OMPS SDR OVERVIEW

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OMPS SDR Team

Outline

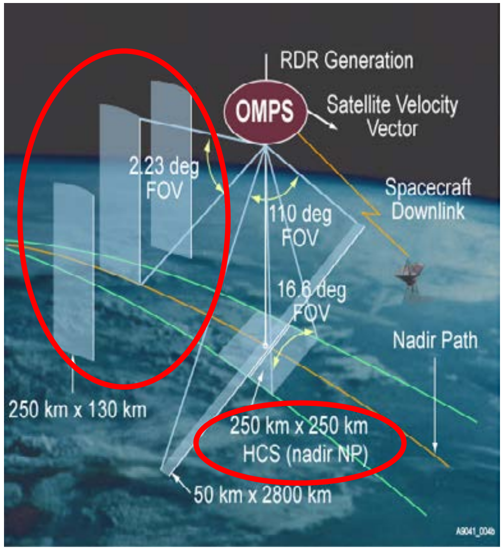
- Cal/Val Team Members
- Sensor Overview
- S-NPP SDR Product Overview
    - SDR Performance Summary
    - Reprocessing Status and Block 2.0 system
    - Long Term Monitoring
    - Users feedback
- JPSS-1 Readiness
    - Significant Algorithm changes from S-NPP to JPSS-1
    - Pre-launch Characterization- Results/Accomplishments
    - Post-Launch Cal/Val Plans
    - Schedules and Milestones
    - Accomplishments and Highlights Moving Towards J1
    - Major Risks/Issues/Challenges/and Mitigation
    - Collaboration with Stake Holders/User Agencies
- Summary and Path Forward

Cal/Val Team Members

PI	Organization	Team Members	Roles and Responsibilities
Fuzhong Weng	NOAA/STAR	C. Pan, T. Beck, Eve-Marie, eve-marie Devaliere, Sri Madhavan, Shouguo Ding, D. Liang	Budget and coordination; instrument and product performance monitoring; TOMRAD/VLIDORT modeling
Glen Jaross	NASA	Tom Kelly, Rama. Mundakkara, Mike Haken, Collin Seftor	Instrument scientist; TVAC data acquisition and analysis; SDR algorithm.
Laura Dunlap	STC/AMP		Algorithm changes coordination; DR and issues tracking
Sarah Lipscy	BATC		Instrument scientist; prelaunch test
Wael Ibrahim	Raytheon	Derek Stuhmer, Daniel Cumpton	IDPS operations

OMPS Instrument Overview

- **Enhanced spatial resolution with new timing patterns**
  - Provides Total Column ozone data w/ 50x50 km^2 IFOV at nadir
  - Provides ozone profiles in 5 ground pixels of $50x50^2$ km at nadir
- **Configuration**
  - Push-broom 110 deg. cross-track FOV telescope
  - Two grating spectrometers
    - NM covers 300 – 380, 420 nm
    - NP covers 250 nm to 310 nm
  - CCD optical detector for each spectrometer
- **Onboard Calibrators**
  - Light-emitting diode provides linearity calibration
  - Reflective quasi-volume diffusers (QVD) maintains calibration stability
- **Products**
  - Provide globe maps every 24 hours of amount of ozone and volumetric concentration in a vertical column of atmosphere with a 4- days revisit



Spatial resolution will be altered to provide low, medium and high spatial resolution data

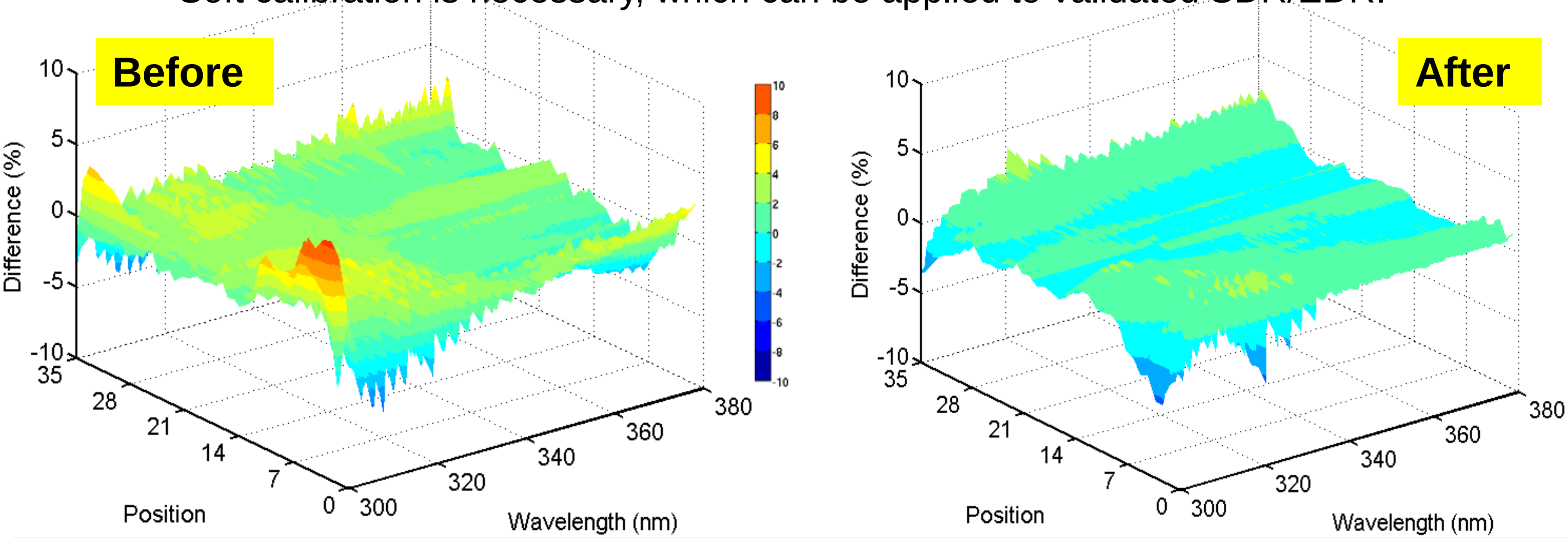
- The LP will not be present for J-1
- NM slit redesigned to reduce "puckering"
- Optical mounts redesigned to improve boresight stability
- Modified optical alignment permits wavelengths up to ~420nm -- potentially enhances science products and help to correct nadir geolocation and stray light OOB.
- Generation of three SDR products: EV SDRs, Cal. SDRs (offline), and GEOs

SNPP SDR Product Overview

- OMPS EV SDR Maturity
  - ✓ Beta since March 2012; Provisional since March 2013 and Validated since September 2015
- OMPS EV SDRs meet SDR performance requirement as well as EDR products requirement
  - ✓ The cross-track direction radiance error is minimized < 2.0
  - ✓ The NM and NP consistency in 300-310 nm has been improved by 2-10%
  - ✓ Sensor orbital performance is stable and meet expectation in general
  - ✓ Geo-location accuracy error < 5.0 km
- OMPS EV SDRs have following features
  - ✓ On-orbit sensor performance is characterized
  - ✓ SDR product uncertainties are defined for representative conditions
  - ✓ Calibration parameters are adjusted according to EDR requirement
  - ✓ High quality documentation is completed
  - ✓ SDR data is well defined for applications and scientific publication

Justification for OMPS EV SDR Quality

- Requirements (Performance Since Validation)
  - Instrument: **meeting specifications with adequate margins.**
  - SDR: **stable (quality and quantity)** and free of major errors.
- SDR software
  - IDPS has been producing satisfactory products.
  - Incremental improvements are planned and will continue.
- Applications:
  - **Information contents are sufficient to make positive impacts**.
  - Soft calibration is necessary, which can be applied to validated SDR/EDR.



Evaluated by comparison w/ MLS on the SDR level and NOAA 19 SBUV/2 on EDR level

SNPP NM Performance Summary

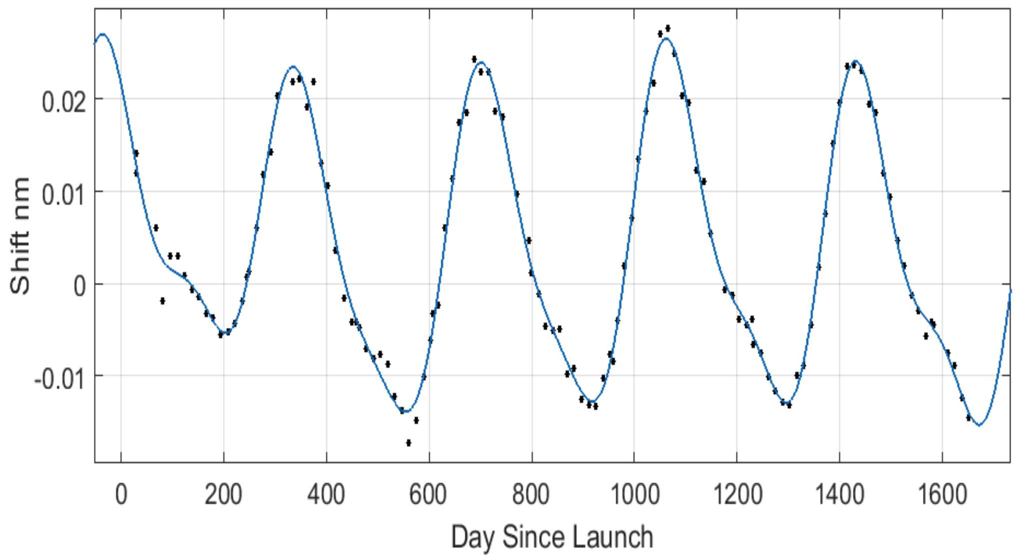
SDR Budget Term	Requirement/Allocation	On-Orbit Performance
Non-linearity Accuracy	< 0.2%	< 0.2%
Stray Light NM Out-of-Band + Out-of-Field Response	≤ 2	≤ 2%
SNR	1000	> 1000
Orbital thermal Wavelength Shift	Allocation (flow down from EDR error budget) = 0.02 nm	~0.006 nm
Absolute Irradiance Calibration Accuracy	< 7%	< 7% for most of the channels
Absolute Radiance Calibration Accuracy	< 8%	< 8%
Albedo Calibration Accuracy	< 2%	< 2% for most of the channels

SNPP NP Performance Summary

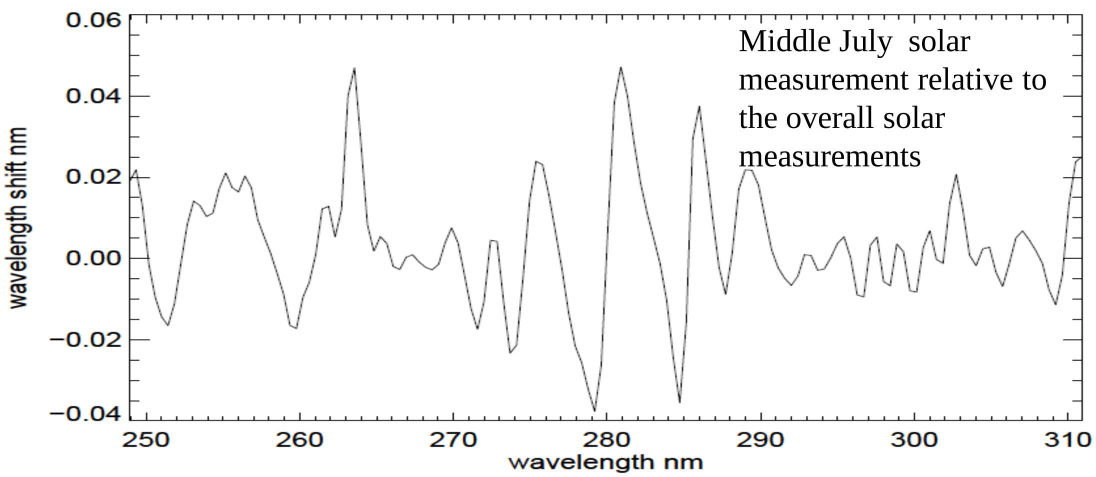
SDR Budget Term	Requirement/Allocation	On-Orbit Performance
Non-linearity Accuracy	< 0.2%	< 0.2%
Stray Light NP Out-of-Band + Out-of-Field Response	≤ 2%	≤ 2% for most of the channels
SNR	45-400 channel dependent	meet requirement
Orbital Thermal Wavelength Shift	Allocation (flow down from EDR error budget) = 0.02 nm	~0.03 nm
Absolute Irradiance Calibration Accuracy	< 7%	< 7% for most of the channels
Absolute Radiance Calibration Accuracy	< 8%	< 8%
Albedo Calibration Accuracy	< 2%	< 2%

Correction of NP Wavelength Shift

- User feedback



f(x) =
a1*sin(b1*x+c1) +
a2*sin(b2*x+c2) +
a3*sin(b3*x+c3) +
a4*sin(b4*x+c4)



Linear model: f(x) = p1*x + p2
Coefficients (@ 95% confidence bounds):
p1 = 32.68 and p2 = 0.006929

Goodness of fit: SSE: 1.32
R-square: 0.8
RMSE: 0.1549

The requirement of 0.02nm shift was waived at the instrument level. The correction will be made on SDR level to meet EDR requirements.

Why Reprocessing OMPS SDR

Beta
Since Mar. 05, 2012

Provisional
Since Mar. 01, 2013

Validated
Since Sept. 2015

- Calibration and EV SDR separation
- Wavelength, solar day one and dark update
- Earth view sample table update
- RDR truncation correction

Mx6.2 - 2012-08-10

Mx7.1-Mx7.2 Feb. 28 2013

- SAA dark LUT update Mx7.1, May 20, 2013
- Error in Scene ascending/descending condition Flag Mx7.1, May 20, 2013
- TC SL correction was resumed - Mx7.2, Aug. 21, 2013

- TC Wavelength ajustement - Mx8.2
- NP SL LUT - Mx8.3 Mar. 18, 2014
- OMPS Bias LUT correction for negative smears in TC SDR – Mx8.5 July 22, 2014
- TC SL LUT update – Mx8.6, Nov. 21, 2014
- NP wavelength

Mx8.2- Feb. 20 , 2014

Mx8.11 2015-09-09

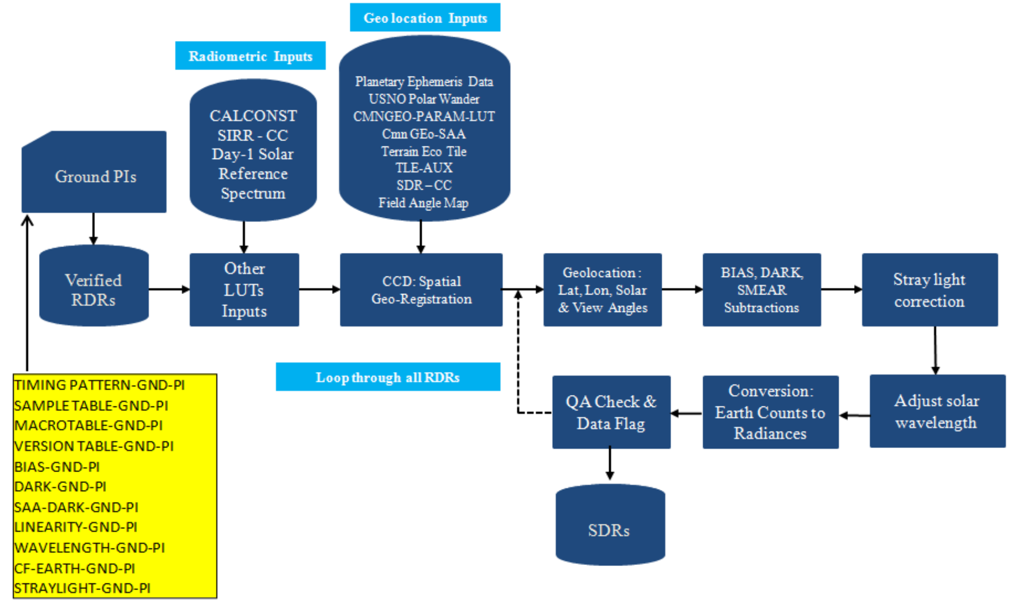
- TC Wavelength ajustement
- NP Wavelength ajustement
- TC and NP Solar day one LUTs update
- TC and NP radiance constants update
- TC wavelength LUT format change to include wavelength shift component
- SDR code change to process the changed wavelength format.

- ➢ SDR quality chronologically improved since launch via measurement sequence, algorithm, LUTs, ground operational codes
- ➢ Produce consistent SDRs at the attainable quality level.
- ➢ Apply consistent weekly routine dark corrections to all of the data records.
- ➢ Use up-to-dated calibration LUTs and algorithm in OMPS SDR life-cycle with upgraded IDPS system B2.0

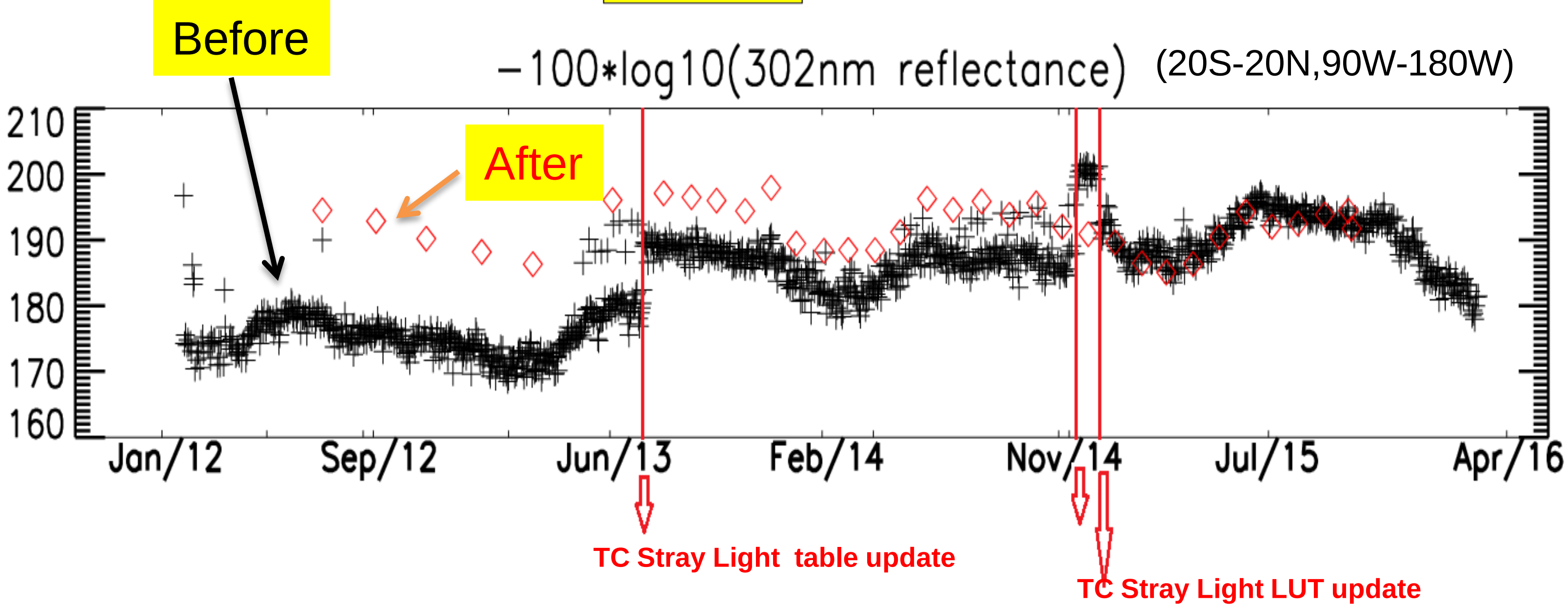
Preliminary Results from Reprocessing

Schematic showing Earth View SDR generation process

Use ADL5.3 tool package



Preliminary reprocessing results of daily average N-value over the Tropical Pacific region from SNPP NP 302 nm channel

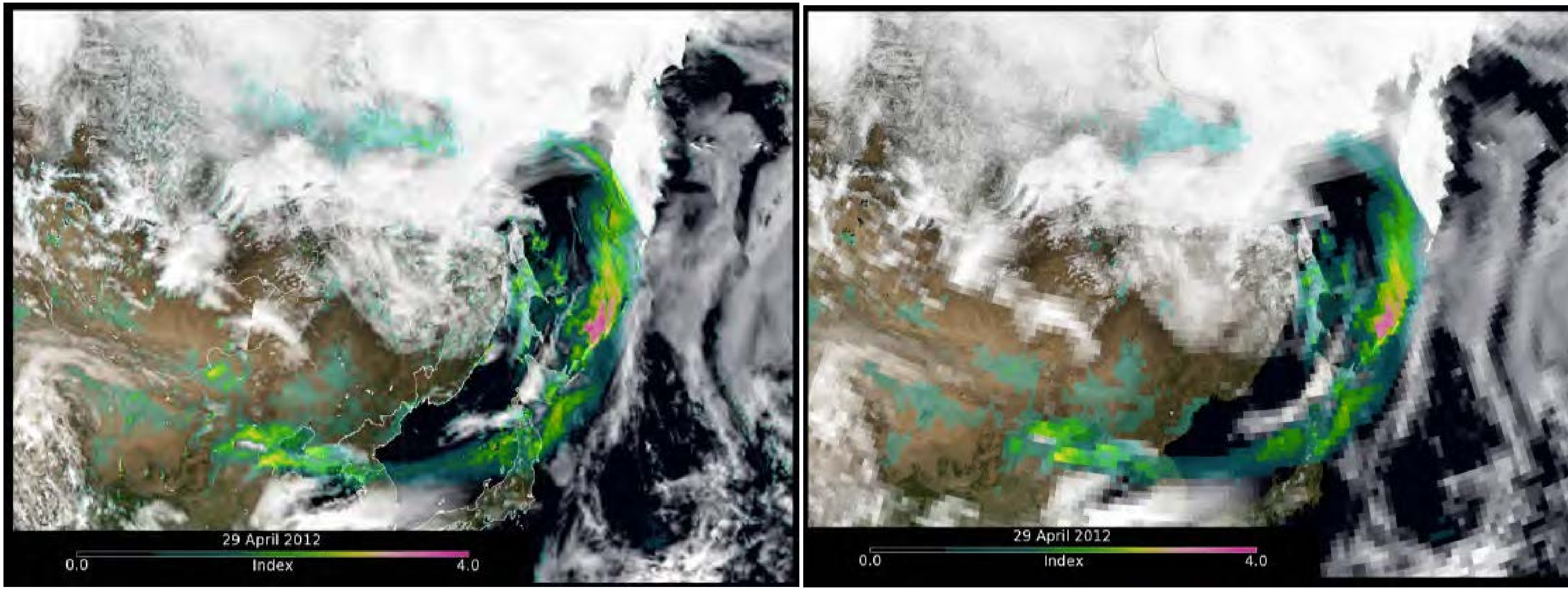


Expected Results from Reprocessing

- No long term time-dependent change relative to NOAA-19 SBUV/2.
  - OMPS NM bias of near zero and NP bias of about 0.5% (V8 algorithm).
- Produce consistent SDRs that meet the users' satisfaction. The SDRs will have
  - Minimized cross-track IFOV radiometric error < 2%.
  - Consistent data records between NP and NM in 300-310 nm.
  - Stray light correction is adequate.
  - Less than 5.0 km geometric uncertainty at nadir using MODIS as reference
  - All channels meet SNR requirement
  - For the most channels the wavelength independent albedo uncertainty is < 2% using MLS as a reference.

Higher Spatial Resolution Data

- User feedback

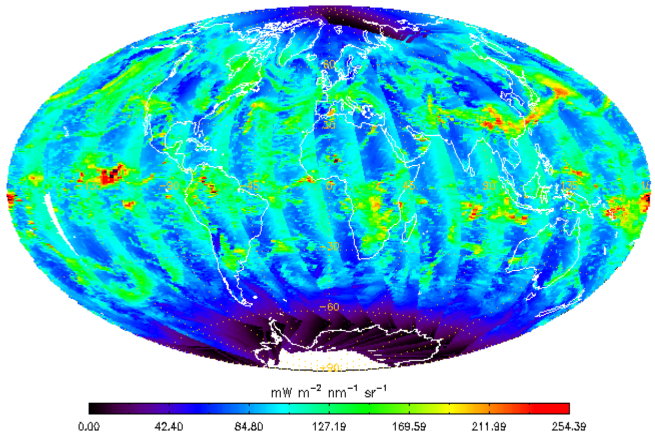


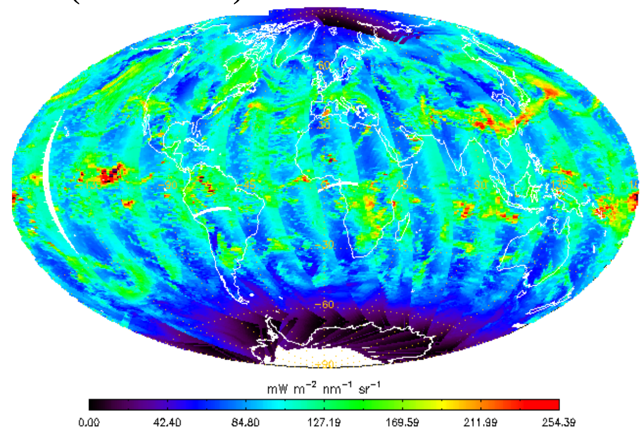
- Aerosol Studies from Colin Seftor/SSAI: On 29 April 2012, OMPS aerosol index data (10 km x10 km data left) captured a dust cloud from China's Taklamaken Desert. Color bar is optical depth. Right is the same scene with the OMPS data degraded to 50 km x 50 km resolution.
- High resolution data collection requires FSW 6.0
- B2.0 SDR algorithm is capable to process 17 km x 17 km resolution data

SNPP B2.0 System Verification

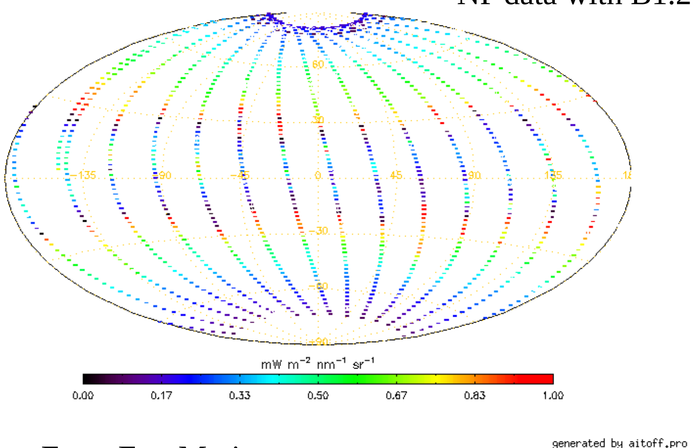
- Delivered B2.0 algorithm tables and LUTs
- Verified SDR science data and geo-location data

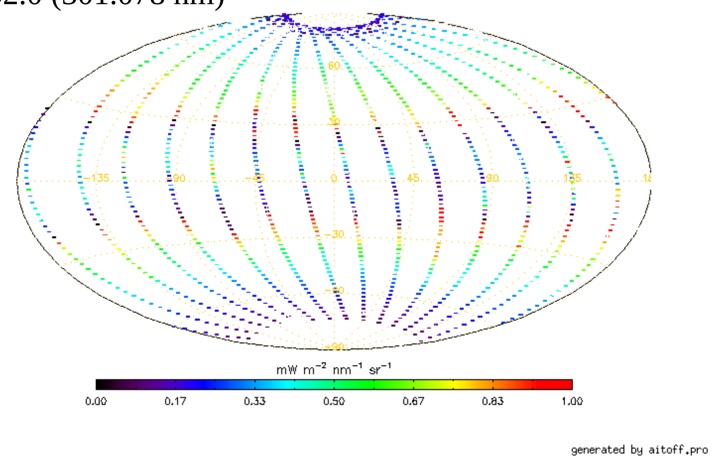
TC data with B1.2 vs. B2.0 (331.434 nm)





NP data with B1.2 vs. B2.0 (301.078 nm)





From Eve-Marie

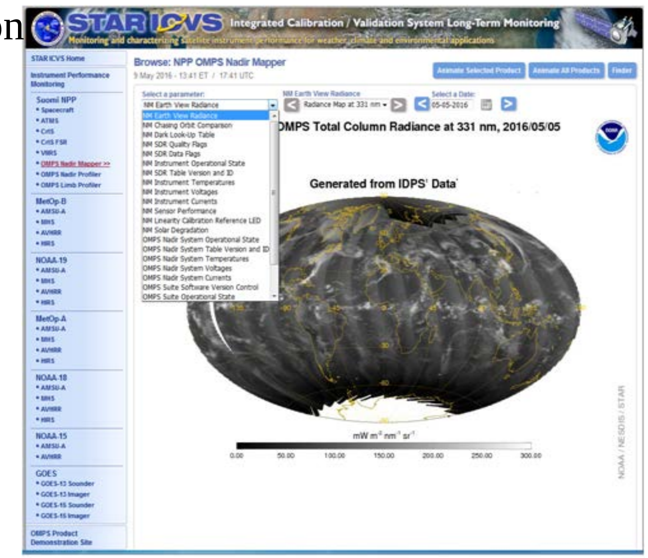
STAR ICVS OMPS Monitoring

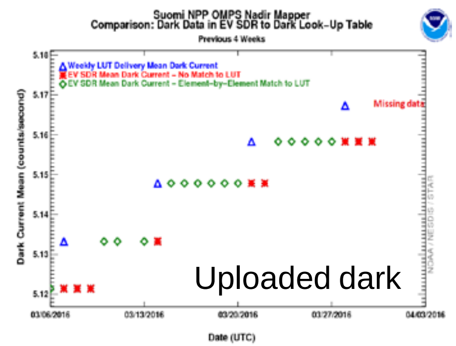
NM: http://www.star.nesdis.noaa.gov/icvs/status_NPP_OMPS_NM.php
NP: http://www.star.nesdis.noaa.gov/icvs/status_NPP_OMPS_NP.php
LP: http://www.star.nesdis.noaa.gov/icvs/status_NPP_OMPS_LP.php

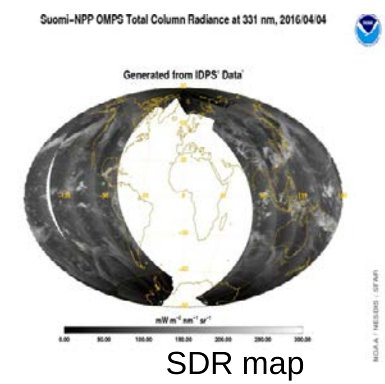
Anomalies

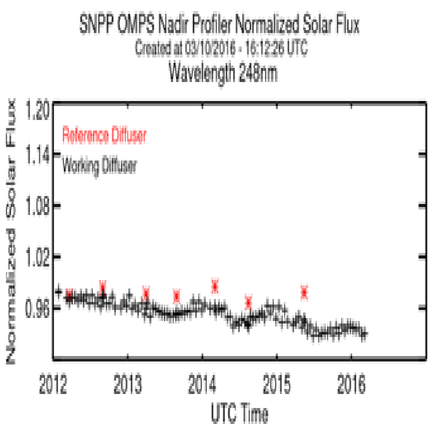
Provides much of the information to characterize the OMPS in the cal/val studies.

