# 2018 JPSS Annual Meeting
# Sounding Session Opening Remarks

Chairs:
Antonia Gambacorta, Chris Grassotti, Larry Flynn

NCWCP August 28, 2018

# Topics of this session

## Part I: NUCAPS Session

Co-Chair: A. Gambacorta

1. Status of the NOAA Unique Combined Atmospheric Processing System (NUCAPS) – A. Gambacorta
2. Validation status of the NOAA Unique Combined Atmospheric Processing System (NUCAPS) - N. Nalli
3. How NUCAPS addresses the mesoscale challenge in now-casting applications – N. Smith

## Part II: MiRS Session

Co-Chair: C. Grassotti

1. Microwave Integrated Retrieval System: Scientific Activities, Milestones, Future Plans – C. Grassotti

## Part III: OMPS Session

Co-Chair: L. Flynn

1. NO2 and HCHO plans – P. Lee
2. Near Real Time Ozone EDR applications – C. Long
3. NOAA-20 OMPS ozone products – L. Flynn

# Status of the NOAA Unique Combined Atmospheric Processing System (NUCAPS)

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With contributions from:
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2018 JPSS Annual Meeting – NUCAPS Session

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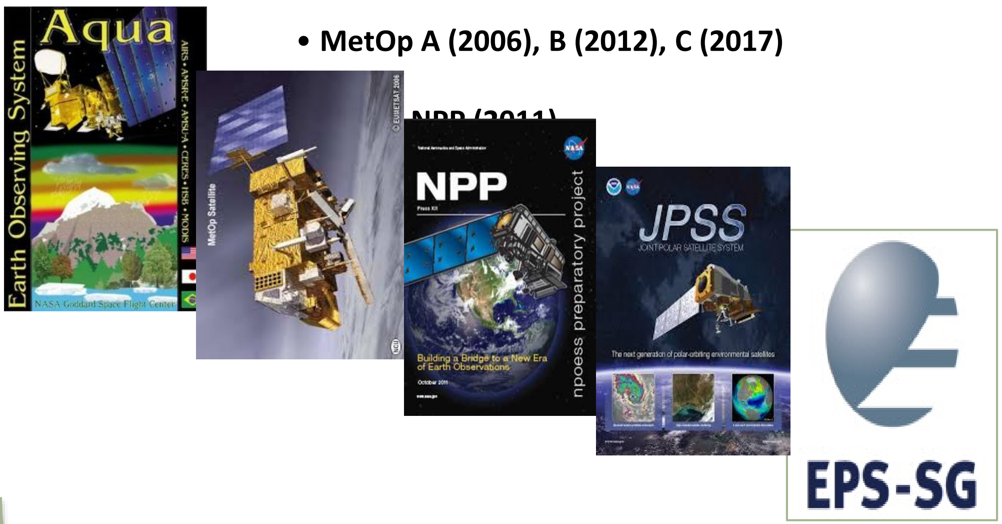
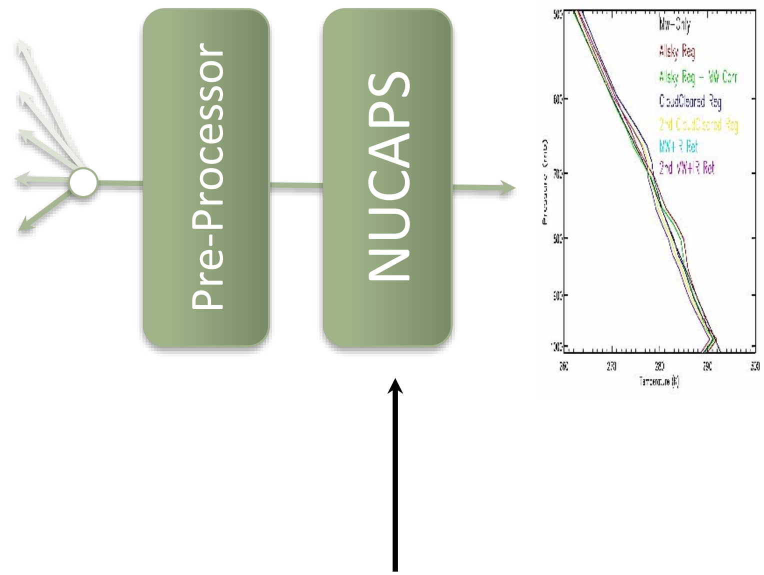
# Outline of this talk

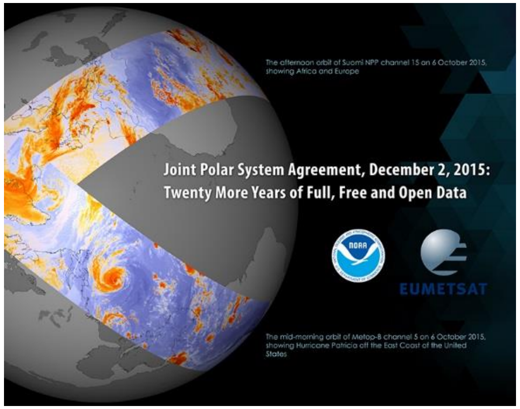
- Introduction to the NUCAPS system
- Overview of the past year's activities
- Current activities
- Future directions

# NOAA Long term strategy of hyperspectral sounding

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




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

# Summary of current NUCAPS retrieval products

| gas | Range ($cm^{-1}$) | Precision | d.o.f. | Interfering Gases |
|---|---|---|---|---|
| T | 650-800<br>2375-2395 | 1K/km | 6-10 | H2O,O3,N2O emissivity |
| $H_2O$ | 1200-1600 | 15% | 4-6 | CH4, HNO3 |
| $O_3$ | 1025-1050 | 10% | 1+ | H2O,emissivity |
| CO | 2080-2200 | 15% | ≈ 1 | H2O,N2O |
| $CH_4$ | 1250-1370 | 1.5% | ≈ 1 | H2O,HNO3,N2O |
| $CO_2$ | 680-795<br>2375-2395 | 0.5% | ≈ 1 | H2O,O3<br>T(p) |
| Volcanic $SO_2$ | 1340-1380 | 50% ?? | < 1 | H2O,HNO3 |
| $HNO_3$ | 860-920<br>1320-1330 | 50% ?? | < 1 | emissivity<br>H2O,CH4,N2O |
| $N_2O$ | 1250-1315<br>2180-2250 | 5% ?? | < 1 | H2O<br>H2O,CO |

http://www.class.ngdc.noaa.gov

# Status of NUCAPS

Validated maturity status:

- ✓ SNPP NUCAPS Temperature, water vapor, ozone, OLR

Provisional maturity status:

- ✓ SNPP NUCAPS carbon trace gases
- ✓ NOAA-20 NUCAPS Temperature and water vapor

Beta maturity status:

- ✓ NOAA-20 NUCAPS OLR, ozone, carbon trace gases

# One year has gone by…

**August 7th, 2018**
NUCAPS MetOp goes live in CSPP

**June 22nd, 2018**
Updated Enterprise NUCAPS Delivery of Algorithm Package (DAP) to ASSISTT
NUCAPS Enterprise algorithm delivery to UW for implementation in CSPP

**June 15th, 2018**
NUCAPS NOAA-20 Temperature and Water Vapor Provisional Maturity review

**April 27th, 2018**
First NOAA-20 NUCAPS Delivery of Algorithm Package (DAP) to ASSISTT

**April 4th, 2018**
Implementation of NUCAPS Enterprise Algorithm (SNPP, NOAA-20, MetOp) in the HEAP

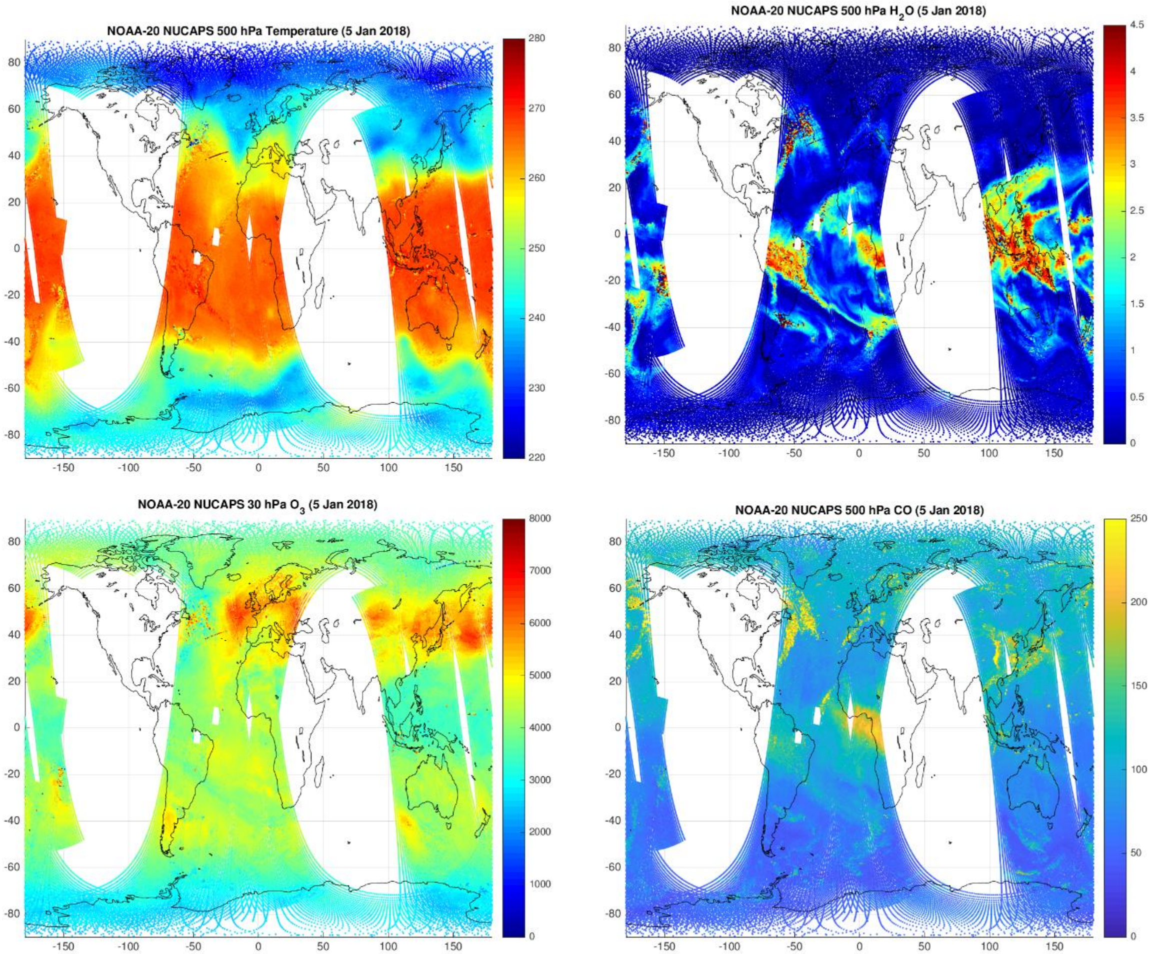
**January 5th, 2018**
NUCAPS NOAA-20 first Light results

**August 31st, 2017**
NUCAPS Phase 4 delivered to UW for implementation in CSPP

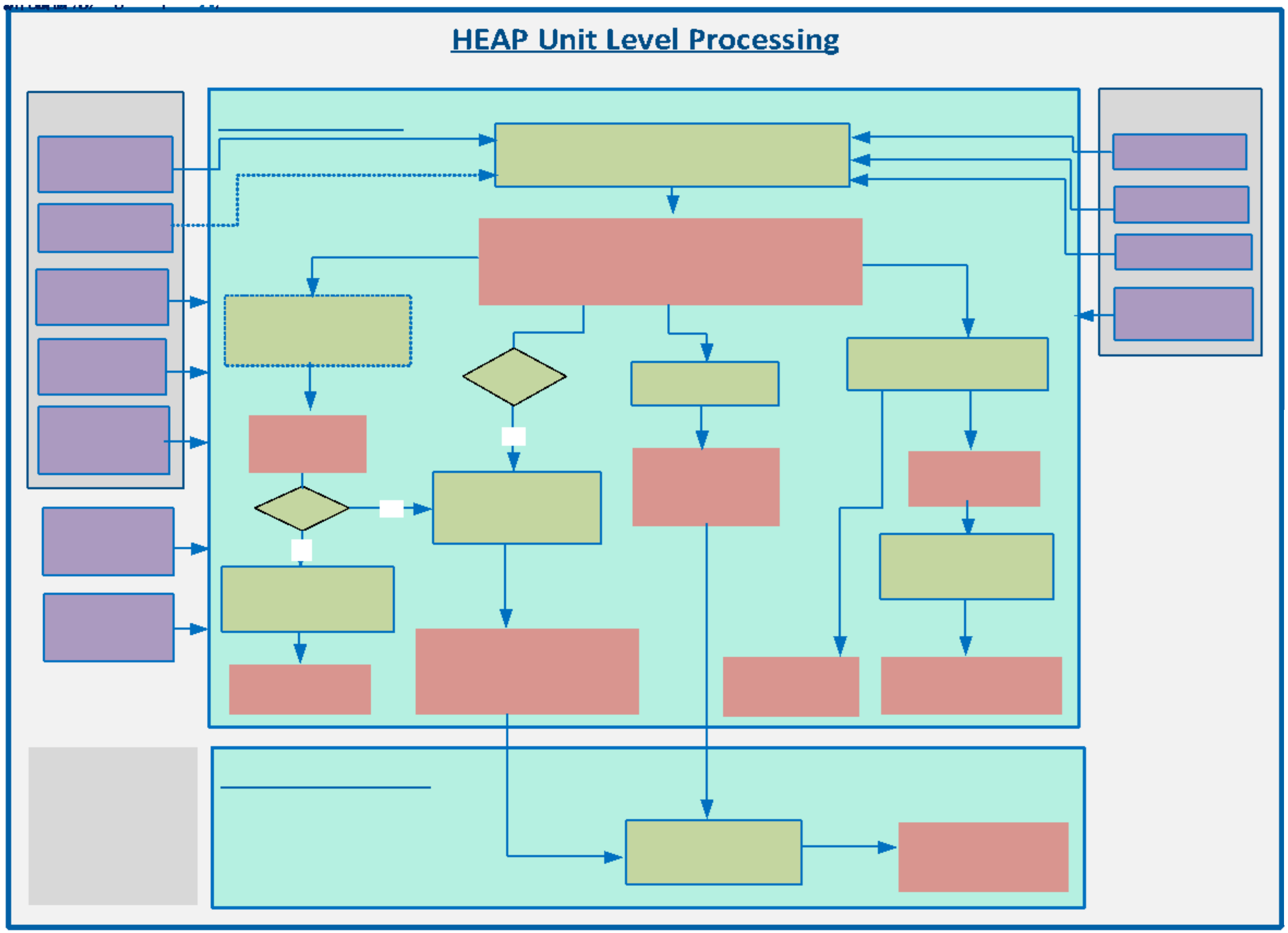
**July 7th, 2017**
NUCAPS Phase 4 Algorithm Readiness Review
NUCAPS Phase 4 Delivery of Algorithm Package (DAP) to ASSISTT

# January 5$^{th}$, 2018:
# NUCAPS NOAA-20 First Light Results

CrIS signal processors and detectors powered up on **January 4$^{th}$, 2018 at 23:47 UTC**.
First Light NUCAPS NOAA-20 results were generated on **January 5$^{th}$, at 21:00 UTC**.



# April 4th, 2018: NUCAPS is implemented in the Hyperspectral Enterprise Algorithm Package (HEAP)

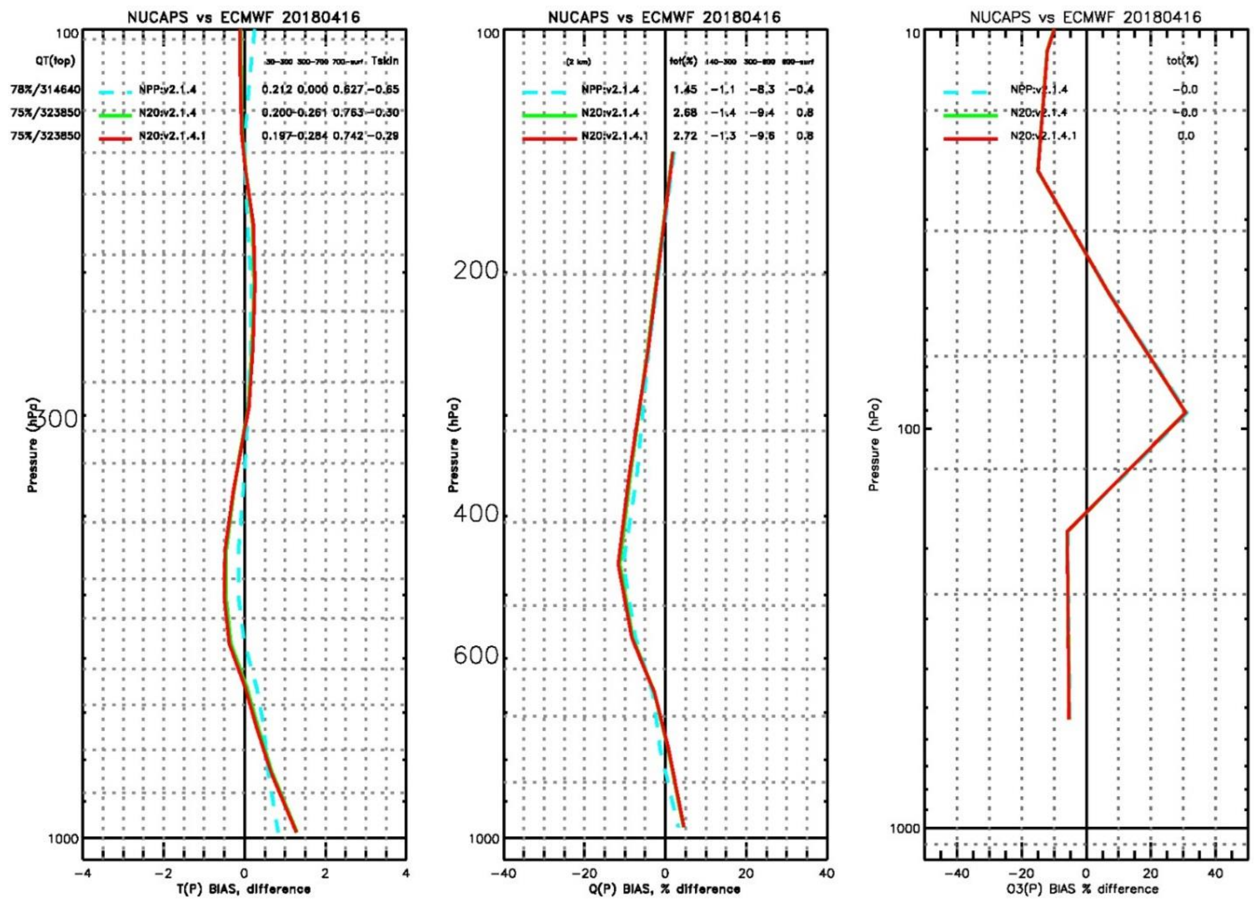



M. Wilson's Poster No. 61

# April 27th, 2018 -NUCAPS NOAA-20 Preliminary DAP
# June 15th, 2018 – NUCAPS NOAA-20 Provisional Maturity Review

**SNPP Operational**
**First Light NOAA-20 (5th Jan. 2018)**
**NOAA20 DAP (27th Apr. 2018)**

First global, multi focus days statistics results showing SNPP and NOAA-20 NUCAPS temperature (left), water vapor (center), ozone (right) remarkably consistent **since first light**, qualifying NOAA-20 NUCAPS temperature, water vapor and ozone for preliminary DAP to ASSISTT and reaching provisional maturity status.



# Improvements since last operational delivery approved by NUCAPS Phase 4 Algorithm Readiness Review (July 2017)

**NUCAPS Version 2.1.12d (June 2018):**

✓NOAA-20 CrIS and ATMS instrument noise files.

✓Optimized temperature, water vapor, cloud clearing and carbon monoxide channel selection.

✓An improved RTA bias correction in the carbon monoxide band.

✓An improved carbon monoxide a priori climatology.

✓An improved carbon monoxide quality control methodology.

**Work in progress towards NUCAPS validated maturity status:**

… improve methane, nitrous oxide and carbon dioxide retrieval modules.

… improve training methodology of statistical regression by removing cloud contamination and supersaturation cases.

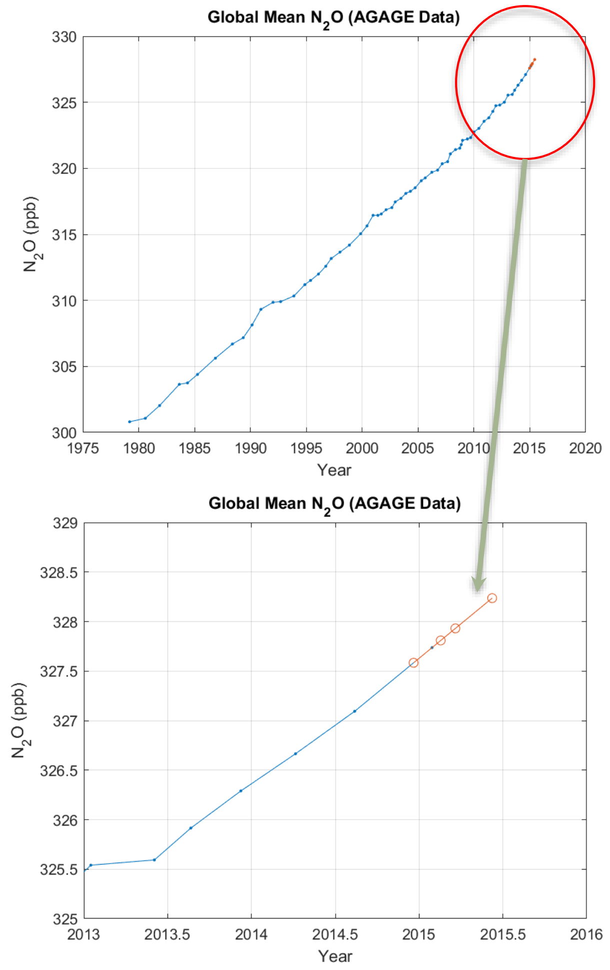
… improve surface emissivity regression algorithm.

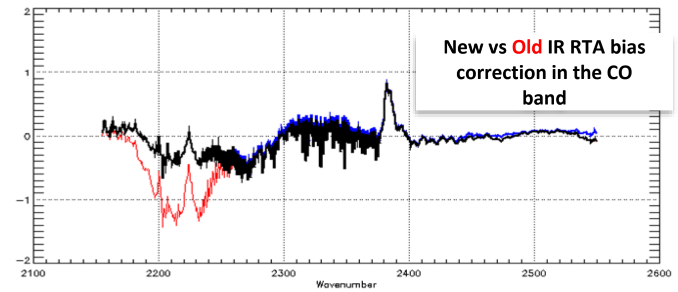
# Towards NUCAPS validated maturity: what's needed?

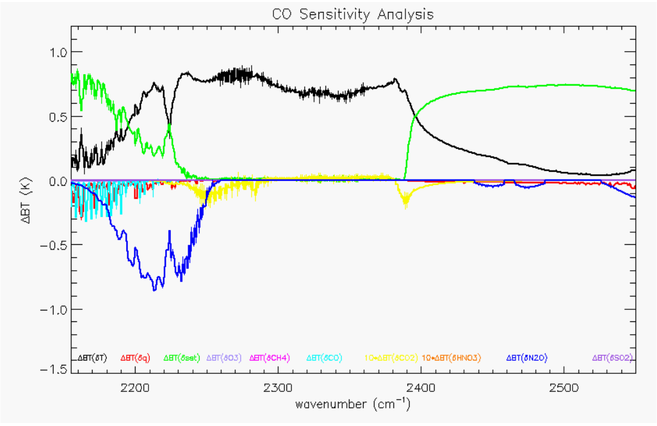
- Inter-consistency of NUCAPS SNPP, NOAA-20 (and MetOp): no requirement specified but inter-consistency is key to several applications of NUCAPS products
  - NUCAPS is in AWIPS and RealEarth: diurnal variability for regional weather forecasting
  - NUCAPS is in IDEA-I: diurnal transport and variability of species for air quality monitoring
  - NUCAPS data record is being reprocessed
  - NUCAPS is in several DA experiments (CO, CH4, CO2, SAL)

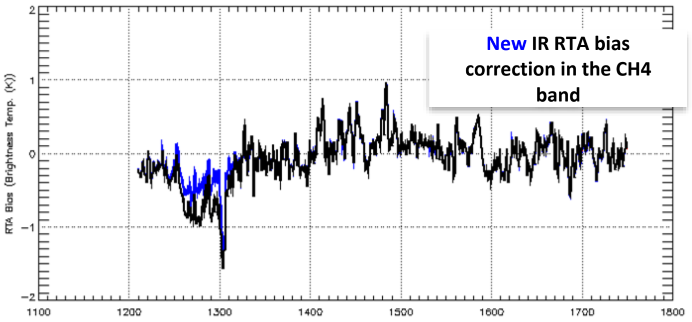
- We have built a robust framework, the HEAP, to provide consistency in the processing (same machine, same executable)
- We employ the same underlying spectroscopy, forward model and LUT methodologies to provide consistency in the scientific retrieval code
- We need very well inter-calibrated SDRs to fulfill NUCAPS mandate: NOAA's operational enterprise algorithm for hyper spectral sounding.
- **Next step**: fine tuning of the NOAA-20 CrIS and ATMS related LUTs.

# A game changer:
# NUCAPS *version 2.1.12d* Carbon Monoxide

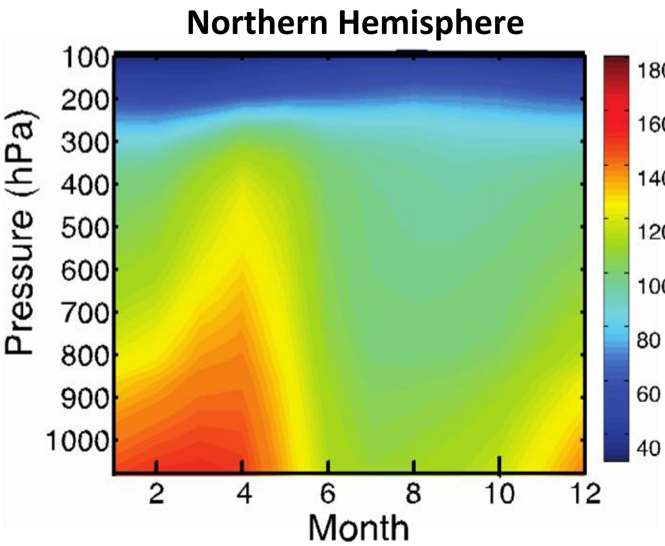


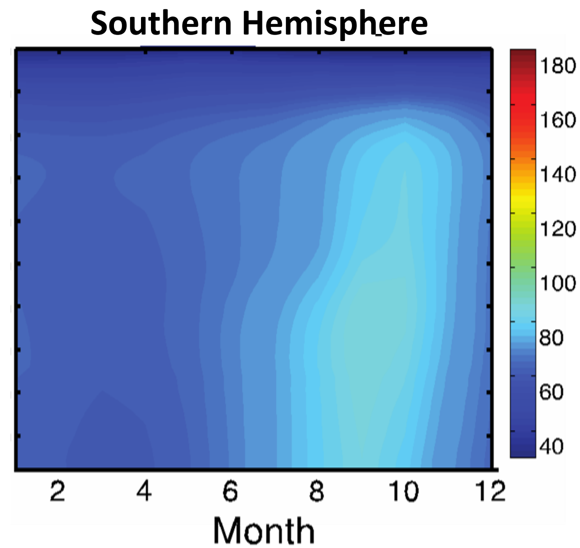



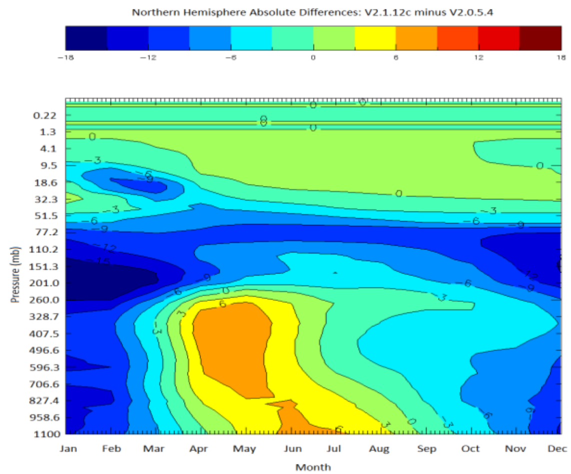



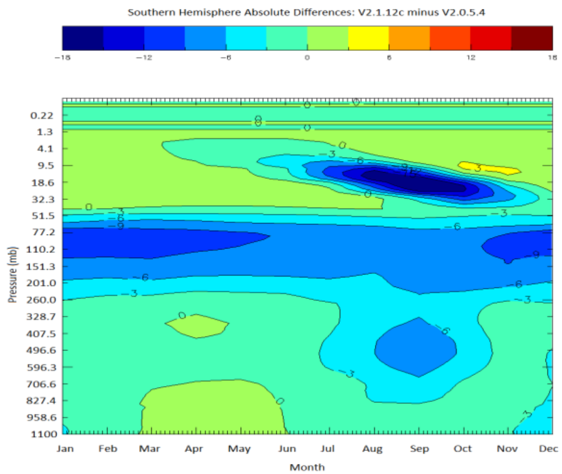



# A game changer:
# NUCAPS *version 2.1.12d* Carbon Monoxide (cont'd)




**Top**

NUCAPS 2.1.12d new CO A priori (ppbv) developed from NCAR MOZART-GEOS5 model

Linear transition between 15N and 15S;

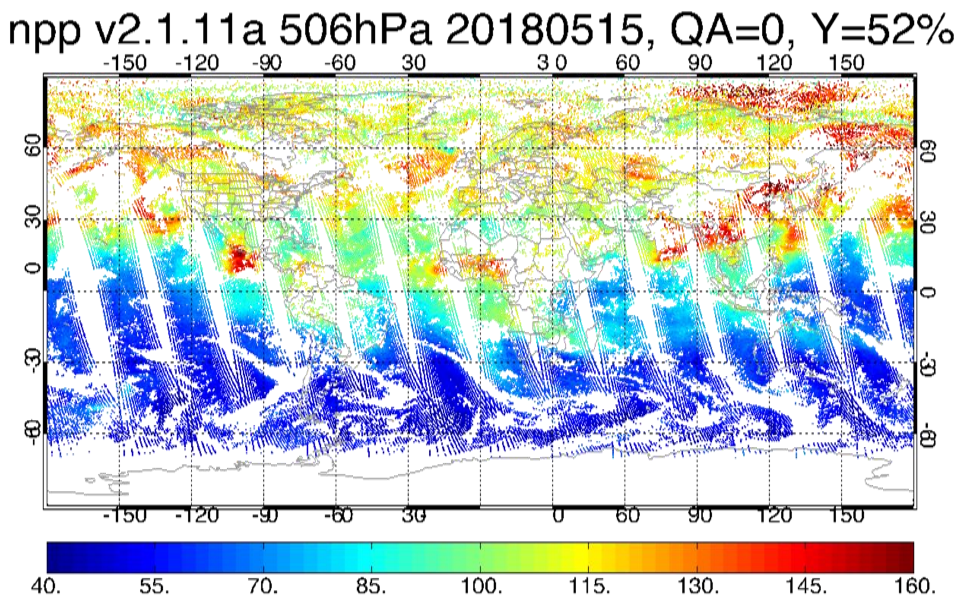
Monthly varying, but no year-to-year variations;

Same approach as for previous version, but using a more updated time period.

