GSICS/CEOS UV Projects

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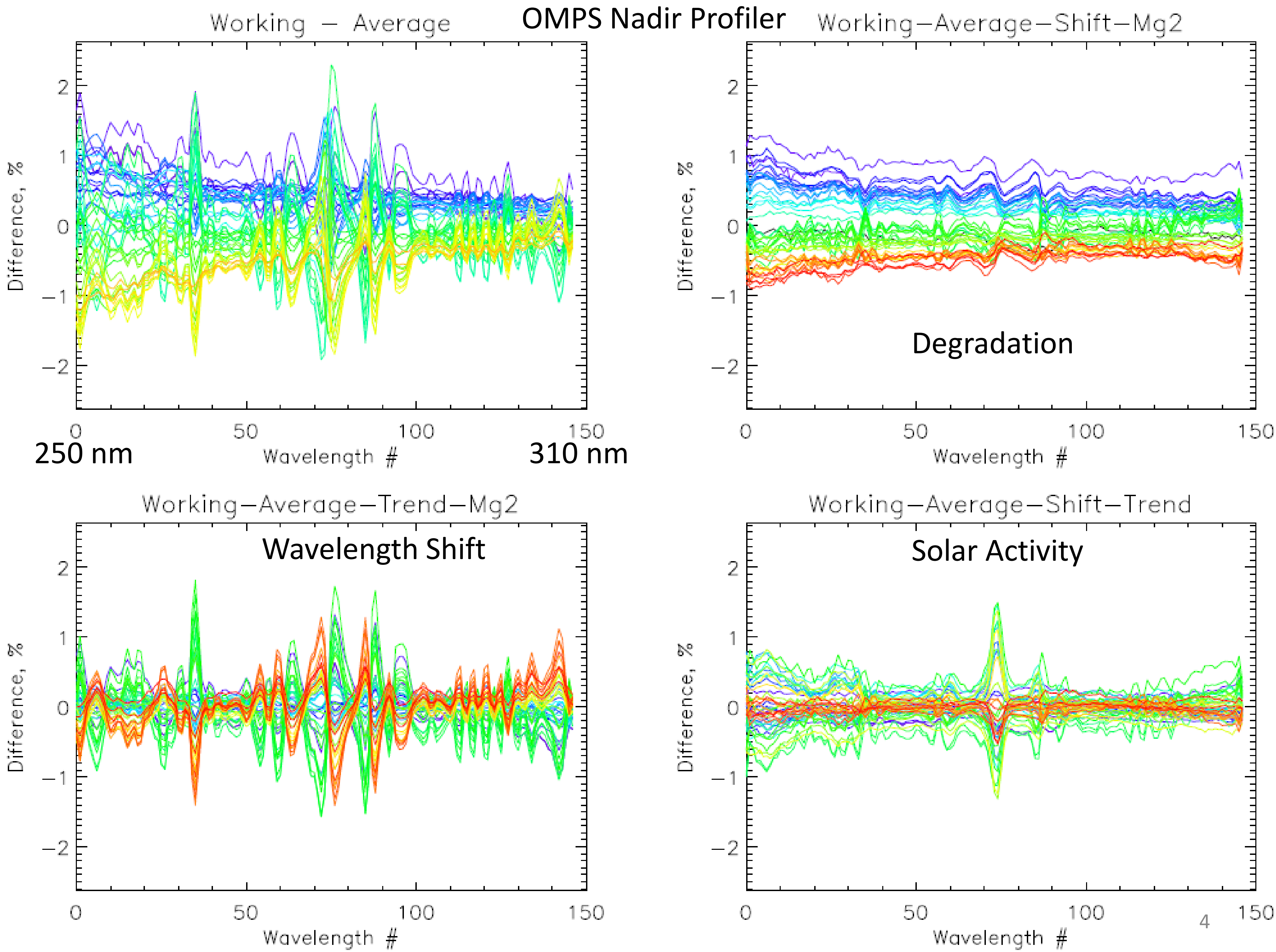
With slides and results from
NOAA, NASA & EUMETSAT
GRWG UV Subgroup participants

Outline

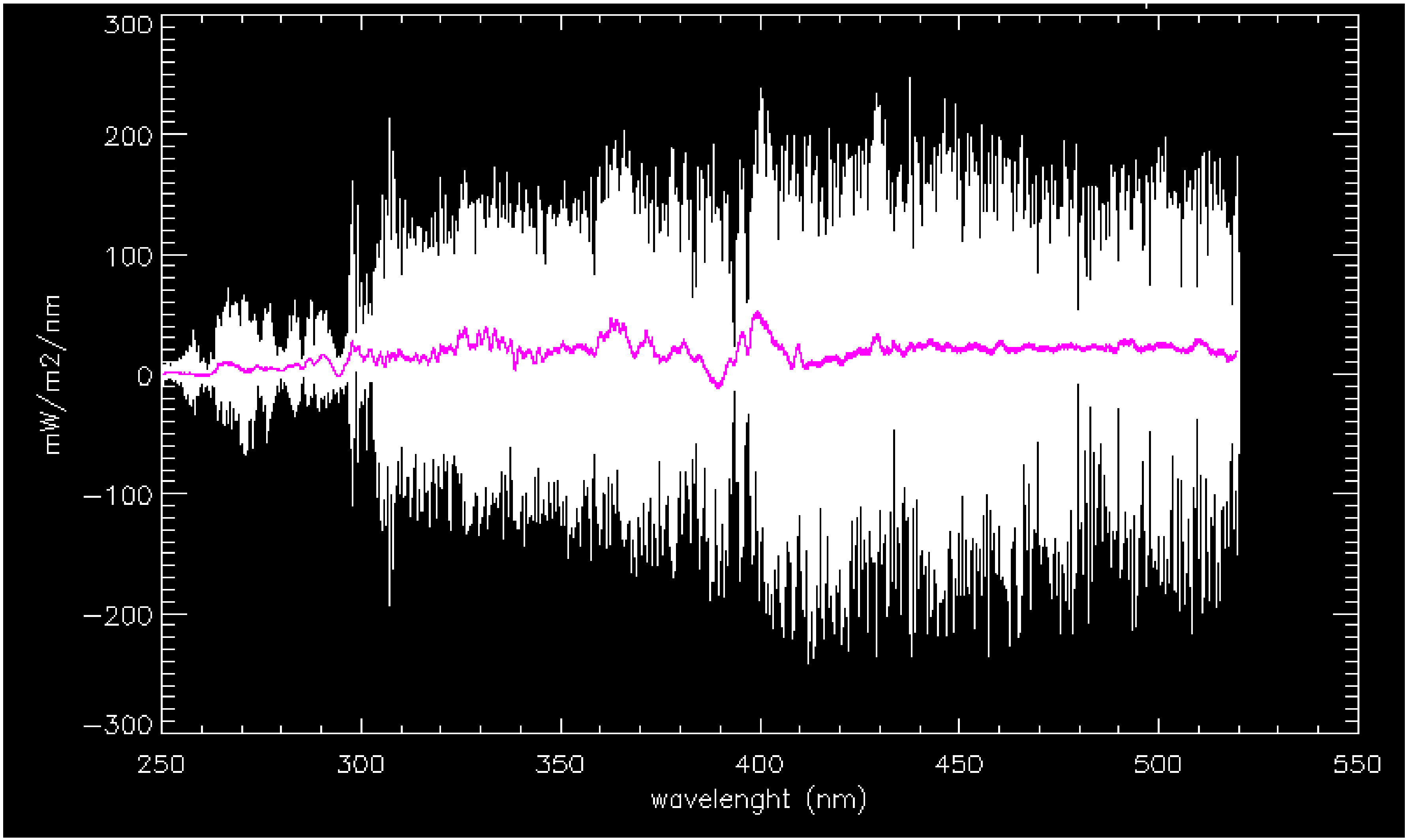
- Comparisons of Solar Spectra
- Comparisons of Effective Reflectivity and Aerosol Indices
- Comparisons of Initial Measurement Residuals
- Key ground-based calibration measurements
- Match-up comparisons

Solar Spectra Project

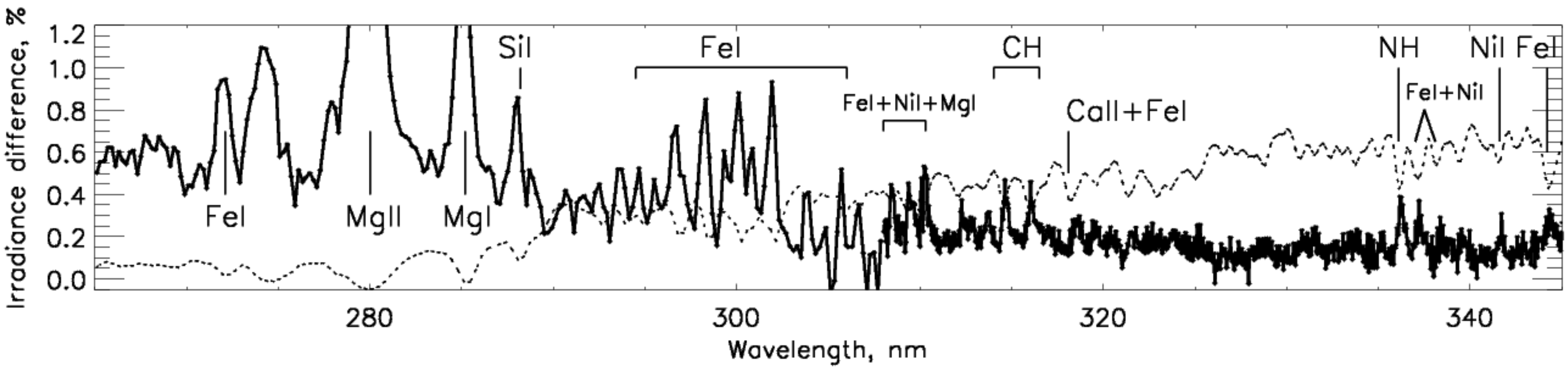
- The purpose of the is project is to compare solar measurements from BUV (Backscatter Ultraviolet) instruments.
- The first step is to catalog high spectral resolution solar reference spectra and agree on a common one to use for the project.
- For each instrument, participants should provide the following datasets:
  - Solar measurement for some date (wavelength scale, irradiance)
  - Wavelength scale and bandpass ($\Delta\lambda$, # of points, bandpass centers, normalized bandpass weights)
  - Synthetic spectrum from common reference (wavelength scale, irradiance)
  - Synthetic for wavelength scale perturbations ($\pm$0.01 nm) from common reference (wavelength scale, irradiance)
  - Synthetic from alternative reference spectra (wavelength scale, irradiance)
  - Solar activity pattern (wavelength, relative change)
  - Mg II index (if 280 nm is covered) Mg II 279.6 Mg I 285.2 (date, index)
  - Ca H/K index (if 391 nm to 399 nm is covered) CA II 393.4 and 396.8.
- Goals:
  - Agreement at 1% on solar spectra relative to bandpass-convolved high resolution spectra as a transfer after identifying wavelength shifts and accounting for solar activity
  - Long-term solar spectra drift and instrument degradation by using OMI solar activity pattern (with internal confirmation from Mg II Indices and scale factors)


