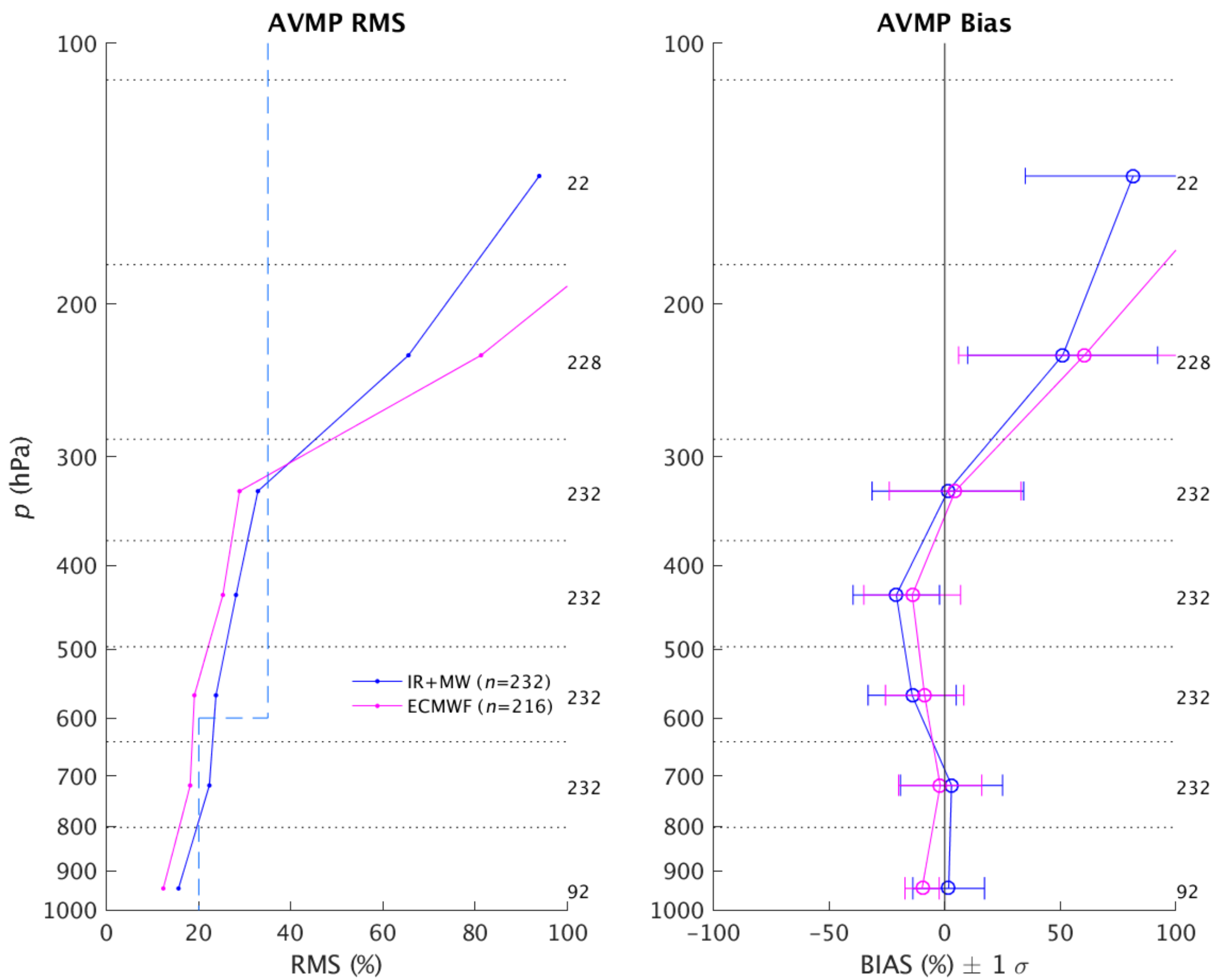


NUCAPS Offline (v1.8.1) AVMP Coarse-Layer Statistics
Nov-Dec 2015 AEROSE Campaign (JPSS Year-4)

AVMP Versus Dedicated RAOB

IR+MW
ECMWF

IR+MW Yield = 85.0%



Summary and Future Work

- **Operational** (offline v1.5) **NUCAPS AVTP/AVMP EDRs** using **CrIS nominal resolution data** are shown to **meet JPSS global requirements**.

- Offline code of **NUCAPS algorithm for full-res CrIS data** (currently v1.8.1) has been **successfully implemented** and is undergoing optimization. Based on Global Focus Day ECMWF model comparison, we find
  - **V1.8.1 AVTP meets JPSS Level 1 requirements** based on Global Focus Day; AVMP meets requirements except lowest layer
  - **V1.8.1 stats agree well with the validated operational version** (offline v1.5).

- **Future Work**
  - **Ongoing NUCAPS Validation and Long-Term Monitoring**
    - Transition operational NUCAPS to full-resolution CrIS SDR
    - **NUCAPS Trace Gas validation** (see presentation in **Session 11 Trace Gases** on Thursday)
    - **Prepare for J-1**
    - VALAR expansion, development and enhancements
      - Participate in the **AEROSE-XI campaign (Atlantic Ocean, Jan-Feb 2017)**
      - Continue support of ARM dedicated RAOBs (including dual-launches, "best estimates")
      - Continue leveraging GRUAN reference RAOBs
      - **GRUAN reprocessing** of RS92 RAOB data (viz., entire AEROSE data record)
  - **Other Related Work**
    - **Apply averaging kernels** in NUCAPS error analyses, including ozone profile EDR
    - Collocation uncertainty estimates
    - calc – obs analyses (CRTM, LBLRTM, SARTA, etc.)
    - Support skin SST EDR validation (e.g., *Oyola et al.* 2016)
    - Support aerosol impact studies
    - Support EDR user applications (AWIPS, AR/SAL, atmospheric chemistry users)

SNPP NUCAPS Products and Validation

THANK YOU! QUESTIONS?

SNPP NUCAPS Products and Validation

EXTRA SLIDES

Assessment Methodology: Reducing Truth to Correlative Layers

- The **measurement equation** (e.g., *Taylor and Kuyatt,* 1994) for retrieval includes forward and inverse operators (*Rodgers*, 1990) to estimate the measurand, $\mathbf{x}$, on forward model layers:

$$\hat{\mathbf{x}} = I[F(\mathbf{x},\mathbf{b}),\mathbf{b},\mathbf{c}]$$

- **Rigorous validation** therefore requires high-resolution truth measurements (e.g., dedicated RAOB) be **reduced to correlative RTA layers** (*Nalli et al.,* 2013, *JGR Special Section on SNPP Cal/Val*)
- **Radiative transfer approach** is to integrate quantities over the atmospheric path (e.g., number densities → column abundances), interpolate to RTA (arbitrary) levels, then compute RTA layer quantities, e.g.,

$$\sum\nolimits_x(z) = \int_{z_t}^{z} N_x(z')\,dz'$$

Assessment Methodology: Statistical Metrics

- Level 1 AVTP and AVMP accuracy requirements are defined over **coarse layers**, roughly 1–5 km for tropospheric AVTP and 2 km for AVMP (Table, Slide 6).
- We have recently introduced rigorous **zonal/land/sea surface area weighting** capabilities to these schemes for dedicated/reference RAOB samples

AVTP

$$\mathrm{RMS}(\Delta T_{\mathfrak{L}}) = \sqrt{\frac{1}{n_j}\sum_{j=1}^{n_j}(\Delta T_{\mathfrak{L},j})^2} \qquad \mathrm{BIAS}(\Delta T_{\mathfrak{L}}) \equiv \overline{\Delta T_{\mathfrak{L}}} = \frac{1}{n_j}\sum_{j=1}^{n_j}\Delta T_{\mathfrak{L},j}$$

$$\mathrm{STD}(\Delta T_{\mathfrak{L}}) \equiv \sigma(\Delta T_{\mathfrak{L}}) = \sqrt{[\mathrm{RMS}(\Delta T_{\mathfrak{L}})]^2 - [\mathrm{BIAS}(\Delta T_{\mathfrak{L}})]^2}$$

AVMP and O_3

- W2 weighting was used in determining Level 1 Requirements
- To allow compatible STD calculation, W2 weighting should be consistently used for both RMS and BIAS

$$\Delta q_{\mathfrak{L},j} \equiv \frac{\hat{q}_{\mathfrak{L},j} - q_{\mathfrak{L},j}}{q_{\mathfrak{L},j}} \qquad \mathrm{RMS}(\Delta q_{\mathfrak{L}}) = \sqrt{\frac{\sum_{j=1}^{n_j} W_{\mathfrak{L},j}(\Delta q_{\mathfrak{L},j})^2}{\sum_{j=1}^{n_j} W_{\mathfrak{L},j}}},$$

water vapor weighting factor, $W_{\mathfrak{L},j}$,

$$\mathrm{BIAS}(\Delta q_{\mathfrak{L}}) = \frac{\sum_{j=1}^{n_j} W_{\mathfrak{L},j}\,\Delta q_{\mathfrak{L},j}}{\sum_{j=1}^{n_j} W_{\mathfrak{L},j}}, \qquad W_{\mathfrak{L},j} = \begin{cases} 1 & , \mathrm{W}^0 \\ q_{\mathfrak{L},j} & , \mathrm{W}^1 \\ (q_{\mathfrak{L},j})^2 & , \mathrm{W}^2 \end{cases}$$

$$\mathrm{STD}(\Delta q_{\mathfrak{L}}) = \sqrt{[\mathrm{RMS}(\Delta q_{\mathfrak{L}})]^2 - [\mathrm{BIAS}(\Delta q_{\mathfrak{L}})]^2}$$

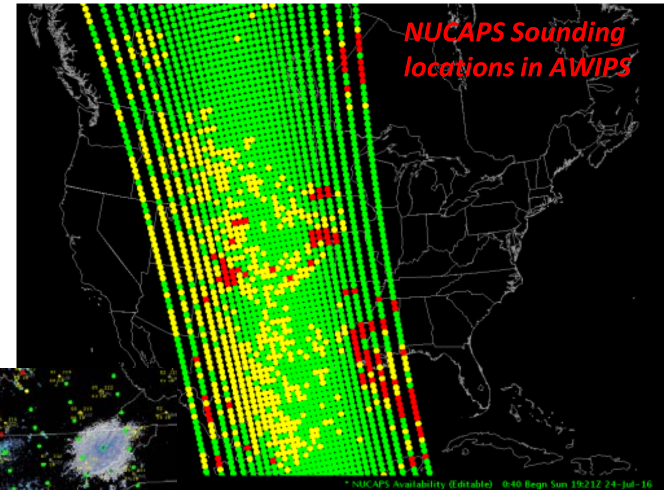
Development and Assessment of Gridded NUCAPS Products for NWS Forecasters

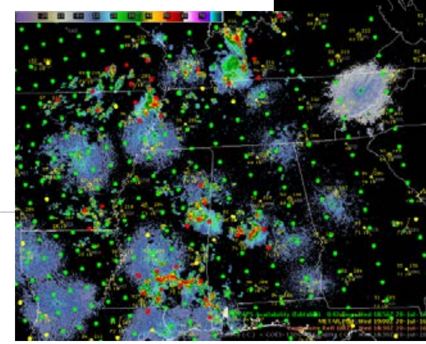
- Brad Zavodsky (SPoRT)
- **Nadia Smith (STC)**
- Jack Dostalek (CIRA)
- Eric Stevens (GINA)
- Kristine Nelson (NWS HQ)
- Chris Barnet (STC)
- Emily Berndt (SPoRT)
- Antonia Gambacorta (STC)
- Tony Reale (NESDIS/STAR)
- Elisabeth Weisz (CIMSS)

Presentation to STAR JPSS 2016 Annual Science Team Meeting
College Park, MD
August 10, 2016

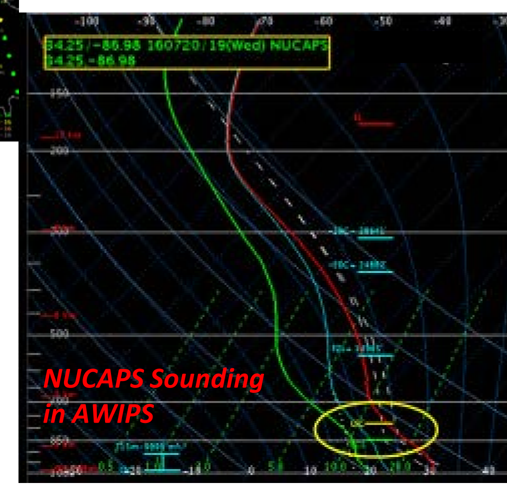
Current Operational NUCAPS Visualization

- NUCAPS is the NOAA Operational Retrieval algorithm for CrIS/ATMS and IASI/AMSU T and q profiles
- Capabilities for displaying individual Skew-T plots are available in the latest versions of AWIPS II with quality control flags
- Skew-Ts are valuable for some forecast challenges, but ***visualizing the data in plan view or cross section may be more useful for others***
- Multi-organization group—started through NUCAPS Initiative—has been funded by JPSS PG/RR to demonstrate these capabilities with NWS forecasters





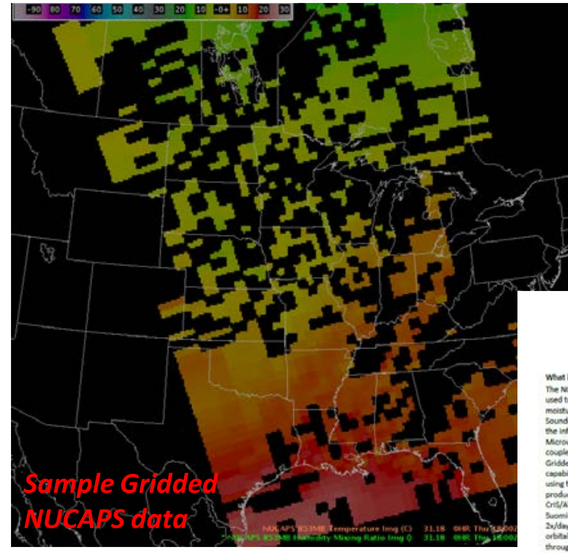
NUCAPS Sounding locations overlaying radar in AWIPS



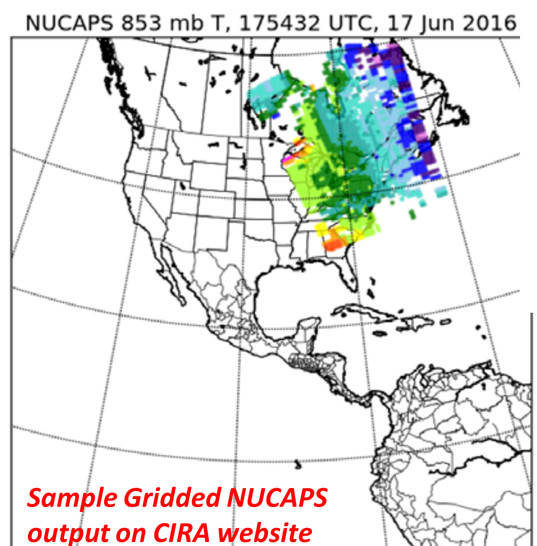
Images by Kris White (NWS HUN/NASA SPoRT)

Gridded NUCAPS for Demonstration

- CIMSS has modified its polar2grid software package to include readers for NUCAPS
- SPoRT obtains Direct Broadcast data, runs polar2grid, and converts output to gridded binary (GRIB2) format for ingest into AWIPS II
- GRIB2 files are pushed to NWS partners in real-time
- CIRA obtains the GRIB2 output and creates graphics for its website that can be linked by forecasters in public statements
- Team has developed training and quick guides that leverage foundational NUCAPS training

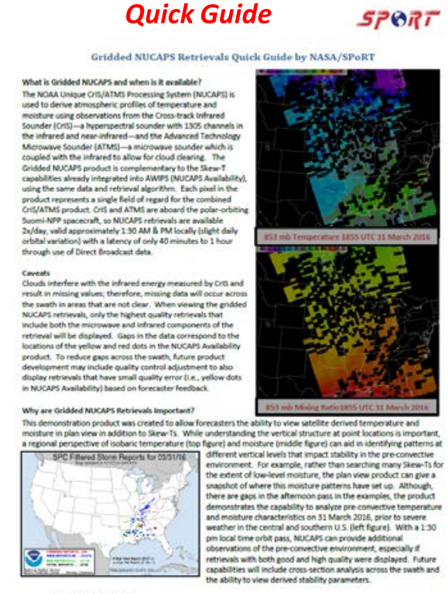


Sample Gridded NUCAPS data



Sample Gridded NUCAPS output on CIRA website

Gridded NUCAPS Quick Guide



Gridded NUCAPS Retrievals Quick Guide by NASA/SPoRT

What is Gridded NUCAPS and when is it available?

The NOAA Unique CrIS/ATMS Processing System (NUCAPS) is used to derive atmospheric profiles of temperature and moisture using observations from the Cross-track Infrared Sounder (CrIS)—a hyperspectral sounder with 1305 channels in the infrared and near-infrared—and the Advanced Technology Microwave Sounder (ATMS)—a microwave sounder which is coupled with the infrared to allow for cloud clearing. The Gridded NUCAPS product is complementary to the Skew-T capabilities already integrated into AWIPS (NUCAPS Availability), using the same data and retrieval algorithm. Each pixel in the product represents a single field of regard for the combined CrIS/ATMS product. CrIS and ATMS are aboard the polar-orbiting Suomi-NPP spacecraft, so NUCAPS retrievals are available 2x/day, valid approximately 1:30 AM & PM locally (slight daily orbital variation) with a latency of only 40 minutes to 1 hour through use of Direct Broadcast data.

Caveats

Clouds interfere with the infrared energy measured by CrIS and result in missing values; therefore, missing data will occur across the swath in areas that are not clear. When viewing the gridded NUCAPS retrievals, only the highest quality retrievals that include both the microwave and infrared components of the retrieval will be displayed. Gaps in the data correspond to the locations of the yellow and red dots in the NUCAPS Availability product. To reduce gaps across the swath, future product development may include quality control adjustment to also display retrievals that have small quality error (i.e., yellow dots in NUCAPS Availability) based on forecaster feedback.

853 mb Mixing Ratio1855 UTC 31 March 2016

Why are Gridded NUCAPS Retrievals Important?

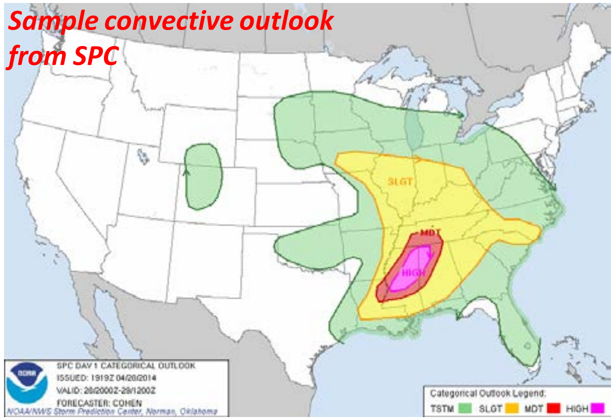
This demonstration product was created to allow forecasters the ability to view satellite derived temperature and moisture in plan view in addition to Skew-Ts. While understanding the vertical structure at point locations is important, a regional perspective of isobaric temperature (top figure) and moisture (middle figure) can aid in identifying patterns at different vertical levels that impact stability in the pre-convective environment. For example, rather than searching many Skew-Ts for the extent of low-level moisture, the plan view product can give a snapshot of where this moisture patterns have set up. Although, there are gaps in the afternoon pass in the examples, the product demonstrates the capability to analyze pre-convective temperature and moisture characteristics on 31 March 2016, prior to severe weather in the central and southern U.S. (left figure). With a 1:30 pm local time orbit pass, NUCAPS can provide additional observations of the pre-convective environment, especially if retrievals with both good and high quality were displayed. Future capabilities will include cross-section analysis across the swath and the ability to view derived stability parameters.

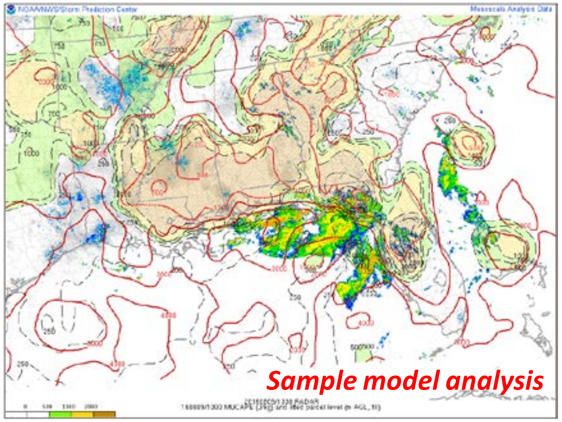
SPC Filtered Storm Reports for 03/31/16

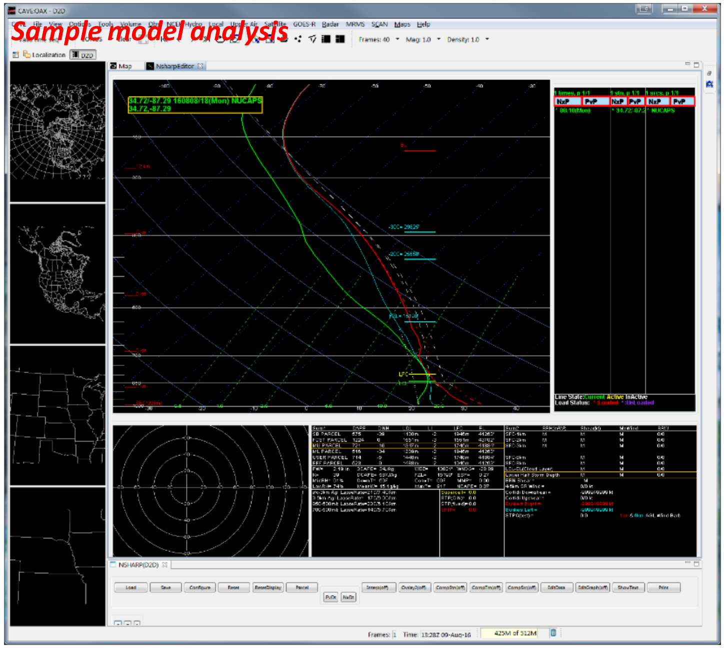
Last Modified April 2016

Forecast Challenge: Diagnosing Convective Environment

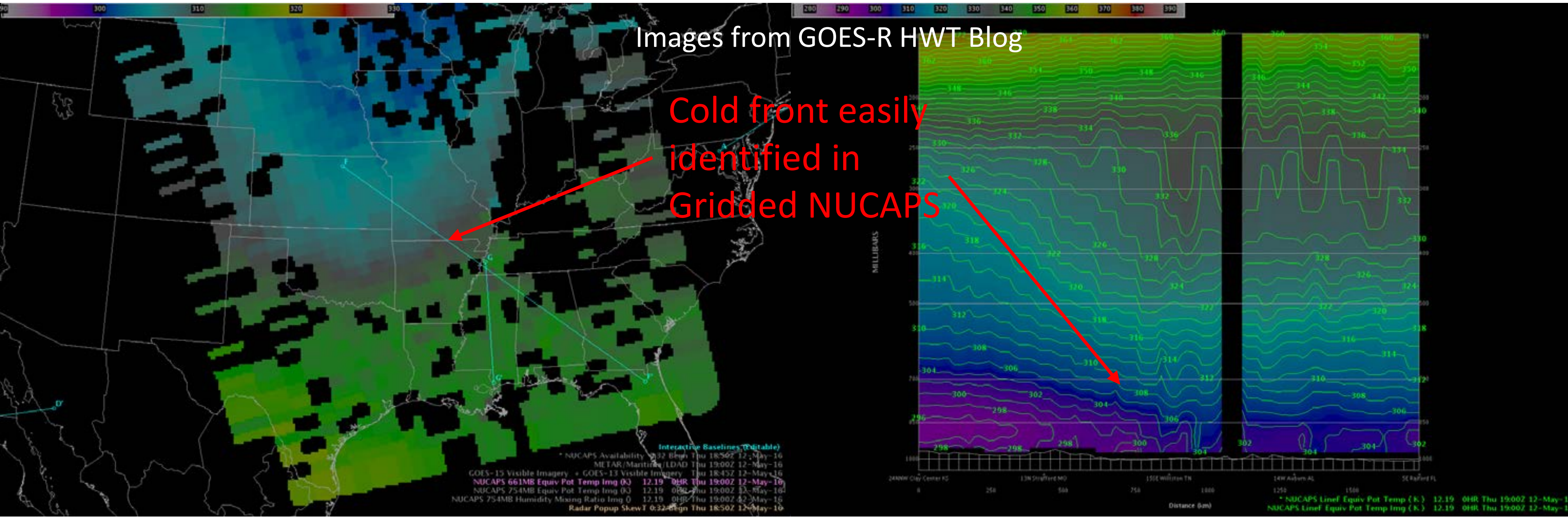
- The vertical distribution of temperature and moisture in the lower atmosphere determines convective potential
- Forecasters use a combination of in situ observations, satellite data, and models to determine the location of boundaries and areas of instability
- Ability to view plan view and cross sections of NUCAPS data in a beta version were demonstrated at the 2016 Hazardous Weather Testbed Experimental Warning Program
- Next slides detail feedback from forecasters at HWT on utility of Gridded NUCAPS products





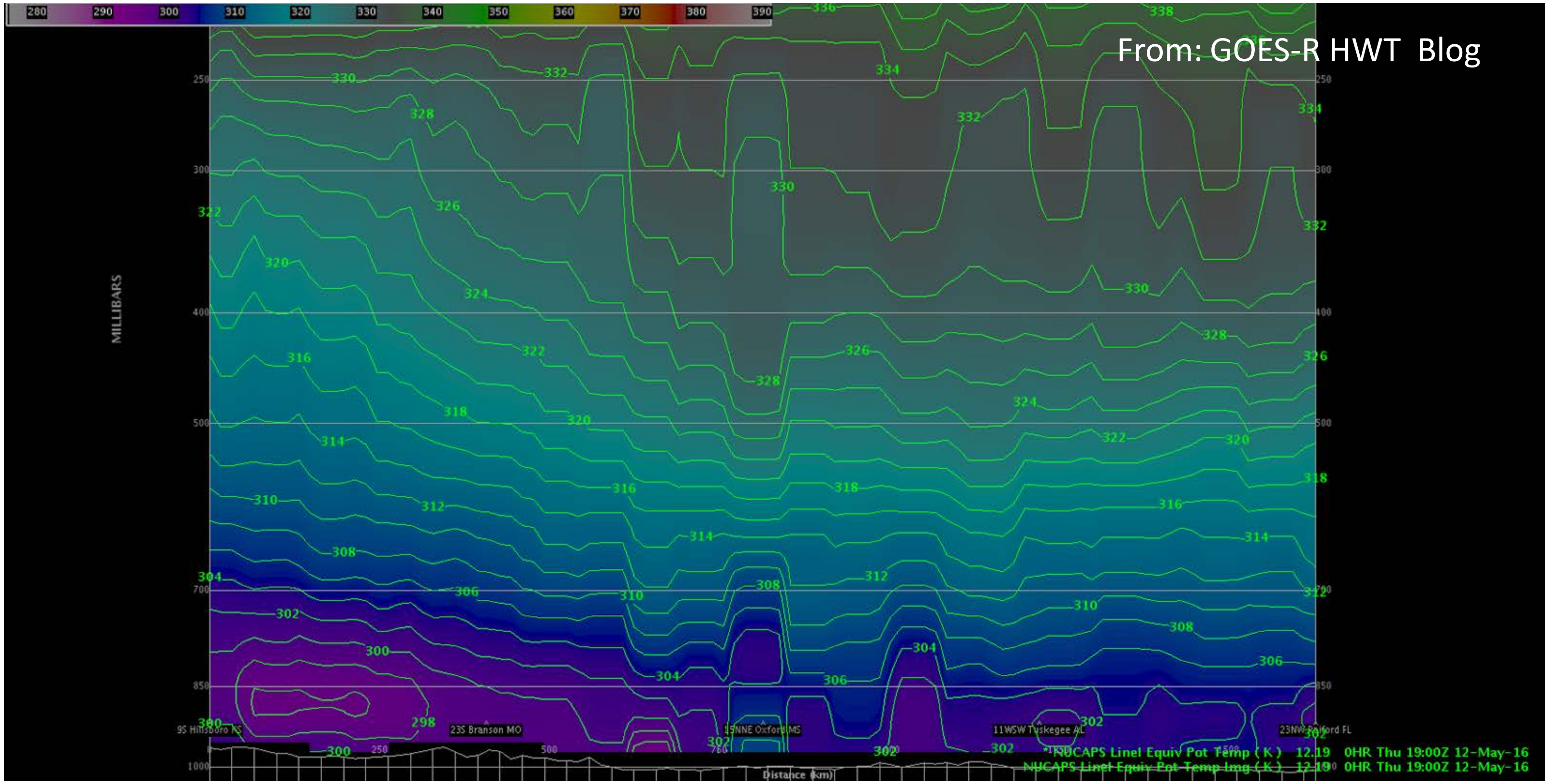


Gridded NUCAPS Convection Application



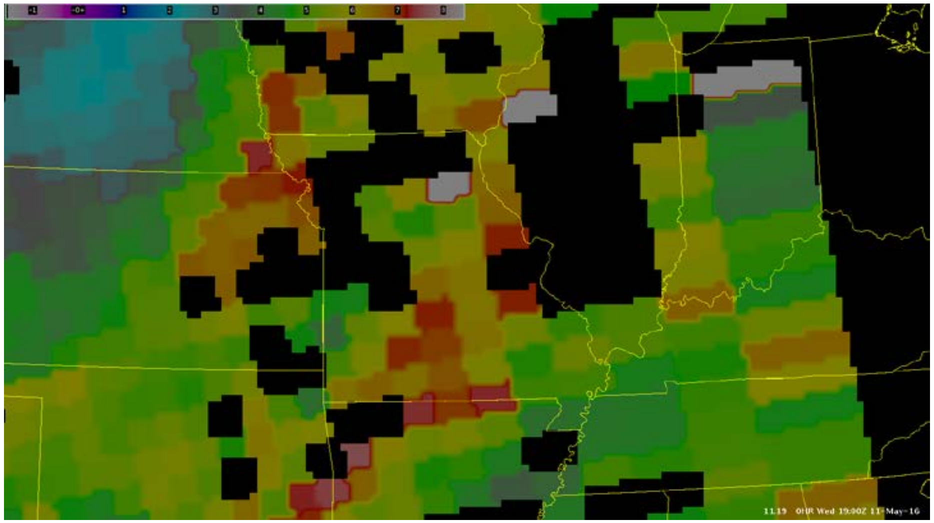
“We recently gained the ability to create cross sections through the NUCAPS swaths. This will be helpful for diagnosing phenomena such as boundaries and convective instability. The first image below is a plan view display of theta-e at 660 mb across the region. Obvious is the much cooler, drier air behind the cold front (low theta-e) with moist, warmer air ahead of it to the east (high theta-e). Also plotted is a line, denoting the location for which the cross-section (image below) was taken, through the cold front. The cross-section depicts theta-e vertically through the atmosphere. This provides another perspective on the cold front, which is obvious in the image.”

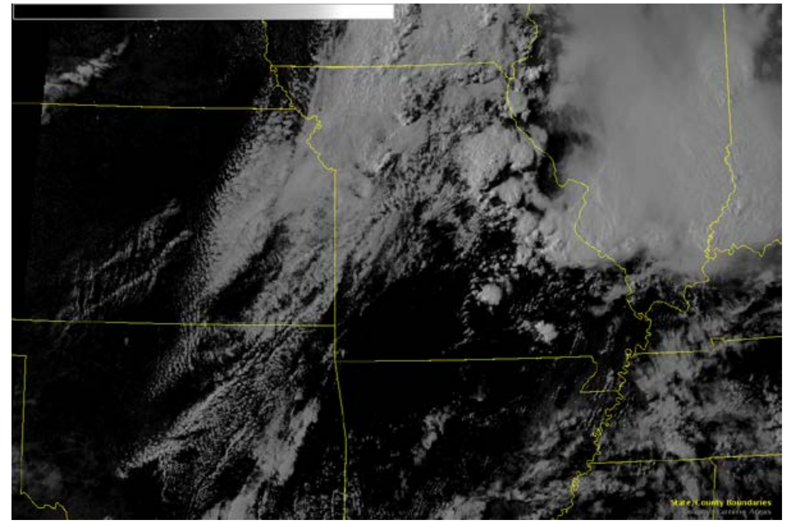
Gridded NUCAPS Convection Application



“In this image, Florida is to the right and Kansas is to the left. Based on METAR observations, the cold front was oriented over central Missouri and Arkansas at 19Z. The cold front appears to be approximately 600 km from western-most point of the cross-section. Lower theta-E values can been at the lower levels west of this point, with the isotherms sloping upward from east to west on the cool side of the frontal boundary. ***This is a cool way to visualize the location and structure of a frontal boundary!*** –JP”

Gridded NUCAPS Convection Application





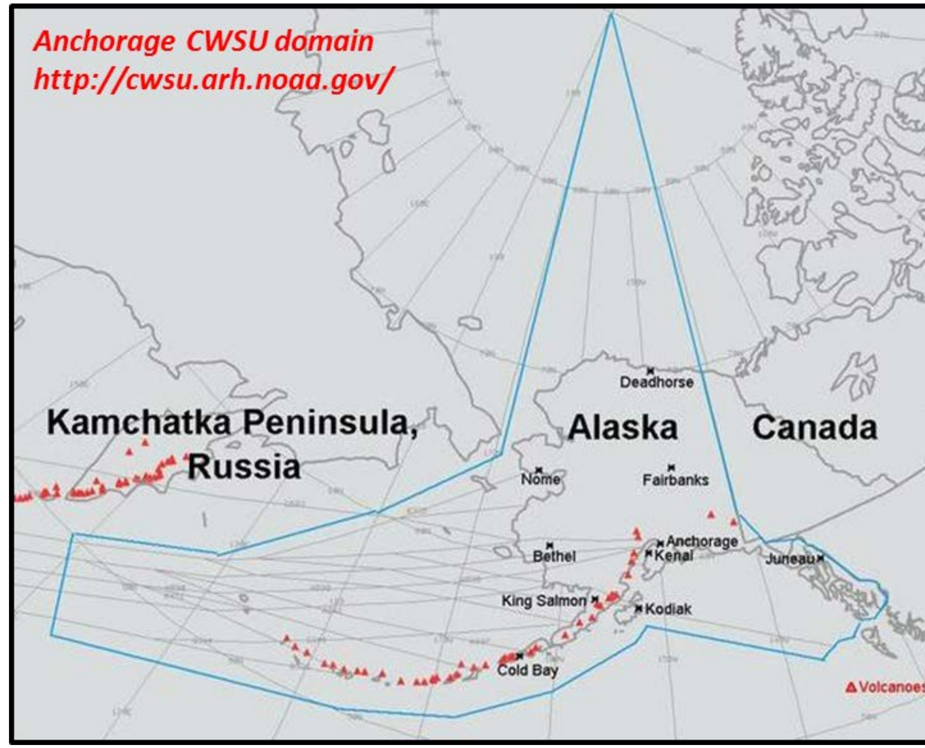
Images from GOES-R HWT Blog

"We took a look at a NUCAPS plan view image of mid-level moisture (754 mb mixing ratio) from 19Z. Image shown below. Areas of higher moisture were apparent over south-central Missouri in our SGF CWA, and over the St. Louis metro area.

Several hours later, we noted that convective activity was focused in these general areas. The few cells that developed over our CWA were over the south-central part of the state. Much more significant convection triggered over the St. Louis area. –JP"

Forecast Challenge: Cold Air Aloft

- Cold Air Aloft (-65°C and below) can lead to freezing airliner fuel
- Center Weather Service Units (CWSU) provide Meteorological Impact Statements (MIS) to Air Traffic Controllers to direct flights around the 3D air features
- In data sparse Alaska, forecasters have relied on analysis and model fields and limited radiosonde observations to guess the 3D extent of the Cold Air Aloft
- Use of satellite observations provides an opportunity for forecasters to observe the 3D extent of the Cold Air Aloft in real-time where conventional observations are lacking




```
FAAK20 KZAN 121458
ZAN MIS 01 VALID 121500-130300
...FOR ATC PLANNING PURPOSES ONLY...
COLD AIR ALOFT
FROM 185NE SCC-65NE ORT-55SW ENN-110NW BRW-185NE SCC
TEMPS -65C OR LESS FM FL350-400. AREA MOVG NE 40 KTS.
CMW NOV 14
```

Lat/Lon Extent of Cold Air from soundings, aircraft reports, model

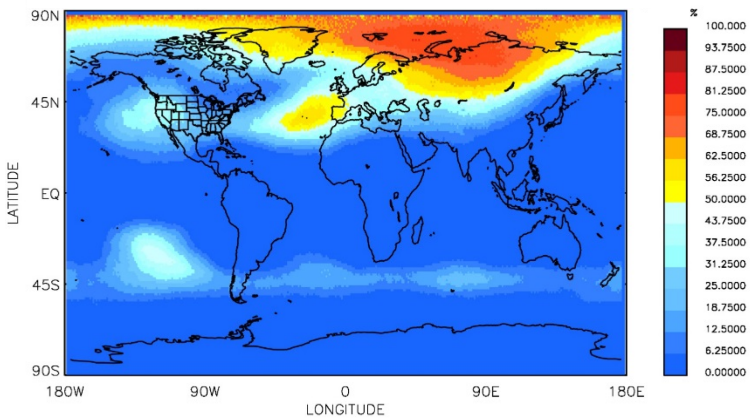
Vertical Extent of Cold Air from soundings/aircraft reports/model

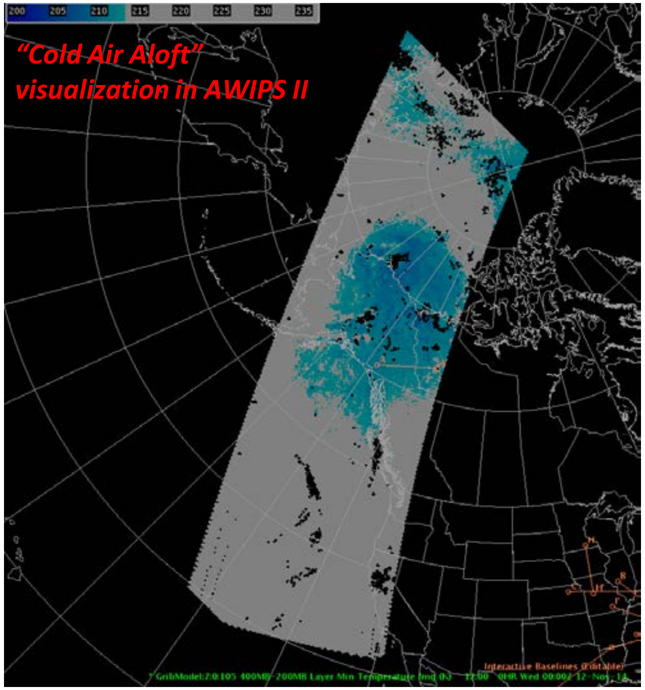
Motion determined from model data

Forecast Challenge: Cold Air Aloft

- Have found that temperatures below -60°C at flight levels occur regularly in the arctic and also pockets of colder air even occur over the mid-latitudes
- Using visualization color curve based on web graphics developed by CIRA, the Gridded NUCAPS products will be evaluated
  - Light blue shading for temperatures anywhere below 100 hPa in the column that are < -60°C
  - Darker blue shading for temperatures anywhere below 100 hPa in the column that are < -65°C
- Will be deploying NUCAPS data and visualization capabilities as part of an operational demonstration with forecasters at the Alaska CWSU in the fall/winter

Probability of observing T ≤ -60°C in AIRS at at 200 hPa from Jan. 2005 to Jan. 2015





"Cold Air Aloft" visualization in AWIPS II

Next Steps

- Demonstration scheduled for November – February with AK CWSU for Cold Air Aloft
- Plan to participate in next HWT Spring Experiment with more robust training on using the gridded products
- Develop unique color curves in AWIPS II for convective variables for easier decision making
- Working with the Experimental Products Development Team to develop gridding capabilities internal to AWIPS II source code that will use NUCAPS files already coming over the Satellite Broadcast Network (SBN) directly into NWS offices to reduce data flow and provide full transition of capability into operations

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MICROWAVE INTEGRATED RETRIEVAL SYSTEM (MIRS):
PRODUCTS OVERVIEW AND POTENTIAL IMPROVEMENTS

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MiRS Team
10 August 2016

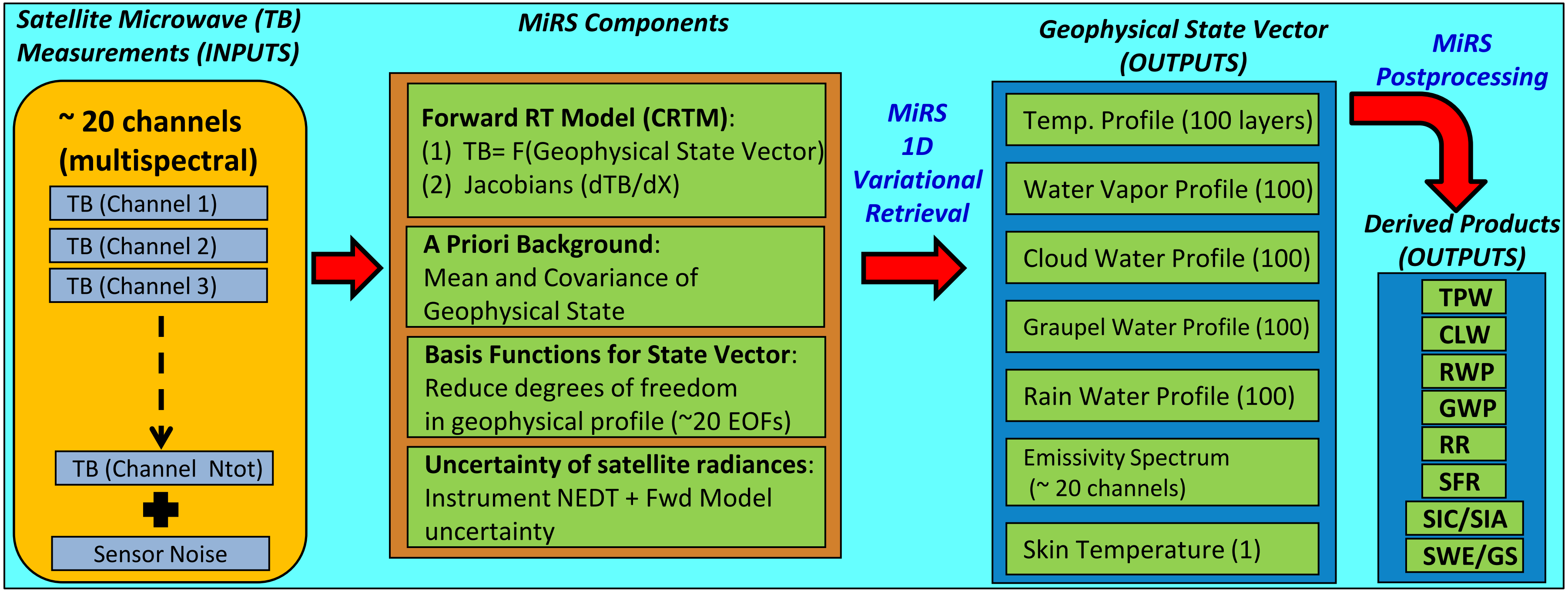
Outline

- Team Members
- Algorithm Overview
- S-NPP Product(s) Overview
  - T, WV Sounding (+ rainy condition sounding improvement)
  - Hydrometeors
  - Snow Water Equivalent Potential Improvements
- JPSS-1 Readiness
  - Algorithm changes
  - Pre-launch activities
  - Post-launch cal/val
- Summary and Path Forward

MiRS Cal/Val Team Members

Team Member	Organization	Roles and Responsibilities
Q. Liu (Project Manager)	NESDIS/STAR/SMCD	Project management
C. Grassotti (Technical Lead)	NESDIS/STAR/SMCD (U. MD./ESSIC/CICS)	Coordination of technical activities; review/deliverable planning
S. Liu	NESDIS/STAR/SMCD (CSU/CIRA)	Precipitation cal/val, SFR integration, DAP preparation
J. Chen	NESDIS/STAR/SMCD (U. MD./ESSIC/CICS)	Sounding and emissivity cal/val, J1 extension, Sounding improvements

Algorithm Overview



- MW Only, Variational Approach: Find the “most likely” atm/sfc state that: (1) best matches the satellite measurements, and (2) is still close to an a priori estimate of the atm/sfc conditions
- At NDE: Currently running v11.1 on SNPP/ATMS data, on J1/ATMS in 2017.
- At OSPO: Initial capability delivered in 2007. Running on N18, N19, MetopA, MetopB, F17, F18, Megha-Tropiques/SAPHIR.
- Recently extended to GPM/GMI [and F19] -> V11.2
- Experimental versions for: TRMM/TMI, Aqua/AMSRE, GCOM-W/AMSR2
- Ancillary data: Currently not required for ATMS (V11.2). But addition of SFR in V11.3 will require GFS
- External Users/Applications: **(1) CIRA TC Analysis/Forecasting (G. Chirokova), (2) MIMIC TPW Animations (T. Wimmers), (3) Blended, Layered PW (J. Forsythe)**, CSPP (Direct Broadcast), others…

MiRS Version History/Product List

Version	Feature	Delivery Date(s)
8.0	SNPP/ATMS to NDE	November 2012
9.0	Extension to Metop-B High Resolution	January 2013
9.1	Added QC DAP capability; netCDF metadata modifications	May 2013
9.2	**Minor netCDF filename convention changes; bug fixes, changes to metadata conventions**	**June 2013 – May 2014**
10.0	Extension to Megha-Tropiques/SAPHIR	March 2014
11.0	HR Extension for AMSUA/MHS, SSMIS; CRTM 2.1.1 implementation, dynamic background, etc.	September 2014
11.1*	**HR Extension for F18, addition of new operational product: SFR for AMSU/MHS (experimental products SGS and SIA); new DAP to NDE for SNPP/ATMS**	**June/July 2015**
11.2	**HR Extension for GPM/GMI**	**~ August 2016**
11.3	**Extension to J1/ATMS; SFR integration**	**~ Late 2016**

V9.2/V11.0
Atmospheric Temp.profile
Atmospheric WV profile
Total Precipitable Water
Land Surface Temperature
Surface Emissivity Spectrum
Sea-Ice Concentration
Snow Cover Extent
Snow-Water Equivalent
Integrated Cloud Liquid Water
Integrated Ice Water Path
Integrated Rain Water Path
Rainfall Rate

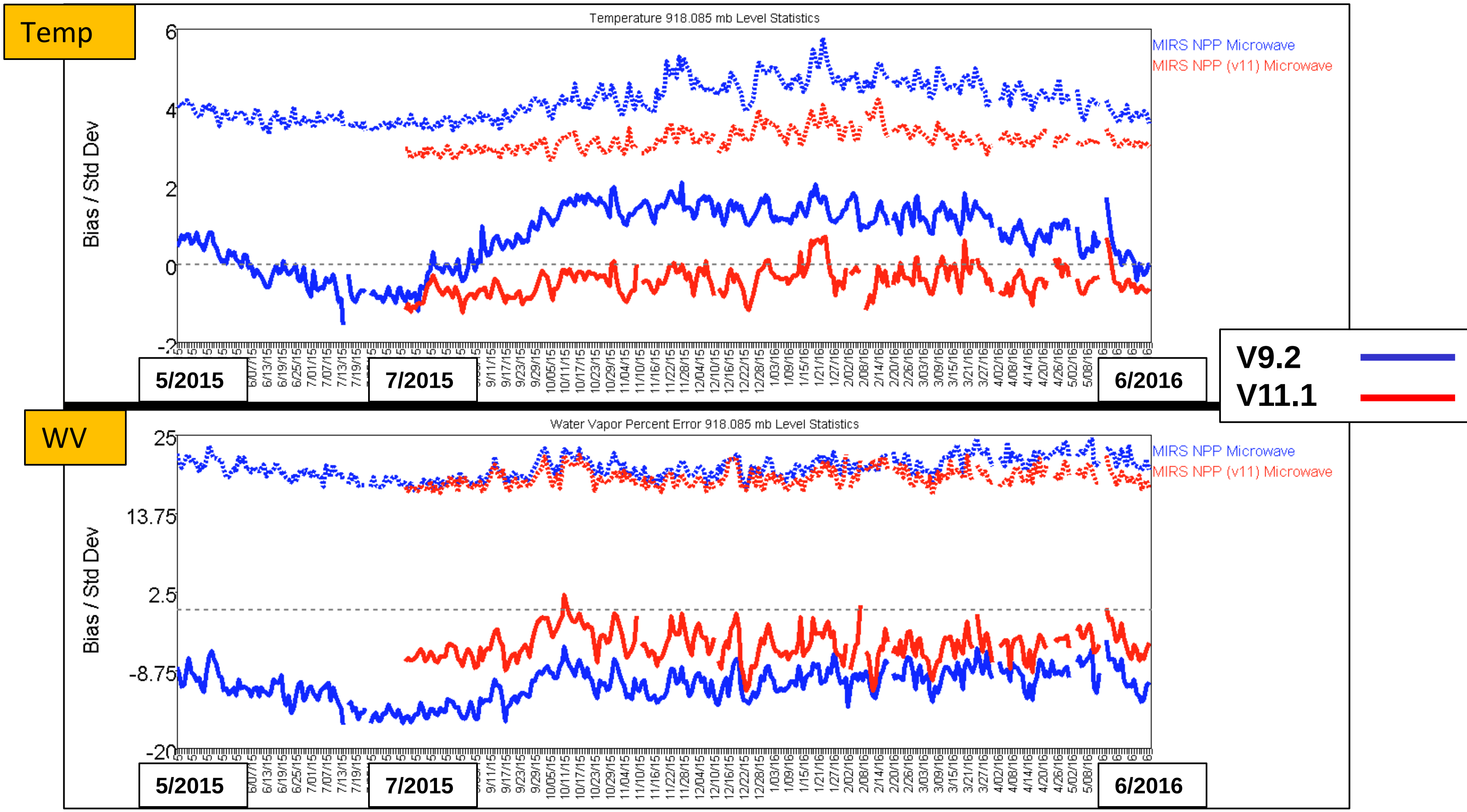
Added V11.1
Snowfall Rate (MSPPS, AMSU/MHS currently, ATMS integration in V11.3)
Sea Ice Age (FY, MY)
Snow Grain Size

Images of many of these products now available on both MiRS (http://mirs.nesdis.noaa.gov/), and long-term monitoring website (http://www.star.nesdis.noaa.gov/jpss/EDRs/products_MiRS.php)

*** For SNPP/ATMS: V11.1 is operational at NDE since October 2015**

MiRS S-NPP Products: T and WV Profile

- Daily, Global, collocations with radiosondes (NPROVS)
- Comparison of MiRS **v9.2** and **v11.1** **at 918 hPa from May 2015 – May 2016**



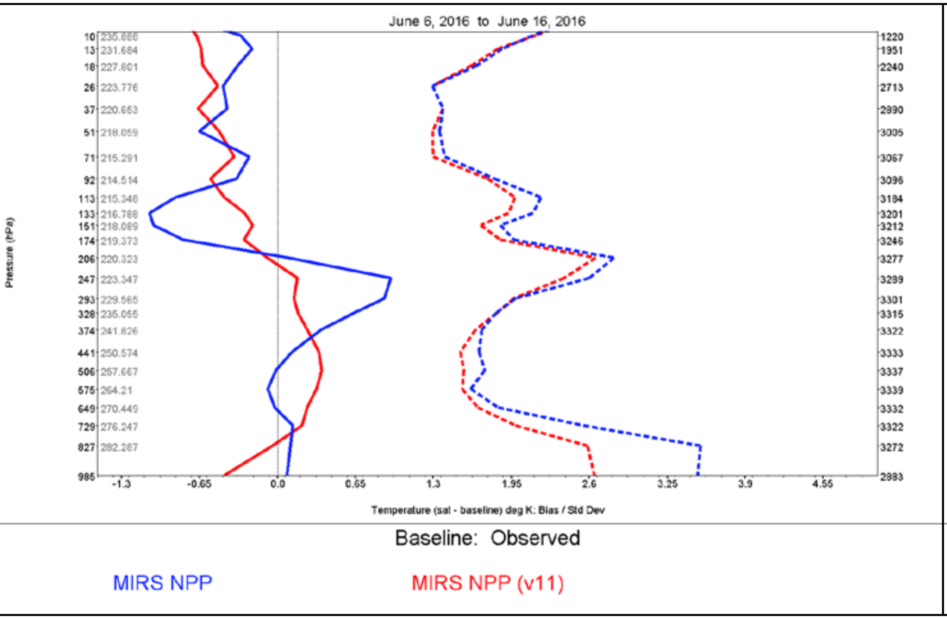
Courtesy of Bomin Sun

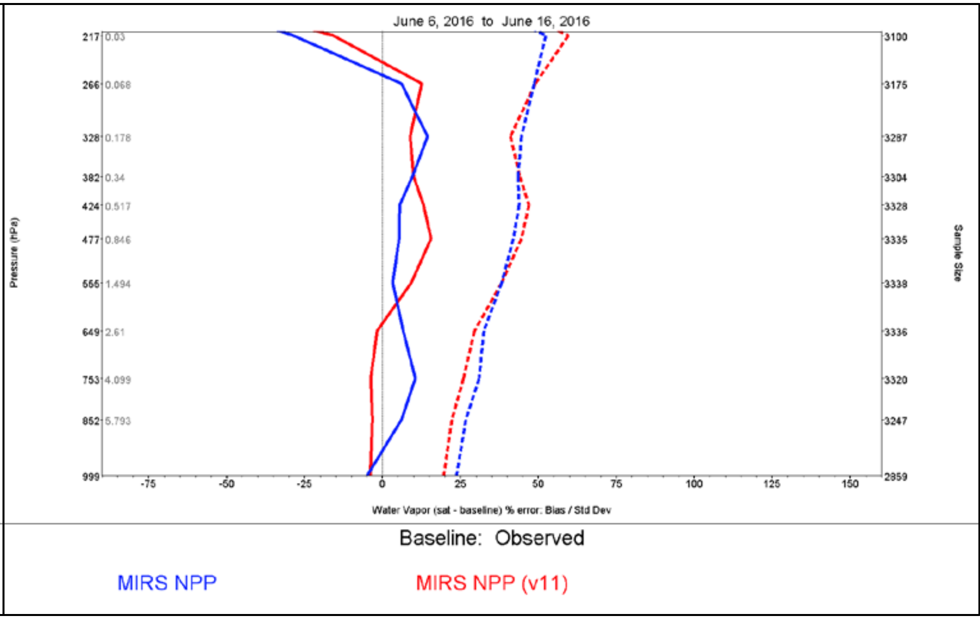
MiRS S-NPP Products: T and WV Profile

- Daily, Global, collocations with radiosondes (NPROVS)
- Comparison of MiRS **v9.2** and **v11.1** for 10-Day Period, 6-16 June 2016

Temp

WV





V9.2
V11.1

Courtesy of Bomin Sun

MiRS S-NPP Products: T and WV Profile

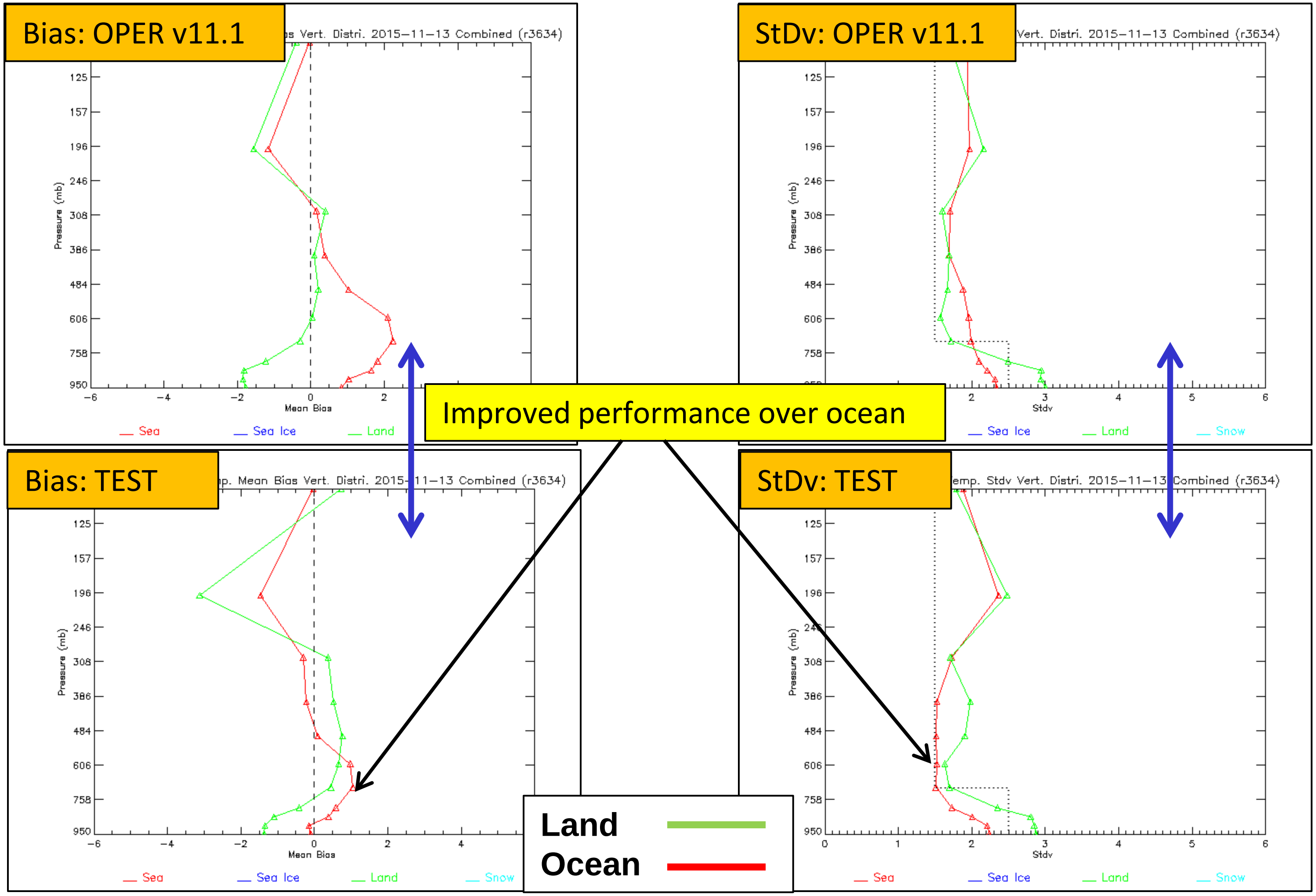
- Daily, Global Collocations with ECMWF and GDAS.
- Periodic Global, collocations with radiosondes (NPROVS)
- Stratified by clear/cloudy, and surface type
- Maturity Level: Validated, Stage 3

Product	Sfc	Condition	Layer (hPa)	Bias (K) (Accuracy)		StDv (K) (Precision)	
				MiRS	Req	MiRS	Req
Temperature	Sea	Clear	100	**-0.5**	**0.5**	**1.7**	**2.0**
			300	**+0.5**	**0.5**	**2.0**	**2.0**
			500	**-0.5**	**0.5**	**1.4**	**2.0**
			900	**+0.5**	**1.5**	**1.8**	**3.0**
		Cloudy	100	**0.0**	**0.8**	**1.8**	**2.0**
			300	**+0.5**	**0.8**	**2.0**	**2.5**
			500	**-0.7**	**0.8**	**1.5**	**2.0**
			900	**+1.0**	**2.0**	**2.0**	**3.0**
	Land	Clear+ Cloudy	100	**-0.5**	**1.0**	**1.5**	**2.0**
			300	**+0.8**	**0.8**	**1.5**	**2.0**
			500	**0.0**	**0.5**	**1.2**	**2.5**
			900	**-1.0**	**2.5**	**2.5**	**5.5**

Product	Sfc	Condition	Layer (hPa)	Bias (%) (Accuracy)		StDv (%) (Precision)	
				MiRS	Req	MiRS	Req
Water Vapor	Sea	Clear	400	**-5.**	**30.**	**50.**	**60.**
			500	**0.**	**20.**	**40.**	**60.**
			700	**-5.**	**20.**	**30.**	**50.**
			900	**+5.**	**20.**	**15.**	**30.**
		Cloudy	400	**+5.**	**30.**	**60.**	**70.**
			500	**0.**	**20.**	**50.**	**65.**
			700	**+5.**	**10.**	**40.**	**60.**
			900	**0.**	**20.**	**20.**	**30.**
	Land	Clear+ Cloudy	400	**+10**	**30.**	**50.**	**60.**
			500	**0.**	**20.**	**40.**	**60.**
			700	**-10.**	**20.**	**30.**	**50.**
			900	**-10.**	**20.**	**20.**	**50.**

MiRS S-NPP: Improving T Profile in Rainy Conditions

- Developed new T and WV Covariance Matrices based on EC137 data set, stratified by atmospheric conditions.
- TEST: Replace current global covariances with rainy covariances when MiRS detects rain.
- One day global ATMS retrievals, comparison with ECMWF on 2015-11-13

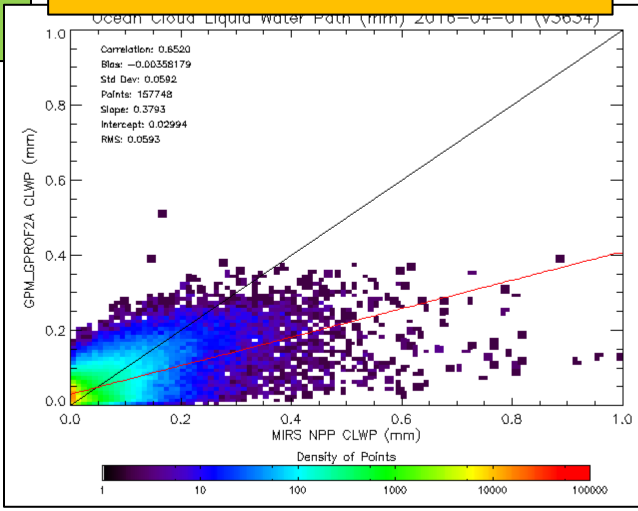


MiRS S-NPP Products: Hydrometeors

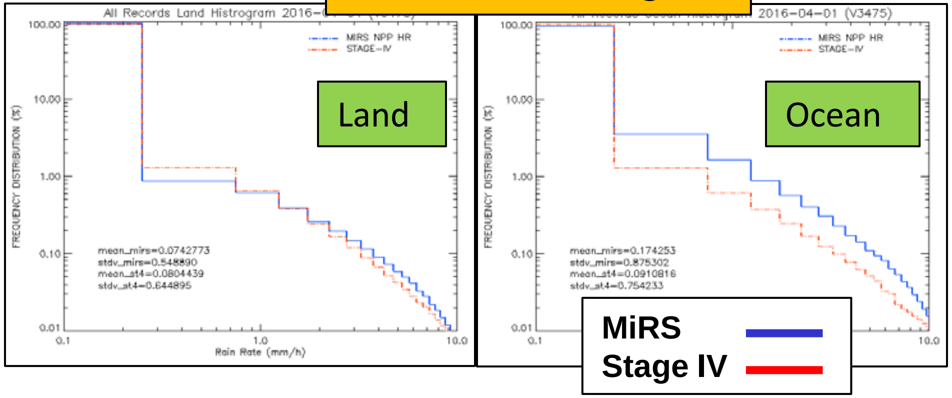
8 Month Collocation Period: August 2015- March 2016
- Rain Rate: MiRS ATMS collocation with Stage IV (CONUS and coastal ocean)
- Rain Rate: MiRS ATMS collocation with GPM GPROF 2A (global land and ocean)
- CLW: MiRS ATMS collocation with GPM GPROF 2A over ocean
- Maturity Level: Validated, Stage 3

Product	Units	Bias (Accuracy)		StDv (Precision)		Npts
		MiRS	Req	MiRS	Req	
Rain Rate (land, Stage IV)	mm/h	0.01	0.05	0.8	1.5	8.7E+06
Rain Rate (ocean, Stage IV)	mm/h	0.08	0.10	1.0	1.0	1.8E+06
Rain Rate (land, GPROF)	mm/h	-0.01	0.05	0.4	1.5	8.1E+04
Rain Rate (ocean, GPROF)	mm/h	-0.01	0.10	0.8	1.0	1.8E+05
CLW (ocean, GPROF)	mm	-0.00	0.03	0.06	0.08	1.6E+05

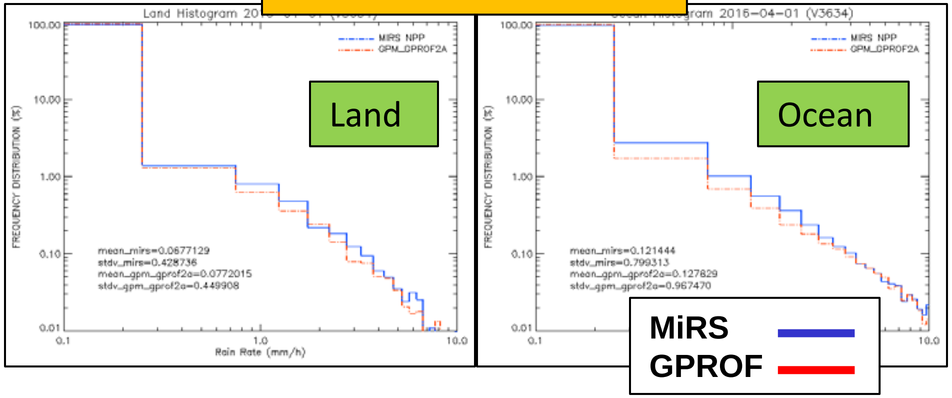
CLW: MiRS and GPROF Ocean



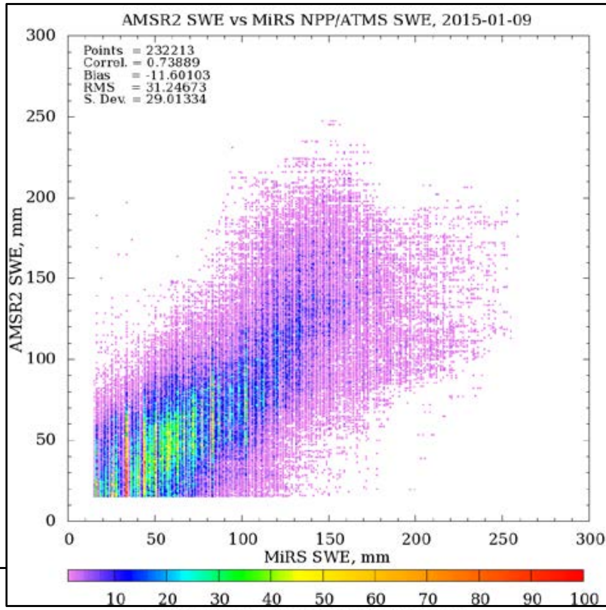
RR: MiRS and Stage IV



RR: MiRS and GPROF

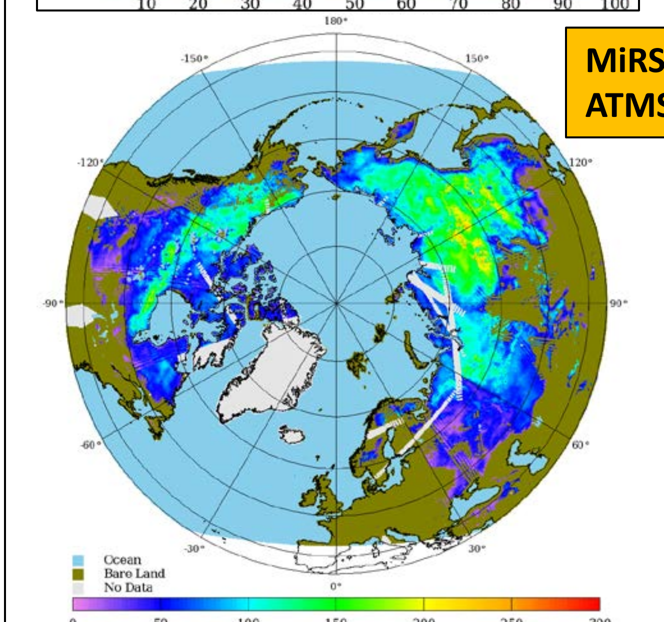


MiRS S-NPP Products: Snow Water Equivalent

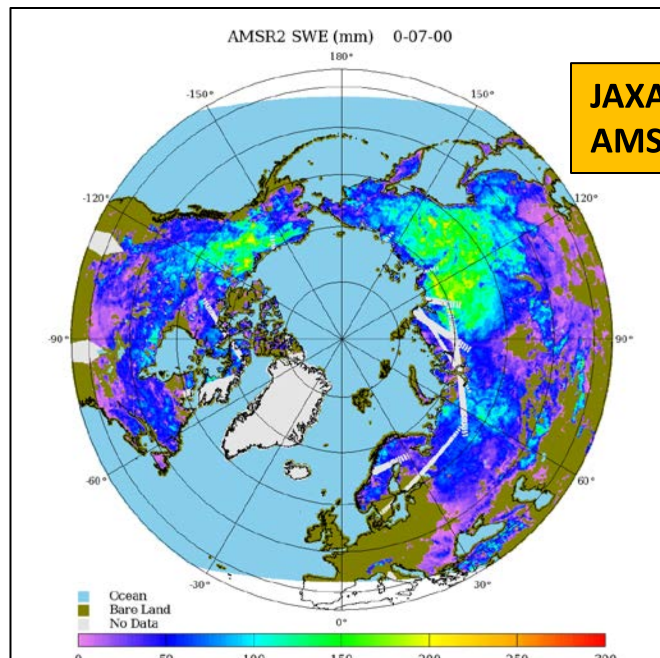


MiRS (v11.1) SWE/Snow cover Performance vs. JAXA/AMSR2
- **JPSS requirement in parentheses**
- **Maturity Level: Validated**

Precision: 2.9 cm (6.0)
Accuracy: -1.2 cm (3.0)
Prob. Detection: 0.85 (0.80)
False Alarm Ratio: 0.06 (0.10)
Heidke Skill Score: 0.62 (0.55)



MiRS ATMS



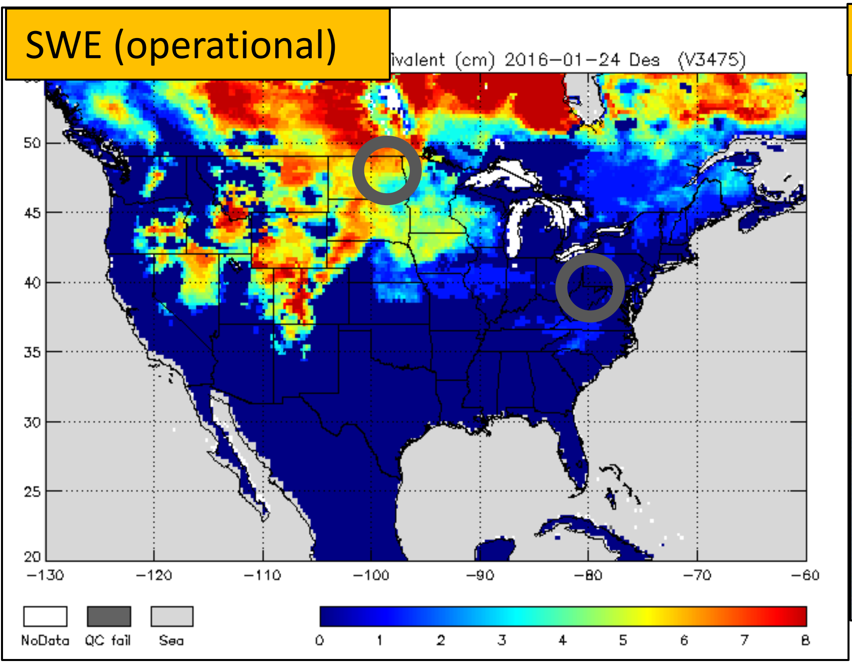
JAXA AMSR2

Snow Water Equivalent: Potential Improvements

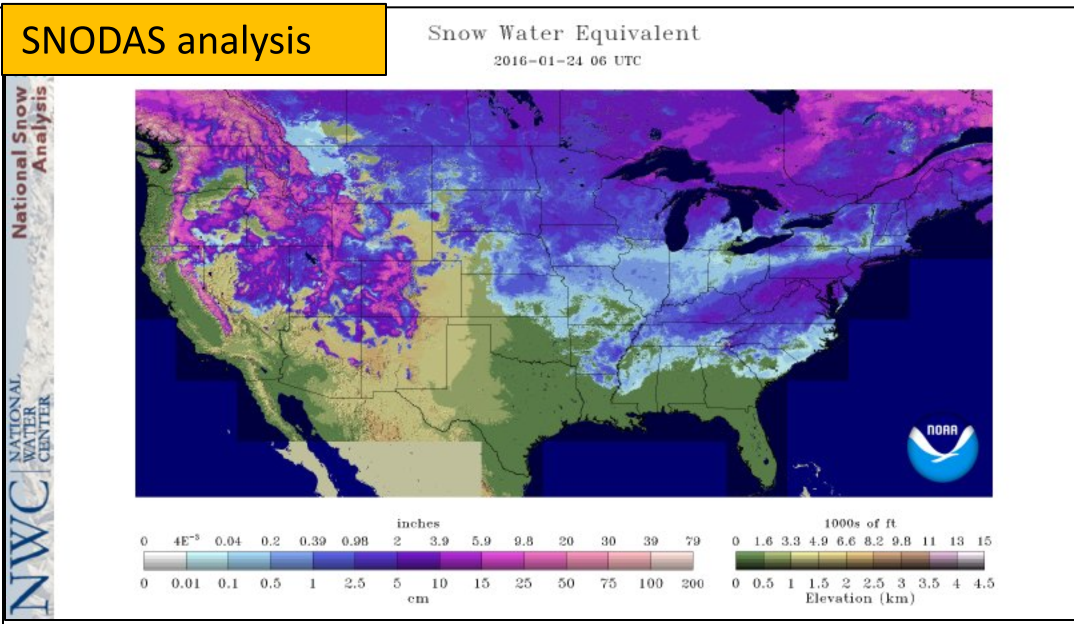
January 23-24, 2016 East Coast Blizzard (“Snowzilla”)

- 1-2+ feet in many locations
- MiRS operational SWE greatly underestimated
- Investigating possible causes/improvements
- Focus on vegetation cover (forest) as contributing factor
- Other factors: snow wetness, emissivity model (lookup table)
- **See poster on Thursday by Carlos Perez on emissivity model assessment**

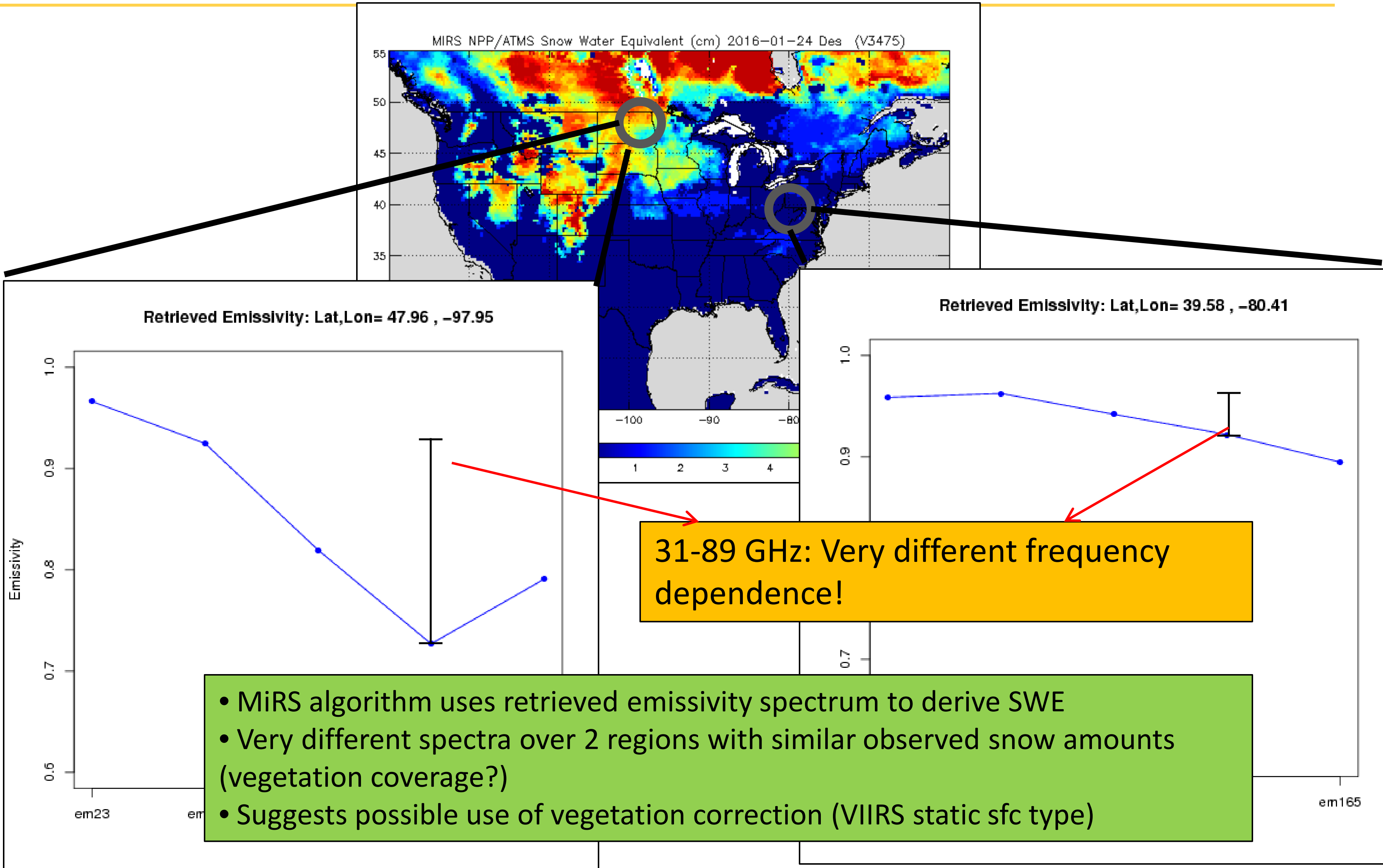
SWE (operational)



SNODAS analysis



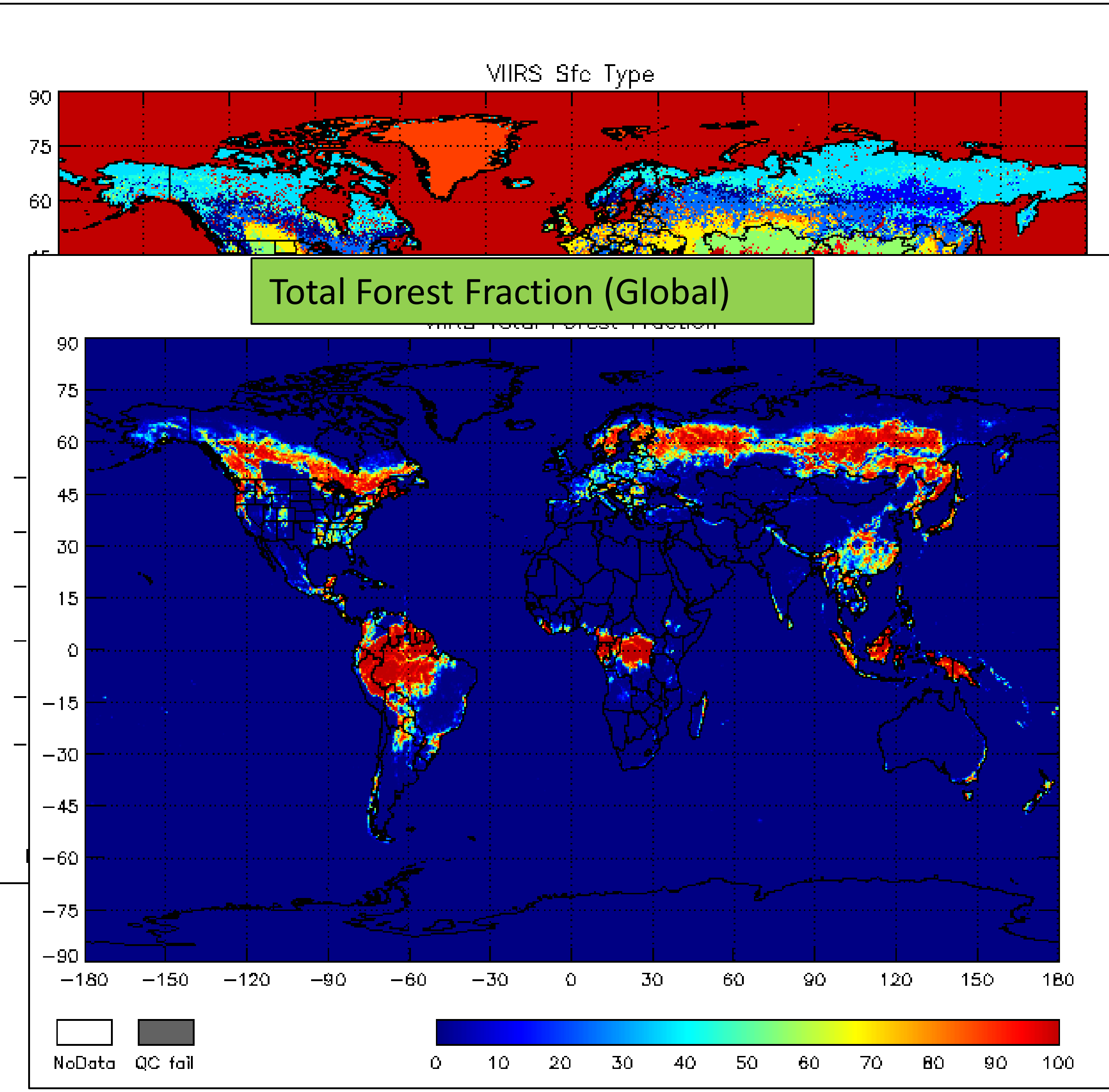
Snow Water Equivalent: Potential Improvements



31-89 GHz: Very different frequency dependence!

- MiRS algorithm uses retrieved emissivity spectrum to derive SWE
- Very different spectra over 2 regions with similar observed snow amounts (vegetation coverage?)
- Suggests possible use of vegetation correction (VIIRS static sfc type)

Snow Water Equivalent: Potential Improvements

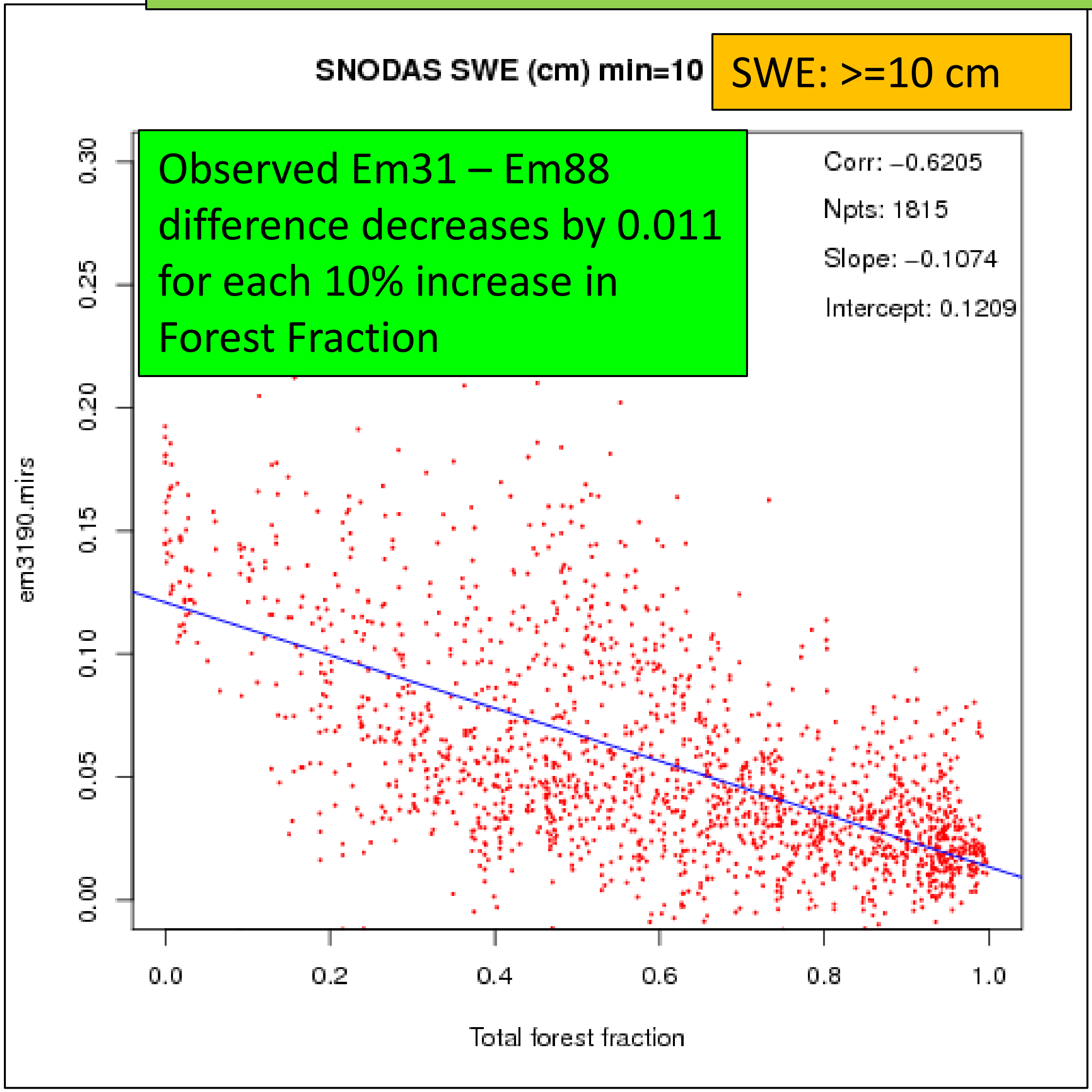


VIIRS Sfc Type database:
- 30 arc second (~ 1 km)
- based on one year of VIIRS data
- 19 potential types:

0= Unclassified
1= Evergreen Needleleaf Forests
2= Evergreen Broadleaf Forests
3= Deciduous Needleleaf Forests
4= Deciduous Broadleaf Forest
5= Mixed Forests
6= Closed Shrublands
7= Open Shrublands
8= Woody Savannas
9= Savannas
10= Grasslands
11= Permanent Wetlands
12= Croplands
13= Urban and Built-up Lands
14= Cropland/Natural Vegetation Mosaics
15= Snow and Ice
16= Barren
17= Water Bodies
18 =No data

Snow Water Equivalent: Potential Improvements

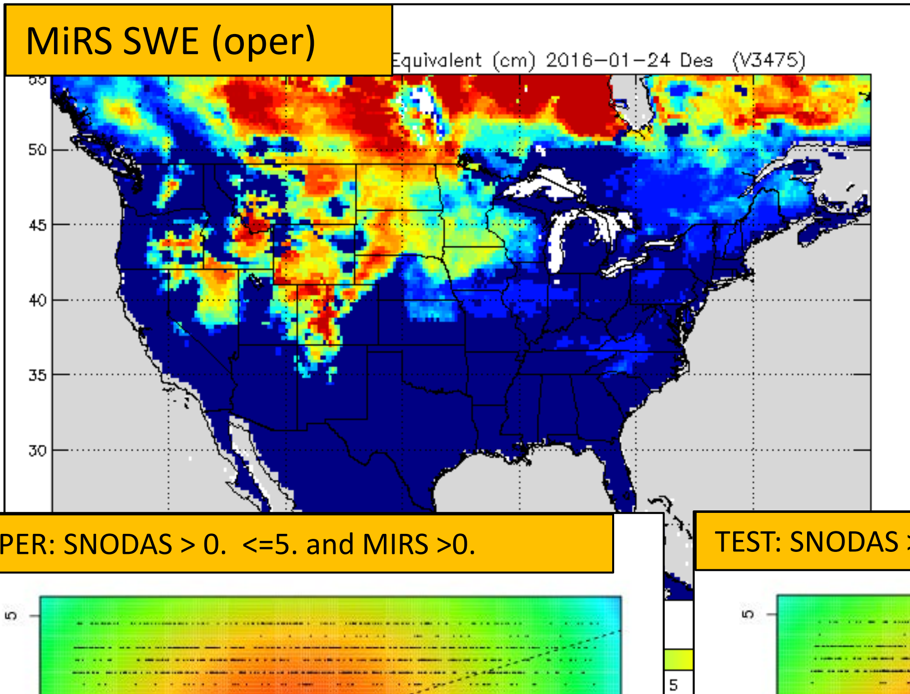
Difference in EM at 31 and 88 GHz as function of Forest Fraction



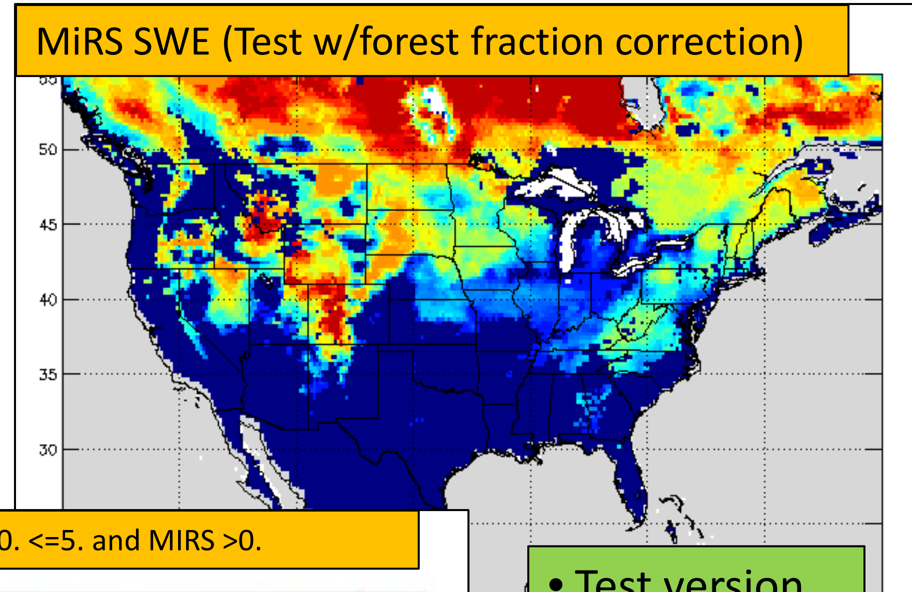
- Based on the regression slopes, can we apply a correction to the Em31-90 gradient of the form: Em3188(cor)=Em3188(ret)+a1*(FF-FF0) ?
- Use corrected Em3188 in lookup table search
- Slope nearly independent of SWE amounts (0 < SWE <= 20)

Snow Water Equivalent: Potential Improvements
Case 1, 2016-01-24

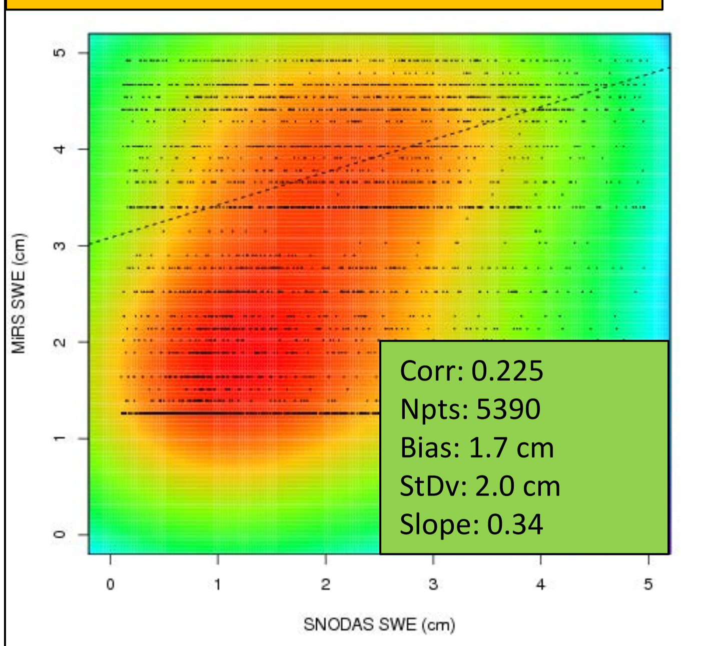
MiRS SWE (oper)



MiRS SWE (Test w/forest fraction correction)

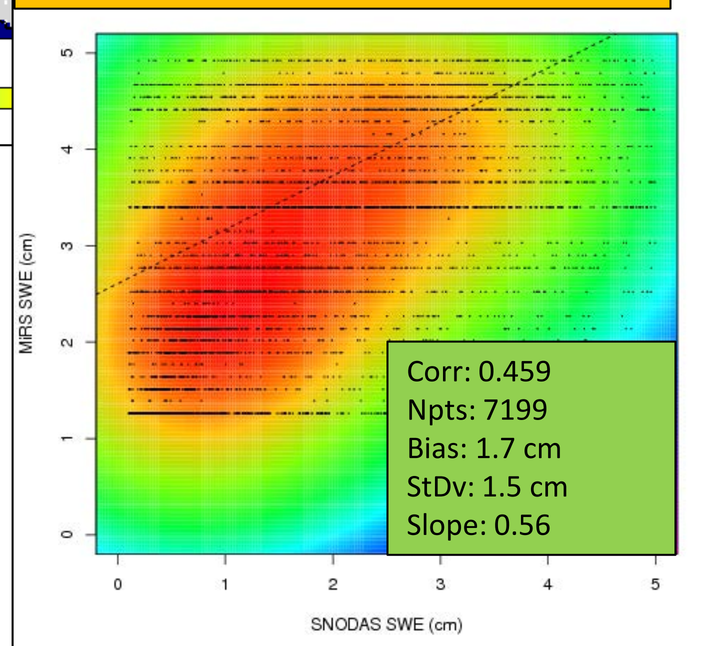


OPER: SNODAS > 0. <=5. and MIRS >0.



Corr: 0.225
Npts: 5390
Bias: 1.7 cm
StDv: 2.0 cm
Slope: 0.34

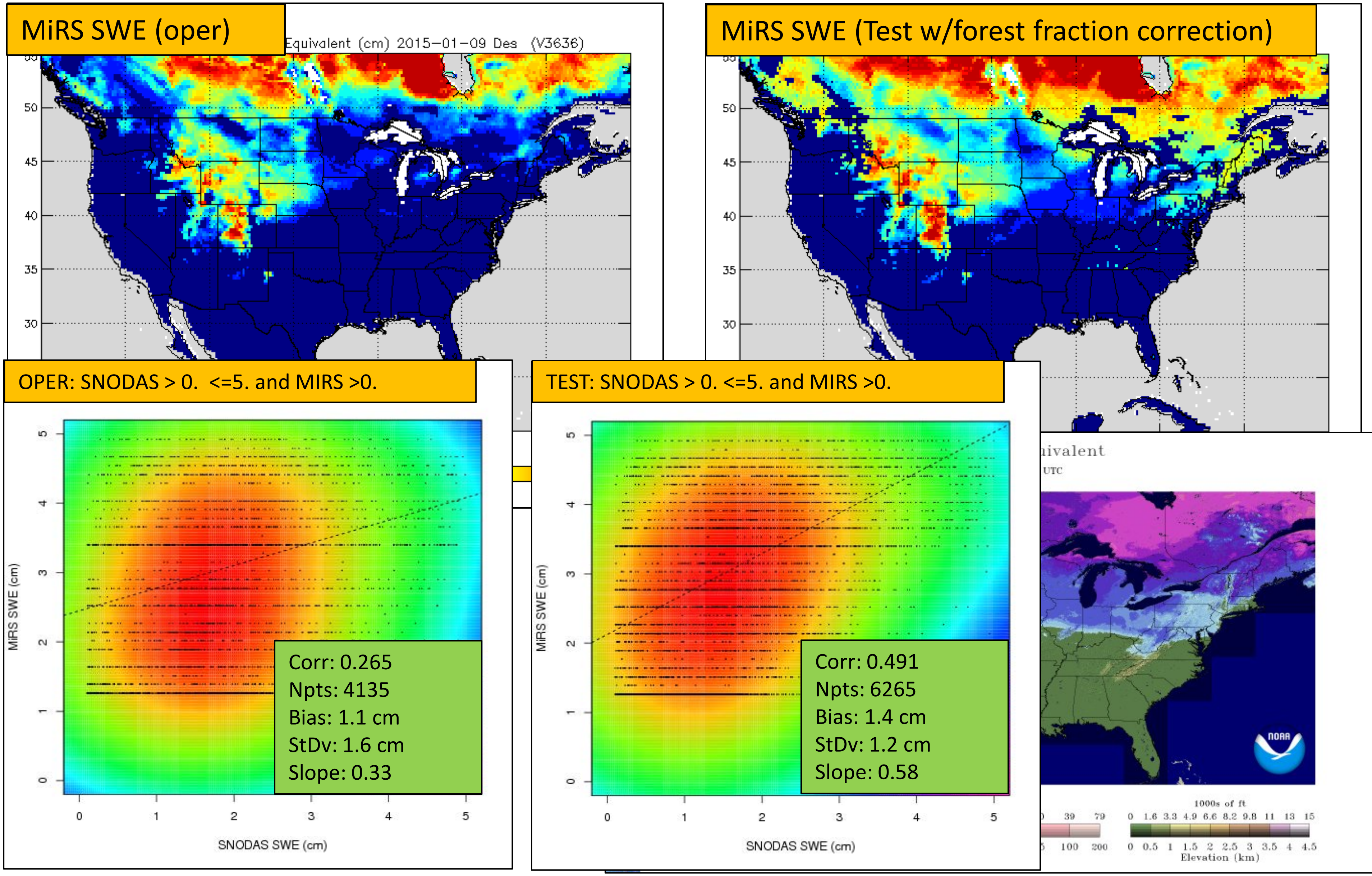
TEST: SNODAS > 0. <=5. and MIRS >0.



Corr: 0.459
Npts: 7199
Bias: 1.7 cm
StDv: 1.5 cm
Slope: 0.56

- Test version has higher correlation, smaller StDv, and regression fit has slope closer to 1
- Note increase in Npts with SWE> 0 in Test version

Snow Water Equivalent: Potential Improvements
Case 2, 2015-01-09



JPSS-1 Readiness

- Significant Algorithm changes from S-NPP to JPSS-1:
  - **Addition of SFR**: will require access to GFS forecasts (will work with NDE during integration and testing; already done for AMSU/MHS). **Already integrated for AMSU/MHS. Huan Meng's presentation next.**
- Pre-launch Characterization
  - Currently extending software to J1: completion planned in Fall 2016, with end to end testing on proxy data. CDR in late 2016. STAR: Daily processing set up prior to launch.
- Post-Launch Cal/Val Plans
  - Data Sets: Update radiometric bias corrections, T and WV sounding (ECMWF, GDAS, raobs), rain rate (Stage IV, NMQ, GPROF), CLW (GPROF, CloudSat), snow (SNODAS, AMSR2, IMS), ice (IMS, OSI-SAF, VIIRS)
  - Milestones: (1) CDR in late 2016, (2) prelaunch preDAP delivery in early 2017, (3) official DAP ~L+6 months (initial cal/val, validated maturity stage 1 (T, WV), or provisional maturity (RR, cryosphere, hydrometeors)).
- Risks and Mitigation: None major, awaiting outcome of chan 17 tests to determine potential impact. (clouds, precipitation)
- Collaboration with Stake Holders: Feedback from OSPO, NDE to identify bugs/issues, other external users/applications.

Summary & Path Forward

- MiRS is relatively mature algorithm; evolution and improvement since SNPP launch (v9.2 -> v11.1)
- Next version: Biggest change from data flow/dependence perspective is integration of SFR requiring GFS data; one focus of pre-launch integration and testing.
- Path Forward
  - FY17 Milestones: (1) CDR in late 2016, (2) prelaunch preDAP delivery in early 2017, (3) official DAP ~L+6 months (initial cal/val).
  - Future Improvements:
    - Snow (vegetation correction)
    - Rainy condition sounding (update a priori constraints)
    - Hydrometeors (improvements to CRTM i.e. scattering, precharacterization of precip type, particle size/shape distribution in CRTM, CLW over land for light rain detection)
    - Air mass-dependent bias corrections
    - Stakeholders/user needs…

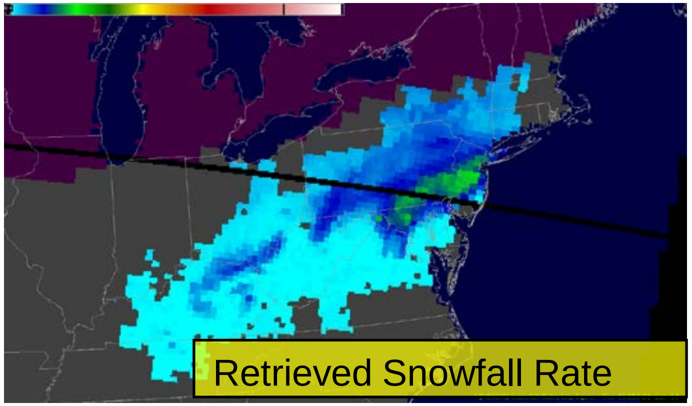
ATMS Snowfall Rate Product to Support NWS

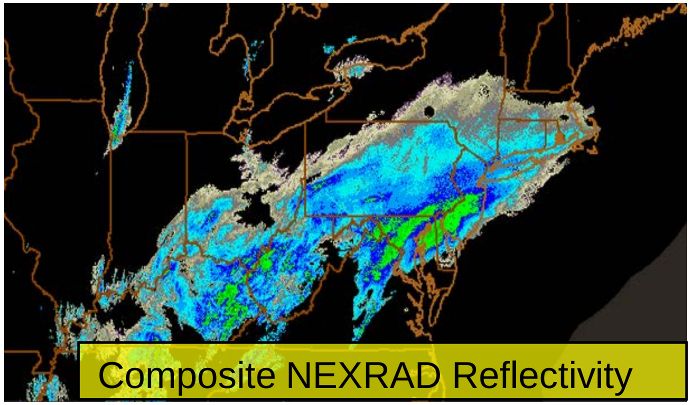
Huan Meng[1], Ralph Ferraro[1], Cezar Kongoli[2], Jun Dong[2], Banghua Yan[3], Nai-Yu Wang[2], Bradley Zavodsky[4]

[1]*NOAA/NESDIS/Center for Satellite Applications and Research (STAR)*
[2]*University of Maryland/Cooperative Institute for Climate and Satellites (CICS)*
[3]*NOAA/NESDIS/Office of Satellite and Product Operations (OSPO)*
[4]*NASA/Short-term Prediction Research and Transition Center (SPoRT)*

Introduction

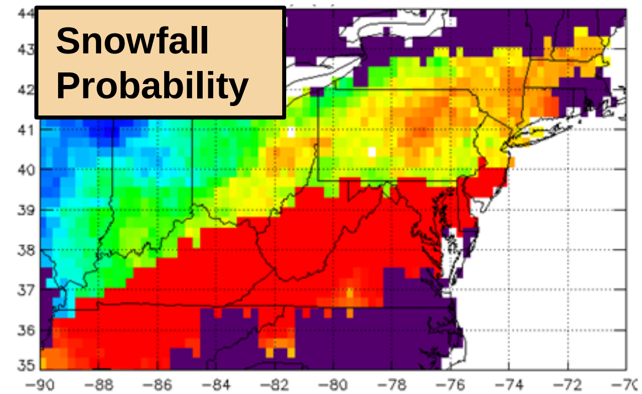
- The ATMS Snowfall Rate (SFR) product was developed with the support of JPSS Proving Ground and Risk Reduction program
- SFR is water equivalent snowfall rate estimate over global land
- The algorithm partially inherits the operational AMSU/MHS SFR, but with many new developments that lead to superior performance
- Currently, SFR is generated from five satellites (S-NPP and four POES and Metop satellites) with about ten estimates per day in mid-latitudes and more in high latitudes
- The AMSU/MHS SFR product has been integrated in MiRS as an operational product

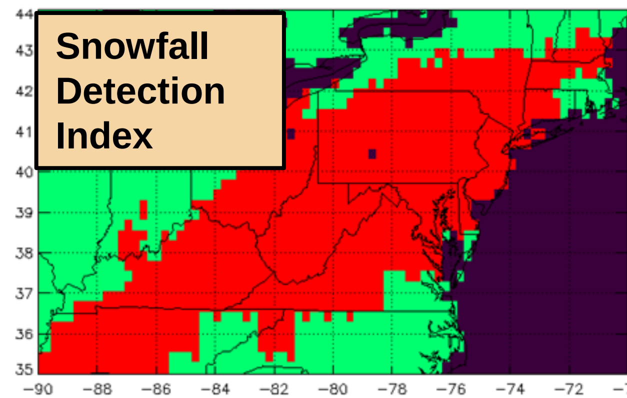


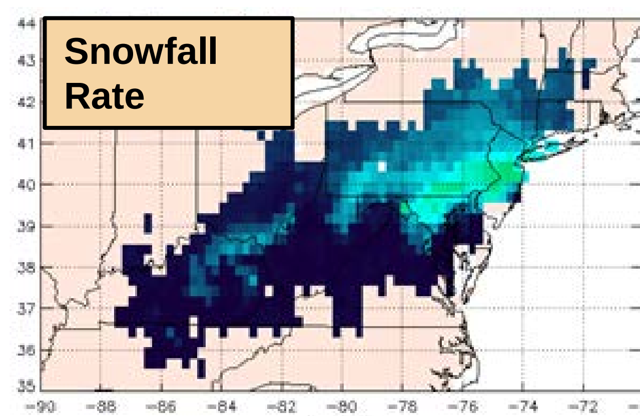


Algorithm

- SFR is composed of a Snowfall Detection algorithm and a Snowfall Rate algorithm
- Snowfall Detection
  - ✓ Statistical algorithm
  - ✓ Coupled principal component and logistic regression model
  - ✓ Use all seven high-frequency channels at and above 88.2 GHz and the temperature sounding channel at 53.6 GHz
  - ✓ Trained with gauge observations
  - ✓ Output is probability of snowfall; use preset thresholds to determine snowfall
  - ✓ Additional NWP model-based filters and screenings to improve the accuracy of snowfall detection







Algorithm (2)

- Snowfall Rate
  - ✓ Physically based algorithm
  - ✓ Retrieve cloud properties using 1D VAR – coupled radiative transfer simulations and an iteration scheme
  - ✓ Derive snowfall rate from cloud properties and an existing snow particle terminal velocity model
  - ✓ Calibration through histogram matching with Multi-Radar Multi-Sensor (MRMS) radar precipitation data

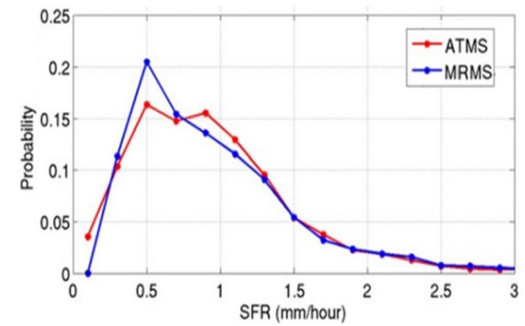
$$SFR = A\int_{D_{min}}^{D_{max}} D^2 e^{-D/D_e}\left[\left(1 + BD^{3/2}\right)^{1/2} - 1\right]^2 dD$$

$$A = \frac{\alpha I_c \delta_0^2 \eta}{24 H \rho_w \rho_a D_e^4} \qquad B = \frac{8}{\delta_0^2 \eta}\sqrt{\frac{g \rho_a \rho_I}{3 C_0}}$$

Validation - Statistics

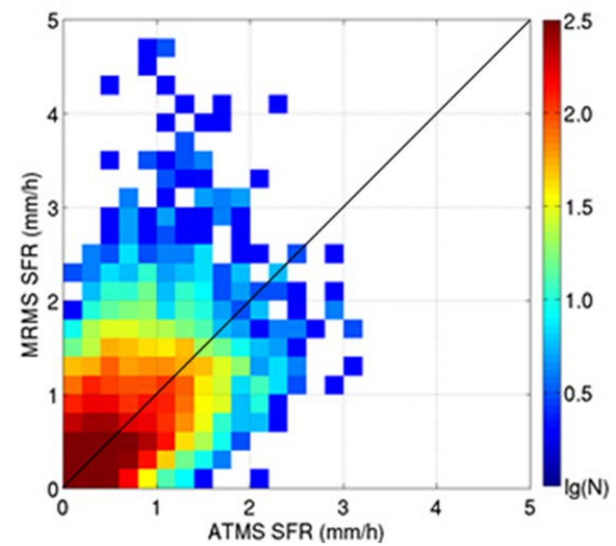
- Snowfall Detection validation
  - ✓ Validation against CONUS gauge data
  - ✓ About 50% of in-situ data is ‘trace’ snow - challenging to detect for satellite product

	POD	FAR
Warm Regime	0.45	0.09
Cold Regime	0.43	0.09



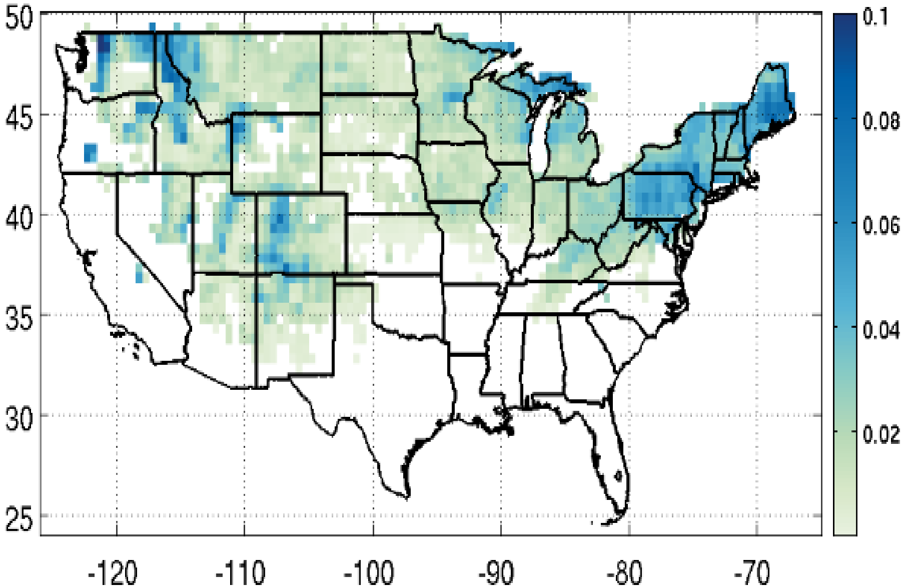
- Snowfall Rate validation
  - ✓ Validation against MRMS radar snowfall rate data

Correlation Coefficient	Bias (mm/hr)	RMSE (mm/hr)
0.52	-0.07	0.55

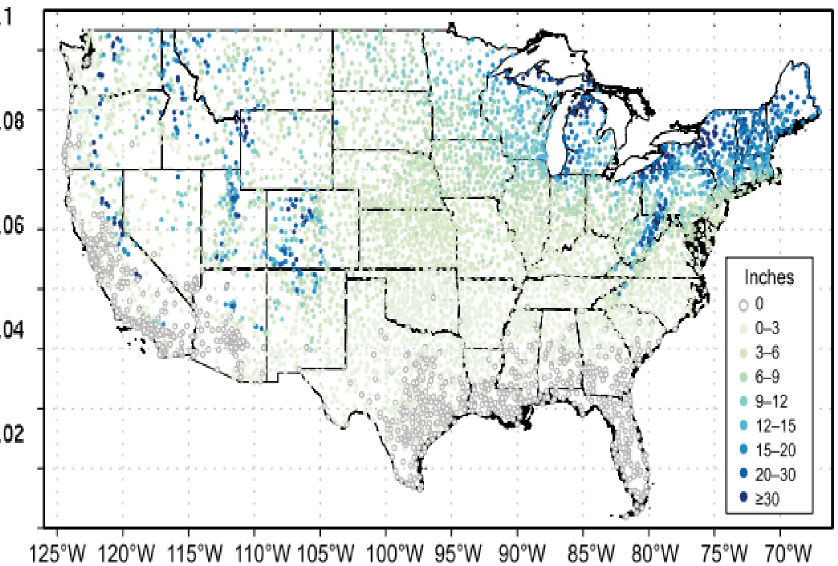


Validation - Climatology

ATMS Snowfall Rate
January Average, 2015-2016



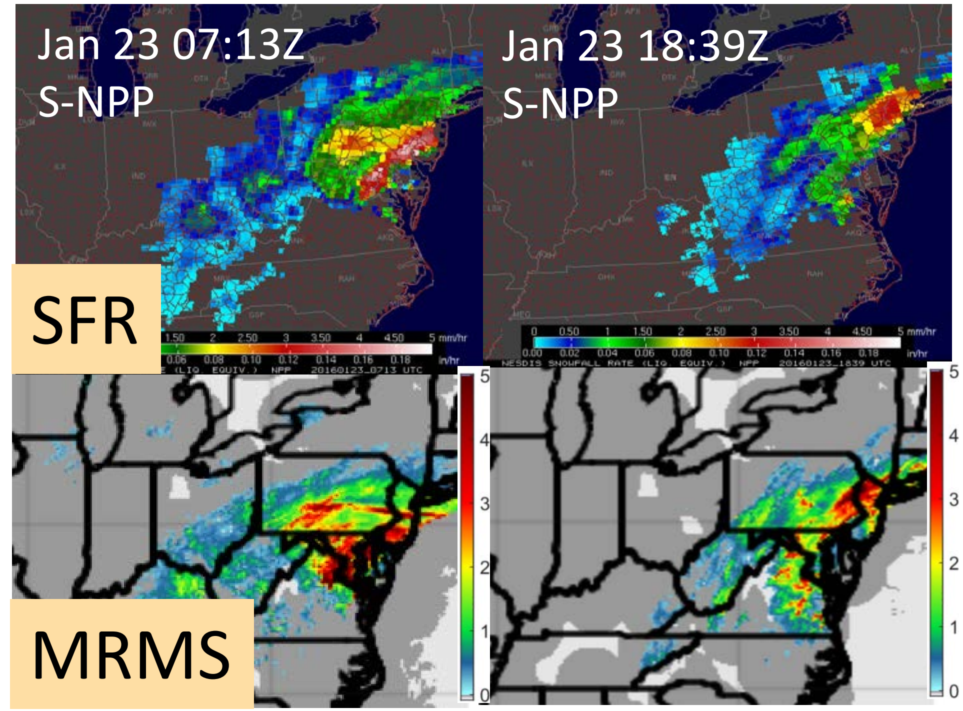
Gauge Accumulated Snowfall
January Average, 1981-2010



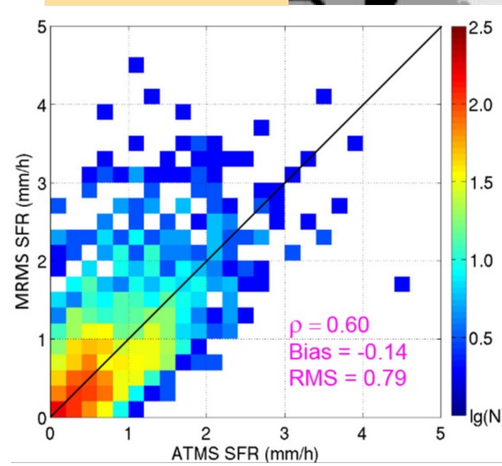
(Durre, 2013)

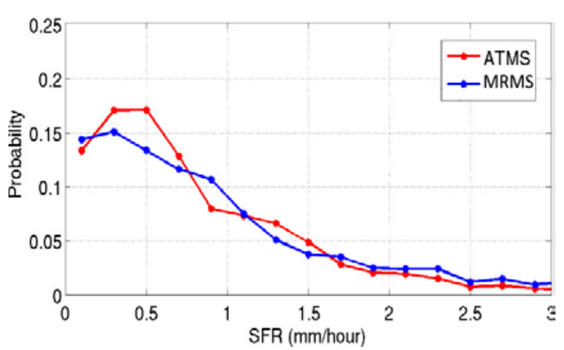
Validation – Case Study

- The 2016 Blizzard hit the Mid-Atlantic region on January 22-24, 2016 and produced record snowfall in many local areas
- The ATMS and MHS SFR products captured the evolution of the blizzard with five satellites including S-NPP, POES and Metop.



