NOAA (and some NASA*) UV GRWSG Activities & Plans

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March 7, 2019

GSICS Annual

Frascati Italy

*Although they didn't know it

Disclaimer

"The contents of this presentation are those of the authors and do not necessarily reflect any position of the US Government or the National Oceanic and Atmospheric Administration."

Outline

- GEO/LEO UV opportunities starting with GEMS
  What is the GSICS role in the CEOS Plans?
- S-NPP OMPS Reprocessed SDR and V8TOz
  What would GSICS products look like?
- V8.6Pro NOAA-16, -17, -18, -19, S-NPP Ozone Profile CDR
  Is there a GSICS Product in there?
- Solar Reference
  How do we really use solar?
- Technical Report on Hyperspectral Sensors slowly in preparation
- Radiative Transfer Forward Model

GEMS to Launch within the next Year

- GEO/LEO – Line-of-Sight underflight.
- CEOS AC-VC GEO Cal/Val Document

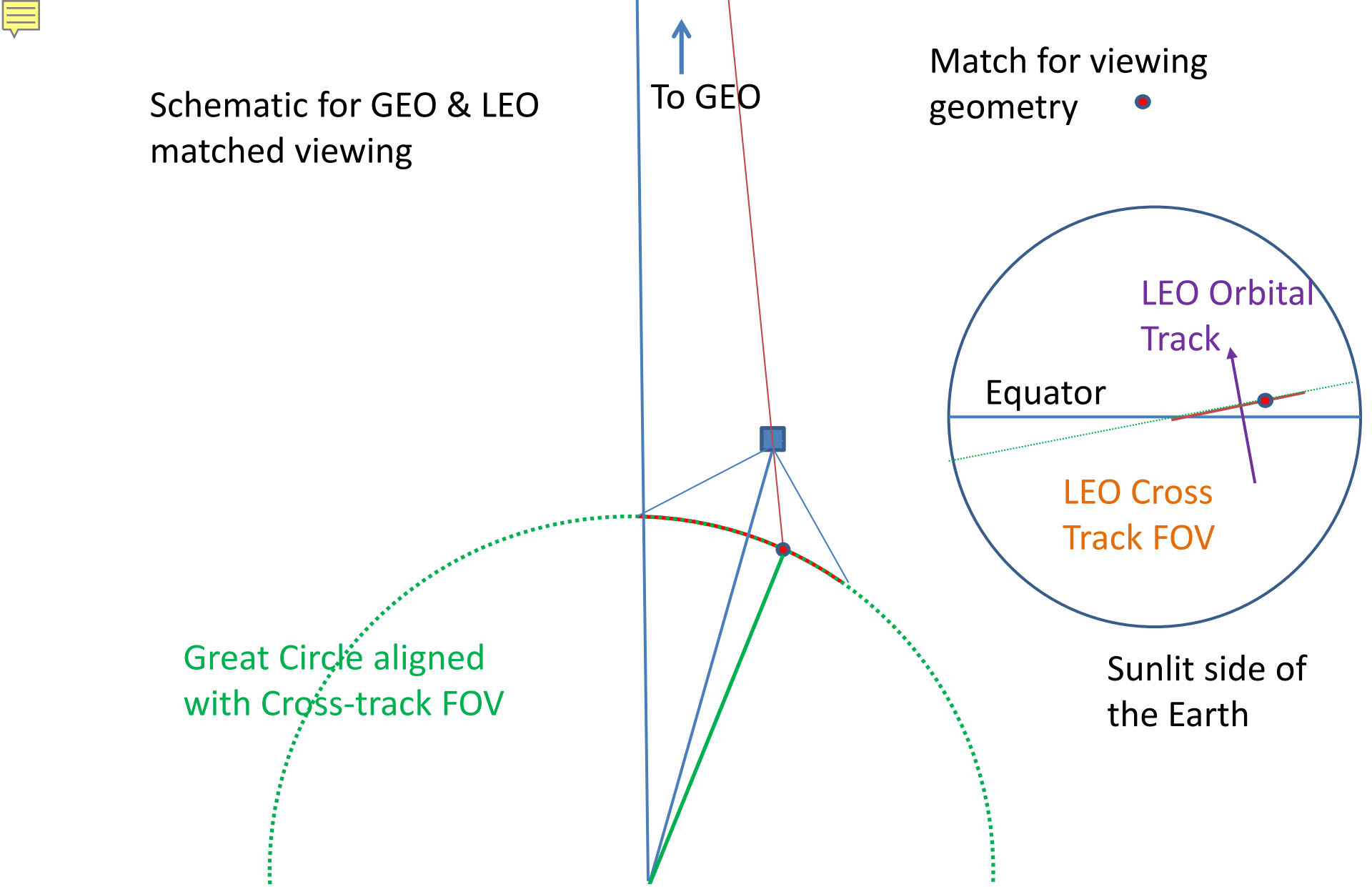
Geostationary Satellite Constellation for Observing Global Air Quality: Geophysical Validation Needs

Draft 0.8, 11 December

4.3. Inter-mission Consistency

4.3.4. LEO satellites as travelling standard for L2

- GEMS Background
- Opportunities for LEO comparisons (including LEO/LEO)



Simultaneous View Path (SVP) match up between GEO and LEO. Matches will be present for aninstrument on a GEO platform with one in a LEO orbit as the LEO orbital tracks pass near the GEO sub-satellite point, e.g., 1200 at GEO sub-satellite point, 1330 at LEO sub-satellite point.

- GEMS Background (http://gems1.yonsei.ac.kr/bbs/board.php?tbl=presentations)

The GEMS instrument is a hyperspectral scanning spectrometer operating from 300 nm to 500 nm with 0.5-nm FWHM and 0.2-nm spacing. It will fly on the GK-2B geostationary platform (current launch window is Oct 2019 to Mar 2020) and make hourly measurements of the eastern hemisphere from 5S to 70N with 7x8 km^2 spatial resolution for most products at Seoul's latitude. The current atmospheric products (with algorithms tested on OMPS, OMI, TropoMI and other data) are O3 (total, tropospheric and stratospheric columns), NO2, SO2, HCHO, Aerosol Optical Depth (AOD at 435 nm), Aerosol index (AI) and Aerosol Effective Height (AEH).

The lead agency for launch is the Korea Aerospace Research Institute (KARI) they have accepted delivery of the GEMS instrument from Ball Aerospace as of Aug 2018 and it is now integrated with the spacecraft. They are joined by the Ministry of Environment (MoE including the National Institute or Environmental Research / NIER and the Korea Environmental Industry and Technology Institute / KEITI), the Korea Meteorological Administration (KMA) and the Korea Ocean R&D Institute (KORDI). The GEMS Science Teams has wide membership include researchers from Yonsei University, Seoul National University, Ewha Women's University, Busan National University, Pukyong University and from the TEMPO Science Team including researchers at Harvard University, NASA and NCAR.

KARI, KMA and NIER are all members of CEOS. There is a CEOS Atmospheric Composition Virtual Constellation (AC-VC) project described in two white papers "Geostationary Satellite Constellation for Observing Global Air Quality: Geophysical Validation"

- http://tempo.si.edu/presentations/April2017/CEOS-Geo-AQ-Constellation-geophysical-validation-needs-draft06apr2017.pdf (Newer Draft Version 0.8, 11 Dec 2018)

and "A Geostationary Satellite Constellation for Observing Global Air Quality: An International Path Forward"

- http://ceos.org/document_management/Virtual_Constellations/ACC/Documents/AC-VC_Geostationary-Cx-for-Global-AQ-final_Apr2011.pdf

The first document gives detailed plans for comparing LEO and GEO measurements and products including those from NOAA OMPS.