OMPS Nadir Profiler
Working – Average
Difference, %
Wavelength #
250 nm
310 nm
Working–Average–Shift–Mg2
Degradation
Difference, %
Wavelength #
Working–Average–Trend–Mg2
Wavelength Shift
Difference, %
Wavelength #
Working–Average–Shift–Trend
Solar Activity
Difference, %
Wavelength #

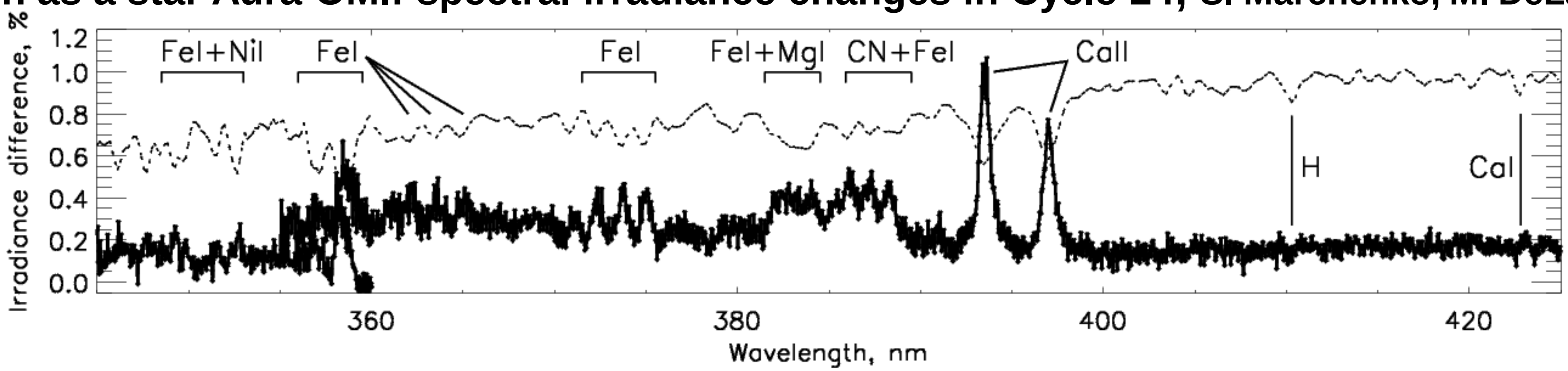
Comparisons for two Reference Spectra

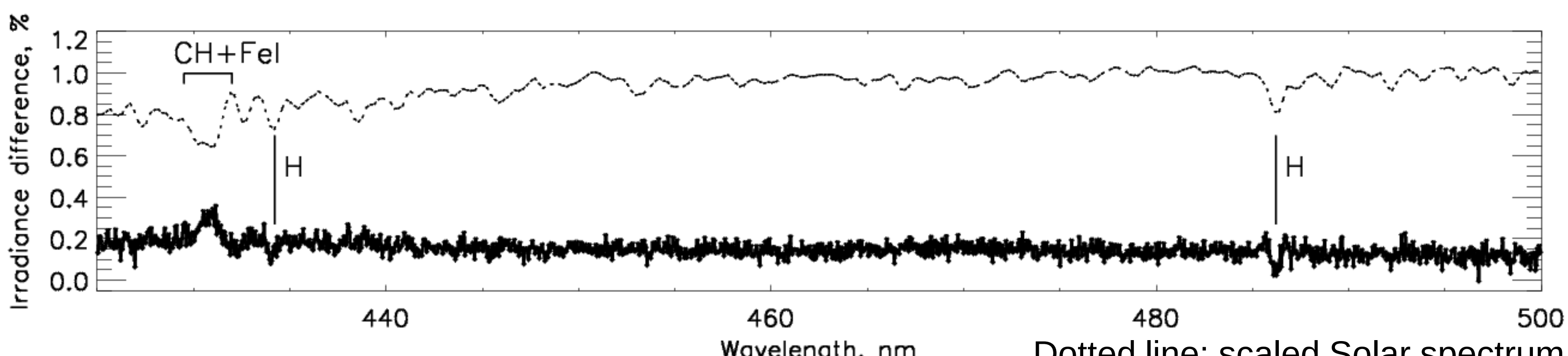


Time-averaged irradiance differences: (mid-y2012+y2013) vs. (mid-y2007+y2008+mid-y2009)



Sun as a star Aura OMI: spectral irradiance changes in Cycle 24, S. Marchenko, M. DeLand





Dotted line: scaled Solar spectrum

Effective Reflectivity Project

The aim is to produce over-pass comparisons of UV/Vis sensors for specific target sites in use by the community. As a first step, summaries of methods and results for target sites currently in use will be collected. We will compare measurements at reflectivity channels from 330 nm to 500 nm.

- Ice, desert and open ocean targets.
- Absolute Radiance/Irradiance check; Track variations over time.
- Reflectivity range/distribution, 1-percentile, Deep Convective Clouds (DCC)
- Wavelength Dependence – Aerosol Indices, Clean atmospheres
- Complications
  - Viewing and Solar angle considerations
  - Sun Glint
  - Surface pressure
  - Partially cloudy scenes
  - Polarisation
  - Inelastic Scattering
  - Turbidity, chlorophyll
- Compare Global monthly surface reflectivity data bases
- Goals
  - Agreement at 1% on cloud free scene reflectivity for 340 nm. Desert, Equatorial Pacific, Polar Ice.
  - Agreement at 1% on aerosol index – wavelength dependence of reflectivity.
  - Long-term reflectivity channels at 0.5% stability

Initial Measurement Residual Project

The purpose of this project is to use initial measurement residuals from the Version 8 ozone profile retrieval algorithm to compare channels from 240 nm to 290 nm. (Note, this will require modification of the first guess creation to use consistent total ozone starting values as inputs.)

- Ascending/descending equivalent channel ideas will be used with hyperspectral measurements.
- Zonal mean and other matchup criteria will be used both to establish offsets and track relative drifts.
- Expand SBUV(/2) results to other sensors (OMPS, SBUS, OMI, GOME-2)
- Monitor time dependence for multiple instruments.

http://www.star.nesdis.noaa.gov/smcd/spb/OMPSDemo/proSBUV2released-2.php
http://www.star.nesdis.noaa.gov/smcd/spb/OMPSDemo/proOMPSbeta.O3PRO_V8.php

- Goals
  - Agreement at 2% for Profile channels by using the Version 8 *A Priori* Profiles with TOMRad Tables and single scattering.

Outline of an Approach for Comparisons of radiance/irradiance ratios from 240 nm to 300 nm

Double Difference using Climatology:

Compute the measurement residuals using a forward model with the effective scene reflectivity of the clouds and surface determined from longer channel measurements, and the ozone profile prescribed by the Version 8 *a priori* climatology. Use viewing geometries and bandpasses are as reported for each instrument.

Compare residuals for channels $\lambda 1$ and $\lambda 2$ where $S1 * \alpha 1 = S2 * \alpha 2$, where S values give the path lengths and α values give the ozone absorption cross sections. That is, works with pairs of wavelengths where the measurement contribution functions are similar.

Perform comparisons (statistical trade off in quantity of matchups vs. quality)

- Simultaneous nadir overpass matchups
- Zonal means (and No-local-time differences zonal means)
- Opportunistic formation flying / Chasing orbits
- Benign geographic regions (e.g., Equatorial Pacific Box)
- Ascending/descending zonal means (In the Summer hemisphere, the same latitude is observed twice so one can obtain a set of internal comparisons.)

Forward model and measurements

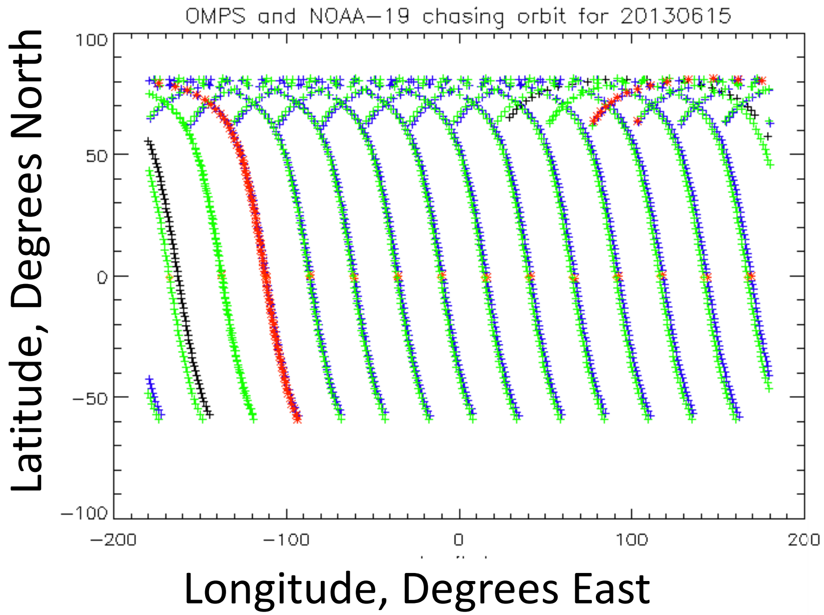
- V8 SBUV/2 forward model and *A Priori* as transfer for Viewing conditions