	Correl. Coeff.	Bias (mm/hr)	RMS (mm/hr)
ATMS	0.60	-0.14	0.79
MHS	0.54	-0.53	0.88

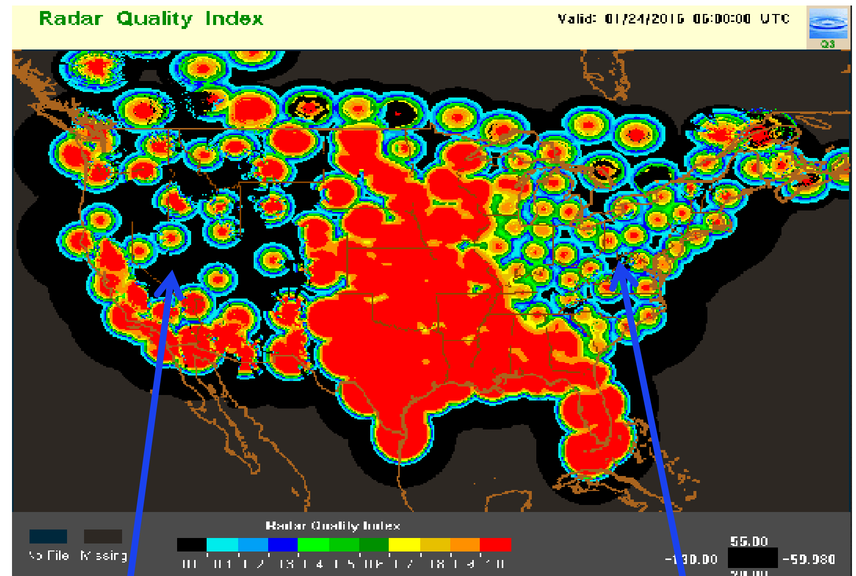




Application in Weather Forecasting

- ATMS and AMSU/MHS SFR was evaluated at several NWS Weather Forecast Offices (WFOs) in a project supported by NASA through collaboration with SPoRT. User feedback indicates that SFR is a useful product for weather forecasting operations
- SFR is especially useful for filling observational gaps in mountains and remote regions where radar and weather stations are sparse or radar blockage and overshooting are common
- SFR also provides quantitative snowfall information to complement snowfall observations or estimations from other sources (stations, radar, GOES imagery data etc.)
- Use CIMSS direct broadcast data to meet latency requirement for weather forecasting

MRMS Radar Precip Quality Index during 2016 East Coast Blizzard



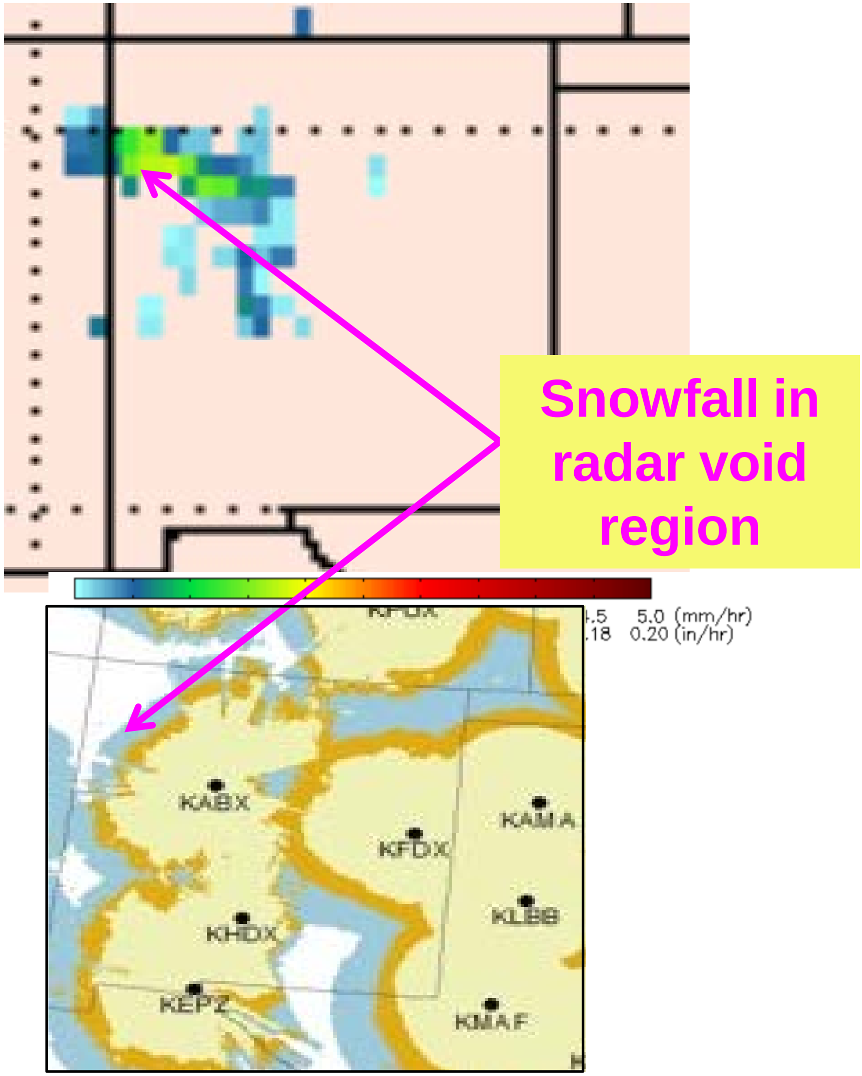
poor coverage

quality degradation during snowfall

Use Case 1: Jan 14, 2015

Albuquerque, NM WFO (ABQ) :
The 919UTC image matched the NAM12 QPF forecast very well within a data void region. From this information I was able to determine the NAM forecast was too slow with the evolution of the precip…The radar values dropped off away from the KABX radar which is expected, whereas the SFR product increased in the area of heaviest snowfall. Rates were close to the observed value at KGUP. The NM DOT web page indicated difficult driving conditions within this region.

ATMS SFR

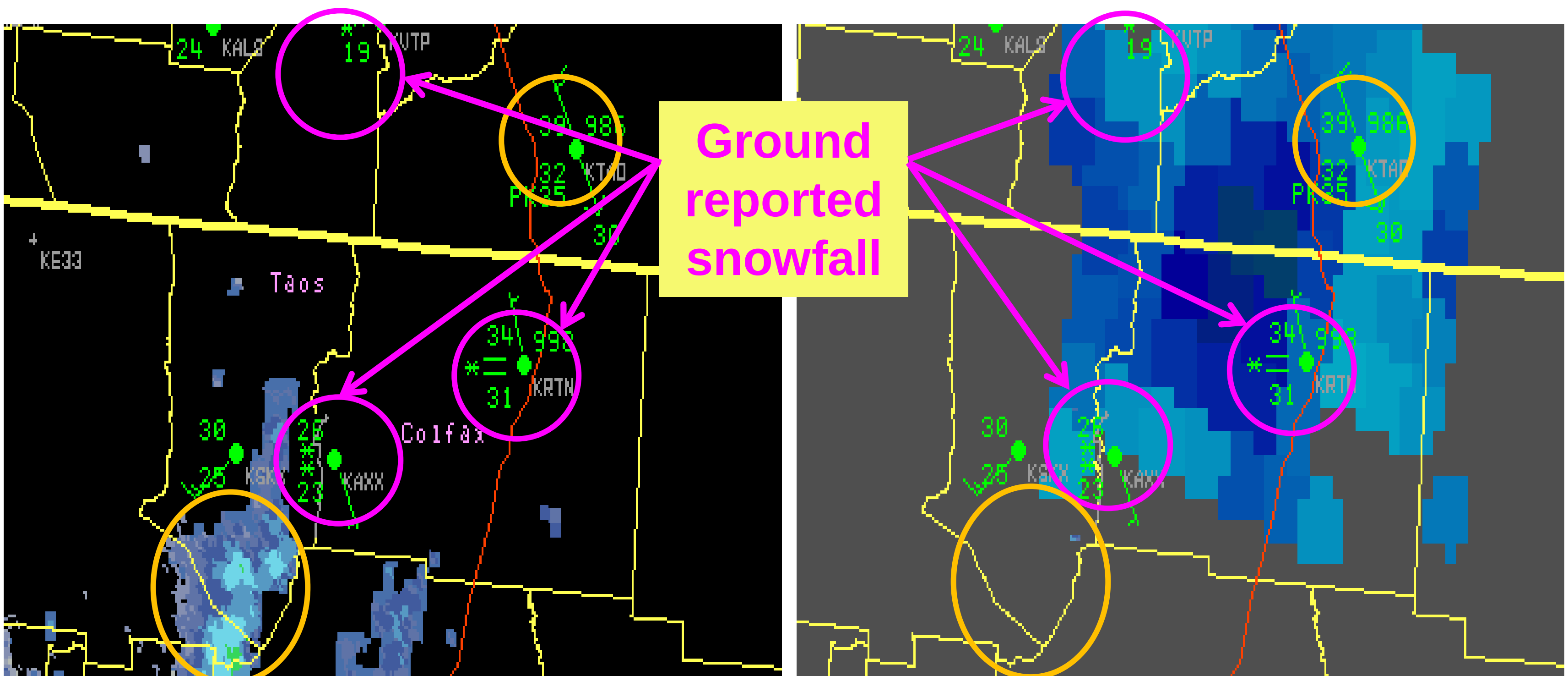


Radar Coverage Map

9

Use Case 2, December 14, 2014

Albuquerque, NM WFO (ABQ): The product (SFR) did validate that we will indeed be able to complement radar void coverage areas in an operational forecast environment using polar-orbiting satellite imagery.

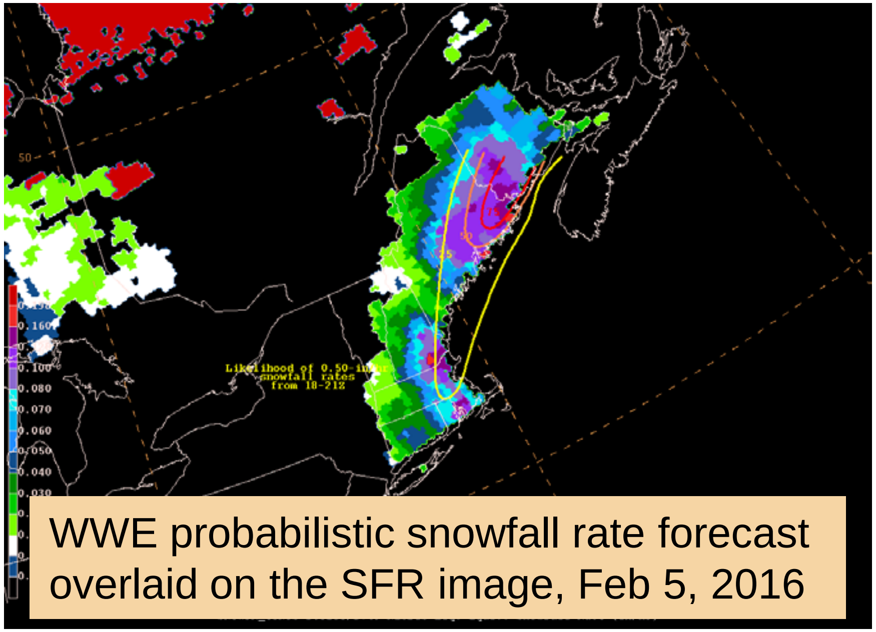


Composite Reflectivity 14-Dec-14 1642Z

Snow Fall Rate Product 14-Dec-14 at 1645Z

Application at WPC

- NWS/Weather Prediction Center (WPC) Hydrometeorological Testbed regularly conducts Winter Weather Experiment (WWE)
- 2016 WWE
  - ✓ Created a probabilistic winter hazards impacts-based product
- Verification challenges
  - ✓ Gauge and radar data all have various issues as verification data source: reliability, latency, precip type only, etc.



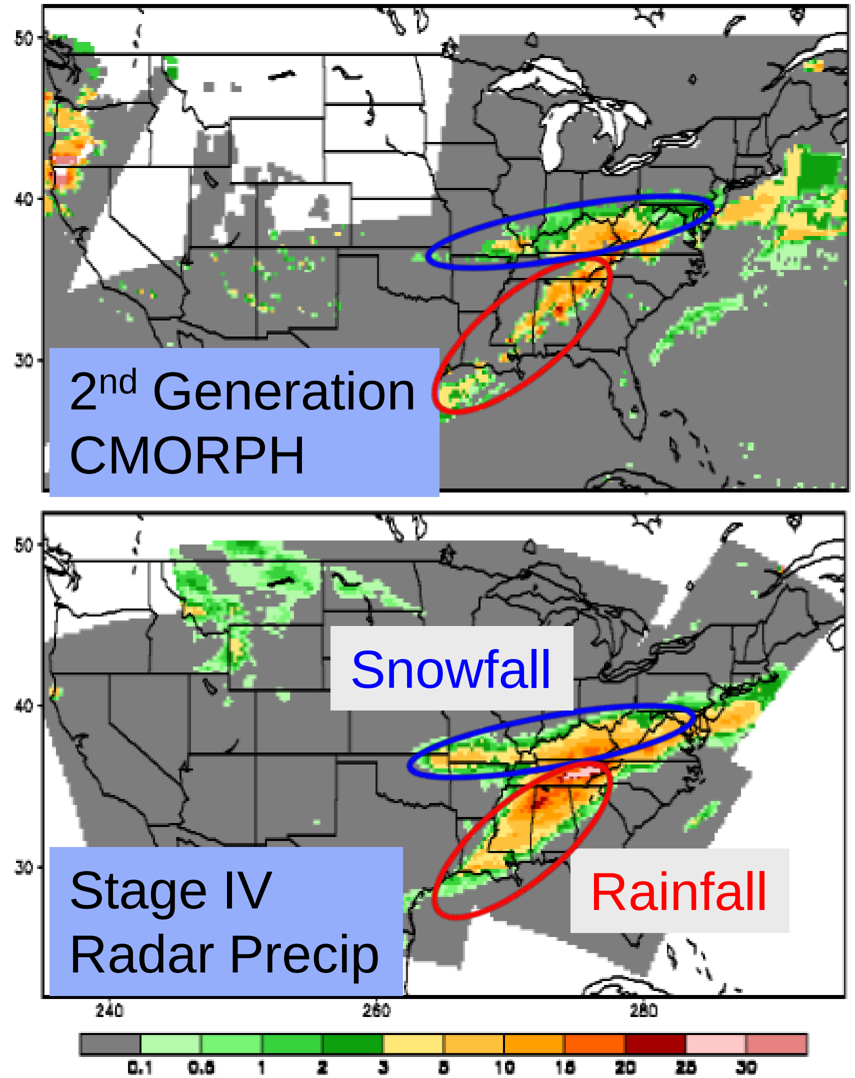
WWE probabilistic snowfall rate forecast overlaid on the SFR image, Feb 5, 2016

- SFR as a verification tool
  - ✓ Case studies show SFR and WWE probabilistic winter hazards product agree well in most cases both in location and intensity
  - ✓ 2017 WWE will utilize SFR to verify probabilistic snowfall rate forecasts
- SFR will be utilized operationally at WPC and SAB
  - ✓ Training will start soon for winter 2016-2017 assessment

Application in Hydrology

Blended Satellite Precipitation Product - CMORPH

- CMORPH is a NWS/NCEP global blended precipitation analysis product with wide-ranging applications (EMC, NWC, etc.)
- The first generation CMORPH only has rain rate. The ATMS and AMSU/MHS SFR is integrated in the second generation CMORPH with the support of JPSS PGRR
- A sample for a major snowstorm over the east coast of US in March 2014 (right)
  - ✓ Stage IV radar precipitation image (bottom) shows a warm band (rainfall) and a cold band (snowfall) of precipitation from a frontal system
  - ✓ The second generation CMORPH (top) captures both bands after integrating SFR



(Xie and Joyce, NCEP/CPC)

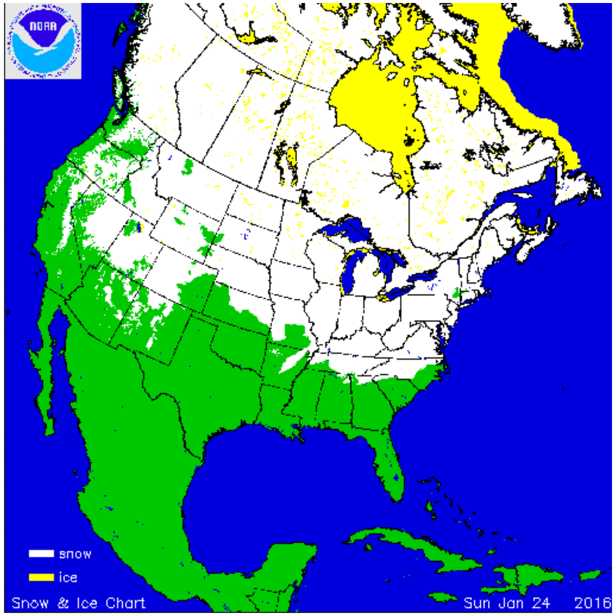
Future Application at National Water Center

- David Kitzmiller (NWC): National Water Center will use the 2nd Generation CMORPH (with SFR) in the precipitation Analysis of Record for Calibration (AORC)
  - ✓ CMORPH is used to disaggregate daily gauge-based precipitation analyses to hourly, over areas without radar coverage
  - ✓ CMORPH's capability to detect snow precipitation is important to the accuracy of the AORC products
  - ✓ CMORPH (hence SFR) will be used on a daily basis
  - ✓ AORC has numerous beneficiaries in the NWC and the general user community
- Ed Clark, Director, Geo Intelligence Division, NWC
  - ✓ NWC staff eagerly anticipate improved precipitation estimates from the SCSB/CICS-MD team, particularly enhanced rainfall and snowfall rate retrievals, achieved through synergistic use of the ABI, GLM and JPSS microwave sensors (ATMS, AMSR2). Such products are vital to improving precipitation monitoring over areas that are beyond effective radar and rain gauge network coverage, particularly large portions of Alaska and Canada, and the products will be used to improve inputs for the National Water Model and for NWC situational awareness.

Future Applications at National Ice Center

- Sean Helfrich (NIC, Science Department Head): NIC's monitoring of snow is mission critical to supporting numerical weather prediction modeling and climate monitoring for NOAA and many other agencies worldwide
  - ✓ NIC can use SFR to determine snow line globally, including Alaska, where surface radar is unavailable and clouds obscure the direct observation from IR and VIS instruments
  - ✓ NIC can use the SFR product to greatly enhance their ability to monitor active and important snow storms worldwide
  - ✓ SFR could also be used to enhance other snow characterization required by NIC such as snow depth and snow water equivalent

NIC's Snow and Ice Product, MIS After 2016 East Coast Blizzard



Summary and Future Plan

- An ATMS Snowfall Rate product has been developed with support from JPSS PGRR
- Extensive validation studies have demonstrated the quality of the product
- ATMS SFR has current and future applications to support NWS
  - ✓ Hydrology: CMORPH (CPC), NWC
  - ✓ Weather Forecasting: WFOs, WPC
  - ✓ NWP Models: CPC and EMC (through NIC MIS and CMORPH)

Future Plan

(Supported by JPSS PGRR)

- Algorithm enhancement
- Development of SSMIS SFR algorithm
- Development of GMI SFR algorithm
- Development of prototype ocean SFR algorithms

Thank You!

Summary and Status of the JPSS Initiatives

Presented by: Chris Barnet
Science and Technology Corporation

With contributions from: Mitch Goldberg (JPSS), Antonia Gambacorta, Nadia Smith, Jonathan Smith, Jim Davies (SSEC), Tom King (STAR), Bill Sjoberg (JPSS), and many more

2016 STAR JPSS Annual Meeting, NCWCP Bldg.

Wednesday, Aug. 10, 2016 (Session 6, 13:20)

My focus: application dependent characterization of NUCAPS

- NOAA is investing in a number of JPSS Sounding Initiatives
  - Goal is to demonstrate new applications with S-NPP
    - Focus is on applications with high societal value
    - These are not the “easy” applications
  - Secondary goal is to encourage interaction between developers and users to tailor soundings to applications
- We currently have a number of active initiatives for sounding
  1. NUCAPS in AWIPS-II: training & improvements
  2. Aviation Weather Testbed (AWT): Cold Air Aloft (N.Smith was 11:00, this session)
  3. Hazardous Weather Testbed (HWT): Convective Initiation (Next talk: Bill Line)
  4. Hydrometeorology Testbed (HMT): Pacific field campaigns
  5. Carbon Monoxide and Methane evaluation (Session 11: A. Gambacorta, N.Smith, B. Pierce, G. Frost)
  6. Use of NUCAPS in NWP applications (G. Chirokova, was 11:45, this session)

Jornada del Muerto

- Jornado del Muerto means “journey of the dead man”
  - Located between Las Cruces and Socorro, New Mexico
    - High plains lava bed (a “malpais”) with little water or refuge
    - A reminder of the resolve of the Spanish settlers in early 17th century
  - I lived and hiked in this region for ~10 years
    - This is my analogy of “the valley of death” our products need cross

Initiatives directly support JPSS end-to-end Science Approach

- See Mitch Goldberg's Session.1 talk for more details
- These activities specifically address:
  - Algorithms & Cal-Val
    - **Develop algorithms** that meet requirements
    - Develop **tools to visualize /validate the products**
    - **Characterize the product**, understanding and correcting outliers
    - Provide science and R2O **maturity artifacts** (Enterprise Life Cycle)
    - Campaigns for **unique validation opportunities**
  - User Readiness
    - Projects to that lead to **improvement in NOAA products**
    - PG Initiative Process for **improved user interactions** (HWT, HMT testbeds)
    - Training on **how to best use our products** in key applications
  - Science
    - To **meet user needs** (*e.g*. understanding/documenting the 2015/16 El Nino)
    - Use of Direct Readout to test new algorithms or to further **reduce latency**

The JPSS initiatives: a recipe for validation and R_2O

- Put yourself in the user’s environment
  - Listen to exactly how they interpret the data
    - This requires institutional knowledge of their application
      - *e.g.*, words we use many not convey the same meaning
  - Tailor product to their syntax and visualization
    - Utilize the user’s metric of success
- If you never leave your “cubicle”, you’ll have difficulty establishing your relevance

These concepts are adapted from Kloos 2016 Esri Arcuser newsletter “The ROI mindset for GIS Managers”

But … you need to ask the right questions

- A question such as “Do you want high spatial resolution” will always be answered “yes”
  - Better to ask “Which is more important, spatial resolution or boundary layer sensitivity”
    - The answer will depend on the application
- The sounding community assumes retrievals would be useful for global or regional models
  - But are we listening to what they really need?
    - We do not have a stable *a-priori.*
      - Radiance assimilation has a mean slightly above zero.
      - Small biases (due to a-priori) can obliterate impact
    - We need to efficiently convey our vertical co-variance and minimize our biases

Initiatives have led to potential improvements to NUCAPS

- Forecasters preferred that NUCAPS **remain independent of models**
  - expressed concern when I said we were considering using model as a-priori
- We could **improve our surface parameters** with additional measurements
  - Could use the NASA MEaSURES MODIS/ASTER emissivity climatology (Borbas, SSEC)
    - Should improve NUCAPS lower tropospheric soundings **over land**
  - Retrieval optimization:
    - Forecaster observation worked well dry regions (did not need correction)
    - Implies that we need to re-look at surface sounding channel selection
    - Maybe employ NASA AIRS SW/LW surface methodology – **may improve moist scenes**
- We need to **improve our quality control** (QC)
  - Original QC was developed to demonstrate that we met requirements
    - Some “green” scenes are bad, some “red” scenes are good
  - We need QC that is tailored for AWIPS application
    - Even where our performance is marginal, these data might have unique value
- Explore **other forms of visualization**
  - Could we display NUCAPS cloud retrieval (height, amount) on the skew-T?
  - Line width or colors could reflect accuracy (larger errors below cloud levels)
  - Some indication (on skew-T or in 1 page user guide) of vertical resolution
    - Provide guidance on whether or not we see capping inversions, etc.

Initiative # 1 / 5

AWIPS-II NUCAPS training module & AWIPS improvements

POCs: Brian Motta (NWS), Dan Nietfeld (SOO at Omaha WFO, now OAR/ESRL/GSD),
Scott Lindstrom (CIMSS)

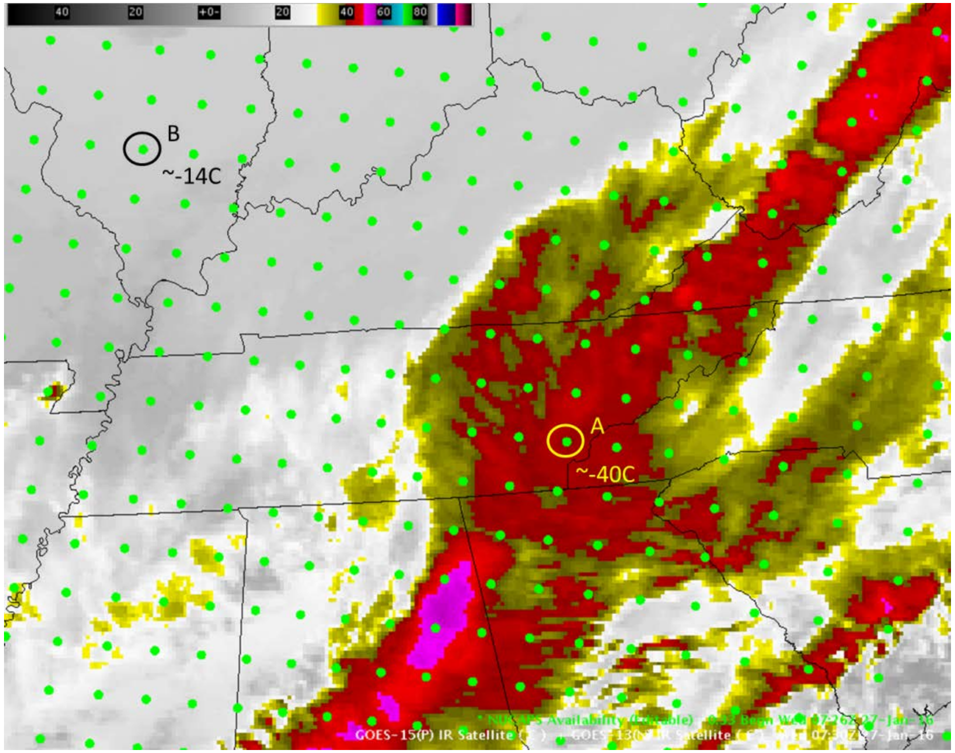
AWIPS-NUCAPS training module and improvements

- NUCAPS is now available in AWIPS-II (at ~100 WFO's)
  - AWIPS-II is visualization tool in USA forecast offices
- Articulated training modules can be viewed at:
  - http://cimss.ssec.wisc.edu/goes/goes-r/training/recordings/NUCAPS/player.html (click here)
  - Describes that soundings are smoother than RAOBS
  - Illustrates how to modify NUCAPS to local conditions
- Forecasters have evaluated improved visualization
  - AWIPS "Plan View" and "Volume Browser" displays
- We learned that forecasters always make corrections of soundings to local conditions.
  - led to a new JPSS sounding initiative (PI: Dan Lindsay, CIRA) to automate the correction process

An Example:
An e-mail exchange with Kris White, (Huntsville WFO) and discussion with Kathryn Shontz, (JPSS program (now OSGS))

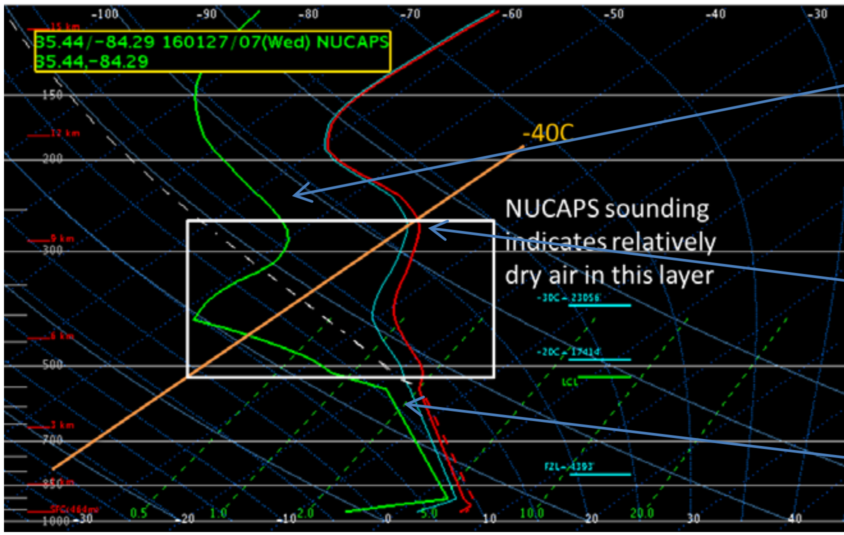
GOES 10.8 µm image
Jan. 27, 2016, ~7:30 UT

- Red region is ~-40 degC BTs, location of sounding "A"
  - Probably cirrus blowing off of tops of severe convection (purple region) SE of Huntsville
- Location "B" has ~-14 degC BTs
  - Most likely lower level
- Gold colored clouds are probably intermediate levels of convection.



Sounding "A"

- Original question: Why does NUCAPS show dry layer at -40 degC level?



There is a moist level at 9 km (300 hPa)

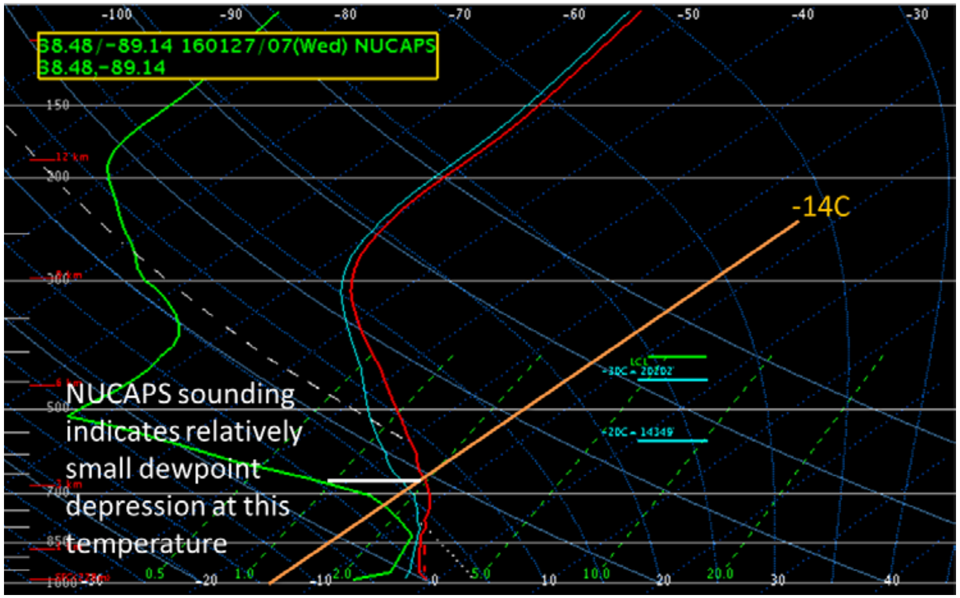
-40 degC corresponds to local maximum in T(p) and minima in q(p)

Bottom cloud top (top of saturation) is closer to -20 degC

- Our interpretation:
  - Diagnostics shows that this case is rejected, extremely cloudy: ~75% in FOR (60-85% in FOVs) at 230 hPa and ~20% at 600 hPa (15-40%)
  - NUCAPS is relatively insensitive to the upper cirrus cloud
    - probably too thin or very cold, easy to cloud clear
  - NUCAPS is significantly different than GFS in this region (not shown)

Sounding "B"

- Where location "B" is consistent with GOES image, top of cloud ~-14 degC



- The amount of cloud is less important than the spatial variability and thermal contract (difference between cloud temperature and surface (or lower cloud deck) temperatures.
- Comparisons to the microwave product would be valuable within the forecasting environment.

  – NUCAPS case is also extremely cloudy, but upper cloud deck is thin (~0% at 230 hPa and lower cloud deck is overcast 100% at 670 hPa (not variable)
    - This case probably should have been rejected, but wasn't

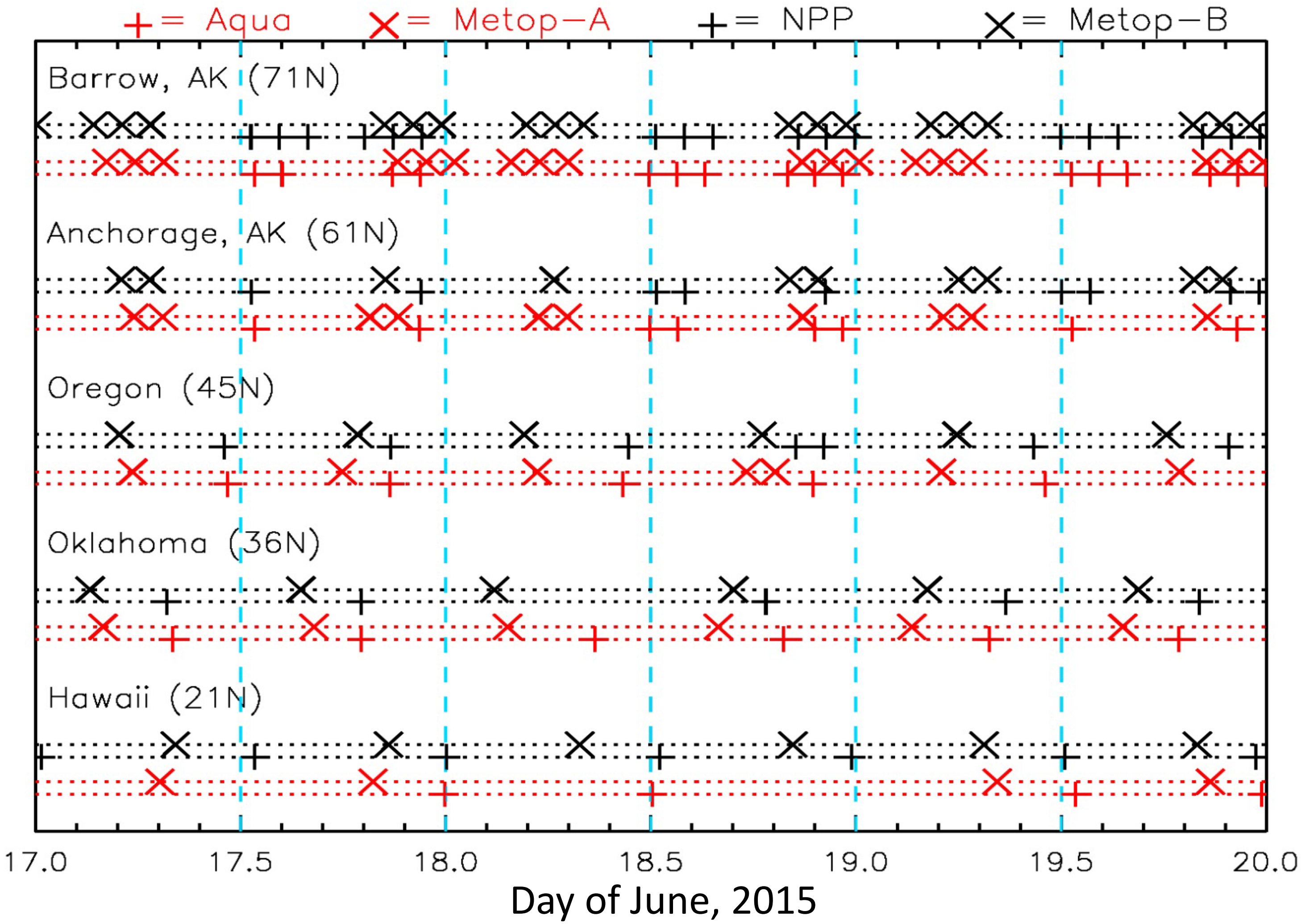
Why is this discussion important?

- Focusing on individual cases helps to illustrate the strengths and weaknesses of NUCAPS
  - Comparison of NUCAPS retrievals (or high resolution IR spectra) with broadband images requires some care
- Interaction between forecaster and developer leads to a better understanding of both imager and sounder information
  - It is always surprising to me (as a developer) how NUCAPS is actually used and, in this case, compared (*e.g.*, to imagers)
  - ***These cases rely more heavily on ATMS***
    - We need to evaluate these cases for CrIS-only systems
      - important given issues with ATMS
      - These kinds of cases are extremely valuable
  - ***Should be used as training examples***
  - Should be used to tailor and improve NUCAPS
    - Understanding these cases are more important to the user than global statisics
  - ***Important to retain and reprocess these cases for verification*** of future upgrades

Future Plans for AWIPS

- NUCAPS-Metop-A & B NOAA IASI/AMSU/MHS retrievals into AWIPS-II
  - Same algorithm as CrIS/ATMS, but 4 hours earlier
  - Version for CSPP direct broadcast is in work,
    - should be operational in mid-2017
- Unfortunately, NUCAPS-AIRS/AMSU is not operational at NOAA (it is a NASA product)
  - It is run-able within the science code.
  - We are considering putting it into CSPP (FY2018)

Constellation of satellites allows more observations between 0Z & 12Z RAOBS



NPP/J-1 will be phased similar to Metop-A/B approx. 6 months after launch of J-1

(Used Aqua as proxy for J-1 in plot)

These are overpasses with satellite elevation > 32 deg (all FOR's)

Initiative #2 / 5

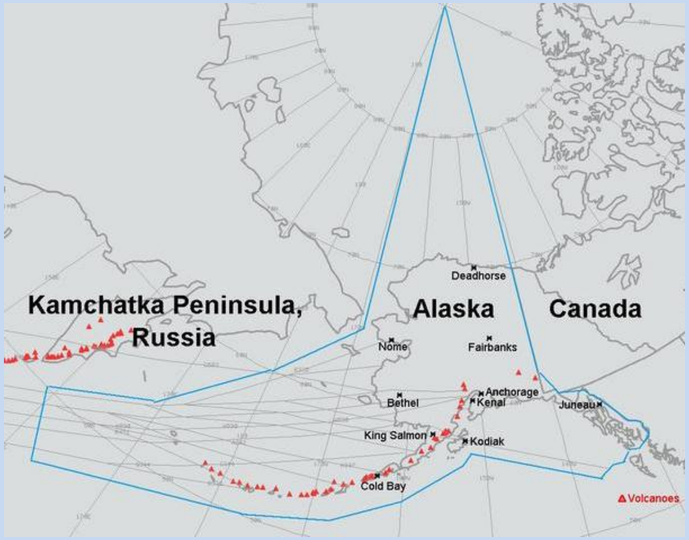
Aviation Weather Testbed: Cold Air Aloft

POC: Brad Zavodsky (NASA/SPoRT), Kristine Nelson (NWS/AR/ARS/CWSU/ANCHORAGE AK)

Aviation Weather Testbed
Cold Air Aloft

In Alaska, forecasters must rely on analysis and model fields and limited radiosonde observations (~4/day) to determine the 3D extent of the cold air aloft

- Airline fuel begins to freeze below -65 degC, need to issue pilot advisories
- Forecasters need to know spatial and vertical location of “bubble” of cold air aloft



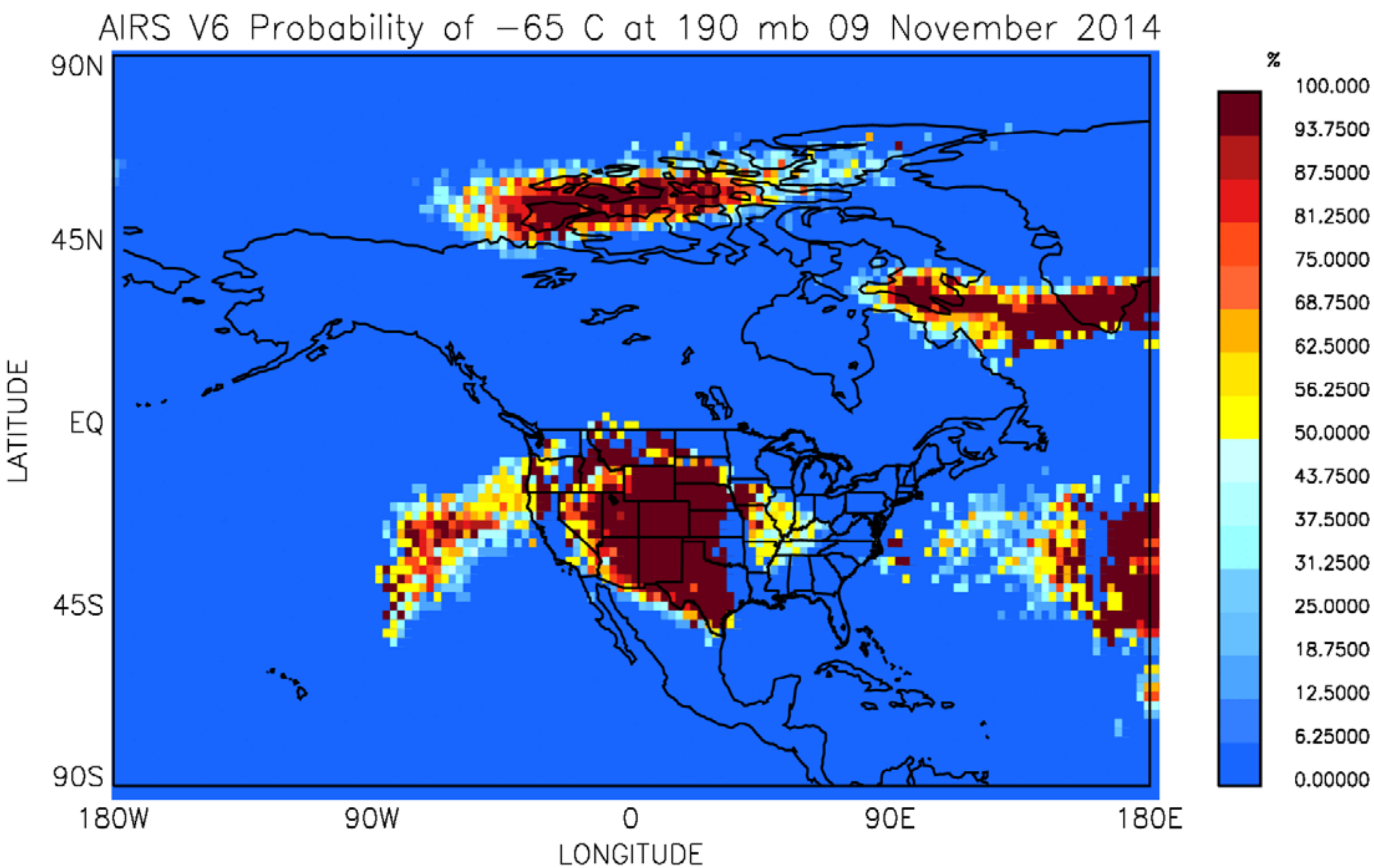
- Anchorage Flight Information Area (FIR) encompasses 2.4 square million miles
- Anchorage Airport was ranked 3rd worldwide for throughput cargo (90% of China to USA) and 1st in the USA for cargo poundage (5.9 Billion lbs)

Daily Cold Air Loft frequency of occurrence at 190 mbar

Used AIRS Level.2 Support Product

Counted occurrences of T(190mb) $\leq$ -65 degC in a 1x1 deg grid

Anchorage Center Weather Service Unit (CWSU) issued warnings on Nov. 11th to 14th



Analysis and graphics by C. Francoeur, STC

Summary of Aviation Weather initiative

- CrIS/ATMS easily sees the cold air aloft in our cross-sections and skew-T plots
- We are investigating if the large areas of cold air aloft off the west USA coast (Hawaii flight track) is important
    - We believe it is real, the tropopause dips down
- GFS ingests CrIS and ATMS, is it good enough?
    – At 200 mbar many CrIS channels/scenes are used
    – Real time NUCAPS (8, 9.5, 11 and 20, 21.5, 23 Z) adds information between the model analysis times (0, 6, 12, 18Z) and gives forecaster more confidence

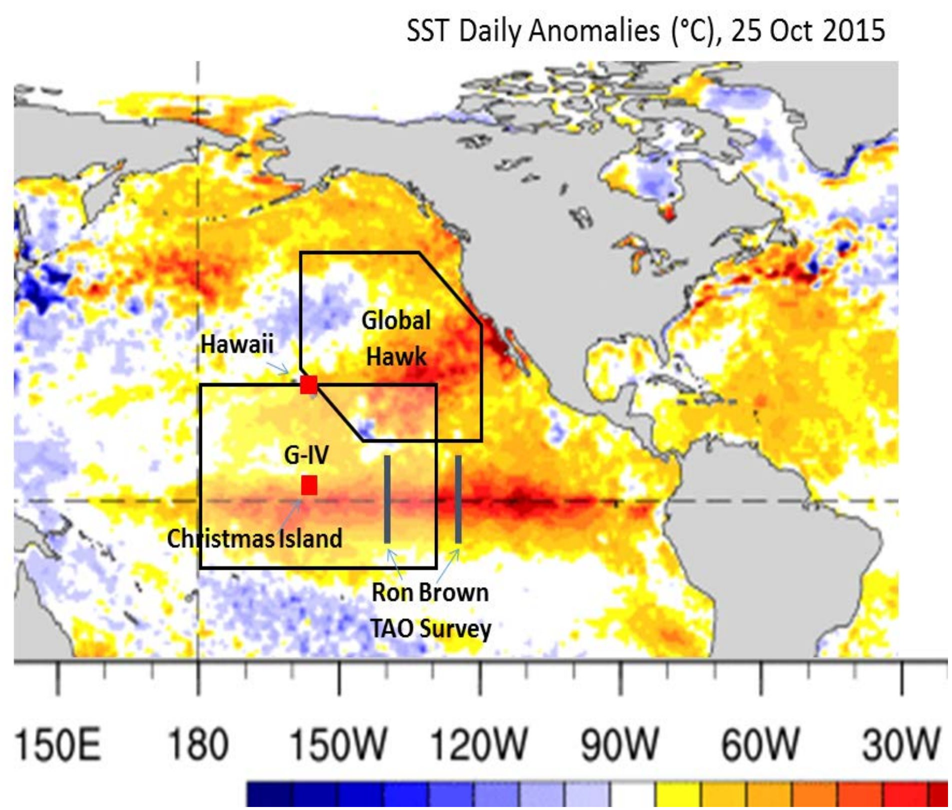
Hydrometeorology Testbed:
El Nino Rapid* Response Field Campaign

* Campaign went from white paper proposal to implementation in less than 2 months

POCs: Chris Barnet (JPSS) & Ryan Spackman (NOAA/ESRL/PSD)

Planned Implementation Strategy

- Gulfstream-IV: Divergent outflow and jet extension processes in central and eastern tropical Pacific
- Global Hawk: Coupling to mid-latitude weather with surveys in eastern Pacific mid-latitudes to evaluate impacts on US West Coast
- R.H. Brown: Survey of atmosphere and ocean conditions in eastern tropical Pacific



Campaign ran from Jan. 19th through Mar. 10th, 2016

- NOAA G-IV deployed from Honolulu International Airport
  - Twenty-two 8-hour flights, Jan. 21 through March 10th
  - 41-45,000', ~25-35 dropsondes/flight
- Global Hawk (GH), part of SHOUT, deployed from NASA/AMES
  - Three 24-hour flights (2/15, 2/16 and 2/21)
  - 55-63,000', ~65 dropsondes/flight
- radiosonde launches at Kiritimati Isl., Kiribati (2N, 157W)
  - first radiosonde 1/26, 2pm HT, will continued though mid-March
  - Close to S-NPP overpass time (0,12Z), 1340 miles south of Honolulu
- NOAA Ron Brown departed Ford Island Tue. 2/16
  - 6 to 8 RS-92 sonde launches per day, continued through mid-March
- Two C-130's, one at each end of AR (Hickam HI and Travis CA)
  - Two flights made (2/18 and 2/21)

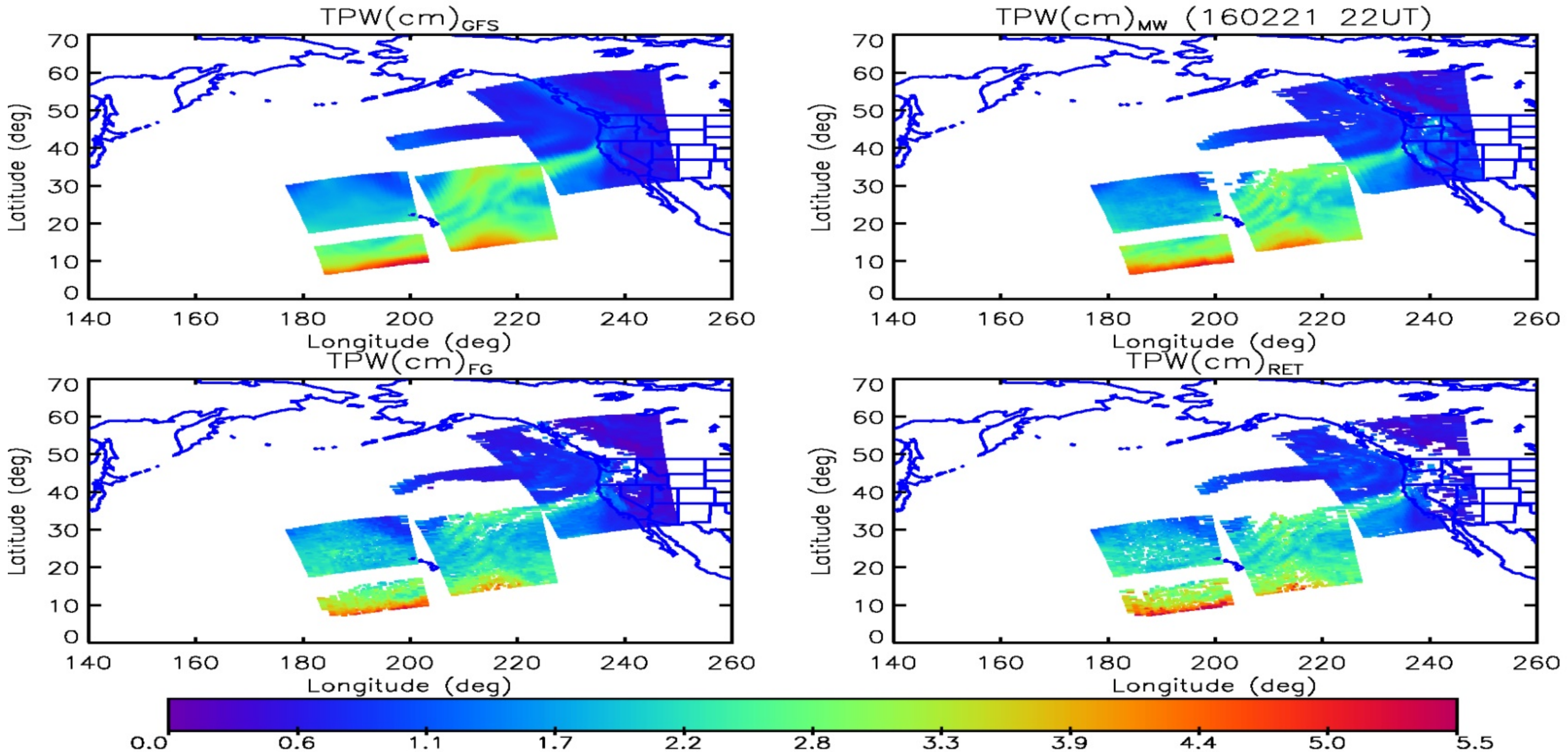
For more information, see field campaign website:
http://www.esrl.noaa.gov/psd/enso/rapid_response/

What we provided

- We performed the same kind of analysis we did for CalWater-2015 and CalWater-2014
  - Provided an overview document on satellite soundings and visualization methods to the campaign scientists
    - Selected pages (e.g., skew-T description) is at end of this document
  - Use both Honolulu HI & Corvallis OR direct broadcast sites
  - Process 1:30 am overpass (~12:30 UT, 2:30 HST, 7:30 EST)
    - Provide analysis to flight forecasters during the planning telecon
  - Process 1:30 pm overpass (~0:30 UT, 14:30 HST, 19:30 EST)
    - Provide scientists an in-flight snapshot at proposed dropsonde locations
- Use archive data (~24 hours later) to re-process entire Pacific domain and provide comparison between retrievals (MW-only and IR+MW), co-located GFS, and dropsondes
  - 1st comparison of dropsondes and satellite sounding
    - Valuable for next days flight planning discussion
    - Capture meta data for campaign archive
  - Employed NUCAPS science code to provide addition diagnostics

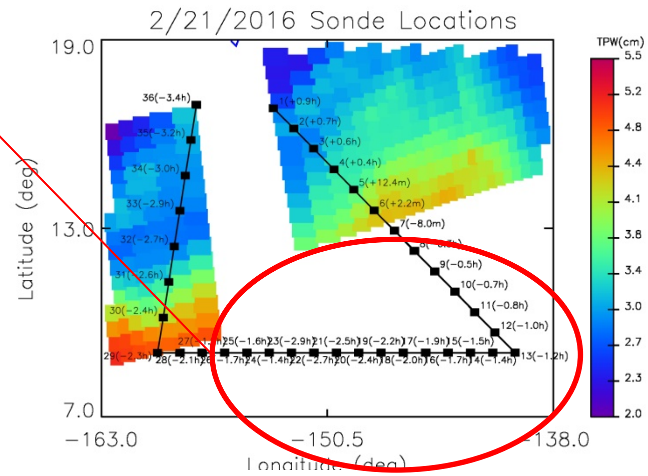
Example of DB coverage

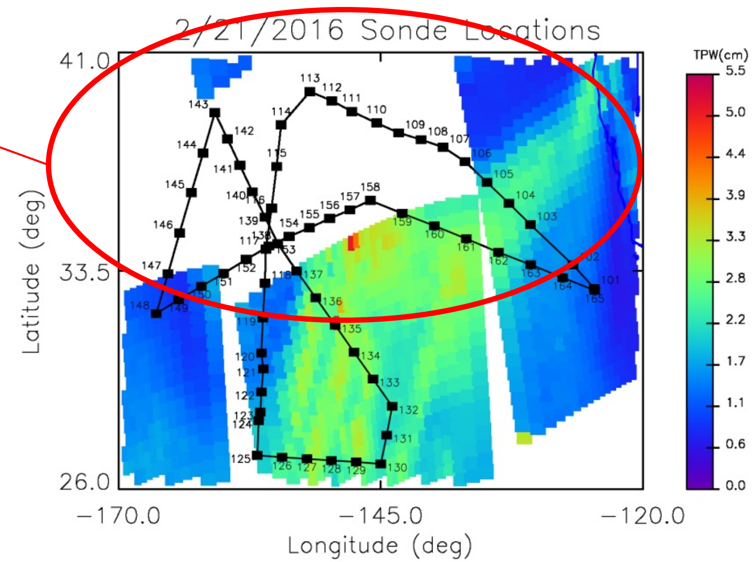
- Feb. 21, 2016 pm coverage from both Corvallis and Hawaii
  - Periodic problems with “antenna shadowing” on NPP
  - Also see missing granules due to ATMS GEO problems



Fetch of DB antenna was a problem for this campaign

- On most days the Hawaii antenna did not "see" far enough south to be useful for flight planning
  - Loss of 2 acquired granules because CrIS requires these data for calibration
- On most days Corvallis antenna didn't "see" far enough west for Global Hawk coverage

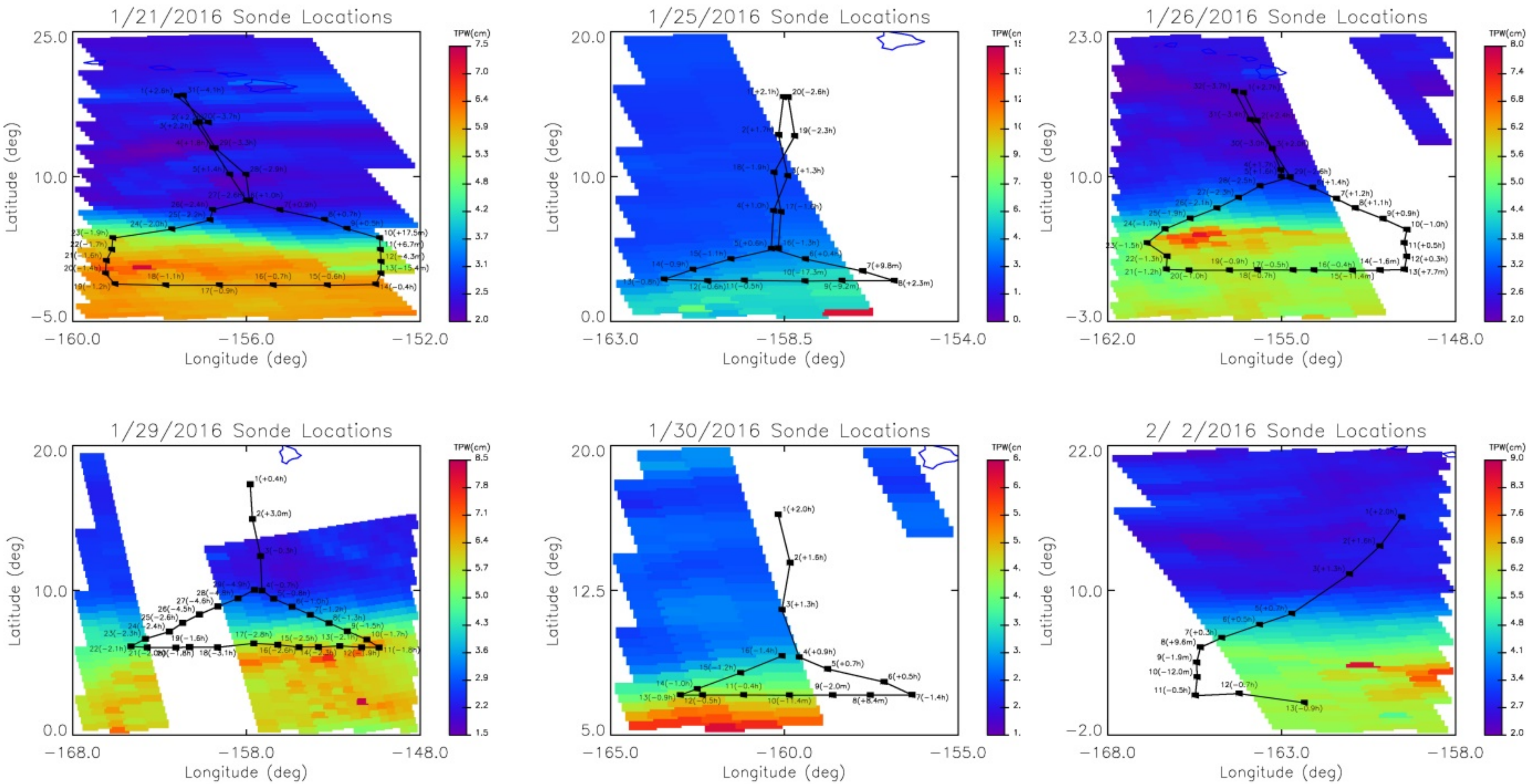




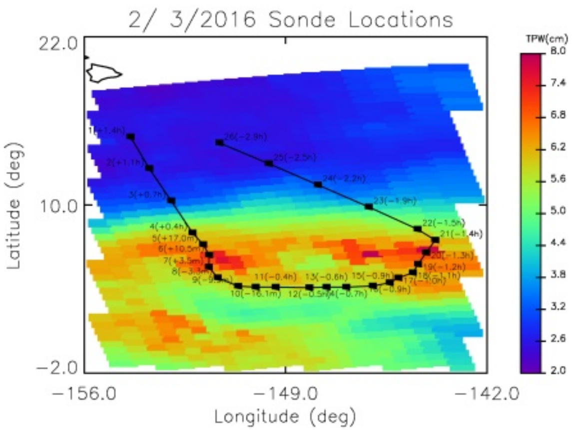
Some lessons learned for flight planning

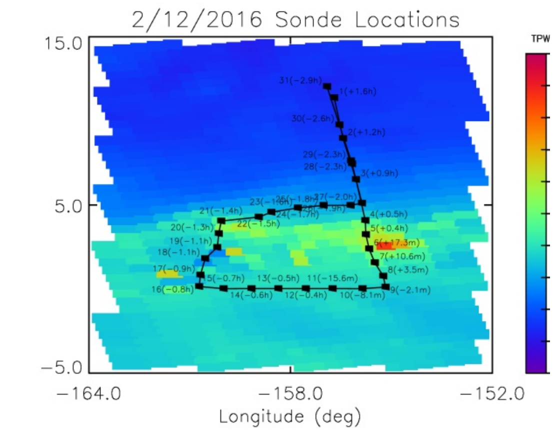
- Demonstrated we could routinely process direct broadcast NPP data
  - total latency (satellite obs to skew-T plots @ aircraft) of $\leq$ 45 minutes
- But for flight planning there is already a plethora of data
  - Real time T(p), q(p) can complement the other data
    - Mostly used to help to decide which forecast model was most representative of current conditions.
    - DB skew-T plots did help guide flight plan
      - at end of mission after trust was established
  - But we need to be able to answer questions like “do you believe that dry layer aloft” on a case by case basis
    - Individual skew-T’s were more valuable than cross-section visualization
    - Morning orbit gave them a preview of the planned dropsonde data acquisition
- Valuable insight into forecaster opinions of satellite soundings
  - They are aware and concerned with our *a-priori* assumptions
  - They assumed, incorrectly, that we could not handle outliers
  - At the “grass roots” level, forecasters became aware of satellite capabilities and limitations.

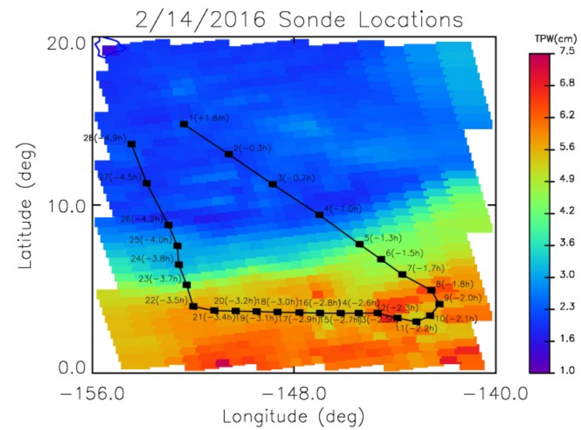
Post-processing from archive: Jan. 21 through Feb. 2

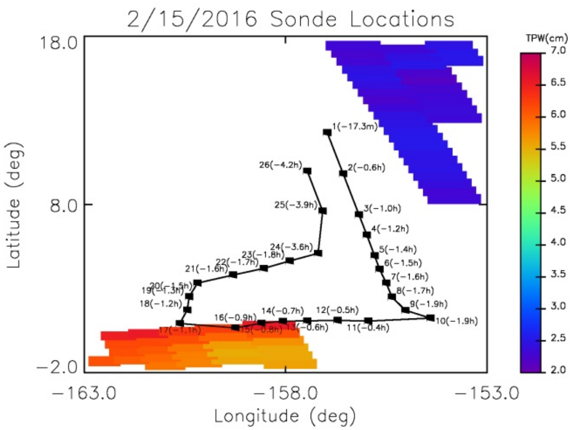


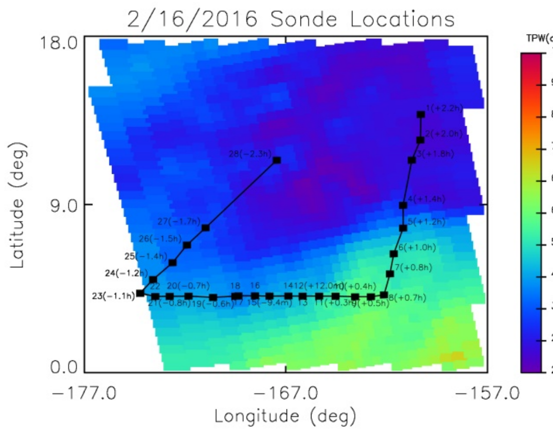
Feb. 3 through Feb. 17 post-processing

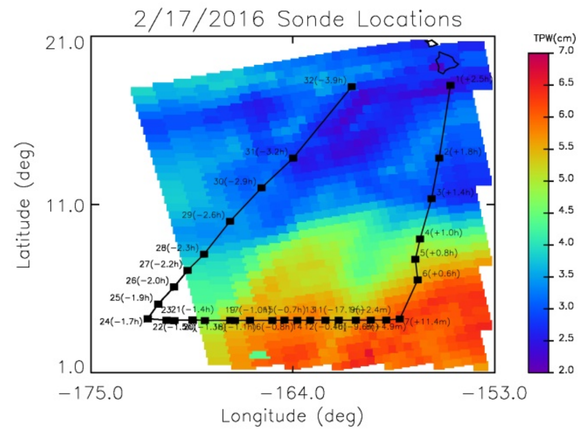




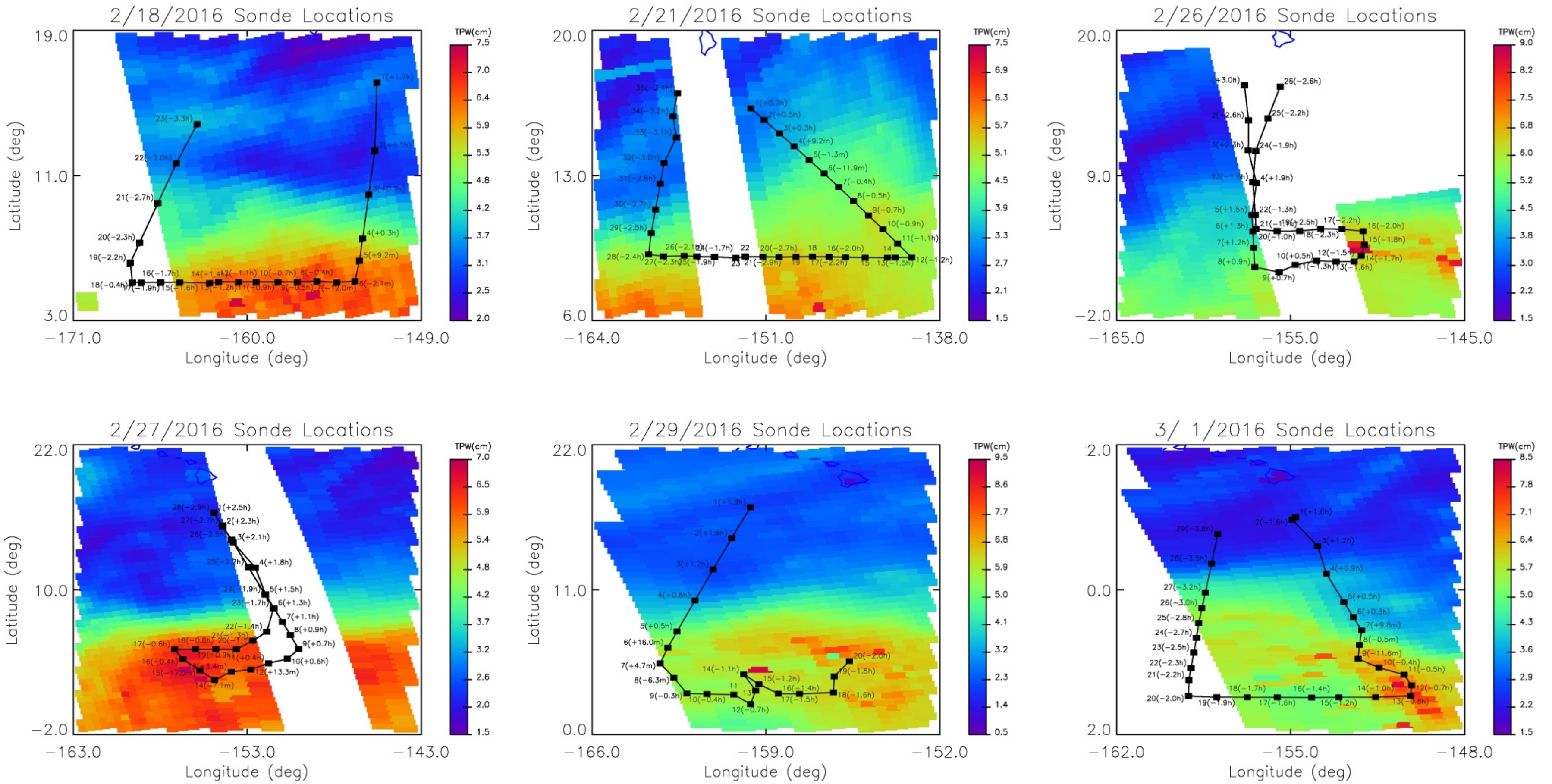






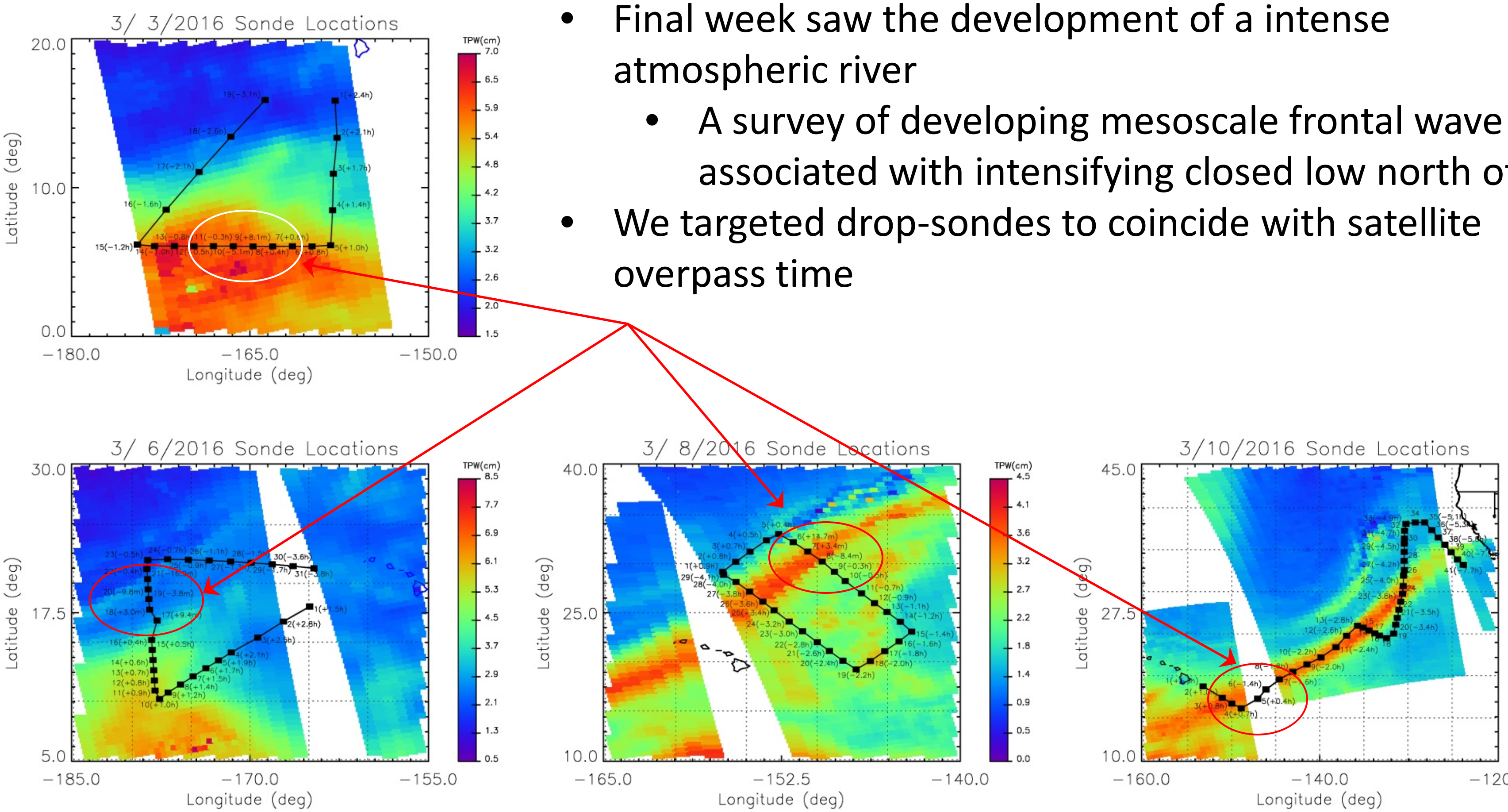


Feb. 18 through Mar. 1 post-processing



Mar. 3 through Mar. 10 post-processing

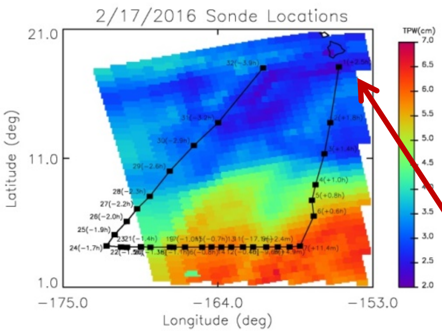
- Final week saw the development of a intense atmospheric river
  - A survey of developing mesoscale frontal wave associated with intensifying closed low north of AR
- We targeted drop-sondes to coincide with satellite overpass time



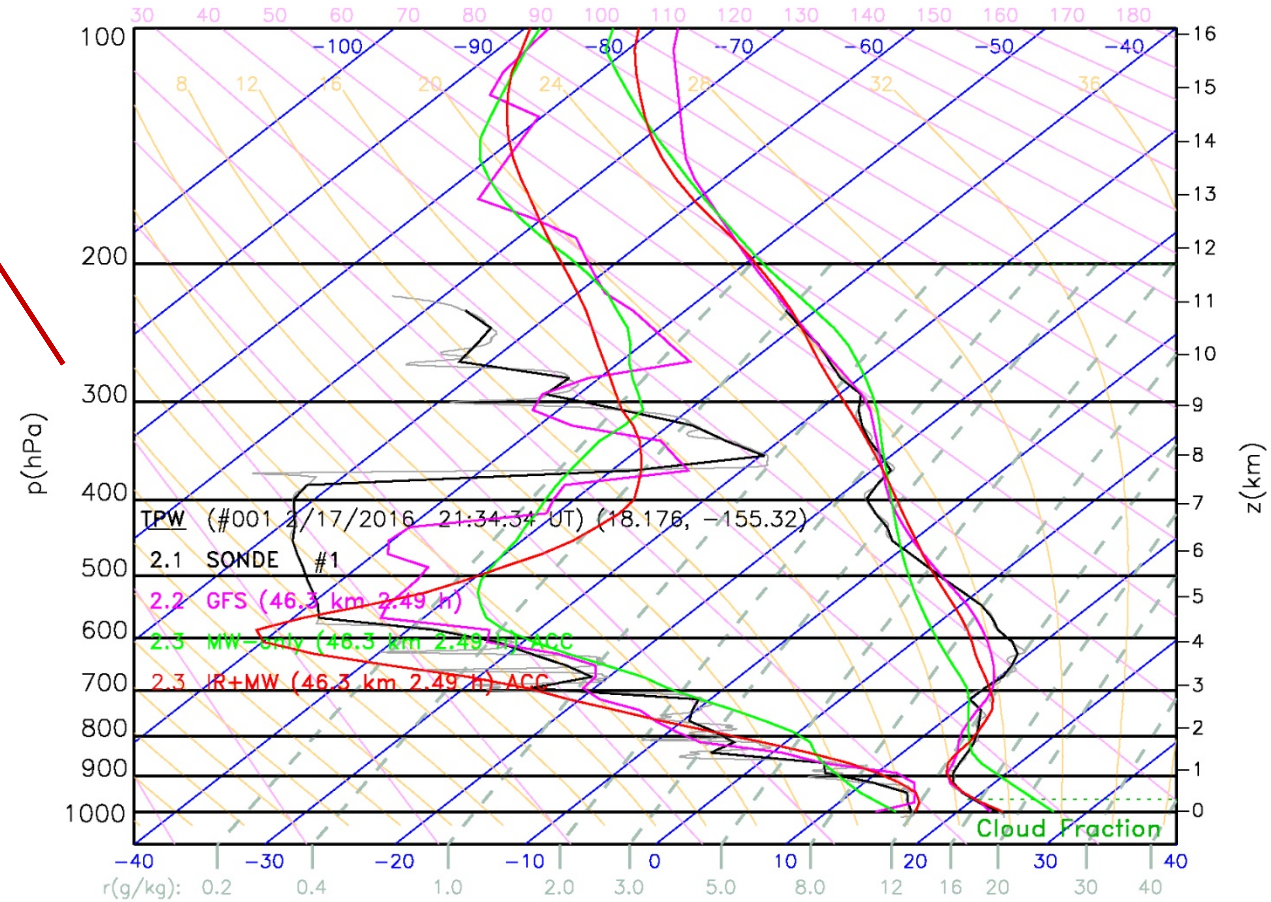
Summary of acquired datasets for validation

flight number	DB sites		flight date	total # sondes	match #skew	overpass sondes	useful match	# of GH sondes	# C130 sondes	RHB sondes	CXI sondes
1	HI	Thu	1/21/2016	31	31	11/12	-4.3 min				
2	HI	Mon	1/25/2016	20	17	08/09	-9.2 min				
3	HI	Tue	1/26/2016	32	24	10/11	-11.4 min				6
4	HI	Fri	1/29/2016	29	22	02/03	-0.3 hour				2
5	HI	Sat	1/30/2016	16	9	08/09	-11.4 min				2
6	HI	Tue	2/2/2016	13	8	07/08	+0.3 hour				2
7	HI	Wed	2/3/2016	26	26	07/08	+ 3 min				2
8	HI + CO	Fri	2/12/2016	31	31	08/09	-2.1 min				2
9	HI	Sun	2/14/2016	28	28	01/02	-0.3 hour		102		2
10	HI + CO	Mon	2/15/2016	26	4	01	-17.3 min	2			2
11	HI + CO	Tue	2/16/2016	28	27	14/15	-9.4 min	22	85	1	2
12	HI	Wed	2/17/2016	32	24	08/09	-2.4 min			5	2
13	HI	Thu	2/18/2016	23	18	05/06	-2.1 min			5	2
14	HI + CO	Sun	2/21/2016	35	32	05/06	-1.3 min	65		6	2
15	HI	Fri	2/26/2016	26	9	10/11	+0.9 hour			0	2
16	HI	Sat	2/27/2016	28	15	12/13	+3.4 min			1	2
17	HI	Mon	2/29/2016	20	20	07/08	+4.7 min			7	2
18	HI	Tue	3/1/2016	29	23	07/08	30 secs			7	2
19	HI	Thu	3/3/2016	19	19	09/10	-5.1 min			6	2
20	HI	Sun	3/6/2016	31	29	18/19	+3.0 min			6	2
21	HI	Tue	3/8/2016	29	29	07/08	+3.4 min			8	2
22	HI + CO	Thu	3/10/2016	41	38	05/06	+0.7 hour			7	2
total acquired			1102	593				89	187	144	89
total analysed			483		483						

Feb. 17, Sonde #1: 2.5 hours before overpass time

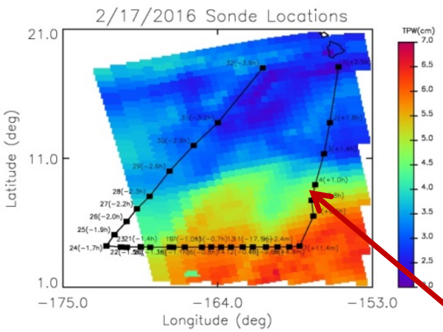


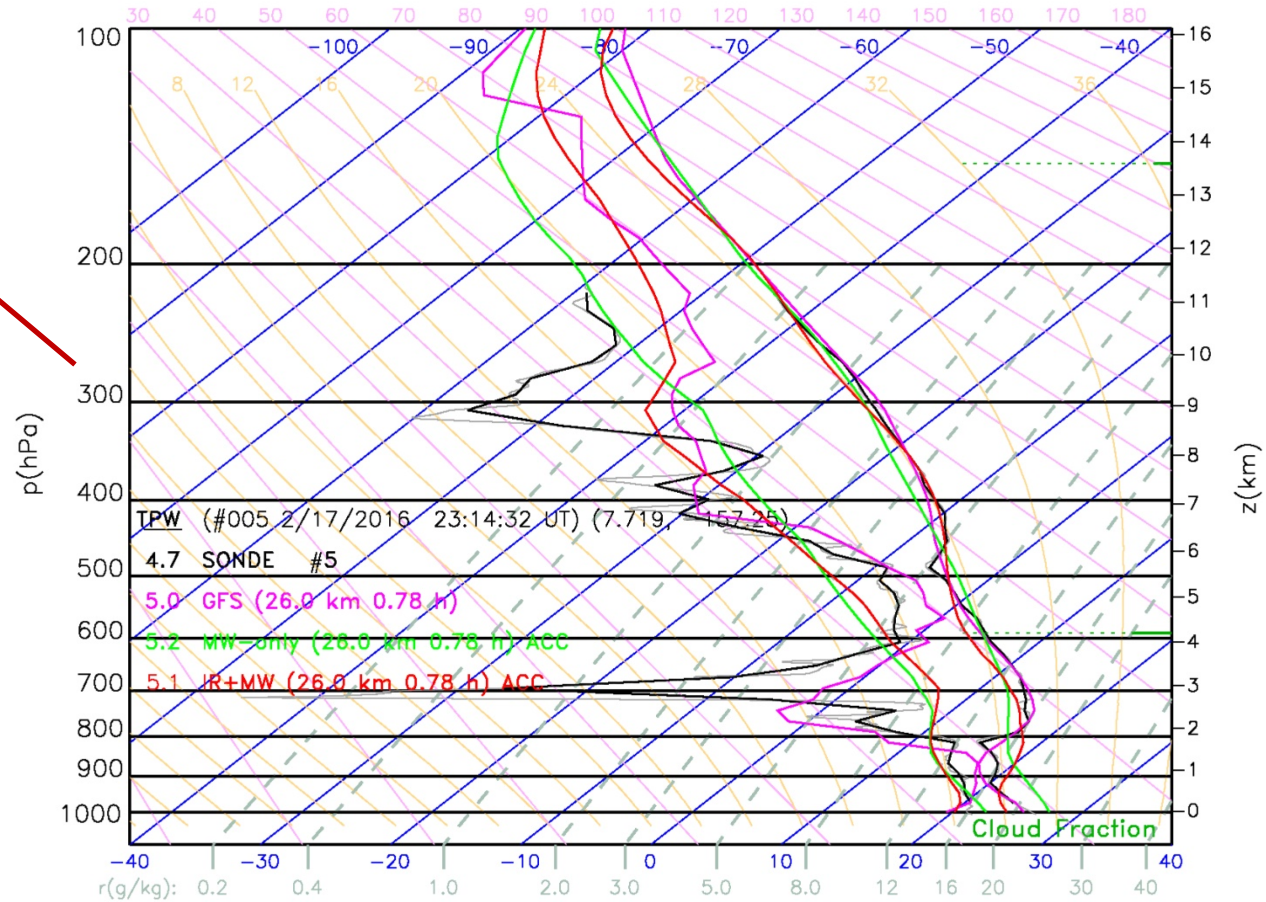
IR+MW tends to capture vertical T(p) and q(p) structure better than MW



For an explanation of our Skew-T plot – see he backup slides

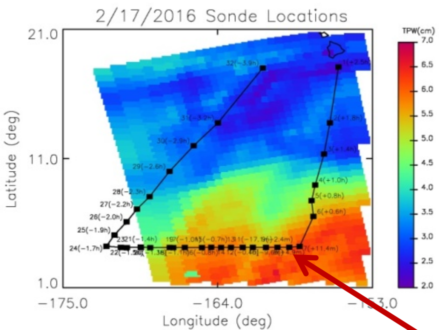
Feb. 17, Sonde #5: 0.8 hours before overpass time



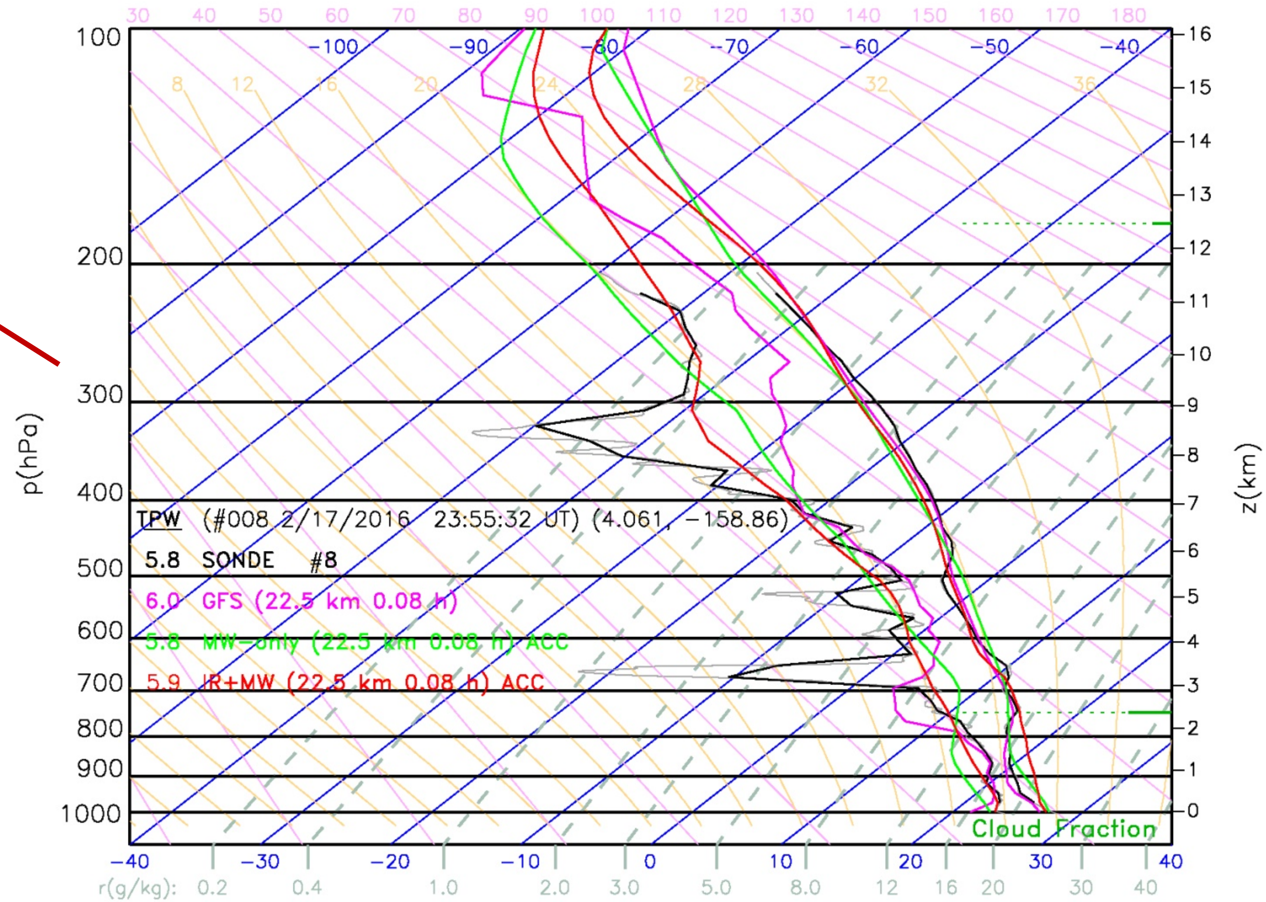


But obviously doesn't have the vertical resolution of a sonde or GFS

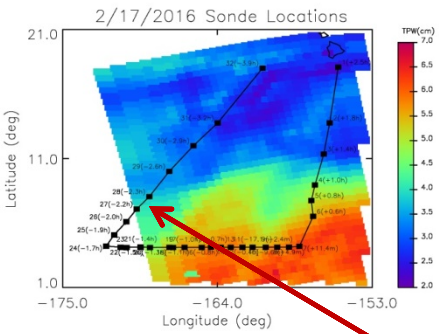
Feb. 17, Sonde #8: near overpass time



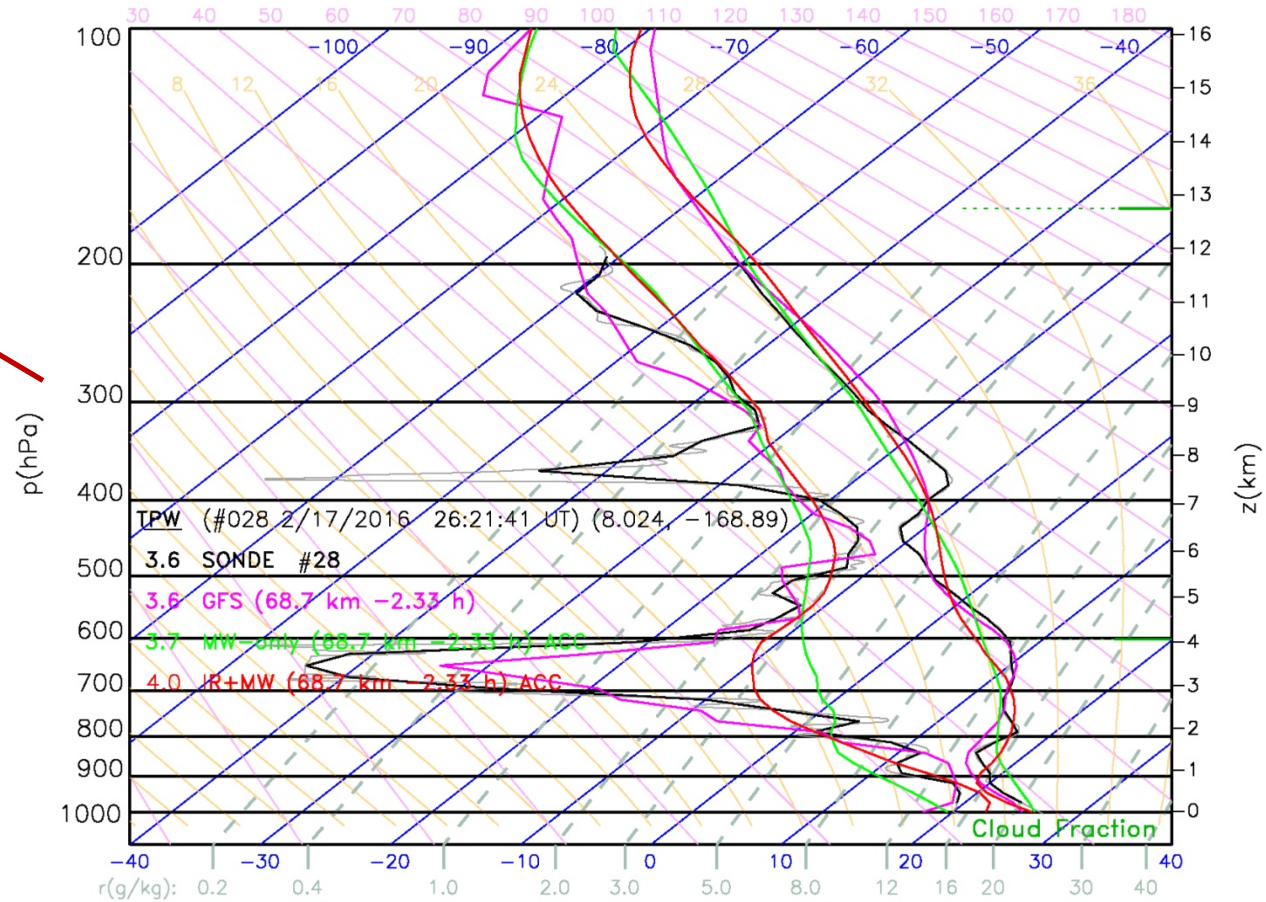
NUCAPS is capturing large scale vertical structures



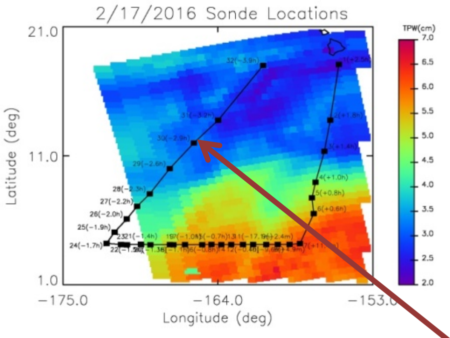
Feb. 17, Sonde #28: 2.3 hours after overpass time

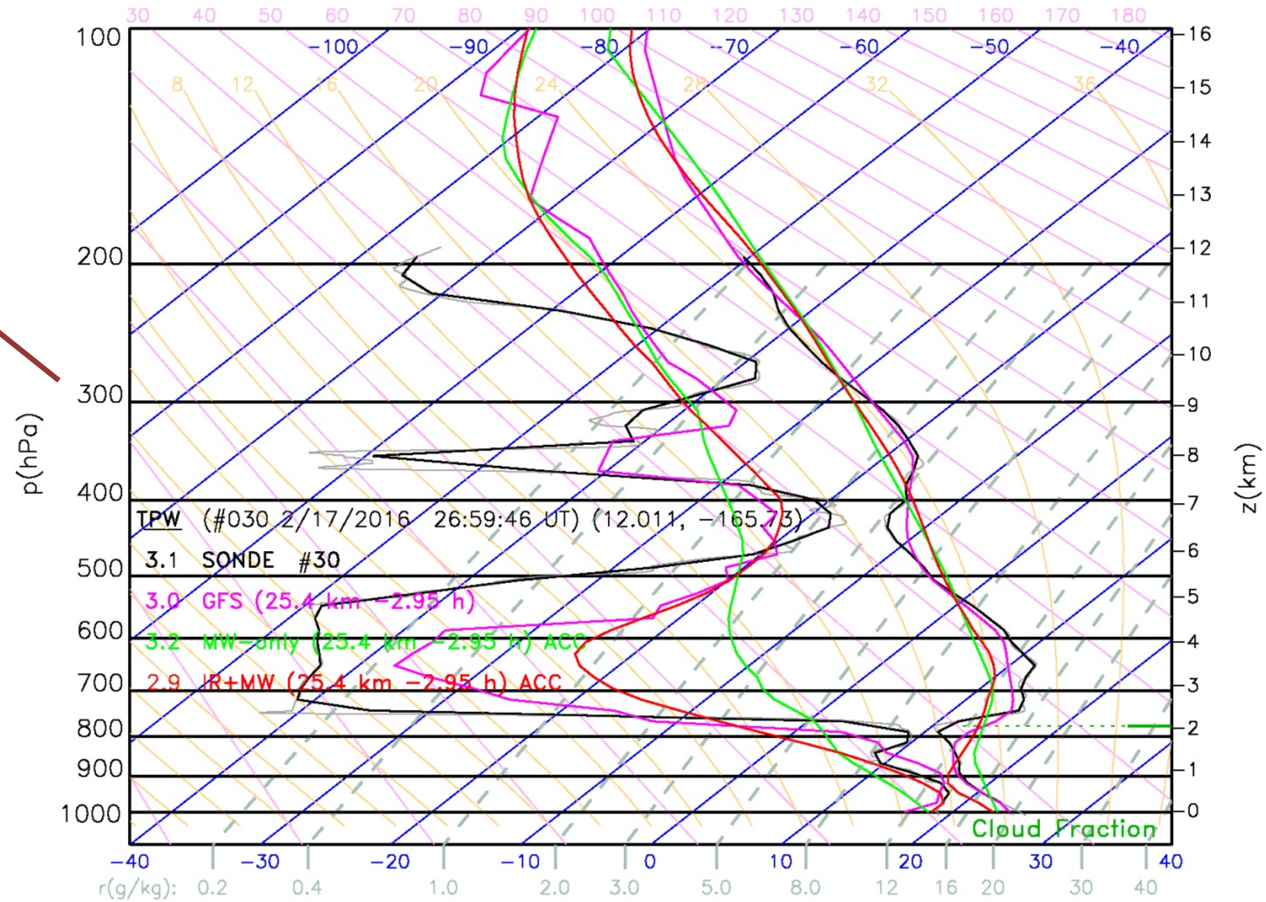


thin layers can be used to estimate vertical response



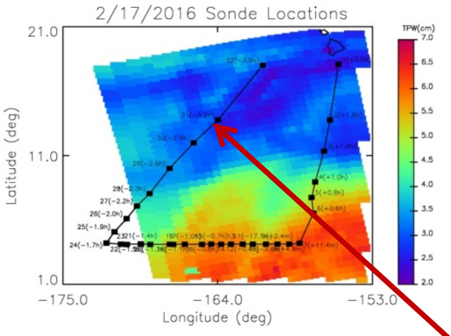
Feb. 17, Sonde #30: 3 hours after overpass time





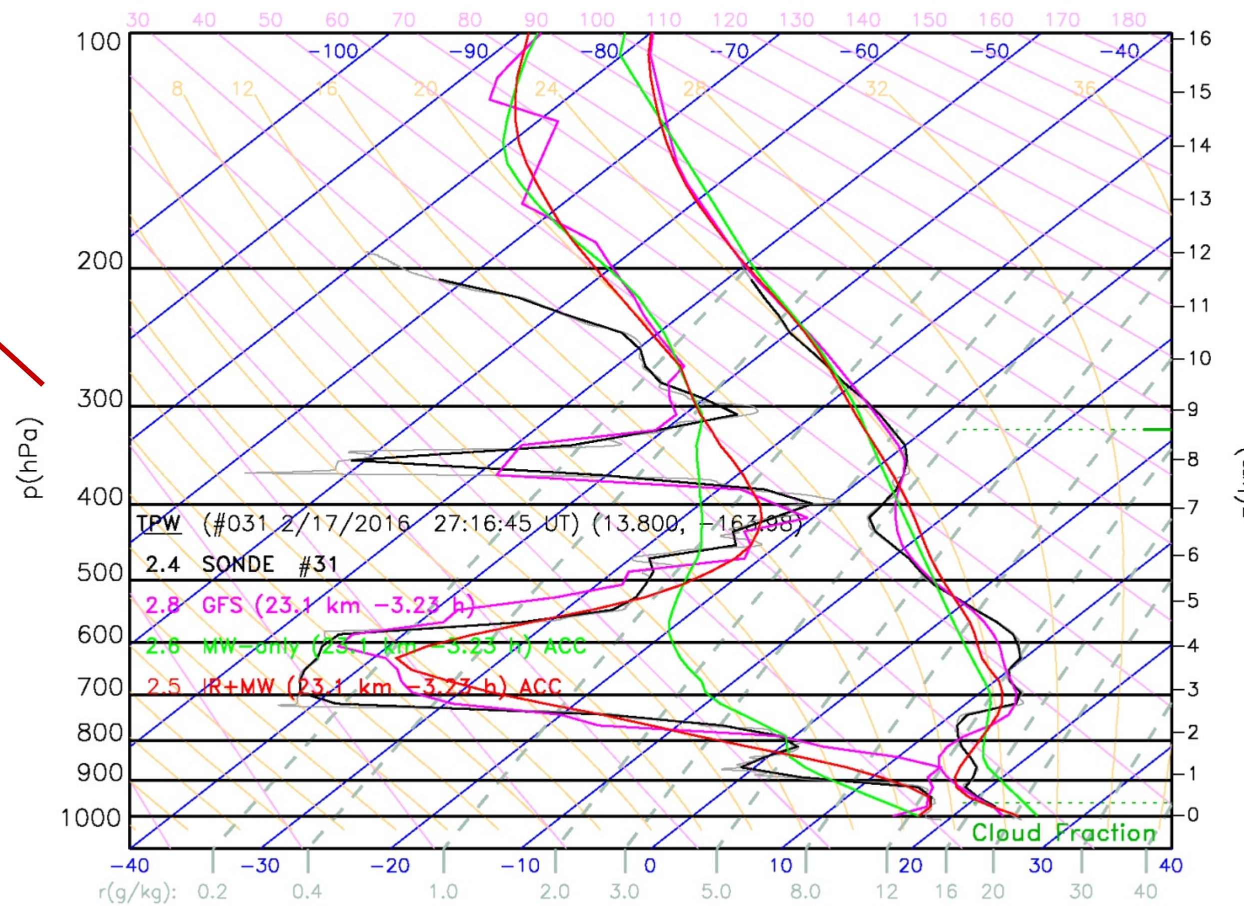
Again, vertical resolution of IR+MW tends to be better than MW-only

Feb. 17, Sonde #31: 3.2 hours after overpass time



But why did this case do so much better?

This will be the focus of the averaging kernal analysis that Antonias showed earlier today



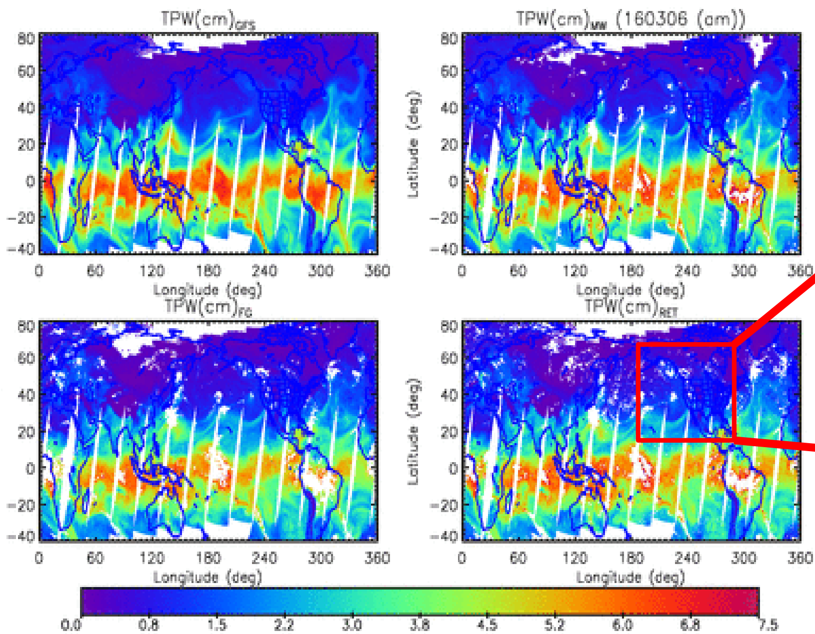
Specific ENRR research topics enabled by these data

- Assess satellite sounding vertical resolution
  - Characterize marine inversions, moist layers aloft
- Assess ability to see moisture extremes
  - 2015/16 El Nino outside of NUCAPS climatology training
  - Can test sensitivity to *a-priori* assumptions
- Support the scientific goals of the field campaign
  - Use of satellite data to test skill of GFS to targeted observations
    - Is USA forecast sensitive to specific regions (e.g., ITCZ outflow)
    - What spatial sub-setting approach would enhance skill.
  - Add NUCAPS to datasets that document the thermodynamic environment of the 2015/16 El Nino
    - Unique value to answer questions on tropical moisture transport
    - Complements the *in-situ* data investment of this field campaign

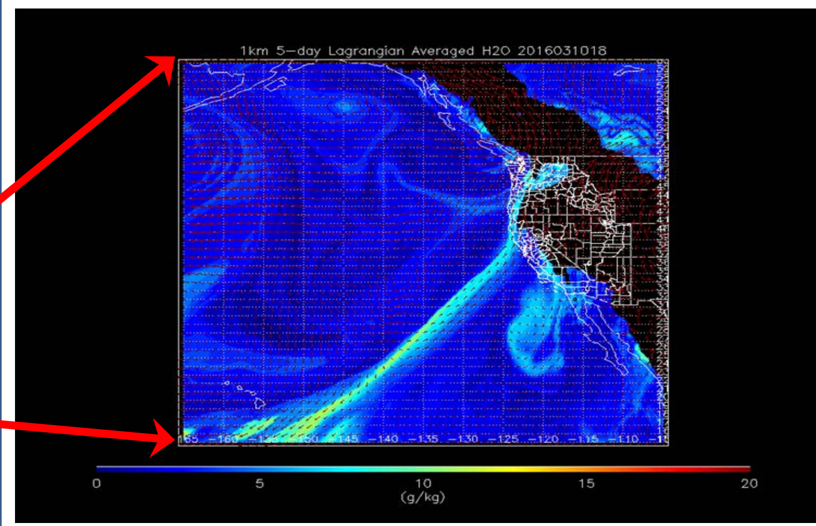
A preview of a recent scientific analysis

- Lagrangian analysis of NUCAPS water vapor (and CO) and can add unique insight into the moisture and pollution transport
- Complements *in-situ* data.

NUCAPS products show moisture in a “Eulerian” frame of reference



Reverse domain filling (RDF) uses modeled transport in “Lagrangian” reference frame to understand origin of moisture at high spatial resolution



RDF analysis of RAQMS courtesy of Brad Pierce, NOAA/STAR

Use of NUCAPS in NWP applications

A number of funded initiatives with a NWS modeling focus

- Much of the NUCAPS retrieval skill comes from use of cloud cleared radiances (CCRs)
  - Jun Li (CIMSS) is doing a study of using NUCAPS CCRs
    - Hindsight analysis of H. Sandy (2012) and Typhoon Haiyan (2013)
  - John LeMarshall (Bureau of Met., Australia) also doing a study with JCSDA of impact of NUCAPS CCRs
  - Andrew Collard (NCEP) looking at using our algorithm directly (compute CCRs from CrIS radiances using model background)
- Emily Berndt (SPoRT) investigation of NUCAPS T(p), q(p), and O3(p) to study extratropical transition of hurricanes
  - Migrate AIRS/SEVIRI product to NUCAPS O3 with VIIRS RGB
  - conduct a product demonstration and assessment with the NHC, WPC, OPC forecasters
- Galina Chirokova (CIRA) will investigate use of VIIRS and NUCAPS to improve moisture flux estimates.
  - Detection of dry air intrusions are important for TC forecasting

Summary

- I have not yet crossed "the valley of death"
- I am certainty within the valley
  - Going up I-25 would have been easier!
  - My Jeep tires have big chucks cut out due to traversing the lava beds
  - I am beaten up by the bumpy ride
  - Jeep radiator is hot, gas and drinking water is low
  - Pretty sure I know my way out, but I've got to admit the vultures circling above me are of concern

THANK YOU!

QUESTIONS?

