NOAA-21 ATMS Beta 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

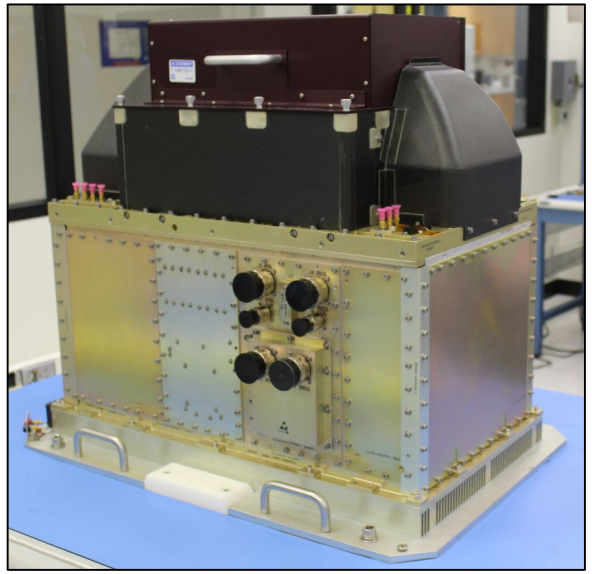
- Algorithm Cal/Val Team Members
- Introduction to ATMS and Product Requirements
- Pre-launch Performance Matrix/Waivers
- Post-launch Cal/Val Timeline
- Post-launch Cal/Val Tasks
- Beta Maturity Performance Validation
  - NOAA-21 ATMS First Light Image
  - NOAA-21 ATMS Instrument On-orbit Status/Performance Assessment
  - NOAA-21 ATMS Science Data Quality Evaluation
- Downstream Product Feedback
- User Feedback
- Conclusion
- Path Forward to Provisional Maturity

JPSS ATMS Cal/Val Team

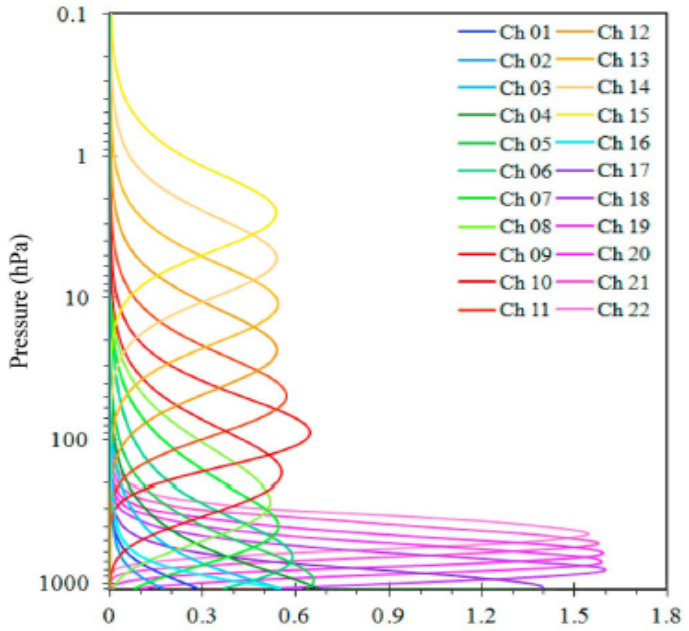
Name	Organization	Major Task
Quanhua (Mark) Liu	NOAA/STAR	NOAA STAR ATMS Cal/Val Team PI
Ninghai Sun	GST, Inc. @ NOAA/STAR	NOAA STAR ATMS Cal/Val Team
Hu (Tiger) Yang	UMD/CISESS @ NOAA/STAR	NOAA STAR ATMS Cal/Val Team
Siena Iacovazzi	GST, Inc. @ NOAA/STAR	NOAA STAR ATMS Cal/Val Team
Jun Zhou	UMD/CISESS @ 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

Advanced Technology Microwave Sounder (ATMS)

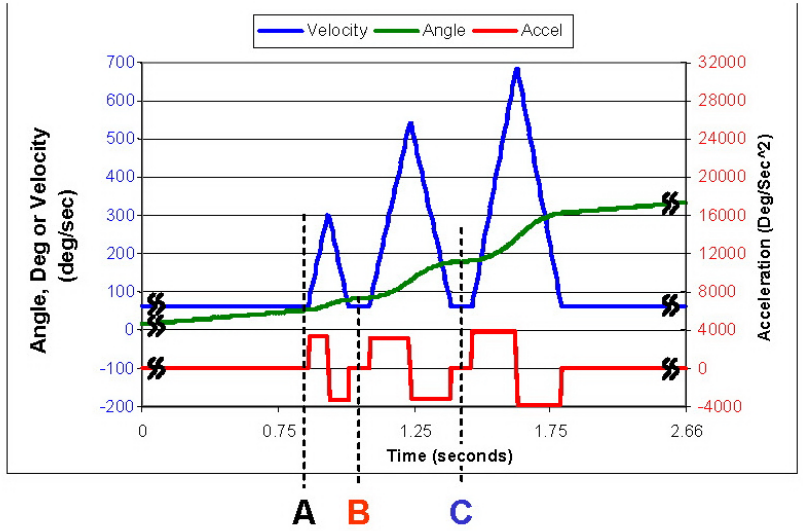
- **Mission:** Provides sounding profiles of atmospheric temperature and moisture
- **Satellites:** SNPP (2011), NOAA-20 (2017), NOAA-21 (2022).
- **Instrument Type:** Total power microwave radiometer.
- **Number of channels:** 22 channels.
- **Frequency range (GHz):** 23 GHz to 183 GHz.
- **Nadir resolution:** 74.8 km (K/KA band), 31.6 km (V-band), 15.8 km (W/G band).
- **Scanning Technique:** Cross-track 96 earth FOVs per scan.
- **Swath width:** 2500+ km.
- **Coverage/Cycle:** Near-global coverage twice per day.

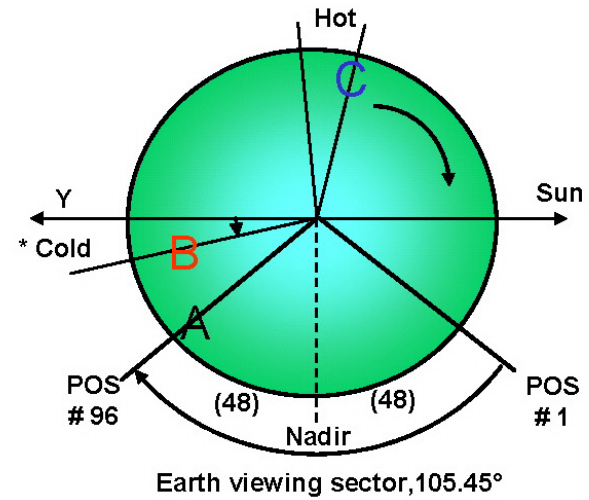


The JPSS-2/ATMS Instrument. Courtesy of Northrop Grumman



ATMS Weighting Function





ATMS Scan Geometry (Flight Direction is Toward Reader). Courtesy of Northrop Grumman

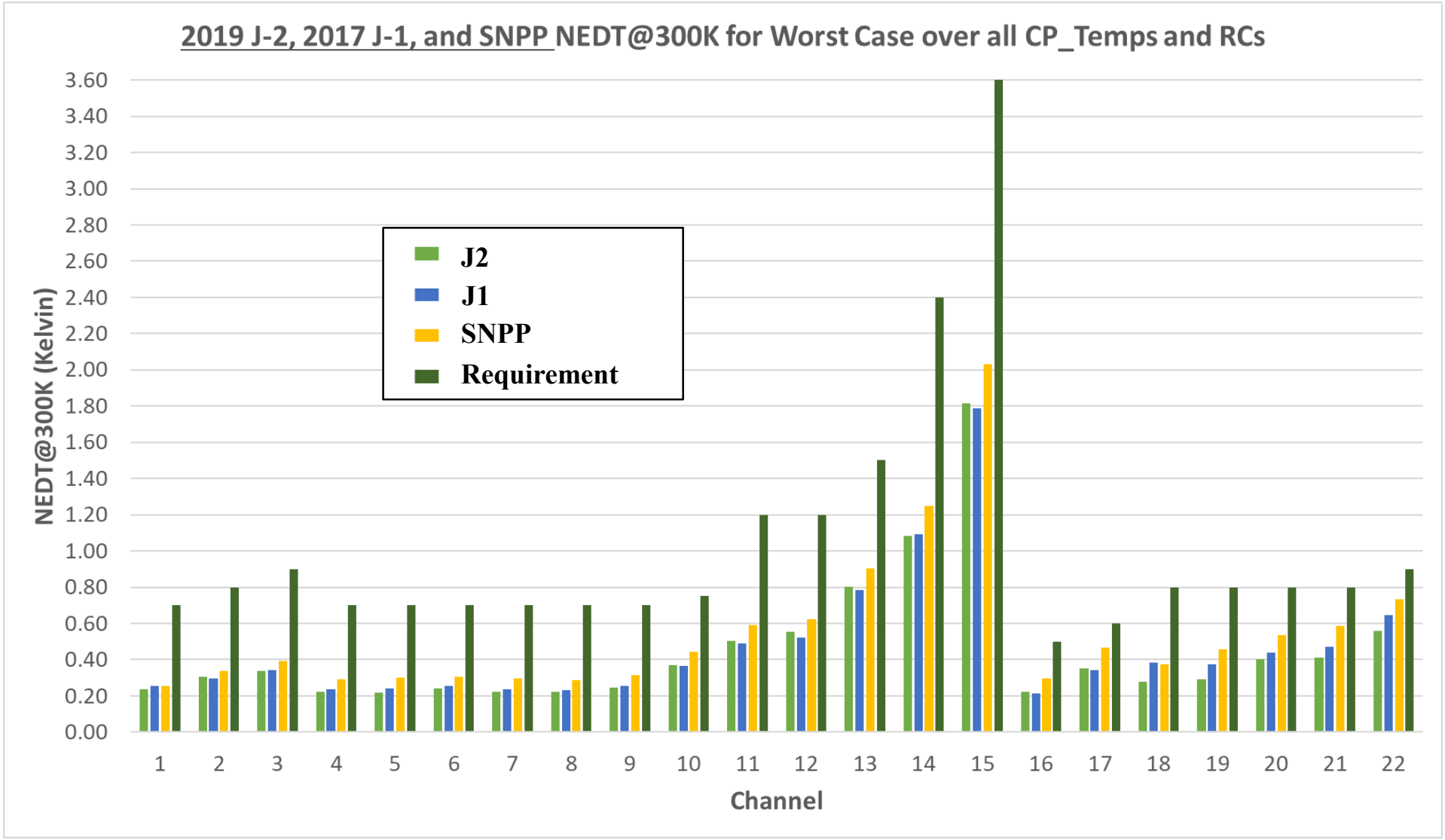
ATMS Flight Requirements

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
2	31400	QV	180	5.2	3-330	1.0	0.8
3	50300	QH	180	2.2	3-330	0.75	0.9
4	51760	QH	400	2.2	3-330	0.75	0.7
5	52800	QH	400	2.2	3-330	0.75	0.7
6	53596±115	QH	170	2.2	3-330	0.75	0.7
7	54400	QH	400	2.2	3-330	0.75	0.7
8	54940	QH	400	2.2	3-330	0.75	0.7
9	55500	QH	330	2.2	3-330	0.75	0.7
10	57290.344(f_o)	QH	330	2.2	3-330	0.75	0.75
11	f_o± 217	QH	78	2.2	3-330	0.75	1.2
12	f_o±322.2±48	QH	36	2.2	3-330	0.75	1.2
13	f_o±322.2±22	QH	16	2.2	3-330	0.75	1.5
14	f_o±322.2±10	QH	8	2.2	3-330	0.75	2.4
15	f_o±322.2±4.5	QH	3	2.2	3-330	0.75	3.6
16	88200	QV	2000	2.2	3-330	1.0	0.5
17	165500	QH	3000	1.1	3-330	1.0	0.6
18	183310±7000	QH	2000	1.1	3-330	1.0	0.8
19	183310±4500	QH	2000	1.1	3-330	1.0	0.8
20	183310±3000	QH	1000	1.1	3-330	1.0	0.8
21	183310±1800	QH	1000	1.1	3-330	1.0	0.8
22	183310±1000	QH	500	1.1	3-330	1.0	0.9

NOAA-21 ATMS Pre-launch Waivers

Waivers	Description	ATMS Chan	Science Rationale
JPSS-W033	Beamwidth Non-compliance (crosstrack beamwidth = 5.78º degrees > 5.72º (5.2º (spec) + 10%))	02 Ka-band	Small exceedance that is in-family with S-NPP and N-20 (beamwidth 5.3º x 5.78º has a geometric mean of 5.53º < 5.72º)
JPSS-W034	Bandwidth Non-compliance (Req. Max bandwidth – 3.000GHz < measured 3.004GHz)	17 at 165 GHz	Small exceedance on a window channel (Analysis shows the error < 0.002K negligible)
JPSS-W035	Center Freq. Stability (Spec < 0.5MHz, measured (worse case) = 0.6MHz)	11 V-band	Small exceedance (0.1 MHz) ar extreme instr. Temp. (50ºC) (Analysis shows the error < 0.01K negligible)
JPSS-W036	Passband Rejection (Req. 40dB, measured 37.5dB for ch. 3)	03 V-band	Bandwidth of exceedance is minimal in neighboring channel (Analysis shows the error < 0.001K negligible)
JPSS-W037	Sideband Balance (Req. $\pm 1dB$, less than measured 2.67dB (primary) and 2.30 (redundant) for ch. 12	12 V-band	Imbalance captured by Spectral Response Functions (Analysis shows the impact bias/std: -0.03/0.012 K with min/max -0.062/0.024 K. Error is small, not totally negligible, accurate SRF required)
JPSS-W041	Bandwidth Non-compliance (Spec. 78MHz < the worse case 78.03MHz)	11 V-band	Small exceedance at extreme instr. temp. (-10°C) (RTM analysis shows the error < 0.005K)