**Bottom**

NUCAPS New - Old CO A priori

# A game changer:
# NUCAPS *version 2.1.12d* Carbon Monoxide (cont'd)




| Module | Lower Limit | Upper Limit |
|---|---|---|
| Chi-square | 0.0 | 1.0 |
| DOFS | 0.3 | 9.9 |
| CO Retrievals | 0.0 | 1.1 |
| Cloud Amplifier Limit | 0.3 | 1.8 |
| Cloud-clearing residual | 0.0 | 0.7 |
| Number of iteration | 0.0 | 5.0 |
| Total cloud fraction | 0.0 | 0.7 |

NUCAPS 2.1.12d new CO QC reduces cloud contamination, but yield is penalized

# Significance to users applications

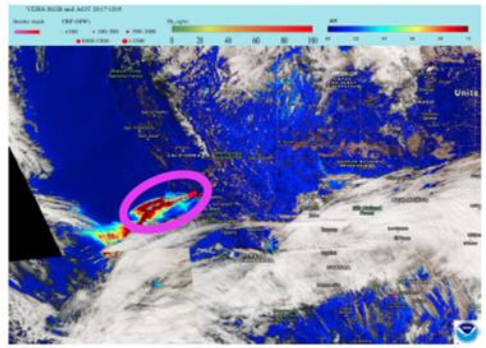
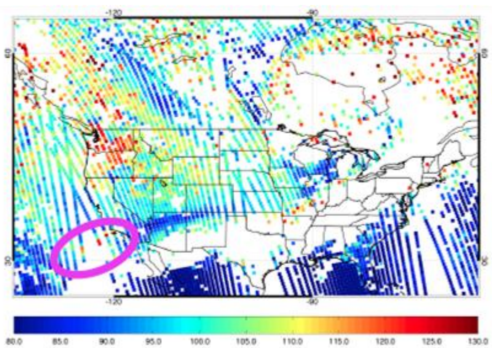
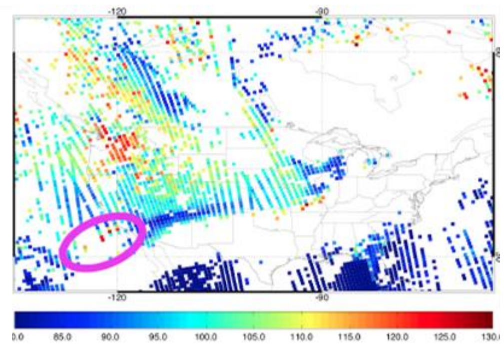


Figure courtesy of Shobha Kondragunta

NUCAPS Version 2.0.5.4





NUCAPS Version 2.1.12d

**CA Thomas Fire, Dec. 5th, 2017**

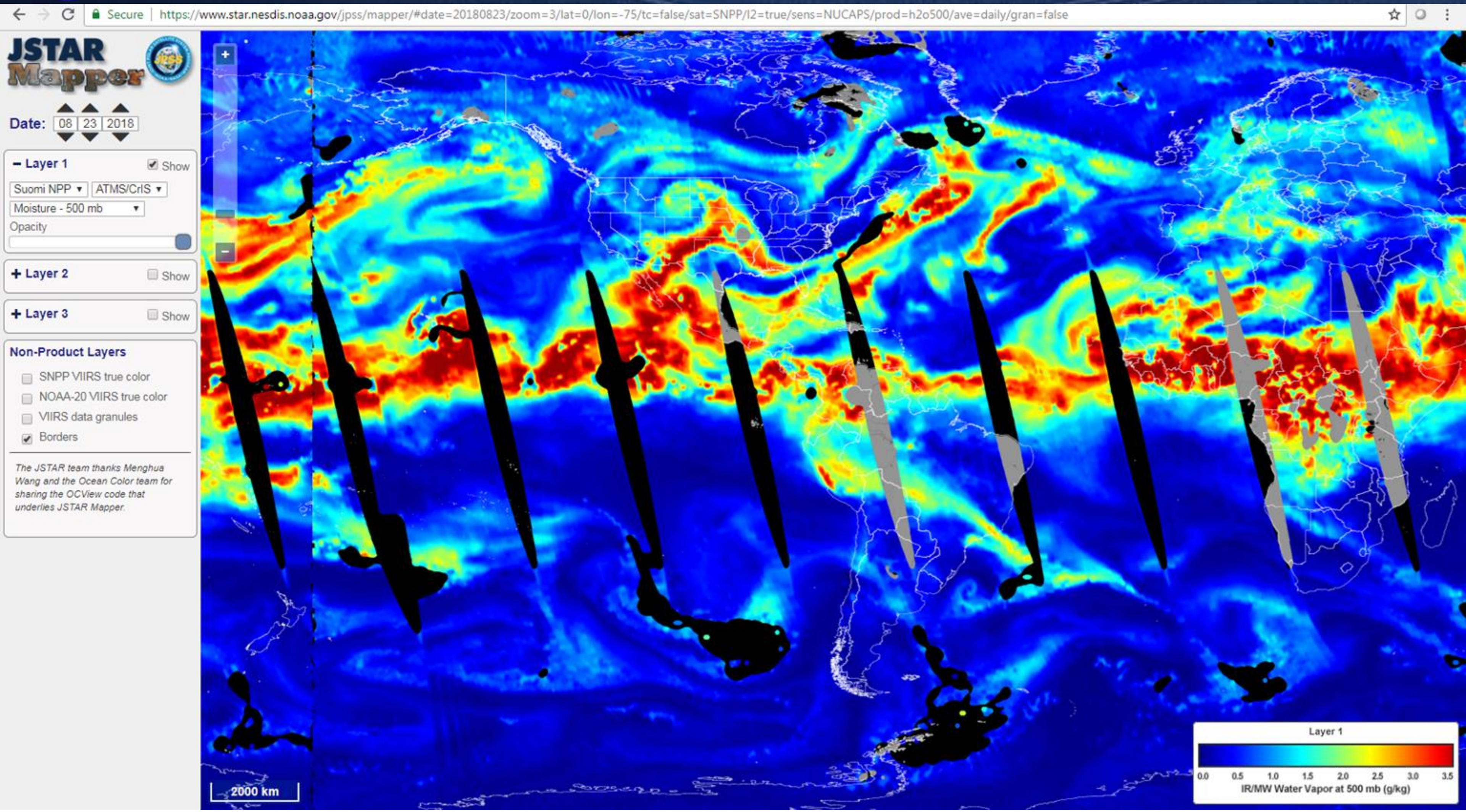
- CO chn selection and tailored QC remove spurious spikes in CO due to poor cloud clearing while preserving the real signal of interest
- CO new a priori and forward model bias correction remove consistent bias observed in previous version (see next talk by Nick Nalli).

# Coming next…

- MetOp C, J2, EPS-SG activities are on the way
- NUCAPS validated maturity review: September 2019

| | S-NPP | JPSS-1 | JPSS-2 |
|---|---|---|---|
| FY18 | CO, CO2, and CH4 products validation | algorithm tuning for J1/SNPP CO, CO2, and CH4 products | |
| FY19 | Maintenance and monitoring | SNPP and J1 EDRs comparisons; AVTP, AVMP, O3, and OLR validation | |
| FY20 | Maintenance and monitoring | CO, CO2, CH4 validation | |
| FY21 | Maintenance and monitoring | Algorithm implementation for new trace gases: ammonia ($NH_3$) | algorithm preparation for AVTP, AVMP, O3, OLR, CO, CO2, CH4 |
| FY22 | Maintenance and monitoring | Maintenance and monitoring | algorithm optimization for AVTP, AVMP, O3, OLR, CO, CO2, CH4 |

# Where to find us




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

# Validation of the SNPP and NOAA-20 NOAA Unique Combined Atmospheric Processing System (NUCAPS)

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**2018 STAR JPSS Annual Meeting**
College Park, Maryland, USA
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# Acknowledgments


- **Sounder EDR Validation Dataset collection**
  - **U.S. DOE Atmospheric Radiation Measurement (ARM) program dedicated RAOBs**
    - *D. Holdridge* and *J. Mather* (ARM Climate Research Facility)
  - **NOAA AEROSE:** *Veronon Morris, E. Joseph, M. Oyola, E. Roper* (HU/NCAS); *P. J. Minnett* (UM/RSMAS); *D. Wolfe* (NOAA/ESRL)
  - **CalWater/ACAPEX:** *R. Spackman* (NASA); *R. Leung* (PNNL); *C. Fairall, J. Intrieri* (NOAA)**;** *N. Hickmon, M. Ritsche*, and ARM Mobile Facility 2 (AMF2)
  - **Beltsville Site:** *R. Sakai, Siwei Li* (HU/NCAS)
  - **GRUAN Lead Center:** *Ruud Dirksen*
  - **World Ozone and Ultraviolet Radiation Data Centre (WOUDC)** data contributors (DWD-GRUAN, & INPE, & KNMI, & NASA-WFF, & SMNA. http://www.woudc.org
  - **SHADOZ: Southern Hemisphere Additional Ozonesondes** (*A. Thompson* et al.)
  - **Carbon Trace Gases:** *Monika Kopacz (NOAA/UCAR), Greg Frost (NOAA/ESRL)*
  - **NASA Sounder Science Team:** *E. Olsen, T. Pagano, E. Fetzer (NASA/JPL)*
  - **Total Carbon Column Observing Network (TCCON)** (*D. Wunch et al.*), TCCON Data Archive, hosted by the Carbon Dioxide Information Analysis Center (CDIAC), tccon.onrl.gov
  - **Atmospheric Tomography (ATom) Mission:** *Kathryn McCain*, *Colm Sweeney (NOAA/ESRL),* https://doi.org/10.3334/ORNLDAAC/1581

- The **NOAA Joint Polar Satellite System (JPSS-STAR) Office** (*M. D. Goldberg, et al.*) and the NOAA/STAR Satellite Meteorology and Climatology Division.

- **SNPP sounder validation effort (past and present)**: *C. D. Barnet* (STC); *A.K. Sharma, M. Pettey, C. Brown, Q. Liu, M. Divakarla, W. W. Wolf* (STAR); *R. O. Knuteson, D. Tobin* (UW/CIMSS)

# Outline

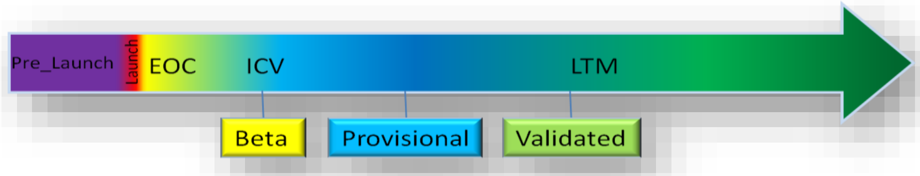
- **JPSS Sounder EDR Cal/Val Overview**
  - JPSS Level 1 Requirements
  - Validation Hierarchy recap
  - NUCAPS Algorithm
    - Overview of Recent Upgrades
- **NUCAPS Validation Status**
  - NUCAPS NOAA-20 Status
    - T/H2O/O3 EDRs versus ECMWF
  - NUCAPS Carbon Trace Gas Status (SNPP)
    - CO, CH4, CO2 versus ATom

NUCAPS Validation

# JPSS SOUNDER EDR CAL/VAL OVERVIEW

# JPSS Program Cal/Val

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




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

- The **JPSS-1 (NOAA-20) sounder EDR Cal/Val Plan** (v1.1) was completed in Dec 2015
  - Although the Cal/Val Plan included validation of carbon trace gas EDRs (CO, $CH_4$ and $CO_2$), the details had not been completely mapped out at that time.

# 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 for sanity checks, bias tuning and regression
   - Limitation: Not independent truth data
2. **Satellite Sounder EDR (e.g., AIRS, ATOVS, COSMIC) *Intercomparisons***
   - Global samples acquired from Focus Days (e.g., AIRS)
   - Limitation: Similar error characteristics
3. **Conventional PTU/O3 Sonde Matchup *Assessments***
   - WMO/GTS operational sondes or O3-sonde network (e.g., SHADOZ)
   - Representation of global zones, long-term monitoring
   - Large samples after a couple months (e.g., *Divakarla et al.,* 2006; *Reale et al.* 2012)
   - Limitations: Skewed 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
   - 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: NOAA CarbonTracker (*Lan et al.* 2017), ECMWF, NCEP/GFS
   - 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**, **ACT-America**, **FIREX**

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

| **CrIS/ATMS Atmospheric Vertical Temperature Profile (AVTP)**<br>**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 |

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

**“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)*

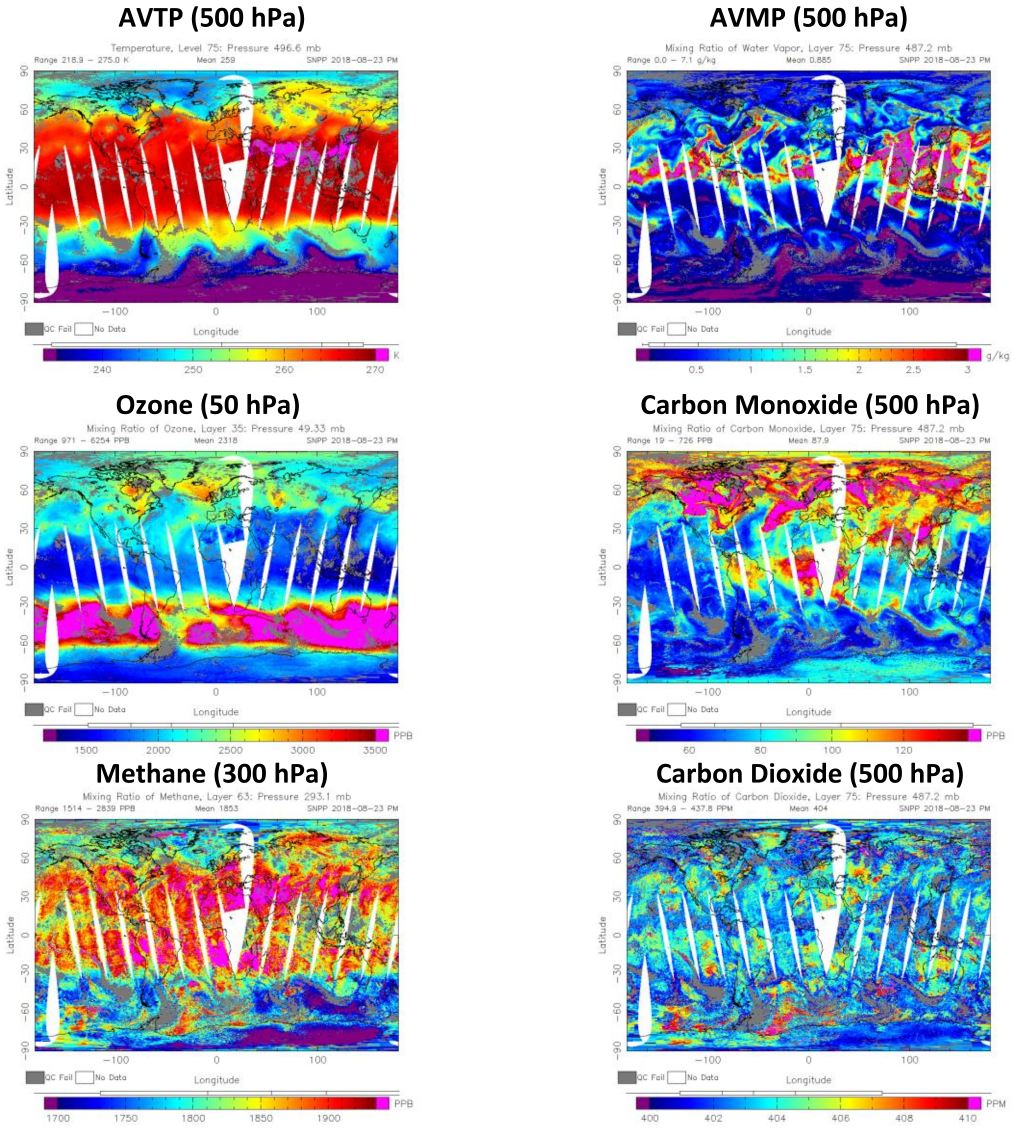
# JPSS Specification Performance Requirements
# CrIS Trace Gas EDR Uncertainty ($O_3$, CO, $CO_2$, $CH_4$)

| CrIS Infrared Trace Gases<br>Specification Performance Requirements | | |
|---|---|---|
| PARAMETER | THRESHOLD | OBJECTIVE |
| $O_3$ **(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% |
| **CO (Carbon Monoxide)** Total Column Precision | 35%, or full res mode 15% | 3% |
| **CO (Carbon Monoxide)** Total Column Accuracy | ±25%, or full res mode ±5% | ±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)*

# NOAA Unique Combined Atmospheric Processing System (NUCAPS) Algorithm

- **Operational algorithm**
  - **NOAA Enterprise Algorithm** for CrIS/IASI/AIRS (*Susskind, Barnet and Blaisdell,* IEEE 2003; *Gambacorta et al.,* 2014)
  - Global non-precipitating conditions
  - **Atmospheric Vertical Temperature** and **Moisture Profiles** (**AVTP**, **AVMP**)
  - **Trace gases: $O_3$, CO, $CO_2$, $CH_4$**
- **Users**
  - **Weather Forecast Offices (AWIPS)**
    - Nowcasting / severe weather
    - Alaska (cold core)
  - NOAA/CPC (OLR)
  - **NOAA/ARL** (IR ozone, trace gases)
  - **NOAA TOAST** product (IR ozone EDR)
  - Basic and applied science research (e.g., *Pagano et al.,* 2014)




https://www.star.nesdis.noaa.gov/jpss/EDRs/products_Soundings_2018.php
http://www.ospo.noaa.gov/Products/atmosphere/soundings/nucaps/index.html

# NUCAPS Development and Offline Versioning

- **Version 1 (CrIS NSR)**
  - **V1.5**
    - **Operational system beginning in September 2013**
    - Ran on **CrIS nominal spectral-resolution (NSR)**
    - **Validated Maturity** for AVTP/AVMP EDR attained Sep 2014
  - V1.8 to V1.9
    - Preliminary offline experimental algorithms in preparation for CrIS full-spectral (FSR) resolution data
    - *Ad hoc* CrIS full-resolution radiative transfer algorithm (RTA) and bias correction coefficients
- **Version 2 (Phase 4, CrIS FSR)**
  - Runs on **CrIS full-res (FSR)** data (FSR SARTA by L. Strow et al., UMBC)
  - Includes **IR-only version** (risk-mitigation for ATMS loss)
  - Phase 4 Algorithm Readiness Review (ARR) delivered on 6 July 2017
    - Draft ATBD delivered August 2017
    - V2.1.2 code delivered and transitioned into operations
  - V2.1.4
    - New "clouds" namelist including new channel selections from Chris Barnet (STC) for cloud clearing and cloud heights
  - V2.1.9 (builds on v2.1.4)
    - New *T, Q*, CCR channels
  - V2.1.10a
    - New CO *a priori*
  - V2.1.10n (builds on v2.1.9)
    - New CO *a priori*
    - New *T, Q*, CCR channels
    - CO QC
    - Old Tuning
  - V2.1.11a, b
    - New CO channels to 2200 $cm^{-1}$
    - New CO and $CH_4$ Tunings
  - V2.1.12
    - Modified "preferred" CO QC from Juying Warner (UMCP) to new "relaxed" CO QC, allowing regions over Africa (for example) to pass where they previously failed
    - V2.1.12b
      - New tuning/rtaerr, returned to the truncated 35 channel CO list ending at 2191.25.
      - These tuning sets caused more issues than they solved.
    - V2.1.12c
      - Partial compromise between the issues in the V2.1.12 namelists and the improvements in V2.1.11 and the code changes. Uses V2.1.11a, but included the truncated CO channels (35) in the ozone namelists and the new "relaxed" CO tuning introduced at NUCAPS V2.1.12.
      - **NOAA-20 Provisional Maturity for AVTP/AVMP, Beta Maturity for O3/CO/CH4/CO2, 15 June 2018**
    - V2.1.12d
      - Deletes a cloud-clearing channel from version v2.1.12c

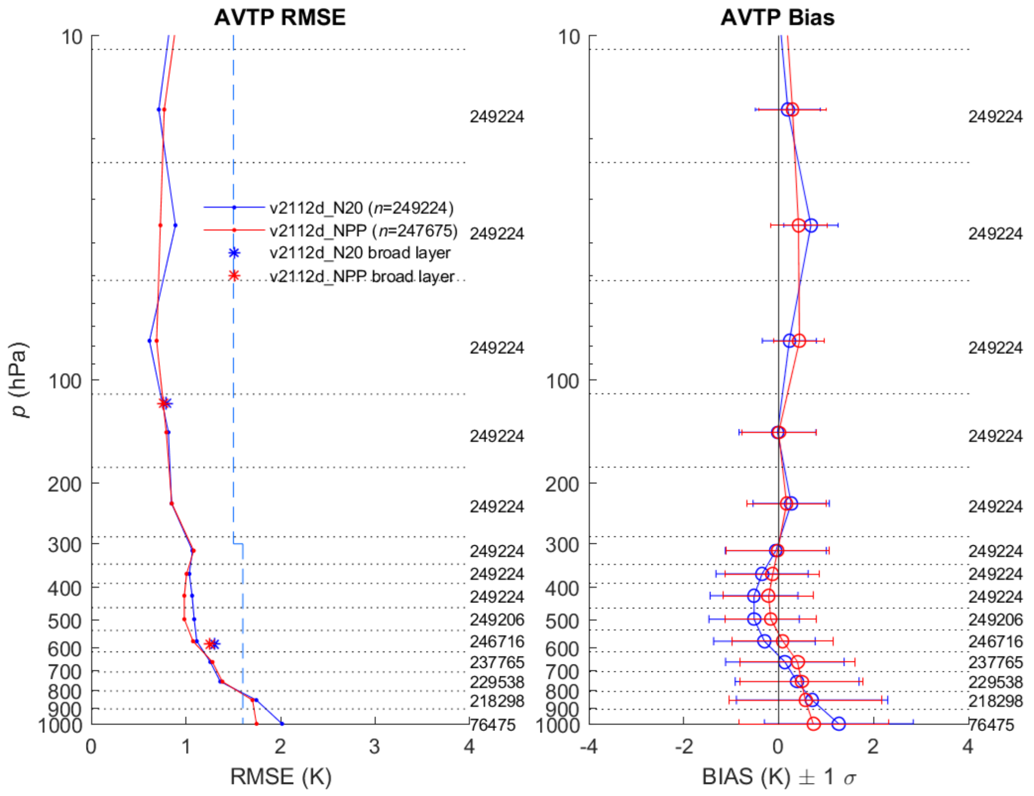
NUCAPS Validation

# NUCAPS NOAA-20 VALIDATION STATUS

# NUCAPS (v2.1.12d) IR+MW $T/H_2O$ EDR Coarse-Layer Statistics
# Baseline: ECMWF Global Focus Day 10-Apr-2018

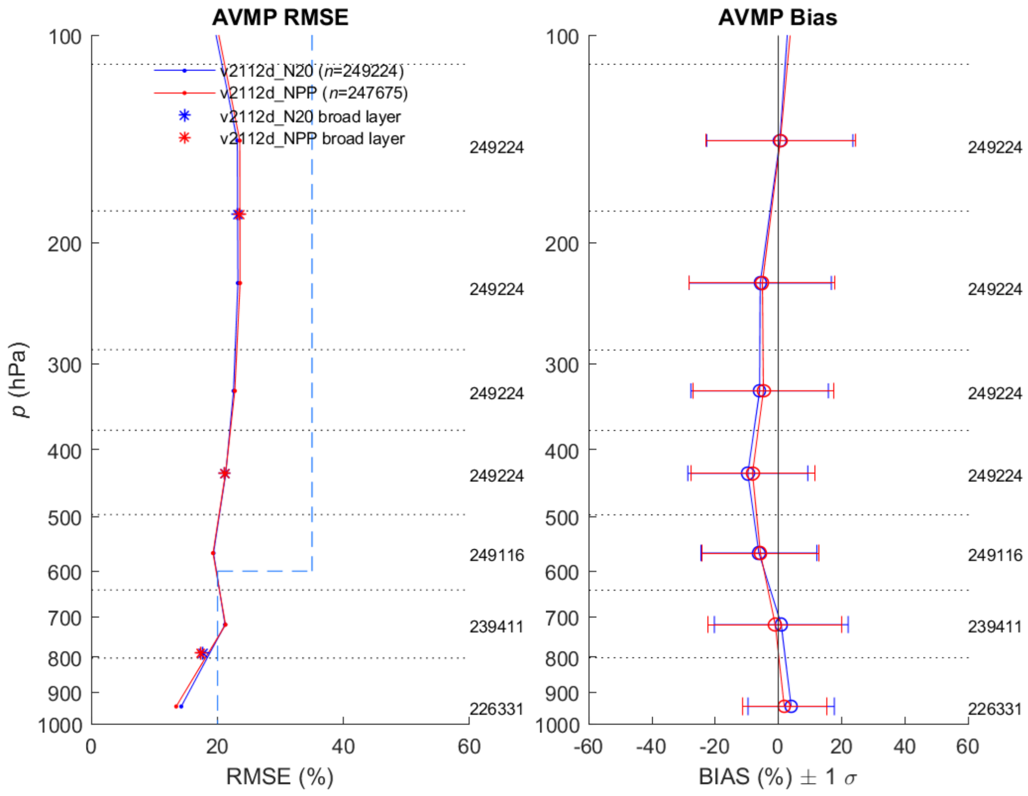
**NOAA-20**
**SNPP**

## AVTP Versus ECMWF




**NOAA-20**
**SNPP**

## AVMP Versus ECMWF



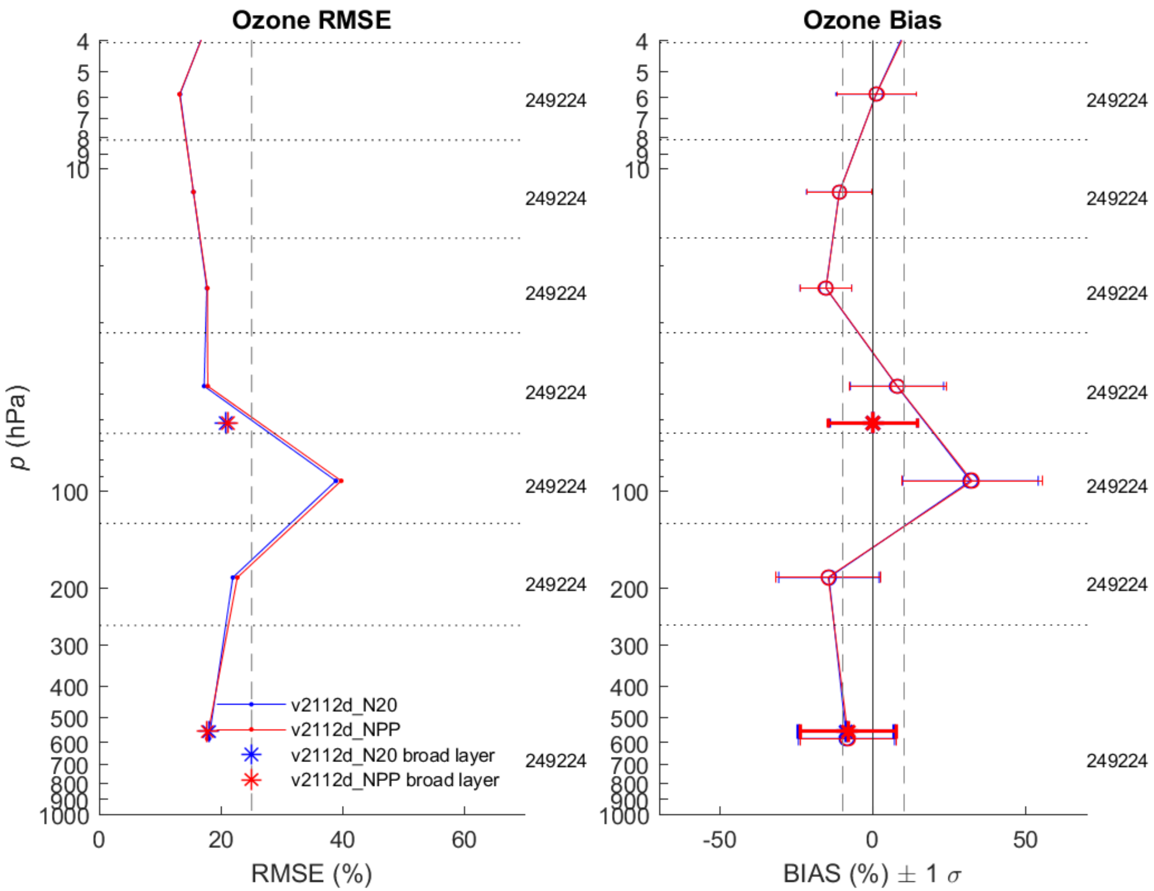

**NOAA-20 Yield = 76.9%**
**SNPP Yield = 79.1%**

# NUCAPS (v2.1.12d) IR Ozone Profile EDR Coarse-Layer Statistics
# Baseline: ECMWF Global Focus Day 10-Apr-2018

## IR Ozone Profile Versus ECMWF

**NOAA-20**
**SNPP**

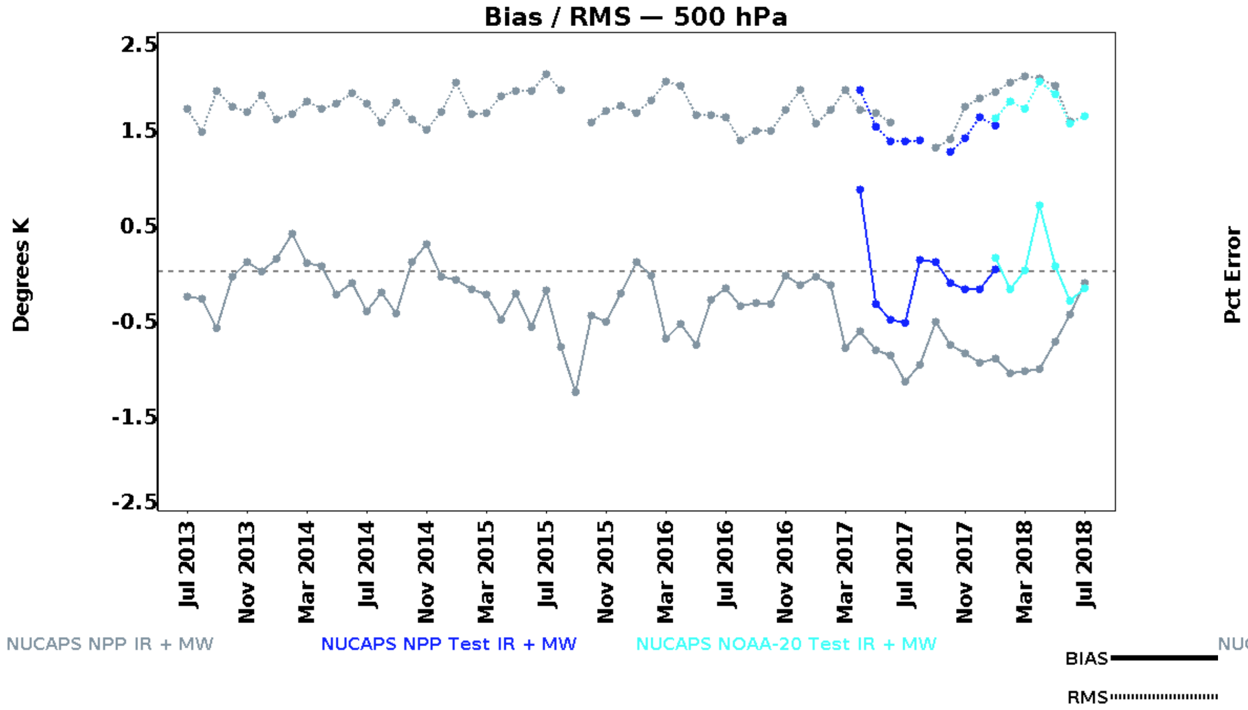
**NOAA-20 Yield = 76.9%**
**SNPP Yield = 79.1%**