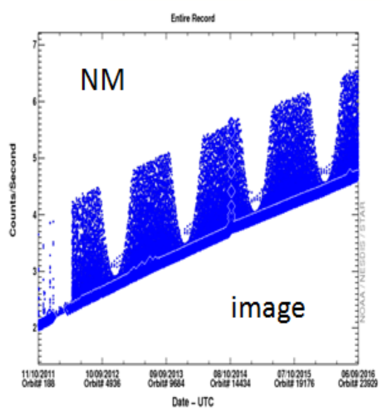
- ➢Instrument Health and Safety
- ➢Sensor Performance
- ➢SDR Product Monitoring
- ➢Data Quality Assessments
- ➢Anomaly Detection and Notification

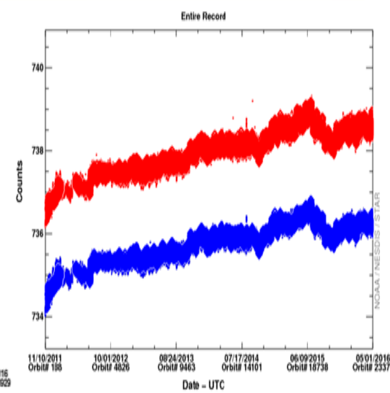


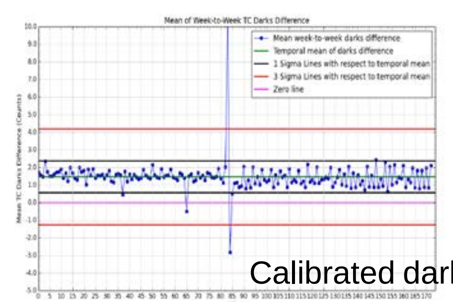












J1 Calibration and Characterization

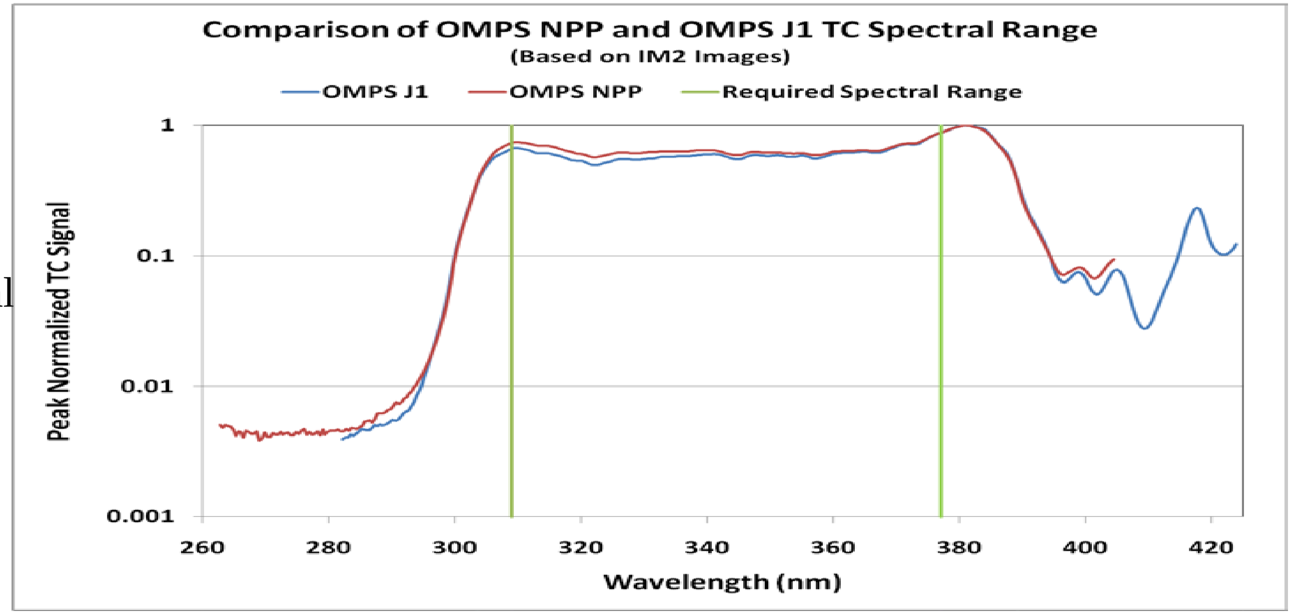
Prelaunch lab test shows that J1 OMPS calibration stability and accuracy meets science requirements

Source of Uncertainty	Absolute 1σ Fractional Uncertainty (%)				Albedo 1σ Fractional Uncertainty (%)			
	Radiance		Irradiance		λ - independent		λ - dependent	
	NP	TC	NP	TC	NP	TC	NP	TC
SNPP Goniometry	0	0	0.38	0.41	0.38	0.41	0.15	0.36
J1 Goniometry	0	0	0.21	0.21	0.21	0.21	0.1	0.11
OMPS NPP RSS Total	3.383	3.067	3.499	3.194	1.653	1.717	0.426	0.497
OMPS J1 RSS Total	2.637	1.646	2.731	1.8	1.587	1.389	0.405	0.437
Requirement	8.0	8.0	7.0	7.0	2.0	2.0	0.5	0.5

- QVD implementation yields improvements in the albedo uncertainty budget.
- Extended wavelength coverage potentially enhances science return and no significant stray light effects.

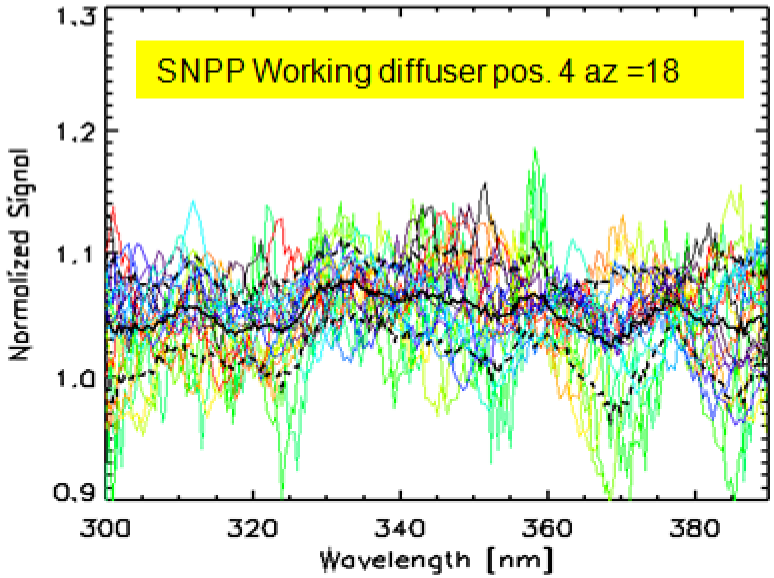
Example of Prelaunch Data Analysis

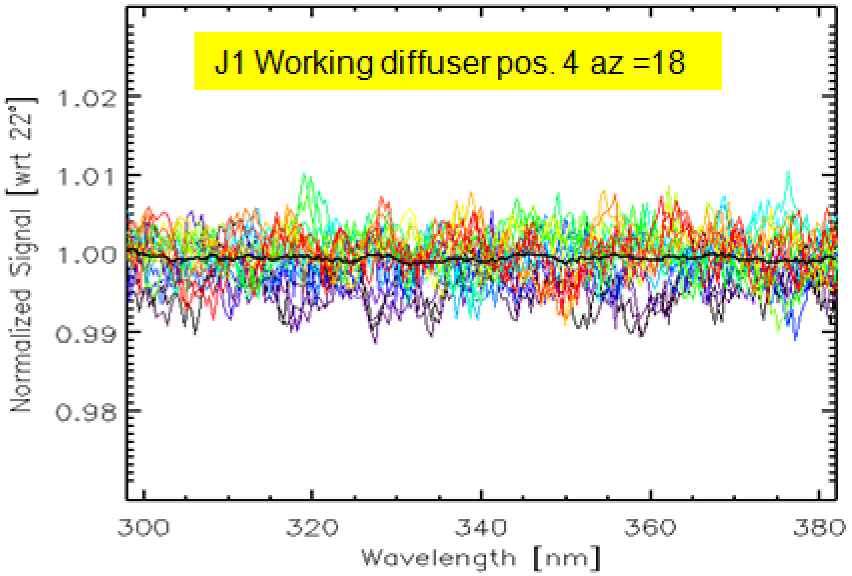
TC: 305-380, 420nm



Diffuser features significantly reduced in J1 QVD.

- Colored lines are individual rows.
- Solid black is the macro-pixel average.

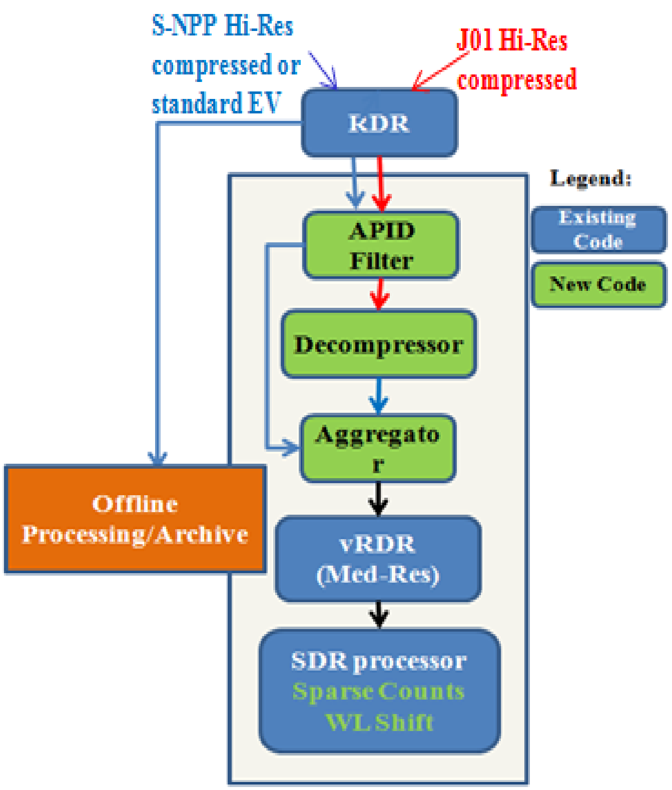




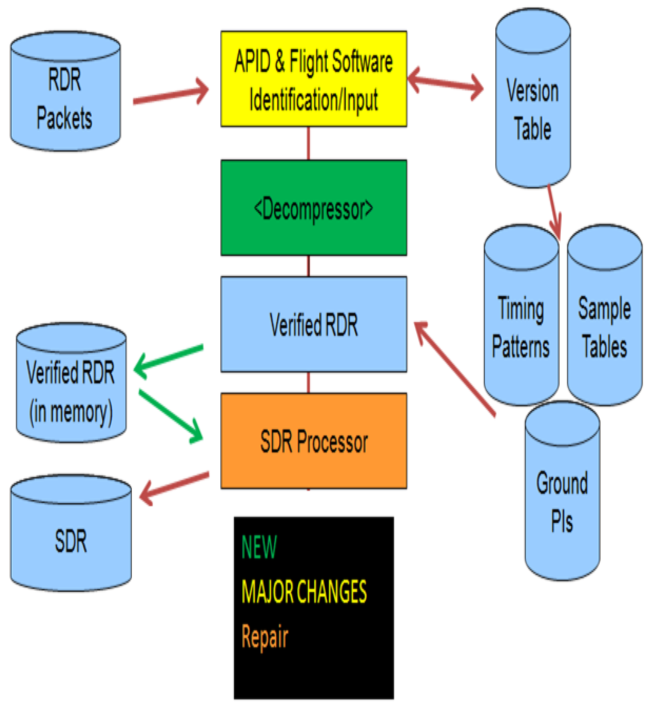
From Matthew Kowalewski /USRA GESTAR

Enhanced J1 SDR Algorithm

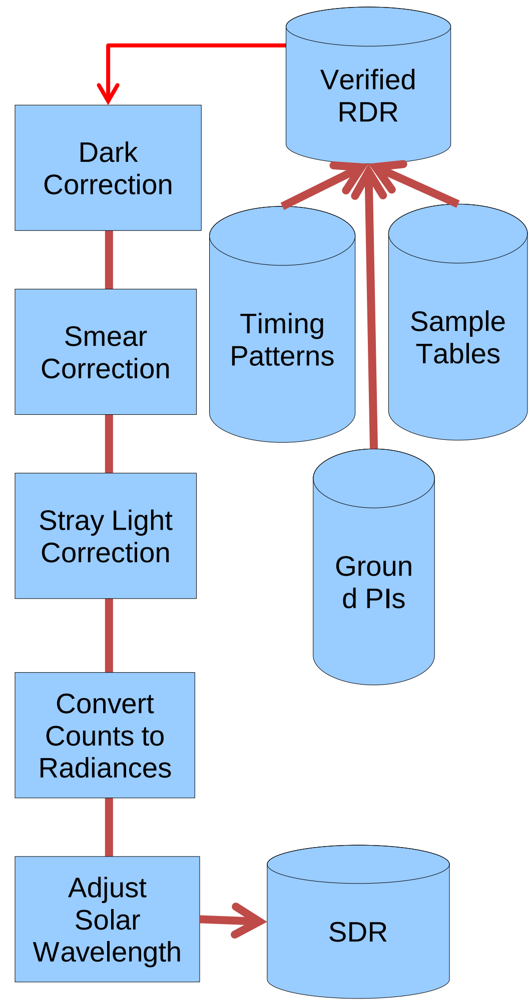
NM upper



NP upper



SDR processor

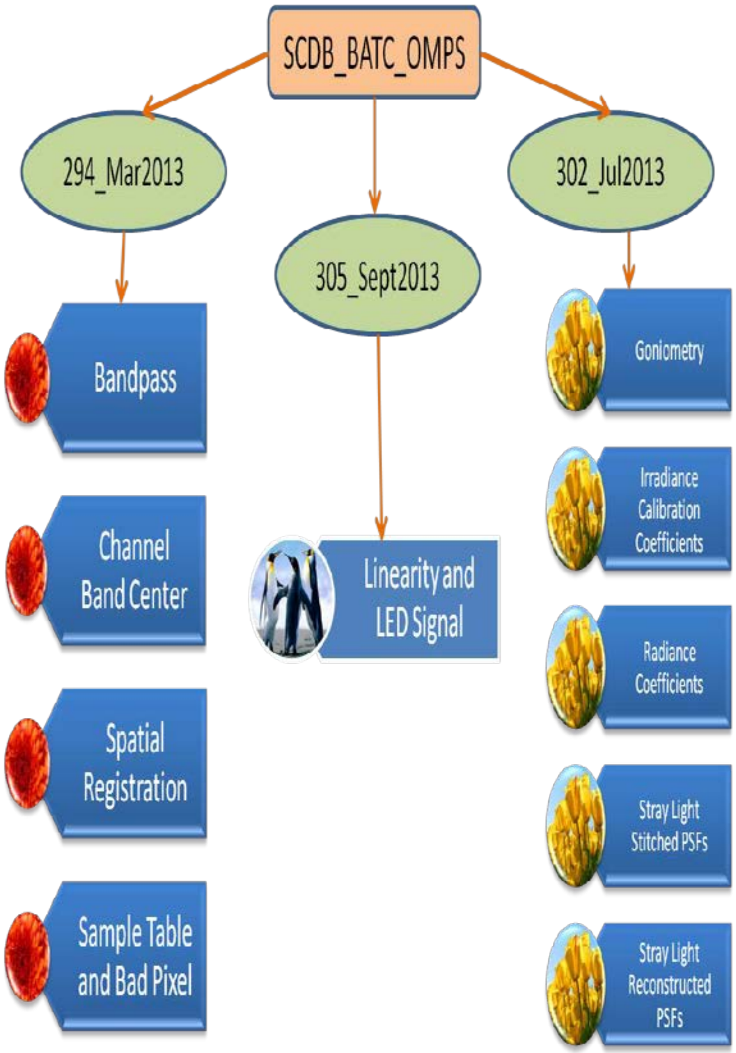


Major changes

- FSW6 engineering headers
- Rice decompression
- Four new APID values
- J1 spacecraft ID
- J1 algorithm LUTs
- NM sparse ST process

SDR Algorithm Lookup Tables

- OMPS algorithm lookup tables (LUTs) were analyzed and generated from the SCDB which are then read and processed, as necessary
- SDR algorithm LUTs
  - Measurement: Earth View Sample Table, Macrotable, Timing Pattern
  - Spectrometric LUTs: Spectral Response, Spectral Registration, Wavelengths
  - Radiometric LUTS: Calibration Coefficients, CF-Earth, Darks, Linearity, Stray Light, Solar Irradiance, Observed Solar, Predicted Solar
  - Geolocation LUT: Mounting Matrix and Field Angle Map
  - Table version LUT map OMPS NM and NP measurement tables to SDR algorithm LUT



OMPS J1 Algorithm Evaluation

Data source

Time shifted used in LG2

JCT2A, JCT3A JCT 3.5 RFR

J1 17-day Proxy dataset-*Capable of RDR/SDR/EDR Earth scenes*

Will have post JCT3.5 RFR

Spacecraft JCT *Ambient -- Capable of RDR only*

Spacecraft TVAC *Cold -- Capable of SDRs*

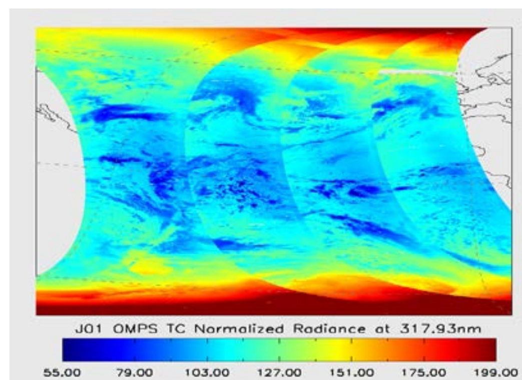
Cal/val. test data have been used to test and evaluate block 2.0 J1 algorithm and algorithm tables/LUTs:

- JCT2.0, JCT3 and JCT3.5; OMPS43A/B
- OMPS closeouts for TVAC – a duration of 50 days
  - All OMPS flight APIDs are expected to be used during TVAC DITL executions
  - OMPS will monitor housekeeping data

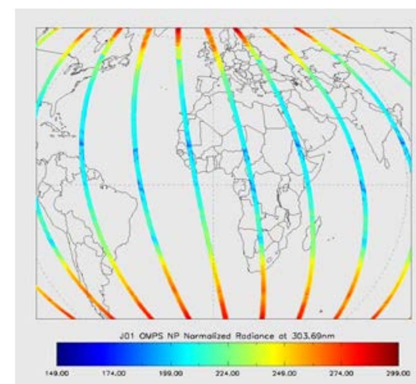
Fix anomalies

- IDPS & LG2 Comparison verified ADL5.3 build: resumed stray-light correction in J1 algorithm, added missing pad back
- OMPS 43 test data analysis found core dump associated with the compressor.
  - PCR057204: LAY-A-341-R. Closed
- Sample tables, timing pattern and other LUTs were modified to generate

Result Example



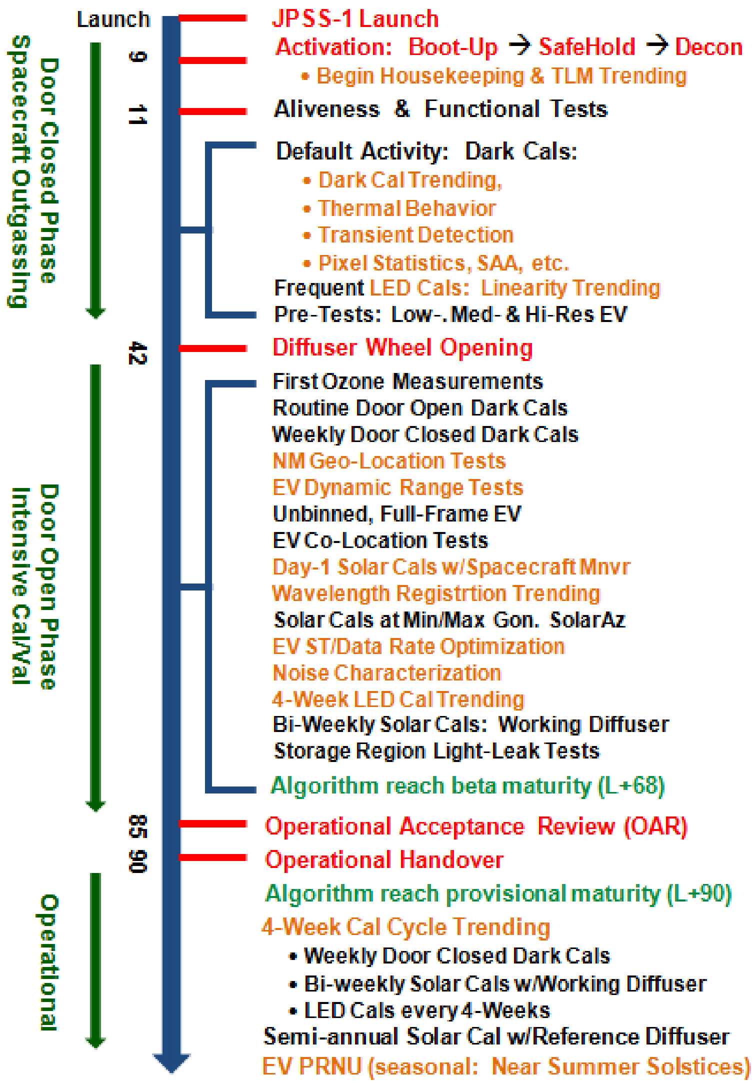
OMPS43A, 103 x 15 TC SDR Radiance



OMPS43A Proxy, NP-SDR 5x5 Radiance

From Trevor

J1 Post-launch Cal/Val Plan



Operational milestones Post-Launch Test (PLT)
Most critical activities SDR maturity

- SDR Maturity Timeline
  - "Beta" L+ 68D
  - "Provisional" around L+ 90D.
  - "Validated/calibrated" around L+9M
- Pre-Launch Calibration/Validation Plans

Year, Phase	Tasks/Activities	Deliverables
2017, PLT to ICV	• Execute the Cal/Val tasks described in the Calval. Plan • Baseline instrument • Adjust instrument settings • Modify measurement sequences when needed • Update appropriate SDR LUTs	Provisional
2018, ICV to LTM	• Improve the calibration; establish LTM • Validate the SDR products • Provide stable and accurate SDR to users.	Validated

OMPS SDR Users/Stake Holders

- OMPS SDR users/stake holders
  - CPC Climate Prediction Center
  - NCEP National Centers for Environmental Prediction
  - NRL Naval Research Laboratory
  - USGS United States Geological Survey
  - EPA Environmental Protection Agency
  - NOAA ARL Air Resources Laboratory
  - NOAA VAAC Volcanic Ash Advisory Center
  - STAR Center for Satellite Applications and Research
  - CLASS Comprehensive Large Array-data Stewardship System

Major Risks/Challenges/and Mitigation

- OMPS SNPP Nadir EV SDR products are table, meet the product requirement.
  - Our current strategy is to stabilize and monitor SDR quality conditions at the already established product maturity that represent sensor attainable levels.
  - Utilize ADL and GADA for testing of calibration tables and data anomaly analysis
  - Deploy already established forward model for cross-sensor calibration
- OMPS J1 plans and tasks are well defined and on schedule. Risk is low for performance.
  - Prelaunch calibration analysis shows OMPS J1 meets system requirement
  - J1 algorithm LUTs and tables were refined and verified through integrated tests from RDR, SDR to EDR.
  - J1 algorithm via IDPS B2.0 are tested, evaluated and reviewed by OMPS science team through a series of JCT tests. Core dump issue was fixed
  - The J1 OMPS products will be used by the users the same way as they use SNPP data. Users won't be negatively impacted with the J1 data that is of comparable quality as SNPP SDR and EDR products.
- The SDR and EDR team have significant interaction and cooperative planning and development at these algorithms move forward.

Summary

- OMPS J1cal/val Tasks and plans are well defined and on schedule. Risk is low.
  - Successfully completed J1 SDR algorithm readiness review
  - Delivered J1 launch ready Tables and LUTs in March (initial) and July (final)
  - Performed ground system test to check J1 algorithm chain of RDR-SDR-EDR
    - SNPP proxy datasets and Brass broad J1 data were used to test full range of spatial and spectral domain of J1 sensor beyond NPP sensor capabilities
    - Fixed anomalies in J1 RDR codes and in SDR algorithm: stray light correction, compressed data process and core dump issue
- SNPP SDRs are stable and produce quality data reflects sensor attainable level that meet users' requirement
  - Reprocessing generates prospective quality SDR that meets users' needs
  - Verified Block 2.0 IDPS
  - There will be refinements in SNPP thermal spectral sensitivity
  - Cal. Dark calibration package were delivered, transition is in progress
- Outreach to Community: AMS, SPIE and IGARSS.

Path Forward

FY17 Milestones

- J1 SDR Beta and provisional status
- Alternate Algorithms and Future Improvements
  - Correction of SNPP NP wavelength thermal sensitivity
  - Generate SNPP high spatial resolution data

J2 and Beyond

- OMPS Limb Profiler SDR algorithm preparation
  - Gridded measurements of atmospheric limb Earth-view measurements for three Nadir orbital track.
  - Spectral coverage from 290 to 1000 nm at 1-KM tangent height spacing.

