OMPS Nadir Profiler Solar Activity and Mg II Index

L. Flynn
with input from
NOAA JPSS and NASA S-NPP Teams

May 13, 2014

Outline

- Definition
- GOME-2 Daily Time Series
- Solar activity presence in measurements
  - Earth View Residuals
  - Solar Spectra
  - Earth View Mg II Index
  - Solar activity of synthetics

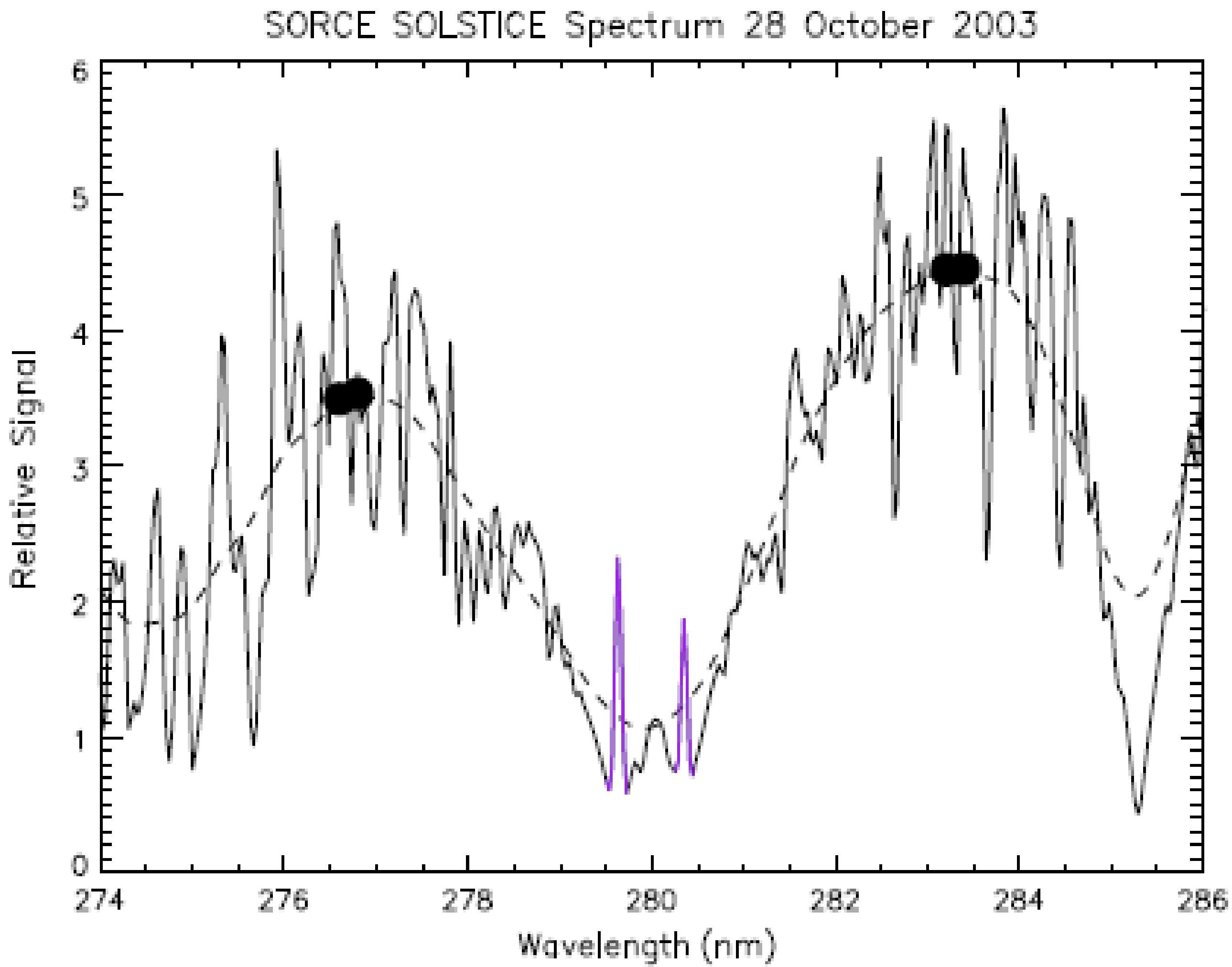


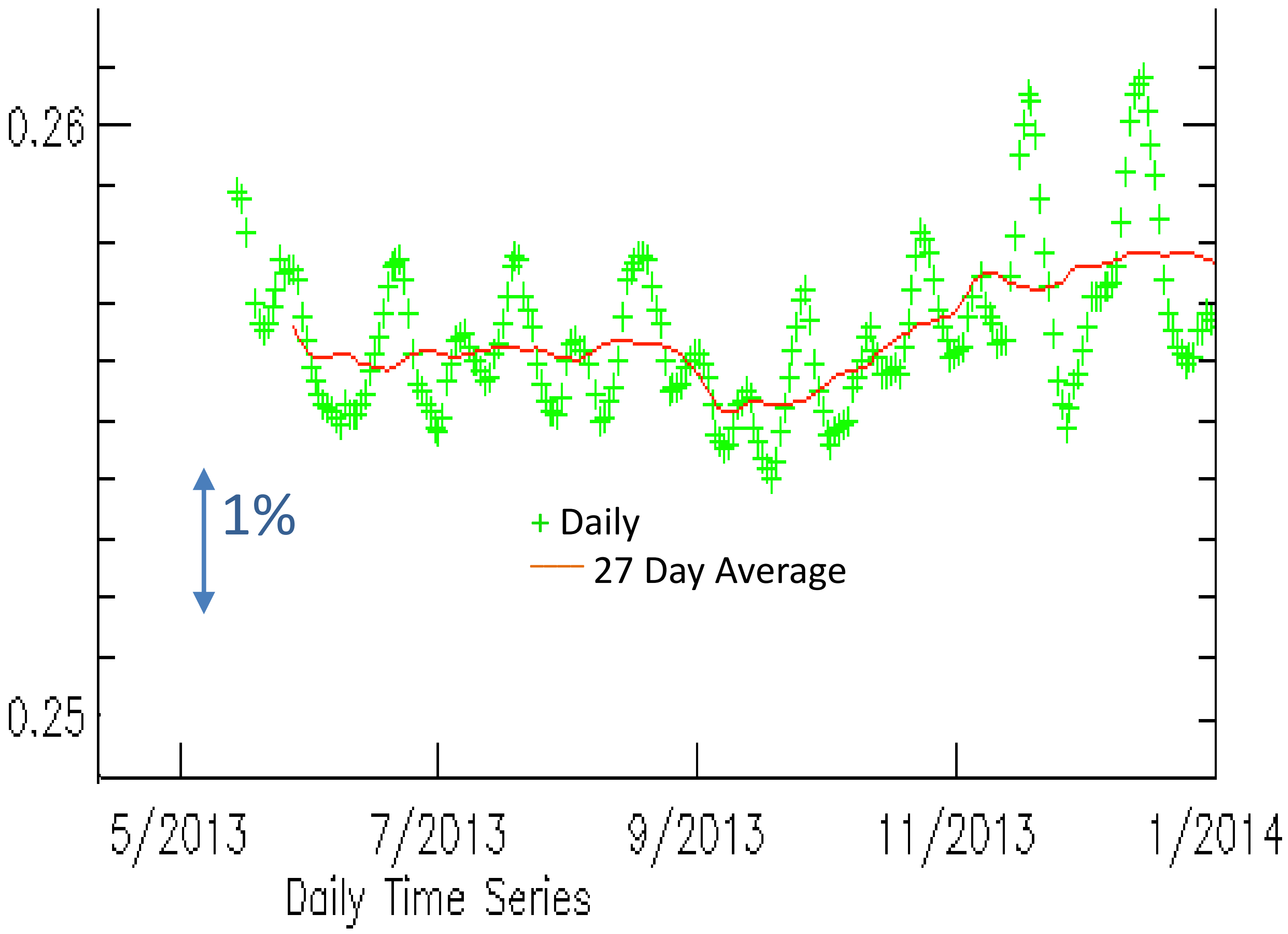
Fig. 2. The MgII doublet region as observed by SORCE SOLSTICE on 28 October 2003. The h & k emission cores are highlighted in purple. The dashed line is the spectrum after convolving it with a 1.1 nm triangular bandpass. Black dots indicate the wing irradiance values used to calculate the index.

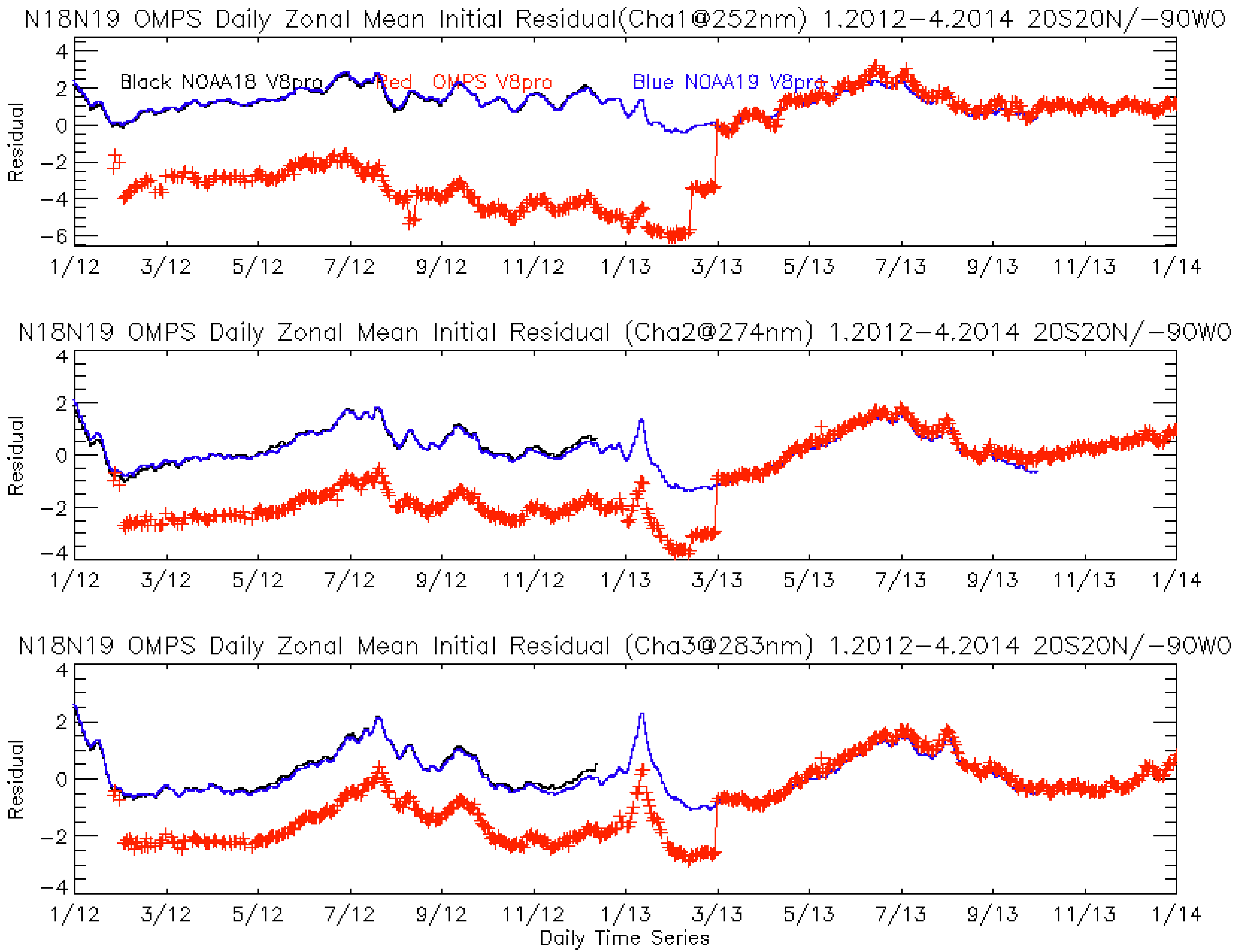
The core radiances at the Mg II doublet are much more responsive to solar activity changes than the wings. By taking a ratio of measurements at 280 nm to those at 277 nm and 284 nm, on creates a Index that is insensitive to relative instrument changes that are linear with wavelength but responds to changes in solar activity.

The response depends on the spectral resolution and the choice of measurement locations.

J. Space Weather Space Clim. 4 (2014) A04 DOI: 10.1051/swsc/2014001 M. Snow et al., Published by EDP Sciences 2014

GOME-2 MetOp-B Mg II Time Series




N18N19 OMPS Daily Zonal Mean Initial Residual(Cha1@252nm) 1.2012-4.2014 20S20N/-90W0
Black NOAA18 V8pro
Red OMPS V8pro
Blue NOAA19 V8pro
Residual
4
2
0
-2
-4
-6
1/12
3/12
5/12
7/12
9/12
11/12
1/13
3/13
5/13
7/13
9/13
11/13
1/14
N18N19 OMPS Daily Zonal Mean Initial Residual (Cha2@274nm) 1.2012-4.2014 20S20N/-90W0
Residual
4
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-2
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3/12
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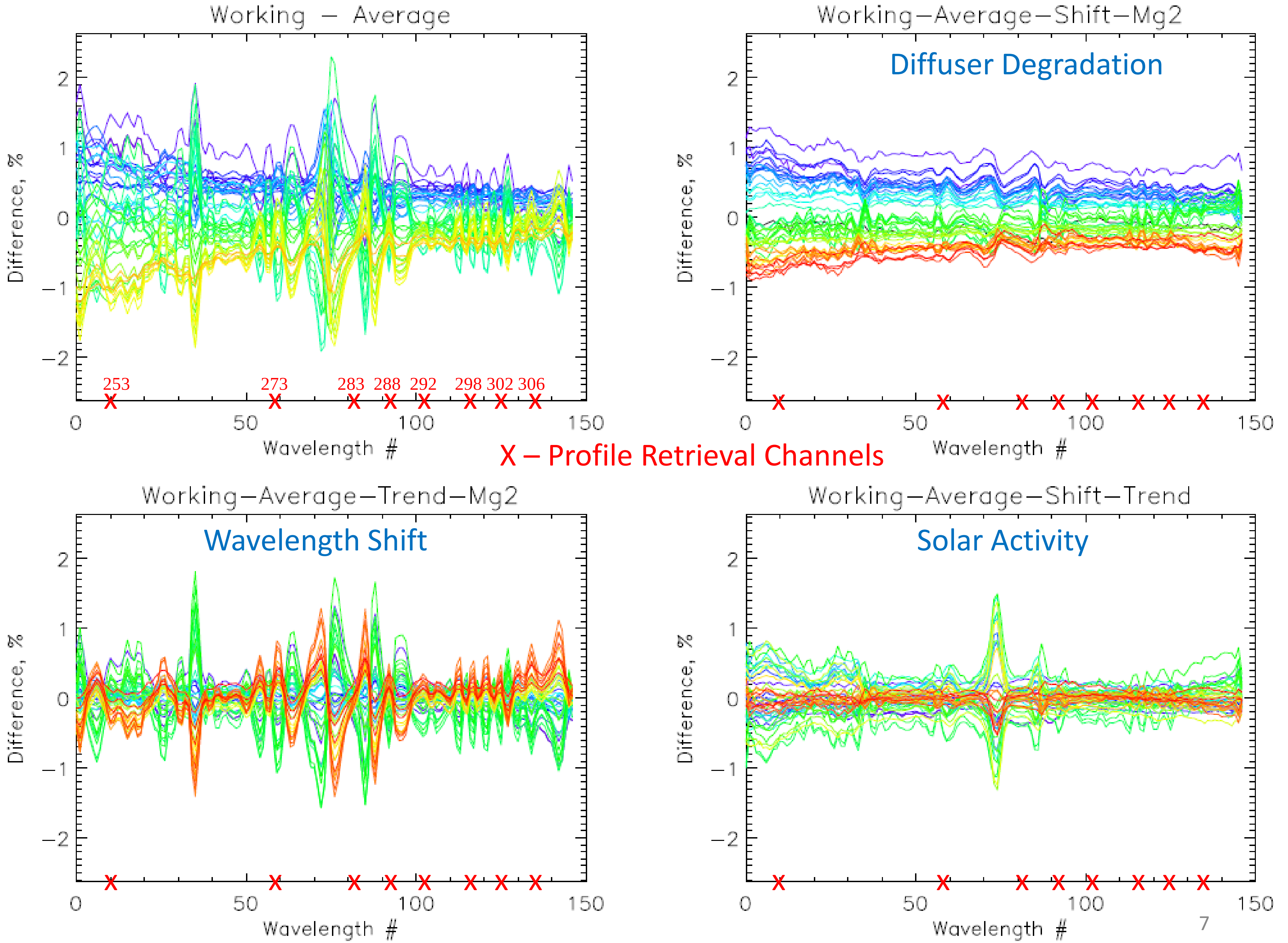
9/13
11/13
1/14
N18N19 OMPS Daily Zonal Mean Initial Residual (Cha3@283nm) 1.2012-4.2014 20S20N/-90W0
Residual
4
2
0
-2
-4
1/12
3/12
5/12
7/12
9/12
11/12
1/13
3/13
5/13
7/13
9/13
11/13
1/14
Daily Time Series