Complications from real diurnal variations in the ozone profiles

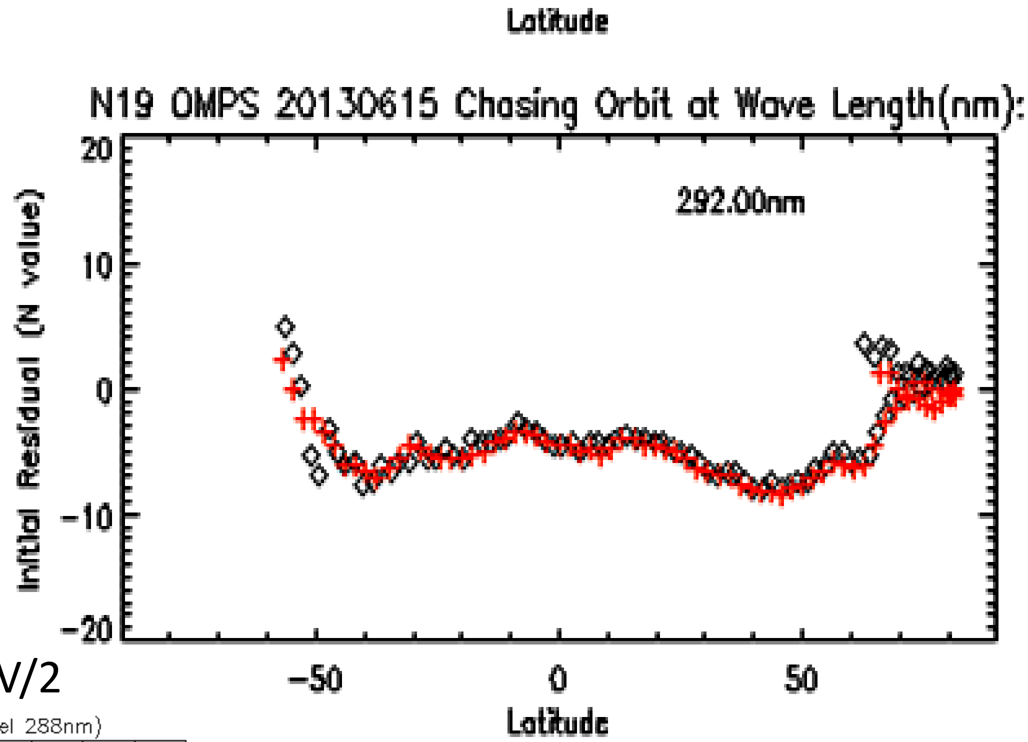
Complications if best ozone product values differ and initial residuals are used

Measurement residuals' correlation with scene reflectivity for longer wavelengths can disclose stray light contamination.

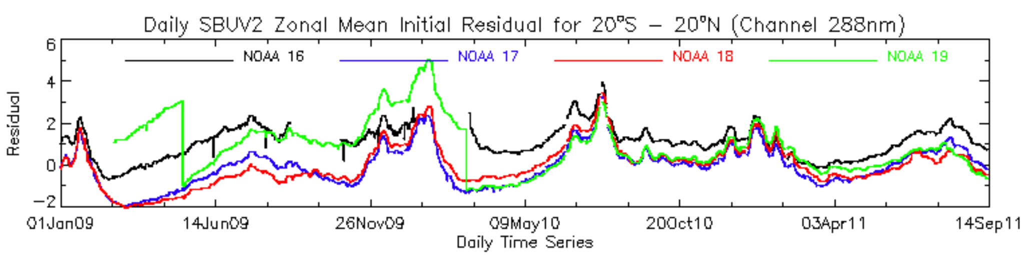
Well-matched Orbits for 6/15/2013

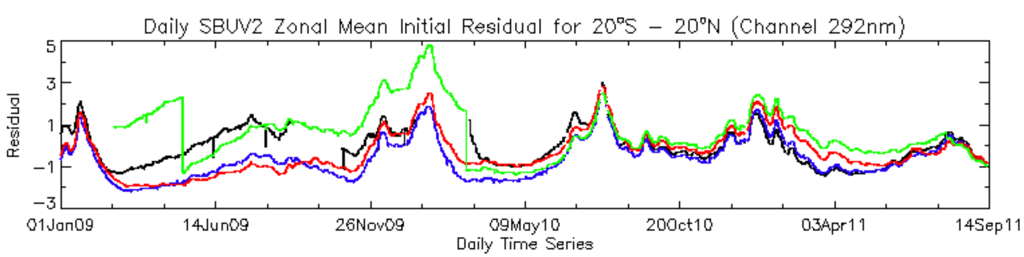


Comparison of Initial V6 Measurement Residuals for S-NPP OMPS NP and NOAA-19 SBUV/2



Operational Initial Residuals for SBUV/2





Daily Means
Equatorial Pacific Box
20S – 20N Latitude
100W to 180W Longitude

Ground-Based Characterization

- White Paper on Ground-based Characterisation of UV/Vis/NIR/SWIR spectrometers [Lead – Rüdiger Lang (EUMETSAT)]
- The aim of this activity is to prepare a white paper documenting best-practises for the on-ground calibration of UV/Vis/NIR/SWIR spectrometers based on in-orbit experience from relevant missions.
- GSICS has a survey that is still open at:

https://docs.google.com/a/noaa.gov/forms/d/1sXbhrq85aPa5Yh-gycNleX47CKkdjDZgb2lMY97-6sY/viewform

Your participation is welcome.

