Beta / Provisional Maturity Science Review for OMPS V2Limb Level 1 / SDR & Level 2 / Ozone Profile EDR

Presented by L. Flynn

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Disclaimer:

"The scientific results and conclusions, as well as any views or opinions expressed herein, are those of the authors and do not necessarily reflect those of NOAA or the Department of Commerce.“

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.

Maturity Review - Entry Criteria

- Product Requirements
- Pre-launch Performance Matrix/Waivers
- Beta / Provisional Maturity Performance Validation
  - On-orbit instrument performance assessment
  - Identify all of the instrument and product characteristics you have verified/validated as individual bullets
  - Identify pre-launch concerns/waivers, mitigation and evaluation attempts with on-orbit data
- Users/Downstream-Products feedback
- Risks, Actions, Mitigations
  - Potential issues, concerns
- Path forward (to the next maturity stage)
- Summary

Maturity Review - Exit Criteria

- **Beta / Provisional 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**
  - **Provide summary of pre-launch concerns/waivers mitigations/evaluation and address whether any of them are still a concern that raises any risk.**
- **Updated Maturity Review Slide Package addressing review committee's comments for:**
  - **Cal/Val Plan and Schedules**
  - **Product Requirements**
  - **Beta/Provisional Maturity Performance**
  - **Risks, Actions, Mitigations**
  - **Path forward (to the next maturity stage)**

BETA / PROVISIONAL MATURITY REVIEW MATERIAL

Outline

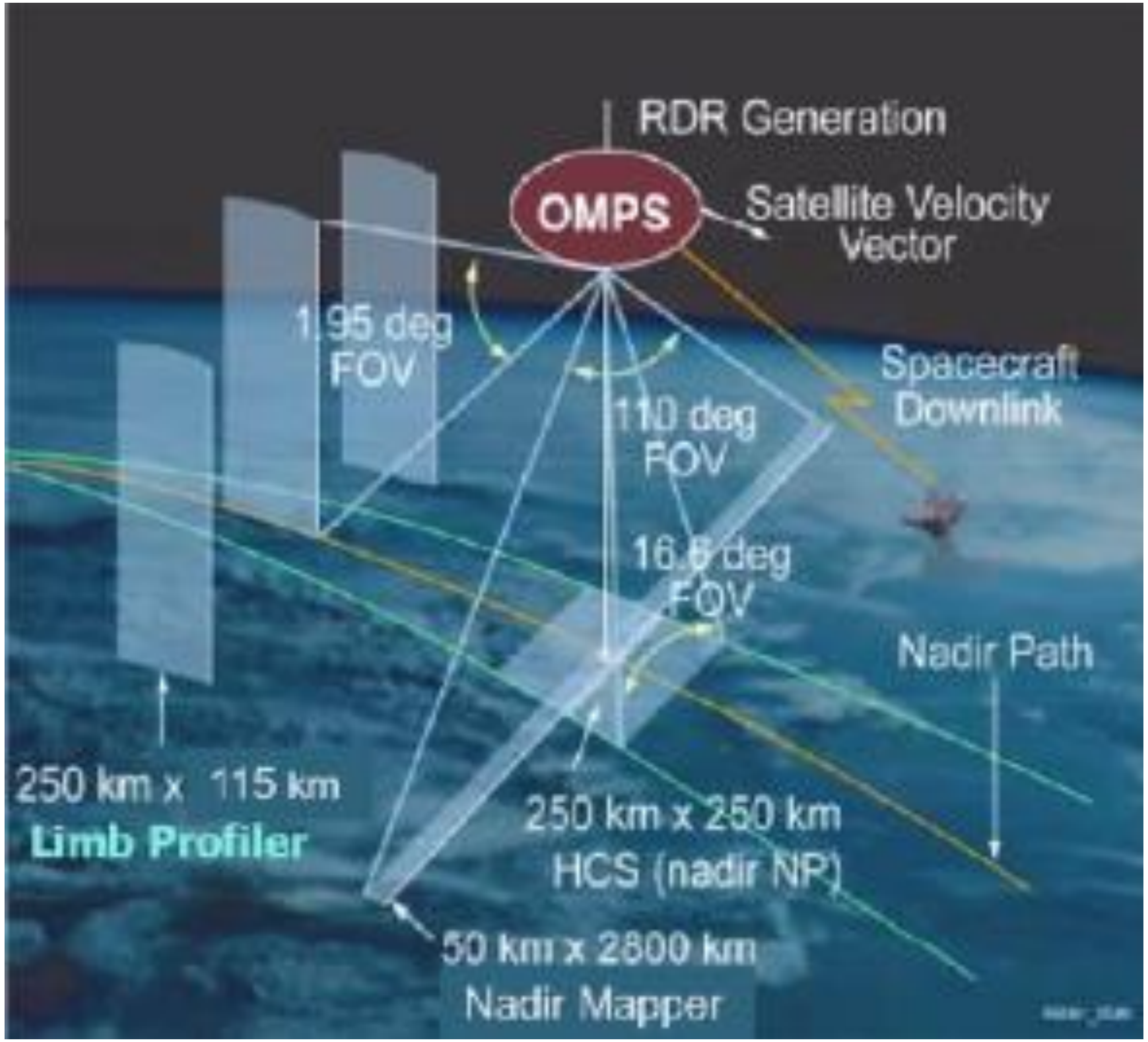
- Algorithm Cal/Val Team Members
- Product Overview/Requirements
- Evaluation of algorithm performance to specification requirements
  - Algorithm version, processing environment
  - Evaluation of the effect of required algorithm inputs
  - Quality flag analysis/validation
  - Error Budget
- User Feedback
- Downstream Product Feedback
- Risks, Actions, and Mitigations
- Documentation (Science Maturity Check List)
- Conclusion
- Path Forward

Ozone Cal/Val/Alg Team Membership for OMPS Limb Profiler

SDR / EDR	Name	Organization	Task
Lead	Lawrence Flynn	NOAA/NESDIS/STAR	Ozone EDR Team
Sub-Lead	Irina Petropavlovskikh	NOAA/ESRL/CIRES	Ground-based Validation
Sub-Lead	Trevor Beck	NOAA/NESDIS/STAR	Trace Gas Algorithm Development & Level 1
Member	Robert Lindsay	STAR/IMSG	Limb Algorithms implementation
Member	Eric Beach	STAR/IMSG	Maintenance, Monitoring
Member	Jeannette Wild	UMD	Applications, CDRs, validation
JAM	Starry Manoharan	JPSS/Aerospace	Coordination
Adjunct	Bigyani Das	ASSISTT	Deliveries to NCCF
PAL	Vaishali Kapoor	OSPO	Atmospheric Chemistry Product Area Lead
NASA	Glen Jaross	NASA	OMPS LP Calibration Lead
NASA	Natalya Kramarova	NASA	OMPS LP Ozone Lead
NASA	Philippe Xu	SAIC	OMPS LP Validation
NASA	Mike Linda	SSAI	OMPS LP Level 1 Codes

Differences Between S-NPP & NOAA-21 OMPS LP

- The NOAA-21 OMPS Limp Profiler does not make measurements for the full spectral range for the “first” slit. It only has measurements longward of 347 nm. This greatly reduces the information at the top of the retrieved profiles for that slit.
- The NOAA-21 OMPS LP makes four scans for each 30-Second granule. The S-NPP OMPS LP makes two scans for each 37.4-Second granule. So the nominal spacing for N21 is 50 KM while it is 125 KM for NPP.
- The NOAA-21 OMPS LP is a NASA-provided instrument. NASA takes the lead on it operations and validation.



Graphic from Ball Aerospace

Requirement Check List – OMPS LP SDR

DPS	Requirement	Performance
DPS-1888	The OMPS-LP SDR product shall provide earth-view radiance calibrated from OMPS limb profiler RDR, for all nominal OMPS-LP earth scene measurements, at the refresh rates of the instrument.	Moved to three slit with granule level processing.
DPS-1889	The OMPS-LP SDR product shall conform with the OMPS-LP SDR performance requirement listed in Table 3-6 (***see next slide***).	
DPS-1952	The OMPS-LP SDR product shall have a derived tangent height for each slit's boresight look vector that is accurate to within 200m at any point in time during regular science measurement.	Along-orbit adjustment.

Table: 3-6 OMPS-LP Performance Requirements

	For J2	Constraints	Performance
Wavelength Range	290 – 1020 nm for Center and Right Slits, 400 – 1020 for Left Slit	Ozone and path length range, aerosol dependence, stray light monitoring, solar features for wavelength scale, RSAS pointing	Slits have the desired coverage.
Bandwidth	1.5 - 40 nm	Distinguish solar lines and O3 absorption features	By design.
Samples/FWHM	> 2	λ-shifts, gridding	By design.
Number of channels	At least 32 for 80 vertical pixels for each integration time and aperture	Gridding/interpolation, Multiple pairs and triplets for O3, reflectivity, aerosols, RSAS pointing	By design / sample table.
Horizontal coverage	3 FOVs Nadir and ±250 km	4 day global coverage	By design.
SNR	***See Tables 3-7, 3-8, and 3-9***	Precision, pixel bin factor of 1, 19-S integration	7.5 S Integration
Polarization Sensitivity	< 3%	Accuracy	Ground
Wavelength registration	< 0.01 pixels	O3 Absorption features and solar registration	By reference Solar
Albedo Calibration	2%	Accuracy and stability	Dual diffusers
Pixel-to-pixel calibration	0.5% max	Accuracy	Dark, Stray, Linearity, PRNU
Albedo deviation error	< 1%	Accuracy and stability between weekly solar	Working Diffuser
Stray Light	< 10% (<25% for >700 nm)* (1)	Accuracy (Instrument performance before SDR correction)	Ground

Notes:

1. Waiver 21925-W-318 Rev B Limb stray light at 1020nm Waiver 472-CCR-19-1817 (J2 Only): Waive O_PRD-16403 to allow the total stray light for OMPS Limb at 1020 nm to exceed the 25% requirement from an altitude of 33km to 45km, where at 45km, the estimated total stray light is 73% for the specified channel. This is a factor of two improvement over the S-NPP sensor at the given wavelength and does not directly translate into a degradation in science since the performance is related to knowledge of stray light rather than its absolute level

Table: 3-7 L1RDS table omps-lp-2a

	290 nm		293 nm		296 nm		299 nm		302 nm	
	snr	**mr**	**snr**	**mr**	**snr**	**mr**	**snr**	**mr**	**snr**	**mr**
61 – 65 km	65	4.45	70	4.33	75	4.20	70	3.47	80	3.67
53 – 60 km	75	5.43	85	5.33	n/a	5.22	n/a	4.36	n/a	4.63
50 – 53 km	105	8.1	125	9.0	145	9.89	145	9.05	170	10.0
47 – 50 km	n/a	7.1	**n/a**	8.45	145	9.8	170	11.6	200	13.4
45 – 47 km	**n/a**	6.67	**n/a**	7.83	**n/a**	8.99	170	11.6	220	16.0
43 – 45 km	**n/a**	6.34	**n/a**	7.38	**n/a**	8.42	160	10.6	240	17.2
38 – 43 km	**n/a**	5.74	**n/a**	6.62	**n/a**	7.49	**n/a**	9.17	**n/a**	17.4
28 – 38 km	**n/a**	5.0	**n/a**	5.73	**n/a**	6.45	**n/a**	7.78	**n/a**	14.3
15 – 28 km	**n/a**	4.42	**n/a**	5.04	**n/a**	5.66	**n/a**	6.8	**n/a**	12.5
Trop – 15 km	**n/a**	4.0	**n/a**	4.55	**n/a**	5.11	**n/a**	6.14	**n/a**	11.3

snr = signal to noise ratio
mr = minimum radiance, 10-4 W/m2/sr/nm
trop = tropopause, 8-15 km depending on latitude
reference = 61-65 altitude averaged