Acronyms

- AIRS = Atmospheric Infrared Sounder
- AMSU = Advanced Microwave Sounding Unit
- AR = Atmospheric River
- ATMS = Advanced Technology Microwave Sounder
- AVHRR = Advanced Very High Resolution Radiometer
- AWIPS = Advanced Weather Interactive Processing System
- AWT = Aviation Weather Testbed
- CCR = Cloud Cleared Radiances
- CIRA = Cooperative Institiute for Research in the Atmosphere
- CrIS = Cross-track Infrared Sounder
- CIMMS = Cooperative Institute for Mesoscale Meteorological Studies
- CIMSS = Cooperative Institute for Meteorological Satellite Studies
- CSPP = (CIMSS) Community Satellite Processing Package
- CWA = (NWS) County Warning Area
- CWSU = (FAA) Center Weather Service Unit
- EUMETSAT = EUropean organization for exploitation of METeorological SATellites
- FOV/FOR = Field Of View/Regard
- GFS = (NCEP) Global Forecast System
- GSFC = (NASA) Goddard Space Flight Center
- HMT = Hydrometeorology Testbed
- HSB = Humidity Sounder Brazil
- HWT = Hazardous Weather Testbed
- IASI = Infrared Atmospheric Sounding Interferometer
- JPSS = Joint Polar Satellite System
- METOP = METeorological Observing Platform
- MHS = Microwave Humidity Sensor
- MODIS = MODerate resolution Imaging Spectroradiometer
- NASA = National Aeronautics and Space Administration
- NCEP = National Centers for Environmental Prediction
- NESDIS = National Environmental Satellite, Data, and Information Service
- NHC = (NCEP) National Hurricane Center
- NOAA = National Oceanographic and Atmospheric Administration
- NPP = National Polar-orbiting Partnership
- NWP = Numerical Weather Prediction
- NWS = National Weather Service
- NUCAPS = NOAA Unique CrIS/ATMS Processing System
- OPC = (NCEP) Ocean Prediction Center
- OSPO = (NESDIS) Office of Satellite and Product Operations
- SOO = Science Operations Officer
- SPC = (NCEP) Storm Prediction Center
- SPoRT = (NASA) Short-term Prediction and Research Transition Center
- STAR = (NESDIS) SaTellite Applications and Research
- STC = Science and Technology Corporation
- UMBC = University of Maryland, Baltimore County
- VIIRS = Visible Infrared Imaging Radiometer Suite
- WFO = (NWS) Weather Forecast Office
- WPC = (NCEP) Weather Prediction Center

For each flight day we provide 3 files on the ENRR campaign google drive

- Each fight day, given by yymmdd, there will be 3 file files
- File = yymmddnpp_am_vs_gfs.pdf contains my analysis of the NPP satellite "am" soundings processed from direct broadcast data
  - "am" overpasses are ~11 to 12 UT over Hawaii region.
  - I am routinely providing this file within ~1 hour of satellite overpass
  - Files contain maps, cross-section plots, and skew-T's at positions along planned dropsonde locations
  - These can be used for pre-flight guidance.
- File = yymmddnpp_pm_vs_gfs.pdf is similar the the "am" file but contains the "pm" overpasses
  - "pm" overpasses are ~23 UT to ~01 UT, again ~1 hour latency
  - These could potentially be used for in-flight corrections to dropsonde locations; however, Hawaii antenna does not fetch data far enough southward
  - Since dropsondes are not available, they are not included in this file
- File = yymmddnpp_pm_vs_g4dropsondes.pdf contains the full satellite coverage for the flight day and comparisons to the G-IV dropsondes.
  - I am using archive data which has a latency of 1 to 2 days, thus this is a hindsight product
  - Can be used for post-flight validation of dropsondes an GFS
  - These are measurements and never will never be included in the forecast or re-analysis (of any NWP center, because we are retrieving in cloudy conditions and models assimilate only clear radiance)
  - **Therefore, these can supplement your in-situ measurements**

Access to the Satellite Data

- The yymmddnpp_pm_vs_g4dropsondes.pdf file gives you an idea of what is satellite data is available over campaign doman
  - NOTE: we globally have 324,000 soundings per day, so I am still limiting the retrievals to a box in the Pacific
  - I could also process non-flight days, if that is useful.
- Our archived satellite files are a packed binary format (1 file for 8 minutes or ~2000 km x 2000km containing 1800 soundings);
  - In the past I converted these to ASCII
    - I strip out exactly the measurements you want
  - For example, Nathalie Gaggini (ESRL/PSD) received some files for her AGU presentation last December with just T(p) and q(p) for the troposphere within 200 km radius of R.H. Brown
  - If you have an ftp site where I could push data to we could do something similar.
    - I would need to know more about what data you want (what products, lat/long range, etc) so I don't overwhelm you with a bunch of stuff you don't want.
    - We can also do other data formats

How GFS in interpolated

- We use the satellite observing time to select 2 GFS files. Here are the pairs used

Table 3.3: AVN truth table

	0z	3z	6z	9z	12z	15z	18z	21z
index	0	1	2	3	4	5	6	7
anal #1	18z	00z	00z	06z	06z	12z	12z	18z
fcst #1	F06	F03	F06	F03	F06	F03	F06	F03
anal #2	18z	00z	00z	06z	06z	12z	12z	18z
fcst #2	F09	F06	F09	F06	F09	F06	F09	F06

- For example, at 23:30 UT we would use the 3 and 6 hour forecast from the 18z analysis.
  - The next orbit to the west at 1:00 UT would use the 6 and 9 hour forecast from the 18z analsis
  - Both of these would be shown on my maps

Our Skew-T plots

- We do our best to emulate traditional skew-T's but we needed to modify the figures because
  - Need to embed it into our satellite processing system
  - Our sounders do not measure wind speed or direction so we cannot include that information
  - We derive cloud top pressure and infrared cloud fraction (derived at 15 microns)
  - We can also derive CAPE, Lifting Index and other stability indices, but these are not currently shown on the plot.
- We want to display dropsonde at both full vertical sampling and also at the same sampling as our retrievals (~50 levels from 100 to 1000 hPa)
  - A thin grey line shows the full vertical sampling, thick black line is smoothed sampling
  - Sonde label shows sonde # (same as on map), sonde date and time, average latitude, longitude of the sonde
- We want to inter-compare dropsonde, GFS, and our accepted retrievals
  - Label shows spatial and temporal displacement from the sonde
  - Accepted retrievals (label="ACC") are spatially displaced from the dropsonde and might also be different locations for the microwave (MW) and infrared (IR+MW) retrievals
    - Displacement in time and space is shown in parenthesis
  - Sometimes there will be 2 GFS soundings shown – one for the MW-only and one for the IR+MW, if the locations are different
    - We use the pair of GFS profiles to estimate how much of the difference between MW-only and IR+MW retrievals is due to spatial differences

Annotated example of our skew-T plot

Grey line: full vertical sampled dropsonde

Black line: smoothed dropsonde

Magenta line: GFS at MW-only retrieval location and time

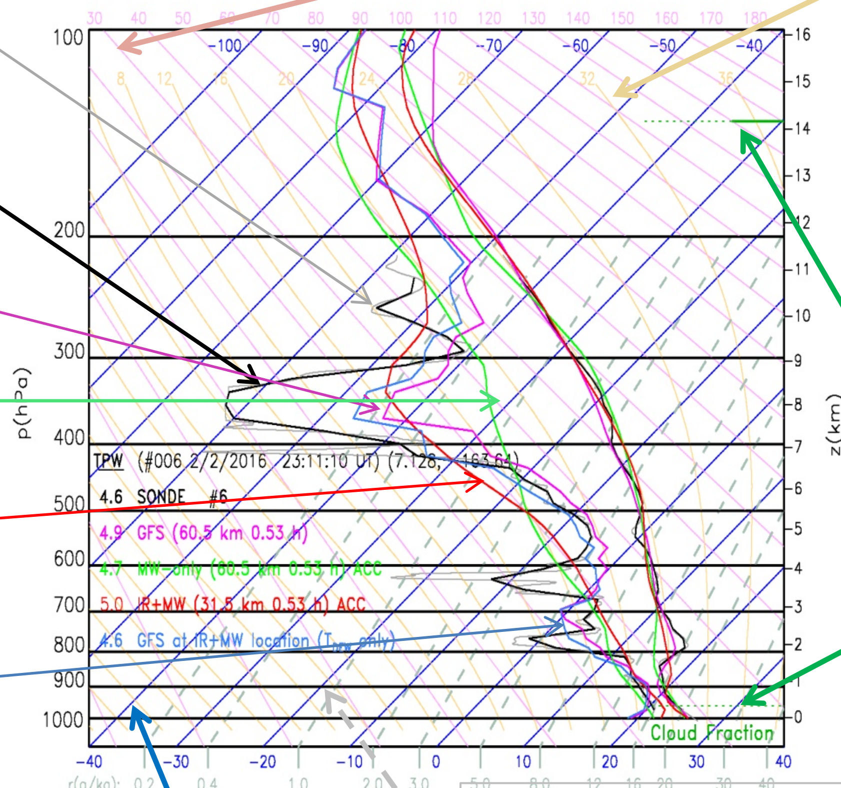
Green line: MW-only retrieval

Red line: IR+MW retrieval

Cyan line: GFS at IR+MW retrieval location if it is different than MW-only location

Dry adiabats ($T_0(\rho/\rho_0)^\kappa$, are shown as faint solid magenta for T_0 = 30 to 180 C (10 C steps)

Moist adiabats are shown in faint solid gold lines for T_0 = 8 to 36 C, 4 C steps



We show green line(s) at the cloud top pressure where the ratio of the solid to dashed lines is the cloud fraction over our 50 km footprint.

In this scene we identified 2 cloud layers:

Top cloud layer is at ~130 hPa (14.1 km) with ~40% cloud cover

Lower cloud layer is at 970 hPa (0.4 km) with negligible cover

Isotherms are in solid blue in degC

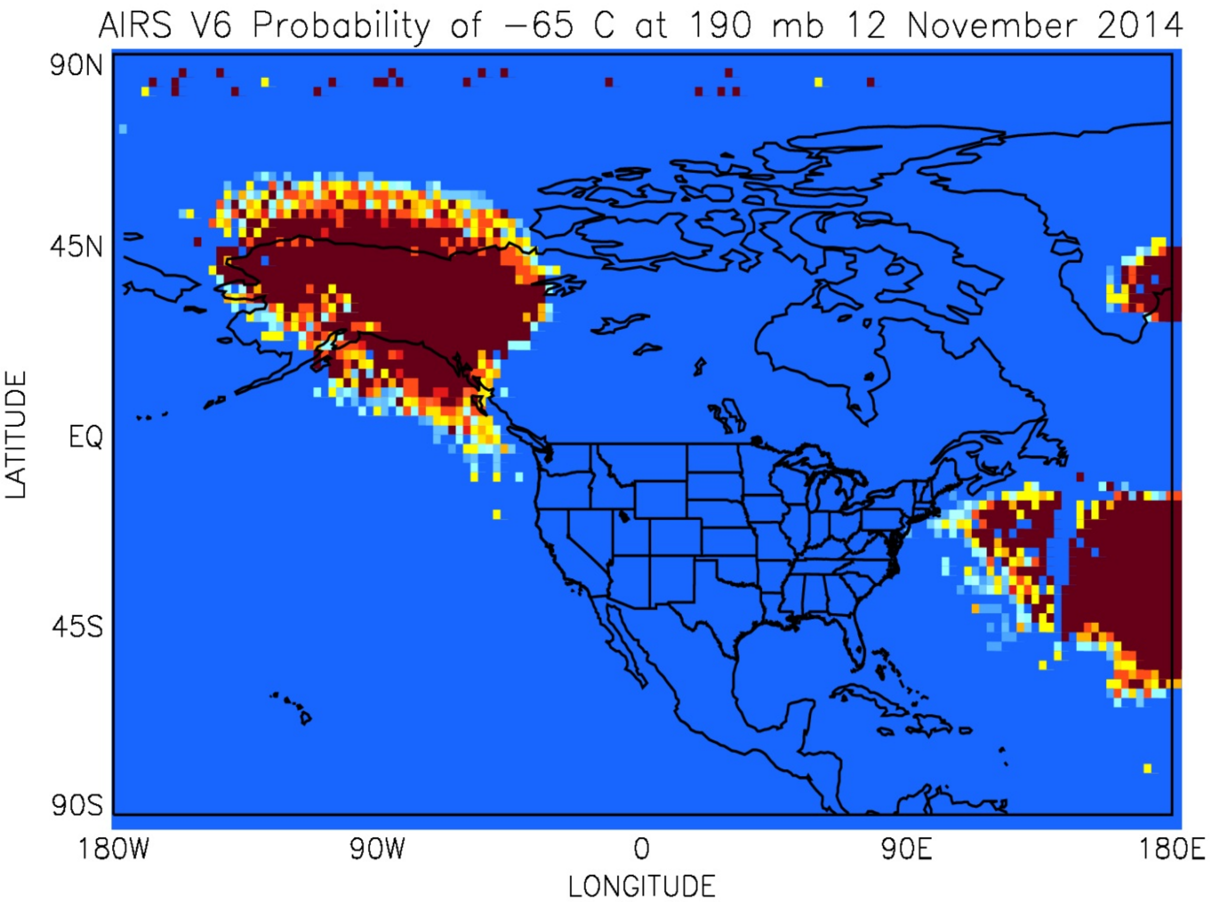
Temperature of saturation shown for saturation mixing ratios (0.2 to 40 g/kg) are in faint blue/purple dashed lines

Daily Cold Air Loft frequency of occurrence (single frame)

Used AIRS Level.2 Support Product

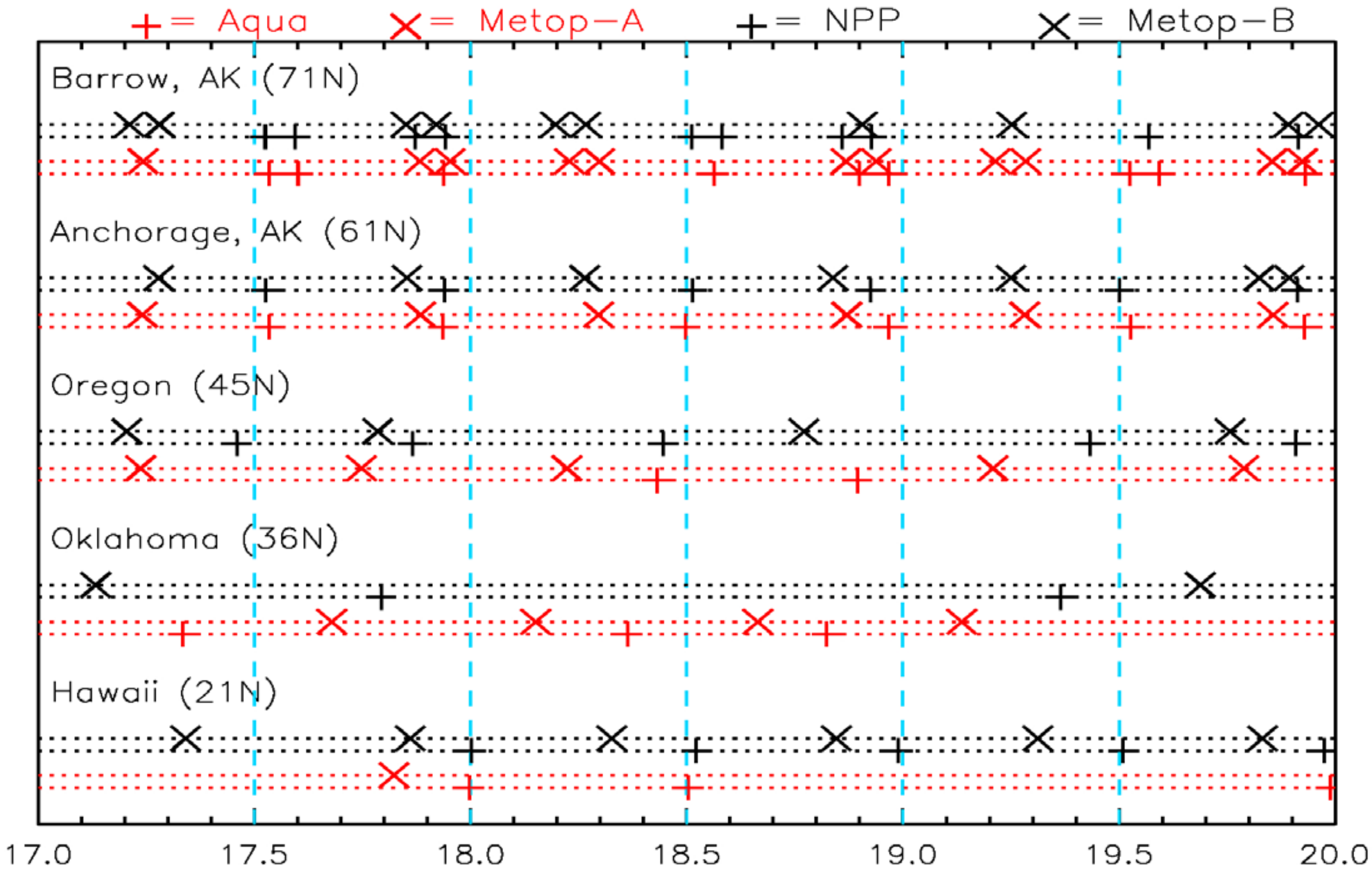
Counted occurrences of T(190mb) $\leq$ -65 degC in a 1x1 deg grid

Anchorage Center Weather Service Unit (CWSU) issues warnings on Nov. 11th to 14th



Analysis and graphics by C. Francoeur, STC

Constellation of satellites allows more observations between RAOBS



Day of June, 2015

NPP/J-1 will be phased similar to Metop-A/B approx. 6 months after launch of J-1

If we included NOAA AMSU/HIRS there would be even more soundings

These are overpasses with satellite elevation > 45 deg (FOR 4-27)

NUCAPS Results from HWT 2016 GOES-R/JPSS Spring Experiment

Bill Line

Research Associate/Satellite Liaison

University of Oklahoma/CIMMS

NOAA/NWS/Storm Prediction Center

Kristin Calhoun, Darrel Kingfield, Tiffany Meyer (CIMMS/NSSL), Gabe Garfield (CIMMS/OUN), John Mecikalski and Chris Jewett (UAH), Justin Sieglaff, John Cintineo, and Jun Li (CIMSS), Geoffrey Stano (SPoRT), Bob Rabin, Dan Lindsey, Mike Pavolonis, Tim Schmit, and Steve Goodman (NOAA/NESDIS), Chris Barnet and Antonia Gambacorta (STC), Mitch Goldberg (NOAA/NESDIS)

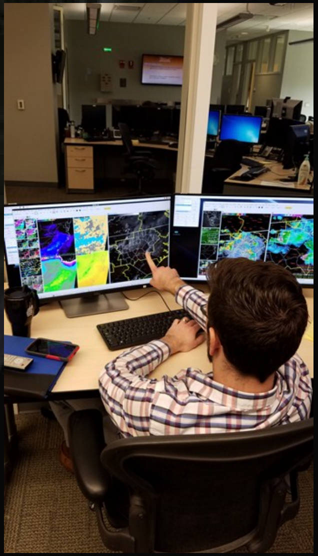
GOES-R and JPSS in the Hazardous Weather Testbed

HWT in Norman, OK

- Product developers observe their recently developed GOES-R and JPSS algorithms being used alongside standard observational and forecast products in a simulated operational forecast and warning environment (Research to Operations, **R2O**)
- Feedback received from participants leads to the continued modification and development of GOES-R and JPSS algorithms (Operations to Research, **O2R**)
- Education and training received by participants helps to enhance **readiness** for the use of GOES-R and JPSS data

HWT 2016 GOES-R/JPSS Spring Experiment

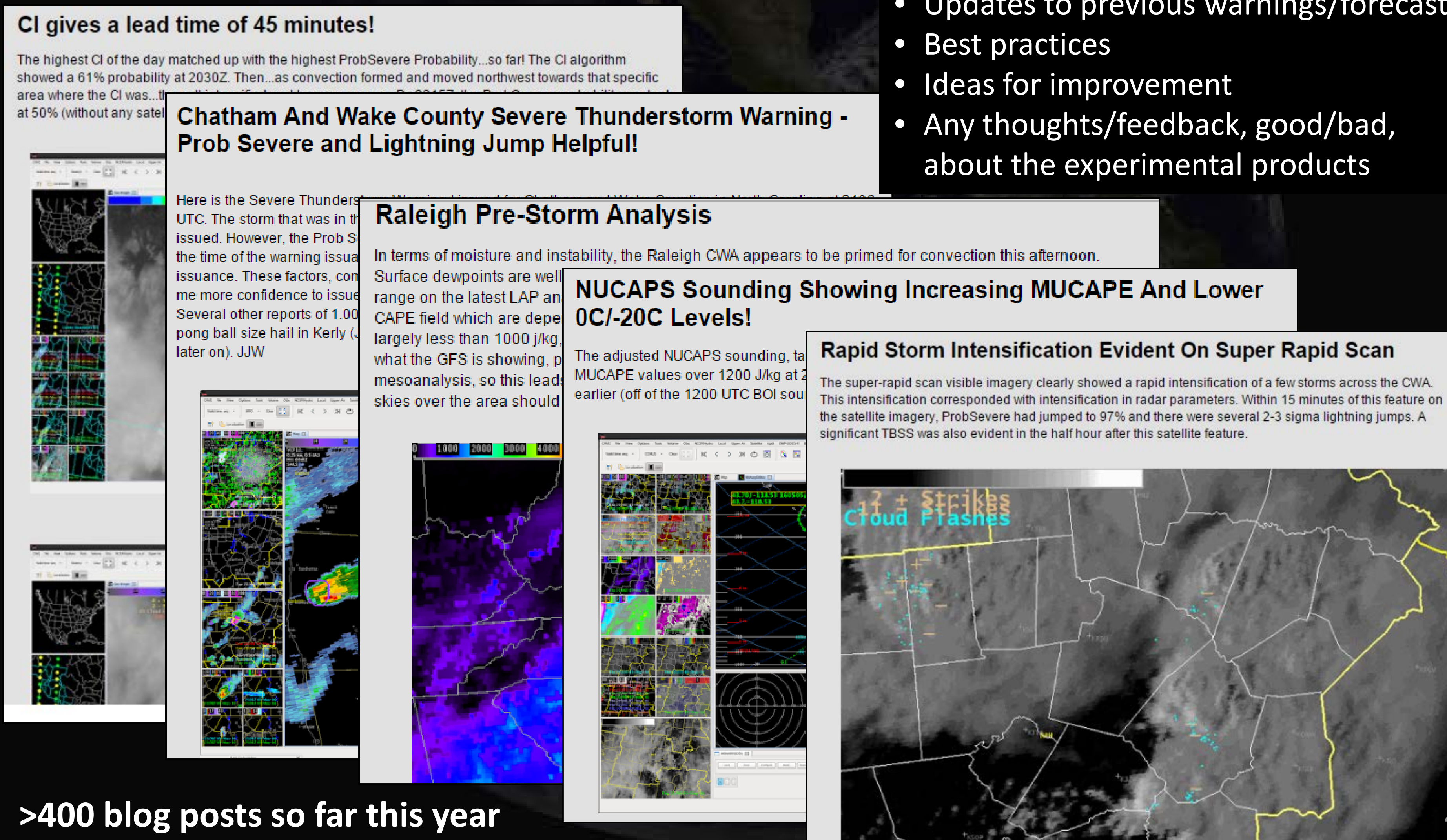
- 4 weeks (18 April, 25 April, 2 May, 9 May)
  - 3 NWS forecasters, 1 broadcast meteorologist per week
  - Mon-Thurs, 8 hr forecast shifts. Friday half day debreif
- Real-time, simulated nowcast/warning environment using AWIPS-II.
  - Can operate anywhere in CONUS; begin prior to CI
  - “mesoscale forecast updates” (via live blog posts)
  - experimental severe t-storm and tornado warnings (via WarnGen).
- Evaluating: GOES-R and JPSS Baseline, Future Capabilities, and Experimental Products
- Training: 2 hours of Articulates
- Feedback: Daily and weekly debriefs, daily and weekly surveys, **blog posts**, discussions, Webinar
- We want forecasters to think about how they are using the experimental products in nowcast and warning decision making.



GOES-R/JPSS HWT Blog

http://goesrhwt.blogspot.com/search/label/NUCAPS

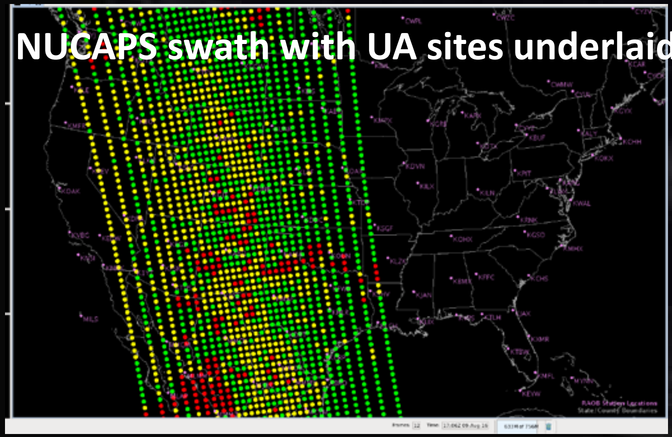
- Mesoscale forecast updates
- Reasoning behind warning decisions
- Updates to previous warnings/forecasts
- Best practices
- Ideas for improvement
- Any thoughts/feedback, good/bad, about the experimental products

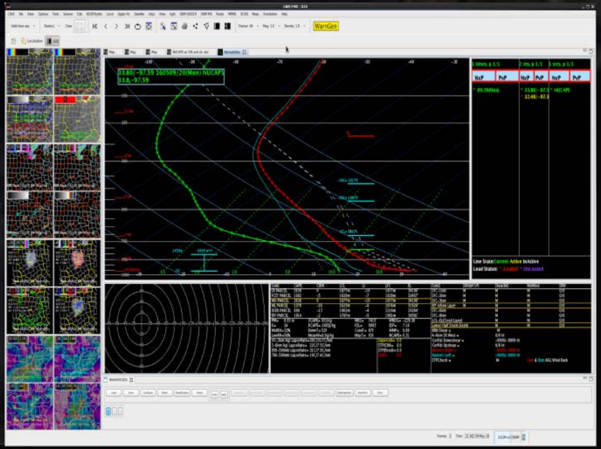


>400 blog posts so far this year

NOAA Unique Combined Atmospheric Processing System (NUCAPS)

- NUCAPS combines both statistical and physical retrieval methods to generate temperature and moisture profiles using information from the CrIS and ATMS instruments aboard Suomi-NPP.
- NUCAPS in AWIPS-II currently:
  - Suomi-NPP only
    - NUCAPS Profile Availability (Time/Location) with quality control flags
    - NUCAPS Vertical Temperature and Moisture Profiles
- Early afternoon timing of Suomi NUCAPS gives it exceptional potential value for convective forecasting.
  - Usually just prior to convective initiation
  - Temporally: Available between morning 1200 UTC and evening 0000 UTC radiosondes
  - Spatially: High density - fills gaps between radiosonde sites





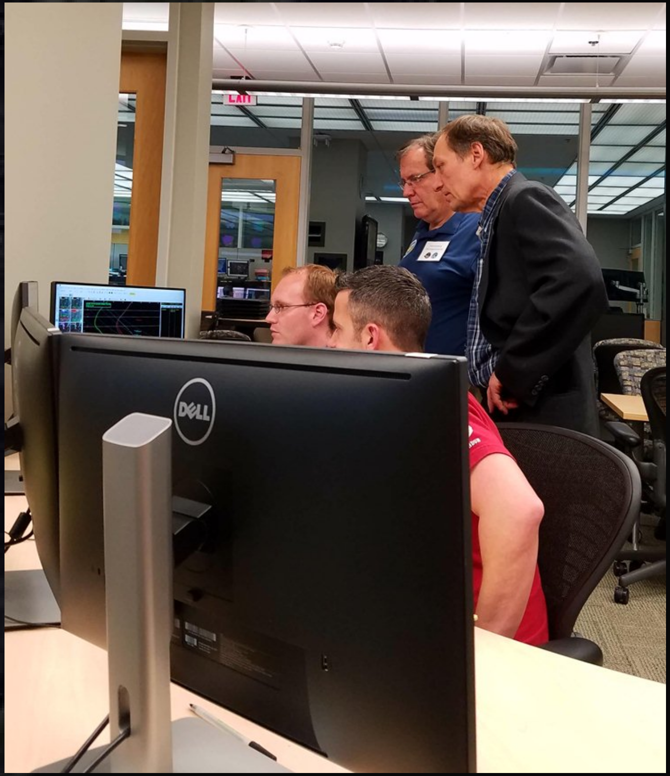
Why NUCAPS in HWT?

- Does NUCAPS provide useful and unique information, particularly for convective forecasting?
- What can be done to make NUCAPS more useful?
- HWT allows for the testing of NUCAPS by operational forecasters in real-time operational test environment

NUCAPS Evaluations in HWT

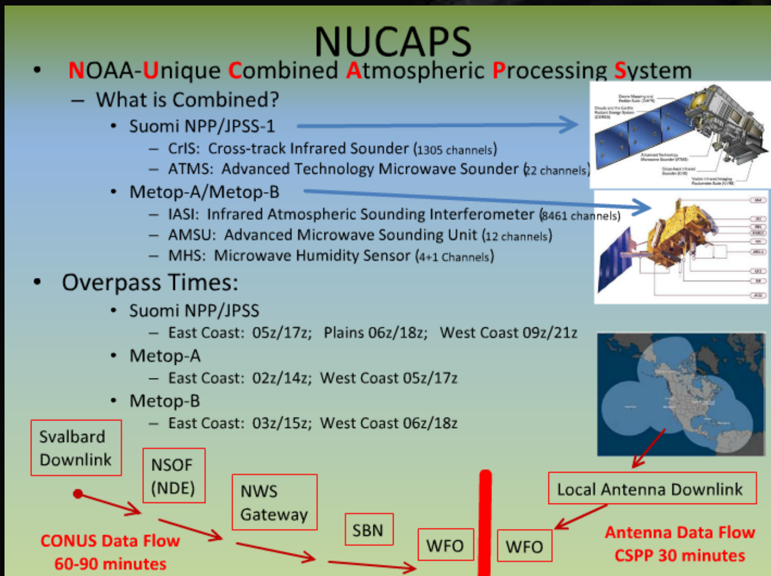
- 2015 NUCAPS Evaluation in HWT
  - First evaluation of NUCAPS
    - Only the temperature and moisture profiles and the profile availability
  - Final Report

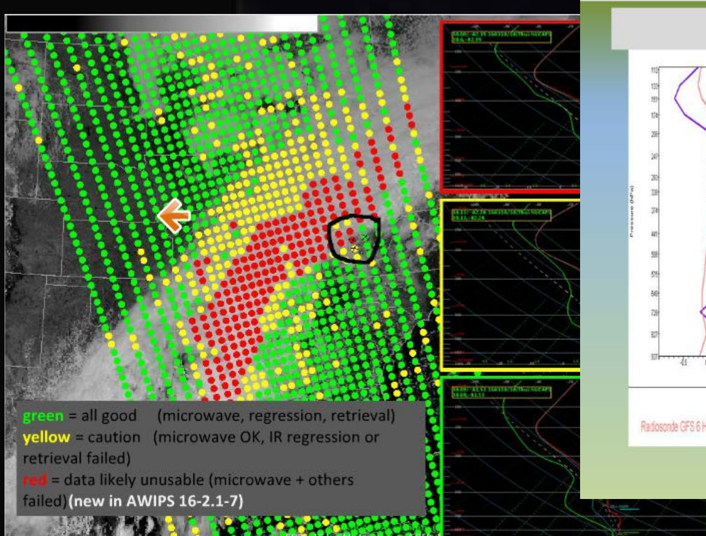
- New for 2016 Evaluation in HWT
  - QC Flags
  - MetOp A/B (Week 4 only)
  - Plan View Display
  - Cross Sections (Week 4 only)
  - Updated Training

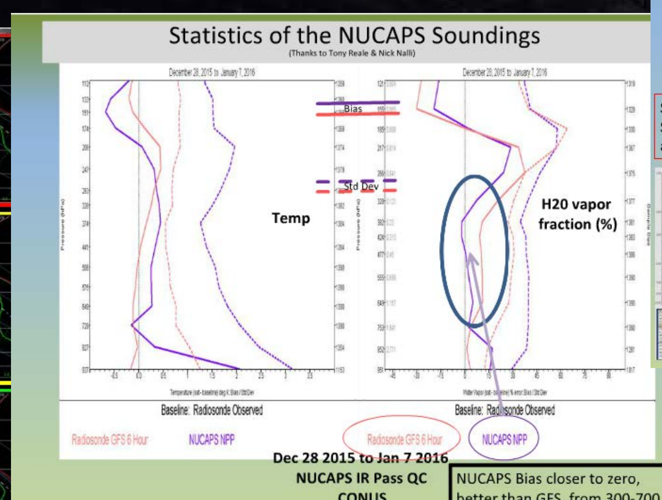


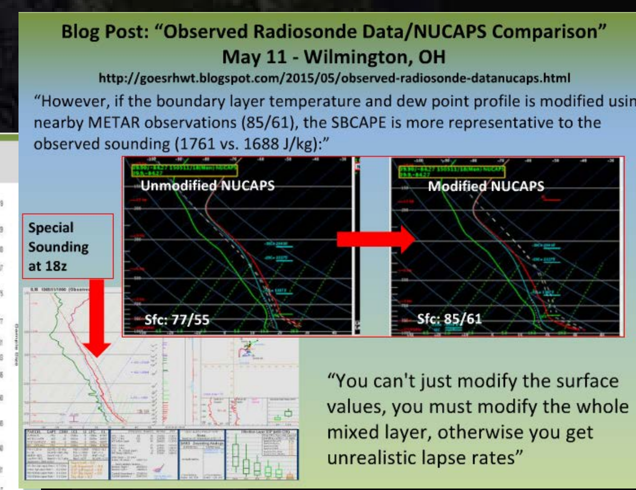
NUCAPS Training

- 15.5 min Articulate PowerPoint
  - Completed prior to arrival in Norman
  - Updates for 2016 Training
    - QC Flags
    - MetOp A/B
    - Verification Statistics
    - Operational use examples (from HWT 2015)
    - Method of surface modification
    - Other minor updates



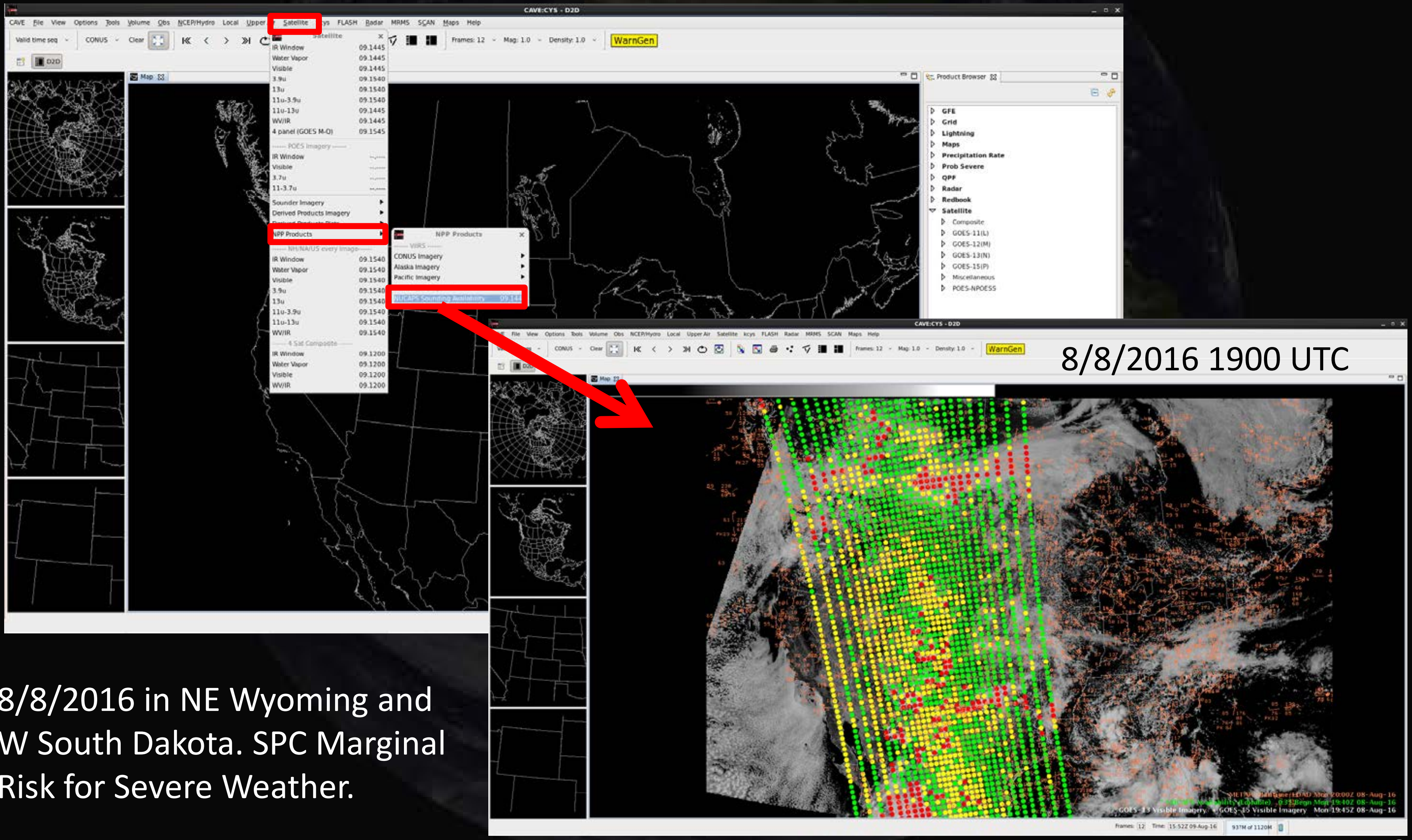






Using NUCAPS in AWIPS-II

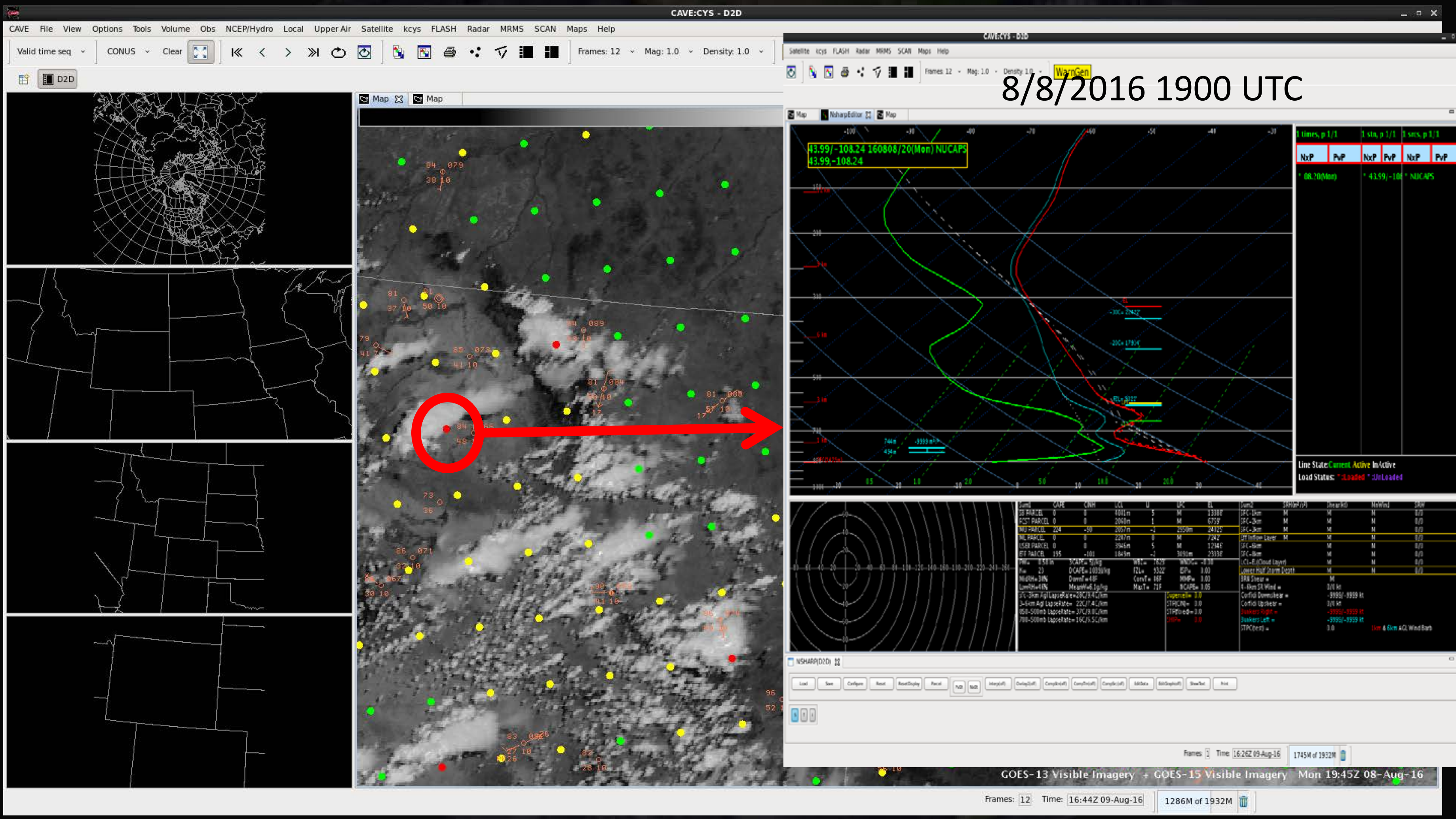
Loading NUCAPS



8/8/2016 in NE Wyoming and W South Dakota. SPC Marginal Risk for Severe Weather.

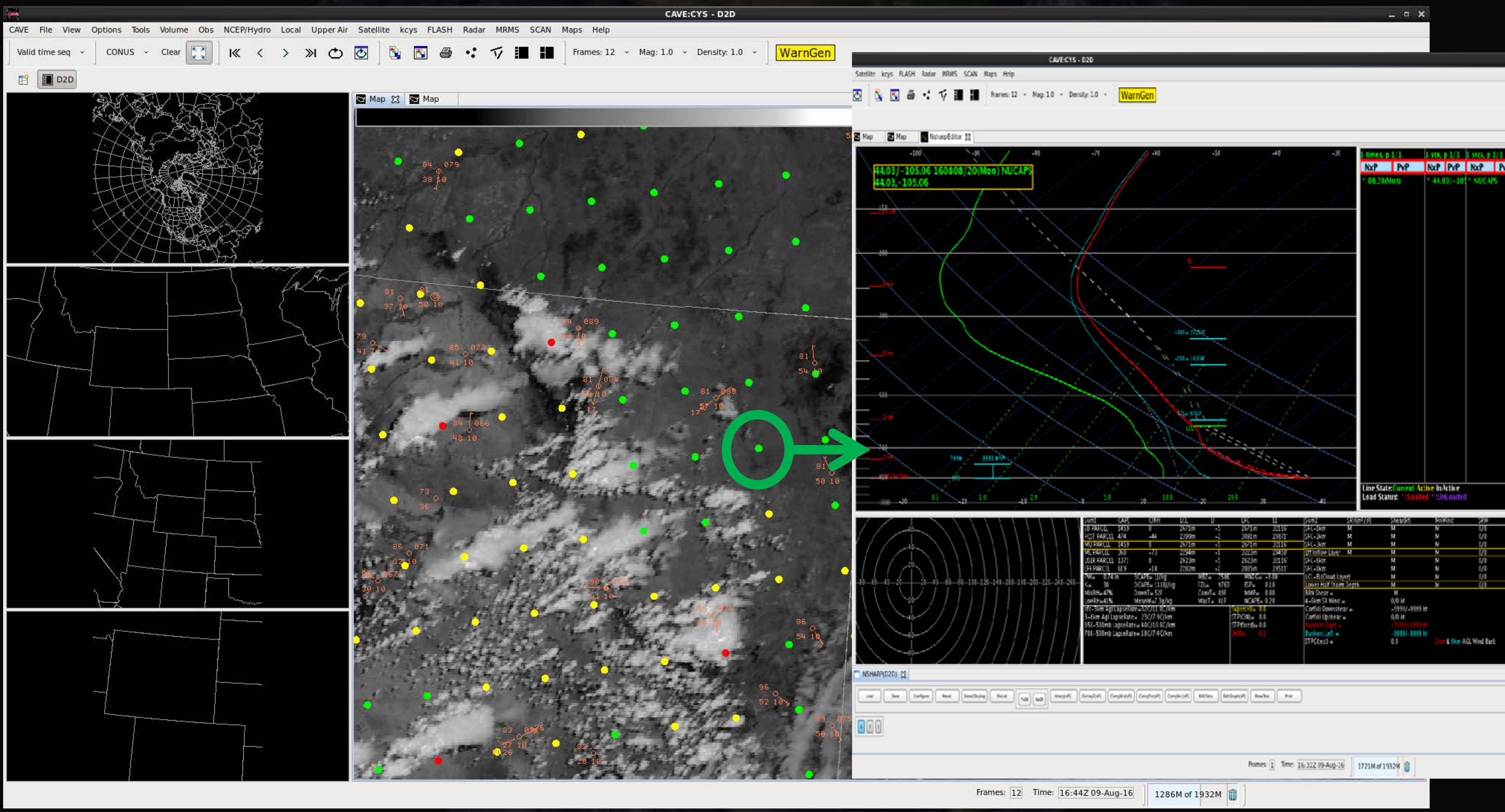
Using NUCAPS in AWIPS-II

Selecting a NUCAPS Profile: Red – Failed QC



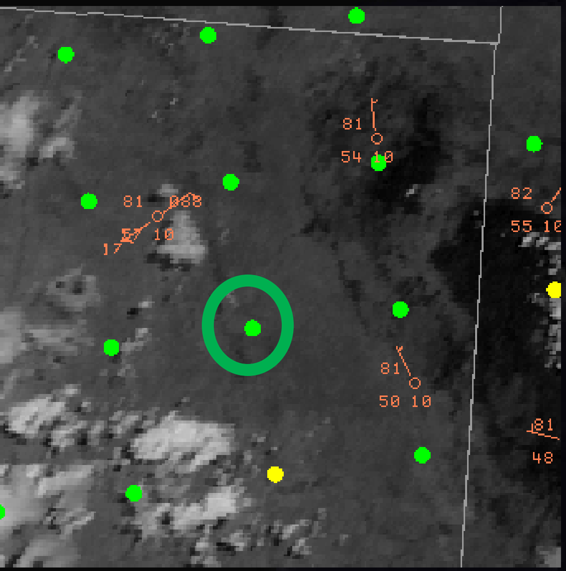
Using NUCAPS in AWIPS-II

Selecting a NUCAPS Profile: Red – Passed QC



Using NUCAPS in AWIPS-II

Modifying NUCAPS Profile - Temp

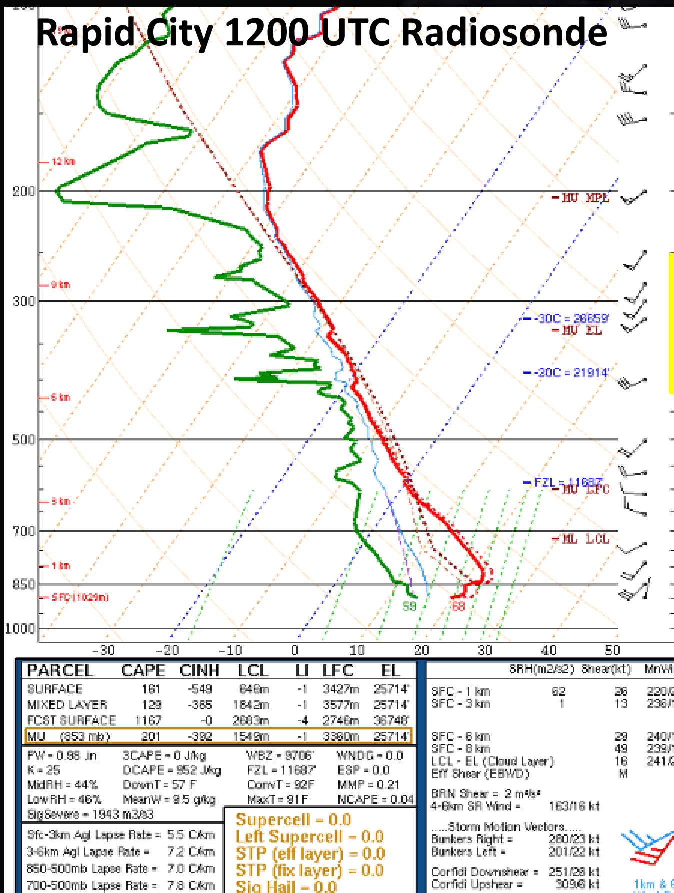


NUCAPS surface temp: 89
METAR surface temp: 81

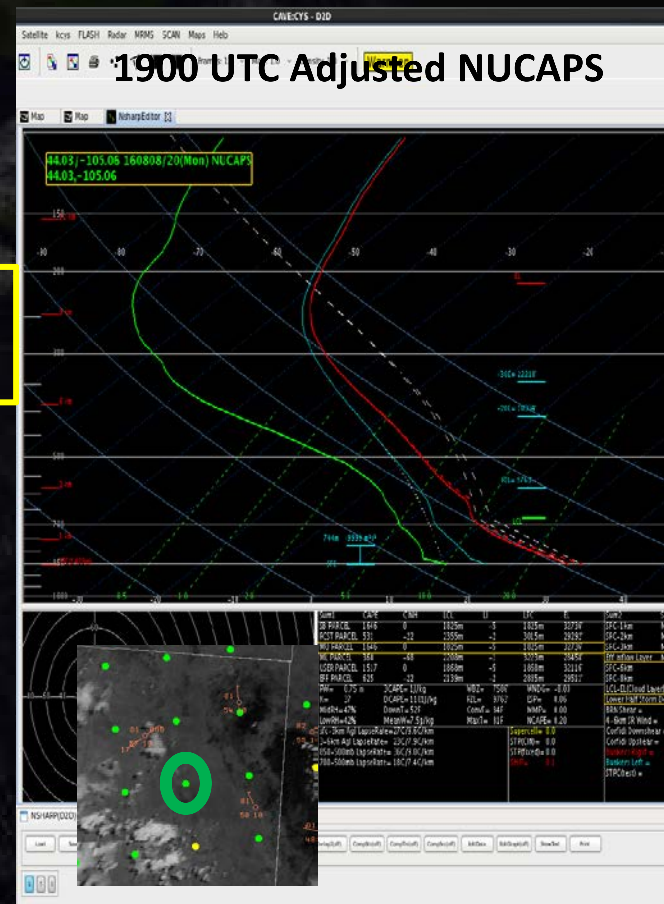
NUCAPS surface dew point: 47
METAR surface dew point: ~53

Using NUCAPS in AWIPS-II

Final adjusted NUCAPS 1900 UTC Profile



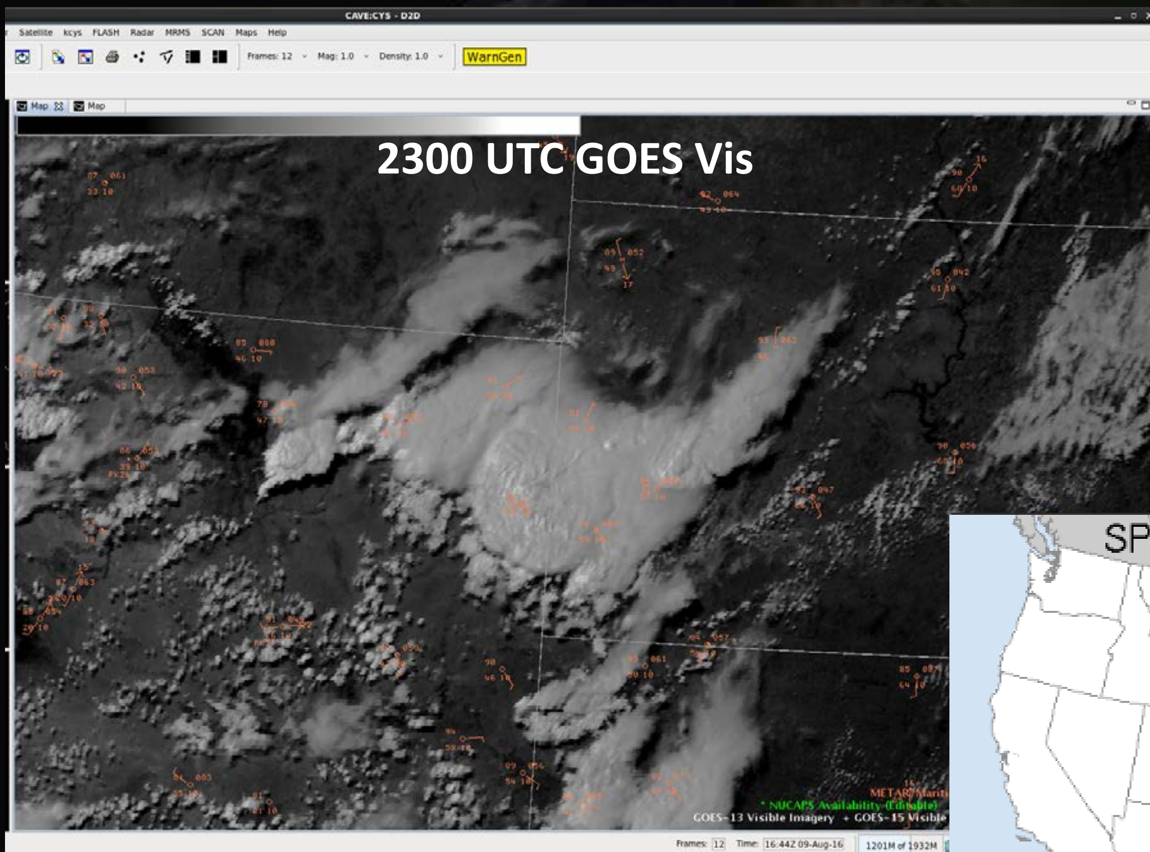
Drying/cooling aloft
Heating surface

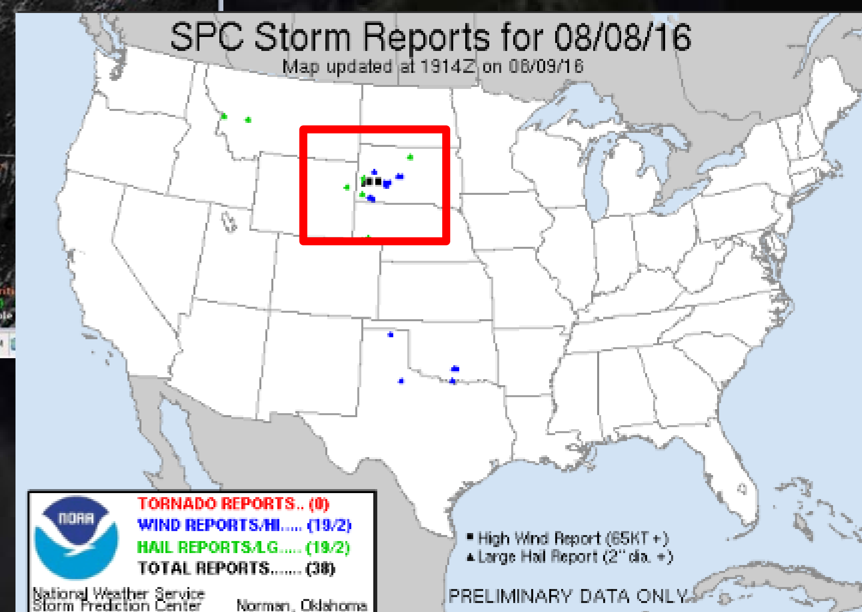


SBCAPE: 161 j/kg
3-6 km LR: 7.2 C/km
FL: 11,700 ft
-20C: 22,000 ft

SBCAPE: 1650 j/kg
3-6 km LR: 7.9 C/km
FL: 9,800 ft
-20C: 19,000 ft

Using NUCAPS in AWIPS-II



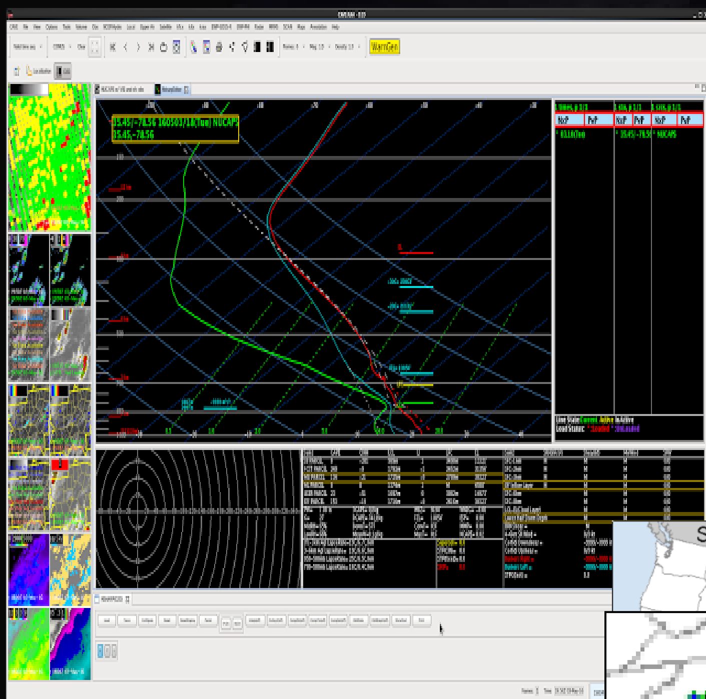


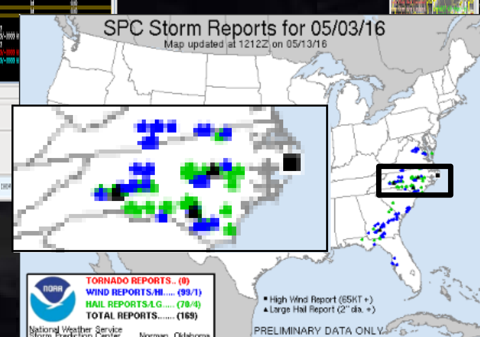
How was NUCAPS used in the HWT?

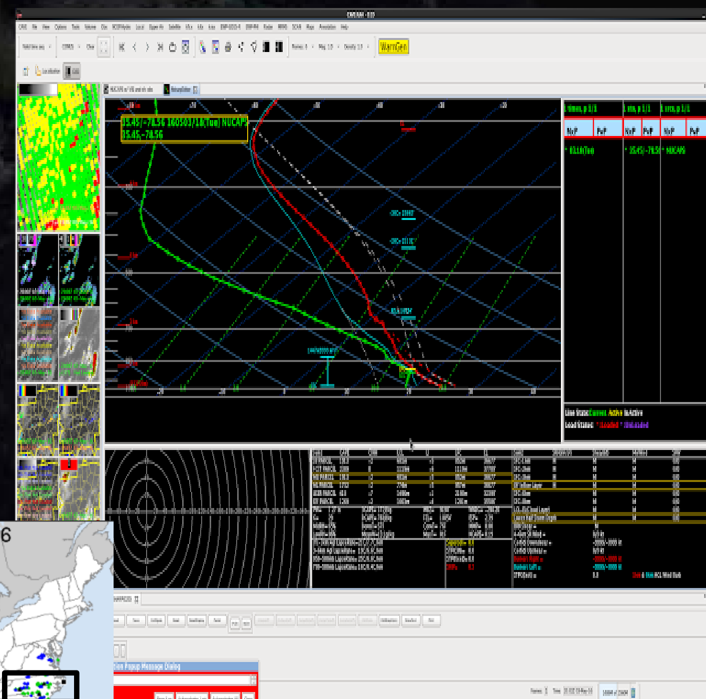
- Assessing the thermodynamic environment…
  - … prior to convective initiation (pre-convective environment)
  - … in the vicinity of ongoing convection
  - … near boundaries
- Comparing with other datasets
  - Water Vapor Imagery
  - Radiosondes
  - NWP

NUCAPS Modification and Severe in North Carolina

- HWT Blog Post: **NUCAPS Sounding Near KJNX Observation 1800 UTC - Adjusting It Is Best For Use By Mesoscale Analyst In Severe Ops.**
- 03 May 2016 – Raleigh, NC







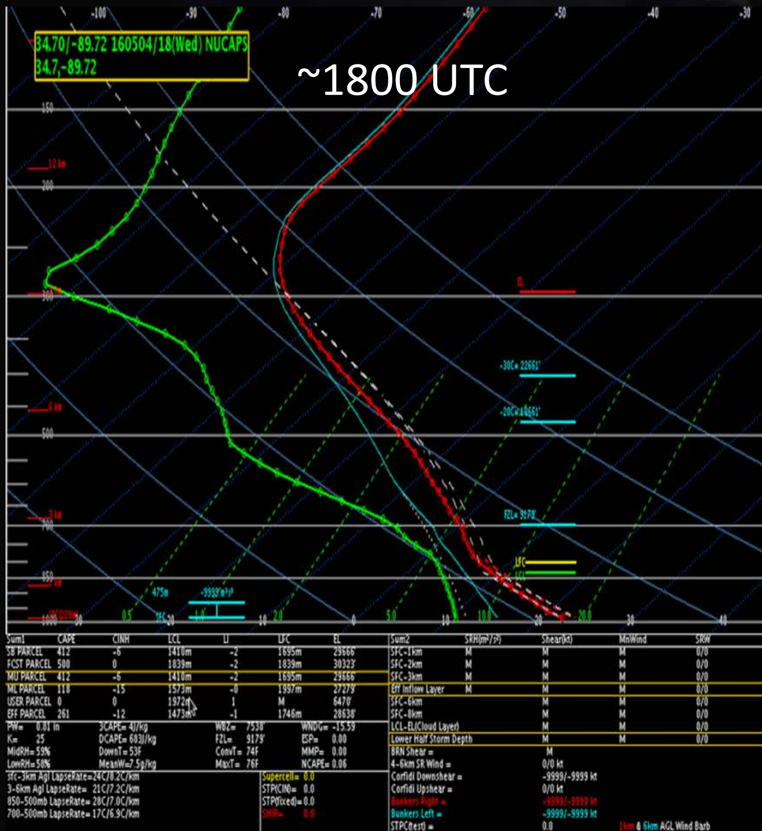
Temp/DP: 70/55
SBCAPE: 0 j/kg

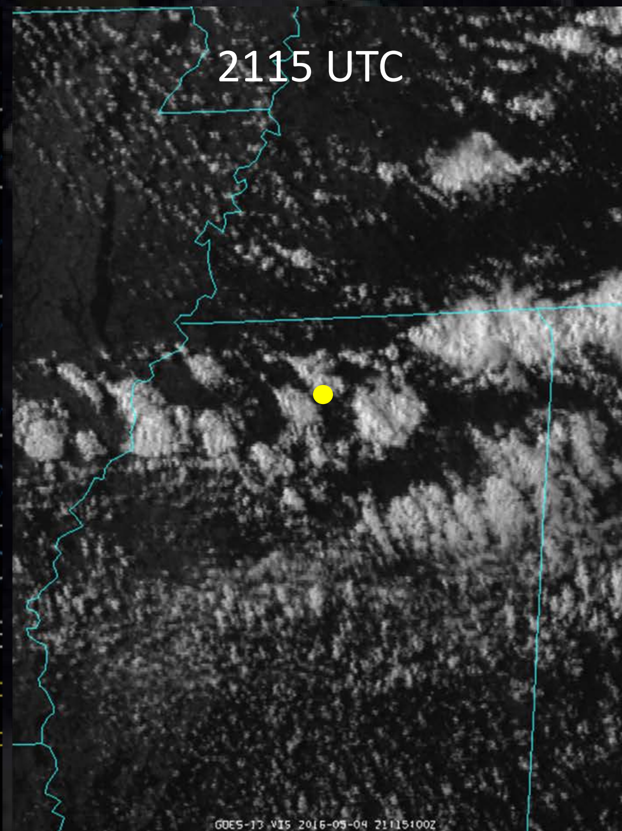
Temp/DP: 75/66
SBCAPE: 1900 j/kg

"It seems that having to adjust the low levels of the NUCAPS sounding would be best handled by the mesoscale forecaster, NOT the warning forecaster. Once you get the hang of adjusting these NUCAPS profiles, they can be useful for near storm environmental monitoring."

Sub-severe in N MS

- HWT Blog Post: **Adjusted NUCAPS Sounding for far north central MS at 1800 UTC - Helpful with estimating CAPE!**
- 05 May 2016 – N MS

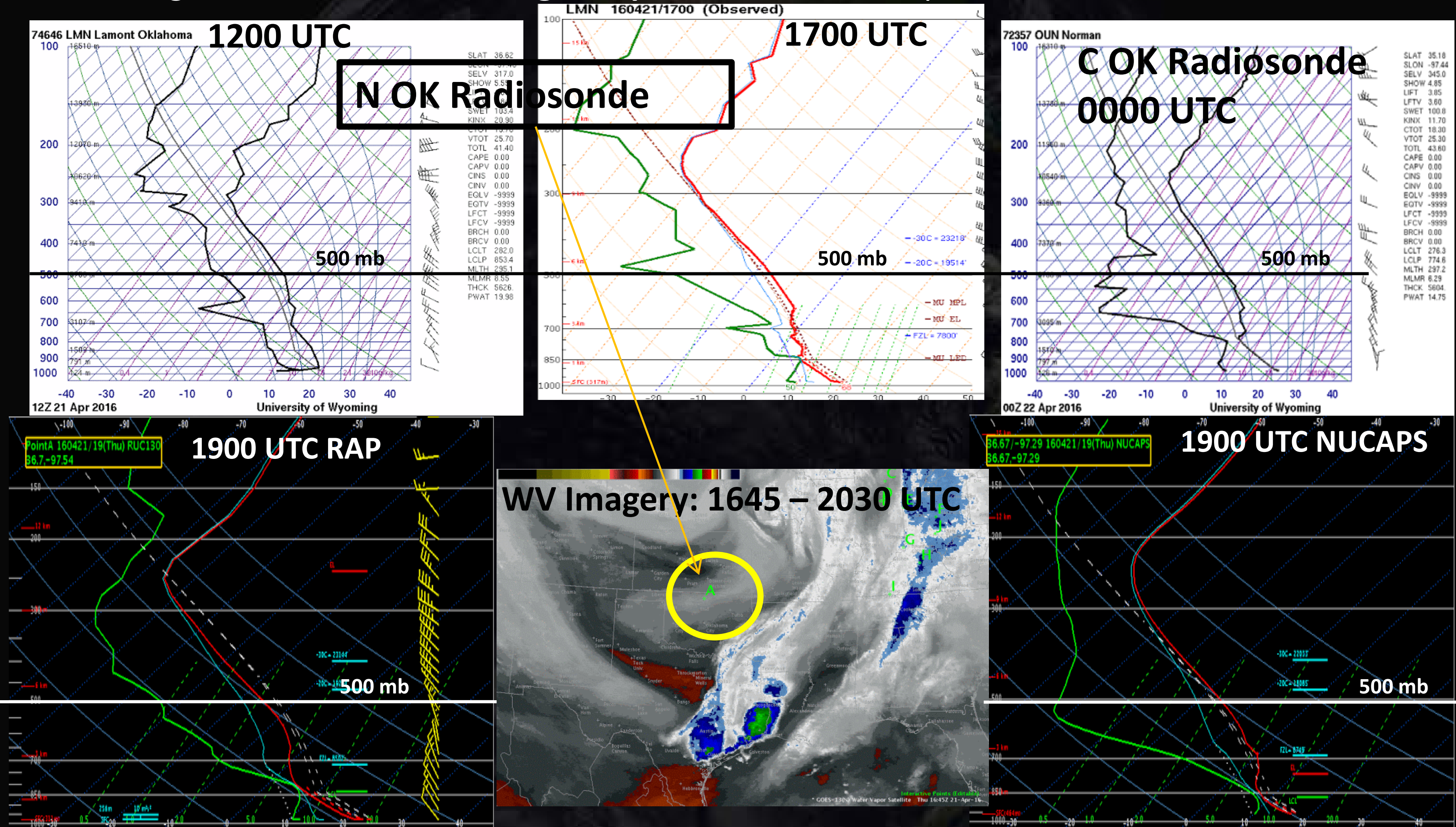




"This would suggest that there is potential for further convective development in this area over the next few hours."

NUCAPS and RAP in Mid-Level Drying

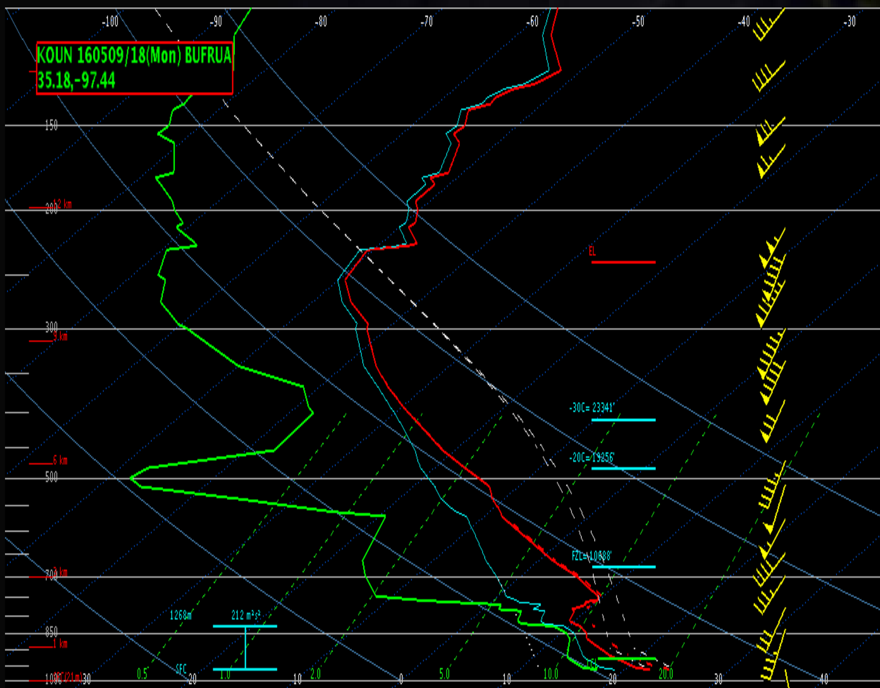
HWT Blog Post: **NUCAPS Sounding Comparison** 21 April 2016 – N OK

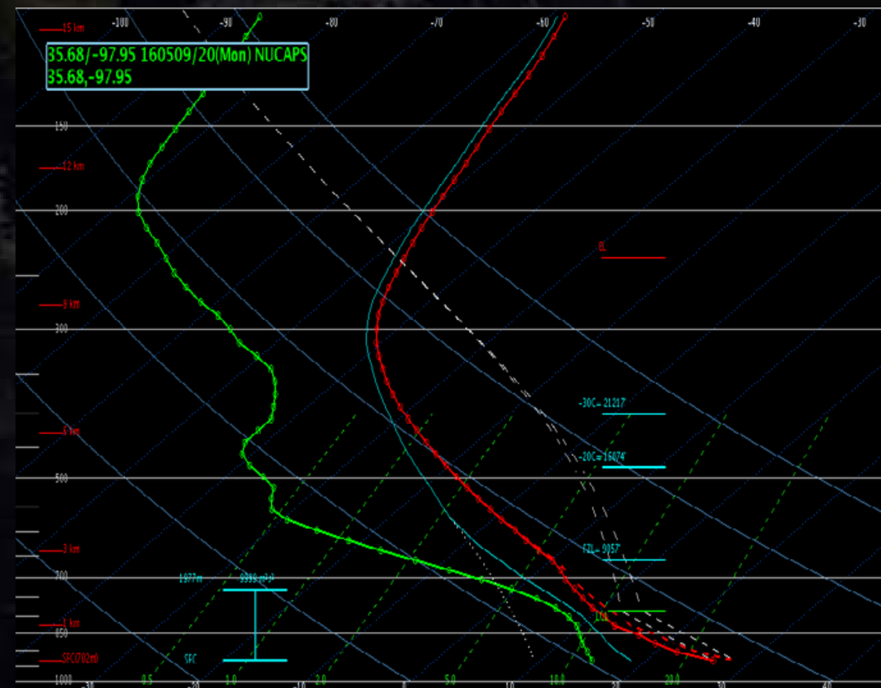


"You can see in the two images that the RAP shows the trend but may not be pronounced enough with the mid-upper dry layer."

NUCAPS Missing Cap

- HWT Blog Post: **NUCAPS Comparison with KOUN Sounding**
- 09 May 2016 – Norman, OK

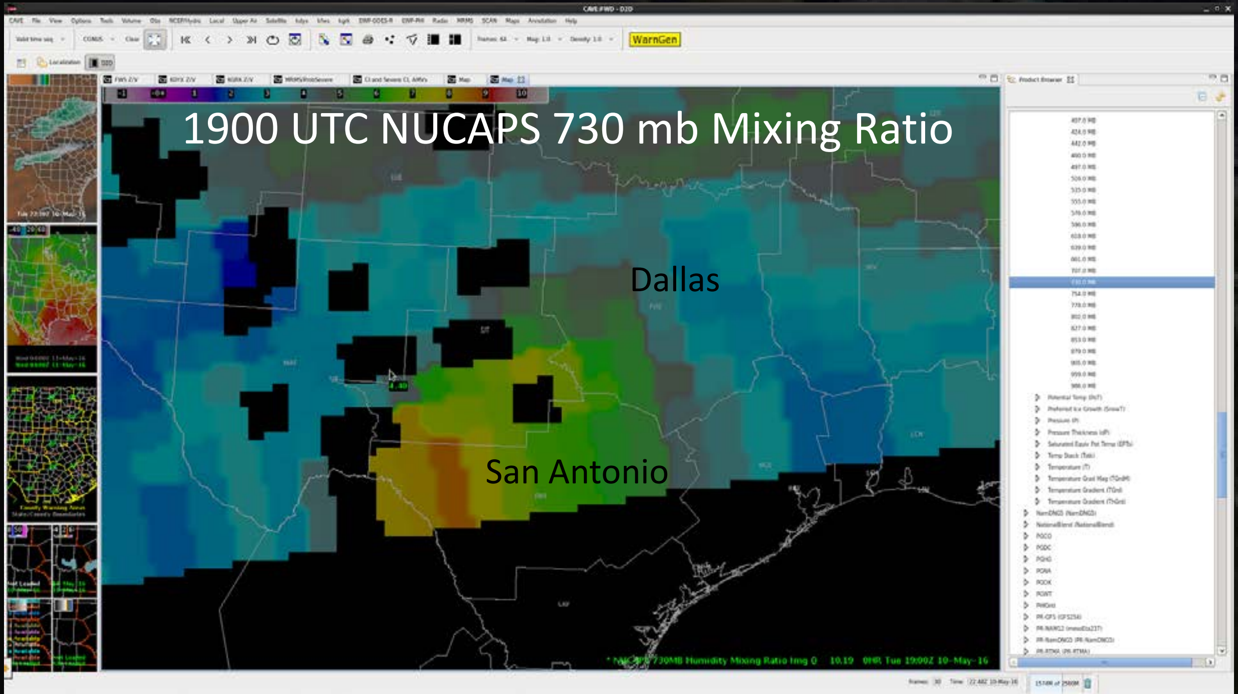




“The smoothed nature of the soundings limits the potential usefulness of the soundings. The inability to see capping inversions and saturated layers is a real drawback.”

NUCAPS Plan View - Moisture

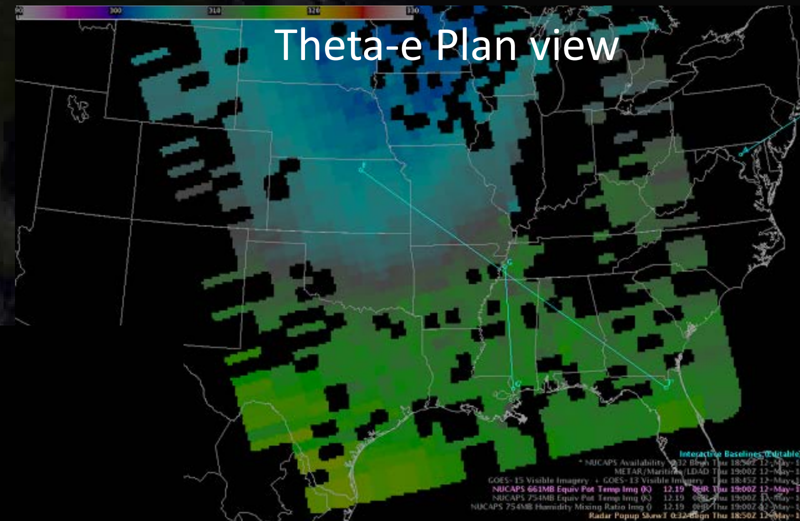
- HWT Blog Post: **NUCAPS Mixing Ratio Plan View**
- 10 May 2016: C Texas

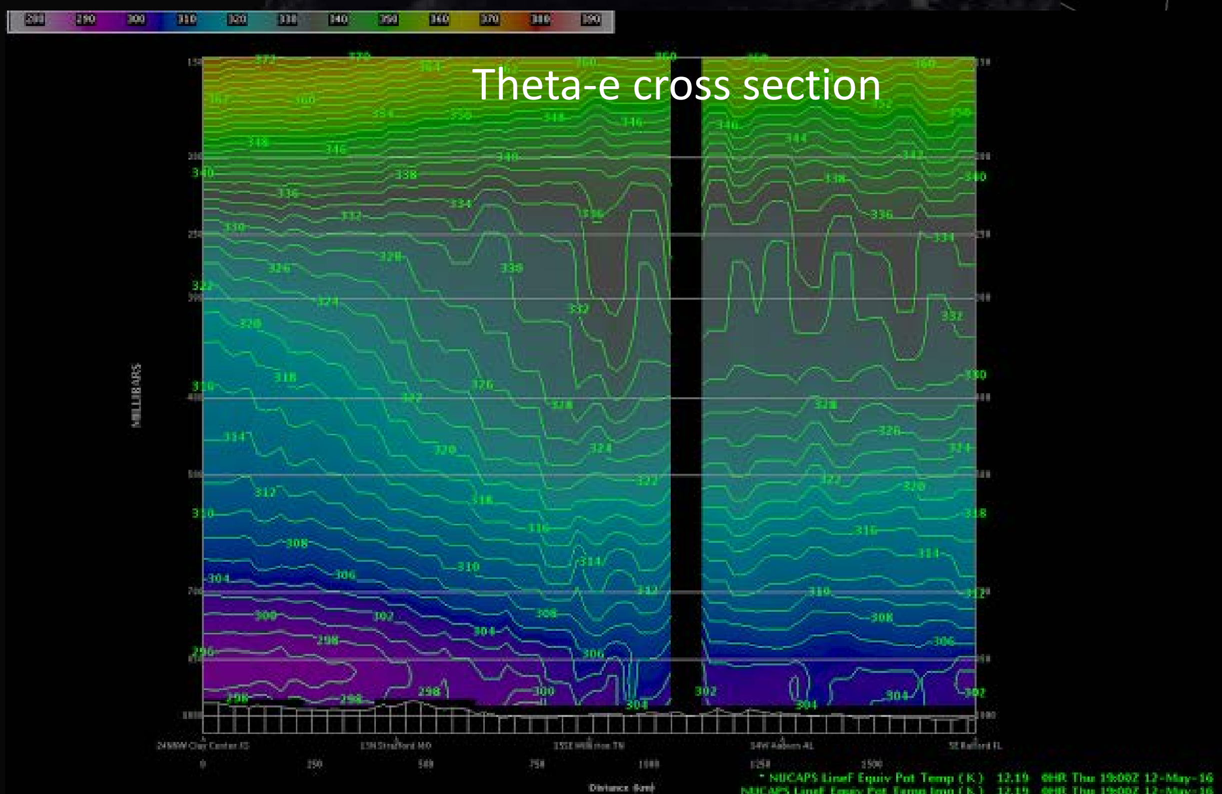


"Storms formed on the border of the FWD and SJT forecast areas but seemed to die out quickly once entering the FWD area. A shot of mixing ratio helps show that **mixing ratios were much better to the southwest**. Travelling further southwest into the EWX area, mixing ratios approached 9 g/kg and just over the Mexican border there was the **longest lived storm of the day** that persisted for a long time... At first I was not convinced at the utility of NUCAPS but these fields show much more promise to me as a forecaster."

Cross Section

- HWT Blog Post: **NUCAPS theta-e Cross Section**
- 12 May 2016 – Southeast US





"We used a cross-sectional view of Theta-E in the afternoon to determine the location of our cold front."

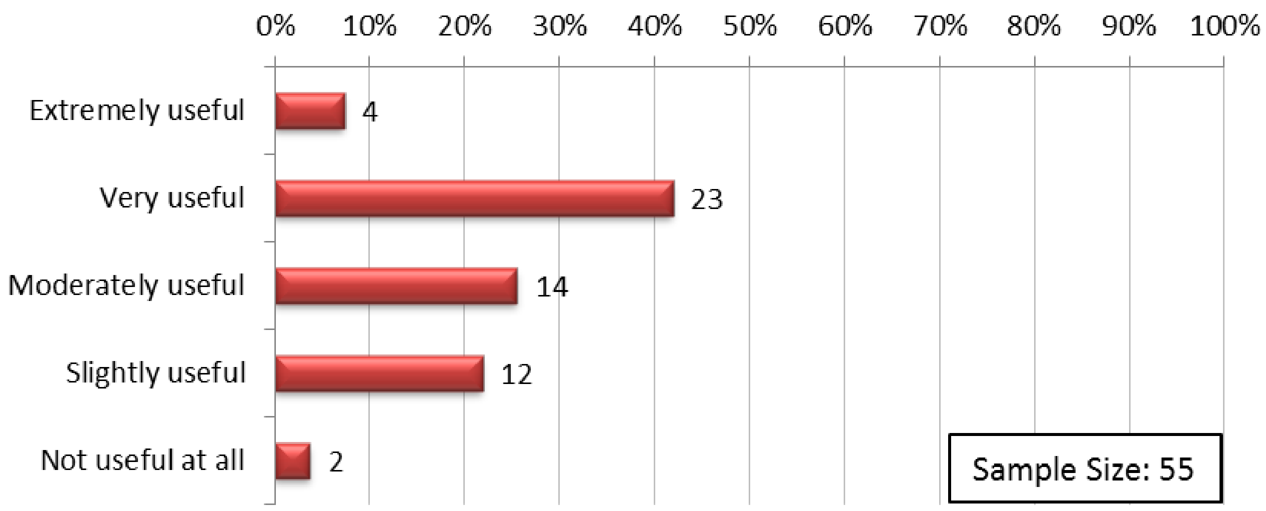
Forecaster General Impressions

- While the upper levels of the profile appear accurate, the surface and low-levels usually contained errors,
  - making manual low-level modifications necessary.
    - Best be made by a mesoscale analyst. Warning forecaster does not have time
  - Upon such modifications, when compared to a radiosonde,
    - although NUCAPS profiles lack the vertical detail of a radiosonde, the general shape of the profile is typically similar, and
    - thermodynamic fields derived from the NUCAPS profile are also typically similar.
      - CAPE, lapse rates, height of freezing level and -20C level, TPW, layer moisture trends

- Based on their use of the data, majority of forecasters felt that NUCAPS provided them with unique/useful information for use in convective forecasting.
  - However, widespread acceptance in the field likely depends on some key improvements (future slide)

End of Day Survey

How useful were the NUCAPS soundings in this particular forecast situation?



Did the NUCAPS soundings provide an effective update on the current state of the thermodynamic environment?

Answered: 54 Skipped: 9

Answer Choices	Responses	
Yes	90.74%	49
No	9.26%	5
Total		54

End-of-Week Survey

Q23 Will you use the NUCAPS soundings at your home office?

Answered: 16 Skipped: 0

Answer Choices	Responses	
Yes, I willstart using NUCAPS as is.	75.00%	12
Yes, but only if/when the surface/low-level modification process is automated.	18.75%	3
I likely will never view NUCAPS in my home office.	6.25%	1
Total		**16**

- “We already use NUCAPS. The main use so far has been to identify mid-level moisture and the potential for elevated convection.”
- “I will start using it now to get a sense of the environment but I will find it much more reliable when the low-level modification is automated.”

Feedback on New Additions

- All new additions for 2016 evaluation went over well with participants!
  - QC Flags
    - Makes profile selection more efficient
    - Were accurate in most situations
  - MetOp NUCAPS
    - Provides more continuity from 1200 UTC radiosonde to afternoon JPSS NUCAPS.
    - Should be processed, available in AWIPS operationally
    - Would welcome application to other satellites for improved continuity
  - Plan view displays
    - Provides quick look at a NUCAPS swath at a given level
      - Temperature, moisture, and variables derived from them
    - Would like to see layer fields added (CAPE, LI, TPW, LPW, LR's, etc.)
    - Cross Sections were used for deeper analysis of synoptic scale features such as frontal boundaries
  - Training
    - Received positive reviews
    - Verification statistics comparing NUCAPS with RAP model
    - Use of Pop-up Skew-T should be included

Key Suggestions

- Improve low levels of NUCAPS soundings
    1. While keeping NUCAPS primarily observational (ideal)
    2. Blend with NWP (RAP)
        - "By introducing model data to the process you could make it look better but you are introducing a second possible source of error into the product."
- Reduce latency into AWIPS
- Improve availability in cloudy sky regions
    - Make microwave only soundings available in AWIPS
- Verification statistics – NUCAPS vs RAP
- AWIPS capabilities
    - Overlay NUCAPS with other soundings in NSHARP
    - Plot nearby observed winds (sfc obs, satellite) in NSHARP

Summary

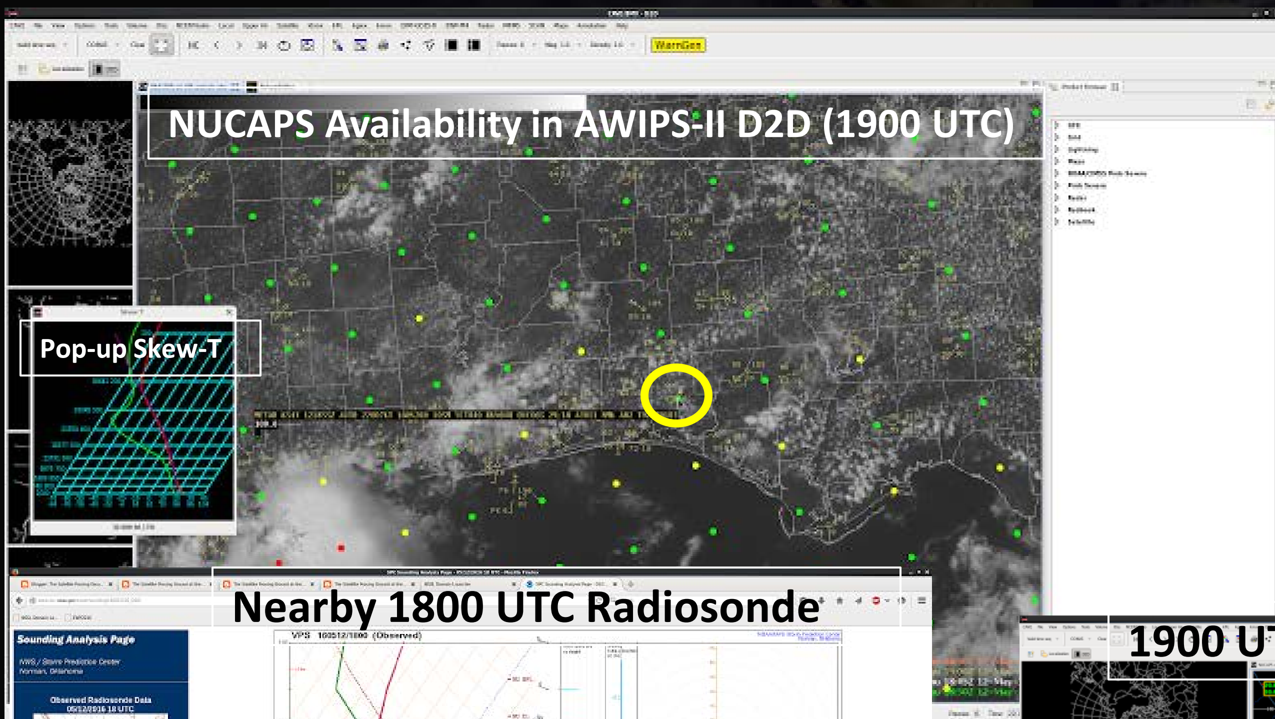
- Generally similar feedback as last year.
  - NUCAPS effective/unique update on thermodynamic environment, however,
    - modifications are time-consuming
    - lack of detail in vertical (primarily inversions) is big negative
  - Would prefer to keep it observationally-driven
- QC Flags were appreciated
- Morning NUCAPS (from MetOp) was useful
- Plan View and Cross-section are great
- **HWT Blog: http://goesrhwt.blogspot.com/search/label/NUCAPS**
- **Final Report Coming**

- New job as meteorologist with NOAA/NWS in Pueblo, CO starting in October. I plan to maintain involvement with satellite community

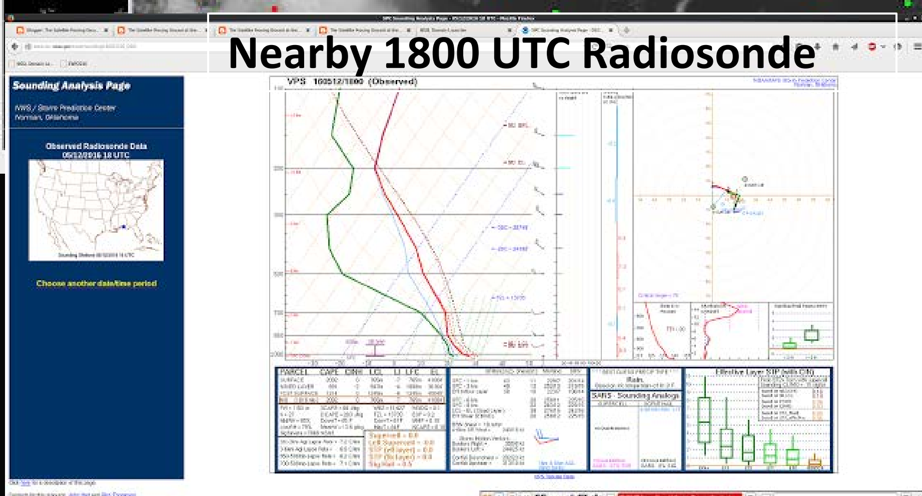
bill.line@noaa.gov

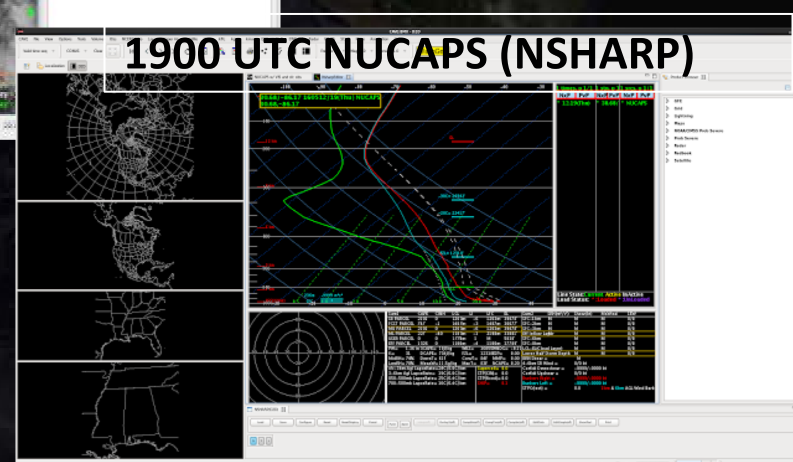
NUCAPS and Pop-up Skew-T

- HWT Blog Post: **Pop-up skew-T for AWIPS**
- 12 May 2016 – NW FL



The AWIPS “Pop-up Skew-T” tool allows forecasters to gain a quick/simple look of the NUCAPS profiles prior to selecting and loading a given profile for interrogation.

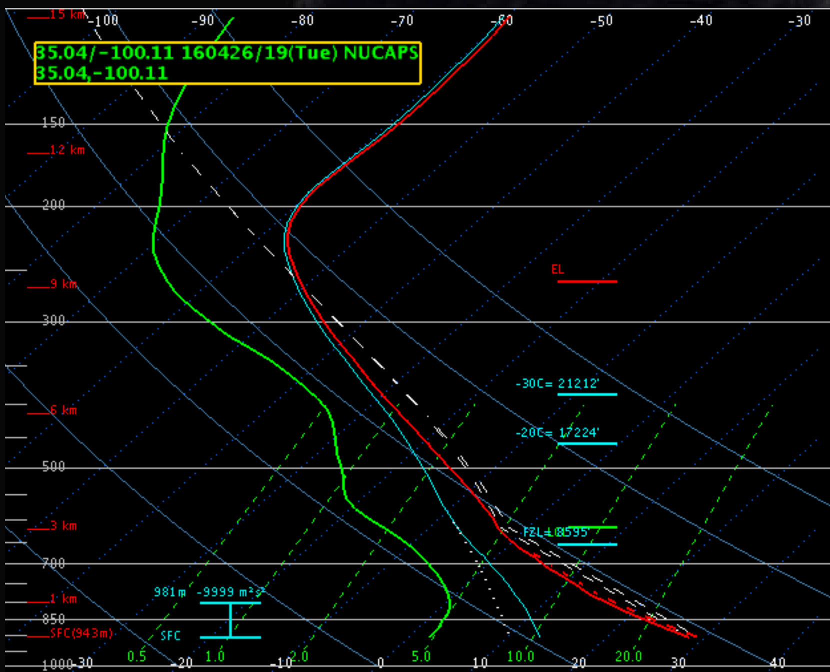




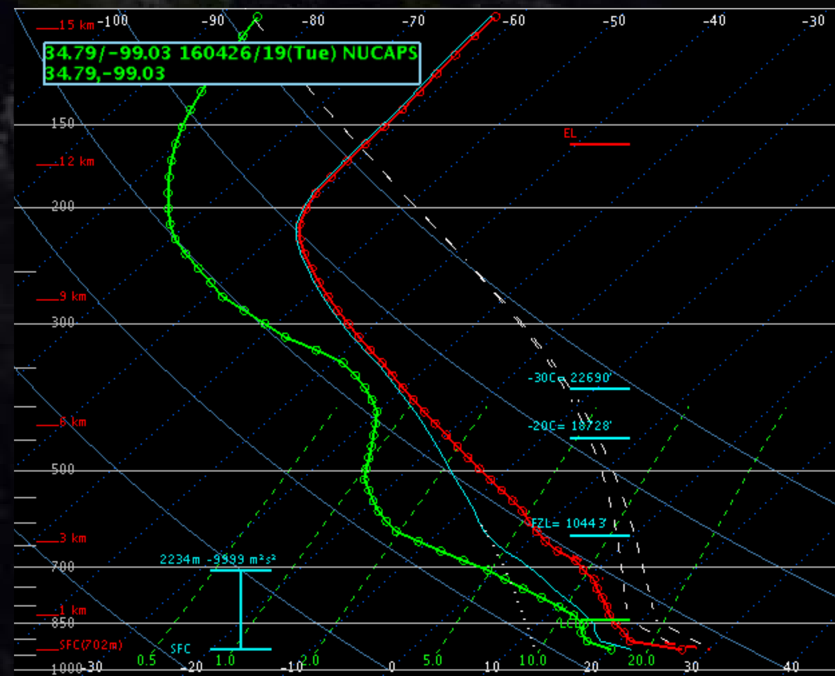
NUCAPS around Dryline

- HWT Blog Post: **NUCAPS Around The Dryline**
- 26 April 2016 – SW OK

Behind Dryline



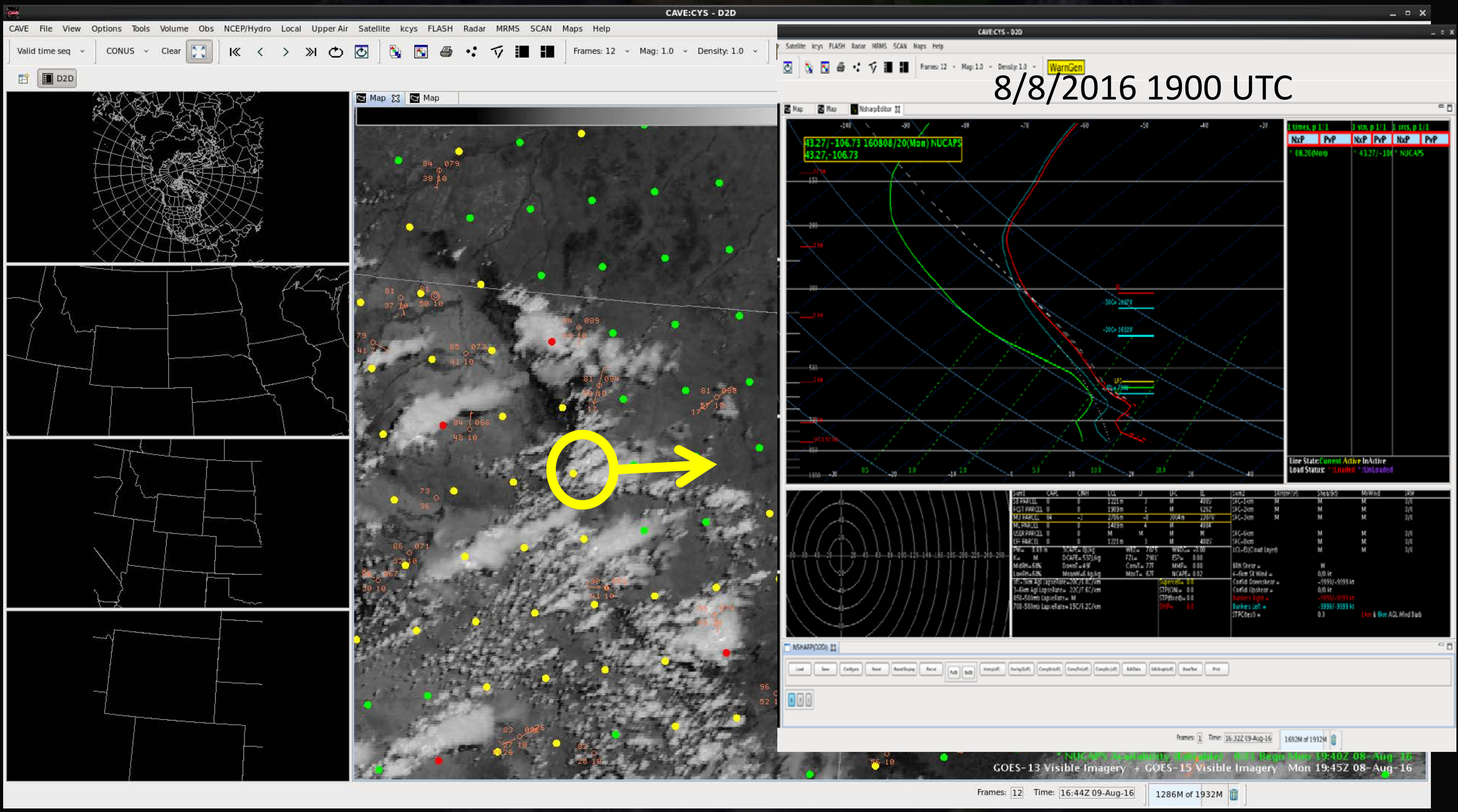
Ahead of Dryline



"The NUCAPS profiles did a good job resloving the dryline in southwestern OK…. Also of note was the moist layer evident on both soundings around 400mb. This matches a moist layer found on 12z and 18z soundings around the area."

Using NUCAPS in AWIPS-II

Selecting a NUCAPS Profile: Yellow – Failed QC



End of Day Survey

How did you use NUCAPS?

In the morning as a check on how unstable the airmass was. We also used a cross-sectional view of Theta-E in the afternoon to determine the location of our cold front.

I used the soundings to verify some of the environmental characteristics I was seeing in RAP sounding such as the amount of instability, lapse rates, and the freezing level.

To look at instability in a fairly data sparse region in the Pueblo CWA. We also looked at a plan view of mixing ratio, which showed a couple of areas of higher moisture. This is where the bulk of convection occurred.

We used it to compare to the Del Rio 1800 UTC sounding, and it matched nicely with the pre-convective environment for the Dallas-Fort Worth area.

Ialso used them to see how the 0C and -20C levels were changing over the afternoon (they decreased in height a few thousand feet each). This was key for warning operations.

There were two soundings in close proximity to each other (within KLWX) only 1 hour apart. These soundings showed the warming and moistening of the lower layers as well as the increase in instability.

End of Week Survey Results

This was the product of the week that provided the most work for the forecaster to get out what they wanted/needed. Having to modify a sounding or make a cross section and then seeing the amount of suspect data will make forecasters very skeptical at first. I suspect that if I trained my staff on it as is, maybe 1 out of 10 forecasters would use it as is. That being said if it can be delivered in a format that is easy to put into a procedure and that they don't have to modify I think buy in will be a lot higher. There can be extreme value in this product, especially if it is kept entirely observational…. I would like to say that having the IASI soundings were very helpful and getting them 4 times per day would be great. N

NUCAPS is a tool I wasn't aware of before this week but am now looking forward to using it in operations (and sharing it with co-workers). The only downfall is the temporal resolution and the luck of the draw with the cloud cover.

NUCAPS has strength in tracking mid-upper level moisture trends as shown in my one blog example, but even then I prefer to not look at a single point but rather use 6.7u/WV loop to see spatial/temporal characteristics of moistening/drying trends aloft.

The inability to see capping inversions and saturated layers is a real drawback.

End of Week Survey Results

I still firmly believe anything that prevents a forecaster from having to manually adjust the sounding is beneficial. If this does not occur, I think it would be a tough sell as forecasters would simply look to other model-derived datasets to make their forecast. Manually adjusting the sounding is labor intensive and potentially confusing as many do not modify soundings on a regular basis.

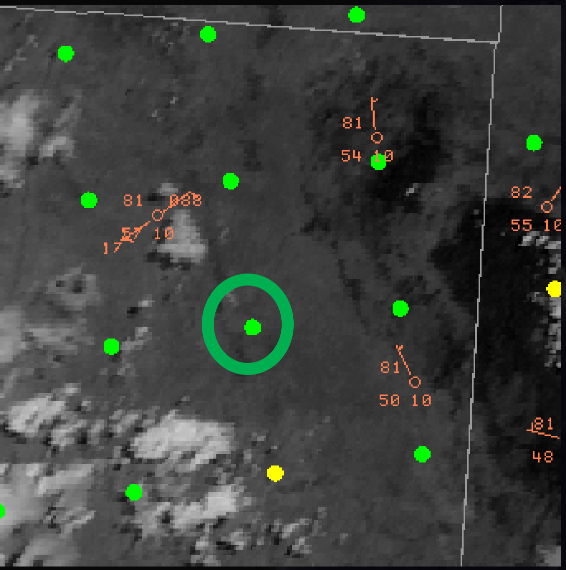
It was nice to have this data going into severe weather events, although changing the values to match the state of the atmosphere better was a little tedious, the information about the freezing level, and -20C level for hail was helpful right before going into a severe weather event.

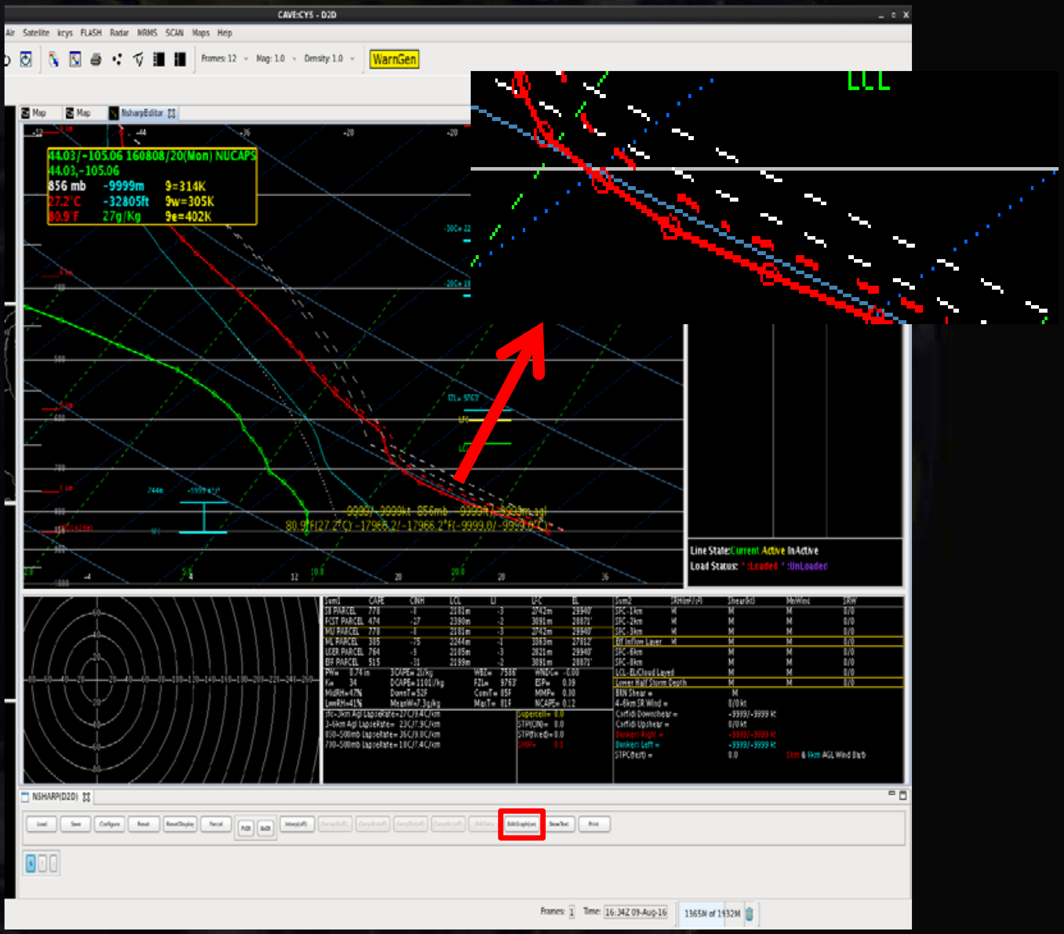
This data could be highly useful, if there was more confidence in the actual profiles. Taking the time to modify a significant portion of the sounding to more accurately match things like RAP analyses, is not necessarily practicle.

We can use this data set to account for when model runs fail to reach AWIPS2 and also for added sampling over higher terrain/sparse data fields over mexico. Our Texas office also has a RAOB gap that can be utilized for some low level moisture return events.