KMA is a member of GSICS. The existing GSCIS products include numerous LEO to GEO comparisons for inter-calibration in the IR and Visible spectral regions and may be extended to the UV with the launch of GEMS, and ensuing NASA Tropospheric Emissions Monitoring of Pollution spectrometer (TEMPO) and the ESA/EUMETSAT Sentinel-4 Ultaviolet, Visible, Near-infrared sounder (UVN).

GEO/LEO and LEO/LEO

- GEO/LEO starting with GEMS (launch 3/2020)
  - 16-day repeat cycles for EOS Aura, S-NPP and NOAA-20. S-NPP and NOAA-20 180° apart will alternate locations every eight days.
  - Metop-B and Metop-C 90° apart. Repeat?
- LEO/LEO (More on these later)
  - Simultaneous Nadir Overpass (SNO) and No-Local-Time Differences for GOME-2 with OMPS or OMI
  - Opportunistic Formation Flying for OMPS with OMI – 227 versus 233 orbits / 16 days.
  - PICS (Pseudo-Invariant Calibration Sites/Statistics)

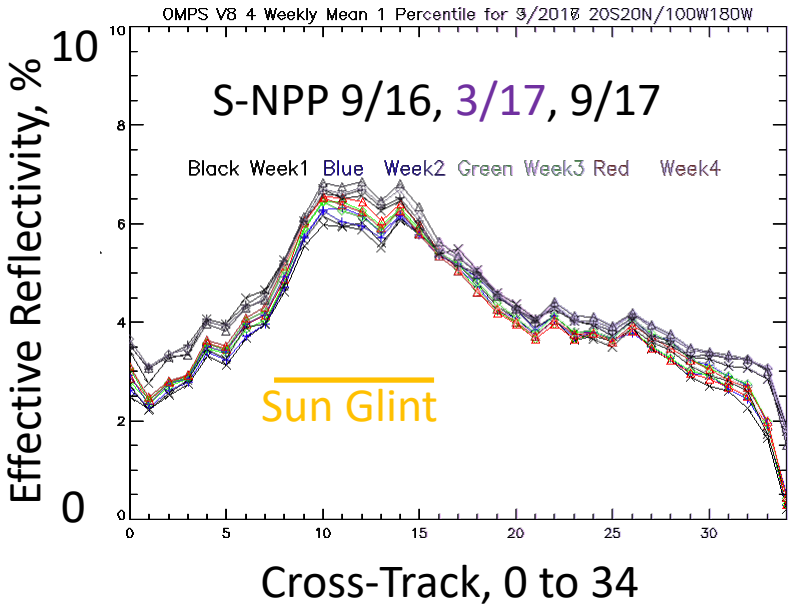
Discrete Total Ozone

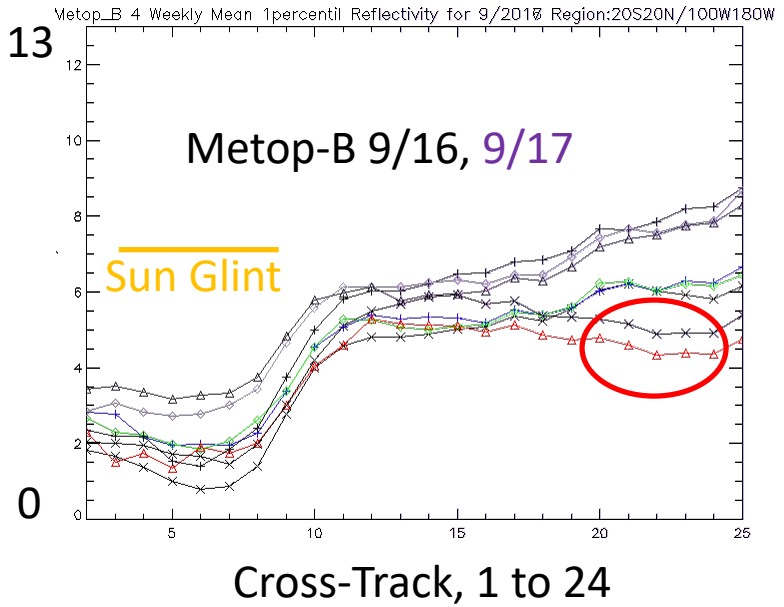
- The S-NPP OMPS Nadir Mapper SDRs (Level 1) have been reprocessed and used to create V8TOz products including total column ozone, effective reflectivity and an aerosol index.
- TropoMI is flying in formation with S-NPP OMPS. OMI has Opportunistic Formation Flying (OFF) every 16 day with 8-day offset for S-NPP versus NOAA-20. (OMI is a transfer for OMPS?)
- Equatorial Pacific Statistics
- What would GSICS Products look like?
  - Reflectivity channel stability and biases
  - Two-channel Aerosol Index stability and biases
  - Ozone channel bias stability
  - What is the Truth or who is the reference?
  - Is 4.L on Ice Radiances a start for reflectivity and aerosol index?
  - Where do Vis PICS and Rayleigh scattering methods fit in?

Equatorial Pacific Statistics

- The figures on the next two pages investigate the stability of statistics over the Equatorial Pacific for the V8TOz algorithm Effective Reflectivity and Aerosol Index Values.
- Away from the Sun Glint cross-track viewing positions, the S-NPP OMPS show very good stability over one year.
- Both Metop-A and Metop-B GOME-2 show time-dependent changes in both products. There is also some evidence of cross-track dependencies to these changes.
- The weekly statistics provide adequate averaging relative to the 16-day orbital repeat cycle.
- Comparisons should be made to the OMI and TropoMI V8TOz products for these statistics.
- We could also inter-compare the weekly mean total ozone but we have to allow for real changes over time.

Comparison of 1-Percentile Effective Reflectivity for the Equatorial Pacific



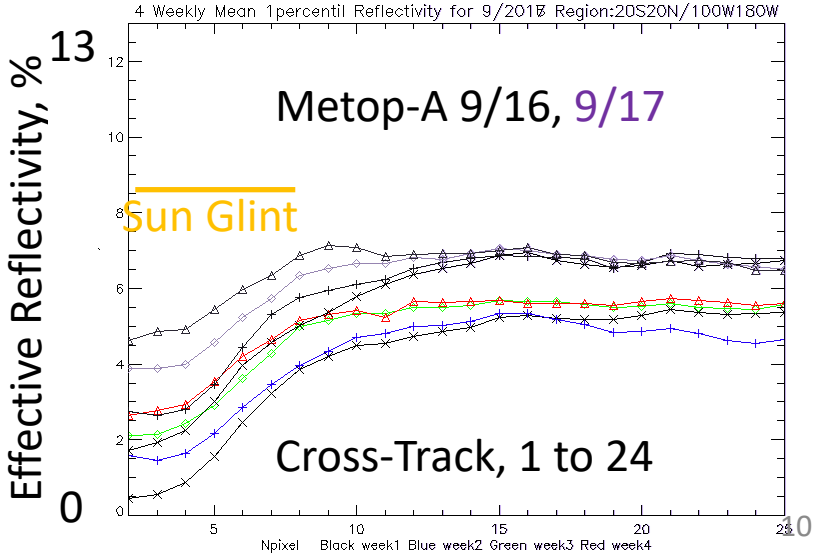


Weekly 1-percentile value for effective reflectivity for 20N-20S, 100W-180W.

