Beta Maturity Science Review For NOAA-21 NUCAPS

Presented by
NUCAPS Team Members
Date: 1 June 2023

Maturity Review – Entry Criteria

- Product Requirements
- Pre-launch Performance Matrix/Waivers
- Beta Maturity Performance Validation
  - On-orbit instrument performance assessment
    - Identify all of the instrument and product characteristics you have verified/validated as individual bullets
      - CrIS SDR/GEO, ATMS TDR/GEO are of Provisional Maturity
      - NUCAPS EDRs: AVTP (*T*), AVMP (H_2O), O_3, CO, CH_4, CO_2, OLR
    - Identify pre-launch concerns/waivers, mitigation and evaluation attempts with on-orbit data
      - None
- Users/Downstream-Products feedback
  - NA/ for Beta Maturity
- Risks, Actions, Mitigations
  - Potential issues, concerns
- Path forward (to the next maturity stage)
- Summary

Maturity Review – Exit Criteria

- Beta 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
      - NUCAPS EDRs: AVTP (*T*), AVMP (H_2O), O_3, CO, CH_4, CO_2, OLR
    - Provide summary of pre-launch concerns/waivers mitigations/evaluation and address whether any are still a concern that raises a risk.
      - None
- Updated Maturity Review Slide Package addressing review committee's comments for:
  - Cal/Val Plan and Schedules: Yes
  - Product Requirements: Yes, in the Supplement
  - Beta Maturity Performance: Yes
  - Risks, Actions, Mitigations: Yes
  - Path forward (to the next maturity stage): Yes, Provisional Maturity

NOAA-21 NUCAPS Beta Maturity Review

NUCAPS EDR Products

Atmospheric Vertical Temperature Profile (AVTP)
Atmospheric Vertical Moisture Profile (AVMP)
Atmospheric Ozone Profile (O_3)
Outgoing Longwave Radiation (OLR)
Carbon Monoxide (CO)
Methane (CH_4)
Carbon Dioxide (CO_2)

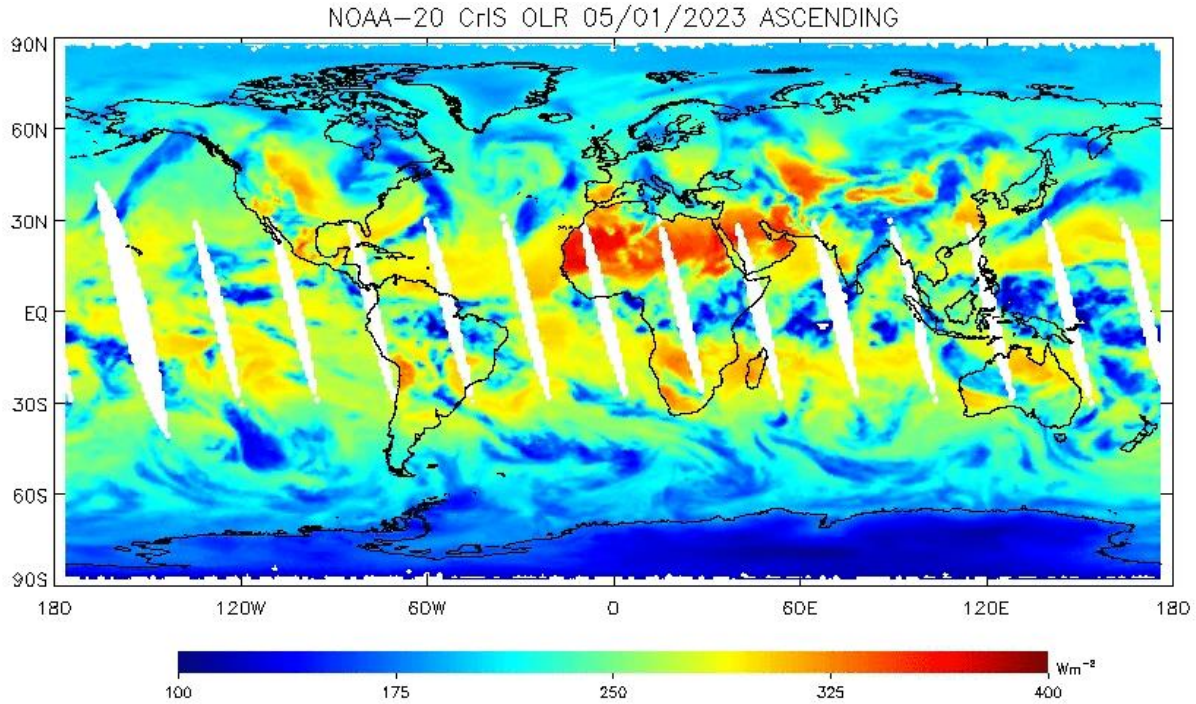
NOAA-21 NUCAPS BETA Maturity Review

Products: AVTP, AVMP, O_3, OLR, CO, CH_4, and CO2

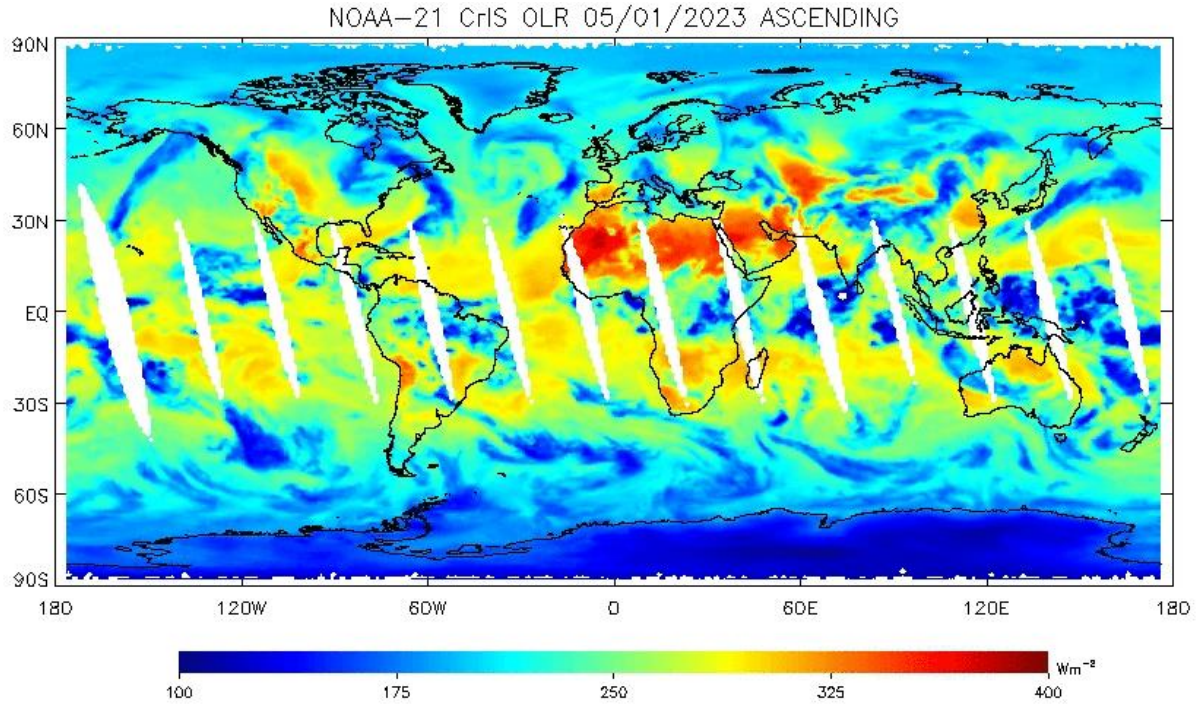
1 June 2023

NUCAPS Outgoing Longwave Radiation (OLR) NOAA-20 vs NOAA-21

1-15 May 2023 NOAA-20 OLR



1-15 May 2023 NOAA-21 OLR



The **NOAA Unique Combined Atmospheric Processing System (NUCAPS)** operationally produces an array of atmospheric composition and trace gas Environmental Data Records (EDRs) from Hyperspectral Thermal Infrared Sounders (NOAA-20/21 CrIS, Metop IASI)

Outline

- NUCAPS Algorithm team members
- Product maturity definitions
- Algorithm version(s), processing environment
- Evaluation of NOAA-21 products to specification requirements
- Documentation
- Summary
- Path forward for Provisional Maturity
- Backup Slides

NUCAPS Algorithm Team Members

Name	Organization	Major Task
Ken Pryor, Laurie Rokke	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	Science/Technical lead
Tong Zhu	IMSG at NOAA/NESDIS/STAR	Algorithm development and maintenance
Nick Nalli	IMSG at NOAA/NESDIS/STAR	Validation lead
Margarita Kulko	IMSG at NOAA/NESDIS/STAR	OLR Algorithm development and maintenance
Juying Warner	Univ. of Maryland College Park	Trace Gases algorithm(s) development
Zaizhong Ma	IMSG at NOAA/NESDIS/STAR	First Guess Regression updates
Mike Wilson, Tish Soulliard	GAMA-1 at NOAA/NESDIS/STAR	STAR-ASSISTT POC for Unified NUCAPS package
Rebekah Esmaili, Chris Barnet, Nadia Smith	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
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 assessment, single CrIS FOV retrieval 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.

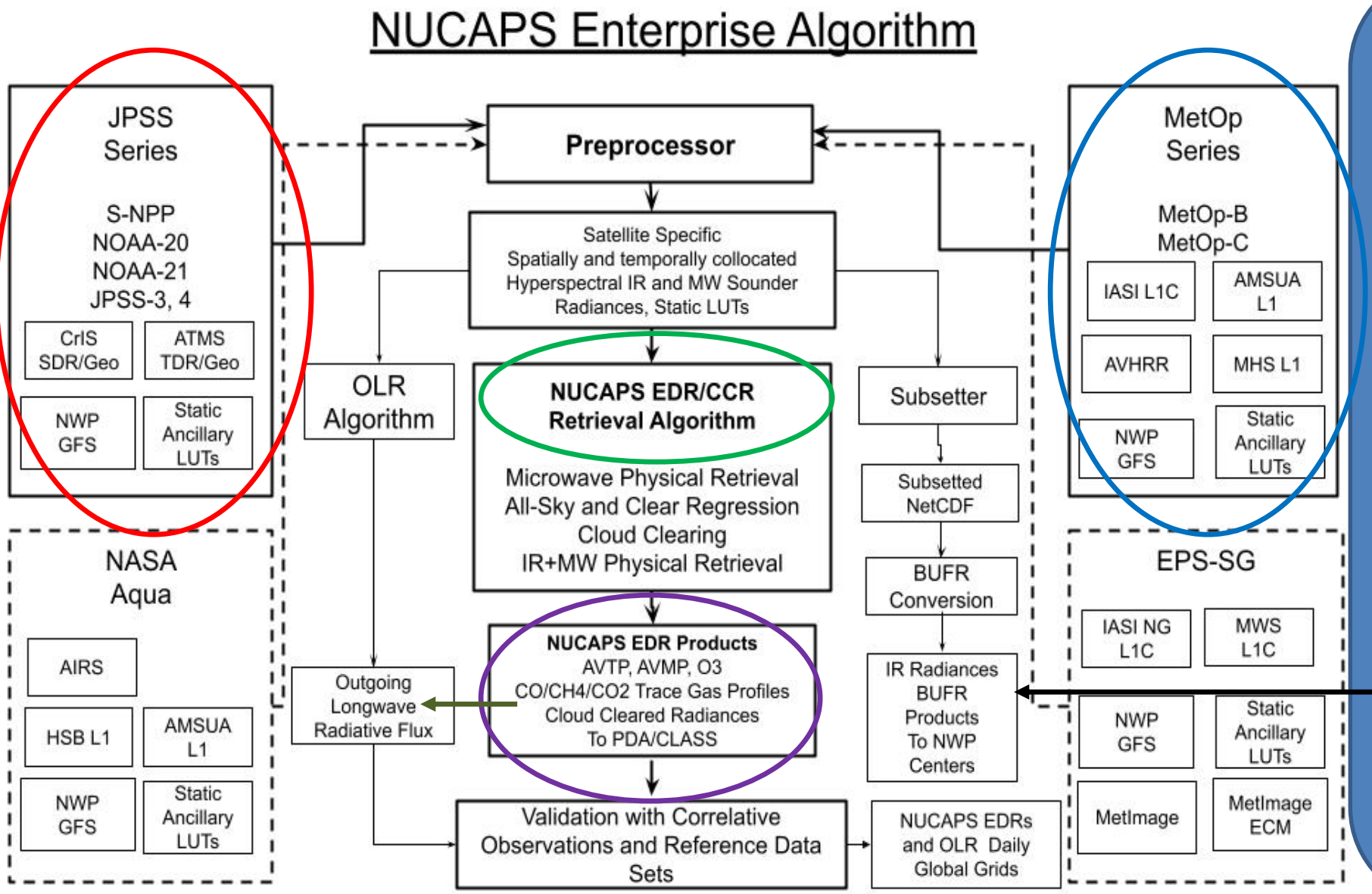
2. **Provisional**
   - Product performance has been demonstrated through analysis of a large, but still limited (i.e., not necessarily globally or seasonally representative) number of independent measurements obtained from selected locations, time periods, or field campaign efforts.
   - Product analyses 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.

- This presentation showcases NOAA-21 NUCAPS EDR products for Beta maturity, and path forward for Provisional and Validated maturity

NOAA Unique Combined Atmospheric Processing System (NUCAPS)

Algorithm Version, Processing Environment, Inputs, Outputs



- NUCAPS runs within the Hyperspectral Enterprise Algorithm Package (HEAP v2.3) and operationally generates AVTP, AVMP, O_3, OLR, CO, CH_4 and CO_2 products from JPSS NOAA-20 CrIS and Metop-B/C IASI hyperspectral infrared sounding instruments.
- HEAP (NUCAPS) v3.0 is currently in operations. Algorithm updates, sensor-independent LUTs, QC/QA are all updated for MetOp-C/B/ using the latest baseline version of NOAA-20
- BUFR product w/NOAA-21 CrIS full spectral radiances, thinned radiance data sets
- 'NOAA-21-Ready' NUCAPS algorithm uses NOAA-20 LUTs

NUCAPS NOAA-21 Version 3.1

Item	V3.0 (December 2020) HEAP 2.3	V3.1 (June 2023) HEAP 2.4	V3.1 NOAA-21-Ready Algorithm
	NOAA-20/Metop-C **Currently in Operations**	NOAA-20/Metop-C CCAP Delivery to NCCF: June 2023	Required Changes for NOAA-21 Provisional Maturity
MW a-priori	✓ 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 /Lon by 5 degrees); 0, 6, 12, and 18 UTC.	✓ No changes – as is for NOAA-20	✓ No changes – as is for NOAA-20
MW Tuning	✓ Two focus days (20190215, 20190815) and MIT forward model	✓ NOAA-20	✓ Currently using NOAA-20 LUT • **Requires an update for NOAA-21**
Cloudy Regression	✓ PC regression using NOAA-20 all-sky radiances matched with ECMWF, Updated with STC regression code; used four Focus Days	✓ No change – as is for NOAA-20	✓ Currently using NOAA-20 LUT • **Requires an update for NOAA-21**
Clear Regression	✓ PC regression using NOAA-20 CCR radiances matched with ECMWF ✓ Used four Focus Days (20180415, 20180715, 20181015, 20190115)	✓ No change – as is for NOAA-20 ✓ Updated regression code	✓ Currently using NOAA-20 LUT • **Requires an update for NOAA-21**
Emissivity Regression	✓ NO change from the operational version (V2.1.12d)	✓ No change – as is for NOAA-20	✓ No changes – as is for NOAA-20 ✓ Experiments on-going to update with CAMEL
IR Tuning	✓ Double Difference Method using NOAA-20 radiances and ECMWF SARTA simulations	✓ No change – as is for NOAA-20	✓ Currently using NOAA-20 LUT • **Requires an update for NOAA-21**
CO climatology/QC	✓ No Change from the operational version (V2.1.12d)	✓ No change – as is for NOAA-20	✓ No changes – as is for NOAA-20
CH_4/N2O a-priori	✓ Updated CH_4/N_2O a-priori; QC flag updates to CH_4	✓ No change – as is for NOAA-20	✓ No changes – as is for NOAA-20
SO_2	✓ Climatology	✓ Retrieval turned on	✓ Retrieval turned on
CO_2 a-priori	✓ Updated CO_2 a-priori and QC flag updates	✓ CO_2 a-priori updates and QC flags	✓ No changes – as is for NOAA-20
CrIS Noise File	✓ No change from the operational version (V2.1.12d)	✓ No change – as is for NOAA-20	✓ Currently using NOAA-20 LUT • **Requires an update for NOAA-21**
Channel Selection for cloud-clearing, T(p),q(p)	✓ Minor updates of channels ✓ Super saturation QC flag implemented	✓ No change – as is for NOAA-20	✓ No changes – as is for NOAA-20
Channels selection for trace gases	✓ No change from the operational version (V2.1.12d)	✓ No change – as is for NOAA-20	✓ No changes – as is for NOAA-20
Averaging Kernels and other product improvements	✓ None in the output file	✓ Added Averaging Kernels to the NUCAPS Product File ✓ Updated ozone a-priori ✓ Surface corrections to alleviate product use ✓ Damping factor update to improve boundary layer biases	✓ Carried forward these additional improvements ✓ No changes – as is for NOAA-20

NUCAPS v3.0 (Currently in OPS) vs v3.1 (going into OPS)

NUCAPS V3.0
NOAA-20
NOAA-21

- NCCF currently generates NOAA-20 and -21 NUCAPS products (in UAT I&T) using NOAA-20 v3.0 LUTs.
- NOAA-21 NUCAPS products (NCCF, v3.0) have been verified for consistency with offline runs and NOAA-20 operational retrievals (v3.0).

NUCAPS V3.1
NOAA-20
NOAA-21

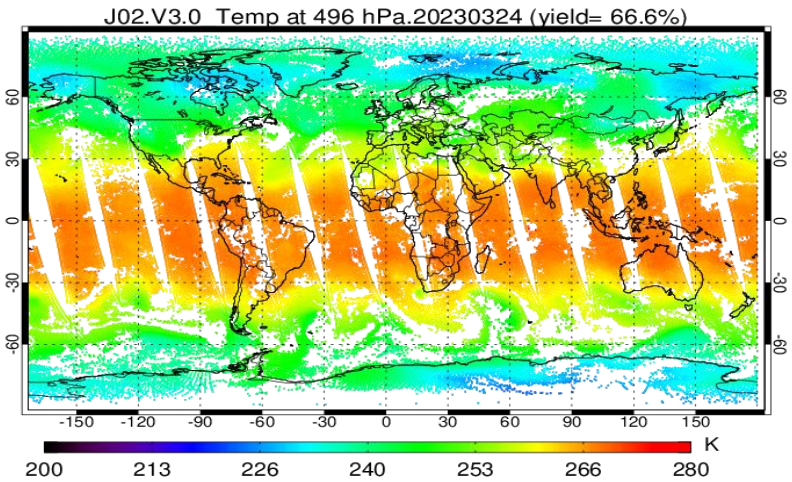
- NUCAPS v3.1 CCAP delivery to NCCF is expected in June 2023.
- OSPO successfully completed Software Code Review (Feb 2023) and the ASSISTT Team plans to submit the CCAP in June 2023 for eventual operations.
  - V3.1 NOAA-20 NUCAPS EDR products (offline code) have been validated using a hierarchy of validation data sets (supplemental slides).
  - No detrimental impact to the operational NOAA-20 NUCAPS products (v3.0)
  - Product improvements over v3.0
- V3.1 NOAA-21 algorithm is “NOAA-21 Ready” algorithm that uses NOAA-20 LUTs.
- Performed NOAA-21 Beta Maturity evaluations using both v3.0 and v3.1 algorithms.
- NOAA-21 v3.1 with updated LUTs will be used for NOAA-21 Provisional Maturity.

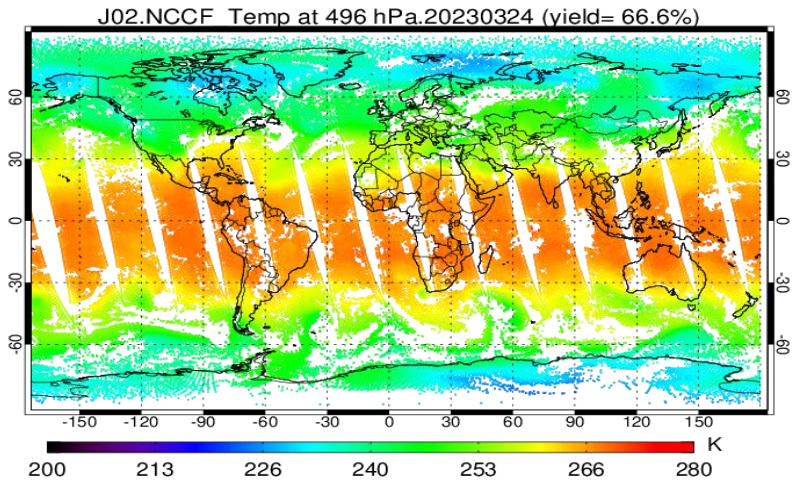
NOAA-21 NCCF Operations vs Offline NUCAPS (v3.0) Product Consistency
24 March 2023 Focus Day

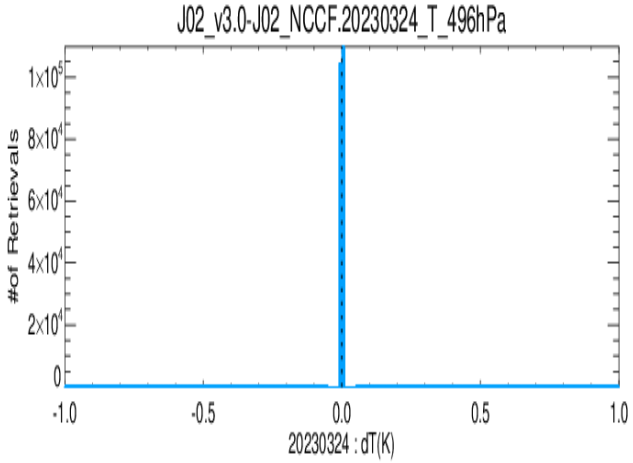
NOAA-21 NUCAPS v3.0 offline

NOAA-21 NCCF HEAP Operations

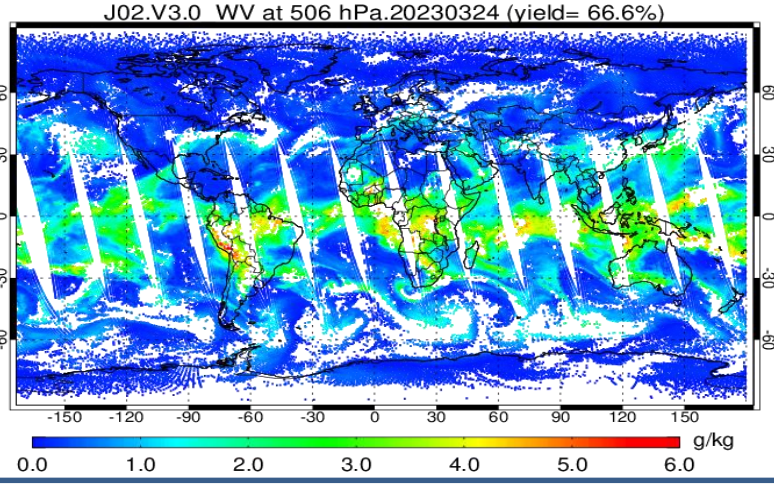
Temperature (496-hPa)

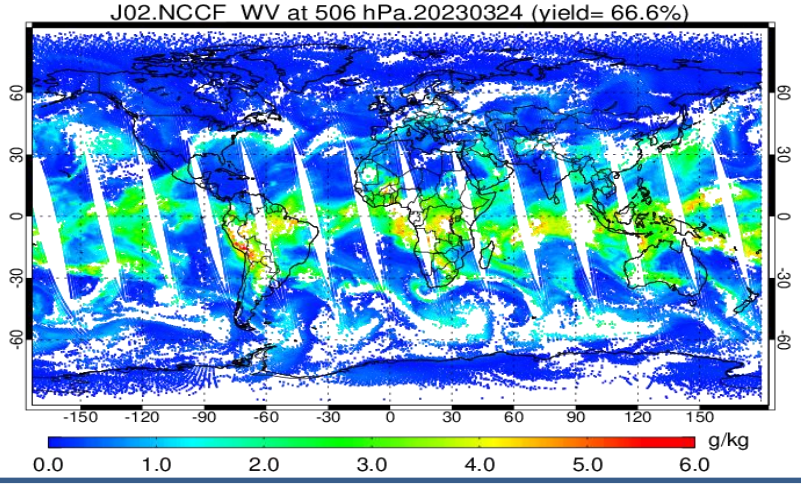


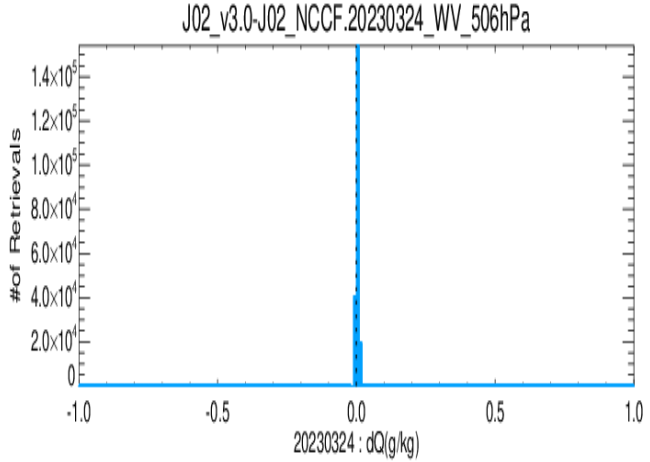




Water Vapor (506-hPa)



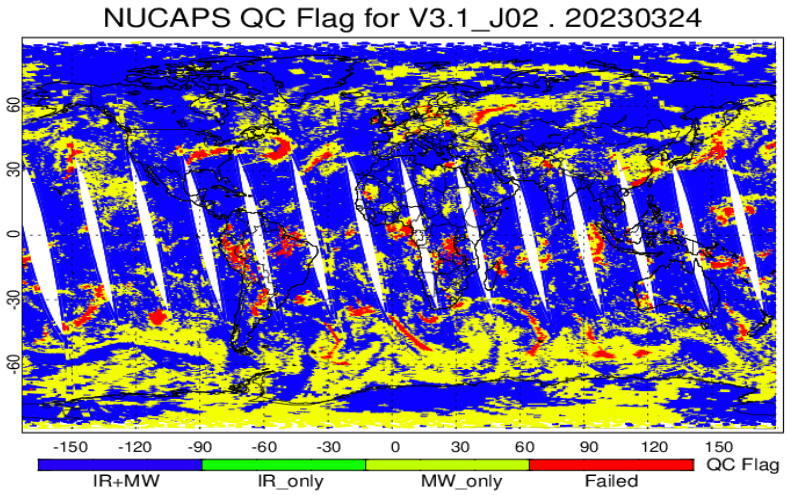




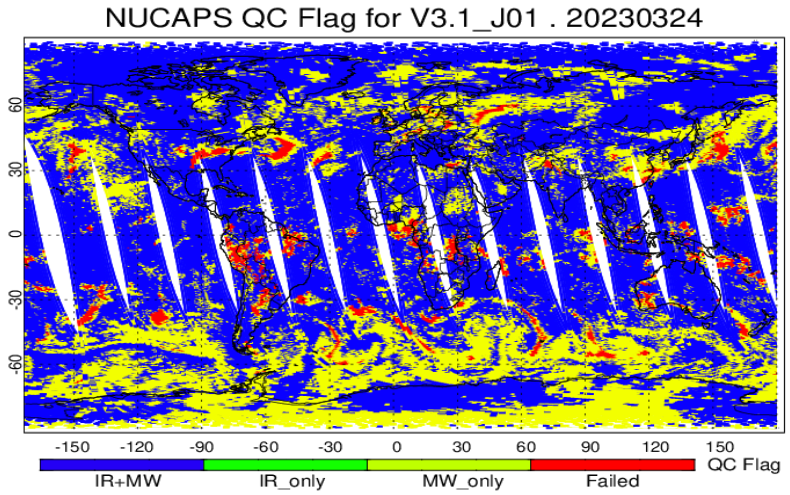
- NCCF operations routinely generates “NOAA-21-Ready” (NUCAPS v3.0) NUCAPS EDR products.
- NCCF products conform to NOAA-21 offline (v3.0) runs.

NUCAPS QC Flags for NOAA-20/21 V3.0/V3.1 (24-Mar-2023)

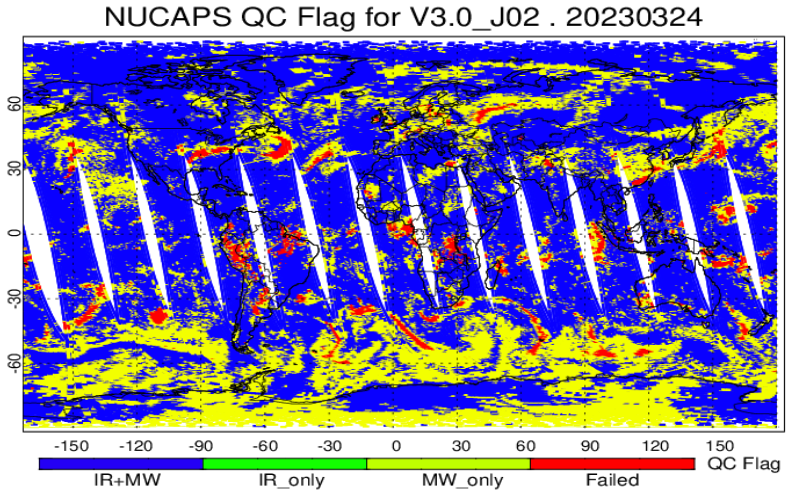
NOAA-21 v3.1



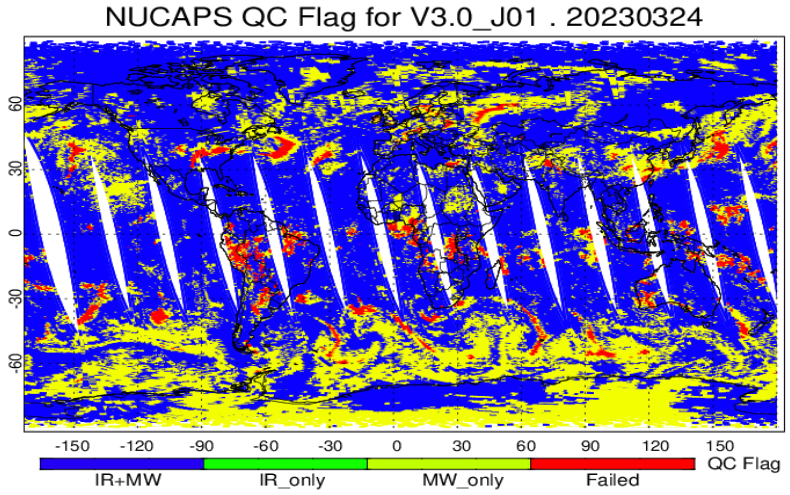
NOAA-20 v3.1



NOAA-21 v3.0 (OPS)



NOAA-20 v3.0 (OPS)



IR+MW pass QC: 65.8%

IR Failed & MW pass QC: 31.3%

Both IR & MW failed: 2.8%

- ✓ NUCAPS v3.0 (OPS) and v3.1 (to be in OPS) are consistent in QC flags and products.
- ✓ V3.1 has no detrimental impact to the operational NOAA-20 NUCAPS products (v3.0) (supplemental slides).
- ✓ $T(p)$, $q(p)$, $O_3(p)$ use IR+MW QC for accepted cases; trace gas products include an additional set QC flags.

