Validated Maturity Science Review For NOAA-20 NUCAPS Algorithm

Presented by NUCAPS Team

Date: 2019/10/24

NUCAPS MATURITY REVIEW
OCTOBER 28, 2019
9:00 – 12:00 EDT

DIAL-IN: TELEPHONE: 866-631-7603 PASSCODE: 6256206

Validated Maturity:

NOAA-20 NUCAPS products: AVTP, AVMP, Ozone, OLR

NUCAPS CO product (SNPP & NOAA-20)

Provisional Maturity:

NUCAPS CH4 product (SNPP & NOAA-20)

	Maturity Review Presentation - Items	Time
1	Management updates	5 minutes (09:00 - 09:05) Presented Ken Pryor

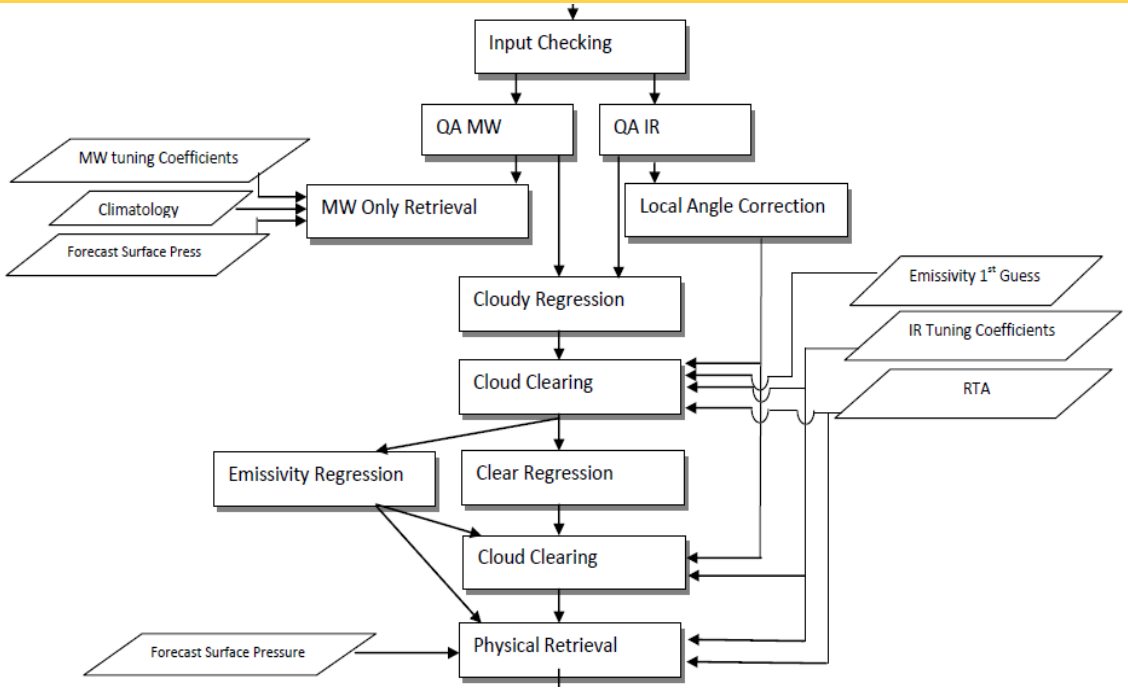
2	**Maturity Review**
	• Algorithm Team Members
	• NUCAPS Operational Products: Current Maturity Status
	• Entrance and Exit Criteria
	• Data Product Maturity Definitions
	• Processing Environment, Algorithm Versions
	• Algorithm Performance to Specification Requirements
	  • NUCAPS Candidate Version: Improvements from Operational Version
	  • Evaluation of the Effect of Required Algorithm Inputs
	  • Cal/Val Activities for NUCAPS Algorithm Performance
	  • Quality Flags (applicable to all NUCAPS products)
		25 minutes (09:05 – 09:30)
		Presented by Murty Divakarla

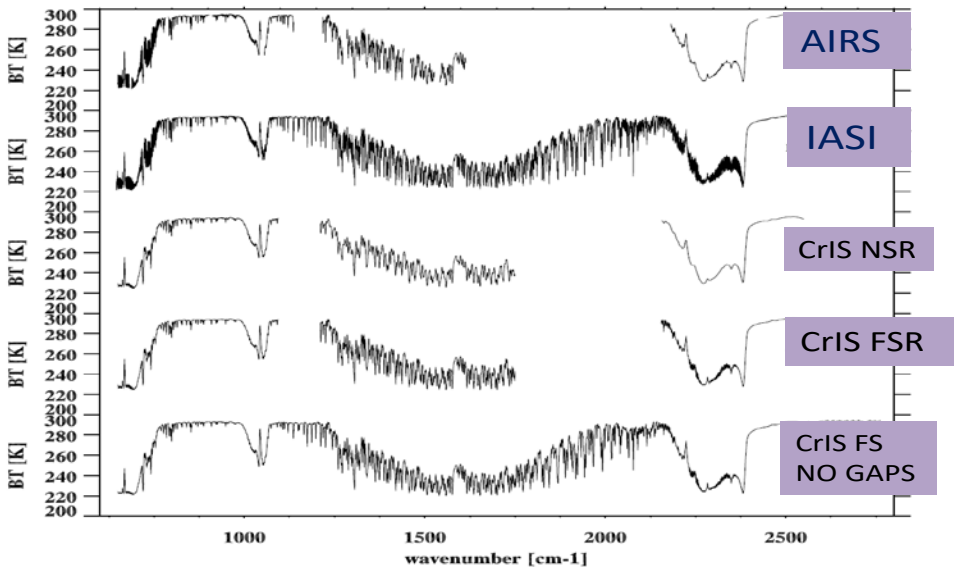
3	**Product Requirements/Validation Results (supplemental slides at end of presentation)**
	  • NOAA-20 T(p), q(p), O3(p) Validated Maturity (9:30 – 10:00)
	  • NOAA-20 OLR Validated Maturity (10:00 – 10:15)
	  • SNPP/NOAA-20 CO Validated Maturity, and CH4 Provisional Maturity (10:15 – 10:45)
	  • Error Budget: AVTP, AVMP, O3, OLR, CO, CH4, CO2 – Slide Mapping
		75 minutes (09:30 – 10:45)
		Presented by
		Nick Nalli and Tianyuan Wang

4	**User Feedback/Downstream product feedback**	30 minutes (10:45 – 11:15) Presented by Ken Pryor
5	• Risks, Actions, and Mitigations • Documentation (Science Maturity Check List) • Conclusions, Path Forward	15 minutes (11:15 – 11:30) Presented by Ken Pryor
6	**Panel Discussion**	30 minutes (11:30 – 12:00)
	Supplemental Slides • Validation plots not presented in the review • JERD Requirements and mapping with slide numbers	

VALIDATED MATURITY REVIEW MATERIAL

NUCAPS Algorithm

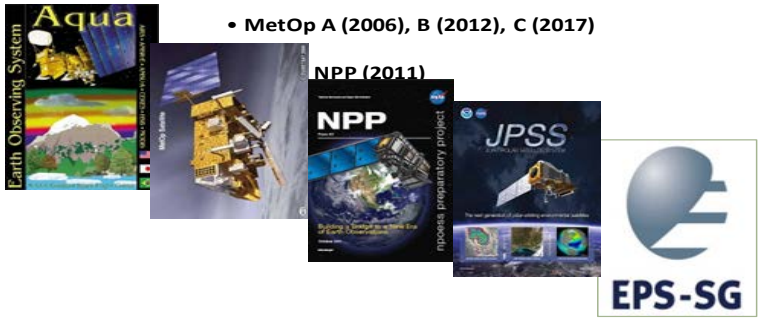




- **I. A microwave retrieval module** which computes Temperature, water vapor and cloud liquid water (Rosenkranz, 2000)
- **II. A fast eigenvector regression** retrieval that is trained against ECMWF and all sky radiances which computes temperature and water vapor (Goldberg et al., 2003)
- **III. A cloud 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 – Enterprise Operational Algorithm for Atmospheric T(p), q(p), and Trace Gas Products.
- Developed by STAR by adapting AIRS Science Team Methodology (Susskind, Barnet, and Blaisdell, IEEE 2003).

- Aqua (2002)
- MetOp A (2006), B (2012), C (2017)
- NPP (2011)



NUCAPS Products and Current Maturity Status

In AWIPS

Experimental Viable Products

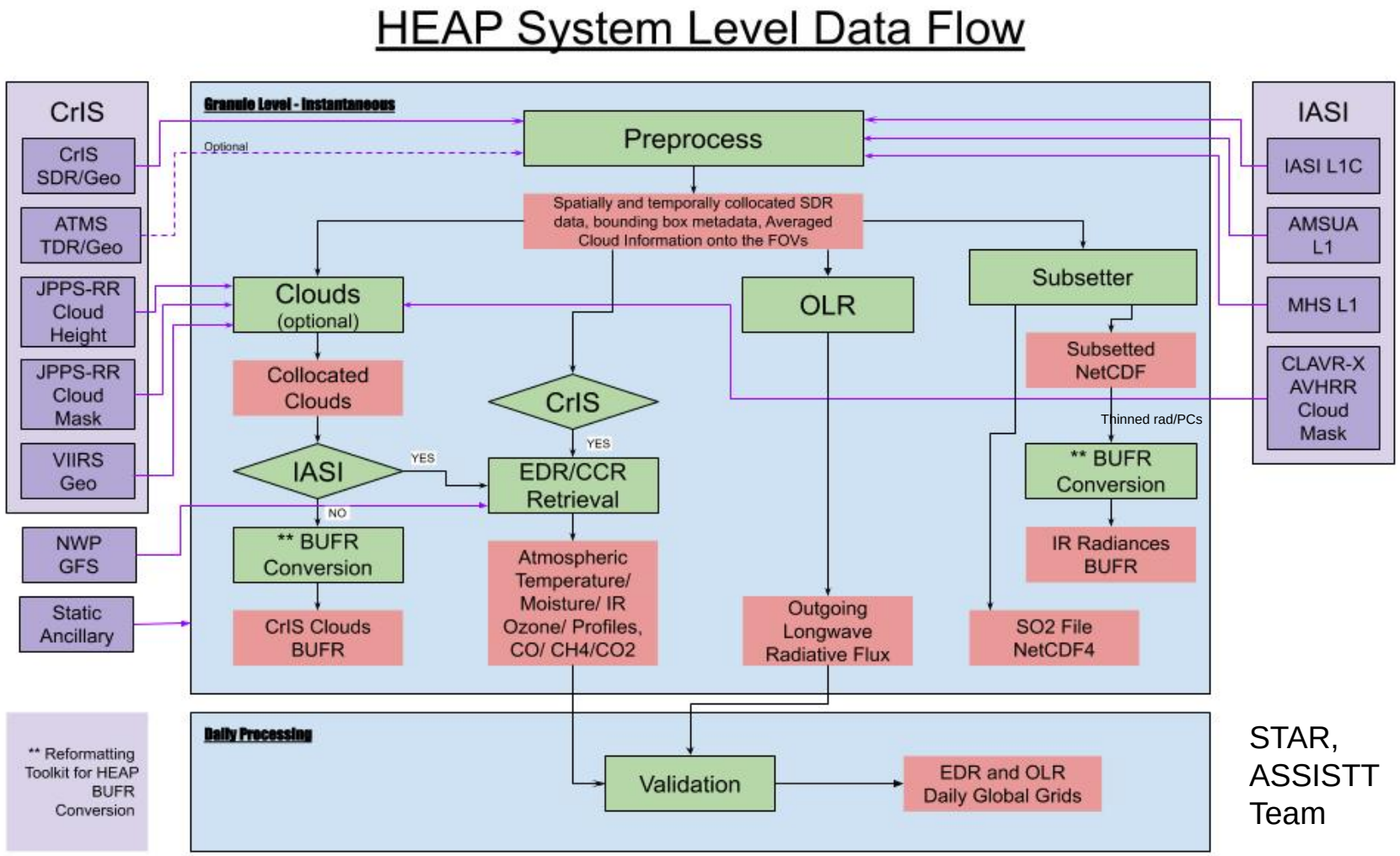
NUCAPS Products
Cloud Cleared Radiances
Atmospheric Vertical Temperature Profile (AVTP)
Atmospheric Vertical Moisture Profile (AVMP)
Cloud Fraction and Top Pressure
Ozone
CO
CH_4
CO_2
Volcanic SO_2
HNO_3
N_2O
NH3
Isoprene
PAN

Sensor	Data Product	Priority	S-NPP		NOAA-20	
			Operational	Maturity	Operational	Maturity
CrIS/ATMS	AVTP (p)	3	✓	Validated	✓	Provisional
CrIS/ATMS	AVMP (p)	3	✓	Validated	✓	Provisional
CrIS/ATMS	O3(p)	3	✓	Validated	✓	Provisional
CrIS	OLR	3	✓	Validated	✓	Provisional
CrIS/ATMS	CO (p)	4	✓	Provisional	✓	Provisional
CrIS/ATMS	CO2 (p)	4	✓	Beta	✓	Beta
CrIS/ATMS	CH4 (p)	4	✓	Beta	✓	Beta

SNPP/NOAA-20 Maturity Review October 24, 2019

- **Validated** Maturity for **NOAA-20**
  - NUCAPS AVTP, AVMP, Ozone, and OLR
- **Validated** Maturity for **SNPP & NOAA-20**
  - NUCAPS **CO**
- **Provisional** Maturity for **SNPP & NOAA-20**
  - NUCAPS **CH4**

Hyper-Spectral Data Processing at NDE/OSPO



STAR, ASSISTT Team

The HEAP provides the pre and post-processing capability for NUCAPS to operationally generate retrieval products from SNPP/NOAA-20 CrIS/ATMS and Metop-A/B IASI/AMSU-A/MHS. The HEAP contains

1) The NUCAPS retrieved products
2) Principal Components
3) OLR
4) Thinned radiance preparation
5) Daily grid generation
6) BUFR product file containing CrIS FSR (2211 channels) and IASI (8461 channels), collocated VIIRS cloud height and cloud fraction, thinned radiances CrIS FSR: 431 channel radiances; IASI: 616 channel radiances; CrIS collocated VIIRS cloud height and cloud fraction.
7) PC reconstruction scores for OSPO product monitoring/quality control tool.

- HEAP is the Delivered Algorithm Package (DAP) to NDE/OSPO for NUCAPS operational products from JPSS CrIS (SNPP/NOAA-20) as well as MetOp series IASI data (MetOp-A, B, C)

Algorithm Team Members

Name	Organization	Major Task
Satya Kalluri, Ken Pryor, Walter Wolf, and Lihang Zhou	NOAA/NESDIS/STAR	Lead budget/schedule planning/coordination. Provide government oversight for soundings ca/val activities, documentations, deliveries
Murty Divakarla	IMSG at NOAA/NESDIS/STAR	NUCAPS Science/Technical lead
Nick Nalli	IMSG at NOAA/NESDIS/STAR	NUCAPS Validation lead
Changyi Tan	IMSG at NOAA/NESDIS/STAR	Algorithm development, integration, and maintenance
Mike Wilson	IMSG at NOAA/NESDIS/STAR	STAR-ASSISTT POC for Unified NUCAPS package optimization
Tianyuan Wang	IMSG at NOAA/NESDIS/STAR	Algorithm development and maintenance
Tong Zhu	IMSG at NOAA/NESDIS/STAR	Algorithm development and maintenance
Juying Warner	Univ. of Maryland College Park	Trace Gases algorithm(s) development
Chris Barnet, Nadia Smith, Rebekah Esmaili	STC	Algorithm development, CAMEL emissivity, user feedback via PGRR initiatives
Tony Reale, Bomin Sun, Mike Pettey	STAR, IMSG at STAR	NUCAPS vs. Global RAOB Validations
Larrabee Strow	UMBC	IR SARTA model development and maintenance
Lori Borg	Univ. of Wisconsin	ARM Site RAOBs dedicated launches
Robert Knuteson	Univ. of Wisconsin	Surface Emissivity collaborator
Xu Liu	NASA/LaRC	NUCAPS product independent assessment, single CrIS FOV retrieval algorithm development
A.K. Sharma	NOAA/OSPO	Product Area Lead (PAL)

JPSS Data Products Maturity Definition

1. Beta

- Product is minimally validated, and may still contain significant identified and unidentified errors.
- Information/data from validation efforts can be used to make initial qualitative or very limited quantitative assessments regarding product fitness-for-purpose.
- Documentation of product performance and identified product performance anomalies, including recommended remediation strategies, exists.

2. Provisional

- Product performance has been demonstrated through analysis of a large, but still limited (i.e., not necessarily globally or seasonally representative) number of independent measurements obtained from selected locations, time periods, or field campaign efforts.
- Product analyses are sufficient for qualitative, and limited quantitative, determination of product fitness-for-purpose.
- Documentation of product performance, testing involving product fixes, identified product performance anomalies, including recommended remediation strategies, exists.
- Product is recommended for potential operational use (user decision) and in scientific publications after consulting product status documents.

3. Validated

- Product performance has been demonstrated over a large and wide range of representative conditions (i.e., global, seasonal).
- Comprehensive documentation of product performance exists that includes all known product anomalies and their recommended remediation strategies for a full range of retrieval conditions and severity level.
- Product analyses are sufficient for full qualitative and quantitative determination of product fitness-for-purpose.
- Product is ready for operational use based on documented validation findings and user feedback.
- Product validation, quality assurance, and algorithm stewardship continue through the lifetime of the instrument.

Validated Maturity Review - Entry Criteria

- Product Requirements **(presented with each EDR)**
- Pre-launch Performance Matrix/Waivers **(None)**
- Validated Maturity Performance Validation
  - On-orbit instrument performance assessment
    - Identify all of the instrument and product characteristics you have verified/validated as individual bullets **(presented with each EDR)**
    - Identify pre-launch concerns/waivers, mitigation and evaluation attempts with on-orbit data **(None)**
- Users/EDRs feedback
- Risks, Actions, Mitigations
  - Potential issues, concerns
- Path forward
- Summary

Validated Maturity Review - Exit Criteria

- Validated Maturity Performance is well characterized and meets/exceeds the requirements:
  - On-orbit instrument performance assessment
    - Provide summary for each identified instrument and product characteristic you have validated/verified as part of the entry criteria **(presented with each EDR)**
    - Provide summary of pre-launch concerns/waivers/mitigations/evaluation and address whether any of them are still a concern that raises any risk. **(None)**
- Updated Validated Maturity Slide Package addressing review committee's comments for:
  - Cal/Val Plan and Schedules
  - Product Requirements
  - Validated Maturity Performance
  - Risks, Actions, Mitigations
  - Path forward

Processing Environment, Algorithm Versions

- NUCAPS current operational algorithm for SNPP and NOAA-20 at NDE
  - Version V2.1.12d, delivered on 2018/08/15.

- V2.5.2.2 is the optimized NUCAPS algorithm
  - Results presented in this Maturity Review are from V2.5.2.2 candidate version for operational implementation.
  - All static ancillary files needed by algorithm are contained within the Delivered Algorithm Package (DAP).
  - Recently delivered V2.5.2.2 to ASSISTT team for cluster integration and parallel runs to produce SNPP/NOAA-20 NUCAPS products, that we used as part of evaluating V2.5.2.2
  - V2.5.2.2 DAP delivery is in plan after the maturity review.

- Validation of NUCAPS products conducted in STAR:
  - Linux servers running f90, IDL, bash, C/C++, libraries (hdf5 and netCDF4)
  - NUCAPS team performs product validation through a variety of validation data sets
  - Once operationalized, NUCAPS products available through STAR SCDR are used as part of regular evaluation. The JSTAR Mapper and JSTAR LTM websites provide visualization of the products produced.
  - We also leverage NPROVS system for NUCAPS operational product evaluations

NUCAPS Retrieval Algorithm Deliveries to OPS.

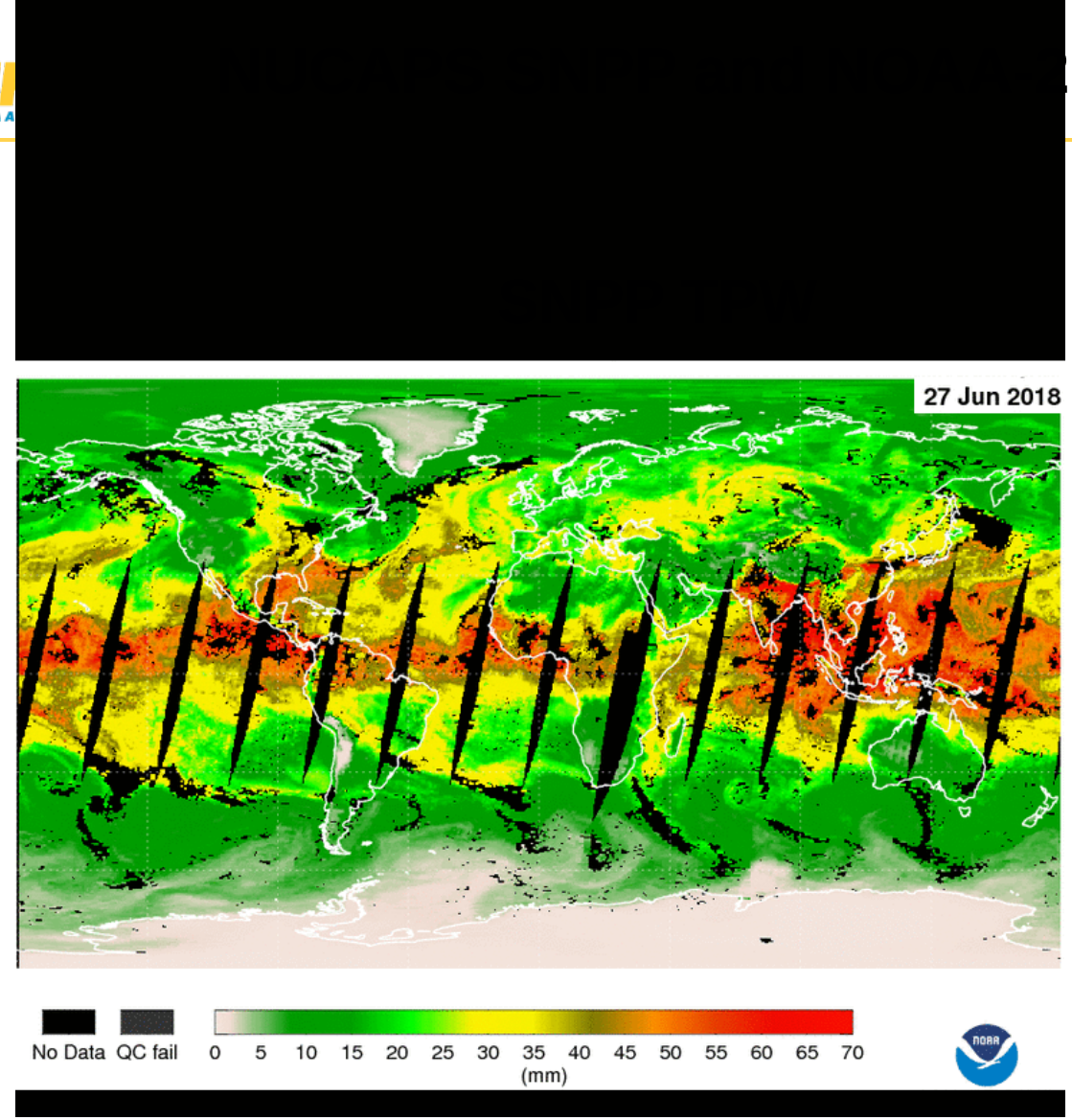
Internal Version	OPS Phase	Approximate Delivery / Start Time	Comments
NUCAPS V1.0	Phase 2	Delivered December 3, 2012. Became Operational in October 2013	Designed for only S-NPP nominal spectral resolution.
NUCAPS V1.5	Phase 3	Delivered May 12, 2015. Became Operational in October 2015.	Maturity update for S-NPP AVTP/AVMP Converted to GNU compilers.
NUCAPS V2.0.5.4	Phase 4	Delivered July 20, 2017. Part 1 Operational: Sept. 13, 2017. Part II Operational on May 03, 2018.	Updated to CrIS Full Spectral resolution. (NUCAPS v1r0 became v2r0 in NOAA CLASS) Can run NOAA-20 using S-NPP Namelists. Included updates to several LUTs and Namelists (channel selection, tuning, regression, trace gas climatology, etc.).
NUCAPS V2.1.12d	V4.3	Delivered August 15, 2018. NOAA-20 became Operational on March 7, 2019.	Trace gas updates (CO retrieval, tuning in N2O region). Added new LUTs to differentiate S-NPP/NOAA-20 (e.g. instrument noise)

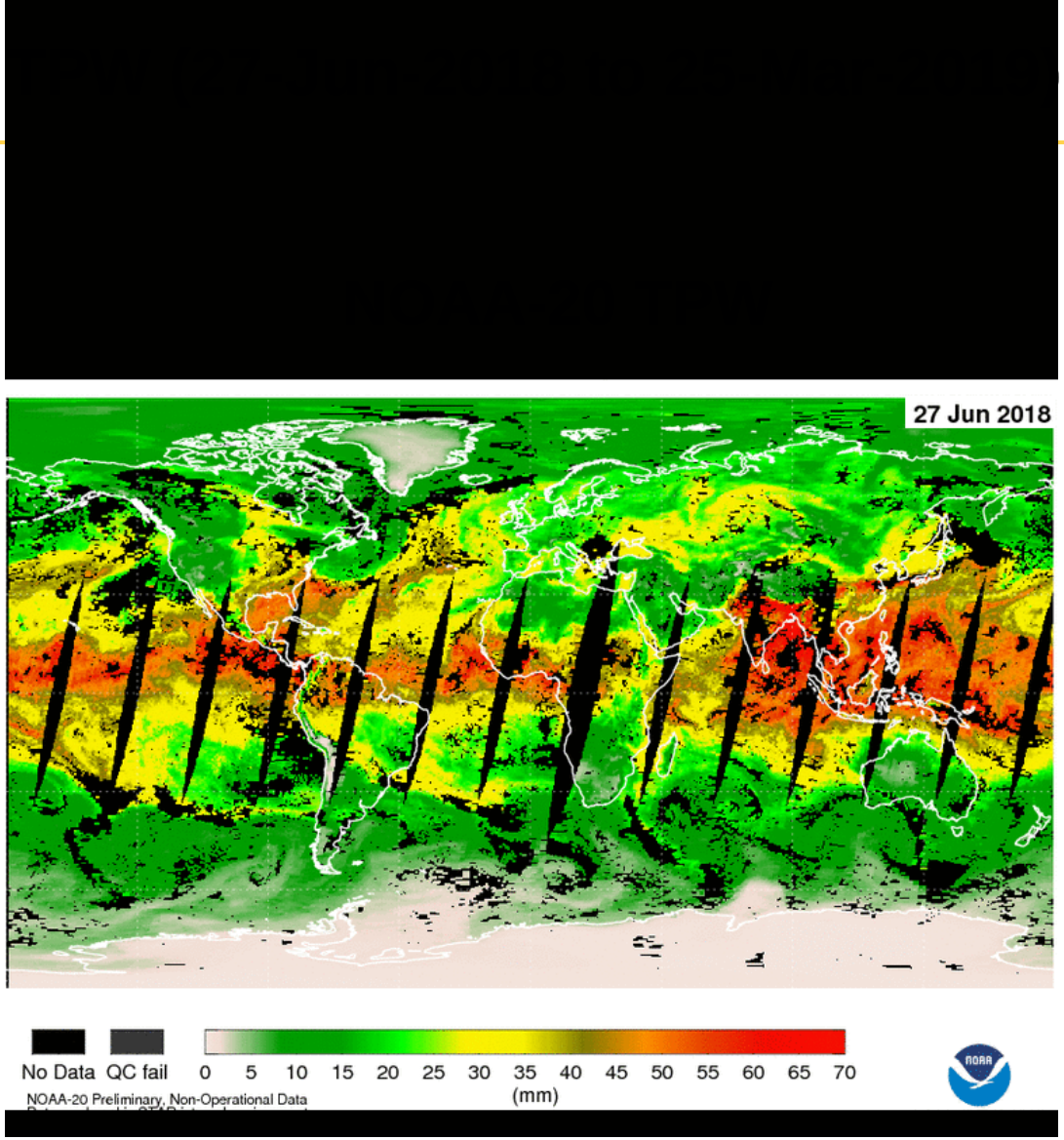
Algorithm performance to specification requirements

- V2.5.2.2 is the current operational DAP. Validation results shown here reflect V2.5.2.2.
- Cal/Val activities for NUCAPS algorithm performance:

Product	Maturity Level			
	SNPP		NOAA-20	
	Current Status	Maturity Level **Aimed**	Current Status	Maturity Level Aimed
NOAA-20 AVTP/AVMP	✓ Validated	✓ Remain Validated	✓ Provisional	❑ Validated
NOAA-20 Ozone	✓ Validated	✓ Remain Validated	✓ Provisional	❑ Validated
NOAA-20 OLR	✓ Validated	✓ Remain Validated	✓ Provisional	❑ Validated
SNPP and NOAA-20 CO	✓ Provisional	❑ Validated	✓ Provisional	❑ Validated
SNPP and NOAA-20 CH4	✓ Beta	❑ Provisional	✓ Beta	❑ Provisional
SNPP and NOAA-20 CO2	✓ Beta	✓ Remain Beta	✓ Beta	✓ Remain Beta

Milestones	Original Date	Forecast Date
NOAA-20 Calibration/Validation		
Validated Maturity: CH4 (SNPP & NOAA-20)	Feb-20	Feb-20
Provisional Maturity: CO2 (SNPP & NOAA-20)	Feb-20	Feb-20
Validated Maturity: CO2 (SNPP & NOAA-20)	Dec-20	FY21



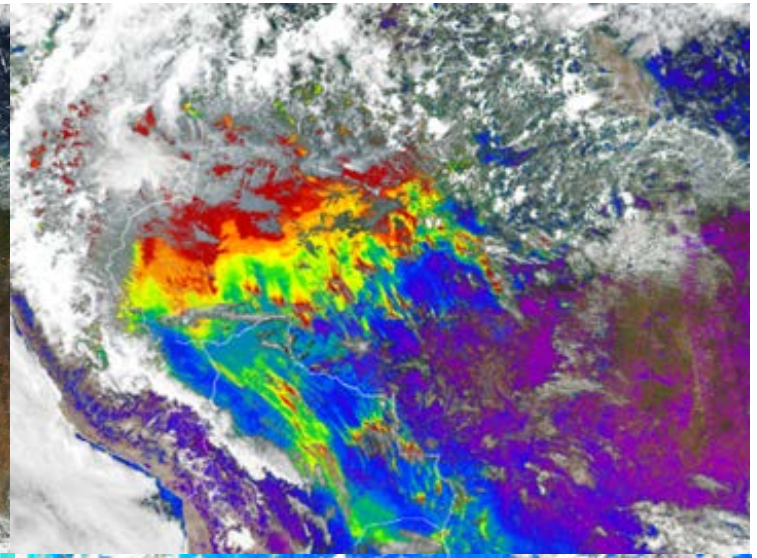


SNPP/NOAA-20 NUCAPS Operational Products (27-Jun-2018 to 25-Mar-2019) Seasonal Evaluations/Visualization (see supplemental slides (Temperature, water vapor, ozone, etc.)
Source: **https://www.star.nesdis.noaa.gov/jpss/EDRs/index.php)**

SNPP Monitoring Amazon Fire 20190814

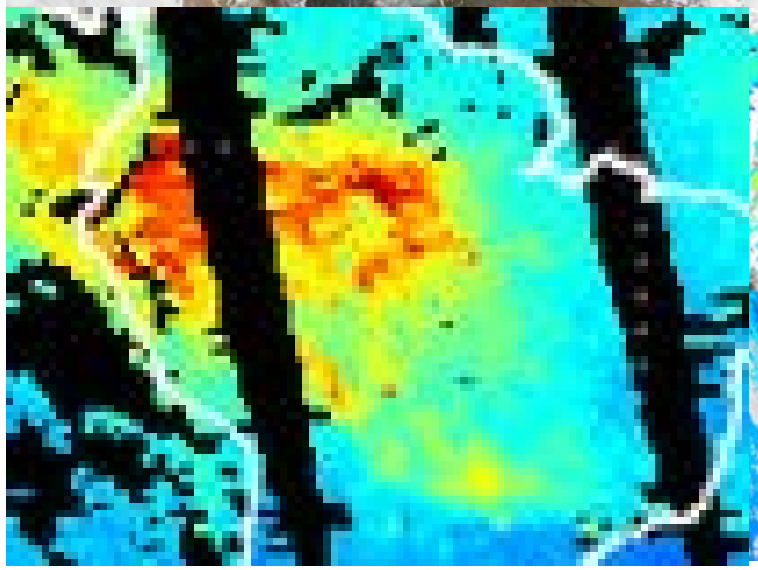
https://www.star.nesdis.noaa.gov/jpss/mapper

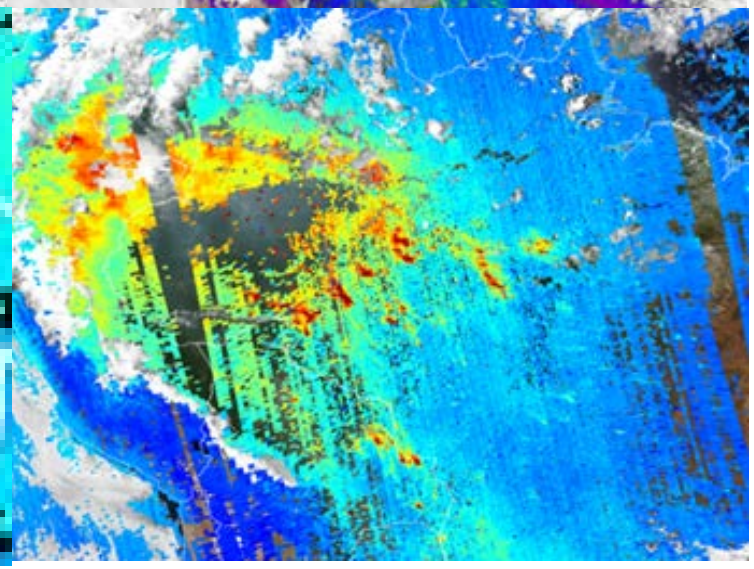
SNPP VIIRS Active Fire



SNPP VIIRS AOD at 550 nm

SNPP NUCAPS CO at 500 hPa



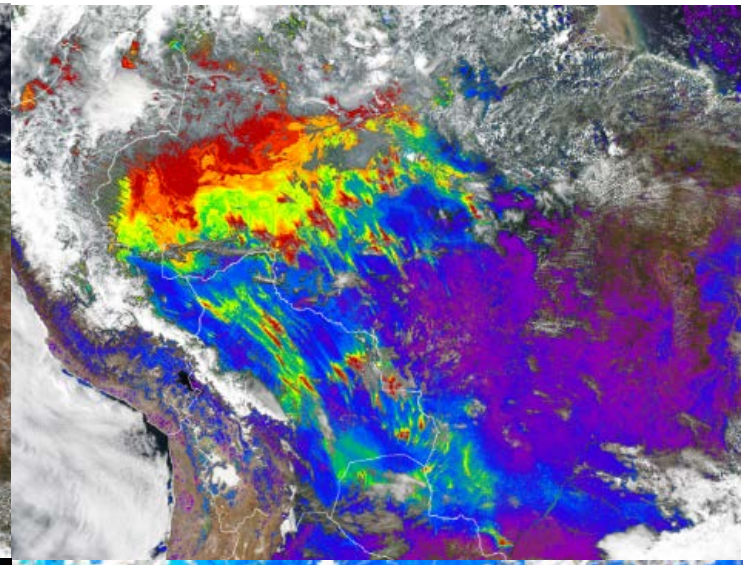


TROPOMI CO total column

NOAA-20 Monitoring Amazon Fire 20190814

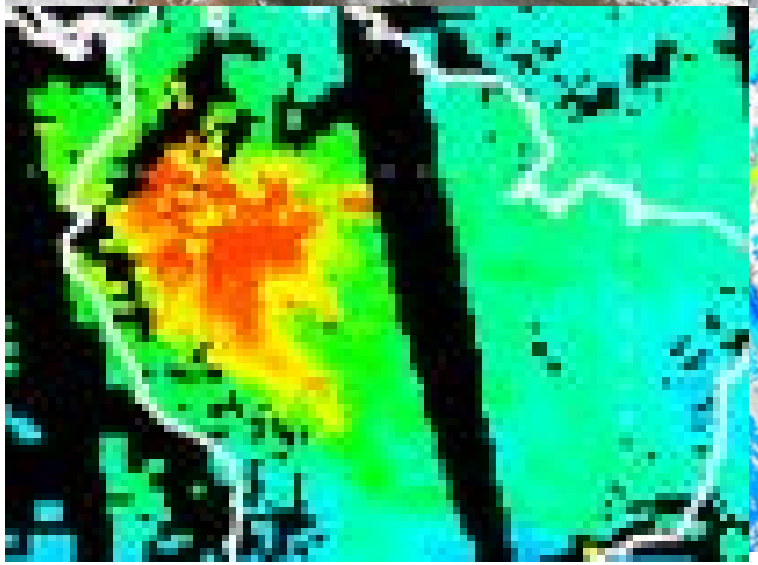
https://www.star.nesdis.noaa.gov/jpss/mapper

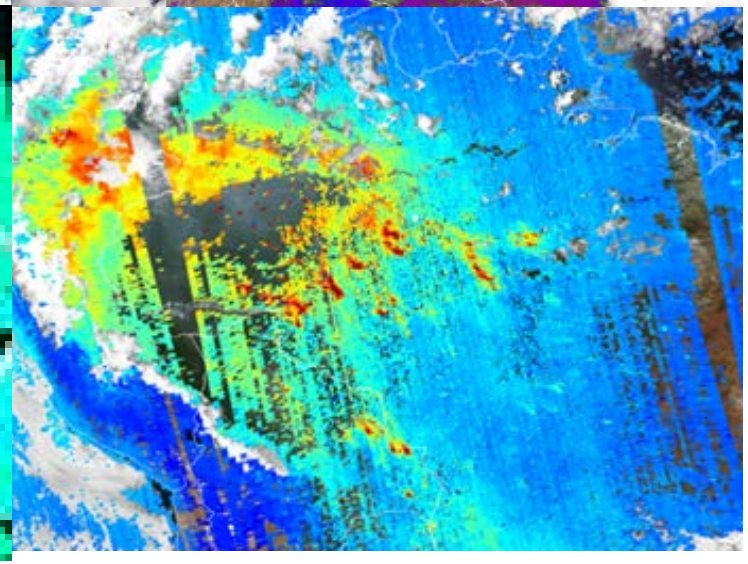
NOAA-20 VIIRS
Active Fire



NOAA-20
VIIRS
AOD at 550
nm

NOAA-20
NUCAPS CO
at 500 hPa



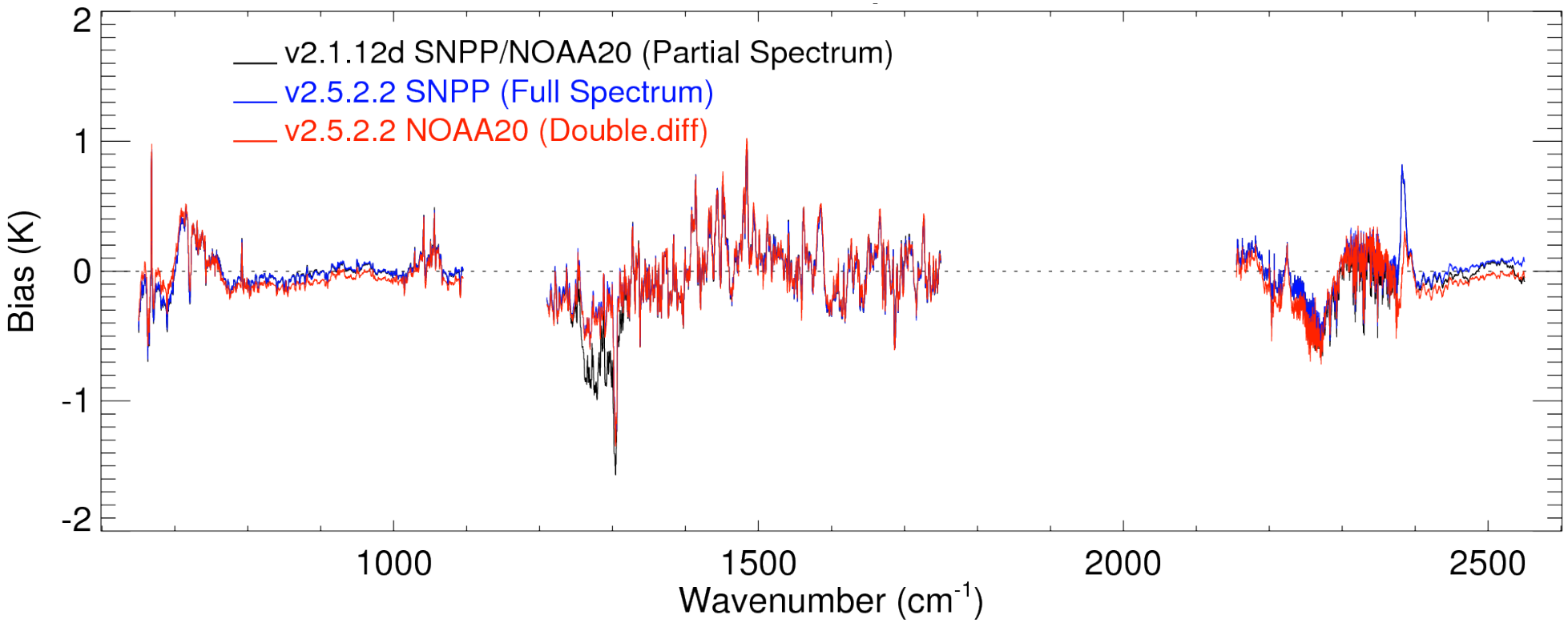


TROPOMI
CO total column

Primary changes in V2.5.2.2 vs. current operational algorithm (V2.1.12d)

Item	Current Operational Version V2.1.12d		Candidate Operational Version V2.5.2.2	
	SNPP	NOAA-20	SNPP	NOAA-20
MW Tuning	✓ Four Focus Days used for MW tuning (20150115, 20150415, 20150715, 20151015) and MIT forward model.	✓ Same as used for SNPP	✓ Two focus days (20190215, 20190815) and SNPP radiances, and MIT forward model.	✓ Two focus days (20190215, 20190815) NOAA-20 radiances and MIT forward model.
Cloudy Regression	✓ PC regression using SNPP all-sky radiances matched with ECMWF ✓ Used four Focus Days (20150115, 20150415, 20150715, 20151015)	✓ Same as used for SNPP	✓ NO Change from the Operational Version	✓ PC regression using NOAA-20 all-sky radiances matched with ECMWF ✓ Used four Focus Days (20180415, 20180715, 20181015, 20190115)
Clear Regression	✓ PC regression using SNPP CCR radiances matched with ECMWF ✓ (20150115, 20150415, 20150715, 20151015)	✓ Same as used for SNPP	✓ NO change from the Operational version	✓ PC regression using NOAA-20 CCR radiances matched with ECMWF ✓ Used four Focus Days (20180415, 20180715, 20181015, 20190115)
Emissivity Regression	✓ Regression using Seebor 5.0 data base and SNPP synthetic radiances	✓ Same as used for SNPP	✓ NO Change from the current operational version	✓ NO change from the current operational version
IR Tuning	✓ Partial tuning (major patch in the CH4 bands)" method using SNPP radiances and ECMWF SARTA simulations	✓ Same as used for SNPP	✓ "Full tuning" method using SNPP radiances and ECMWF SARTA simulations	✓ Double Difference Method using NOAA-20 radiances and ECMWF SARTA simulations.
CO climatology/QC	✓ Updated CO A-priori	✓ Same as used for SNPP	✓ NO Change from the current operational version	✓ NO Change from the current operational version
CH4/N2O A-priori	✓ Not Updated	✓ Same as used for SNPP	✓ Updated CH4/N2O A-priori	✓ Updated CH4/N2O A-priori
CrIS Noise File	✓ SNPP noise file provided by STAR CrIS SDR team	✓ NOAA-20 noise file provided by STAR CrIS SDR team	✓ NO Change from the current operational version	✓ NO Change from the current operational version
Channel Selection for cloud-clearing, T(p), q(p) (included)	✓ Yes	✓ Same as used for SNPP	✓ Minor updates of channels	✓ Minor updates of channels
Channels selection for trace gases	✓ Updated for CO, not CH4	✓ Same as used for SNPP	✓ NO Change from the current operational version	✓ NO Change from the current operational version

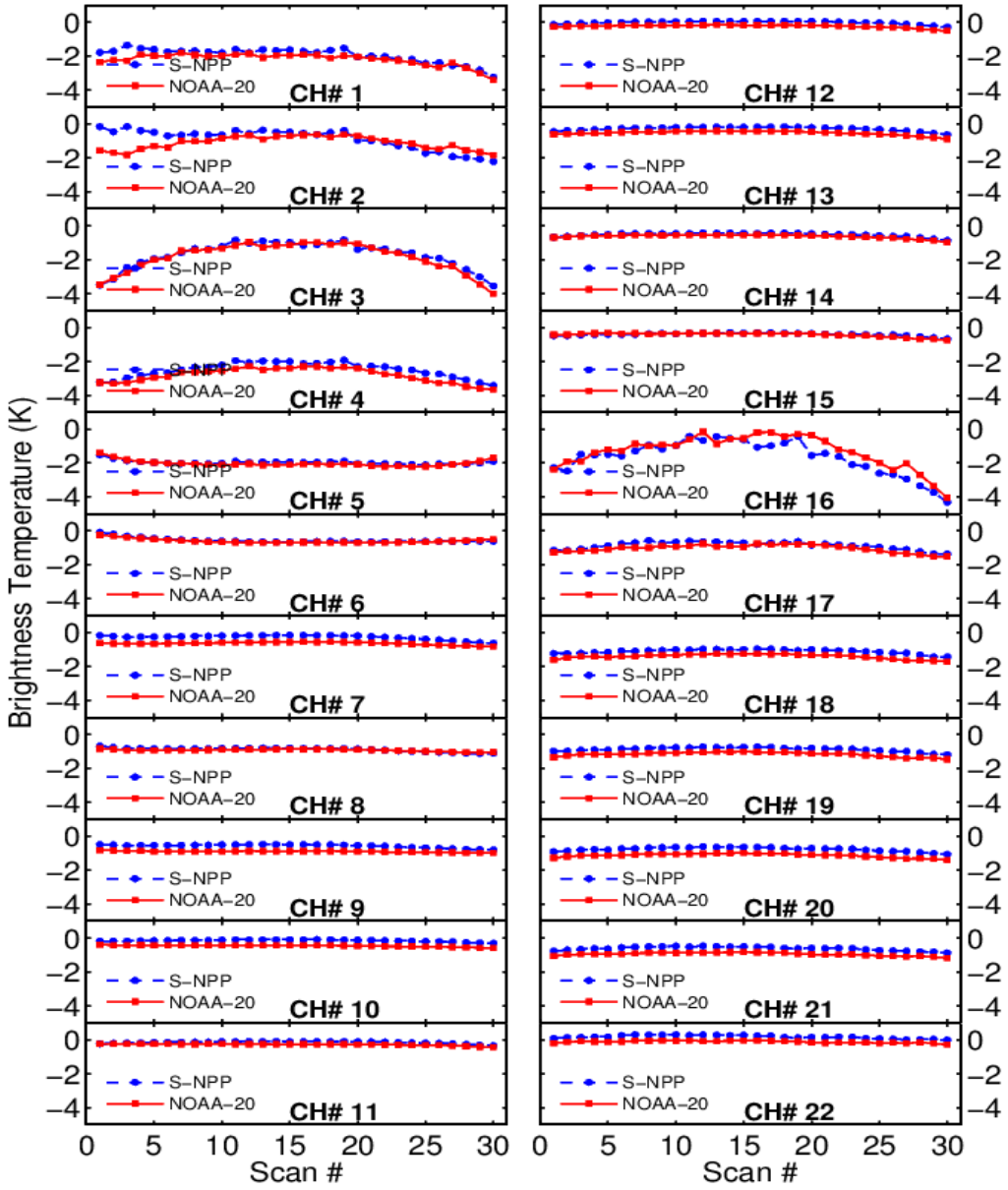
NUCAPS current and new IR Tuning for SNPP/NOAA-20



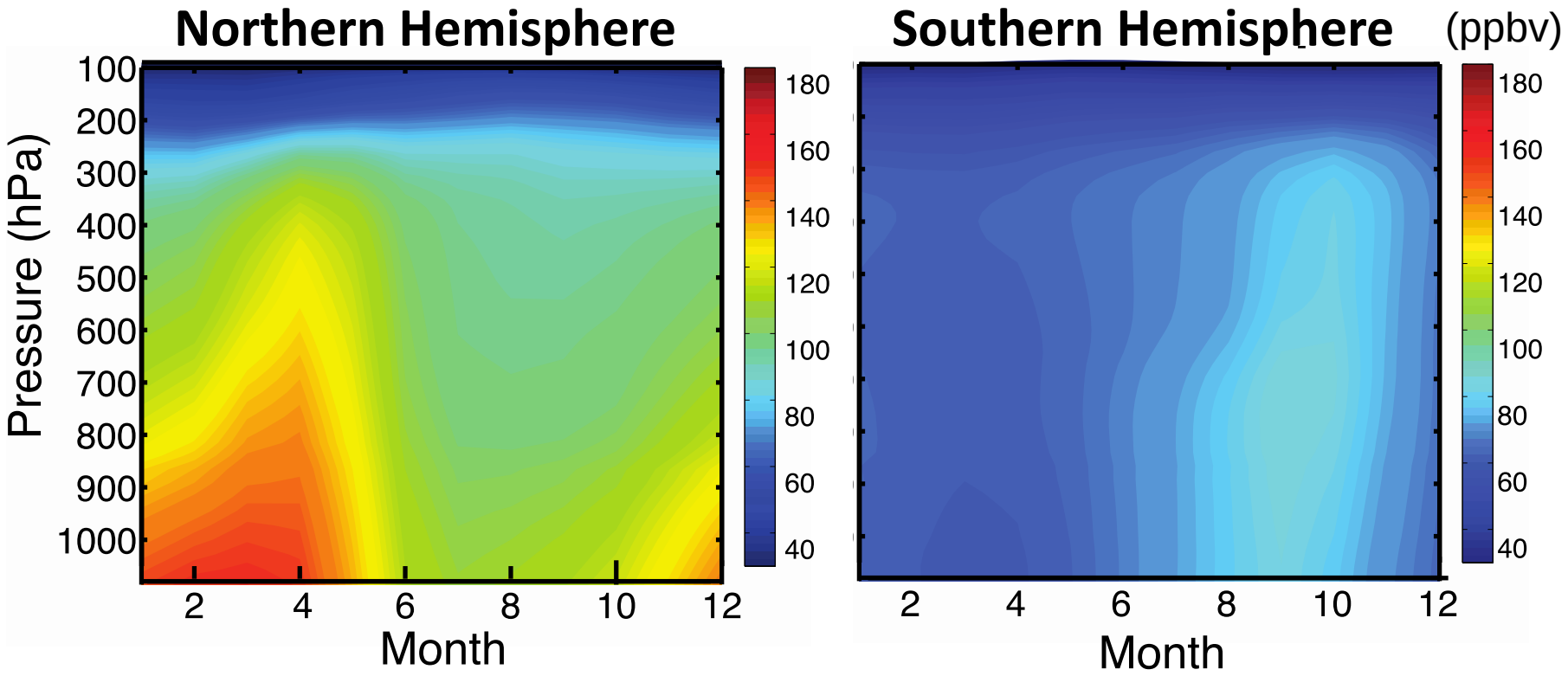
- Current IR Tuning is a combination of a 4-Focus-Day Tuning and an old tuning near 1200 – 1300 cm^{-1}, the CH_4 and N_2O absorption spectrum.
- The new SNPP IR tuning is a Full Spectrum Tuning created with 4-Focus-Day (in 2014,2015) for SNPP_CrIS sensor.
- The new NOAA-20 IR tuning is based on above Full-Tuning plus the double difference between NOAA-20 and SNPP.

MW Bias tuning for NOAA-20 (V2.5.2.2)

- In the operational version NOAA-20 has been using SNPP MW bias tuning. Consequently, operational NOAA-20 retrievals (v2.1.12d) has slightly larger bias than the SNPP operational product. This has necessitated the need for NOAA-20 MW bias tuning.
- V2.5.2.2 has NOAA-20 Bias tuning.
  - Two Focus Days (20190215, 20190815) , ocean only, non-frozen ±60°



SNPP & NOAA-20 NUCAPS CO *a priori* for Operational and V2.5.2.2



- Two hemispheric CO profiles (ppbv) developed from NCAR MOZART-GEOS5 model;
- Linearly transition between 15N and 15S;
- Monthly varying, but no year-to-year variations;
- Same approach as for AIRS, but updated to current values for NUCAPS.

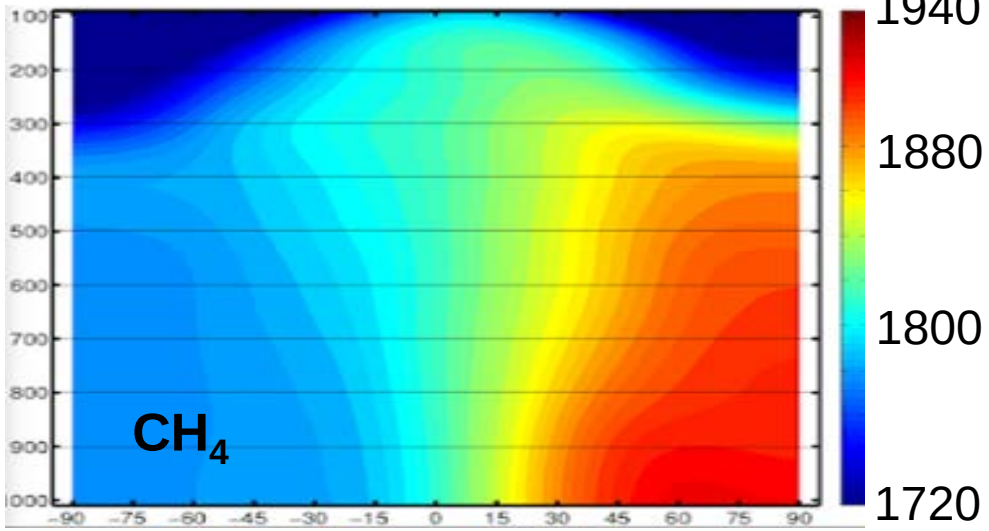
Contributed by: Juying Warner and Zigang Wei

CH_4 and N_2O *a priori* Improvements Towards CH_4 Provisional Maturity

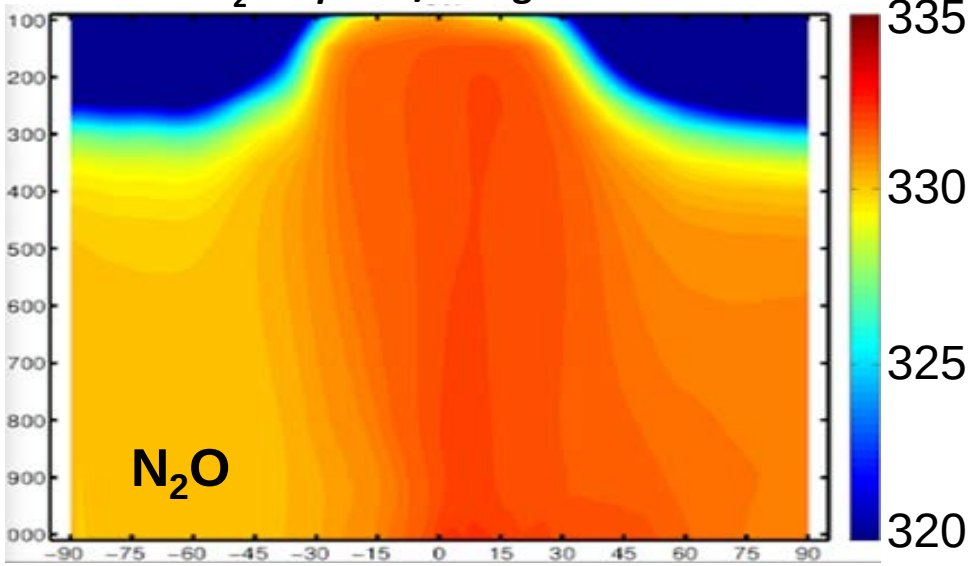
- Findings/Issues from Beta Review
  - The Beta versions were based on unrealistic *a priori* for CH_4;
  - The Beta versions used 1970's N_2O *a priori* values, which needed to be updated
- Improvements since Beta Review
  - Updated CH_4/N_2O *a priori*
    - N_2O AP are based on Chemistry Transport Model (CTM) from NASA/GSFC, with yearly change, so not for N_2O retrievals;
    - CH_4 AP are based on in situ measurement;
    - N_2O AP are used to improve CH_4 retrievals;
    - V2.5.2.2 validation include these upgrades
  - Improved CH_4 agreements with in situ and other satellite measurements
- Algorithm performance evaluation
  - Truth data sets
  - TROPOMI
  - AIRS

Contributed by: Juying Warner and Zigang Wei

CH_4 *a priori*/first guess (ppbv)



N_2O *a priori*/first guess

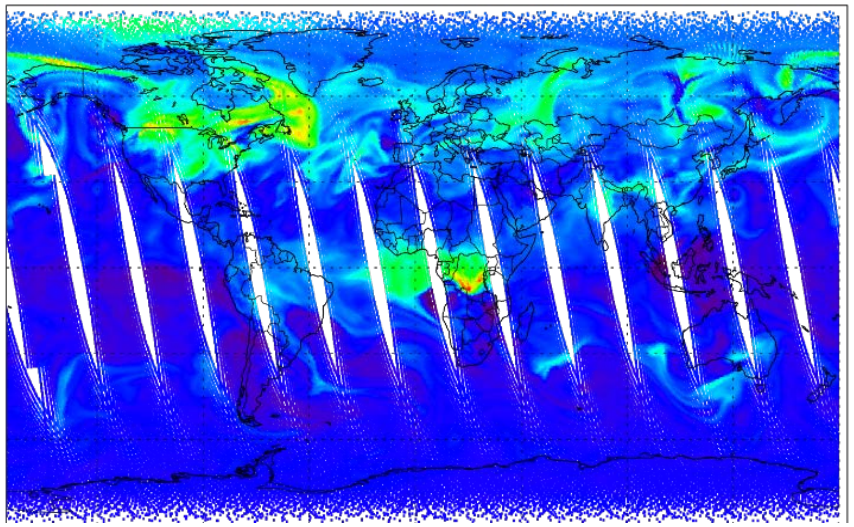


Evaluation of the effect of required algorithm inputs

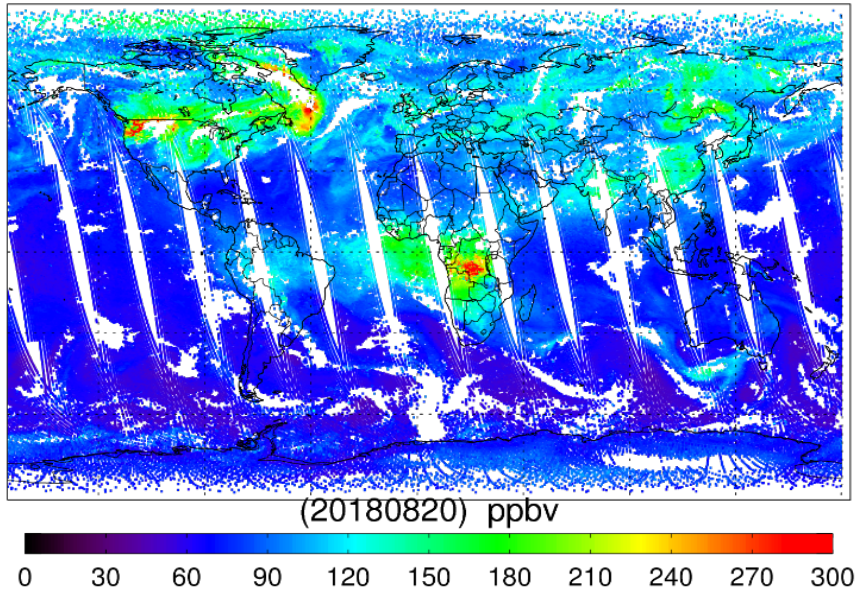
- Required Algorithm Inputs
  - Primary Sensor Data: NUCAPS requires (1) CrIS SDRs (2) ATMS TDRs, and (3) geolocation files for retrieval.
  - CrIS/ATMS sensor noise characteristics
  - MIT MW fast model for Microwave Retrievals.
  - All-sky and cloud-cleared PC regression coefficients (generated offline using focus day data sets)
  - Static tables/files needed for sarta radiative transfer algorithm:
    - These are provided by UMBC->STC->STAR
  - MW and IR bias-tuning LUTs
  - Ancillary Data: GFS (0.5 deg) data to provide surface pressure as initial boundary condition (not validated in this review)
  - *A priori* for O_3, CO, CH_4, CO_2, and other trace gases
- Upstream algorithms: None (if/when TDR/SDR processing changes, we evaluate impacts and update MW and IR bias tuning/corrections if needed)
- Evaluation of the effect of required algorithm inputs
  - Input static LUTs are all verified. Only dynamic inputs are in the TDR/SDR/GEO data.

Algorithm performance to specification requirements

- Cal/Val activities for NUCAPS algorithm performance (V2.5.2.2):
  - We follow a hierarchy of validation (models, correlative data sets, truth measurements, RAOBs, etc.) as discussed in the later portions of this presentation
  - In addition to truth measurements, ECMWF, we added Copernicus Atmospheric Monitoring Service (CAMS) Trace Gas Data set for trace gas evaluations as well as future IR bias-tuning exercises.
  - Validation of each EDR product is presented in the subsequent sections.
- Feedback from external users and the PGRR initiatives help to tailor NUCAPS product improvements, and future plans of NUCAPS product improvements/developments.



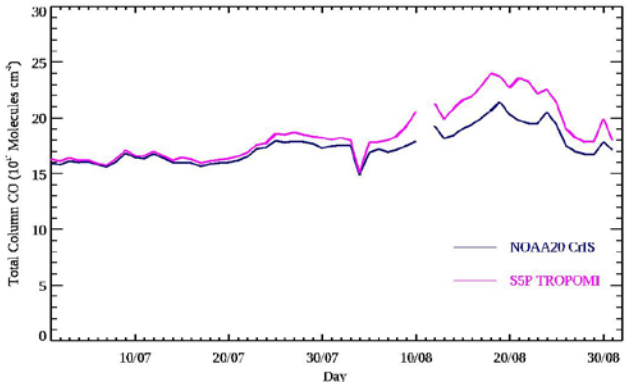
CAMS CO at 506 hPa 08/20/2018

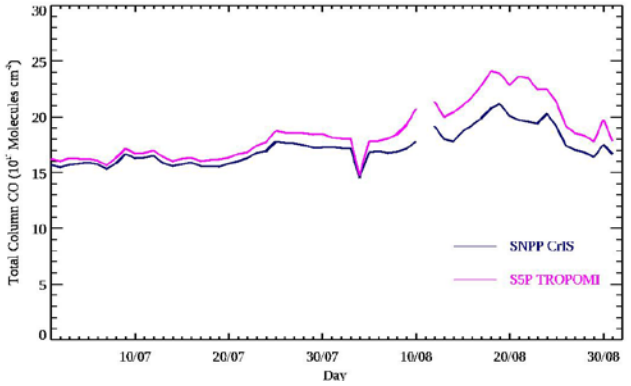


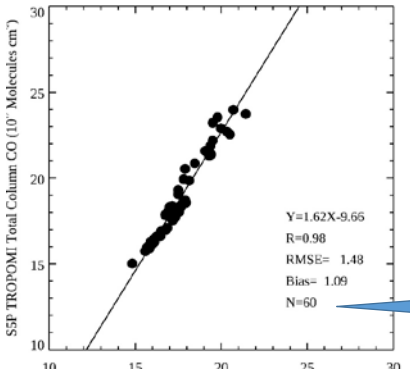
NUCAPS NOAA-20 CO at 506 hPa 08/20/2018

TROPOMI as Another Source of Evaluation for NUCAPS Trace Gases

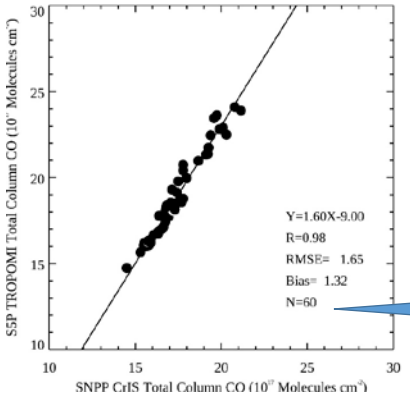
- Cal/Val activities for NUCAPS algorithm performance (V2.5.2.2):
  - Two months of SNPP/NOAA-20 data (July and August 2018) reprocessed with the NUCAPS candidate version 2.5.2.2
  - Used TROPOMI as another source of evaluation for NUCAPS
  - Shobha Kondragunta's presentation at Joint Satellite Conference (September 29th – October 4, 2019, Boston)
  - More results in subsequent validation sessions.



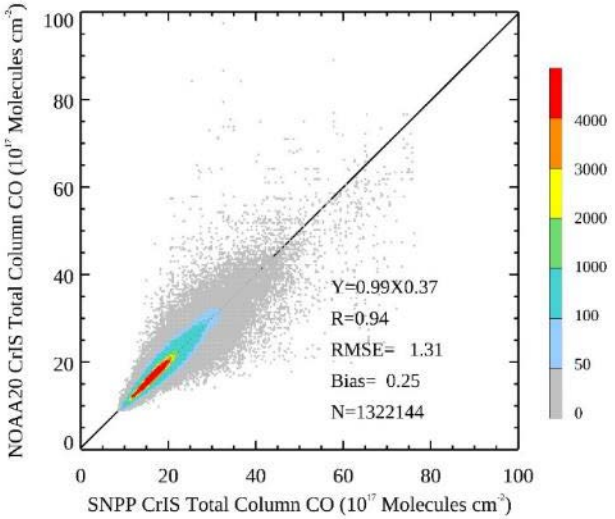


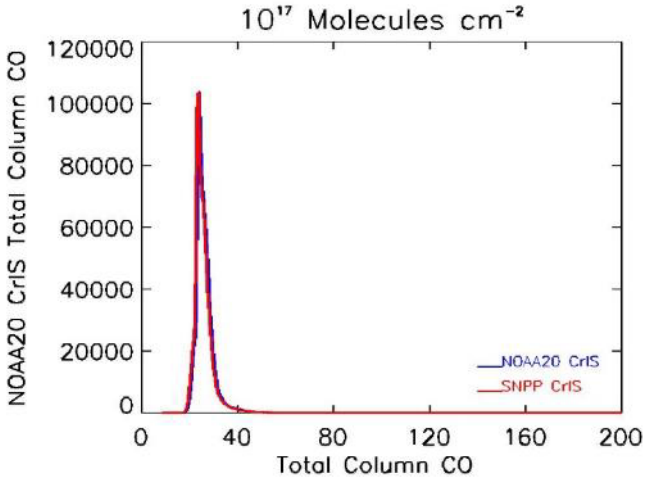


Two months



Two months





More than a million matched observations between NOAA-20 and SNPP CrIS CO. Both products show similar distribution with a mean bias of 0.25 x 10^{17} molecules/cm^2)

Quality flag Analysis/Validation

- NUCAPS Quality Flags
- In the EDR file, there is a variable called 'Quality_Flag.' Values in this field correspond to the chart below.
- Normally sufficient to utilize top level QC flag, along with geophysical situation for filtering

EDR Quality Flag	Meaning
0 (Blue)	*Clear Sky/Partly Clear Conditions* Successful infrared (IR) + microwave (MW) NUCAPS retrieval.
1 (Yellow)	*Cloudy Conditions* *Failed IR+MW retrieval. Successful MW-only retrieval*
9 (Red)	*Precipitating Conditions* *Failed IR+MW retrieval. Failed MW-only retrieval*
17 (Yellow) NOTE: RARE	*Cloudy Conditions* *Failed IR+MW retrieval via NOAA IR retrieval.* *Successful MW-only retrieval*
25 (Red) NOTE: RARE	*Precipitating Conditions* *Failed IR+MW retrieval via NOAA IR retrieval.* *Failed MW-only retrieval*

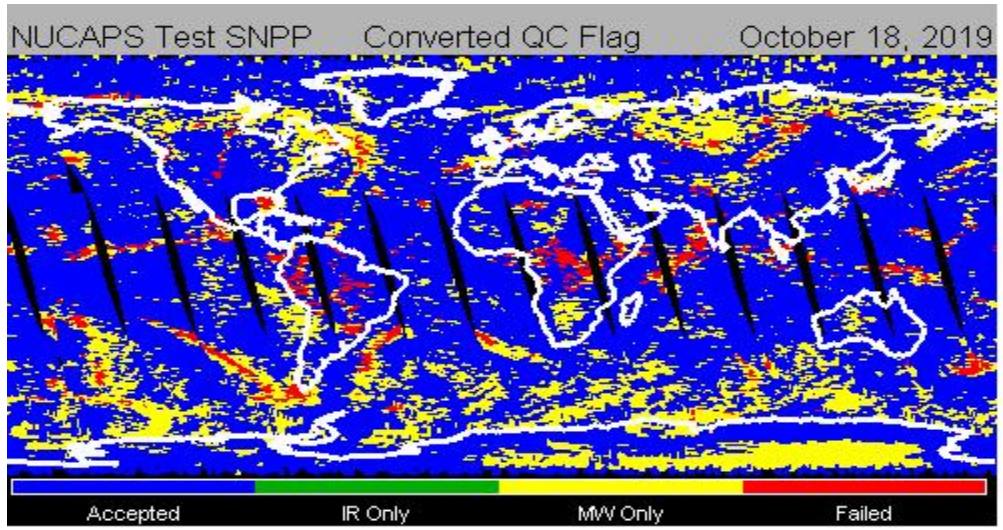
NPROVS Team provided quality flag analysis/validation

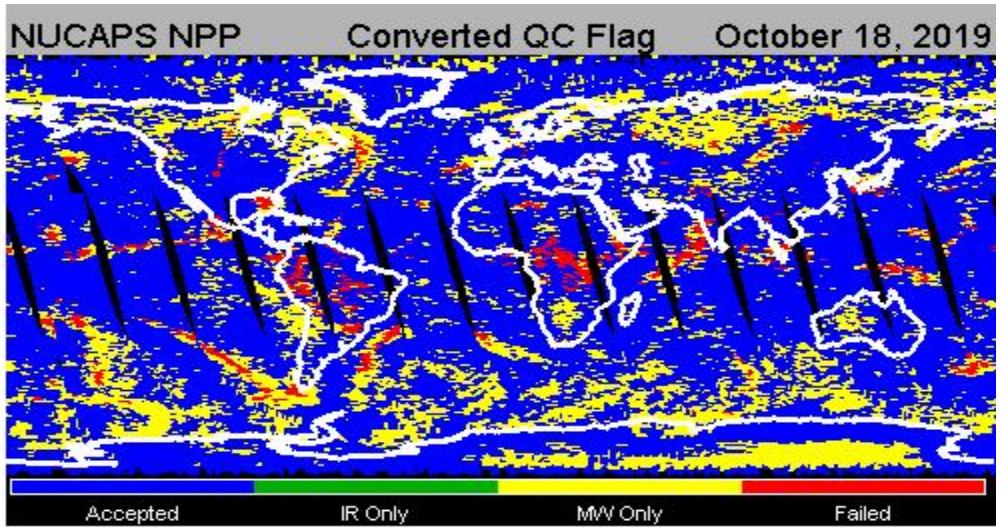
Quality Flags from NPROVS System (Ascending)

October 18 2019

NPP Test v2.5.2.2

IR+MW: 76%
MW-only: 21%



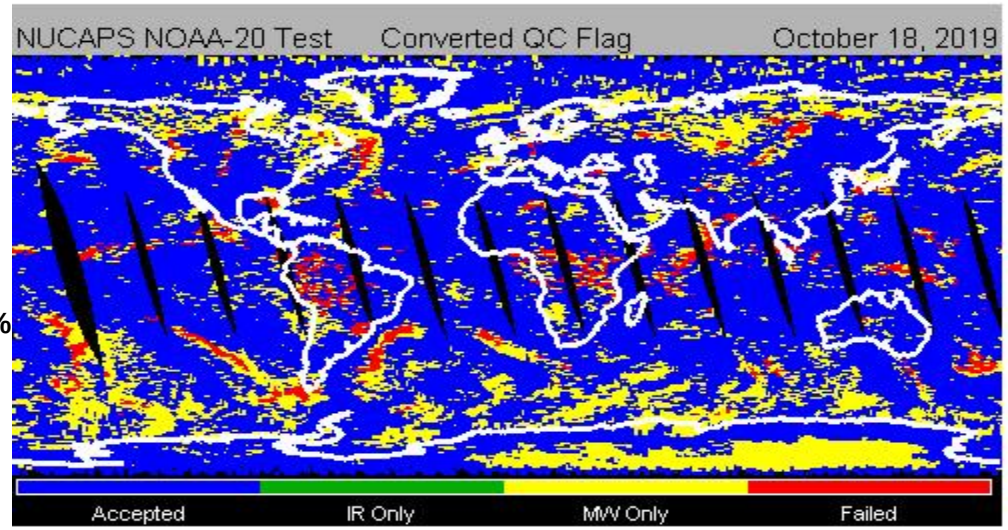


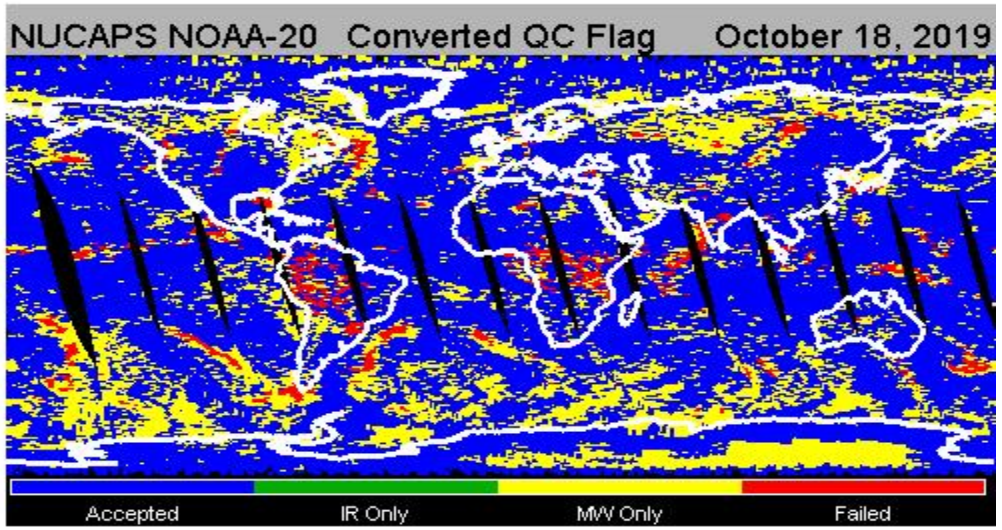
NPP Oper v2.1.12c

IR+MW: 75%
MW-only: 22%

N-20 Test v2.5.2.2

IR+MW: 76%
MW-only: 21%





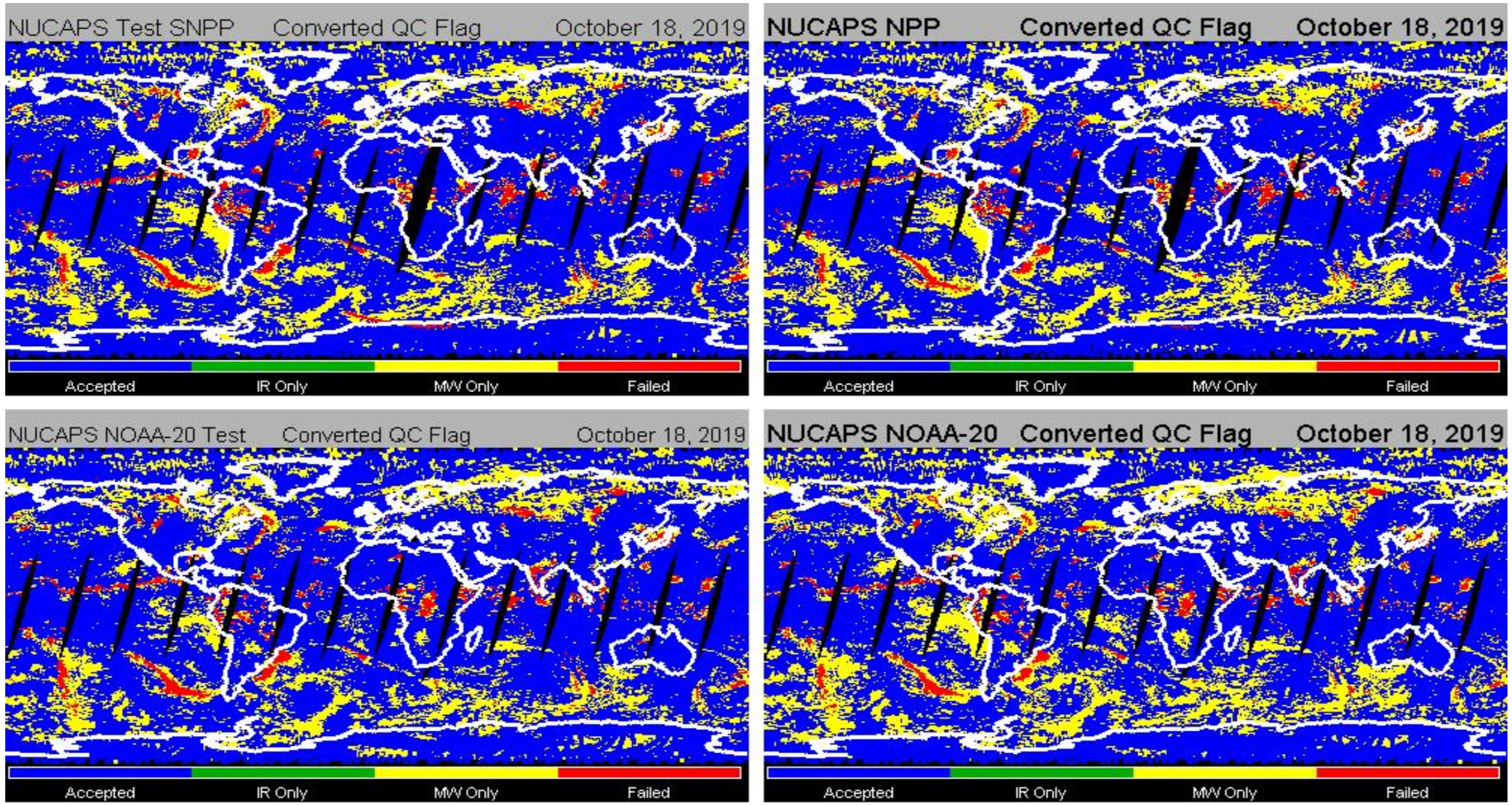
N-20 Oper v2.1.12c

IR+MW: 72%
MW-only: 25%

IR+MW pass (Blue), MW-only pass (Yellow) and Both fail (Red)

Quality Flags from NPROVS System (Descending)

October 18 2019



IR+MW pass (Blue), MW-only pass (Yellow) and Both fail (Red)

Retrieved 695 mb Temperature from NPROVS System (Ascending)

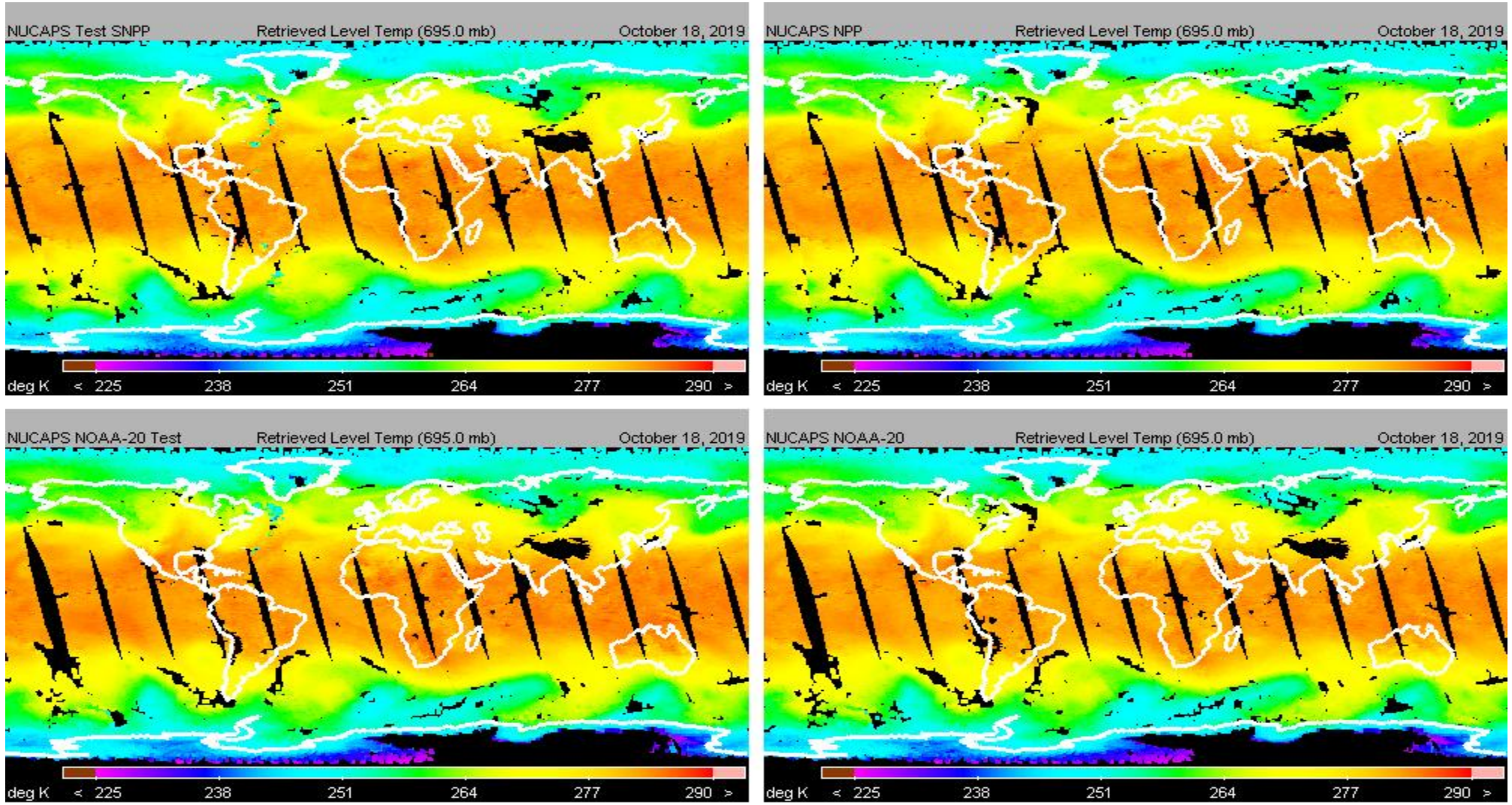
October 18 2019

NPP Test v2.5.2.2

NPP Oper v2.1.12c

N-20 Test v2.5.2.2

N-20 Oper v2.1.12c



IR+MW Pass QC
Temperature (695 hPa)

Retrieved 695 mb water vapor (g/kg) from NPROVS System (Ascending)

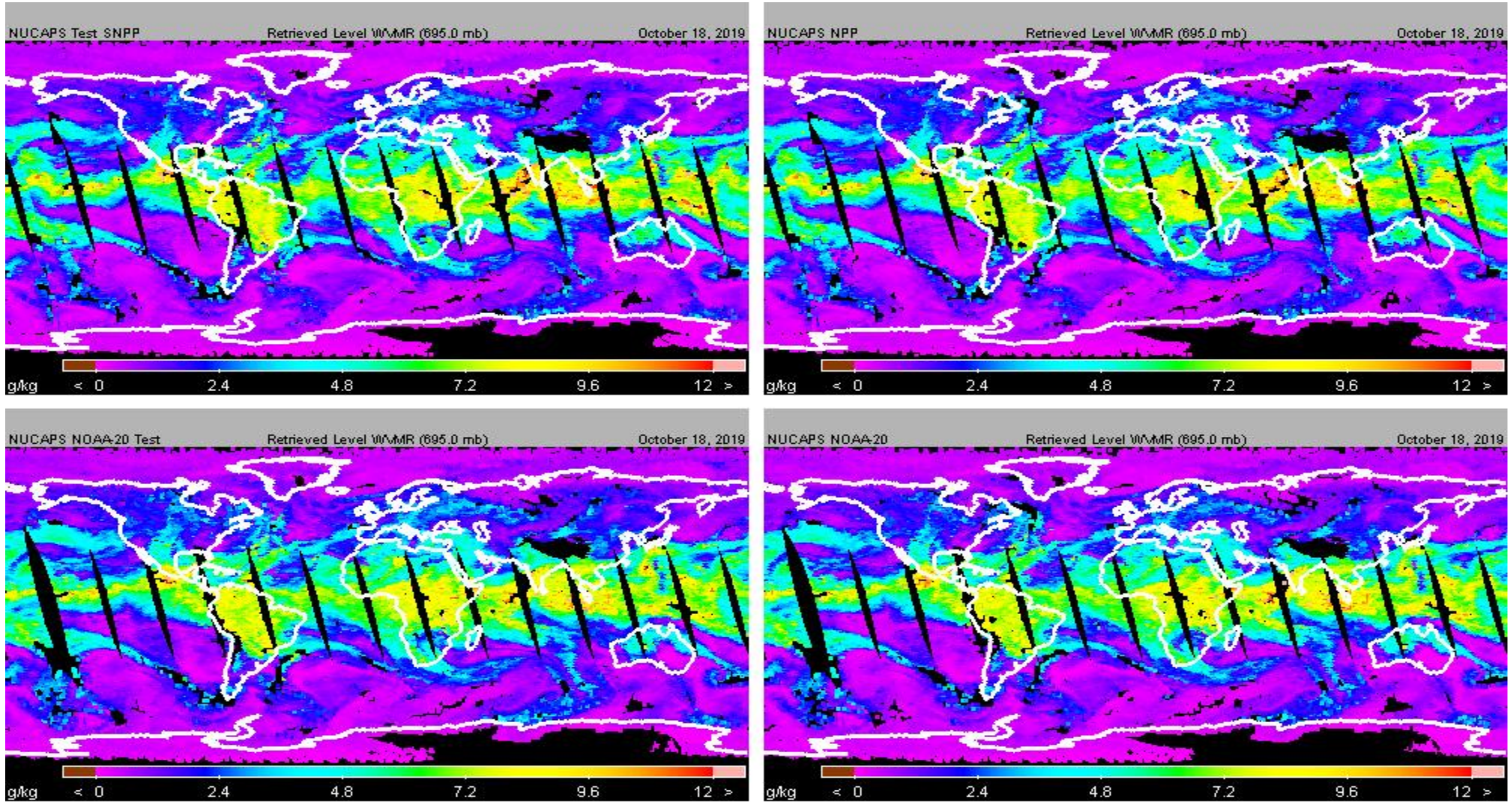
October 18 2019

NPP Test v2.5.2.2

NPP Oper v2.1.12c

N-20 Test v2.5.2.2

N-20 Oper v2.1.12c

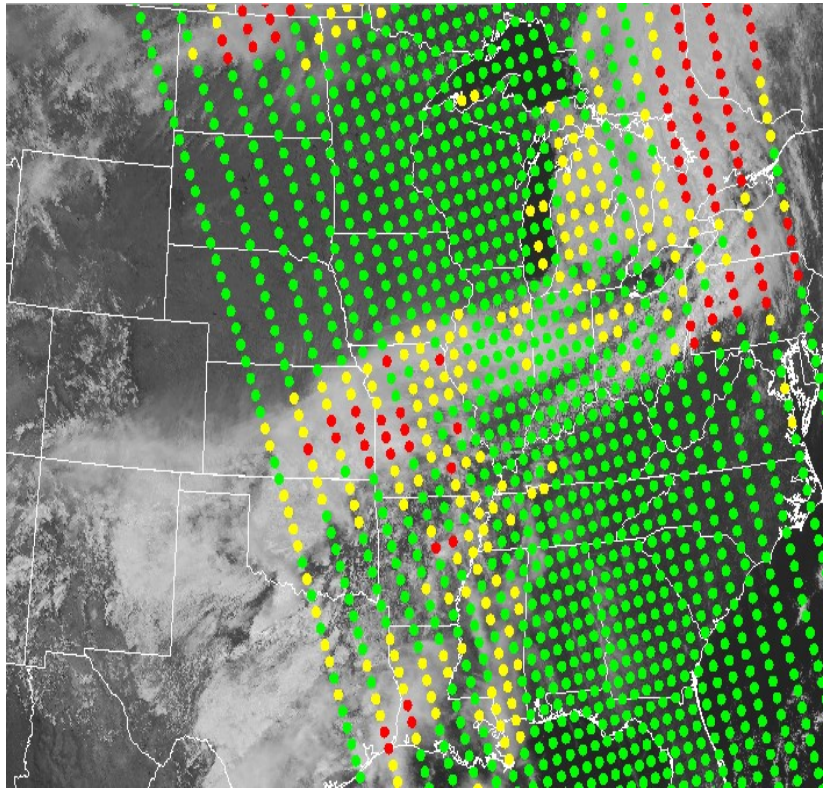


IR+MW Pass QC

H2O Vapor Mixing Ratio (g/kg) (695 hPa)

Quality Flags used in AWIPS

AWIPS Dot Color And EDR Quality	EDR Quality Indicator	Meaning
Green	0	*Clear Sky/Partly Clear Conditions* Successful infrared (IR) + microwave (MW) NUCAPS retrieval.
Yellow	1 or 17	*Cloudy Conditions* Failed *IR+MW retrieval.* *Successful MW-only retrieval.*
Red	9 or 25	*Precipitating Conditions* Failed *IR+MW retrieval.* Failed *MW-only retrieval.*



Source: NOAA-20 NUCAPS and GOES-16 0.64 ! m in AWIPS at 18:26Z on April 19, 2019, STC, Inc.

