NOAA-21 ATMS Provisional Maturity Review Material

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JPSS/GOES-R Data Product Validation Maturity Stages – COMMON DEFINITIONS (Nominal Mission)

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.

Outline

- Algorithm Cal/Val Team Members
- ATMS Data Product Requirements
- Post-launch Cal/Val Timeline – Updated after Beta Maturity
- Post-launch Cal/Val Tasks – Updated after Beta Maturity
- Post Beta Maturity Performance Validation
  - NOAA-21 ATMS Instrument On-orbit Status/Performance Assessment
  - NOAA-21 ATMS Science Data Quality Evaluation
- Downstream Product Feedback
- User Feedback
- Conclusion
- Path Forward to Validated Maturity

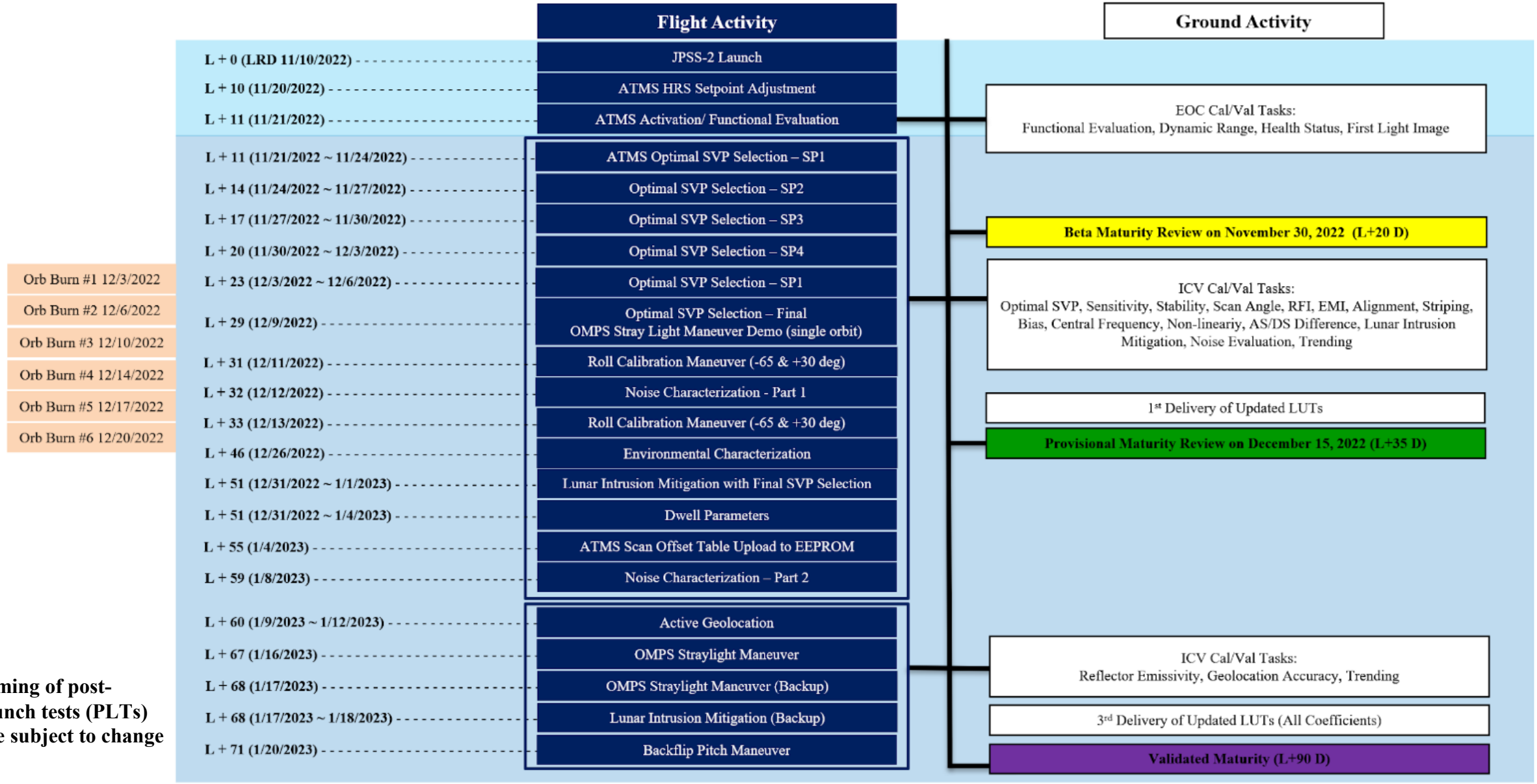
JPSS ATMS Cal/Val Team

Name	Organization	Major Task
Quanhua (Mark) Liu	NOAA/STAR	NOAA STAR ATMS Cal/Val Team PI
Ninghai Sun	GST, Inc. @ NOAA/STAR	NOAA STAR ATMS Cal/Val Team
Hu (Tiger) Yang	UMD/CISESS @ NOAA/STAR	NOAA STAR ATMS Cal/Val Team
Siena Iacovazzi	GST, Inc. @ NOAA/STAR	NOAA STAR ATMS Cal/Val Team
Jun Zhou	UMD/CISESS @ NOAA/STAR	NOAA STAR ATMS Cal/Val Team
Vincent Leslie	MIT/LL	MIT/LL ATMS Cal/Val Team
James Eshbaugh	MIT/LL	MIT/LL ATMS Cal/Val Team
Deirdre Bolen	SAIC @ NOAA/JPSS	JPSS Algorithm Manager
Edward J. Kim	NASA/GSFC	NASA ATMS Team PI
Matthew W. Sammons	FIBERTEK, Inc. @ NASA/GSFC	NASA ATMS Team
Cheng-Hsuan (Joseph) Lyu	Morgan @ NASA/GSFC	NASA ATMS Team
Saji Abraham	SGT, Inc. @ NASA/GSFC	NASA ATMS Team
James Fuentes	Northrop Grumman – Azusa	ATMS Instrument Builder
James G. Kam	Northrop Grumman – Azusa	ATMS Instrument Builder

ATMS Flight Requirements with On-orbit Assessment
N21 values in parentheses meet the requirements and have good margin

Ch.	Center Frequency (MHz)	Polarization	Max Bandwidth (MHz)	Static Beamwidth (deg)	Dynamic Range (K)	Calibration Accuracy (K)	NEΔT @300K (K)
1	23800	QV	270	5.2	3-330	1.0	0.7 (0.221)
2	31400	QV	180	5.2	3-330	1.0	0.8 (0.277)
3	50300	QH	180	2.2	3-330	0.75	0.9 (0.309)
4	51760	QH	400	2.2	3-330	0.75	0.7 (0.211)
5	52800	QH	400	2.2	3-330	0.75	0.7 (0.204)
6	53596±115	QH	170	2.2	3-330	0.75	0.7 (0.219)
7	54400	QH	400	2.2	3-330	0.75	0.7 (0.207)
8	54940	QH	400	2.2	3-330	0.75	0.7 (0.211)
9	55500	QH	330	2.2	3-330	0.75	0.7 (0.228)
10	57290.344(f_o)	QH	330	2.2	3-330	0.75	0.75 (0.339)
11	f_o± 217	QH	78	2.2	3-330	0.75	1.2 (0.459)
12	f_o±322.2±48	QH	36	2.2	3-330	0.75	1.2 (0.502)
13	f_o±322.2±22	QH	16	2.2	3-330	0.75	1.5 (0.715)
14	f_o±322.2±10	QH	8	2.2	3-330	0.75	2.4 (1.01)
15	f_o±322.2±4.5	QH	3	2.2	3-330	0.75	3.6 (1.660)
16	88200	QV	2000	2.2	3-330	1.0	0.5 (0.196)
17	165500	QH	3000	1.1	3-330	1.0	0.6 (0.326)
18	183310±7000	QH	2000	1.1	3-330	1.0	0.8 (0.267)
19	183310±4500	QH	2000	1.1	3-330	1.0	0.8 (0.273)
20	183310±3000	QH	1000	1.1	3-330	1.0	0.8 (0.379)
21	183310±1800	QH	1000	1.1	3-330	1.0	0.8 (0.381)
22	183310±1000	QH	500	1.1	3-330	1.0	0.9 (0.527)