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

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

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

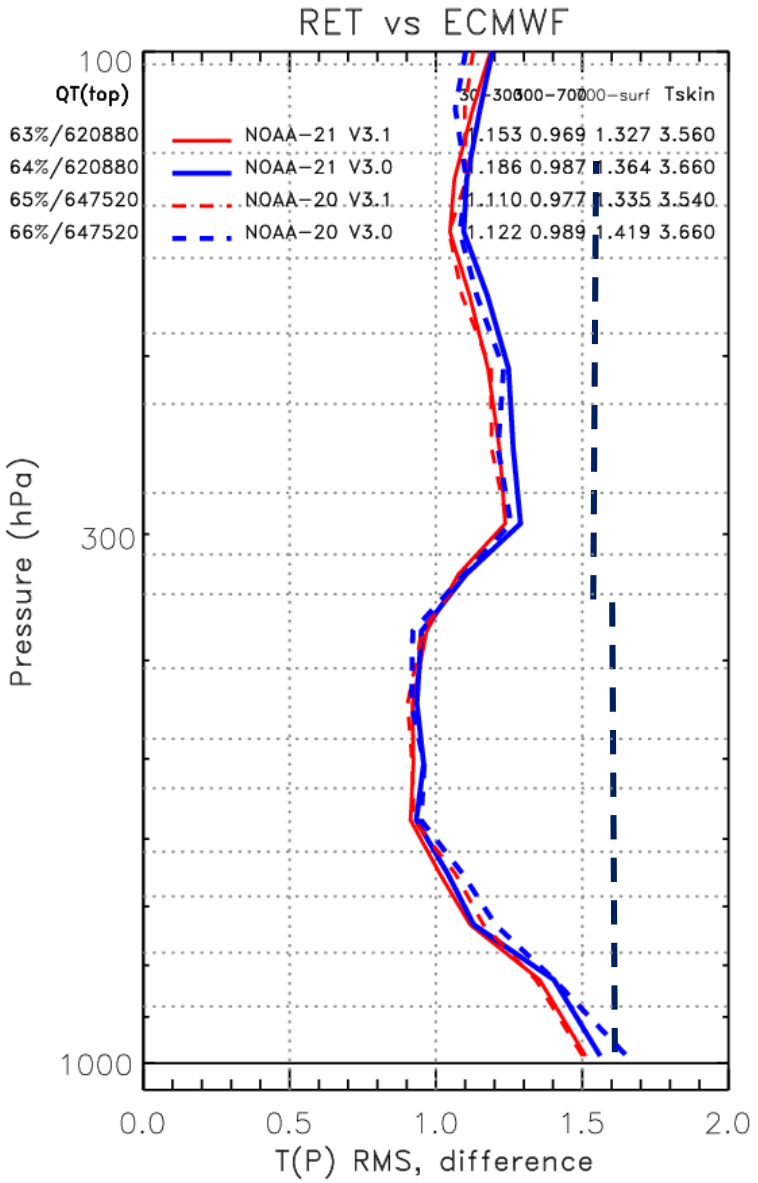
Moisture Profile

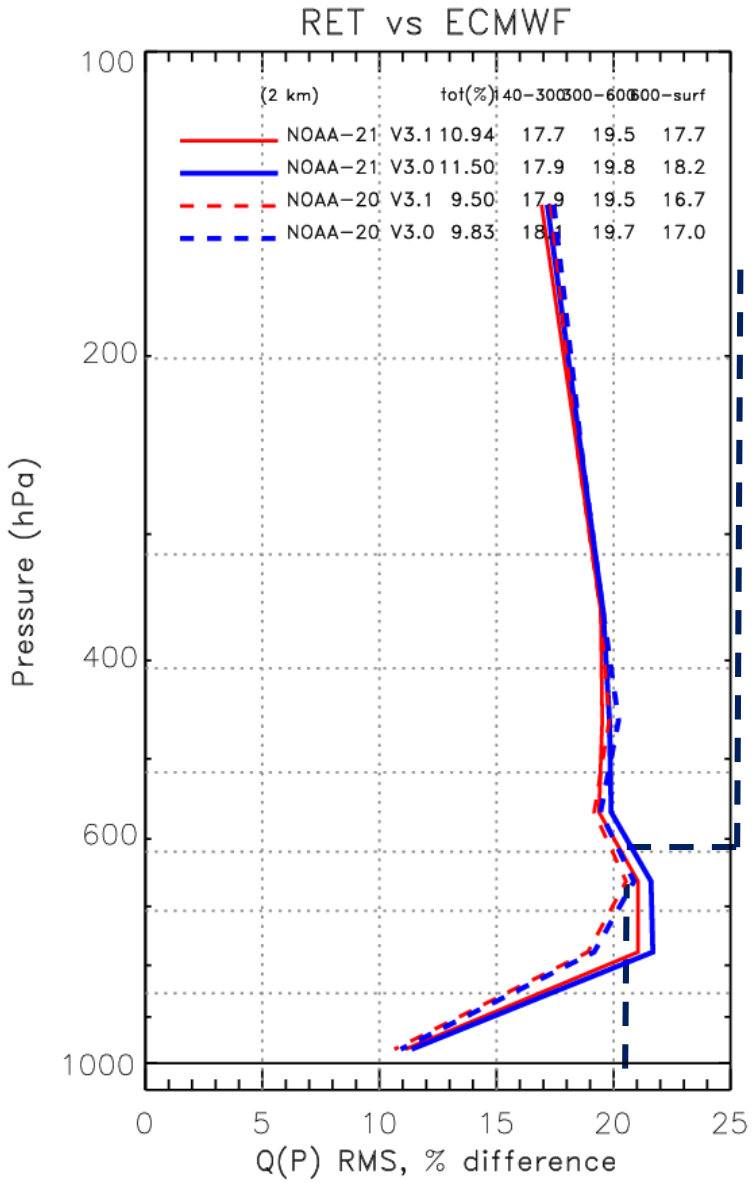
CrIS/ATMS Atmospheric Vertical Moisture Profile (AVMP) Measurement Uncertainty – 2-km Layer Average Mixing Ratio % Error		
PARAMETER	**THRESHOLD**	**OBJECTIVE**
AVMP, Cloud fraction < 50%, surface to 600 hPa	Greater of 20% or 0.2 $g \cdot kg^{-1}$ / 2-km layer	10%
AVMP, Cloud fraction < 50%, 600–300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

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)

NUCAPS v3.0 (OPS) and v3.1 Product Consistency
AVTP and AVMP wrt ECMWF (Focus Days Used: 2023/03/24, 2023/02/27)





NOAA-21 Global v3.1
NOAA-21 Global v3.0 (OPS)
NOAA-20 Global v3.1
NOAA-20 Global v3.0 (OPS)

- NOAA-21 and NOAA-20 NUCAPS *T*(*p*), *q*(*p*) RMS differences with matched ECMWF show very similar characteristics.
- NUCAPS v3.1 shows slightly better agreement than the current operational version v3.0 (more figures in supplemental slides).
- NOAA-21 NUCAPS Beta maturity evaluations are based on the NUCAPS v3.1.

NOAA-21 NUCAPS EDR Products Evaluation

- NCCF operationally generates NOAA-21 NUCAPS products using “NOAA-21 Ready” Algorithm that uses NOAA-20 v3.0 LUTs.
  - ✓ NUCAPS v3.0 products from NOAA-20/21 show consistency both qualitatively and quantitatively.
- NOAA-21 Beta Maturity evaluations are performed using v3.0 and v3.1 algorithms.
  - ✓ NOAA-21 vs NOAA-20 EDR Products:
    - Quality flag evaluations
    - Products consistency (qualitative as well as quantitative)
    - Preliminary validations, error budget
    - Enterprise nature, product consistency: NOAA-20, NOAA-21, and MetOp-C
  - ✓ Products evaluated:
    - Atmospheric Vertical Temperature and Moisture Profiles (AVTP, AVMP)
    - Ozone profile product (O_3)
    - Outgoing Longwave Radiation (OLR)
    - Trace Gas profile products: CO(p), CH_4(p), CO_2(p)
  - ✓ NUCAPS v3.1 shows improved performance compared to the current operational v3.0.

NUCAPS Product Validation Methodology Hierarchies

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

$T/H_2O/O_3$ Profiles

1. **Numerical Model (e.g., ECMWF, NCEP/GFS) Global Comparisons**
   - Large, truly global samples acquired from Focus Days
   - Useful as "transfer standard" (via double-differences), bias tuning and regression
   - Limitation: Not independent truth data
2. **Satellite Sounder EDR (e.g., AIRS, COSMIC) *Intercomparisons***
   - Global samples acquired from Focus Days (**NOAA-20/NOAA-21**)
   - Limitation: Similar error characteristics
3. **Conventional PTU/O3 Sonde Matchup Assessments**
   - WMO/GTS operational sondes (NPROVS) or O3-sonde network (e.g., SHADOZ)
   - Representation of global zones, long-term monitoring (*Reale et al.* 2012; *Sun et al.* 2017)
   - Large samples after a couple months (e.g., *Divakarla et al.,* 2006)
   - Limitations: Skewed distributions; mismatch errors; non-uniform radiosondes, assimilated
4. **Dedicated/Reference PTU/O_3 Sonde Matchup *Assessments***
   - *Dedicated* for the purpose of satellite validation
   - Reference sondes: CFH, **GRUAN** corrected RS92/RS41
   - **ARM sites** (e.g., *Tobin et al.,* 2006), **AEROSE**, **HUBC**; collocations facilitated via NPROVS (*Reale et al.* 2012; *Sun et al.* 2017)
   - Limitation: Small sample sizes, geographic coverage
5. **Intensive Field Campaign *Dissections***
   - Include dedicated sondes, some *not* assimilated into NWP models
   - Include ancillary datasets, ideally funded aircraft campaign(s)
   - E.g., **SNAP, AEROSE, RIVAL, CalWater**, JAIVEX, AWEX-G, EAQUATE

Carbon Trace Gases

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

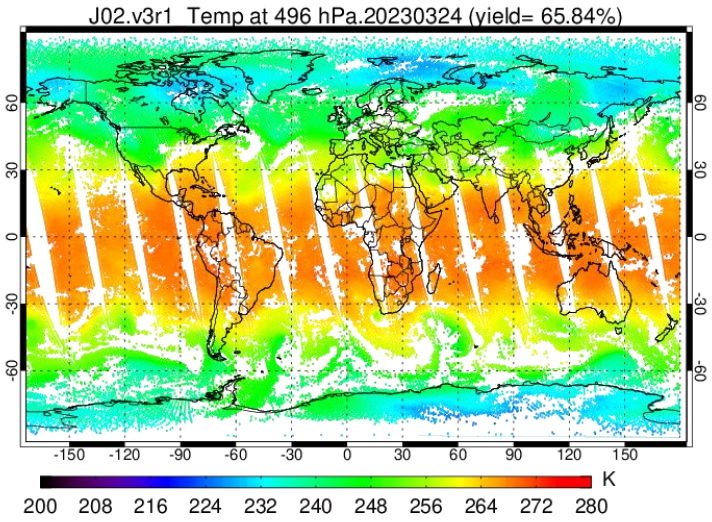
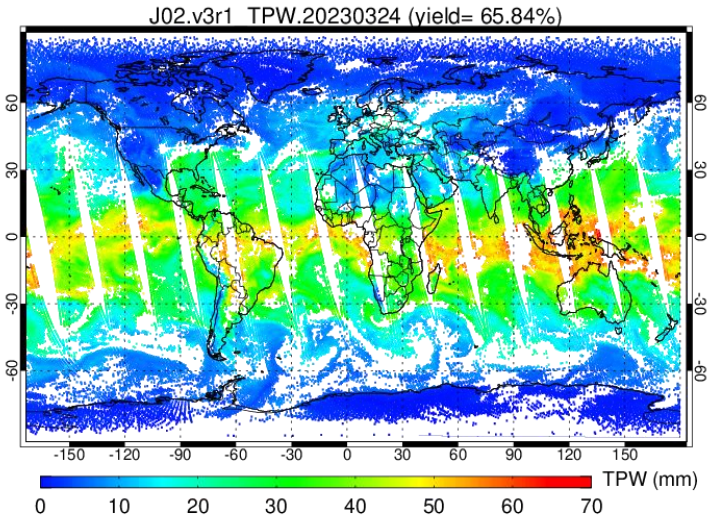
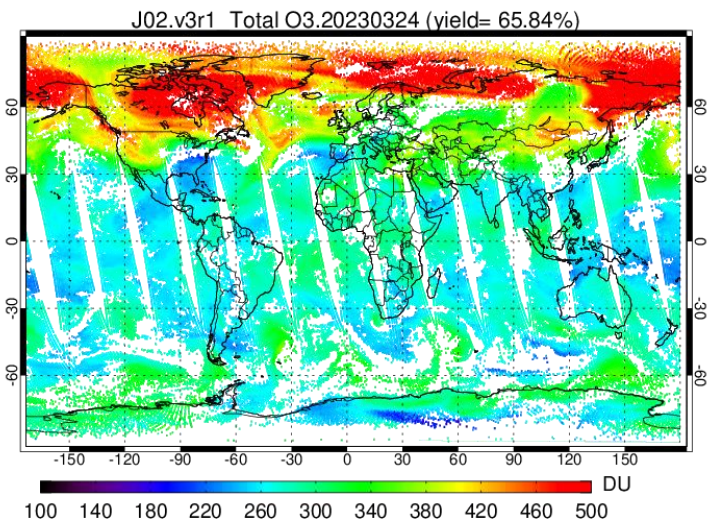
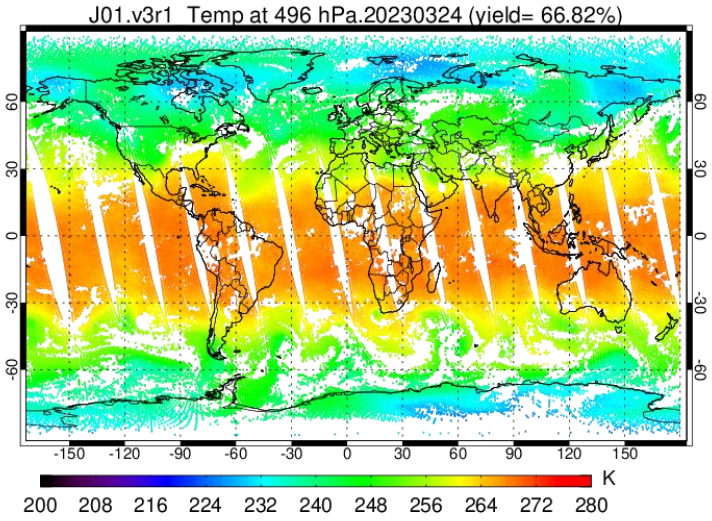
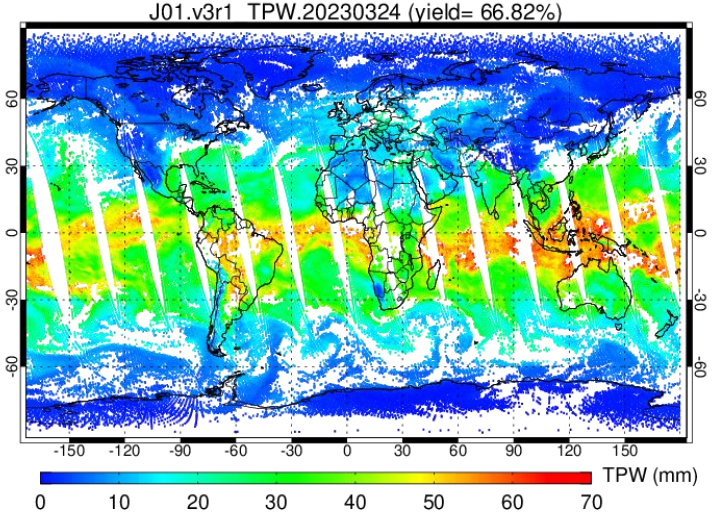
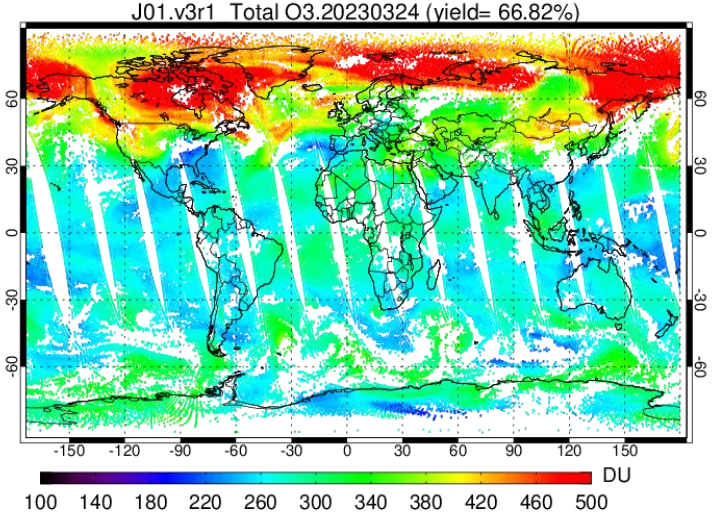
Datasets Used for NOAA-21 NUCAPS EDR Products Evaluation

Focus Days	CrIS Eng Cal/Val Pckg	NOAA-20 (v3.1)	NOAA-21 (v3.1)	ECMWF	TROPOMI	OCO-2	TCCON	AIRS OLR
02/16/2023 02/20/2023	✓ **EP v208*** ✓ **EP v210**	✓ **Yes**	✓ **Yes**	✓ **Yes**	✓ **Yes**	✓ **Yes**	• **Not Available**	✓ **Yes**
02/27/2023 **03/24/2023**	✓ **EP v211**** ✓ **EP v211****	✓ **Yes**	✓ **Yes**	✓ **Yes**	✓ **Yes**	✓ **Yes**	• **Not Available**	✓ **Yes**

*pre-launch cal/val engineering packet (EP)
**CrIS SDR attained provisional maturity with EP v211 cal/val engineering package

- NOAA-20 NUCAPS v3.1 (v3.0 Operational version + updates)
- **NOAA-21 Ready NUCAPS v3.1**
  - ✓ **AVTP, AVMP, O_3:** NOAA-20,-21 global maps and statistical metrics versus **ECMWF** baseline
  - ✓ **CO, CH_4,** and **CO_2:** NOAA-20,-21 global maps versus **TROPOMI** (CO, CH_4), and **OCO-2 v11** (CO_2) baselines
    - TCCON and other in-situ reference measurement matches will be included for Provisional Maturity (require time to collect sample, lag-time between measurement time and availability)
  - ✓ **OLR:** NOAA-21 global maps versus **NOAA-20** and **AIRS OLR** baselines
    - CERES OLR reference data matchups not yet available for Beta Maturity

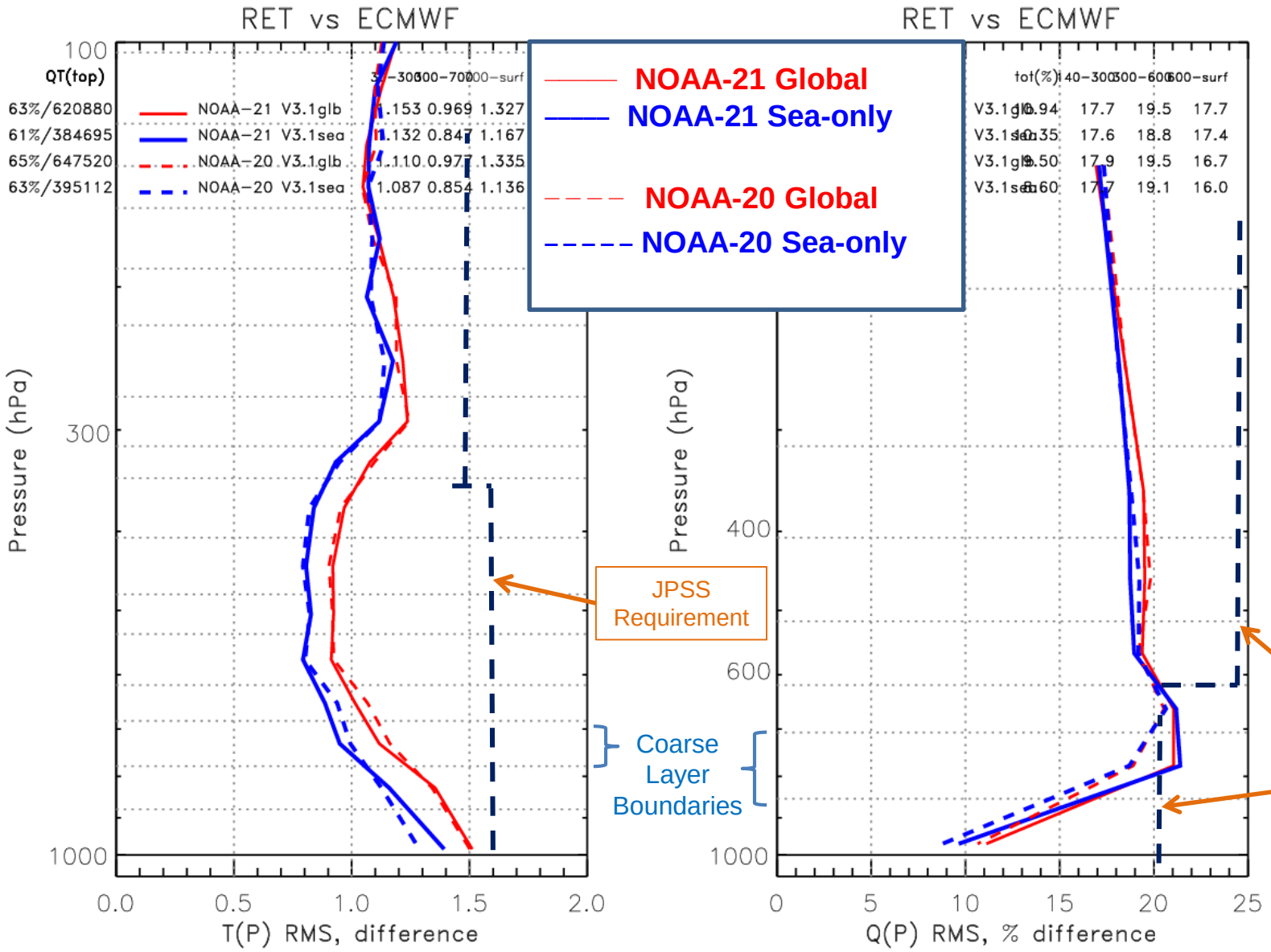
NOAA-21 vs NOAA-20 NUCAPS EDR Retrievals for 24 March 2023 (EP v211)

	Temperature at 496 hPa	TPW (mm)	Total Ozone (DU)
NOAA-21			
NOAA-20			

NOAA-21 NUCAPS EDR retrievals from NOAA-21-Ready algorithm matches very well both qualitatively and quantitatively with the NOAA-20 NUCAPS EDRs. The algorithm produces vertical profiles of temperature, water vapor, O_3, OLR, CO, CH_4, and CO_2. Retrieved profiles (100 layers) span from surface to 0.01 hPa.

NOAA-21 and NOAA-20 AVTP & AVMP Statistical Metrics with ECMWF

Focus Days: 27 February and 24 March 2023 (EP v211)

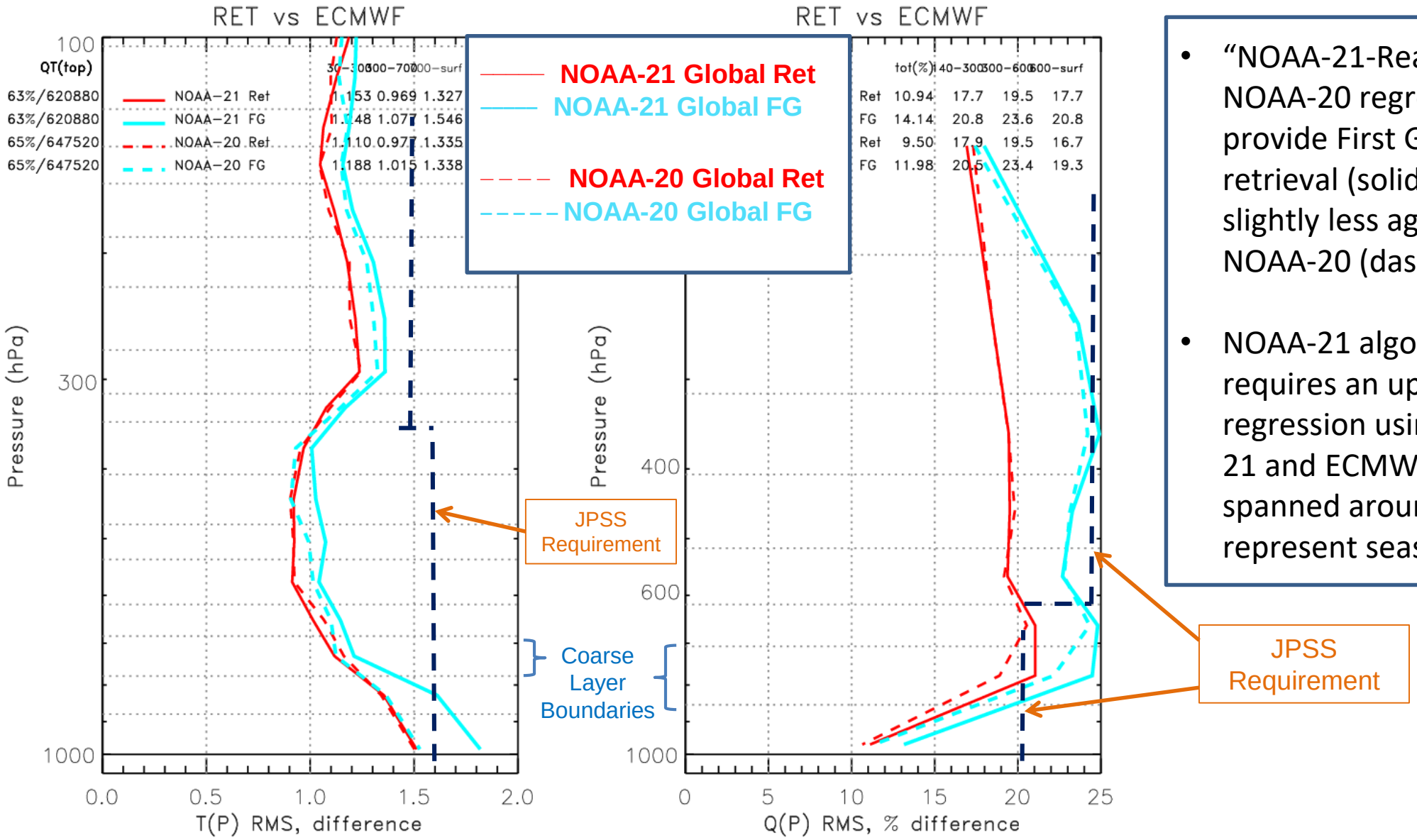


- NOAA-21 and NOAA-20 NUCAPS $T(p)$, $q(p)$ RMS differences with matched ECMWF show very similar characteristics
- Differences in CrIS SDR engineering packets* have no significant impact in the NUCAPS AVTP/AVMP EDRs

*Cal/Val EP v210 (2023/02/20) versus EP v211 (2023/02/27, 2023/03/24)

NOAA-21 and NOAA-20 AVTP & AVMP First Guess vs Final Retrieval

Focus Days: 27 February and 24 March 2023 (EP v211)



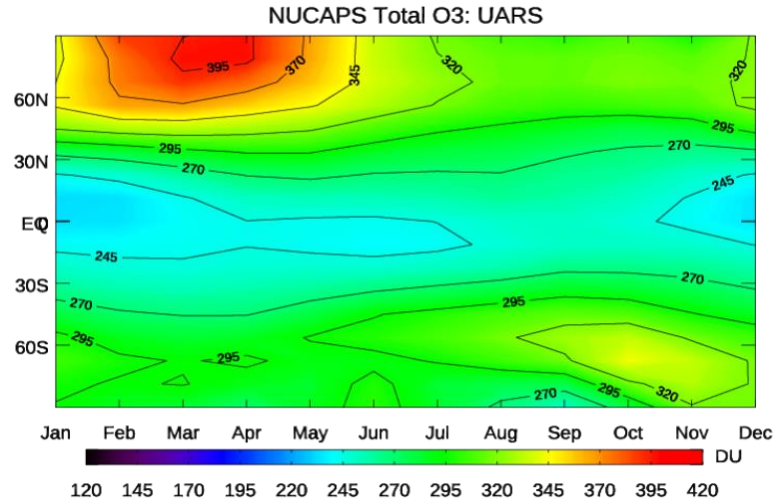
- "NOAA-21-Ready" algorithm uses NOAA-20 regression LUTs to provide First Guess. NOAA-21 FG retrieval (solid cyan) shows slightly less agreement than NOAA-20 (dashed cyan)
- NOAA-21 algorithm eventually requires an update to the FG regression using matched NOAA-21 and ECMWF collocations spanned around the year to represent seasonality

NOAA-21 and NOAA-20 Ozone Statistical Metrics with ECMWF

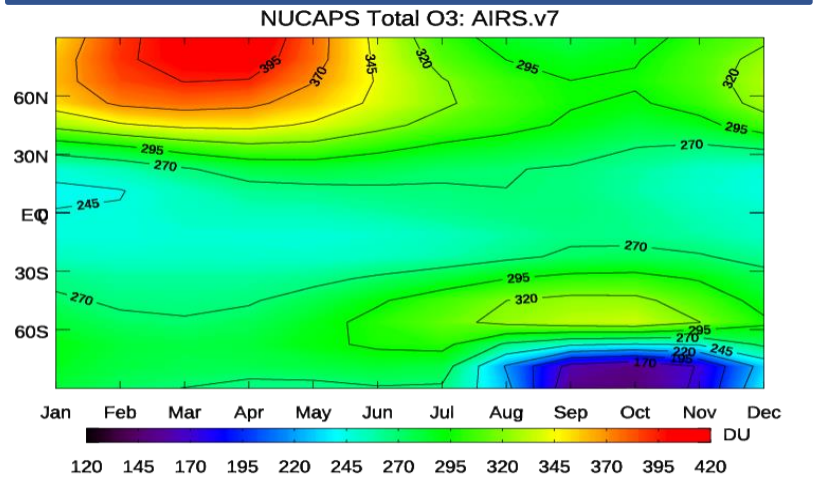
Focus Days: 27 February and 24 March 2023 (EP v211)

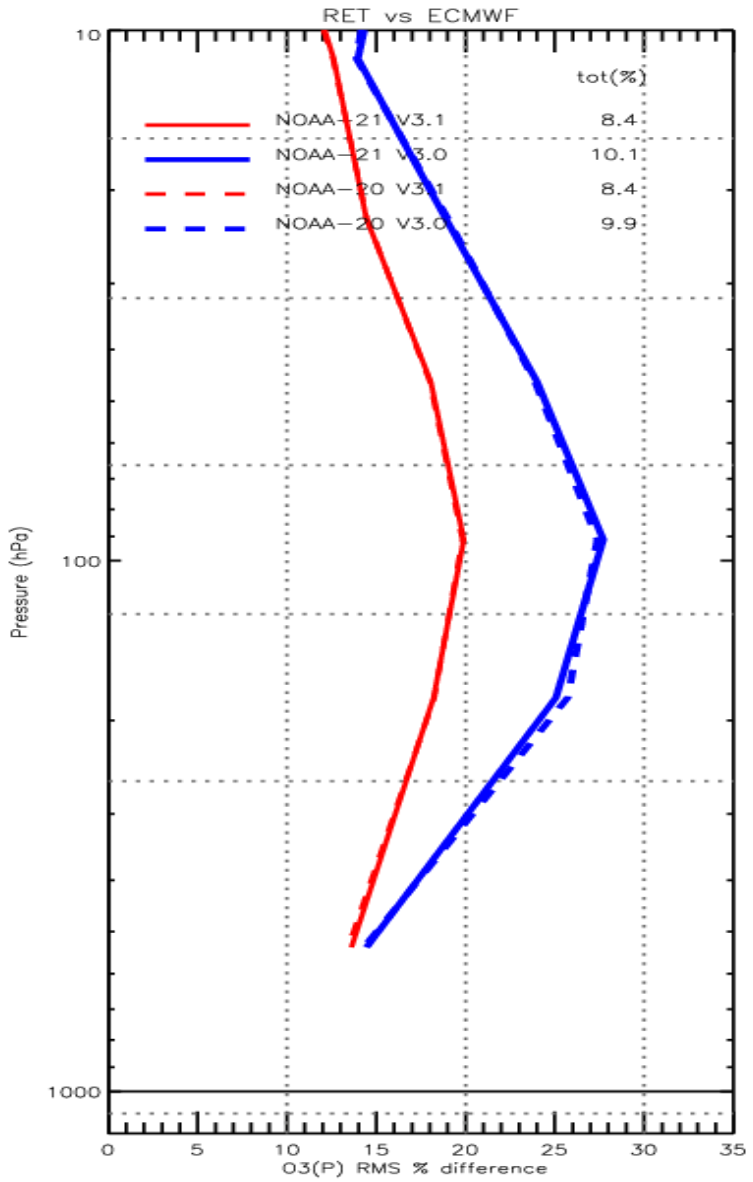
Ozone a-priori changes v3.0 vs 3.1

NUCAPS OPS (v3.0): O_3 a-priori



NUCAPS OPS (v3.1): O_3 a-priori





NOAA-21 Global v3.1

NOAA-21 Global v3.0 (OPS)