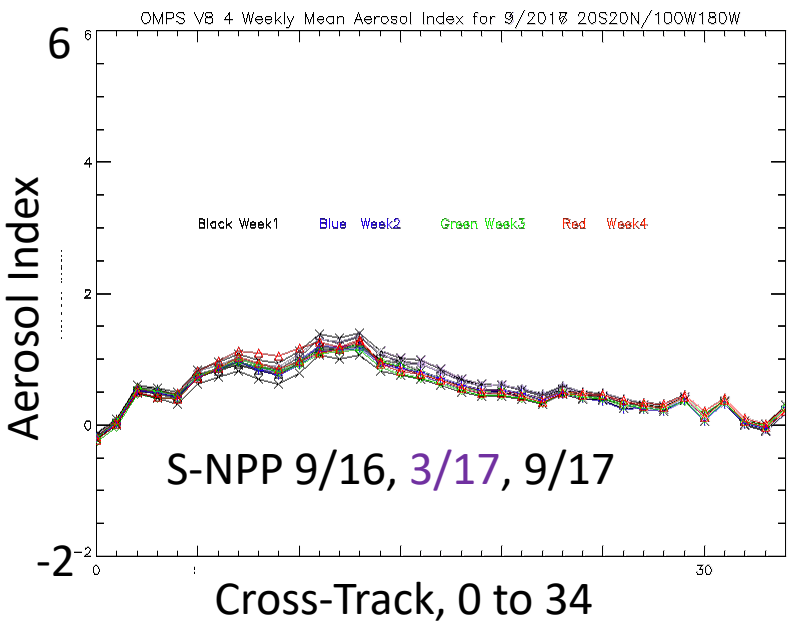
3/17 is in Purple above, 9/17 is in Purple to the right.

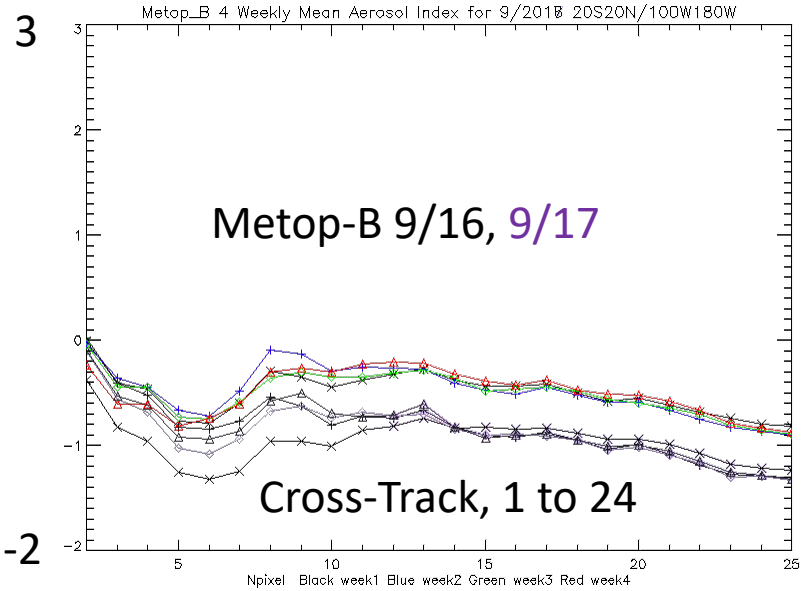
Metop-B was incorrectly filtered for Narrow Swath data.

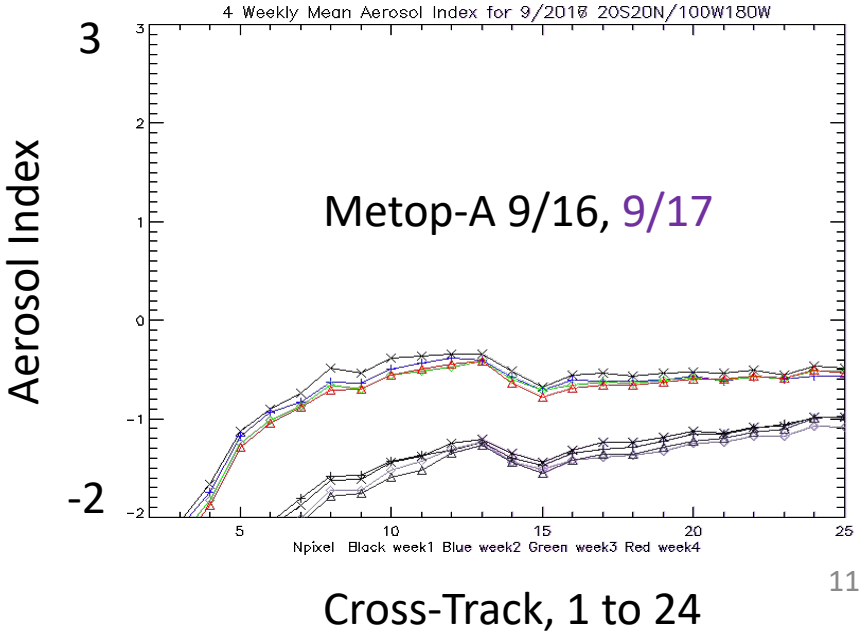
Metop-A has half the swath width of Metop-B so Sun-glint is shifted in cross-track location. What is the solar CT?



Comparison of Weekly Mean Aerosol Index for the Equatorial Pacific



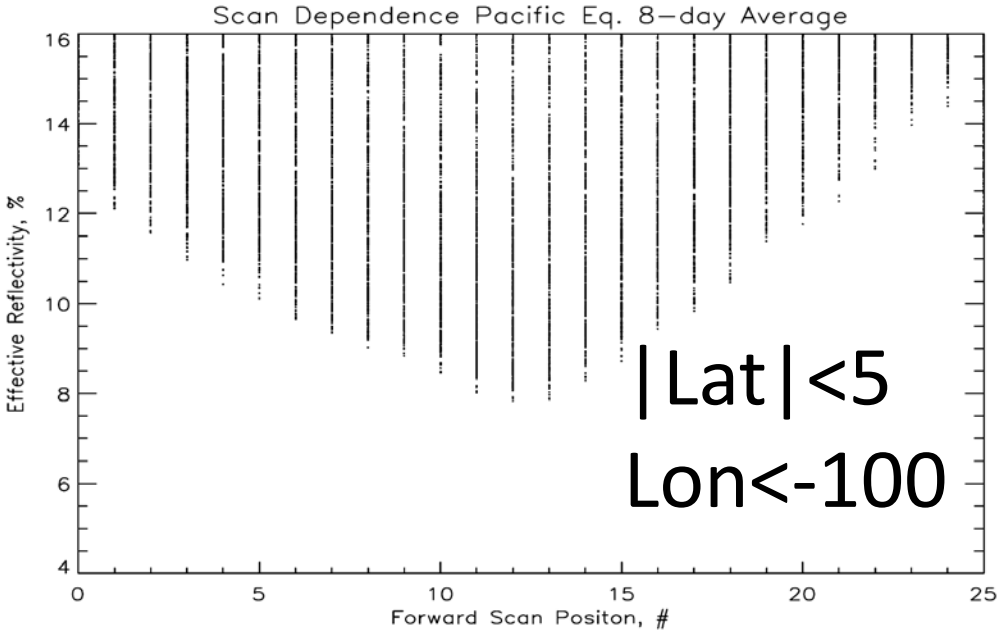


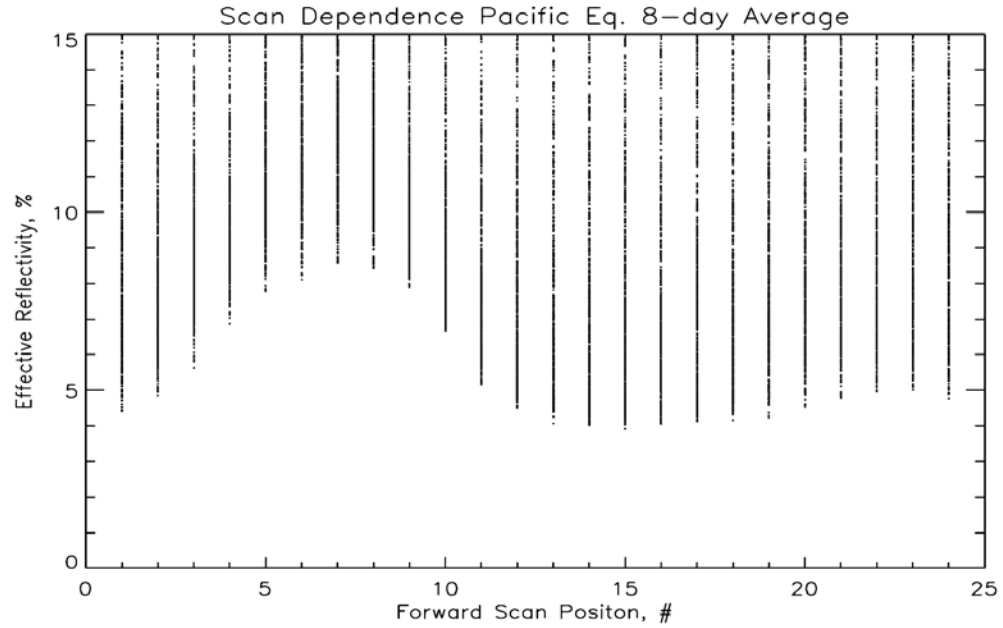


Weekly mean values for Aerosol Index (no cloud filter) for 20N-20S, 100W-180W.