J1 OMPS GROUND SYSTEMS TESTS AT STAR

Trevor Beck
NOAA OMPS SDR Science team
NOAA NESDIS STAR

Outline

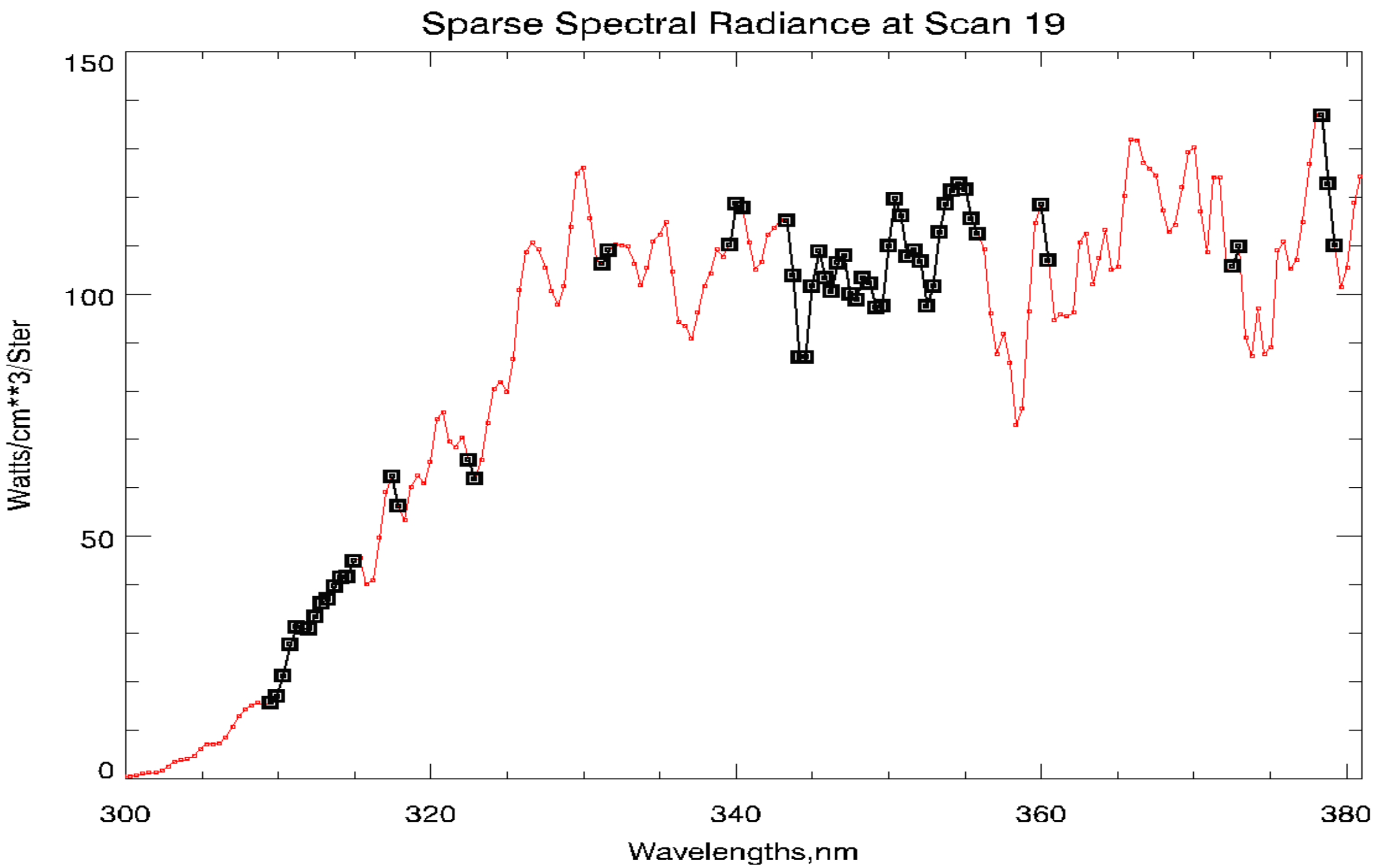
- Review of J01 Uppers in BLK2.0
- The RDR test Datasets, medRes and HiRes
- Analysis Tools created: readers, converters, RDR aggregator.
- JCT Delivered tables, at launch tables
- Medium and High resolution TC SDR
- Medium Resolution NM-SDR

Review of J01 Algorithm Updates

474-CCR-15-2432 **OMPS TC EV SDR J1 Upper Modifications** - ADR 7248 - 7340 - Phase 2
474-CCR-15-2469 **NP SDR Modification for Medium Resolution** Phase 2 - ADR 7249

OMPS Decompression - SZIP decompression, compression factor is better than 2. Both NM and NP are compressed. Only the measurement counts are compressed.
sparse spectral RDR – Not all measurement counts in RDR, to limit the amount of data downlinked from OMPS certain wavelengths are excluded in the RDR. There are bandwidth constraints on the amount of data that can be transferred during the ground contact.
NM High and Medium resolution Modes. Unlike S-NPP NM the nominal operating mode will have 17kmx17km ground pixel size and J01 NM will have many more ground pixels than S-NPP.
spatial aggregation – The number of pixels measured in the field of view dimension may be as high as 210 pixels. The IDPS product size is limited to 105. Pixel aggregation is done reduce the spatial dimension to 104 across-track pixels.
temporal aggregation - Along track pixels can be combined. The IDPS data product size is limited to 15 scans per granule. The J01 is capable of measuring 30 scans per granule. The number of scans per granule or orbit is reduced my an integral value.
Modified LUT table formats – NM In / Out aggregation specified by Sample, Macro, timing patterns.
NP 5x5 SDR – There will be 400 scans per orbit and 5 Cross-Track pixels per scan. There will be 25 times as many ground pixels as NPP – Nadir Profiler.

BLK2.0 Supports Sparse Spectral



Sparse Spectral example. The black squares are the measurements in the RDR. The red line shows where the measurements are clipped. The measurements are made but not included in the RDR. There are 61 measured values, 135 values are not present.

Ground System Test Data

- **OMPS MDR43A NPP Proxy data**
- **OMPS MDR43B BBMEB**

sparse spectral HiRes, compressed, entire day, proxy is derived from NPP. BBMEB is dark measurement.

- **JCT2 Medium Resolution**
- **JCT3 High Resolution**

full spectral, med & HiRes, compressed, several orbits, no spacecraft diary, at launch configuration. Dark measurement.

- **S-NPP diagnostic 2016/04/02**

full spectral, 35x5 NM and 5x5 NP. Real data, used primarily to generate test SDR for Version 8 ozone algorithms. NM also upsampled to 103x5 SDR for EDR testing.

J01 Test Data RDR Configurations

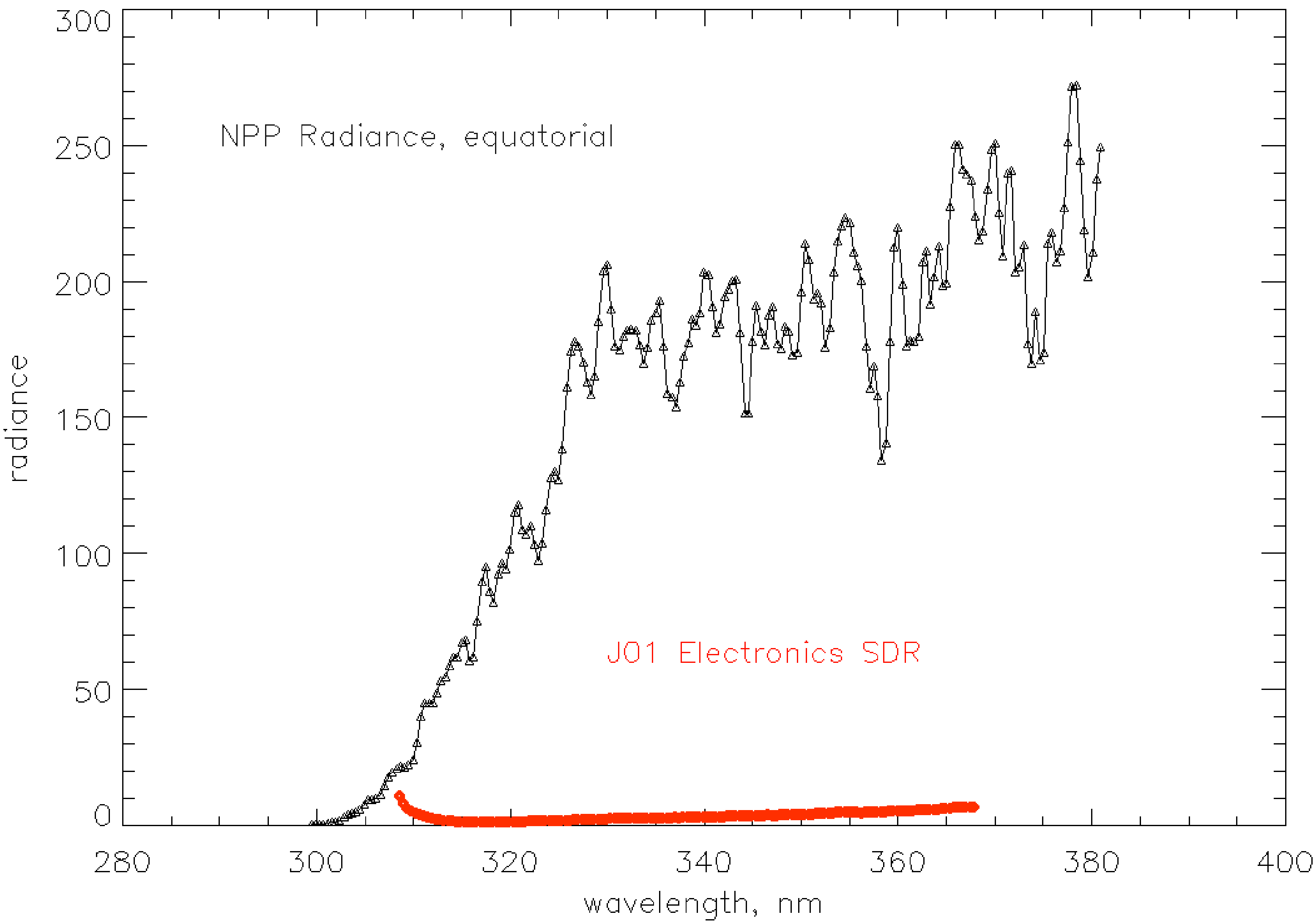
Description	NmacroPixel	Spectral x Spatial	nTimes	Source
OMPS43A NM RDR MedRes	10042	61 x 156	30	S-NPP
OMPS43A NM RDR HiRes	30870	147 x 208	30	J1 Electronics
OMPS43B NP RDR MedRes	894	147 x 5	5	S-NPP
OMPS43B NP RDR MedRes	942	157 x 5	5	J1 Electronics
JCT2 NM RDR	36040	340 x 104	15	J1 Electronics
JCT3 NM RDR	31952	340 x 146	30	J1 Electronics
JCT3 NP RDR	900	150 x 5	5	J1 Electronics
S-NPP NM Diagnostic	7448	196 x 36	5	S-NPP
S-NPP NP Diagnostic	882	147 x 5	5	S-NPP

J1 At-Launch Tables Delivered

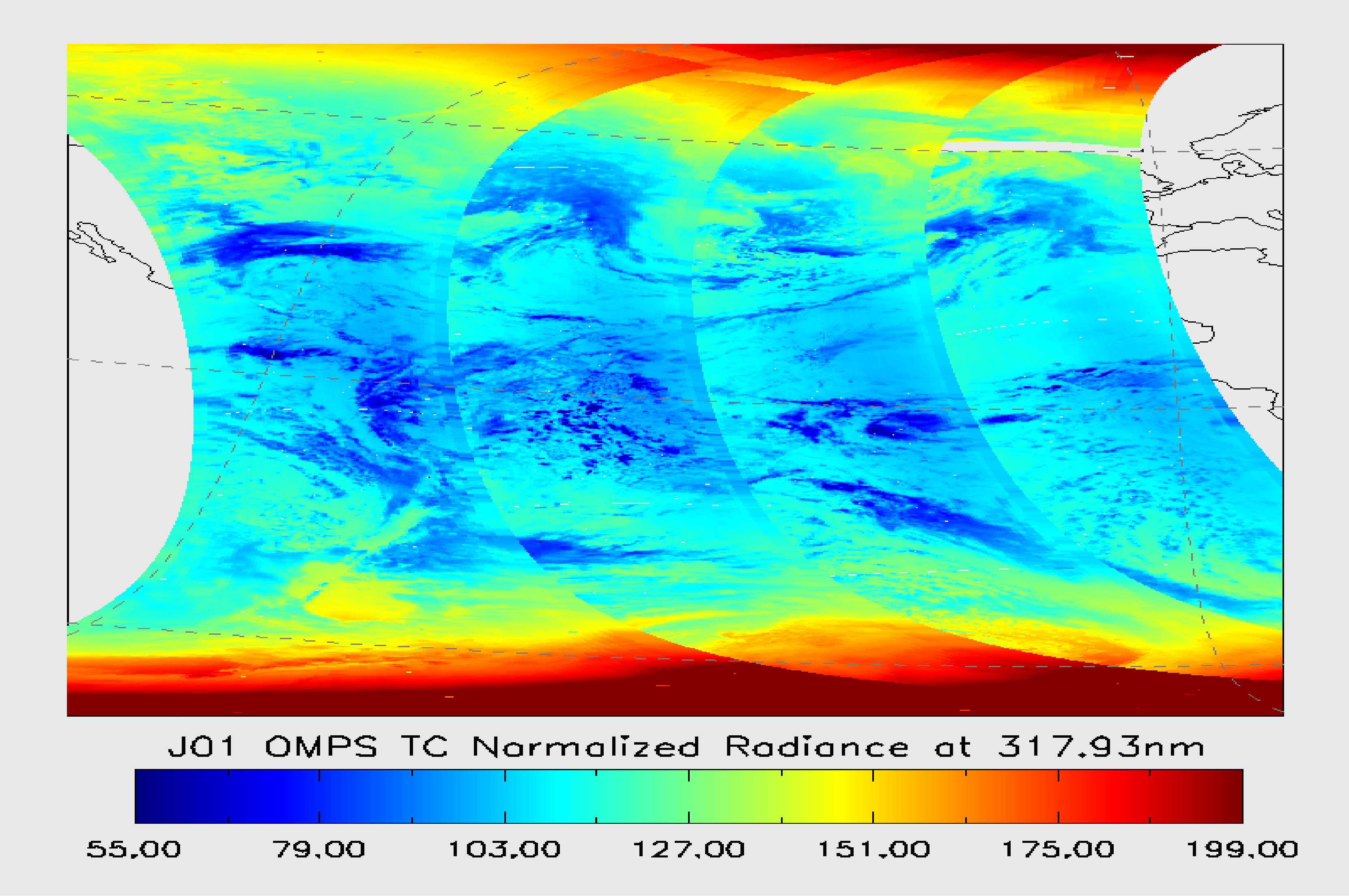
DR 8211 CCR 16-2962 Nadir Mapper
DR 8212 CCR 16-2963 Nadir Profiler

- Second Delivery of table has passed DPES testing.
- Expecting J01 SDR fast track status soon.
- LoRes, MedRes, HiRes Nadir Mapper tables
- MedRes 5x5 Nadir Profile Tables
- Nadir Version Table(NVT) developed by NASA PEATE.
- Includes Mounting matrix derived from post-environment testing(but will be updated later due to unforeseen complications).
- Major accomplishment for STAR SDR team.

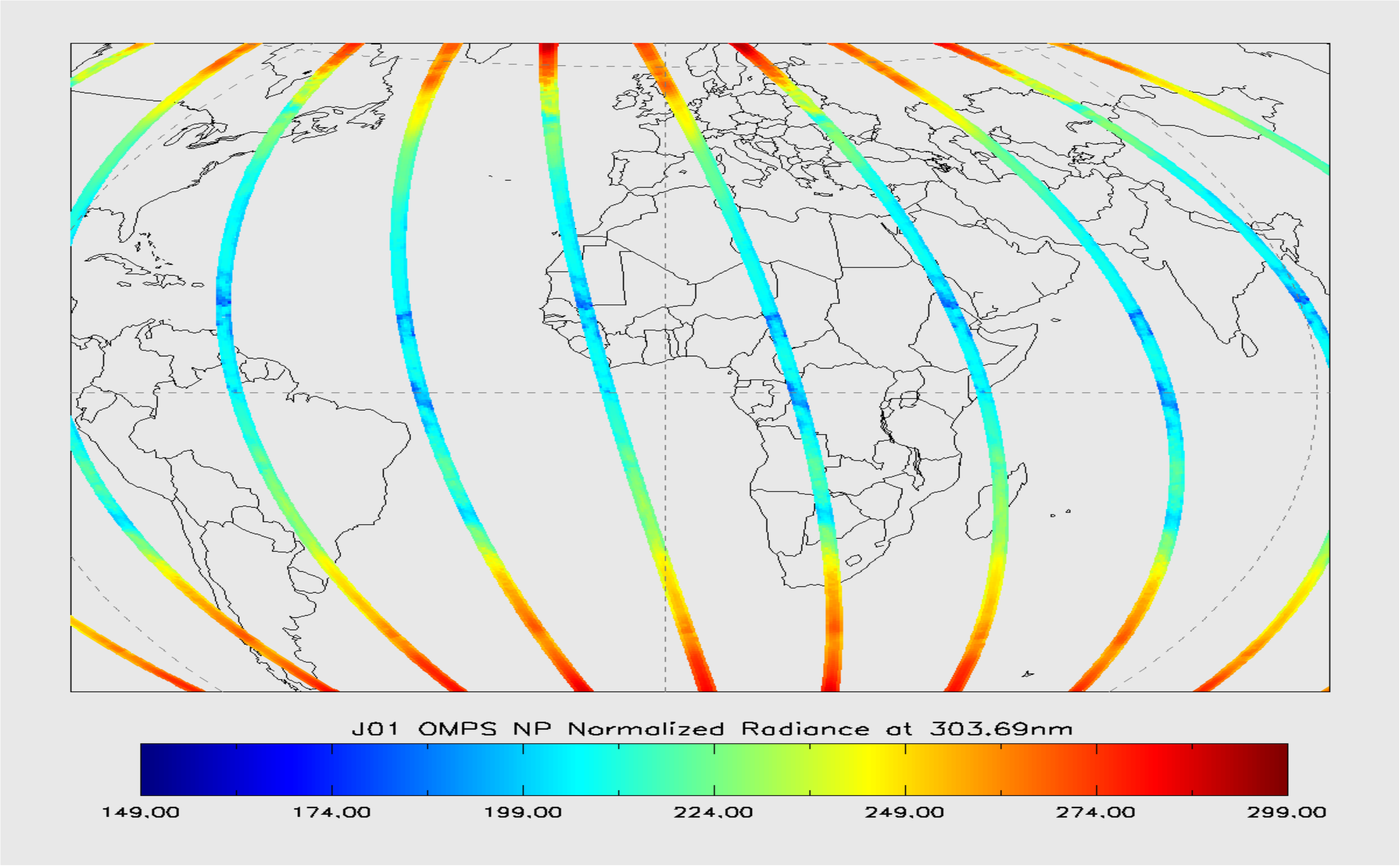
Radiance for JCT Tests are Dark



OMPS 43A 103 x 15 TC Radiance



OMPS43A NP-SDR 5x5 Radiance



Tools Devedloped for Off-line Analysis

- RDR Readers for the new APIDs, compression, measurement modes.
- Off-line scripts to convert from measurement counts to radiance. This is an IDL implementation of the ADL OMPS science code(does not do geolocation).
- APID converter(developed by Derek Stuhmer, Raytheon). Convert diagnostic RDR to nominal RDR(the ADL can only handle nominal APID modes). This is a new tool in BLK2.0.
- RDR aggregation tool. This is a tool to create ~38 second scan RDR datasets from the S-NPP diagnostic mode datasets. It is an IDL script to aggregate a sequence of RDRs into a single RDR(subsequent slides).
- Ozone retrieval algorithms: A very good check on the SDR is to run ozone retrievals. If there are problems with the measurements they will be apparent in the retrieved ozone.
- Radiative Transfer comparisons: See presentation on validation by RT by Fuzhong Weng and Shouguo Ding.

S-NPP Diagnostic with BLK2 medRes

- No requirement to process OMPS diagnostic data with ADL.
- Necessary to generate datasets for testing medRes NDE ozone retrieval algorithms for J01.
- April 2, 2016 S-NPP/ Nadir Profile RDR are in diagnostic mode with 5x5 NP 35x5 NM. We converted to nominal APID RDR.
- This configuration of SDR is what we expect in the first year of OMPS NM and NP measurements.

Conversion to Nominal APID

BLK2.0 has a tool to convert OMPS RDR APIDs, for example :

./writeOmpsFile.exe -i InputRDR_Blob 3 577 -o OutputFile NPP 3 561

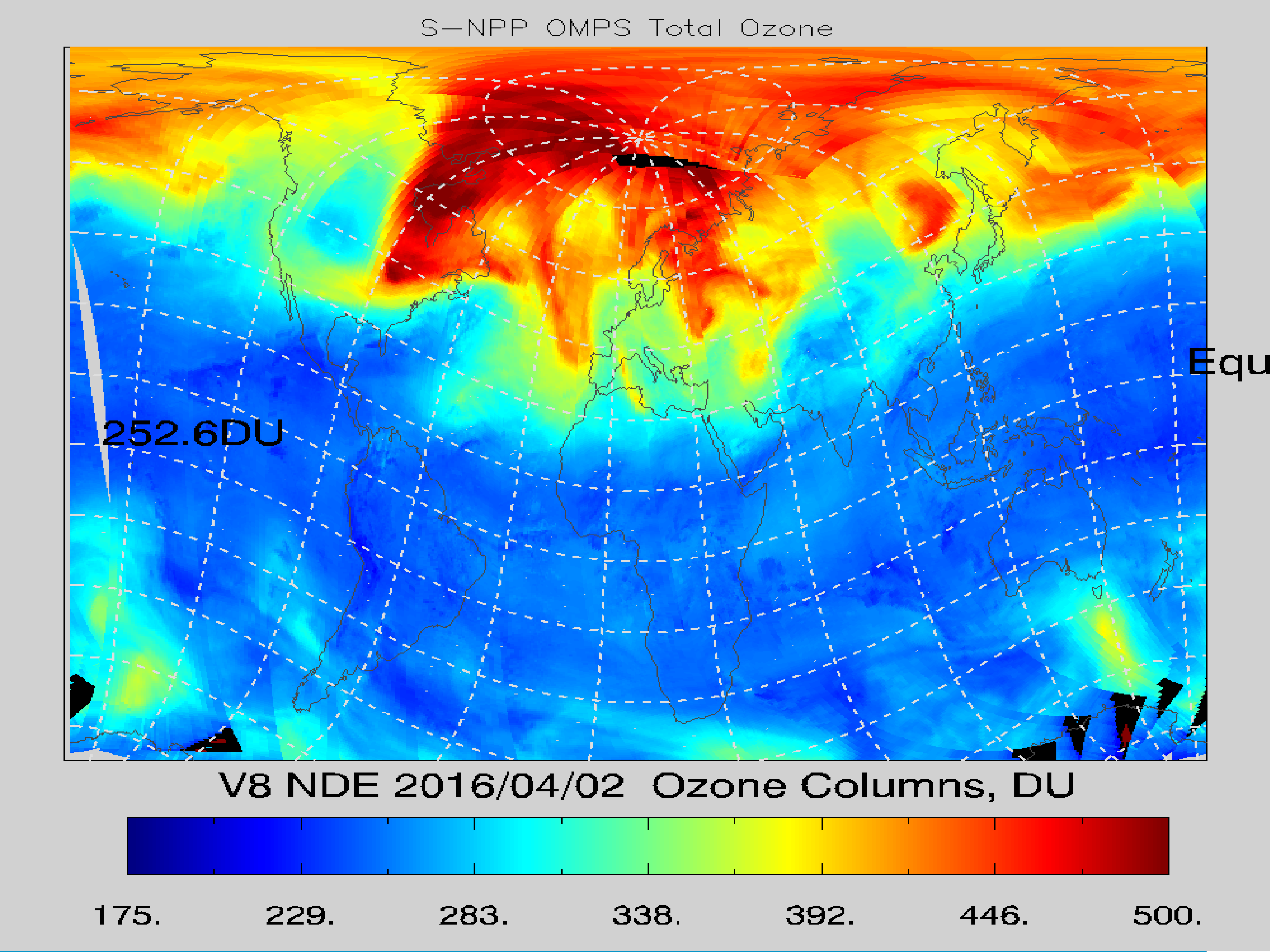
Converter executable found in $ADL_HOME/tools/bin

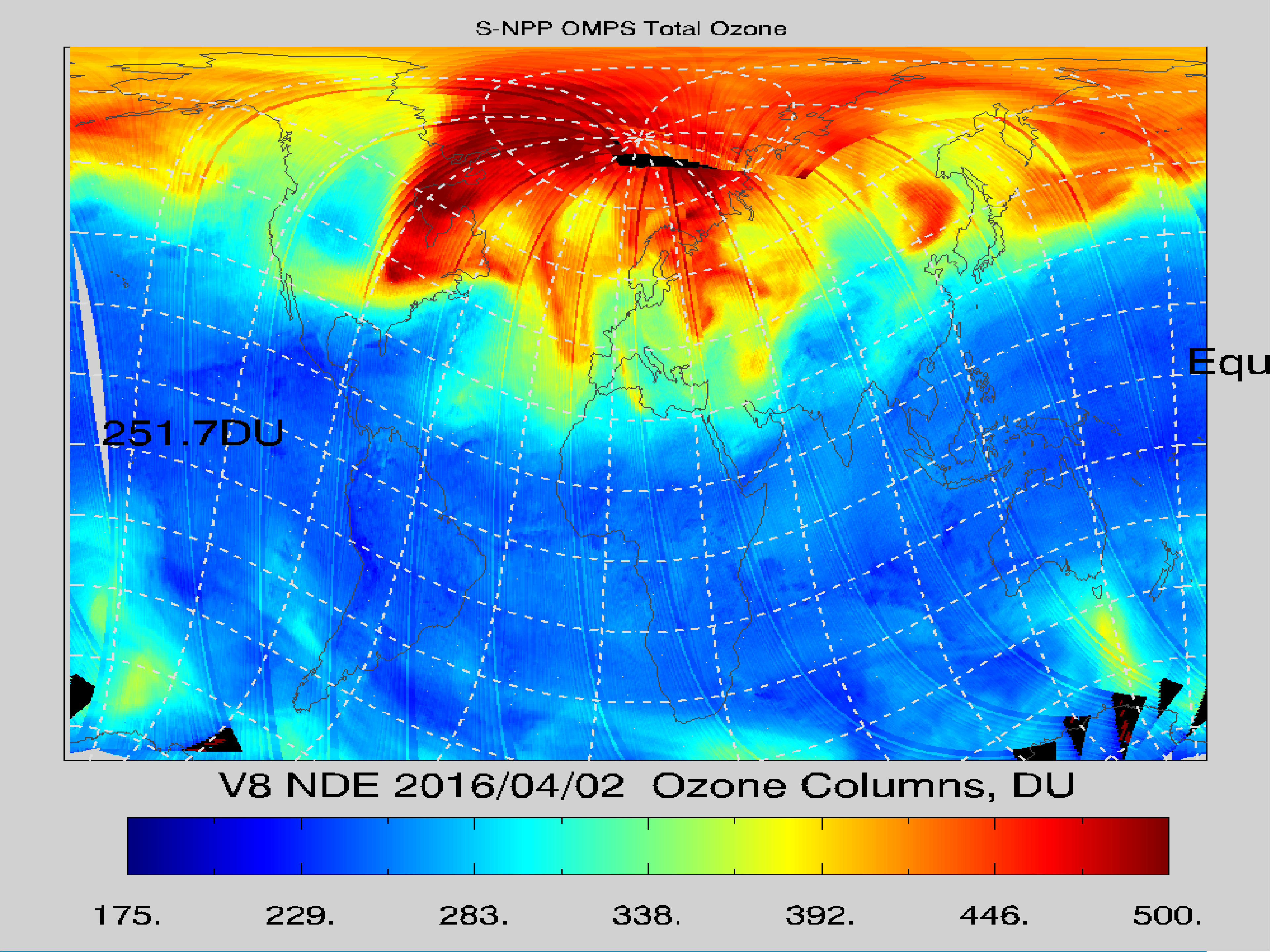
One TODO with the ADL writeOmps tool is to implement RDR aggregation. The utility converts one granule at a time. All of the diagnostic RDR we've encountered have one scan per granule. So the resulting SDR files each have one measured scan and 4 fill valued scans. ADL / IDPS enforces the 38 seconds granule time by inserting fill values for the scans not found in the input RDR.