Signal-to-noise ratio allocations to the limb sensor channels as a function of wavelength and altitude

Table: 3-8 L1RDS table omps-lp-2b

	310 nm		320 nm		347 nm		353 nm		400 nm	
	snr	mr	snr	mr	snr	mr	snr	mr	snr	mr
61 – 65 km	95	3.87	135	5.08	150	4.76	150	4.69	90	4.31
53 – 60 km	n/a	4.91	**n/a**	6.46	180	6.05	180	5.97	110	5.48
50 – 53 km	**n/a**	11.0	**n/a**	14.8	300	14.1	300	13.9	190	12.7
47 – 50 km	**n/a**	15.3	**n/a**	21.1	360	20.3	360	20.0	240	18.3
45 – 47 km	**n/a**	20.5	**n/a**	29.6	460	29.1	460	28.7	300	26.4
43 – 45 km	320	23.8	440	36.9	500	37.1	500	36.7	360	33.7
38 – 43 km	320	25.6	500	45.1	500	47.5	500	46.9	400	43.3
28 – 38 km	**n/a**	20.9	500	67.0	500	88.8	500	87.7	500	82.3
15 – 28 km	**n/a**	18.1	**n/a**	69.6	500	315	500	312	500	317
Trop – 15 km	**n/a**	16.4	**n/a**	69.1	n/a	568	n/a	570	n/a	829

Signal-to-noise ratio allocations to the limb sensor channels as a function of wavelength and altitude

Table: 3-9 L1RDS table omps-lp-2c

	500 nm		525 nm		575 nm		602 nm		675 nm		1000 nm	
	snr	mr	snr	mr	snr	mr	snr	mr	snr	mr	snr	mr
61 – 65 km	n/a	2.88	**n/a**	1.44	**n/a**	1.11	**n/a**	0.786	**n/a**	0.416	**n/a**	0.0414
53 – 60 km	**n/a**	3.66	**n/a**	1.84	**n/a**	1.42	**n/a**	0.999	**n/a**	0.528	**n/a**	0.0527
50 – 53 km	**n/a**	8.5	**n/a**	4.26	**n/a**	3.29	**n/a**	2.32	**n/a**	1.23	**n/a**	1.22
47 – 50 km	**n/a**	12.2	**n/a**	6.12	**n/a**	4.72	**n/a**	3.32	**n/a**	1.76	**n/a**	0.122
45 – 47 km	**n/a**	17.6	**n/a**	8.79	**n/a**	6.78	**n/a**	4.76	**n/a**	2.53	**n/a**	0.253
43 – 45 km	440	22.5	320	11.2	320	8.63	280	6.06	220	3.23	25	0.322
38 – 43 km	500	28.8	360	14.4	360	11.1	320	7.74	260	4.14	30	0.414
28 – 38 km	500	54.8	500	27.3	500	20.9	460	14.4	360	7.89	55	0.793
15 – 28 km	500	210	500	103	500	76.0	500	49.1	500	31.4	180	3.42
Trop – 15 km	500	619	500	410	500	269	500	129	500	196	440	32.5

Signal-to-noise ratio allocations to the limb sensor channels as a function of wavelength and altitude

Requirement Check List – OMPS-LP EDR

DPS	Requirement	Performance
DPS-1955	The OMPS-LP product shall provide ozone measurements in clear daytime conditions for solar zenith angles less than 80 degrees.	Up to 86 degrees
DPS-1956	The OMPS-LP BUFR product shall provide ozone measurements converted from the Ozone Limb Profile product in BUFR format.	Added to RF Toolkit
DPS-1957	The OMPS-LP product shall provide ozone measurements with a horizontal cell size of 250 km.	Path through atmosphere
DPS-1958	The OMPS-LP product shall provide ozone measurements with a horizontal reporting interval of 125 km or better along track.	50 km
DPS-1959	The OMPS-LP product shall produce ozone measurements with a vertical coverage of TH to 60 km (Note 1).	Cloud top to 57 km
DPS-1960	The OMPS-LP product shall produce ozone measurements with a vertical reporting interval of 1 km.	Check
DPS-1961	The OMPS-LP product shall produce ozone measurements with a vertical resolution of: N/A from 0 to TH (Note 1); 5km from TH to 25 km (Note 1); 5 km from 25 to 60 km	Better than 3 km vertical resolution
DPS-1962	The OMPS-LP product shall produce ozone measurements with a mapping uncertainty (1 sigma) of <25 km.	< 5 km
DPS-1963	The OMPS-LP product shall produce ozone measurements with a measurement range of: N/A from 0 to TH (Note 1); 0.1 to 15 ppmv for TH – 60 km	Range achieved
DPS-1964	The OMPS-LP product shall produce ozone measurements with a measurement precision of: N/A from 0 to TH (Note 1) ; Greater of 10% or 0.1 ppmv from TH to 15 km (Note 1); Greater of 3% or 0.05 ppmv from 15 to 50 km; Greater of 10% or 0.1 ppmv from 50 to 60 km	3-4 % for 50 km reporting.
DPS-1965	The OMPS-LP product shall produce ozone measurements with a measurement accuracy of: N/A from 0 to TH (Note 1); Greater of 20% or 0.1 ppmv from TH to 15 km; Greater of 10% or 0.1 ppmv from 15 to 60 km	Center slit comparisons to NPP and EOS AURA MLS. Climatology above 57 km 10% slit differences
DPS-1966	The OMPS-LP product shall produce ozone measurements with a refresh of at least 75% coverage of the globe every 4 days (monthly average) (Note 2).	3 slits space 250 km apart cross track
DPS-1967	The OMPS-LP product shall produce ozone measurements with long term stability of 2% over 7 years.	Dual Diffuser system

Notes:

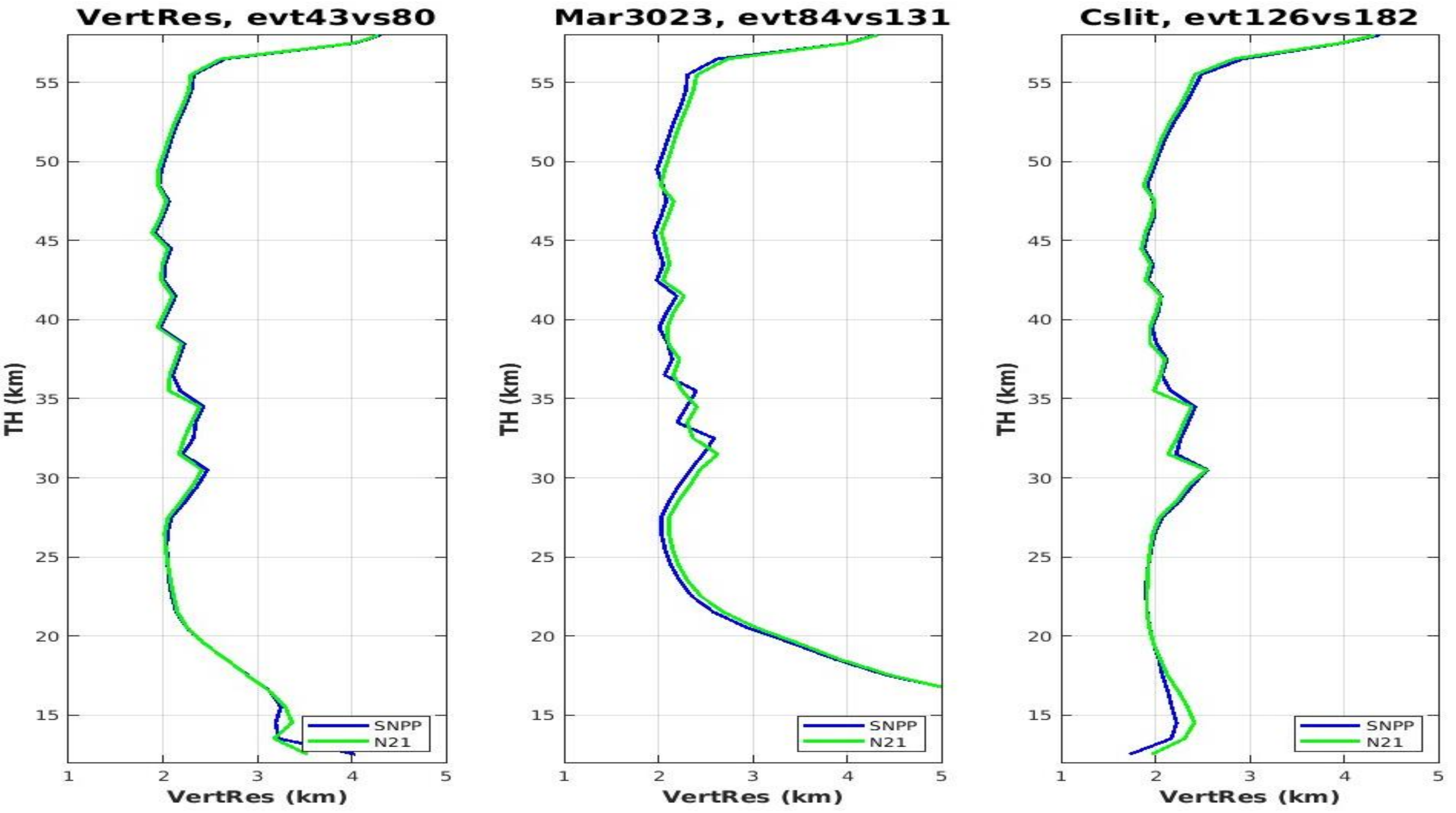
1. TH is Tropopause Height or 8 km, whichever is greater as determined by ancillary data.
2. All OMPS measurements require sunlight, so there is no coverage in polar night areas. With three limb curtains (each with a Vertical FOV of ~ 1.85°) positioned at Nadir and 250 km (+/- 4.3 degrees) on each side, the measurements are taken to give a good representation of the ozone profile in the central 750 km of the orbital track. With a 4-day repeat cycle in the orbital tracks, this will yield a 4-day revisit time (approximately) for 30,000 km out of 40,000 km equator.