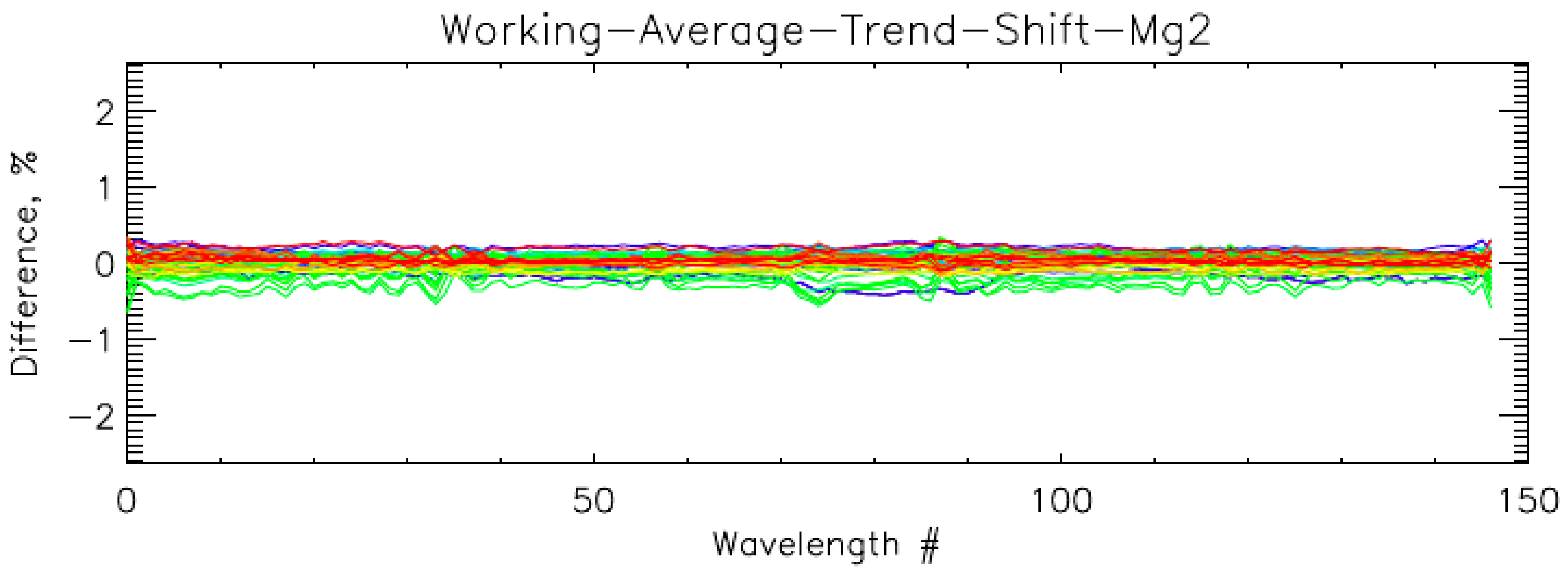
- Comparison of OMPS NP Working Diffuser Solar spectra to their average.
- Fits of the differences with a model using three patterns of the form:

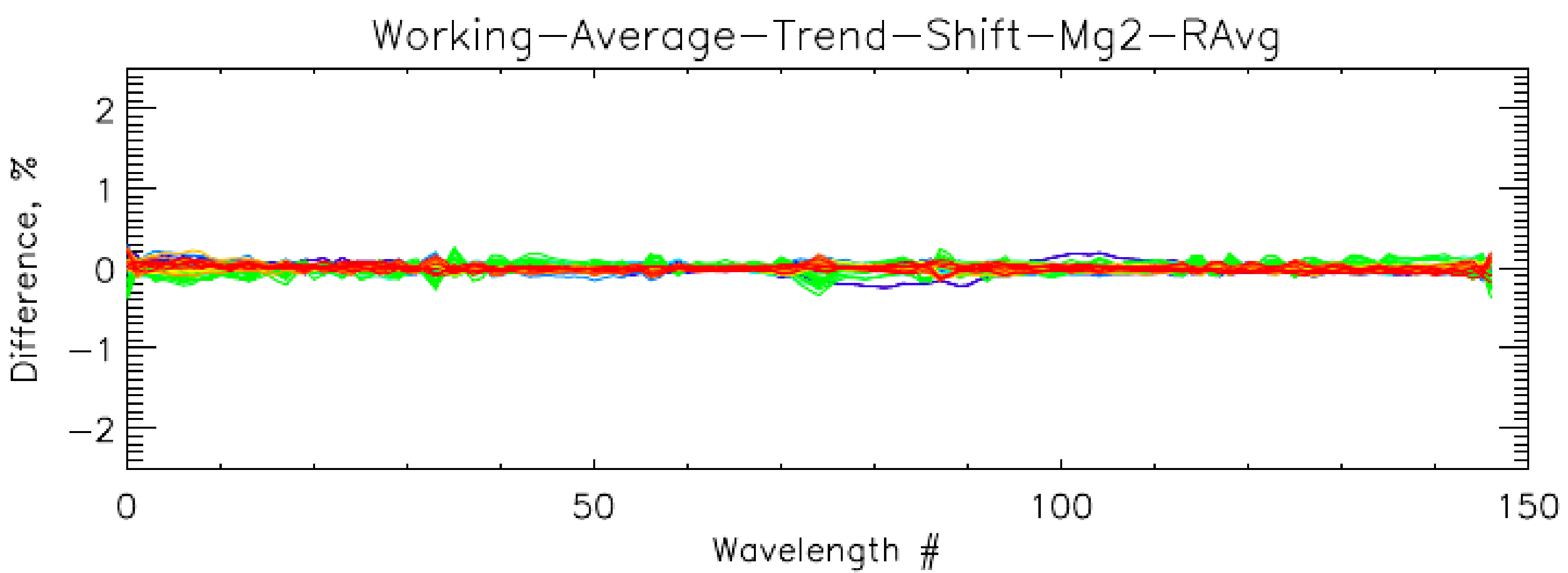
$A1(t)*WavelengthShift(\lambda)+a2(t)*SolarActivity(\lambda)+t*Degradation(\lambda)$



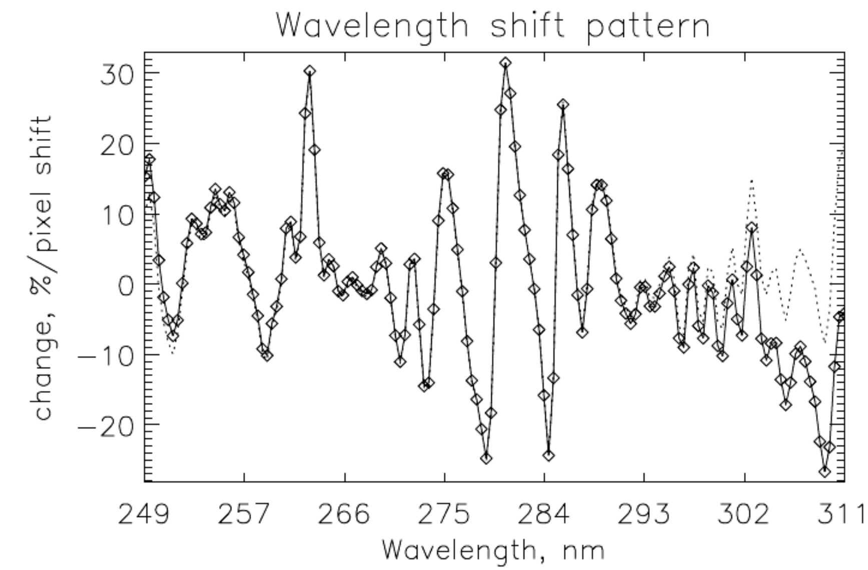
Working – Average
Difference, %
Wavelength #
253
273
283
288
292
298
302
306
Working–Average–Shift–Mg2
Diffuser Degradation
X – Profile Retrieval Channels
Working–Average–Trend–Mg2
Wavelength Shift
Working–Average–Shift–Trend
Solar Activity

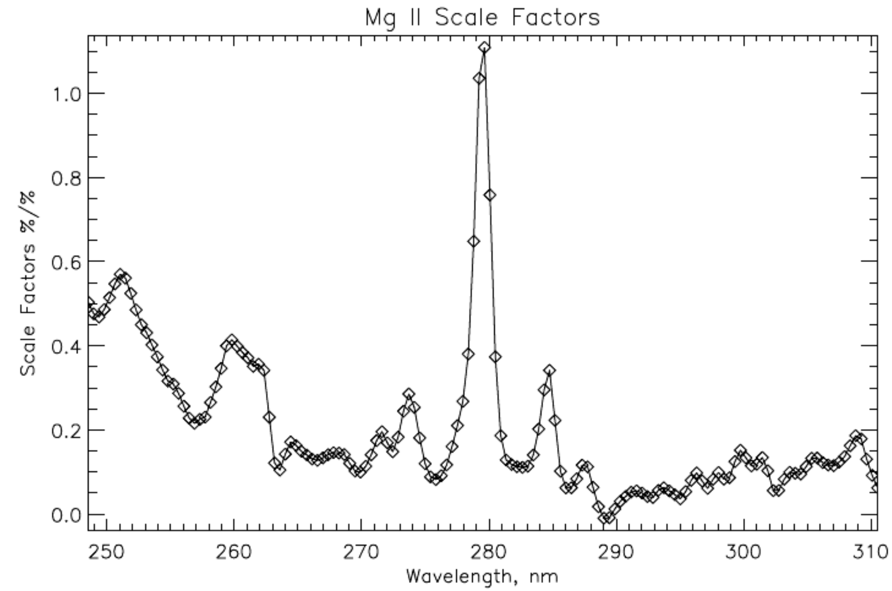
OMPS NP Working Solar residuals after fits

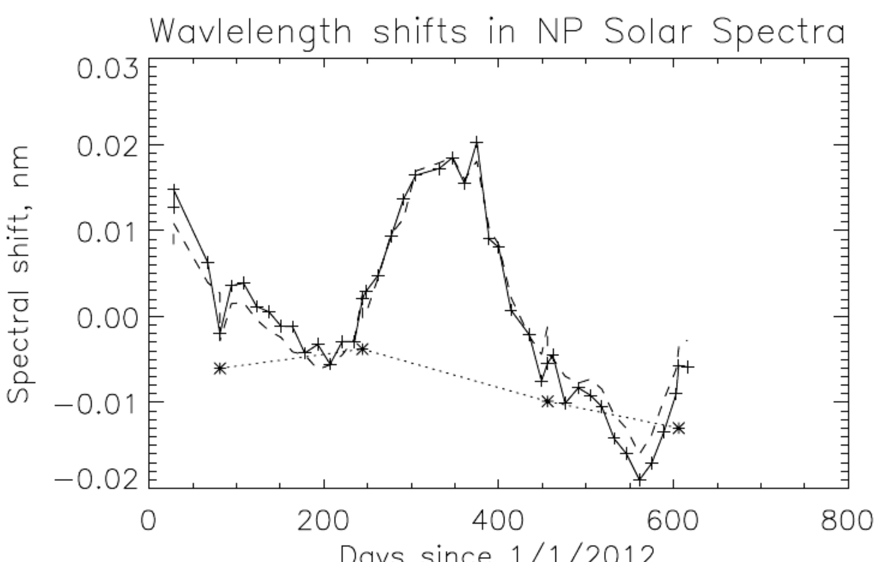


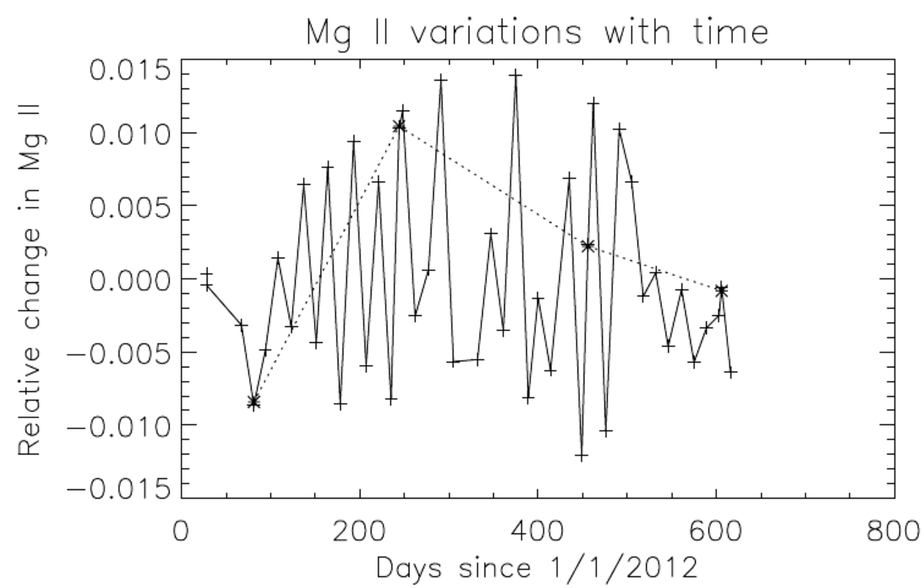


Wavelength shift and solar activity patterns in 44 Working and 4 Reference spectra