3/17 is in Purple above, 9/17 is in Purple to the right.

Metop-A has half the swath width of Metop-B so Sun-glint is shifted in cross-track location.





EAST

WEST

Metop-A GOME-2 Version 8 331-nm Reflectivity for a box in the Equatorial Pacific.
Need to repeat for Metop-B and Metop-C at start of mission.

The unadjusted values in the top plot reach a minimum of 8% (higher than expected for the open ocean) for the Nadir scan position.

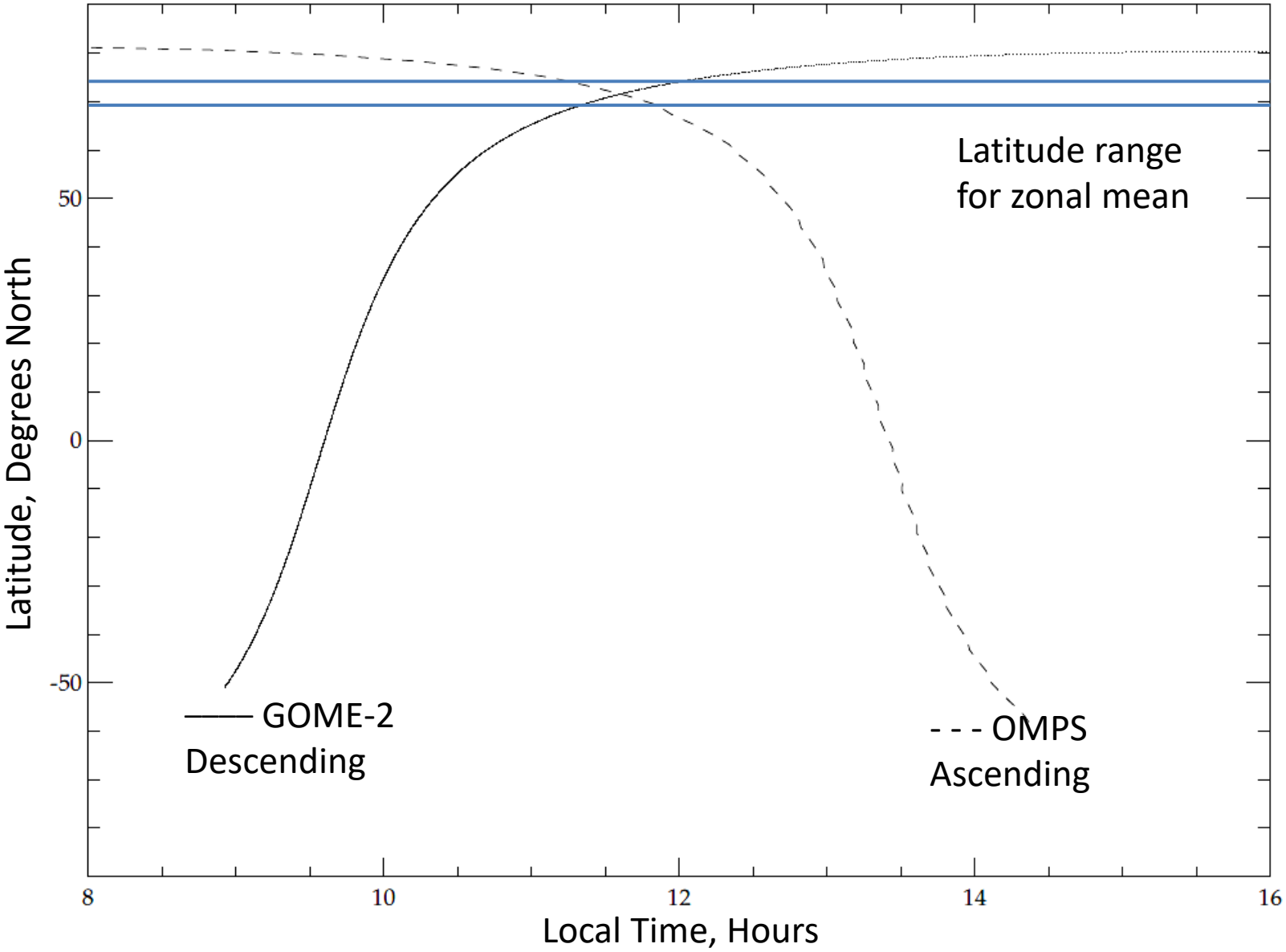
A single calibration adjustment to the 331-nm channel lowers this value to 4% and also flattens out the scan dependence for West-viewing positions. The East-viewing results are not as good but there is sun glint contamination for those angles.