PRODUCT REQUIREMENTS/VALIDATION RESULTS

Validation Methodology Hierarchies

$T/H_2O/O_3$ Profiles

(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 as "transfer standard" (via double-differences), 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)
   - Limitation: Similar error characteristics
3. **Conventional PTU/O3 Sonde Matchup *Assessments***
   - WMO/GTS operational sondes (NPROVS) or O3-sonde network (e.g., SHADOZ)
   - Representation of global zones, long-term monitoring (*Reale et al.* 2012; *Sun et al.* 2017)
   - Large samples after a couple months (e.g., *Divakarla et al.,* 2006)
   - Limitations: Skewed distributions; mismatch errors; non-uniform radiosondes, assimilated into NWP
4. **Dedicated/Reference PTU/O3 Sonde Matchup *Assessments***
   - *Dedicated* for the purpose of satellite validation
   - Reference sondes: CFH, **GRUAN** corrected RS92/RS41
   - E.g., **ARM sites** (e.g., *Tobin et al.,* 2006), **AEROSE**, **CalWater/ACAPEX ,** BCCSO, PMRF; collocations facilitated via NPROVS (*Reale et al.* 2012; *Sun et al.* 2017)
   - Limitation: Small sample sizes, geographic coverage
5. **Intensive Field Campaign *Dissections***
   - Include dedicated sondes, some *not* assimilated into NWP models
   - Include ancillary datasets, ideally funded aircraft campaign(s)
   - E.g., **SNAP, AEROSE, RIVAL, CalWater**, JAIVEX, AWEX-G, EAQUATE

Carbon Trace Gases

1. **Numerical Model Global *Comparisons***
   - Examples: ECMWF CAMS
   - Large, truly global samples acquired from Focus Days
   - Limitation: Not independent truth data
2. **Satellite Sounder EDR *Intercomparisons***
   - Examples: **AIRS,** OCO-2, MLS
   - Global samples acquired from Focus Days (e.g., AIRS)
   - Limitation: Similar error characteristics
3. **Surface-Based Network Matchup *Assessments***
   - **Total Carbon Column Observing Network (TCCON)** spectrometers (*Wunch et al.* 2010, 2011)
   - **AirCore** balloon-borne *in situ* profile observations (*Membrive et al.* 2017)
   - Provide routine independent measurements representing global zones akin to RAOBs
   - Limitations: Small sample sizes, uncertainties in unit conversions, different sensitivities to atmospheric layers
4. **Intensive Field Campaign *In Situ* Data *Assessments***
   - Include ancillary datasets, ideally funded aircraft campaign(s)
   - **ATom**, WE-CAN, FIREX, ACT-America

JPSS Specification Performance Requirements
CrIS/ATMS Temperature and Moisture Profile EDR Uncertainty

Temperature Profile

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

Moisture Profile

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 $g \cdot kg^{-1}$ / 2-km layer	10%
AVMP, Cloud fraction < 50%, 600–300 hPa	Greater of 35% or 0.1 $g \cdot kg^{-1}$ / 2-km layer	10%
AVMP, Cloud fraction < 50%, 300–100 hPa	Greater of 35% or 0.1 $g \cdot kg^{-1}$ / 2-km layer	10%
AVMP, Cloud fraction ≥ 50%, surface to 600 hPa	Greater of 20% of 0.2 $g \cdot kg^{-1}$ / 2-km layer	10%
AVMP, Cloud fraction ≥ 50%, 600–400 hPa	Greater of 40% or 0.1 $g \cdot kg^{-1}$ / 2-km layer	10%
AVMP, Cloud fraction ≥ 50%, 400–100 hPa	Greater of 40% or 0.1 $g \cdot kg^{-1}$ / 2-km layer	NS

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

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

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)

JPSS Specification Performance Requirements
CrIS Trace Gas EDR Uncertainty (O_3, CO, CO_2, CH_4)

	CrIS Infrared Trace Gases Specification Performance Requirements		
	PARAMETER	**THRESHOLD**	**OBJECTIVE**
Ozone Profile	**O_3 (Ozone)** Profile Precision, 4–260 hPa (6 statistic layers)	20%	10%
	O_3 (Ozone) Profile Precision, 260 hPa to sfc (1 statistic layer)	20%	10%
	O_3 (Ozone) Profile Accuracy, 4–260 hPa (6 statistic layers)	±10%	±5%
	O_3 (Ozone) Profile Accuracy, 260 hPa to sfc (1 statistic layer)	±10%	±5%
	O_3 (Ozone) Profile Uncertainty, 4–260 hPa (6 statistic layers)	25%	15%
	O_3 (Ozone) Profile Uncertainty, 260 hPa to sfc (1 statistic layer)	25%	15%
Carbon Gases	**CO (Carbon Monoxide)** Total Column Precision	15% (CrIS FSR)	3%
	CO (Carbon Monoxide) Total Column Accuracy	±5% (CrIS FSR)	±5%
	CO_2 (Carbon Dioxide) Total Column Precision	0.5% (2 ppmv)	1.05 to 1.4 ppmv
	CO_2 (Carbon Dioxide) Total Column Accuracy	±1% (4 ppmv)	NS
	CH_4 (Methane) Total Column Precision	1% (≈20 ppbv)	NS
	CH_4 (Methane) Total Column Accuracy	±4% (≈80 ppmv)	NS

Source:
(L1RD, 2014, pp. 45-49)

AVTP (T), AVMP (H2O), & IR OZONE PROFILE (O3) EDRS

NUCAPS Product Maturity: AVTP, AVMP, O3

Product	Maturity Level			
	SNPP		NOAA-20	
	Current Status	Maturity Level **Aimed**	Current Status	Maturity Level Aimed
NOAA-20 AVTP/AVMP	✓ Validated	✓ Remain Validated	✓ Provisional	❑ Validated
NOAA-20 Ozone	✓ Validated	✓ Remain Validated	✓ Provisional	❑ Validated

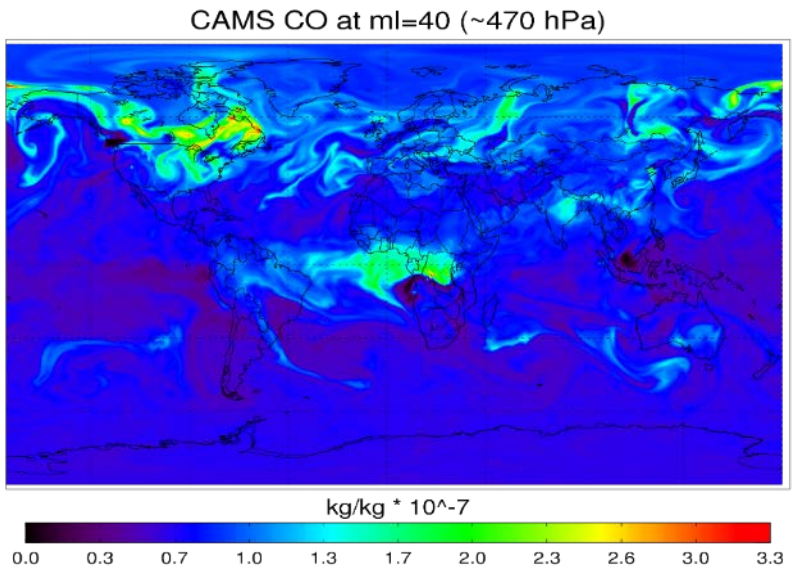
- Processing Environment and Algorithms (Alg. Version, LUTs, Effective date)

  ✓ V2.5.2.2 DAP is the optimized NUCAPS algorithm for SNPP/NOAA-20 products.

  - **NOAA-20 AVTP, AVMP, Ozone for validated maturity**
  - NOAA-20 SNPP/NOAA-20 CO for validated maturity
  - OLR for validated maturity
  - SNPP/NOAA-20 CH4 for provisional maturity.
  - SNPP/NOAA-20 CO2 Currently Beta (Maturity Review planned for February 2020)

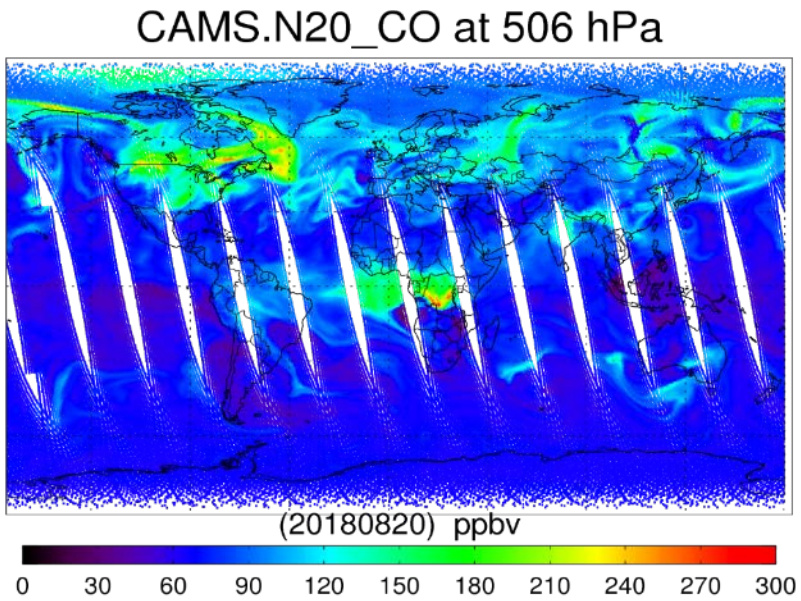
ECMWF Copernicus Atmosphere Monitoring Service (CAMS)

- **Purpose:**
  - Use CAMS data for NUCAPS IR Tuning for Trace Gas Products inter-Comparison
- **CAMS data:**
  - A trace gas data set generated by ECMWF 4DVAR system for the following: **CO, CH4, O3, CO2, SO2, HNO3**
  - Horizontal resolution: **0.4° × 0.4°**
  - Vertical sigma levels from surface to 0.1 hPa:
    - **60 levels** from July 2012 to July 8, 2019
    - **137 levels** starting from July 9, 2019
  - Temporal resolution: 4 times a day, **00, 06, 12, 18 UTC**



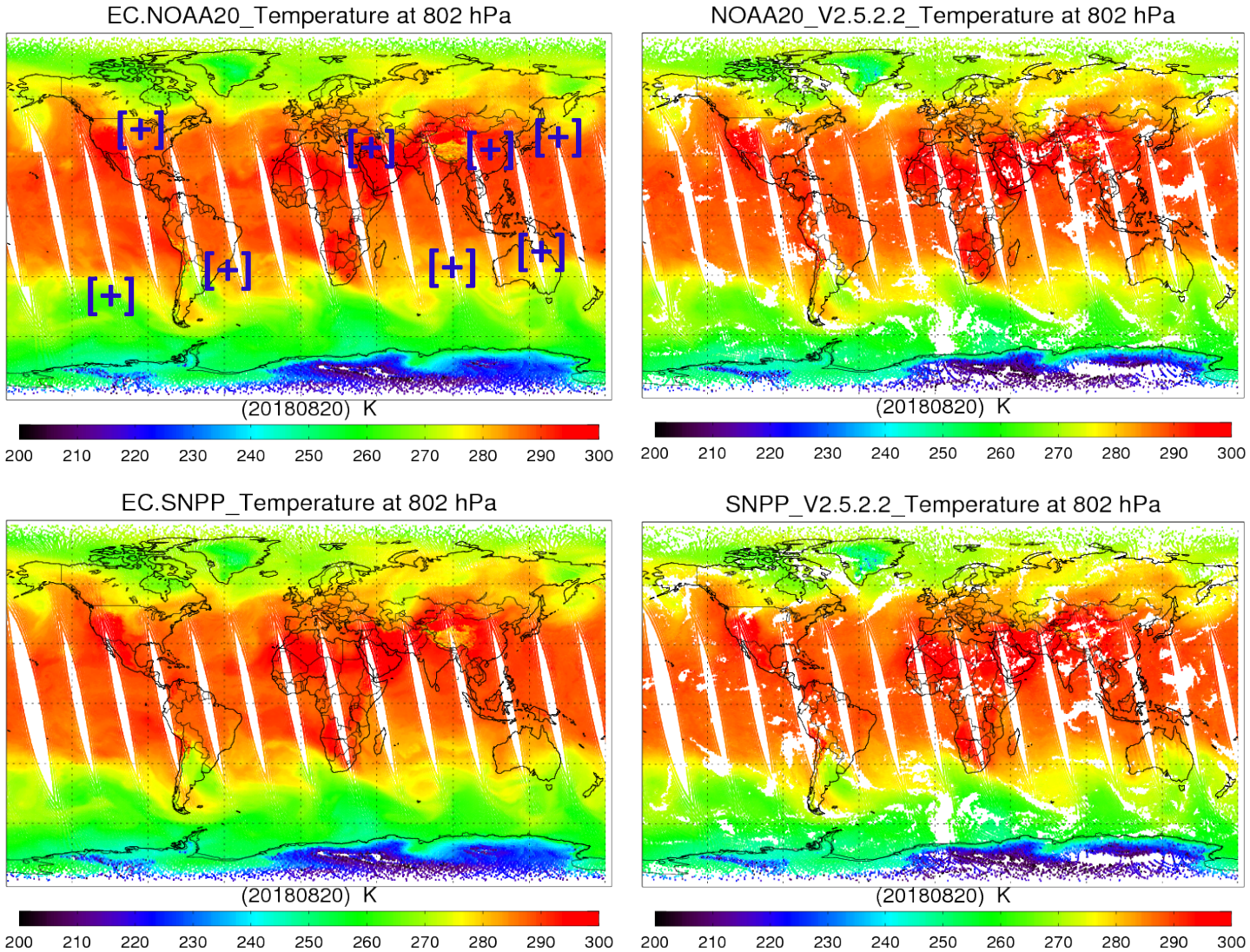
CAMS CO (40-m.level, ~470 hPa)

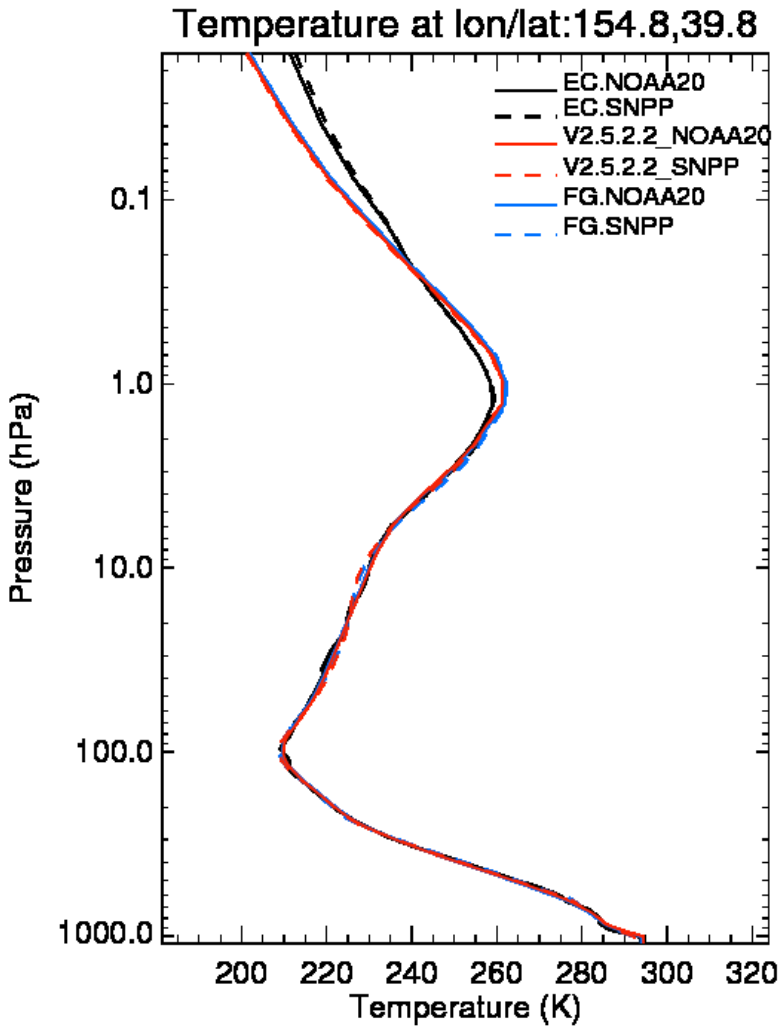
Convert to



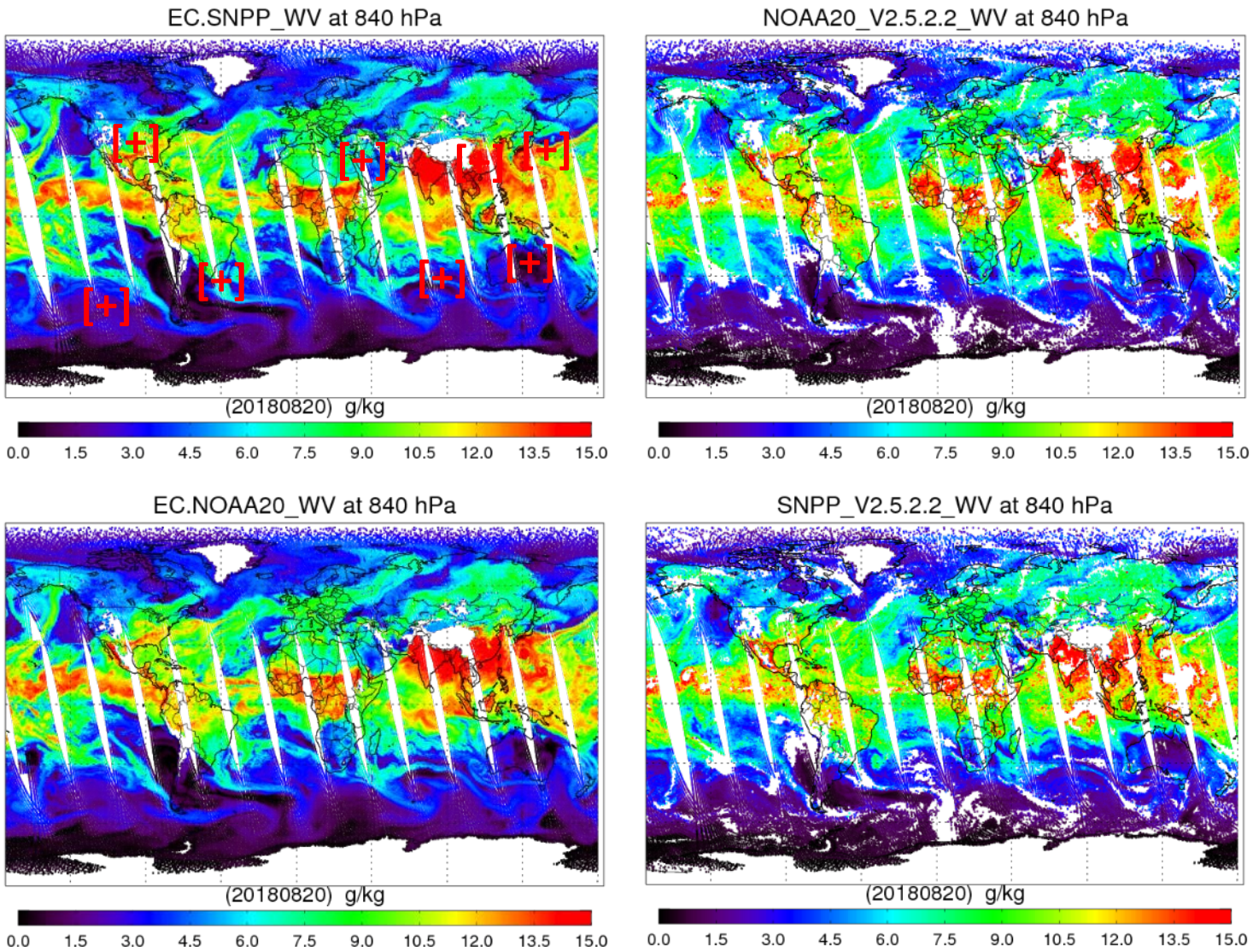
CO on NOAA-20 swath

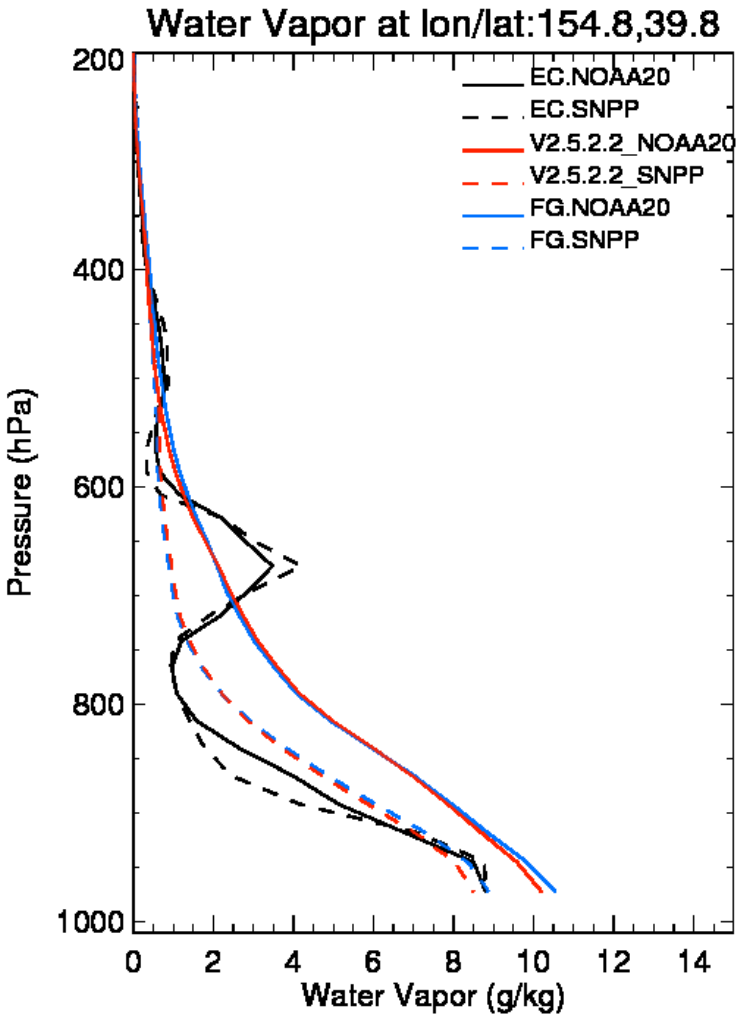
NUCAPS and ECMWF Temperature at 802 hPa on 20-Aug-2018





NUCAPS and ECMWF Water Vapor at 840 hPa on 20-Aug-2018





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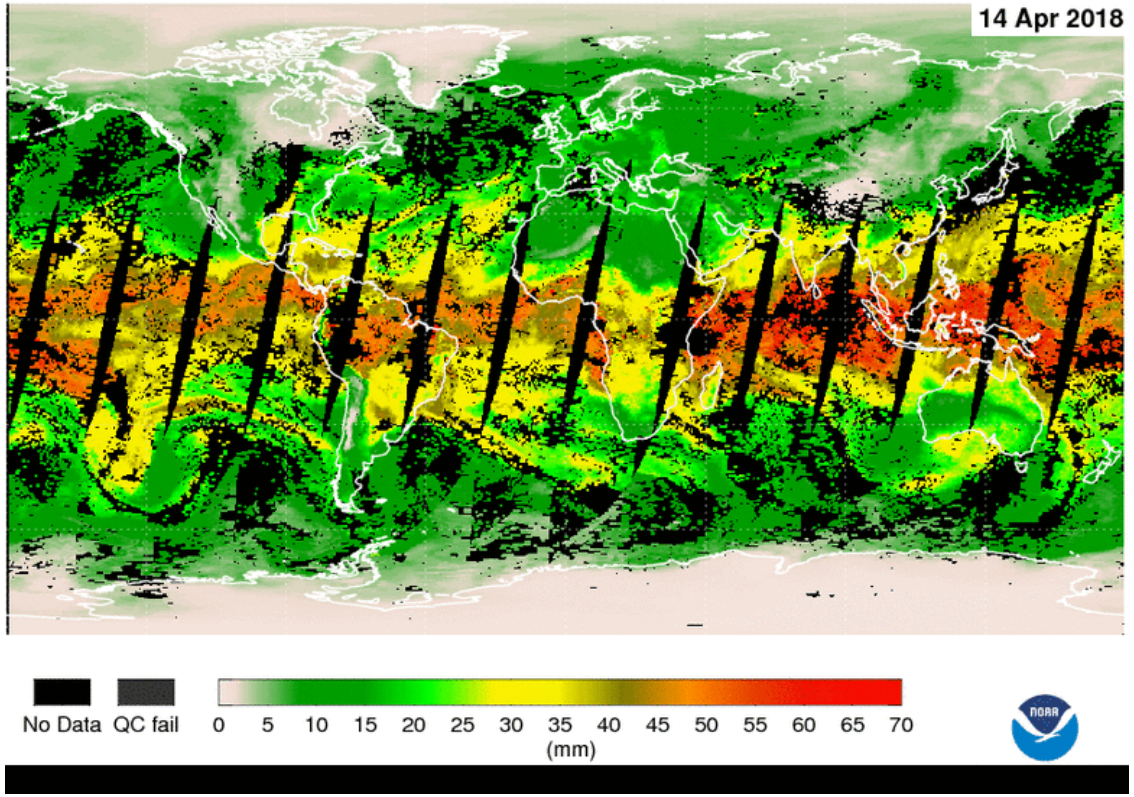

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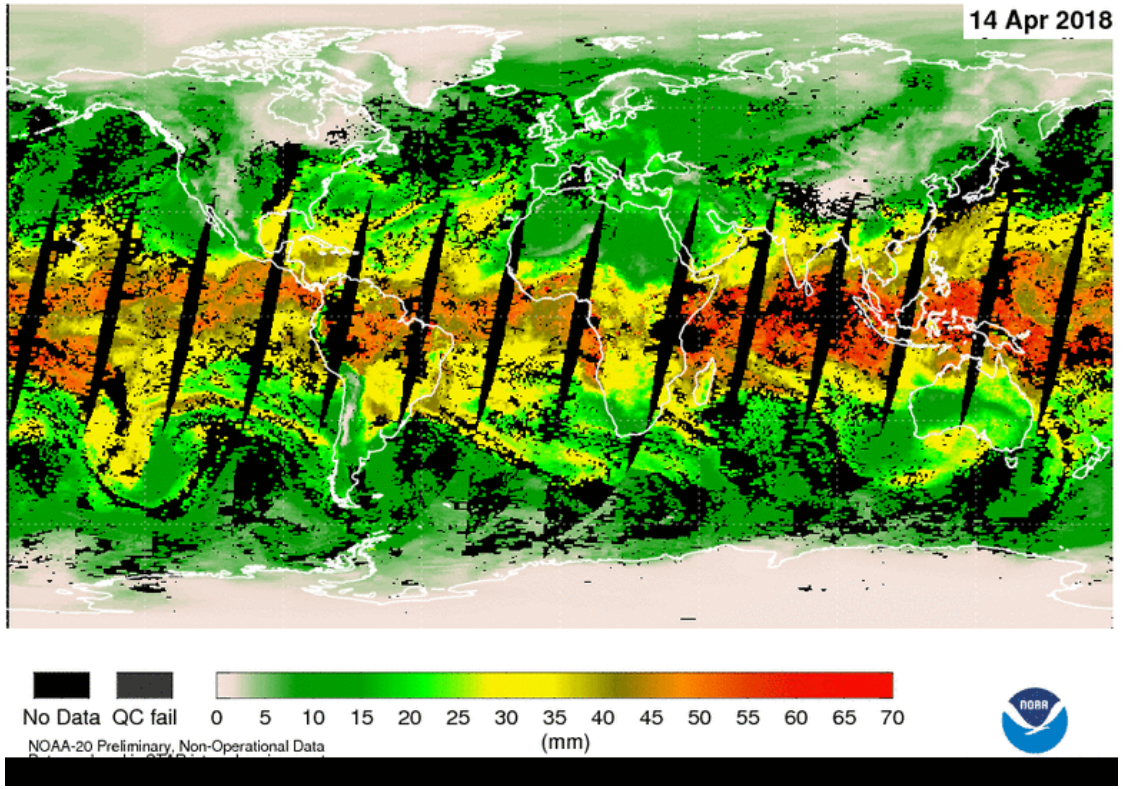
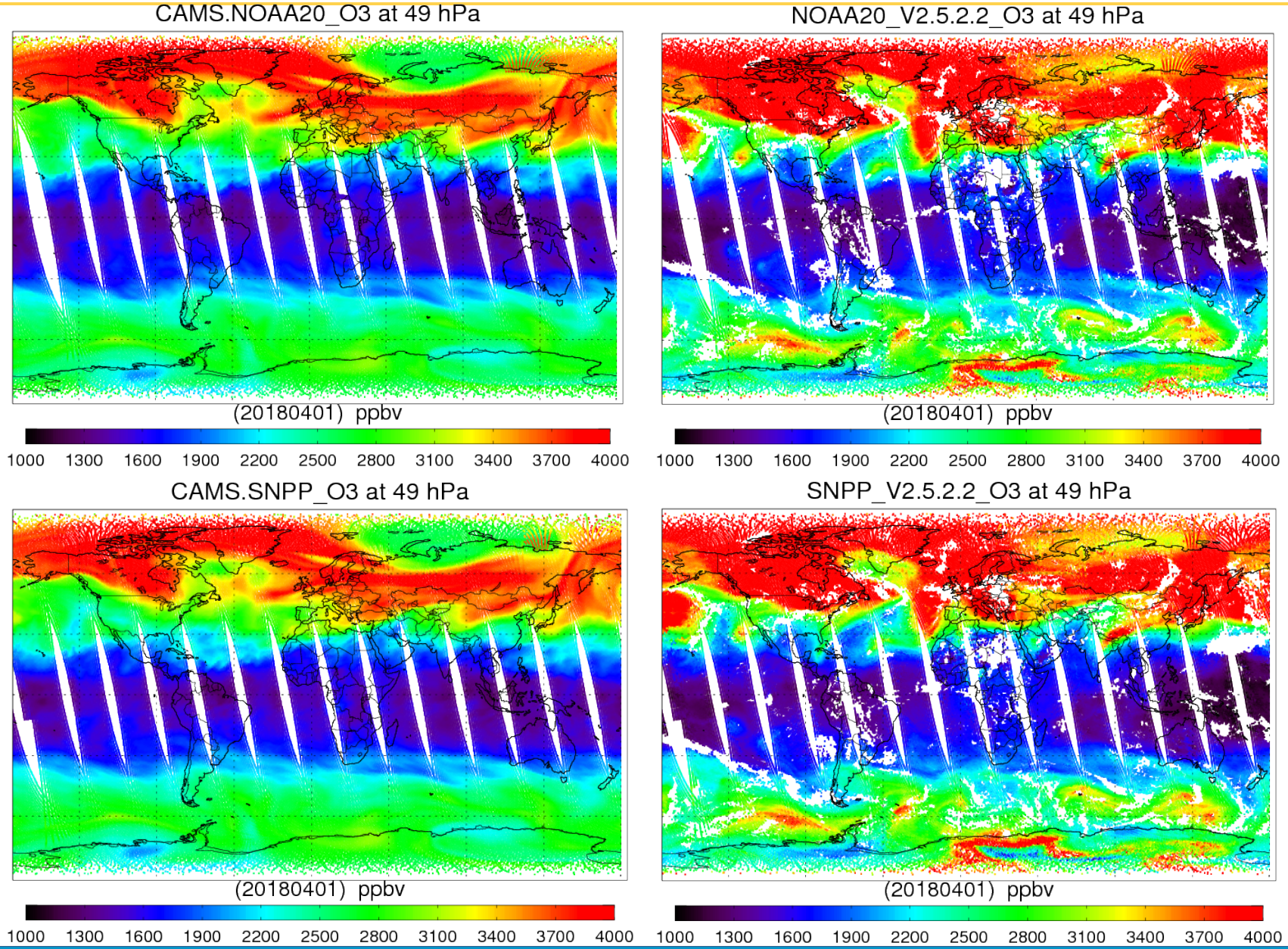
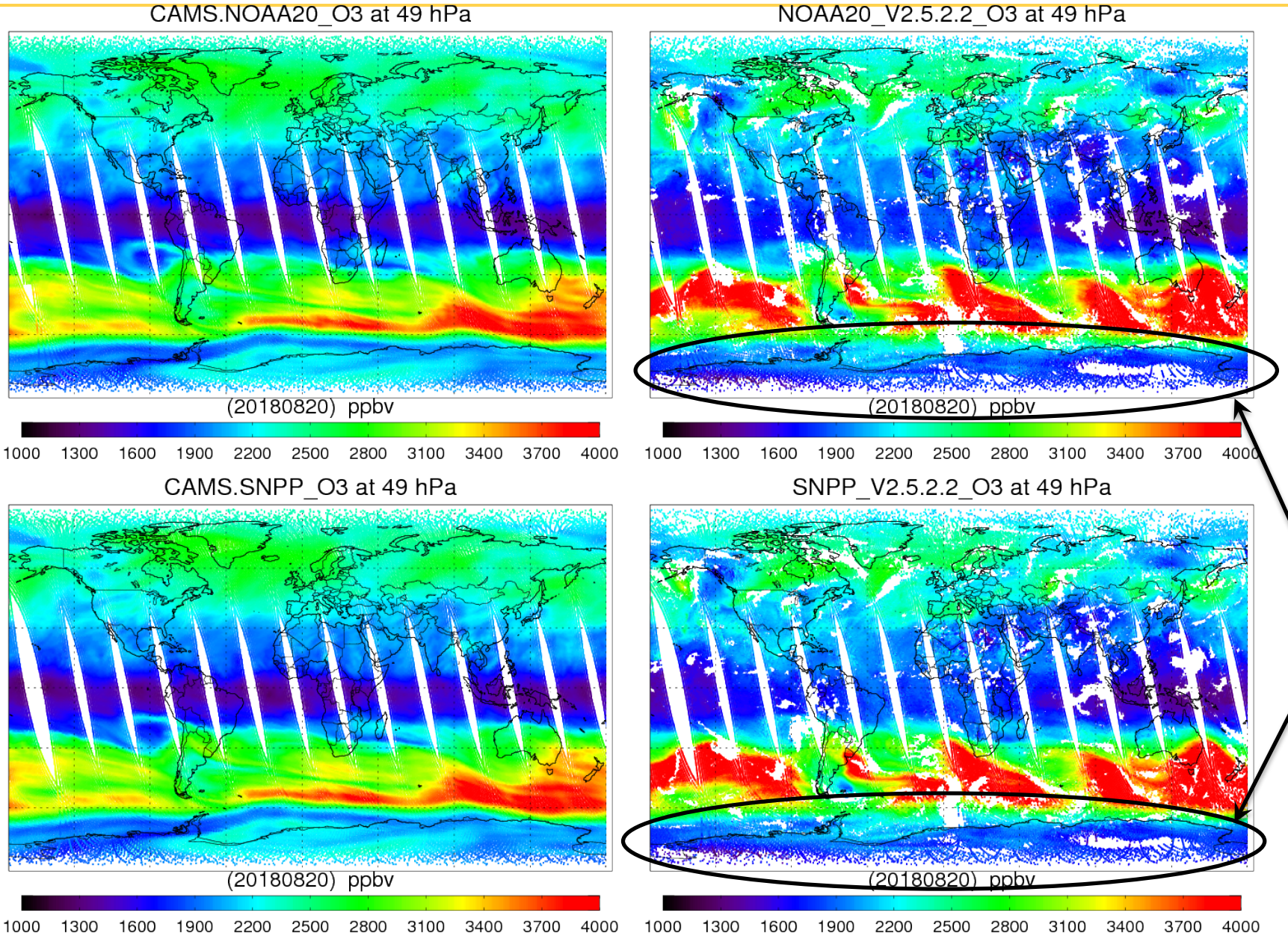


NUCAPS and CAMS O_3 on 1-Apr-2018



NUCAPS and CAMS O_3 on 20-Aug-2018



Onset of seasonal depletion of Antarctic ozone

NOAA-20/SNPP AVTP/AVMP/O_3 EDR Reference Data, Time Periods

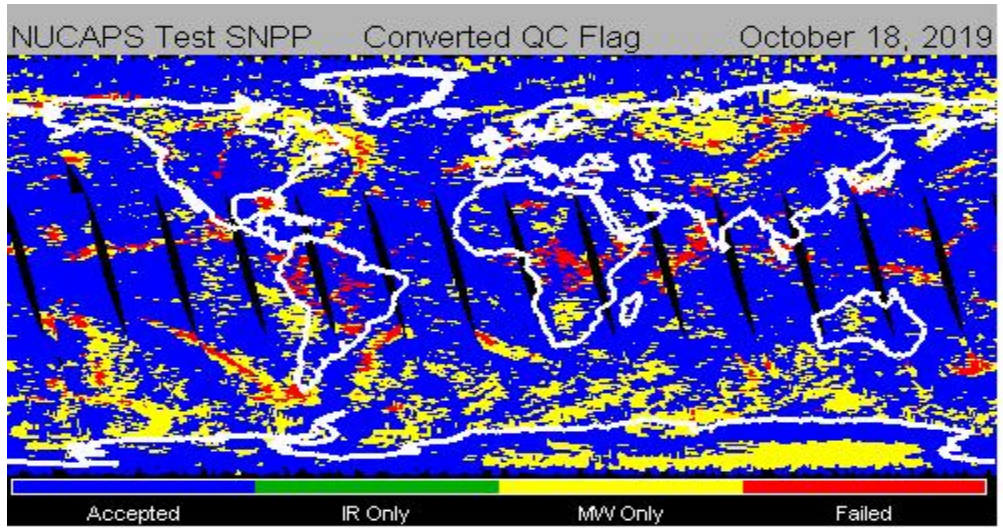
Observation Type	Reference Data	Time Period	Validation	Remarks
Dedicated radiosonde observations (RAOBs)	Balloon-borne *in situ* T(p) and q(p) from • ARM sites • GRUAN sites • AEROSE 2019 campaign • Beltsville site	May 2018 to September 2019	✓ IR+MW AVTP/AVMP meet all global broad-layer requirements ✓ MW-Only AVTP/AVMP meet requirements in upper-troposphere broad-layer and marginal in low-to-mid troposphere	VALAR archive of SDR/TDR granule collocations is facilitated via NPROVS collocation files (*Reale et al.* 2012; *Sun et al.* 2017)
Conventional RAOBs	Balloon-borne *in situ* T(p) and q(p) from NPROVS conventional global RAOB collocations	9–20 August 2018	✓ RMS overall consistent between N20 and SNPP for v2.5.2.2; however there is a difference in bias for IR+MW AVTP ✓ IR+MW AVTP meets requirement for N20 & SNPP; H2O marginal (depending on interpretation) for N20 & NPP	NPROVS provides routine graphical and statistical analysis tools and collocates single closet FOR
Global ECMWF forecast/ analysis fields	Global T(p), q(p), O3(p) model output	Focus Day 20 August 2018	✓ IR+MW AVTP/AVMP meet all global broad-layer requirements ✓ IR ozone profile meets all global broad-layer requirements ✓ MW-Only AVTP/AVMP meet requirements for mid-to-upper troposphere broad-layers excluding SH polar cap	MW-only Notes: • There are no users of the MW-only product at this time • MiRS is recommended for JPSS users, but is necessary component of and some users have expressed interest • Ice and snow flags were not in MW-only QA, so we removed SH polar cap from analysis
Ozonesondes	Balloon-borne *in situ* O3(p) • WOUDC sites • SHADOZ sites • AEROSE 2019 • HUBC	• WOUDC: Feb 2018 to June 2019 • SHADOZ: Feb 2018 to Dec 2018 • AEROSE: Mar 2019	✓ IR ozone profile meets global broad-layer requirements	Dedicated ozonesondes are launched during AEROSE campaigns and from the HUBC site

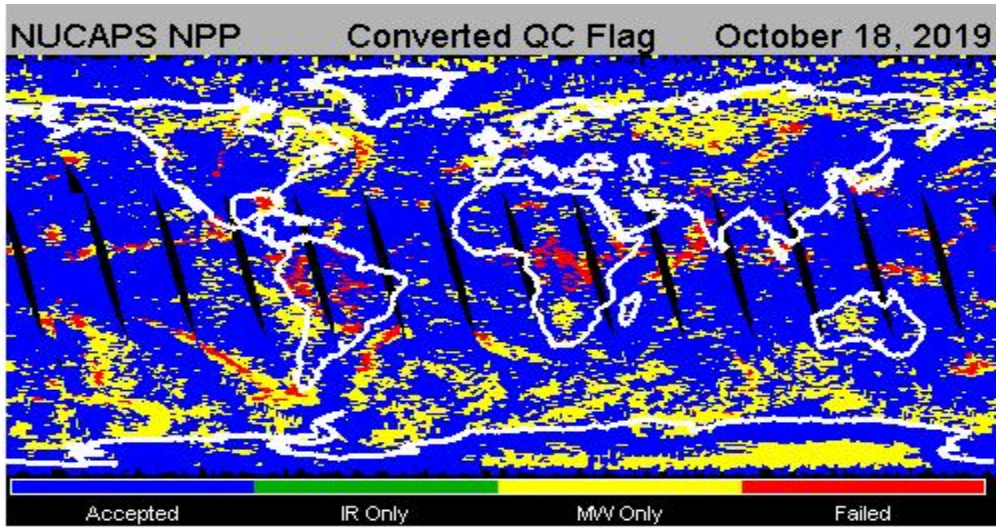
NUCAPS QA Acceptance Flags, Ascending (NPROVS ODS)

October 18 2019

NPP Test
v2.5.2.2

IR+MW: 76%
MW-only: 21%



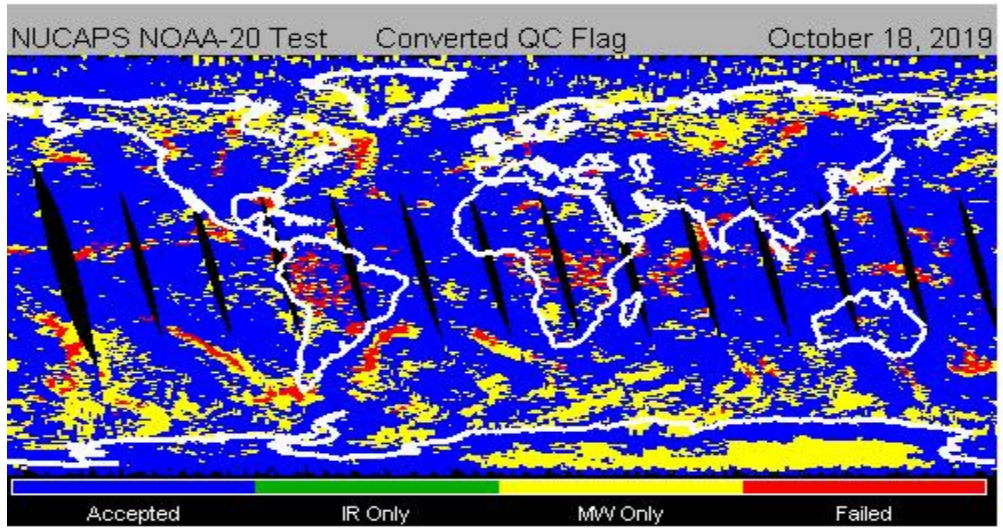


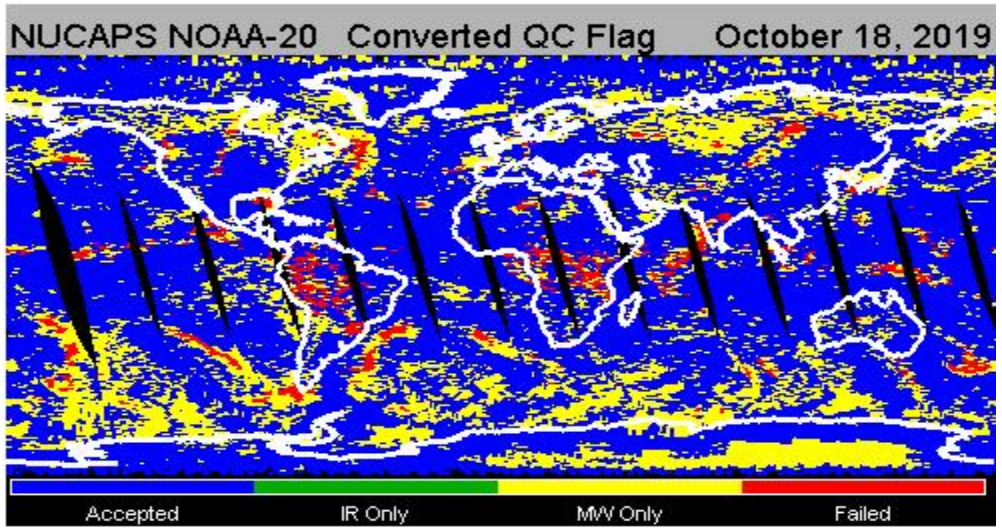
NPP Oper
v2.1.12c

IR+MW: 75%
MW-only: 22%

N-20 Test
v2.5.2.2

IR+MW: 76%
MW-only: 21%





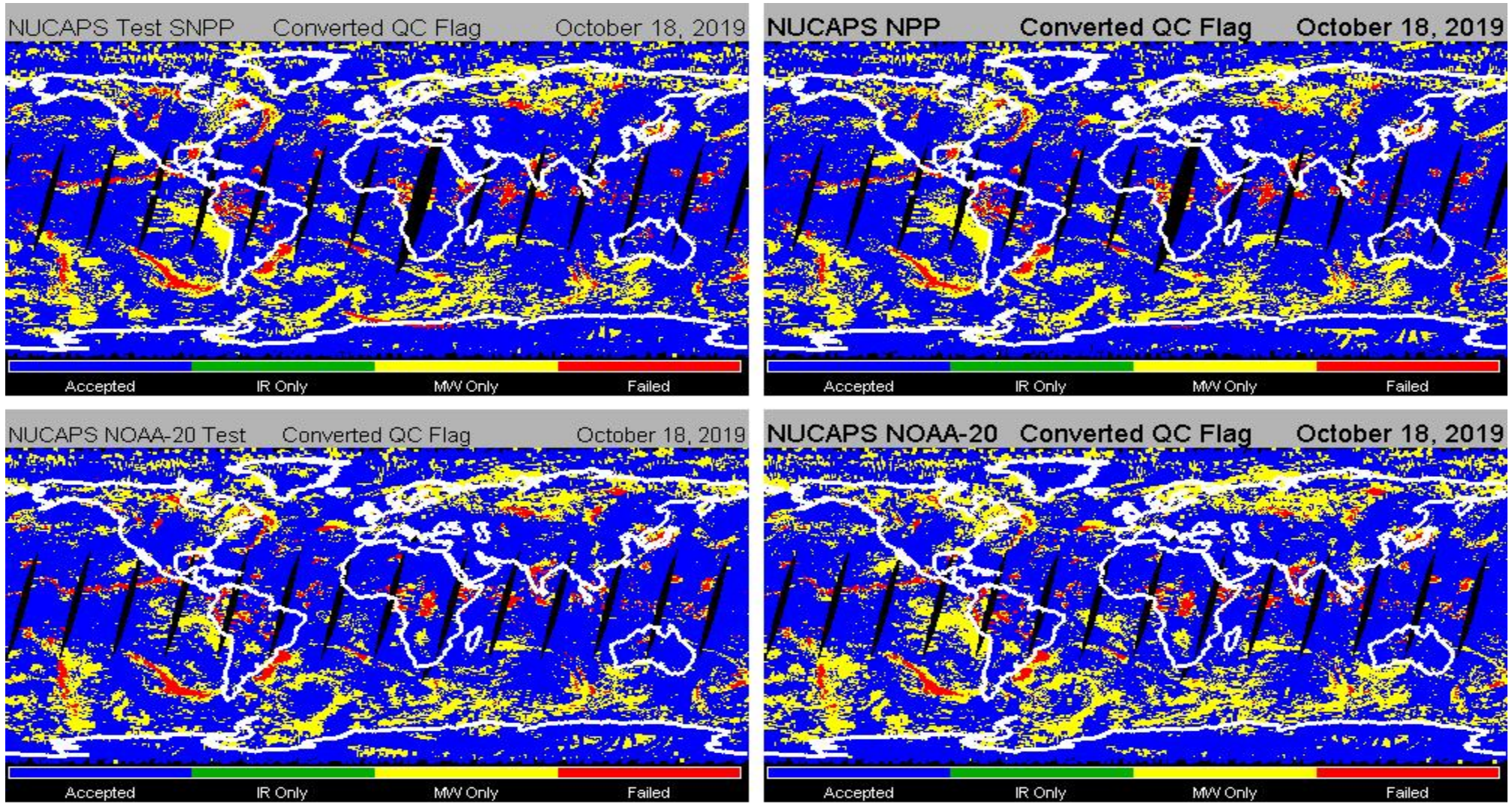
N-20 Oper
v2.1.12c

IR+MW: 72%
MW-only: 25%

IR+MW pass (Blue), MW-only pass (Yellow) and Both fail (Red)

NUCAPS QA Acceptance Flags, Descending (NPROVS ODS)

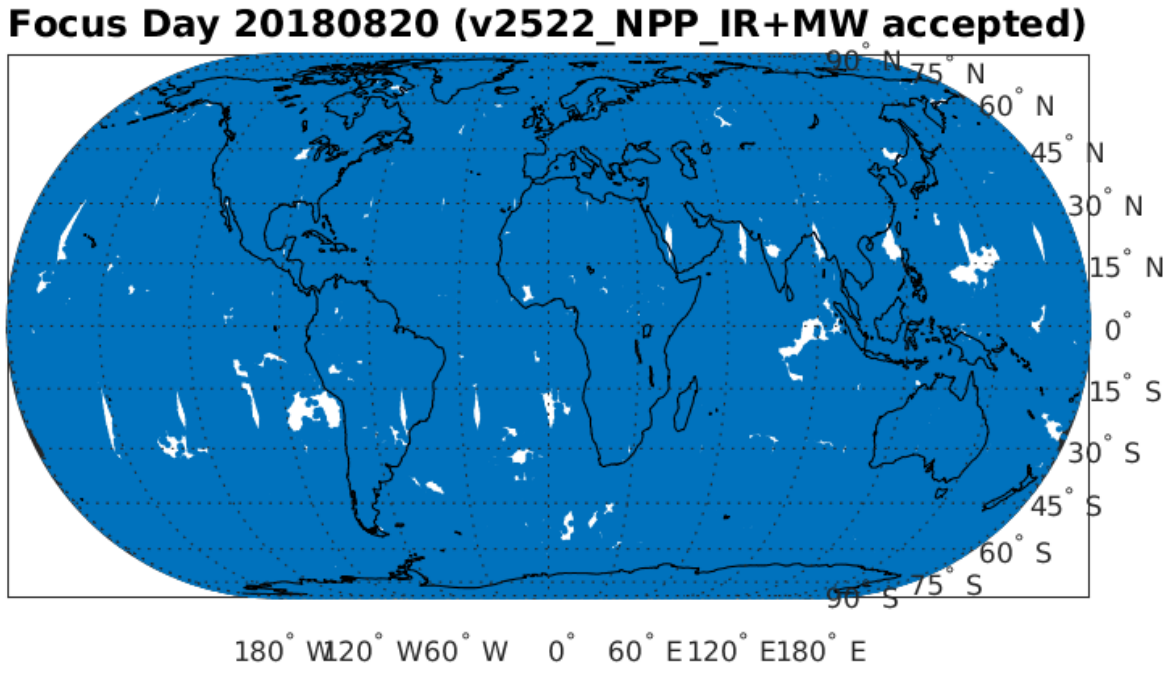
October 18 2019



IR+MW pass (Blue), MW-only pass (Yellow) and Both fail (Red)

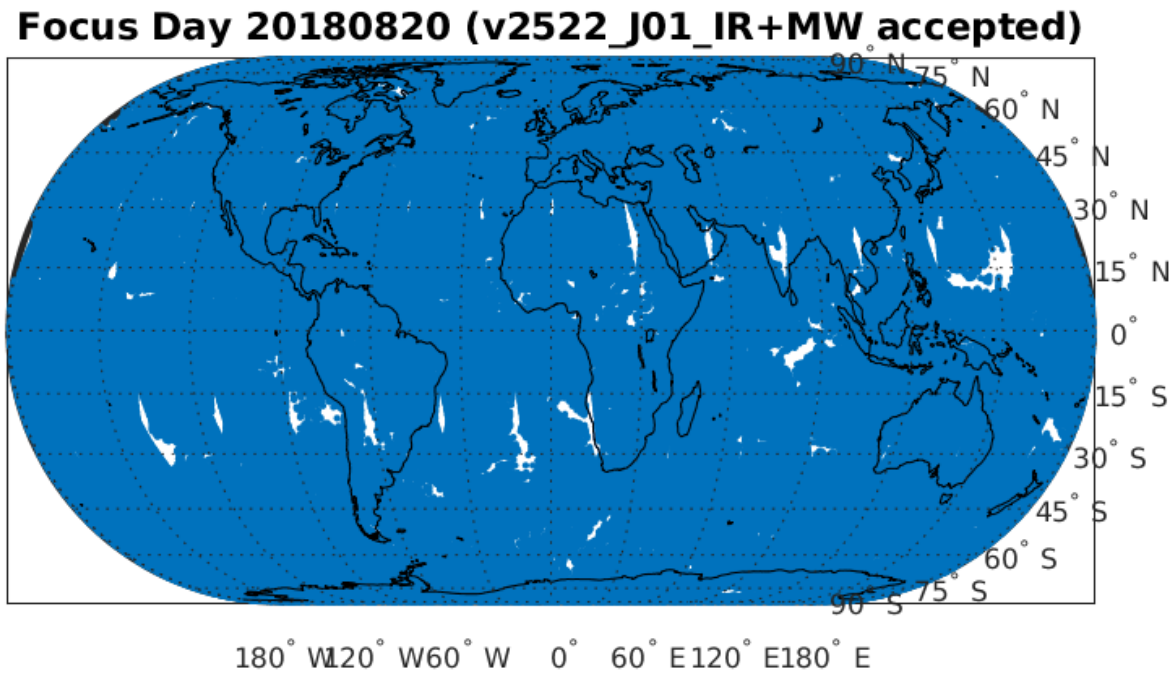
ECMWF Focus Day 20 August 2018 IR+MW Global Sample

SNPP



N = 239223

NOAA-20



N = 245492

ECWMF Focus Day Advantages:

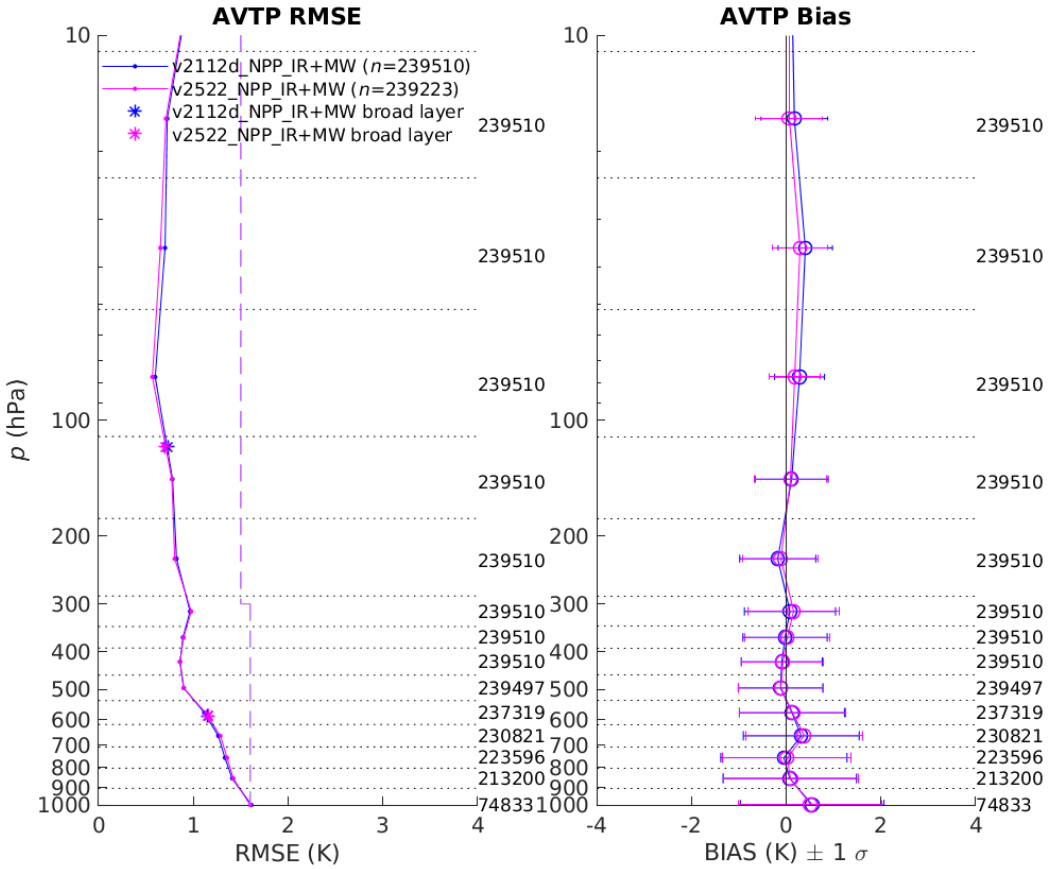
- Large, truly global samples
- Extremely useful as “transfer standard” (via double-differences)