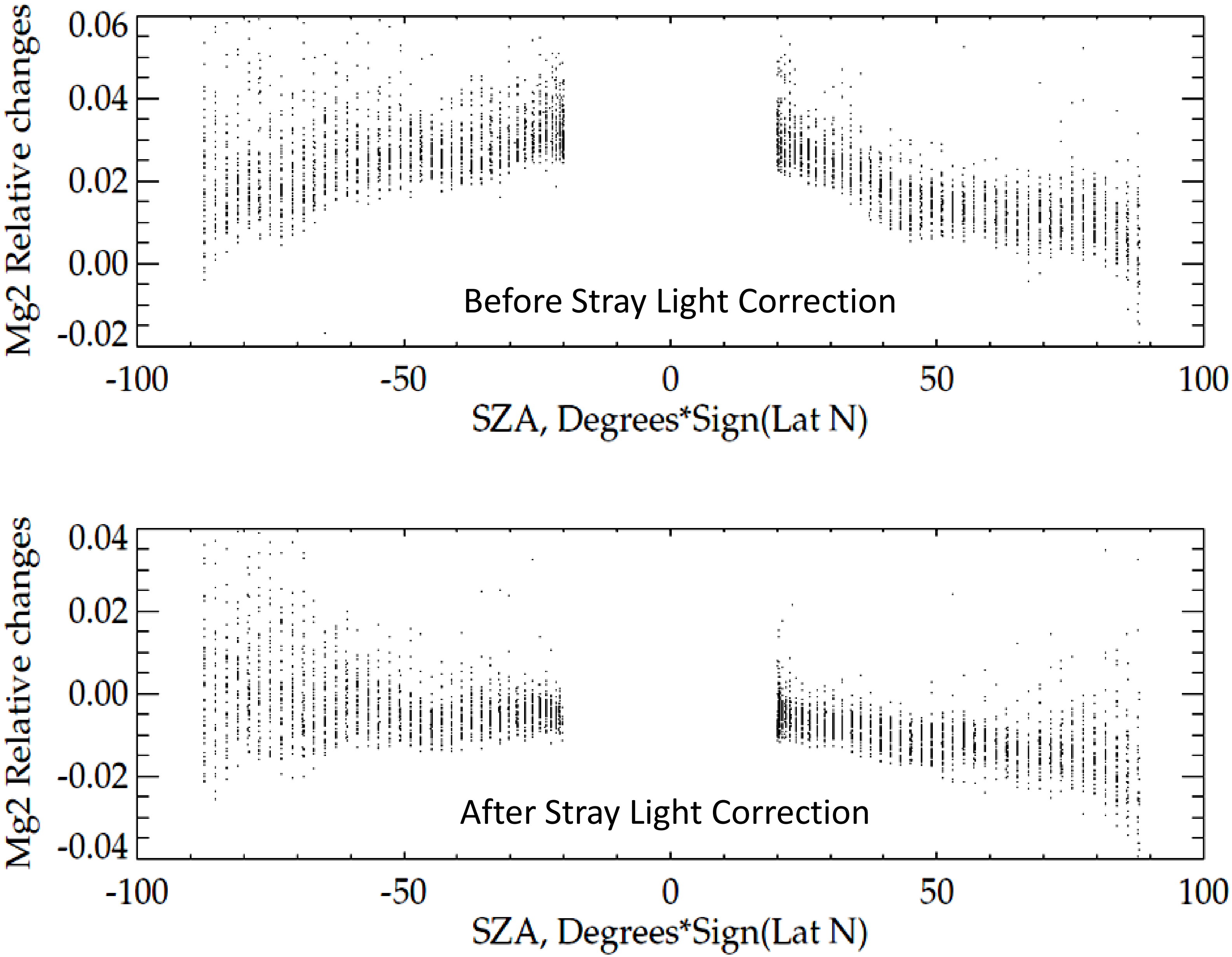






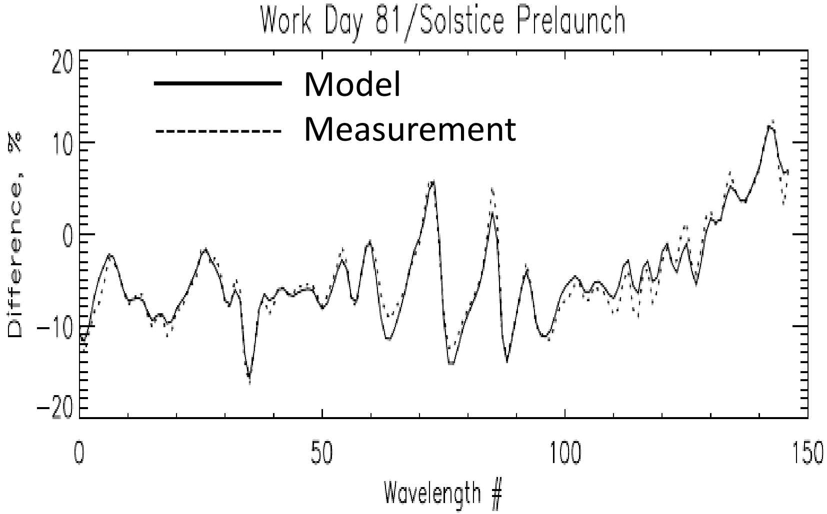


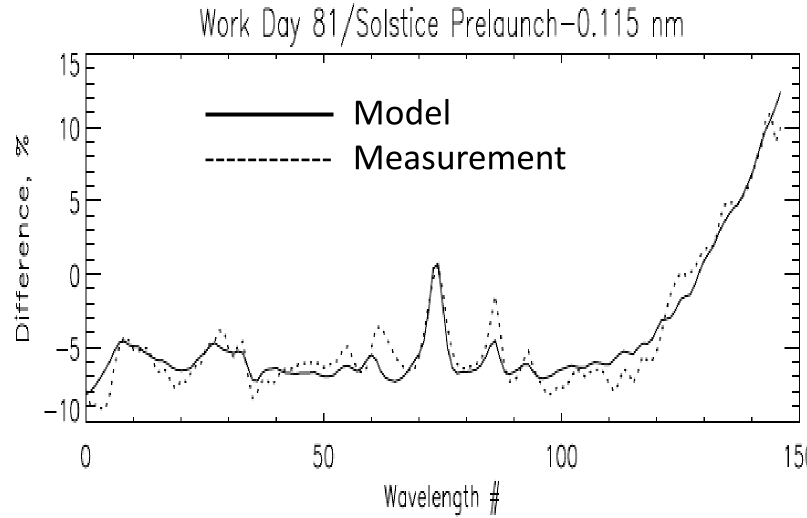
Earth-view Mg II Index for March 2014

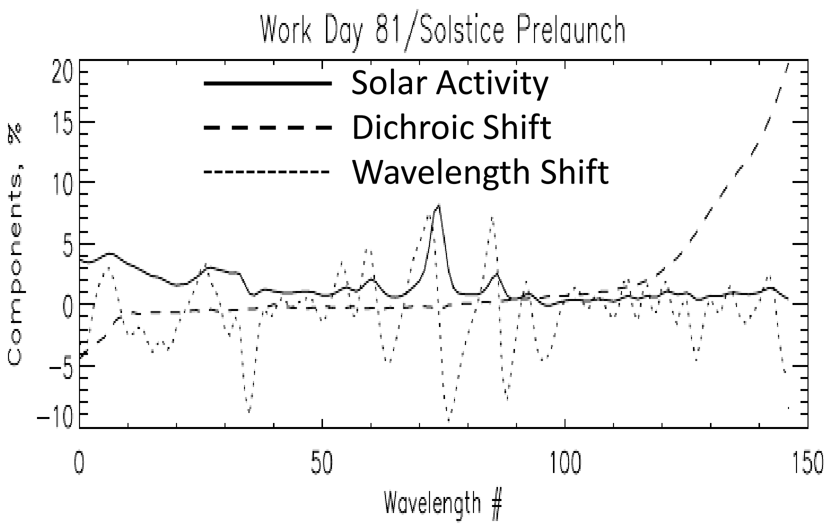


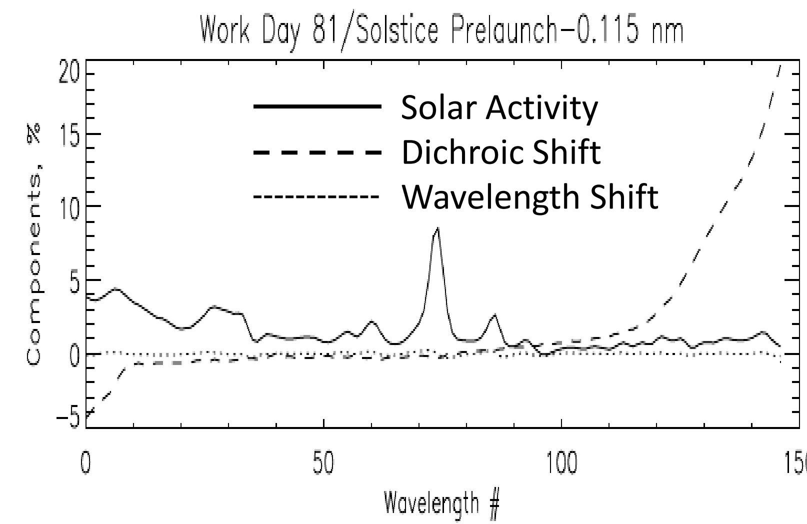
Comparison of OMPS NP Solar spectrum to synthetic from Solstice and prelaunch data. Fits of the differences with a model using three patterns of the form:

Meas/Synth = a0 + a1*WavelengthShift + a2*SolarActivity + a3*DihroicShift









Working Day 81 vs Solstice Synthetic (1.1% rmsr)

%offset	%Mg II	Shift nm	Dich nm
-7.3	7.3	-0.127	-0.349

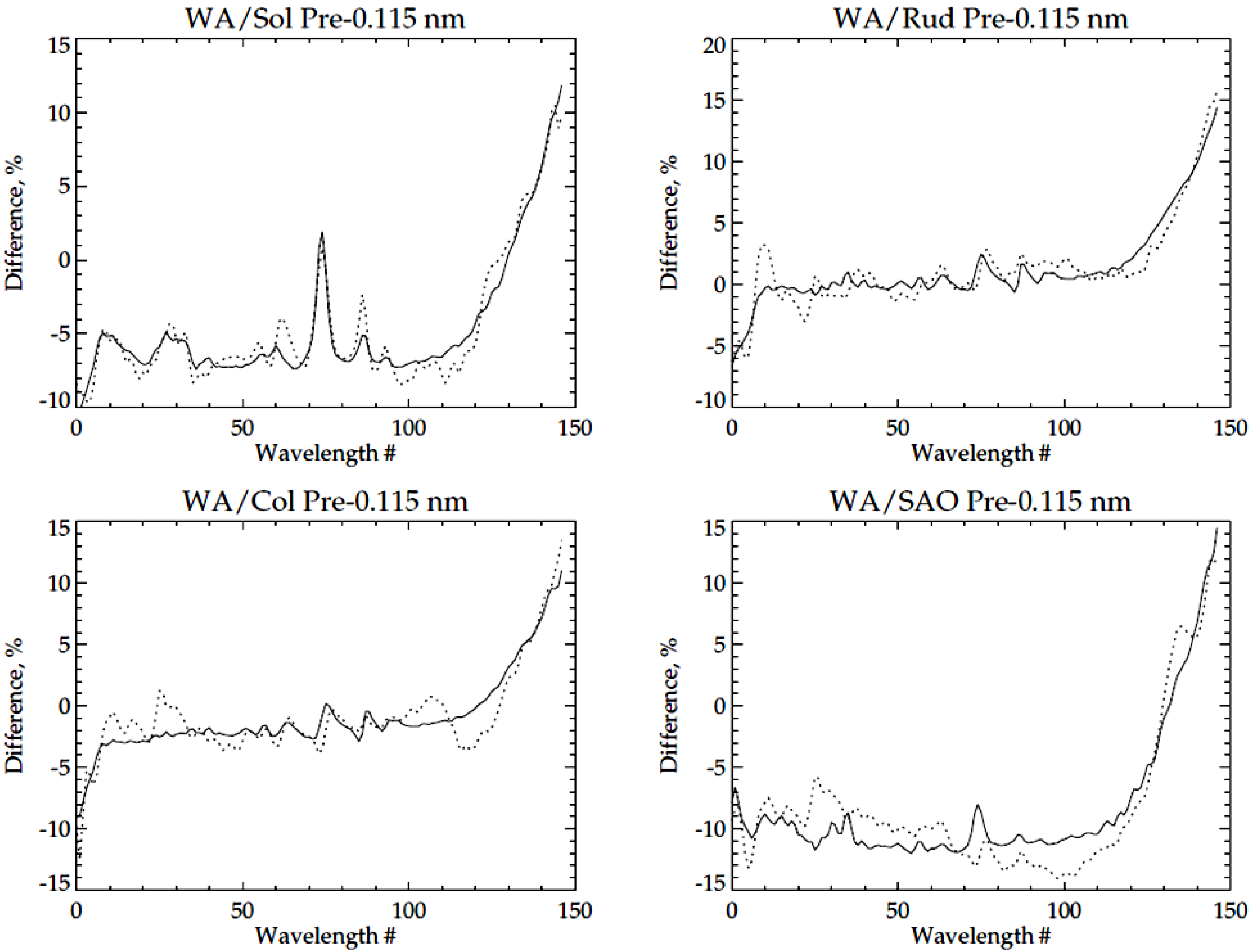
Working Day 81 vs Solstice Synthetic (1.1% rmsr)

%offset	%Mg II	Shift nm	Dich nm
-7.5	7.7	-0.004	-0.347

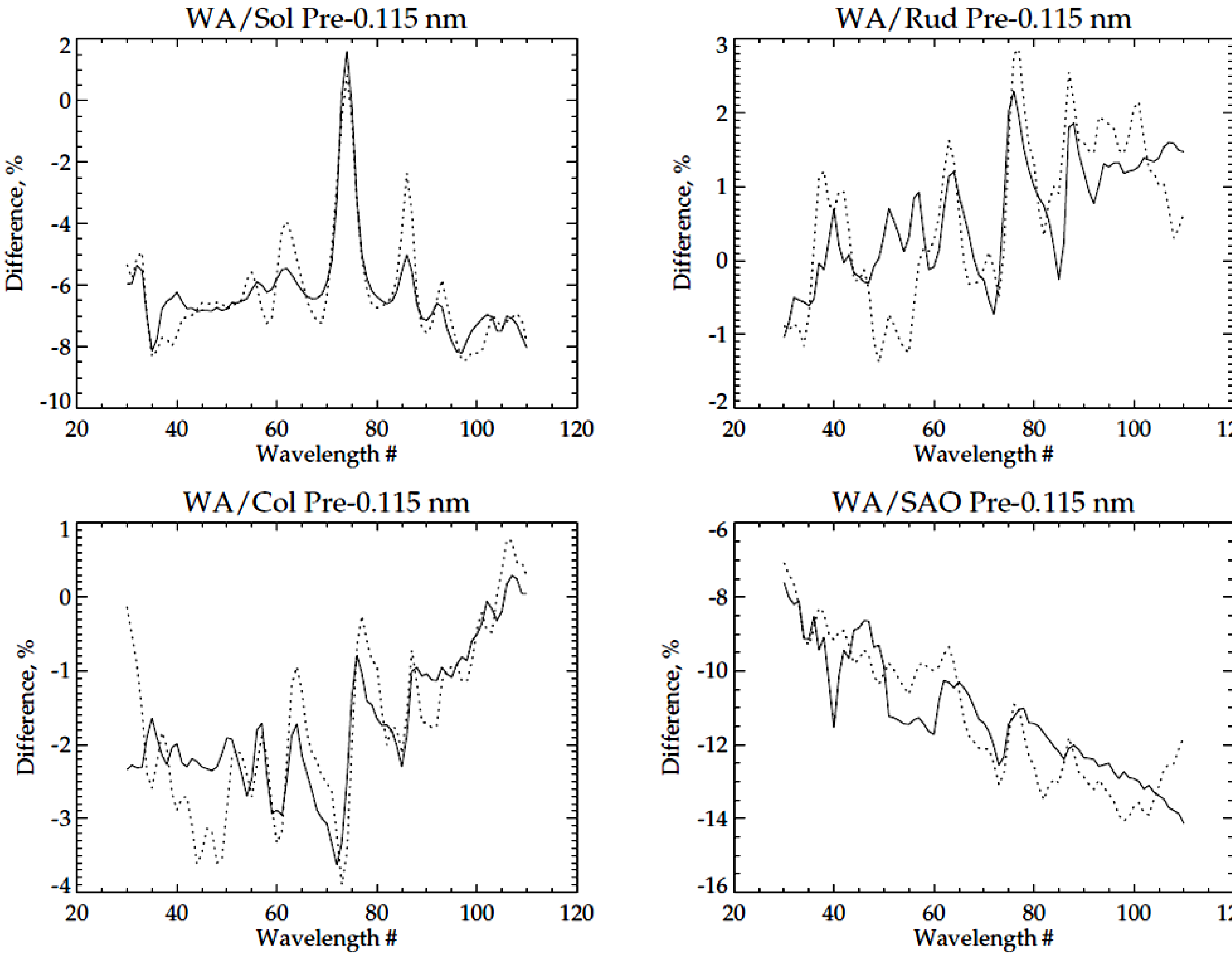
Summary and Conclusions

- The Earth View radiances at 253 nm and 273 nm respond to solar flux changes.
- These variations will be aliased as ozone changes if a constant Day 1 solar spectrum is used.
- Daily estimates of the Mg II Index changes can be combined with Scale Factors to provide estimates of the solar flux on a daily basis.
- Real solar variations will complicate analysis of solar measurements.