NOAA-21 ATMS Pre-launch Instrument Evaluation – NEΔT

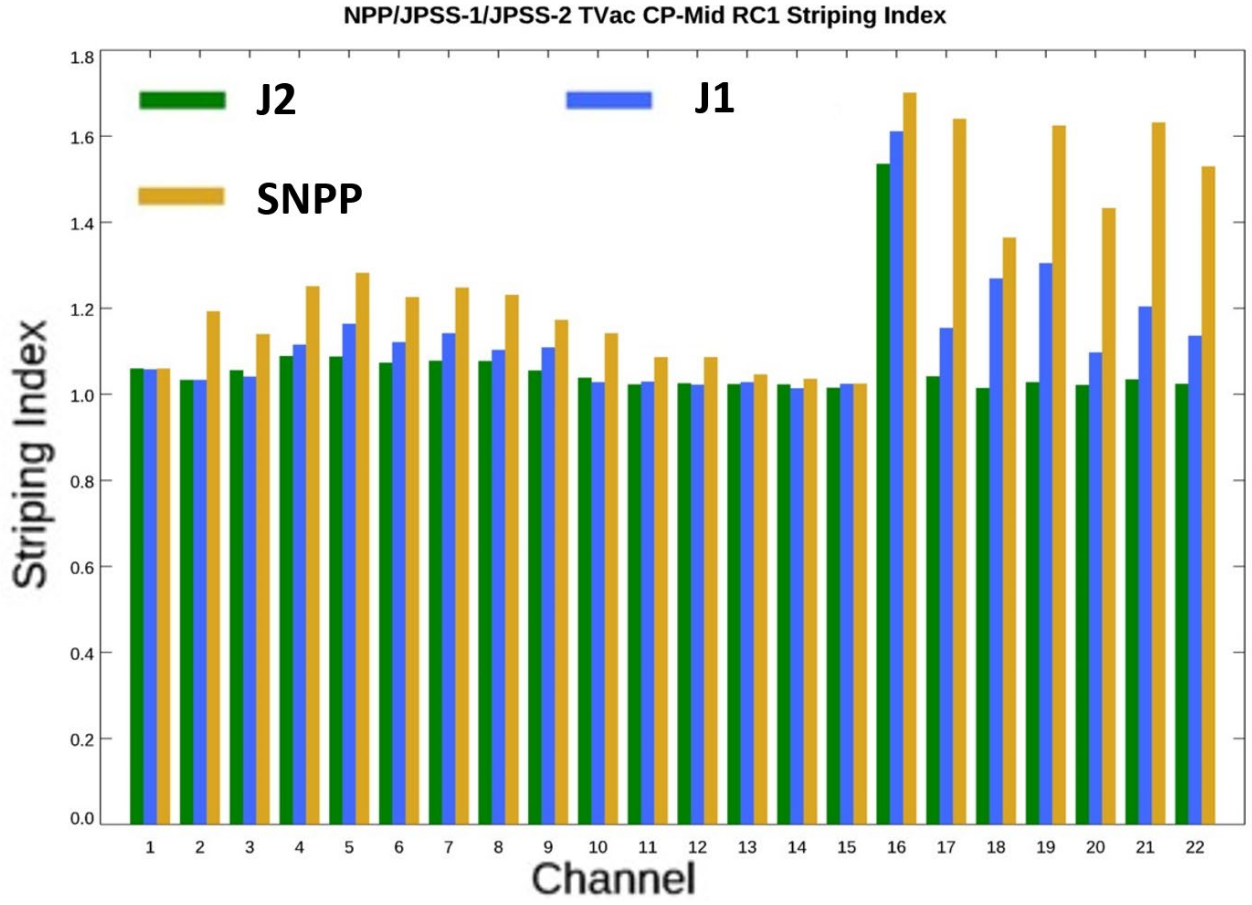


NASA/GSFC

All J2 results are in family with J1 and SNPP. J2 NEDT better than J1 & SNPP for CH 18-22.

NOAA-21 ATMS Pre-launch Instrument Evaluation – Striping Index

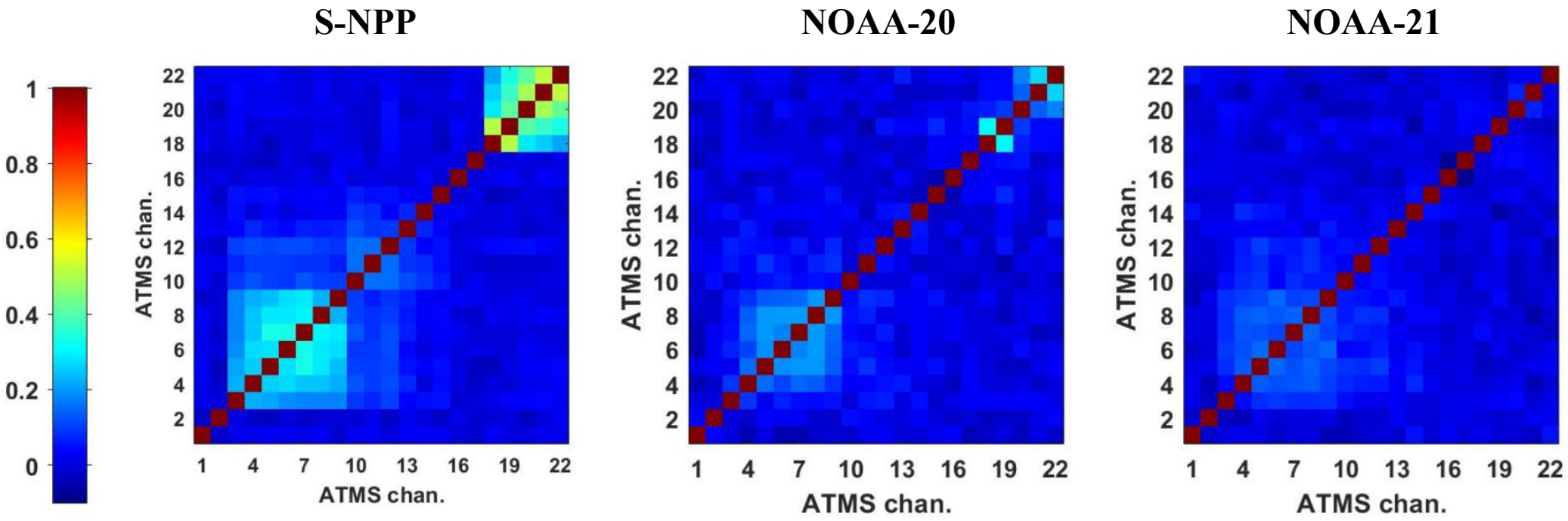
- Striping index = variance along-track / variance cross-track. Ratio of 1 indicates no striping.
- Redundancy Configuration 1 shown



NOAA-21 ATMS has significant striping reduction in G-band and lower V-band

NOAA/STAR

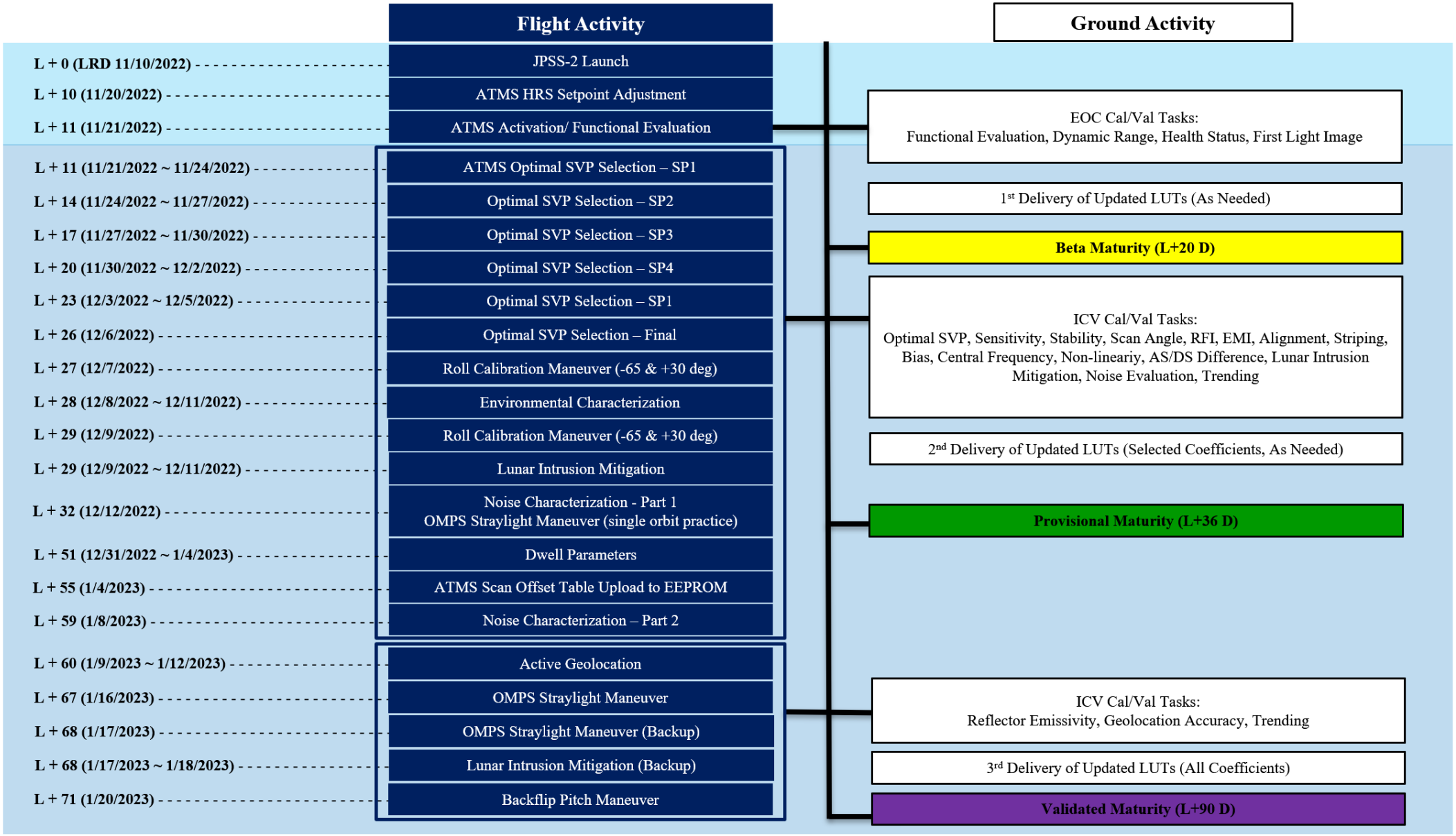
Channel to Channel Correlation



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

MIT/LL

NOAA-21 ATMS Post-launch Cal/Val Timeline



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

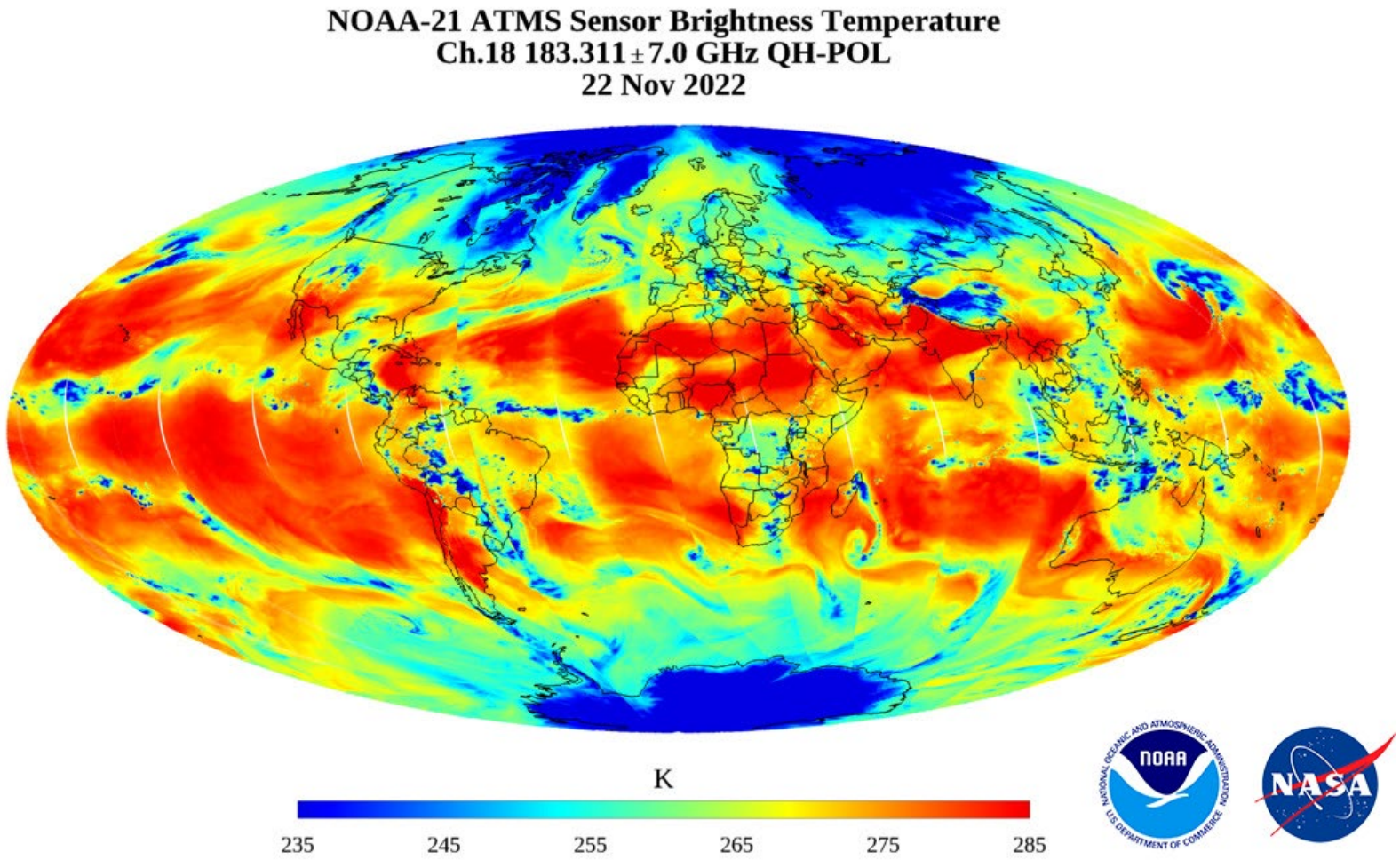
NOAA-21 ATMS Post-launch Cal/Val Tasks

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	Continuous Sampling Mode	NOAA/STAR, MIT/LL	L+28, Environmental Characterization PLT
15	Lunar Intrusion Evaluation	NOAA/STAR, NASA/GSFC, MIT/LL	L+29, Lunar Intrusion Mitigation PLT(L+29)
16	Striping Analysis and Noise Evaluation	NOAA/STAR, MIT/LL	L+32, Noise Characterization – Part 1 PLT

NOAA-21 ATMS Post-launch Cal/Val Plan

Task #	Title	Teams	Data Available Date & Related PLTs
17	GPS-RO Bias Characterization	NOAA/STAR	L+36
18	SNO Bias Characterization	NOAA/STAR	L+36
19	Geolocation Verification and Correction	NOAA/STAR, MIT/LL	L+36
20	Instrument to Spacecraft Alignment	NOAA/STAR	L+36
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
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 First Light Image