NUCAPS IR+MW AVTP vs ECMWF

Focus Day 20 August 2018: Global Clear-to-Partly Cloudy

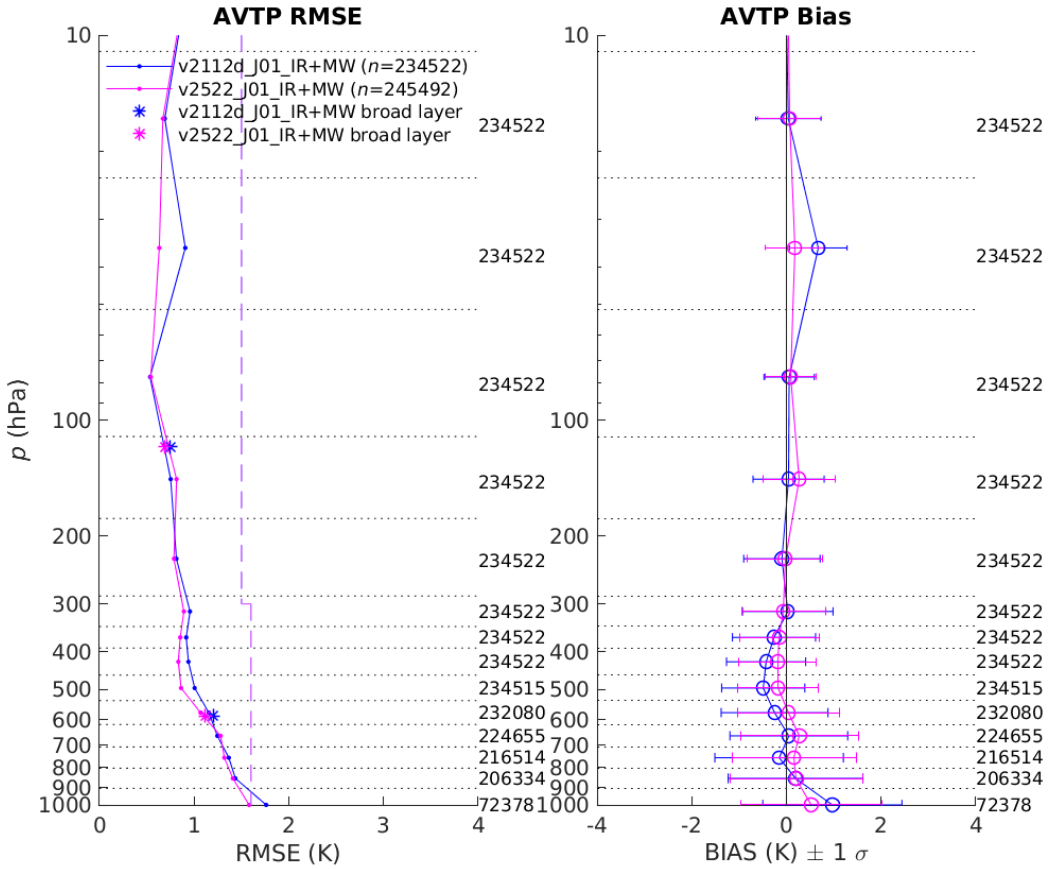
v2.1.12d
v2.5.2.2

SNPP



V2.1.12d
V2.5.2.2

NOAA-20

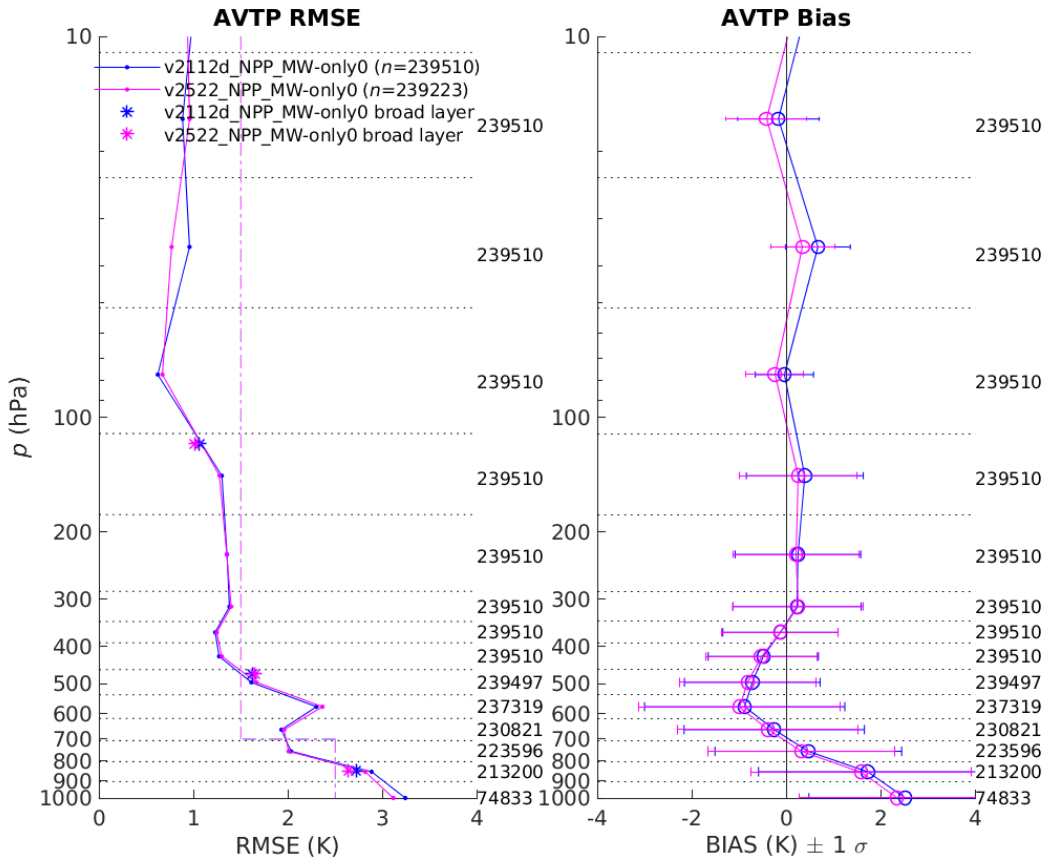


NUCAPS MW-Only AVTP vs ECMWF

Focus Day 20 August 2018: Global Clear-to-Partly Cloudy

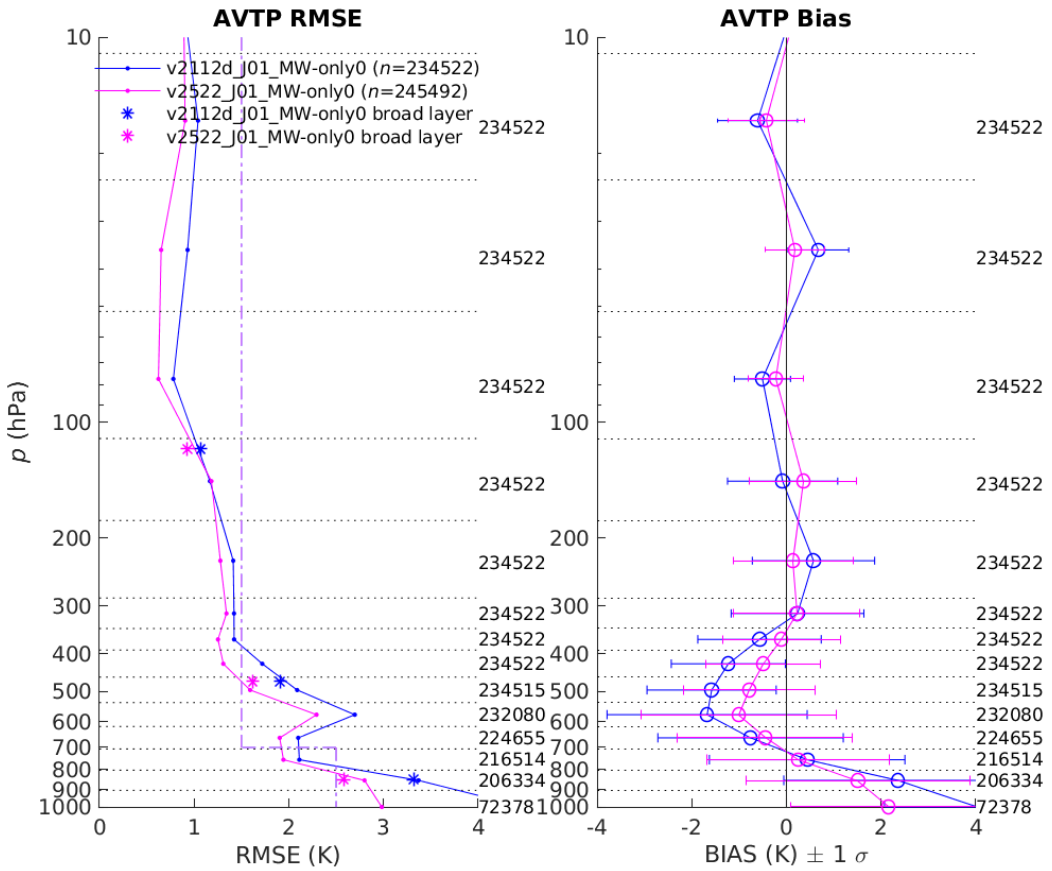
v2.1.12d
v2.5.2.2

SNPP



V2.1.12d
V2.5.2.2

NOAA-20

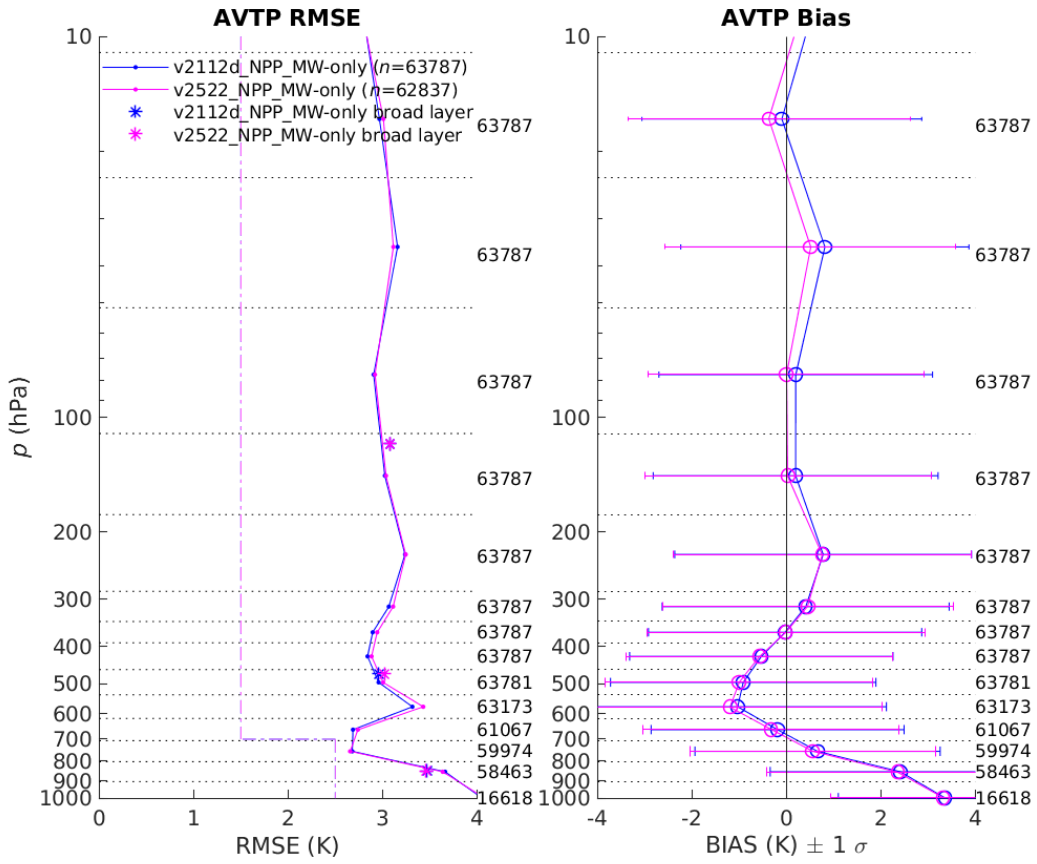


NUCAPS MW-Only AVTP vs ECMWF

Focus Day 20 August 2018: Global Cloudy

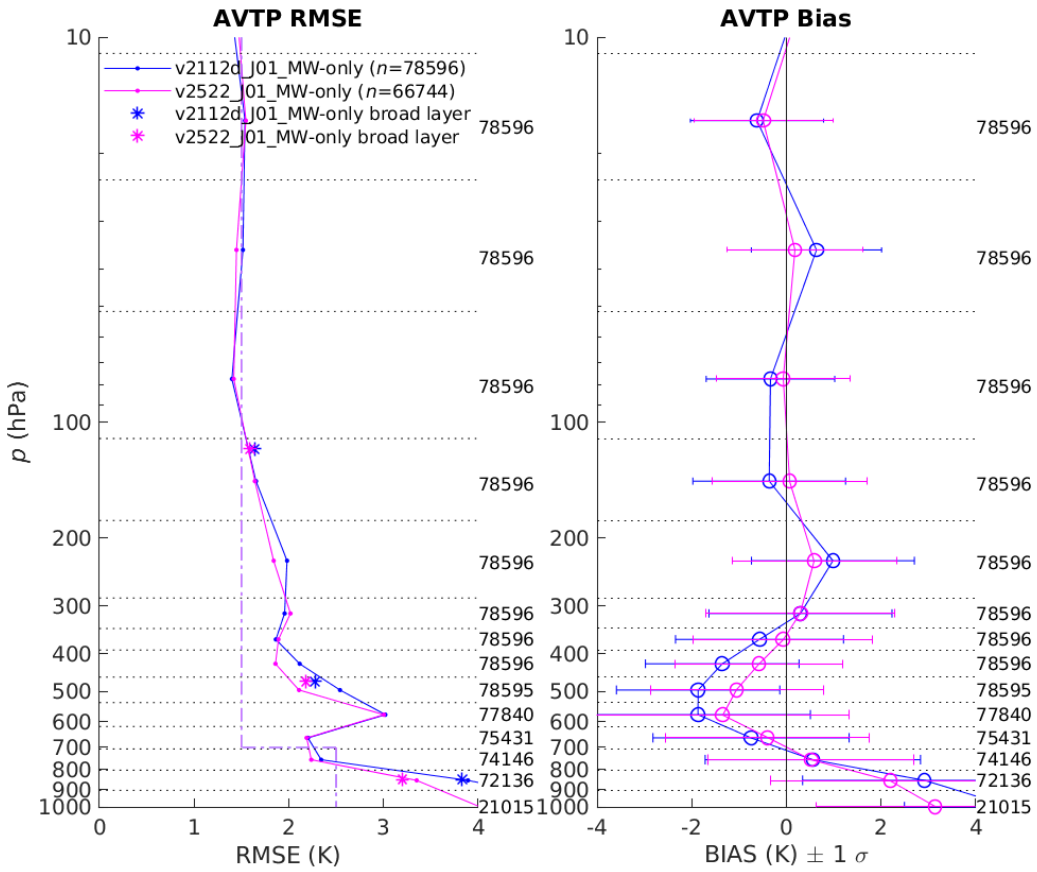
v2.1.12d
v2.5.2.2

SNPP



V2.1.12d
V2.5.2.2

NOAA-20

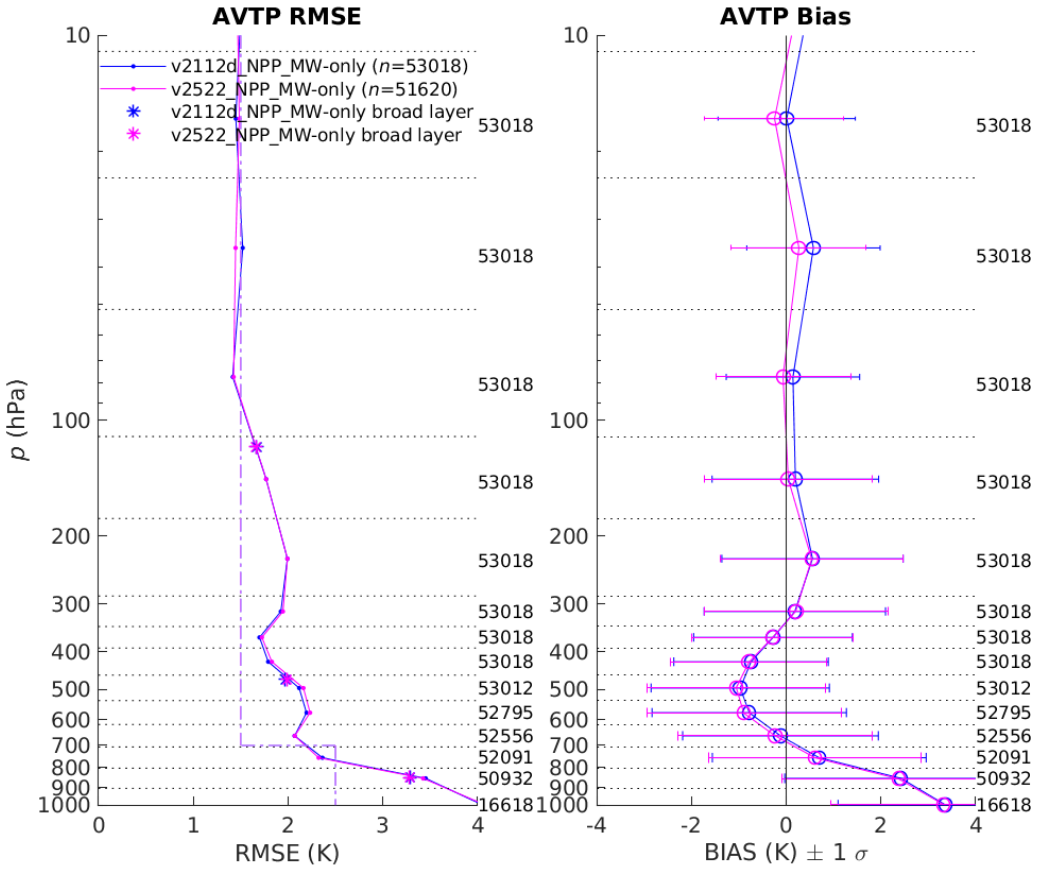


NUCAPS MW-Only AVTP vs ECMWF

Focus Day 20 August 2018: Cloudy Excluding SH Polar Cap

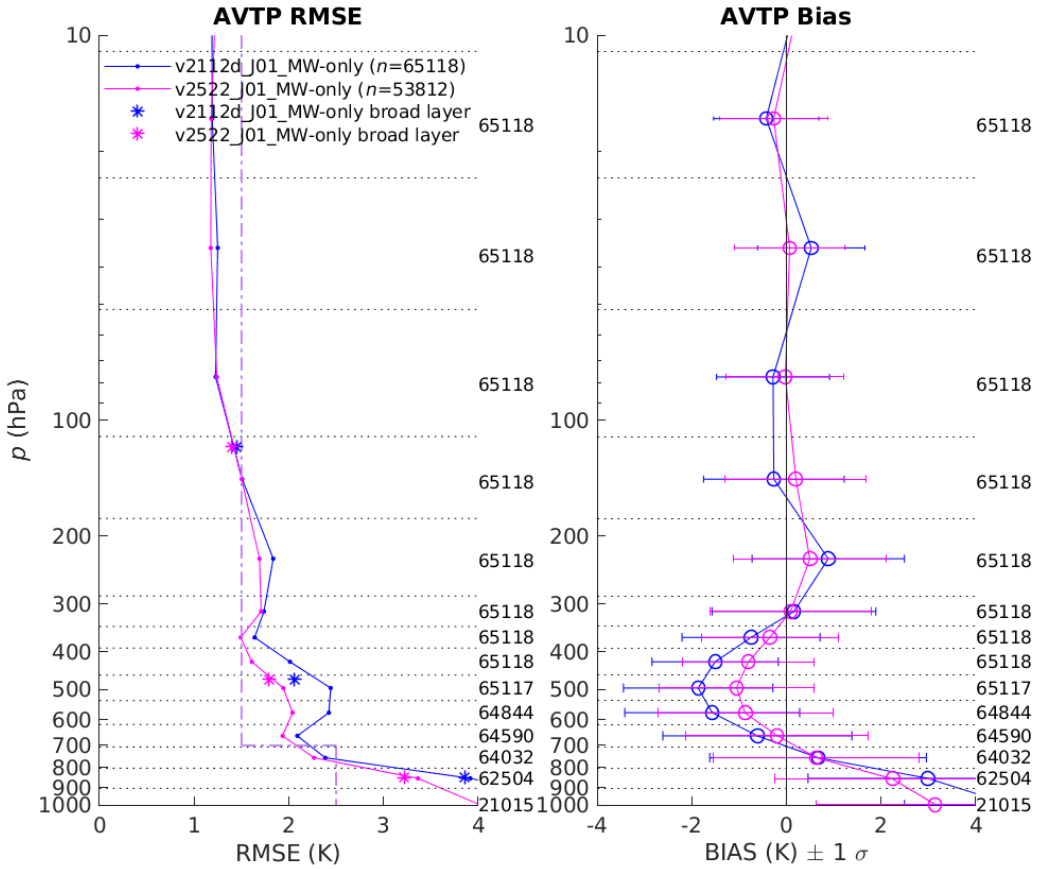
v2.1.12d
v2.5.2.2

SNPP



V2.1.12d
V2.5.2.2

NOAA-20

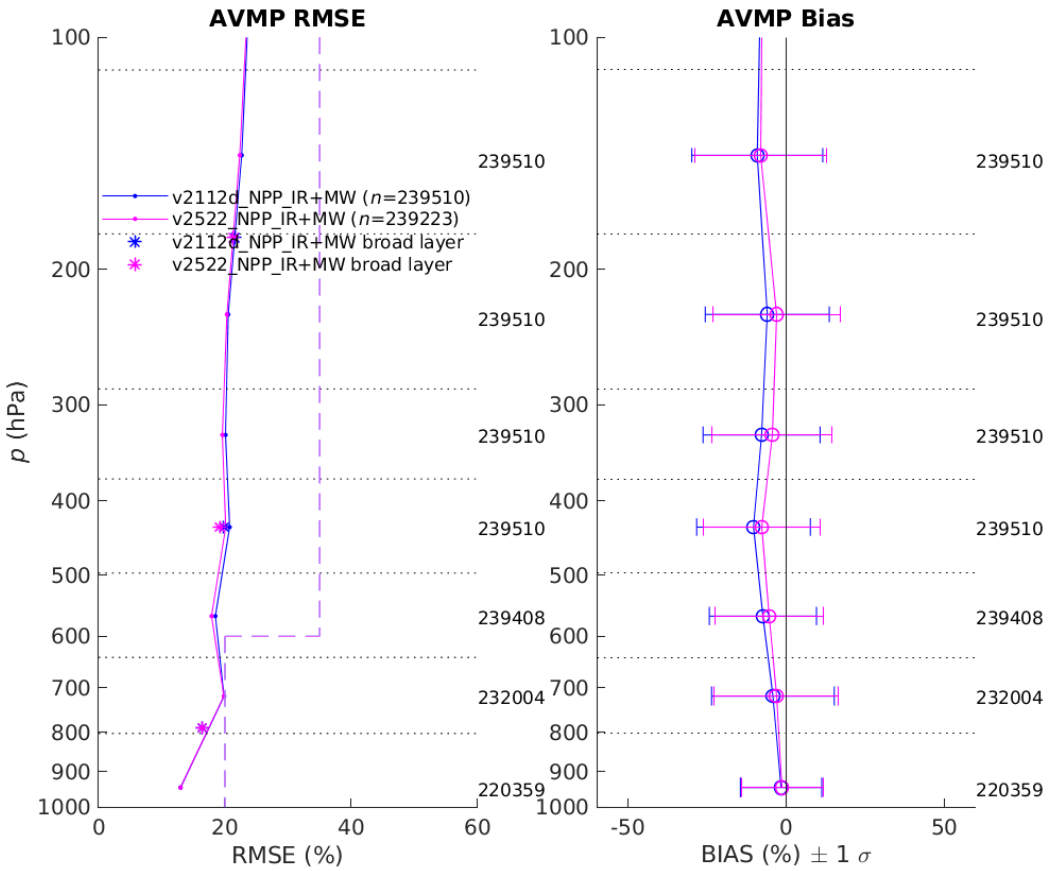


NUCAPS IR+MW AVMP (H_2O) vs ECMWF

Focus Day 20 August 2018: Global Clear-to-Partly Cloudy

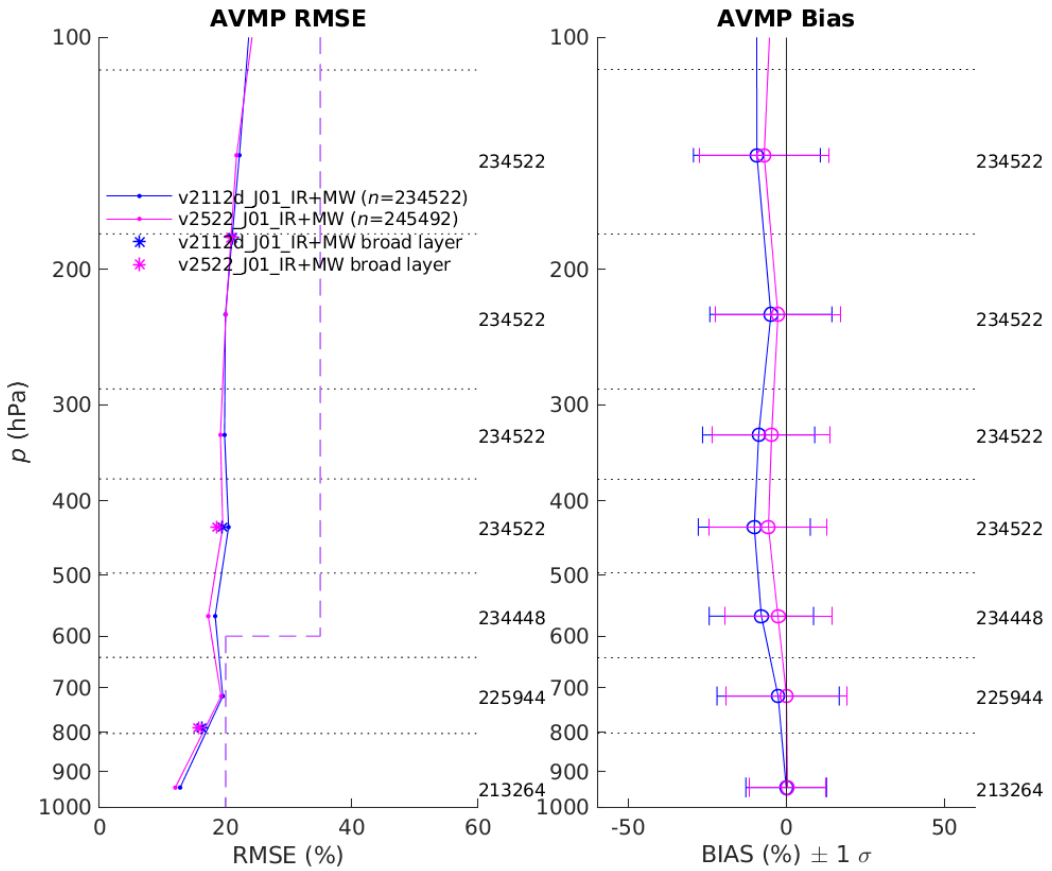
v2.1.12d
v2.5.2.2

SNPP



V2.1.12d
V2.5.2.2

NOAA-20

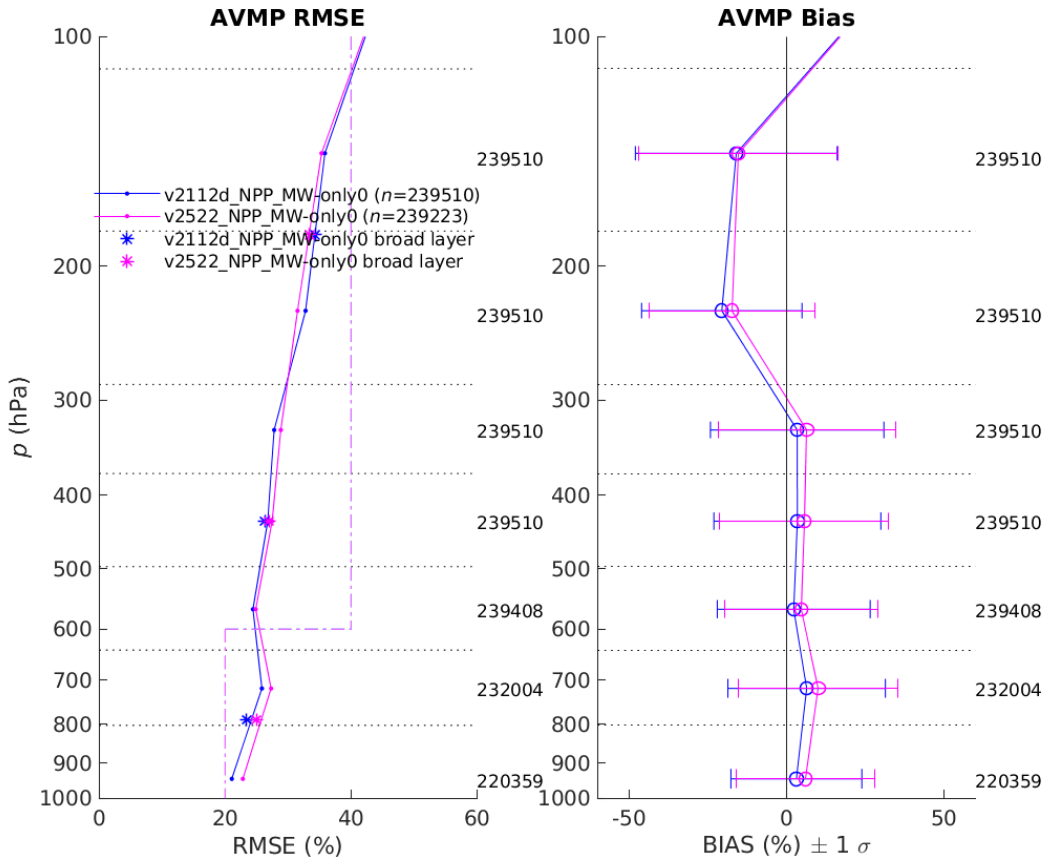


NUCAPS MW-Only AVMP (H_2O) vs ECMWF

Focus Day 20 August 2018: Global Clear-to-Partly Cloudy

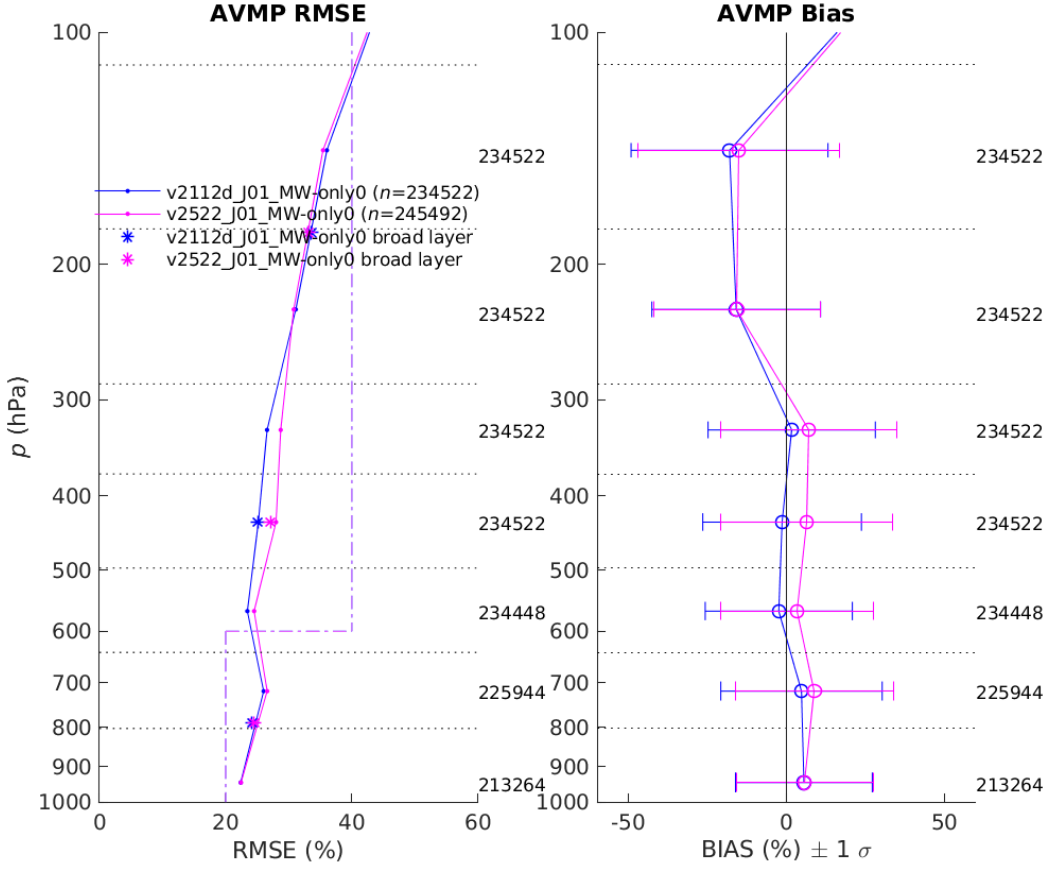
v2.1.12d
v2.5.2.2

SNPP



V2.1.12d
V2.5.2.2

NOAA-20

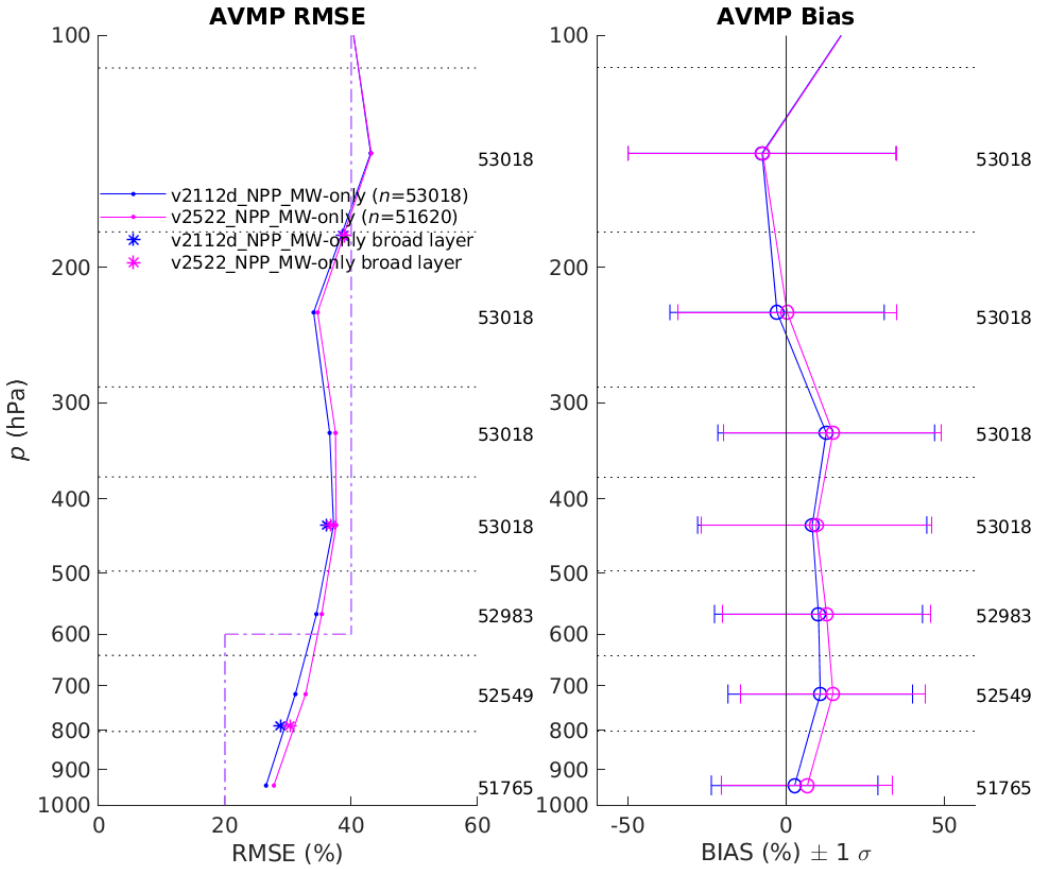


NUCAPS MW-Only AVMP (H_2O) vs ECMWF

Focus Day 20 August 2018: Cloudy Excluding SH Polar Cap

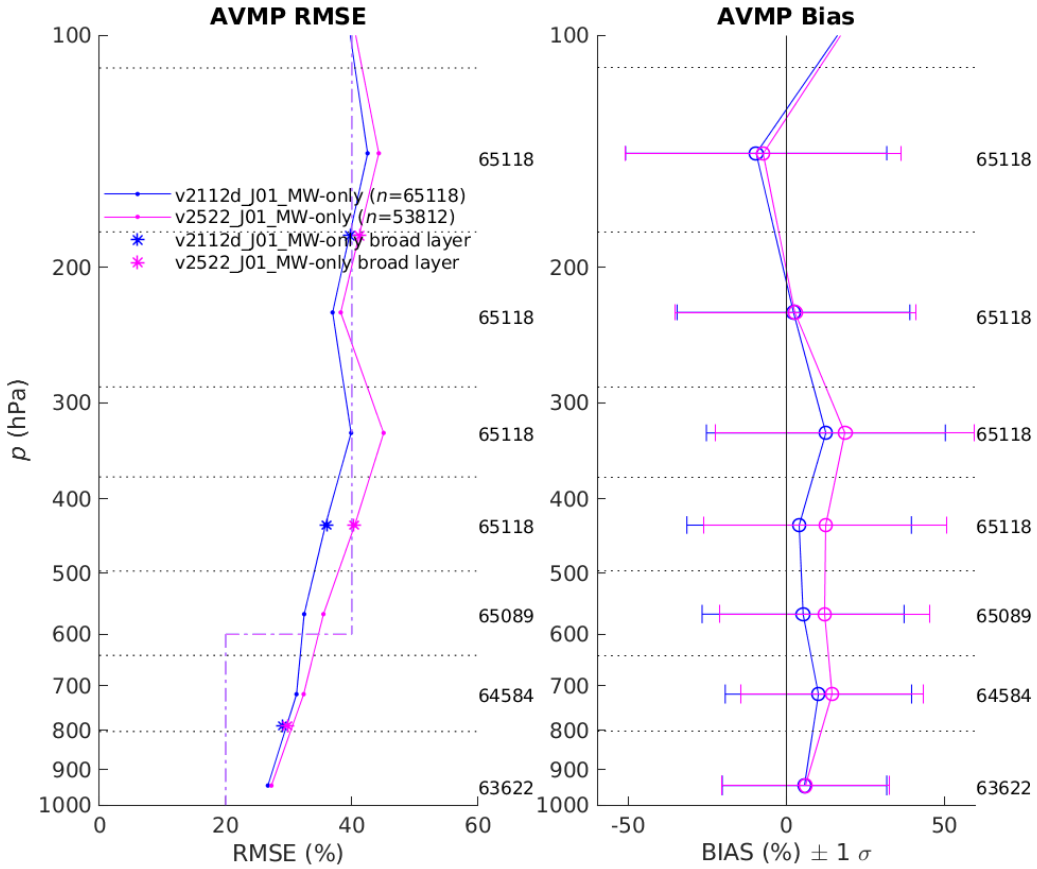
v2.1.12d
v2.5.2.2

SNPP



V2.1.12d
V2.5.2.2

NOAA-20

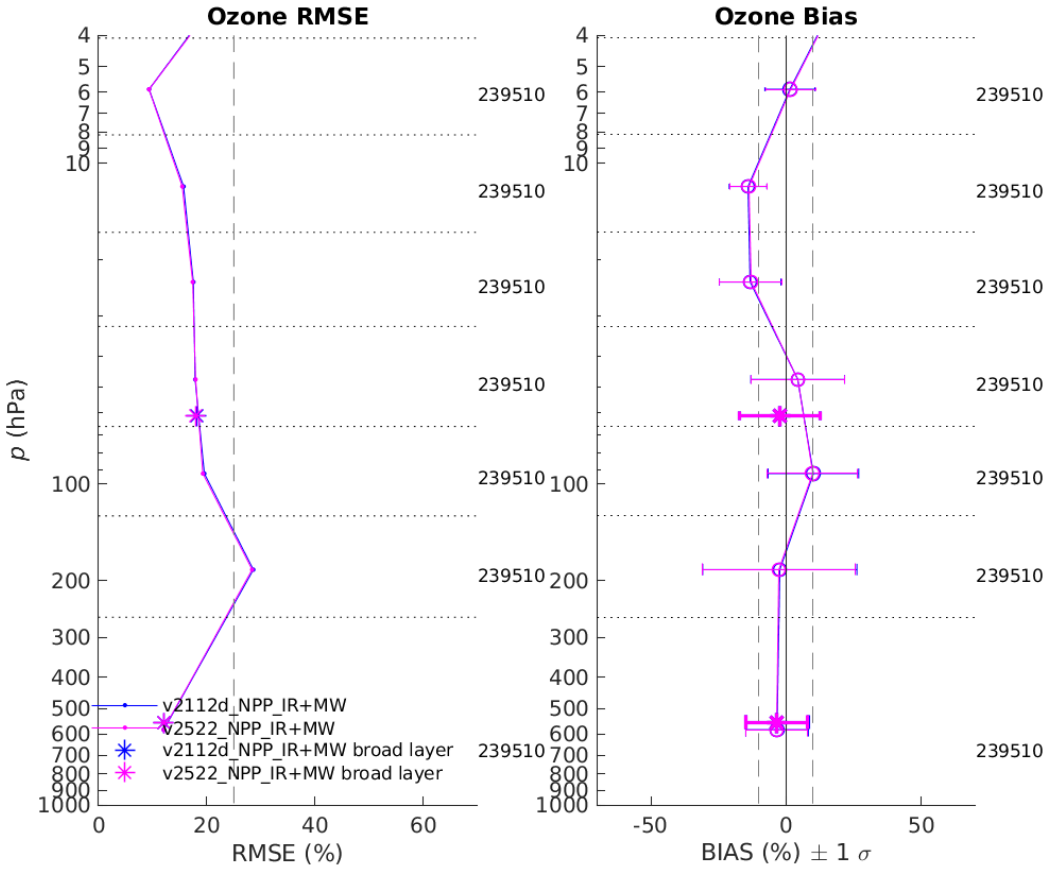


NUCAPS IR Ozone Profile (O_3) vs ECMWF

Focus Day 20 August 2018: Global Clear-to-Partly Cloudy

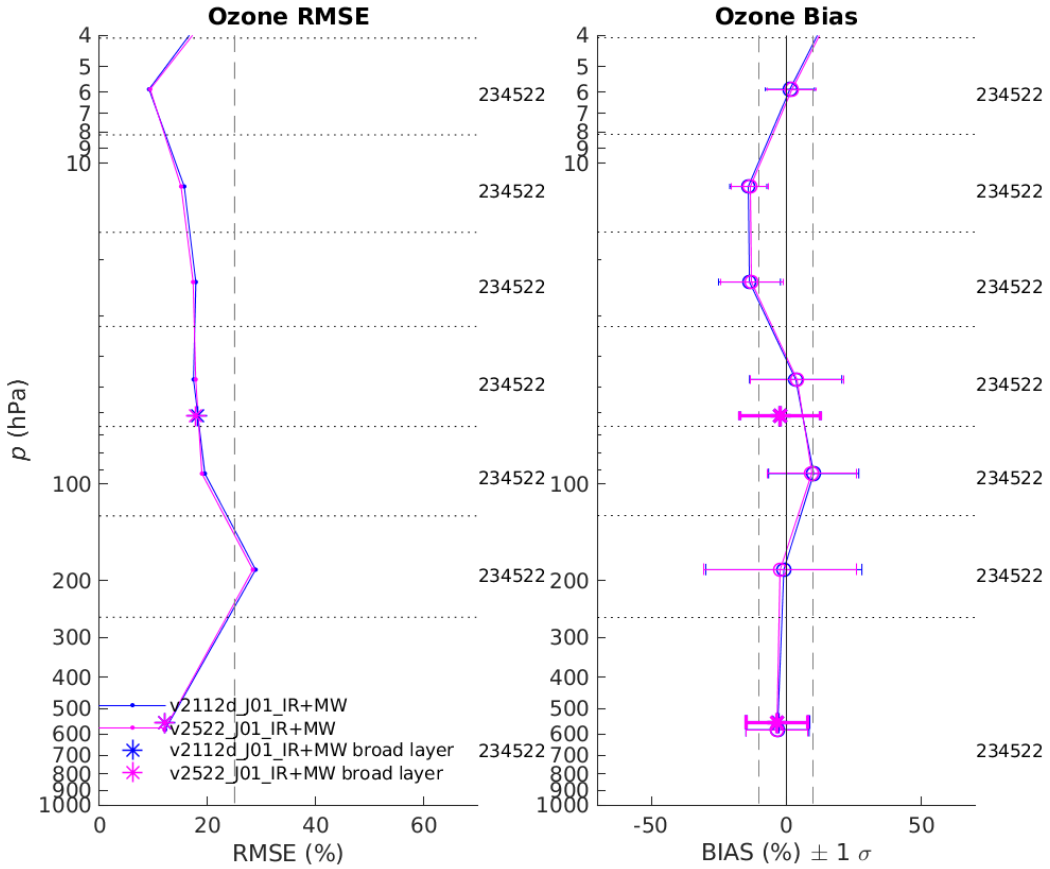
v2.1.12d
v2.5.2.2

SNPP

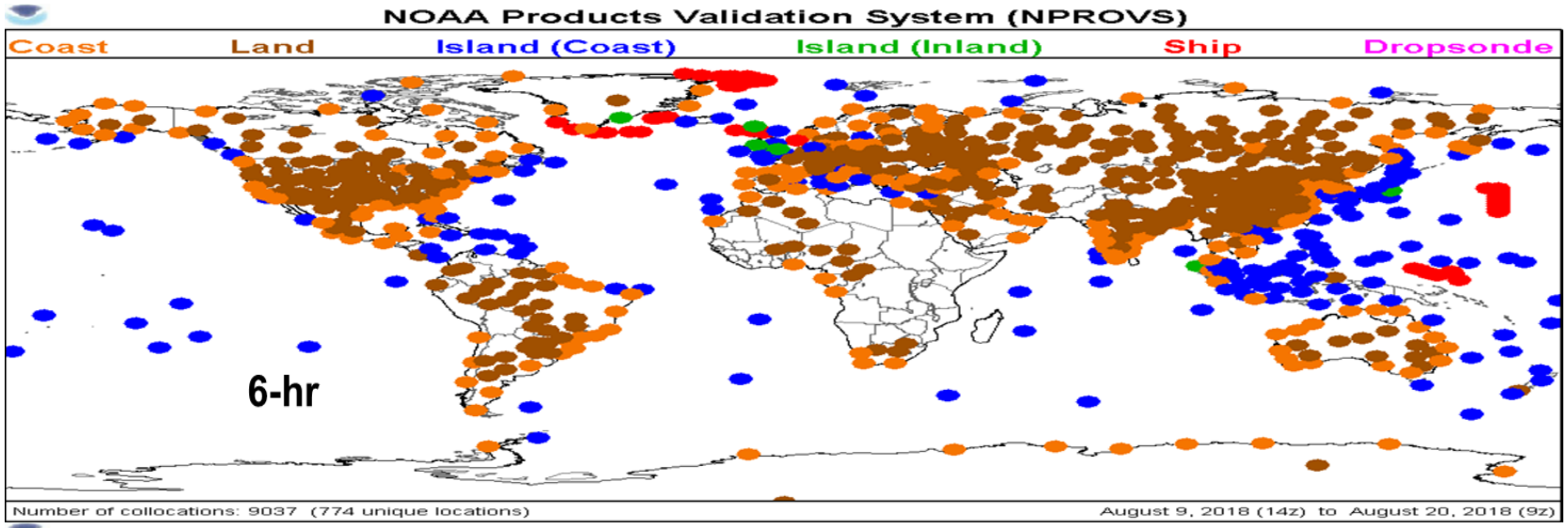


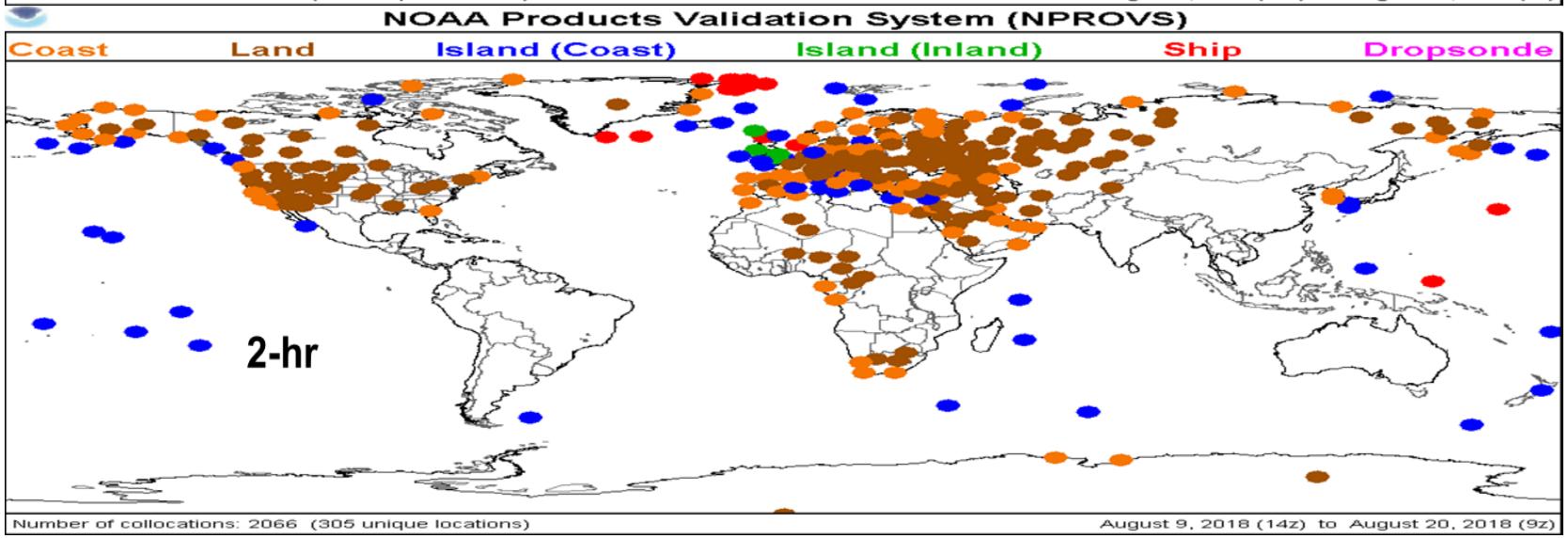
V2.1.12d
V2.5.2.2

NOAA-20



NOAA Products Validation System (NPROVS) Conventional RAOB Collocations





Collocated Radiosonde and N20/NPP NUCAPS (IR+MW pass QC) … 10-20 Aug 2018

NPROVS

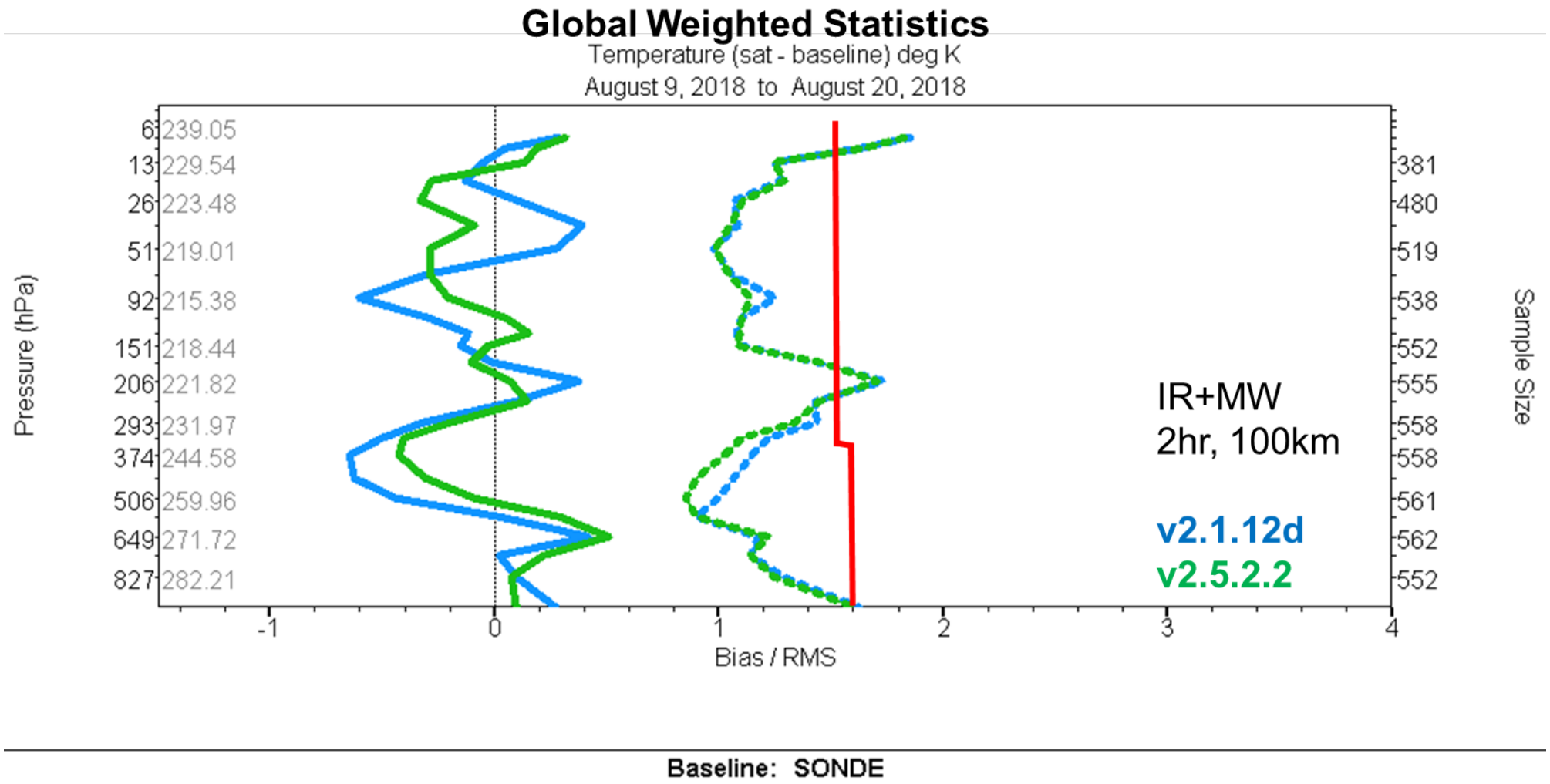
(*Reale et al.* 2012; *Sun et al.* 2017)

Global Weighted Statistics
0.3 (Land) + 0.7 (Sea)

Land:
Satellite (Land, Coast … ice, snow, glacier)
RAOB (**Land, Coast, Island inland**

Sea:
Satellite (Sea, Coast)
RAOB (**Island, Ship)**

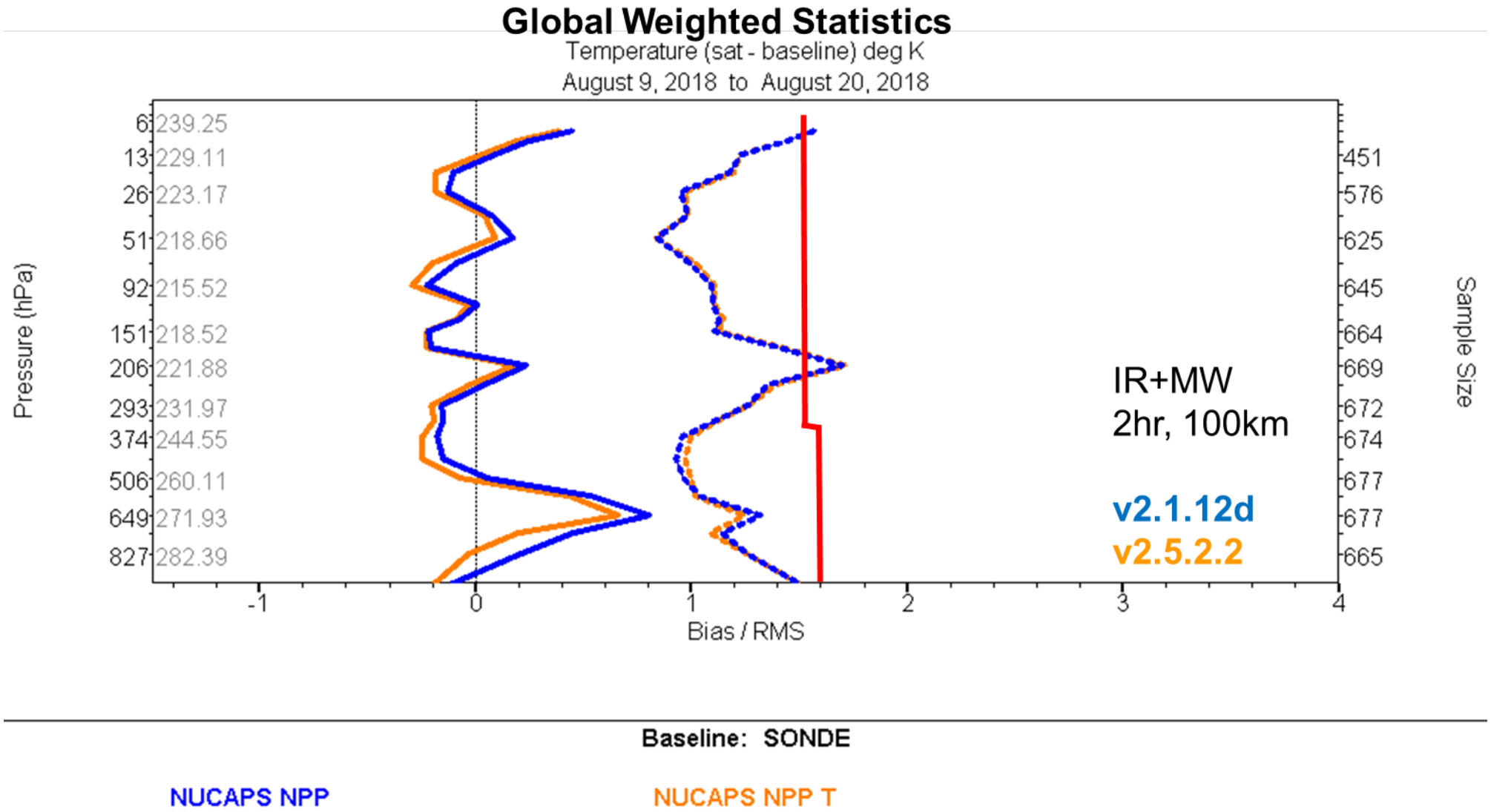
NOAA-20 NUCAPS IR+MW AVTP vs NPROVS Conventional RAOB



Collocated Radiosonde and NOAA-20 NUCAPS (IR+MW pass QC) … Aug 10-20, 2018

(Requirement)

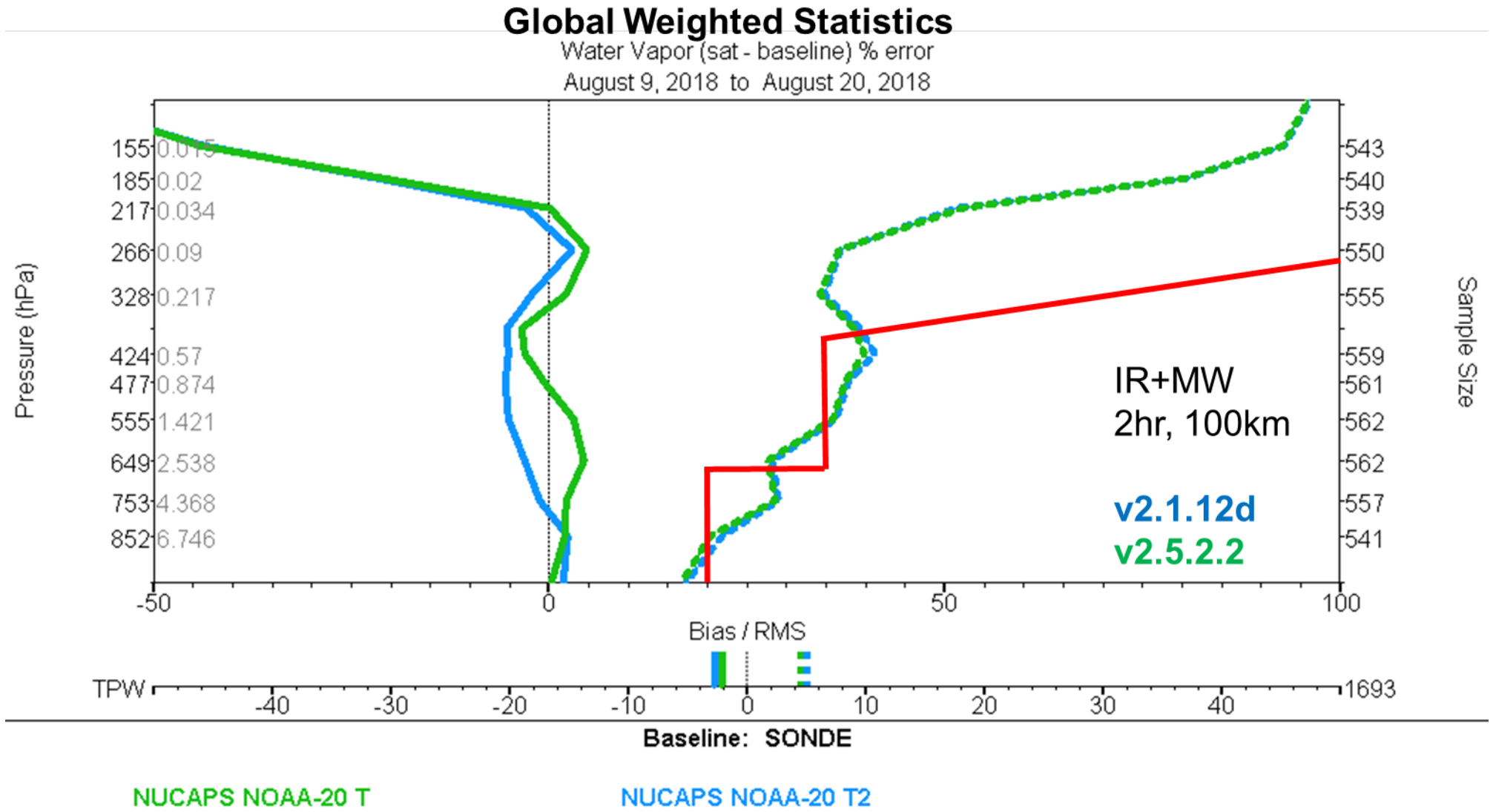
SNPP NUCAPS IR+MW AVTP vs NPROVS Conventional RAOB



Collocated Radiosonde and SNPP NUCAPS (IR+MW pass QC) … Aug 10-20, 2018

(Requirement)

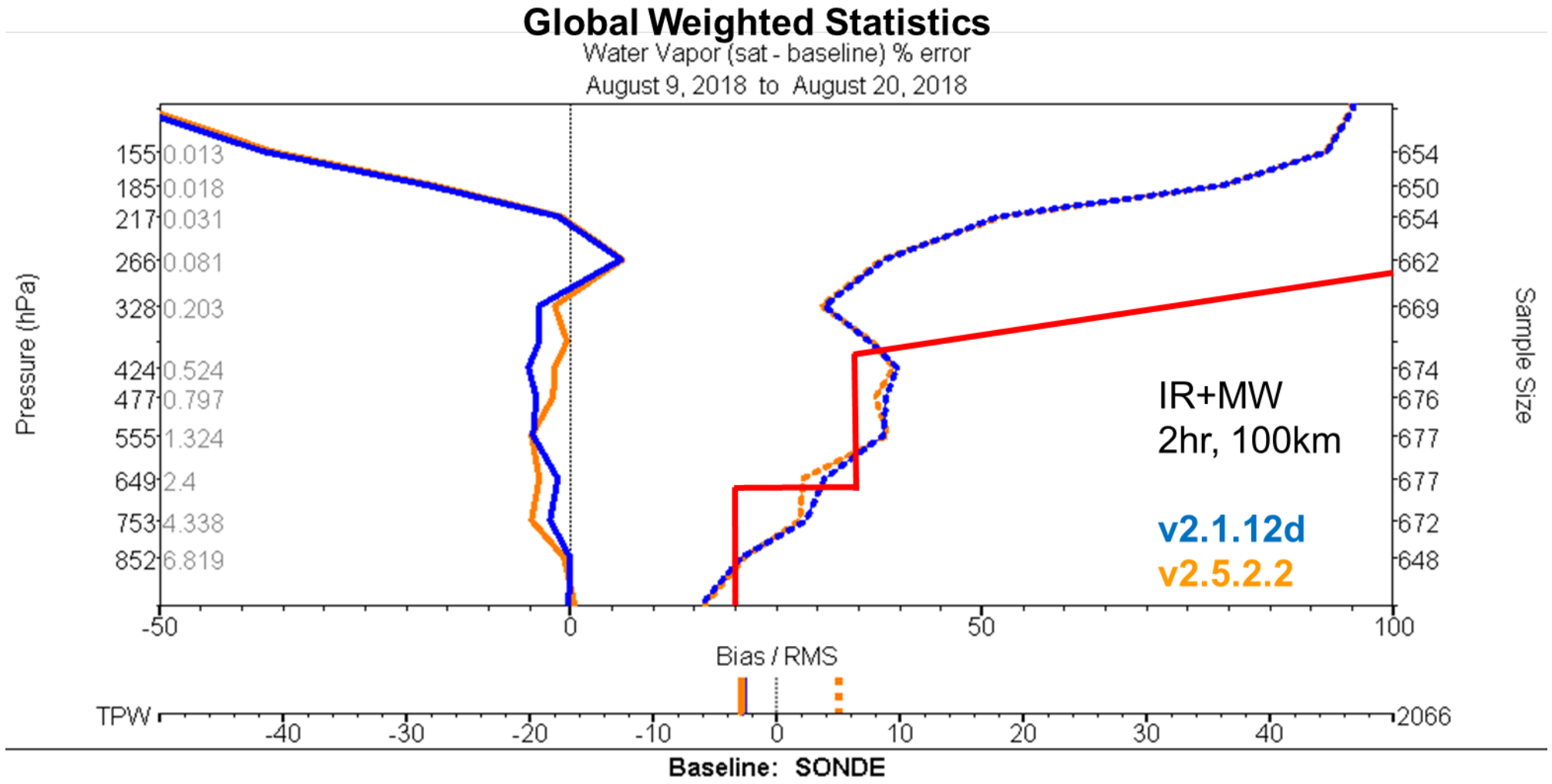
NOAA-20 NUCAPS IR+MW AVMP vs NPROVS Conventional RAOB



Collocated Radiosonde and NOAA-20 NUCAPS (IR+MW pass QC) … Aug 10-20, 2018

(Requirement)

SNPP NUCAPS IR+MW AVMP vs NPROVS Conventional RAOB



NUCAPS NPP NUCAPS NPP T

Collocated Radiosonde and SNPP NUCAPS (IR+MW pass QC) … Aug 10-20, 2018

(Requirement)

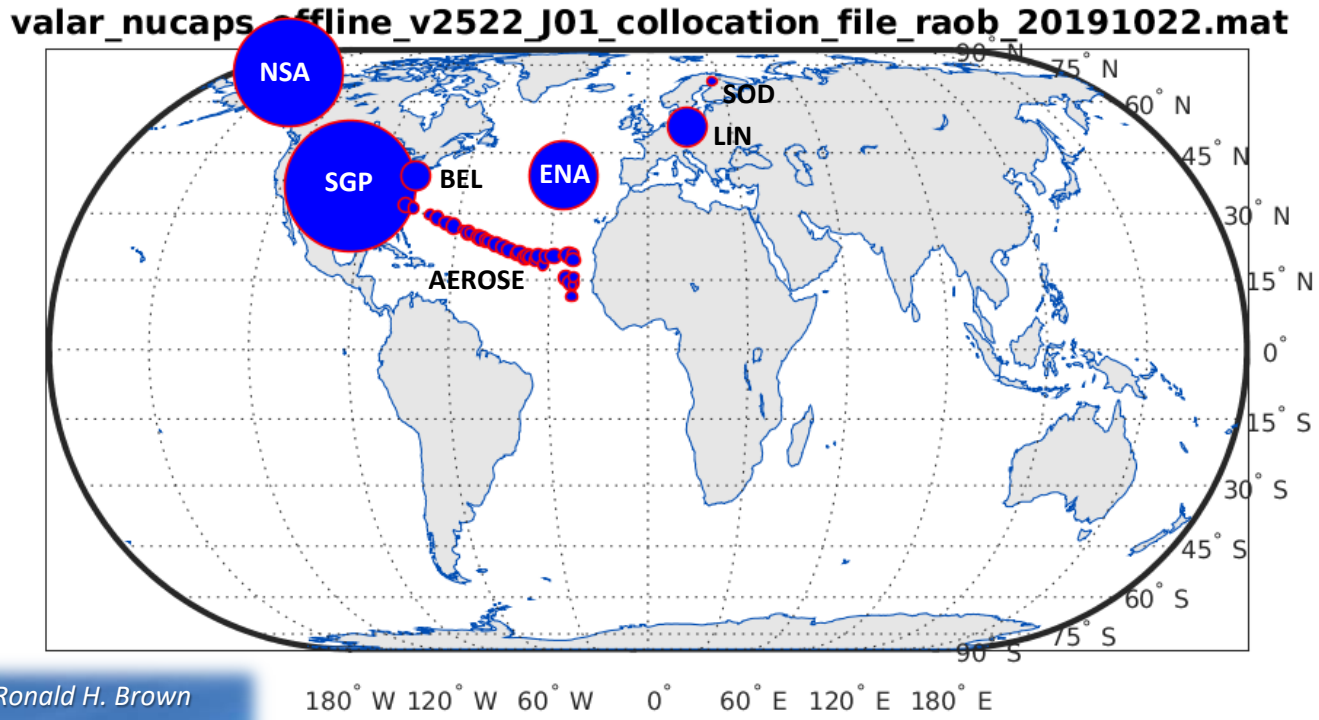
VALAR NUCAPS Dedicated RAOB Collocations

Validation Archive (VALAR)

- CrIS/ATMS granules SDR/TDR matched with truth data using NPROVS collocation files
  - **Atmospheric Radiation Measurement (ARM)** Sites (*Tobin et al.* 2006)
    - Eastern North Atlantic (ENA)
    - Southern Great Plains (SGP)
    - North Slope of Alaska (NSA)
    - Radiosonde Intercomparison and Validation (RIVAL) campaign
  - **GRUAN** Sites (Bodeker et al. 2016)
    - Lindenberg, Germany (LIN)
    - Sodankyla, Finland (SOD)
    - Beltsville, Maryland (BEL/HUBC)
  - **2019 NOAA AEROSE** campaign (*Nalli et al.* 2011; *Morris et al.* 2006)
    - Mar 2019, tropical Atlantic Ocean

Geographic Histogram of Dedicated RAOB NOAA-20 Collocations (Equal Area)

($\delta x \leq$ 100 km, $-100 < \delta t < +5$ min)

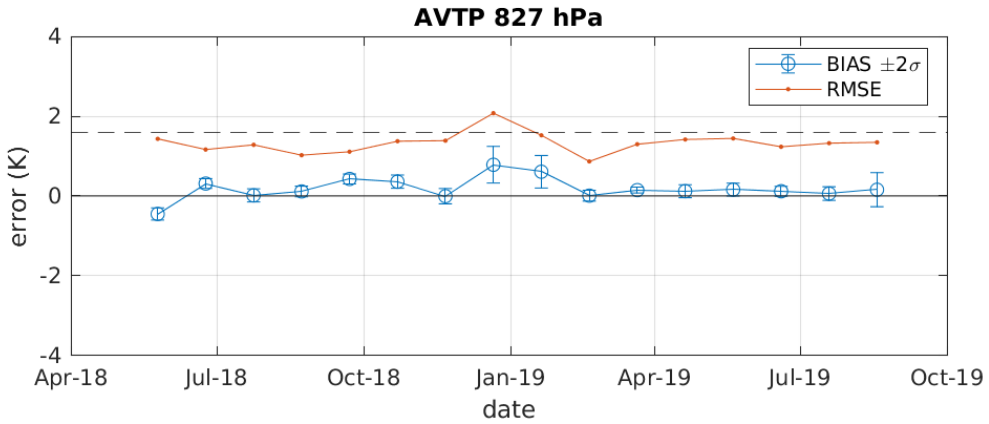


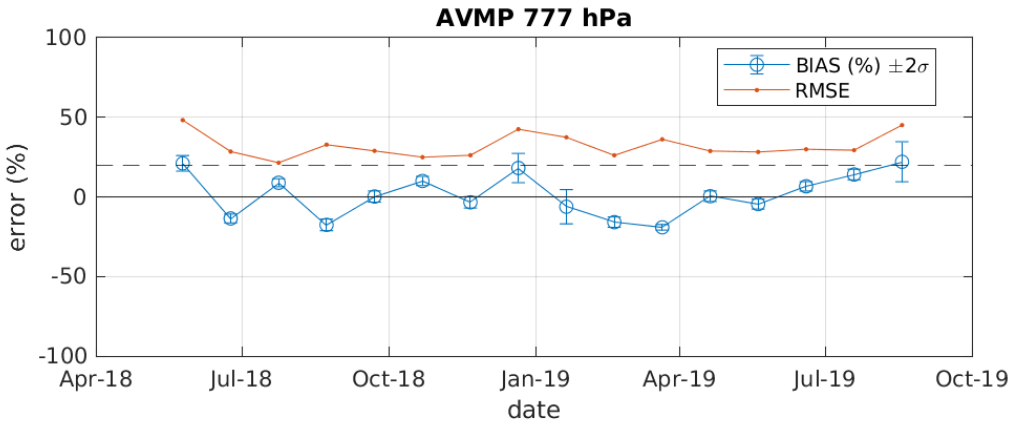
Rigorous zonal and land/sea surface area weighting are applied to VALAR collocation sample statistics.

NUCAPS NOAA-20 AVTP/AVMP vs Dedicated RAOB: 30-Day Time Series

Bias ±2σ
RMSE

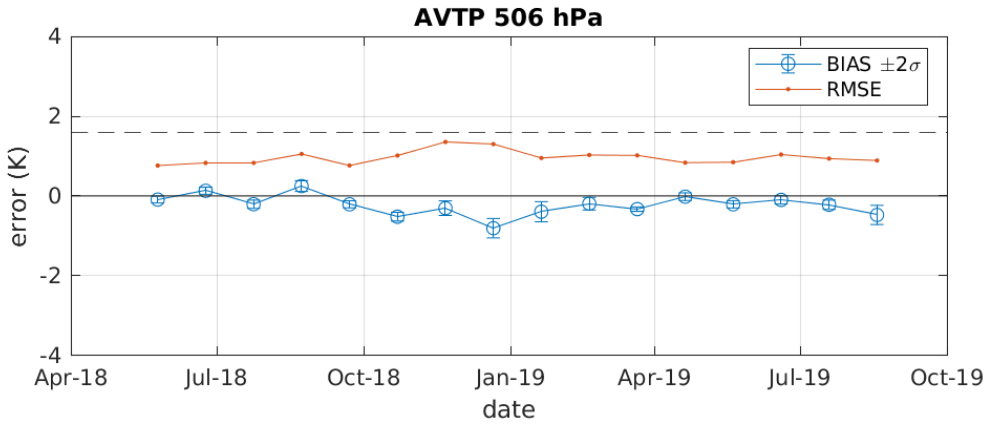
Lower Troposphere (≈850 hPa)

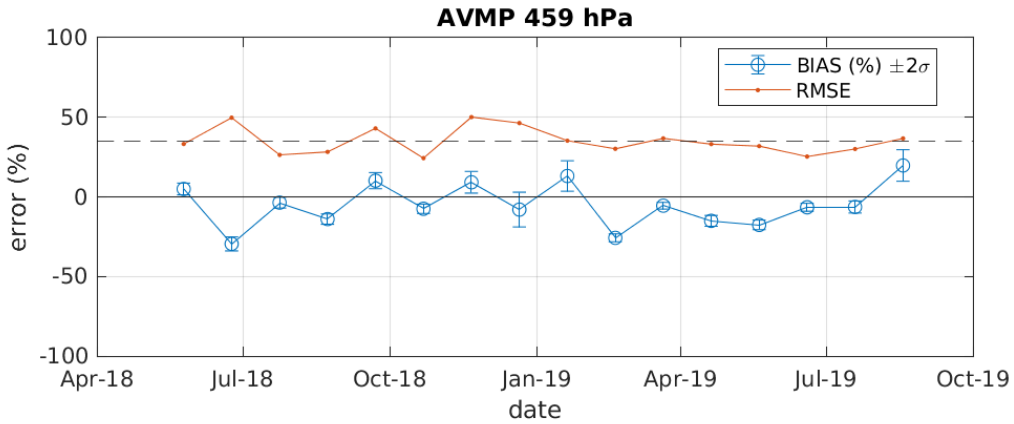




Bias ±2σ
RMSE

Mid-Troposphere (≈500 hPa)

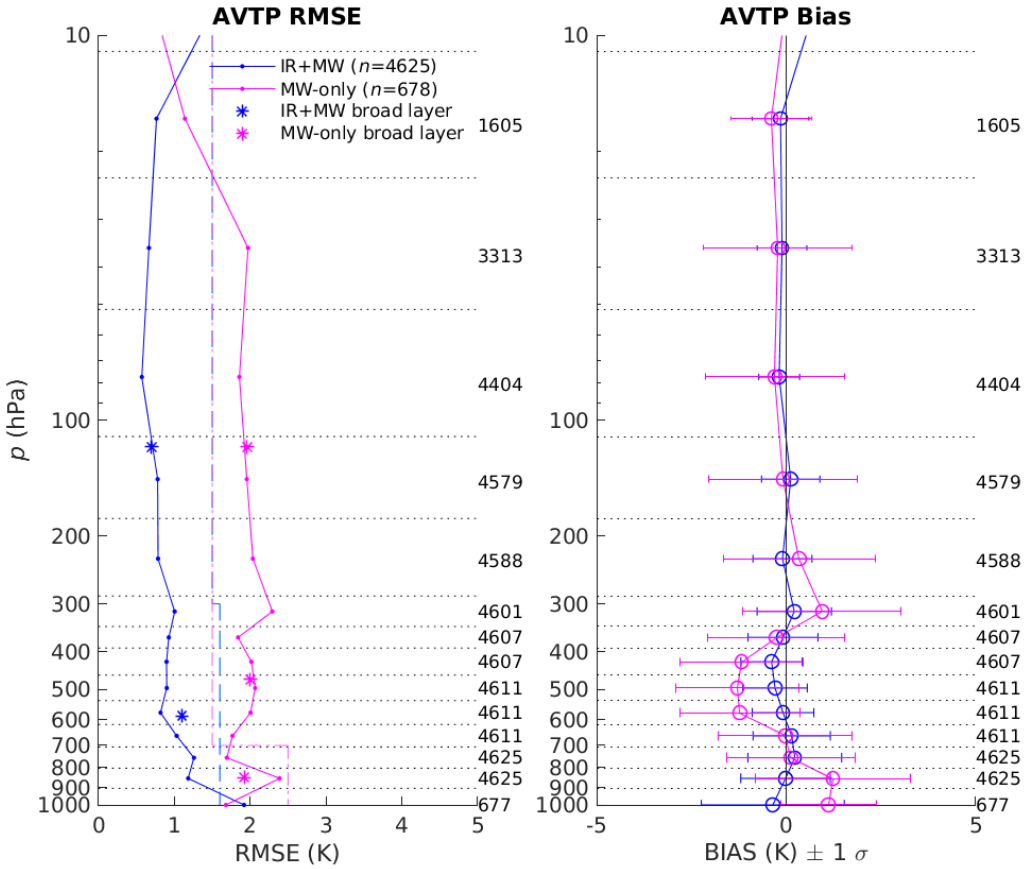




NUCAPS NOAA-20 AVTP/AVMP vs Dedicated RAOB

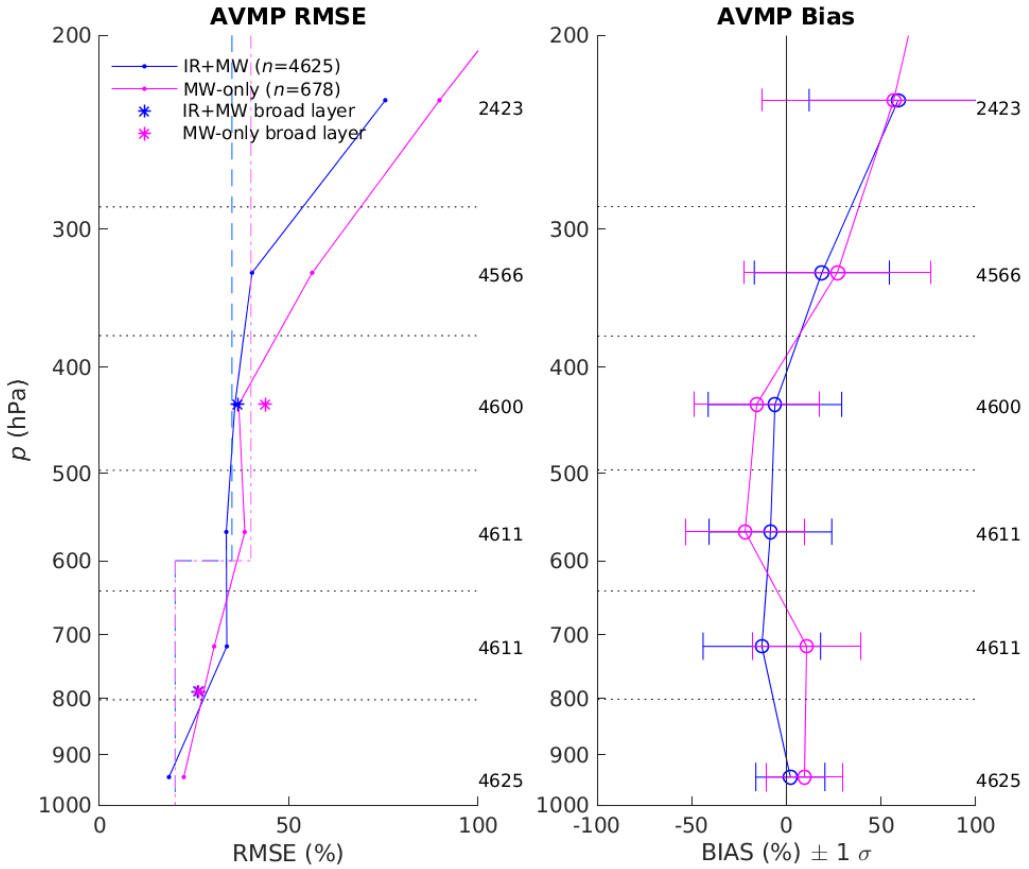
IR+MW
MW-Only

AVTP



IR+MW
MW-Only

AVMP



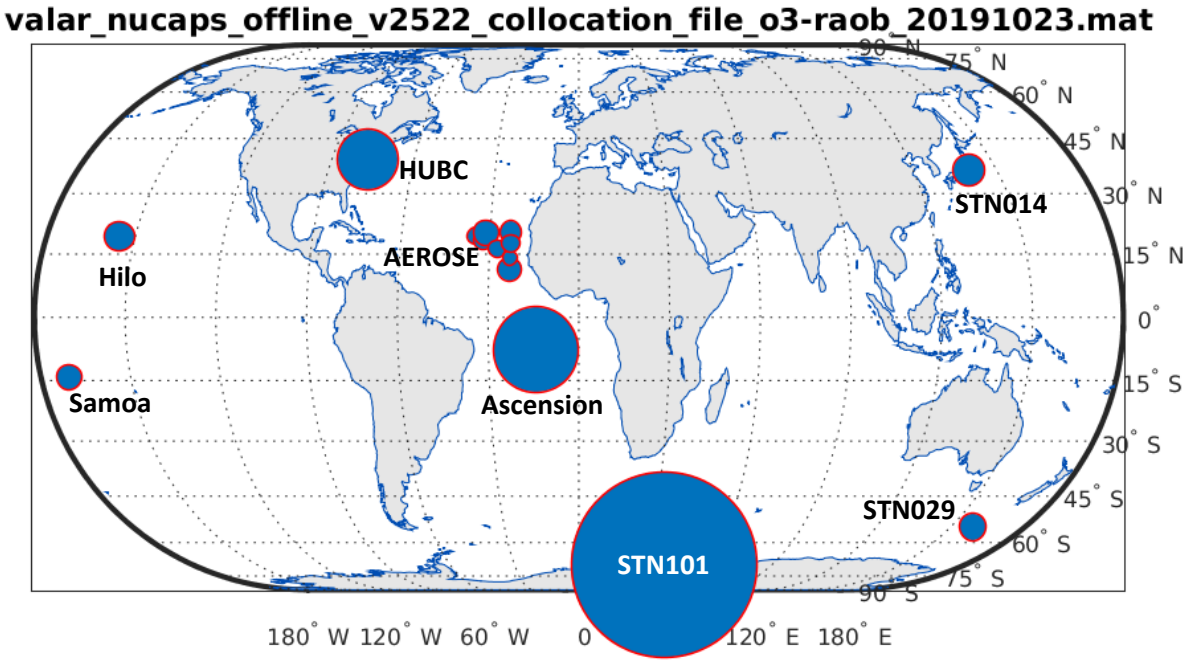
VALAR Ozonesonde Collocations

- **Dedicated Ozonesondes**
  - 2019 AEROSE campaign (*Nalli et al.* 2011; *Morris et al.* 2006)
  - Howard University Beltsville (HUBC) site

- **Land-Based Sites**
  - **World Ozone and Ultraviolet Radiation Data Centre (SHADOZ)** (*Thompson et al.* 2004, 2007)
    - Ascension
    - Hilo
    - American Samoa
  - **WMO World Ozone and Ultraviolet Radiation Data Centre (WOUDC)**
    - STN014
    - STN029
    - STN101

Geographic Histogram of NOAA-20 Ozonesonde Collocations (Equal Area)

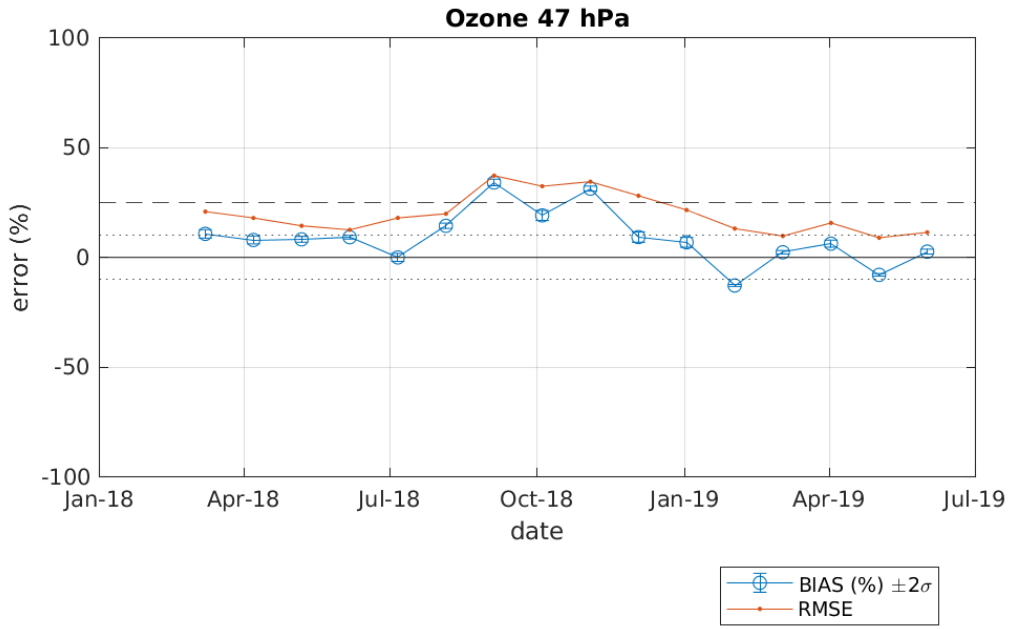
($\delta x \leq$ 125 km, $-240 < \delta t < +120$ min)



NUCAPS NOAA-20 IR Ozone Profile vs Global Ozonesondes: 30-Day Time Series

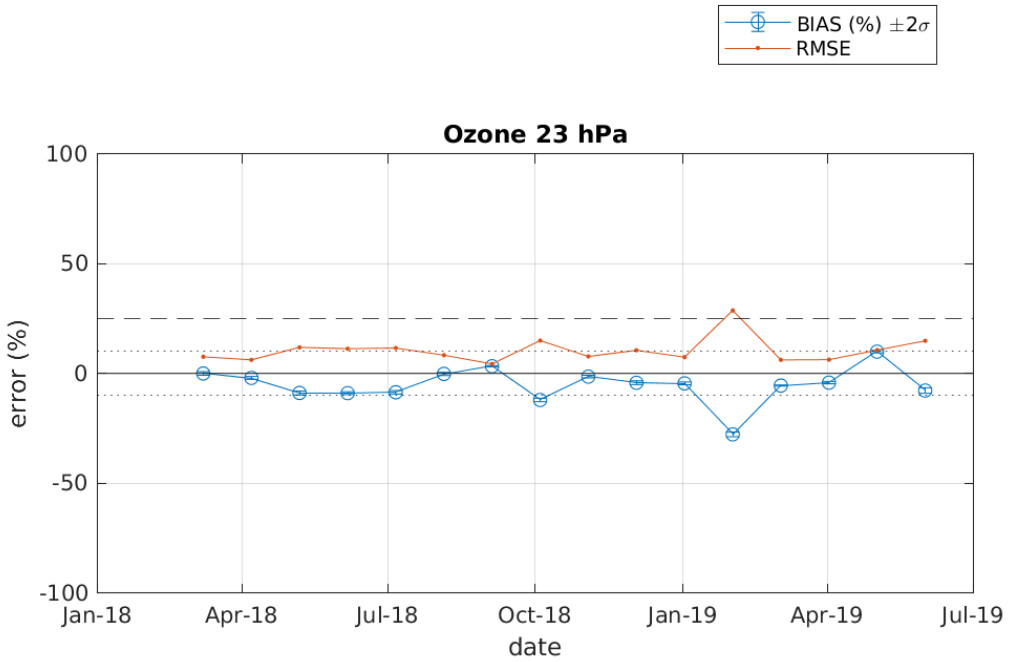
Bias ±2σ
RMSE

UT/LS (47 hPa)



Bias ±2σ
RMSE

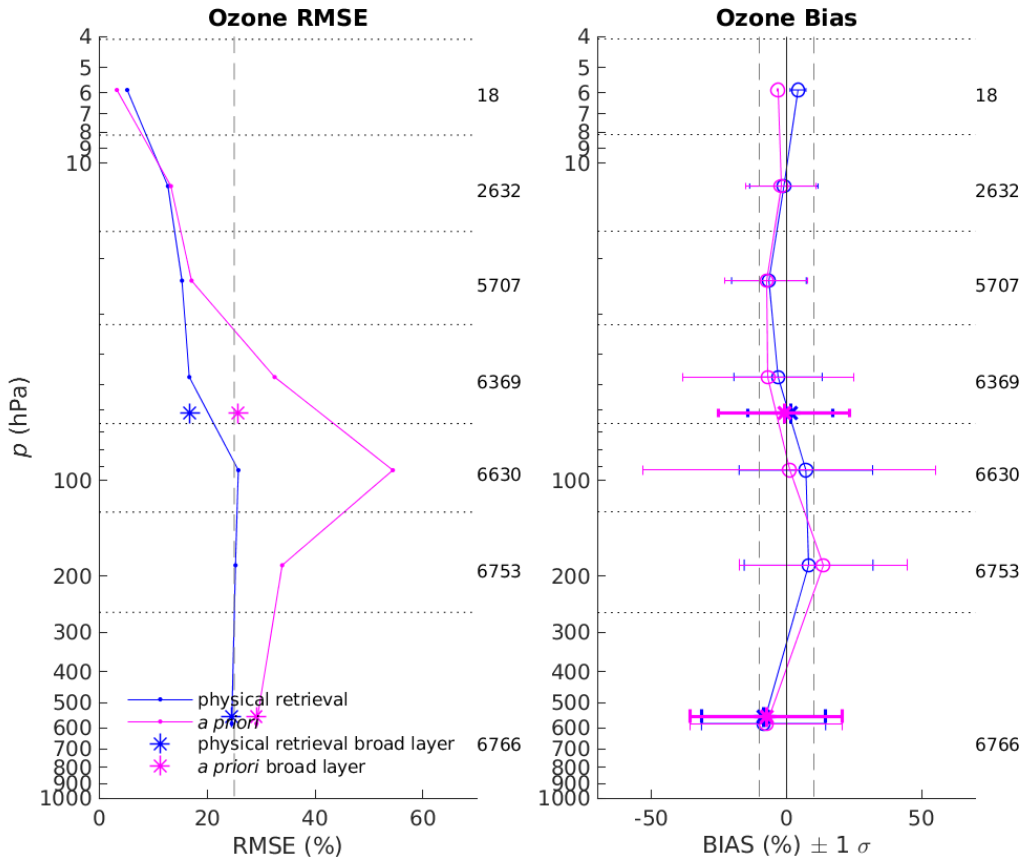
UT/LS (23 hPa)



NUCAPS NOAA-20 IR Ozone Profile vs Global Ozonesondes

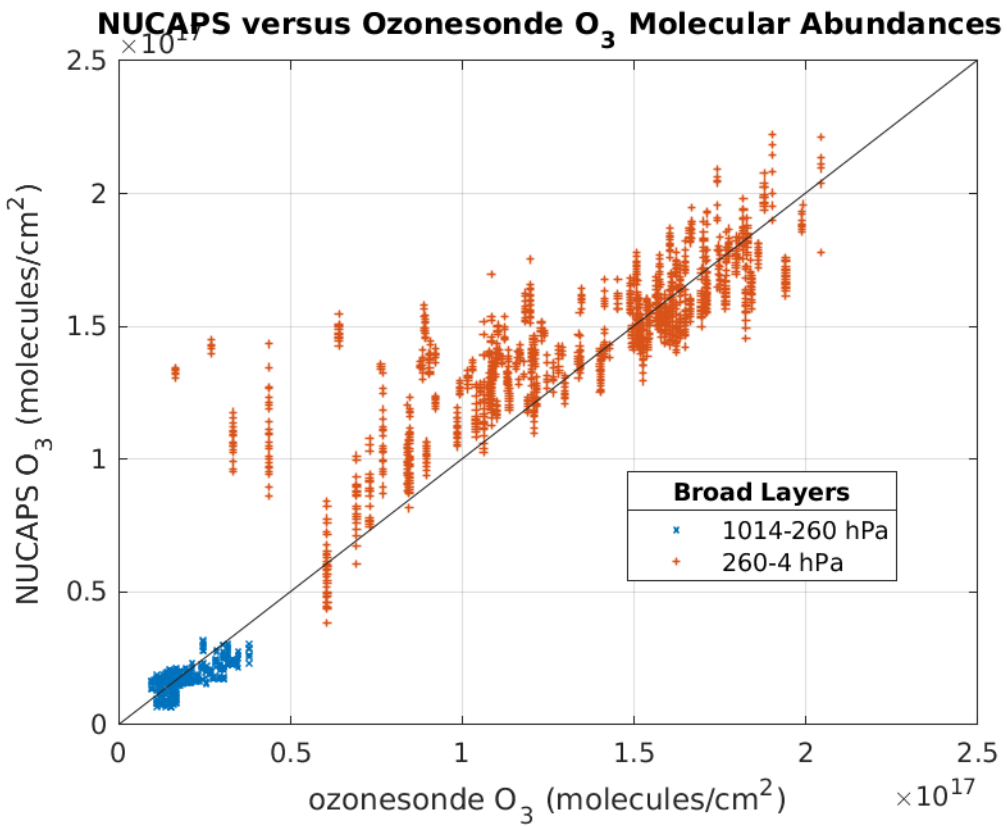
Retrieval
A Priori

Coarse-Layer Statistics



Troposphere
UT/LS

Broad-Layer Scatterplot



AVTP/AVMP Summary Table (v2.5.2.2 vs ECMWF, 20 Aug 2018)

AVTP

Scene	Broad Layer (hPa)	Absolute	
		NUCAPS	Req
Clear-to-Partly Cloudy (IR+MW)	sfc-300	1.2 (1.2)	1.7 K
	300-30	0.75 (0.73)	1.5 K
	30-1	1.5 (1.5)	1.5 K
Cloudy (MW- only*)	sfc-700	3.2 (3.3)	2.5 K
	700-300	1.8 (2.0)	1.5 K
	300-30	1.4 (1.7)	1.5 K
	30-1	1.5 (1.8)	1.5 K
Clear-to-Partly Cloudy (MW-only)	sfc-700	2.6 (2.6)	NA
	700-300	1.6 (1.7)	NA
	300-30	0.93 (1.0)	NA
	30-1	1.3 (1.4)	NA

AVMP

Scene	Broad Layer (hPa)	Fractional		Absolute	
		NUCAPS	Req	NUCAPS	Req
Clear-to-Partly Cloudy (IR+MW)	sfc-600	15.7 (16.4)	20%	0.96 (1.0)	0.2 g/kg
	600-300	18.6 (19.2)	35%	0.20 (0.21)	0.1 g/kg
	300-100	20.9 (21.3)	35%	0.01 (0.01)	0.1 g/kg
Cloudy (MW- only*)	sfc-600	29.8 (30.3)	20%	2.0 (1.9)	0.2 g/kg
	600-300	40.3 (36.8)	40%	0.50 (0.48)	0.1 g/kg
	300-100	41.2 (38.9)	40%	0.02 (0.02)	0.1 g/kg
Clear-to-Partly Cloudy (MW-only)	sfc-600	24.5 (25.0)	NA	1.8 (1.9)	NA
	600-300	27.1 (27.0)	NA	0.29 (0.29)	NA
	300-100	33.1 (33.4)	NA	0.01 (0.01)	NA

NOAA-20 Global Yields:
Clear-to-Part Cld = 72.5%
Cloudy = 14.4%

SNPP Global Yields:
Clear-to-Part Cld = 76.3%
Cloudy = 12.2%

*Cloudy MW-only stats exclude SH polar cap

Values in ( ) indicates SNPP

Meets requirement **Marginal (± 30%)** **Outside Requirement**

AVTP/AVMP Summary Table (NOAA-20 v2.5.2.2 vs Dedicated RAOBs)

AVTP

Scene	Broad Layer (hPa)	Absolute	
		NUCAPS	Req
Clear-to-Partly Cloudy (IR+MW)	sfc-300	1.1 K	1.7 K
	300-30	0.7 K	1.5 K
	30-1	1.2 K	1.5 K
Cloudy (MW- only)	sfc-700	1.9 K	2.5 K
	700-300	2.0 K	1.5 K
	300-30	2.0 K	1.5 K
	30-1	0.9 K	1.5 K

AVMP

Scene	Broad Layer (hPa)	Fractional		Absolute	
		NUCAPS	Req	NUCAPS	Req
Clear-to-Partly Cloudy	sfc-600	26.0%	20%	1.3	0.2 g/kg
	600-300	36.5%	35%	0.21	0.1 g/kg
	300-100	75.5%	35%	0.03	0.1 g/kg
Cloudy (MW- only)	sfc-600	26.3%	20%	1.9	0.2 g/kg
	600-300	43.8%	40%	0.46	0.1 g/kg
	300-100	113.2%	40%	0.01	0.1 g/kg

NOAA-20 Global Yields:
Clear-to-Part Cld = 87%
Cloudy = 10%

Meets requirement

Marginal (± 30%)

Outside Requirement

IR Ozone Profile Summary Table (v2.5.2.2)

Versus ECMWF 20 Aug 2018 Focus Day

Scene	Broad Layer (hPa)	Precision		Accuracy		Combined Uncertainty	
		NUCAPS	Req	NUCAPS	Req	NUCAPS	Req
Clear to Partly-Cloudy	sfc-260	(11.5) 11.5	20%	−3.5 (−3.4)	±10%	12.0 (12.0)	25%
	260-4	(15.0) 14.9	20%	−2.3 (−2.3)	±10%	17.8 (18.1)	25%

Global Yields:
IR+MW = 72.5% (76.3)%

Versus VALAR Ozonesondes

Scene	Broad Layer (hPa)	Precision		Accuracy		Combined Uncertainty	
		NUCAPS	Req	NUCAPS	Req	NUCAPS	Req
Clear to Partly-Cloudy	sfc-260	23.0	20%	−8.5	±10%	24.5	25%
	260-4	15.7	20%	+1.5	±10%	16.8	25%

Global Yields:
IR+MW = 89.0%

Values in ( ) indicates SNPP

Meets requirement | Marginal (± 25%) | Outside Requirement

NOAA-20 Validated Maturity – AVTP, AVMP, and Ozone

Validated Maturity End State	Assessment
Product performance has been demonstrated over a large and wide range of representative conditions (i.e., global, seasonal).	Yes. See slides 33-69
Comprehensive documentation of product performance exists that includes all known product anomalies and their recommended remediation strategies for a full range of retrieval conditions and severity level.	Yes. See slide 164
Product analyses are sufficient for full qualitative and quantitative determination of product fitness-for-purpose.	Yes. See slides 33-69.
Product is ready for operational use based on documented validation findings and user feedback.	Yes. See User Feedback and Downstream Products Feedback slides 119-160.
Product validation, quality assurance, and algorithm stewardship continue through the lifetime of the instrument	Yes. See planned activities slide 168-172.

CRIS OUTGOING LONGWAVE RADIATION (OLR) EDR

NUCAPS Product Maturity: OLR

Product	Maturity Level			
	SNPP		NOAA-20	
	Current Status	Maturity Level **Aimed**	Current Status	Maturity Level Aimed
NOAA-20 OLR	✓ Validated	✓ Remain Validated	✓ Provisional	❑ Validated

- Processing Environment and Algorithms (Alg. Version, LUTs, Effective date)

  ✓ V2.5.2.2 DAP is the optimized NUCAPS algorithm for NOAA-20 products.
  - NOAA-20 AVTP, AVMP, Ozone for validated maturity
  - **NOAA-20 OLR for validated maturity**
  - SNPP/NOAA-20 CO for validated maturity
  - SNPP/NOAA-20 CH4 for provisional maturity.
  - SNPP/NOAA-20 CO2 Currently Beta (Maturity Review planned for February 2020)

NUCAPS-OLR Reference data, Time Periods

NUCAPS-OLR	Reference Data	Time Period	Validation
• NOAA-20 daily OLR	• CERES Aqua OLR • CrIS SNPP OLR	• 2018-09-16	✓ All Good ✓ Meets the requirement.
• NOAA-20 monthly OLR	• CERES Aqua monthly OLR • CrIS SNPP monthly OLR	• 2018-08	✓ All Good ✓ Meets the requirement.
• NOAA-20 yearly OLR	• CERES Aqua yearly OLR • CrIS SNPP yearly OLR	• 20180414 • 20180516 • 20180615 • 20180716 • 20180813 • 20180916 • 20181015 • 20181114 • 20181215 • 20190117 • 20190215 • 20190316	✓ All Good ✓ Meets the requirement

Summary:
NUCAPS NOAA-20 OLR meets all maturity review requirements.