NOAA-21 ATMS Post-launch Cal/Val Timeline



Note: Timing of post-launch tests (PLTs) are subject to change

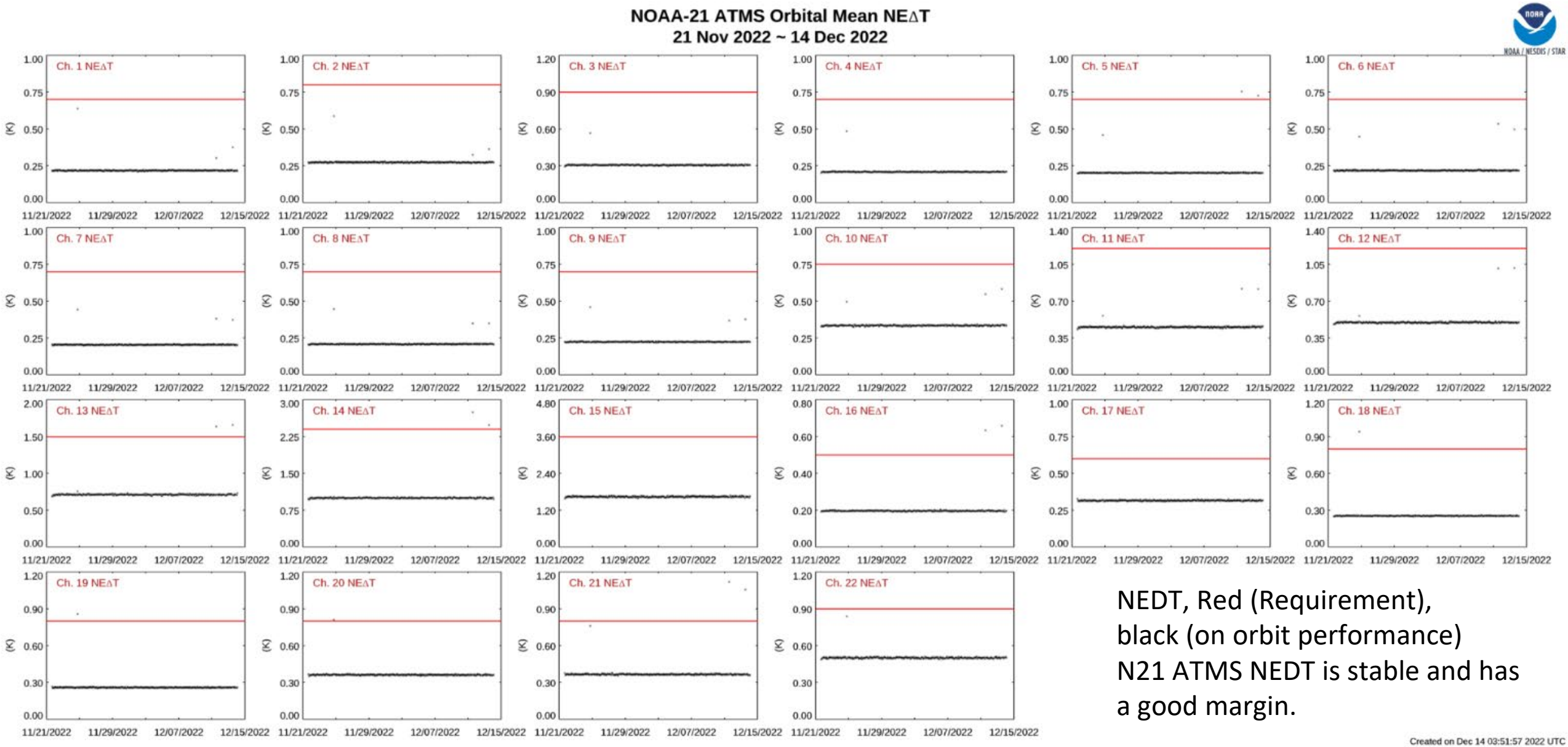
NOAA-21 ATMS Post-launch Cal/Val Tasks

Task #	Title	Teams	Data Available Date & Related PLTs
1	Proxy Instrument Data	NOAA/STAR, MIT/LL, NASA/GSFC, NG	Pre-launch
2	Independent Analysis of TVAC Data	NOAA/STAR, MIT/LL, NG	Pre-launch
3	Analysis of Antenna Pattern Data	NOAA/STAR, MIT/LL, NG	Pre-launch
4	Analysis of Spectral Response Function	NOAA/STAR, NASA/GSFC	Pre-launch
5	Parameter Trending	NOAA/STAR, MIT/LL	L+11
6	Functional Evaluation	MIT/LL, NOAA/STAR, NG	L+11, Activation/Functional Evaluation PLTs
7	Dynamic Range Evaluation	MIT/LL, NASA/GSFC, NOAA/STAR	L+11
8	Digitization Artifacts	MIT/LL, NOAA/STAR, NG	L+11
9	Scan Angle Evaluation	NOAA/STAR, MIT/LL, NASA/GSFC	L+11
10	Temperature Stabilization	MIT/LL, NASA/GSFC, NOAA/STAR, NG	L+11
11	Radiometric Sensitivity Evaluation	NOAA/STAR, MIT/LL, NASA/GSFC, NG	L+11
12	NWP Bias Characterization	NOAA/STAR	L+11
13	Optimal Space View Selection	NOAA/STAR, MIT/LL, NASA/GSFC	L+26, Optimal SVP Selection PLT
14	Striping Analysis and Noise Evaluation	NOAA/STAR, MIT/LL	L+32, Noise Characterization – Part 1 PLT
15	GPS-RO Bias Characterization	NOAA/STAR	L+36
16	SNO Bias Characterization	NOAA/STAR	L+36
17	Geolocation Verification and Correction	NOAA/STAR, MIT/LL	L+36
18	Instrument to Spacecraft Alignment	NOAA/STAR	L+36

NOAA-21 ATMS Post-launch Cal/Val Plan

Task #	Title	Teams	Data Available Date & Related PLTs
19	Continuous Sampling Mode	NOAA/STAR, MIT/LL	L+46, Environmental Characterization PLT
20	Lunar Intrusion Evaluation	NOAA/STAR, NASA/GSFC, MIT/LL	L+51, Lunar Intrusion Mitigation PLT
21	Point and Stare Data for Gain Fluctuation Assessment	NOAA/STAR, MIT/LL, NASA/GSFC, NG	L+59, Noise Characterization – Part 2 PLT
22	Pitch Maneuver Analysis	MIT/LL, NOAA/STAR, NASA/GSFC, NG	L+71, Backflip Pitch Maneuver PLT
23	EMI From Spacecraft Transmitter	MIT/LL, NOAA/STAR, NG	L+71, Backflip Pitch maneuver PLT
24	TDR to SDR Conversion Analysis	NOAA/STAR, MIT/LL	L+71, Backflip Pitch Maneuver PLT
25	Effective Field of View	NOAA/STAR	L+71, Roll & Pitch Maneuver PLTs
26	Polarization Response Angle	NOAA/STAR	L+71, Backflip Pitch Maneuver PLT
27	Central Frequency Stability Assessment	MIT/LL, NOAA/STAR	L+80
28	SDR Validation through Product Retrievals	NOAA/STAR	L+80
29	Warm Load and Space View Bias	NOAA/STAR, MIT/LL	L+80, Roll Maneuver PLT
30	Spatial Resampling Assessments	NOAA/STAR	L+80, Scan Offset PLT (EDR)
31	Terrestrial and Direct TV Sources RFI Detection	NOAA/STAR, MIT/LL	L+80
32	NUCAPS/MiRS Convergence	NOAA/STAR	L+80

NOAA-21 ATMS NEΔT Monitoring

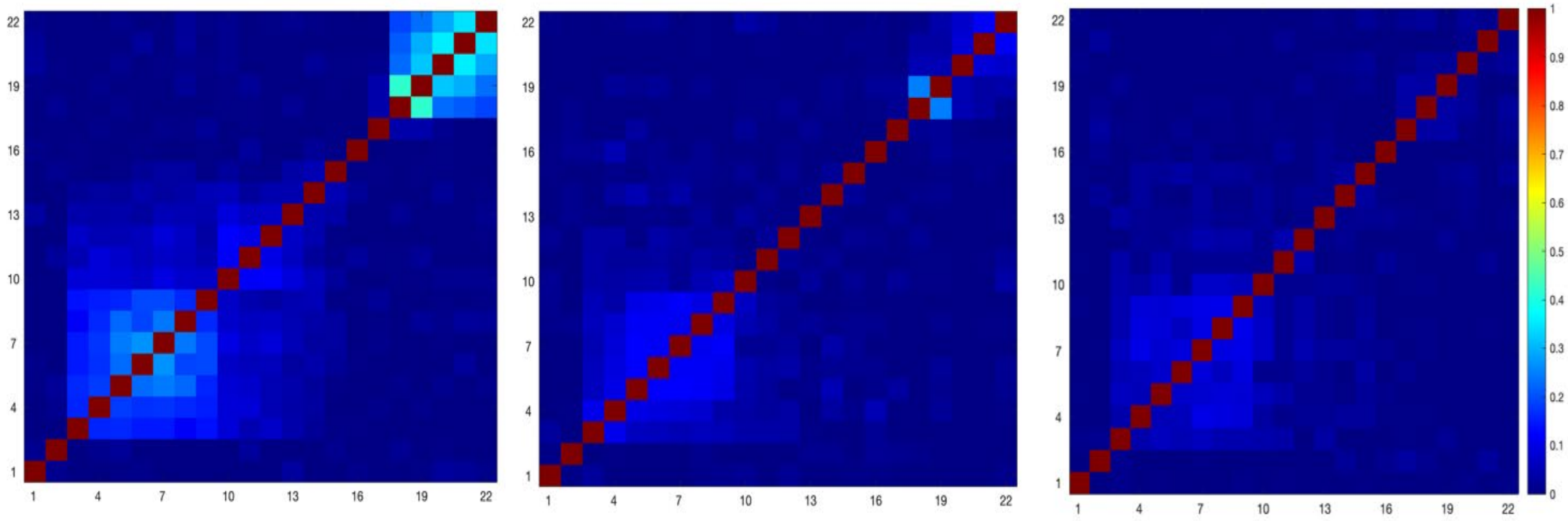


NEDT, Red (Requirement), black (on orbit performance) N21 ATMS NEDT is stable and has a good margin.

NOAA-21 ATMS On-orbit Channel Correlation

- G-band channel correlation further reduced in NOAA-21 compared to NOAA-20

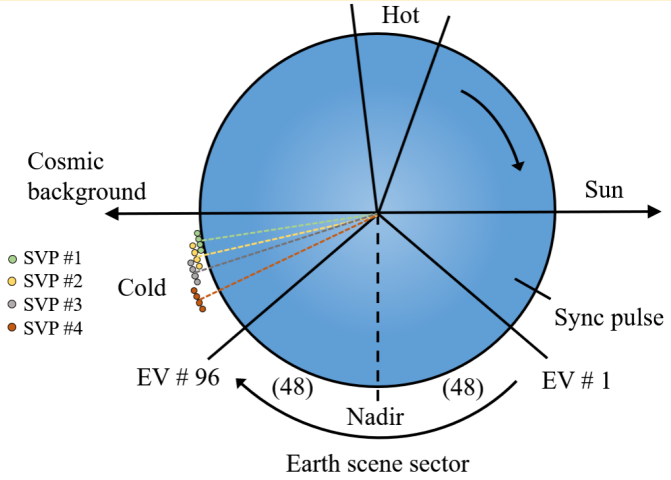
S-NPP **NOAA-20** **NOAA-21**



The reduced NOAA-21 cross-channel noise correlation will ease data assimilation into forecast models compared to previous ATMS builds

NOAA-21 ATMS Optimal Space View Profile Selection

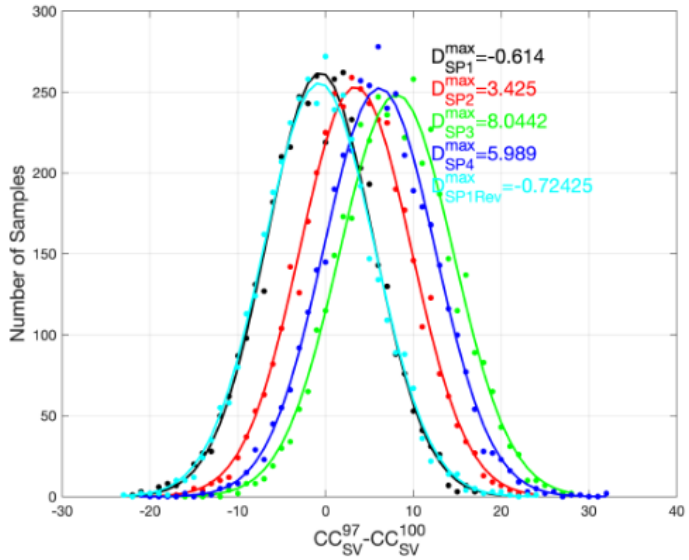
- Space view (SV) counts may be contaminated by near field radiation from spacecraft or far field radiation from earth
- There are four space view count readings each scan from only one space view profile (SVP)
- The bias between space view reading 1 and 4 are used to determine the optimal space view profile



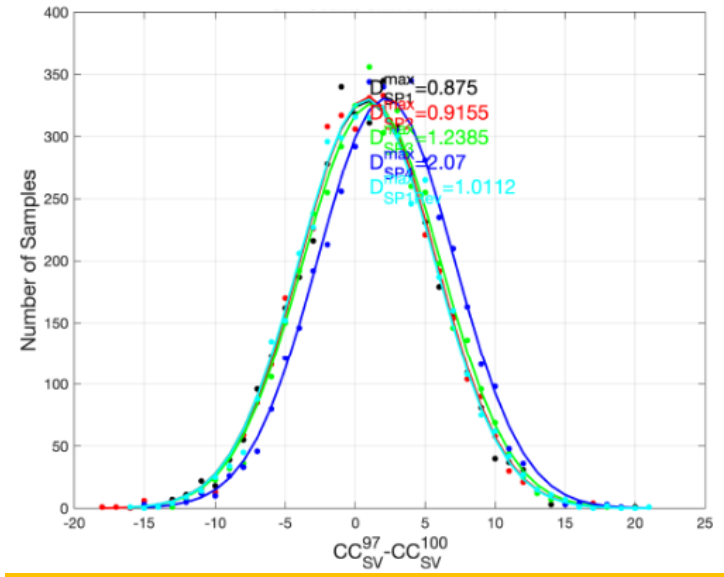
Schematic diagram of SVP

#	Angle	Starting Time	Ending Time
SVP 1	83.34°	15:31:34 Nov. 21, 2022	18:26:25 Nov. 24, 2022
SVP 2	81.67°	18:26:36 Nov. 24, 2022	23:11:08 Nov. 27, 2022
SVP 3	80.00°	23:11:16 Nov. 27, 2022	22:43:24 Nov. 30, 2022
SVP 4	76.67°	22:44:32 Nov. 30, 2022	23:13:13 Dec. 3, 2022
SVP 1	83.34°	23:13:13 Dec. 3, 2022	-