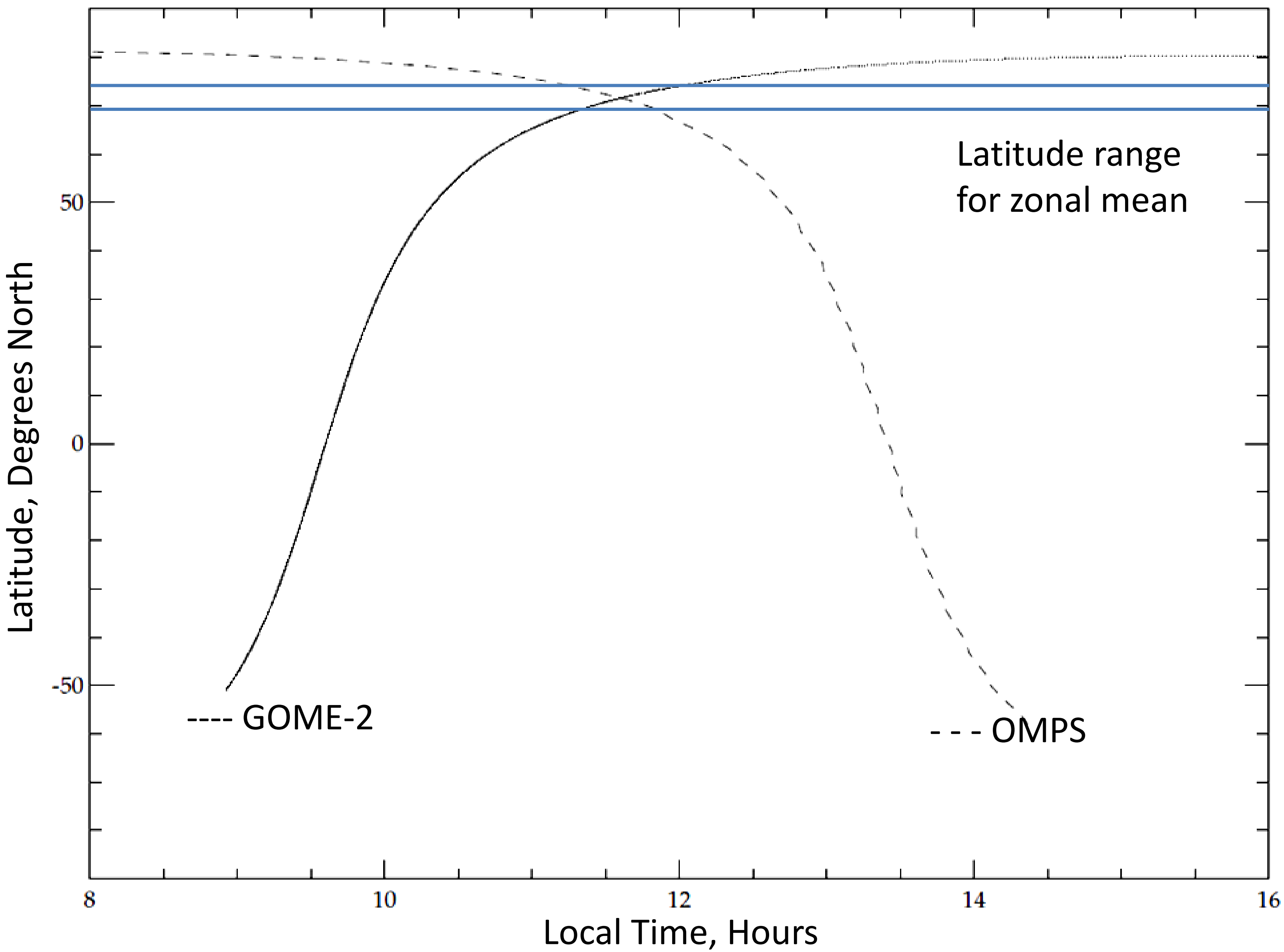
Match-Up Comparisons

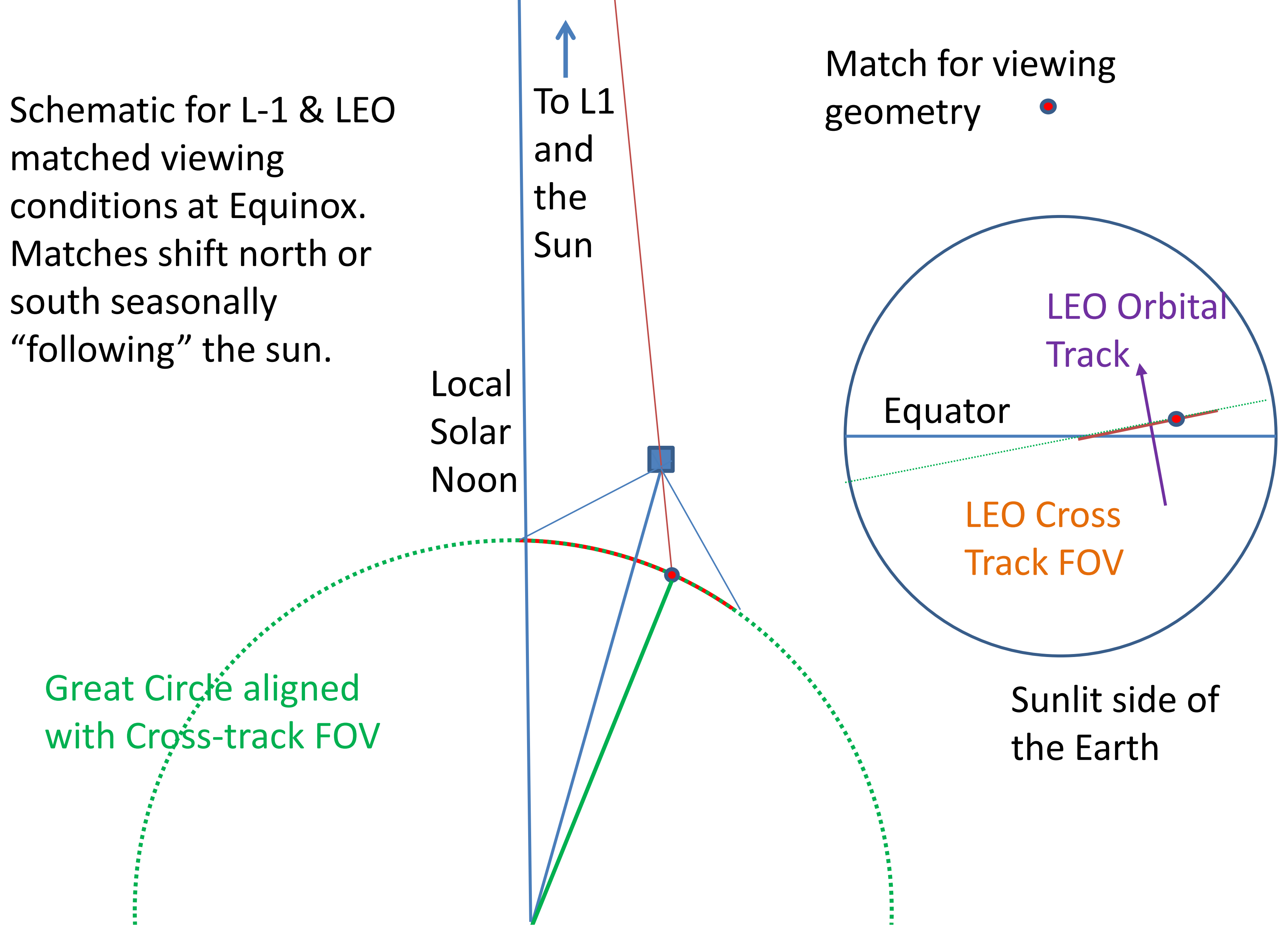
We would also like to expand the use of matchup comparisons for UV instruments. Current approaches include:

- Zonal Means (including ascending/descending repeat coverage – $S1*\alpha1 = S2*\alpha2$)
- LEO vs LEO Simultaneous Nadir Overpass (and its non-simultaneous No-Local-Time-Difference zonal means)

  Can OMPS monitor VIIRS 420 nm channel degradation?
- Chasing Orbits (Opportunistic Formation Flying)
  - S-NPP and EOS-Aura have 16-day repeat cycles but one makes 227 orbits and the other 233 so every 64 hours they are flying with orbital tracks within (360/14)*110*3/(14*8*2) ~ 40 km of each other, 15 minutes apart.
  - For NOAA-19 and S-NPP, the matchups are every 12 days – (360/14)*110/(14*12*2) ~ 9 km.
- LEO underflights of GEO and L-1 instruments – Coincident Line-of-Sight Observations. (GOME-2 vs. SEVIRI, OMPS vs. TEMPO)

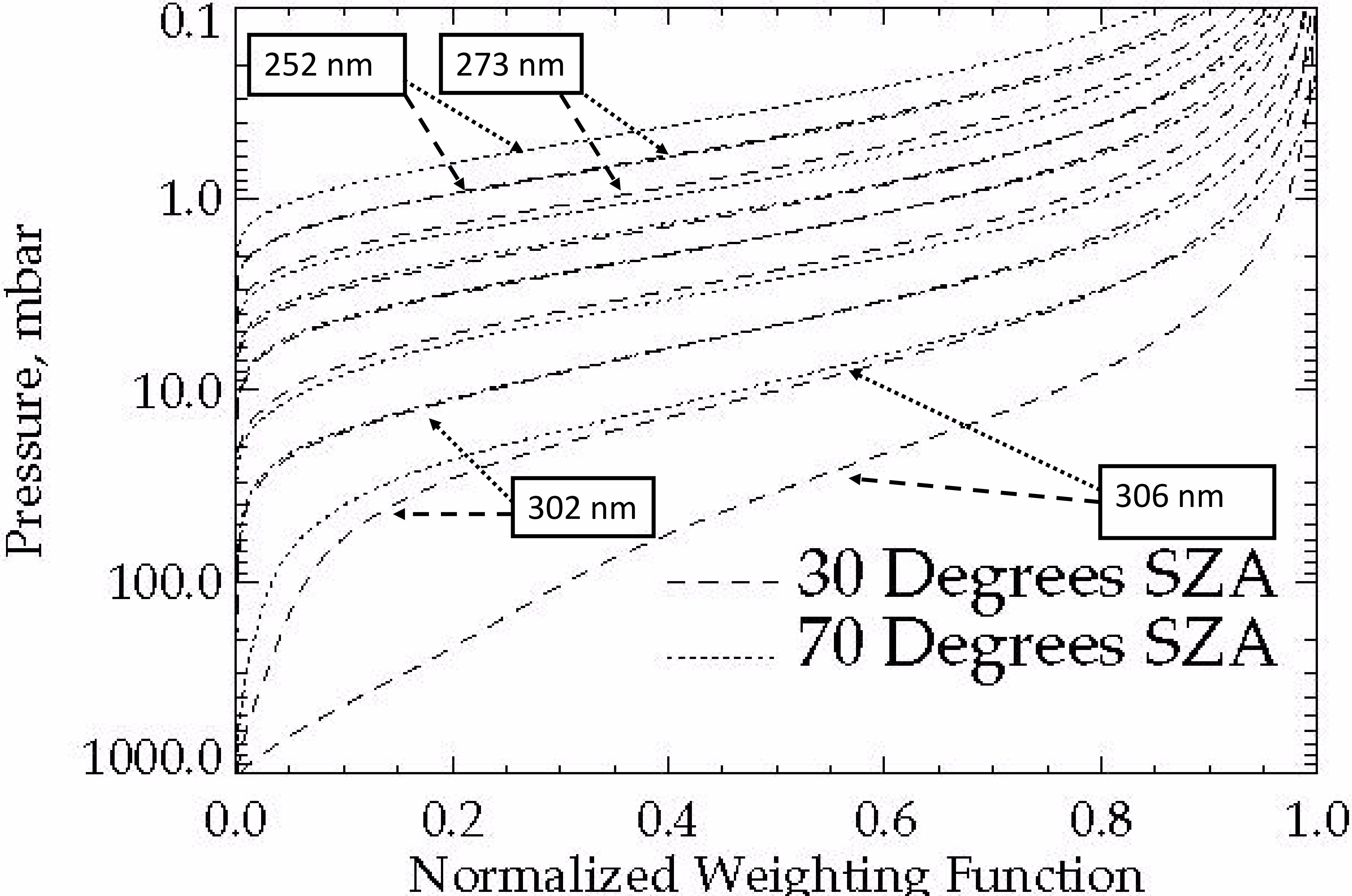
Simultaneous Nadir Overpass and No Local Time Difference Comparisons





Simultaneous View Path (SVP) match up between DSCOVR EPIC at 0° offset with the Earth/Sun line and S-NPP OMPS. Matches will be present for any BUV instrument on a GEO platform with one in a LEO orbit as the LEO orbital tracks pass near the GEO sub-satellite point.

Backup



$S1 * \alpha 1 = S2 * \alpha 2$, $Si = 1 + \sec(SZAi)$ for nadir viewing

Instrument and Project Leads

Instrument	Main Contact Web Site	Reflectivity/ Aerosols	Solar Spectra	Ozone Profiles	Calibration
ACE/MAESTRO					
EPIC 2015					
GEMS 2018					
GOME					
GOME-2	R. Lange EuMetSat				R. Lange
GOMOS					
MLS					
OMI		O. Torres	M. DeLand		
OMPS Nadir	L. Flynn NOAA			L. Flynn	
OMPS Limb	G. Jaross NASA				
OMS					
OSIRIS					
SAGE III	D. Flittner NASA				
SBUS	F-X. Huang CMA			F-X. Huang	
SBUV/2	L. Flynn NOAA			L. Flynn	
SCIAMACHY	M. Weber Bremen		M. Weber		
TEMPO	K. Chance SAO				
TOMS					
TOU	W-H. Wang CMA	W-H. Wang			
TropOMI					
UVN					Berit/Marcel

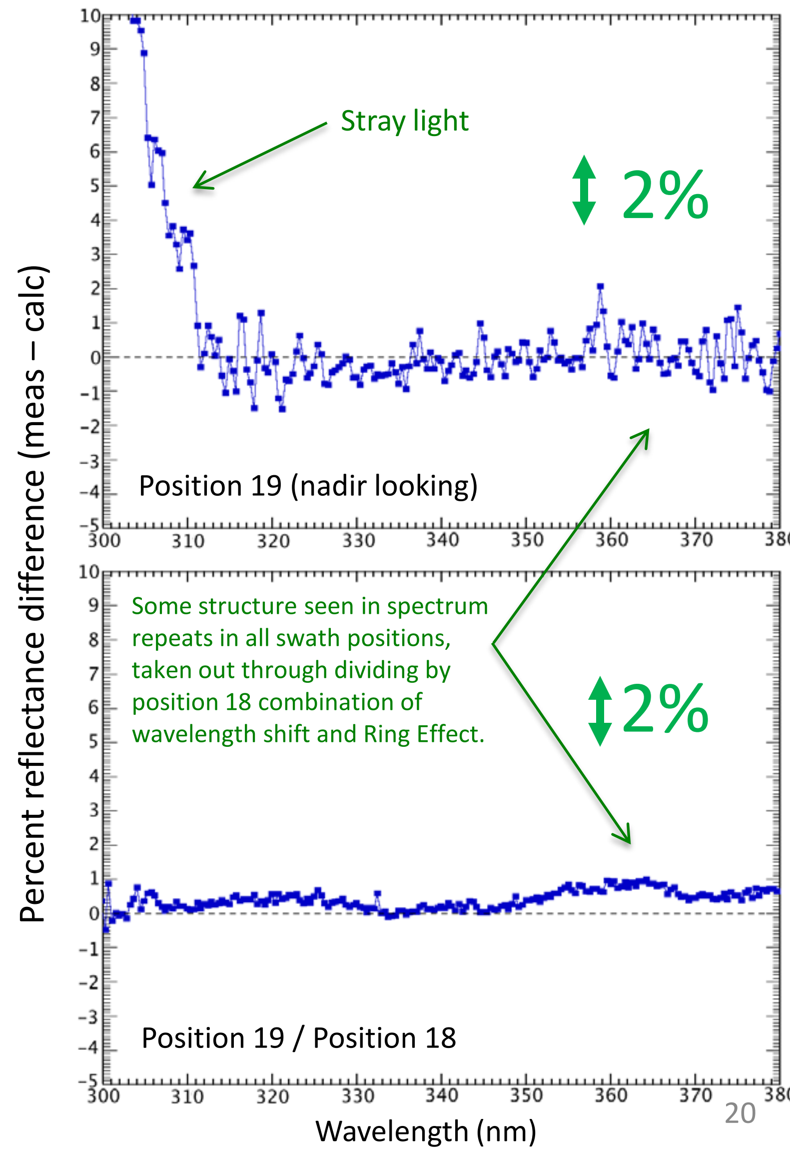
Project to Compare Solar Measurements

- High resolution solar reference spectra
  - Reference high resolution solar Spectra (SOLSTICE, SIM, Kitt Peak, etc. – Everybody has a favorite. How do they compare?)
  - Mg II Index time series, Scale factors at high resolution
- Instrument data bases
  - Bandpasses, wavelength scales (Shift & Squeeze codes)
  - Day 1 solar, time series with error bars (new OMI product) (Formats, Doppler shifts, 1 AU adjustments)
  - Mg II Indices and scale factors at instrument resolution
  - Reference calibration and validation papers
- Using the information from above we can compare spectra from different instruments and times