NUCAPS-OLR Reference Data: CERES Aqua

Raw data

CER_SSF_Aqua-FM3-MODIS_Edition4A

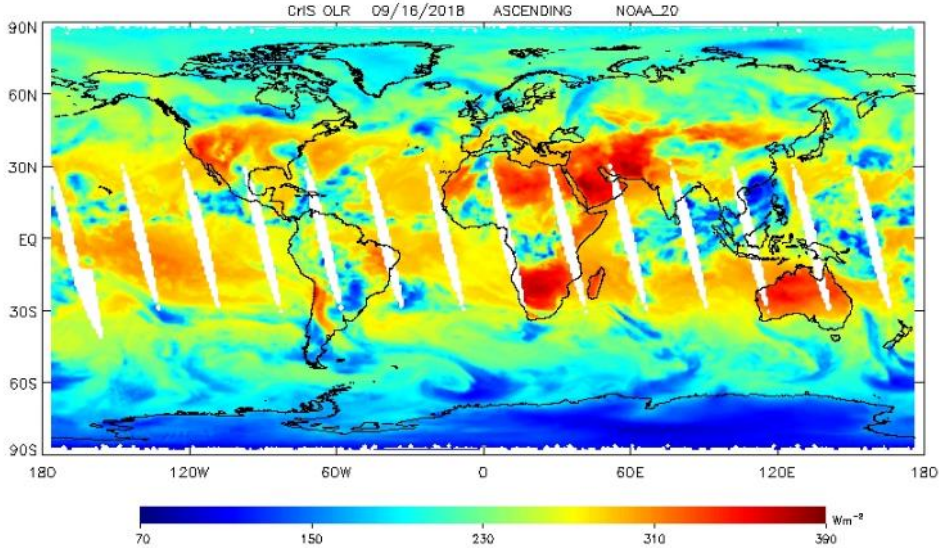
https://search.earthdata.nasa.gov/search/granules?p=C7460996-LARC_ASDC&m=0!0!0!1!0!0%2C2&tl=1548791354!4!!&q=CER_SSF_Aqua-FM3-MODIS&ok=CER_SSF_Aqua-FM3-MODIS&ac=true

Processed data

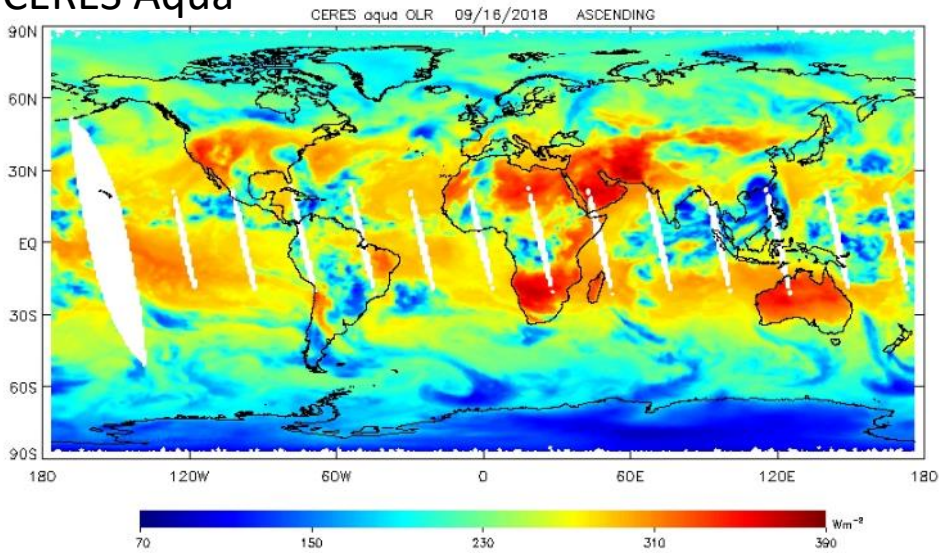
Averaged CERES OLR on 1° lat/lon grid

NUCAPS CrIS NOAA-20 OLR Validation –Daily OLR (16-Sep-2018 Ascending)

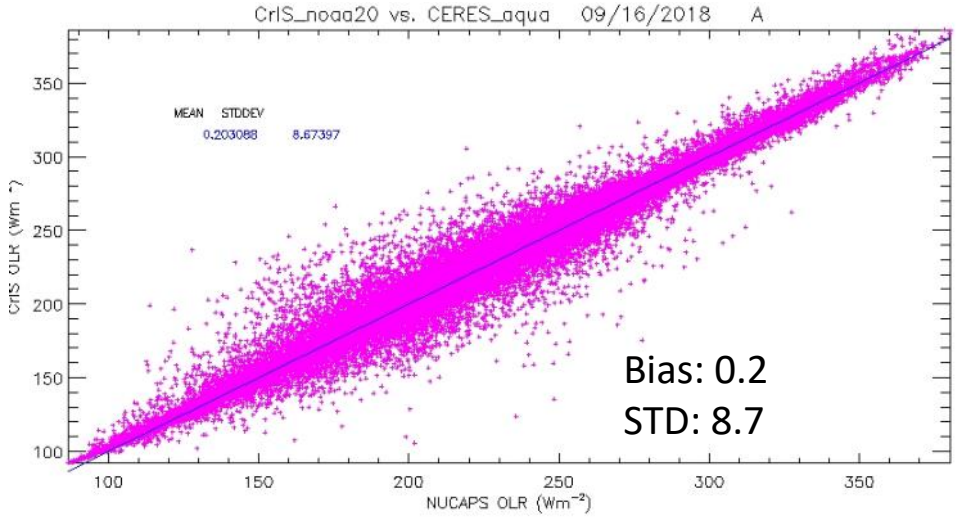
CrIS NOAA-20



CERES Aqua

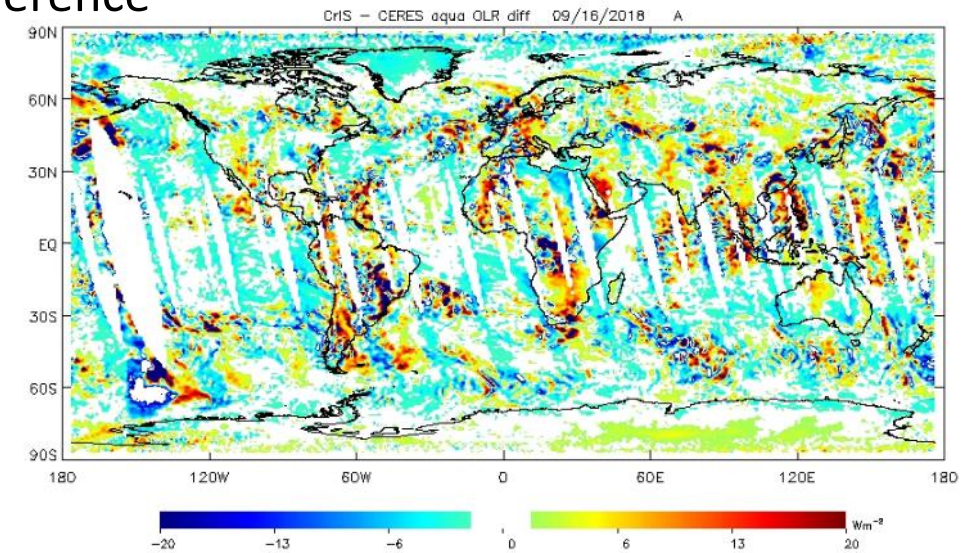


CrIS NOAA-20 OLR vs CERES Aqua OLR



CrIS NOAA-20 agrees well with CERES Aqua and meets requirements

Difference

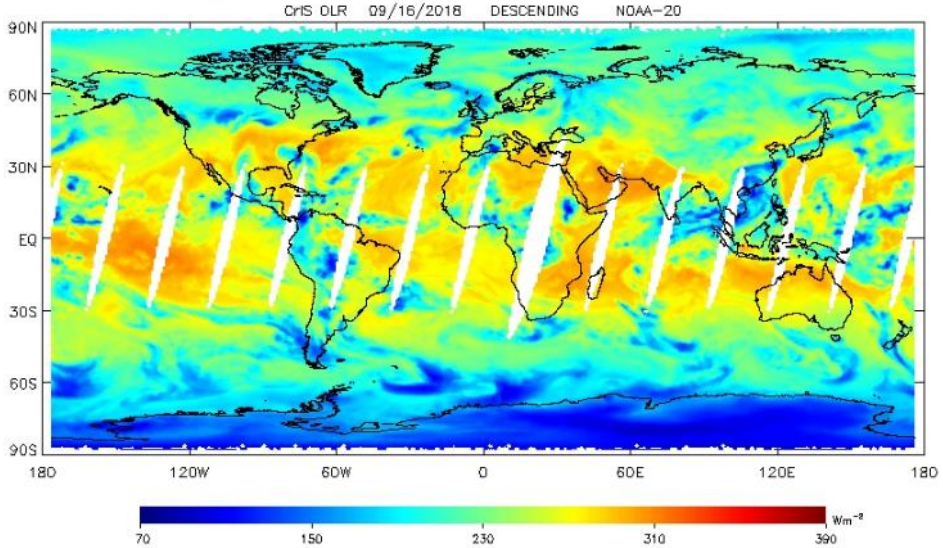


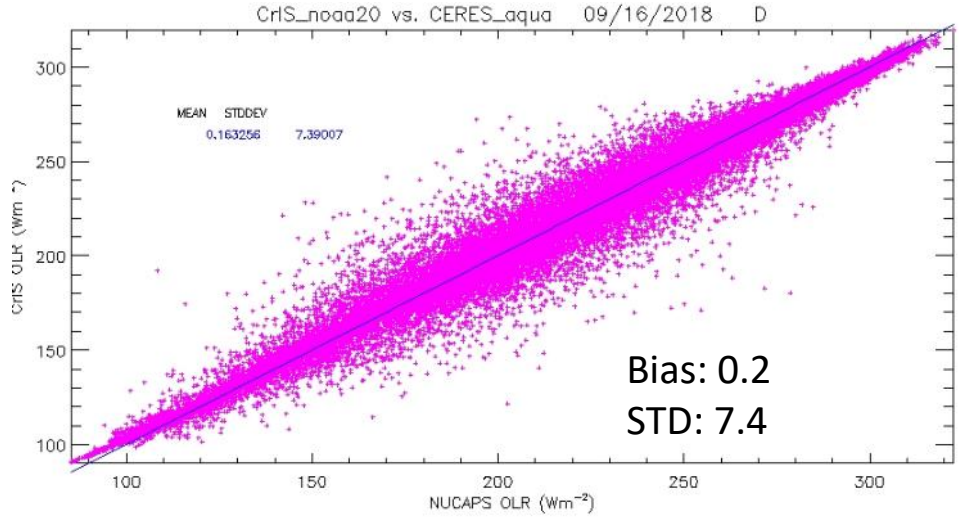
W/m²	BIAS	STD
Requirement	5.0	12.0
CrIS NOAA-20	0.2	8.7

NUCAPS CrIS NOAA-20 OLR Validation –Daily OLR (16-Sep-2018 Descending)

CrIS NOAA-20 OLR vs CERES Aqua OLR

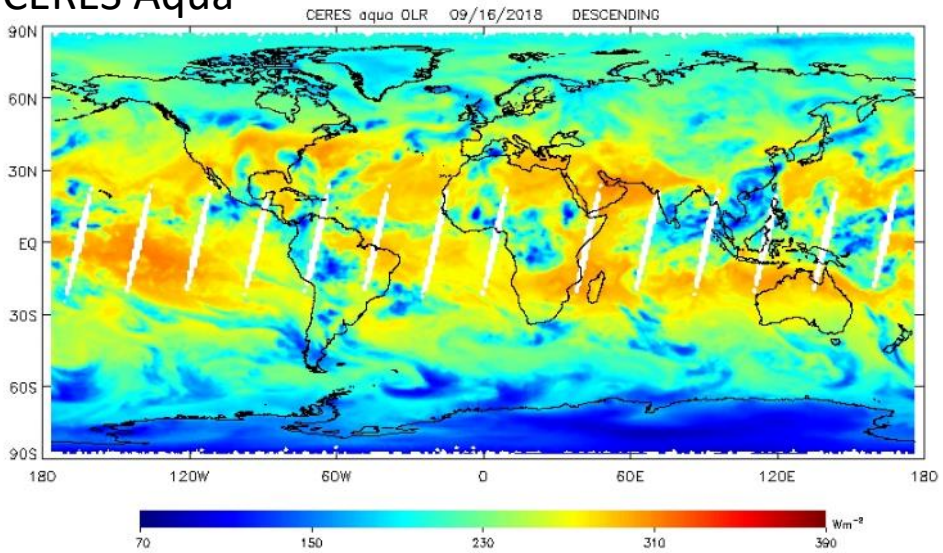
CrIS NOAA-20



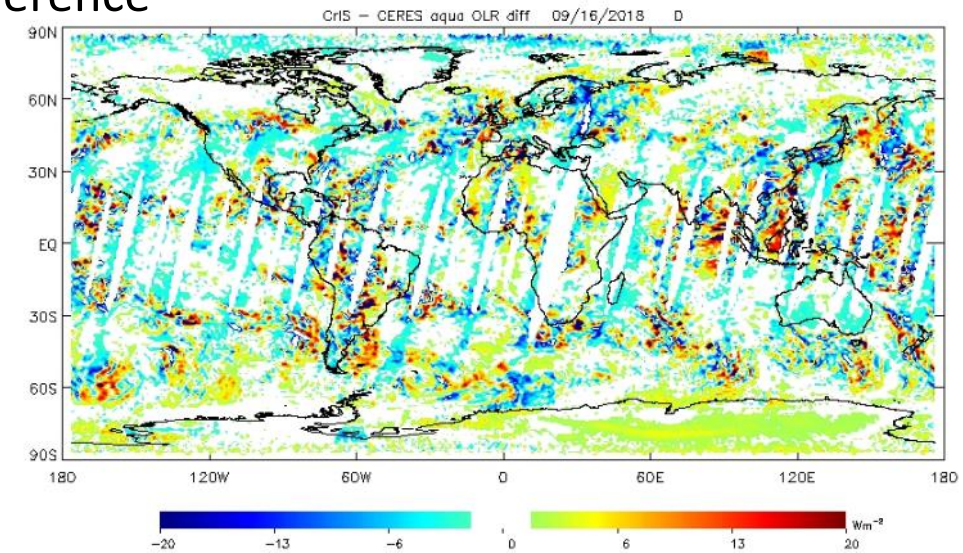


CrIS NOAA-20 agrees well with CERES Aqua and meets requirements

CERES Aqua



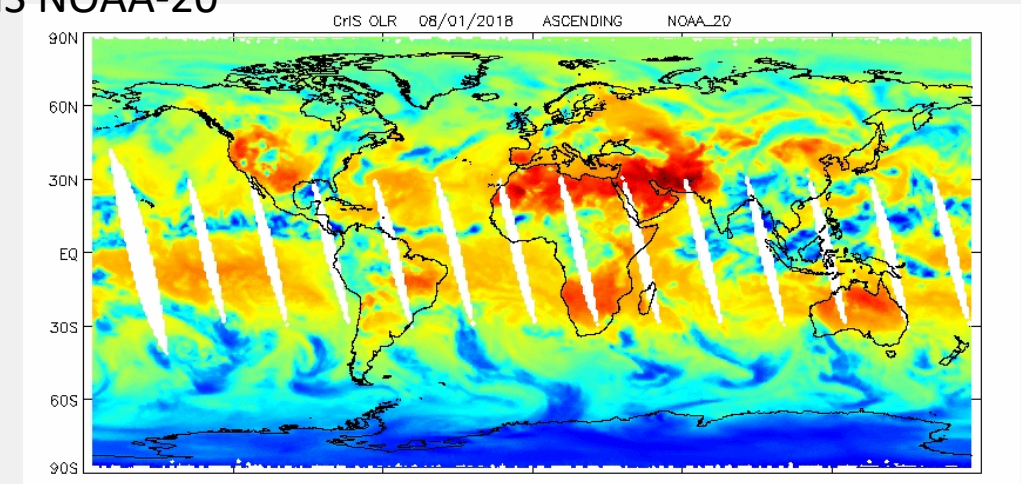
Difference



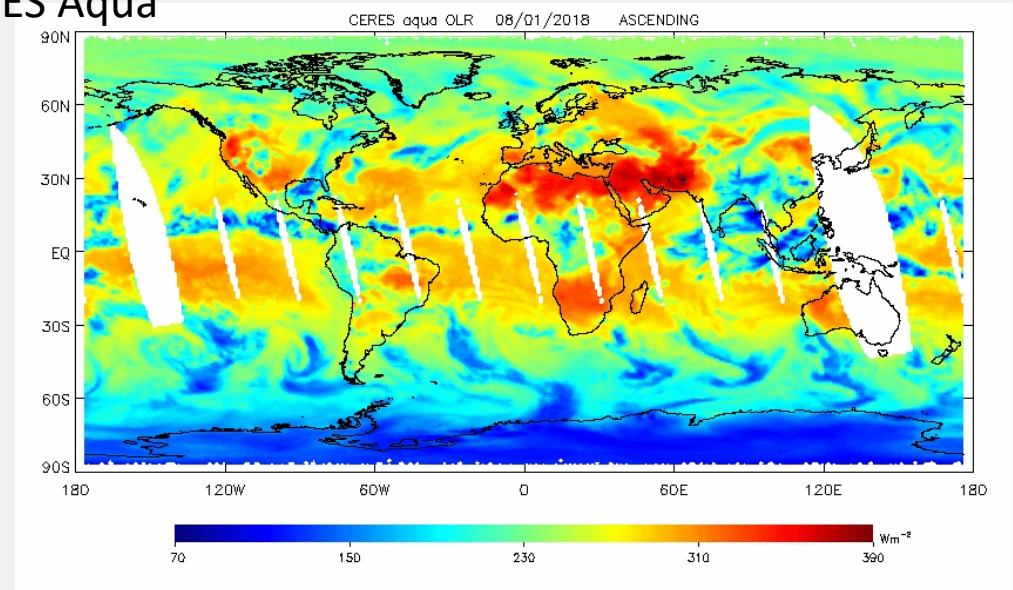
W/m²	BIAS	STD
Requirement	5.0	12.0
CrIS NOAA-20	0.2	7.4

NUCAPS CrIS NOAA-20 OLR Validation –Monthly OLR (August 2018 Ascending)

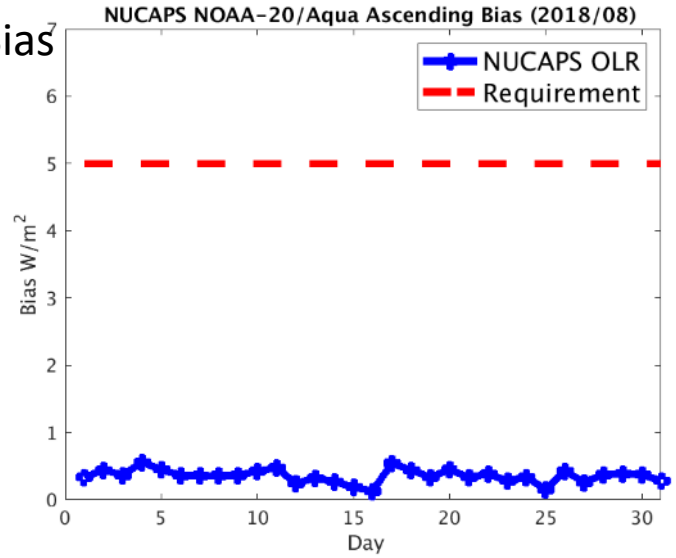
CrIS NOAA-20



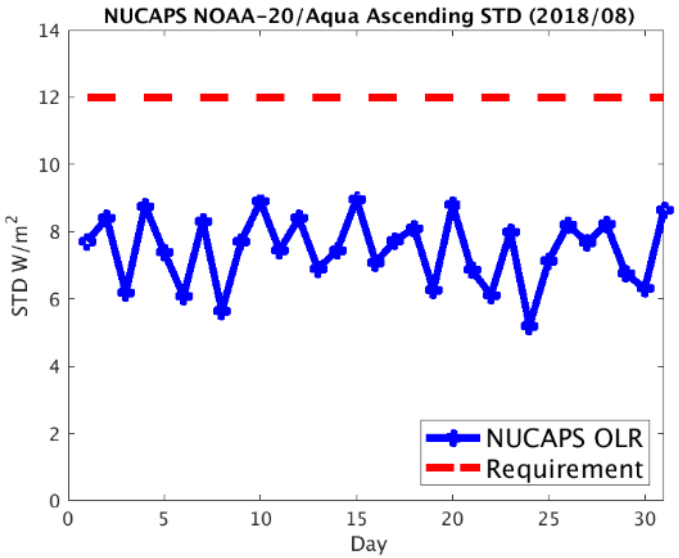
CERES Aqua



Bias



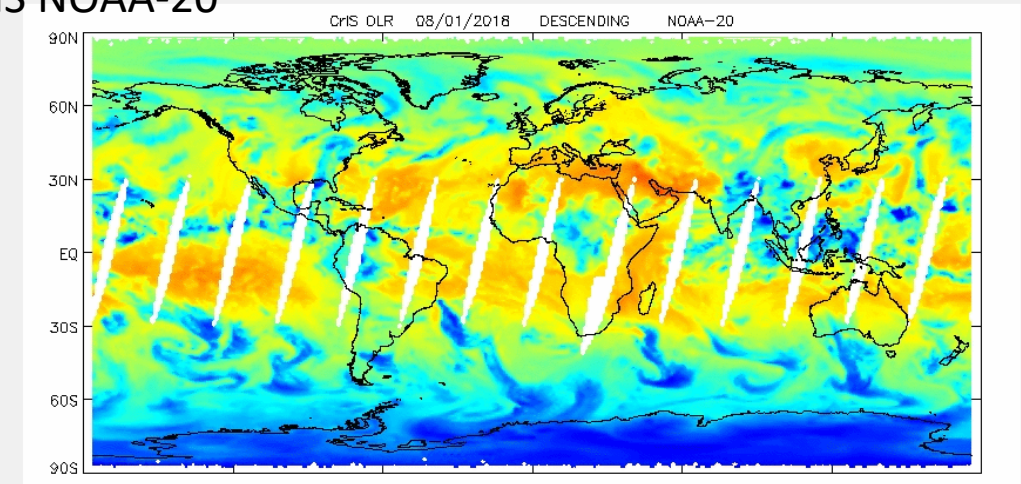
STD



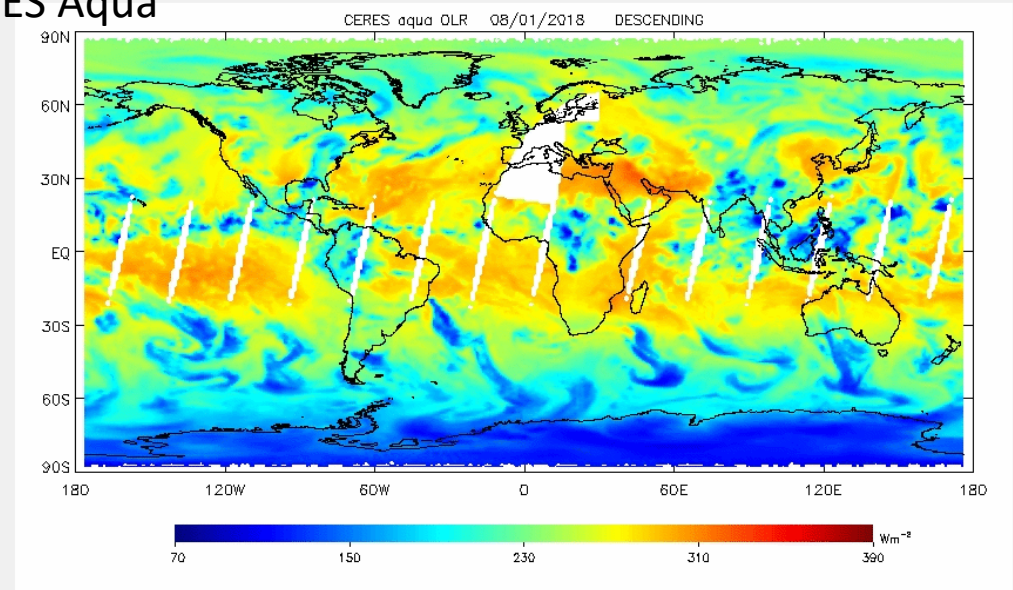
CrIS NOAA-20 agrees well with CERES Aqua and meets requirements

NUCAPS CrIS NOAA-20 OLR Validation –Monthly OLR (August 2018 Descending)

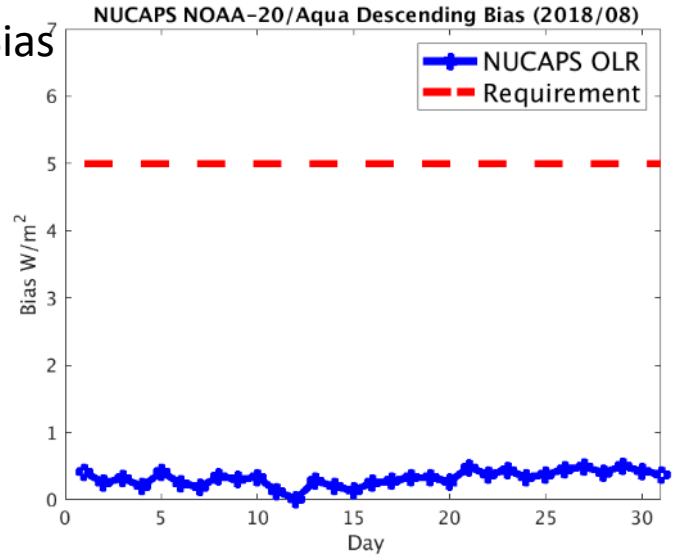
CrIS NOAA-20



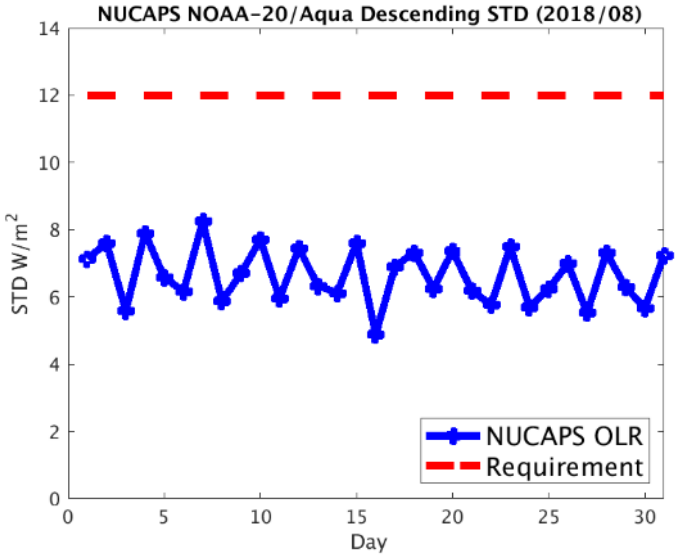
CERES Aqua



Bias



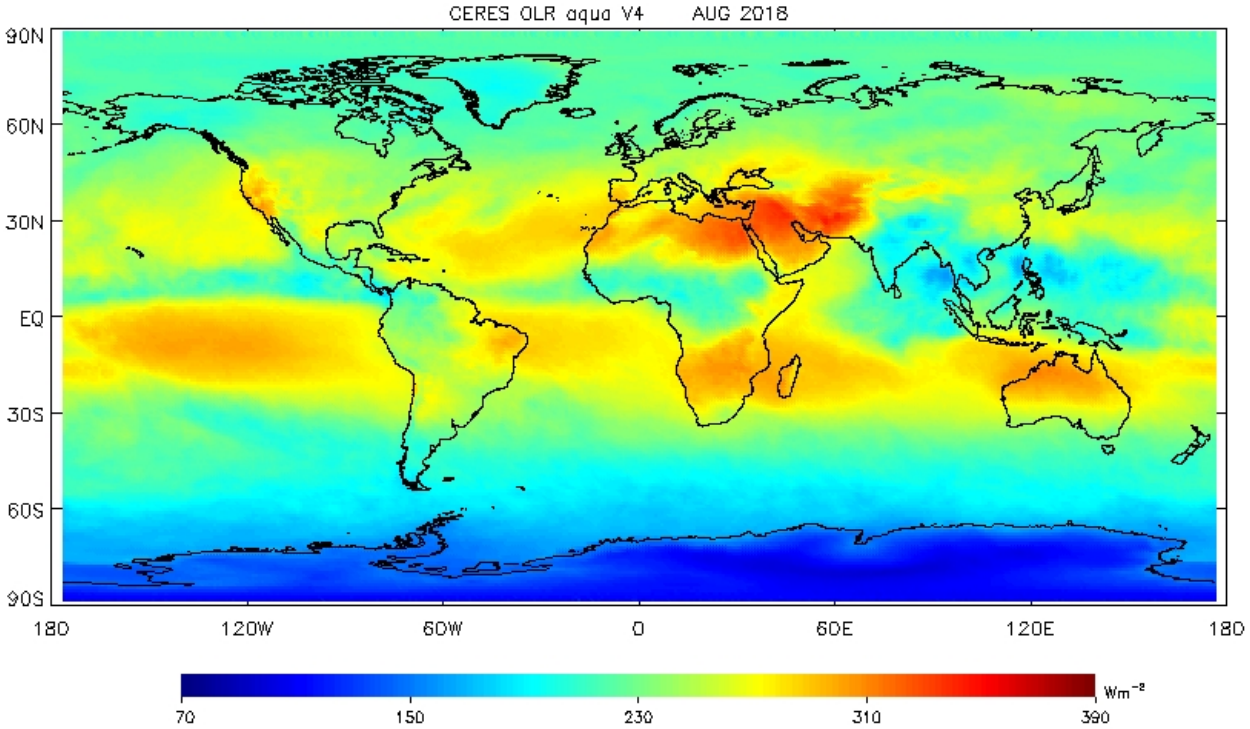
STD



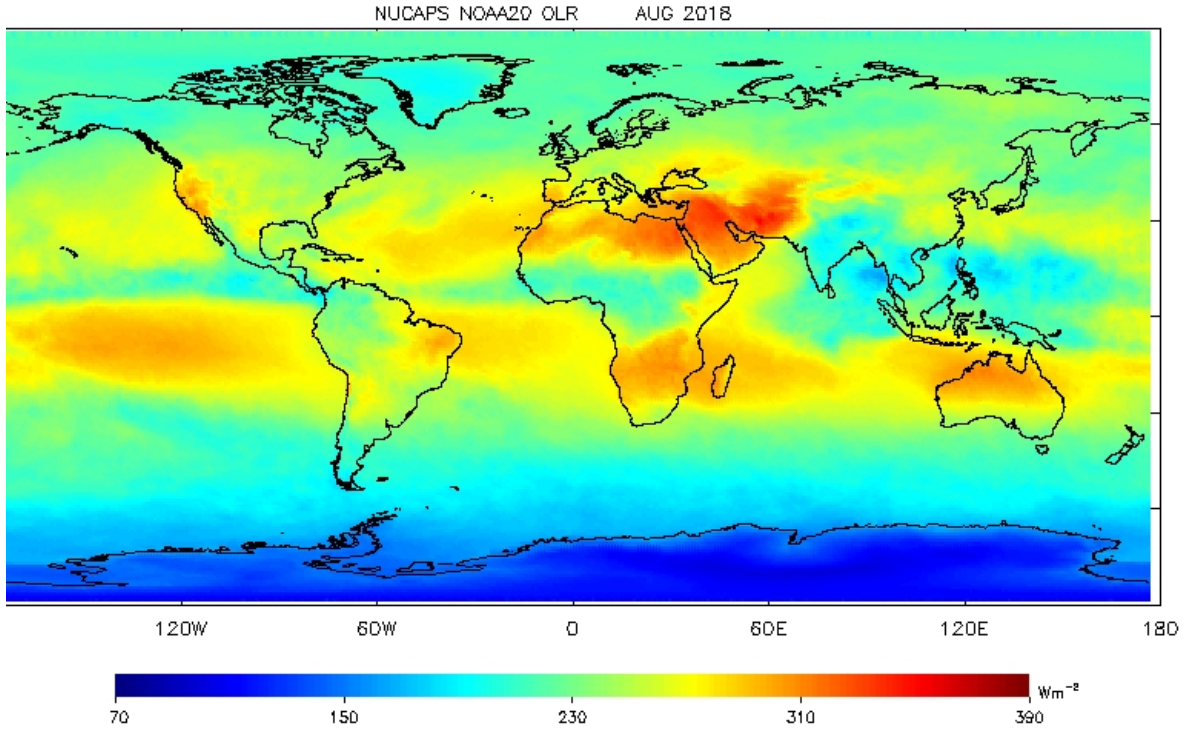
CrIS NOAA-20 agrees well with CERES Aqua and meets requirements

NUCAPS CrIS NOAA-20 OLR Validation –Monthly OLR (August 2018)

CrIS NOAA-20 OLR vs CERES Aqua OLR (Monthly mean)



CERES Aqua OLR

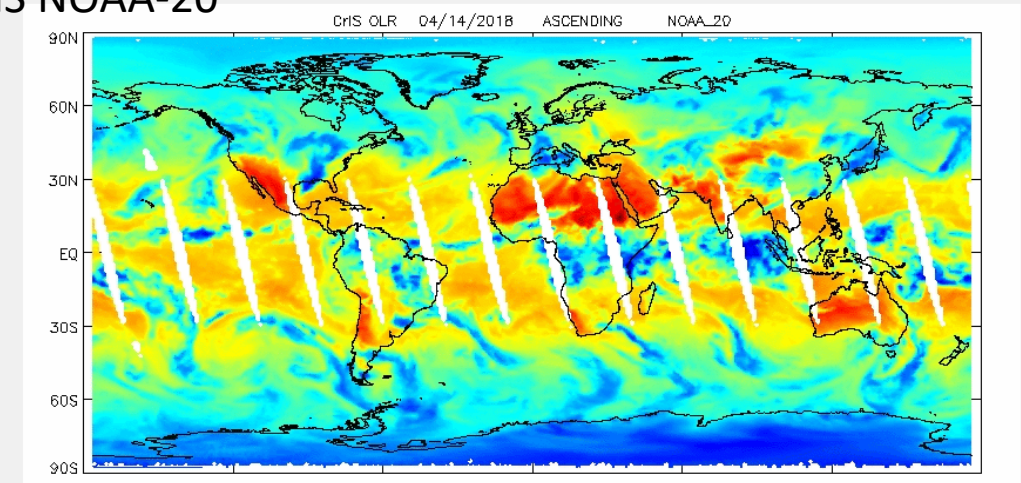


NUCAPS NOAA-20 OLR

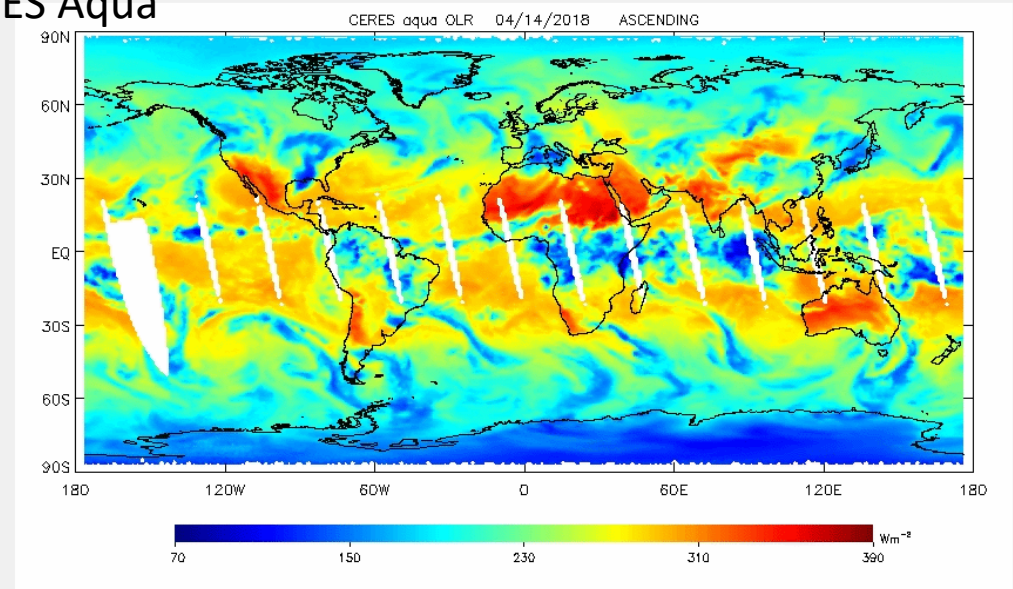
- Spatial patterns agree well

NUCAPS CrIS NOAA-20 OLR Validation –yearly OLR (Ascending Apr-2018 thru Mar-2019)

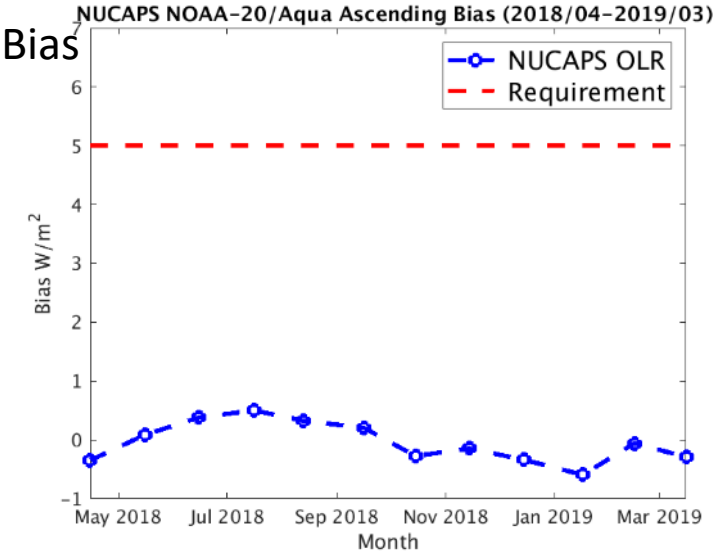
CrIS NOAA-20



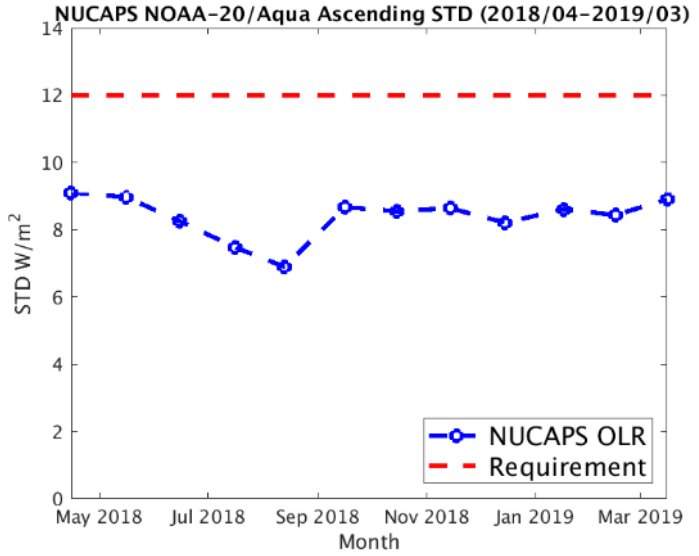
CERES Aqua



Bias



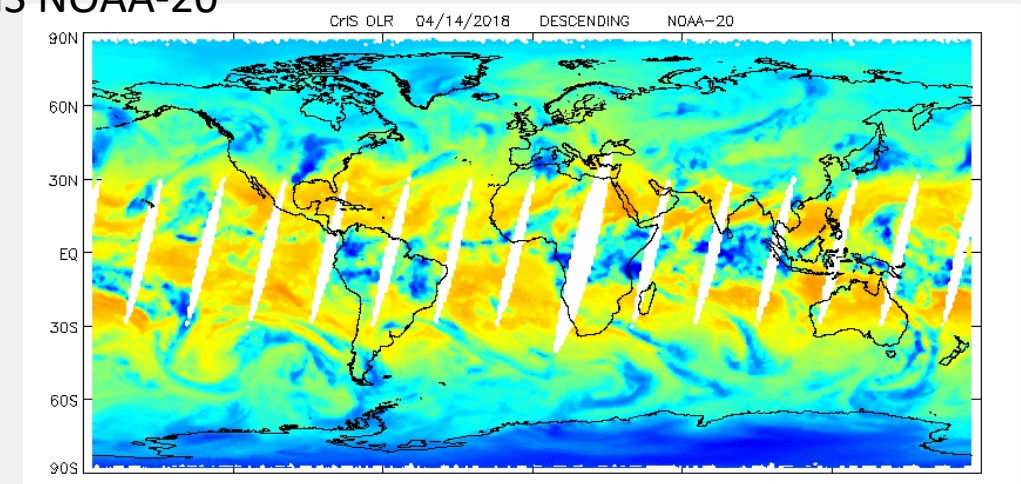
STD



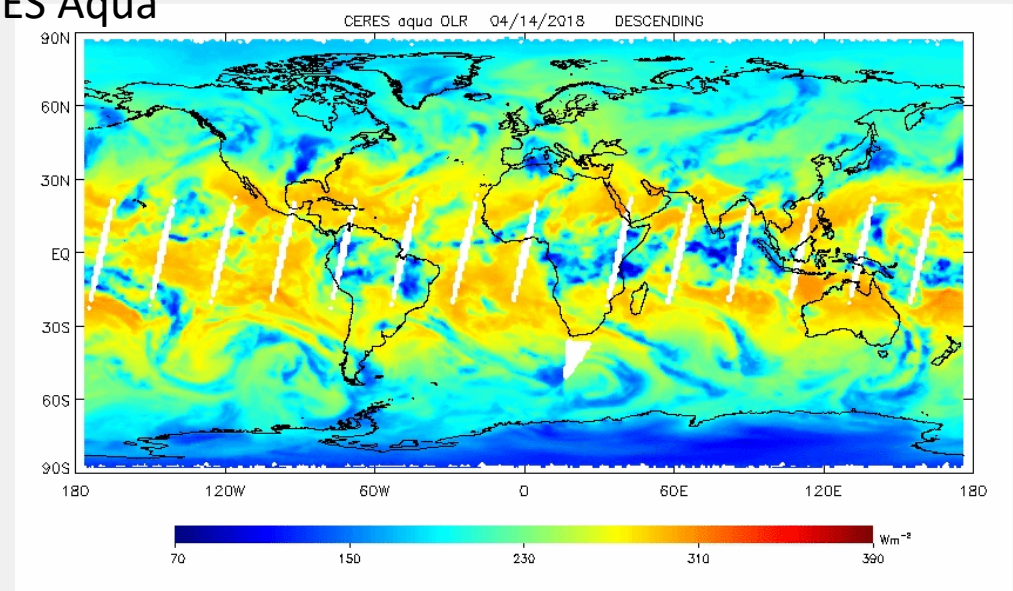
CrIS NOAA-20 agrees well with CERES Aqua, and meets the requirements

NUCAPS CrIS NOAA-20 OLR Validation –yearly OLR (Descending Apr-2018 thru Mar-2019)

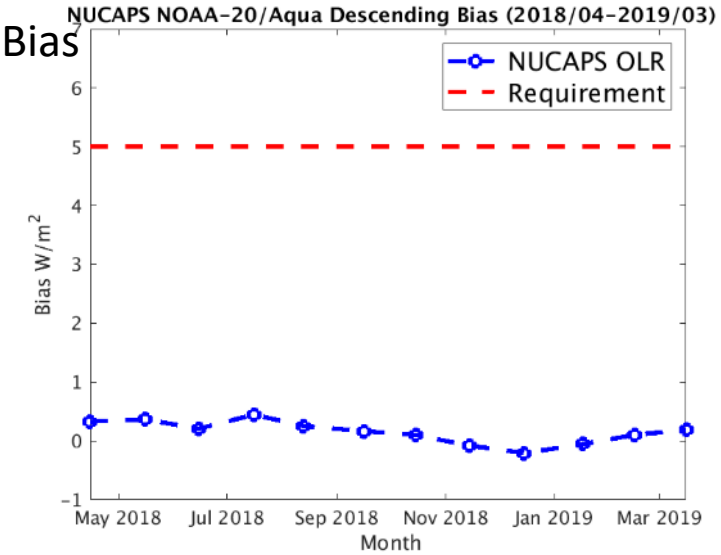
CrIS NOAA-20



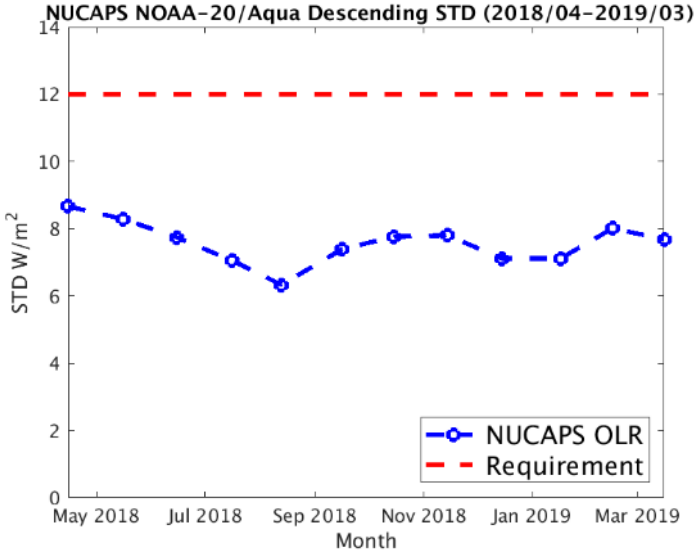
CERES Aqua



Bias



STD

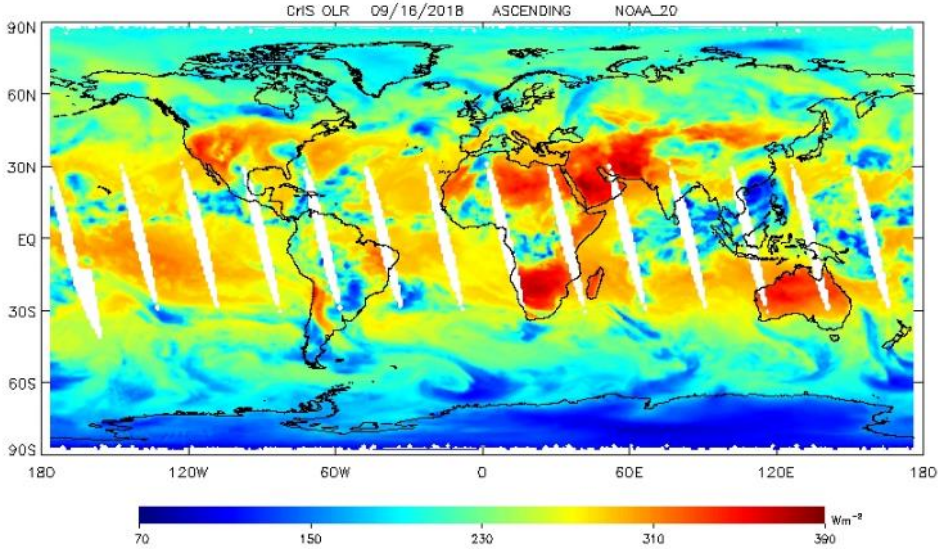


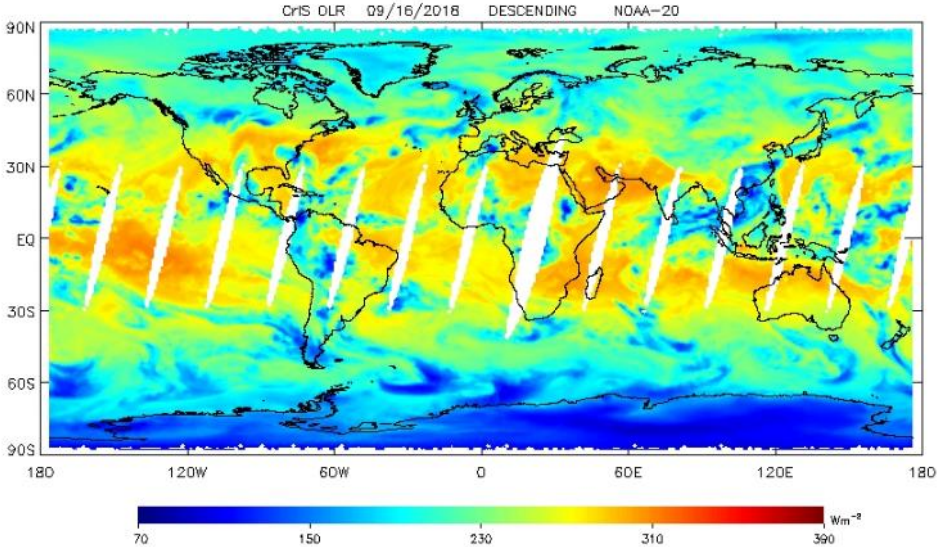
CrIS NOAA-20 agrees well with CERES Aqua, and meets the requirements

NUCAPS CrIS NOAA-20 OLR Validation –Daily OLR (16-Sep-2018)

CrIS NOAA-20 OLR vs CrIS SNPP OLR

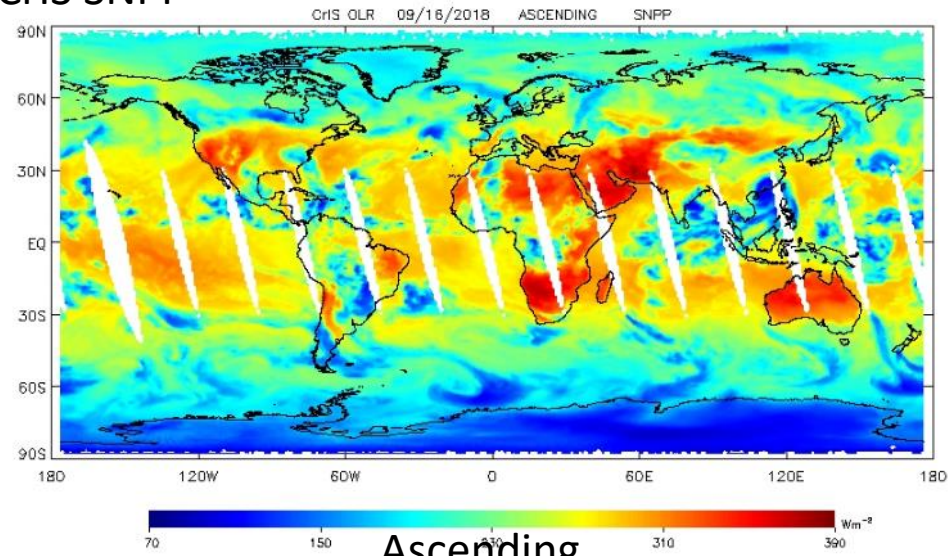
CrIS NOAA-20



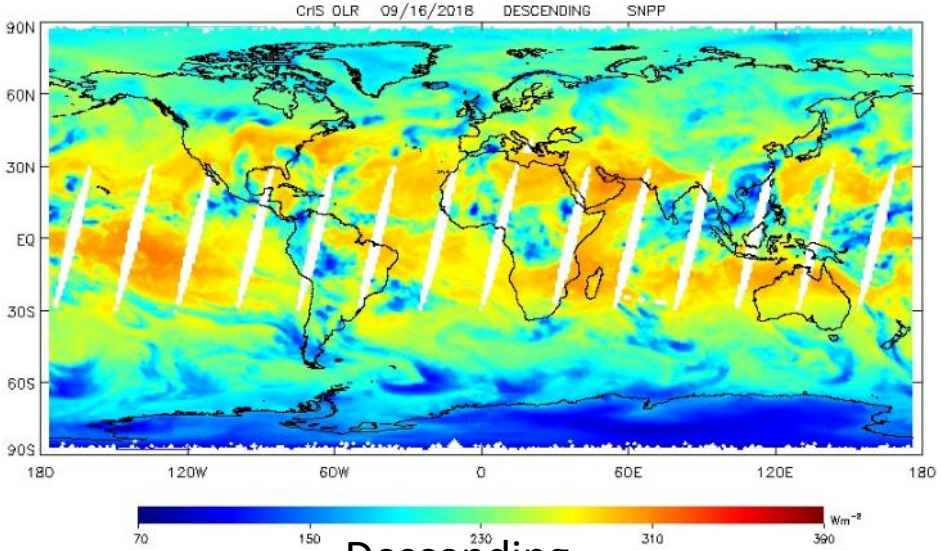


CrIS NOAA-20 is consistent with CrIS SNPP

CrIS SNPP



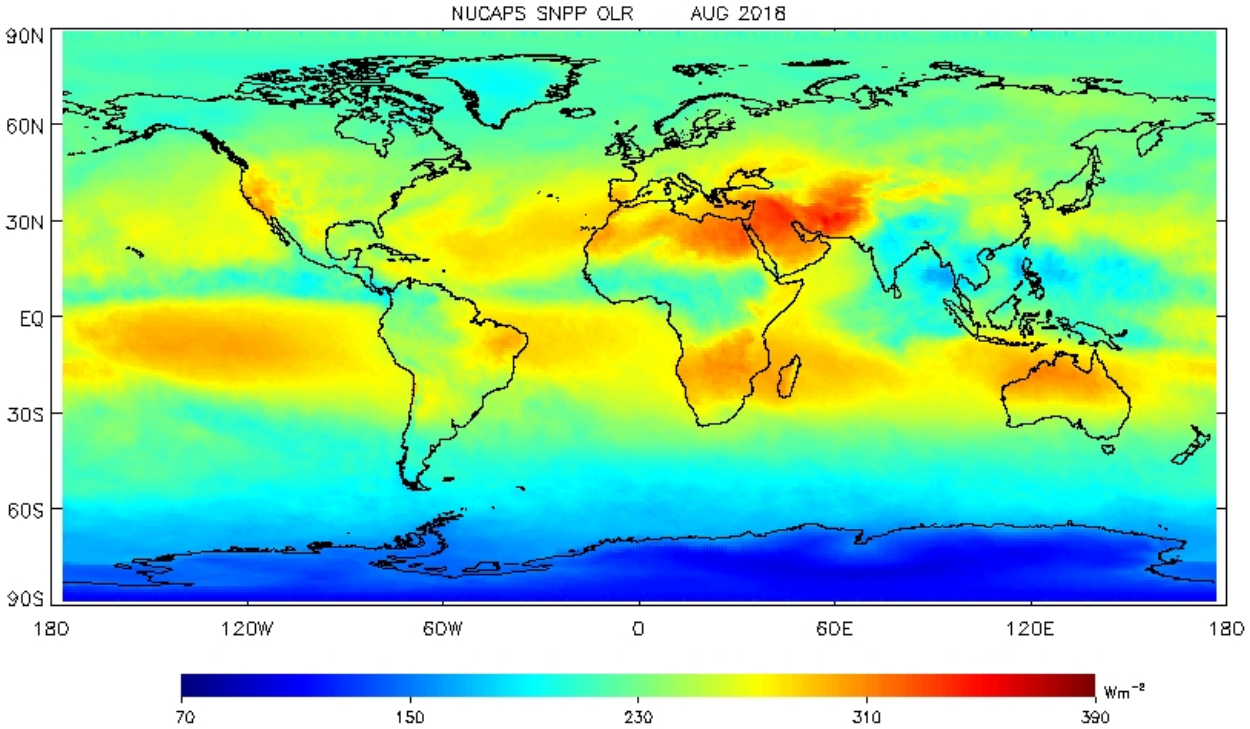
Ascending



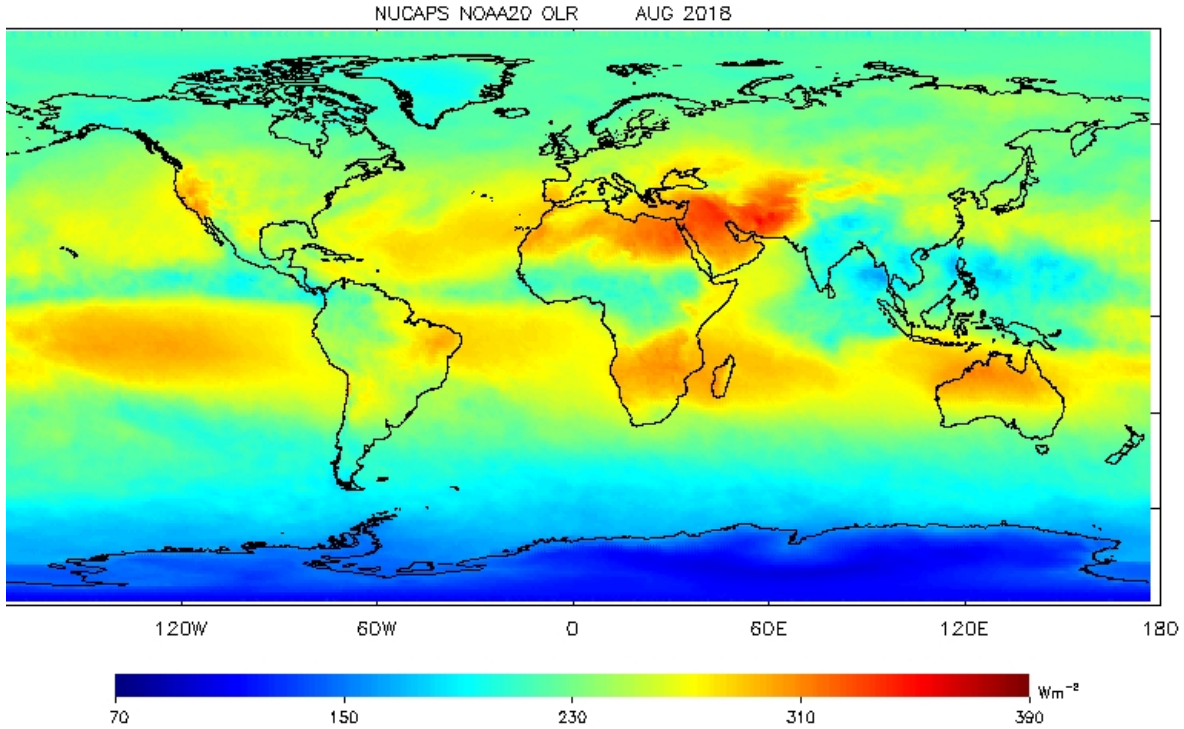
Descending

NUCAPS CrIS NOAA-20 OLR Validation –Monthly OLR (August 2018)

CrIS NOAA-20 OLR vs CrIS SNPP OLR (Monthly mean)



CrIS SNPP OLR



CrIS NOAA-20 OLR

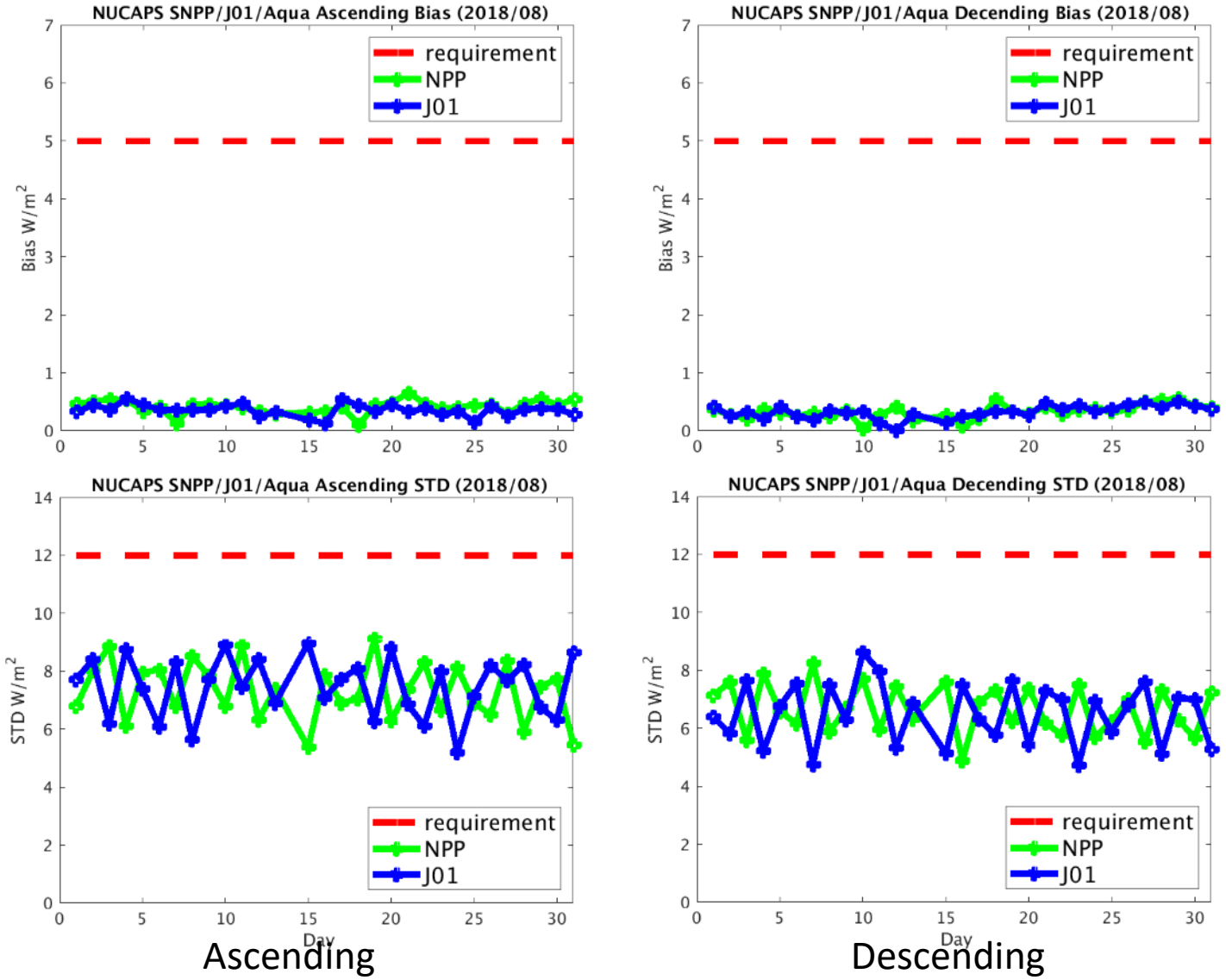
- Spatial patterns agree well

NUCAPS CrIS NOAA-20 OLR Validation –Monthly OLR (August 2018)

CrIS NOAA-20 OLR vs CrIS SNPP OLR (Monthly)

Bias

STD



Ascending

Descending

W/m²	BIAS	STD
Requirement	5.0	12.0
CrIS SNPP	<0.6	<9.1
CrIS N20	<0.6	<9.0

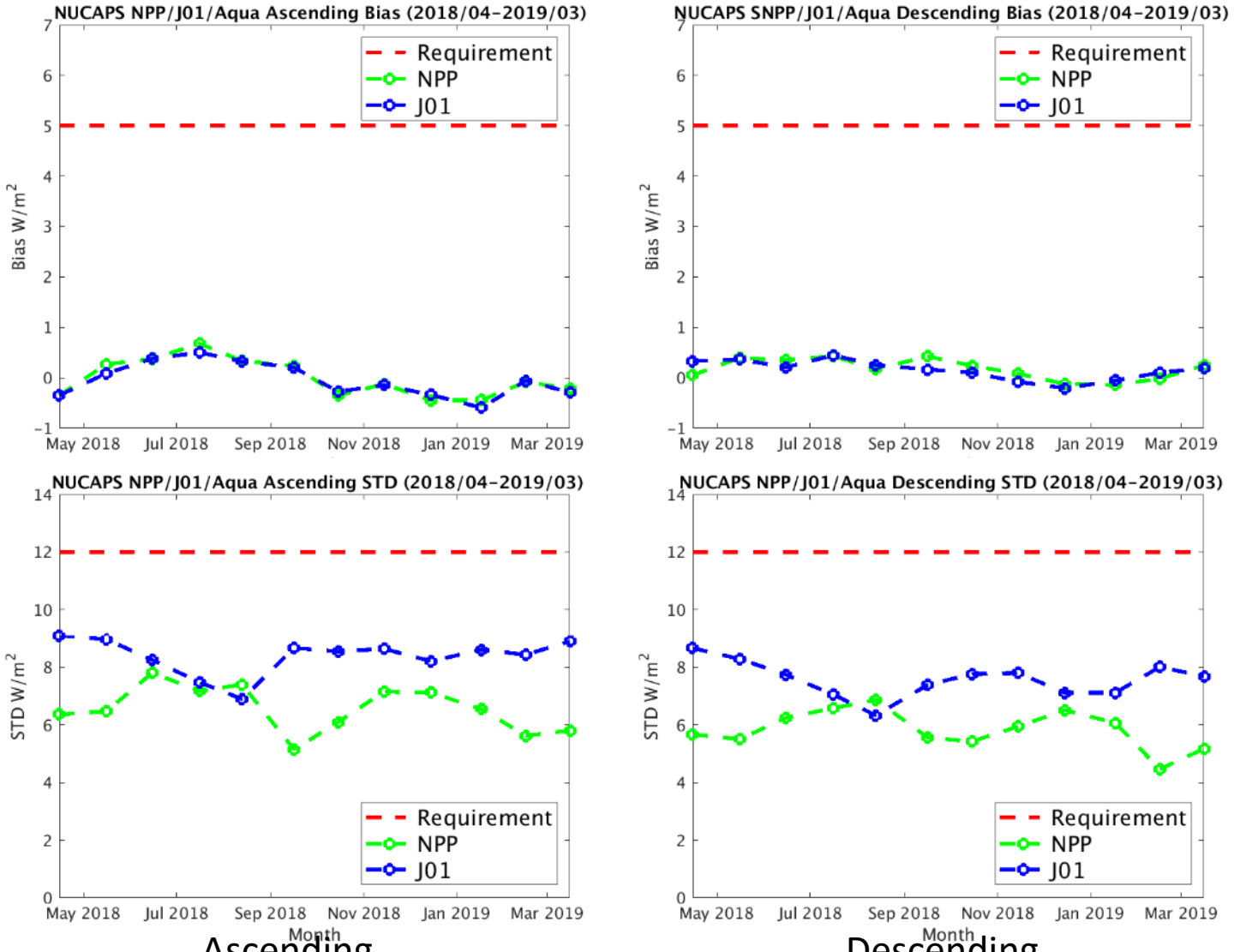
- Bias and STD are similar
- Product performance meets the requirements

NUCAPS CrIS NOAA-20 OLR Validation –yearly OLR (Apr-2018 thru Mar-2019)

CrIS NOAA-20 OLR vs CrIS SNPP OLR(yearly)

Bias

STD



Ascending

Descending

W/m²	BIAS	STD
Requirement	5.0	12.0
CrIS SNPP	<0.7	<7.8
CrIS N20	<0.6	<9.1

- Bias and STD are similar
- Product performance meets the requirements

NOAA-20 Validated Maturity – Outgoing Longwave Radiation (OLR)

Validated Maturity End State	Assessment
Product performance has been demonstrated over a large and wide range of representative conditions (i.e., global, seasonal).	Yes. See slides 73-85.
Comprehensive documentation of product performance exists that includes all known product anomalies and their recommended remediation strategies for a full range of retrieval conditions and severity level.	Yes. See slide 164
Product analyses are sufficient for full qualitative and quantitative determination of product fitness-for-purpose.	Yes. See slides 73-85.
Product is ready for operational use based on documented validation findings and user feedback.	Yes. See User Feedback and Downstream Products Feedback slides 152-158.
Product validation, quality assurance, and algorithm stewardship continue through the lifetime of the instrument	Yes. See planned activities slide 87, 168-172.

Potential Future OLR Work

- Update Radiance Correction Coefficients with NOAA-20 data
- Compare CrIS NOAA-20 OLR with the OLR of following four products:
  1. CERES NOAA-20
  2. AIRS
  3. Metop-A
  4. Metop-B

CARBON TRACE GAS (CO, CH_4 CO_2) EDRS

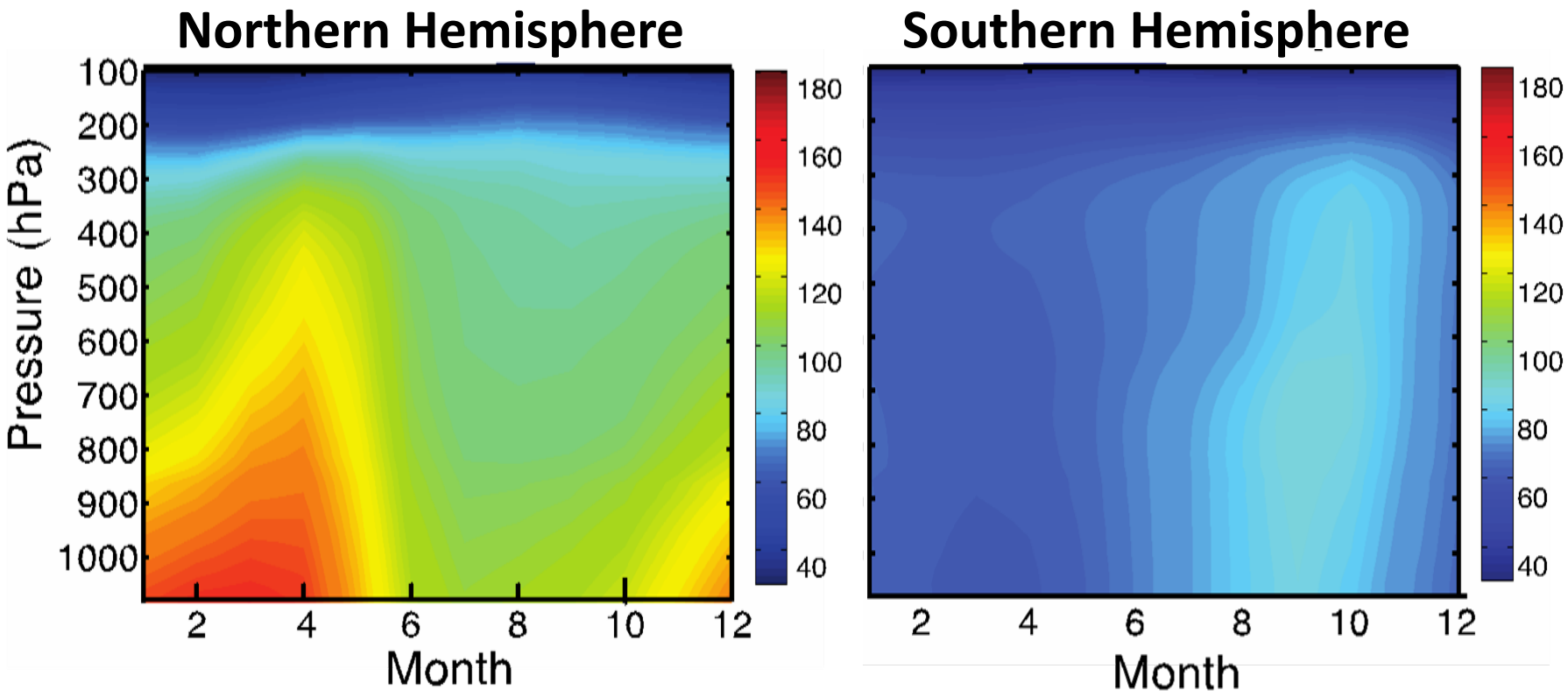
NUCAPS Product Maturity: SNPP and NOAA-20 CO

Product	Maturity Level			
	SNPP		NOAA-20	
	Current Status	Maturity Level **Aimed**	Current Status	Maturity Level Aimed
SNPP and NOAA-20 CO	✓ Provisional	❑ Validated	✓ Provisional	❑ Validated

- Processing Environment and Algorithms (Alg. Version, LUTs, Effective date)

  ✓ V2.5.2.2 DAP is the optimized NUCAPS algorithm for NOAA-20 products.
  - NOAA-20 AVTP, AVMP, Ozone for validated maturity
  - NOAA-20 OLR for validated maturity
  - **SNPP/NOAA-20 CO for validated maturity**
  - SNPP/NOAA-20 CH4 for provisional maturity.
  - SNPP/NOAA-20 CO2 Currently Beta (Maturity Review planned for February 2020)

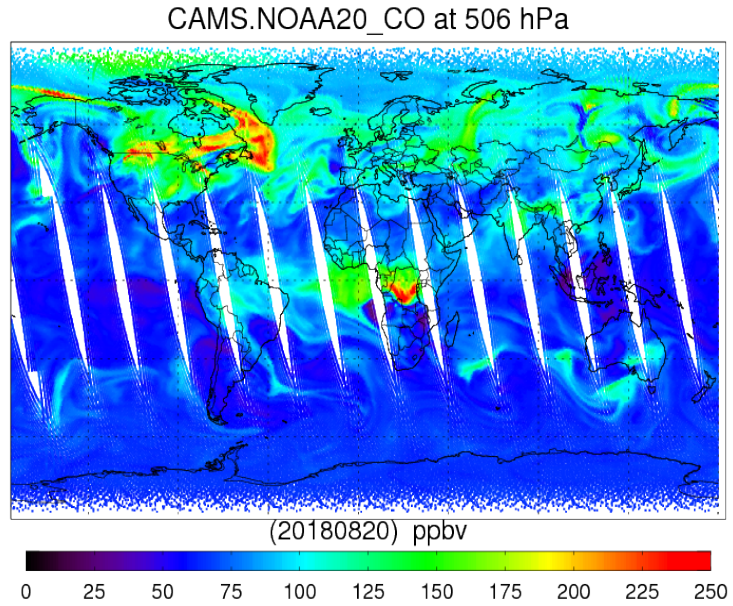
SNPP & NOAA-20 NUCAPS CO *a priori* for V2.5.2.2

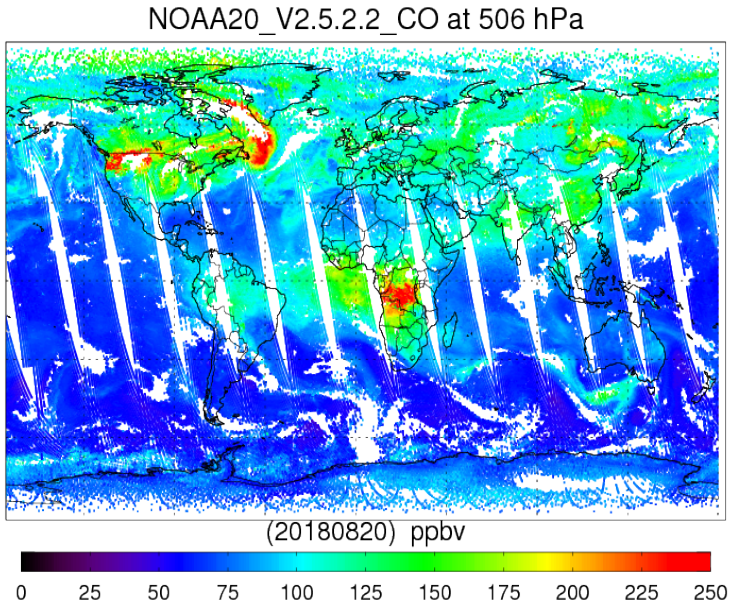


- Two hemispheric CO profiles (ppbv) developed from NCAR MOZART-GEOS5 model;
- Linearly transition between 15°N and 15°S
- Monthly varying, but no year-to-year variations
- Same approach as for AIRS, but updated to current values for NUCAPS

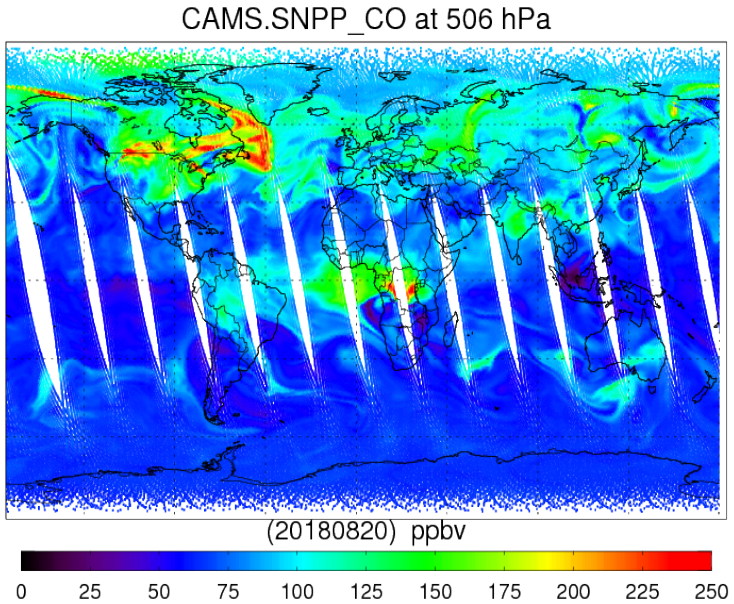
Contributed by: Juying Warner and Zigang Wei

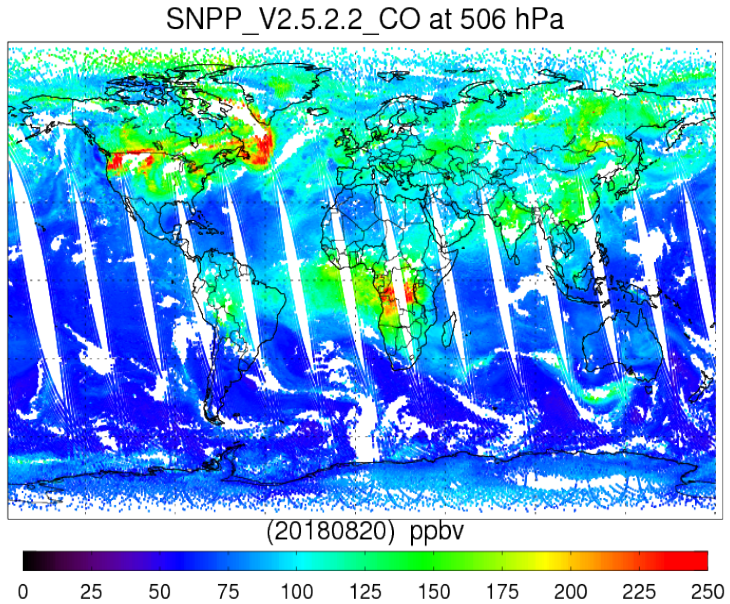
NUCAPS, CAMS and AIRS CO on 20-Aug-2018

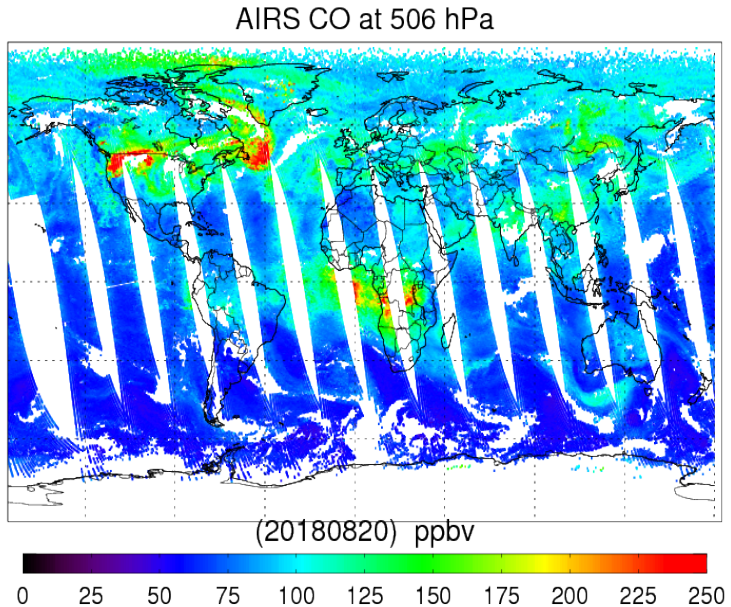




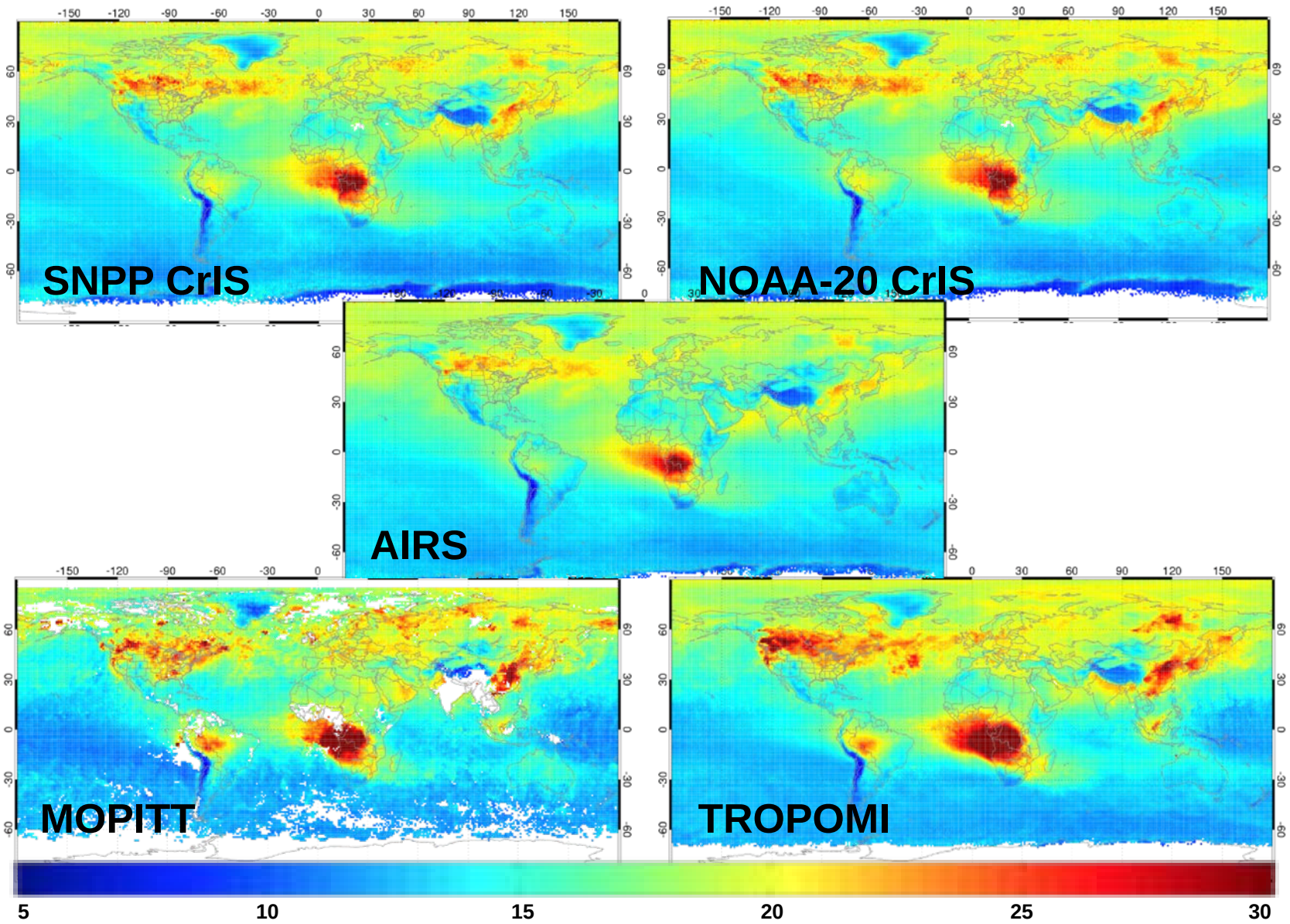
- The CO from NUCAPS, AIRS, CAMS have similar pattern and similar magnitude.
- NOAA-20, with ~50min leading, captures a maximum center in southern Africa.







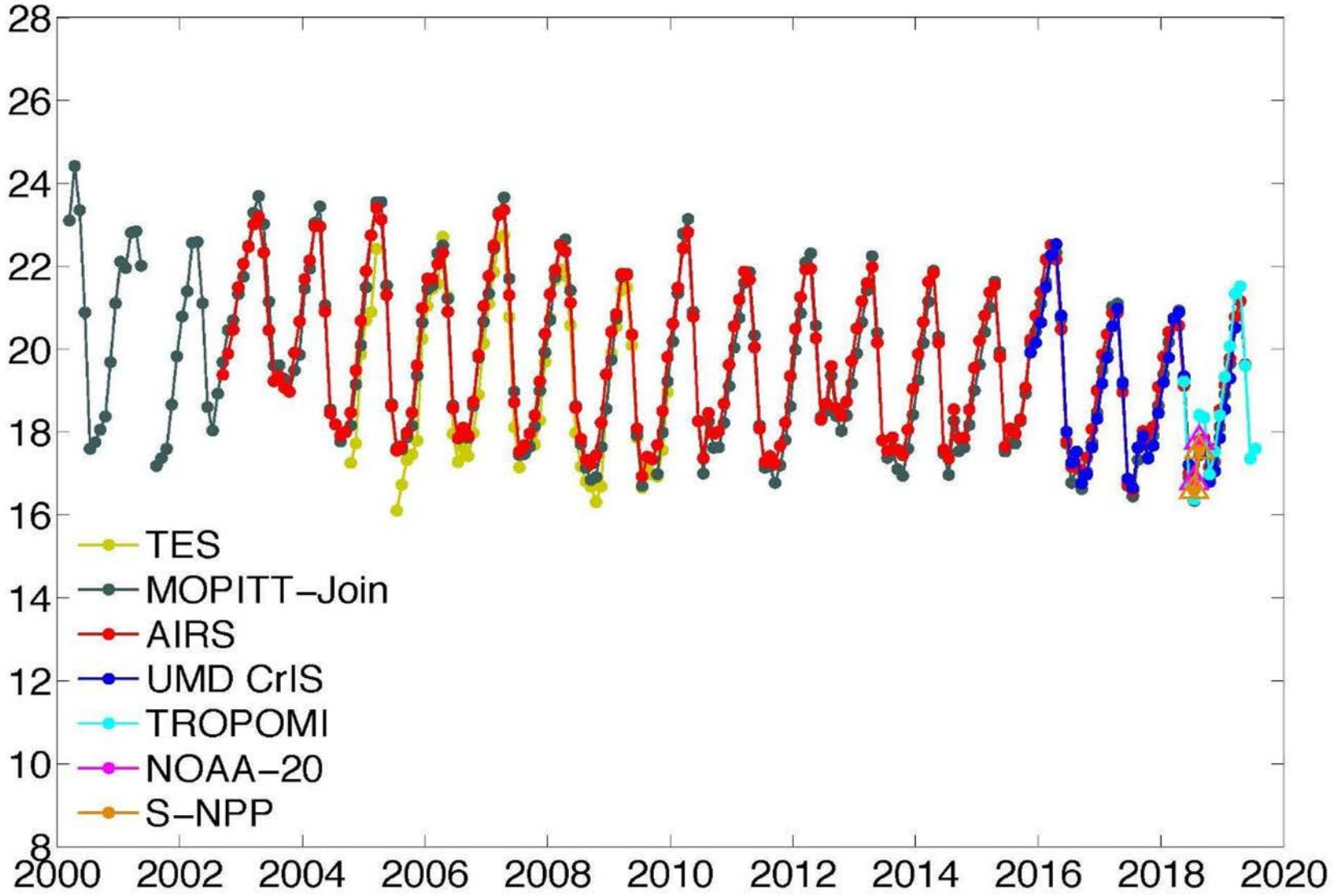
Comparisons of CO Column ($x10^{17}$ mols/cm^2) Aug 2018



($x10^{17}$ mols/cm^2)

Contributed by: Juying Warner and Zigang Wei

Trend of CO Total Column (x10^{17} mols/cm^2)



CO from all sensors agree very well in the Northern Hemisphere!

Contributed by: Juying Warner and Zigang Wei

SNPP and NOAA-20 Validated Maturity for Carbon Monoxide (CO)

Validated Maturity End State	Assessment
Product performance has been demonstrated over a large and wide range of representative conditions (i.e., global, seasonal).	Yes. See slides 91-93, 103-117.
Comprehensive documentation of product performance exists that includes all known product anomalies and their recommended remediation strategies for a full range of retrieval conditions and severity level.	Yes. See slide 164
Product analyses are sufficient for full qualitative and quantitative determination of product fitness-for-purpose.	Yes. See slides 103-117 (together with other trace gas products)
Product is ready for operational use based on documented validation findings and user feedback.	Yes. See User Feedback and Downstream Products Feedback slides 136-141.
Product validation, quality assurance, and algorithm stewardship continue through the lifetime of the instrument	Yes. See planned activities slide 168-172.

