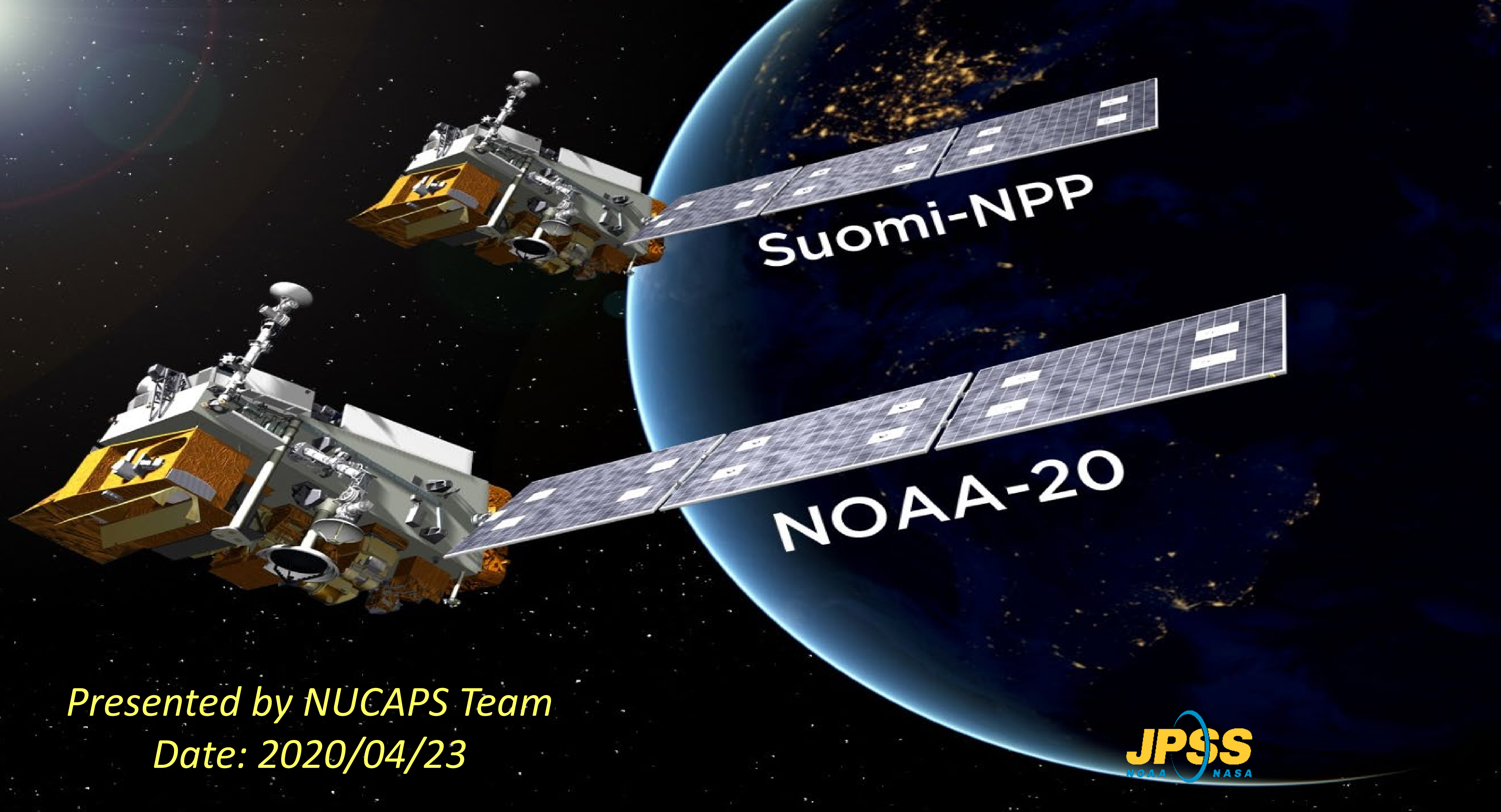
Validated Maturity Science Review
For NOAA-20 NUCAPS Algorithm



Presented by NUCAPS Team
Date: 2020/04/23

JPSS NOAA NASA

NUCAPS MATURITY REVIEW

APRIL 23, 2020

10:00 – 11:30 EDT

Validated Maturity:

NOAA-20 & S-NPP NUCAPS CH4 Product

Provisional Maturity:

NUCAPS CO2 product (SNPP & NOAA-20)

JPSS	Maturity Review Presentation - Items	Time
1	**Management updates**	5 minutes (10:00 – 10:05) Presented Ken Pryor

2	**Maturity Review**
	• Algorithm Team Members; Entrance and Exit Criteria; 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
	    • Processing Environment, Algorithm Versions
	    • Algorithm Performance to Specification Requirements.
	    • Address RFA from October 2019 Maturity Review
	    • Requirements, Documentation (Science Maturity Check List)
		20 minutes (10:05 – 10:25)
		Presented by Murty Divakarla

3	**Product Requirements/Validation Results (supplemental slides at end of presentation)**
	    • Ensure latest algorithm changes did not adversely affect retrieval products that are already of validated maturity.
	    • Validation of CH_4 and CO_2 product
	        • NUCAPS product evaluations with other correlative data sets (AIRS, TROPOMI)
	        • CH_4 and CO_2 validation and statistical metrics with Expanded Truth Data
		40 minutes (10:25 – 11:05)
		
		Presented by
		Nick Nalli
		Juying Warner

4	**NUCAPS Trace Gas Products in Environmental Monitoring**
	    • Australian Fires – NUCAPS CO and TROPOMI
	    • Coronavirus studies using NUCAPS CO as a Tracer
		15 minutes (11:05 – 11:20)
		Presented by Ken Pryor

5	**User Feedback** **Risks, Actions, and Mitigations** **Conclusions, Path Forward**	10 minutes (11:20 – 11:30) Presented by Ken Pryor
6	**Supplemental Slides** • Validation plots not presented in the review • NUCAPS Team collaborations with external agencies for Risk Mitigation	

MATURITY REVIEW MATERIAL

NUCAPS Operational Products and Current Maturity Status

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

In AWIPS: AVTP, AVMP, Cloud Fraction and Top Pressure

Experimental Viable Products: Volcanic SO_2, HNO_3, N_2O, NH3, Isoprene, PAN

Data Product	Priority	Current Maturity Status	
		SNPP	NOAA-20
AVTP/AVMP	3	✓ Validated	✓ Validated
Ozone (p)	3	✓ Validated	✓ Validated
OLR	3	✓ Validated	✓ Validated
CO (p)	4	✓ Validated	✓ Validated
CH4 (p)	4	✓ Provisional	✓ Provisional
CO2 (p)	4	• Beta	• Beta

S-NPP/NOAA-20 Validated Maturity Review
https://www.star.nesdis.noaa.gov/jpss/AlgorithmMaturity.php

SNPP/NOAA-20 Maturity Review - April 23, 2020

- **Validated** Maturity for **SNPP & NOAA-20**
  - NUCAPS **CH4**
- **Provisional Maturity for SNPP & NOAA-20**
  - NUCAPS **CO2**

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 cal/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, Tish Soulliard	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, Charlie Brown	STAR, IMSG at STAR	NUCAPS vs. Global RAOB Validations NUCAPS vs. MiRS MW-only evaluations
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

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.

Processing Environment, Algorithm Versions

- NUCAPS current operational algorithm(s) for SNPP and NOAA-20 at NDE
  - Version V2.1.12d, delivered on 2018/08/15.
  - Version V2.5.2.2, delivered on 2019/10/29
    - Currently on OSPO I&T string as part of HEAP 2.1
    - SPSRB Briefing towards promoting to operations: April 15, 2020

- V2.7.2. is the current NUCAPS algorithm
  - Results presented in this Maturity Review are from V2.7.2 candidate version for operational implementation.
  - All static ancillary files needed by algorithm are contained within the Delivered Algorithm Package (DAP).
  - Recently delivered V2.7.2 to ASSISTT team for cluster integration to produce pre-operational runs for SNPP/NOAA-20
  - ASSISTT team transitions NUCAPS V2.7.2 as part of HEAP V2.2.

- Validation of NUCAPS products conducted in STAR:
  - Linux servers running f90, IDL, bash, C/C++, libraries (hdf5 and netCDF4)
  - NUCAPS team performs product validation using a hierarchy 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 N_2O region). • Added new LUTs to differentiate S-NPP/NOAA-20 (e.g. instrument noise)
NUCAPS V2.5.2.2	HEAP 2.1	• Delivered October 29, 2019 • Currently on I&T String • SPSRB Briefing for OPS: April 15,2020	• Trace gas updates (CO, CH4, QC) • NOAA-20 specific LUTs.
NUCAPS V2.7.2	HEAP 2.2	• Delivered to ASSISTT – April 16, 2020 • NDE DEV and I&T OPS (?)	• Maturity Review (April 23, 2020) • CH4 Validated, CO2 Provisional

Algorithm performance to specification requirements

- Validation results shown here reflect V2.7.2.
- Cal/Val activities for NUCAPS algorithm performance:

Data Product	Priority	Current Maturity Status		Maturity Review
		SNPP	NOAA-20	
AVTP/AVMP	3	✓ Validated	✓ Validated	✓ October 2019
Ozone (p)	3	✓ Validated	✓ Validated	✓ October 2019
OLR	3	✓ Validated	✓ Validated	✓ October 2019
CO (p)	4	✓ Validated	✓ Validated	✓ October 2019
CH4 (p)	4	• Aiming for Validated	• Aiming for Validated	• Today's review
CO2 (p)	4	• Aiming for Provisional	• Aiming for Provisional	• Today's review

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

Primary changes in NUCAPS v2.7.2 vs. v2.5.2.2 (October 2019)

Item	V2.5.2.2 (October 2019) – HEAP 2.1		V2.7.2 (April 2020) HEAP 2.2
	SNPP	NOAA-20	S-NPP/NOAA-20
MW A-priori	✓ Zonal monthly climatology composed of NCEP and UARS Upper Tropo/Stratosphere measurements. (V2.1.12d)	✓ Zonal monthly climatology composed of NCEP and UARS Upper Tropo/Stratosphere measurements.(V2.1.12d)	✓ MiRS Climatology as A-priori. One year of ECMWF (2012), T(p), WV(p) ✓ Evenly spaced 5 days/month averaged to represent monthly average; Lat (-90.0 to 90.0 by 5 degrees); lon (0.0 to 360.0 by 5 degrees); 0, 6, 12, and 18 UTC.
MW Tuning	✓ **Two focus days (20190215, 20190815) and SNPP radiances, and MIT forward model.**	✓ Two focus days (20190215, 20190815) NOAA-20 radiances and MIT forward model.	✓ No change – as is for S-NPP/NOAA-20
Cloudy Regression	✓ NO Change from the operational Version (V2.1.12d)	✓ PC regression using NOAA-20 all-sky radiances matched with ECMWF ✓ Used four Focus Days (20180415, 20180715, 20181015, 20190115)	✓ No change – as is for S-NPP/NOAA-20 ✓ Updated with Chris' regression code, but the result remain the same.
Clear Regression	✓ NO change from the operational version (V2.1.12d)	✓ PC regression using NOAA-20 CCR radiances matched with ECMWF ✓ Used four Focus Days (20180415, 20180715, 20181015, 20190115)	✓ No change – as is for S-NPP/NOAA-20 ✓ Updated with Chris's regression code, but the results remain the same.
Emissivity Regression	✓ NO Change from the operational version (V2.1.12d)	✓ NO change from the operational version (V2.1.12d)	✓ No change – as is for S-NPP/NOAA-20
IR Tuning	✓ "Full tuning" method using SNPP radiances and ECMWF SARTA simulations	✓ Double Difference Method using NOAA-20 radiances and ECMWF SARTA simulations.	✓ No change – as is for S-NPP/NOAA-20
CO climatology/QC	✓ NO Change from the operational version (V2.1.12d)	✓ NO Change from the operational version (V2.1.12d)	✓ No change – as is for S-NPP/NOAA-20
CH_4/N_2O A-priori	✓ Updated CH_4/N_2O a-priori	✓ Updated CH_4/N_2O A-priori	✓ No change – as is for S-NPP/NOAA-20 ✓ QC flag updates to CH_4
CO_2 A-priori	✓ No Change from the operational version (V2.1.12d)	✓ No change from the operational version (V2.1.12d)	✓ Updated CO_2 a-priori and QC flag updates
CrIS Noise File	✓ NO change from the operational version (V2.1.12d)	✓ NO change from the operational version (V2.1.12d)	✓ No change – as is for S-NPP/NOAA-20
Channel Selection for cloud-clearing, T(p), q(p) (included)	✓ Minor updates of channels	✓ Minor updates of channels	✓ No change – as is for S-NPP/NOAA-20 ✓ Super saturation QC flag implemented
Channels selection for trace gases	✓ NO change from the operational version (V2.1.12d)	✓ NO change from the operational version (V2.1.12d)	✓ No change – as is for S-NPP/NOAA-20

Algorithm Performance to Specification Requirements

Cal/Val Activities for NUCAPS Algorithm Performance (v2.7.2)

Items		Slides
• Address RFA from October 2019 Maturity Review, Requirements Check List	• RFA-1 (Addressed in Nov. 2019 after Oct 2019 Review) • RFA-2 & 3 Addressed in this maturity review	29–26
• Ensure latest algorithm changes (MW-Climatology, CO2 *a priori* CH4 and CO2 QC) did not adversely affect retrieval products that are already of Validated Maturity.	• v2.7.2 (latest NUCAPS version) *vs.* v.2.5.2.2 (October 2019) evaluations for AVTP, AVMP, O3(p), CO(p) reveal that the product accuracies with the latest algorithm are either improved or remained the same.	33–44
• Validation of CH4 and CO2 product • Hierarchy of Validation data sets	• Validation with Focus Days: Depiction of Seasonality • NUCAPS Product evaluations with other correlative data • Validation of CH4 and CO2 with reference data sets	47–59, 66 47–59 60–81
• NUCAPS Trace Gas Products in Environmental Monitoring, • User Applications and Feedback	• Australian Fires – NUCAPS CO and TROPOMI • Coronavirus studies using NUCAPS CO as a Tracer • CH4 and CO2 user applications and feedback	82–113
• Risks, Summary and Conclusions	• CH4 and CO2 requirements are all met. • NUCAPS team recommends CH4 Validated and CO2 Provisional Maturity.	114–117
• Path Forward	• Potential future work • NUCAPS Milestones	118
• Supplemental slides	• Additional slides T(p), q(p), O3(p), and CO(p) Product Consistency • NUCAPS Team Collaborations with External Agencies for Risk Mitigation	123

RFAS FROM OCTOBER 2019 MATURITY REVIEW

Action Items from October 2019 NUCAPS Maturity Review

RFA-1:

- ✓ In order to fully demonstrate the validated maturity, the review team suggested to add the time series of statistics; or statistics for multiple focus days throughout different months of the year. (Provided to the Review Panel on 11/8/2019)

RFA-2:

- MW-NUCAPS retrieval showed deviation from the microwave spec; recommend the team to address the MW-NUCAPS performance in the next stage and give updates on the coming annual science team meeting 2020; provide some comparisons with MiRS temperature and water vapor profile retrievals.

RFA-3:

- To check the output files from CrIS and ensure consistent with those from IASI; especially files such as 3x3 global grids, PCS files, etc. and report back to the review team when those files can be generated from CrIS.

v2.7.2 SNPP & NOAA-20 NUCAPS MW-Only *A Priori*

✓ MW-only Retrieval Improvements

- Ingest MiRS Climatology into NUCAPS system as a new a-priori
  - MiRS Climatology
    - One year of ECMWF (2012), T(p), WV(p)
    - Evenly spaced 5 days/month averaged to represent monthly average,
    - Lat (-90.0, 90.0 by 5) /lon (0.0, 360.0, 5); 0, 6, 12, and 18 UTC.
  - NUCAPS Climatology
    - Zonal monthly climatology composed of NCEP and UARS Upper Tropo/Stratosphere measurements.
- Evaluation with Focus Days
  - Evaluation of NUCAPS MW-only retrievals with ECMWF
  - NUCAPS *vs.* MiRS Retrievals for Focus days

RFA-2:

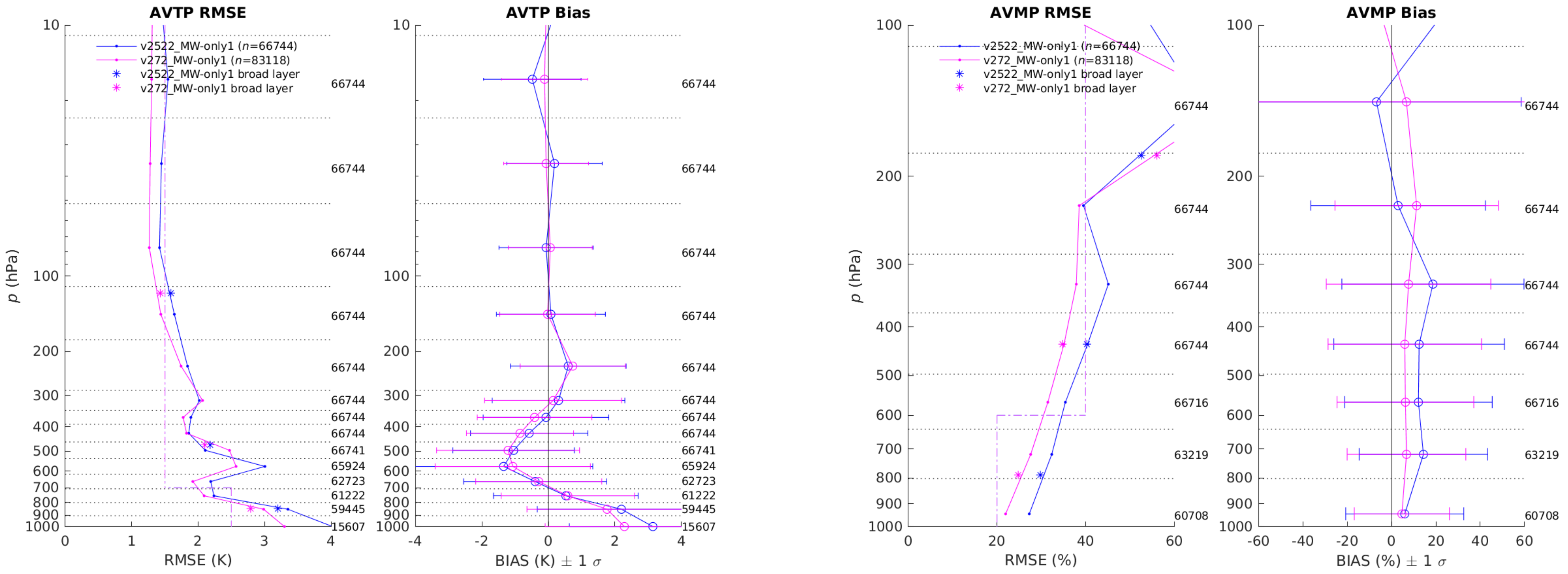
- MW-NUCAPS retrieval showed deviation from the microwave spec; recommend the team to address the MW-NUCAPS performance in the next stage and give updates on the coming annual science team meeting 2020; provide some comparisons with MiRS temperature and water vapor profile retrievals.

NOAA-20 MW-Only "Cloudy Cases" (20 Aug 2018) vs ECMWF

AVTP

OPS (v2.5.2.2)
Candidate (v2.7.2)

AVMP

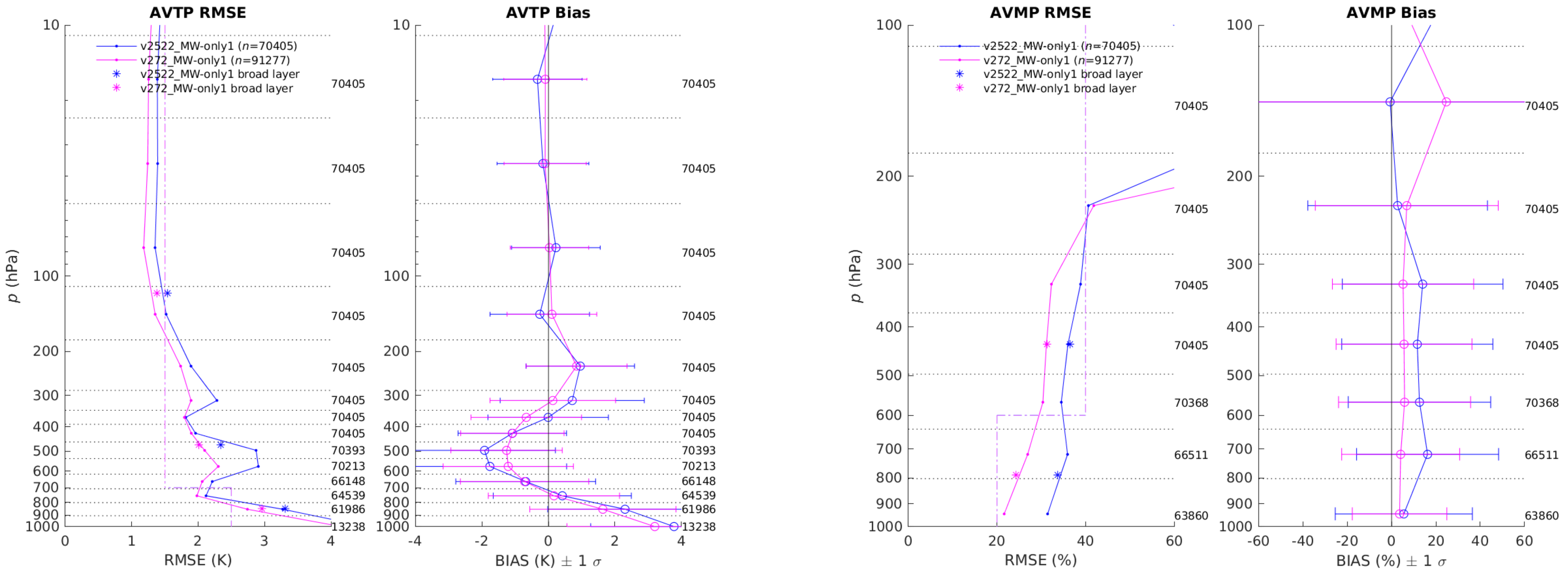


NOAA-20 MW-Only “Cloudy Cases” (23 Jan 2020) vs ECMWF

AVTP

OPS (v2.5.2.2)
Candidate (v2.7.2)

AVMP

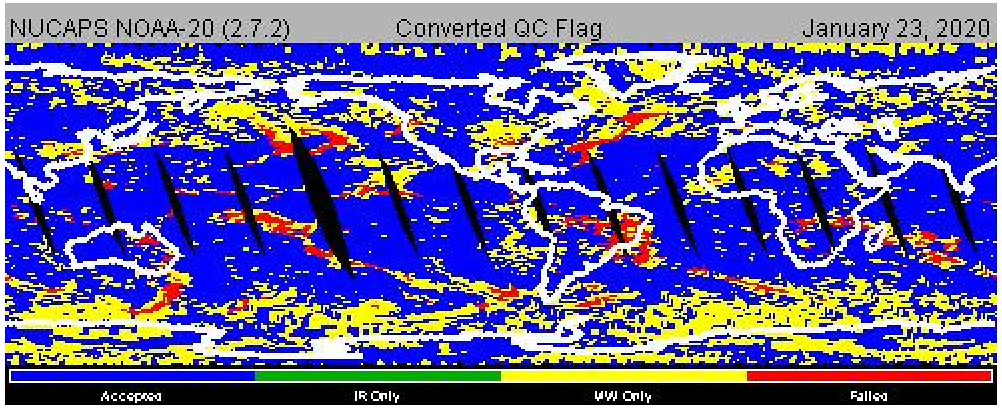


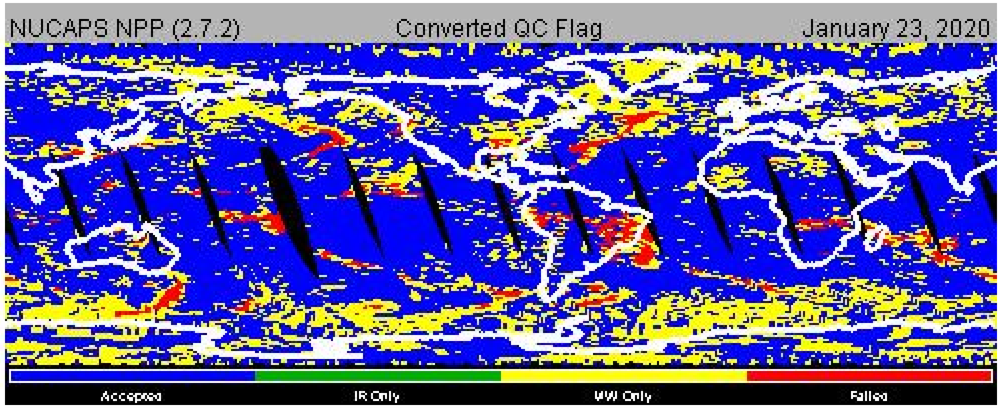
2020-03-04

NPROVS Orbital Display System (ODS) – 23 Jan 2020 Focus Day

QC acceptance yields between for NUCAPS 2.7.2 and 2.5.2.2 (baseline)

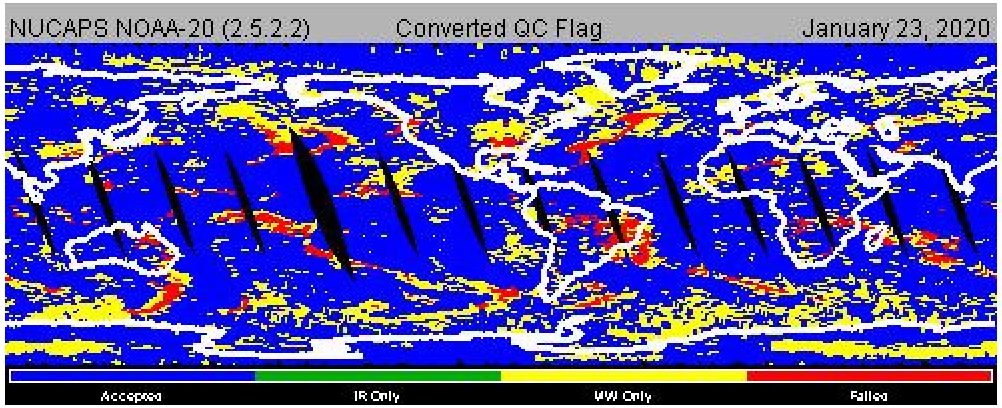
N20 2.7.2
1/23/20
IR+MW: 69%
MW-only: 28%

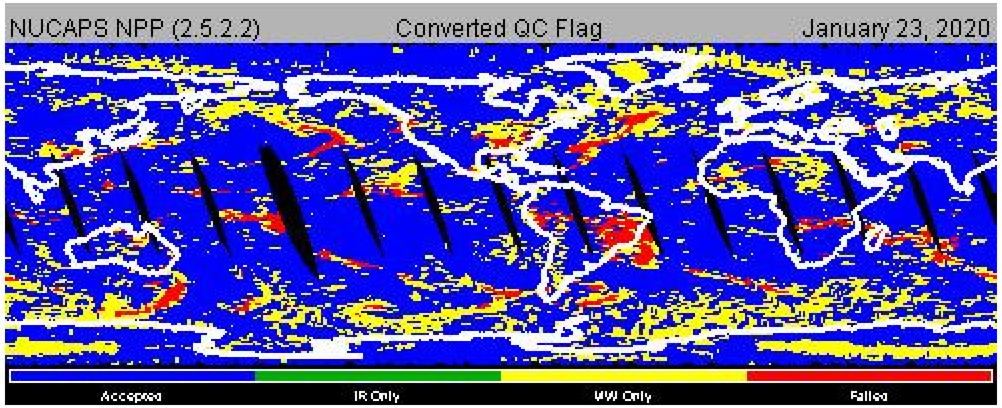




NPP 2.7.2
1/23/20
IR+MW: 69%
MW-only: 28%

N20 2.5.2.2
1/23/20
IR+MW: 75%
MW-only: 22%





NPP 2.5.2.2
1/23/20
IR+MW: 74%
MW-only: 22%

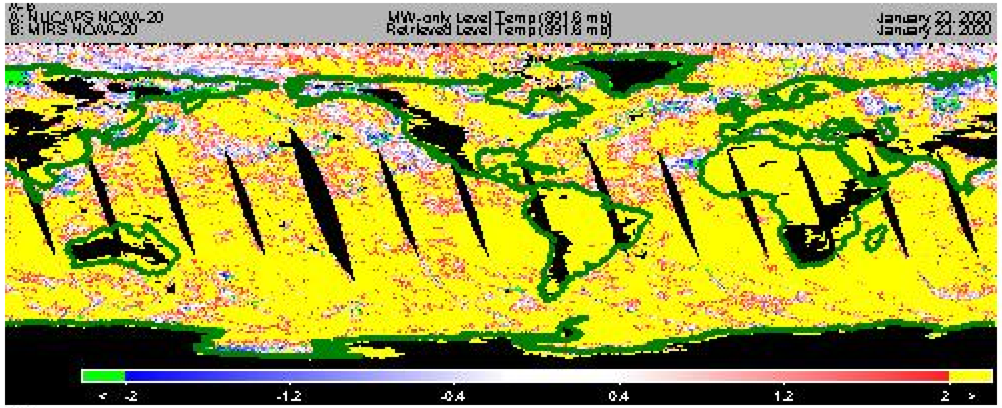
Blue, IR+MW pass **Yellow, MW-only pass** **Red, Both failed**

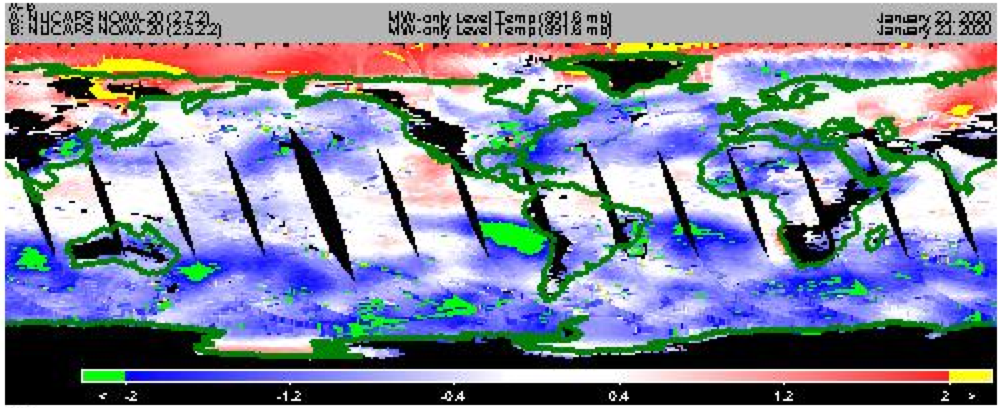
Courtesy of NPROVS Team
Tony Reale, Michael Pettey, Bomin Sun, Charlie Brown, Ryan Smith

NPROVS ODS MW-Only vs MIRS – 23 Jan 2020 Focus Day
Significant reduction in differences between NUCAPS and MiRS

891 hPa MW-Only Temperature

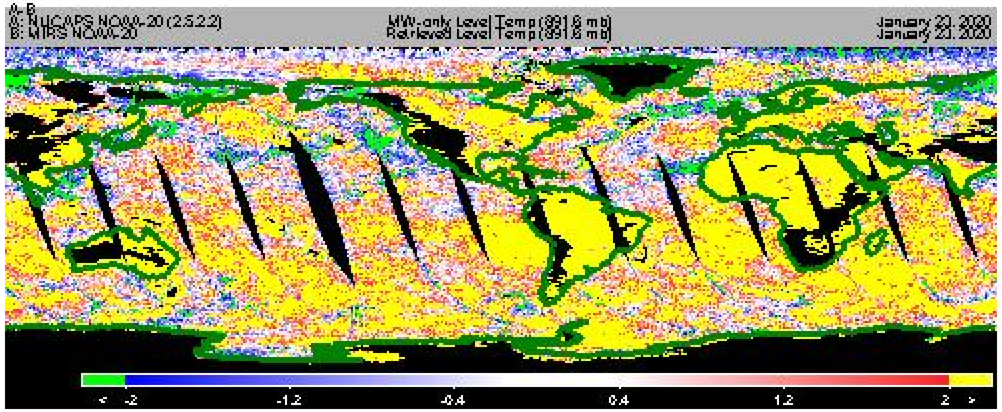
NUCAPS OPS minus MiRS

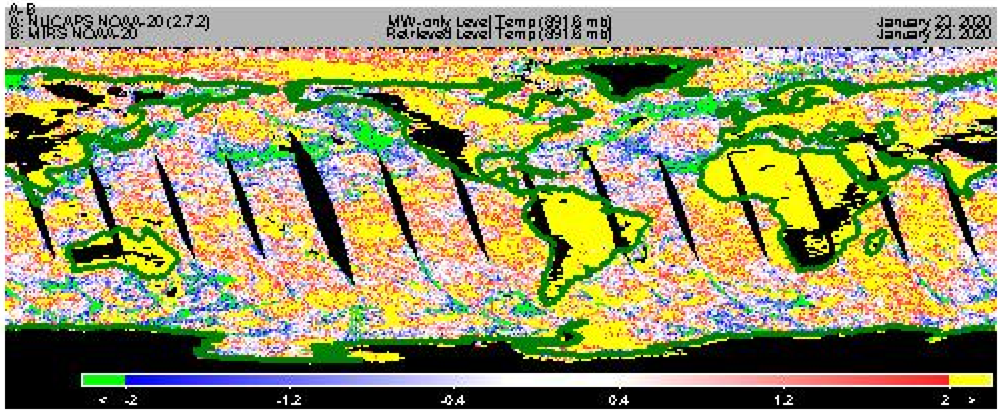




NUCAPS v2.7.2 minus v2.5.2.2

NUCAPS OPS Oct-DAP v2.5.2.2 minus MiRS





NUCAPS Candidate v2.7.2 minus MiRS

NUCAPS Improvements: (MW tuning)

ECMWF *a priori*

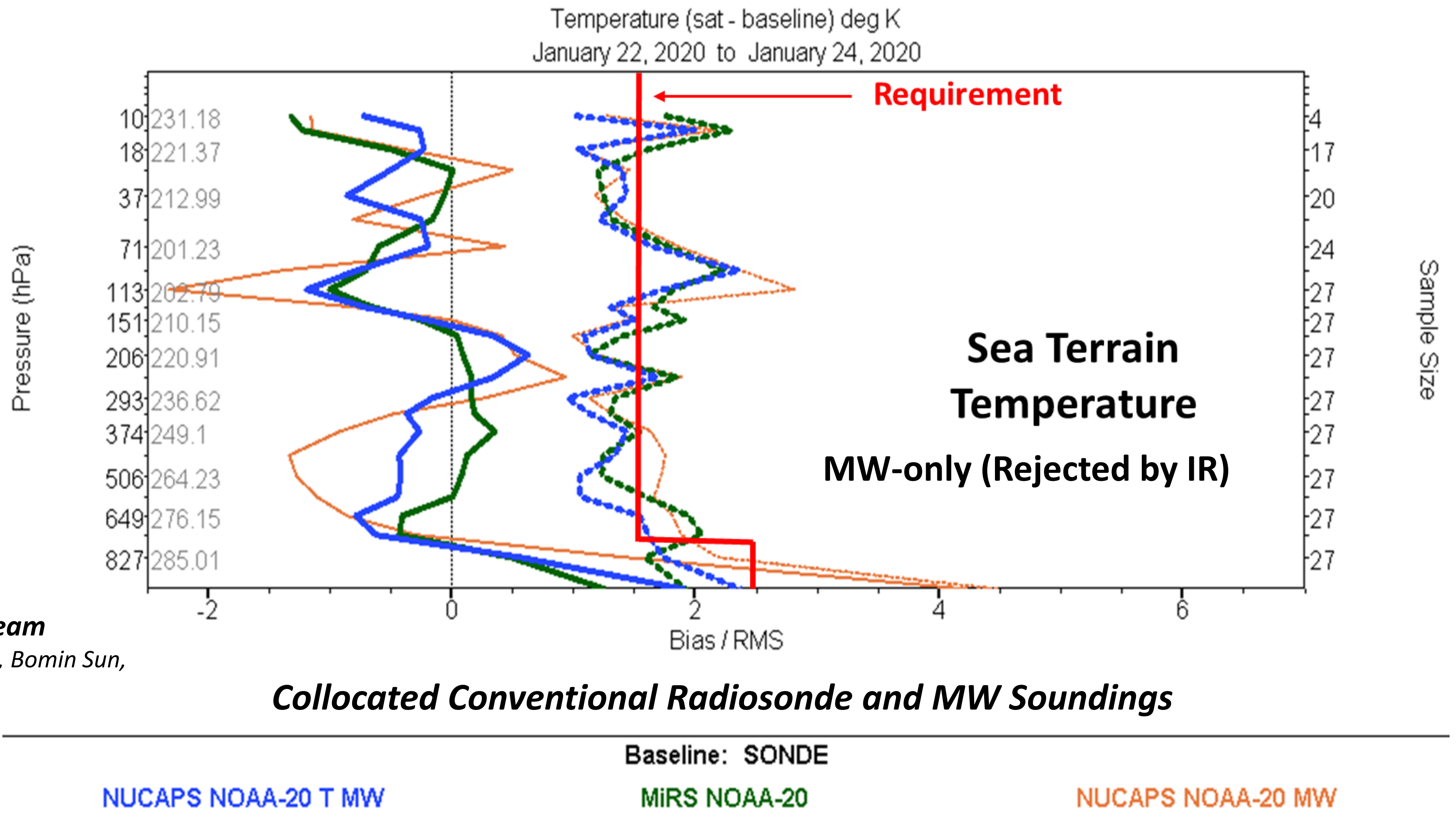
Courtesy of NPROVS Team

Tony Reale, Michael Pettey, Bomin Sun, Charlie Brown, Ryan Smith

- Upper Left, Lower left and lower right shows progression of improved agreement with MiRS
- Upper right shows difference between NUCAPS v 2.7.2 and v2.5.2.2 (baseline) relative to MiRS NOAA-20

NPROVS Profile Statistics (PDISP) – 23 Jan 2020 Focus Day
Robust agreement between NUCAPS and MiRS for very difficult cases

NOAA-20 NUCAPS v2.7.2 vs OPS vs MiRS Microwave Sounding



Courtesy of NPROVS Team
Tony Reale, Michael Pettey, Bomin Sun, Charlie Brown, Ryan Smith

Collocated Conventional Radiosonde and MW Soundings

NUCAPS 2.7.2 meeting Requirement (comparable to MiRS) with reduced Bias and significantly better than Operations …

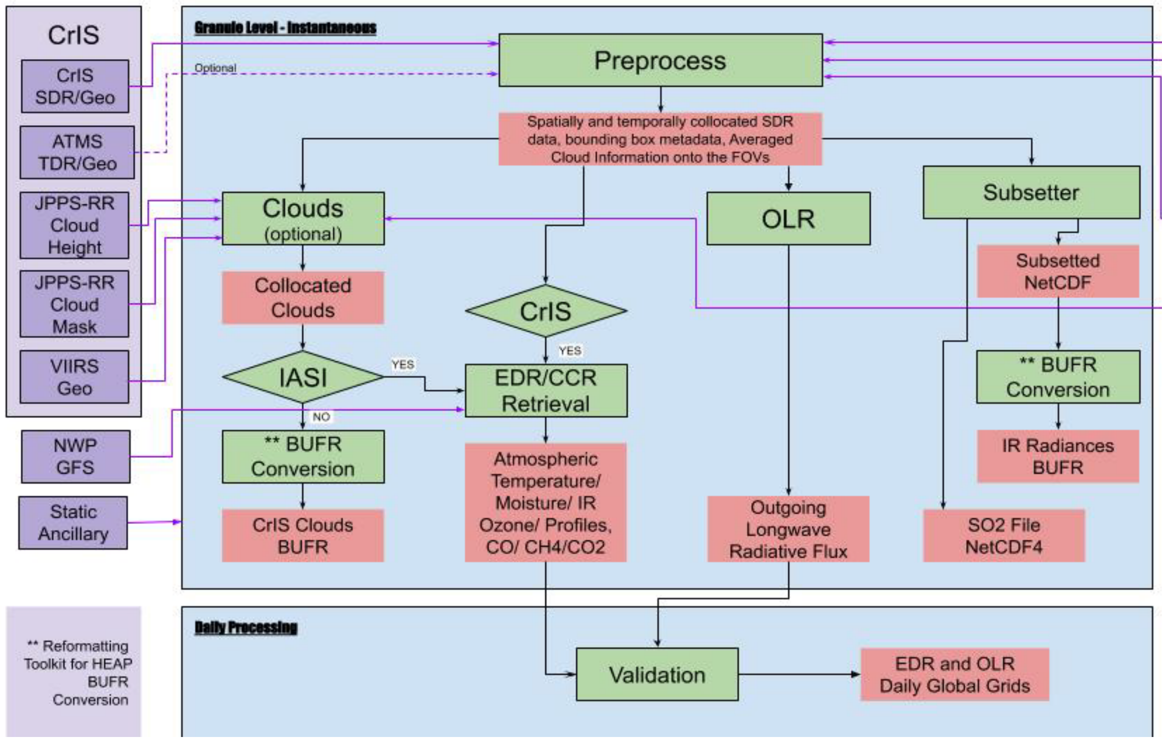
Response to RFA-2

- MW-NUCAPS retrieval showed deviation from the microwave spec; recommend the team to address the MW-NUCAPS performance in the next stage and give updates on the coming annual science team meeting 2020; provide some comparisons with MiRS temperature and water vapor profile retrievals

- NUCAPS team improved MW retrieval step in the candidate NUCAPS version (v2.7.2).
  - Major improvements to OPS version: MW-tuning and new a-priori based on ECMWF climatology
- Analysis of MW-only retrievals (IR+MW rejected cases, MW-only pass) with ECMWF show significant improvement in RMSE and bias characteristics.
- NPROVS analysis of NUCAPS MW-only retrievals (over Sea) with matched RAOBs and MiRS retrievals show close statistical agreement.
  - Global temperature differences at 891 hPa with respect to MiRS are reduced for NUCAPS v2.7.2 vs. current operational version. Similar for S-NPP.
  - Comparisons against collocated radiosondes show overall reduced differences for NUCAPS v2.7.2 vs. current operational version with v2.7.2 meeting requirements over Sea.
- Possible future improvements:
  - QC flag fine tuning (IR+MW, MW-only)
  - Update T(p) and q(p) covariance associated with the MW a-priori into the MIT retrieval module.
  - Investigate and seek recommended upgrades to the MIT retrieval from NASA/JPL for inclusion into the NUCAPS MIT module.

Hyper-Spectral Data Processing at NDE/OSPO

HEAP System Level Data Flow



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.

Satellite	Instrument
JPSS (SNPP, NOAA-20, J2,J3)	CrIS/ATMS (currently SNPP/NOAA-20)
MetOp-A, B, C	IASI/AMSU-A/MHS (total 3 currently)
EPS-SG Augmentation	IASI-NG/MWS
Total data volume	2x 49GB/day (JPSS) + 3x 67GB/day (MetOp)

- HEAP is the Delivered Algorithm Package (DAP) to NDE/OSPO for NUCAPS products from JPSS CrIS (SNPP/NOAA-20) as well as MetOp series IASI data (MetOp-A, B, C)
- NUCAPS products from MetOp-A/B (IASI/AMSU-A/MHS) are expected to have similar product accuracies. We are currently adapting the NUCAPS system for MetOp-C (IASI/AMSU-MHS)

RFA-3: To check the output files from CrIS and ensure consistent with those from IASI; especially files such as 3x3 global grids, PCS files, etc.. and report back to the review team when those files can be generated from CrIS.

NUCAPS Output Products

	Product	NUCAPS JPSS Products		NUCAPS MetOp Products		Users
		Number of Files/Day	Size/Day	Number of Files/Day	Size/Day	
1	NUCAPS ALL FOVs	2700*	25 G	480&	47 G	BUFR toolkit and OSPO
2	NUCAPS 431 (CrIS), 616 (IASI) ALL FOVs Thinned Radiances	2700	5.4 G	480	5.9 G	BUFR toolkit
3	NUCAPS PCS Monitoring	2700	11 M	480	2.0 M	OSPO
4	NUCAPS Retrieval Monitoring	2700	11 M	480	11M (next DAP)	OSPO
5	L1C Metadata.xml (for IASI only)	N/A	N/A	480	12 M	CLASS
6	EDR NetCDF	2700	7.8 G	480	7.0 G	CLASS and OSPO
7	CCR Archive NetCDF	2700	3.3 G	480	5.9 G	CLASS
8	OLR NetCDF	2700	170 M	480	60 M	CPC
9	0.5 × 2 NUCAPS EDR global grids	2	1.4 G	2	1.4 G	OSPO
10	0.5 × 2 OLR global grids	2	6.1M	2	6.1 M	OSPO
	Total	**16204**	**43.1 G**	**3364**	**67.2 G**	

*S-NPP/NOAA-20 CrIS granules contain 4 scan lines each of 30 FORs (3 × 3 FOVs)

&MetOp IASI granules contain 22 or 23 scan lines each of 30 FORs (2 × 2 FOVs)

- NUCAPS products and files for NOAA-20/S-NPP, and for MetOp-IASI are consistent (such as global grids, PCS)

REQUIREMENTS CHECK LIST

SNPP and NOAA-20 Validated Maturity for CH4

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 46–81.
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 slides 46–81.
Product analyses are sufficient for full qualitative and quantitative determination of product fitness-for-purpose.	Yes. See slides 46–81.
Product is ready for operational use based on documented validation findings and user feedback.	Yes. See slides 82–113.
Product validation, quality assurance, and algorithm stewardship continue through the lifetime of the instrument	Yes. See slides 115, 119, 122

SNPP and NOAA-20 Provisional Maturity for CO_2

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 46–81.
Product analysis is sufficient to communicate product performance to users relative to expectations (Performance Baseline).	Yes. See slides 46–81.
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 46–81.
Product is ready for operational use and for use in comprehensive cal/val activities and product optimization.	Yes. See slides 82–113.

Requirement Check List – Carbon Dioxide (CO_2)

DPS	Requirement	Performance
DPS-389	The Carbon Dioxide product shall provide carbon dioxide volume density, geolocated, globally, for the total vertical column, in all weather conditions, day and night, at the refresh rates of the instrument	Yes. The NUCAPS algorithm produces a CO2 product geolocated, globally, for the total vertical column, in all weather conditions, day and night, at the refresh rates of the instrument. See slide 55.
DPS-390	The Carbon Dioxide product shall provide carbon dioxide volume density with a measurement range of 300 to 500 parts per million by volume (ppmv)	Yes. See slide 125.
DPS-391	The Carbon Dioxide product shall provide carbon dioxide volume density with a horizontal resolution of 100 km	Yes. The 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.
DPS-393	The Carbon Dioxide product shall provide carbon dioxide volume density with a measurement precision of 0.5% or 2 ppmv	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 also recommends proper use of averaging kernels (AKs) as part of assessments.
DPS-394	The Carbon Dioxide product shall provide carbon dioxide volume density with a measurement accuracy of 1% or 4 ppmv	As above.

Requirement Check List – Methane (CH4)

DPS	Requirement	Performance
DPS-382	The Methane product shall provide methane volume density, geolocated, globally, for the total vertical column, in all weather conditions, day and night, at the refresh rates of the instrument	Yes, see slide 51.
DPS-381	The Methane product shall provide methane volume density with a measurement range of 1100 to 2250 parts per billion by volume (ppbv)	Yes, see slide 125.
DPS-383	The Methane product shall provide methane volume density with a horizontal resolution of 100 km	Yes. The 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.
DPS-385	The Methane product shall provide methane volume density with a measurement precision of 1% or 20 ppbv	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. The team recommends a waver for a relaxed total/partial column CH4 precision requirement (TBD), along with the proper use of averaging kernels (AKs).
DPS-386	The Methane product shall provide methane volume density with a measurement accuracy of 4% or 80 ppbv	As above regarding *in situ* data collection.

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

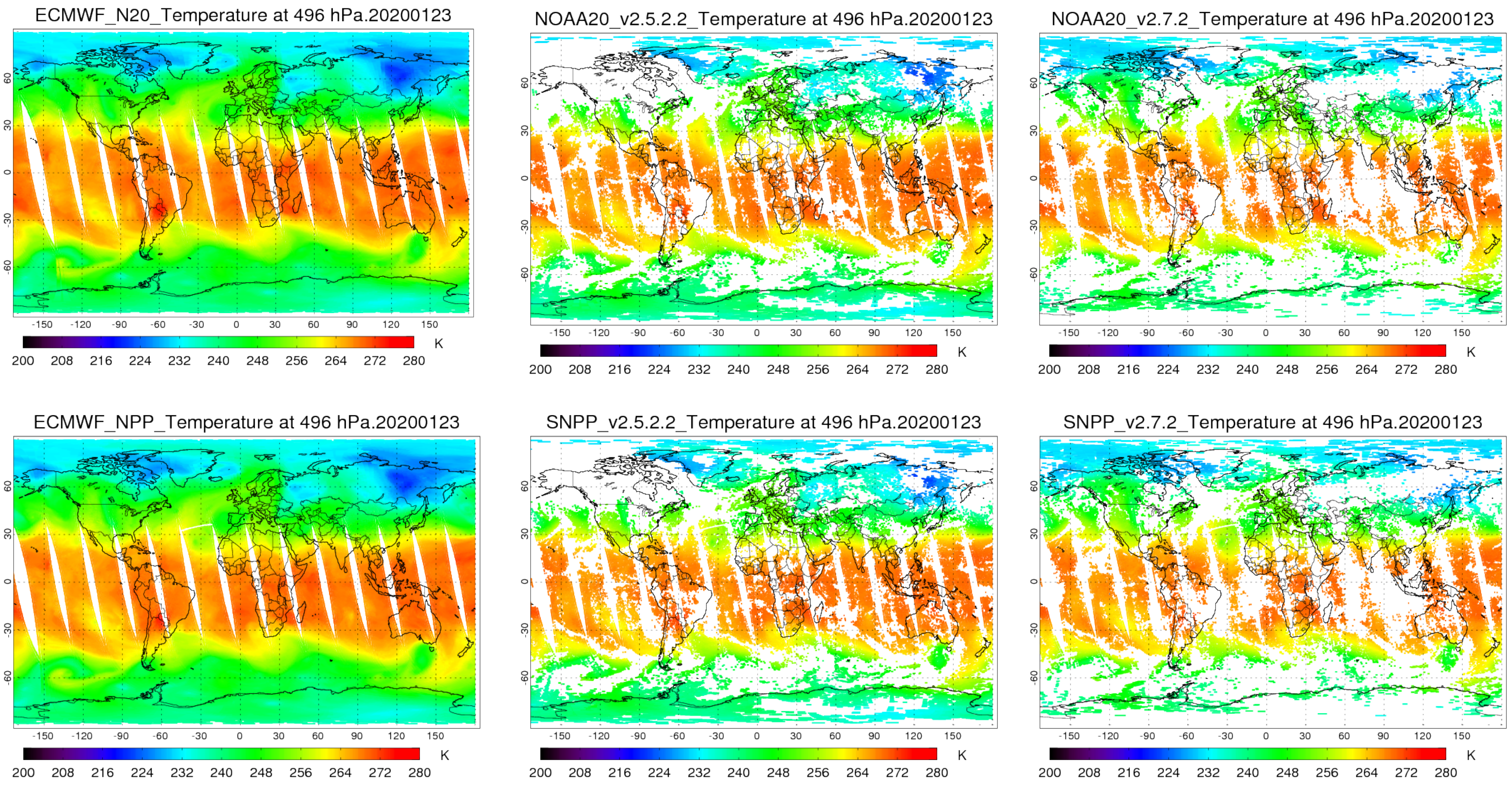
ATBD, External/Internal Users Manual, System Maintenance Manual available upon request, and as part of DAP

T(p), q(p), O3(p), and CO(p) Product Consistency of the NUCAPS Algorithm

Data Product	Priority	Current Maturity Status		Maturity Review
		SNPP	NOAA-20	
AVTP/AVMP	3	✓ Validated	✓ Validated	✓ October 2019
Ozone (p)	3	✓ Validated	✓ Validated	✓ October 2019
OLR	3	✓ Validated	✓ Validated	✓ October 2019
CO (p)	4	✓ Validated	✓ Validated	✓ October 2019
CH4 (p)	4	• Aiming for Validated	• Aiming for Validated	• Today's review
CO2 (p)	4	• Aiming for Provisional	• Aiming for Provisional	• Today's review

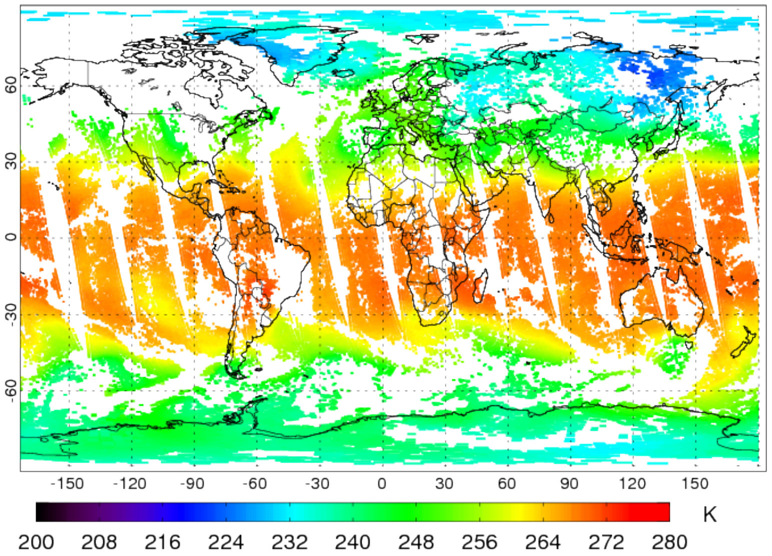
- **Ensure latest algorithm changes (MW-Climatology, CO2 A-priori CH4 and CO2 QC) did not adversely affect retrieval products that are already of validated maturity.**
  - Performed evaluations of NUCAPS products (Latest v2.7.3) vs. V2.5.2.2 (October 2019 DAP) using two focus day data sets (20180820, 20200123).
  - Supplemental slides provide evaluations for the focus day 20200123 (NOAA-20, SNPP)

v2.5.2.2 vs v2.7.2 Temperature at 496 hPa (20200123)

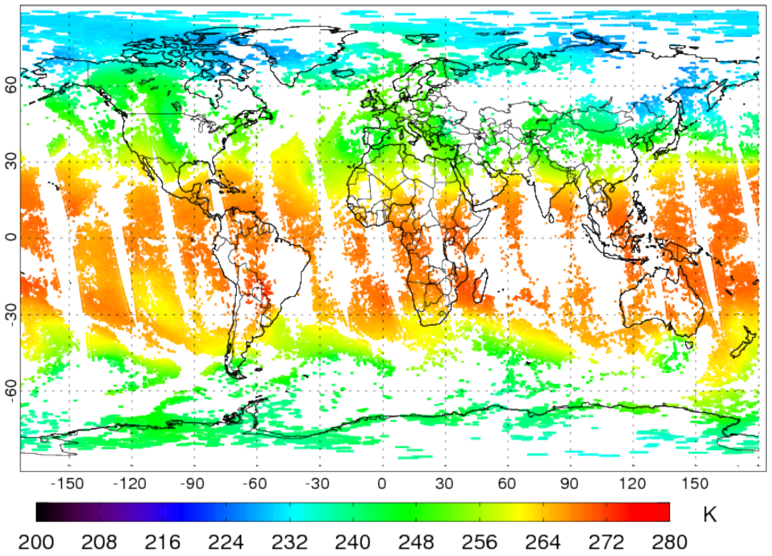


NOAA-20 20200123 Temperature (496 hPa)
v2.5.2.2 vs v2.7.2

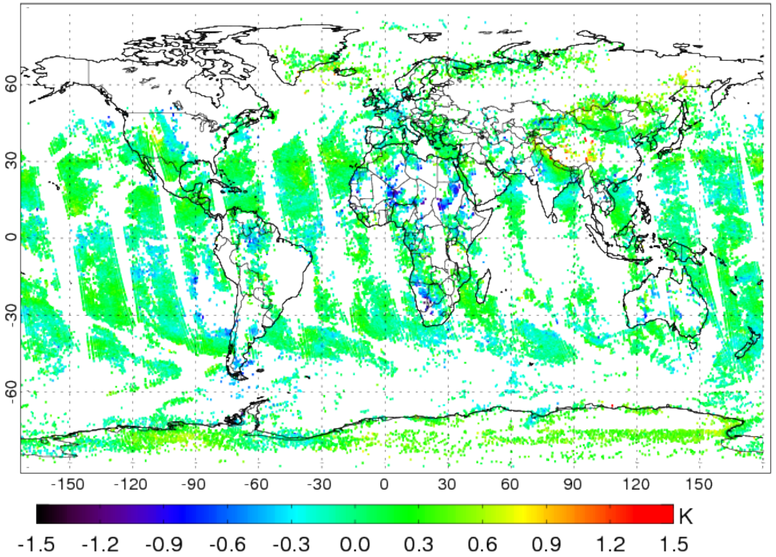
NOAA20_v2.5.2.2_Temperature at 496 hPa.20200123



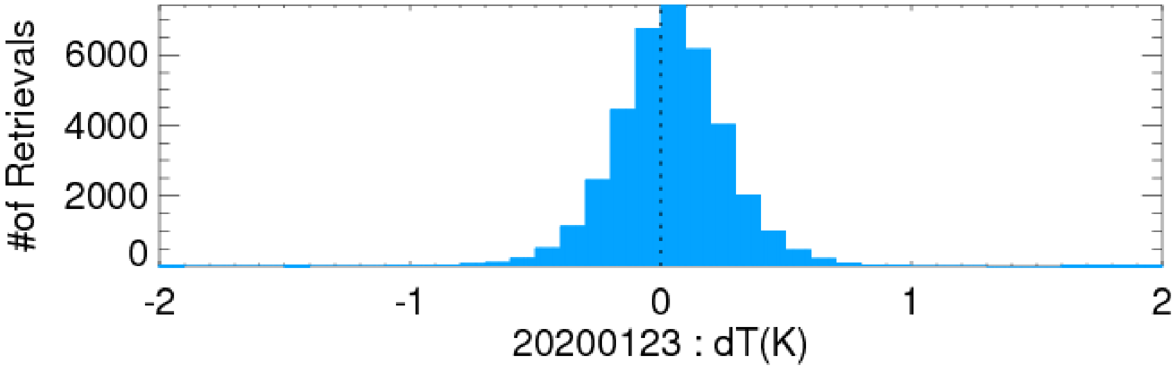
NOAA20_v2.7.2_Temperature at 496 hPa.20200123



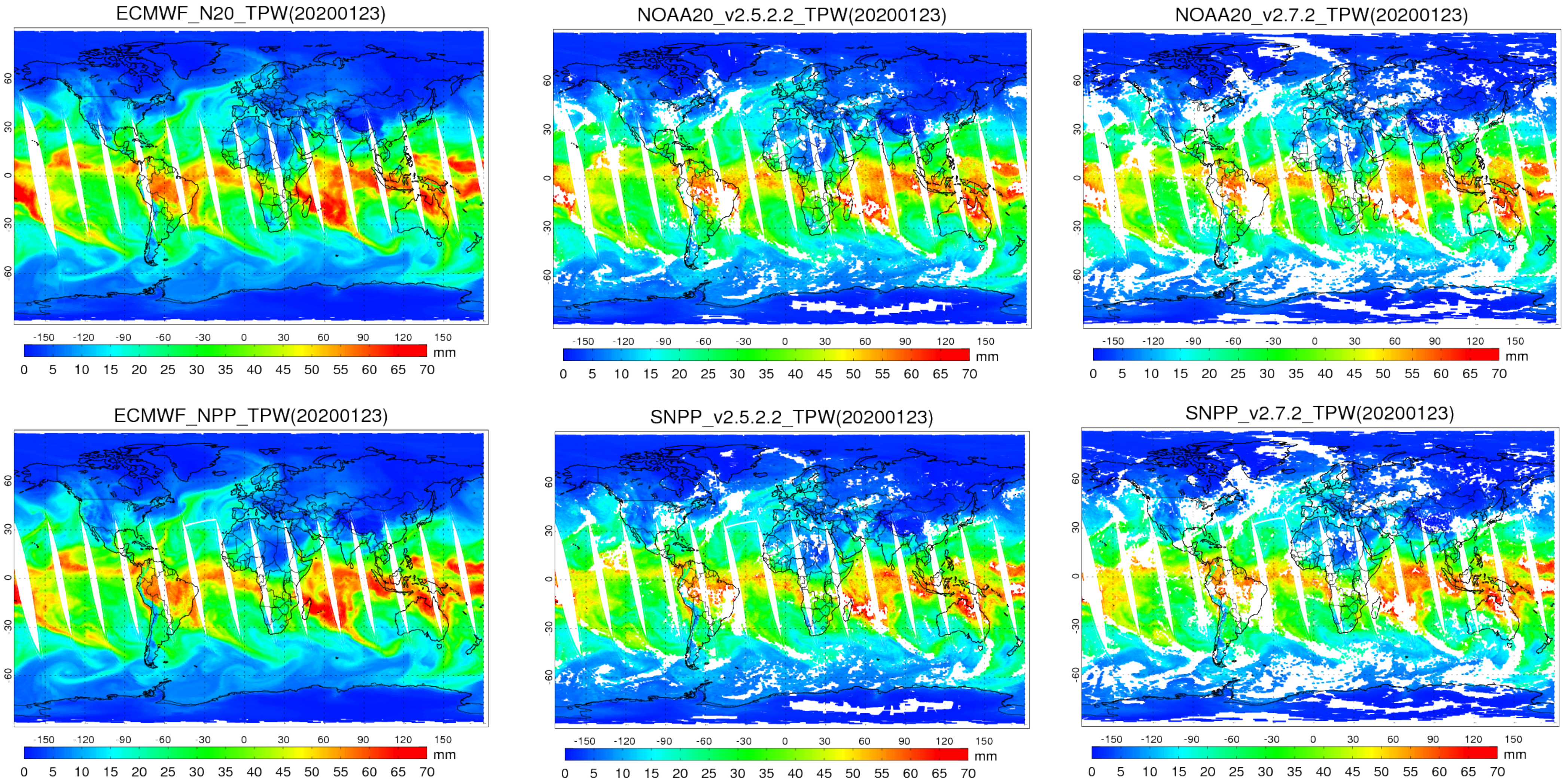
NOAA20_v2.7.2-v2.5.2.2_Temp at 496 hPa.20200123



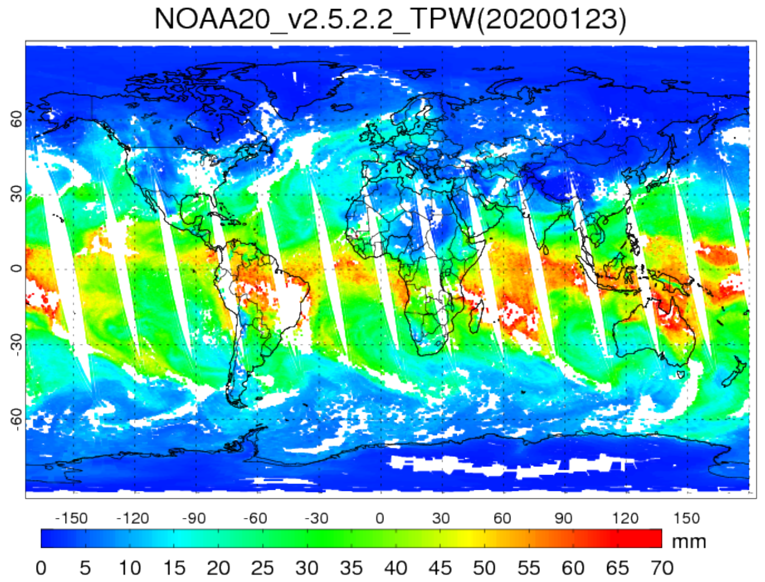
NOAA20_v2.7.2-NOAA20_v2.5.2.2_T_496hPa

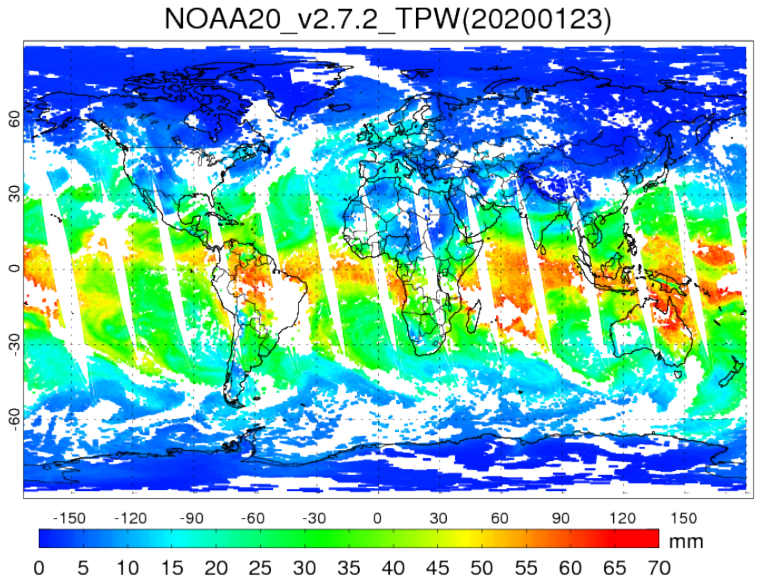


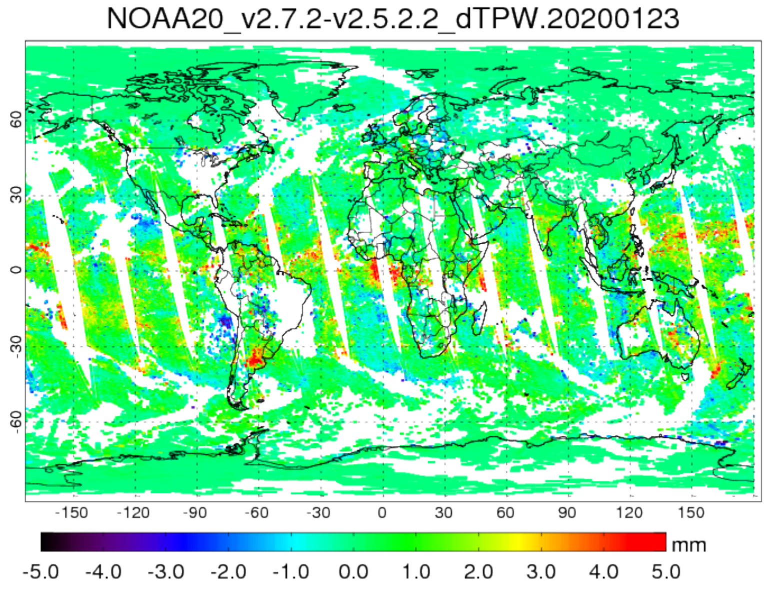
v2.5.2.2 vs 2.7.2 Total Precipitable Water (20200123)