To create an SDR without fill value scans we aggregate the RDR into 5 scans(assuming the RDR scan time is ~7.5 seconds). An IDL script was written to aggregate the RDR.

When the RDR is aggregated the RawHeader, ApidList, and PacketTracker need to be updated. A new GranuleID is assigned according to the rules for OMPS granules.

Next page: Demonstration of converted diagnostic data. The image shows the global ozone field.

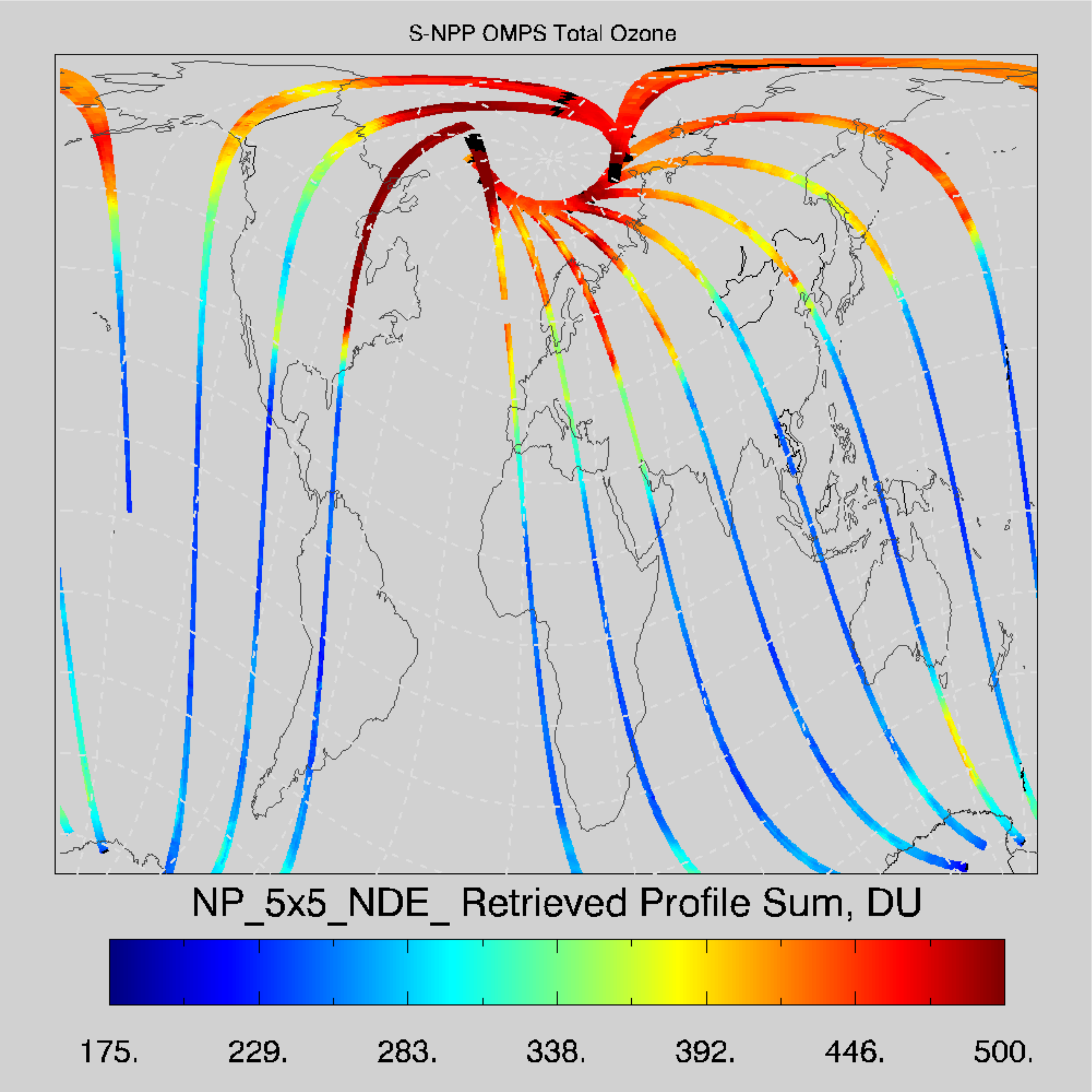

S-NPP OMPS Total Ozone
Equ
252.6DU
V8 NDE 2016/04/02 Ozone Columns, DU
175.
229.
283.
338.
392.
446.
500.


S-NPP OMPS Total Ozone
251.7DU
Equ
V8 NDE 2016/04/02 Ozone Columns, DU
175.
229.
283.
338.
392.
446.
500.

NP End-to-End test

- The Nadir Profile diagnostic converted to nominal APID and run through ozone profile EDR.
- Next slide shows 5x5 retrieved ozone profile sum for the same day, 2016/04/02.
- Identified problem with wavelength registration from 2016/04/02 5x5 SDR processing.
- EDR processing is useful to find problems with SDR.
- See talk by T. Beck in afternoon session, "*Omps Small Field of View Products*" on 5x5 EDR ozone profile algorithm.

NP EDR 5x5 Test

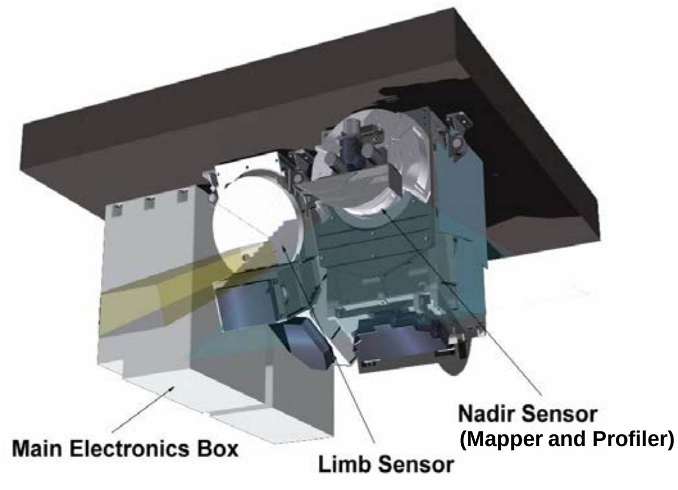


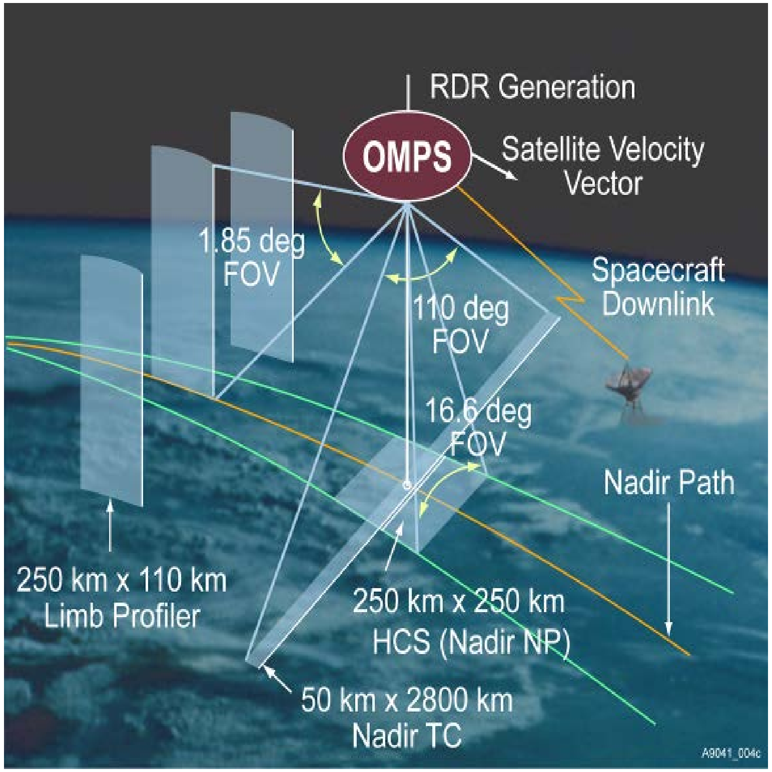
Conclusion

- Worked with partners to implement and test J01 code updates for IDPS BLK2.0 system.
- Delivered at launch J01 tables for OMPS-NM and OMPS-NP.
- Developed tools to read and convert J01 RDR diagnostic and nominal datasets.
- Demonstrated that BLK2.0 PSAT21 and later are capable of processing medium resolution data with a minor XML configuration changes(103x15 J01 TC-SDR output). *next slide lists the required change.*
- Short granule problems still remain, this impacts capability in of the SDR processor to handle 30 scan granules.

OMPS Limb Performance

G. Jaross and OMPS Core Team





Currently released Level 1 product: v2.0

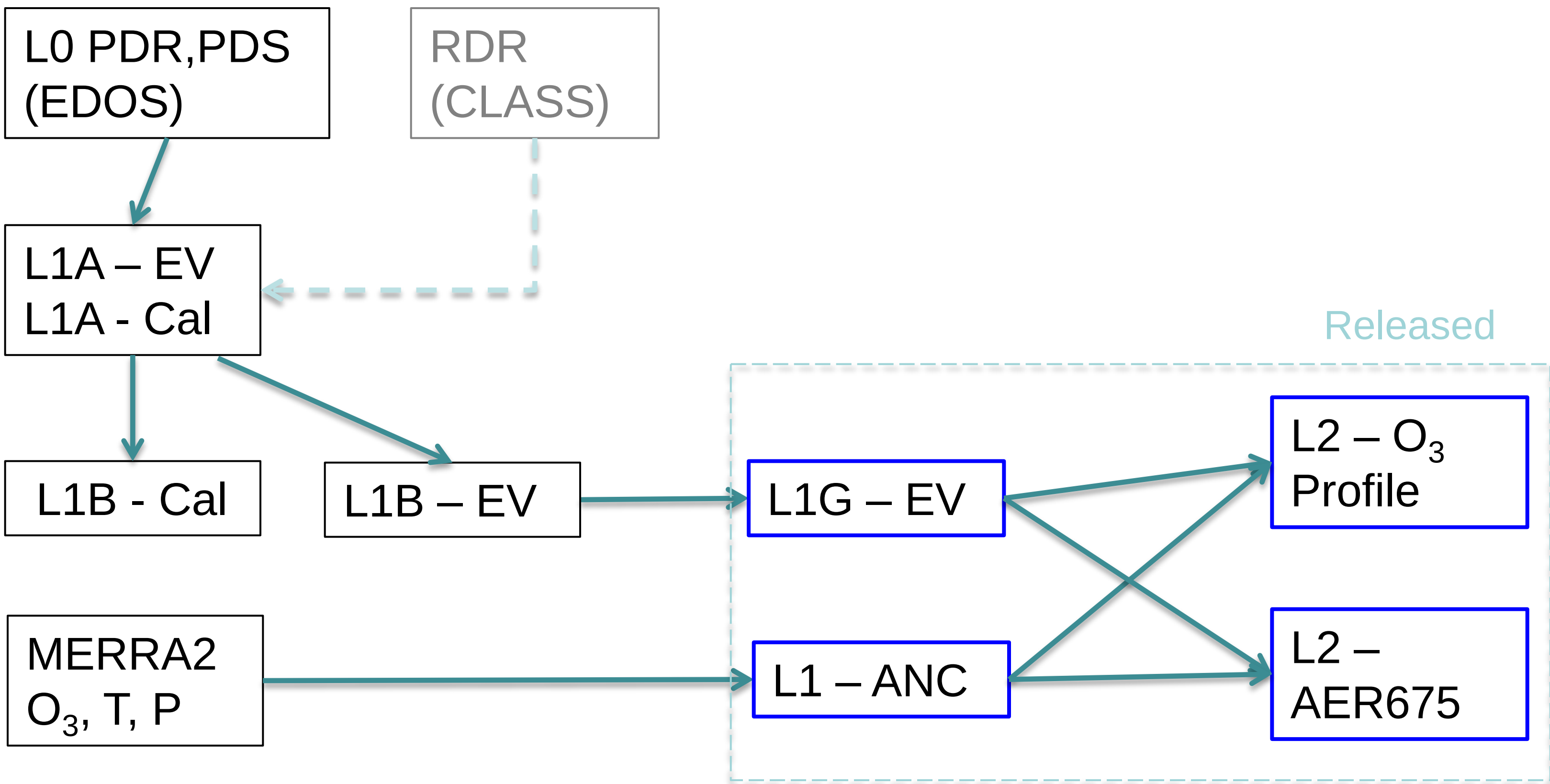
v2.5 to be released within next few months

Limb Profiler Sensor (SNPP only)

- Wavelength range: 280 nm to 1000 nm
- Prism spectrometer w/CCD detector
- Spectral resolution: 1 nm – 30 nm
- 3 profiles separated by 250 km in longitude
- Vertical : 5 – 80km at 1km sampling

Limb Data Products

APIDs : 562, 563, 566, 578, 579, 582



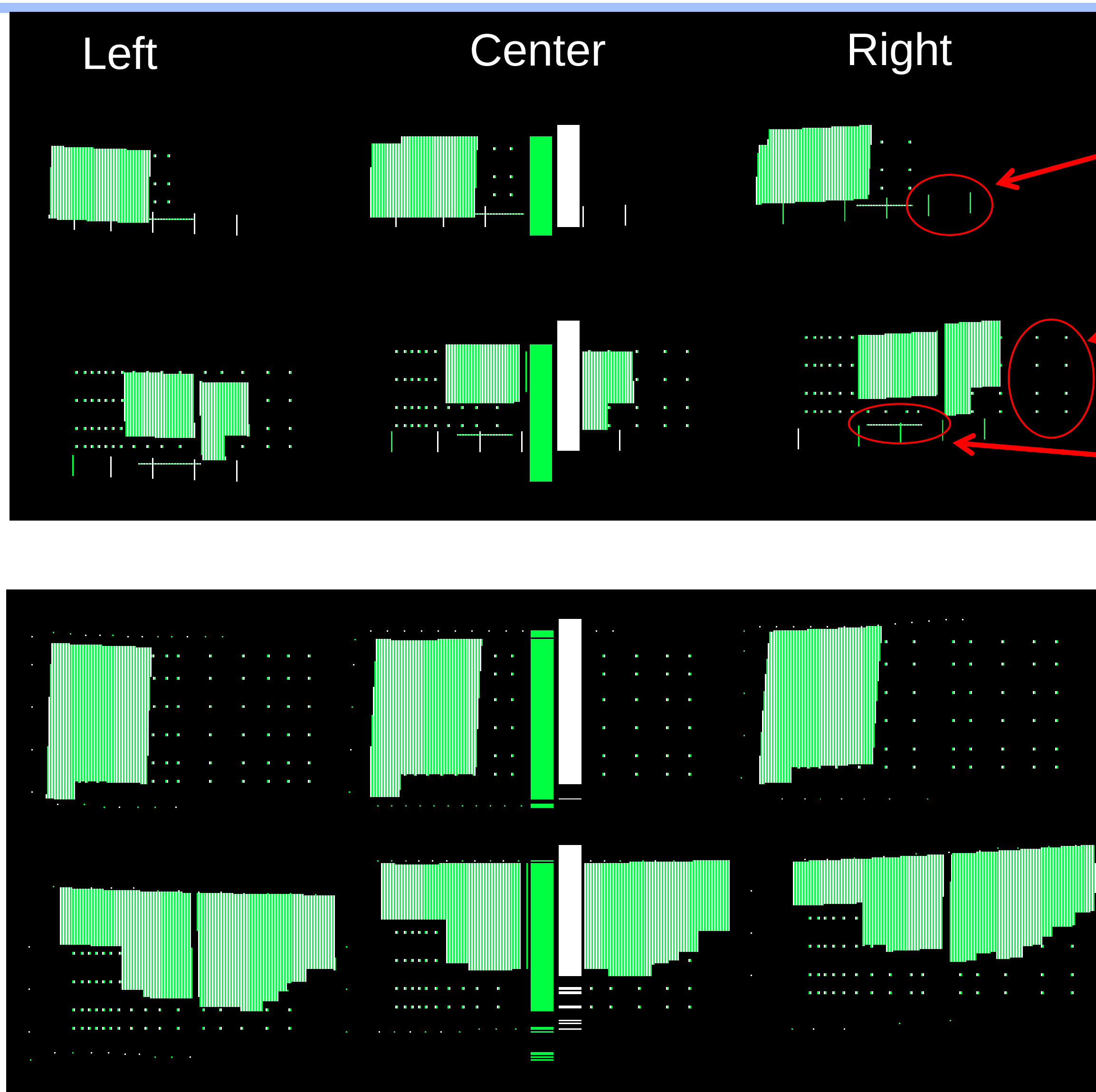
The Level 1G product :

- Interpolates TOA reflectances to uniform altitude grid and non-uniform wavelength grid
- Consolidates Low and High Gains for each slit

Current Limb sample tables

Short

Long



Slit edge pixels

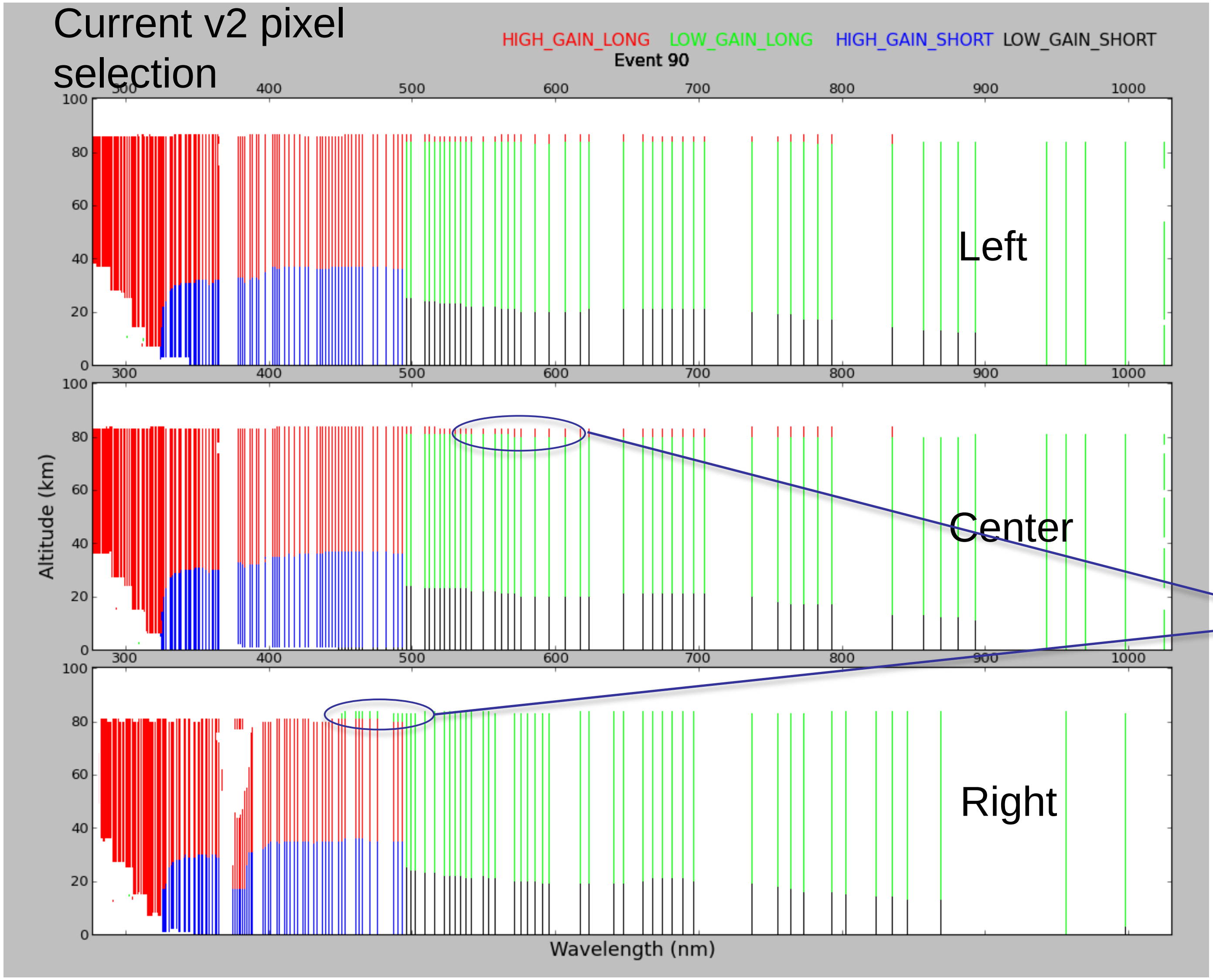
Stray light pixels

Wavelength registration pixels

Stepped integration will combine Long and Short into a single sample table

← Wavelength

Gridded radiances have few spectral gaps



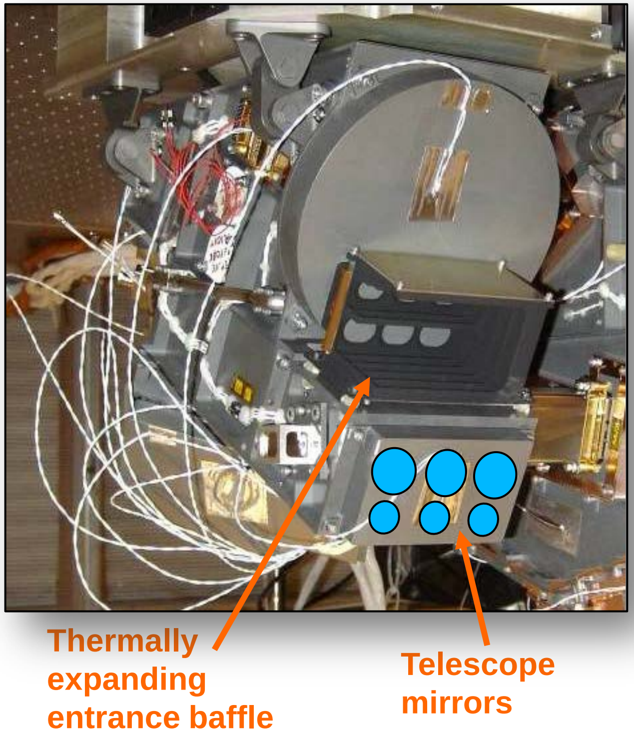
Changes for v2.5

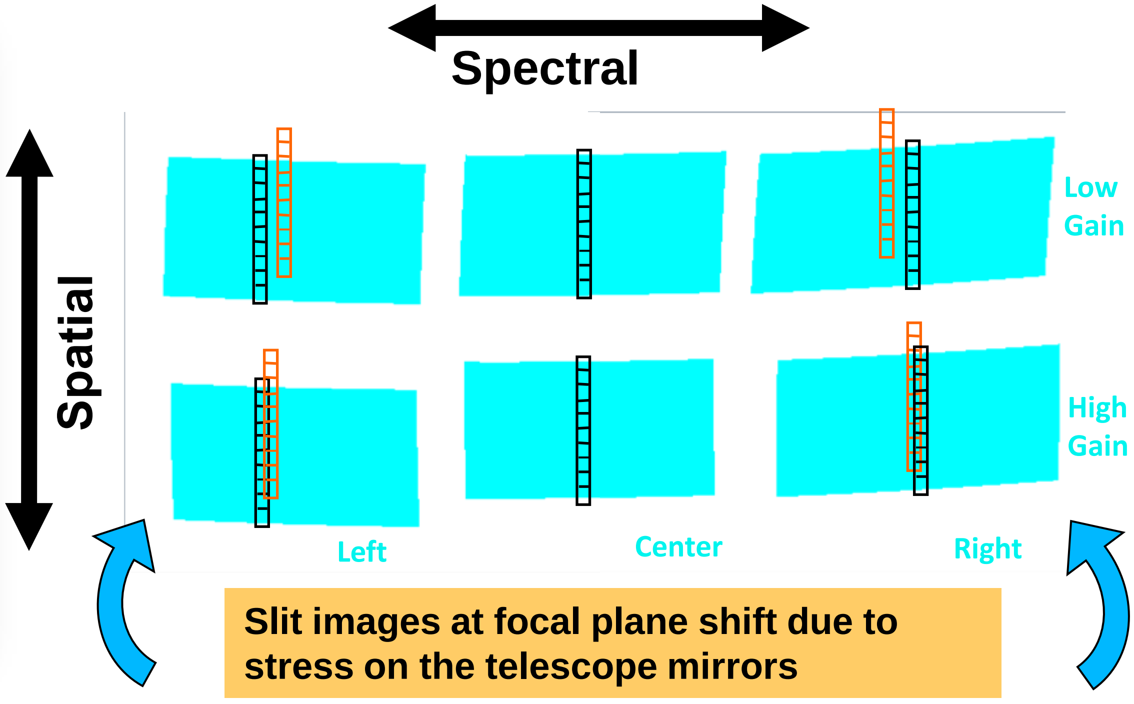
- Lower HG/LG switch to 450nm
- Change from HG priority (280-450nm), LG priority (450-1000nm) to HG-only, LG-only. Eliminates high altitude intrusions

Focal plane image shifts

Spectral/Spatial shifts are ground-to-orbit, intra-orbital, and seasonal

Courtesy of Ball Aerospace

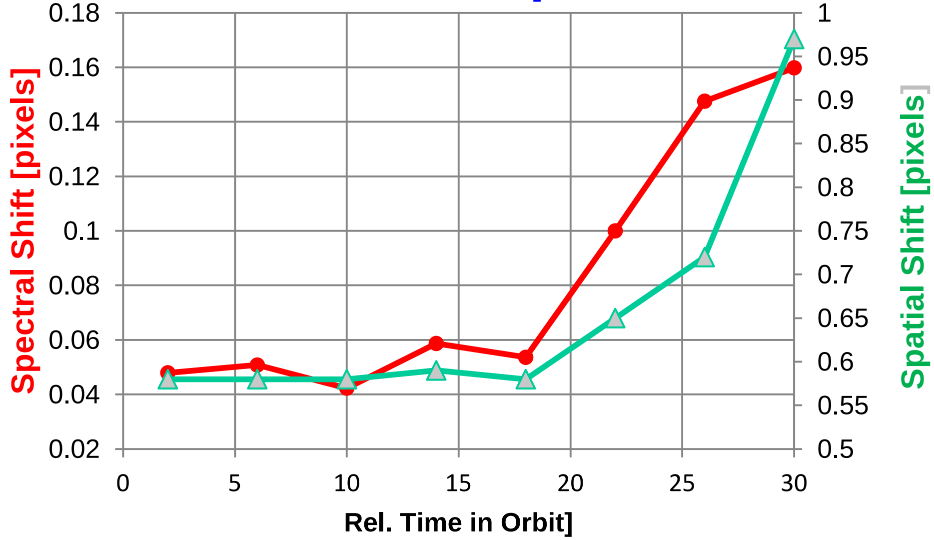




Shifts occur when sunlight illuminates the entrance baffle

Image shifts are mostly corrected

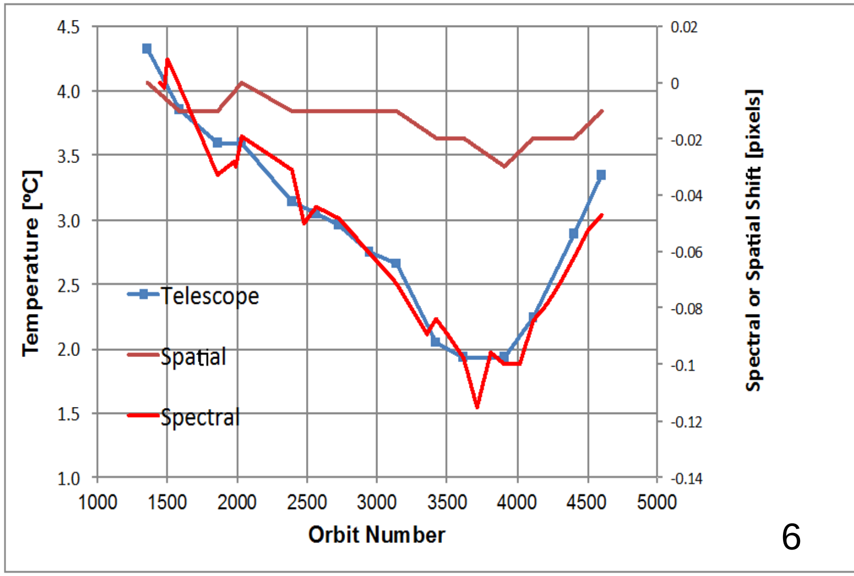
Intra-orbital focal plane shifts



Corrections mostly unchanged from v2.0 to v2.5

- Intra-orbital spectral/spatial uses time in orbit
- Seasonal spectral/spatial uses solar beta angle
- Small seasonal spatial shift (60m) added in v2.5