NUCAPS Product Maturity: CH_4

Product	Maturity Level			
	SNPP		NOAA-20	
	Current Status	Maturity Level **Aimed**	Current Status	Maturity Level Aimed
SNPP and NOAA-20 CH4	✓ Beta	❑ Provisional	✓ Beta	❑ Provisional

- Processing Environment and Algorithms (Alg. Version, LUTs, Effective date)

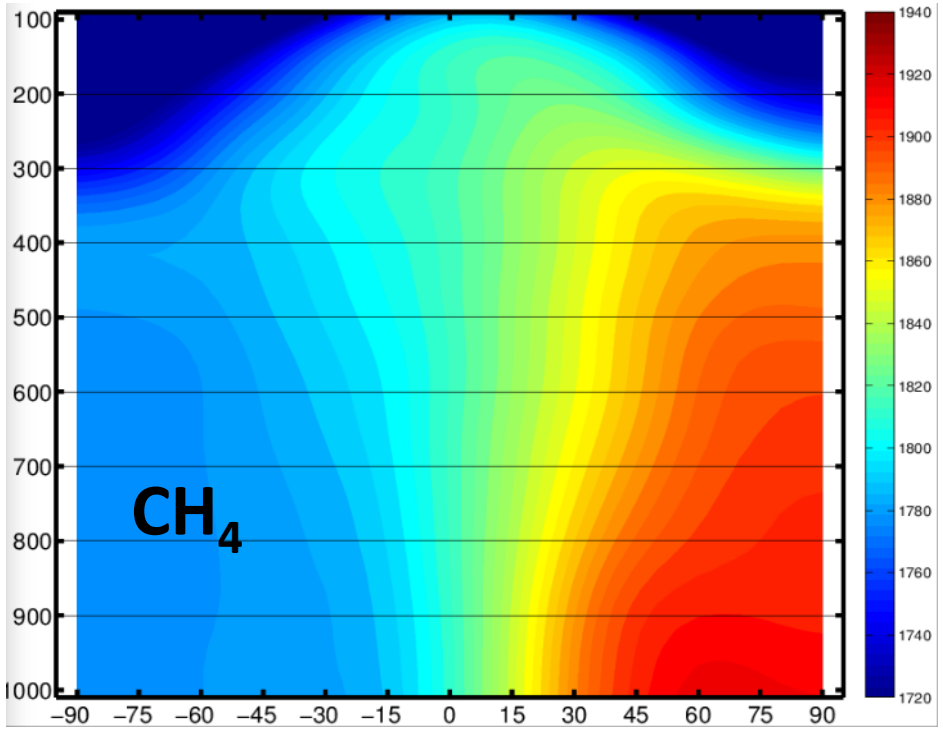
  ✓ V2.5.2.2 is the optimized NUCAPS algorithm for NOAA-20 products.
  - NOAA-20 AVTP, AVMP, Ozone for validated maturity
  - NOAA-20 OLR for validated maturity
  - SNPP/NOAA-20 CO for validated maturity
  - **SNPP/NOAA-20 CH4 for provisional maturity.**
  - SNPP/NOAA-20 CO2 Currently Beta (Maturity Review planned for February 2020)

Milestones	Original Date	Forecast Date
NOAA-20 Calibration/Validation		
Validated Maturity: CH4 (SNPP & NOAA-20)	Feb-20	Feb-20

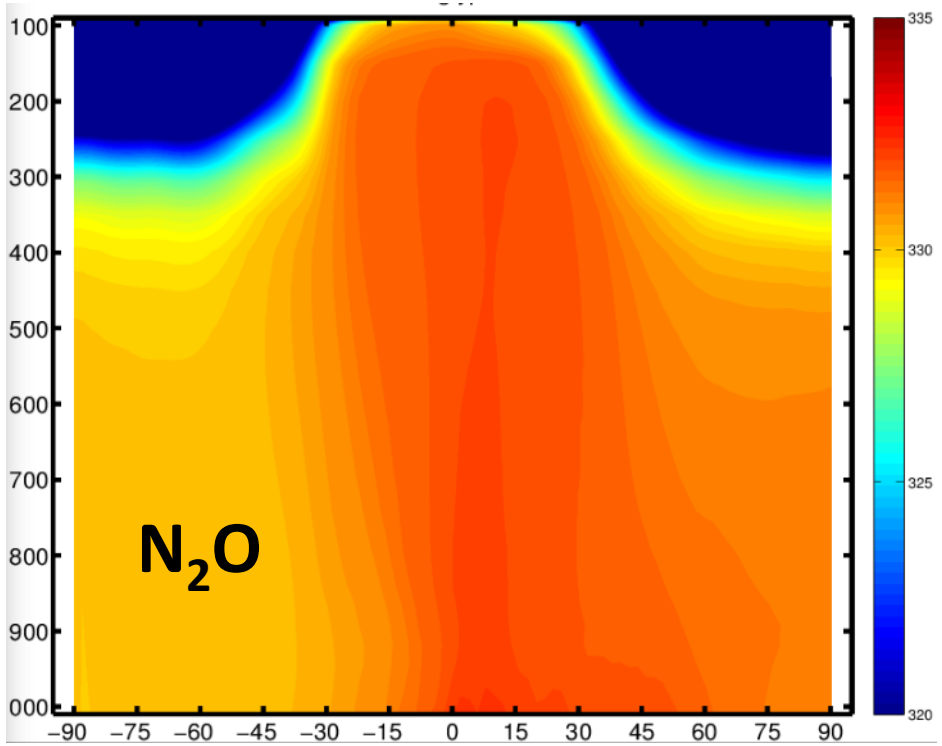
CH_4 *a priori* / first guess

N_2O *a priori* / first guess

CH4fgtype=9 (ppbv)



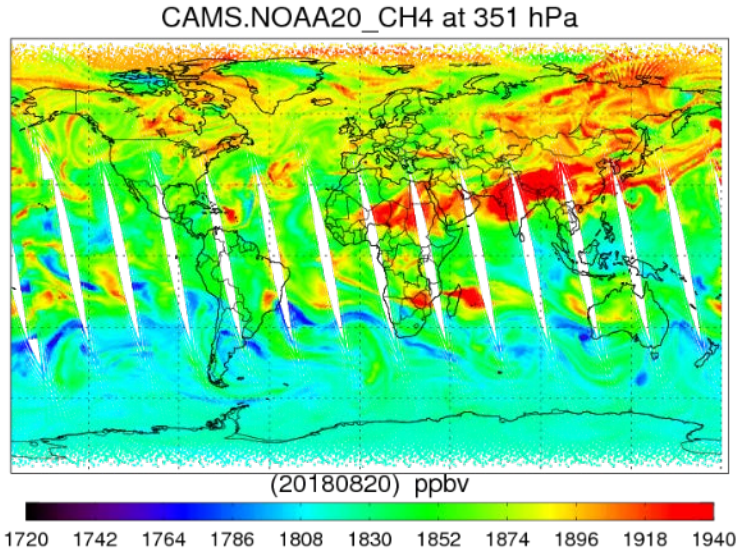
N2Ofgtype=4 (ppbv)

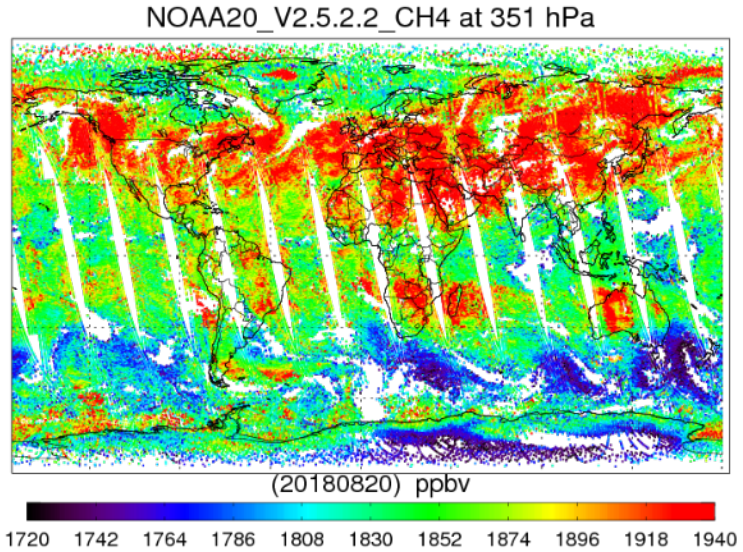


- N_2O *a priori* are based on CTM from NASA/GSFC, with yearly change, so not for N_2O retrievals
- CH_4 AP are based on in situ measurement
- N_2O AP are used to improve CH_4 retrievals
- V2.5.2.2 validation include these upgrades

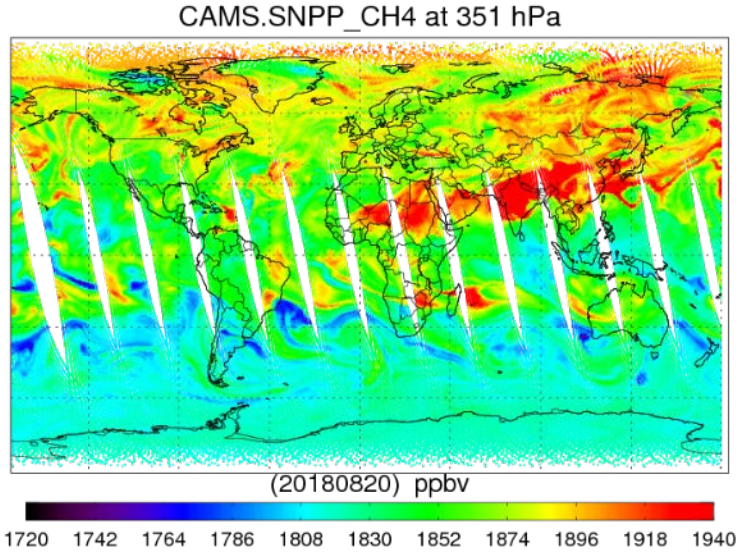
Contributed by: Juying Warner and Zigang Wei

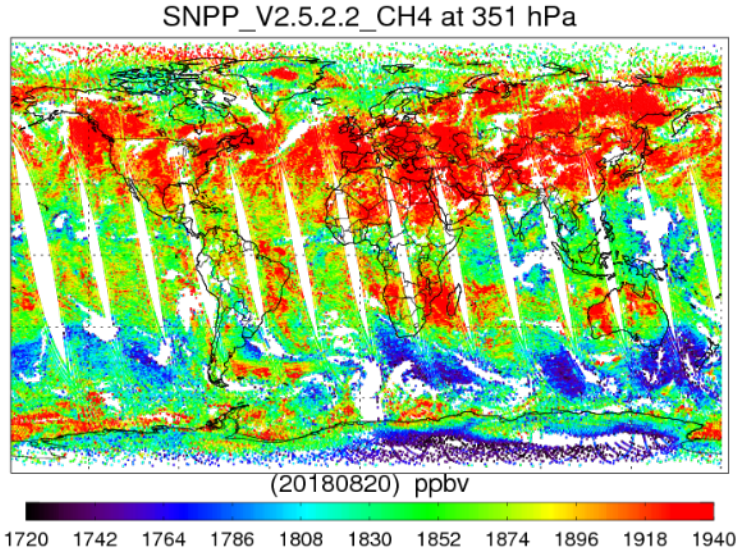
NUCAPS, CAMS and AIRS CH_4 on 20-Aug-2018

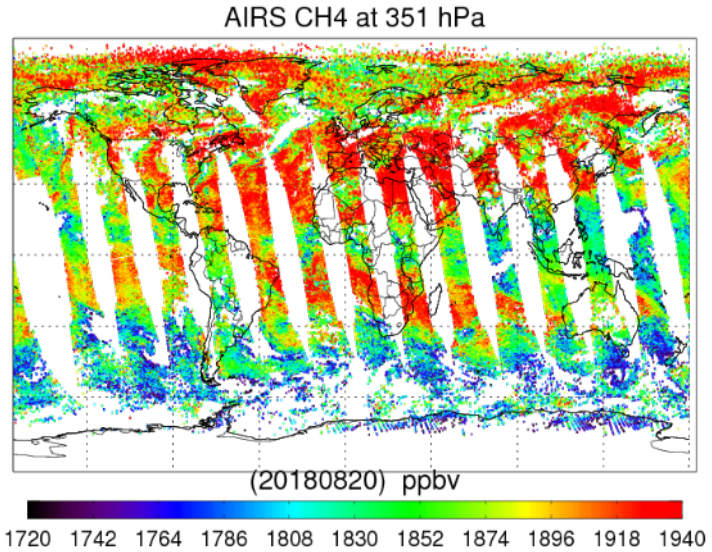




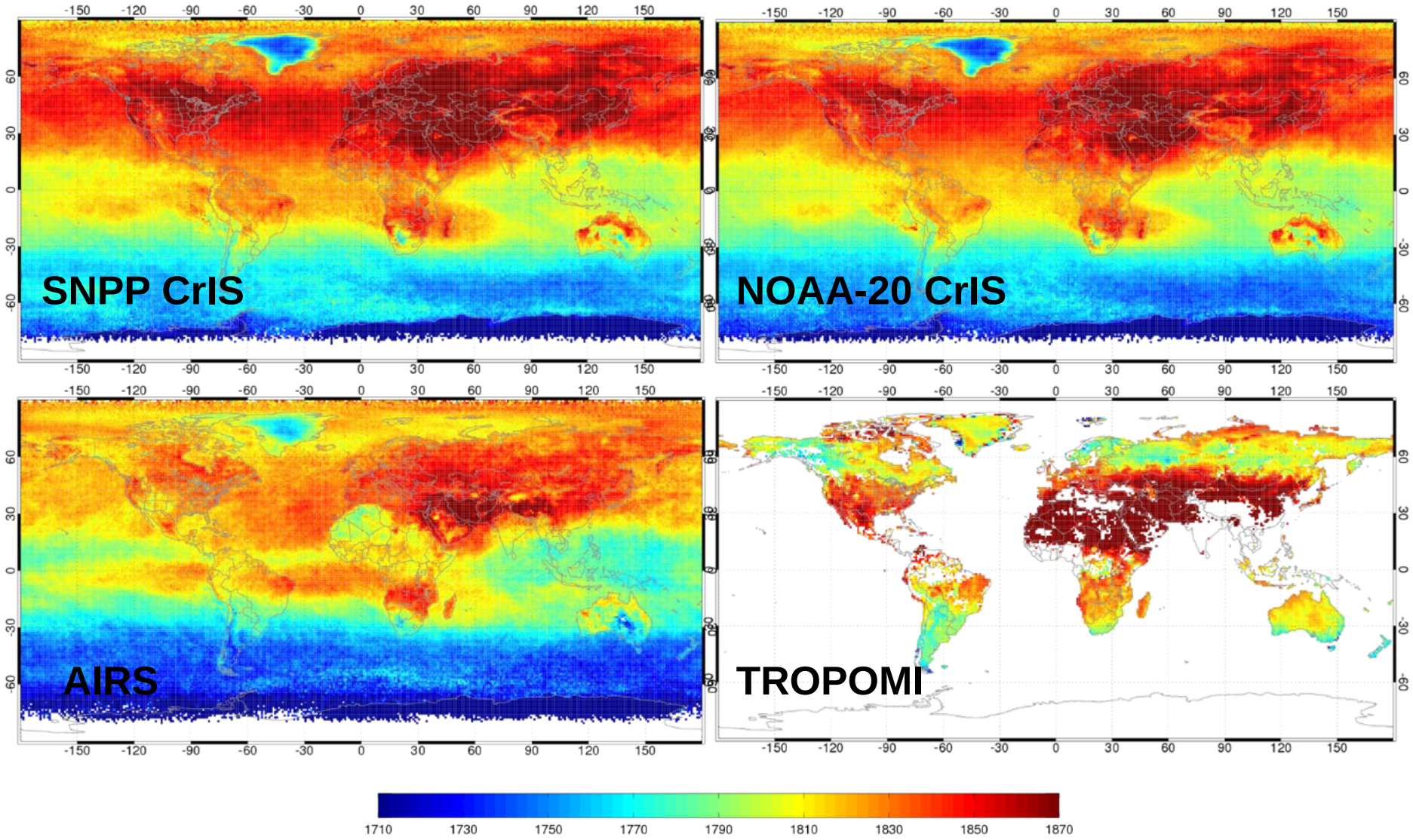
- The CH4 from NUCAPS, AIRS, and CAMS has similar pattern.
- The CH4 of NUCAPS and AIRS retrieval have similar magnitude.
- The CH4 of CAMS has smaller dynamic range in term of both minimum and maximum values.





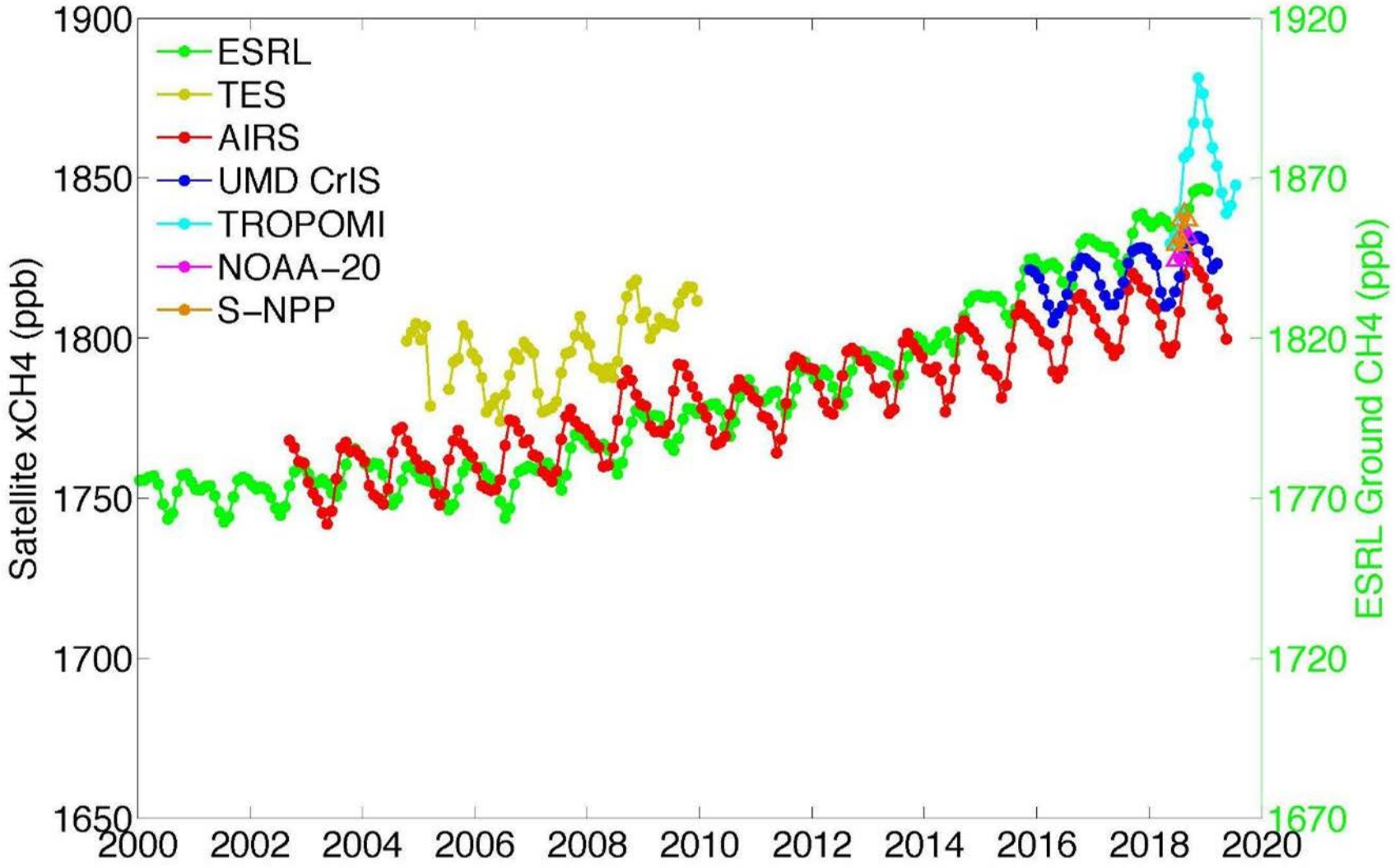


xCH_4 Total Column Comparison (Monthly Mean: August 2018)



Contributed by: Juying Warner and Zigang Wei

xCH_4 Column Trend Comparison



CrIS CH_4 is more agreeable to recent increases than AIRS.

Contributed by: Juying Warner and Zigang Wei

SNPP and NOAA-20 Provisional Maturity for Methane (CH_4)

Provisional Maturity End State	Assessment
Product performance has been demonstrated through analysis of a large, but still limited (i.e., not necessarily globally or seasonally representative) number of independent measurements obtained from select locations, periods, and associated ground truth or field campaign efforts.	Yes. See slides 97-99, 103-117.
Product analysis is sufficient to communicate product performance to users relative to expectations (Performance Baseline).	Yes. See slide 103-117
Documentation of product performance exists that includes recommended remediation strategies for all anomalies and weaknesses. Any algorithm changes associated with severe anomalies have been documented, implemented, tested, and shared with the user community.	Yes. See slides 164
Product is ready for operational use and for use in comprehensive cal/val activities and product optimization.	Yes. See slides 103-11.

NUCAPS Product Maturity: CO_2

Product	Maturity Level			
	SNPP		NOAA-20	
	Current Status	Maturity Level **Aimed**	Current Status	Maturity Level Aimed
SNPP and NOAA-20 CO2	✓ Beta	✓ Remain Beta	✓ Beta	✓ Remain Beta

- Processing Environment and Algorithms (Alg. Version, LUTs, Effective date)

✓ V2.5.2.2 DAP is the optimized NUCAPS algorithm for NOAA-20 products.

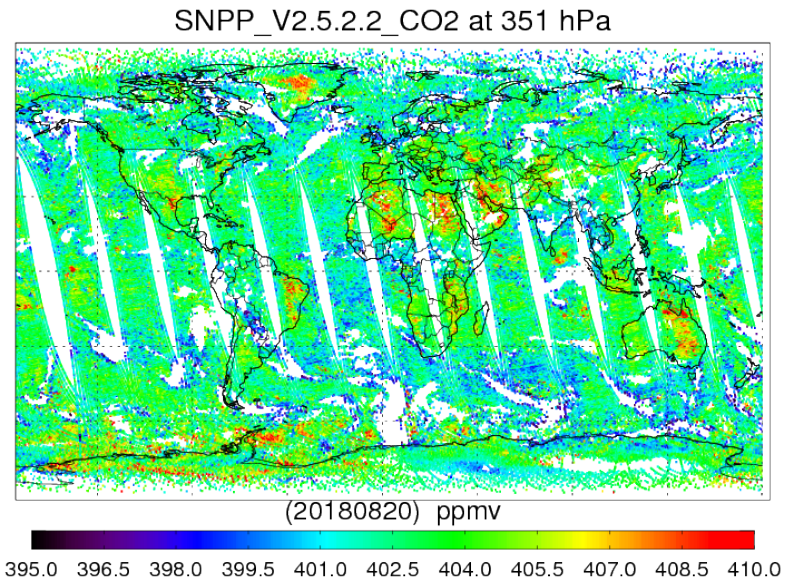
- NOAA-20 AVTP, AVMP, Ozone for validated maturity
- NOAA-20 OLR for validated maturity
- SNPP/NOAA-20 CO for validated maturity
- SNPP/NOAA-20 CH4 for provisional maturity.
- SNPP/NOAA-20 CO2 Currently Beta (Maturity Review planned for February 2020)

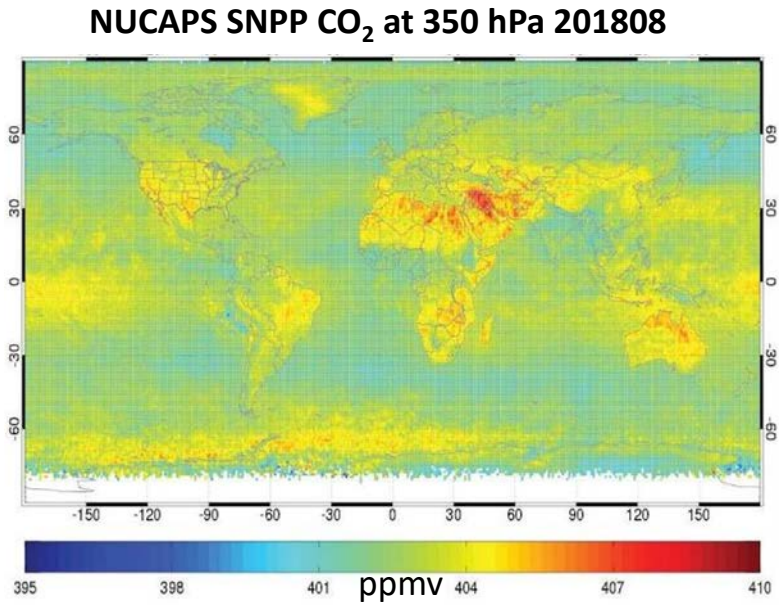
Milestones	Original Date	Forecast Date
NOAA-20 Calibration/Validation		
Provisional Maturity: CO2 (SNPP & NOAA-20)	Feb-20	Feb-20
Validated Maturity: CO2 (SNPP & NOAA-20)	Dec-20	FY21

Daily and Monthly NUCAPS CO_2 for SNPP and NOAA-20

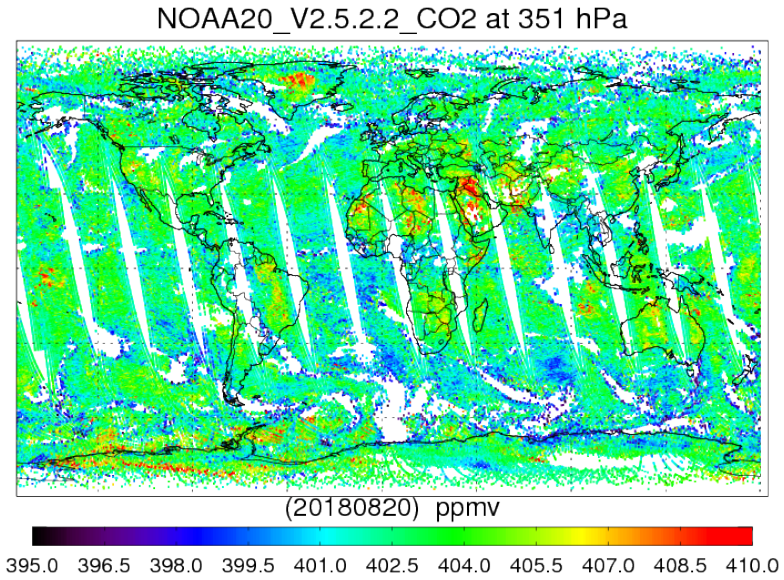
Daily:
20-Aug-2018

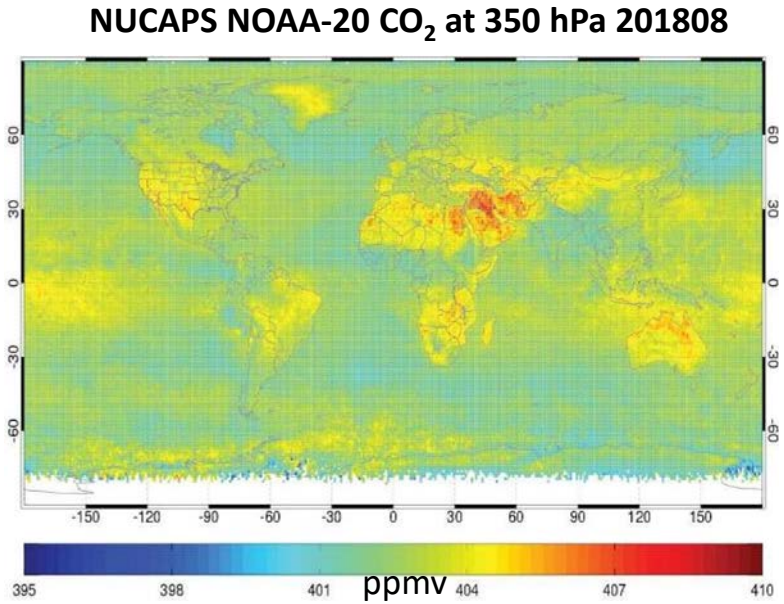
SNPP CO_2
351 hPa





NOAA-20 CO_2
351 hPa





Monthly: August 2018

- Maturity Review planned for 2020.
- Focus on CO_2 retrievals as done for CH_4
  - CO_2 *a priori*
  - Channel selection
- Thorough comparison to OCO-x, as well as *in situ* measurements

Figure Contributed by:
Juying Warner and Zigang Wei

NUCAPS Carbon Trace Gas EDR Reference data, Time Periods

Observation Type	Reference Data	Time Period	Validation	Remarks
Atmospheric Tomography Mission (ATom)	• DC-8 aircraft based *in situ* air samples • Profiles of volume mixing ratios (ppmv) obtained using NOAA/ESRL Picarro G2401m analyzer	ATom-1 and -2: July 2016 to February 2017	✓ CO meets requirements in sensitive layers (where AKs peak) ✓ CH4 meets bias requirement throughout column ✓ CO2 meets bias requirement in sensitive layers	ATom (*Wofsy et al.* 2018) acknowledgment • Kathryn McCain, Colm Sweeney (NOAA/ESRL) • https://doi.org/10.3334/ORNLDAAC/1581
AirCore	• Balloon-borne *in situ* air samples collected in "core" • Profiles of dry mole fractions (DMF) obtained using Picarro analyzer	March to September 2018	✓ CO meets precision requirement throughout column ✓ CH4 meets bias requirement throughout column	AirCore (*Membrive et al.* 2017; *Karion et al.* 2010) acknowledgment • Colm Sweeney, Bianca Baier (NOAA/ESRL) • Monika Kopacz (NOAA/CPO)
Total Carbon Column Observing Network (TCCON)	• Ground-based network of uplooking spectrometers • Total column DMF retrieved from near-IR solar spectrum	1 April 2018 20 August 2018	✓ CO meets total column requirements ✓ CH4 meets total column bias requirement ✓ CO2 meets total column bias requirement	TCCON (*Wunch et al.* 2010, 2011) acknowledgment • Debra Wunch (CalTech)

Applying NUCAPS Effective Averaging Kernels (AKs)

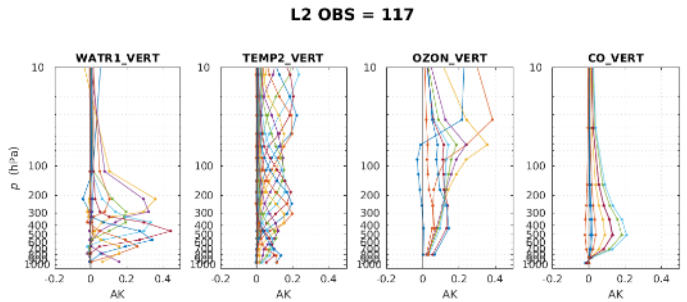
- **AKs** define the **vertical sensitivity** of the sounder measurement system

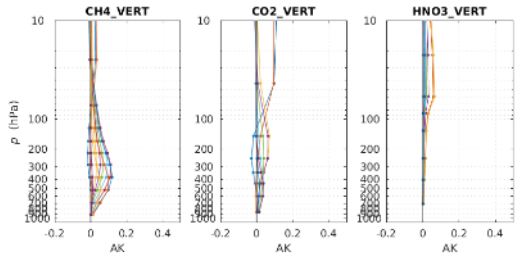
$$\mathbf{A} \equiv \frac{\partial \hat{\mathbf{x}}}{\partial \mathbf{x}}$$

- This facilitates **intercomparisons** of measurements obtained by two different observing systems

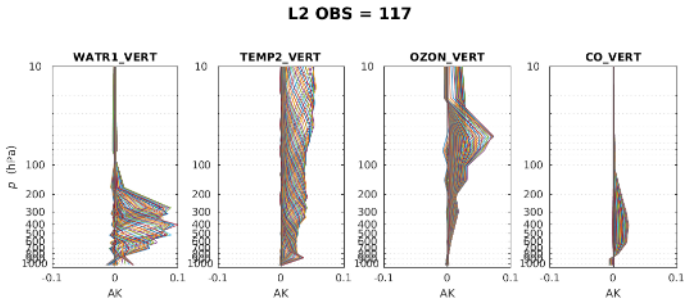
- The **NUCAPS effective AKs**, $\mathbf{A_e}$, (*Maddy and Barnet* 2008) can be used to "smooth" correlative truth (at RTA layers), thereby **removing null-space errors** otherwise present, i.e.

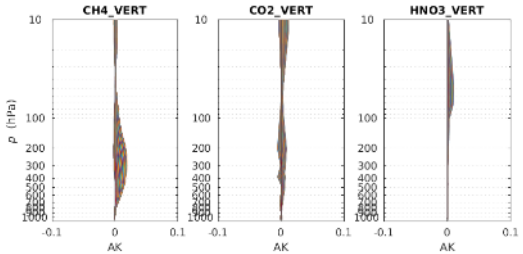
$$\mathbf{x_S} = \exp\{\ln(\mathbf{x_0}) + \mathbf{A_e}[\ln(\mathbf{x}) - \ln(\mathbf{x_0})]\}$$





SNPP NUCAPS component AKs from F93 files





RTA-layer **effective AKs** (*Maddy & Barnet* 2008)

Atmospheric Tomography (ATom) Mission (*Wofsy et al.* 2018)

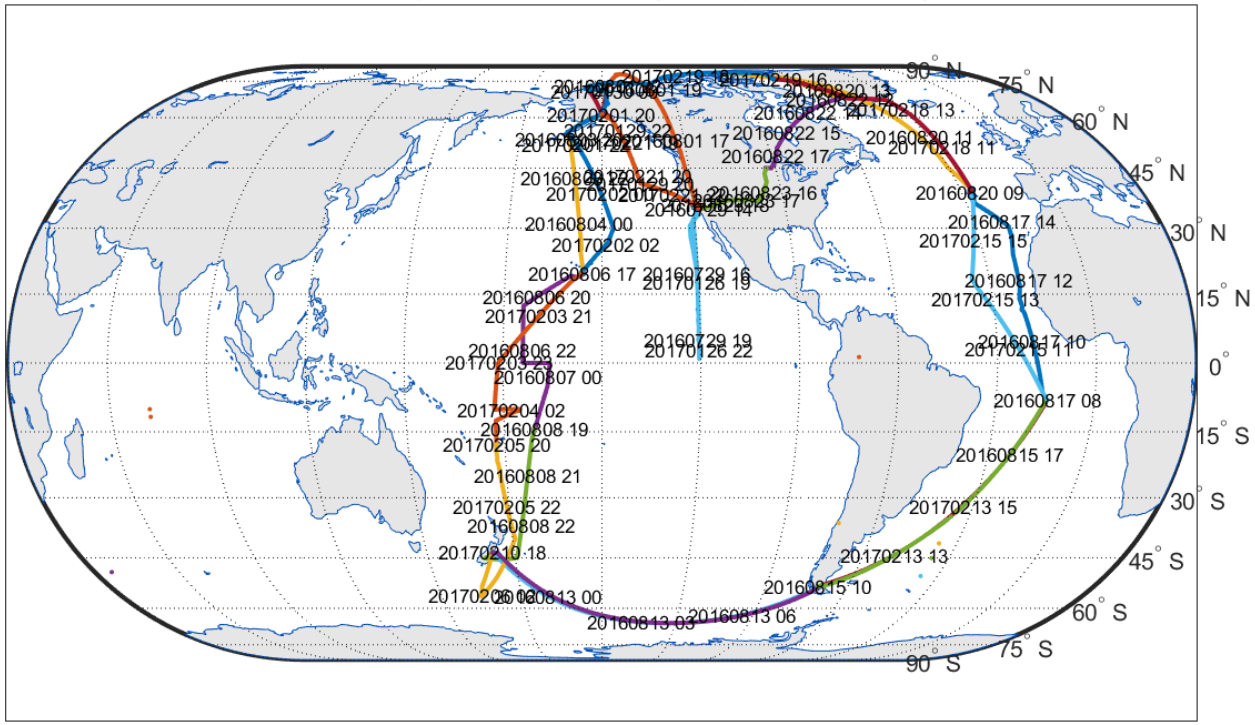
- **ATom** deployed extensive gas and aerosol payloads on the **NASA DC-8** aircraft for global-scale sampling of the atmosphere, **profiling continuously from 0.2–12 km altitude**

- **Flights** occurred spanning 4 seasons originating from the Armstrong Flight Research Center, Palmdale, California
  - North to western Arctic, south to South Pacific, east to Atlantic, north to Greenland, and return to CA across central North America

- In this work we use the **NOAA Picarro** ATom-1 and -2 datasets
  - PIs: Kathryn McKain and Colm Sweeney (CIRES, U. of Colorado, NOAA/ESRL)

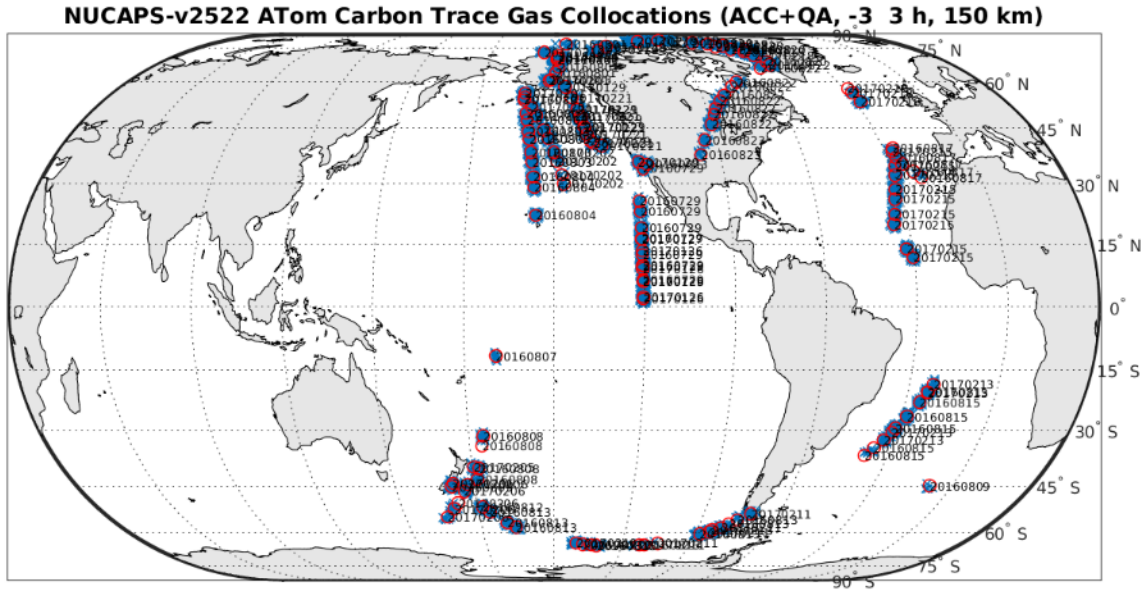
- ***Source:*** ***https://espo.nasa.gov/atom/***

ATom Flights 2016-2017 (Wofsy et al. 2018)



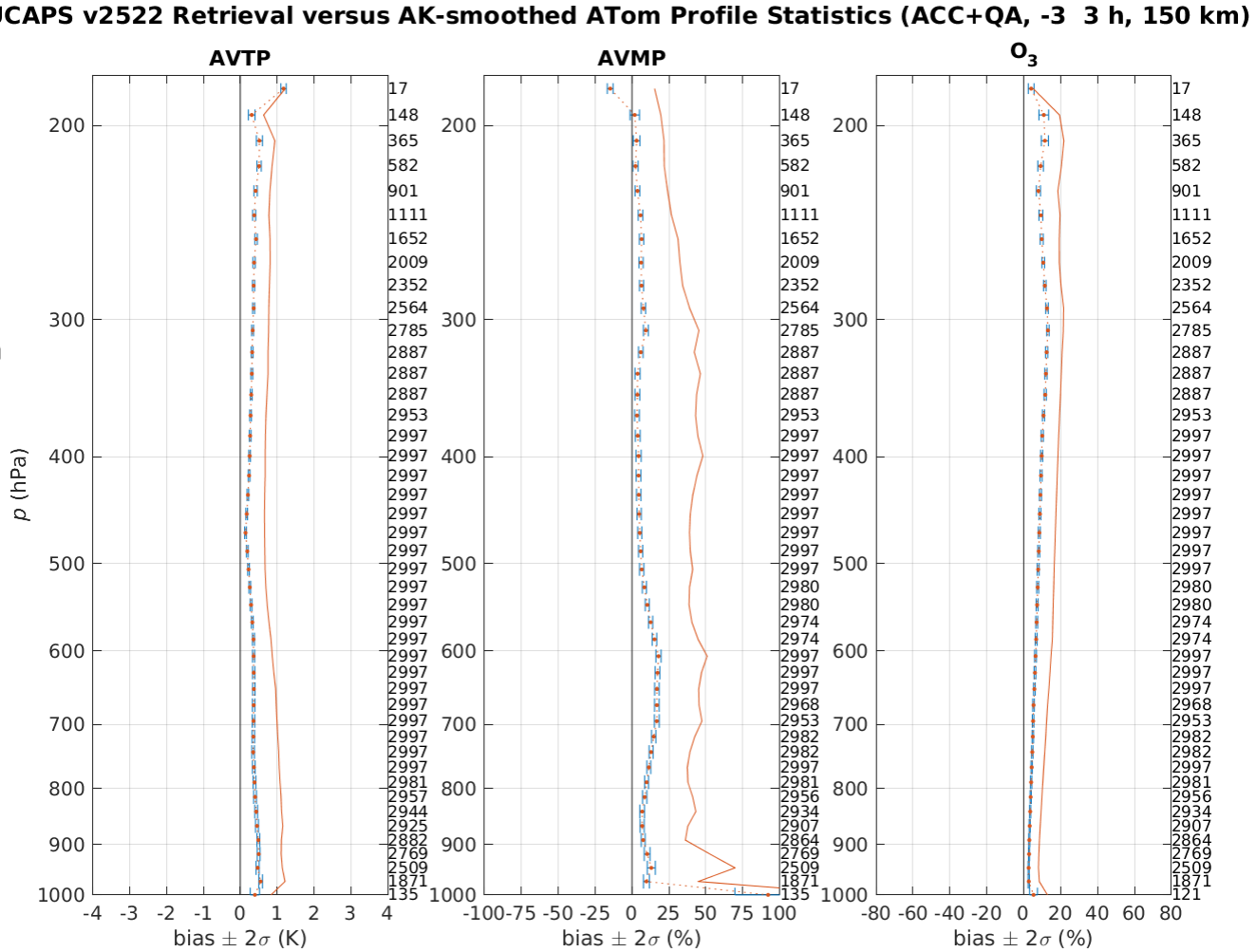
SNPP NUCAPS-ATom Collocations

Accepted + CO Trace Gas QA



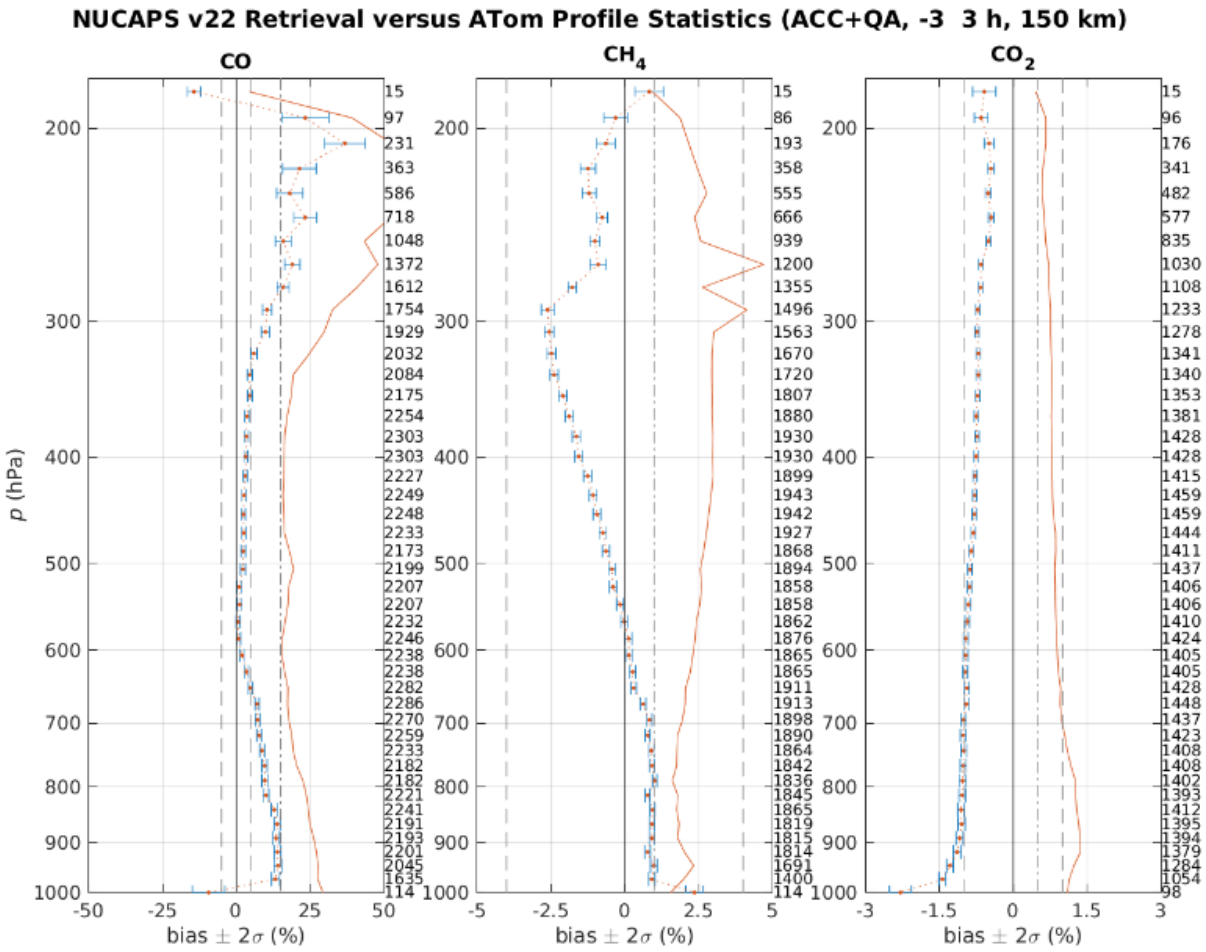
ATom (*Wofsy et al.* 2018)

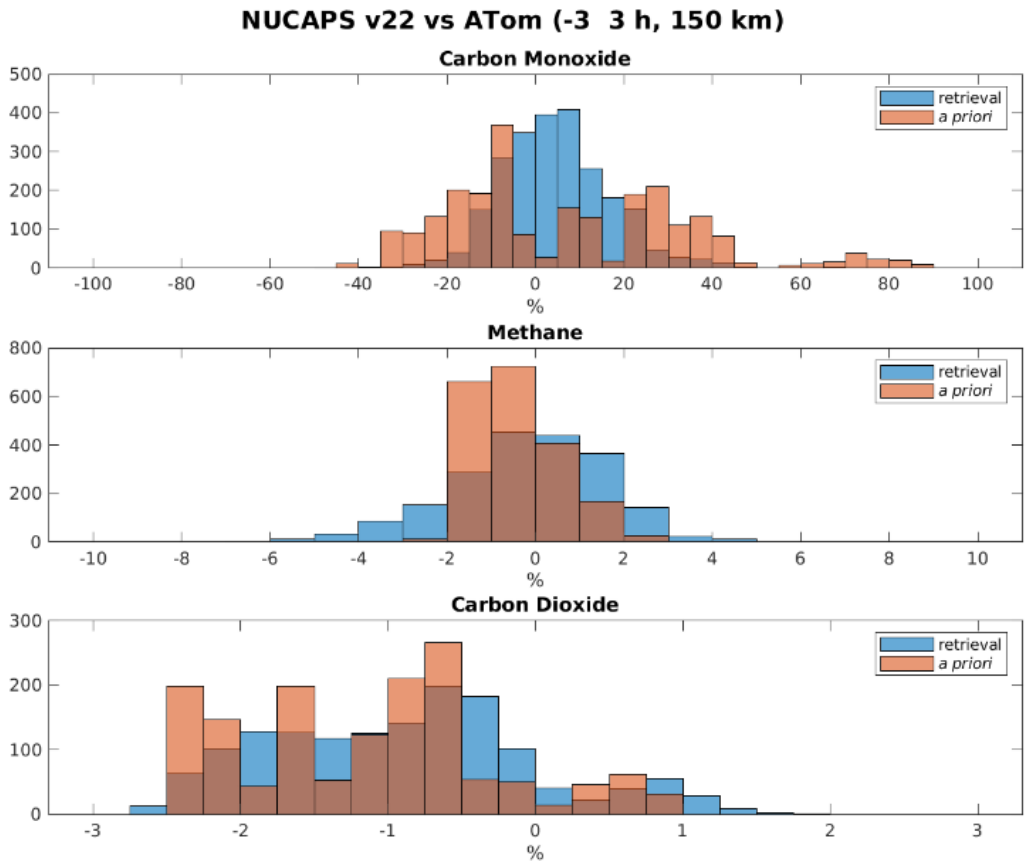
$T/H_2O/O_3$ Statistics



NUCAPS SNPP (OPS v2.1.12d) versus ATom

Accepted+QA, ±3 hr, 150 km

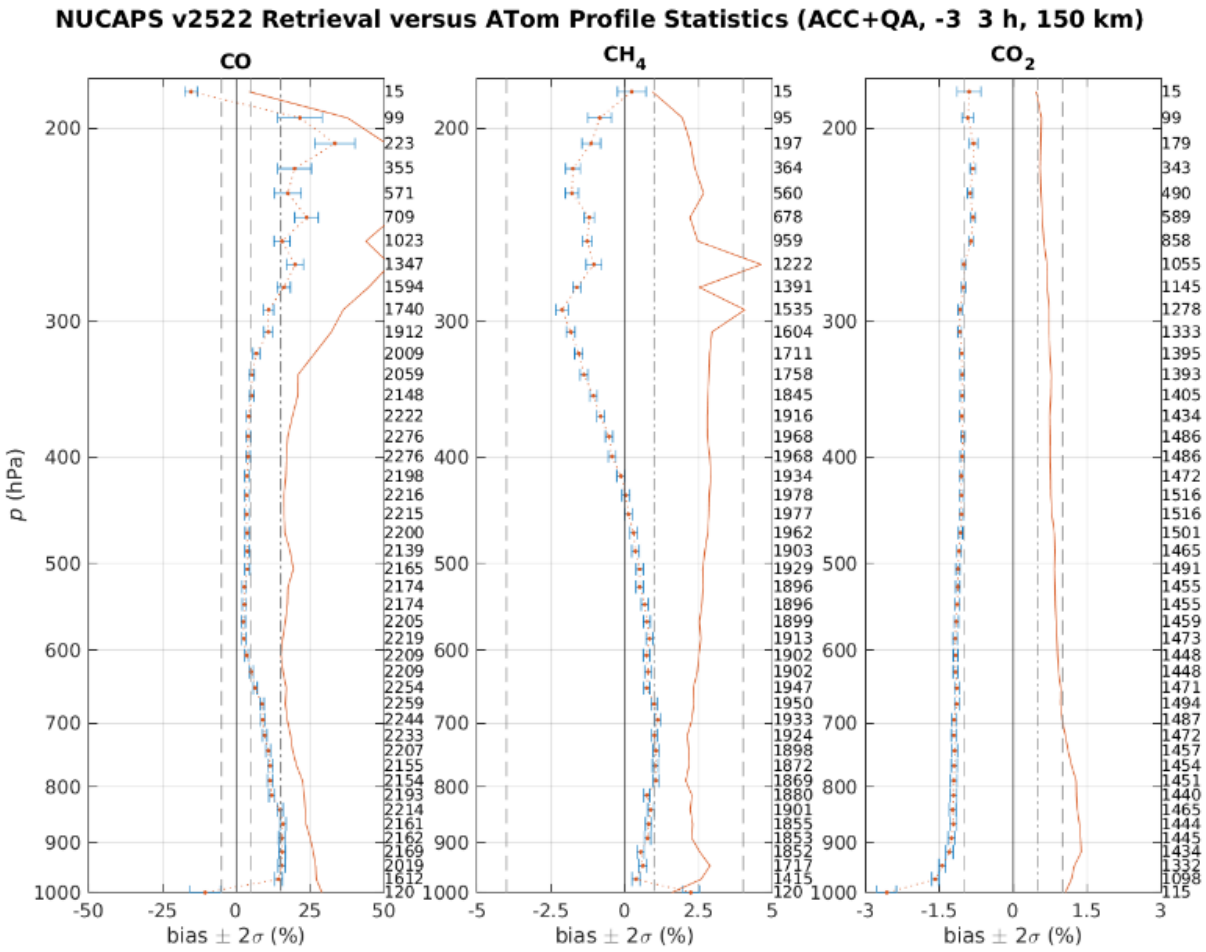


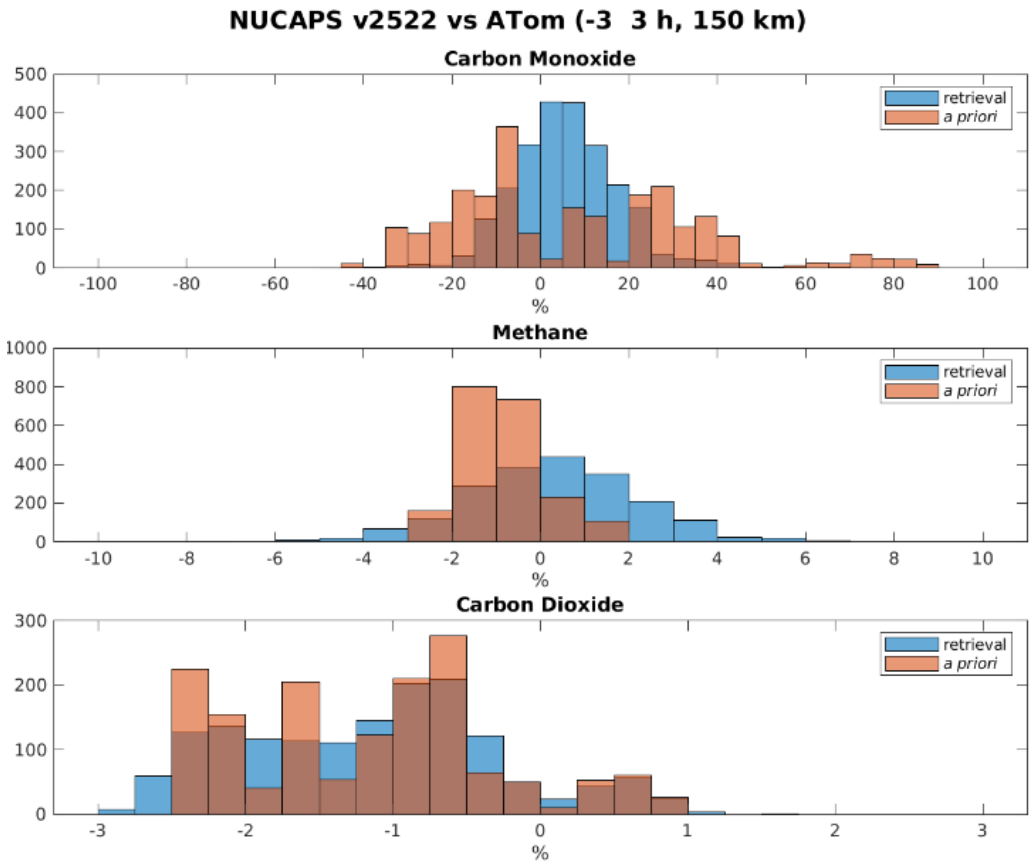


ATom (*Wofsy et al.* 2018)

NUCAPS SNPP (v2.5.2.2) versus ATom

Accepted+QA, ±3 hr, 150 km

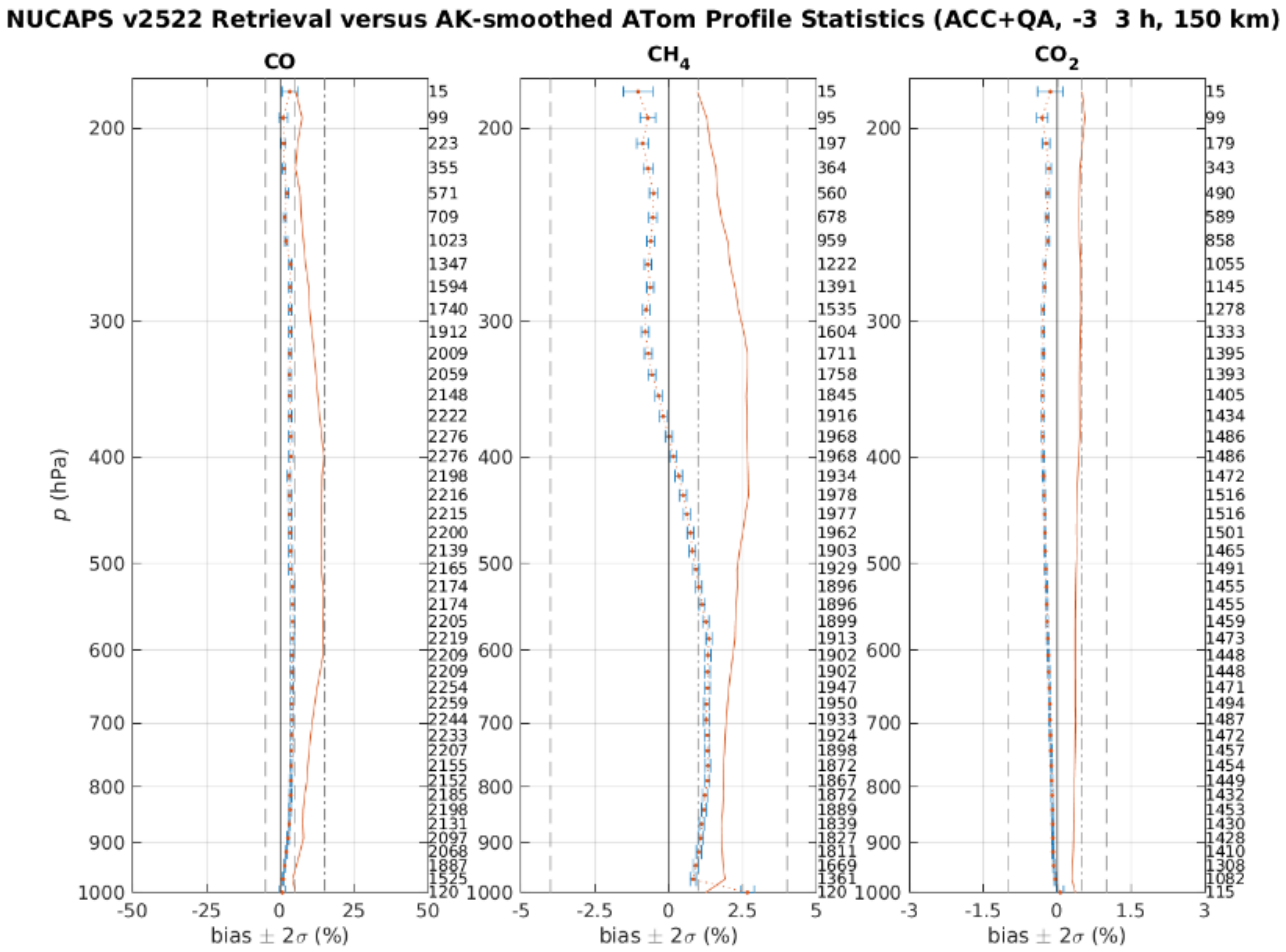


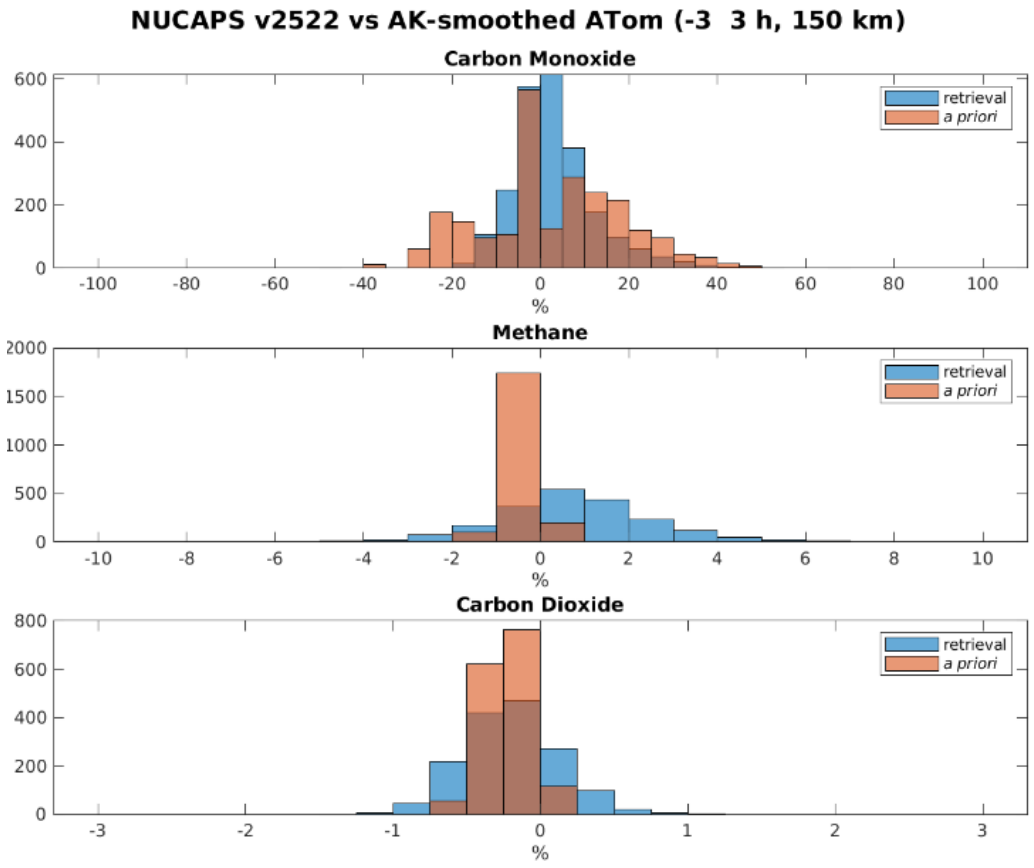


ATom (*Wofsy et al.* 2018)

NUCAPS SNPP (v2.5.2.2) versus ATom AK-Smoothed

Accepted+QA, ±3 hr, 150 km



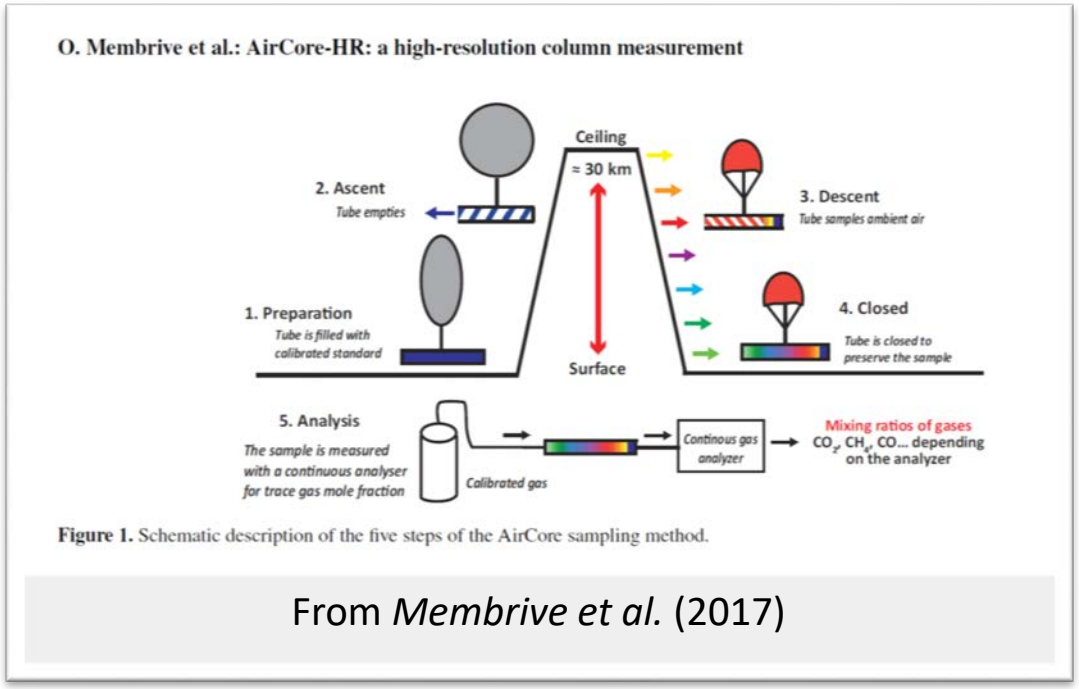


ATom (*Wofsy et al.* 2018)

NOAA ESRL AirCore Sampling System (*Membrive et al.* 2017; *Karion et al.* 2010)

- **Innovative, balloon-borne *in situ* sampling system**
- Uses long stainless steel tube, open at one end and closed at the other
- **Collects a sample (or "core") of the ambient atmospheric air column** during its descent.
- The "core" is recovered, sealed, then brought back to the lab for analysis using a **Picarro trace gas analyzer**.
- Measures mole fractions for trace gases CO, CH_4 and CO_2
- Advantages
  - Geographic coverage over land
  - Relatively high vertical resolution profiles over full tropospheric column

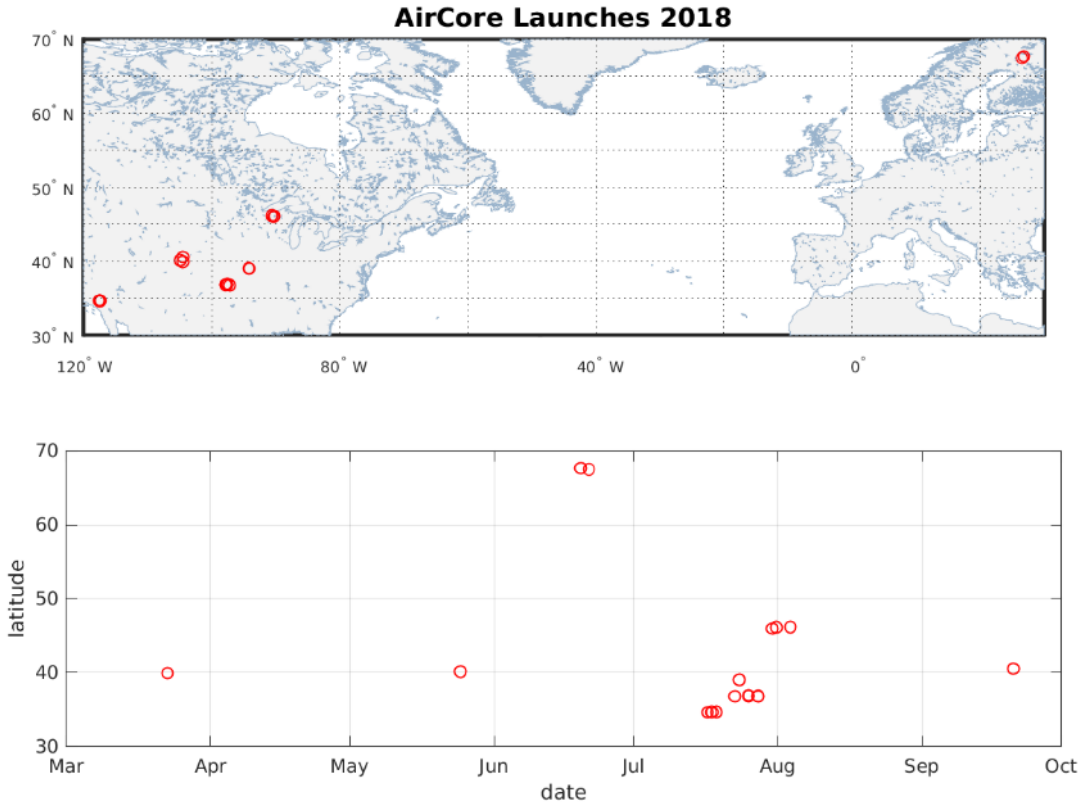
- We obtained ~27 soundings since March 2018 for the NOAA-20 validation effort (courtesy of Colm Sweeny and Monika Kopacz)
  - Balloon launches were timed for satellite overpasses
  - Original soundings rigorously reduced to 100 layer RTA
  - Serves as **SNPP ↔ NOAA-20 transfer standard**



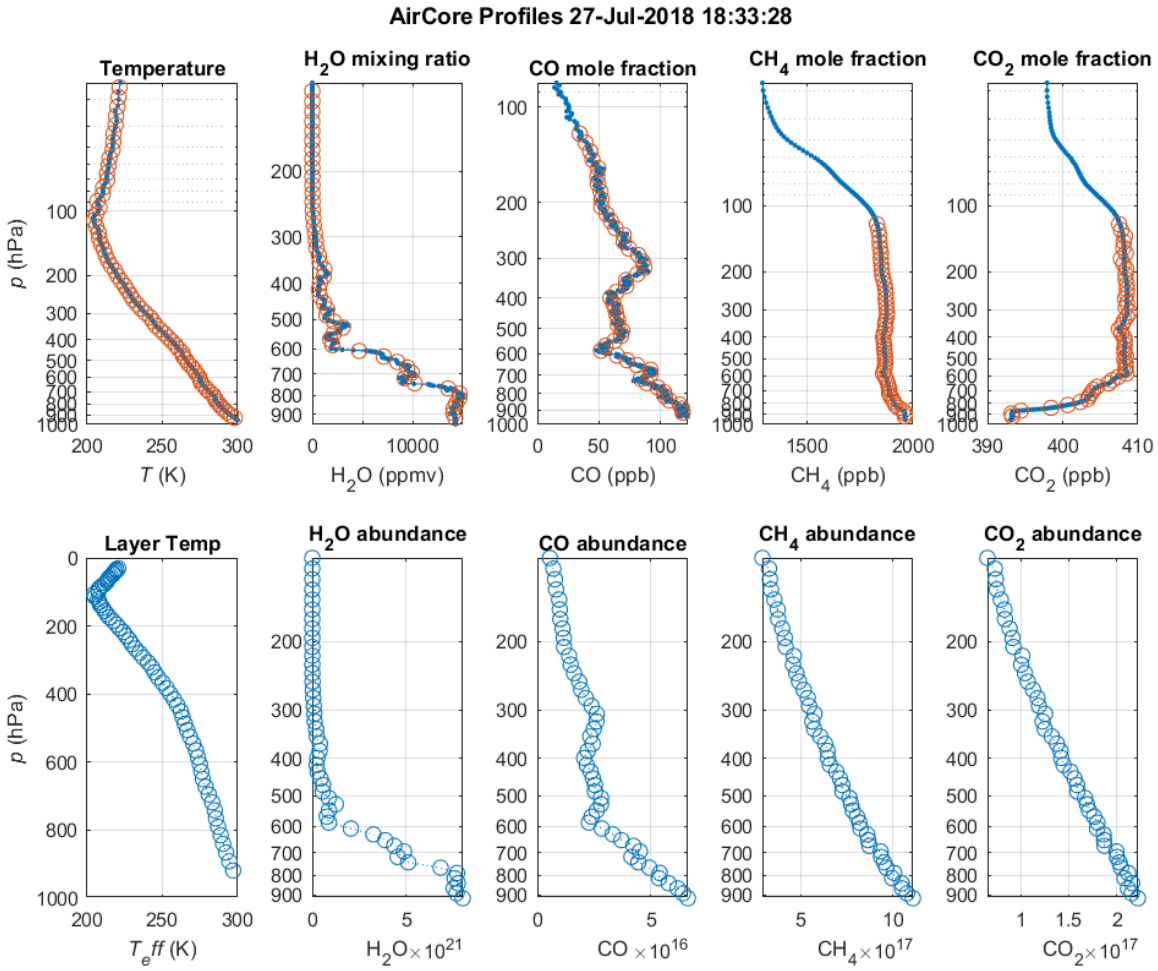
From *Membrive et al.* (2017)

AirCore Profile Sample

Launch Space-Time Locations

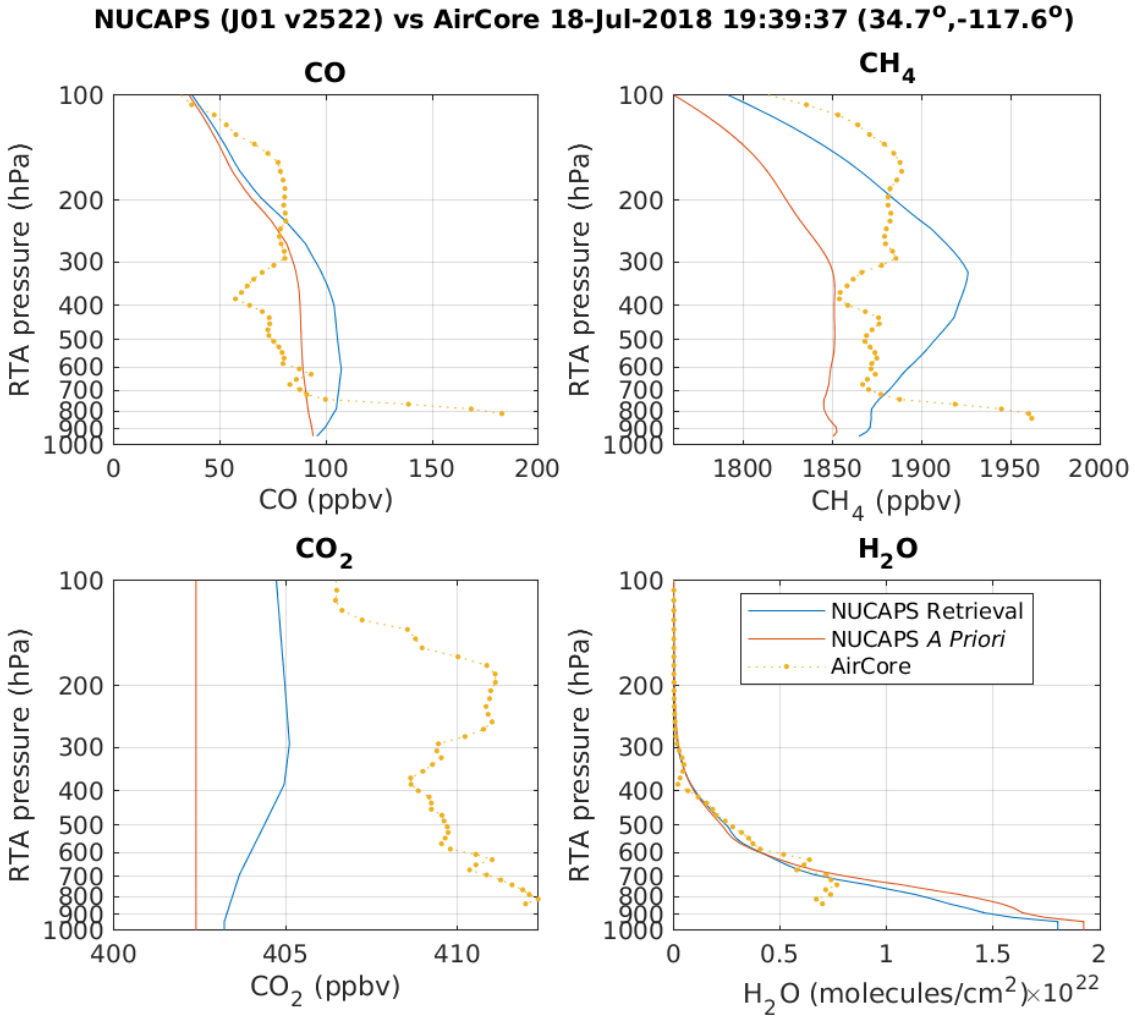


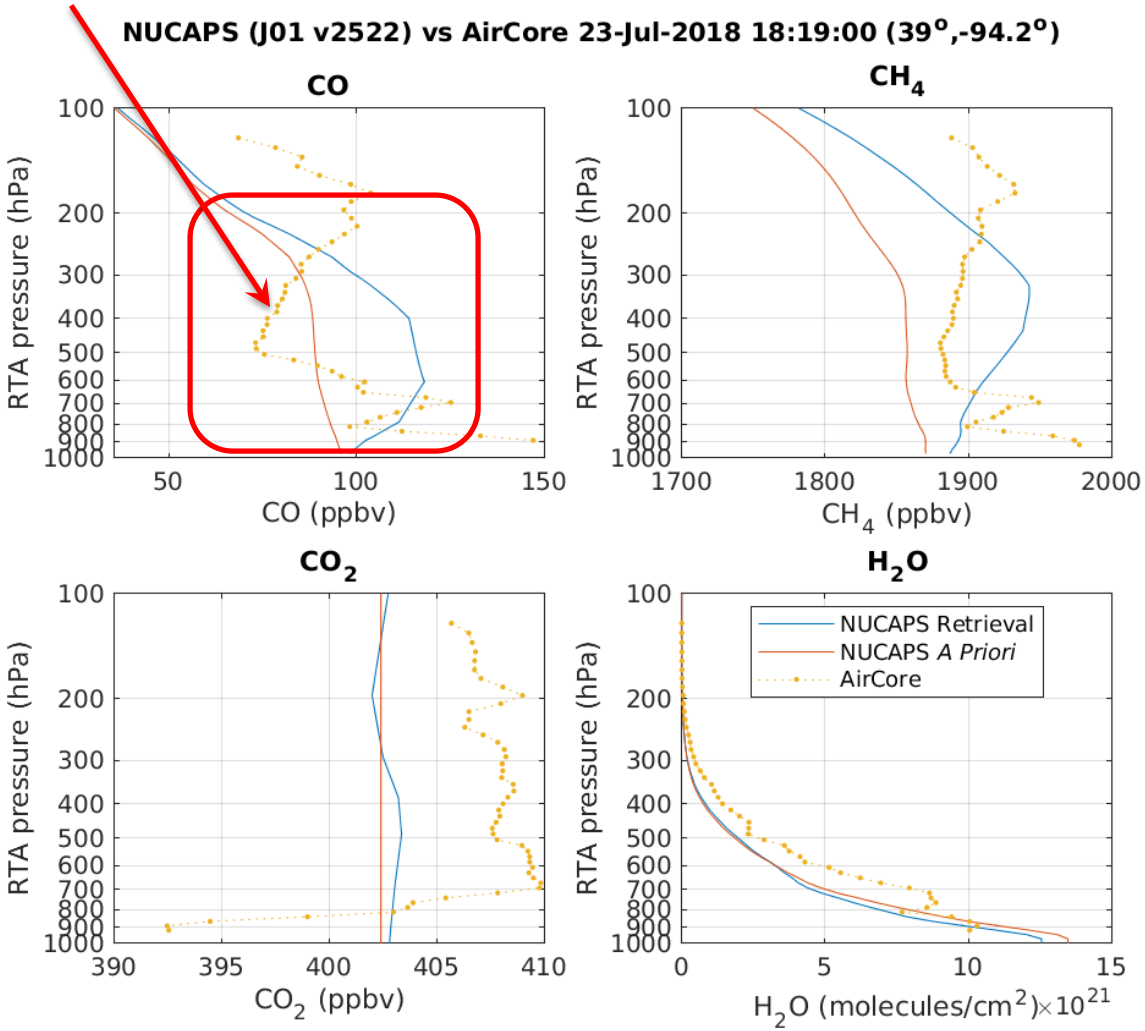
Sample 100 Layer RTA



The AirCore sample represents "pathological" cases over land

Note vertical gradients surpassing resolution of CrIS and diametrically opposed to the *a priori*





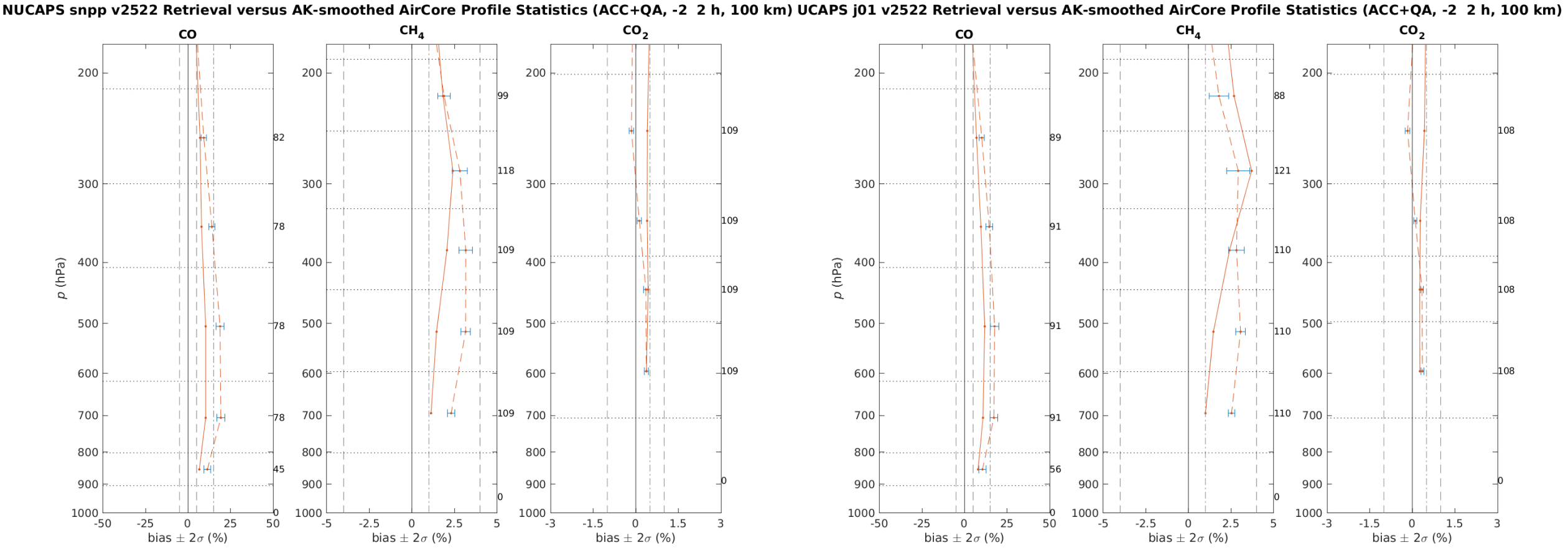
NUCAPS (v2.5.2.2) versus AirCore

AK-Smoothed, Accepted Cases + QA, ±2 hr, 100 km

AirCore

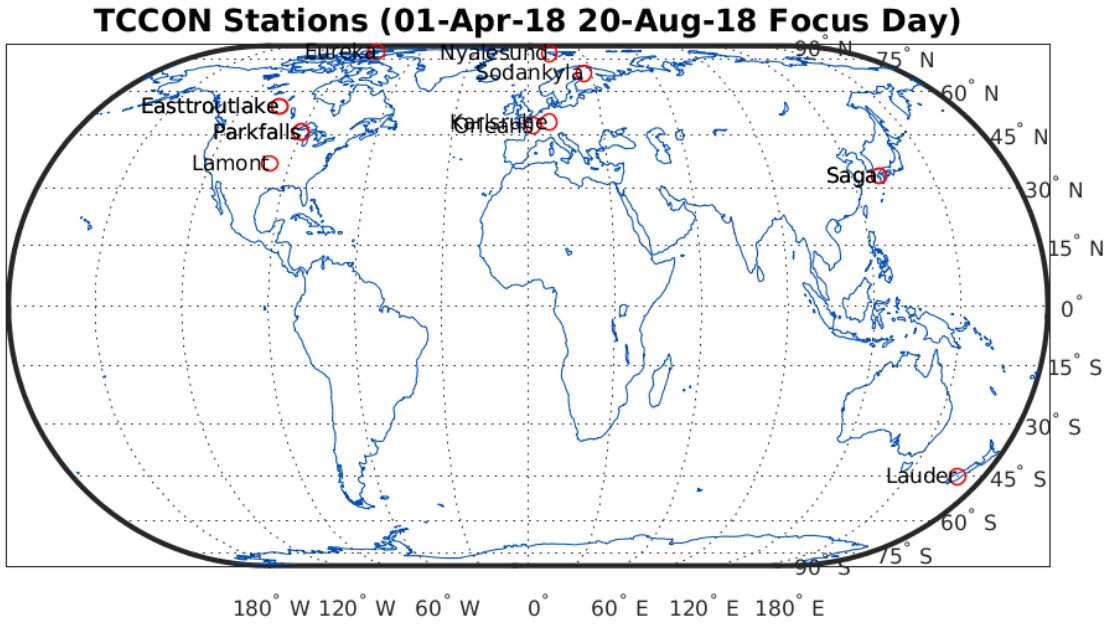
(*Membrive et al.* 2017; *Karion et al.* 2010)

SNPP **NOAA-20**

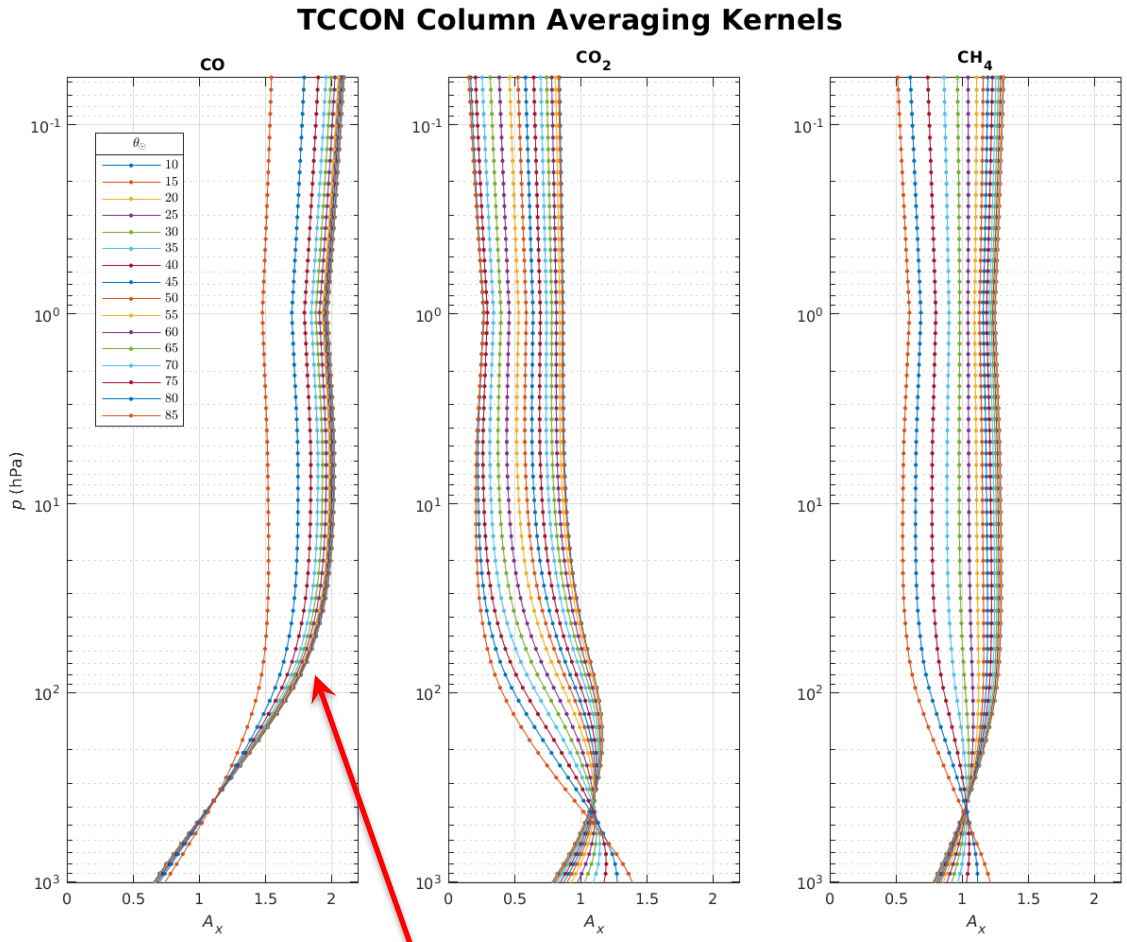


Total Carbon Column Observing Network (TCCON)
(*Wunch et al.* 2011)

Focus Day Station Collocations
(1-Apr-18, 20-Aug-18)



- **Global network of ground-based FTS** that accurately measure total column abundances of CO_2, CO, CH_4, N_2O trace gases
- Serves as **SNPP ↔ NOAA-20 transfer standard**, complementing the SNPP ATom analysis



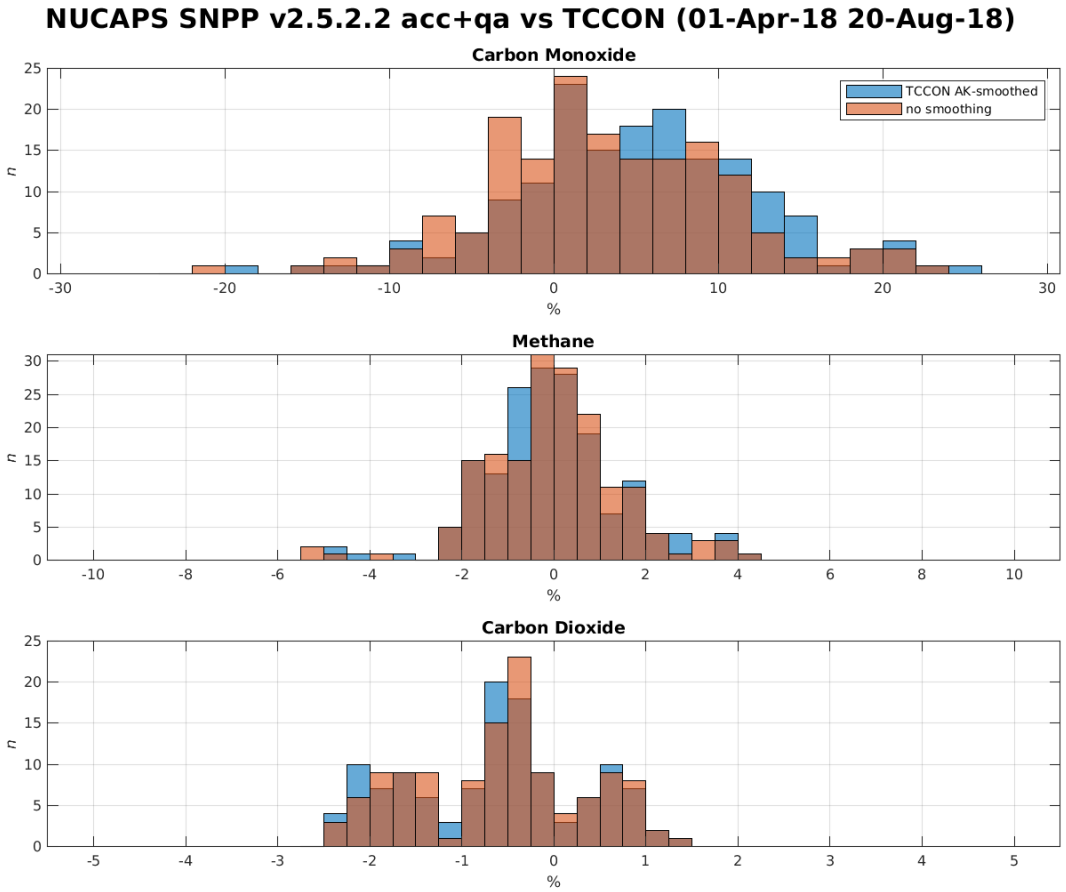
TCCON CO sensitivity peaks above troposphere for all solar angles

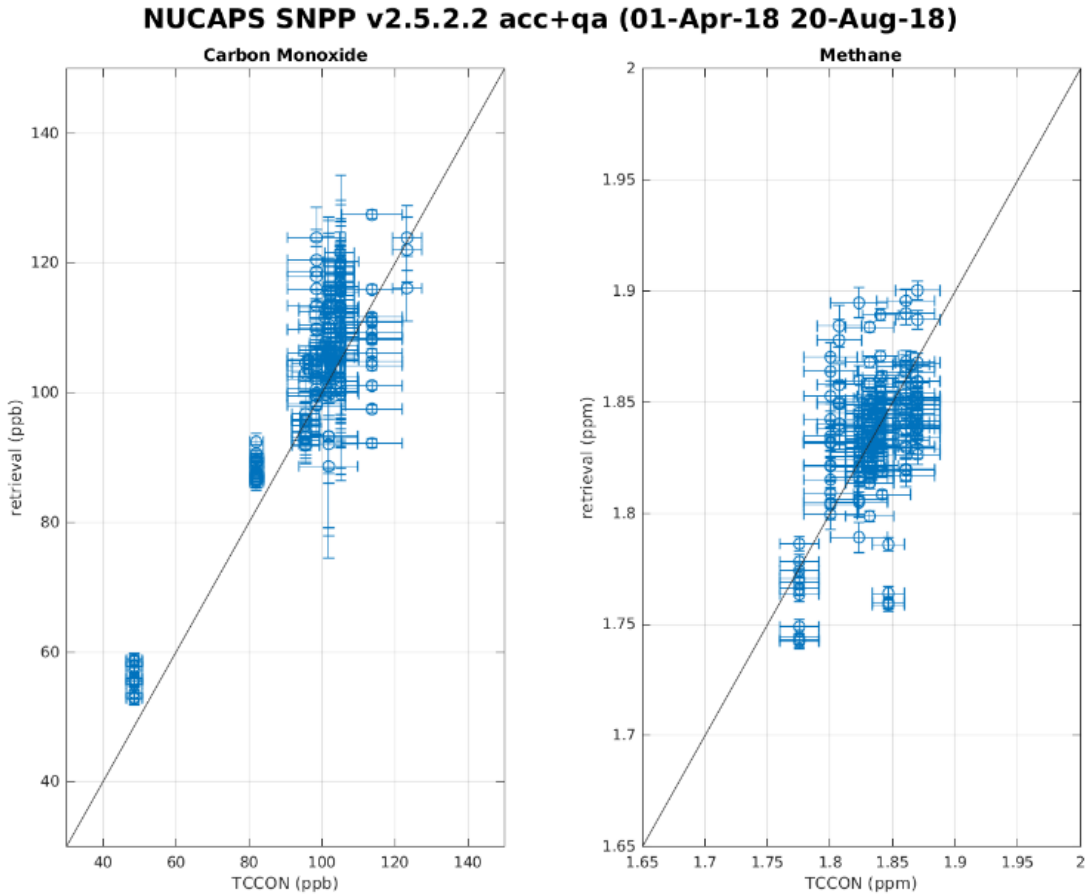
SNPP NUCAPS v2.5.2.2 Total Column Trace Gases vs TCCON

Focus Days: 1 April and 20 August 2018

TCCON

(*Wunch et al.* 2011)



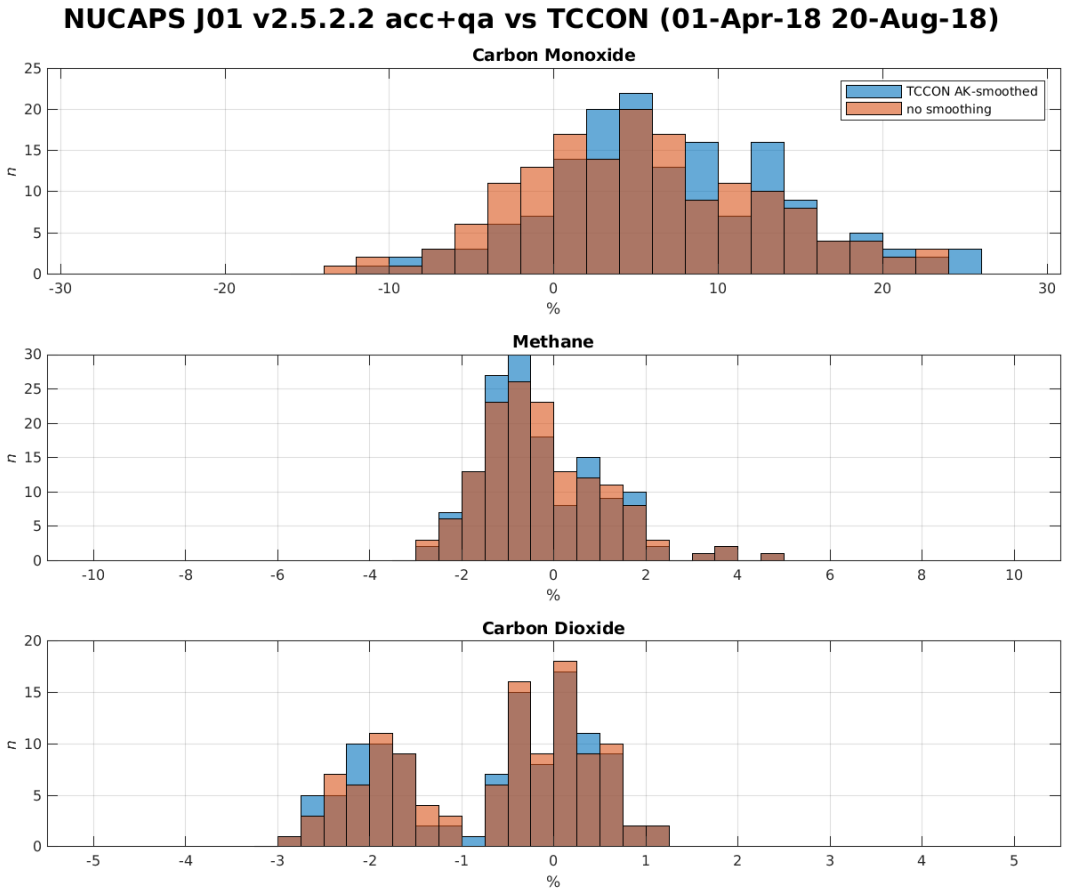


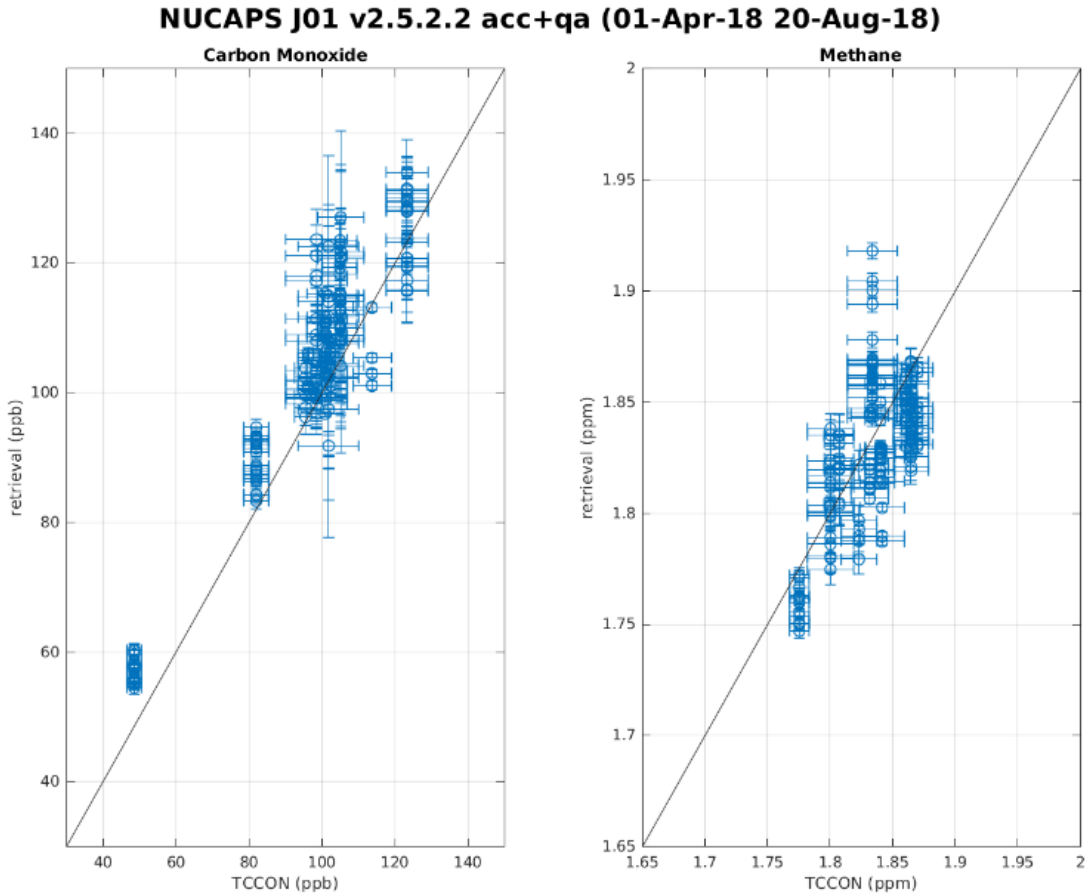
NOAA-20 NUCAPS v2.5.2.2 Total Column Trace Gases vs TCCON

Focus Days: 1 April and 20 August 2018

TCCON

(*Wunch et al.* 2011)





Carbon Gas Summary Tables (v2.5.2.2 vs ATom and TCCON)

ATom (SNPP)

Parameter	Stat	Raw Total Column		NUCAPS AKs applied	
		NUCAPS	Req	NUCAPS	Req
CO	Precision	(11.8)	15%	(9.5)	15%
	Accuracy	(+6.0)	±5%	(+3.0)	±5%
CH4	Precision	(1.9)*	1%* (20 ppmv)	(1.7)*	1% (20 ppmv)
	Accuracy	(+0.3)	4% (80 ppmv)	(+0.8)	4% (80 ppmv)
CO2	Precision	(0.9)*	0.5%* (2 ppmv)	(0.3)	0.5% (2 ppmv)
	Accuracy	(−1.1)	±1% (4 ppmv)	(−0.2)	±1% (4 ppmv)

TCCON (SNPP↔NOAA-20 Transfer Standard)

Parameter	Stat	Raw Total Column		TCCON AKs applied	
		NUCAPS	Req	NUCAPS	Req
CO	Precision	7.4 (7.4)	15%	7.3 (7.5)	15%
	Accuracy	+5.3 (+3.2)	±5%	+7.1 (+5.1)	±5%
CH4	Precision	1.3 (1.5)*	1%* (20 ppmv)	1.4 (1.5)*	1% (20 ppmv)
	Accuracy	−0.3 (+0.0)	4% (80 ppmv)	−0.3 (+0.0)	4% (80 ppmv)
CO2	Precision	1.1 (0.9)*	0.5%* (2 ppmv)	1.1 (1.0)*	0.5% (2 ppmv)
	Accuracy	−0.7 (−0.6)	±1% (4 ppmv)	−0.7 (−0.6)	±1% (4 ppmv)

ATom SNPP Global Yields:
CO = 62.5% ($N \approx 2200$)
CH4 = 54.3% ($N \approx 1900$)
CO2 = 47.7% ($N \approx 1500$)

*Precision requirements for CH4 and CO2 are now know to be too stringent and will require waver.