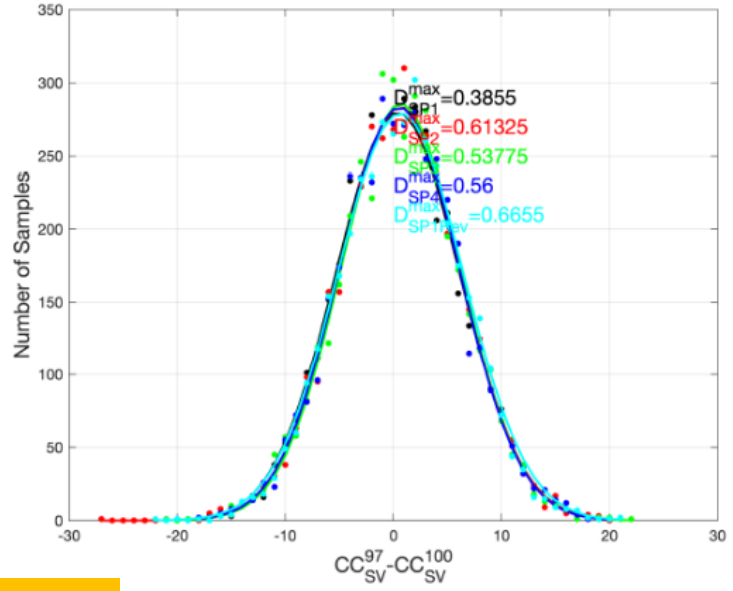
Channel 1 (BW=5.2°)



Channel 16 (BW=2.2°)



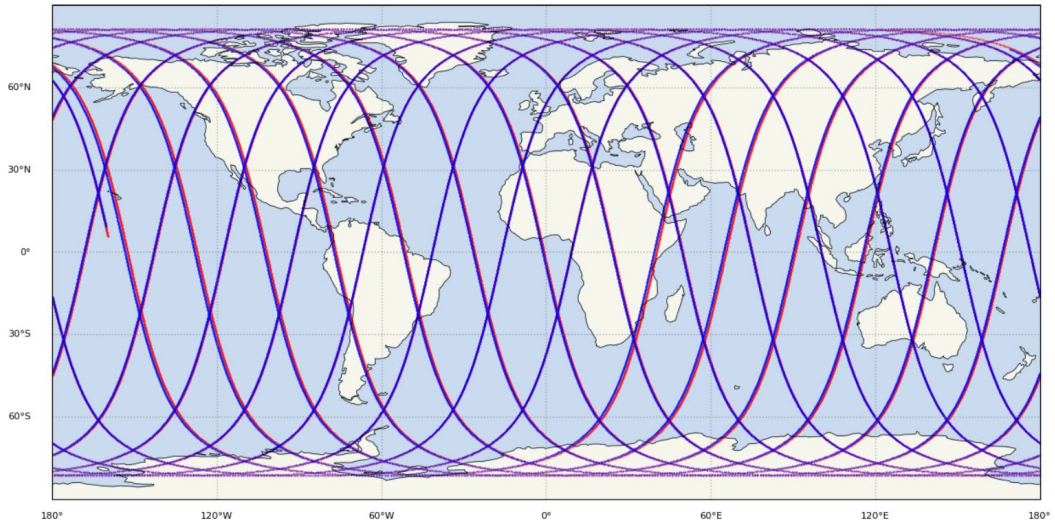
Channel 18 (BW=1.1°)



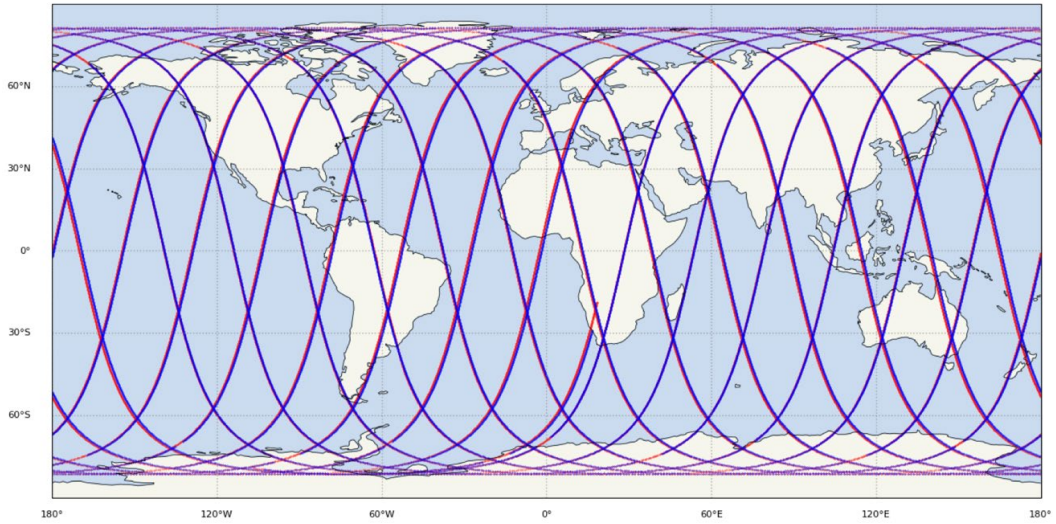
Space View Profile #1 is the optimal SVP

Direct Comparison of NOAA-21 ATMS and NOAA-20 and S-NPP ATMS During Satellite Overlaps