Seasonal focal plane shifts



TOA Reflectance (I / F)

V2.0

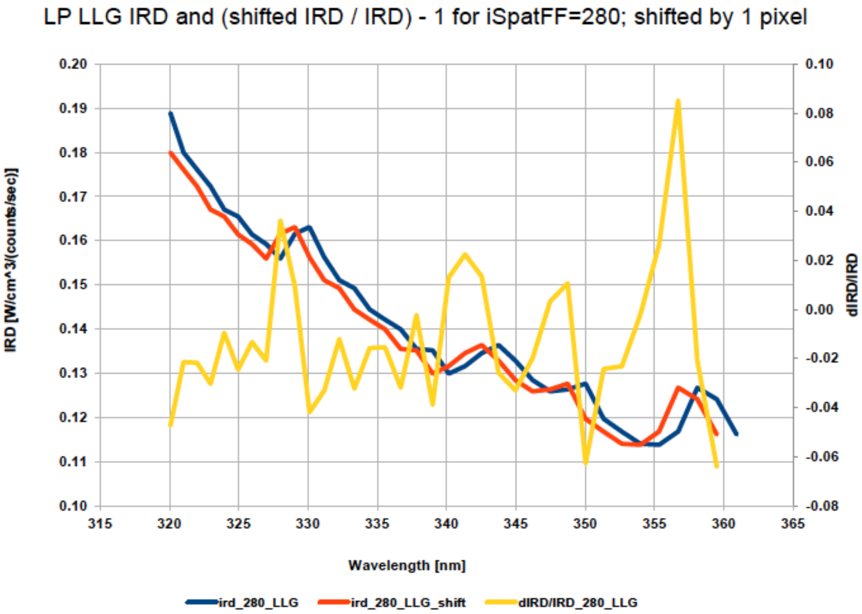
- Wavelengths follow EV radiances
- Day 1 solar is static

V2.5

- Day 1 solar is adjusted dynamically to EV wavelength scale

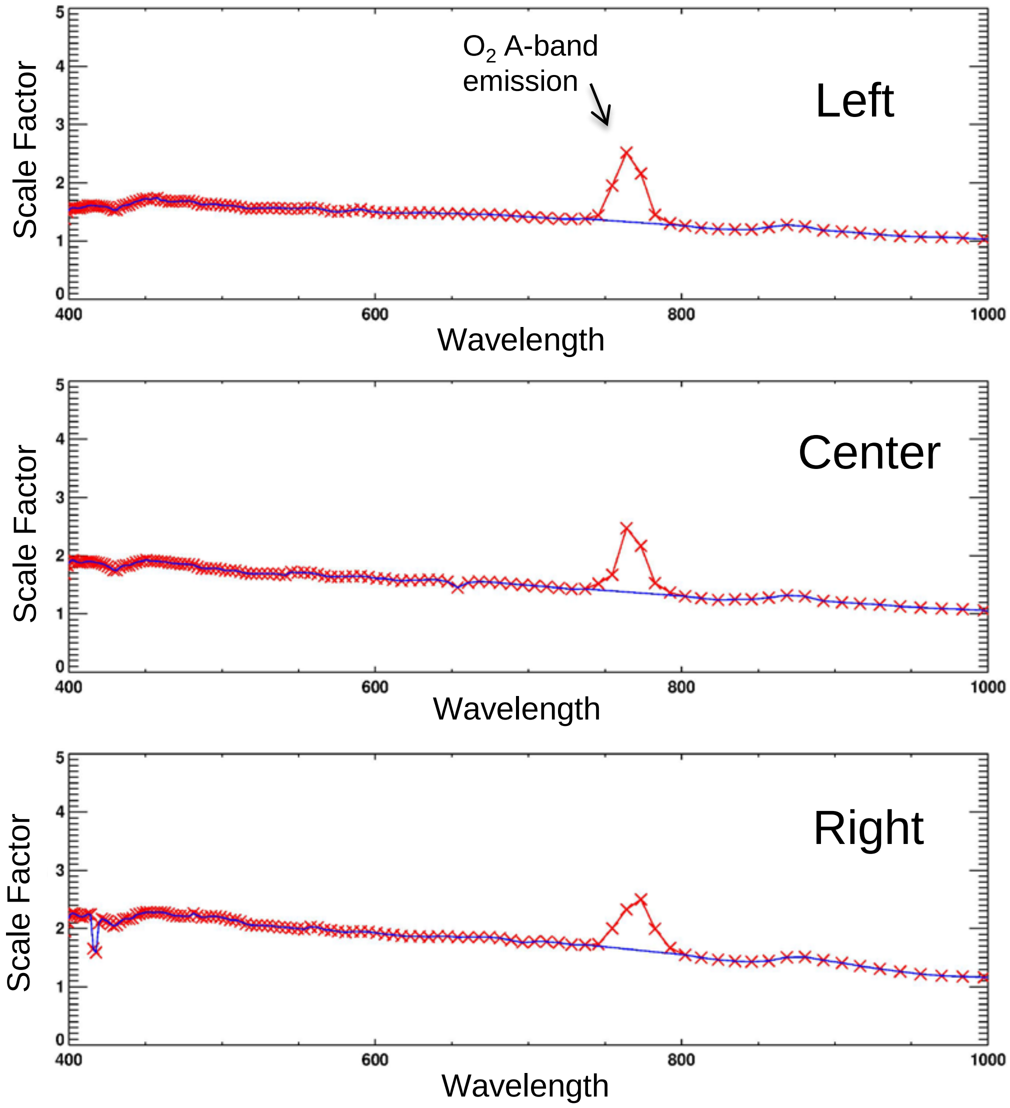
Future

- Day 1 solar adjusted (one time) for Gnd-to-Orb spectral shift
- EV radiance coeffs. adjusted dynamically for spectral shifts



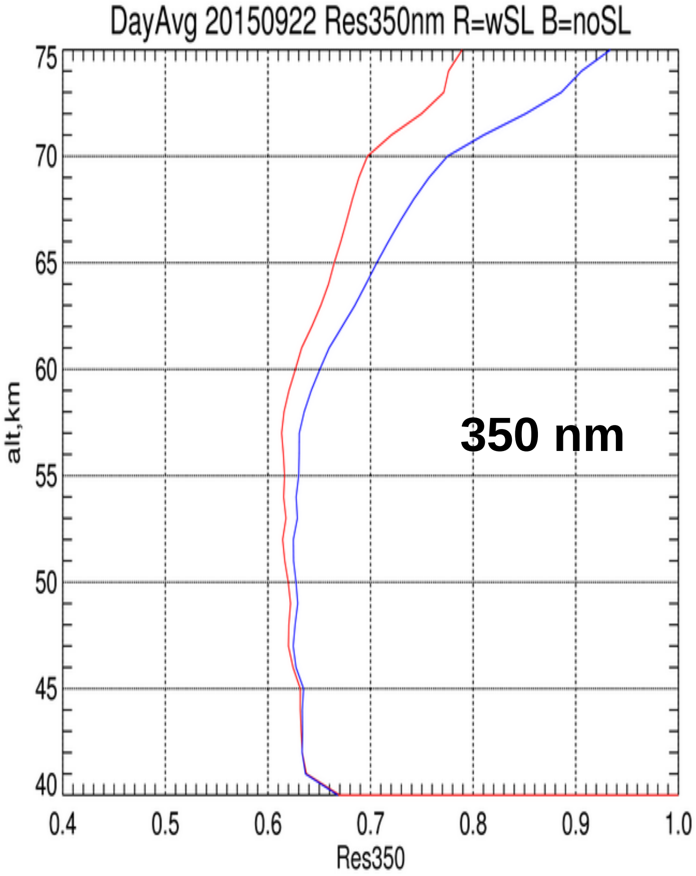
Stray light correction boosted in VIS

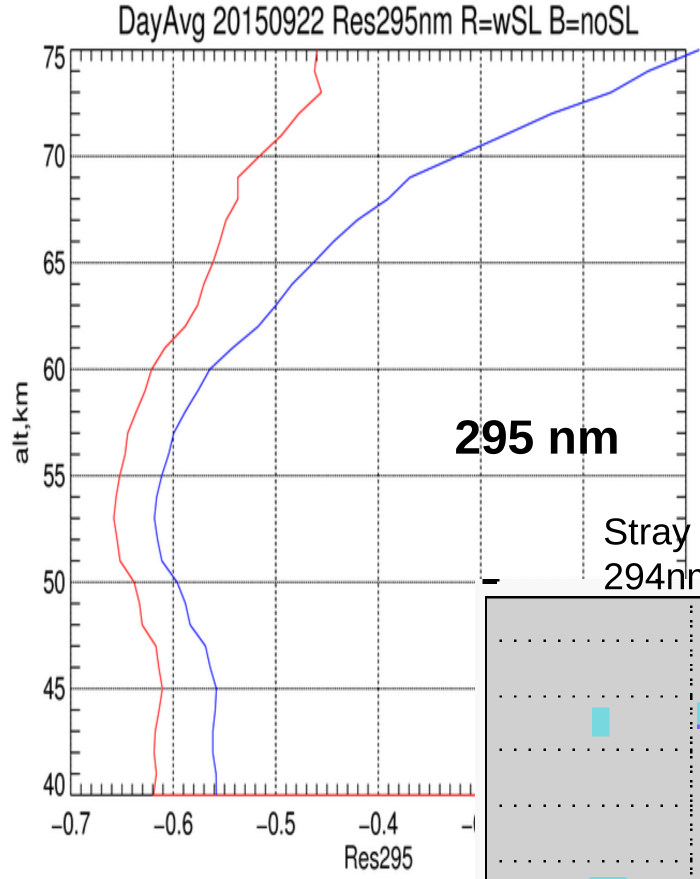
- Interim adjustment for the benefit of aerosol product; has small effect on O_3
- Based on analysis of high altitude radiance gradient (forced exponential)
- Scale factor applied to existing SL correction at all altitudes
- No adjustment in UV



Residual stray light in UV

Radiance residuals relative to MERRA2 assimilated P, O_3 profiles

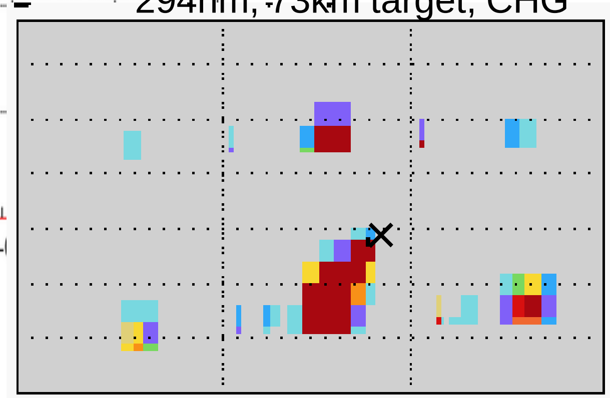




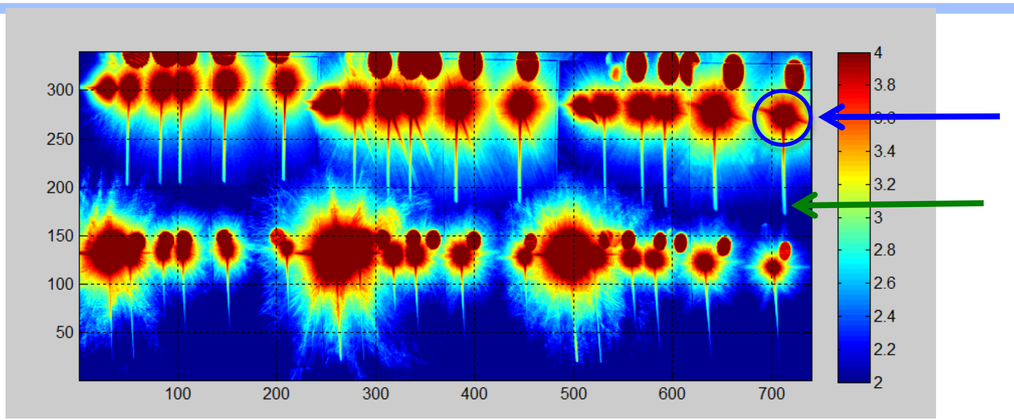
Residual SL (~8% at 75km) appears to be independent of wavelength

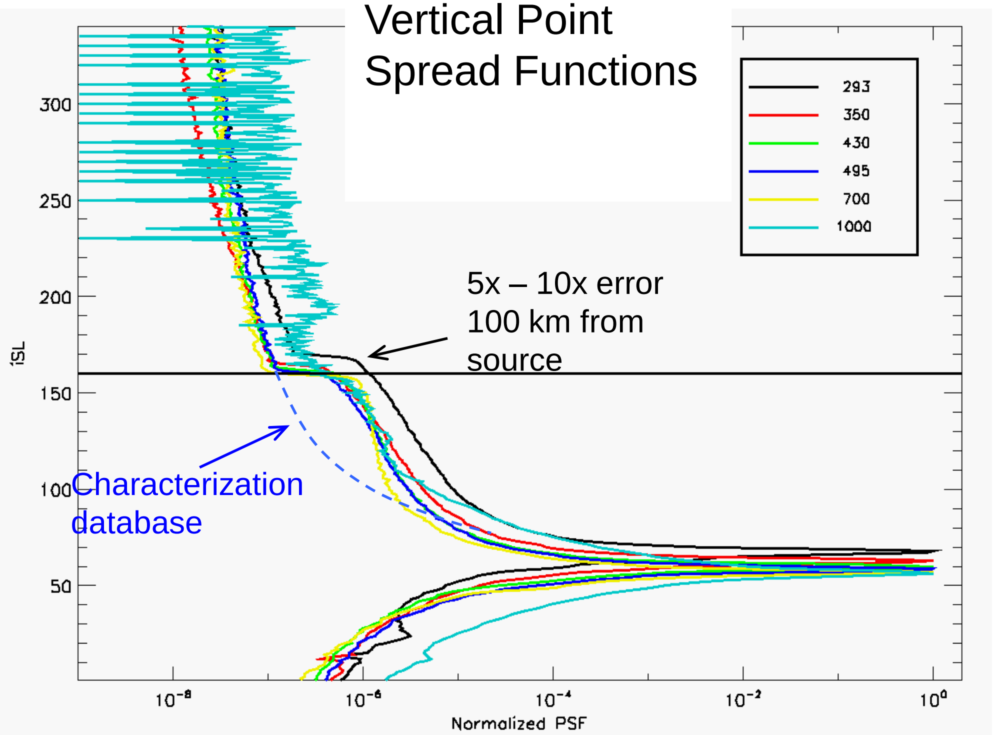
295nm SL sources are out-of-band

Stray Light Sources
294nm, 73km target, CHG



Future plans to remove more SL

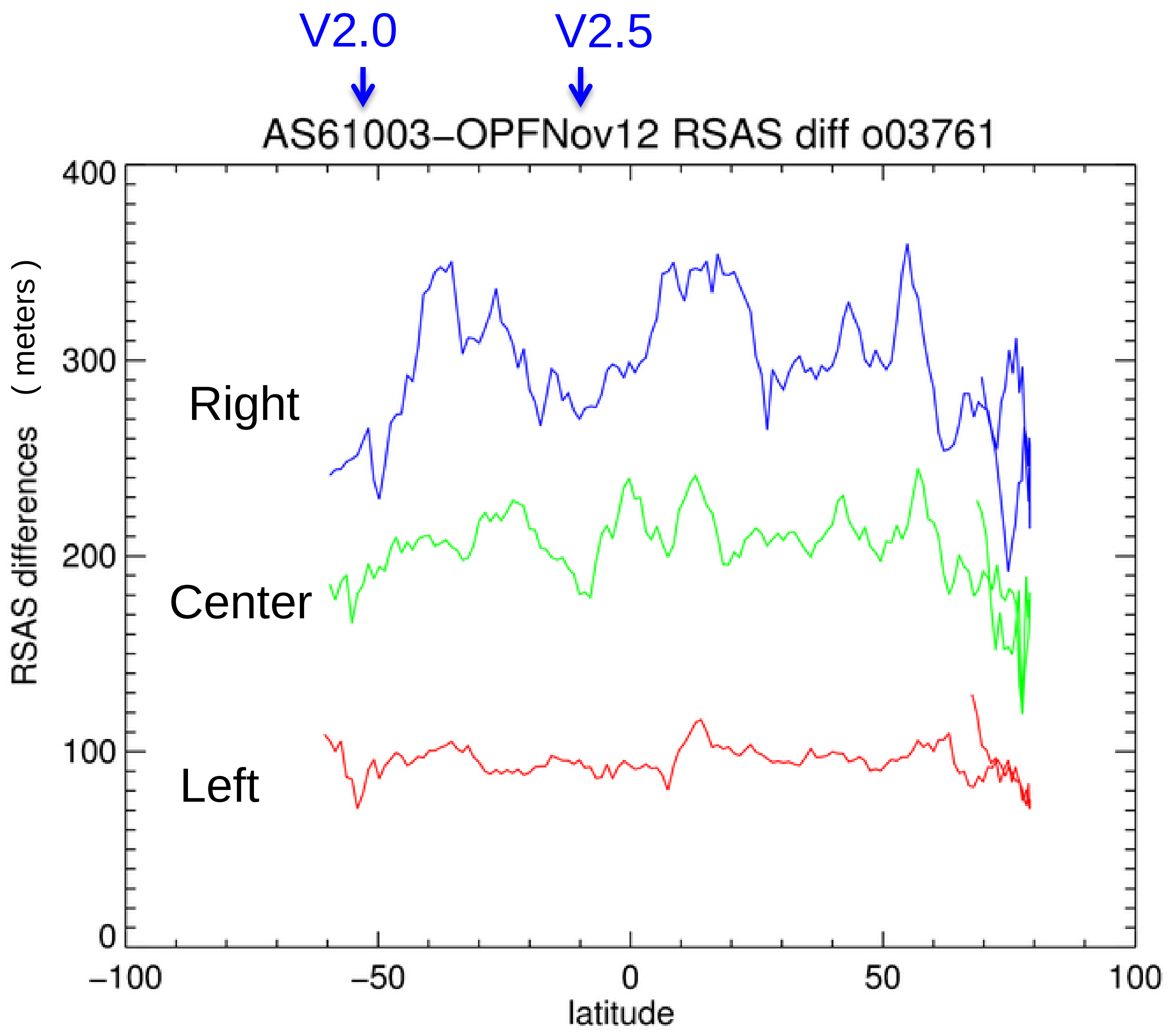




Telescope scatter was ignored in pre-launch measurements and is probable source of additional error

Fine tuning Day 1 pointing in v2.5

RSAS results vary with latitude and season, ±200m

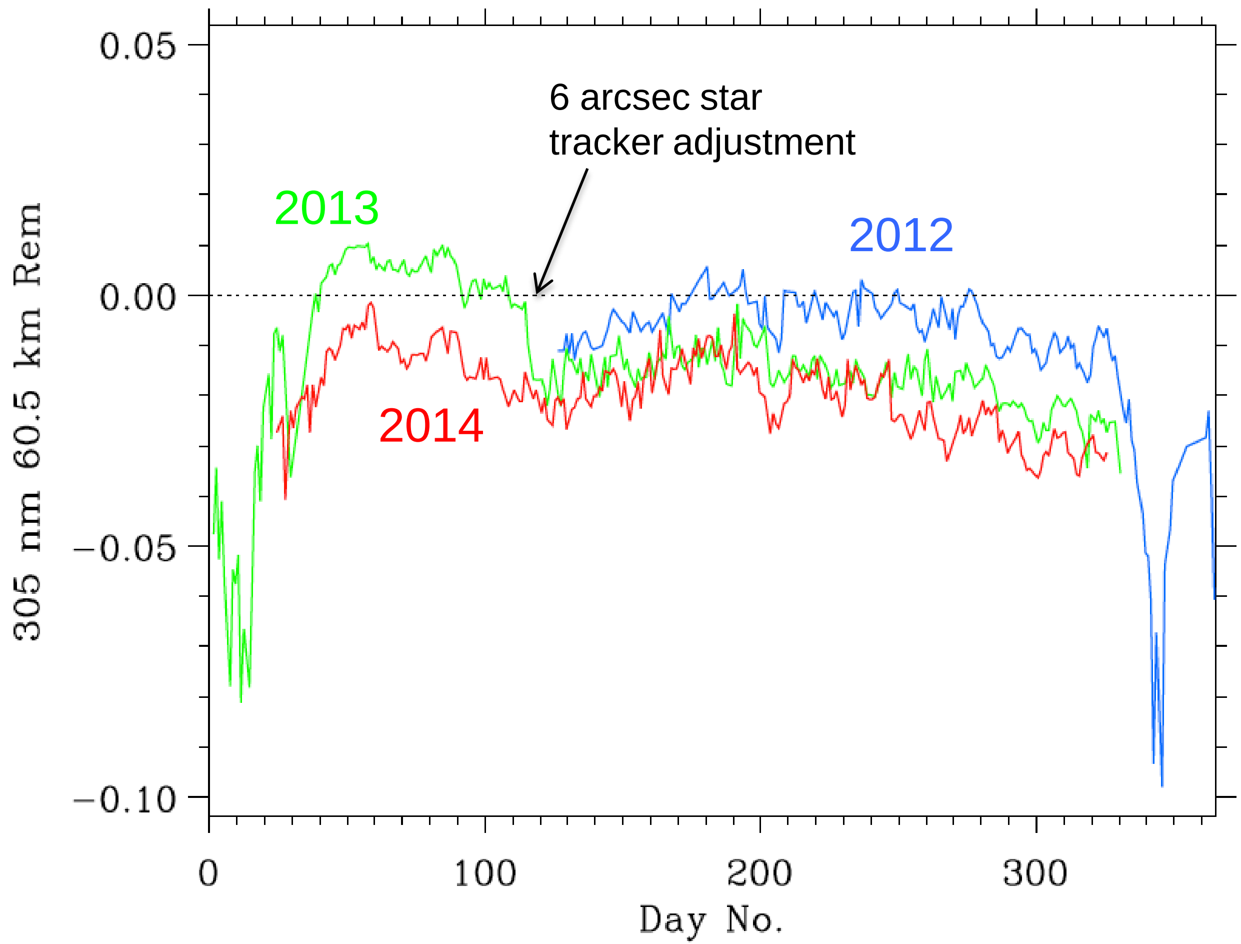


295 nm “Remainder” validates TH time dep.

The 295REM is insensitive to O_3 errors, SL errors, surface refl. variations

The 295REM also suggests 400m (linear) latitude dependence in TH that is not corrected.

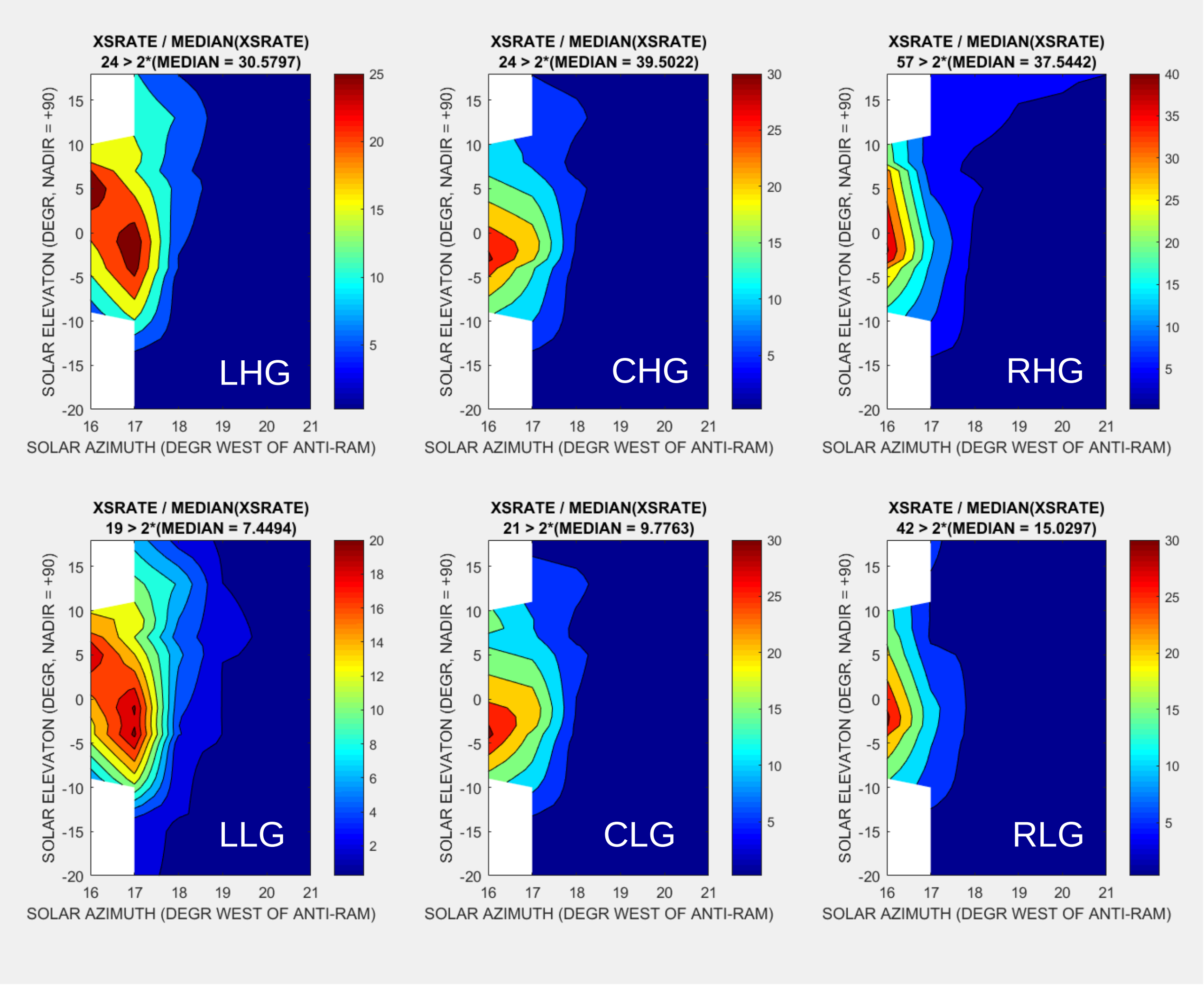
Center slit
Event nos: 20-25 +0.03 cal adj