TCCON Global Yields:
CO = (64.8)%, N = 156 (166)
CH4 = (66.8) %, N = 145 (171)
CO2 = (47.7) %, N = 116 (122)

Values in ( ) indicates SNPP

Meets requirement **Marginal (± 25%)** **Outside Requirement**

Error Budget: AVTP, AVMP, O3, OLR, CO, CH4, CO2

Attribute Analyzed	L1RD Threshold Accuracy/Precision	Maturity Status	Analysis/Validation Result	Error Summary	Support Artifacts
NOAA-20 AVTP	See Slide 34	Validated	Meets all requirements	See Slides 67-68	
NOAA-20 AVMP	See Slide 34	Validated	Meets all requirements	See Slides 67-68	
NOAA-20 O3	See Slides 35	Validated	Meets all requirements	See Slide 69	
NOAA-20 OLR	See Slide 75	Validated	Meets all requirements	See Slide 75-76, 85	
SNPP/NOAA-20 CO	See Slide 35	Validated	Meets all requirements	See Slide 117	
SNPP/NOAA-20 CH4	See Slide 35	Provisional	Meets all requirements	See Slide 117	
SNPP/NOAA-20 CO2	See Slides 35	Beta	N/A	N/A	

USER FEEDBACK AND TESTIMONIALS

NUCAPS Users

- Many users use NUCAPS products for operational applications and research.
- NUCAPS: Temperature, water vapor, cloud fraction, cloud height
  - CSPP generates NUCAPS products as part of Direct Broadcast Network
  - The Weather Forecast Offices nationwide currently ingest NUCAPS temperature, water vapor, and cloud fraction information into the Advanced Weather Interactive Processing System (AWIPS-2) for analyzing atmospheric instabilities, potential outbreaks of severe weather, and in now-casting applications.
  - Also used by: NOAA/NASA, ESRL, EPA, NFS, USDA, CPO-AC4, ESRL/CSD, ESRL/GMD, GFDL, NWP Assimilation Groups
- NUCAPS: Ozone - used to make TOAST
- NUCAPS: CO and CH4, and other trace gases – Synergistic use for day-to-day events
- Relevant Technical Interchange Meetings (TIM) Notes
  - JPSS - CPO TIM https://www.star.nesdis.noaa.gov/jpss/documents/meetings/2016/JPSS_CPO/JPSS_CPO_AC4_REPORT.pdf
  - JPSS – MAPP Exploring JPSS Data Application for Earth System Data Assimilation https://www.star.nesdis.noaa.gov/jpss/documents/meetings/2017/JPSS_CPO_MAPP/JPSS_CPO_MAPP_REPORT.pdf

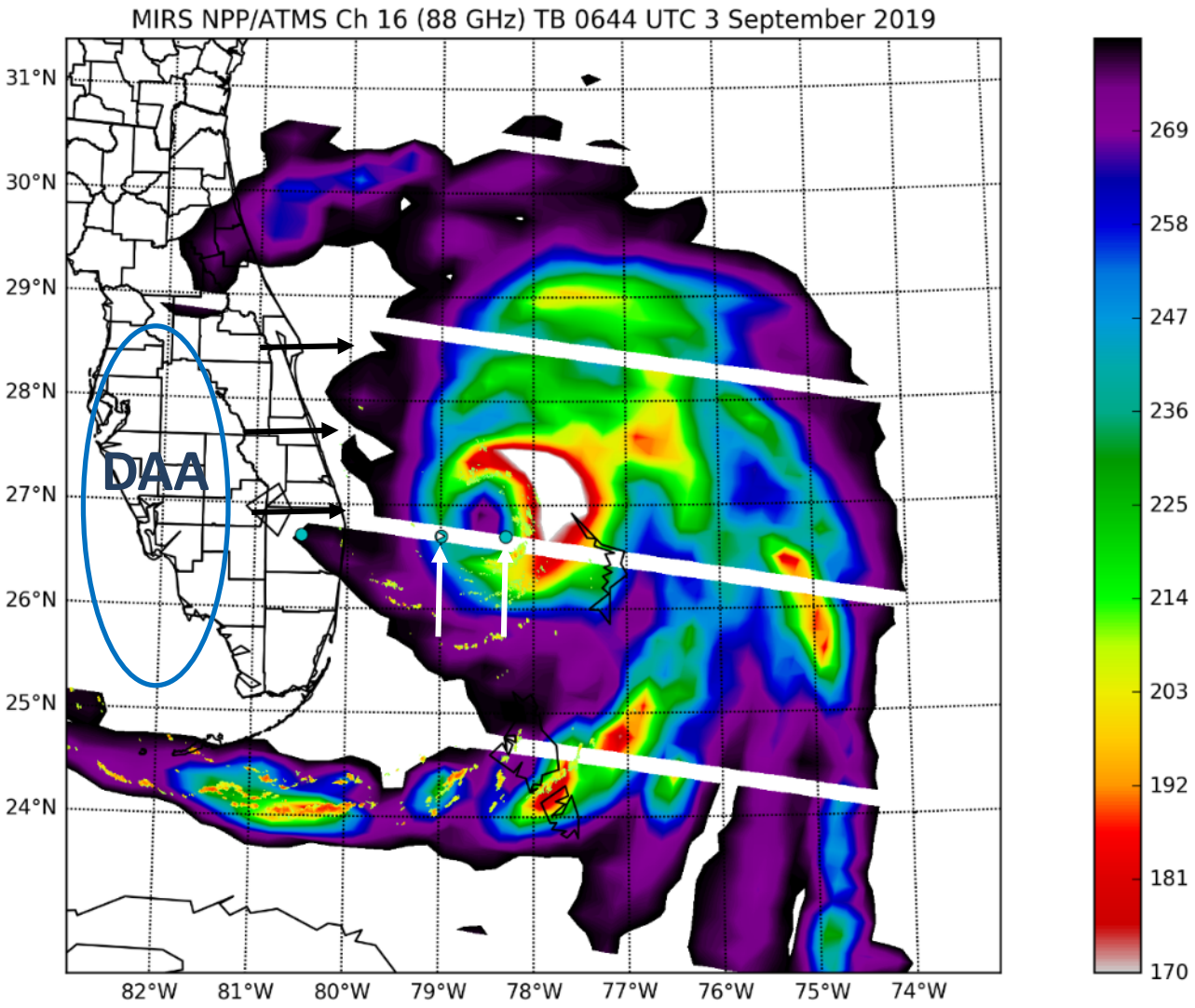
User Feedback

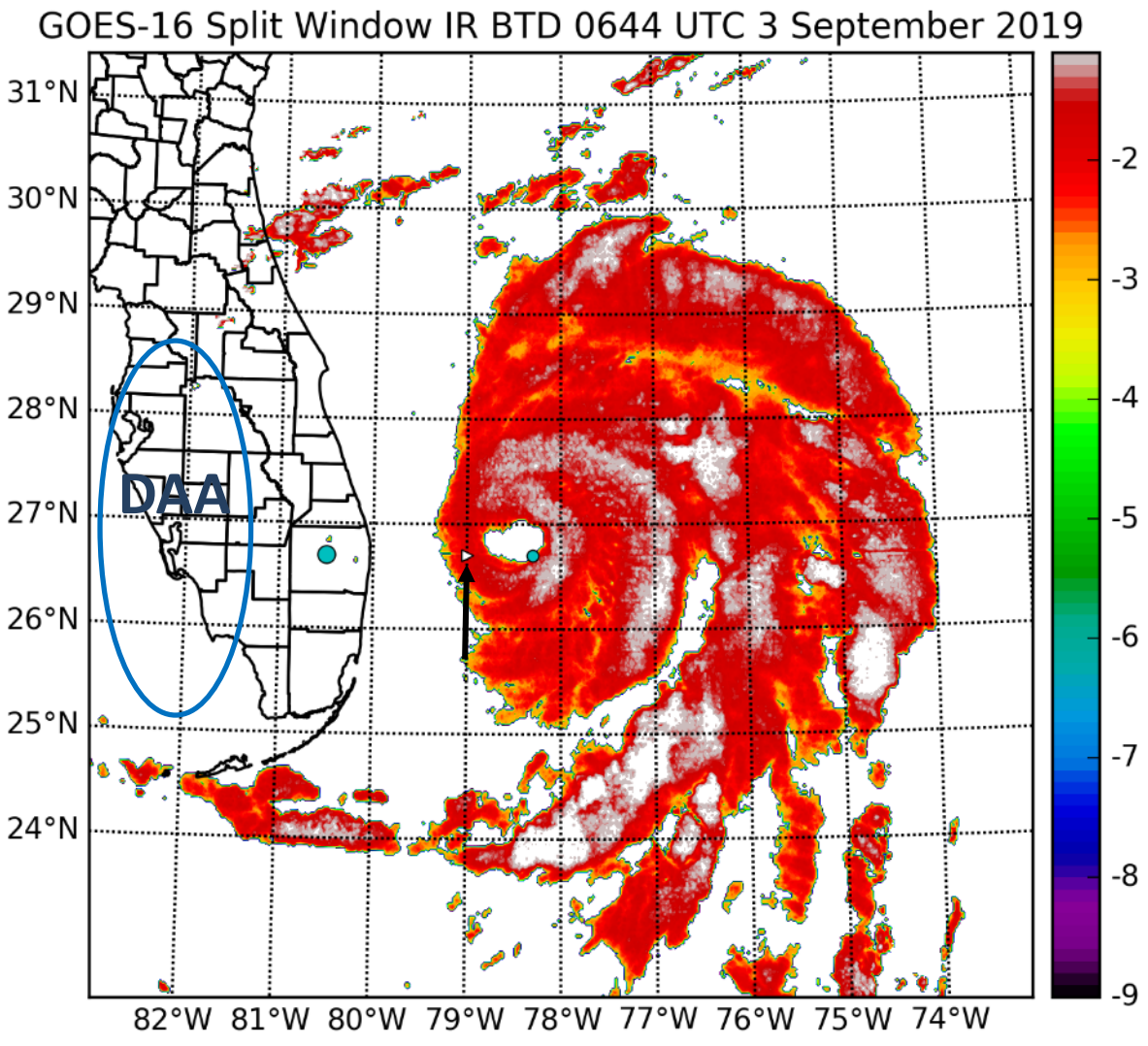
Algorithm	Product	User Feedback
NUCAPS	AVTP, AVMP, TPW	Ken Pryor, NWS/AWIPS
NUCAPS	O3	Larry Flynn, TOAST
NUCAPS	OLR	Pingping Xie
NUCAPS	CO	Greg Frost, Shobha Kondragunta, Juying Warner
NUCAPS	CH4	Juying Warner

Analysis of Hurricane Dorian

Ken Pryor (STAR/SMCD/OPDB)

Hurricane Dorian

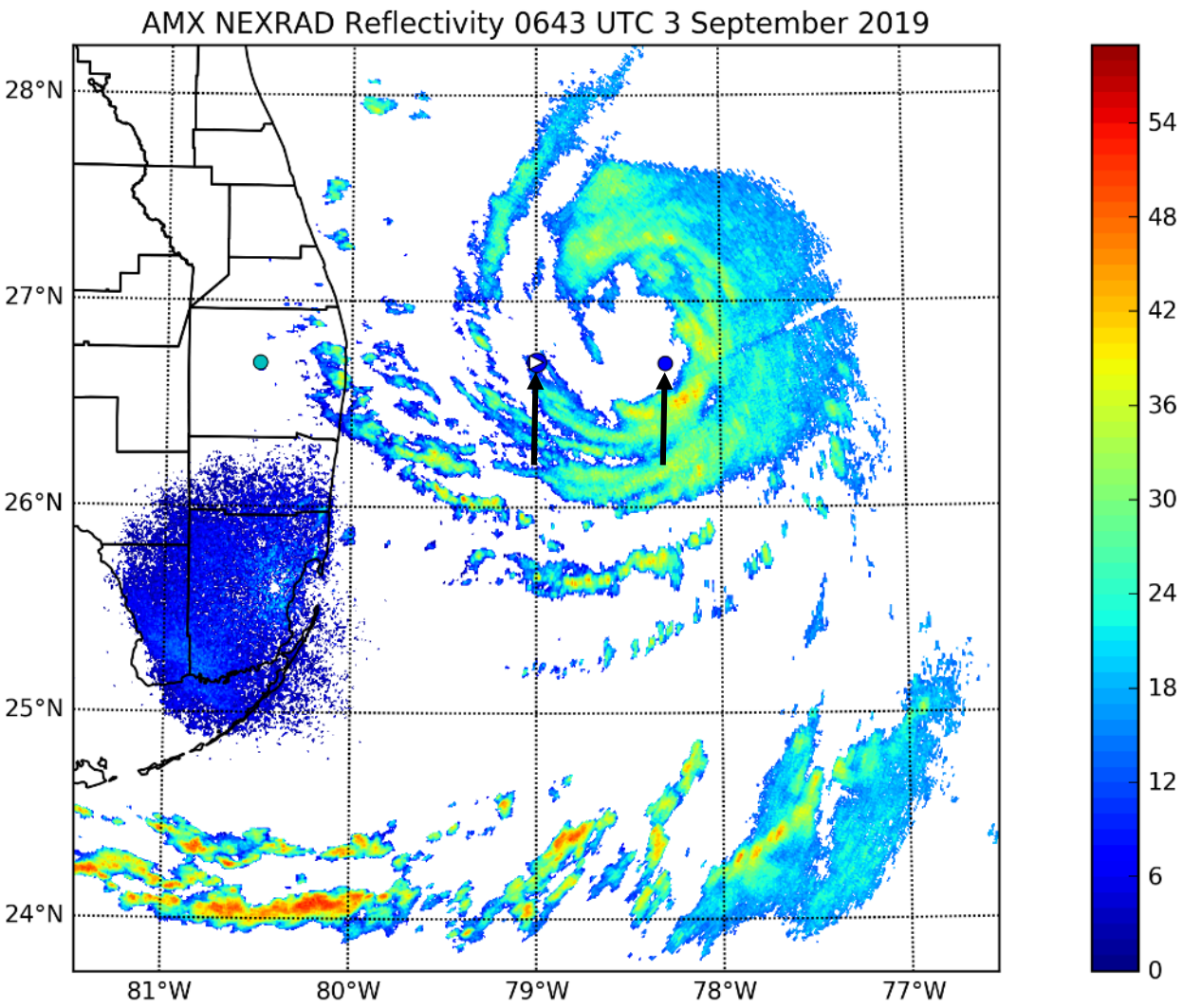


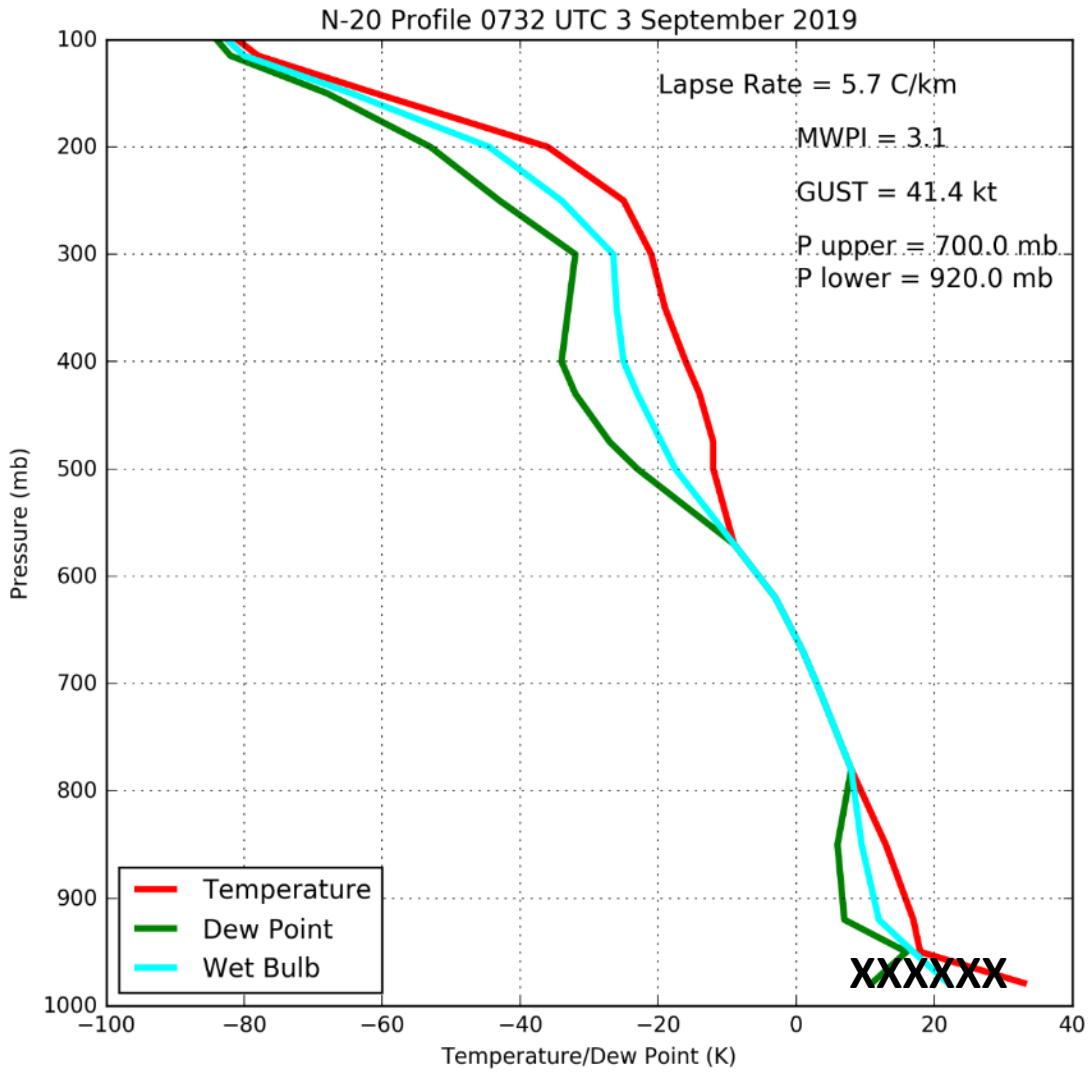


Event Summary

- During the overnight hours of September 2-3, 2019, category 4 Hurricane Dorian was nearly stationary over Grand Bahama Island.
- Microwave Integrated Retrieval System (MiRS)-generated Advanced Technology Microwave Sounder (ATMS) 88 GHz imagery generated from the early morning SNPP descending node pass (0644 UTC) revealed mid-tropospheric drying in the western semicircle of Dorian while intense convective storm activity concentrated in the eastern semicircle of the eye wall. This pattern was also echoed by GOES-16 and NEXRAD (Doppler radar) imagery.
- A NUCAPS sounding at 0732 UTC just within the eye wall over Grand Bahama Island displayed the presence of a mid-tropospheric unsaturated layer overlying an elevated mixed layer. This thermodynamic configuration favors large potential instability in the inner periphery of the eye wall.
- A concurrent NUCAPS sounding over Palm Beach County, FL, about 110 Nmi west of the eye, displayed a significant mid-tropospheric dry air layer.

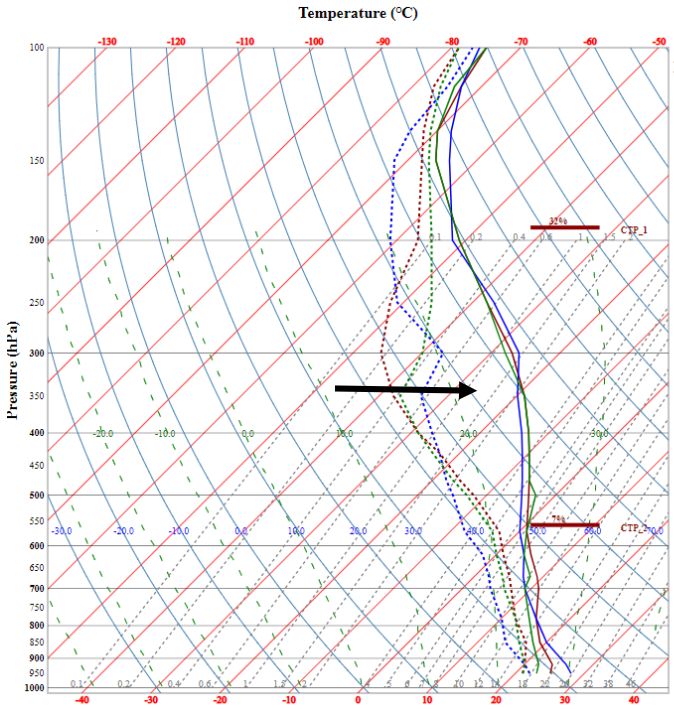
Hurricane Dorian: Selection of NUCAPS Sounding Retrievals





NUCAPS Sounding Retrieval Comparison

Palm Beach County, FL



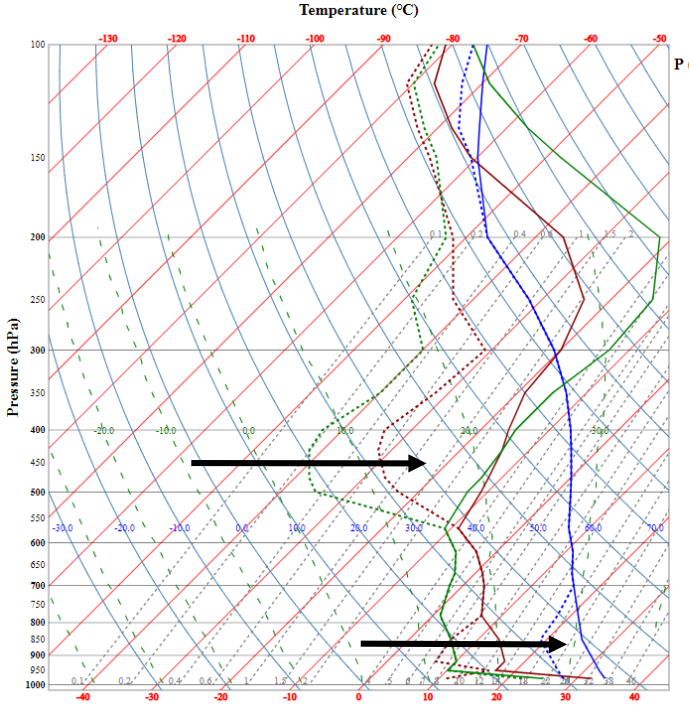
P (hPa)	T(°C)	DP (°C)
1003	28	23
950	25	22
920	24	20
850	20	17
780	16	13
700	11	7
670	9	5
620	5	1
570	1	-4
500	-4	-12
475	-6	-16
430	-10	-24
400	-13	-29
350	-20	-39
300	-28	-47
250	-39	-52
200	-52	-58
150	-66	-68
135	-70	-72
115	-74	-77
100	-75	-79

Param	MW_IR	MW	Units
VIEW	-38		°
SOLZ	133		°
DSC			
ELEV	5	5	m
PARP	953	953	hPa
PART	28	29	°C
PARD	75	24	°C
TSKN	29		°C
PW	61	55	mm
L.I.	-1	-8	°C
CAPE	160	4779	J/kg
NCAP	10	32	cm/s2
MXHAIL	0	0	cm
CINH	101	5	J/kg
K.I.	38	35	
TT	45	46	
SHOW	-2	-2	°C
LR8-5	6	6	K/km
CVT	281	308	°C
LCL	928	883	hPa
LFC	653	850	hPa
EL	419	120	hPa
ELT	-70	-72	°C
CCL	848	850	hPa
MCL	953	846	hPa
-20C	8622	8540	m
15TH		5835	m
87TH	1653	1647	m
FRZL	5057	4830	m
PCPT	R	R	

MW+IR Regr Dew Pt Temp
MW+IR Phys Dew Pt Temp
MW Phys Dew Pt Temp
MW Phys Temperature
MW+IR Regression Temp
Cloud Top Fraction
MW+IR Phys Temp

Lat: 26.7 deg Lon: -80.5 deg
2019-09-03 07:32:45 UTC
Platform: N20
Accepted

Grand Bahama Island



P (hPa)	T(°C)	DP (°C)
979	33	11
950	18	16
920	17	7
850	13	6
780	8	8
700	3	3
670	1	1
620	-3	-3
570	-9	-9
500	-12	-23
475	-12	-27
430	-14	-32
400	-16	-34
350	-19	-33
300	-21	-32
250	-25	-43
200	-36	-53
150	-61	-68
135	-69	-74
115	-78	-82
100	-81	-84

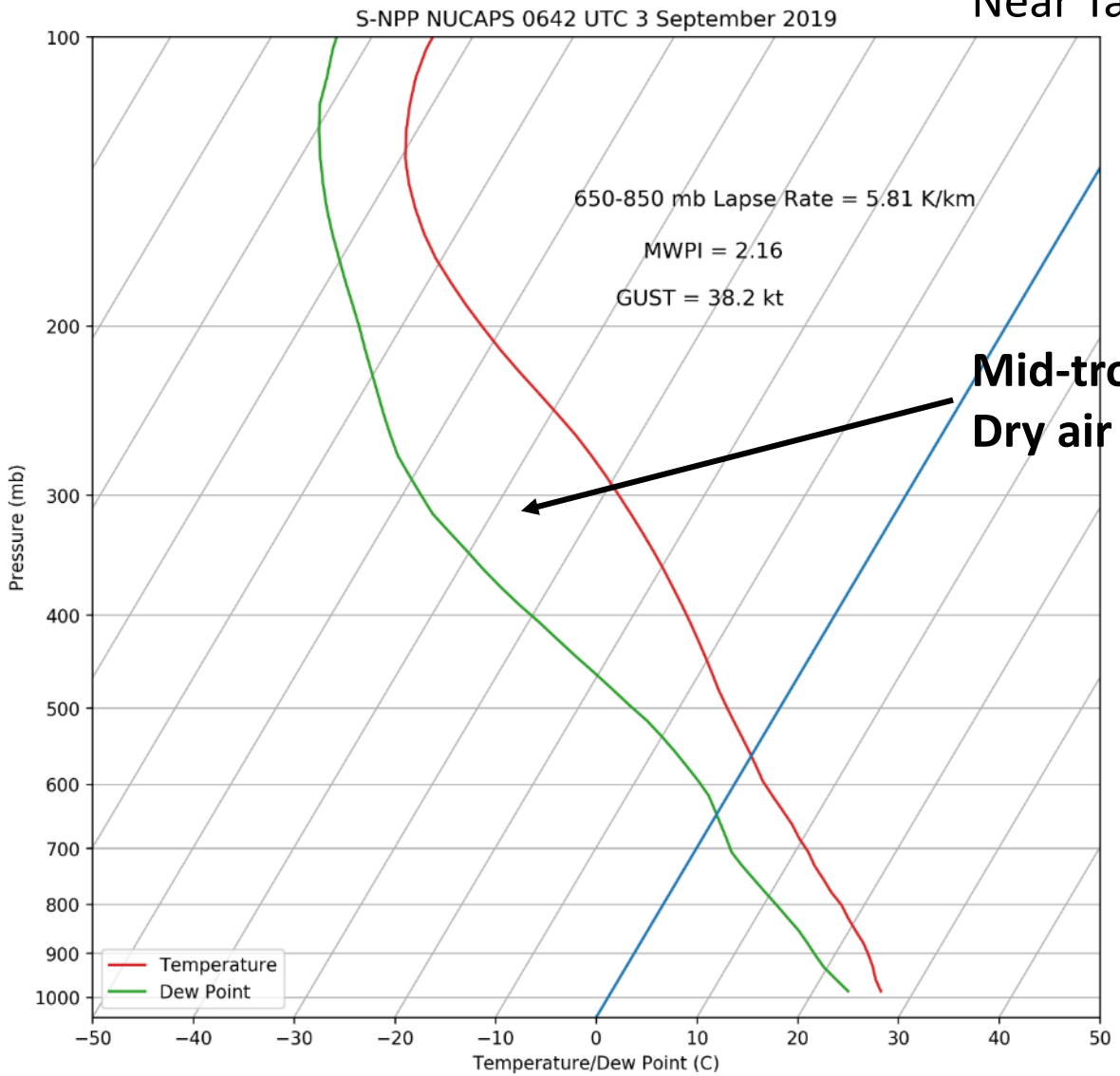
Param	MW_IR	MW	Units
VIEW	-45		°
SOLZ	132		°
DSC			
ELEV	1	1	m
PARP	929	929	hPa
PART	28	31	°C
PARD	51	26	°C
TSKN	8		°C
PW	34	91	mm
L.I.	2	-4	°C
CAPE	3	0	J/kg
NCAP	1	0	cm/s2
MXHAIL	0	0	cm
CINH	0		J/kg
K.I.	32	43	
TT	43	40	
SHOW	3	-0	°C
LR8-5	6	5	K/km
CVT	279	314	°C
LCL	784	860	hPa
LFC	766	843	hPa
EL	727		hPa
ELT	-10		°C
CCL	788	797	hPa
MCL	928	0	hPa
-20C	8635	9515	m
15TH		5755	m
87TH	1607	1689	m
FRZL	3347	6184	m
PCPT	R	R	

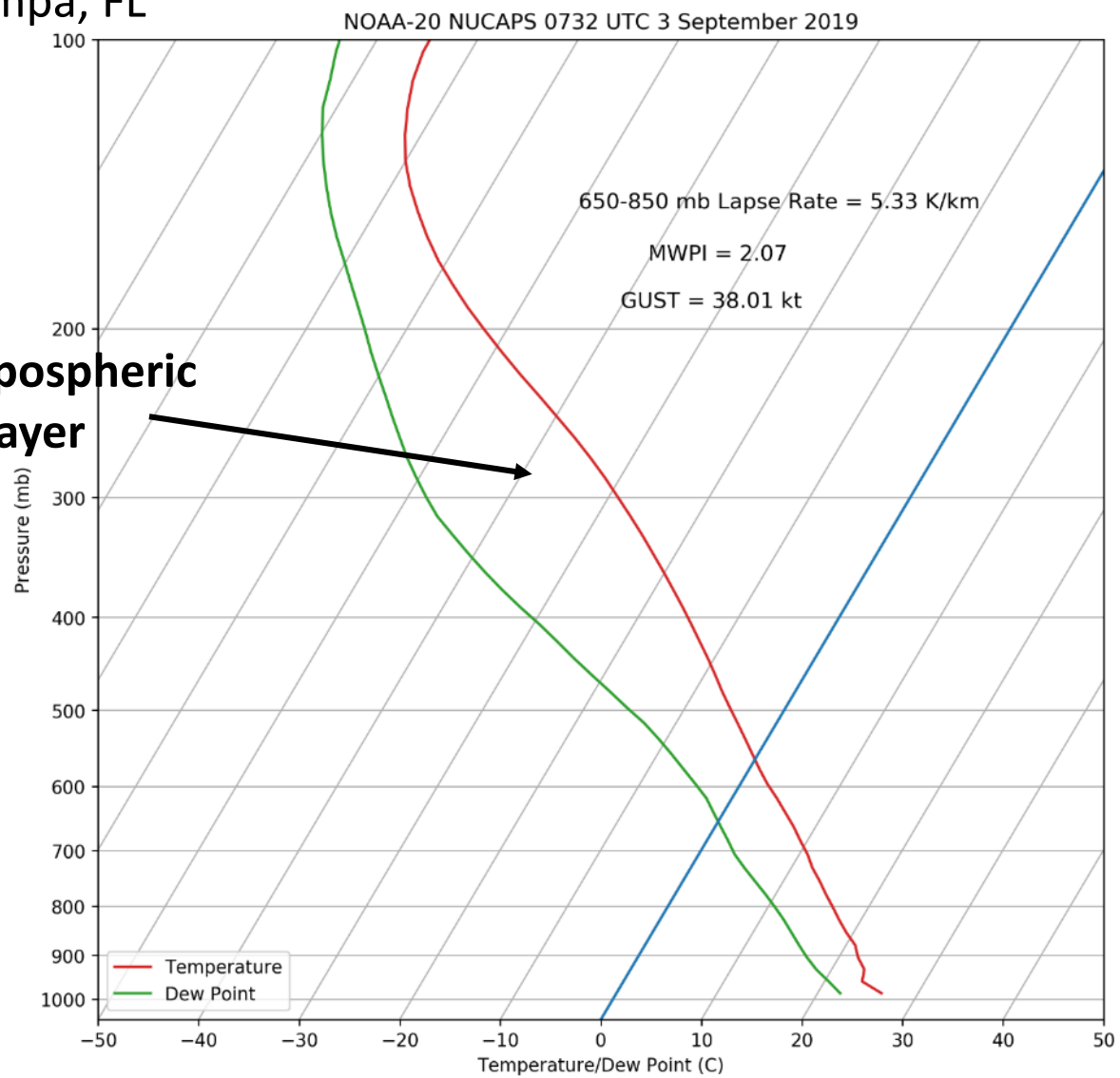
MW+IR Regr Dew Pt Temp
MW+IR Phys Dew Pt Temp
MW Phys Dew Pt Temp
MW Phys Temperature
MW+IR Regression Temp
Cloud Top Fraction
MW+IR Phys Temp

Lat: 26.7 deg Lon: -78.3 deg
2019-09-03 07:32:13 UTC
Platform: N20
Rejected by Physical and MW

NPP-NOAA-20 NUCAPS Comparison

Near Tampa, FL

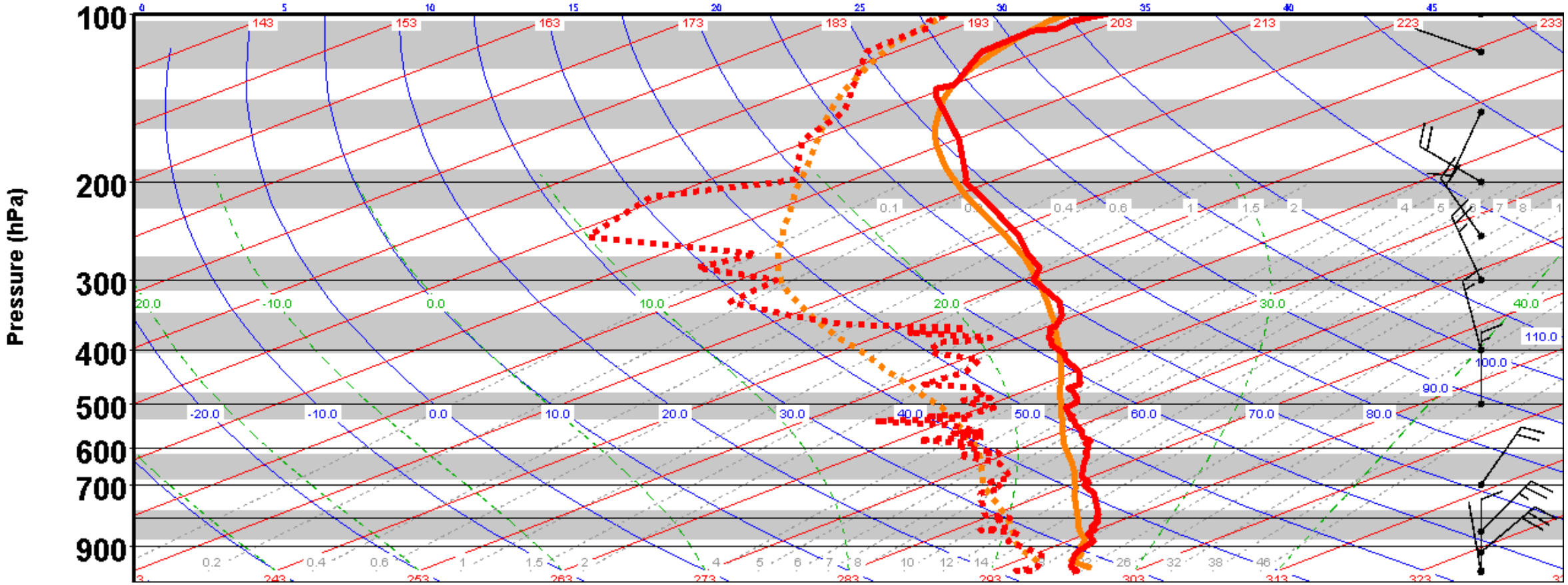




Mid-tropospheric Dry air layer

NOAA Products Validation System (NPROVS)

Dewpoint / Temperature (deg K)



SONDE 72210 (182) SONDE **9/3/2019 5:06:00Z** **27.7 N / 82.4 W**

NUCAPS NOAA-20 **9/3/2019 7:32:09Z (2.4 hours)** **27.6 N / 82.6 W (26.5 km)**

NOAA's Need for an Atmospheric Composition Observing Capability

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Acknowledgements
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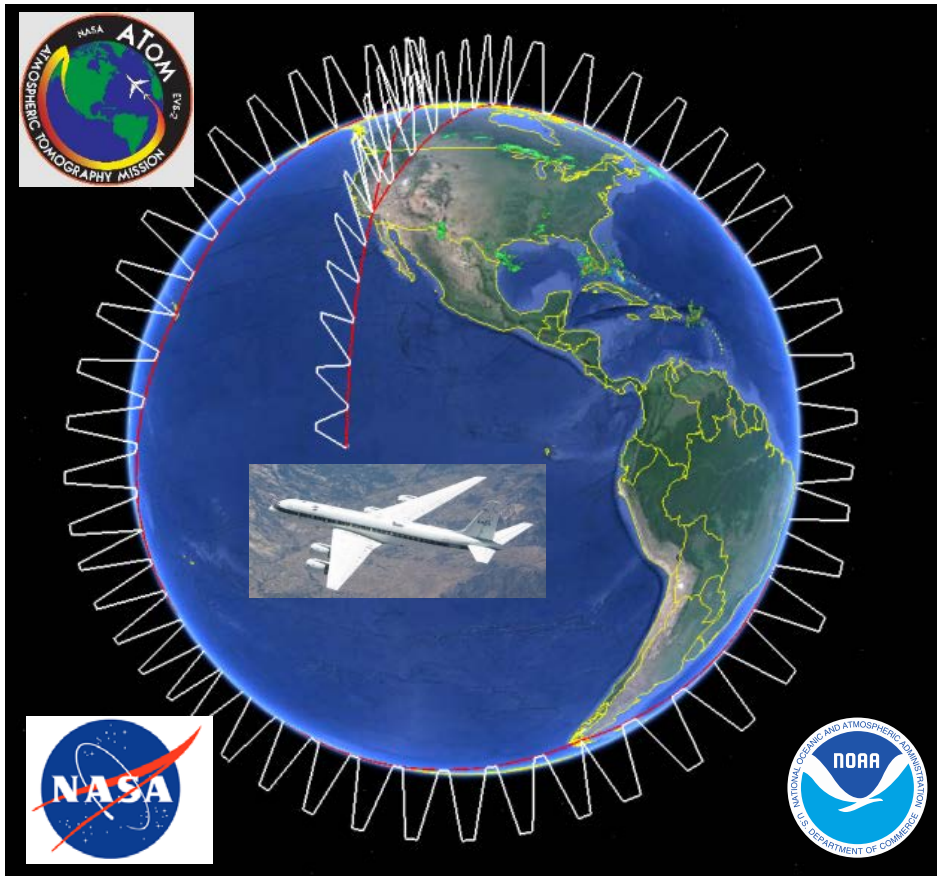
Harvard University, Cambridge, MA d

JPSS Proving Ground/ Risk Reduction Program

[1]Also at CIRES, University of Colorado, Boulder, CO
[2]Now at University of La Réunion, St. Denis, France
[3]Now at California Air Resources Board, Sacramento, CA
[4]Also at Laboratoire d'Aérologie, Toulouse, France
[5]Now at Yonsei University, Seoul, Korea
[6]Now at Colorado State University, Ft Collins, CO
[7]Also at IM Systems Group, Rockville, MD
[8]Now at Columbia University & Lamont-Doherty Earth Observatory, New York, NY

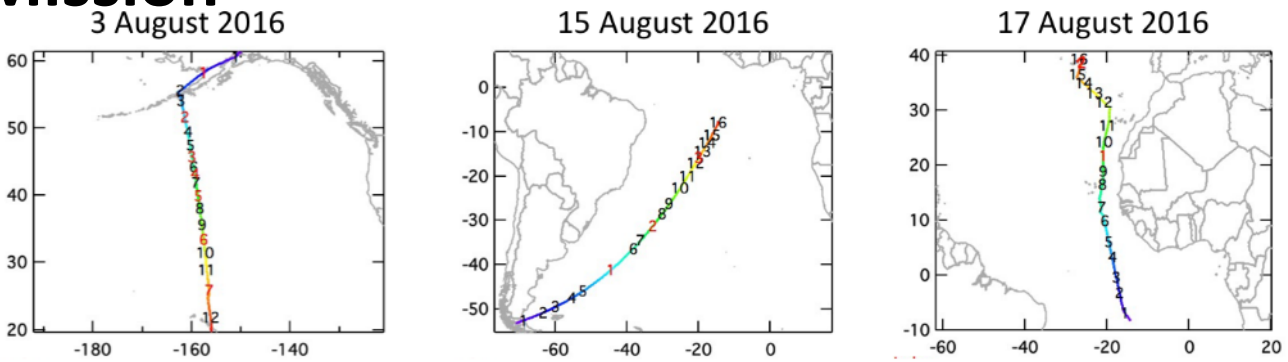
Atmospheric Tomography Mission



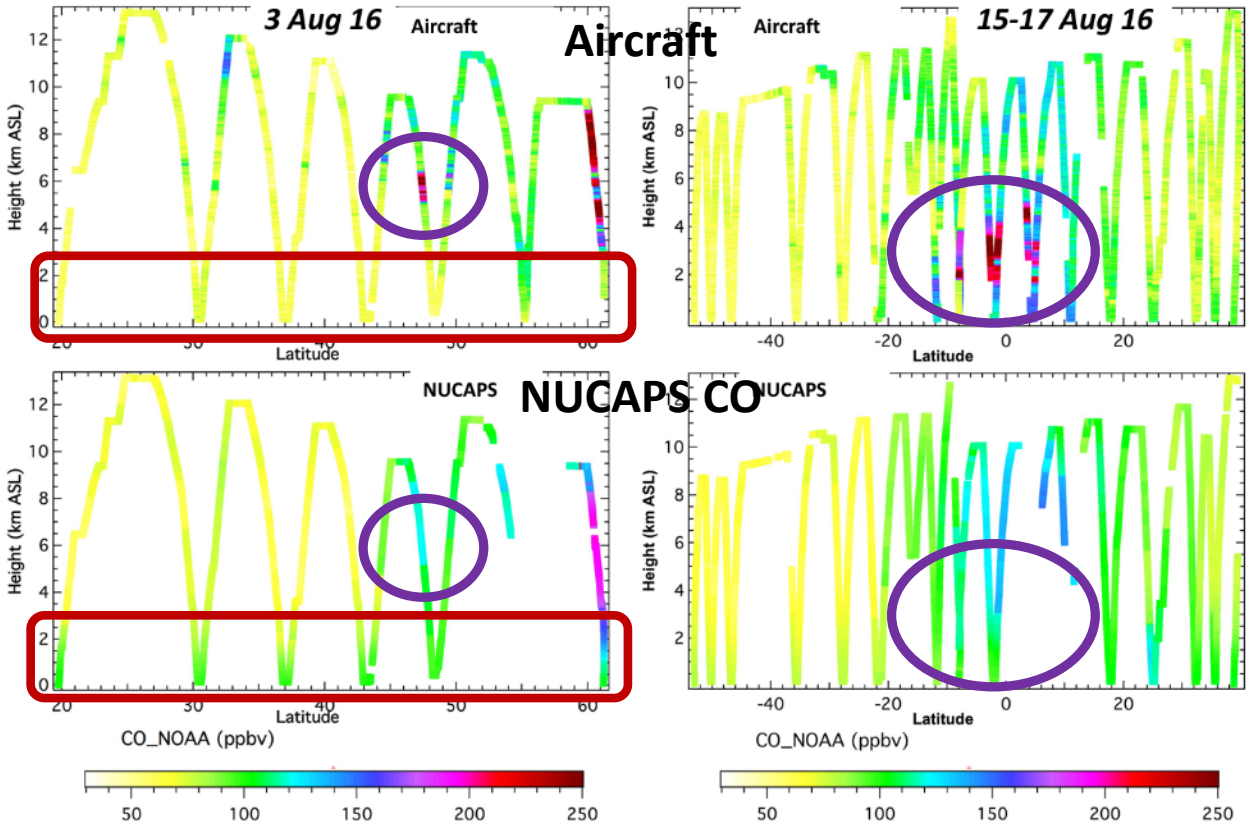
https://espo.nasa.gov/home/atom/content/ATom

ATom provides excellent evaluation opportunities for Suomi-NPP and JPSS trace gas products

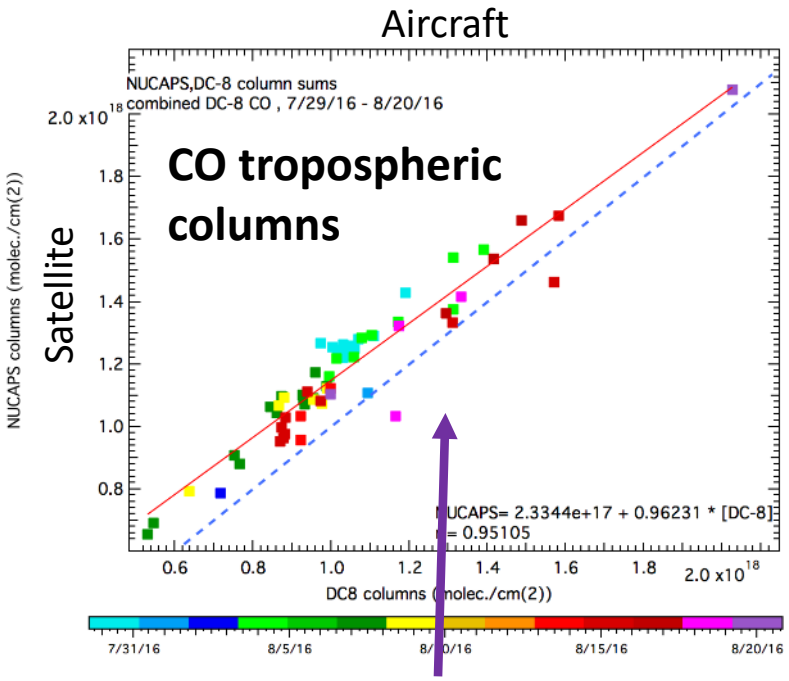
Aircraft Flight Tracks



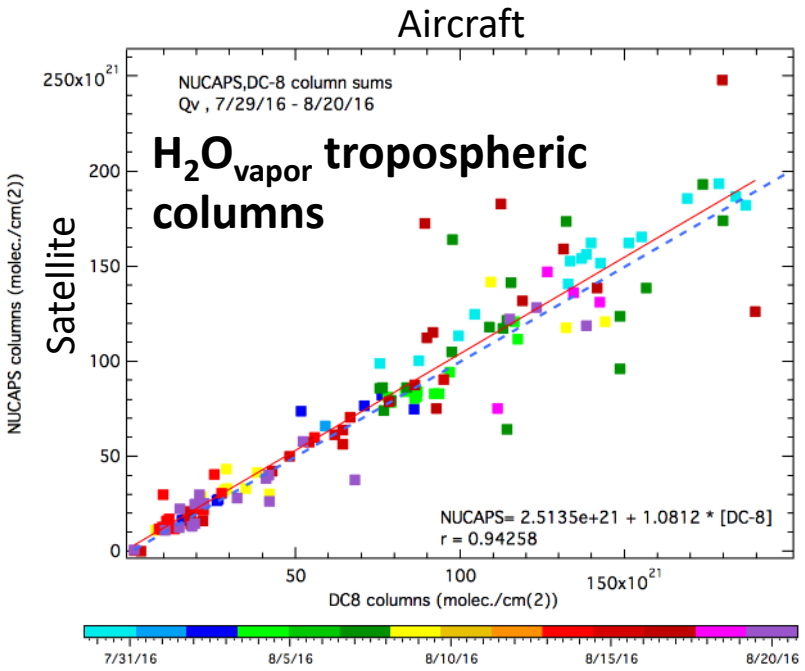
CO Mixing Ratios

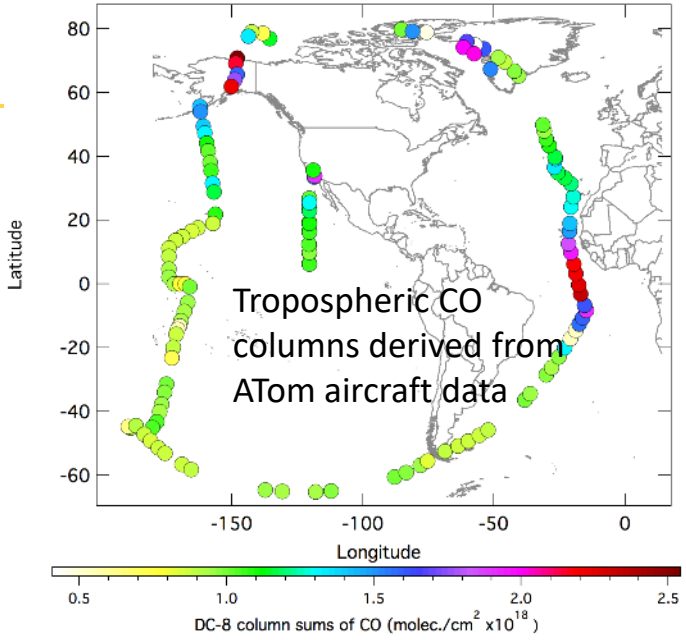


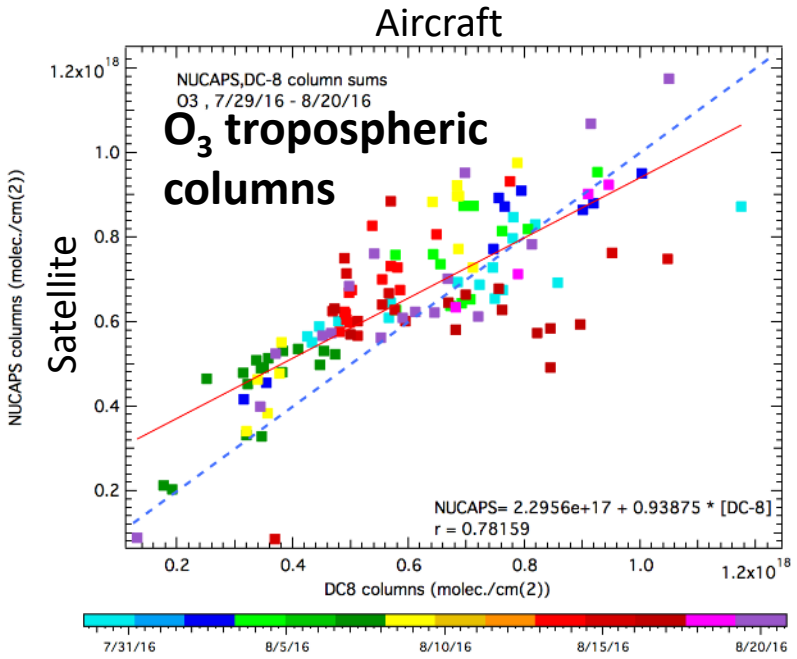
ATom Analysis of NUCAPS CrIS/ATMS Retrievals



Profiles over strong fire plumes removed

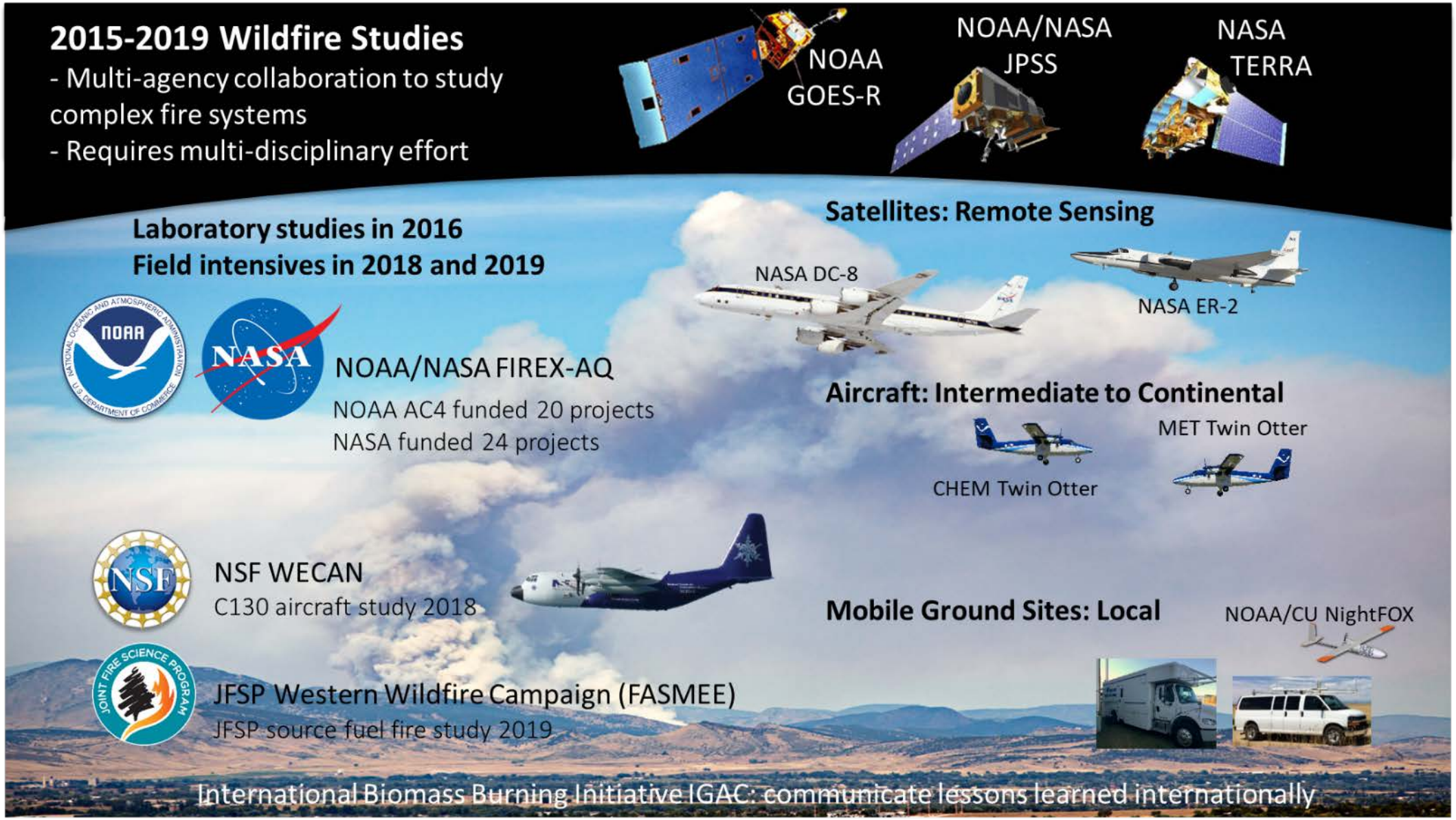






- ATom data provide confidence in NUCAPS trace gas data
- CrIS mid-tropospheric CO and H_2O data are reliable
- CrIS has more limited skill in measuring tropospheric O_3
- NUCAPS retrievals over fire plumes need additional work

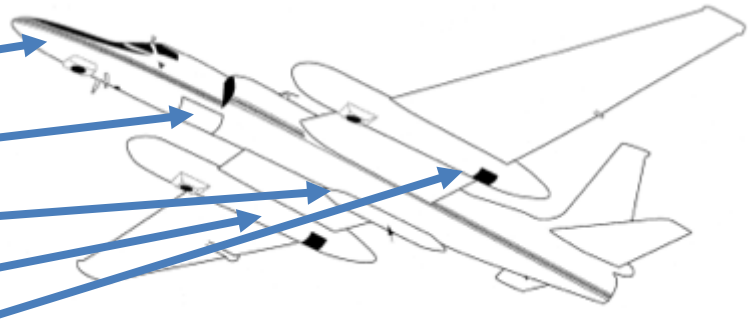
FIREX-AQ 2019 Coordinated Activities



FIREX-AQ 2019: ER-2 deployment and CrIS implications

Instruments

- AirMSPI-1 (JPL)
- AVIRIS-C (JPL)
- S-HIS (UW)
- CPL (GSFC) and eMAS (ARC/GSFC)
- GCAS (GSFC) and NAST-I (LaRC)



Thanks to JPSS office for supporting ER-2 deployment in FIREX-AQ!

Relevant Retrieved Geophysical Variables:

- Effective fire temperature/FRP (AVIRIS-C, eMAS, HyTES)
- Smoke plume structure/heights (CPL and AirMSPI)
- Atmospheric thermodynamic profiles (S-HIS and NAST-I)
- Aerosol amount and properties (eMAS, AirMSPI, CPL)
- Total column trace gas amount in plume and downwind (GCAS, HyTES)
- Trace gas profiles (S-HIS and NAST-I)
- Nearby fuels (AVIRIS-C)
- Winds (from plume displacements in time-resolved imagery)

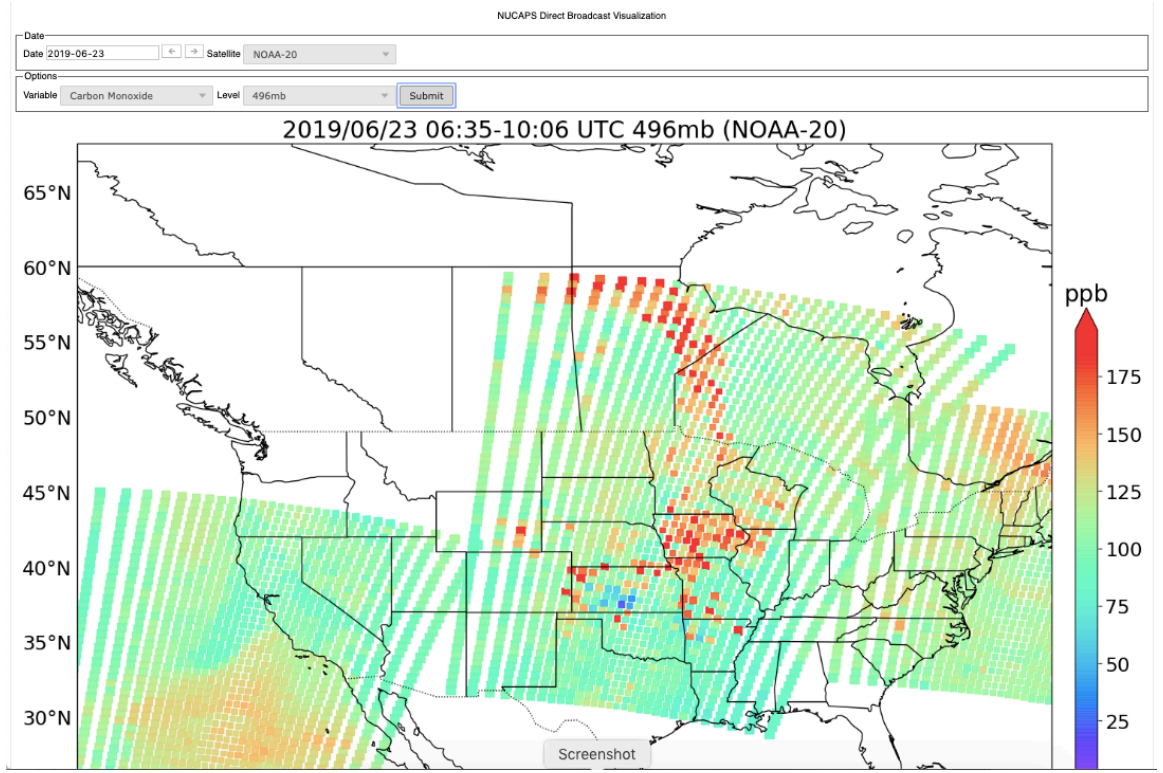
FIREX-AQ ER-2 Science Scorecard

- Priority 1 objectives = Critical to success of FIREX-AQ science
- Priority 2 objectives = Important to success of FIREX-AQ
- Priority 3 objectives = Useful for science, demonstration, or validation but not directly related to FIREX-AQ

➢ **Overall ~94% of the objectives met!**

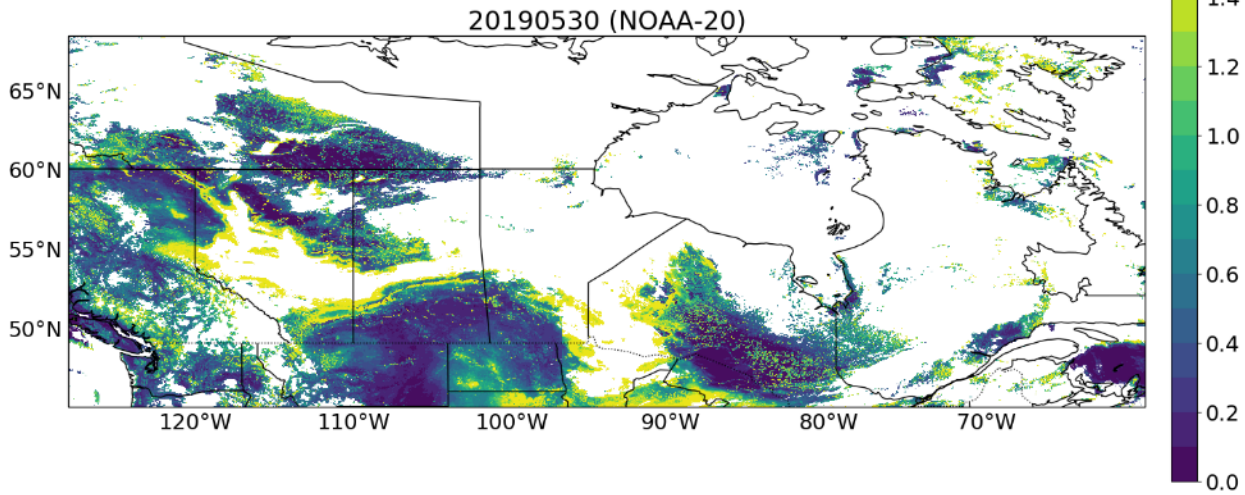
FIREX-AQ 2019: CrIS data used for mission planning

NUCAPS Direct Broadcast Viewer

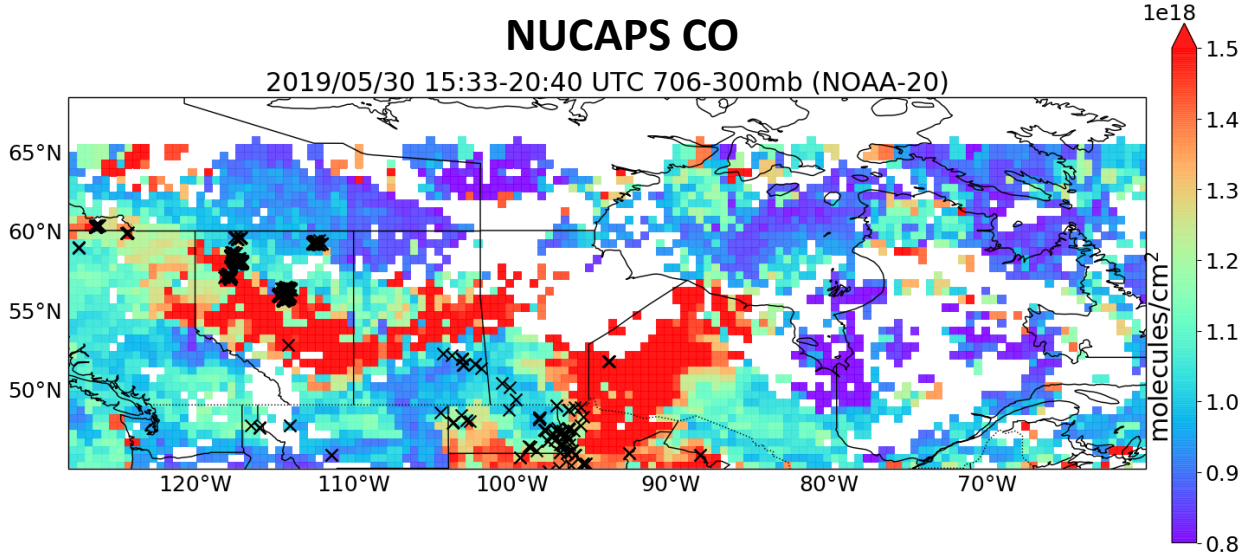


Science & Technology Corp Web Viewer
http://sigma.umd.edu/resmaili/nucaps.html
Rebekah Esmaili et al.

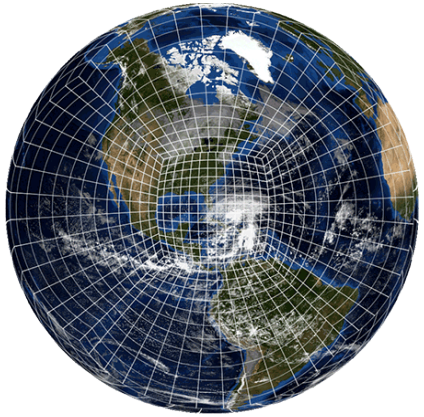
VIIRS AOD



NUCAPS CO



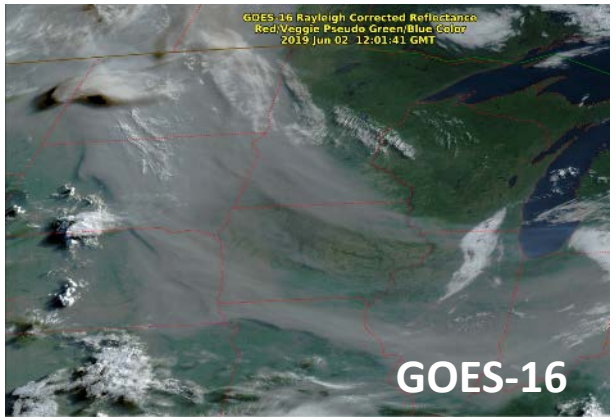
Future application of JPSS data: NOAA forecasting



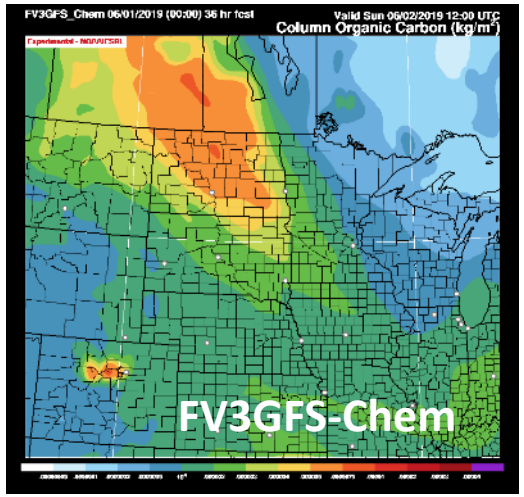
Implementing atmospheric composition into operational FV3GFS

FV3GFS-Chem forecasts fire plume transport

June 2, 2019 – 12:00 UTC

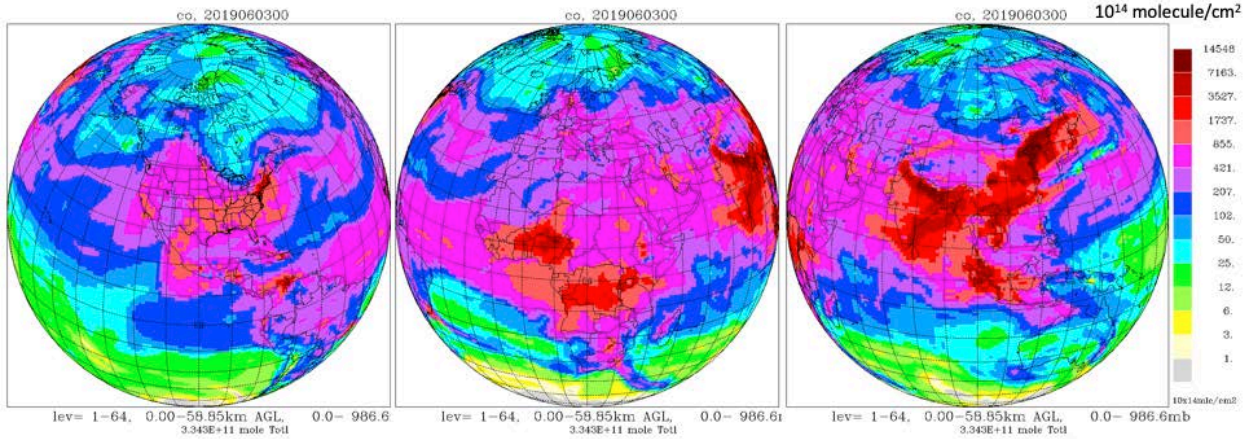


http://dustdevil.aos.wisc.edu/goes16/grb/rgb/mw/goes16_mw.html



https://fim.noaa.gov/FV3chem

Total column CO, FV3GFS-Chem + CO tracer, 6/3/19 00:00 UTC



Initial results with CO tracer in FV3GFS-Chem model, which will be used in future to assimilate CrIS data and improve forecasts.