OMPS TC comparisons with modeled Top-of-atmosphere reflectances using MLS ozone retrievals as truth are quite good

- Co-locate MLS temperature and ozone profiles to OMPS TC measurements
  - Reflectivity < 0.10
  - -20 < latitude < 20 degrees
  - June 2012
- Calculate TOA reflectances (radiance / solar flux) from TC viewing conditions, MLS profiles using radiative transfer code (TOMRAD)
- Compare measured OMPS TC reflectance with calculated reflectance
  - Agreement seen to within 1% for wavelengths > 312 nm
- Stray light seen for wavelengths < 312 nm
  - Consistent with pre-launch sensor characterization

MLS results from C. Seftor, SSAI for NASA GSFC



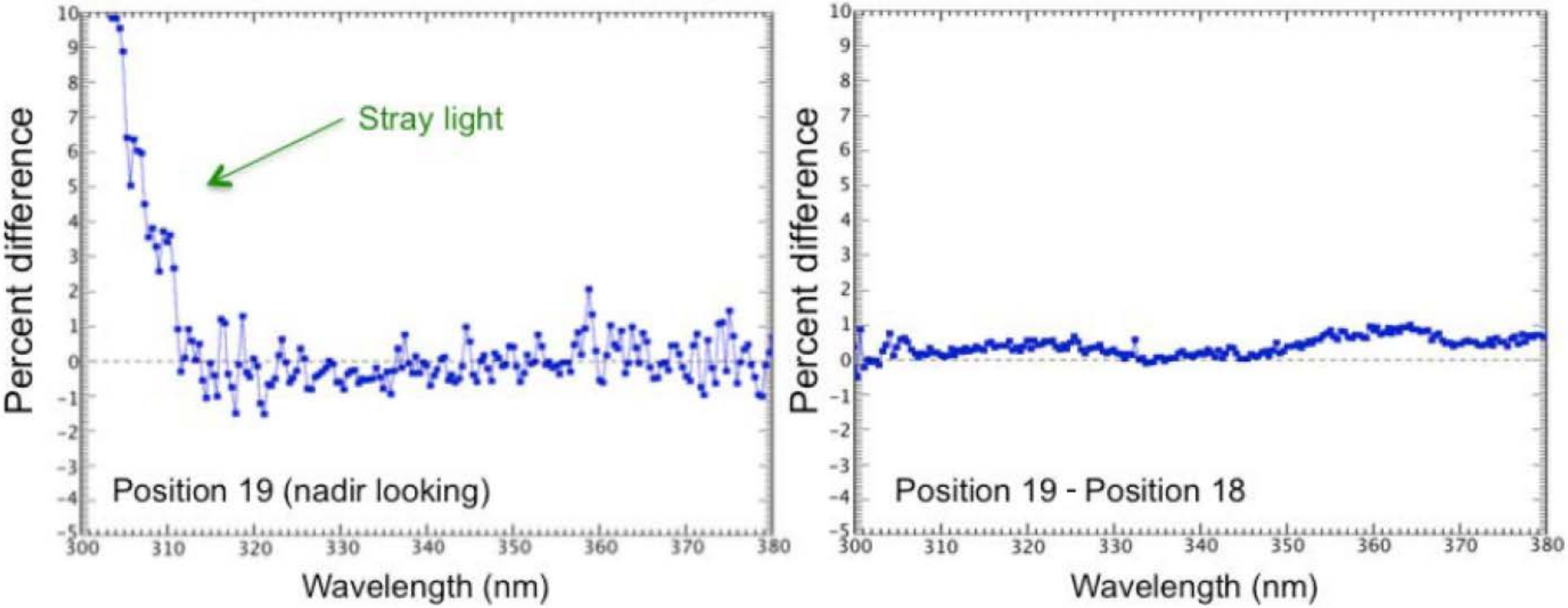


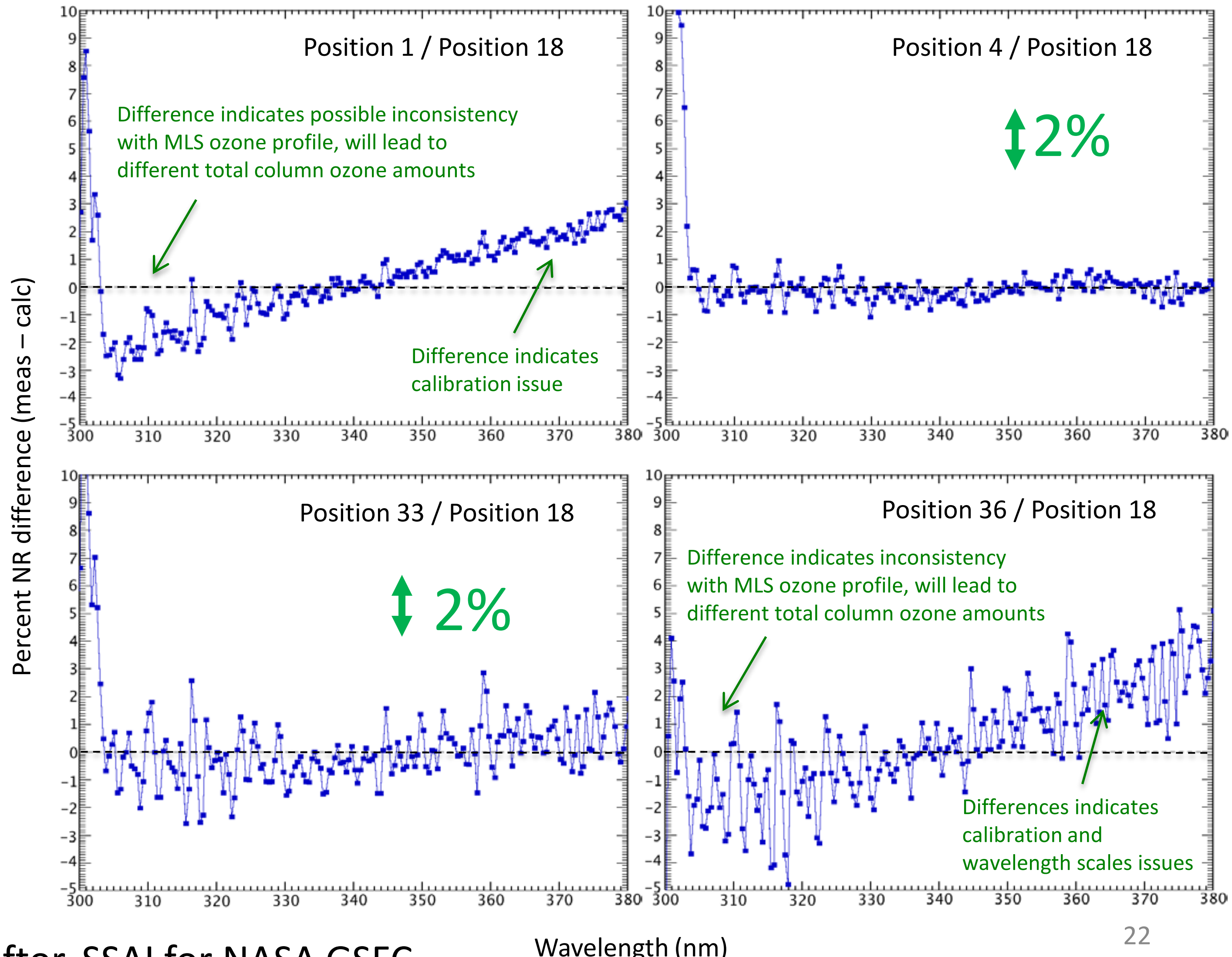
Figure 4: The left plot shows a comparison of normalized radiances calculated using MLS ozone and temperature profiles co-located with OMPS retrievals using the OMPS viewing conditions for cross-track position 19. The average is over 20 degrees south to 20 degrees north latitude for June. In the right plot, the difference for position 18 is subtracted from position 19.

Results from C. Seftor, SSAI for NASA GSFC

OMPS TC cross-track calibration is typical;
Will require soft calibration adjustments.

Problems at the far off-nadir positions lead to swath dependent ozone effects

Not unusual but should be corrected.