SBUV(/2) & OMPS V8Pro Climate Data Record

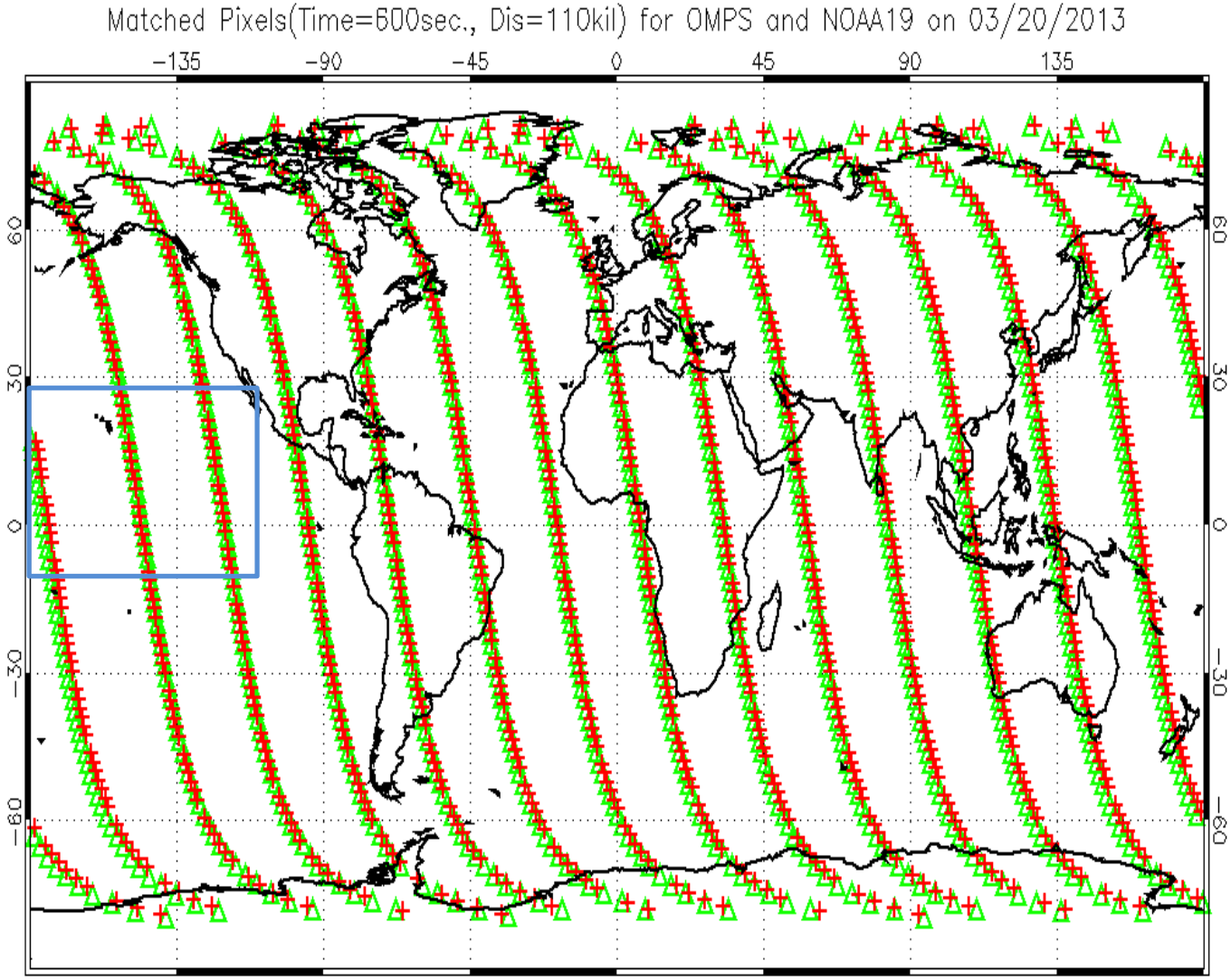
- NASA has created a consistent set of measurements for NOAA-16, -17, -18 & -19 SBUV/2 by using Ice Radiances (checked with vegetative scene minima) and No-Local-Time Difference Zonal Means to establish instrument to instrument biases at the 12 wavelengths. The soft calibration biases are used to produce the V8.6 ozone profile record.
- NASA and NOAA are extending this time series by adjusting S-NPP OMPS (NP and NM) to NOAA-19 SBUV/2 by using zonal means or chasing orbits in 2012/2013.
- We will produce and post a full set of figures (daily time series of initial and final measurement residuals and Best Total minus Profile Total Ozone and monthly retrieved versus a priori profiles) for these new data sets. It will live here:

  https://www.star.nesdis.noaa.gov/smcd/spb/OMPSDemo/index.php
- There are some small differences in the NASA and NOAA approaches to the OMPS NP degradation and some even more minor differences on solar activity.
- Are the inter-instrument adjustments potential GSICS Products.

Simultaneous Nadir Overpass and No Local Time Difference Comparisons



Chasing Orbits for S-NPP and NOAA-19 POES: adjusting STAR re-processed OMPS V8PRO to agree with SBUV/2 results



Two sets of Day-1 albedo adjustments (From L.-K, Huang 6/14/2018 OPT meeting)

OMPS Prelaunch Calibration with NM
+2.5% increase to be consistent with NP

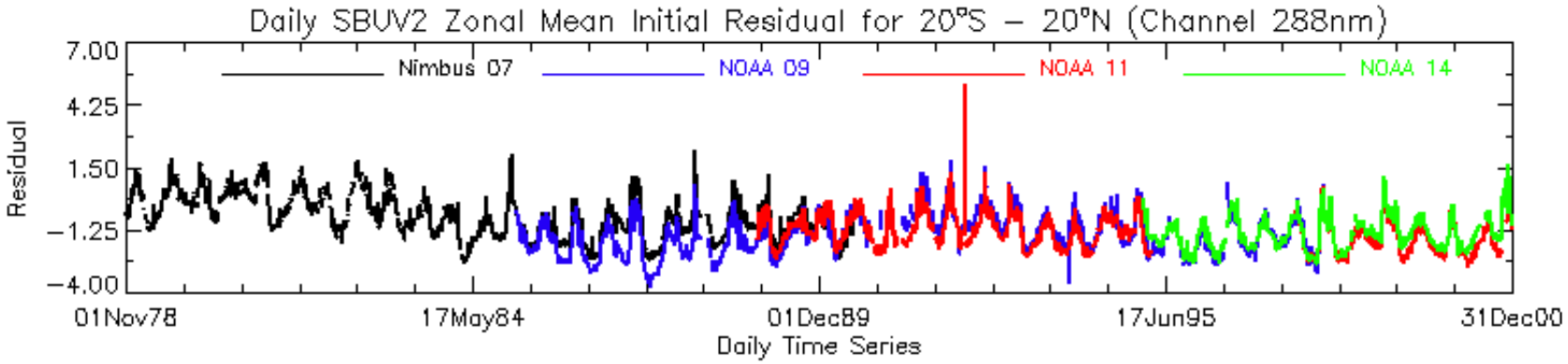
λ (nm)	dN-values
252.04	0.000
2.3.70	0.000
283.16	0.000
287.73	0.000
292.360	0.000
297.64	0.000
302.03	0.000
305.90	0.000
312.67	-1.072
317.60	-1.072
331.32	-1.072
339.92	-1.072
378.78	-1.072

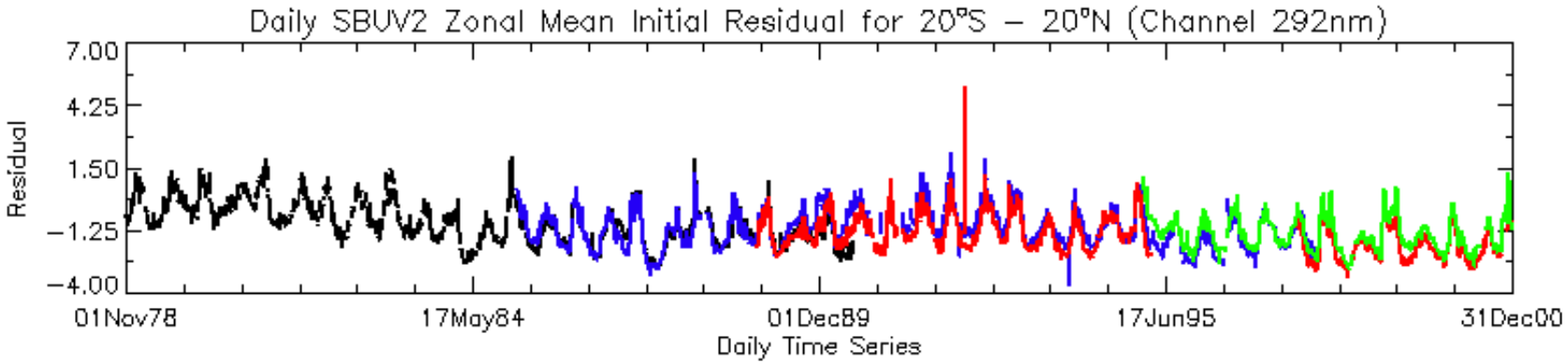
OMPS Prelaunch Calibration with NM
+2.5% increase, and NP adjusted to N19