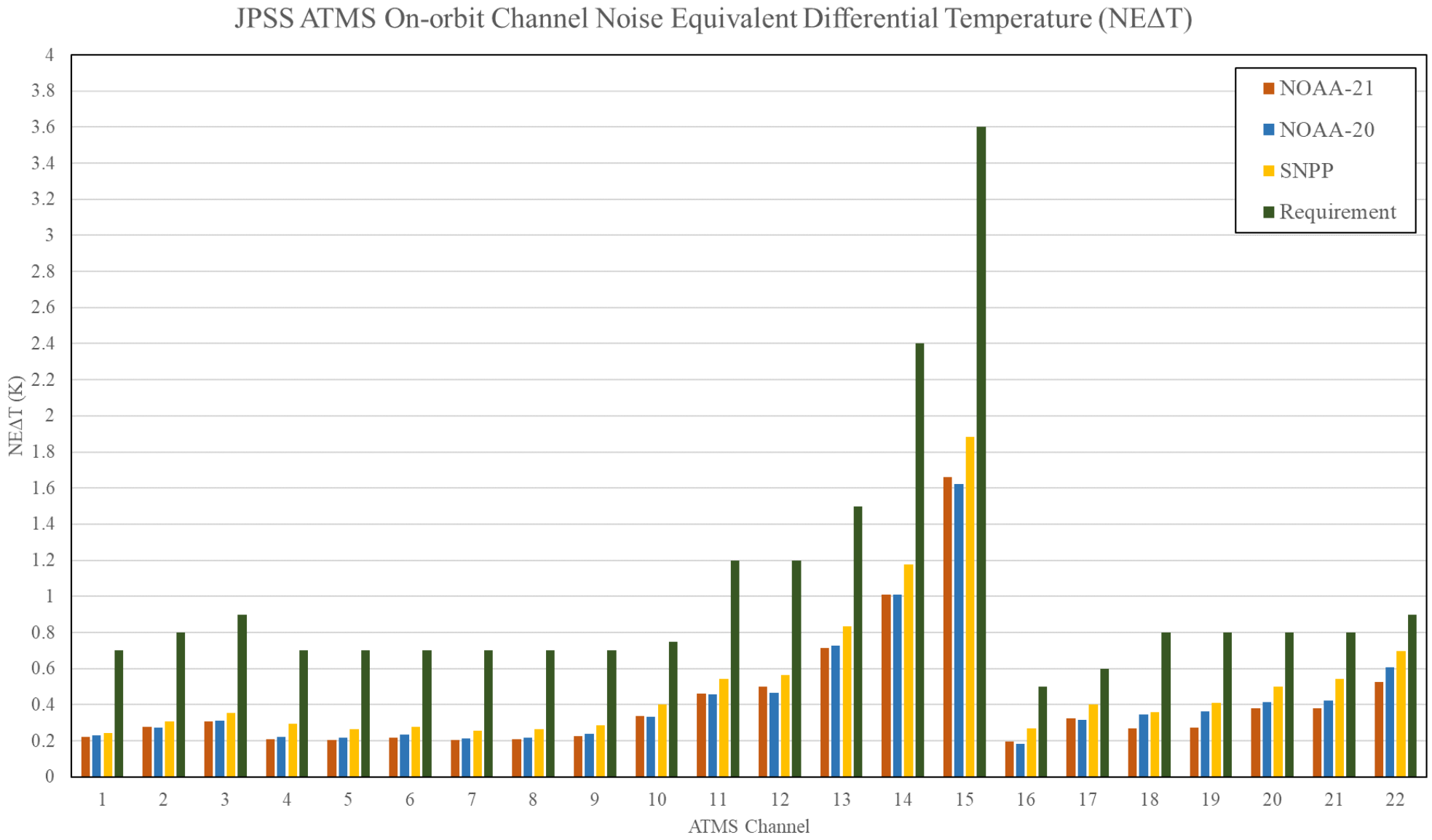


ATMS channel 18 at 183.31+/- 7Ghz is used to acquire water vapor information in the atmosphere.

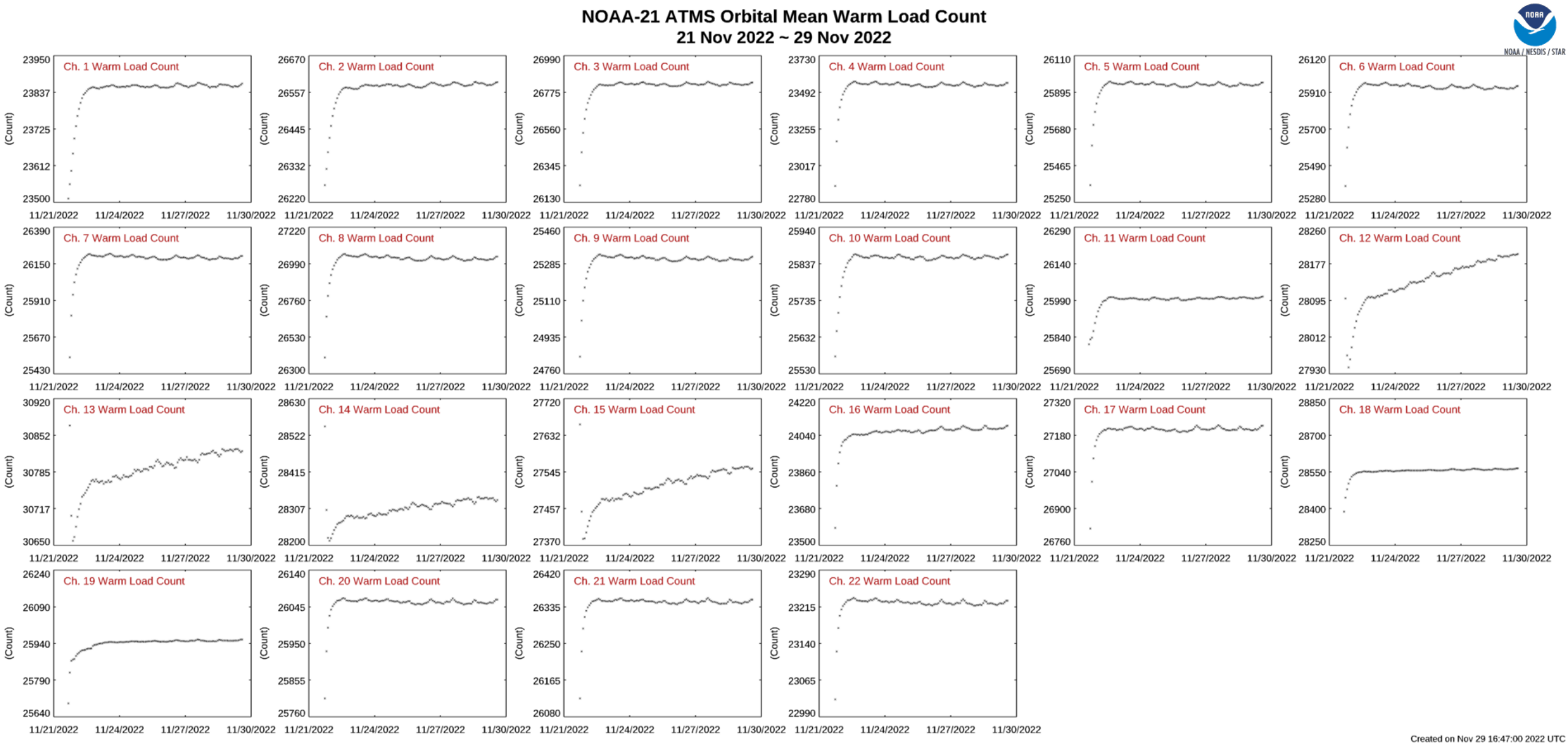
The ATMS instrument gives weather forecasters a global 3D picture of our atmosphere's temperature and moisture—the most fundamental information needed by weather models that forecast daily weather and warn us of hurricanes, floods, droughts, heat waves, snowstorms, and other weather events.

https://www.nesdis.noaa.gov/news/first-light-image-noaa-21s-atms-sensor

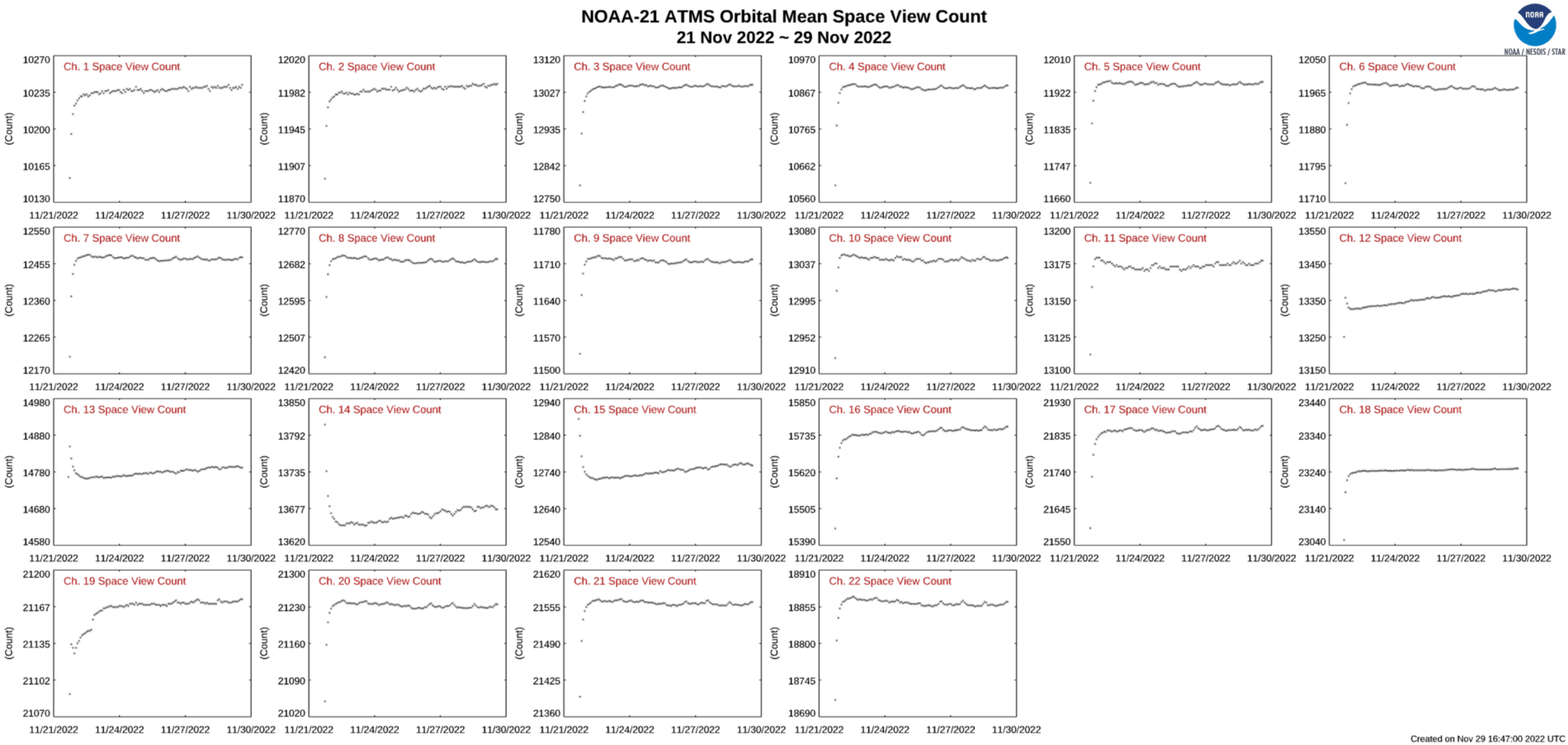
NOAA-21 ATMS On-orbit NEΔT



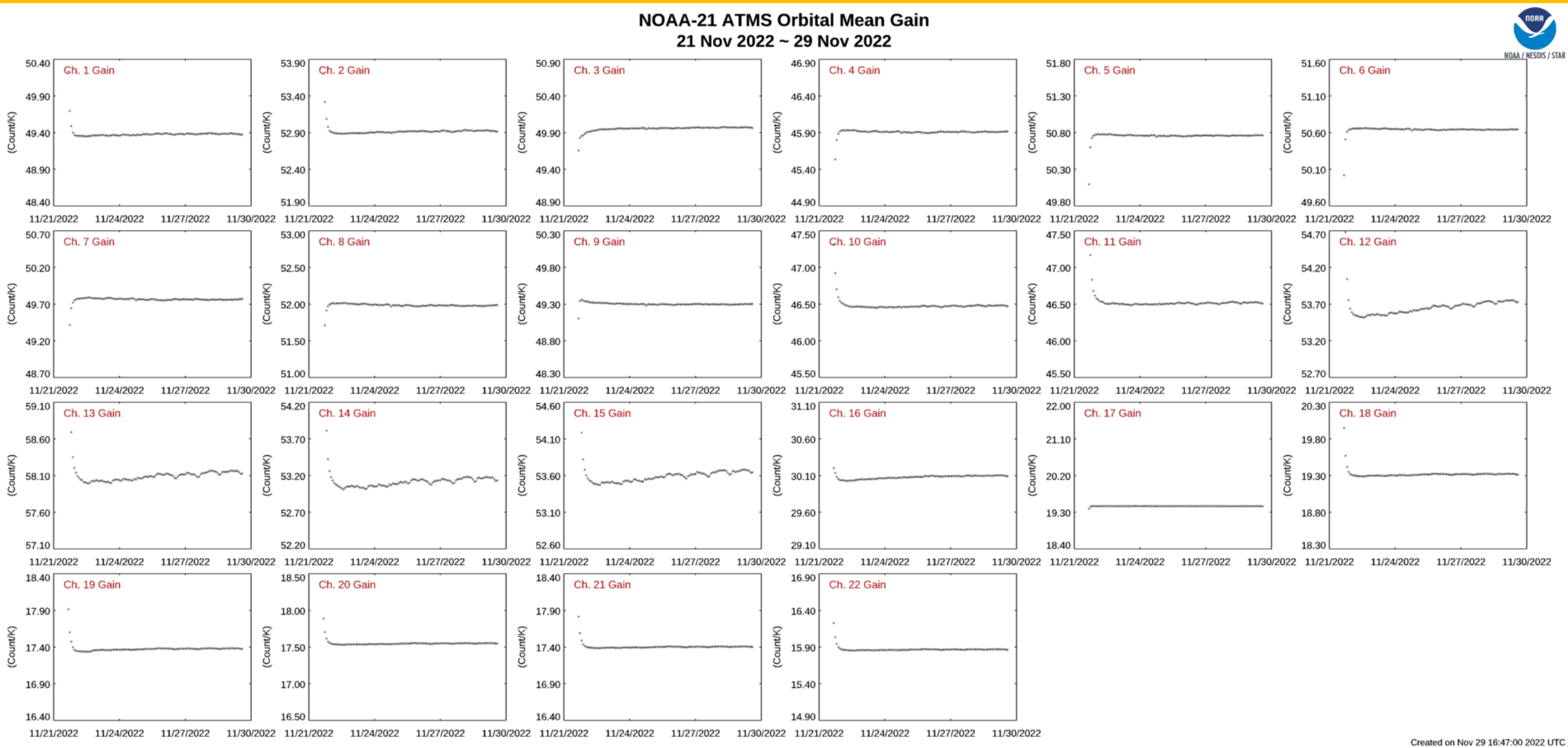
NOAA-21 ATMS On-orbit Calibration Targets