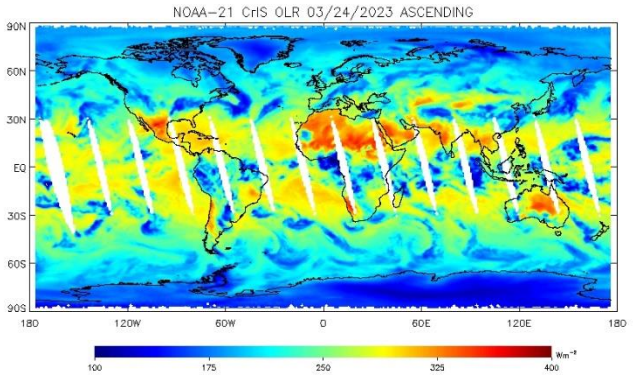
NOAA-20 Global v3.1

NOAA-20 Global v3.0 (OPS)

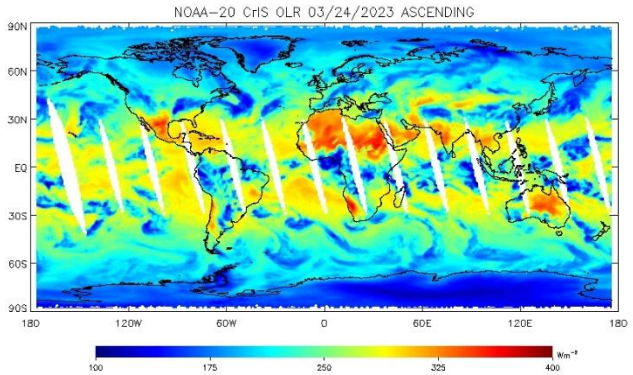
- NOAA-21 and NOAA-20 NUCAPS $O_3(p)$ RMS differences with matched ECMWF show very similar characteristics.
- NUCAPS v3.1 shows improved $O_3(p)$ retrievals in comparison to the current operational v3.0

CrIS Outgoing Longwave Radiation (OLR) NOAA-21 vs NOAA-20 (24 March 2023)

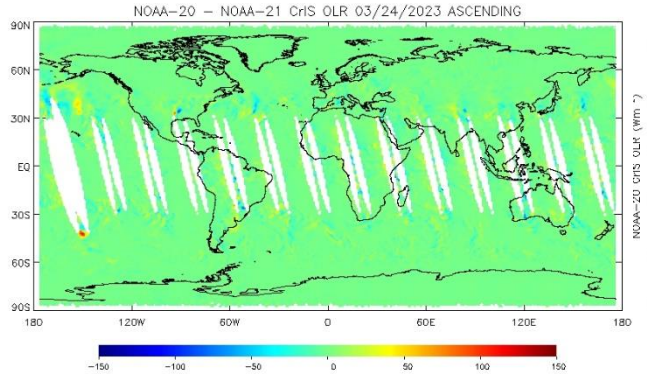
CrIS NOAA-21 Ascending

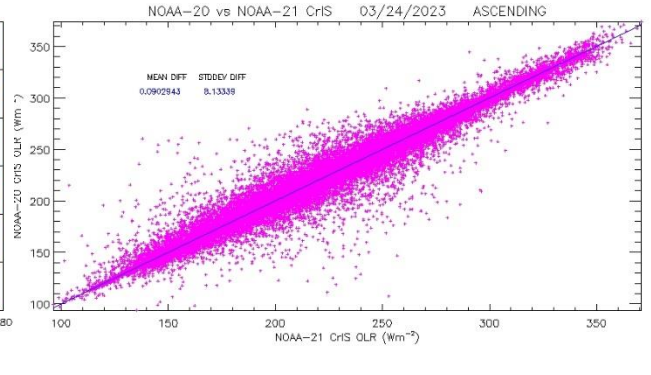


CrIS NOAA-20 Ascending



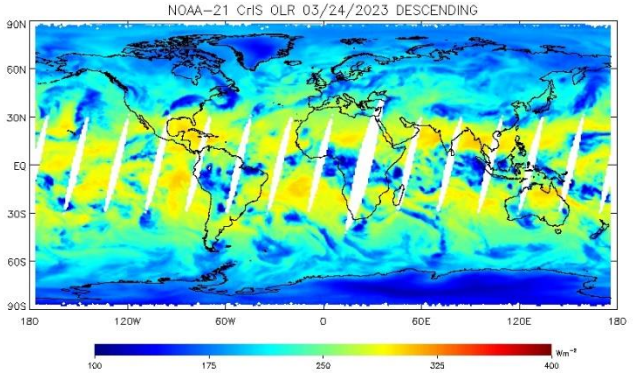
OLR Differences



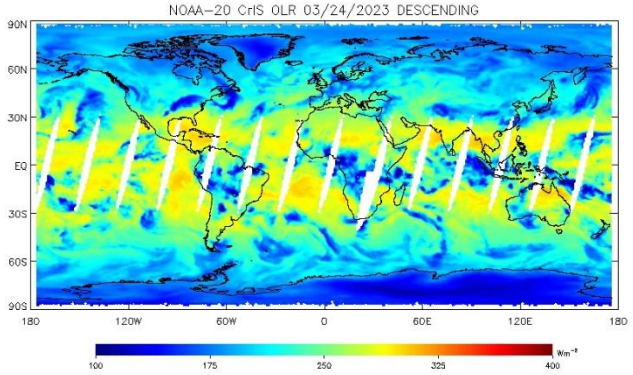


Ascending Mean Diff (W/m²)	0.1
STDev (W/m²)	8.1

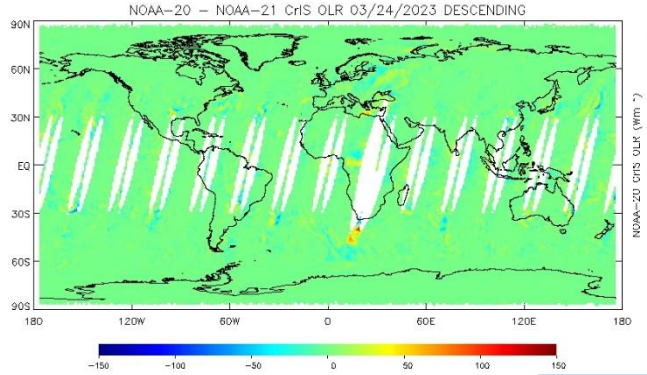
CrIS NOAA-21 Descending

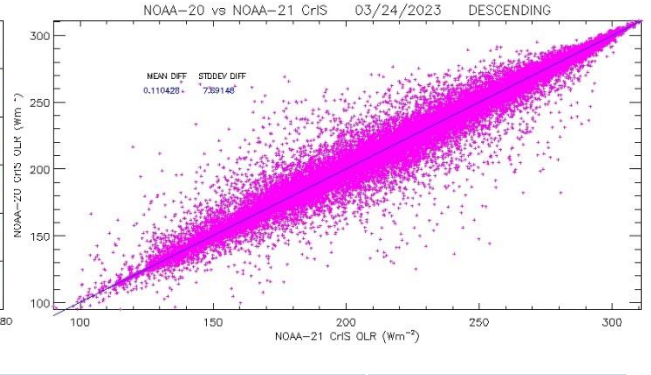


CrIS NOAA-20 Descending



OLR Differences



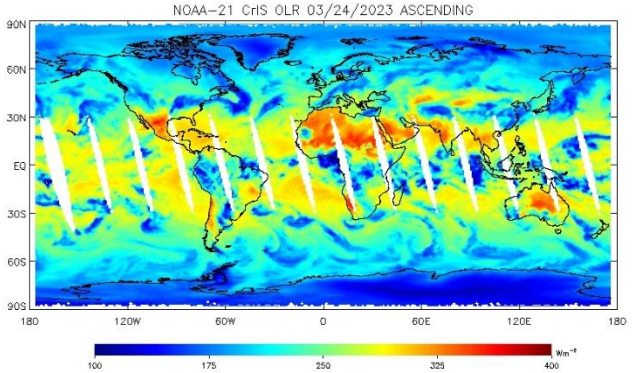


Descending Mean Diff (W/m²)	0.1
STDev (W/m²)	7.7

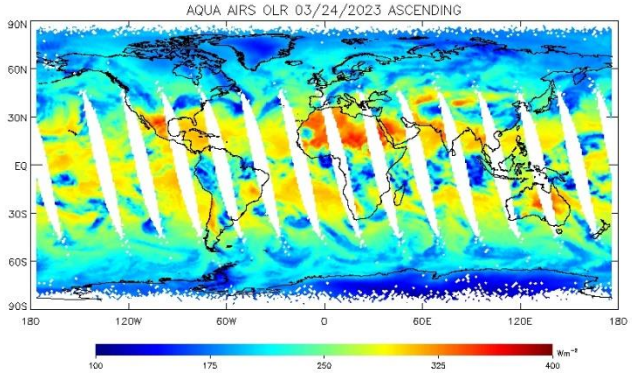
✓ NOAA-21 OLR agrees well with NOAA-20 for both ascending and descending orbits.

CrIS OLR NOAA-21 vs AIRS (24 March 2023)

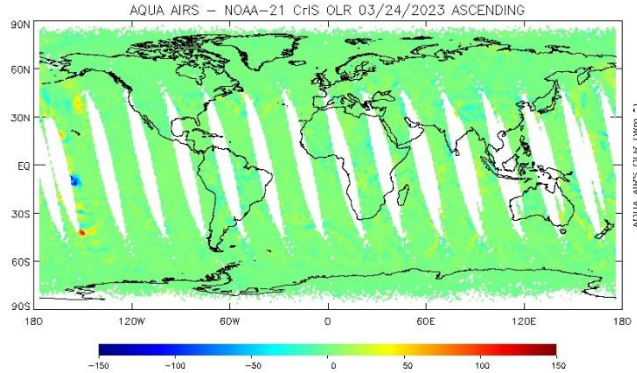
CrIS NOAA-21 Ascending

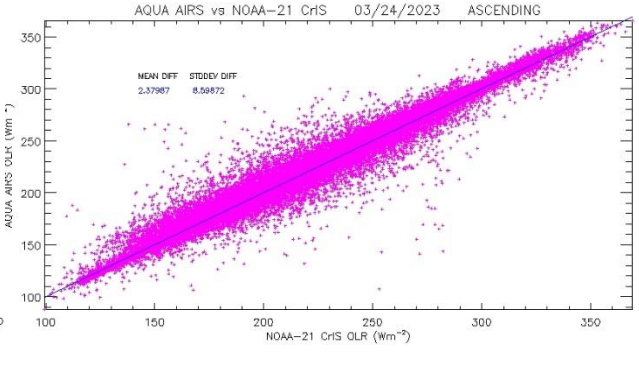


AIRS Ascending



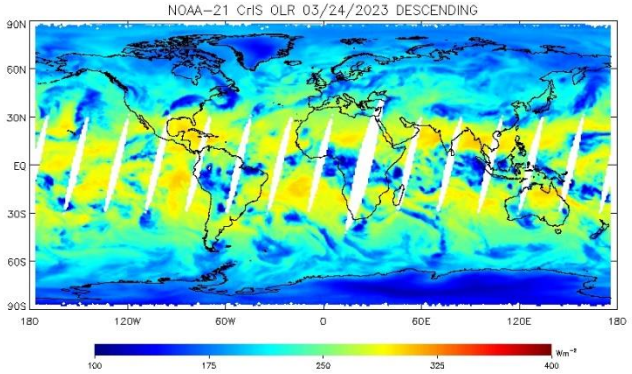
OLR Differences



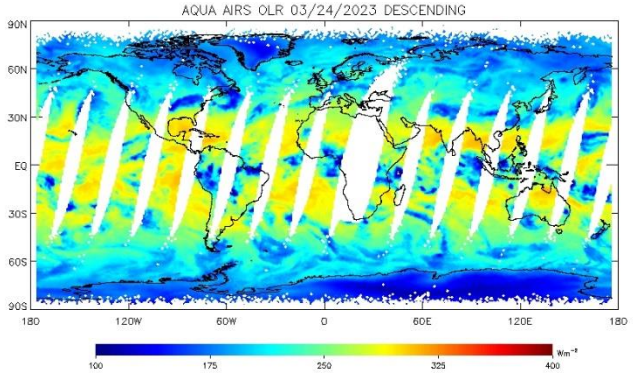


Ascending Mean Diff (W/m²)	2.4
STDev (W/m²)	8.6

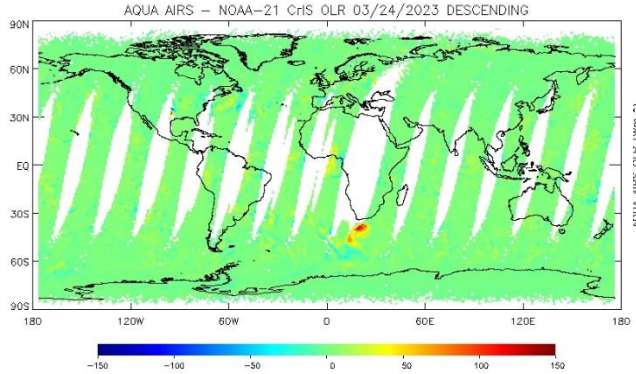
CrIS NOAA-21 Descending

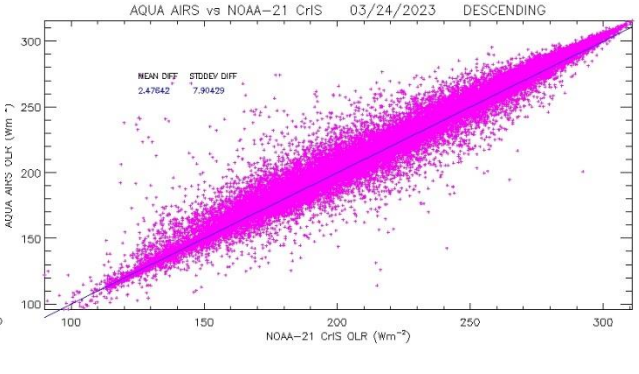


AIRS Descending



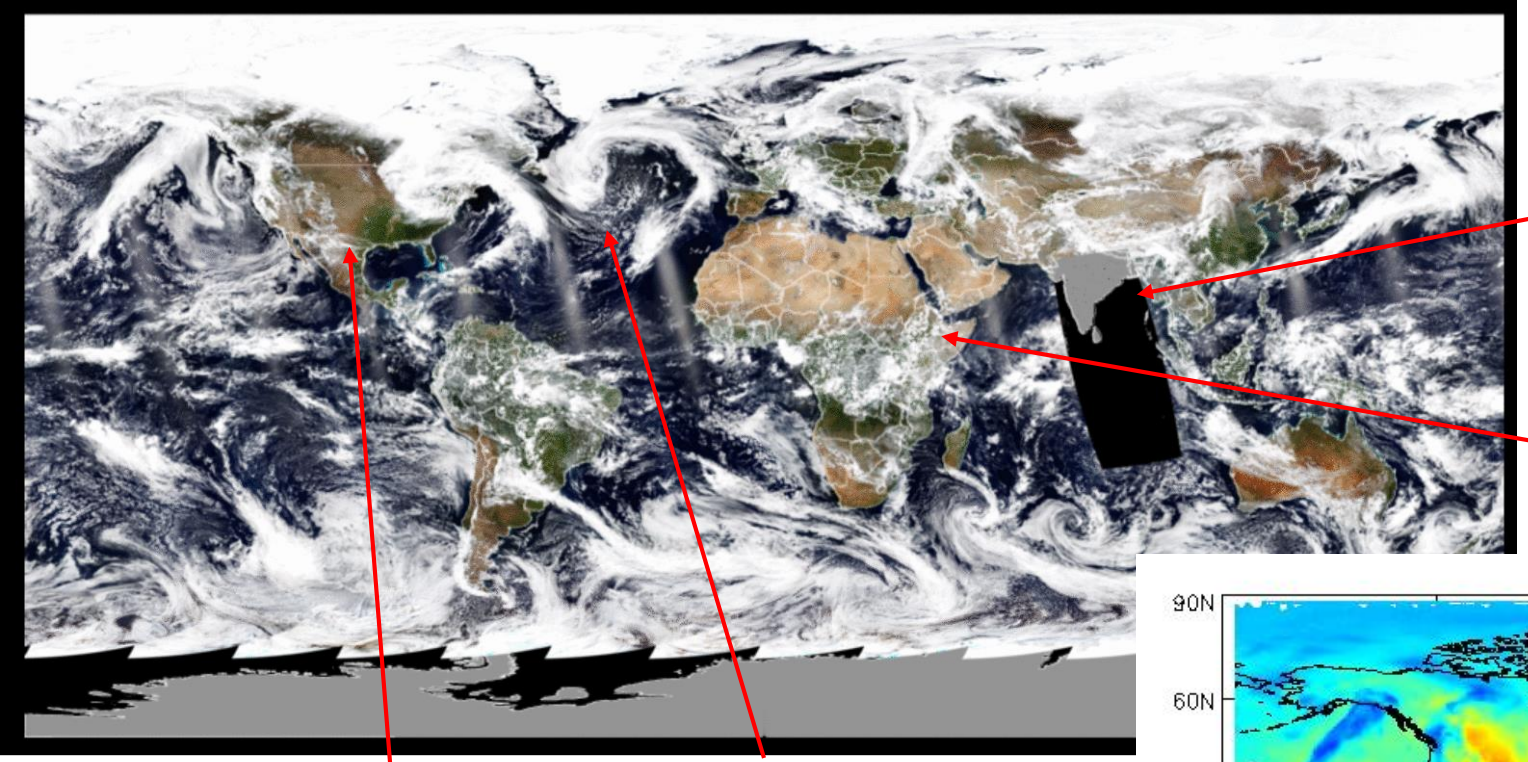
OLR Differences





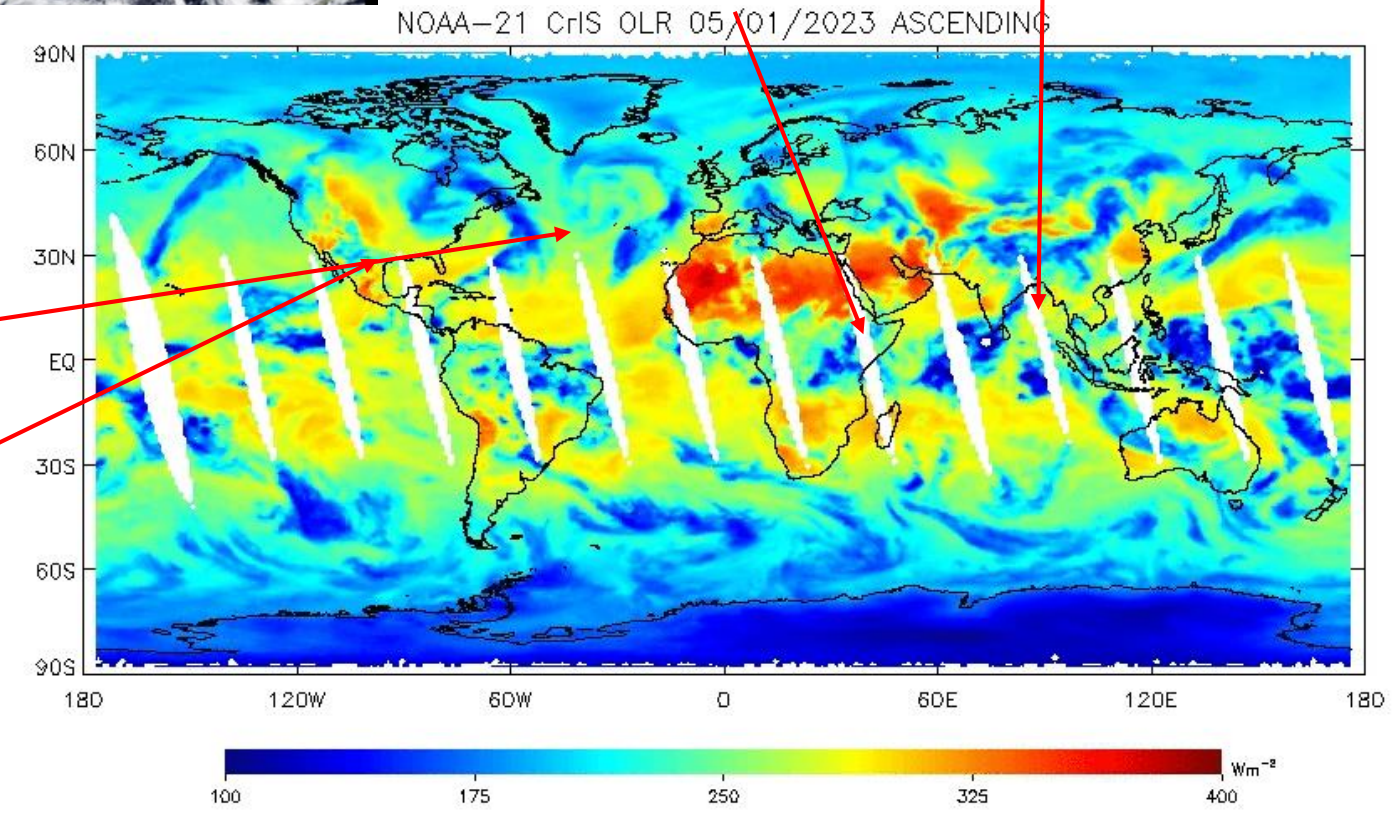
Descending Mean Diff (W/m²)	2.5
STDev (W/m²)	8.0

✓ NOAA-21 OLR agrees well with AIRS for both ascending and descending orbits.



Cyclone Mocha was first noted as a low-pressure area in the North Indian Ocean on May 8 and became a category 5 tropical cyclone on May 14, before making a landfall in Myanmar and Bangladesh.

Heavy rainfall on May 2 through May 4 across East Africa lead to flash flooding and landslides.

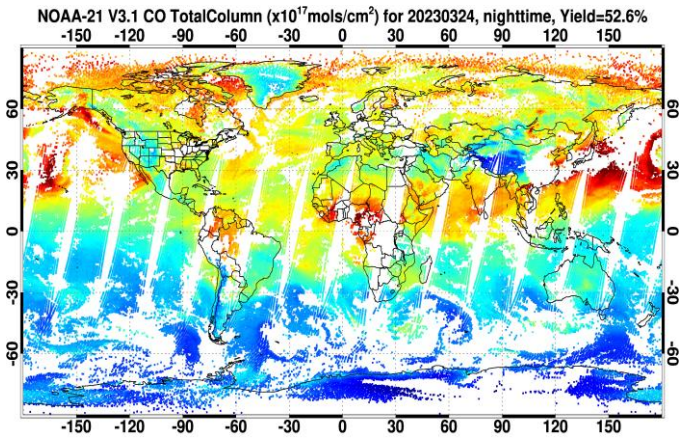
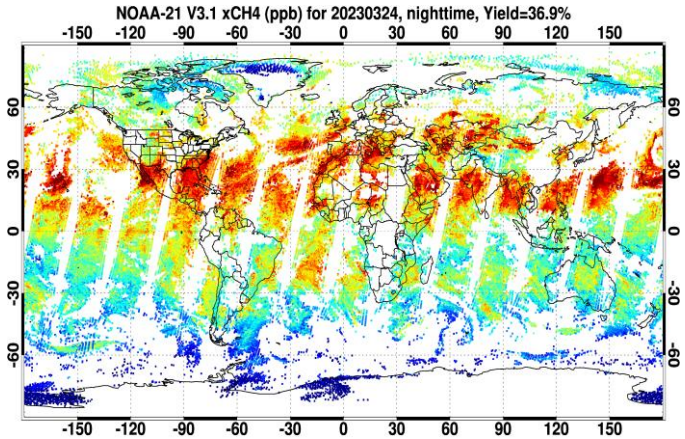
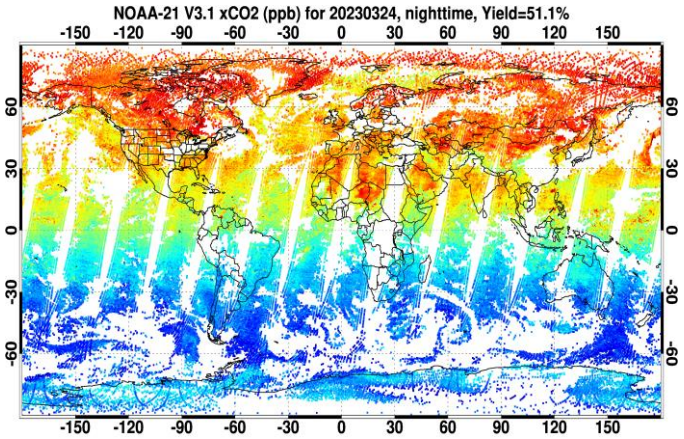
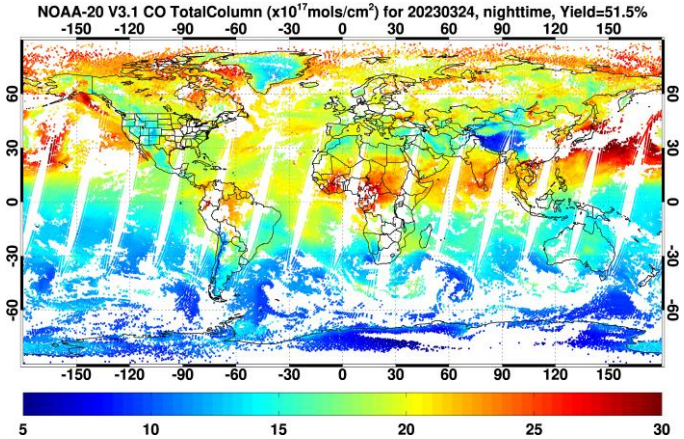
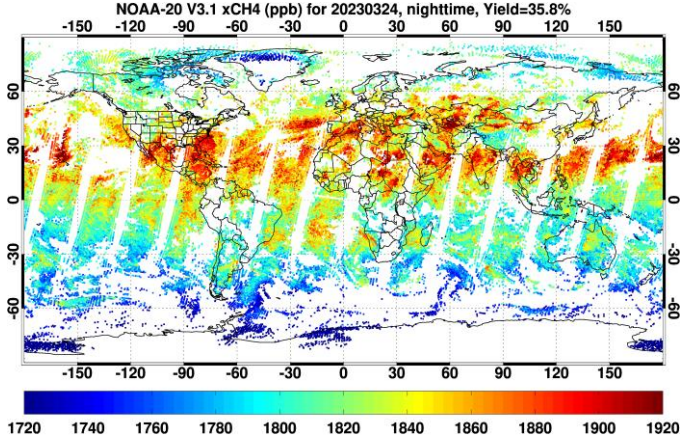
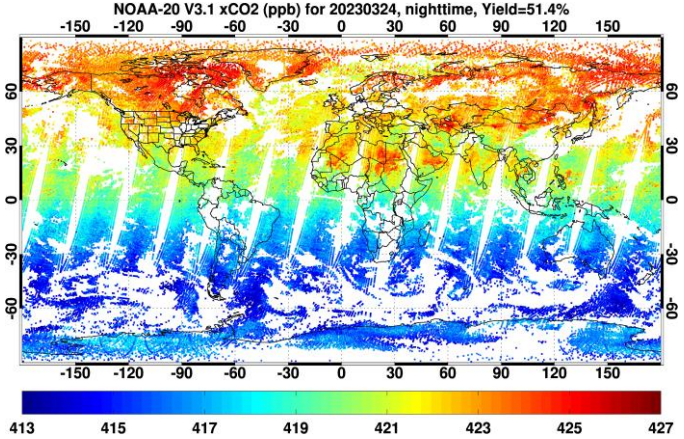


Negative North Atlantic Oscillation is fueling the conveyor belt of low pressure weather systems.

Moisture from the Pacific Ocean and the Gulf of Mexico combined with low pressure and unstable high levels triggered an **unusually wet May in the Southwest US** and Northern Mexico.

Acknowledgement: JSTAR Mapper; thanks to Tom Atkins for the tiles script

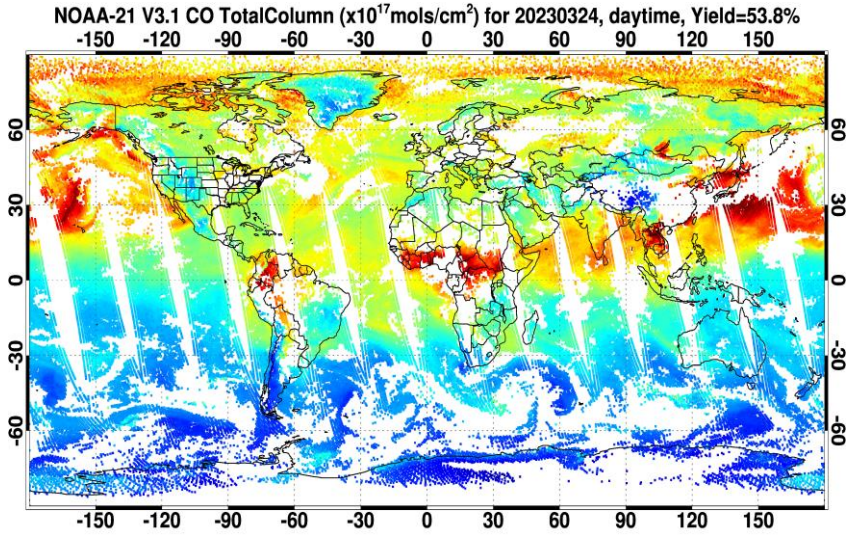
NOAA-21 *vs* NOAA-20 NUCAPS Trace Gas EDR Products (2023/03/24 Nighttime; EP v211)
Descending Orbit (Nighttime)

	Total Column CO	Total Column CH_4	Total Column CO_2
NOAA-21			
NOAA-20			

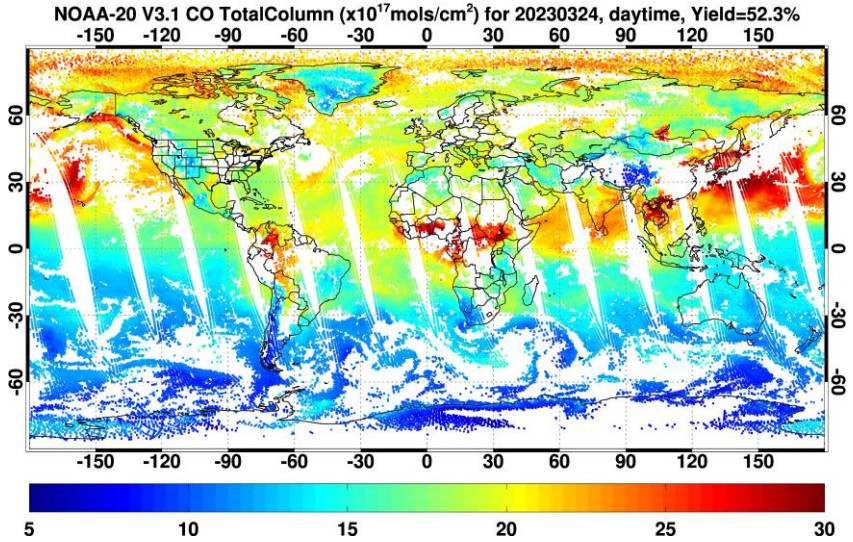
NOAA-21 NUCAPS trace gas EDR products from NOAA-21-Ready algorithm match very well both qualitatively and quantitatively with the NOAA-20 NUCAPS products. Retrieved trace gas profiles (100 layers) span from surface to 0.01 hPa. Figures show Total Column CO, CH_4, and CO_2 products. We have evaluated these products with TROPOMI/OCO-2 products. TCCON in-situ measurements require time to accumulate.