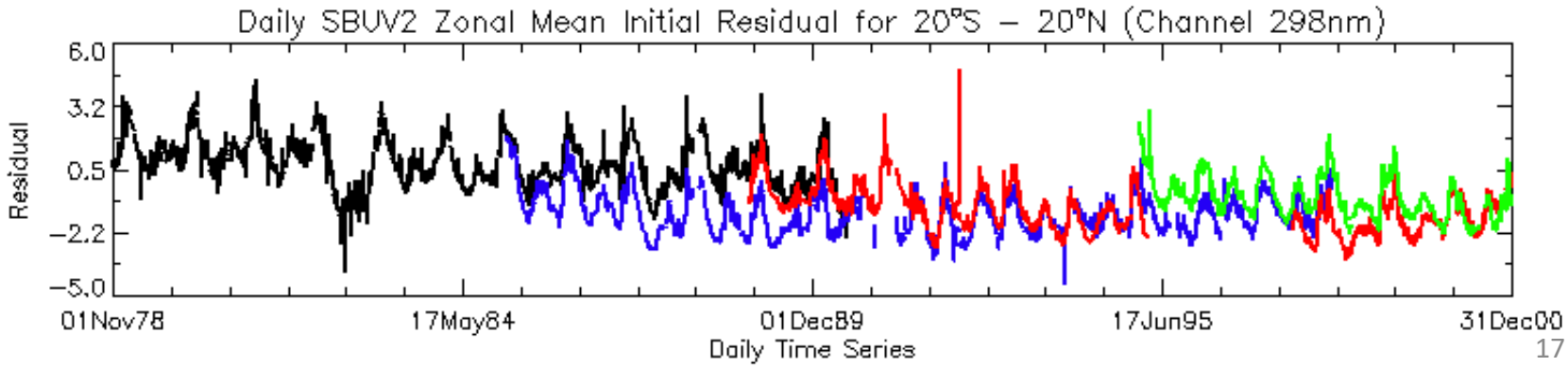
λ (nm)	dN-values		
	N19/NP	**N17/N19**	**N17/NP**
252.04	0.363	1.079	1.442
273.70	-0.100	0.387	0.287
283.16	0.294	-0.112	0.182
287.73	0.087	0.214	0.301
292.360	0.217	0.436	0.653
297.64	0.587	0.586	1.173
302.03	0.775	0.661	1.436
305.90	0.260	0.200	0.460
312.67			-1.072
317.60			-1.072
331.32			-1.072
339.92			-1.072
378.78			-1.072

Long-term Inter-calibrated Initial Measurement Residuals for SBUV/2

New record will extend this from 2001 to 2018.

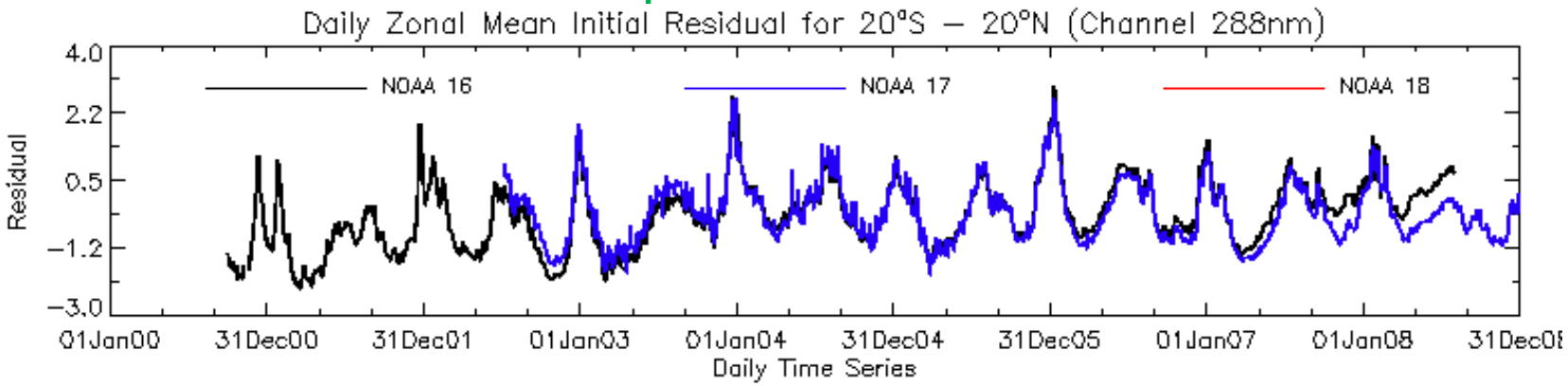


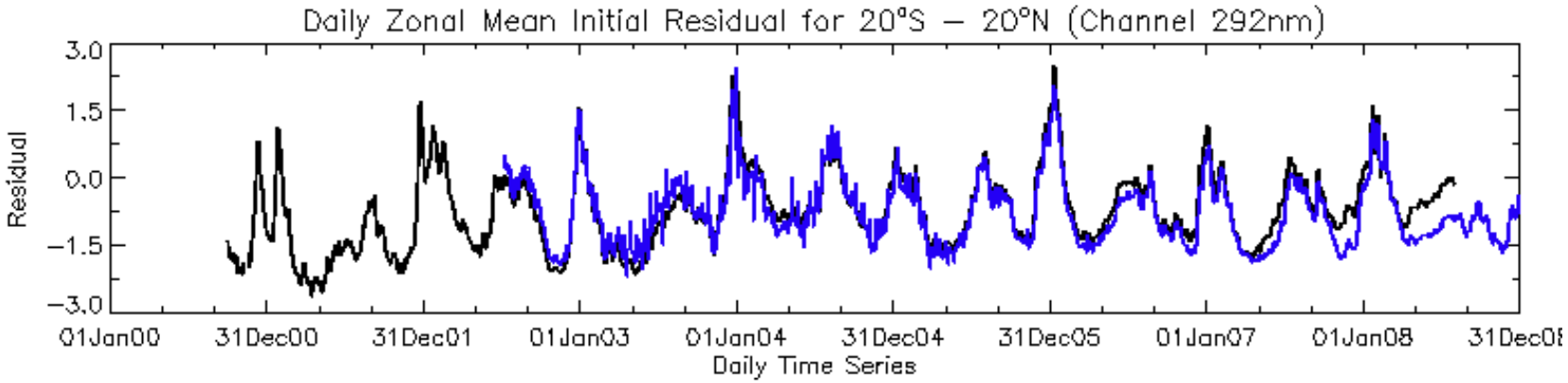


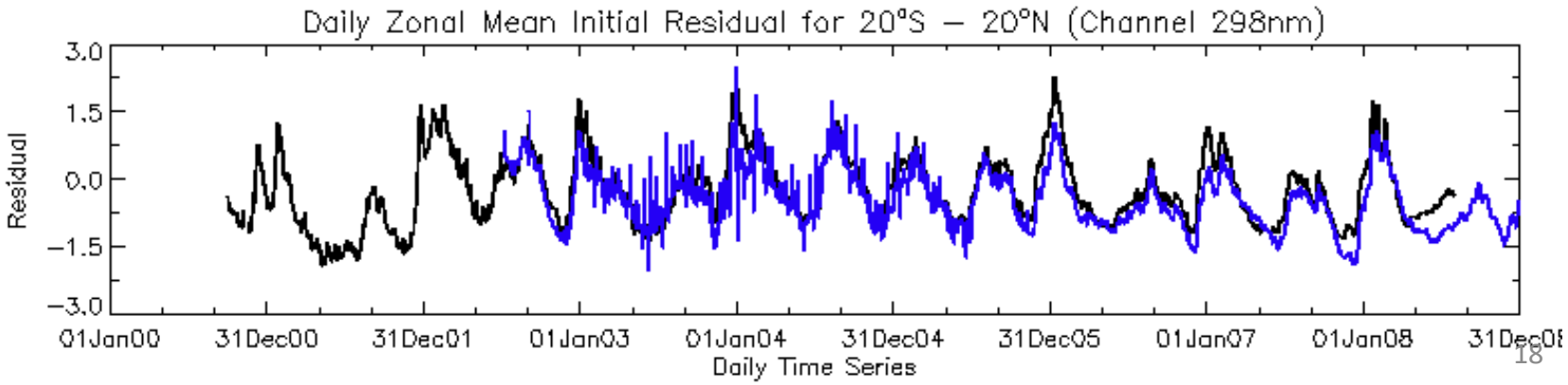


Time series of Initial Measurement Residuals for 20S -20N

New record will replace and extend this one.