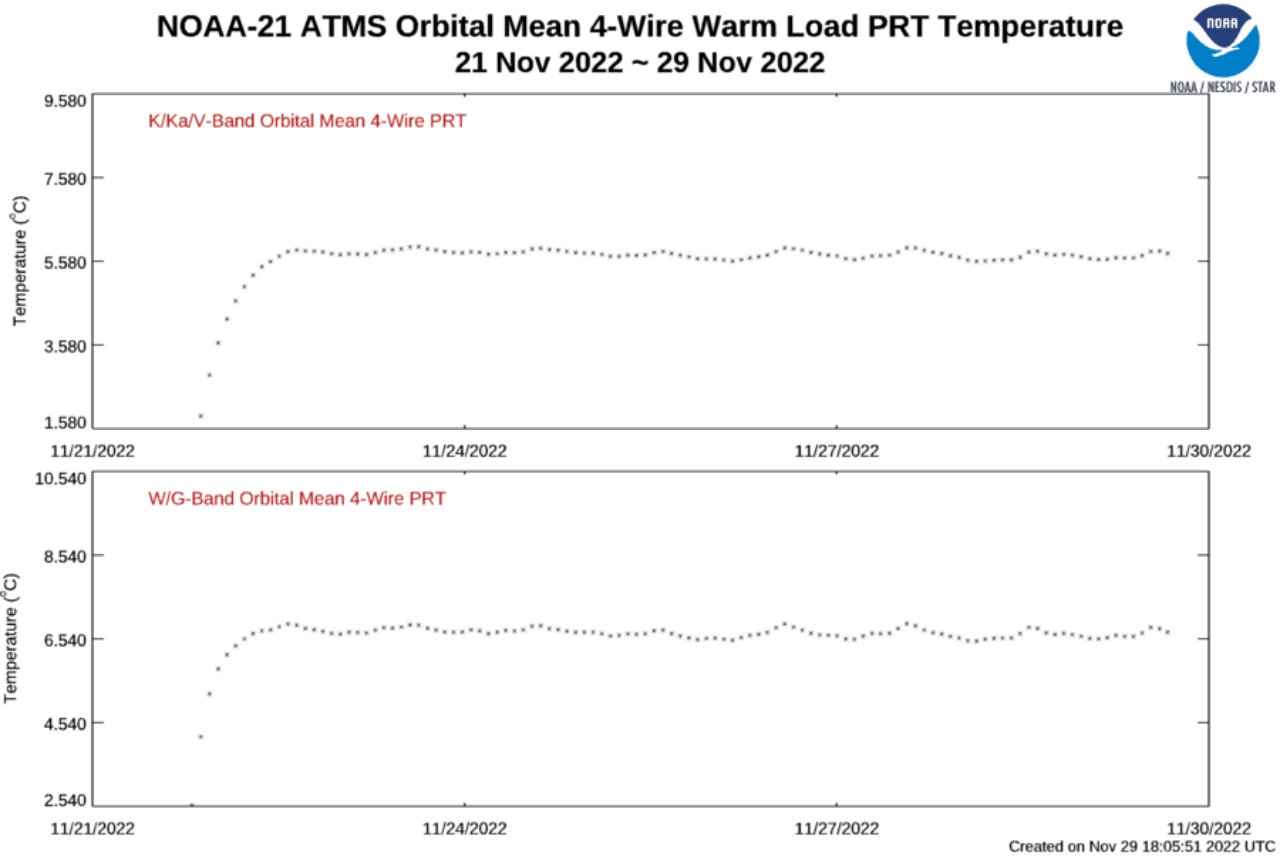
NOAA-21 ATMS On-orbit Calibration Targets

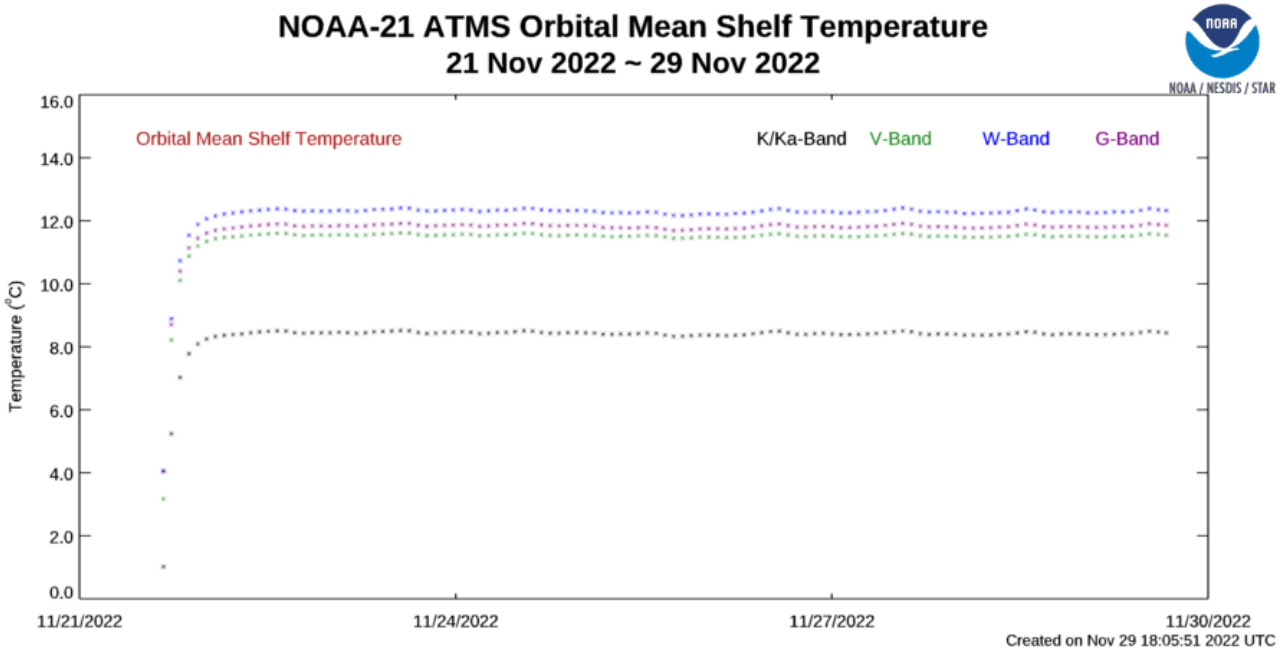


NOAA-21 ATMS On-orbit Calibration Gain



NOAA-21 ATMS On-orbit Calibration and Instrument Temperatures

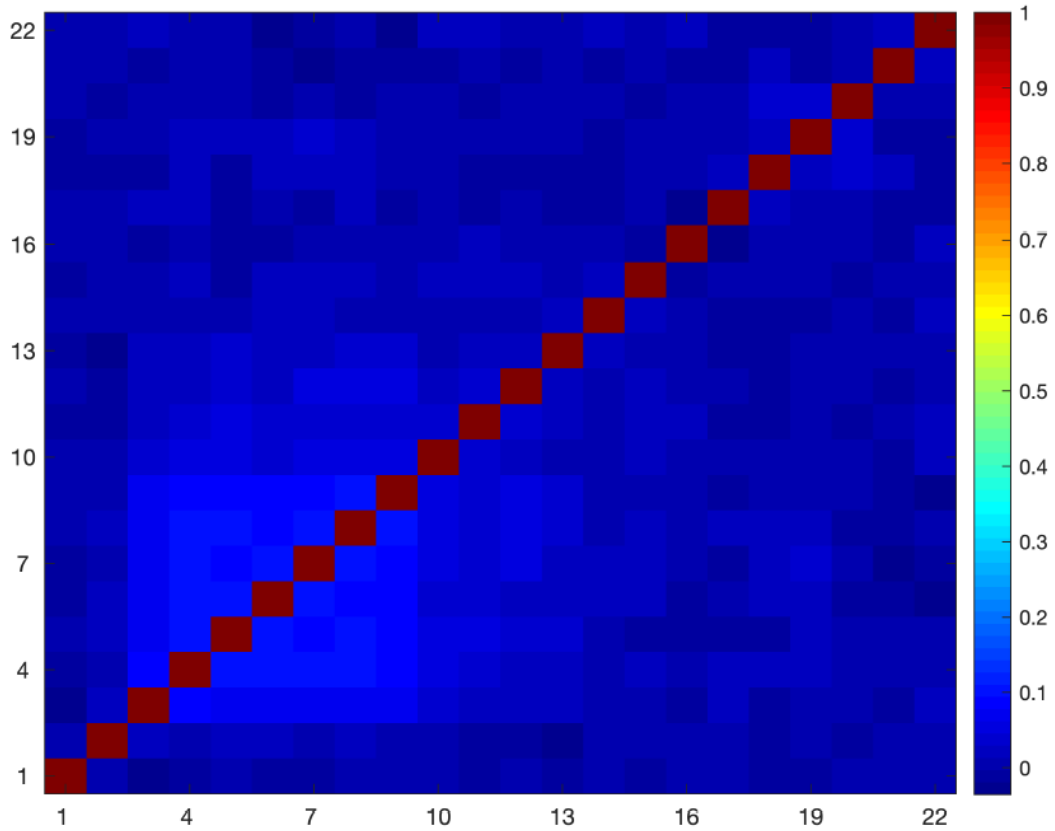




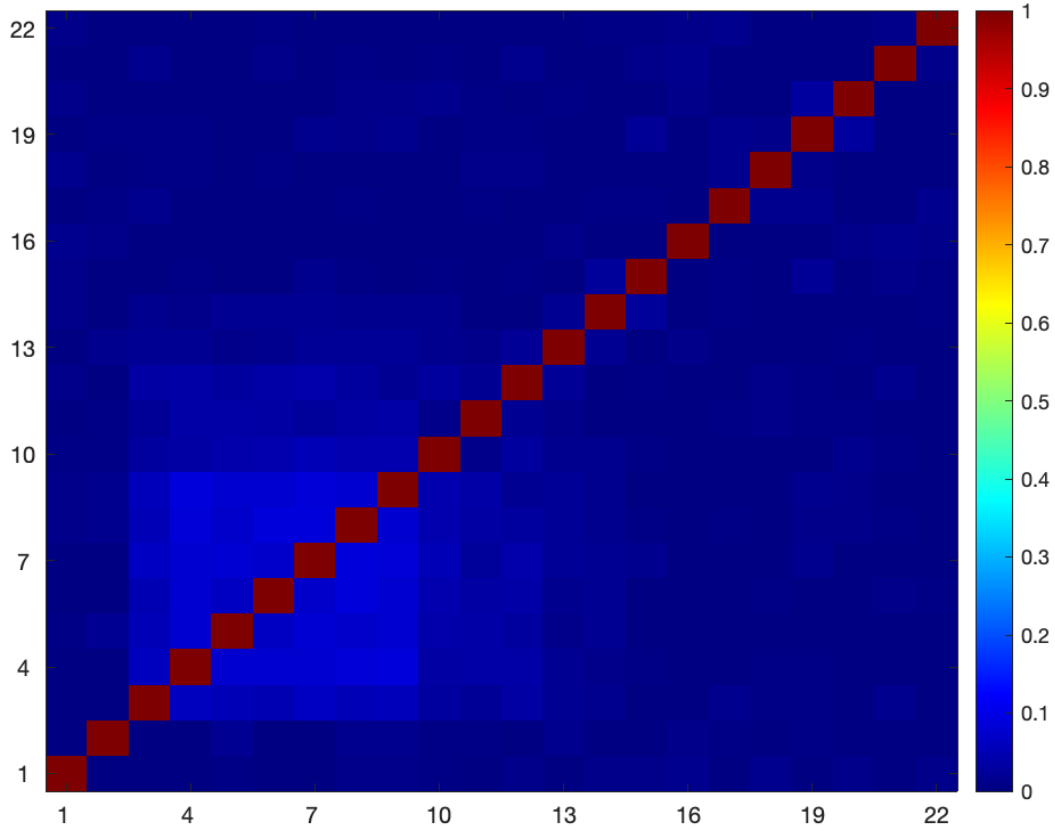
NOAA-21 ATMS On-orbit Channel Correlation

Channel to channel correlation is calculated from the warm load temperature noise

NOAA-21 ATMS Pre-launch TVAC

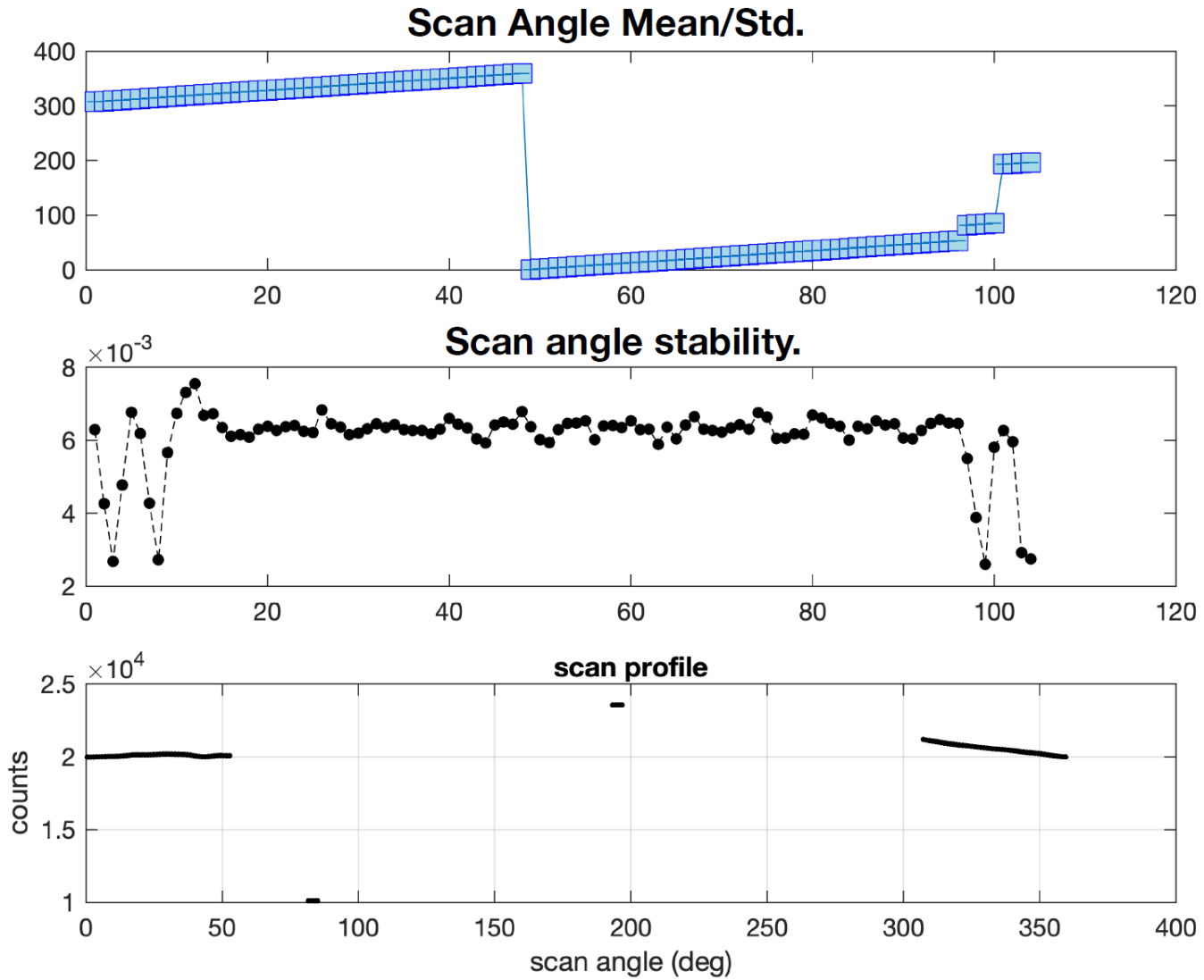


NOAA-21 ATMS On-orbit



On-orbit channel correlation is consistent with the pre-launch TVAC analysis results