Analysis of SNPP and NOAA-20 CrIS CO Retrievals

Shobha Kondragunta and Chuanyu Xu
NESDIS/STAR

NUCAPS CO data (version 2.5.2.1) reprocessed and provided by Juying Warner, UMD
TROPOMI CO data courtesy of ESA

Objective

- To improve VIIRS Fire Radiative Power (FRP) Retrieval Using NUCAPS Carbon Monoxide (CO/CO2) for High Resolution Rapid Refresh (HRRR) Model Applications

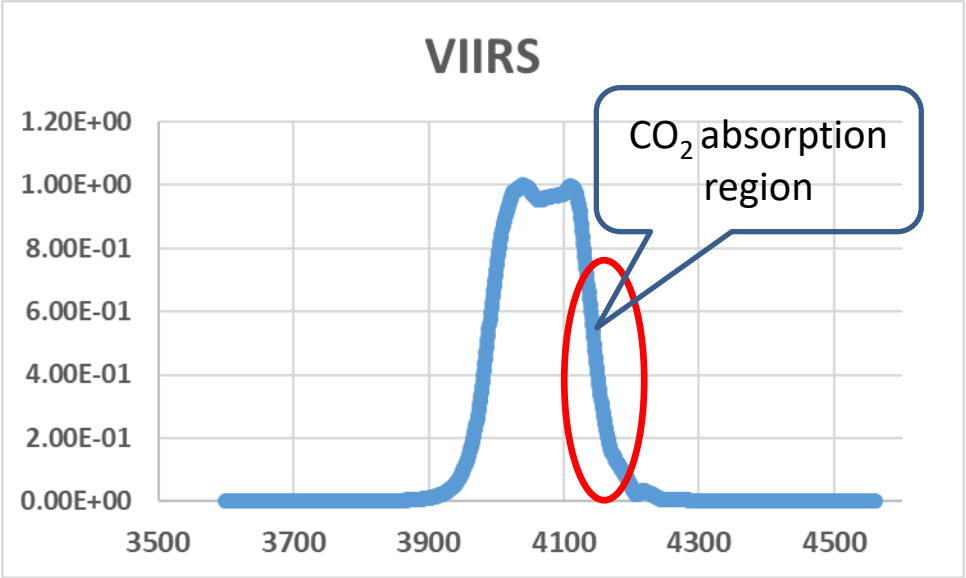
- Introduce CO2 transmittance dependence in FRP algorithm. NUCAPS CO is used as proxy for CO2

- Prior to using NUCAPS CO, analyze and validate the product

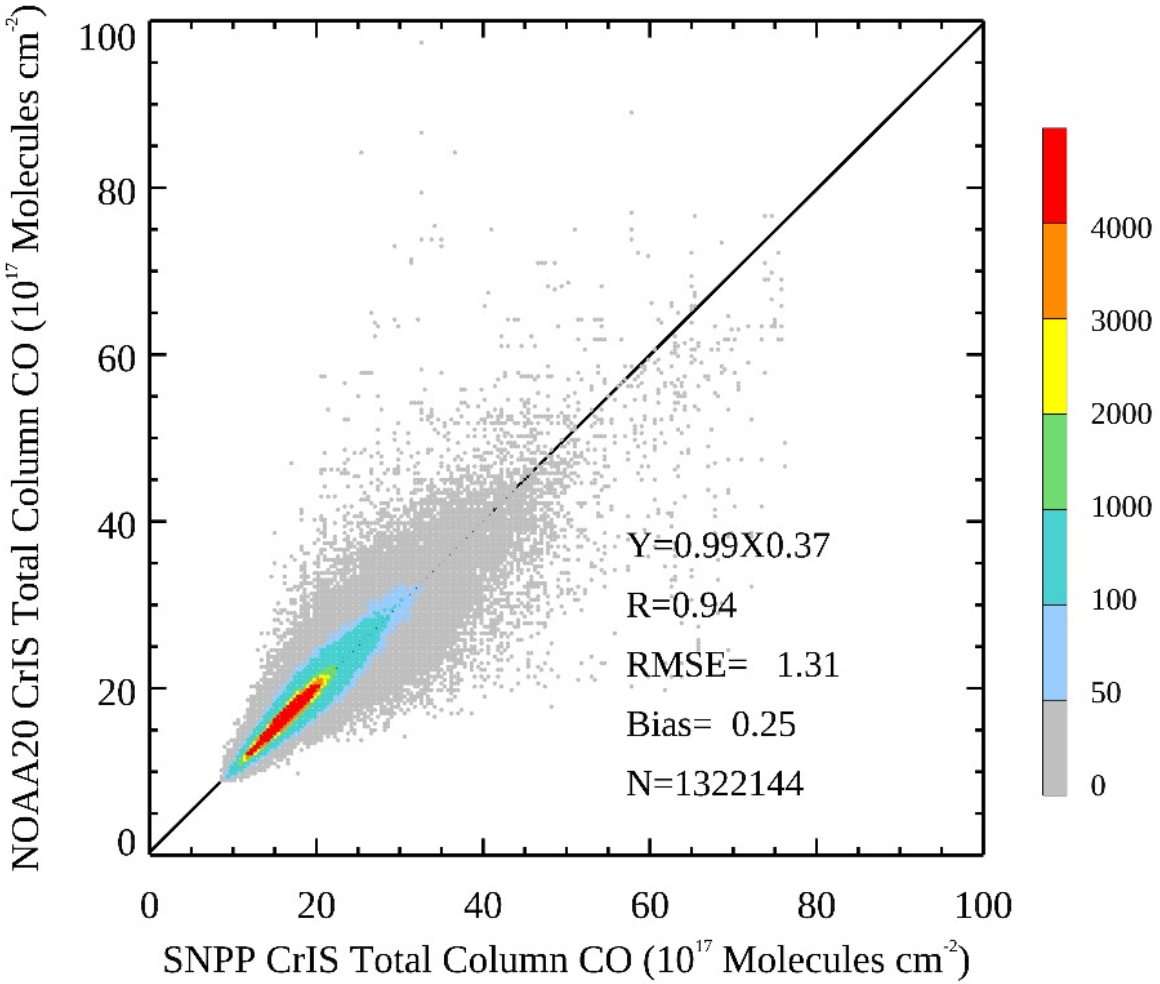
- This report presents results from analysis of NOAA-20 and SNPP CO by comparing to S5P TROPOMI CO for July and August 2018 when significant CO amounts were released from fires in California, Pacific Northwest, and Canada

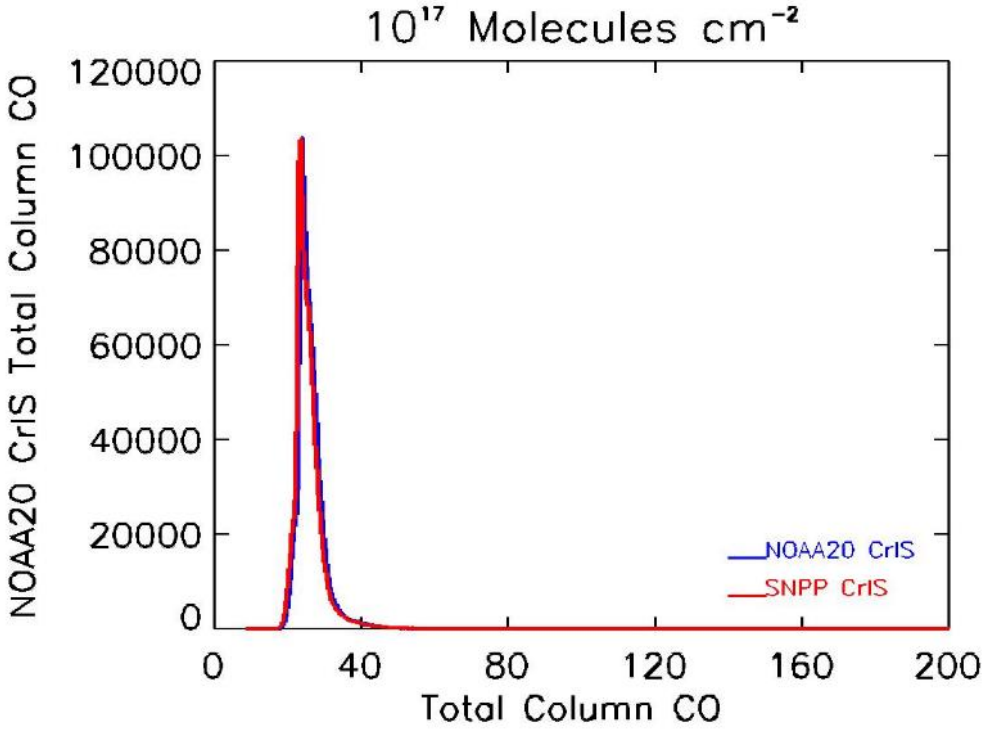
CO2 transmittance set to unity in FRP algorithm

$$FRP = \frac{T\, S_p\, \sigma\, (L_f - L_b)}{c}\, 10^{-6}$$



Comparison of NOAA-20 and SNPP CO

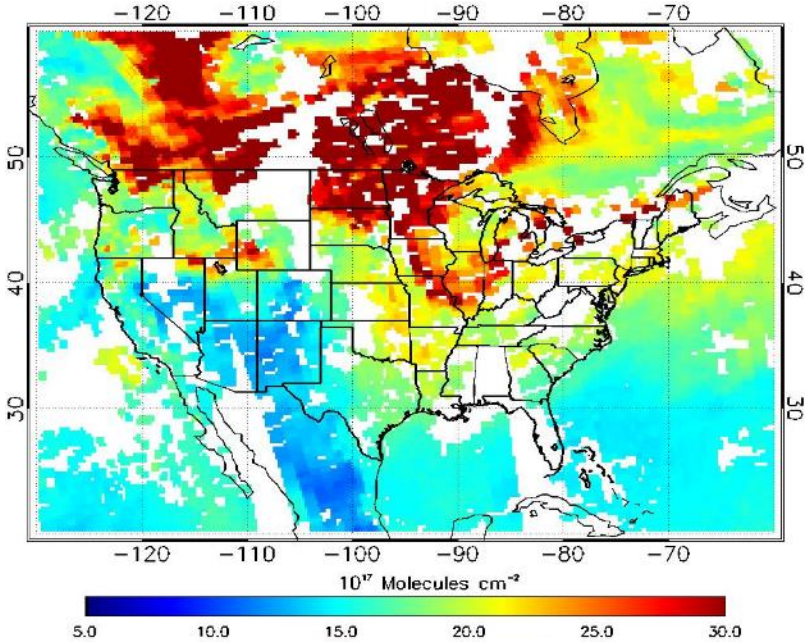




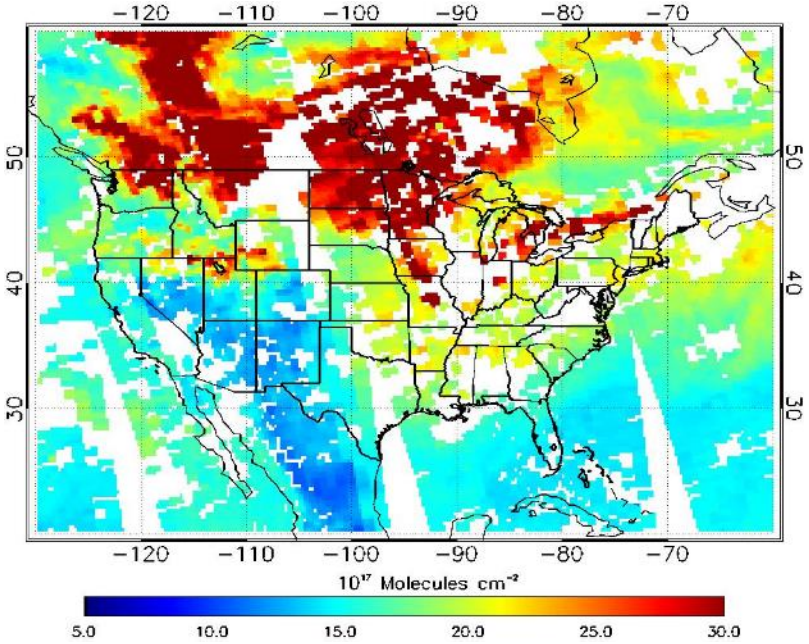
More than a million matched observations between NOAA-20 and SNPP CrIS CO. Both products show similar distribution with a mean bias of 0.25 x 10^{17} molecules/cm^2)

18 August 2018

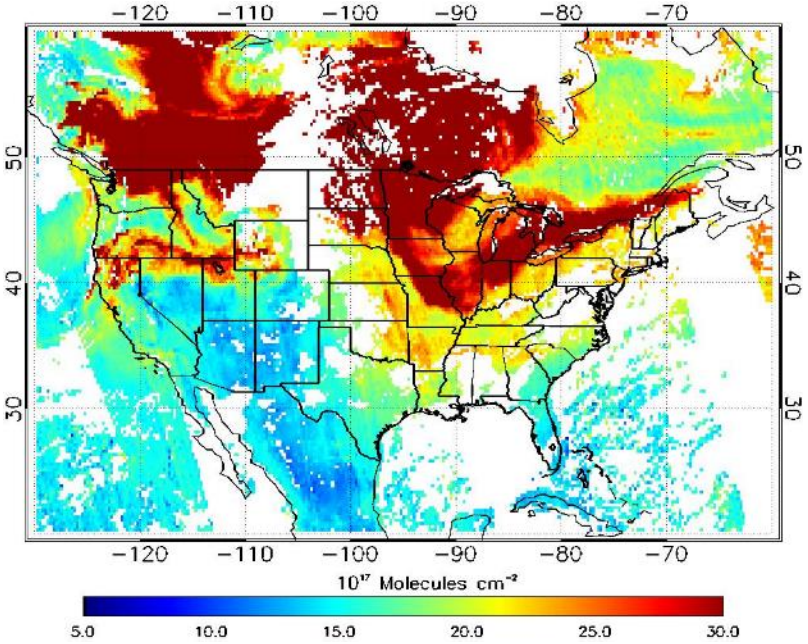
NOAA-20 CrIS Total Column CO



SNPP CrIS Total Column CO

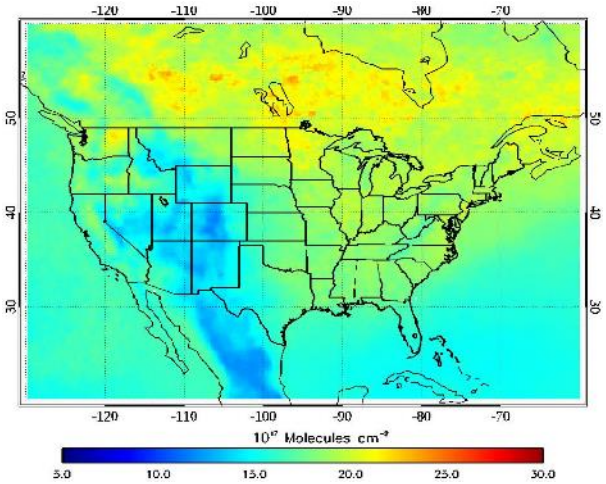


S5P TROPOMI Total Column CO

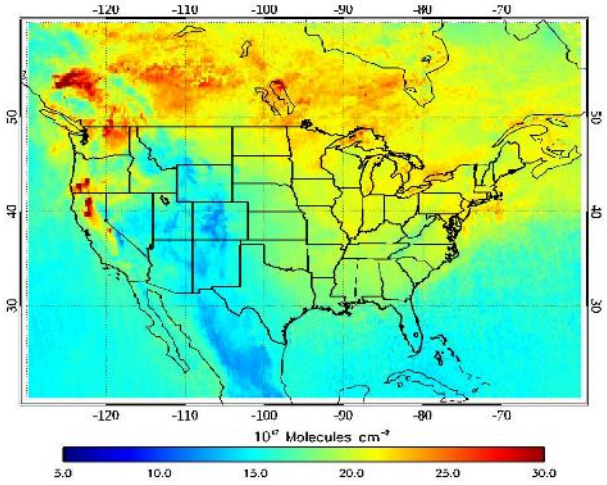


Two-month Mean Comparison

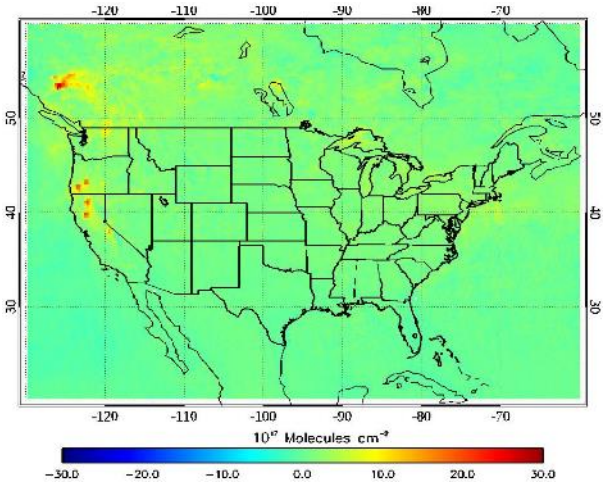
NOAA-20 CrIS



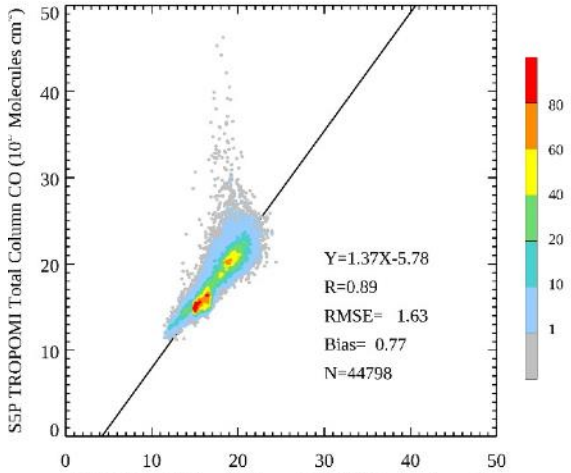
S5P TROPOMI



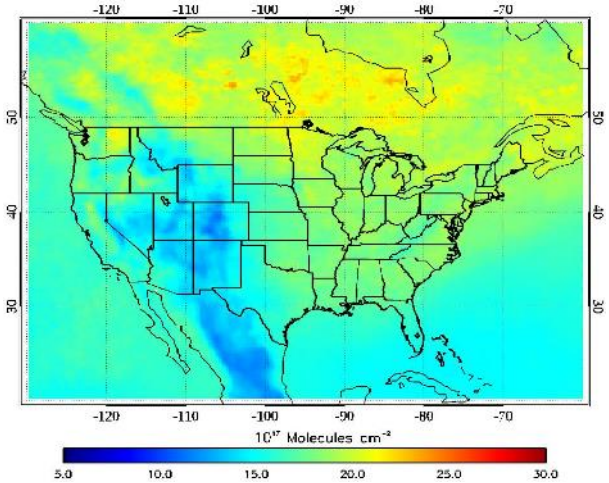
TROPOMI – NOAA-20



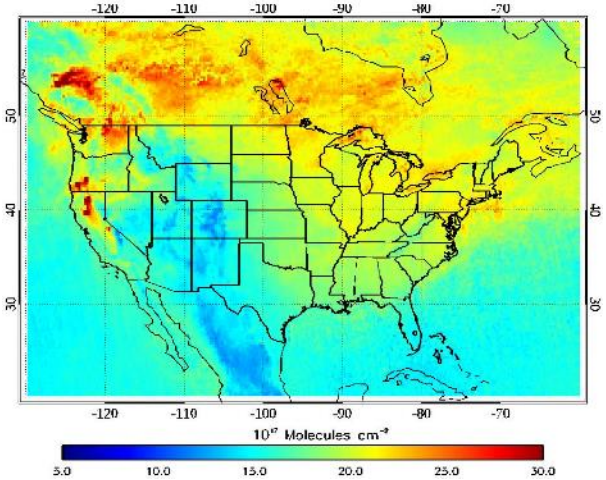
NOAA-20 vs TROPOMI



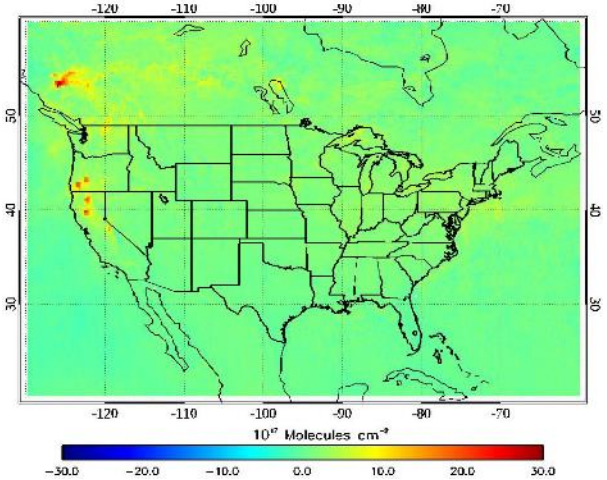
SNPP CrIS



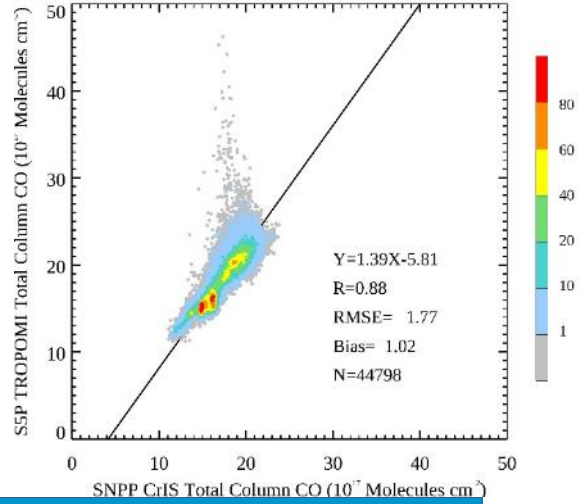
S5P TROPOMI



TROPOMI – SNPP



SNPP vs TROPOMI



Conclusions

- Spatial features of CO from TROPOMI and NOAA-20/SNPP CrIS match well
  - Biomass burning in Africa, pollution in Asia
- CrIS CO is lower, especially when intense fires are a source, compared to TROPOMI because of lack of sensitivity to CO in the lower atmosphere closer to the surface
  - Most of the biases are near source regions where CO has not reached elevated layers of the atmosphere
- SNPP and NOAA-20 CrIS CO agree very well, with a very small bias (0.25×10^{17} molecules/cm^2) and rms difference of 1.31×10^{17} molecules/cm^2
  - Small differences expected as the overpass time is different by ~50 minutes
- As a potential user of the product for FRP algorithm improvements, we recommend that NOAA-20 and SNPP CrIS CO products be promoted to full validated maturity

NUCAPS Operational Users and Applications

Prepared by Rebekah Esmaili, Nadia Smith, Chris Barnet
Science and Technology Corporation

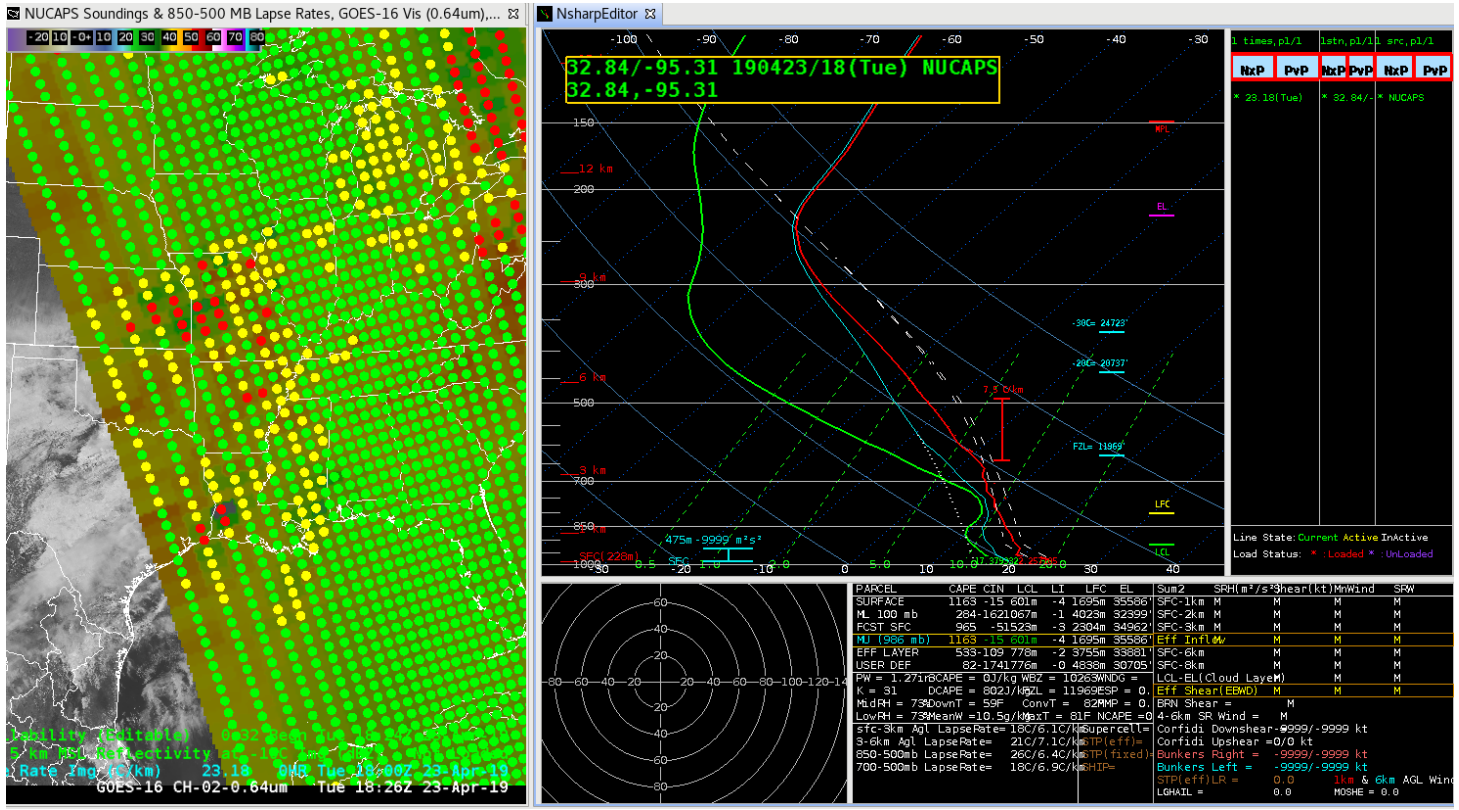
With contributions by many from JPSS PGRR initiatives:

NWS Users of NUCAPS Soundings

NUCAPS soundings supplement radiosondes with wide swaths of model-independent soundings from JPSS satellites, multiple times during the day.

Gridded NUCAPS provides plan views at temperature, moisture, and stability indices (CAPE, lapse rate, etc.) at specific pressure level(s).

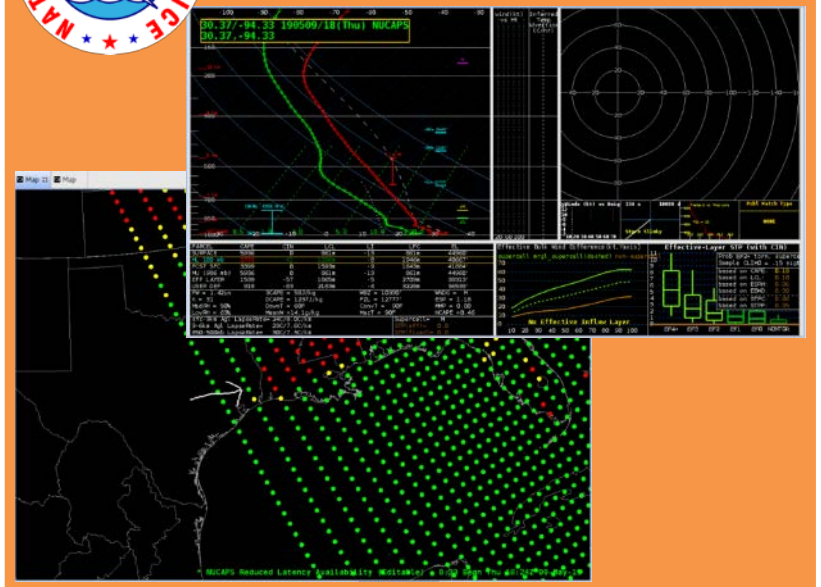
Example: Albuquerque has a NOAA-20 overpasses at ~9Z and 20Z, with a typical latency of 20-30 mins. This is when convective activity is at it's daily peak.



Dot Color Meaning

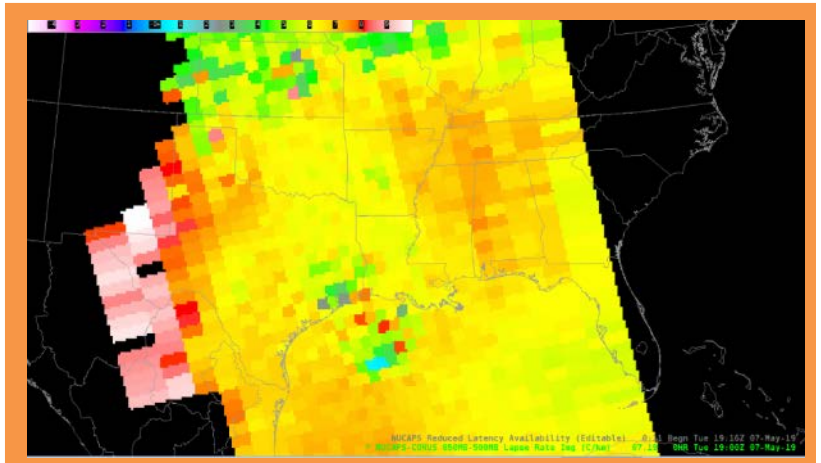
Green	Yellow	Red
Successful infrared (IR) + microwave (MW) NUCAPS retrieval under clear or partly cloudy conditions	Failed IR + MW NUCAPS retrieval. Successful MW-only NUCAPS retrieval under cloudy conditions	Failed IR + MW NUCAPS retrieval. Failed MW-only NUCAPS retrieval under precipitating cloudy conditions

Severe Weather Forecasting with NUCAPS



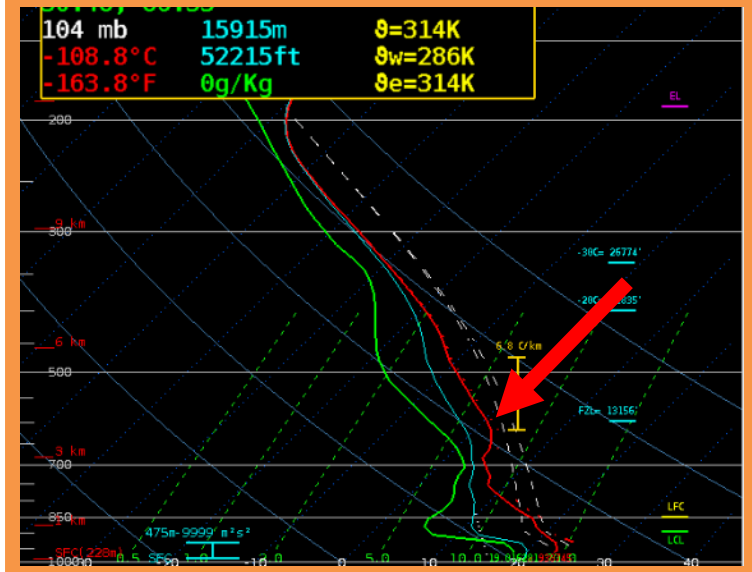
May 9, 2019

- Forecaster used NUCAPS soundings to observing capping, which diagnosed why convection was delayed when compared to models in Houston, TX.



May 7, 2019

- Forecaster used gridded NUCAPS to see mid-level Lapse Rate across West Texas, which indicates convective potential. Values above reflect the drier air advancing east leading to steeper lapse rates.



April 25, 2019

- Forecaster diagnosed building instability ahead of a line of convective storms. The warm "nose" can impact storm intensity due to decreased CAPE.

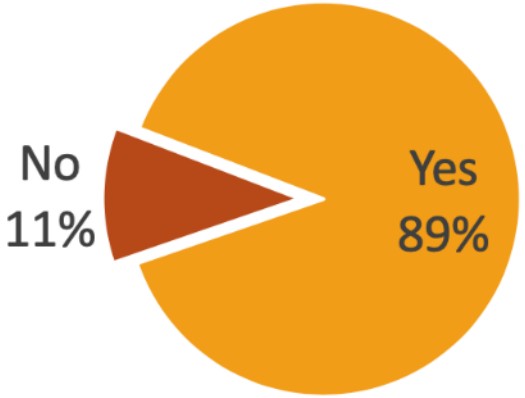
Feedback from the Hazardous Weather Testbed 2019

Severe Weather Forecasting with NUCAPS

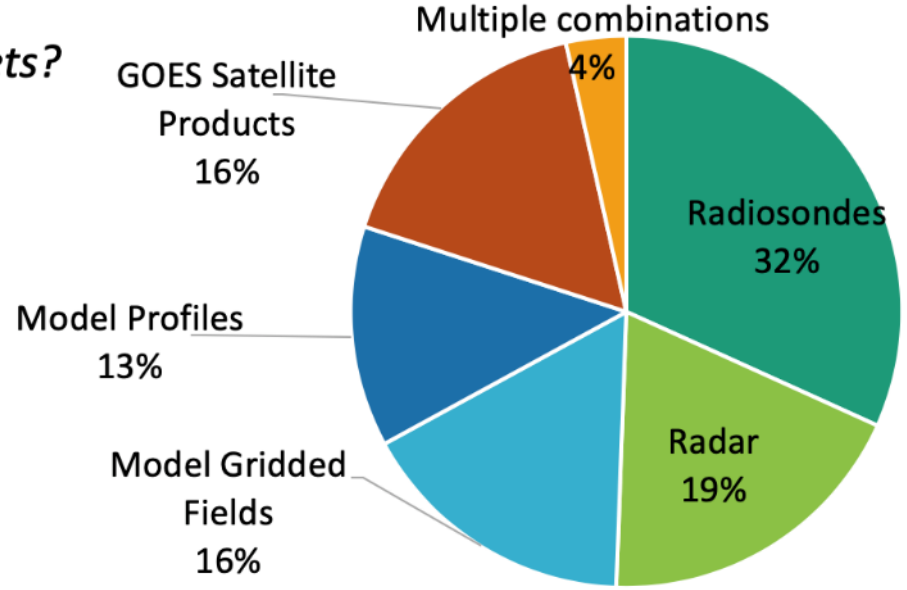
How can NUCAPS products could be more useful in the future?
50% of respondents indicated more satellite overpasses would be helpful

How often would you use NUCAPS in the future?
60% of HWT 2019 responses indicate NUCAPS Soundings and/or Gridded products would be used “sometimes”, “usually”, or “always”

Did you use NUCAPS with other datasets to enhance your forecasting decision?



Which datasets?

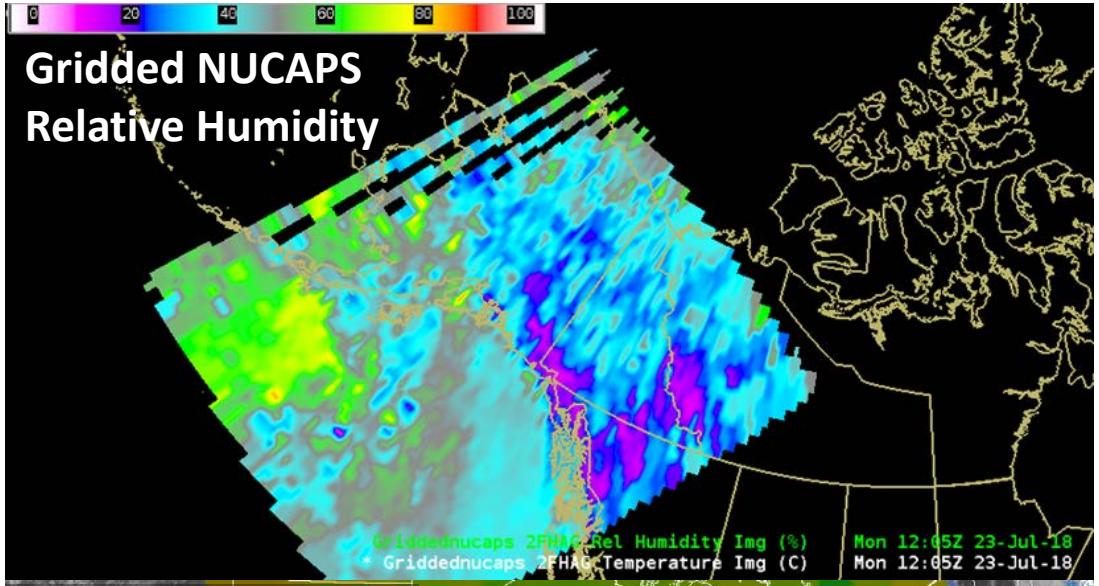


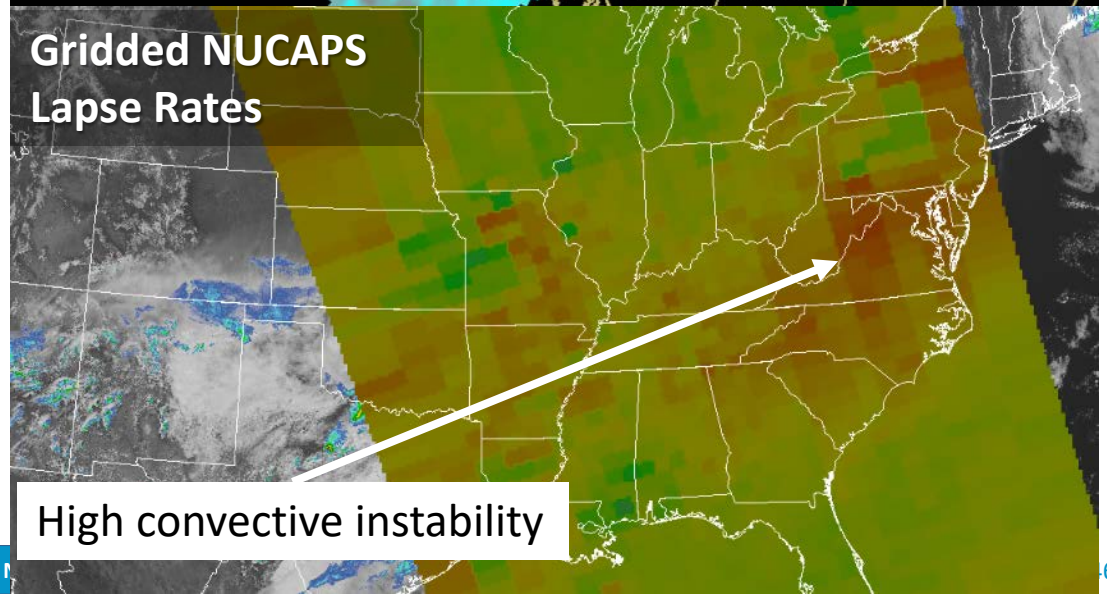
Feedback from the Hazardous Weather Testbed 2019

New in 2019 NWS Operations

Gridded NUCAPS

- Capability to create gridded plan-view and cross section displays of NUCAPS Soundings
  - Temperature and moisture at standard/non-standard pressure levels on spatial grid
  - Forecasters now have ability to visualize convective stability gradients and tropopause height to quickly identify areas of interest and hazardous hot spots
  - Facilitate forecaster decision making and enhance situational awareness

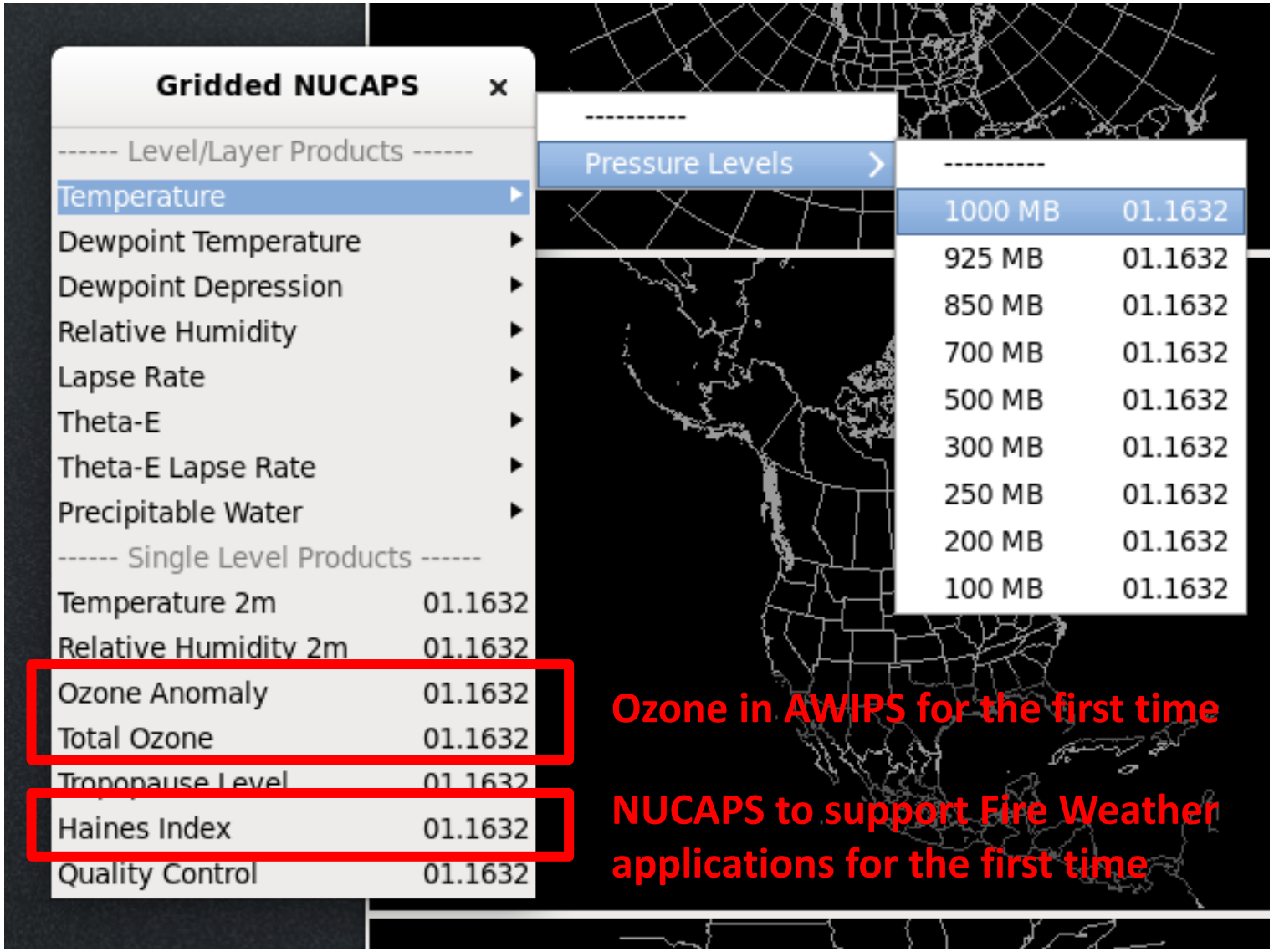




New in 2019 NWS Operations

- NUCAPS Ozone anomaly successfully transitioned from research to operations
  - https://nasasport.wordpress.com/2014/05/15/sport-expands-ozone-products/

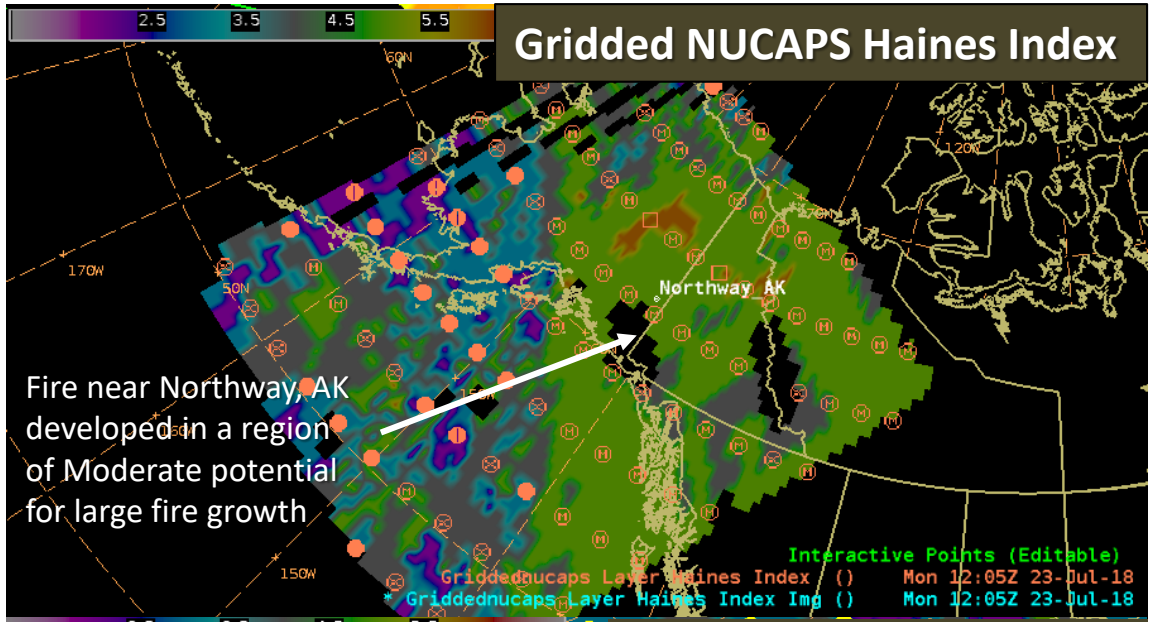
- NUCAPS Haines Index available for the first time to support Fire Weather forecasting
  - https://nasasport.wordpress.com/2019/08/14/transition-of-research-to-operations-gridded-nucaps/

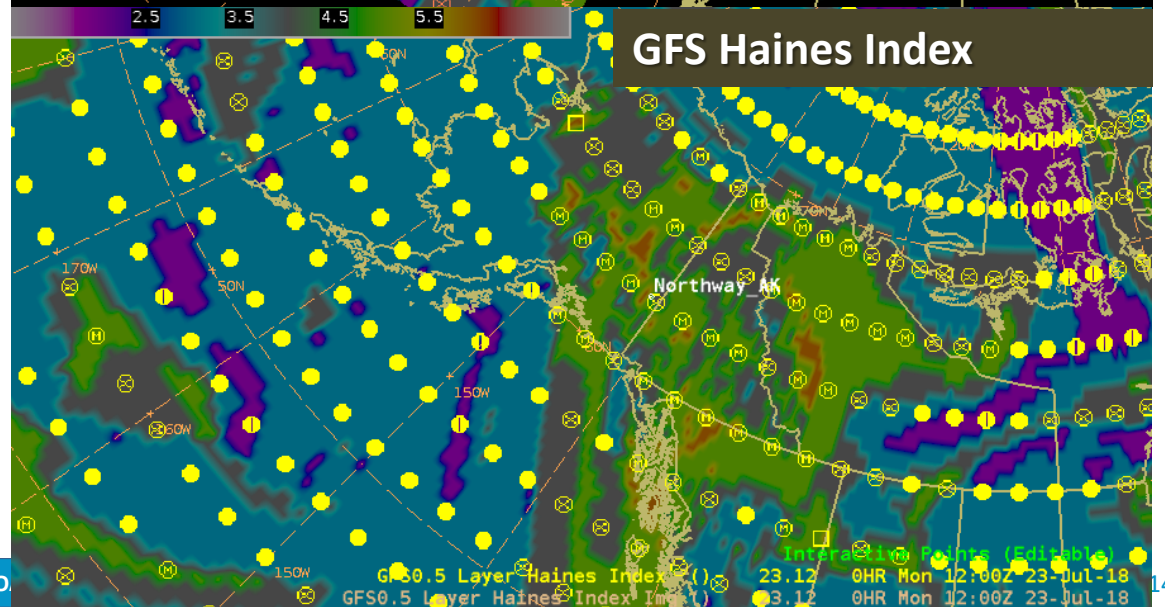


Forecasting wildfires and fire weather

Example: Taixtsalda Hill Fire near Northway, AK burned ~27,000 acres; started on July 23, 2018

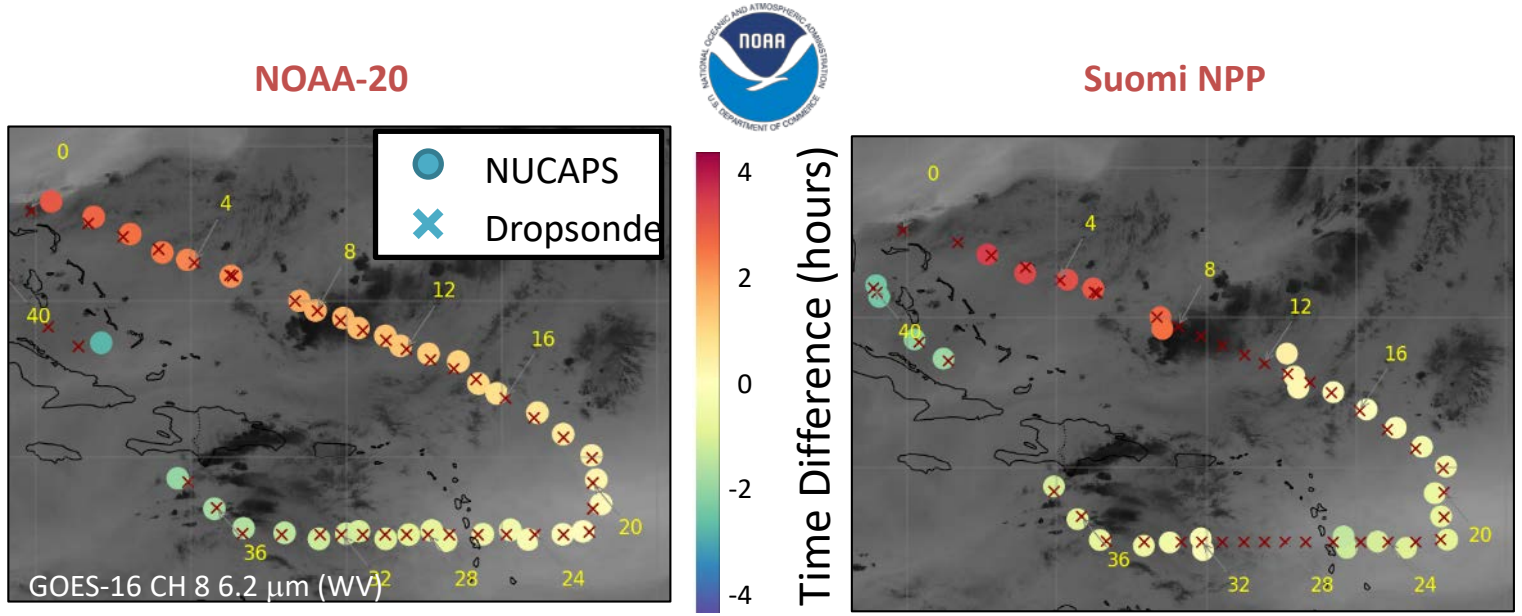
- Gridded NUCAPS in AWIPS is a unique opportunity to analyze fields derived from temperature and moisture variables
- Haines Index is a new capability that will be available with the release of Gridded NUCAPS in AWIPS 19.2.1
- This example, shows NUCAPS depicts a similar Haines Index spatial pattern compared to 0.5 deg GFS to indicate a Moderate potential for large fire growth
- Currently investigating the ability of NUCAPS to capture the pre-fire environment (warm, dry conditions).





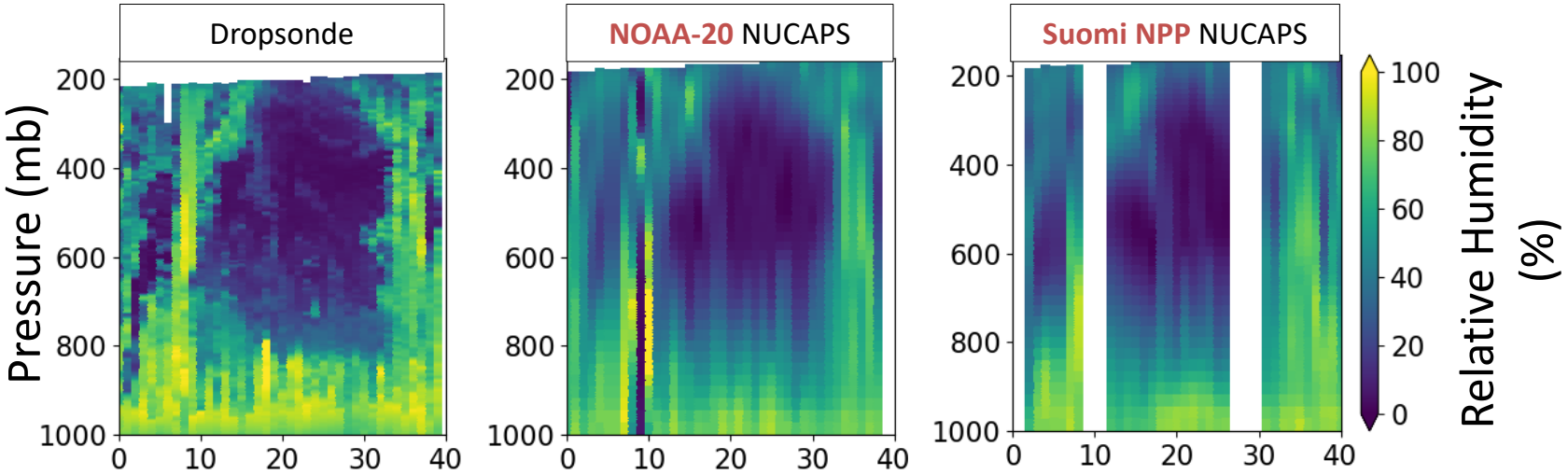
Courtesy of Emily Berndt, NASA/SPoRT

Hurricane Field Program 2018



- Sampled Saharan Air Layer (SAL), a warm and dry pocket of air that originates over the Saharan Desert and propagates over the Atlantic. This can potentially suppress tropical cyclone formation.
- Gulfstream-IV flight patterns and take-off times will be adjusted to sample targets that maximize temporal and spatial overlap with overpasses by the NOAA-20 and Suomi NPP..

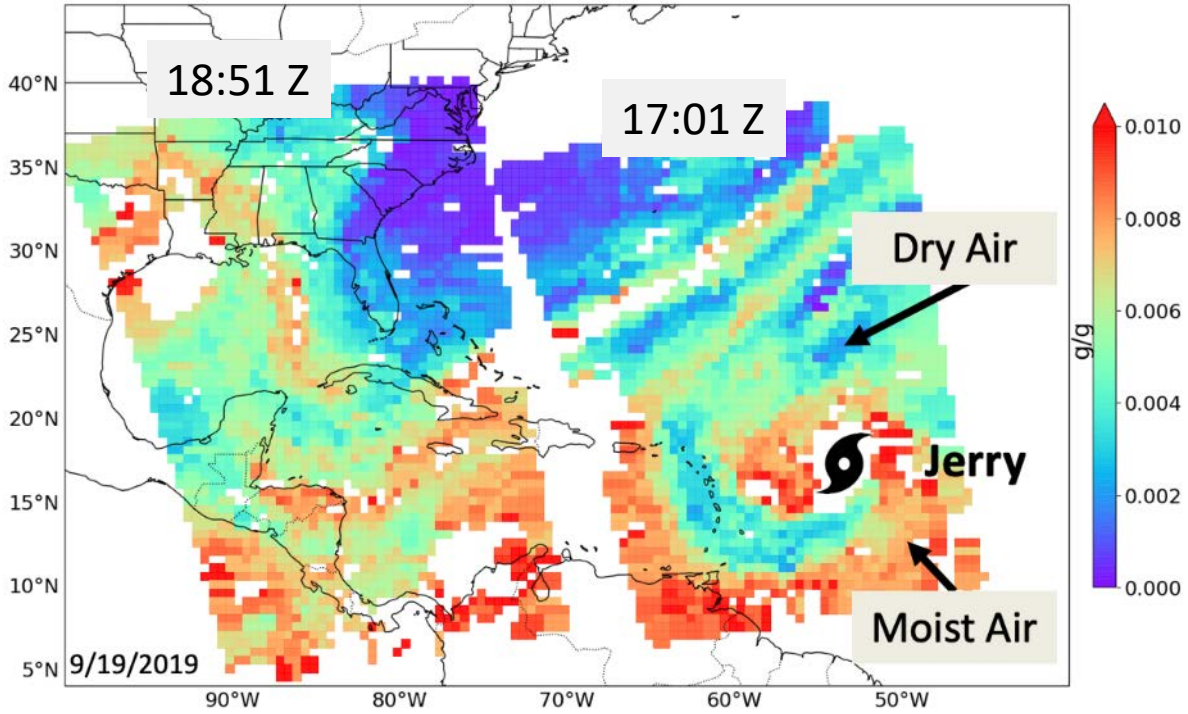
- GPS dropsonde timed to be ≤1 hr and ≤50 km of collocated NUCAPS sounding granules.
- The SAL extends from 850-500mb, examining a strong case that goes to 200mb.
- NUCAPS captures the dry layer feature well.



Hurricane Field Program 2019

- Conducted three research flights over **Hurricane Jerry** and **Hurricane Lorenzo**
- Total of 120 dropsondes of data collected
- Provided real-time NUCAPS images to NOAA's Hurricane Research Division in Miami, FL

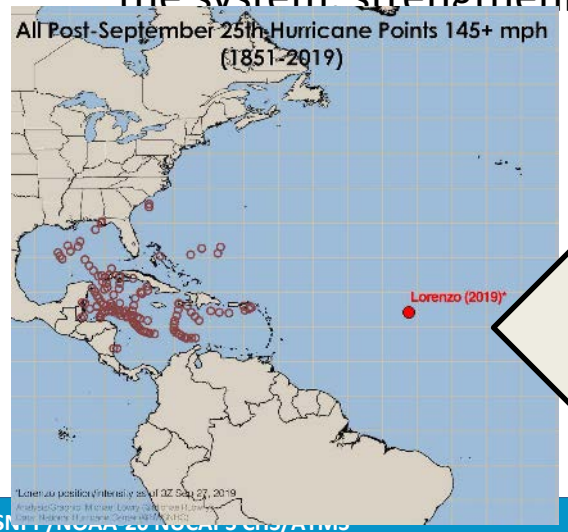
750mb Water Vapor (**NOAA-20**)



Hurricane Jerry

Hurricane Jerry

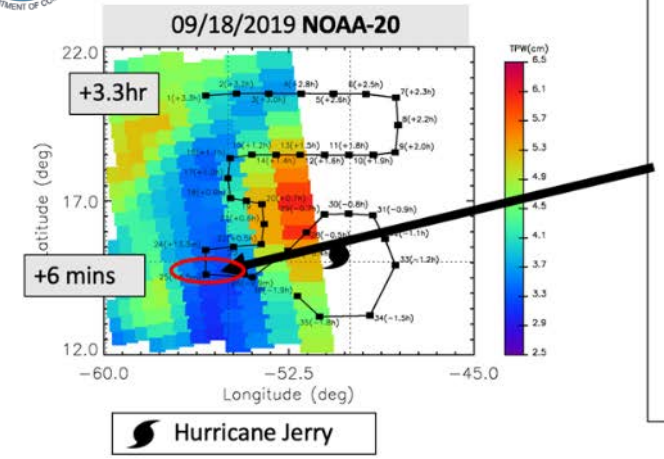
- Dry air entrainment is playing a role in Jerry's development.
- Jerry was on the leading edge SAL, which can suppress hurricane development by forming an atmospheric inversion, which prevents air from rising and forming convection.
- To the south, there is moist tropical air mass that is feeding the system, strengthening development.

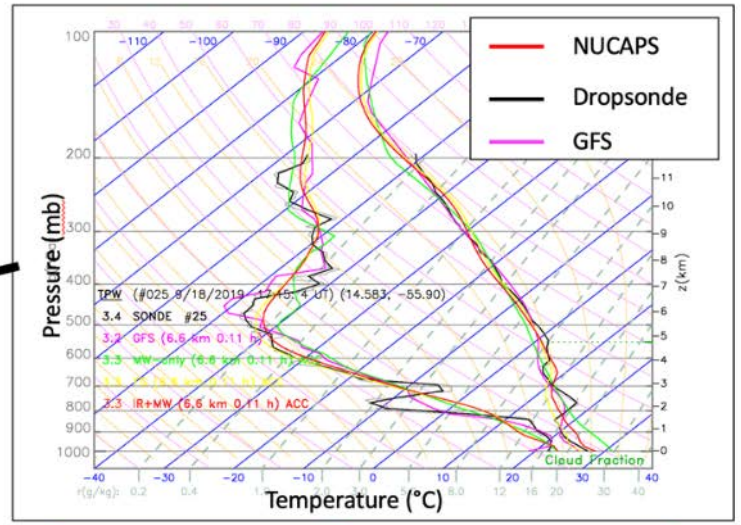


Hurricane Lorenzo: Produced a case study of a historically powerful Hurricane in the eastern Atlantic.

Direct Broadcast NUCAPS visualization tool set-up for the field campaigns, http://sigma.umd.edu/resmaili/nucaps.html.

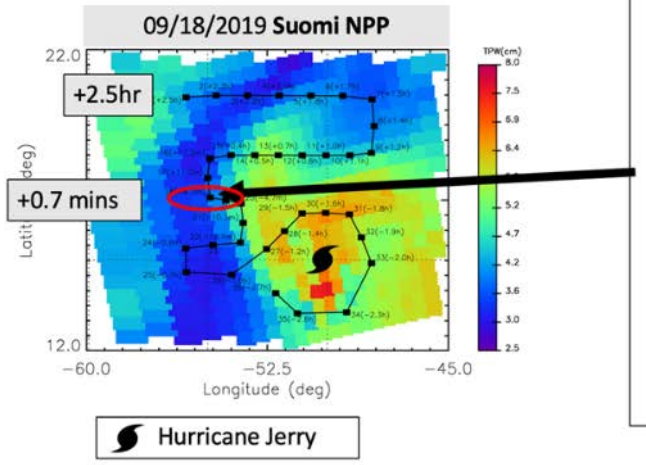
Hurricane Field Program 2019

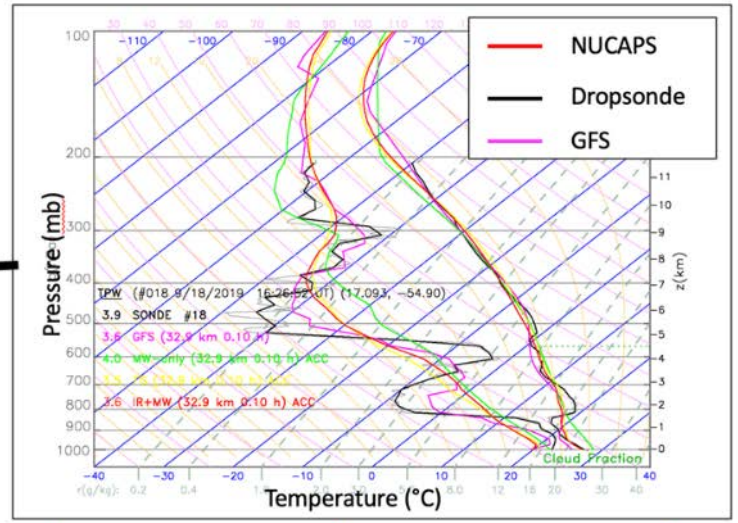




-6.6 mins from overpass | 6.6 km away from dropsonde

Using **direct broadcast**, able to generate match-ups every 20 minutes as the dropsonde data was made available.





-6.0 mins from overpass | 33 km away from dropsonde

- Flights enable feedback on the value of NUCAPS for Atlantic forecasting
- Discussed the pros and cons of NUCAPS with HRD
- Led to the successfully implemented of two approaches to direct broadcast for scientific field campaign support
  - On-line visualization tool to display Direct Broadcast NUCAPS
  - Manually running NUCAPS to generate dropsonde, GFS, and NUCAPS Skew-T's in real time
- We acquired 120 dropsondes that can be used for evaluation and improvement of NUCAPS/Suomi NPP and NOAA-20

It's just awesome to get these kind of analyses so quickly.
– Jason Dunion, Hurricane Research Division

Enhancing Climate Monitoring and Diagnostics at NOAA/CPC with Hyperspectral OLR

Pingping Xie

NOAA Climate Prediction Center

October 24, 2019

Background

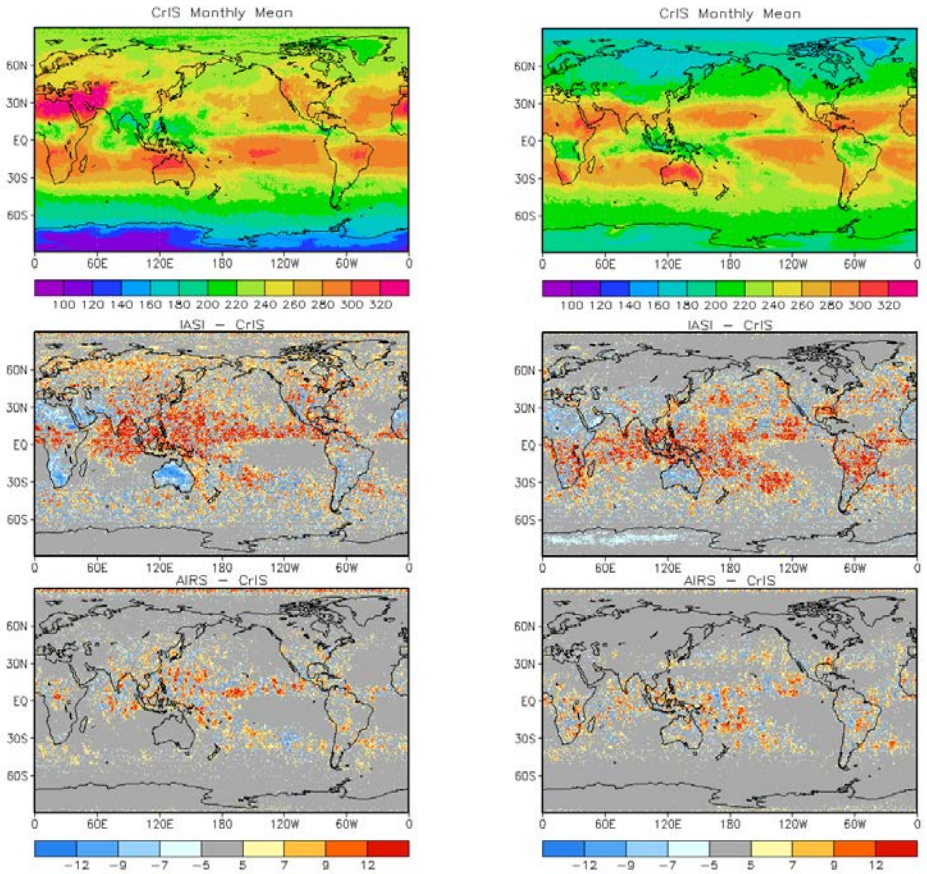
Hyperspectral OLR for improved climate monitoring

- Broadband OLR not available on a real-time (<1day) basis
- Techniques developed to derive OLR from **the hyperspectral** measurements of infrared radiance from advanced sensors:
  - *The Atmospheric Infrared Sounder (AIRS)*
  - *The Infrared Atmospheric Sounding Interfermeter (IASI), and*
  - *The Cross-track Infrared Sounder (CrIS)*
- NESDIS Operations has started the routine production of the level-2 OLR orbit data from the IASI and CrIS;

Current Status

Reprocessing

- **We have completed the reprocessing of hyperspectral OLR for all sensors for the entire of their respective life spans with the L2 algorithm provided by NESDIS/STAR**
- **We have performed examinations of the hyperspectral OLR from various sensors and confirmed their quality and consistencies**

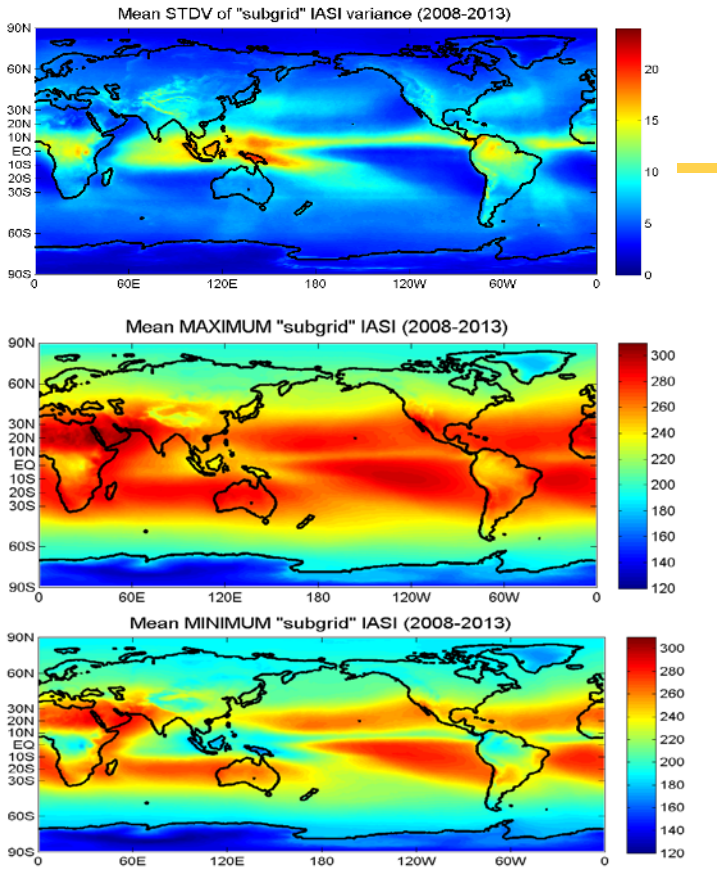


Monthly mean hyperspectral OLR (W/m2) derived from CrIS (top) and its differences with that from IASI (middle) and AIRS (bottom). Results for July and December 2018 are plotted in the left and right panels, respectively.

Applications of Hyperspectral OLR

Improved capacity to detect strong convection

- **While we wait for the completion of the final blended hyperspectral OLR global analysis, we have started using hyperspectral OLR from individual sensors to explore its values in enhancing and improving climate operations;**
- **The hyperspectral OLR exhibits improve capacity to detect strong convection**
  - With a refined spatial resolution of 0.25°lat/lon, hyperspectral OLR is capable of quantifying the intensity of convection at a meso-scale cloud systems scale;
  - Standard deviation of OLR inside a 1°lat/lon grid is very large, especially over ITCZ and land areas of strong convection where the standard deviation may reach 15W/m^2 or greater;
  - Climate monitoring using OLR data on a 1°lat/lon grid, like the current operational AVHRR OLR, may substantially under-estimate the intensity of convective activities.

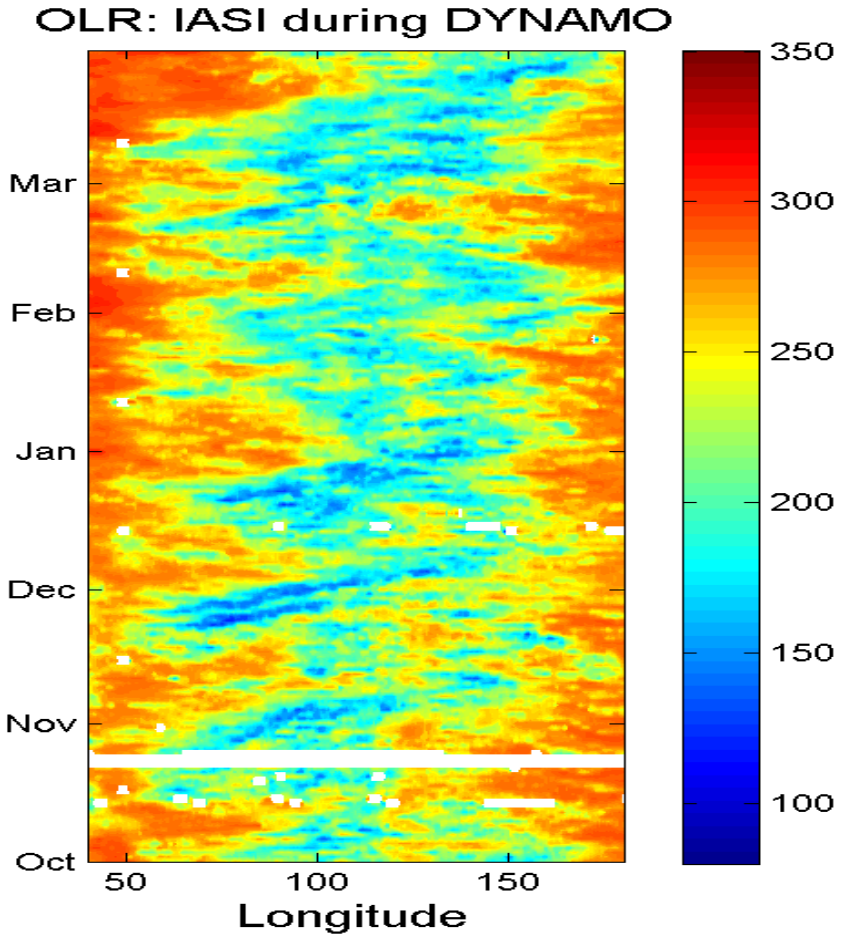


(Top) standard deviation, (middle) maximum, and (bottom) minimum of OLR values over 16 0.25°lat/lon grid boxes with a 1°lat/lon grid box. Statistics are averaged over 6 year period from 2008 to 2013. Units are all in W/m^2.

Applications of Hyperspectral OLR

Enhancing the tropical monitoring

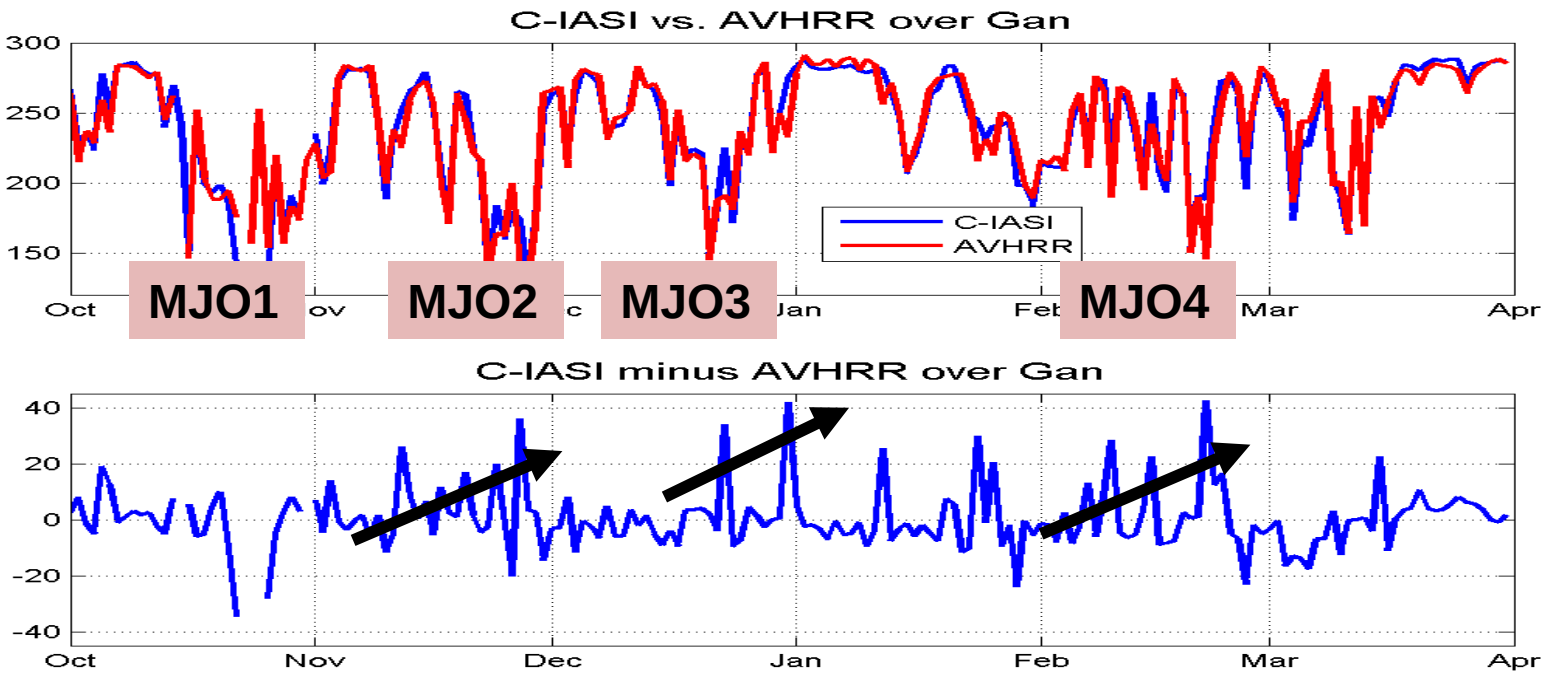
- **With refined spatial resolution and improved capacity to detect strong convection, hyperspectral OLR provides a powerful mean to monitor tropical convection and its evolution;**



Time-longitude section of equatorial (5°S-5°N) mean hyperspectral OLR during the DYNAMO experiment (Oct.2009 – Mar.2010).

Applications of Hyperspectral OLR

Accurate quantification on MJO evolution



Time series of OLR derived from the operational AVHRR (top, red) and the hyperspectral OLR (top, blue), as well as the difference between them (bottom), at a grid box over Gan Island during the DYNAMO field experiment period (Oct.2009 – Mar.2010).

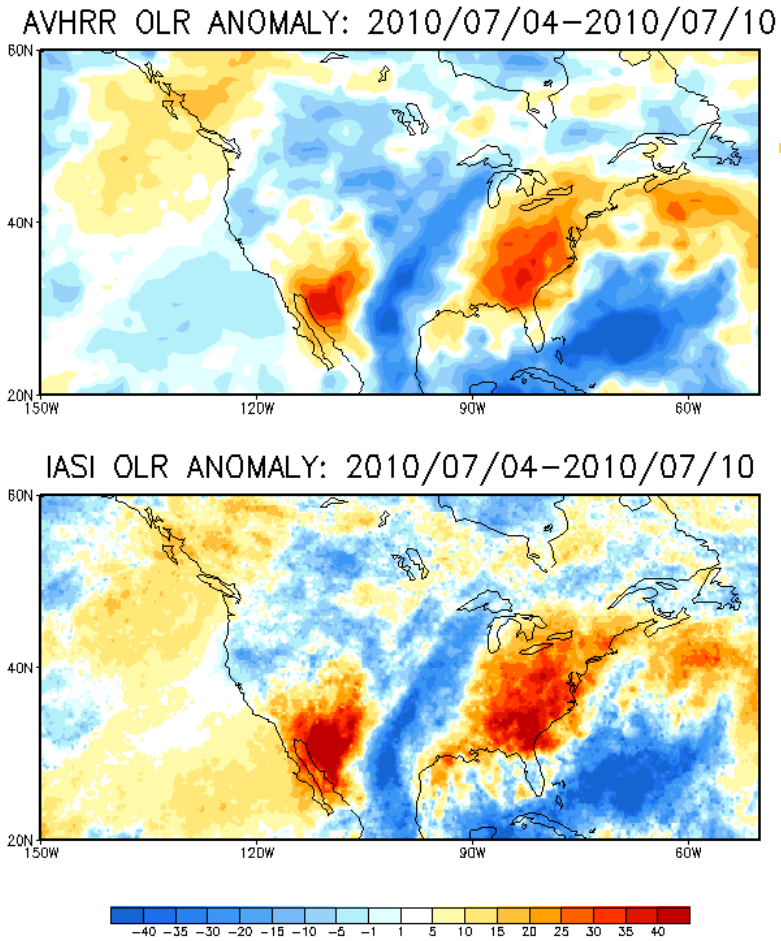
- **While both the IASI and AVHRR capture the MJO quite well, differences between them present a tendency in association with the evolution of MJO, suggesting possibility of aliased OLR quantification by the AVHRR OLR;**
- **Further work is underway to take advantage of this difference to improve the climate diagnostics;**

Applications of Hyperspectral OLR

Improved heat wave detection and quantification

- **(top) Based on a 30+ year technology and derived from AVHRR infrared window channel measurements blind of water vapor variations, capacity of the operational OLR data to detect and quantify heat waves is compromised;**

- **(bottom) Hyperspectral OLR presents better skills in capturing and quantifying the heat wave.**



OLR anomaly (W/m2) associated with the heat wave of Jul. 4-10, 2010, derived from the operational AVHRR (top) and hyperspectral (bottom) data sets.

NUCAPS Ozone as part of TOAST

Larry Flynn (STAR/SMCD/OPDB)

NUCAPS Ozone as part of Total Ozone Analysis from Stratospheric and Tropospheric (TOAST) Satellite Sources

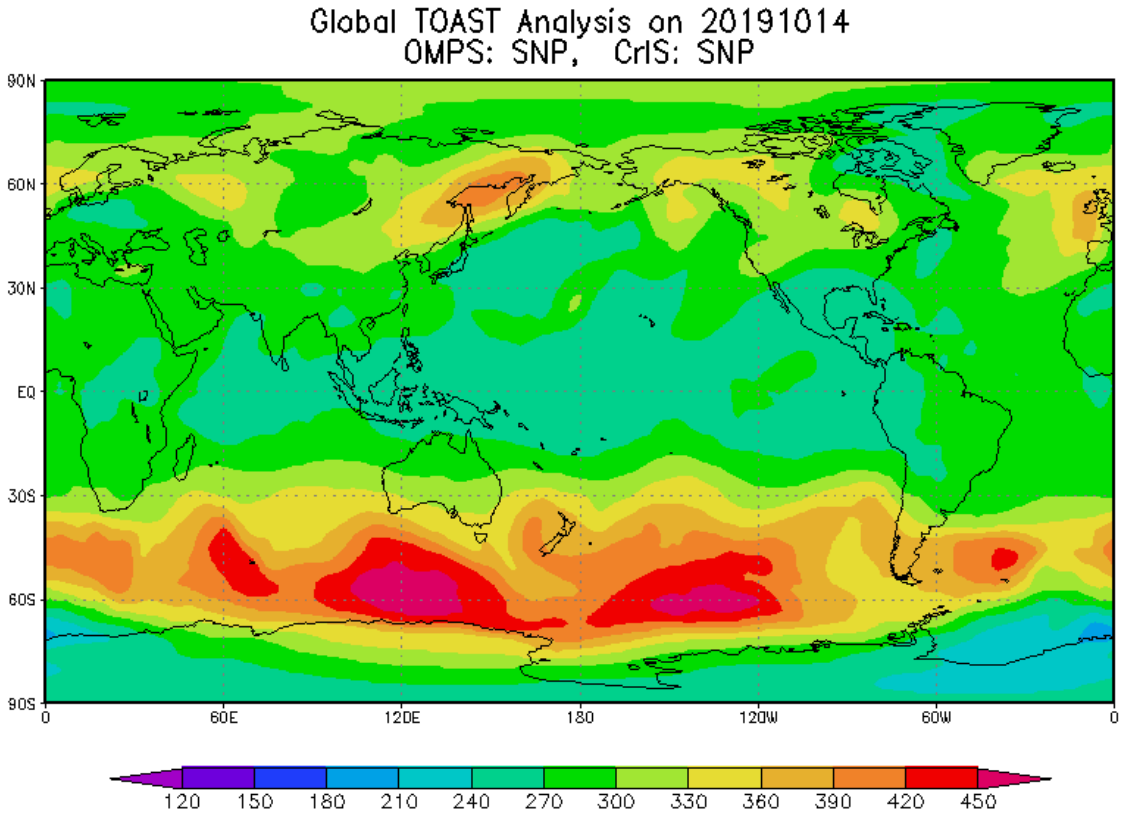
This new algorithm has been developed to replace the legacy TOAST products. Instead of estimating the UTLS ozone by HIRS provided total amount retrieval, a full troposphere and lower stratosphere (FTLS) ozone has been accurately derived based on the fine height resolution profile retrieved from CrIS NUCAPS Ozone profiles. The mid-to-upper stratosphere (MSUS) ozone has been analyzed using the new generation ozone profiler OMPS NP V8Pro profiles to replace the SBUV/2 ones. Layers are at https://www.ospo.noaa.gov/Products/atmosphere/ntoast/cris_layer.html and https://www.ospo.noaa.gov/Products/atmosphere/ntoast/omps_layer.html

-------- Forwarded Message --------

Murty and Ken,

We have been using the SNPP and NOAA-20 NUCAPS as the inputs for the TOAST Products: https://www.ospo.noaa.gov/Products/atmosphere/ntoast/index.html
We switched to the NOAA-20 NUCAPS Ozone products when the SNPP NUCAPS Ozone products were offline, and saw similar performance. We have now switched back to an all SNPP product (OMPS V8Pro + NUCAPS) but will make an all NOAA-20 product when the NOAA-20 OMPS V8Pro becomes operational.

Larry Flynn



NOAA-20 TOAST has yet to reach operational status since NOAA-20 V8PRO is still not operational.

SUMMARY AND CONCLUSIONS

NUCAPS

Milestones	Original Date	Forecast Date	Actual Completion Date	Variance Explanation
NOAA-20 Calibration/Validation				
Beta Maturity			06/15/18	
Provisional Maturity: AVTP, AVMP			06/15/18	
Provisional Maturity: Ozone, OLR, CO			10/02/18	
Validated Maturity: AVTP, AVMP, Ozone, OLR	Oct-19	Oct-19		
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Cal/Val visualization and LTM tool development/improvement	Sep-20	Sep-20		
Peer reviewd paper on NUCAPS HEAP cal/val	Sep-20	Sep-20		

Risks, Actions, and Mitigations

Identified Risk	Description	Impact	Action/Mitigation and Schedule
	None Identified		Discuss within STAR internal meetings as well as NUCAPS All-Hands Meetings to work out an action plan.

Documentation

Science Maturity Check List	Yes ?
Readme for Data Product Users	Yes
Algorithm Theoretical Basis Document (ATBD)	Yes
Algorithm Calibration/Validation Plan	Yes
(External/Internal) Users Manual	Yes
System Maintenance Manual (for ESPC products)	Yes
Peer Reviewed Publications (Demonstrates algorithm is independently reviewed)	Yes, additional papers in progress
Regular Validation Reports (at least annually) (Demonstrates long-term performance of the algorithm)	In progress

ATBD, External/Internal Users Manual, System Maintenance Manual available upon request, and as part of DAP

Check List - Validated Maturity

Validated Maturity End State	Assessment
Product performance has been demonstrated over a large and wide range of representative conditions (i.e., global, seasonal).	Yes. See slides 70 (AVTP, AVMP, O3), 86 (OLR), and 94 (CO).
Comprehensive documentation of product performance exists that includes all known product anomalies and their recommended remediation strategies for a full range of retrieval conditions and severity level.	Yes. See slide 164
Product analyses are sufficient for full qualitative and quantitative determination of product fitness-for-purpose.	Yes. See slides 33-69 (AVTP, AVMP, O3), 73-85 (OLR), 103-117 (CO).
Product is ready for operational use based on documented validation findings and user feedback.	Yes. See User Feedback and Downstream Products Feedback slides 119-150.
Product validation, quality assurance, and algorithm stewardship continue through the lifetime of the instrument	Yes. See planned activities slides 168-172.

Conclusions

- Team recommends NUCAPS algorithm **Validated Maturity** for **NOAA-20 AVTP**, **AVMP**, **IR Ozone Profile**, and **CrIS OLR**
- Team recommends NUCAPS algorithm **Validated Maturity** for **SNPP/NOAA-20 CO**
- Team recommends NUCAPS algorithm **Provisional Maturity** for **SNPP/NOAA-20 CH_4**

Product	Maturity Level			
	SNPP		NOAA-20	
	Current Status	Maturity Level **Aimed**	Current Status	Maturity Level Aimed
NOAA-20 AVTP/AVMP	✓ Validated	✓ Remain Validated	✓ Provisional	❑ Validated
NOAA-20 Ozone	✓ Validated	✓ Remain Validated	✓ Provisional	❑ Validated
NOAA-20 OLR	✓ Validated	✓ Remain Validated	✓ Provisional	❑ Validated
SNPP and NOAA-20 CO	✓ Provisional	❑ Validated	✓ Provisional	❑ Validated
SNPP and NOAA-20 CH4	✓ Beta	❑ Provisional	✓ Beta	❑ Provisional
SNPP and NOAA-20 CO2	✓ Beta	✓ Remain Beta	✓ Beta	✓ Remain Beta

Summary

- Candidate NUCAPS version (V2.5.2.2) is
  - Producing consistent results between SNPP and NOAA-20
  - Producing results of equal or better quality than the current operational version
  - Producing results generally meeting JPSS L1 Requirements versus independent correlative datasets (model outputs, RAOBs, ozonesonde, satellite EDRs, ATom, etc.) and model output
- User feedback is positive
  - In Hurricane Dorian case, NUCAPS demonstrates capability to detect signatures that are operationally relevant and physically significant
  - Many PGRR Initiatives are using NUCAPS products and found them extremely useful for their applications
- Delivered v2.5.2.2 to ASSISST team for cluster integration and parallel runs to produce SNPP/NOAA-20 NUCAPS products
  - Verified pre-operational products generated by the ASSISST cluster runs

PATH FORWARD

Path Forward: NUCAPS algorithm Improvements

Planned FY20-21 NUCAPS algorithm improvements to HEAP:

- ✓ Improvements to emissivity retrieval as well as CAMEL emissivity lookup approach as a method to improve land surface spectral emissivities.
- ✓ Improvements to ocean surface IR emissivity model (currently in progress with partial funding from JCSDA).
- ✓ Optimized cloud clearing through Local Angle Corrections (LAC) and improved namelist parameters and channel selection.
- ✓ Update NUCAPS code for stability indices and use of ancillary data to improve boundary layer.
- ✓ Characterize the NUCAPS averaging kernels for T(p), q(p), and O3(p) and implement into the NUCAPS OPS code and output formats.
- ✓ NUCAPS product format improvements based on user requirements from Green House Gas Monitoring Meetings.
- ✓ Explore the use of alternate technologies for certain NUCAPS modules such as AI based regression.