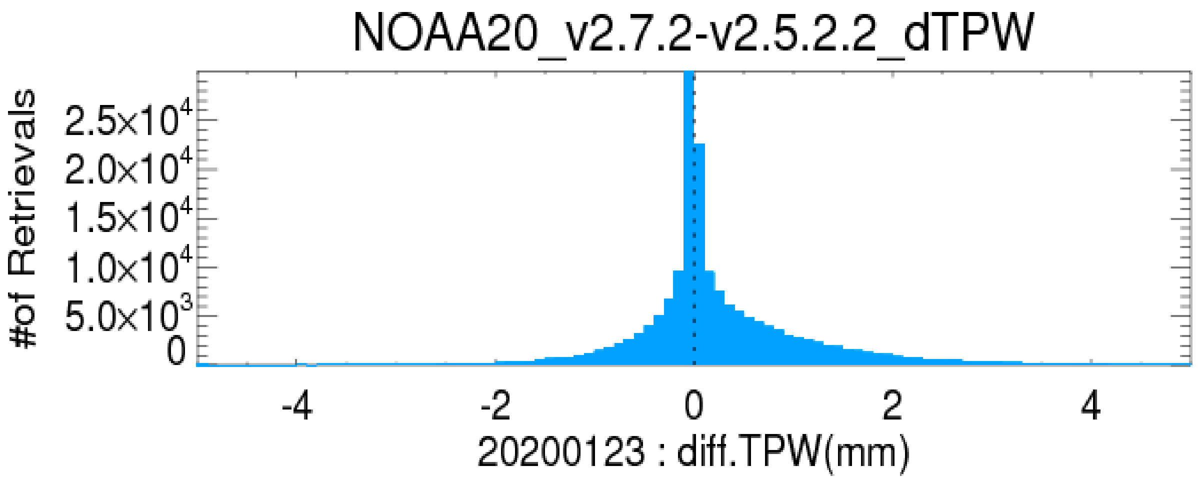


NOAA20 20200123 Total Precipitable Water (TPW) v2.5.2.2 vs v2.7.2

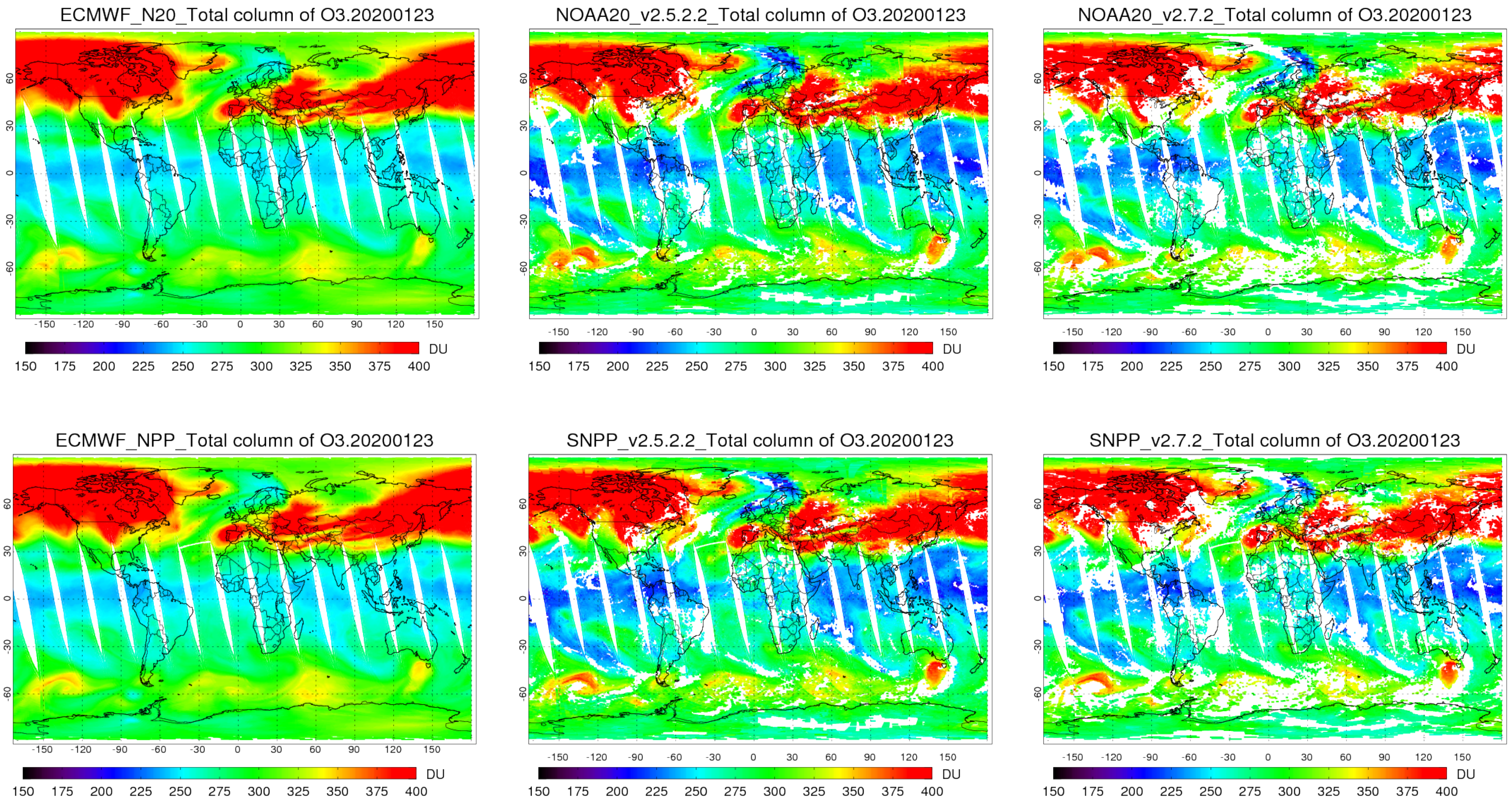




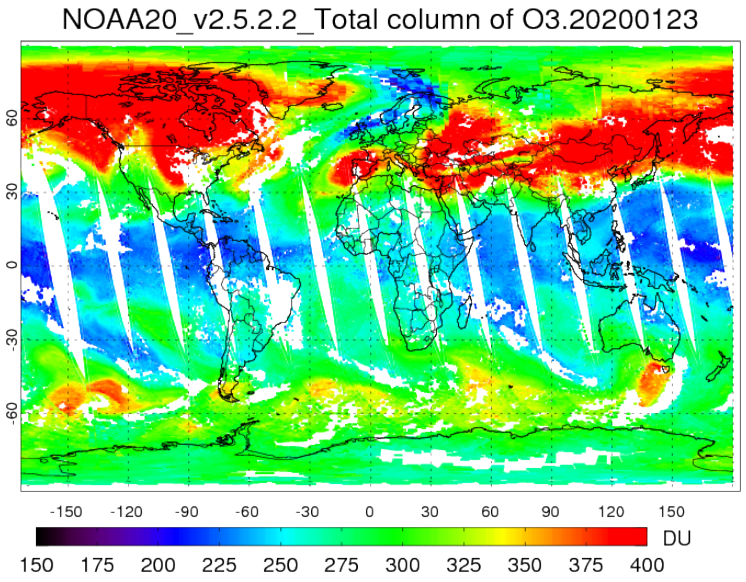


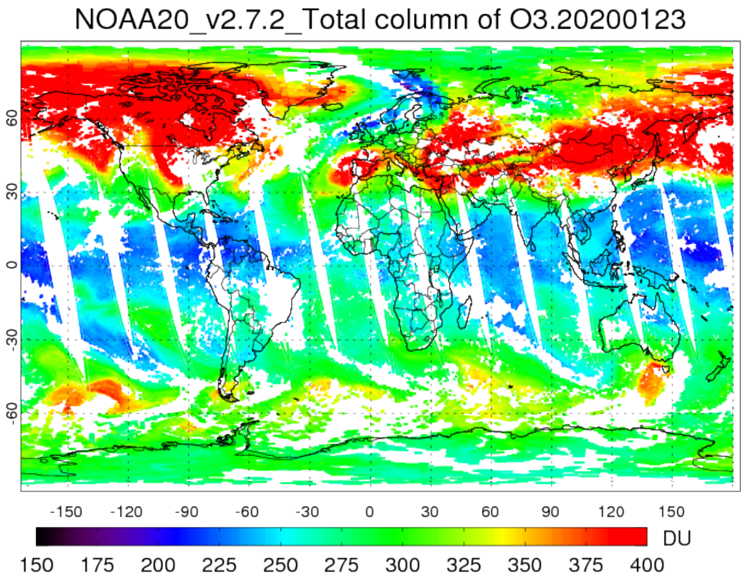


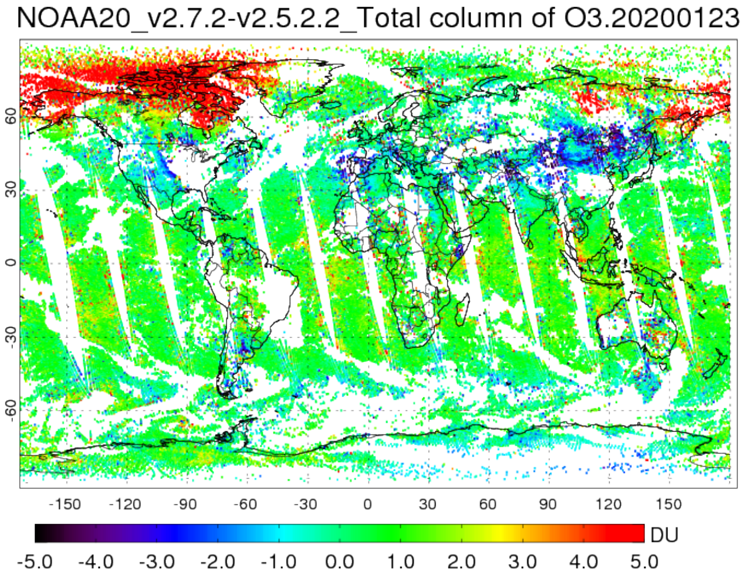
v2.5.2.2 vs 2.7.2 Total Column Ozone (20200123)

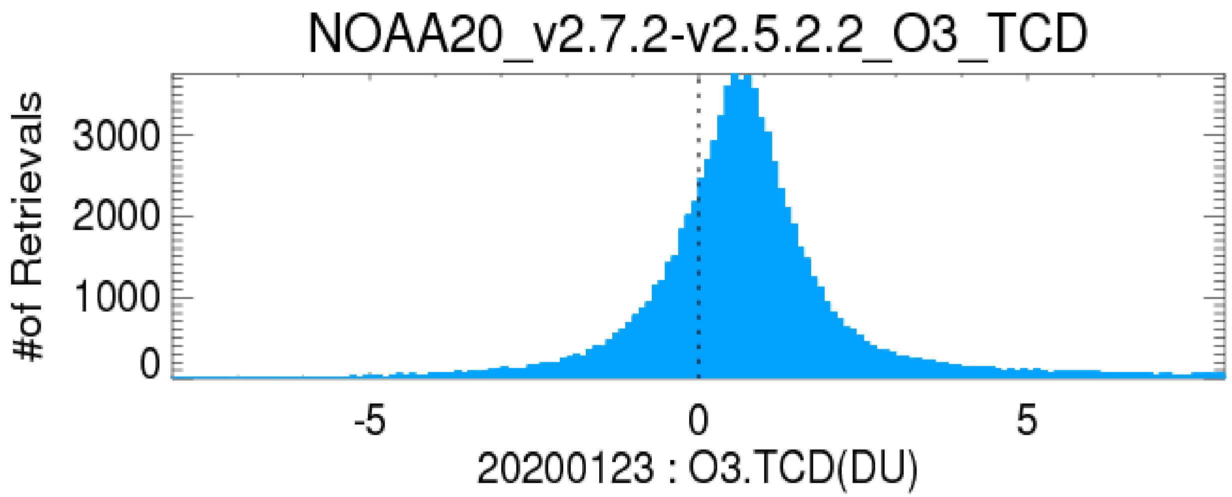


NOAA20 20200123 Total Column of Ozone v2.5.2.2 vs v2.7.2

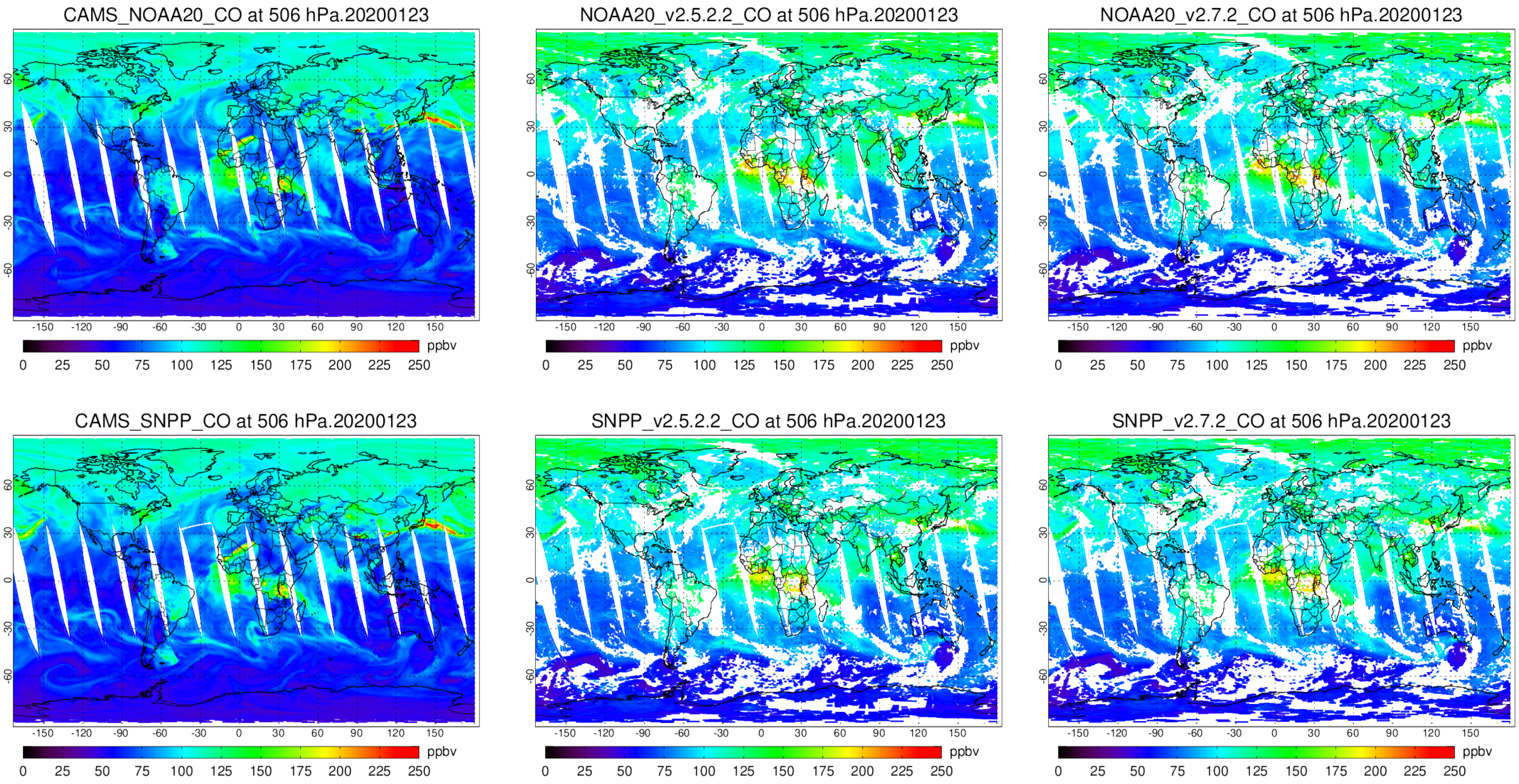




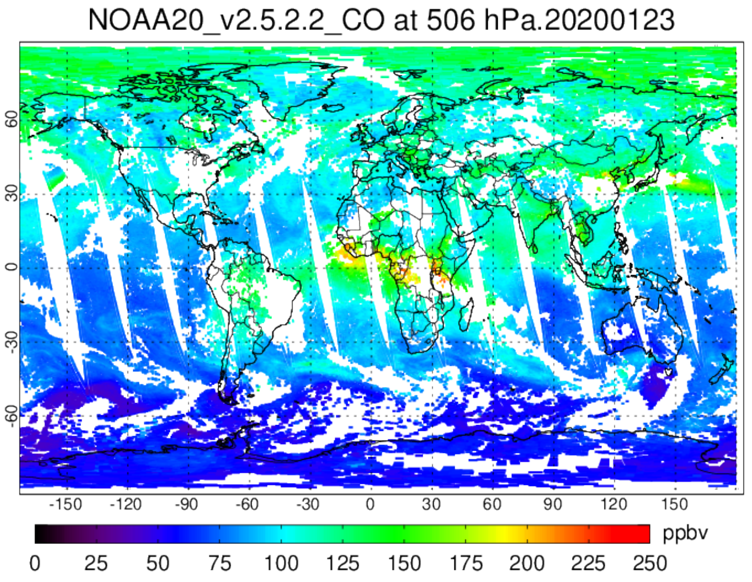


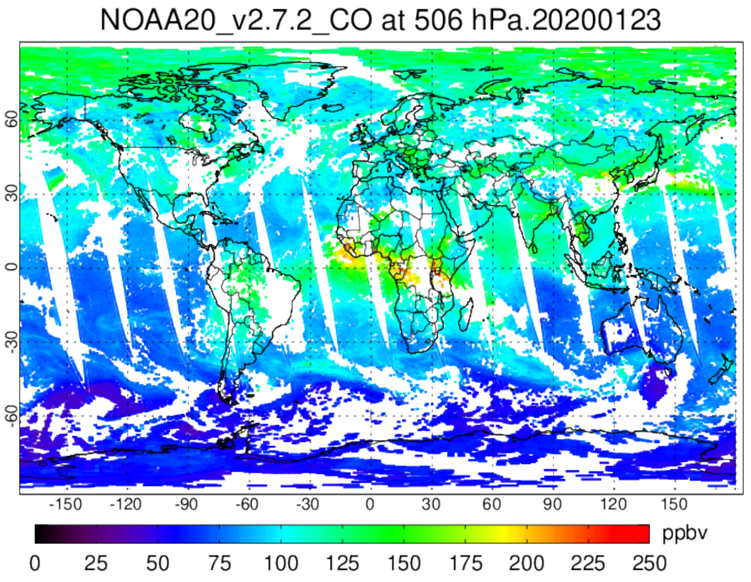


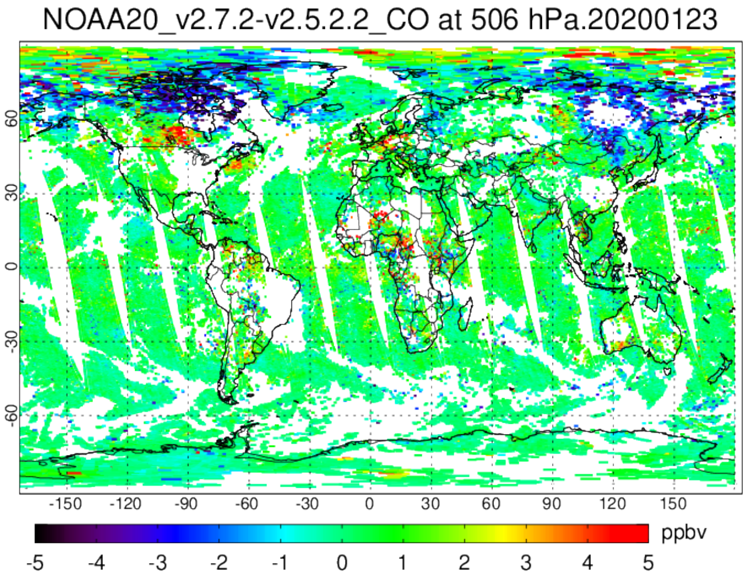
v2.5.2.2 vs 2.7.2 CO at 506 hPa (20200123)

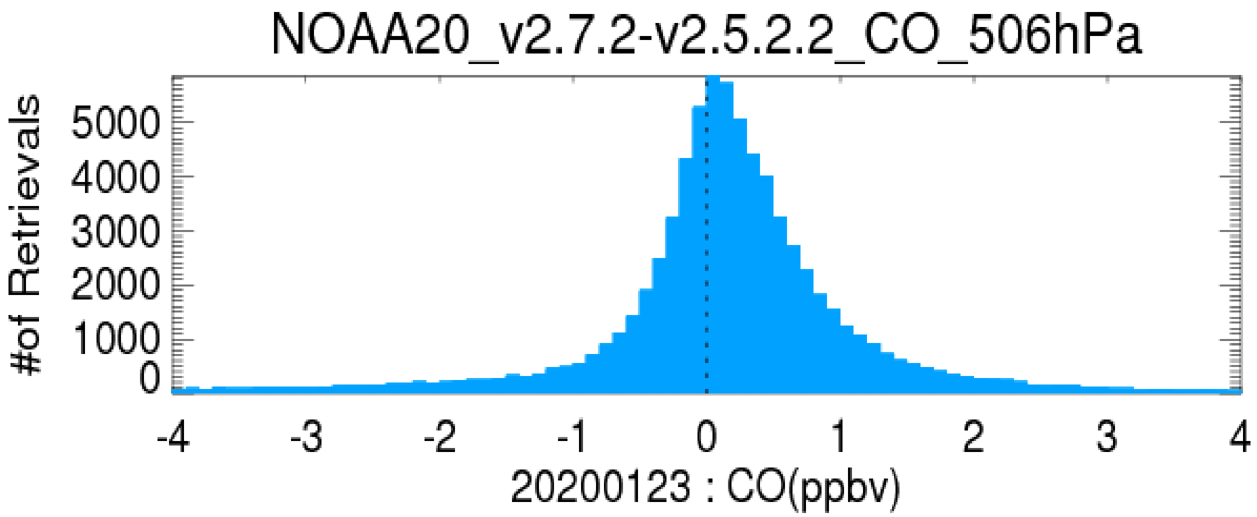


NOAA20 20200123 CO at 506 hPa
v2.5.2.2 vs v2.7.2





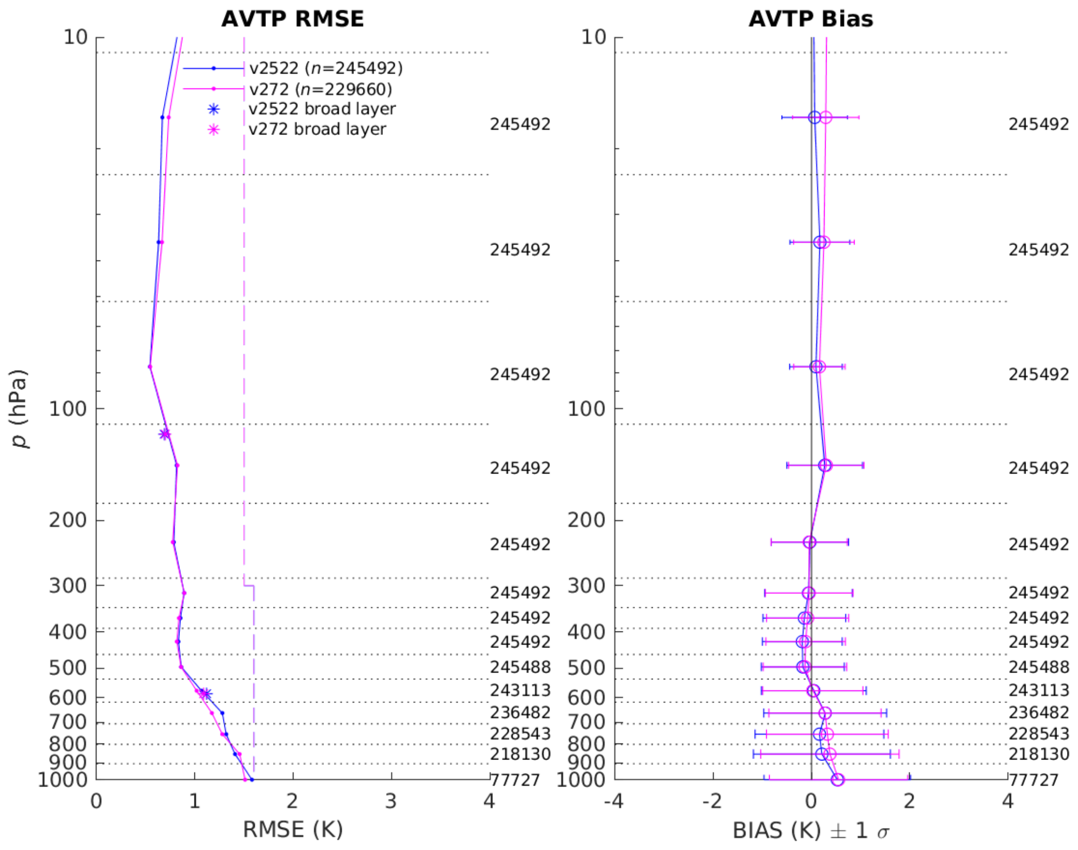




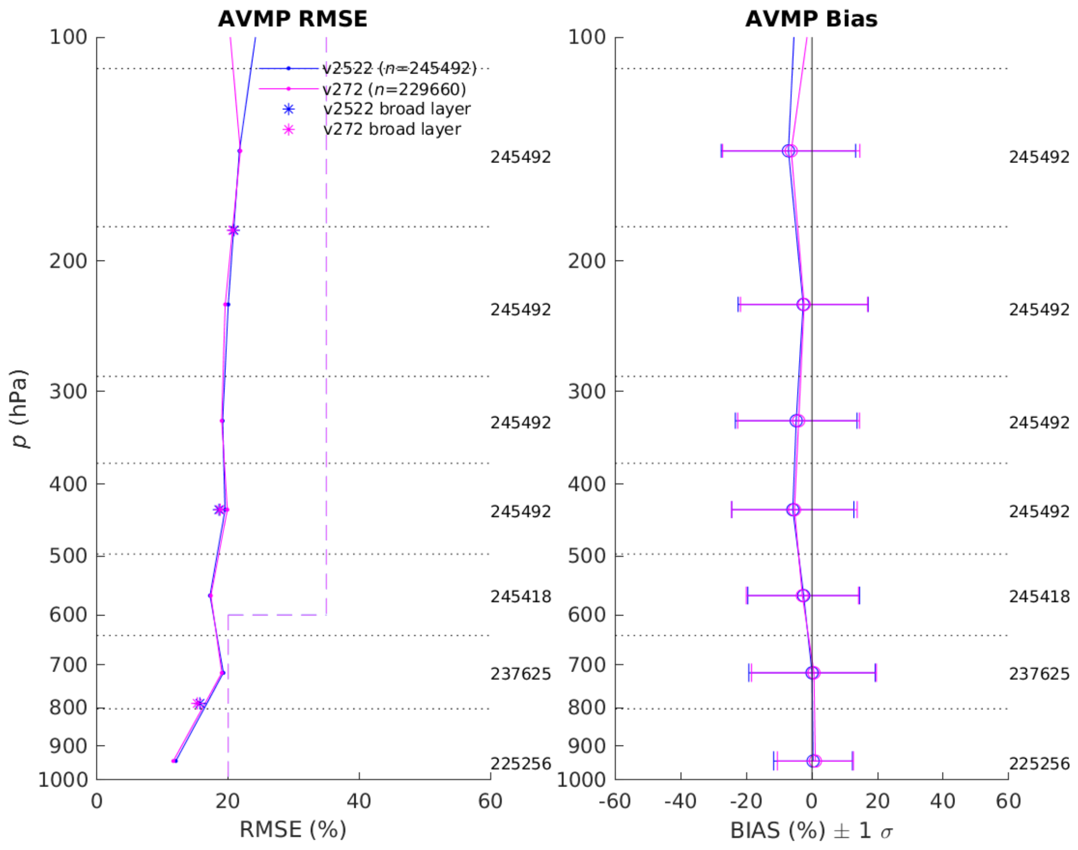
NOAA-20 IR+MW (20 August 2018)

v2.7.2 vs v2.5.2.2

AVTP



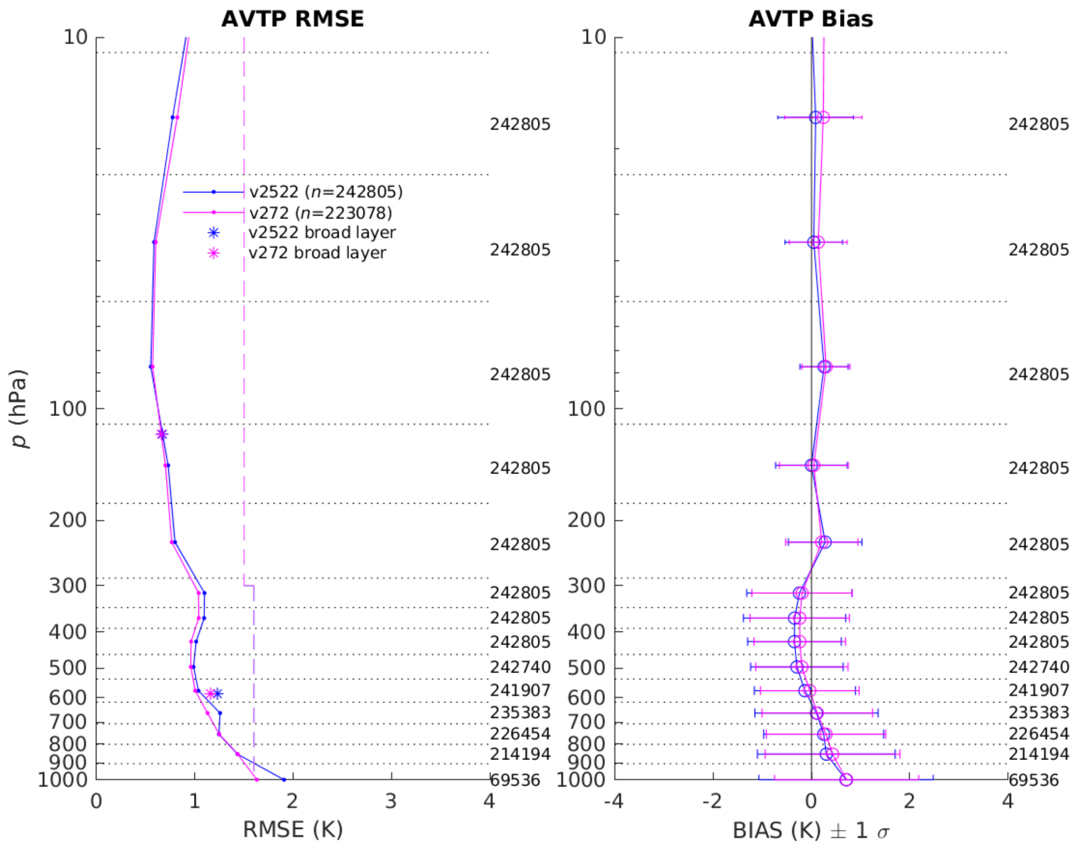
AVMP



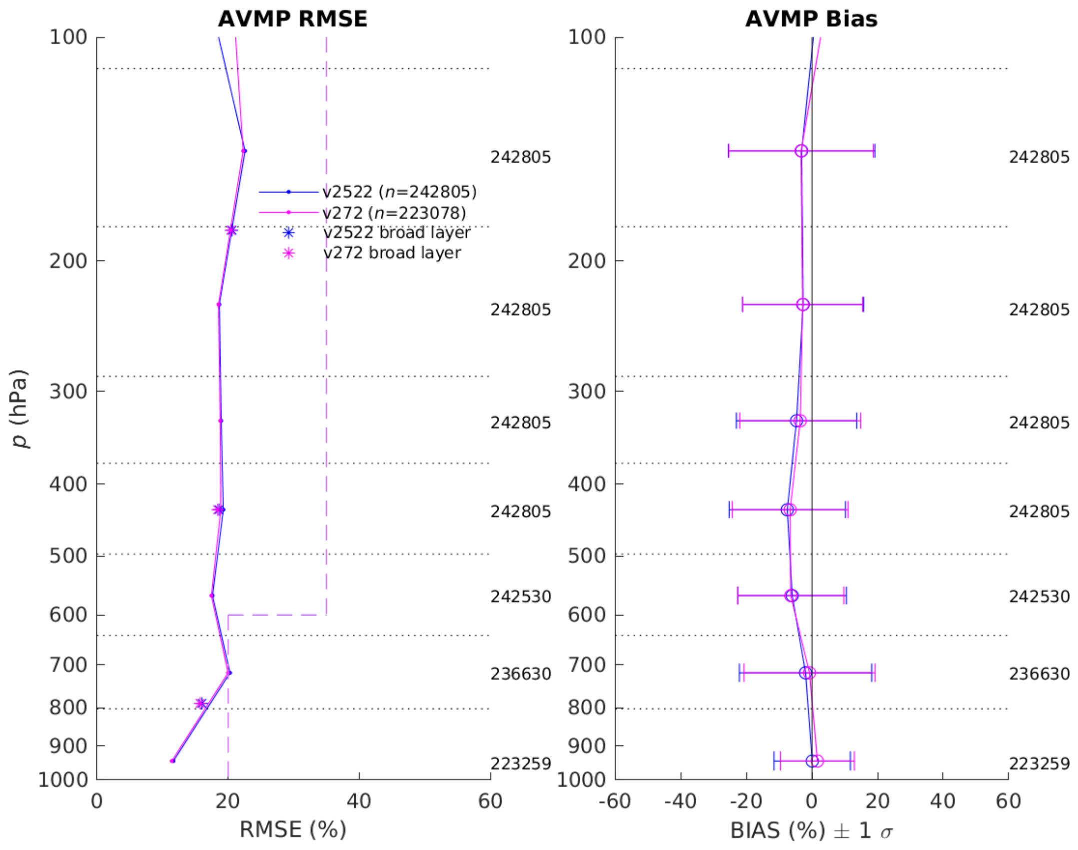
NOAA-20 IR+MW (23 January 2020)

v2.7.2 vs v2.5.2.2

AVTP

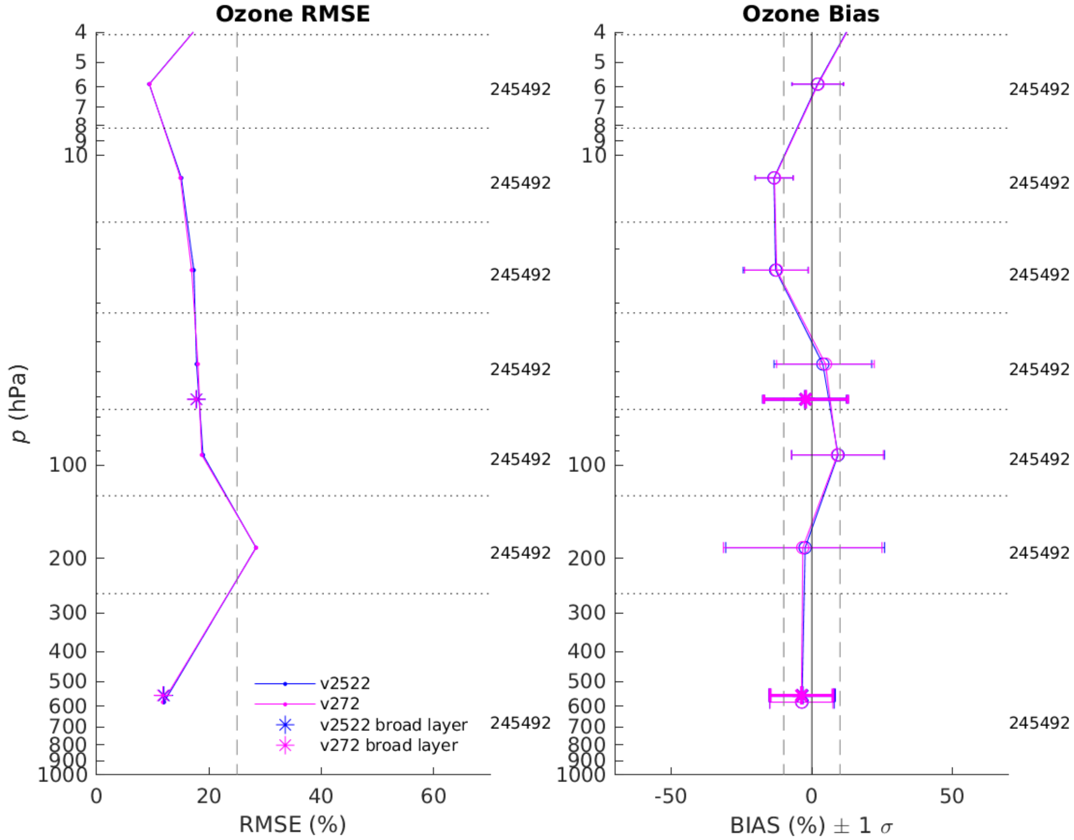


AVMP

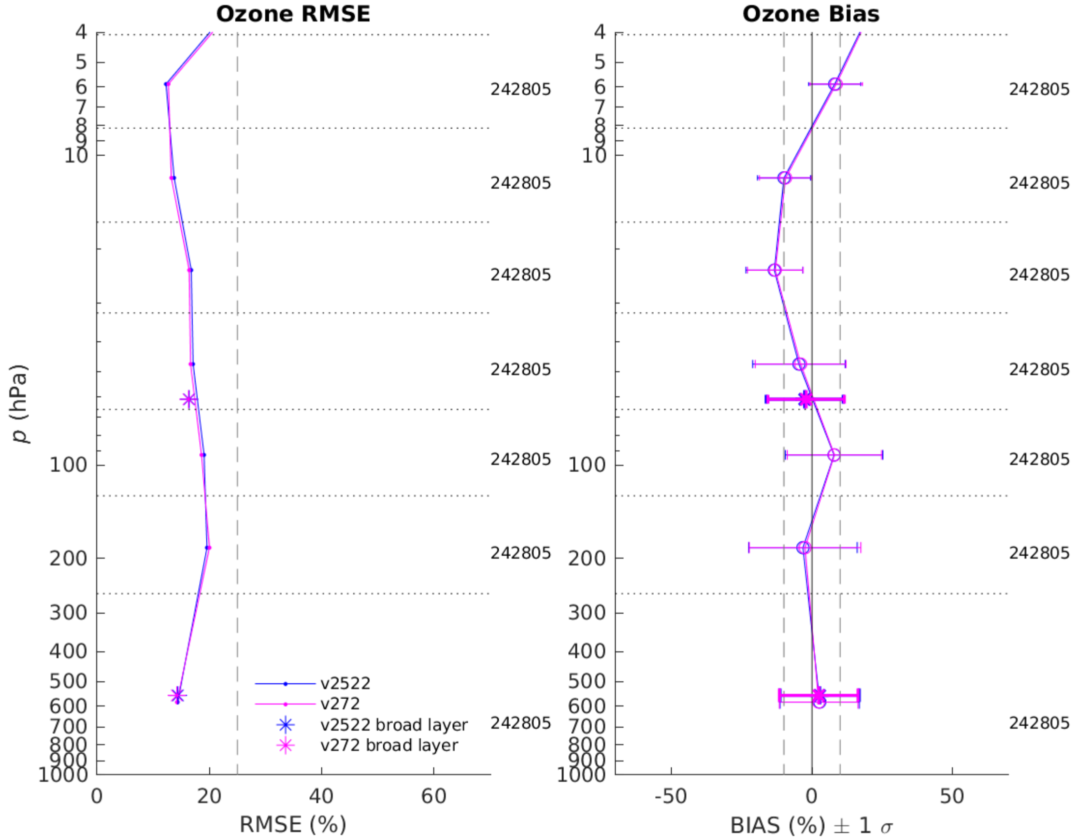


NOAA-20 IR Ozone Profile
v2.7.2 vs v2.5.2.2

20 Aug 2018



23 Jan 2020



NUCAPS PRODUCT EVALUATIONS WITH OTHER CORRELATIVE DATA SETS

- **Hierarchy of validation strategies**
  - NUCAPS product evaluations with other correlative data sets (AIRS, TROPOMI) (Juying Warner)
  - Expanded truth data sets and statistical plots for validation of CH_4 and CO_2 (Nick Nalli)

NUCAPS Carbon Trace Gas EDR Reference data, Time Periods

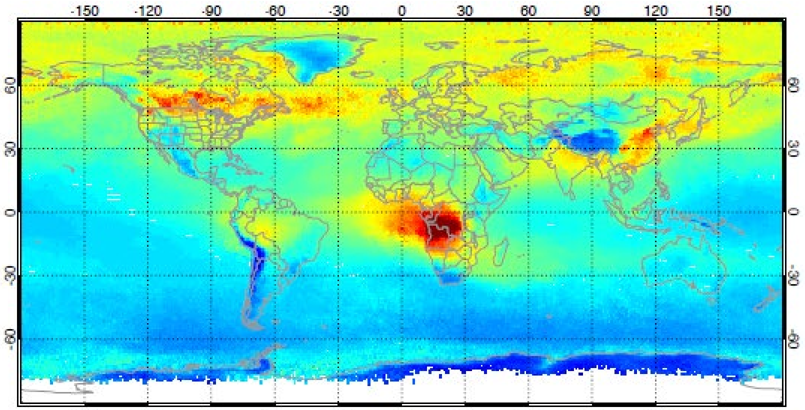
Observation Type	Reference Data	Time Period	Validation	Remarks
Atmospheric Tomography Mission (ATom)	• DC-8 aircraft based *in situ* air samples • Profiles of volume mixing ratios (ppmv) obtained using NOAA/ESRL Picarro G2401m analyzer	ATom-1,-2: Jul 2016 to Feb 2017 ATom-4: Apr-May 2018	✓ CO meets requirements in sensitive layers (where AKs peak) ✓ CH4 meets bias requirement throughout column ✓ CO2 meets bias and precision requirements throughout column	ATom (*Wofsy et al.* 2018) acknowledgment • Kathryn McCain, Colm Sweeney (NOAA/ESRL) • https://doi.org/10.3334/ORNLDAAC/1581
Total Carbon Column Observing Network (TCCON)	• Ground-based network of uplooking spectrometers • Total column DMF retrieved from near-IR solar spectrum	6 Focus Days: Apr, Jun, Aug, Oct, Dec 2018, and Feb 2019	✓ CO meets total column requirements ✓ CH4 meets total column bias requirement ✓ CO2 meets total column requirements	TCCON (*Wunch et al.* 2010, 2011) acknowledgment • Debra Wunch (CalTech)

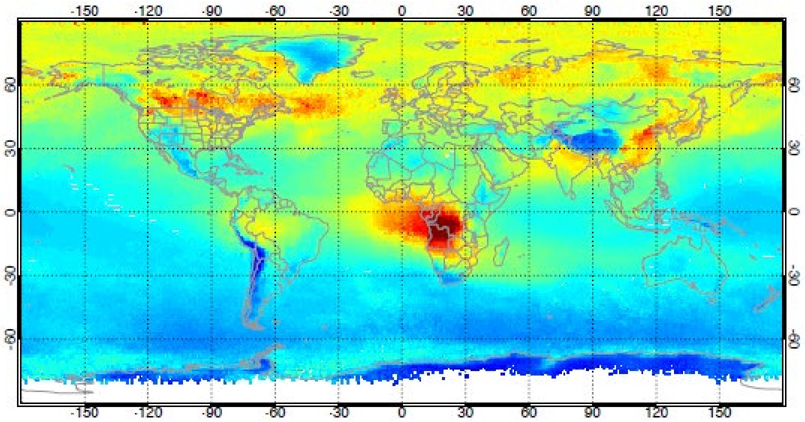
Dates Selected for Apr 2020 Review

Review Apr 2020	CrIS/SDRs ATMS/TDR		ECMWF		CAMS	TCCON
	SNPP	NOAA-20	SNPP	NOAA-20		
20180401	√		√		√	√
20180516	√		√		√	
20180615	√	√	√	√	√	√
20180716	√	√	√	√	√	
20180816	√	√	√	√	√	
20180820	√	√	√	√		√
20180916	√	√	√	√	√	
20181015	√	√	√	√	√	√
20181114	√	√	√	√	√	
20181215	√	√	√	√	√	√
20190115	√	√	√	√	√	
20190215	√	√	√	√	√	√
20190316	√	√	√	√	√	
20190415		√		√	√	
20190515		√		√	√	

Comparisons of v2.7.2 CO Column ($x10^{17}$ mols/cm^2) Aug 2018

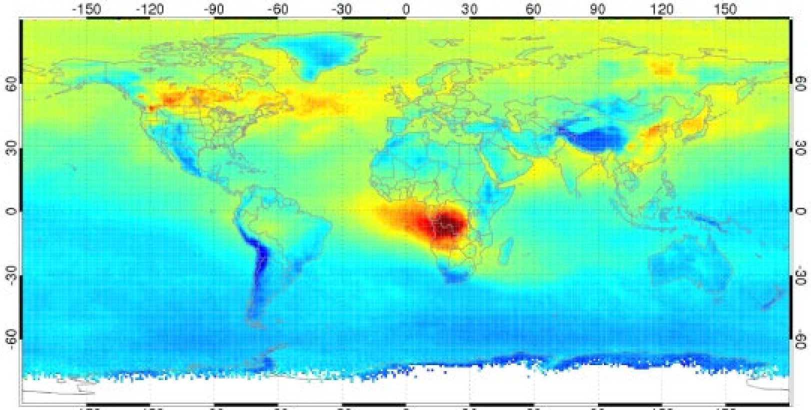
NUCAPS SNPP CrIS





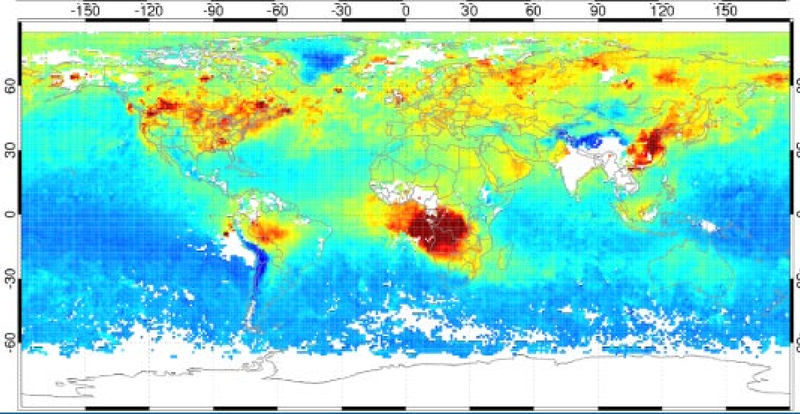
NUCAPS NOAA-20 CrIS

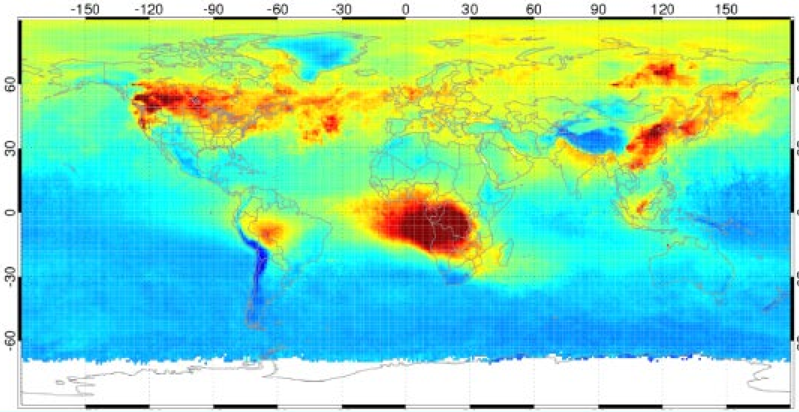
AIRS



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

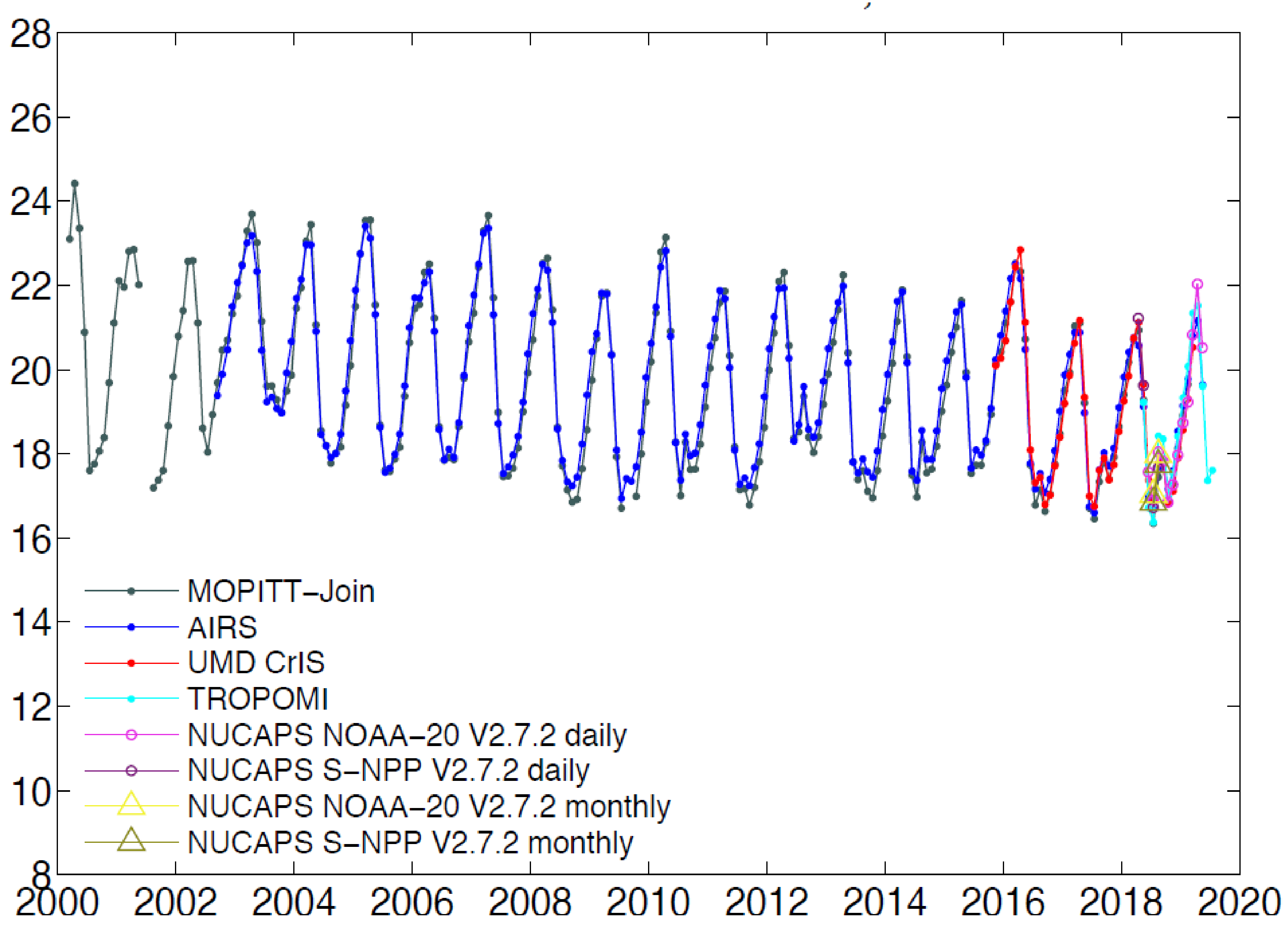
MOPITT





TROPOMI

CO Total Column Trends NH for v2.7.2

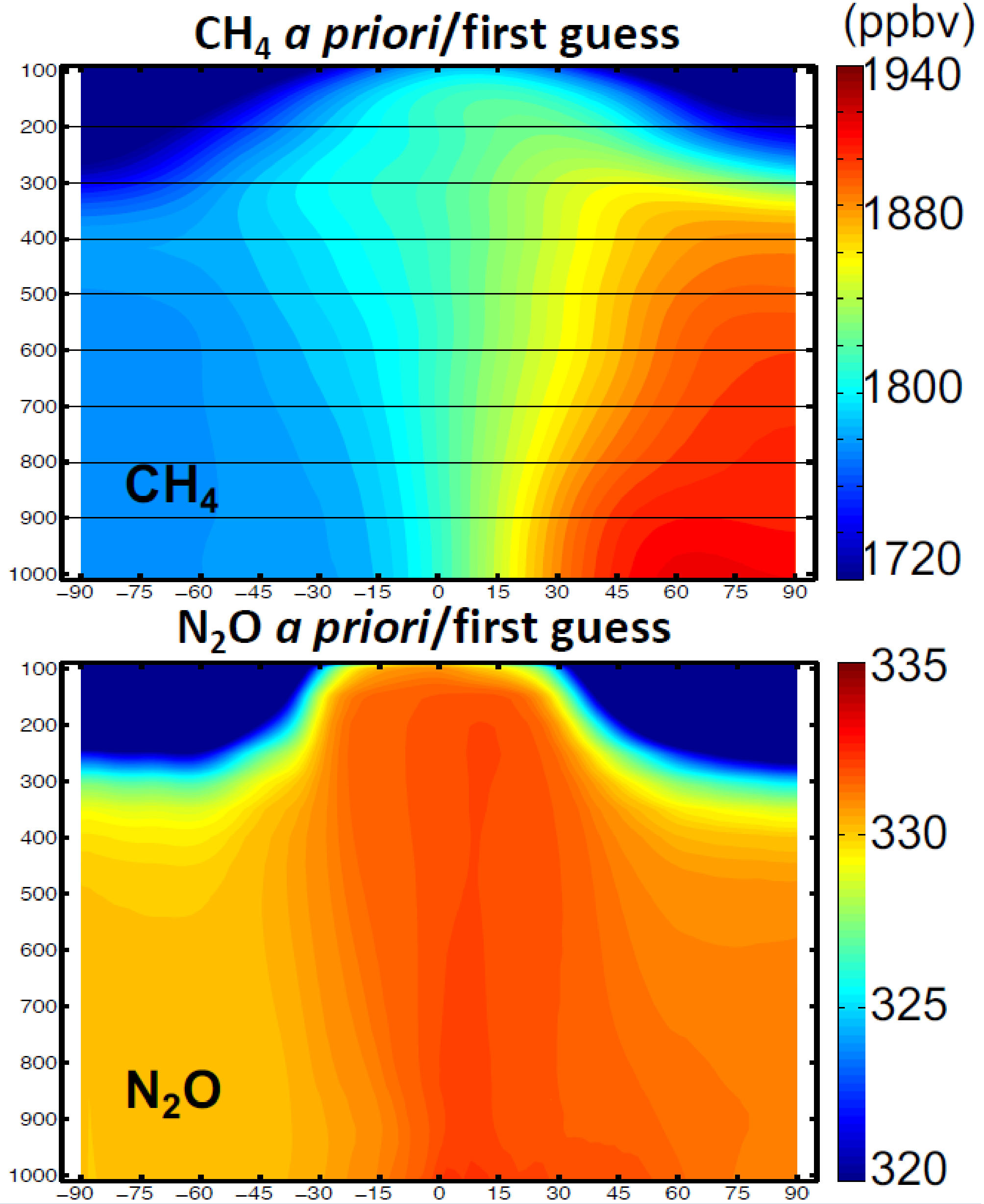


- MOPITT-join: MOPITT NIR & IR
- AIRS: operational
- UMD CrIS: NASA L1 & NUCAPS V2.7.2 *Credit to Chris Barnet's help with NASA L1 usage
- TROPOMI: operational
- NUCAPS SNPP/NOAA-20 v2.7.2 daily (NOAA CrIS SDR): one day data from each month for 12 months to show seasonality
- NUCAPS SNPP/NOAA-20 v2.7.2 monthly (NOAA CrIS SDR): Two monthly means July and August 2018

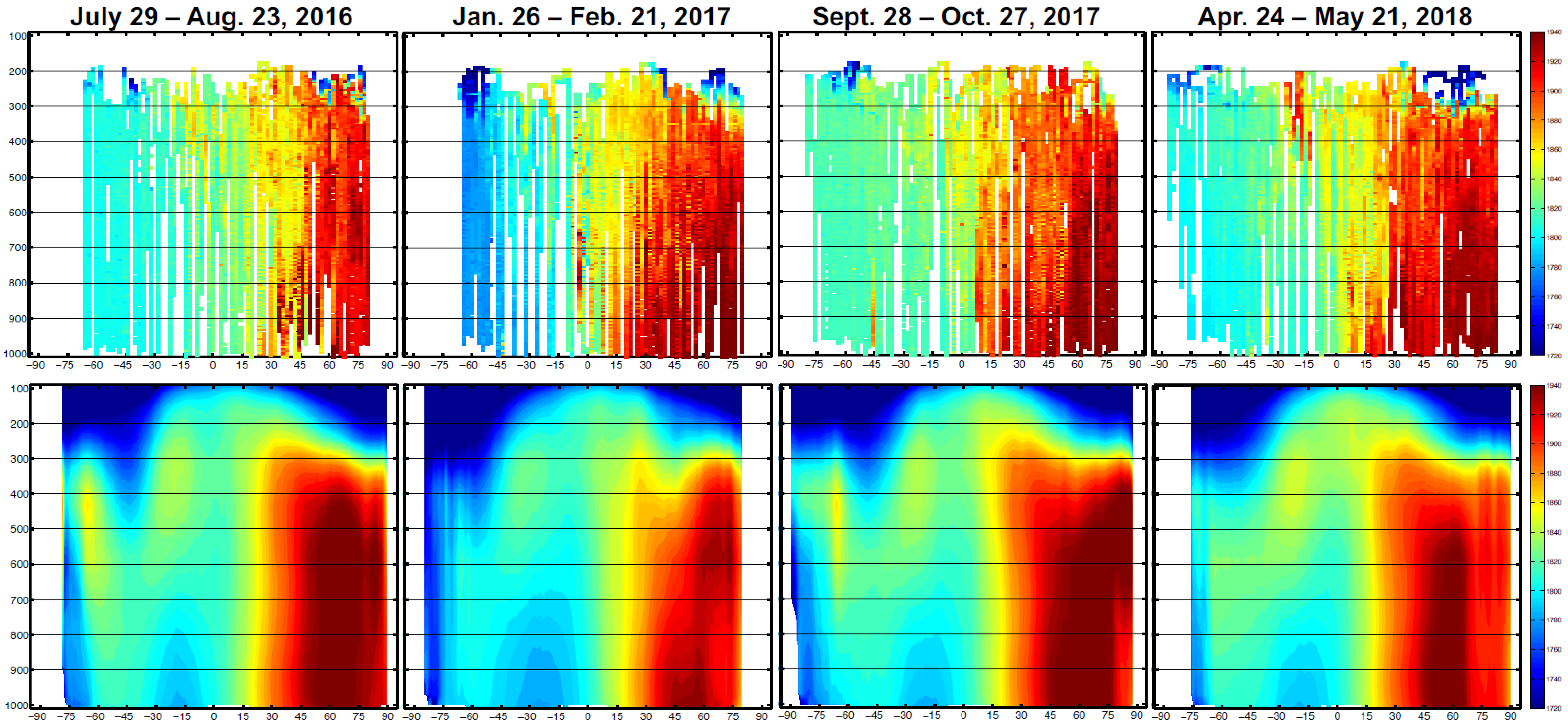
v2.7.2 CH_4 and N_2O *a priori* (same as in OPS v2.5.2.2)

- Improvements since Provisional Review
  - Updated CH_4/N_2O *a priori*
    - Same as for Provisional
  - Improved CH_4 agreements against *in situ* and other satellite measurements

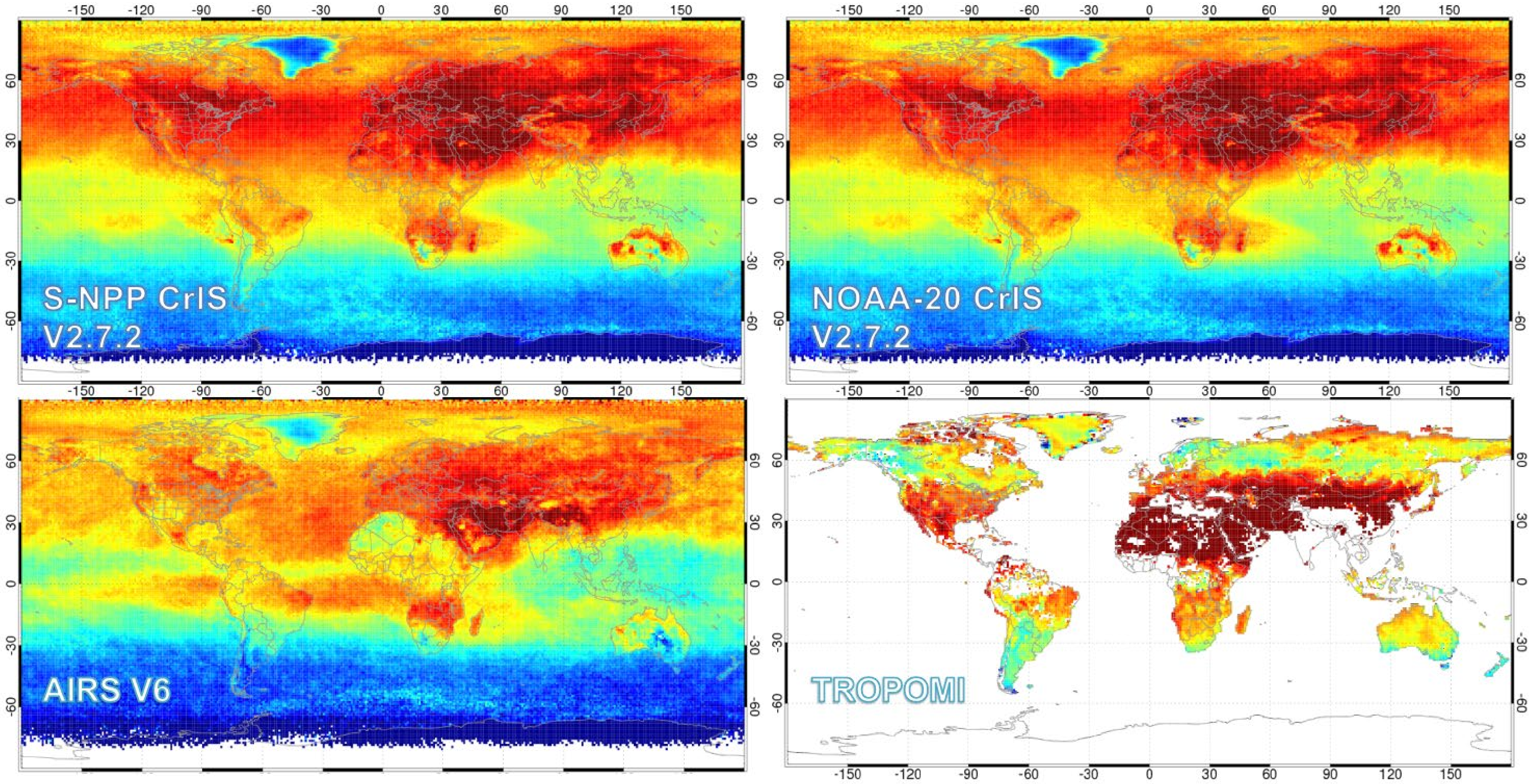
- Algorithm performance evaluation for Validated Maturity
  - Expanded Truth data sets
  - QC flag updates
  - TROPOMI
  - AIRS



NUCAPS SNPP v2.7.2 CH_4 Retrievals (lower) against ATom1–4 Curtains (upper)

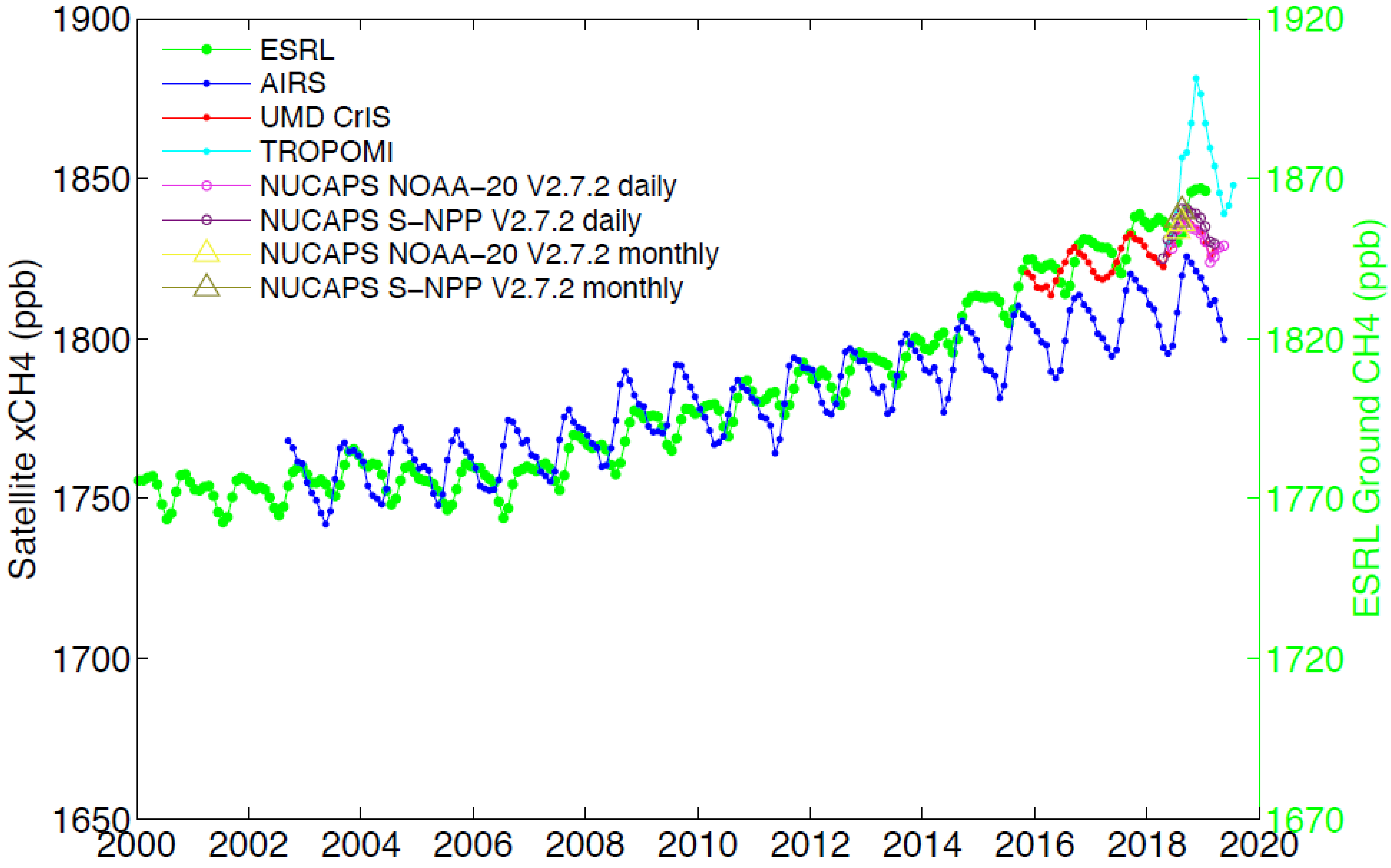


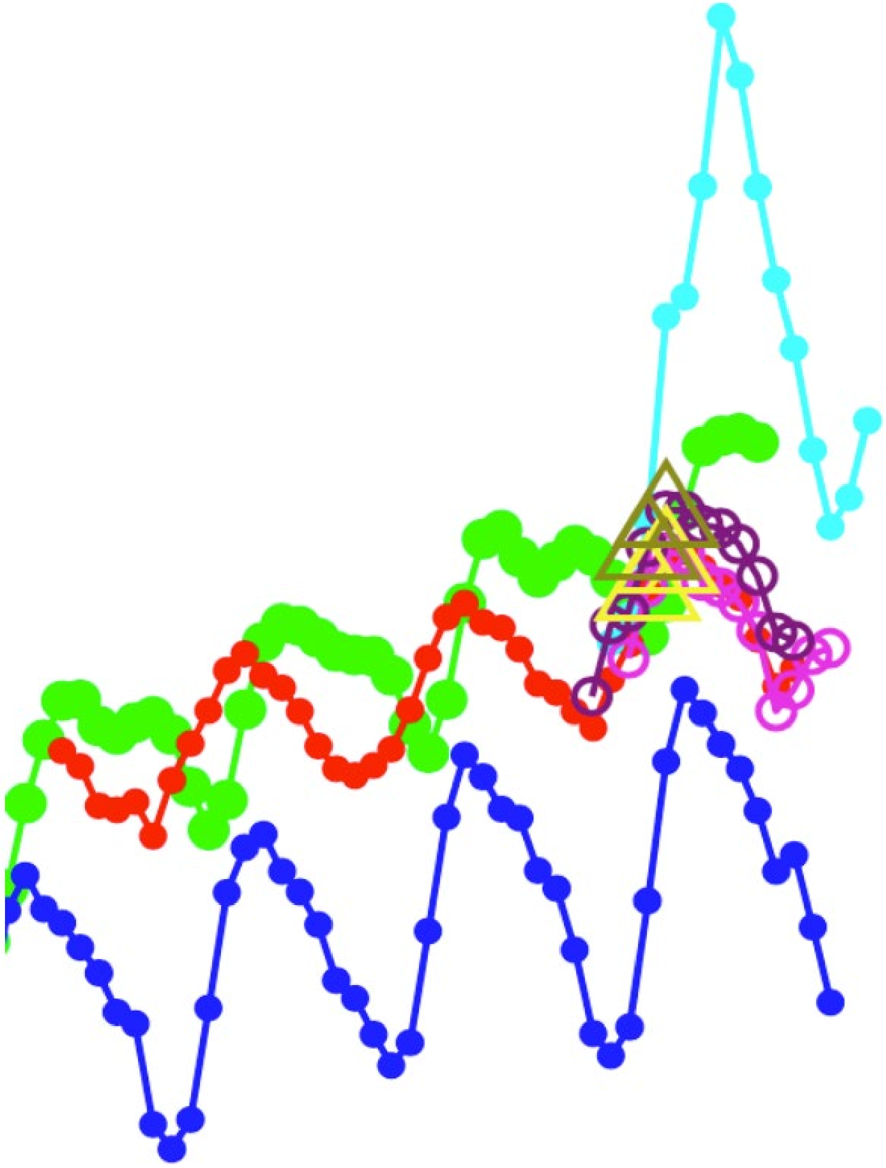
NUCAPS xCH_4 v2.7.2 Compared to AIRS and TROPOMI Aug 2018 Monthly Mean



- CrIS CH_4 is slightly higher than AIRS; but agree with TROPOMI mid- and low- latitudes better.