Using NUCAPS in AWIPS-II

Modifying NUCAPS Profile - Temp

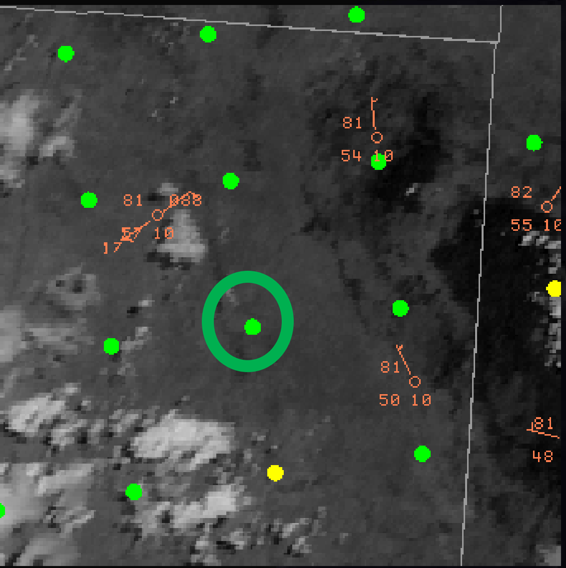




NUCAPS surface temp: 89
METAR surface temp: 81

Using NUCAPS in AWIPS-II

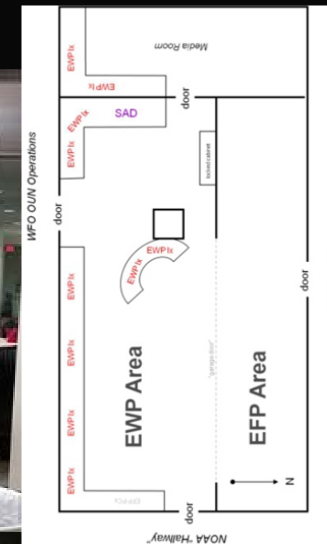
Modifying NUCAPS Profile – Dew Point



NUCAPS surface dew point temp: 47
METAR surface dew point temp: ~53

Hazardous Weather Testbed

Not just a facility…



… but an organization as well

Experimental **F**orecast **P**rogram

*Prediction of hazardous weather events from **a few hours to a week in advance***

Experimental **W**arning **P**rogram

*Detection and prediction of hazardous weather events **up to several hours in advance***

Introducing NUCAPS at NWS Alaska Region

Eric Stevens, Carl Dierking, Tom Heinrichs, Jessica Cherry, and Dayne Broderson

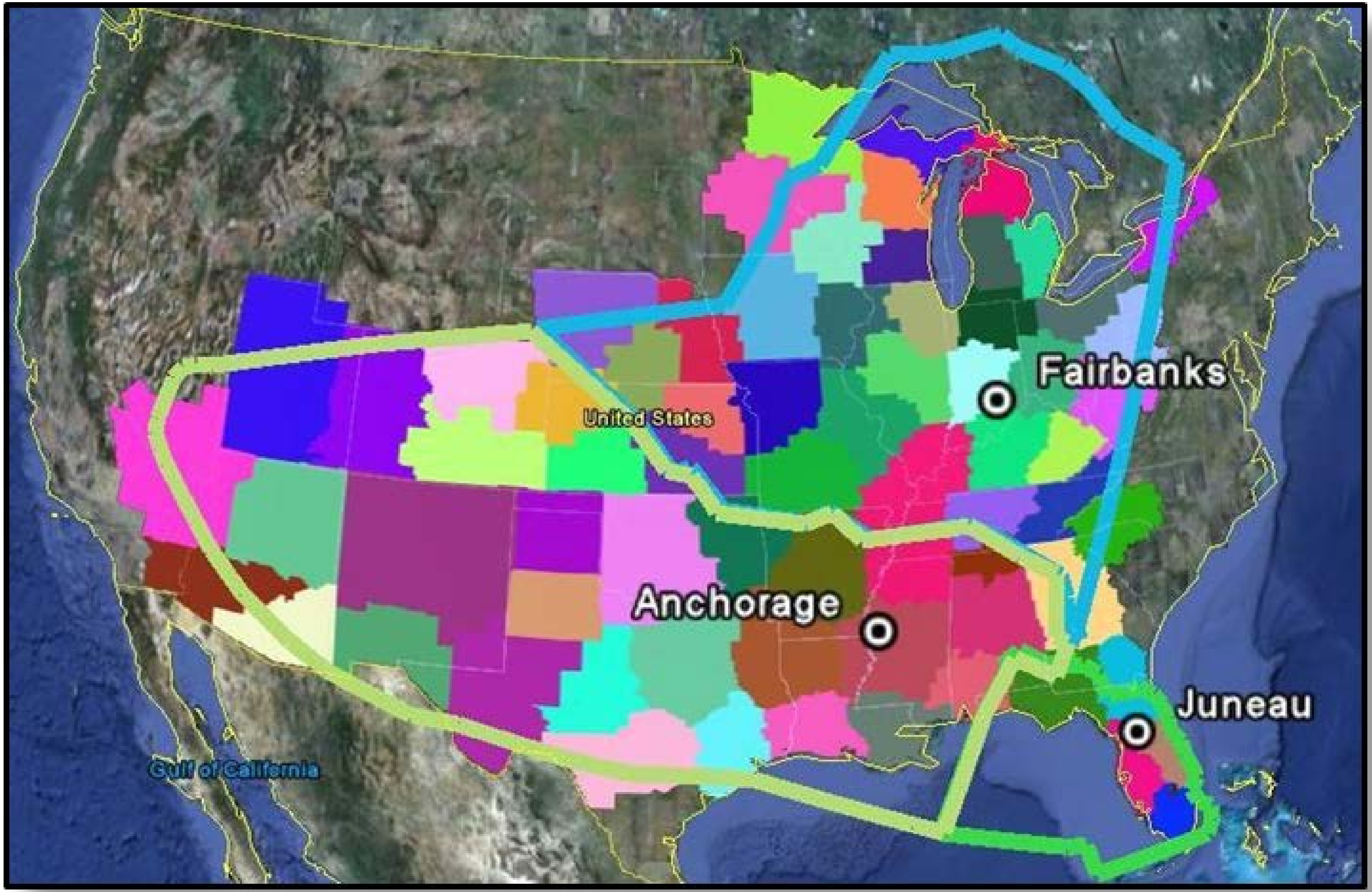
Geographic Information Network of Alaska (GINA)

Roadmap

- Challenges and advantages in Alaska
- The role of UAF/GINA
- Assessment of NUCAPS in Alaska during the 2016 wildfire season
- Plans for the future

The Alaska Challenge

- Areas of responsibility are (comparatively) huge
- The land portion of these areas of responsibility are topographically complex, yielding myriad microclimates
- Many observational networks (such as 88Ds) are very sparse…
    - *This is a big problem because the first step in forecasting is analyzing and understanding the weather now at time=0*
- The specter of climate change being concentrated in the high latitudes means that old “rules of thumb” may suffer from diminishing relevance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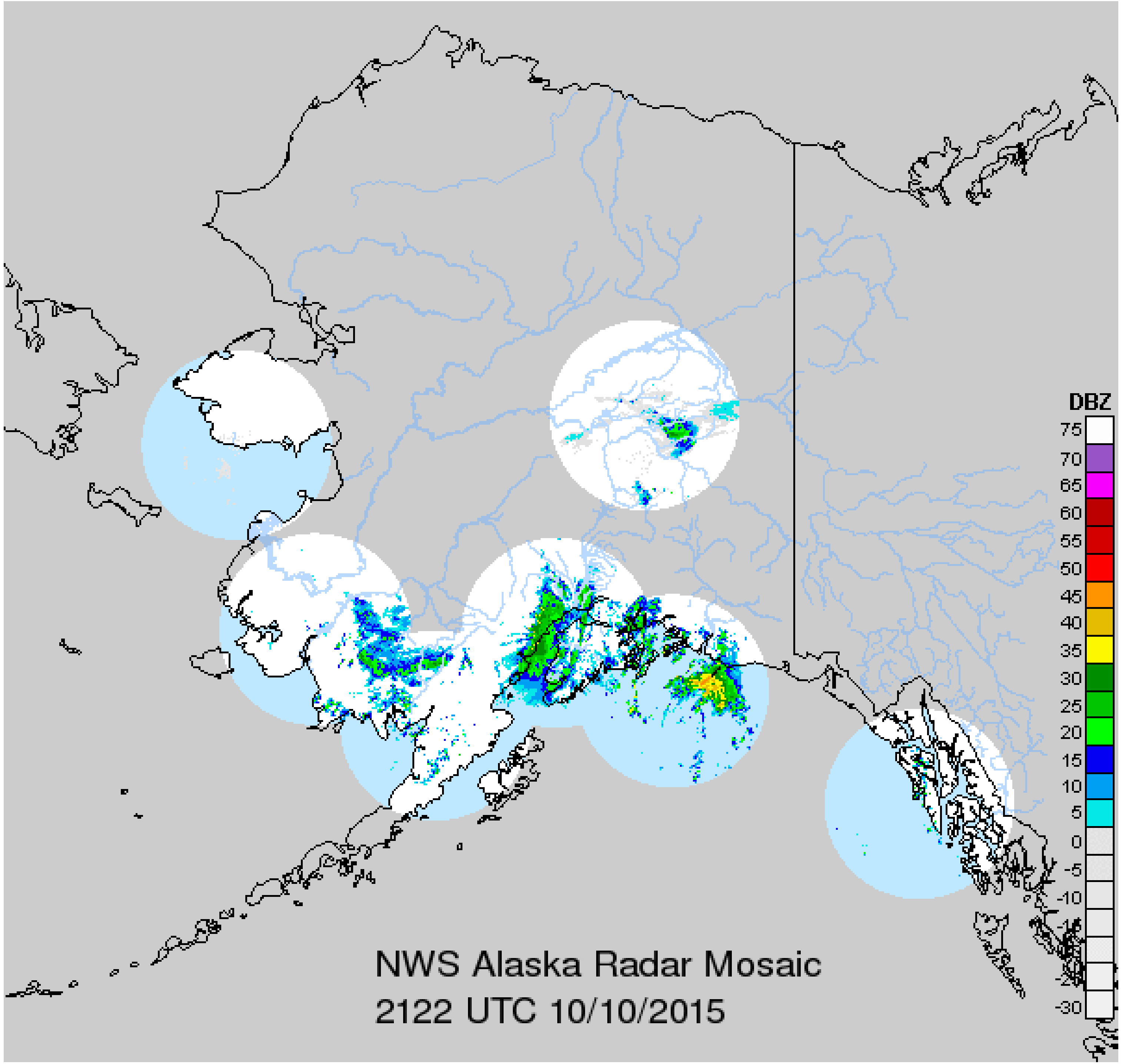
United States
Anchorage
Juneau
Gulf of California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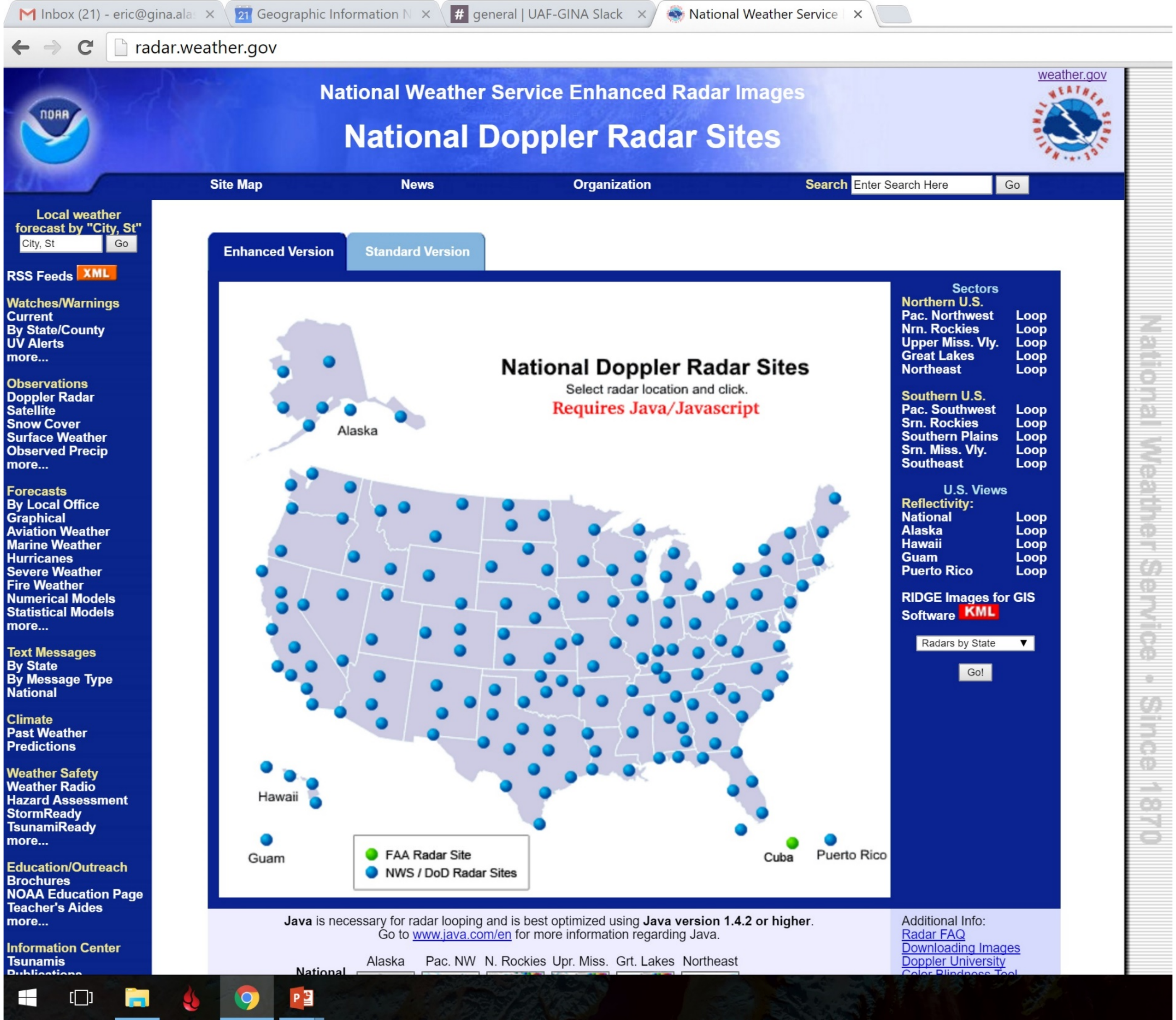
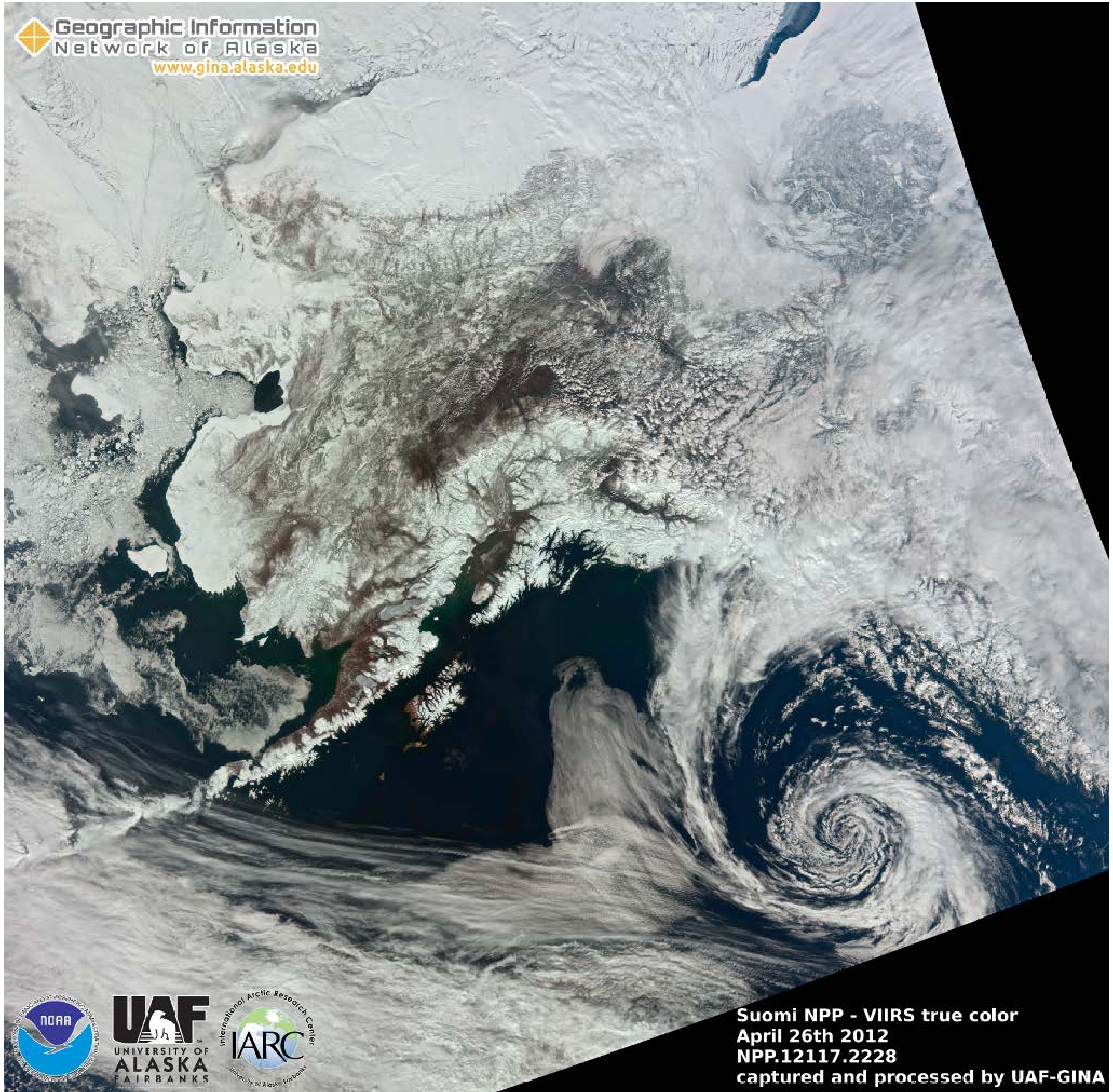
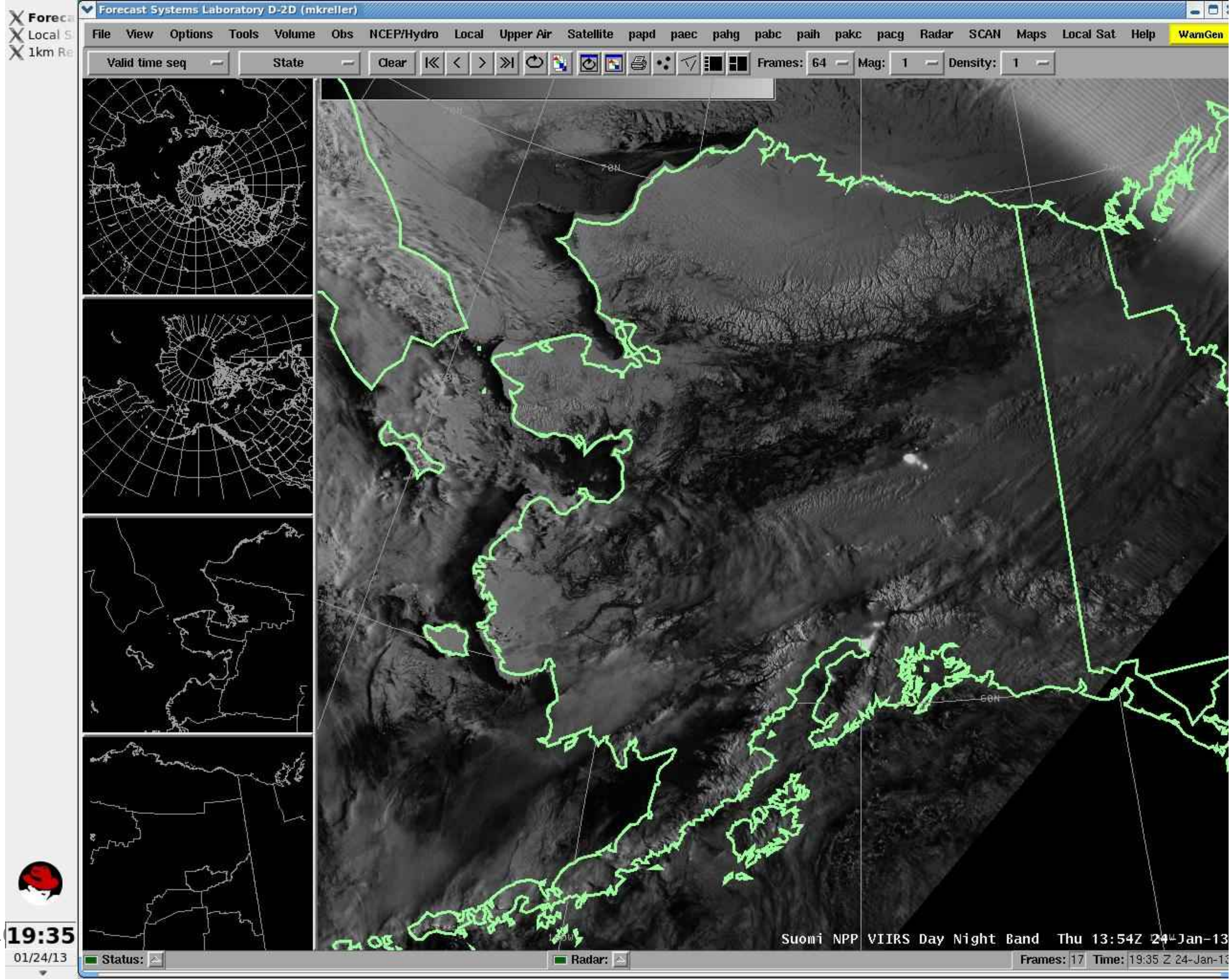
NWS Alaska Radar Mosaic
2122 UTC 10/10/2015


Inbox (21) - eric@gina.ala
Geographic Information N
general | UAF-GINA Slack
National Weather Service
radar.weather.gov
weather.gov
National Weather Service Enhanced Radar Images
National Doppler Radar Sites
Site Map
News
Organization
Search
Enter Search Here
Go
Local weather forecast by "City, St"
City, St
Go
RSS Feeds
XML
Watches/Warnings
Current
By State/County
UV Alerts
more...
Observations
Doppler Radar
Satellite
Snow Cover
Surface Weather
Observed Precip
more...
Forecasts
By Local Office
Graphical
Aviation Weather
Marine Weather
Hurricanes
Severe Weather
Fire Weather
Numerical Models
Statistical Models
more...
Text Messages
By State
By Message Type
National
Climate
Past Weather
Predictions
Weather Safety
Weather Radio
Hazard Assessment
StormReady
TsunamiReady
more...
Education/Outreach
Brochures
NOAA Education Page
Teacher's Aides
more...
Information Center
Tsunamis
Enhanced Version
Standard Version
National Doppler Radar Sites
Select radar location and click.
Requires Java/Javascript
Alaska
Hawaii
Guam
Cuba
Puerto Rico
FAA Radar Site
NWS / DoD Radar Sites
Sectors
Northern U.S.
Pac. Northwest Loop
Nrn. Rockies Loop
Upper Miss. Vly. Loop
Great Lakes Loop
Northeast Loop
Southern U.S.
Pac. Southwest Loop
Srn. Rockies Loop
Southern Plains Loop
Srn. Miss. Vly. Loop
Southeast Loop
U.S. Views
Reflectivity:
National Loop
Alaska Loop
Hawaii Loop
Guam Loop
Puerto Rico Loop
RIDGE Images for GIS Software
KML
Radars by State
Go!
Java is necessary for radar looping and is best optimized using Java version 1.4.2 or higher.
Go to www.java.com/en for more information regarding Java.
Additional Info:
Radar FAQ
Downloading Images
Doppler University
National
Alaska
Pac. NW
N. Rockies
Upr. Miss.
Grt. Lakes
Northeast
National Weather Service • Since 1870

The Alaska Advantage

- Thanks to its high latitude, Alaska enjoys frequent coverage from polar orbiting satellites
  - Polar orbiters are quite useful for weather surveillance
- The Geographic Information Network of Alaska (GINA) at the University of Alaska Fairbanks (UAF) receives data from a number of polar orbiting satellites, including S-NPP and (in the future) JPSS-1
  - The data are then processed into AWIPS-ready imagery, as well as into non-AWIPS image formats
  - The resulting imagery is delivered to the NWS via Local Data Management (LDM)
- This “direct broadcast” approach minimizes latency


Geographic Information
Network of Alaska
www.gina.alaska.edu
Suomi NPP - VIIRS true color
April 26th 2012
NPP.12117.2228
captured and processed by UAF-GINA
UAF
UNIVERSITY OF ALASKA FAIRBANKS
IARC


Forecast Systems Laboratory D-2D (mkreller)
File View Options Tools Volume Obs NCEP/Hydro Local Upper Air Satellite papd paec pahg pabc paih pakc pacg Radar SCAN Maps Local Sat Help WarnGen
Valid time seq
State
Clear
Frames: 64
Mag: 1
Density: 1
Suomi NPP VIIRS Day Night Band Thu 13:54Z 24-Jan-13
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Radar:
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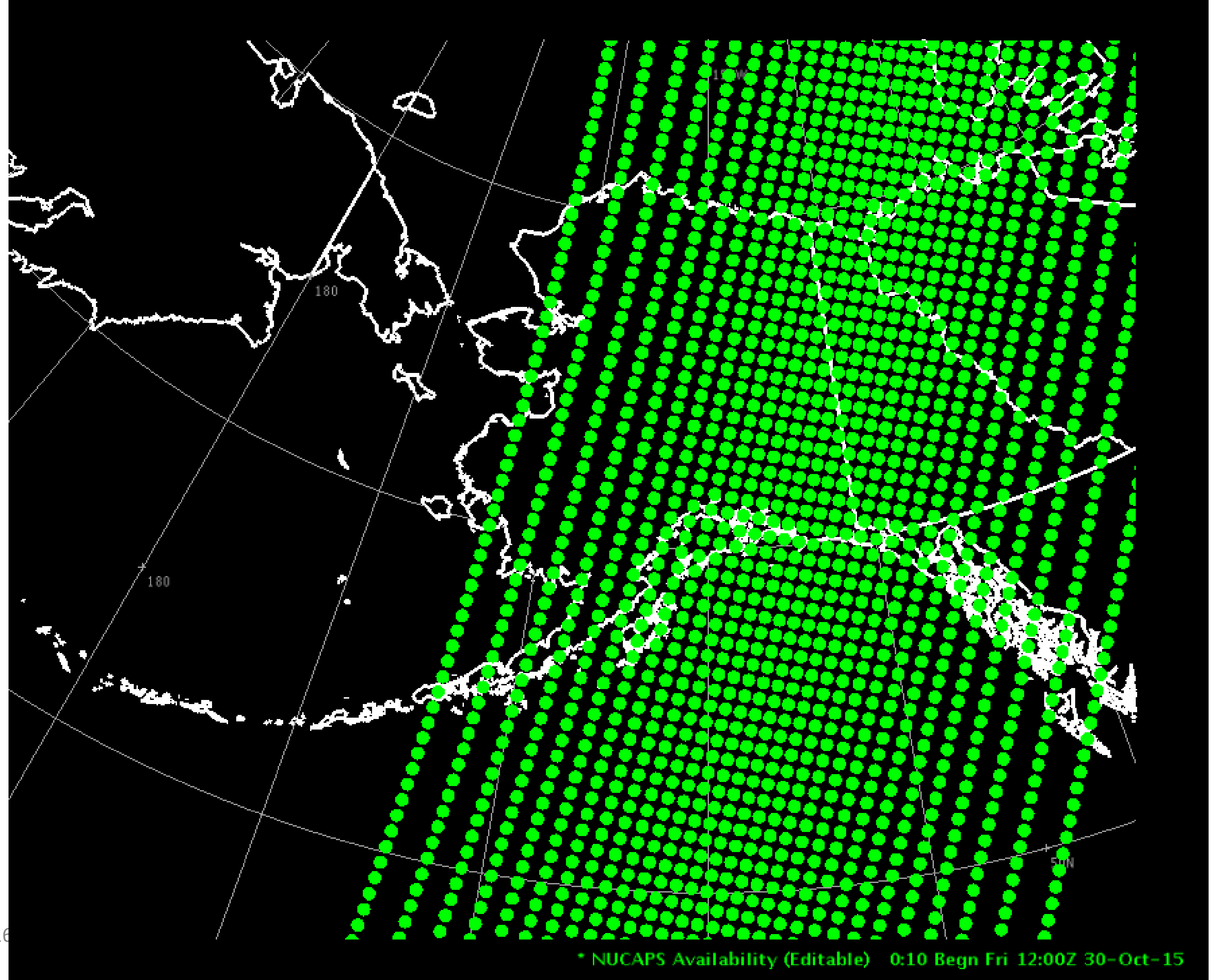
19:35
01/24/13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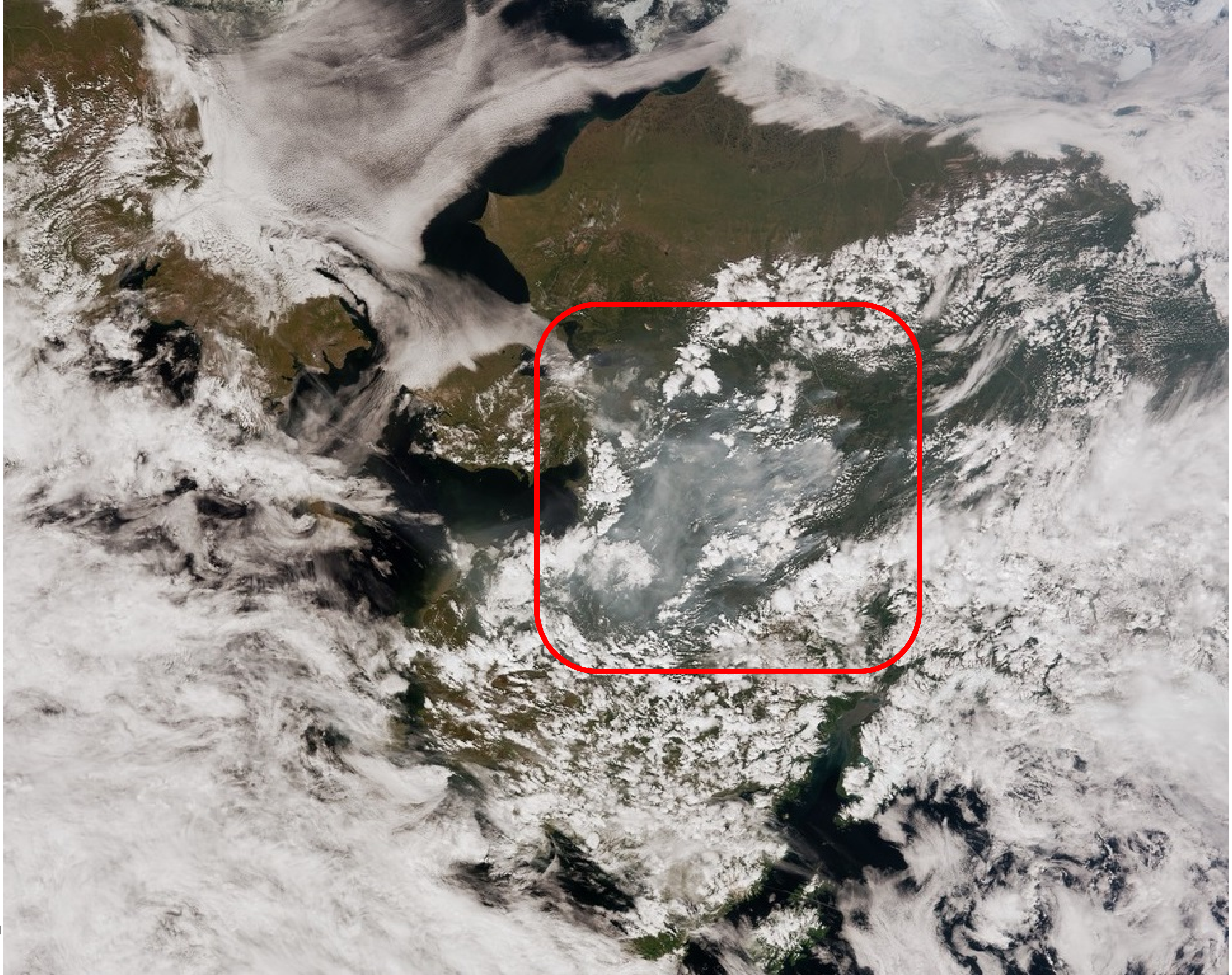


Assessment of NUCAPS in Alaska

- Goal is to assess utility of NUCAPS in the operational NWS environment during the 2016 wildfire season
  - Assessment modeled after previous collaborations between NASA/SPoRT and NWS Alaska as well as on work at the Hazardous Weather Testbed
- Outreach to NWS Alaska via…
  - Series of conference calls, with occasional guest experts such as Bill Line and Dan Nietfeld to present lessons learned with NUCAPS in the CONUS
  - Website nucapsalaska.blogspot.com
  - Web-based survey
  - In-person training
  - Contributions from student volunteer at WFO Fairbanks

NUCAPS in Alaska: 2016-0

nucapsalaska.blogspot.com/

NUCAPS in Alaska

FRIDAY, JUNE 10, 2016

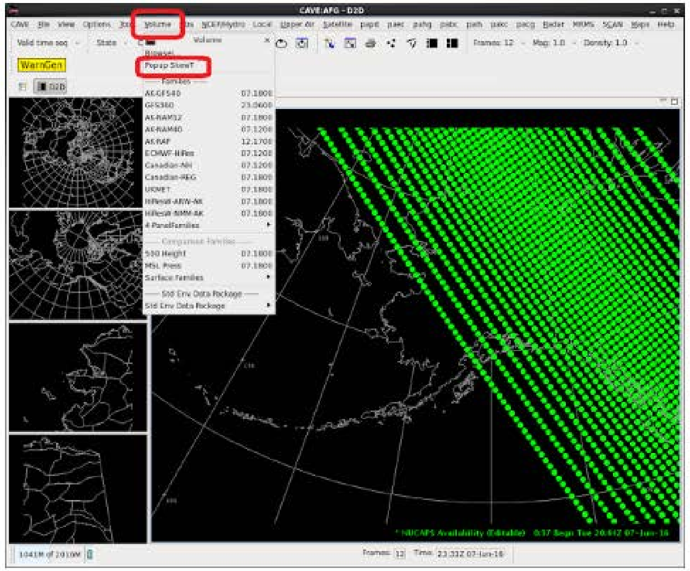
Popup Skew T to the Rescue

NUCAPS presents us with a challenge...remember, there are no "problems" in the modern professional world, just "challenges." The challenge is this: NUCAPS represents a 3-D volume of observational data, yet AWIPS D2D only displays info in two dimensions (hence the name D2D). How do you interrogate a 3-D volume on a 2-D screen?

NUCAPS offers a swath of dots along the SNPP satellite's flight path, with each dot representing a vertical profile of temperature and moisture...you click on a dot, and the display changes to the NSHARPS application to reveal the detailed (as detailed as satellite-based soundings can be) vertical info at that particular point. See the blog post from May 20th for examples of this.

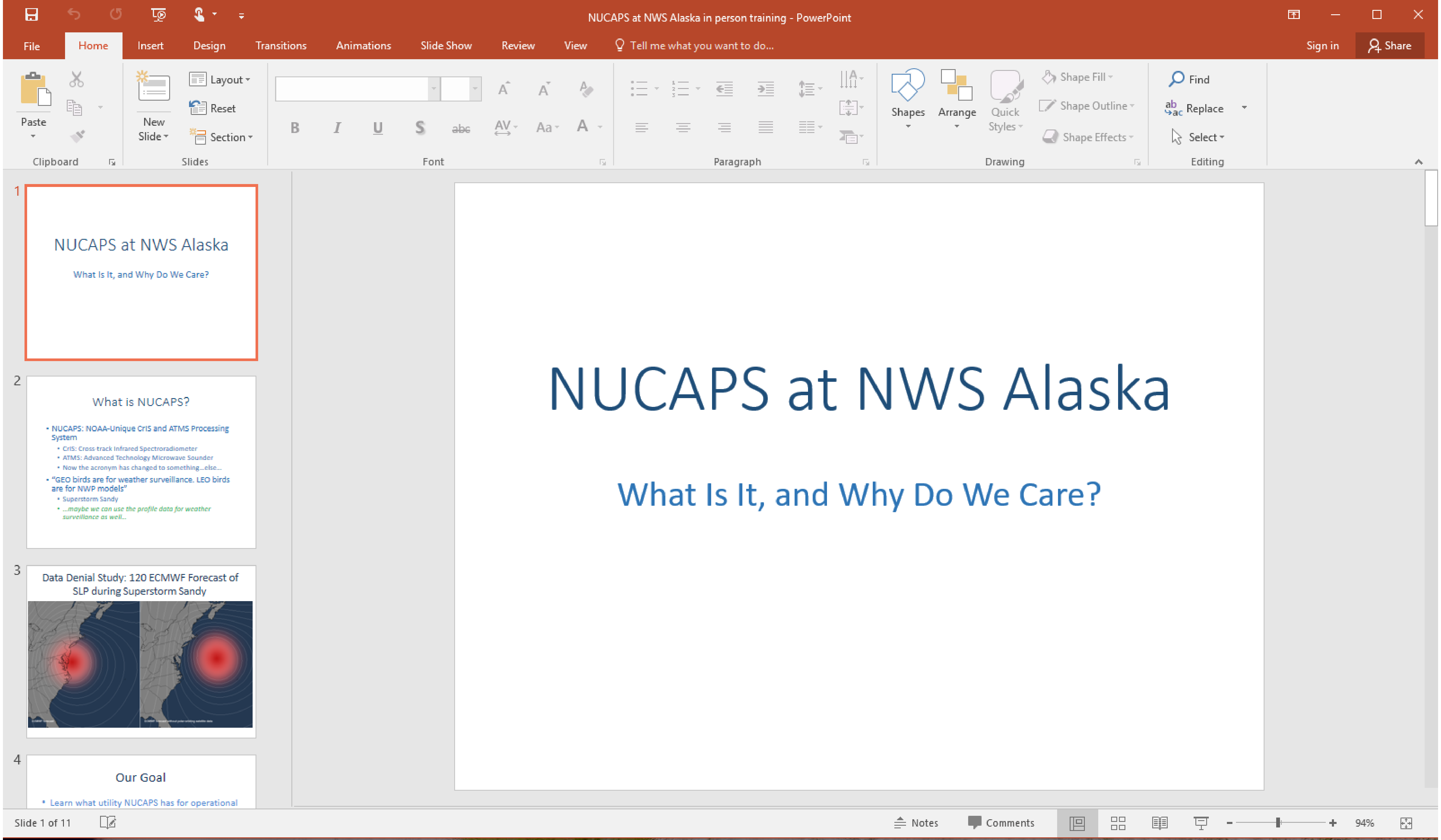
But jumping back and forth between a screen with the swath of dots and the individual profiles in NSHARPS can be disorienting. A not uncommon reaction among forecasters is, "Wait a minute, which green dot did I click on to get this profile? Was it *this* dot...or maybe *this* dot...or was it *this* dot. Grrrrr...the world was a better place when all we had was the LFM model on DIFAX printouts." Luckily, the "Popup Skew T" application in AWIPS can help, at least somewhat, to mitigate the disorientation that can occur when interrogating NUCAPS points. Here is a quick knobology demo on how to use the Popup Skew T in that capacity...

The first step is to call up a swath of NUCAPS points. Next, per the image below, click "Volume" and then "Popup SkewT."



BLOG ARCHIVE

▼ 2016 (6)
► 06/19 - 06/26 (1)
► 06/12 - 06/19 (2)
▼ 06/05 - 06/12 (2)
Popup Skew T to the Rescue
Which Secret AWIPS Menu Hides the NUCAPS?
► 05/15 - 05/22 (1)

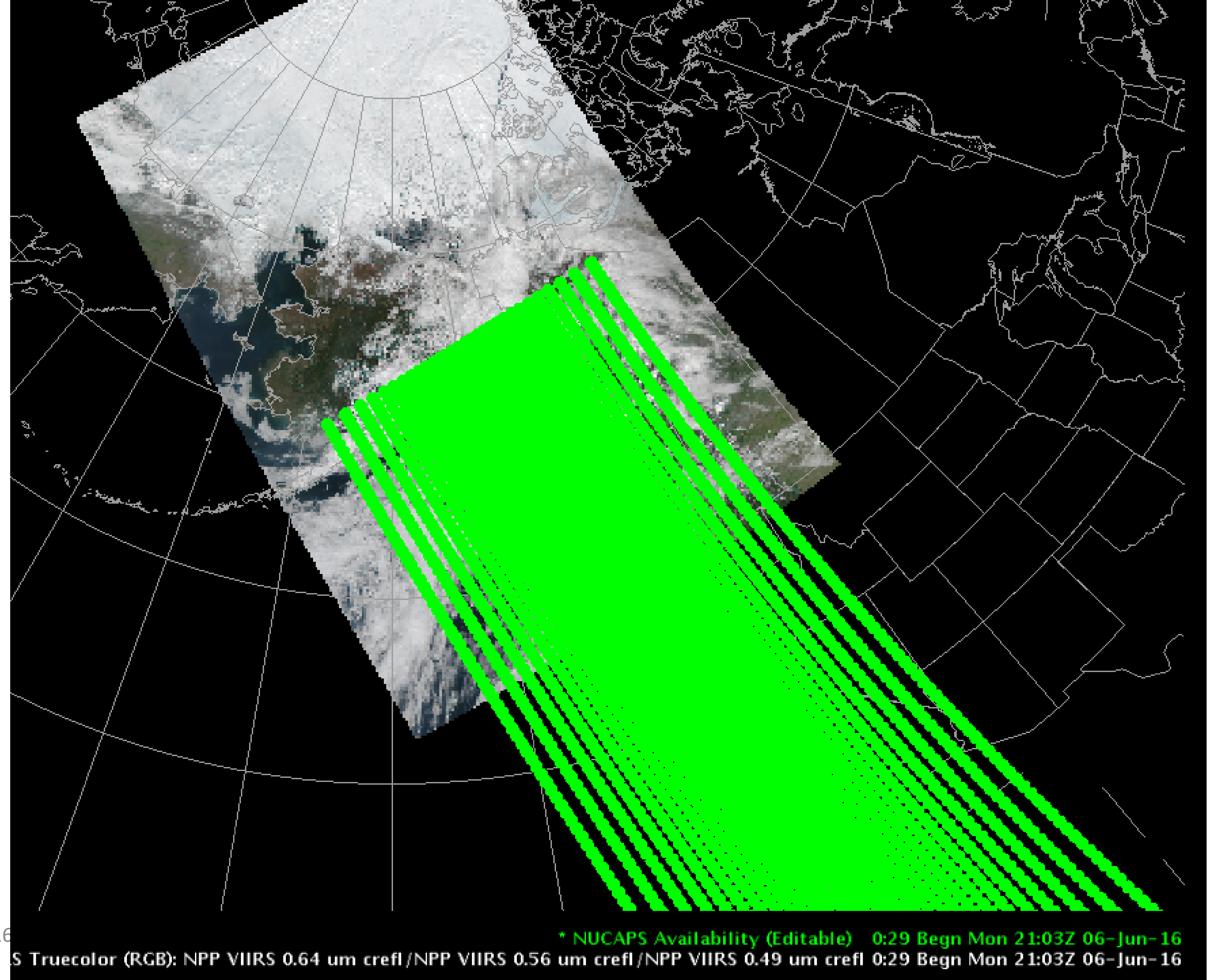

NUCAPS at NWS Alaska in person training - PowerPoint
File
Home
Insert
Design
Transitions
Animations
Slide Show
Review
View
Tell me what you want to do...
Sign in
Share
Paste
Clipboard
New Slide
Layout
Reset
Section
Slides
Font
Paragraph
Shapes
Arrange
Quick Styles
Shape Fill
Shape Outline
Shape Effects
Drawing
Find
Replace
Select
Editing
NUCAPS at NWS Alaska
What Is It, and Why Do We Care?
What is NUCAPS?
NUCAPS: NOAA-Unique CrIS and ATMS Processing System
CrIS: Cross track Infrared Spectroradiometer
ATMS: Advanced Technology Microwave Sounder
Now the acronym has changed to something...else...
"GEO birds are for weather surveillance. LEO birds are for NWP models"
Superstorm Sandy
...maybe we can use the profile data for weather surveillance as well...
Data Denial Study: 120 ECMWF Forecast of SLP during Superstorm Sandy
Our Goal
Learn what utility NUCAPS has for operational
NUCAPS at NWS Alaska
What Is It, and Why Do We Care?
Slide 1 of 11
Notes
Comments
94%

Lessons Learned from 2016 Assessment

- Biggest success was simply in making forecasters aware of NUCAPS
  - capabilities of the instruments
  - Menu-ology and knob-ology of using NUCAPS in AWIPS
  - Good problem to have: forecasters have so many new tools and resources, it can be tough to keep up with it all and maintain proficiency… *how does NUCAPS break into this "crowded marketplace"?*

Lessons Learned:
Remaining Challenges *and Solutions*

- Still a low level of familiarization and fluency among forecasters… *in-person training at AWIPS workstations seems to be well-received*
- Problematic latency of the SBN feed into AWIPS… *can the "direct broadcast" feed from GINA into AWIPS' LDM reduce latency?*
- Forecasters' ability to look back in time constrained by storage in AWIPS… *some degree of local configuration is possible*
- Planar views and cross sections not yet available… *on the way*
- QC flags not yet available… *on the way*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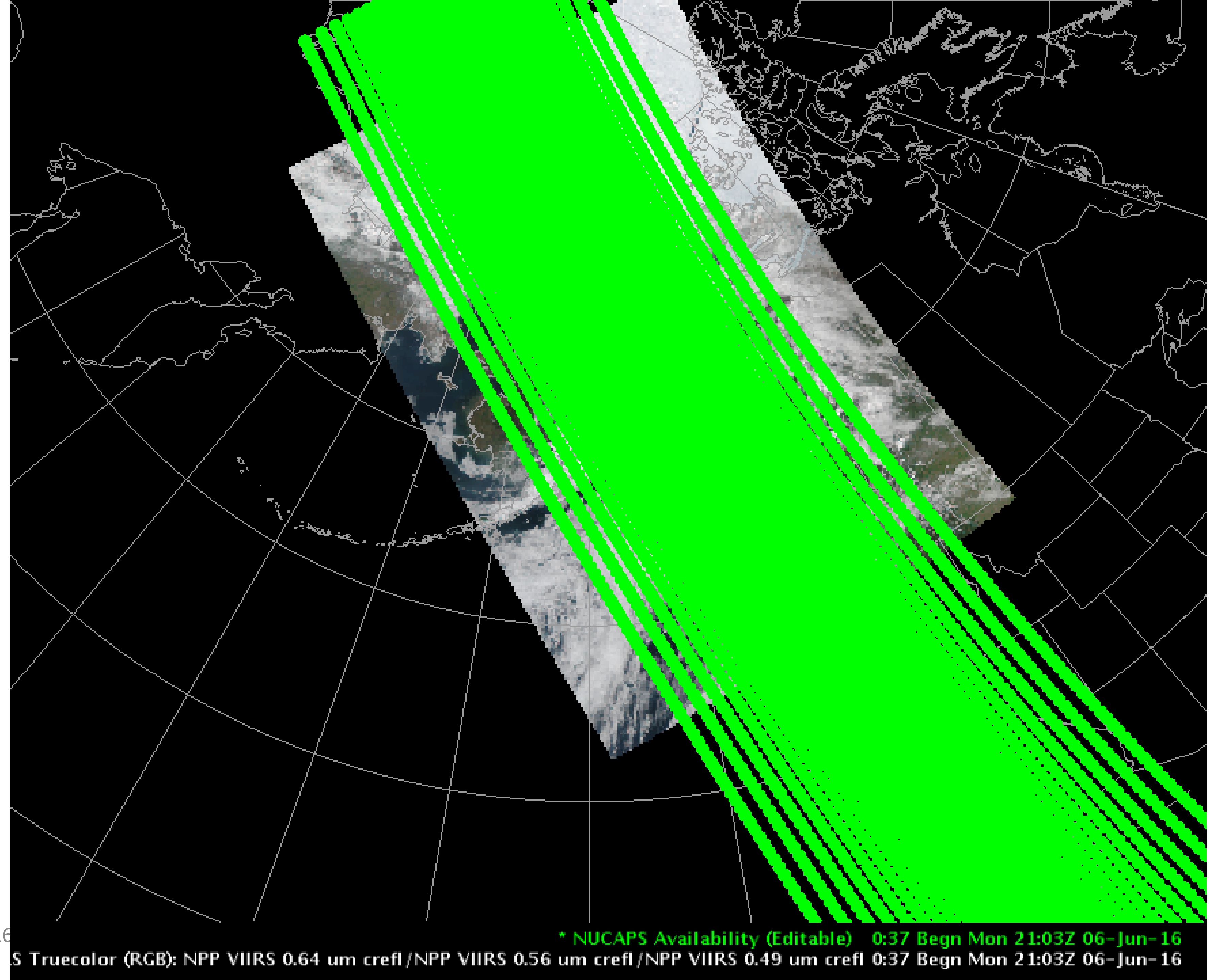
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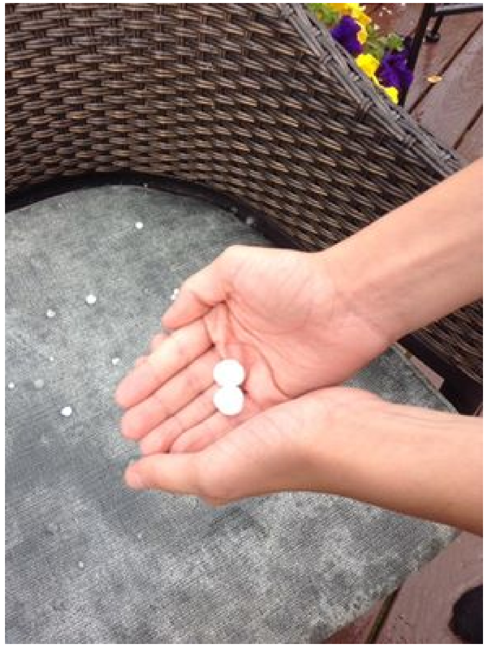
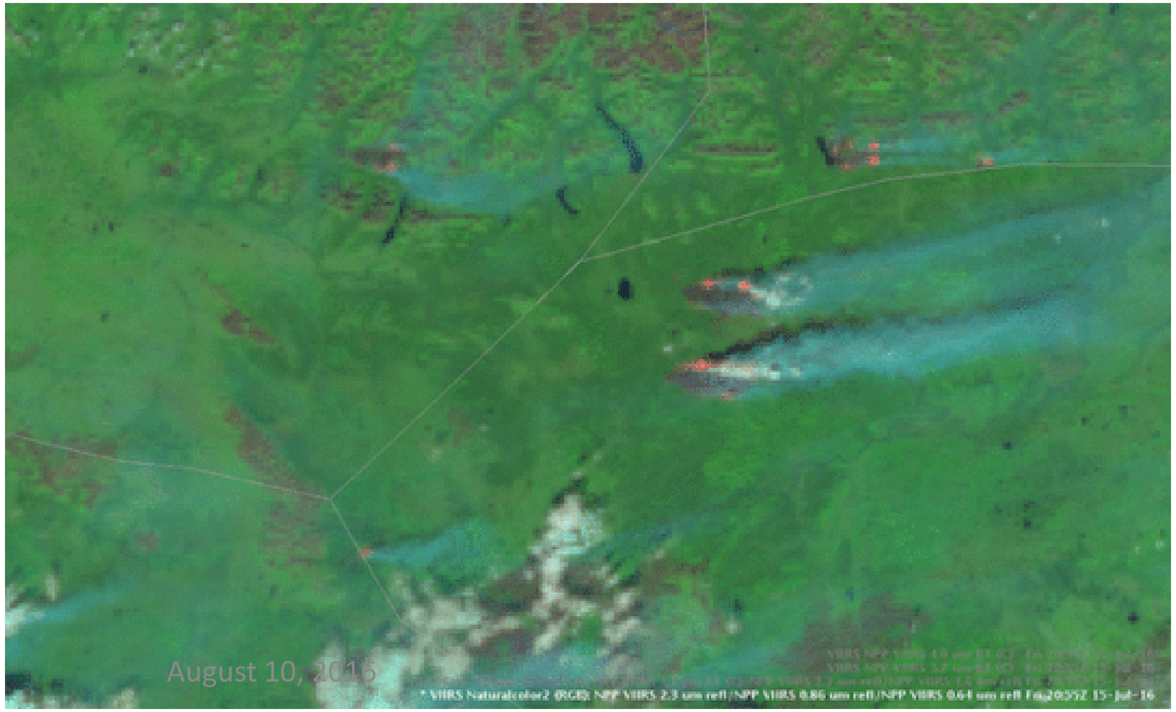
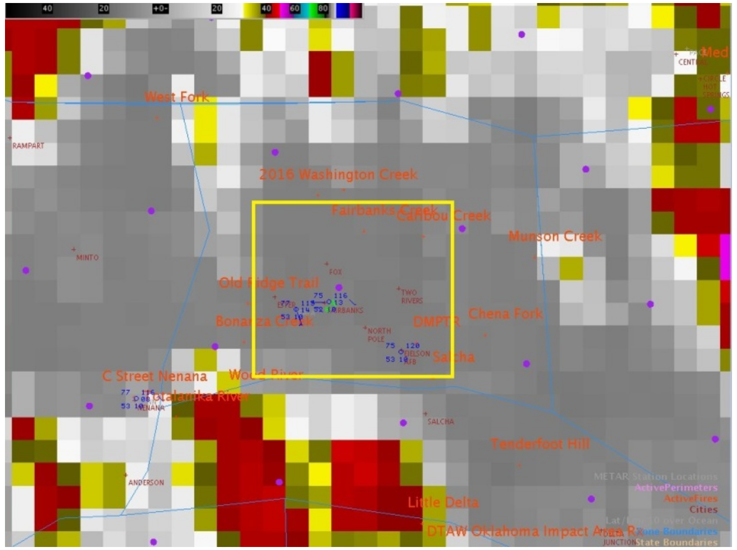


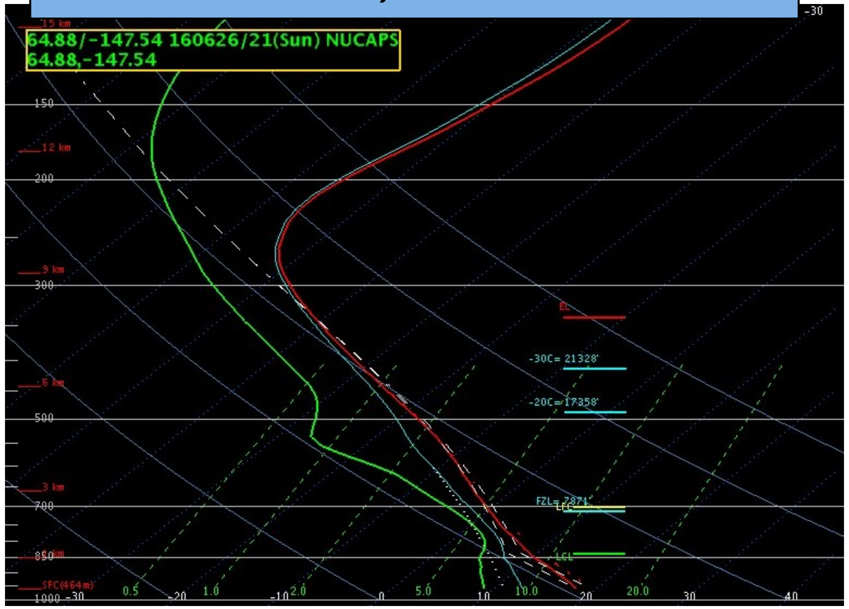
Specific Cases to Investigate

- June 26th: Convection over Interior Alaska, complete with "large" hail (above left)
- July 15th: weather conducive active if not extreme fire behavior (VIIRS RGB below left)
- WFO Fairbanks student Christina Persch has worked with Tony Reale to access archived NUCAPS profiles for specific cases

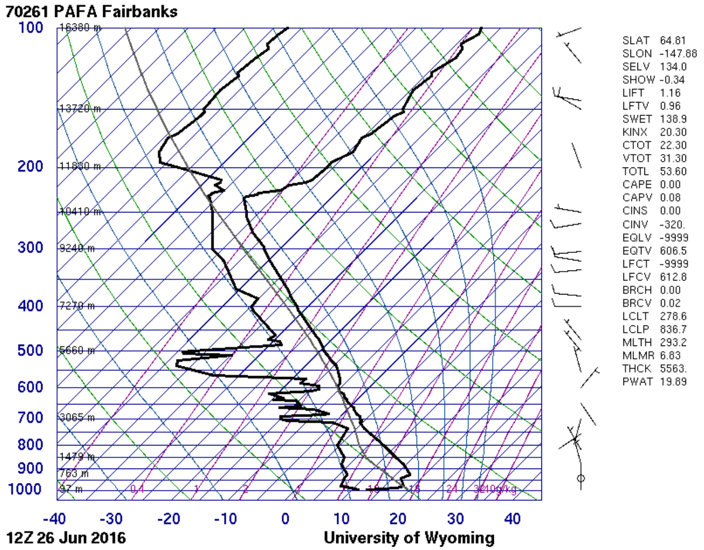




NUCAPS (64.88, -147.54) at 21Z on June 26, 2016



- NUCAPS pass at 21Z
- One sounding very close to Fairbanks was chosen for analysis



Fairbanks RAOB Sounding at 12Z on June 26, 2016

Consider The Future

- Additional training with NWS forecasters needed
  - Basic familiarization and fluency
  - Emphasize uses for NUCAPS beyond just the wildfire season
- A couple of events from summer of 2016 will be investigated
- Improvements to infrastructure: latency and storage

Thank You!

- eric@gina.alaska.edu

S-NPP EDR Validation at ARM (GRUAN) Sites

Lori Borg, David Tobin, Michelle Feltz, Robert Knuteson,
Tony Reale, Quanhua (Mark) Liu,
Donna Holdridge, Jim Mather

Cooperative Institute for Meteorological Satellite Studies
Space Science and Engineering Center
University of Wisconsin-Madison, USA

STAR JPSS Annual Science Team Meeting, 8-12 August 2016, College Park, MD

JPSS Radiosonde Program

Who is involved?

- Coordinated effort involving:

ARM CLIMATE RESEARCH FACILITY

WISCONSIN

JPSS

What is being done?

- Radiosondes launched from ARM sites coincident with S-NPP overpasses

Goals:

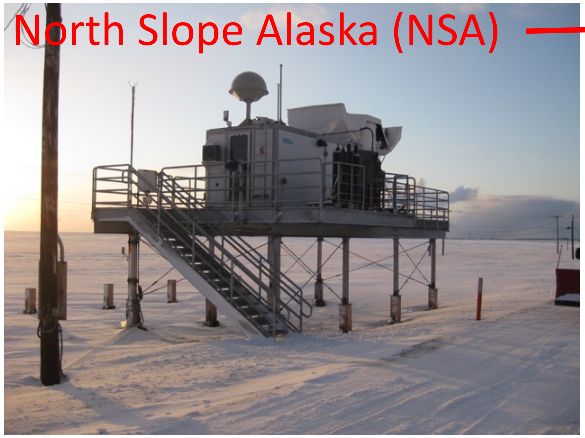
- Assessment of S-NPP soundings
- Accurate & on-going validation data

Heritage:

- Follows efforts by Tobin et. al., 2006 in the assessments of AIRS temperature and water vapor soundings

JPSS Radiosonde Program

North Slope Alaska (NSA)



Southern Great Plains (SGP)

Eastern North Atlantic (ENA)

- S-NPP launches started Feb 2015

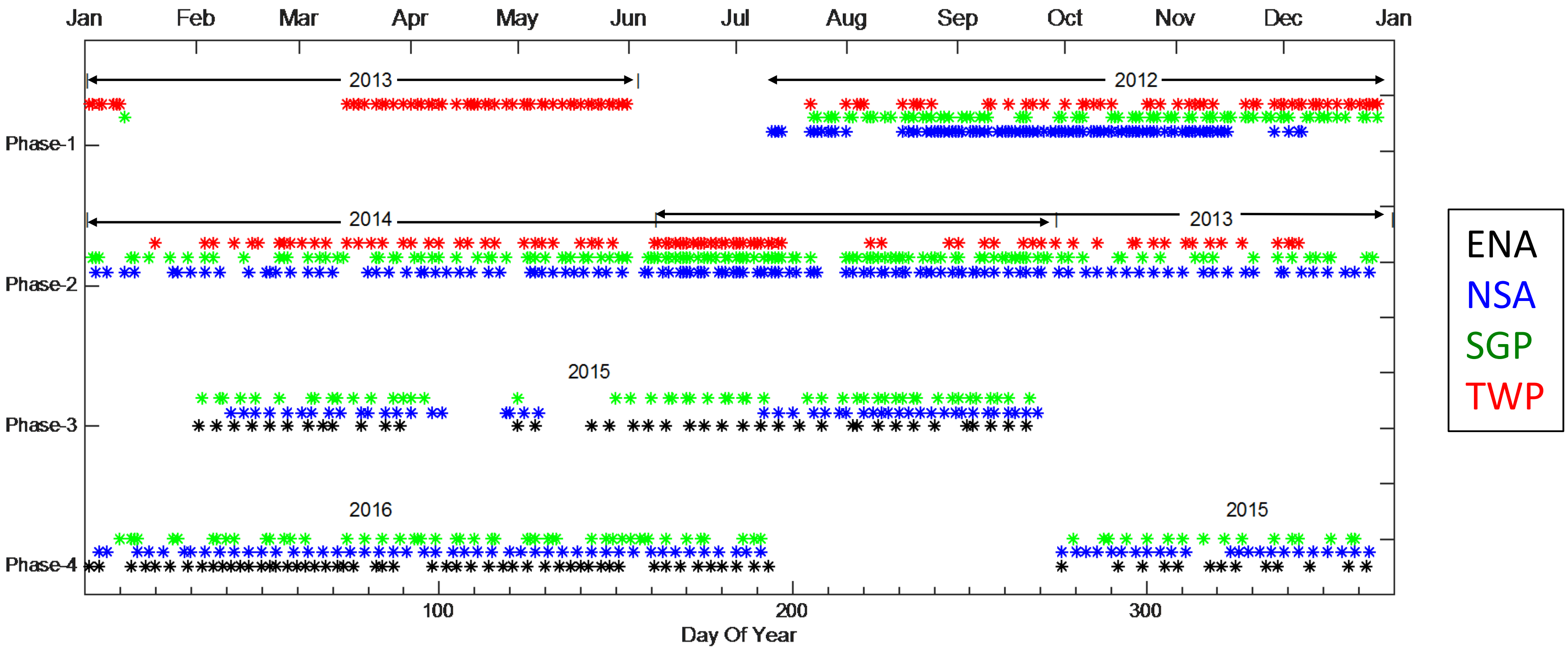
Tropical Western Pacific (TWP)

- site closed May 2014

JPSS Radiosonde Program

Logistics:

- S-NPP radiosonde launches began in July 2012 and are ongoing …



- Radiosondes launched across seasons to sample a range of atmospheres

- Phase-5 begins October 1, 2016 & will run ~1-year

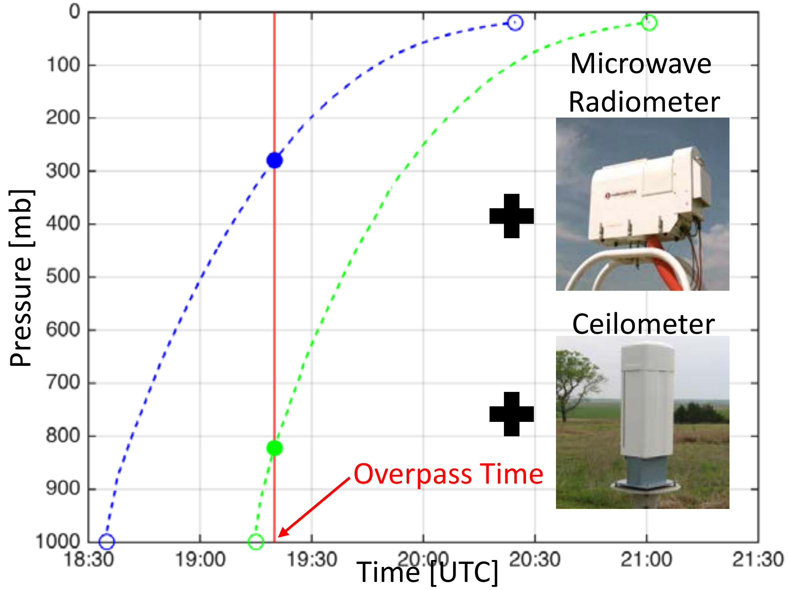
JPSS Radiosonde Program

Logistics:

- Launching for ‘acceptable’ overpasses at each site:
  - view angle criteria (<=30 deg)
  - not fully overcast
  - not heavily precipitating
- Launches occurring every ~4 days at each site

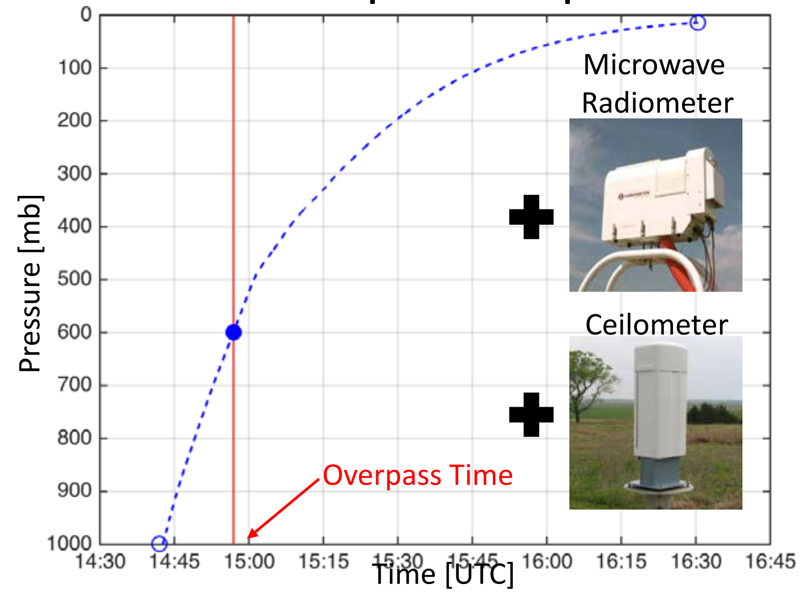
Dual Launch Strategy: NSA & SGP

~45 min and ~5 min prior overpass



Single Launch Strategy: ENA & TWP

~15 min prior to overpass



Best Estimate of Atmospheric State (BE)

Logistics:

- **Many issues:**
  - Helium shortages, gasoline shortages
  - Autosonde failures at NSA & SGP
  - Communications & hardware failures at TWP

- **ARM extremely supportive of this effort. Thank You!**

Special Thanks to …

Donna Holdridge (ANL)
Sonde Instrument Mentor

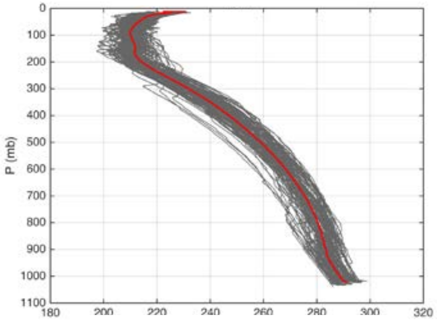
&

Jim Mather (PNNL)

Radiosonde Temperature & WV Profile Distributions

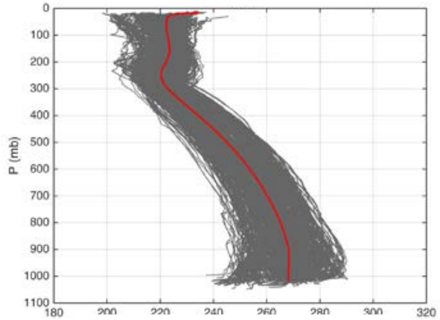
- While the collection sites are limited in number, the profiles consist of highly accurate measurements of a wide range of climatic conditions

ENA



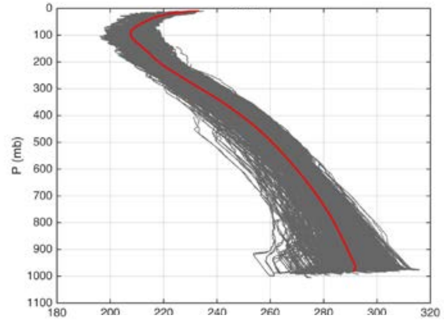
Temperature (K)

NSA



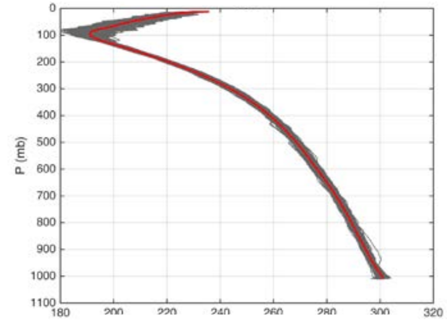
Temperature (K)

SGP

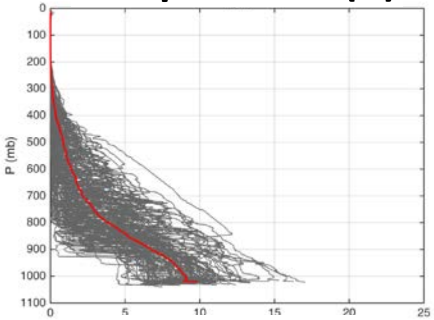


Temperature (K)

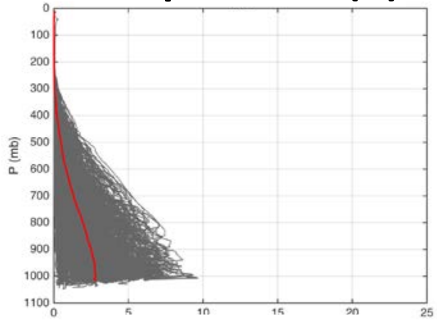
TWP



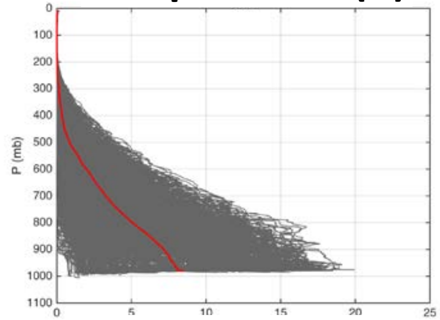
Temperature (K)



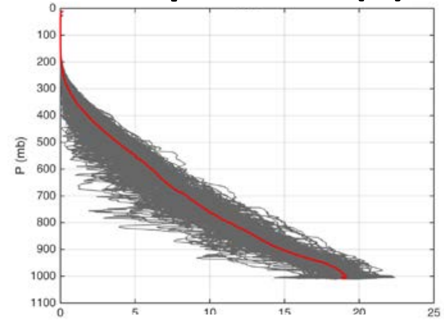
H2O (g/kg)



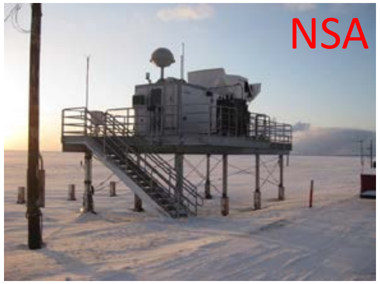
H2O (g/kg)



H2O (g/kg)



H2O (g/kg)

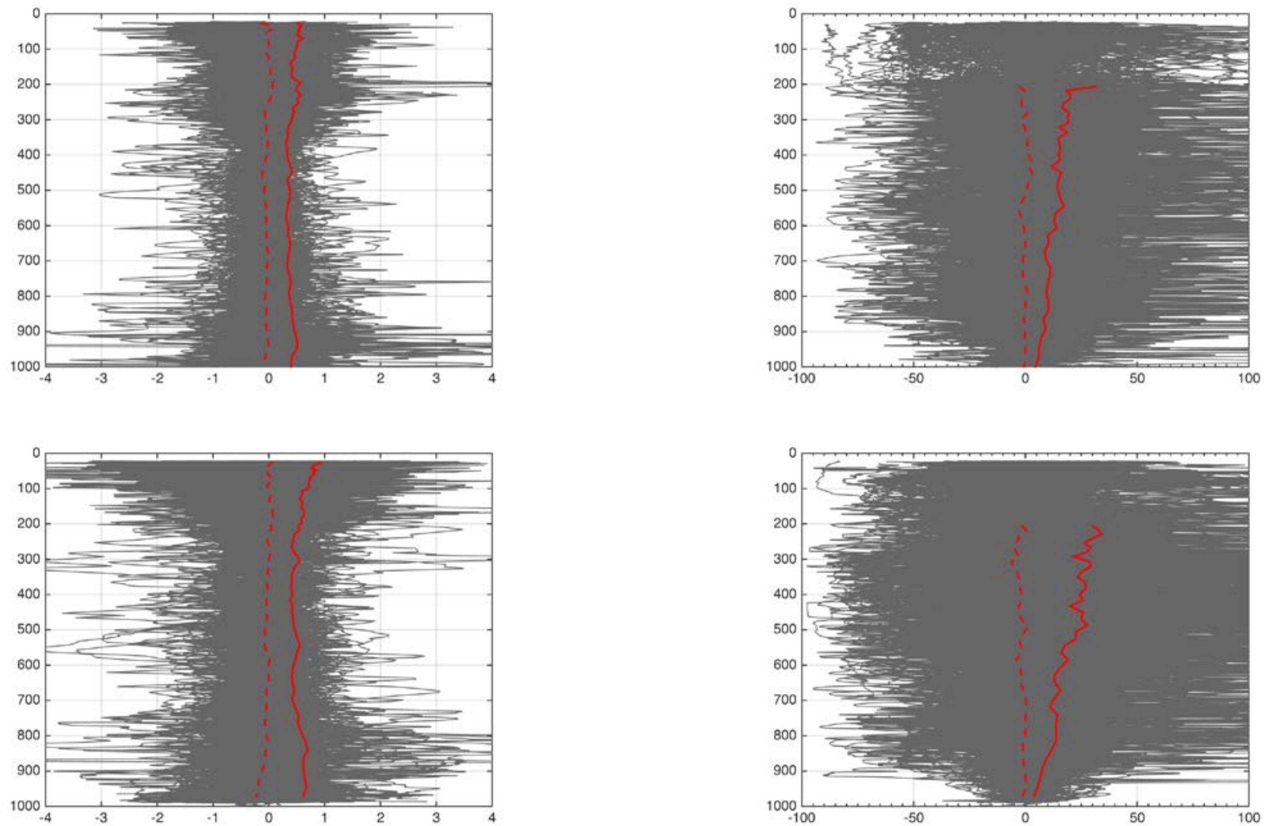


Short Term Variability at NSA & SGP

- Differences between sonde pairs are shown
- mean (dashed) & RMS (solid) differences shown in red for 1km (temp) & 2km (h2o) layers
- The variability in temperature that occurs within ~40 minutes is 3/4°K
- The water vapor RMS percent differences range from 5-30%

NSA

SGP



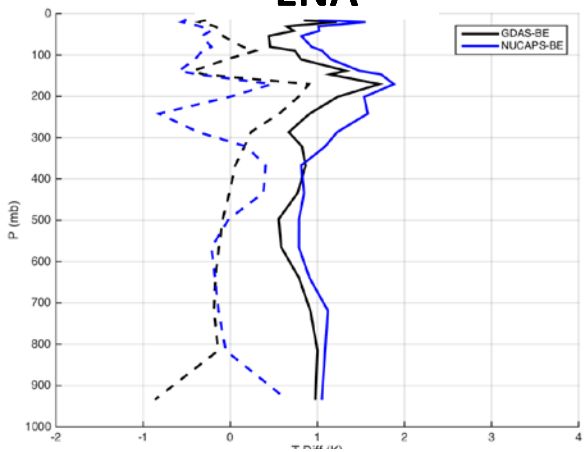
Temperature (K)

H2O (%)

Validation of NUCAPS Temperature Retrievals

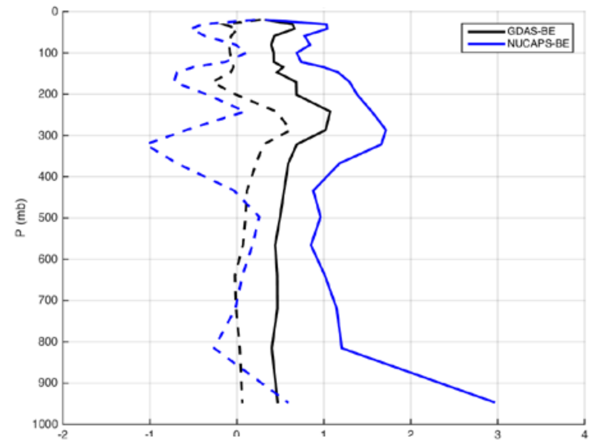
- 1km layer differences shown for each ARM site for ALLSky conditions
- mean (dashed) & RMS (solid) differences shown

ENA



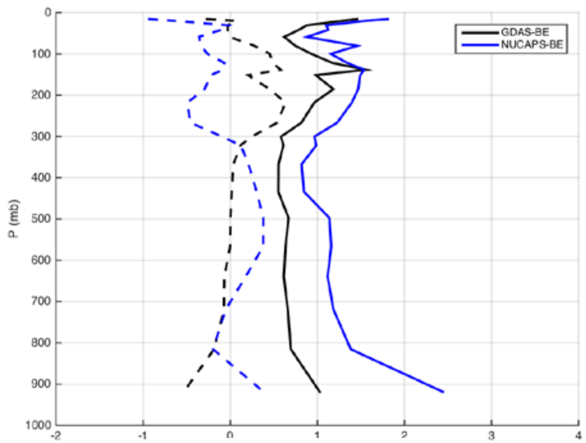
Temperature (K)

NSA



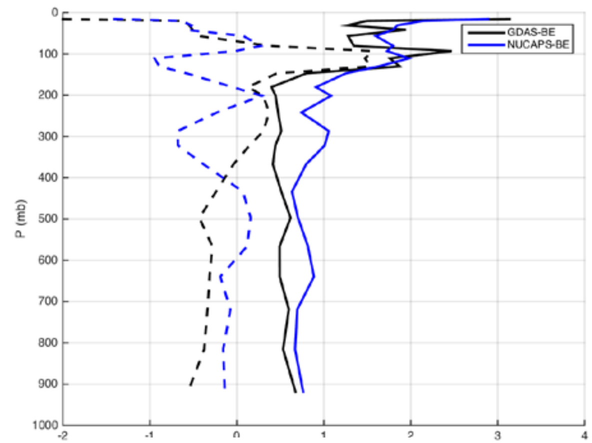
Temperature (K)

SGP



Temperature (K)

TWP

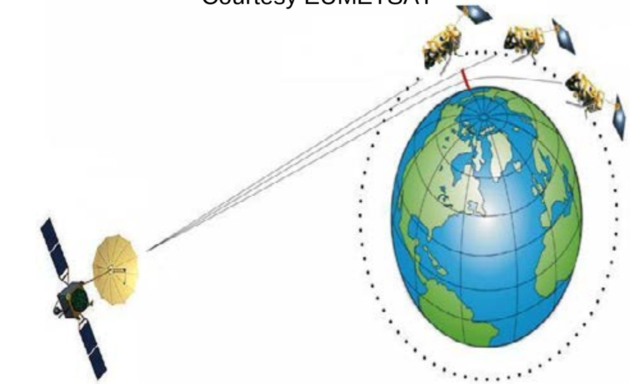


Temperature (K)

UTLS Temperature Validation using GPS RO

- Radiosondes often not best suited in measuring UTLS temperatures
- GPS RO offers potential produce climate quality measurements w/SI traceability

GRAS RO Measurement Depiction
Courtesy EUMETSAT



Stratospheric Temperature Trends

Our Evolving Understanding

and

Applications of GNSS-RO Observations

Dian Seidel
NOAA Air Resources Laboratory
College Park, Maryland, USA

ECMWF - ROM SAF Workshop on Applications of GPS-RO Observations
ECMWF, Reading, UK 16-18 June 2014

Current questions for climate applications of GPS RO

- Vertical domain of useful measurements
- Variables of most utility (refractivity, T_{dry} ?)
- Expected longevity of measurements
- Ground-based measurements needed to optimize long-term record. Possible coordination with GCOS Reference Upper Air Network (GRUAN)

23

- **Lack of reference-quality observations a major problem**
- **GPS RO & GRUAN can help resolve trends & ambiguities in stratospheric temperature**

GRUAN

The Global Climate Observing System (GCOS) Reference Upper Air Network (GRUAN)

What is GRUAN?

- International reference observing network
- Currently consisting handful ground sites but envisaged contain 30-40 sites
  - NSA & SGP becoming GRUAN certified

Goals:

- provide long-term climate records from surface, through troposphere, and into stratosphere
- Focus efforts on characterizing observational biases
- Ensure long-term stability by managing instrumental changes
- Tie measurements to internationally accepted standards
- Ensure that potential gaps in satellite programs do not invalidate long-term climate record, thus leading to improved satellite data products

ARM – GRUAN – JPSS Collaboration

GRUAN ICM-8, April 2016 Boulder, CO

- Many overlapping goals
- Proposal of ARM Intensive Operational Period (IOP)

Radiosonde Intercomparison & VALidation (RIVAL) IOP

- **Primary focus:** RS-92 to RS-41 radiosonde transition
- JPSS sondes launched w/both RS-92 and RS-41 for 1-2 years at SGP (ENA & NSA)
- GRUAN interested in radiosonde comparison statistics
- JPSS project gets targeted overpasses with more instrumentation
- In discussions with Vaisala to loan necessary ground stations to ARM program

UTLS Temperature Validation using GPS RO

How often GPS RO & JPSS radiosonde matchups?

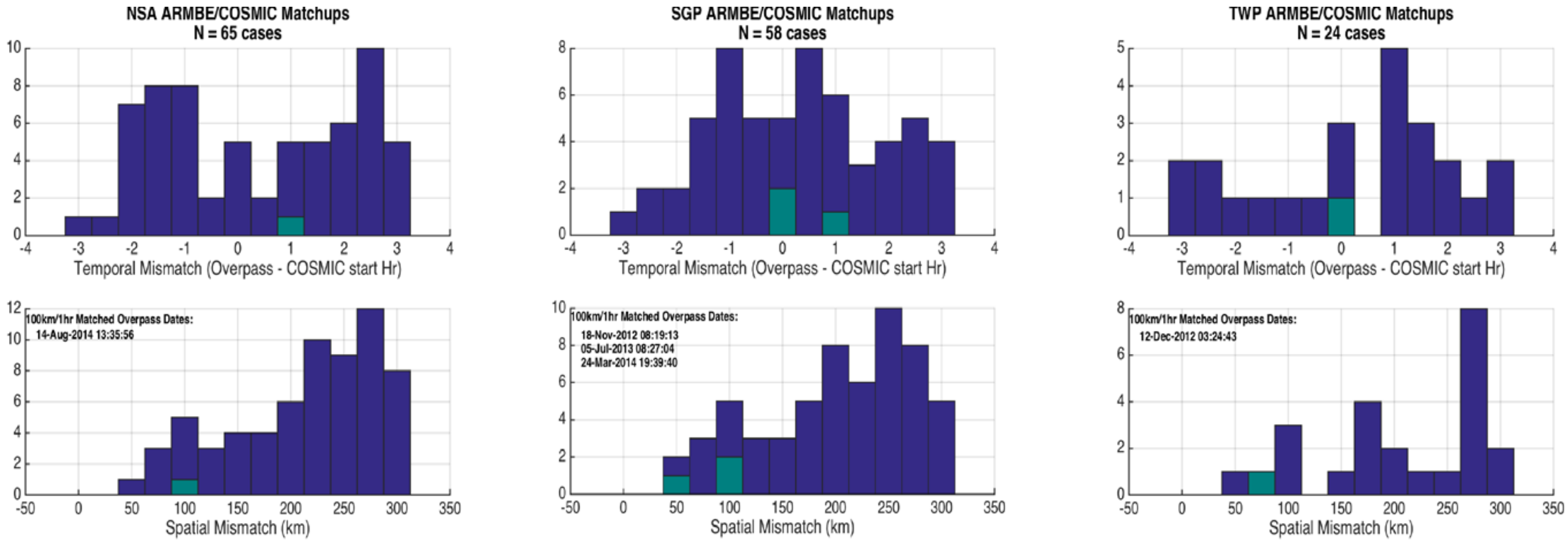
- Depends on matchup criteria
- Not often

Need ability to predict GPS RO occultations:

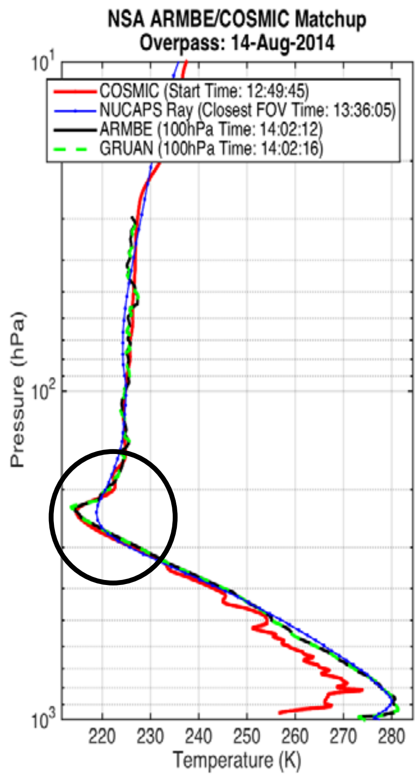
- Currently working with EUMETSAT to establish this capability with METOP-A/B (Axel Von Engeln) & with UCAR for COSMIC

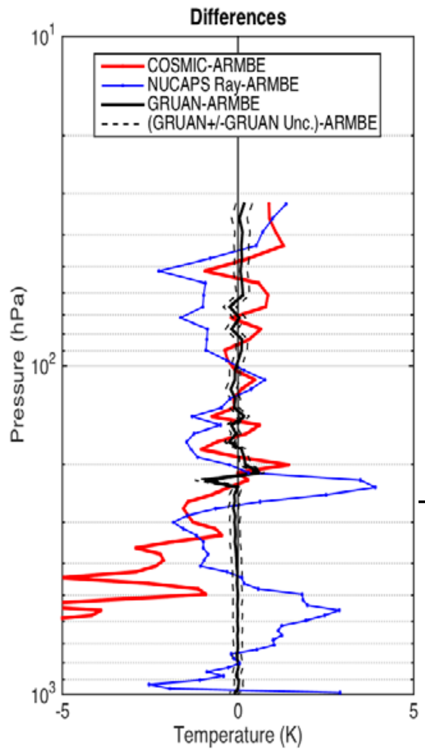
Matchup Criteria:

- **300km/3hr**
- **100km/1hr**



S-NPP Validation: GPS RO (COSMIC) Case Study at NSA





Matchup Criteria:

- **100km/1hr**

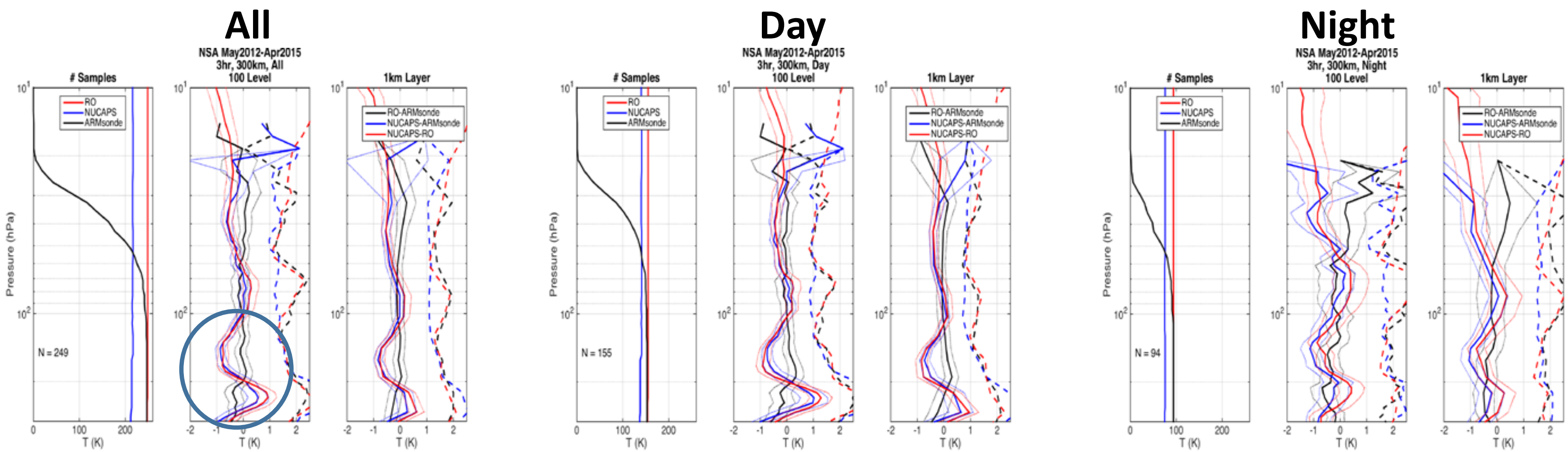
Oscillation (blue line) is seen in NUCAPS statistics

- This is an example showing benefit of RO & sonde over IR sounder
- RO & sonde pick up coldest layer at tropopause
- NUCAPS captures general structure well, but not able to pick up finer vertical structures

S-NPP Validation: COSMIC Matchups w/Routine Launches at NSA

- May 2012 thru April 2015
- Criteria: 3hrs, 300km
- Small sample numbers
- Average over all seasons

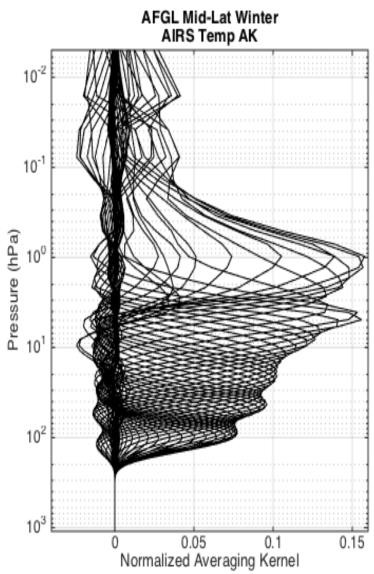
LEGEND:
Solid: bias
Dashed: RMS
Dotted: bias +/- 2*(bias uncertainty)



- NUCAPS has a ~1K cold/warm bias at ~150hPa/250hPa respectively
- Bias btwn RO and sonde less than 0.5K where there's more samples and no water vapor contamination. Also true at SGP (not shown).

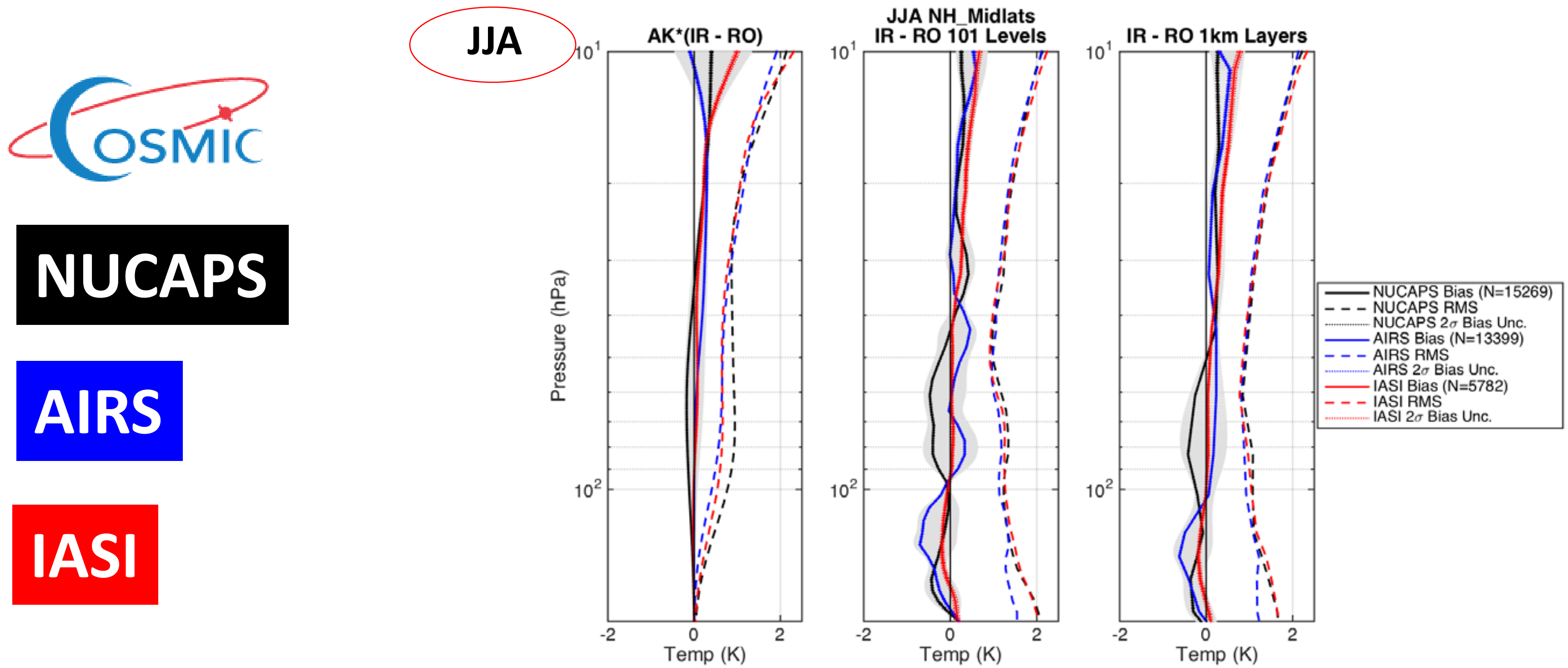
COSMIC & Operational Sounders Matchups

- **Comparisons of:**
  - COSMIC2013 vs. EUMETSAT **IASI B** v6 — 1 yr: May 2013-April 2014
  - COSMIC2013 vs. **AIRS v6** — 3 yr: May 2012-April 2015
  - COSMIC2013 vs. **NUCAPS** — 3 yrs: May 2012-April 2015
  - Updated COSMIC version 2013.3520 (climate and post processed versions) is used
- **Matchup Method**
  - IR raypath technique accounts for estimated RO horizontal resolution & geometry
  - 1 hr time criterion
- **Averaging Kernel (AK) Calculation**
  - AKs calculated for each matchup case for 15um region channels



COSMIC & Operational Sounders Matchups

IR-RO profiles



- Seasonal zonal IR-RO bias (solid), RMS (dashed)
- **NUCAPS, AIRS, IASI**
- 200-10 hPa region bounding where COSMIC & RO processing most accurate
- grey shading marks +/-2 stnd dev from mean of 3 different sounder biases
- averaging kernels applied (left), 101 levels (middle), 1km layers (right)

COSMIC & Operational Sounders Matchups

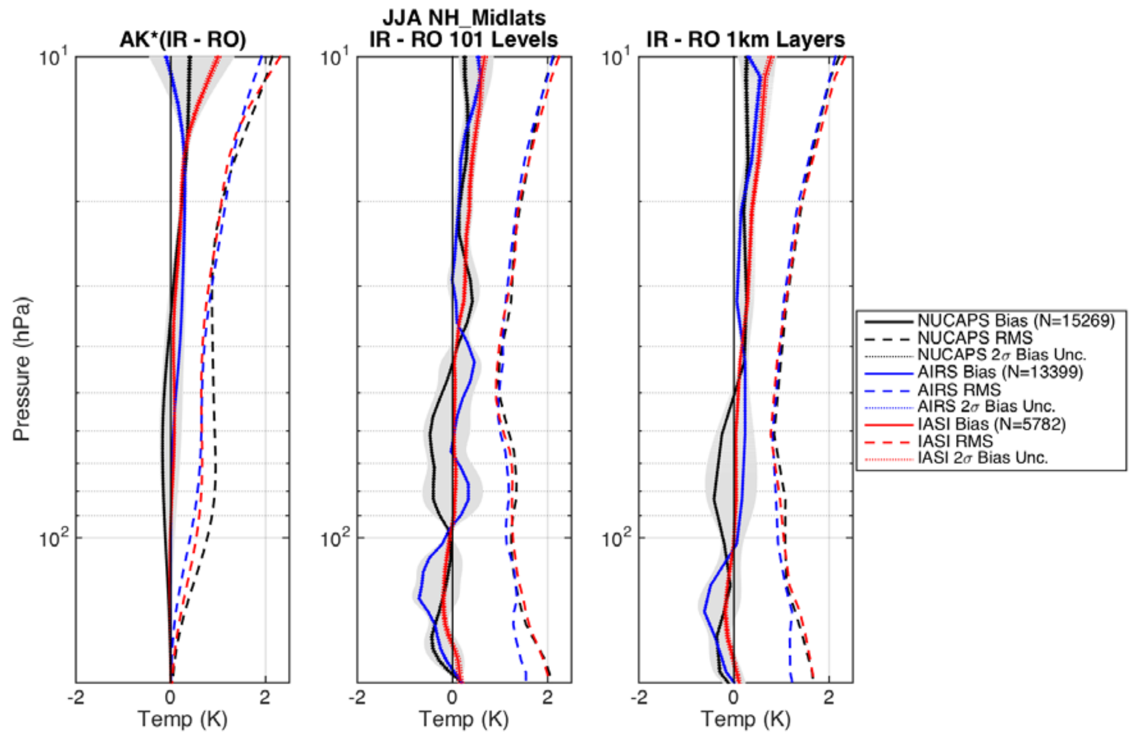
IR-RO profiles

NUCAPS

AIRS

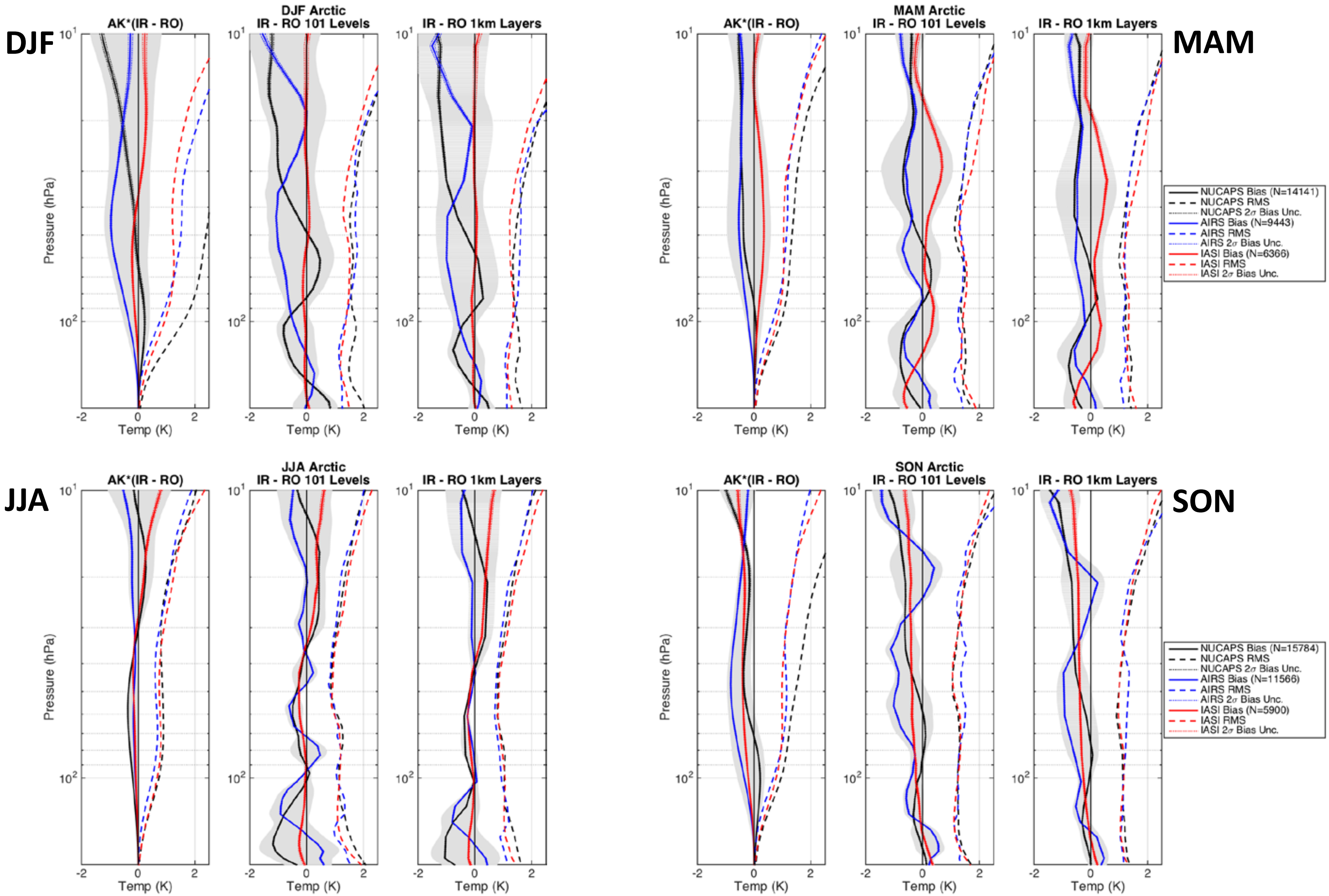
IASI

JJA



- AK reduces biases (solid) to within ~ 0.5K
  - True for most zones and seasons (excluding JJA & MAM Antarctic & DJF Arctic)
- AK RMS similar to those at 101 levels & are under ~2K and often below 1.5K below ~30hPa
- 1km layering reduces RMS (dashed) within 40-150 hPa region by over 0.25K
- 1km layering removes smaller magnitude vertical oscillations

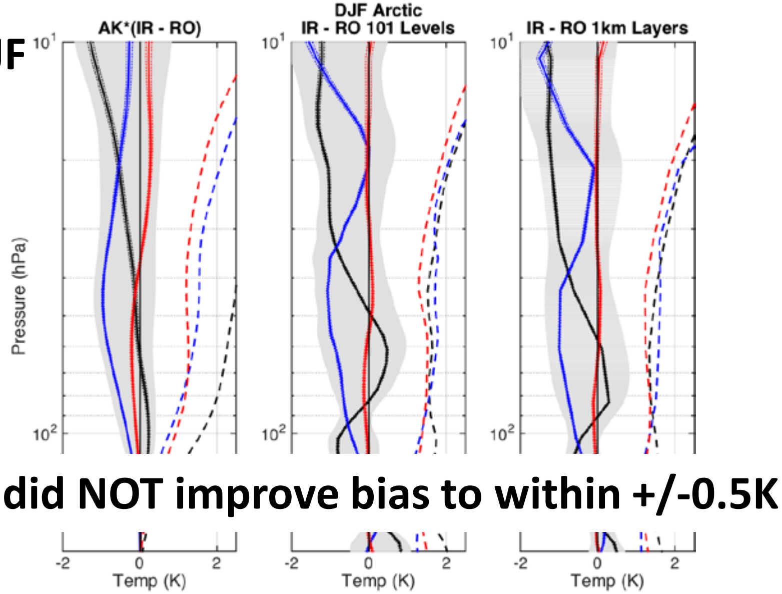
COSMIC & Operational Sounders Matchups: Arctic



courtesy of Michelle Feltz

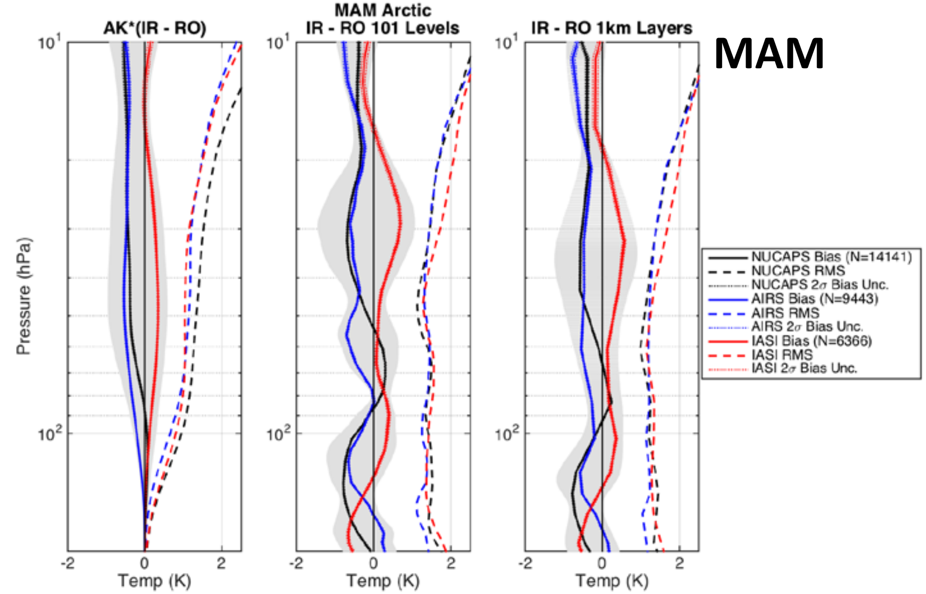
COSMIC & Operational Sounders Matchups: Arctic

DJF

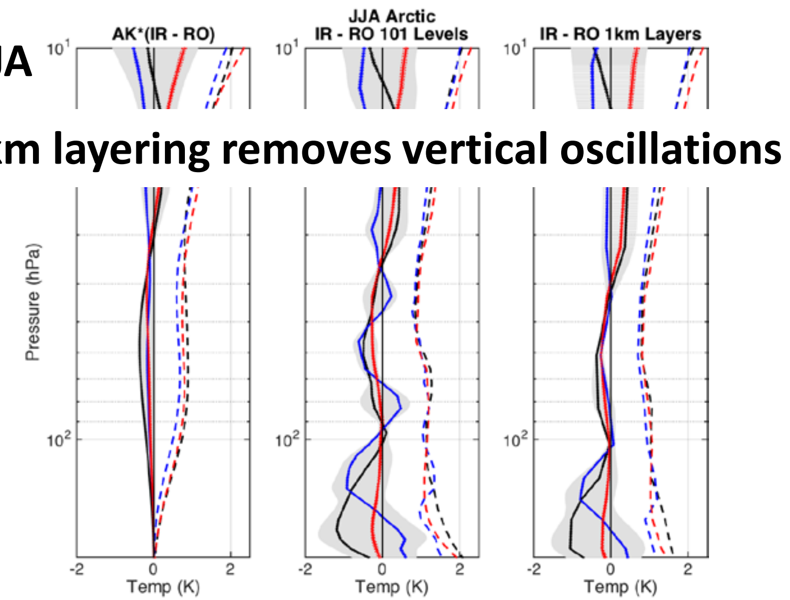


AK did NOT improve bias to within +/-0.5K

MAM

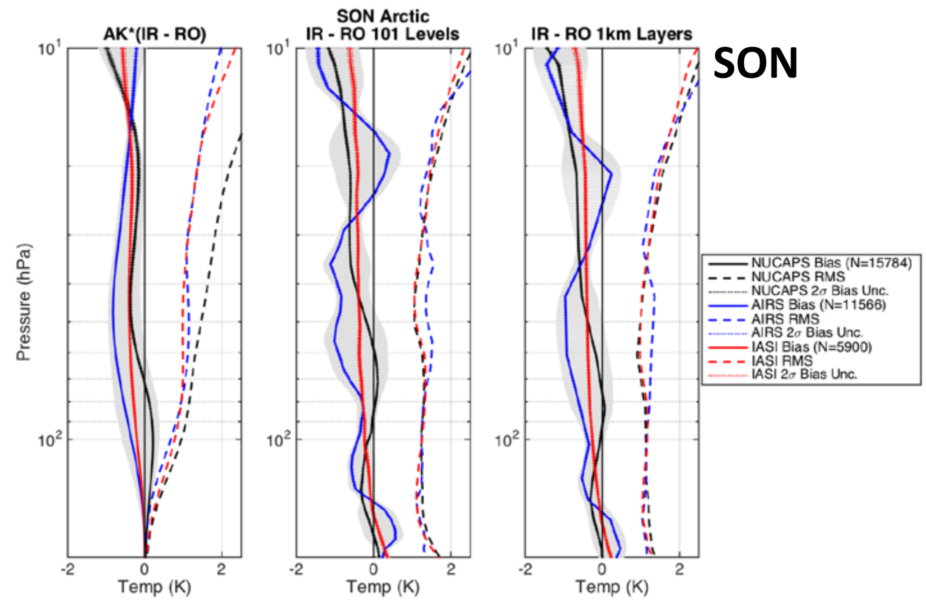


JJA

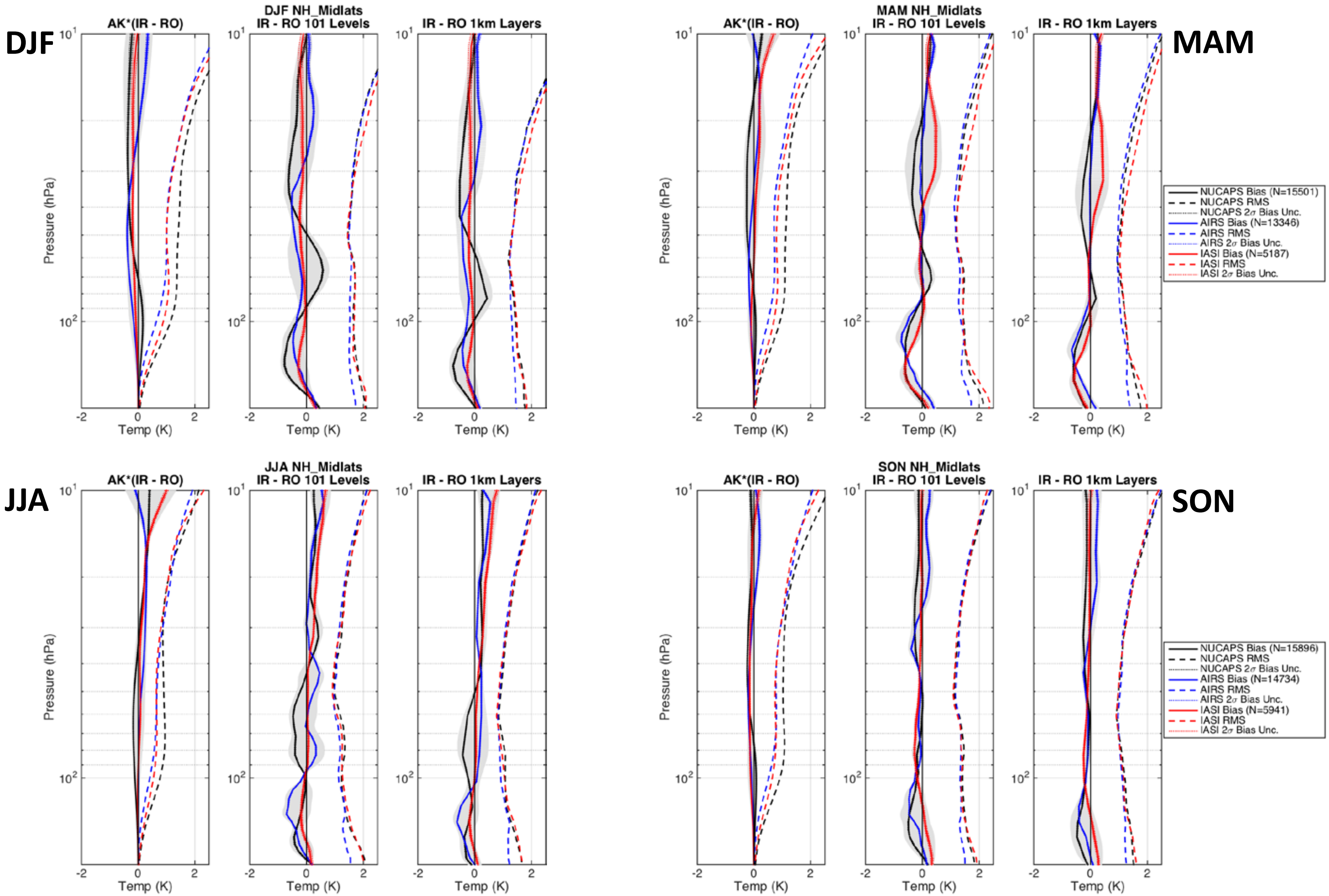


1km layering removes vertical oscillations

SON

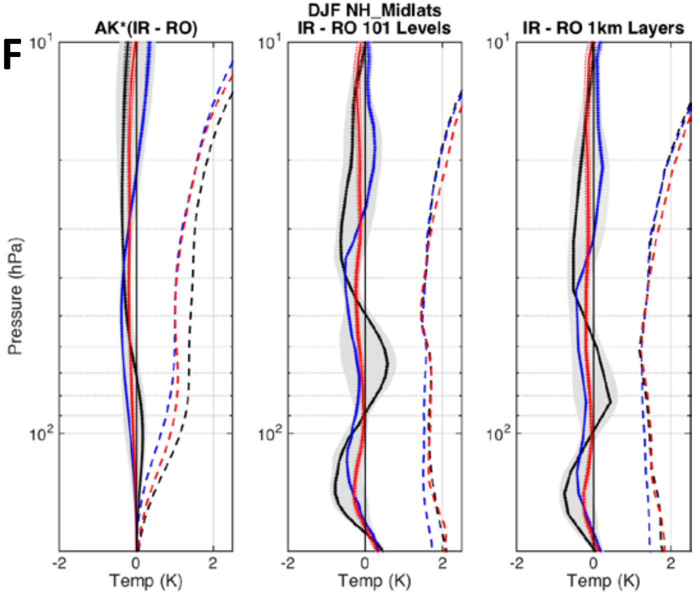


COSMIC & Operational Sounders Matchups: NH-Midlat

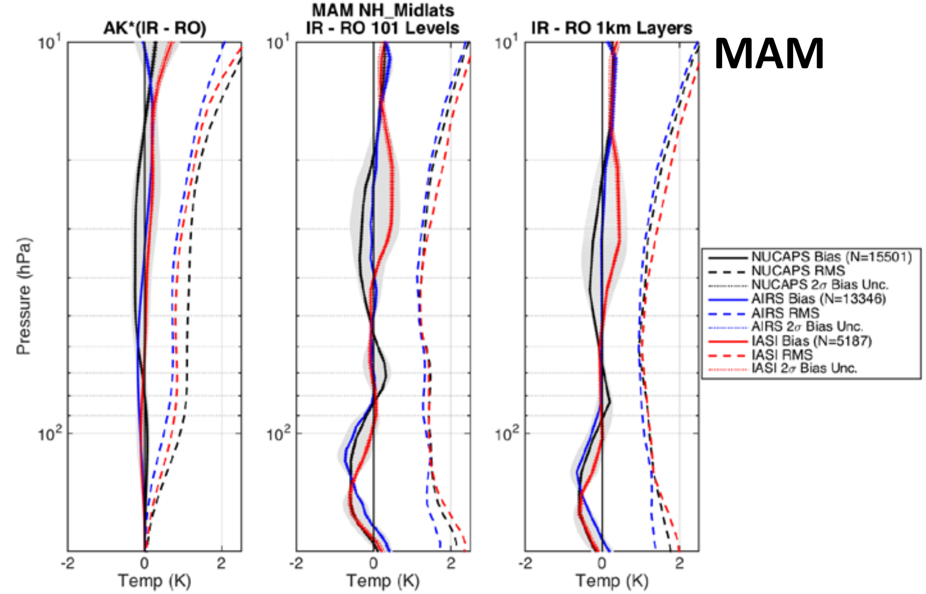


COSMIC & Operational Sounders Matchups: NH-Midlat

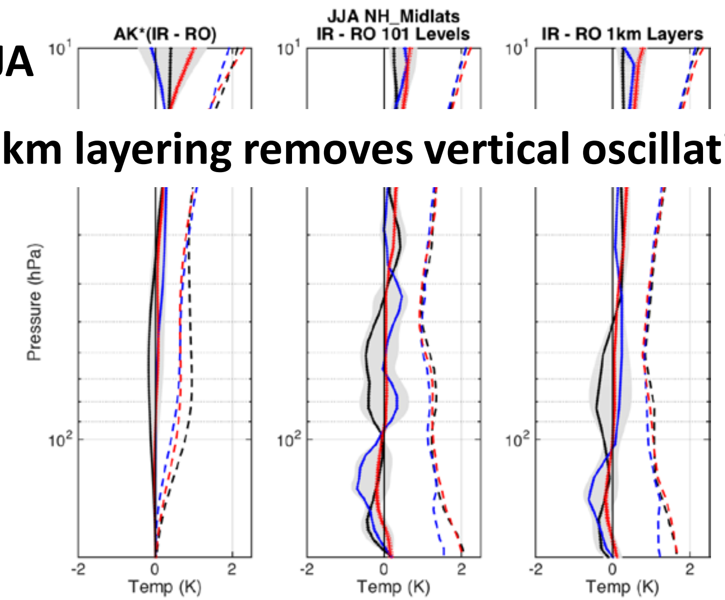
DJF



MAM

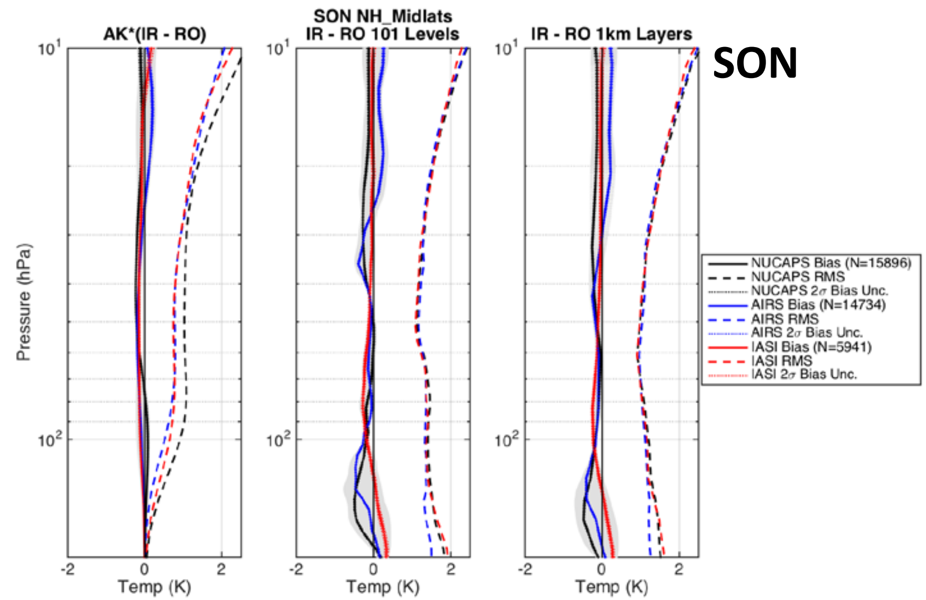


JJA



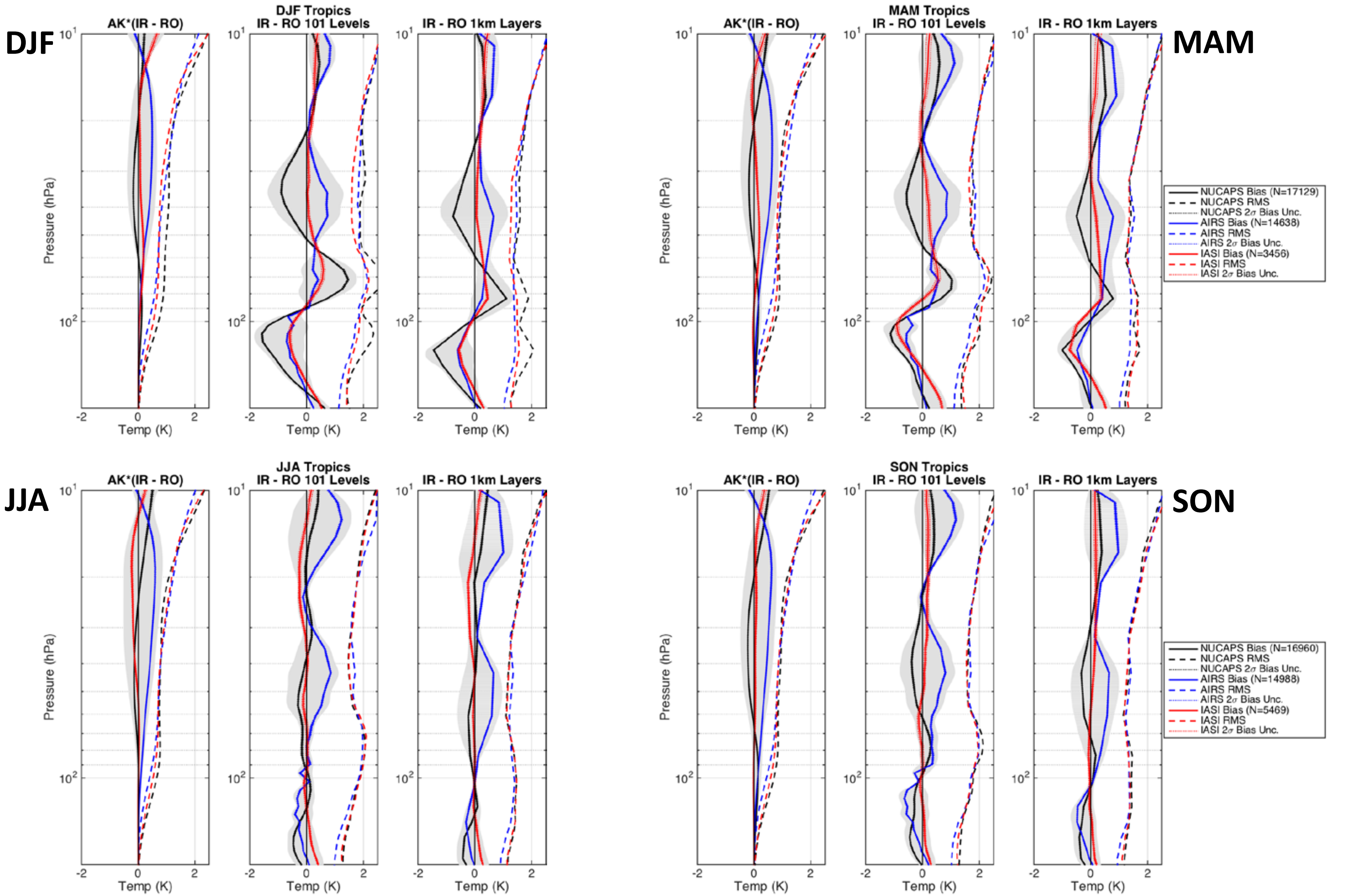
1km layering removes vertical oscillations