Solar intrusion affects high altitudes, NH

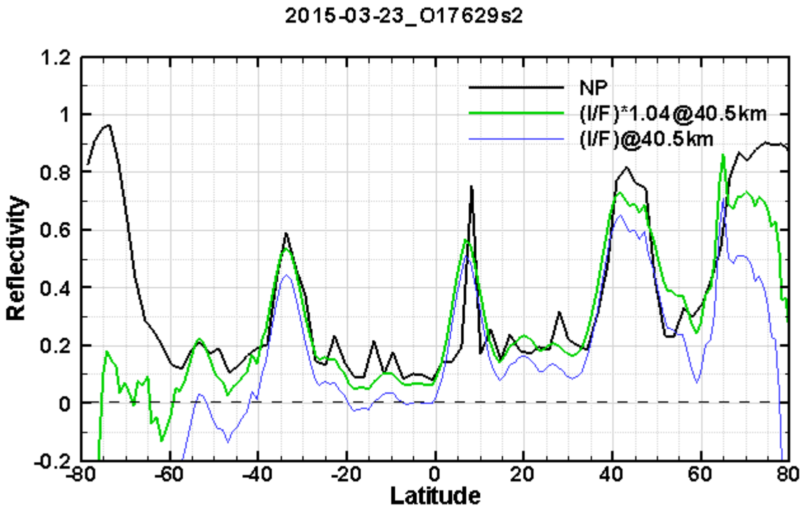
- Same absolute error at all altitudes
- Signals at 80km can be 20x-40x .gt. normal
- Max. error in July-Aug
- Largest effect in LHG, but intrusion affects more latitudes in RHG

Signal ratio: Above/Below slit edge (~80km)

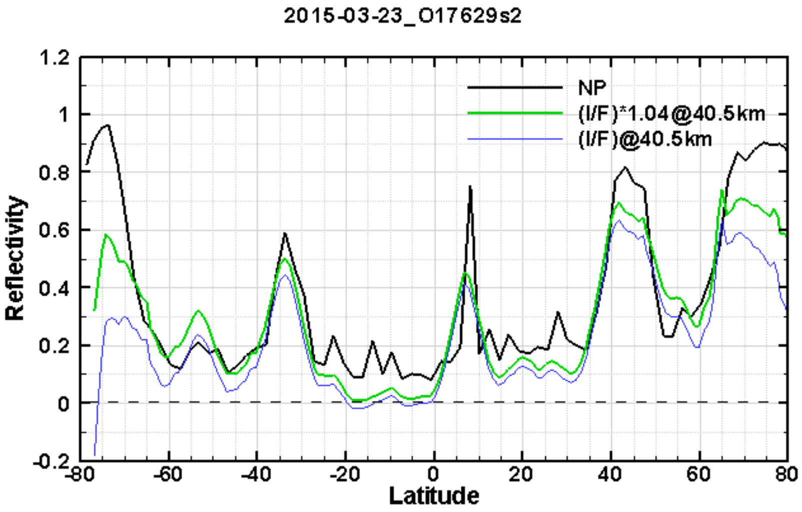


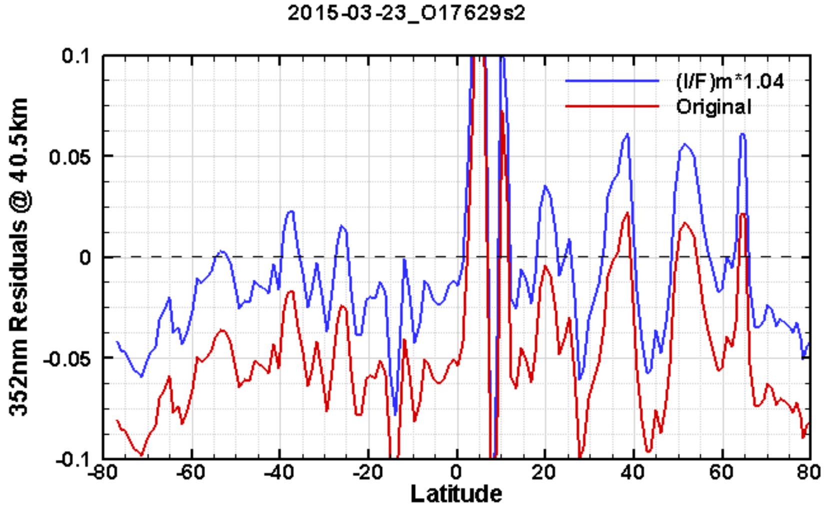
Future adjustments to calibration

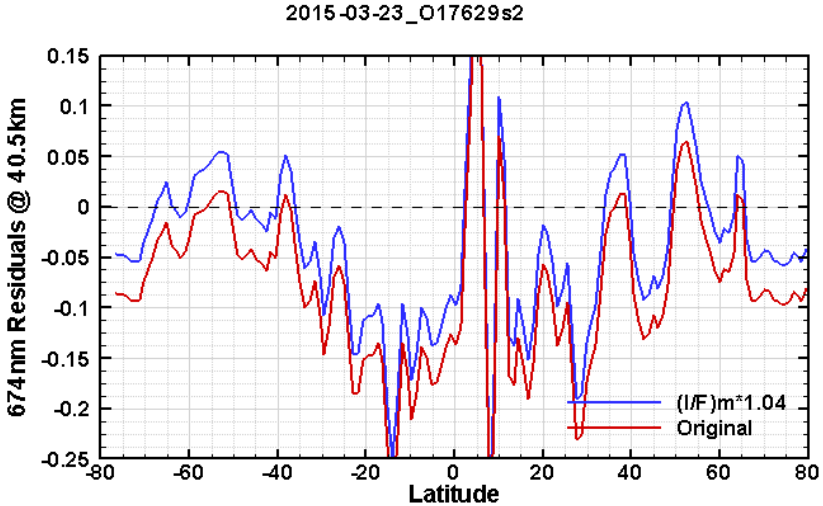
352nm



674nm







Future Work

- Test new Stepped IT timing pattern
  - will require significant L1B code changes to implement
  - we can drop 20 - 30K pixels from sample table
- Further refine stray light model by removing slit image
  - Long-term goal is to improve correction in IR
- Adjust UV calibration to NP. Develop strategy for VIS calibration adjustments
- Derive a 1^{st} order correction for solar intrusion based on above/below slit edge ratio
- Improve flagging and anomalous pixel rejection (before gridding)

SNPP OMPS Nadir Calibration Updates

Colin Seftor[1], Glen Jaross[2], Liang-Kang Huang[1],
Michael Haken[1], Mark Kowitt[1], Grace Chen[1], Jason Li[1]

[1]Science Systems and Applications, Inc
[2]NASA Goddard Space Flight Center

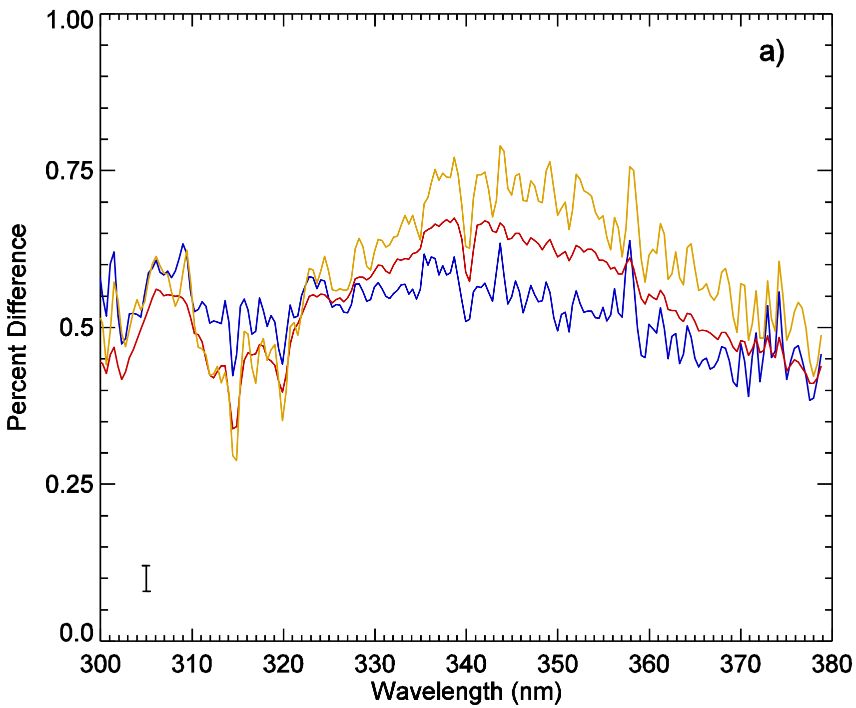
NASA OMPS Science Team / SIPS

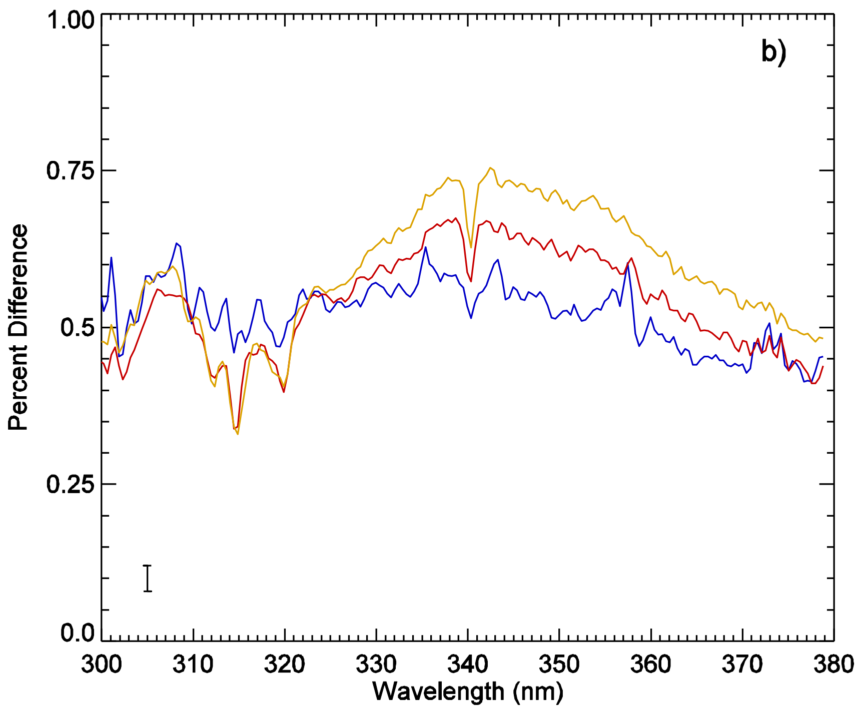
Summary

- We have performed detailed analysis of the OMPS radiances from both the NM and NP sensors to improve the calibration of the instruments
- Results from our analysis will be presented in the following areas:
  - Improved calibration sequence
  - Calibration coefficients
  - Along-orbit and "seasonal" wavelength shifts
  - Dichroic effects on the 290-310 nm radiances
  - Long-term stability

Small (.002 nm) seasonal wavelength shift seen in NM sensor

- Comparisons of reference solar flux measurements on 31 Aug 2012, 4 Apr 2013, and 28 Aug 2013 with 21 Mar 2012
  - Left – No shift in wavelengths
  - Right – 0.002 nm shift for **31 Aug 2012** and **28 Aug 2013**

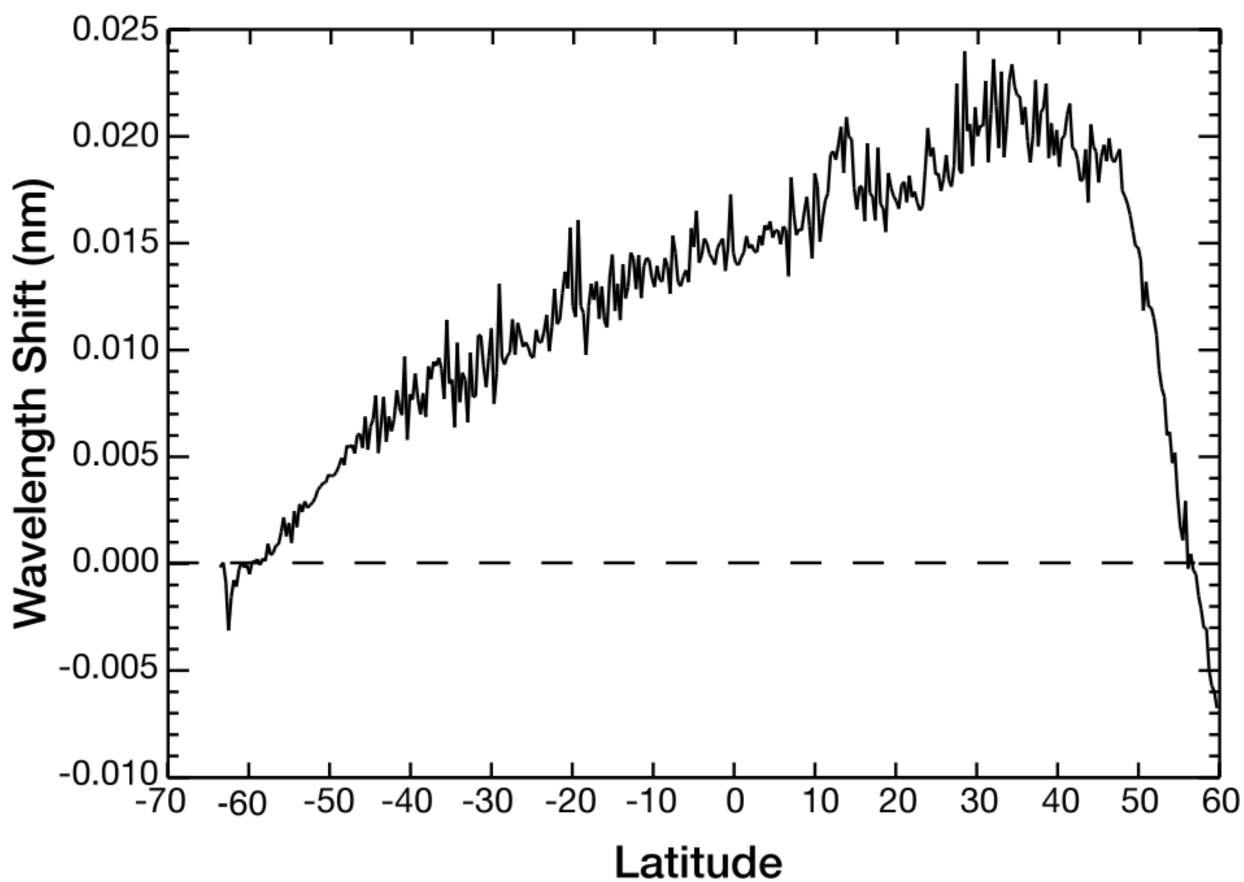




Intra-orbital wavelength shifts are seen in NM sensor

Comparison of Earth measured radiances for non-ozone absorbing wavelengths compared to synthetic solar flux

This shift is now accounted for in our V2 retreivals

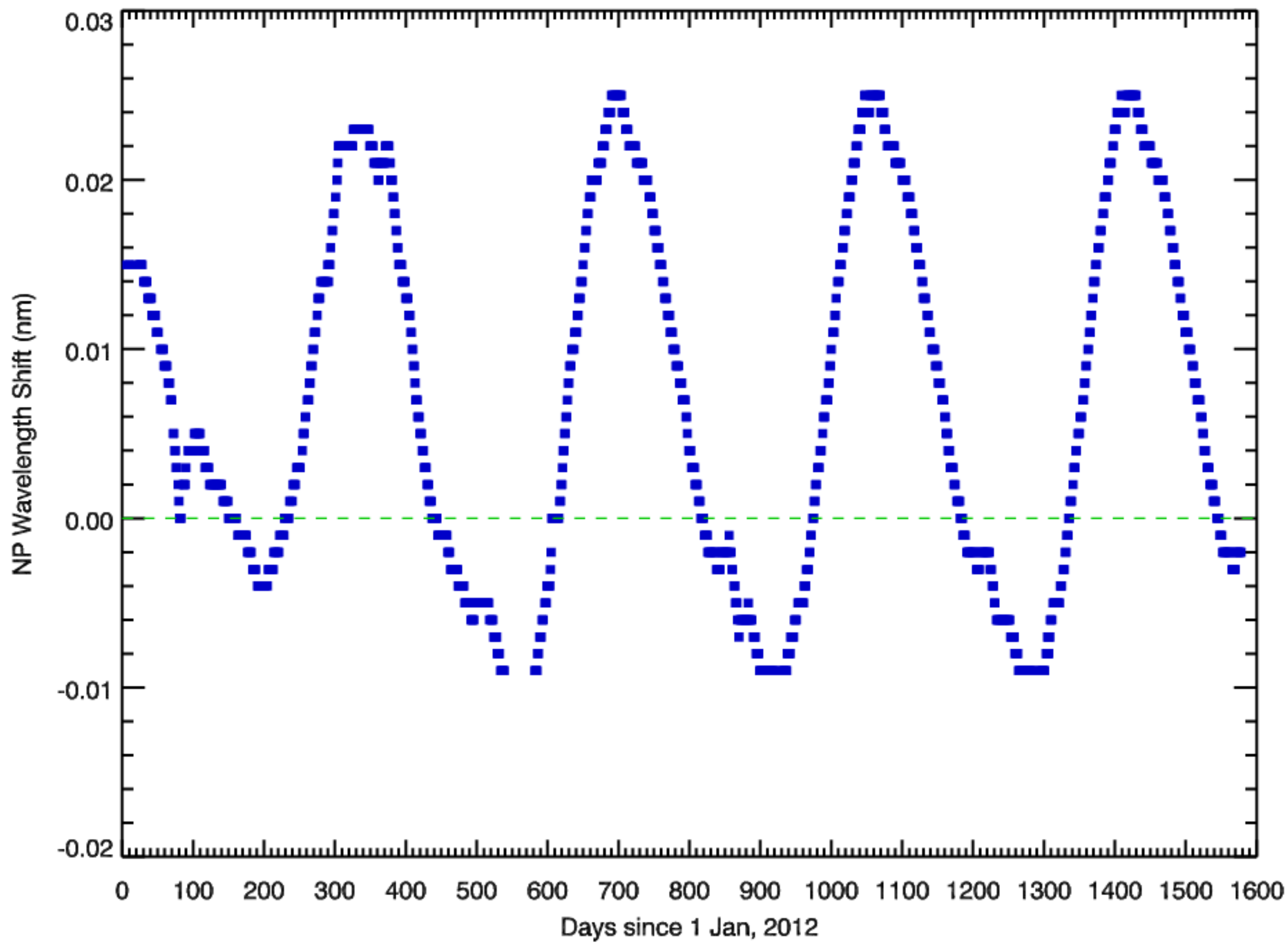


NP Wavelength Shift

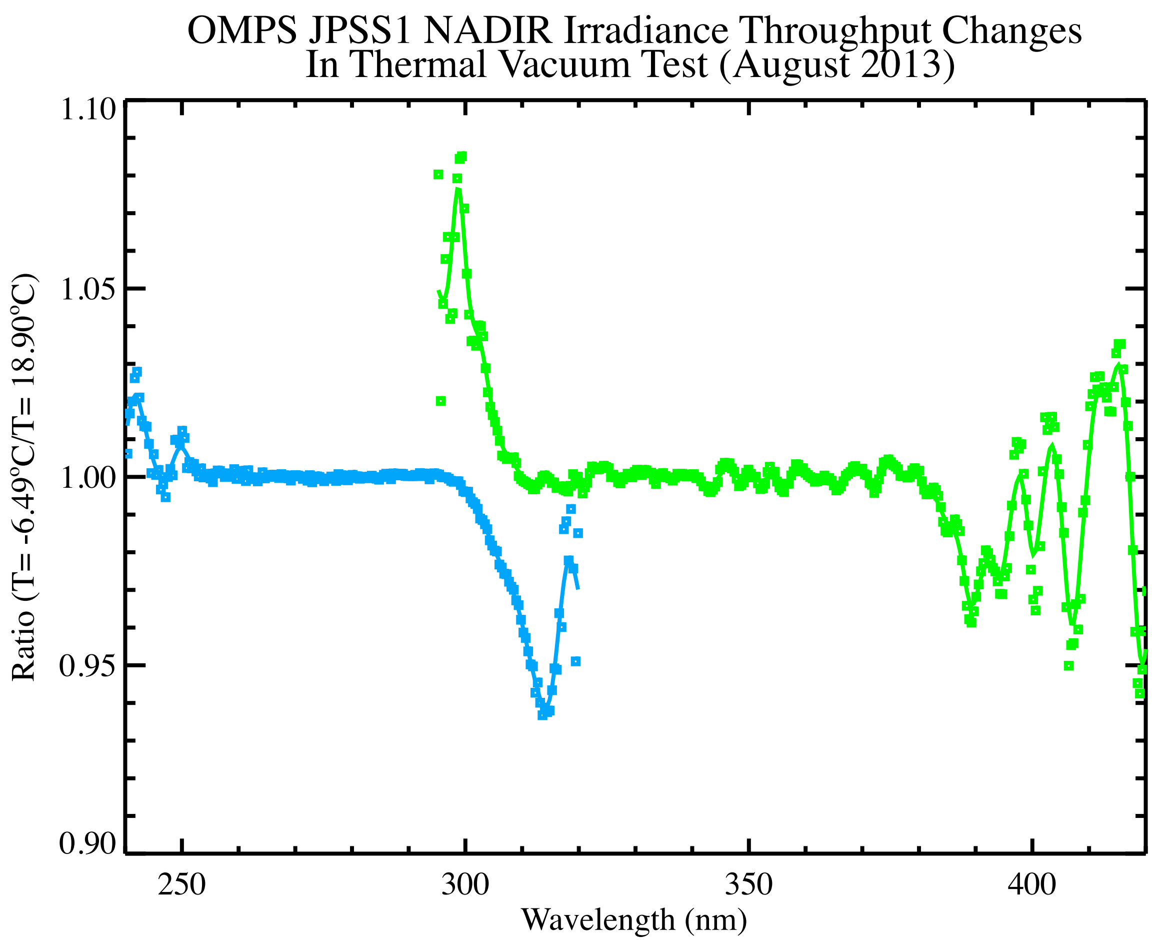
Comparison of solar irradiances with synthetic solar flux shows a seasonal wavelength shift

Again, this shift is now accounted for in our V2 retreivals

No significant intra-orbital shift is indicated

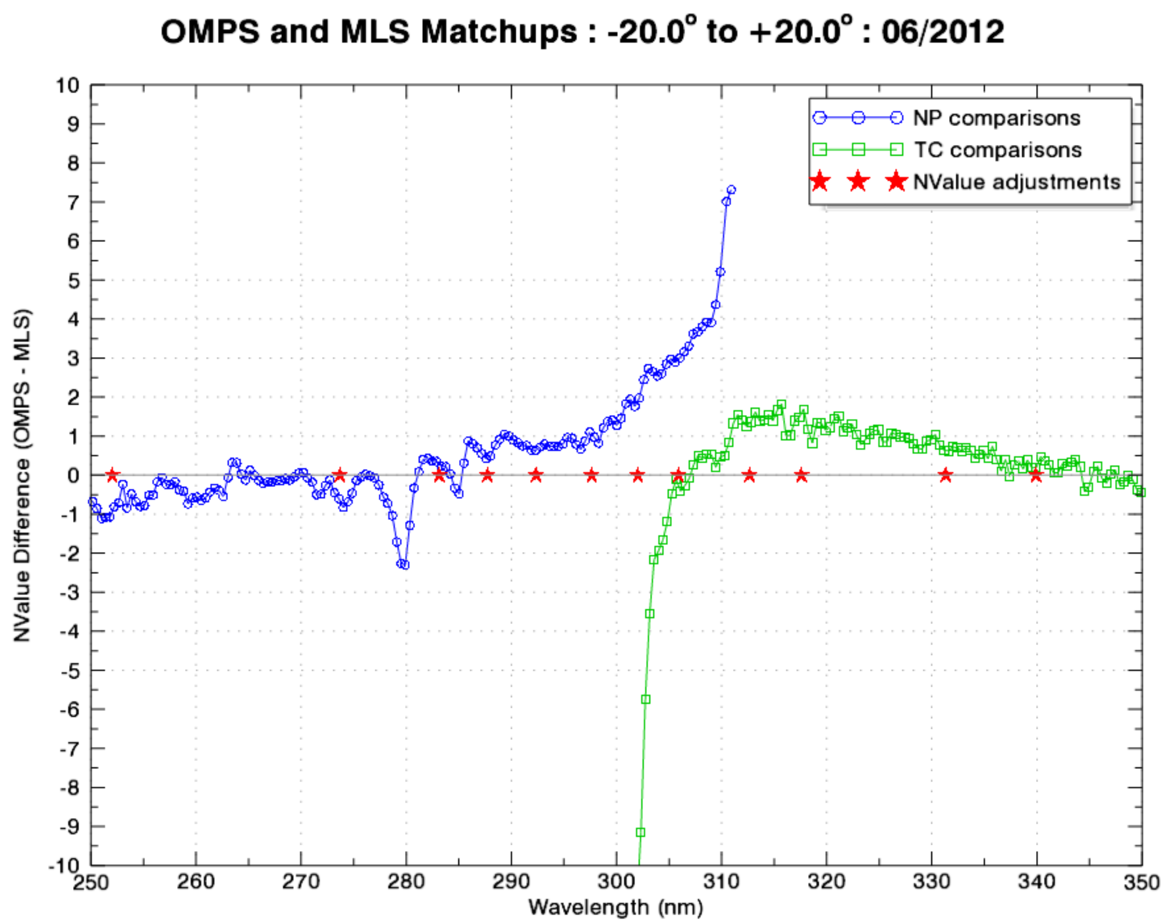


Adjustments needed to account for changes in throughput, particularly in dichroic region

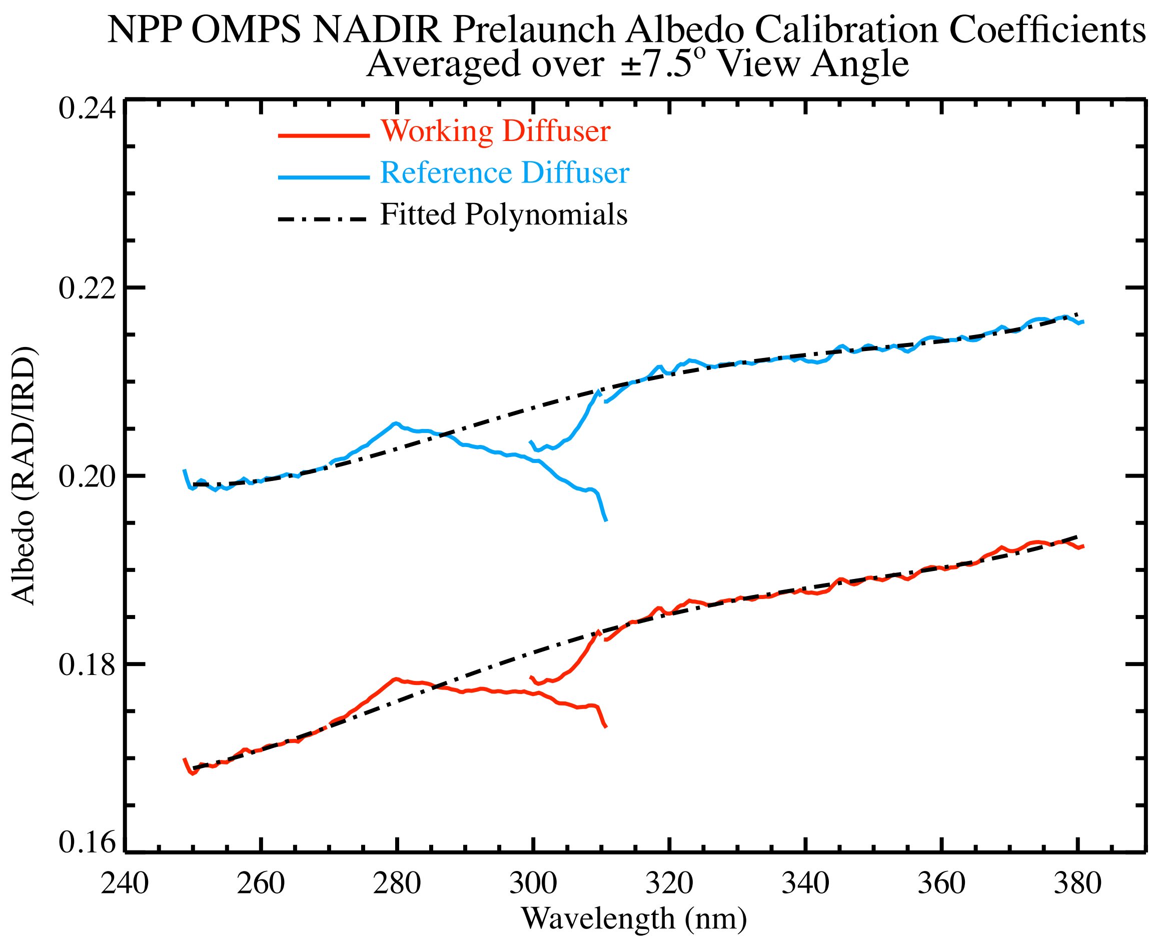


V1 OMPS/MLS matchup comparisons showed problems unrelated to dichroic adjustment

- MLS ozone/temp profiles from matched up dataset used in radiative transfer calculations of normalized radiances
- Calculated NR compared to OMPS measured NR
- N values difference compared
  - $N = -100\log_{10}(NR)$
  - $\Delta N = -2.3\%$ radiance difference