NOAA-21 and NOAA-20 Nadir Track on November 25, 2022

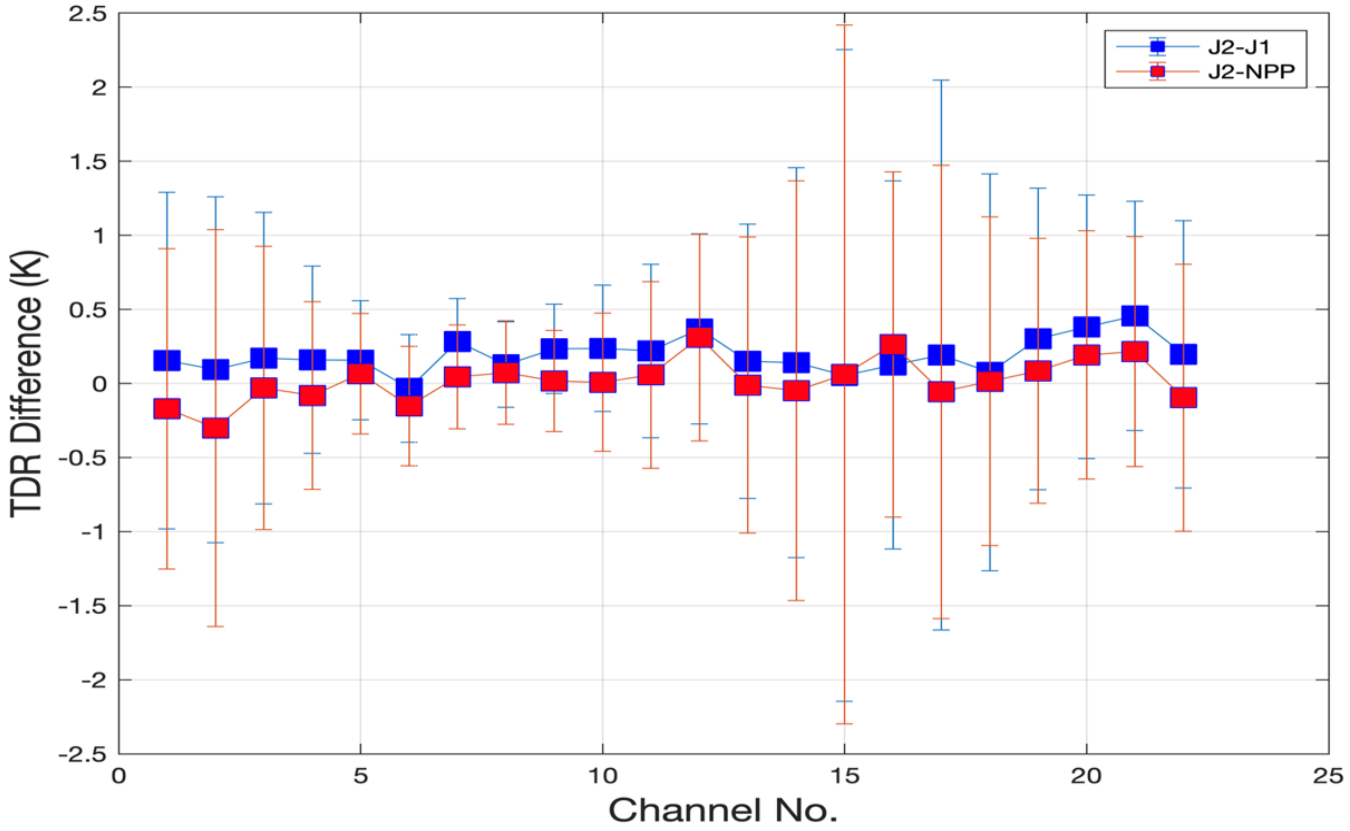


NOAA-21 and S-NPP Nadir Track on December 6, 2022

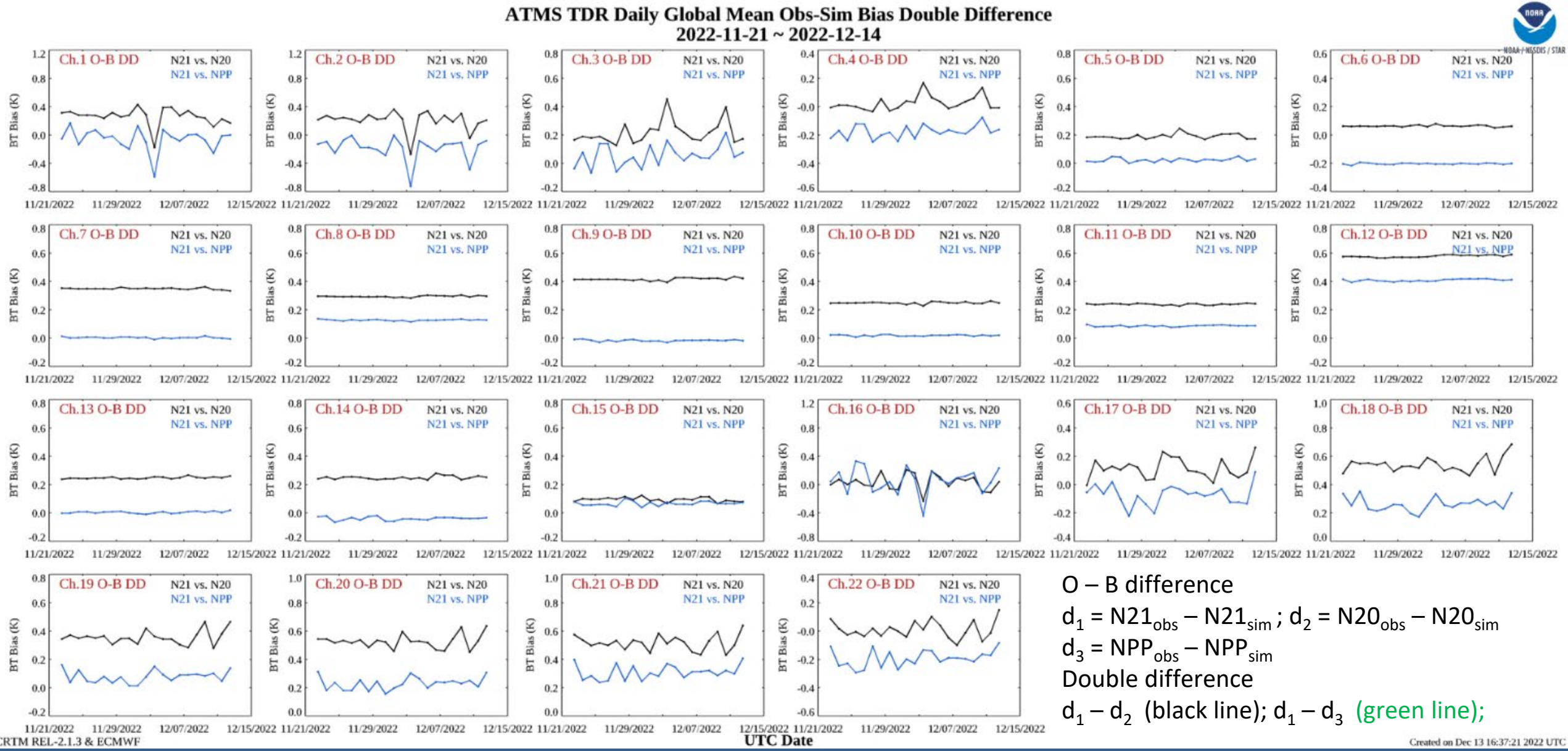


Unique opportunity for direct comparisons between NOAA-21 and NOAA-20/S-NPP ATMS during their orbital overlapping because of the orbit adjustment activities

TDR brightness temperature direct comparison between NOAA-21 and NOAA-20/S-NPP ATMS



ATMS TDR Comparison by O-B Double Difference



O – B difference

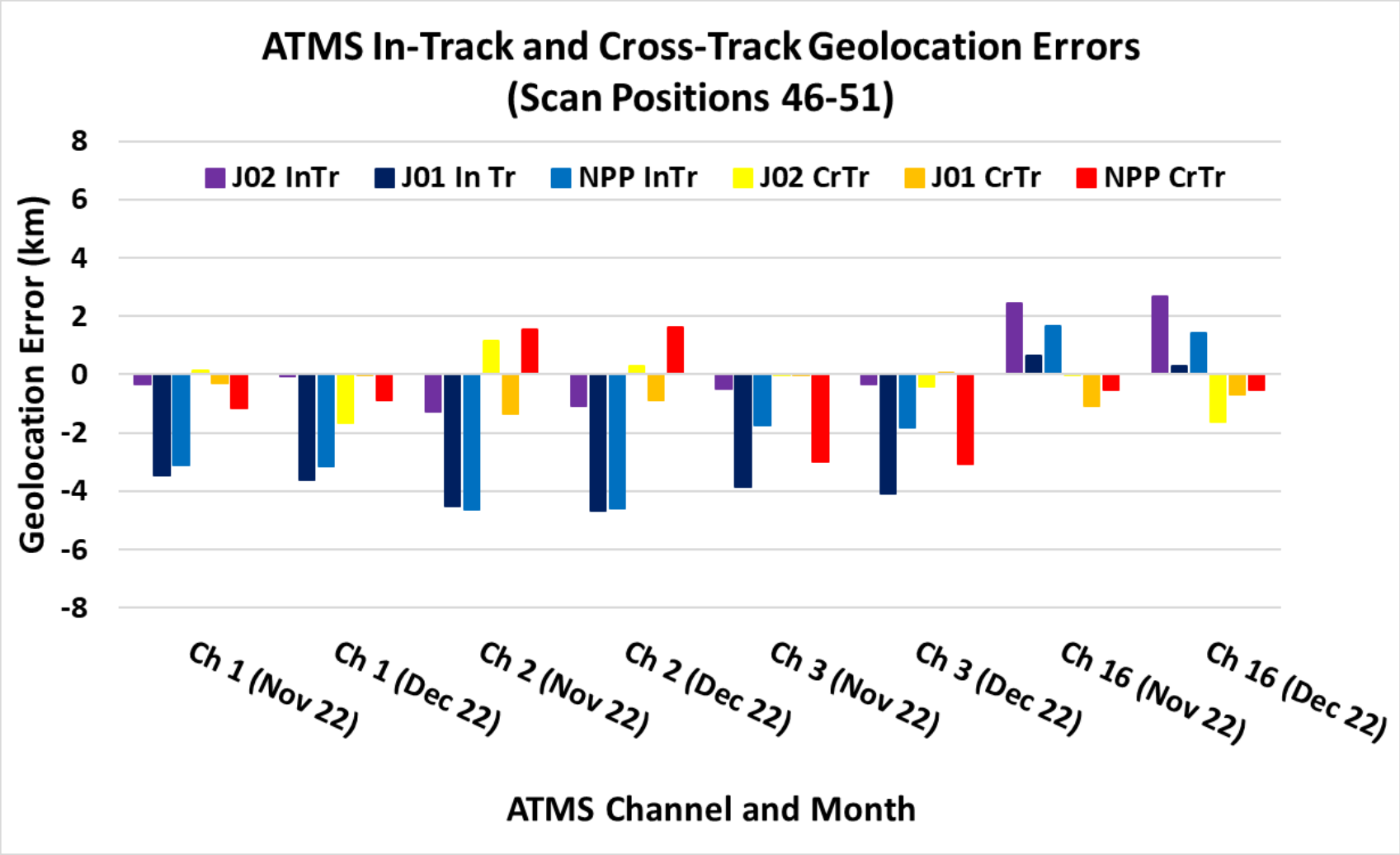
$d_1 = N21_{obs} - N21_{sim}$; $d_2 = N20_{obs} - N20_{sim}$

$d_3 = NPP_{obs} - NPP_{sim}$

Double difference

$d_1 - d_2$ (black line); $d_1 - d_3$ (green line);

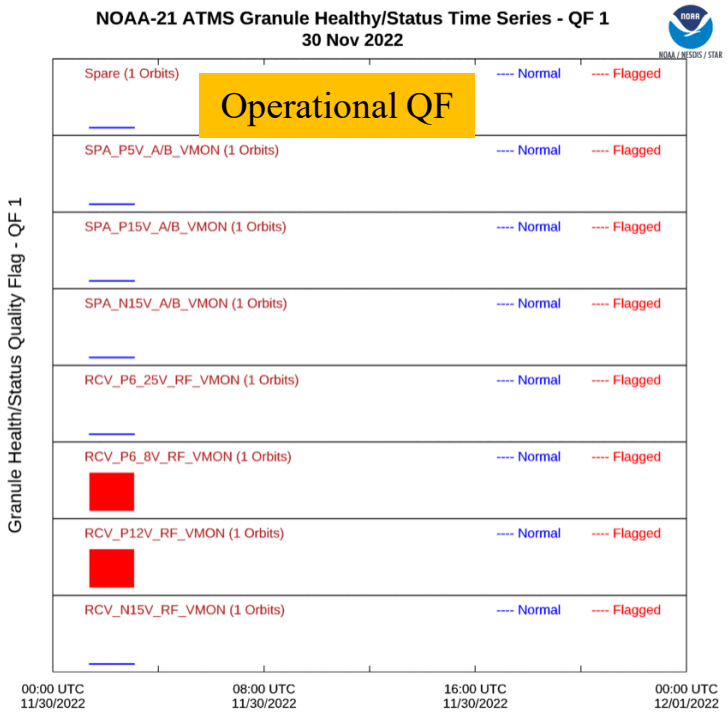
NOAA-21 ATMS On-orbit Geolocation Accuracy



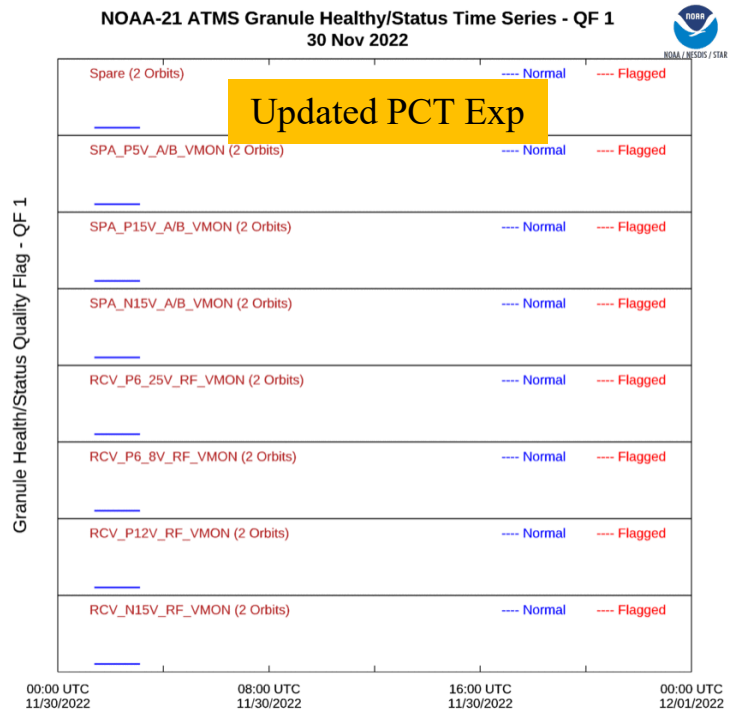
ATMS imagery mapping uncertainty (3 sigma) 5 km.

Initial NOAA-21 ATMS geolocation assessments show that geolocation error is usually in-family or better than NOAA-20 or S-NPP ATMS". Caveat: the orbit is still changing, and this results is preliminary.