NUCAPS CH_4 Trends v2.7.2 and Comparisons to AIRS and TROPOMI

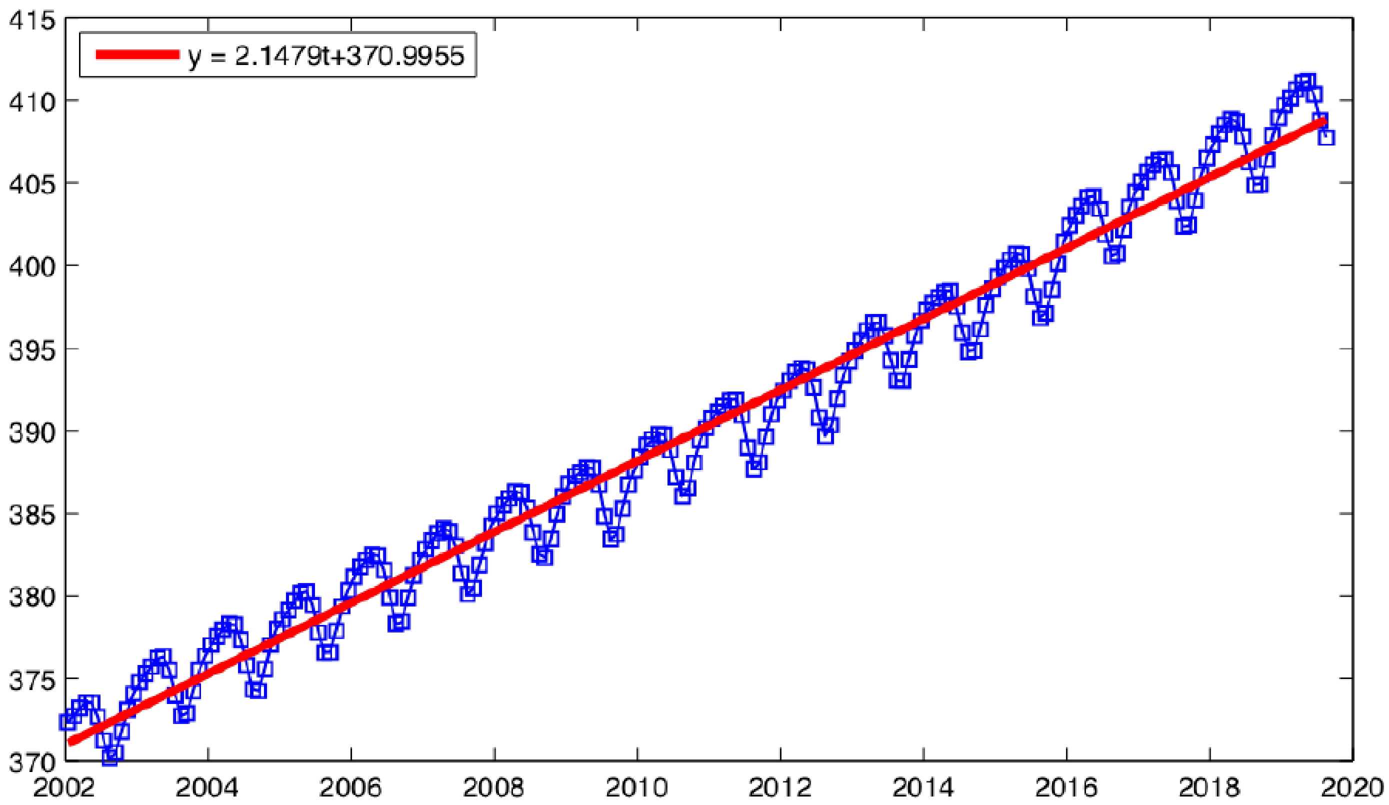




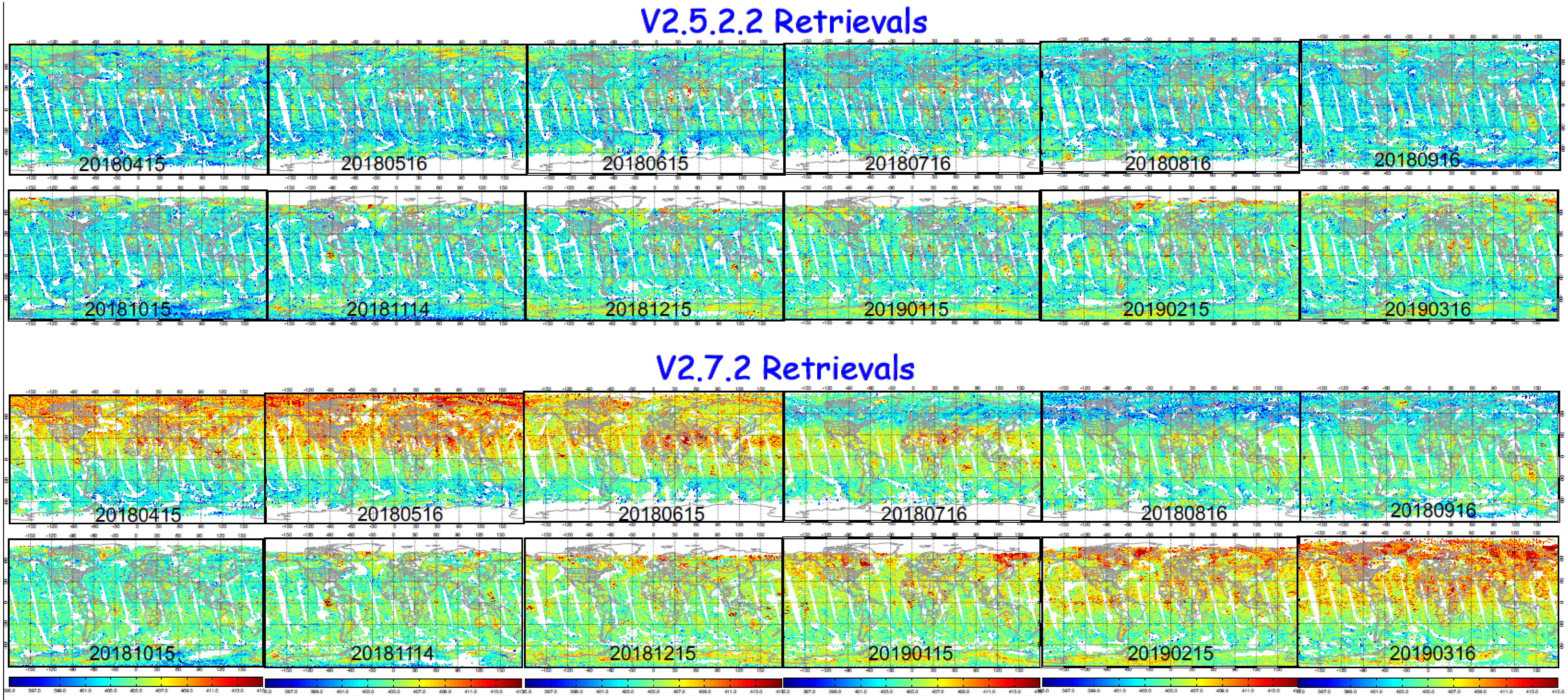
- AIRS did not show the sudden increase in 2015, while CrIS shows much higher values than AIRS, in better agreement with ESRL in situ measurements.
- TROPOMI is land-only, so higher values than all other.

- Findings/Issues from Beta Review
  - Value ranges, distributions, and trends were incorrect
- Improvements since Beta Review
  - Primarily new *a priori*
- Algorithm performance evaluation for Provisional Maturity
  - Expanded Truth data sets – ATom 1–4
  - Comparing against OCO-2
  - AIRS

1. Latitudinal variations, and
2. Seasonality from Carbon Tracker
3. Linear trend from ESRL surface measurements
4. Climatology uses anomaly from ESRL data

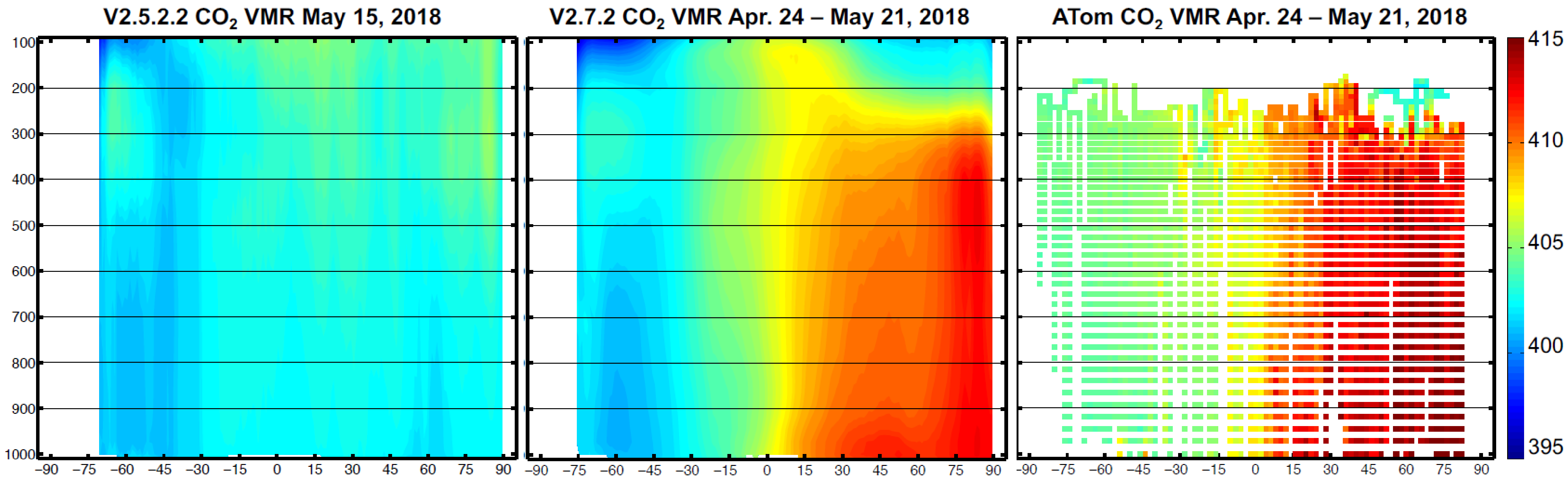


NUCAPS SNPP CO_2 v2.5.2.2 vs v2.7.2 at 307 hPa 12-Months Seasonality



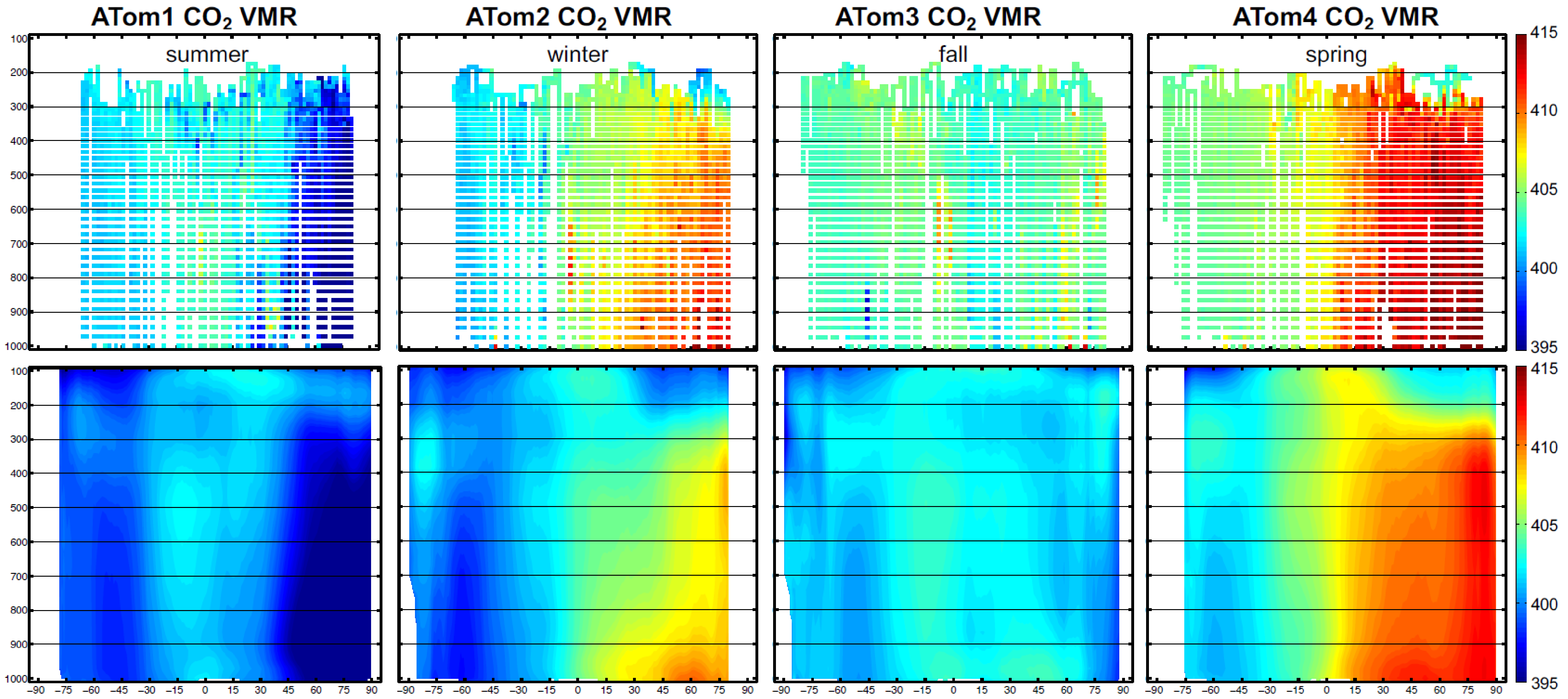
- V2.7.2 shows significantly more seasonality.

NUCAPS CO_2 VMR (ppbv) v2.5.2.2 vs v2.7.2 Retrievals Against ATom-4



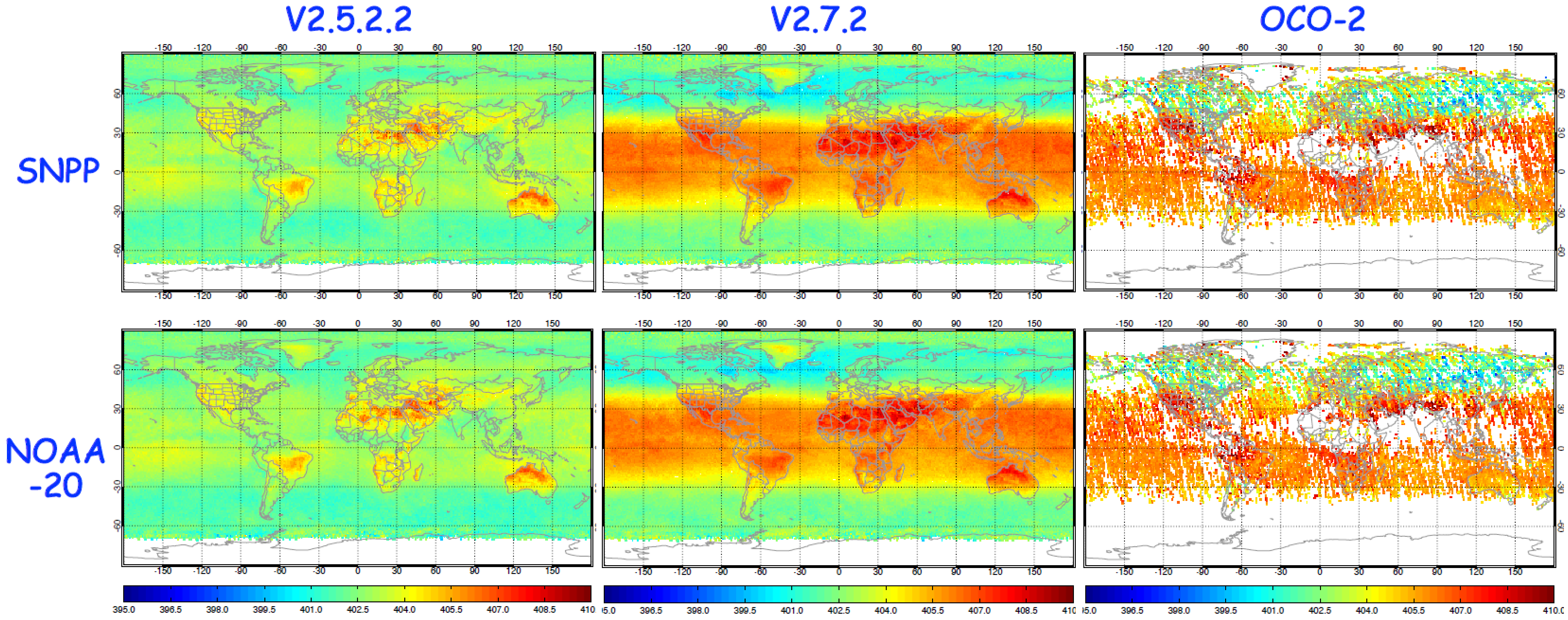
- Note V2.5.2.2 (left) is a single day curtain, while V2.7.2 and ATom are entire mission period;
- V2.7.2 agrees with in situ measurements significantly better.

SNPP CrIS CO_2 v2.7.2 Validate Against ATom 1–4 All Sensors



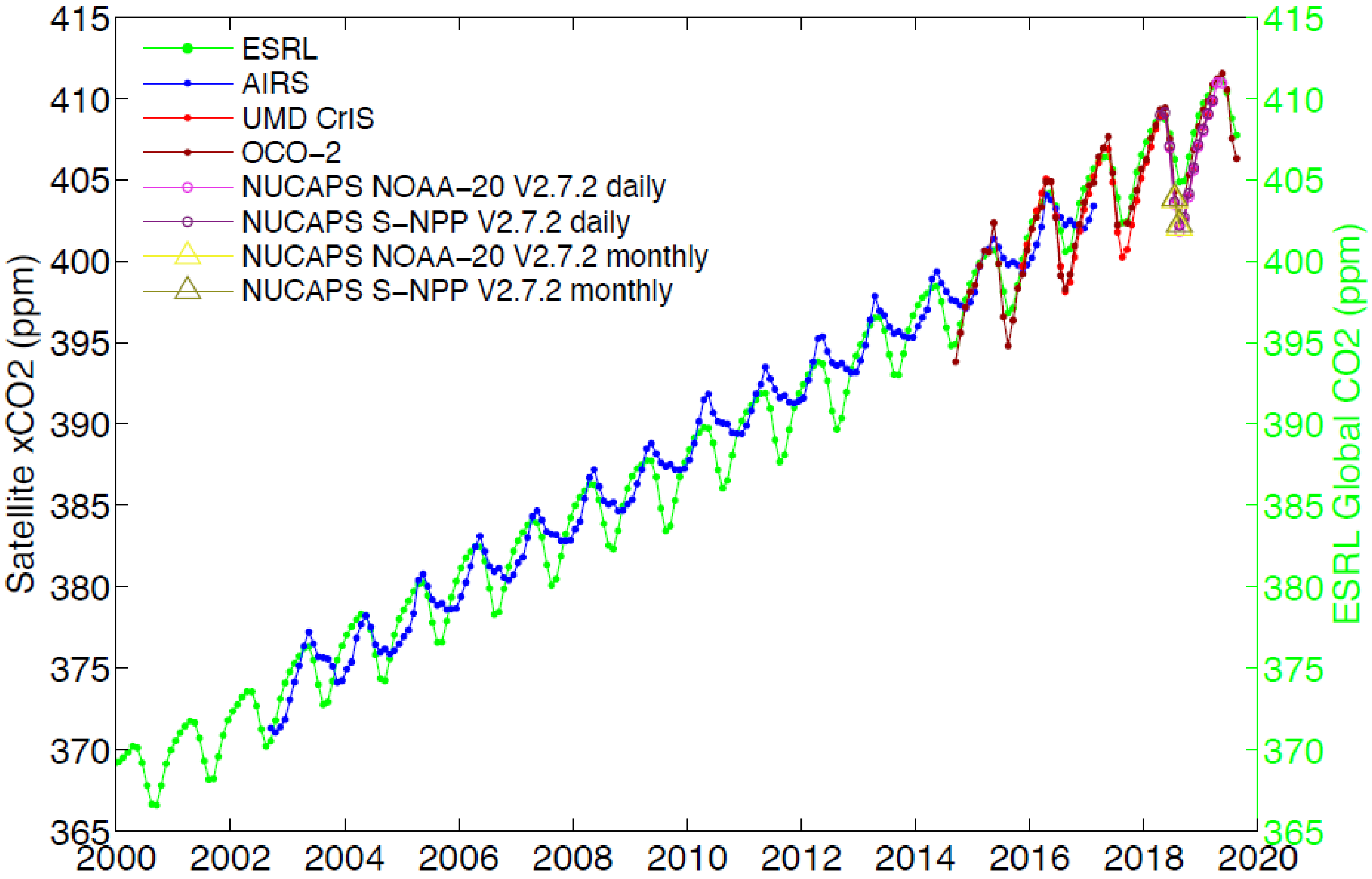
- Main reason for the differences are: ATom are single tracks but CrIS is global zonal mean

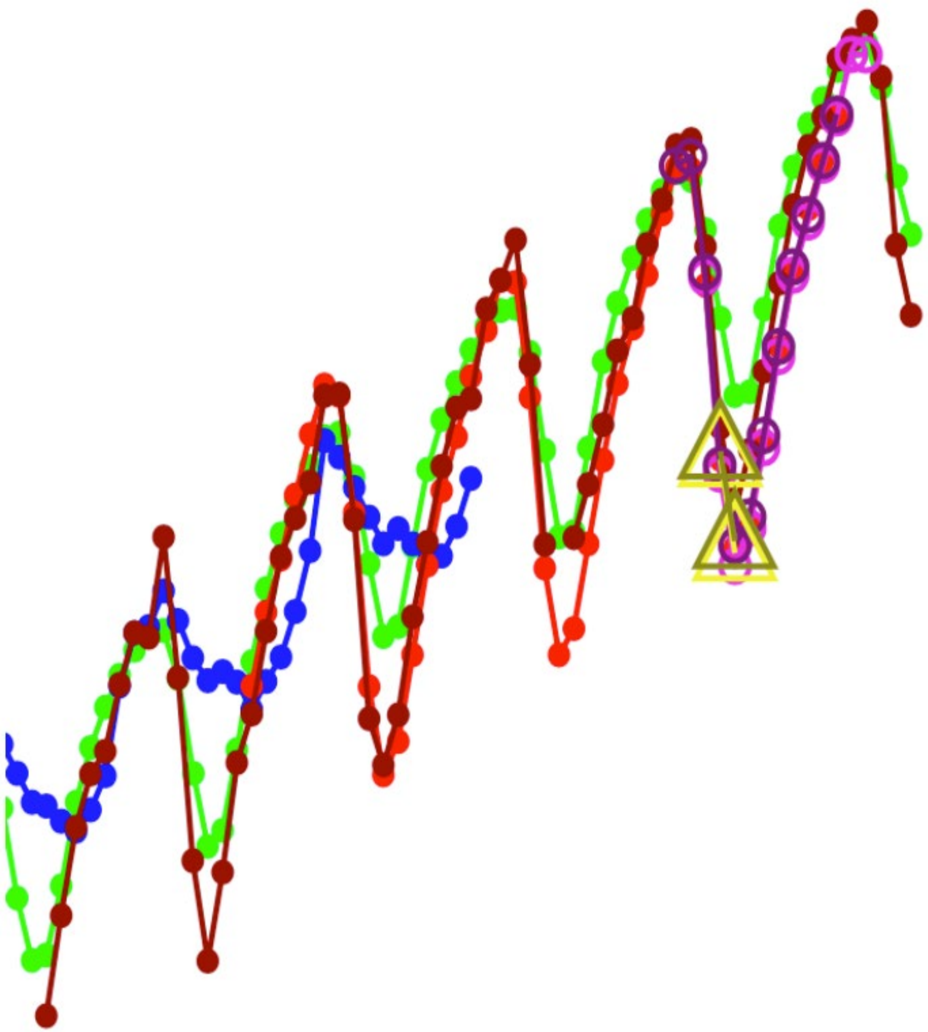
NUCAPS xCO_2 Retrievals Comparison with OCO-2 July 2018 Monthly Mean



- The V2.7.2 CO_2 agrees much better with the OCO-2 than V2.5.2 did!

NUCAPS S-NPP xCO_2 Trends v2.7.2 Compared with OCO-2 and AIRS





- NUCAPS CO2 retrievals agree very well with OCO-2 trends and magnitudes, as well as the trends from ESRL!

VALIDATION RESULTS WITH TRUTH DATA SETS

- **Hierarchy of validation strategies**
  - NUCAPS product evaluations with other correlative data sets (AIRS, TROPOMI) (Presented by Juying Warner)
  - Truth data sets and statistical plots for validation of CH_4 and CO_2 (Presented by Nick Nalli)

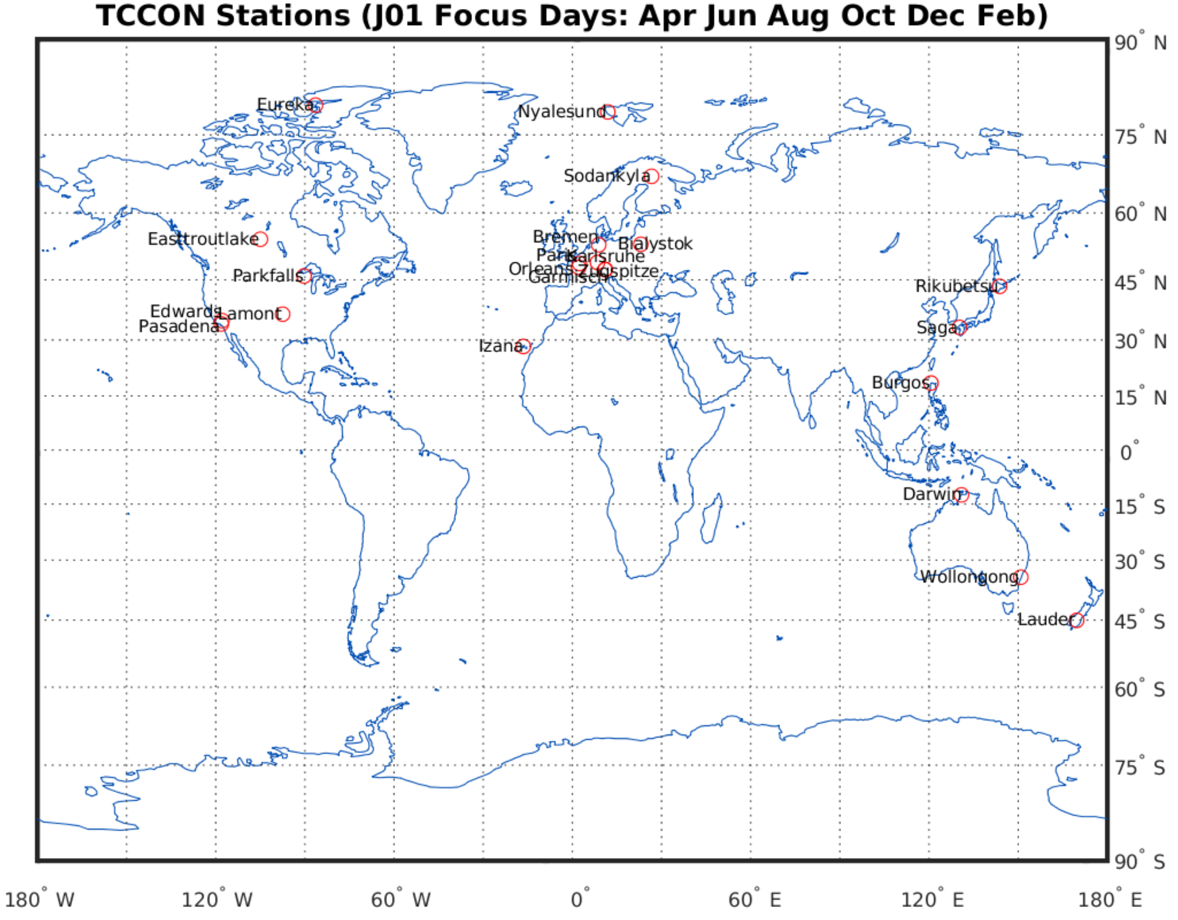
NUCAPS v2.7.2 versus TCCON Statistical Analysis

Collocations from 6 Focus Days:

20180401, 20180615, 20180820, 20181015, 20181215, 20190215

TCCON Stations and Averaging Kernels (AKs)

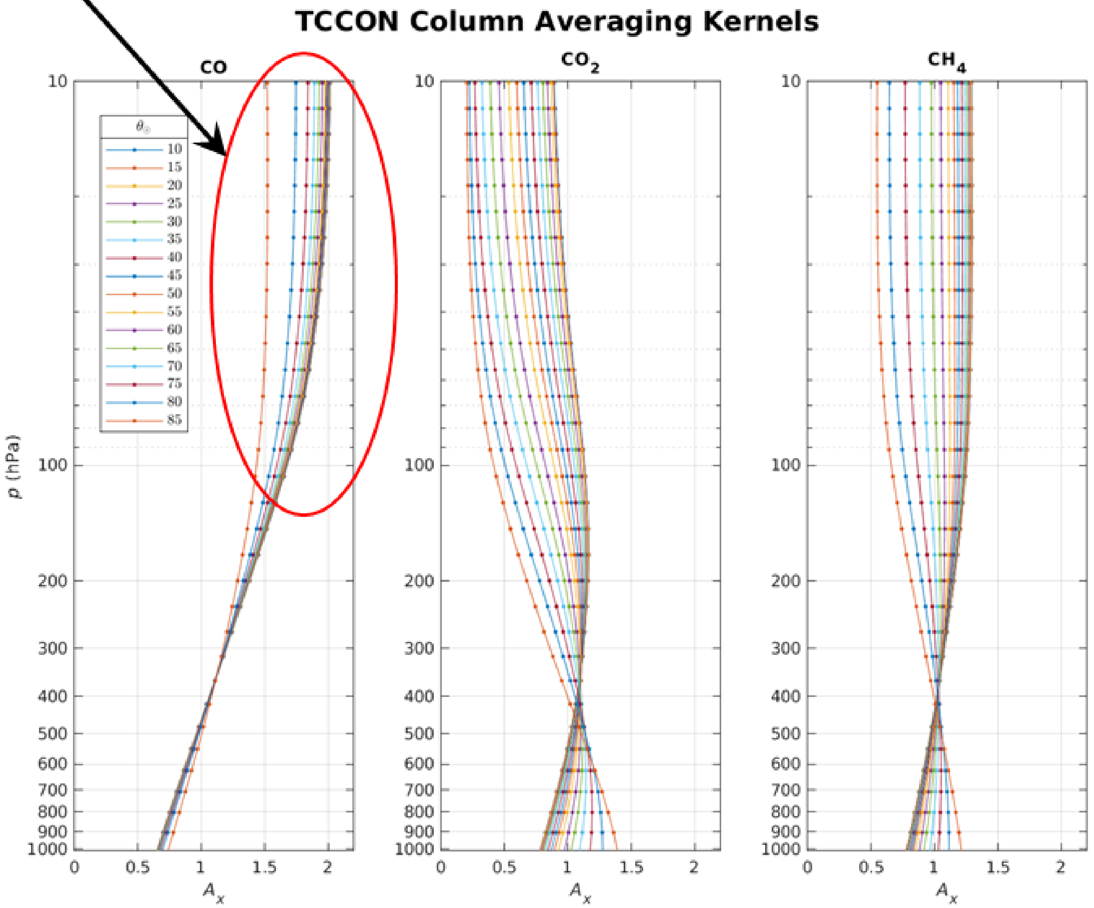
Collocated Focus Day Stations
NOAA-20 Trace Gas QA, ±2 hr, 125 km



- **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 ATom analysis

Column AKs

TCCON CO sensitivity is only above the troposphere

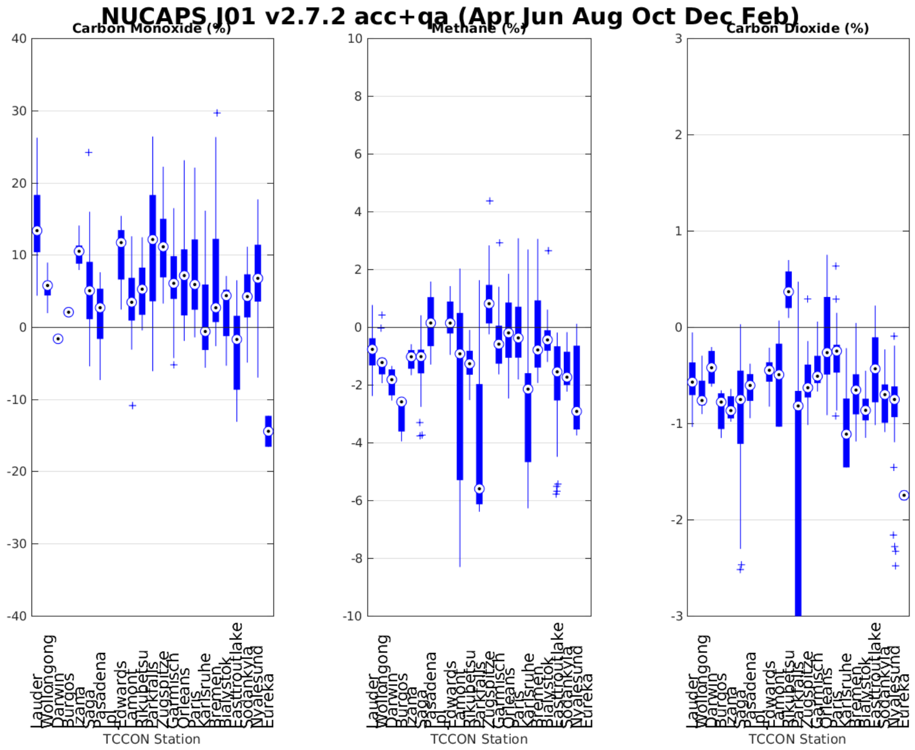


NUCAPS v2.7.2 Total Column Trace Gases vs TCCON: Statistical Analysis

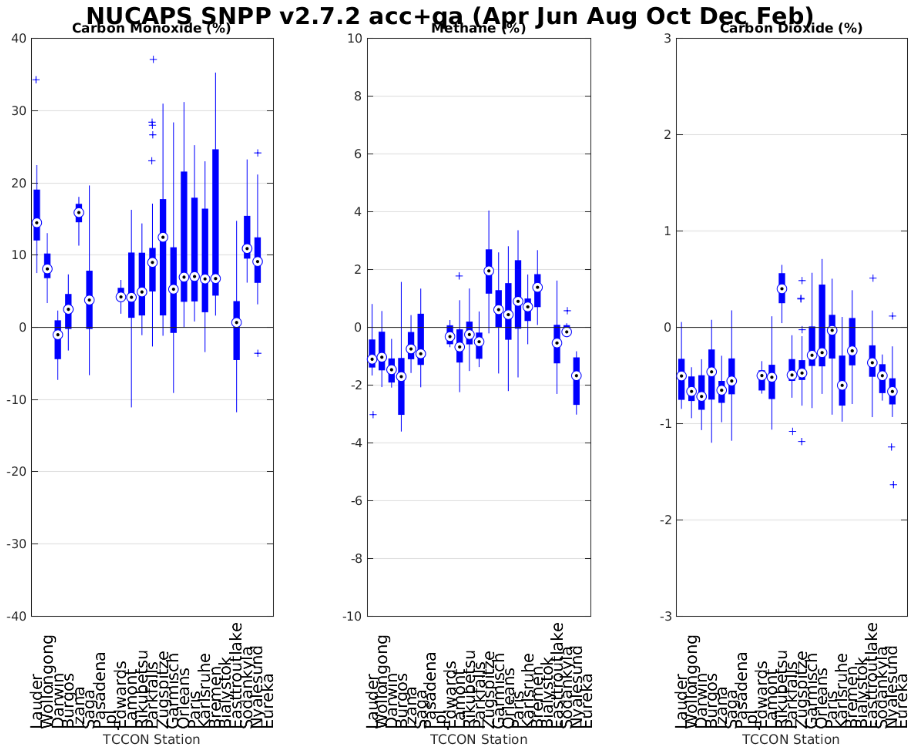
Box-Whisker Statistics by TCCON Station

(Sorted in order of latitude)

NOAA-20



SNPP

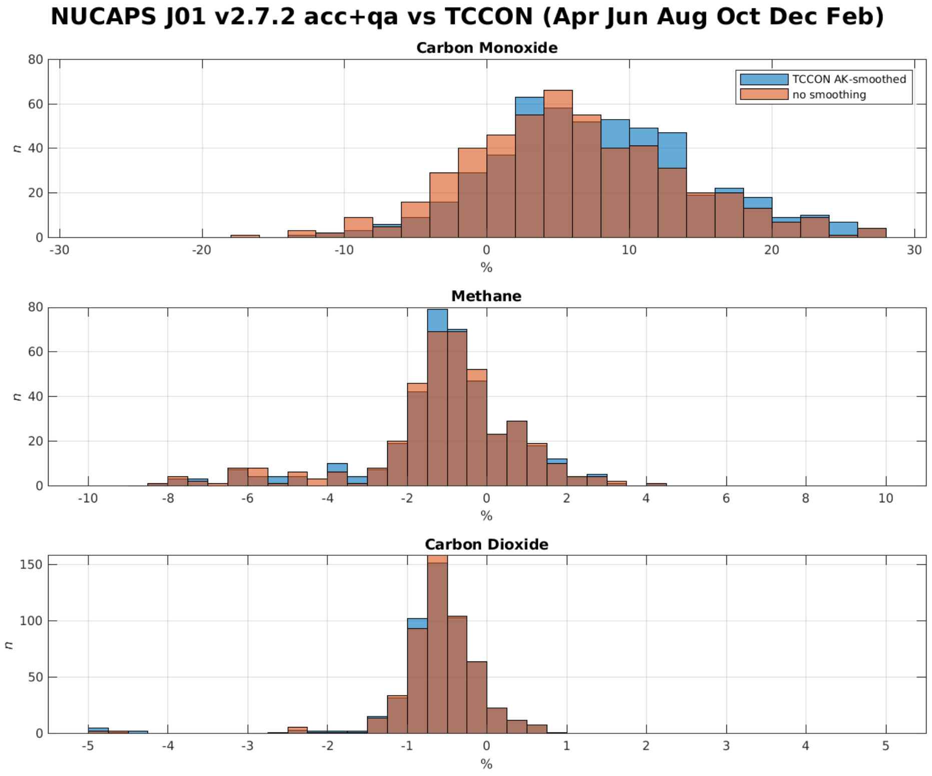


NUCAPS – TCCON

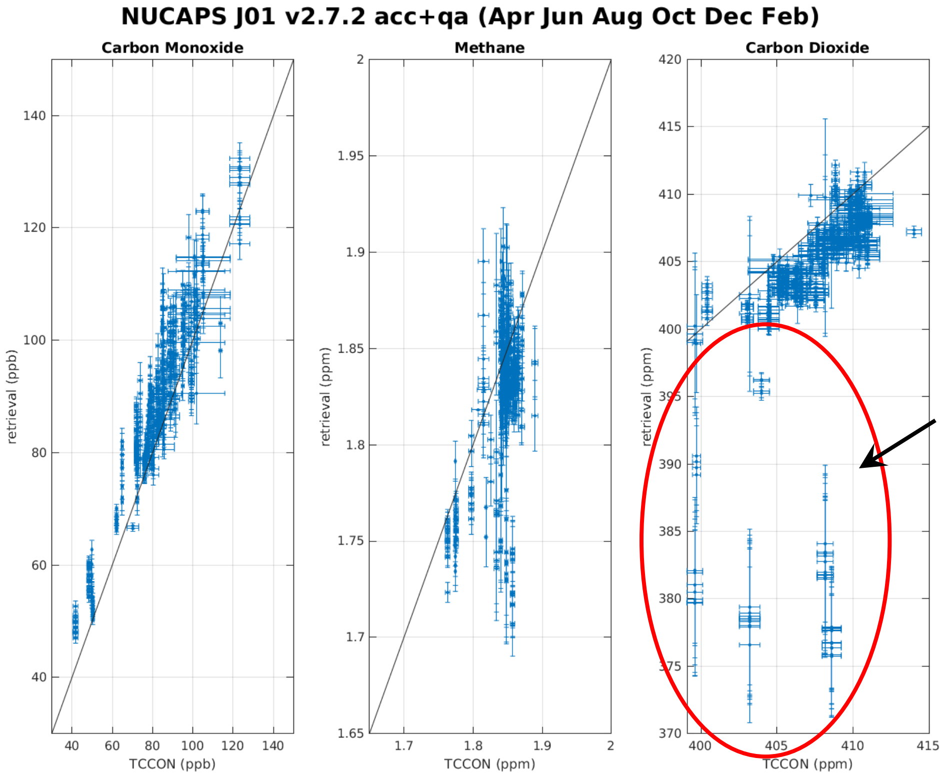
NOAA-20 NUCAPS v2.7.2 Total Column Trace Gases vs TCCON

Statistical Analysis Focus Days: 20180401, 20180615, 20180820, 20181015, 20181215, 20190215

Histograms



Scatterplots



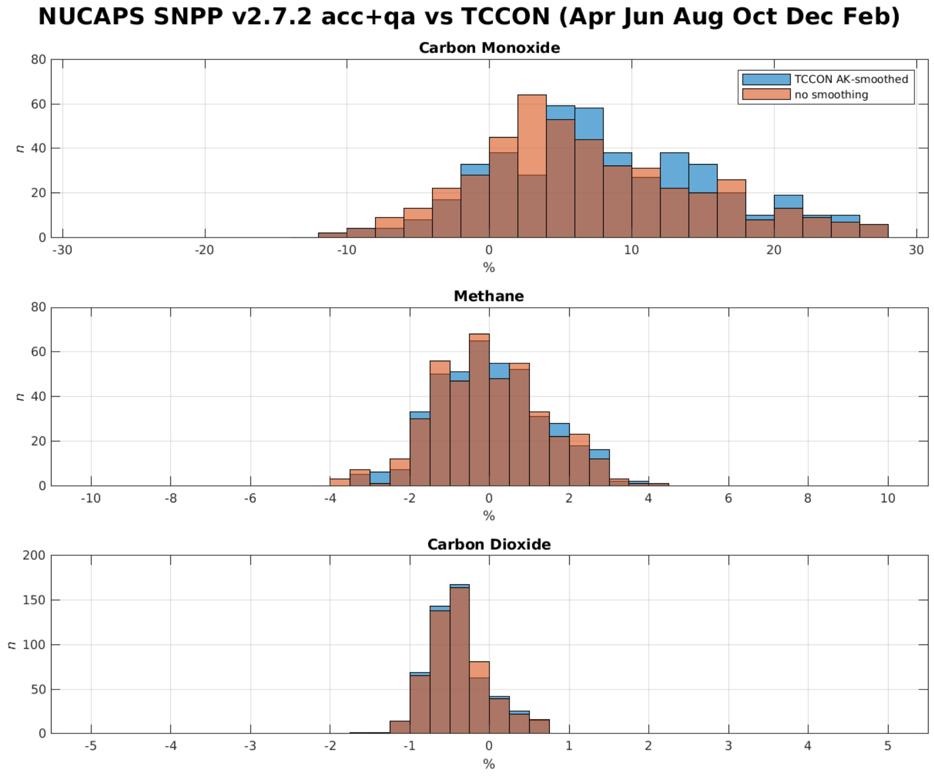
Outlier cases expected to be removed when new QA flags become available

NUCAPS – TCCON

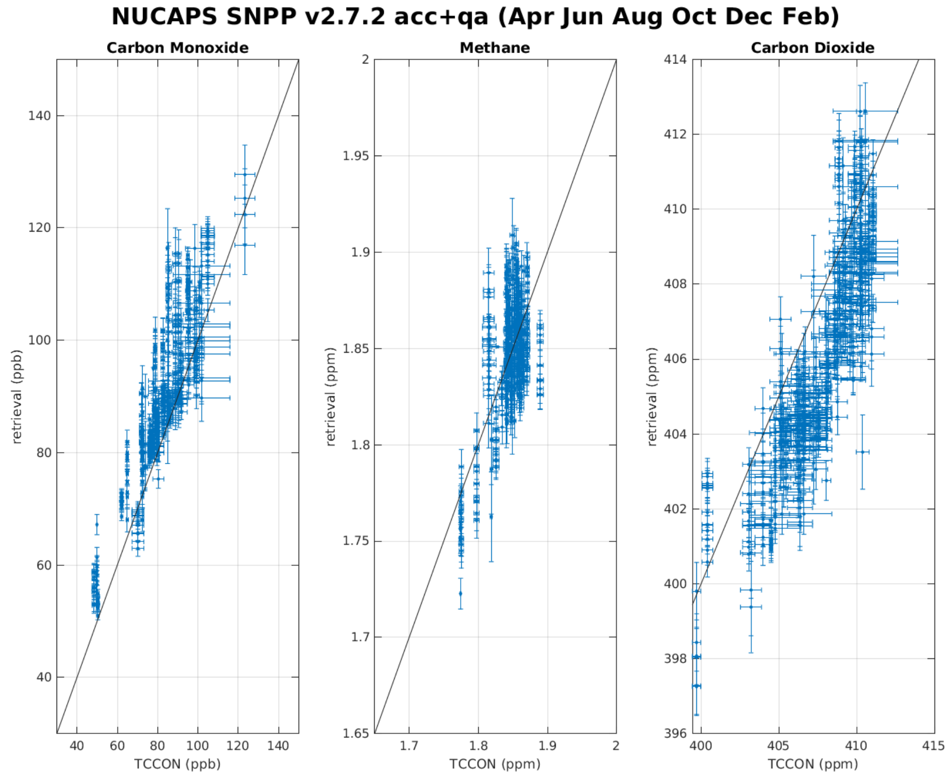
SNPP NUCAPS v2.7.2 Total Column Trace Gases vs TCCON

Statistical Analysis Focus Days: 20180401, 20180615, 20180820, 20181015, 20181215, 20190215

Histograms



Scatterplots

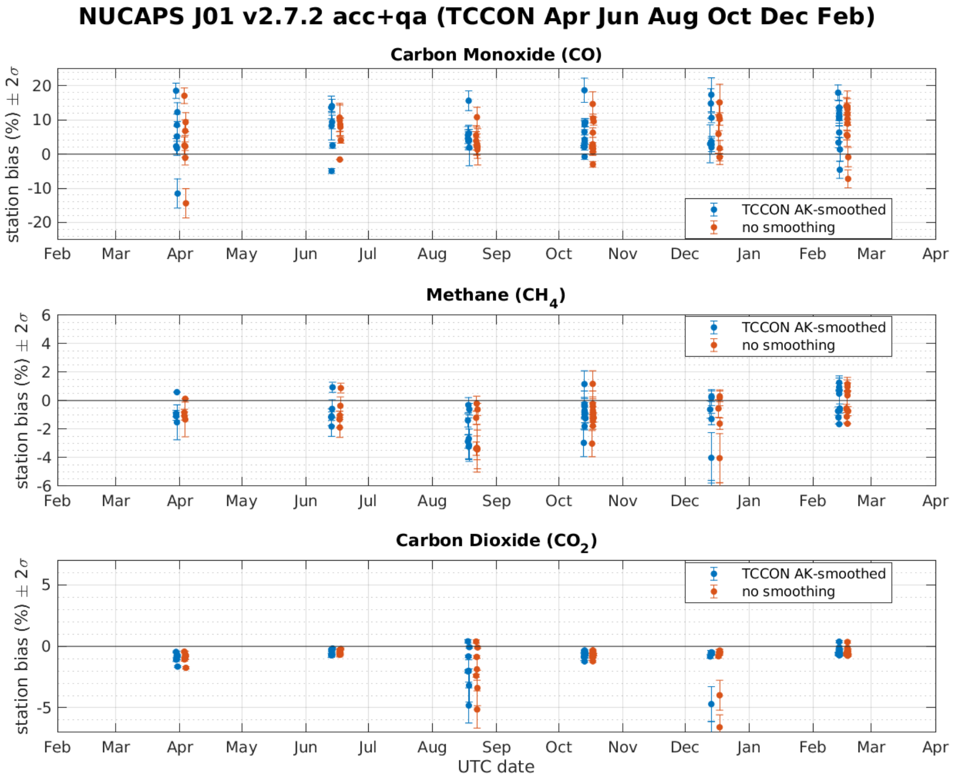


NUCAPS – TCCON

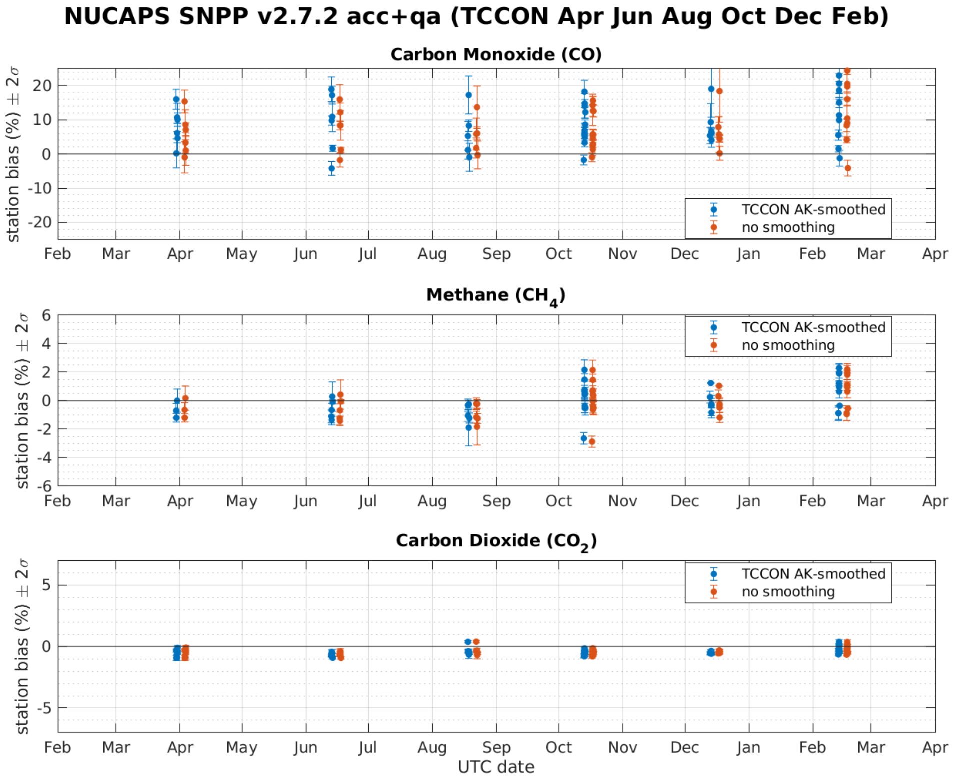
Focus Day Time Series Spanning Annual Cycle

20180401, 20180615, 20180820, 20181015, 20181215, 20190215

NOAA-20



SNPP



NUCAPS – TCCON

NUCAPS V2.7.2 versus TCCON: Statistical Summary

SNPP↔NOAA-20 Transfer Standard

Parameter	Stat	Raw Total Column		TCCON AKs applied	
		NUCAPS	Req	NUCAPS	Req
CO	Precision	7.4 (8.7)	15%	7.2 (8.4)	15%
	Accuracy	+6.1 (7.7)	±5%	+7.7 (8.8)†	±5%
CH4	Precision	2.0 (1.4)*	1%* (20 ppmv)	1.9 (1.4)*	1% (20 ppmv)
	Accuracy	−1.1 (+0.0)	4% (80 ppmv)	−1.0 (+0.0)	4% (80 ppmv)
CO2	Precision	1.5‡ (0.4)	0.5% (2 ppmv)	1.6‡ (0.4)	0.5% (2 ppmv)
	Accuracy	−1.0 (−0.4)	±1% (4 ppmv)	−1.0 (−0.4)	±1% (4 ppmv)

Values in ( ) indicates SNPP

- Meets requirement
- Marginal (± 30%)
- Outside Requirement (with explanation)

NOTES

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

†NUCAPS CO sensitivity peaks in mid-troposphere whereas TCCON peaks above 100 hPa.

‡ This includes some large NUCAPS outliers at one of the TCCON stations.

V2.7.2 Global Yields:

CO = 75.5 (74.3)%, *N* = 514 (472)

CH4 = 58.3 (66.5)%, *N* = 397 (422)

CO2 = 82.5 (85.0)%, *N* = 562 (540)

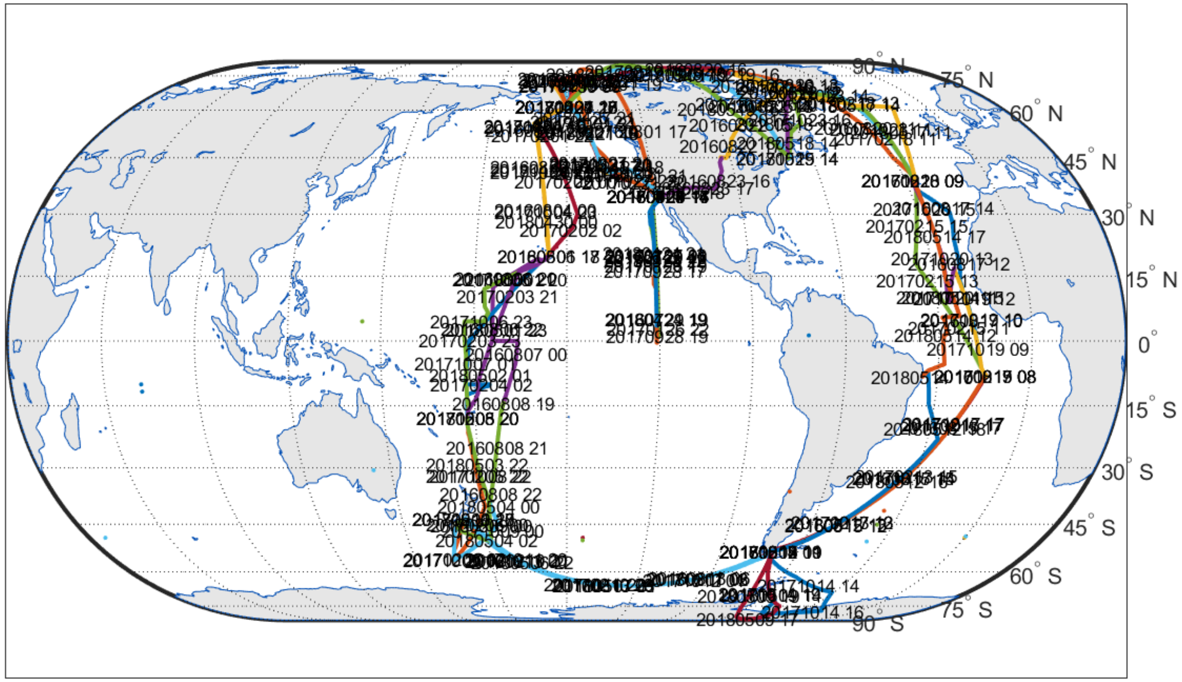
NUCAPS v2.7.2 Versus ATom Statistical Analysis

ATom-1,-2 and -4 Aircraft Campaigns 2016-2018

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
- We use the **NOAA Picarro ATom-1, -2** and **-4** datasets (2016-2018)
  - We have fully implemented the **ATom VALAR dataset for NOAA-20**, based upon **2018 ATom-4**
  - Additionally, we have enhanced the **SNPP ATom VALAR dataset**
    - **Updated the ATom-1,-2** truth profiles with the latest release versions
    - Included the **ATom-4** along with the **ATom-1,-2** data, creating a larger collocation ensemble

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



NOAA Picarro PIs: Kathryn McKain and Colm Sweeney (CIRES, U. of Colorado, NOAA/ESRL)

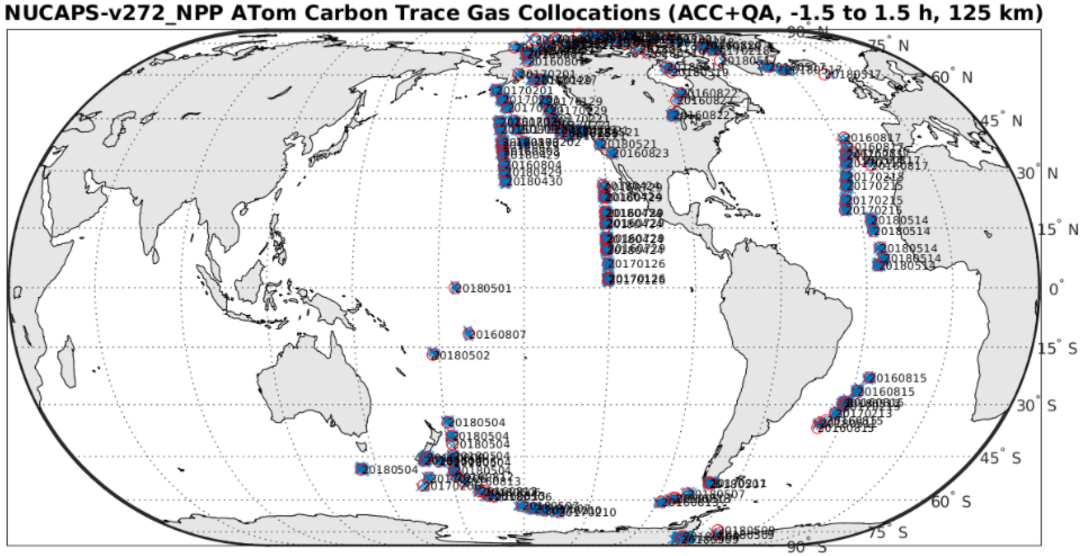
Source: [*https://espo.nasa.gov/atom/*](https://espo.nasa.gov/atom/)

NUCAPS ATom Trace Gas Statistical Summary

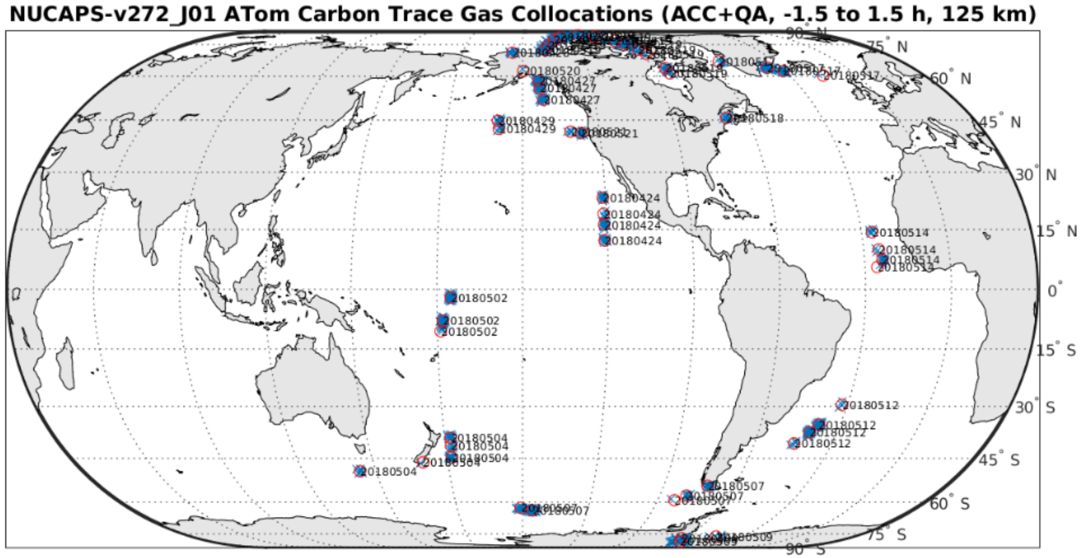
- **SNPP** and **NOAA-20** retrievals are comparable
- ***T/H_2O/O_3*** favorably compare with ATom truth, are comparable with OPS and have not suffered any degradation
- **SNPP OPS** and **v2.7.2 CO** retrievals are comparable to Oct 2019 results and have not suffered degradation
- **NUCAPS CO, CH_4** and **CO_2 trace gas retrievals improve the *a priori*** in the layers of sensitivity
- **CH_4 retrievals** are **slightly improved** over OPS (offline v2.5.2.2)
- **CO_2 retrievals** and ***a priori*** are **significantly improved** over OPS
- **CO** and **CO_2 retrievals** are "near-perfect" after applying AKs to the ATom data
- **With the exception of CH_4**, which does not meet the overly-stringent precision requirement of 1%, **NUCAPS trace gas retrievals** using averaging kernels (AKs) **meet JPSS L1 Requirements**

ATom-NUCAPS v2.7.2 Extended Sample Collocations (ATom-1,-2,-4)

SNPP Extracted ATom Profile Collocations



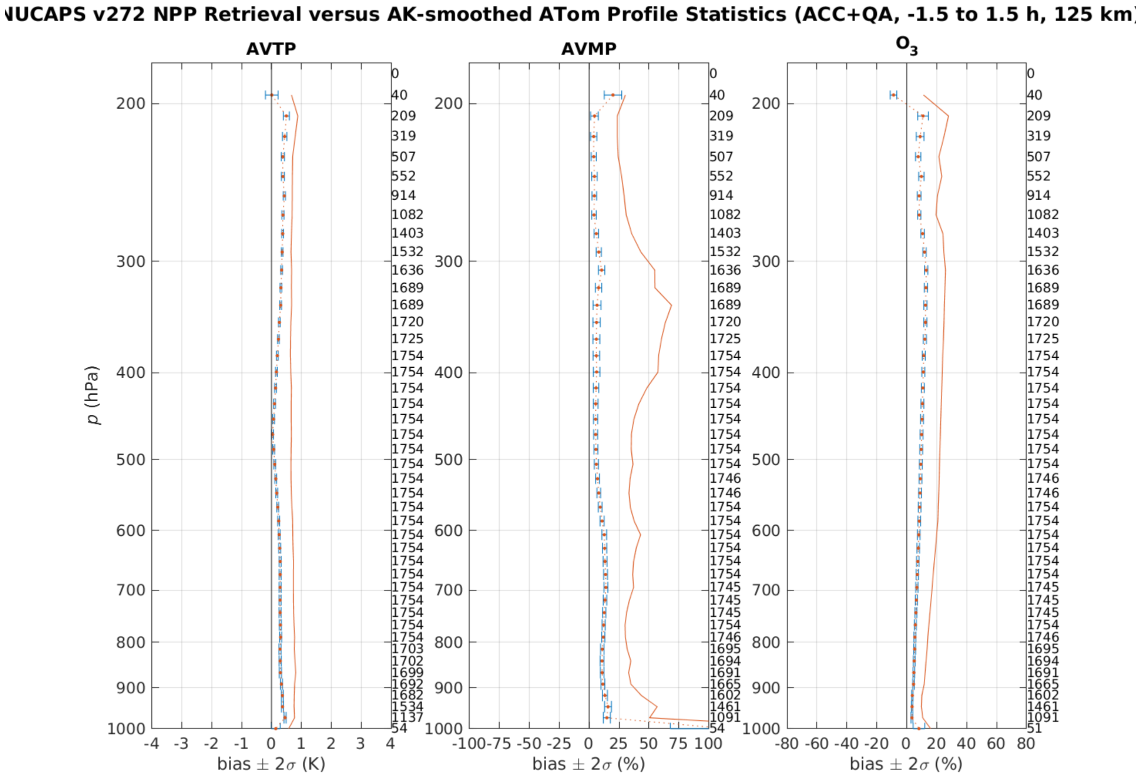
NOAA-20 Extracted ATom Profile Collocations



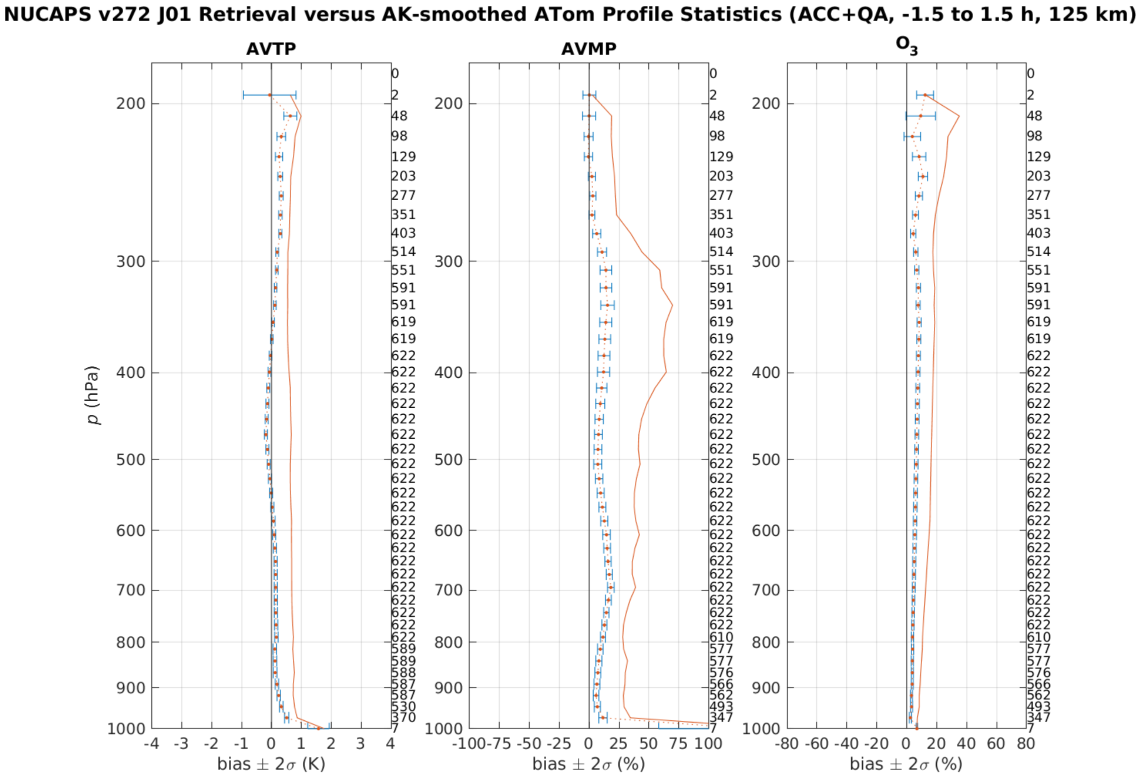
NUCAPS v2.7.2 Retrieval vs ATom w AKs: 100 Layer Profile Statistical Analysis

Temperature / H_2O / O_3

SNPP



NOAA-20

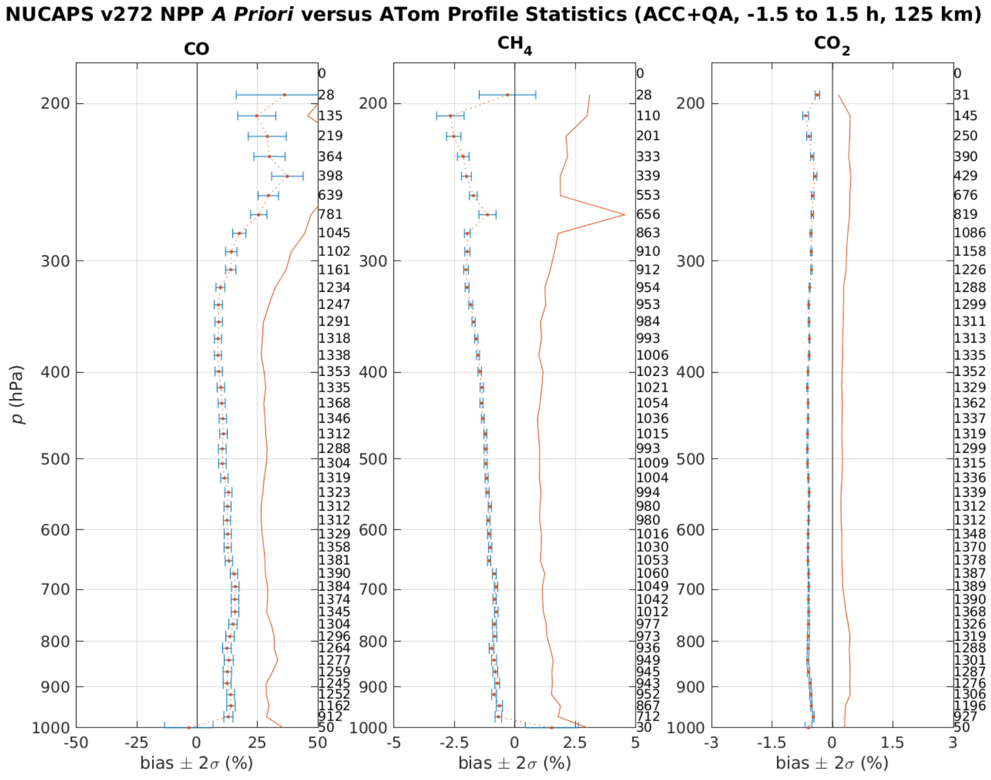


NUCAPS – ATom

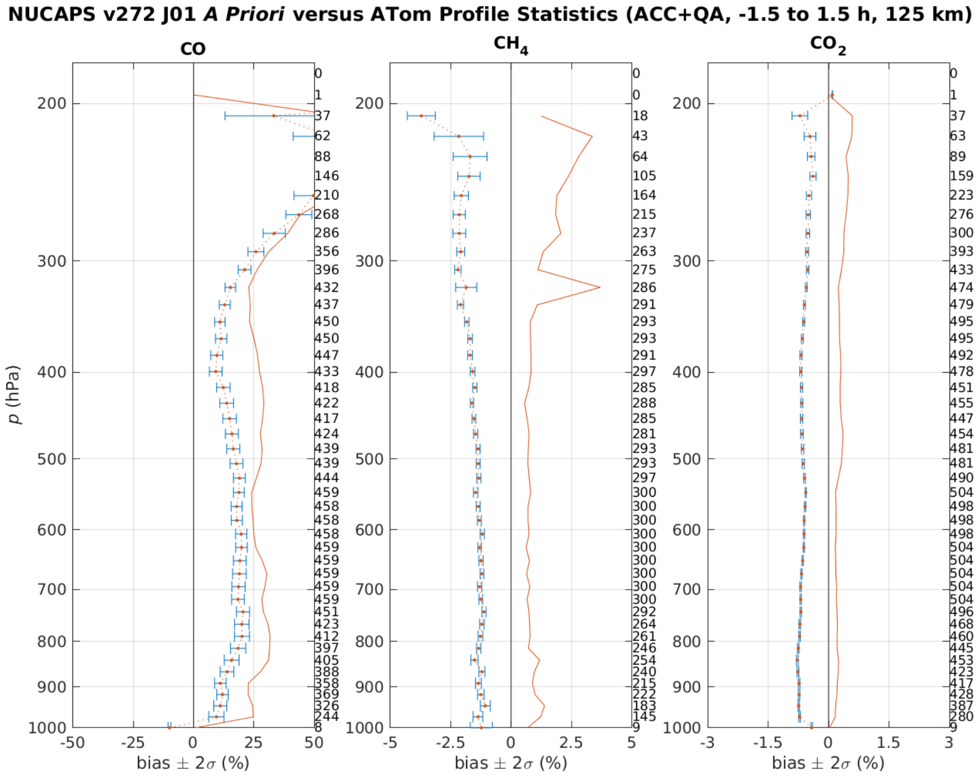
NUCAPS v2.7.2 *A Priori* vs ATom: 100 Layer Profile Statistical Analysis