- *Would Benefit Retrieval Product Improvements for all platforms: (SNPP, NOAA-20, Metop-A, B, C)*
- *Would Benefit NUCAPS Augmentation to IASI-NG/MWS*

Path Forward: Validation Activities

- MetOp-C NUCAPS products– Algorithm Optimization, Product Evaluation
  - NUCAPS is running operationally on IASI Metop-A and B at OSPO.
  - OSPO version requires updates and adaptation for Metop-C IASI.
  - Updates/Adaptations become precursor for EPS-SG: NUCAPS for IASI-NG

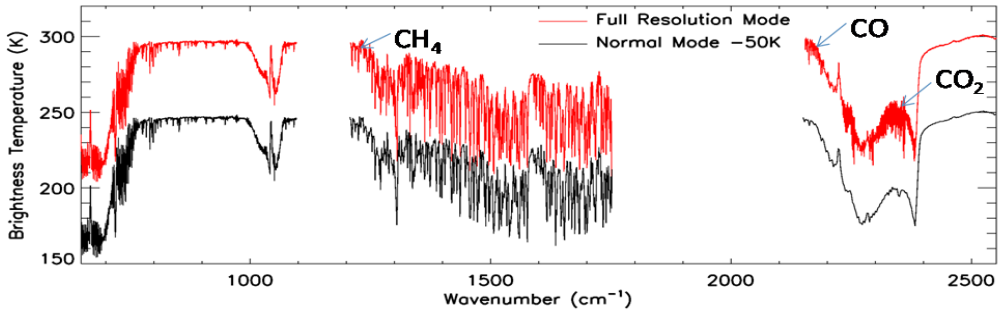
- Planned/ongoing validation activities
  - NOAA-20/SNPP: All Products: Continue daily assessments (as posted via JSTAR Mapper)
  - NOAA-20/SNPP: O3(p): Continue to leverage WOUDC, SHADOZ, AEROSE and other field campaigns
  - NOAA-20/SNPP: CO, CH4: Continue to leverage FIREX, We-Can, and other field campaigns
  - NOAA-20/SNPP: T(p), q(p): Continue to leverage NPROVS system for global EDR sounder evaluation using global RAOBs

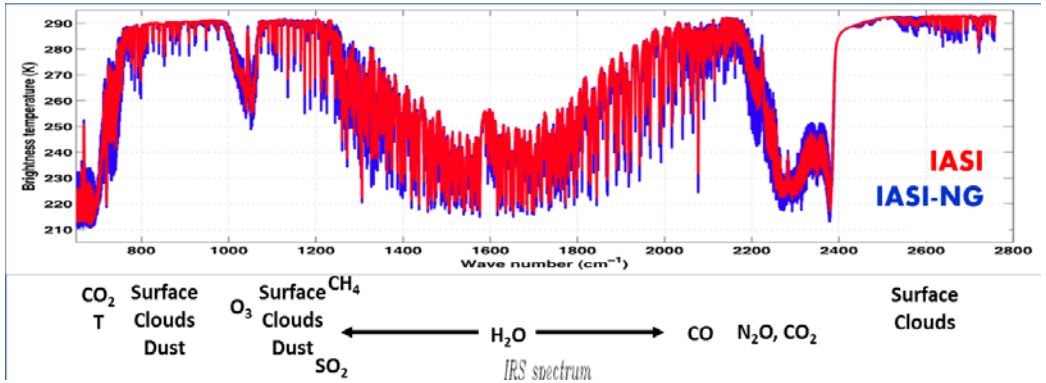
- Reprocessing of SNPP/NOAA-20 mission data (Summer 2020)

- NUCAPS products from EPS-SG IASI-NG: Algorithm development, optimization, and augmentation

JPSS/MetOp-SG sensor Inter-comparison

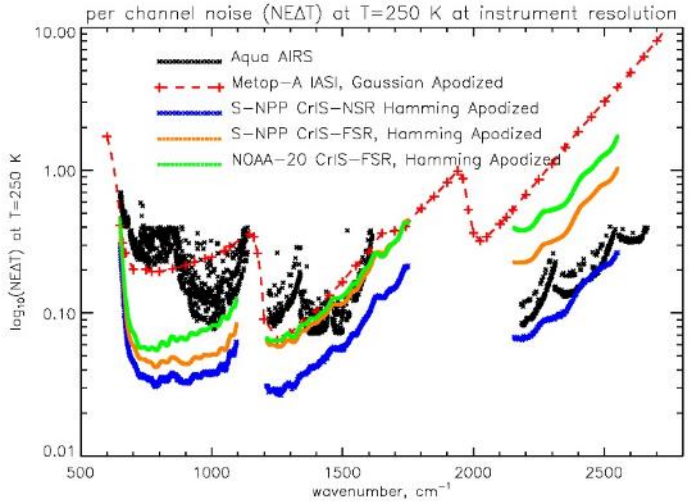
IASI-NG vs. IASI and CrIS

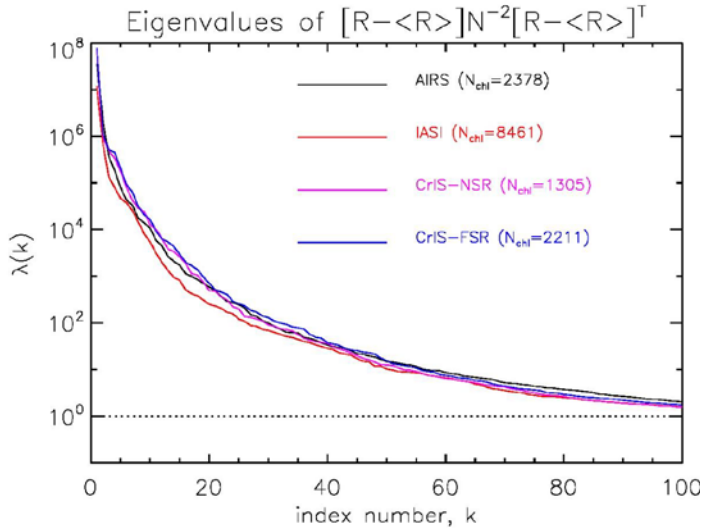




	CrIS	IASI	IASI-NG
Spectral Range And Spectral Resolution	650-1095, 1210-1750, 2155-2550 cm-1 0.625 cm-1	645-2760 cm-1 0.625 cm-1	645-2760 cm-1 0.125 cm-1
FOV Footprint	14 Km at Nadir	12 Km at Nadir	12 Km at Nadir
Number of FOVS for Field of Regard (FOR) Retrieval	3 x 3	2 x 2	4 x 4
Number of Channels	2211	8461	16,821

- With the increase in spectral resolution combined with reduced radiometric noise at least by a factor of 2 compared to IASI (as stated on the IASI-NG website), IASI-NG should be able to retrieve some additional trace gas products, and with a slightly improved accuracy than CrIS/IASI
- However, we have no information from the vendor on the IASI-NG instrument noise characteristics. Hence, it is difficult to ascertain the information content available from IASI-NG, and achievable product accuracy.
- At a minimum, IASI-NG would produce products at least with comparable accuracy to CrIS and IASI.





The 1st 100 significant Eigen vectors from the operational NUCAPS regression training. (From Chris Barnet)

NUCAPS

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NUCAPS Validated Maturity Review

SUPPLEMENTAL SLIDES

Path Forward : Operational Algorithm Upgrades (Collaborations among STAR, STC, UMD, UW)

Optimize unified algorithm package combining algorithm merits/research performed by STAR-NUCAPS, STC-NUCAPS team, and other agencies working on NUCAPs improvements

Item	V2.5.2.2 Operational Version Unified/Merged code from STAR and STC		V2.5.2 Unified Code STAR/STC	STC Team Chris Barnet/ Nadia/Rebekah
	S-NPP	NOAA-20		
MW Tuning	✓ Two focus days (20190215, 20190815) S-NPP radiances, and MIT forward model.	✓ Two focus days (20190215, 20190815) NOAA-20 radiances and MIT forward model.	✓ STAR	• MIT Line-by-Line model updates • MW Fast Forward model
Cloudy Regression	✓ NO Change from the Operational Version	✓ PC regression using NOAA-20 all-sky radiances matched with ECMWF; Used four Focus Days (20180415, 20180715, 20181015, 20190115)	✓ STAR	• Robust code, easy to work for various situations (e.g. CrIS Side-A issue, impact studies, CrIS polarization)
Clear Regression	✓ NO change from the Operational version	✓ PC regression using NOAA-20 CCR radiances matched with ECMWF; Used four Focus Days (20180415, 20180715, 20181015, 20190115)	✓ STAR	• Robust code
Emissivity Regression	✓ NO Change from the Operational version	✓ NO change from the Operational version	✓ STAR	
IR Tuning	✓ "Full tuning" method using S-NPP radiances and ECMWF SARTA simulations	✓ Double Difference Method using NOAA-20 radiances and ECMWF SARTA simulations.	✓ STAR	• UMBC: SARTA Forward model • STC: Wrapper scripts to make sarta LUTs for NUCAPS use
CO A-priori/QC	✓ NO Change from the Operational version	✓ NO Change from the Operational version	Created by Univ. of MD	
CH4/N2O A-priori	✓ Updated CH4/N2O A-priori	✓ Updated CH4/N2O A-priori	Created by Univ. of MD	
CrIS Noise File	✓ NO Change from the current operational version	✓ NO Change from the current operational version		
Channel Selection for cloud-clearing, T(p), q(p)	✓ Minor updates of channels	✓ Minor updates of channels	✓ STAR	• Updates to cloud clearing channels.
Channel selection for trace gases	✓ NO Change from the current operational version	✓ NO Change from the current operational version	✓ STAR/STC updates	
CAMEL Emissivity	❑ Possible upgrade	❑ Has shown to improve emissivity characteristic		• STC Expertise • Workshop on emissivity conducted with STAR, STC, UW (Bob Knuteson)
Local Angle Corrections (LAC)	❑ Possible upgrade	❑ Potential improvements towards swath edges.		• STC developed algorithm. Code available for integration
Super Saturation Flag	❑ Super Saturation Flag	❑ Potential improvements to quality control near cloud edges.		• STC developed necessary QC flag, Integration in progress

Requirement Check List – Atmospheric Vertical Temperature Profile

JERD	Requirement	Performance
JERD-2209	The algorithm shall produce the AVTP product under Day and Night conditions	Yes, slides 45-46
JERD-2210	The algorithm shall produce an AVTP product under cloud-free, partly cloudy, and cloudy conditions	Yes, slide 67
JERD-2211	The algorithm shall produce an AVTP product that has a horizontal cell size of 50 km at nadir	Yes, NUCAPS retrieval FOR is 45 km
JERD-2212	The algorithm shall produce an AVTP product that has a vertical reporting interval of: 20 mb from the surface to 850 mb; 50 mb from 850 mb to 300 mb; 25 mb from 300 mb to 100 mb; 20 mb from 100 mb to 10 mb; 2 mb from 10 mb to 1.0 mb, and 0.2 mb from 1.0 mb to 0.5 mb.	Addressed separately.
JERD-2213	The algorithm shall produce an AVTP product that has a mapping uncertainty (3 sigma) of 5 km	Yes. The mapping uncertainty of NUCAPS is contingent upon the SDR/TDR mapping uncertainties.
JERD-2214	The algorithm shall produce an AVTP product that has a measurement uncertainty expressed as an error in layer average temperature of: 1.6 K per 1 km layer for cloud-free to partly cloudy, surface to 300 mb over ocean; 1.5 K per 3 km layer for cloud-free to partly cloudy, 300 mb to 30 mb; 1.5 K per 5 km layer for cloud-free to partly cloudy, 30 mb to 1 mb; 3.5 K per 5 km layer for cloud-free to partly cloudy, 1 mb to 0.5 mb; 2.5 K per 1 km layer for cloudy, surface to 700 mb; 1.5 K per 1 km layer for cloudy, 700 mb to 300 mb; 1.5 K per 3 km layer for cloudy, 300 mb to 30 mb; 1.5 K per 3 km layer for cloudy, 30 mb to 1 mb; and 3.5 K per 5 km layer for cloudy, 1 mb to 0.5 mb.	Yes, slide 67

Requirement Check List – Atmospheric Vertical Temperature Profile

JERD0	Requirement	Performance
JERD-2212	The algorithm shall produce an AVTP product that has a vertical reporting interval of: 20 mb from the surface to 850 mb; 50 mb from 850 mb to 300 mb; 25 mb from 300 mb to 100 mb; 20 mb from 100 mb to 10 mb; 2 mb from 10 mb to 1.0 mb, and 0.2 mb from 1.0 mb to 0.5 mb.	Verification data for the SNPP NUCAPS atmospheric vertical temperature profile (AVTP) EDR retrieval provided limited validation up to 1 hPa using merged RAOB and Lidar data obtained from the PMRF site operated by the Aerospace Corp. in collaboration with NOAA/NESDIS/STAR. These results have been published in the peer-reviewed paper Nalli, N. R. et al., 2018: Validation of atmospheric profile retrievals from the SNPP NOAA-Unique Combined Atmospheric Processing System. Part 1: Temperature and moisture, IEEE Trans. Geosci. Remote Sens., 56(1), 180-190, doi:10.1109/TGRS.2017.2744558. Without these data for NOAA-20 NUCAPS, the only practical means for doing this will be using collocated ECMWF ouptut and/or collocated satellite sounders (e.g., AIRS, SNPP NUCAPS), although it should be noted that ECMWF assimilated RAOBs, which typically have burst altitudes around 50 hPa. Thus it is extremely difficult to obtain reliable verification data above these levels. The vertical reporting interval of the NUCAPS products (including AVTP, AVMP, IR ozone, trace gases) is predetermined by the radiative transfer algorithm (RTA), which is established at 100 standard pressure levels from 1100 mb to 0.005 mb. It is not advisable (nor possible) to change the standard pressure spacing of the RTA, but the vertical pressure interval varies from 20-30 hPa from the surface to 600 mb, 10-20 mb from 600 mb to 200 mb, and < 10 mb from 200 mb to the TOA. Thus it may be noted that these values are reasonably close to (within 10 mb), or better than, the specified values.

Action to Program: Waive requirements or update requirements as per science community standards.

Requirement Check List – Atmospheric Vertical Moisture Profile

JERD	Requirement	Performance
JERD-2219	The algorithm shall produce the AVMP product under Day and Night conditions	Yes, slides 45-46
JERD-2220	The algorithm shall produce the AVMP product under cloud-free, partly cloudy, and cloudy conditions	Yes, slide 67
JERD-2221	The algorithm shall produce the AVMP product that has a horizontal cell size of 50 km at nadir	Yes, NUCAPS retrieval FOR is 45 km
JERD-2222	The algorithm shall produce the AVMP product that has a vertical reporting interval of: 20 mb from surface to 850 mb and 50 mb from 850 mb to 100 mb	Yes, slide 67
JERD-2223	The algorithm shall produce the AVMP product that has a mapping uncertainty (3 sigma) of 5 km	Yes. The mapping uncertainty of NUCAPS is contingent upon the SDR/TDR mapping uncertainties.
JERD-2224	The algorithm shall produce the AVMP product that has a measurement uncertainty (expressed as a percent of average mixing ratio in 2 km layers) of: Greater of 20 % or 0.2 g/kg for cloud-free to partly cloudy, surface to 600 mb; Greater of 35 % or 0.1 g/kg for cloud-free to partly cloudy, 600 mb to 300 mb; Greater of 35 % or 0.1 g/kg for cloud-free to partly cloudy, 300 mb to 100 mb; Greater of 20 % or 0.2 g/kg for cloudy, surface to 600 mb; Greater of 40 % or 0.1 g/kg for cloudy, 600 mb to 400 mb; and Greater of 40 % or 0.1 g/kg for cloudy, 400 mb to 100 mb.	Yes, slide 67
JERD-2225	The algorithm shall produce the AVMP product that incorporates fill and quality flag conditions including degraded, excluded or other applicable quality conditions	Yes, 28. 45-46

Requirement Check List – CrIS Infrared Ozone Profile

JERD	Requirement	Performance
JERD-2191	The algorithm shall produce an infrared ozone profile product that has a horizontal cell size of 50 km at nadir	Yes. The NUCAPS algorithm produces a O3 product on a field-of-regard consisting of 3 x 3 CrIS fields-of-view, constituting a nominal nadir spatial resolution of 45 km.
JERD-2192	The algorithm shall produce an infrared ozone profile product on the native retrieval reporting interval (usually the forward model's vertical grid) such that users can vertically remap the product without the loss of vertical information content	Yes, the retrieval algorithm produces all products on the forward model's vertical grid reporting interval.
JERD-2193	The algorithm shall produce an infrared ozone profile product that has a mapping uncertainty (3 sigma) of 10 km	Yes. The mapping uncertainty of NUCAPS is contingent upon the SDR/TDR mapping uncertainties.
JERD-2194	The algorithm shall produce an infrared ozone profile product that has a measurement precision of: 20% from 4 hPa to 260 hPa (6 statistic layers) and 20% form 260 hPa to the surface (1 statistic layer)	Yes, slide 69
JERD-2195	The algorithm shall produce an infrared ozone profile product that has a measurement accuracy of: 10% from 4 hPa to 250 hPa (6 statistic layers) and 10% from 260 hPa to the surface (1 statistic layer)	Yes, slide 69
JERD-2196	The algorithm shall produce an infrared ozone profile product that has a measurement uncertainty of: 25% from 4 hPa to 250 hPa (6 statistic layers) and 25% from 260 hPa to the surface (1 statistic layer)	Yes, slide 69

Requirement Check List – Carbon Monoxide (CO)

JERD	Requirement	Performance
JERD-2164	The algorithm shall produce a CO product that has a vertical coverage of the total column	Yes. The NUCAPS algorithm produces a CO product on the 100 layer RTA that spans the surface to 0.005 hPa.
JERD-2165	The algorithm shall produce a CO product that has a horizontal resolution of 100 km	Yes. The NUCAPS algorithm produces a CO product on a field-of-regard consisting of 3 x 3 CrIS fields-of-view, constituting a nominal nadir spatial resolution of 45 km.
JERD-2166	The algorithm shall produce a CO product that has a mapping uncertainty (3 sigma) of 25 km (5 km)	Yes. The mapping uncertainty of NUCAPS is contingent upon the SDR/TDR mapping uncertainties.
JERD-2167	The algorithm shall produce a CO product that has a measurement range of 0 to 200 ppbv	Yes. The NUCAPS algorithm CO product has a measurement range that far surpasses 200 ppbv. (slides 193,194)
JERD-2168	The algorithm shall produce a CO product that has a measurement precision of 15%	Addressed separately
JERD-2169	The algorithm shall produce a CO product that has a measurement accuracy of 5%	Addressed separately

Requirement Check List – Carbon Monoxide (CO)

JERD	Requirement	Performance
JERD-2168	The algorithm shall produce a CO product that has a measurement precision of 35%.	The carbon trace gas EDRs are relatively new requirements, these being "downstream" products that depend on AVTP, then AVMP, then ozone. The operational algorithm for the first couple of years of the SNPP mission was the CrIMSS algorithm, which did not retrieve carbon trace gases. For CrIS nominal spectral resolution (NSR), the CrIS sensor did not have adequate sensitivity to CO. For full spectral resolution (FSR) CrIS, which became available operationally in March 2017, the precision requirement was increased to 15%. Global validation of carbon trace gases requires acquisition periods for in situ data collection, with AirCore, TCCON and aircraft campaigns (e.g., ATom) having a lag time between observation and pubic release of QA products. Because the CO retrieval only has skill where averaging kernels (AKs) peak, the team recommends the proper use of AKs in formal assessments of CO versus high resolution truth data.

Action to Program: Waive requirements or update requirements as per science community standards.

Requirement Check List – Carbon Monoxide (CO)

JERD	Requirement	Performance
JERD-2169	The algorithm shall produce a CO product that has a measurement accuracy of ±25%.	The carbon trace gas EDRs are relatively new requirements, these being "downstream" products that depend on AVTP, then AVMP, then ozone. The operational algorithm for the first couple of years of the SNPP mission was the CrIMSS algorithm, which did not retrieve carbon trace gases. For CrIS nominal spectral resolution (NSR), the CrIS sensor did not have adequate sensitivity to CO. For full spectral resolution (FSR) CrIS, which became available operationally in March 2017, the accuracy requirement was increased to ±5%. Global validation of carbon trace gases requires acquisition periods for in situ data collection, with AirCore, TCCON and aircraft campaigns (e.g., ATom) having a lag time between observation and pubic release of QA products. Because the CO retrieval only has skill where averaging kernels (AKs) peak, the team recommends the proper use of AKs in formal assessments of CO versus high resolution truth data.

NUCAPS team should present the best possible validation data and propose requirement change during the provisional maturity review scheduled for September 2018 (Action for NUCAPS team)

Action to Program: Waive requirements or update requirements as per science community standards.

Requirement Check List – Carbon Dioxide (CO_2)

JERD	Requirement	Performance
JERD-2173	The algorithm shall produce a CO_2 product that has a vertical coverage of the total column	Yes. The NUCAPS algorithm produces a CO2 product on the 100 layer RTA that spans the surface to 0.005 hPa.
JERD-2174	The algorithm shall produce a CO_2 product that has a horizontal resolution of 100 km	Yes. he NUCAPS algorithm produces a CO2 product on a field-of-regard consisting of 3 x 3 CrIS fields-of-view, constituting a nominal nadir spatial resolution of 45 km.
JERD-2175	The algorithm shall produce a CO_2 product that has a mapping uncertainty (3 sigma) of 25 km	The mapping uncertainty of NUCAPS is contingent upon the SDR/TDR mapping uncertainties.
JERD-2176	The algorithm shall produce a CO_2 product that has a measurement range of 300 to 500 ppmv	Yes. The NUCAPS algorithm CO2 product has a measurement range that far surpasses the range of 300 to 500 ppmv. (slides 193-194)
JERD-2177	The algorithm shall produce a CO_2 product that has a measurement precision of 0.5% (2 ppmv)	Addressed separately
JERD-2178	The algorithm shall produce a CO_2 product that has a measurement accuracy of +/-1% (4 ppmv)	Addressed separately

Requirement Check List – Carbon Dioxide (CO_2)

JERD	Requirement	Performance
JERD-2177	The algorithm shall produce a CO_2 product that has a measurement precision of 0.5% (2 ppmv)	The carbon trace gas EDRs are relatively new requirements, these being "downstream" products that depend on AVTP, then AVMP, then ozone. The operational algorithm for the first couple of years of the SNPP mission was the CrIMSS algorithm, which did not retrieve carbon trace gases. Global validation of carbon trace gases requires acquisition periods for in situ data collection, with AirCore, TCCON and aircraft campaigns (e.g., ATom) having a lag time between observation and pubic release of QA products. Recent field measurements (conducted since the time when the requirements were devised) suggest that the CO2 precision threshold is too stringent. Furthermore, from a fundamental error analysis perspective it makes little sense to have a CO2 precision requirement twice as stringent as the accuracy. Bias error contributes to the total combined uncertainty error (RMSE) in the same manner that precision error does, with the exception that there is no practical way to reduce unknown bias. The team recommends a relaxed total/partial column CO2 precision requirement (TBD), along with the proper use of averaging kernels (AKS).

Action to Program: Waive requirements or update requirements as per science community standards.

Requirement Check List – Carbon Dioxide (CO_2)

JERD	Requirement	Performance
JERD-2178	The algorithm shall produce a CO_2 product that has a measurement accuracy of +/-1% (4 ppmv)	The carbon trace gas EDRs are a new requirement, these being "downstream" products that depend on AVTP, then AVMP, then ozone. The operational algorithm for a first couple of years of the SNPP mission was the CrIMSS algorithm, which did not retrieve carbon trace gases. Global validation of carbon trace gases requires acquisition periods for in situ data collection, with AirCore, TCCON and aircraft campaigns (e.g., ATom) having a lag time between observation and pubic release of QA products. The team recommends the proper use of averaging kernels (AKs) in formal assessments of CO2 versus high resolution truth data.

NUCAPS team should present the best possible validation data and propose requirement change during the provisional maturity review scheduled for September 2018 (Action for NUCAPS team)

Action to Program: Waive requirements or update requirements as per science community standards.

Requirement Check List – Methane (CH_4)

JERD	Requirement	Performance
JERD-2182	The algorithm shall produce a CH_4 product that has a vertical coverage of the total column	Yes. The NUCAPS algorithm produces a CH4 product on the 100 layer RTA that spans the surface to 0.005 hPa.
JERD-2183	The algorithm shall produce a CH_4 product that has a horizontal resolution of 100 km	Yes. The NUCAPS algorithm produces a CH4 product on a field-of-regard consisting of 3 x 3 CrIS fields-of-view, constituting a nominal nadir spatial resolution of 45 km.
JERD-2184	The algorithm shall produce a CH_4 product that has a mapping uncertainty (3 sigma) of 25 km	The mapping uncertainty of NUCAPS is contingent upon the SDR/TDR mapping uncertainties, and the EDR teams adheres to the mapping uncertainty proven by the SDR/TDR teams.
JERD-2185	The algorithm shall produce a CH_4 product that has a measurement range of 1100 to 2250 ppbv	Yes. The NUCAPS algorithm CH4 product has a measurement range that far surpasses the range of 1100 to 2250 ppmv (slides 193,194)
JERD-2186	The algorithm shall produce a CH_4 product that has a measurement precision of 1% (~ 20 ppbv)	Addressed Separately
JERD-2187	The algorithm shall produce a CH_4 product that has a measurement accuracy of +/- 4% (~ 80 ppbv)	Addressed Separately

Requirement Check List – Methane (CH_4)

JERD	Requirement	Performance
JERD-2186	The algorithm shall produce a CH_4 product that has a measurement precision of 1% (~ 20 ppbv)	The carbon trace gas EDRs are relatively new requirements, these being "downstream" products that depend on AVTP, then AVMP, then ozone. The operational algorithm for the first couple of years of the SNPP mission was the CrIMSS algorithm, which did not retrieve carbon trace gases. Global validation of carbon trace gases requires acquisition periods for in situ data collection, with AirCore, TCCON and aircraft campaigns (e.g., ATom) having a lag time between observation and pubic release of QA products. Recent field measurements (conducted since the time when the requirements were devised) suggest that the CH4 precision threshold is too stringent. Furthermore, from a fundamental error analysis perspective it makes little sense to have a CH4 precision requirement 4 times as stringent as the accuracy. Bias error contributes to the total combined uncertainty error (RMSE) in the same manner that precision error does, with the exception that there is no practical way to reduce unknown bias. The team recommends a relaxed total/partial column CH4 precision requirement (TBD), along with the proper use of averaging kernels (AKS).

Action for NUCAPS team to present the proposed requirement change during the provisional maturity review scheduled for September 2018.
Action to Program: Waive requirements or update requirements as per science community standards.

Requirement Check List – Methane (CH_4)

JERD	Requirement	Performance
JERD-2187	The algorithm shall produce a CH_4 product that has a measurement accuracy of +/-4% (~ 80 ppbv)	The carbon trace gas EDRs are a new requirement, these being "downstream" products that depend on AVTP, then AVMP, then ozone. The operational algorithm for a first couple of years of the SNPP mission was the CrIMSS algorithm, which did not retrieve carbon trace gases. Global validation of carbon trace gases requires acquisition periods for in situ data collection, with AirCore, TCCON and aircraft campaigns (e.g., ATom) having a lag time between observation and pubic release of QA products. The team recommends the proper use of averaging kernels (AKs) in formal assessments of CH4 versus high resolution truth data. The science teams shall attempt to provide validation data meeting the requirements for 3 broad layers in N-20 validated maturity review.

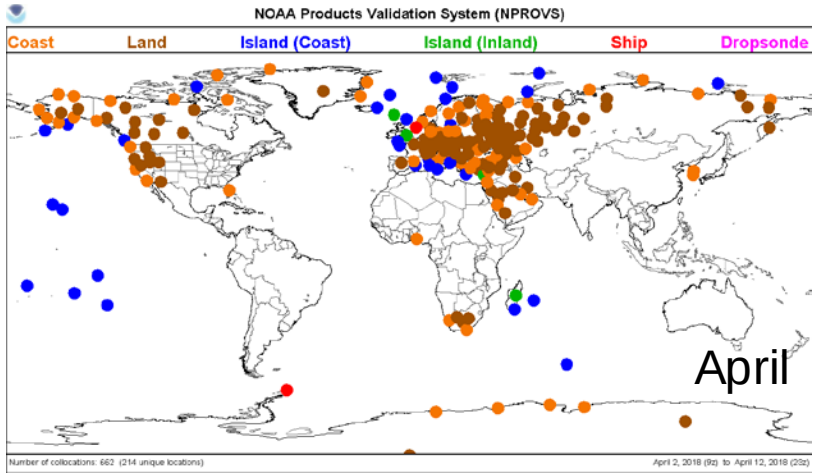
Action for NUCAPS team to present the proposed requirement change during the provisional maturity review scheduled for September 2018.

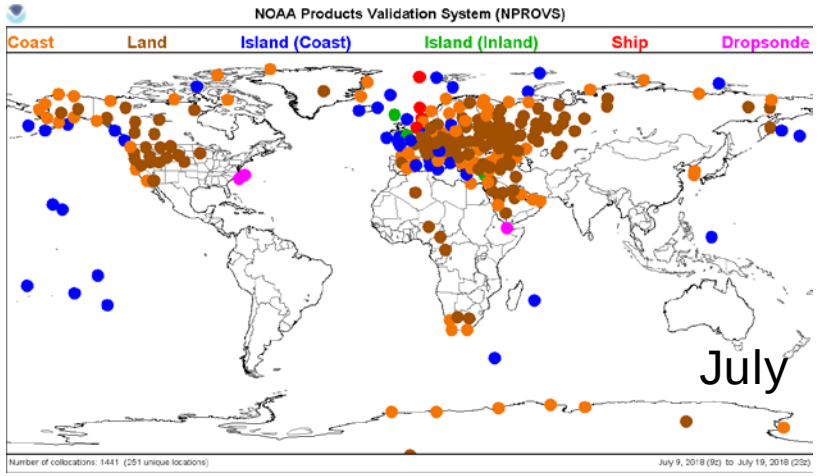
Action to Program: Waive requirements or update requirements as per science community standards.

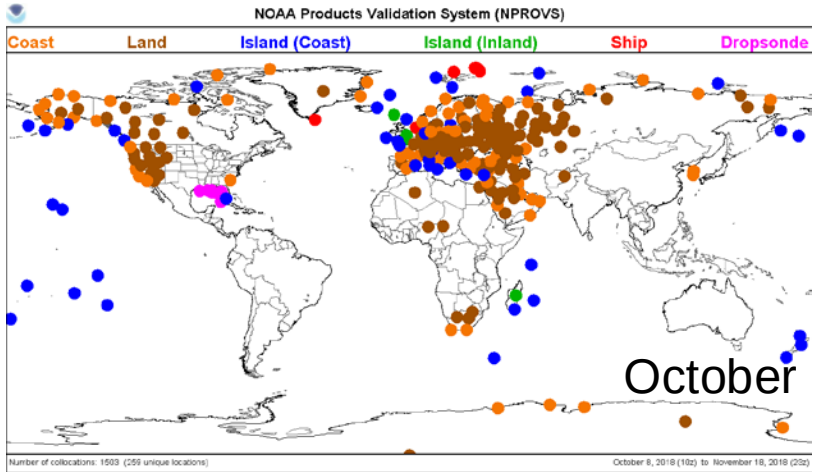
Requirement Check List – Outgoing Longwave Radiation

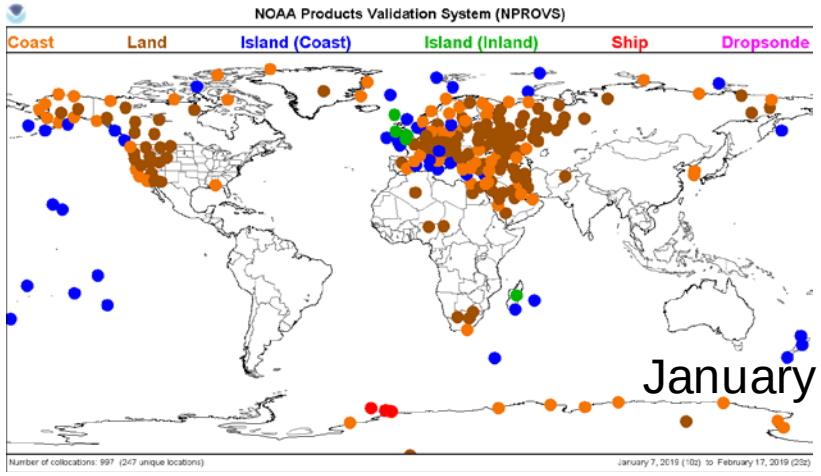
JERD	Requirement	Performance
JERD-2200	The algorithm shall produce an OLR product during daytime and nighttime, regardless of sky conditions	Yes, slides 75, 76
JERD-2201	The algorithm shall produce an OLR product that has a horizontal cell size of 25 km at nadir	Yes. OLR is produced at CrIS FOV
JERD-2202	The algorithm shall produce an OLR product that has a mapping uncertainty (3 sigma) of 5 km at nadir	Yes. The mapping uncertainty of NUCAPS is contingent upon the SDR/TDR mapping uncertainties.
JERD-2203	The algorithm shall produce an OLR product that has a measurement range of 0 to 500 W/m^2	Yes. For better color definition, figures have a range of 70-390 W/m2 (scatter plot on slide 75)
JERD-2204	The algorithm shall produce an OLR product that has a measurement precision of 12 W/m^2	Yes, slide 75
JERD-2205	The algorithm shall produce an OLR product that has a measurement accuracy of 5 W/m^2	Yes, slide 75

NPROVS Validation of NUCAPS AVTP/AVMP Retrievals
2 hrs/50 km RAOB collocations

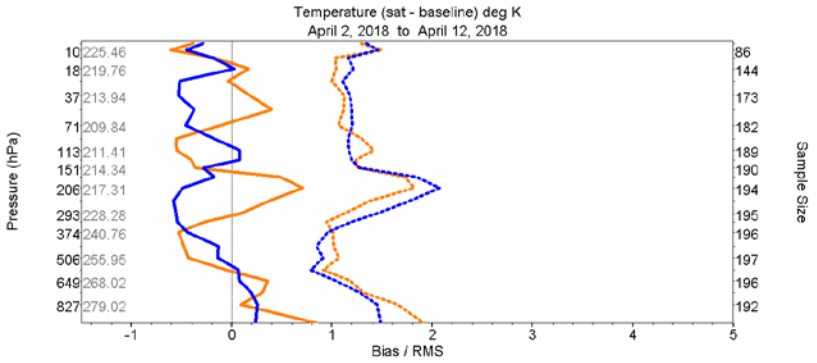






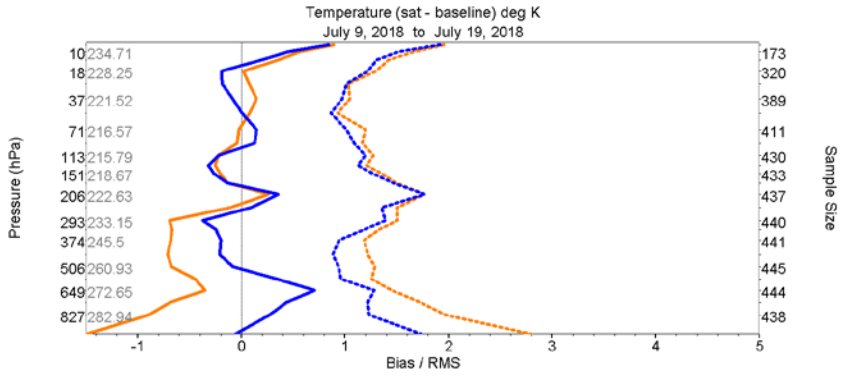


NPROVS Validation of NUCAPS Products
AVTP Retrievals 2 hrs/50 km collocations



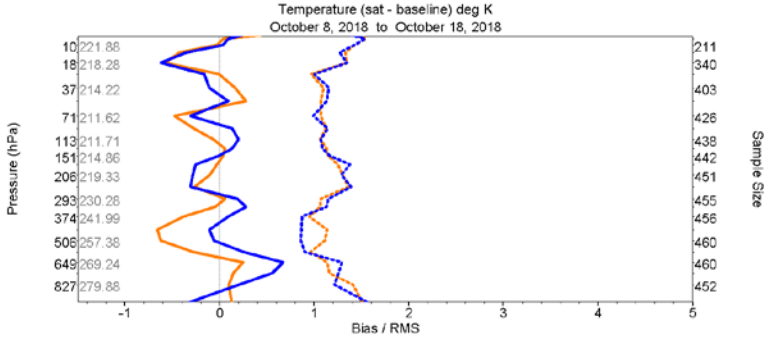
Baseline: SONDE

NUCAPS NPP NUCAPS NOAA-20 TEST



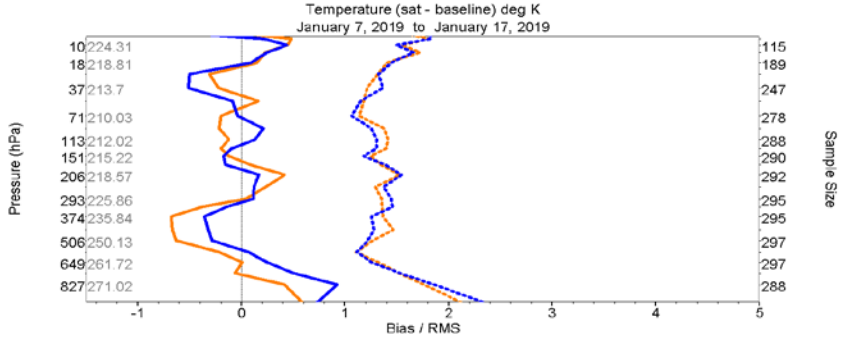
Baseline: SONDE

NUCAPS NPP NUCAPS NOAA-20 TEST



Baseline: SONDE

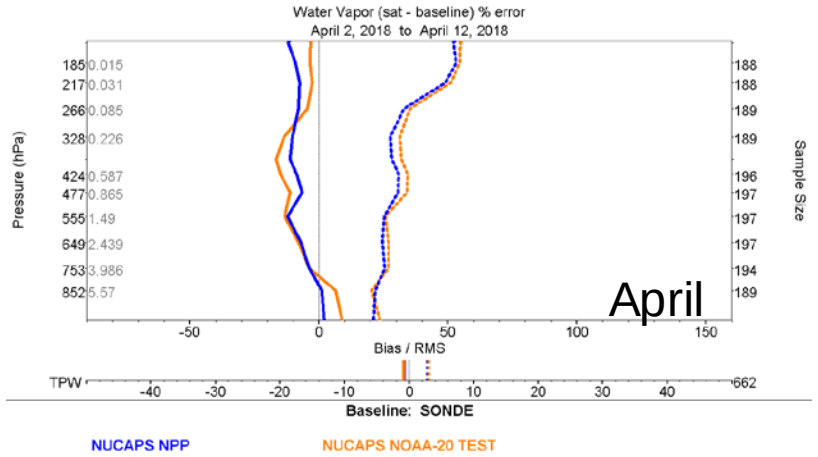
NUCAPS NPP NUCAPS NOAA-20 TEST

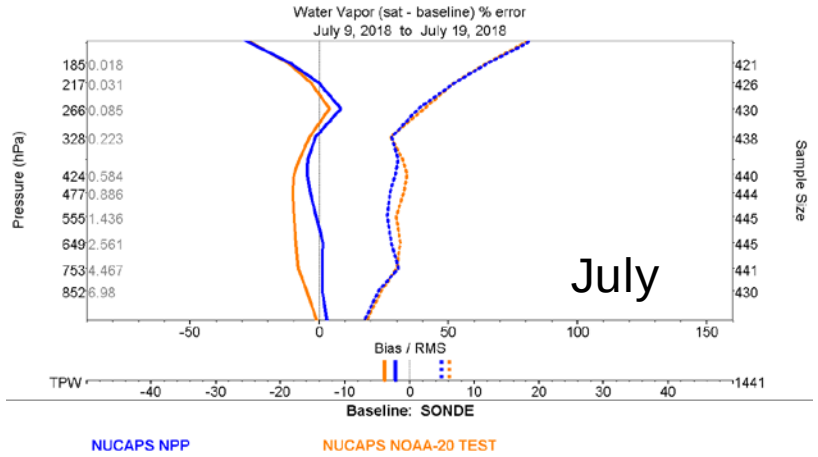


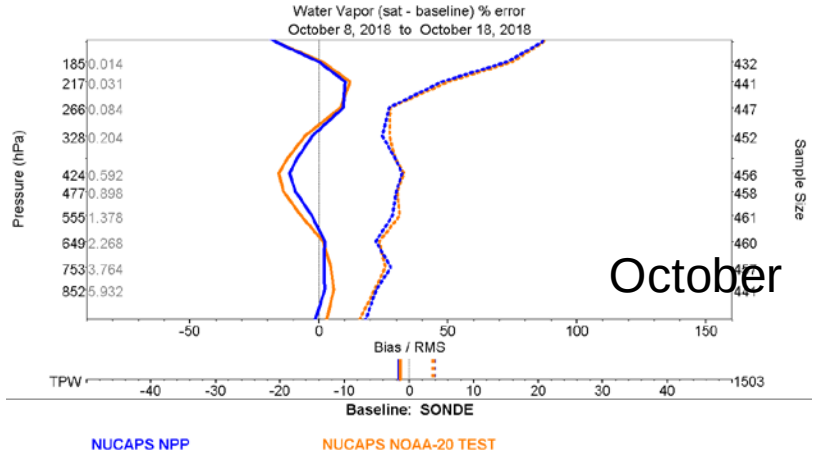
Baseline: SONDE

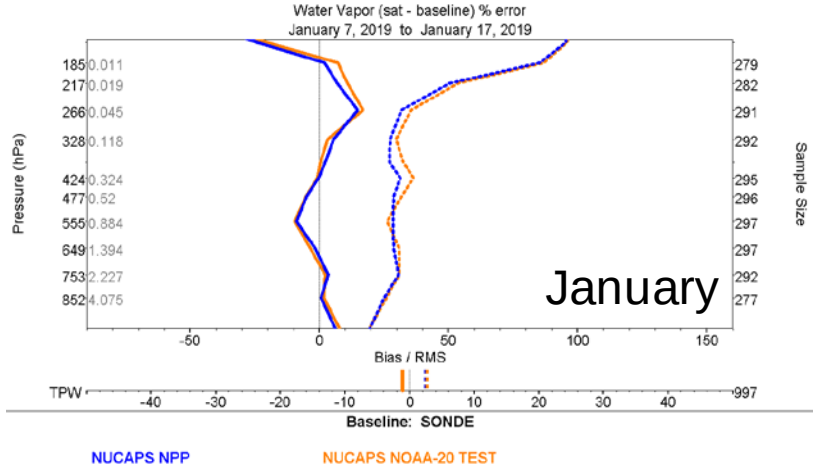
NUCAPS NPP NUCAPS NOAA-20 TEST

NPROVS Validation of NUCAPS
AVMP Retrievals with 2 hrs/50 km collocations





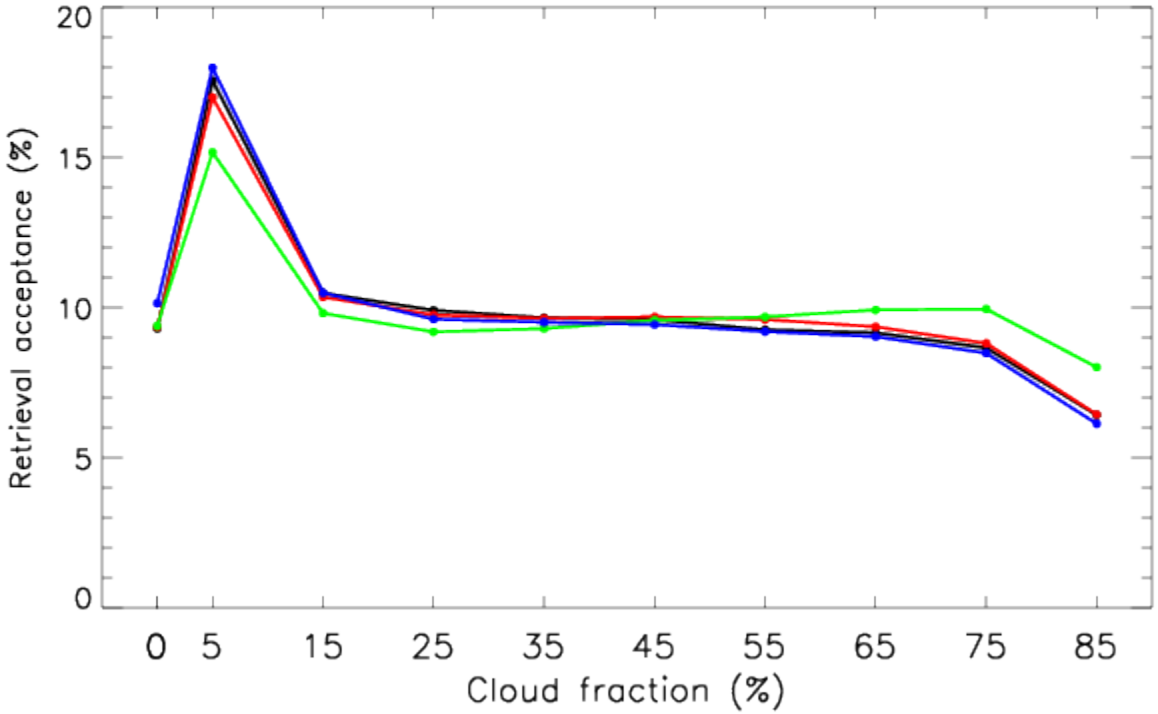




NPROVS Observed Dependence on Clouds

Percentage of IR+MW pass QC retrievals sorted by effective cloud fraction
Based on Oct 18 2019 data

Summation of the percentage values from all the cloud-fraction bins are equal to 100%.



Black: npp oper
Red: npp v2.5.2.2

Green: n20 oper
Blue: n20 v2.5.2.2

Sample Trace Gas Retrieval Ranges

Sensor		SNPP		NOAA-20	
Date	Gas	min	max	min	max
20180820	CO (ppbv)	0	2081	0	2003
	CH4 (ppbv)	0	2334	0	2319
	O3 (ppbv)	0	16034	0	16270
	CO2 (ppmv)	373	450	372	443
20180401	CO (ppbv)	0	1801	0	1804
	CH4 (ppbv)	0	2439	0	2577
	O3 (ppbv)	0	21133	0	18861
	CO2 (ppmv)	381	452	382	442

Sample Trace Gas Retrieval Ranges (04/01, 08/20, 2018)

	Min	Max
CO (ppbv)	0	2080
CH4 (ppbv)	0	2577
O3 (ppbv)	0	21133
CO2 (ppmv)	372	452

OLR Validation Summary

Attribute	Requirement	Observed/validated
Geographic coverage	shall produce an OLR product during daytime and nighttime, regardless of sky conditions	Meets Requirement
Horizontal Cell size	25 km at nadir	14 km (CrIS nadir FOV)
Mapping Uncertainty(3σ)	5 km at nadir	Meets Requirement
Measurement Range	0 -500 W/m^2	0 -500 W/m^2
Measurement Accuracy	5 W/m^2	< 0.6 W/m^2
Measurement Precision	12 W/m^2	<9.1 W/m^2

CrIS NOAA-20 OLR meets maturity review requirements

CrIS OLR workflow

Least square regression

Least square regression

CERES OLR on Aqua

"Truth"

→

AIRS radiances

"transfer"

→

CrIS radiances

- Collocation of AIRS radiances and CERES SSF TOA flux
- Training least-squares regression coefficients related CERES OLR with AIRS radiances

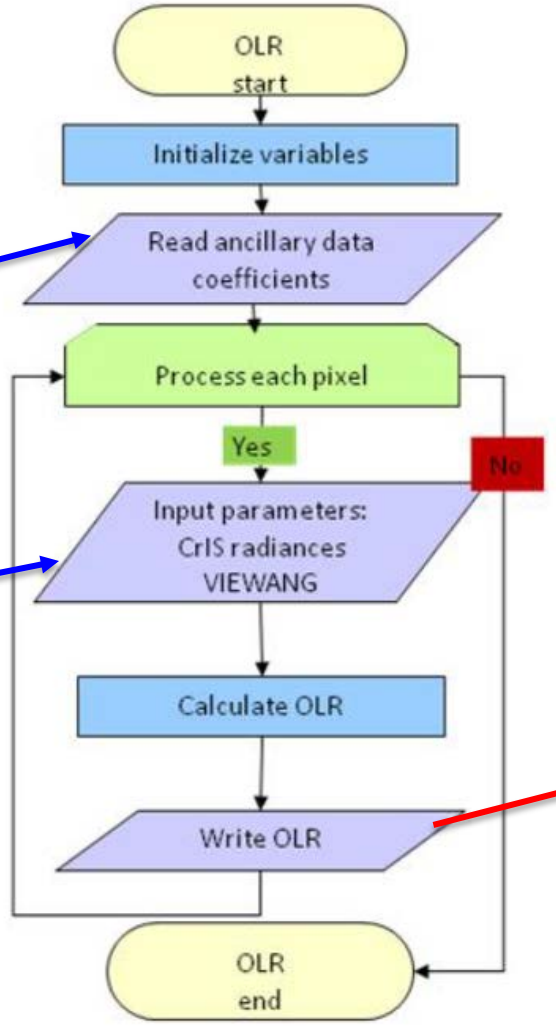
- Simulation of Radiance adjustment regression database between AIRS and CrIS
- Training least-square regression coefficients for the correction from CrIS pseudo channel

CrIS OLR Algorithm

Input data

Ancillary Data:
1. Parameters of Pseudo Channel
2. OLR regression Coefficient
3. Radiance Correction Coefficients

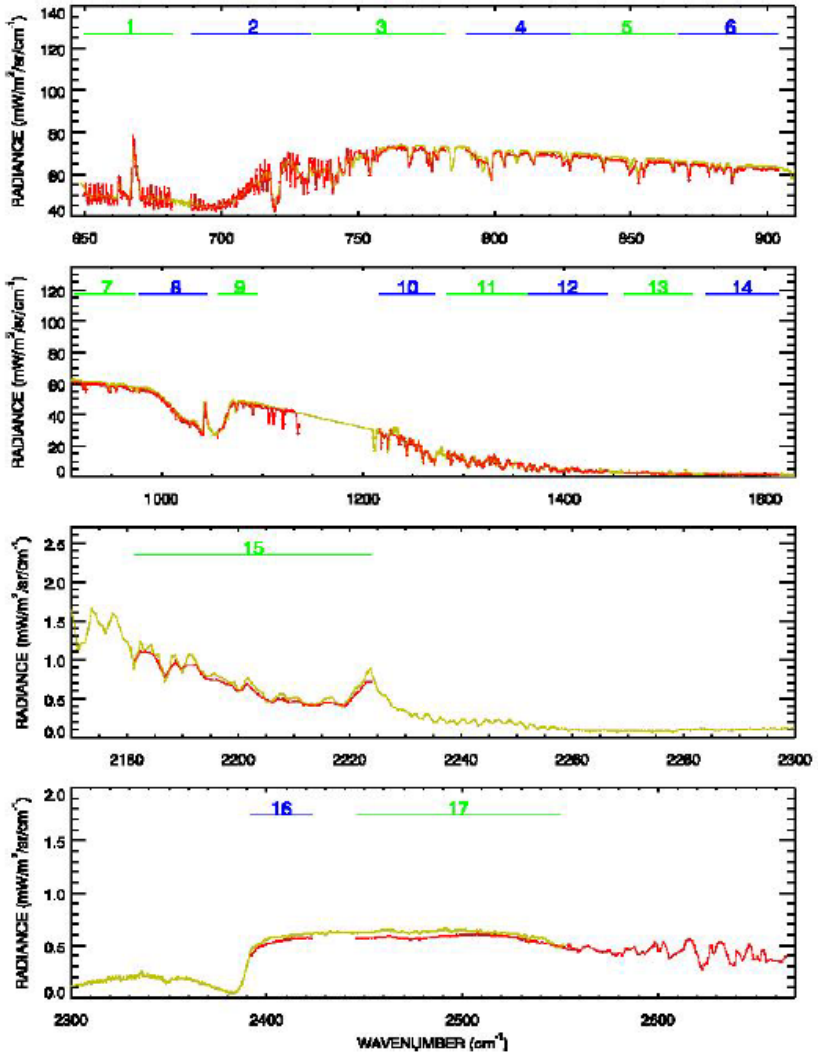
Primary Sensor Data:
1. CrIS apodized radiances of 2211 channels
2. View angles
3. Quality flags



Output data

1. Latitudes of each FOV
2. Longitudes of each FOV
3. UTC time as milliseconds from 1/1/1970
4. Satellite zenith angle for each FOV
5. Satellite height for each FOV
6. CrIS view angles for each FOV
7. Estimated CrIS OLR at TOA
8. CrIS OLR quality flag
9. CrIS OLR acceding/deced-ning indicator

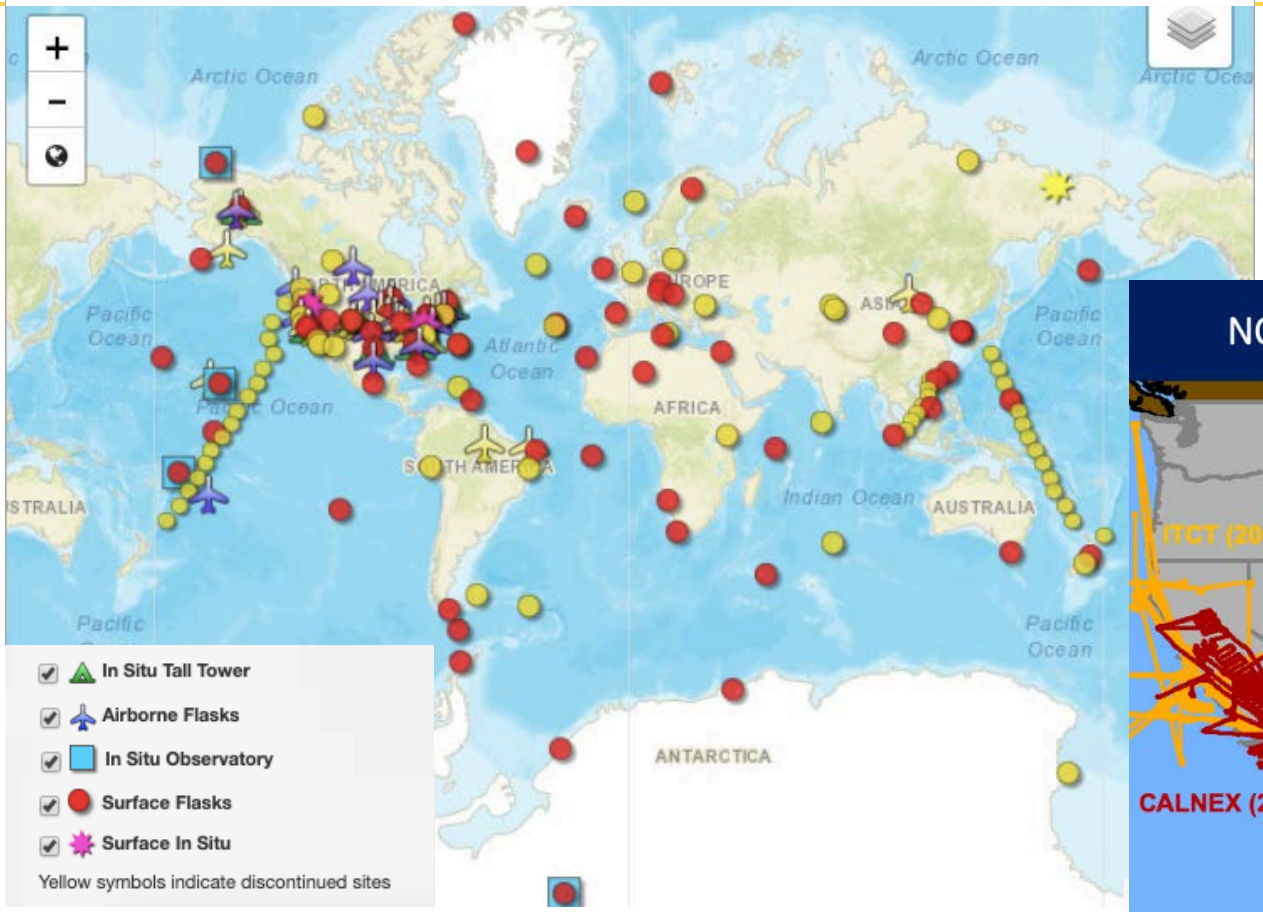
CrIS OLR Pseudo-Channels



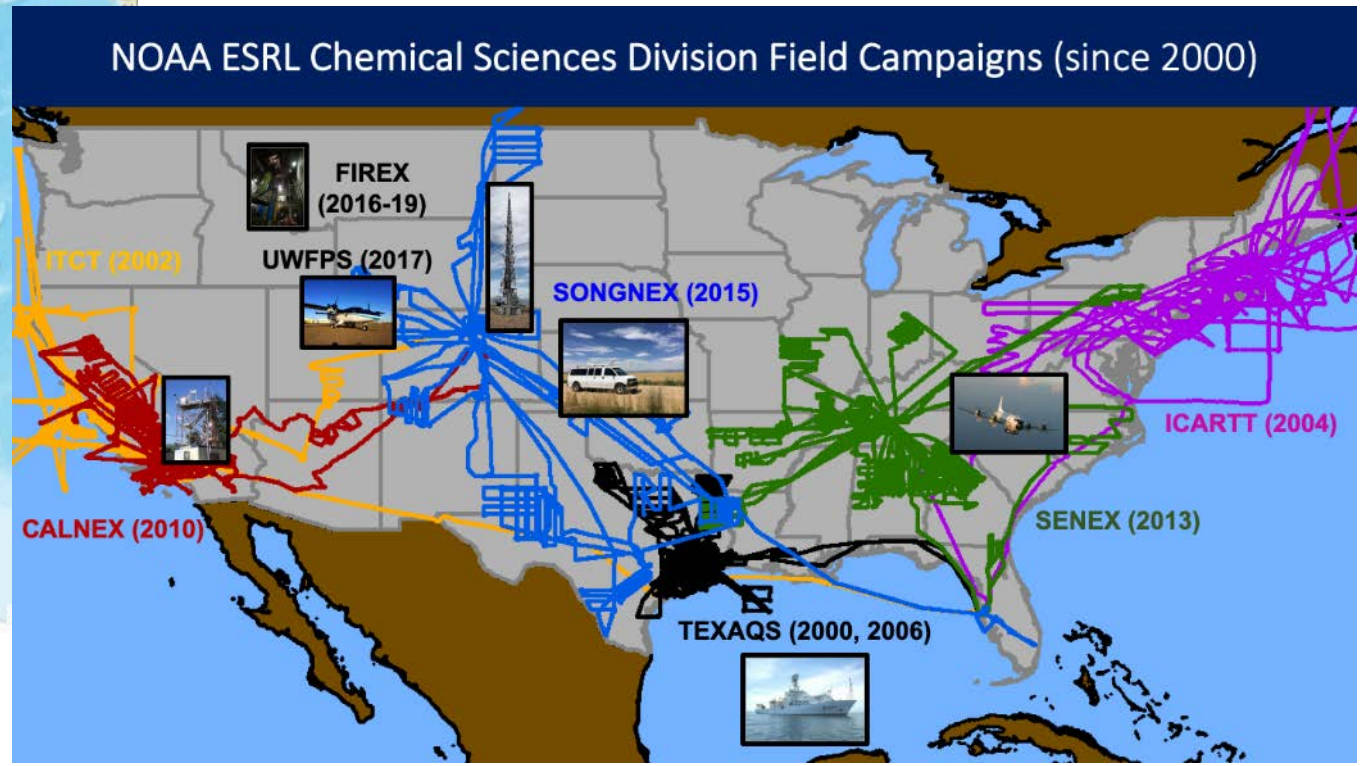
Pseudo channel range within simulated CrIS (yellow) AIRS (red) radiance spectra.

NOAA In-Situ Atmospheric Composition Observations

NOAA ESRL Global Monitoring Division Greenhouse Gas Reference Network

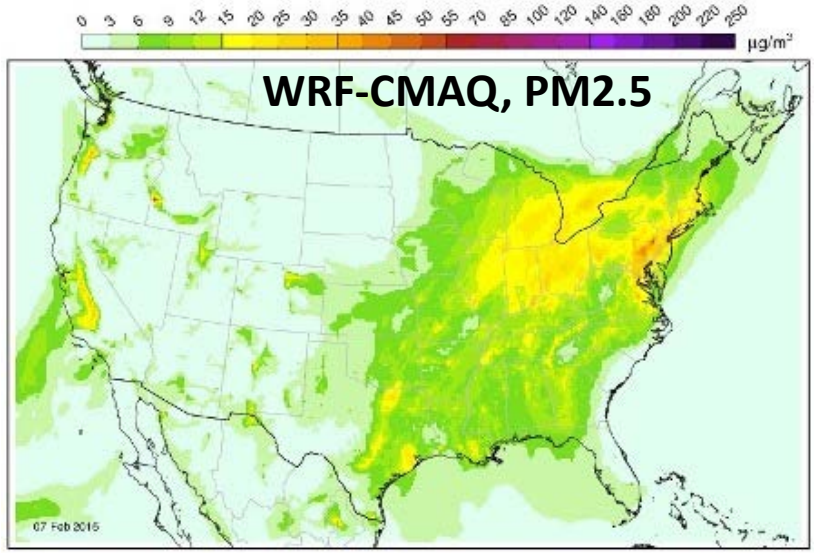


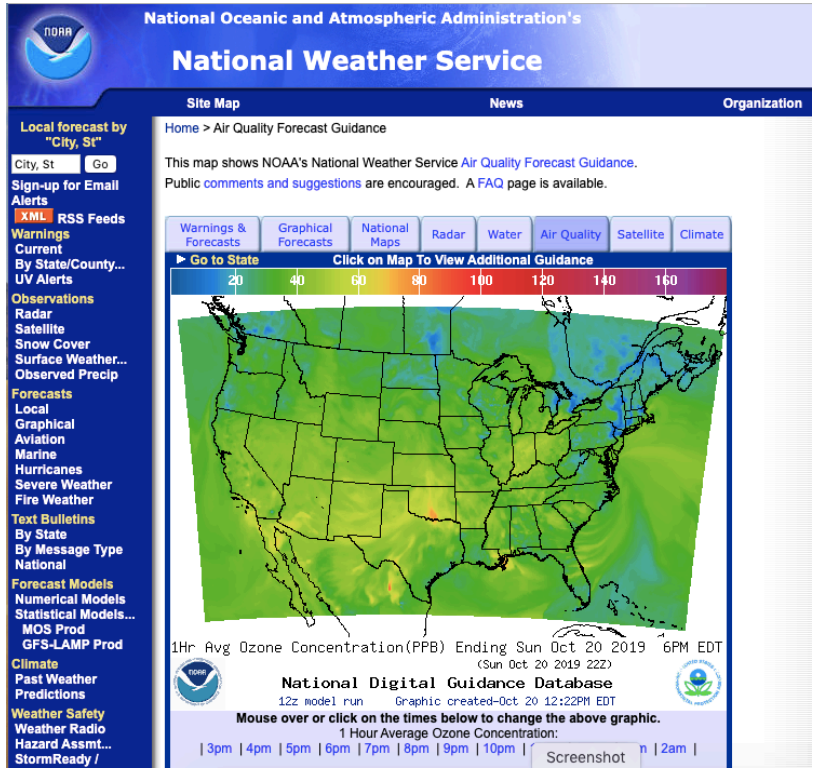
Long term monitoring network for climate change detection and climate model validation



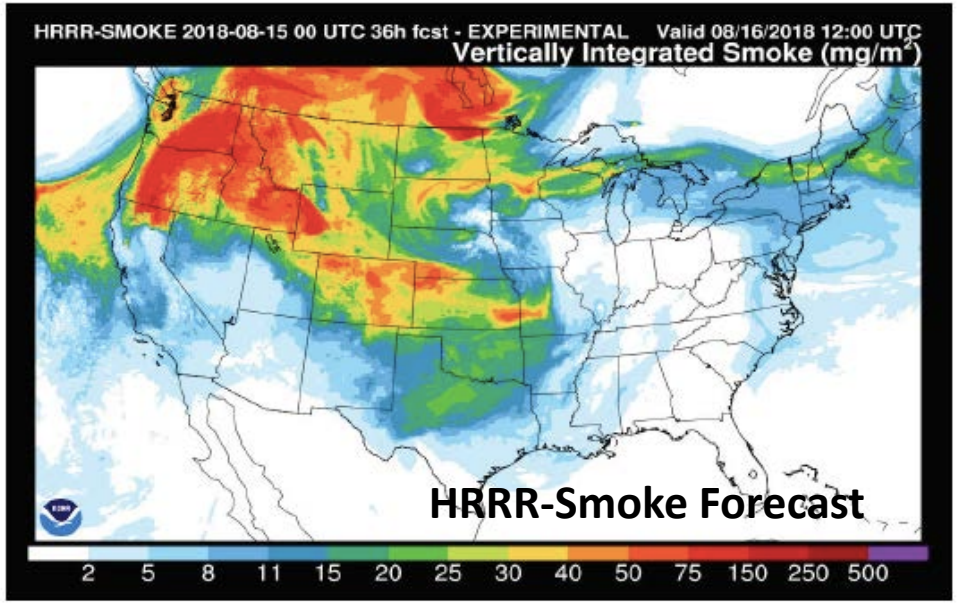
Targeted field observations for process-level understanding and air quality model validation

NOAA Air Quality Forecasting





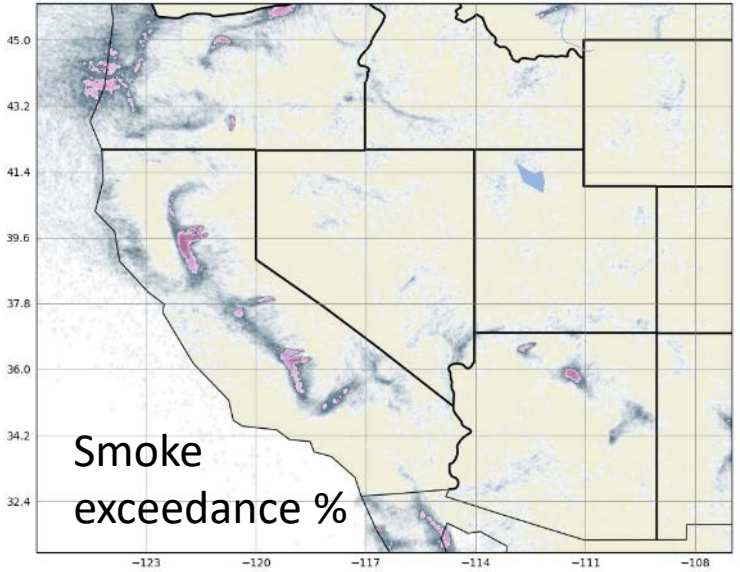
https://airquality.weather.gov/

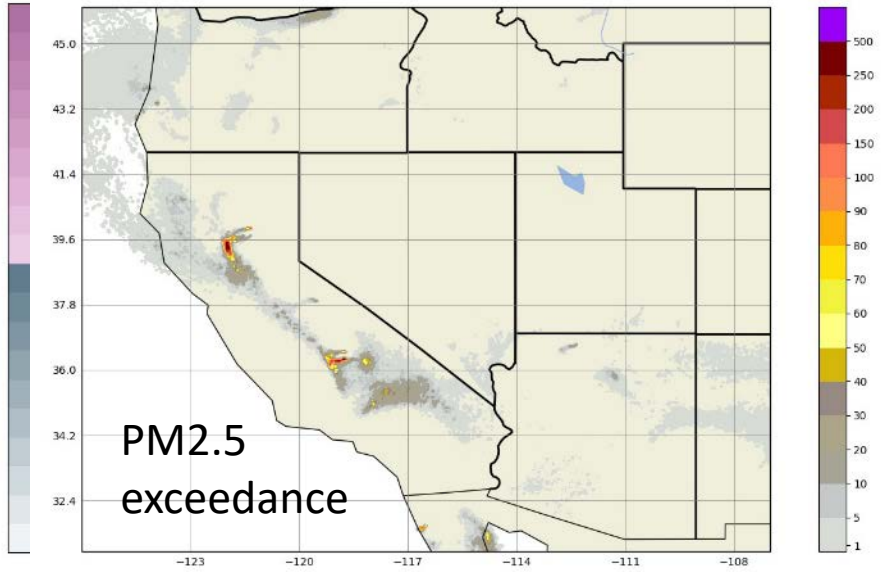


https://www.arl.noaa.gov/

https://esrl.noaa.gov/gsd

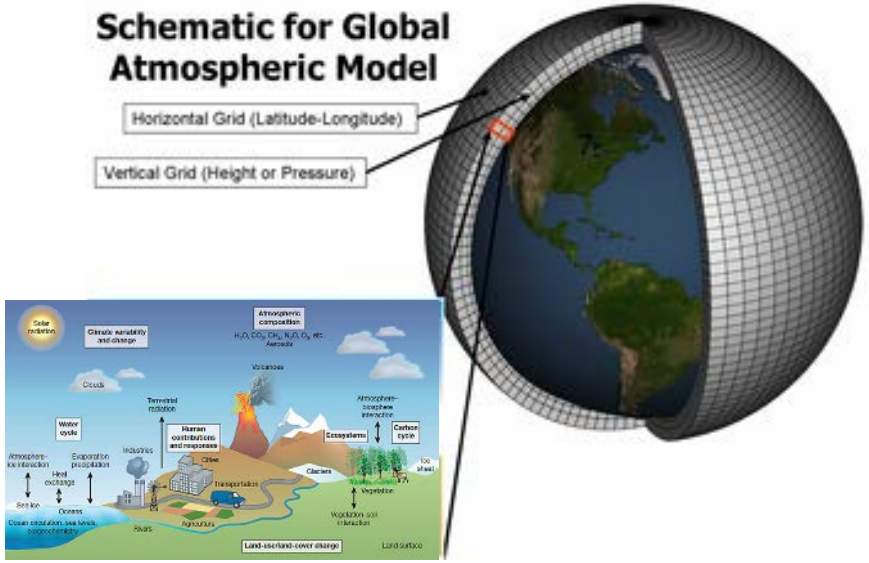
HYSPLIT Smoke Forecast

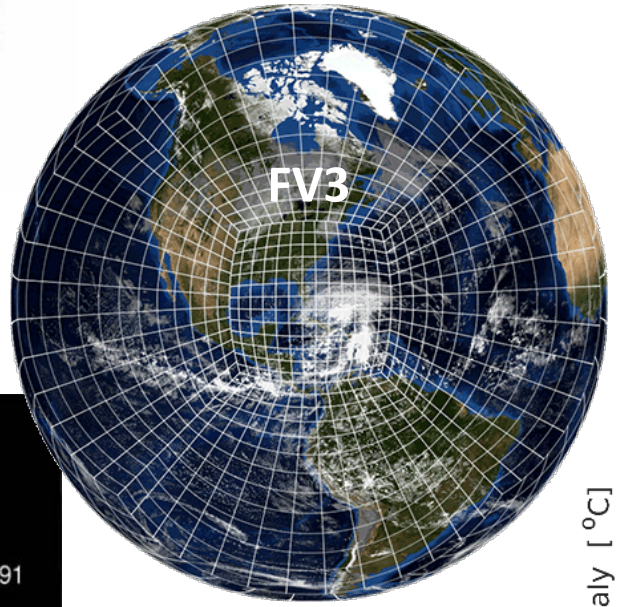


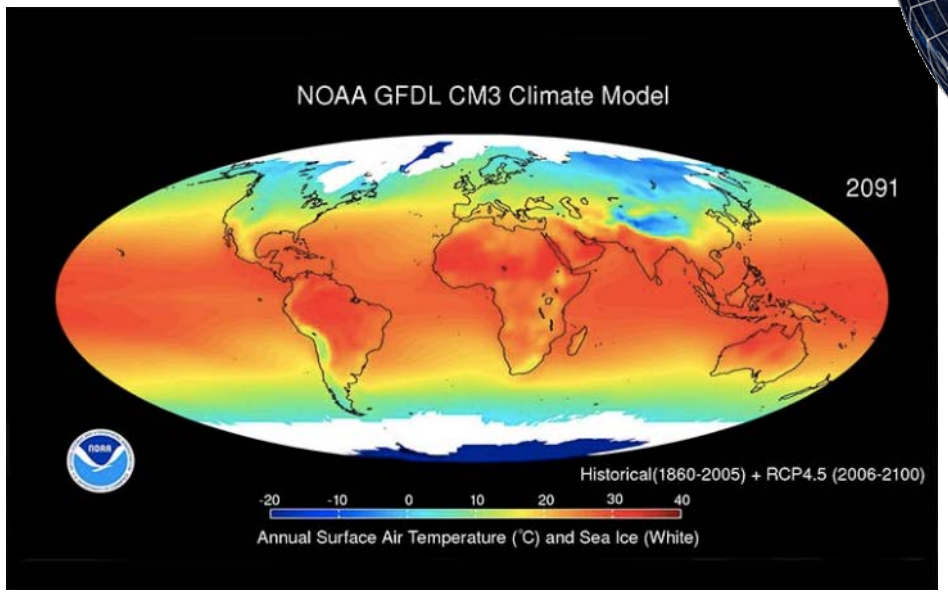


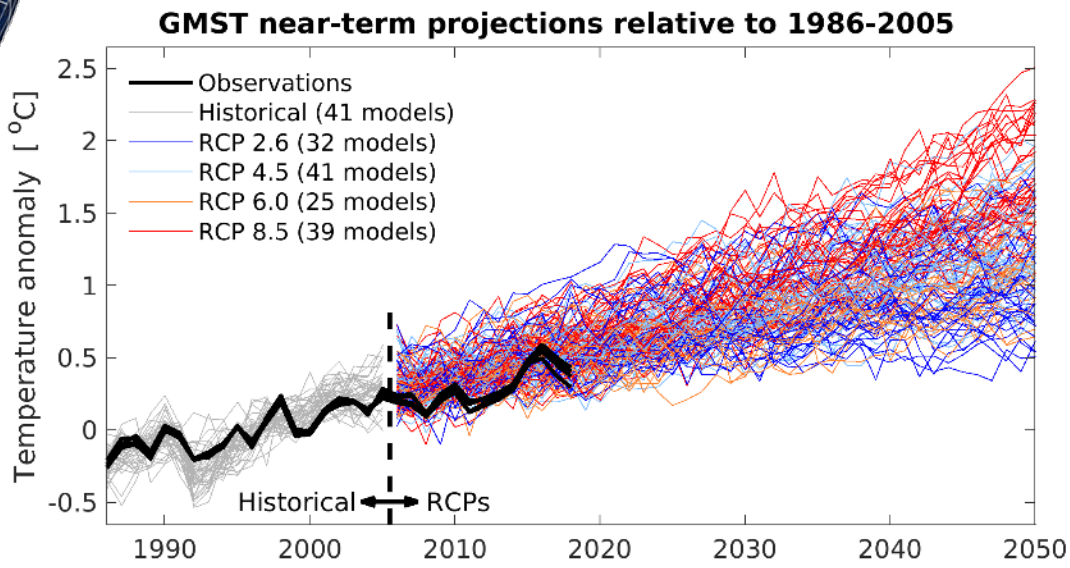
NOAA Climate Modeling

https://www.gfdl.noaa.gov/







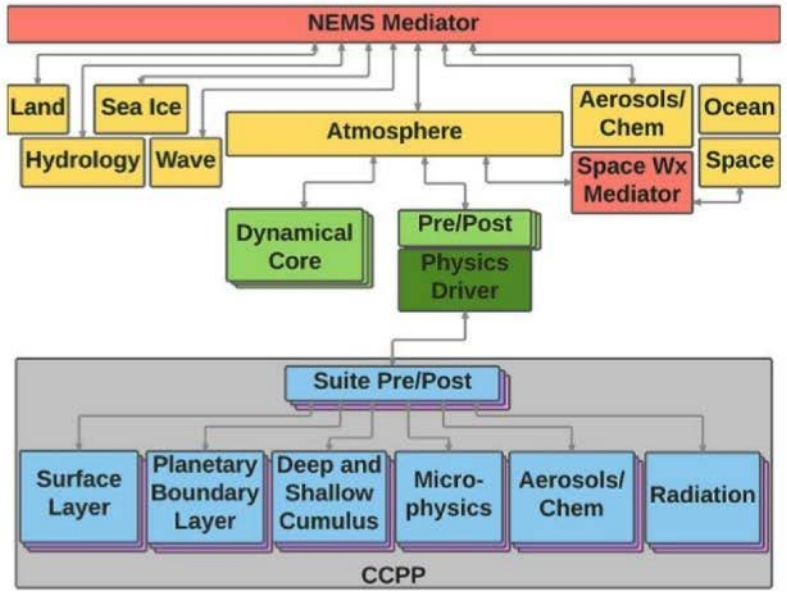


NOAA Unified Forecast System

Unified Forecast System for Operational Earth System Prediction (2018)

ESMF/NUOPC/NEMS architecture enables unified global and regional coupled modeling and DA

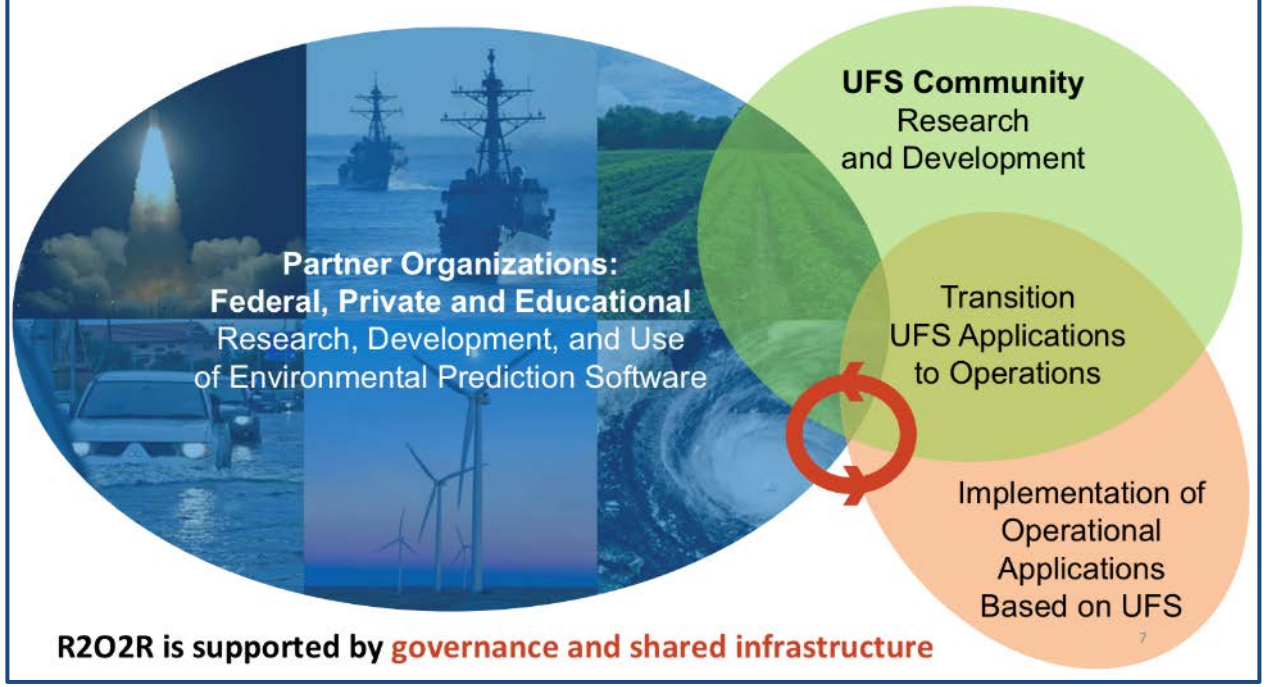
Consistent with broader community (CESM) and US National ESPC



Courtesy Developmental Testbed Center

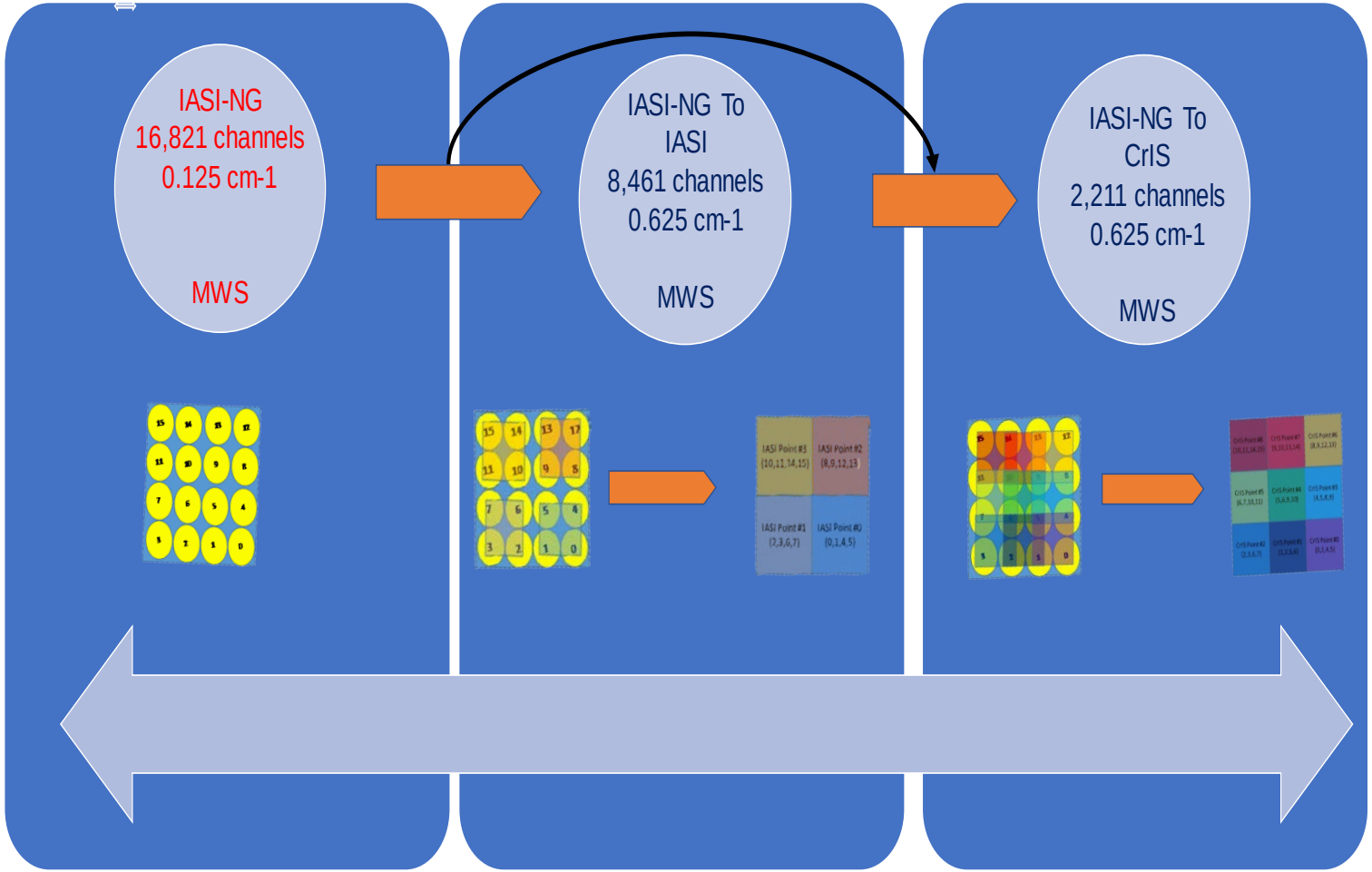
Community-Based Development

The Unified Forecast System (UFS) is a comprehensive, **community-based** Earth modeling system, designed as both a research tool and as the basis for NOAA's operational forecasts.

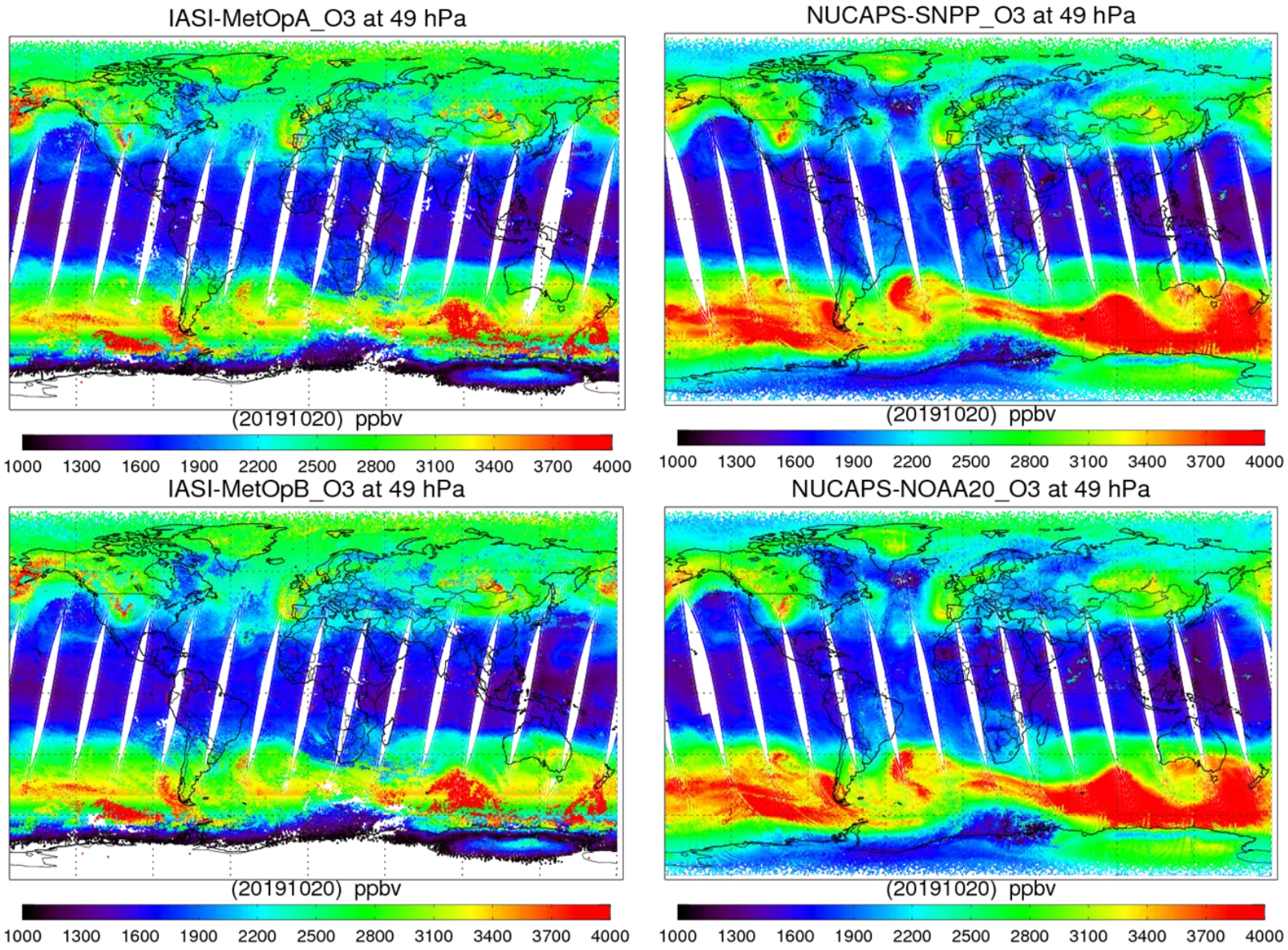


R2O2R is supported by governance and shared infrastructure

NUCAPS for IASI-NG - System Configuration Possibilities



Three System configurations are possible.

- Develop a system at IASI-NG native spectral channels and resolution with MWS
  - Huge amount of work
- Transform IASI-NG hyper spectral radiances to IASI, and derive Day-1 IASI-NG/IASI products.
  - Relatively easy adaptation from current IASI/AMSU-A/MHS system to IASI-NG (IASI)/MWS
  - Generate all NUCAPS products including netCDF/BUFR products
- Transform IASI-NG hyper spectral radiances to CrIS, and derive Day-1 IASI-NG/CrIS products.
  - Relatively easy adaptation from current CrIS/ATMS system to IASI-NG (CrIS)/MWS
  - Generate all NUCAPS products including netCDF/BUFR products

Enterprise Algorithm: NUCAPS IASI versus CrIS IR Ozone Profile