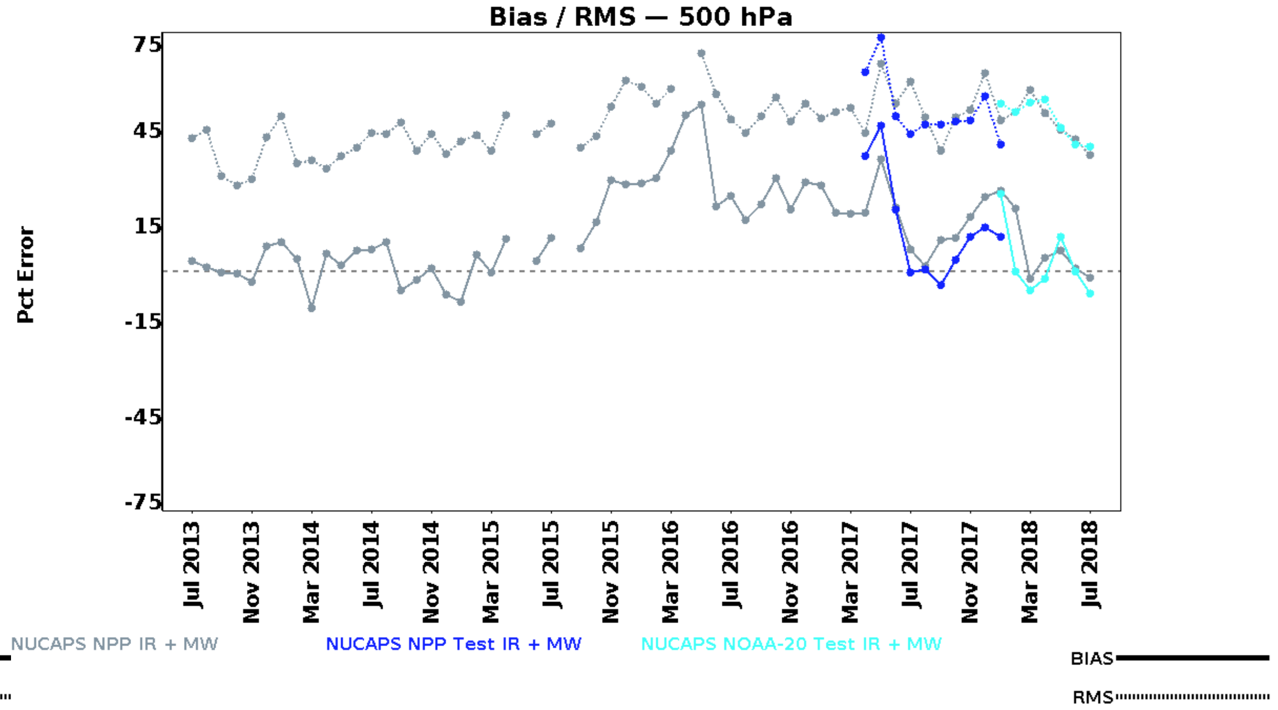

*From Nalli et al. (2017b)*

# SNPP and NOAA-20 NUCAPS Long-Term Monitoring
## (via NPROVS NARCS)

## AVTP (500 hPa)




## AVMP (500 hPa)



NUCAPS Validation

# NUCAPS CARBON TRACE GAS VALIDATION STATUS (SNPP)

# Overview of Carbon Trace Gas Validation

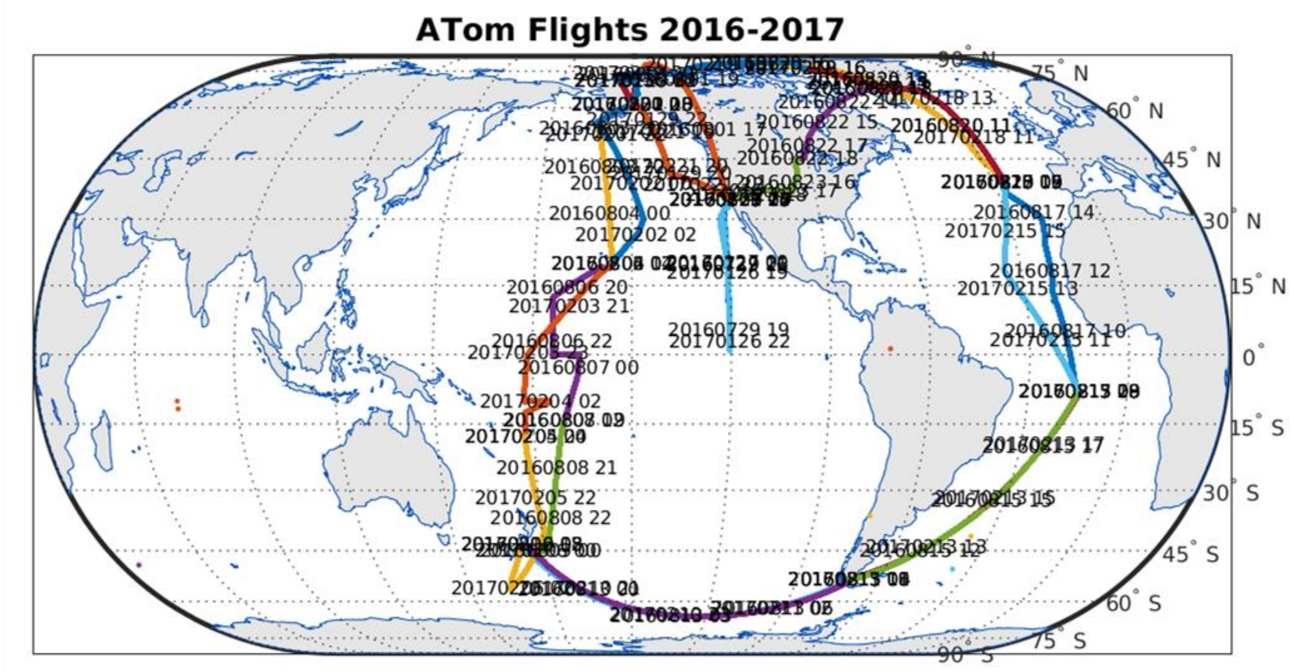
- **Carbon trace gas EDR validation** versus JPSS program established uncertainty specifications is a **new sounder validation requirement** that began during the transition period to the FSR CrIS NUCAPS

- **In response to these new requirements, a validation strategy was devised** with preliminary validation of NUCAPS carbon trace gas EDRs conducted leveraging global truth datasets, including
  - ECMWF from Global Focus Days (Cal/Val Method #1)
  - **Satellite EDRs from Global Focus Days** (Cal/Val Method #2)
    - Of particular value for **inter-satellite stability**
    - **Aqua AIRS v6**
    - Potential future work: OCO-2, MLS
  - **Total Carbon Column Observing Network (TCCON)** (*Wunch et al.* 2011) (Cal/Val Method #3)
    - Global network of ground-based FTS that accurately measure total column abundances of $CO_2$, CO, $CH_4$, $N_2O$ trace gases
    - Provides “spot checks” for verifying NUCAPS and AIRS
  - **ATom campaigns** (Cal/Val Method #4)
  - **AirCore** (Cal/Val Method #3, future work)

- **Collocation Methodologies**
  - 2-D linearly interpolated FOR – used for AIRS versus NUCAPS
  - “VALAR method”
    - NUCAPS/AIRS versus mean TCCON
    - NUCAPS versus ATom profiles
    - Include all FOR within threshold radius (e.g., 150 km) time window (e.g., ±3 hours)
  - Quality assurance (QA)
    - NUCAPS IR+MW quality flag and AIRS trace gas quality flags
    - NUCAPS trace gas QA flags are undergoing development

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

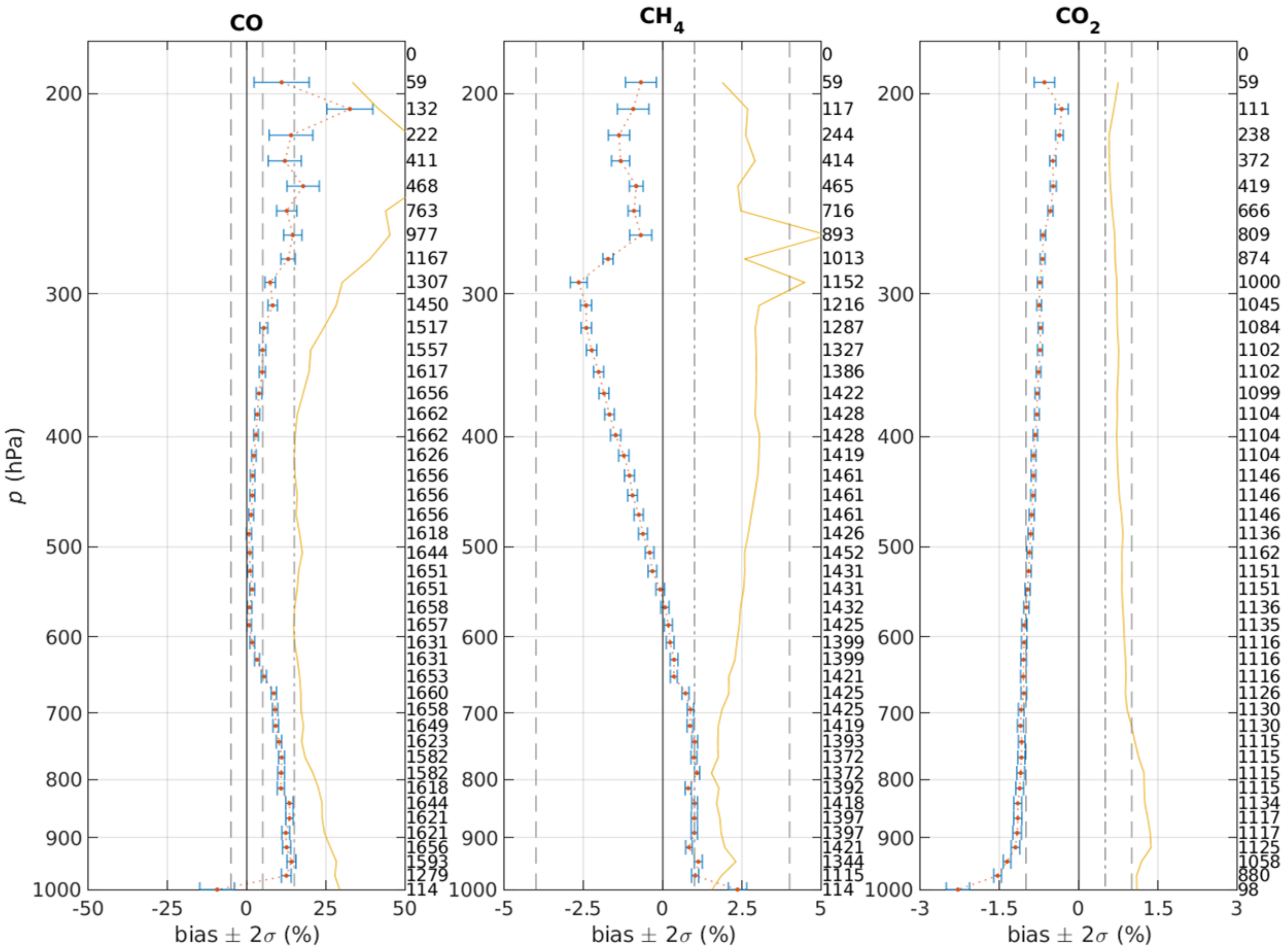
- **ATom** deploys extensive gas and aerosol payloads on the **NASA DC-8** aircraft for global-scale sampling of the atmosphere, profiling continuously from 0.2–12 km altitude
- **Flights** occur in each of 4 seasons over a 4-year period, originating from the Armstrong Flight Research Center in Palmdale, California
  - North to western Arctic, south to South Pacific, east to the Atlantic, north to Greenland, and return to California across central North America
  - ATom establishes a single, contiguous global-scale data set
- **Source:** https://espo.nasa.gov/atom/

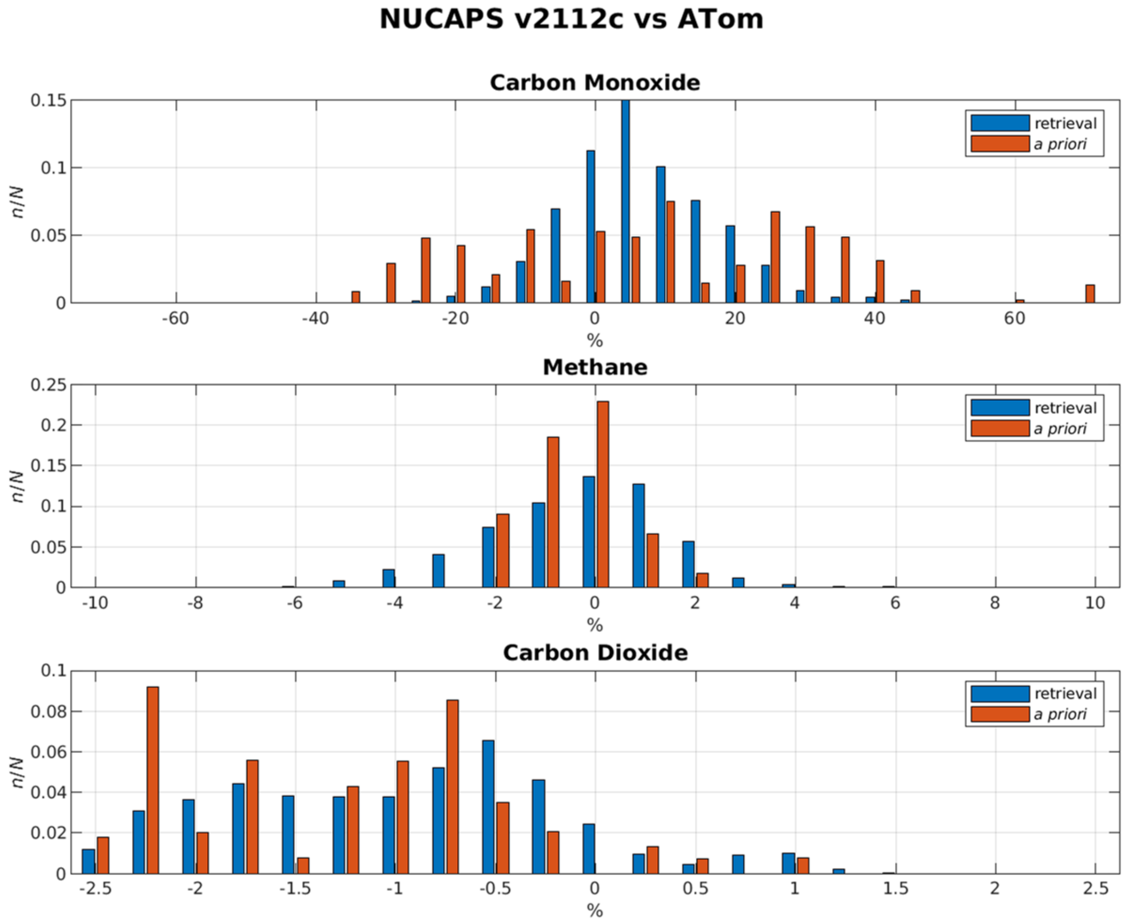


# NUCAPS SNPP (v2.1.12c) versus ATom

## Accepted+QA, ±2 hr, 150 km

**NUCAPS v2112c Retrieval versus ATom Profile Statistics (ACC+QA, -2  2 h, 150 km)**



# SNPP NUCAPS EDR Maturity Status

*Slide courtesy of Lihang Zhou, STAR/JPSS*

## JPSS S-NPP EDR Validated Maturity Oct. 2016-Current: NUCAPS

| Sensor | Product | Priority | Validated Maturity Review Date & Status | | Review Panel Recommendations |
|---|---|---|---|---|---|
| CrIS/ATMS | Atm. Vertical Moisture Profile (AVMP) | 3 | * | ✓V | September 2014 |
| CrIS/ATMS | Atm. Vertical Temperature Profile (AVTP) | 3 | * | ✓V | September 2014 |
| CrIS/ATMS | Ozone Profile EDR | 3 | Oct-2016 | ✓V | Panel recommended the following: (1) Work with EMC and NWS on user applications (2) Validate against OMPS NP data (3) Extend validation to more ozonesondes |
| CrIS | Outgoing Longwave Radiation | 3 | Oct-2016 | ✓V | Panel recommended the following: (1) Investigate the use of VIIRS for helping to understand the differences between OLR from CrIS and CERES. (2) Compare anomaly events from CERES OLR (e.g. ENSO, MJO) to CrIS OLR data (3) Provide information about how algorithm will be updated to utilize CrIS FS data |
| CrIS/ATMS | **Carbon Monoxide** | 4 | & | ✓P | Validated Maturity Review for Fall 2017 |
| CrIS/ATMS | **Carbon Dioxide** | 4 | & | ✓P | Validated Maturity Review for Fall 2017 |
| CrIS/ATMS | **Methane** | 4 | & | ✓P | Validated Maturity Review for Fall 2017 |

*Product reached validated maturity in September 2014.

&Product reached provisional maturity in January 2013. NUCAPS Phase IV/Part II ARR completed on July 6, 2017.

✓ **Validated** ✓ **Provisional**

5

# Summary and Future Work

- SNPP NUCAPS NSR (v1.5) $T/H_2O/O_3$ EDRs have all met JPSS global requirements
  - Validated Maturity attained
- Offline **NOAA-20 and SNPP NUCAPS (v2.x FSR)** have been successfully implemented and tested. Based on Global Focus Day ECMWF model comparisons and limited RAOBs
  - **AVTP/AVMP EDRs** have attained **Provisional Maturity**
  - **IR Ozone Profile EDR** has attained **Beta Maturity**
  - IR-Only EDR products have been successfully implemented and show reasonable performance
  - **Carbon trace gas EDR validation** versus program-established uncertainty specifications was a **new task** beginning with the transition to the FSR CrIS NUCAPS
    - **Recent NUCAPS upgrades have focused on upgrades/optimizations of the CO trace gas EDR product**
    - **Preliminary validation** versus AIRS, TCCON and ATom truth datasets show the products are close to meeting JPSS requirements

- **Future Work**
  - **Ongoing NUCAPS development, Cal/Val and Long-Term Monitoring**
    - **Continue v2.x algorithm optimizations**
    - **NUCAPS Trace Gas Validated Maturity Review**
      - **Utilize field campaign datasets (viz., ATom)**
      - **Upgrades/optimizations for $CH_4$ and $CO_2$ products**
    - **NOAA-20 NUCAPS validation**
      - Continue support of dedicated RAOBs (including **ARM, RIVAL, AEROSE**)
      - **Next AEROSE campaign is scheduled for Feb-Mar 2019**
  - **Other Related Work**
    - **Apply averaging kernels** in NUCAPS error analyses, including carbon trace gases and ozone profile EDRs
    - Collocation uncertainty estimates
    - calc − obs analyses (CRTM, LBLRTM, SARTA, etc.)
    - Support skin SST EDR validation
    - Support EDR user applications (**AWIPS**, **AR/SAL**, **atmospheric chemistry users**)

NUCAPS Validation

# THANK YOU! QUESTIONS?

NUCAPS Validation

# EXTRA SLIDES

# MICROWAVE INTEGRATED RETRIEVAL SYSTEM (MIRS):

## Scientific Activities, Project Milestones, Future Plans


**Chris Grassotti**

**CICS-MD and NOAA/NESDIS/STAR**

**MiRS Team: S. Liu, R. Honeyager, Y-K. Lee, Q. Liu**

**Help from: G. Chirokova, B. Sun, J. Forsythe**

**christopher.grassotti@noaa.gov**


**28 August 2018**

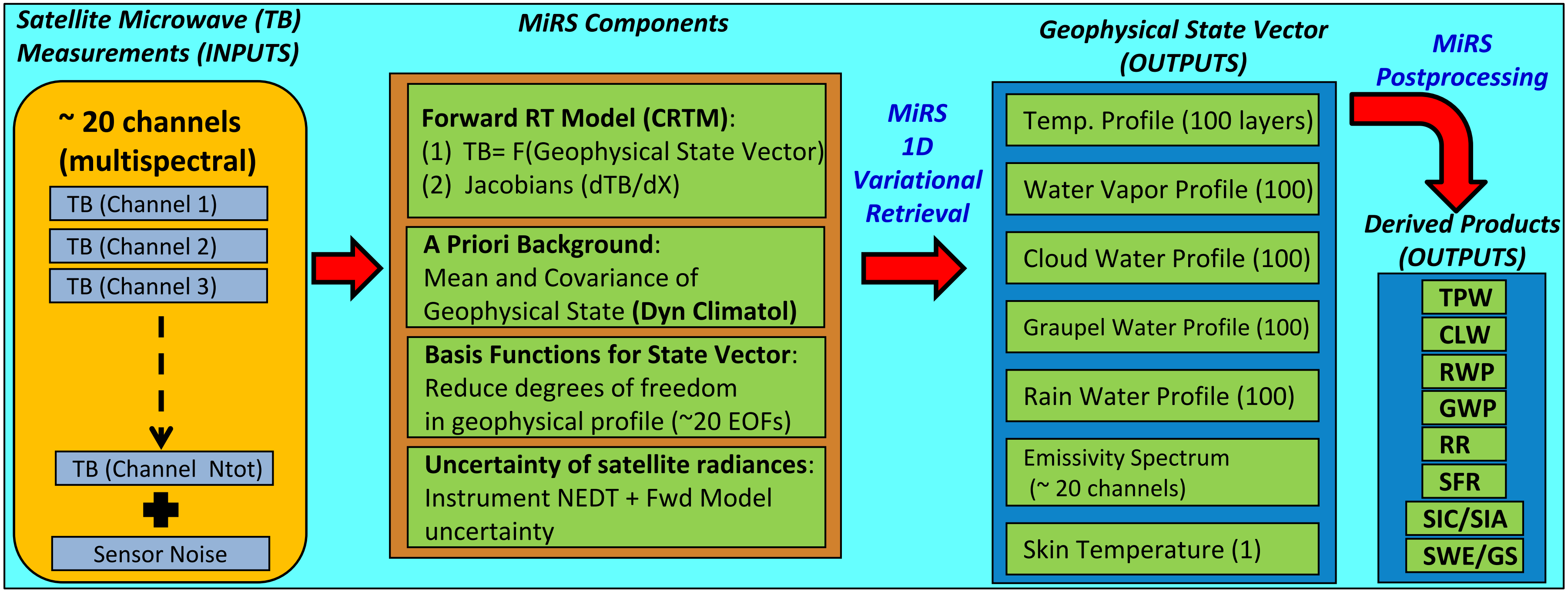
# MiRS N20/ATMS Validation/Delivery Status

- **Beta Maturity** since 29 Nov 2017 (L+11 days)
- **Provisional Maturity** declared on 29 March 2018
- **V11.3 Preliminary DAP delivered to NDE/OSPO on** 8 June
- Possibly operational in September
- Additional validation ongoing, e.g. RR, cryosphere, T and WV vs. raobs, LST, and LSE, etc.
- An updated DAP will be delivered in late 2018/early 2019
- Also delivered to CSPP/DB in July (CSPP_MIRS 2.1)

# MiRS Version 11.3 Changes

- Extension to NOAA-20/ATMS
- Addition of snowfall rate (SFR) to SNPP and N20 (not fully validated); SFR already implemented for AMSU-MHS
- Implementation of forest fraction emissivity correction in SWE algorithm for ATMS and AMSU-MHS (improved estimation in forested regions, e.g. eastern CONUS)
- Incorporation of cloud liquid water over land in RR algorithm for all satellites (improved detection/estimation of light rain)
- Miscellaneous fixes, changes to nc metadata, modifications to output nc file names

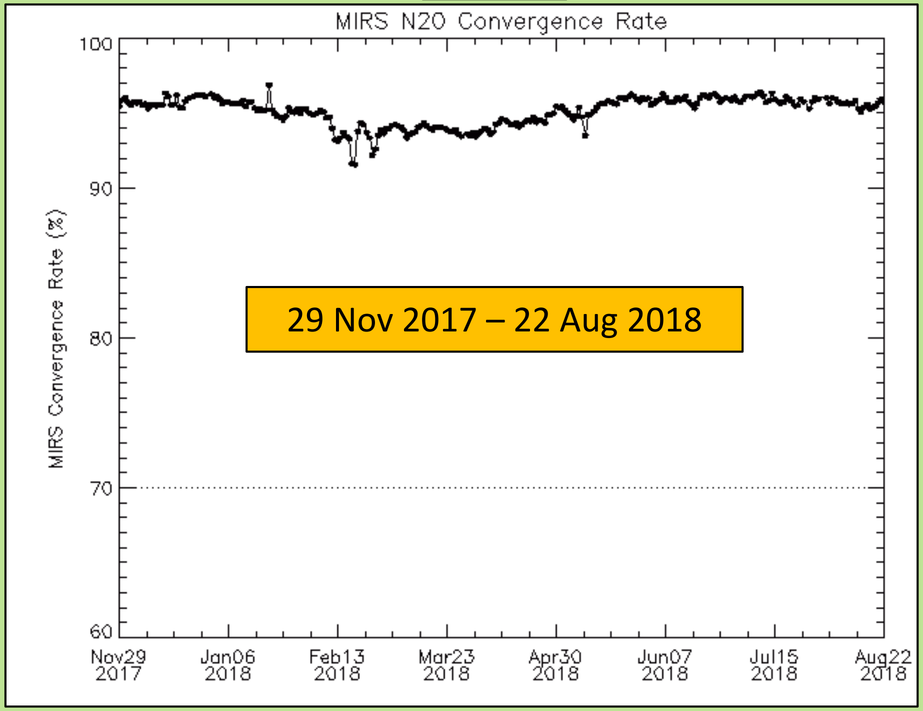
# Algorithm Overview



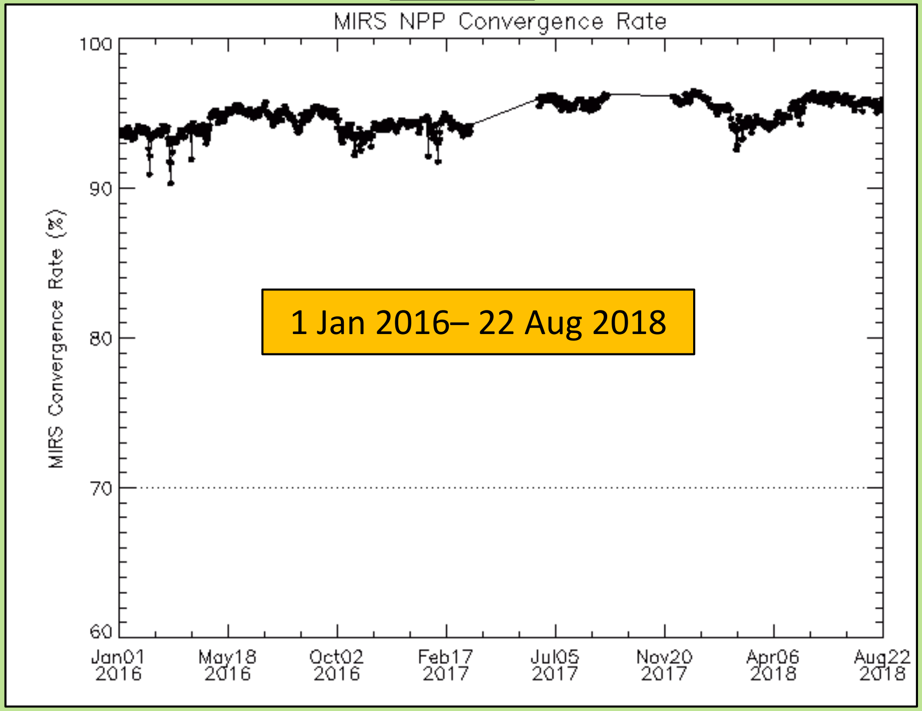

- MW Only, Variational Approach: Find the “most likely” atm/sfc state that: (1) best matches the satellite measurements, and (2) is still close to an a priori estimate of the atm/sfc conditions.
- **“Enterprise” Algorithm: Same core software runs on all satellites/sensors; facilitates science improvements and extension to new sensors.**
- Initial capability delivered in 2007. Running v11.2 since Jan 2017 on SNPP/ATMS, N18, N19, MetopA, MetopB, F17, F18, GPM/GMI, Megha-Tropiques/SAPHIR. (eventually MetopC…)
- Delivery of v11.3 (extended to NOAA-20/ATMS) to operations on **8 June**.
- External Users/Applications: TC Analysis/Forecasting at NHC, Blended Total/Layer PW Animations at NHC and WPC Animations (CSU/CIRA, U. Wisconsin/CIMSS), CSPP Direct Broadcast (U. Wisconsin), NFLUX model (NRL, Stennis), Global blended precipitation analysis at NOAA/CPC (CMORPH),…
- **All N20 results here are generated with MiRS v11.3 (offline processing in STAR), and TDR data generated in IDPS (Block 2 processing).**