CO / CH_4 / CO_2

SNPP



NOAA-20

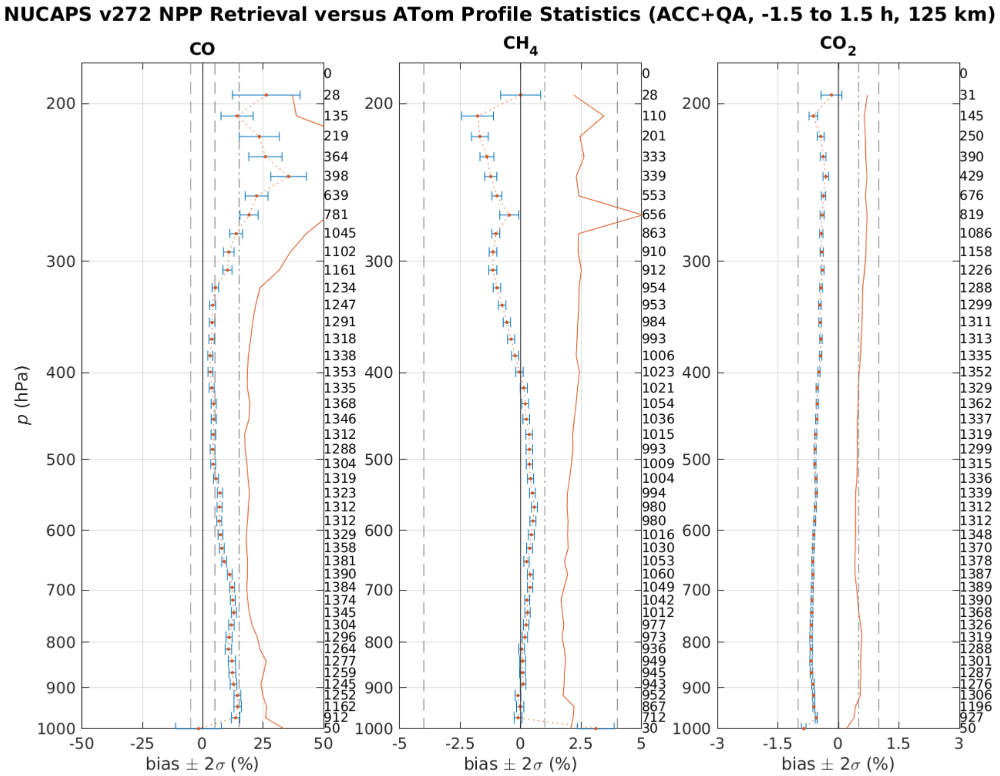


NUCAPS – ATom

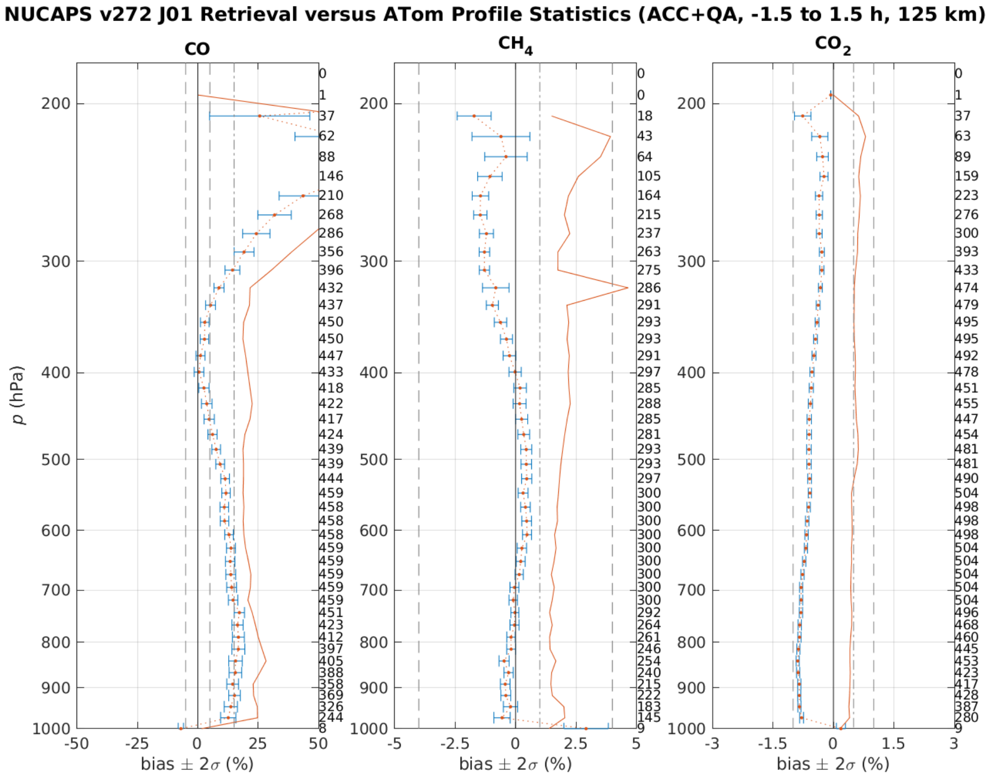
NUCAPS v2.7.2 Retrieval vs ATom: 100 Layer Profile Statistical Analysis

CO / CH_4 / CO_2

SNPP



NOAA-20

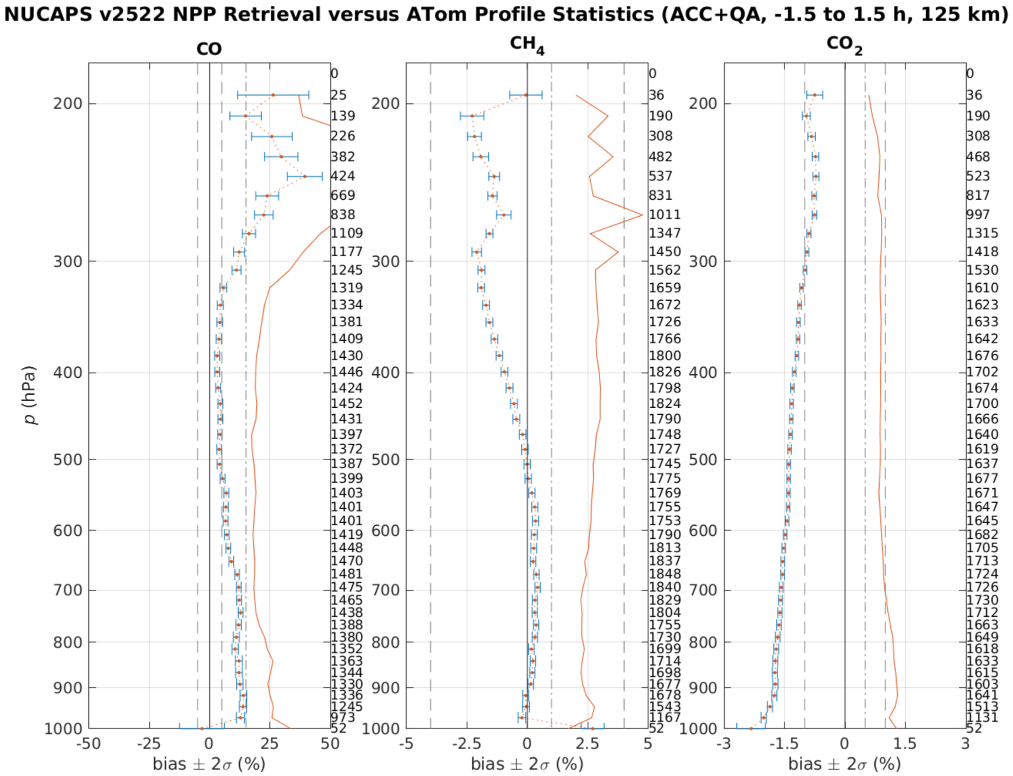


NUCAPS – ATom

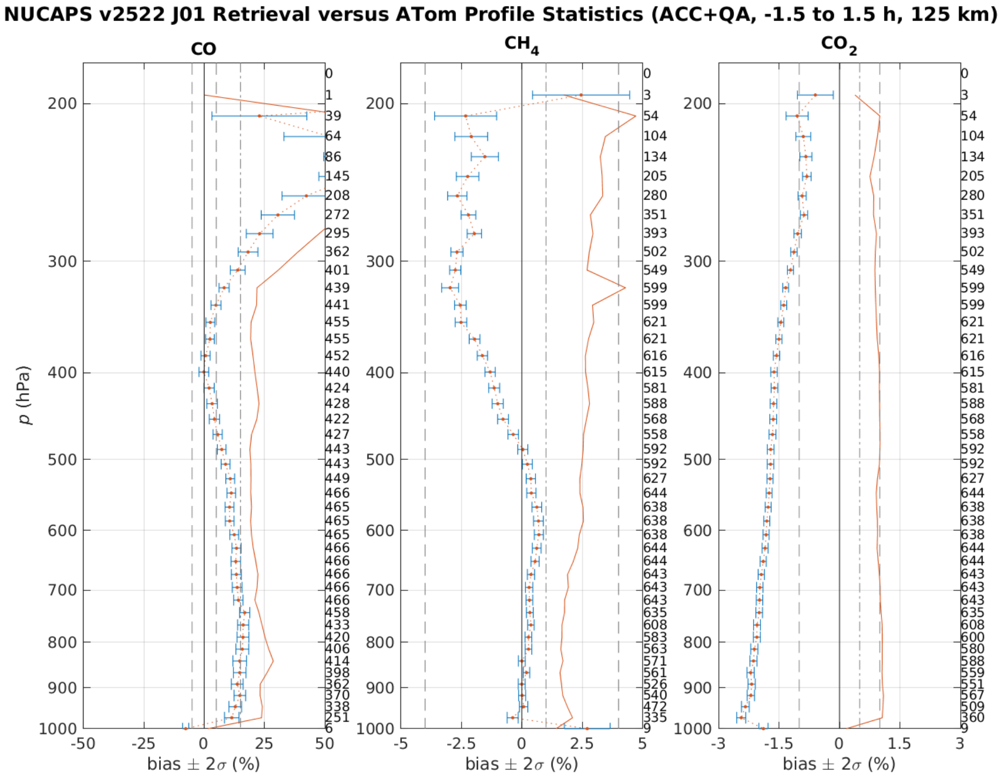
NUCAPS OPS (v2.5.2.2) Retrieval vs ATom: 100 Layer Profile Statistical Analysis

CO / CH_4 / CO_2

SNPP



NOAA-20

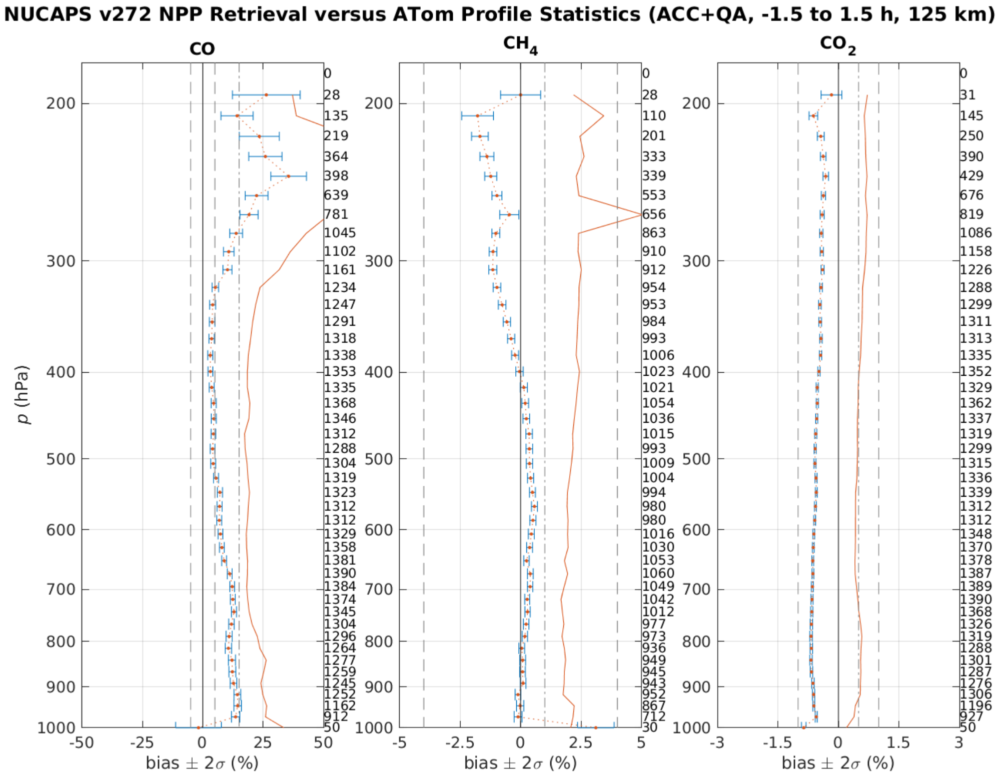


NUCAPS – ATom

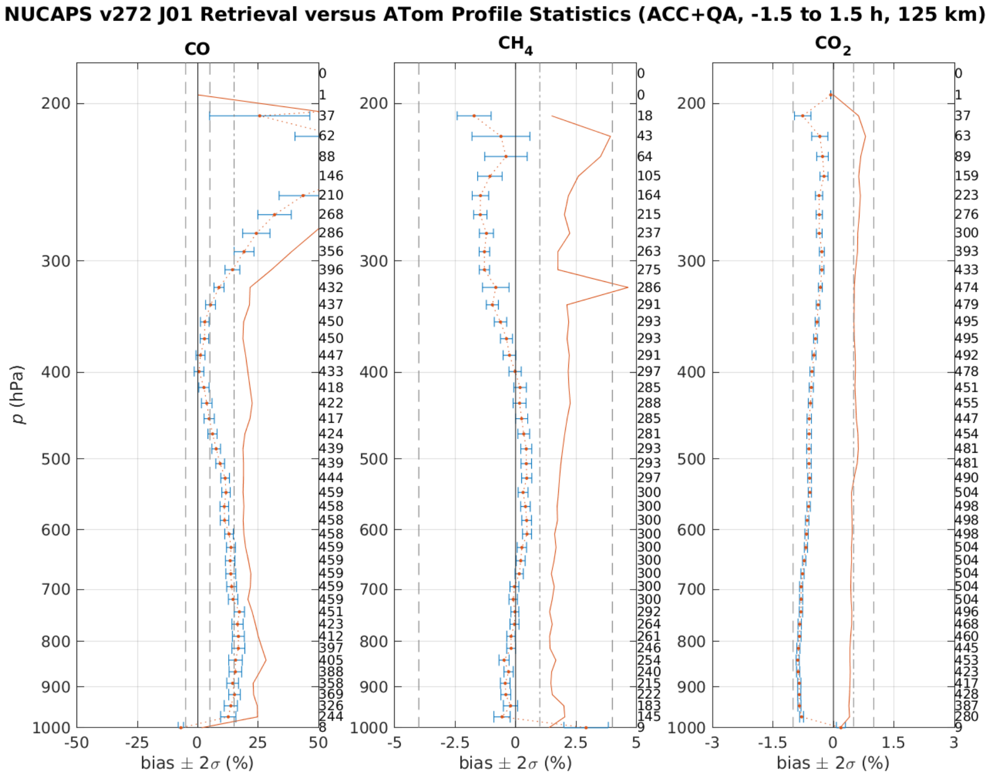
NUCAPS v2.7.2 Retrieval vs ATom: 100 Layer Profile Statistical Analysis

CO / CH_4 / CO_2

SNPP



NOAA-20

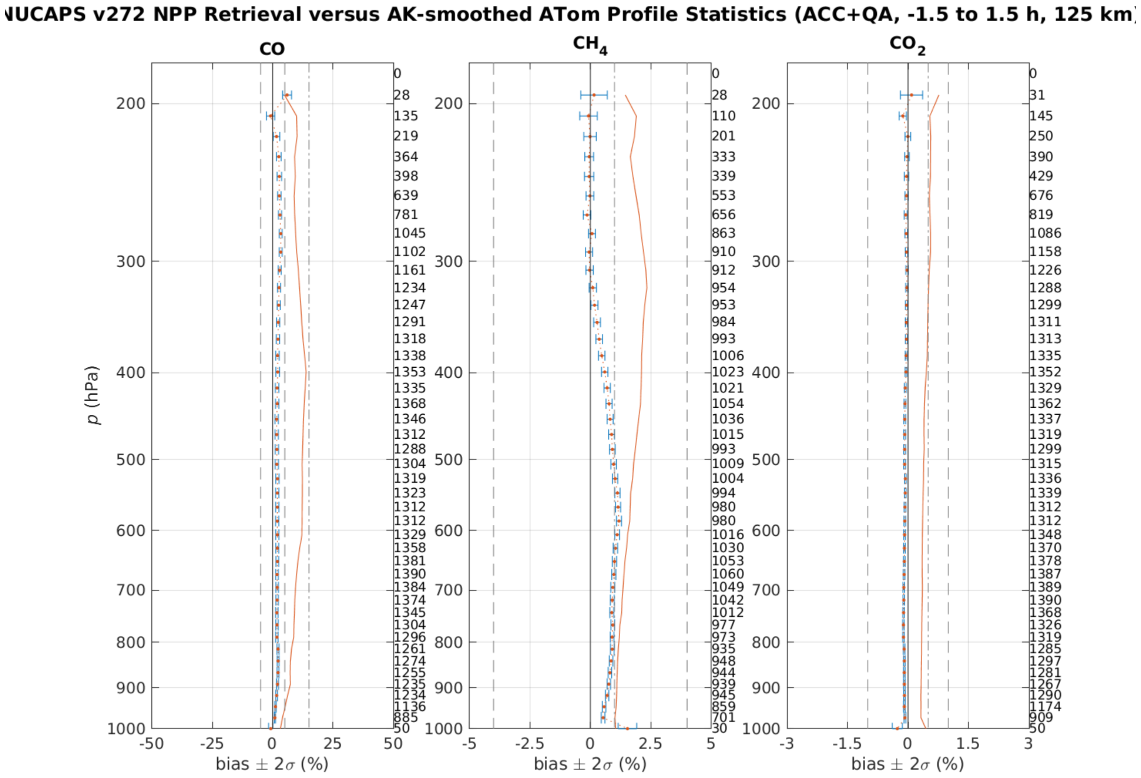


NUCAPS – ATom

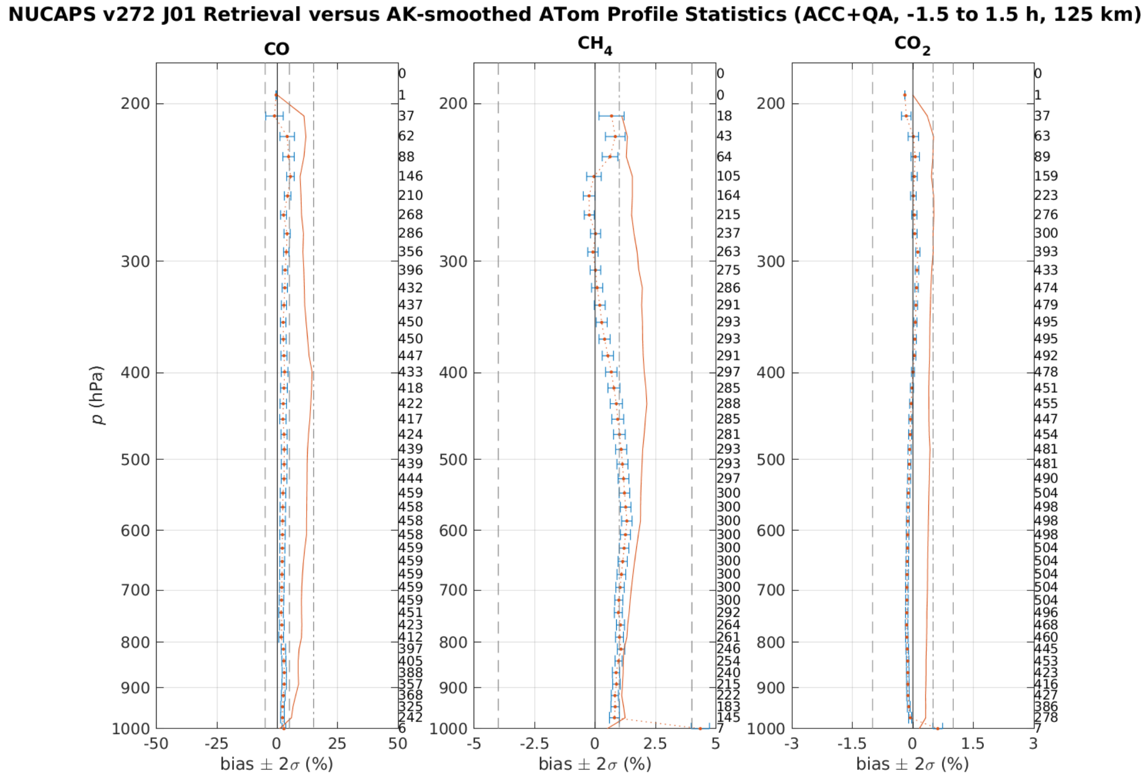
NUCAPS v2.7.2 Retrieval vs ATom w AKs: 100 Layer Profile Statistical Analysis

CO / CH_4 / CO_2

SNPP



NOAA-20

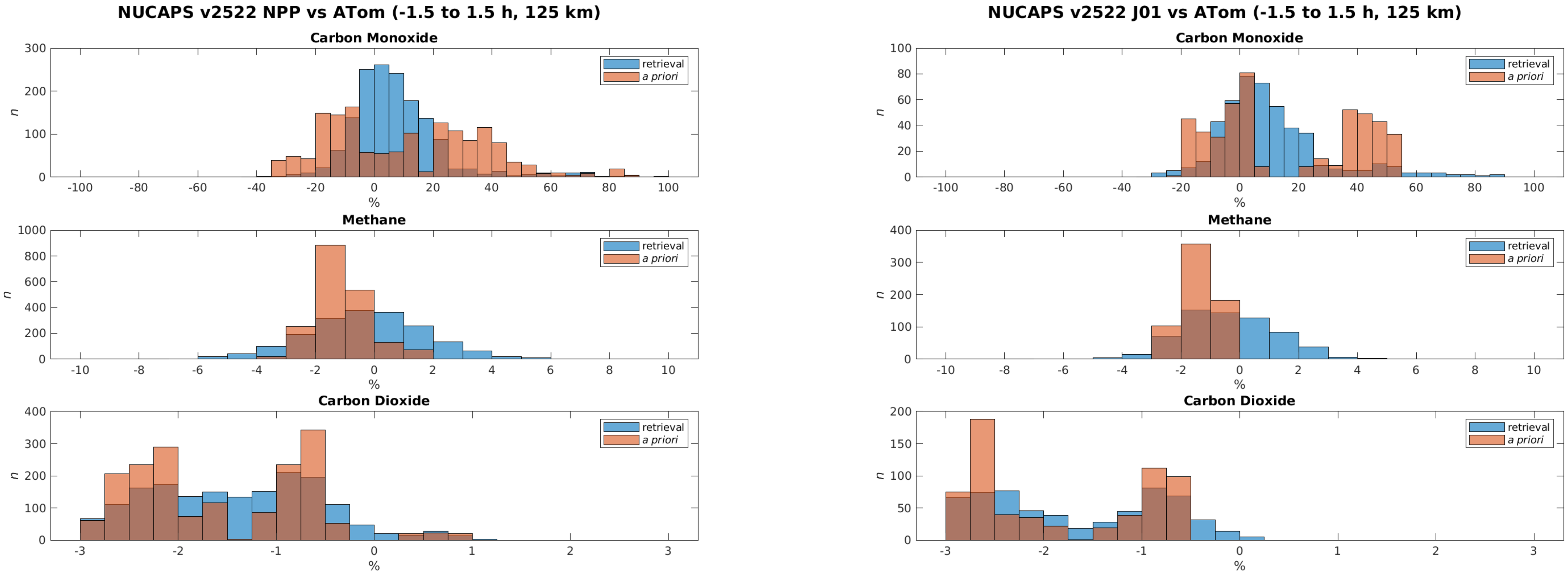


NUCAPS – ATom

CO / CH_4 / CO_2

SNPP

NOAA-20

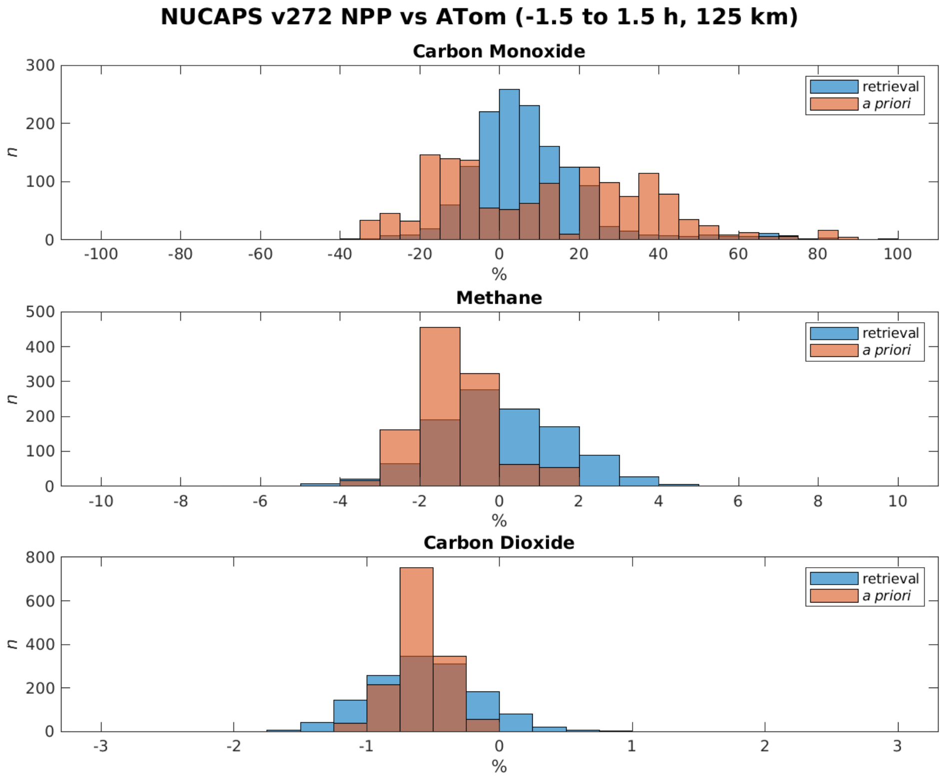


NUCAPS – ATom

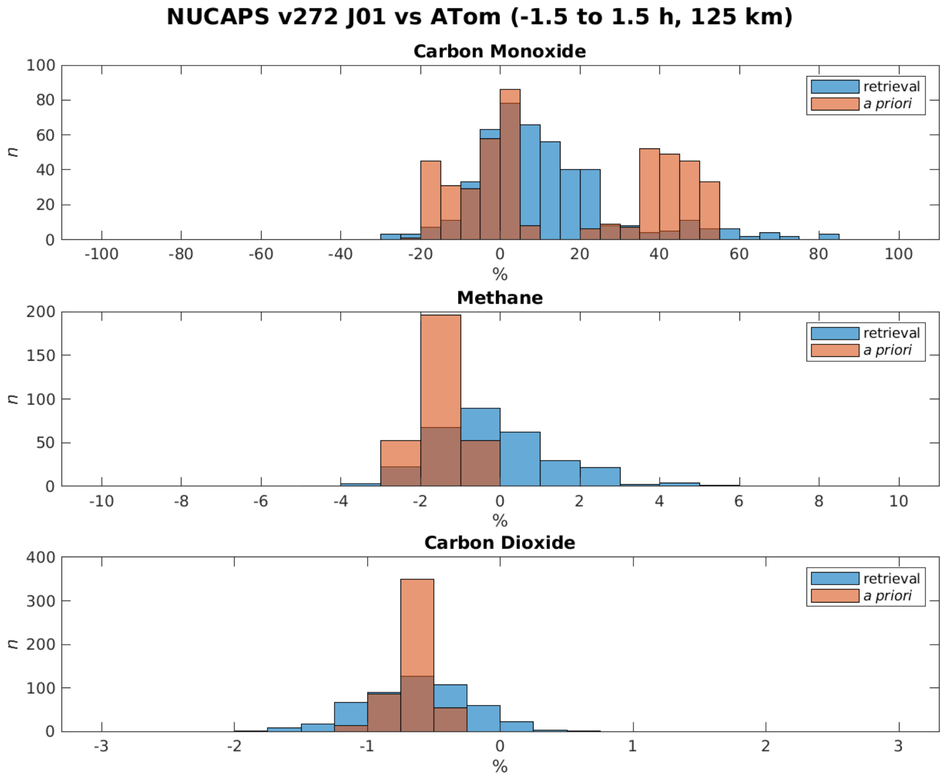
NUCAPS v2.7.2 *A Priori* & Retrieval vs ATom: Total Column Statistical Analysis

CO / CH_4 / CO_2

SNPP



NOAA-20



NUCAPS – ATom

NUCAPS V2.7.2 versus ATom: Statistical Summary

Parameter	Stat	Raw Total Column		NUCAPS AKs applied	
		NUCAPS	Req	NUCAPS	Req
CO	Precision	18.1 (15.4)	15%	9.5 (8.8)	15%
	Accuracy	+10.8 (+7.4)†	±5%	+2.4 (+1.8)	±5%
CH4	Precision	1.5 (1.6)*	1%* (20 ppmv)	1.4 (1.3)*	1% (20 ppmv)
	Accuracy	−0.2 (+0.0)	4% (80 ppmv)	+0.8 (+0.7)	4% (80 ppmv)
CO2	Precision	0.4 (0.4)	0.5% (2 ppmv)	0.3 (0.3)	0.5% (2 ppmv)
	Accuracy	−0.6 (−0.6)	±1% (4 ppmv)	−0.1 (−0.1)	±1% (4 ppmv)

Values in ( ) indicates SNPP

- Meets requirement
- Marginal (± 30%)
- Outside Requirement (with explanation)

NOTES

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

†NUCAPS CO sensitivity peaks in mid-troposphere, so the AK results are more reflective of the algorithm performance..

V2.7.2 Global Yields:

CO = 57.7 (63.6)%, *N* = 459 (1407)

CH4 = 37.7 (48.4)%, *N* = 300 (1072)

CO2 = 63.3 (67.9)%, *N* = 504 (1502)

Error Budget: CH_4, CO_2

Attribute Analyzed	JPSS Data Product Specifications	Maturity Status	Analysis/Validation Result	Error Summary	Support Artifacts
SNPP/NOAA-20 CH4	See Slides 30, 124	Validated	Meets requirements	See Slide 80	
SNPP/NOAA-20 CO2	See Slides 31, 124	Provisional	Meets requirements	See Slide 80	

NUCAPS Trace Gas Products in Environmental Monitoring

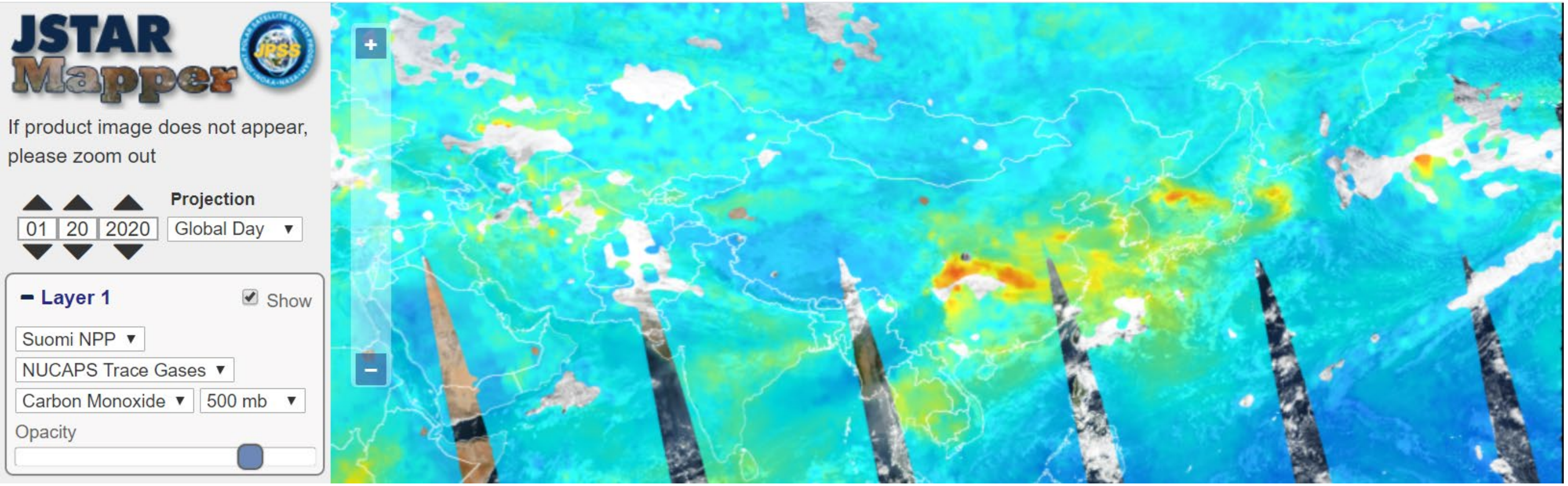
User Applications and Feedback

AUSTRALIAN FIRES

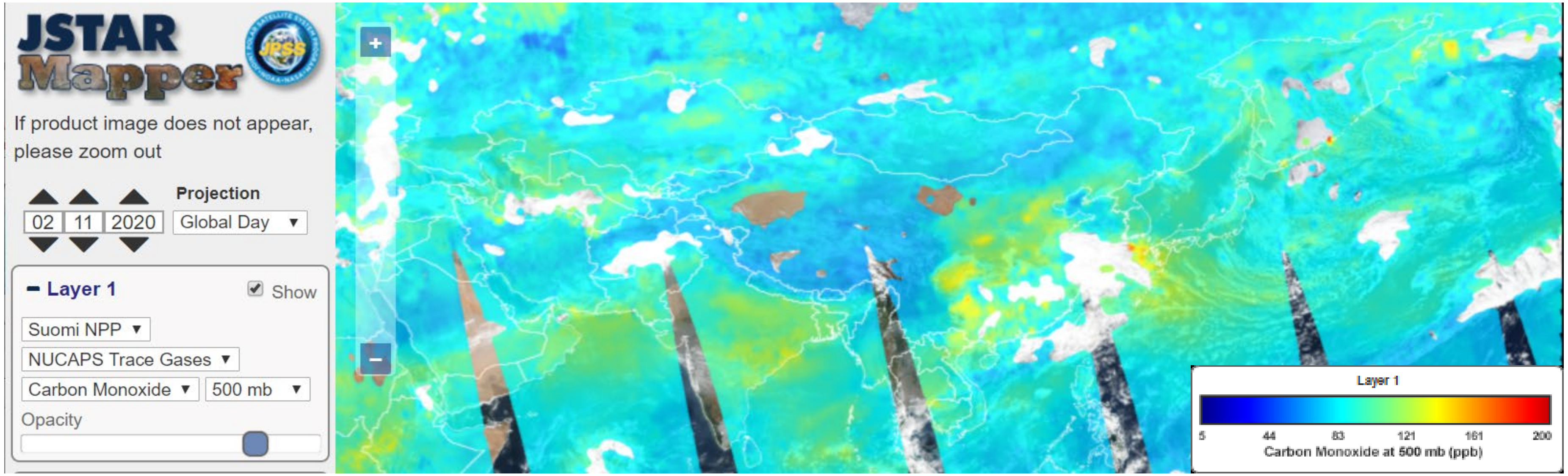
CORONAVIRUS

NUCAPS Retrievals on JSTAR Mapper
COVID-19 Impacts over China

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



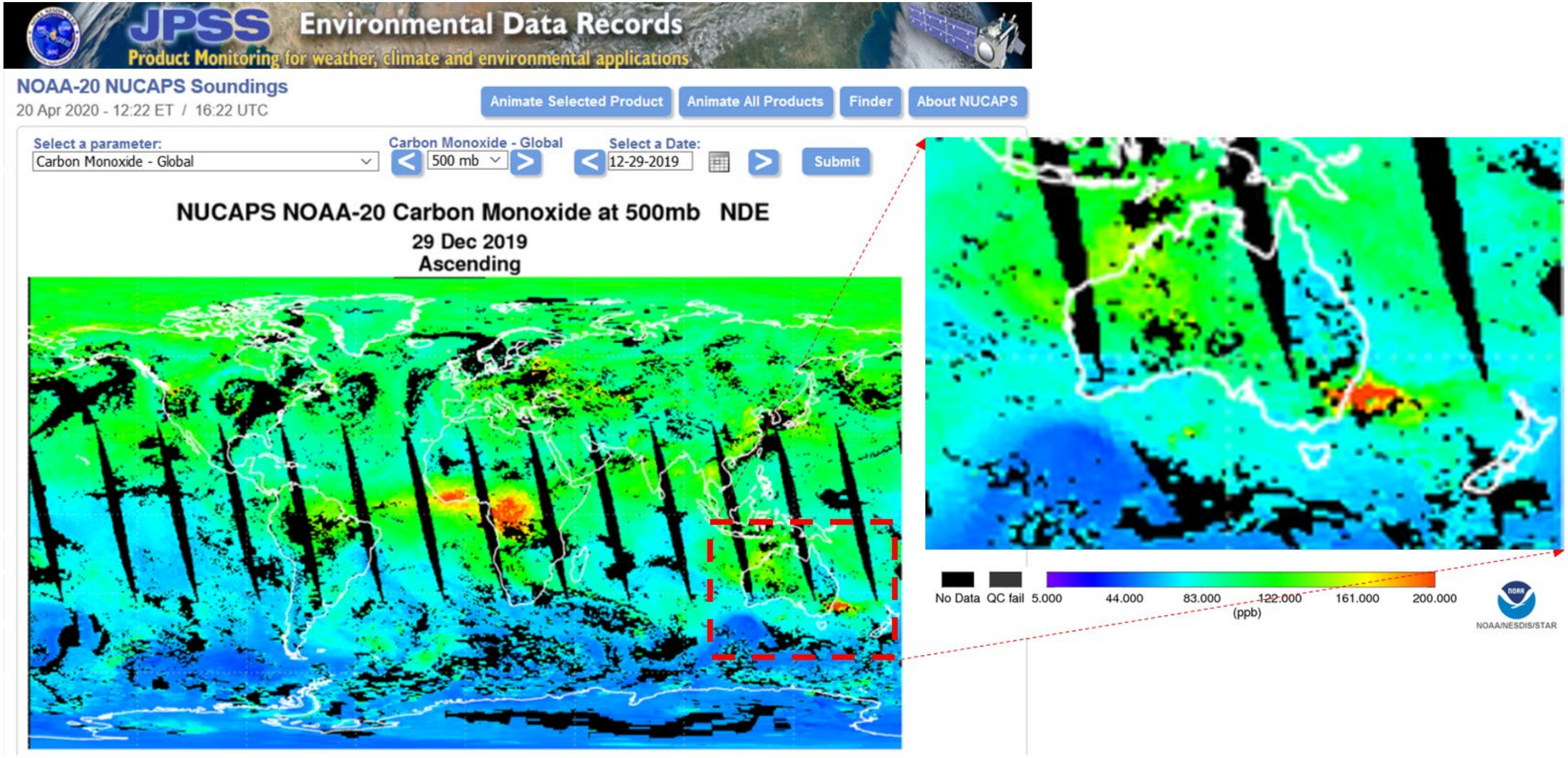
CO at 500hPa
Jan 20, 2020



CO at 500hPa
Feb 11, 2020

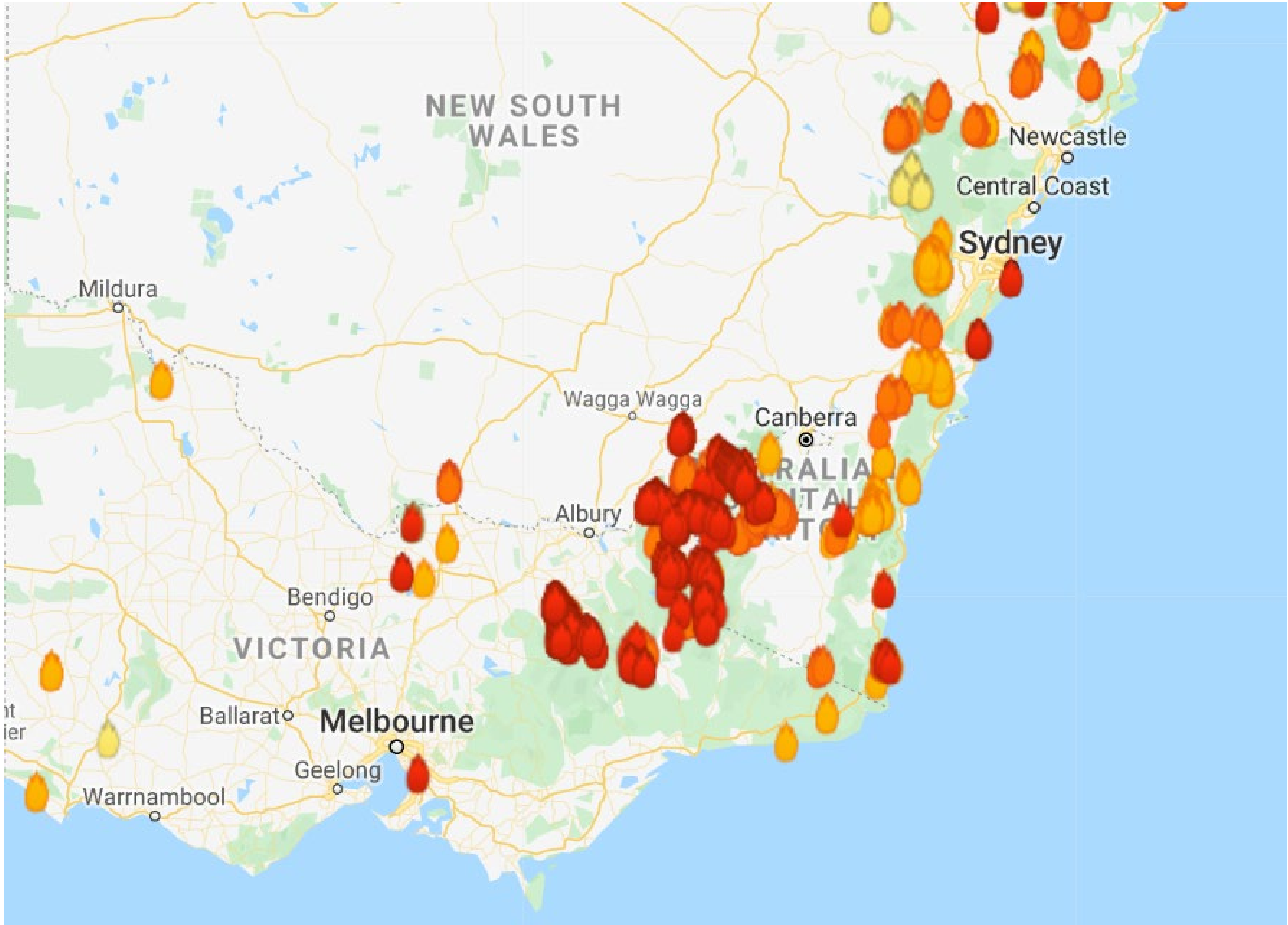
NUCAPS Retrievals on JPSS EDRs LTM
CO monitoring Australia Wildfire – Dec 29, 2019

https://www.star.nesdis.noaa.gov/jpss/EDRs/products_Soundings_N20.php



Southeast Australia Wildfires January 2020

Tong Zhu and Ken Pryor

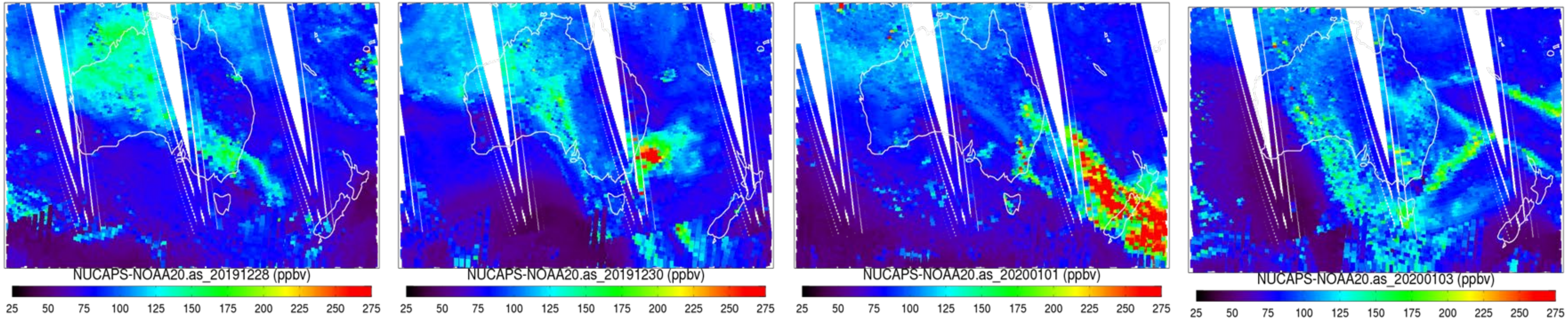


Australian 2019-2020 New Year Fires – Detected by NUCAPS

NUCAPS Mid-Tropospheric (500 hPa) Carbon Monoxide (ascending orbit)

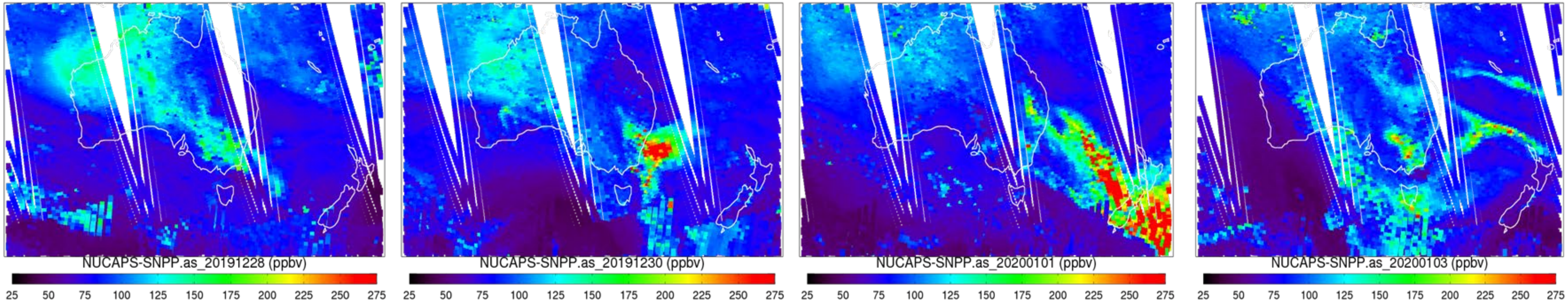
12/28/2019 | 12/30/2019 | 01/01/2020 | 01/03/2020

NOAA20



NUCAPS CO product shows large wildfires that released high concentrations that drifted nearly 2000 km to New Zealand.

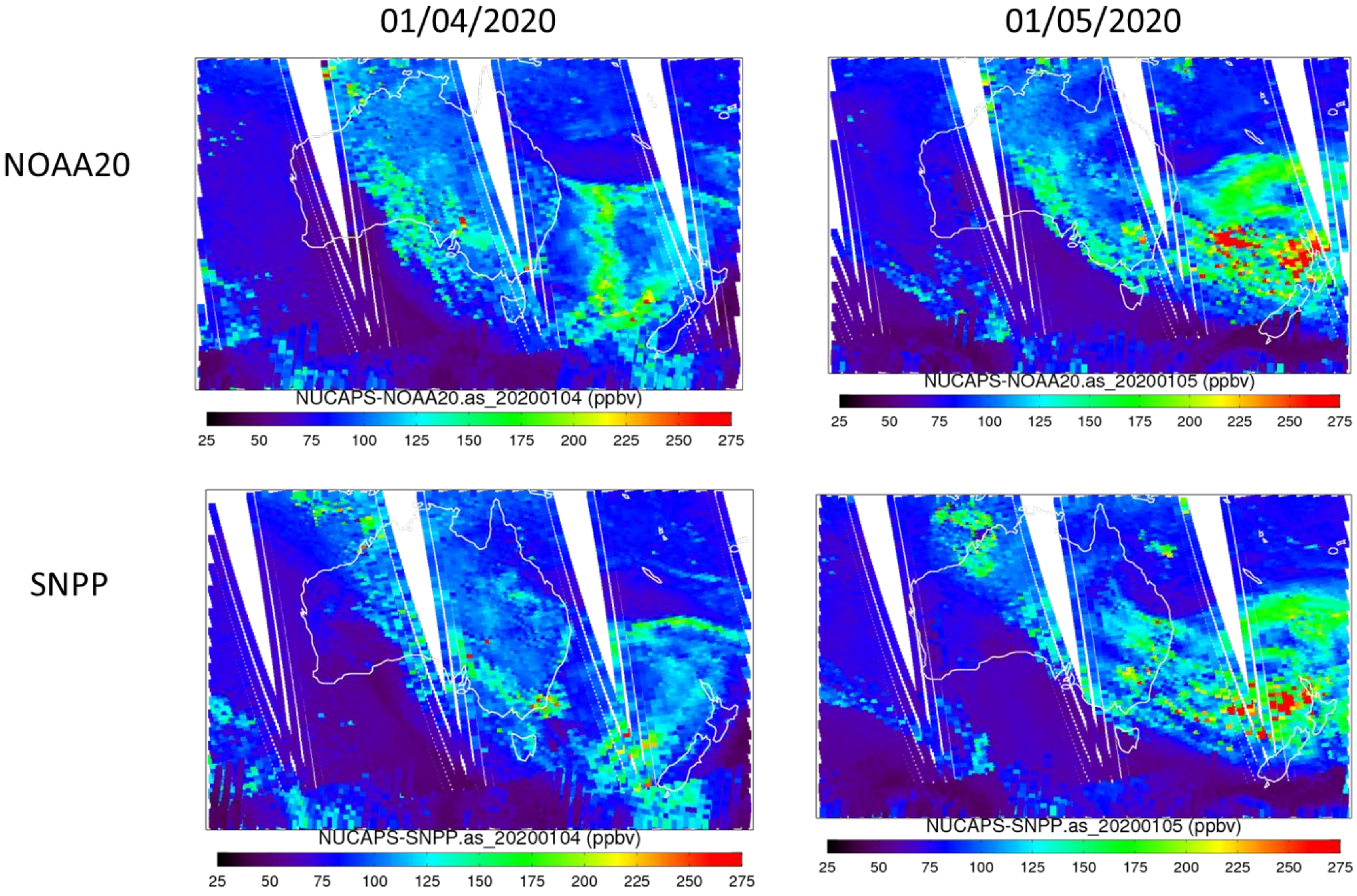
SNPP



Courtesy Tong Zhu

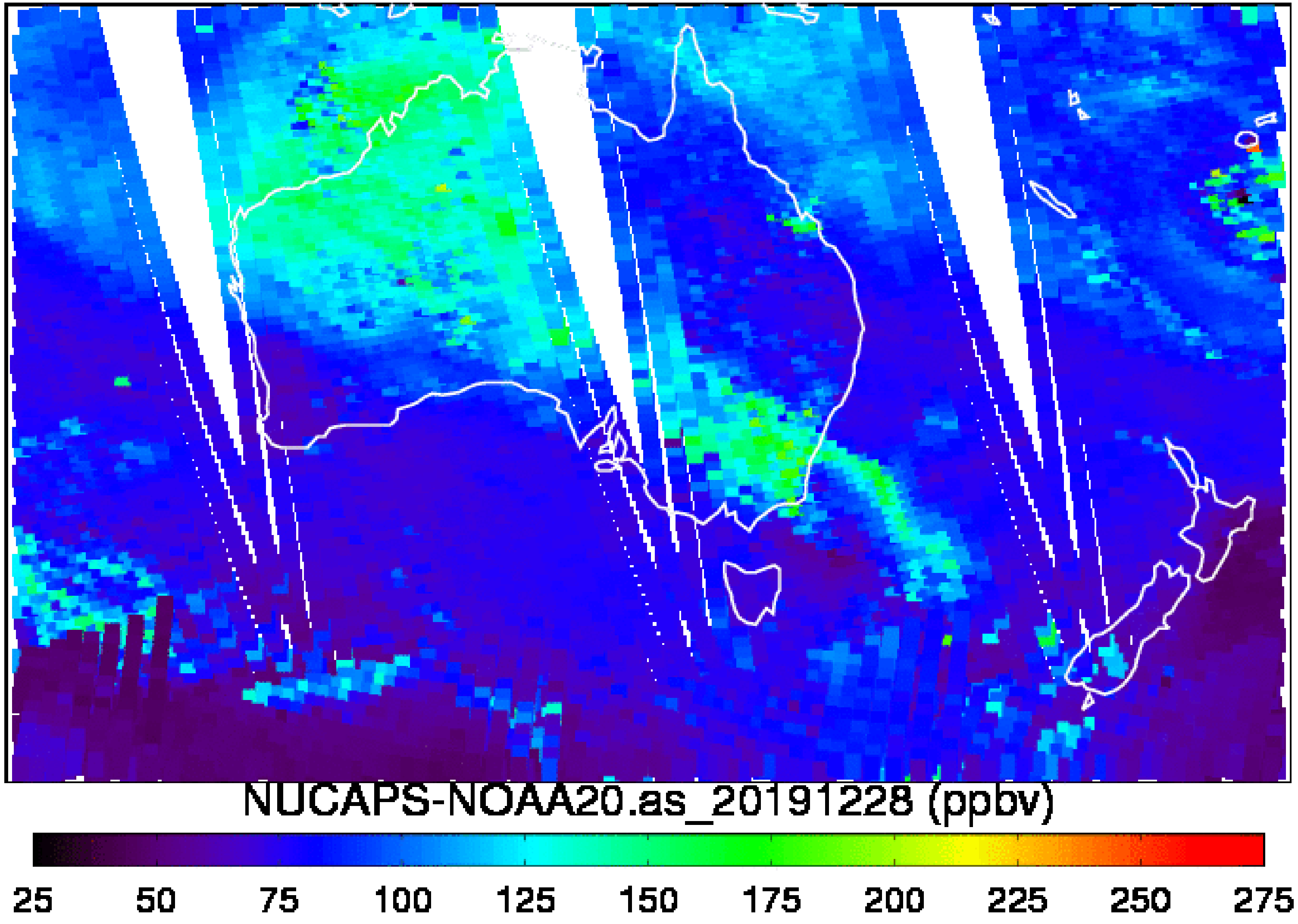
Australian 2019-2020 New Year Fires – Detected by NUCAPS

NUCAPS Carbon Monoxide (ascending orbit) at 500 hPa



NOAA-20 and SNPP NUCAPS Mid-Tropospheric CO (506 hPa)

Orbital Data Animation from 28 Dec 2019 to 05 Jan 2020



Haines Index

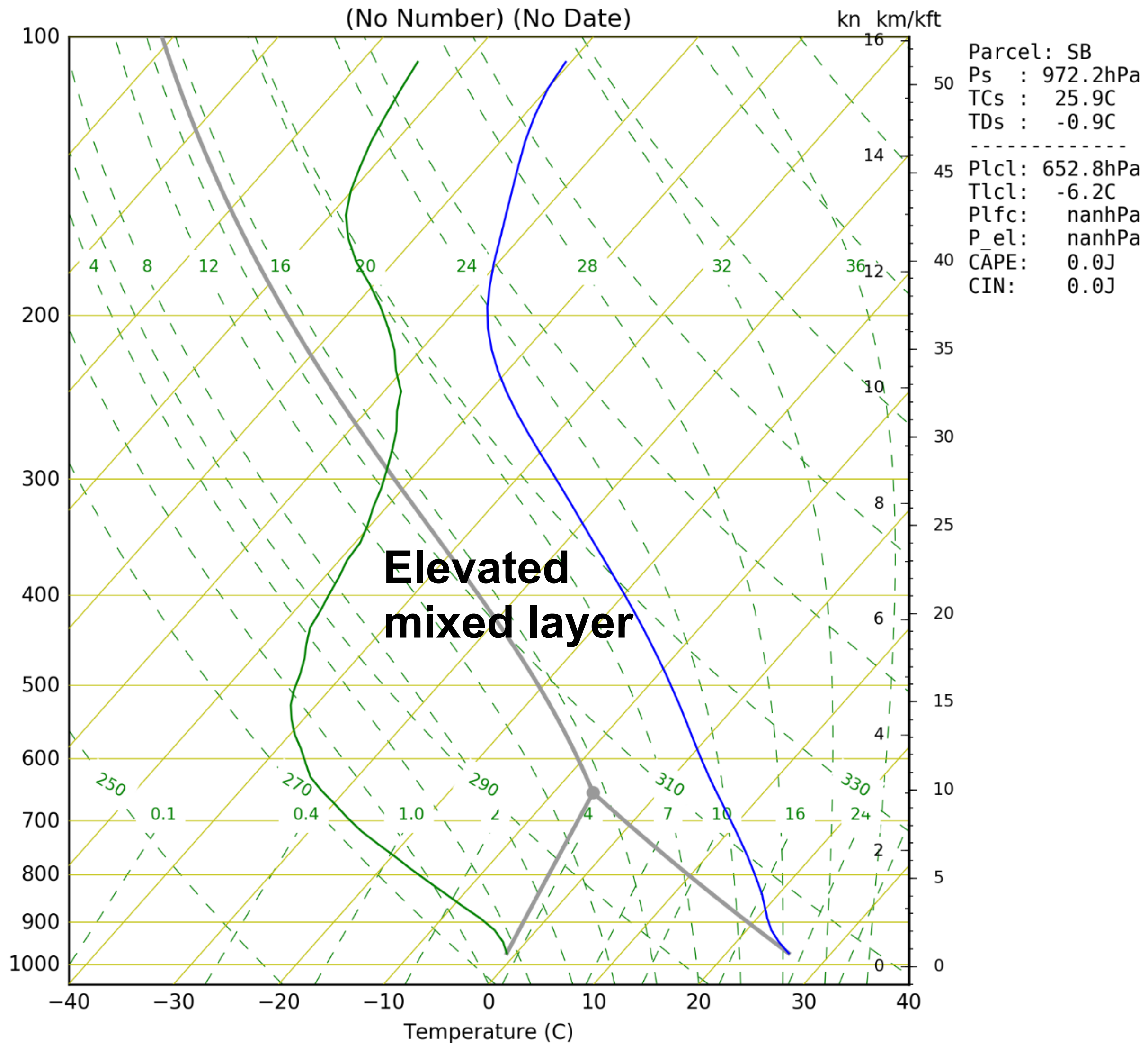
Haines, D.A., 1988: A lower atmosphere severity index for wildland fires. National Weather Digest, 13, 23-27.