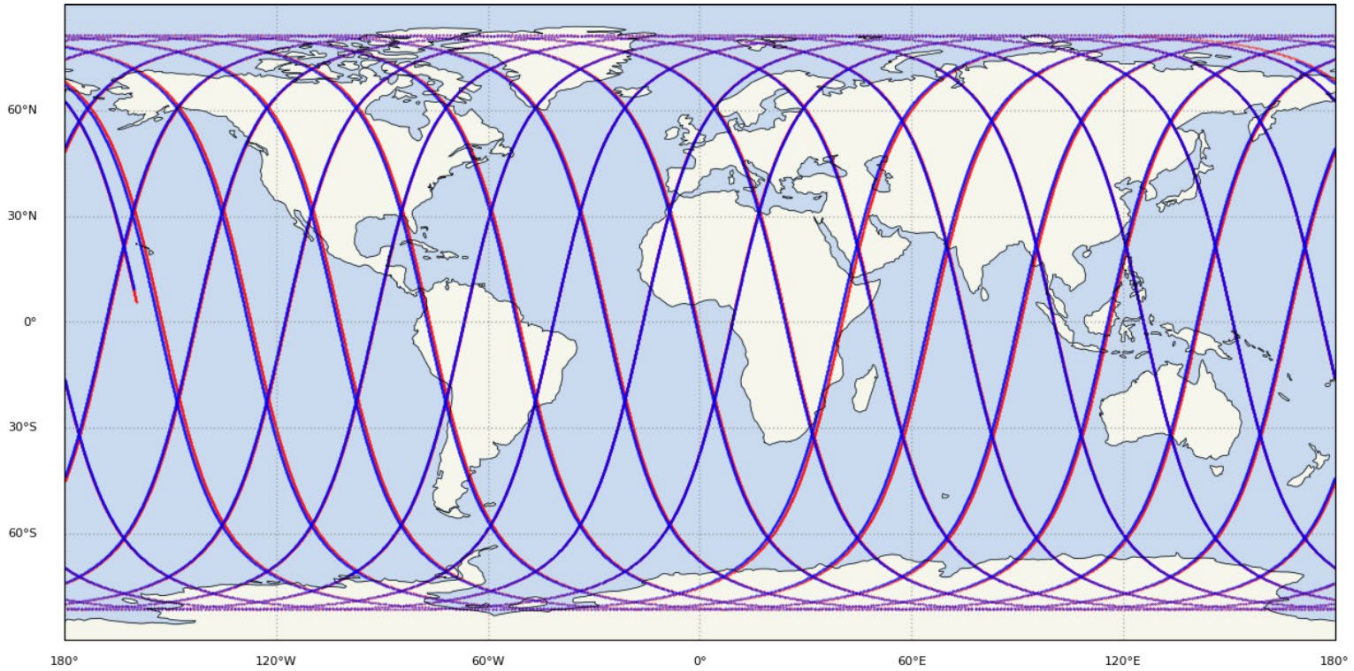
NOAA-21 ATMS On-orbit Scan Angle Evaluation



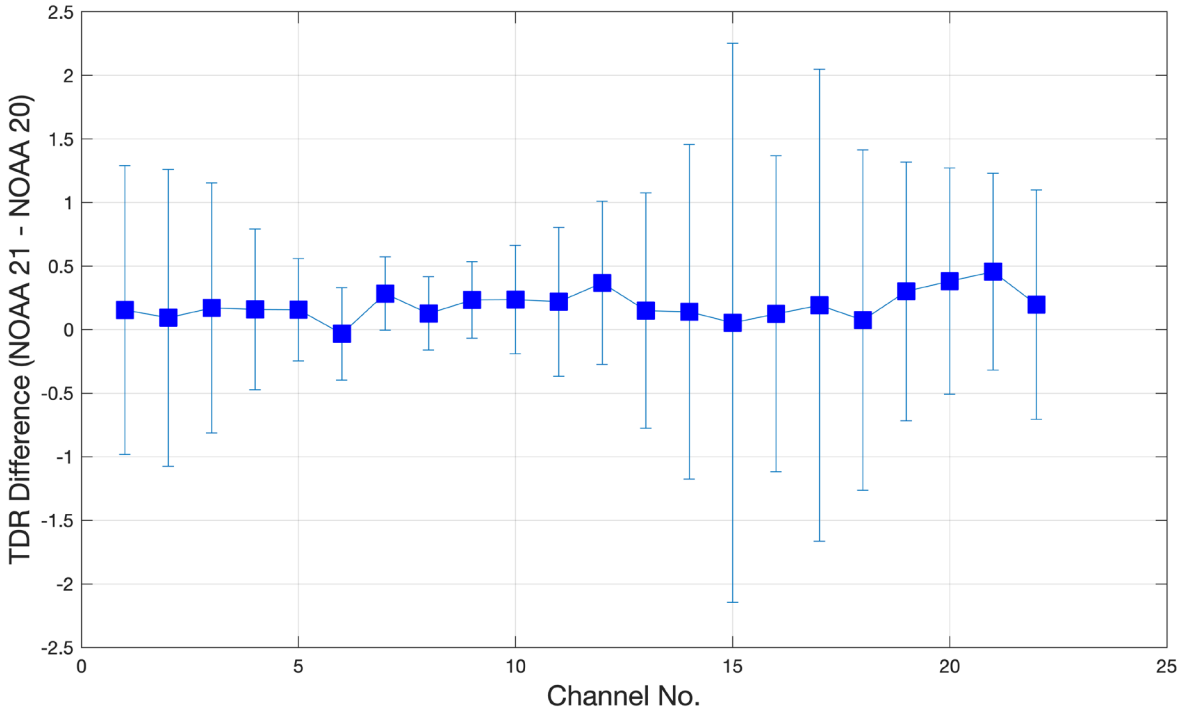
Scan angle is stable. The maximum scan-to-scan variation is < 0.01 degree.

NOAA-21 and NOAA-20 Orbital Overlapping for Direct ATMS TDR Comparisons

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

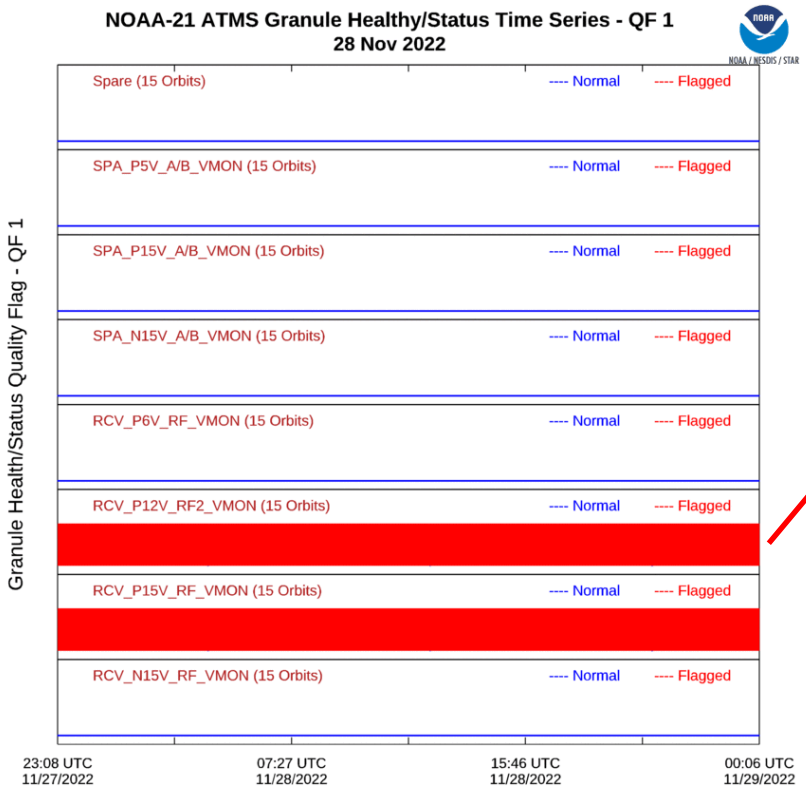


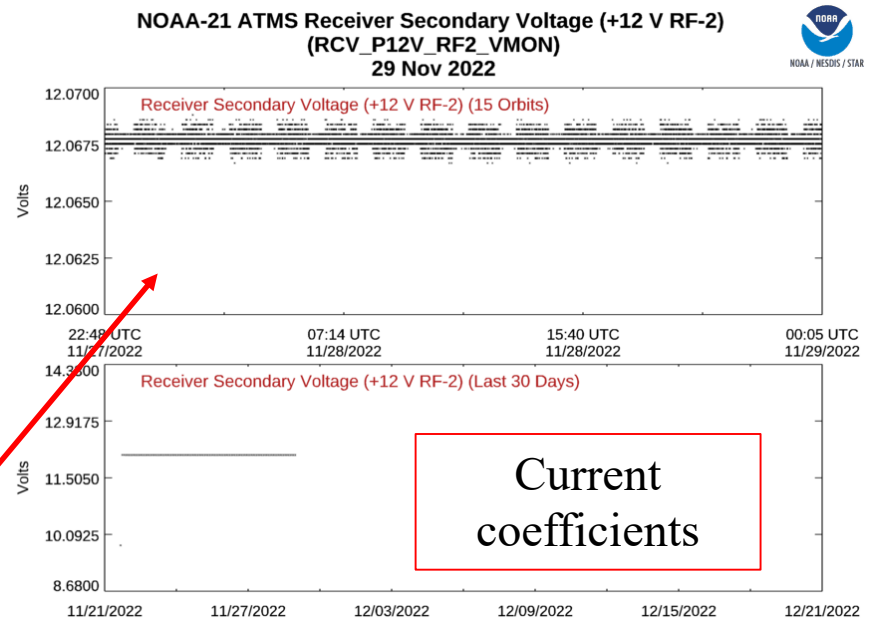
Brightness temperature difference between NOAA-21 and NOAA-20

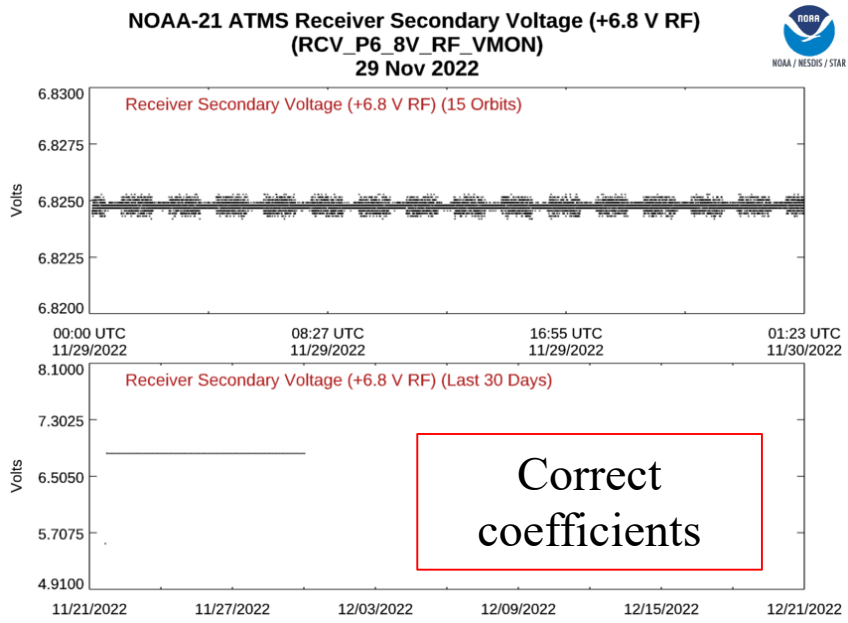


Unique opportunity for direct comparisons between NOAA-20 and NOAA-21 ATMS during their orbital overlapping between November 24 and 25, 2022

NOAA-21 ATMS SDR Quality Flag – Health Status







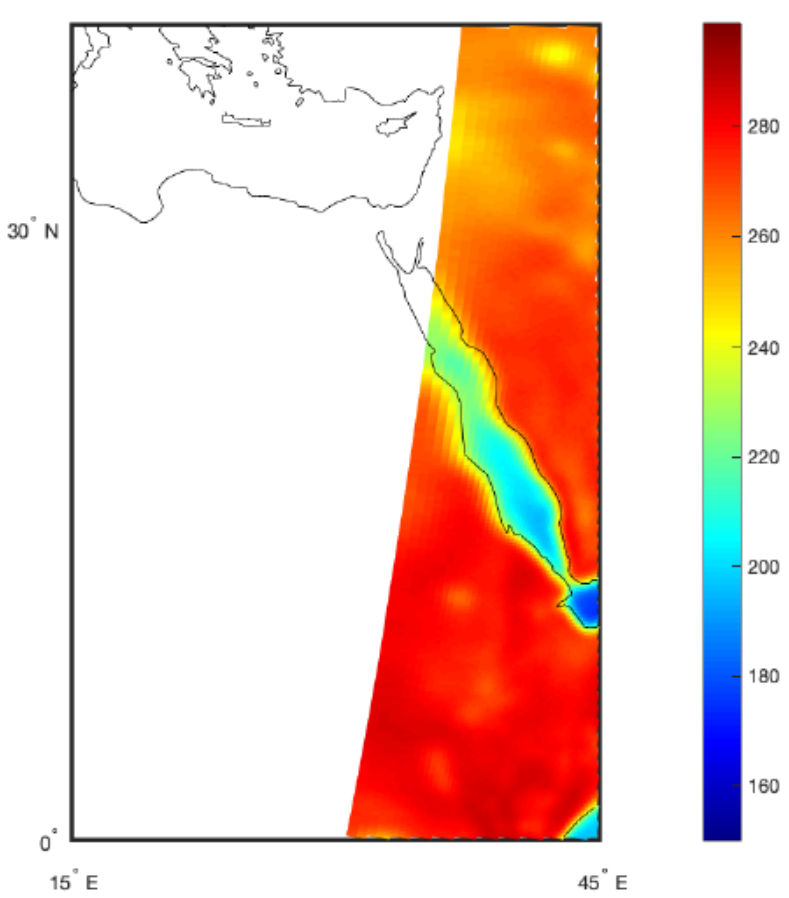
#	SNPP/NOAA-20	NOAA-21
4	RCV +6V RF [5.75,6.5]	RCV +6.25V RF [6.0,6.5]
5	RCV +12V RF-2 [11.25,12.75]	RCV +6.8V RF [6.45,7.15]
6	RCV +15V RF [14.25,15.75]	RCV +12V RF [11.47,12.42]

- 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
- IDPS ATMS calibration algorithm program update is ongoing. Will submit code update in next available release to fix it.