# Retrieval Convergence Rate

N20

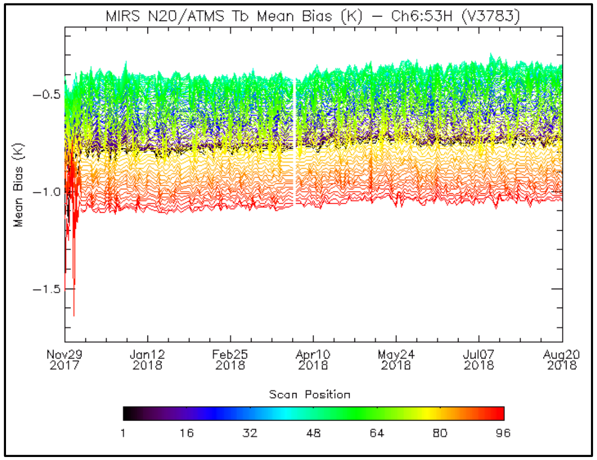



SNPP

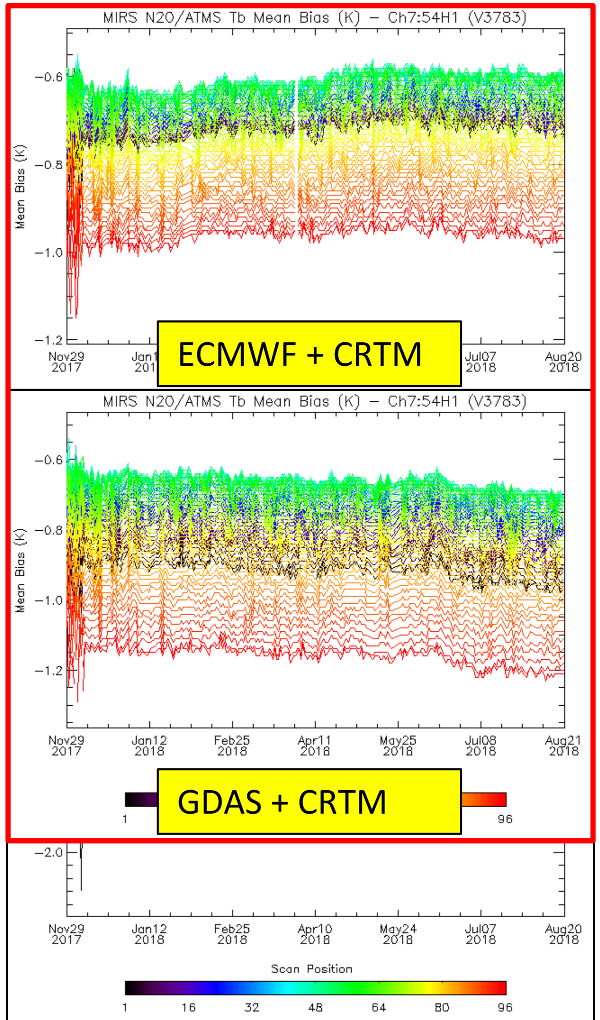


# Radiometric Biases: Time Series TDR Obs-Sim (29 Nov – 20 Aug)

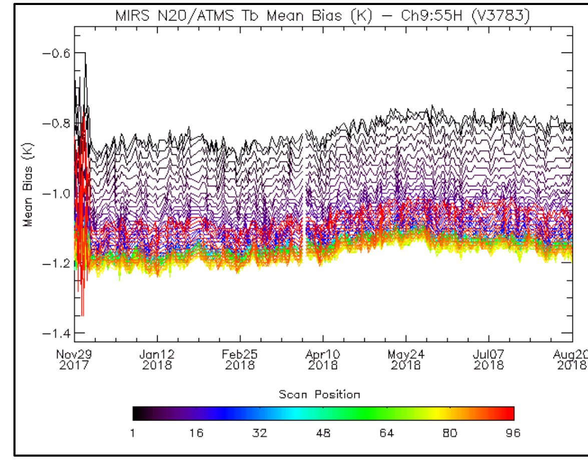
**Chan 6 (53.6 ± 0.12 GHz)**



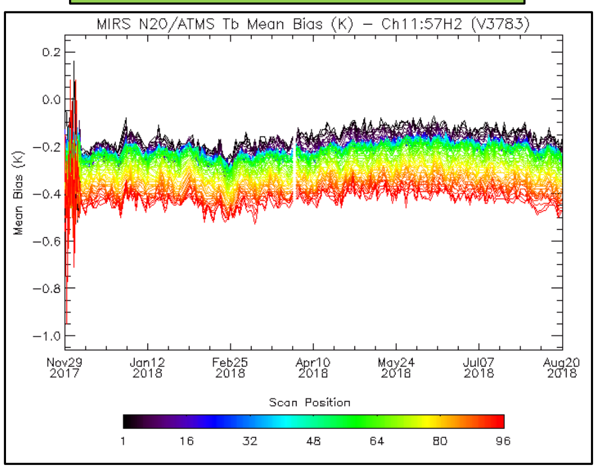

**Chan 7 (54.4 GHz)**



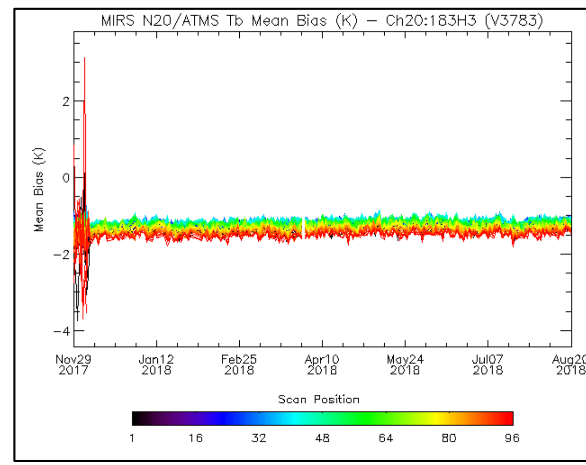

**Chan 9 (55.5 GHz)**




**Chan 11 (57.29 ± 0.22 GHz)**




**Chan 20 (183.31 ± 3 GHz)**

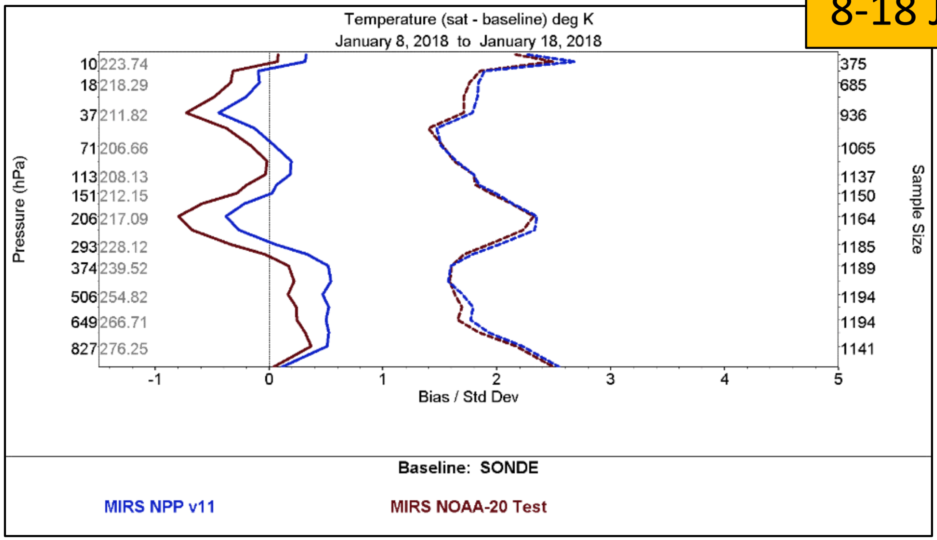


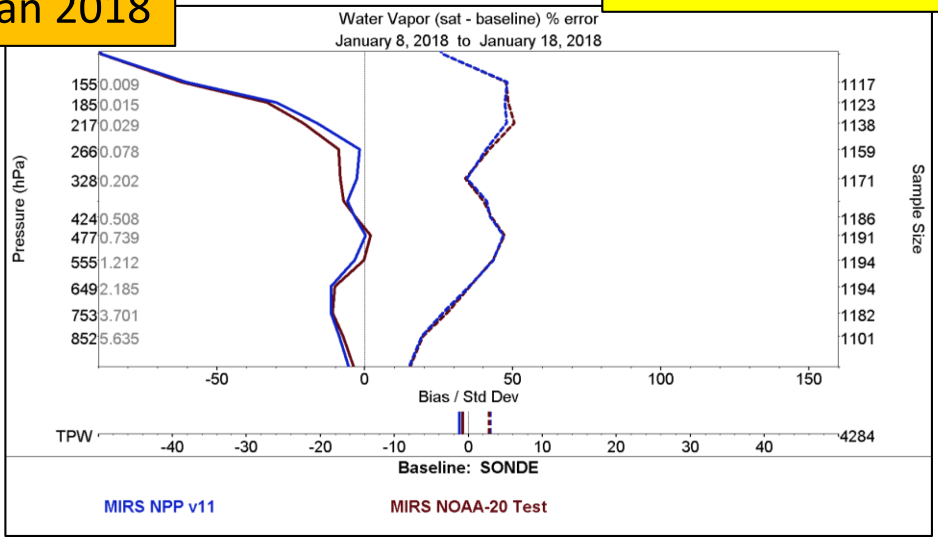

- Simulated TBs: ECMWF + CRTM (v2.1.1), clear ocean

# Temperature and WV Bias and Std Dev: Global (Land+Ocean) Comparison with Raobs

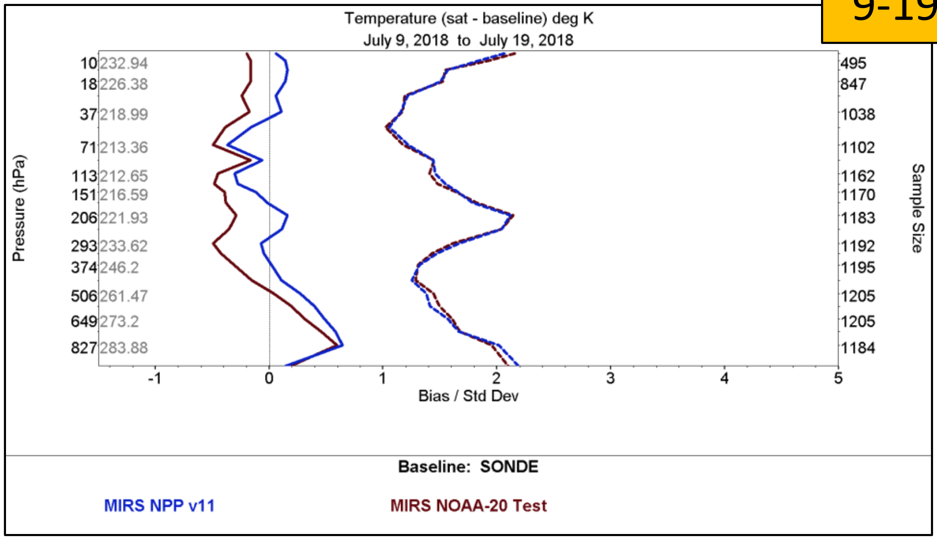
*Courtesy of Bomin Sun*

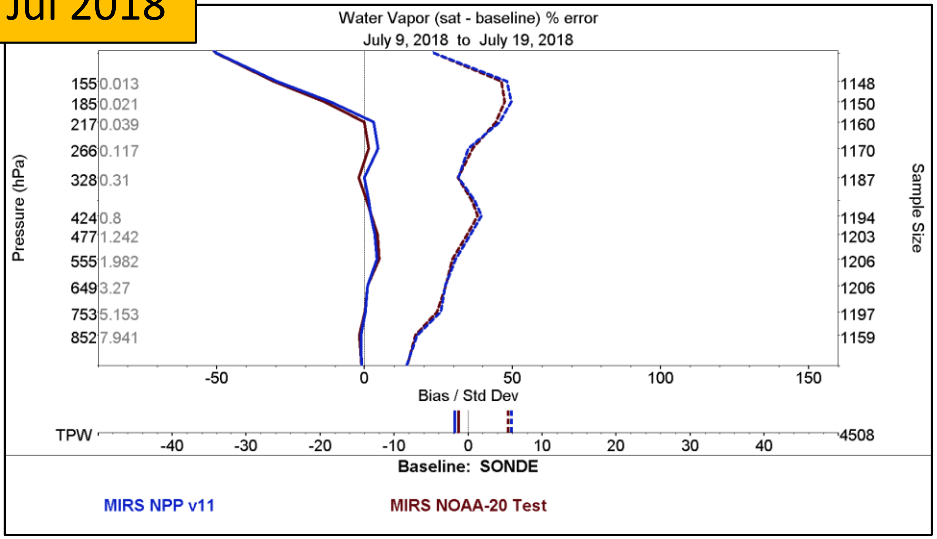
**8-18 Jan 2018**



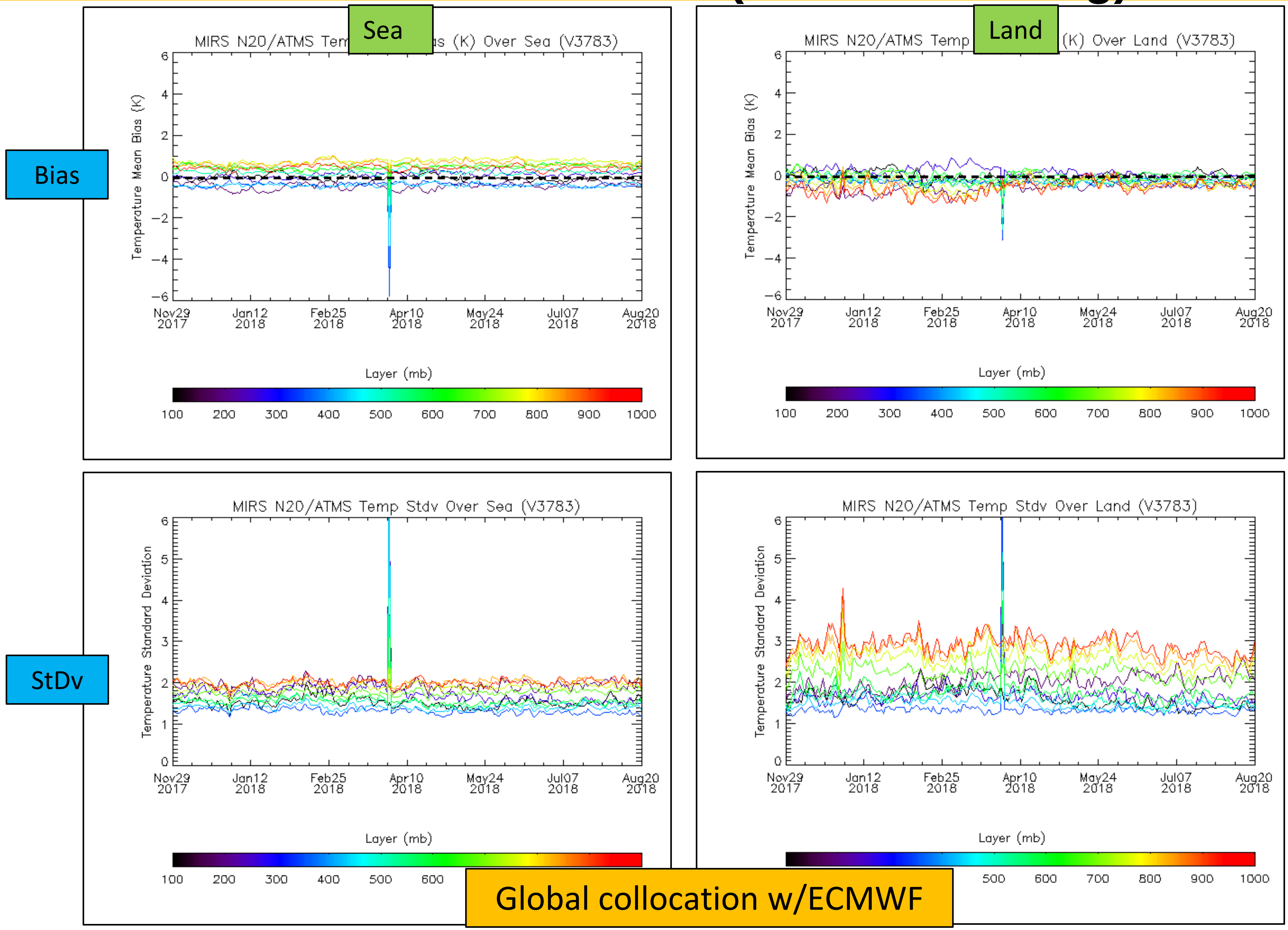




**9-19 Jul 2018**

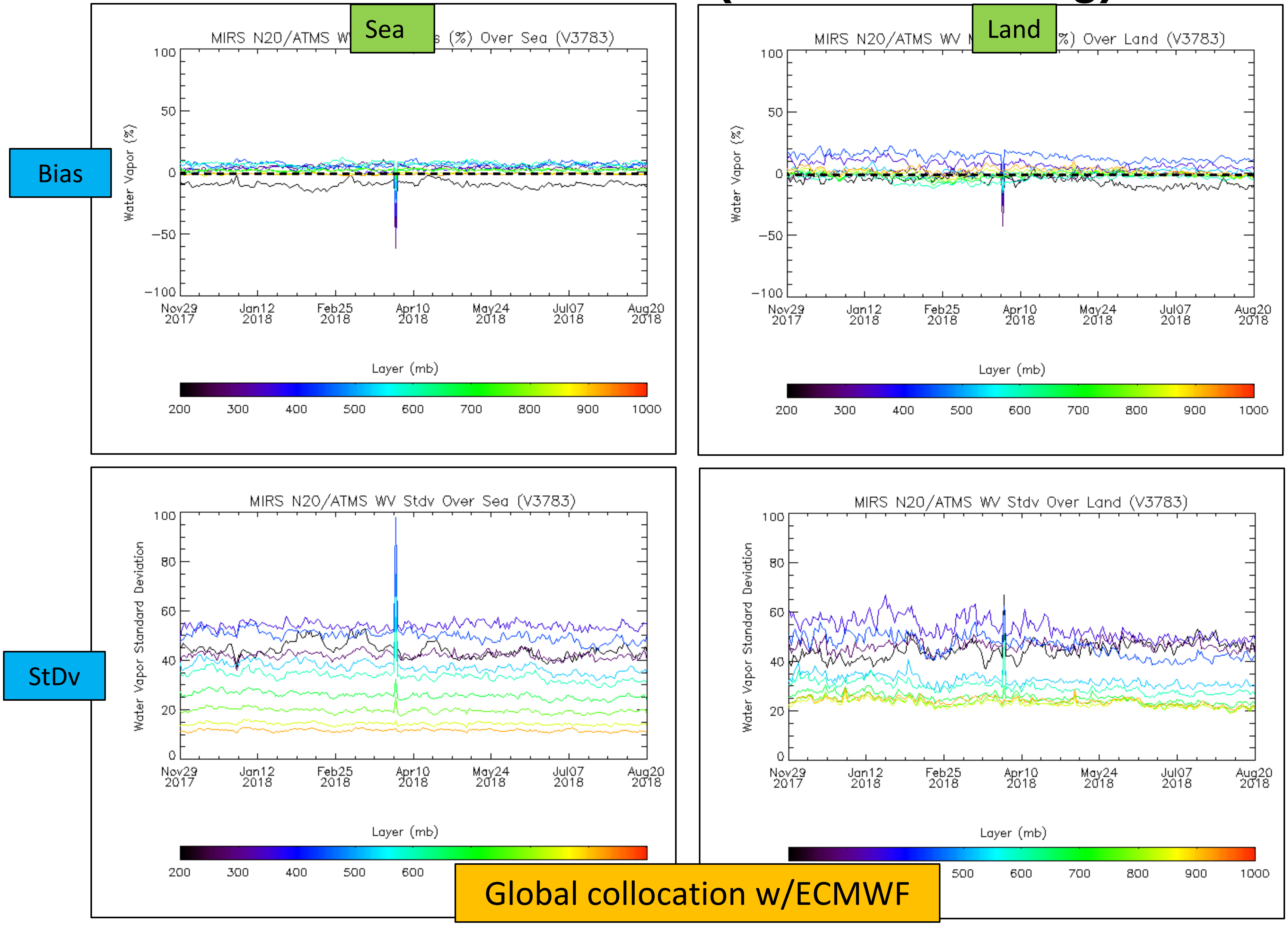


# Temperature Bias and Std Dev: Time Series (29 Nov – 20 Aug)



# Water Vapor Bias and Std Dev: Time Series (29 Nov – 20 Aug)



# Application Using MiRS Data: Hurricane Intensity and Structure Algorithm (HISA)

HISA provides MW-based TC Intensity estimates:

- Global
- Objective
- Independent of Dvorak

Input:

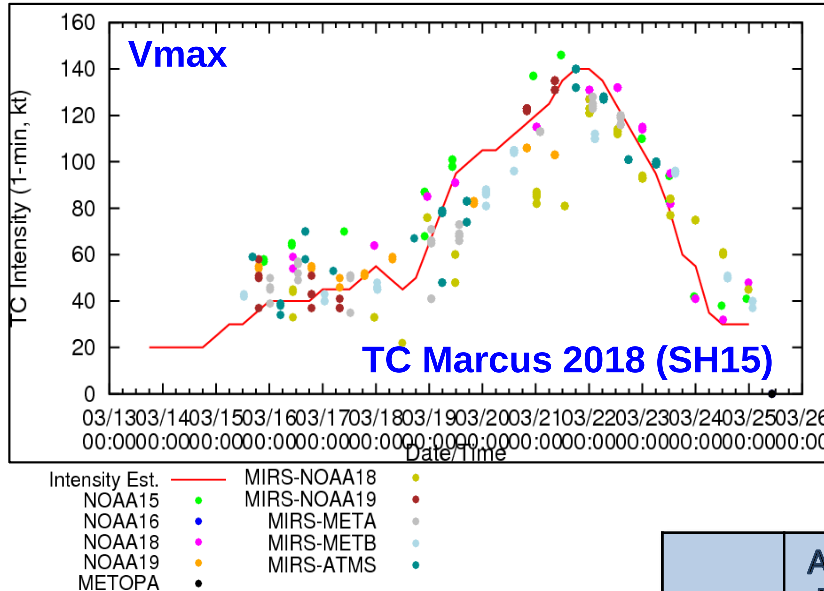
- Temperature profile, CLW from **AMSU/ATMS-MiRS** or statistical retrievals
- GFS boundary conditions
- ATCF TC track data

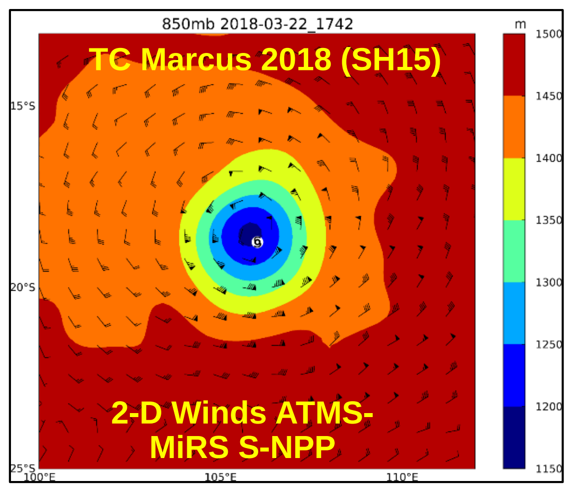
Output:

1) Intensity estimates, provided via f-deck
   - Maximum sustained wind (Vmax, kt)
   - Minimum Sea Level Pressure (MSLP, hPa)
2) Surface Wind Radii Estimates (nmi), provided via f-deck
   - R34, R50, R64 for NE, NW, SE, and SW TC quadrants
3) Azimuthally-averaged gradient winds as a function of geopotential height and distance from TC center.
4) Horizontal 2-D balanced winds (kt) for the local TC environment

Operational on ATMS and AMSU on 7 satellites, is upgraded to work with NOAA20 ATMS

Users: NHC, CPHC, JTWC




| | ATMS-MIRS MAE | AMSU-MIRS MAE |
|---|---|---|
| Vmax (kts) | 11.1 (1565) | 13.2 (4346) |
| Pmin (hPa) | 7.0 (1565) | 8.4 (4347) |
| R34 (nmi) | 20.0 (344) | 24.9 (1044) |
| R50 (nmi) | 12.0 (215) | 10.6 (601) |
| R64 (nmi) | 12.0 (134) | 8.9 (336) |

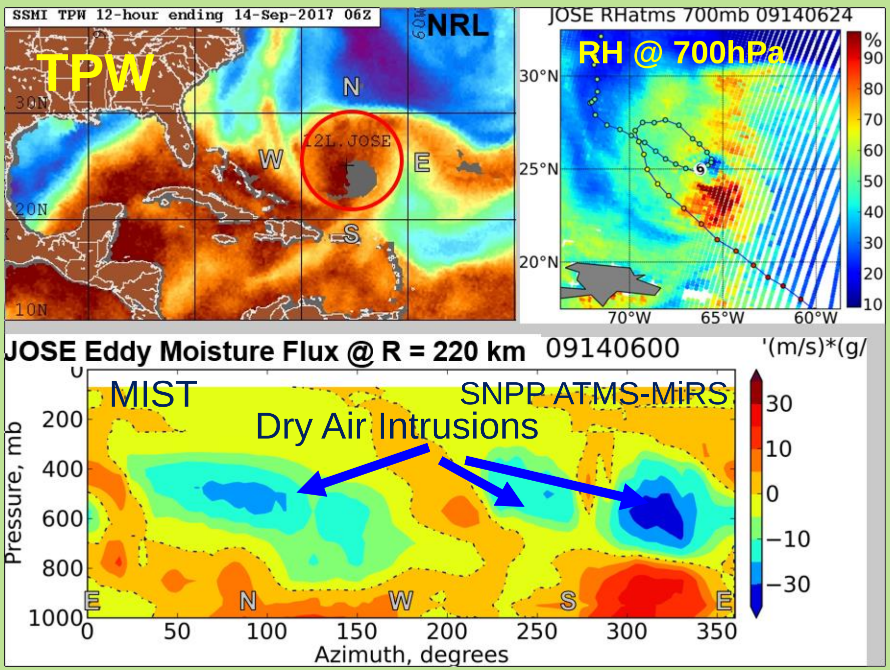
*Galina Chirokova (CIRA), John Knaff (NOAA/NESDIS), Scott Longmore (CIRA), Mark DeMaria (NOAA/NWS/NHC), Jack Dostalek (CIRA)*

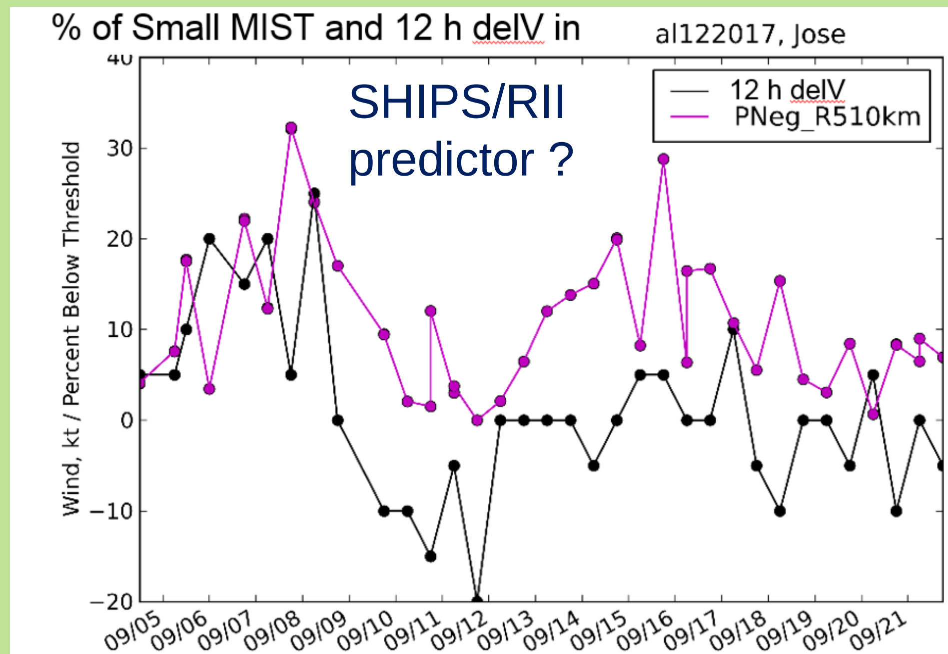
**Dry-air intrusions:**

- adversely affect TCs: inhibit convection, enhance cold downdrafts, contribute to storm asymmetry
- detected with TPW, LPW, WV imagery which do not provide quantitative information and do not always reflect moisture changes at mid-levels

**MIST:**

- detects and quantifies dry-air intrusions
- potential predictor for statistical TC intensity forecast models (SHIPS, LGEM, RII)




MIST shows moisture flux at R = 220 km from the storm center as a function of azimuth