Elevation	Stability Term		Moisture Term
LOW ELEVATION **Near surface**	Stability Term (T950-T850) 1....3 deg C or less 2...4 to 7 deg C 3...8 deg C or gtr	+	Moisture Term (T850-Td850) 1...5 deg C or less 2...6 to 9 deg C 3...10 deg C or gtr
* MID ELEVATION **1000-3000 feet** **300-900 meters**	Stability Term (T850-T700) 1...5 deg C or less 2...6 to 10 deg C 3...11 deg C or gtr	+	Moisture Term (T850-Td850) 1...5 deg C or less 2...6 to 12 deg C 3...13 deg C or gtr
HIGH ELEVATION **> 3000 feet** **> 900 meters**	Stability Term (T700-T500) 1..17 deg C or less 2...18 to 21 deg C 3...22 deg C or gtr.	+	Moisture Term (T700-Td700) 1...14 deg C or less 2...15 to 20 deg C 3...21 deg C or gtr

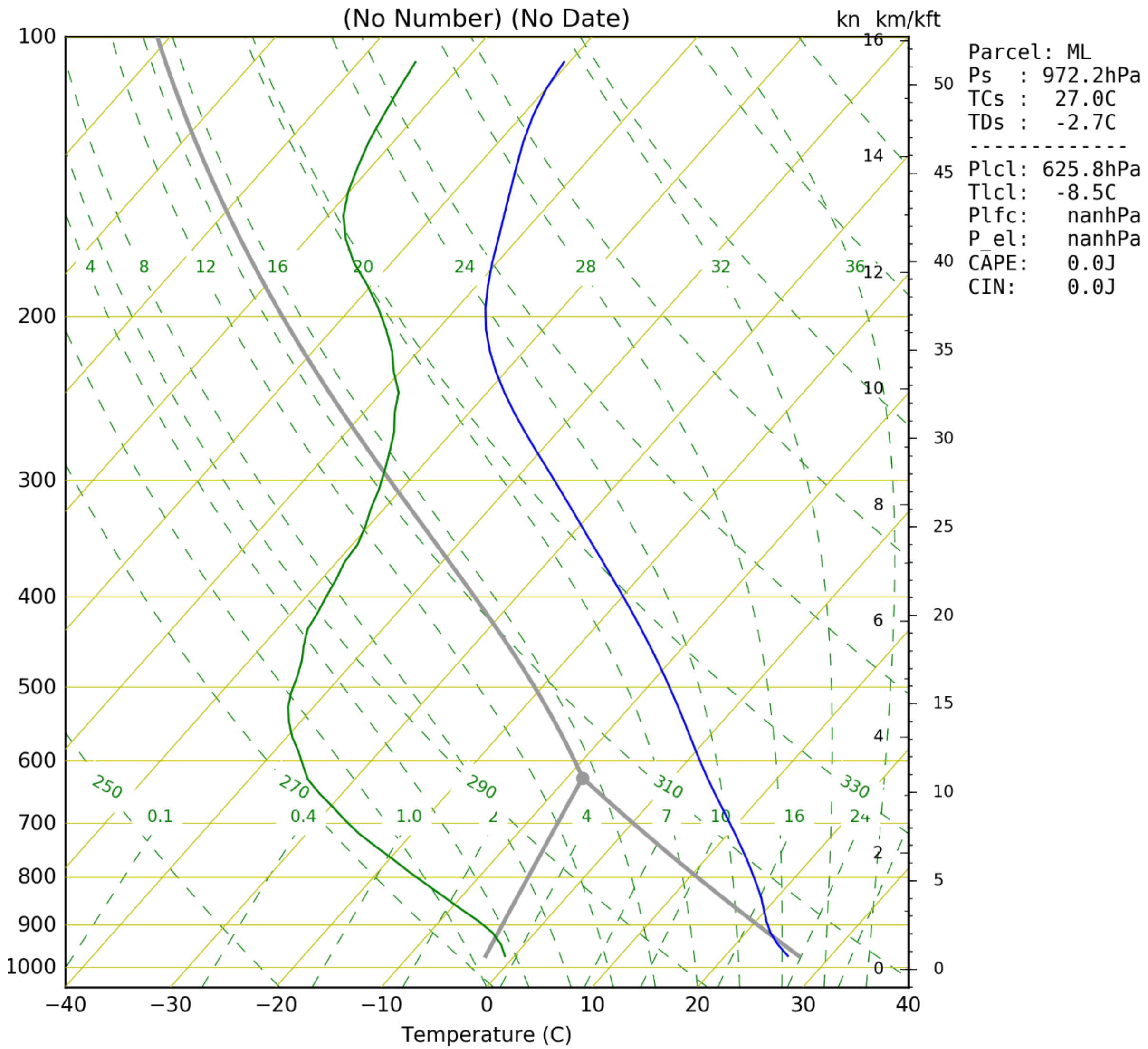
2-4 = low ROS, 5 = moderate ROS, 6 = high ROS

Near Canberra, ACT, AU

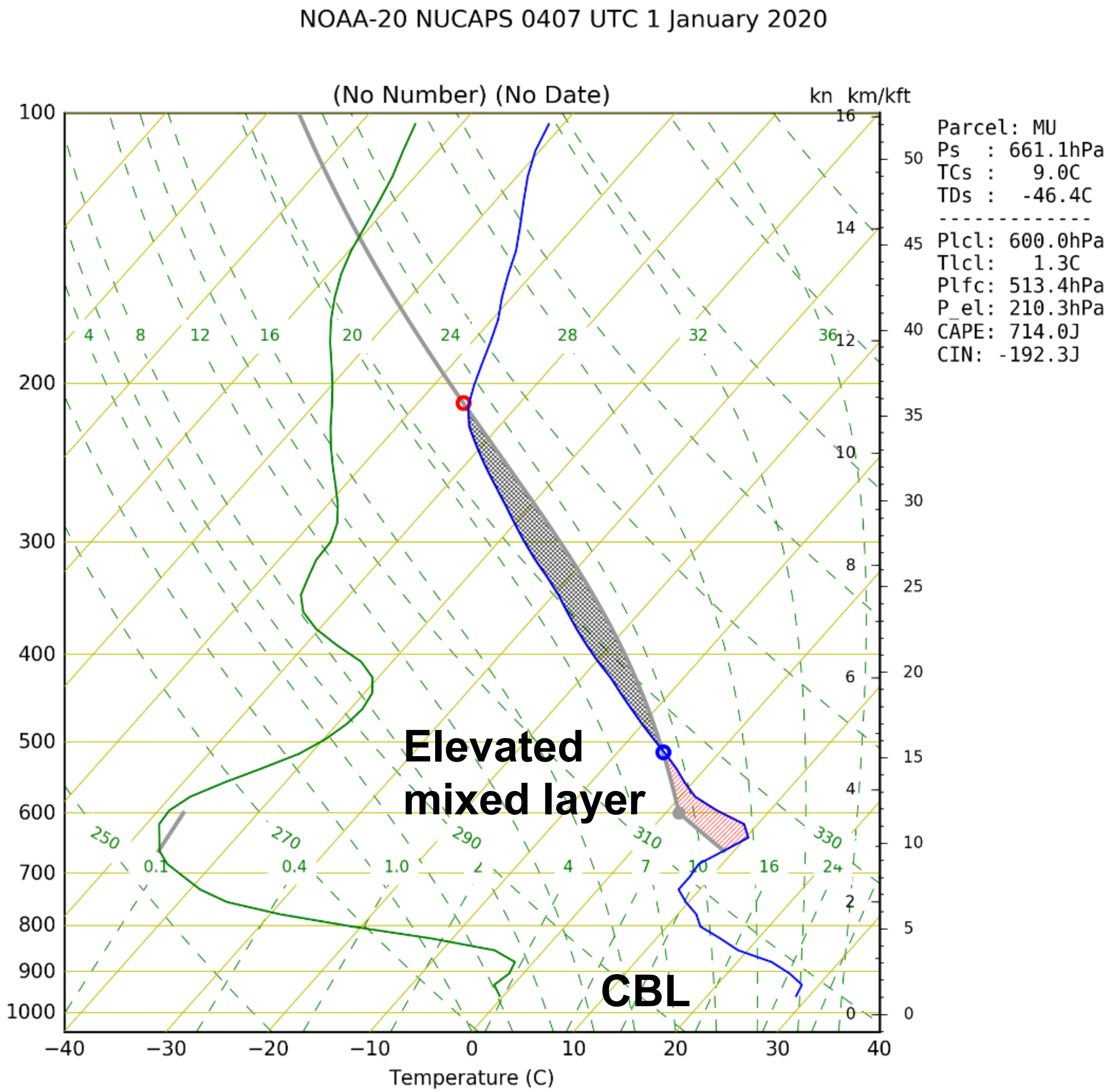
NOAA-20 MIRS 0407 UTC 1 January 2020

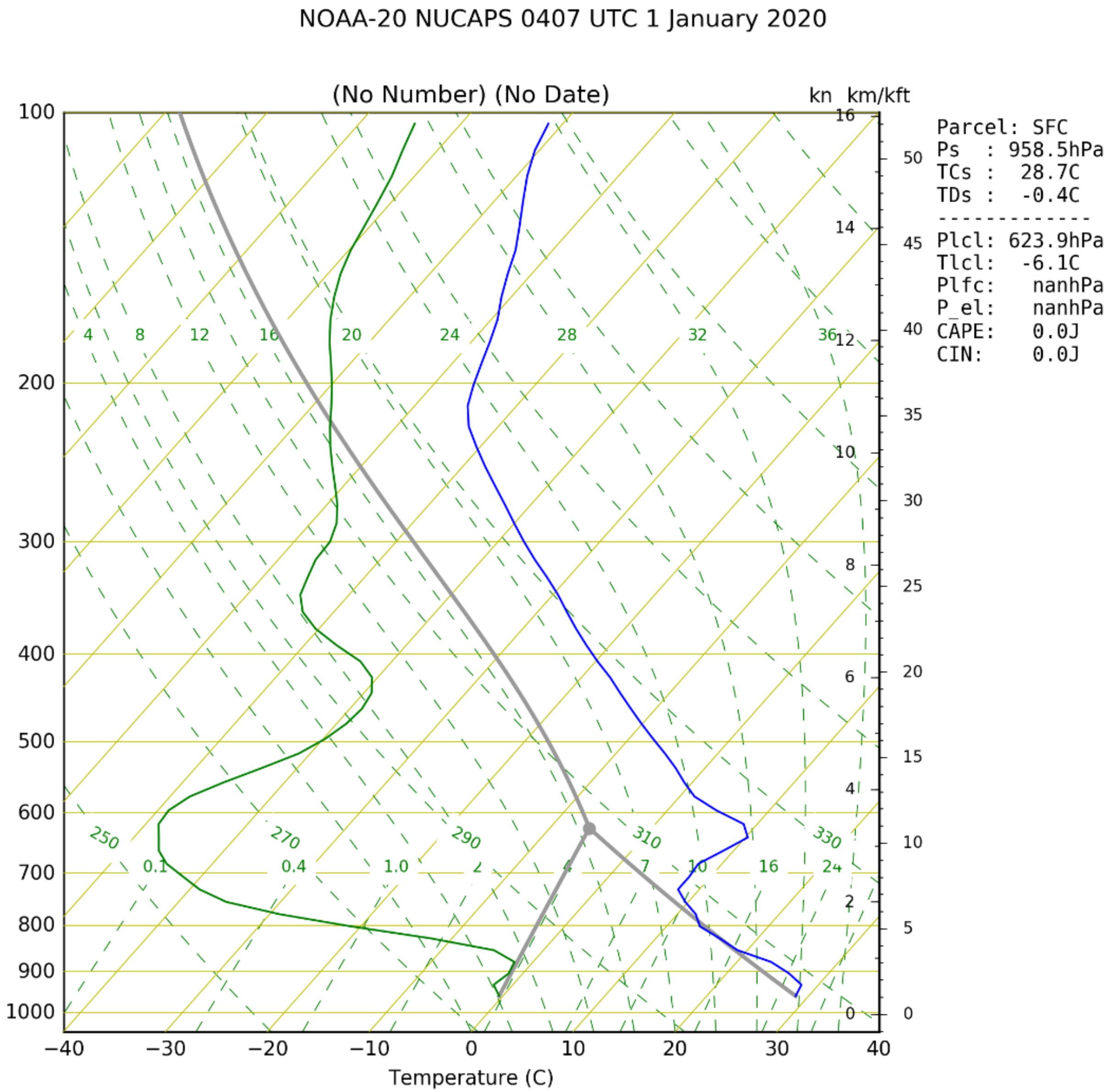


NOAA-20 MIRS 0407 UTC 1 January 2020



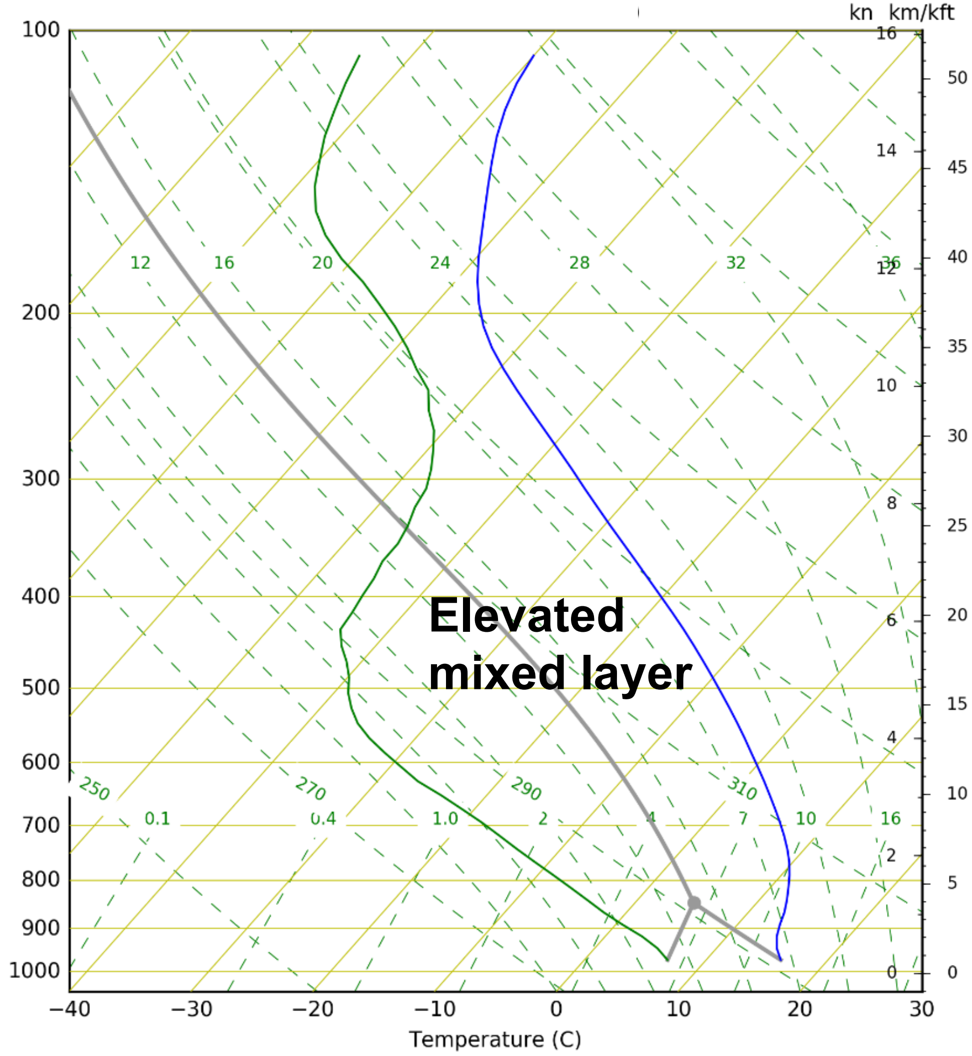
Near Canberra, ACT, AU





Melbourne, VIC, AU

METOP-B MIRS 1231 UTC 1 January 2020



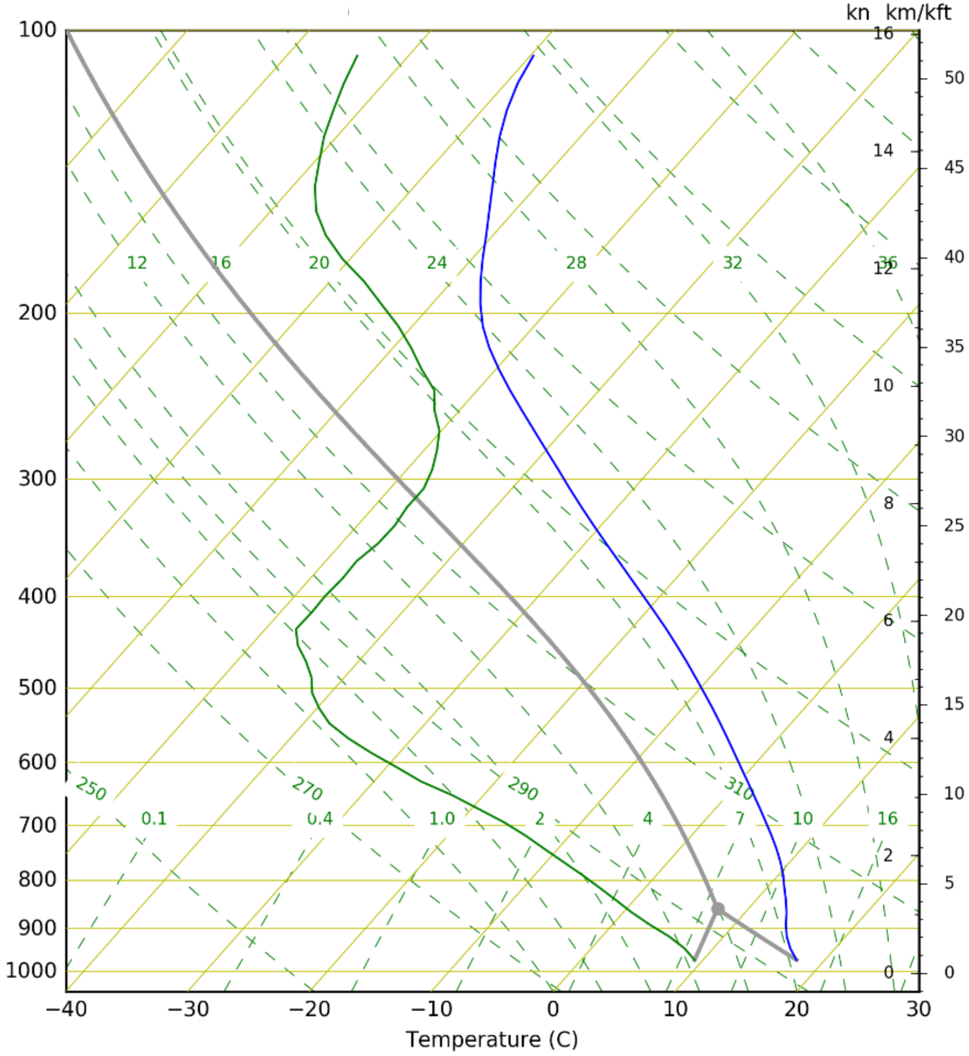
Parcel: SB
Ps : 972.2hPa
TCs : 16.1C
TDs : 6.8C

Plcl: 845.6hPa
Tlcl: 4.8C
Plfc: nanhPa
P_el: nanhPa
CAPE: 0.0J
CIN: 0.0J

Column:
TPW: 11.1 mm

HI = 5
C-HI = 5

METOP-C MIRS 1152 UTC 1 January 2020



Parcel: SB
Ps : 972.2hPa
TCs : 17.7C
TDs : 9.3C

Plcl: 858.1hPa
Tlcl: 7.5C
Plfc: nanhPa
P_el: nanhPa
CAPE: 0.0J
CIN: 0.0J

Column:
TPW: 12.9 mm

HI = 5
C-HI = 5

Event Summary

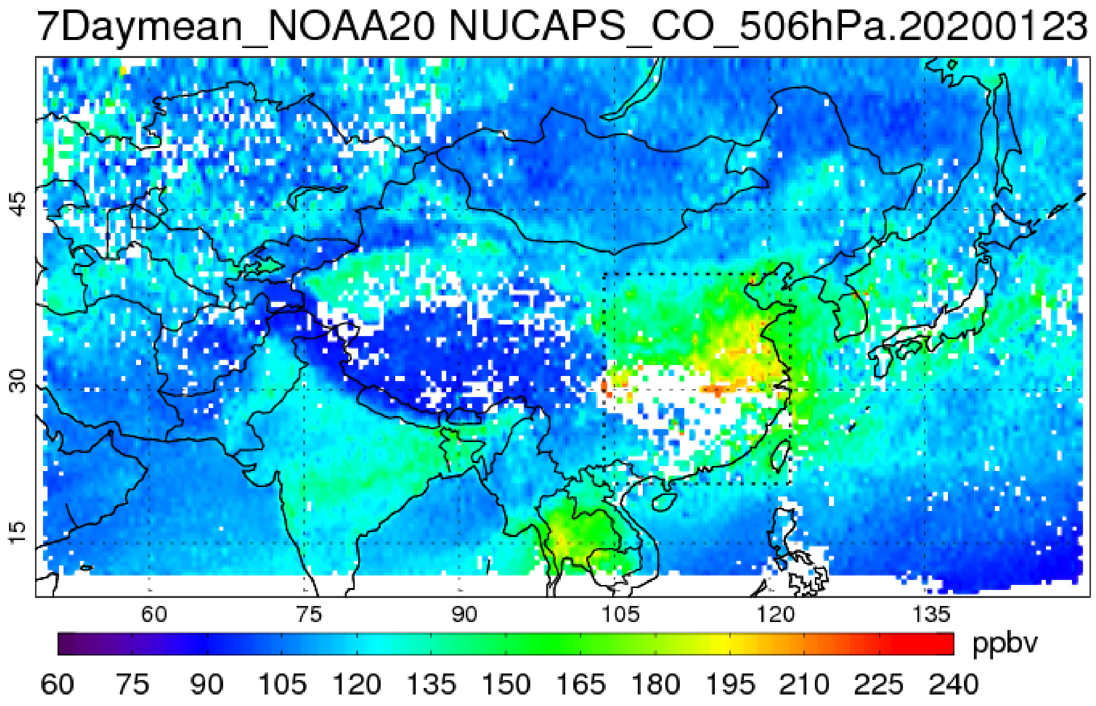
- NUCAPS has effectively measured carbon monoxide (CO) concentration and generated vertical sounding profiles over SE Australia and adjacent coastal waters in association with two widespread wildfire outbreaks:
  - 30 December 2019 – 1 January 2020
  - 5 -8 January 2020
- NOAA-20 and SNPP NUCAPS CO product captured a smoke plume that advected from the Australian Alps southeastward over the Tasman Sea toward New Zealand.
- NOAA-20 NUCAPS sounding profiles effectively captured a dry, unstable environment over SE Australia associated with elevated Haines Index values and resultant fire potential.
- This event will be investigated further for the enhancement of thermodynamic invigoration and the occurrence of pyro-convection that could further enhance wildfire intensification and spreading.

NUCAPS CO Over SE Asia During COVID-19 January – March, 2020

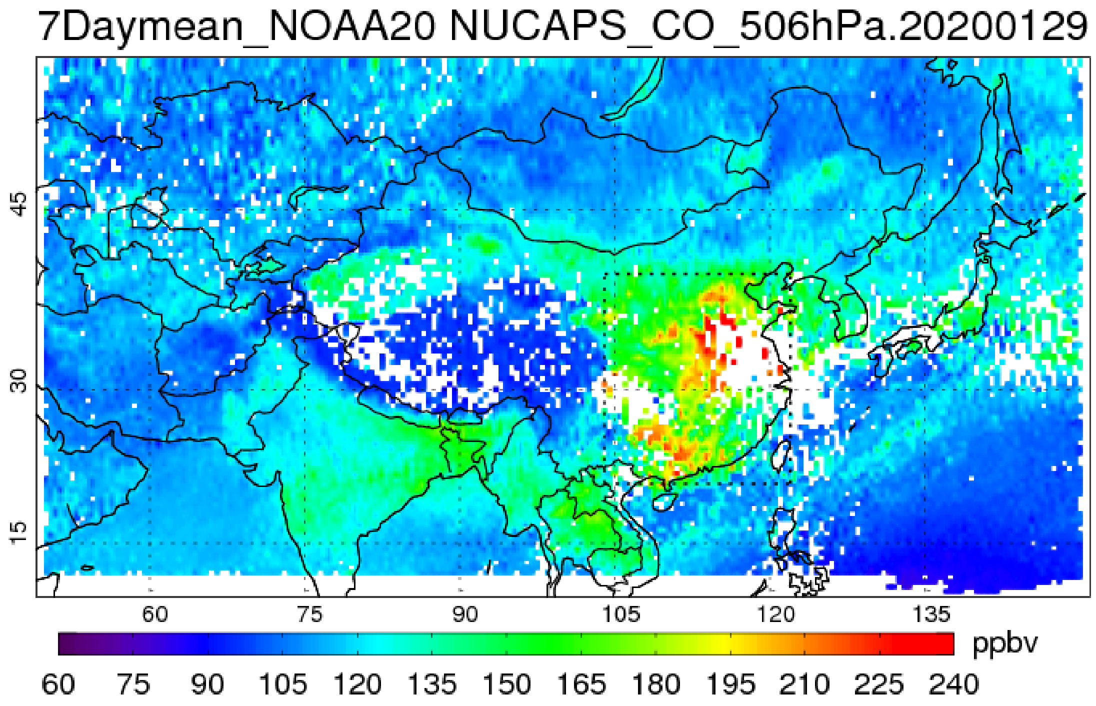
- Collected NOAA20 SDR data over 50E-150E, 10N-55N,
  - 60 days: 01/17 – 03/16, 2020 (starting 9 days before Chinese New Year)
  - 30 days: 01/28 – 02/26, 2019 (starting 9 days before Chinese New Year)
- Run NUCAPS NOAA20 v2.7.2 retrieval for above 90 days
- Analyzed NUCAPS CO retrievals at 506 hPa:
  - 7-day composite CO(mean) figures
  - Animation of 7-day composite CO
  - Time series of CO averaged over 104E-122E, 21N-40N

7-day composite (mean) of NUCAPS CO (before & starting of lockdown)

17 – 23 Jan 2020

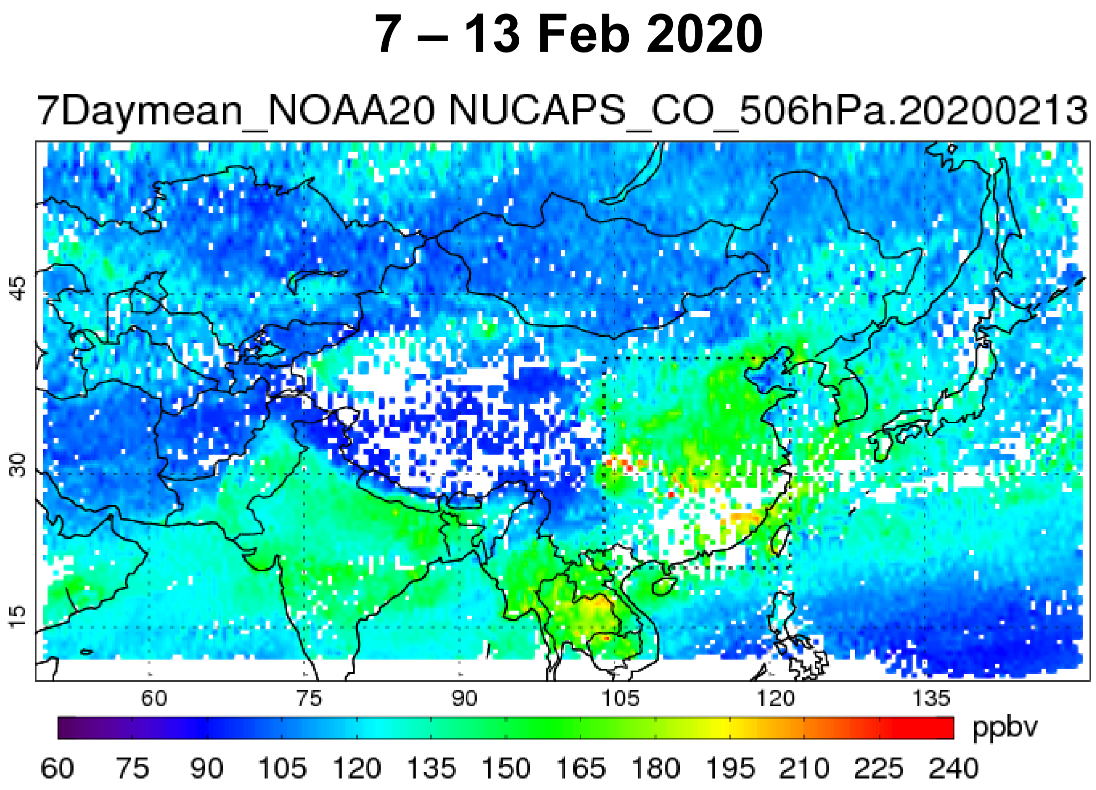


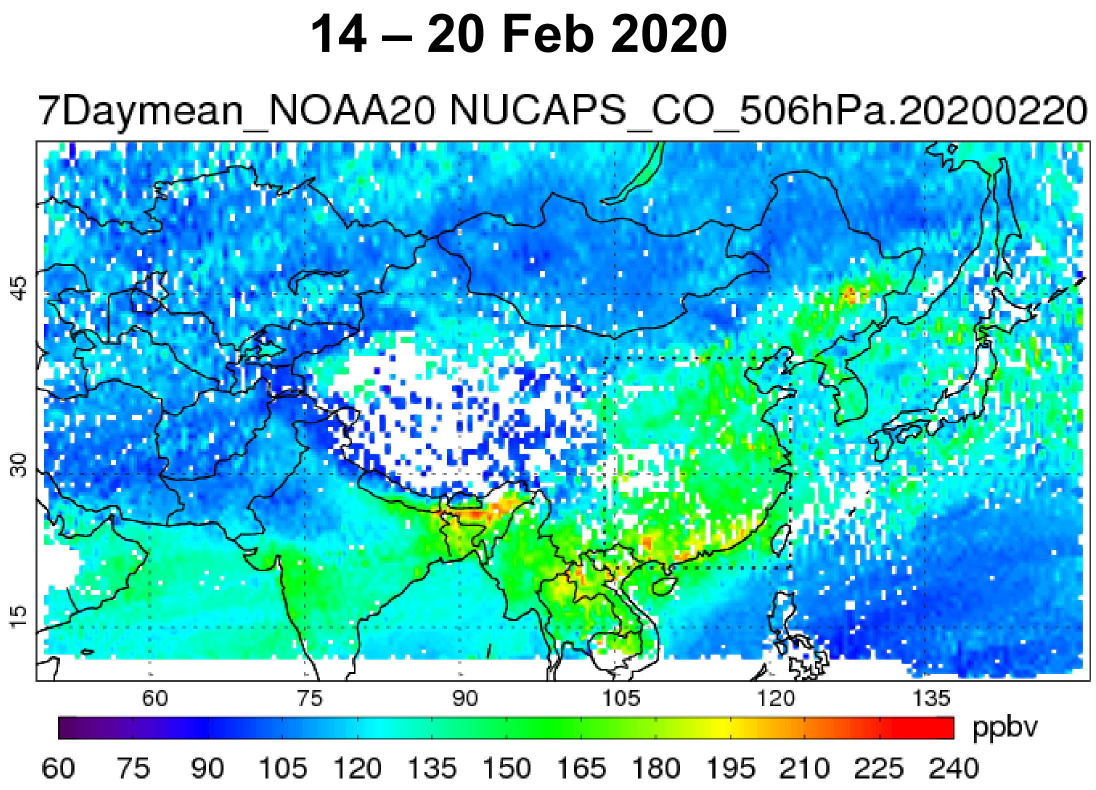
23 – 29 Jan 2020



- Start lockdown of 4 cities in Hubei province on Jan 23, 2020
- Expends to 27 cities over Southeast China by Feb 4, 2020

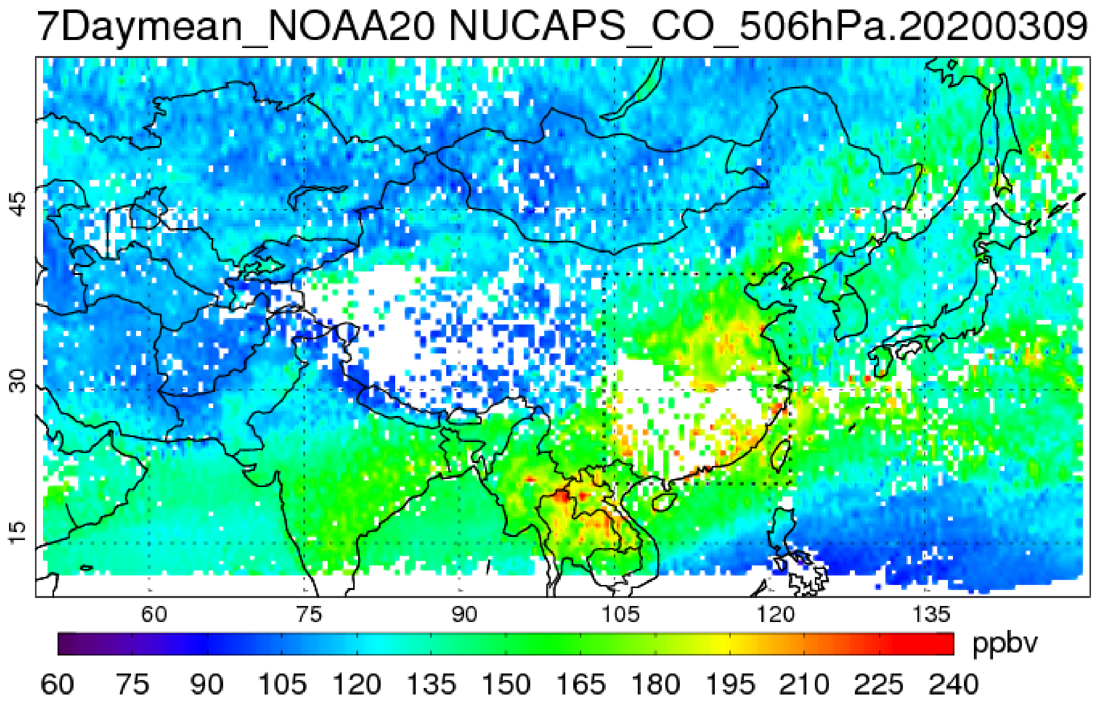
7-day composite (mean) of NUCAPS CO (before & starting of lockdown)



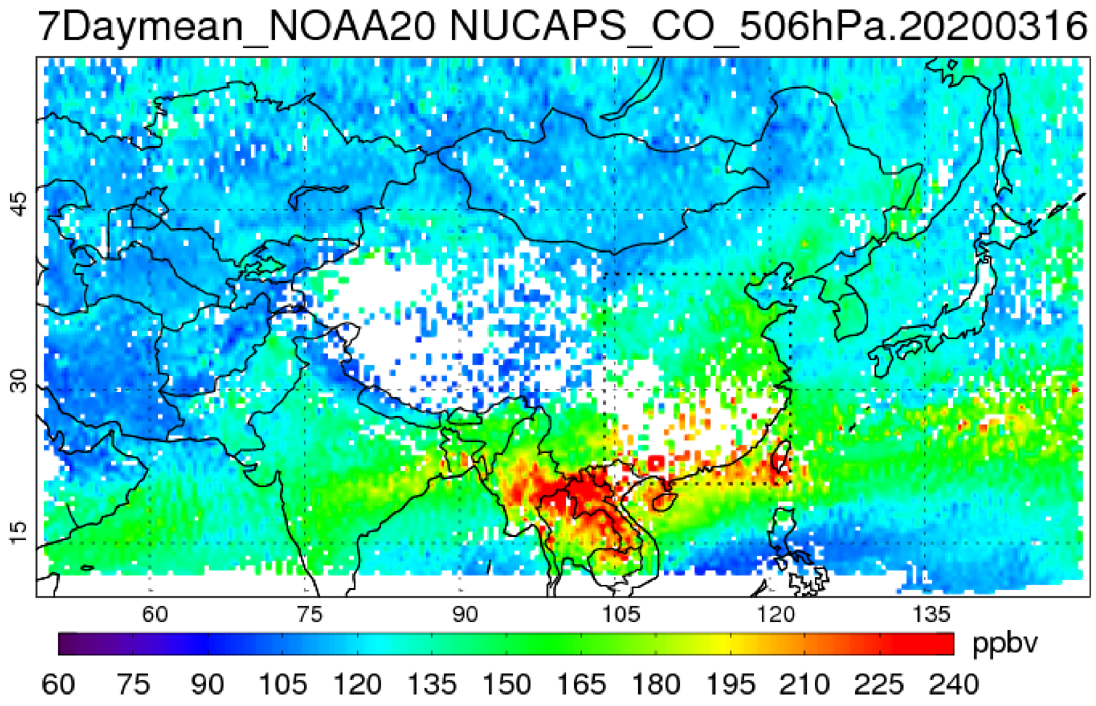


7-day composite (mean) of NUCAPS CO (after lockdown)

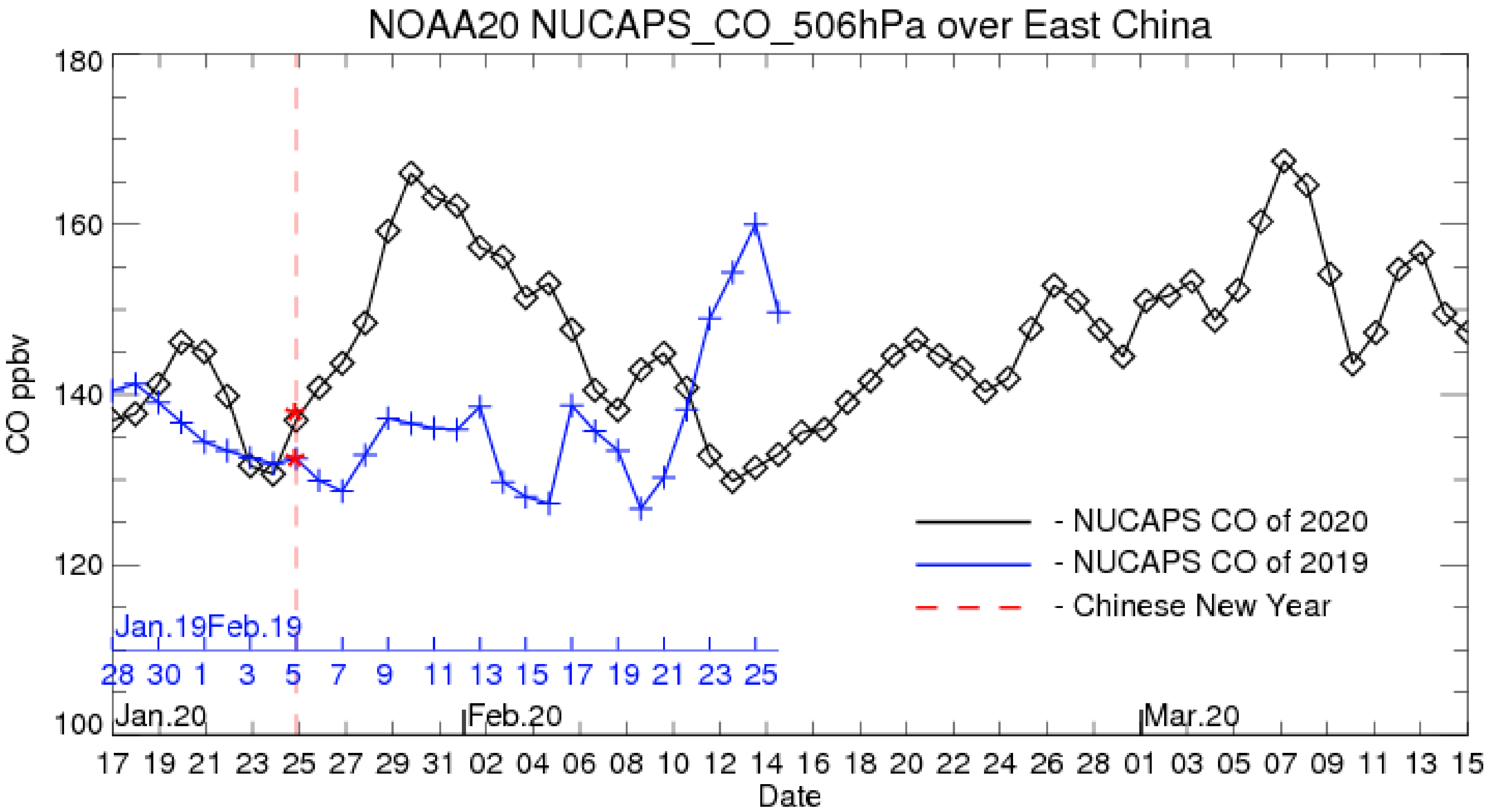
3 – 9 Mar 2020



10 – 16 Mar 2020



Time series of NUCAPS CO



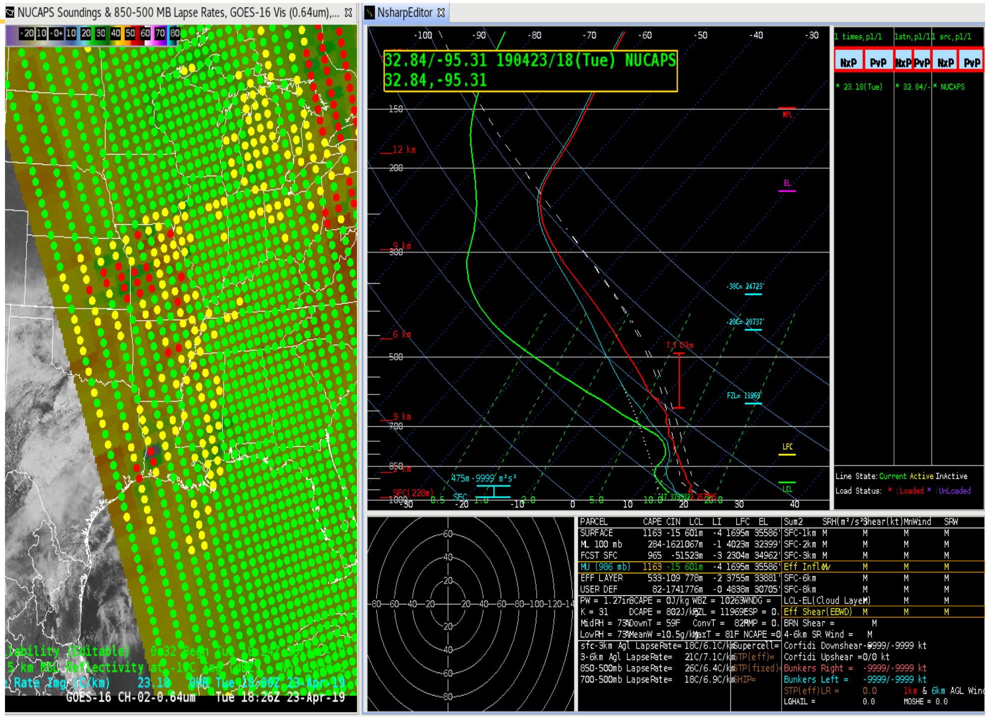
- Averaged over 104E-122E, 21N-40N
- 2019 dates are shifted based on Chinese New Year date

USER FEEDBACK AND TESTIMONIALS

NUCAPS

- NUCAPS produces consistent results with Suomi-NPP and NOAA-20. Products are available through CLASS for worldwide users.
- CSPP generates NUCAPS products as part of Direct Broadcast (DB) Network for regional applications

  WFOs nationwide uses NUCAPS temperature, water vapor, and cloud fraction information through Advanced Weather Interactive Processing System (AWIPS-2)
- Other Users: NOAA/NASA, ESRL, EPA, CPO-AC4
- NUCAPS Ozone - used with OMPS Ozone to generate Total Ozone Analysis from Stratospheric and Tropospheric Satellite Sources (TOAST) product
- CO and other trace gases – Synergistic use with other products (e.g. TROPOMI) for day-to-day events
- Many PGRR Initiatives are using NUCAPS products and found them extremely useful for their applications
- S-NPP/NOAA-20 Validated Maturity Review
  – https://www.star.nesdis.noaa.gov/jpss/AlgorithmMaturity.php



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

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

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

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	CO	Shobha Kondragunta, STAR
NUCAPS	CH4	Lori Bruhwiler, ESRL
NUCAPS	CO2	Lori Bruhwiler, ESRL

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

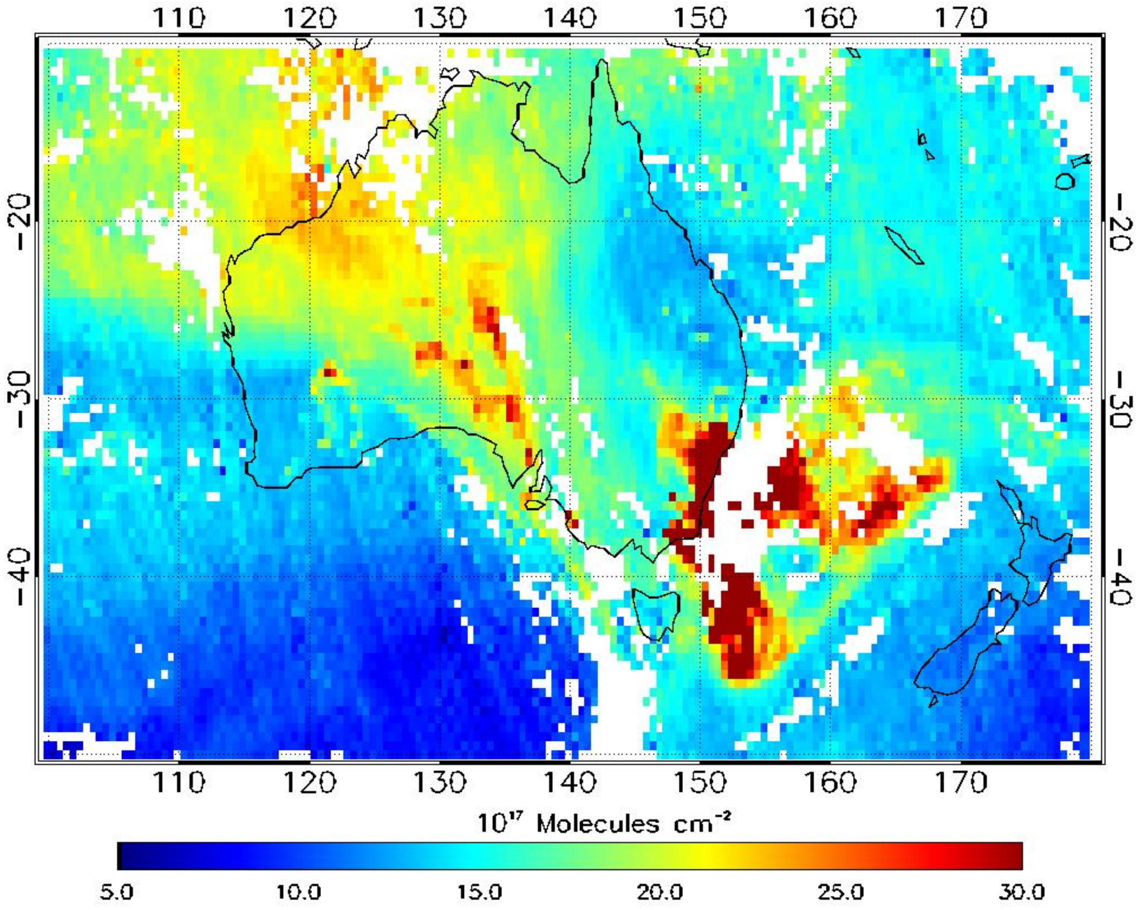
TROPOMI CO data courtesy of ESA

Data Analysis and Disclaimer

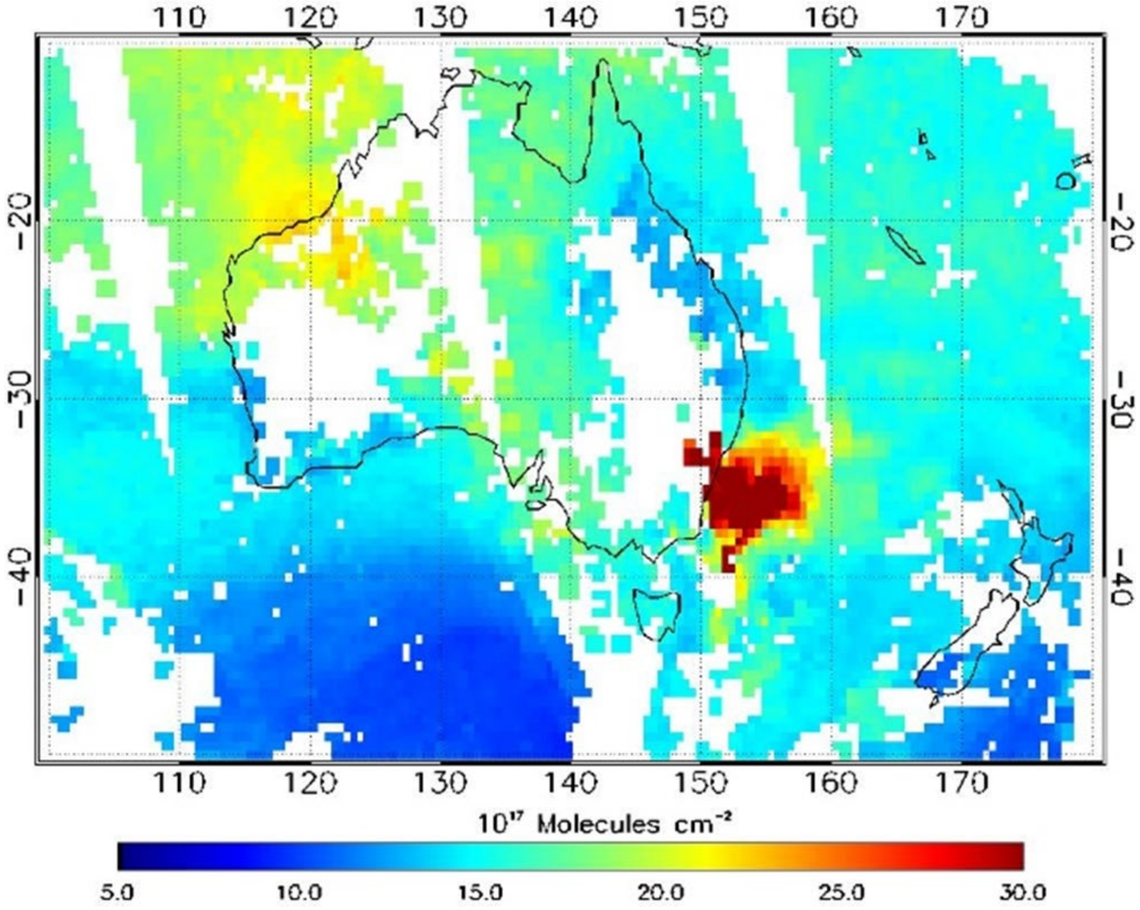
- TROPOMI and CrIS CO comparisons
  - Individual pixel matchups
  - Remapped TROPOMI (7 km x 7 km) and CrIS (50 km x 50 km) to 0.5^o x 0.5^o gridded data
- TROPOMI is a total column CO whereas CrIS has peak sensitivity in mid-troposphere. Bias between the two products is expected.
- This analysis is focused on Extreme Fires in Australia. Fires raged in Australia in December 2019 and January 2020. What we want to show in this evaluation process is that spatial and temporal features in CO for these fires are captured by both sensors
- Quality flags used
  - CrIS: general quality flag “0” and CO quality flag
  - TROPOMI: > 0.5

CO from TROPOMI and NUCAPS SNPP CrIS (30 Dec 2019)

Dec. 30 2019
S5P TROPOMI CO

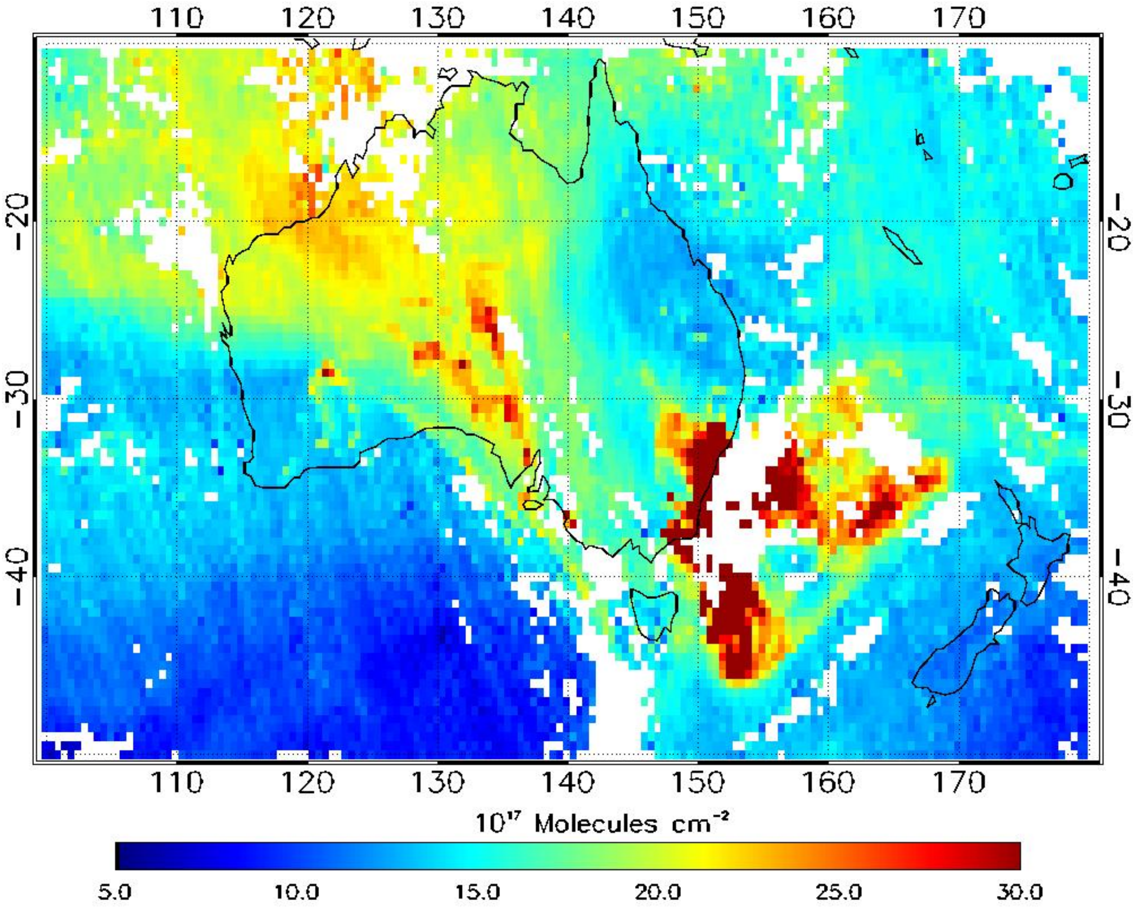


Dec. 30 2019
SNPP CrIS CO

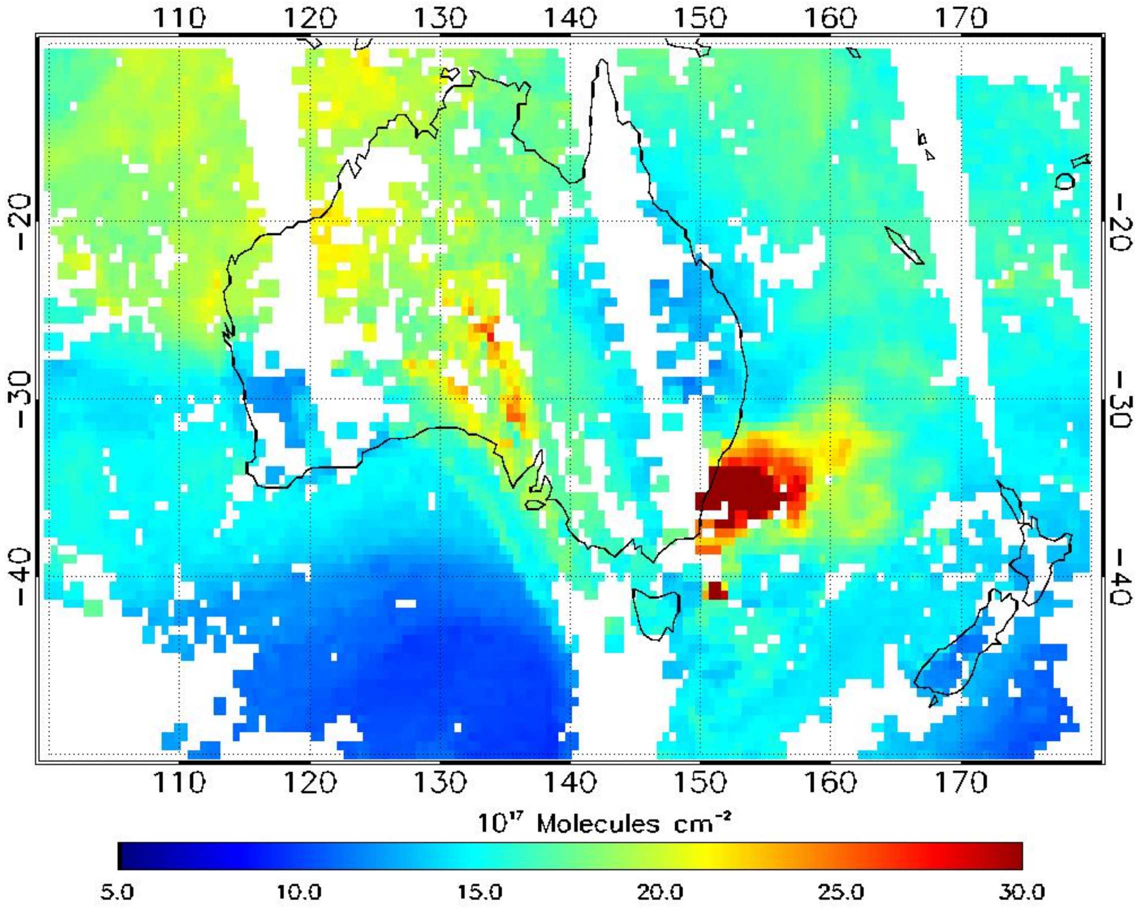


CO from TROPOMI and NUCAPS NOAA-20 CrIS (30 Dec 2019)

Dec. 30 2019
S5P TROPOMI CO

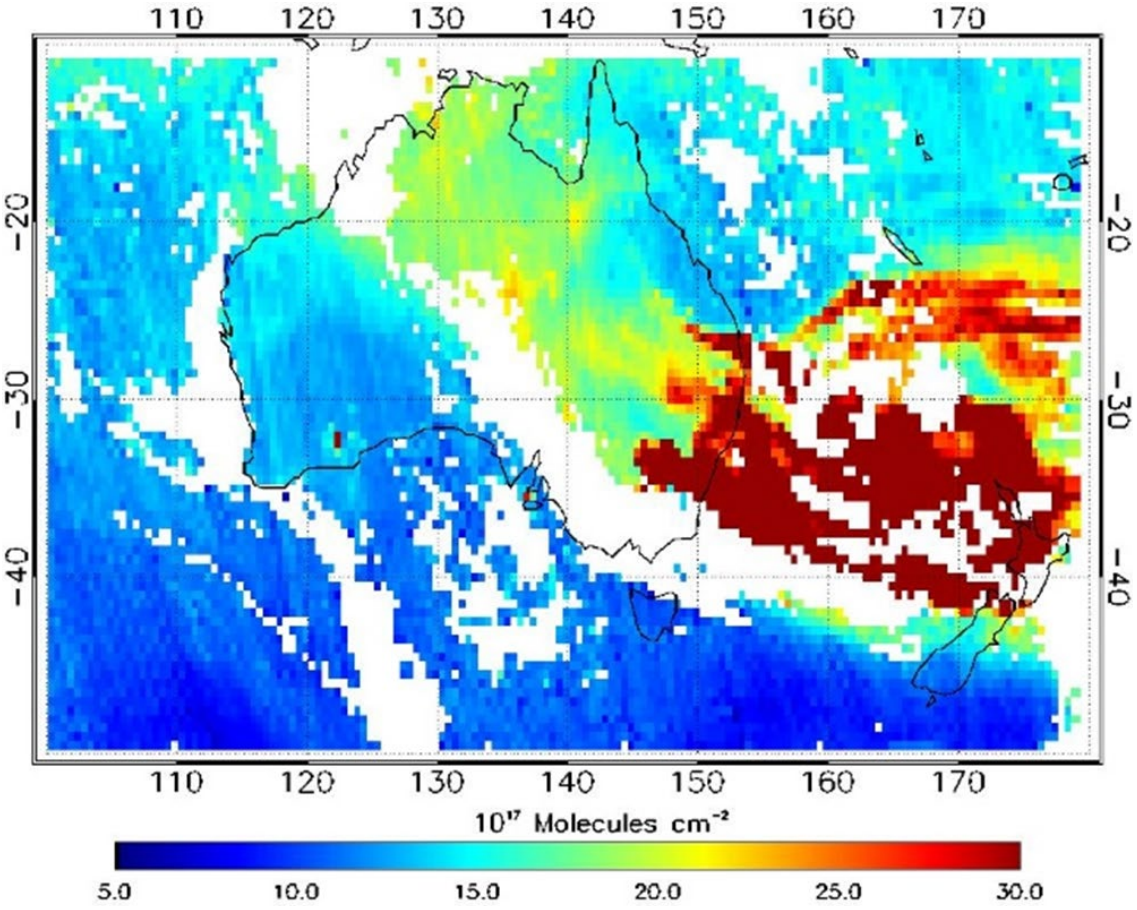


Dec. 30 2019
NOAA-20 CrIS CO

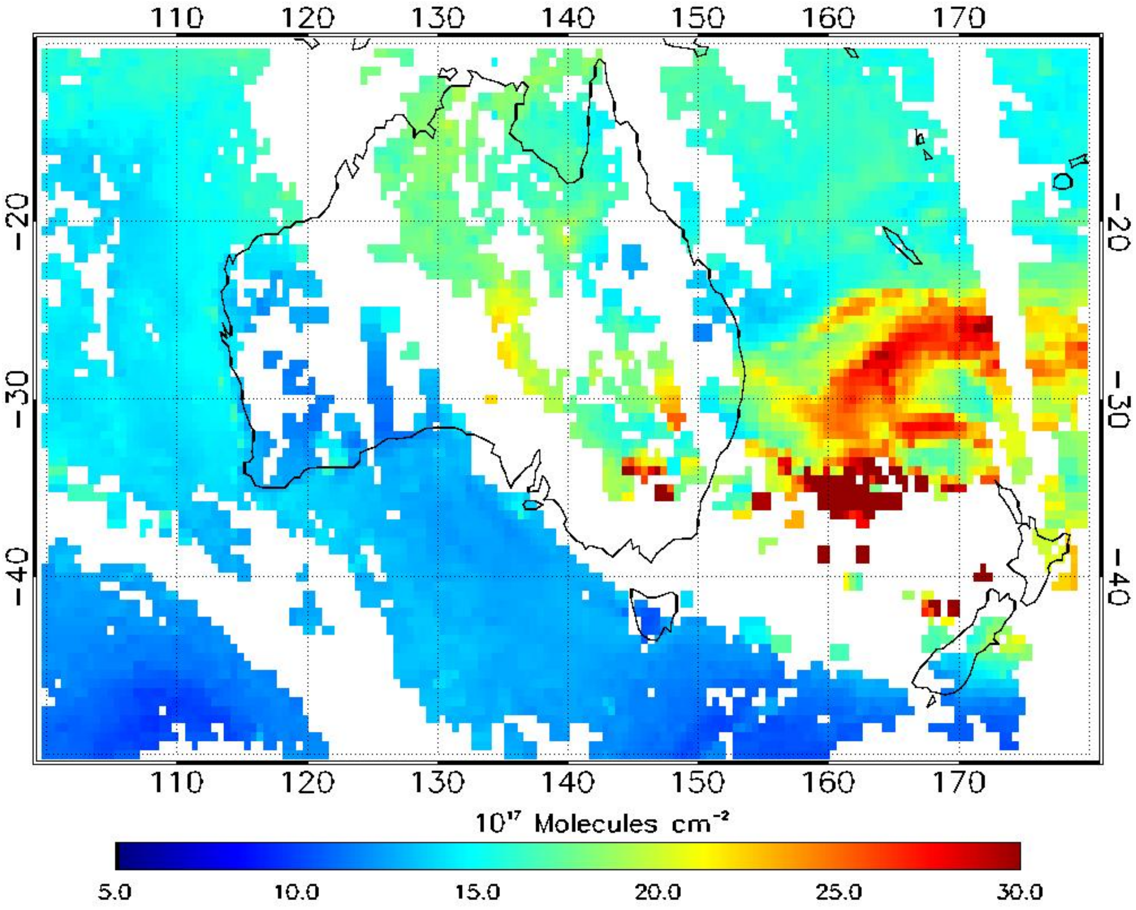


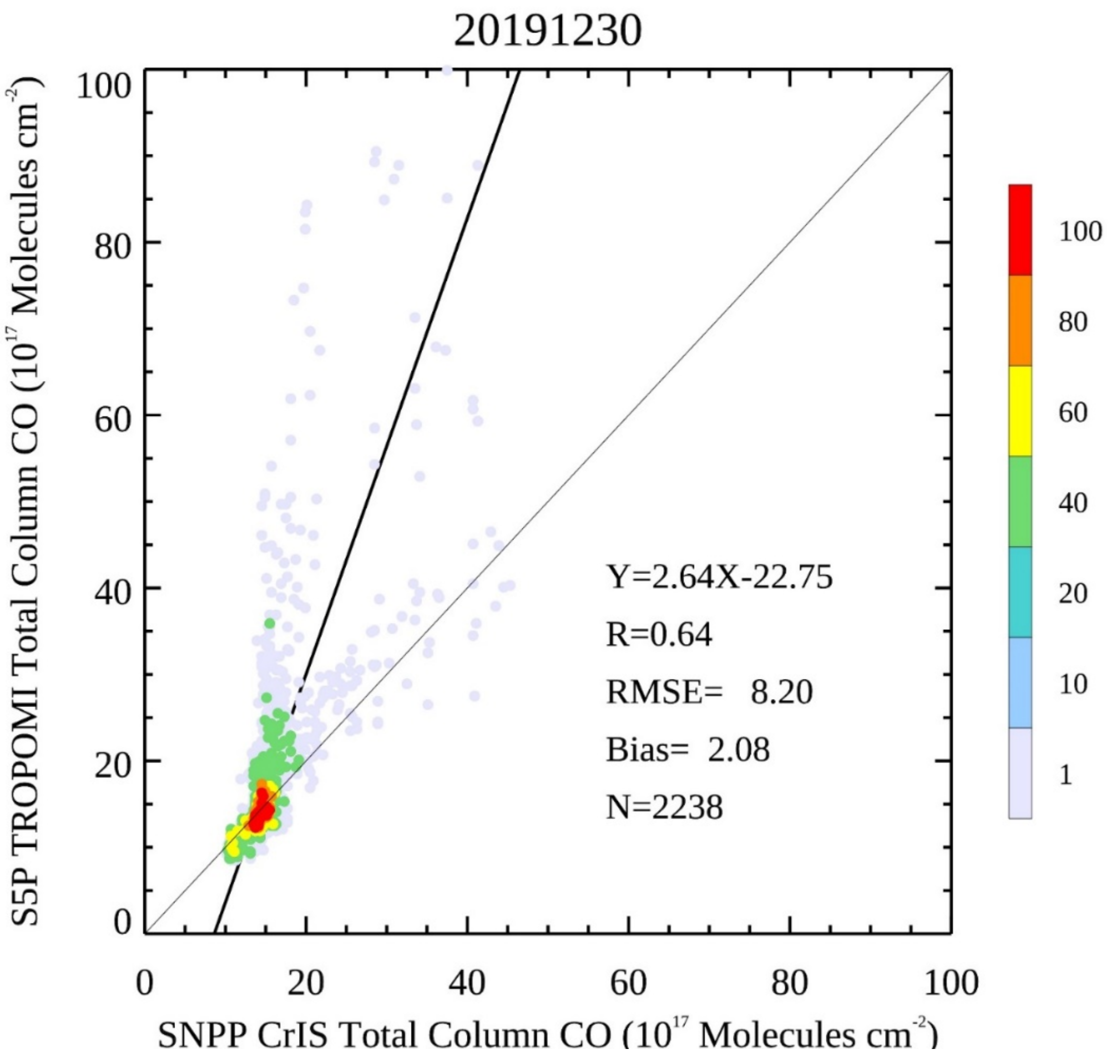
CO from TROPOMI and NUCAPS NOAA-20 CrIS (5 Jan 2020)

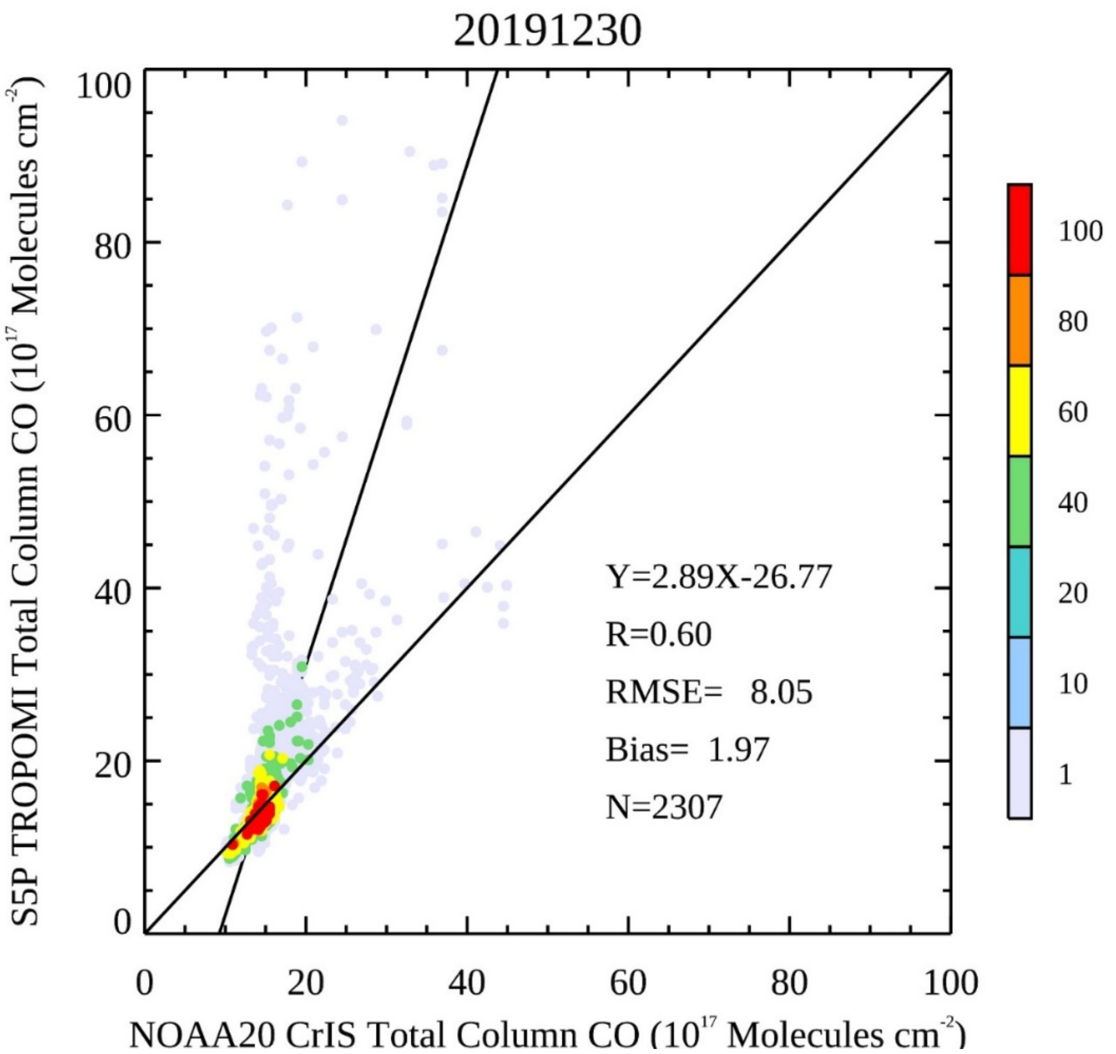
5 Jan 2020
S5P TROPOMI CO



5 Jan 2020
NOAA-20 CrIS CO

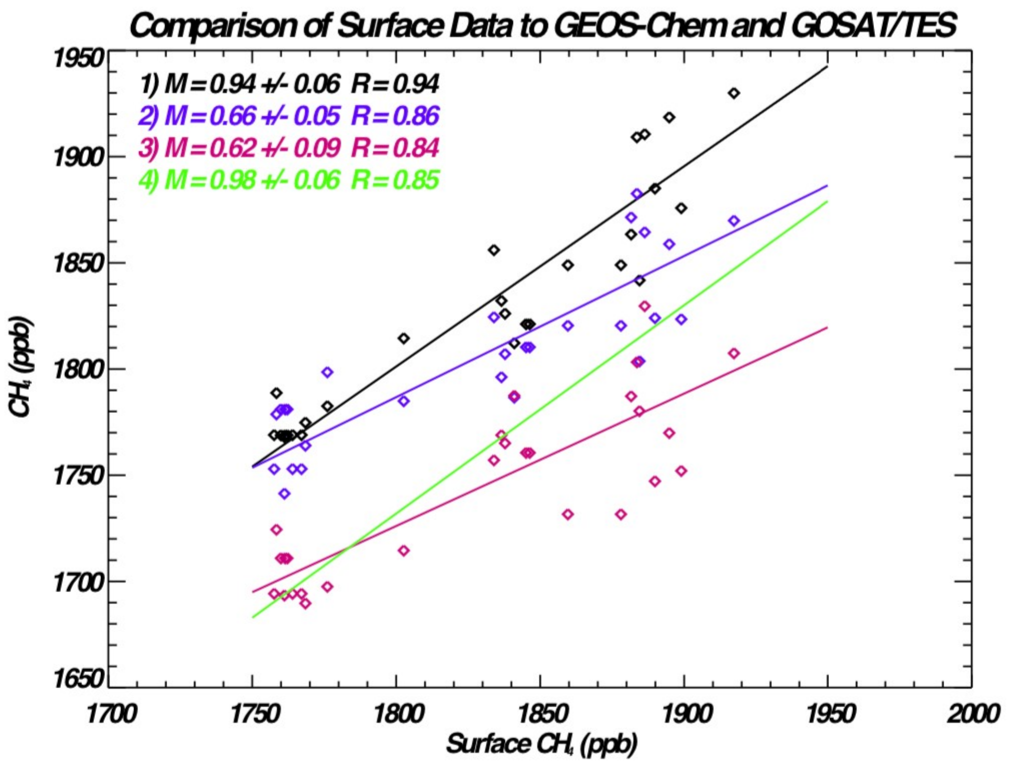


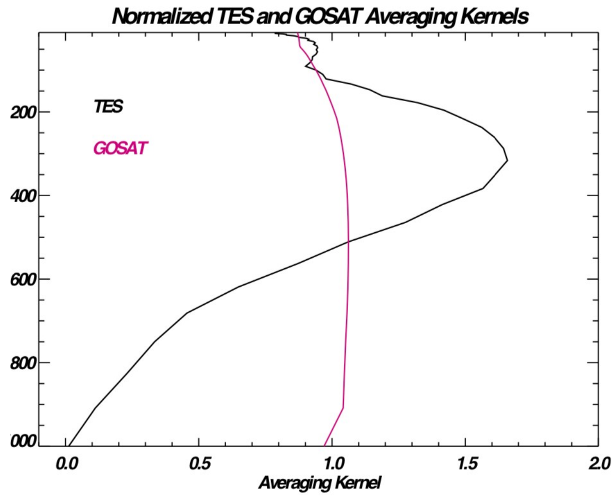

20191230
S5P TROPOMI Total Column CO (10^17 Molecules cm^-2)
SNPP CrIS Total Column CO (10^17 Molecules cm^-2)
Y=2.64X-22.75
R=0.64
RMSE= 8.20
Bias= 2.08
N=2238
100
80
60
40
20
10
1


20191230
S5P TROPOMI Total Column CO (10^17 Molecules cm^-2)
NOAA20 CrIS Total Column CO (10^17 Molecules cm^-2)
Y=2.89X-26.77
R=0.60
RMSE= 8.05
Bias= 1.97
N=2307
100
80
60
40
20
10
1

Analysis of SNPP and NOAA-20 CrIS CH_4 Retrievals

Multi-Spectral Approach for Retrieving Lower Tropospheric CH_4





Precision: 10-30 ppb (monthly averages)

Bias vs. Model: 65 ppb

Accuracy: 6 ppb

(after bias removal)

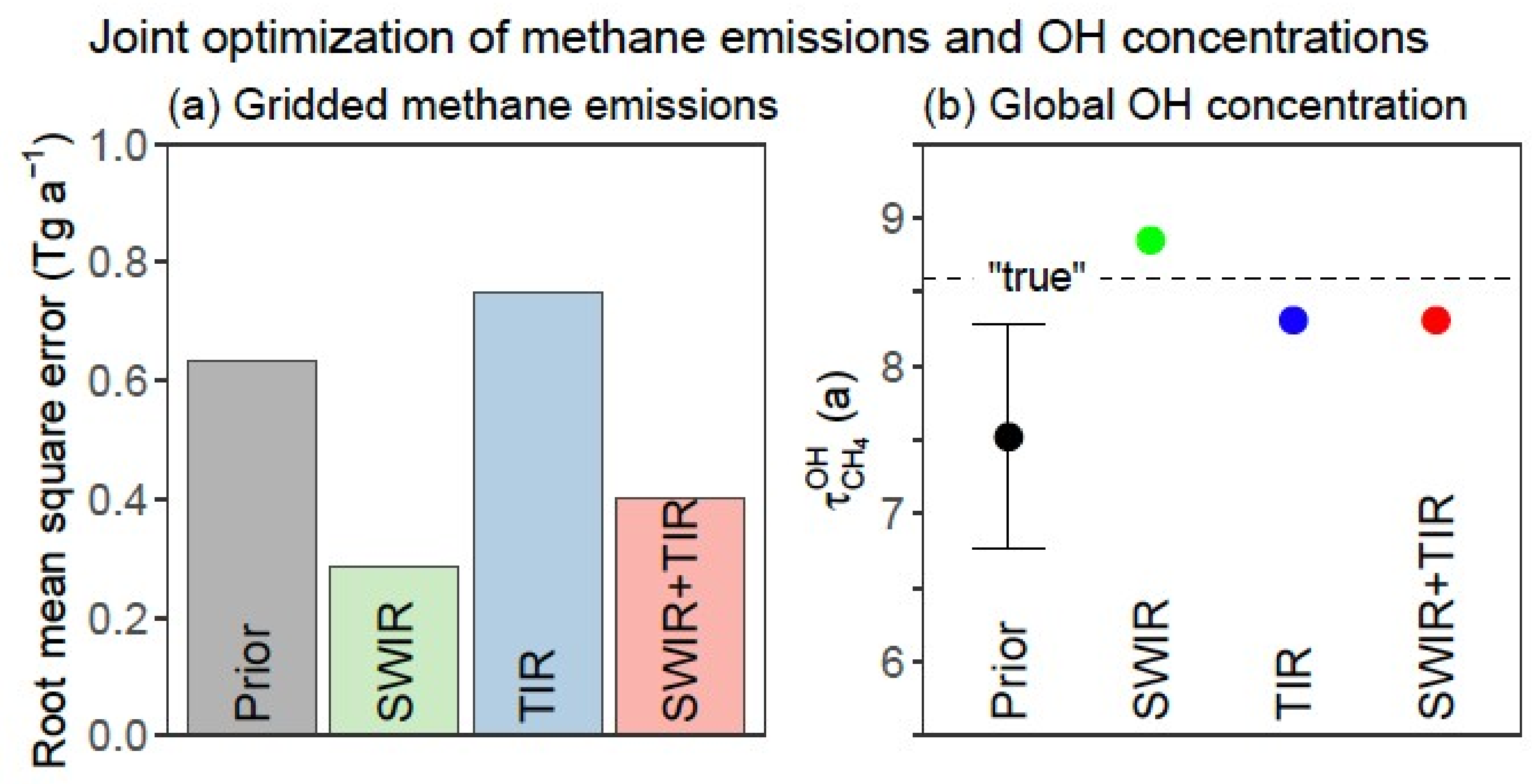
Worden et al., 2017:

Satellite-based CO and CH4 concentration measurements are important for mitigation and characterization of uncertainties due to (1) errors in transport and chemistry, (2) uncertainties in partitioning CO emissions, and (3) uncertainties in the CH4/CO emission factors.