Total Column CO NOAA-21,-20 NUCAPS 3.1 vs TROPOMI (24-Mar-2023)

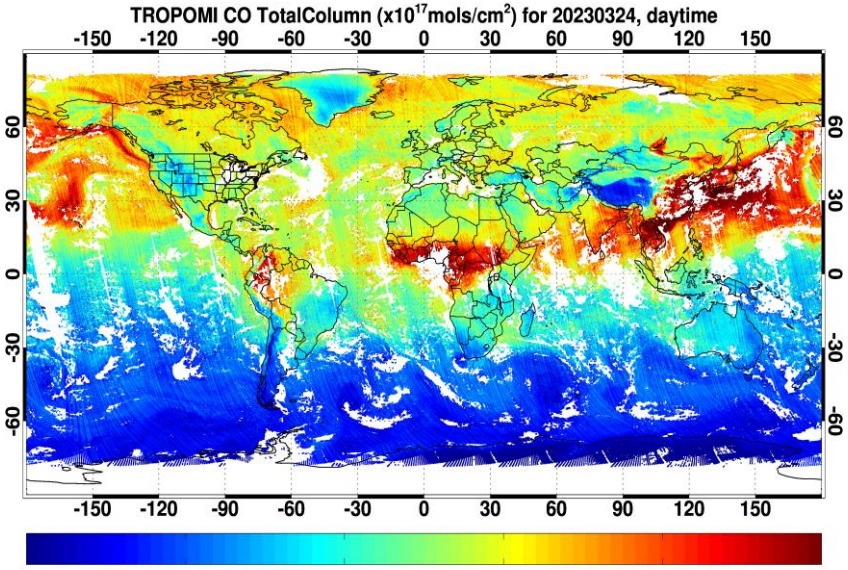
NOAA-21



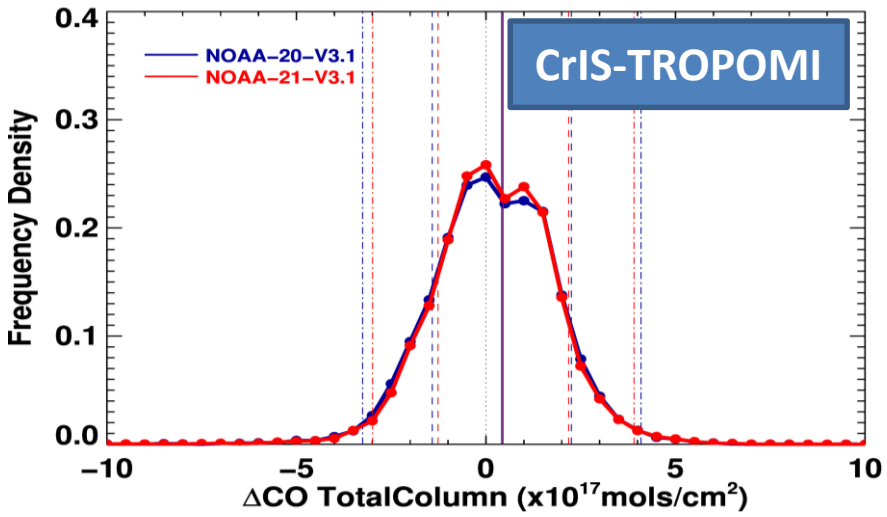
NOAA-20



TROPOMI



CrIS-TROPOMI

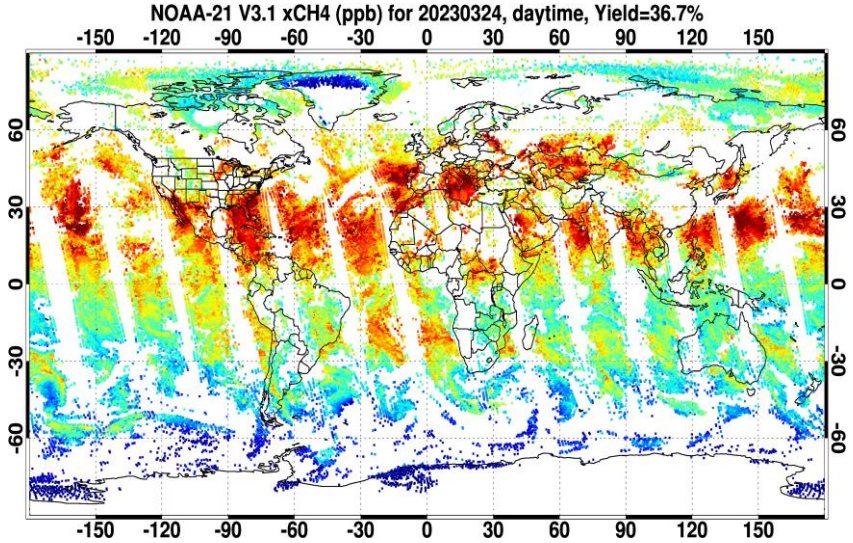


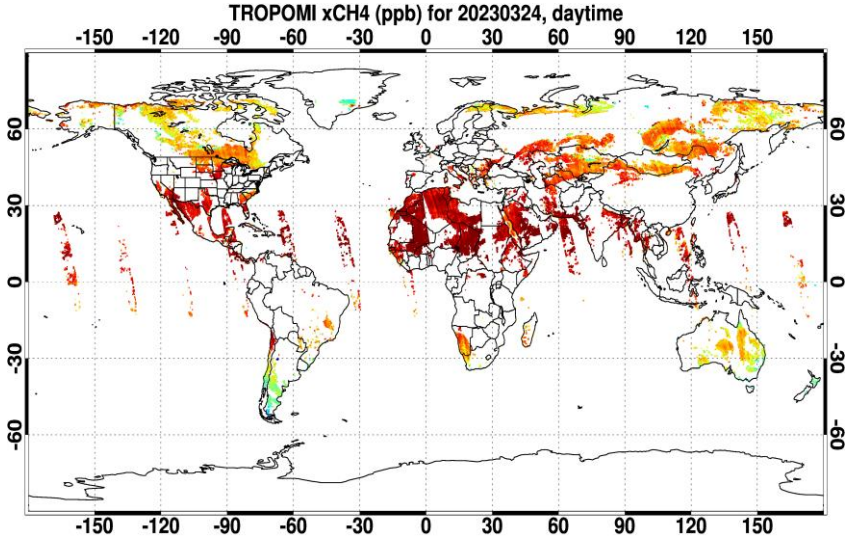
- NUCAPS EDR products are generated for both daytime and nighttime.
- TROPOMI uses solar spectrum to retrieve CO and comparisons are possible for daytime only.

NOAA-21 NUCAPS CO product retrieval from NOAA-21-Ready algorithm matches very well both qualitatively and quantitatively with the NOAA-20 NUCAPS product. Retrieved CO profile (100 layers) spans from surface to 0.01 hPa. Shown here is the total column CO vs TROPOMI.

Total Column CH_4 NOAA-21,-20 NUCAPS 3.1 vs TROPOMI (24-Mar-2023)

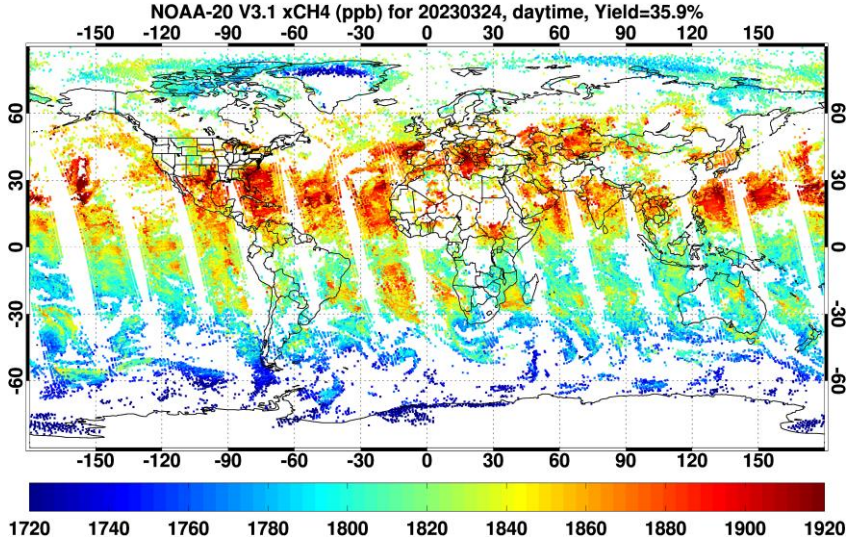
NOAA-21

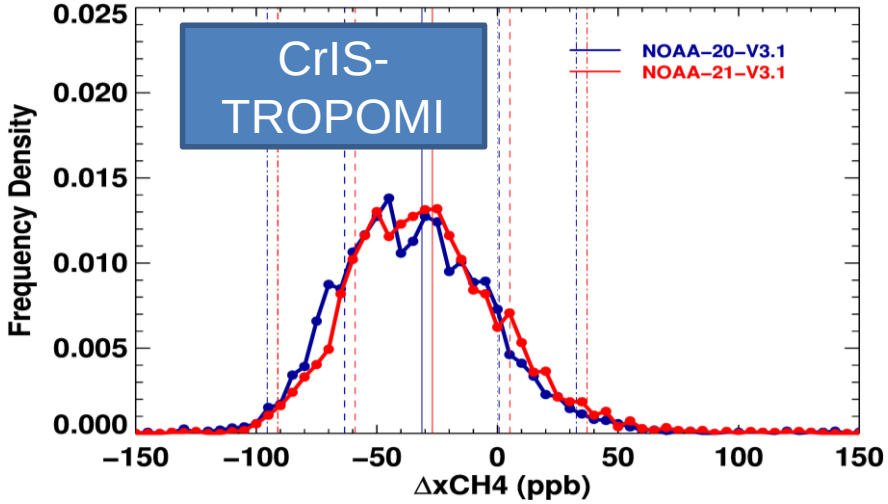




TROPOMI

NOAA-20





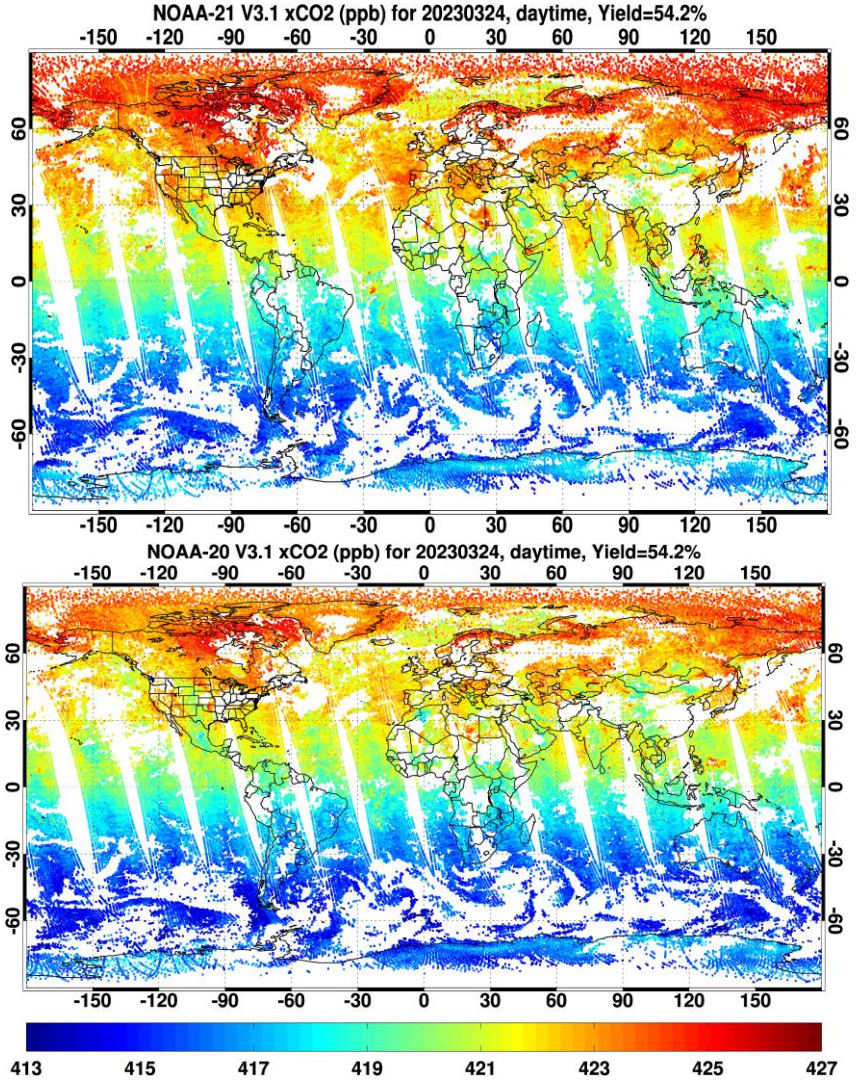
- NUCAPS EDR products are generated for both daytime and nighttime.
- TROPOMI uses solar spectrum to retrieve CH_4 and comparisons are possible for daytime only.

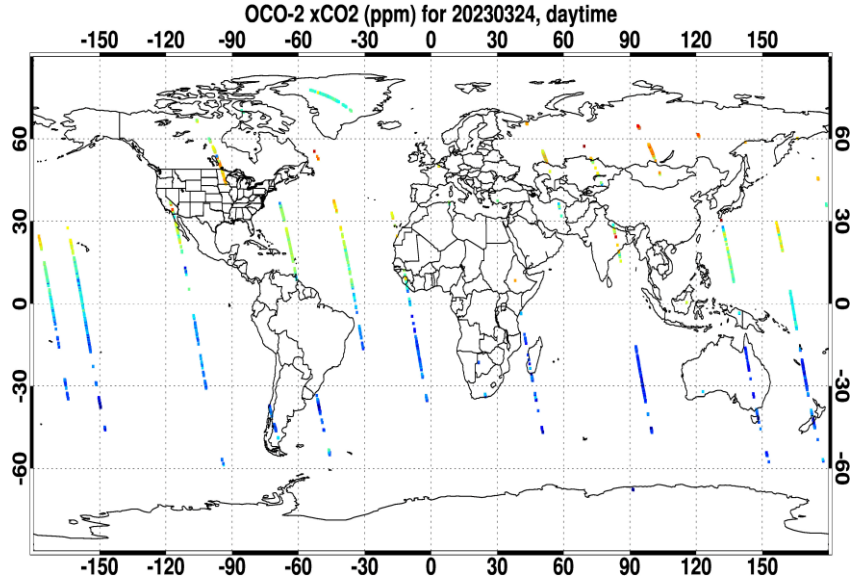
NOAA-21 NUCAPS CH_4 retrieval from NOAA-21-Ready algorithm matches very well both qualitatively and quantitatively with the NOAA-20 NUCAPS product. Retrieved CH_4 profile (100 layers) spans from surface to 0.01 hPa. Shown here is the total column CH_4 vs TROPOMI.

Total Column CO_2 NOAA-21,-20 NUCAPS 3.1 vs OCO-2 (24-Mar-2023)

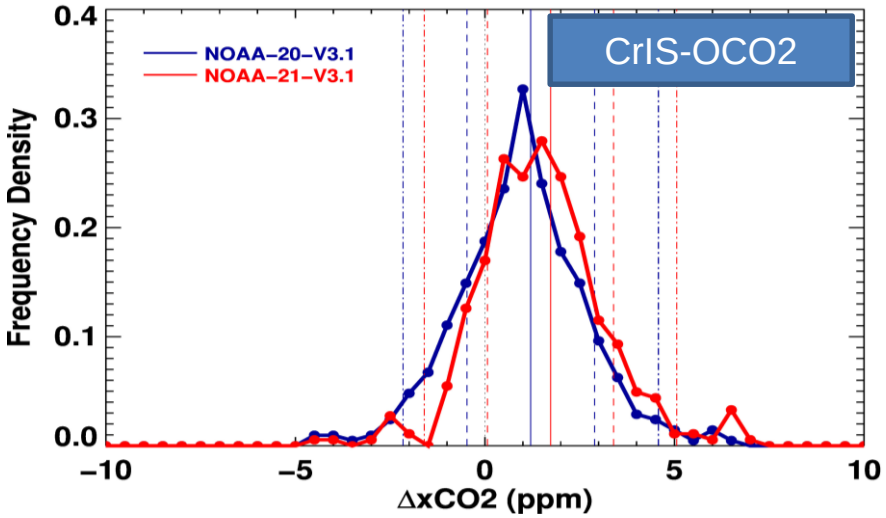
NOAA-21

NOAA-20





OCO-2 v11



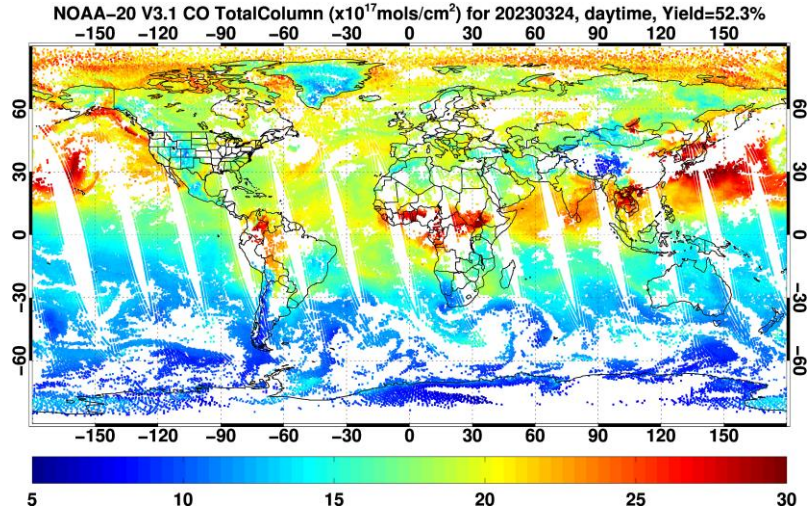
- NUCAPS products are generated for both daytime and nighttime.
- OCO-2 uses solar measurements to retrieve CO_2 and comparisons are possible for daytime only.
- NOAA-21 EP v211 improved CO_2 product matches between NOAA-20 and NOAA-21.

NOAA-21 NUCAPS CO_2 retrievals from NOAA-21 Ready algorithm match very well both qualitatively and quantitatively with NOAA-20 NUCAPS product. Retrieved trace gas profiles (100 layers) span from surface to 0.01 hPa. Shown here is the total column CO_2 vs OCO-2.

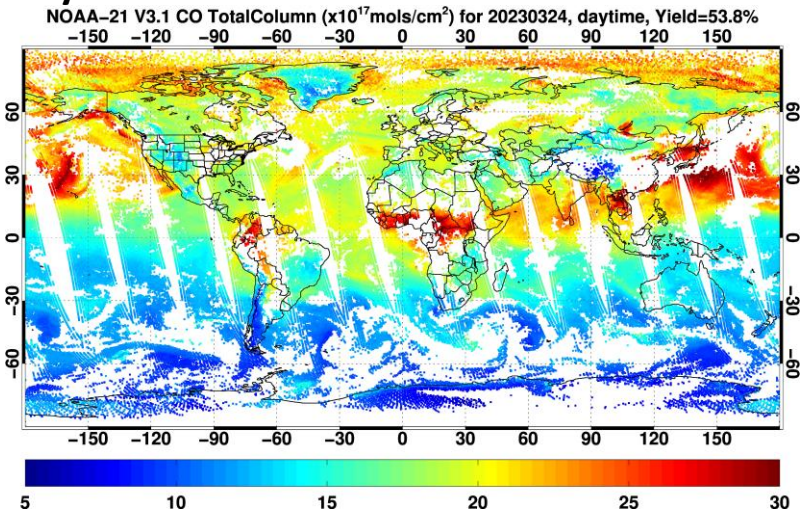
NUCAPS Enterprise Algorithm (v3.1) CO Comparison with TROPOMI

24 March 2023 Focus Day

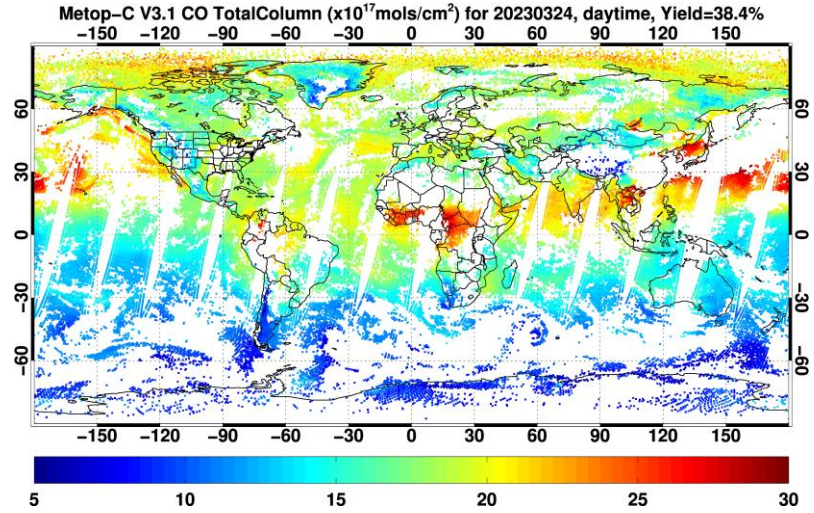
NUCAPS NOAA-20



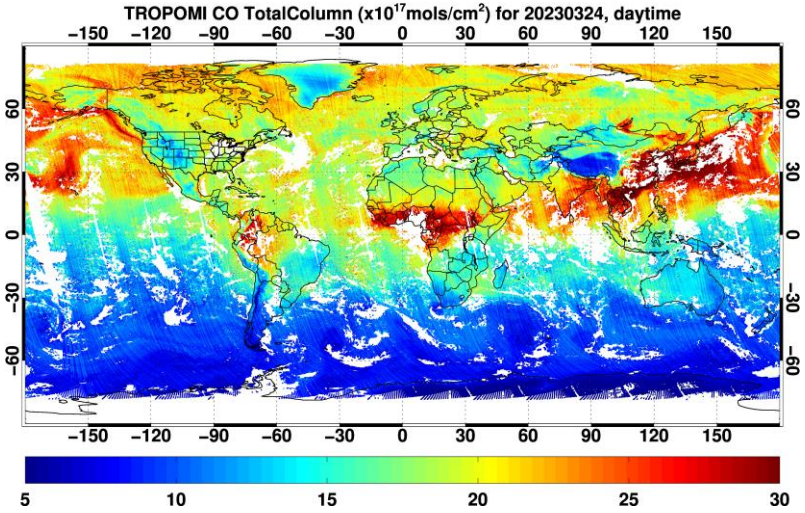
NUCAPS NOAA-21

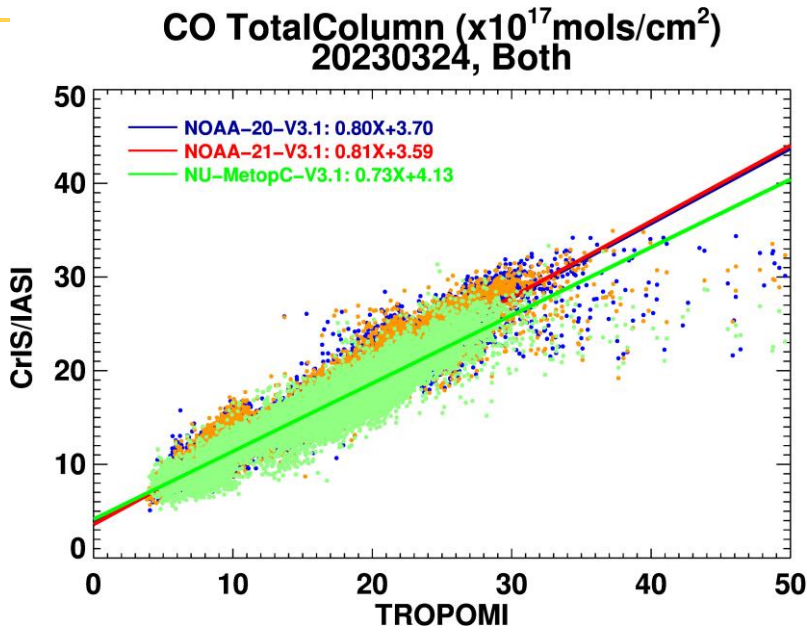


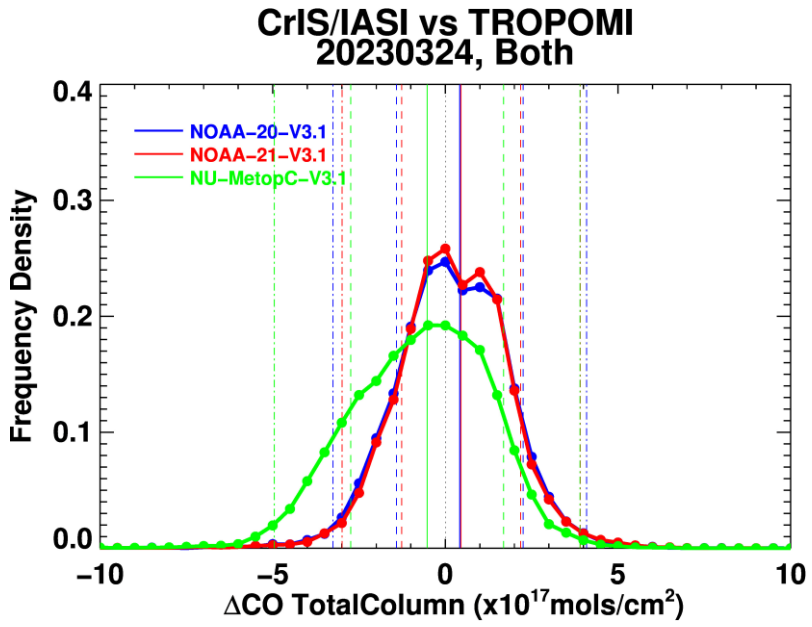
NUCAPS Metop-C



TROPOMI

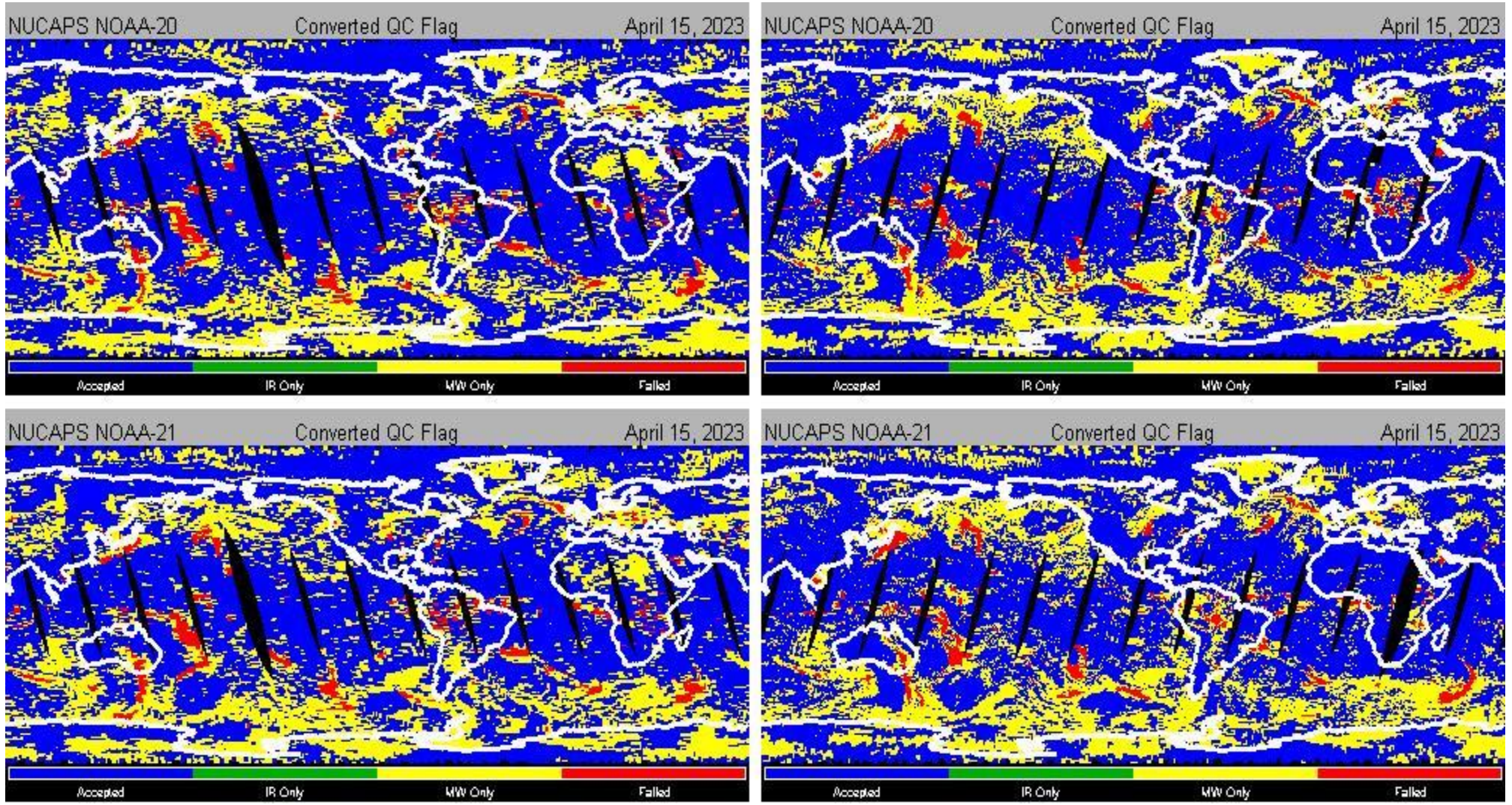






Supplemental slides provide CH_4 and CO_2 products

NPROVS Team Assessment of NOAA-21 vs. NOAA-20 (QC Flags)
(Downstream User Feedback, more in backup slides)



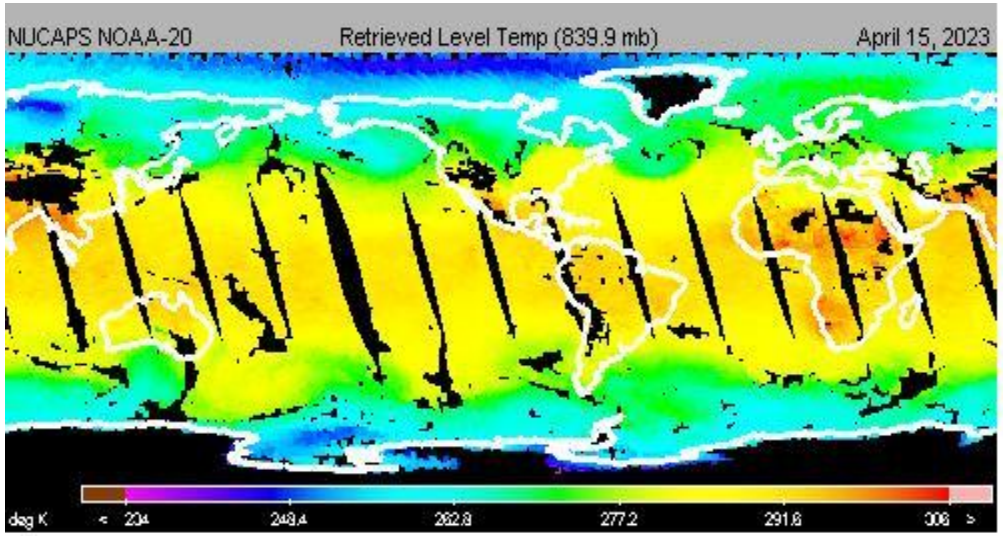
IR+MW Pass **MW-only Pass** **Both Fail**