Backup Slides



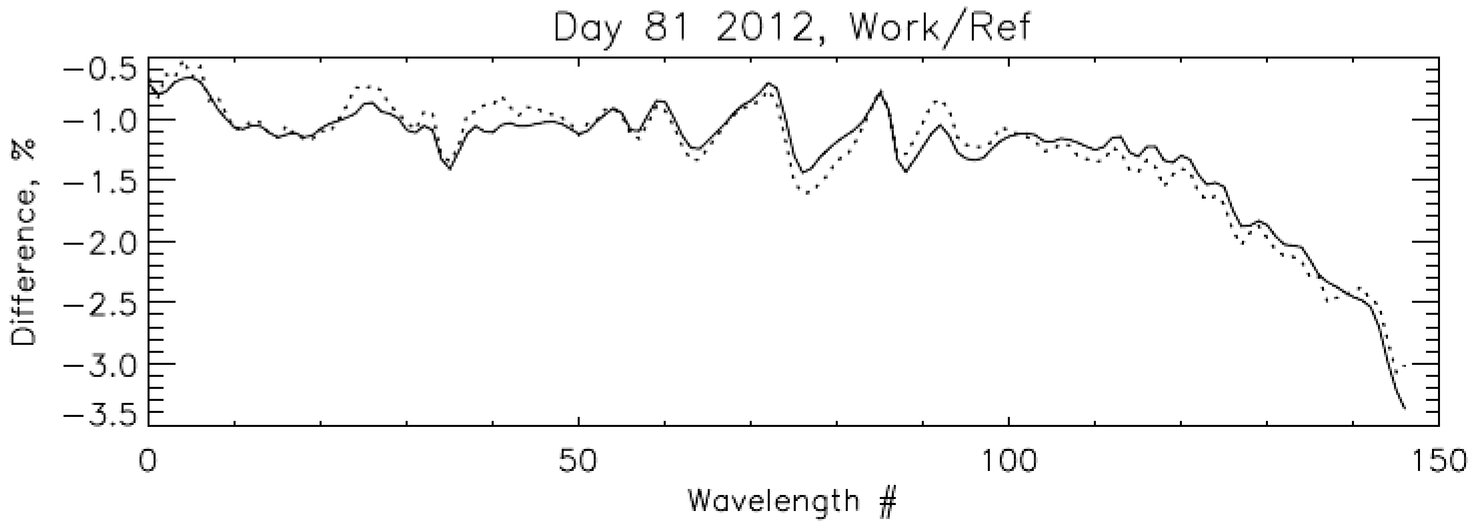
WA/Sol Pre-0.115 nm
WA/Rud Pre-0.115 nm
WA/Col Pre-0.115 nm
WA/SAO Pre-0.115 nm
Difference, %
Wavelength #

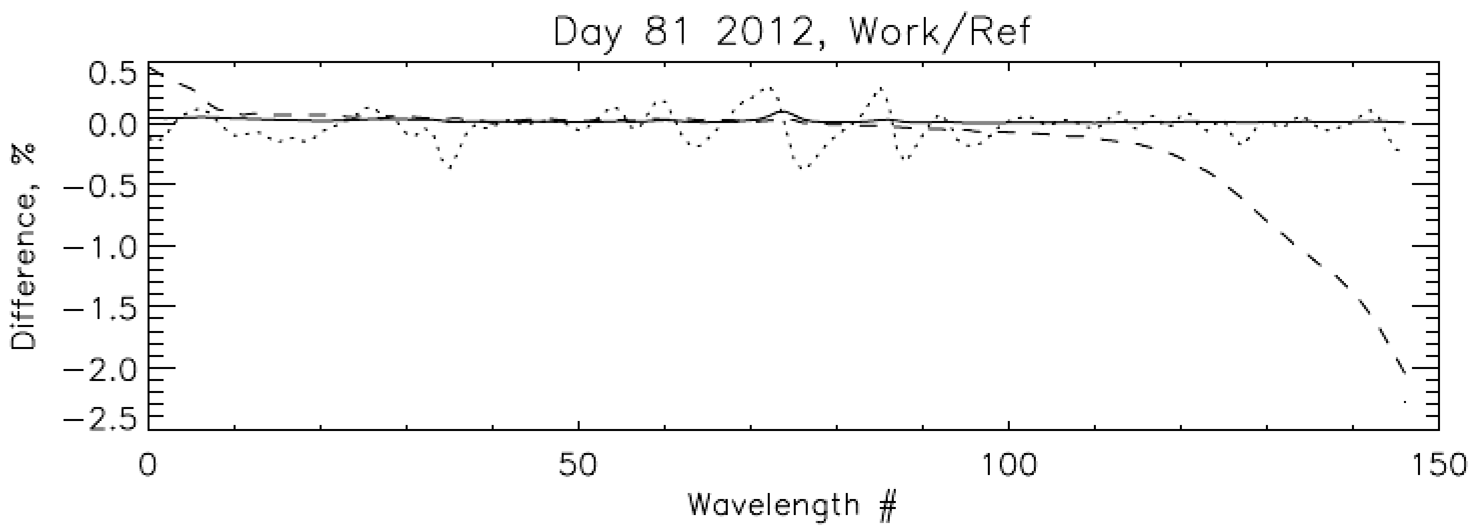


WA/Sol Pre-0.115 nm
Difference, %
Wavelength #
WA/Rud Pre-0.115 nm
Difference, %
Wavelength #
WA/Col Pre-0.115 nm
Difference, %
Wavelength #
WA/SAO Pre-0.115 nm
Difference, %
Wavelength #

Outline

- OMPS NP Solar Spectra – internal comparisons
  - Annual wavelength scale variations
  - Mg II and solar activity
  - Instrument throughput trending
- OMPS NP Solar Spectra – external comparisons
  - Absolute wavelength Scale
  - Comparisons to synthetics
  - Dichroic variations
- OMPS NM Intra-orbit wavelength scale

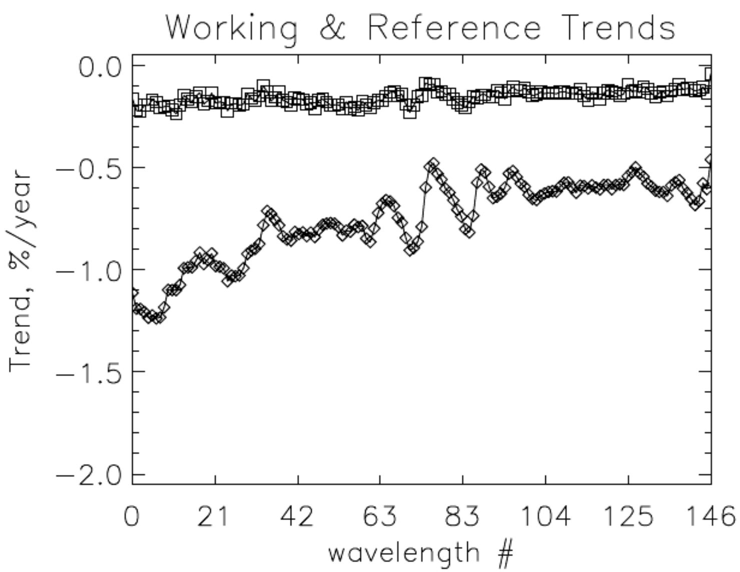


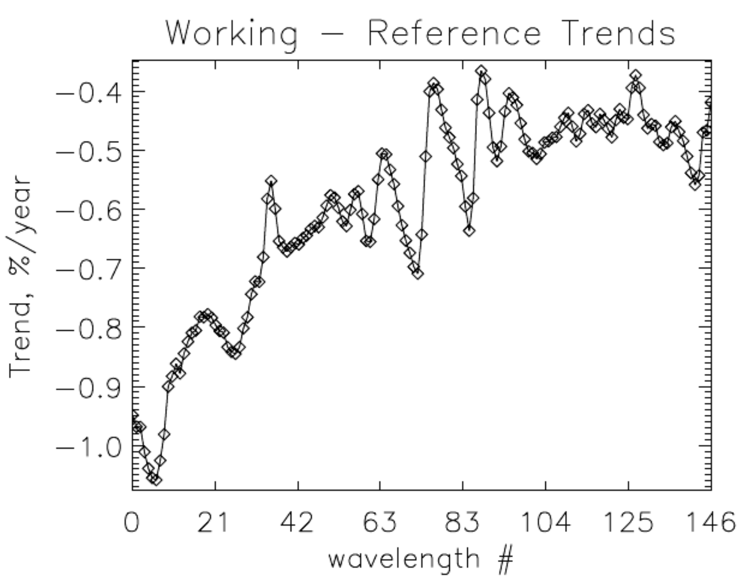


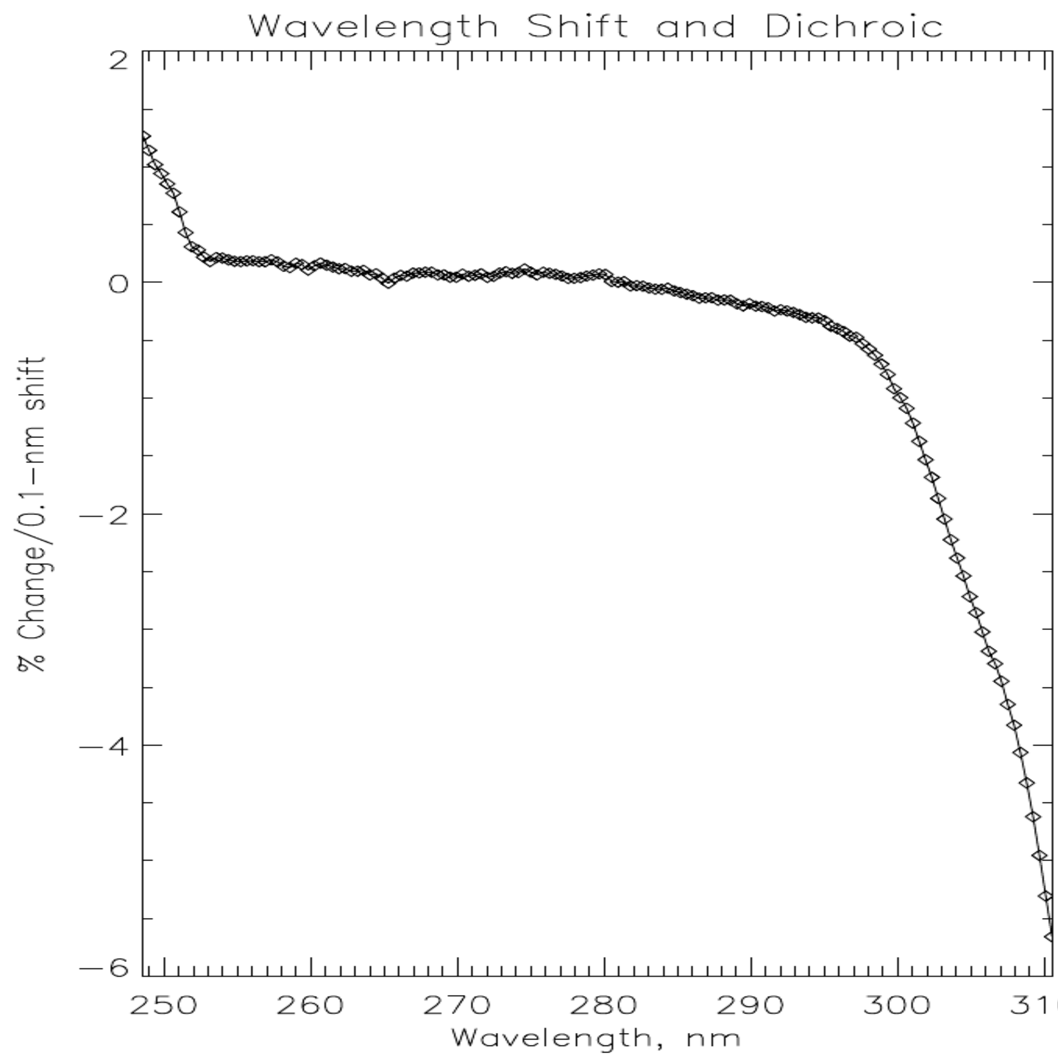
Working Day 81 vs Reference Day 81 (0.1% rmsr)

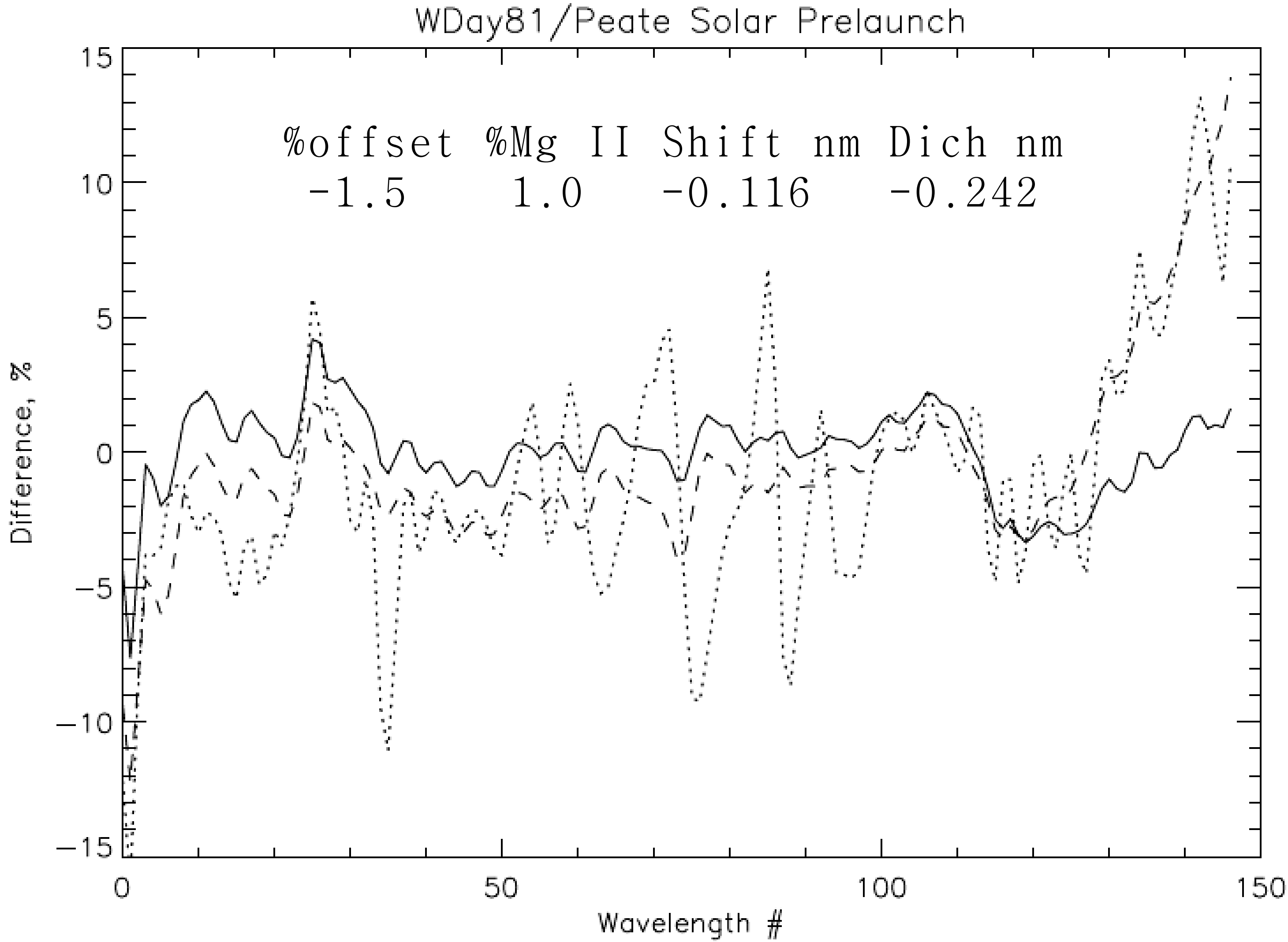
%offset	%Mg II	Shift nm	Dich nm
-1.1	0.1	-0.005	0.036