Satellite observations are useful in the tropics where *in situ* observations are especially scarce.

NUCAPS will serve as an important cross-comparison data source to GOES-Chem and TES.

Can we use TIR and SWIR soundings to jointly constrain CH_4 emissions and *the CH_4 lifetime?*



Zhang et al., 2018

Resolution of Emissions – 4x5

Error bars very small

<u>**Use of TIR CO retrievals could provide an important constraint on emissions of CO2 and CH4 from biomass burning (e.g. Worden et al.,2017), especially considering that emissions from fires are likely to be lofted high into the troposphere.**</u>

Analysis of SNPP and NOAA-20 CrIS CO2 Retrievals

Other Types of Satellite Observations that Can Help Constrain Carbon Budgets

NUCAPS CO2 product will serve as an important independent data source for carbon budget monitoring.

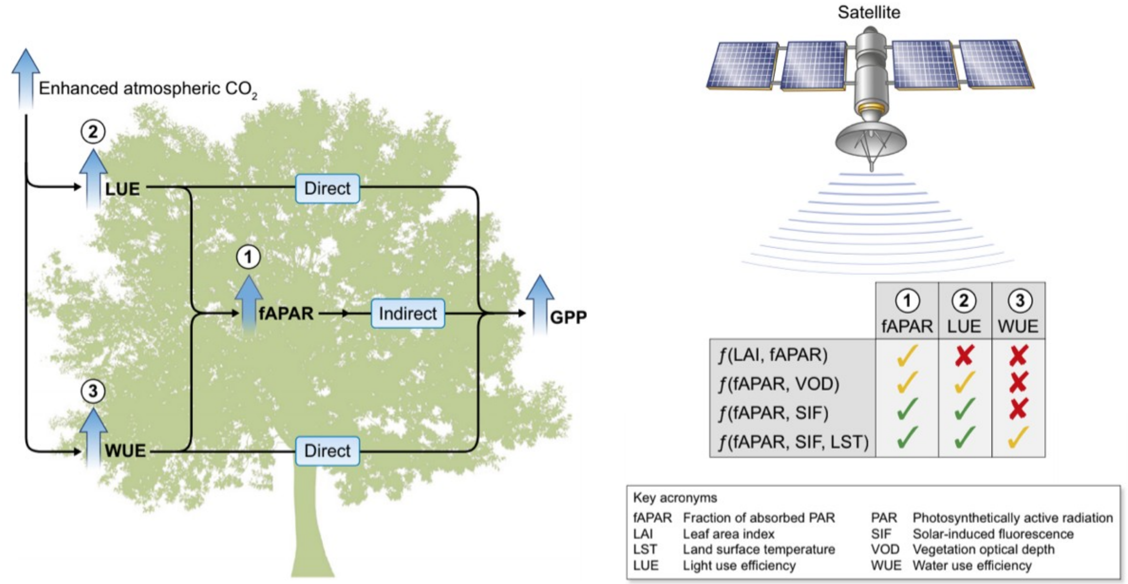


Fig. 1 Schematic of the pathways by which CO_2 fertilization effects (CFE) can increase gross primary productivity (GPP) and the potential ways satellite observations could be combined to constrain the CFE pathways. We define CFE pathways to include increases in light use efficiency (LUE), increases in water use efficiency (WUE), and increases in the fraction of photosynthetically active radiation (fAPAR). Satellite indices include leaf area index (LAI) and fAPAR, land surface temperature (LST), vegetation optical depth (VOD) and solar-induced Chl fluorescence (SIF). We show different combinations of these satellite records and indicate their potential to globally constrain (green ticks), regionally constrain (yellow ticks) or fail to constrain (red crosses) a given CFE pathway. Regional constraints (yellow ticks) are most often limited by atmospheric effects and/or signal saturation in dense canopies, such as tropical forest ecosystems.

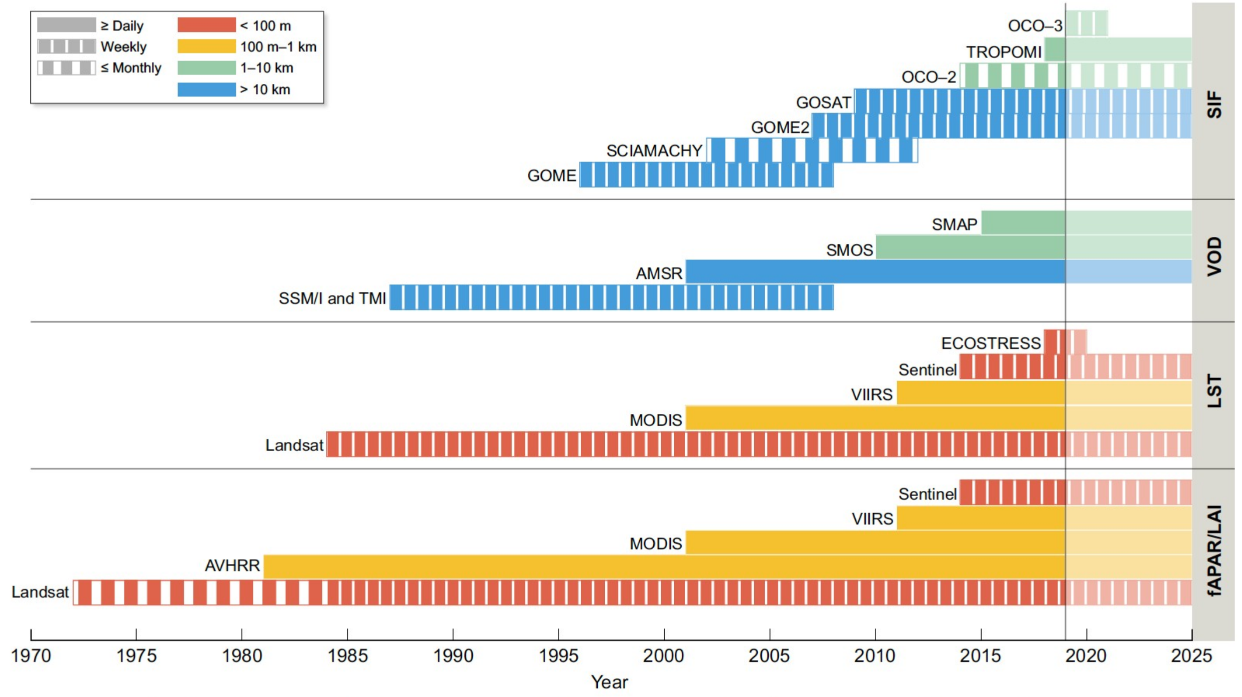


Fig. 2 A timeline of satellite observations of leaf area index (LAI) and fraction of photosynthetically active radiation (fAPAR), land surface temperature (LST), vegetation optical depth (VOD) and solar-induced fluorescence (SIF). Observation timelines are provided for context and are not meant to provide a comprehensive overview of all available sensors. This timeline clearly demonstrates the availability of diverse, multidecadal satellite observation records that are rapidly increasing in spatiotemporal resolution.

Smith et al. (2019)
Can we learn about carbon fertilization using space-based data records?

Use of TIR CO retrievals could provide an important constraint on emissions of CO2 and CH4 from biomass burning (e.g. Worden et al.,2017), especially considering that emissions from fires are likely to be lofted high into the troposphere.

NUCAPS Validated Maturity Review

RISKS, SUMMARY, AND CONCLUSIONS

Risks, Actions, and Mitigations

Identified Risk	Description	Impact	Action/Mitigation and Schedule
	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. Aircraft campaigns provide the highest quality *in situ* profile data, but are episodic and not routinely collected data. Future high quality in situ profile validation will be contingent upon the availability of aircraft campaign data.		TCCON sites provide routine measurements of total column trace gases. Other satellites can provide independent satellite-derived EDRs (e.g., AIRS, TROPOMI, OCO-2, etc.). AirCore soundings can provide in situ measurements, but they have not become a routine dataset yet, and they are still a rather new data source. These are datasets that can be used for cal/val without aircraft campaigns, but they not be of the same quality for this purpose.
	Implementation of SARTA and MW fast forward models for future satellite instrument configurations (e.g. MetOp-SG IASI/MWS, JPSS-2,3)		STAR NUCAPS team holds cross-training and technical interchange Q&A sessions with STC and other agencies. Details are provided in the supplemental slides – Subset #2 NUCAPS Team Collaborations with External Agencies for Risk Mitigation

Summary

- Candidate NUCAPS version (V2.7.2) is
  - Producing consistent results between SNPP and NOAA-20
  - Did not adversely impacted any NUCAPS products that are of validated maturity. Producing results of equal or better quality than the current operational version
  - Producing results generally meeting JPSS Data Product Specification (DPS) with independent correlative datasets (model outputs, satellite EDRs, in situ reference data TCCON, ATom, etc.)
- Delivered v2.7.2 to ASSISST team for cluster integration to produce SNPP/NOAA-20 NUCAPS products
  - Currently verifying pre-operational products generated by the ASSISST cluster runs
- NUCAPS trace gas products are available on the JPSS STAR EDR LTM and JSTAR Mapper websites.
  - https://www.star.nesdis.noaa.gov/jpss/mapper
  - https://www.star.nesdis.noaa.gov/jpss/EDRs/products_Soundings_N20.php
- User feedback is positive
  - Many PGRR Initiatives are using NUCAPS products and found them extremely useful for their applications

Conclusions

- Team recommends NUCAPS algorithm **Validated Maturity** for the **SNPP/NOAA-20 CH_4 Trace Gas EDR**
- Team recommends NUCAPS algorithm **Provisional Maturity** for the **SNPP/NOAA-20 CO_2 Trace Gas EDR**

NUCAPS Future Plans/Schedules/Milestones

PATH FORWARD

NUCAPS Milestones	Delivery Date
• SNPP/NOAA-20 Validated Maturity for CH_4 and Provisional Maturity for CO_2 Trace Gas EDRs	• April 2020
• Metop-C Delivered Algorithm Package (DAP) to ASSISTT for implementation in the Cloud	• Preliminary – April 2020 • Final- August 2020
• NUCAPS for IASI-NG/MWS Prototype Augmentation	• April 2020
• J2 Schedules: Cal/Val Plan (draft and final) • J2 Pre-launch test data/analysis, J2 Ready Algorithm initial DAP	• June, December 2020 • August 2020
• Validated Maturity for NUCAPS S-NPP/NOAA-20 CO_2 EDR • NUCAPS product improvements based on user requirements (e.g. output averaging kernels, Engineering Assessment with CLASS and NCEI to accommodate file size increase); • Emissivity regression vs. CAMEL land emissivity database lookup and validation, and implementation for improved Land Surface Spectral Emissivities • Implementation of improved IR sea surface effective-emissivity (IRSSE) physical model and validation • Peer-reviewed journal articles on NUCAPS- Hyperspectral Enterprise Algorithm Product Suite, OLR, and Trace Gas Validation in MDPI /Remote Sensing/	• December 2020
• Exploration of alternate technologies for NUCAPS modules such as AI based regression, bias-tuning, implementation strategies • Mission-long reprocessing of JPSS NUCAPS products • J2 algorithm optimization and final DAP delivery • Verification and validation of alternate technologies, feasibility to replace operational NUCAPS modules with AI based technologies • Algorithm improvements, implementation new trace gas products (e.g. N_2O, HNO_3, NH_3), maintenance and monitoring. • Publication of reference book on field measurements for remote sensing including chapters on NUCAPS	• February 2021 • April 2021 • June 2021 • September 2021 • FY21-FY22
• Algorithm optimization and post-launch Cal/Val and maturity reviews for J2, maintenance and monitoring • NUCAPS LEO and GEO hyperspectral sounder development	• September 2022 • FY22

OLR Work (since last review)

- ***Completed tasks***

  Comparison of CrIS NOAA-20 OLR with

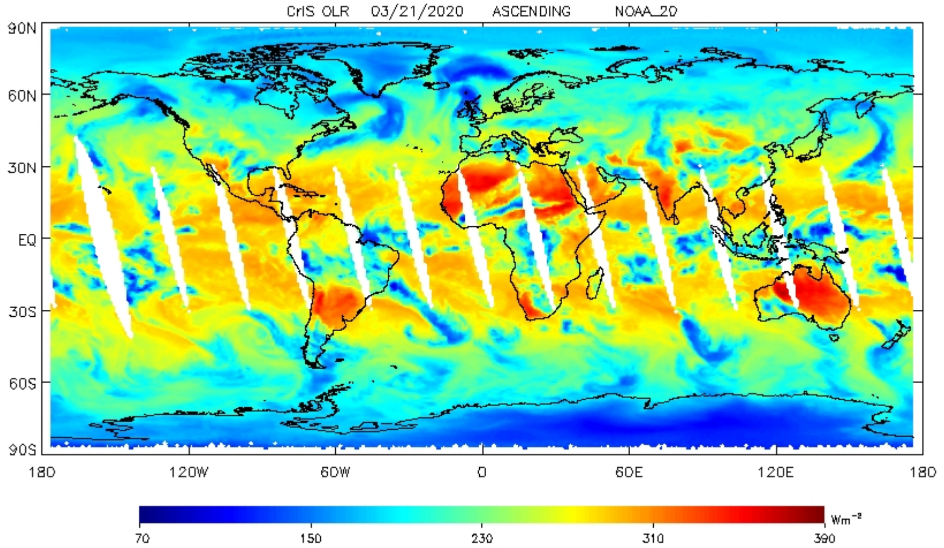
  1. CERES NOAA-20 (daily, monthly)
  2. AIRS (daily,monthly)
  3. MetOp-A (daily)
  4. MetOp-B (daily)
  5. MetOP-C (daily)

- ***Ongoing tasks***

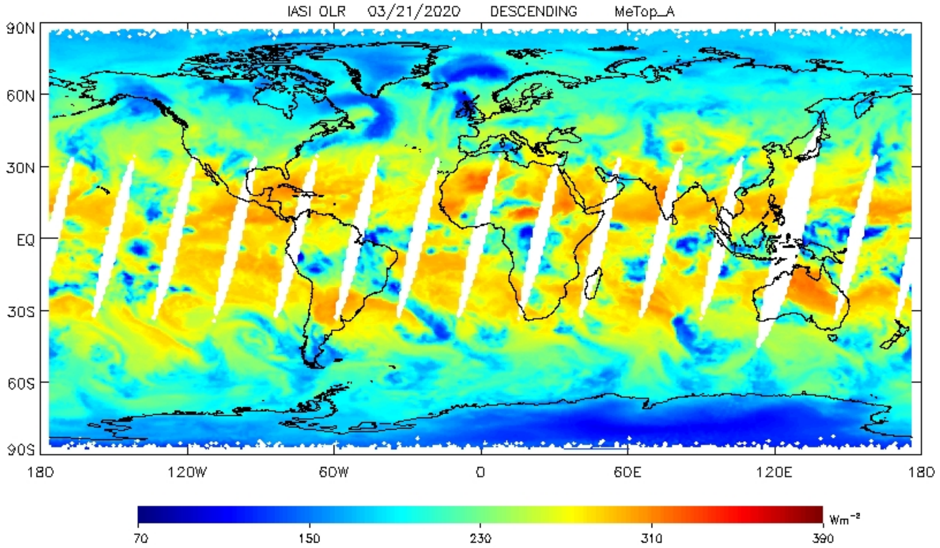
  1. Investigate OLR scan angle dependencies
  2. Analyze OLR seasonal variability (for the products listed above)

Daily NUCAPS CrIS NOAA-20 OLR vs IASI MetOP OLR (Daytime 03/21/2020)

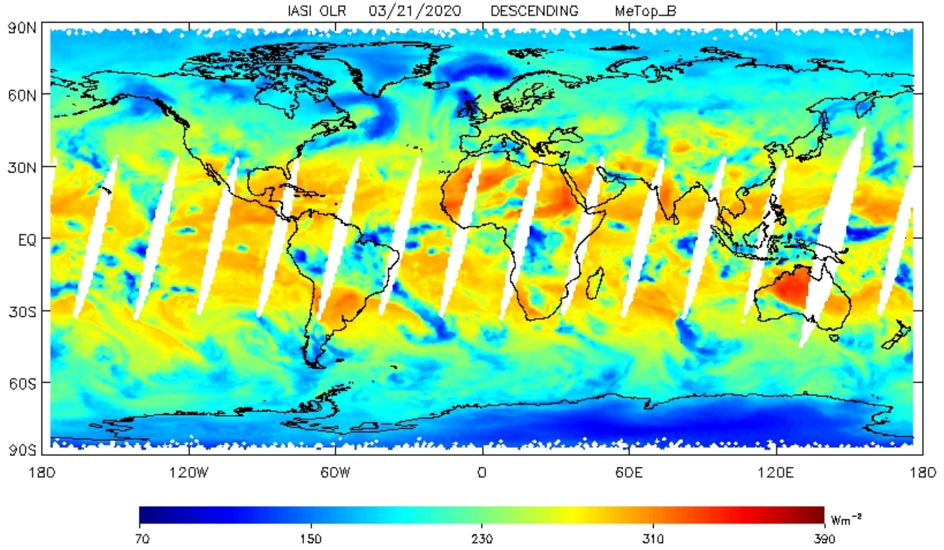
CrIS NOAA-20



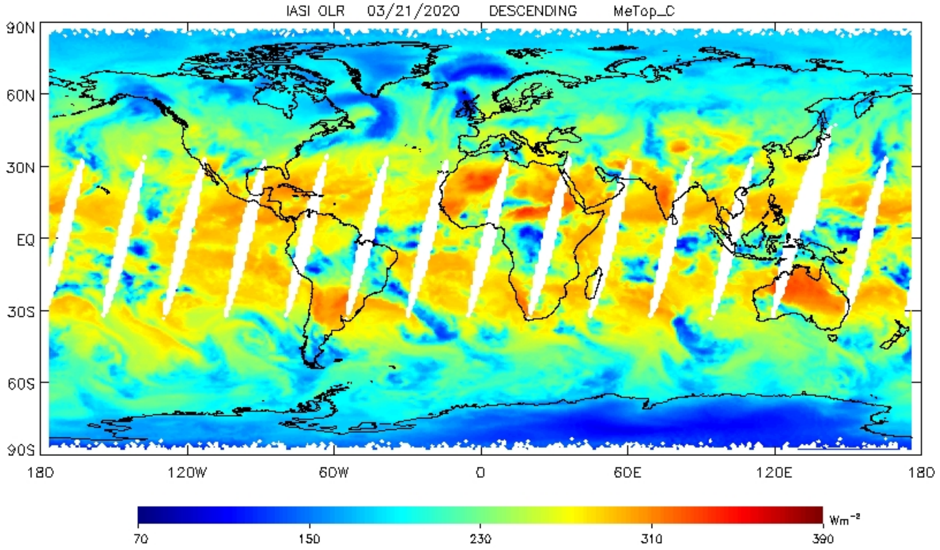
IASI MetOp-A



IASI MetOp-B



IASI MetOp-C



Main points:

- Spatial patterns look similar
- The differences are substantial

	BIAS	STD	CC
A	2.71	23.01	0.89
B	1.62	21.00	0.91
C	1.73	21.40	0.91

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*

SUPPLEMENTAL SLIDES

Set	List of Supplemental Slides	Slide Numbers
1	Additional slides T(p), q(p), O3(p), and CO(p) Product Consistency	127–161
2	NUCAPS Team Collaborations with External Agencies for Risk Mitigation	162–168

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

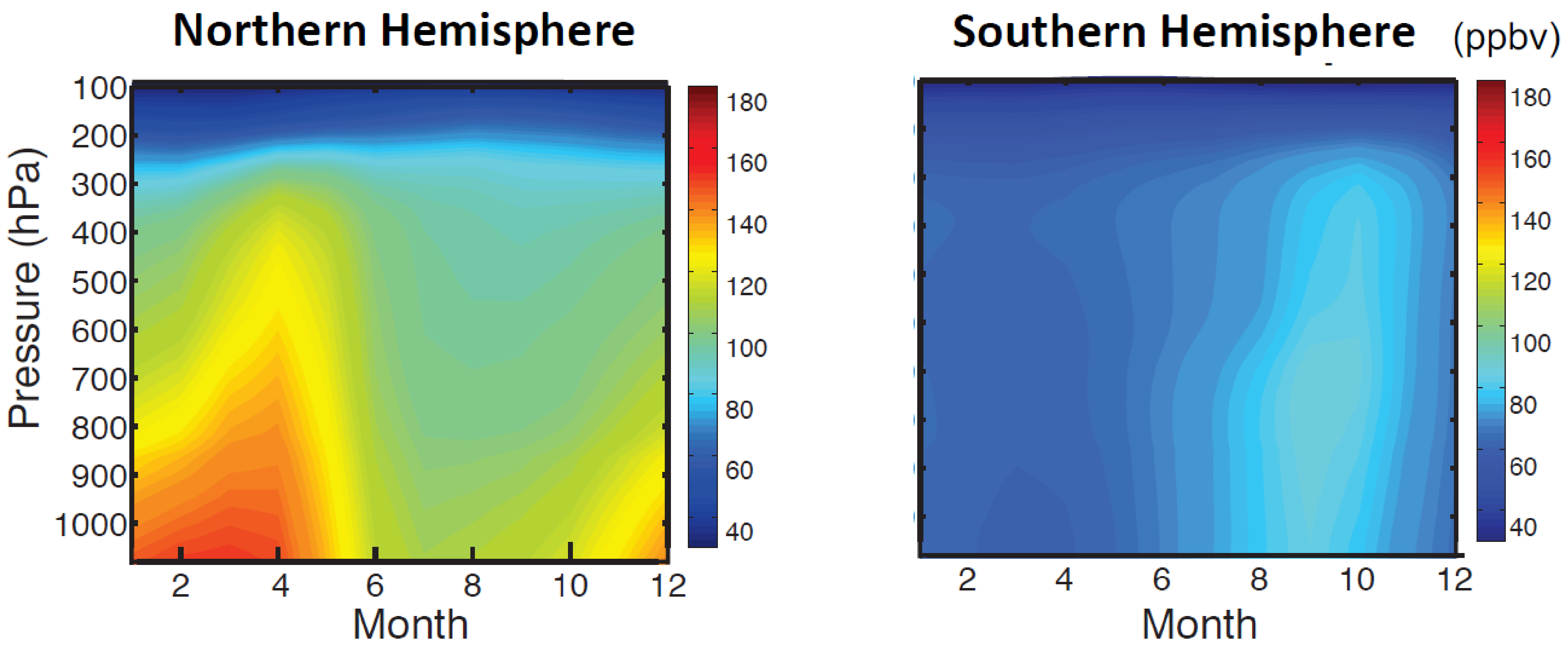
	CrIS Infrared Trace Gases Specification Performance Requirements		
	PARAMETER	THRESHOLD	OBJECTIVE
Ozone Profile	O_3 **(Ozone)** Profile Precision, 4–260 hPa (6 statistic layers)	20%	10%
	O_3 **(Ozone)** Profile Precision, 260 hPa to sfc (1 statistic layer)	20%	10%
	O_3 **(Ozone)** Profile Accuracy, 4–260 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)

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

v2.7.2 SNPP & NOAA-20 NUCAPS CO *a priori* (OPS v2.5.2.2, October 2019)



- 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.
- **NUCAPS CO has reached Validated Maturity in October 2019. No additional changes**

Supplemental Slides

SET 1. T(P), Q(P), O3(P), AND CO(P) PRODUCT CONSISTENCY

Data Product	Priority	Current Maturity Status		Maturity Review
		SNPP	NOAA-20	
AVTP/AVMP	3	✓ Validated	✓ Validated	✓ October 2019
Ozone (p)	3	✓ Validated	✓ Validated	✓ October 2019
OLR	3	✓ Validated	✓ Validated	✓ October 2019
CO (p)	4	✓ Validated	✓ Validated	✓ October 2019
CH4 (p)	4	• Aiming for Validated	• Aiming for Validated	• Today's review
CO2 (p)	4	• Aiming for Provisional	• Aiming for Provisional	• Today's review

- **Ensure latest algorithm changes (MW-Climatology, CO2 A-priori CH4 and CO2 QC) did not adversely affect retrieval products that are already of validated maturity.**
    - Performed evaluations of NUCAPS products (Latest v2.7.3) vs. V2.5.2.2 (October 2019 DAP) using two focus day data sets (20180820, 20200123).
    - Supplemental slides provide evaluations for the focus day 20200123 (NOAA-20, SNPP)

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·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

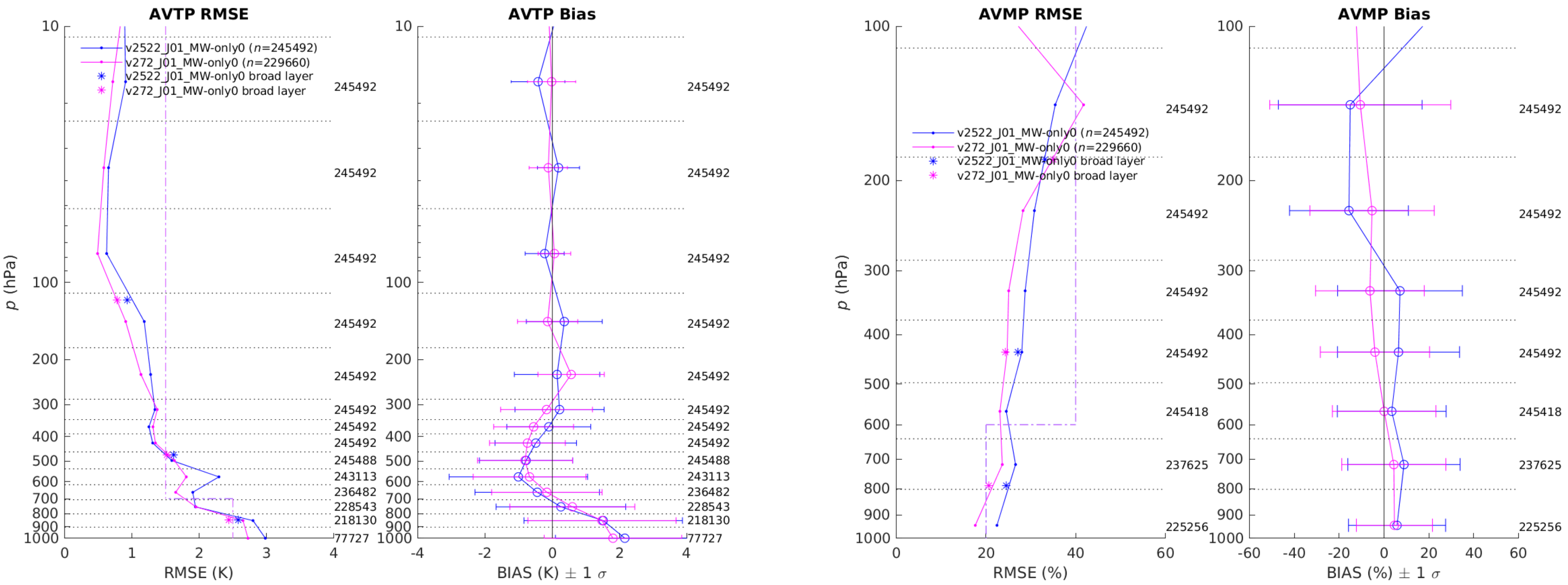
Global requirements defined for lower and upper atmosphere subdivided into 1-km and 2-km layers for AVTP and AVMP, respectively.

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

NOAA-20 MW-Only "Clear-to-Partly Cloudy Cases" (20 Aug 2018) v2.7.2 vs v2.5.2.2

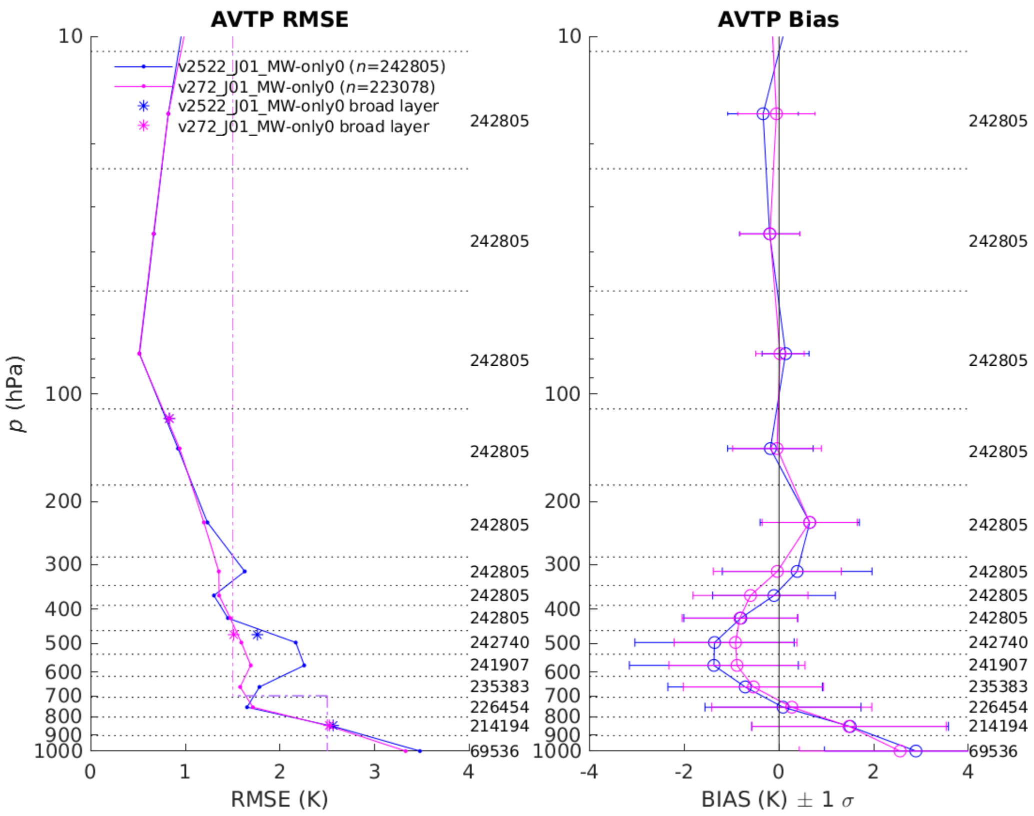
AVTP

AVMP

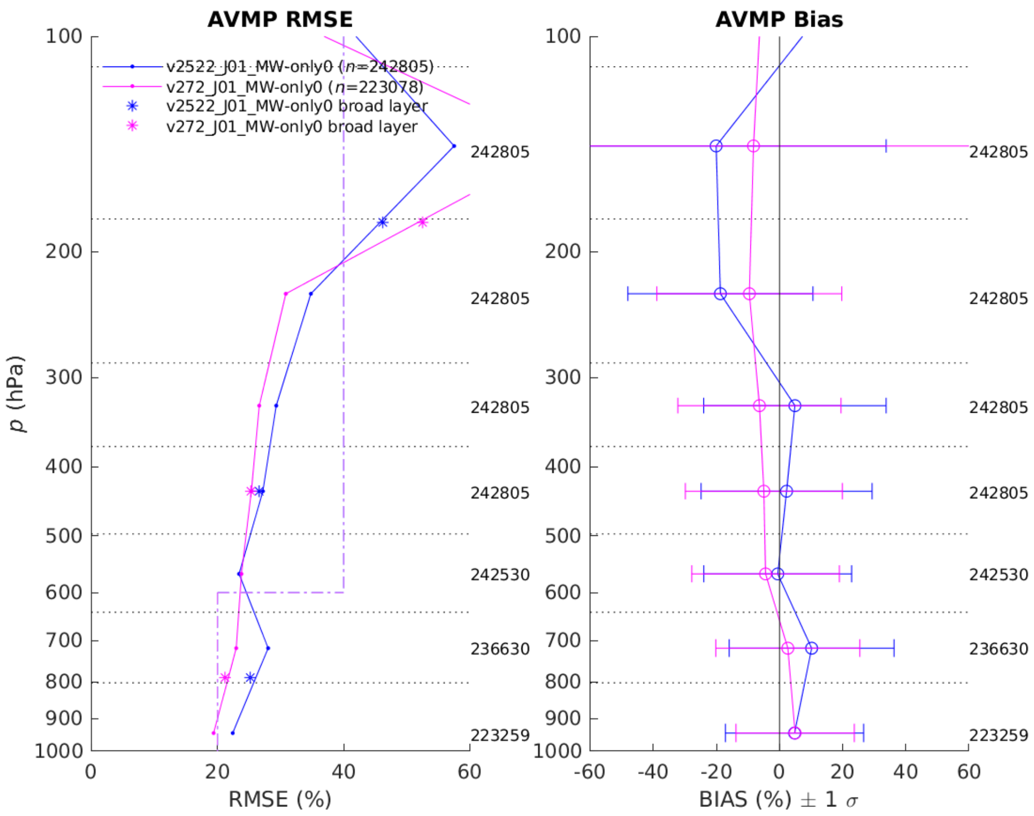


NOAA-20 MW-Only “Clear-to-Partly Cloudy Cases” (23 Jan 2020) v2.7.2 vs v2.5.2.2

AVTP



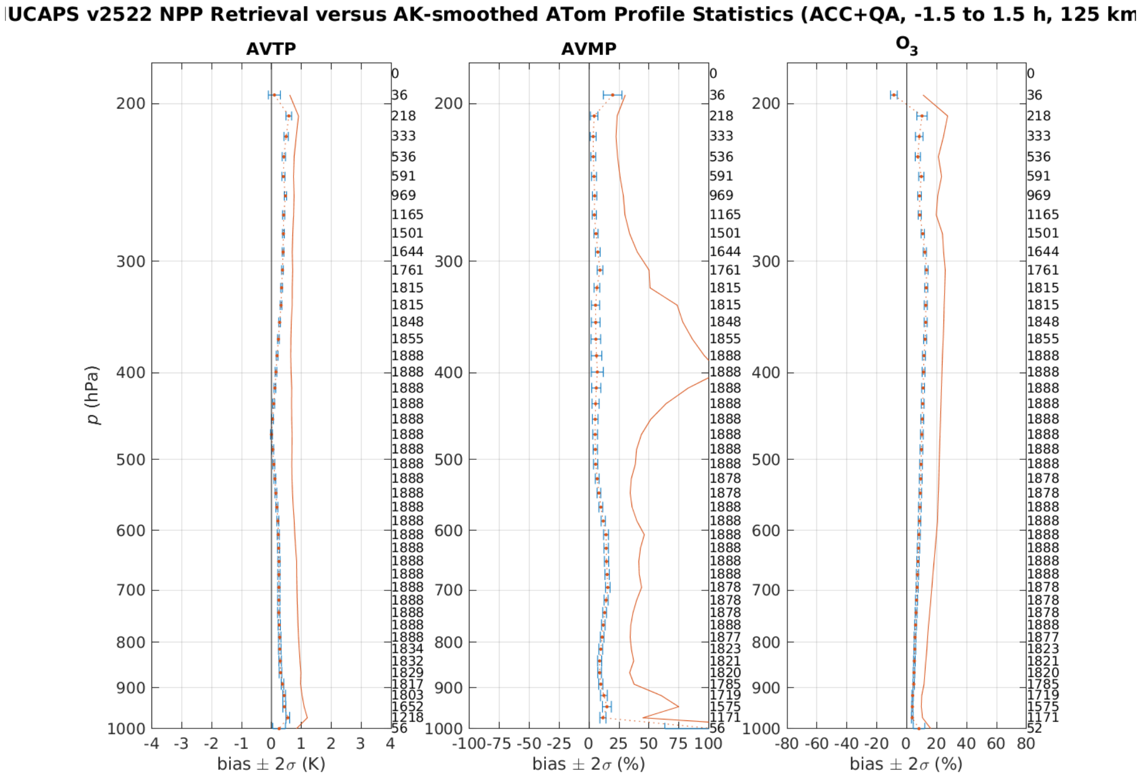
AVMP



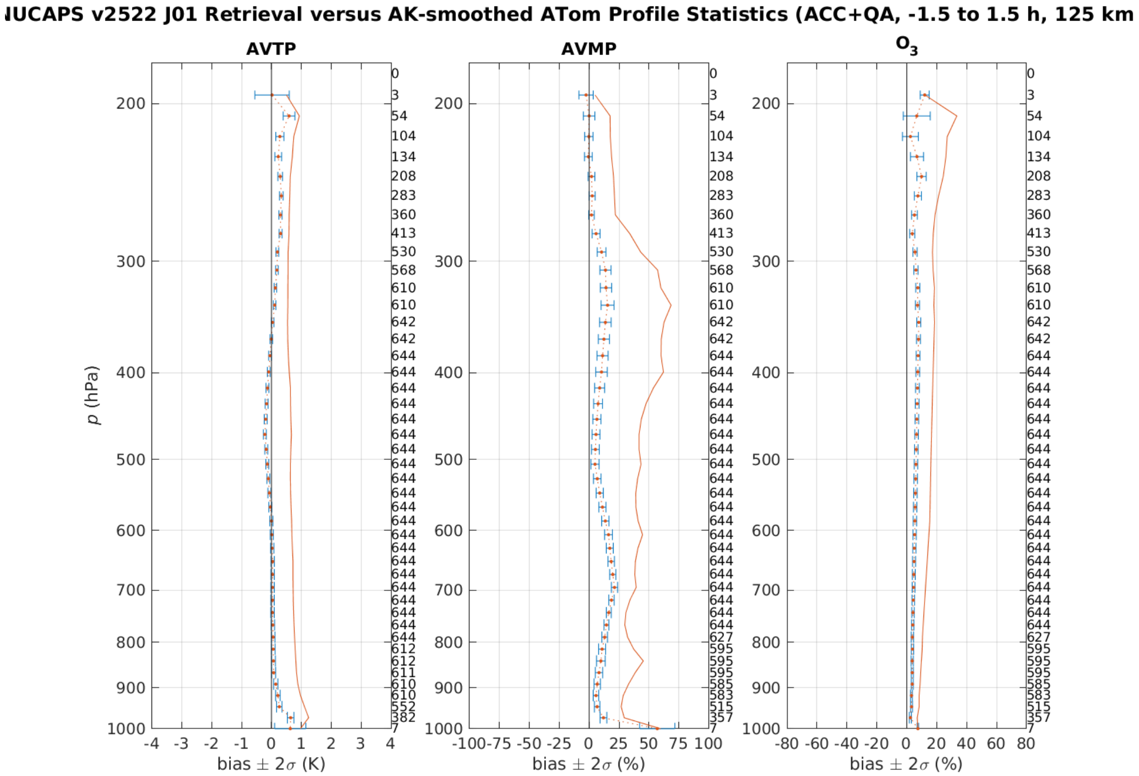
NUCAPS OPS Retrieval vs ATom w AKs: 100 Layer Profile Statistical Analysis

Temperature / H_2O / O_3

SNPP



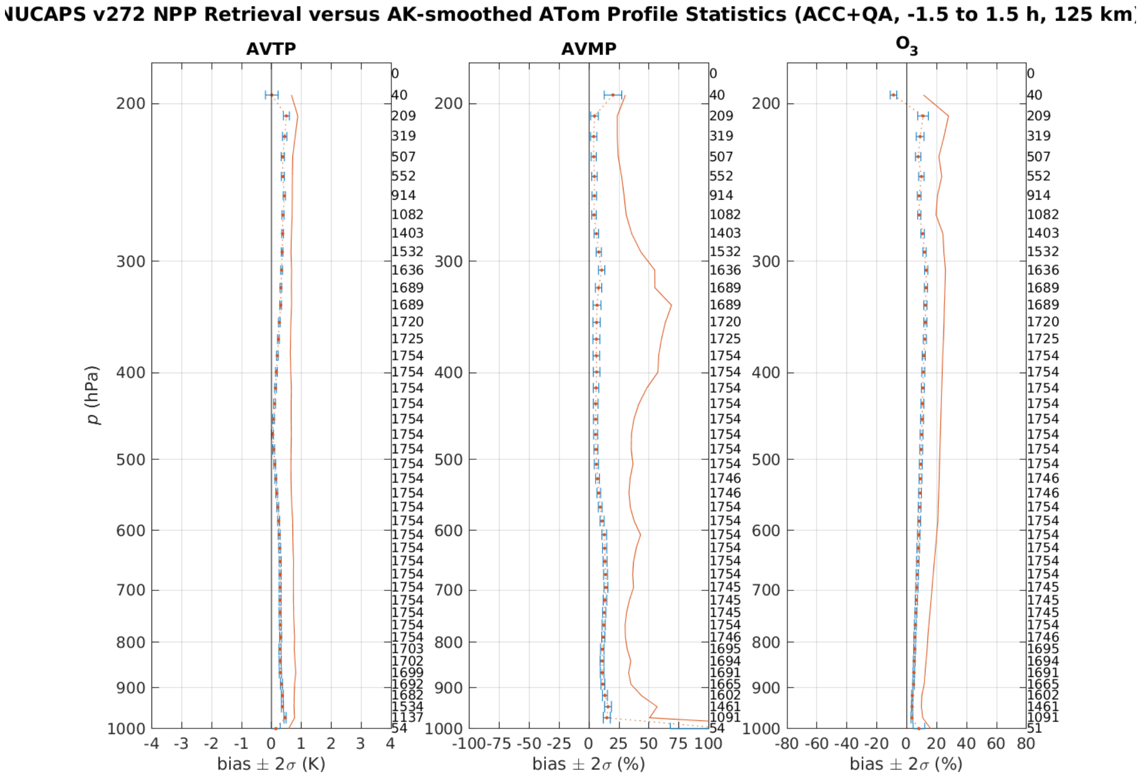
NOAA-20



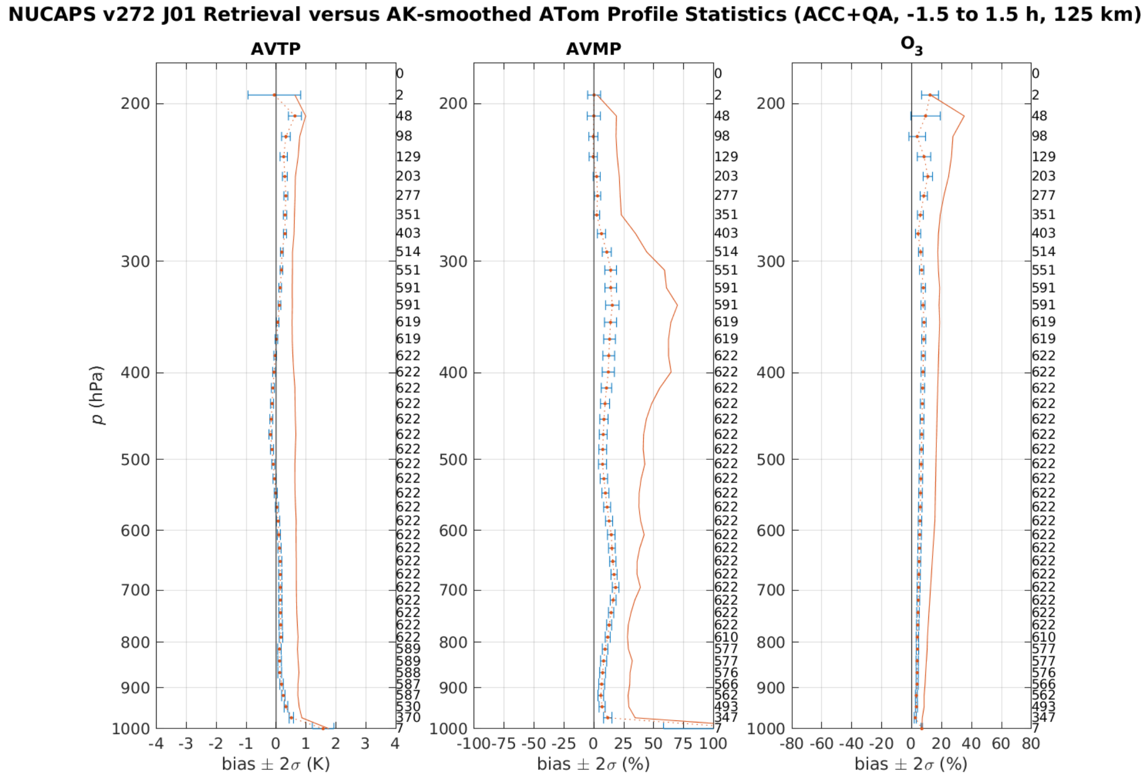
NUCAPS v2.7.2 Retrieval vs ATom w AKs: 100 Layer Profile Statistical Analysis

Temperature / H_2O / O_3

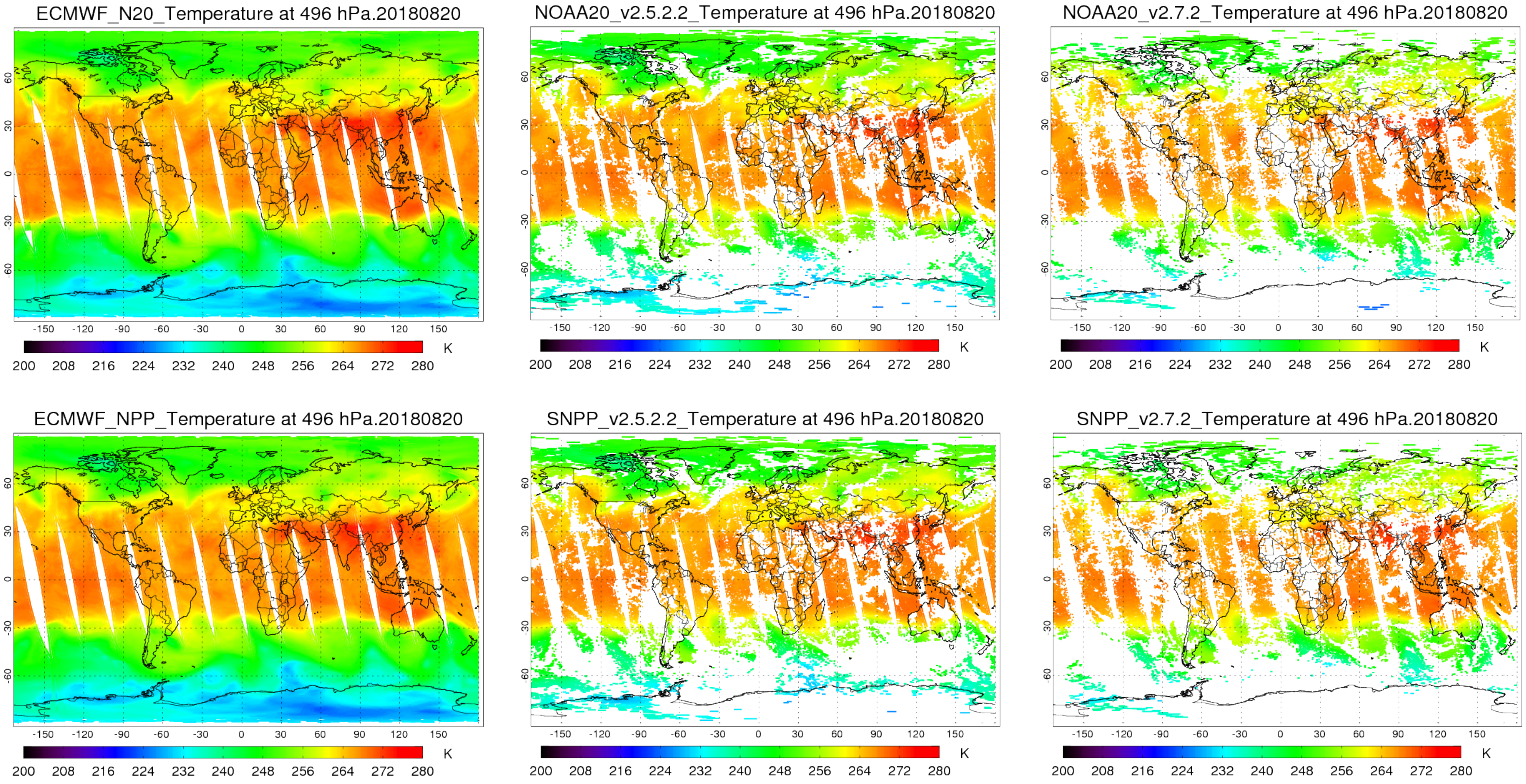
SNPP



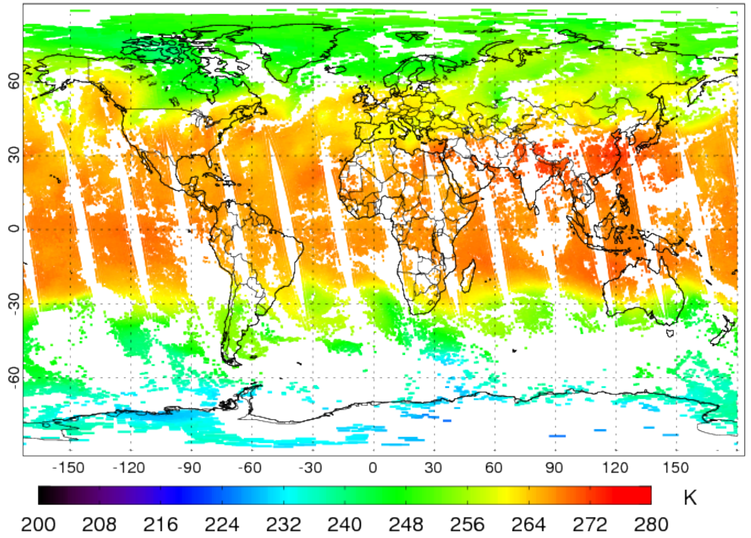
NOAA-20

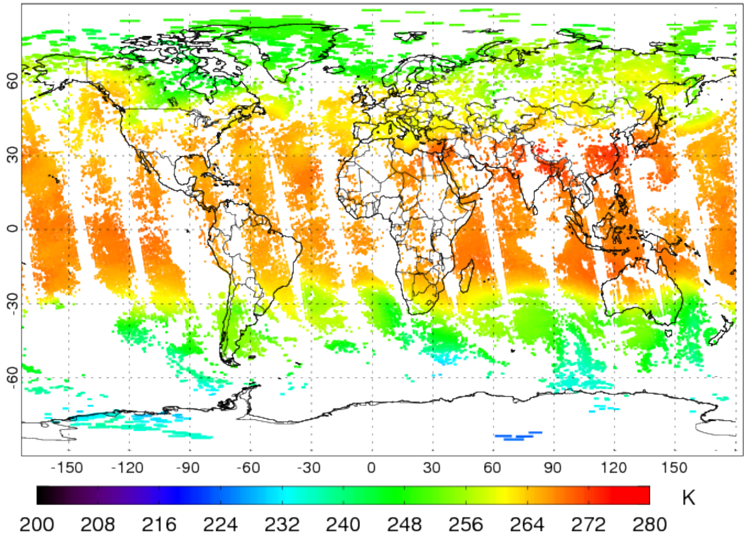


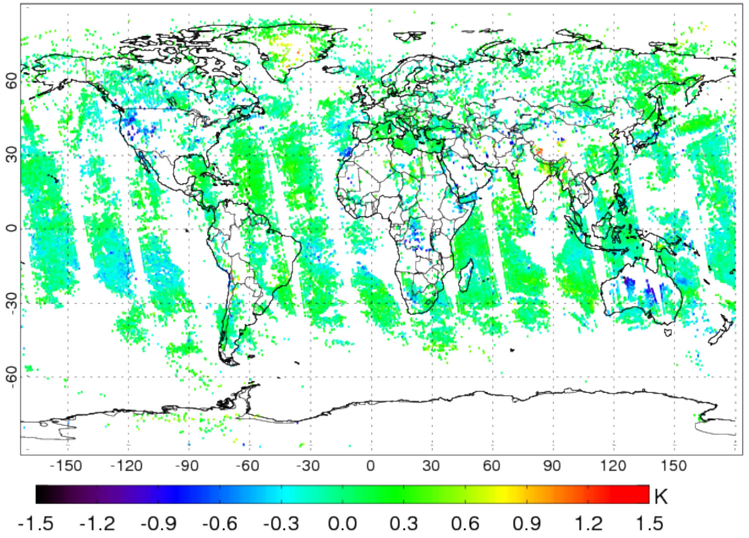
V2.5.2.2 vs. 2.7.2 Temperature at 496 hPa (20180820)

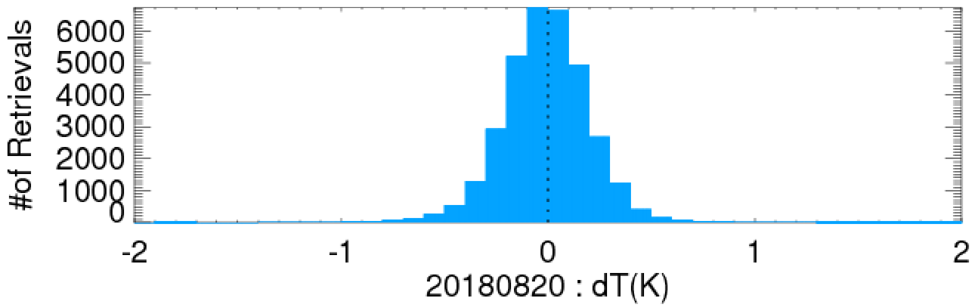


NOAA-20 20180820 Temp (496 hPa) v2.5.2.2 vs. v2.7.2



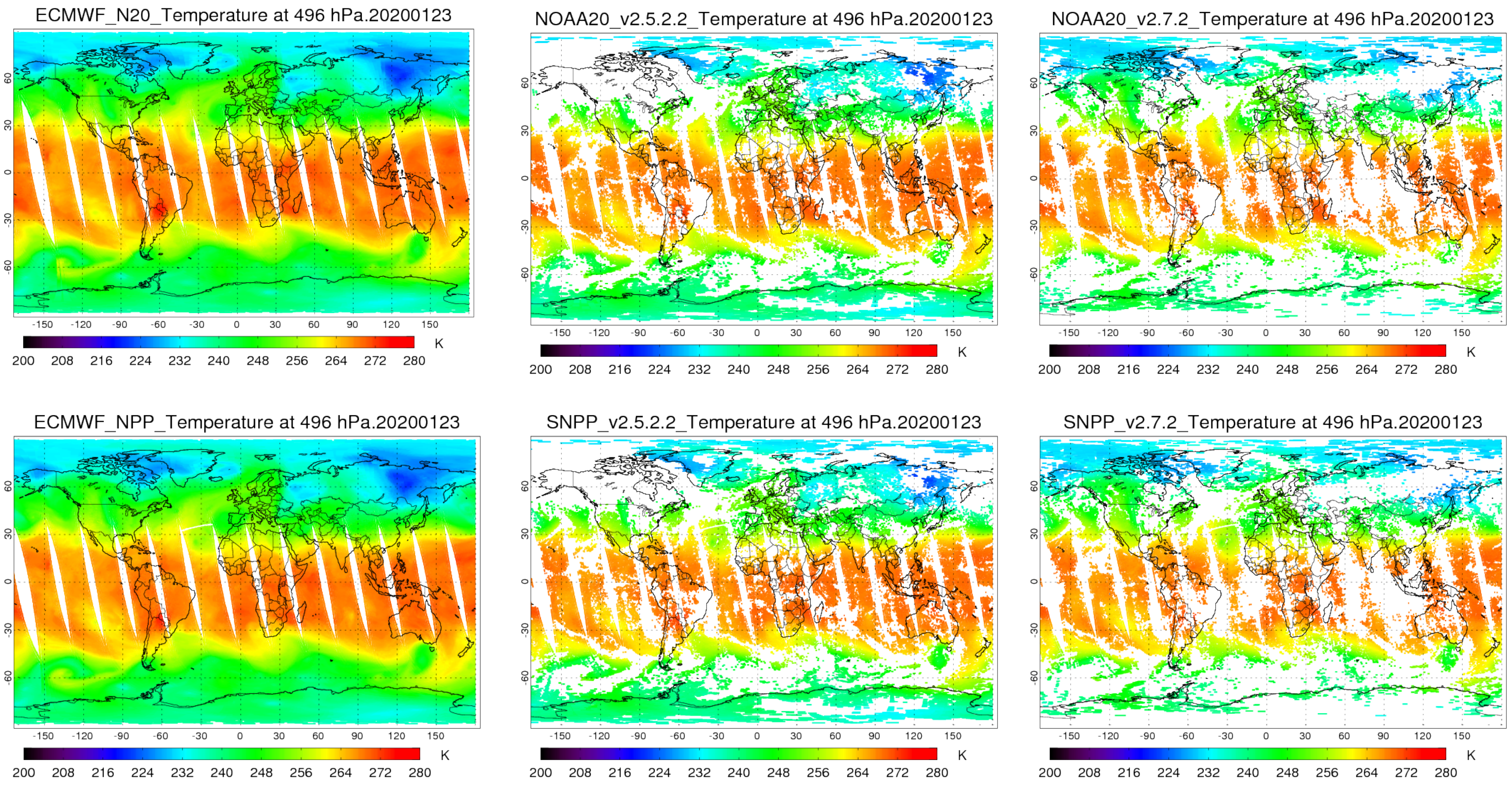




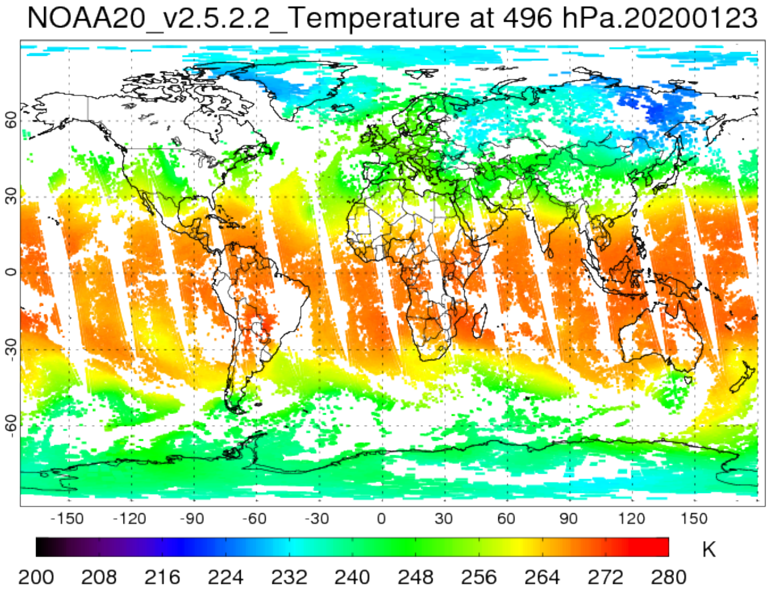


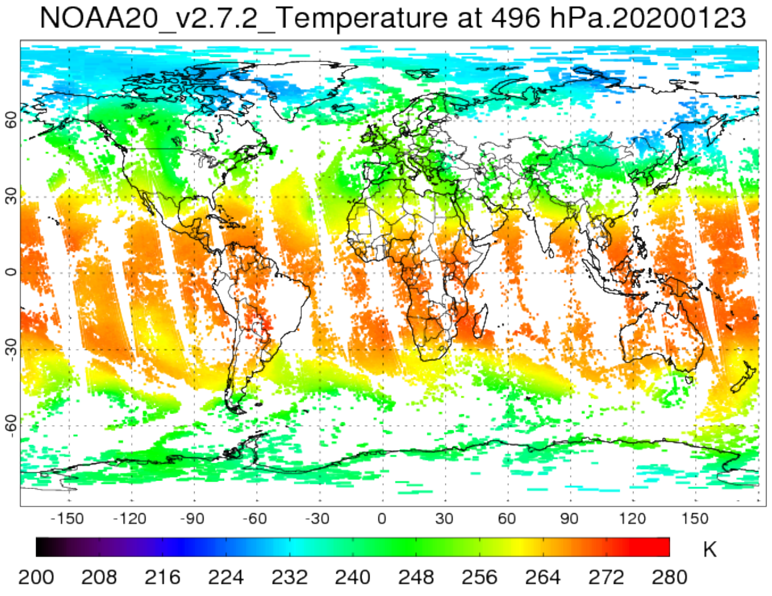
- #of Retrieval dT>0.5K: 904/33610 ~2.7%
- #of Retrieval dT>1.0K: 48/33610 ~0.1%

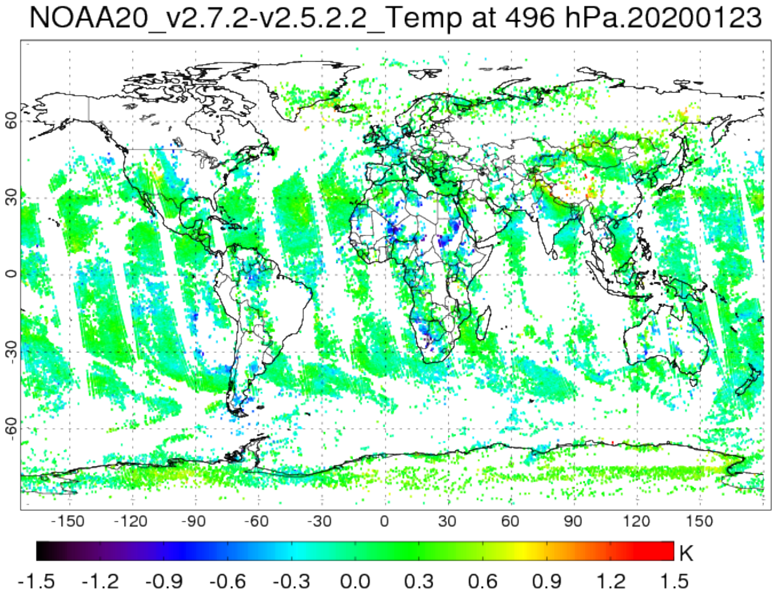
V2.5.2.2 vs. 2.7.2 Temperature at 496 hPa (20200123)

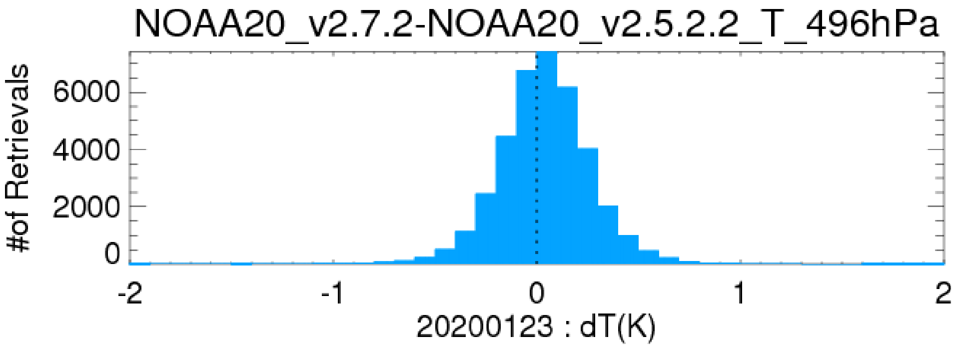


NOAA-20 20200123 Temp (496 hPa)
v2.5.2.2 vs. v2.7.2



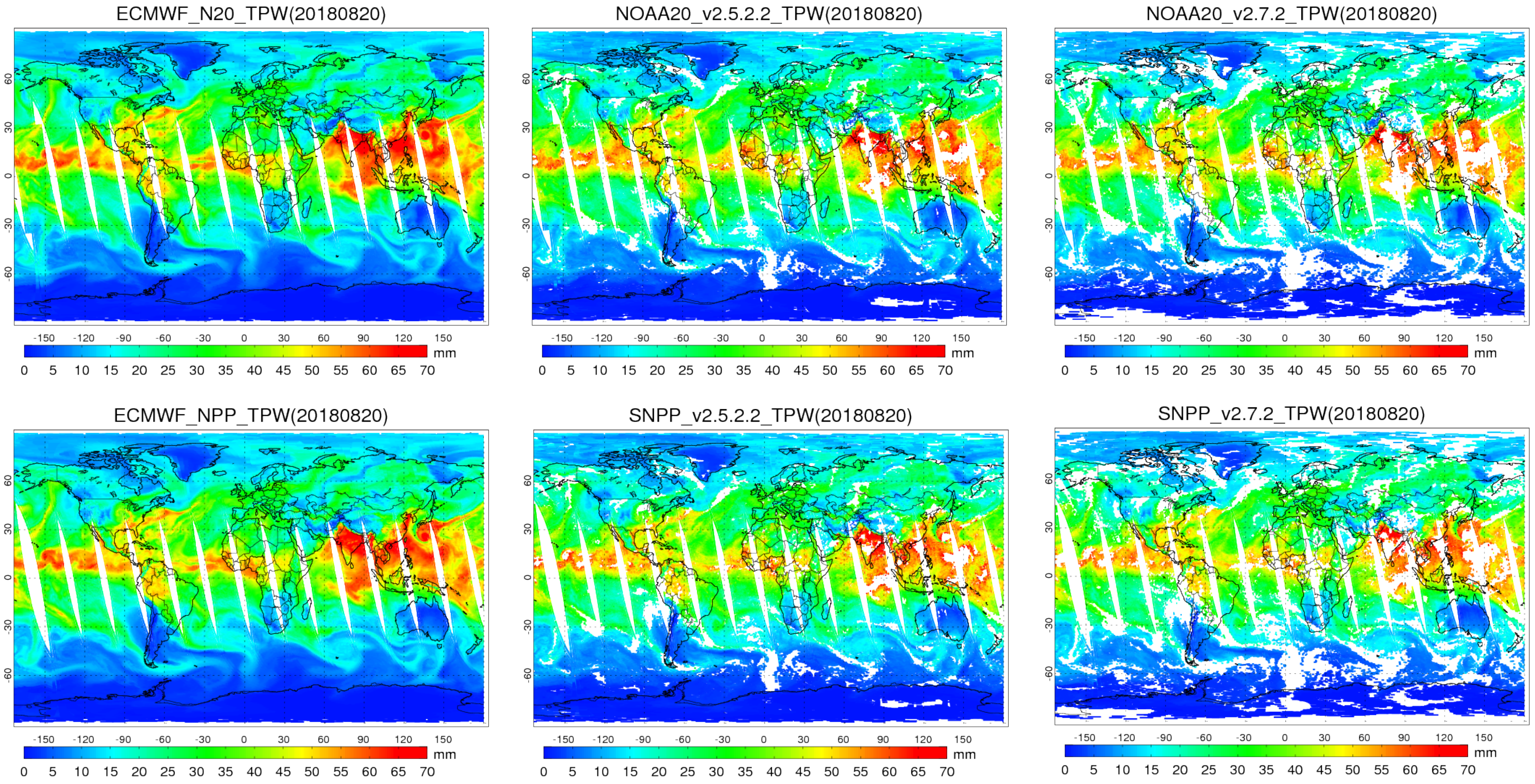




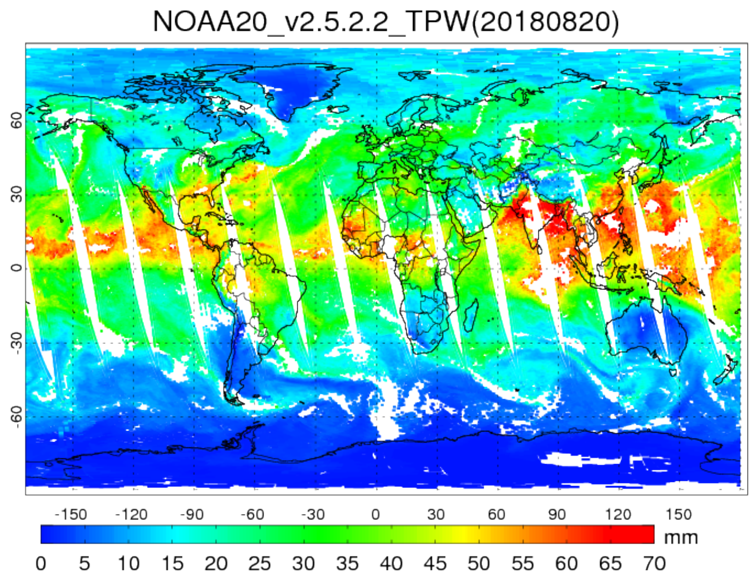


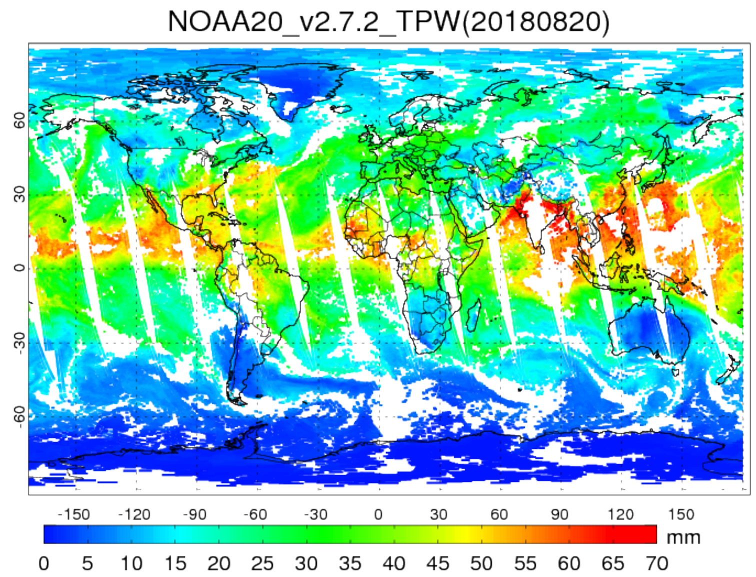
- #of Retrieval dT>0.5K: 1421/37411 ~ 3.8%
- #of Retrieval dT>1.0K: 90/37411 ~0.2%