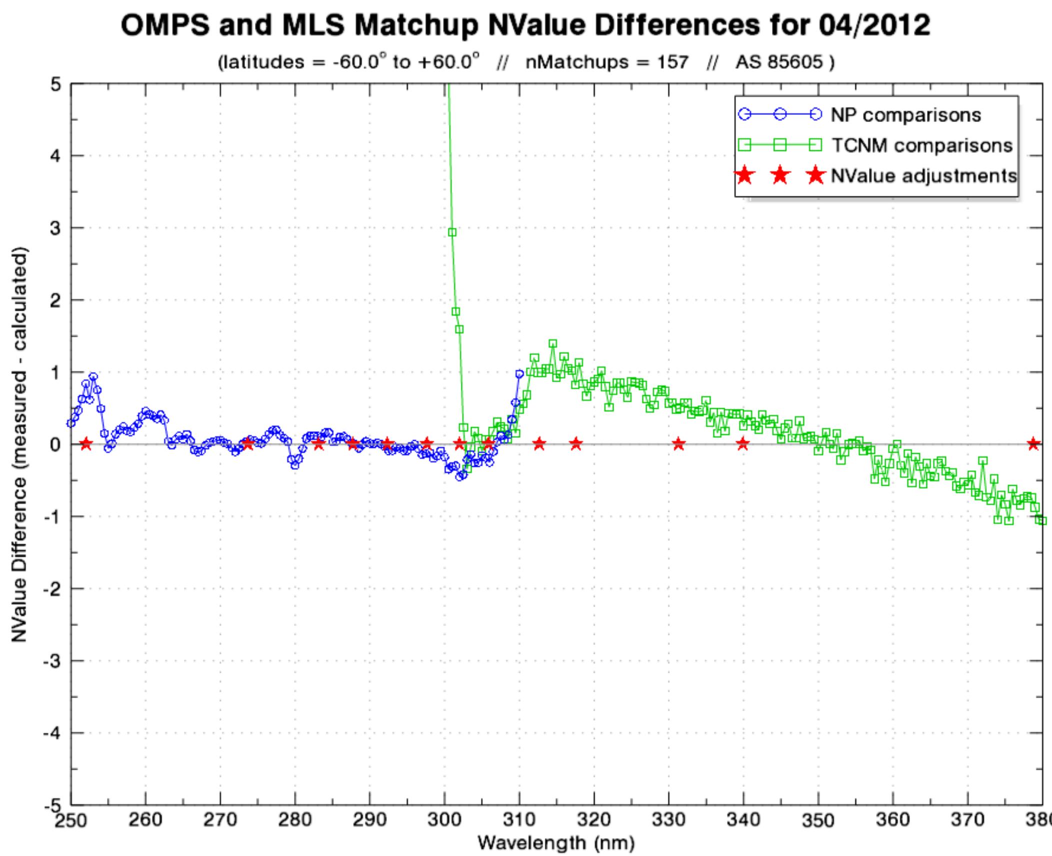


Adjustments needed to account for "unphysical" behavior of cal coefficients

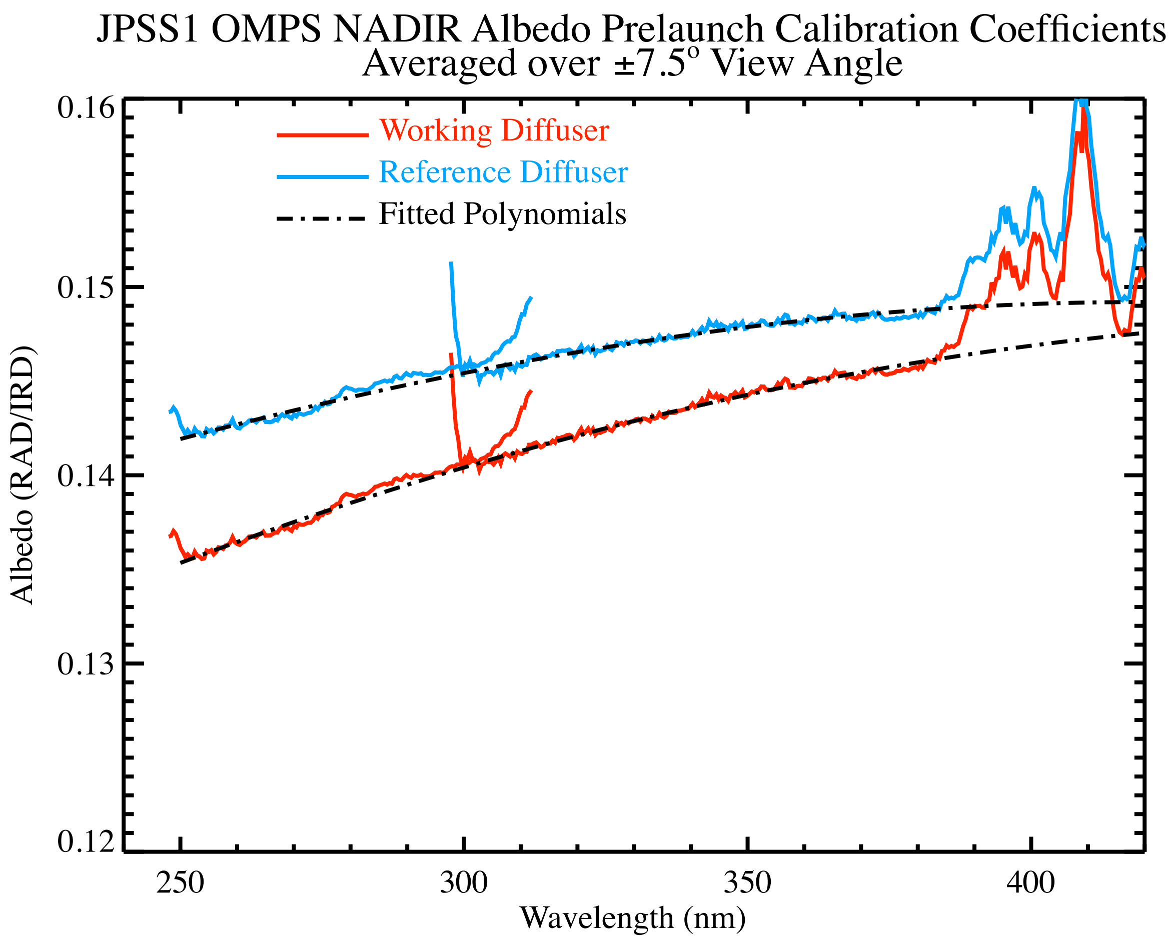


V2 OMPS/MLS Matchup Comparisons showed better performance with new coefficients

- Includes corrections for dichroic region
- Includes corrections for stray light

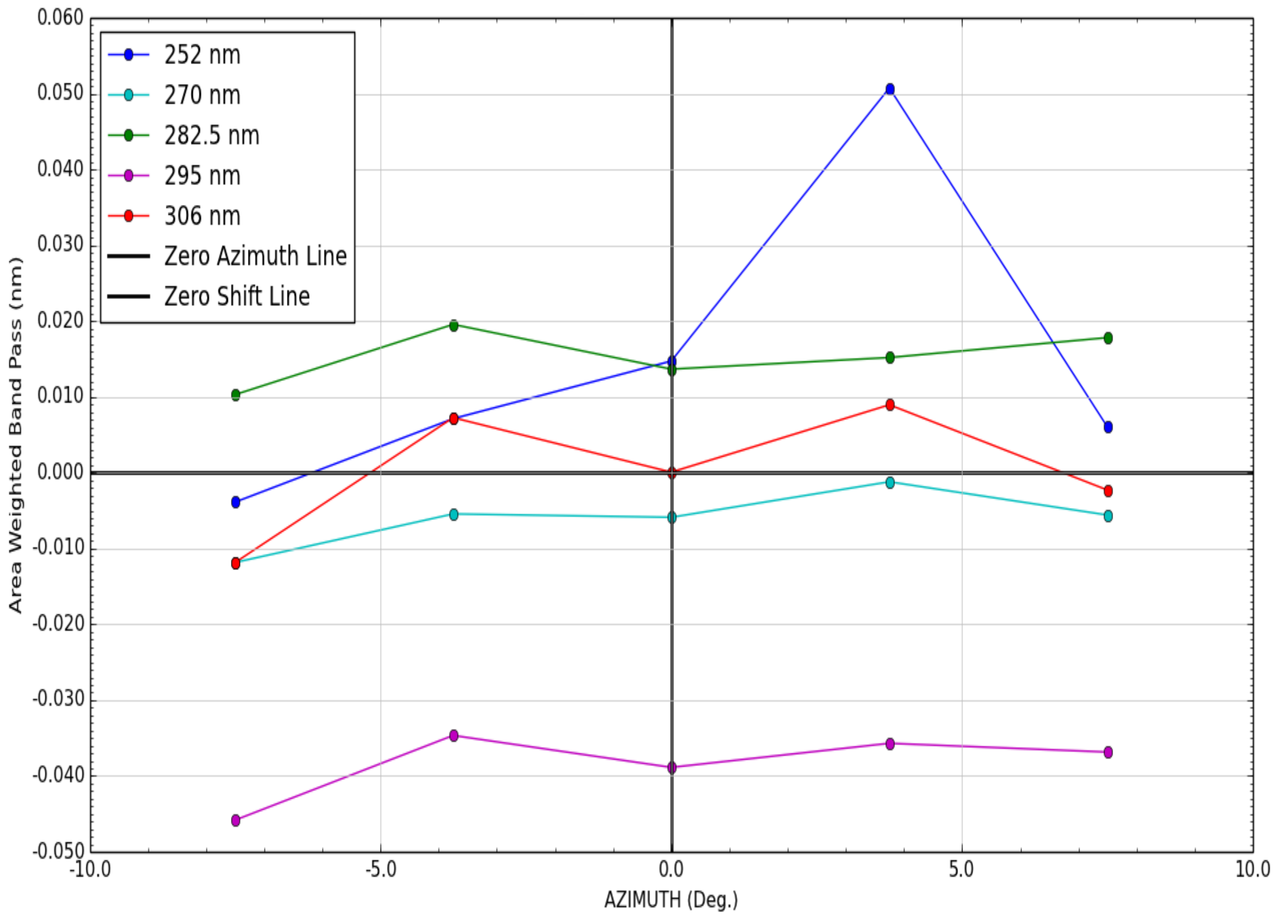


J1 calibration coefficients show the same type of unphysical behavior



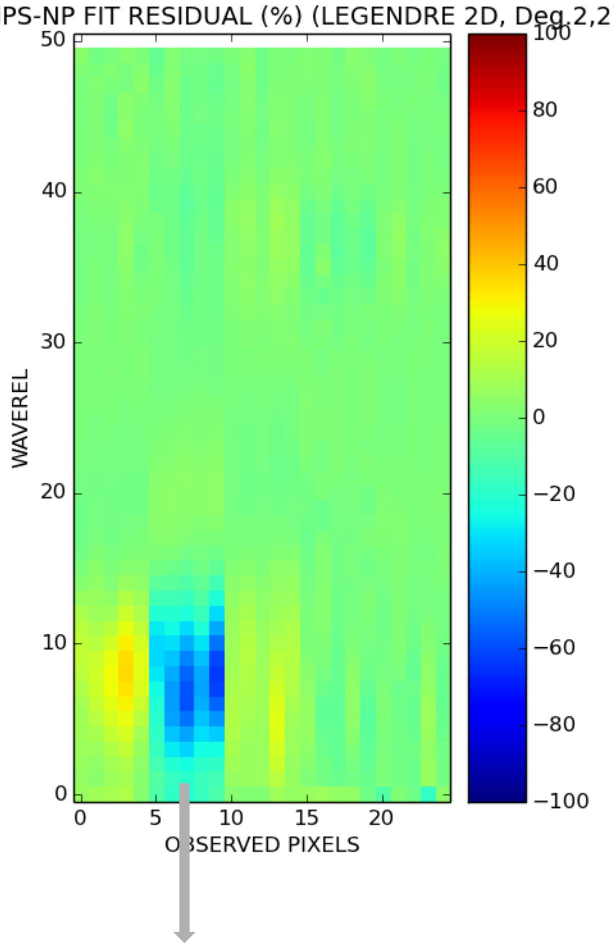
NP Bandpass Issue Near 295 NM

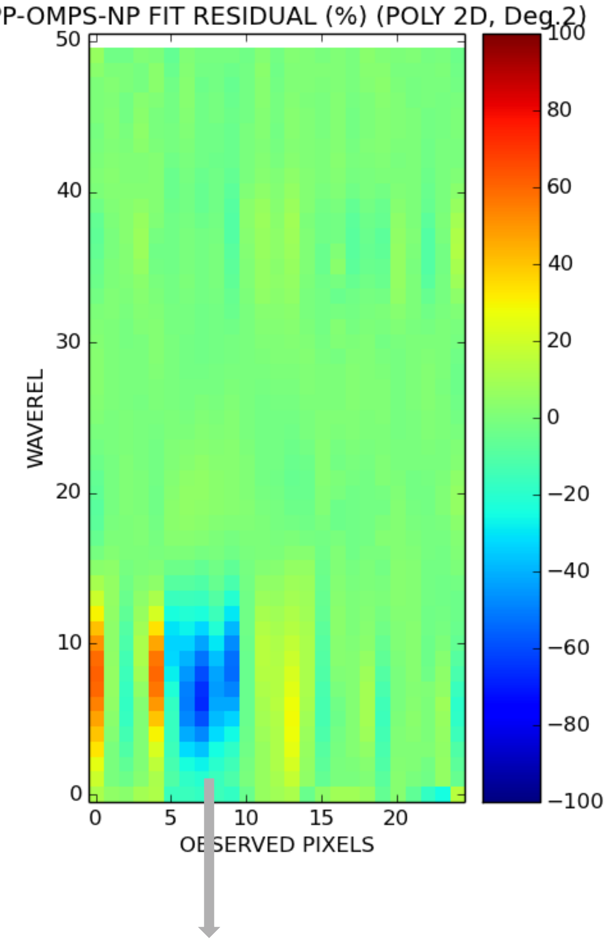
Weighted-average central wavelength does not match Ball's Channel Band Center (CBC) wavelength



NP Bandpass Issue Near 295 NM

Our own fitting analysis indicates that there is something wrong with the 295 nm Data





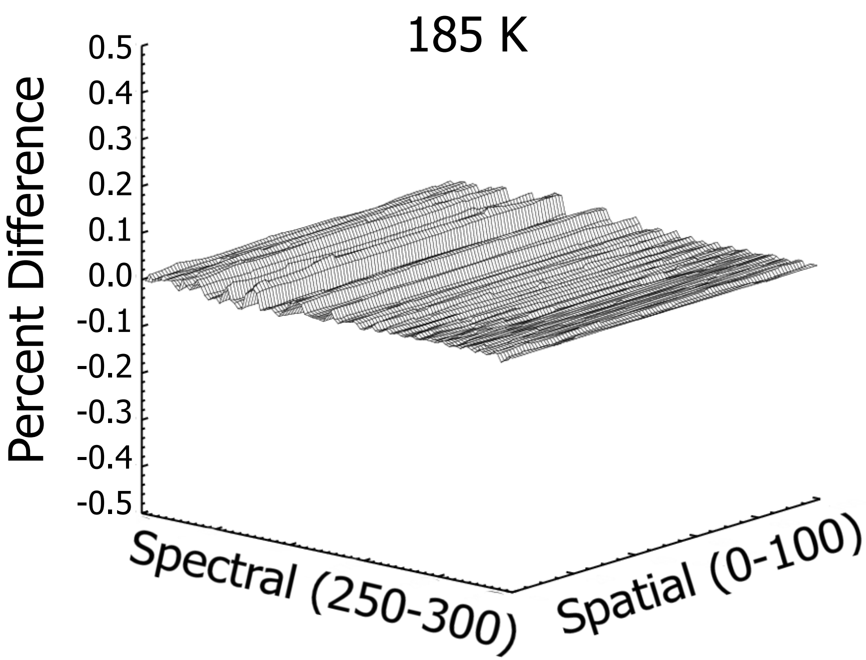
Relatively large fit residuals for pixels corresponding to 295 nm (pixel index 5 - 9). These are happening at the tails. The degree of polynomials used for fitting is 2.

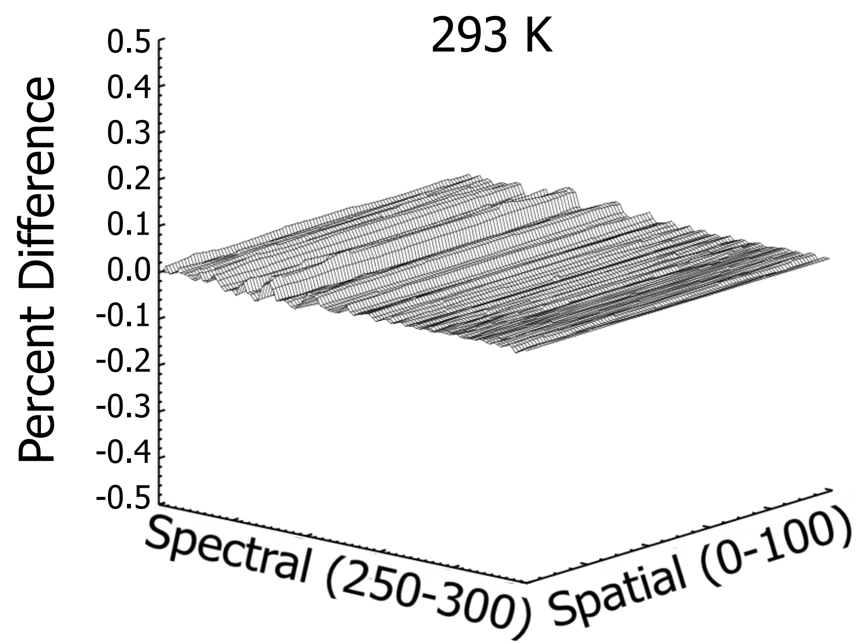
Effect is negligible

We re-fit without the 295 nm Ball data

We calculated effective absorption coefficients for low and high temperatures and compared to coefficients calculated using a fit that included 295 nm data

Results show negligible effect (< 0.1%)

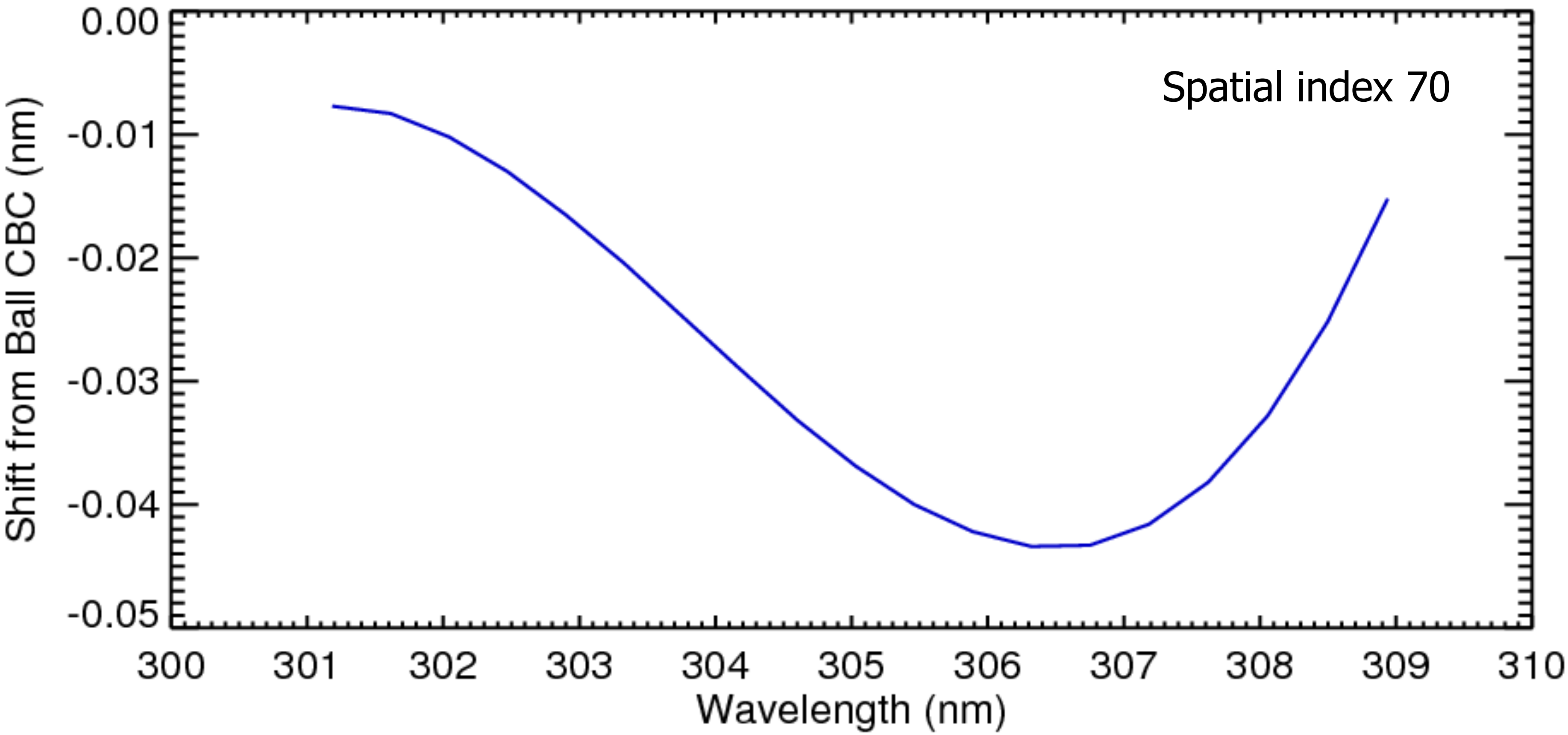




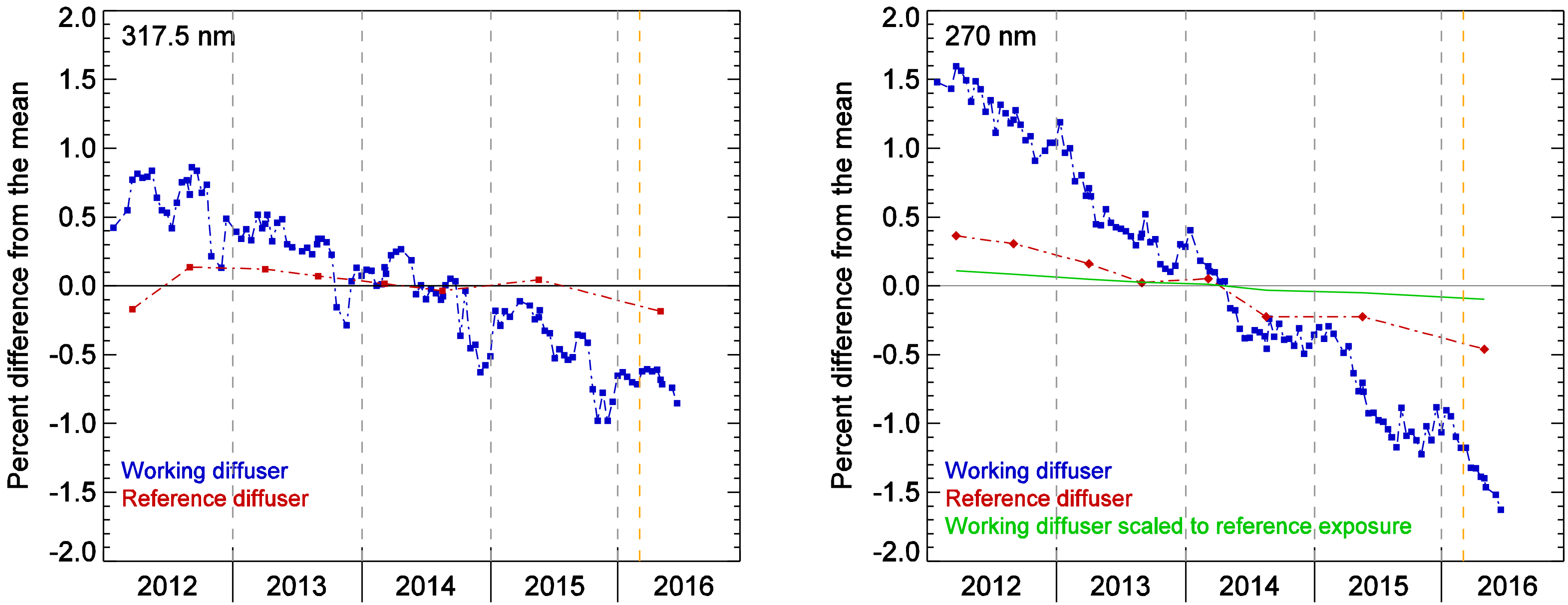
Bandpass Issues in Dichroic Region

- Bandpass measurements taken by Ball in dichroic region are OK
  - However, Ball's analysis using those measurements did not include the dichroic's sensitivity factor
  - Their analysis led to incorrect wavelength assignments within dichroic region
- We did our own analysis to account for this sensitivity
  - We did no implement any change to the NM because predicted shift made the irradiance residuals worse
  - Resulted in noticeable wavelength shift for NP, irradiance residuals did not get worse
    - We implemented this change