Profile Future

- Drifting orbit complications
  - Diurnal variations in ozone field
  - Differing biases for different wavelengths and information placement versus solar zenith angle.
- Can OMI help with hyperspectral coverage and differing satellite viewing angles, i.e., off nadir? Should we revisit Ascending/Descending.
- Can OMPS hyperspectral coverage help with drifting NOAA-19 orbit by creating equivalent channels.

Solar Reference Outline

- We only use small scale structure from Solar References in creating Radiative Transfer results for Radiance / Irradiance ratios.
- Solar in SDR/Level 1 – Differing philosophies for degradation, solar activity, Earth/Sun distance.
- We can predict solar spectral variations well from Mg II Index values (with both model and empirical), and we have good records for those.
- Should Mg II and Sun Spot time series be GSICS Deliverables?

Will bring up at GSICS Solar Reference meeting.

Given sets of normalized bandpass weights, $\{b_k\}$, monochromatic radiative transfer albedo results, $\{A_{\lambda k}\}$, and high-resolution solar irradiances, $\{F_{\lambda k}\}$, we can compute an estimate of the measured radiance / irradiance ratio as follows:

$$\bar{F}_\lambda = \sum_{k=1}^{K} b_k F_{\lambda k}$$

$$\bar{R}_\lambda = \sum_{k=1}^{K} b_k A_{\lambda k} F_{\lambda k}$$

$$A_{model} = \bar{R}_\lambda \; / \; \bar{F}_\lambda$$

where all of the $\{b_k\}$, $\{F_{\lambda k}\}$ and $\{A_{\lambda k}\}$ are for the same K discrete, equally-spaced wavelengths, $\{\boldsymbol{\lambda}_k\}$, about the target central wavelength. Notice that a constant, shared, relative bias by all of the $F_{\lambda k}$ values will cancel in the ratio.

Solar in SDR/Level 1

- Earth – Sun distance in SDR/Level 1
  - NOAA: Solar at 1 AU, adjust at Rad/Irrad ratio step
  - NASA & EUMETSAT: Solar for local Earth-Sun distance
- Degradation
  - GOME-2: In both Earth and Solar
  - NASA OMPS: Only in Earth (Albedo Correction Factor)
  - NOAA OMPS: In both (biweekly solar update)
- Solar activity
  - GOME-2: Daily measurements (or modeled Metop-A)
  - NASA OMPS: Solar activity time series of adjustments for reprocessing
  - NOAA OMPS: Solar activity in biweekly solar for NRT, in daily solar for reprocessed

Technical Report Outline

- **SECTION 0. Mathematical Tools**
- **SECTION 1. Instruments to Measure Ultraviolet and Visible Spectra**
- **Subsection 1.1. Detectors (CTE, QE, storage, overclock)**
- **Subsection 1.2. Counts A to D+ (Linearity)**
- **Subsection 1.2.1 Electrons**
- **Subsection 1.2.2 Offset**
- **Subsection 1.2.3 Dark Current**
- **Subsection 1.2.4 Stray light**
- **Subsection 1.3. Calibration**
- **Subsection 1.3.1. Optical Elements**
- **Subsection 1.3.2. Wavelength Scale**
- **Subsection 1.3.3. Wavelength Bandpass**
- **SECTION 2. Solar Irradiance**
- **SECTION 3. Earth Radiance**
- **SECTION 4. Summary and Conclusions**
- **ACKNOWLEDGMENTS**
- **BIBLIOGRAPHY**
- **WEB RESOURCES**
- **APPENDIX A. IDL Code to Conduct Analysis**

***Something good to come out of the shutdown. Uses experience with OMI, OMPS and GOME (-2)**

VLIDORT Activities

- NASA and Harvard SAO are actively working to create scripts to simplify the use of VLIDORT.
- The SAO package will include application of instrument bandpasses and use the Jacobians to create DOAS retrievals.
- NOAA is keeping track of these activities with an eye to expanding the spectral coverage of the Community Radiative Transfer Model (CRTM).

Backup

Support to GRWG Activities
UV Subgroup

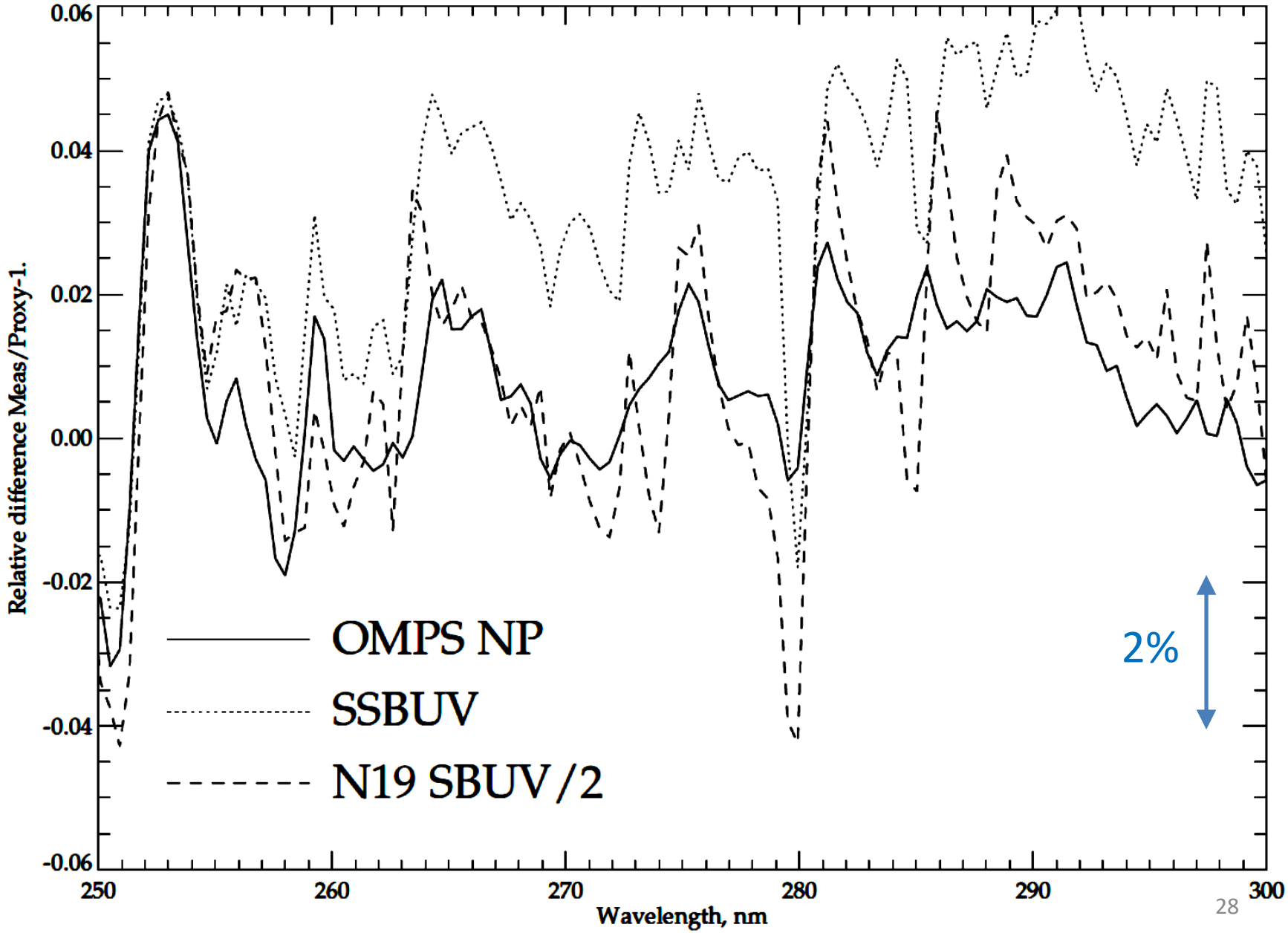
- *NOAA is participating in all four UV Subgroup projects*
  - *Leading the Ozone Profile Measurement residual comparison study – currently working with NOAA SBUV/2 and OMPS NP instruments. We are creating time series to track the V8Pro initial residuals for the nine profile channels from 253 nm to 313 nm for operational and reprocessed data sets.*
  - *Participating in the UV reflectivity channel comparison study – currently working with NOAA OMPS NM and EUMETSAT GOME-2. We are tracking statistics on reflectivity and UV absorbing aerosol index values over the Equatorial Pacific. We are looking forward to working with the Vis Subgroup and their Rayleigh calibration project.*
  - *Participating in the solar reference and comparison study. We are modelling OMPS solar measurements with comparison to proxies from multiple sources. We are creating Mg II Index time series from OMPS NP and GOME-2 products.*
  - *Participating in the Best Practices for Calibration project. L. Flynn is working on a NESDIS Technical Report to capture the experiences and lessons learned from trending and error analysis of hyperspectral UV instrument measurements.*
- NOAA is providing monitoring of our Level 2 and Level 1 products at