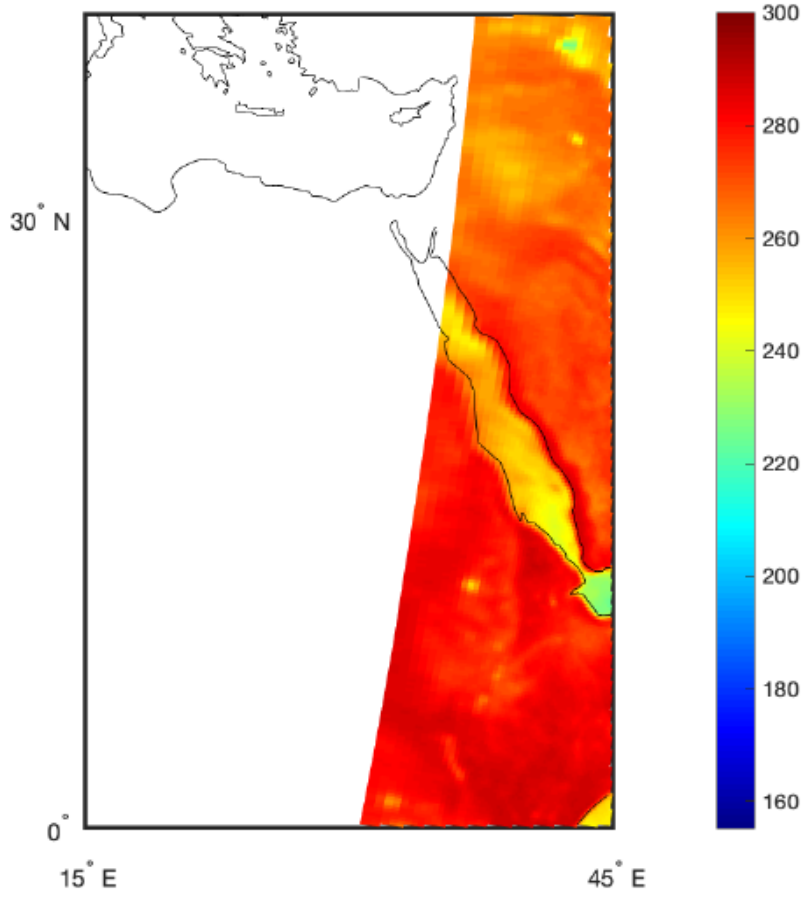
NOAA-21 ATMS Geolocation

Geolocation accuracy qualitative quick check didn't observe obvious bias. Quantitative assessment results will be provided when enough coastline inflection point data samples are available

Channel 1



Channel 16

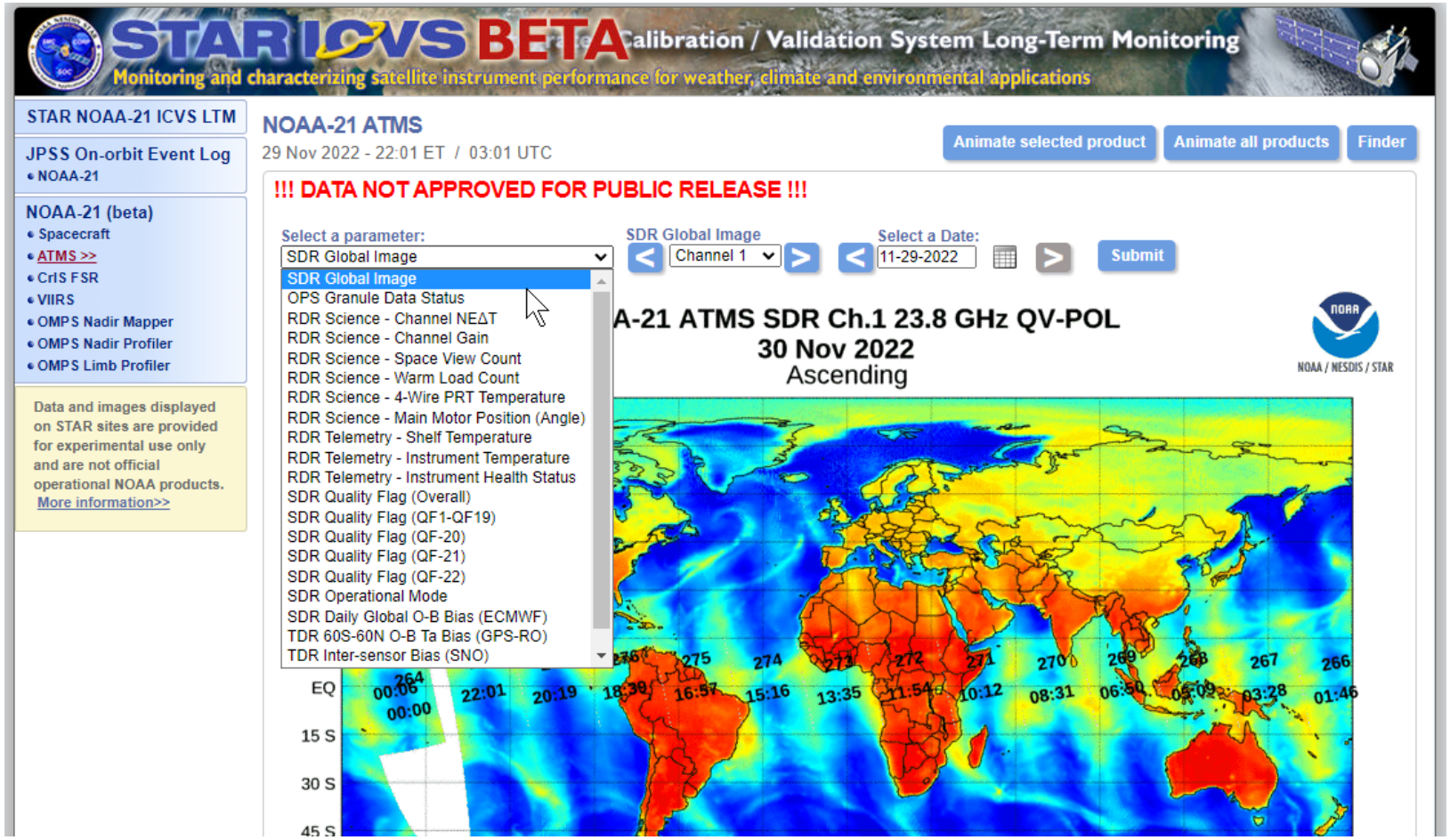


NOAA-21 ATMS Instrument/Science Data On-orbit Monitoring

JPSS-2 ATMS instrument on-orbit health status/performance and science data quality NRT monitoring is provided in STAR Integrated Calibration/Validation System Long-Term Monitoring (ICVS-LTM) web pages (Password Protected)

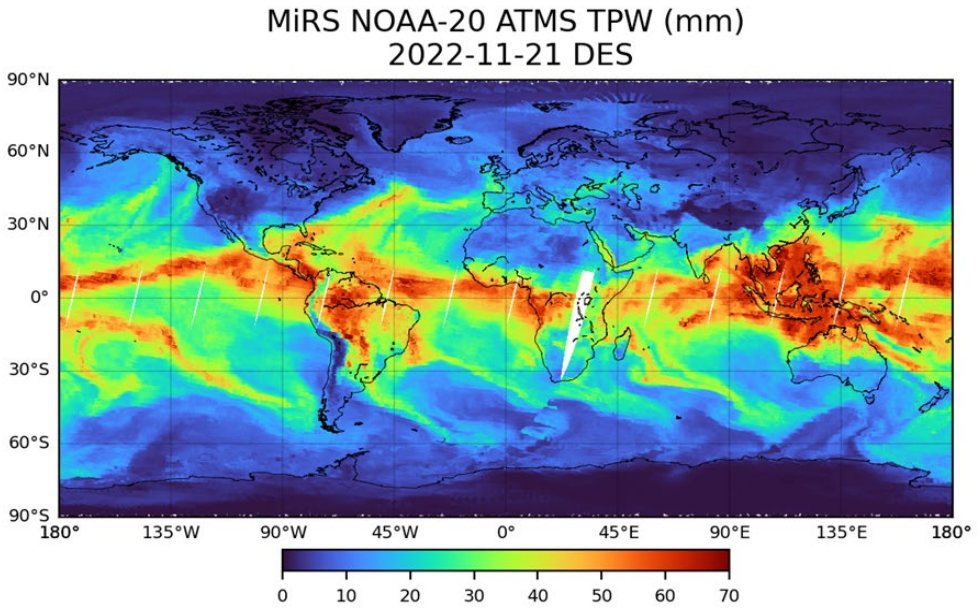
https://www.star.nesdis.noaa.gov/icvs-j2/status_J02_ATMS.php (Password Protected)

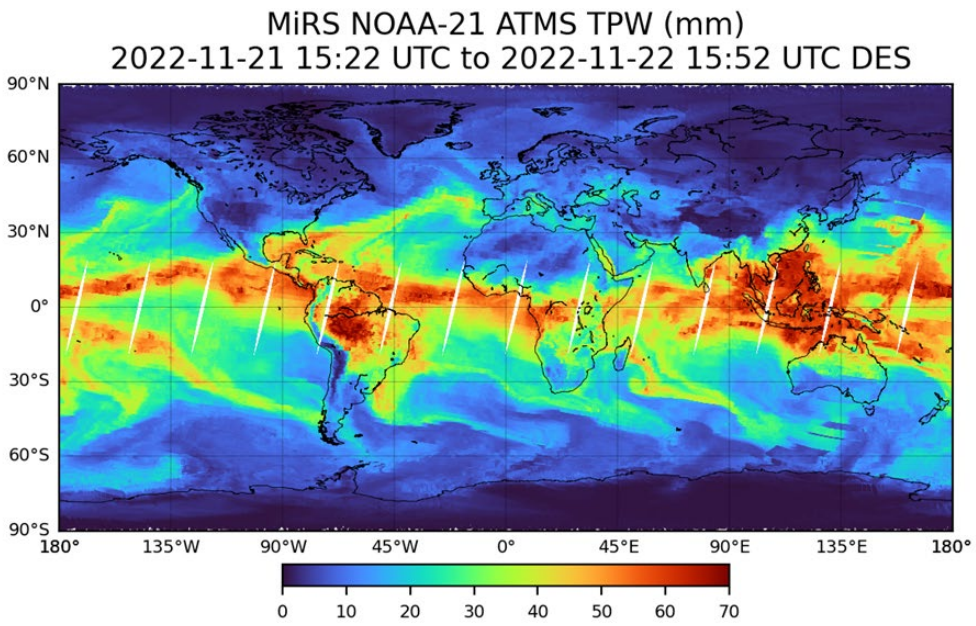
https://www.star.nesdis.noaa.gov/icvs-beta/status_J02_ATMS.php (NOAA CAC/Email Access)



NOAA-21 ATMS MiRS First Image

NOAA-20 vs NOAA-21 Total Precipitable Water



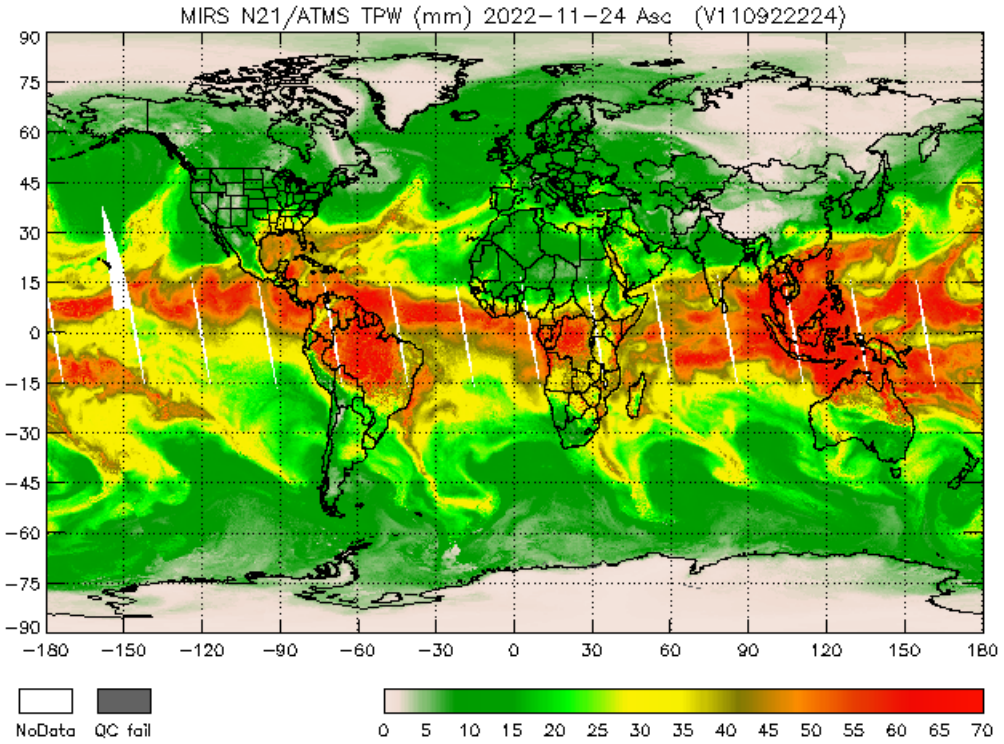


Produced by the MiRS Algorithm Development Team at NOAA/NESDIS/STAR

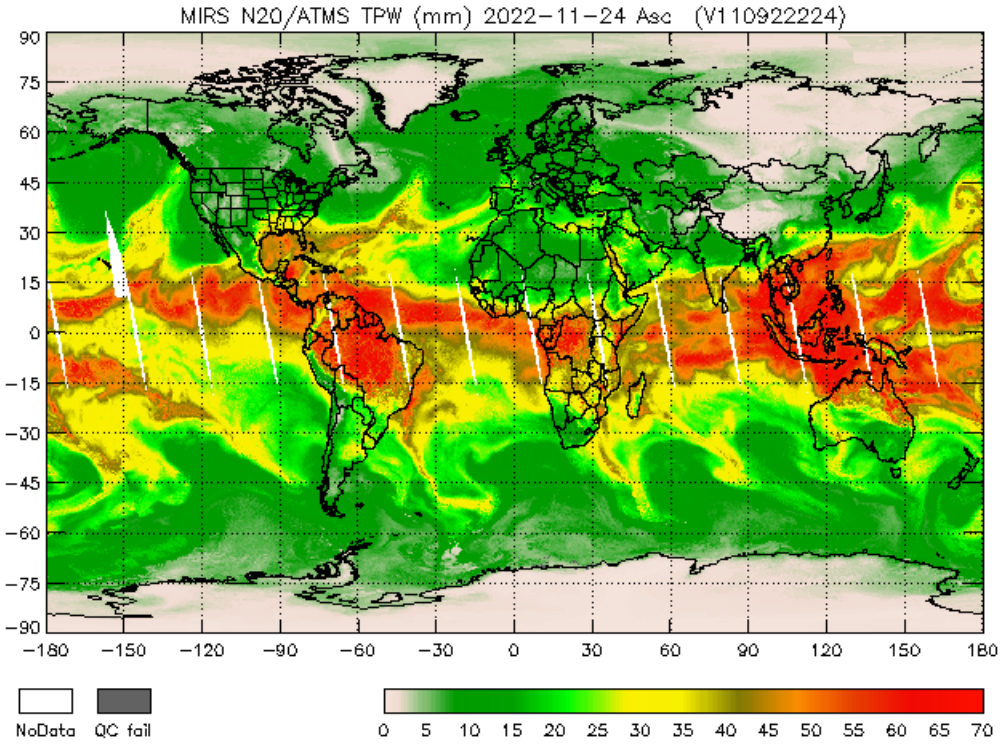
NOAA-21 Preliminary, Non-Operational Data

