L1B Calibration & L2 Help

L. Flynn NOAA
With contributions from OMPS, GEMS, TEMPO and ACX Team Members., etc.

May 8th, 2024 9:00 AM

GeoXO ACX Science Team Meeting
NCWCP College Park, MD

NOAA
National Satellite and Information Service
Center for Satellite Applications and Research

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.“

Outline

- Related Activities
- What can/must be done well on the ground?
- What can be done well in space?
  - Solar irradiance modeling and trending
  - Dark current trending
  - Wavelength scale confirmation and trending
  - Stray light tuning
  - Lunar views?
- What can be learned from Level 2 products?
  - Precision and accuracy
  - Wavelength scales (and bandpasses)

Related Activities

- A CEOS/GSICS Workshop on Pre-flight Calibration & Characterisation of Optical Satellite Instruments for Earth Observation will be hosted by ESA/ESTEC on Noordwijk, The Netherlands from 19 to 22 November 2024. See details at: https://atpi.eventsair.com/pre-flight-calibration-workshop
- The 2024 TEMPO/GEMS Joint Science Team Workshop will take place from 26 to 30 August 2024 in Hawaii: https://meeting-info.org/tempo-gems-2024/
- CEOS has organized an SI-Traceable Satellite (SITSat) Task Group*. Missions include CLARREO, TRUTHS, LIBRA.^

* https://calvalportal.ceos.org/sitsat
^ https://space.oscar.wmo.int/satellites/view/iss_clarreo_pf https://space.oscar.wmo.int/satelliteprogrammes/view/clarreo
https://space.oscar.wmo.int/satellites/view/truths https://www.eoportal.org/satellite-missions/libra

Planned Activities for GSICS for 2024

- Three planned UVN-S Topical Meetings (fifth Thursday of the month)
  - Evaluating and modeling solar measurements
    - Diffuser degradation
    - Instrument throughput degradation
    - Solar activity
    - Wavelength shifts and Bandpasses
    - Stray Light
  - Matchup Inter-comparisons for LEO/GEO, LEO/GEO/Lagrange-1, LEO/LEO
    - Simultaneous Nadir Overpass
    - Ray tracing
    - Using Radiative Transfer Forward models to account for viewing differences (V8TOz examples)
  - Use of Targets and Statistical approaches
    - Principal Component Analysis
    - Ice Radiances
    - Open Ocean
    - Land (PICS, etc.)
    - Deep Convective Clouds
    - Aerosol Indices

Basics – Ground

- What needs to be done well on the ground?
  - Maintain high cleanliness standards and dry nitrogen purge. Check all possible sources of contaminants – glues, seals, paints, any outgassing materials.
  - Justify moving parts. Trade off the simplicity of operations versus flexibility.
  - Include optical bench and detector temperature monitoring. Consider the values of stability and knowledge.
  - Make consistent radiance and irradiance measurements. Provide clearly traceable descriptions of goniometric viewing angles.
  - Provide spatial and spectral calibration with scale and bandpass for the latter.
  - Provide dark current, stray light, and nonlinearity measurements and models
    - For dark, determine detector temperature effects.
    - For stray light, provide spatial and spectral, in-band and out of band test results. (aggregation)
    - For nonlinearity, use the lower signal levels to set the linearity term to avoid discretization errors.
  - Allow for diagnostic modes with higher data volumes.
  - Characterize polarization sensitivity. Provide clear descriptions of test orientations.

Basics – Space

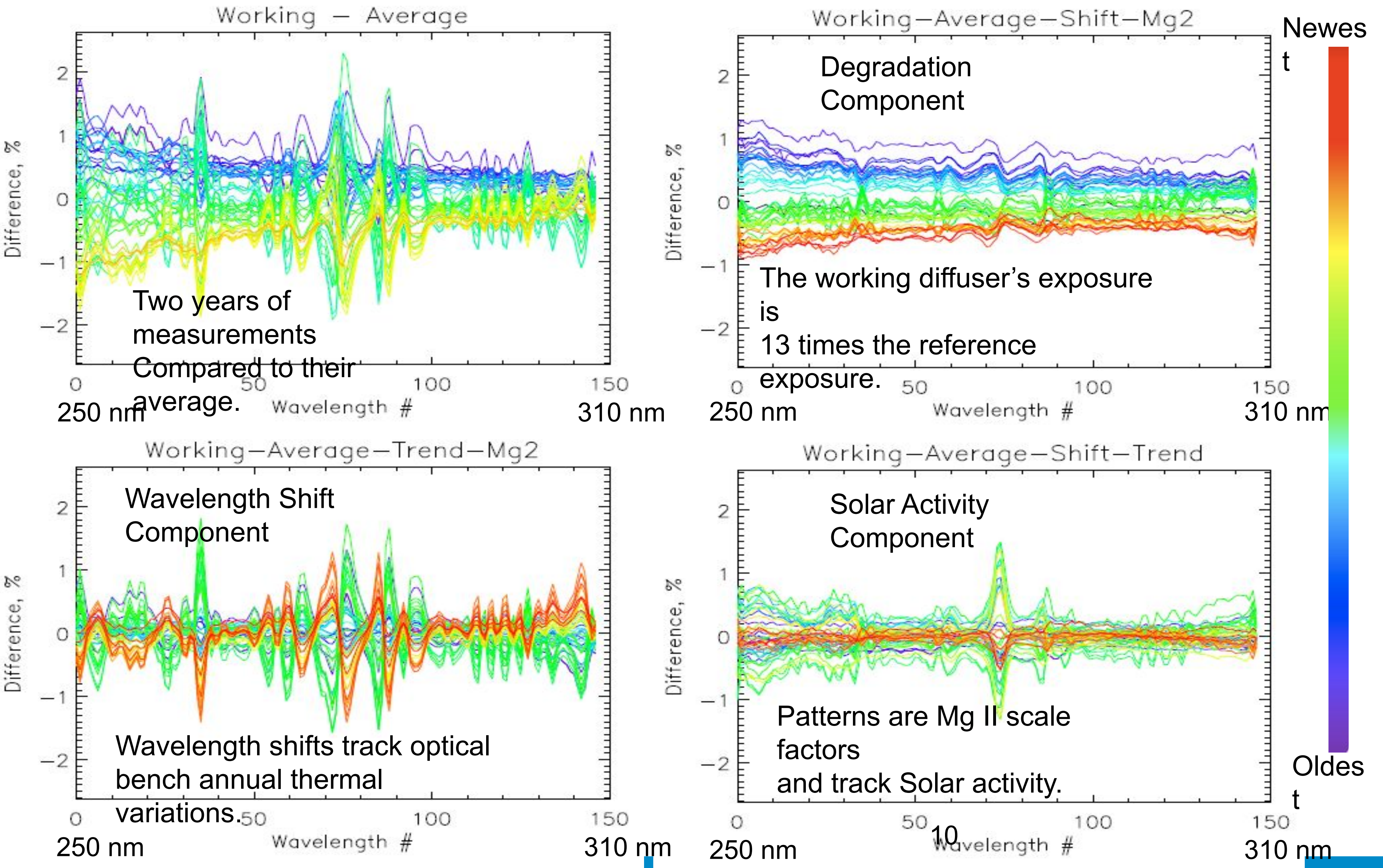
- What can be done well in space?
  - Solar Measurements: Dual diffusers measurements can provide characterization of throughput degradation, solar activity, wavelength scale shifts and bandpass changes. Consistent solar signals can be used to bootstrap finer goniometric parameterization. Averaging can reduce spectral features, and provide flat fielding.
  - Lunar Measurements – Are they worth it?
  - Viewing LED sources for nonlinearity and flat field checks.
  - Dark measurements – Door closed (diurnal) and nighttime.
- Frequency of calibration updates – Human in the Loop or automation (NOAA versus NASA approaches for OMPS + original OMPS concept).
- Don’t be afraid to take diagnostic measurements. Better science measurements are worth the gaps in coverage.