SON



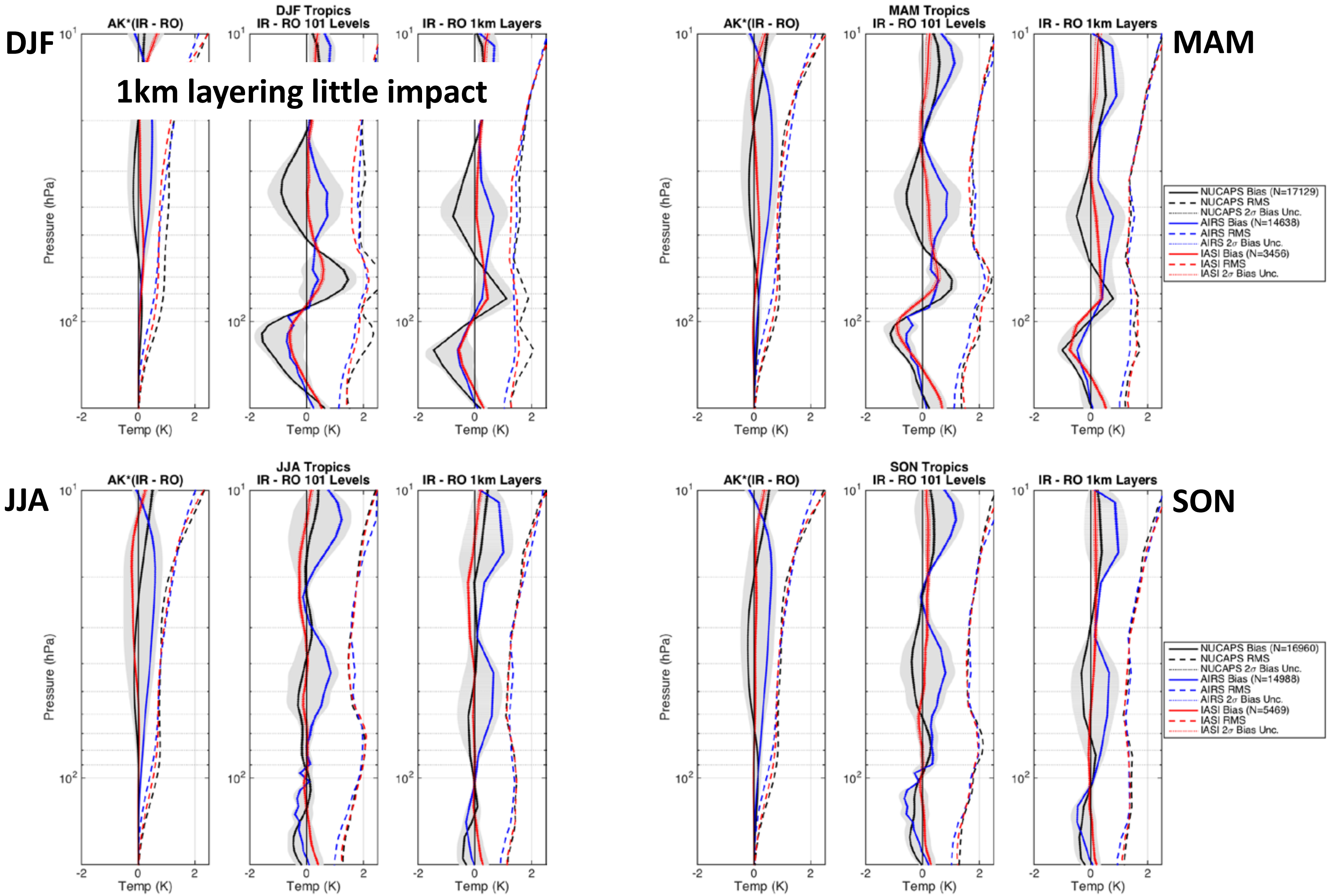
courtesy of Michelle Feltz

COSMIC & Operational Sounders Matchups: Tropics

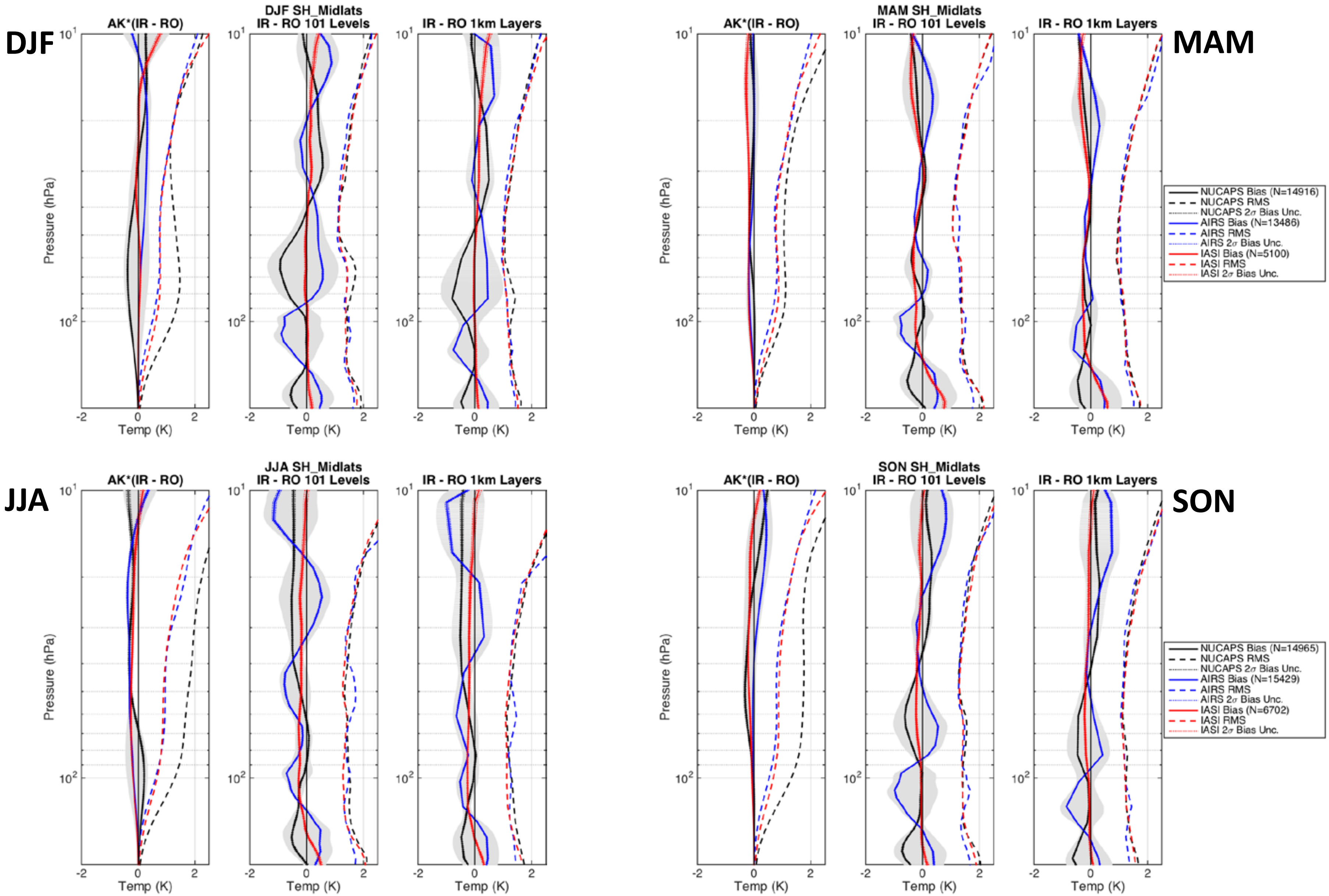


courtesy of Michelle Feltz

COSMIC & Operational Sounders Matchups: Tropics



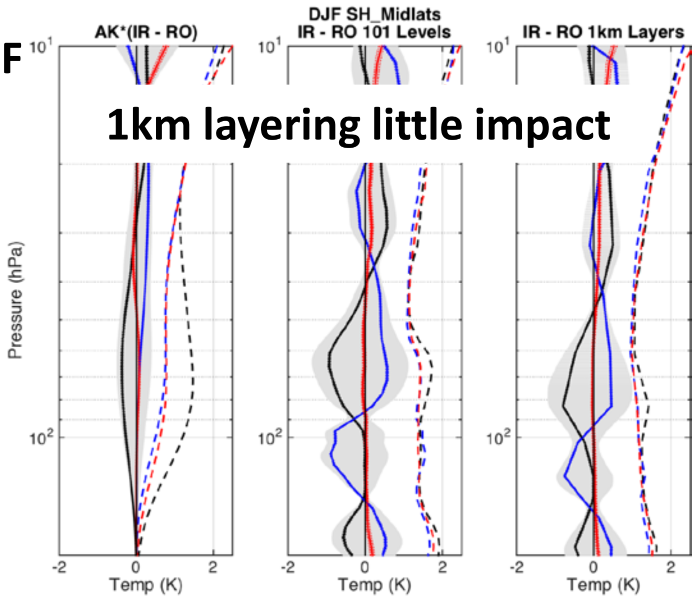
COSMIC & Operational Sounders Matchups: SH-Midlat



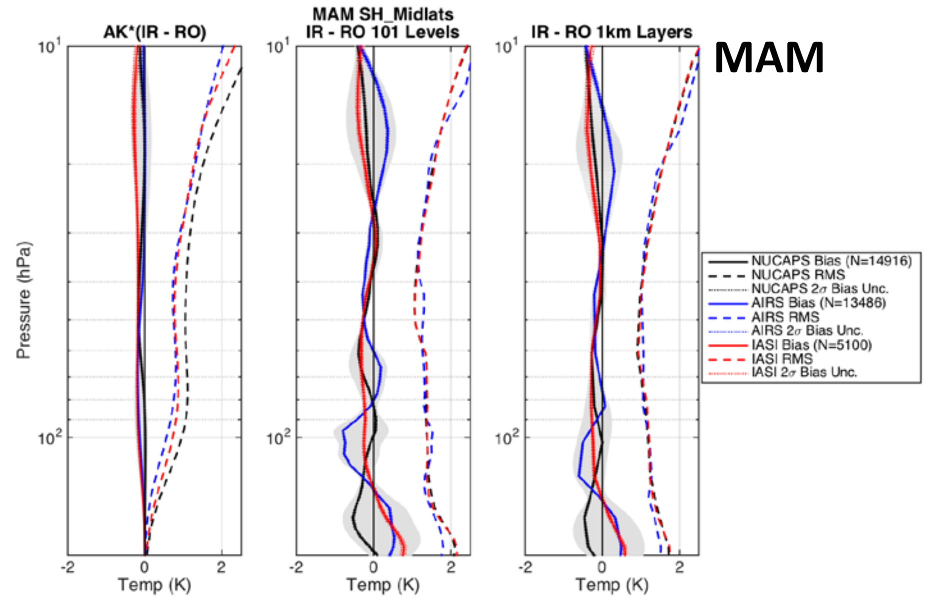
courtesy of Michelle Feltz

COSMIC & Operational Sounders Matchups: SH-Midlat

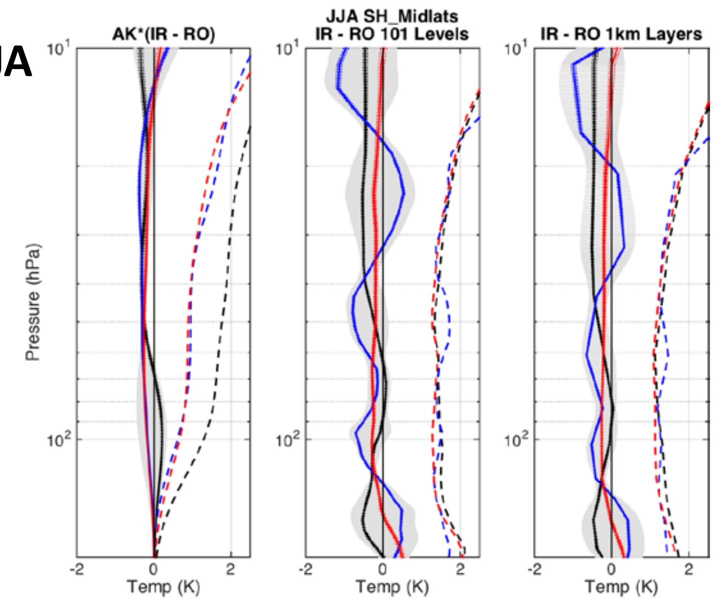
DJF



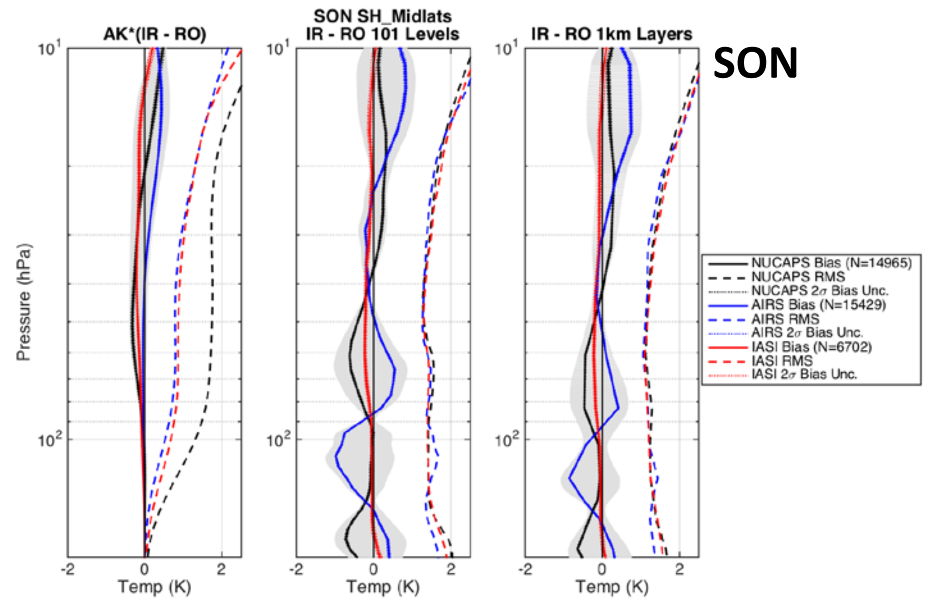
MAM



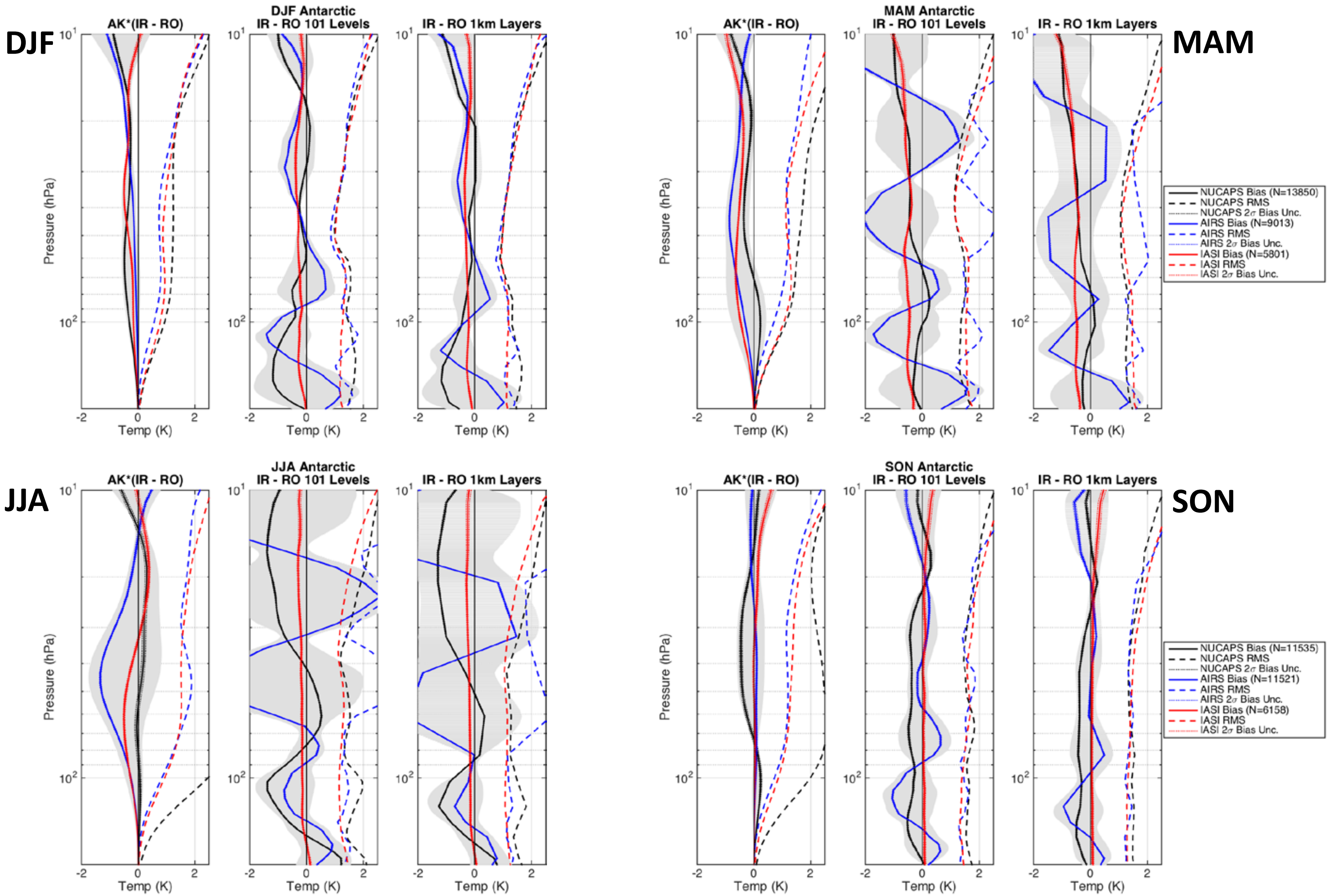
JJA



SON

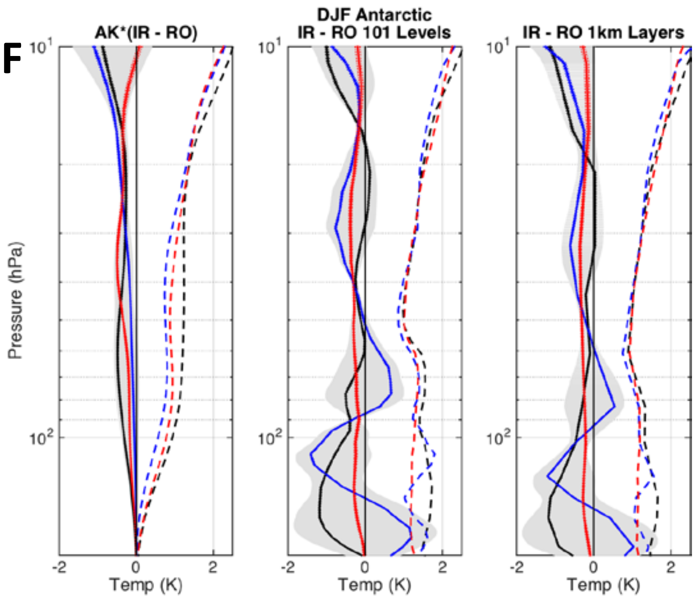


COSMIC & Operational Sounders Matchups: Antarctic

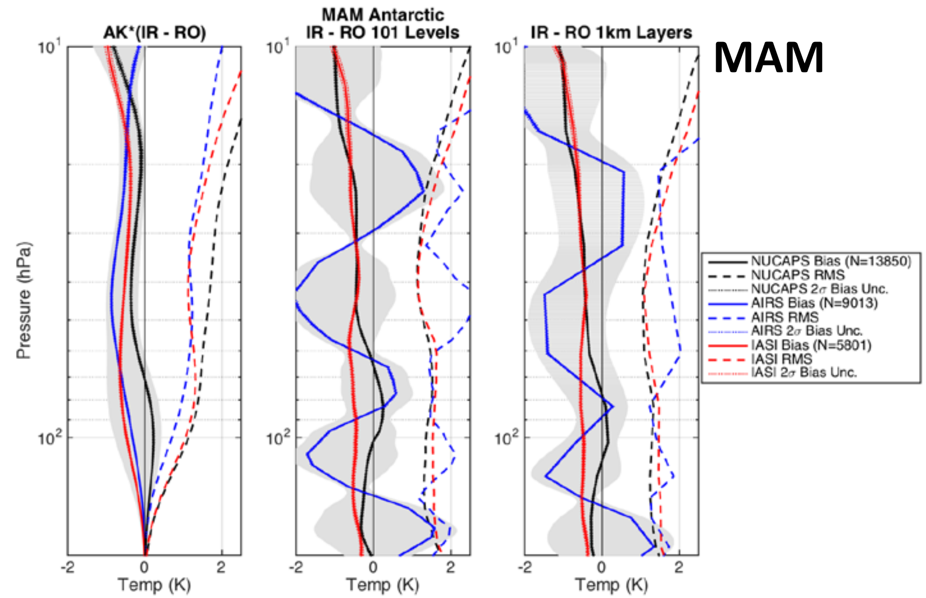


COSMIC & Operational Sounders Matchups: Antarctic

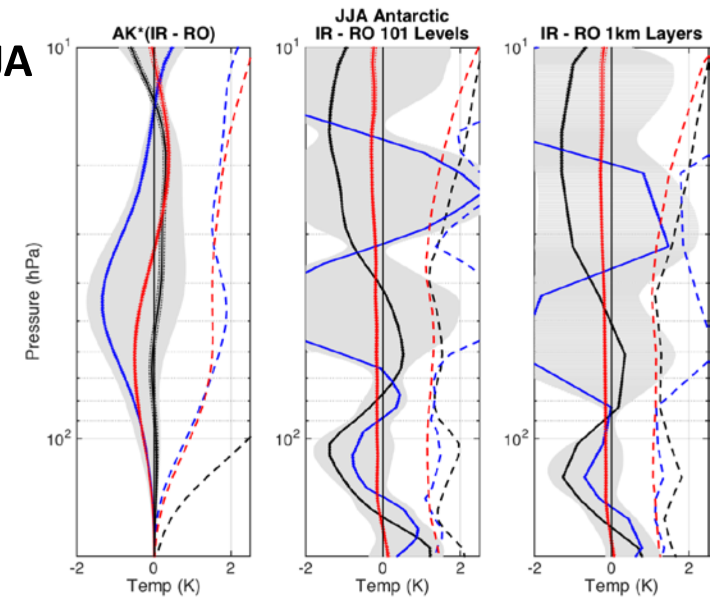
DJF



MAM



JJA



MAM & JJA:

- 1km layering little impact
- AK did NOT improve bias to within +/-0.5K
- AIRS (blue) non degraded results (center subplots) point to unphysical large vertical oscillation in AIRS temperature profiles

COSMIC & Operational Sounders Matchups

COSMIC NUCAPS AIRS IASI

Results:

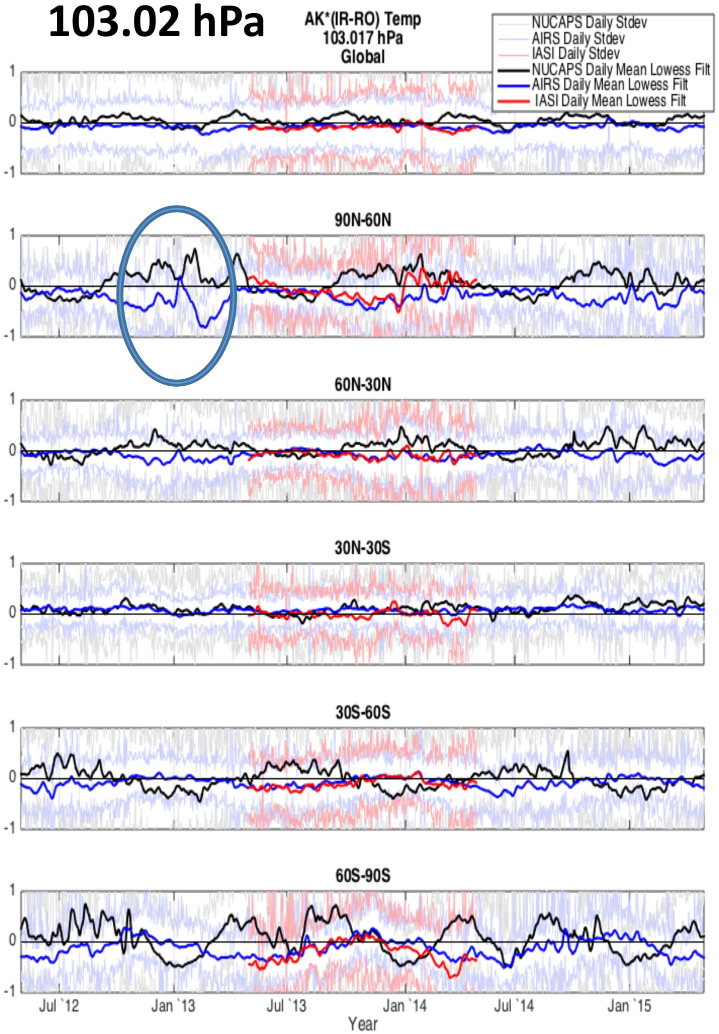
- Largest biases occur in the polar zones
- IASI in general has smaller biases then AIRS & NUCAPS
- For all zones the AK smoothed differences are within ~1K except for the JJA Antarctic
- RO and IR sounders on zonal scales are agreeing to within 1K. In some zones (e.g. Mid-lats) this agreement is even better (within ~0.5K)
- AK smoothed NUCAPS bias is well behaved and not far from ~0.25K below 30 hPa.
- For NUCAPS, the 1km DJF & MAM tropics region of largest differences

courtesy of Michelle Feltz

COSMIC/Operational Sounders Matchups:

- **Daily Mean Lowess Filter (AK smoothed temp biases)**

103.02 hPa

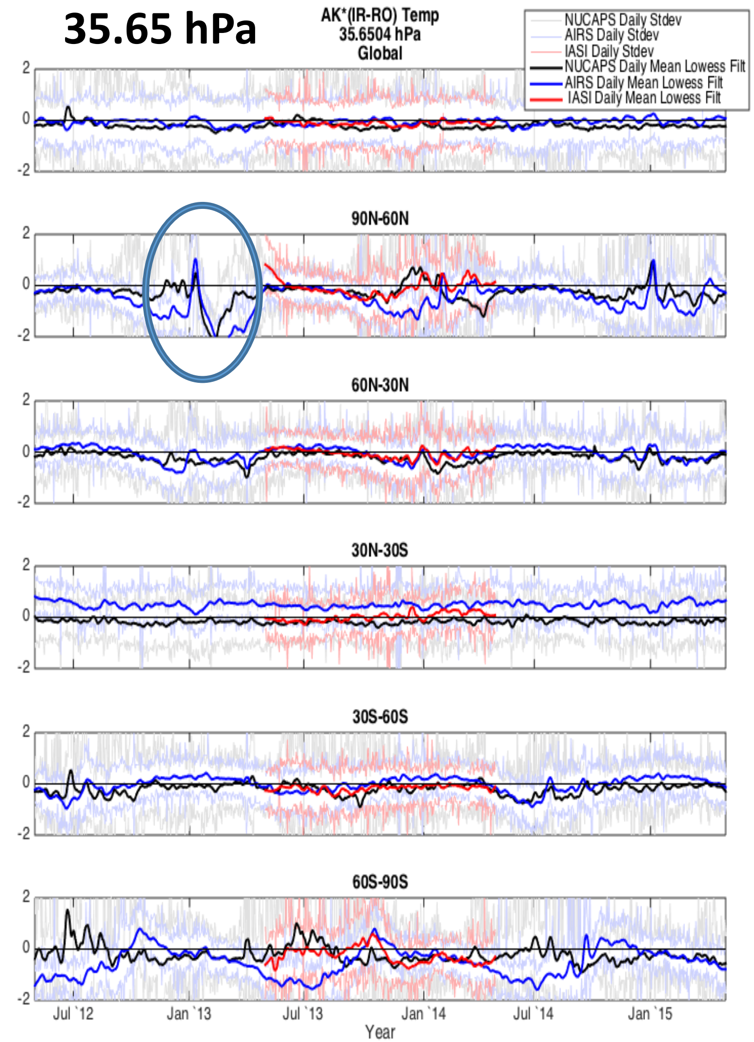


COSMIC is known to have a warm bias in polar winters, but nucaps is often warmer than cosmic in those locations

global and tropical panels show good (less than 0.3K?) agreement btwn RO and IR sounders

Polar zones reveal larger differences and some seasonal dependences of bias

35.65 hPa



Future Work:

- Phase-5 of radiosonde launches begins October 1, 2016
- Work towards synchronizing sonde launches w/COSGPS RO
- Continue working with GRUAN and ARM IOP
- Use NPROVS+ as repository for Best Estimates
- A Better Best Estimate
    - AERI OS
    - VIIRS cloud mask
    - OBS-CALCs using LBLRTM

NOAA/STAR JPSS Annual Science Team Meeting
August 8-12, 2016
College Park, MD

Assessment of NUCAPS S-NPP CrIS/ATMS Sounding Products Using Reference and Conventional Radiosondes

Bomin Sun[1,2], Tony Reale[2], Frank Tilley[1,2], Mike Pettey[1,2], Nick Nalli[1,2] and Chris Barnet[3]

1 I. M. Systems Group, Inc., Rockville, Maryland
2 NOAA/NESDIS/Center for Applications and Research (STAR), College Park, Maryland
3 Science and Technology Corp., Columbia, MD

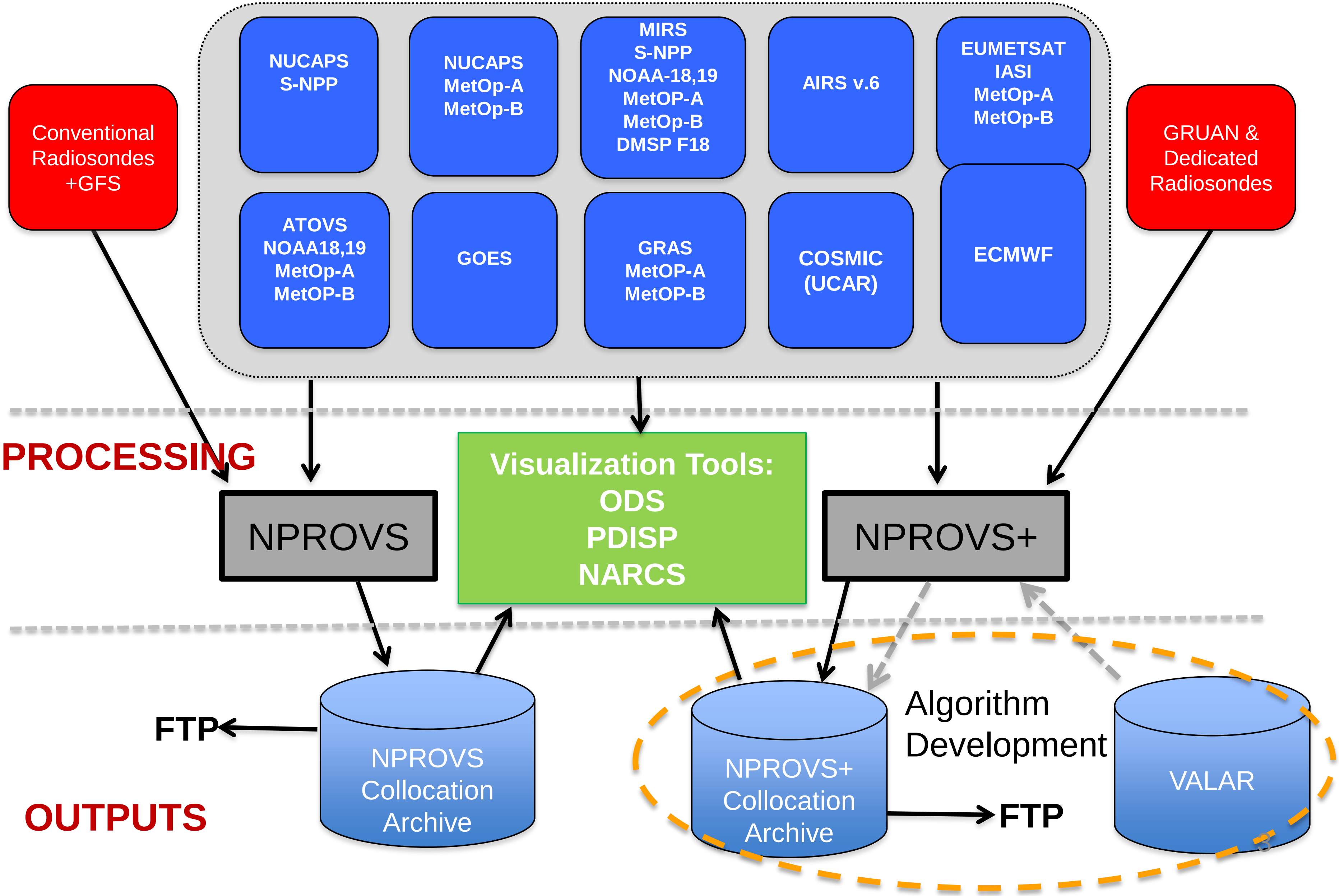
Outline

- The NOAA Products Validation System (NPROVS) & and its expansion (NPROVS+)

- Discussion on uncertainty arising from
  - Time/space mismatch in radiosonde and satellite observations
  - Radiosonde measurement accuracy
  - Radiosonde and satellite vertical resolution differences

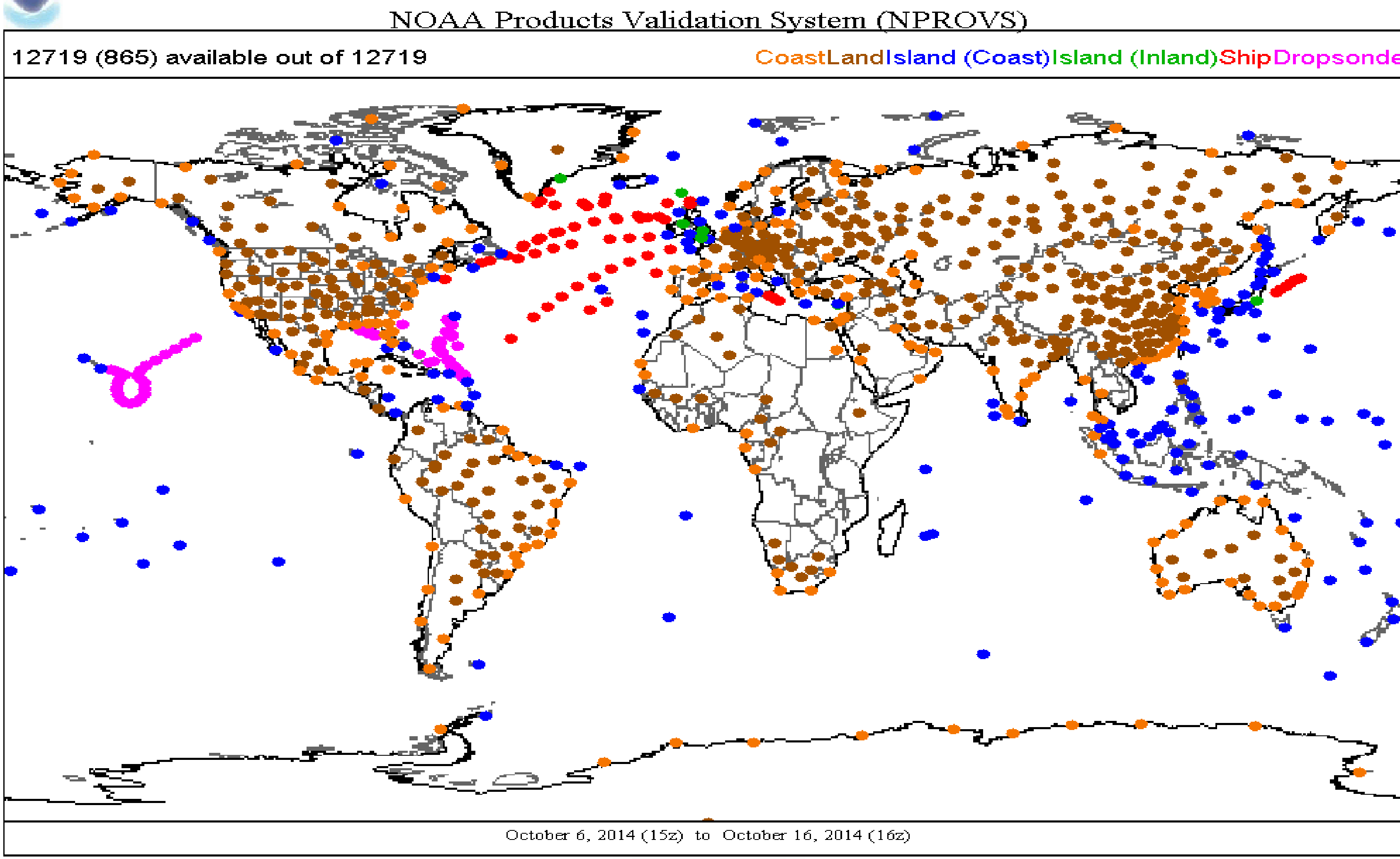
- Analysis of S-NPP CrIS/ATMS temperature and water vapor retrievals (IR+MW) based on collocations with Reference (3-yr) and conventional RAOBs (6 mons).
  - Global
  - Individual sites

NOAA Products Validation System: NPROVS and NPROVS+



STAR Center for Satellite Applications and Research
formerly ORA — Office of Research and Applications

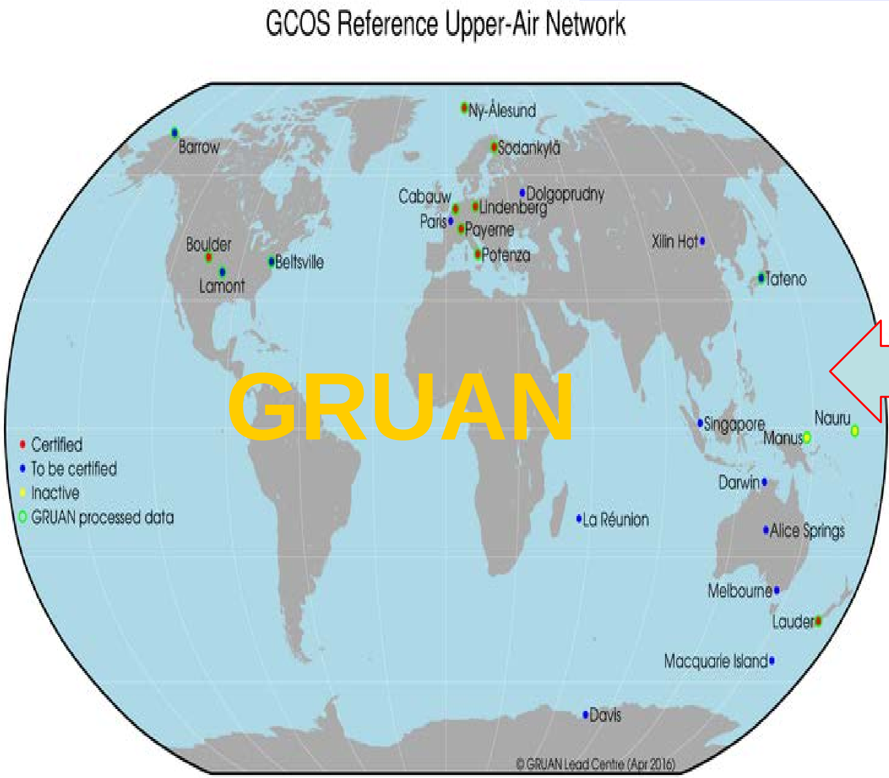
N P R O V S



Typical NPROVS Global Collocations (1000 per day)

Vaisala RS92 (28%), Vaisala RS41 (6%)

N P R O V S +: Reference RAOBs in satellite cal/val



Global Climate Observing System (GCOS)
Reference Upper Air Network (GRUAN)

JPSS Funded Dedicated RAOB

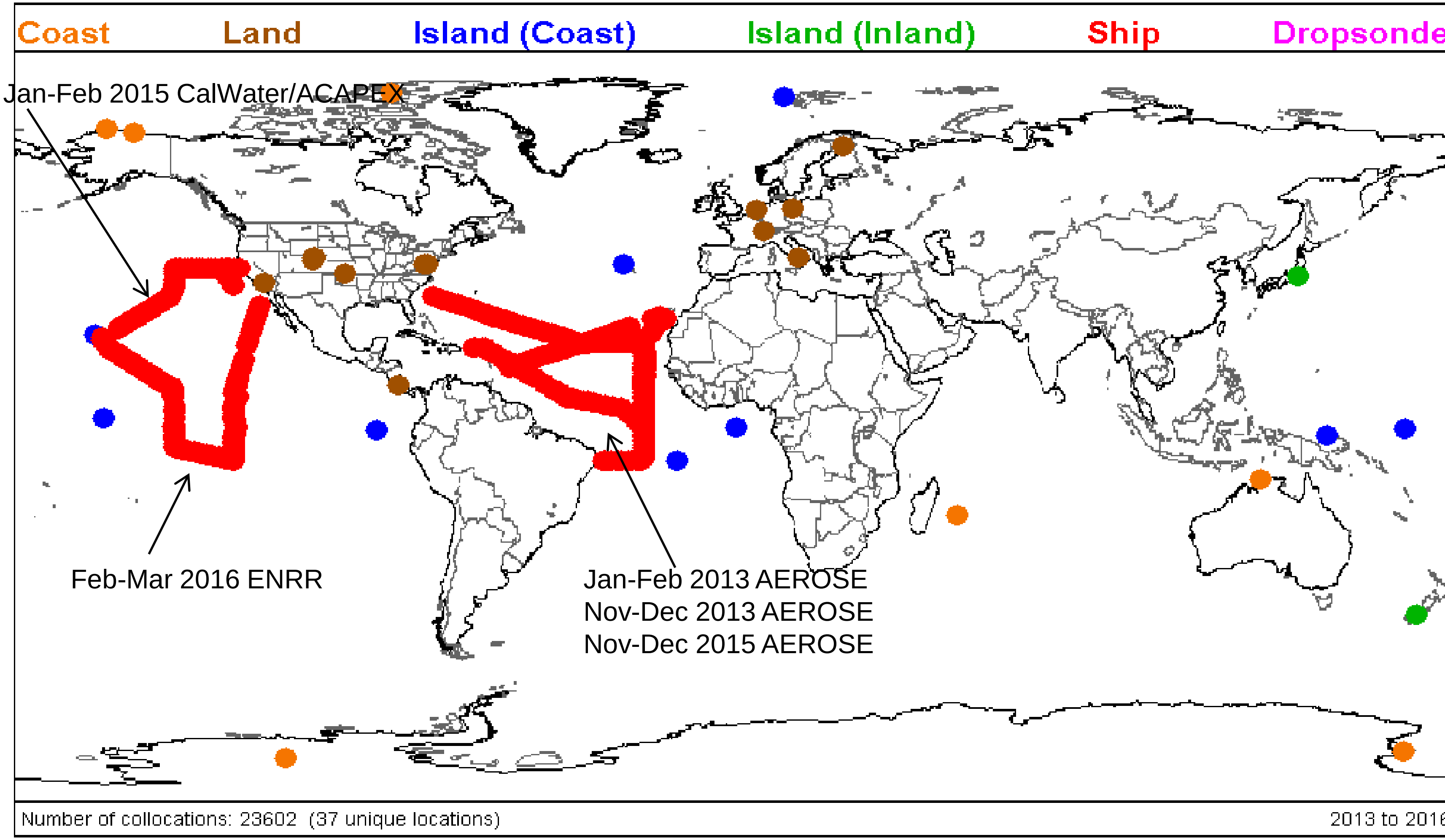
- DOE ARM (SGP, NSA, ENA)
  - ✓SSEC/Madison …
  - ✓(2) per week
  - ✓ dual vs single, etc
- AEROSE
- CALWATER
- El Nino Rapid Response
- **GRUAN processed**

Ongoing coordination with "other" field experiments particularly if synchronized with S-NPP

- Sterling Test Site
- ARM Mobile Sites
- CIRA/CSU

N P R O V S +

NOAA Products Validation System (NPROVS)



GRUAN and JPSS funded Dedicated (S-NPP) RAOB Sites

Of 23,600 RAOBs, 5,600 are synchronized (1373 via JPSS/ARM) since Jan 2013 thru Jun 2016

GRUAN/Dedicated radiosonde sites and date ranges January 2013 to mid-July 2016 (01)

RAOB Site	Date Range & Number of launches	Active
Ascension Island ARM site (ASCENS, 80)	2016-04-29 to (175)	yes
CIRA/CSU (CIRA, 114)	2016-05-06 to 2016-06-28 (18)	No
AWARE Antarctic ARM site (AWARE, 80)	2015-12-04 to 2016-01-18 (169)	No
Barrow, AK ARM site (70027, 272, 81, 80)	2013-07-01 to (2579)	Yes
Beltsville, MD (BELTSV,114, 80, 272)	2013-07-01 to (178)	Yes
Boulder, CO (BOULDE, 272)	2013-07-09 to (147)	Yes
Cabauw, Netherlands (06260, 272)	2013-07-01 to (1201)	Yes
Kritimati Island ENRR (CXENRR, 80)	2016-01-26 to 2016-03-13 (96)	No
Darwin, Australia ARM site (94120, 80)	2014-04-01 to 2015-01-14 (714)	No
Eastern North Atlantic Azores ARM site (GRACIO, 80)	2013-09-28 to (2086)	Yes
Lauder, New Zealand (LAUDER, 123)	2013-07-03 to (234)	Yes
Lindenberg, Germany (10393, 272)	2013-07-01 to (4357)	Yes
Manus Island, Papua New Guinea ARM site (92036, 272, 80)	2013-07-01 to 2014-07-06 (110)	No
McMurdo, Antarctica ARM site (89664, 80)	2015-11-30 to 2016-03-31 (364)	No

GRUAN/Dedicated radiosonde sites and date ranges January 2013 to mid-July 2016 (02)

RAOB Site	Date Range & Number of launches	Active
Nauru Island ARM site (91532, 272)	2013-07-01 to 2013-08-26 (717)	No
Ny-Alesund, Norway (01004, 272)	2013-07-01 to (1270)	Yes
Oliktok Point, AK ARM site (OLIKTO,80)	2013-09-10 to (944)	Yes
Payerne, Switzerland (06610, 272)	2013-07-02 to (106)	Yes
Potenza, Italy (16300, 272)	2013-12-19 to (73)	Yes
La Reunion Island, France ARM site (REUNIO, 272) Indian ocean away from Africa	2015-05-05 to 2016-05-28 (19)	No
San Cristobal Island, Ecuador (84008, 272) sea terrain	2013-07-26 to 2015-01-26 (142)	No
Southern Great Plains, OK ARM site (74646, 272, 80)	2013-07-01 to (4740)	Yes
Juan Santamaria, Costa Rica (78762, 272)	2013-07-11 to 2014-02-21 (39)	No
Sodankyla, Finland (02836, 272)	2013-07-03 to (2250)	Yes
Sterling, VA 71000 (81) 72403 (182) 72000 (152)	2015-10-28 to (724)	Yes
Tateno, Japan (47646, 272)	2013-07-01 to (296)	Yes
Table Mountain Facility, CA (TMFJPL, 272)	2014-12-05 to (27)	Yes
Pacific Missile Range Facility, HI (91162, 80)	2014-04-11 to 2014-04-26 (23)	No

GRUAN/Dedicated radiosonde sites and date ranges January 2013 to mid-July 2016 (03)

RAOB Site	Date Range & Number of launches	Active
Eureka, Northwestern terrority of Canada (71917, 272)	2013-01-10 to 2013-02-13 (17)	No
AEROSE Jan-Feb 2013	2013-01-09 to 2013-02-13 (109)	No
AEROSE Nov-DEC 2013	2013-11-12 to 2013-12-07 (96)	No
AEROSE Jan-Feb 2015	2015-11-17 to 2015-12-13 (90)	No
CalWater/ACAPEX Jan-Feb 2015	2015-01-12 to 2015-02-10 (171)	No
ENRR Feb-Mar 2016	2016-02-16 to 2016-03-16 (166)	No

Roles of NPROVS in sounding EDR cal/val

- Routine product monitoring (e.g., anomaly/outlier detection and long-term stability).
- Characterize product performance in a variety of meteorological conditions.
- Identify problem areas in retrieval algorithm in support of algorithm development.
- Provide independent oversight for operational product implementation.
- Provide support to AWIPS for NUCAPS applications in severe weather detection and prediction.

Outline

- The NOAA Products Validation System (NPROVS) & and its expansion (NPROVS+)

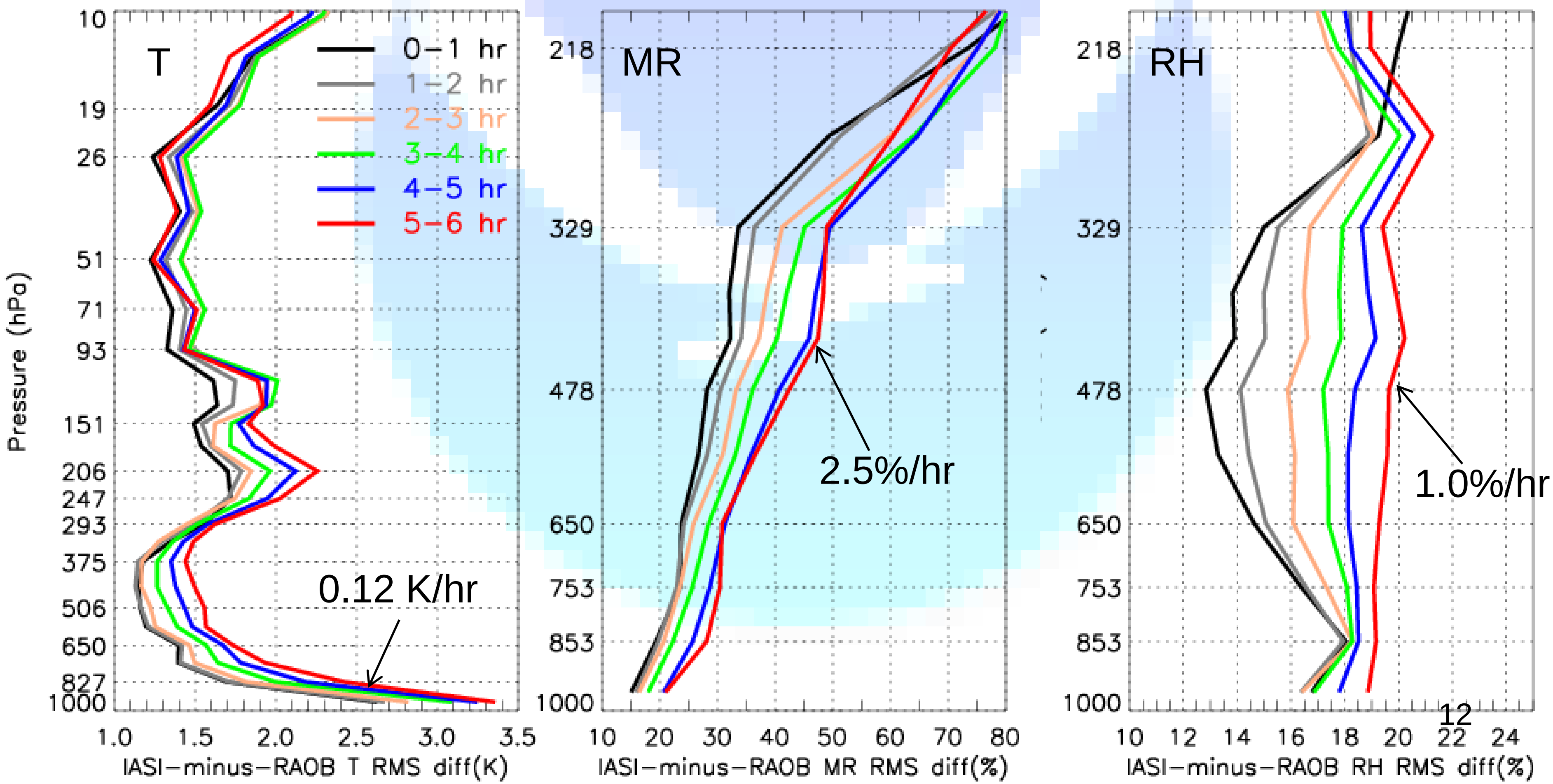
- **Discussion on uncertainty arising from**
  - **Time/space mismatch in radiosonde and satellite observations**
  - **Radiosonde measurement accuracy**
  - **Radiosonde and satellite vertical resolution differences**

- Analysis of S-NPP CrIS/ATMS temperature and water vapor retrievals (qc-accepted IR+MW)
  - Global collocations
  - Individual sites

Satellite-RAOB Time Mismatch Impact

RMS error changes with time mismatch

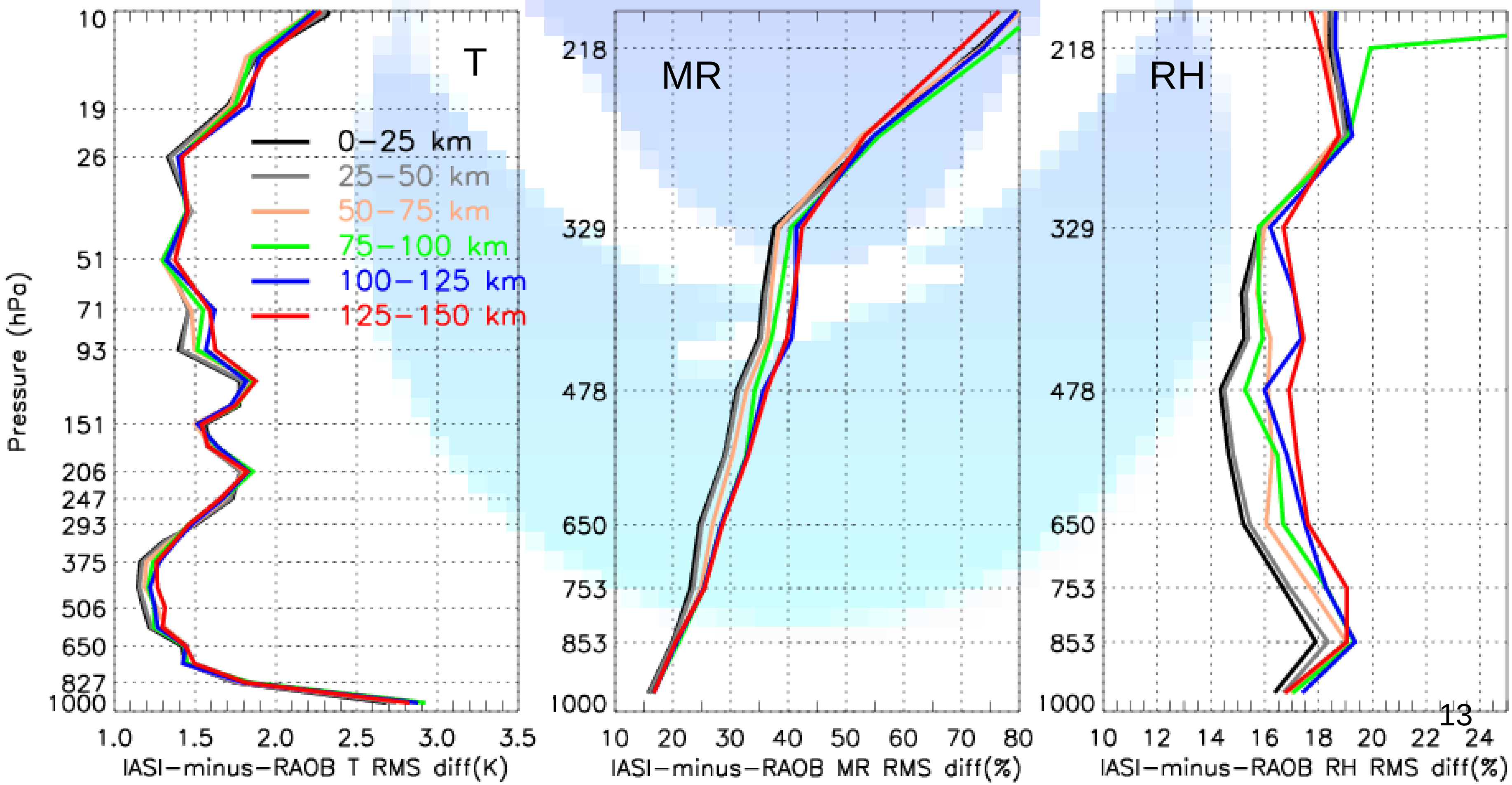
- Based on the analysis of 3-yr global IASI-RAOB collocations (506,354)



Satellite-RAOB Distance Mismatch Impact

RMS error changes with distance mismatch

- Based on the analysis of 3-yr global IASI-RAOB collocations (506,354)

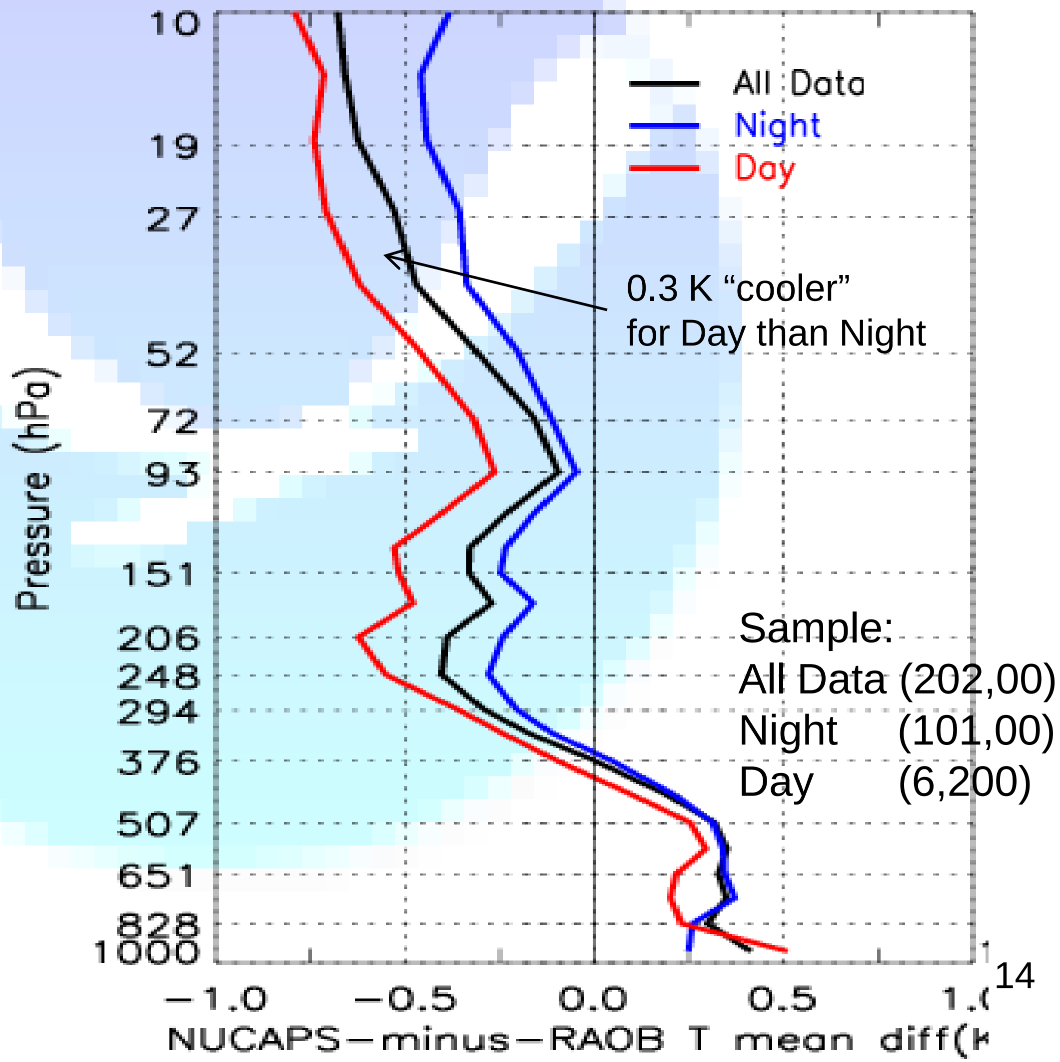


Radiosonde temperature radiation bias impact

- **Radiosondes tend to have a radiation induced warm bias in the UTLS during daytime.**

- **The RAOB T bias at 10-70 hPa is 0.18 K for all-the –day and 0.39 K for daytime (Sun et al., JGR 2013)**

NUCAPS S-NPP IR+MW - minus - RAOB

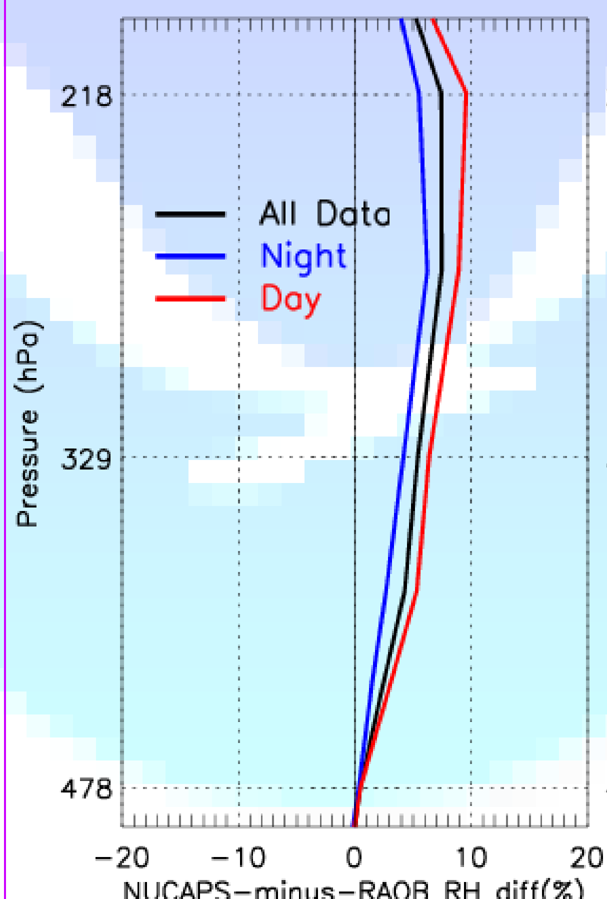


Radiosonde Humidity Dry Bias Impact

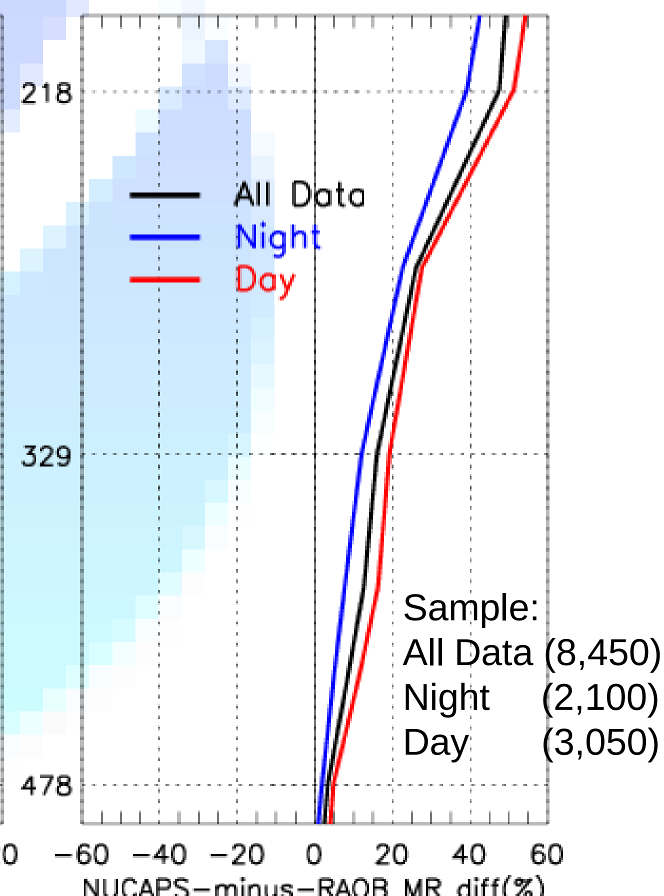
(Vaisala RS92 as an example *vs* S-NPP NUCAPS IR+MW)

- **Most radiosondes tend to have a dry bias in the UTLS particularly daytime.**
- **The RAOB RH bias at 300 hPa is ~7% for Day and ~3% (Sun et al., JGR 2011)**

NUCAPS-minus-RAOB **RH**

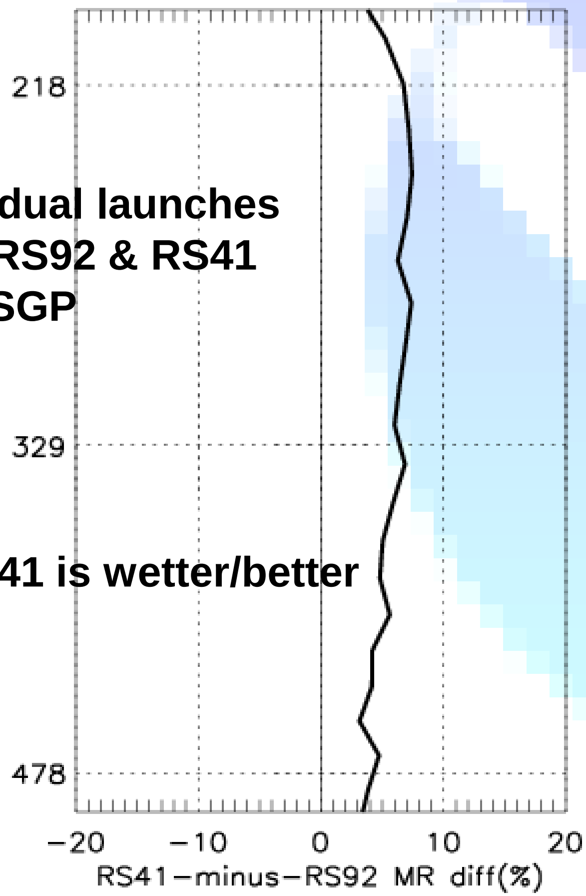


NUCAPS-minus-RAOB **MR %**



RS41 Improvement over RS92

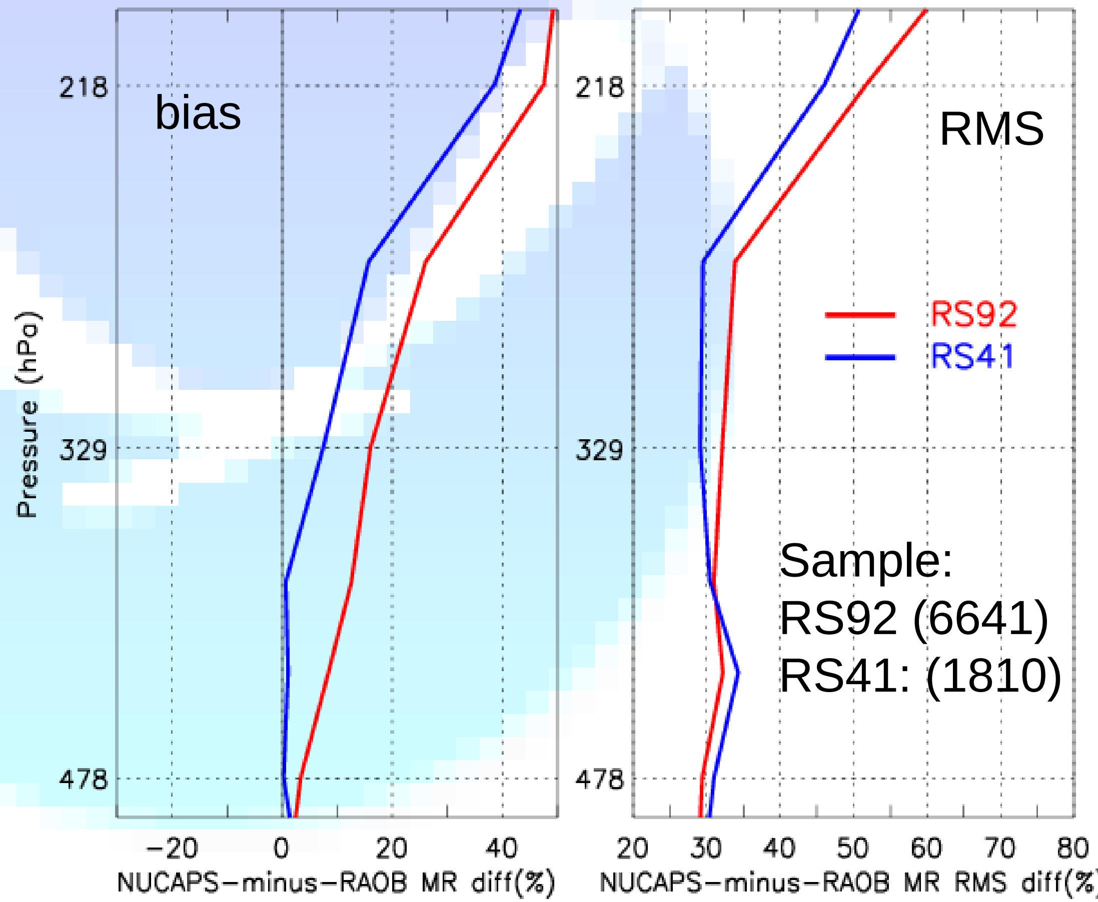
RS41-minus-RS92 MR %



20 dual launches of RS92 & RS41 at SGP

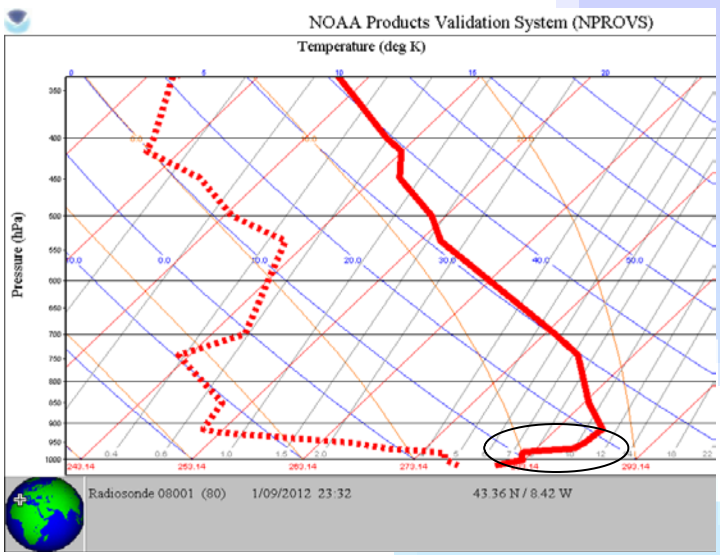
RS41 is wetter/better

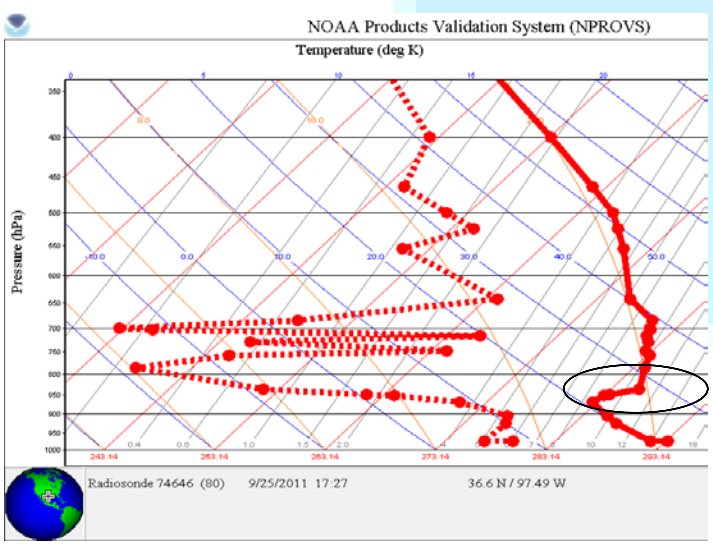
S-NPP IR+MW - minus - RAOB MR (%)

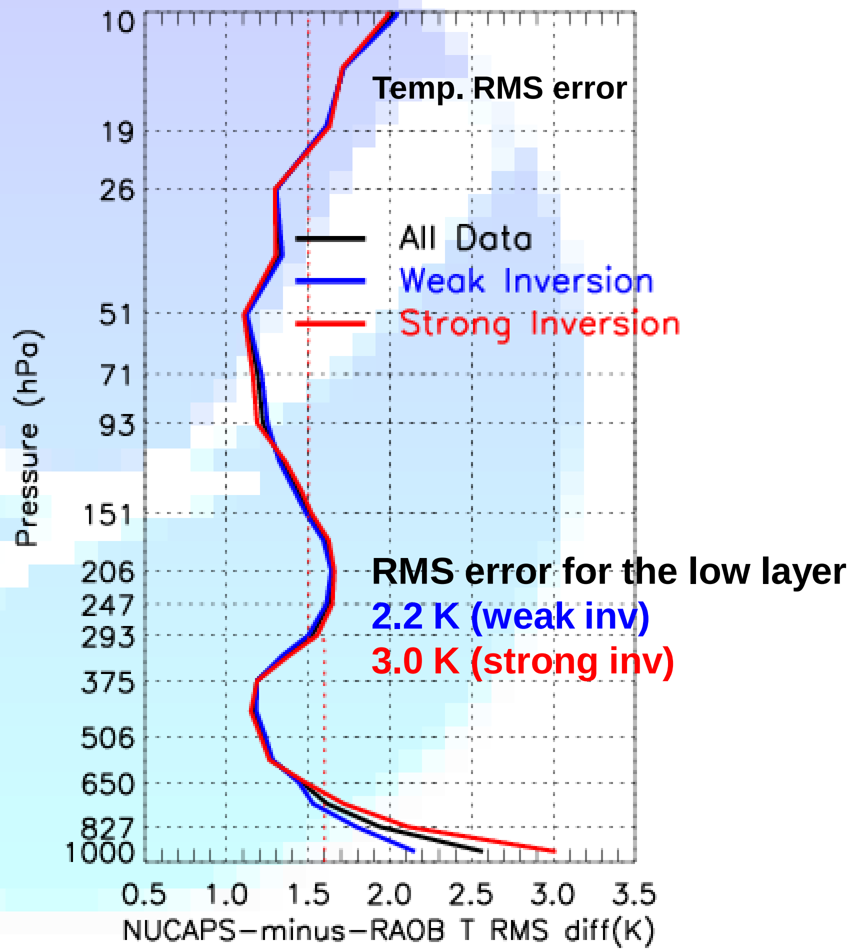


Radiosonde *vs.* Satellite Vertical Sensitivity Impact

(example of Temp inversion)





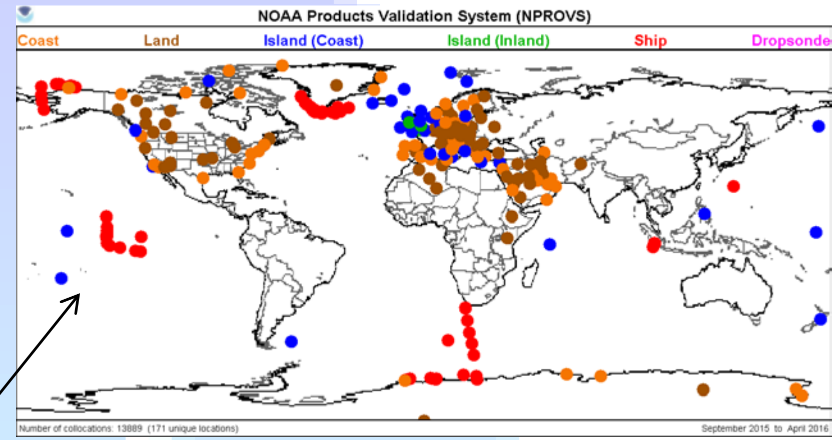


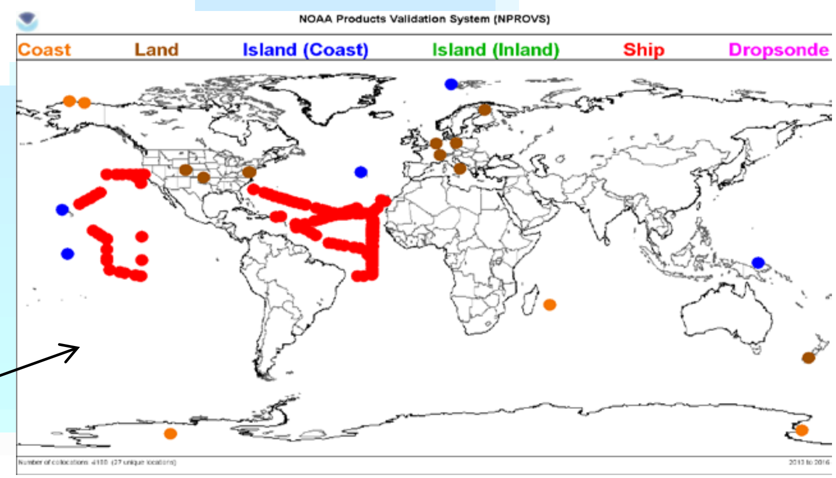
Sample:
Strong inv (13,500)
Weak inv (10,500)

Datasets used for S-NPP NUCAPS retrieval analysis

- NUCAPS-RAOB collocation data
  - Time mismatch: <1 hr
  - Distance mismatch: < 50 km
- Sonde types
  - Vaisala RS92 and RS41 **(conventional)**
  - Vaisala RS92 **(Reference)**

- **Conventional RAOBs (NPROVS, 6 mons)**
  - 14, 000 (global), 255 (sea)
- **Reference RAOBs (NPROVS+, 3 yrs)**
  - 4, 200 (global), 167 (sea)





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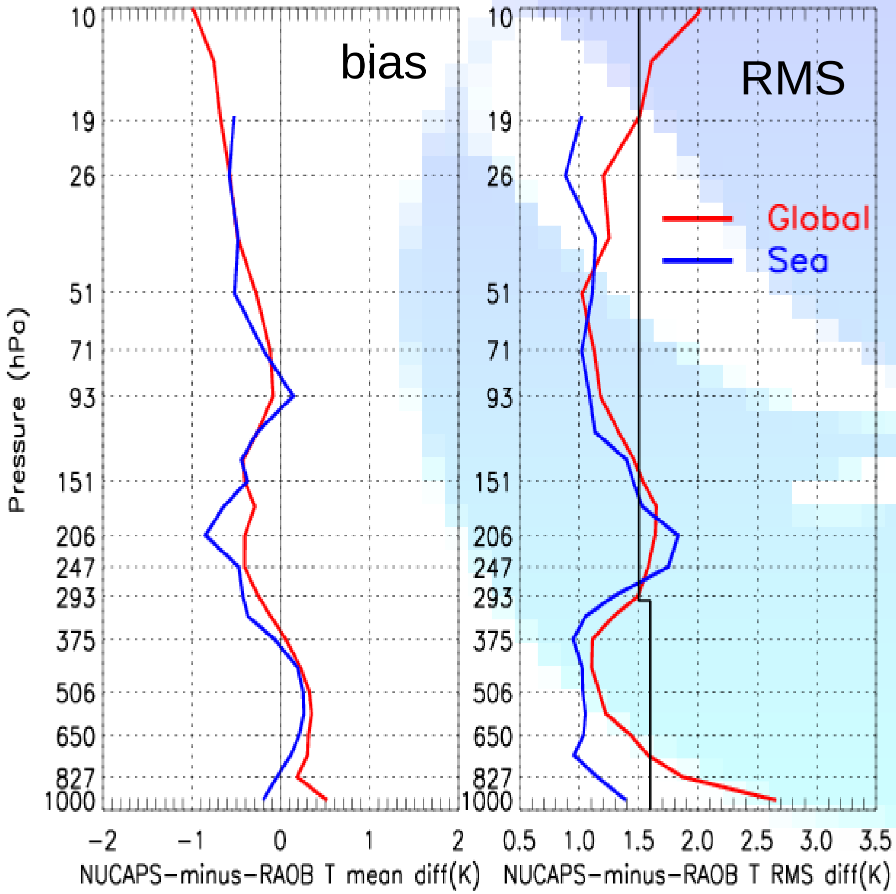
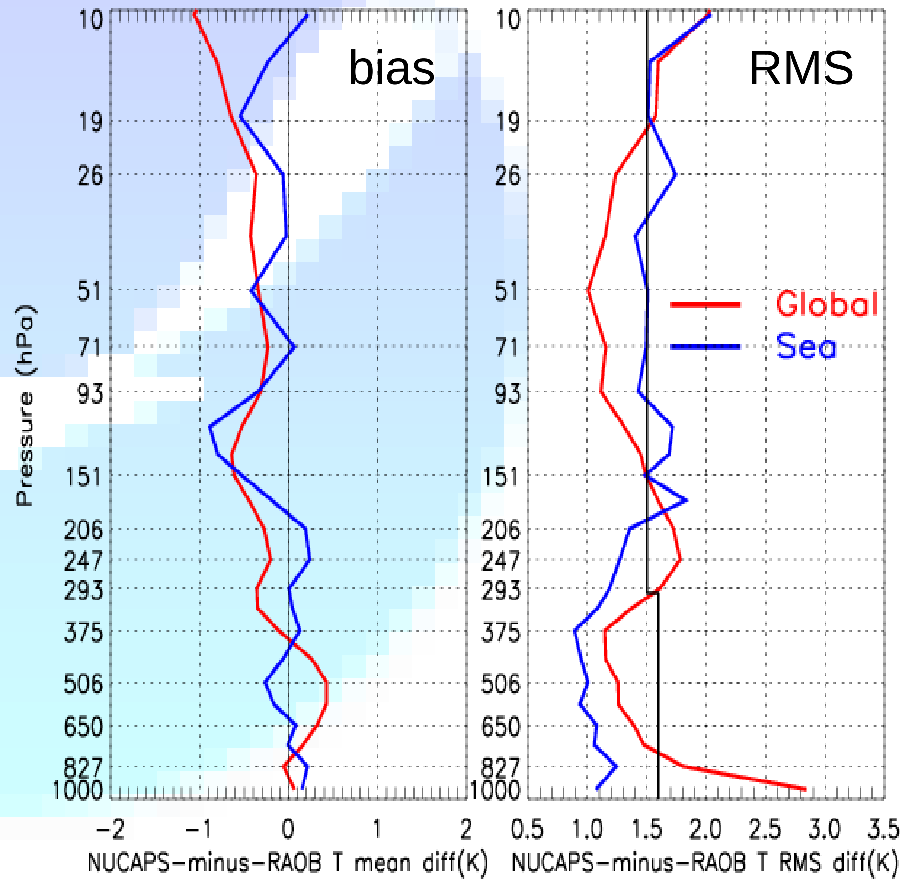
S-NPP NUCAPS IR+MW Temperature Statistics (K)

Relative to **Conventional** RAOBs



8881 (global), 101 (sea)

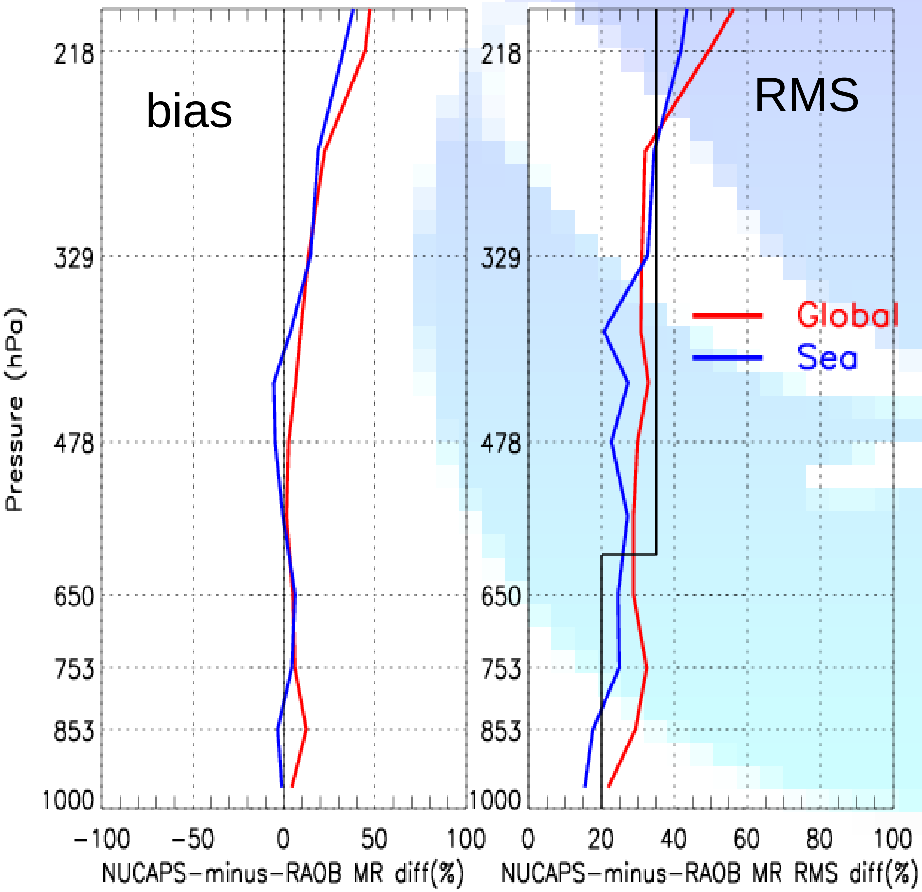
Relative to **Reference** RAOBs



3074 (global), 167 (sea)

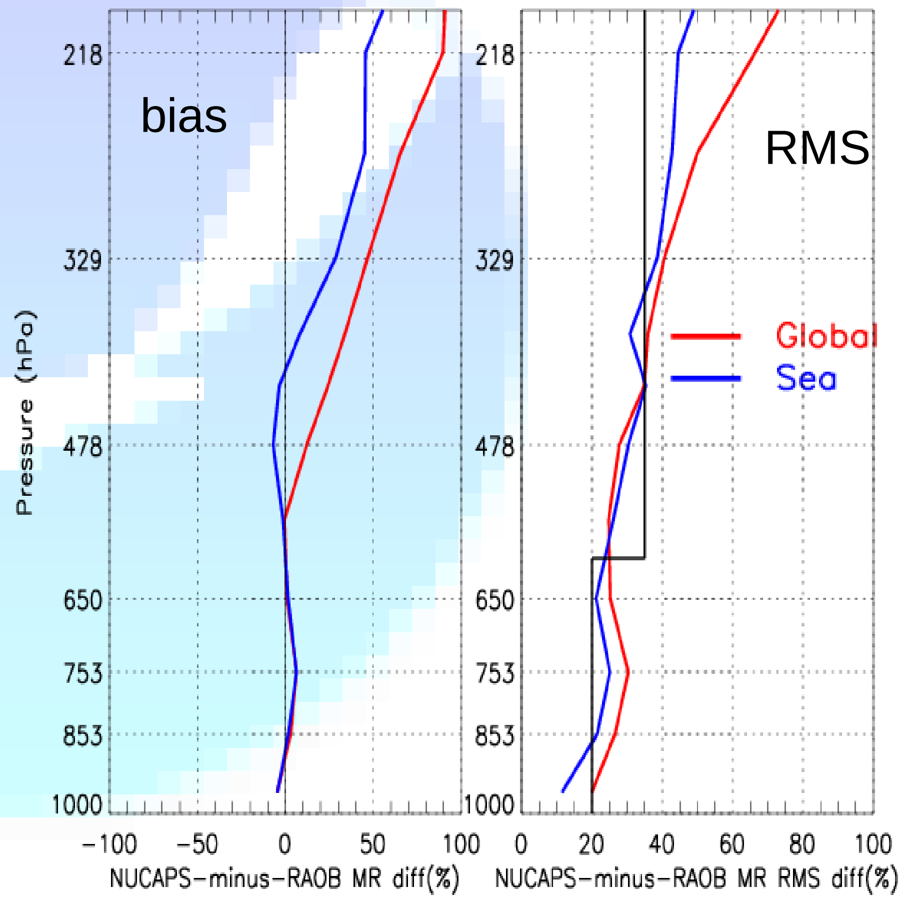
S-NPP NUCAPS IR+MW H20 Vapor MR Statistics (%)

Relative to **Conventional** RAOBs



8881 (global), 101 (sea)

Relative to **Reference** RAOBs



3074 (global), 167 (sea)

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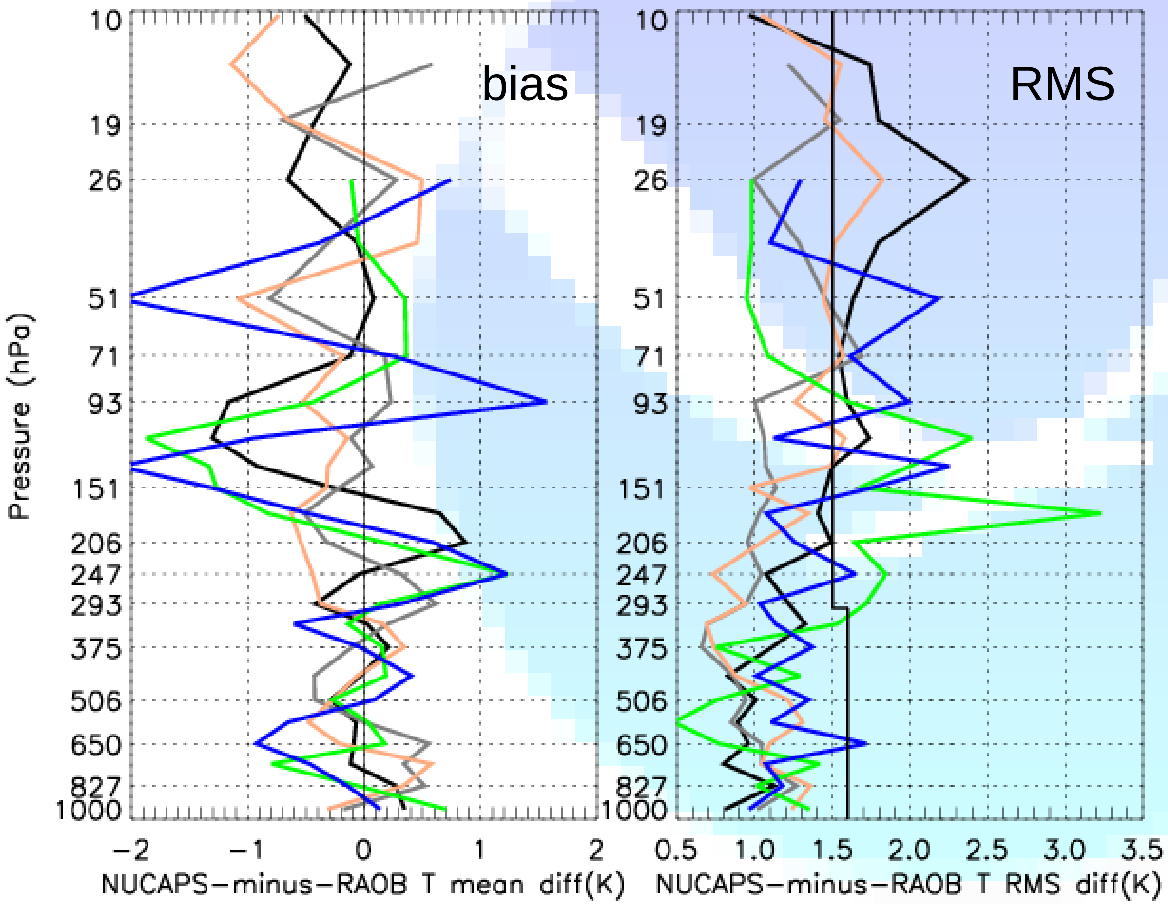
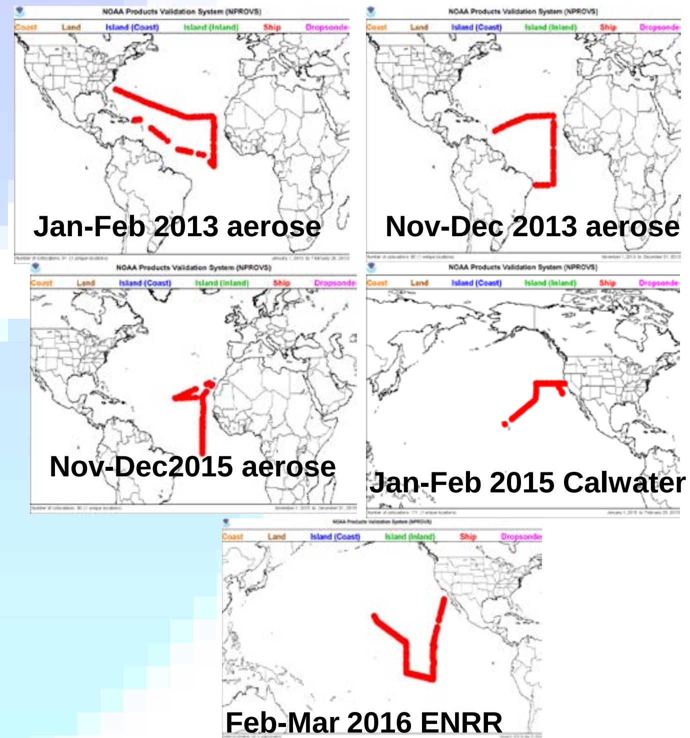
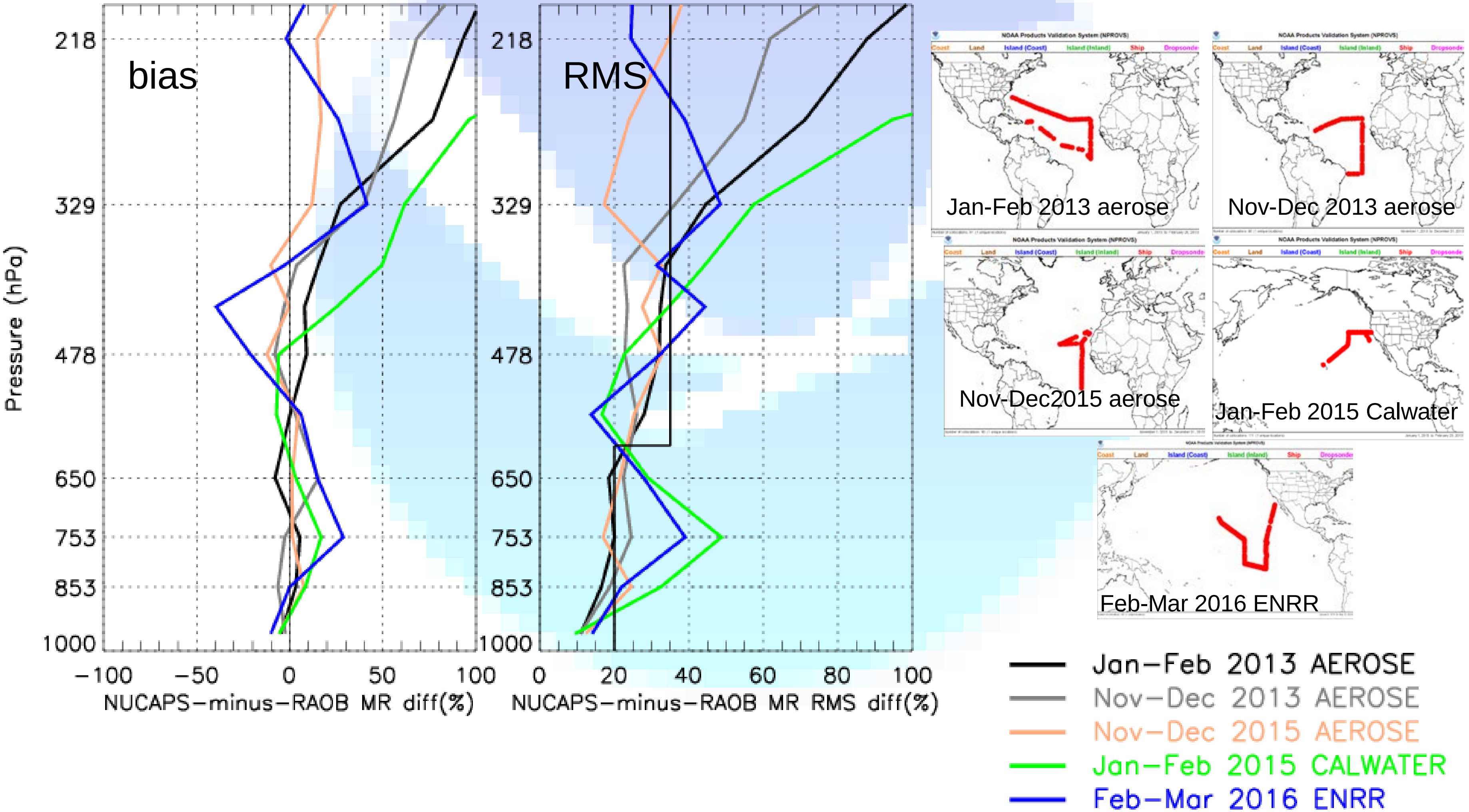
Suomi-NPP NUCAPS IR+MW Temperature Statistics





Jan−Feb 2013 AEROSE
Nov−Dec 2013 AEROSE
Nov−Dec 2015 AEROSE
Jan−Feb 2015 CALWATER
Feb−Mar 2016 ENRR

Suomi-NPP NUCAPS IR+MW Water Vapor Statistics



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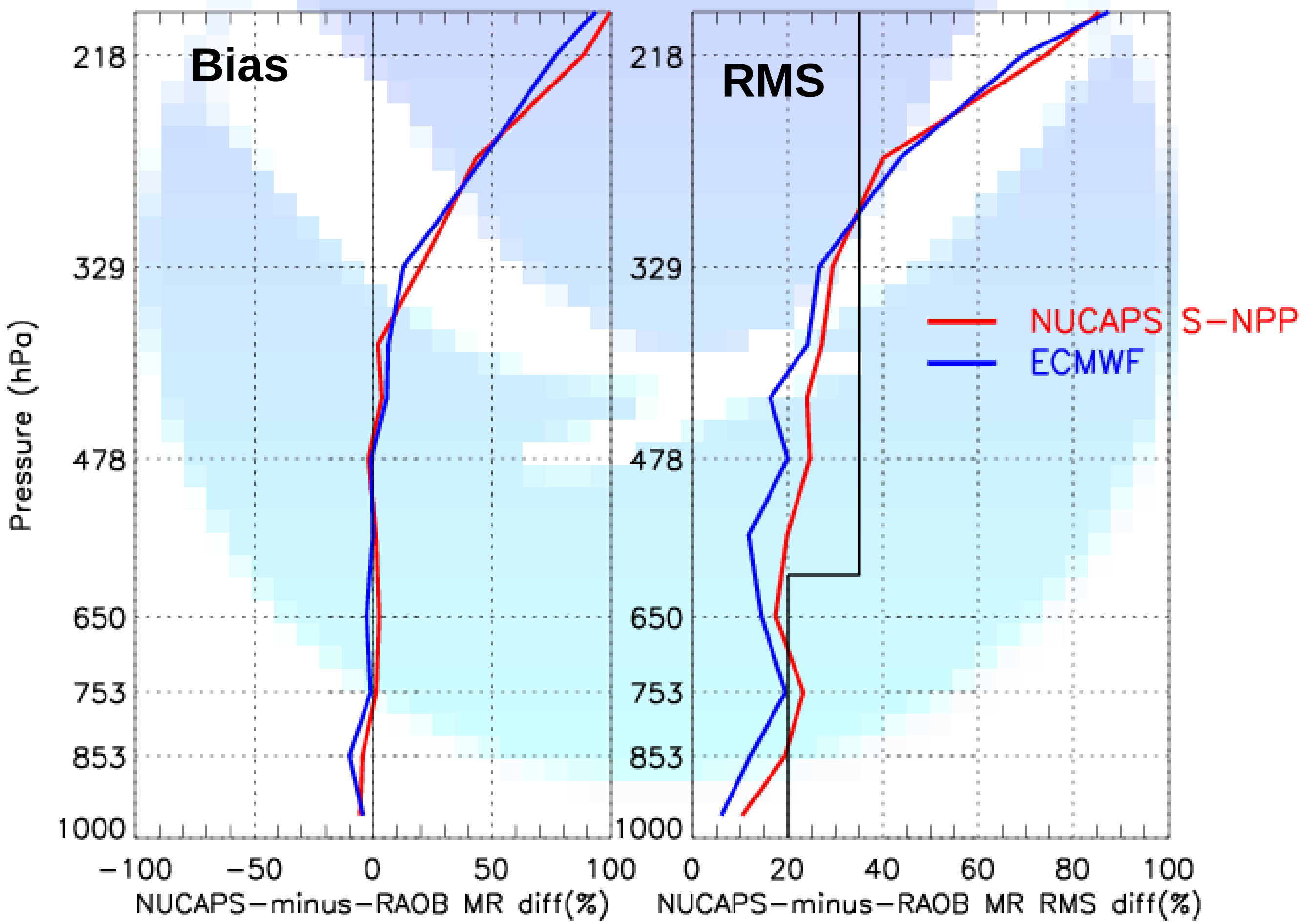
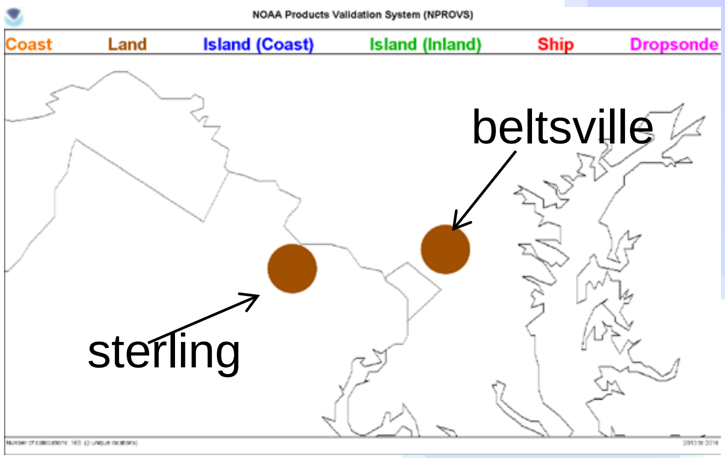
NUCAPS IR+ MW *vs.* ECMWF analysis

relative to JPSS funded field campaign ship RAOBs

Water Vapor Mixing Ratio % diff.