MLS results from C. Seftor, SSAI for NASA GSFC

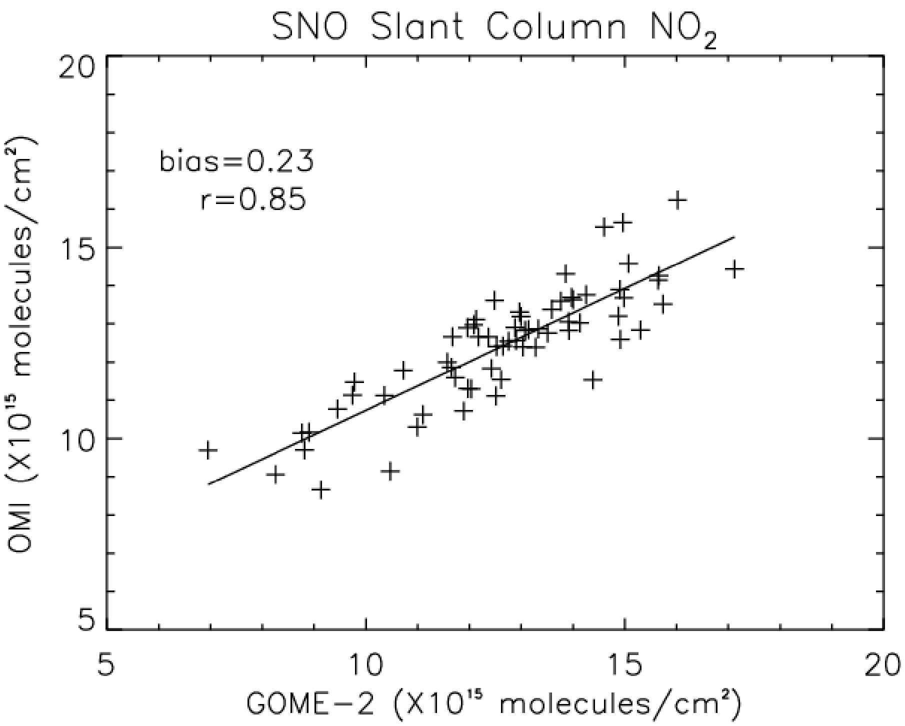
Validation by comparison to OMI.
15 months of GOME-2 and OMI slant column NO_2 data (2008-2009) were compared using SNO analysis.
Number of matchups for this analysis were 77.

SNO matchup criteria

- **± 2 minutes overpass**
- **Solar zenith angles less than 80º**
- **View zenith angles less than 40º (nadir)**
- **OMI row anomaly flag used**

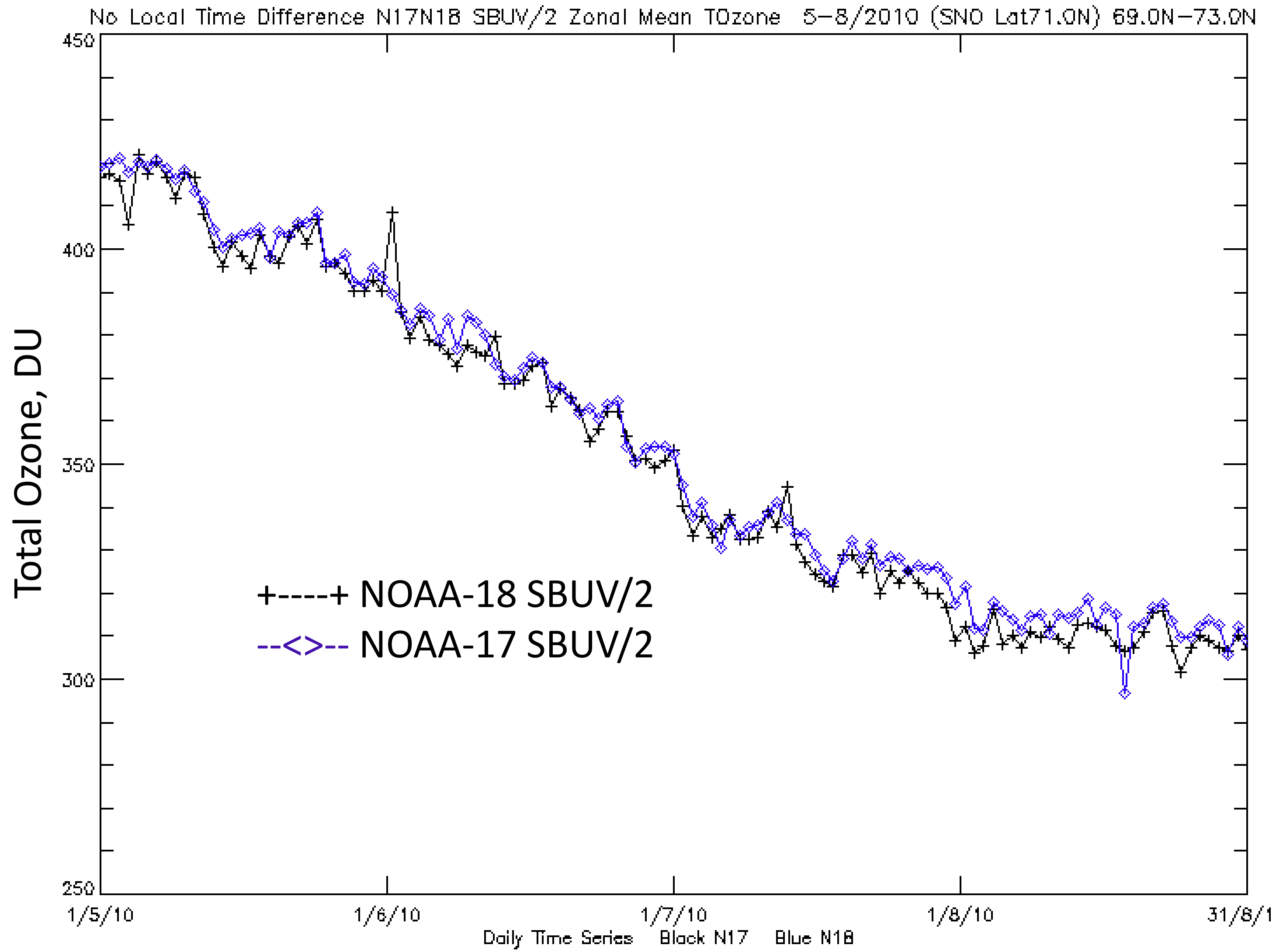
Results

- **Mean bias is 0.23 (~ 2%)**
- **Correlation coefficient is 0.85**

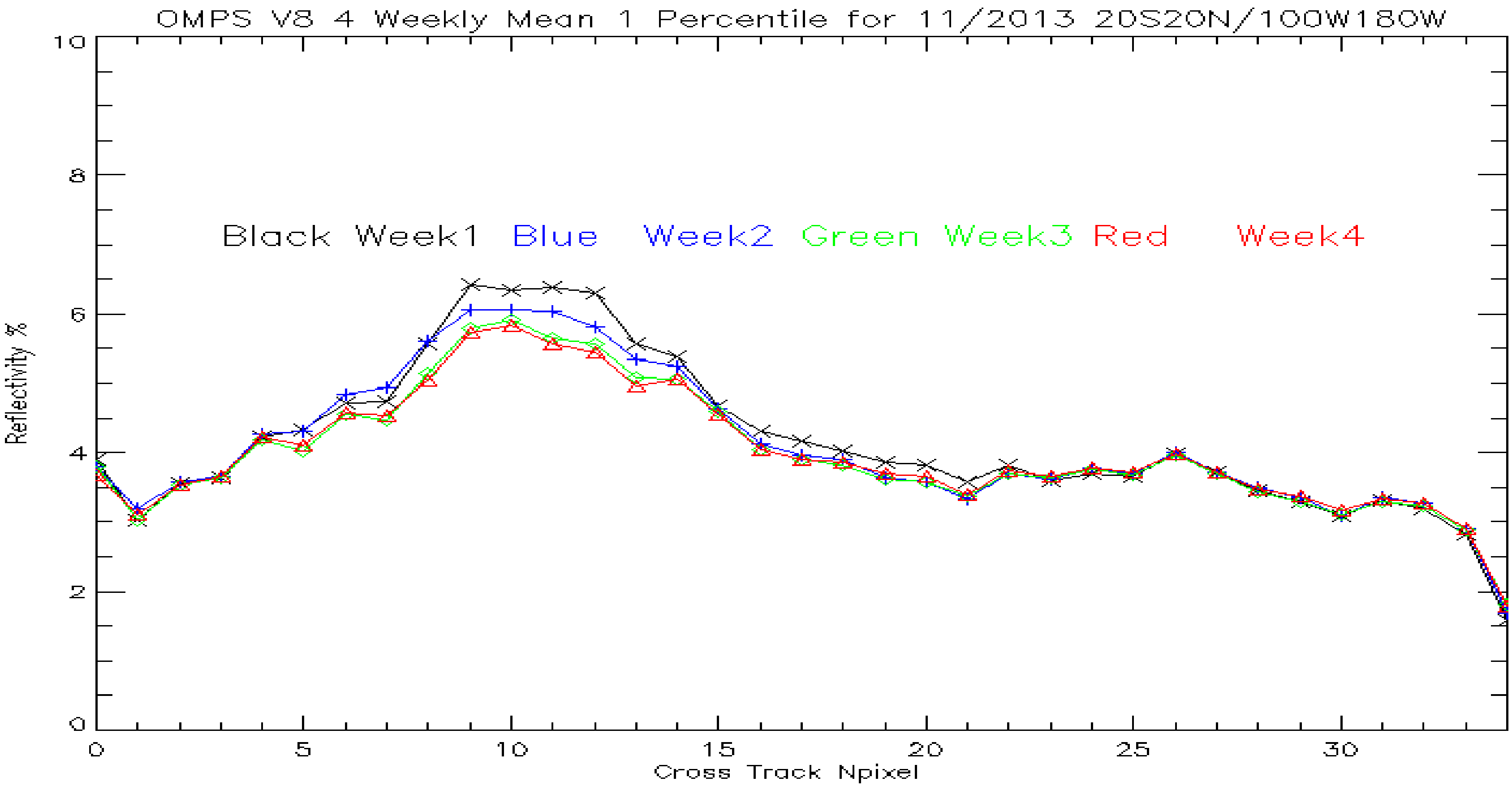


Results from J. Niu for NOAA

No Local Time Difference Comparisons, NOAA-17 SBUV/2 & NOAA-18 SBUV/2 May-August 2010, 69 N to 73 N, Daily Zonal Mean