Trends in Solar from model fits and counts to radiance wavelength





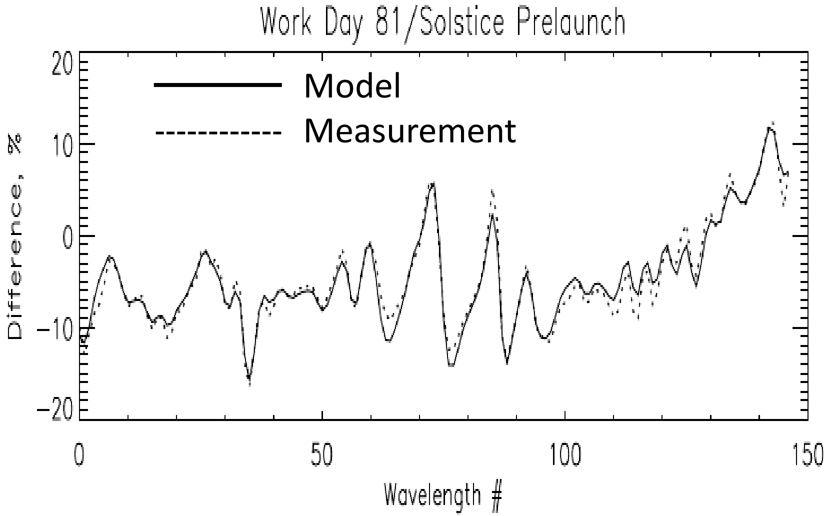


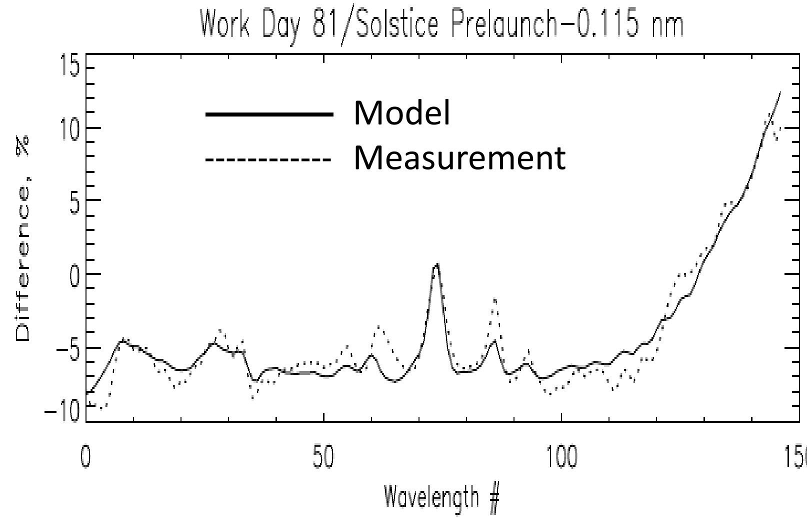


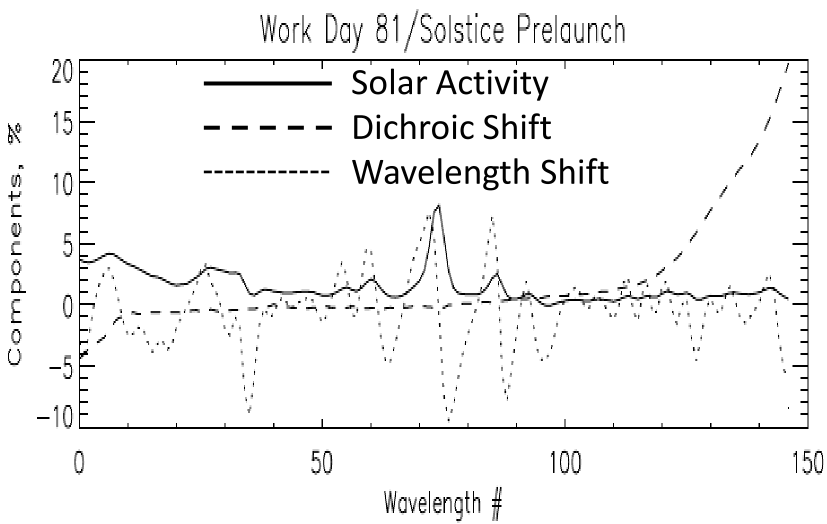
Synthetic solar created from the PEATE high resolution spectrum compared to the day 81 of 2012 Working Diffuser solar measurement using the pre-launch wavelength scale.
The dotted line is the relative difference (measured/synthetic - 1). The dashed line is after a uniform -0.12-nm shift of the wavelength scale without accounting for the dichroic. The solid line is after removing a -1.5% offset, a -1.0% Mg II activity term, a -0.242-nm counts to radiance shift (dichroic and other influences), and an additional 0.004-nm wavelength shift.

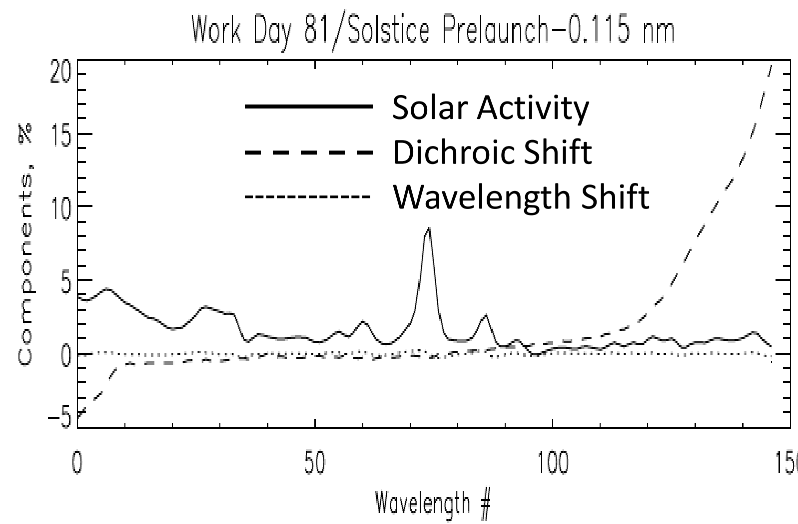
Comparison of OMPS NP Solar spectrum to synthetic from Solstice and prelaunch data. Fits of the differences with a model using three patterns of the form:

Meas/Synth = a0 + a1*WavelengthShift + a2*SolarActivity + a3*DihroicShift









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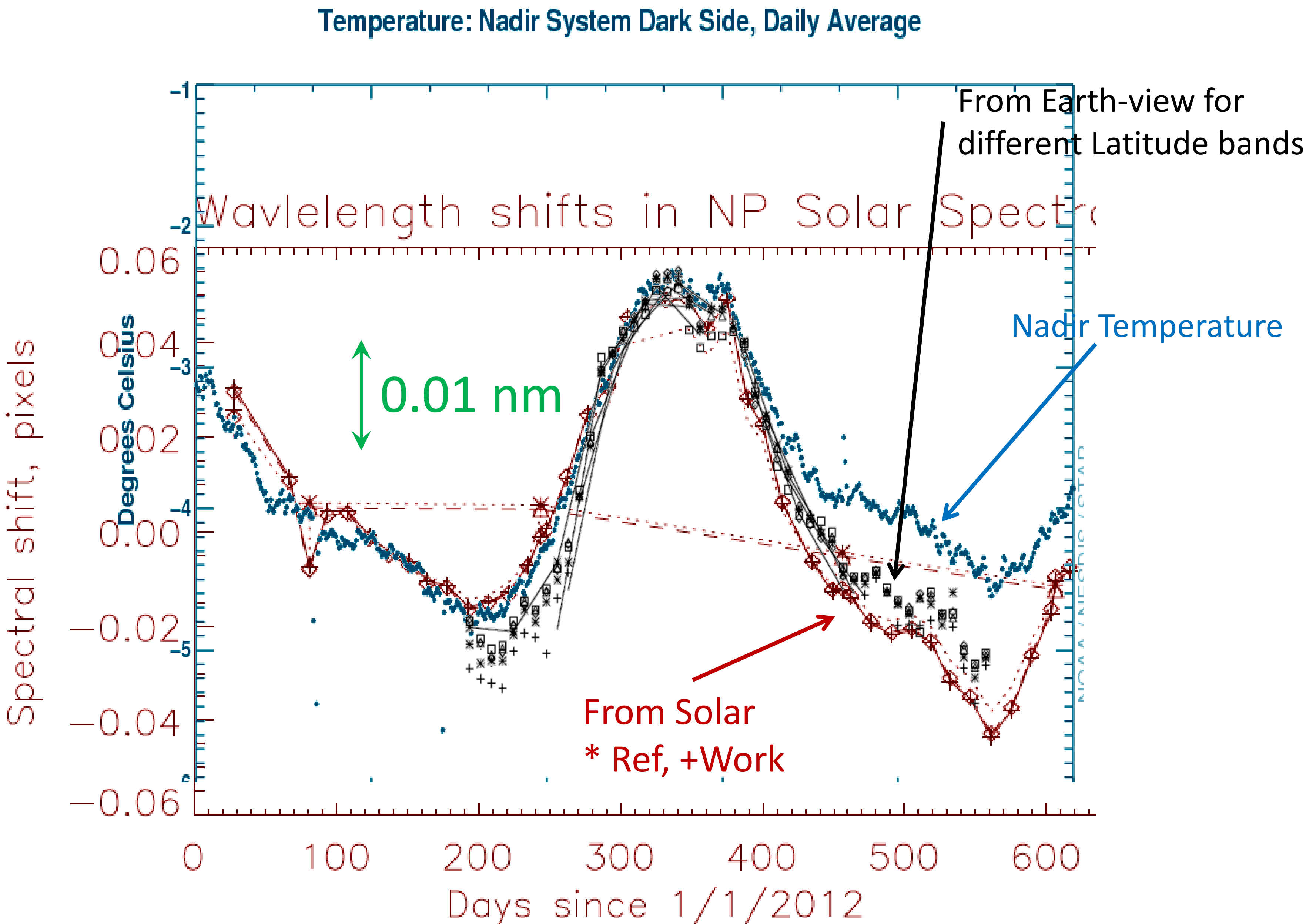
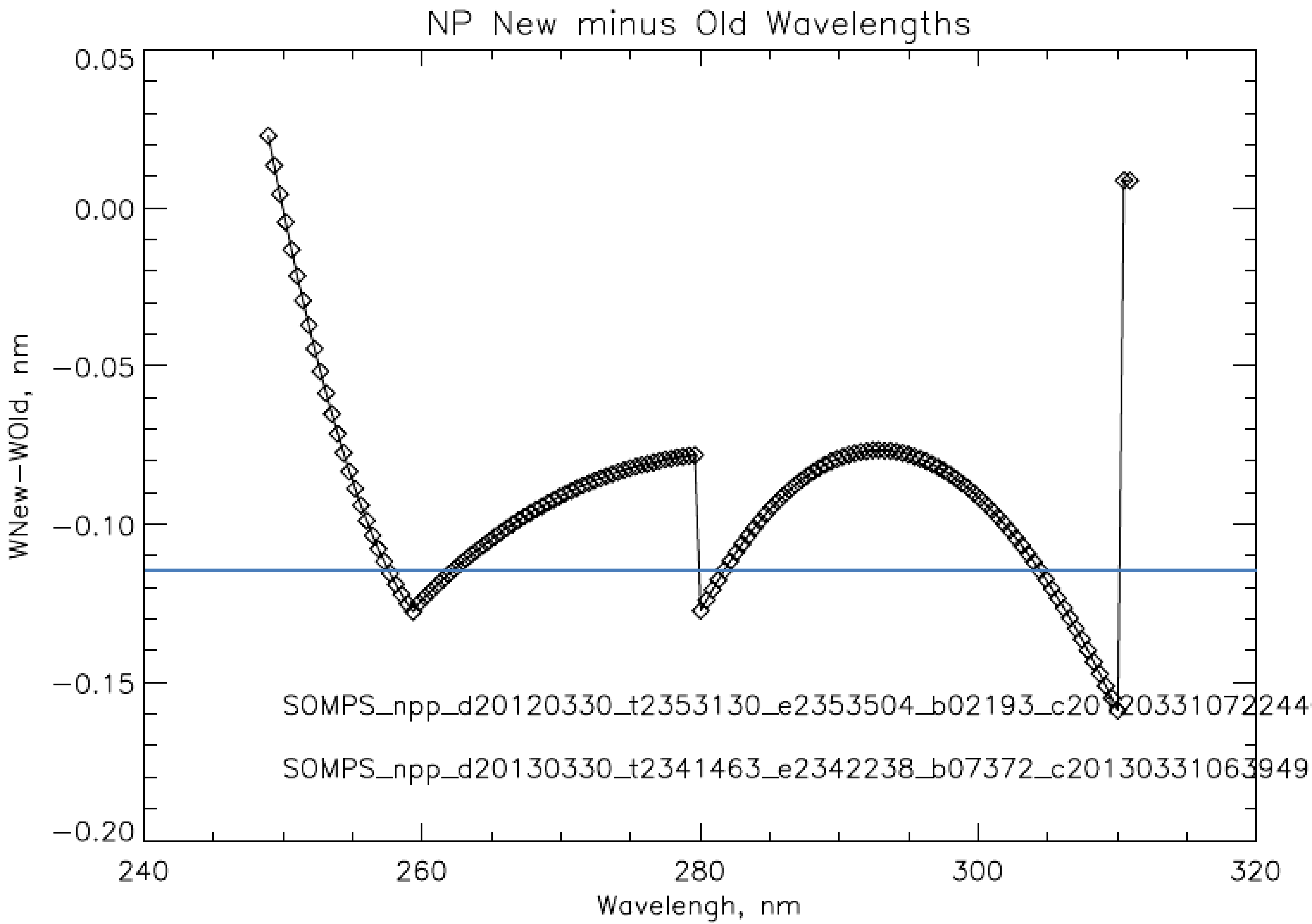
Working Day 81 vs Solstice Synthetic (1.1% rmsr)