MiRS N21 and N20 TPW Comparison with ECMWF

N21



N20



2022-11-24

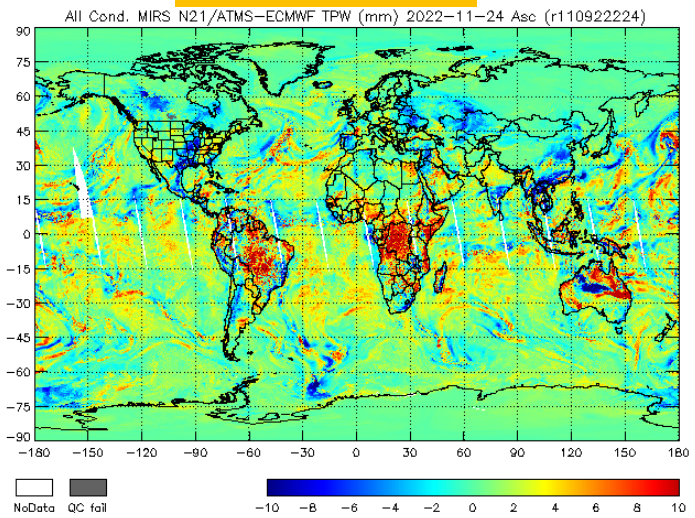
NOAA-21 Preliminary, Non-Operational Data

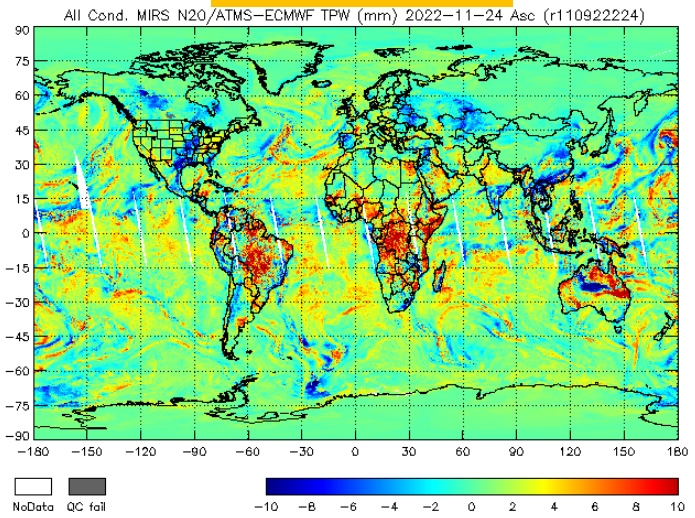
MiRS N21 and N20 TPW Comparison with ECMWF