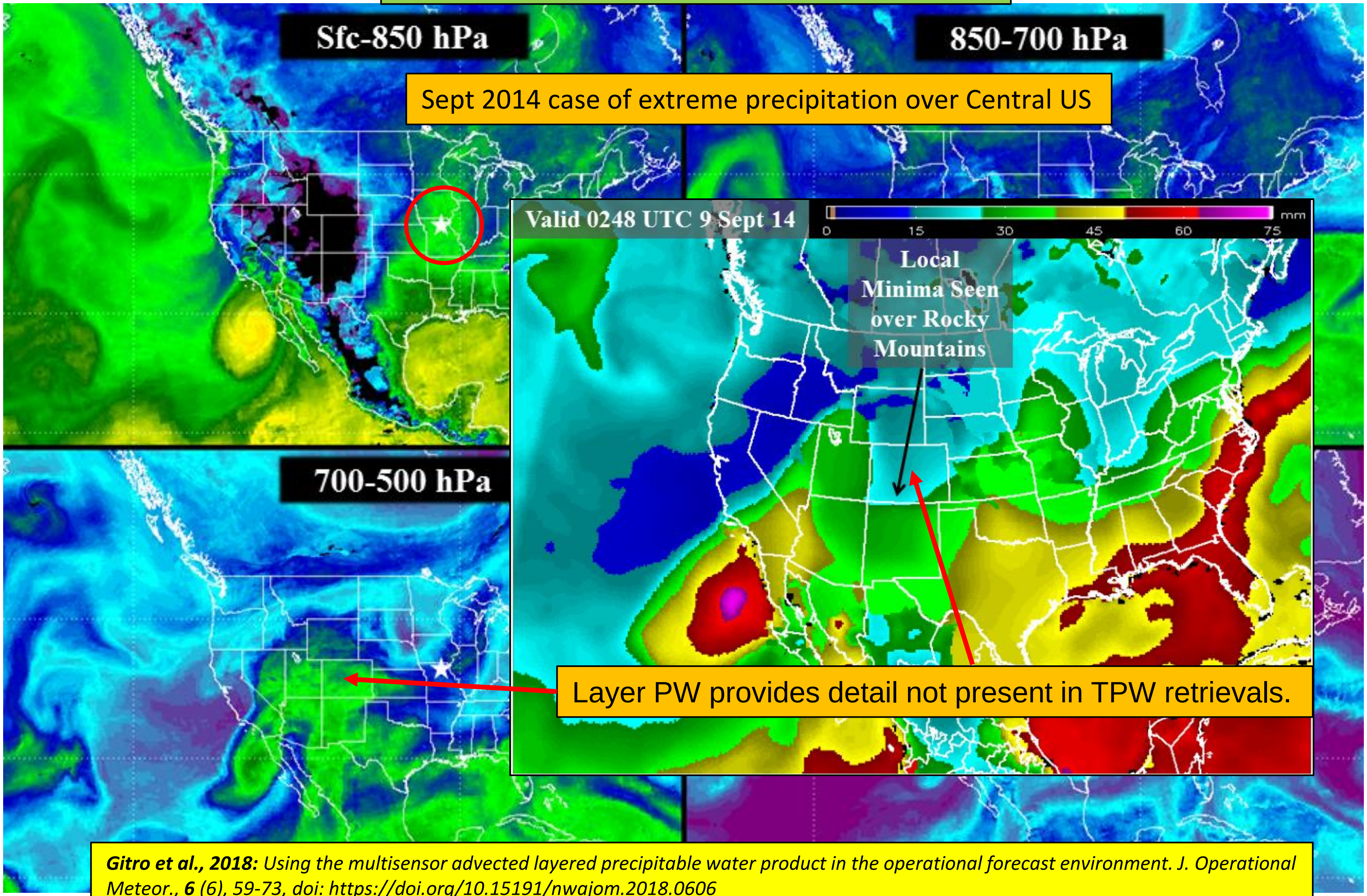

*Galina Chirokova (CIRA), Mark DeMaria (NOAA/NWS/NHC), John Knaff (NOAA/NESDIS)*

# Application: Blended Layer Precipitable Water

## *Combines MiRS WV from up to 7 Polar Satellites for Rapid Refresh and Advection (NWP-based winds)*

To be implemented at NHC and WPC

*Courtesy of John Forsythe*

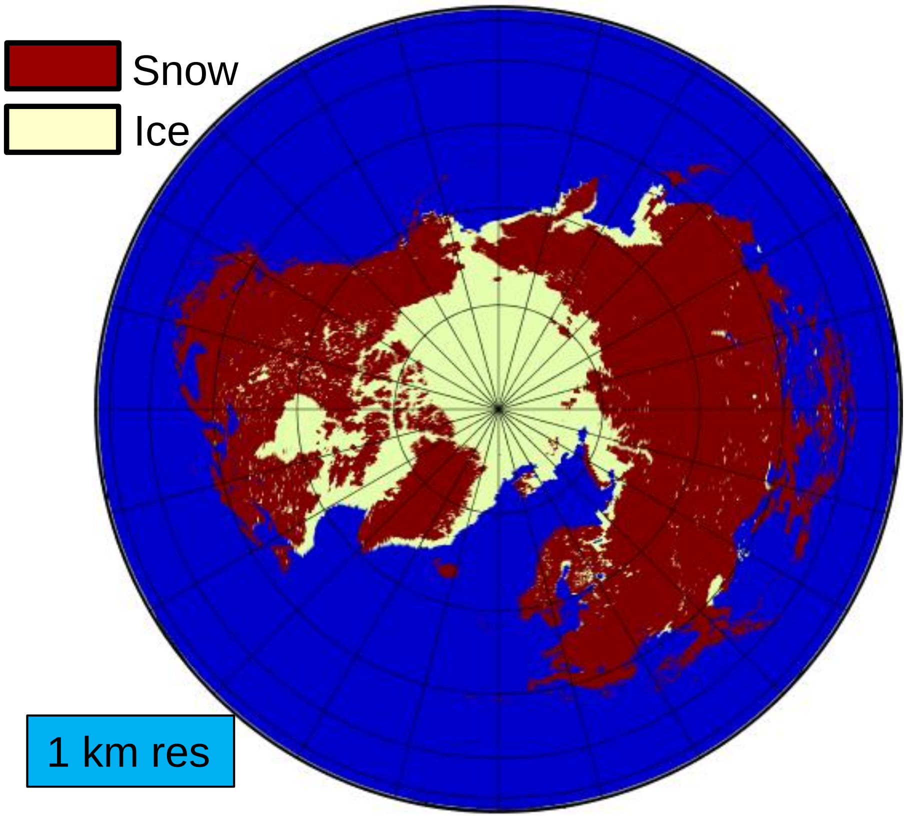



***Gitro et al., 2018:*** *Using the multisensor advected layered precipitable water product in the operational forecast environment. J. Operational Meteor.,* ***6*** *(6), 59-73, doi:* *https://doi.org/10.15191/nwajom.2018.0606*

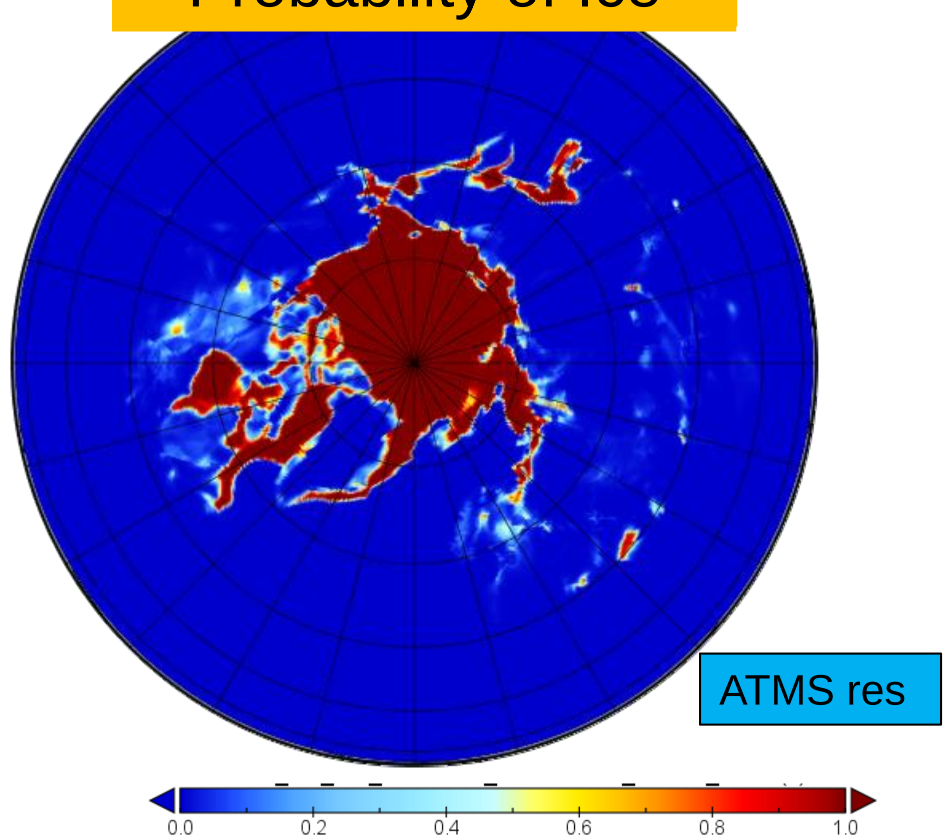
# Future Development:
# Surface Classifier Using Machine Learning

- Current MiRS surface type classifier is categorical (no mixed types): ocean, land, snow, ice
- Using TensorFlow to train a neural network to probabilistically classify surface types with IMS operational analyses as truth data
- Probabilistic surface type can be used to condition the a priori conditions for mixed surface types (e.g. emissivity) with potential impact on retrievals (e.g. ice concentration, snow water, T, WV profiles)

IMS (Observed)



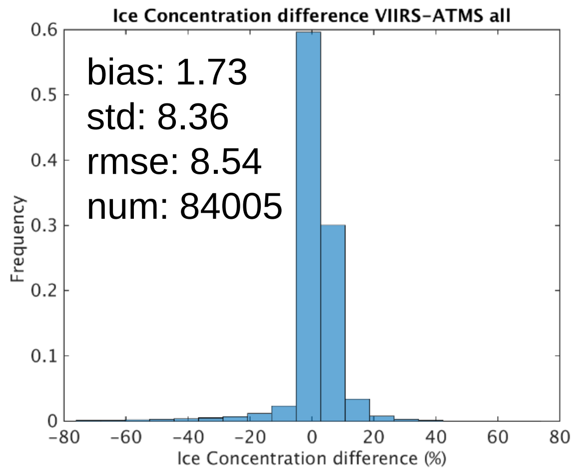

Neural Net (Predicted)
Probability of Ice

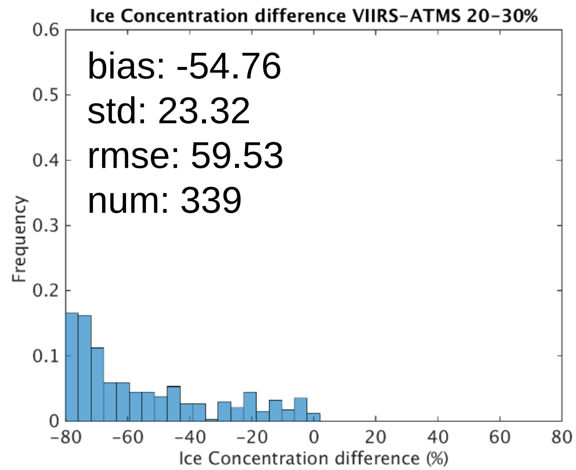


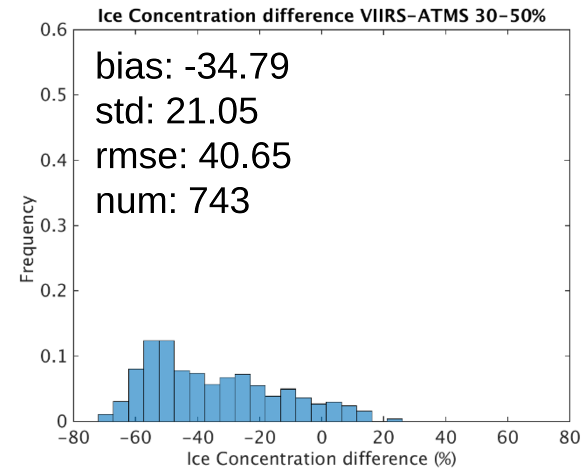

9 Jan 2016

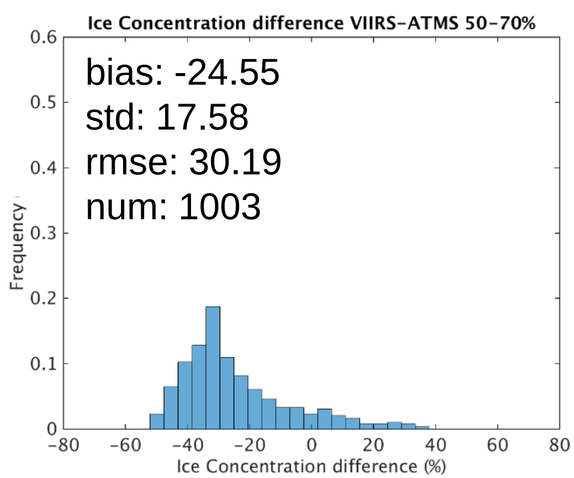
# SNPP/ATMS Sea Ice Concentration and Age: Comparisons with VIIRS

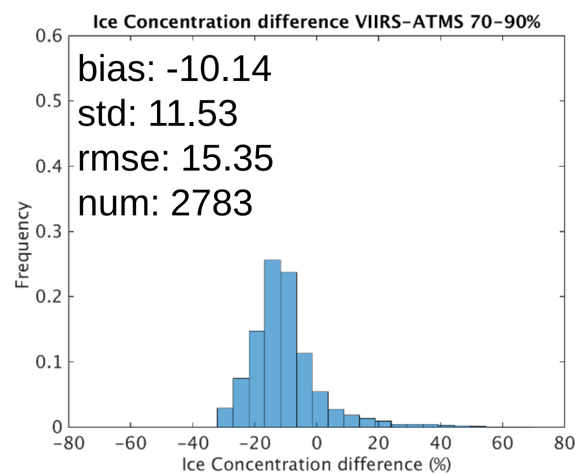
- Collocations of VIIRS pixels that fall within each ATMS FOV
- Example from one day of global data: 29 Jan 2018

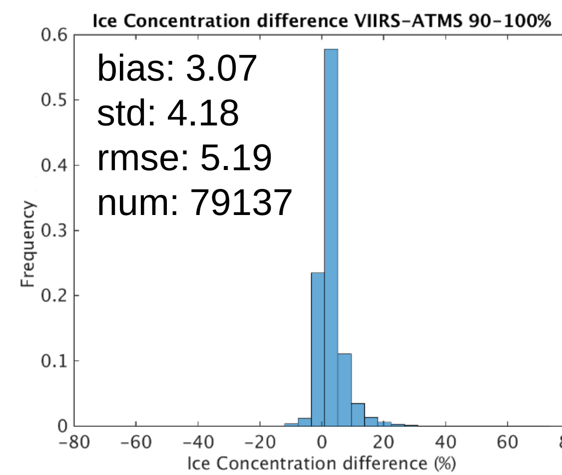


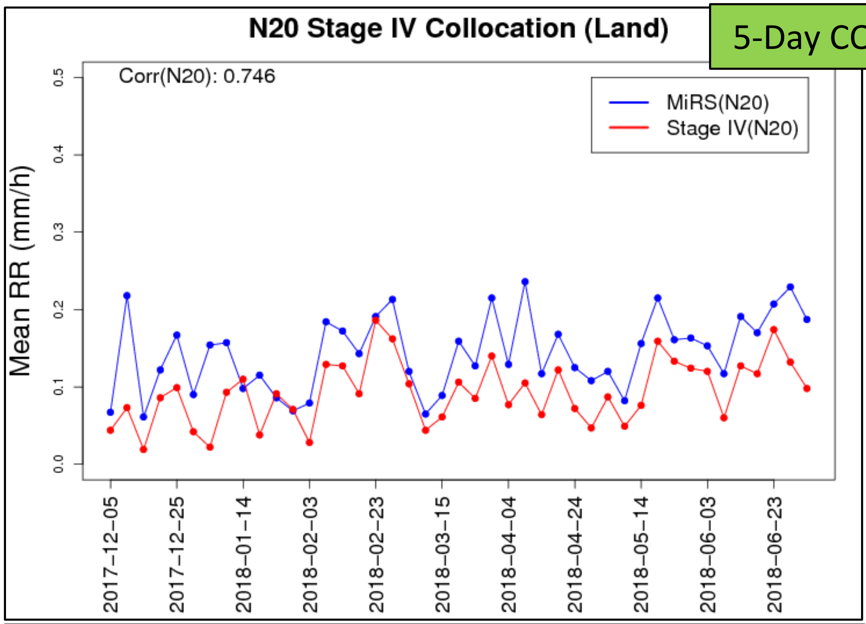



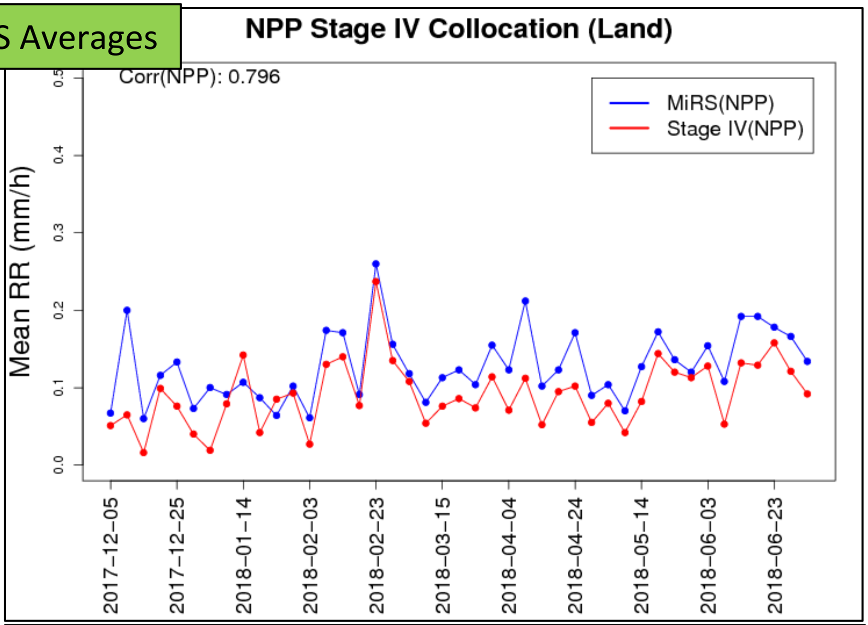



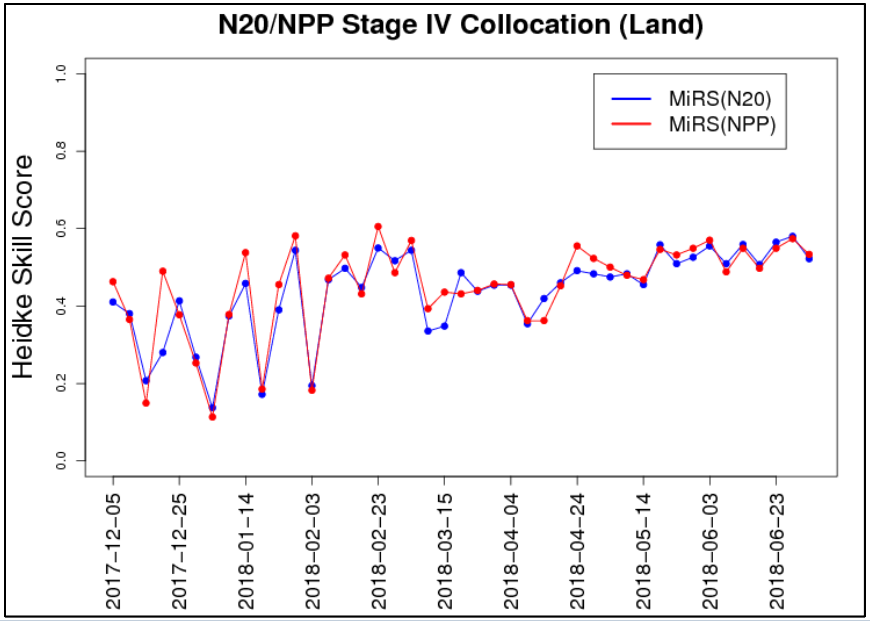



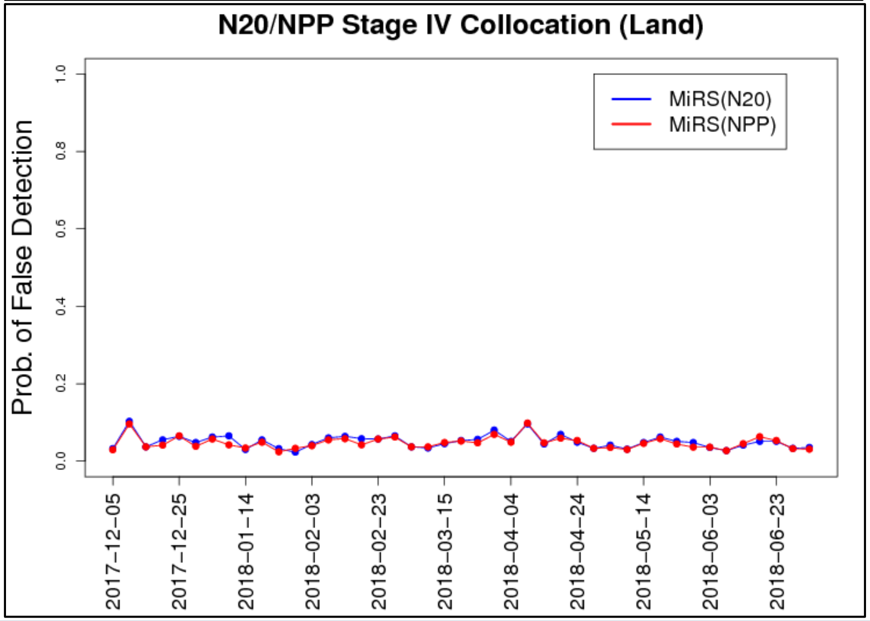
# RR validation: N20 and SNPP vs. Stage IV (Dec 2017 – Jul 2018)

5-Day CONUS Averages

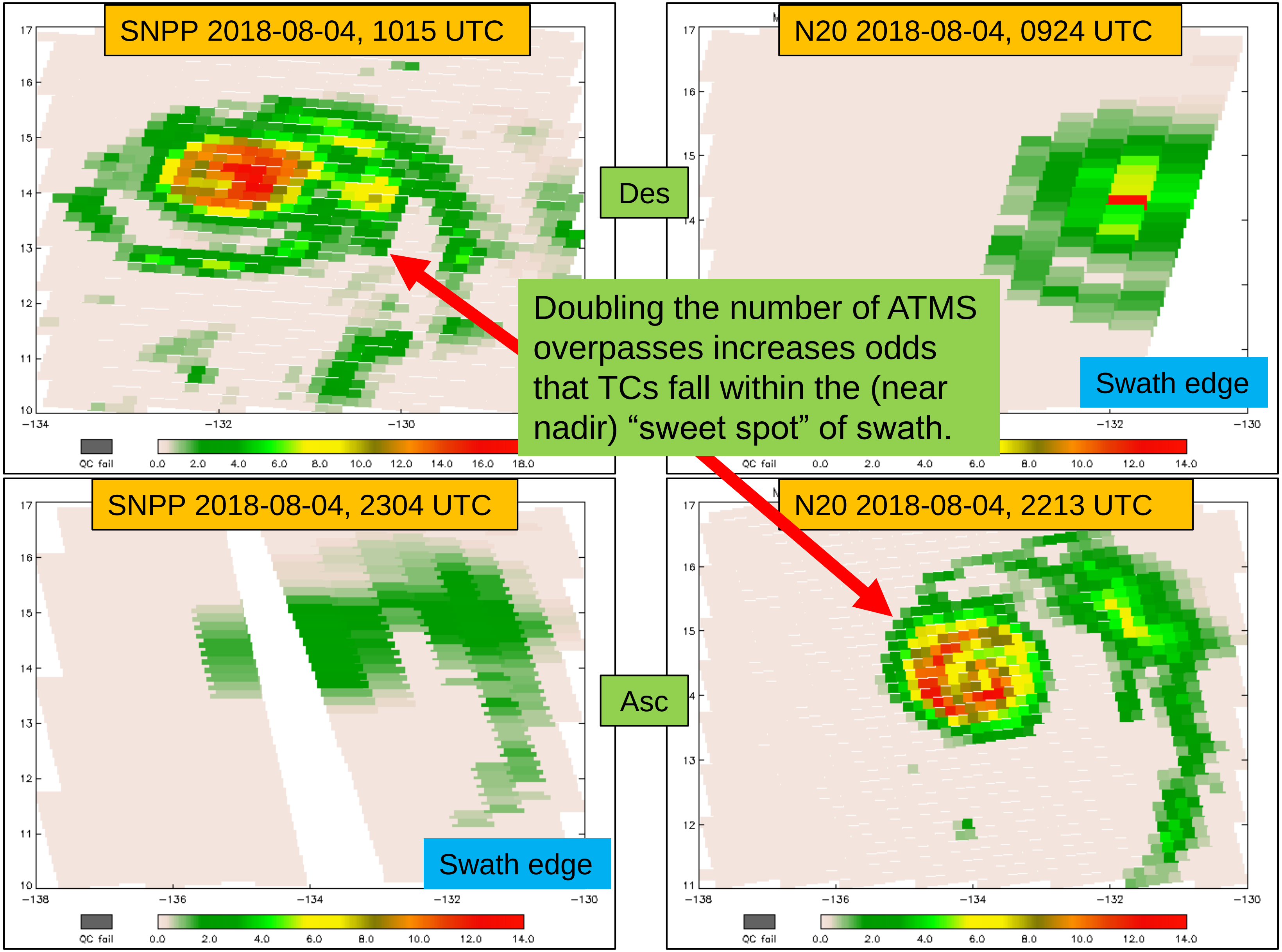


# Two Operational ATMS Better Than One: MiRS Rain Rate for Hurricane Hector



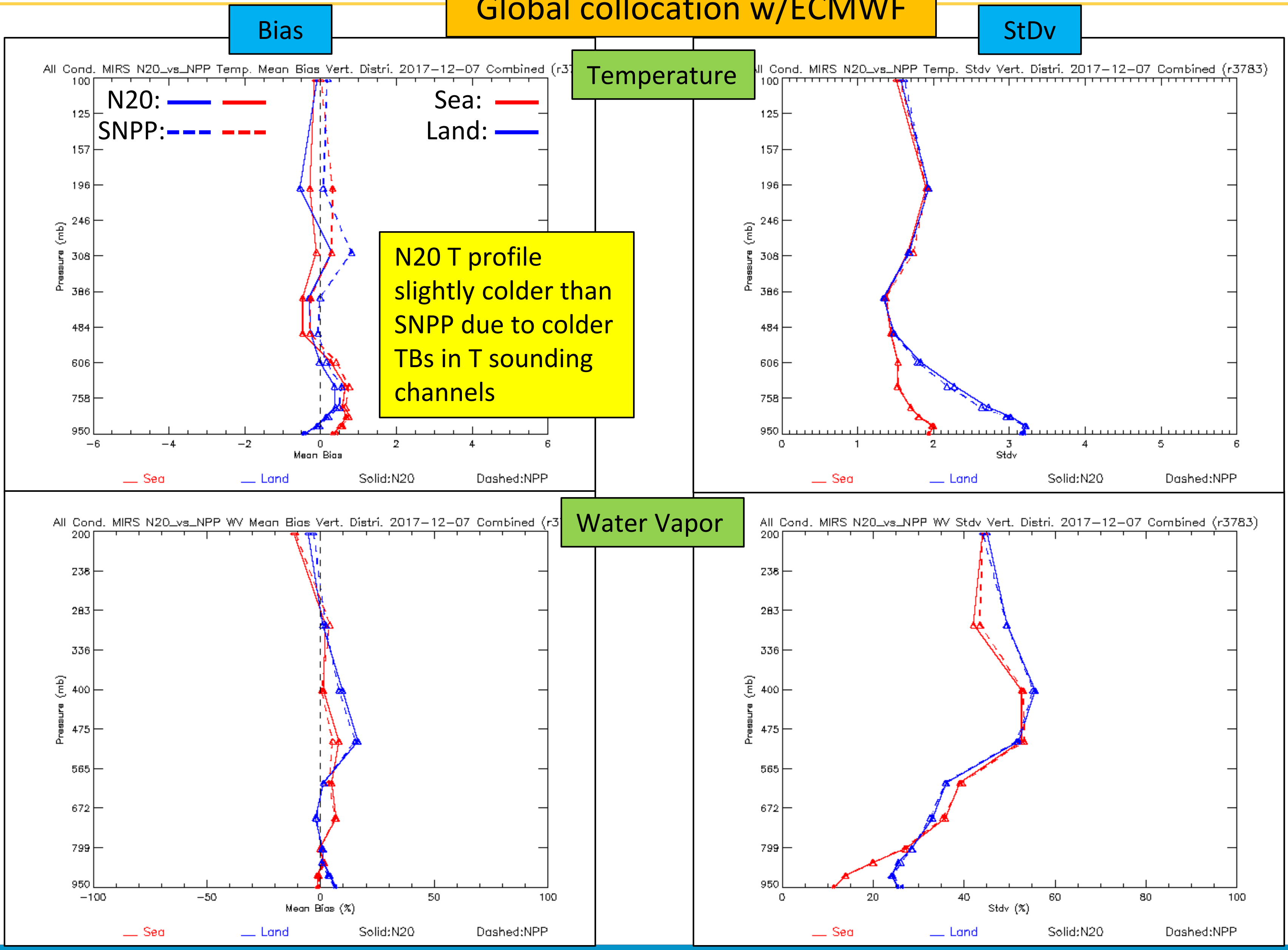
# Summary

- Continued N20 validation indicates **extremely good agreement** with SNPP, and performance against external references very similar to SNPP; additional validation necessary
- Validation maturity status: Provisional maturity
- MiRS v11.3: Extension to N20 ATMS processing, delivered to OSPO/NDE on 8 June
- Path Forward
  - Continued validation, e.g. rain rate, CLW, cryosphere, T, WV,…
  - Additional DAP delivery in late 2018 (updated radiometric bias corrections, possible science improvements)
  - Extend to MetopC in 2019, JPSS-2, etc.
  - Science improvements (e.g. surface classification, bias correction, rainy sounding)
  - Longer term: EON-MW (SmallSats), Metop-SG (sounding, surface, and ice cloud missions)
  - Stakeholders/user needs; <u>continue collaboration with applications developers and users</u>…
- MiRS data available at CLASS, and STAR ftp (S-NPP/ATMS, NOAA-20/ATMS, GPM/GMI)
- Software package available for download **https://www.star.nesdis.noaa.gov/mirs**

# Extra Slides

# Temperature and Water Vapor Profile (2017-12-07)

Global collocation w/ECMWF



# Potential $NO_2$ Application to Support NWS $O_3$ Forecasting

**Pius Lee**
NOAA National Air Quality Forecast Capability (NAQFC)
NOAA Air Resources Lab

**With contribution from:**

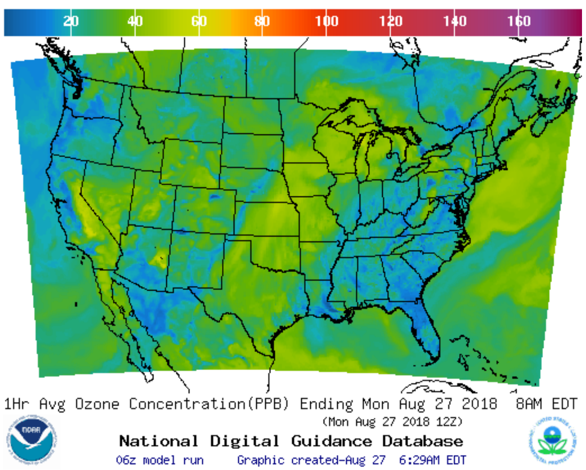
**ARL Team: Daniel Tong, Li Pan, Charles Ding, Youhua Tang and Pius Lee**
**NWS: Ivanka Stajner and Jeff McQueen**
**NESDIS: Shobha Kondragunta, Larry Flynn**
**NASA: Lok Lamsal and Kenneth E. Pickering**

# NOAA National Air Quality Forecast Capability (NAQFC)

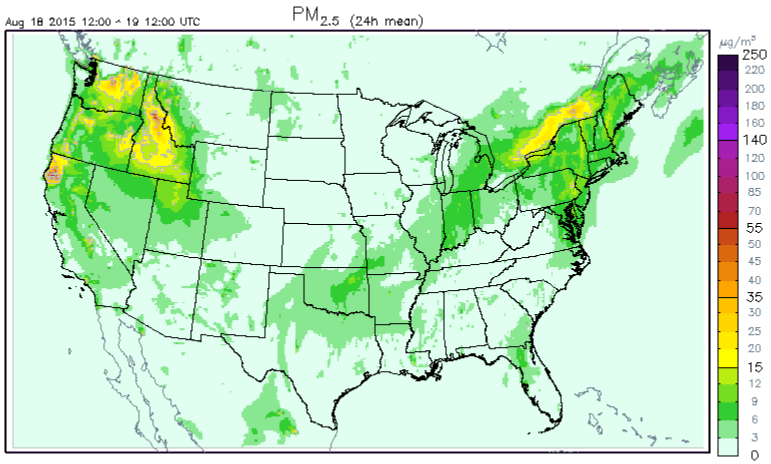
- **Developed by OAR/Air Resources Laboratory; Operated by National Weather Service (NWS) (PM: I. Stajner).**

- **Provides national numerical air quality guidance for ozone (operational product) and $PM_{2.5}$ (particulate matter with diameter < 2.5 $\mu$m);**

**$O_3$ Forecasting**




**$PM_{2.5}$ Forecasting**




**http://airquality.weather.gov/**

**<u>NAQFC is one of the major gateways to disseminate NOAA satellite observations and model prediction of air quality to the public.</u>**

# Challenges in NAQFC Emission Forecasting

- **Time lag is a major obstacle for NAQFC emission forecasting.**

**Forecasters want:** ***emission of tomorrow;***

**Data availability:** ***emission data 4+ years old*****.**
**(three years labor, one year QA, post-processing and release).**

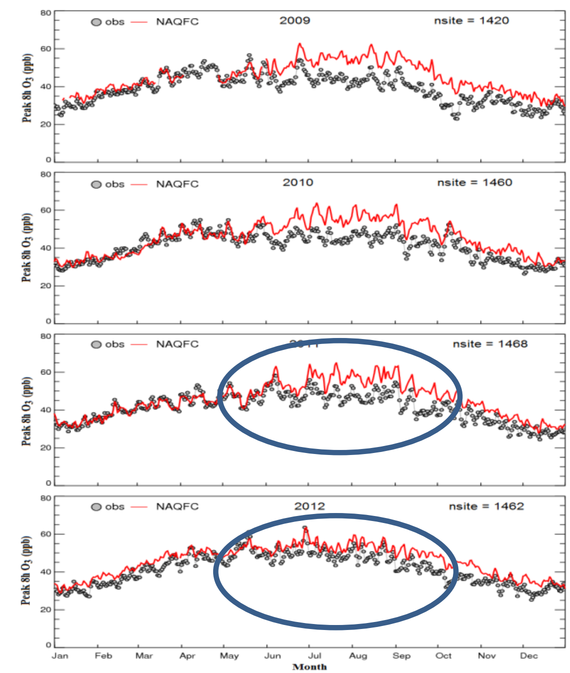
## How to overcome this problem?