NOAA-21 ATMS SDR Health Status Quality Flag Update

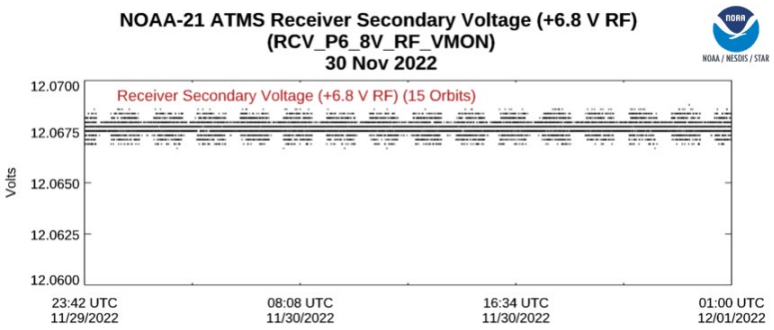


Operational QF

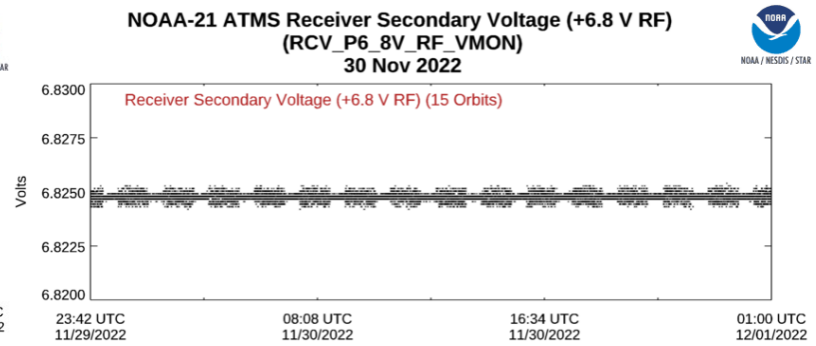


Updated PCT Exp

- No impact on science data quality. Instrument health status monitoring purpose only.
- Three telemetry parameters have been changed in NOAA-21 ATMS
- Hard coded conversion coefficients in IDPS are for S-NPP and NOAA-20
- Short term solution: PCT update to extend the quality range
- Permanent solution: Update IDPS code to include satellite dependent conversion coefficients



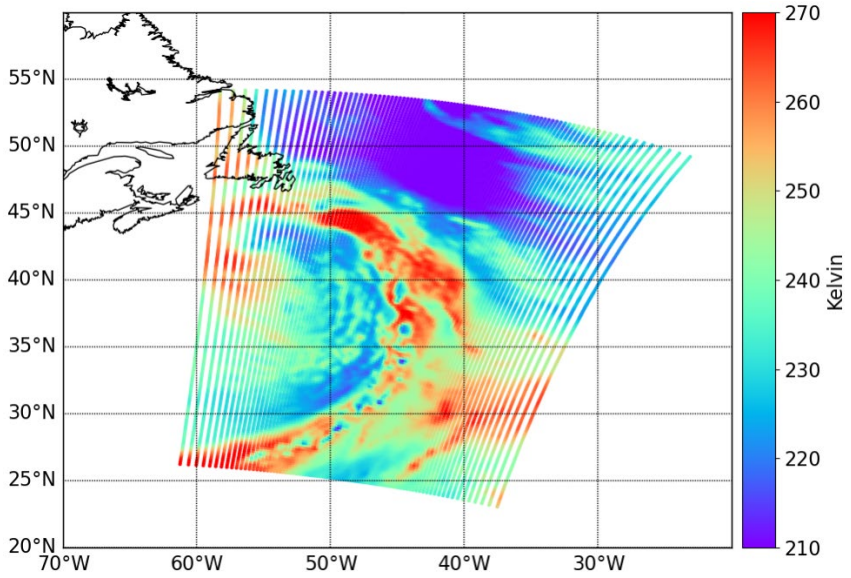
Operational Values



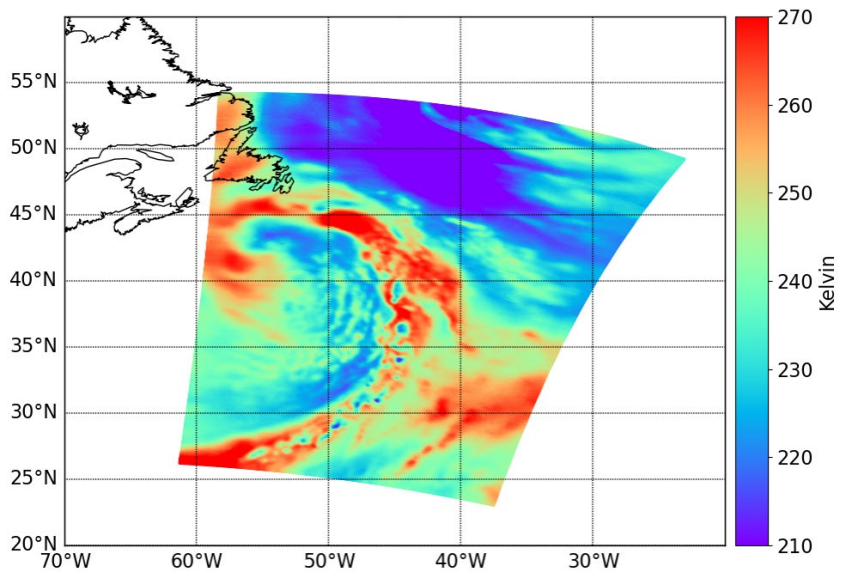
Correct Values

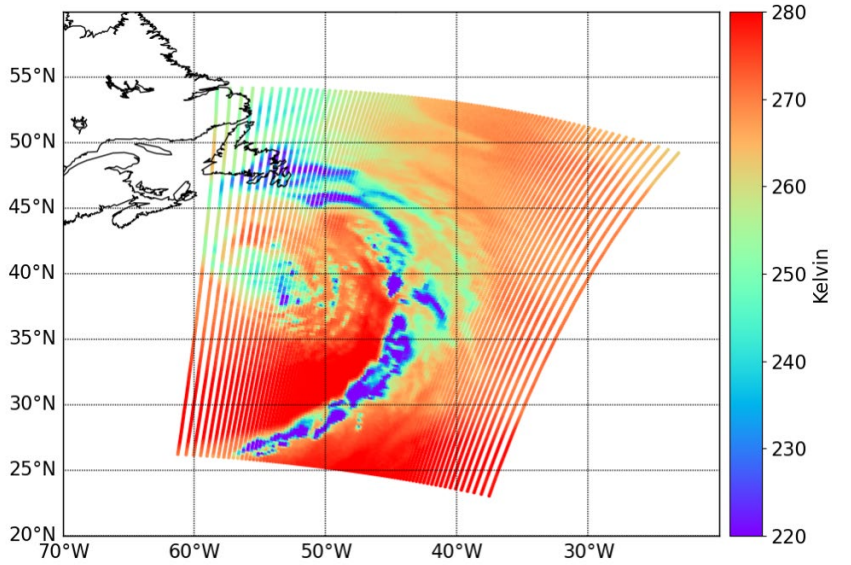
bit #	SNPP/NOAA-20	NOAA-21	NOAA-21 Update
4	RCV +6V RF [5.75, 6.5]	RCV +6.25V RF [6.0, 6.5]	Mean: ~ 6.0 [5.0, 7.0]
5	RCV +12V RF-2 [11.25, 12.75]	RCV +6.8V RF [6.45, 7.15]	Mean: ~ 12.0 [11.0, 13.0]
6	RCV +15V RF [14.25, 15.75]	RCV +12V RF [11.47, 12.42]	Mean: ~ 14.25 [13.25, 15.25]

NOAA-21 ATMS Limb-corrected and AI Resolution Enhanced Images

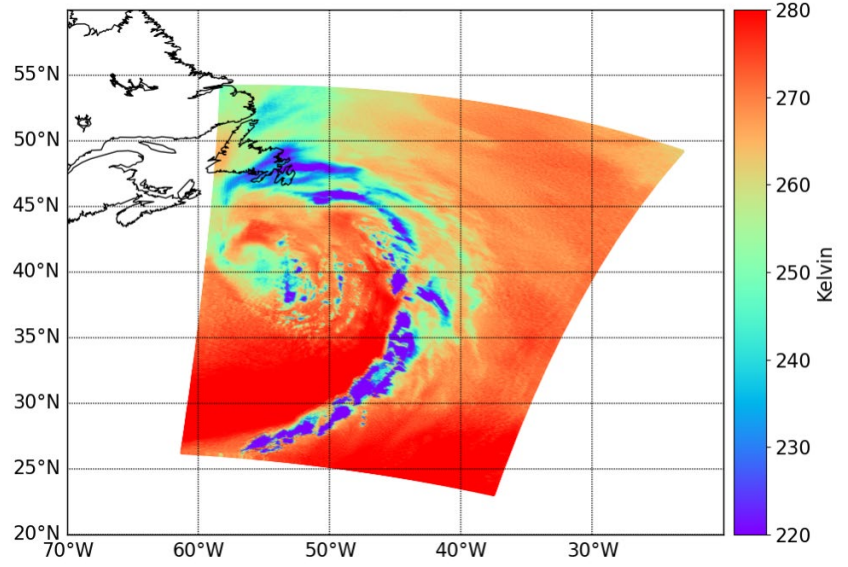


Ch.16





Ch. 18



Limb-correction makes cross-scan observations as a nadir-looing.

The second step AI algorithm enhanced the limb-corrected Images by a factor of 4.

The two steps algorithms deliver good visualization for weather patterns.

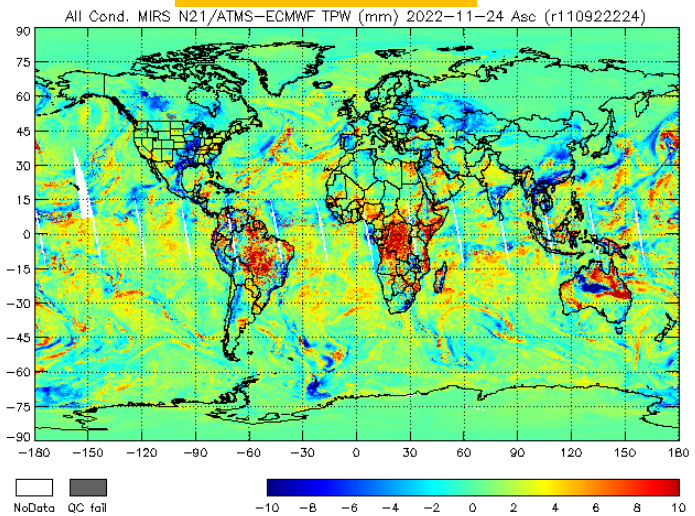
NOAA-21 Preliminary, Non-Operational Data

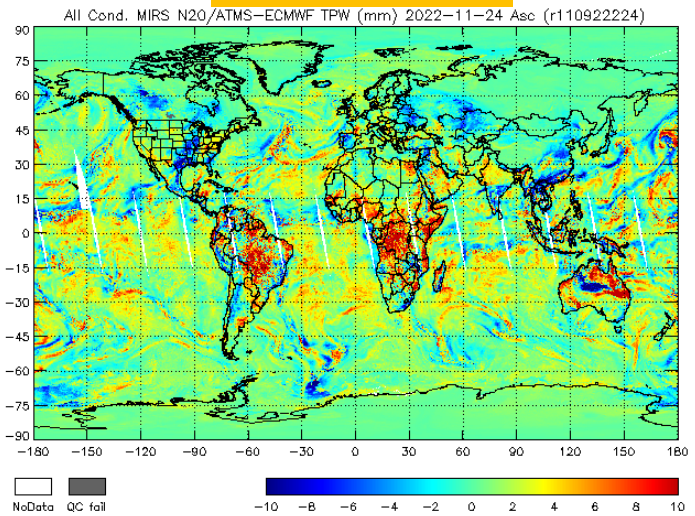
MiRS N21 and N20 TPW Comparison with ECMWF