https://www.star.nesdis.noaa.gov/smcd/spb/OMPSDemo/proOMPSbeta.TOZ_N20_V8.php

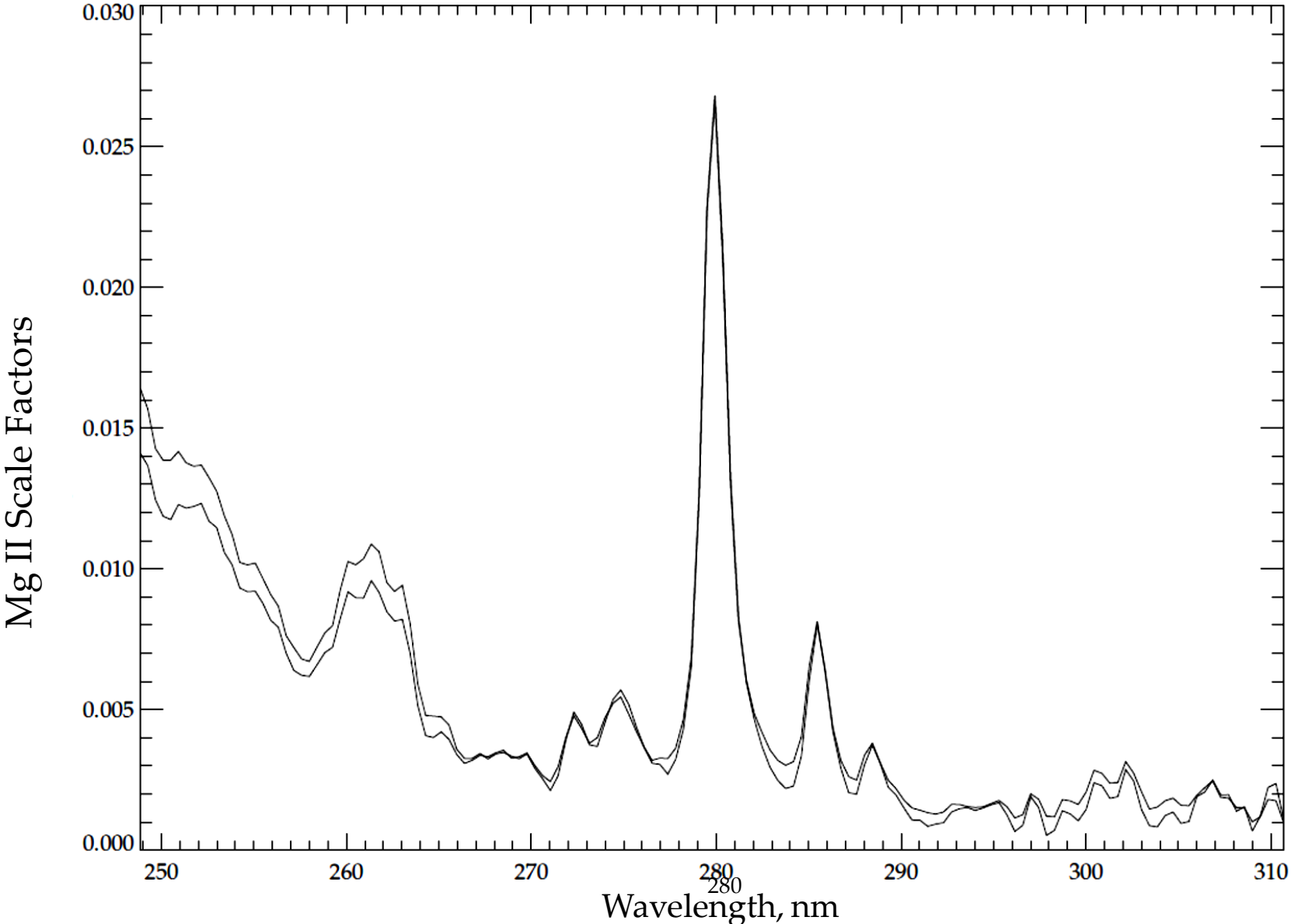
https://www.star.nesdis.noaa.gov/icvs/status_N20_OMPS_NP.php

- 1. Comparisons of Reflectivity and Aerosol Index channel calibration among BUV instruments.
  The goals for this topic are to share methods and results for using target sites and matchups to compare channels with little trace gas absorption both for internal consistency and external bias estimates. Researchers are invited to present their approaches and methods for validating or comparing the calibration of channels from 330 nm to 500 nm by using Earth targets. Current reflectivity targets and statistical approaches include the following: Antarctic and Greenland ice fields, desert sites, minimal land reflectivity, minimal open ocean reflectivity, simultaneous nadir overpass, no-local time difference zonal means, and maximum cloud reflectivity. Comparisons between aerosol index values can provide another consistency check. The choice of channels and cloud and surface reflectivity models will affect the comparisons.
- V8TOZ results for OMPS NM (N20 and S-NPP) and GOME-2 (METOP-A and METOP-B)
- There is obvious overlap between this topic and methods in use or development in the visible subgroup (Deep Convective Cloud and Rayleigh Scattering approaches) and between this topic and efforts to produce global surface UV reflectivity, cloud reflectivity and aerosol climatologies or climate data records.
  2. Comparisons of solar measurements and reference spectra in the UV.
  The goals for this topic are to share results of comparisons and characterization of solar measurement in the UV. Researchers are invited to present results of their investigations into solar measurements in the UV. Results may be for any of the following: characterization or calibration of measurements from single instruments, comparisons of measurements between sensors, modeling of time dependence of measurements, comparisons of reference spectra, comparisons of measured spectra by using proxy solar spectra created from reference spectra, and investigation of model-based solar spectra. Participants are asked to be prepared to provide access to the data sets used in their studies. (Comparison of Mg II Index time series and Wavelength.
- Possible additional topics or maybe just areas of interest.
  3. Comparisons of BUV Nadir Profile measurements residuals with respect to forward model calculations using climatological A Prioris.
- 4. White Paper on Best Practices for UV sensor calibration and characterization.
- 5. Direct radiance comparisons from Simultaneous Nadir Overpass (SNO) and LEO/GEO mathups.

Solar Measurement Comparisons to KNMI Proxy



S-NPP OMPS Mg II Relative Scale Factors from 4-week up/down excursions



Analysis of Time Series of Solar Spectra

The OMI, GOME-2 and OMPS teams have generated models of their time series of solar measurements by using

- Solar activity
  - With proxies (e.g., Mg II Indices)
  - Directly estimating pattern over solar rotations
- Wavelength shifts
  - With proxies (e.g., optical bench temperatures)
  - Directly from fits of solar features
- Diffuser and instrument degradation
  - With proxies (e.g., diffuser exposure times)
  - From working and reference diffuser measurements
  - From residual changes after identifying activity and wavelength changes
  - Considering albedo changes over targets or compared to other sensors

OMPS Nadir Profiler Solar Measurements