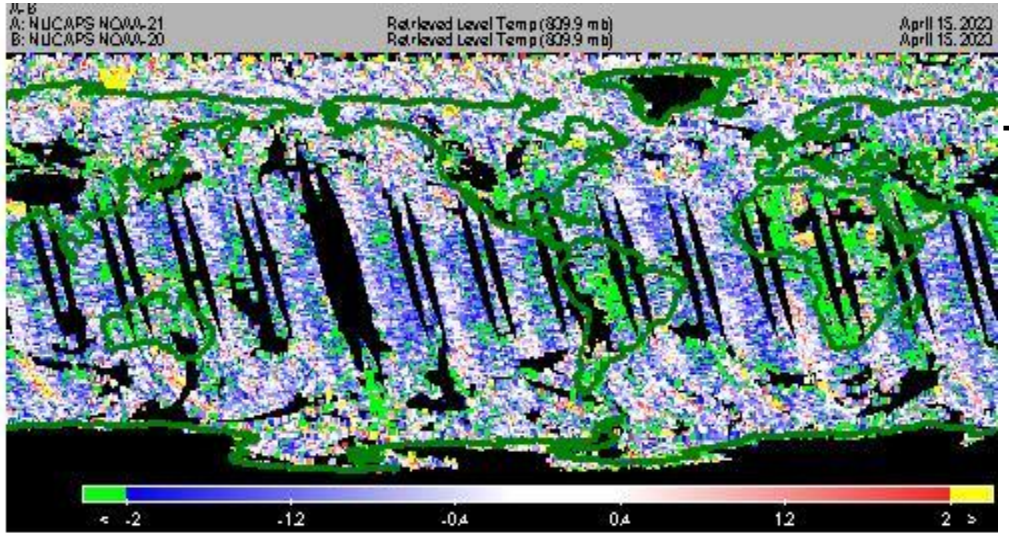
v3 (N20) / v3 (N21)

… via 5 day running archive (*courtesy NUCAPS team*)

NPROVS Team Assessment of AVTP:NOAA-21 vs NOAA-20 (Downstream User Feedback, more in backup slides)

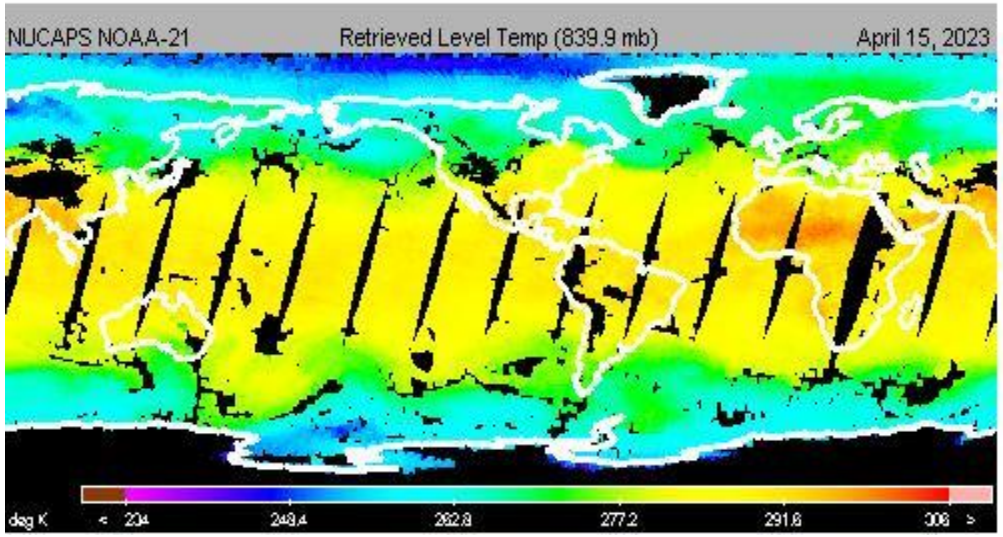
839 hPa Temp

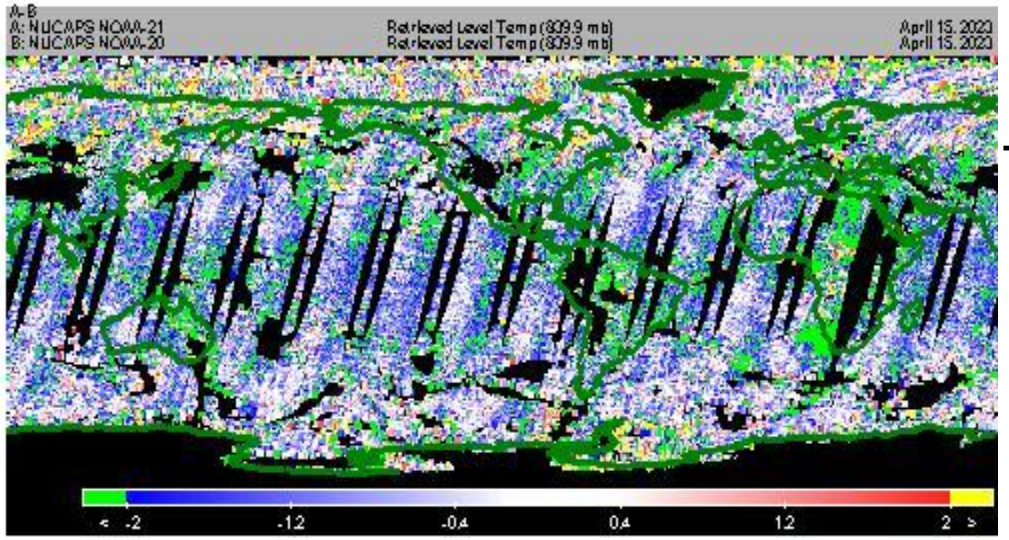




Temperature Difference N21-N20 (+/-2)

839 hPa Temp



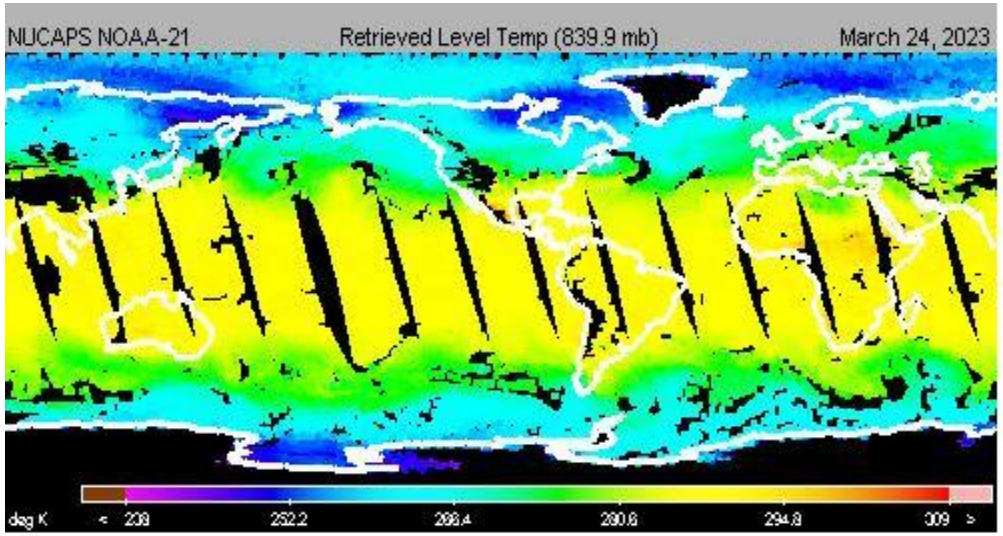


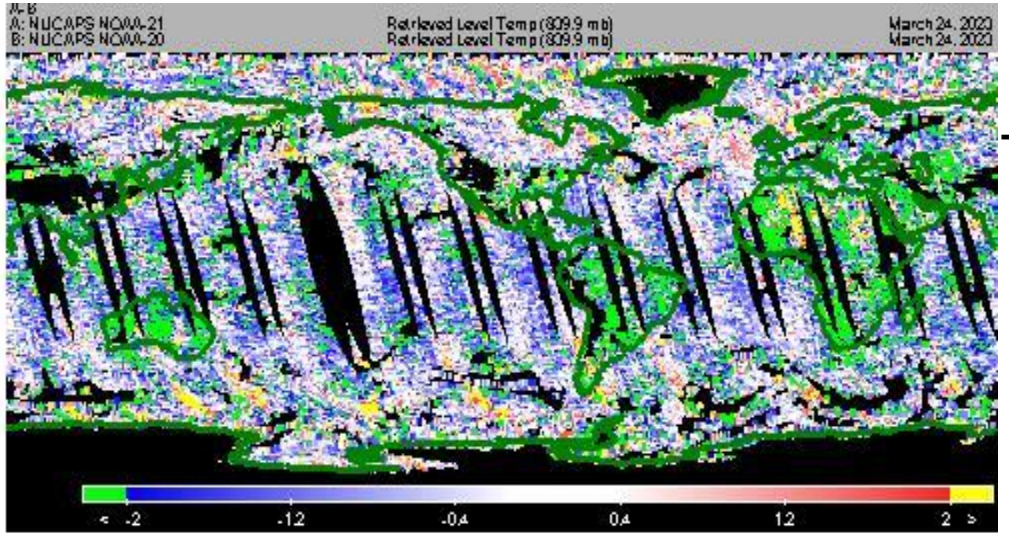
Temperature Difference N21-N20 (+/-2)

V3 (N20) / v3 (N21)

NPROVS Team Assessment of AVTP:NOAA-21 vs NOAA-20 (Downstream User Feedback, more in backup slides)

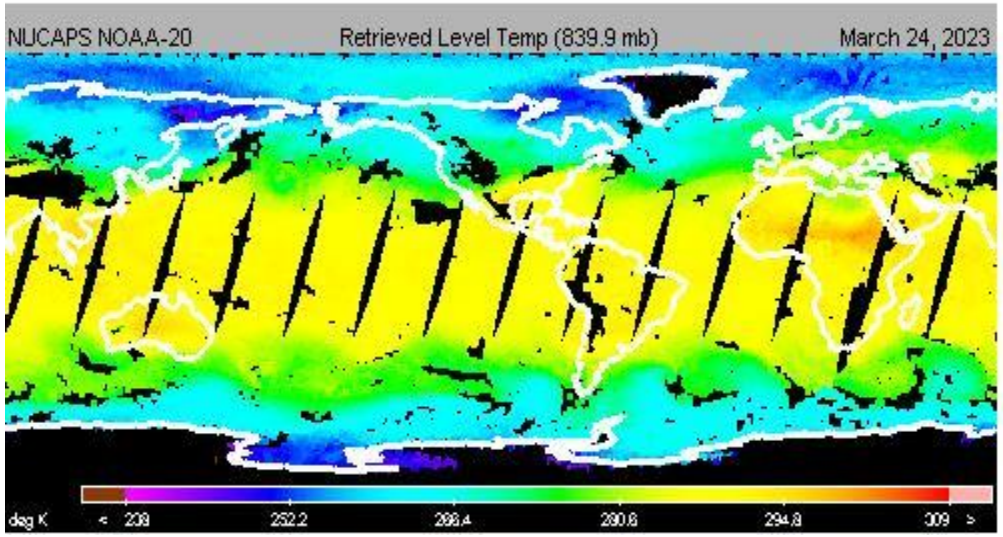
839 hPa Temp

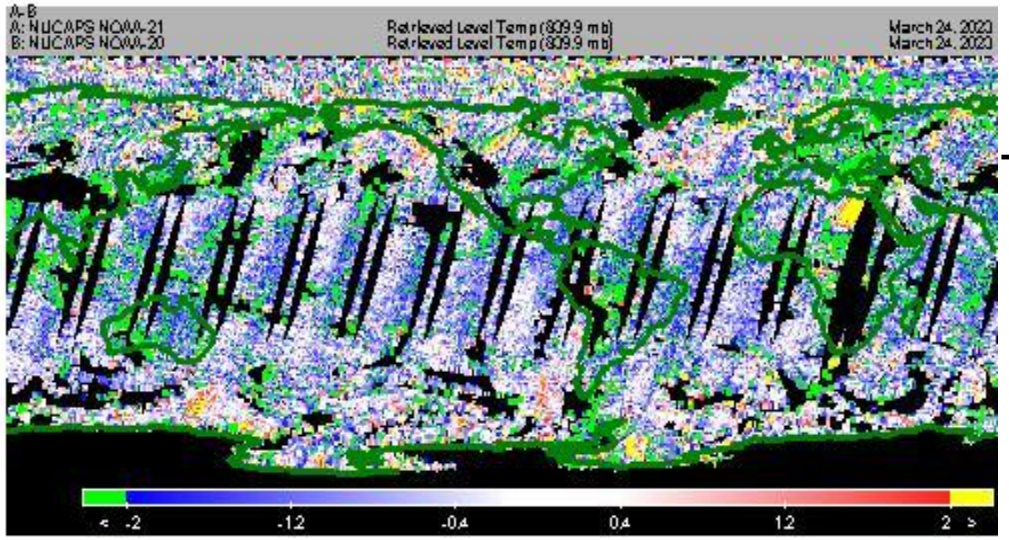




Temperature Difference N21-N20 (+/-2)

839 hPa Temp





Temperature Difference N21-N20 (+/-2)

V3.1 (N20) / v3.1 (N21)

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 (See below)
Regular Validation Reports (at least annually) (Demonstrates long-term performance of the algorithm)	✓ Yes

Peer Reviewed Publications and Conference Presentations

1. Nalli, N. R., et al., 2023: Validation of carbon trace gas profile retrievals from the NOAA-Unique Combined Atmospheric Processing System for the Infrared Atmospheric Sounding Interferometer, manuscript in prep for *Remote Sens*. special issue.
2. Kalluri, S., C. Barnet, M. Divakarla, R. Esmaili, N. R. Nalli, K. Pryor, T. Reale, N. Smith, C. Tan, T. Wang, J. Warner, M. Wilson, L. Zhou, and T. Zhu, 2022: Validation and Utility of Satellite Retrievals of Atmospheric Profiles in Detecting and Monitoring Significant Weather Events, *Bull. Amer. Meteorol. Soc., 103*(2), E570-E590, doi: 10.1175/BAMS-D-20-0126.1.
3. Kuciauskas, A., A. Reale, R. Esmaili, B. Sun, N. R. Nalli, and V. R. Morris, 2022: Investigating NUCAPS Skill in Profiling Saharan Dust for Near-Real-Time Forecasting, *Remote Sens., 14*(17), 4261, doi:10.3390/rs14174261.
4. Nalli, N. R., et al., 2020: Validation of carbon trace gas profile retrievals from the NOAA-Unique Combined Atmospheric Processing System for the Cross-Track Infrared Sounder, *Remote Sens.*, *12*(19), 3245, doi:10.3390/rs12193245
5. Nalli, N. R., et al., 2018b: Validation of atmospheric profile retrievals from the SNPP NOAA-Unique Combined Atmospheric Processing System. Part 2: Ozone, *IEEE Trans. Geosci. Remote Sens., 56*(1), 598-607, doi:10.1109/TGRS.2017.2762600.
6. Nalli, N. R., et al., 2018a: Validation of atmospheric profile retrievals from the SNPP NOAA-Unique Combined Atmospheric Processing System. Part 1: Temperature and moisture, *IEEE Trans. Geosci. Remote Sens., 56*(1), 180-190, doi:10.1109/TGRS.2017.2744558
7. Sun, B., A. Reale, F. H. Tilley, M. E. Pettey, N. R. Nalli, and C. D. Barnet, 2017: Assessment of NUCAPS S-NPP CrIS/ATMS sounding products using reference and conventional radiosonde observations, *IEEE J. Sel. Topics Appl. Earth Observ., 10*(6), 2499-2509, doi: 10.1109/JSTARS.2017.2670504
8. Numerous presentations given at domestic and international conferences (e.g. AMS, AGU, etc.)

Check List - Beta Maturity

Beta Maturity End State	Assessment
Product is minimally validated, and may still contain significant identified and unidentified errors	Yes, slides 12-17
Information/data from validation efforts can only be used to make initial qualitative or very limited quantitative assessments regarding product fitness-for-purpose	Yes, slides 18-29
Documentation of product performance and identified product performance anomalies, including recommended remediation strategies, exists	Yes, slides 30-33

Summary

- Performed global evaluation of all the NOAA-21 NUCAPS products
  - ✓ Quality flags and data formats for consistency for both ascending and descending orbits.
  - ✓ Global maps (Asc/Desc) and statistical metrics (NOAA-20 & NOAA-21) *vs* ECMWF (*T*, *q*, O3)
    - ✓ Assessment of AVTP and AVMP with global RAOB matches (NPROVS)
  - ✓ Global maps (Asc/Desc) of CO, CH_4, and CO_2 (NOAA-20 & NOAA-21 *vs* TROPOMI CO, CH_4, and OCO-2 v11
  - ✓ OLR global (Asc/Desc) maps: NOAA-21 vs NOAA-20 and AIRS show very good consistency.
- NOAA-21 products show very good performance and high degree of agreement with NOAA-20 products, consistent with Beta Maturity criteria.
- Preliminary validations of NOAA-21 products show very good promise.
- No NOAA-21 specific caveats or risks observed.
- **NUCAPS Team recommends NOAA-21 Beta Maturity, effective 23 March 2023.**

Path Forward

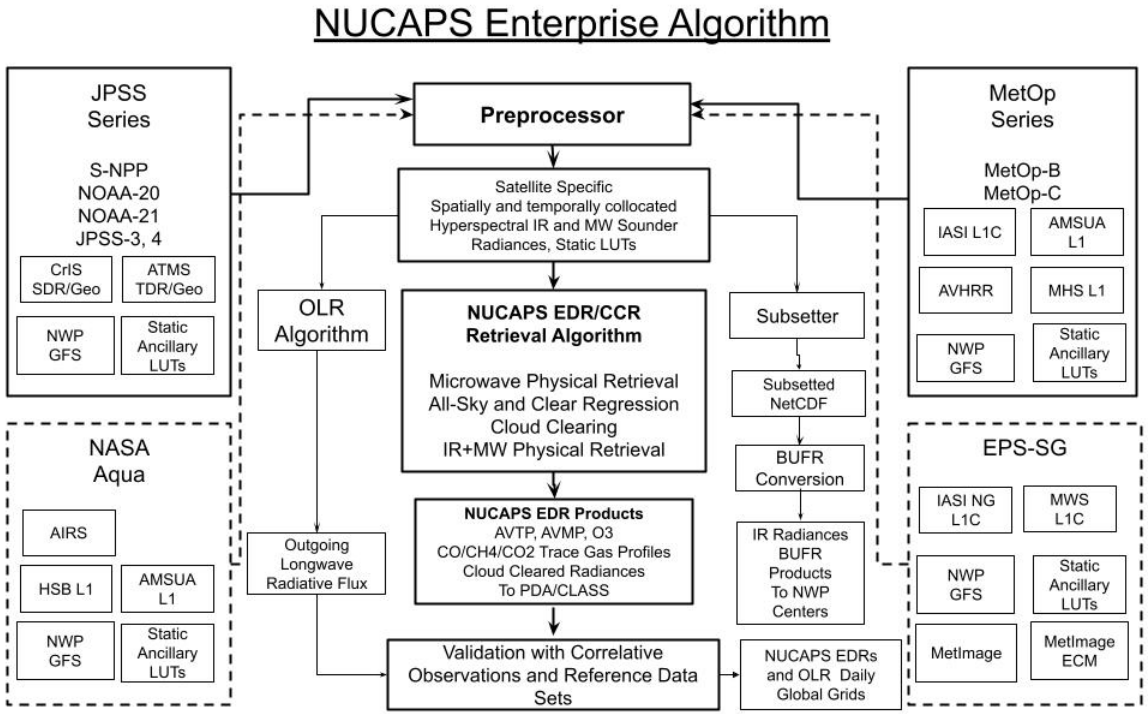
- Planned activities moving from “NOAA-21 Ready” to NOAA-21 NUCAPS algorithm
  - » NOAA-21 cloudy and clear regression LUT updates using focus days spanning different seasons
    - ✓ Setup and preliminary evaluations completed (supplemental slides).
  - » NOAA-21 Microwave and IR bias tuning
    - ✓ Preliminary set up completed and evaluations in progress (supplemental slides).
- Continue validations exercises following the product validation methodology hierarchies
  - » Continue global evaluation of NUCAPS products with focus data sets spanned around a year and collocated ECMWF and other models; correlative satellite retrieved products (AIRS, TROPOMI, OCO-2)
  - » Temperature and water vapor validations using daily collections of Validation Archive (VALAR) data sets, global RAOB collocations, WOUDC-O_3 measurements, and special campaigns of opportunity (supplemental slides)
  - » Trace gas product validations with TCCON and other *in situ* measurements
  - » OLR product evaluation with CERES and other satellite observations (AIRS)
- Attaining Provisional and Validated Maturity following the set forth criteria

BACKUP SLIDES

NOAA Unique Combined Atmospheric Processing System (NUCAPS)

Algorithm Version, Processing Environment, Inputs, Outputs

NUCAPS runs within the Hyperspectral Enterprise Algorithm Package (HEAP v2.3) and operationally produces AVTP, AVMP, O3, OLR, CO, CH_4 and CO_2 products from JPSS NOAA-20 CrIS and Metop-B/C IASI hyperspectral infrared sounding instruments.



The HEAP provides the pre- and post-processing capability for The NUCAPS retrieved products and generates

1) NUCAPS 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), 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

Retrieved Parameter	Spectral Range Used (cm^{-1})
AVTP	**650-800** **2375-2395**
AVMP	**1200-1600**
Cloud P, T, fraction	**700-900**
O_3	**996-1068**
CO	**2155-2200**
CH_4	**1220-1370**
CO_2	**666-795**

- HEAP (NUCAPS) v3.0 is currently in operations. Algorithm updates, sensor-independent LUTs, QC/QA are all updated for MetOp-C/B/ using the latest baseline version of NOAA-20
- 'NOAA-21-Ready' NUCAPS algorithm uses NOAA-20 LUTs

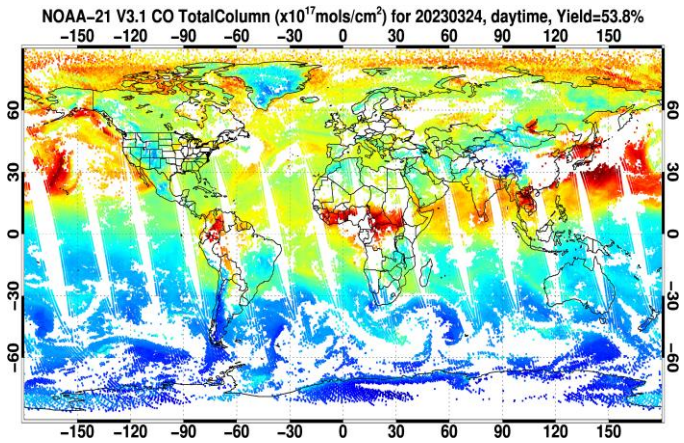
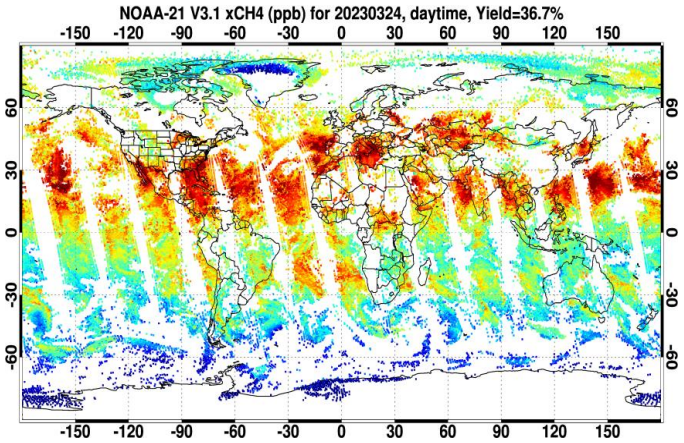
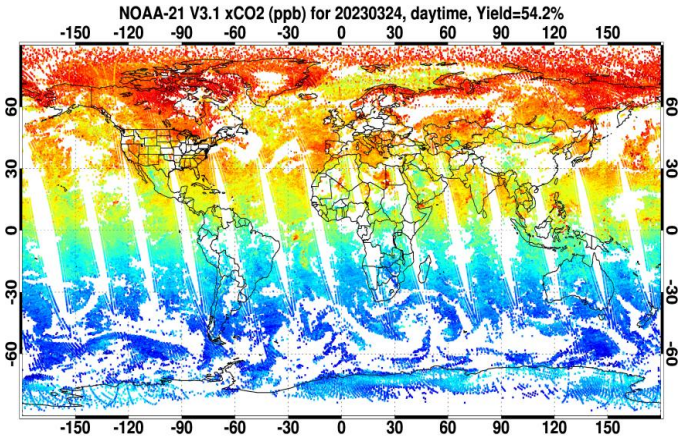
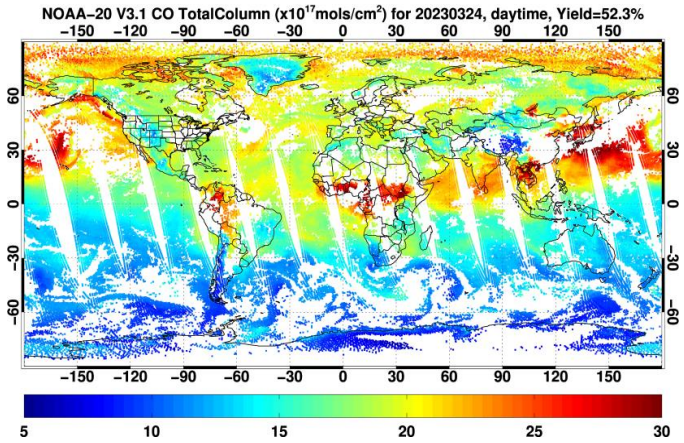
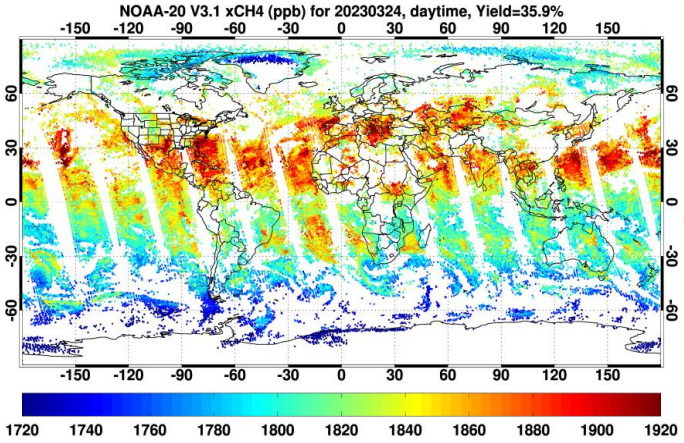
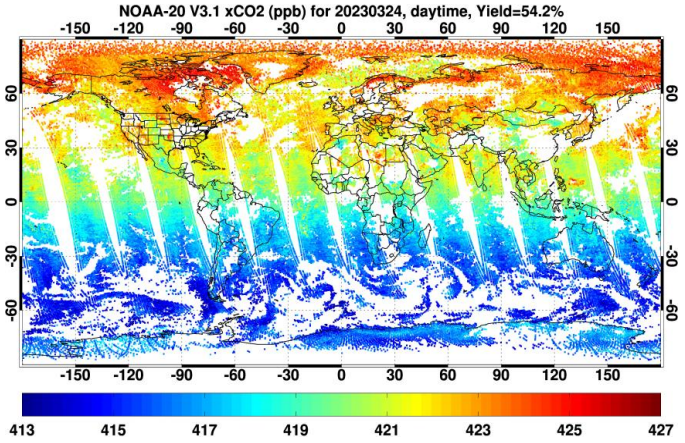
Satellite	Instrument
JPSS NOAA-20/21, J3)	CrIS/ATMS; S-NPP products discontinued due to unavailability CrIS midwave band
MetOp-B, C	IASI/AMSU-A/MHS

NUCAPS Output Products (NOAA-20 and NOAA-21)

	Product	NUCAPS JPSS Products		NUCAPS JPSS Products with Averaging Kernels		Users
		Number of Files/Day	Size/Day	Number of Files/Day	Size/Day	
1	NUCAPS ALL FOVs	2700*	25 G	2700	25 G	BUFR toolkit and OSPO
2	NUCAPS 431 (CrIS), 616 (IASI) ALL FOVs Thinned Radiances	2700	5.4 G	2700	5.4 G	BUFR toolkit
3	NUCAPS PCS Monitoring	2700	11 M	2700	11 M	OSPO
4	NUCAPS Retrieval Monitoring	2700	11 M	2700	11 M	OSPO
5	L1C Metadata.xml (for IASI only)	N/A	N/A	N/A	N/A	CLASS
6	EDR NetCDF	2700	7.8 G	2700	9.4 G	CLASS and OSPO
7	CCR Archive NetCDF	2700	2.9 G	2700	2.9 G	CLASS
8	OLR NetCDF	2700	170 M	2700	170 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	6.1 M	2	6.1 M	OSPO
	Total	**16204**	**38.7 G**	**16204**	**40 G**	

NUCAPS Enterprise System has been implemented on both JPSS NOAA-20 and NOAA-21.The NUCAPS daily product output file sizes are approximately of the same order for both NOAA-20 and NOAA-21.

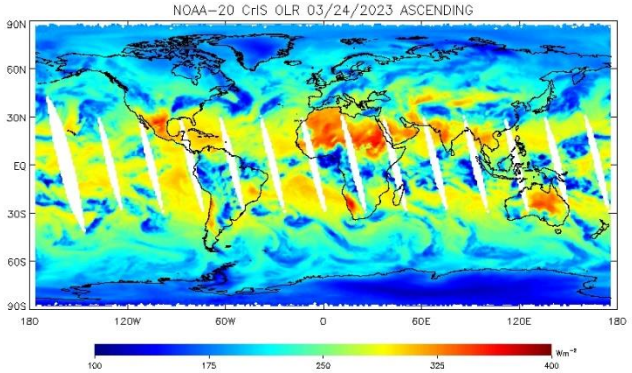
NOAA-21 *vs* NOAA-20 NUCAPS Trace Gas EDR Products (2023/03/24 Daytime; EP v211) (Ascending Orbit)

	Total Column CO	Total Column CH_4	Total Column CO_2
NOAA-21			
NOAA-20			

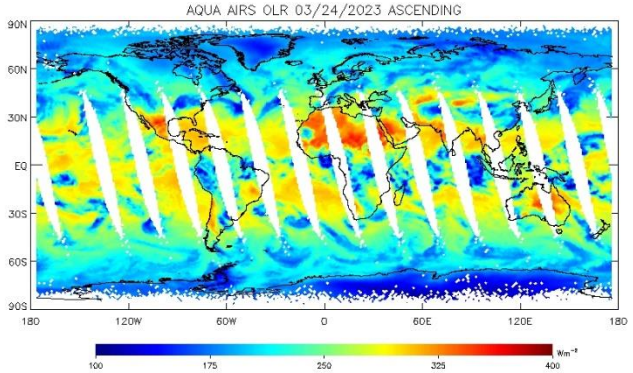
NOAA-21 NUCAPS trace gas EDR products from NOAA-21-Ready algorithm matches very well both qualitatively and quantitatively with the NOAA-20 NUCAPS products. Retrieved trace gas profiles (100 layers) span from surface to 0.01 hPa. Figures show Total Column CO, CH_4, and CO_2 Products. We have evaluated these products with TROPOMI/OCO-2 products. The TCCON in-situ measurements are currently unavailable.