Solar

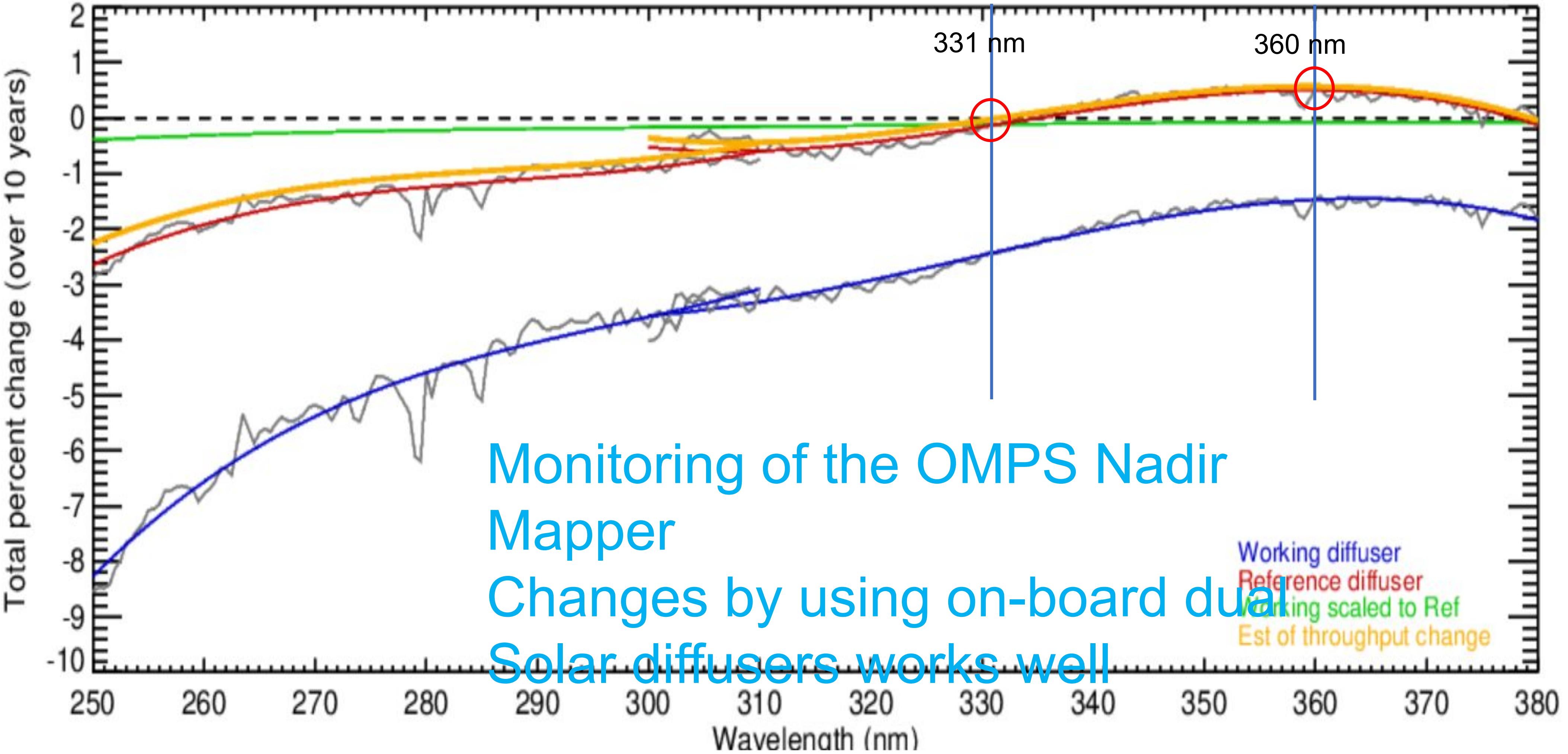
- Comparisons to TSIS-1 HSRS Version 2
  - Absolute to 1%
  - Wavelength scale to 0.01 * FWHM (Quadratic shift coefficients)
  - Check on Bandpass by feature broadening
  - Daily time series with solar activity. Check stray light / bandpass
- Working / Reference
  - Repeat Reference annually at the same viewing geometry
  - Frequency of deployment / Degradation rates (Lessons Learned from GEMS)
  - Solar Activity from Ca II H & K Lines’ S-Index (also in radiances)
  - Wavelength scale cycles from working or Earth-view S-Index
  - Careful tracking of goniometric angle parameterization (LL from TEMPO)
  - Experience with meshes and transmissive diffusers (LL from GOME-2, GEMS & TEMPO)
- Choices for solar in the Level 1B
  - 1 AU or Earth/Sun distance adjusted, Doppler shifted or not.
  - Day 1, latest working (what frequency?), or degradation corrected (or all three)
    - Latest working has wavelength scale and solar activity in it

- OMPS Lessons Learned
  - Dark current measurements / Corrections
    - Science timing pattern at night. Trevor Plot
    - Integration time: Power law and Storage versus Active regions
    - Arrhenius Law noise*2 / 5 K
    - Temperature dependence (Additional Lessons Learned from GEMS / TEMPO)
  - Dual Diffusers
    - Annual Repeat, Track wavelength scale and solar activity, check bandpass
    - Consider options for duty cycles, e.g., accelerated or switched deployment
    - Measurement variations can be explained at the 0.1% level with three components.
  - Wavelength scales (shifts G-to-O, diurnal, Irrad to Rad, Quadratic Coefficients.) and Bandpasses Ca H&K Earth Radiance Plot
    - Centering – First Moments
    - Modeling SRF functions , finite slit and inhomogeneous scenes.
  - Level 2
    - DOAS versus Discrete Channel retrievals
    - Back to Pair Justification
  - Pixel or wavelength-based calibration
  - Broad bandpasses or small scale (DOAS vs V8TOz) Aerosol Plot, NO2 Plot.
  - Stray Light and correlations (Ca H&K vs reflectivity)
- Experiences and what to look for from TEMPO and GEMS
  - PCA Patterns: striping causes, noise estimates, stray light
  - Diurnal complications