%offset	%Mg II	Shift nm	Dich nm
-7.5	7.7	-0.004	-0.347

Comparison of OMPS NP Solar and Earth Wavelength Shifts & Temperatures



Change from pre-launch in current wavelength scale

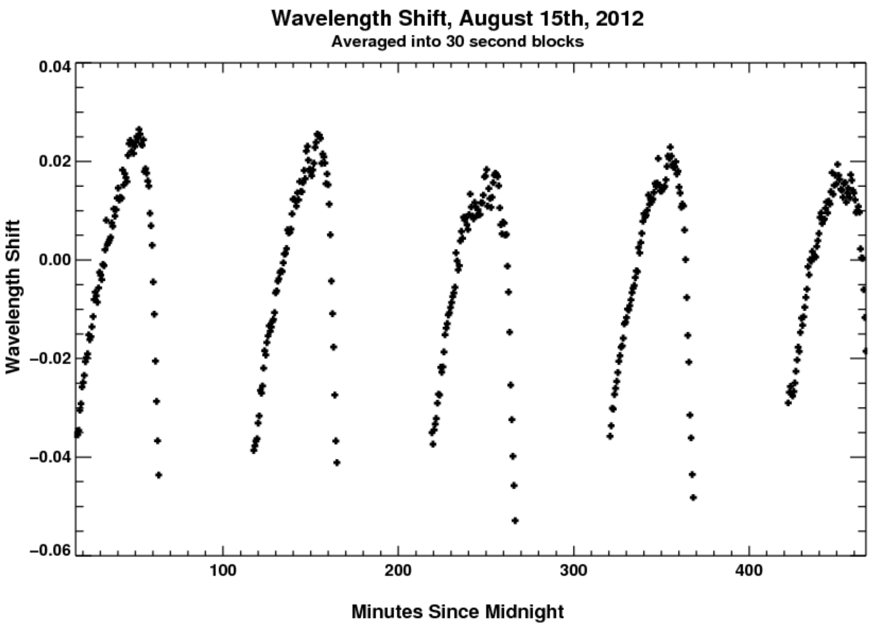


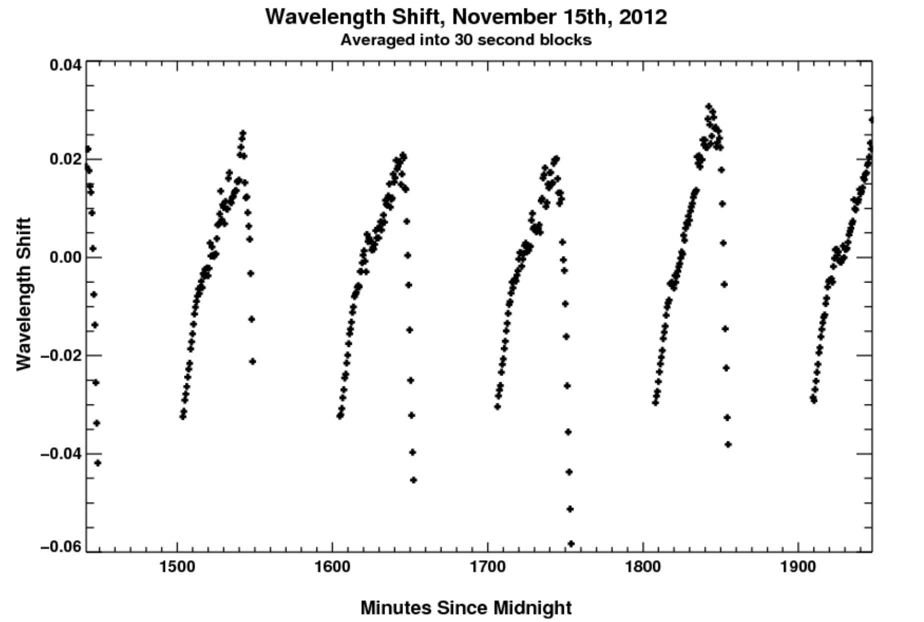
OMPS NM Intra-orbit Shifts

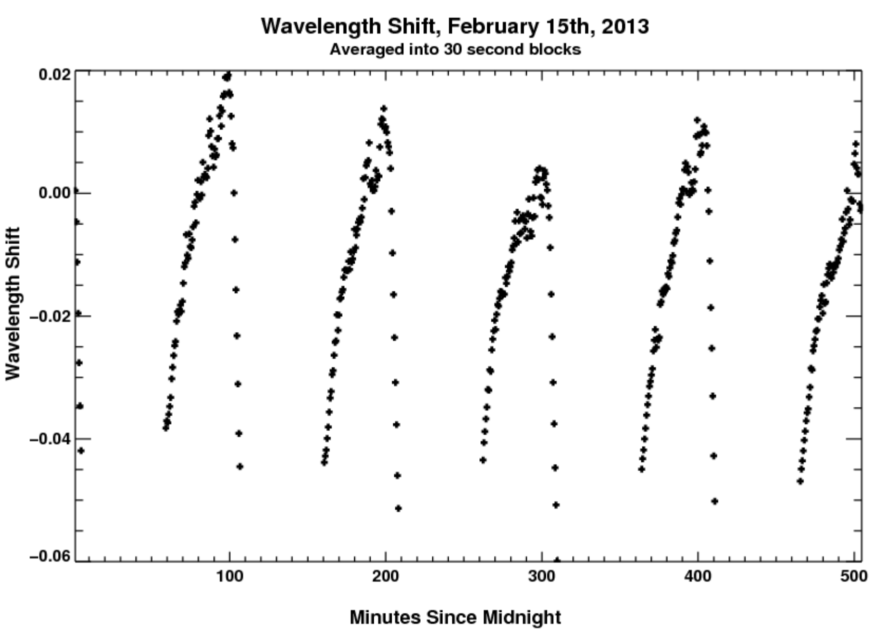
- The OMPS Nadir Mapper Earth-view measurements have been found to have intra-orbital shifts in the wavelength scales.
- They are associated with temperature gradients as the satellite's thermal exposure varies.
- The pre-launch models predicted shifts smaller than the 0.01 nm performance requirement.
- On-orbit analysis has detected shifts greater than +-0.02 nm from the orbital average. In addition, the solar measurements are taken at the northern terminator where solar thermal influences are at an extreme.
- We are implementing a measurement-based estimate of these changes on a granule by granule basis within the SDR algorithm to provide better knowledge of the wavelength scale to the total ozone retrieval algorithm.
- The evidence and then the approach are described in the following slides.

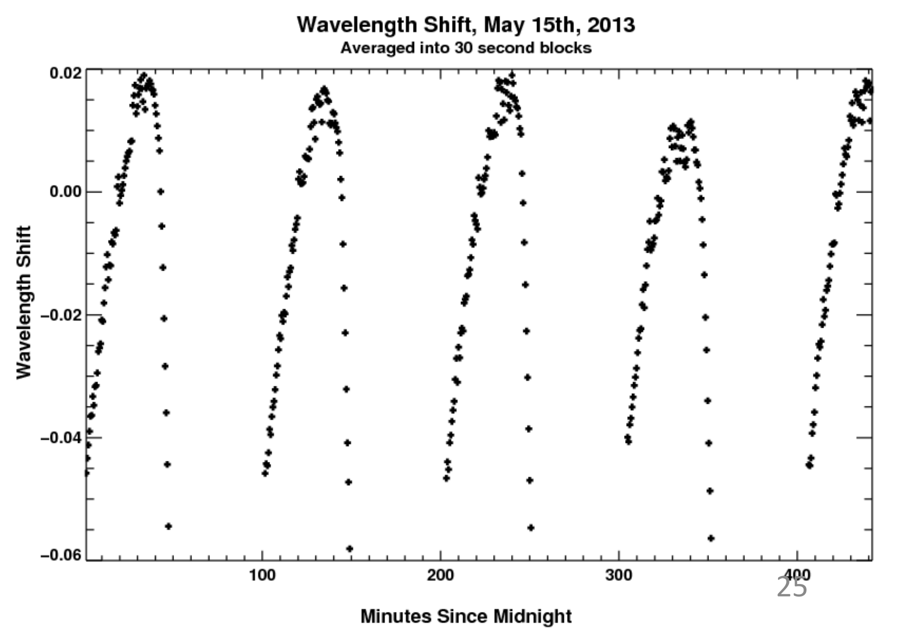
- The panels in Slide 14 show the estimated wavelength shifts for four orbits per day for one day every three months. The shifts are for a single cross-track position and computed relative to a fixed Day 1 solar spectrum.
- The panels in Slide 15 show the differences in two temperature sensors (TC Housing and Nadir Calibration Housing) for the same four days in Figure 1. These two sensors had differences with the best correlation to the results in Slide 14. The undifferenced temperature values have large annual cycles not seen in the spectral shift estimates. There is a lag (~5 minutes) between these particular temperature differences and the shift but the pattern coherence along orbit, among different orbits, and month after month is impressive.
- The two panels in Slide 16 compare shift estimates from two different methods and show the Cross-track dependence. The primary variations in the cross-track dependence of the shift are related to the spectral scales of the different cross-track solar references and are not thought to be an instrument effect.

Wavelength scale shift estimates for the OMPS NM nadir FOV for first four orbits every four months

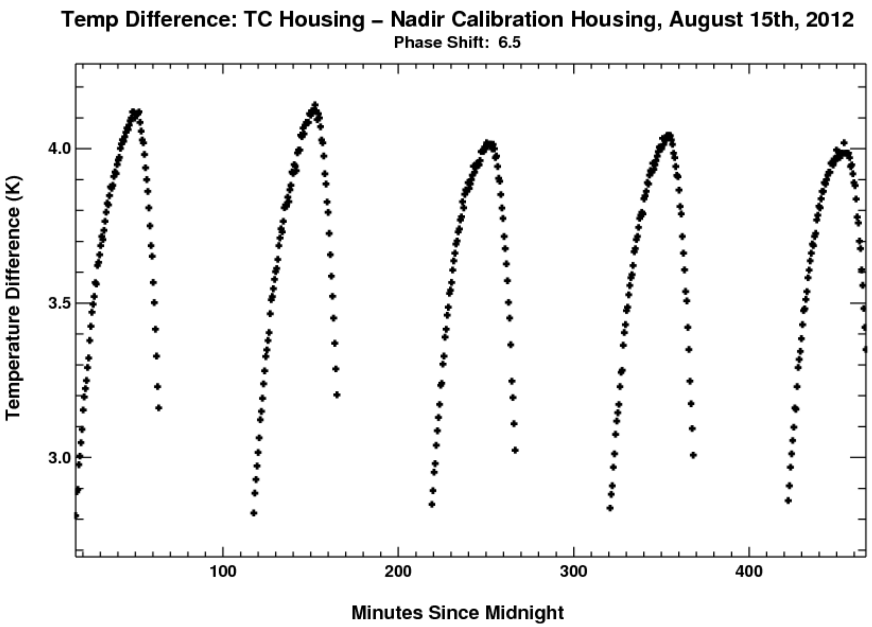


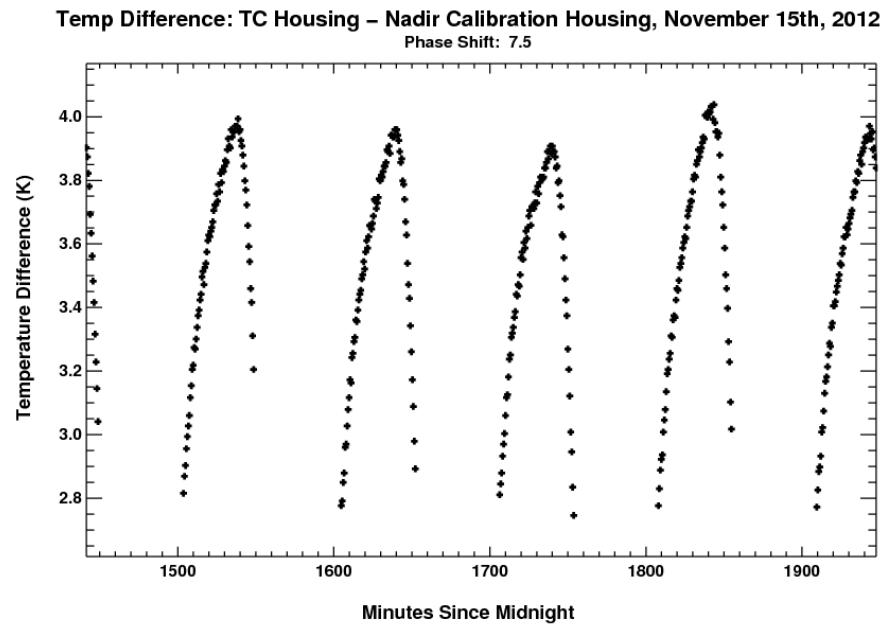


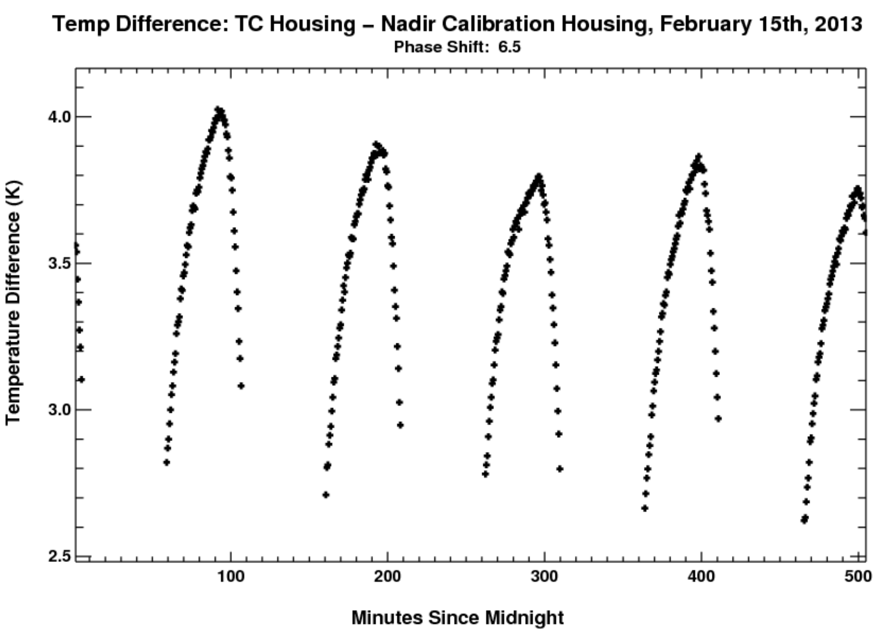


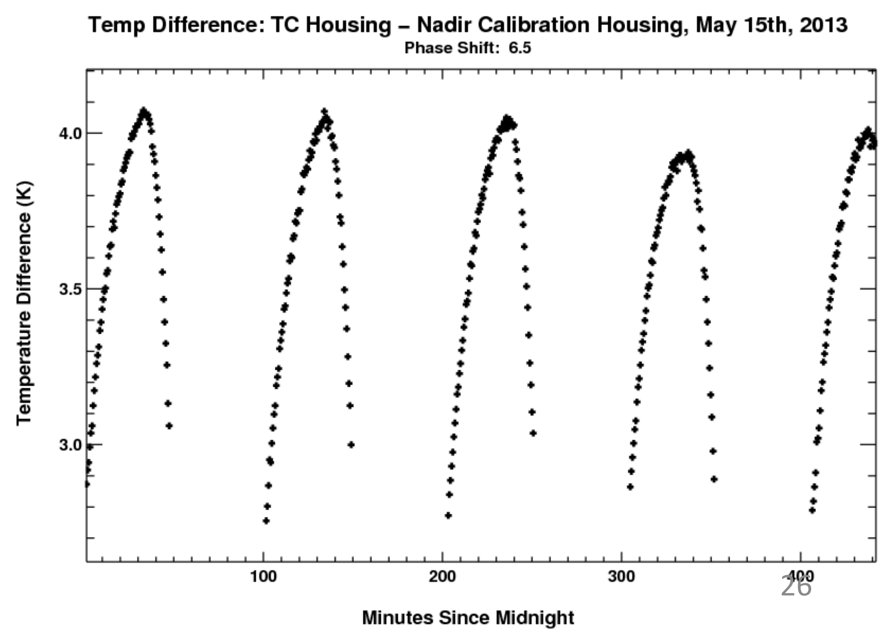


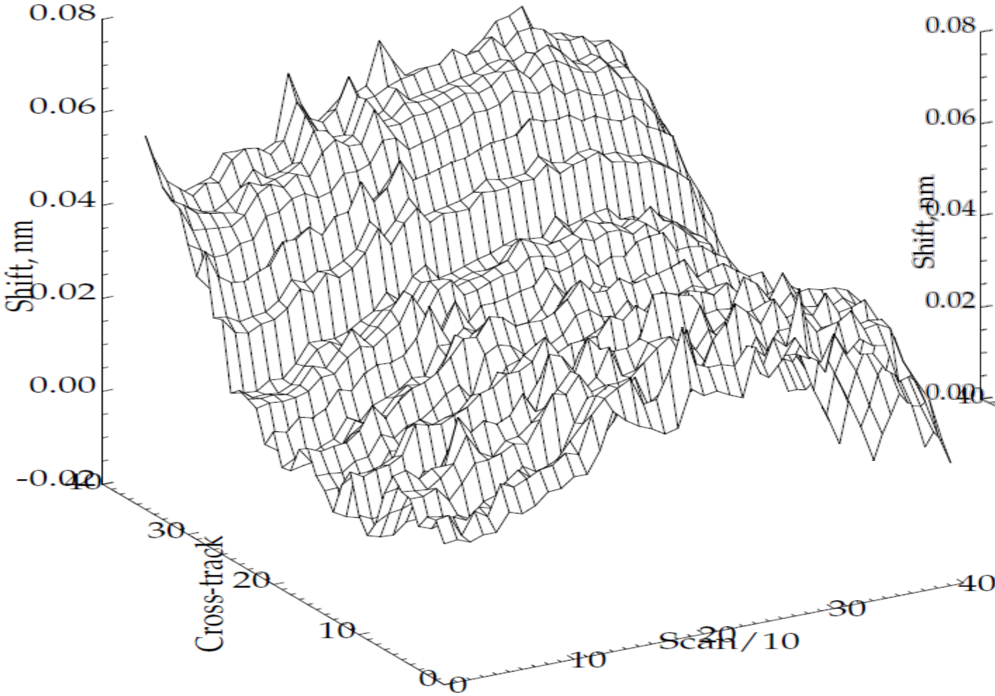
Select temperature differences for same orbits