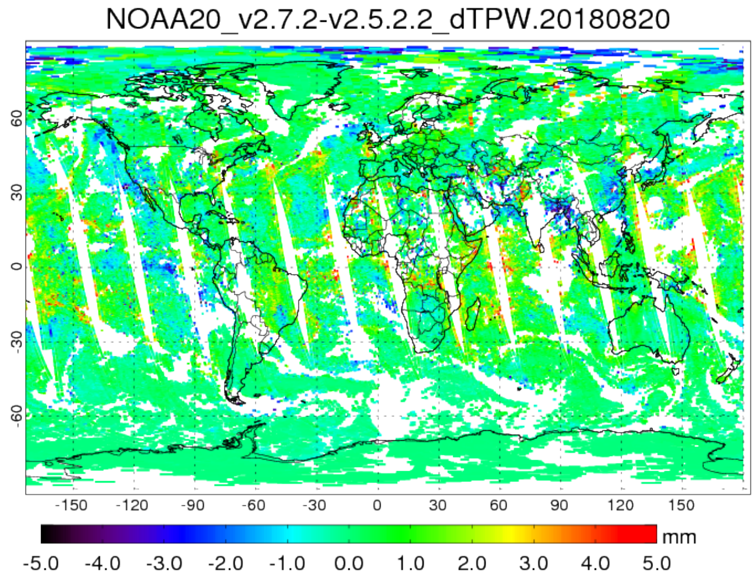
V2.5.2.2 vs. 2.7.2 Total Precipitable Water (20180820)

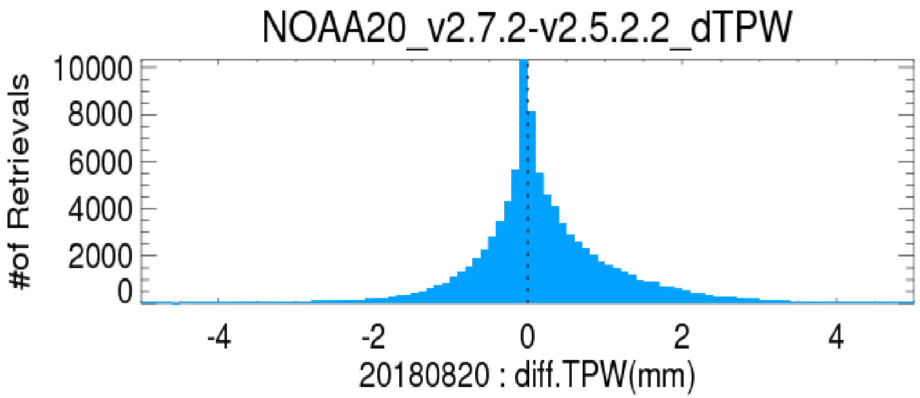


NOAA20 20180820 Total Precipitable Water (TPW) v2.5.2.2 vs. v2.7.2



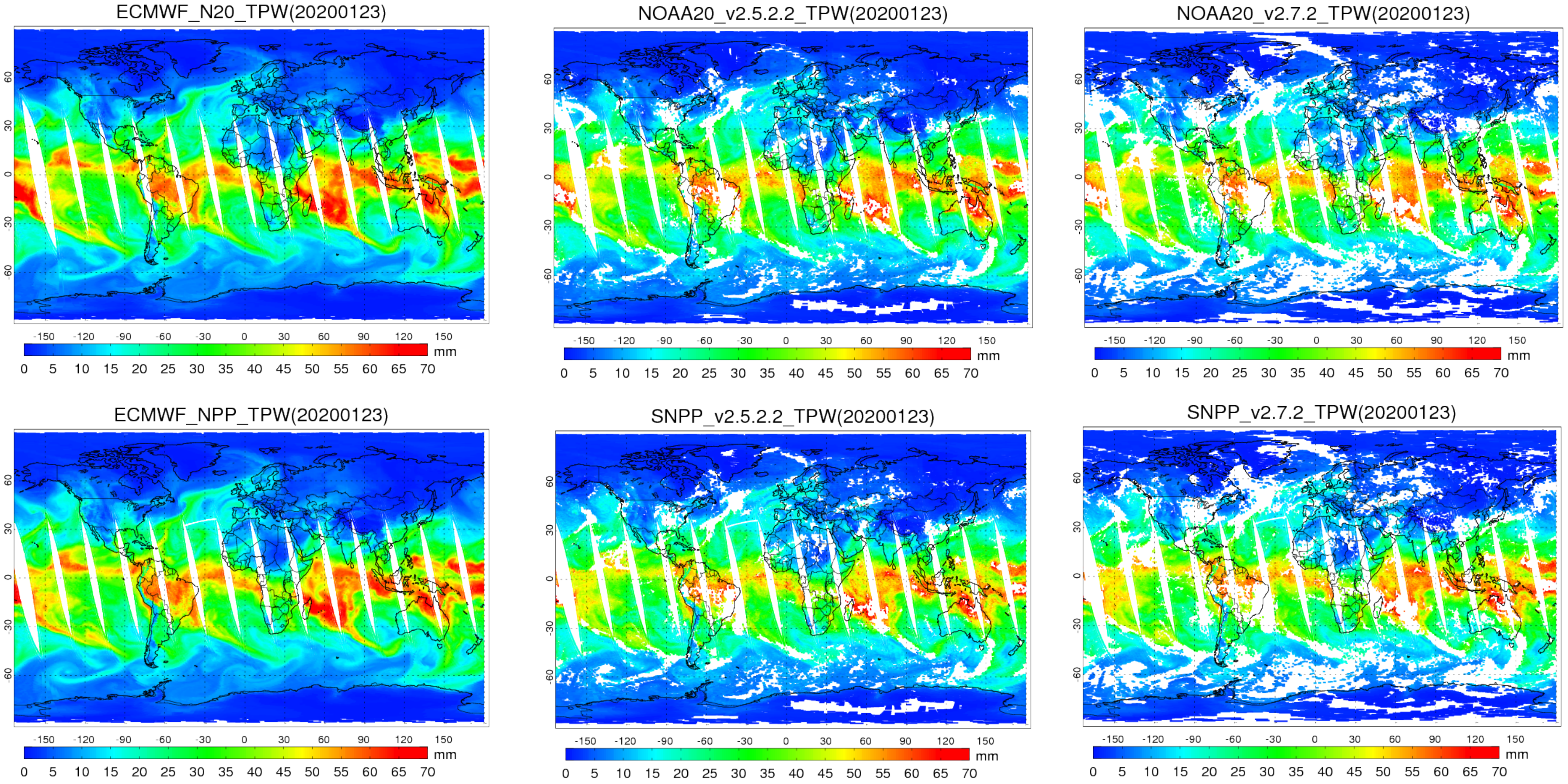




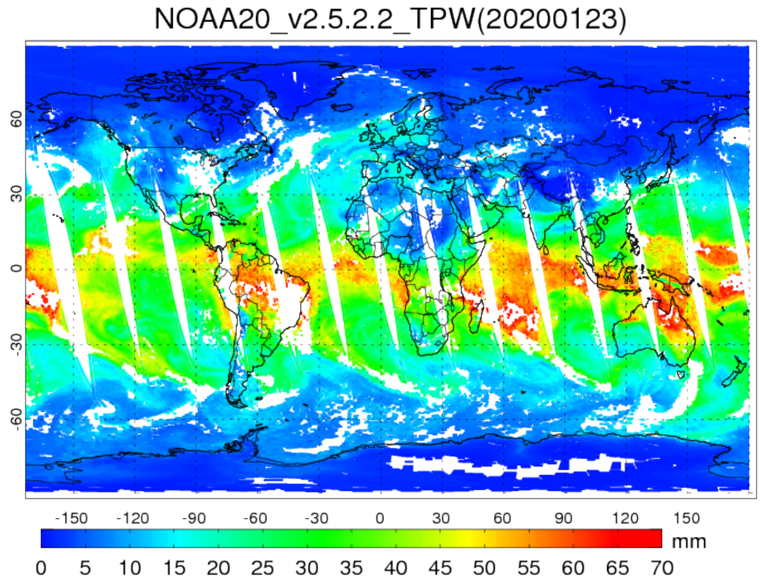


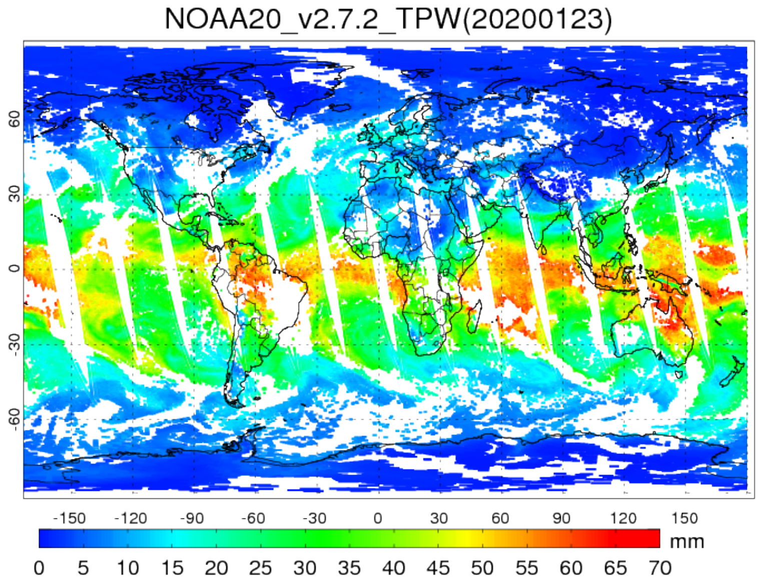
- #of Retrieval dTPW > 2mm: 5391/92023 ~5.9%
- #of Retrieval dTPW > 4mm: 467/92023 ~0.5%

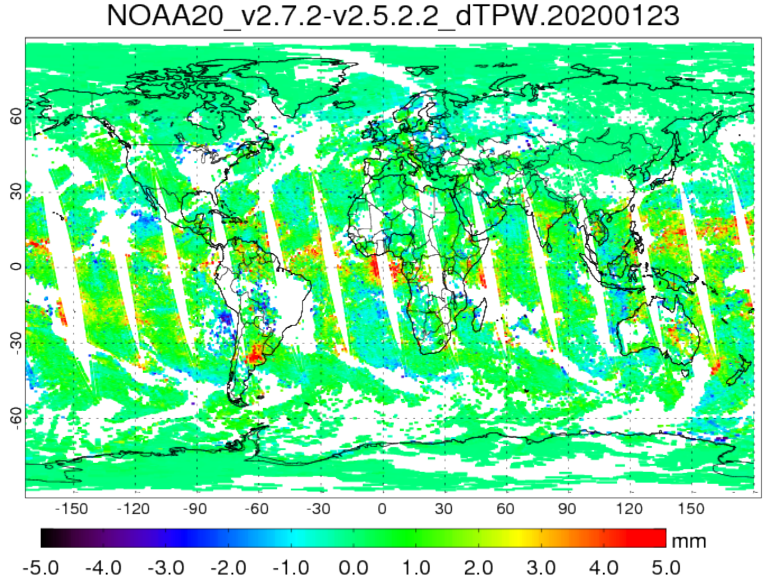
V2.5.2.2 vs. 2.7.2 Total Precipitable Water (20200123)

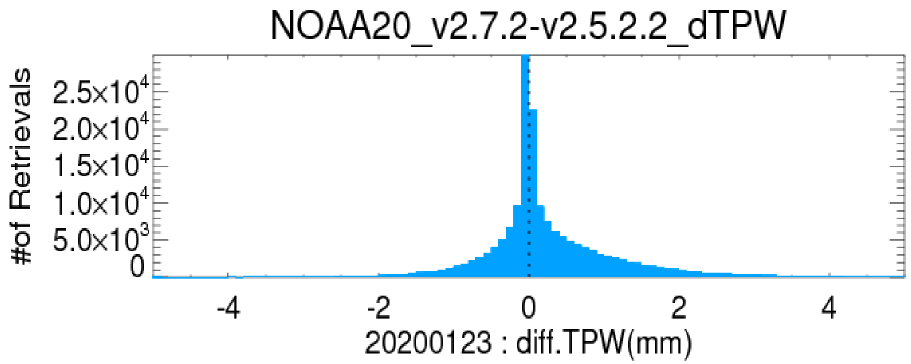


NOAA20 20200123 Total Precipitable Water (TPW) v2.5.2.2 vs. v2.7.2



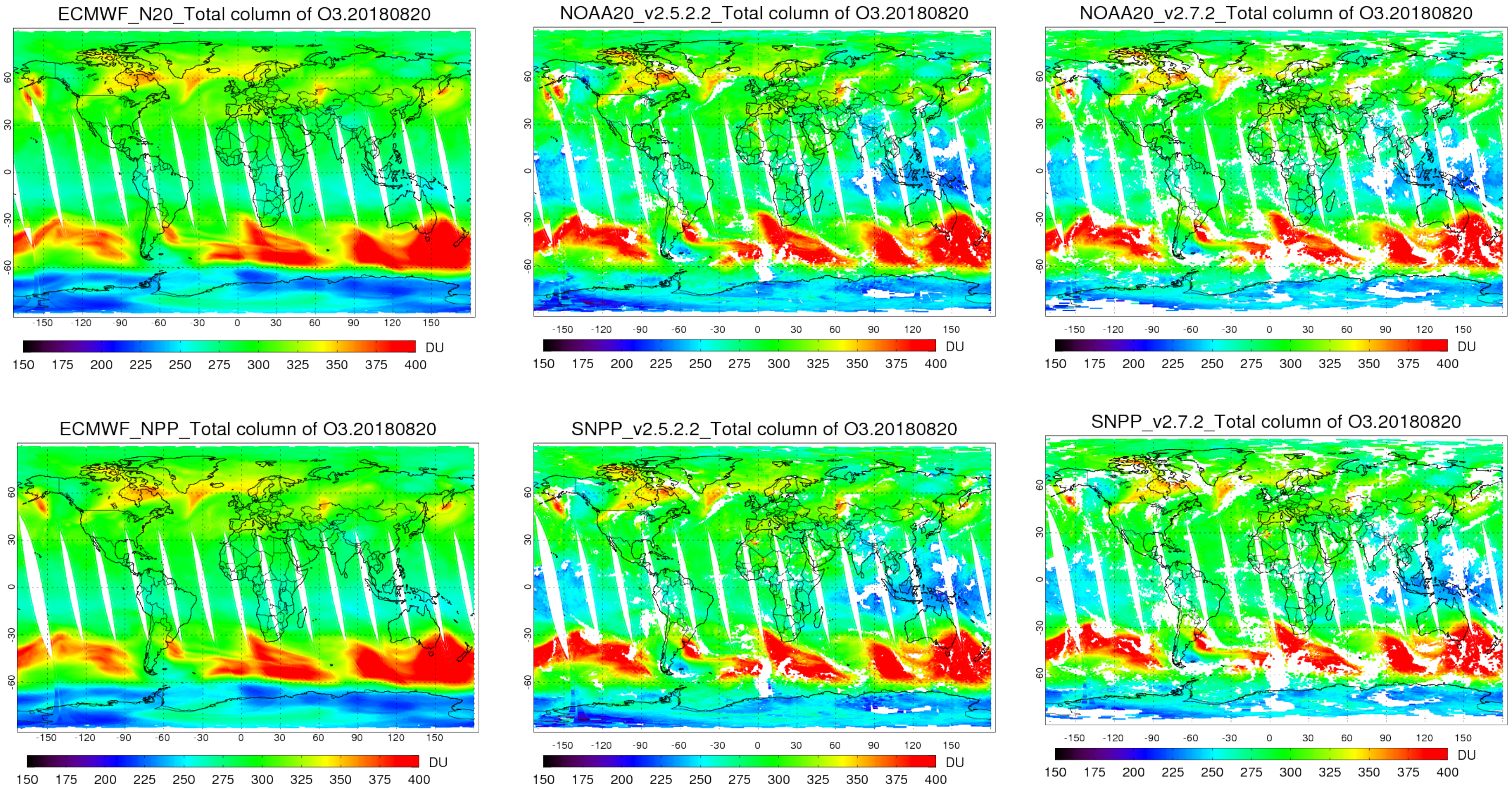




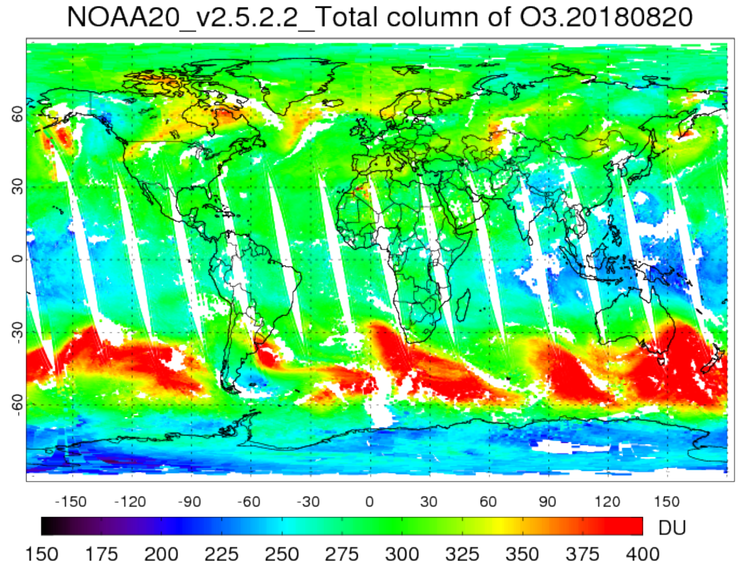


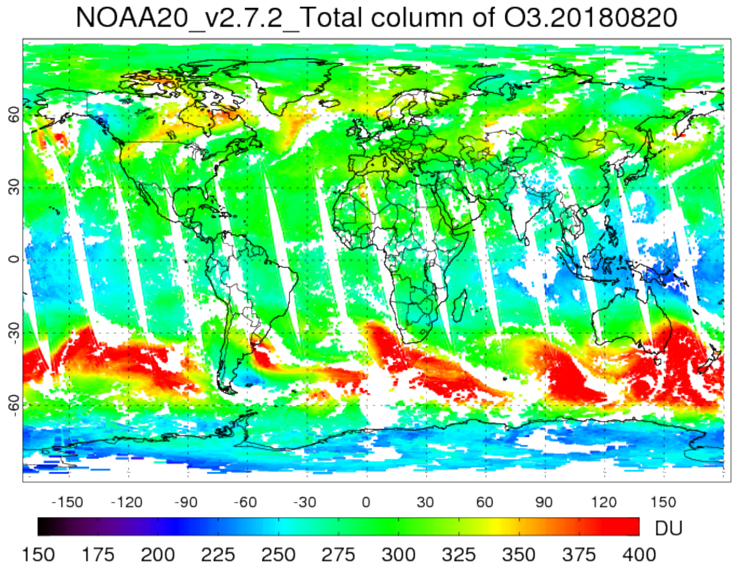
- #of Retrieval dTPW > 2mm: 5245/85888 ~6.1%
- #of Retrieval dTPW > 4mm: 524/85888 ~0.6%

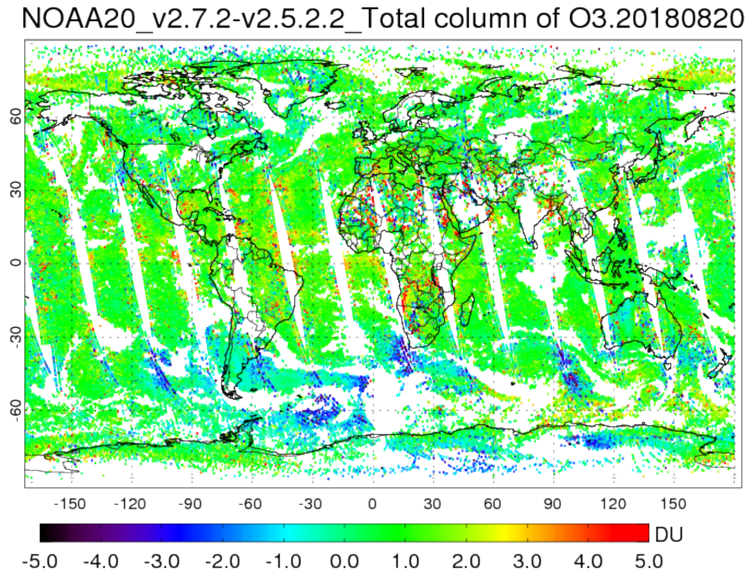
V2.5.2.2 vs. 2.7.2 Total Column Ozone (20180820)

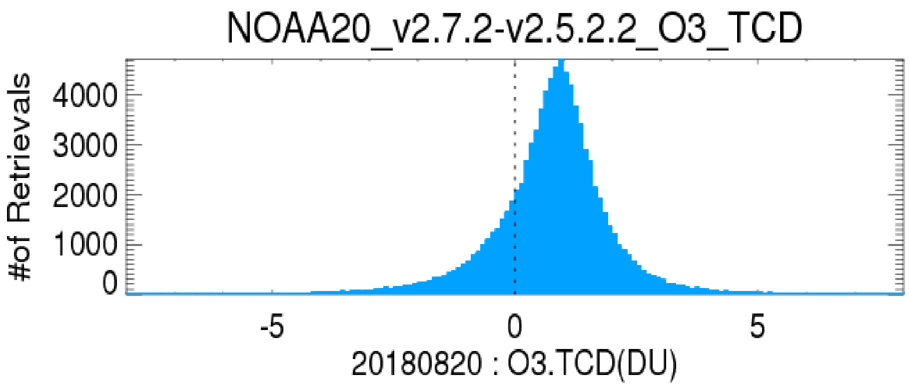


NOAA20 20180820 Total Column of Ozone v2.5.2.2 vs. v2.7.2





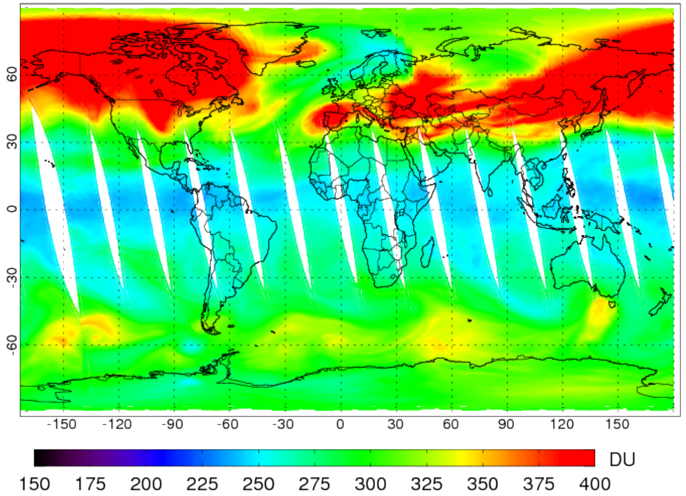




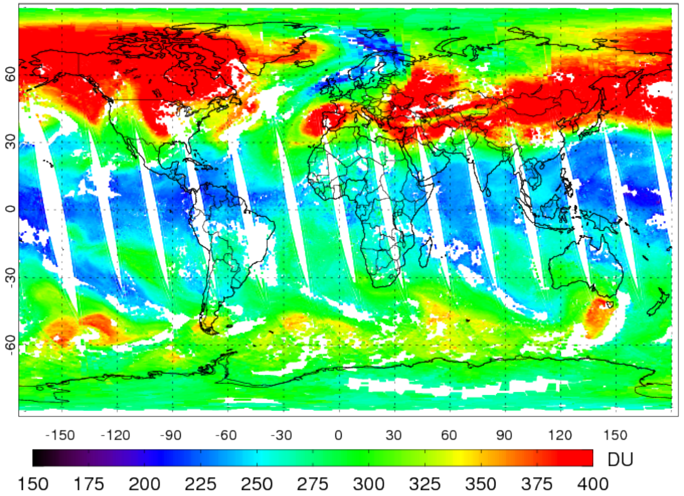
- #of Retrieval dO3 > 2.5DU: 7230/92023 ~7.9%
- #of Retrieval dO3 > 5DU: 1154/92023 ~1.3%

V2.5.2.2 vs. 2.7.2 Total Column Ozone (20200123)

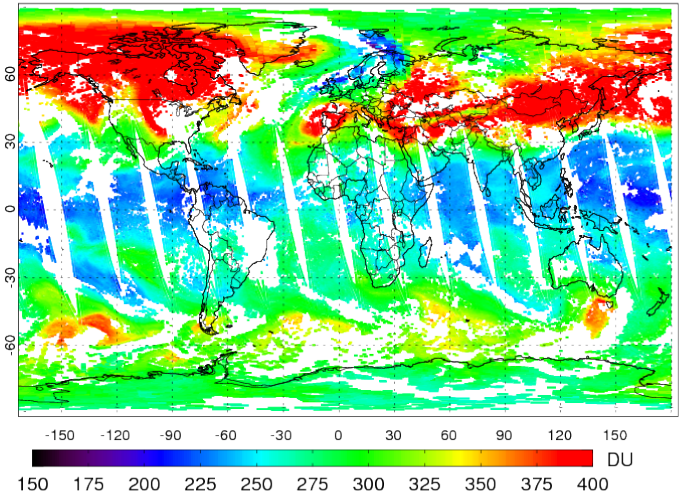
ECMWF_N20_Total column of O3.20200123



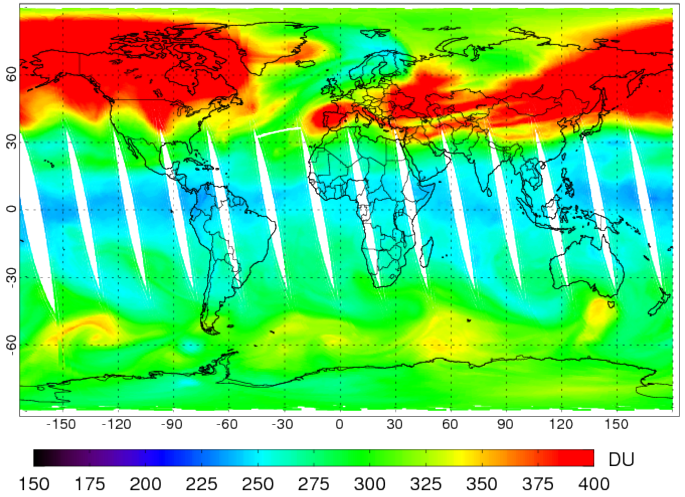
NOAA20_v2.5.2.2_Total column of O3.20200123



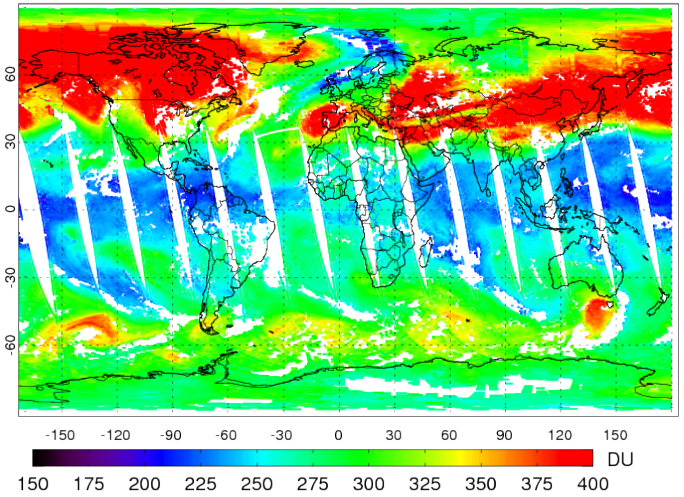
NOAA20_v2.7.2_Total column of O3.20200123



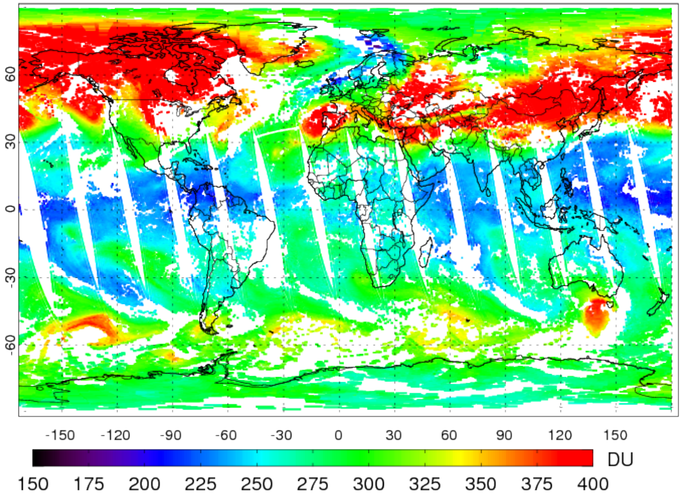
ECMWF_NPP_Total column of O3.20200123



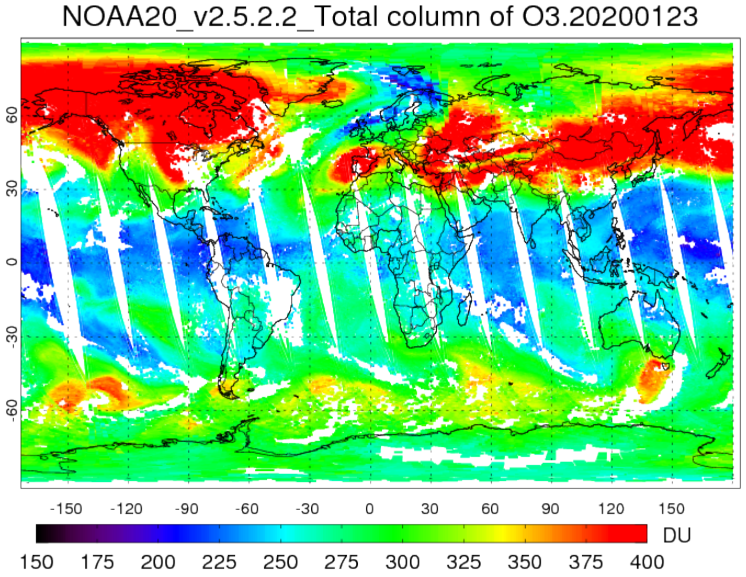
SNPP_v2.5.2.2_Total column of O3.20200123

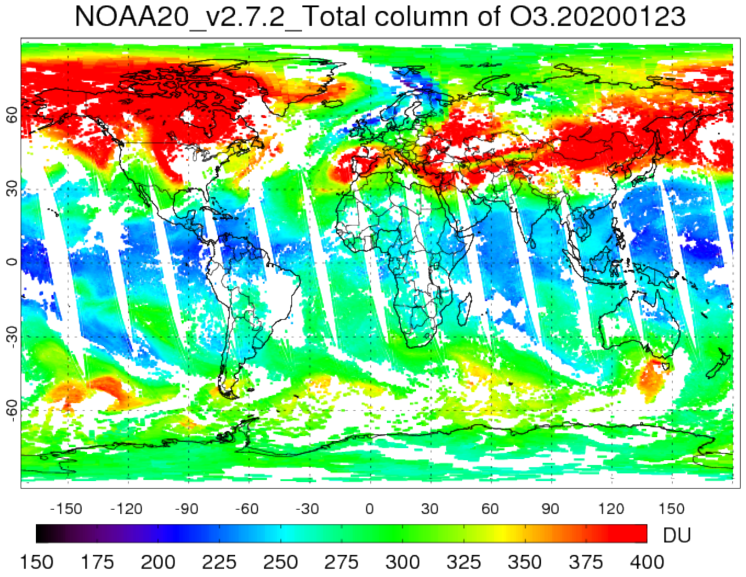


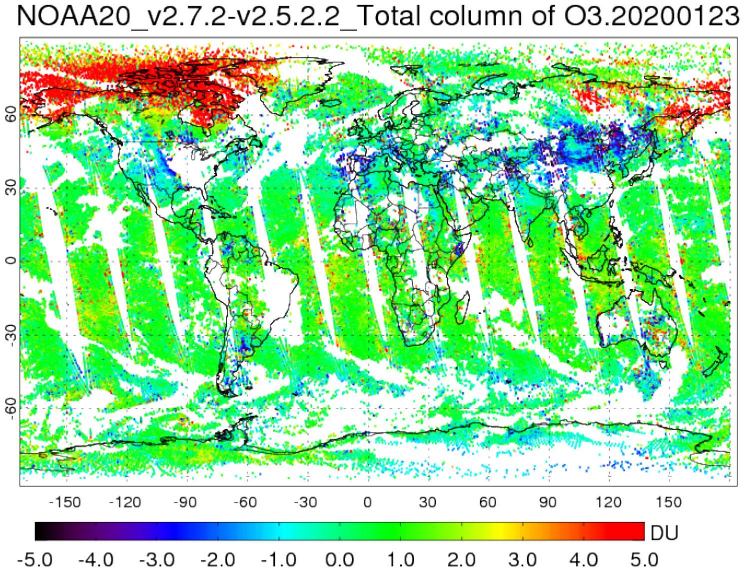
SNPP_v2.7.2_Total column of O3.20200123

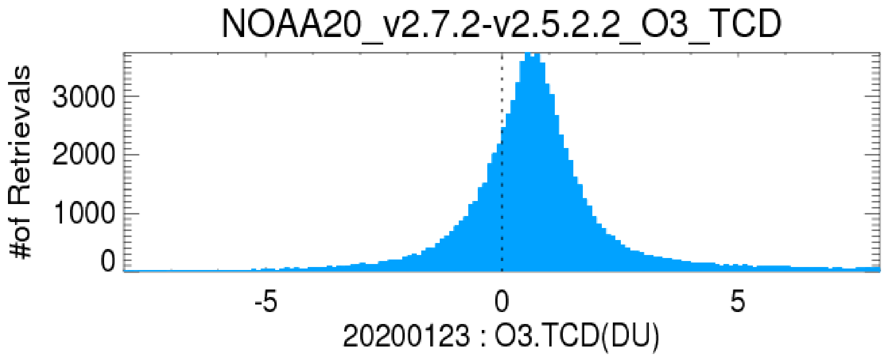


NOAA20 20200123 Total Column of Ozone v2.5.2.2 vs. v2.7.2



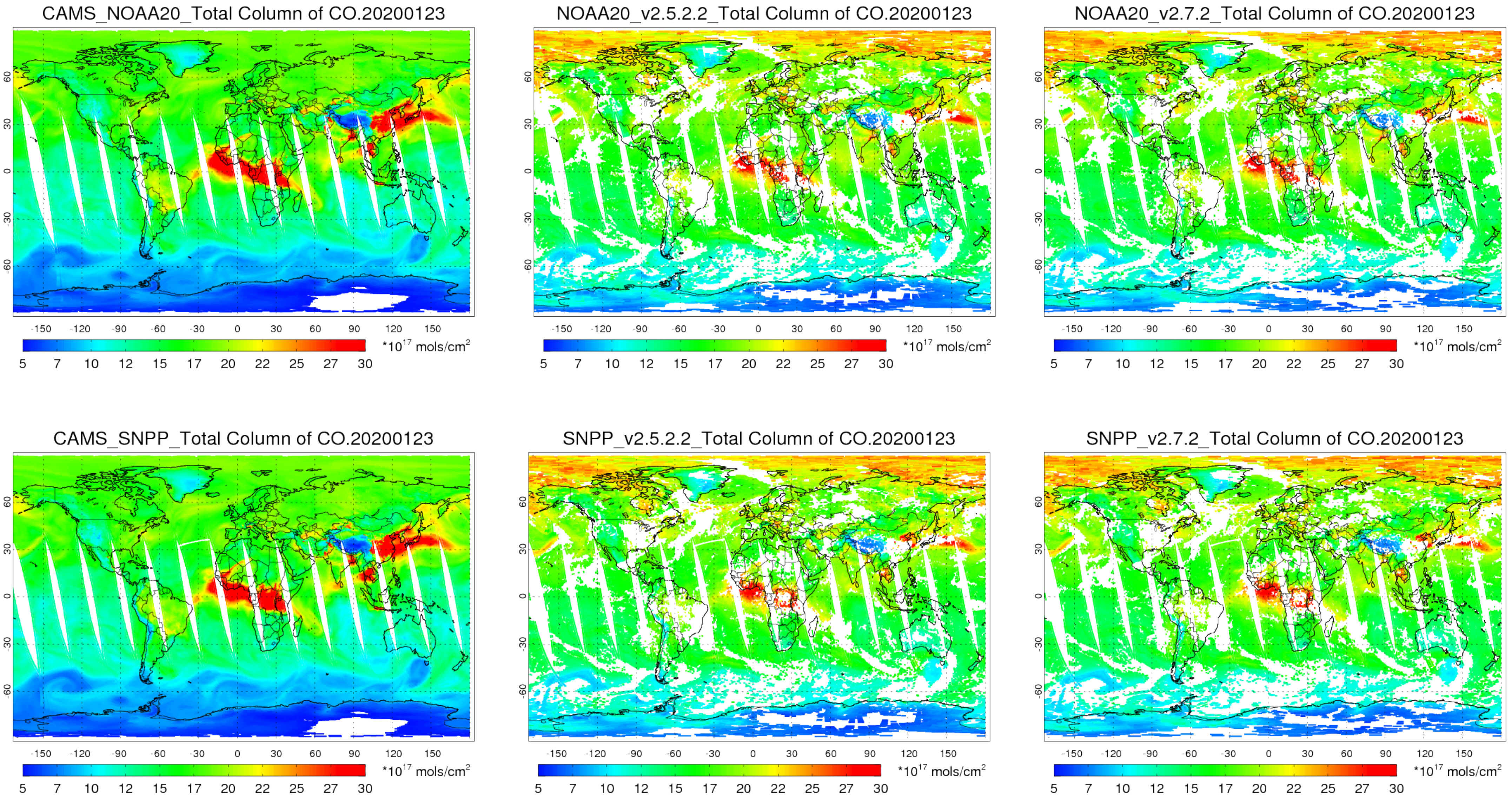




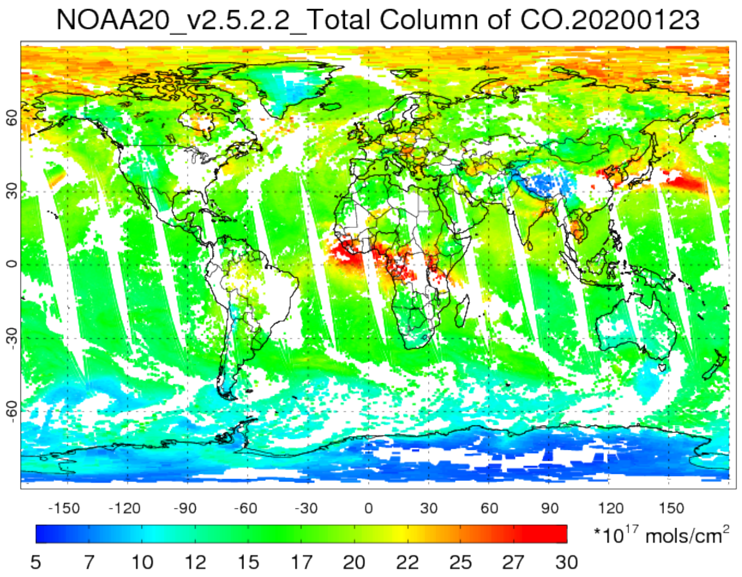


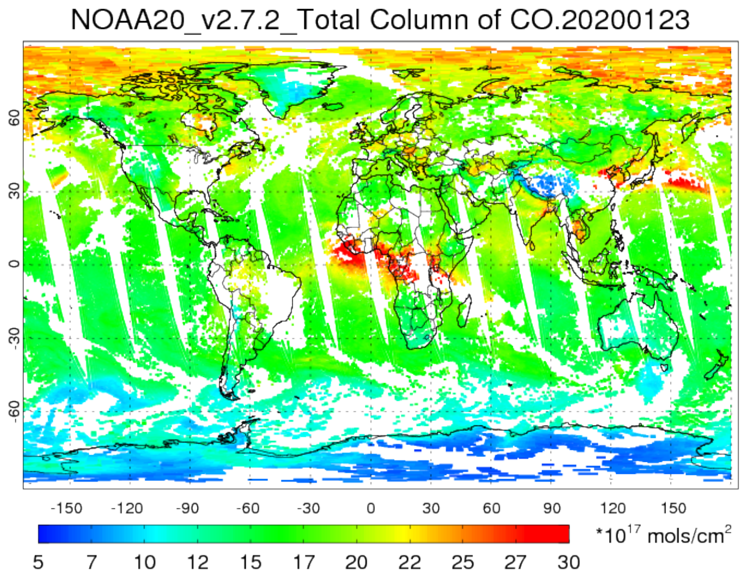
- #of Retrieval dO3 > 2.5DU: 12062/85888 ~14.0%
- #of Retrieval dO3 > 5DU: 4703/85888 ~5.5%

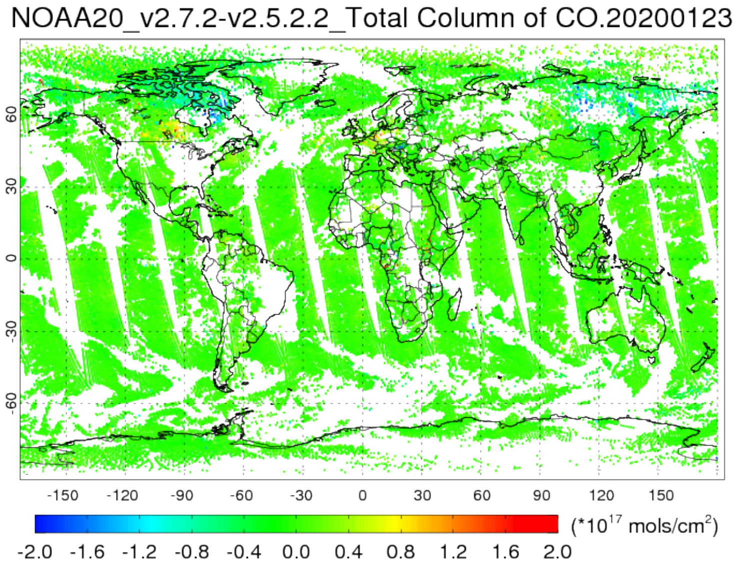
V2.5.2.2 vs. 2.7.2 Total Column CO (20200123)

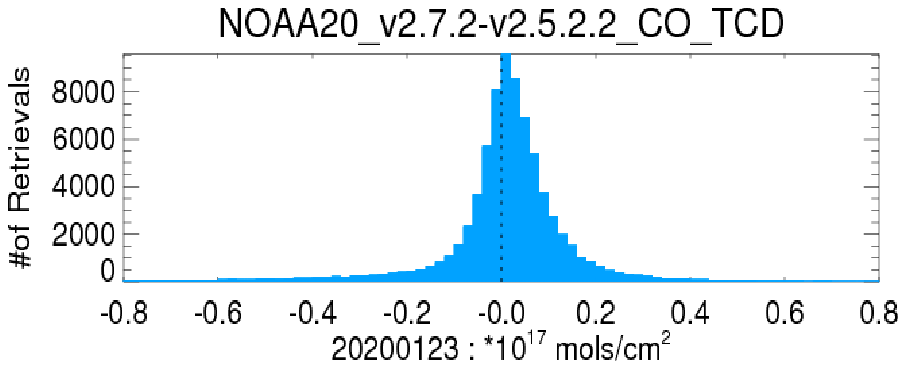


NOAA20 20200123 Total Column of CO
v2.5.2.2 vs. v2.7.2







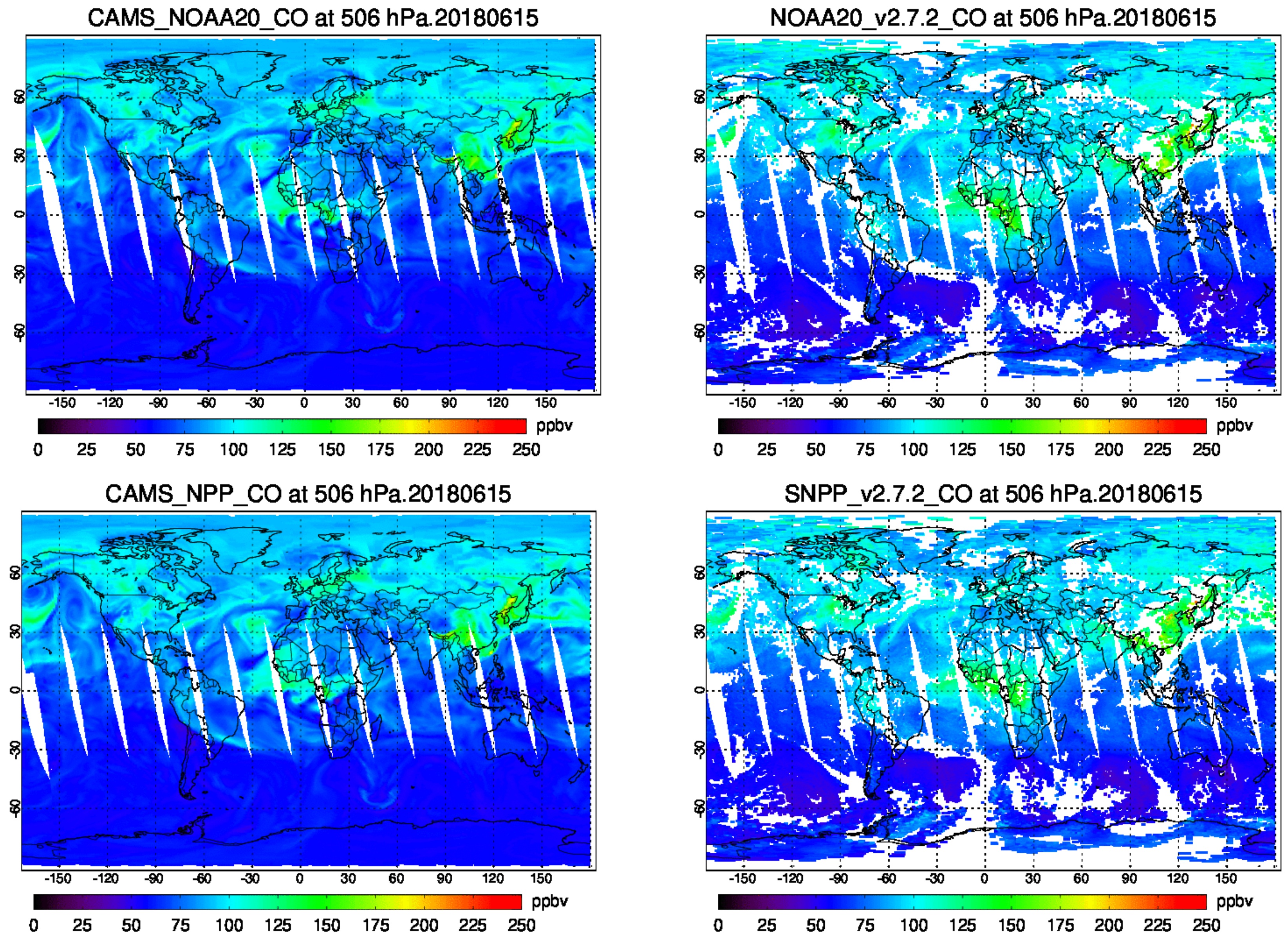


- #of Retrieval dCO > 0.2: 8767/75974 ~11.5%
- #of Retrieval dCO > 0.4: 3313/75974 ~4.4%

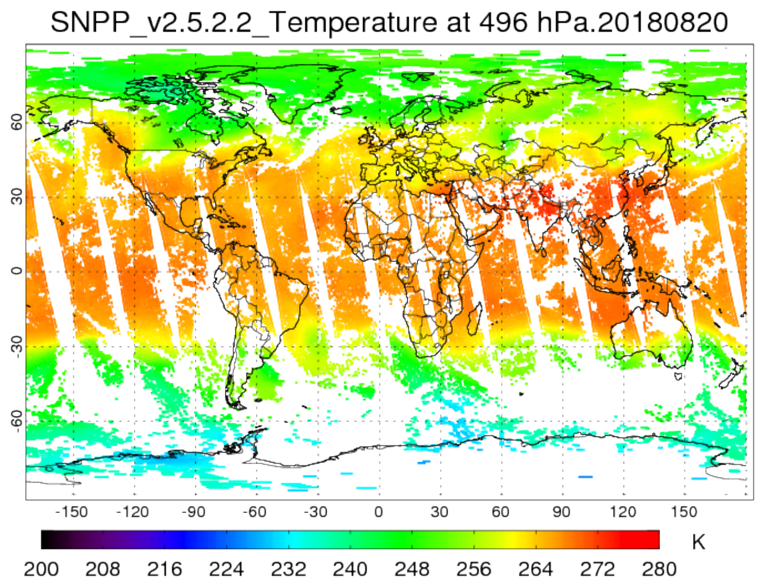
v2.7.2 CO for each focus day with CAMS

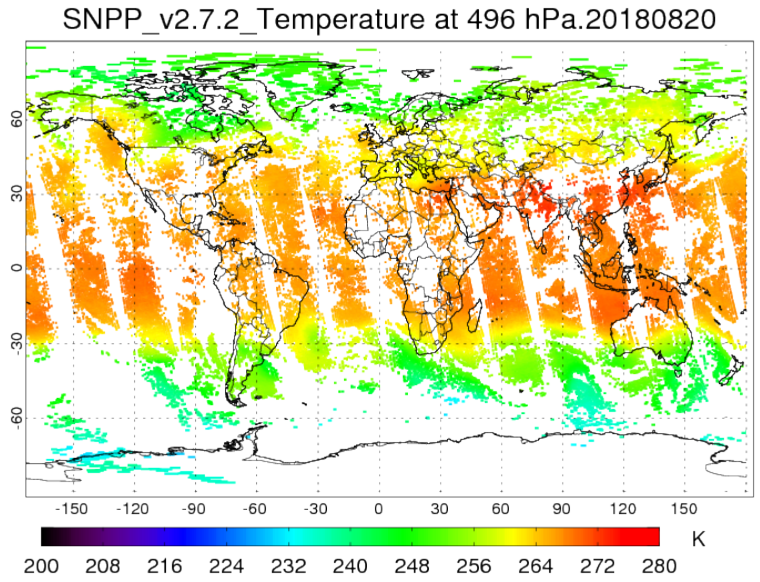
Animation for NOAA-20
20180615 - 20190515

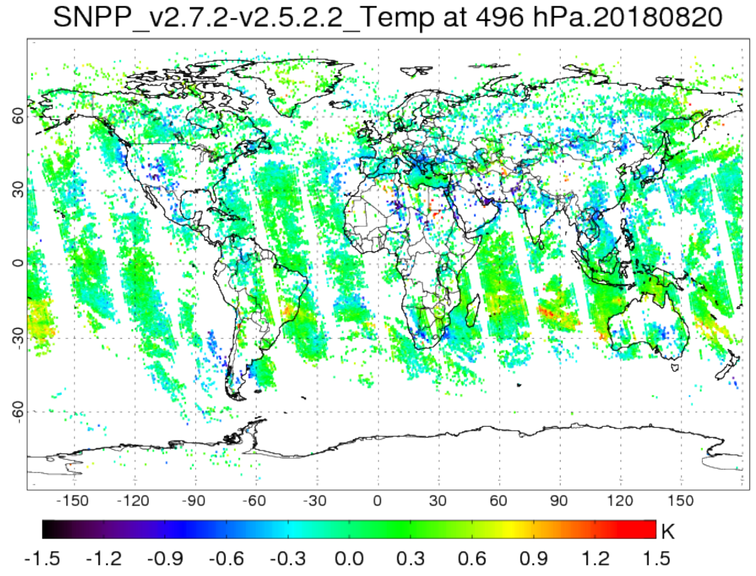
Animation for SNPP
20180415 - 20190316

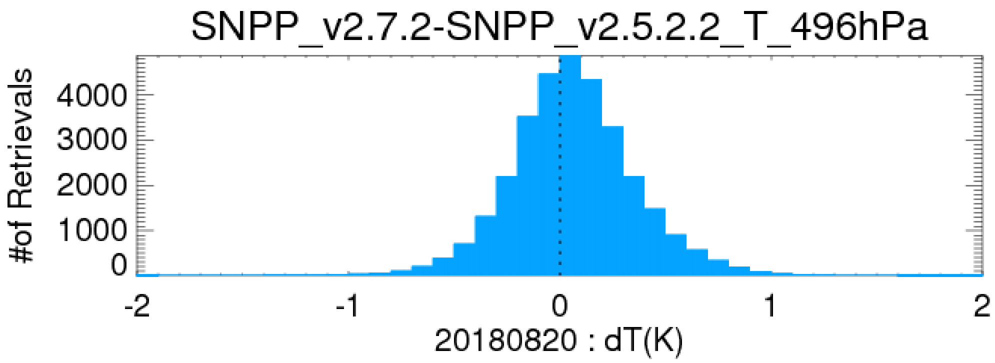


SNPP 20180820 Temp (496 hPa)
v2.5.2.2 vs. v2.7.2



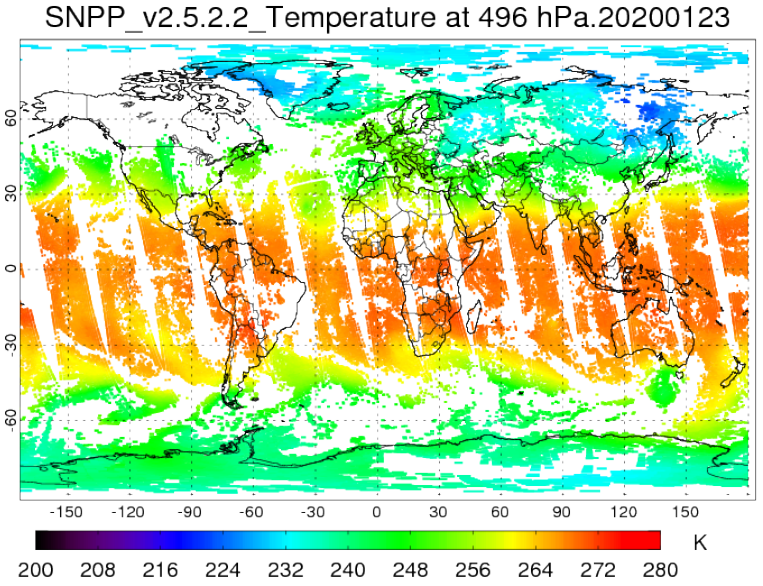


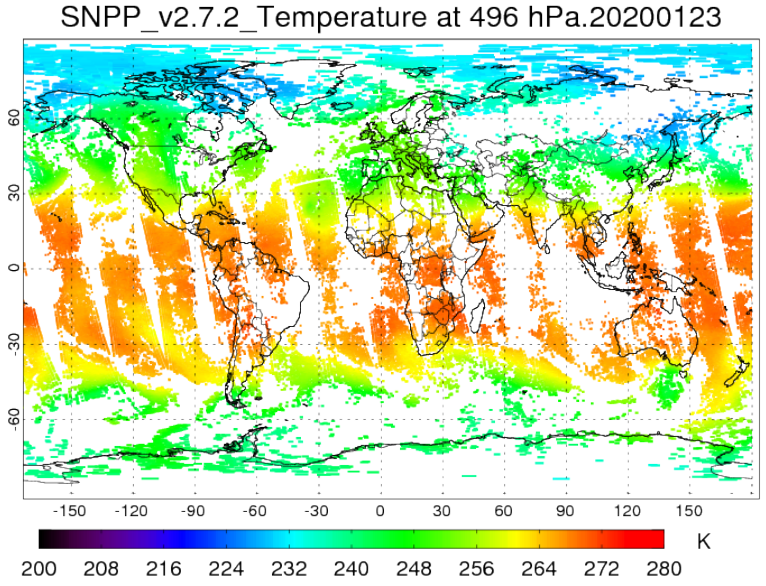


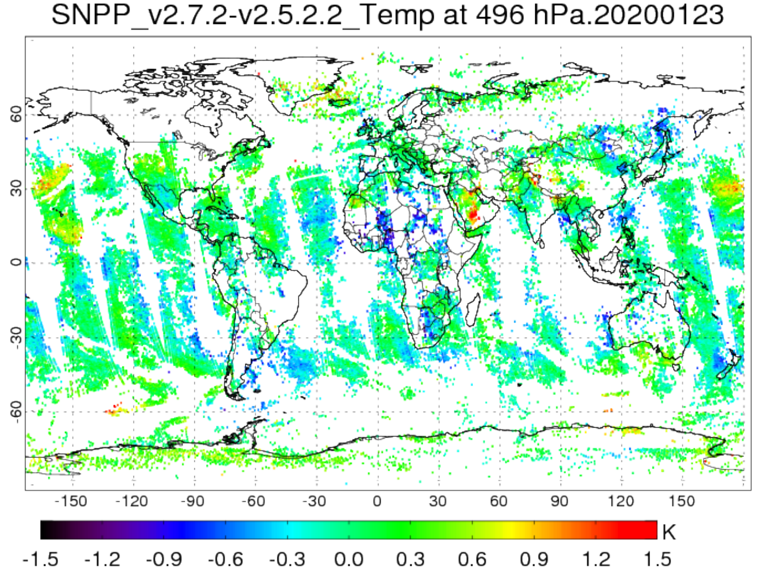


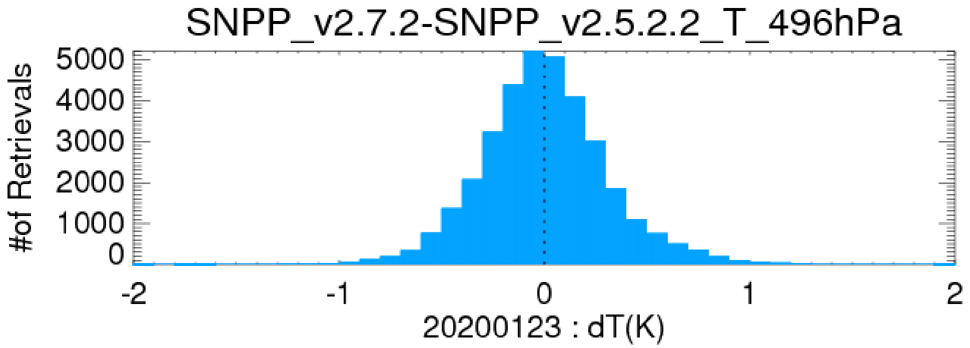
- #of Retrieval dT>0.5K: 3105/31514 ~9.9%
- #of Retrieval dT>1.0K: 185/31514 ~0.6%

SNPP 20200123 Temp (496 hPa)
v2.5.2.2 vs. v2.7.2



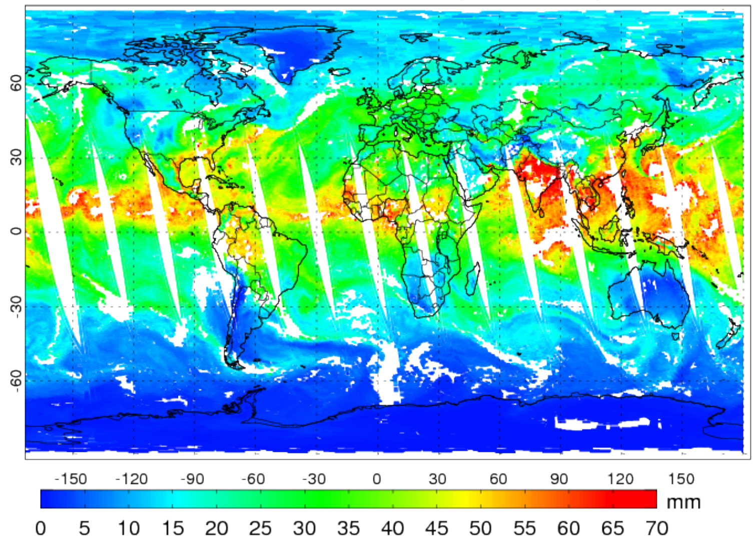


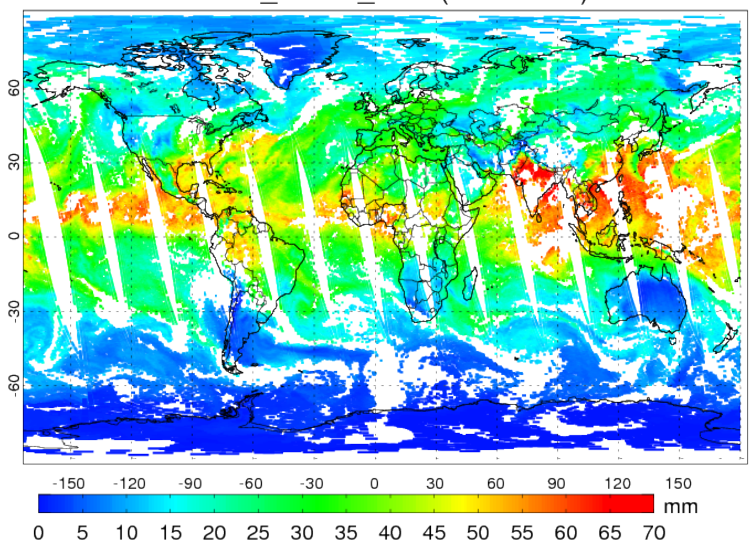


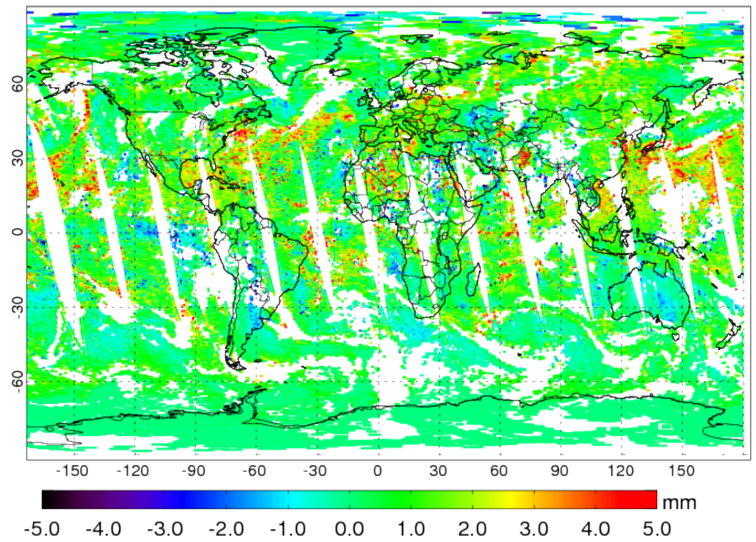


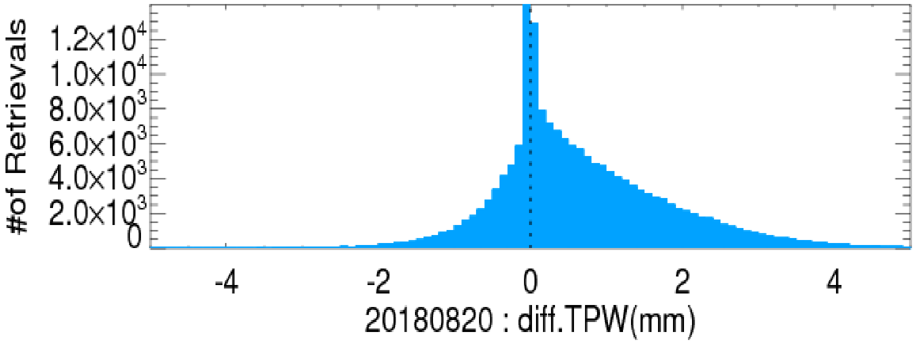
- #of Retrieval dT>0.5K: 3632/35069 ~10.3%
- #of Retrieval dT>1.0K: 244/35069 ~0.7%

SNPP 20180820 Total Precipitable Water (TPW)
v2.5.2.2 vs. v2.7.2



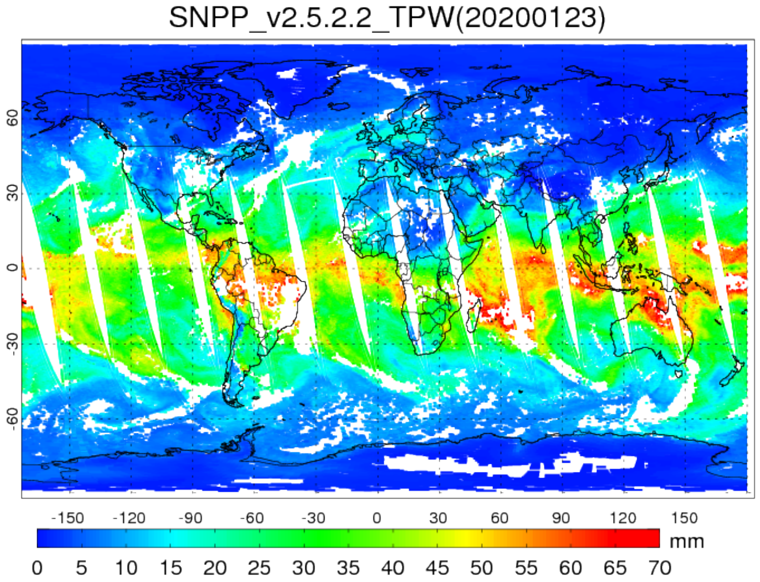


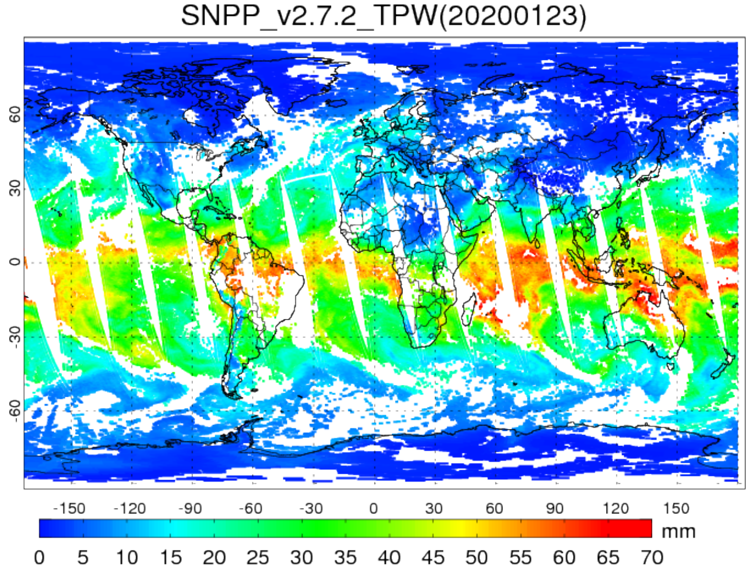


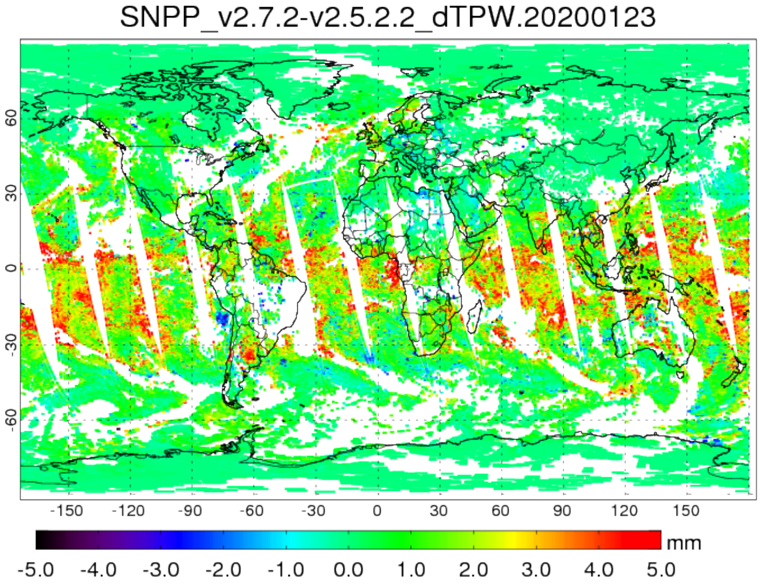


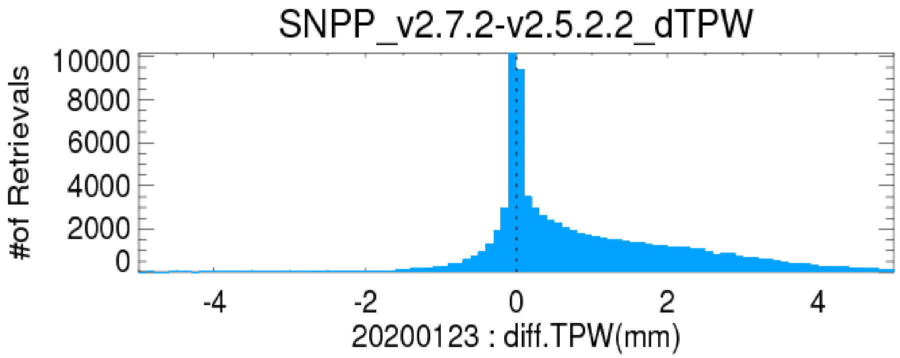
- #of Retrieval dTPW > 2mm: 12412/86099 ~14.4%
- #of Retrieval dTPW > 4mm: 1330/86099 ~1.5%