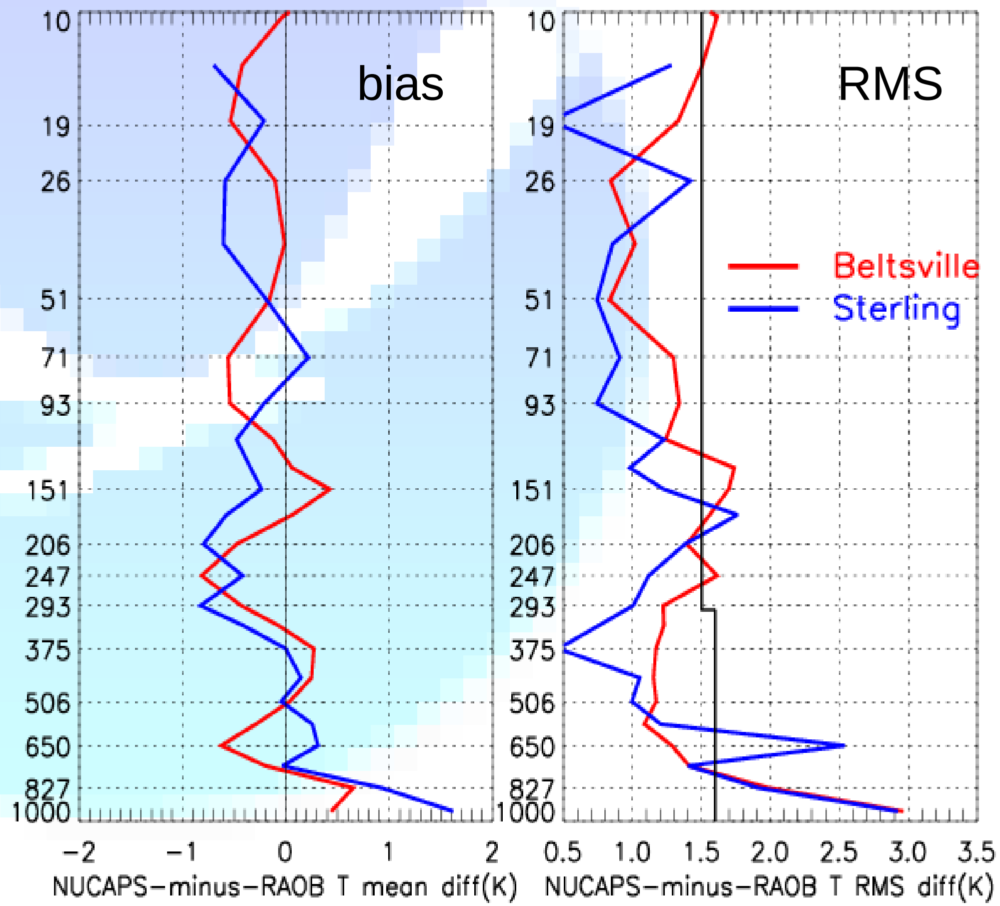
Beltsville & Sterling RAOBs for S-NPP Evaluation



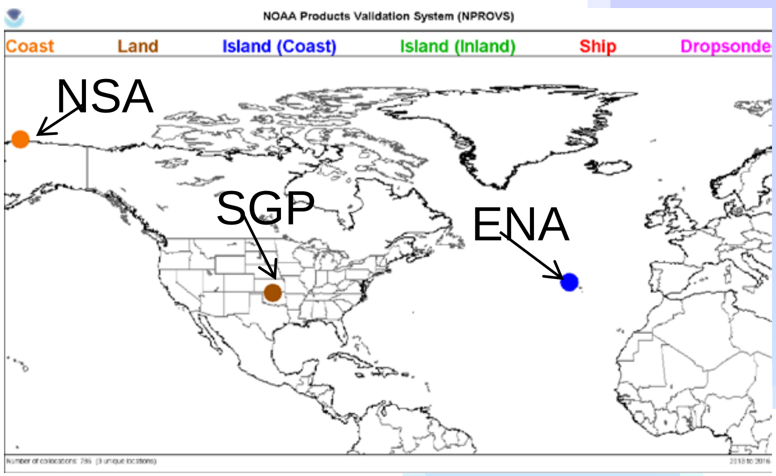
Launch Synchronizations Summary

- **8** Sterling synchronized to S-NPP
- **90** Beltsville synchronized to S-NPP
- 4 Sterling / Beltsville synchronized to S-NPP:
- 10/10/15 7100 1733 Z
- 3/18/16 7200 1730 Z
- 4/15/16 7100 1705 Z
- 4/18/16 7100 0700 Z

S-NPP IR+MW Temperature

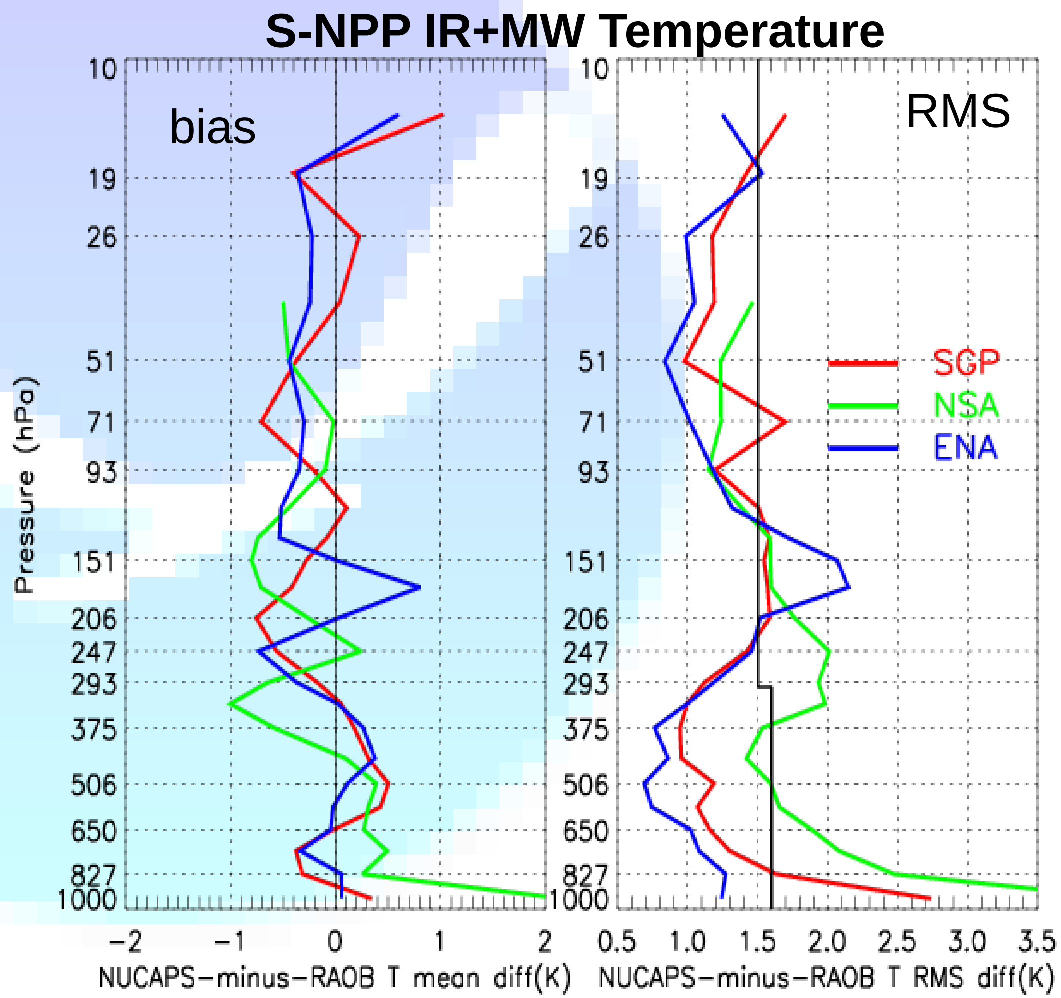


ARM RAOBs for S-NPP Evaluation

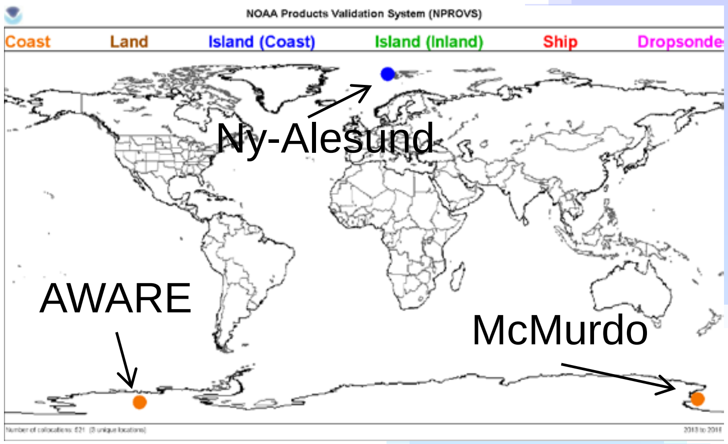


RAOB Launches synchronized with S-NPP

- **367 at SGP site**
- **341 at NSA site**
- **73 at ENA**



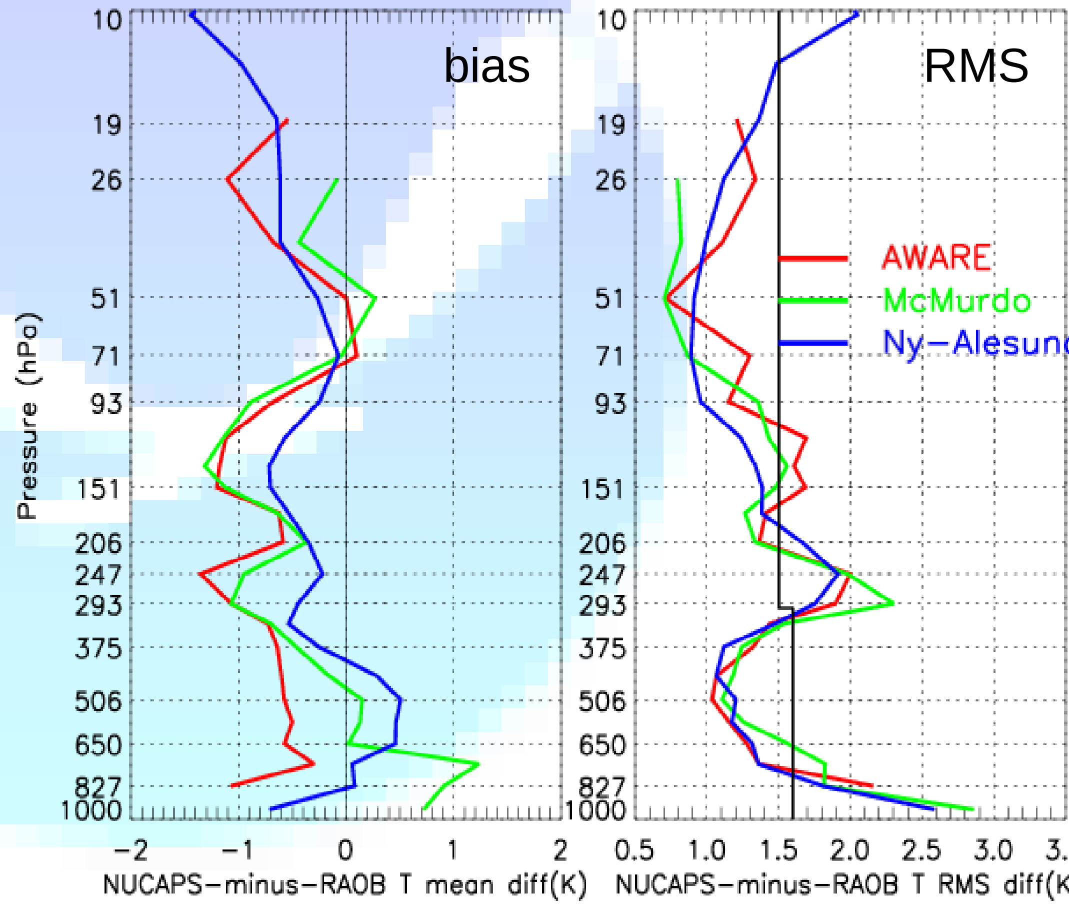
North and South Polar RAOBs for S-NPP Evaluation



RAOB Launches within 1hr/50km of S-NPP

- **30 at AWARE ARM site**
- **28 at McMurdo ARM site**
- **398 at Ny-Alesund, Norway**

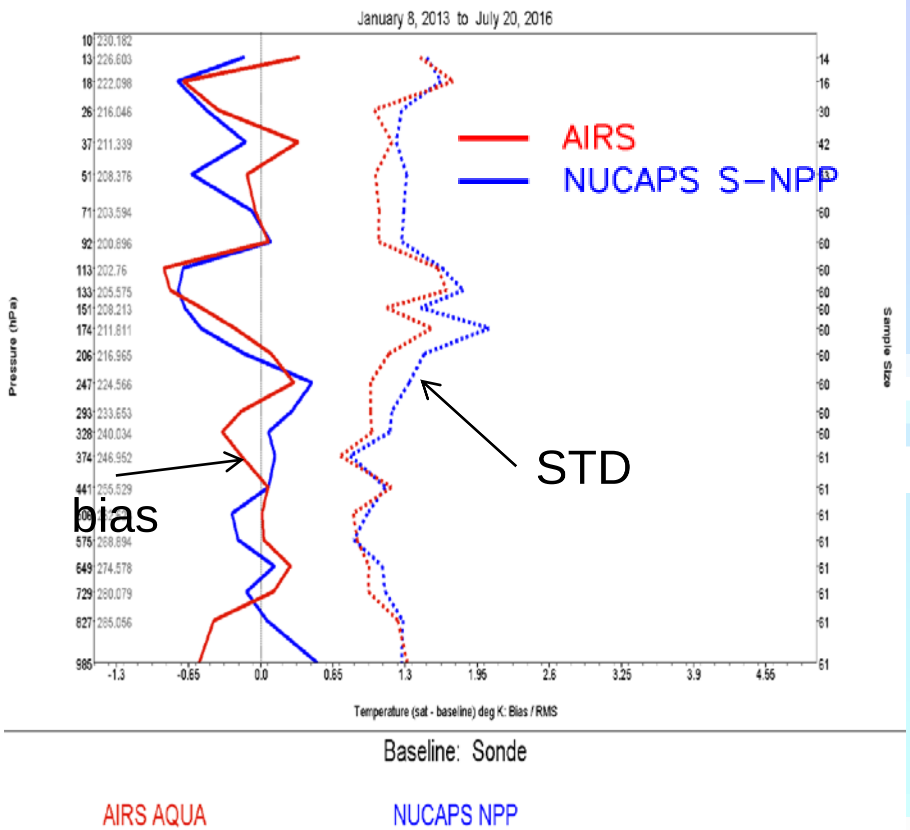
S-NPP IR+MW Temperature



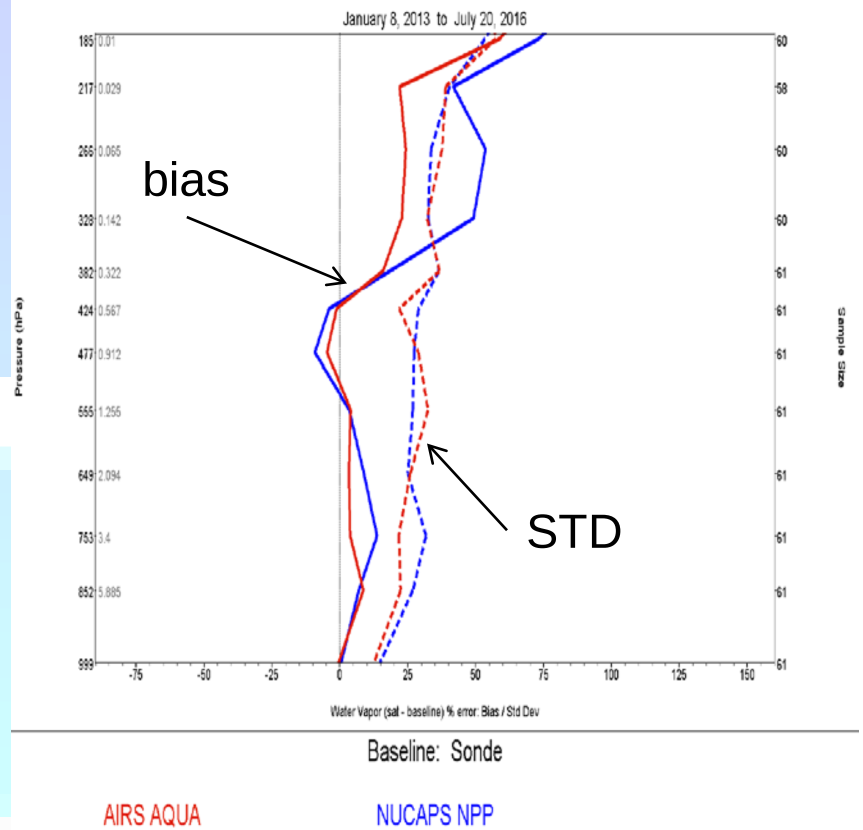
IR+MW NUCAPS S-NPP vs. AIRS Retrieval Statistics

(Sea data, relative to Reference sondes)

Temperature



Water Vapor Mixing Ratio



Sample: 60 collocations (+/- 1.5 hr & 50 km)

Summary

- NPROVS+ (anchored to Reference RAOBs) and NPROVS (anchored to *conventional* RAOB) are complementary in support of JPSS atmospheric sounding EDR cal/val

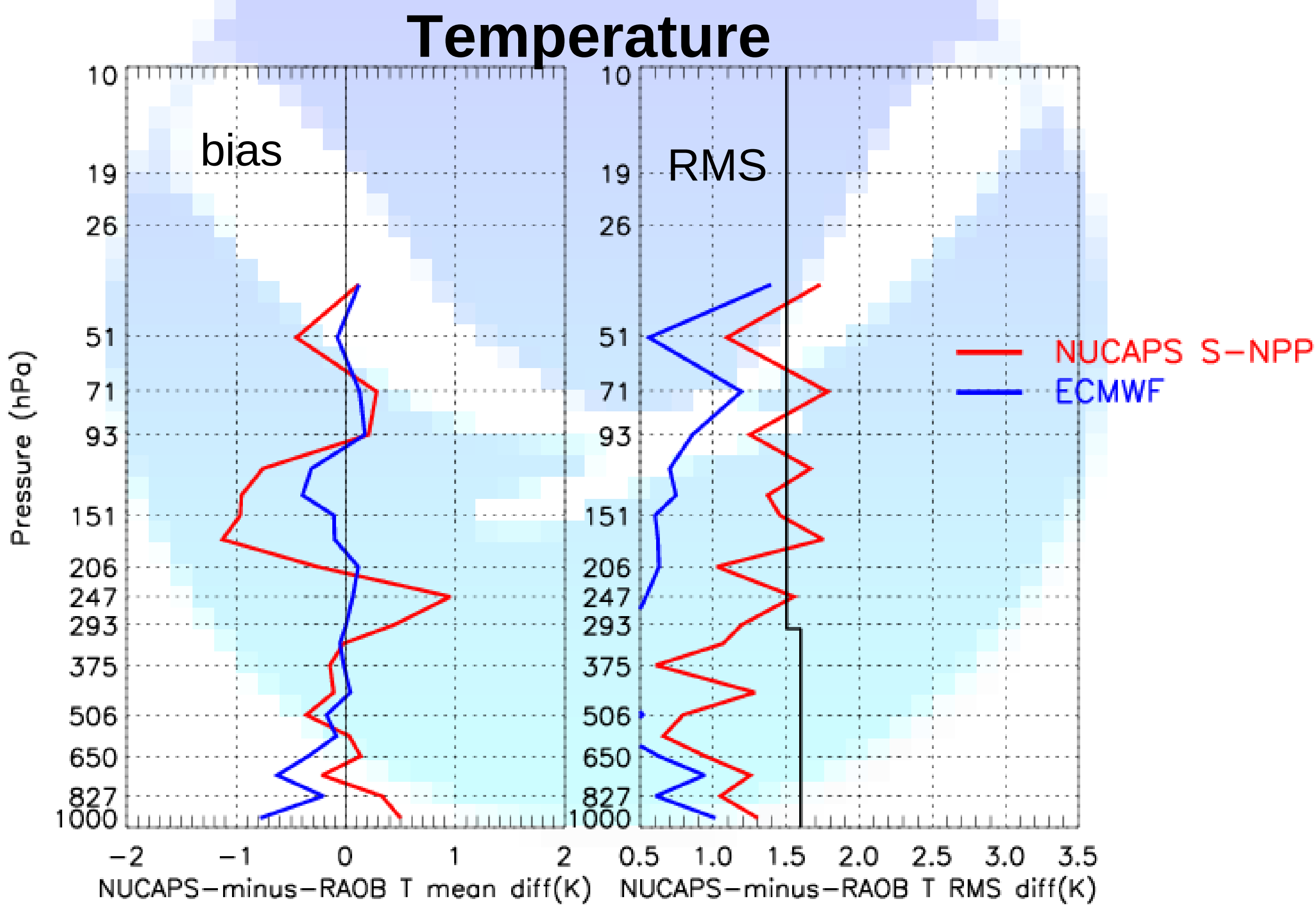
- Analysis of satellite collocations with conventional (6 months) and with Reference RAOBs (3 yrs), done globally and at individual sites, indicated
  - NUCAPS IR+MW temperature and water vapor retrievals perform well

- Uncertainties were discussed in the context of hyperspectral sounder retrieval validation:
  - Time mismatch matters
  - Satellite *vs*. radiosonde vertical resolution inconsistency
  - Radiosonde accuracy including warm T and dry humidity at the upper levels

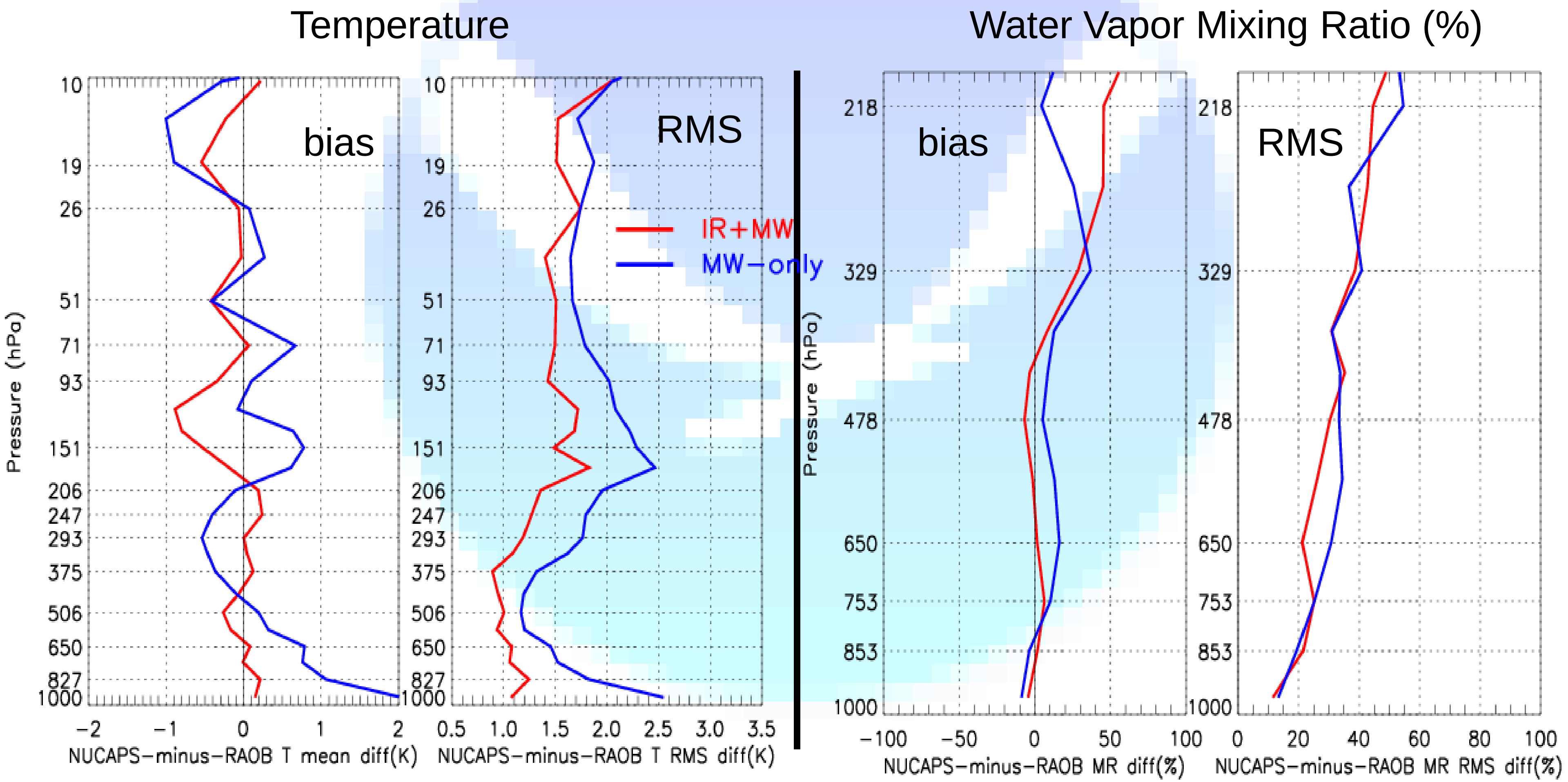
- END

NUCAPS IR+ MW *vs.* ECMWF analysis

relative to NOAA field campaign ship RAOBs



S-NPP NUCAPS IR+MW *vs*. MW-only Retrieval Statistics (Sea data; relative to Reference sondes)



IR+MW (122), MW-only (185)

GRUAN / NOAA (STAR) Coordination

Tony Reale

NOAA/NESDIS

Center for Satellite Applications and Research (STAR)

Bomin Sun, Michael Pettey, Frank Tilley, Charles Brown and Nick Nalli

(IMSG)

NOAA Center for Weather and Climate Prediction

College Park, Md

July 28, 2016

Outline

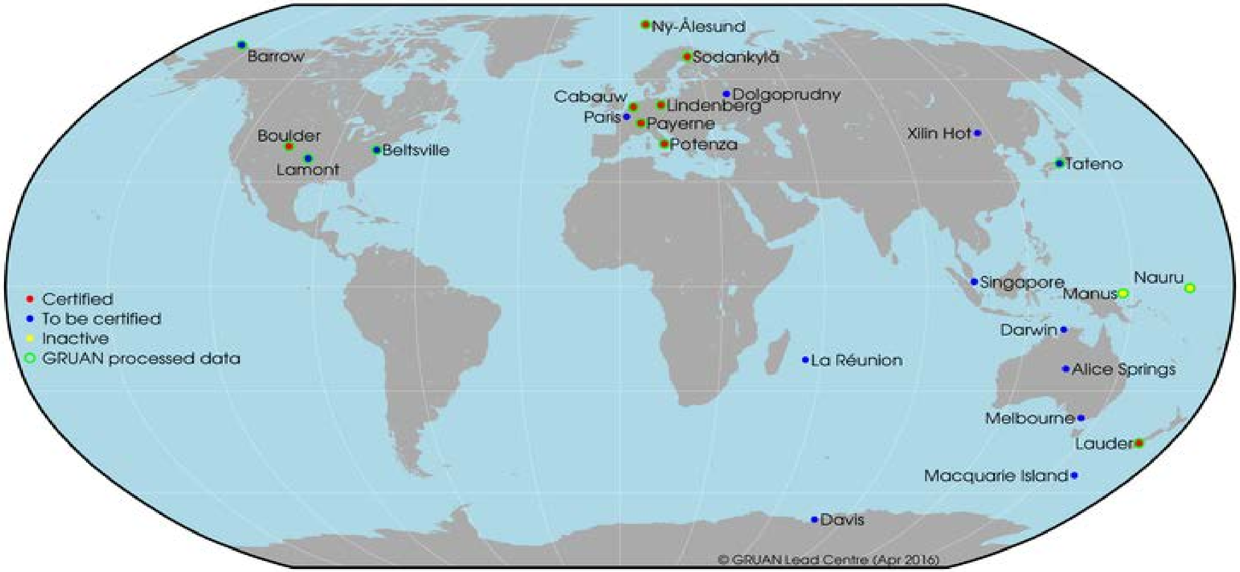
- GRUAN and NPROVS+
  - JPSS Products Cal/Val Support
- GRUAN and Uncertainty Integration Analytical directions
  - EDR cal/val … SDR cal/val
  - Examples (NUCAPS, NWP, GPSRO …)
- Summary

GRUAN

Peter Thorne (Maynooth, Ireland) , Greg Bodeker (New Zealand)
Ruud Dirksen (Lead Center, DWD, Lindenberg, Germany) …

GRUAN reference observations are calibrated through an unbroken traceability chain to SI or community standards with the uncertainty interval in each step in the chain "fully characterized", meaning the resulting estimates can be used with high confidence that the true measurement is within the interval …

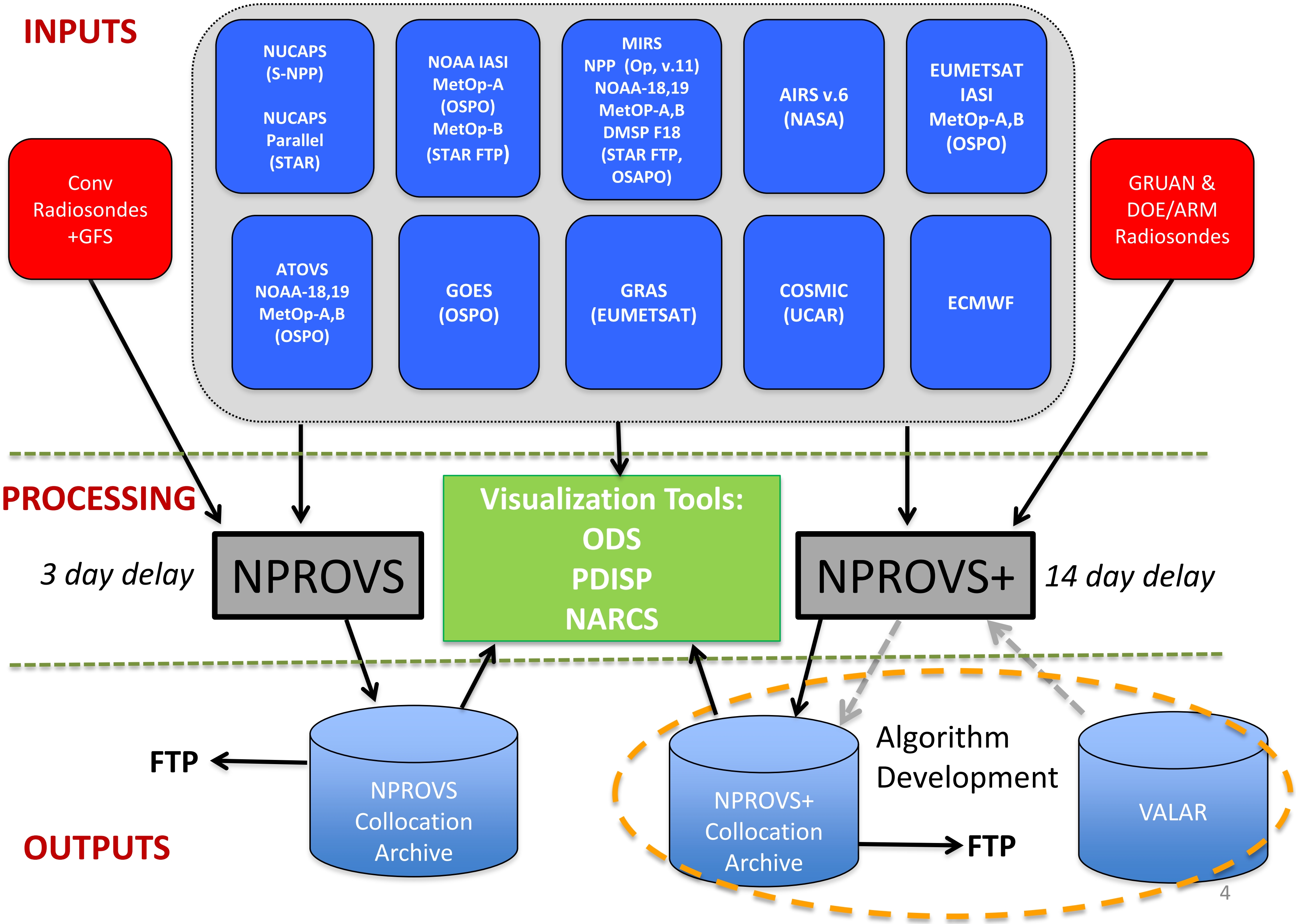
GCOS Reference Upper-Air Network



Among the primary objectives of GRUAN is the constraining and inter-calibration of data from other more spatially extensive observing systems such as satellites and the current radiosonde network.

WWW.GRUAN.ORG

NPROVS/NPROVS+ Data Management Schematic



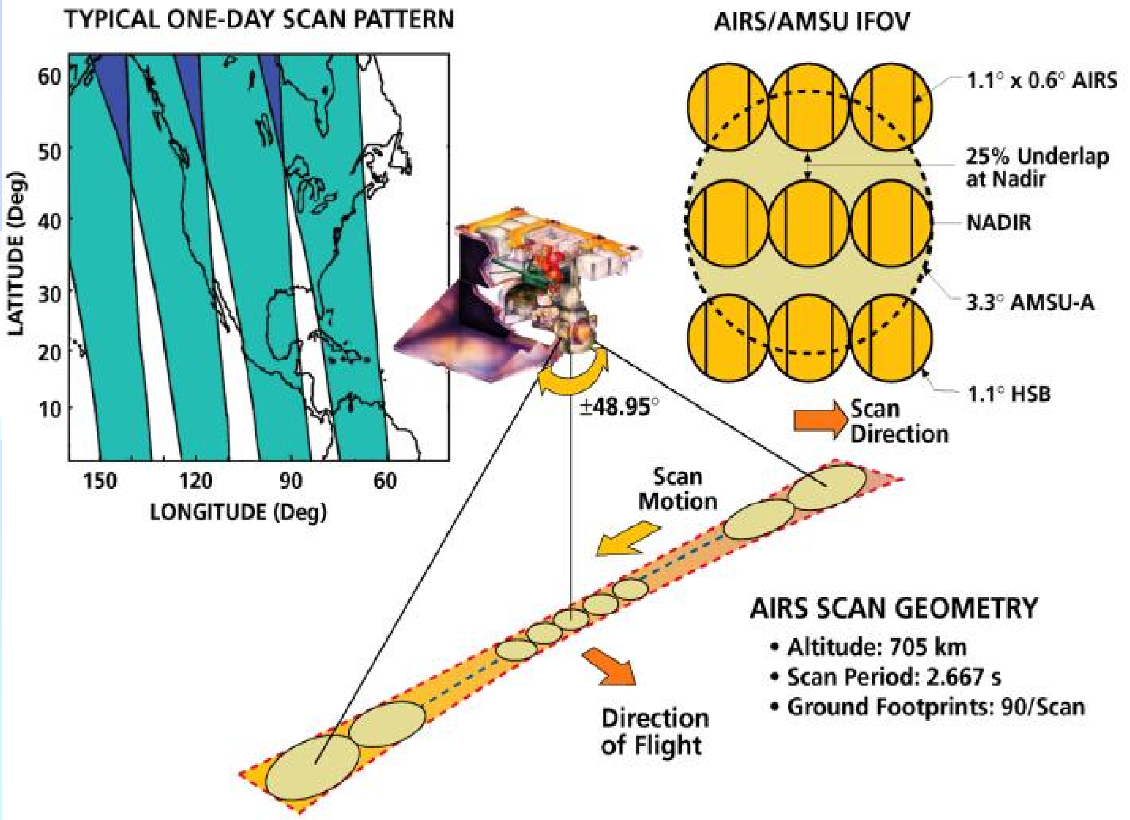
Collocation Criteria:

+/- 6-hour

250 km

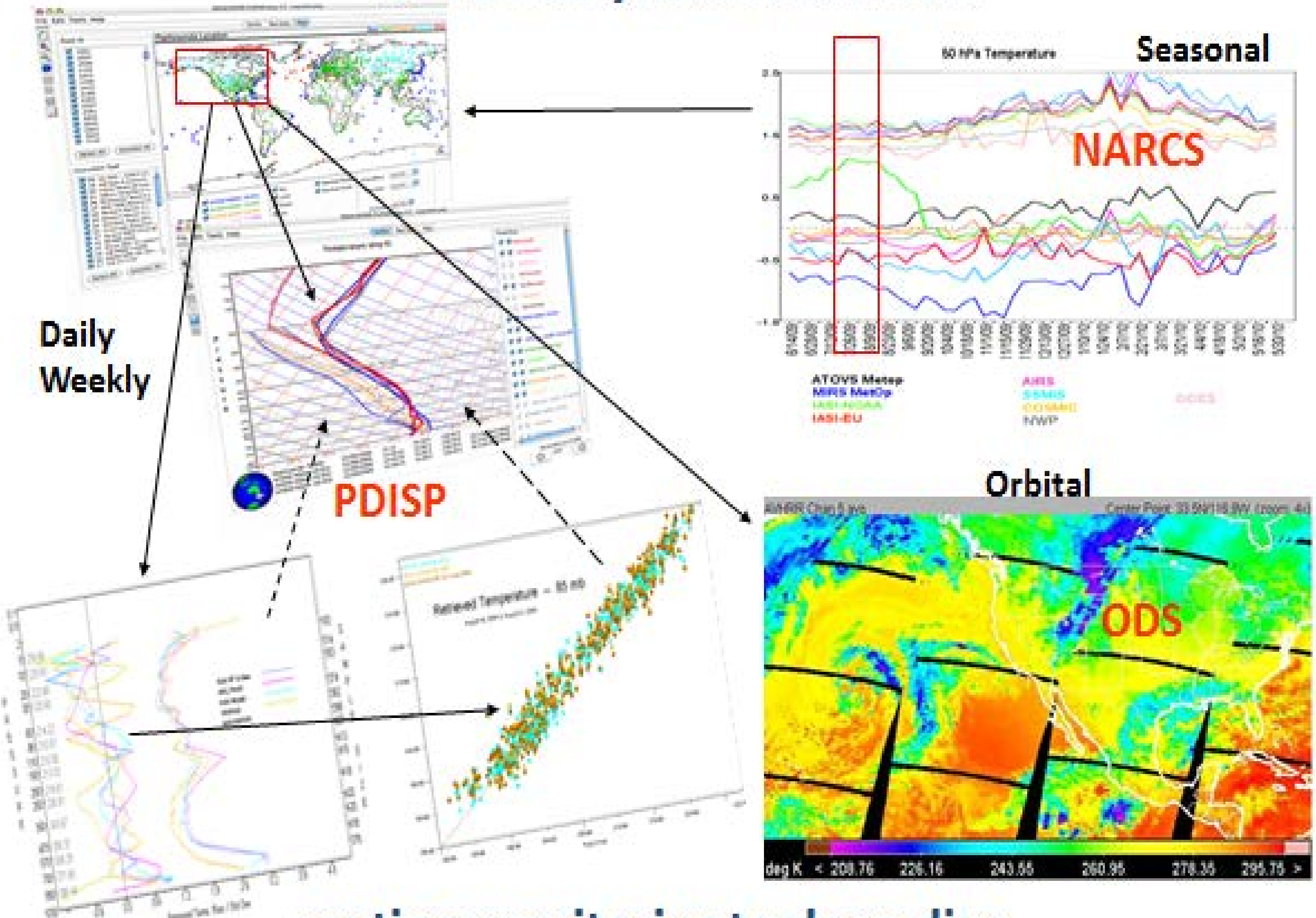
Single Closest
(anchored to Field-of Regard)

- Sounding is performed on 50 km field of regard (FOR).
- FOR is currently defined by the size of the microwave sounder footprint.
- IASI/AMSU has 4 IR FOV's per FOR
- AIRS/AMSU & CrIS/ATMS have 9 IR FOV's per FOR.



Barnet, Prov

EDGE Analytical Interface ...



... routine monitoring to deep dive

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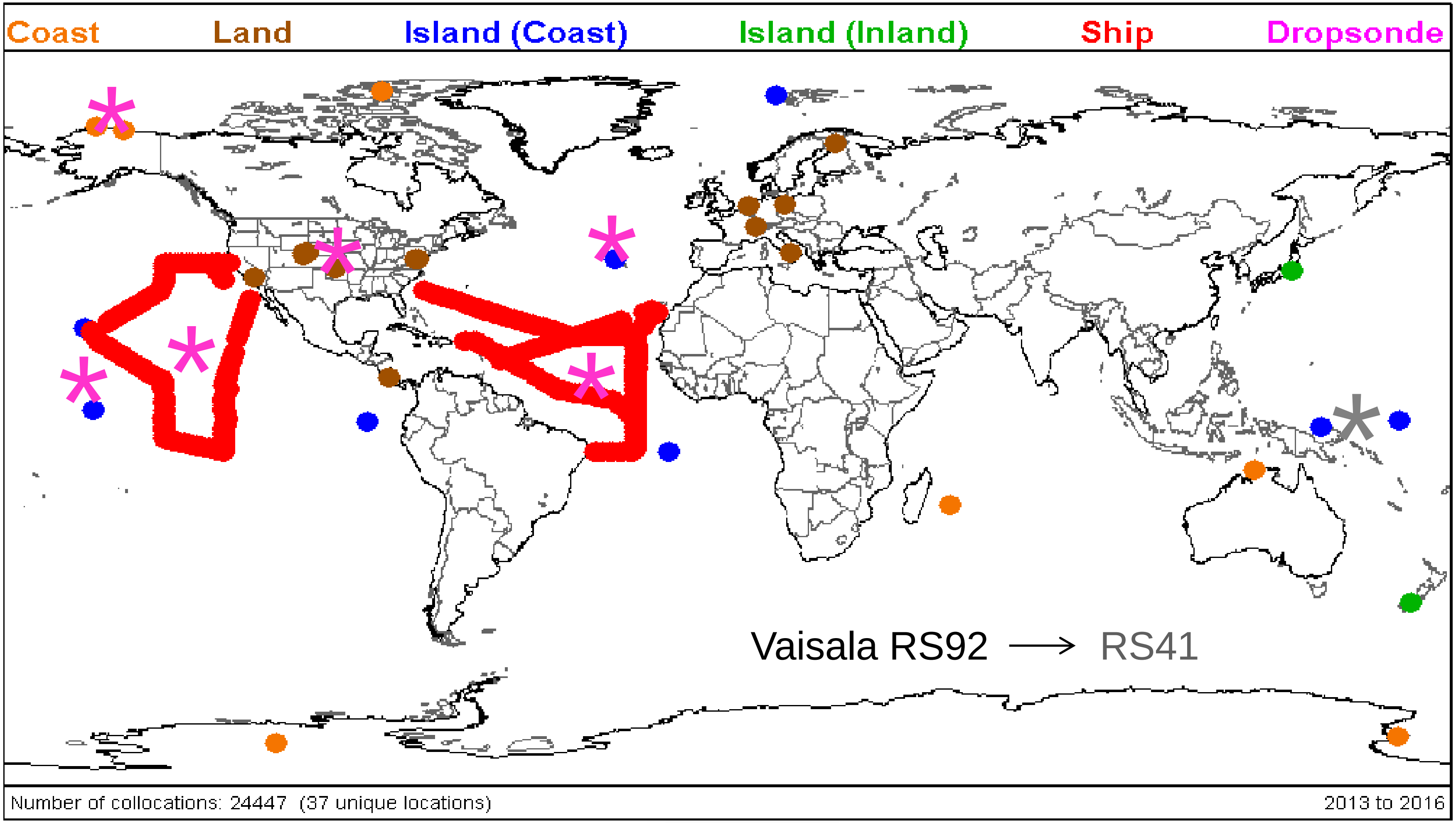
NPROVS+

NOAA Products Validation System (NPROVS)

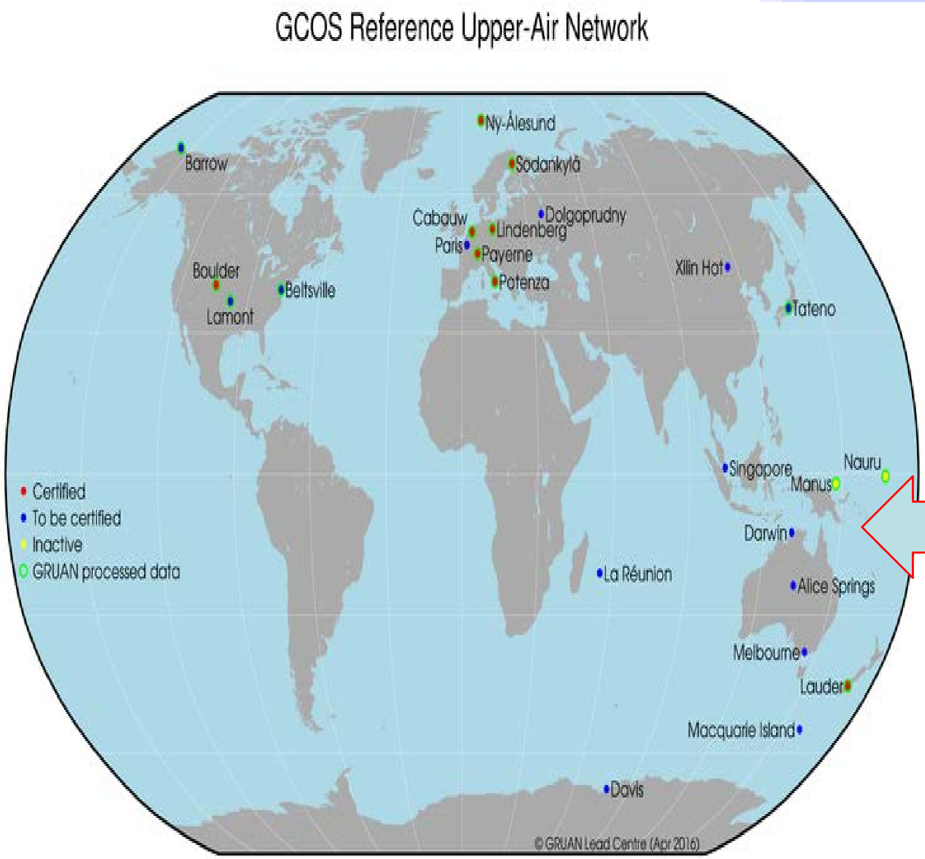


GRUAN and JPSS funded Dedicated (S-NPP *) RAOB Sites

January 2013 to July 2016

(JPSS / ARM provide significant global component of S-NPP synchronized Raob)

NPROVS+



Global Climate Observing System (GCOS) Reference Upper Air Network (GRUAN)

JPSS/ARM Funded Dedicated RAOB

(Lihang Zhou (STAR), Lori Borg (SSEC), Donna Holdridge (Argonne) , Jim Mather (ARM) …)

- DOE ARM (SGP, NSA, ENA)
  - ✓SSEC, ANL …
  - ✓(2) per week
  - ✓**GRUAN Processed (v2 → v3)**
  - ✓ includes dual sequential …
- AEROSE **(GP)**
- CALWATER, El-Nino RR

- *ARM Mobile*
- *Sterling Test Site*
- *CIRA*

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GRUAN Uncertainty Integrated in NPROVS+ analytic interface (PDISP)

GRUAN Reference Measurement Principles

Given two measurement (m1, m2), their uncertainty (u_1, u_2) and variability (σ), then two observations are consistent if:

“k” .le. 2:

$$|m_1 - m_2| < k\sqrt{\sigma^2 + u_1^2 + u_2^2}$$

Worst case “k” for SAT:

“k” = ABS(SAT – GRUAN) / u2

where u2 is GRUAN uncertainty, sigma and u1 equal 0

GRUAN Reference Measurement Principles

Given worst case “k” profile, what is value of ($\sigma^2 + u_1^2$)
such that that “k=2” ?

$\sigma^2 + u_1^2$ ~ ((“k”/2)^2 –1) (u2)^2

Assume sigma small:

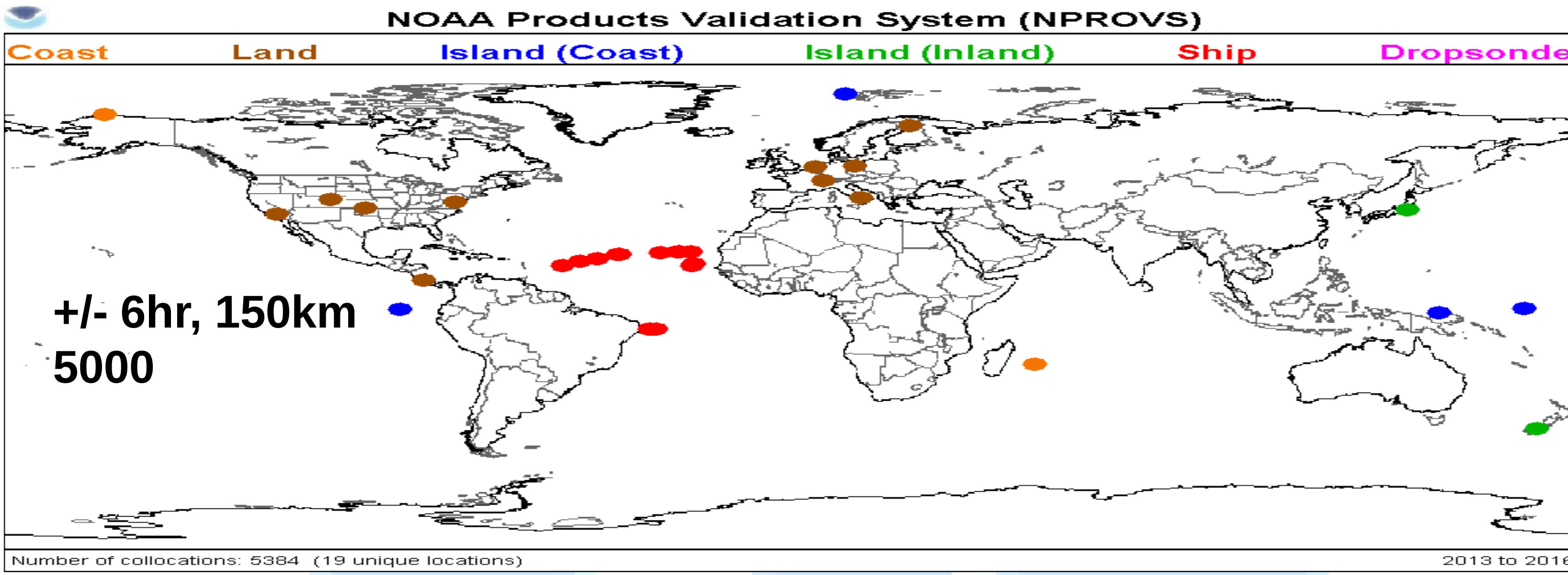
u_1 = ((“k”/2)^2 –1)$^{1/2}$ (u2)

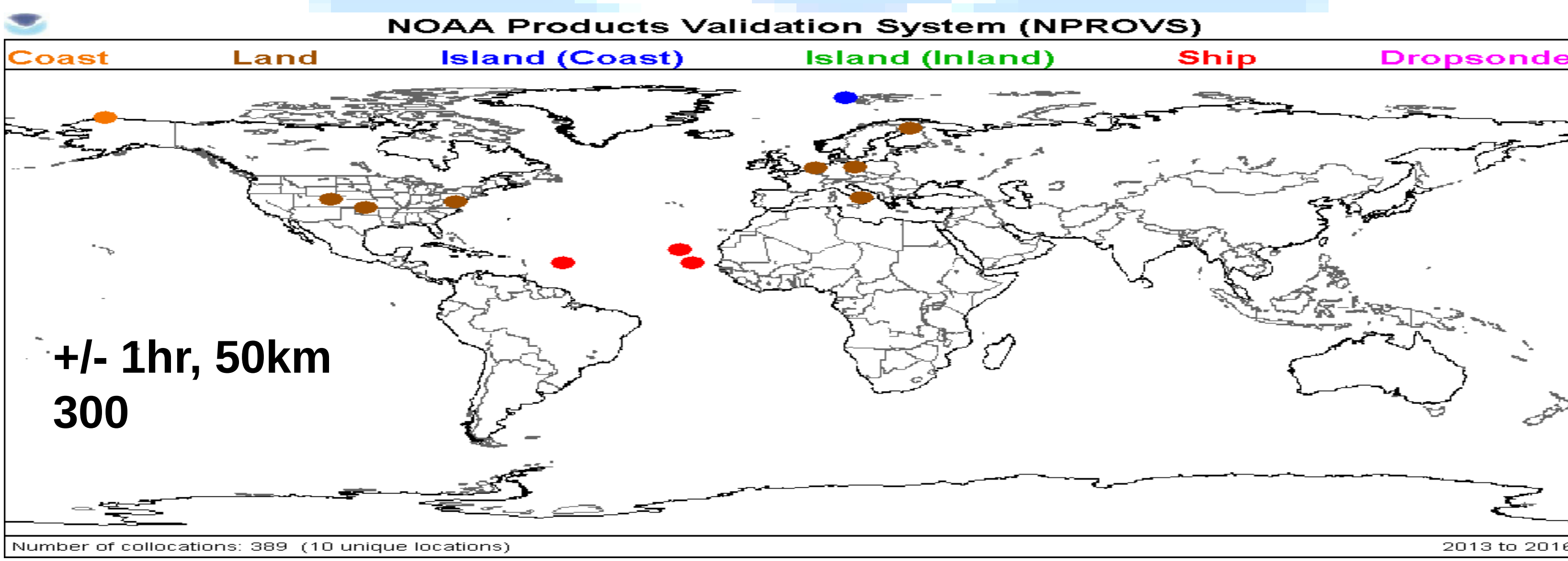
Assume $u_1 = a(u_2)$:

σ = ((“k”/2)^2 –1 – a^2)$^{1/2}$ (u2)

… uncertainty due to measurement differences and mismatch

… estimate uncertainties for satellite products





GRUAN Processed and Accepted; IR pass QC

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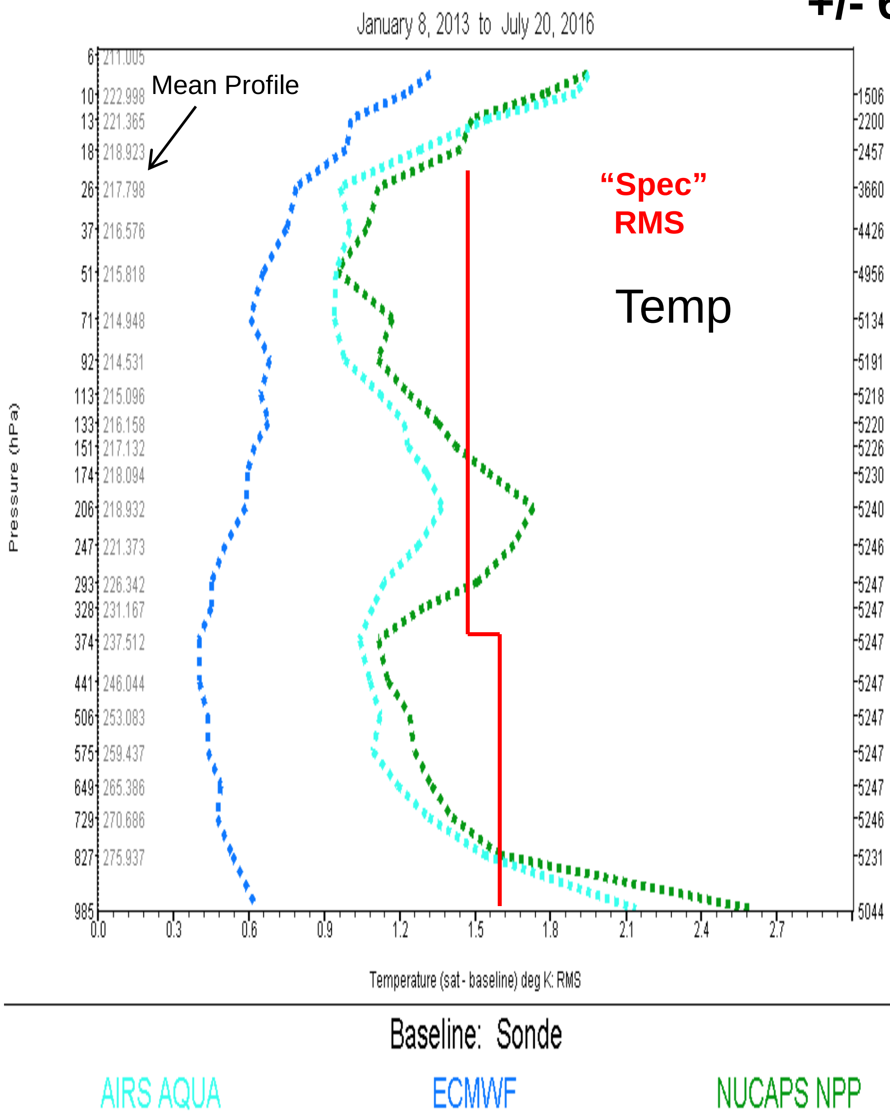
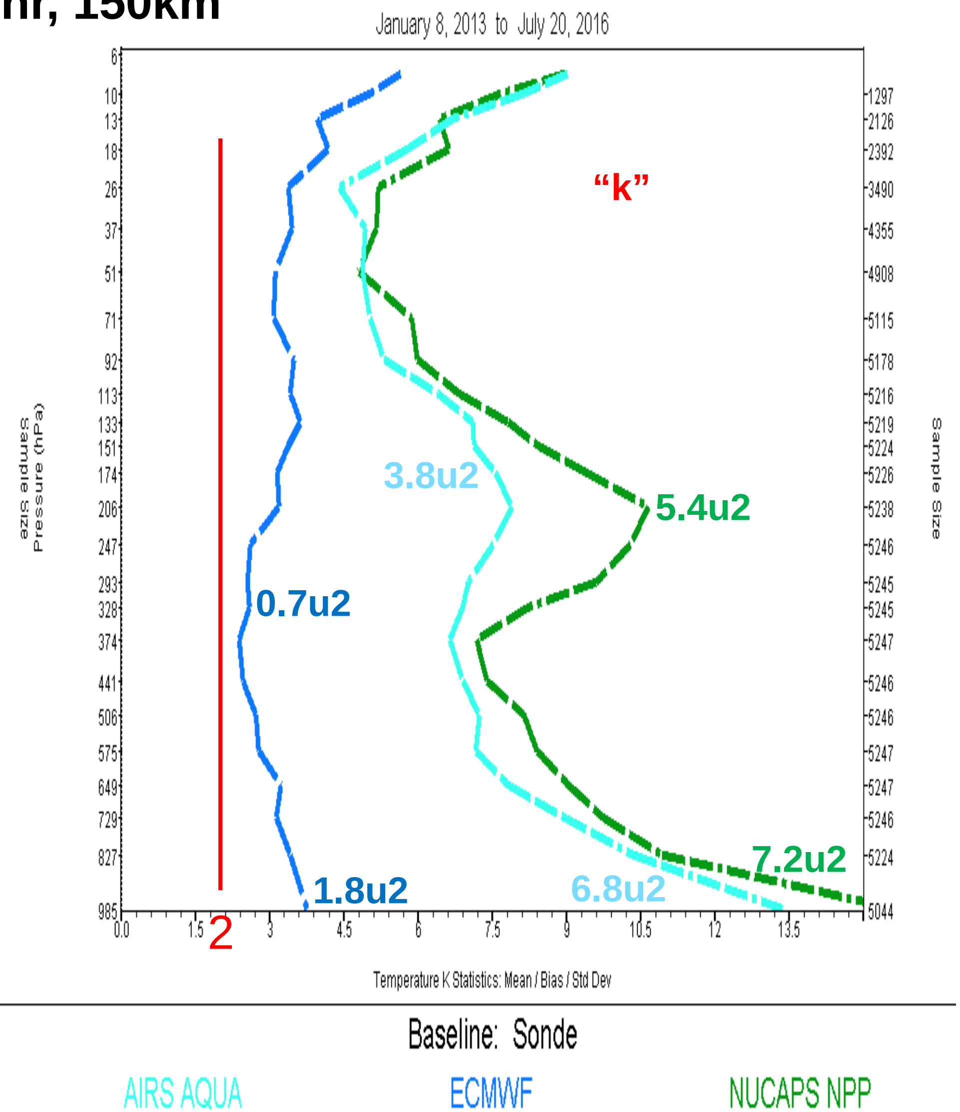
+/- 6hr, 150km





GRUAN Processed and Accepted; IR pass QC

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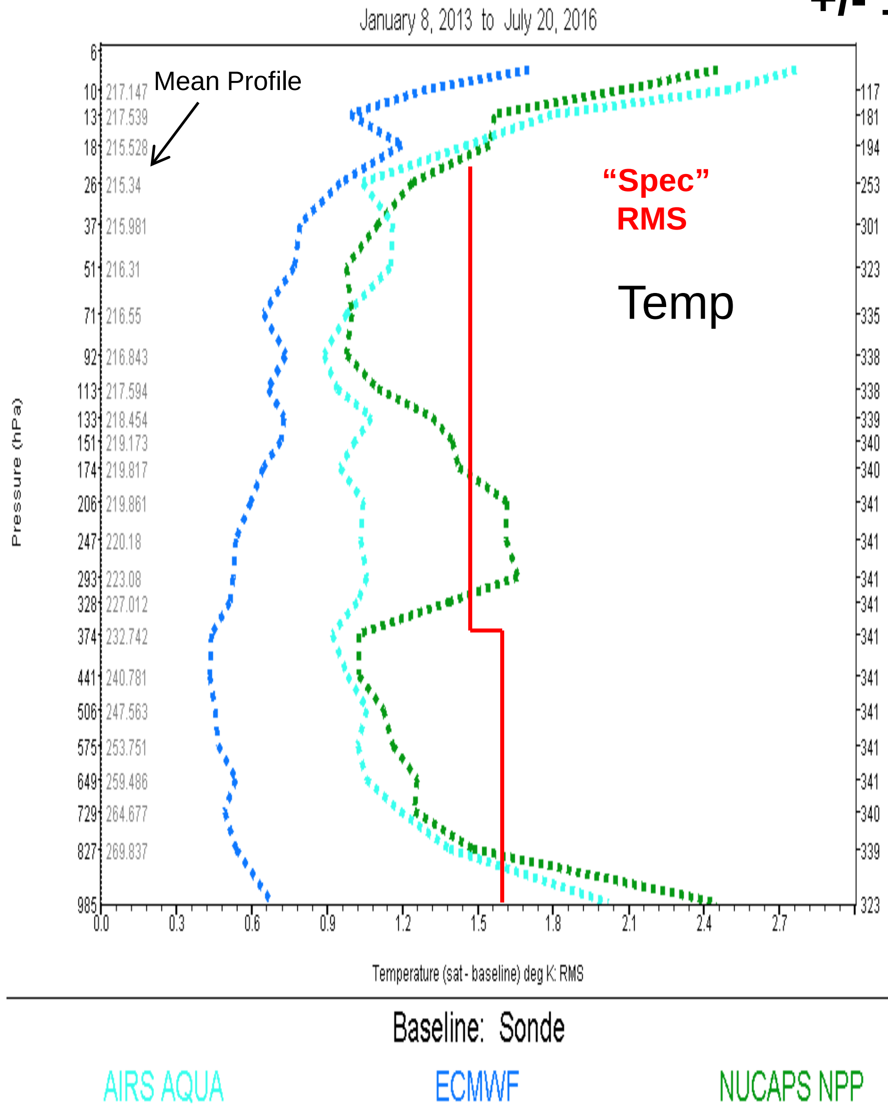
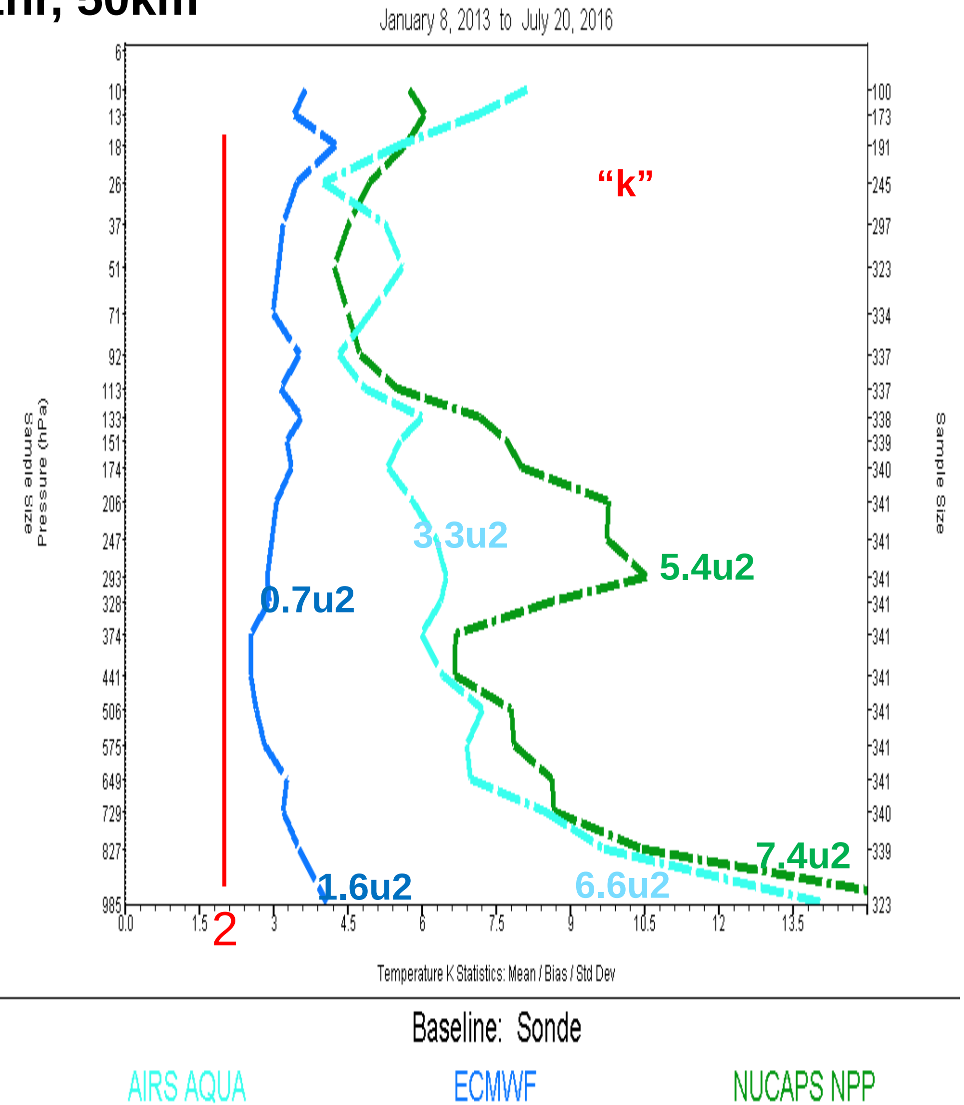
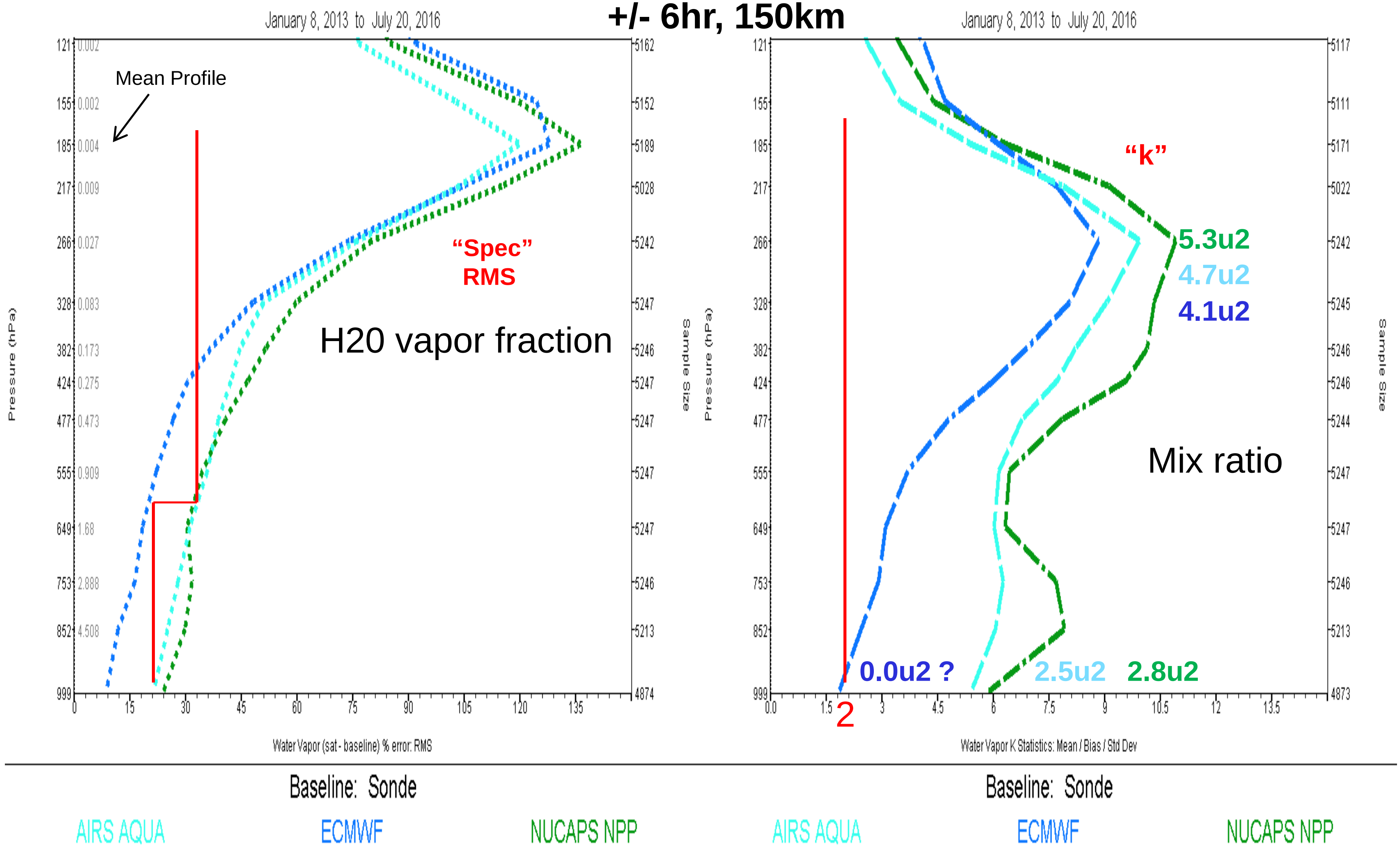
+/- 1hr, 50km





GRUAN Processed and Accepted; IR pass QC

+/- 6hr, 150km



GRUAN Processed and Accepted; IR pass QC

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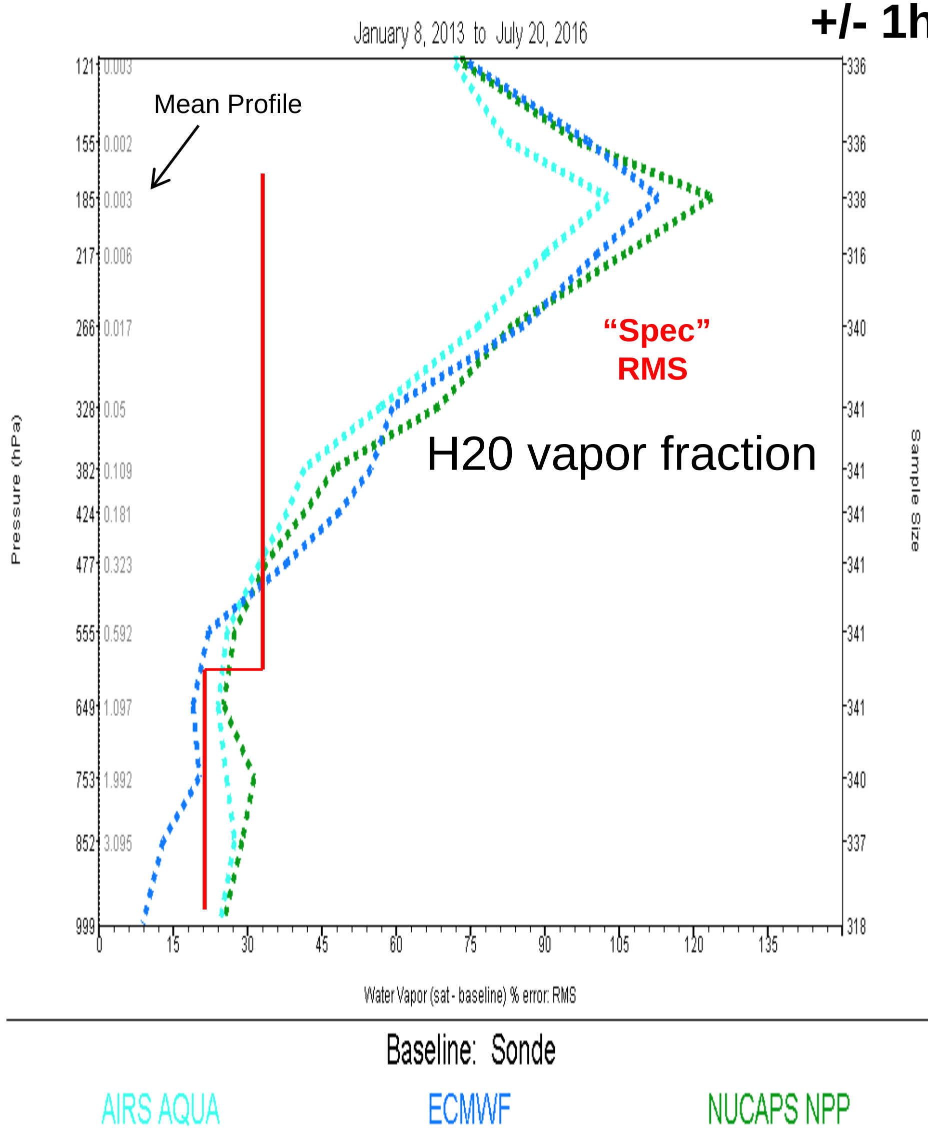
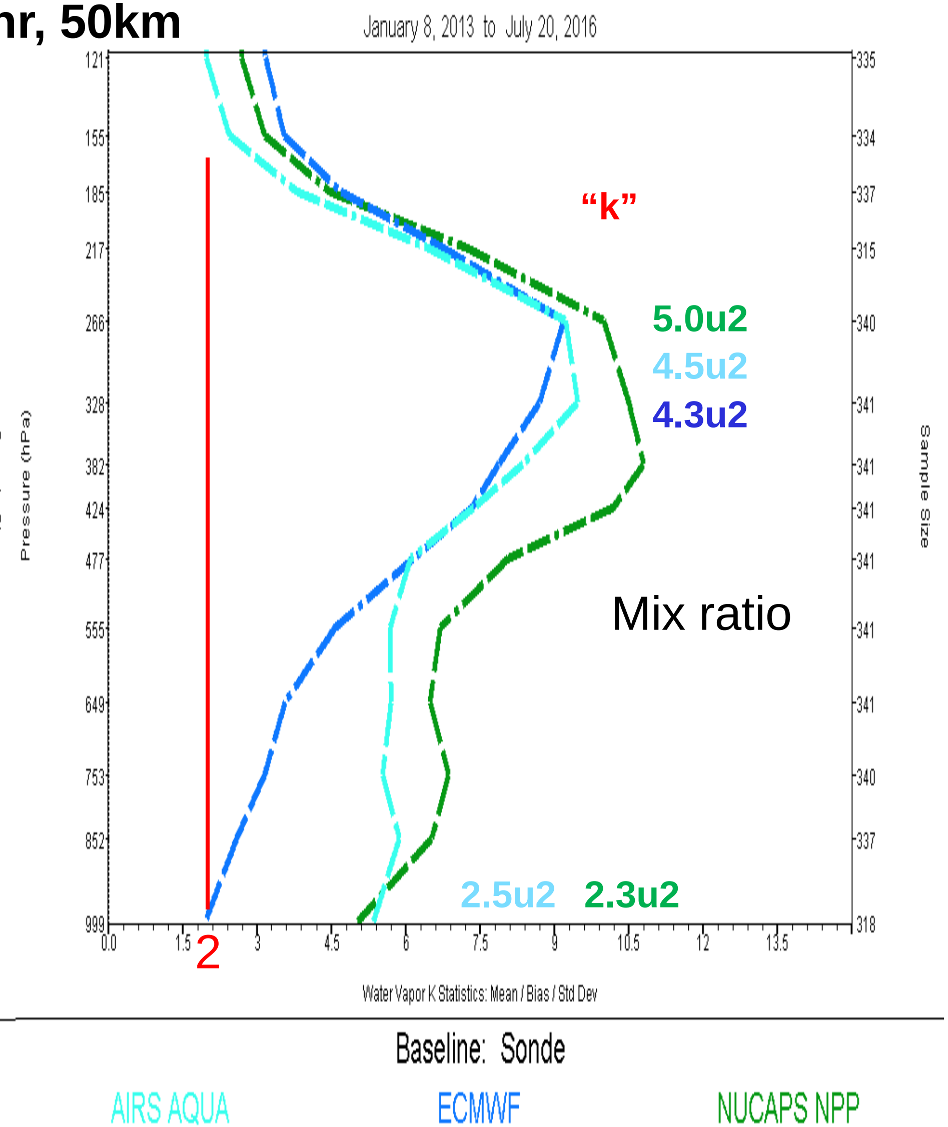
+/- 1hr, 50km





GRUAN Processed and Accepted; IR pass QC

… informal email exchange Geir Braathen (WMO) and dale Hurst (NOAA ESRL)

Geir,
About a year ago I did a quick study of the UT water vapor biases between MLS and FPs at Hilo and Costa Rica (i.e., tropical sites). I looked only at 121 and 147 hPa because I was interested in the differences in the amounts of water vapor input to the TTL implied by the different data sets.
The mean biases at 147 hPa over both sites were 3-4 ppmv, with MLS drier than the FPs. The FP mixing ratios at 147 hPa ranged from 5-25 ppmv, most were 10-25 ppmv, and the 3-4 ppmv differences occurred at mixing ratios >15 ppmv.
Cheers, Dale

Hello again Dale,
Thank you for these details. Despite the dry bias of MLS that you describe, the MERRA and ERA Interim reanalysis remain quite wet compared to the FP measurements. The MLS dry bias you indicate is not enough to compensate for the 150% wet bias in the reanalysis, as far as I can see.
Cheers, Geir

Hi Geir,
I was not claiming that the wet biases in the reanalysis wrt MLS would go away if the MLS dry biases were considered, only that the wet reanalysis biases might be reduced when FPs are used instead.
Cheers,Dale

Hi Dale,
I did not think that you meant to claim that. But it was just good to make sure that I understood you correctly. I think the main conclusion is that we need many more water vapour measurements in the UTLS region.
Cheers, Geir

The Forgotten Water Vapor at High Altitudes
Scientists find that estimations of high-altitude atmospheric water, critical for the greenhouse effect, are not as accurate as previously thought.

https://eos.org/research-spotlights/the-forgotten-water-vapor-at-high-altitudes

… estimate "sigma"

GSICS Global Space-based Inter-Calibration System
Quarterly
Newsletter – Summer 2015 Issue
Volume 9 Number 2
2015
doi: 10.7289/V5XKK8CHN
Manik Bali, Editor

CMA • CNES • EUMETSAT • IMD • ISRO • JAXA • JMA • KMA • NASA • NIST • NOAA • ROSHYDROMET • USGS • WMO

Quantifying uncertainty when comparing Space-based and Ground Observations

By Tony Reale, NOAA and Xavier Calbet, AEMET

A problem in satellite product cal/val is that uncertainty budgets are typically overlooked. Uncertainty originates in the native measurement space, for example the radiances from satellites or temperature from radiosonde observations (RAOB). Uncertainty is not solely an "intrinsic" property of the observations, but also has "secondary" components that are introduced when comparing measurements with different spatial and/or temporal characteristics including mismatch. Quantifying these components is needed for robust inter-comparison, validation and integration, for example, in WMO Integrated Global Observing System (WIGOS). Addressing such issues through strict comparison of reference RAOB, satellite IR/MW sounding

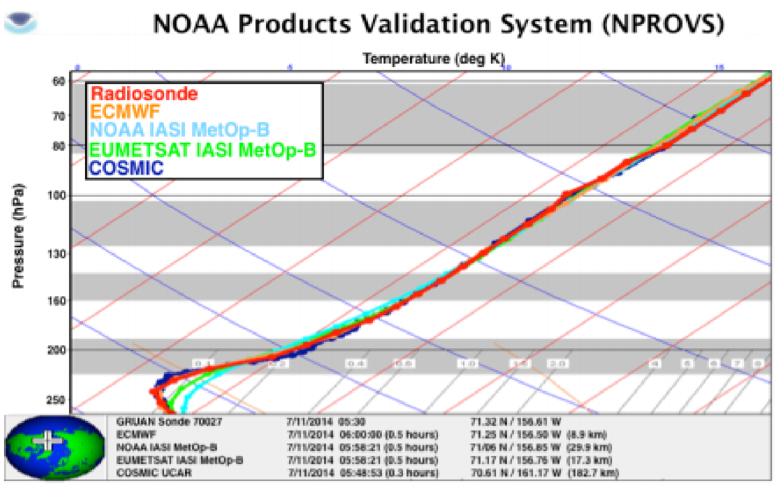
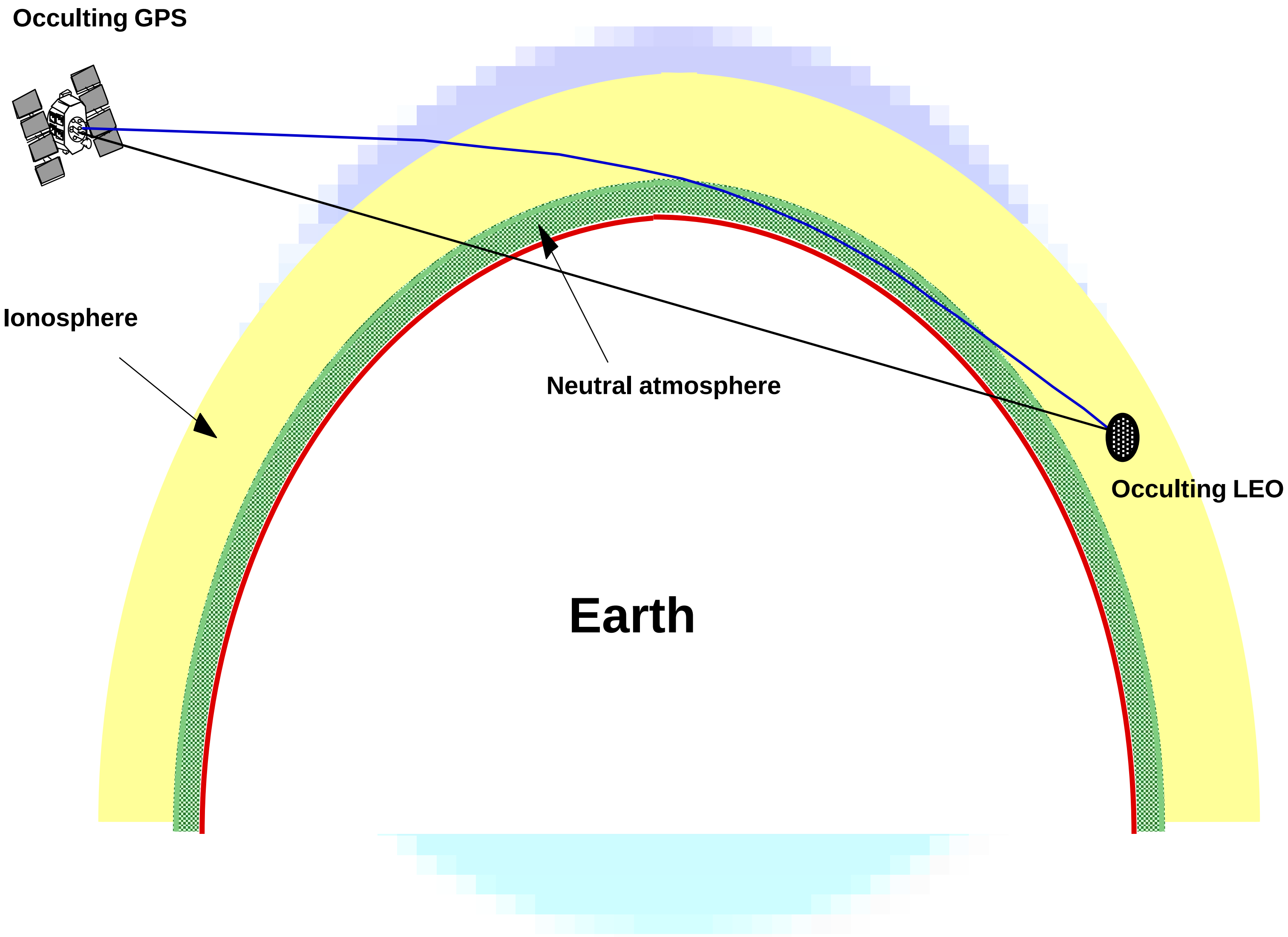
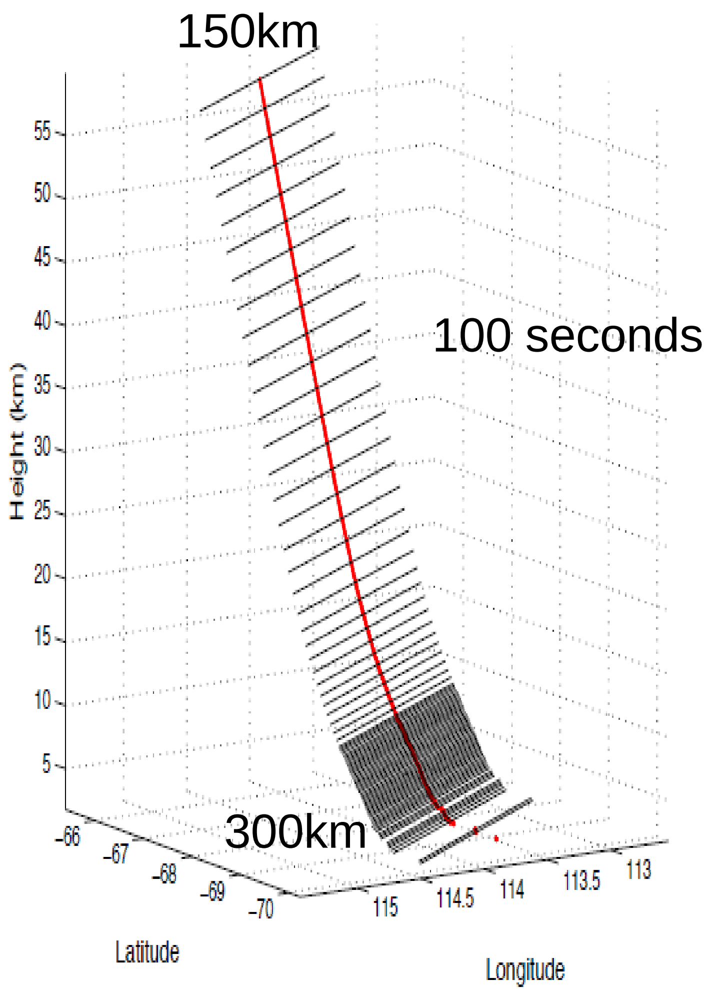


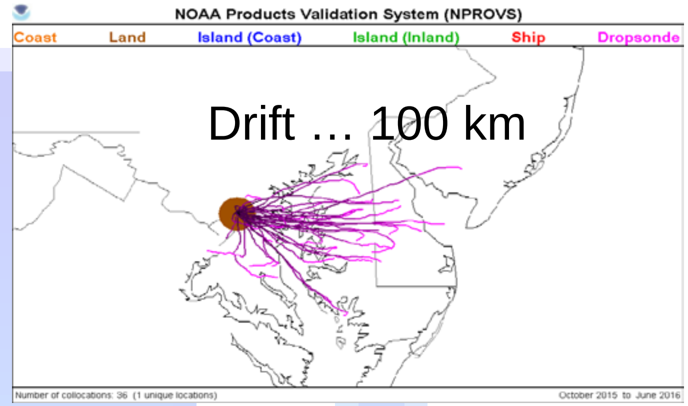
Figure 1: Collocated temperature profiles from GRUAN RAOB, COSMIC (Tdry), MetOp-B IASI soundings from NOAA and EUMETSAT and European Center for Medium-Range Weather Forecasts (ECMWF) analysis within 30 minutes and 30 km of RAOB except for COSMIC at 183 km.

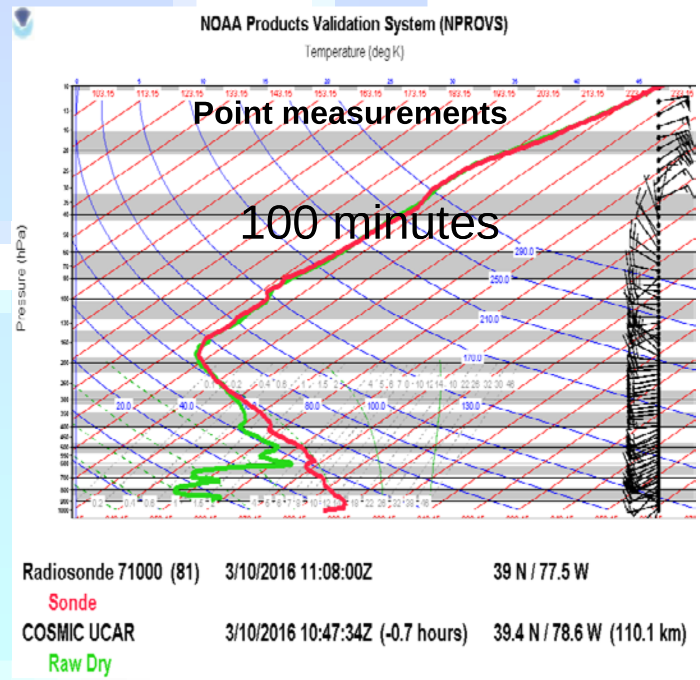


(COSMIC GPSRO provides candidate reference temperature in stratosphere)



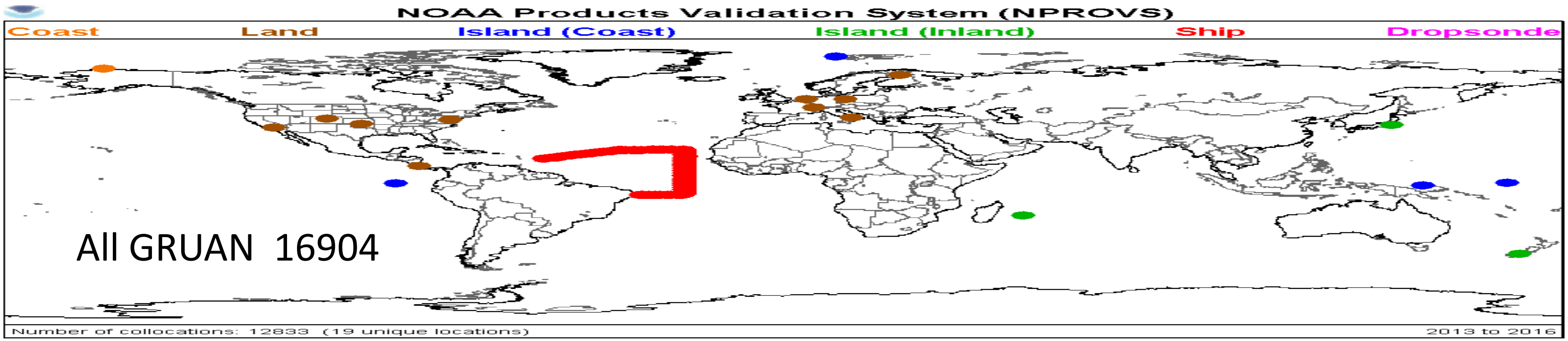
GPSRO

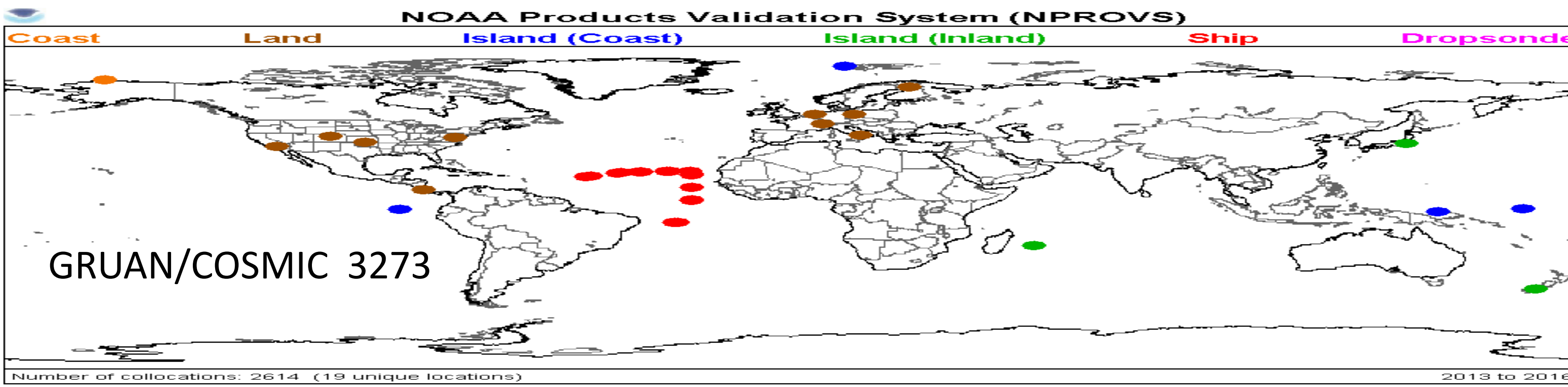


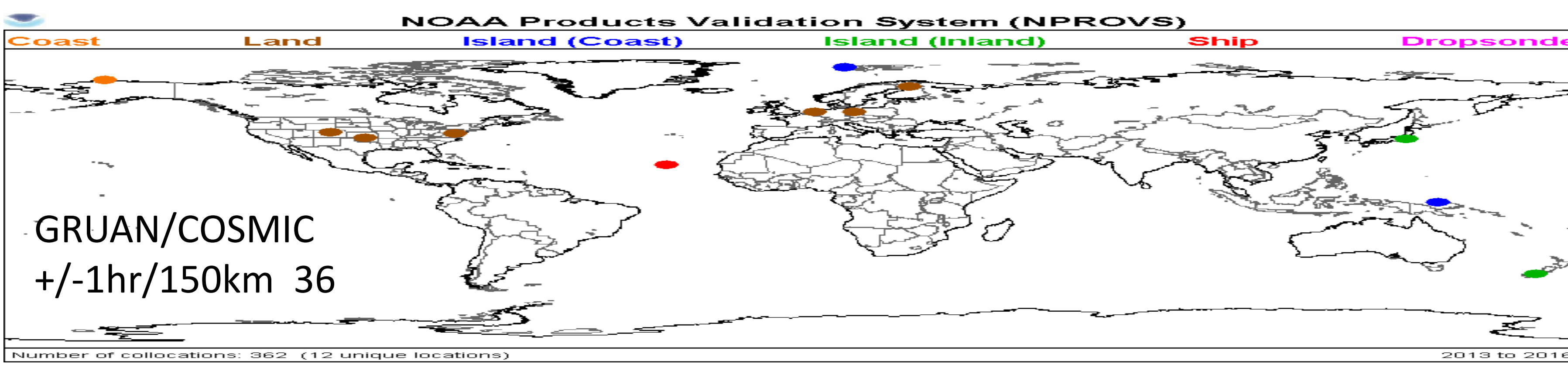


RAOB

“Sigma” for RAOB vs GPSRO can be significant even if observations timely

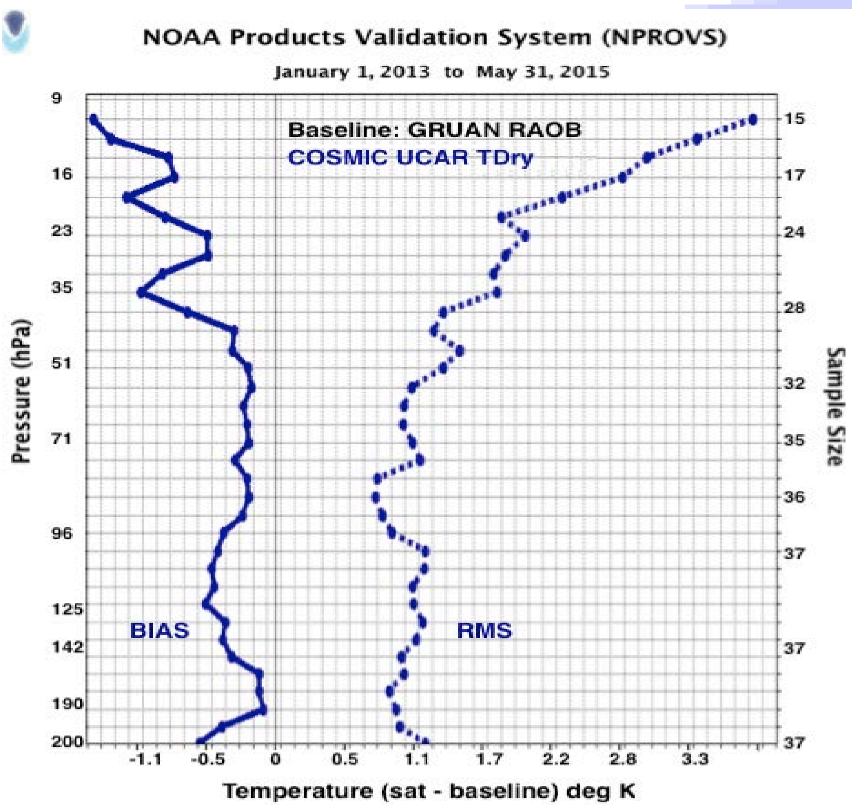




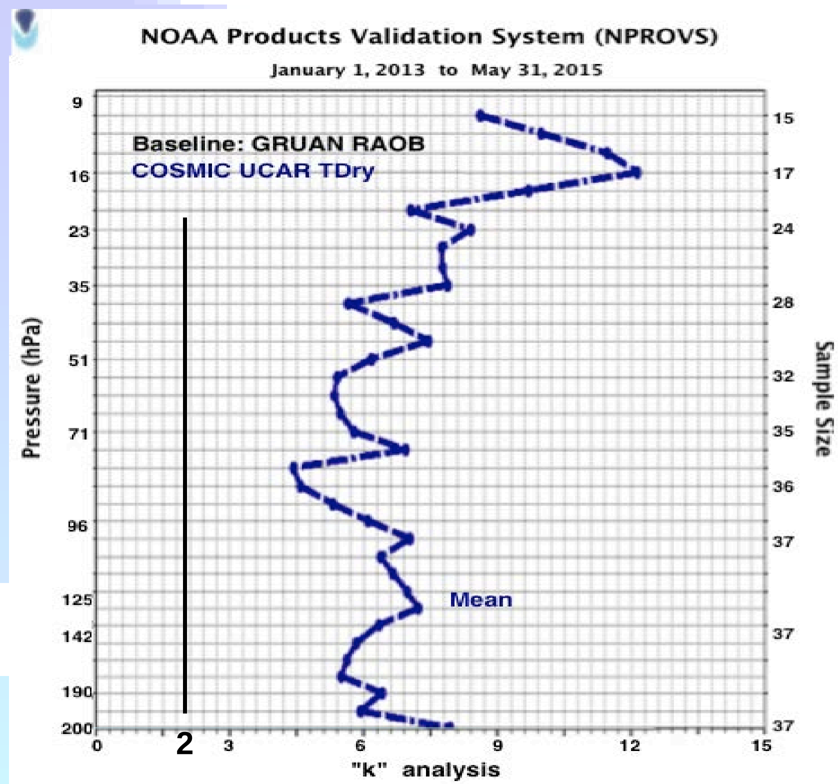


Need to better target GRUAN collocations with GPSRO (and polar satellites)

COSMIC-minus-GRUAN



"k" profile analysis … slide 19

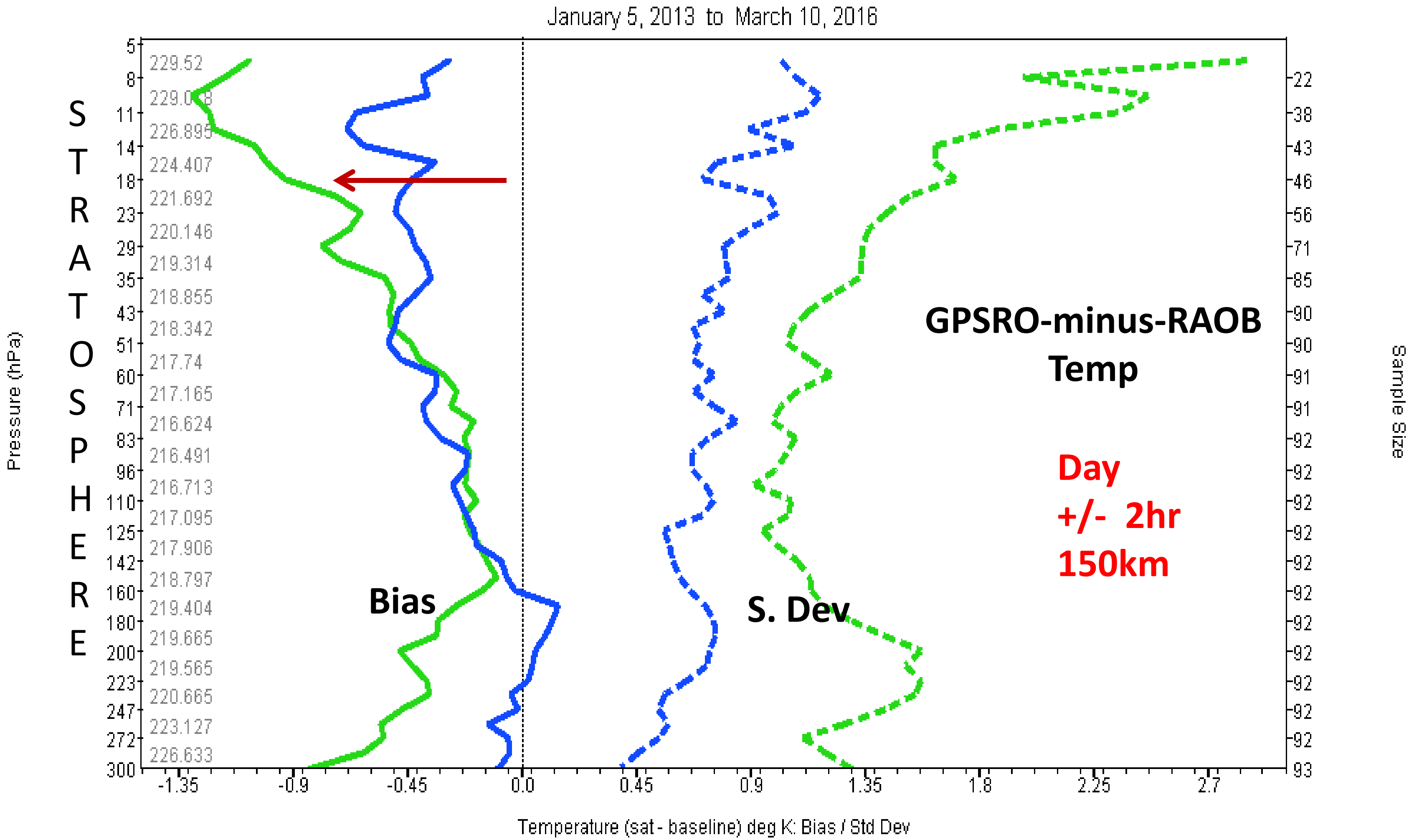


… assuming that u1 is some multiple of u2 simplifies an estimation of the more elusive σ. For example, setting u1 equal to u2, and substituting the mean u1 for the 36 profiles, approximately 0.15 K**, yields an order of magnitude estimate of 0.40 K for σ ("k~6") over the layer 100 to 50 hPa (see slide 13**).

Given these, Fig (2) suggests that 1.1 K RMS difference is within the margin of consistency for GRUAN RAOB and COSMIC temperature profiles collocated within one (1) hour and 100 km for the layer

… feedback to GRUAN

Feedback to GRUAN …

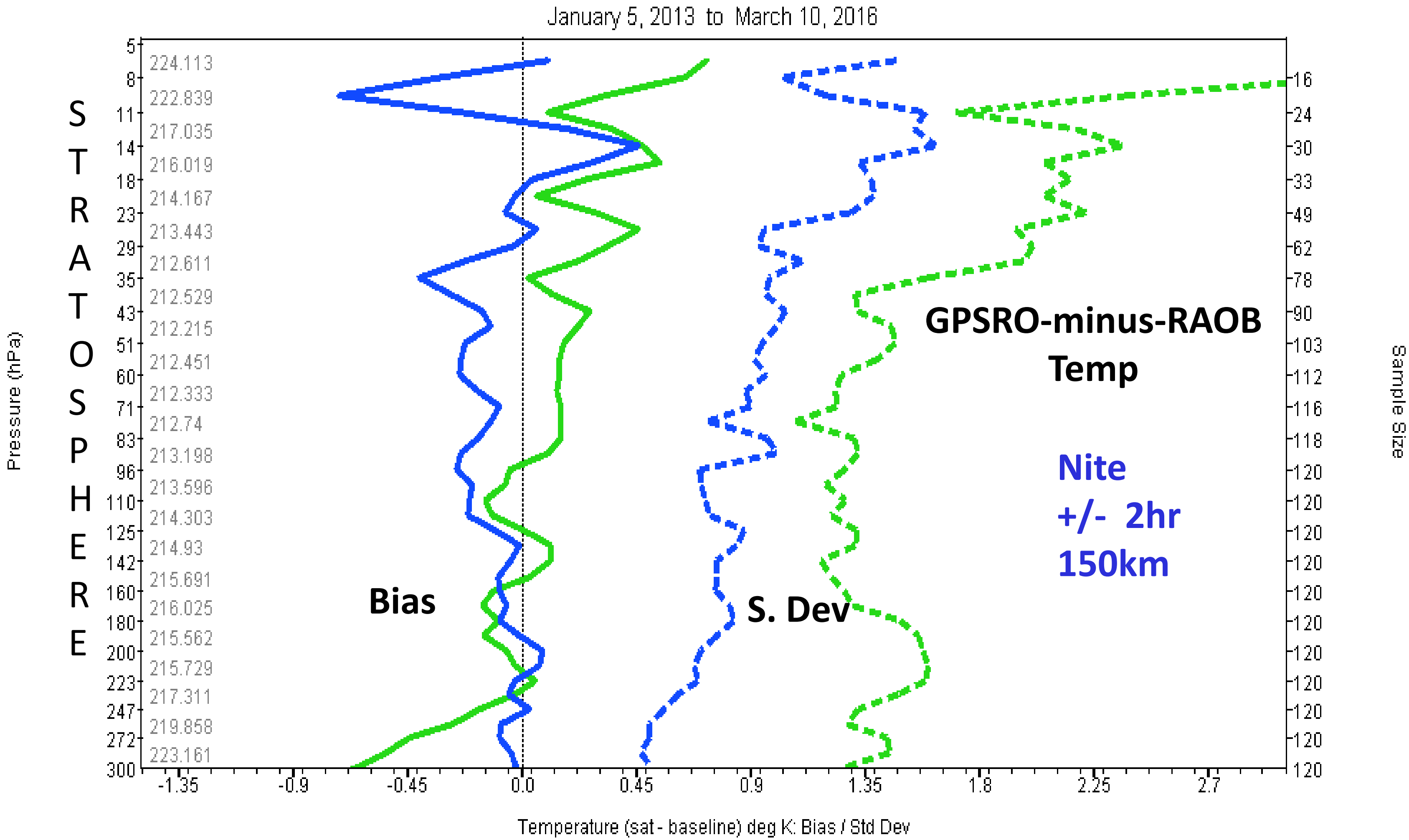


Baseline: Sonde

ECMWF COSMIC UCAR Raw Dry

GPSRO suggest GRUAN (and ECMWF) too warm aloft during day … Sun et.al, JGR, 2013

Feedback to GRUAN …

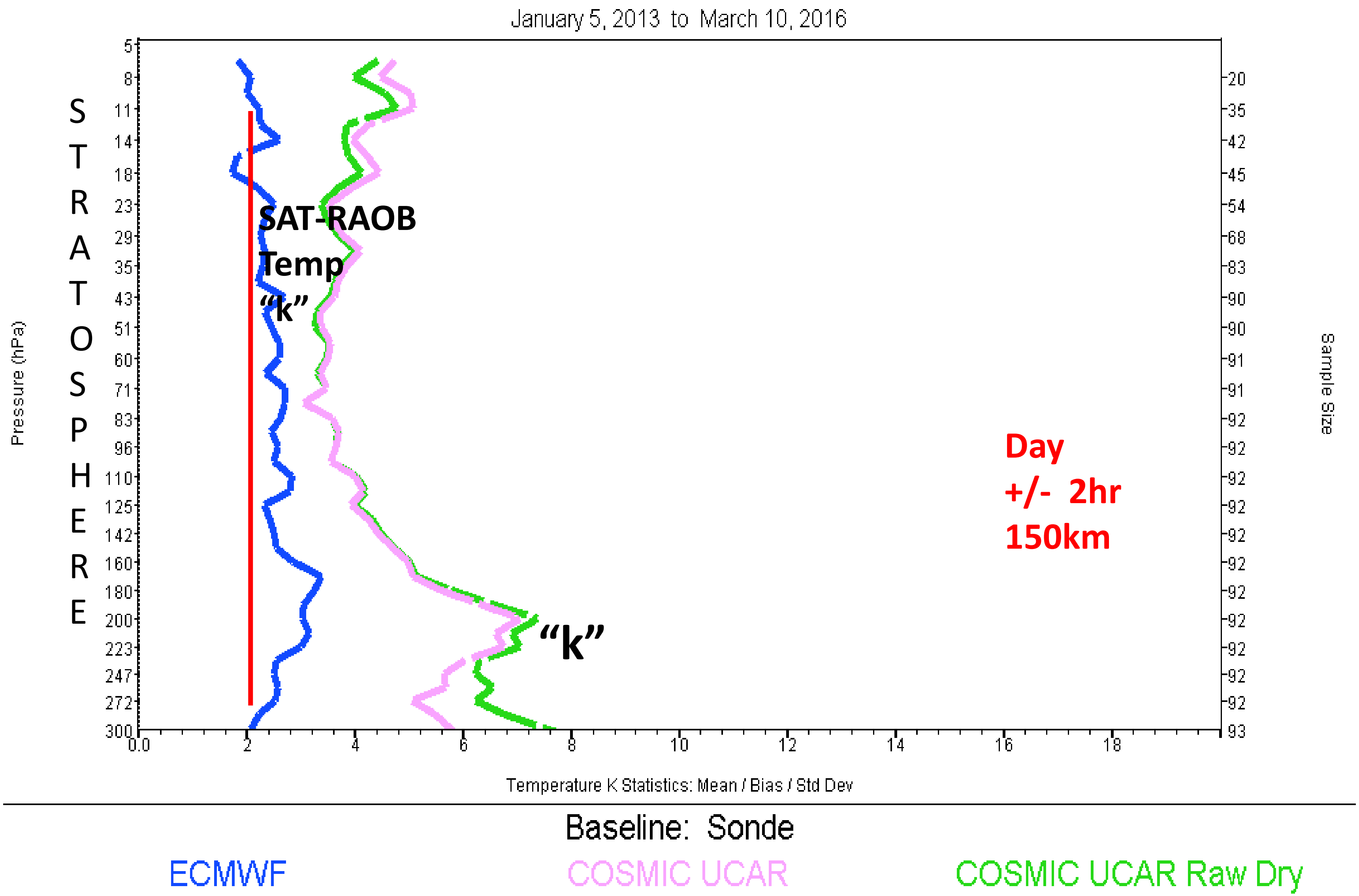


Baseline: Sonde

ECMWF COSMIC UCAR Raw Dry

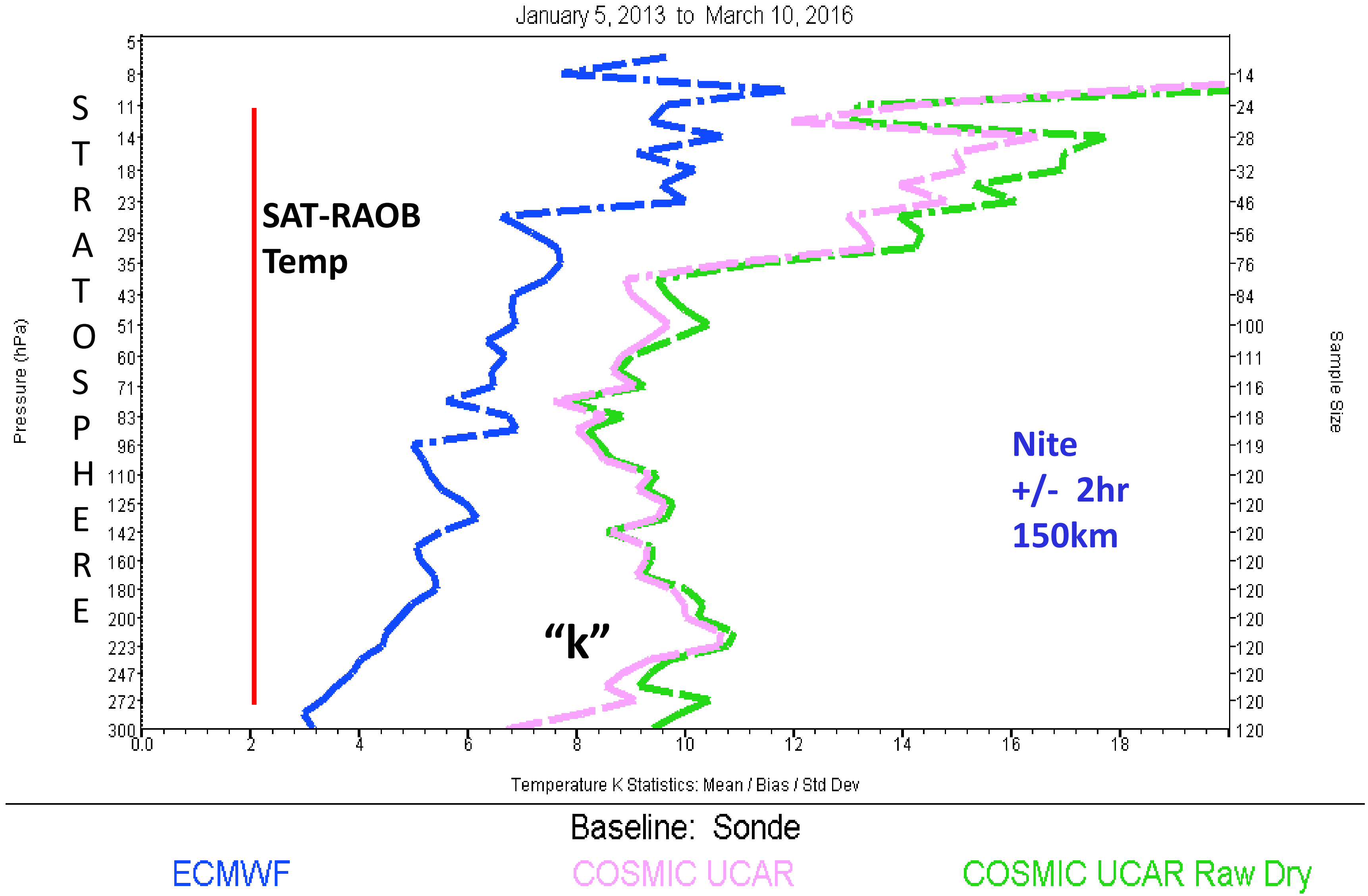
GPSRO suggest GRUAN (and ECMWF) OK at night … Sun et.al, JGR, 2013

Feedback to GRUAN …



“k” analysis suggests GRUAN uncertainty estimate may be too large during day …

Feedback to GRUAN …



"k" analysis suggests GRUAN uncertainty estimate may be too low during day …

Summary

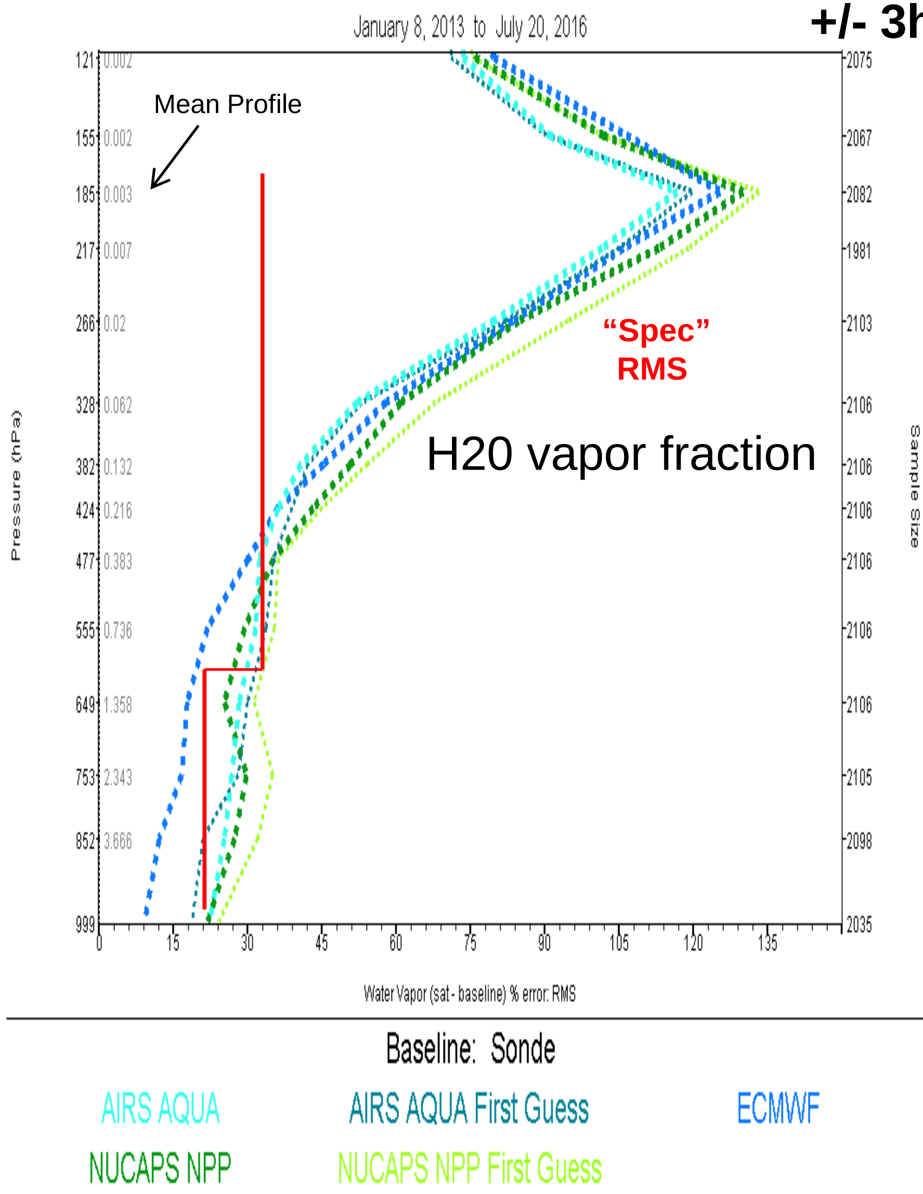
- NPROVS+ operated at STAR provides long-term stewardship of collocated GRUAN and (multiple) Satellite observations

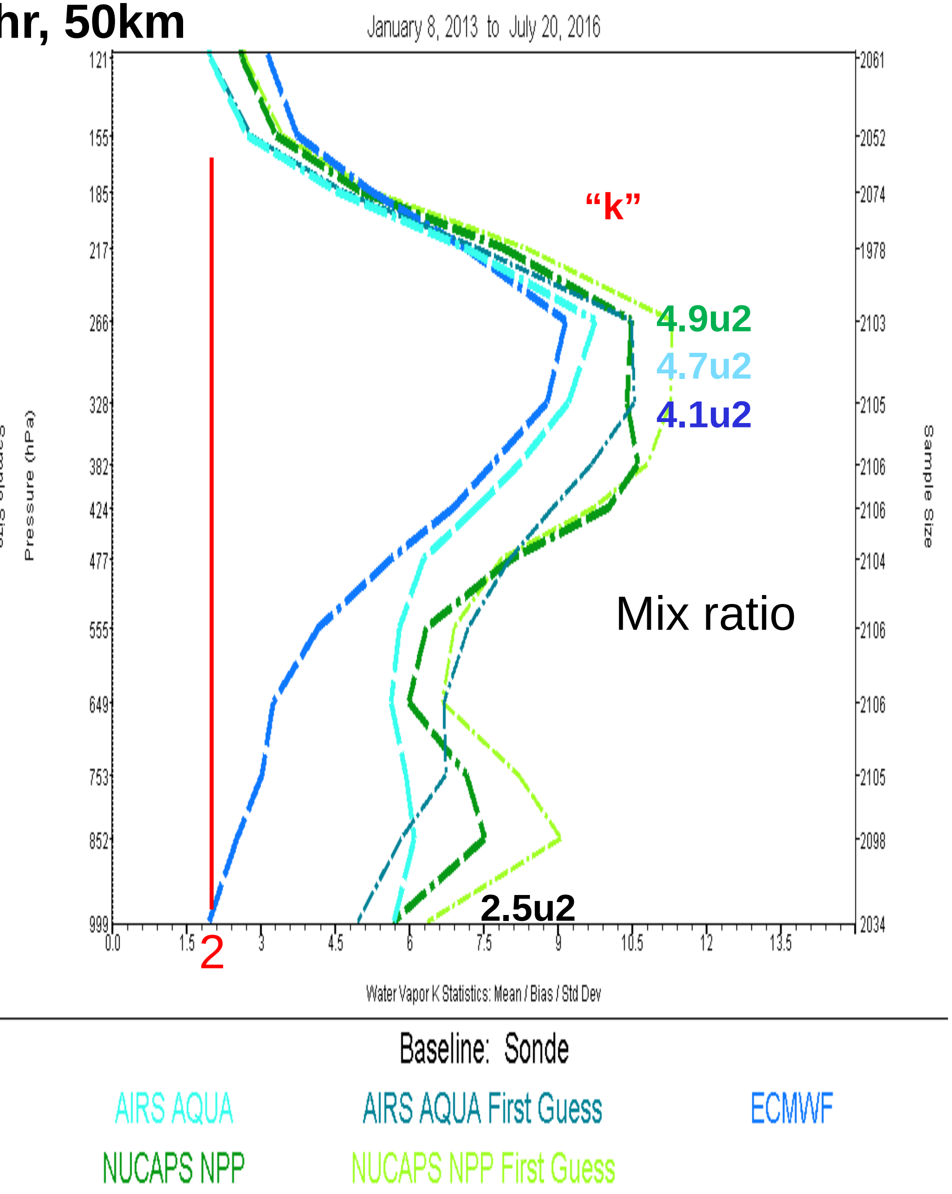
- Satellite synchronized (dedicated) radiosondes funded through JPSS (and ARM) effectively expands GRUAN and provide key observations for accuracy assessments

- Integration of the GRUAN uncertainty can provide estimates of satellite product uncertainty (albeit constrained to validation dataset) … *and sigma*

- Integration of the GRUAN uncertainty provides feedback to GRUAN

+/- 3hr, 50km



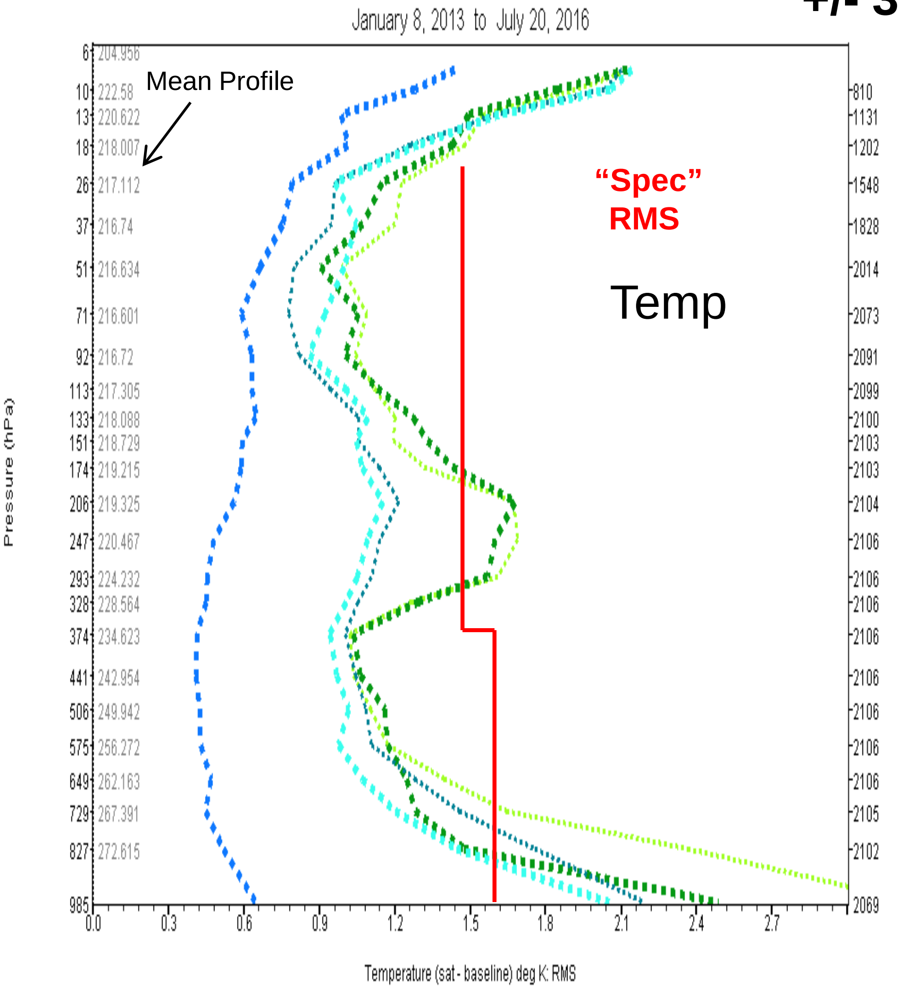


GRUAN Processed and Accepted; IR pass QC

STAR Center for Satellite Applications and Research

formerly ORA — Office of Research and Applications

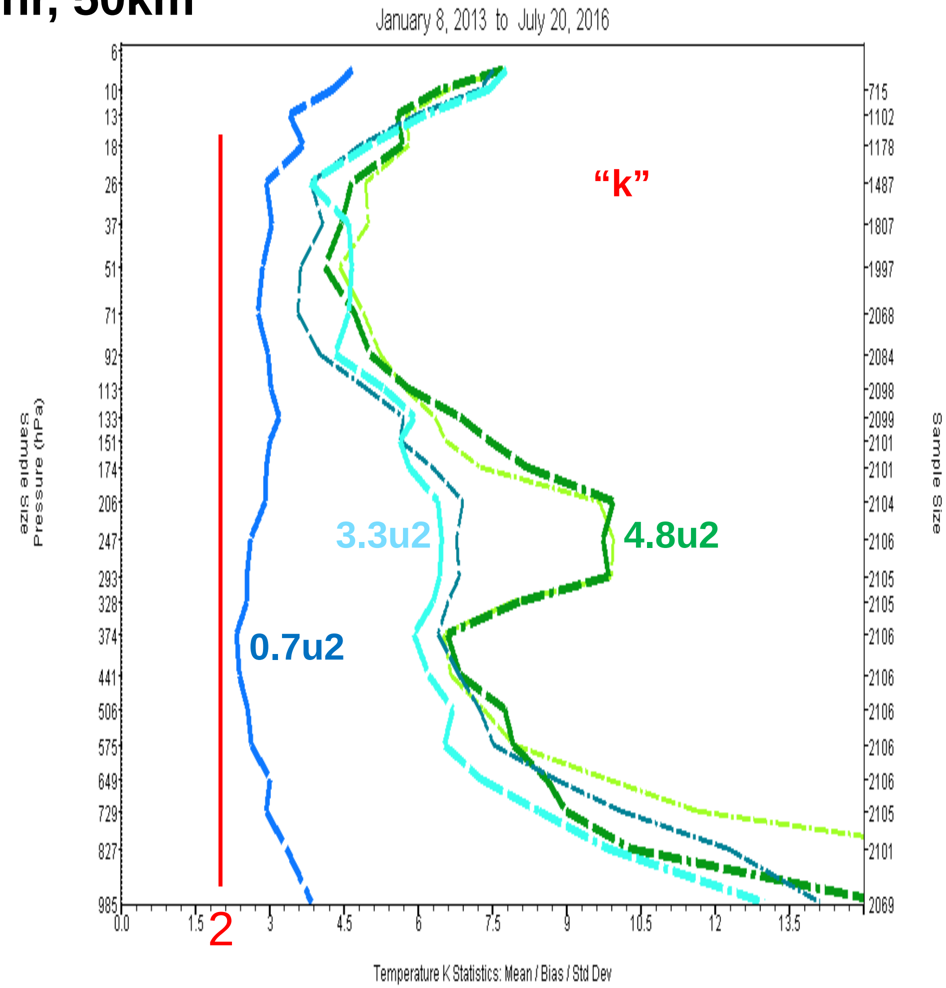
+/- 3hr, 50km



Baseline: Sonde

AIRS AQUA | AIRS AQUA First Guess | ECMWF

NUCAPS NPP | NUCAPS NPP First Guess



Baseline: Sonde

AIRS AQUA | AIRS AQUA First Guess | ECMWF

NUCAPS NPP | NUCAPS NPP First Guess

GRUAN Processed and Accepted; IR pass QC

STAR GCOM-W1/AMSR2 PROJECT UPDATE AND STATUS

STAR GCOM-W1 Project Team
Presented by Paul Chang

Paul Chang, Ralph Ferraro, Zorana Jelenak, Suleiman Alsweiss, Patrick Meyers, Qi Zhu, Mark Romer, Xiwu Zhan, Jicheng Liu, Eileen Maturi, Fuzhong Weng, Andy Harris, Jeff Key, Cezar Kongoli, Walt Meier, Yong-Keun Lee, Walter Wolf, Tom King, Letitia Soullaird, Peter Keehn, Mike Wilson …

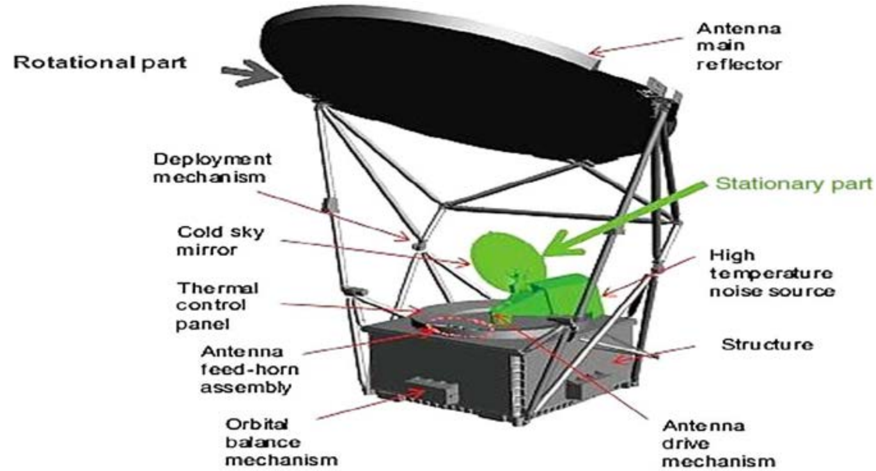
Outline

- Sensor Overview
- AMSR2 EDRs and Project Schedule
- Ongoing validation activities
- Long term monitoring and science maintenance
- Summary and Path Forward

AMSR2 Instrument Overview

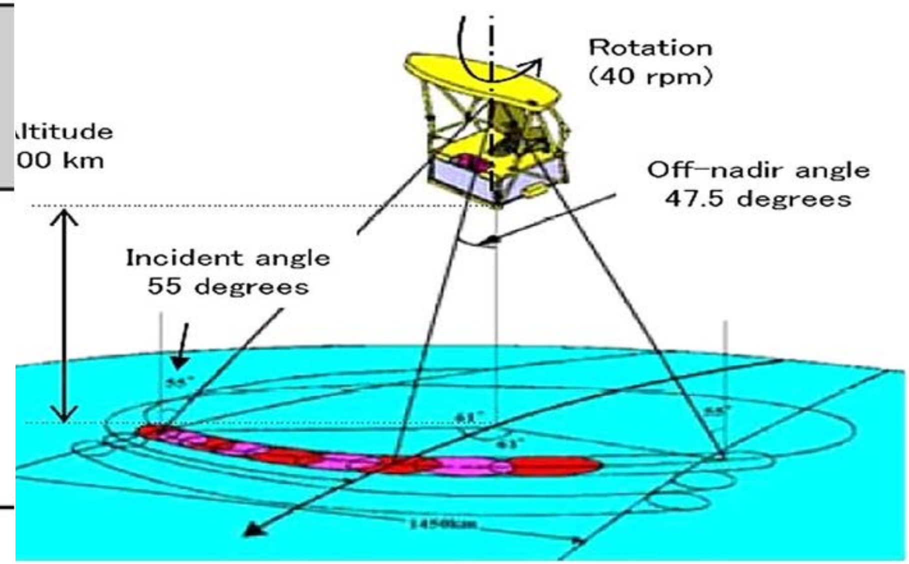
General Information

- Launched: JAXA, 05/2012
- Swath: 1450 km
- EIA: 55°
- Rate: 40 rpm



(a)

Center freq. (GHz)	Band width (MHz)	Beam width (3 dB, deg.)	Ground IFOV (km)	Sampling interval (km)
6.925/7.3	350	1.8	35 x 62	10
10.65	100	1.2	24 x 42	
18.7	200	0.65	14 x 22	
23.8	400	0.75	15 x 26	
36.5	1000	0.35	7 x 12	
89.0	3000	0.15	3 x 5	5



(b)

STAR GAASP Development

- GCOM-W1 AMSR2 Algorithm Software Processor (GAASP) development :

- Day 1 Delivery:
  - Products
    - Microwave Brightness Temperature (MBT)
    - Total Precipitable Water (TPW)
    - Cloud Liquid Water (CLW)
    - Sea Surface Temperature (SST)
    - Sea Surface Wind Speed (SSW)
    - Precipitation Type/Rate (PT/R)
  - Reformatting Capability for MBT and SST into BUFR
  - SPSRB documentation

4

STAR GAASP Development

- Day 2 Delivery:
  - Products
    - Snow Cover/Depth (SC/D)
    - Snow Water Equivalent (SWE)
    - Sea Ice Characterization (SIC)
    - Soil Moisture (SM)
    - Surface Type (ST) – CCR being worked to remove
  - Reformatting Capability for Sea Ice into GRIB2
  - Updated SPSRB Documentation

- Update deliveries annually or as needed in response to issues such as sensor aging, calibration updates, etc.:
  - Updates and enhancements to existing EDRs

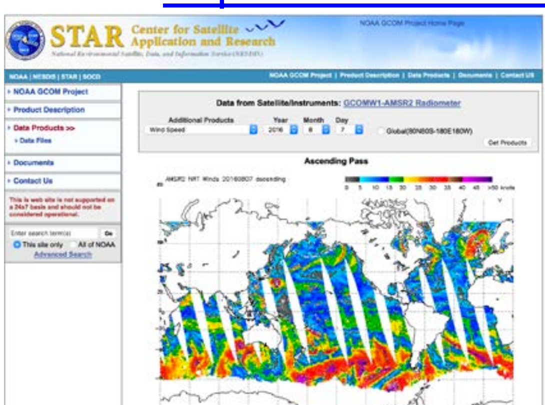
Project Schedule Overview

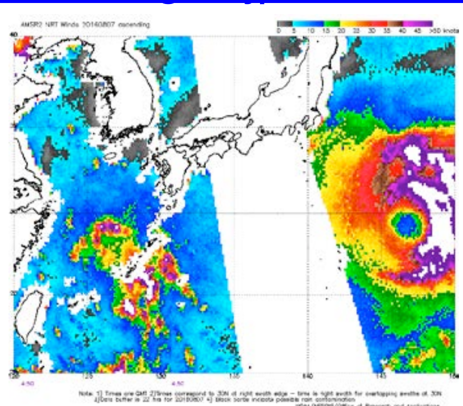
- Key Milestones –Project Milestones Day 1
  - Preliminary Design Review – Nov 8, 2012
  - Critical Design Review – May 1, 2013
  - Software Code Review – Sept 18, 2013
  - Algorithm Readiness Review – Dec 19, 2014
  - Operational Readiness Review – Aug 21, 2015
  - SPSRB Decision Briefing – Sept 23, 2015
  - Operations Commenced - November 4, 2015
  - Algorithm Readiness Review (Day 2) - May 9, 2016

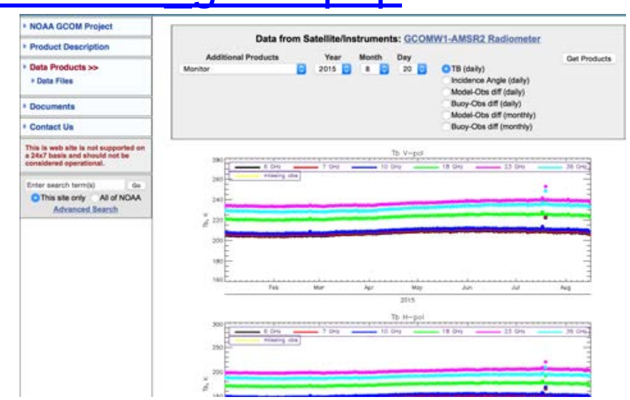
- Since June 2013: Products available in near real-time to users (NHC, JTWC, NRL, etc.) via the GAASP on the STAR GCOM-W1/AMSR2 product development and validation system
- Discontinuities were found the level 1 files that were introduced by the IDPS granules. This necessitated moving to full orbit contacts through IDPS which which will be implemented in NDE 2.0 with IDPS B2.0.
  - Currently NDE is ingesting AMSR2 L1B files directly from JAXA (via NASA)
  - When IDPS2.0 is implemented NDE 2.0 will ingest AMSR RDRs and process to L1 locally utilizing JAXA provided software

Ongoing Validation Activiites

- Collocation of numerical model, objective analysis and satellite data with GCOM-W1/AMSR2 measurements
- Collocation of in-situ data from gauges and field experiments
- Statistical analysis of AMSR2 brightness temperature measurements (level 1 products) utilizing CRTM to characterize residual calibration errors that will impact higher level products
- Statistical analysis of NOAA AMSR2 level 2 products
- Responding to user feedback and questions
- STAR quality monitoring and product display for visual analysis of AMSR2 products
  - http://manati.star.nesdis.noaa.gov/gcom/
- STAR AMSR2 EDR quick look product page
- http://www.star.nesdis.noaa.gov/jpss/EDRs/products_gcom.php







Long Term Monitoring and Science Maintenance

- Extend validation datasets (spatially and temporally collocated numerical model and satellite data) to account for seasonal and annual trends.
- Collect in-situ data from relevant field experiments to support validation and quality assurance not possible by utilizing existing satellite or numerical model datasets. For example, characterization of product performance in extreme environmental conditions (tropical and winter storms) generally require specialized datasets.
- Algorithm sustainment, such as, updates to the algorithms when quality issues are identified in operation or when Level 1 processing updates are implemented by JAXA
- Other event-driven anomalies, such as, channel loss, sensor degradation, which will impact the measurements and thus the derived products

Summary & Path Forward

- Implement EDR improvements and enhancements resulting from ongoing validation activities and user feedback into GAASP updates
- Calibration updates, product updates and continued monitoring and quality control
    - Continue working with JAXA on Level 1 calibration improvements
    - Address JAXA updates to Level 1 processing software as needed
    - Continue validation and product monitoring and implement product updates as needed
    - User product training and outreach
- Provide support to JAXA as appropriate to help them realize a GCOM-W1 follow-on mission.