- **NAQFC Practices:**

**Option 1, no update (2007-2011) - Dear price paid;**

**Option 2, use EPA emission projection (2012-2015).**

***Option 3, emission data assimilation (2016-?).***




**(Tong et al., Atmos. Environ. 2015)**

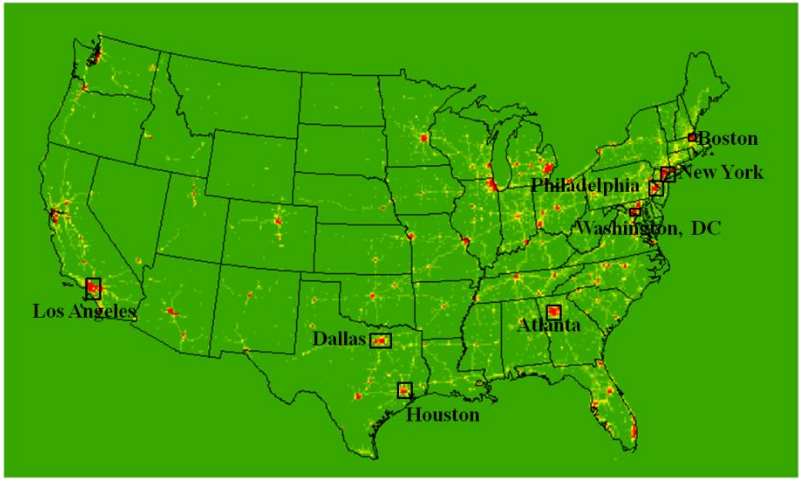
# Impact of the Great Recession on US Air Quality

- **Starting – Ending time: December 2007 – October 2009;**
- **Cause: Bursting of the housing bubble in 2007, followed by a subprime mortgage crisis in 2008;**
- **Impacts:**
  - **Unemployment rate: 4.7% in Nov 2007 → 10.1% in Oct 2009.**
  - **Income level: dropped to 1996 level after inflation adjustment;**
  - **Poverty rate: 12% → 16% (50 millions);**
  - **GDP: contract by 5.1%;**
- **Worst economic recession since the Great Depression**

**Question: What does it mean to Air Quality (and Emissions)?**

# Methodology

- **Emission Indicator – Urban NOx in Summer**
  - **Short lifetime → proximity to emission sources**
  - **Urban NO2 dominated by local sources;**
  - **High emission density → low noise/signal ratio;**
- **NOx Data sources**
  - **Satellite remote sensing (OMI-Aura NO2).**
  - **Ground monitoring (EPA AQS NOx);**
  - **Emission data ( NOAA National Air Quality Forecast Capability operational emissions);**
- **Deriving the trend:** $(Y2-Y1)/Y1 \times 100\%$
- **Selection of urban areas**

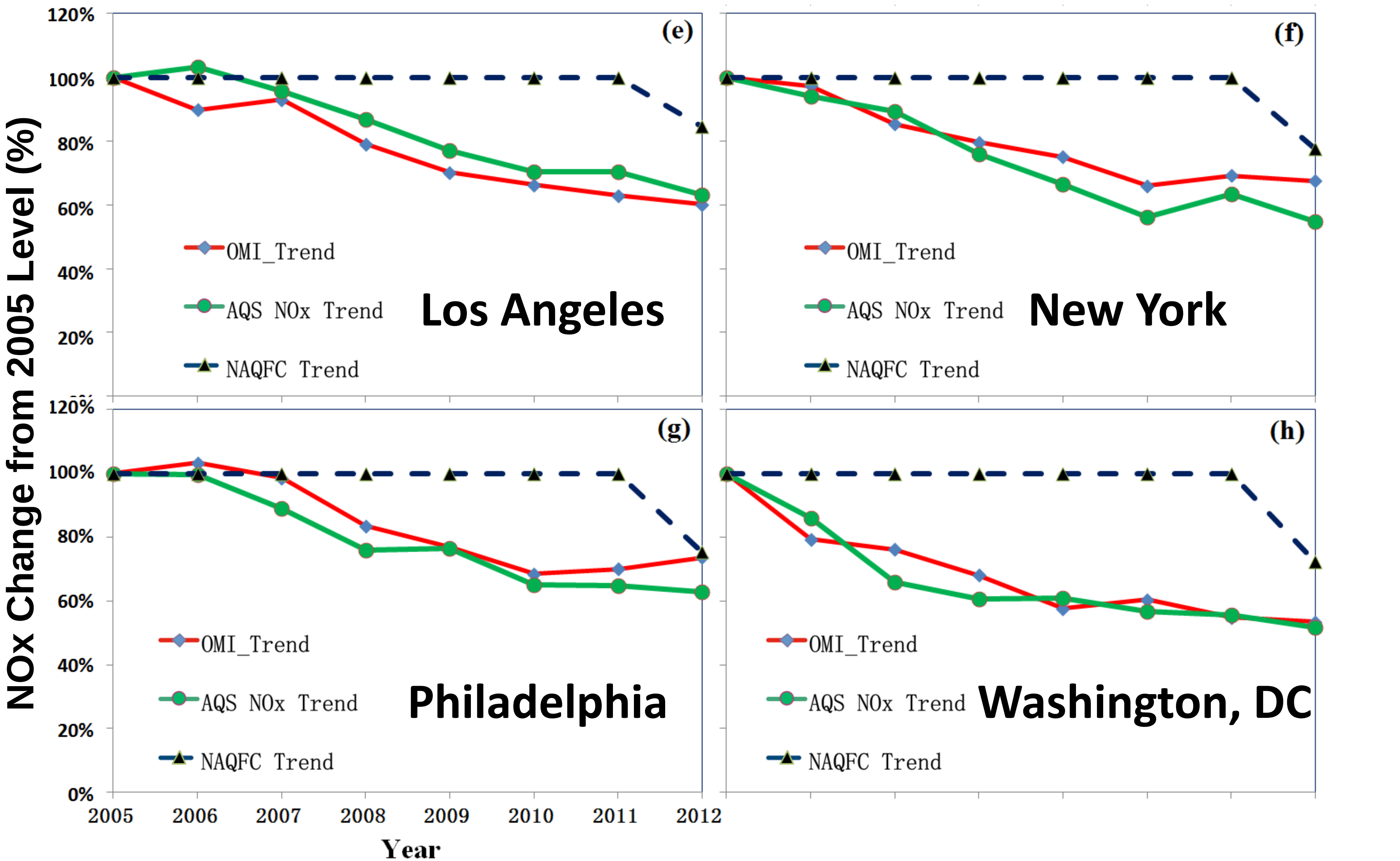


# NOx Changes
# Prior to, during and after the Recession

| Stage | Sources | Atlanta | Boston | Dallas | Houston | Los Angeles | New York | Philadel-phia | Washing-ton, DC | Mean |
|---|---|---|---|---|---|---|---|---|---|---|
| Before | OMI SP | -11.7 | -9.4 | -7.5 | -5.7 | -3.3 | -7.5 | -0.6 | -12.3 | -7.3 |
| | AQS | -9.9 | -2.1 | -5.2 | 0.7 | -2.0 | -5.5 | -5.5 | -18.7 | -6.0 |
| During | OMI SP | -5.5 | -7.5 | -8.9 | -7.9 | -13.1 | -6.2 | -11.7 | -13.0 | -9.2 |
| | AQS | -17.5 | -7.0 | -13.0 | -14.0 | -10.3 | -13.6 | -7.0 | -3.7 | -10.8 |
| After | OMI SP | -6.0 | -3.3 | -2.1 | 0.4 | -5.0 | -3.2 | -1.2 | -2.3 | -2.8 |
| | AQS | 1.4 | -6.1 | 0.1 | 0.2 | -6.4 | -5.4 | -6.1 | -5.3 | -3.4 |

- **Distinct regional difference;**
- **Average NOx changes are consistent for OMI and AQS data;**
- **-6%/yr - -7%/yr prior to Recession;**
- **-9%/yr - -11%/yr during Recession;**
- **-3%/yr after Recession (Recovery?).**

# Inter-Comparison of OMI, AQS and NAQFC



# Feasibility Study: Emission Data Assimilation

**(Project funded by OAR USWRP program, PM: J. Cortinas)**

***Can satellite data be used to rapidly refresh NOx emission?***

**Approach: Replace EPA projection factors by observation-based factors**

**Use both satellite and ground observations;**

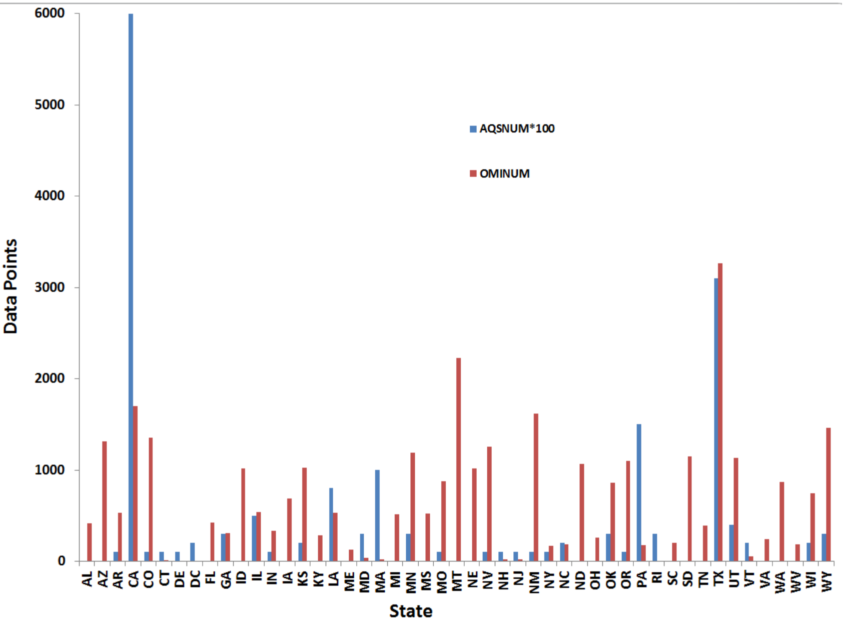
**Optimal data fusion algorithm.**

$$AF = \frac{\Delta S \times f_S + \Delta G \times f_G}{N_S \times f_S + N_G \times f_G}$$

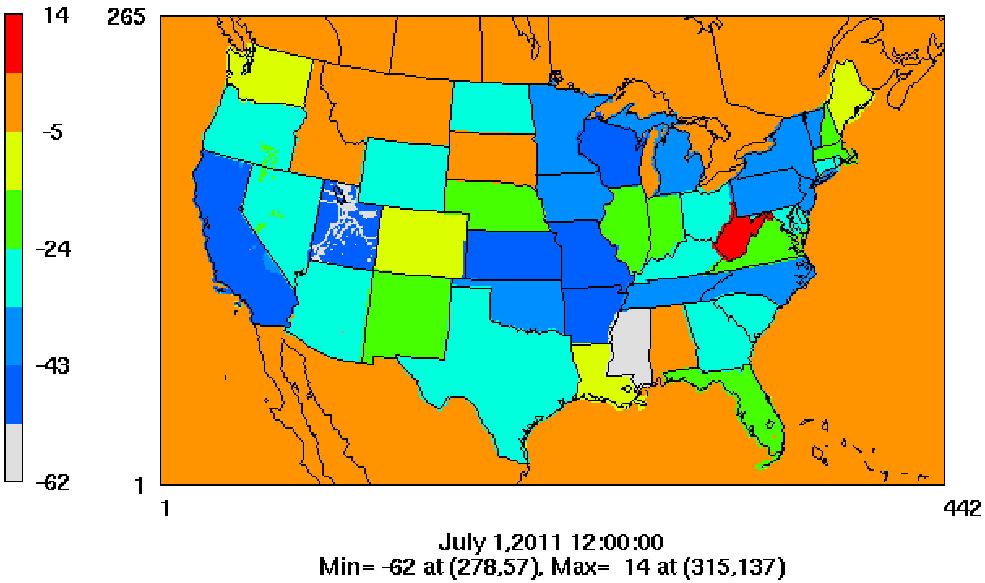
$\Delta S$ and $N_S$ - changing rate and data number of satellite data;
$\Delta G$ and $N_G$ -- rate and number of ground data;
$f_S$ and $f_G$ -- weighting factors for satellite and ground data;

# Why both satellite and ground observations?

## Comparison of OMI and AQS (x100) Samples



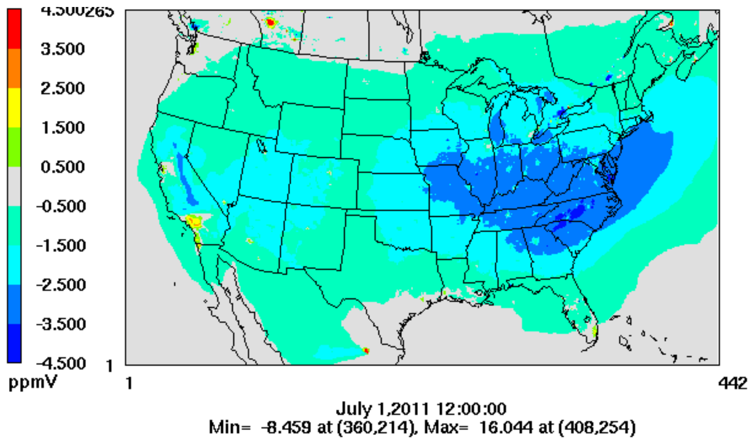

## State-level Projection Factors from OMI and AQS



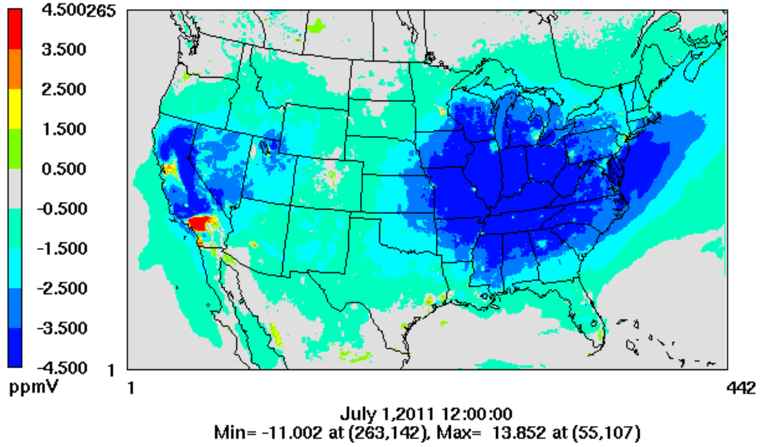

**OMI Preprocessing: 1) Quality filter; 2) Set a cut-off value; 3) Calculate lower and higher 25% percentiles**

# Performance Evaluation of NAQFC $O_3$ Forecasting

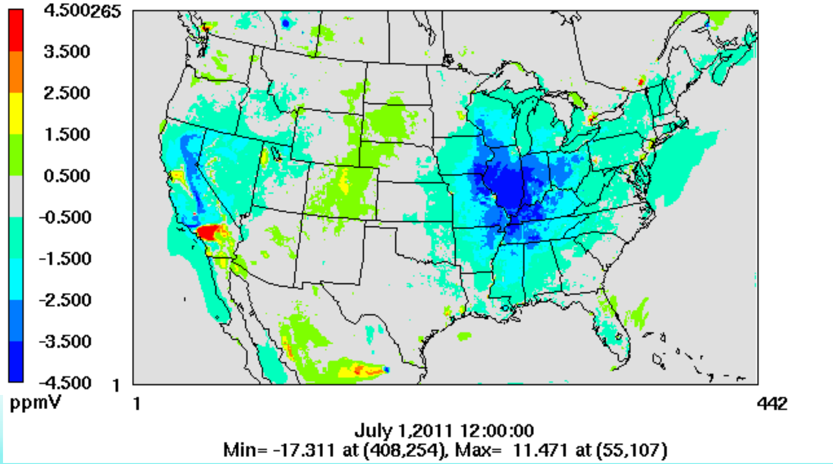
## Effect of Using EPA Projection




## Effect of Using New Factors




## Difference



# Model Performance Evaluation

## Performance Metrics

| | | | MOD_MEAN | | | RMSE | | | NME | | | MB | | | NMB | | | R | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TYPE | COUNT | OBS_MEA | BASE | NEI2012 | JPSS | BASE | NEI2012 | JPSS | BASE | NEI2012 | JPSS | BASE | NEI2012 | JPSS | BASE | NEI2012 | JPSS | BASE | NEI2012 | JPSS |
| Hourly | | AQS | NEI2005 | PROJ2012 | NOx_EDA | NEI2005 | PROJ2012 | NOx_EDA | NEI2005 | PROJ2012 | NOx_EDA | NEI2005 | PROJ2012 | NOx_EDA | NEI2005 | PROJ2012 | NOx_EDA | NEI2005 | PROJ2012 | NOx_EDA |
| CONUS | 15930 | 40.09 | 52.37 | 52 | 51.58 | 23.25 | 23.07 | 22.68 | 43.11 | 42.83 | 41.94 | 12.28 | 11.91 | 11.49 | 30.63 | 29.71 | 28.67 | 0.57 | 0.56 | 0.58 |
| NE | 2055 | 39.83 | 40.41 | 39.94 | 39.57 | 14.38 | 14.39 | 14.27 | 26.71 | 26.82 | 26.42 | 0.59 | 0.11 | -0.25 | 1.47 | 0.28 | -0.63 | 0.61 | 0.61 | 0.62 |
| SE | 2805 | 45.7 | 58.11 | 57.38 | 56.97 | 24.01 | 23.8 | 23.17 | 40.39 | 40.42 | 39.12 | 12.41 | 11.68 | 11.28 | 27.16 | 25.56 | 24.67 | 0.51 | 0.5 | 0.53 |
| UM | 3615 | 46.74 | 57.94 | 57.54 | 56.02 | 23.11 | 22.82 | 22.09 | 35.38 | 34.86 | 33.75 | 11.2 | 10.8 | 9.27 | 23.96 | 23.09 | 19.84 | 0.48 | 0.48 | 0.49 |
| LM | 2190 | 32.35 | 53.15 | 52.99 | 52.16 | 27.32 | 27.17 | 26.4 | 68.74 | 68.32 | 66.09 | 20.8 | 20.64 | 19.81 | 64.31 | 63.8 | 61.23 | 0.57 | 0.56 | 0.58 |
| RM | 1560 | 43.38 | 55.25 | 55.09 | 55.34 | 22.83 | 22.61 | 22.73 | 37.63 | 37.28 | 37.54 | 11.87 | 11.71 | 11.96 | 27.36 | 27 | 27.57 | 0.56 | 0.57 | 0.57 |
| PC | 2160 | 39.06 | 54.24 | 54.57 | 55.61 | 26.63 | 26.63 | 26.85 | 49.62 | 49.78 | 49.83 | 15.18 | 15.52 | 16.55 | 38.87 | 39.72 | 42.37 | 0.65 | 0.66 | 0.68 |

| | | | MOD_MEAN | | | RMSE | | | NME | | | MB | | | NMB | | | R | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Max 8hr | | AQS | NEI2005 | PROJ2012 | NOx_EDA | NEI2005 | PROJ2012 | NOx_EDA | NEI2005 | PROJ2012 | NOx_EDA | NEI2005 | PROJ2012 | NOx_EDA | NEI2005 | PROJ2012 | NOx_EDA | NEI2005 | PROJ2012 | NOx_EDA |
| CONUS | 1062 | 48.57 | 59.32 | 58.44 | 58.32 | 21.85 | 21.52 | 21.44 | 31.73 | 31.19 | 31.11 | 10.75 | 9.87 | 9.74 | 22.13 | 20.32 | 20.06 | 0.52 | 0.51 | 0.52 |
| NE | 137 | 47.36 | 46.35 | 45.22 | 45.16 | 11.29 | 11.61 | 11.57 | 18.78 | 18.91 | 18.83 | -1.02 | -2.15 | -2.21 | -2.15 | -4.53 | -4.66 | 0.77 | 0.77 | 0.75 |
| SE | 187 | 56.42 | 63.83 | 62.52 | 62.77 | 19.62 | 19.19 | 18.91 | 25.75 | 25.51 | 25.07 | 7.4 | 6.1 | 6.34 | 13.12 | 10.8 | 11.24 | 0.51 | 0.49 | 0.53 |
| UM | 241 | 55.32 | 64.33 | 63.25 | 61.94 | 20.83 | 20.49 | 20.15 | 25.04 | 24.71 | 24.57 | 9.01 | 7.93 | 6.61 | 16.28 | 14.33 | 11.96 | 0.48 | 0.47 | 0.46 |
| LM | 146 | 39.47 | 62.72 | 62.09 | 61.45 | 29.32 | 28.95 | 28.23 | 60.42 | 59.25 | 57.61 | 23.25 | 22.61 | 21.97 | 58.89 | 57.28 | 55.66 | 0.43 | 0.4 | 0.43 |
| RM | 104 | 51.88 | 61.85 | 60.98 | 61.65 | 21.11 | 20.61 | 20.98 | 26.16 | 25.35 | 25.93 | 9.97 | 9.1 | 9.77 | 19.21 | 17.53 | 18.83 | 0.44 | 0.45 | 0.45 |
| PC | 144 | 49.61 | 63.96 | 63.9 | 65.3 | 25.75 | 25.62 | 26.42 | 34.75 | 34.34 | 35.44 | 14.36 | 14.3 | 15.69 | 28.94 | 28.82 | 31.63 | 0.52 | 0.53 | 0.54 |

**Prediction with the new assimilated emission data outperforms the current operational system.**

# Remaining Issues with $NO_2$ data assimilation

- NO2 Vertical Column Density != local emissions
- Pixel by pixel adjustment → emissions adjusted at wrong places;
- More problematic with high-res modeling;

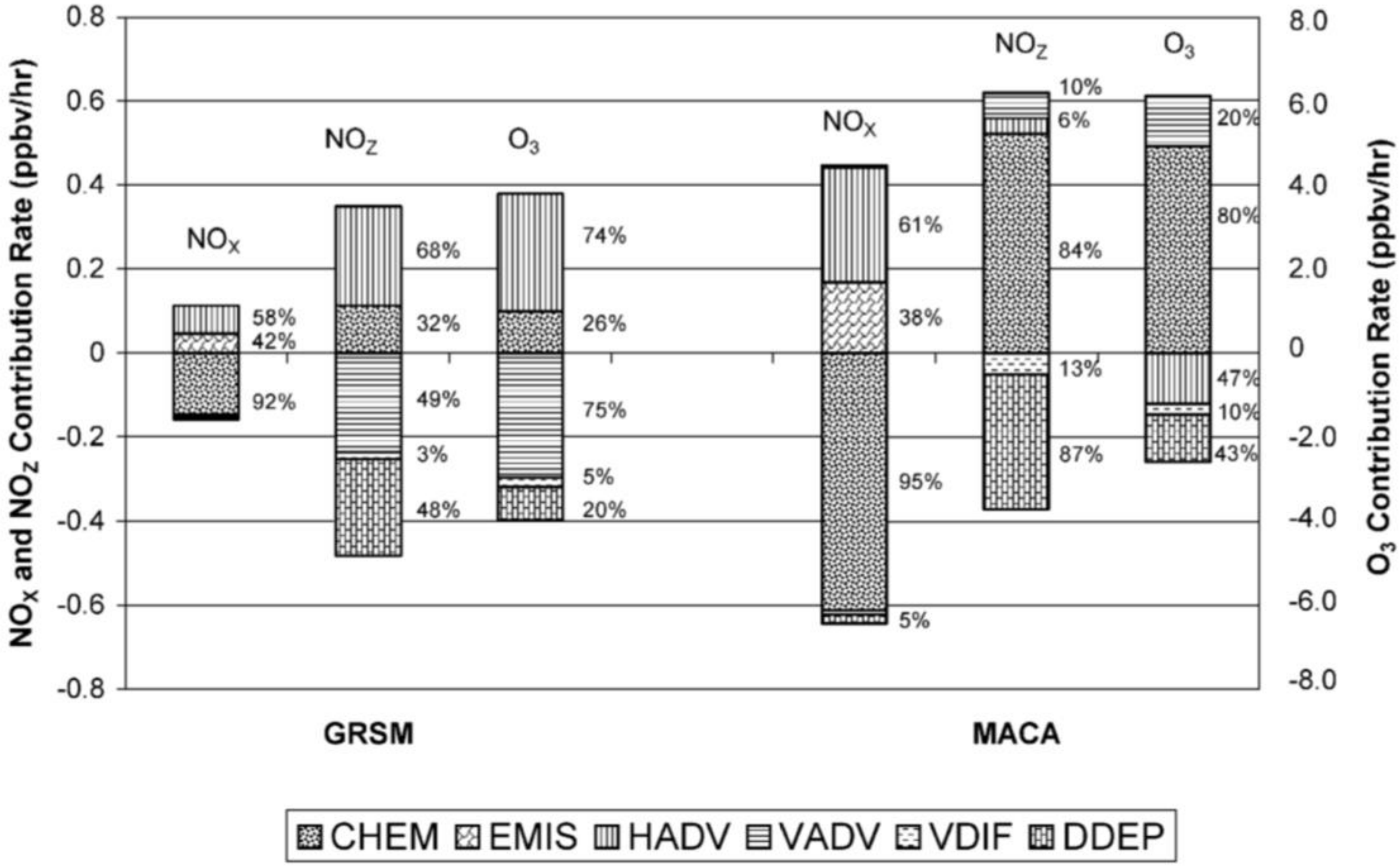
Need to consider contribution of emission, chemistry and transport to NO2 vertical column density.

# Process Budget Analysis

- Eulerian models utilize the technique of operator splitting.
- In operator splitting, partial differential equations (PDEs) are solved by separating the continuity equation for each species into several simpler PDEs or ordinary differential equations (ODEs) that give the impact of only one or two processes.
- These simpler PDEs or ODEs are then solved separately to arrive at the final concentration.
- As a result, it is relatively easy to obtain quantitative information about the contribution of individual processes to total concentrations.