OMPS Nadir Profiler Solar Measurements

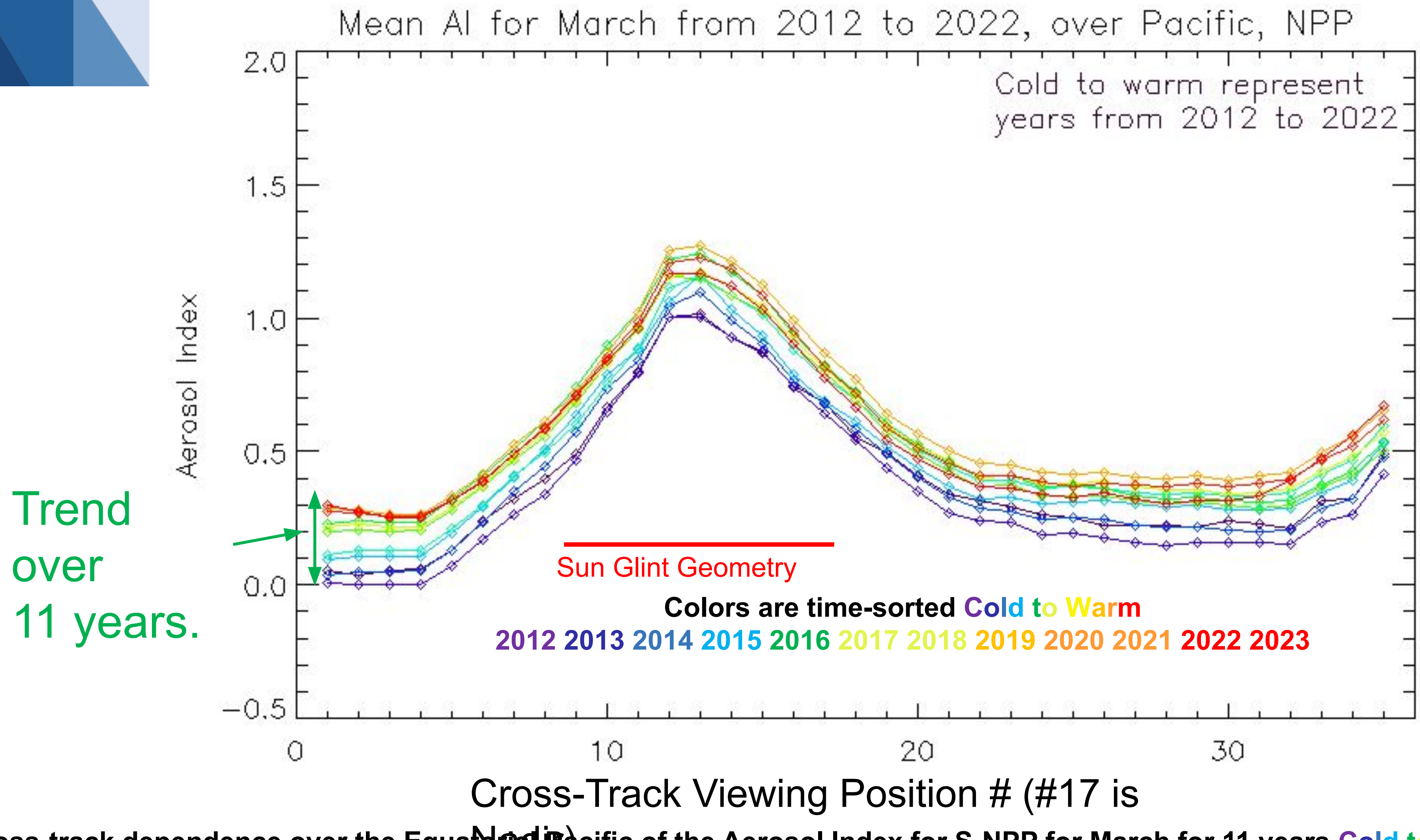


Monitoring of the OMPS Nadir Mapper Changes by using on-board dual Solar diffusers works well



Relative trend over 11 years

Estimates of the total wavelength-dependent throughput changes for the S-NPP OMPS over ten years (2012 to 2022). The blue curve is from linear fits of the changes of the bi-weekly solar measurements from the working diffuser. The red curve is from linear fits of the changes of the annual solar measurements from the reference diffuser. The green curve is a scaling of the blue curve accounting for the difference in exposure frequency for the reference versus the working diffusers. The orange curve is the red curve minus the green curve. It gives an estimate of the throughput degradation for the shared optical path for the radiance measurements. Notice that the instrument throughput changes for the OMPS NM (300 nm to 380 nm) are well within the +-1% level. (This figure was created and provided by Colin Seftor of SSAI for the NASA GSFC Ozone Team.)



UV Aerosol Index 331/360 nm Pair

Cross-track dependence over the Equatorial Pacific of the Aerosol Index for S-NPP for March for 11 years Cold to Warm.
The cross-track pattern for the Aerosol Index is also very stable year-after-year and the absolute values are stable at the 0.4 level. The figure on the slide before does show (two 's) a trend in the instrument throughput for the 360 nm channel relative to 331 nm which has not been adjusted in any calibration, so some time dependence in this figure is not unexpected. Figure created by Zhihua Zhang (IMSG)

Nightside Dark Current Measurements

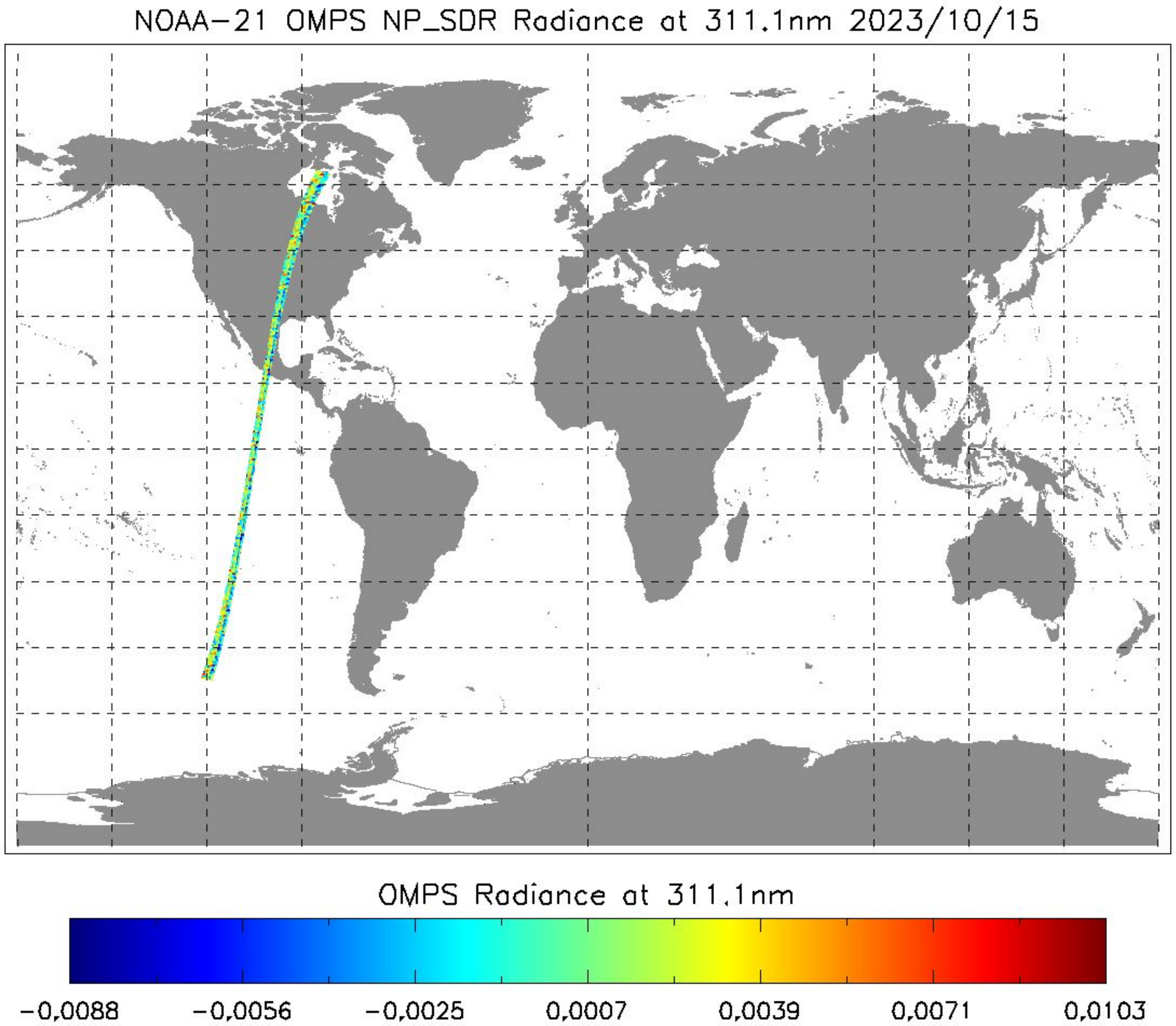
This and the next slide were provide by Trevor Beck (NOAA)

EV360 Measurements

Usually OMPS stops the EV (EarthView) measurement mode at the northern terminator crossing. Once per week the OMPS does EV360 measurements. The EV360 mode continues the nominal measurement mode into the night side.