N21

N20

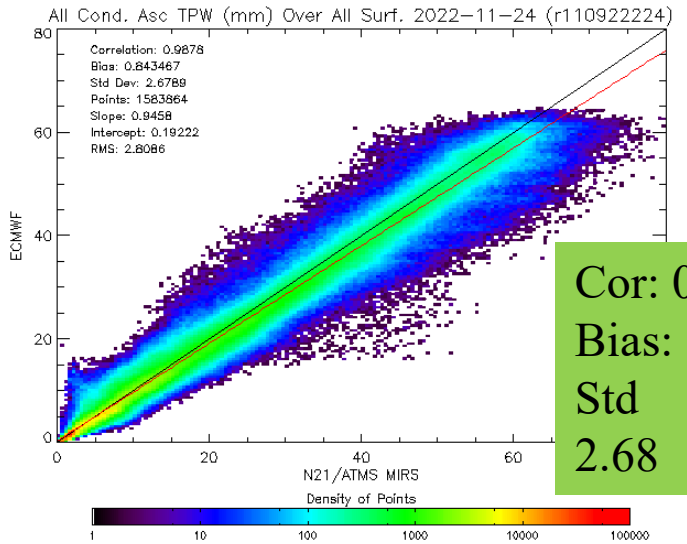
MiRS-ECMWF



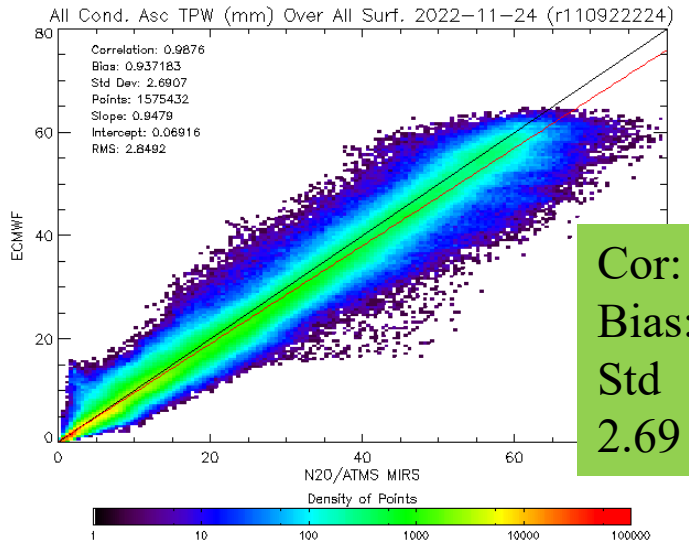


2022-11-24

MiRS vs. ECMWF



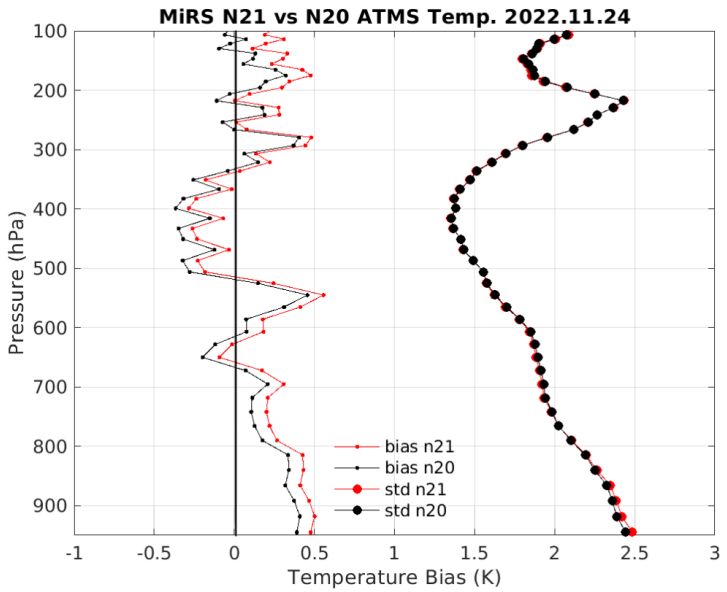
Cor: 0.988
Bias: 0.84
Std Dev: 2.68

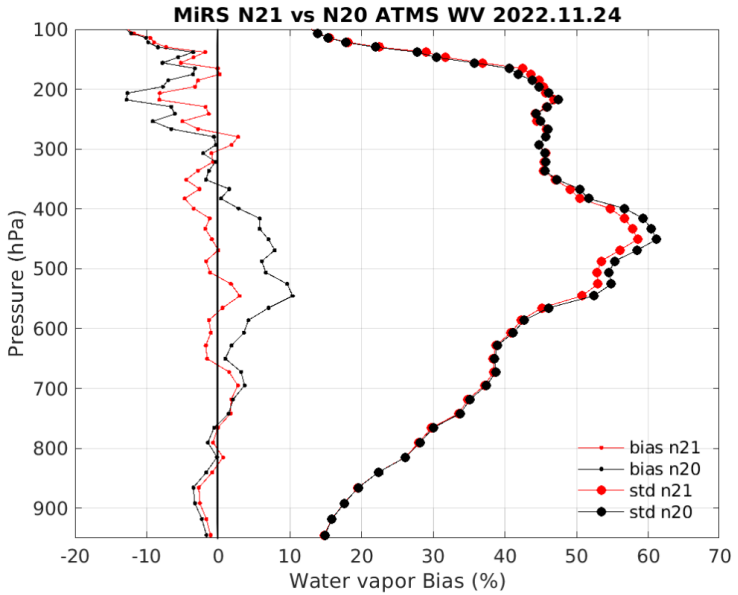


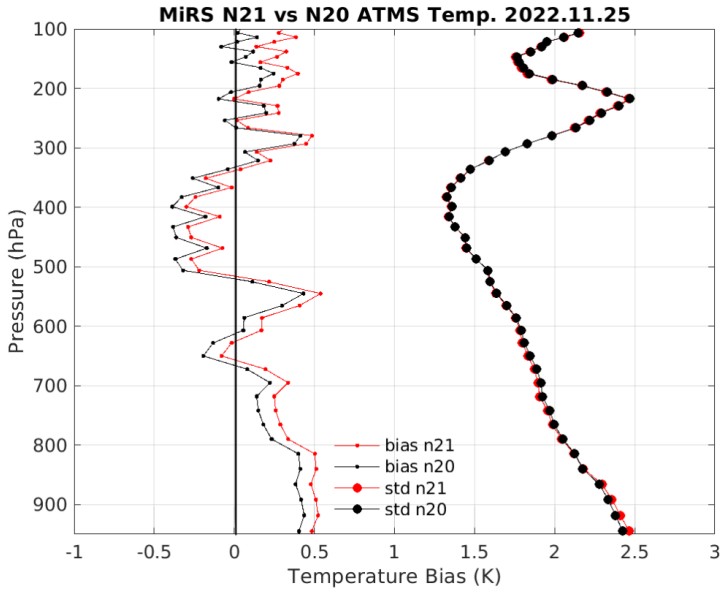
Cor: 0.988
Bias: 0.94
Std Dev: 2.69

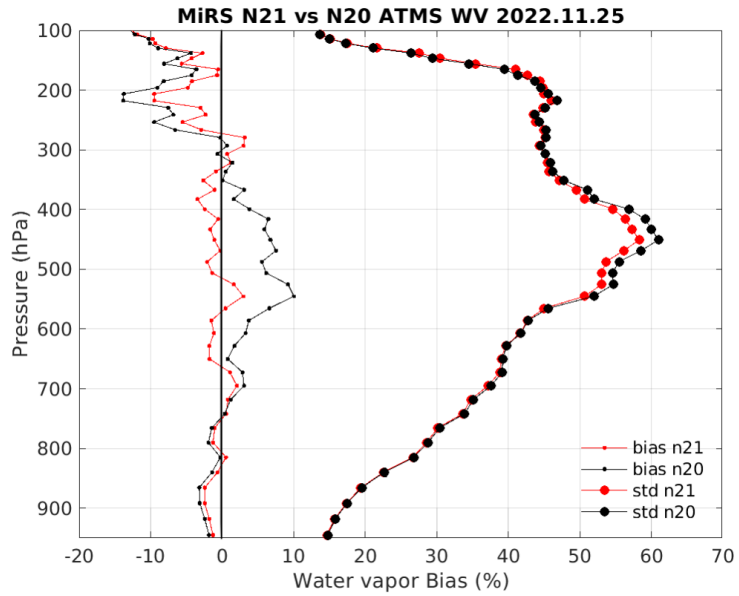
NOAA-21 Preliminary, Non-Operational Data

MiRS N21 and N20 Temperature & Moisture Profiles Comparison with ECMWF









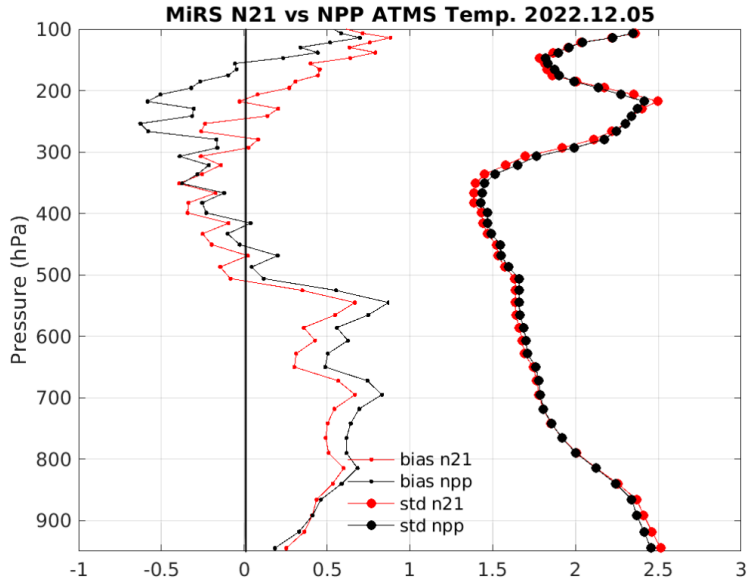
2022-11-24

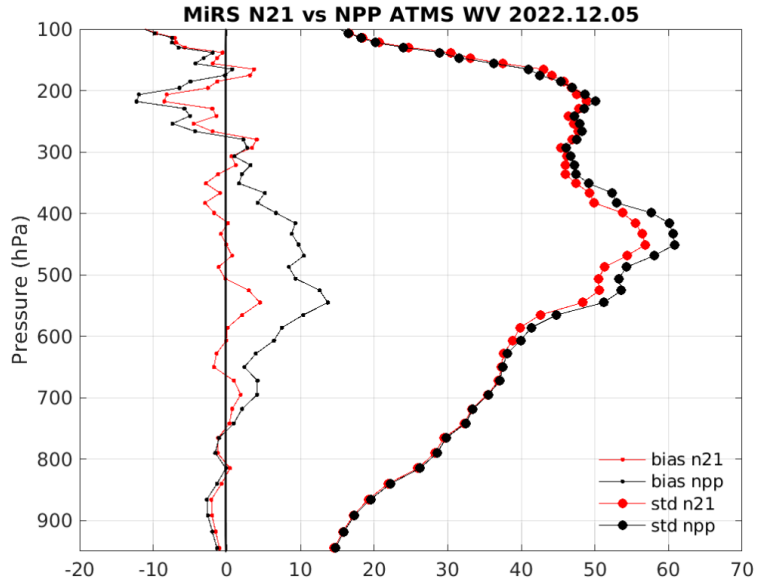
Low noise of N21 water vapor channels improved water vapor retrieval (red line for N21 vs black line for N20).