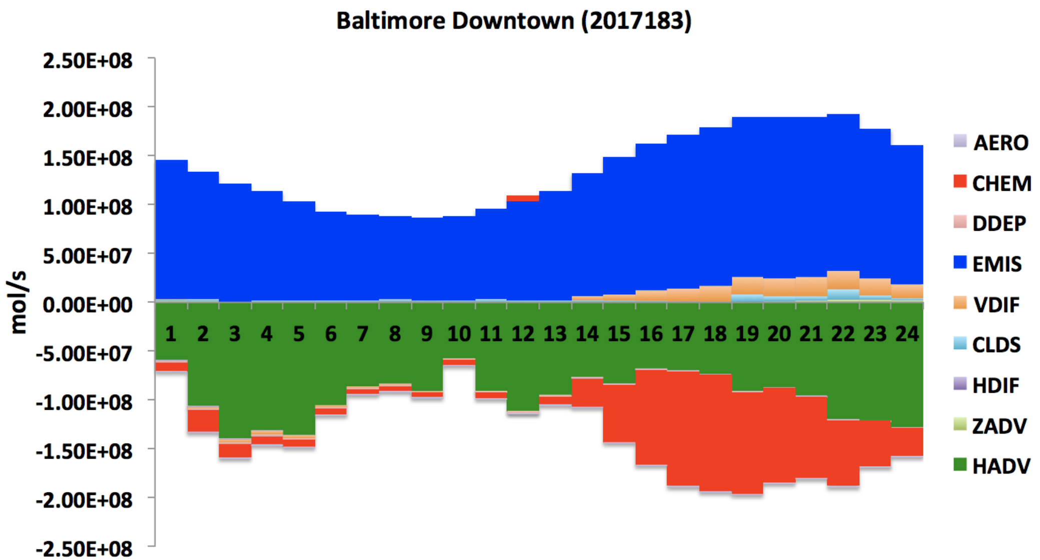
(Jeffries and Tonneson, 1994)

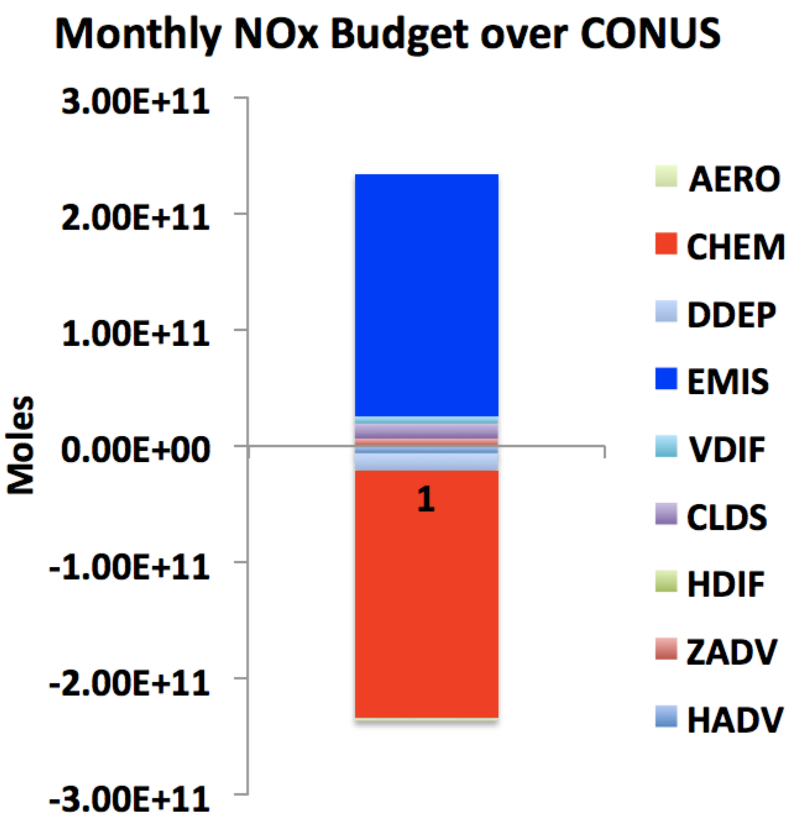
# Process Budget Analysis




(Tong et al., 2005)

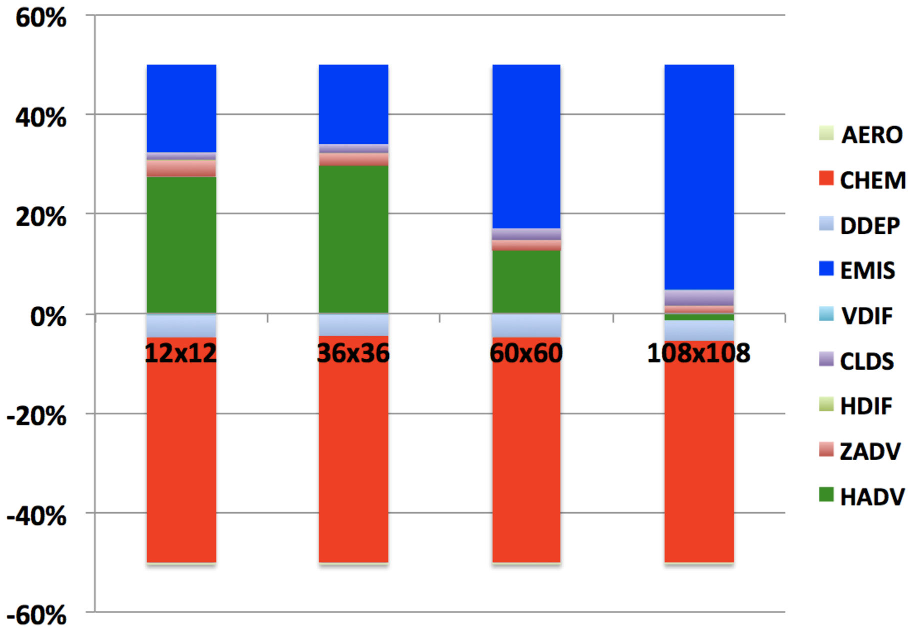
# Process Budget of NOx over CONUS



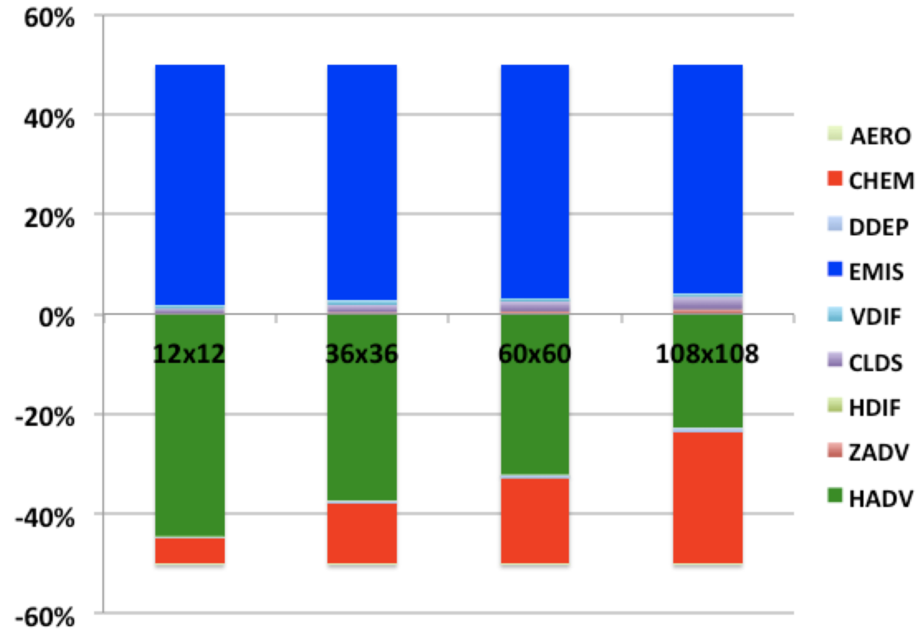




**Chemistry (CHEM), Emission (EMIS) and Transport (Horizontal Advection - HADV) are the dominant processes to determine NOx budget locally and nationally.**

# Process Budget vs Model Resolution




(Rural Area)



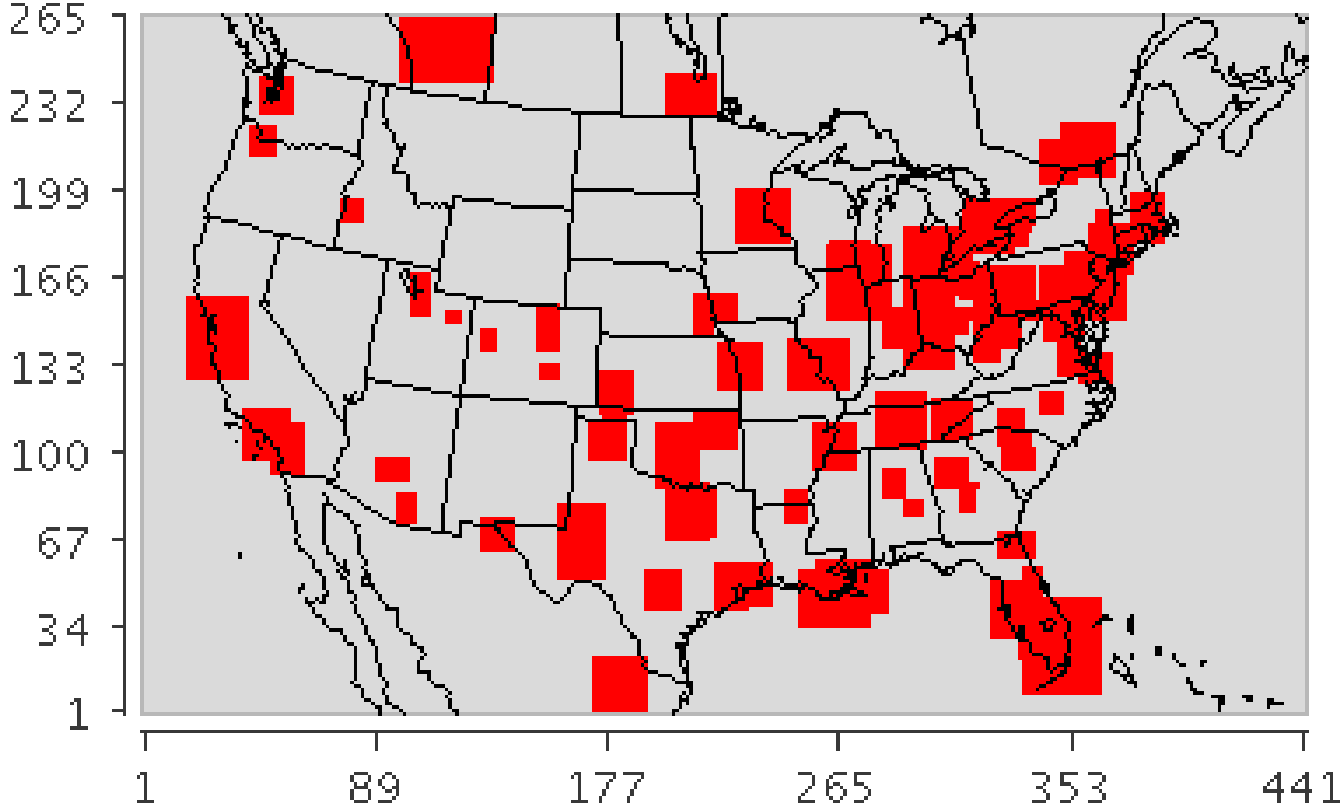

(New York City)

- Local emission dominates NOx build-up in urban areas, but transport is more influential in rural areas;
- Transport influence decreasing with lower model resolution.

# Process-aware Chemical Regimes for $NO_2$ Data Assimilation

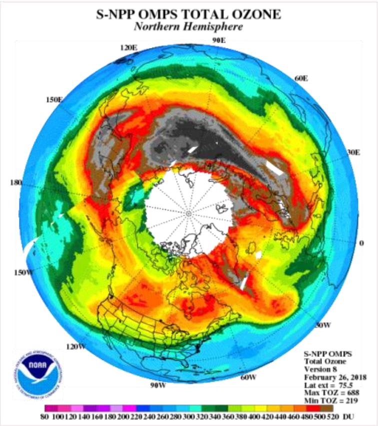
**Criteria:**

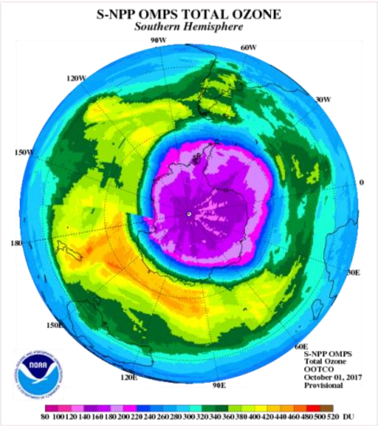
1) Emission contribution >= 75%;
2) Outflow <= 25%;
3) What else?



# Summary & Future Plan

- Satellite observations can be used to detect emission changes consistent with ground observations;
- Demonstrate the feasibility of assimilating satellite and ground observations to rapidly update anthropogenic emissions;
- The assimilated emission data can improve NAQFC forecasting capability, outperforming the current operational system.
- A new budget-aware emission data assimilation algorithm is being developed at ARL to assimilate satellite NO2 data into air quality forecasting models.




# NCEP usage of OMPS EDR

Craig S. Long[1]

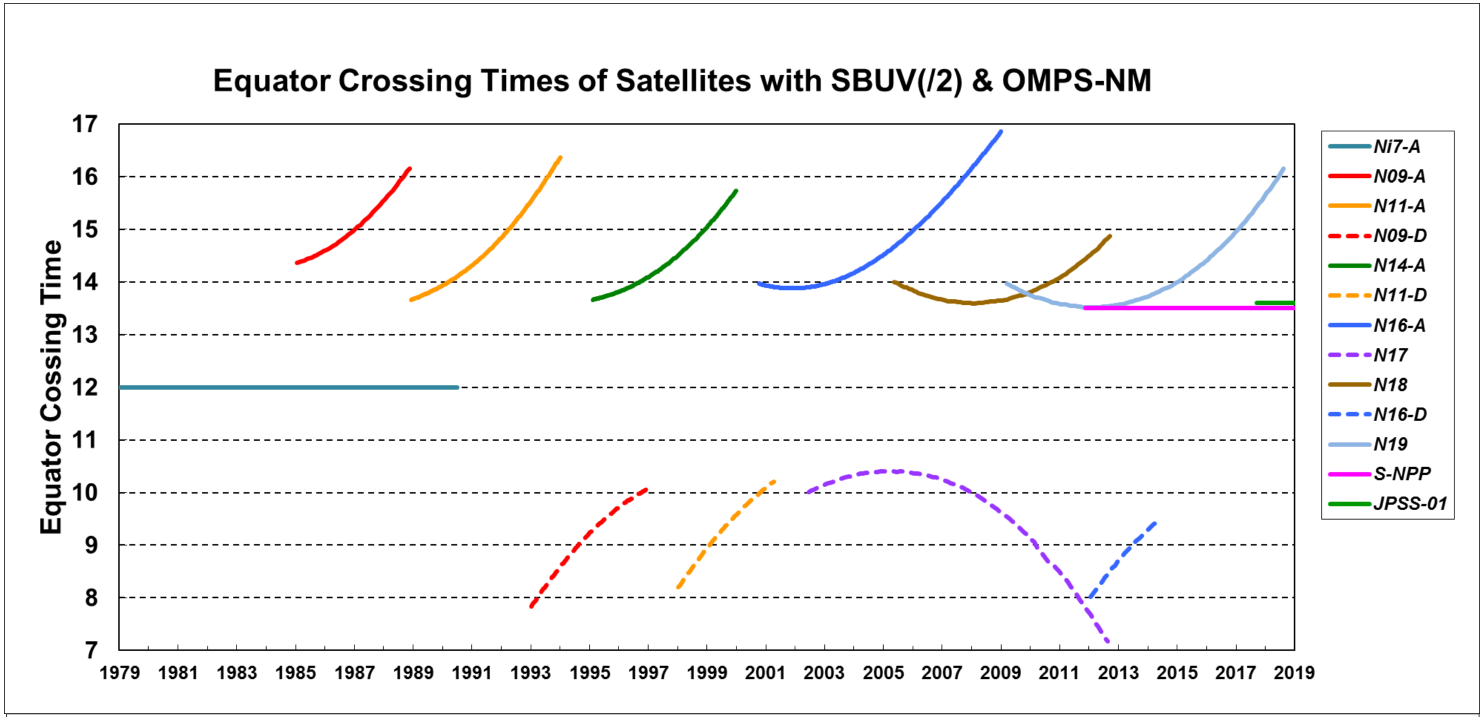
Jeannette Wild[1], Hiaxia Liu[2]

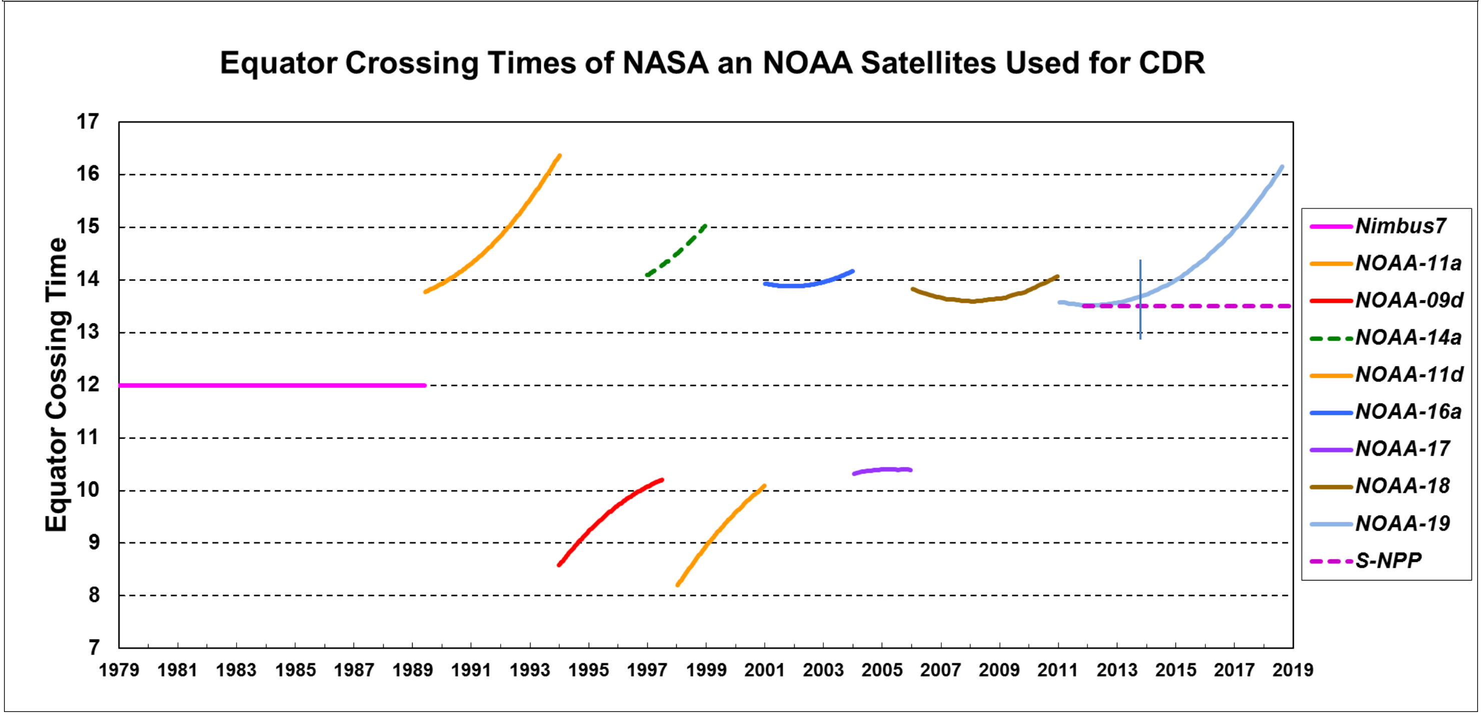
*[1]NCEP/Climate Prediction Center*

*[2]NCEP/Environmental Modeling Center*

# Ozone Monitoring and Data Assimilation

- OMPS-NP extends the climate monitoring initiated using the SBUV(/2)
  - 1979-present : *combining Nimbus-7, N11, N9, N14, N16, N17, N18, N19, NPP*
  - Ozone depletion / Ozone Recovery
  - Effects of climate change on ozone trends at various parts of stratosphere
  - Complete reprocessing is needed when changes made to ozone processing
- Ozone Hole monitoring
  - OMPS stable orbit is welcome compared to drifting orbit of earlier NOAA POES.
  - Addition of Nadir Mapper enhances NOAA's ability to monitor the ozone hole.
- Assimilation into NCEP/Global Forecast System
  - Currently assimilating N19 SBUV/2 profile and NASA OMI total column ozone
    - Large number of OMI's scan positions are unusable.
  - NPP NP and NM v8 products became available in December 2017
    - Monitoring mode
    - Need to replace N19 SBUV/2 (declining area coverage due to orbital drift)
  - NPP LP product test data made available.


Equator Crossing Times of Satellites with SBUV(/2) & OMPS-NM
Equator Cossing Time
17
16
15
14
13
12
11
10
9
8
7
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
2015
2017
2019
Ni7-A
N09-A
N11-A
N09-D
N14-A
N11-D
N16-A
N17
N18
N16-D
N19
S-NPP
JPSS-01


Equator Crossing Times of NASA an NOAA Satellites Used for CDR
Equator Cossing Time
17
16
15
14
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12
11
10
9
8
7
1979
1981
1983
1985
1987
1989
1991
1993
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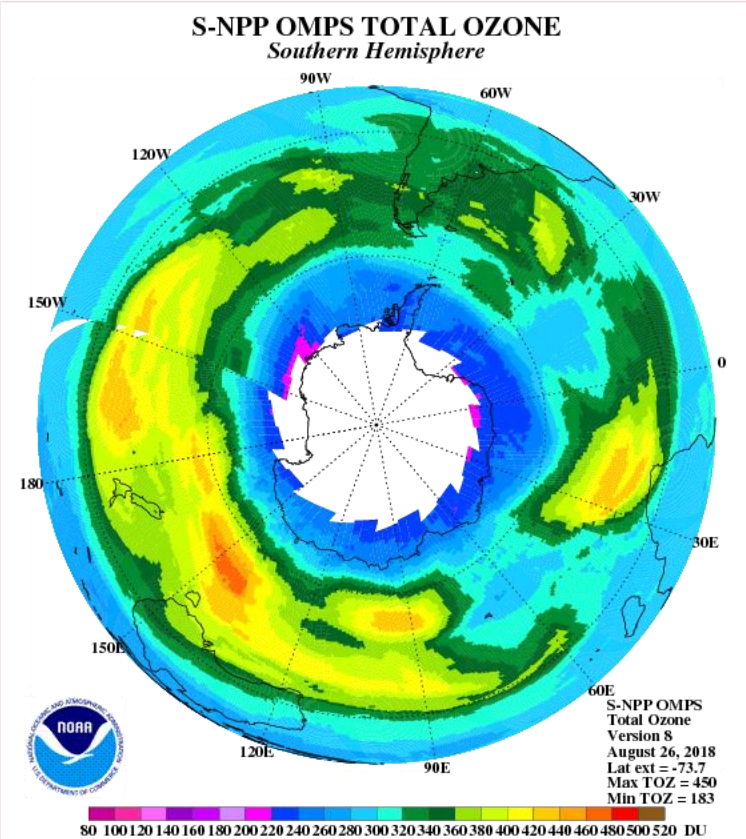
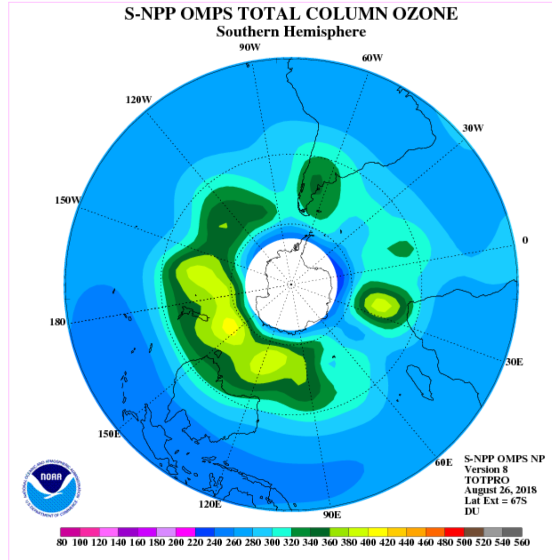
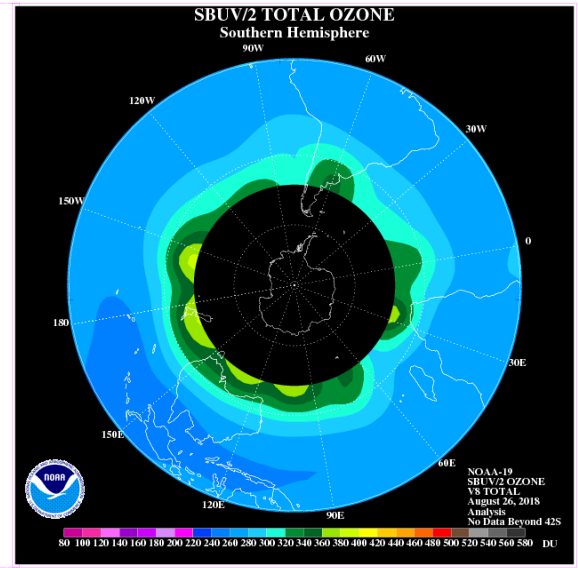
2005
2007
2009
2011
2013
2015
2017
2019
Nimbus7
NOAA-11a
NOAA-09d
NOAA-14a
NOAA-11d
NOAA-16a
NOAA-17
NOAA-18
NOAA-19
S-NPP