Ozone Profile Retrievals from NOAA-21 OMPS Limb Profiler: Summary

Philippe Q. Xu, Natalya A. Kramarova, & Glen R. Jaross
Poster A41O-2859, AGU Fall Meeting, December 14, 2023, San Francisco, USA
Acknowledgements: Sincere thanks to the OMPS LP Team J. Warner, D. Kahn, T. Zhu, L. Moy, G. Chen, S.Madhaven, R.Mundakkara, G.Taha and C. Seftor for the valuable contributions. The OMPS LP team is supported by the NASA Earth Science Division through SAMDA contract NNG17HP01C.

- Preliminary results indicate that the OMPS LP on N21 can deliver ozone profiles with the same or even slightly better performance than SNPP. We analyzed average kernels, vertical resolution and estimated precision and found a good consistency between N21 and SNPP.
- Our results validate initial calibrations applied to N21.
- There are about 10%-20% differences in retrieved aerosol extinction between N21 and SNPP. Note that the stray light correction for N21 is not completed.
- Ozone comparisons with MLS indicates that N21 has smaller biases with reduced vertical oscillations compared to SNPP.
- N21 Level 1 data will be released in early 2024. N21 ozone profiles will be released shortly after following the initial quality evaluation.

Ozone Vertical Resolution

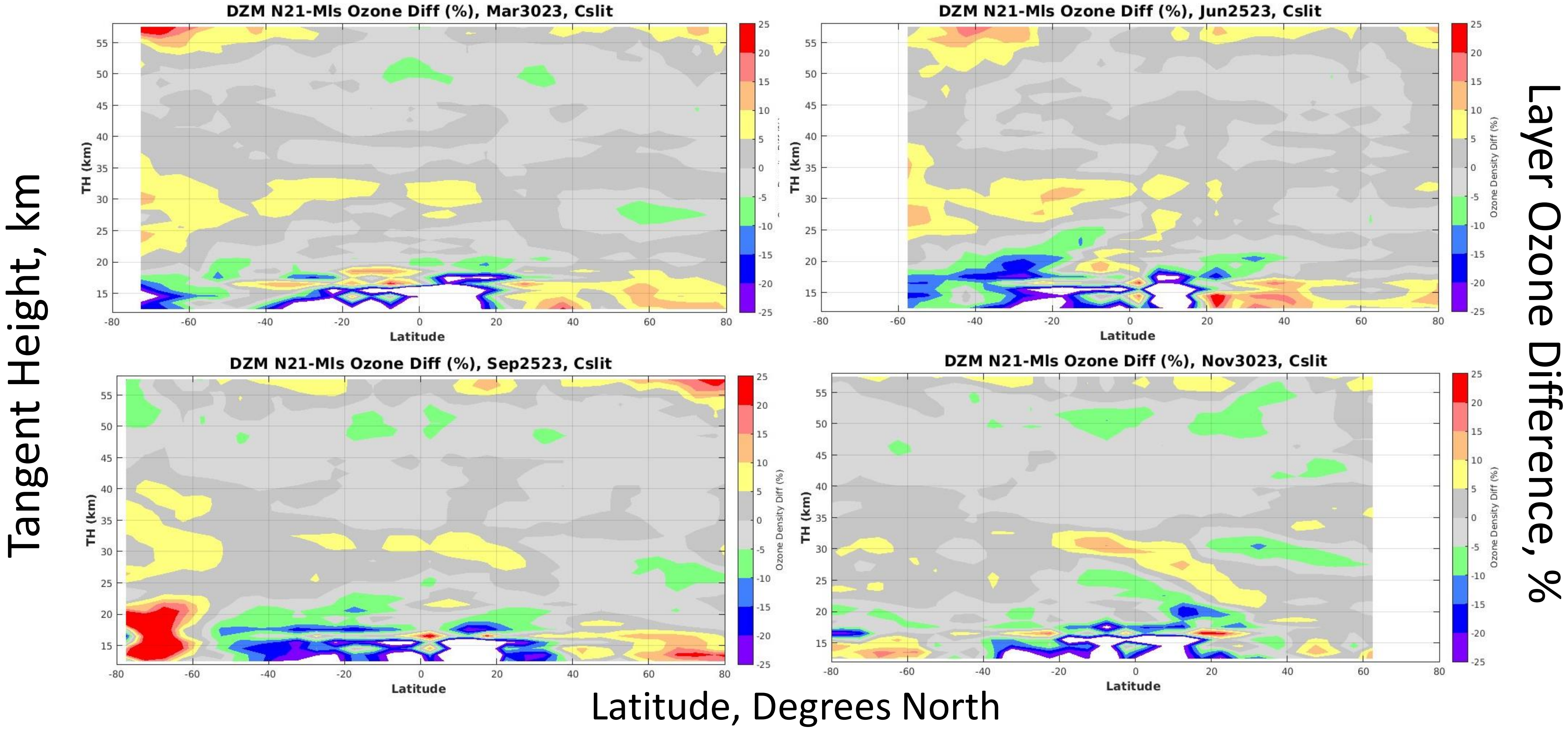


Vertical Resolution, km

Vertical resolution derived from averaging kernels for SNPP and N21 in mid-latitudes and tropics. Both instruments show consistent vertical resolution of approximately 2 km in the stratosphere.

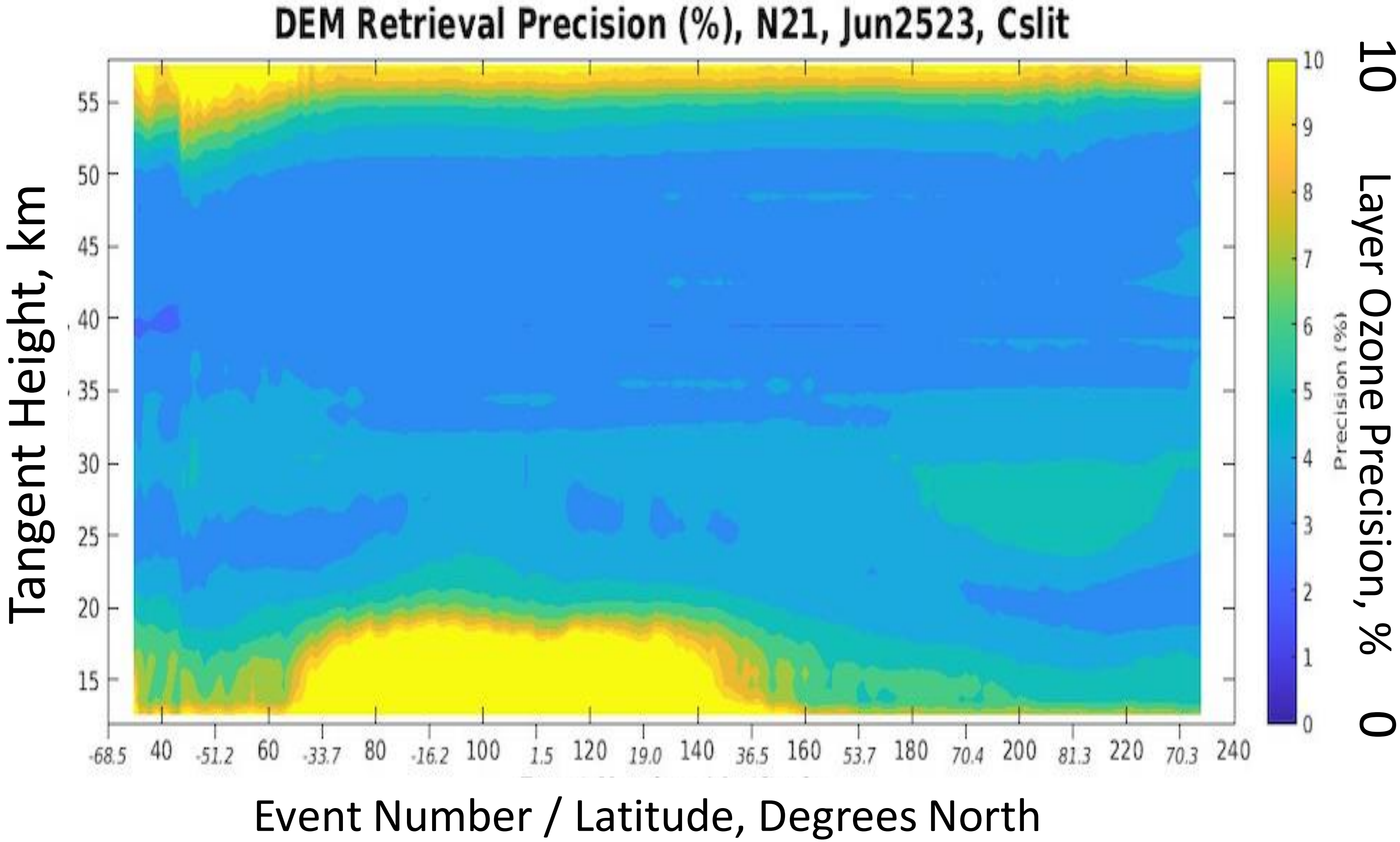
P. Xu et al. Poster Figure 4: DZM VR at 45S, 0N and 45N Latitude, from left to right.

Zonal Mean Ozone comparisons with MLS/Aura



P. Xu et al. Poster Figure 5a: DZM ozone difference between N21 and MLS v5 on 03/30/23(top left), 06/25/23 (top right), 09/25/23 (bottom left) and 11/30/23 (bottom right)

Estimated Precision



N21 precision is 3 to 4% for most altitudes and increases to 5% in some areas. N21 precision values are very similar to those from SNPP.

P. Xu et al. Poster Figure 6: Estimated precision (N21, 9/25/23)

Validation References

- **OMPS Limb ATBD**

https://www.star.nesdis.noaa.gov/jpss/documents/ATBD/ATBD_OMPS_LP_SDR_NASA.pdf

- P. Xu et al., "Ozone Profile Retrievals from NOAA-21 OMPS Limb Profiler". Poster A41O-2859, AGU Fall Meeting, December 14, 2023, San Francisco, USA
- Natalya A. Kramarova, et al., "Decade-long Ozone Profile Record from Suomi NPP OMPS Limb Profiler: Assessment of Version 2.6 Data." *ESS Open Archive* . April 12, 2024. Submitted JGR Atmospheres. **DOI: 10.22541/essoar.171288980.01678231/v1**
- OMPS LP version 2.6 (**DOI** 10.5067/8MO7DEDYTBH7) Kramarova, N. A., & DeLand, M. (2023). README Document for the Suomi-NPP OMPS LP L2 O3 Daily Product (Version 2.6). Goddard Earth Sciences Data and Information Services Center (GES DISC) (36 pp.). https://disc.gsfc.nasa.gov/datasets/OMPS_NPP_LP_L2_O3_DAILY_2.6/summary\
- Petropavlovskikh et al., Tracking ozone recovery with S-NPP OMPS Nadir and Limb profiler satellite and ground-based ozone records. 2023, 12th Limb Workshop. https://events.spacepole.be/event/146/timetable/ Talk #49.
- Kramarova, N. A., et al., "Validation of ozone profile retrievals derived from the OMPS LP version 2.5 algorithm against correlative satellite measurements," Atmos. Meas. Tech., 11, 2837–2861, https://doi.org/10.5194/amt-11-2837-2018, 2018.
- Jaross et al., 2014, "OMPS Limb Profiler instrument performance assessment," **https://doi.org/10.1002/2013JD020482**