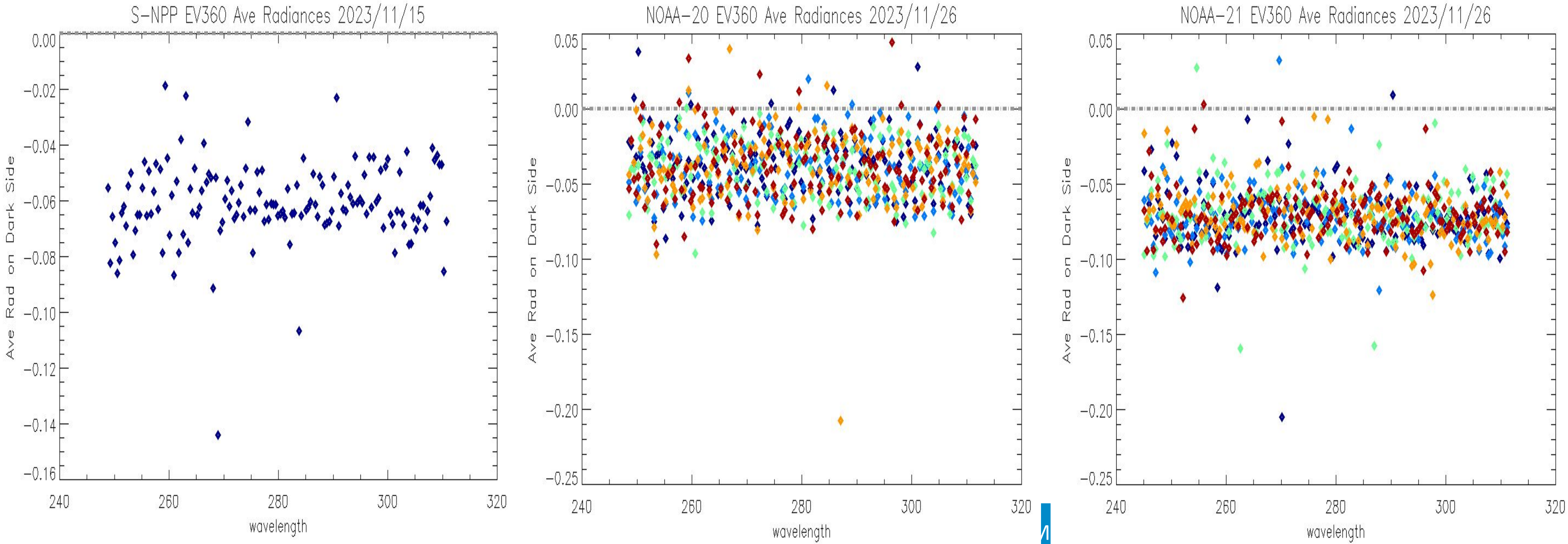
Ideally the average of the dark side measurements would on average be zero. The weekly EV360 measurements show a persistent negative bias indicating the dark is over corrected. (importance of not cutting off radiances at zero)

Right: NOAA-21 EV360 data on 2023/10/15 where SZA > 118

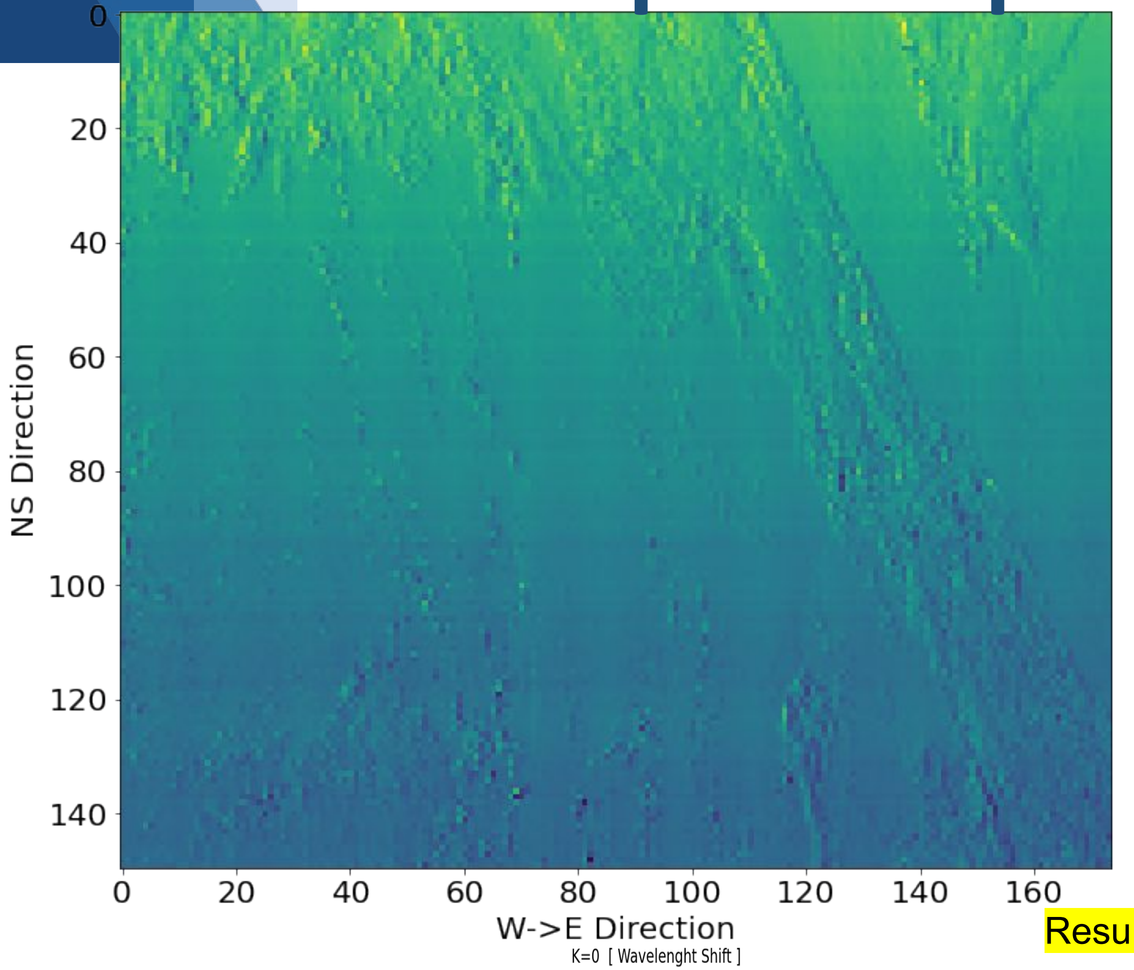


EV360 Averaged Radiance for the three OMPS-NP, SZA > 118 Degrees

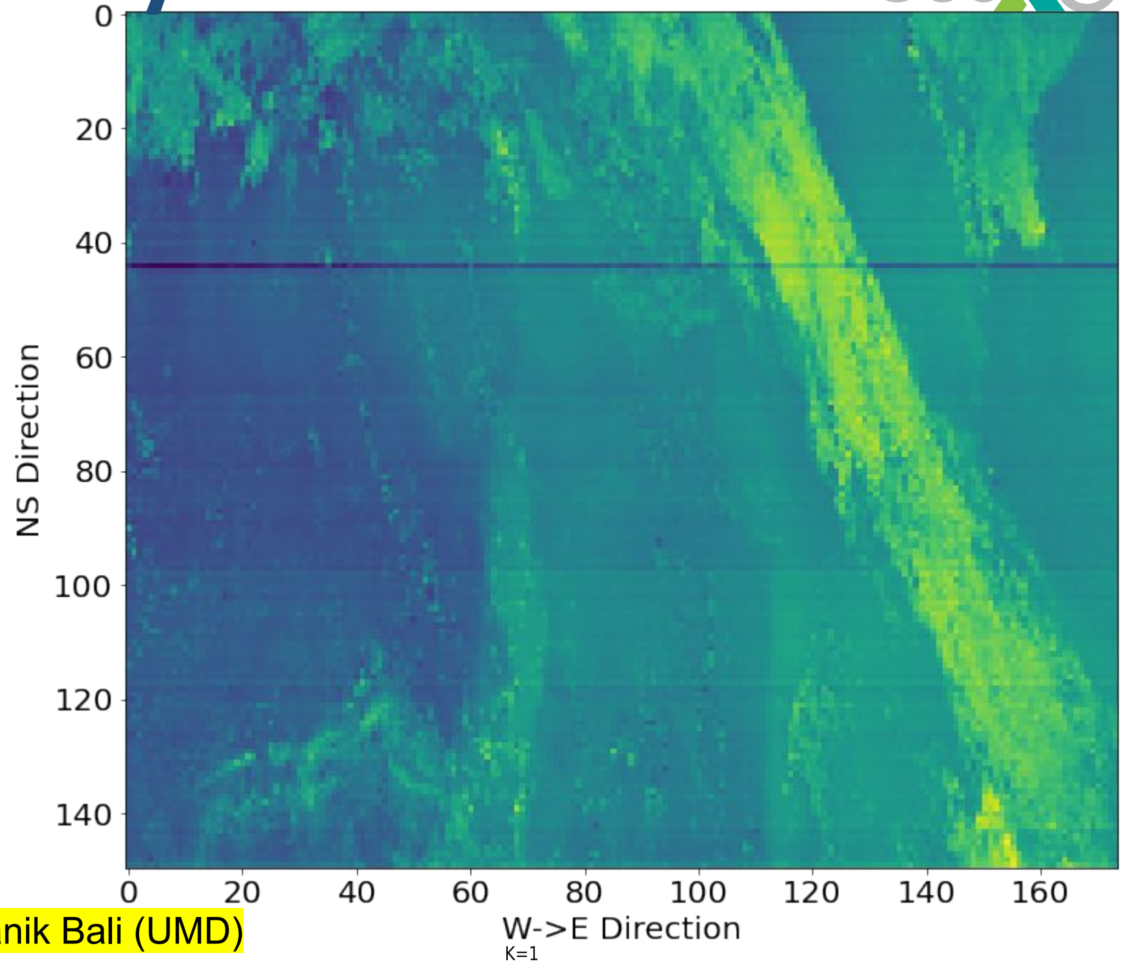
Left: NPP Middle: NOAA-20 Right: NOAA-21