# Ozone Product Imagery

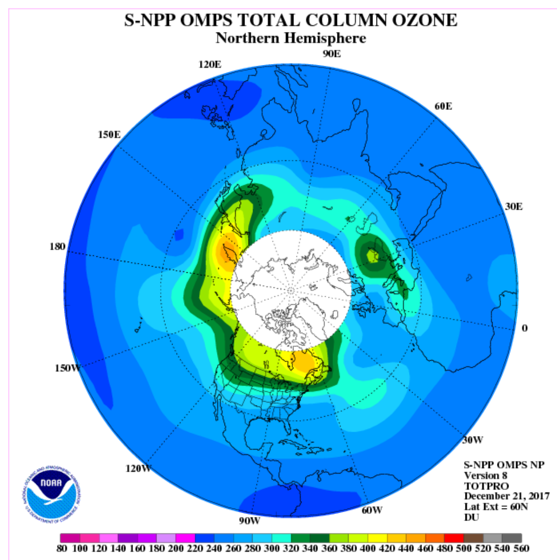


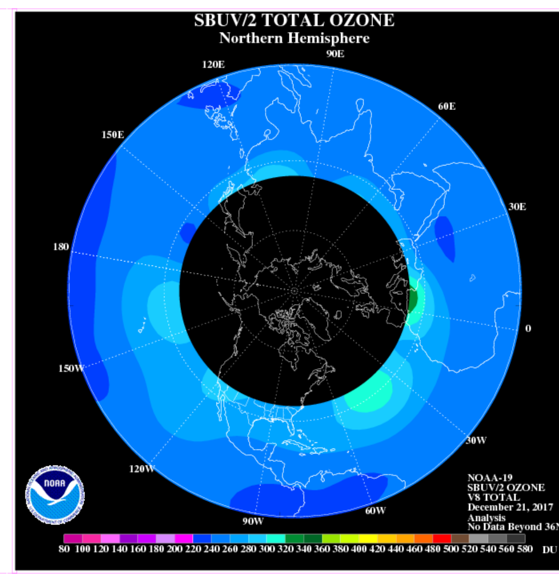

Current SH : 67S vs 42S




NH Solstice : 60N vs 36N



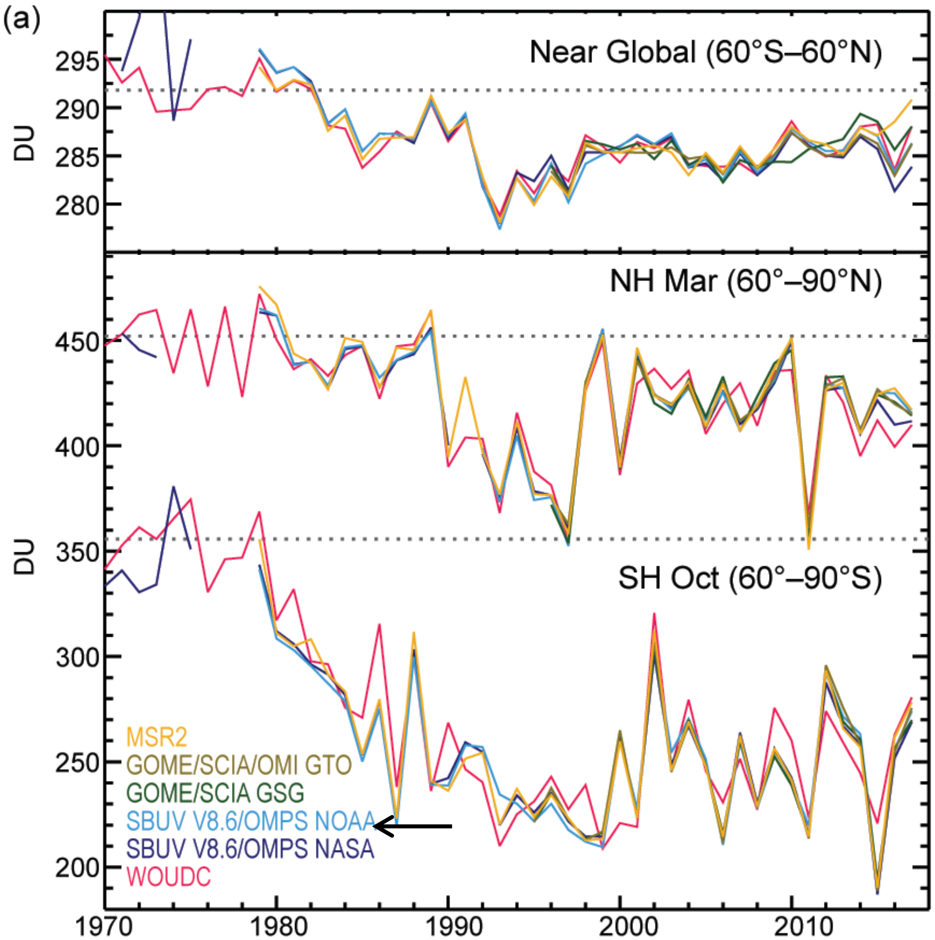




OMPS has greater area coverage than N19 SBUV/2

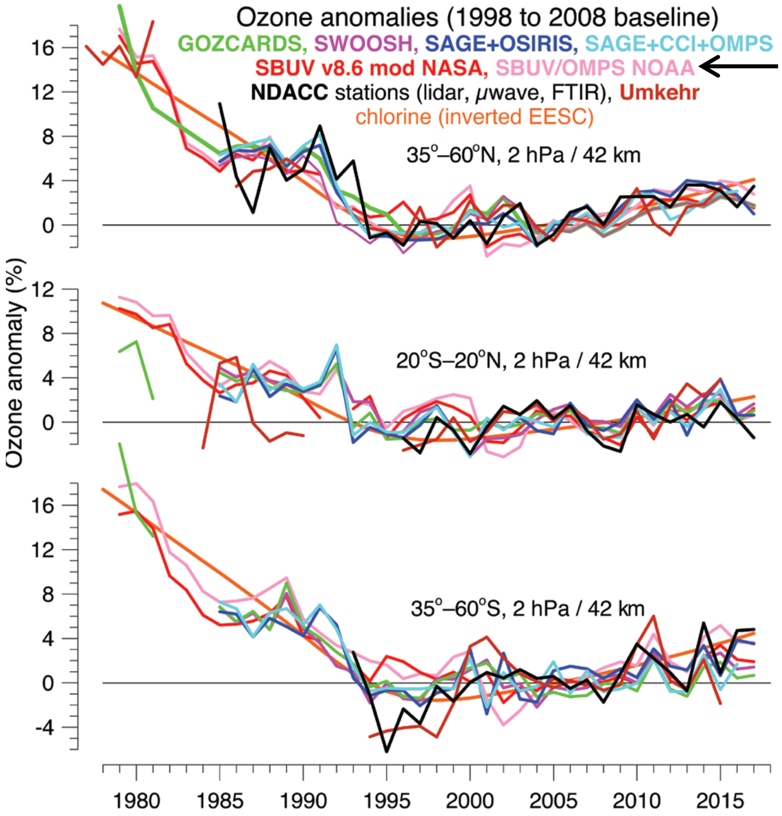
Cressman analyses using NP data

# Ozone CDR used in State of Climate Assessment

***Total Column Ozone***

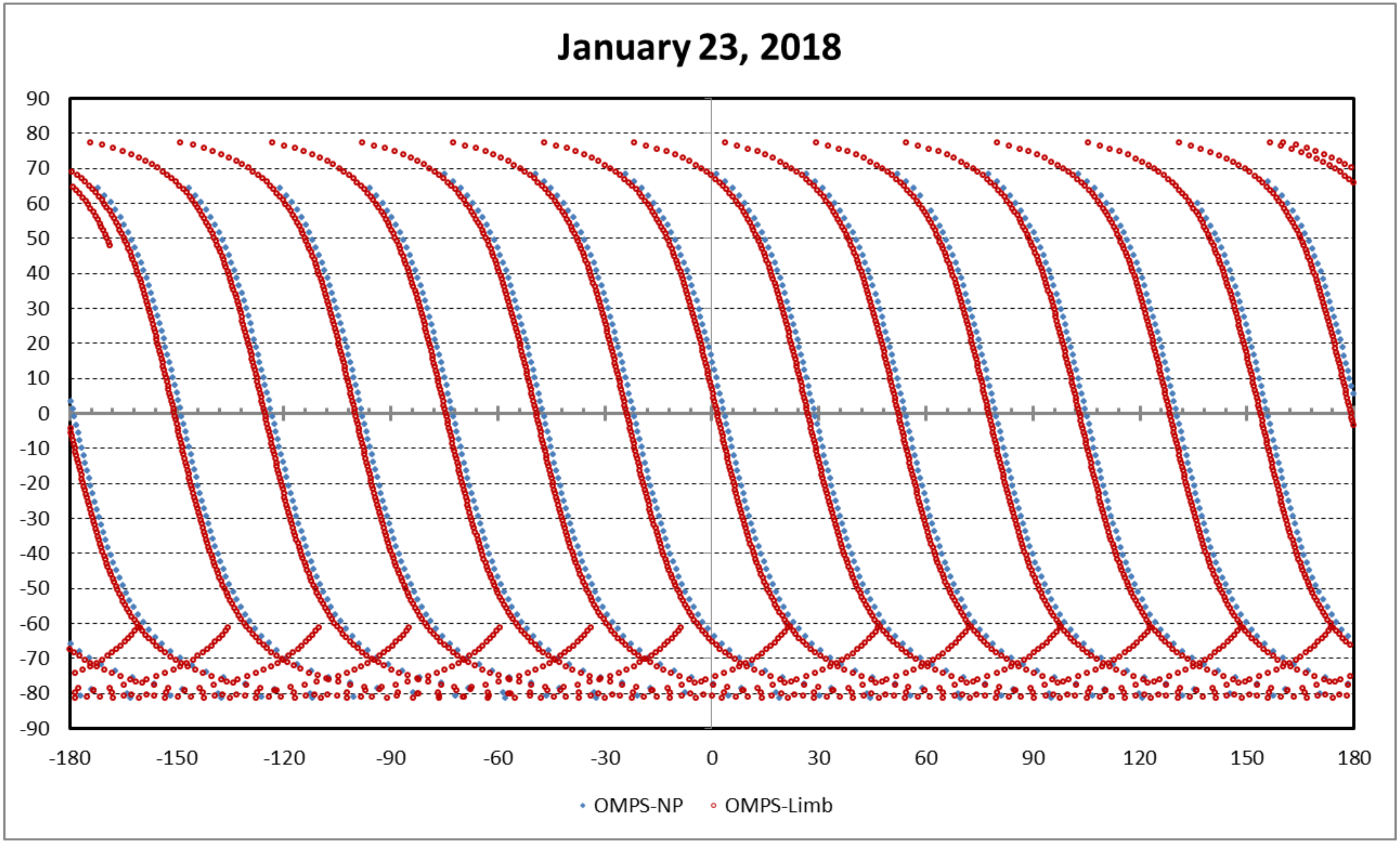



***2hPa Ozone mixing ratio***



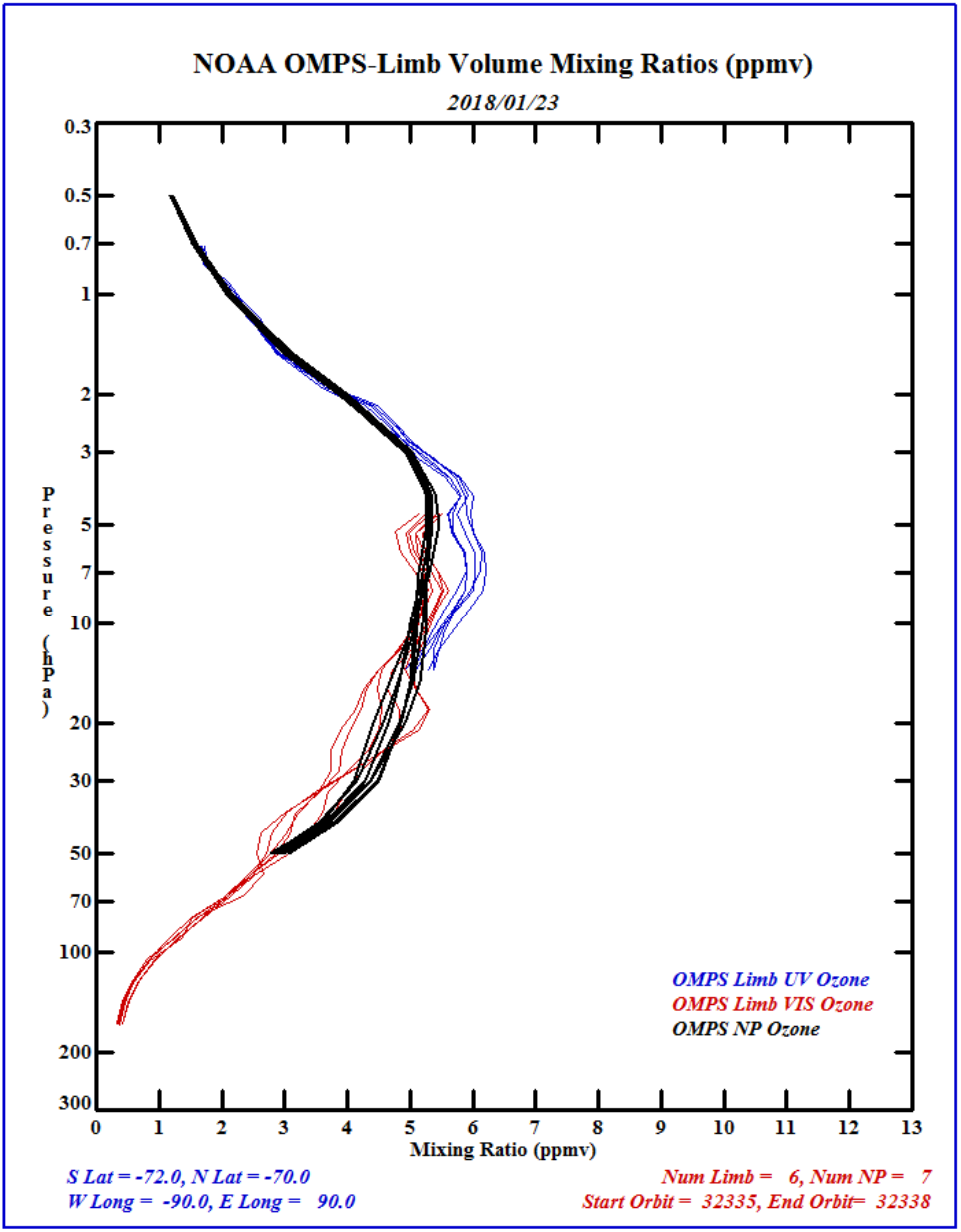

*OMPS contribution for data set used here uses NASA products*

# Lat/Lon locations of Limb and NP profiles

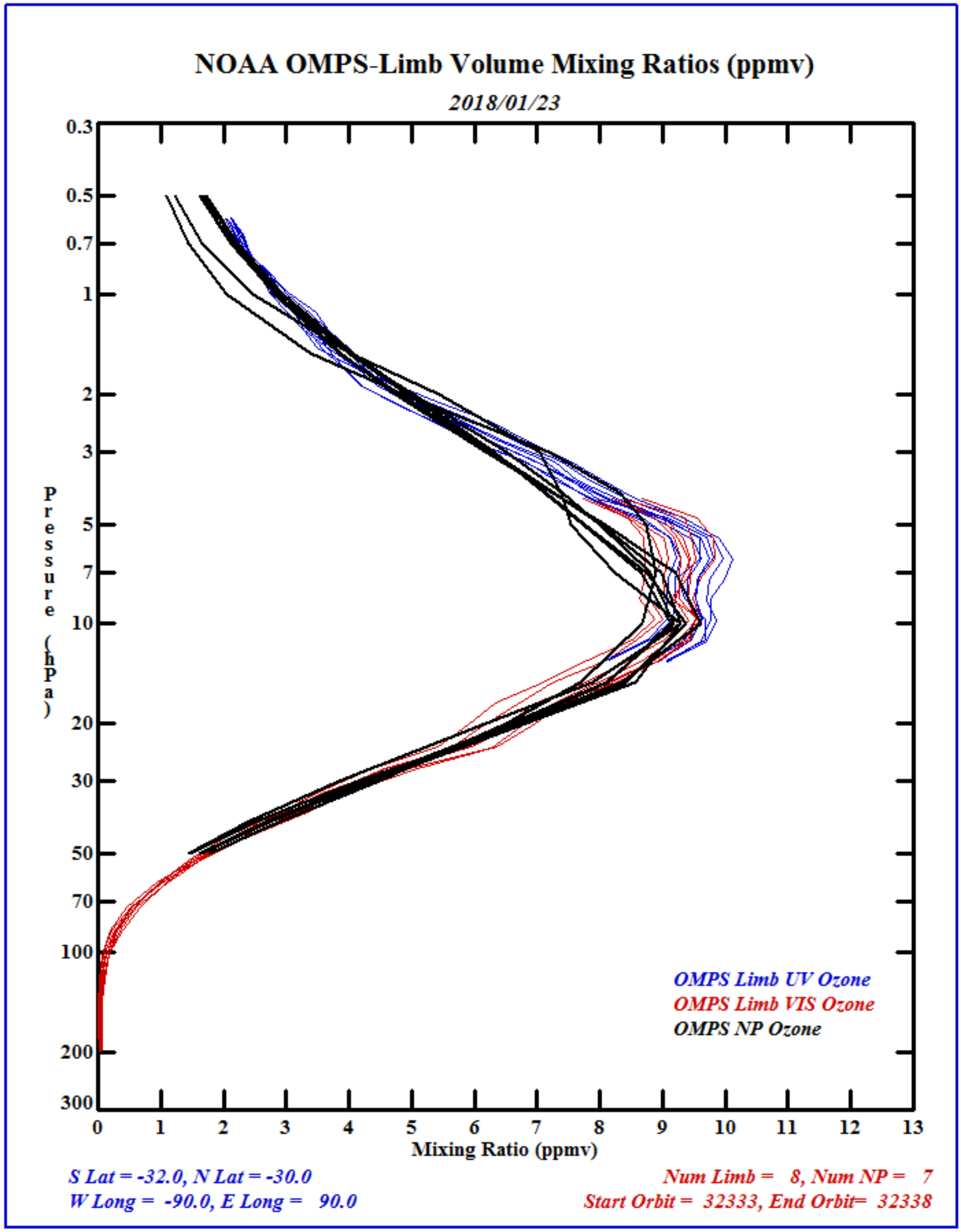


# OMPS-Limb (NESDIS) and OMPS-NP v8 ppmv profiles

## *72S-70S, 90W-90E*

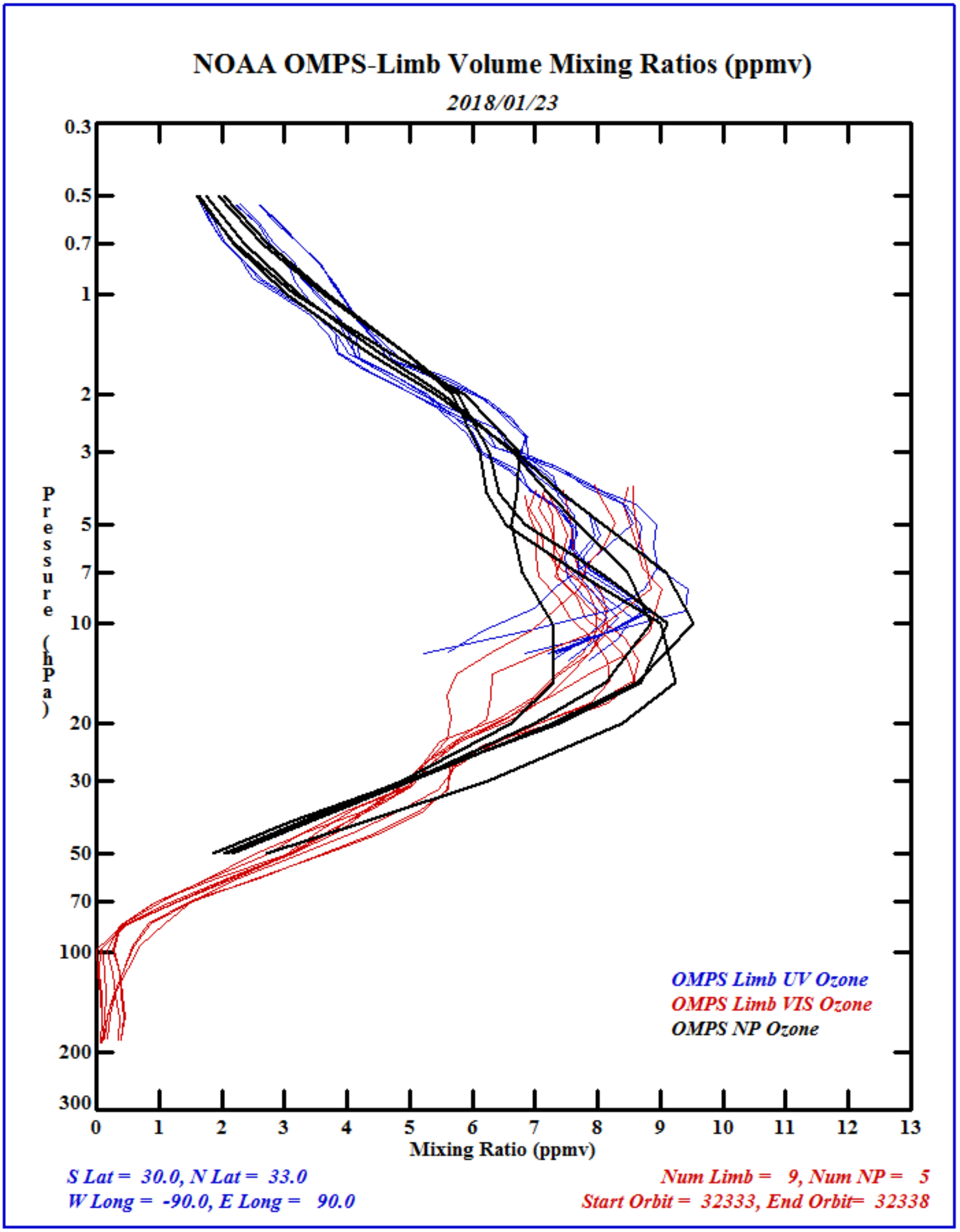



## *32S-30S, 90W-90E*

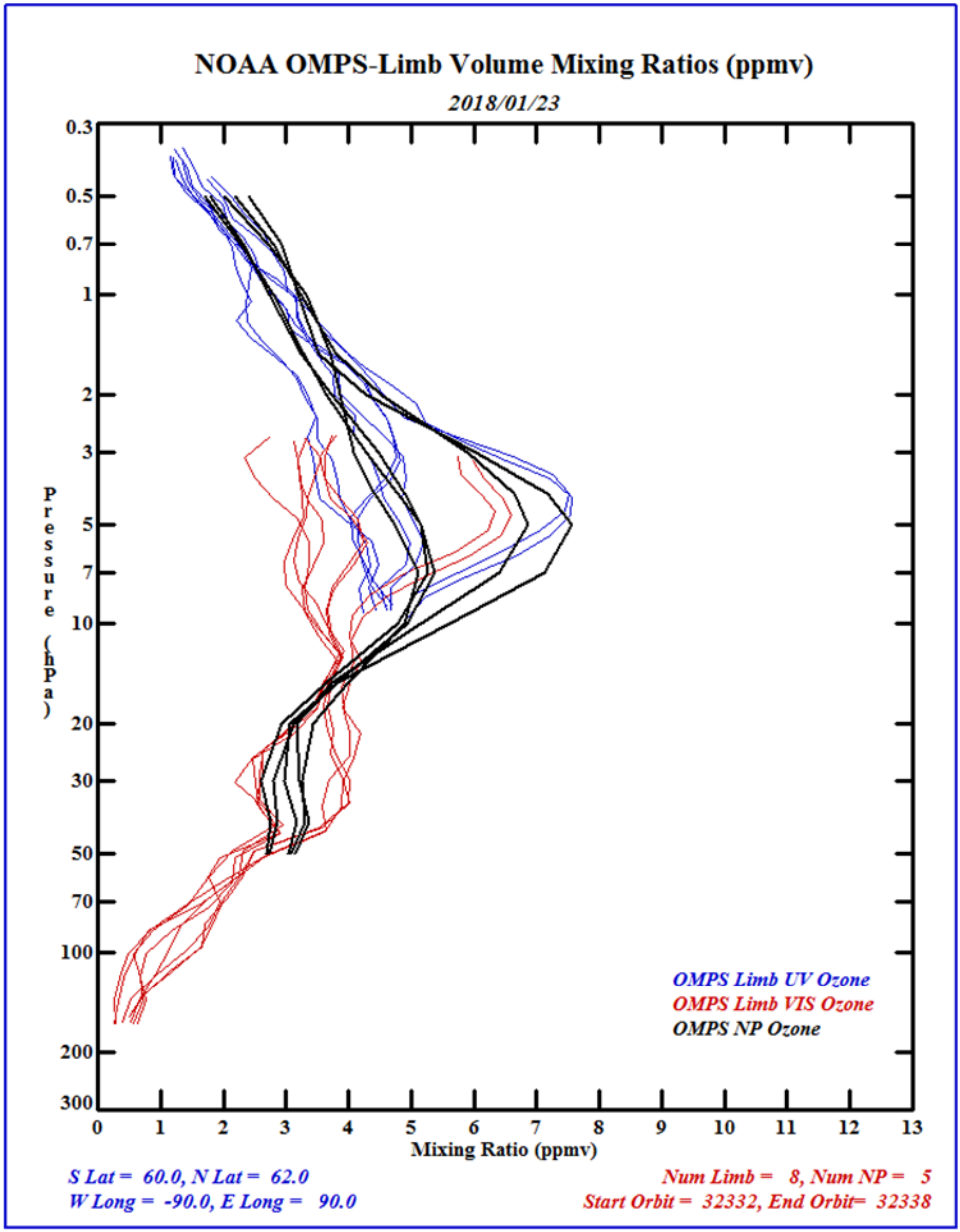


# OMPS-Limb (NESDIS) and OMPS-NP v8 ppmv profiles

*30N-32N, 90W-90E*




*60N-62N, 90W-90E*



# Summary

- NCEP/CPC (*along with other international users*) utilize OMPS-NP, NM (and LP) products for monitoring on various time scales.
- NCEP/EMC utilizes the same for weather model assimilation.
- S-NPP, N20 and future JPSS satellites in stable orbit
  - No loss of observations due to satellite drift
- Reprocessing needed for entire data sets for use in CDR
  - Mid-January 2019
- Hope to assimilate S-NPP OMPS products within the year.
- Evaluate OMPS-Limb this year (*when BUFR products come from NDE*)
- Will evaluate N20 products when those become available.

- Ozone from NCEP GFS used to generate UV Index forecasts and for Stratospheric Intrusion monitoring/forecasting.

# NOAA-20 OMPS OZONE PRODUCTS

**Presented by Lawrence.E.Flynn@noaa.gov**

**with contributions from members of the SDR and EDR teams at NOAA, NASA and Raytheon**

# Outline

- Cal/Val Team Members
- Sensor/Algorithm Overview
- N-20 Ozone Product Performance
- Concerns and Issues
- Future Plans / Improvements
- Summary

# Ozone Cal/Val/Alg Team Membership

| | Name | Organization | Task |
|---|---|---|---|
| Lead | Lawrence Flynn | NOAA/NESDIS/STAR | Ozone EDR Team |
| Sub-Lead | Irina Petropavlovskikh | NOAA/ESRL/CIRES | Ground-based Validation |
| Sub-Lead | Craig Long | NOAA/NWS/NCEP | Product Application |
| Sub-Lead | Trevor Beck | NOAA/NESDIS/STAR | Trace Gas Algorithm Development |
| Member | Jianguo Niu | STAR/IMSG/SRG | Algorithm development, trouble shooting, Limb Profiler science |
| Member | Eric Beach | STAR/IMSG | Validation, ICVS/Monitoring, Data management |
| Member | Zhihua Zhang | STAR/IMSG | V8 Algorithms implementation and modification |
| JAM | Laura Dunlap | JPSS/Aerospace | Coordination |
| Adjunct | Bigyani Das | STAR/AIT | Deliveries |
| PAL | Vaishali Kapoor | OSDPD | Atmospheric Chemistry Product Area Lead |

10/25/2018

# Algorithm Status and Approach V8TOz

- The Version 8 total ozone algorithm (V8TOz) and Linear Fit SO2 (LFSO2) algorithm were develop by NASA Ozone Science Team. Versions of the total ozone algorithm have been in use at NOAA for operational processing of SBUV/2 and GOME-2 measurements.
- The V8TOz is implemented on a granule processing to create EDRs. The algorithm combines radiance/irradiance ratios at 12 channels with climatological information and radiative transfer tables for standard ozone profiles to compute estimates of total column ozone, effective reflectivity and aerosols.
- The LFSO2 algorithm uses the measurement residuals from the V8TOz retrievals to estimate the $SO_2$ using three sensitive channels and adjusts the final ozone estimate for the $SO_2$ absorption interference effects.
- The algorithms uses the OMPS NM SDR and GEO products, climatological ancillary data, and radiative transfer look-up tables. We expect to refine the ancillary data in the future, e.g., use daily snow/ice tiles in place of climatology.
- The algorithms use a set of soft calibration adjustments that are updated infrequently.
- The EDR consists of a NetCDF file containing estimates of the total column ozone and SO2, effective reflectivity and UV absorbing aerosols and error flags, measurement residuals and retrieval sensitivities from the algorithm.

# Algorithm Status and Approach V8Pro

- NASA developed the Version 8 nadir ozone profile algorithm (V8Pro) over ten years ago. It has been in use for the NOAA SBUV/2 and OMPS programs.
- The V8Pro is implemented on granule processing to create an EDR. The algorithm combines radiance/irradiance ratios at 12 channels with climatological information and radiative transfer tables for standard ozone profiles to compute maximum likelihood estimates of ozone vertical profiles and effective reflectivity.
- The algorithm uses the OMPS NM and NP SDR and GEO products, climatological ancillary data, and radiative transfer look-up tables. We expect to refine the ancillary data in the future, e.g., use daily snow/ice tiles in place of climatology.
- The algorithm uses a set of soft calibration adjustments that are updated infrequently.
- The EDR consists of a NetCDF file containing estimates of vertical ozone profile, total column ozone and effective reflectivity and error flags, a priori profiles, averaging kernels, measurement residuals and retrieval sensitivities from the algorithm.

# Total Column Ozone Product Overview/Requirements

- Product performance requirements from JPSS L1RD supplement (threshold) versus observed/provisional maturity

| Attribute | Threshold | NOAA-20 Observed/validated |
|---|---|---|
| Geographic coverage | 90% Daily Global Earth | SZA < 70° |
| Vertical Coverage | 0-60 km | 0-60 km (RT tables, physics) |
| Vertical Cell Size | NA | NA |
| Horizontal Cell Size | 50x50 $km^2$ at nadir | 50x17 $km^2$ at nadir |
| Mapping Uncertainty | 5 km at nadir | 3 km at nadir (SDR Team) |
| Measurement Range | 50 – 650 DU | 90-700 DU (SDR range and past algorithm performance) |
| Measurement Accuracy | | |
| X < 250 DU | 9.5 DU | 0 to -5 DU, vs. NPP |
| 250 DU < X < 450 DU | 13.0 DU | 0 to -5 DU, vs. NPP |
| X > 450 DU | 16.0 DU | Insufficient data |
| Measurement Precision | | |
| X < 250 DU | 6.0 DU | 2.3 DU RMSDD, 6.0 DU NPPMU |
| 250 DU < X < 450 DU | 7.7 DU | 2.0 DU RMSDD, 6.0 DU NPPMU |
| X > 450 DU | 2.8 DU + 1.1% | Insufficient data |

# Nadir Ozone Profile Product Overview/Requirements

- Product performance requirements from JPSS L1RD supplement (threshold) versus observed/beta maturity

| Attribute | Threshold | NOAA-20 Observed/validated |
|---|---|---|
| Geographic coverage | 60% Global Earth 7 days | SZA < 86°, orbital track |
| Vertical Coverage | 0-60 km | 0-60 km |
| Vertical Cell Size | 3-km reporting, 7-20 km | 21 layers, averaging kernel |
| Horizontal Cell Size | 250x250 $km^2$ | 250x50 $km^2$ |
| Mapping Uncertainty | 25 km | 5 km |
| Measurement Range | 0.1-15 ppmv | 0.1-15 ppmv |
| Measurement Accuracy | | At Beta |
| h < 25 km | 10% | |
| 25 km < h < 50 km | 5-10% | |
| h > 50 km | 10% | |
| Measurement Precision | | At Beta |
| h < 25 km | 20% | |
| 25 km < h < 50 km | 5-10% | |
| h > 50 km | 10% | |

# Current NOAA-20 OMPS Issues and Concerns

| Identified Concern/Issue | Description | Impact | Action/Mitigation and Schedule |
|---|---|---|---|
| NDE Table Updates | Soft Calibration adjustment tables will be updated as SDRs mature. We do not know how long this process will take. | Delays in reaching validated maturity | Identify a process for NDE similar to the "Fast Track" table approach at IDPS. |
| NDE Code Updates | Codes to reduce the effects of noise and outliers are being developed. These improvement will enter the queue for implementation at NDE. | Delays in reaching validated maturity for Medium FOVs | Should be delta deliveries as only 30 lines of code in one subroutine and one new data set will be added. |
| Change in OMPS NM Sample Table | There is a sub-optimal match in the CCD pixels for the OMPS-TC and OMPS-NP sample tables. There is a report on this issue, DR_8617, "FOV Mismatch between N20-OMPS-TC and N20-OMPS-NP". | New SDR tables and EDR soft calibration adjustments are under development. | This work will delay when the EDR products will achieve validated maturity. |
| Discretization Error | The NOAA-20 OMPS-NP non-linearity correction is causing a discretization error for low signal levels. The error is causing a signal level dependent 2% error at shorter channels. The error can be removed by uploading a new non-linearity table to the NOAA-20 and updating the calibration coefficient file in the IDPS. DR_8730 was opened on this topic. | This will require a new flight nonlinearity table upload. It will have a positive impact on the SDR and EDR performance when completed. | Little impact on EDR product validation and development as errors from this effect are well-characterized. |

# Future Plans and Improvements

- We are implementing methods to reduce the effects of transient signals in the medium resolution NOAA-20 OMPS NM and NP SDRs on the V8TOz and V8Pro EDRs. The approaches under development for V8TOz use representations with a limited set of Empirical Orthogonal Function Patterns. The approaches under development for V8Pro use polynomial fits of radiance irradiance ratios of wavelength intervals around the algorithm channels to identify and remove outliers and to provide estimates at the selected wavelengths with reduced noise. See talk in OMPS SDR Splinter.
- The NOAA-20 OMPS NM will convert to full medium resolution processing (17x17 $km^2$ at nadir) sometime in 2019.
- The S-NPP OMPS Limb Ozone Profile product is in testing at the development area at NDE. The Limb Profiler will return with JPSS-2.
- NASA has developed an algorithm to generate UV cloud optical centroids. These measurement-based values can be used to replace the current climatological cloud top pressure.
- S-NPP OMPS SDR and EDR reprocessing will take place as resources allow.

# Web Resources for NOAA-20 OMPS Ozone Products

- Additional information is available in the OMPS V8TOz and V8Pro algorithm theoretical basis documents (ATBDs) and the SDR beta maturity review briefing, which can be accessed at:

https://www.star.nesdis.noaa.gov/jpss/Docs.php
https://www.star.nesdis.noaa.gov/jpss/AlgorithmMaturity.php

- Provisional NOAA-20 OMPS SDR near-real-time status and performance monitoring web page will become available at the open website:
- https://www.star.nesdis.noaa.gov/icvs/index.php
- Pre-operational NOAA-20 OMPS EDR near-real-time status and performance monitoring web pages will become available at the following websites:

http://www.ospo.noaa.gov/http://www.ospo.noaa.gov/Products/atmosphere/index.html
https://www.star.nesdis.noaa.gov/smcd/spb/OMPSDemo/proOMPSbeta.php
https://www.star.nesdis.noaa.gov/jpss/EDRs/products_ozone.php
https://ozoneaq.gsfc.nasa.gov/omps/n20/activity

- Products will become available at the CLASS website:

https://www.class.ncdc.noaa.gov/saa/products/search?datatype_family=JPSS_OZONE

# Summary

- The NOAA-20 OMPS instruments are performing well.
- The SDR team has identified improvements on the path to validated maturity.
- The EDR team will be providing soft calibration adjustments in communication with the SDR team and BUFR product users.
- Approaches to improve performance for the higher spatial resolution EDRs are progressing well.