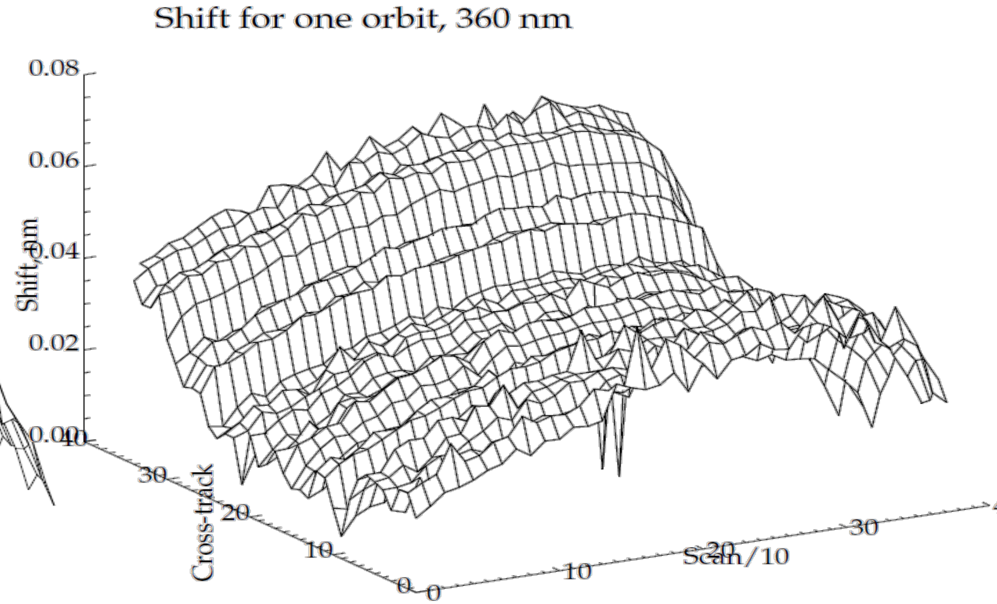












Comparison of cross-track and orbital patterns of estimated Earth radiance scales relative to the current day 1 solar from the proposed method using 346 nm to 380 nm with those from an analysis in an SO_2 product formulation. The two sets of results agree well in both along orbit and cross track variations. The results for every tenth scan are used to create the figures.

Backup

Comparison of Results for Test Granule

SOMTC_npp_d20130205_t1500128_e1500502_b06615_c20130205221511027836_noaa_ops.h5

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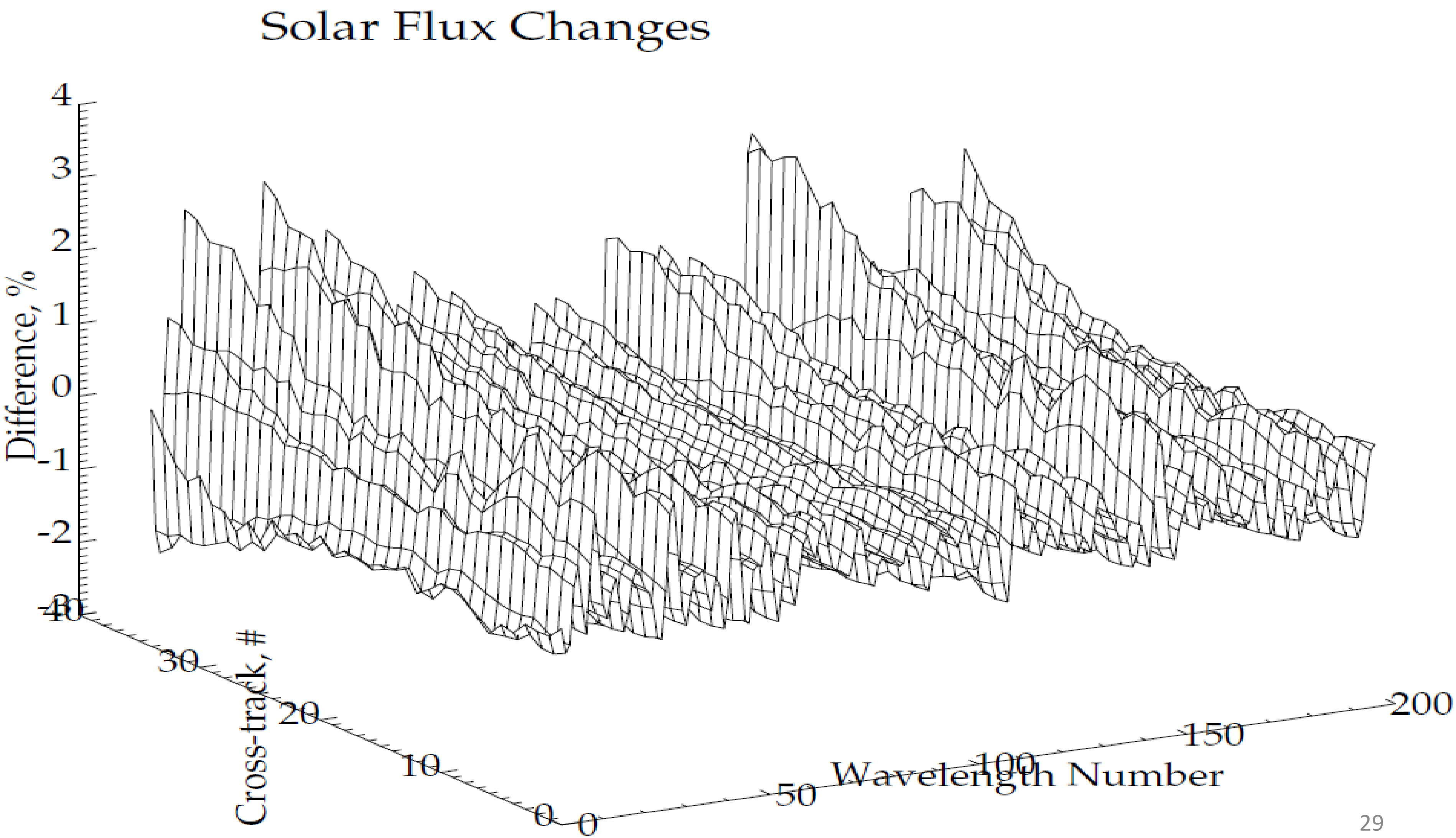
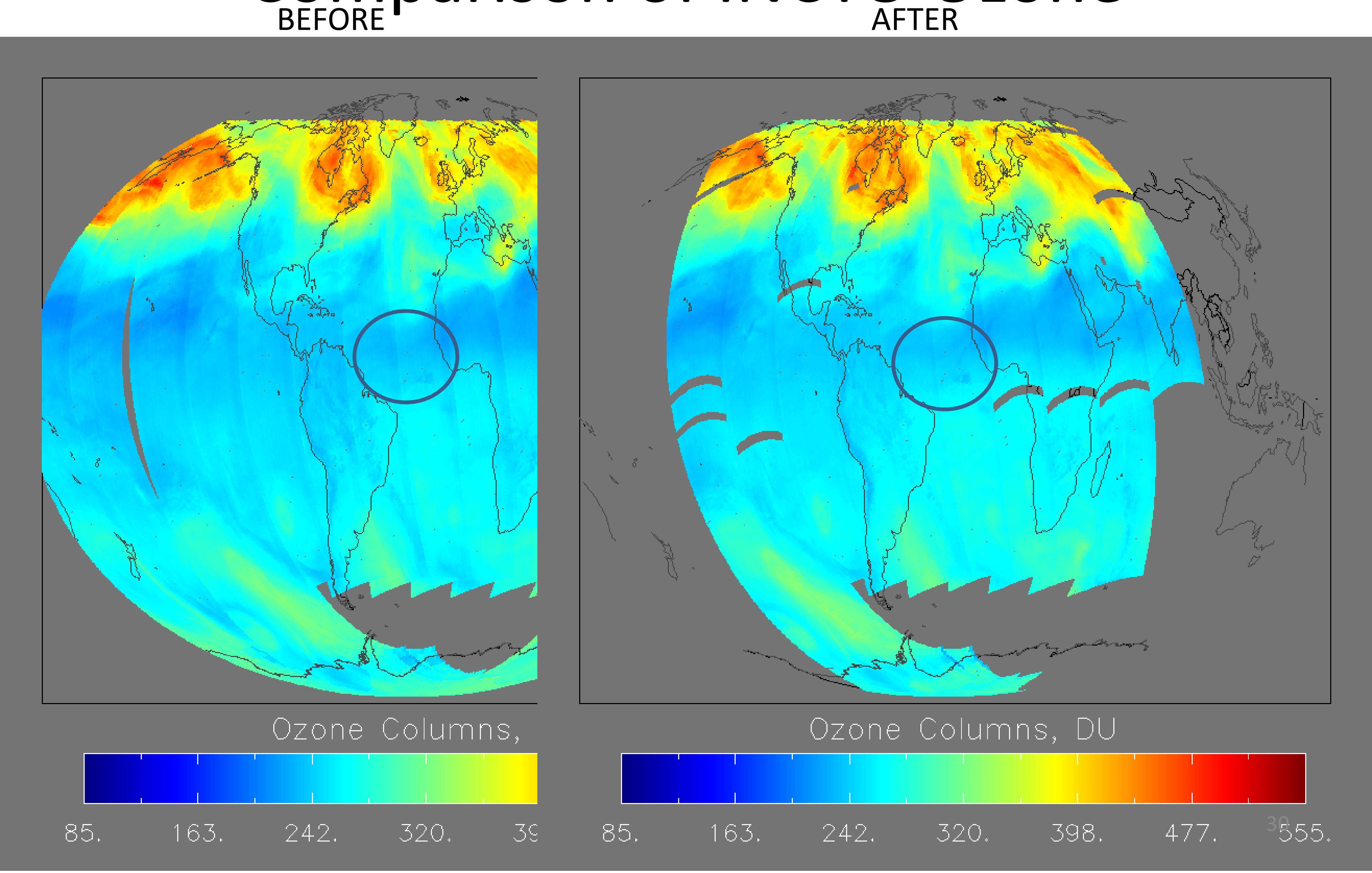
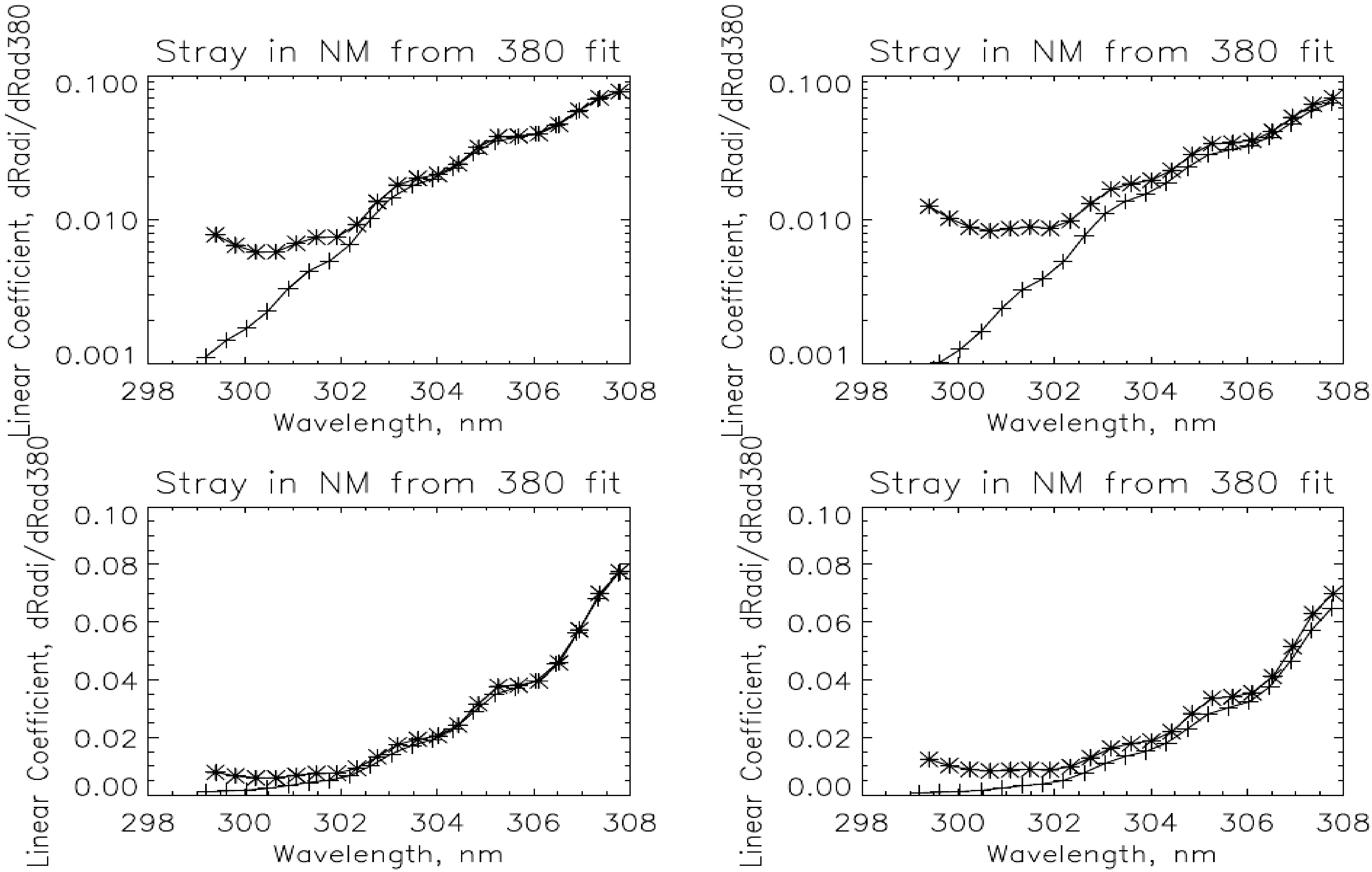


Comparison of INCTO Ozone



Notice reduced striping – better cross track consistency



A correlation study of 380 nm variations at small SZA versus variations at NP and NM channels below 308 nm. The method subtracts a smooth function of latitude from the radiances for all of the data sets and then looks for a linear relationship between the remaining variations at 380 nm with those for each of the target channels. At 380 nm, these variations are dominated by changes in the scene brightness. The figures on the left show the results for the current IDPS product. It has the stray light correction (but with the OOR set at 0). The figures on the right show the results for IDPS prior to the implementation of the stray light correction. The + symbols are for the NP channels and the * symbols are for the NM channels. The NP results show the expected fall off in sensitivity of radiances to scene brightness with decreasing wavelength (increasing ozone absorption.) These coefficients are in units of target radiance / source radiance .