N21

N20

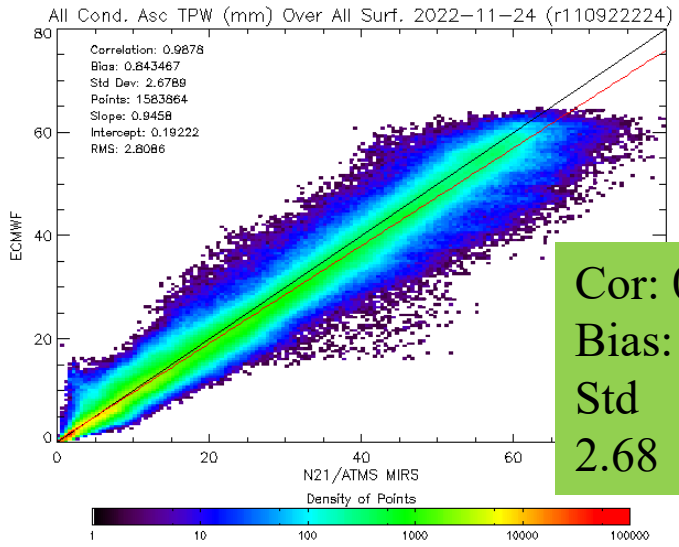
MiRS-ECMWF



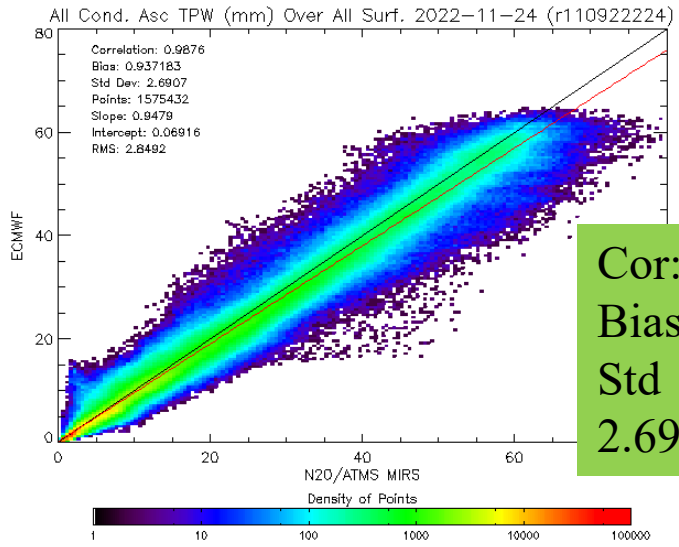


2022-11-24

MiRS vs. ECMWF



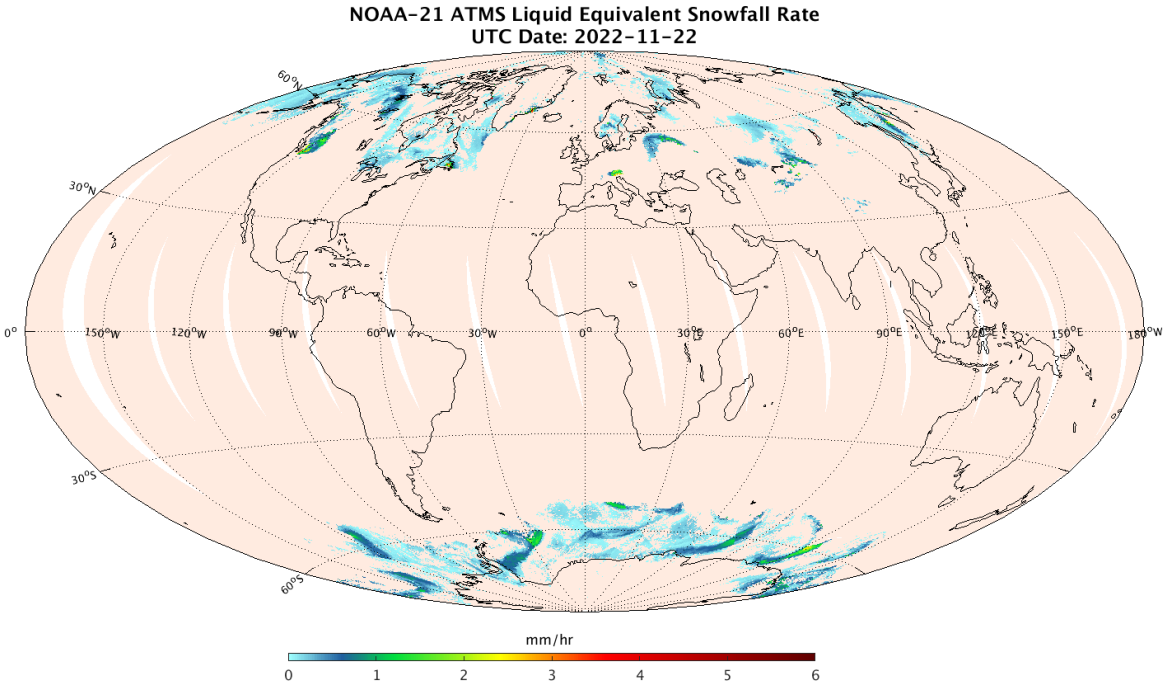
Cor: 0.988
Bias: 0.84
Std Dev: 2.68

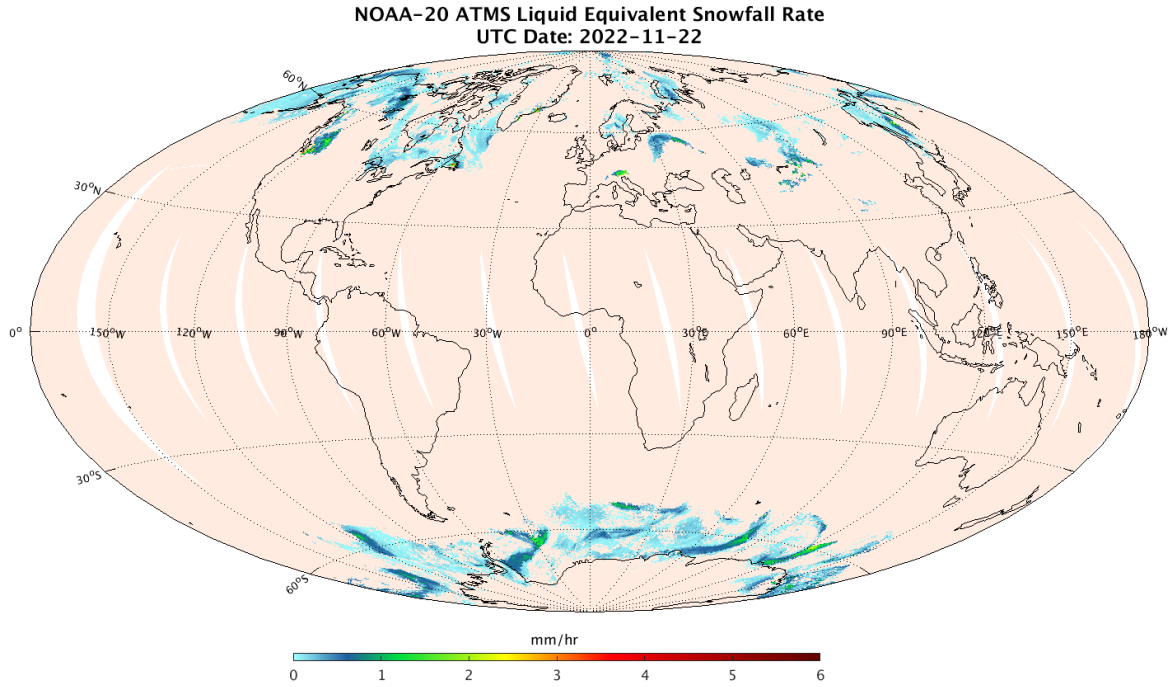


Cor: 0.988
Bias: 0.94
Std Dev: 2.69

NOAA-21 Preliminary, Non-Operational Data

NOAA-21 Snow Fall Rate Products

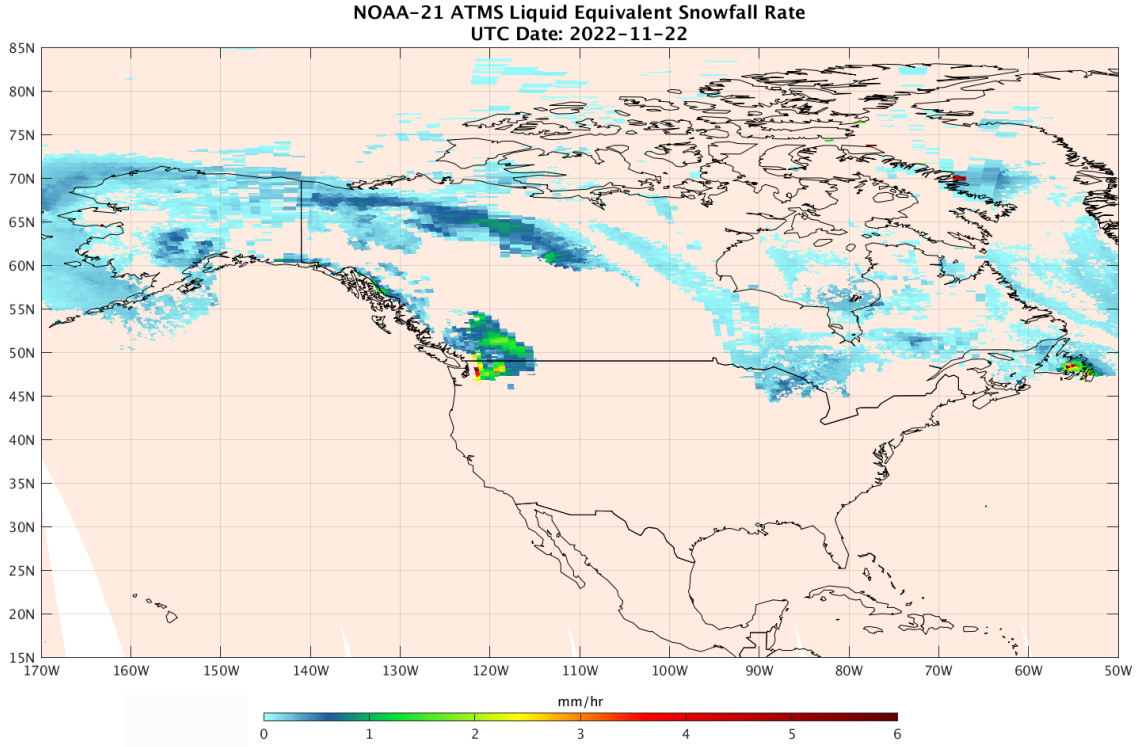


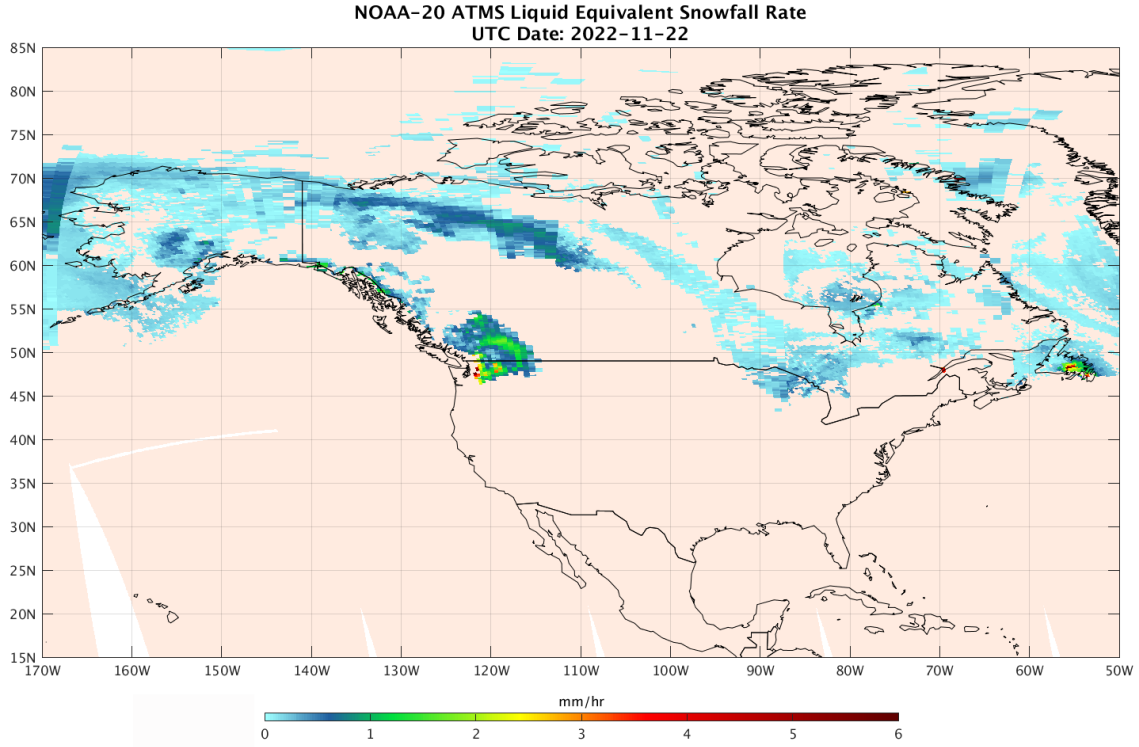


Provided by Huan Meng, SFR Science Team at NOAA/NESDIS/STAR

NOAA-21 Preliminary, Non-Operational Data

NOAA-21 Snow Fall Rate Products





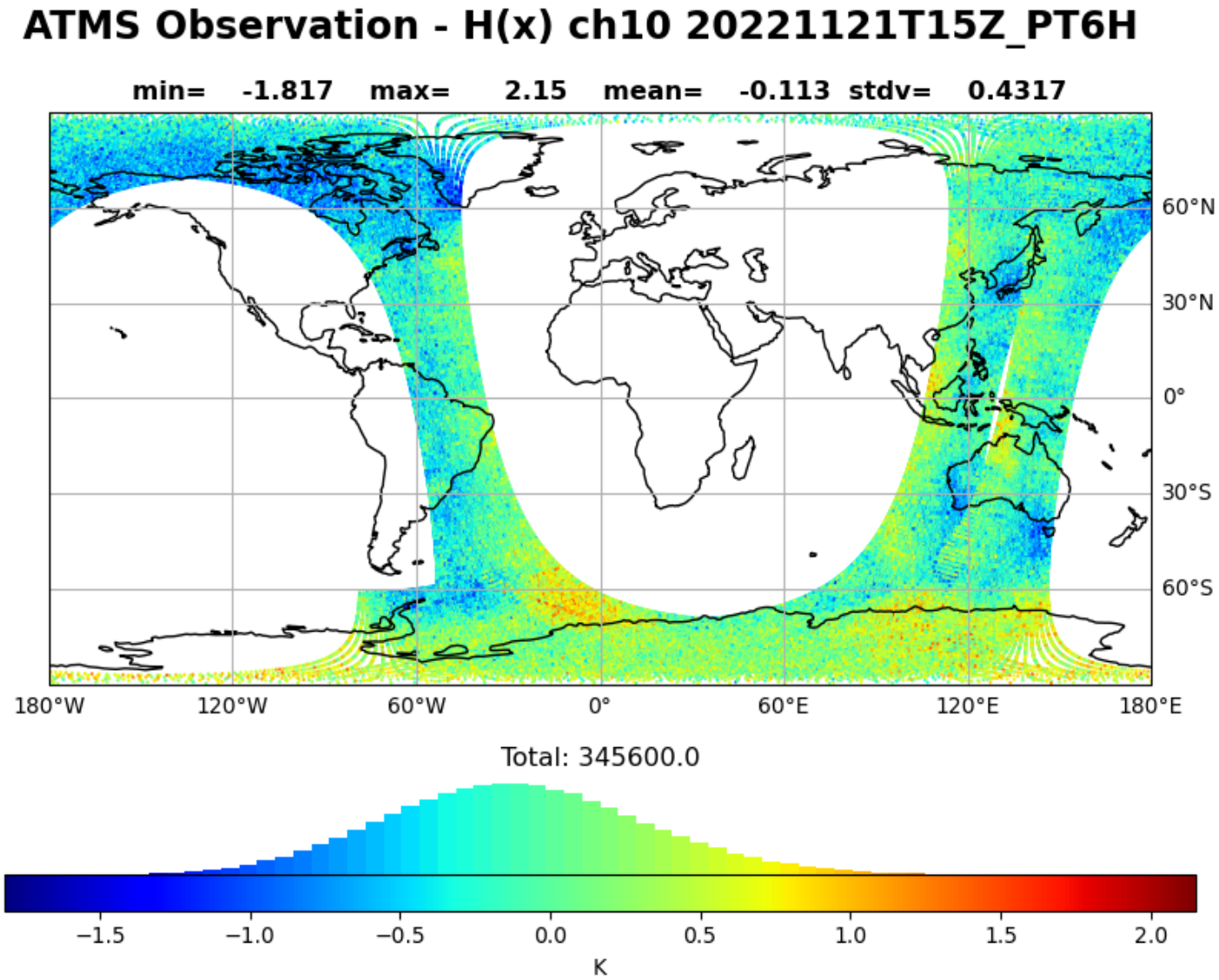
Provided by Huang Meng, SFR Science Team at NOAA/NESDIS/STAR

NOAA-21 Preliminary, Non-Operational Data

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.



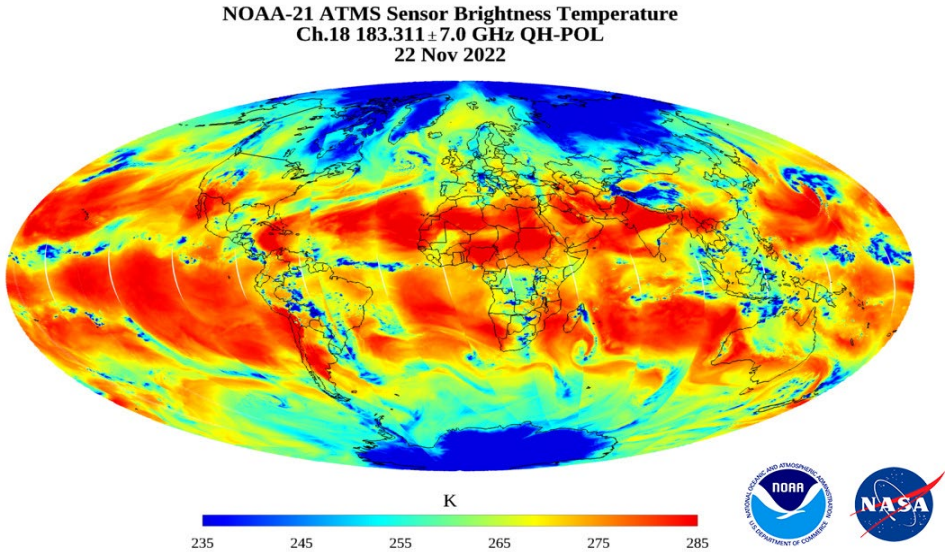
NOAA-21 Preliminary, Non-Operational Data

Check List – Beta Maturity

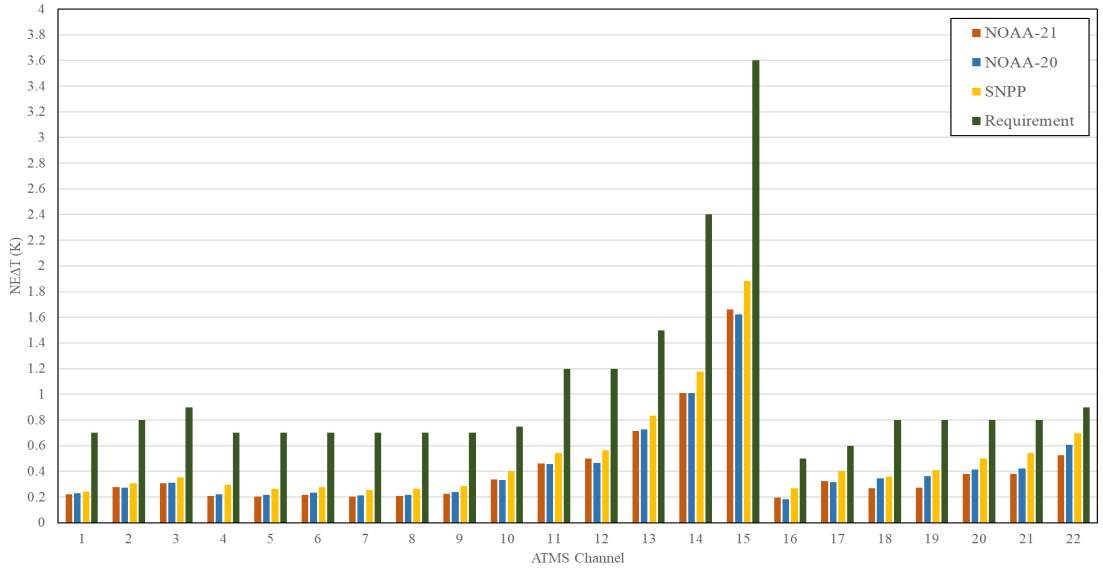
Beta Maturity End State	Assessment
Product is minimally validated, and may still contain significant identified and unidentified errors	NOAA-21 ATMS instrument performance and science data (TDR/SDR/GEO) have been verified through early orbit checkout (EOC) data analysis. No significant error has been identified to affect the data quality.
Information/data from validation efforts can only be used to make initial qualitative or very limited quantitative assessments regarding product fitness-for-purpose	NOAA-21 ATMS science data have met the beta maturity requirements and can be used to make initial qualitative or quantitative assessments for downstream products.
Documentation of product performance and identified product performance anomalies, including recommended remediation strategies, exists	NOAA-21 ATMS beta maturity science data quality README file has been created as a user reference. Calibration related documents are also released to support general data users.

NOAA-21 ATMS Highlights

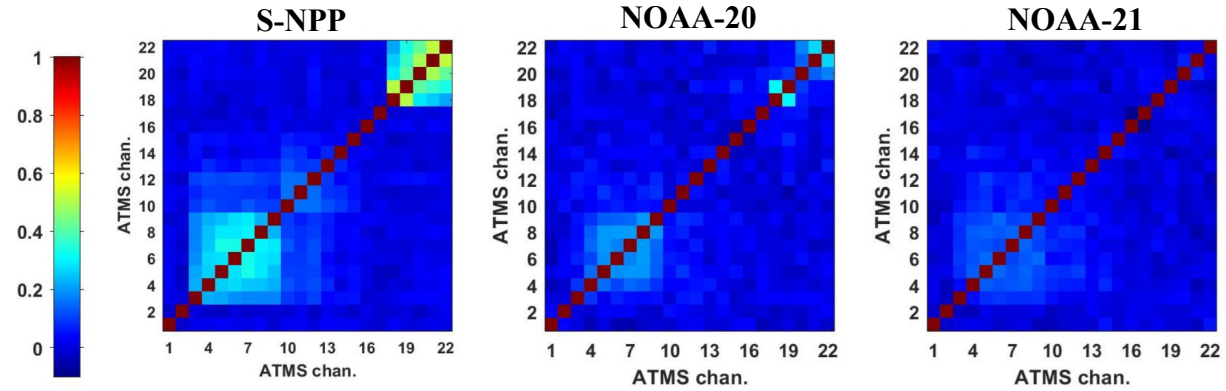
NOAA-21 ATMS First Light Image



ATMS channel NEΔT

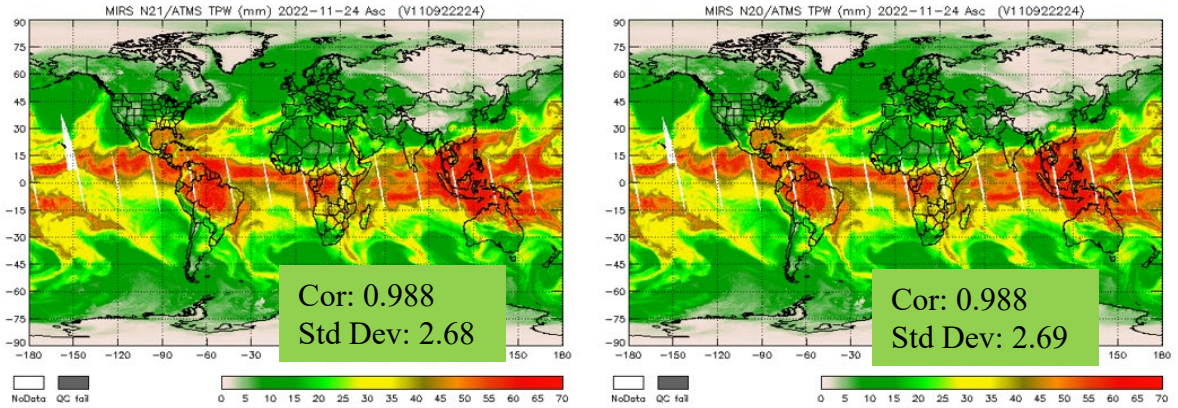


NOAA-21 ATMS channel to channel noise correlation



MiRS vs ECMWF TPW

N21 | 2022-11-24 | N20



OSPO planned N21 ATMS BUFR data beta release at 2:30 pm EST (19:30Z), December 1, 2022

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 Beta Maturity Status Summary

- ✓ NOAA-21 ATMS starts generating radiance data (TDR/SDR/GEO) from Nov. 21, 2022
- ✓ ATMS telemetry data show a nominal condition after the activation
- ✓ NOAA-21 images appear nominal
- ✓ ATMS channel NEΔTs are stable and comparable to NOAA-20
- ✓ NOAA-21 ATMS channel striping index and channel noise correlation are within the ATMS family
- ✓ For water vapor channels (G-bands), NOAA-21 ATMS has better performances in NEΔT, channel striping index and channel noise correlation
- ✓ Details are referred to https://www.star.nesdis.noaa.gov/icvs-beta/status_J02_ATMS.php
- ✓ Initial satellite products from MiRS and MiRS-SFR are comparable to that for NOAA-20

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

Path Forward to Provisional 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 Provisional maturity review following the Cal/Val plan
  - Select the optimal space view sector
  - Analyze instrument maneuver data to characterize instrument performance
  - Analyze lunar intrusion data to determine the optimal lunar intrusion mitigation 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, and many more
- Update ATMS instrument heath status telemetry calculation coefficients and program in IDPS to reflect the changes from NOAA-21