Comparisons of NASA & NOAA Processing

- Differences between NPP and NOAA-21
- Differences between NASA and NOAA processing
- Comparisons between NASA and NOAA Level 1
- Comparisons between temperature files
- Comparisons between NASA and NOAA Level 2
- Required Ancillary and Table Deliveries

Differences NASA / NOAA N21 L1B

```
Wavelengths max(abs(r1bn.calibrationdata.bandcenterwavelengths._data(*,mub)-
                    r1bs.calibrationdata.bandcenterwavelengths._data(*,0)))
        0.00000 nm
Calibration max(abs(r1bn.calibrationdata.CALIBRATIONFACTORS._data-
                    r1bs.calibrationdata.CALIBRATIONFACTORS._data))
        0.00000
Solar Irradiance max(abs(r1bn.calibrationdata.irradiance._data(*,mub:mub+3)/
                    r1bs.calibrationdata.irradiance._data(*,0:3)-1.0))
        0.0000 %
Earth Radiance max(abs(r1bns.radiance._data(*,mub:mub+3)/
                    r1bss.radiance._data(*,0:3)-1.0))
        0.0000 %
Latitude max(abs(r1bng.tangentpointlatitude._data(*,mub:mub+3)-
                    r1bsg.tangentpointlatitude._data(*,0:3)))
        0.001 Deg.
Longitude max(abs(r1bng.tangentpointlongitude._data(*,mub:mub+3)-
                    r1bsg.tangentpointlongitude._data(*,0:3)))
        0.0002 Deg.
Solar Zenith Angle max(abs(r1bng.tangentpointsolarzenithangle._data(*,mub:mub+q)-
                    r1bsg.tangentpointsolarzenithangle._data(*,0:q)))
        6.7e-05 Deg
Tangent Height max(abs(r1bng.tangentpointheight._data(*,mub:mub+3)-
                    r1bsg.tangentpointheight._data(*,0:3)))
        0.047 M
```

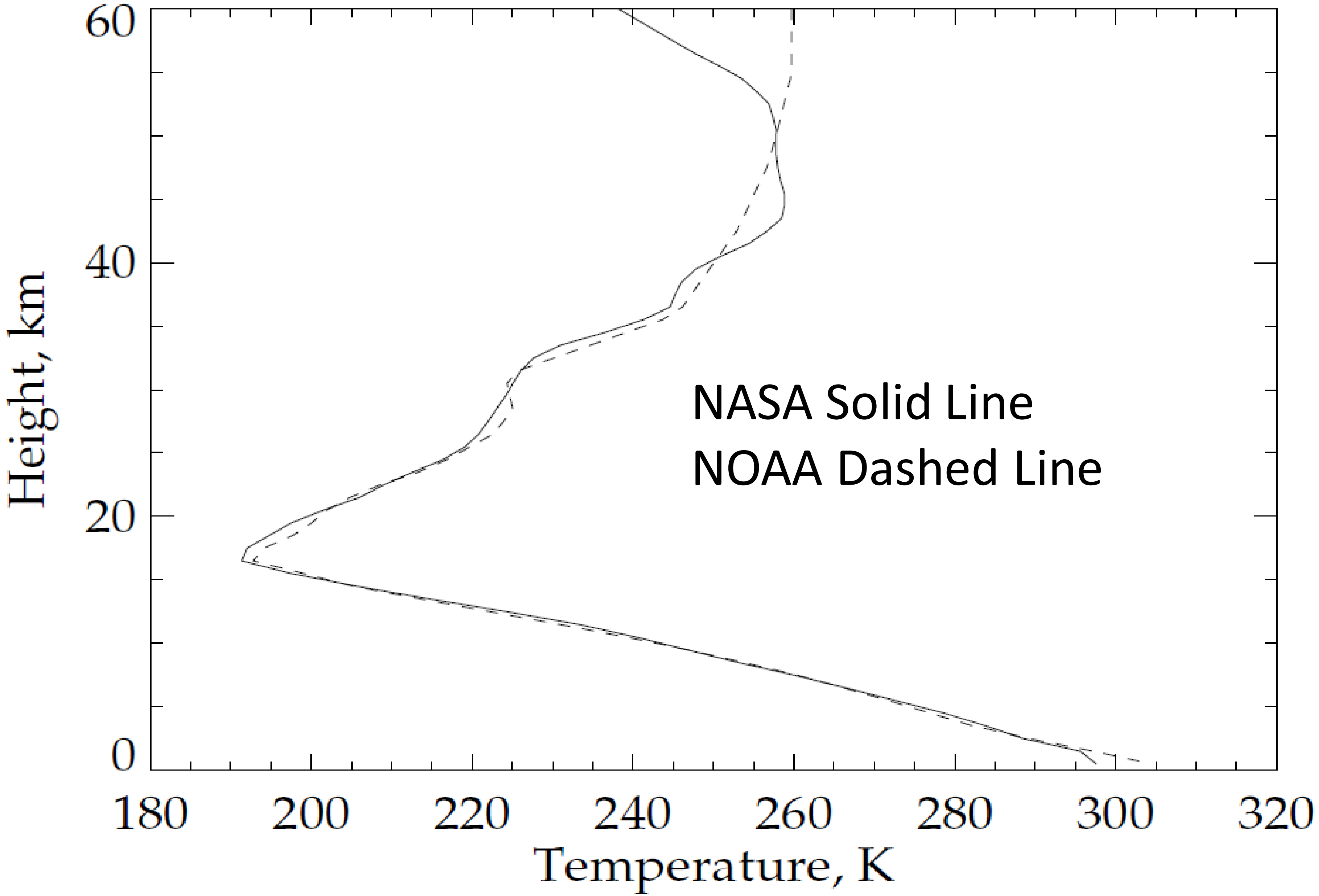
OMPS-N21_LPEV-L1B-p002_v1.2_2024m0111t111405_o06061_2024m0111t144903.h5
OMPS-N21_LPEV-L1B-p000_v2.2_2024m0111t114911_o06061_2024m0417t160224.h5

Differences NASA / NOAA N21 L1G

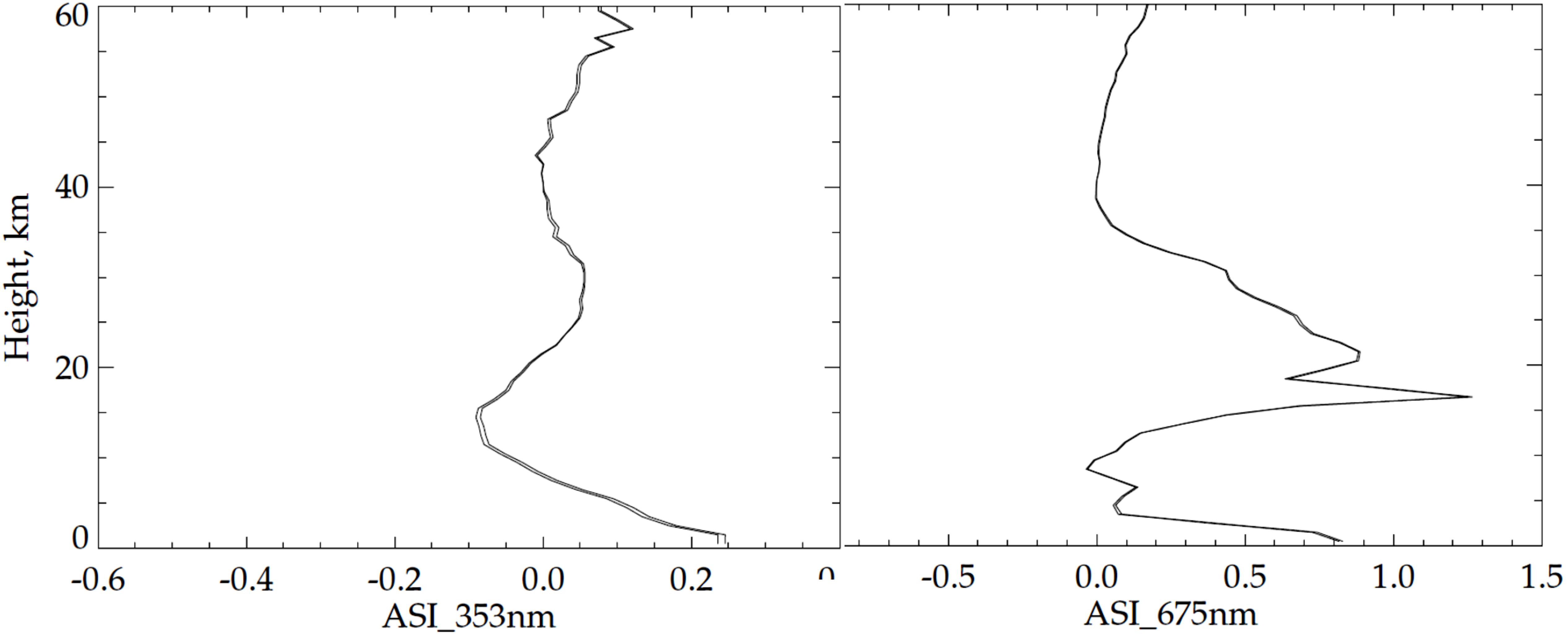
Radiance max(abs(r1gss.radiance._data/
r1gns.radiance._data(*,*,*,mug:mug+3)-1.0))
0.03 %
Sun Normalized Radiance max(abs(r1gss.sunnormalizedradiance._data/
r1gns.sunnormalizedradiance._data(*,*,*,mug:mug+3)-1))
0.03 %
Latitude max(abs(r1gsg.latitude_35km._data-
r1gng.latitude_35km._data(*,mug:mug+3)))
0.000004 Deg.
Longitude max(abs(r1gsg.longitude_35km._data-
r1gng.longitude_35km._data(*,mug:mug+3)))
0.000002 Deg.