IMPACT AND APPLICATIONS OF GCOM-W OCEAN PRODUCTS AT NOAA

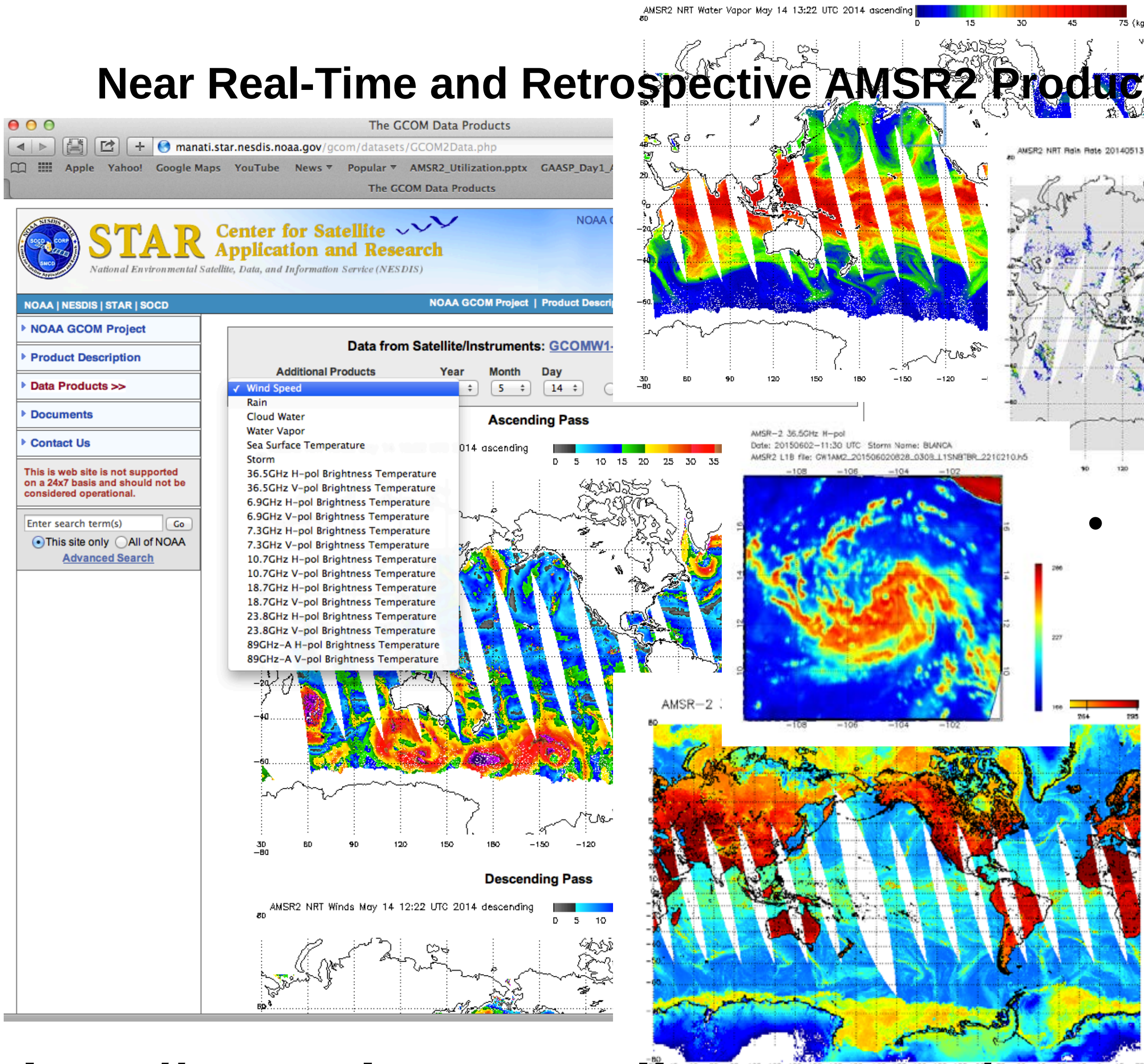
NOAA/NESDIS/STAR
Zorana.Jelenak@noaa.gov
Zorana Jelenak, Suleiman Alsweiss, Paul S Chang

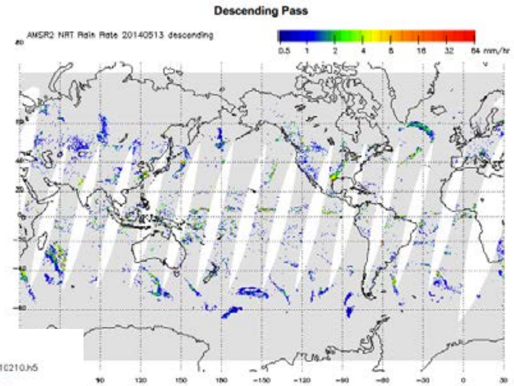
Outline

- AMSR-2 Ocean Products Introduction
- AMSR-2 Utilization Examples:
  - Near-real time tropical cyclone forecasting: Tropical cyclone structure, location and intensity analysis
  - Near real time and research impact: SST measurements indicating the onset of rapid intensity decay in a tropical cyclone
  - Extratropical (ET) transition process and ET cyclone structure analysis
- Conclusions

STAR GCOM-W AMSR2 Ocean Products Web Page

Near Real-Time and Retrospective AMSR2 Product Portal





- Ocean NRT Products
  - **MW brightness temperature**
    - Tropical Cyclone forecasting
    - Data assimilation
  - **SST, Wind Speed ,Cloud liquid water, Water Vapor, Rain Rates**
    - Blended Products
    - NWP Model validation
    - Climate studies
    - Research

3

http://manati.star.nesdis.noaa.gov/gcom

Current Users of Near Real-time GCOM – W Data

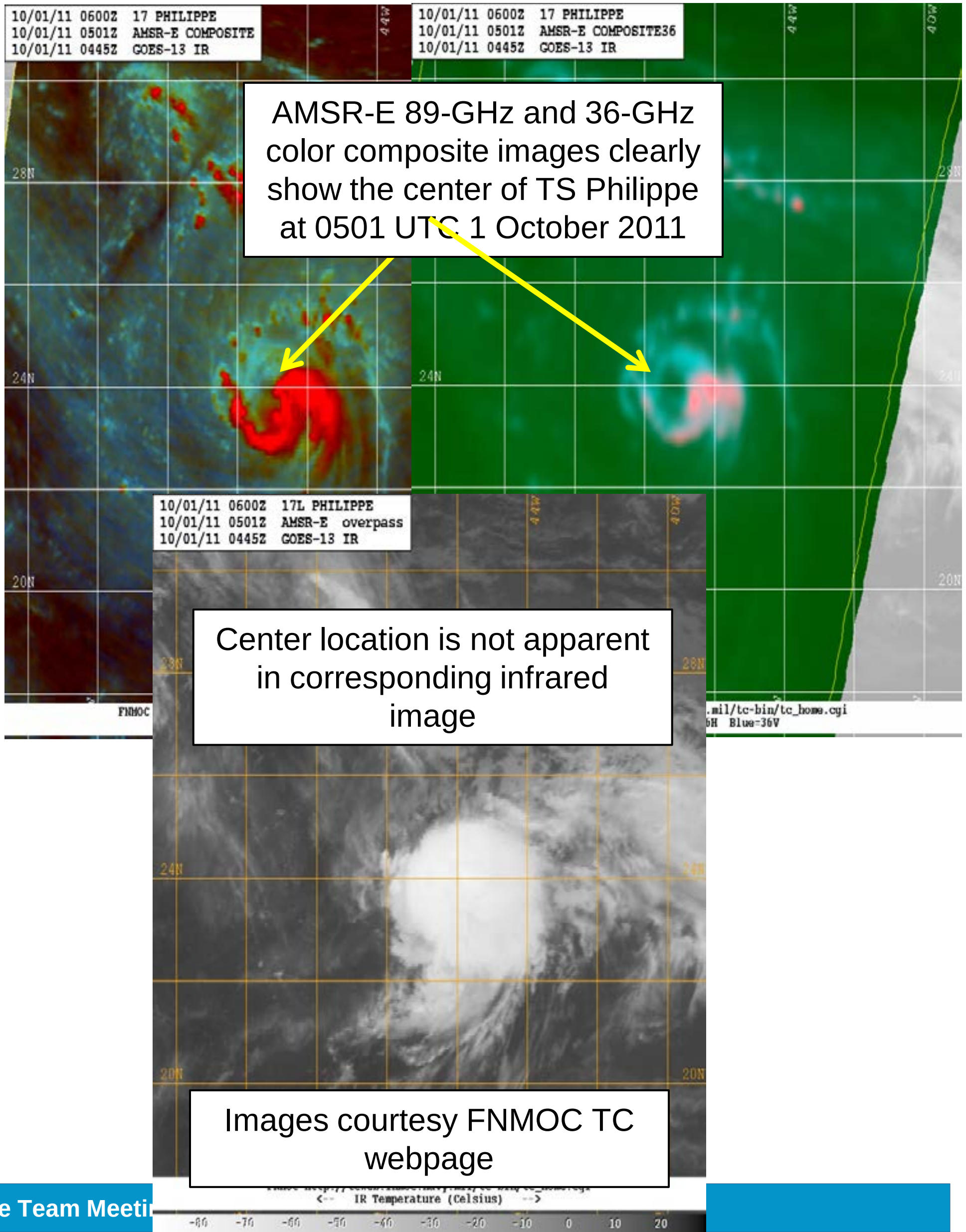
- US NOAA National Weather Service
  - Tropical Cyclone Monitoring and Forecasting
  - Numerical Weather Prediction Model Assimilation
  - Marine Forecasting and Monitoring
  - Hydrological and Precipitation Forecasting and Monitoring
  - Seasonal and Climate Forecasting
- US National Ice Center
- US Department of Defense
  - AFWA
  - FNMOC
  - NAVO
  - Naval Research Laboratory
    - Joint Typhoon Warning Center
    - Oceanographer of Navy
- Leading Numerical Weather Prediction Centers outside US including: Japan, ECMWF

US NWS GCOM Data Product Priorities (initial) for AWIPS2
AMSR-2 Imagery (36H, 36V, 89H, 89V, GHz)
AMSR-2 Cloud Liquid Water
AMSR-2 Precipitation (Type/Rate)
AMSR-2 Precipitable Water
AMSR-2 Sea Surface Wind Speed
AMSR-2 Snow Cover/Depth
AMSR-2 Snow Water Equivalent
AMSR-2 Soil Moisture
AMSR-2 Sea Ice Characterization
AMSR-2 Sea Surface Temperature (SST)
AMSR-2 Surface Type

AMSR-2 MICROWAVE IMAGERY FOR TROPICAL CYCLONE FORECASTING

Uses of Microwave Imagery
Overview

- Determining if a formative system has a well-defined center, a requirement to initiate advisories
- Locating the center of TCs when the center is not apparent in conventional visible or infrared imagery, especially for weaker systems at night
- Assessing trends in TC structure and intensity, such as eyewall formation and eyewall replacement cycles



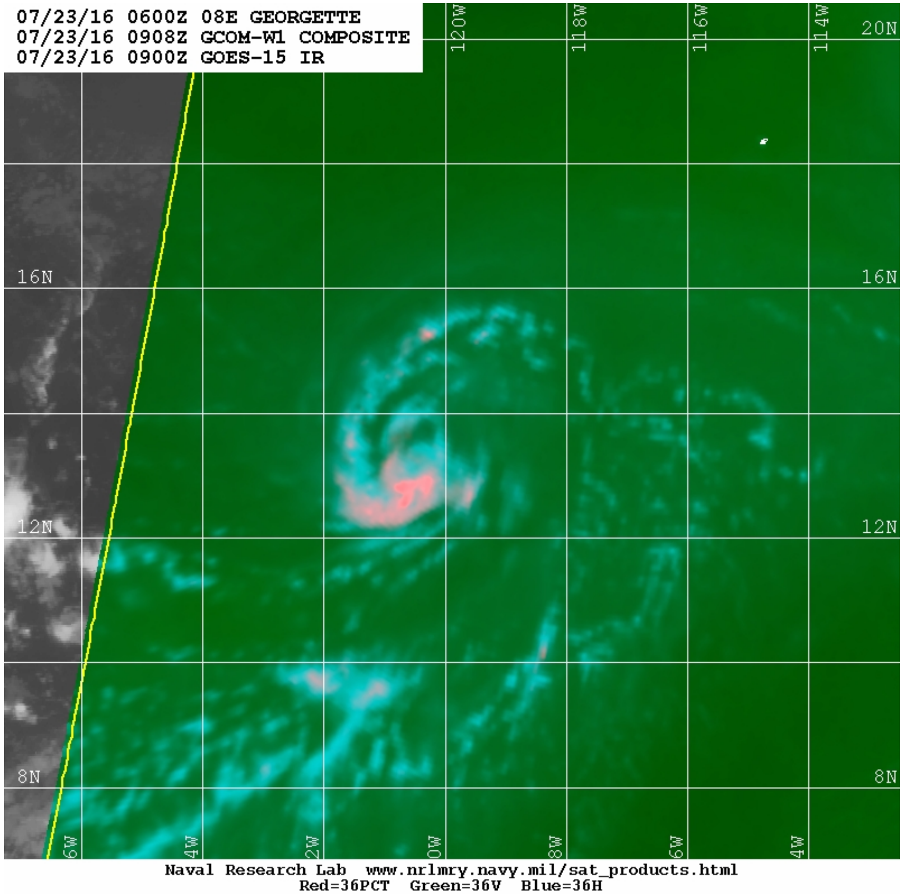
Tropical Storm Georgette 23rd July 2016

ZCZC MIATCDEP3 ALL TTAA00

KNHC DDHHMM TROPICAL STORM GEORGETTE

DISCUSSION NUMBER 8 NWS NATIONAL HURRICANE CENTER MIAMI FL EP082016 800 AM PDT SAT JUL 23 2016

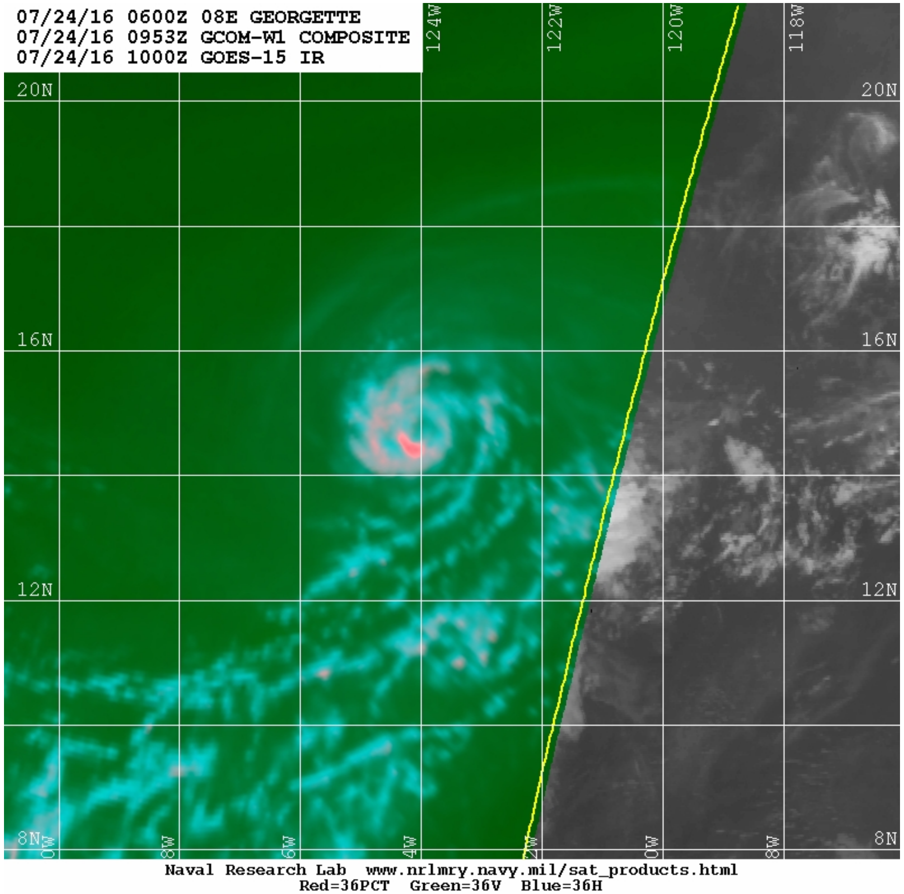
With the help of the above-mentioned AMSR pass, the initial motion is estimated to be 290/11. There is no change to the track forecast reasoning, as Georgette will be steered by a strong mid-level ridge to the north that will weaken and shift westward during the next several days.



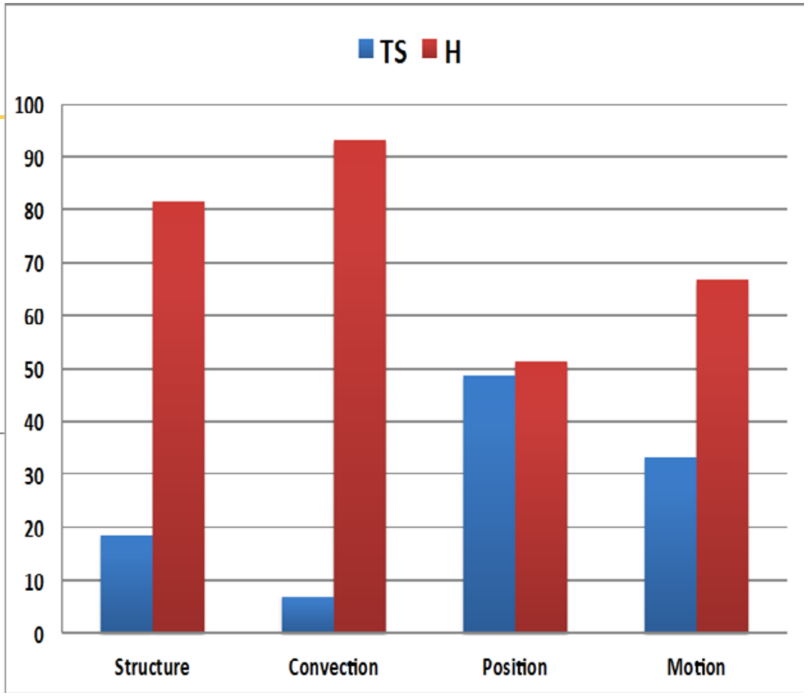
Hurricane Georgette 24th July 2016

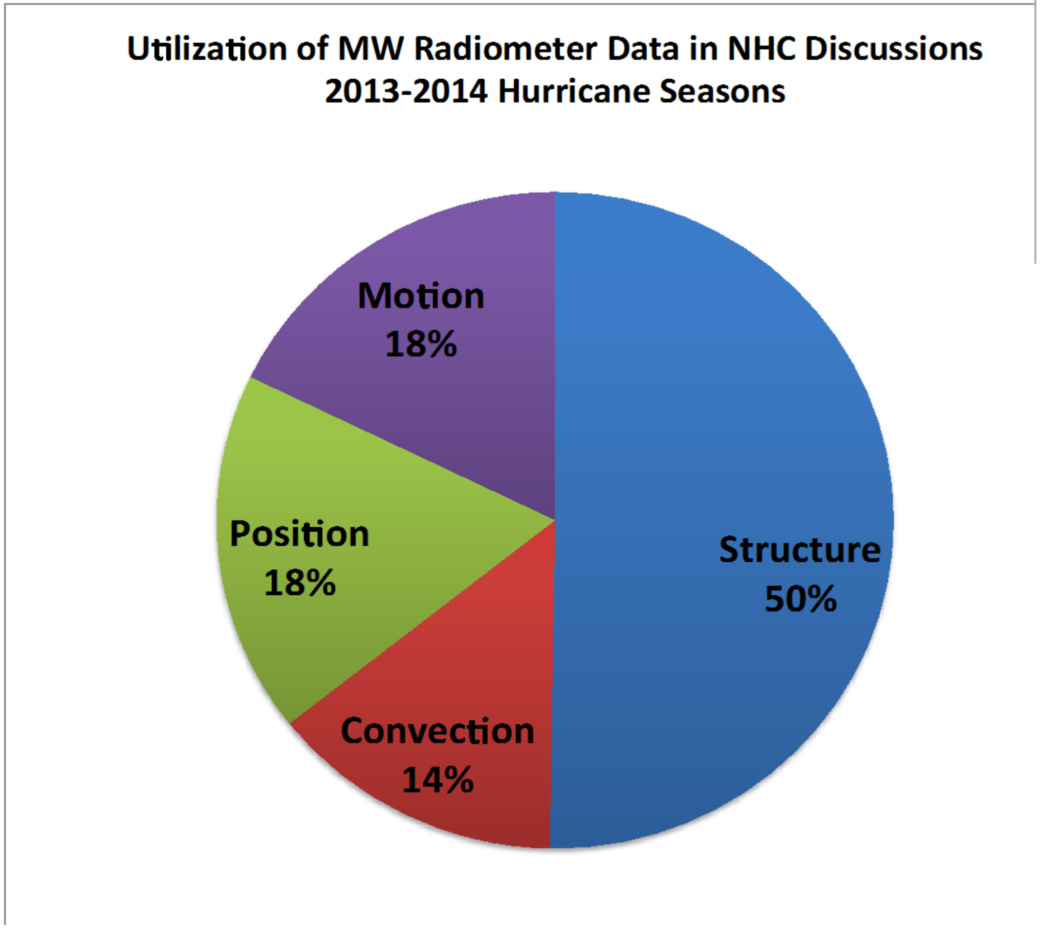
ZCZC MIATCDEP3 ALL TTAA00 KNHC DDHHMM HURRICANE GEORGETTE DISCUSSION NUMBER 12 NWS NATIONAL HURRICANE CENTER MIAMI FL EP082016 800 AM PDT SUN JUL 24 2016

The coverage of cold convective tops has increased over the past few hours **and a 0921Z GPM pass and 0935Z AMSR pass showed that the center of Georgette was near the middle of the CDO feature**. Based on the improved convective organization, the initial intensity has been set to 75 kt, which is close to the latest Dvorak estimates from SAB and UW-CIMSS. The hurricane has an opportunity to strengthen a bit more in the short term before SSTs cool below 26C by 24 hours.



AMSR2 Utility at NHC



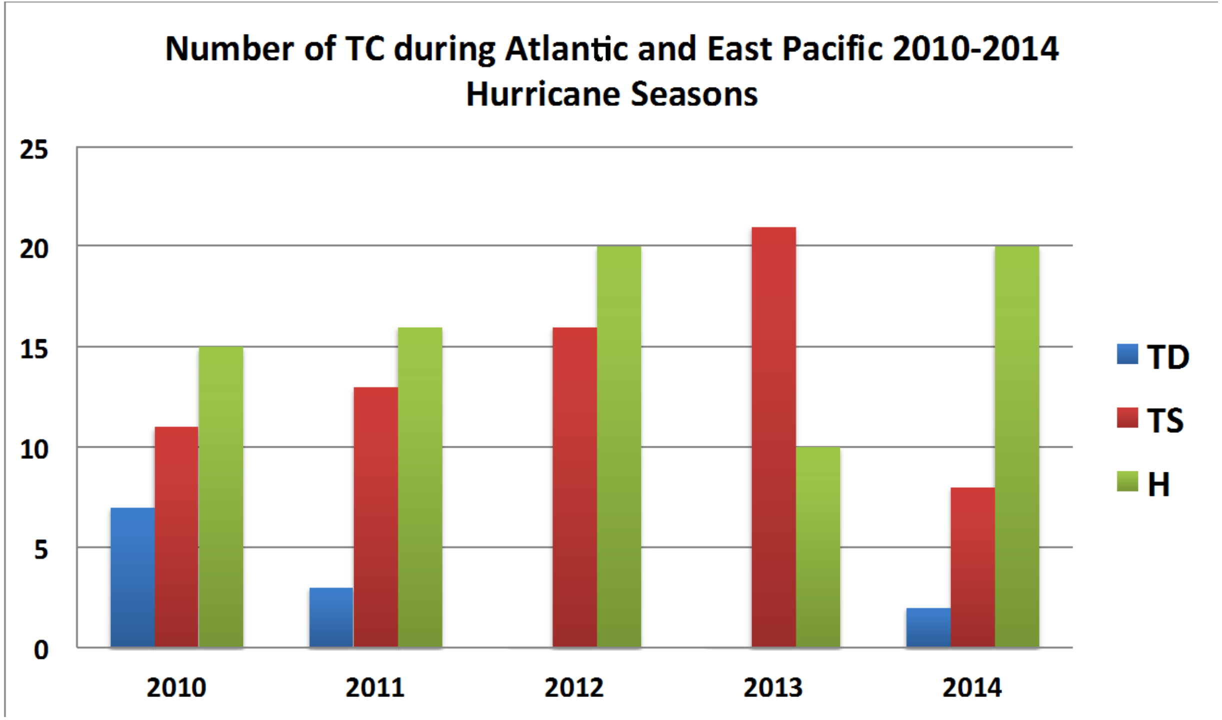


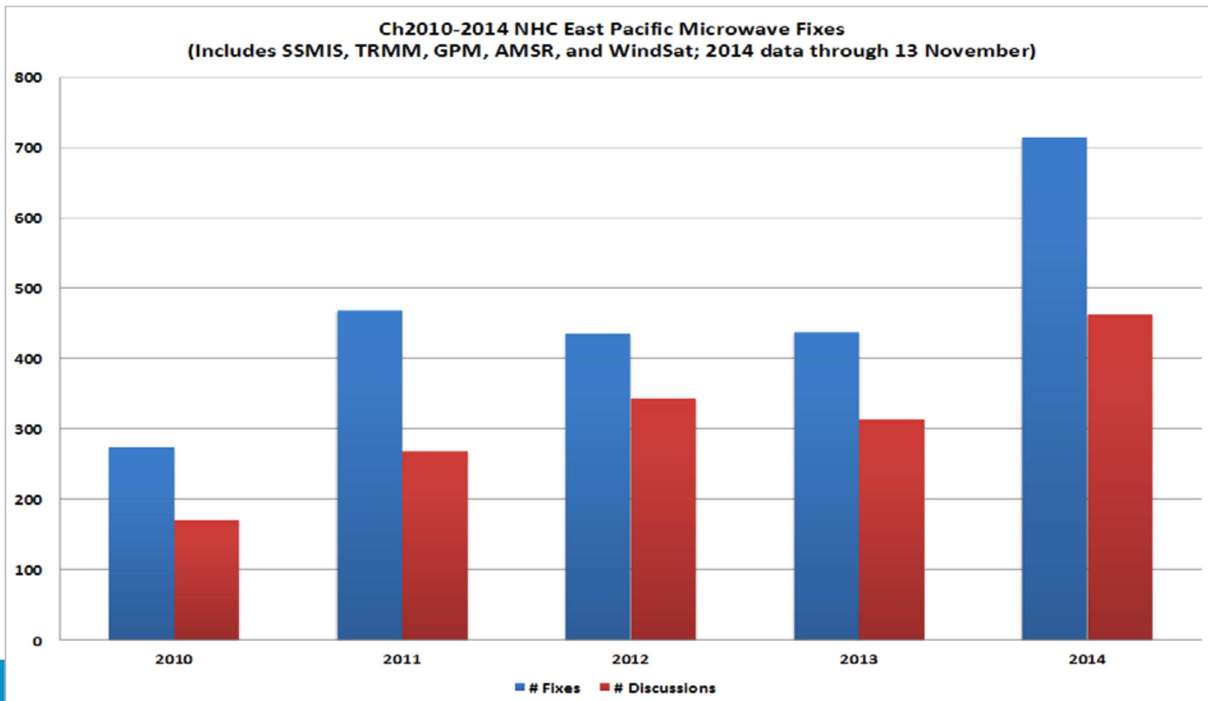
- MW data is most useful for monitoring changes in storm convection and structure and within 2013-2014 season data has been used almost 50% of time in this purpose

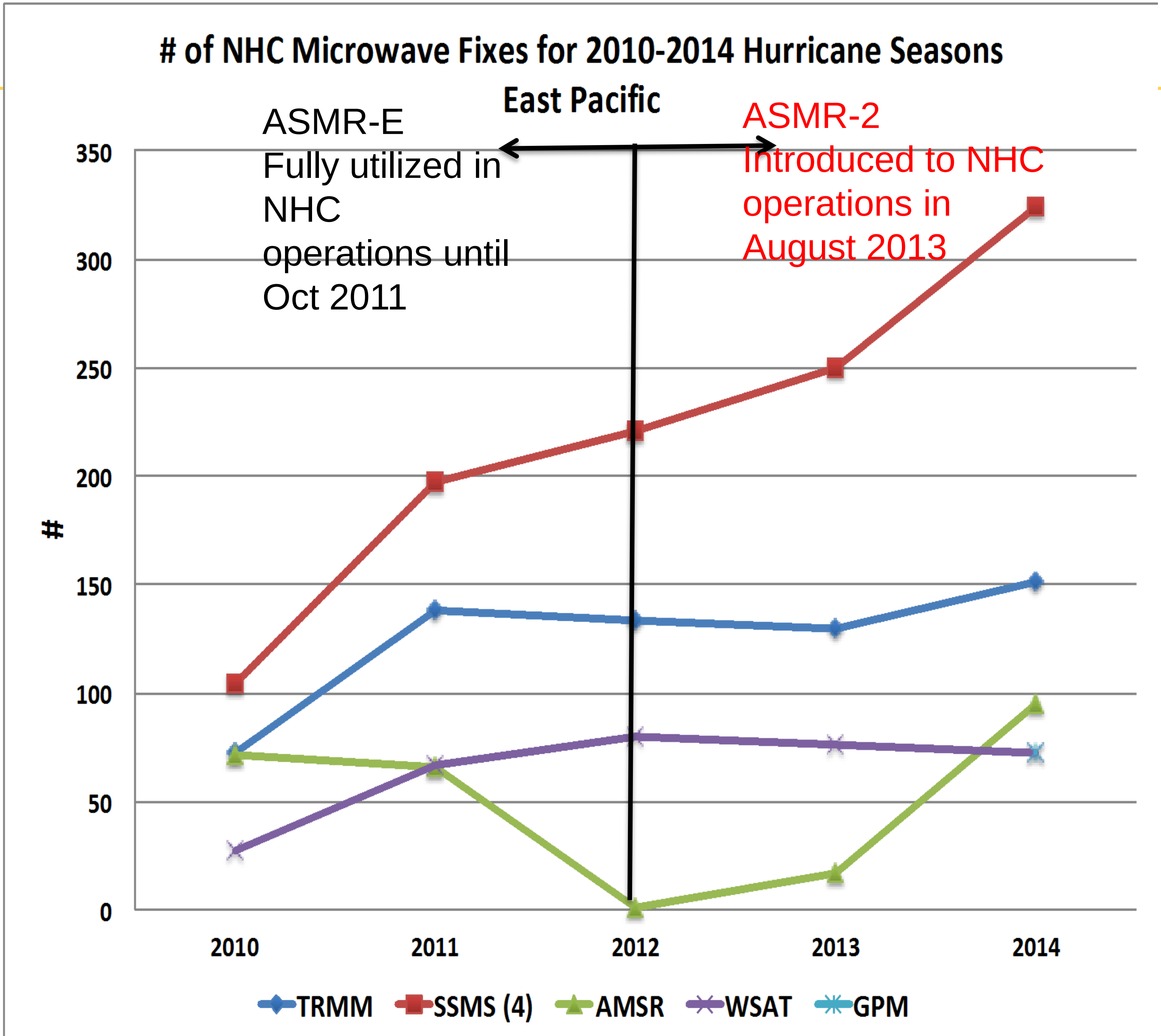
Quantifying Impact of Microwave Data on TC Forecasting

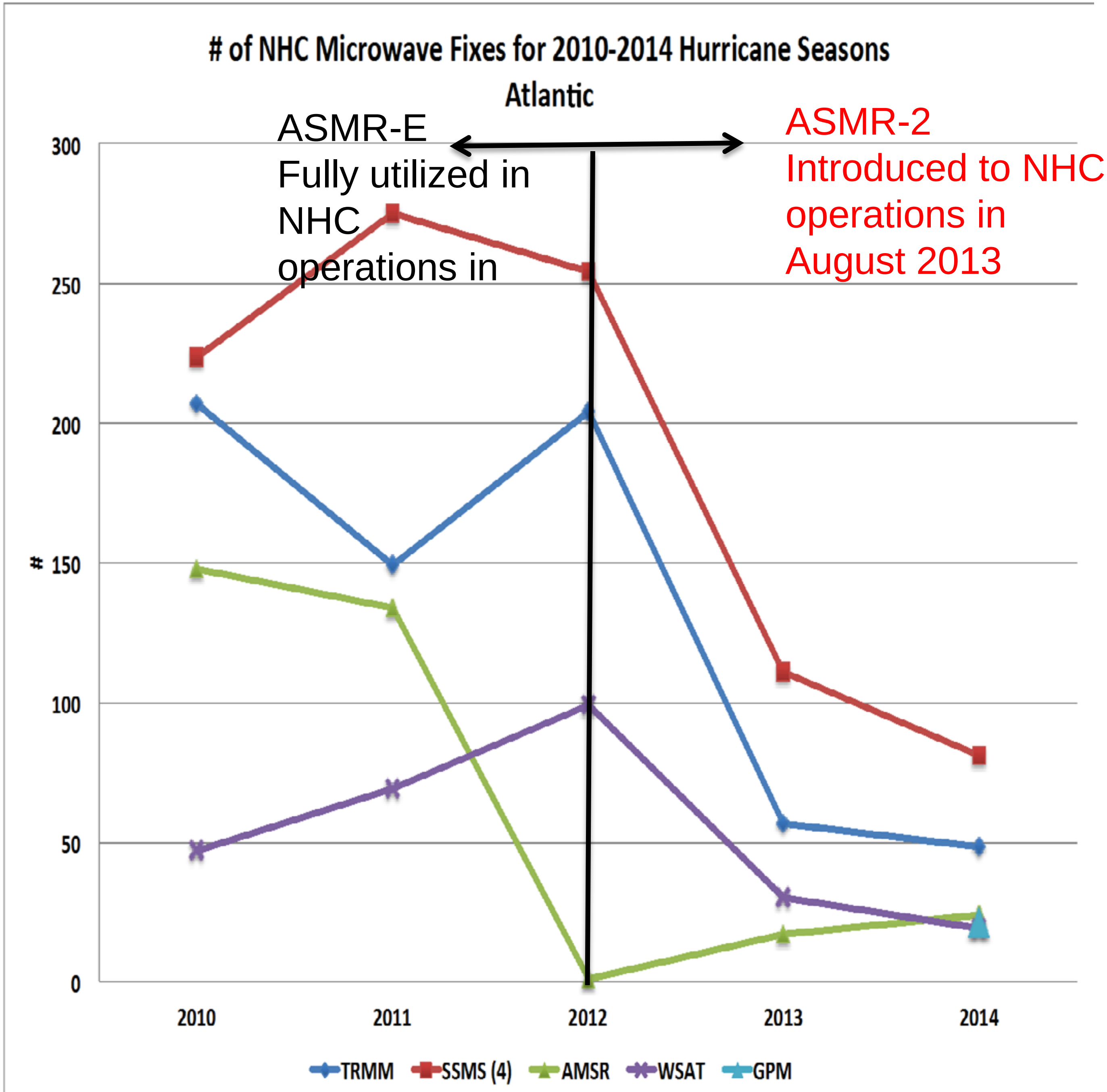
- To asses impact of MW radiometer on NHC operations we examined usage of MW data during 2010-2014 Atlantic and East Pacific hurricanes seasons in Automatic Tropical Cyclone Forecast system
- We have also examined NHC discussions issued 4 times a day during TC event
- MW radiometers used are TRMM, DMSP SSMIS (F16,17 and 18) and SSMI (F15), and AMSR-E and AMSR2

10


Number of TC during Atlantic and East Pacific 2010-2014 Hurricane Seasons
25
20
15
10
5
0
2010
2011
2012
2013
2014
TD
TS
H


Ch2010-2014 NHC East Pacific Microwave Fixes
(Includes SSMIS, TRMM, GPM, AMSR, and WindSat; 2014 data through 13 November)
800
700
600
500
400
300
200
100
0
2010
2011
2012
2013
2014
Fixes
Discussions


# of NHC Microwave Fixes for 2010-2014 Hurricane Seasons
East Pacific
ASMR-E
Fully utilized in NHC operations until Oct 2011
ASMR-2
Introduced to NHC operations in August 2013
350
300
250
200
150
100
50
0
#
2010
2011
2012
2013
2014
TRMM
SSMS (4)
AMSR
WSAT
GPM

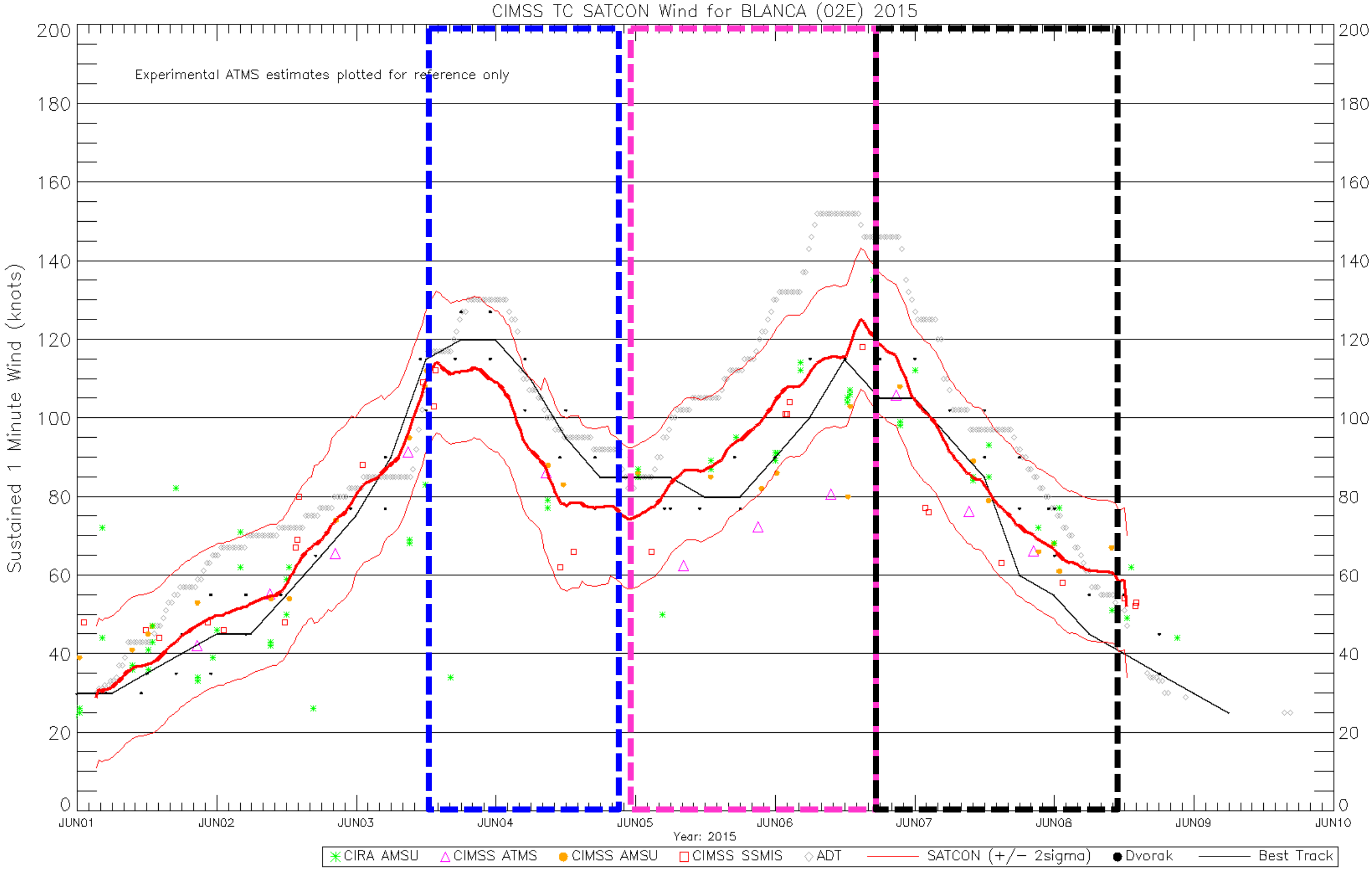


# of NHC Microwave Fixes for 2010-2014 Hurricane Seasons
Atlantic
ASMR-E
Fully utilized in
NHC
operations in
ASMR-2
Introduced to NHC
operations in
August 2013
300
250
200
#
150
100
50
0
2010
2011
2012
2013
2014
TRMM
SSMS (4)
AMSR
WSAT
GPM

EXAMPLE OF AMSR-2 IMPACT ON NEAR REAL TIME FORECAST AND RESEARCH: EAST PACIFIC HURRICANE BLANCA JUN 2015

Plots courtesy of Michael Brennan, NHC

Peter Black, NRL

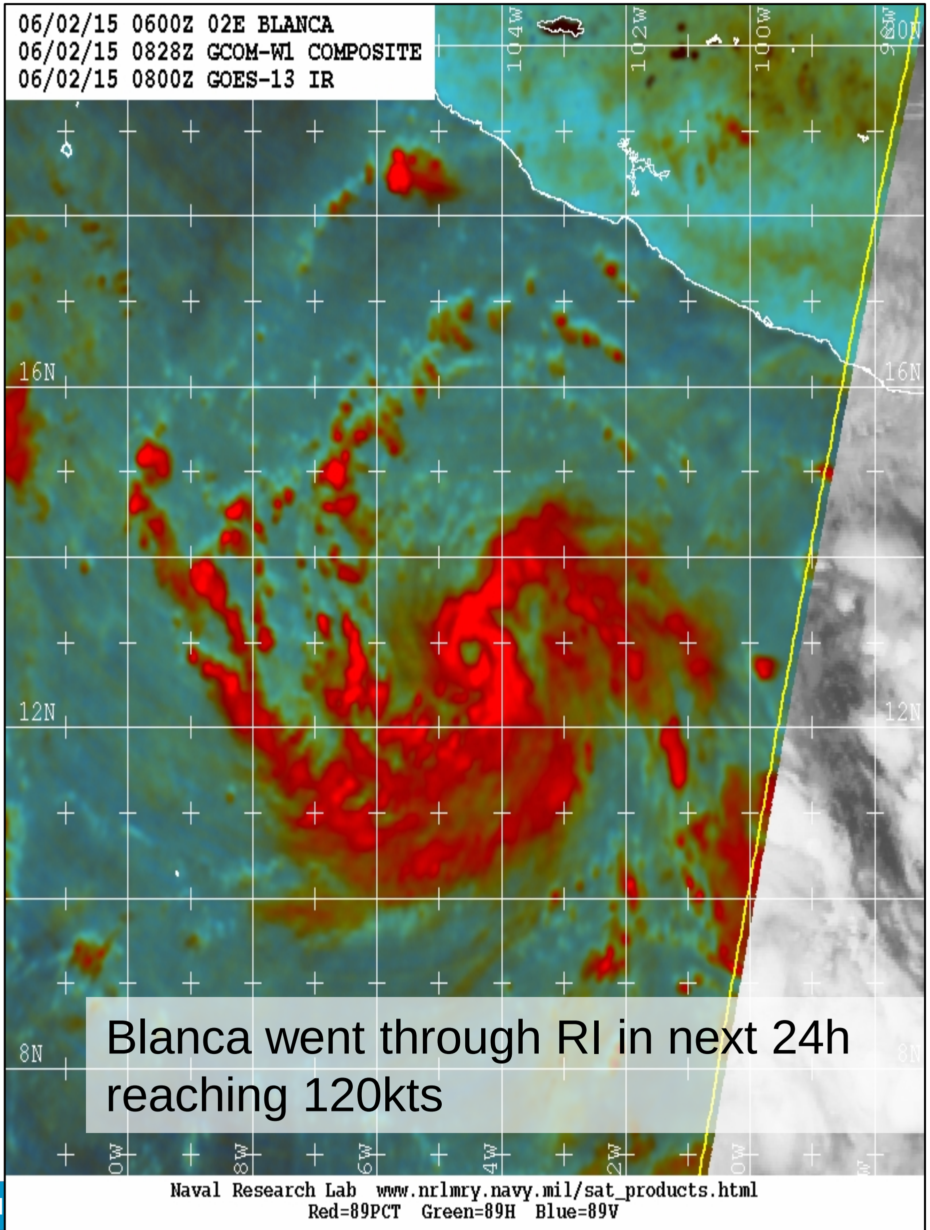

CIMSS TC SATCON Wind for BLANCA (02E) 2015
Experimental ATMS estimates plotted for reference only
Sustained 1 Minute Wind (knots)
200
180
160
140
120
100
80
60
40
20
0
JUN01
JUN02
JUN03
JUN04
JUN05
JUN06
JUN07
JUN08
JUN09
JUN10
Year: 2015
CIRA AMSU
CIMSS ATMS
CIMSS AMSU
CIMSS SSMIS
ADT
SATCON (+/- 2sigma)
Dvorak
Best Track

Tropical Storm Blanca
2 June 2015

TROPICAL STORM BLANCA DISCUSSION NUMBER 8
NWS NATIONAL HURRICANE CENTER MIAMI FL EP022015
1000 AM CDT TUE JUN 02 2015

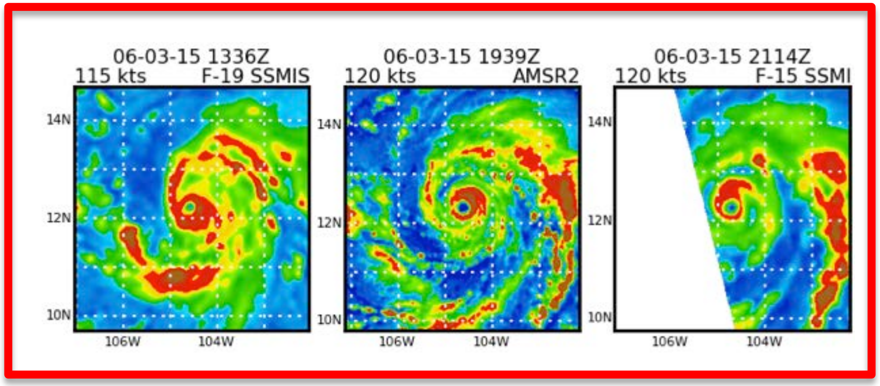
Blanca is intensifying. Geostationary imagery shows a CDO and prominent banding features, and a **0828Z AMSR-2 image from GCOM-W1 showed a low- and mid-level eye feature.** The latest Dvorak estimates from TAFB and SAB are T3.5/55 kt, and the latest ADT is T4.5/77 kt. The initial intensity is set to 60 kt for this advisory. **Given that Blanca has developed the inner-core features seen in microwave imagery and the shear is now below 10 kt, the cyclone appears to be poised for a period of rapid intensification.**

The NHC forecast is near the highest guidance, showing Blanca becoming a major hurricane tomorrow, and conditions appear favorable for continued strengthening through 72 hours, when the SHIPS, LGEM and FSU Superensemble all show a peak near 120 kt. However, even this forecast could be conservative given that the SHIPS RI index shows a 95 percent chance of a 40-kt increase in the first 24 hours.

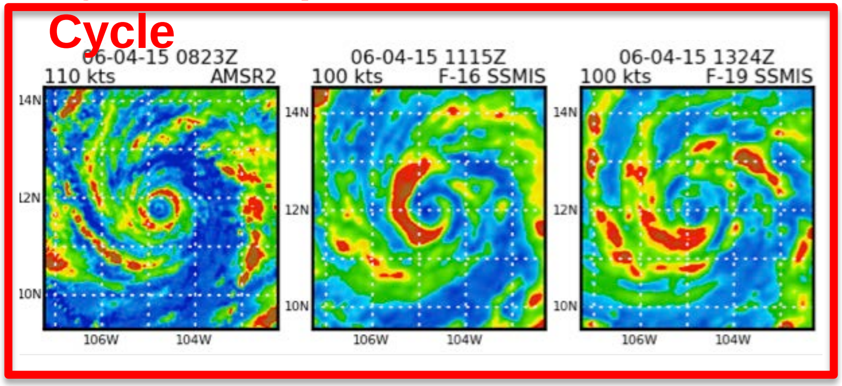


Blanca's Development through MW Imager Eyes

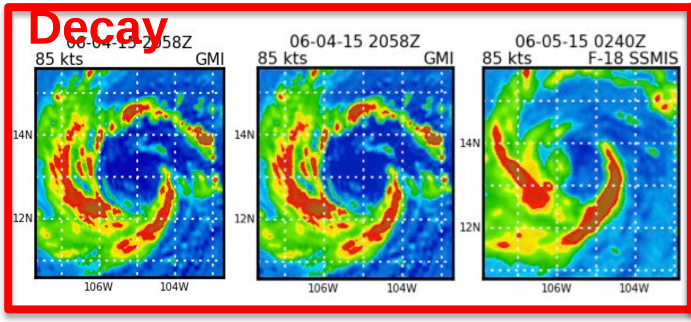
Pinhole Eye Development



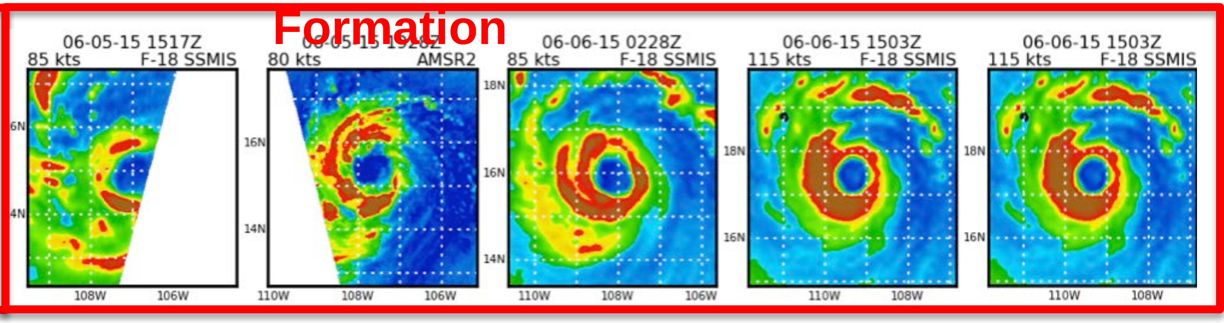
Eyewall Replacement Cycle



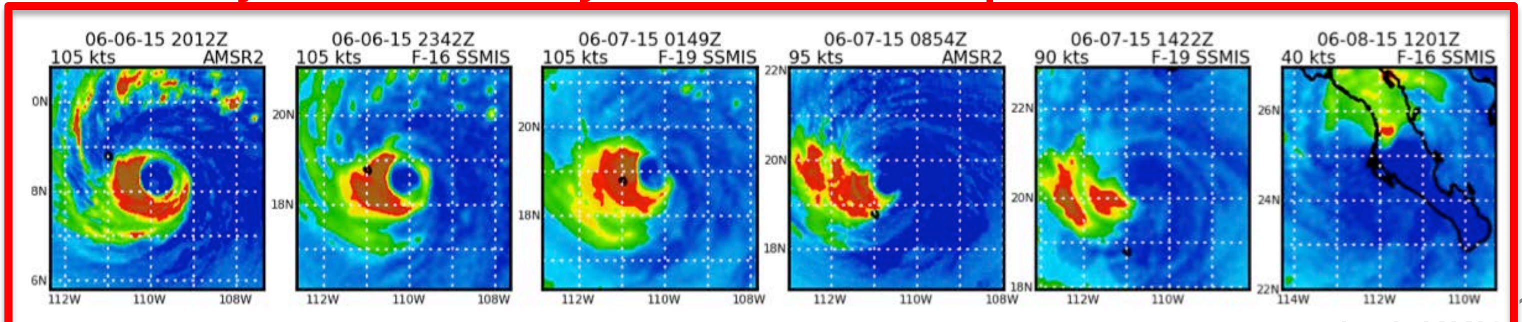
Eyewall Collapse during Rapid Decay

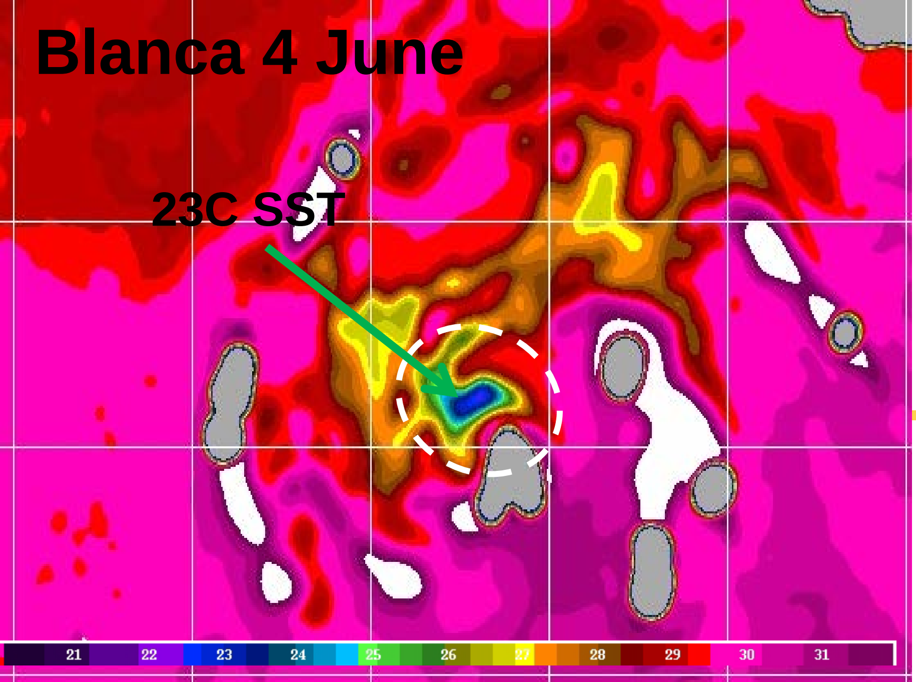


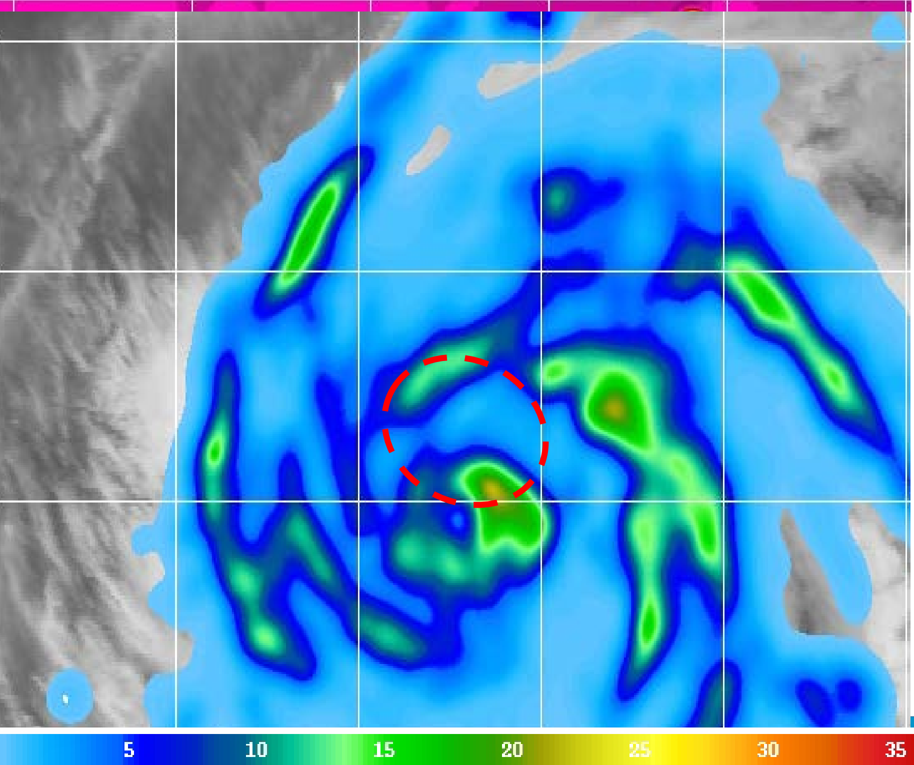
Second RI with Single Eye Formation

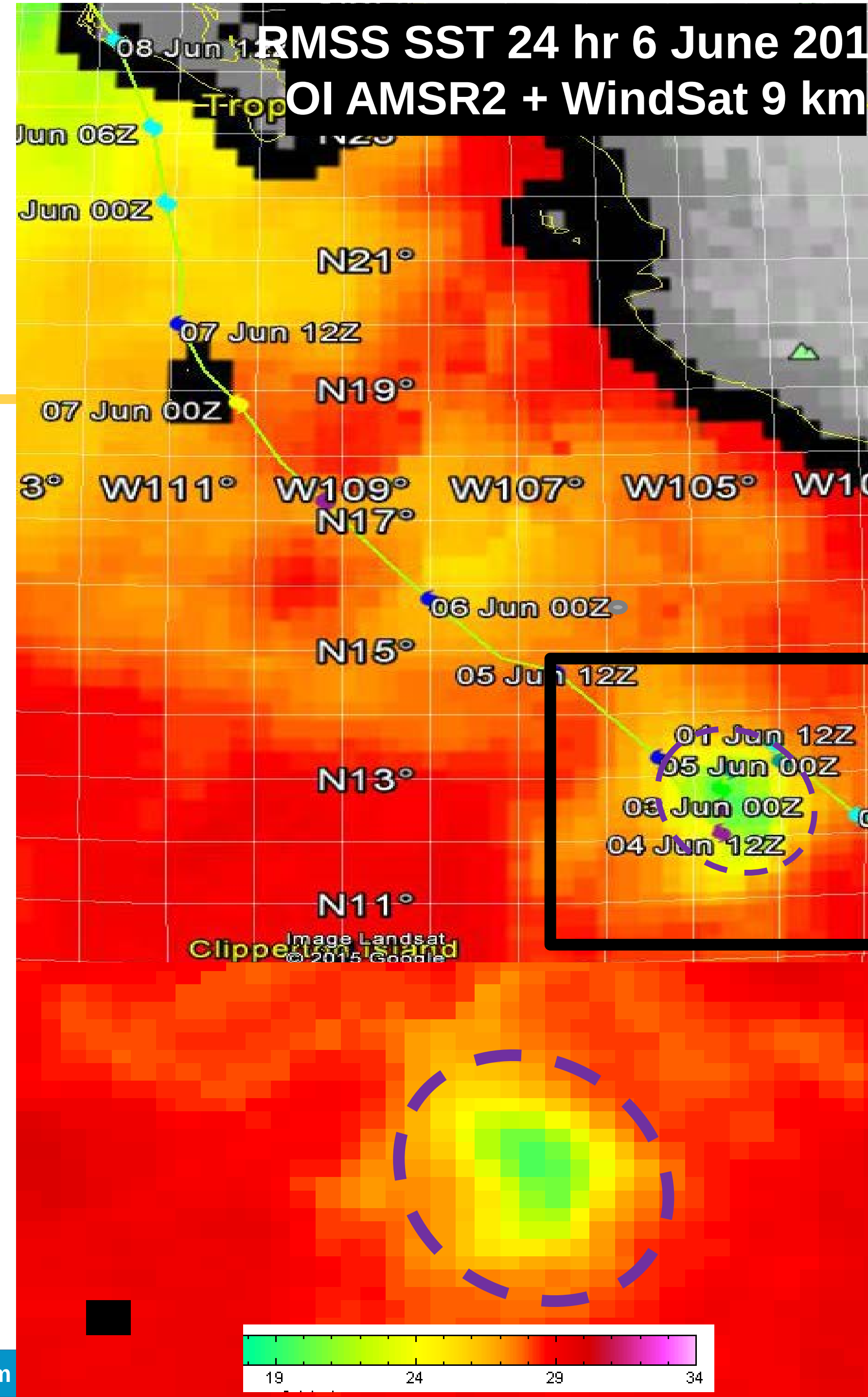


Asymmetric Decay over cold water prior to Landfall




Blanca 4 June
23C SST
21 22 23 24 25 26 27 28 29 30 31

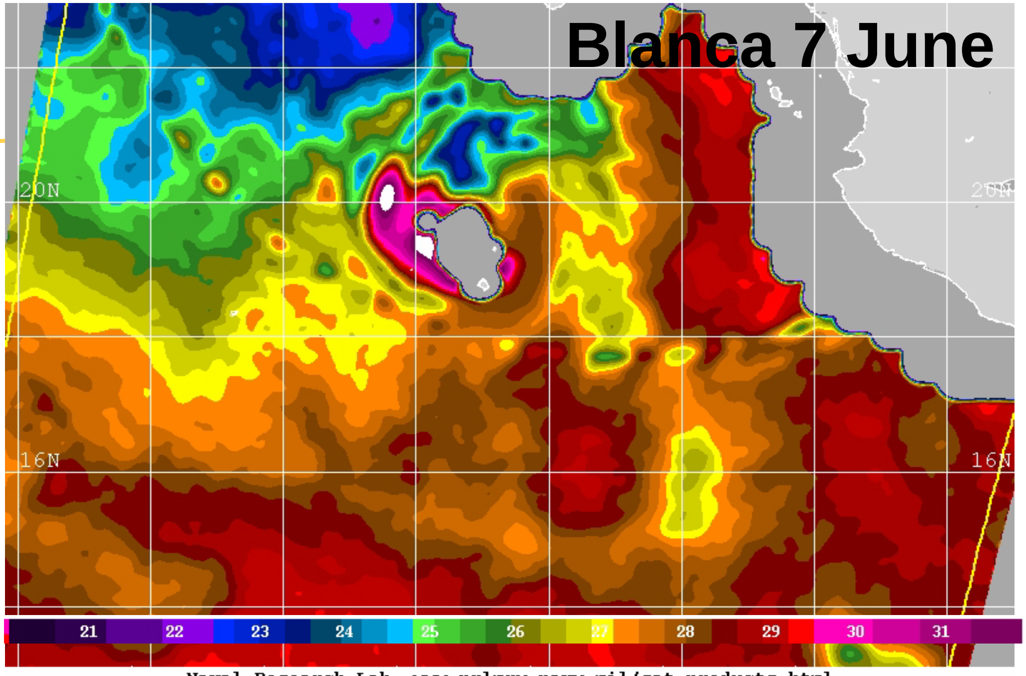

5 10 15 20 25 30 35

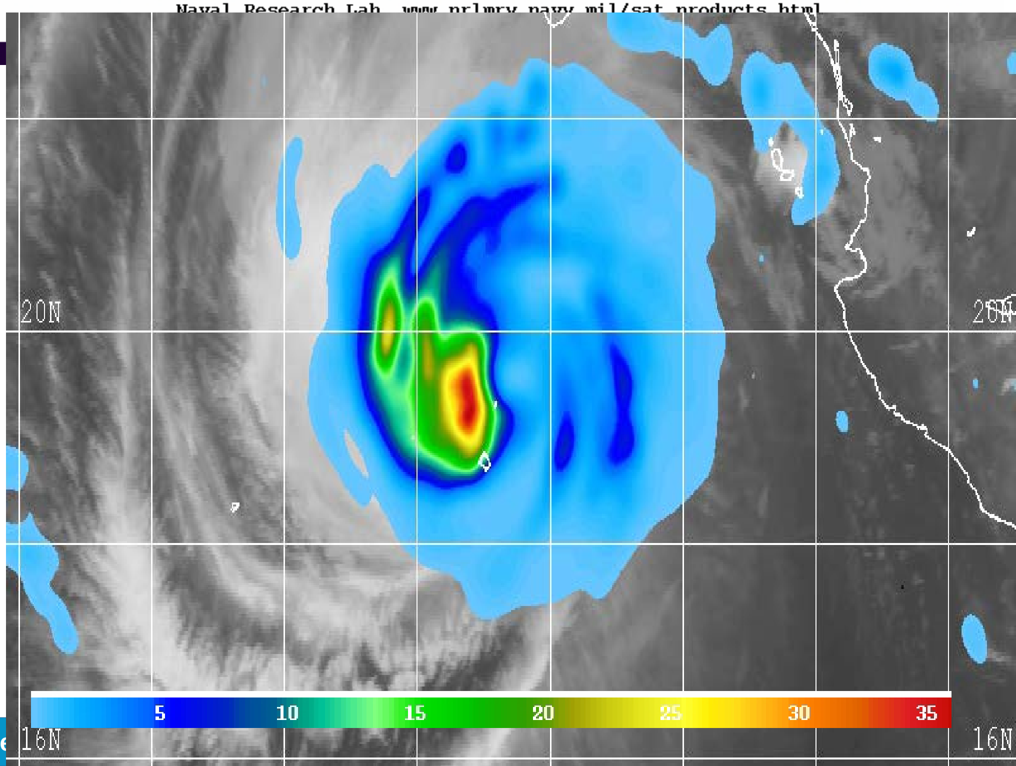

RMSS SST 24 hr 6 June 2015
OI AMSR2 + WindSat 9 km
08 Jun 12Z
Jun 06Z
Jun 00Z
N21°
07 Jun 12Z
N19°
07 Jun 00Z
W111° W109° W107° W105°
N17°
06 Jun 00Z
N15°
05 Jun 12Z
01 Jun 12Z
05 Jun 00Z
N13°
03 Jun 00Z
04 Jun 12Z
N11°
Clipperton Island
Image Landsat
© 2015 Google
19 24 29 34

ASMR-2 SST indicate possibility of Rapid Decay

- Second radip decay occurred as Blanca crosses San Lucas front into cold SSTs < 26C and landfall on Baja detected by AMSR-2 SST

- “Only rain rates greater than about 10 mm/hr (dark blue) impair SST estimation”
  - Flagging scheme doesn’t need to be too conservative for forecasting uses as required by data assimilation

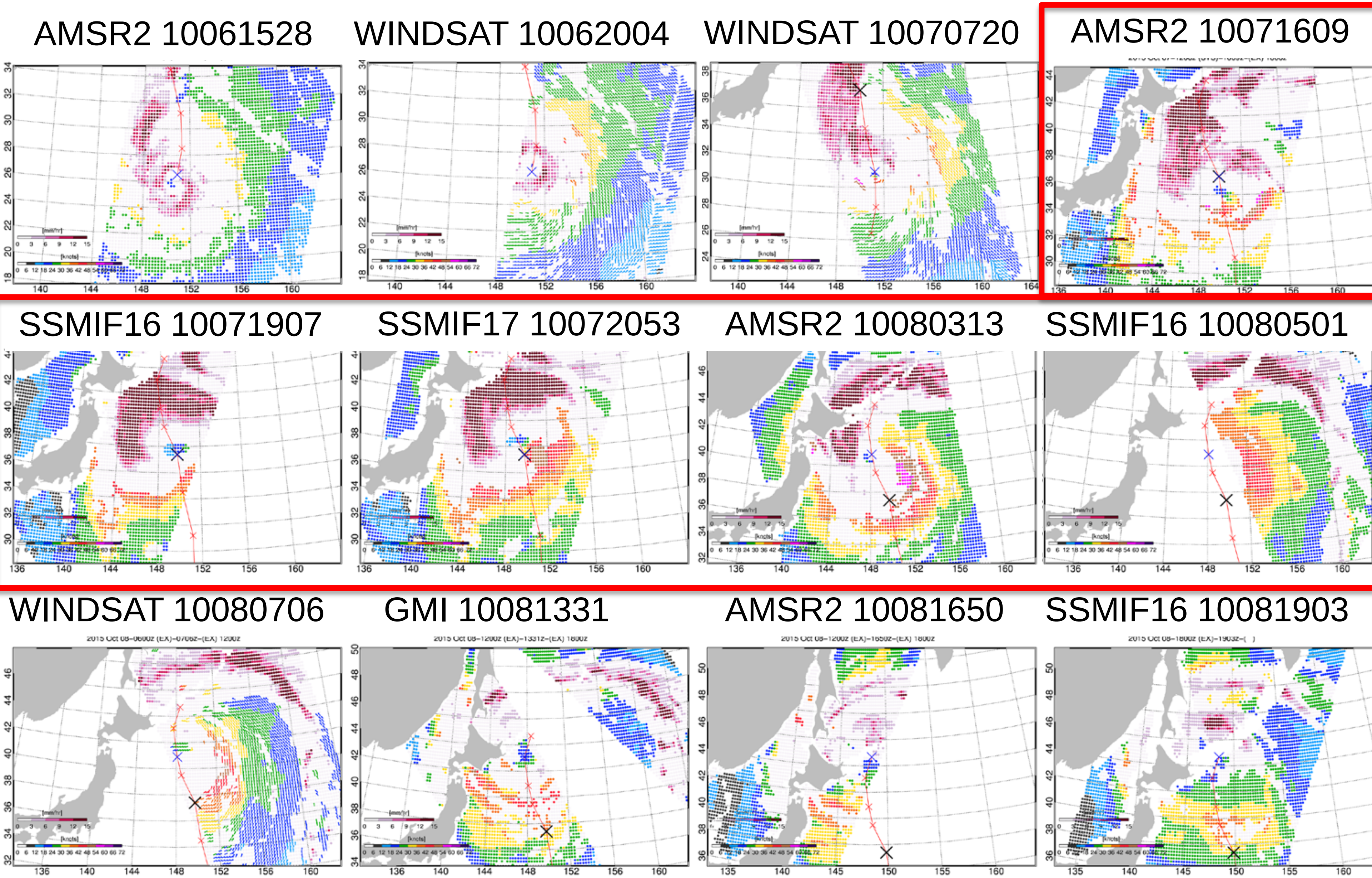




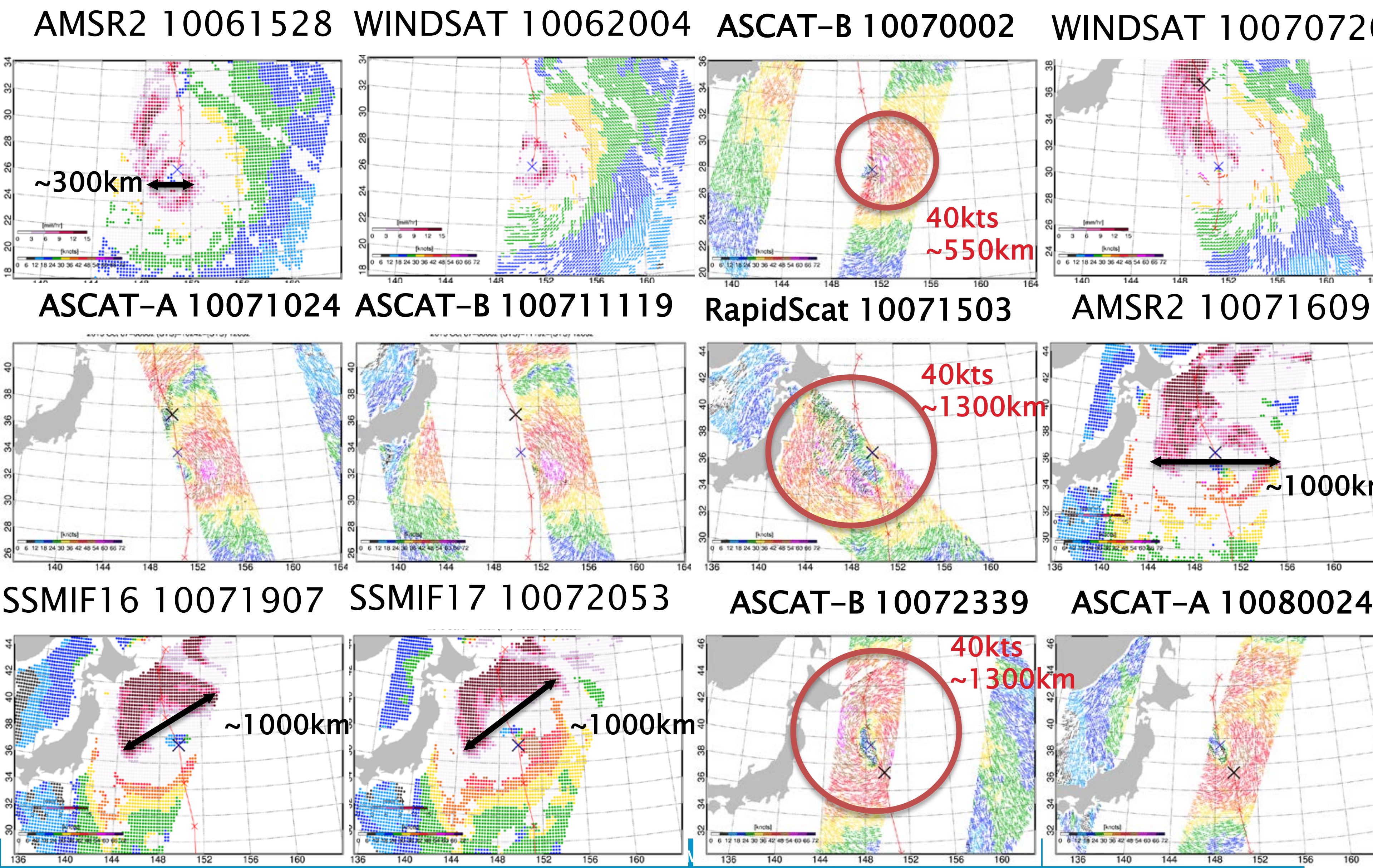
MONITORING EXTRATROPICAL TRANSITIONS

ExtraTropical Transition
West Pacific 06-08 October 2015

Radiometer Observations – Wind and Rain Fields

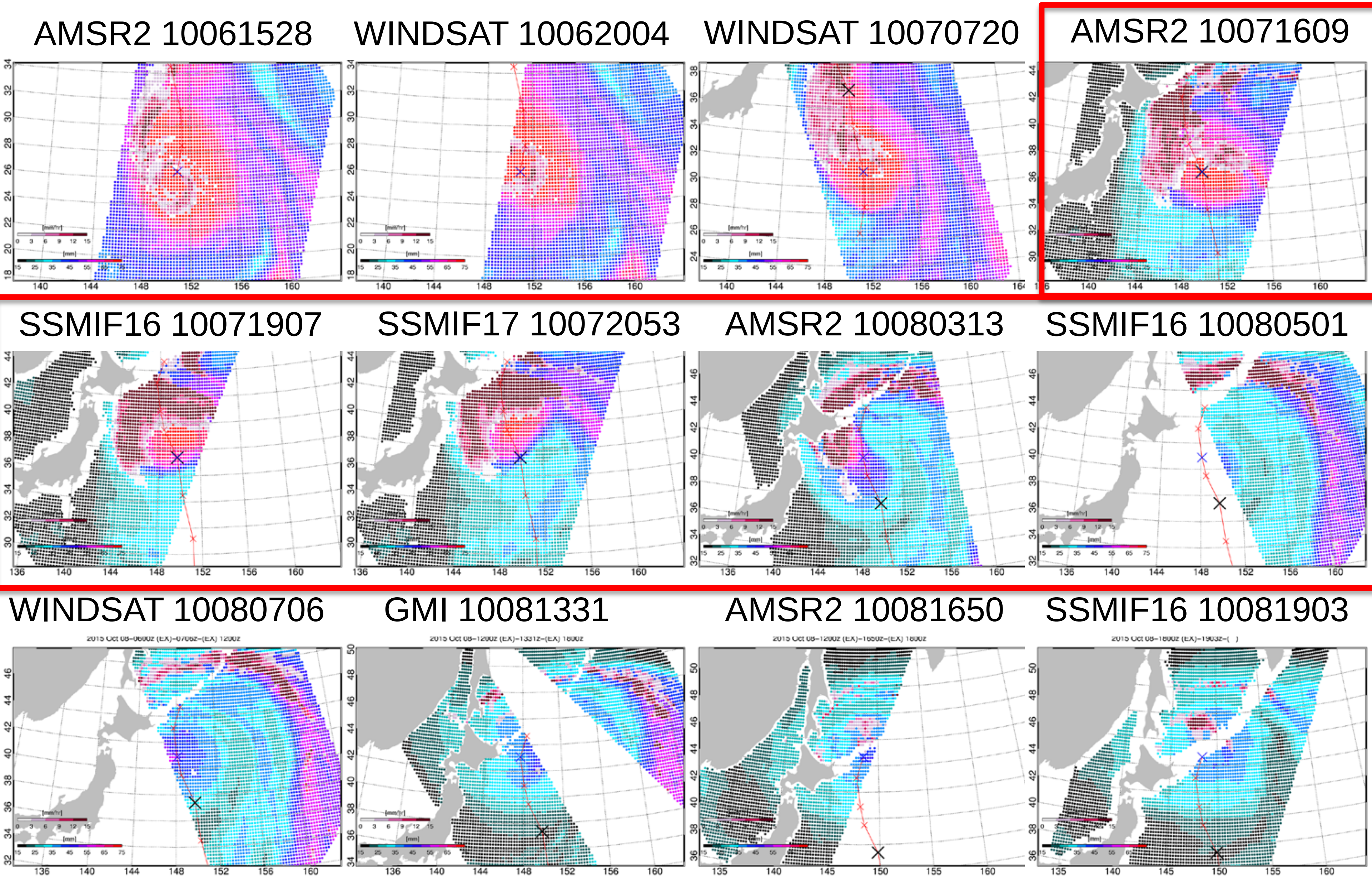


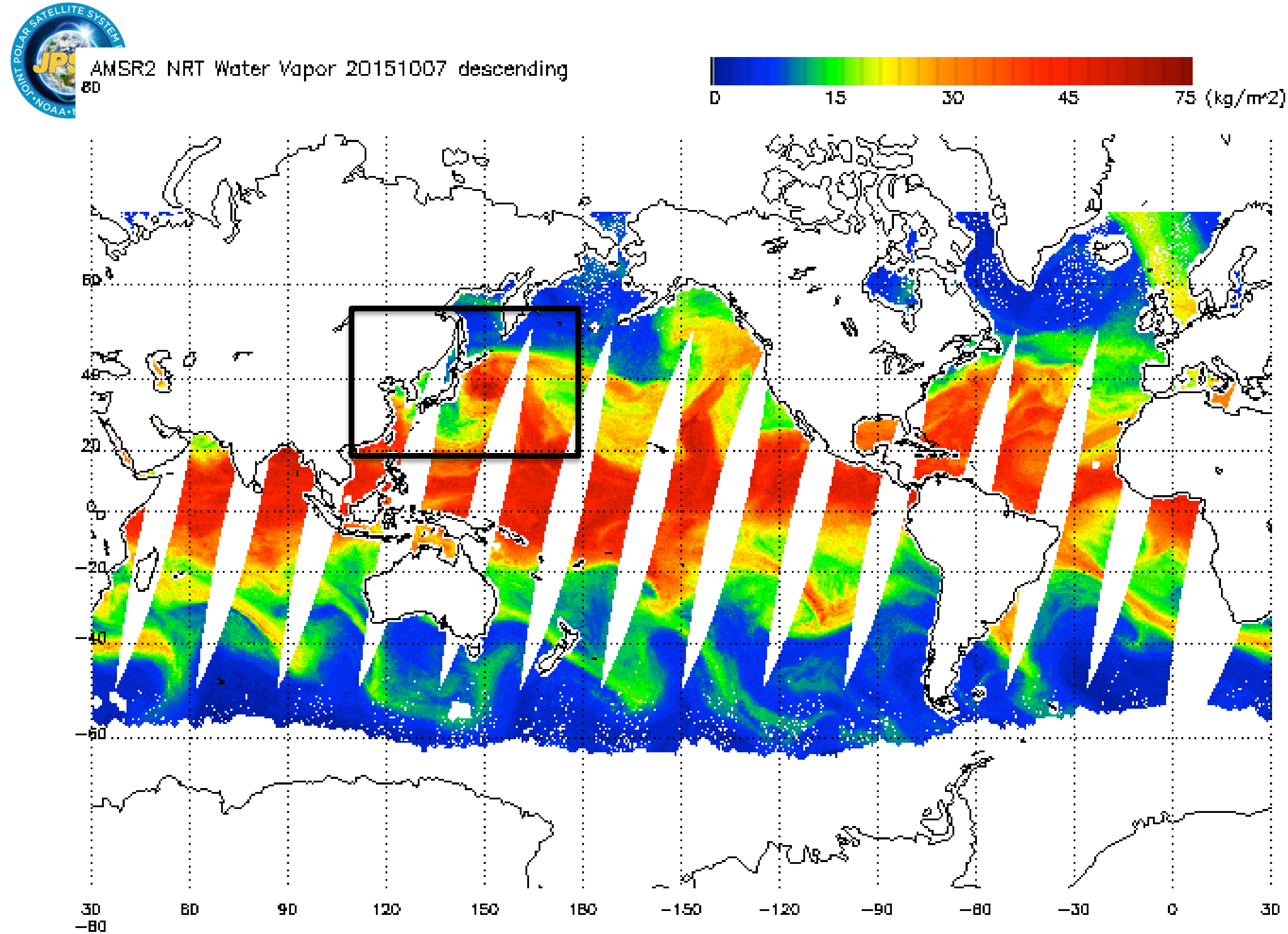
ExtraTropical Transition
West Pacific 06-08 October 2015
Scatterometer + Radiometer Observations



ExtraTropical Transition
West Pacific 06-08 October 2015

Radiometer Observations – Water Vapor and Rain Fields

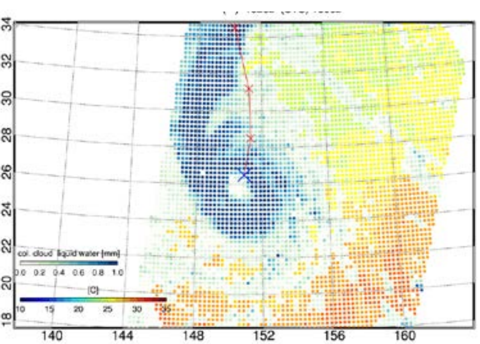



AMSR2 NRT Water Vapor 20151007 descending
0
15
30
45
75 (kg/m^2)
80
60
40
20
0
−20
−40
−60
−80
30
60
90
120
150
180
−150
−120
−90
−60
−30
0
30

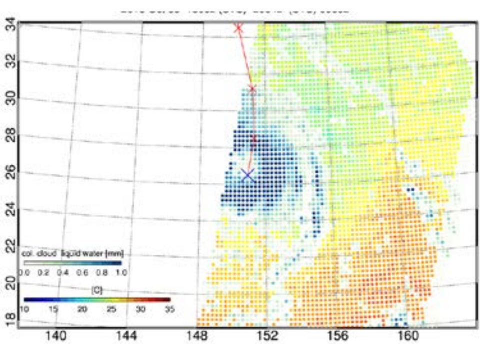
ExtraTropical Transition
West Pacific 06-08 October 2015

Radiometer Observations –SST and Cloud Fields

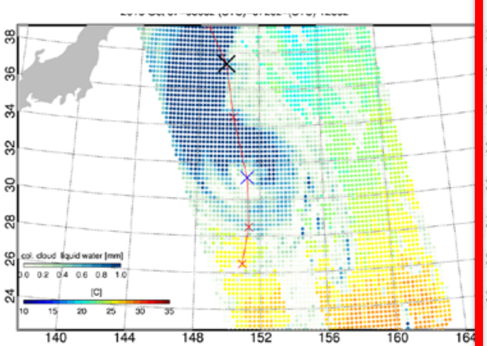
AMSR2 10061528



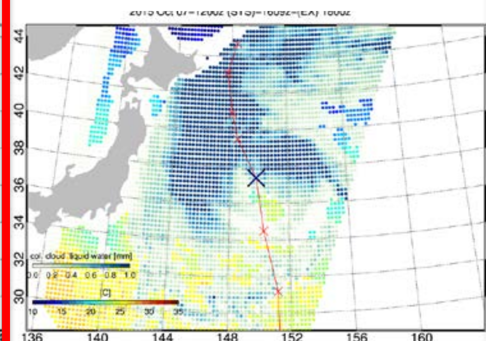
WINDSAT 10062004



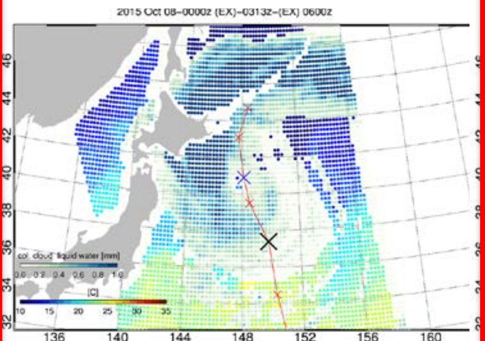
WINDSAT 10070720



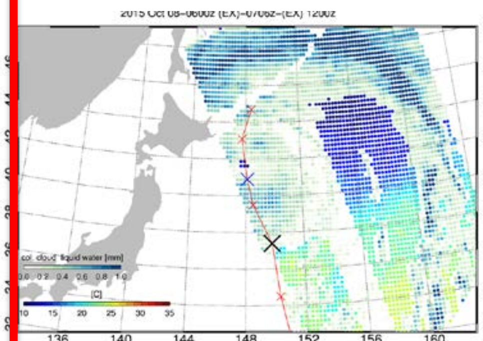
AMSR2 10071609



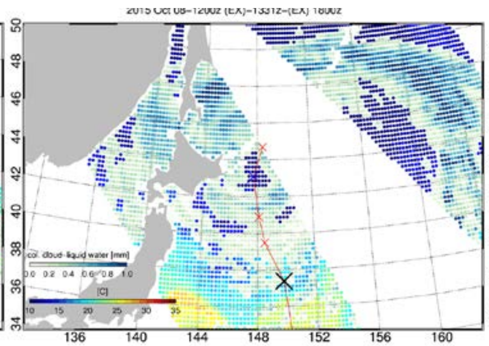
AMSR2 10080313



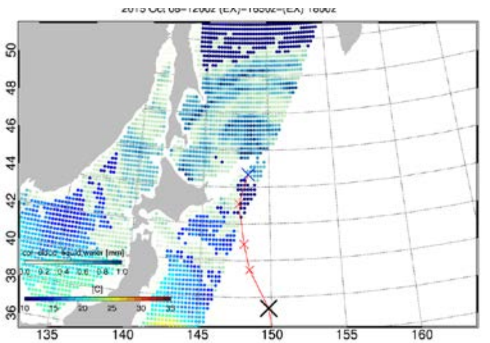
WINDSAT 10080706



GMI 10081331



AMSR2 10081650



Conclusions

- AMSR2 provides all-weather information critical for tropical cyclone forecasting, hydrological applications such as extreme precipitation, flash flood forecasting and drought forecasting, and marine environmental weather information (wind speed, which contributes to wave height forecasting, and sea surface temperature).
- NOAA's JPSS program's level 1 requirements for microwave imagery are met by GCOM-W1 AMSR2. JPSS provides real-time access via Svalbard to meet NOAA and Japan's latency requirements.
- Microwave imager observations from AMSR2 are routinely used by NOAA, DoD, Japan, EUMETSAT, and other environmental agencies for weather forecasting and environmental monitoring applications.
  - Importance of AMSR2 data for tropical cyclone forecasting is evident in many forecast discussions from the National Hurricane Center and Joint Typhoon Warning Center.
  - Continuity of AMSR2 type observations are important to the operational weather and research communities.