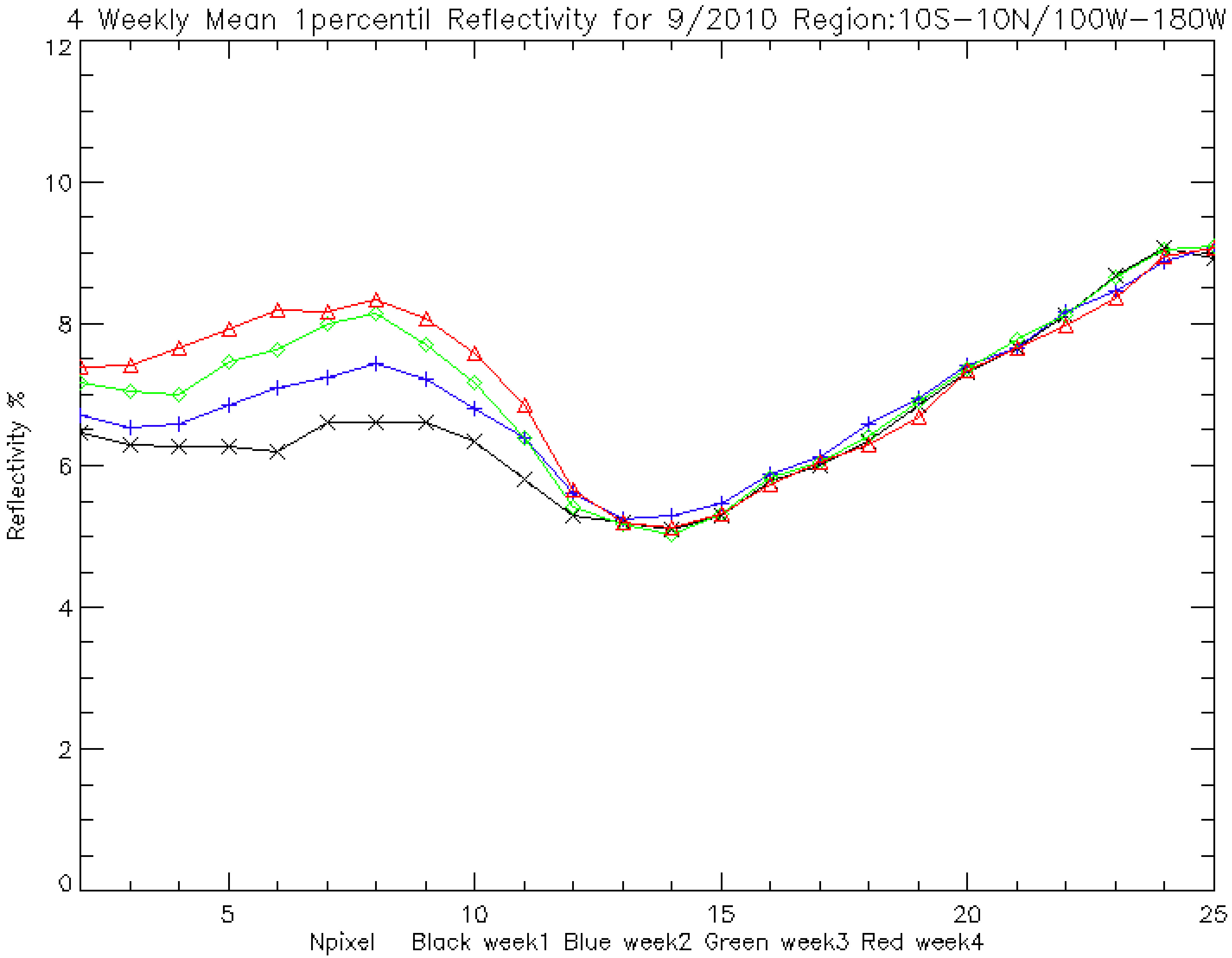


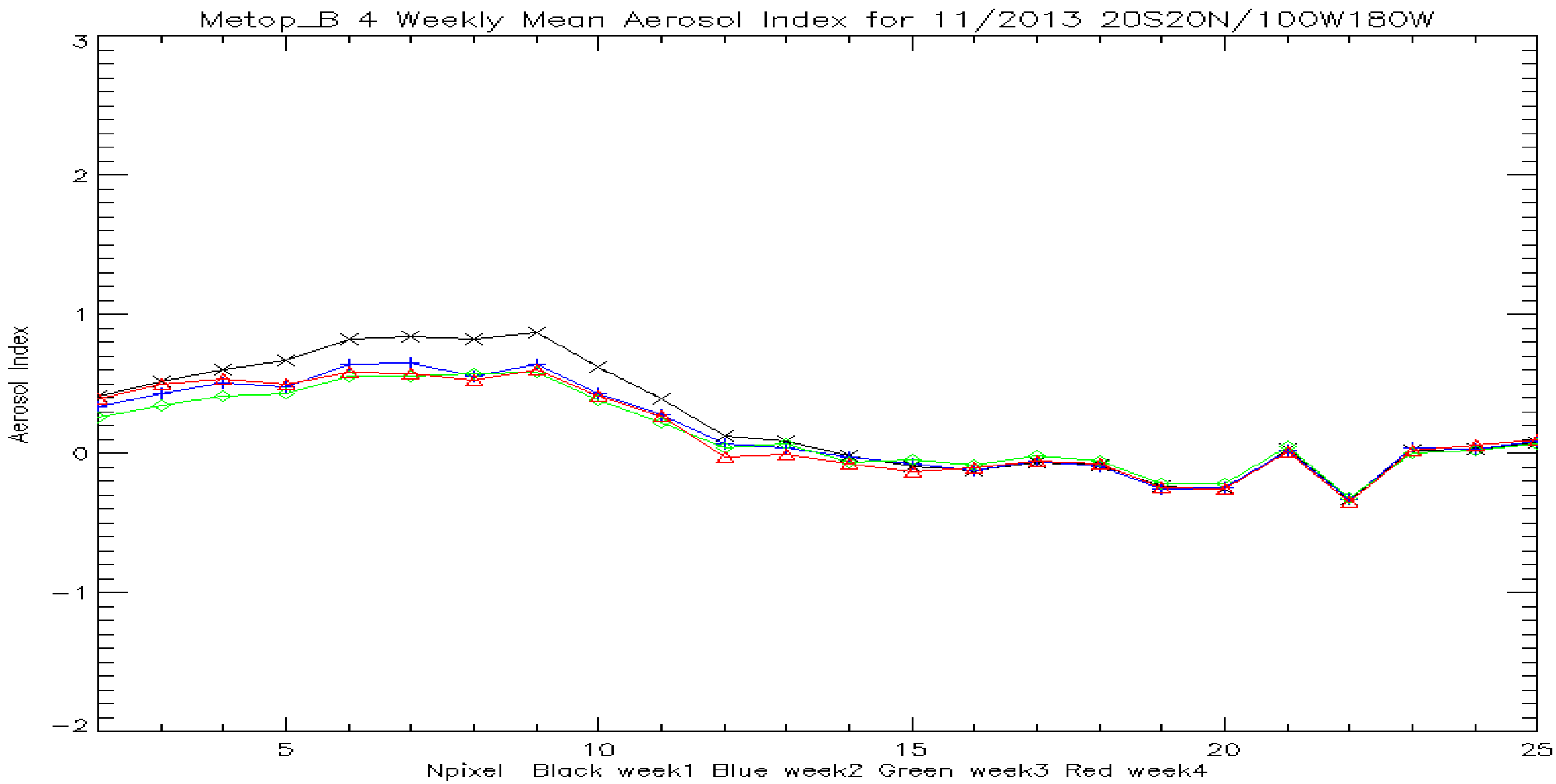
Daily Time Series



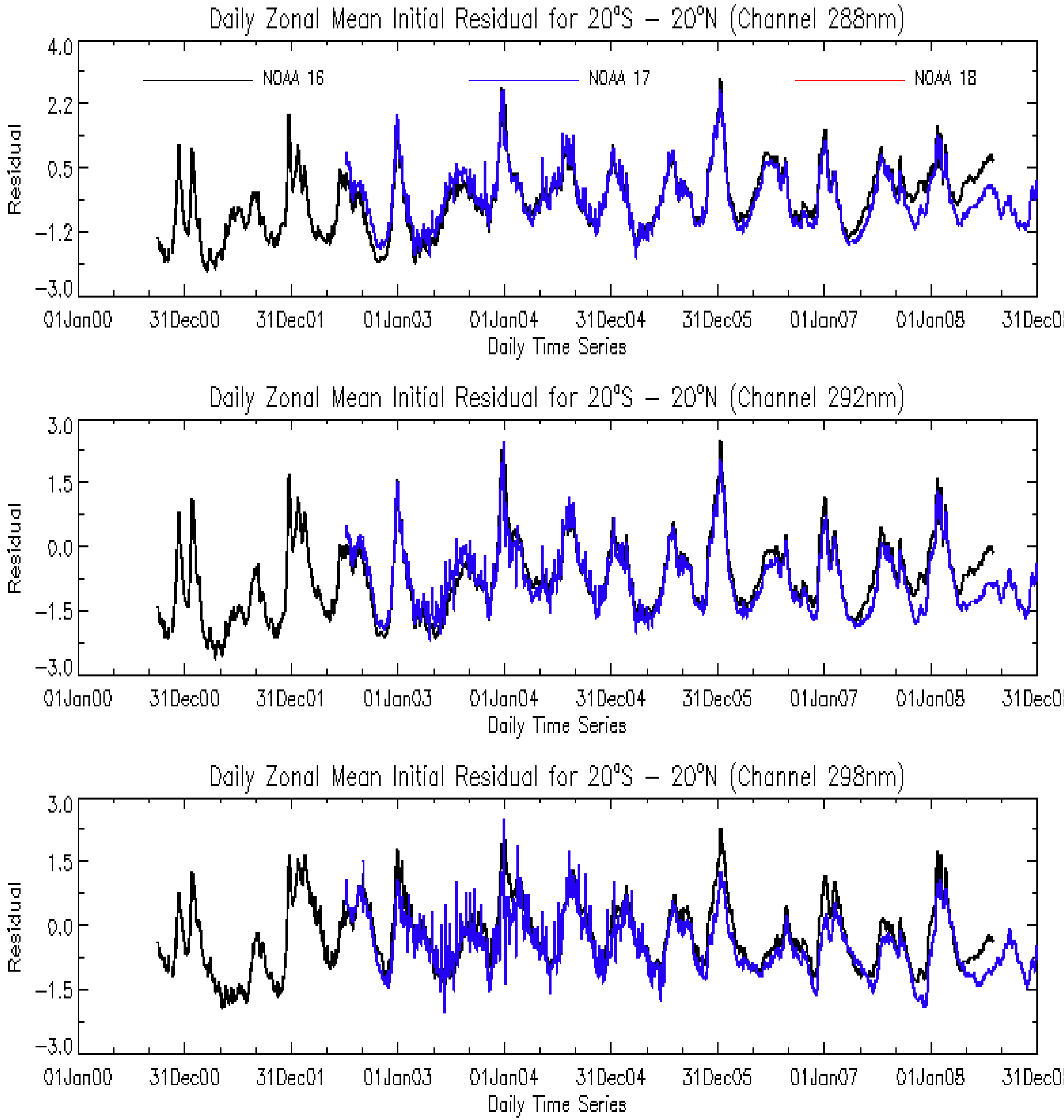
The lines show the S-NPP OMPS weekly, one-percentile effective reflectivity values for the Version 8 algorithm (331-nm channels) for November 2013 for all the data in a latitude/longitude box in the Equatorial Pacific versus cross-track view position. (17 is the nadir position and 0 and 34 are the extreme viewing angles.) We expect the one-percentile effective reflectivity values to be approximately 4% for this region of the globe from climatological measurements made by other instruments. The cross-track variations for positions 5 to 15 are related to sun glint effects. Consistent deviations by position are from imperfections in calibration coefficients across the CCD array and intra-orbit wavelength scale shifts.