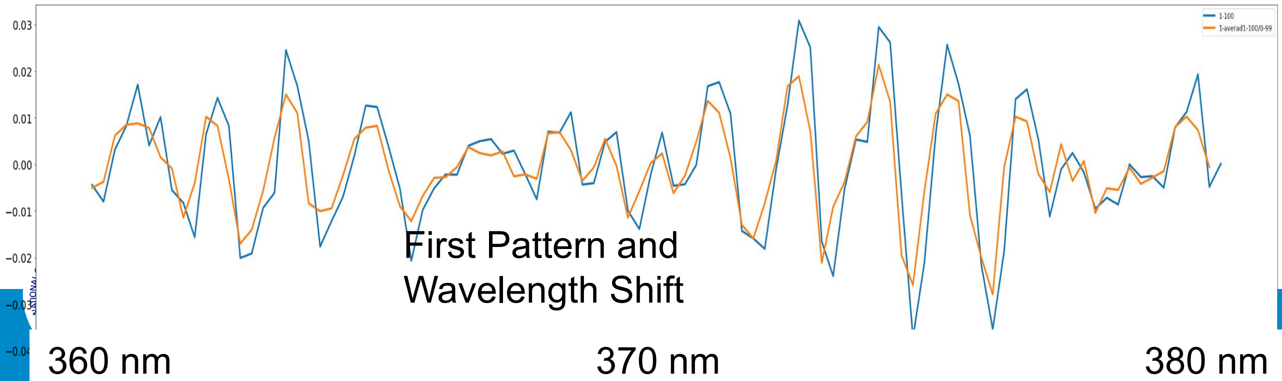


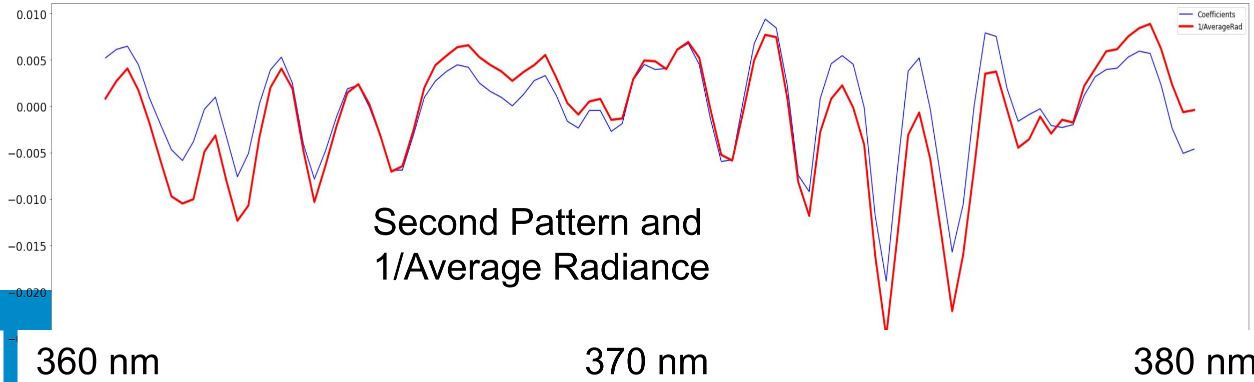
Principal Components Analysis for GEMS



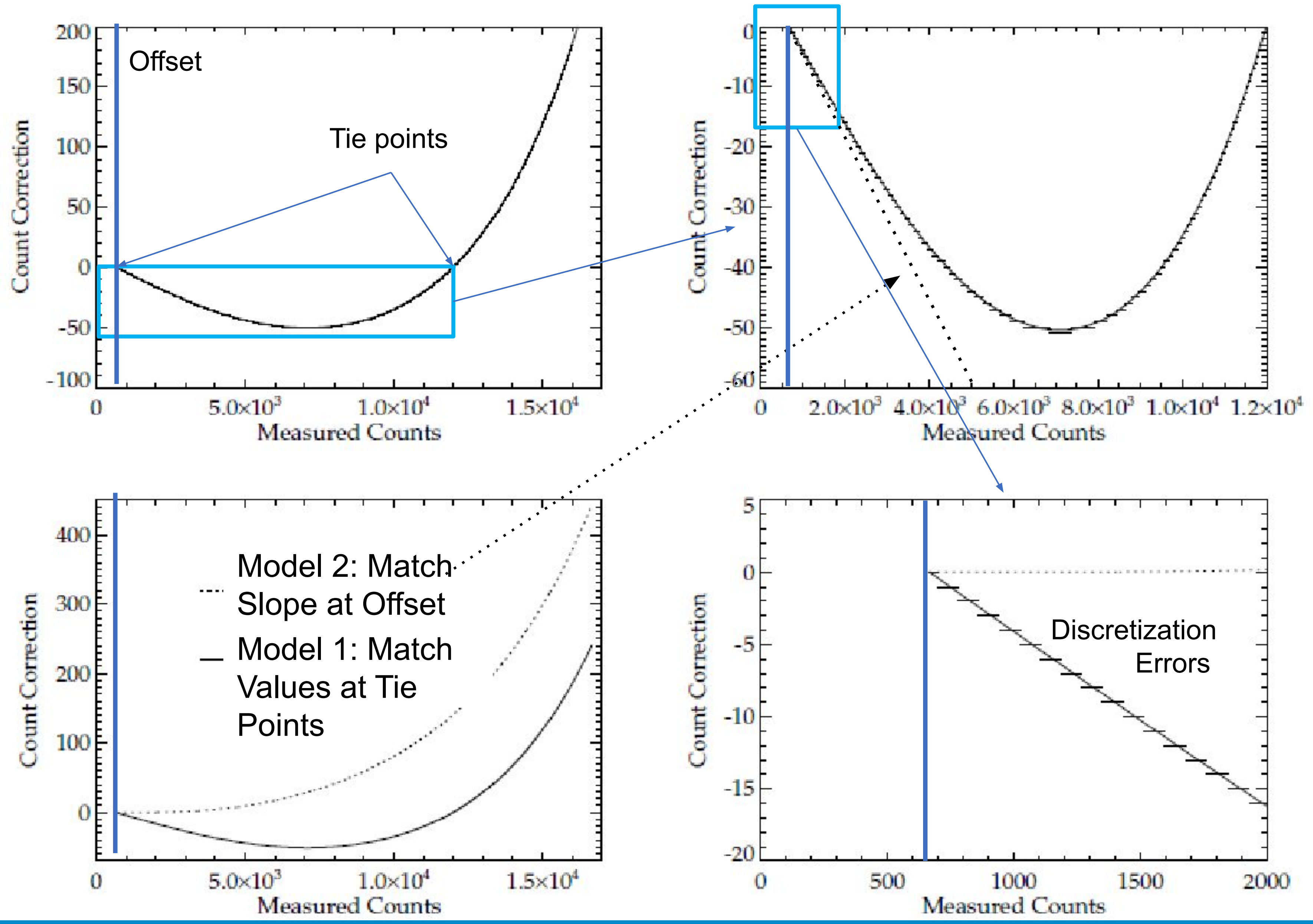
Results provided by Manik Bali (UMD)