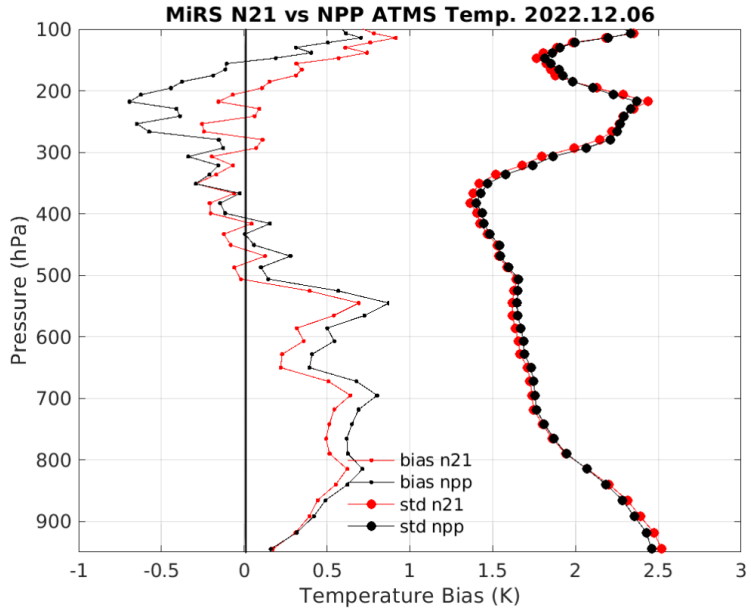
2022-11-25

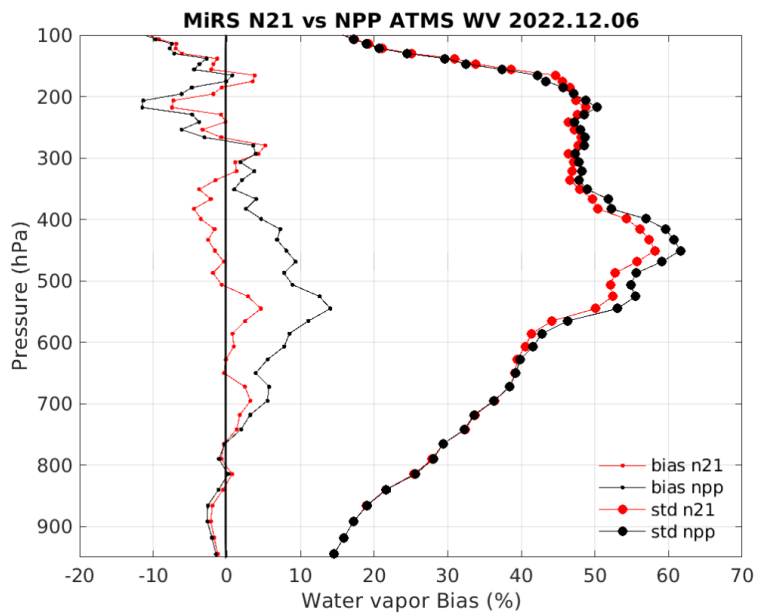
NOAA-21 Preliminary, Non-Operational Data

MiRS N21 and SNPP Temperature & Moisture Profiles Comparison with ECMWF









2022-12-05

Low noise of N21 water vapor channels improved water vapor retrieval (red line for N21 vs black line for NPP).

2022-12-06

NOAA-21 Preliminary, Non-Operational Data

NOAA/EMC Summary and Plan

- ATMS N21 channel statistics for data over the data behaves similarly to N20 and NPP
- No significant stripping observed in N21
- Noticeable scan bias remains after antenna correction
- The radiances calculated using a boxcar SRF coefficients are more accurate than the ones using the measured SRF for surface sensitive channels
- ATMS N21 will be tested in parallel experiment and is expected to be operational in March

Courtesy: Emily Liu and Andrew Collard

User Feedback – ECMWF

- After bias correction, NOAA-21 ATMS is mostly in line with other ATMS instruments

- Subject to assimilation trials, we would expect to be able to use NOAA-21 ATMS in a similar way as other ATMSs
  - However, current phasing is highly sub-optimal for NWP (almost complete overlap with NOAA-20). Due to thinning, very little extra data would be used. We assume this will be changed after cal/val.

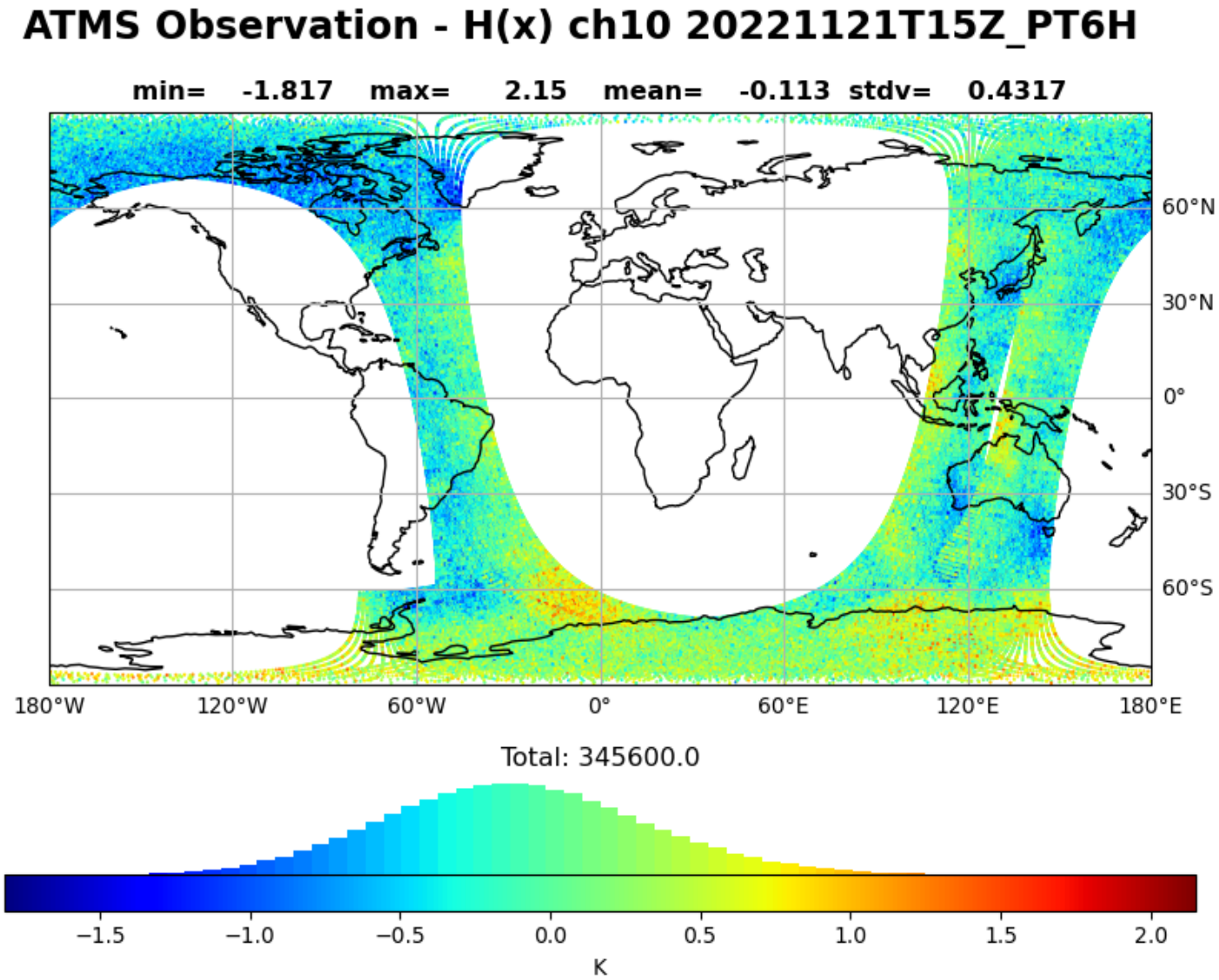
- Some minor aspects noted:
  - More asymmetric and less flat scan-biases, esp. for temperature-sounding channels. Possibly due to unoptimized antenna pattern correction?
  - Slightly higher stdev(o-b) before bias correction for the temperature-sounding channels. Probably linked to the scan-bias pattern.
  - Cross-track striping qualitatively similar to NOAA-20, but not evaluated quantitatively here.

Courtesy: Niels Bormann

NOAA-21 Radiance Assessment in Radiance Assimilation System

Dr. Ruston at JCSDA provided the comparison between NOAA-21 ATMS measurements and DA simulations.

The difference displays gaussian Distribution and looks normal for the first look.



NOAA-21 Preliminary, Non-Operational Data

ATMS NOAA-21: Preliminary non-operational

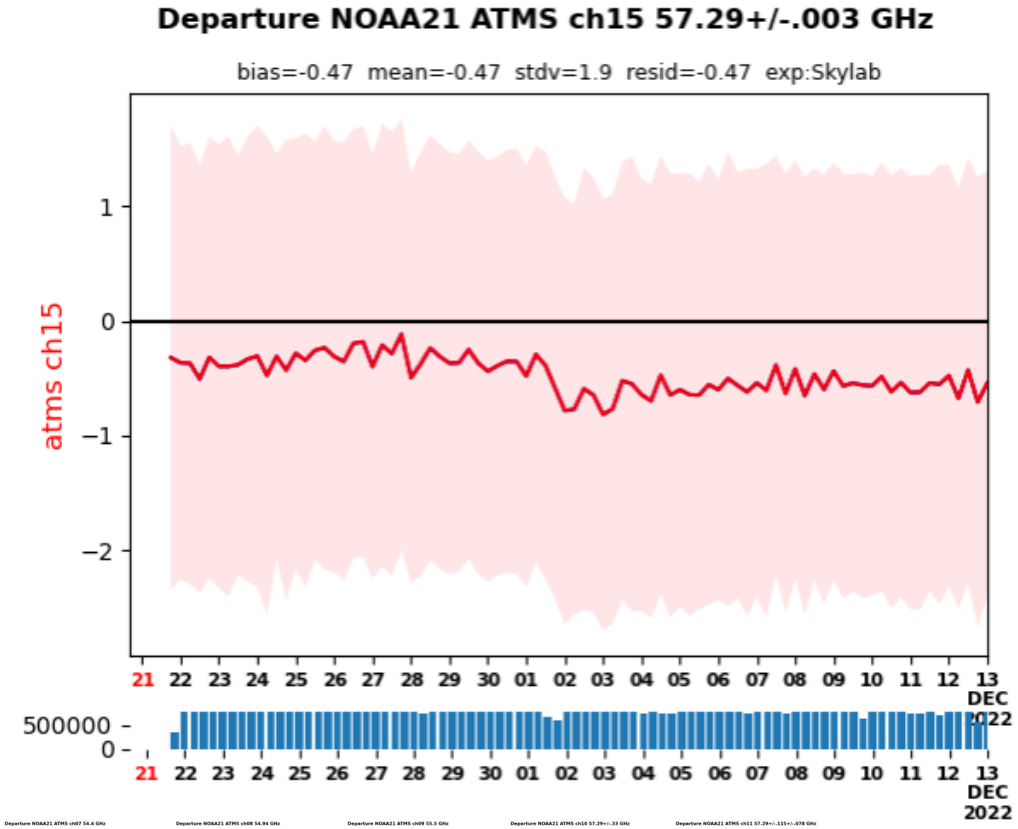
Courtesy: Benjamin Ruston, Joint Center for Satellite Data Assimilation

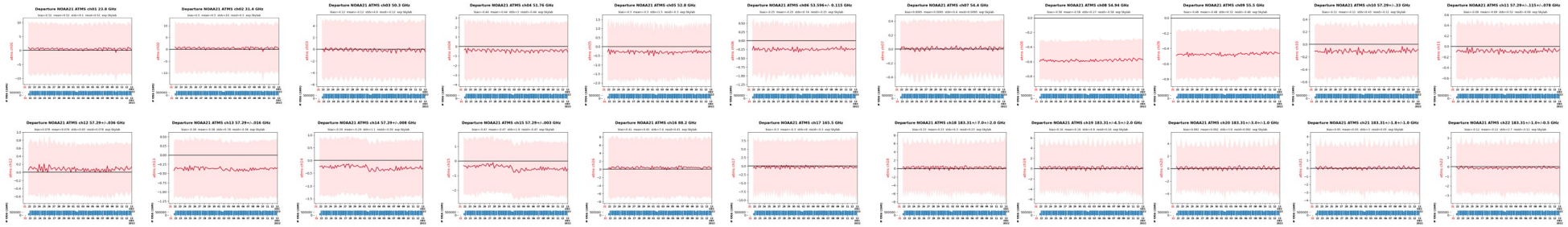
Trend analysis

All channels exhibited stable behavior in time
~750K “native” resolution obs per 6-hourly cycle

A small anomaly was found which occurred during the update on 01Dec2022. This was found to be restricted to a small change in bias for channels 14 and 15.