OMPS-N21_LP-L1G-EV_v2.6_2024m0111t111405_o06061_2024m0111t200328.h5
OMPS-N21_LP-L1G-EV_v2.2_2024m0111t114911_o06061_2024m0417t160224.h5

Sample Temperature Profiles NASA & NOAA

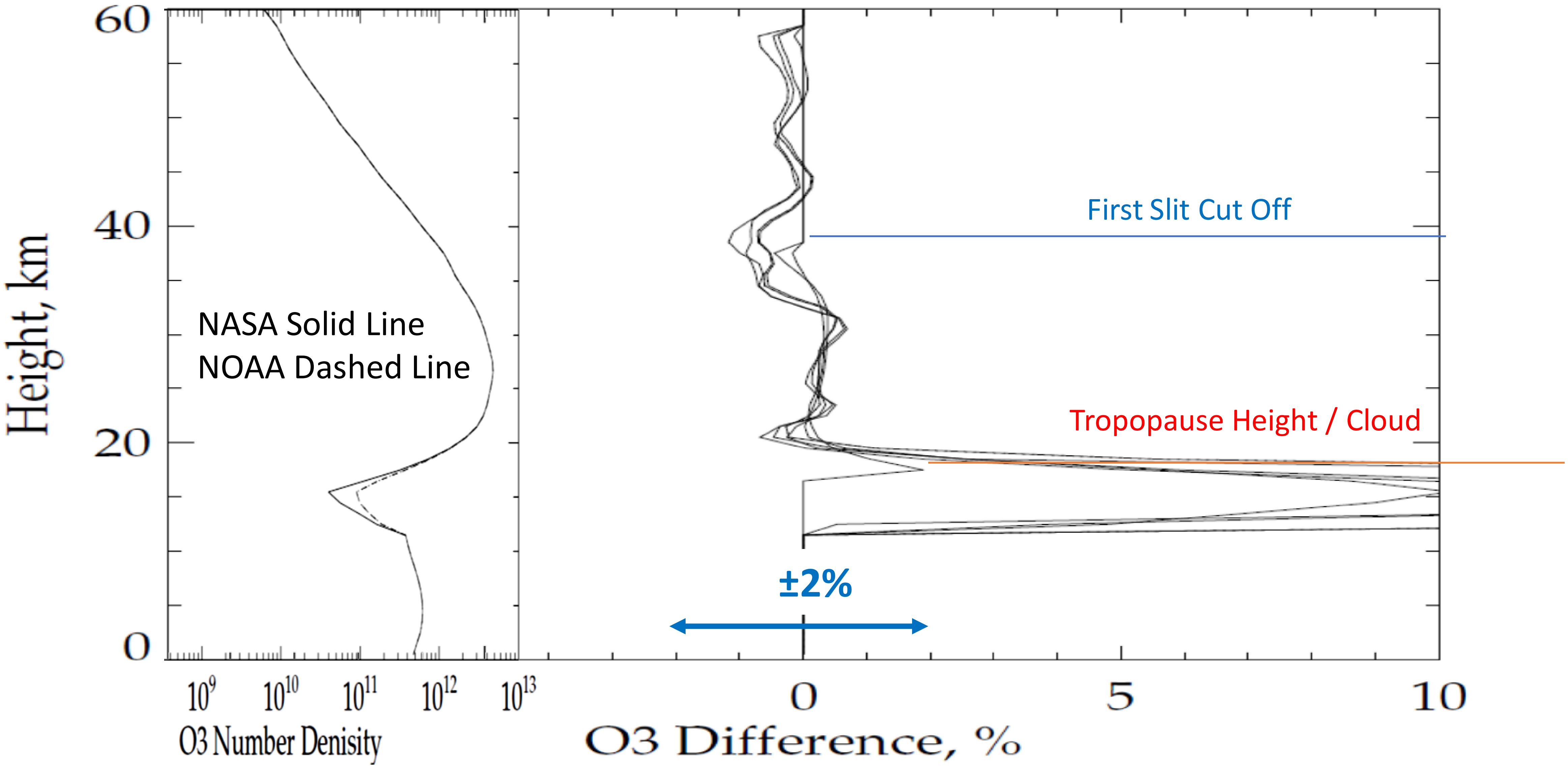


Sample Aerosol Scattering Index Profiles for NASA & NOAA for the 353 nm and 675 nm channels



Aerosol Scattering Index Values

Sample Ozone Profile Differences NASA/NOAA



Ozone Number Density

Unit Level Data Flows – L1B IO Table (1/2)

Interface Item	Interface Type	Source	Description
LP EV L1A	Input	OMPS LP	LP EV Formatted Raw Data Record
OMPS-LP_Weekly_Wave	Input	STAR/PDA (NEW)	OMPS Limb Profiler Wavelength Calibration Tables
OMPS-LP_Weekly_Dark	Input	STAR/PDA	OMPS Limb Profiler Dark Calibration Tables
OMPS-LP Weekly Orbit	Input	STAR/PDA	OMPS Limb Profiler Orbital Definition File
Leapsec & Utcpole from USNO	Input	Ancillary Mini-DAP	Leap Second & UTC Polar Wander For the SDPTK toolkit
Temperature & Pressure 6-Hr Forecast	Input	GFS Mini-DAP	Temperature & Pressure Interpolated from the GFS Model
Calibration Tables OMPS-NPP-NPP-LP_BPS* OMPS-NPP-LP_CBC* OMPS-NPP-NPP-LP_FOV* OMPS-NPP-LP_IRF* OMPS-NPP-LP_JCB* OMPS-NPP-LP_RAD* OMPS-NPP-LP_SRG* OMPS-NPP-LP_SLT*	Input	OMPS LP DAP	 OMPS Limb Profiler Band Pass OMPS Limb Profiler Channel Band Center OMPS Limb Profiler Field Of View OMPS Limb Profiler Solar Irradiance OMPS Limb Profiler Jacobians OMPS Limb Profiler Radiometric Calibration* OMPS Limb Profiler Spatial Registration OMPS Limb Profiler Stray Light^

Purple = Static
*Updates for PRNU

Black - Dynamic

Unit Level Data Flows – SDR IO Table (2/2)

Interface Item	Interface Type	Source	Description
Instrument Tables OMPS-NPP-LP-TP* OMPS-NPP-LP-STB*	Input	OMPS LP DAP	OMPS Limb Profiler Timing Pattern OMPS Limb Profiler Sample Table
Coefficient Files	Input	OMPS LP DAP	OMPS Limb Profiler Coefficient Files^
PCF File	Input	OMPS LP	PCF File for SDP Toolkit (Geolocation)
LP EV L1B	Output	OMPS LP/ LPEV-L1B App	LP EV Sensor Data Record (e.g.: OMPS_LP_L1B_EV_v2.5r0_npp_s201911200009245_e201911200010019_c201911271000220.h5)

Purple = Static
^Updates for Height Correction

Black - Dynamic

Processing Environment and Algorithms

- **Description of processing environment and algorithms used to achieve the maturity stage:**
  - **Algorithm version V2.7Limb Level 1 and V2.6Limb Level 2**
  - **Version of LUTs**
    - **1/1/2024 for corrections for pointing and solar irradiance**
    - **1/1/2024 for calibration tables except as noted below**
    - **12/15/2023 New Timing Pattern**
    - **4/4/2024 New Sample Table**
    - **Regularly updated tables & ancillary for Wavelength Scale, Darks, Orbital Definition, Polar Wander and Leap Second files.**
    - **6-Hour NCEP Temperature forecasts**
  - **Algorithm will move to NCCF in August 2024**

Evaluation of algorithm performance to specification requirements

- **Improvements since V2.5 NPP**
  - **Single retrieval combining UV / Visible using additional ozone channels**
  - **Revised Intermediate Aerosol Retrieval**
  - **See references and backup slides for comparisons.**
- **Algorithm performance evaluation**
  - **STAR internal and ICVS monitoring are tested.**
  - **OSPO Curtain Plot Monitoring will use new file content.**
- **Inter-sensor comparison**
  - **Comparisons for the last year to EOS Aura MLS Ozone Profiles**
  - **Comparisons for the last year to NPP OMPS Limb Measurements, Ozone and Aerosols.**

Quality flag analysis/validation

- **Defined Quality Flags**
  - **O3Flag: Valid altitude range for UV-VIS ozone retrieval (1 Valid, -999 Invalid/Climatology) First slit is up to 38 km.**
  - **O3Quality: Wavelength shift flags for ozone channels; bcdefg.i; shift=1: b-295;c-302;d-306;e-312;f-317;g-322;i-606}**
  - **O3Status: Number of iterations for UV-VIS ozone retrieval (usually two or three)**
  - **Error Code: Processing error code. Non-zero value = retrieval failure**
  - **Ozone Profile Precision Estimates:**
    - **Calculated precision of each ozone profile layer number density (cm^{-3})**

User Feedback will be obtained for NASA products and after Provisional NOAA Data is available.

Name	Organization	Application	User Feedback - User readiness dates for ingest of data and bringing data to operations

Downstream Product Feedback

Algorithm	Product	Downstream Product Feedback - Reports from downstream product teams on the dependencies and impacts
L1A	L1A	Used by L1B
L1B	L1B (in HDF and NetCDF)^	Used by L1G
L1G	L1G	Used by L2 Aerosol and Ozone
L2 Aerosol	L2 Aerosol	Used by L2 Ozone
L2 Ozone	L2 Ozone (in HDF and NetCDF)^	Used by BUFR Toolkit

^Only the L1B and L2 Ozone NetCDF Files and the BUFR files are sent on from NCCF to users and to CLASS

Risks, Actions, and Mitigations

Identified Risk	Description	Impact	Action/Mitigation and Schedule
Ephemeris Failure	Ephemeris interval misses first of four scans half of the time.	Missing Geolocation	Three options: Expand ephemeris interval, apply NASA orbital on one granule, or extrapolate ephemeris information. Solution implementation expected in one month.
Stray light	Level 1B / SDR stray light tuning is not complete	Profile errors	NASA is developing an improved characterization / correction table. Implementation expected in two months.
Pointing errors	Along-orbit pointing errors require corrections.	Profile height shifts	NASA is evaluating the current linear correction and may update the parameters. Implementation expected in two months.
Code Complexity	This is a very extensive code and has somewhat complex inter-dependencies.	Delayed operations	An earlier version is running at NDE and NASA is regularly processing all of the measurements, so there is some experience and expertise to fall back upon.
Pixel Response	Pixel Response non-uniformity may need additional tuning	Height dependent	NASA is continuing work on the calibration.

Documentation Check List

Science Maturity Check List	
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 (Updates Needed)
Peer Reviewed Publications	Submitted by NASA
Regular Validation Reports (at least annually)	First report here

Check List - Beta Maturity

Beta Maturity End State	Assessment
Product is minimally validated, and may still contain significant identified and unidentified errors	Product performance is similar to NPP. Delivered code fails due to an ephemeris problem for 1/8th of the scans.
Information/data from validation efforts can only be used to make initial qualitative or very limited quantitative assessments regarding product fitness-for-purpose	Information can be used to assess the utility of the products for assimilation.
Documentation of product performance and identified product performance anomalies, including recommended remediation strategies, exists	Plans for improved stray light correction and evaluation of pointing are in progress. Options to resolve failure for 1/8 of the scans are under study / code testing.

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 select locations, periods, and associated ground truth or field campaign efforts.	NASA products have demonstrated good performance. NOAA will reproduce these results in near-real-time.
Product analyses are sufficient for qualitative, and limited quantitative, determination of product fitness-for-purpose.	Performance is at a level that can be used to begin quantitative and fitness testing of ozone profile products.
Documentation of product performance, testing involving product fixes, identified product performance anomalies, including recommended remediation strategies, exists.	Plans are in place to develop improved stray light and pointing corrections. NOAA transition team is working on 1/8th scan failure problem.
Product is recommended for potential operational use (user decision) and in scientific publications after consulting product status documents.	NASA plans to release their Level 1 products next month, and the Level 2 products the month after.