NUCAPS CrIS OLR NOAA-20 vs AIRS (3/24/2023)

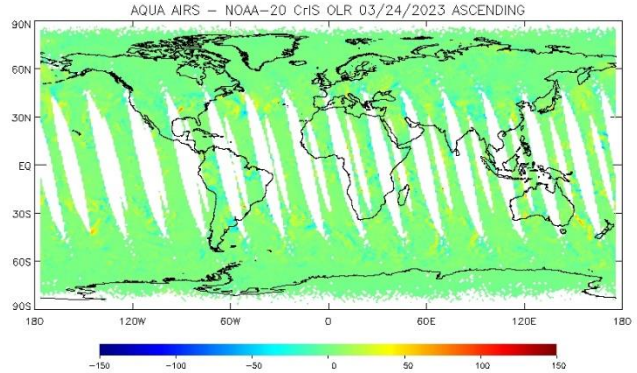
CrIS NOAA-20 Ascending

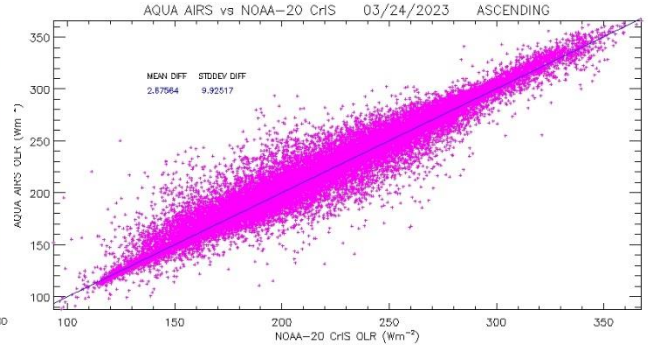


AIRS Ascending



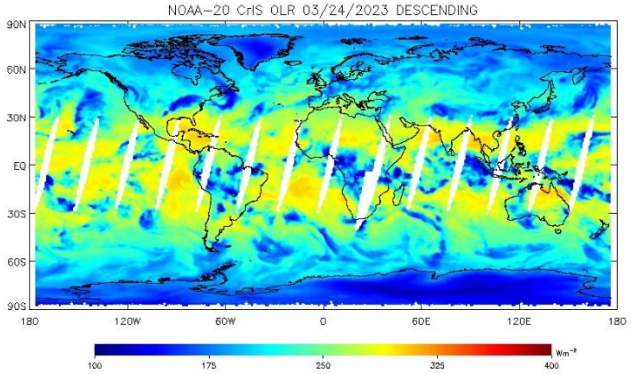
OLR Differences



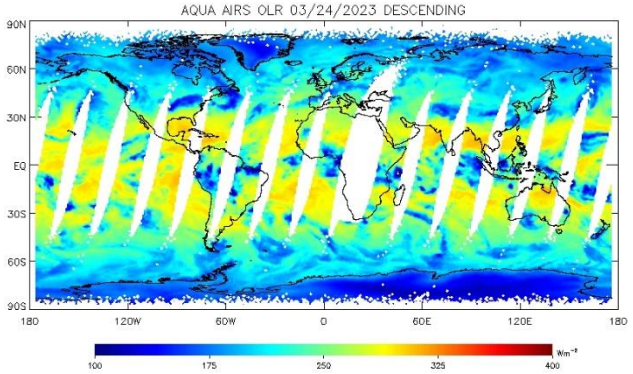


Ascending Mean Diff (W/m²)	2.7
STDev (W/m²)	10

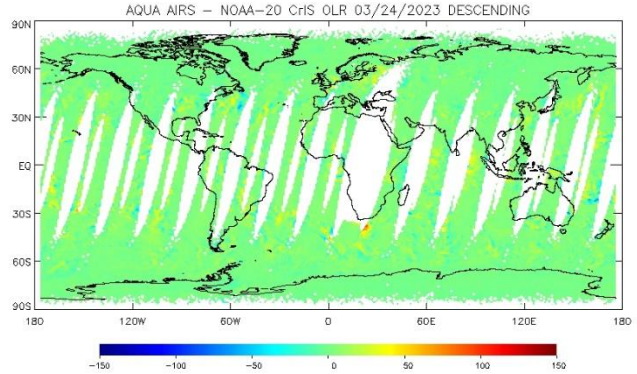
CrIS NOAA-20 Descending

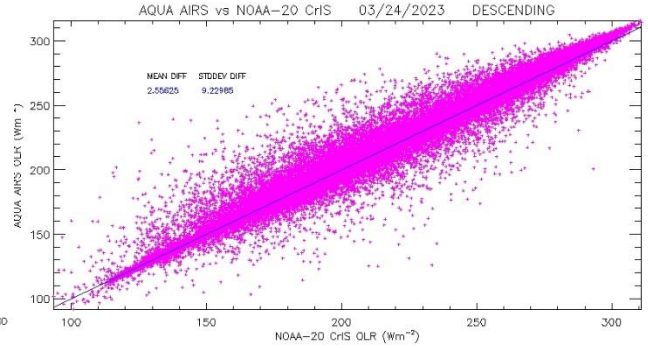


AIRS Descending



OLR Differences



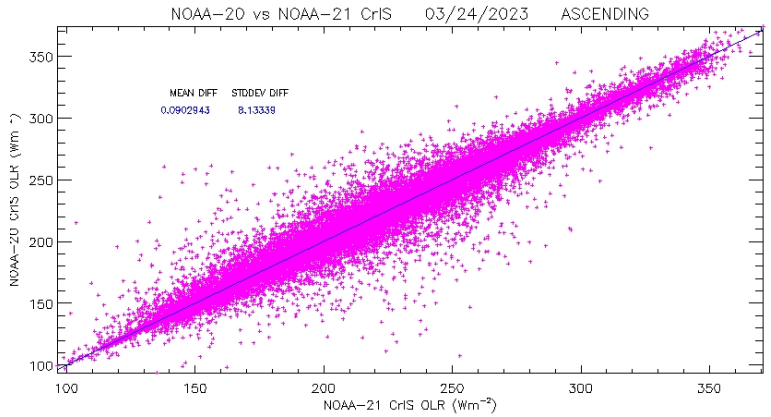


Descending Mean Diff (W/m²)	2.6
STDev (W/m²)	9

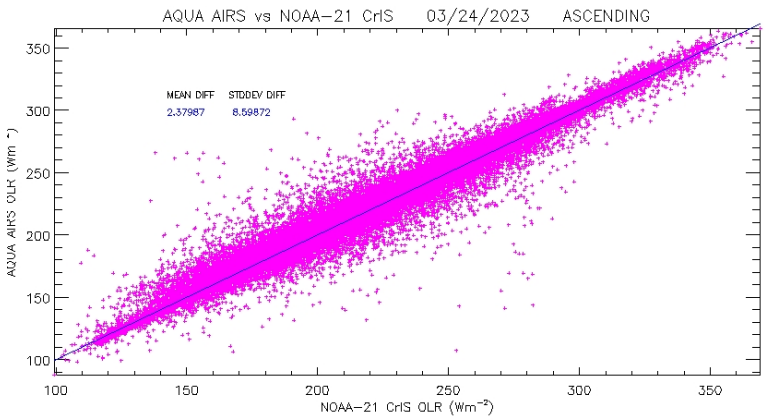
✓ NOAA-20 OLR agrees well with AIRS for both ascending and descending orbits.

NOAA-21 OLR Agrees well with NOAA-20 and AIRS OLR Product

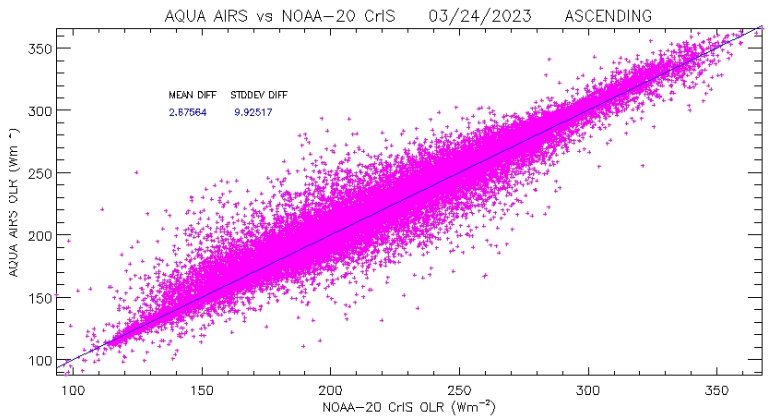
NOAA-20 vs NOAA-21 Ascending



AIRS vs NOAA-21 Ascending

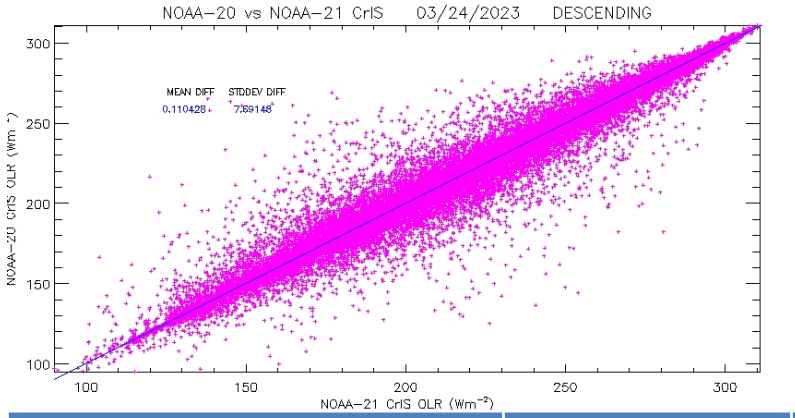


AIRS vs NOAA-20 Ascending

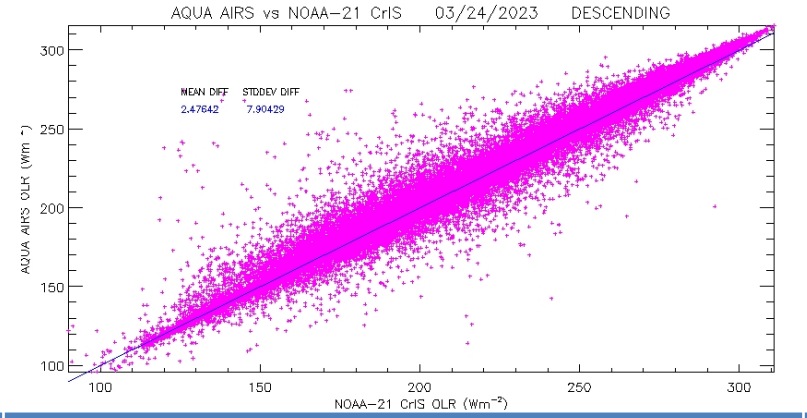


Ascending Mean Diff (W/m²)	0.1	2.4	2.7
STDev (W/m²)	8.1	8.6	10

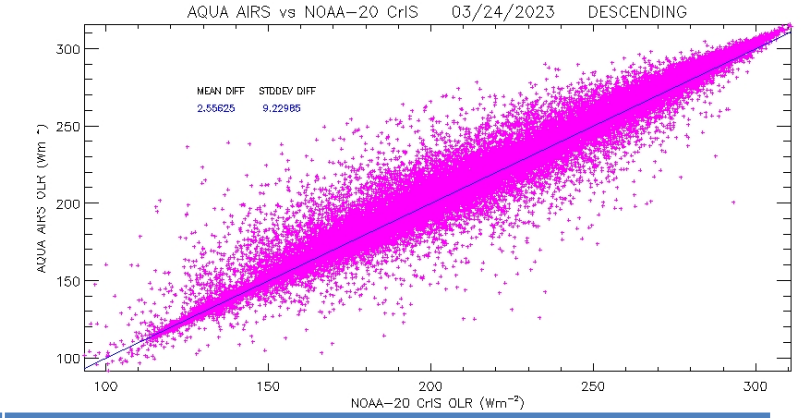
NOAA-20 vs NOAA-21 Descending



AIRS vs NOAA-21 Descending



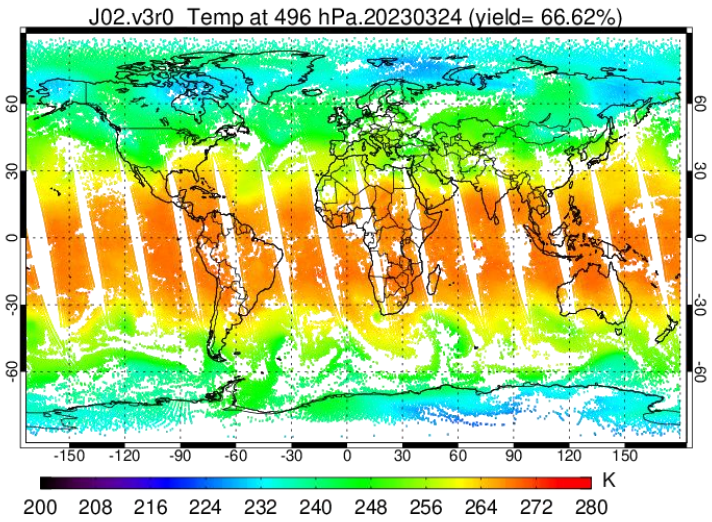
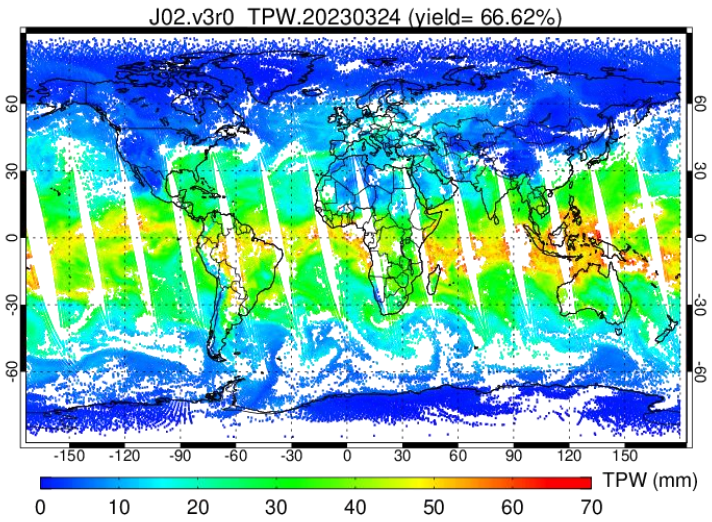
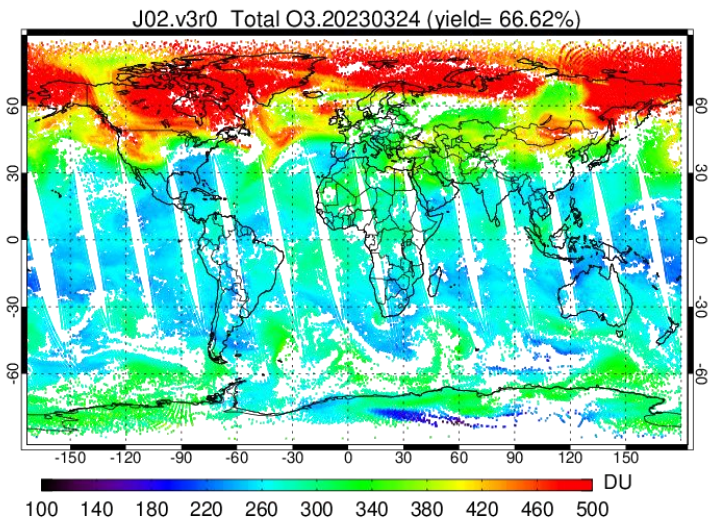
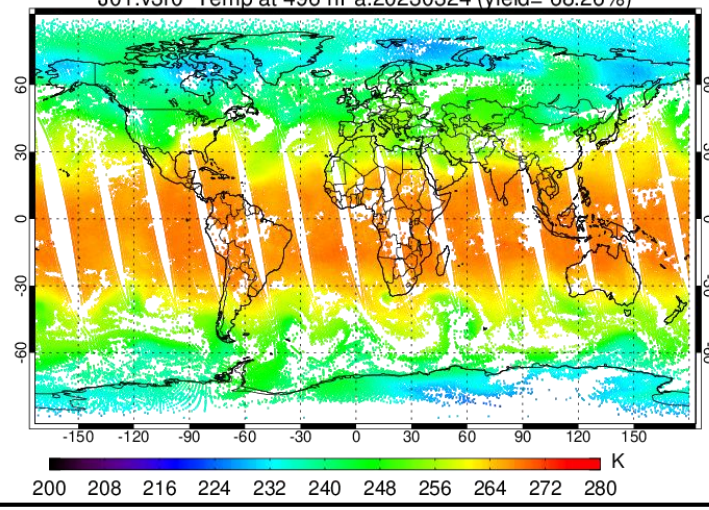
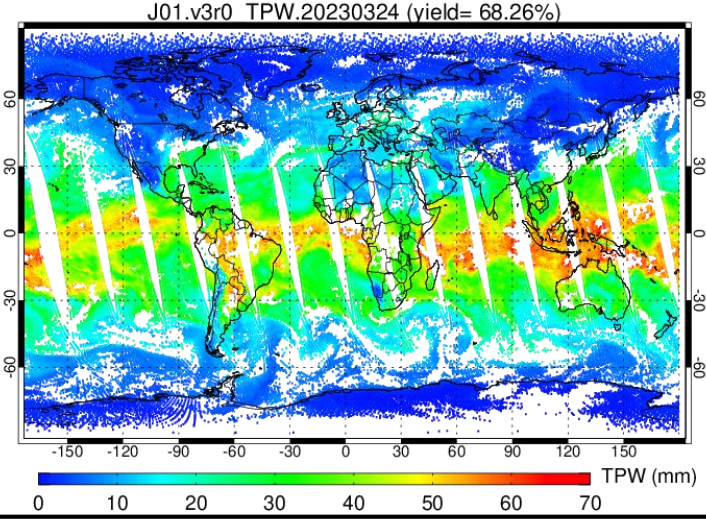
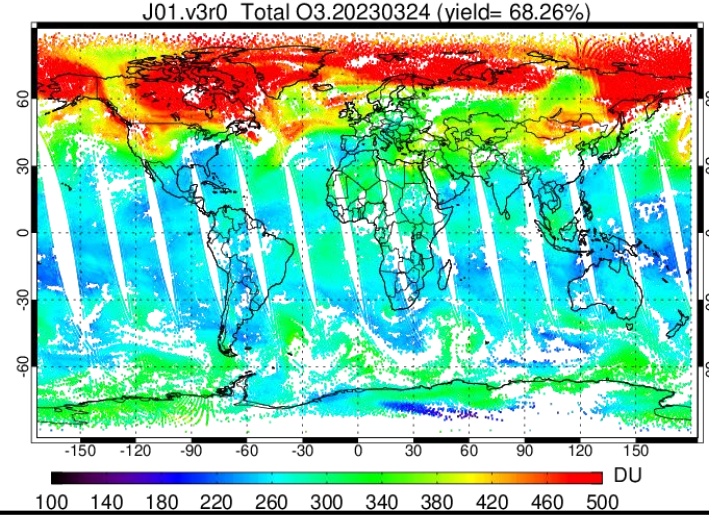
AIRS vs NOAA-20 Descending



Descending Mean Diff (W/m²)	0.1	2.5	2.6
STDev (W/m²)	7.7	8.0	9

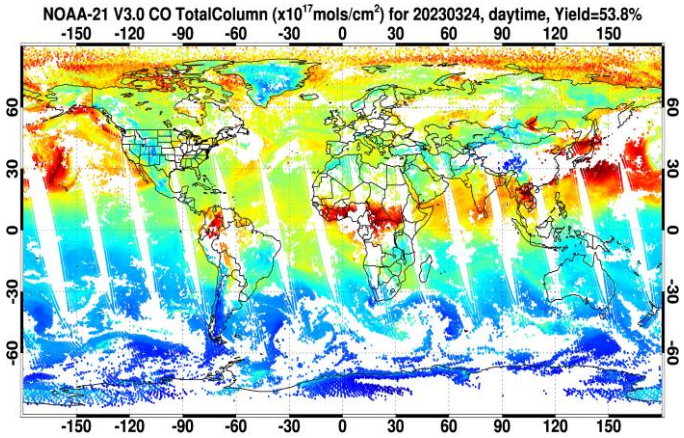
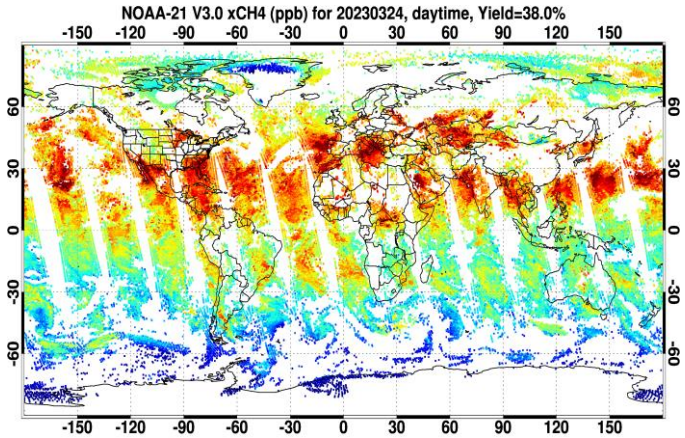
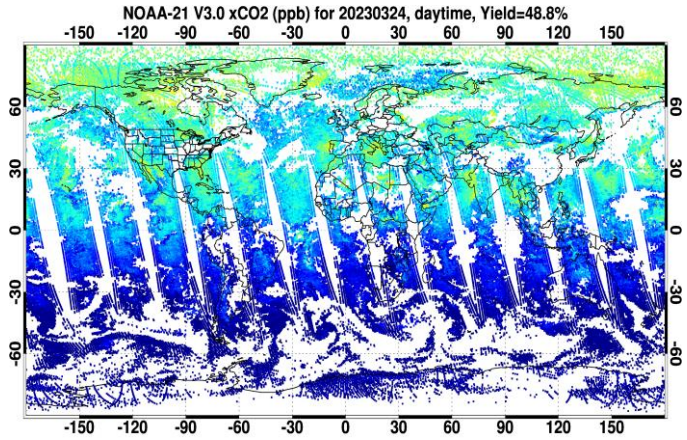
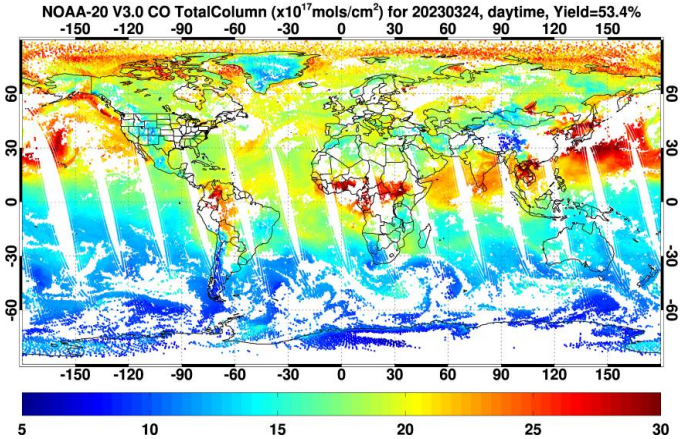
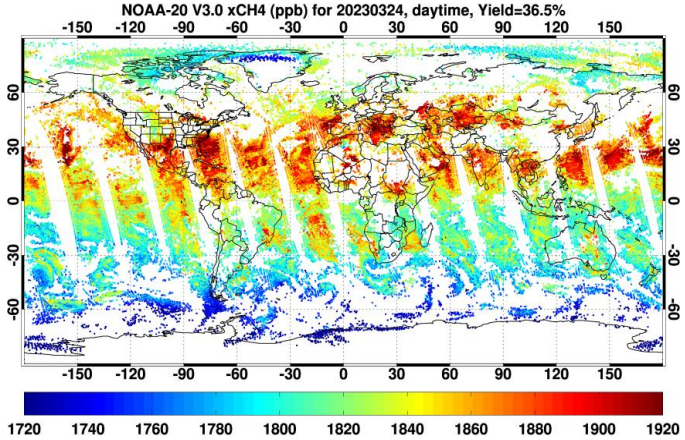
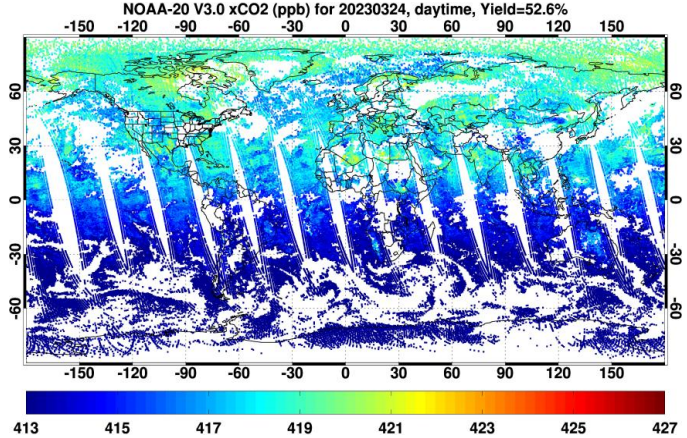
version 3.0 maps

NOAA-21 *vs* NOAA-20 NUCAPS V3.0 EDR Retrievals for 2023/03/24 (EP v211)

	Temperature at 496 hPa	TPW (mm)	Total Ozone (DU)
NOAA-21			
NOAA-20			

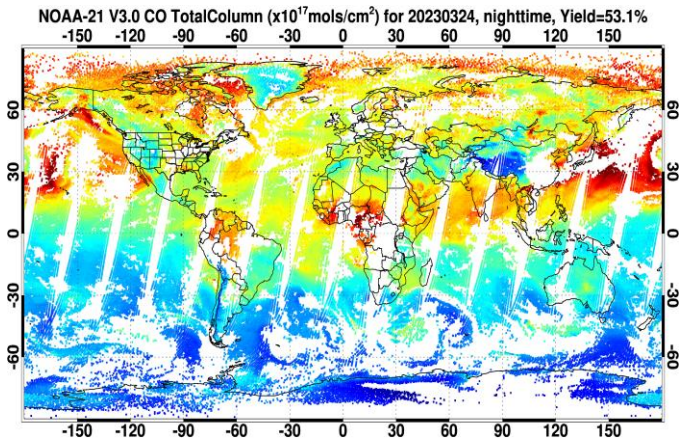
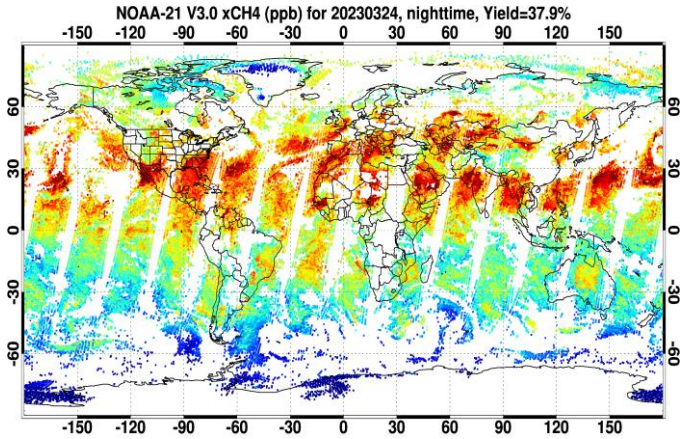
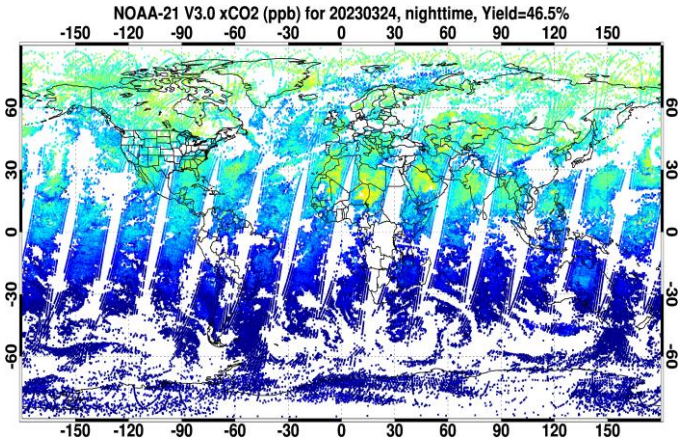
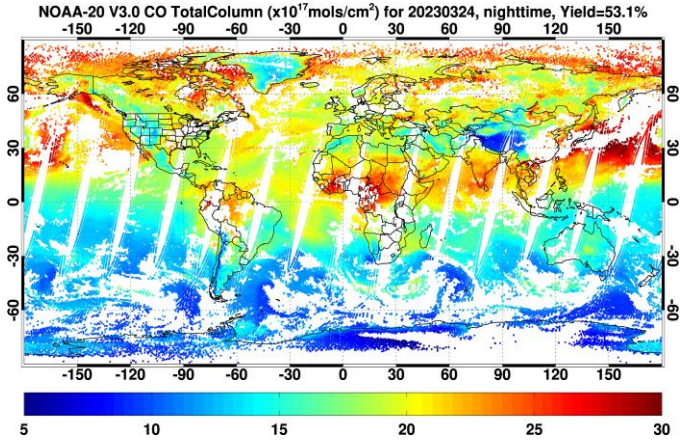
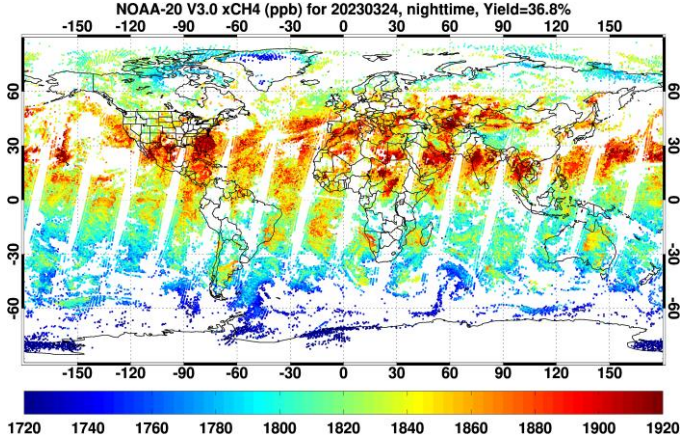
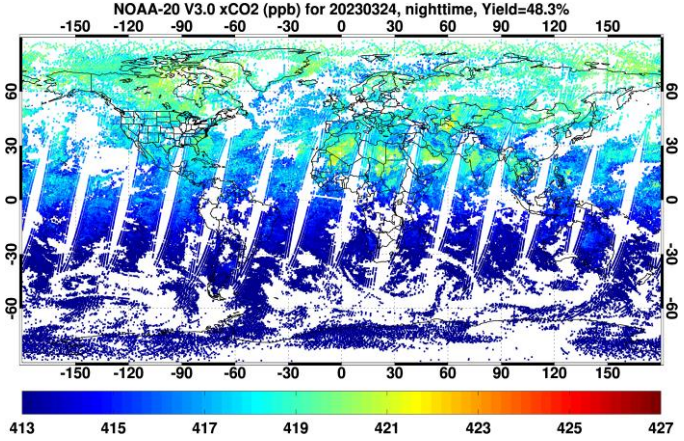
NOAA-21 NUCAPS EDR retrievals from J2-Ready algorithm matches very well both qualitatively and quantitatively with the NOAA-20 operational NUCAPS EDRs. The algorithm produces vertical profiles of temperature, water vapor, ozone, OLR, CO, CH4, and CO2. Retrieved profiles (100 layers) span from surface to 0.01 hPa.

NOAA-21 *vs* NOAA-20 NUCAPS Trace Gas EDR Products (2023/03/24 Daytime; EP v211) Ascending Orbit (Daytime) v3.0

	Total Column CO	Total Column CH_4	Total Column CO_2
NOAA-21			
NOAA-20			

NOAA-21 NUCAPS trace gas EDR products from NOAA-21-Ready algorithm matches very well both qualitatively and quantitatively with the NOAA-20 NUCAPS products. Retrieved trace gas profiles (100 layers) span from surface to 0.01 hPa. Figures show Total Column CO, CH_4, and CO_2 Products. We have evaluated these products with TROPOMI/OCO-2 products. TCCON in-situ measurements require time to accumulate.