SNPP 20200123 Total Precipitable Water (TPW) v2.5.2.2 vs. v2.7.2



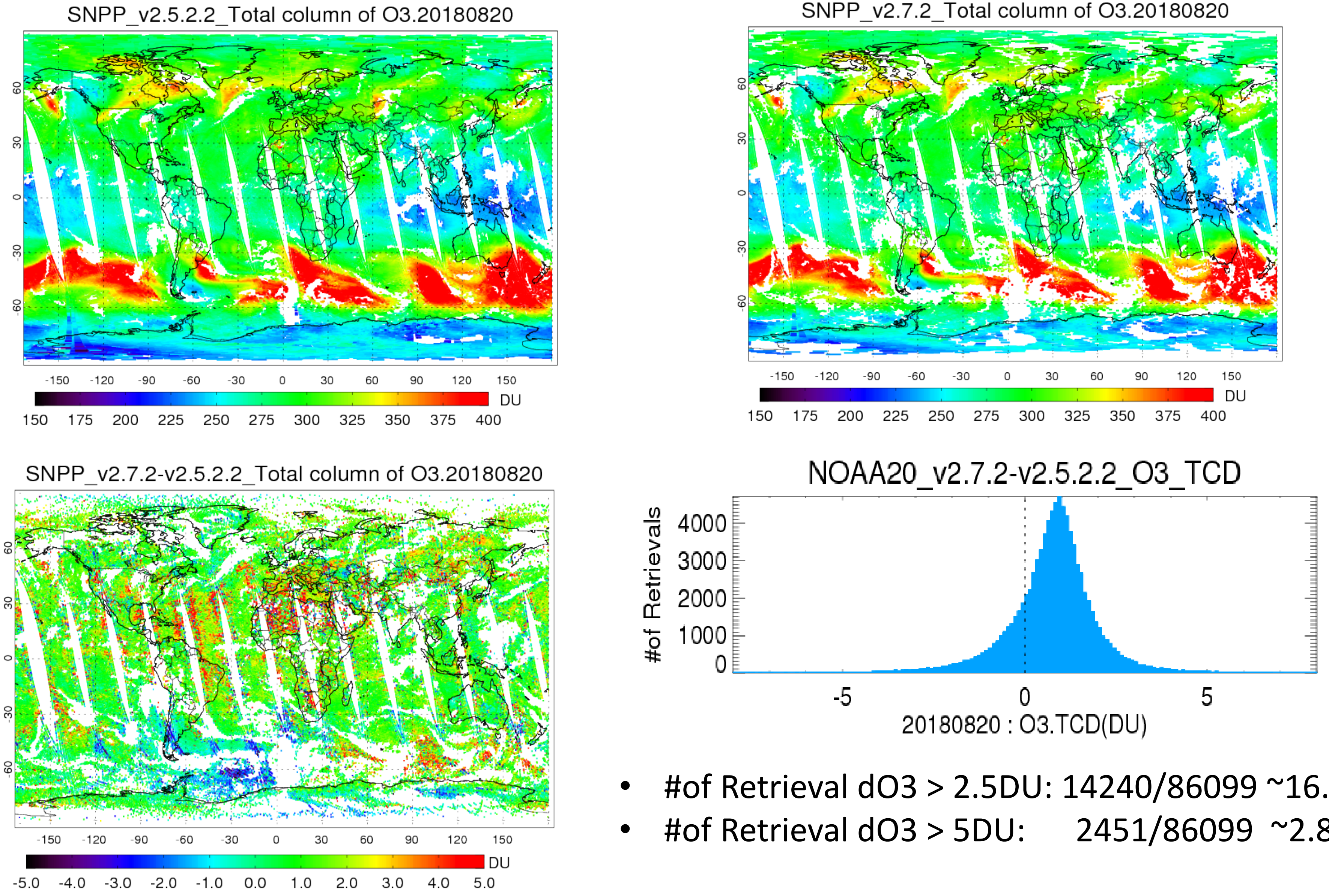






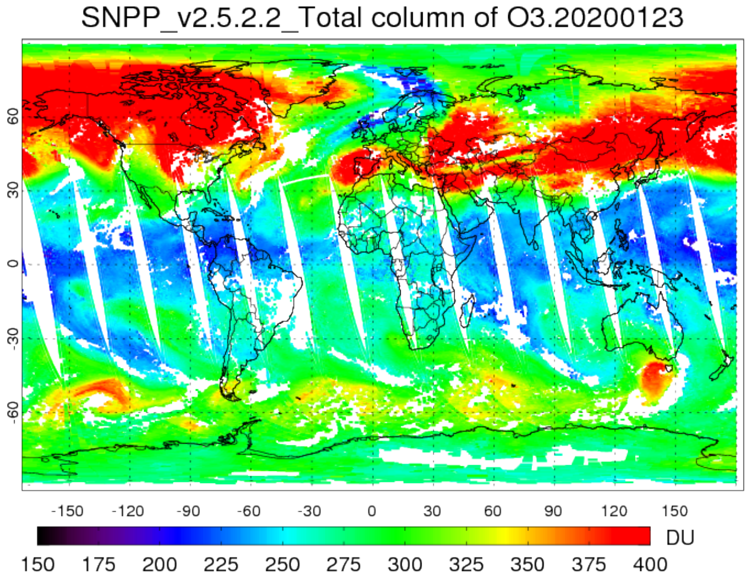
- #of Retrieval dTPW > 2mm: 18342/84063 ~21.8%
- #of Retrieval dTPW > 4mm: 3013/84063 ~3.6%

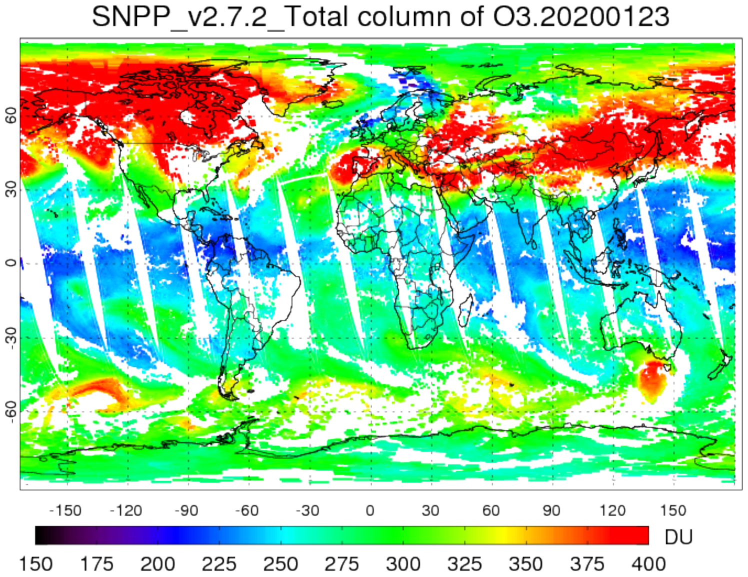
SNPP 20180820 Total Column of Ozone v2.5.2.2 vs. v2.7.2

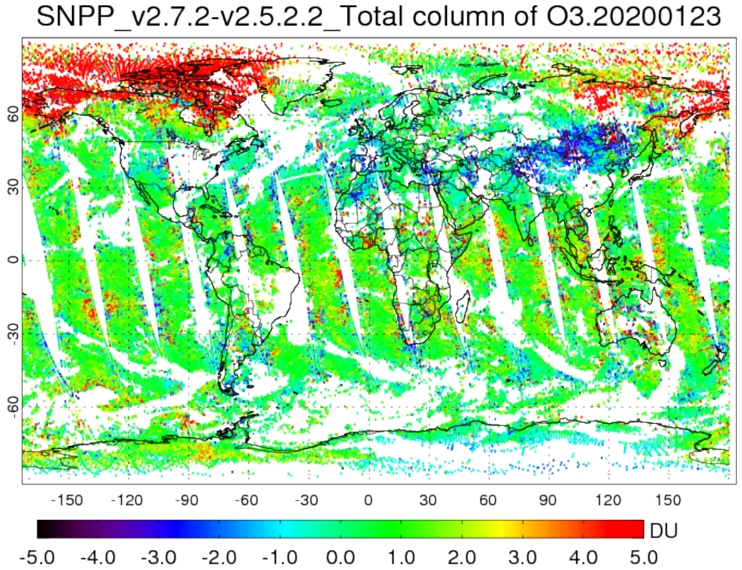


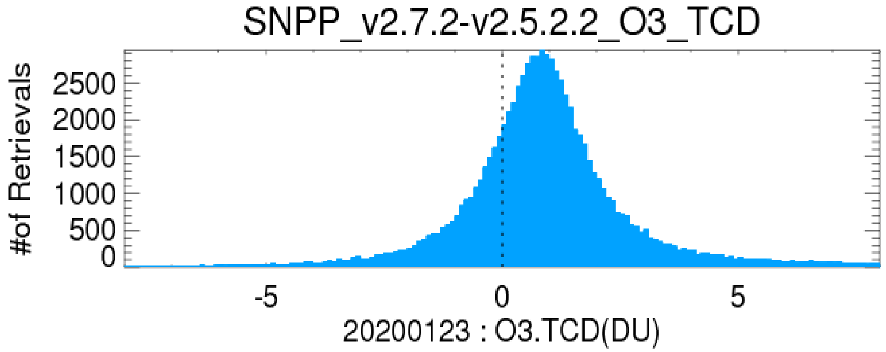
- #of Retrieval dO3 > 2.5DU: 14240/86099 ~16.5%
- #of Retrieval dO3 > 5DU: 2451/86099 ~2.8%

SNPP 20200123 Total Column of Ozone
v2.5.2.2 vs. v2.7.2



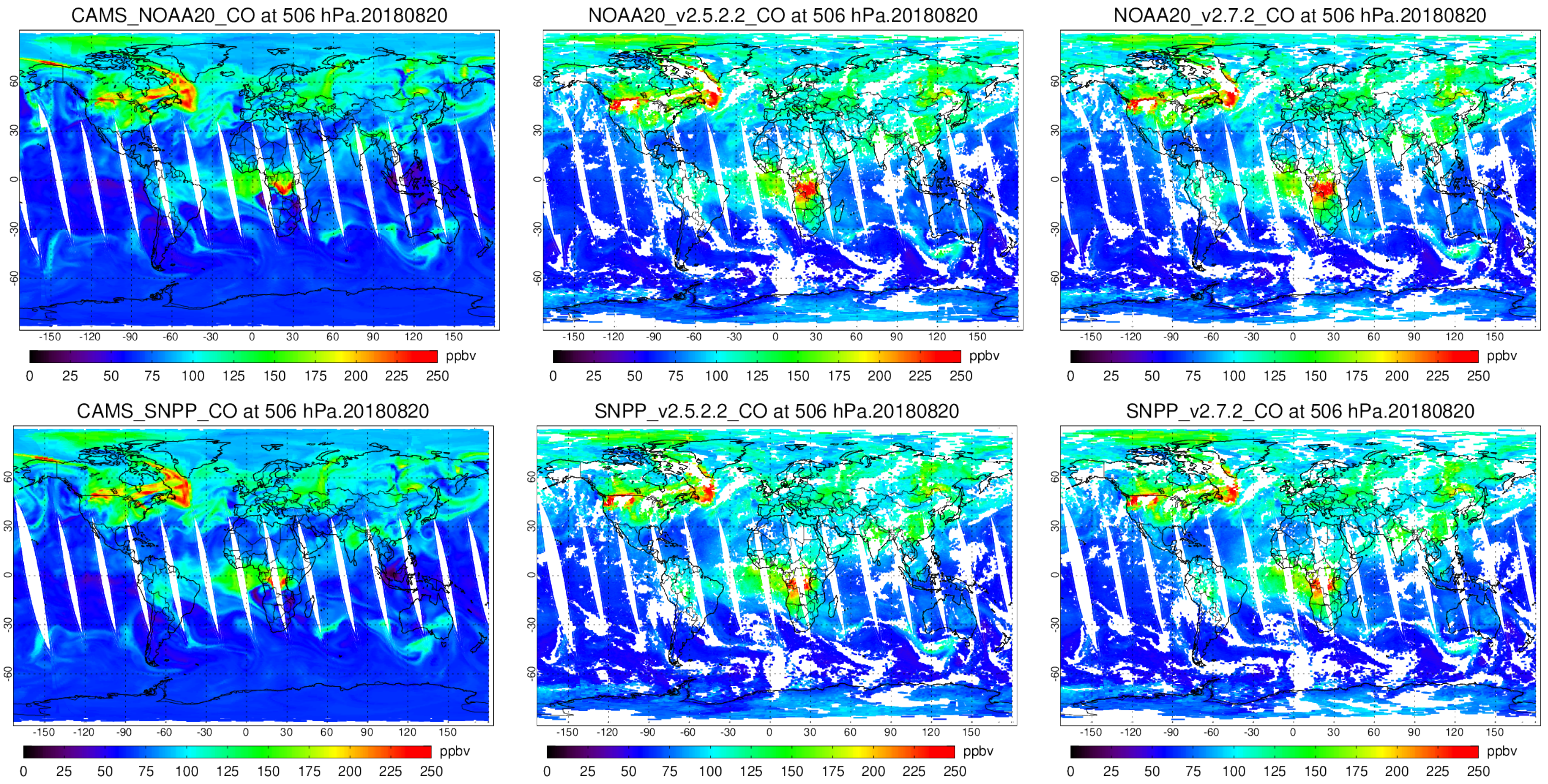




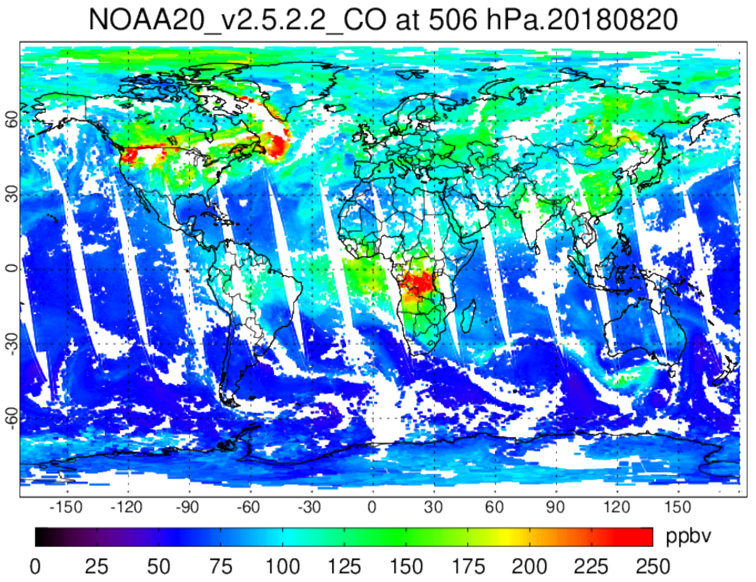


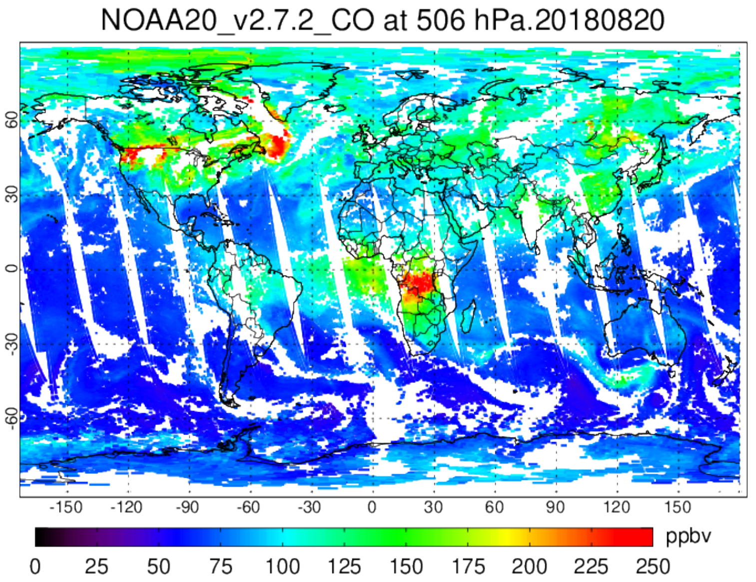
- #of Retrieval dO3 > 2.5DU: 15580/84063 ~18.5%
- #of Retrieval dO3 > 5DU: 5409/84063 ~6.4%

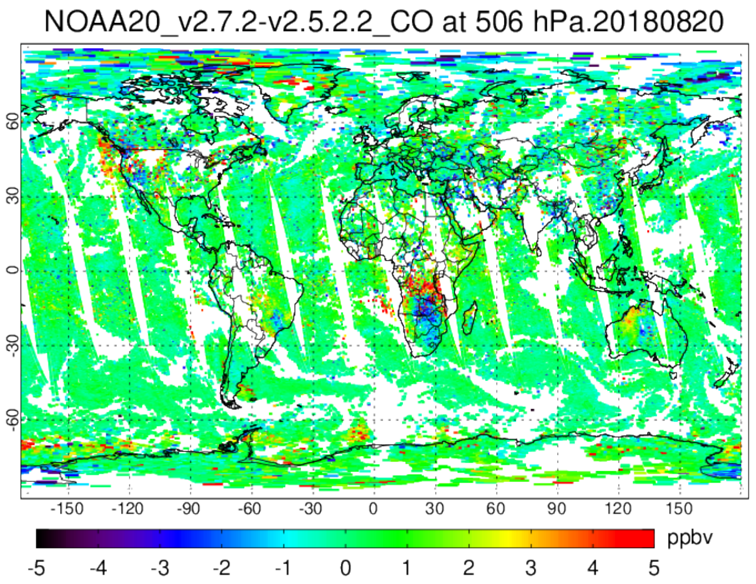
V2.5.2.2 vs. 2.7.2 CO@506-hPa (20180820)

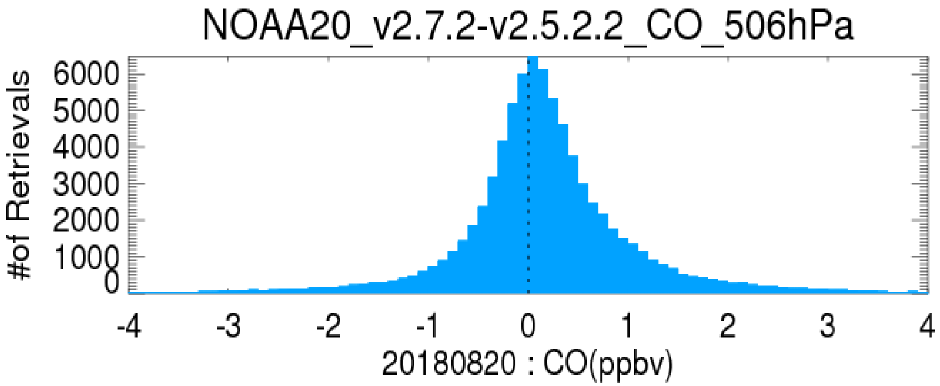


NOAA20 20180820 CO@506-hPa
v2.5.2.2 vs. v2.7.2



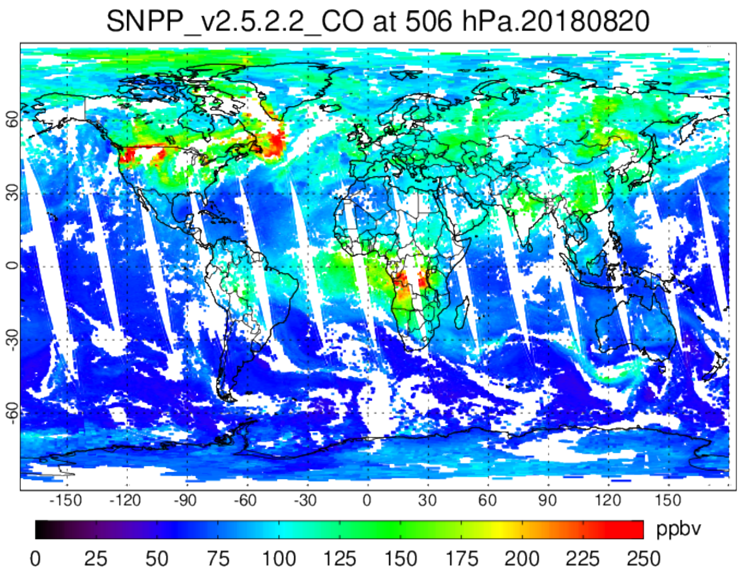


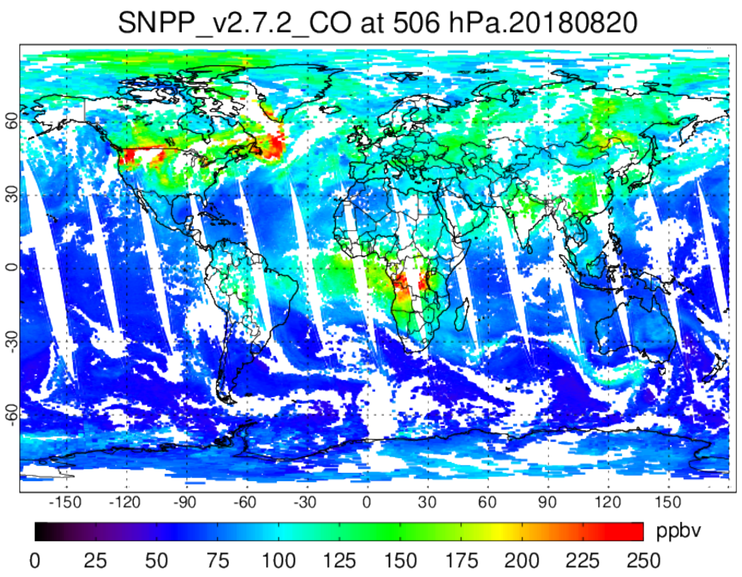


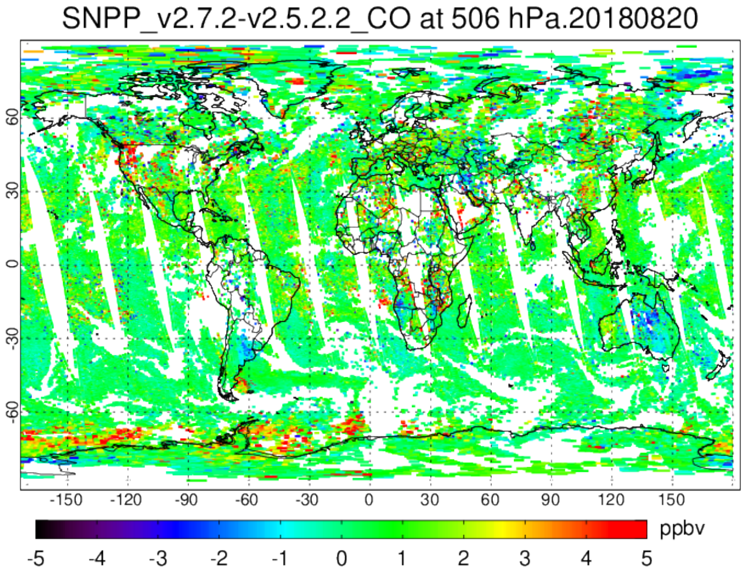


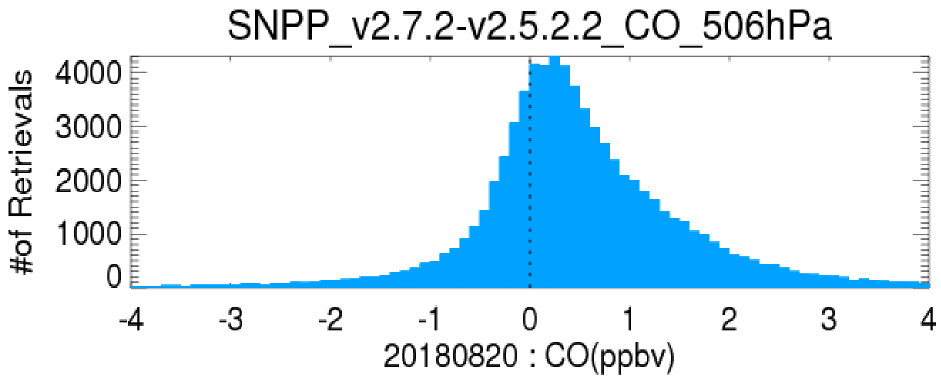
- #of Retrieval dCO > 1.0: 15671/79880 ~19.6%
- #of Retrieval dCO > 2.0:   5433/79880 ~6.8%

SNPP 20180820 CO@506-hPa
v2.5.2.2 vs. v2.7.2



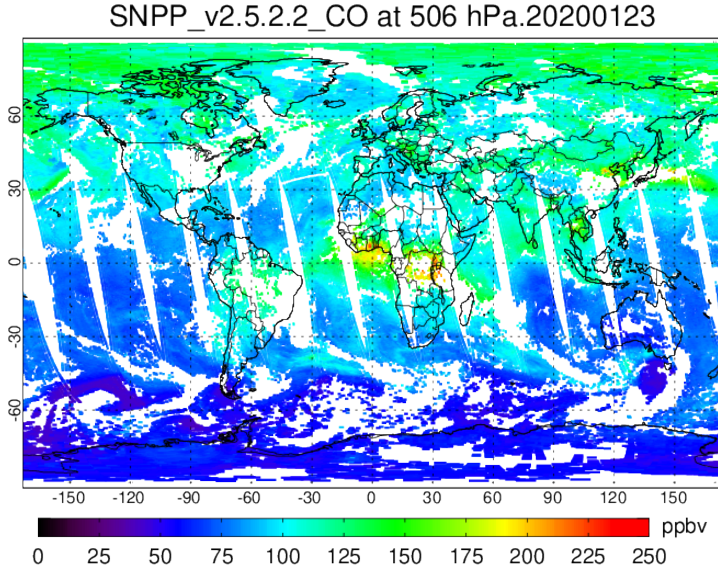


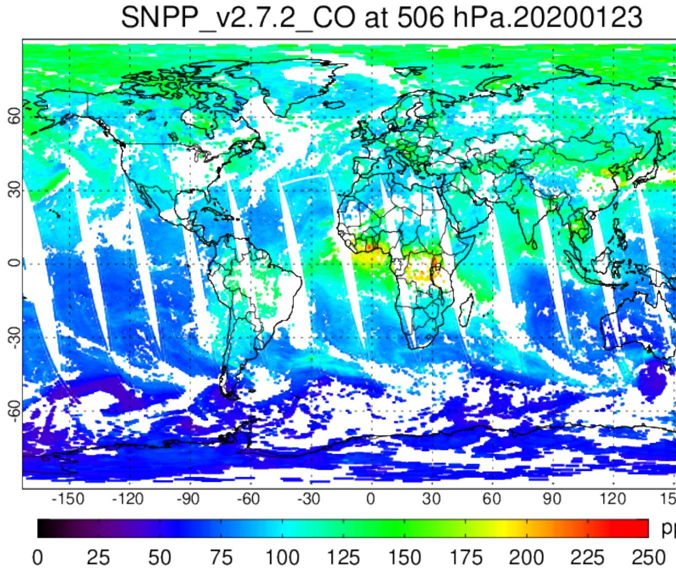


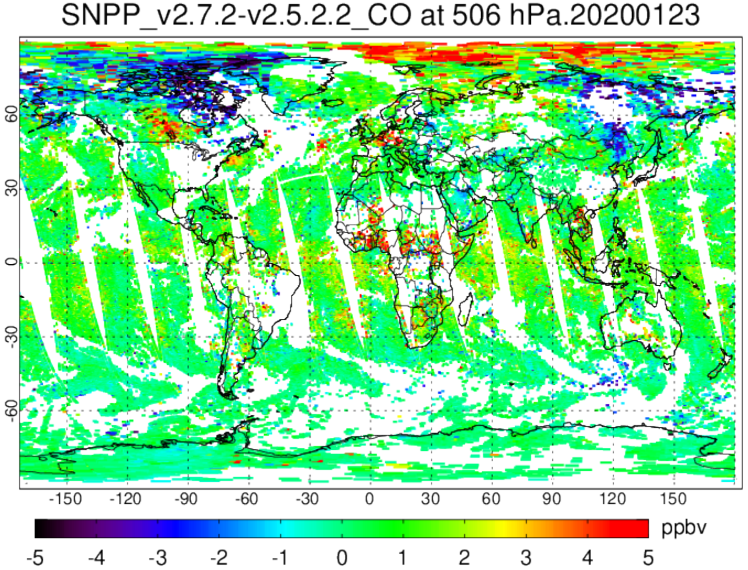


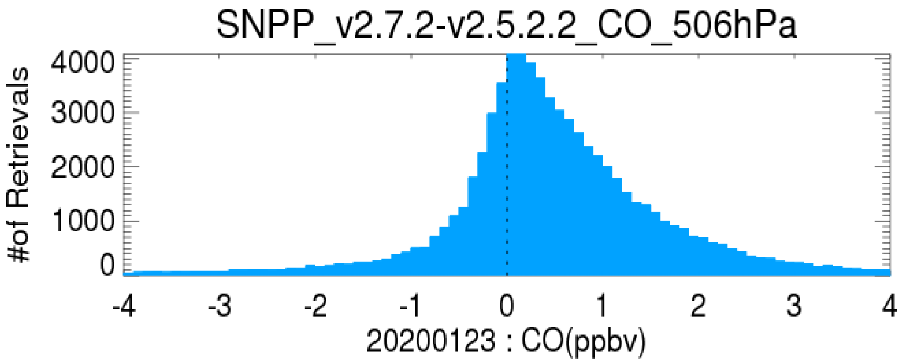
- #of Retrieval dCO > 1.0: 24003/74437 ~32.2%
- #of Retrieval dCO > 2.0: 8521/74437 ~14.4%

SNPP 20200123 CO@506-hPa
v2.5.2.2 vs. v2.7.2





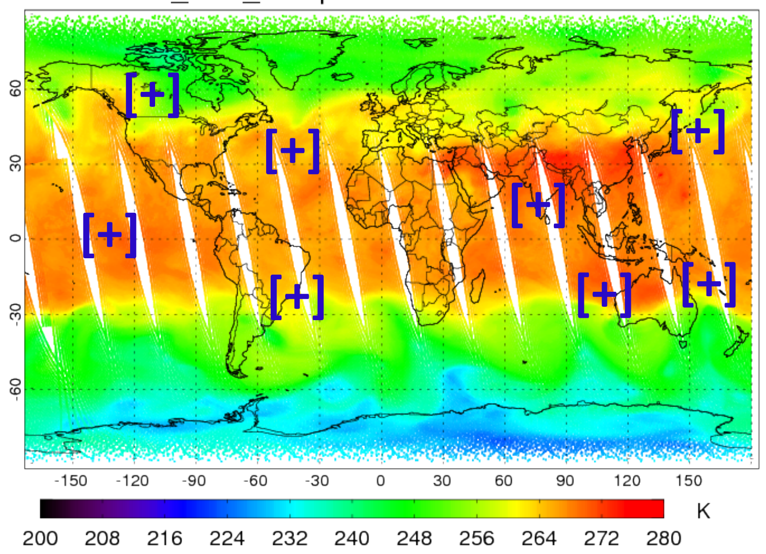




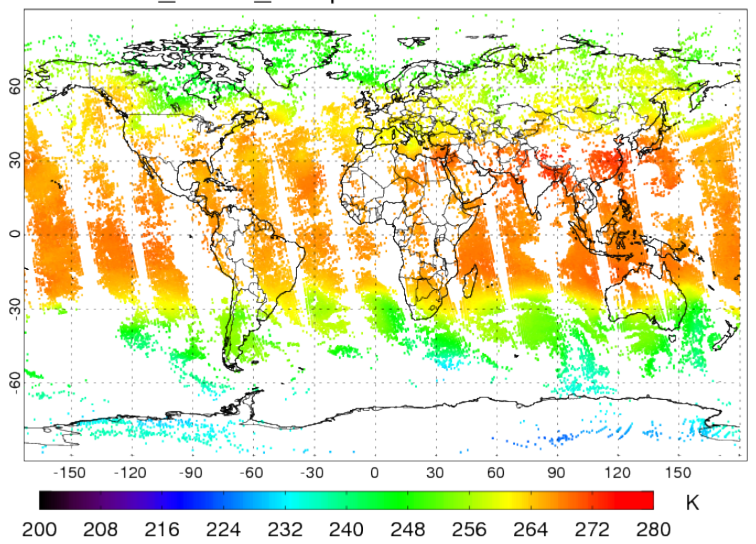
- #of Retrieval dCO > 1.0: 25861/73543 ~35.2%
- #of Retrieval dCO > 2.0: 10605/74543 ~14.4%

ECMWF, NOAA20 and SNPP Temp. (v2.7.2) 20180820

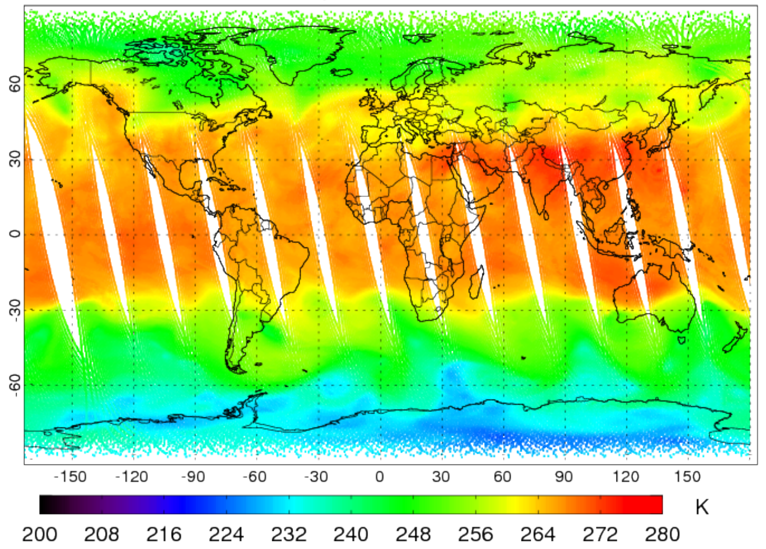
ECMWF_N20_Temperature at 496 hPa.20180820



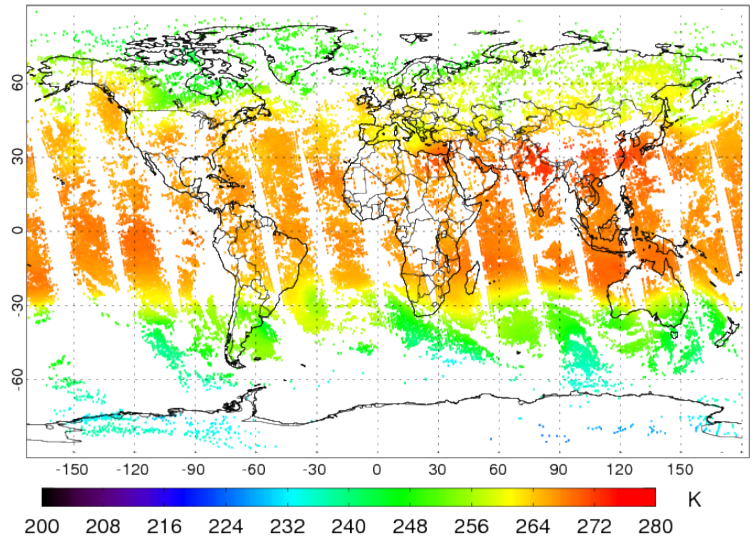
NOAA20_v2.7.2_Temperature at 496 hPa.20180820



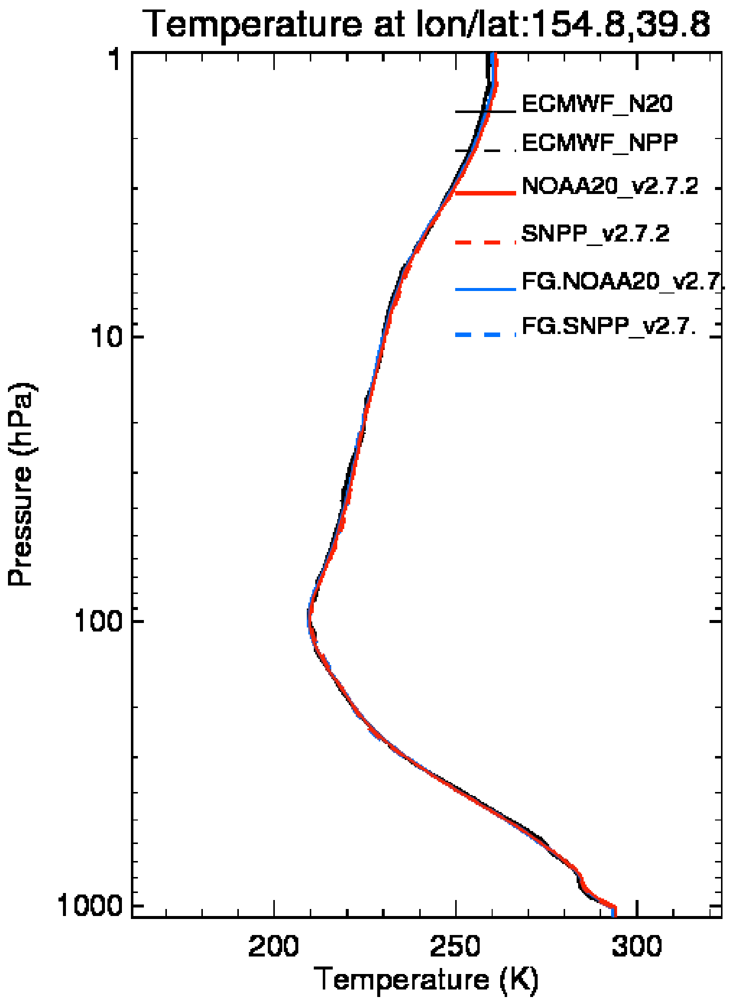
ECMWF_NPP_Temperature at 496 hPa.20180820



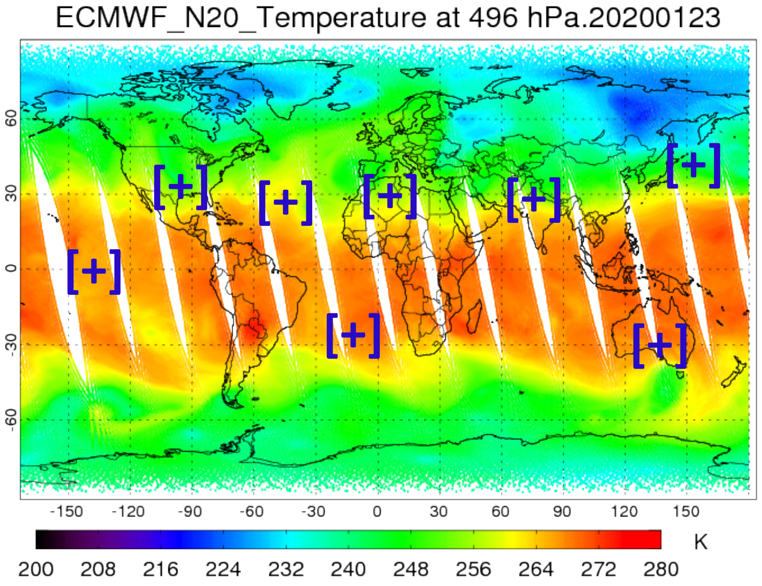
SNPP_v2.7.2_Temperature at 496 hPa.20180820

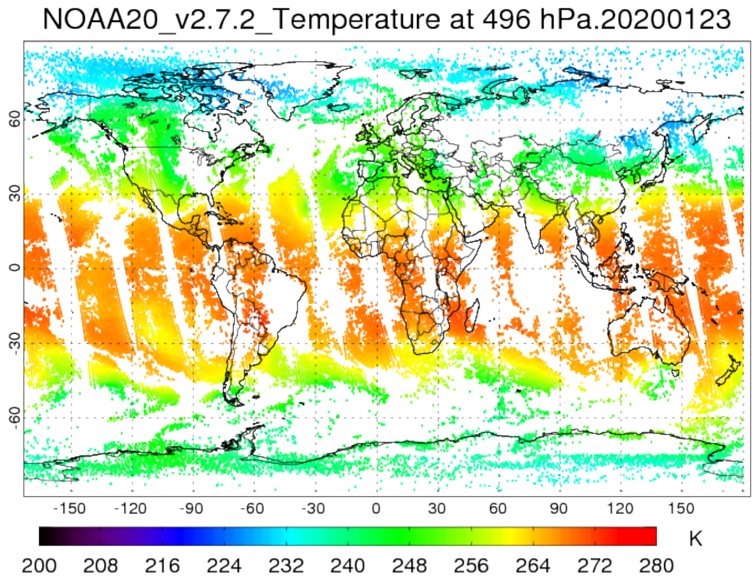


[+] Profile location

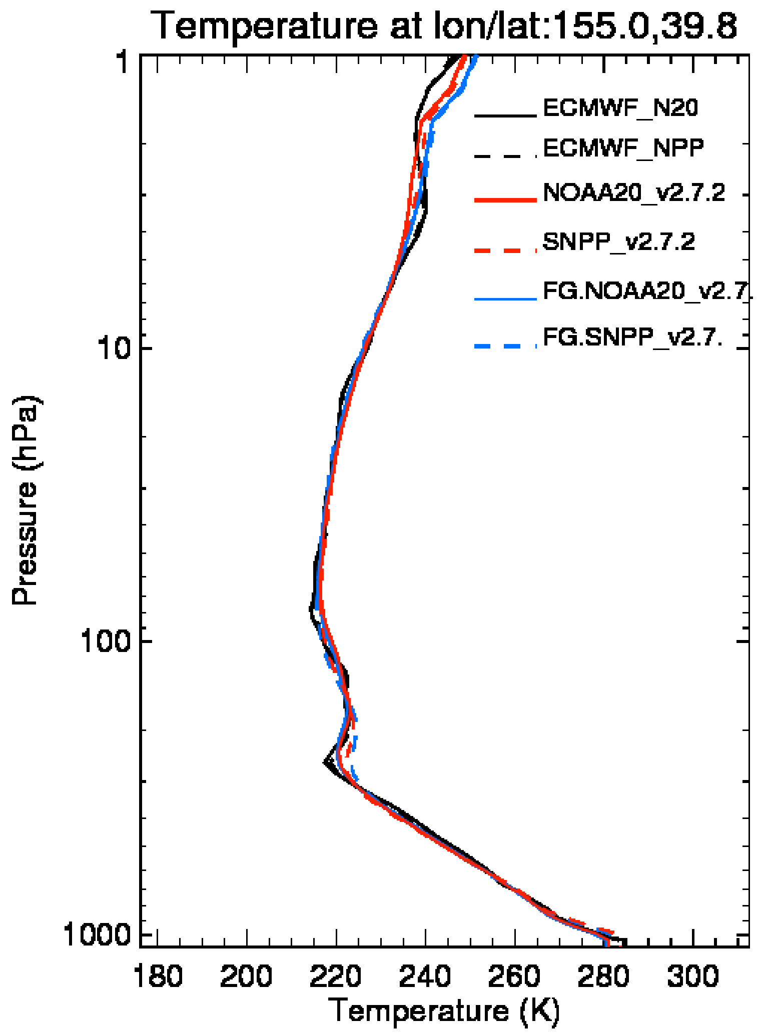


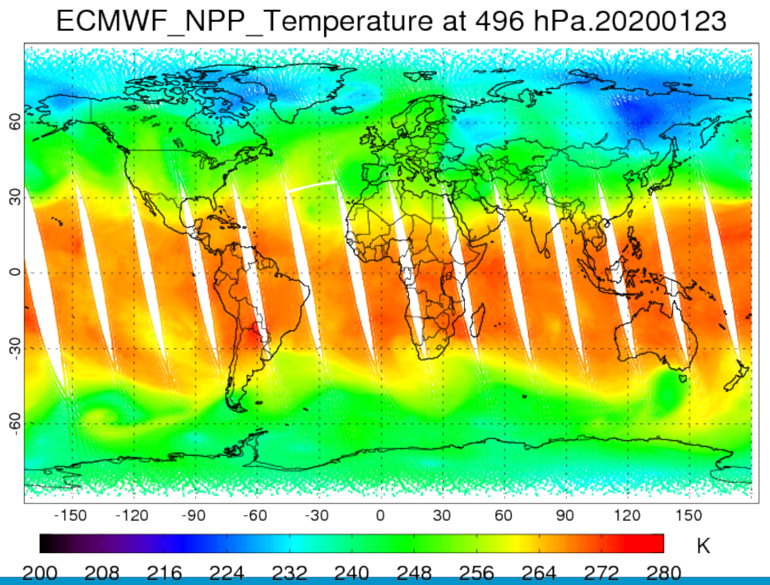
ECMWF, NOAA20 and SNPP Temp. (v2.7.2) 20200123

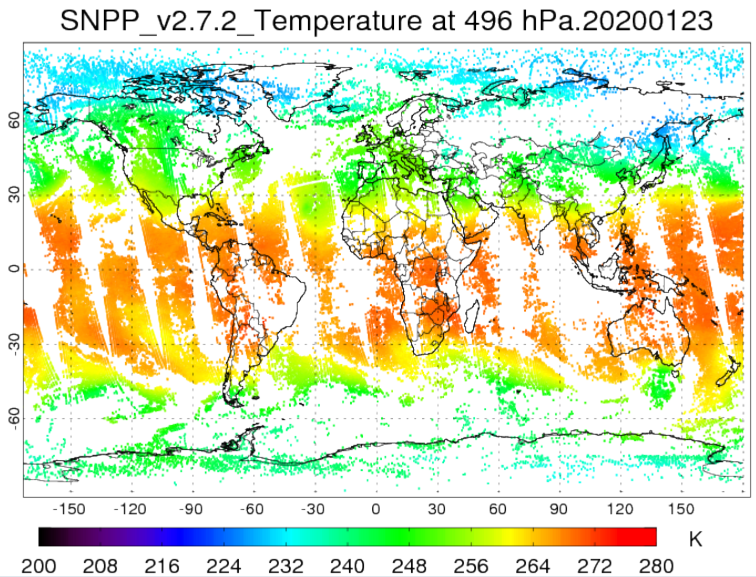




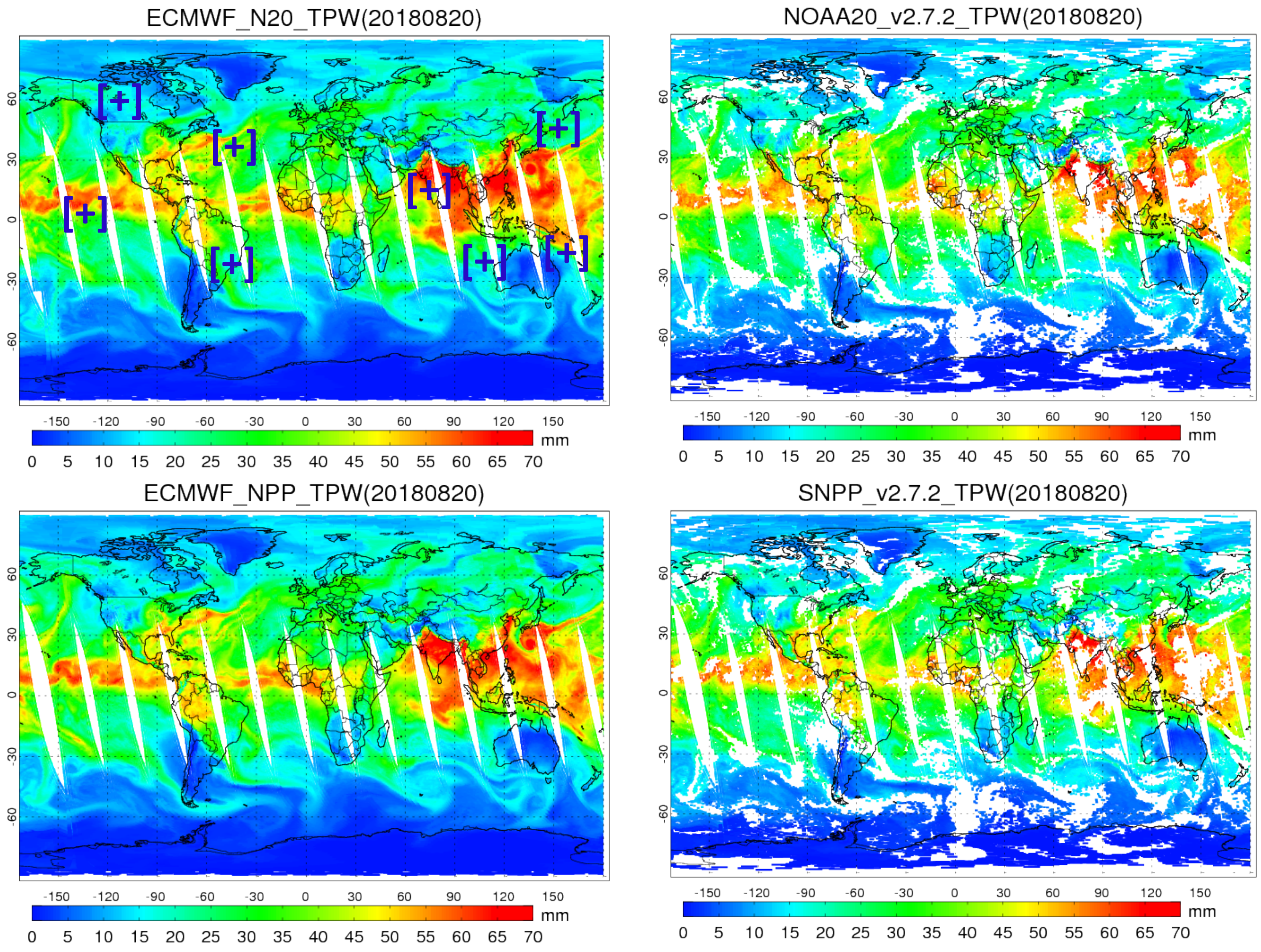
[+] Profile location

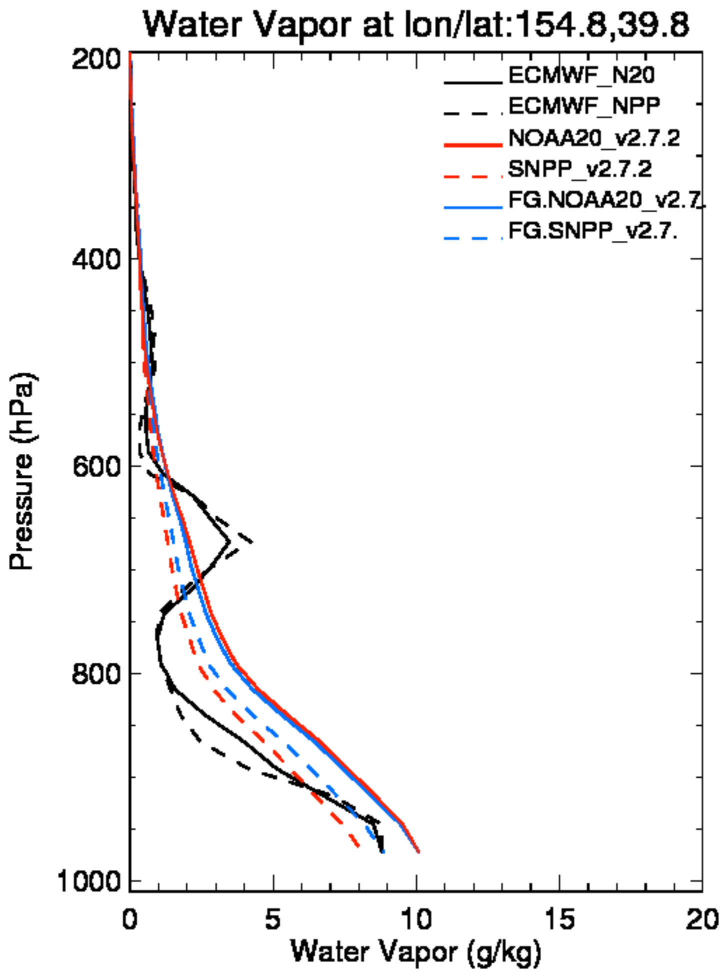






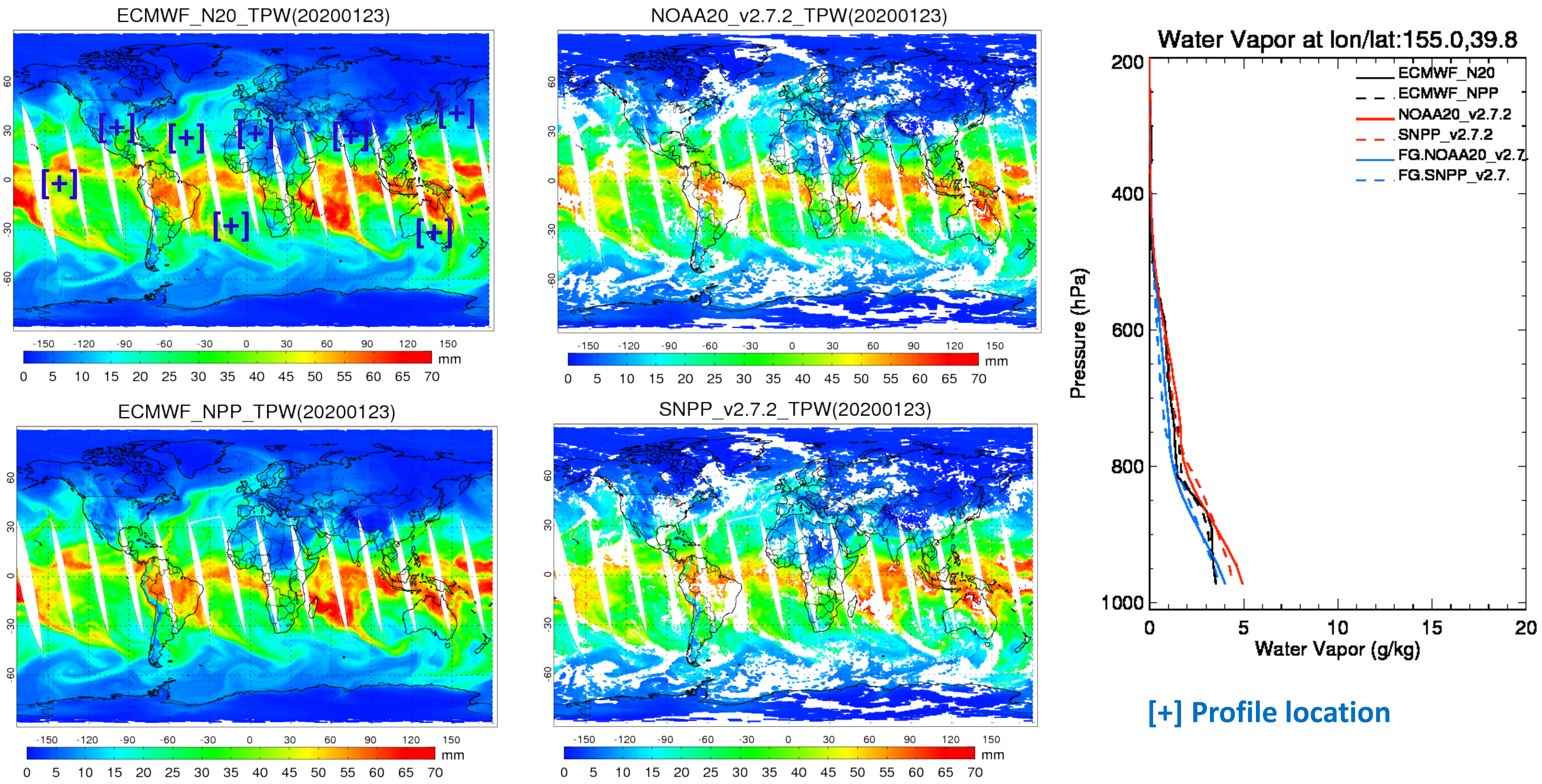
ECMWF, NOAA20 and SNPP TPW (v2.7.2) 20180820





[+] Profile location

ECMWF, NOAA20 and SNPP TPW (v2.7.2) 20200123



[+] Profile location

Supplemental Slides

SET 2. NUCAPS TEAM COLLABORATIONS WITH EXTERNAL AGENCIES FOR RISK MITIGATION

Criticality

HIGH
MED
LOW

NUCAPS Team Collaborations with External Agencies for Risk Mitigation

Topic	POCs	Ongoing Actions/Mitigation Efforts	Risk
1. Sarta code updates, wrapper scripts. There is a wrapper script to convert SARTA RTA coefficients to NUCAPS RTA format, and without knowing the knowhow, it would be hard to generate NUCAPS RTA updates in future. Chris Barnet provided the knowhow to STAR NUCAPS team members (POC: Tong Zhu).	Chris Barnet (STC) Tong Zhu (STAR) Changyi Tan (STAR) Murty Divakarla (STAR) Ken Pryor (STAR)	• STAR NUCAPS teams may look into any hard-coded constants and QA with Chris Barnet (04/14/2020) ✓ STAR NUCAPS team is self sufficient and has the knowhow to receive future SARTA updates from Larrabee and implement for stand-alone radiance simulations (comprad), and implementation as part of NUCAPS algorithm ✓ NUCAPS team repeated the wrapper scripts and converted the updated SARTA coefficients to NUCAPS RTA format, and performed benchmark tests. ✓ STAR team worked with Chris Barnet, received and verified results (12/17/2019, Tong Zhu) ✓ Larrabee delivered updated code for MetOp-C.	**Medium**
2. All-sky and clear regression first guess code, implementation for JPSS (CrIS/ATMS) and MetOp (IASI, AMSU-A/MHS) systems. STAR NUCAPS team has the regression codes separated out for different systems (CrIS/ATMS, IASI/AMSU-A/MHS). STC Team has a robust, well documented code that can be used for different satellites. STAR NUCAPS team felt it good to have a better documented code. So, experimented with STC teams' code for future implementations.	Chris Barnet (STC) Tianyuan Wang (STAR) Changyi Tan (STAR) Murty Divakarla (STAR) Ken Pryor	• STAR NUCAPS team is more or less self sufficient, and do not need any major assistance from the STC team except some QA. ✓ The "cleaned-up" code is nearly well documented. What we need to do is to dive deeper to fully understand/maintain the code, and to complete all documentations. For future developments (for MetOp-C, IASI-NG and JPSS-x), we only need to modify the code slightly for replacing the instruments. ✓ STAR team evaluated and found it good. Made updates to the regression code to adapt to MetOP IASI, and AMSU-A/MHS ✓ Received from Chris Barnet. (12/12/2019)	**Low**

NUCAPS Team Collaborations with External Agencies for Risk Mitigation

Topic	POCs	Ongoing Actions/Mitigation Efforts	Risk
3. Augmenting NUCAPS to IASI-NG/MWS After a group discussion among STAR Management, NUCAPS team, Larrabee Strow (UMBC), Chris Barnet (STC), based on prons and cons, it was decided to implement NUCAPS for IASI-NG/MWS by truncating the IASI-NG (16,821 channels) to IASI (8461).	Satya Kalluri (STAR) Murty Divakarla (STAR) Ken Pryor (STAR) Chris Barnet (STC) Changyi Tan (STAR) Mike Wilson (STAR)	• MWS simulations and fast forward model development for MWS using Rosenkranz's line-by-line model (STC) • Mapping MWS to IASI is another important preprocessing steps that may require some suggestions/verifications from STC team (see Topic 4) • First requires MetOp-C IASI/AMSU-A/MHS NUCAPS augmentation, and verify product accuracies meeting requirements ✓ With IASI-NG truncated to IASI, the MetOp-C IASI SARTA can be implemented as the NUCAPS RTA to augment for IASI-NG/MWS. ✓ During the CrIMSS EDR algorithm development, STAR NUCAPS team has developed the procedures/capability to truncate IASI (8461 channels) to CrIS (1305 NR). This methodology was tested to truncate IASI-NG (16, 821 channels) to IASI (8461 channels) and works well. Require a minor discussion with Chris regarding IASI-NG instrument characteristics, and understanding (OPDs) in finalizing this approach.	**Medium**
4. Rosenkranz's Microwave Line by Line Model and generation of NUCAPS MW-only Fast Forward Model Currently, we have the MW RTA simulation capability (coefficients) for ATMS, AMSU-A, and MHS. We need to create new microwave RTA tunings for the microwave instruments on the JPSS-2, Metop-C etc. This requires collaboration with STC on how to create a fast MW forward model using the existing Rosenkranz MW line by line model.	Chris Barnet (STC) Tong Zhu (STAR) Murty Divakarla (STAR)	• Requires documentation from Chris Barnet. • We will perform benchmark tests for updating NUCAPS MW RTA after receiving the MW wrapper (MW line-by-line model to generating fast MW model for MW-only retrievals) from Chris Barnet. • Had a discussion with Chris Barnet (STC) and he agreed to provide a cross-training for technical interchange. • We need the cross-training from Chris Barnet for updating ATMS/AMSU/MHS RTA from the Rosenkranz's model and we need the MW RTA wrapper from Chris Barnet.	**Medium**

NUCAPS Team Collaborations with External Agencies for Risk Mitigation

Topic	POCs	Ongoing Actions/Mitigation Efforts	Risk
5. Emissivity regression vs. CAMEL emissivity database lookup as a-priori for land surface spectral emissivities. NUCAPS team wish to test the CAMEL emissivity database lookup to replace emissivity regression. STC team has integrated CAMEL lookup table approach, and a Technical Interchange Meeting was held on the use of CAMEL emissivity database for a-priori, replacing the current regression approach.	Nadia Smith (STC) Chris Barnet (STC) Changyi Tan (STAR) Mike Wilson (STAR) Nick Nalli (STAR) Murty Divakarla (STAR) Ken Pryor (STAR SME) Satya Kalluri (STAR SME)	• Preliminary results of CAMEL look-up approach did not show appreciable improvements. The CAMEL database currently implemented is a very old (2007) version. Requires a discussion with STC whether they plan on updating the database. Otherwise, the NUCAPS team needs to rely on UW (Bob Knuteson). ✓ STAR NUCAPS team implemented CAMEL look-up approach into the NUCAPS operational version (v2.7.3), verified. ✓ Version 2 of CAMEL data base implementation by STC (cross-training, 8/20/2019). STAR, STC, and UW teams coordinated through a emissivity cross-training.	**Medium**
6. Preparing an unified code (STAR NUCAPS team and STC updates) for future NUCAPS development Combine NUCAPS algorithm improvements/suggestions made by other agencies (e.g., STC, AIRS science team) and update STAR NUCAPS algorithm to generate a unified NUCAPS operational code.	Chris Barnet (STC) Mike Wilson (STAR) Changhyi Tan (STAR) Murty Divakarla (STAR) Ken Pryor (STAR SME) Satya Kalluri (STAR SME)	• What are the most important updates based on the improvements observed through CLIMCAPS? • STAR NUCAPS team need knowhow to generate local angle correction LUT files for both JPSS and MetOP series. Do we need the capability? • V2.7.3 STAR NUCAPS algorithm has included updates provided by Chris Barnet's delivery from July 24, 2019.	**Medium**

NUCAPS Team Collaborations with External Agencies for Risk Mitigation

Topic	POCs	Ongoing Actions/Mitigation Efforts	Risk
7. Averaging Kernels For T(p), q(p), and O3(p), and other trace gases During the JPSS/GOES-R summit, many users discussed the need for averaging kernels as part of NUCAPS output files.	Nadia Smith (STC) Chris Barnet (STC) Mike Wilson (STAR) Changyi Tan (STAR) Nick Nalli (STAR) Juying Warner (UMD) Murty Divakarla (STAR) Ken Pryor (STAR SME) Satya Kalluri (STAR SME)	• Since STC already implemented the file structure for NASA CLIMCAPS, STAR NUCAPS team needs a cross-training or technical knowhow from STC to append the file structure to the NUCAPS output files. • Consult NOAA JPSS office on the implementation guidance • During the JPSS/GOES-R summit, many users have discussed the need for averaging kernels as part of NUCAPS output files. • Files sizes of NUCAPS output product archived at CLASS will increase by 30%. JPSS program needs to initiate a dialogue with CLASS and any necessary budget for archiving larger data volumes, and requires coordination with CLASS/NCEI. • Chris Barnet mentioned that Nadia Smith developed the whole infrastructure for the averaging kernels, and the validated code to add averaging kernels to the NUCAPS output files is available for operational implantation.	**Medium**
8. Improved IR sea surface effective-emissivity (IRSSE) physical model implementation in the NUCAPS SARTA RTA. This is an on-going activity with JCSDA by Nick Nalli. NUCAPS team may like use	Nick Nalli (STAR) Tong Zhu (STAR) Changyi Tan Murty Divakarla Ken Pryor (STAR SME) Satya Kalluri (STAR SME)	• STAR NUCAPS team should be sufficient to implement that IRSSE upgrade into SARTA. However, a "working group" meeting on this topic, with Chris, Changyi, Tong, me, along with the UMBC SARTA team (Larrabee, Chris, and Sergio) may resolve issues in moving forward. • Assistance from STC team (Chris Barnet) along with corporate knowledge in the SARTA "reflected downwelling" approximation would be helpful.	**Low**

NUCAPS Team Collaborations with External Agencies for Risk Mitigation

Topic	POCs	Ongoing Actions/Mitigation Efforts	Risk
9. Algorithm improvements, implementation of new trace gas products (e.g. N2O, HNO3, NH3) An in-depth discussion on producing new trace gas products from NUCAPS would help future NUCAPS algorithm upgrades.	Juying Warner (UMD) Nick Nalli (STAR) Murty Divakarla (STAR) Changyi Tan (STAR) Chris Barnet/STC Ken Pryor (STAR SME) Satya Kalluri (STAR SME)	• Juying Warner provides necessary trace gas related improvements to the NUCAPS team. She was funded by NASA for over 10 years to specifically develop these 3 products, among other things, for AIRS. Juying's expertise would suffice NUCAPS needs. • a "working group" meeting on this topic with other stake holders and users may resolve issues in moving forward.	Medium to Low
10. NUCAPS augmentation for GEO hyperspectral sounding product development We need communications with STC (Chris Barnet) regarding the FOR configurations in the preprocessor and relevant LUTs.	Changyi Tan (STAR) Tong Zhu (STAR) Tianyuan Wang (STAR) Murty Divakarla (STAR) Nick Nalli (STAR) Mike Wilson (STAR) Ken Pryor (STAR SME) Satya Kalluri (STAR SME)	• The GEO-CrIS will not have a microwave instrument and we need to optimize IR-only retrievals. Earlier results of IR-only implementations at STAR yielded larger RMS differences with very high yield, and Chris Barnet has implemented some quality flags mitigating the unavailability of microwave QC. Thus we need Chris's input on this. • Examine cloud-clearing methodologies based on temporal sequence of hyper spectral radiance availability ✓ Use the proxy data provided by STAR SDR team and develop IR-only retrievals.	Medium

NUCAPS Team Collaborations with External Agencies for Risk Mitigation

Topic	POCs	Ongoing Actions/Mitigation Efforts	Risk
10. Field campaigns and user feedback Get recommendations on NUCAPS products implementations	Juying Warner (UMD) Nick Nalli (STAR) Murty Divakarla (STAR) Changyi Tan (STAR) Chris Barnet/STC Ken Pryor (STAR SME) Satya Kalluri (STAR SME)	▪ Chris Barnet has been a POC on field campaigns pertaining to the JPSS PGRR Initiatives, for example FIREX, ENRR, Hurricane dropsonde campaigns, among others. Originally there was division of tasks with STC taking the lead on JPSS PGRR and STAR taking the lead on cal/val, but we would benefit from more collaboration and I think Chris is now onboard with that (i.e., since we've been having the "All-Hands" coordination meetings). ▪ STAR NUCAPS team has independently established the necessary collaborations for the ongoing PNE/AEROSE campaigns. Our primary collaborators (whom we depend on) are Howard University NCAS, NOAA/ESRL and NOAA/AOML. ▪ Discussion with Chris and the STC Team will be needed for establishing a "MOU" between STAR and STC regarding PGRR Initiatives and campaigns associated with them.	**Medium**