Description of the Approach for OMPS NM Solar

The Earth radiance spectra have very similar features to the solar spectra over the 345 nm to 380 nm range, that is, there is little absorption by atmospheric constituents and modest wavelength dependence to scattering and reflectivity. Thus the Fraunhoffer structure is well-reproduced. These common features cancel in properly aligned/coregistered radiance/irradiances ratios so deviations from a flat albedo can be used to estimate the relative wavelength scale difference between a Day 1 Solar and a current Earth radiance measurement. The process is as follows:

1. Estimate the expected pattern in a solar spectrum that a wavelength shift would produce by using the day 1 solar spectrum at 0.42-nm resolution and the wavelength to wavelength variations. (Recall that the OMPS Nadir Mapper has 1.0-nm resolution)

This pattern is computed by finding the slope of a quadratic fit of the irradiances for three adjacent values and normalizing the irradiance/pixel slopes by the irradiance spectrum.

2. Estimate the expected pattern in the Earth spectrum that would be produced by inelastic scattering (Ring effect) contributions.

This pattern is computed by taking the reciprocal of the solar spectrum.

3. Find the normalized albedo patterns from non-smooth contributions.

This set of variations is determined by taking the radiance/irradiance ratio and normalizing by the averages of the two and removing a cubic polynomial in wavelength.

4. Remove similar smooth functions of wavelength from the patterns in 1. and 2. so that all three are relative quantities varying about zero.

This is performed by finding and removing polynomial fits for each pattern. Cubics are found to work well.
For the Earth-view spectra, this model component is designed to account for the smooth variations in Earth albedo due to the wavelength dependent effects of aerosols, elastic Rayleigh scattering, and cloud and surface reflectivity. Since we take a smooth pattern out of the Earth data we need to take it out of the other two patterns too.

5. Find the components in the normalized albedo related to the two patterns to estimate the wavelength scale shift between the Earth and solar spectra.

This is calculated by using the relative variations from 3. and 4. [the Earth albedo (radiance/irradiance ratios) using for measured radiances and the reported solar by using the two patterns (shift and Ring)] in a multiple linear regression.

Normalized Earth Albedo = C1 * Normalized Shift pattern + C2 * Normalized Ring Pattern

6. Use the coefficient for the shift pattern from 4. and the shift pattern to adjust the solar spectrum to the Earth wavelength scale and report the new solar spectrum and the shifted scale as outputs in the SDR product.

This simply uses the value of C1 and the shift pattern in 1. to create the adjusted output.

New Subroutine in the SDR Algorithm

OMPS_NM SDR 474-00077_OAD

Section 2.1.2.3.67 Subroutine sol_wscale_shift.f

This subroutine estimates the Earth-view radiances wavelength scale relative to the solar spectrum wavelength scale and returns the new wavelength scale and an appropriately adjusted solar spectrum.

Changes in the output

ALL_DATA.OMPS_TC_SDR_ALL.solarflux (SolarFlux*) contains the day 1 solar flux spectra as input and the wavelength-shifted solar flux spectra as output.

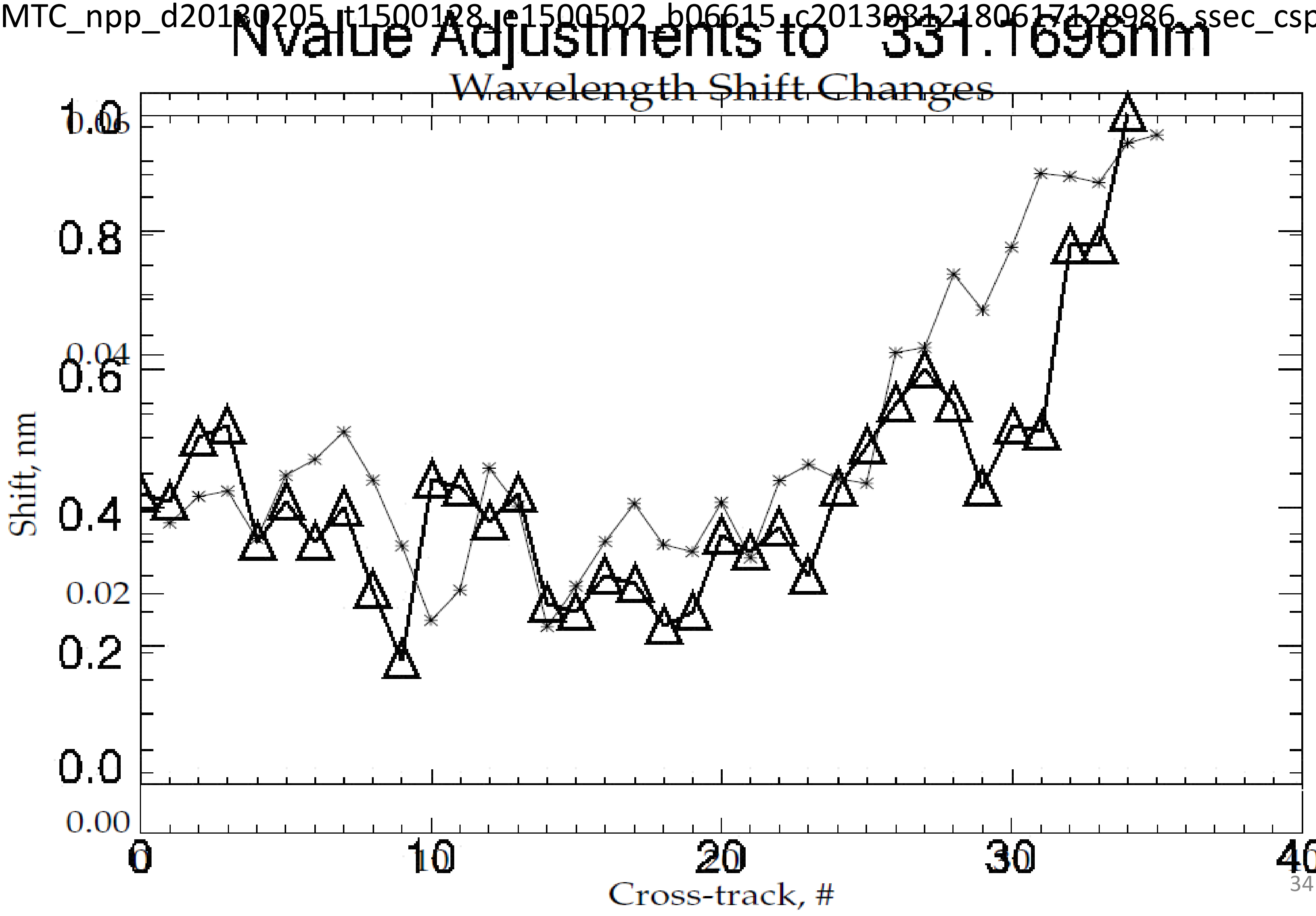
ALL_DATA.OMPS_TC_SDR_ALL.wavelengths (Wavelengths*) contains the day 1 solar flux wavelength scales on input and the earth radiance wavelength scales on output. The last spectral position (260) is overwritten with the shift in nm.

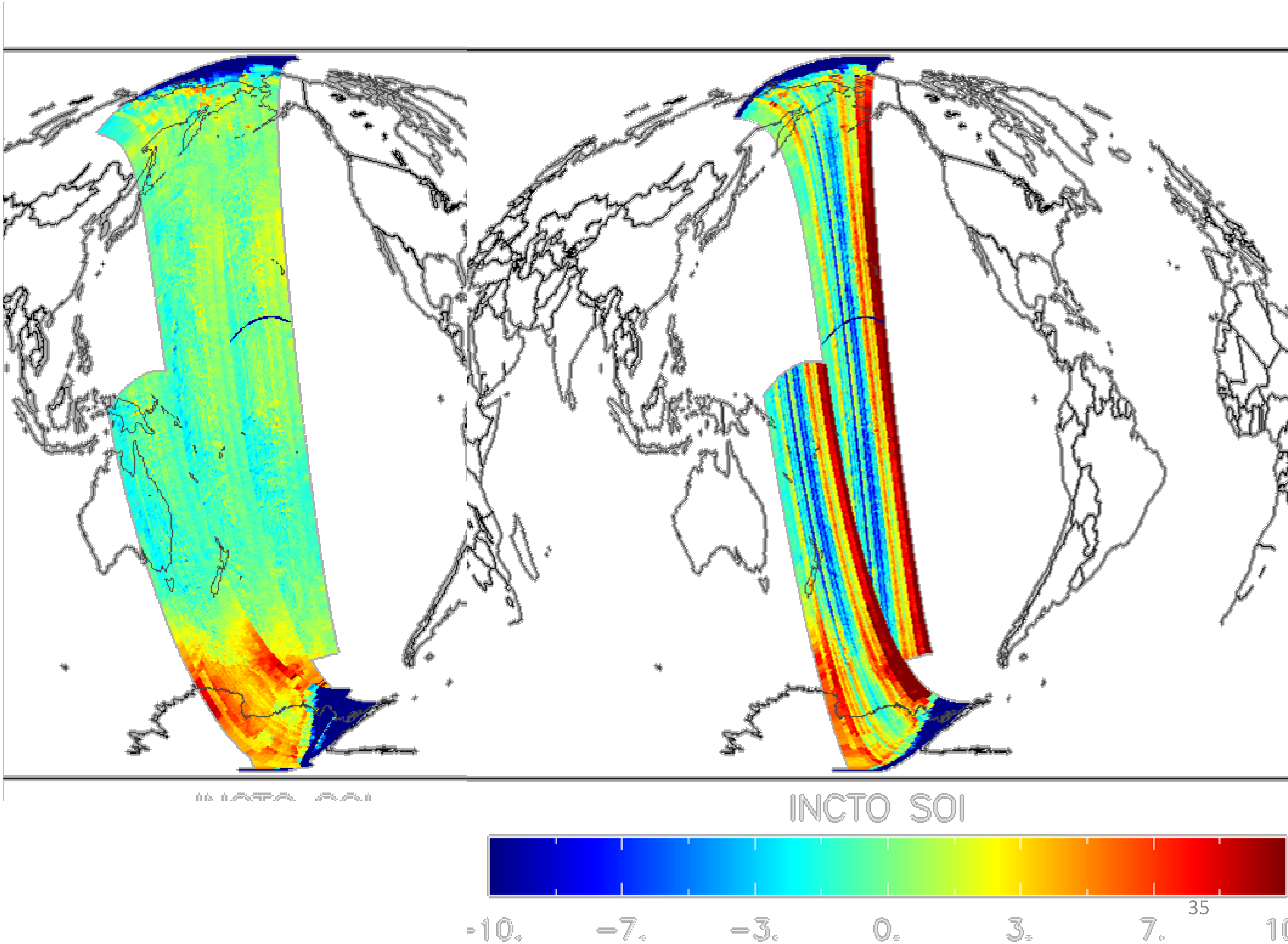
***CDFCB_X_Vol_3 Table 2.10.1.1-1, OMPS TC SDR Data Content Summary**

Comparison of Results for Test Granule

SOMTC_npp_d20130205_t1500128_e1500502_b06615_c20130205221511027836_noaa_ops.h5

SOMTC_npp_d20130205_t1500128_e1500502_b06615_c20130812180617128986_ssec_cspp.h5




INCTO SOI
-10.
-7.
-3.
0.
3.
7.

For each stage of Validation, the Calibration and Validation Team shall develop a Validation Package that includes the following:

Algorithm Assessment

Evaluation of algorithm performance to specification requirements

Evaluation of the effect of required algorithm inputs such as, but not limited to, the following:

Ancillary Data

Sensor Data Record(s)

Upstream Environmental Data Records

Upstream Intermediate Products

Look Up Tables (LUTs)

Processing Coefficient Tables (PCTs)

Error Budget

Quality Flag analysis/validation

Input from key users

Identification of the processing environment

IDPS Build Number and effectivity date

Version of LUT(s) used

Version of PCT(s) used

Description of environment used to achieve particular stage of Validated

Documentation

Current or updated ATBD

Current or updated OAD (algorithm-related redline updates, if applicable)

README file for CLASS

Product User's Guide (Recommended)

User Precautions

Identify known issues

List closed Discrepancy Reports between previous maturity milestone and current maturity milestone.

Provide assessment of outstanding Discrepancy Reports

Validation Stages	Definition
Validated Stage 1	Using a **limited** set of samples, the algorithm output is shown to meet the threshold performance attributes identified in the **JPSS Level 1 Requirements Supplement with the exception of the S-NPP Performance Exclusions**
Validated Stage 2	Using a **moderate** set of samples, the algorithm output is shown to meet the threshold performance attributes identified in the **JPSS Level 1 Requirements Supplement with the exception of the S-NPP Performance Exclusions**
Validated Stage 3	Using a **large** set of samples representing global conditions over four seasons, the algorithm output is shown to meet the threshold performance attributes identified in the **JPSS Level 1 Requirements Supplement with the exception of the S-NPP Performance Exclusions**
Validated Stage 4	Using a **large** set of samples representing global conditions over four seasons, the algorithm output is shown to meet or exceed the objective performance attributes identified in the **JPSS Level 1 Requirements Supplement with the exception of the S-NPP Performance Exclusions**

I am trying to sort out the interactions of the three subject complications and I have some comments, questions and observations.

The first observation is that the NP and NM wavelength scales as provided in Spring 2012 have approximately -0.1-nm shifts in the wavelength scales for both relative to the ground-based results. Since, as Glen notes, we have a pixel-based calibration for OMPS and the dichroic is wavelength-based in its action, there needs to be adjustments to both NP and NM and to both irradiances and radiances for these two shifts, or to the calibration coefficients. I know Colin has looked at a 0.15 shift for the NM (In the radiances only I assume?).

Are any adjustments applied to the NM or NP solar data for the -0.1 nm wavelength shift effects through the dichroic?

(Note: If not, then since the EV data are not currently adjusted for this effect of the shift, the errors should cancel in the ratios.)

The second observation is that both of the wavelength shifts I see in the data (intra-orbital for the NM and intra-annual for the NP) need corresponding adjustments for their interactions with the dichroic. (I find that including the effects of the shift on the dichroic throughput as coupled with a wavelength shift improves the fits of the NP working solar data.) I have not yet looked at the effects of the NM intra-orbital shifts from this interaction. (We could adjust the irradiances for the expected dichroic effects in the wavelength scale shift code as implemented at IDPS when we make the solar match the earth.)

The third observation is that there are still correlations between the NM radiances differenced with the NP radiances in the 300-310 nm interval and the scene brightness as determined from longer wavelengths. That is, the stray light correction (at IDPS w/o an OOR correction) is leaving a significant variation with a stray light signature. While this variation is apparent at low SZAs with scene brightness correlation analysis, it will also be present at higher SZAs with a different dependence as the relative radiance at longer and shorter channels changes systematically. Since this is dependent on the source wavelength it is hard to determine how it will vary along an orbit.

Are there any adjustments/corrections to the solar for the NM or NP for stray light?

What stray light corrections are currently in the PEATE Earth-View SDR processing?

How large are the planned OOR corrections for NM stray light? What are their scene brightness and SZA dependent aspects?

I think the first questions to answer are:

Have the solar spectra have been adjusted for the dichroic/shift interactions?

Have they have been corrected for stray light?

The next question is whether comparison of the two in the overlap region show what's expected given the answers to these two questions.