Conclusions

- Team recommends algorithm as delivered be promote to Beta Maturity.
- Team recommends algorithm be promoted to Provisional Maturity pending resolution / delivery of 1/8th scan problem solution.
- Team will provide a new briefing for Validated Maturity pending development and delivery of improved pointing and stray light correction tables as recommended by NASA OMPS Limb Profiler Team.

Path Forward

- **Lessons learned for NOAA-22 Cal/Val Plan.**
  - **Instrument operations is expected to parallel NOAA-21 for operations and algorithm version.**
- **Planned improvements**
  - **See next slide for issues under investigation at NASA.**
- **Future Cal/Val activities / milestones**
  - **Briefing for Validated Maturity in two to three months.**
  - **Feedback from users for NASA products and provisional NOAA products.**
  - **Provide offline processing of full orbits of NetCDF data products for testing of monitoring systems.**

Known / Active Issues (Glen Jaross, GSFC)

- The West Slit exhibits evidence of radiometric errors in the UV. These seem to lower the ozone at higher altitudes by as much as 20% in comparison with S-NPP. These same errors affect the RSAS results (~800 m), though they are not used for TH adjustments.
- CCD timing pattern changes prior to launch resulted in radiometric changes, especially PRNU (pixel response non-uniformity), that are not accounted for. This affects detector non-linearity and Day 1 spectral registration.
- Telescope primary mirror scattering is currently ignored in the stray light correction, resulting in an under-correction especially in NIR wavelengths. The larger errors are at higher altitudes, in particular measurements used for normalization.
- The bandpass information provided in this product is simplified to a Gaussian FWHM. While this representation does capture the correct area-weighted mean of the function, it does not capture higher moments. Higher moments are prevalent in the UV.
- On Dec. 15, 2023 the image report period was decreased from 15 s to 7.5 s, effectively doubling the number of images in each orbital file. This results in a small decrease in the S/N ratio for measurements above 40 km.

Backup Slides and NPP information

Ozone Profile Retrievals from NOAA-21 OMPS Limb Profiler

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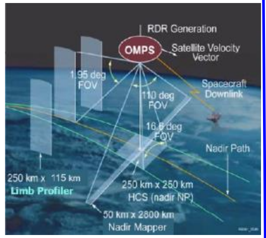
Science Applications Int'l Corp. Reston VA[1], NASA Goddard Space Flight Center, Greenbelt, MD USA[2]

Poster A41O-2859, AGU Fall Meeting, December 14, 2023, San Francisco, USA

Introduction

The Ozone Mapping and Profile Suite Limb Profiler (OMPS LP) on board of NOAA-21 (JPSS-2) is the second limb scattering instrument in the JPSS OMPS series. The instrument design and characteristics are similar to those of Suomi NPP with minor improvements:

a) stray light reduction;
b) solar heating reduction;
c) increased vertical coverage to 100 km;
d) variable integration time to avoid saturation;
e) Signal to noise (SNR) improvement.



The instrument optical characteristics:

- Spectral range: 280 nm to 1020 nm
- Spectral resolution: 1 nm to 40 nm
- Afocal telescope with three 1.95° vertical FOVs (with about 1.5 km IFOV vertical resolution).

NOAA-21 (N21) OMPS LP data were processed with operational version 2.6 algorithm. N21 satellite is ½ orbit ahead of SNPP increasing the spatial coverage that the two instruments provide. To compare retrievals from the two instruments we used daily zonal mean averages.

Contact: philippe.xu@nasa.gov

This poster presents comparisons between N21 and SNPP OMPS LP for:

- Aerosol extinction retrieved at 675 nm;
- Surface reflectivity at 8 wavelengths;
- Ozone vertical profiles;
- Ozone algorithmic parameters (vertical resolution, precision, averaging kernels).

N21 and SNPP ozone profile retrievals were also compared with Aura MLS ozone profiles.

Summaries of LP retrieval algorithms

- LP ozone retrieval algorithm version 2.6 is based on Rogers' Optimal Estimation with both a-priori constraints and the Tikhonov regulation.

$$x_{i+1} = x_i + S^{-1} \cdot [(S_a^{-1} + \Gamma \cdot R^T \cdot R) \cdot (x_a - x_i) + K_i^T \cdot S_e^{-1} \cdot (y - f(x_i))]$$

with $S = [S_a^{-1} + \Gamma \cdot R^T \cdot R + K^T \cdot S_e^{-1} \cdot K]^{-1}$

- Single ozone profile is retrieved between 12.5 km (or cloud top) and 57.5 km using 6 UV pairs (295, 302, 306, 312, 317 and 322 nm paired with 353 nm) and one VIS triplet (606 nm combined with 510 nm and 675 nm).
- Radiances are normalized at 60.5 km for UV and 40.5 km for VIS;
- Convergence criteria $d_i^2=(x_i-x_{i+1})^T S^{-1}(x_i-x_{i+1}) << n$ where n=10.
- Surface reflectivity is retrieved at 40.5 km at 8 wavelengths assuming no aerosol.
- Aerosol algorithm (V1.5) uses Chahine's nonlinear relaxation method to retrieve aerosol extinction at 675 nm assuming the gamma-function particle size distribution.
- Ozone algorithms extrapolate aerosol to shorter

Preliminary Results

Surface Reflectivity at eight wavelengths

Surface reflectivity retrievals depend on the absolute calibration and accuracy of altitude registration. There is a good correspondence between N21 and SNPP reflectivity values with improved performance of N21 at VIS and NIR channels.

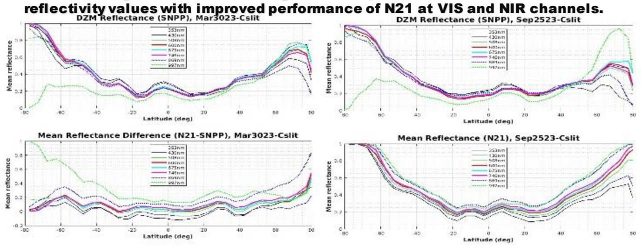


Figure 1a: Daily zonal mean (3/30/2023) retrieved surface reflectivity at 8 wavelengths from SNPP (top panel). Differences in surface reflectivity between N21 and SNPP for the 8 wavelengths for the same day (bottom panel).

Figure 1b: Daily zonal mean (9/25/2023) retrieved surface reflectivity at 8 wavelengths from SNPP (top panels) and N21 (bottom panel).

Aerosol extinction at 675 nm

Retrieved aerosol extinction at 675 nm from SNPP and N21 on 9/25/2023 show similar patterns. Differences between the two instruments are mostly within 10%-20%.

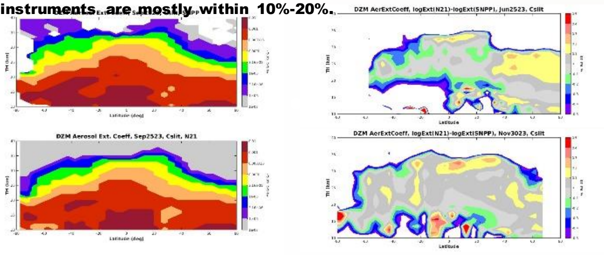


Figure 2a: Daily zonal mean (9/25/2023) retrieved aerosol extinction at 675 nm top: SNPP; bottom: N21.

Figure 2b: The difference of extinction log(N21)-log(Snpp) top: 6/25/2023; bottom: 11/30/2023.

Averaging Kernels from ozone retrievals

Averaging kernels for ozone retrievals at 45S and in the tropics for SNPP and N21. The consistent widths in the stratosphere lead to a

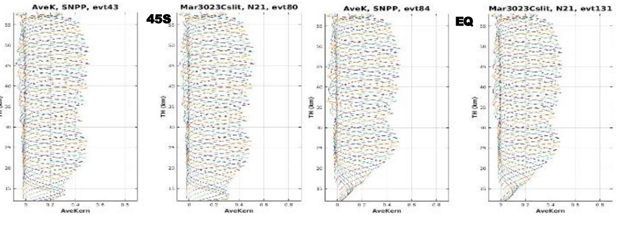


Figure 3a: AK at 45S; left: SNPP, right: n21

Figure 3b: AK at tropics; left: SNPP, right: n21

Ozone vertical resolution

Vertical resolution derived from averaging kernels for SNPP and N21 in mid-latitudes and tropics.. Both instruments show consistent vertical resolution of about 2

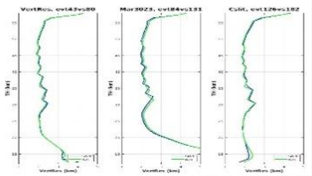


Figure 4: DZM VR at 45S, EQ and 45N from left to right

Ozone comparisons with MLS/Aura

We compared N21 ozone profiles with MLS/Aura at 4 different days. Daily zonal mean biases between N21 and MLS are mostly with +/-5% (grey colors). We found slightly larger positive biases ~ 30 km at altitudes where UV and VIS measurements are merged. Larger biases are observed in the lower stratosphere below 18 km. N21 has smaller biases with MLS than SNPP.

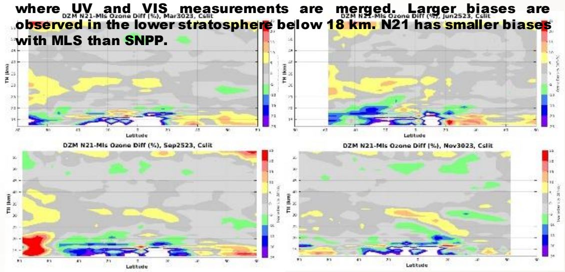


Figure 5a: DZM ozone difference between N21 and MLS v5 on 03/30/23(top left), 06/25/23 (top right), 09/25/23 (bottom left) and 11/30/23 (bottom right)

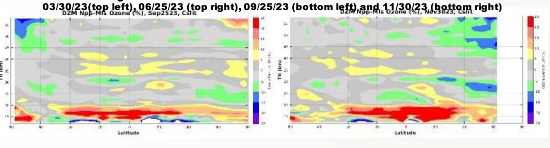


Figure 5b: DZM ozone differences between SNPP and MLS v5 Left: 09/25/23 Right: 11/30/23

Estimated Precision

N21 precision is about 3~4% for most altitudes and increase to 5% in some areas. N21 precision values are very similar to those from SNPP.

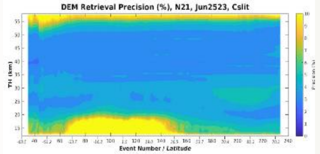


Figure 6: Estimated precision (N21, 6/25/23)

Summary

- Preliminary results indicate that the OMPS LP on N21 can deliver ozone profiles with the same or even slightly better performance than SNPP. We analyzed average kernels, vertical resolution and estimated precision and found a good consistency between N21 and SNPP.
- Our results validate initial calibrations applied to N21.
- There are about 10%-20% differences in retrieved aerosol extinction between N21 and SNPP. Note that the stray light correction for N21 is not completed.
- Ozone comparisons with MLS indicates that N21 has smaller biases with reduced vertical oscillations compared to SNPP.
- N21 Level 1 data will be released in early 2024

Acknowledgements: Special thanks to the OMPS LP team: J.Warner, L.Kahn, Z.Chen, ... S.Madhaven, R.Mundakkara, G.Taha and C. Seftor for the valuable contributions. The OMPS LP team is supported by the NASA Earth Science Division through SAMDA contract NNG17HP01C.