NOAA-21 *vs* NOAA-20 NUCAPS Trace Gas EDR Products (2023/03/24 Nighttime; EP v211) Descending Orbit (Nighttime)

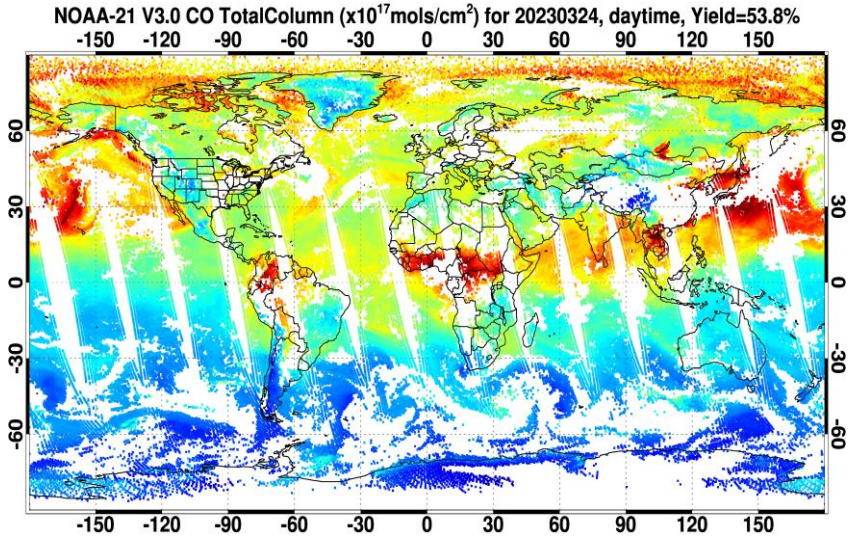
	Total Column CO	Total Column CH_4	Total Column CO_2
NOAA-21			
NOAA-20			

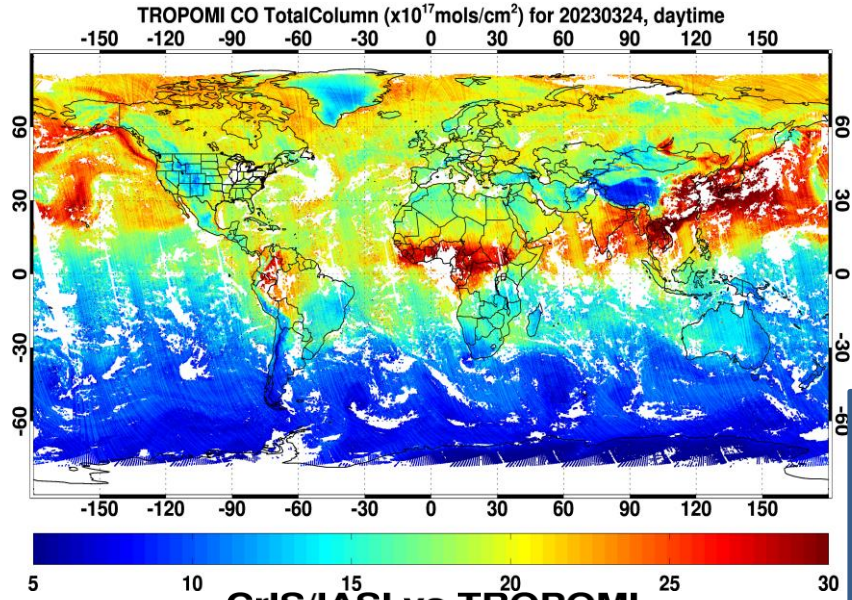
NOAA-21 NUCAPS trace gas EDR products from NOAA-21-Ready algorithm matches very well both qualitatively and quantitatively with the NOAA-20 NUCAPS products. Retrieved trace gas profiles (100 layers) span from surface to 0.01 hPa. Figures show Total Column CO, CH_4, and CO_2 Products. We have evaluated these products with TROPOMI/OCO-2 products. TCCON in-situ measurements require time to accumulate.

Total Column CO NOAA-21,-20 NUCAPS 3.0 vs TROPOMI (24-Mar-2023)

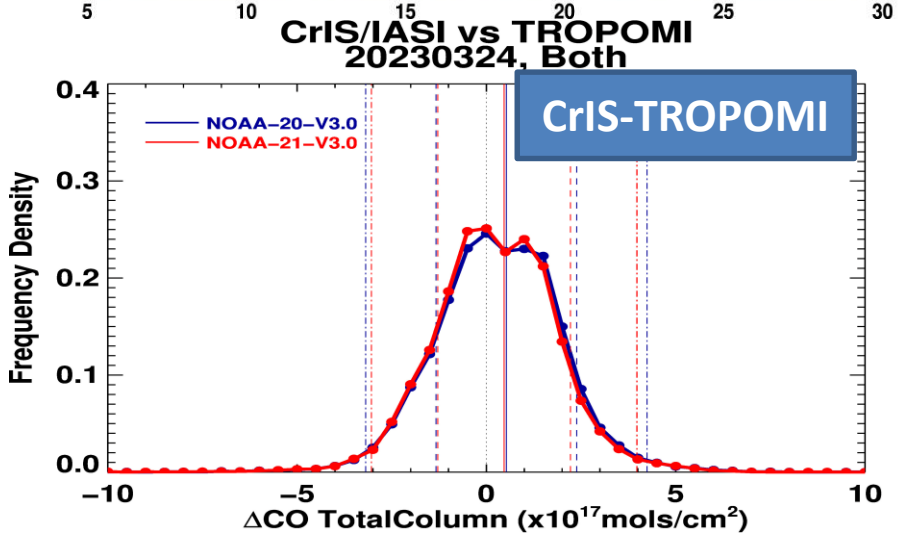
NOAA-21

NOAA-20





TROPOMI



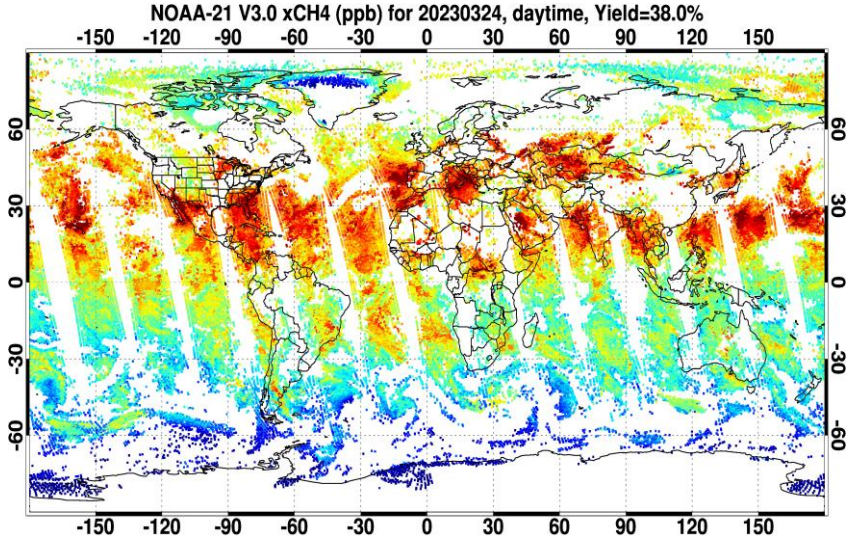
CrIS-TROPOMI

- NUCAPS EDR products are generated for both daytime and nighttime
- TROPOMI uses solar spectrum to retrieve CO and comparisons are possible for daytime only

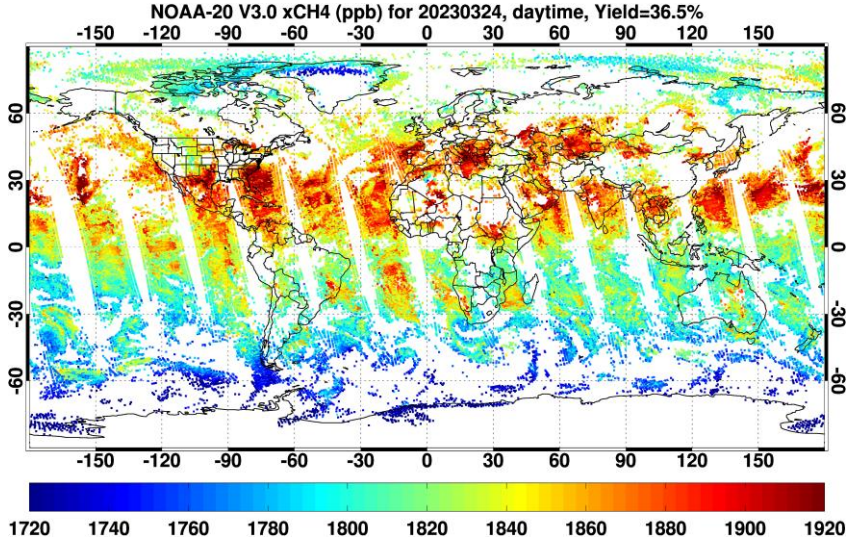
NOAA-21 NUCAPS CO product retrieval from NOAA-21-Ready algorithm matches very well both qualitatively and quantitatively with the NOAA-20 NUCAPS product. Retrieved CO profile (100 layers) span from surface to 0.01 hPa. Shown here is the total column CO vs TROPOMI.

Total Column CH_4 NOAA-21,-20 NUCAPS 3.0 vs TROPOMI (24-Mar-2023)

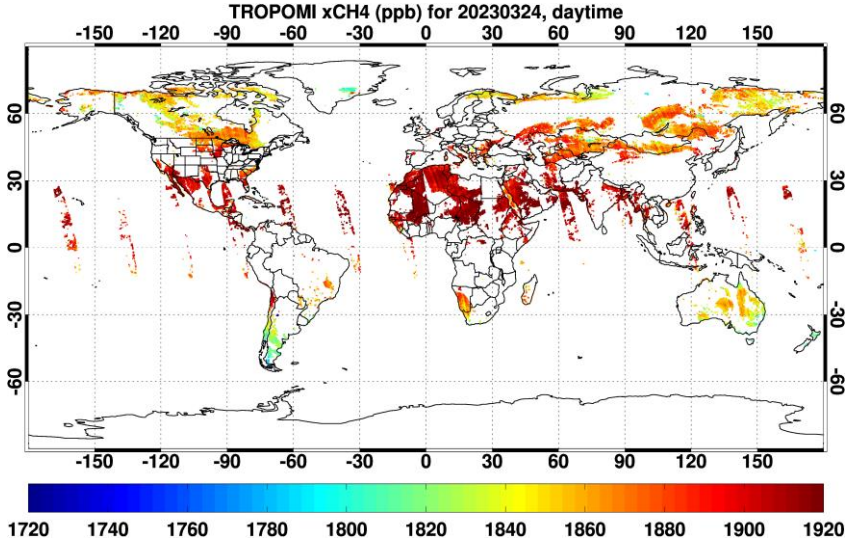
NOAA-21



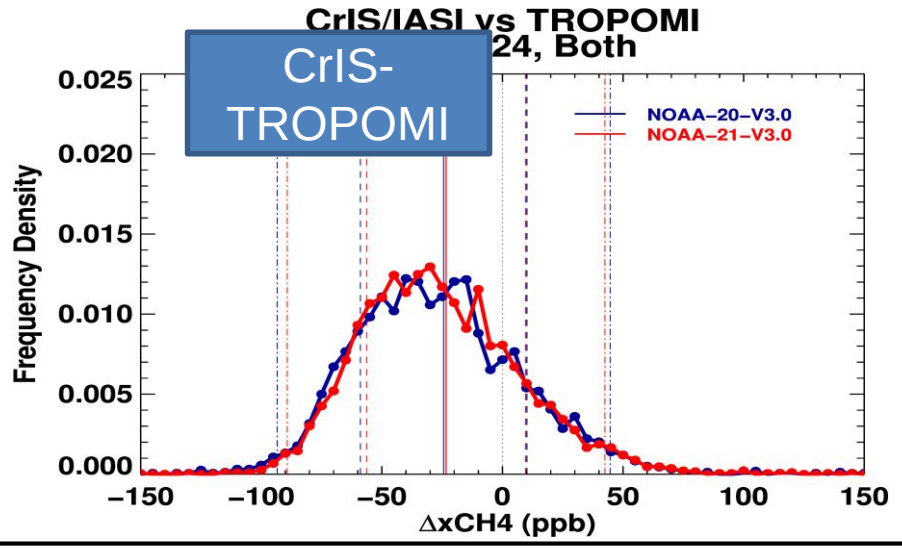
NOAA-20



TROPOMI



CrIS-TROPOMI



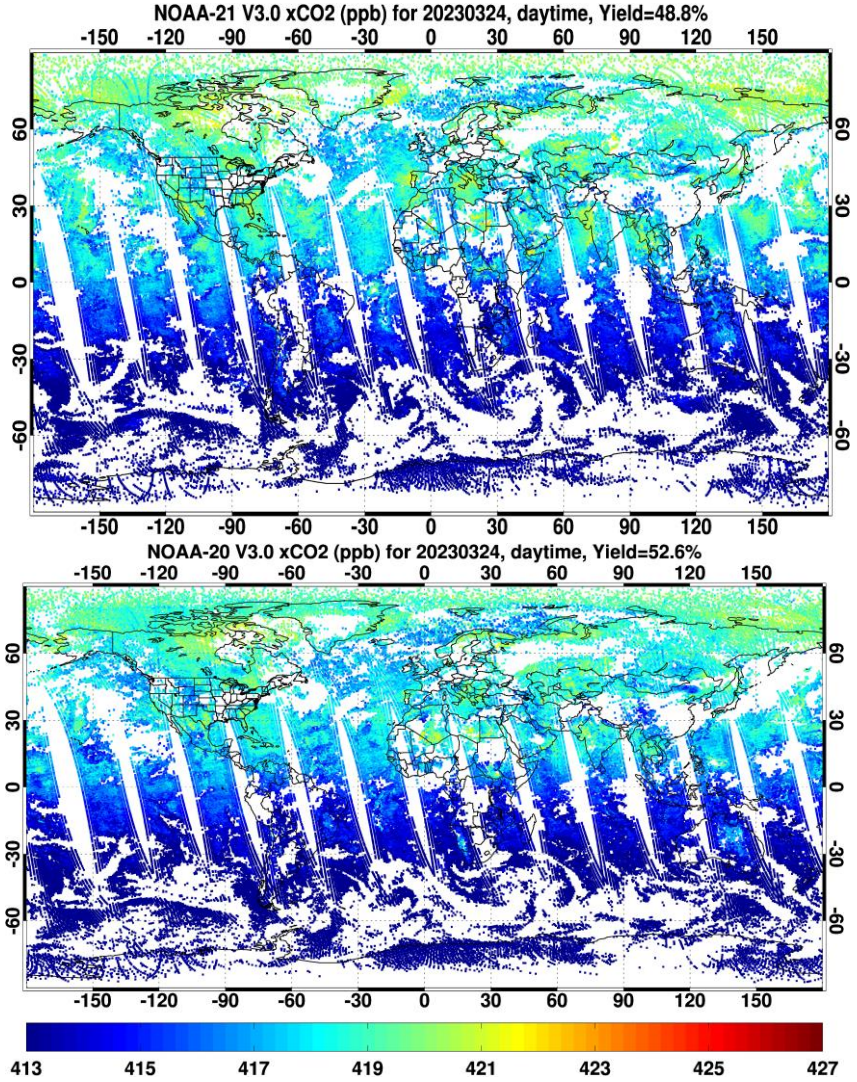
- NUCAPS EDR products are generated for both daytime and nighttime
- TROPOMI uses solar spectrum to retrieve CO and comparisons are possible for daytime only

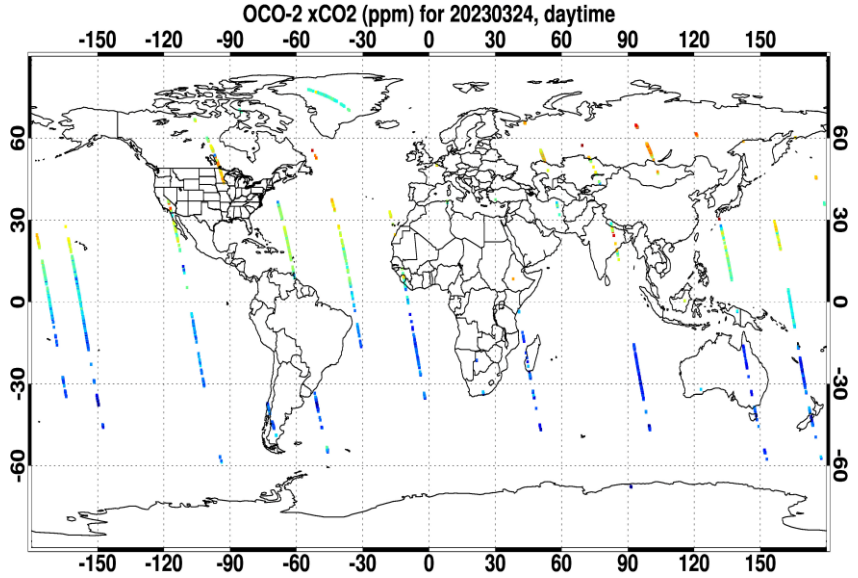
NOAA-21 NUCAPS CH_4 retrieval from NOAA-21-Ready algorithm matches very well both qualitatively and quantitatively with the NOAA-20 NUCAPS product. Retrieved CH_4 profile (100 layers) span from surface to 0.01 hPa. Shown here is the total column CH_4 vs TROPOMI

Total Column CO_2 NOAA-21,-20 NUCAPS 3.0 vs OCO-2 (24-Mar-2023)

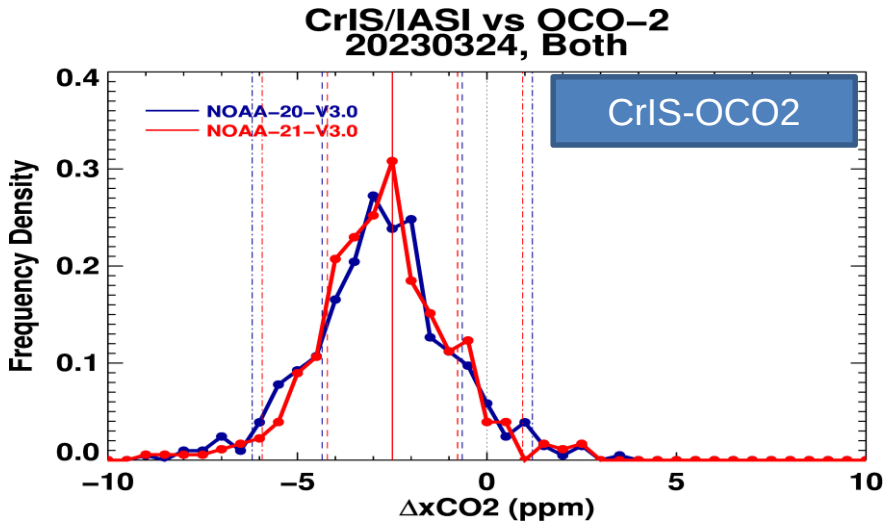
NOAA-21

NOAA-20





OCO-2 v11



CrIS-OCO2

- NUCAPS products are generated for both daytime and nighttime
- OCO-2 Uses solar measurements to retrieve CO2 and comparisons are possible for daytime only
- NOAA-21 EP v211 improved CO_2 product matches between NOAA-20 and NOAA-21

NOAA-21 NUCAPS CO_2 retrievals from NOAA-21 Ready algorithm matches very well both qualitatively and quantitatively with NOAA-20 NUCAPS product. Retrieved trace gas profiles (100 layers) span from surface to 0.01 hPa. Shown here is the total column CO_2 vs OCO-2.

COMPLETE SET OF SUPPLEMENTAL SLIDES AVAILABLE IN SEPARATE SLIDE PACKET

Set	List of Supplemental Slides	Slide Numbers
S.1	Ongoing Efforts Towards Provisional Maturity	
S.2	NOAA-21 Product Evaluations for Other Focus Days	Supplement
S.3	NPROVS Evaluations	
S.4	NUCAPS v3.1 Improvements	Supplement
S.5	NUCAPS Products Requirements	

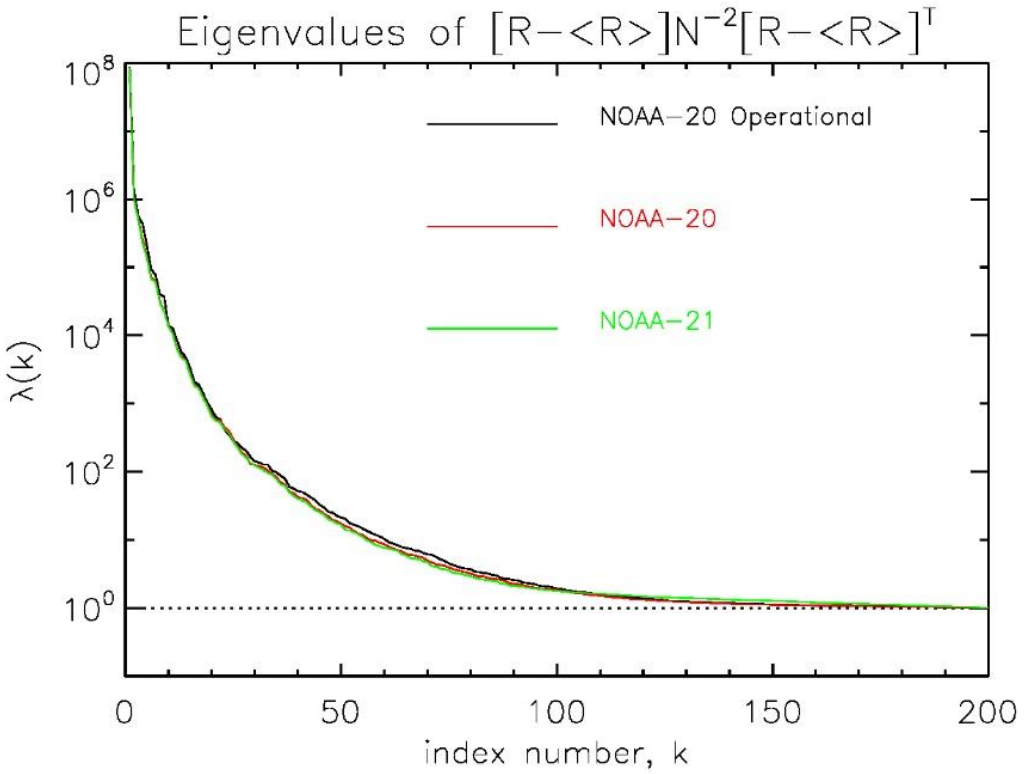
(S.1) Ongoing Efforts Towards Provisional Maturity

NOAA-21 NUCAPS Version – Path Forward: First Guess Regression

Detailed Plan

Cloudy and Clear Regression

- Use Four Focus Days (2/16, 2/20, 02/27, 03/24) for both NOAA-21 and NOAA-20
  - Generate Cloudy and Clear Regression LUTs for both NOAA-21, and NOAA-20 (CrIS and ATMS), (CrIS only)
  - Apply these coefficients on a different day and generate retrievals for both NOAA-20 and NOAA-21 (New Focus Day: 4/5?)
    - Compare the FG vs ECMWF for NOAA-21 and NOAA-20 using 4/5/23
      - "NOAA-21-Ready" New FG retrievals vs ECMWF; NOAA-20 new FG vs ECMWF for global and ocean cases
      - NOAA-20 operational FG vs ECMWF; NOAA-20 new FG vs ECMWF for global and ocean cases
- Apply coefficients on NOAA-20 focus days (12-focus day data set)
  - Compare NOAA-20 OPS FG vs. ECMWF; NOAA-20 new FG vs ECMWF
- Assess whether additional Focus Days over different seasons are needed for the regression
- This approach facilitates expediting the NUCAPS Provisional Maturity

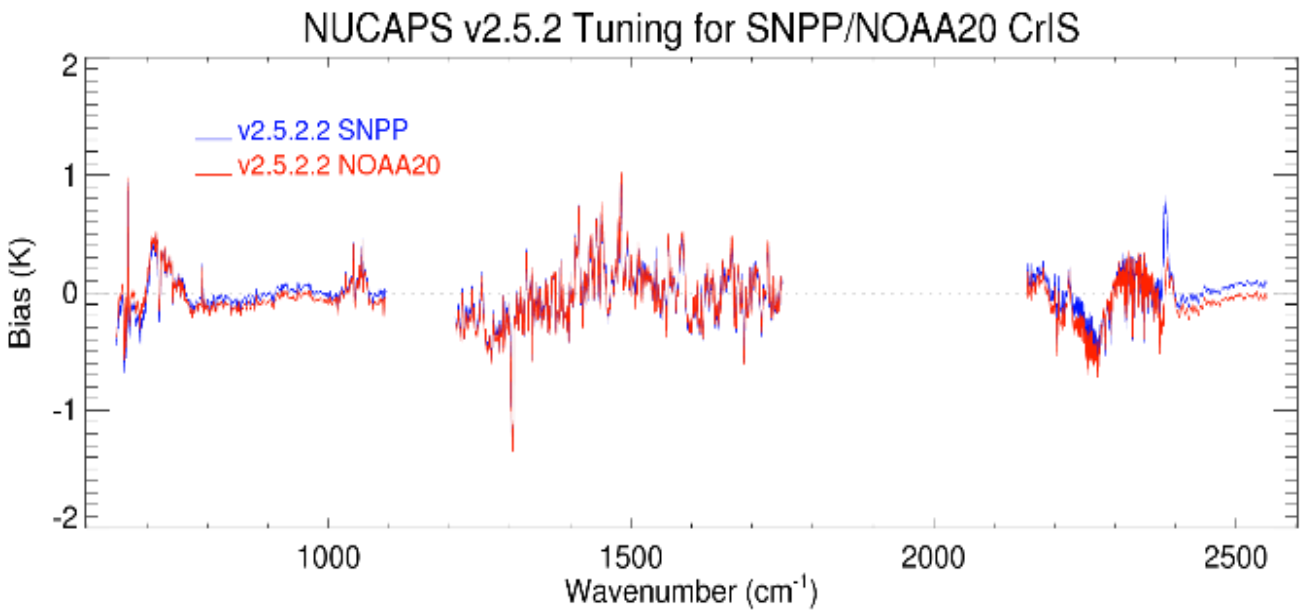


- Regression setup and preliminary evaluations completed
- Evaluation of NOAA-21 regression LUT updates and results on an independent data is in progress

NOAA-21 NUCAPS Version – Path Forward: Tuning

NOAA-21 IR and Microwave Tuning Plan

- Initiate Microwave and IR Tuning for NOAA-21 based on two Focus Days (2/27, 03/24)
  - **IR Tuning for NOAA-21**
    - Option I: Double Difference method
      - Using S-NPP, and perform double differences similarly for NOAA-20
      - Select (2/27, 03/24) ECMWF data for T(p), q(p), O_3(p)
      - Run SARTA v11a version
    - Option II: Obs-Calc method
      - NOAA-21 CrIS Radiances
      - ECMWF analysis data: T(p), q(p) and CAMS model trace gases
      - Reinvestigate how to download data, and try one day first
      - Try to find other alternatives models
      - Observation data selection criteria same as S-NPP (Would be same for both IR and MW)
- Assess whether we need tuning for NOAA-21
- This approach facilitates expediting the NUCAPS Provisional Maturity



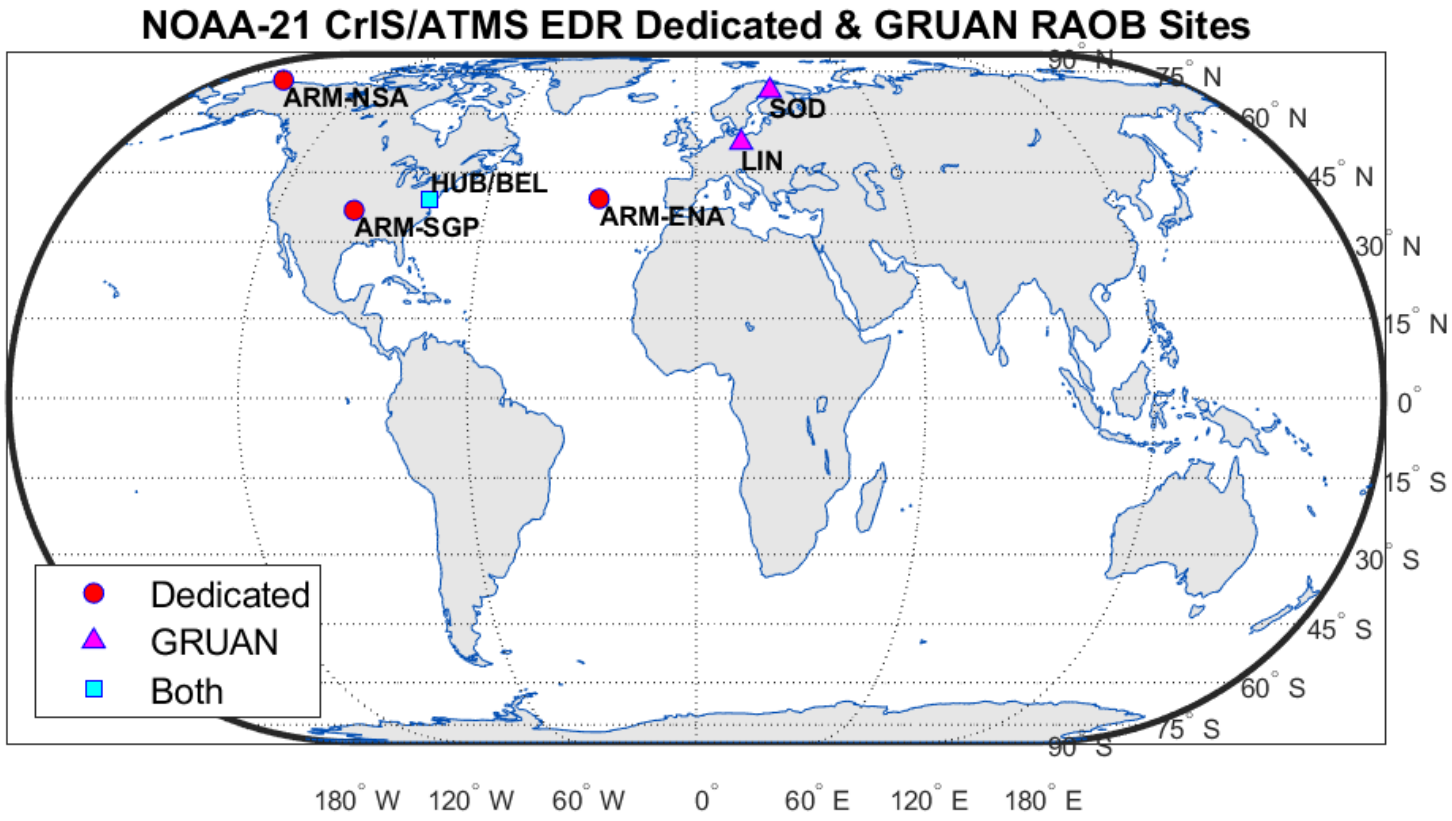
Double difference method: SNPP tuning + double difference

VALAR NUCAPS Dedicated RAOB Collocations

Validation Archive (VALAR)