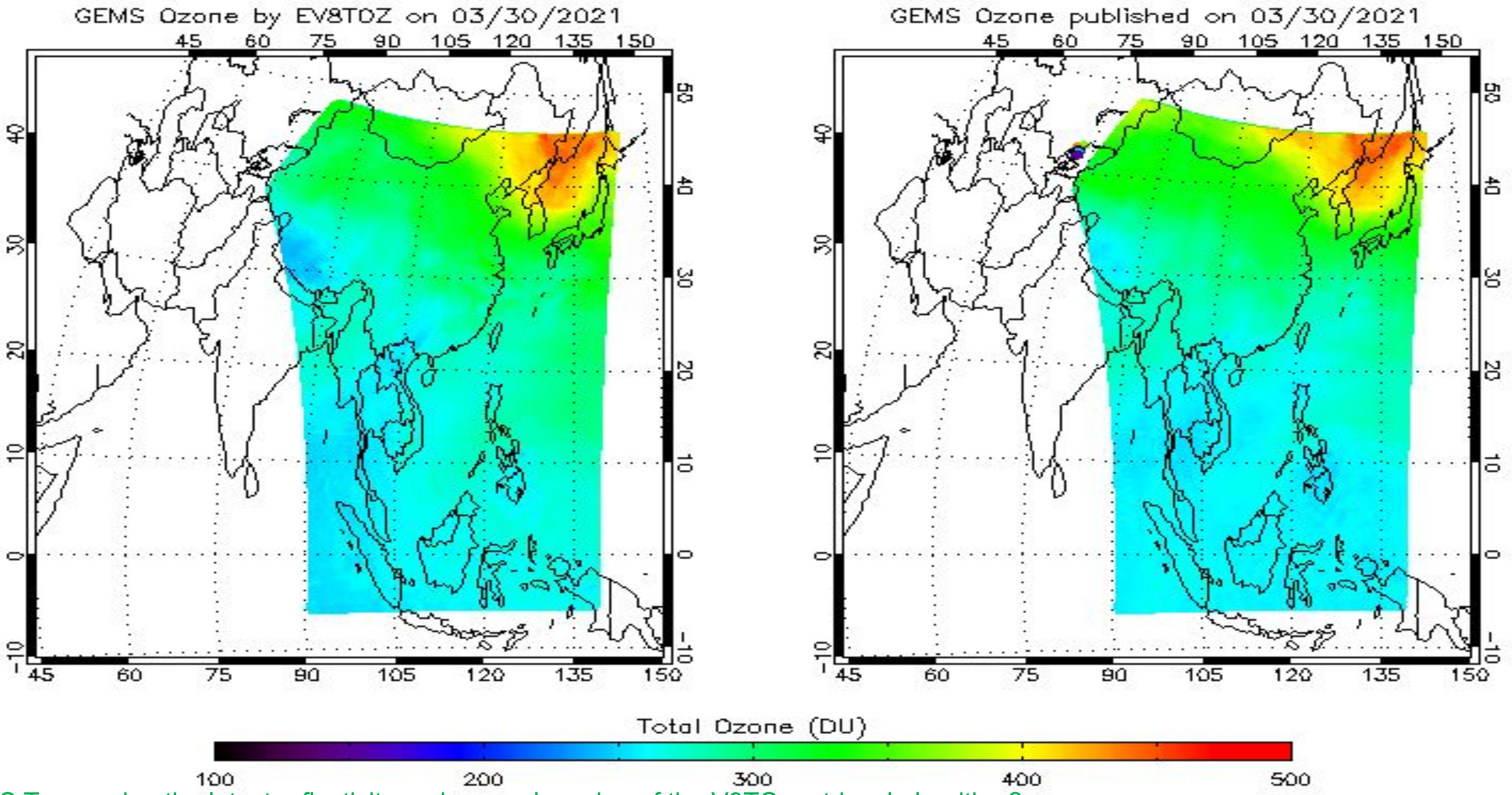




Nonlinearity Corrections
Plots of Discrete Correction Versus Polynomial Models



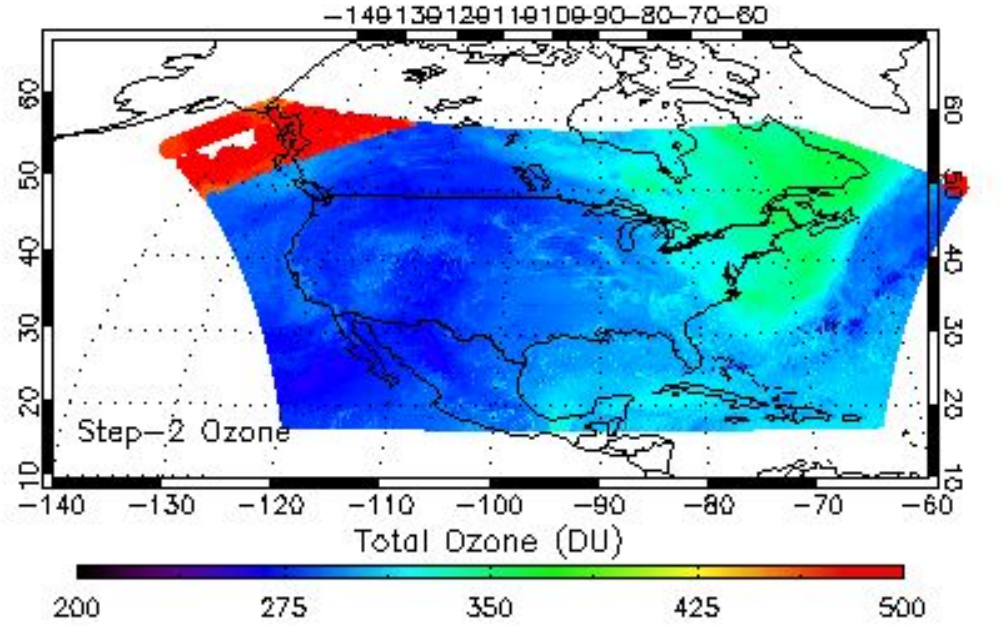
NOAA EV8TOz & GEMS Team V9TOz Retrieved Total Column Ozone for 20210330_0145