Differences NASA / NOAA NPP L1B

Wavelengths max(abs(r1bn.calibrationdata.bandcenterwavelengths._data(*,mub)-
r1bs.calibrationdata.bandcenterwavelengths._data(*,0)))
0.00000 nm
Calibration max(abs(r1bn.calibrationdata.CALIBRATIONFACTORS._data-
r1bs.calibrationdata.CALIBRATIONFACTORS._data))
0.00000
Solar Irradiance max(abs(r1bn.calibrationdata.irradiance._data(*,mub:mub+1)/
r1bs.calibrationdata.irradiance._data(*,0:1)-1.0))
0.000 %
Earth Radiance max(abs(r1bns.radiance._data(*,mub:mub+1)/
r1bss.radiance._data(*,0:1)-1.0))
0.000 %
Latitude max(abs(r1bng.tangentpointlatitude._data(*,mub:mub+1)-
r1bsg.tangentpointlatitude._data(*,0:1)))
0.000622 Deg.
Longitude max(abs(r1bng.tangentpointlongitude._data(*,mub:mub+1)-
r1bsg.tangentpointlongitude._data(*,0:1)))
0.000141 Deg.
Tangent Height max(abs(r1bng.tangentpointheight._data(*,mub:mub+1)-
r1bsg.tangentpointheight._data(*,0:1)))
0.0664 M

OMPS-NPP_LPEV-L1B-p000_v2.2_2023m1108t121537_o62342_2023m1201t210644.h5
OMPS-NPP_LPEV-L1B-p000_v2.7_2023m1108t114456_o62342_2023m1108t151610.h5

TRACKING OZONE RECOVERY WITH S-NPP OMPS NADIR AND LIMB PROFILER SATELLITE AND GROUND-BASED OZONE RECORDS

I. Petropavlovskikh (CIRES/NOAA), K. Miyagawa (NOAA), L. Flynn (NOAA/NESDIS), P. Effertz (CIRES/NOAA), J. Wild (CISESS/UMD and NOAA/NESDIS), E. Beach (IMSG), T. Beck (NOAA/NESDIS), Chunhui Pan (CISESS/UMD), Zhihua Zhang (IMSG), G. McConville (ORES/NOAA), B. Johnson (NOAA/GML), Natalia Kramarova (NAA/Goddard), Rob Damadeo (NASA/Langley), S. Godin-Beekmann (LATMOS)

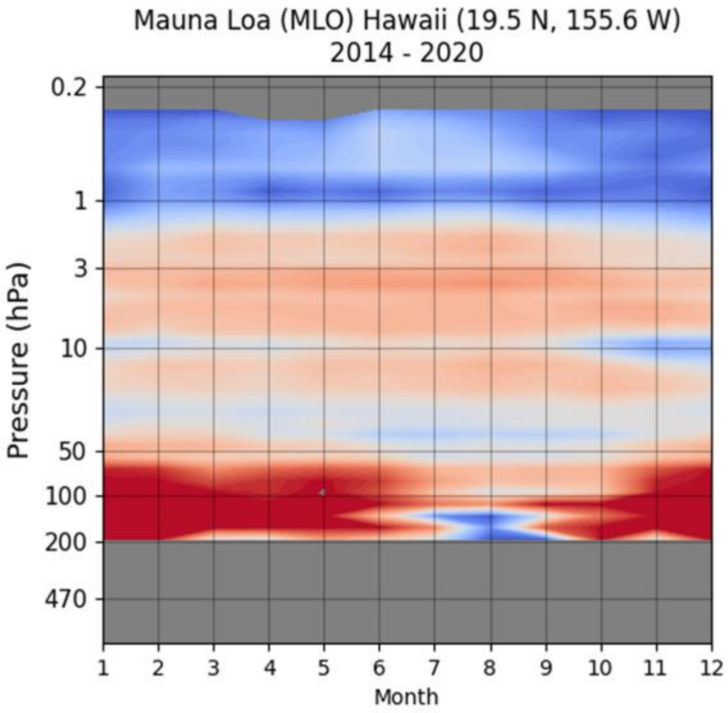
OMPS LP V 2.5 vs 2.6 and MLS V4

- **Suomi NPP OMPS LP-L2-O3-DAILY (v2.6)**
- **https://avdc.gsfc.nasa.gov/pub/data/satellite/Suomi_NPP/L2OVP/LP-L2-O3-DAILY_v2.6/**
- **Suomi NPP OMPS LP-L2-O3-DAILY (v2.5)**

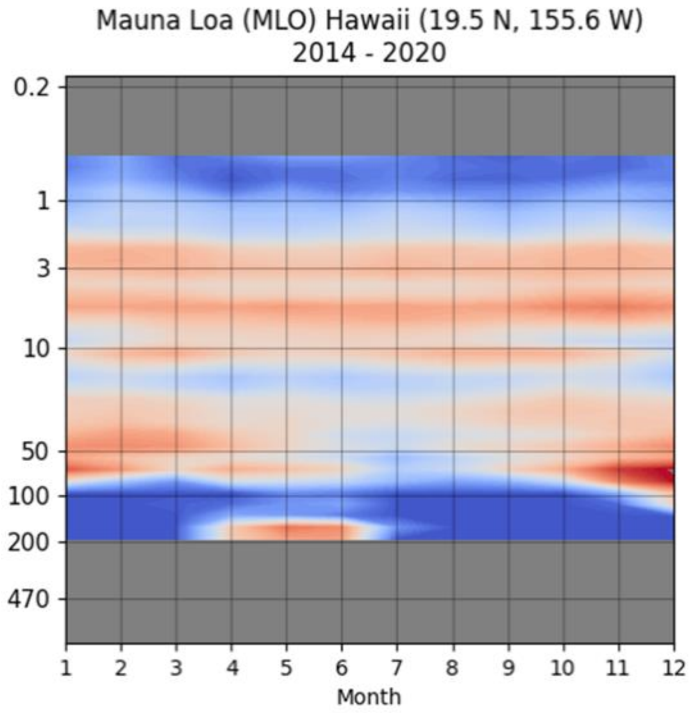
- **EOS Aura MLS_L2GP-O3_v04**
- **55 Pressure levels**
- **https://avdc.gsfc.nasa.gov/pub/data/satellite/Aura/MLS/V04/L2GPOVP/O3/**

Comparisons over MLO

•



OMPS_LP (v2.6) – Aura_MLS



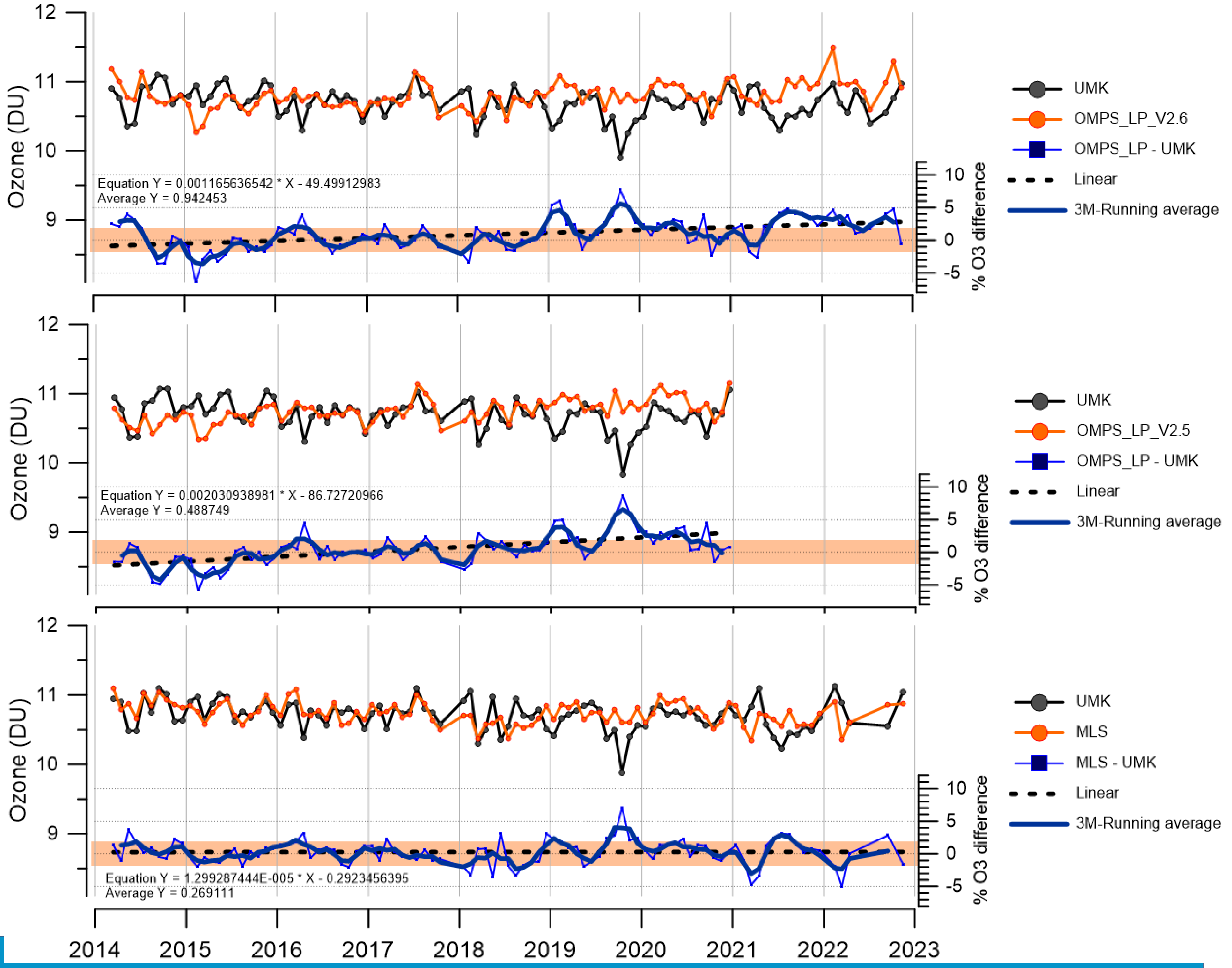
OMPS_LP (v2.5) – Aura_MLS

MLO
Layer 8
2~4 hPa

OMPS_LP_V2.6
Bias: 0.9% (0.6%)
Bias drift: 0.44%/yr. (0.42%/yr.) (Used 2014-2020)

OMPS_LP_V2.5
Bias: 0.5%
bias drift: 0.73%/yr.

MLS
Bias: 0.3%
bias drift: 0.00%/yr.