From an NWP perspective: this small change would have very little impact, particularly if bias correction was generated pre- and post-event.



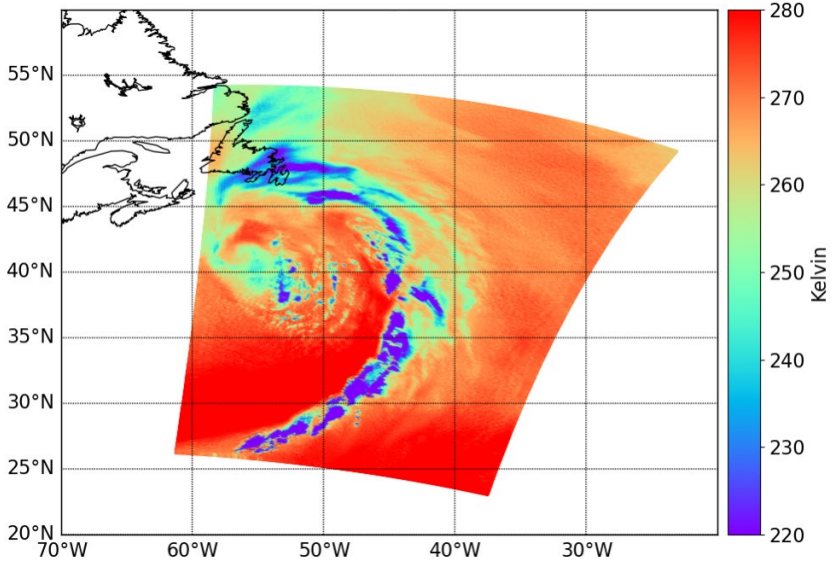


Check List – Provisional Maturity

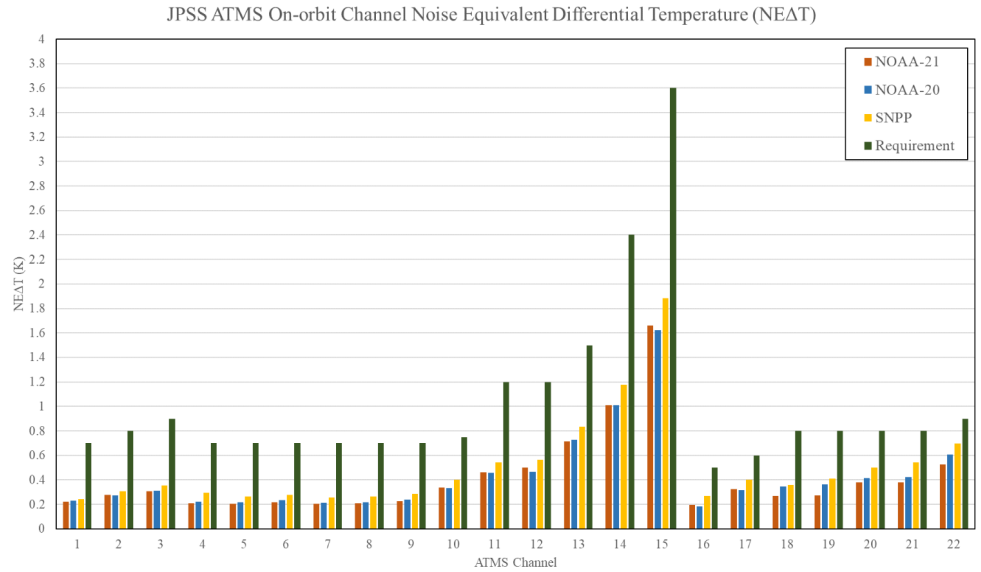
Provisional Maturity End State	Assessment
Product performance has been demonstrated through analysis of a large, but still limited (i.e., not necessarily globally or seasonally representative) number of independent measurements obtained from selected locations, time periods, or field campaign efforts.	ATMS global science data (TDR/SDR/GEO) have been thoroughly analyzed using different evaluation methods and tools since it was switched to operational mode. NWP centers and MiRS EDR results support the key point.
Product analyses are sufficient for qualitative, and limited quantitative, determination of product fitness-for-purpose.	Major instrument health status/performance and science data quality evaluation tasks have been performed. Results indicate that all index have met the quality requirements. Data are sufficient for limited quantitative determination.
Documentation of product performance, testing involving product fixes, identified product performance anomalies, including recommended remediation strategies, exists.	ATMS provisional maturity data user README file has been updated to reflect the new findings and improvements after the beta maturity review. It can be used as the reference for data users. Calibration documents are also released to support users.
Product is recommended for potential operational use (user decision) and in scientific publications after consulting product status documents.	ATMS science data products are recommended for operational testing in various applications following the recommendations in README file.

NOAA-21 ATMS SDR Provisional Maturity Highlights

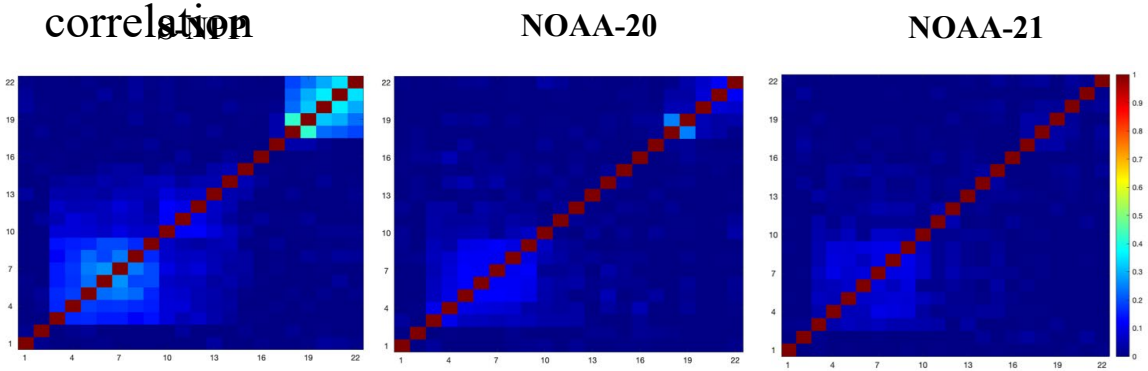
ATMS limb-corrected and AI resolution enhanced, ch. 18

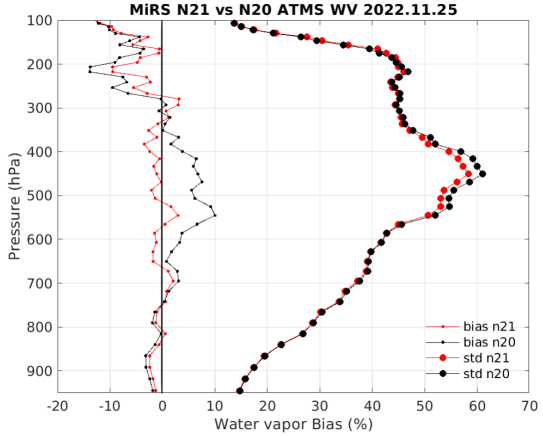


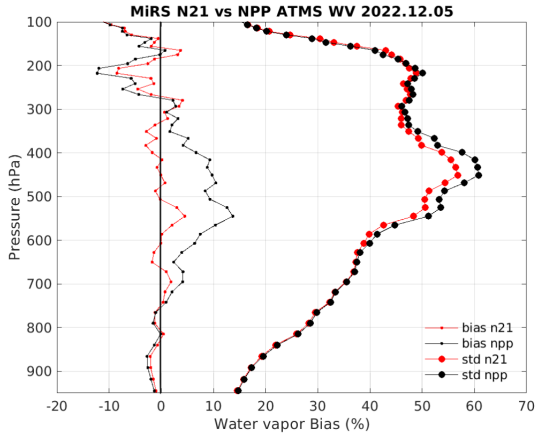
On orbit ATMS channel



On orbit ATMS channel to channel noise correlation







MiRS vs ECMWF water vapor

OSPO planned N21 ATMS BUFR data beta are available for restricted use.

Documentations

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	In-Progress
Instrument Calibration Data Book	Yes
Instrument Spectral Response Functions (SRF) Public Release	Yes
System Maintenance Manual (for ESPC products)	N/A
Peer Reviewed Publications (Demonstrates algorithm is independently reviewed)	Yes
Regular Validation Reports (at least annually) (Demonstrates long-term performance of the algorithm)	

NOAA-21 ATMS Provisional Maturity Status Summary

- ✔ Through PLT, optimal Space View Profile Selection (SP1) is found and in operation;
- ✔ On orbit channel-to-channels noise correlations among S-NPP, NOAA-20, and NOAA-21 are analyzed. NOAA-21 ATMS is the best;
- ✔ NOAA-21 ATMS channel NEΔTs are stable and comparable to NOAA-20;
- ✔ Good agreement between nearly simultaneous NOAA-21 and NOAA-20 ATMS measurements;
- ✔ Good agreement between nearly simultaneous NOAA-21 and S-NPP ATMS measurements;
- ✔ NOAA-21 ATMS starts generating radiance data (TDR/SDR/GEO) from Nov. 21, 2022;
- ✔ ATMS telemetry data show a nominal condition after the activation;
- ✔ Low noise of NOAA-21 ATMS water vapor channels improves MiRS water vapor EDR performance;
- ✔ Details are referred to https://www.star.nesdis.noaa.gov/icvs-beta/status_J02_ATMS.php
- ✔ ECMWF Analysis showed “After bias correction, NOAA-21 ATMS is mostly in line with other ATMS instruments”.

ATMS SDR science team recommended that NOAA-21 ATMS SDR meets Provisional maturity.

Path Forward to Validated Maturity

- Continue to monitor ATMS instrument stability and performance, as well as science data (TDR/SDR/GEO) quality
- Keep assessing science data quality based on additional PLTs and report assessment results in Validated maturity review following the Cal/Val plan
- Update IDPS ATMS calibration algorithm Processing Coefficient Table (PCT) based on the overall on-orbit data analysis results, including reflector emissivity, antenna pattern correction coefficients, warm/cold bias correction coefficients, and others
- Update ATMS instrument heath status telemetry calculation coefficients and program in IDPS to reflect the changes from NOAA-21
- Analyze scan-dependent bias