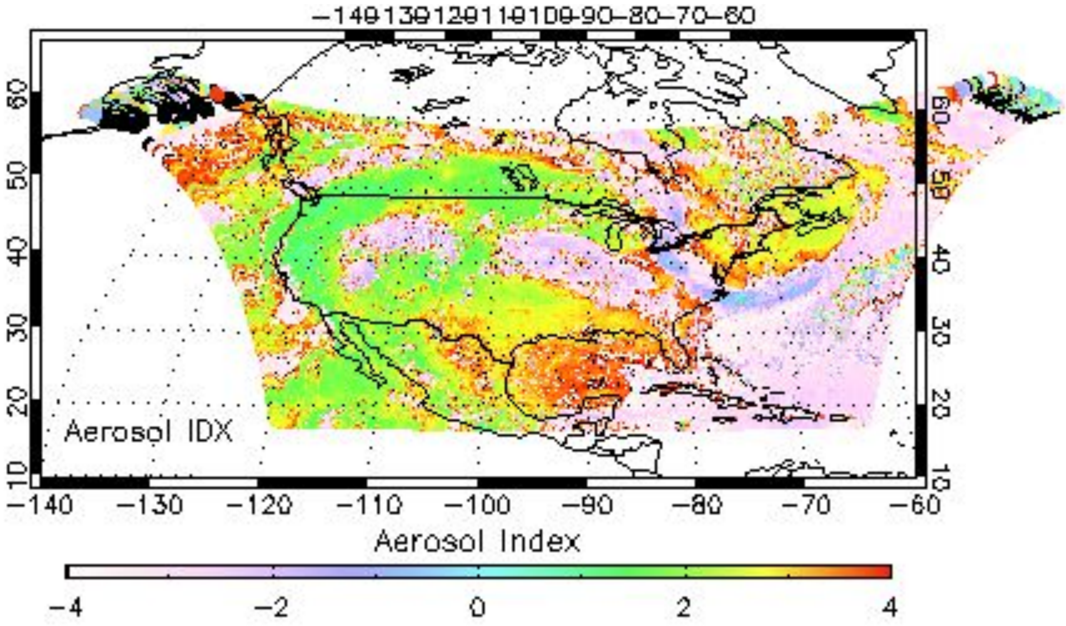


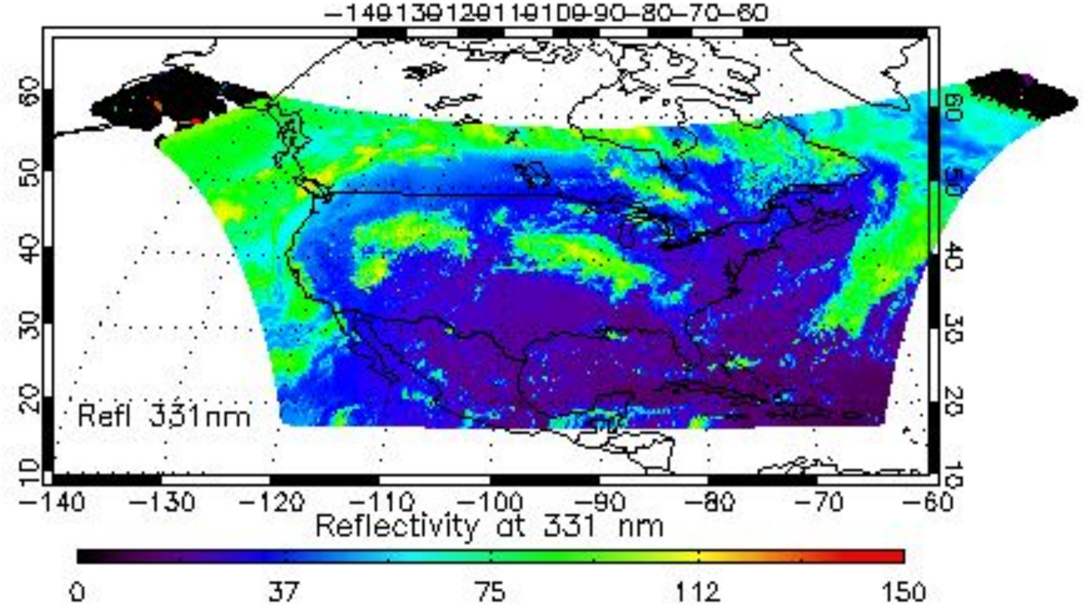
Is the GEMS Team using the latest reflectivity and aerosol version of the V9TOz retrieval algorithm?

Figure created by Jianguo Niu (IMSG)

TEMPO Retrievals from V8TOz







Processing Version-2 solar & L1b data on the Aug. 2, 2023.

Figure created by Jianguo Niu (IMSG)

N21 OMPS Retrievals from V8TOz

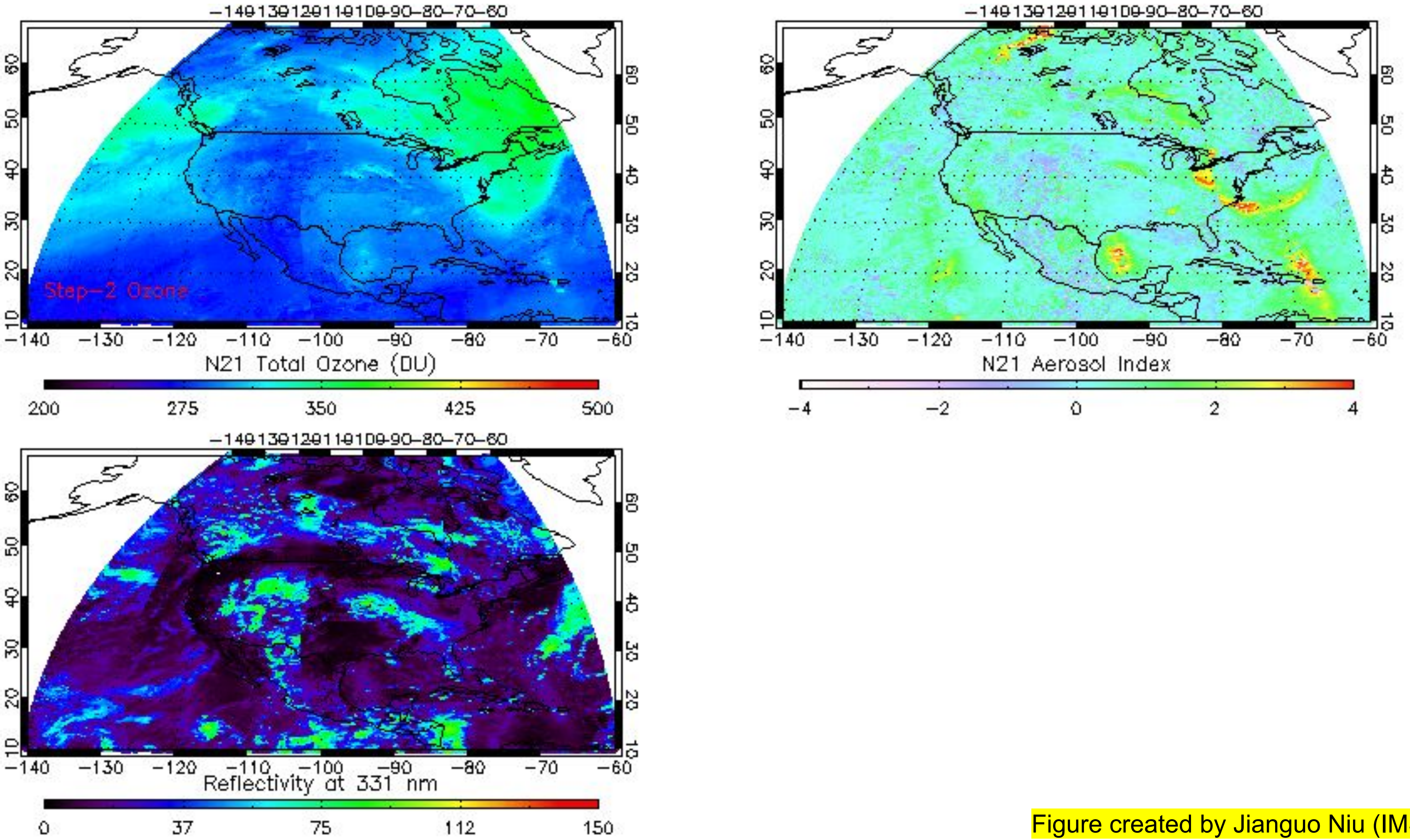


Figure created by Jianguo Niu (IMSG)

Converting Ozone or Reflectivity differences to and from Radiances differences by using V8TOz dN/dR, dN/dxi and dN/dΩ

If you want to increase R and Ω by ΔR and ΔΩ then increase the N-values by

$\Delta N318 = \Delta R\ dN318/dR + \Delta\Omega\ dN318/d\Omega = \Delta R\ A1 + \Delta\Omega\ B1$

$\Delta N331 = \Delta R\ dN331/dR + \Delta\Omega\ dN331/d\Omega = \Delta R\ A2 + \Delta\Omega\ B2$

If you increase the N values by ΔN318 and ΔN331, then the R and Ω increase by

$\Delta R = [C1 * B2 – C2 * B1] / [A1 * B2 – A2 * B1]$

$\Delta\Omega = [C1 * A2 – C2 * A1] / [A2 * B1 – A1 * B2]$

$A1 = dN318/dR$, $B1 = dN318/d\Omega$, $C1 = \Delta N318$

$A2 = dN331/dR$, $B2 = dN331/d\Omega$, $C2 = \Delta N331$

$D = [A1 * B2 – A2 * B1]$ $–D = [A2 * B1 – A1 * B2]$

Given an ozone profile $X = \{x_i\}$ (i=1,N), and sensitivities $dN318/dx_i$ and $dN331/dx_i$, the relative layer efficiencies, E_i, for B-pair are computed as follows:

$C1_i = \Delta N318_i = dN318/dx_i$ $C2_i = \Delta N331_i = dN331/dx_i$

$\Delta\Omega_i = [A2 * C1_i – A1 * C2_i] / [A2 * B1 – A1 * B2]$

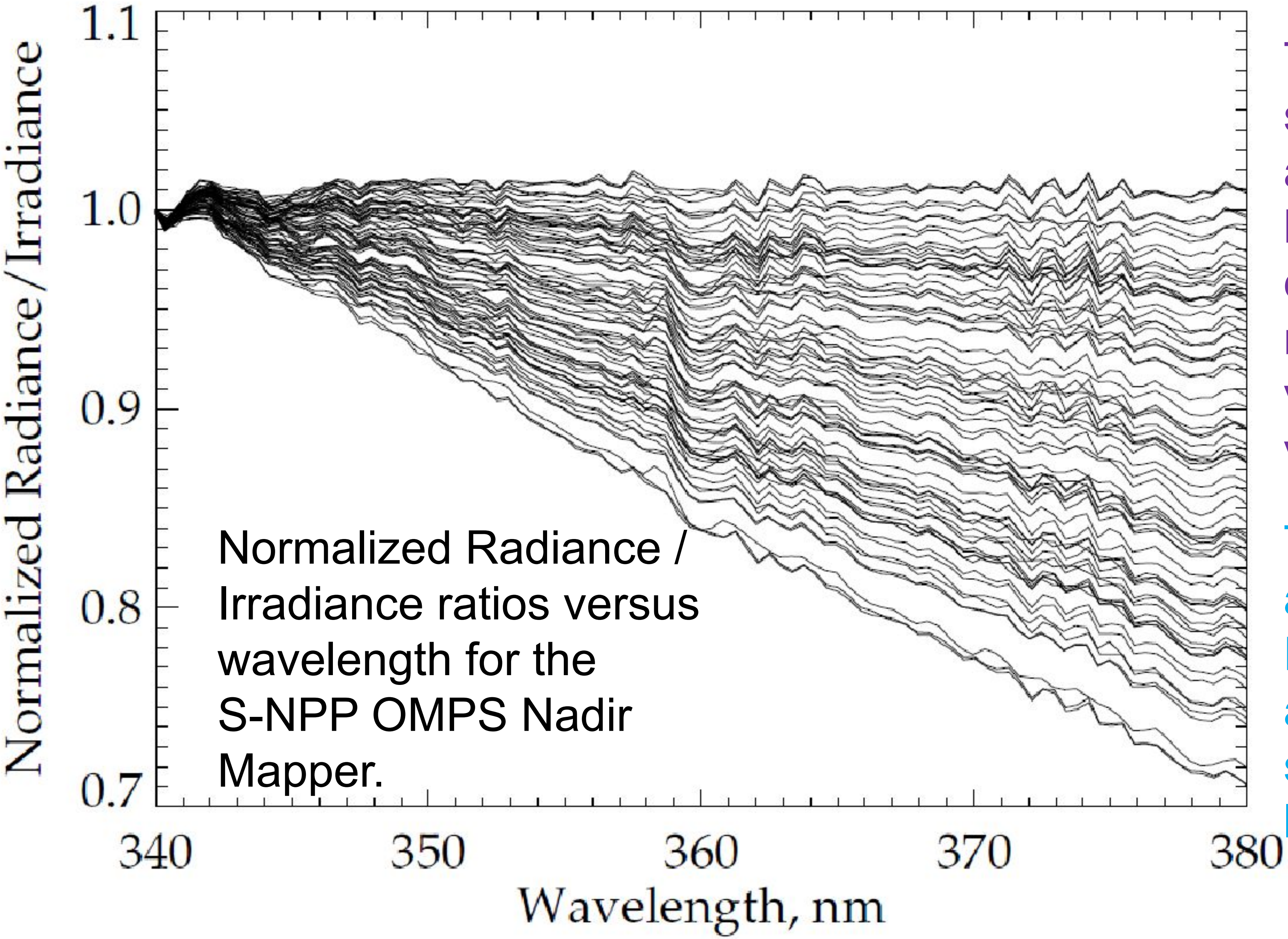
$E_i = \Delta\Omega_i / [SUM(\Delta\Omega_i) / N]$

This assumes all ozone changes are absolute (e.g., in DU). These values should blend the clear and cloudy results appropriately by using the radiative fractions.

One can check the consistency of alternative profile, $Xf = \{xf_i\}$, by computing

$SUM[E_i * (x_i – xf_i)]$

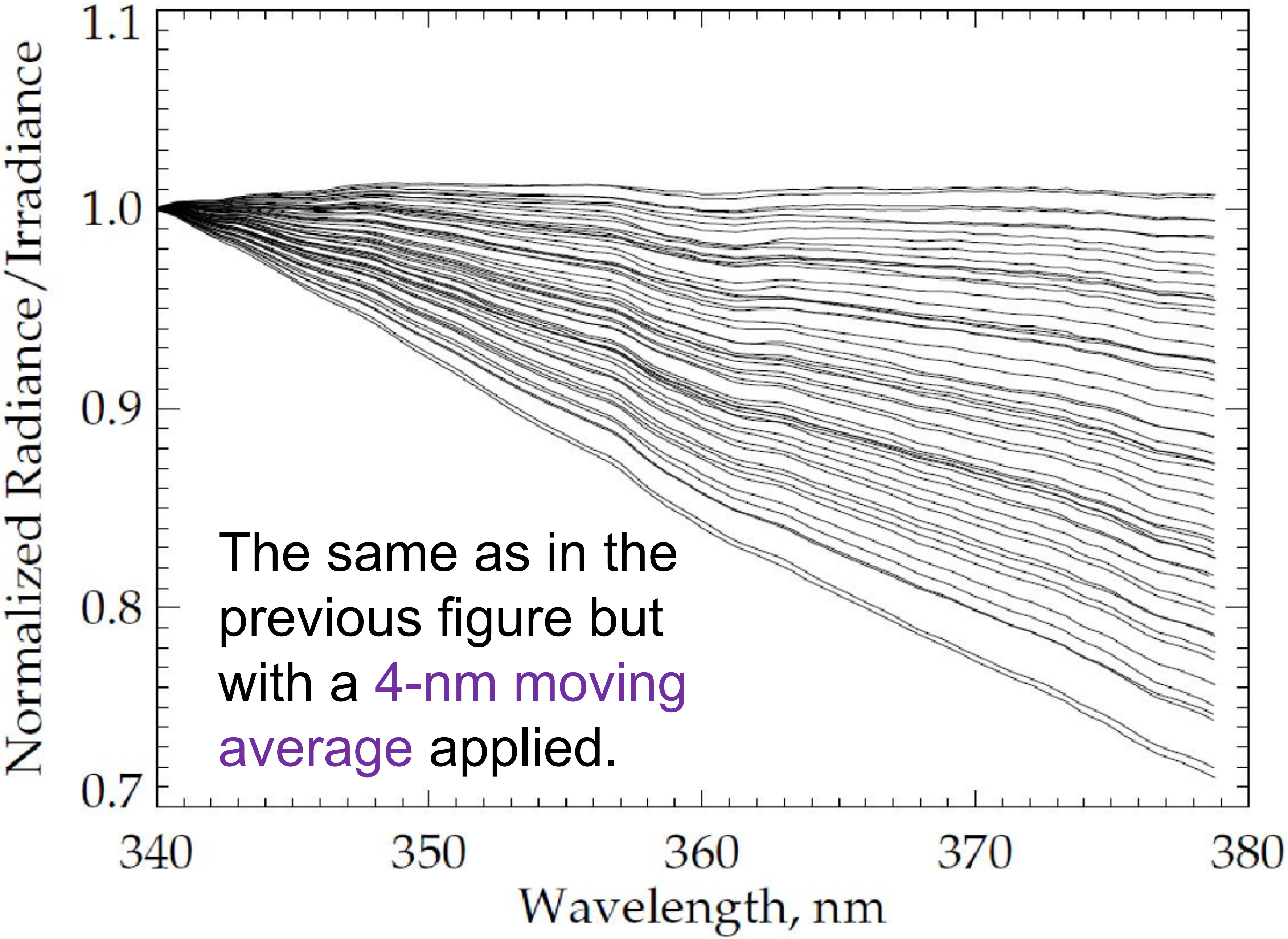
Ω is total ozone in DU, R is effective reflectivity, and N is -100*log10(I/F)



Normalized Radiance / Irradiance ratios versus wavelength for the S-NPP OMPS Nadir Mapper.

The clouds, Rayleigh scattering and absorbing aerosol signals create the broad wavelength dependence in the radiances as scenes and viewing and solar angles vary.

The small scale features are produced by Ring Effect, trace gas absorption, wavelength scale shifts and stray light.



The same as in the previous figure but with a 4-nm moving average applied.

The absorbing aerosol signals are preserved but small scale features are greatly reduced.

For retrievals of some aerosol properties, we can degrade the spectral resolution and treat OMPS and other spectrometer as a filter instruments.