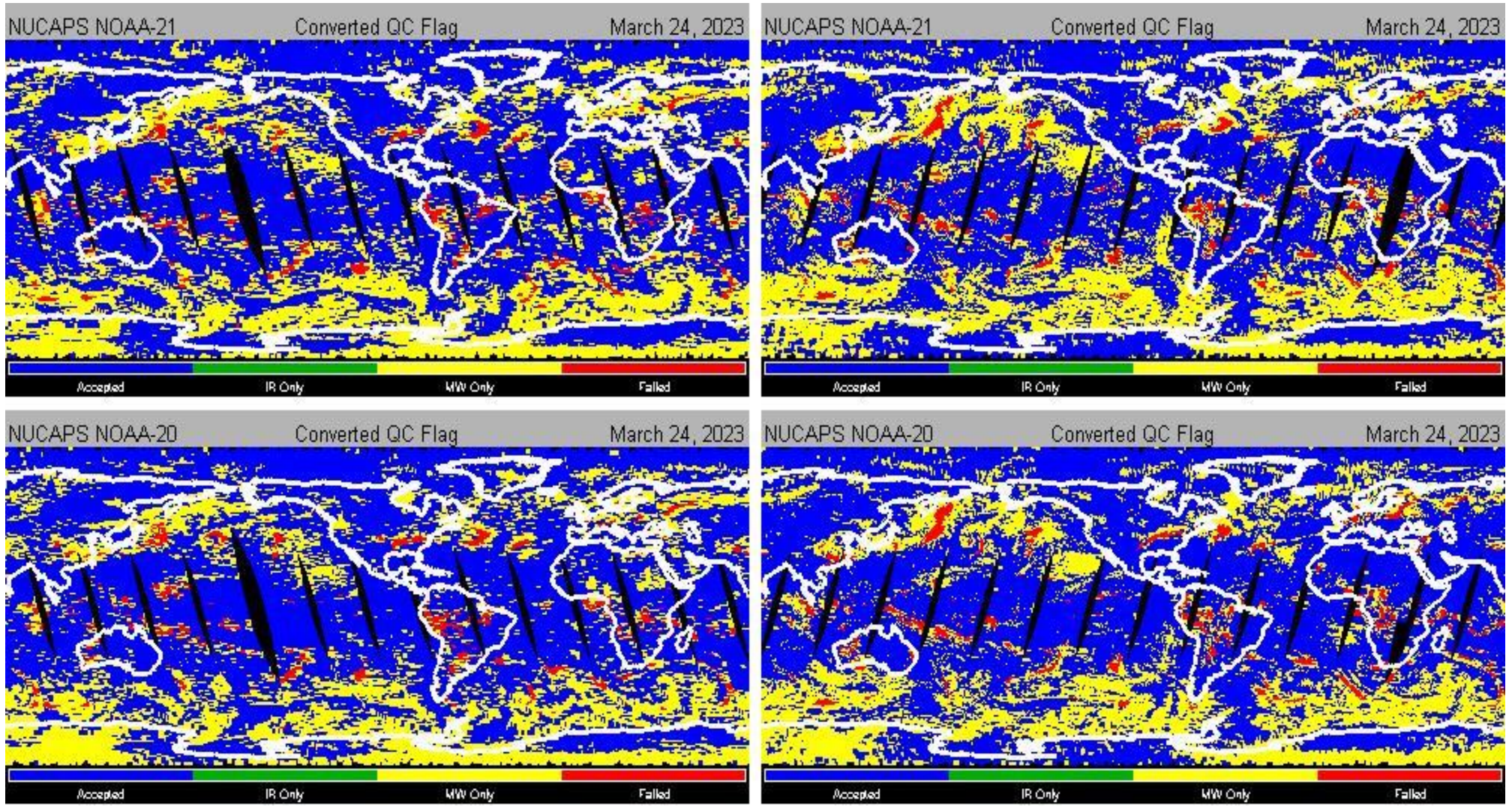
- **CrIS/ATMS granules** (SDR/TDR) matched with truth data for offline retrievals using NPROVS collocation files
  - **Atmospheric Radiation Measurement (ARM)** Sites (*Tobin et al.* 2006)
    - Eastern North Atlantic (ENA)
    - Southern Great Plains (SGP)
    - North Slope of Alaska (NSA)
    - Radiosonde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

NOAA-21 Dedicated & GRUAN RAOB Sites



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

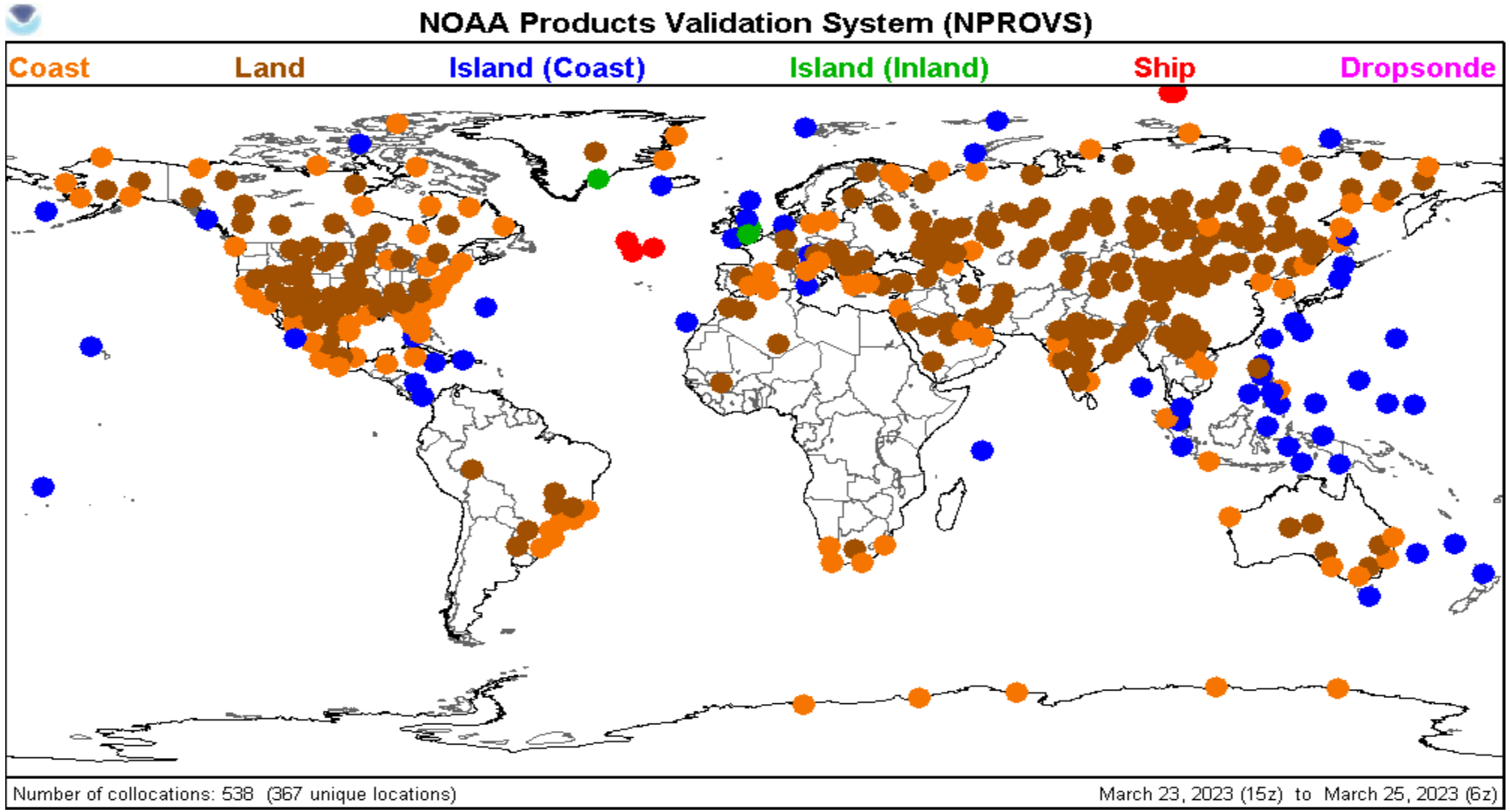
(S.3) NPROVS Evaluations with Conventional RAOBs



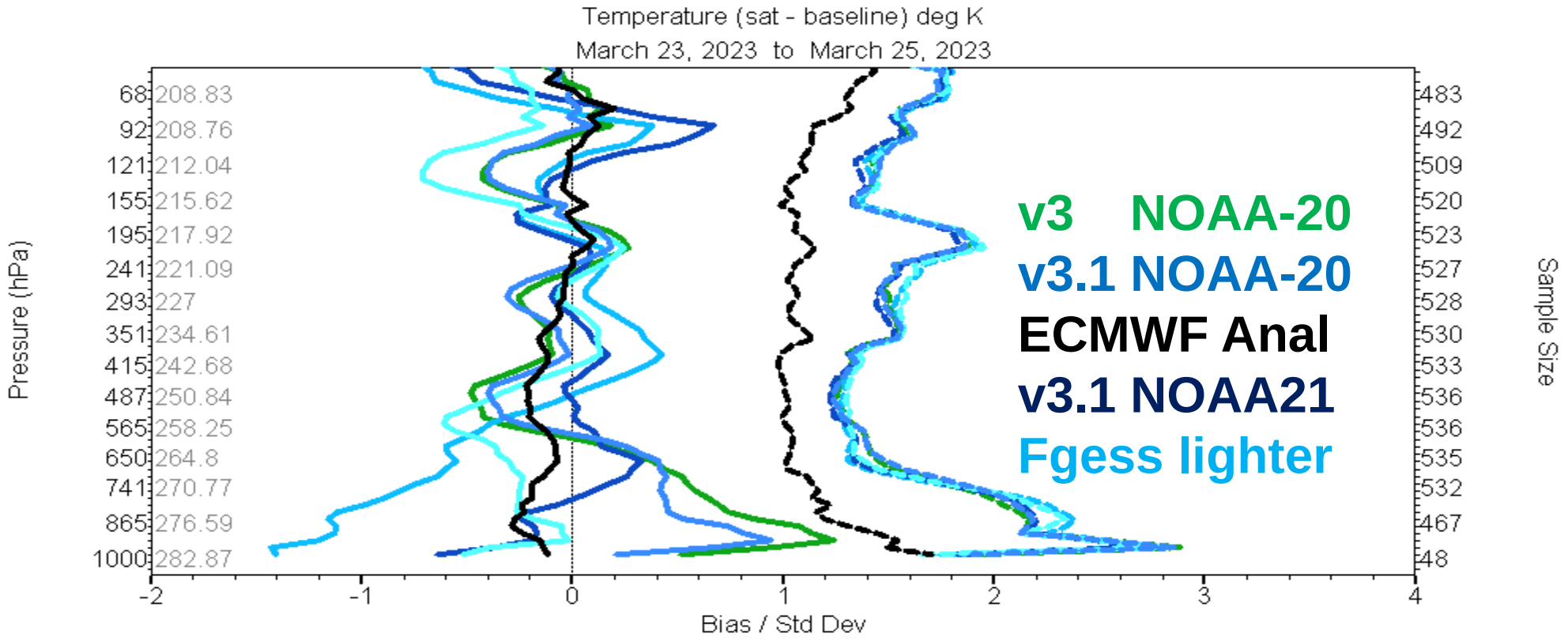
IR+MW Pass **MW-only Pass** **Both Fail**

V3.1 (N20) / v3.1 (N21)

Focus Day March 24, 2023



March 24, 2023 Focus day



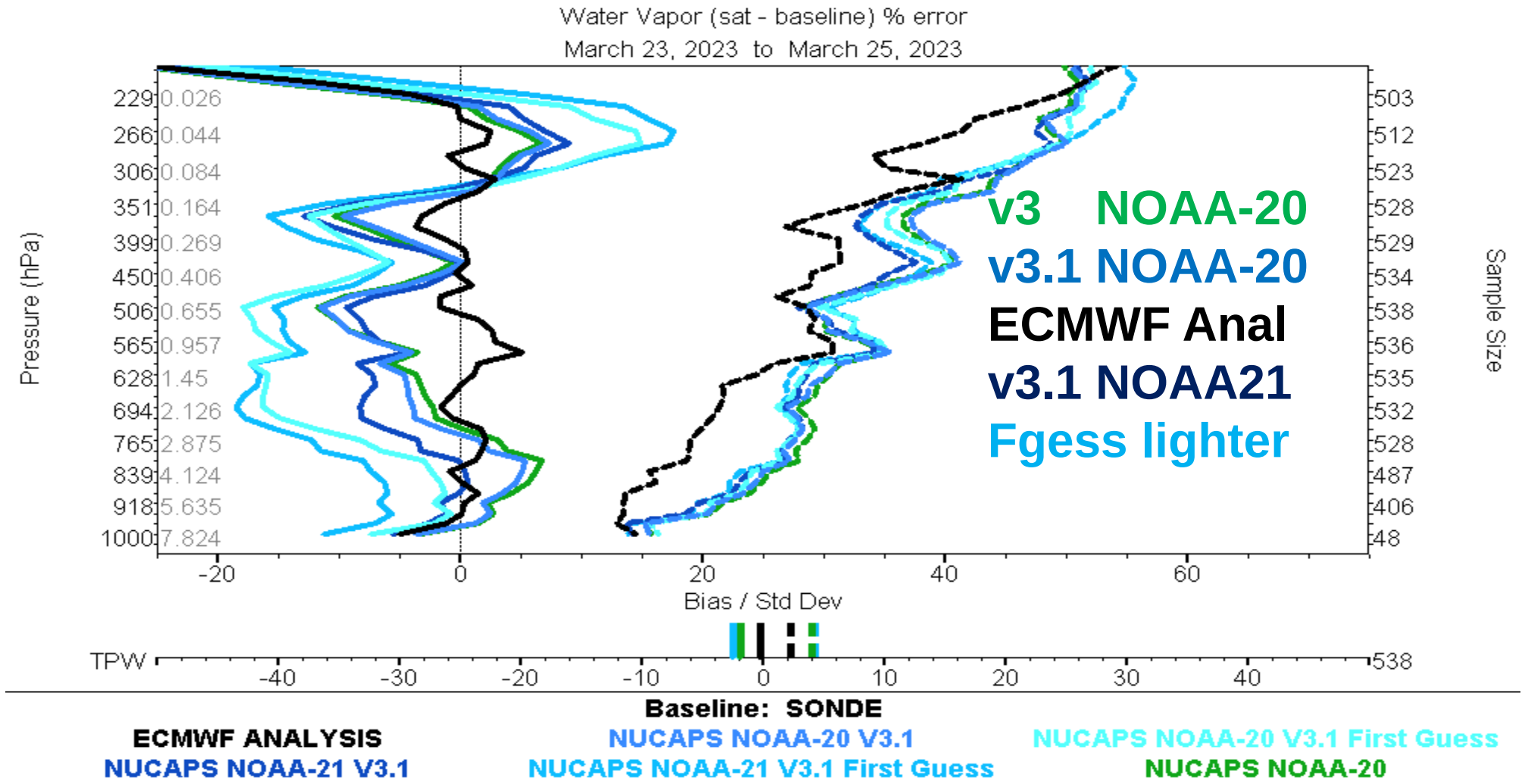
Baseline: SONDE

ECMWF ANALYSIS
NUCAPS NOAA-21 V3.1

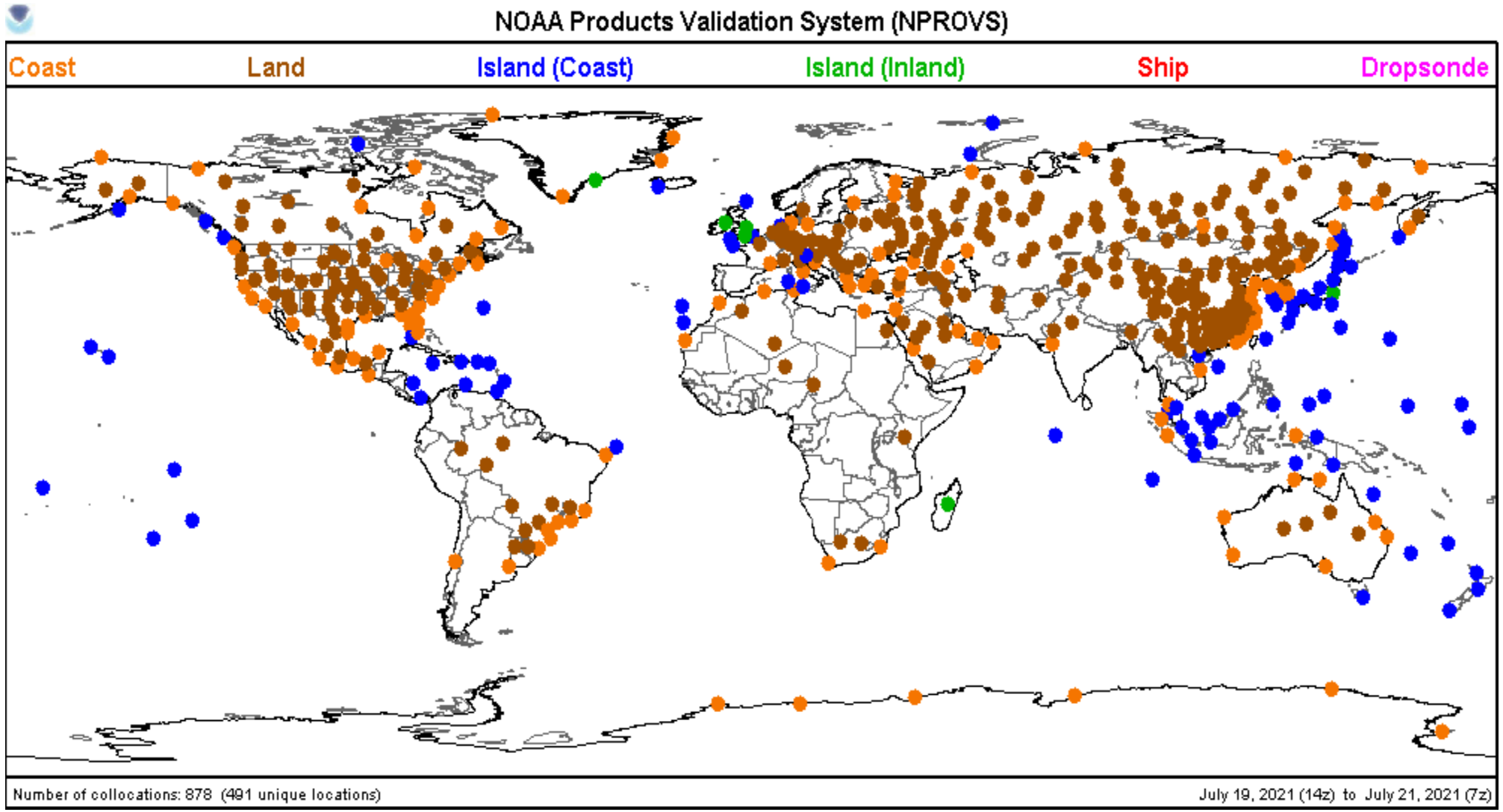
NUCAPS NOAA-20 V3.1
NUCAPS NOAA-21 V3.1 First Guess

NUCAPS NOAA-20 V3.1 First Guess
NUCAPS NOAA-20

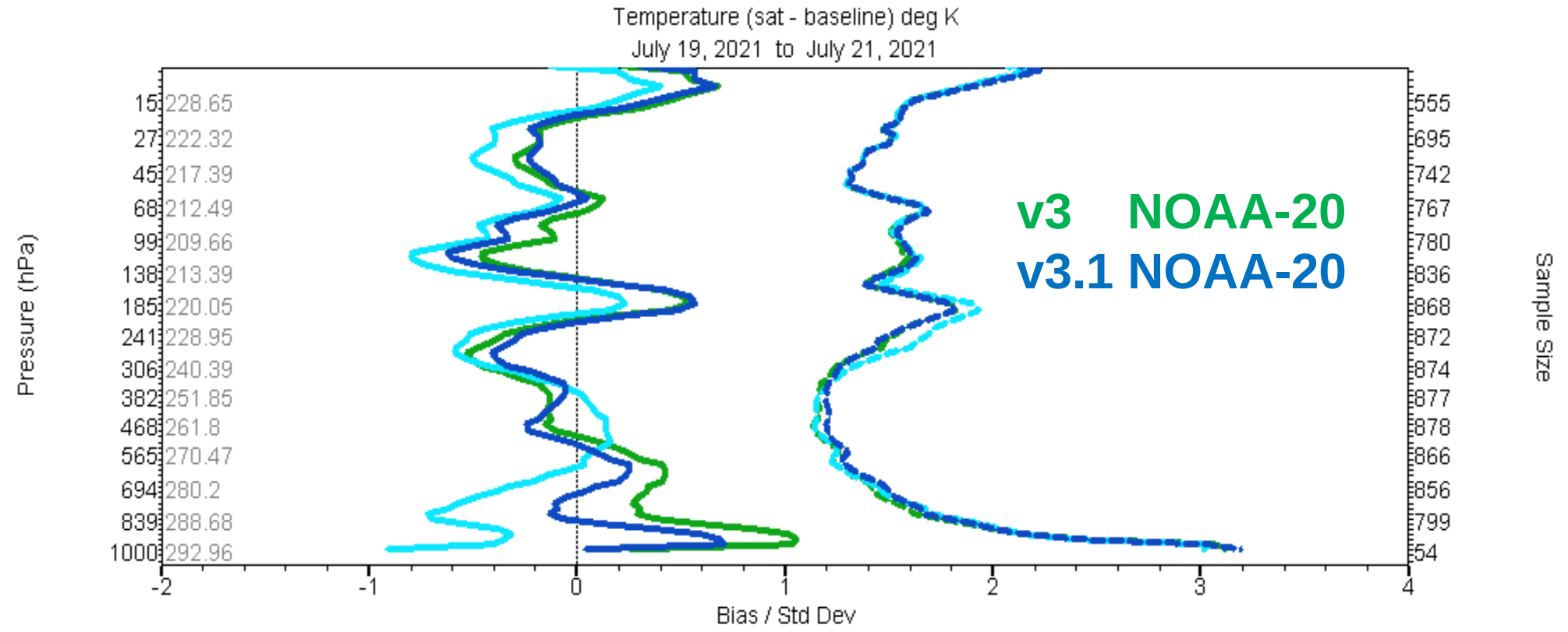
March 24, 2023 Focus day



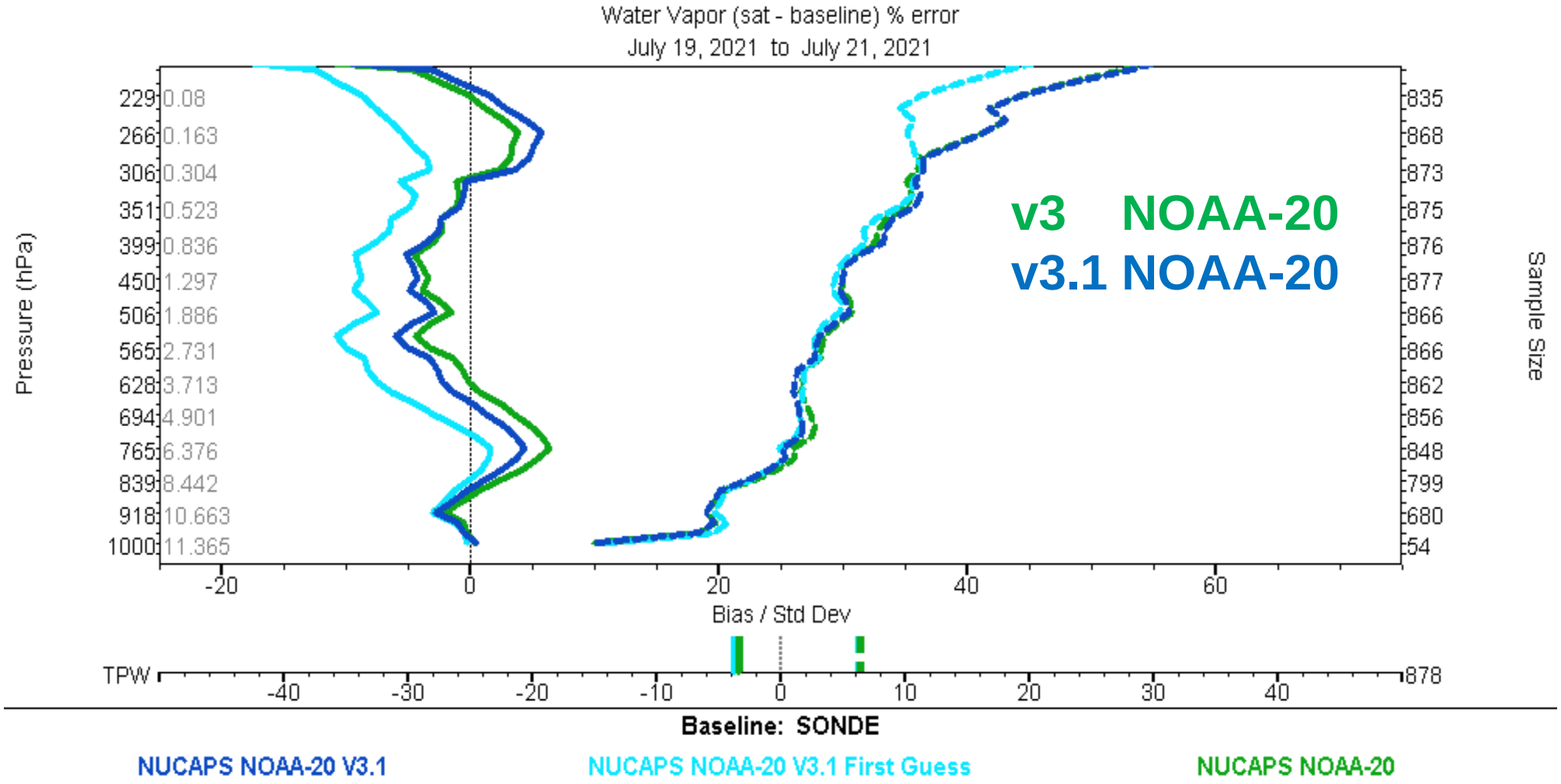
March 24, 2023 Focus day



July 20, 2021 Focus day

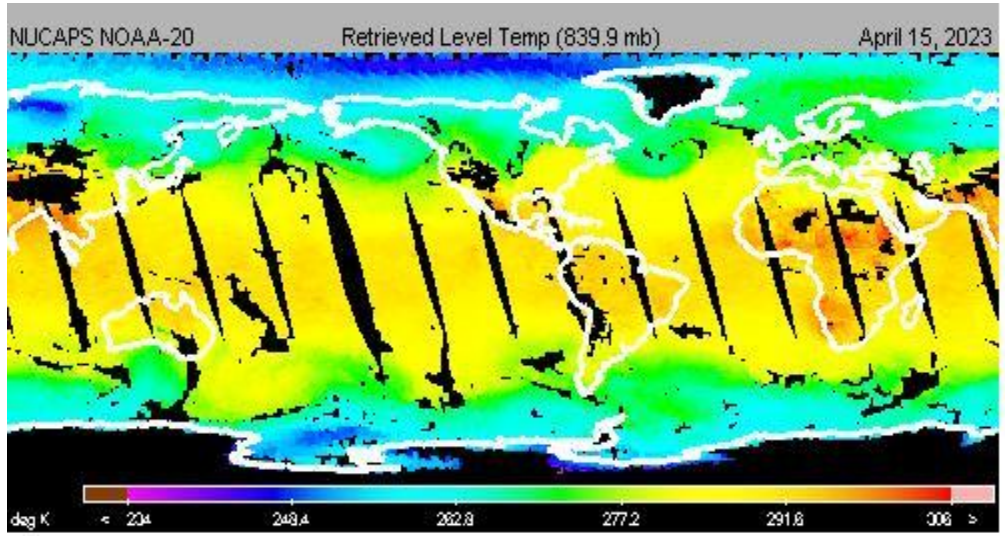


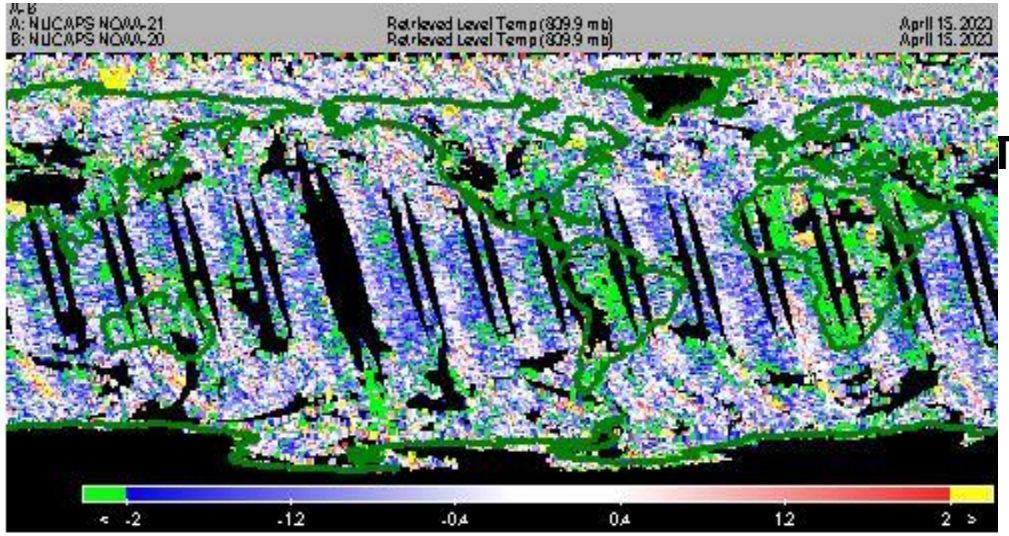
July 20, 2021 Focus day
Global 6-hr, 100km
100 layer



July 20, 2021 Focus day
Global 6-hr, 100km
100 layer

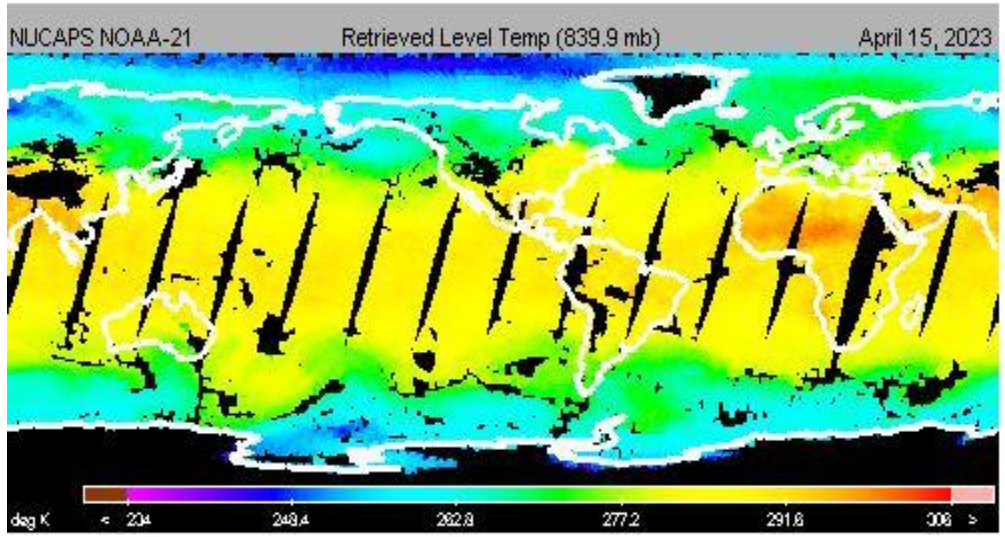
839 hPa Temp

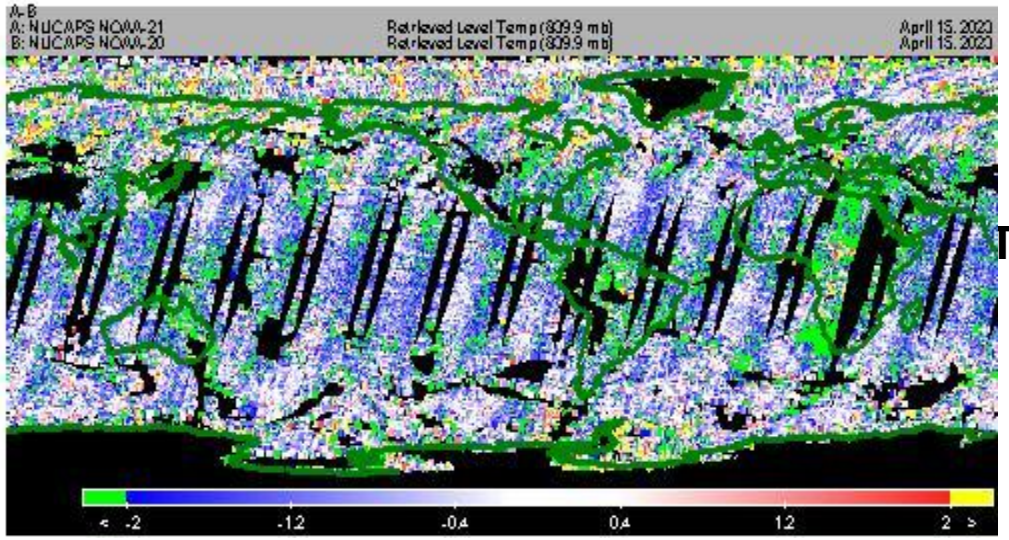




Temperature Difference N21-N20 (+/-2)

839 hPa Temp





Temperature Difference N21-N20 (+/-2)

V3 (N20) / v3 (N21)

(S.5) NUCAPS Products Requirements

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)