Reflectivity for GOME-2 on METOP-A





The lines show the MetOP-B GOME-2 weekly aerosol index values for the V8 algorithm (measurement residuals for wavelengths in the 360-nm range using effective reflectivity calculated for the 331-nm range) for November 2013 for all the data in a latitude/ longitude box in the Equatorial Pacific versus cross-track view position. (12/13 are the nadir position and 2 and 25 are the extreme viewing angles.) We expect the aerosol index values to be approximately zero N-values for this region of the globe. The cross-track variations for positions 4 to 10 are related to sun glint effects. Consistent deviations by position are probably from calibration imperfections but are surprising given the scanning nature of GOME-2.



The figures show the initial measurement residuals for three profile wavelengths (Top 288 nm, Middle 292 nm, and Bottom 298 nm) for the V8PRO product for the equatorial daily zonal means (20N to 20S). The two sets of data are for the NOAA-16 SBUV/2 and the NOAA-17 SBUV/2. The units are N-values (~2.3%). The Version 8 algorithm a priori ozone profiles and forward model have been used to allow direct comparison of the radiance/irradiance ratios for the two instruments. NOAA-16 was an afternoon satellite and NOAA-17 was a morning satellite during this period. By the end of the record, the NOAA-16 satellite was in a late afternoon orbit.

Adjustments using A, K, and Dy

The Averaging Kernel, A, is the product of the Jacobian of partial derivatives of the measurements with respect to the ozone profile layers, K, and the measurement retrieval contribution function, Dy:

A = Dy # K

For a linear problem, the retrieved profile, Xr, is the sum of the A Priori Profile, Xa, plus the product of the Averaging Kernel, A, times the difference between the Truth Profile, Xt, and Xa:

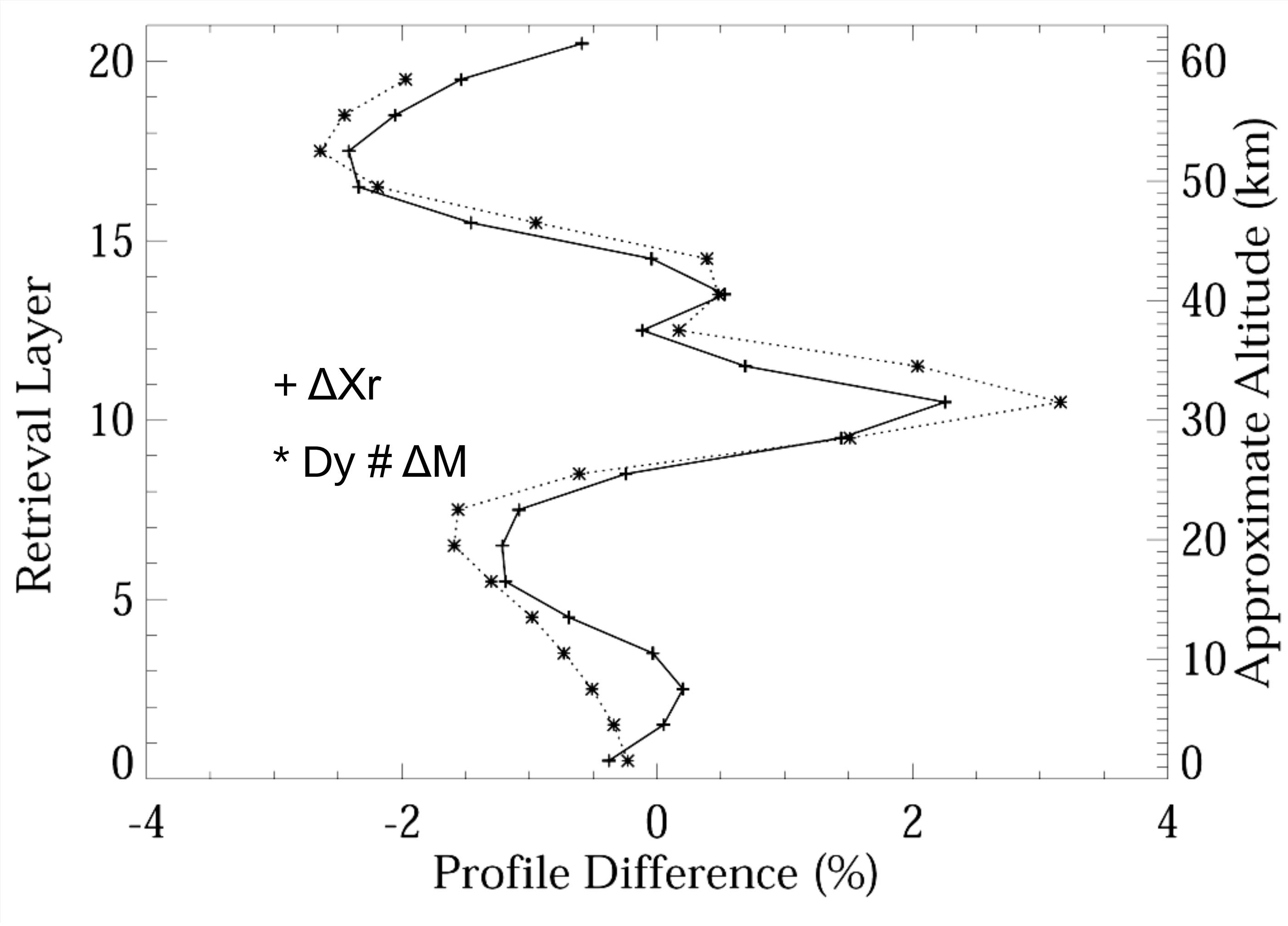
Xr = Xa + A # [Xt – Xa]

The measurement change, ΔM, is the Jacobian times a profile change, ΔX:

ΔM = K # ΔX

The retrieval change, ΔXr, is the contribution function times a measurement change, ΔM:

ΔXr = Dy # ΔM



Comparison of actual differences in annual tropical zonal mean profiles retrieved by NOAA-16 and NOAA-17 SBUV/2 for 2003 with those predicted by the differences in their initial residuals. The “+” symbols are **ΔXr** computed directly and the * symbols are **Dy** Δ**M**.

Comparison Considerations

- Different spectral and spatial resolution
  – Forward models can remove these dependencies
- Chasing orbits
  – If orbital periods are slightly off, then beat frequency matchups are better.
- SNO for AM with PM (+product comparisons?)
  – No-local-time difference zonal means
- Asc/Desc Langley –> S1*alpha1 = S2*alpha2

Possible Goals/Topics for the UV Subgroup

1. Exchanges and traceability of standards
   - NIST and SIRCUS
   - Integrating Spheres, diffusers, lamps, lasers, etc.
2. Establish a library of solar measurements
   - Reference high resolution solar (SOLSTICE, SIM, Kitt Peak, etc.)
   - Mg II Index time series, Scale factors at resolution (new OMI)
3. Establish a library of instrument data bases
   - Bandpasses, calibration constants, wavelength scales
   - Day 1 solar, time series with error bars
   - Mg II Indices and scale factors
   - FOVs, Polarization sensitivity,
   - Reference papers, ATBDs, validation, Shift & Squeeze,
4. Establish a library Absorption data bases
   - O3 in the UV with wavelength and temperature dependence
     - at instrument resolution – from DOAS?
   - UV compared to Visible and IR
   - other species -- SO2, NO2, etc.
5. Standard climatologies; vicarious calibration & residual studies
   - Ozone and temperature profiles, covariances
   - Neural net, with tropopause information
   - Averaging kernels or efficiency factors, measurement contribution functions, and Jacobians
6. Analysis of on-board systems
   - Diffusers, stable orbits
   - White lights, spectral lamps, LEDs
   - Moon views

Stray light, linearity, gains, offsets, mirrors, polarisation, λ-scale, bandpass

7. Considerations for comparisons
   - Complications from diurnal variations, SZA, SVA, RAA
   - Zonal means
   - Simultaneous nadir overpass (Rad/Irrad or products)
   - Formation flying / Chasing orbits
   - No-local-time differences
   - Ice, desert and open ocean targets
   - Pacific Box
   - LEO to GEO to L1
8. Internal consistency techniques
   - Ascending/descending -- Langley methods
   - Pair justification
   - DOAS (and EOF analysis) (Closure polynomials)
   - Stray light correlation
   - Wavelength scale, shift and squeeze, etc.
   - Measurement Residuals, reflectivity range/distribution
9. Forward model and measurements
   - Rayleigh
   - Absorption
   - Spherical geometry
   - Inelastic scattering (Ring Effect), Stray light, solar activity
   - Aerosols
   - Polarization
   - TOMRAD, VLIDORT, SCIATrans, CRTM, etc.
   - V8 SBUV/2 and *A Priori* as transfer for Viewing conditions…
10. Reflectivity
    - Surface (database and snow/ice forecasts), Variations in surface reflectivity with season, sza and sva.
    - Surface pressure
    - Clouds (Cloud top pressure)
    - Cloud-optical-centroids (Ring Effect, 02-02, O2 A band)
11. Aerosols
    - Climatology/Type, height
    - Wavelength or polarization dependence (Aerosol Indices)
12. Nadir Instruments LEO
- TropOMI, GOME(-2), OMPS, TOU/SBUS, OMS,
- SCIAMACHY, OMI, TOMS, SBUV(/2)

12. Nadir Instruments GEO or L1
- TEMPO, GEMS, UVN and EPIC

13. Limb instruments
- SAGE III, ACE/MAESTRO, OSIRIS, MLS,
- GOMOS, SCIAMACHY, OMPS-LP

14. Ground-based
- WOUDC, Dobson, Brewer, Lidar, MW and Ozonesondes