GCOM-W/AMSR2 PRECIPITATION EDR

NOAA/CICS-MD

(301) 405-2045, pmeyers@umd.edu

Patrick Meyers, Ralph Ferraro, Paul Chang

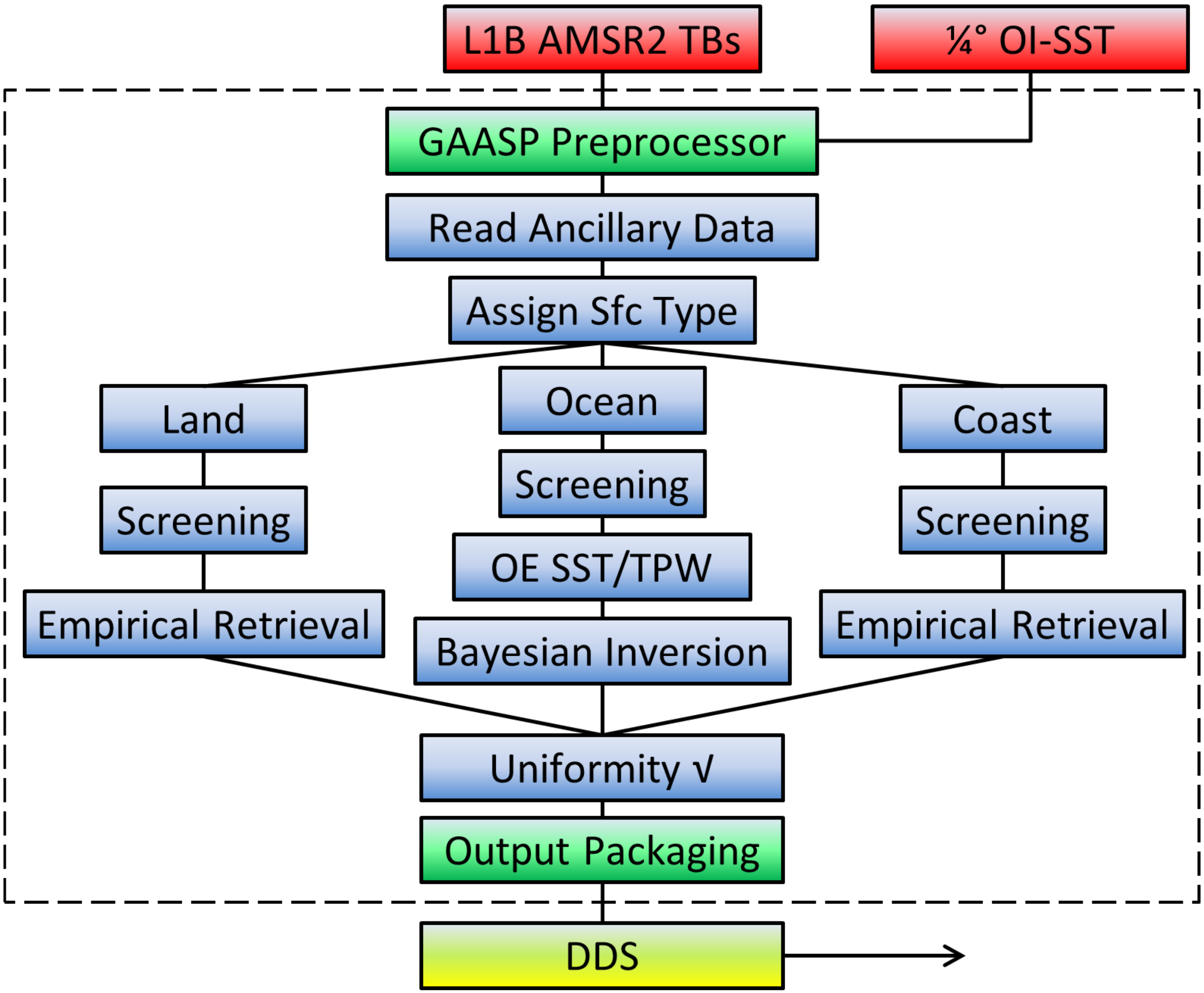
Outline

- Precipitation Team Members
- GPROF2010V2 Precipitation Algorithm Overview
- GCOM/AMSR2 Rain Product Overview
- GCOM/AMSR2 Readiness & Validation
- Path Forward
- Summary

Precipitation Team Members

PI	Organization	Team Members	Roles and Responsibilities
Patrick Meyers Ralph Ferraro	CICS-MD / NOAA/STAR		Development, Validation, Testing, and Monitoring
Tom King	IMSG	Letitia Soulliard	System Integration and Algorithm Transition

Rain Rate Retrievals



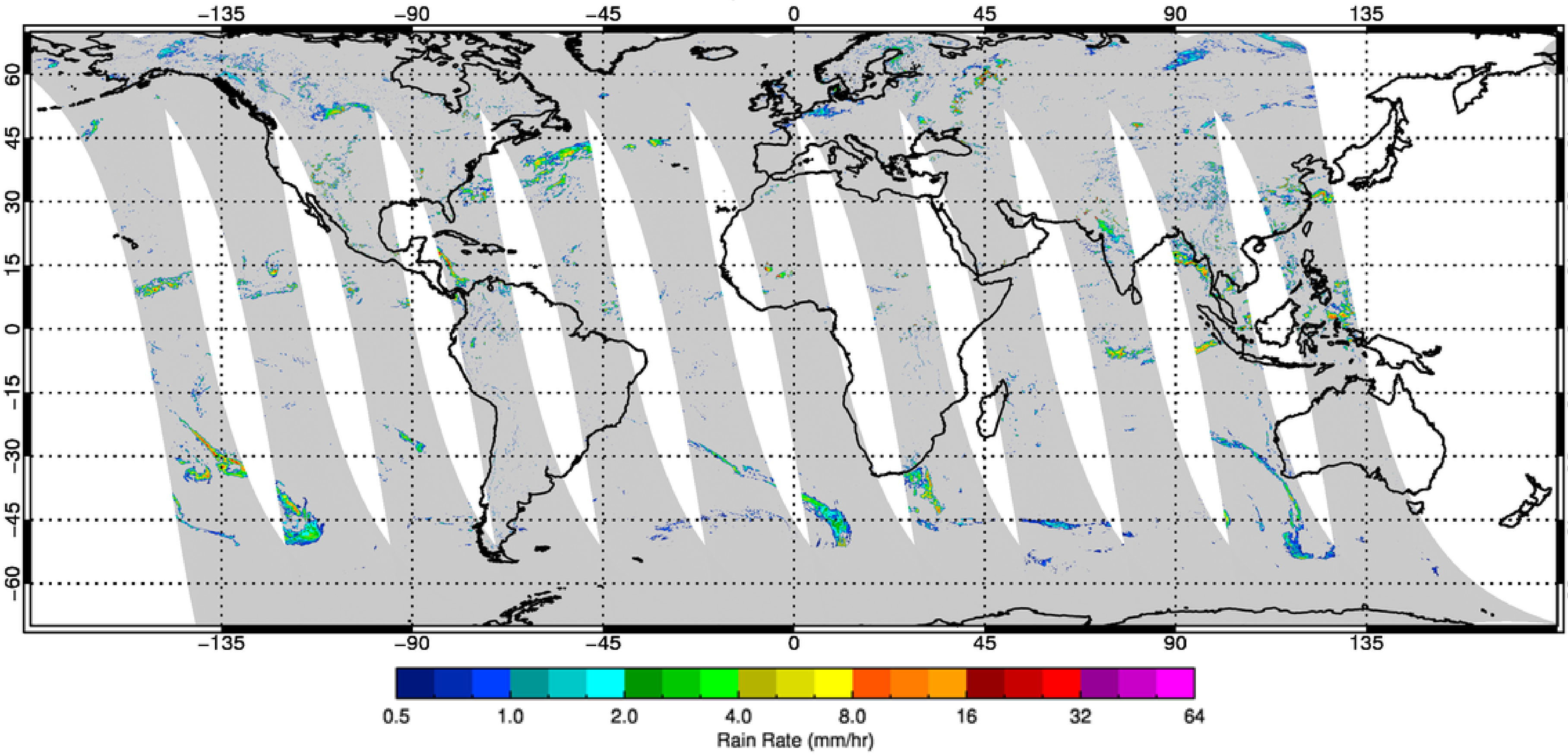
AMSR2 Precipitation Product Overview

JPSS Requirements - GCOM Precipitation Type/Rate		
EDR Attribute	Threshold	AMSR2 EDR
Applicable conditions		Delivered under "all weather" conditions
Horizontal cell size	5 km land (89 GHz FOV); 10 km ocean (37 GHz FOV size); 5-10 km sampling	5.0 km (land); 10 km (ocean)
Mapping uncertainty, 3 sigma	< 5 km	~2.5 km
Measurement range	0 – 50 mm/hr	0 – 75 mm/hr
Measurement precision	0.05 mm/hr	0.01 mm/hr
Measurement uncertainty	2 mm/hr over ocean; 5 mm/hr over land	1.3 mm/hr (ocean) 3.6 mm/hr (land)
Refresh	At least 90% coverage of the globe about every 20 hours (monthly average)	91% every 20 h
Precipitation type	Stratiform or convective	Convective rain rate
Latency	25 minutes	8 min

AMSR2 Precipitation Output

GPROF2010 Rain Rates for GCOM/AMSR2

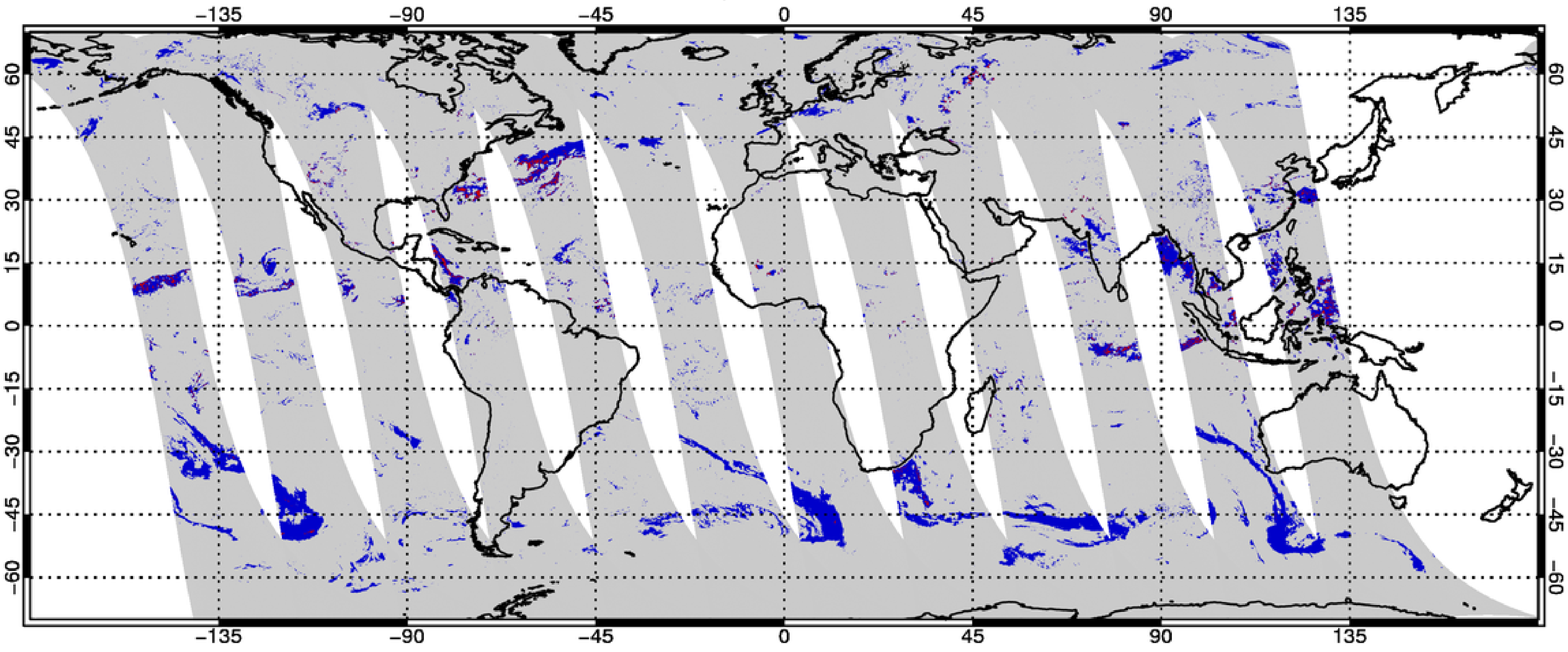
August 3rd, 2016



AMSR2 Precipitation Output

Convective/Stratiform Precipitation Separation

August 3rd, 2016

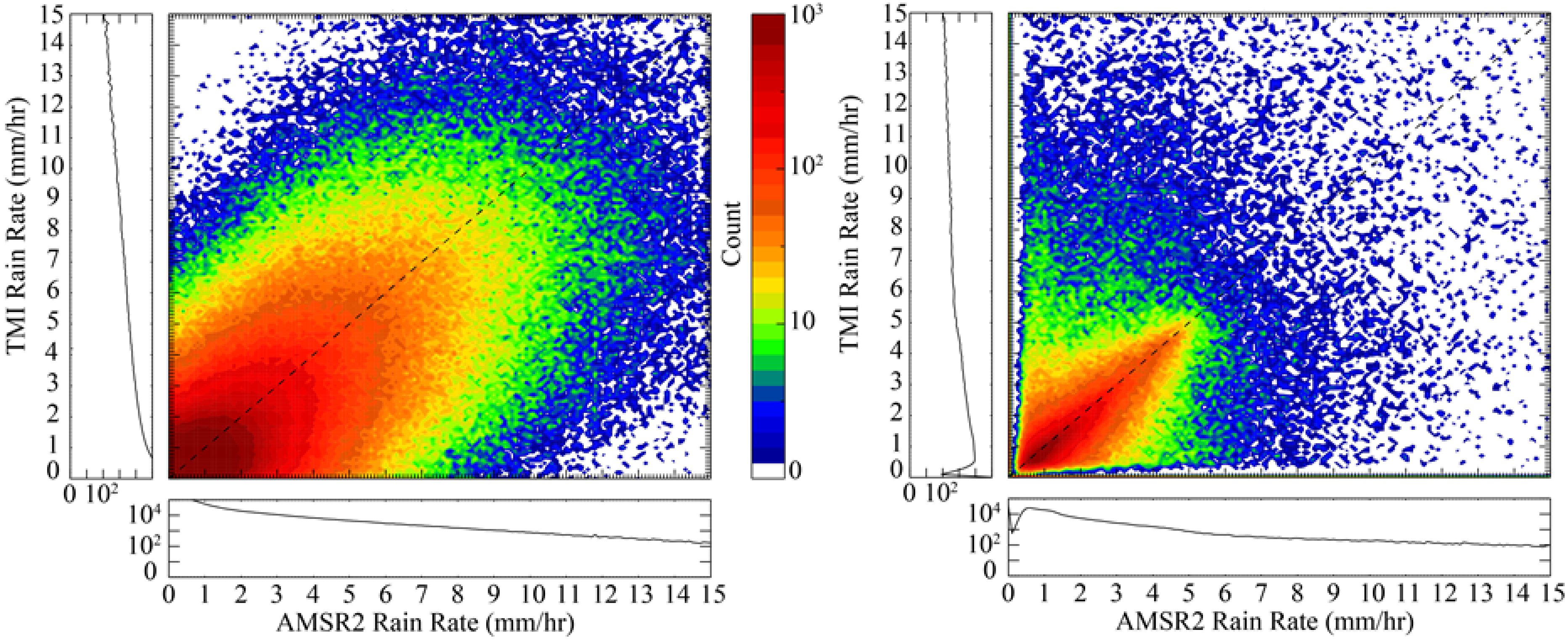


Validation - Instantaneous

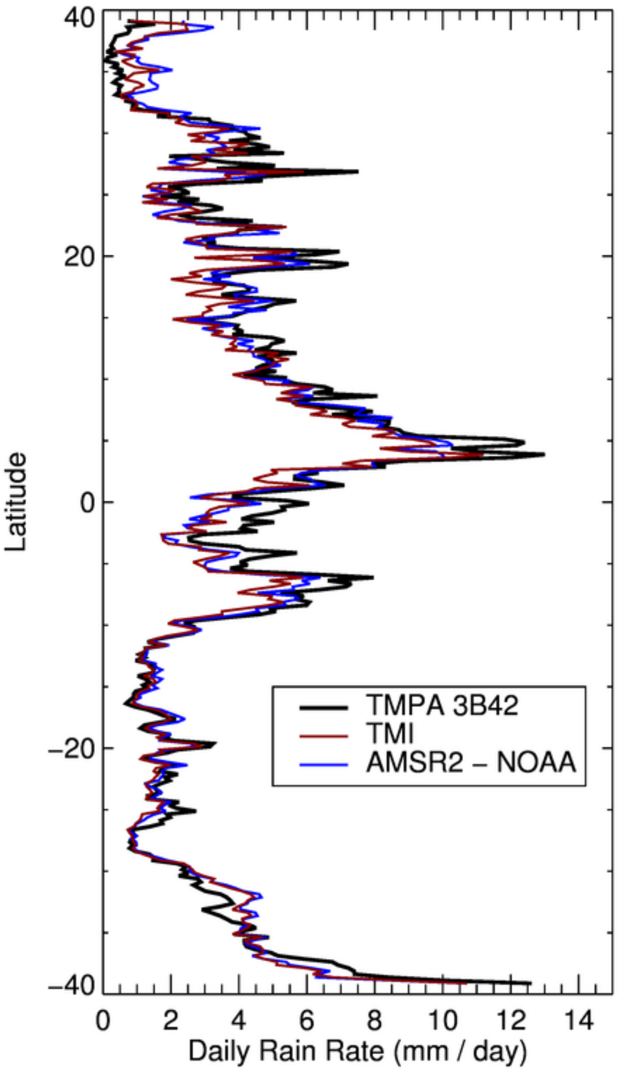
GCOM-W vs. TMI Collocated Observations

Ocean

Land



Validation - Instantaneous

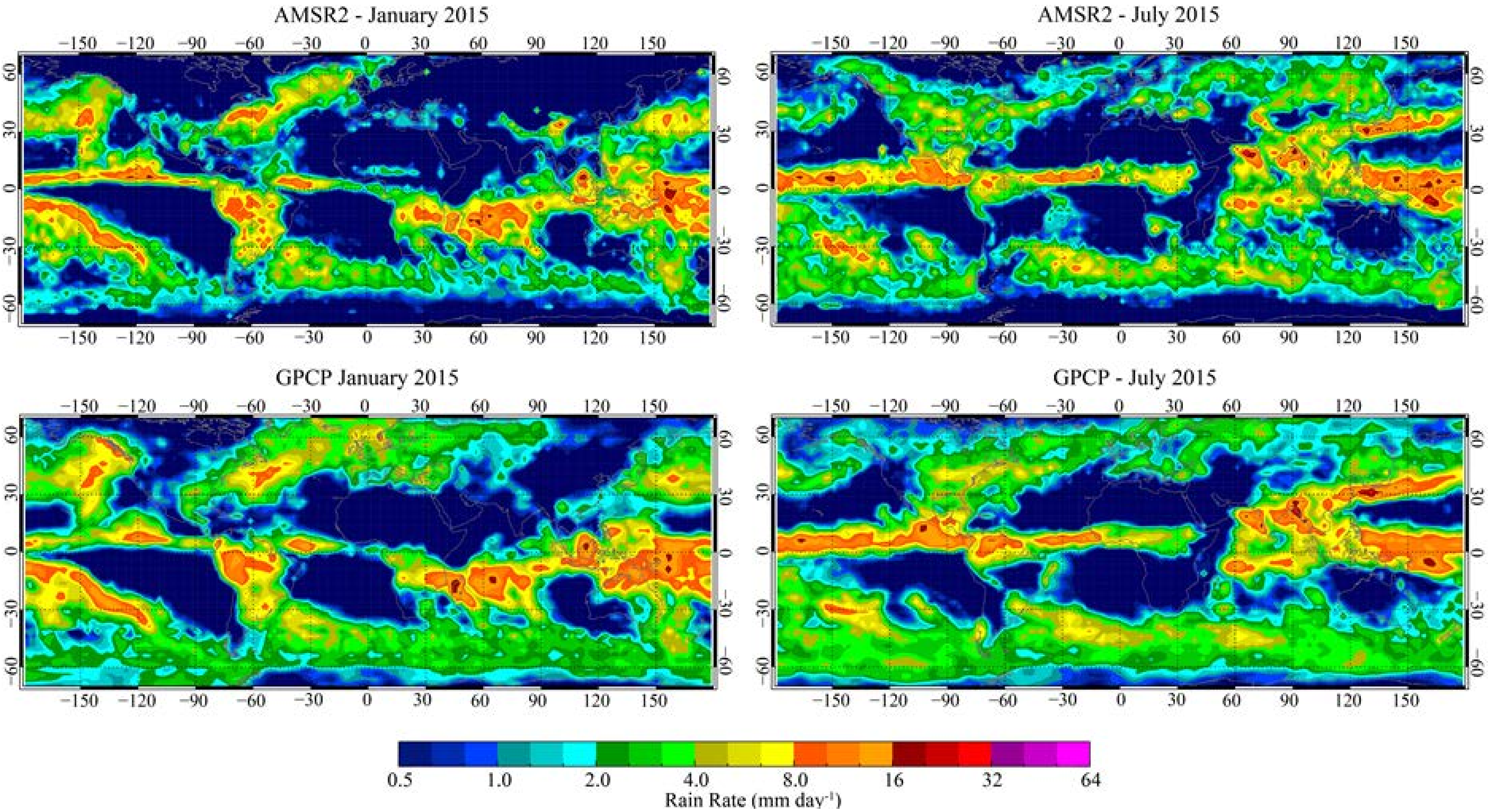


Instantaneous Rain Rate RMSD relative to TRMM Products

RMSD (mm/hr)	Land	Ocean	Overall
Requirements	5.0	2.0	–
TMI & TMPA	3.1	1.2	1.6
AMSR2 & TMI	3.6	1.2	1.8
AMSR2 &TMPA	3.1	1.4	1.9

Validation - Seasonal

GCOM-W vs. GPCP Monthly Precipitation

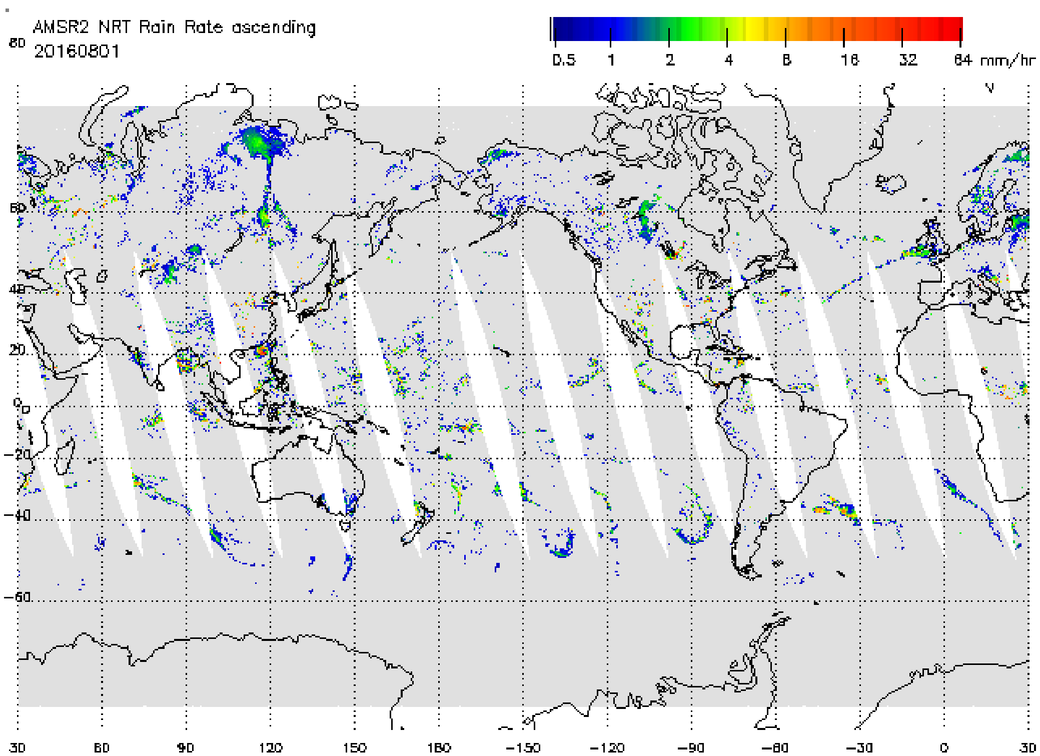


OSPO Product Monitoring

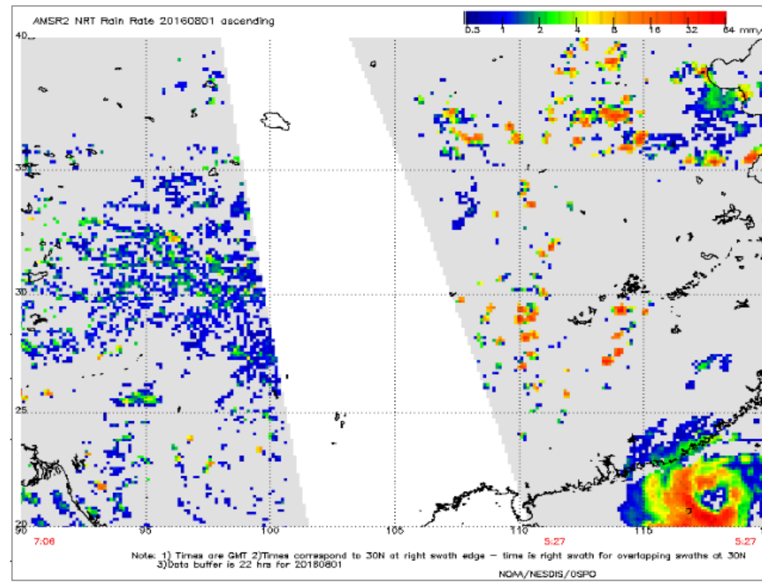
NOAA Operational GCOM-W1 AMSR-2 Products Maps

Map Types	Products	Available Dates
Daily	BTs / GPs	2016-08-03
Realtime	CLW SSW RR SST TPW	2016-08-02
Storms		2016-08-01
		2016-07-31
		2016-07-30
		2016-07-29
		2016-07-28

Ascending Pass



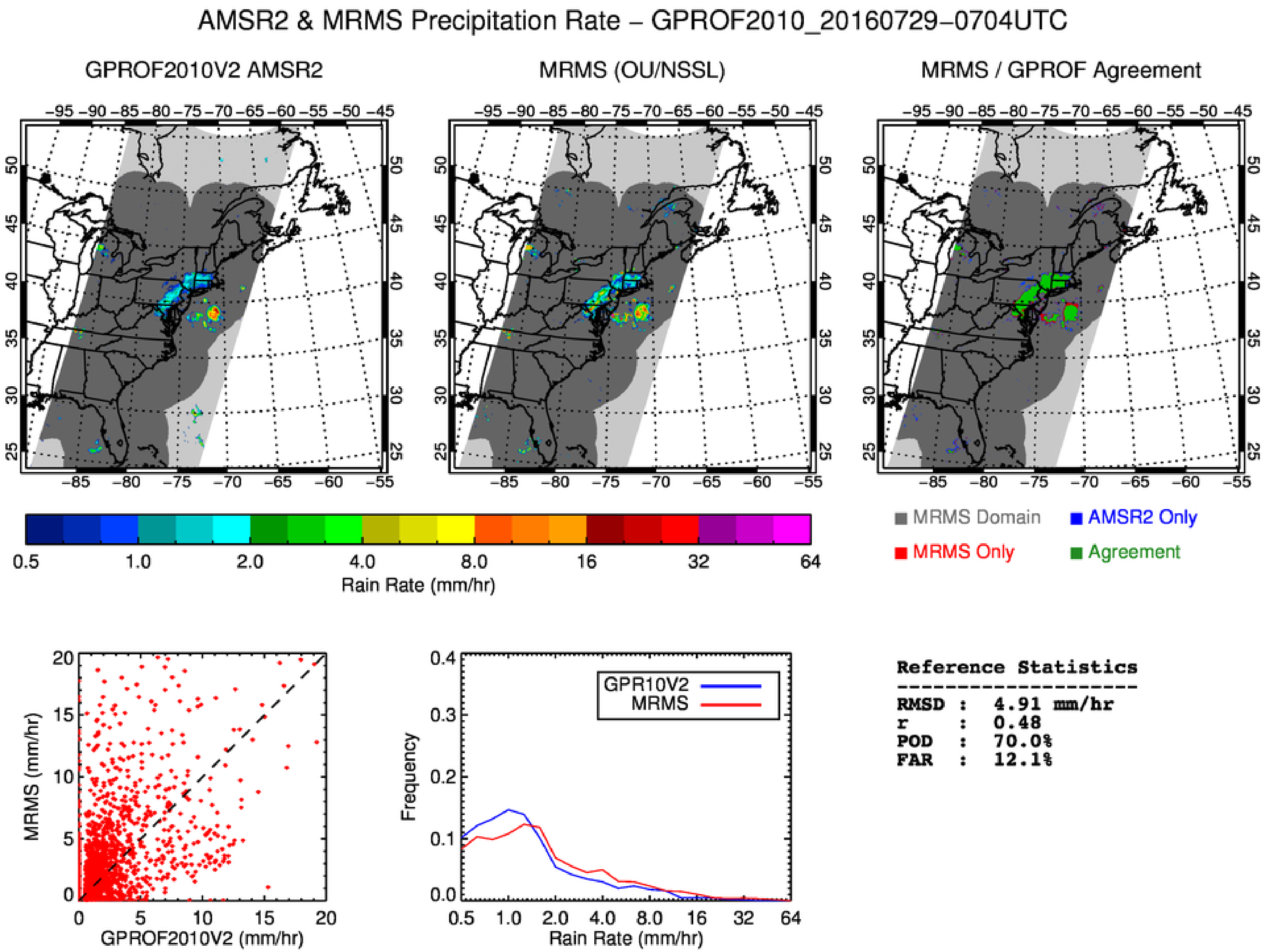
Zoomable Sectors



Typhoon Nida (Aug 1st 2016)

http://www.ospo.noaa.gov/Products/atmosphere/gpds/

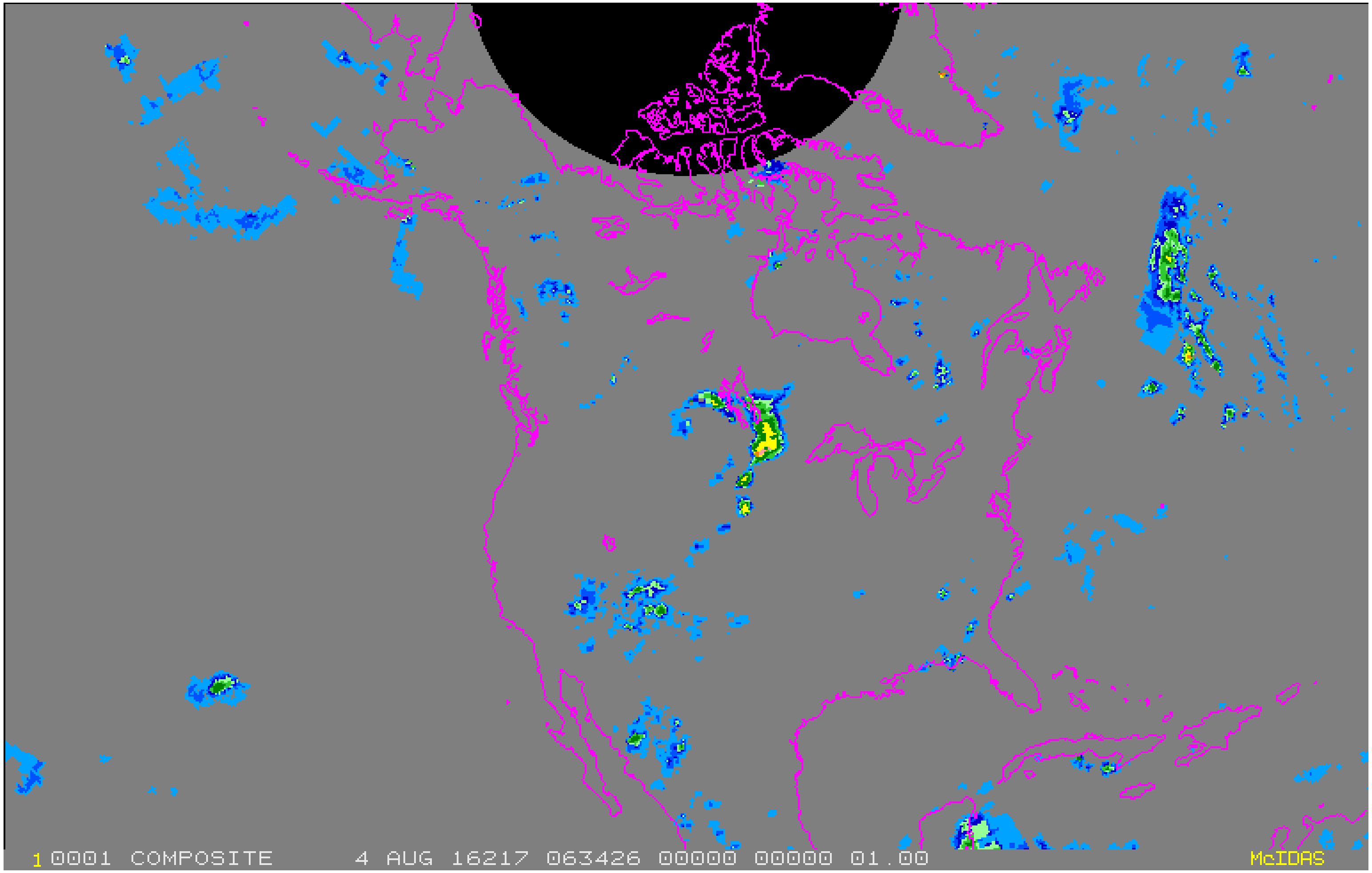
Routine Swath Validation



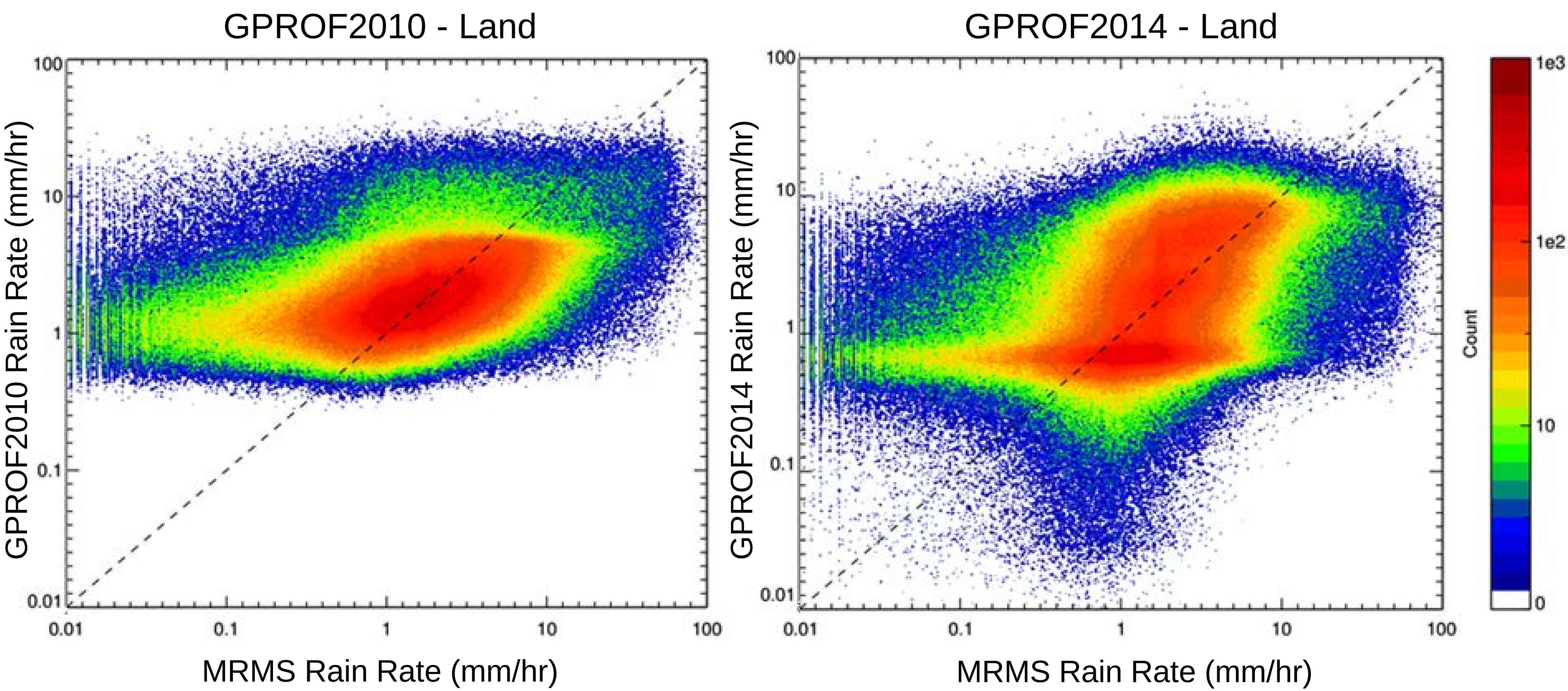
http://cics.umd.edu/ipwg/index.html

Level 3 Users

- NESDIS Operational Blended Rain Rate Product (Below)
- Ensemble Tropical Rainfall Potential (eTRaP)
- Working on incorporation into CMORPH



Looking Ahead: Evaluating GPROF2014

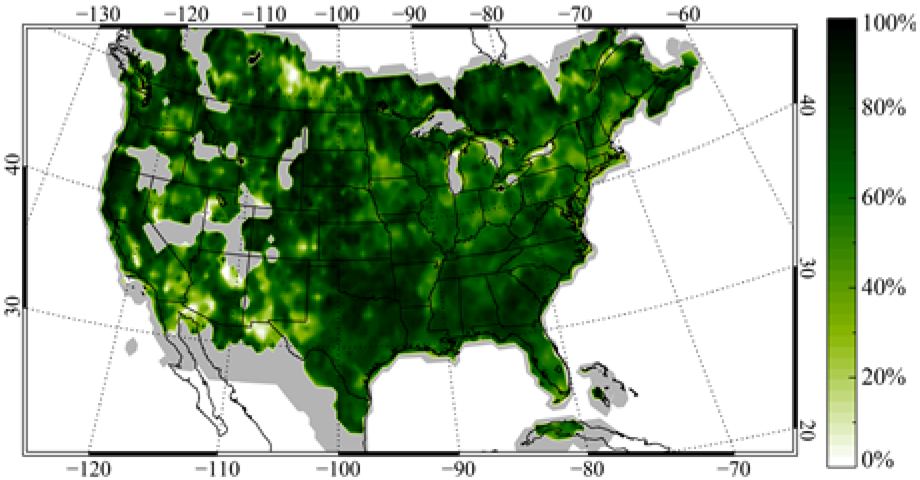


- Empirical Retrieval
- Continuation from AMSR-E algorithm

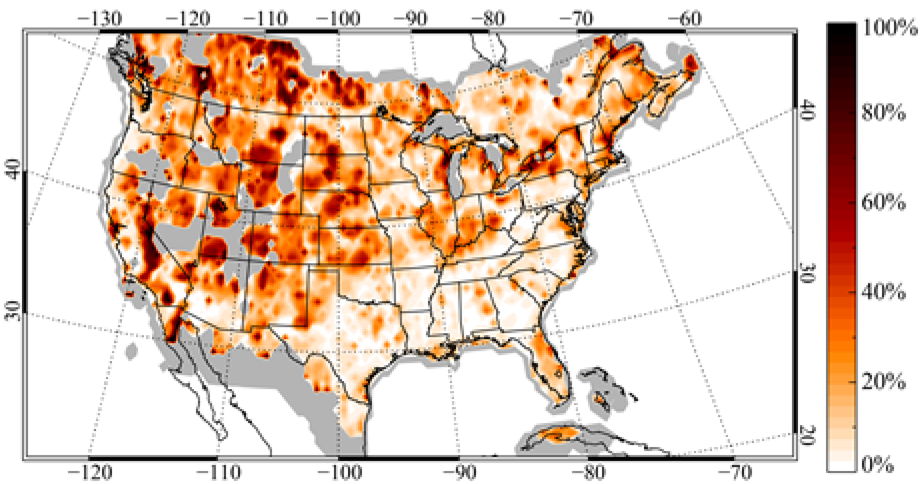
- Fully Bayesian Scheme
- Collaboration with NASA/GPM
- Still under development/testing

Issues to Address / Future Improvements

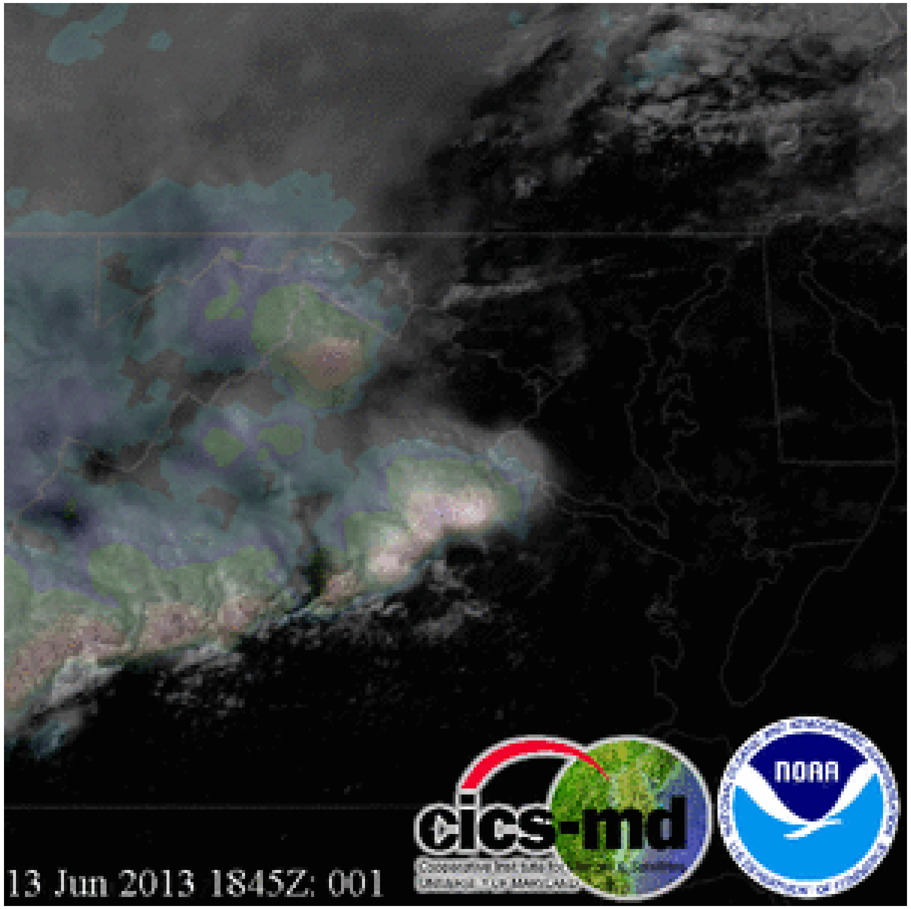
Probability of Detection



False Alarm Ratio

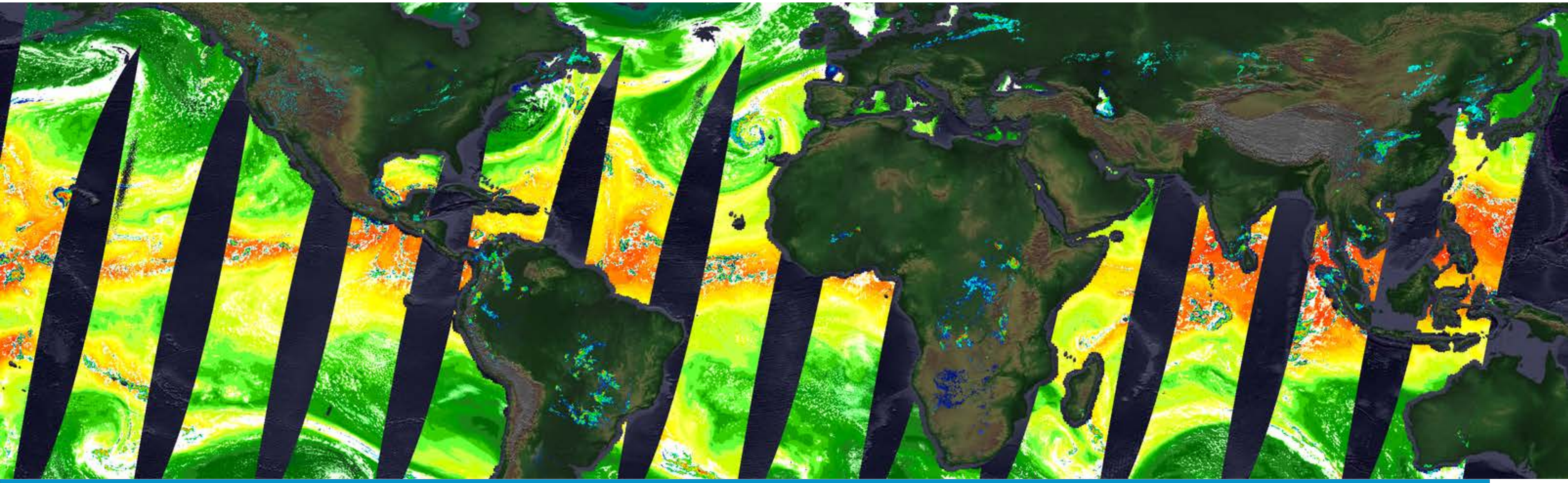


Incorporate Multi-Sensor Inputs



Summary

- GCOM-W/AMSR2 rain rate computed with GPROF2010
- Rain Rate EDR meets JPSS reqs.
- Routine monitoring by OSPO and CICS-MD/IPWG
- Address night-time surface cooling in screening procedures
- Explore GPROF2014 as algorithm replacement
  - Collaboration with NASA



NOAA AMSR2 SNOW AND ICE PRODUCTS

Jeff Key

NOAA/NESDIS

Madison, Wisconsin USA

AMSR-2 Snow and Ice Products

- Snow Cover (SC) – Presence/absence of snow
- Snow Depth (SD) – The depth of snow on land
- Snow Water Equivalent (SWE) – The amount of water in the snowpack
- Sea Ice Characterization (SIC) – Ice concentration (area fraction in a pixel) and an age class (first-year or multiyear concentration)

Snow and ice algorithms are built around heritage products with important, but low-risk, improvements.

Cryosphere Team

- **Jeff Key** (lead), NOAA/NESDIS
- **Yong-Keun Lee**, University of Wisconsin: snow
- **Cezar Kongoli**, CICS/University of Maryland: snow
- **Walt Meier**, NASA: sea ice
- Scott Stewart, Julienne Stroeve, U. Colorado: sea ice

NOAA AMSR2 SNOW PRODUCTS

Yong-Keun Lee[1] and Cezar Kongoli[2], Jeff Key[3]

[1]Cooperative Institute for Meteorological Satellite Studies (CIMSS), University of Wisconsin-Madison

[2]Cooperative Institute for Climate Studies (CICS), University of Maryland

[3]NOAA/NESDIS

Snow Cover and Depth Requirements

Table 5.0 GCOM Snow Cover/Depth		
EDR Attribute	**Threshold**	**Objective**
Applicable conditions		Delivered under "all weather" conditions
Sensing depth	0 – 60 cm	1 m
Horizontal cell size	10 km	5 km
Mapping uncertainty, 3 sigma	5 km	1 km
Snow depth ranges	5 – 60 cm	> 8 cm; > 15 cm; > 30 cm; > 51 cm; > 76 cm
Measurement uncertainty		
-- Clear	80% probability of correct snow/no snow classification; Snow Depth: 20 cm (30 cm if forest cover exceeds 30%)	10% for snow depth
-- Cloudy	80% probability of correct snow/no snow classification; Snow Depth: 20 cm	Not Specified
Refresh	At least 90% coverage of the globe about every 20 hours (monthly average)	Not Specified

SWE Requirements

Table 11.0 GCOM Snow Water Equivalent		
EDR Attribute	**Threshold**	**Objective**
Applicable conditions		Delivered under "all weather“ conditions
Horizontal cell size	10 km	5 km
Mapping uncertainty, 3 sigma	5 km	1 km
Measurement range	10 – 200 mm	Not Specified
Measurement uncertainty		Not Specified
-- Shallow to moderate snow packs (10 – 100 mm)	20 mm or 50%	Not Specified
-- High snow accumulation (above 100 mm)	70%	Not Specified
Refresh	At least 90% coverage of the globe about every 20 hours (monthly average)	Not Specified

Snow Detection Algorithm

- Grody's 1991 SSMI Algorithm
  - The most cited microwave snow cover algorithm
  - Continues to be a baseline algorithm
  - Applied to SSMIS and AMSU instruments at similar AMSR-E channels.
  - Matured through 30 years of improvements at NOAA/NESDIS
  - NOAA's AUTOSNOW (input to IMS) uses Grody's SSMI algorithm

- Enhancements to Grody SSMI algorithm
  - Climatology test: probability of snowfall occurrence from IMS
  - Wet snow exclusion using 36 GHz brightness temperature
  - Adapt the algorithm to AMSR2 configuration

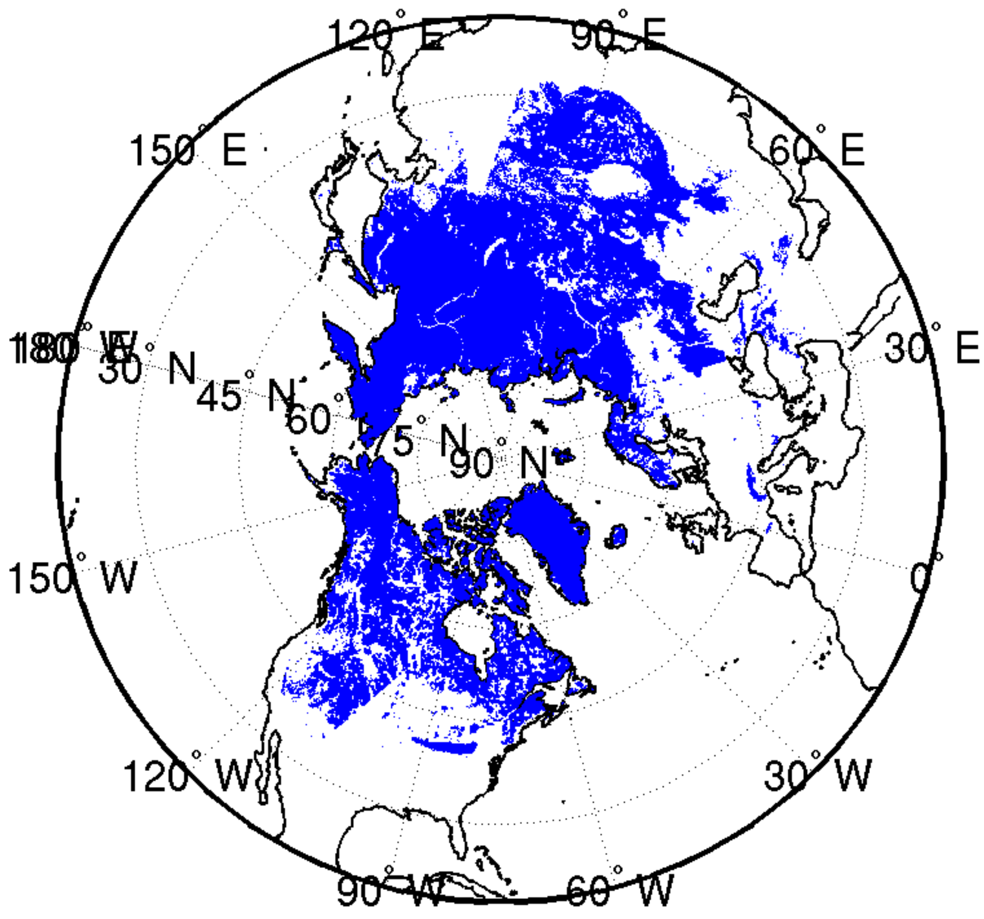
SWE Algorithm

NASA AMSR-E SD/SWE approach (Kelly, 2009; Tedesco and Narvekar, 2010)

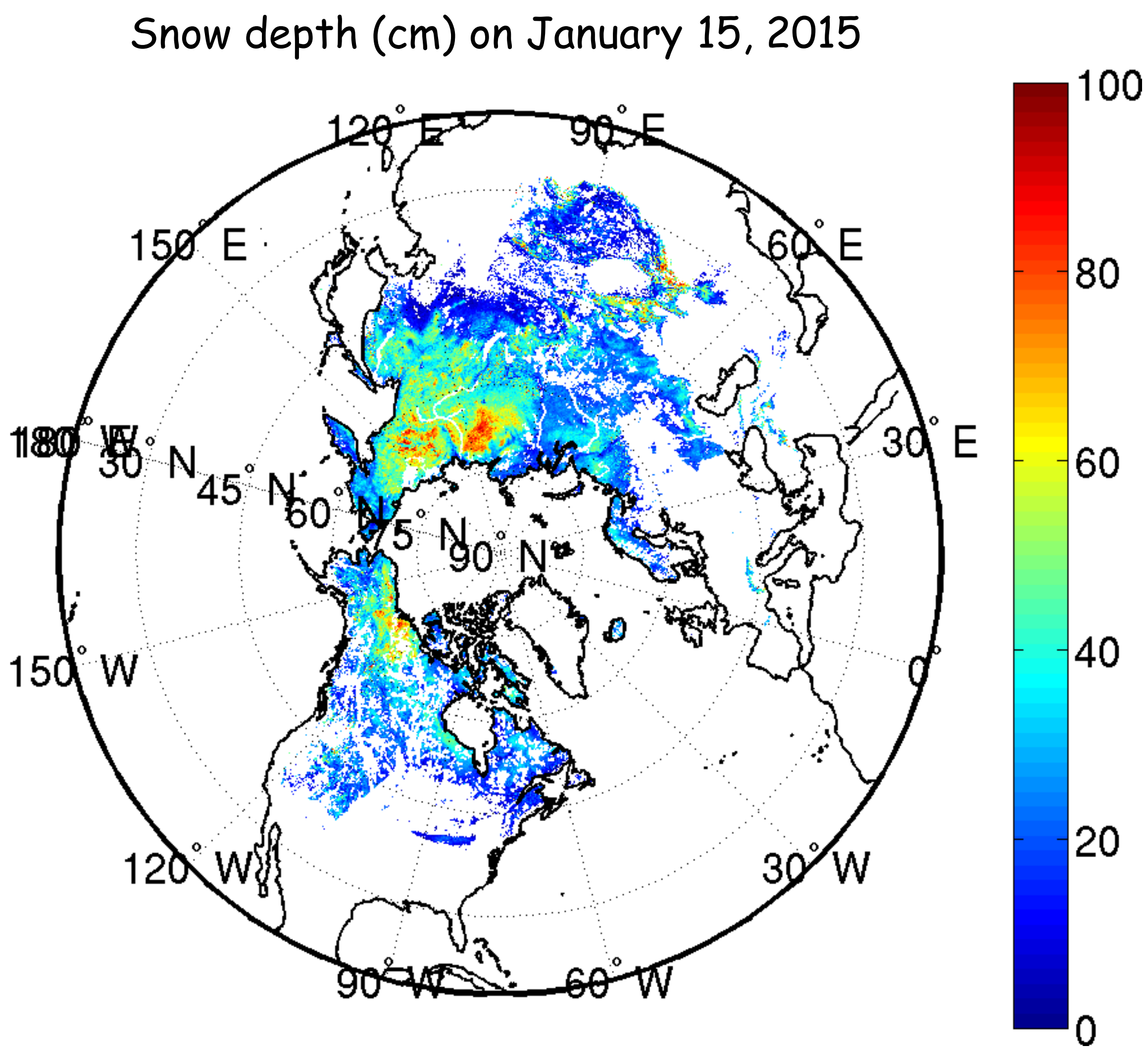
- Brightness temperature differences at 10, 18 and 37 GHz (the Chang et al. approach) but with non-linear spatially and varying coefficients computed from brightness temperatures at horizontal and vertical polarizations
- Use of 10 & 18 GHz channels over the non-forested portion of the AMSR-E pixel for deeper snow retrievals
- Retrievals of pixel SD are weighted between forest and non-forest fractions
- Algorithm coefficients are tuned to SD, and SWE is estimated using a spatially and seasonally varying snow density climatology.

Product Examples: Snow Cover

Snow cover on January 15, 2015

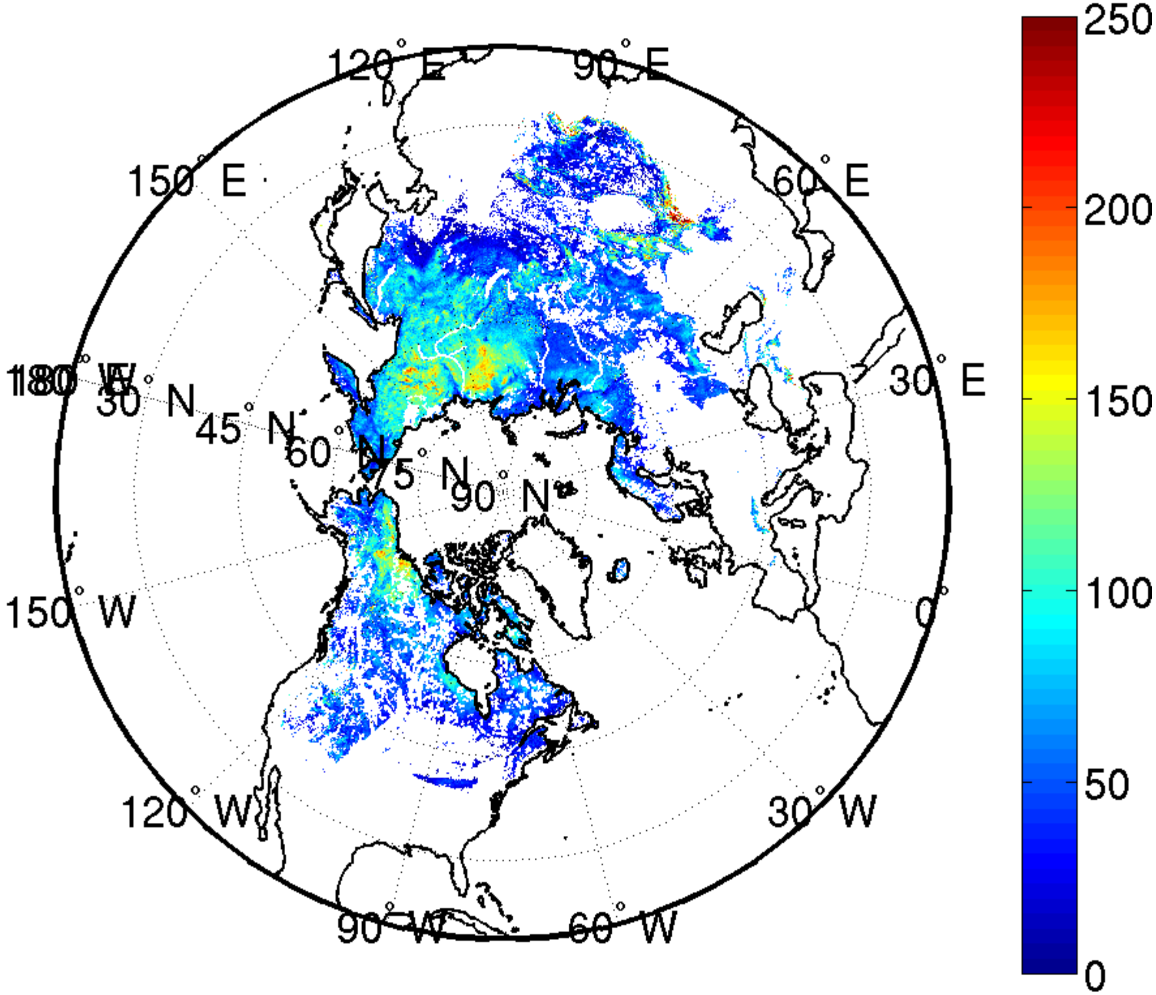


Product Examples: Snow Depth



Product Examples: SWE

Snow water equivalent (kg/m^2) on January 15, 2015



Validation Results

Snow cover	GAASP
Overall accuracy	81.17 % ✓
Snow detection rate	78.34 %
Commission	1.78 %
Omission	17.05 %
Number of pixels	1504245

Snow depth	GAASP
bias	-0.50 cm
RMSE	18.7 cm ✓
Number of pixels	2432

SWE	GAASP
bias	-0.22 mm
RMSE	31.35 mm ✓
Number of pixels	26639
Mean (AMSR2)	62.06 mm

See notes section for validation strategy.

Valid on January 15, 2015

GAASP: GCOM AMSR2 Algorithm Software Package

Future Plans for Snow Products

- Evaluation of AMSR2 snow products over a long period for regionally and globally.
- Further investigation is needed for wet snow detection and each criteria regarding precipitation, cold desert, and frozen ground (for snow cover detection).
- Atmospheric correction can be considered for the further improvement in snow products.
- Adjustment of the weights for each channel may improve the snow depth calculation.

AMSR2 SEA ICE CHARACTERIZATION

Walt Meier[1], Scott Stewart[2], Julienne Stroeve[2]

[1]NASA Goddard Space Flight Center

[2]National Snow and Ice Data Center
Cooperative Institute for Research in the Environmental Sciences
University of Colorado, Boulder

Requirements

As noted in the ARR, ”Uncertainty” may be the incorrect term. Using “accuracy” (absolute value of mean bias) and the same value (10%) would be consistent with ice concentration requirements for GOES-R ABI (accuracy: 10%) and JPSS VIIRS (accuracy: 10%; uncertainty: 25%). Perhaps accuracy is what was intended.

Table 8.0.1 GCOM Sea Ice Characterization

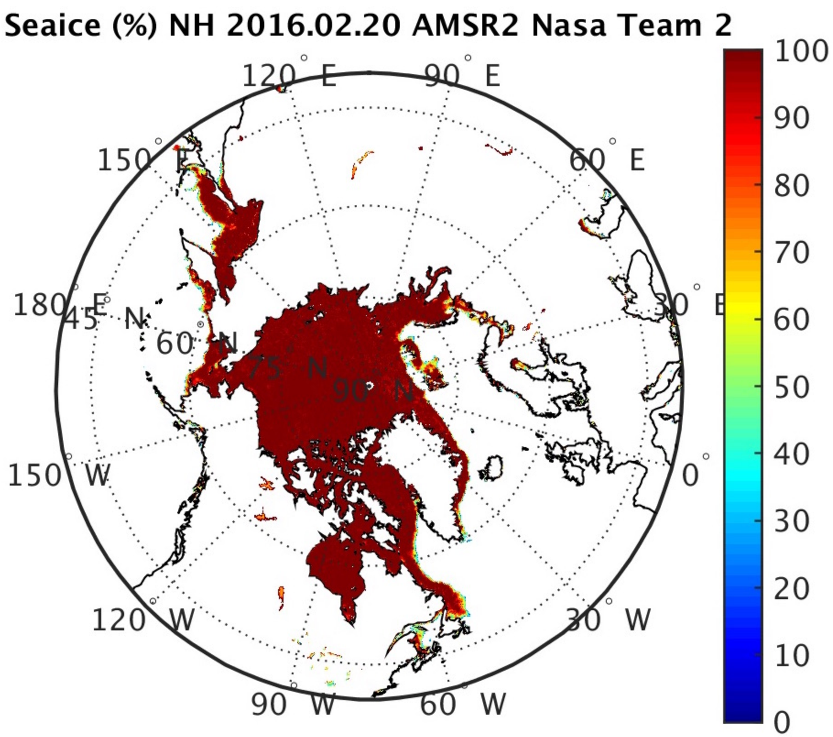
EDR Attribute	Threshold	Objective
A		
V		
H		
M		
Measurement range		
-- Ice concentration	1/10 – 10/10	0 – 100%
-- Ice age classes	Ice free, first-year, multiyear ice	Ice free, nilas, grey grey-white, white, first year medium, first year thick, second year, and multiyear; smooth and deformed ice
Measurement uncertainty		
-- Ice concentration	10%	5%
Probability of correct typing of ice age classes	70%	90%
Refresh	At least 90% coverage of the globe about every 20 hours (monthly average)	Not Specified
Geographic coverage	All ice-covered regions of the global ocean	All ice-covered regions of the global ocean

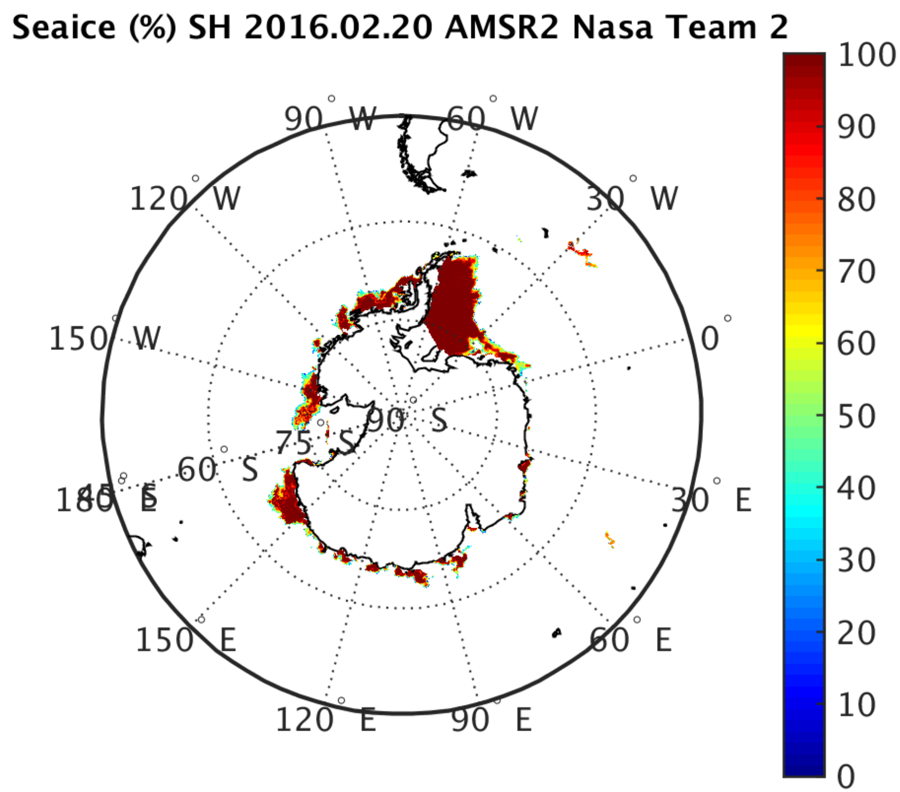
Sea Ice Algorithm

NASA Team 2 (NT2) and Bootstrap (BT) algorithms are used

- Characteristics
  - NT2 includes use of high frequency channels (89 GHz) for better sensitivity to surface variability, with an atmospheric correction to mitigate weather effects
  - BT uses heritage approach from SMMR through AMSR-E, with daily varying tiepoints to account for seasonal changes in surface properties
- The NOAA product will contain both, but NT2 is primary.
  - Allows known errors to be mitigated:
    - NASA Team 2: atmospheric emission
    - Bootstrap: low (cold) temperatures and melt
- Difference in concentrations between algorithms provides a confidence indicator
- Iteration for NASA Team 2 atmospheric correction provides a quantitative error estimate

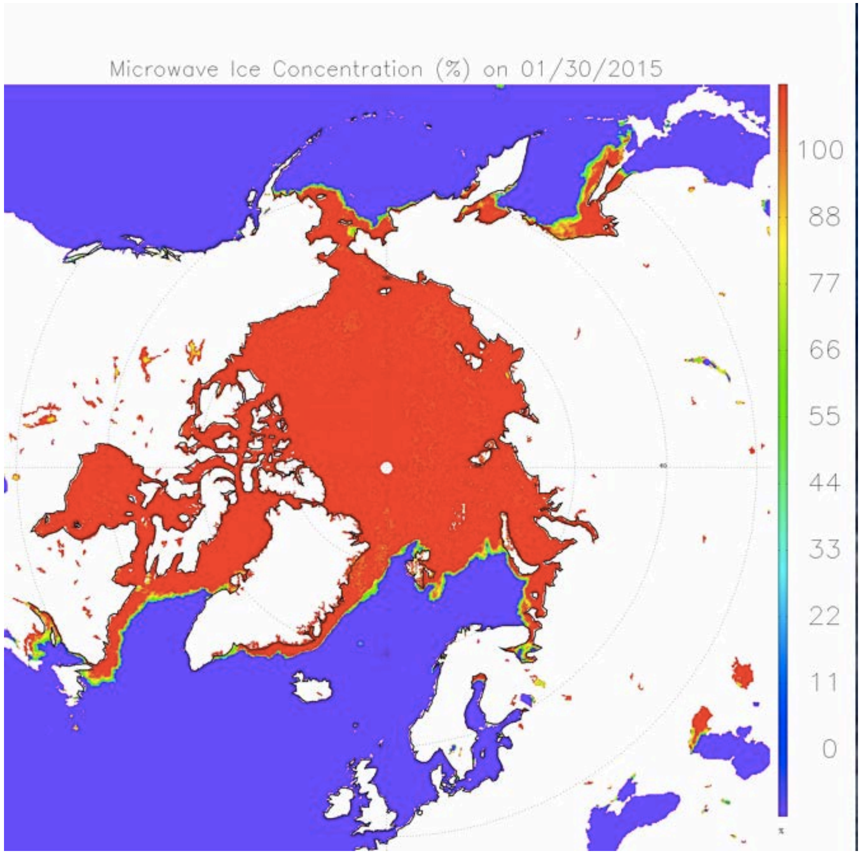
Product Examples



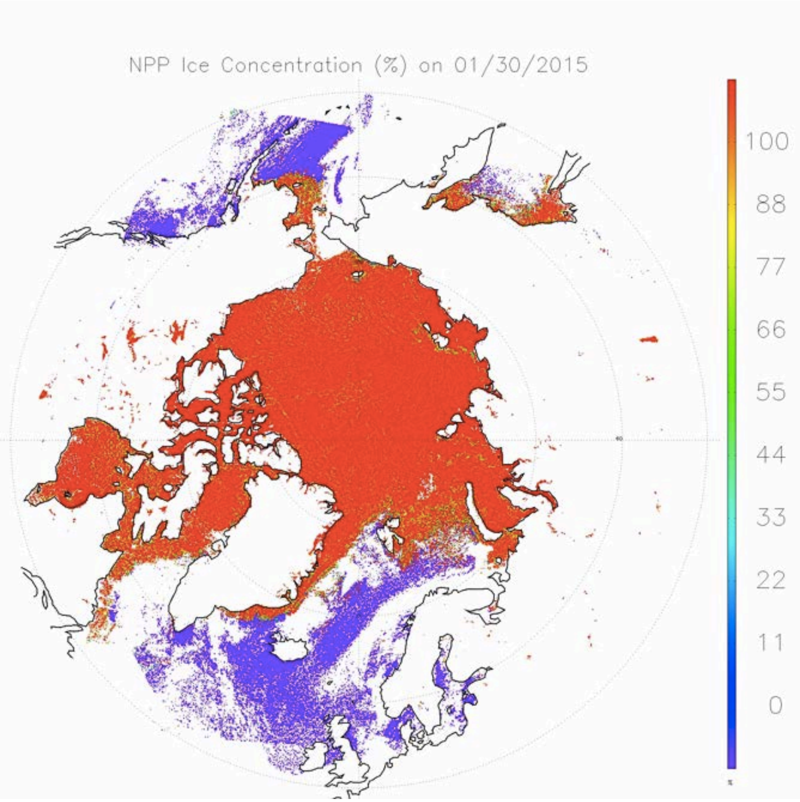


Examples of AMSR2 sea ice concentration over the Arctic (above) and Antarctic (right) on 20 February 2016.

Validation



Comparison of AMSR2 (left) and VIIRS (below) sea ice concentration over the Arctic on 31 January 2015.



Additional information on validation is in the notes section of this slide

Validation Results

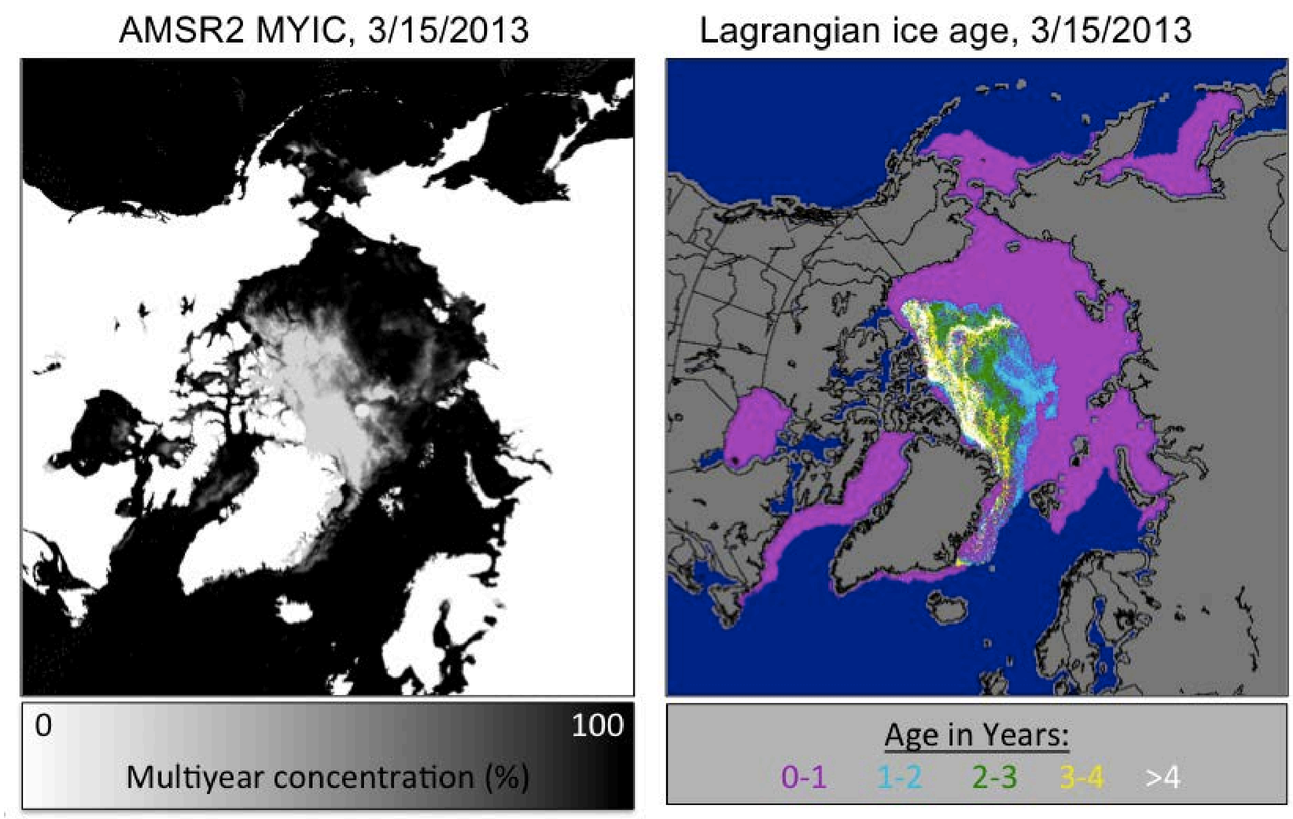
Statistical results of the comparison in sea ice concentration between AMSR2 (AIT) and VIIRS.

Maximum (red) and minimum (blue) values in each column are highlighted.

	Arctic			Antarctic		
	Accu	Prec	Cases	Accu	Prec	Cases
01/30	1.61	***8.76***	123747	0.50	21.45	22776
01/31	1.62	9.10	***124514***	1.53	***22.03***	***19556***
02/27	2.05	9.91	122376	1.04	20.19	20101
02/28	2.03	9.35	120343	***0.21***	20.88	22256
03/30	2.45	10.01	122108	1.52	14.90	48343
03/31	2.12	9.39	118841	2.48	15.24	43737
04/30	3.02	11.98	88959	1.85	12.64	79228
04/31	3.01	11.87	79756	2.24	12.62	82094
05/30	3.20	11.46	65418	2.19	13.03	99093
05/31	***3.22***	11.92	70990	1.80	12.97	104142
06/30	2.19	14.05	56864	1.55	***11.08***	121964
06/31	1.89	14.41	55580	1.56	11.78	123805
07/30	1.89	18.33	35577	2.43	12.62	***142350***
07/31	2.53	18.20	38069	2.58	12.34	138524
08/30	***0.25***	***18.48***	28727	2.79	11.87	133027
08/31	0.61	17.19	***27315***	***2.95***	12.71	142208

Multiyear Ice Validation

The multi-year ice concentration (MYIC) parameter has not been thoroughly validated and is still considered to be experimental. Initial comparison with independent ice age fields (using Lagrangian tracking of ice parcels) indicates good agreement in terms of the spatial distribution of multi-year ice cover.

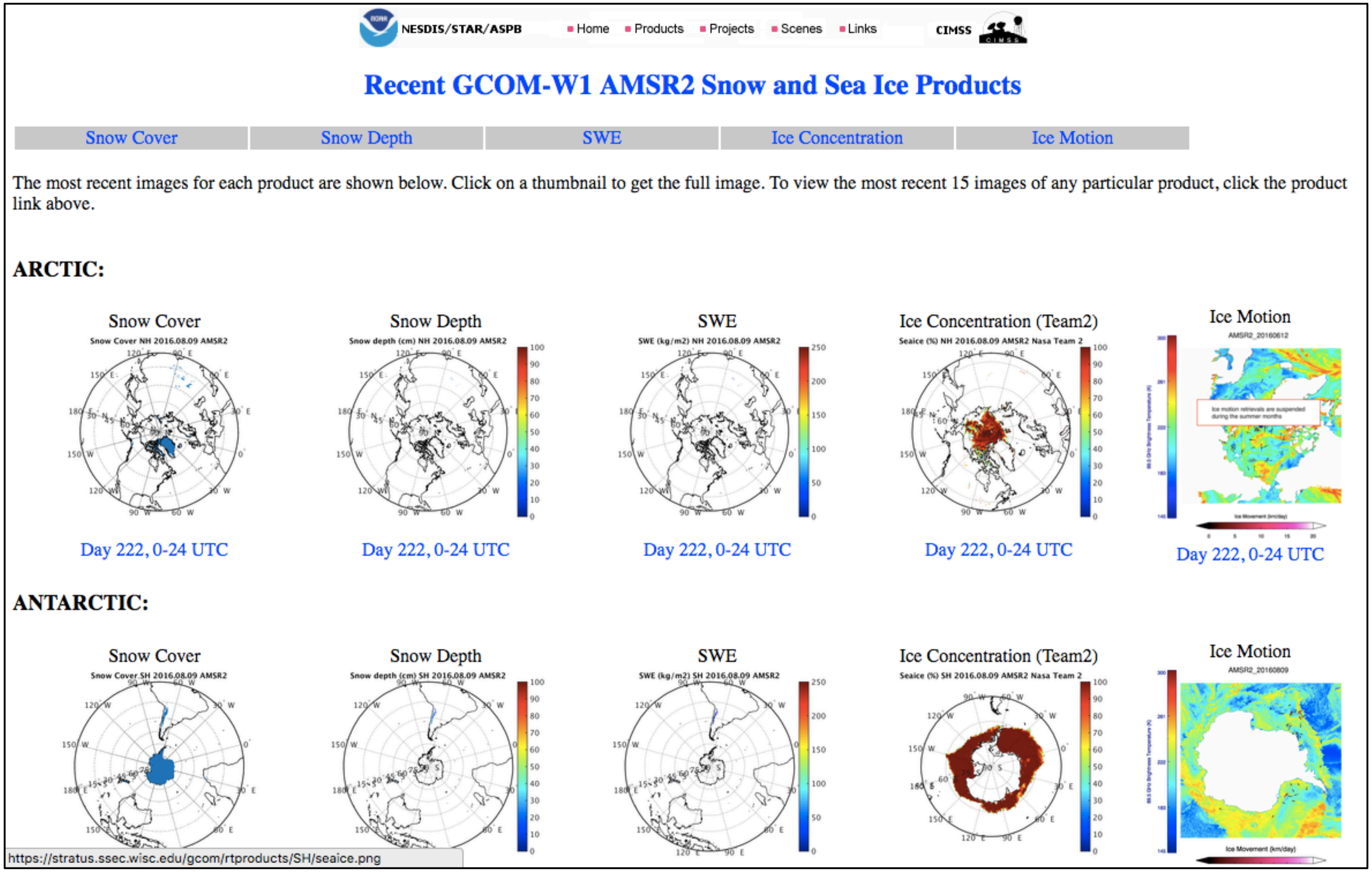


Future Plans for Sea Ice Products

- Further development and validation of ice type and publication of ice type methodology.

Near Real-time Products

All products described here, plus ice motion (experimental), are generated daily at CIMSS. Plots are available at http://stratus.ssec.wisc.edu/gcom/rtproducts.



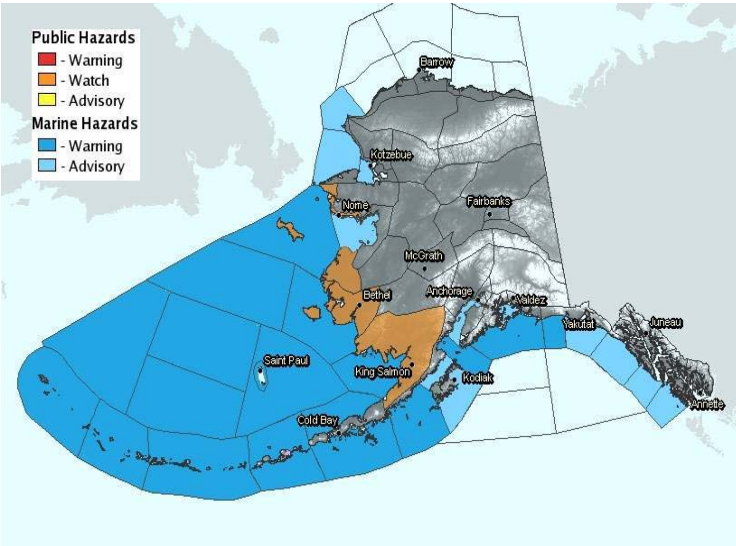
Snow and Ice Product Users (planned)

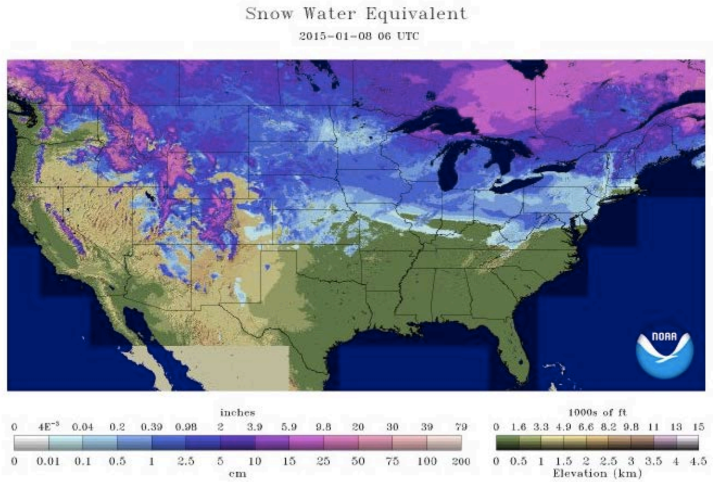
Operational Ice Services

- U.S. National Ice Service
- North American Ice Service
- Anchorage Ice Desk

Modeling

- Snow: National Operational Hydrologic Remote Sensing Center Snow Data Assimilation System (SNODAS)
- Snow: Weather forecasting, e.g., NCEP
- Ice: Naval Research Lab, Arctic Cap Nowcast/Forecast System (ACNFS)





GCOM-W1/AMSR2 SOIL MOISTURE

NOAA NESDIS STAR

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X. Zhan, J. Liu, T. King, R. Ferraro, P. Chang

Outline

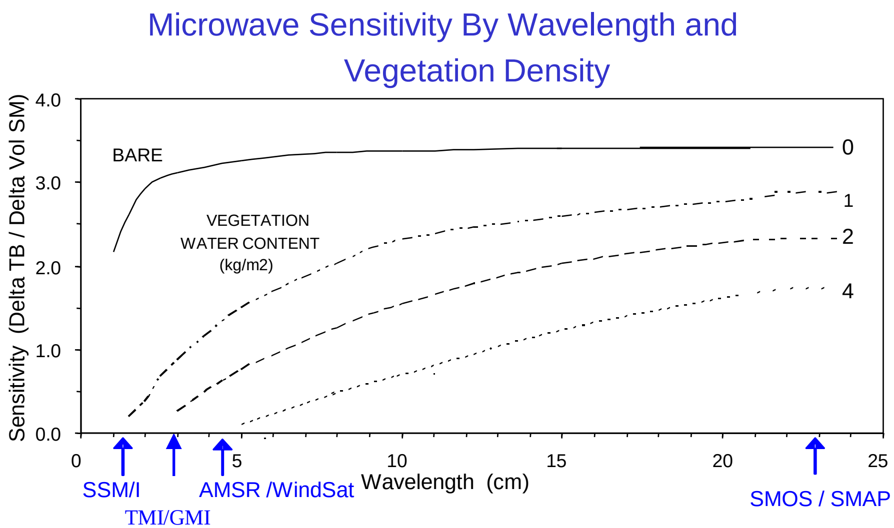
- AMSR2 Soil Moisture EDR Team Members
- Soil Moisture Sensor Overview
- AMSR2 Soil Moisture Algorithm
- AMSR2 Soil Moisture Data Product
- Summary and Path Forward

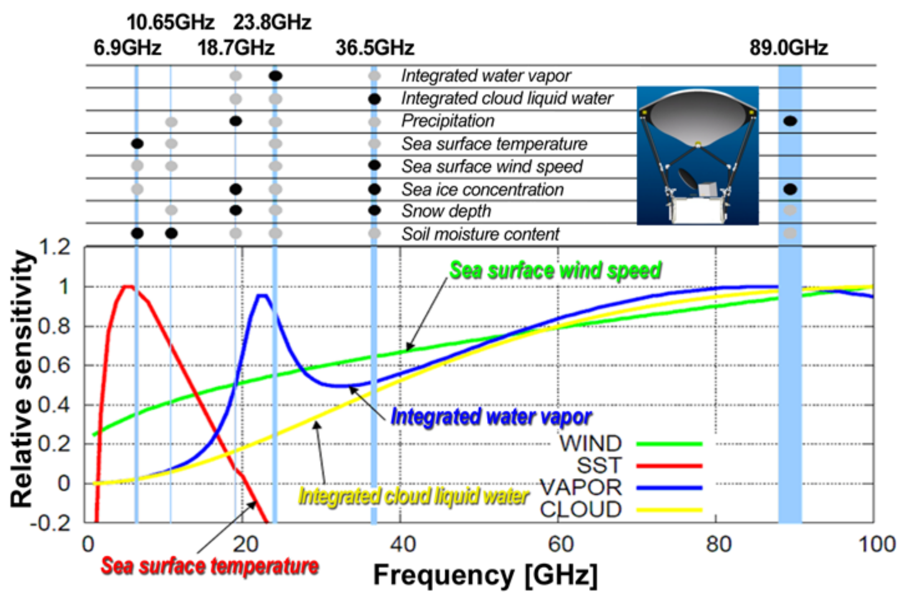
AMSR2 Soil Moisture Team Members

Team Member	Organization	Roles and Responsibilities
Xiwu Zhan	NESDIS-STAR	AMSR2 Soil Moisture Team Lead
Jicheng Liu	UMD-CICS/ NESDIS-STAR	SM Algorithm and Validation Lead
Tom King	IMSG/ NESDIS-STAR	GAASP Development Lead
Zorana Jelenak	UCAR/ NESDIS-STAR	JPSS GCOM-W1 EDR Lead
Ralph Ferraro	NESDIS-STAR	JPSS GCOM-W1 Project Deputy
Paul Chang	NESDIS-STAR	JPSS GCOM-W1 Project Lead

Soil Moisture Sensor Overview

- Soil Moisture remote sensing is based on the sensitivity of L/C/X band microwave emission to soil dielectric constant
- Soil moisture capable passive microwave satellite sensors include: SMMR, SSM/I and SSMIS, AMSR/AMSR-E, WindSat, **SMOS**, **AMSR2**, **GMI** and **SMAP**
- AMSR2 on board of JAXA's GCOM-W1 satellite is currently the only **operational passive microwave soil moisture** sensor in NASA-NOAA JPSS program





JPSS Requirements for AMSR-2 Soil Moisture EDR

Table 6.1.10 - GCOM-W Soil Moisture		
EDR Attribute	Threshold	Objective
Applicable conditions	Delivered under “all weather” conditions	Delivered under “all weather” conditions
Sensing depth	Surface to -0.1 cm (skin layer)	Surface to -80 cm
Horizontal cell size	25 km (1)	3 km
Mapping uncertainty, 3 sigma	5 km	1 km
Measurement Uncertainty	6% volumetric RMSE (goal) with VWC < 1.5 kg/m^2 or GVF < 0.5 and < 2 mm/hr precip rate	Surface: 5% 80 cm column: 5%
Measurement range	0 – 50%(2)	0 – 50%
Refresh	At least 90% coverage of the globe about every 20 hours (monthly average)(3)	n/s

Note:
(1) Per AMSR-E legacy and user convenience, 25km can be obtained with resampling AMSR-2 footprints to 25km. 3km could be obtained by interpolation with VIIRS optical observations
(2) Absolute soil moisture unit (m^3/m^3 volume %) is preferred by most users of NWP community
(3) This Refresh requirement is consistent with the AMSR-2 Cross-track Swath Width design of 1450 km for a single orbit plane

JPSS Requirements for AMSR-2 Surface Type EDR

Table 6.1.11 - Surface Type (AMSR-2)		
EDR Attribute	Threshold [1]	Objective
Applicable conditions	Delivered under "all weather" conditions	Delivered under "all weather" conditions
a. Horizontal cell size	25 km	1 km
b. Mapping uncertainty, 3σ	5 km	1 km
c. Measurement Range	8 hydrological classes[2]	13 classes of land types listed in Note [3]
d. Measurement Precision	5%	2%
e. Measurement Accuracy	70% for 17 types	80%
f. Refresh	>90% coverage of globe every 20 hrs [4]	n/s

Note:

(1) Satisfied by VIIRS under "probably clear" and "probably cloudy" conditions.

(2) 1) Standing water, 2) Dense veg (jungle), 3) Herb veg, 4) Desert, 5) Snow, 6) Urban, 7) Wetland, 8) Raining area

(3) 1) Standing water/flooded, 2) Dense veg (jungle), 3) Ag/range land, 4) Dry arable soil, 5) Moist soil, 6) Semi-arid surface, 7) Desert, 8) Dry snow, 9) Refrozen snow, 10) Wet snow, 11) Veg/water mix, 12) soil/water mix, 13) Indeterminate.

(4) Consistent with AMSR2 cross-track swath width of 1450km.

Soil Moisture Algorithm Overview

Multi-channel Inversion (MCI) Algorithm

(Njoku & Li, 1999)

$$\min\{\chi^2 = \sum_{i=1}^{6}\left(\frac{T_{B,i}{}^{obs} - T_{B,i}{}^{cmp}}{\sigma_i}\right)^2\}$$

$$T_{B,i}{}^{cmp} = T_s\,\{e_{r,i}\exp(-\tau_i/\cos\theta) + (1-\omega)[1-\exp(-\tau_i/\cos\theta)][1+(1-e_{r,i})\exp(-\tau_i/\cos\theta)]\}$$

$\tau_i = b * VWC$

$e_{r,i} = f(e_s, h)$

$e_s = f(\varepsilon)$ -- *Fresnel Equation*

$\varepsilon = f(SM)$ -- *Mixing model (Dobson et al)*

$T_{B,i}{}^{obs} = T_{B06h}, T_{B06v}, T_{B10h}, T_{B10v}, T_{B18h}, T_{B18v}$

Soil Moisture Algorithm Overview

Land Parameter Retrieval Model (LPRM) :

(Owe, de Jeu & Holmes, 2008)

$$\min\{delta = T_{Bh}{}^{obs} - T_{Bh}{}^{cmp}\}$$

$$T_{Bh}^{cmp} = T_s \{e_{h,r} \exp(-\tau/\cos\theta) + (1 - \omega)[1 - \exp(-\tau/\cos\theta)][1 + (1 - e_{h,r})\exp(-\tau/\cos\theta)]\}$$

$\tau = f(MPDI)$, $MPDI = (T_{Bv} - T_{Bh})/(T_{Bv} + T_{Bh})$

$e_h = f(e_s, h, Q)$

$e_s = f(\varepsilon)$ -- Fresnel Equation

$\varepsilon = f(SM)$ -- Mixing model (Wang & Schmugge)

$T_s = f(T_{B37v})$ or T_s^{LSM}

$T_{Bh}^{obs} = T_{B06h}$, T_{B10h} or T_{B18h}

Soil Moisture Algorithm Overview

Single Channel Algorithm (SCA) :

(Jackson, 1993)

$$T_{B10h} = T_s \, [1 - (1 - e_r) \exp(-2\tau / \cos\theta)]$$

$$\tau = b * VWC, \; VWC = f(NDVI)$$

$$e_h = f(e_v, h, Q)$$

$$e_s = f(\varepsilon) \qquad \text{-- Fresnel Equation}$$

$$\varepsilon = f(SM) \qquad \text{-- Mixing model}$$

$$T_s = f(T_{B37v}) \text{ or } T_s^{LSM}$$

AMSR2 Soil Moisture Algorithm

SCA: Inverse tau-omega equation of a TB_h (C/X-band) for *SM* with *tau* from *NDVI* and T_s from TB_{36v}. Used in SMOPS

LPRM: Inverse tau-omega equations of TB_h and TB_v (C/X-band) for *tau* and *SM* with T_s from TB_{36v}

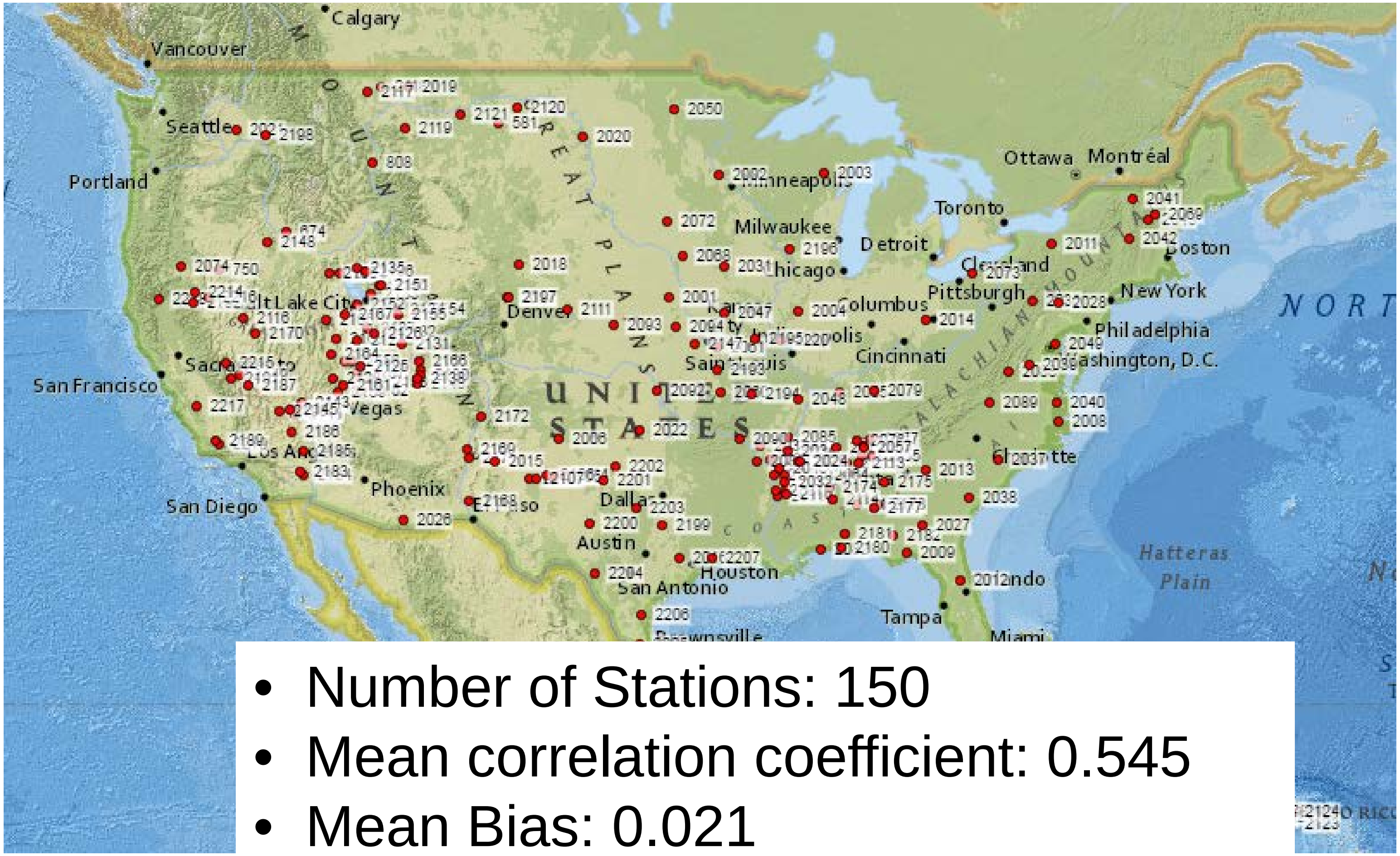
Hybrid: Use LPRM inversed *tau* in SCR for AMSR2 soil moisture EDR

AMSR2 Soil Moisture Products

- AMSR2 soil moisture EDR is generated with the hybrid algorithm implemented in NESDIS GCOM-W1 AMSR2 Algorithm Software Processor (GAASP) using AMSR2 6.9/7.3GHz H-pol TB data, available as Level 2 swath product
- Global 0.25 degree (Level 3) gridded AMSR2 soil moisture data product are made available through NESDIS Global Soil Moisture Operational Product System (SMOPS) in 6 hour or daily NetCDF and GRIB2 files
- Algorithm Readiness Review for the Day 2 EDR of GCOM-W1 products was held in May 2016
- SMOPS update for AMSR2 to provide Level 3 global soil moisture product for users was delivered to OSPO in July and Operation Readiness Review (ORR) of the SMOPS update is arranged later this month

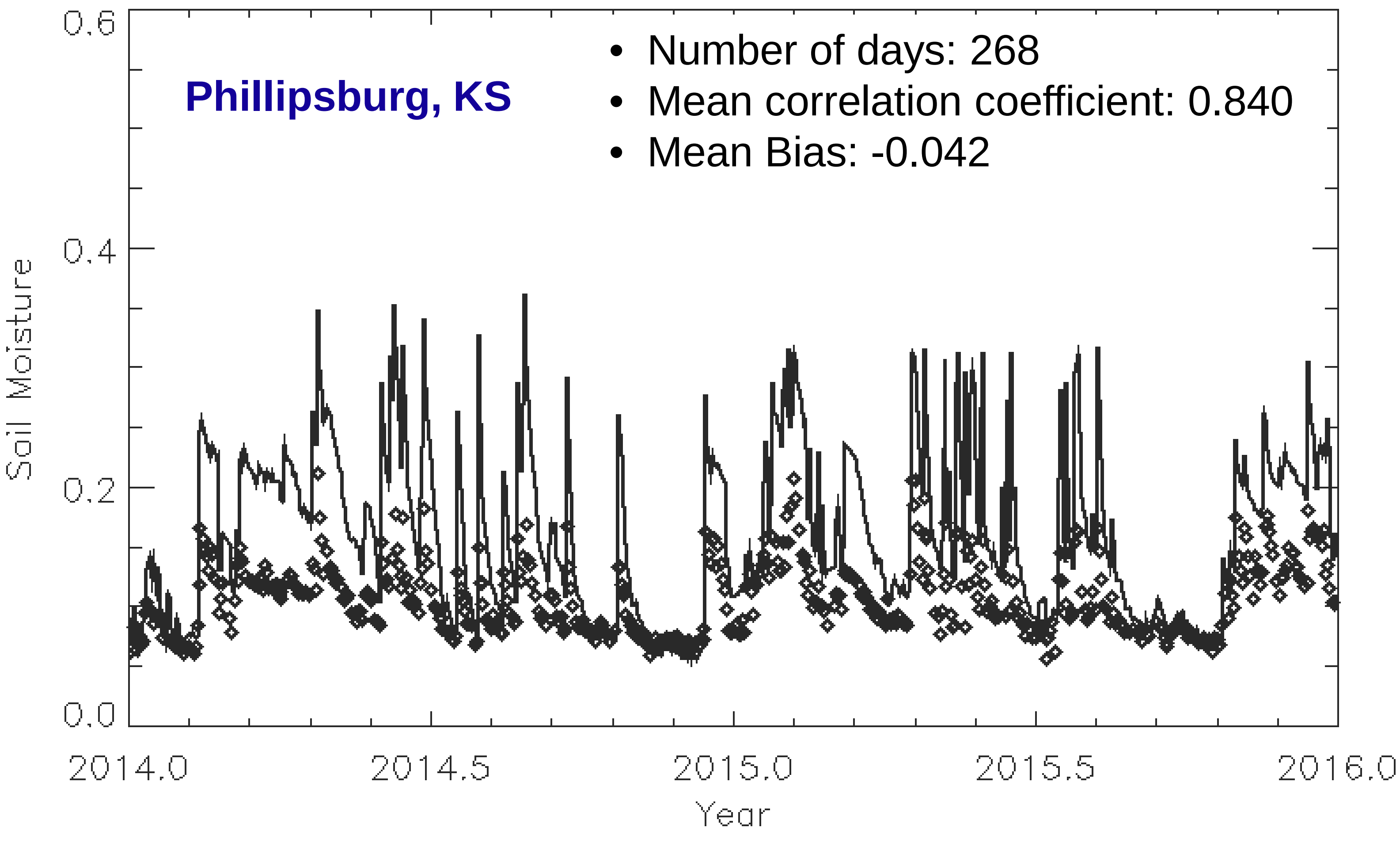
AMSR2 Soil Moisture Performance

Comparison with in situ Measurements of SCAN Sites

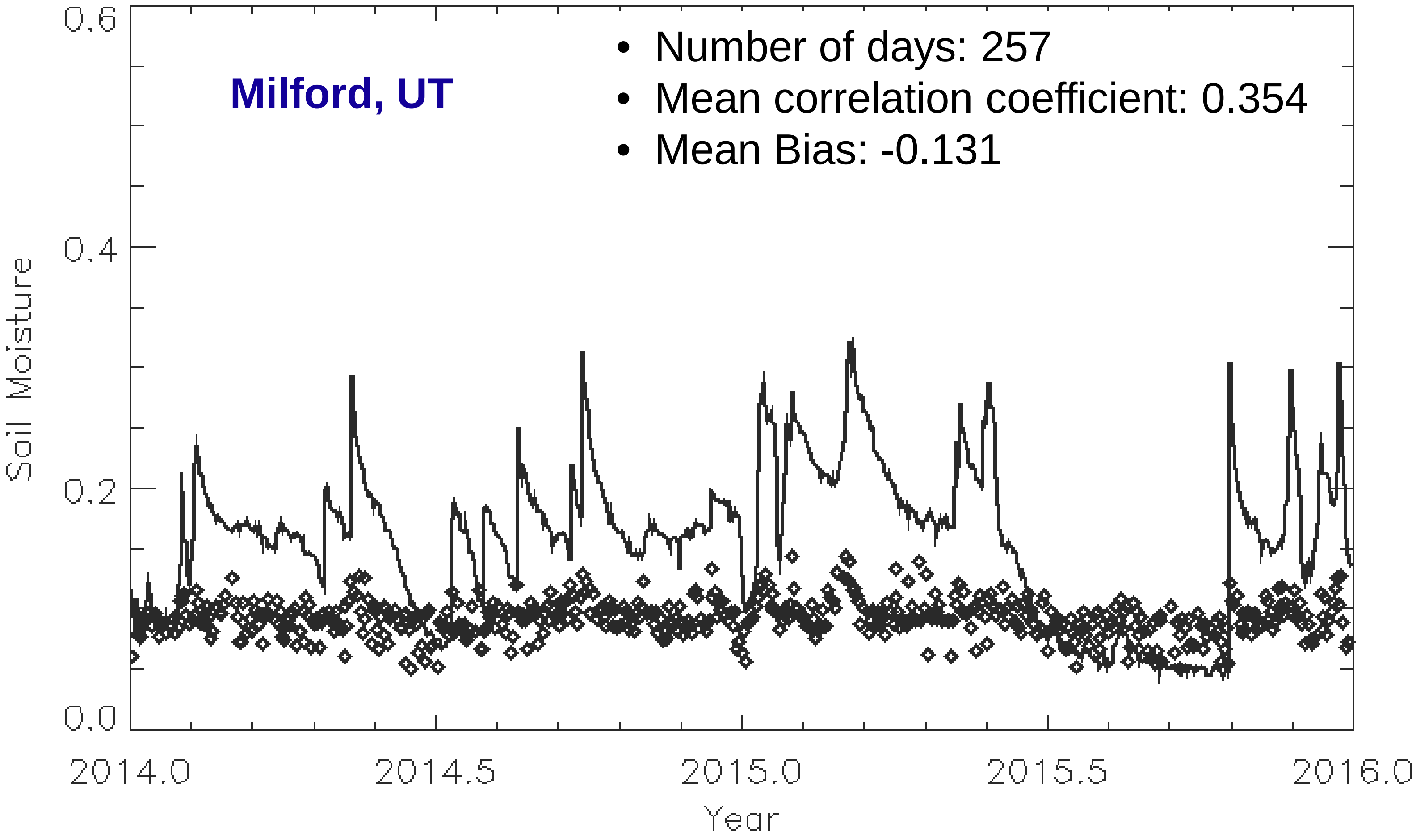


- Number of Stations: 150
- Mean correlation coefficient: 0.545
- Mean Bias: 0.021
- Mean RMSE: 0.038

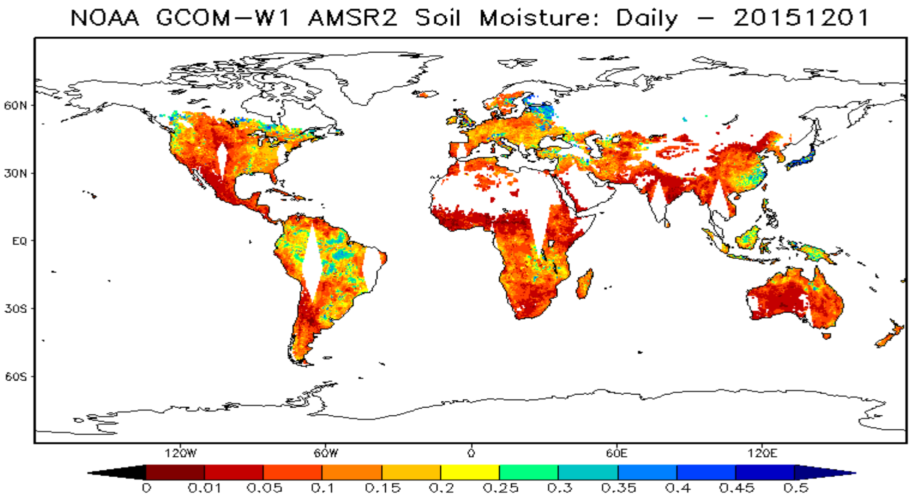
AMSR2 Soil Moisture Performance

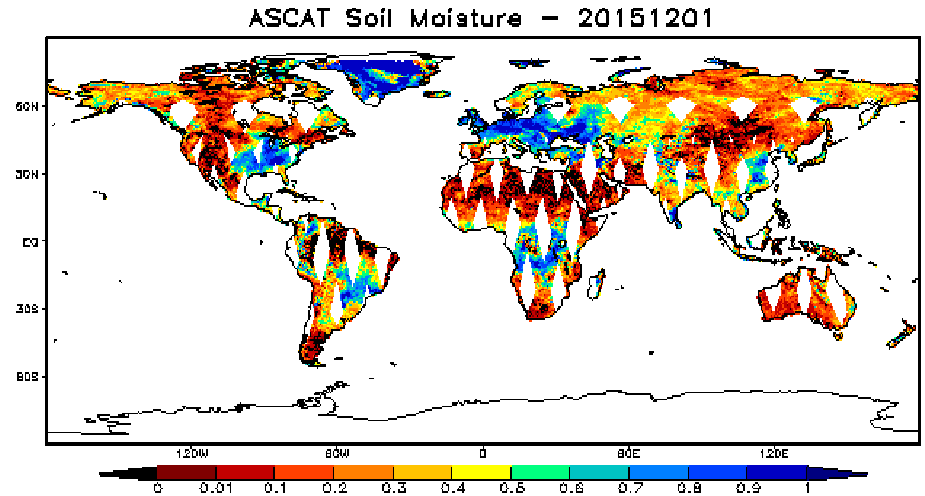


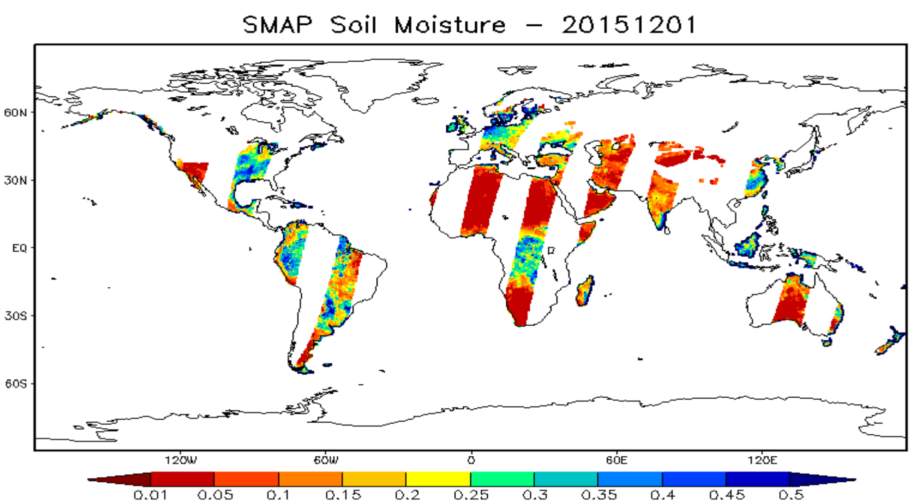
AMSR2 Soil Moisture Performance

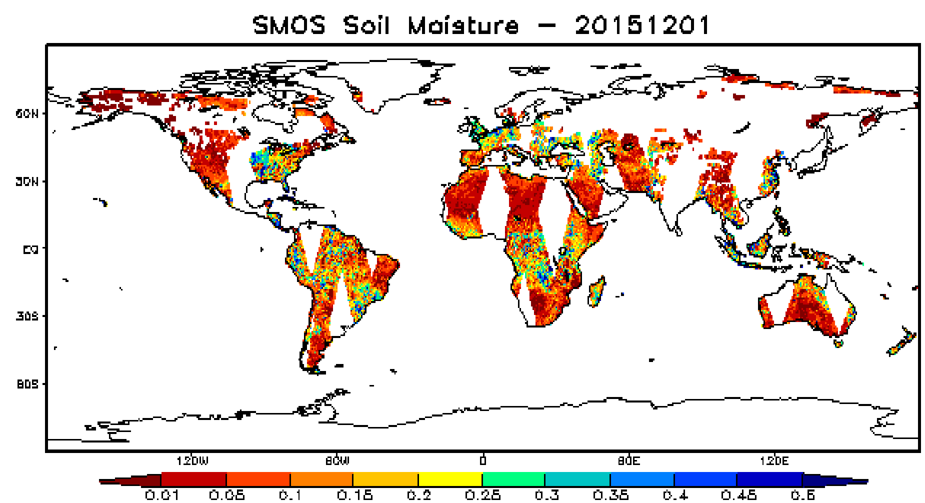


AMSR2 SM vs Other SM Products



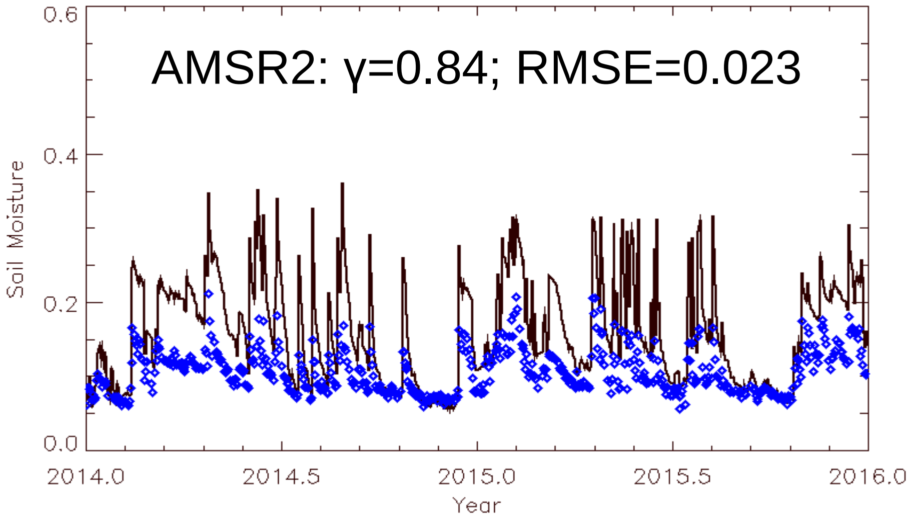


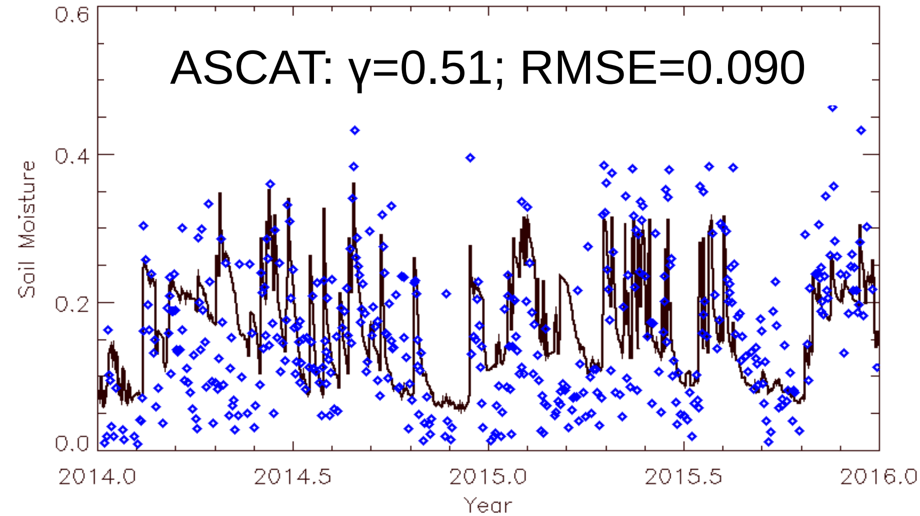


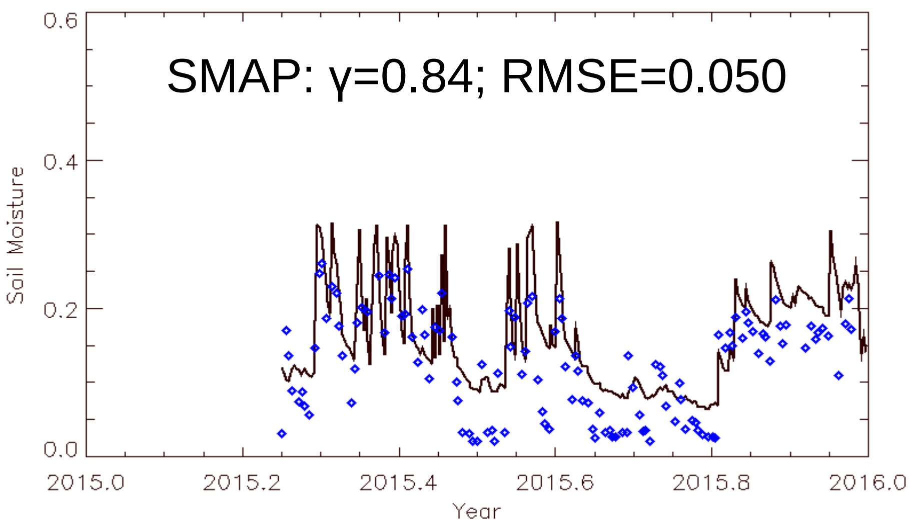


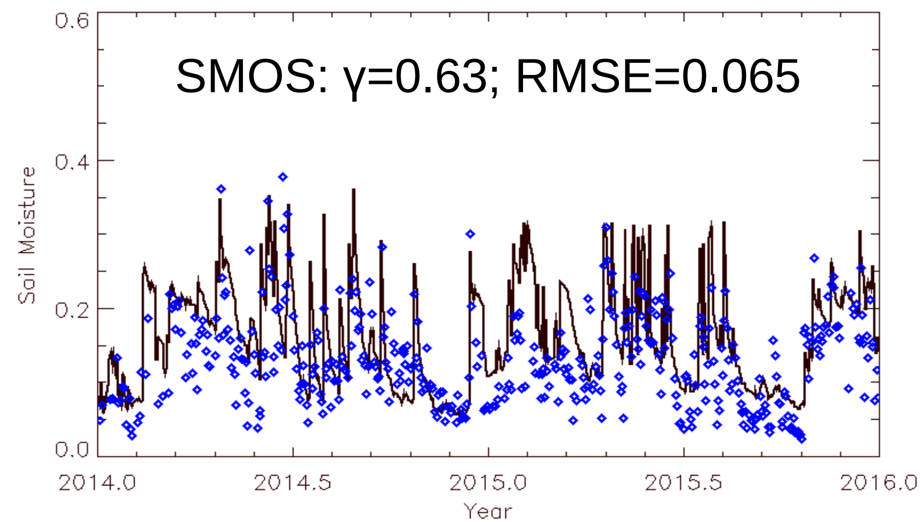
AMSR2 SM vs Other SM Products: Phillipsburg, KS

(γ: correlation coefficient; RMSE: Root Mean Square Error)



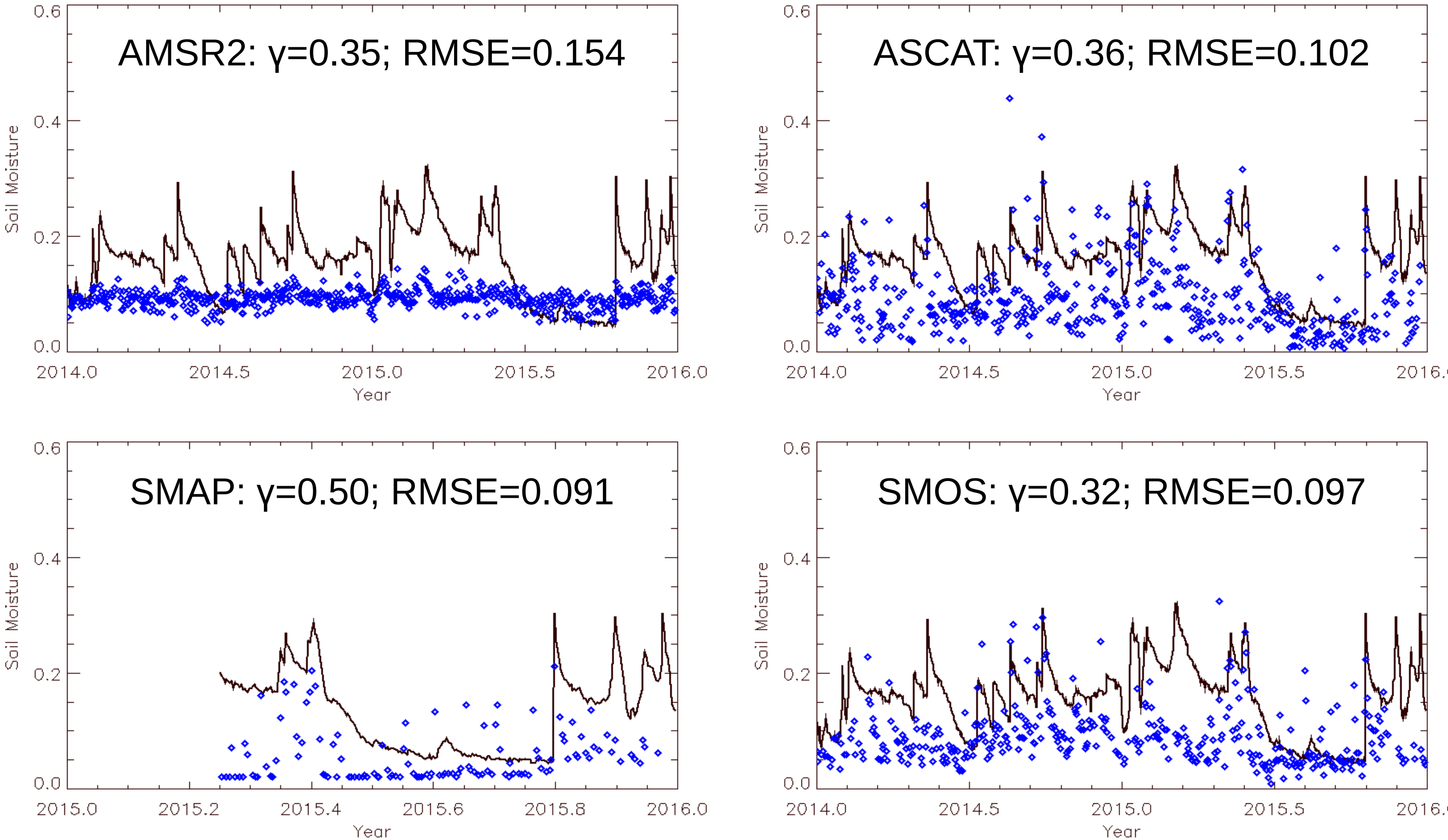






AMSR2 SM vs Other SM Products: Milford, UT

(γ: correlation coefficient; RMSE: Root Mean Square Error)



AMSR2 Soil Moisture EDR Overview

- Performance generally meets requirements
- Reprocessing Plan/Status: in development
- Long Term Monitoring/Website Links:
  - SMOPS website at STAR is in development
    - https://www.star.nesdis.noaa.gov/smcd/emb/soilmoisture/SMOPSMaps.php
  - SMOPS update for AMSR2 at OSPO is ready for review later this month
    - http://www.ospo.noaa.gov/Products/land/smops/smops_loops.html?Imap=6H
- Enterprise Algorithm Status: SMOPS?
- Users Feedback:
  - NCEP use of SMOPS data are in research mode
  - SMOPS products are used in DoD AFWA and USDA FAS operationally
  - SMOPS products are used for Blended Drought Index

Readiness for Follow-on Satellites

- Significant Algorithm changes is planned for GCOM-W2 if any
  - SCA will be calibrated with VIIRS EVI or LAI for better counting of vegetation water content impact
- Pre-launch Characterization
  - N/A
- Post-Launch Cal/Val Plans
  - Data Sets/Planned Field Campaigns : N/A
  - Schedules and Milestones: N/A
- Accomplishments and Highlights Moving forward
  - A NASA funded project may leverage an effort of downscaling AMSR2/3 soil moisture data product for high resolution data need
- Major Risks/Issues/Challenges/ and Mitigation
  - No GCOM-W1 follow-on satellite is approved yet
- Collaboration with Stake Holders/User Agencies
  - Interaction with user community has been frequent

Summary

- GCOM-W1/AMSR2 soil moisture EDR has been generated by NESDIS GAASP as Day 2 product
- AMSR2 soil moisture EDR quality is compatible with other available satellite products and meets JPSS accuracy requirements generally
- NESDIS SMOPS is going to ingest AMSR2 soil moisture EDR and merge it with other global soil moisture data products to provide NCEP and other operational users with 6 hour and daily gridded products from next month

Path Forward

- FY17 Milestones:
  - AMSR2 soil moisture EDR comprehensive validation with global in situ measurement networks and other soil moisture data products
  - Improve user applications by providing more quality control information of products
- Alternate Algorithms and Future Improvements
  - Algorithm refinement and validation with VIIRS EVI replacing NDVI as input
  - Downscaling algorithm development and validation for high resolution data needs
- Preparation for future satellites: n/a

Thanks!