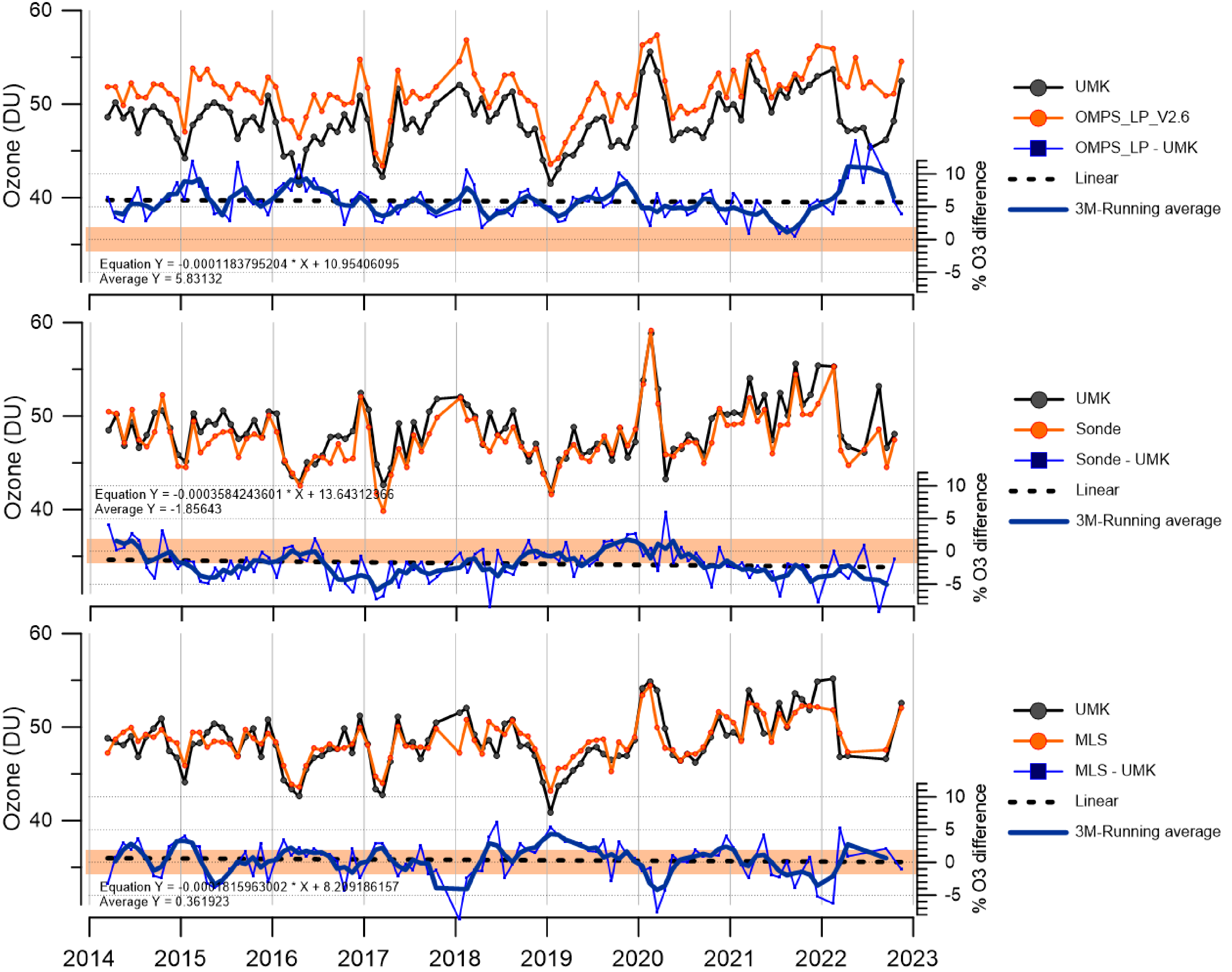


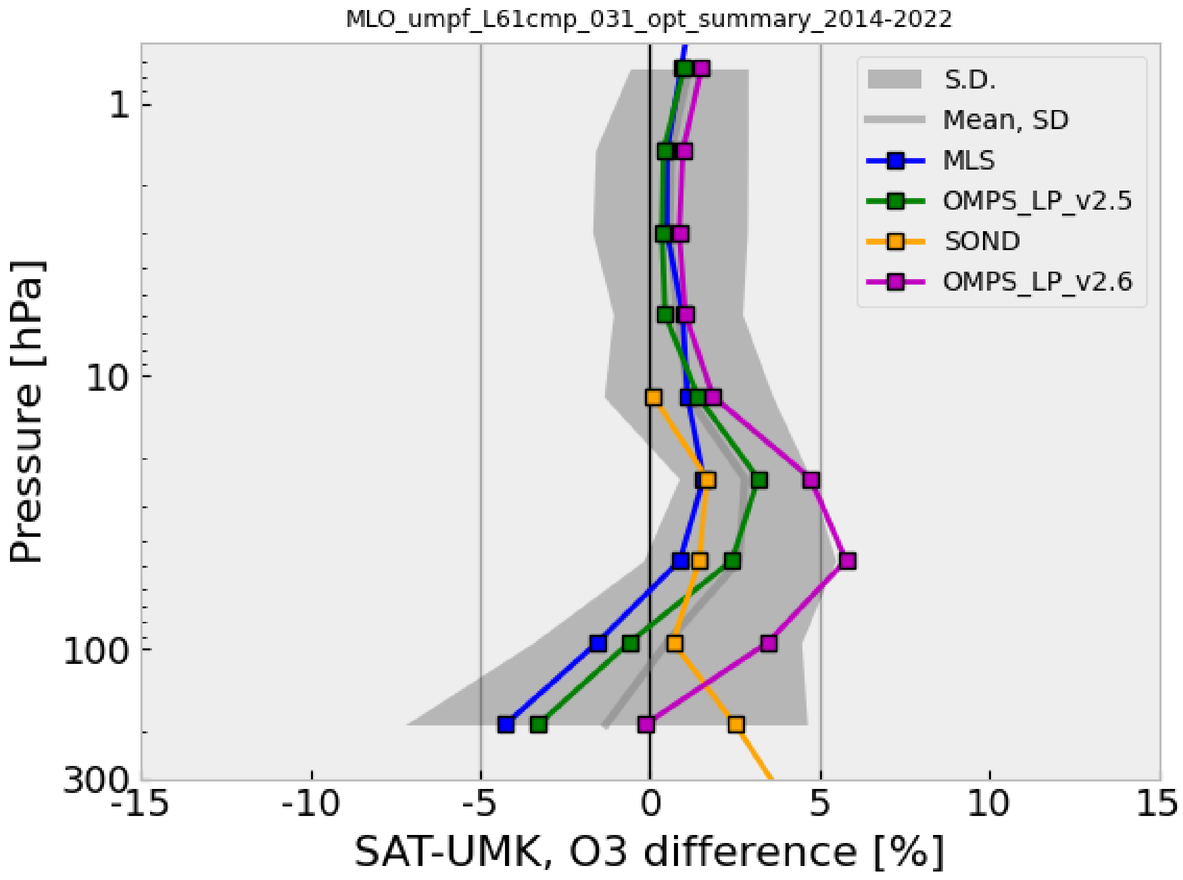
MLO
Layer 4
32~63 hPa

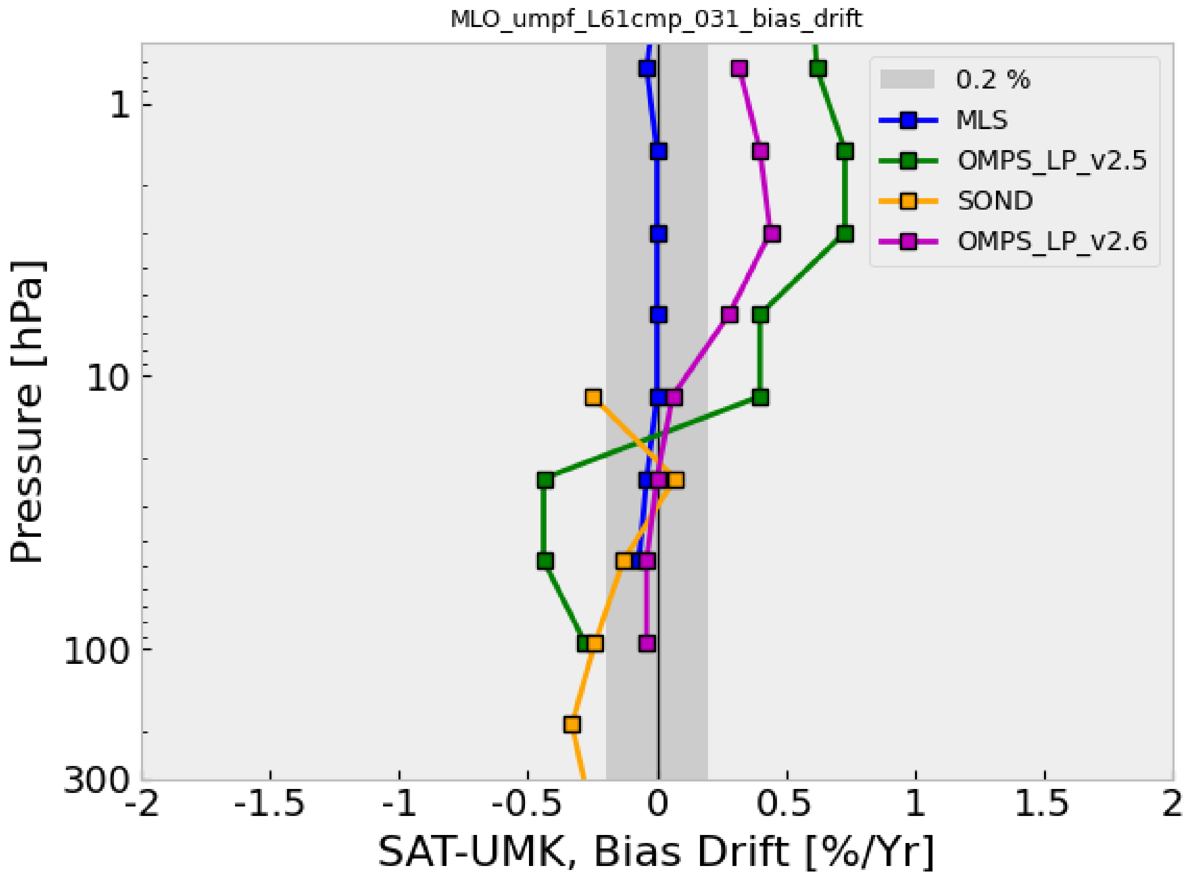
OMPS_LP_V2.6
Bias: 5.8%
Bias drift: -0.04%/yr.

O3sonde
Bias: -1.9%
A drop-off correction of +3.6% is assumed
bias drift: -0.13%/yr.

MLS
Bias: 0.4%
bias drift: -0.07%/yr.







Bias
Ozonesonde in Hilo has drift since 2014.
Summary period for 2010-2013.
OMPS_LP_V2.5 for 2014-2020

Bias Drift
MLS and OMPS_LP_V2.6 for 2014-2022
Ozonesonde for 2014-2022
OMPS_LP_V2.5 for 2014-2020