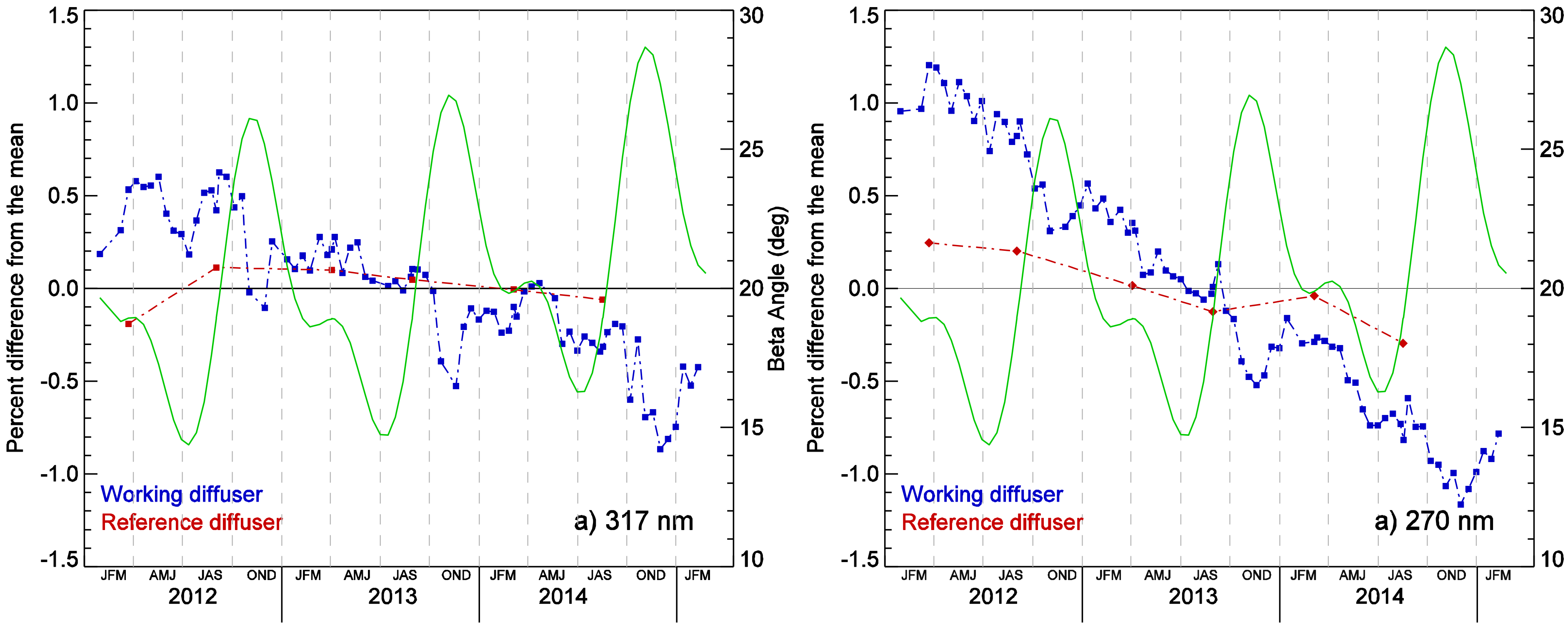
NP Shifts Become Sizeable



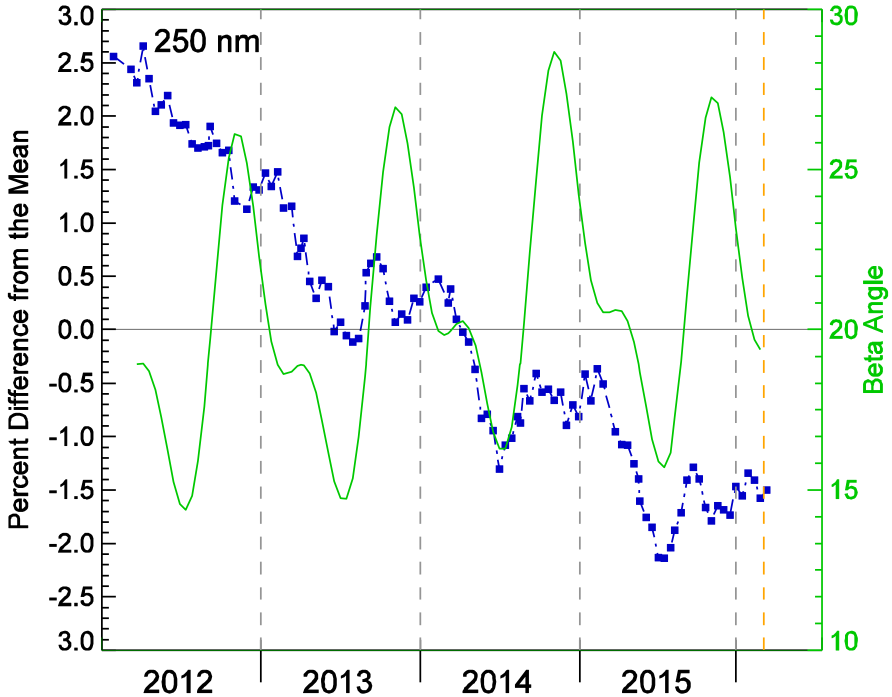
Working and Reference Diffuser (Solar Flux) Measurements

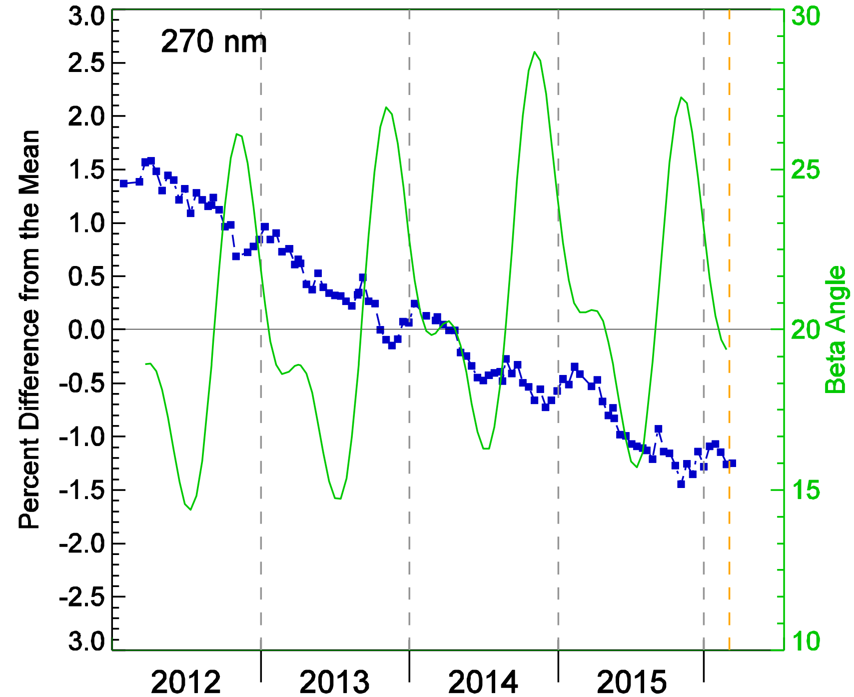


Compared to Beta Angle

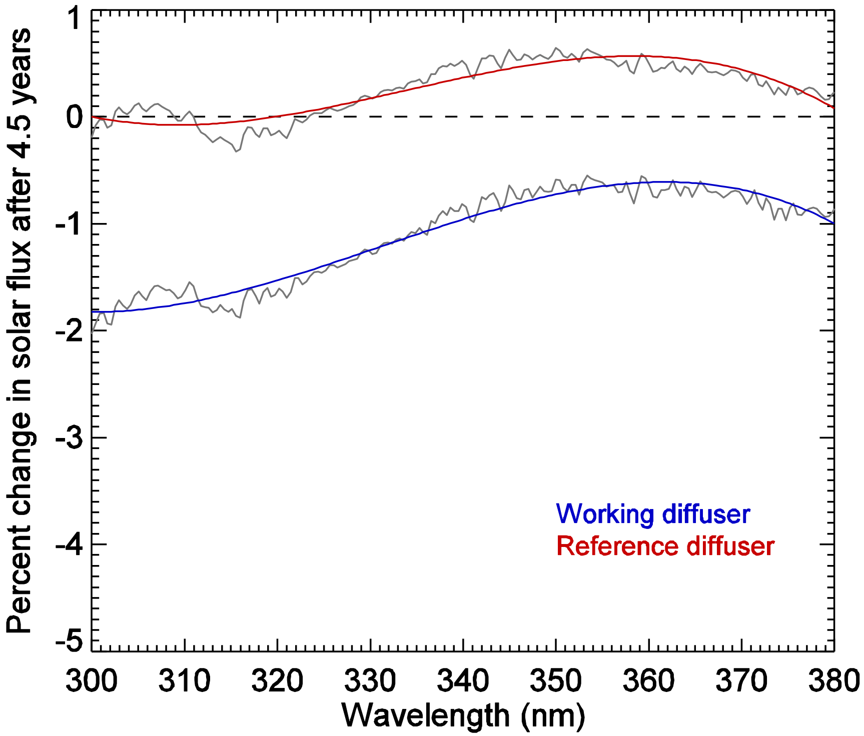


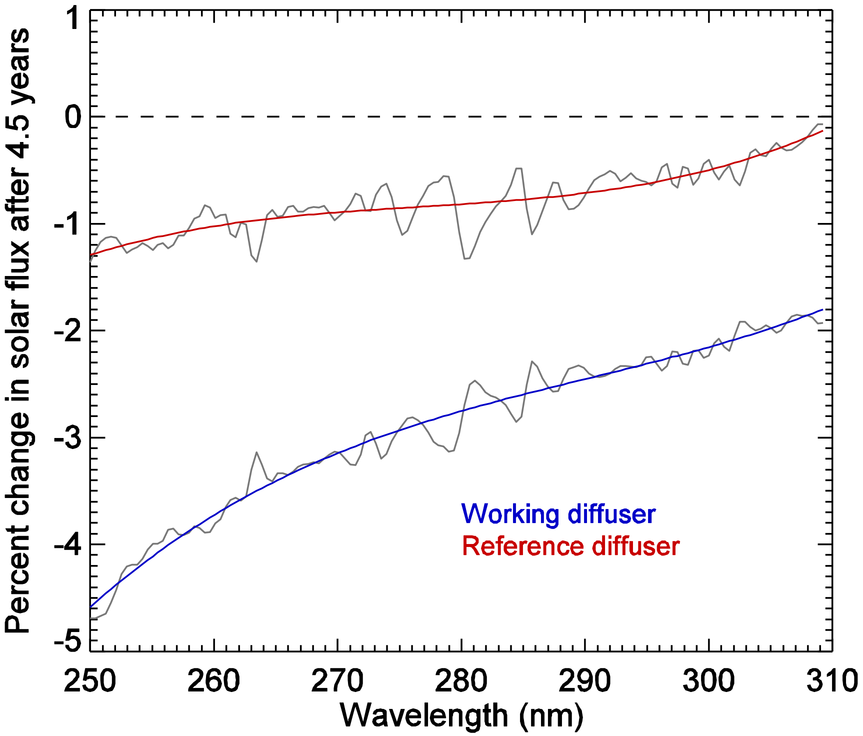
Compared to Beta Angle



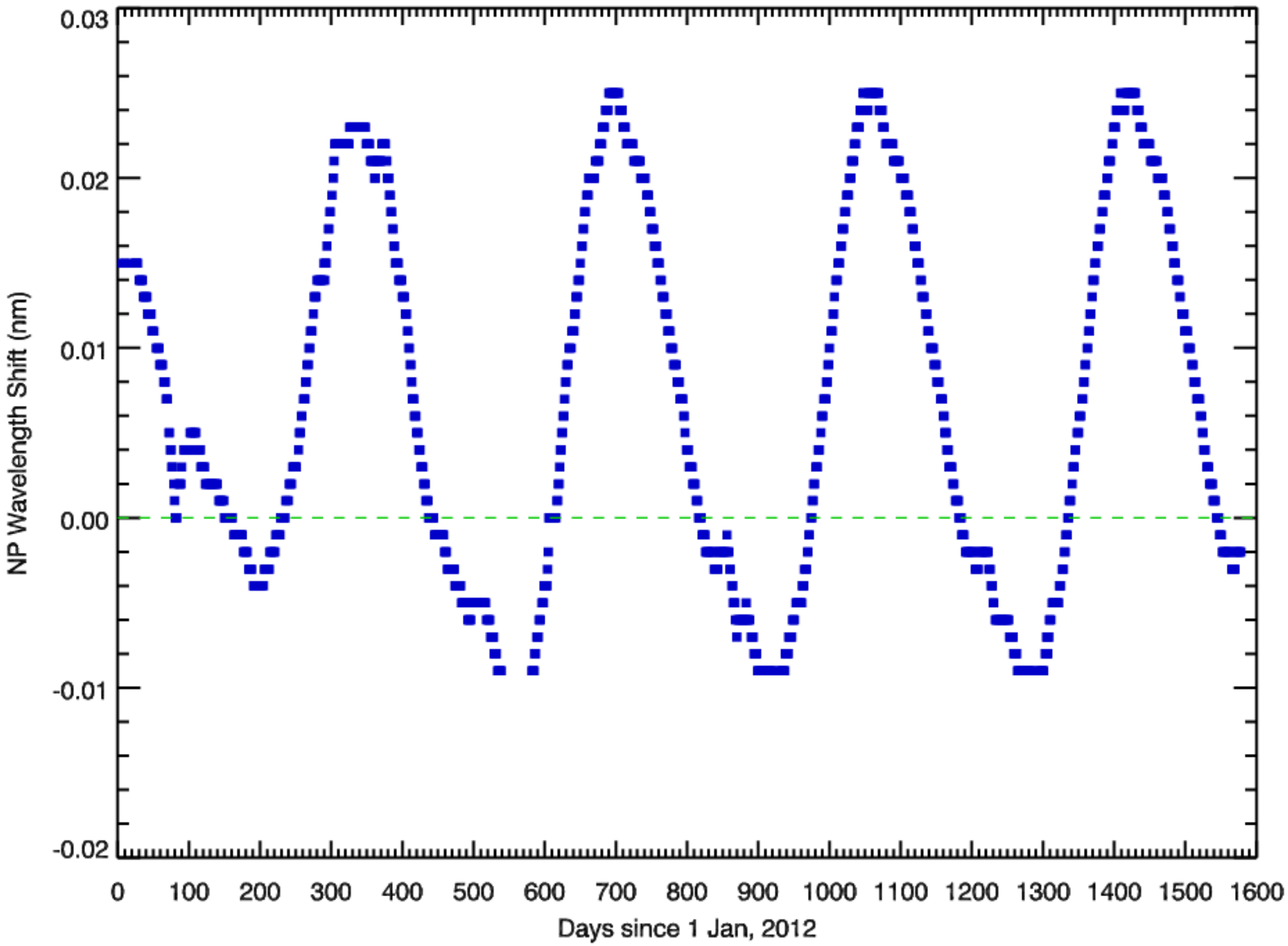


Change After 4.5 Years

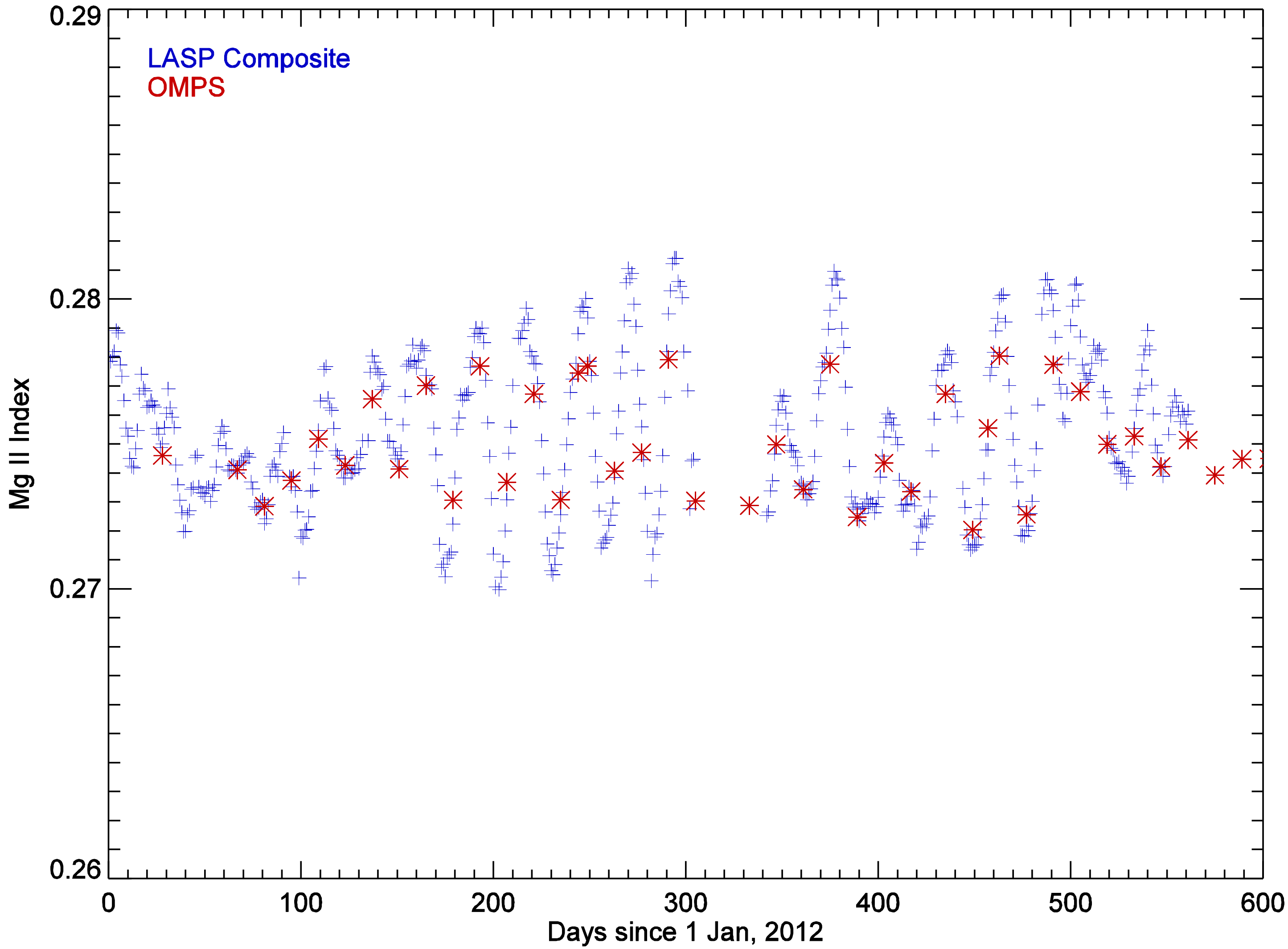




NP Wavelength Shift

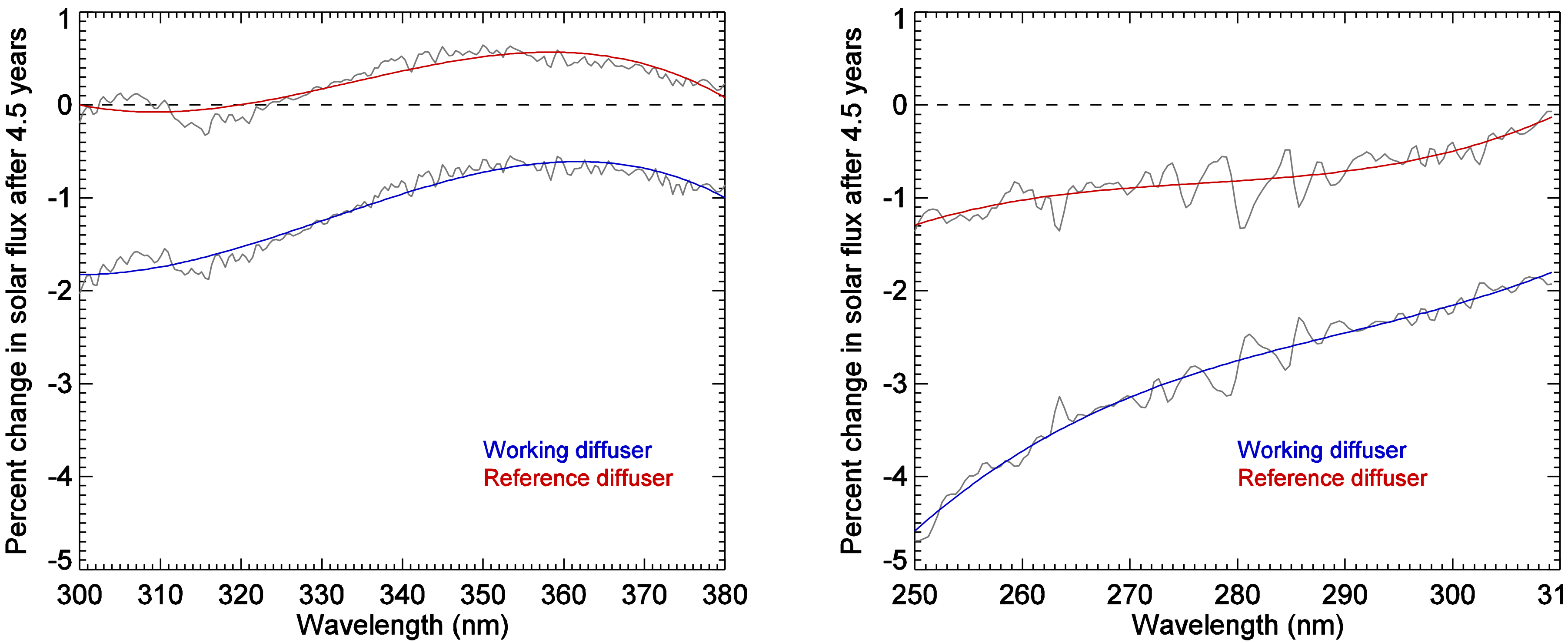


Mg II Index

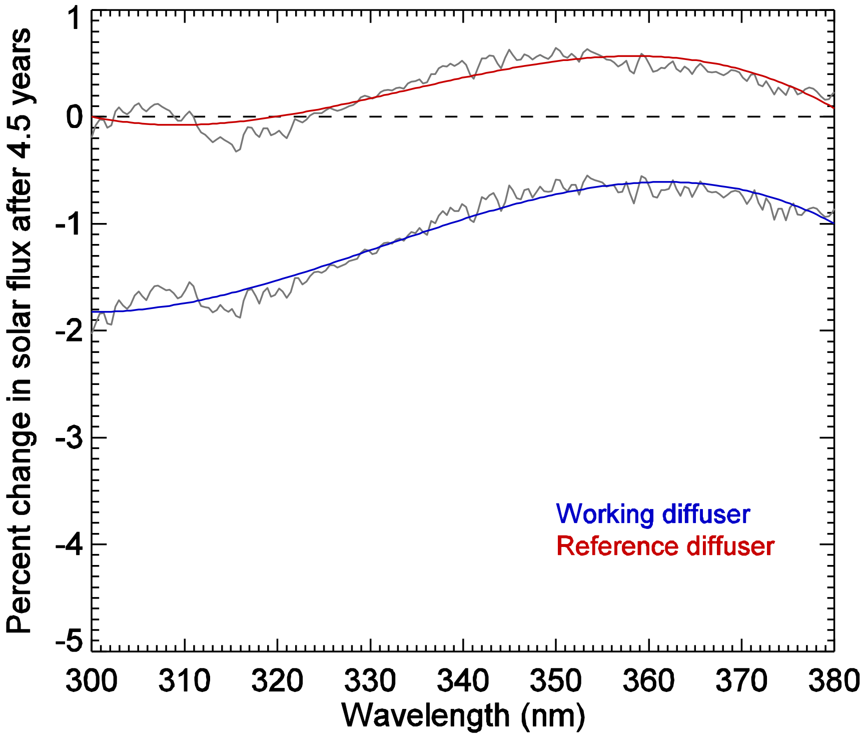


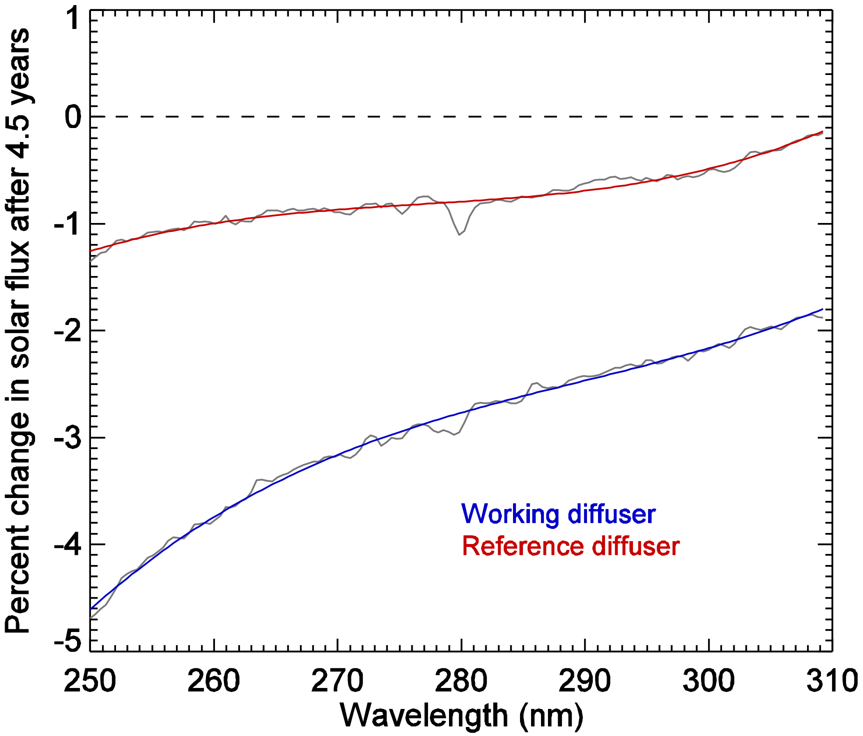
LASP Composite
OMPS
Mg II Index
0.29
0.28
0.27
0.26
0
100
200
300
400
500
600
Days since 1 Jan, 2012

Change After 4.5 Years

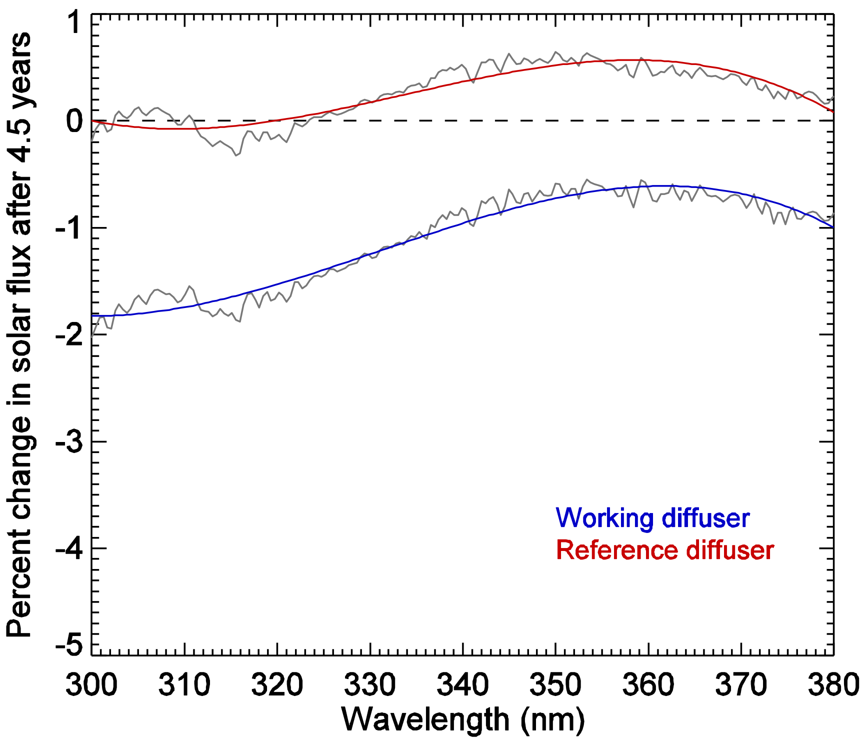


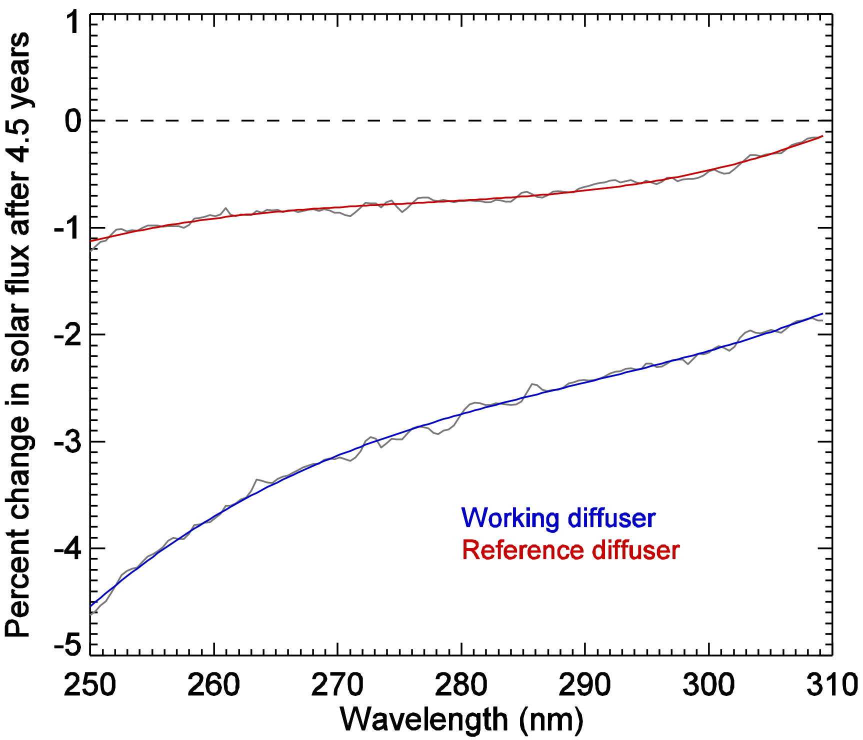
Change after taking into account wavelength shift



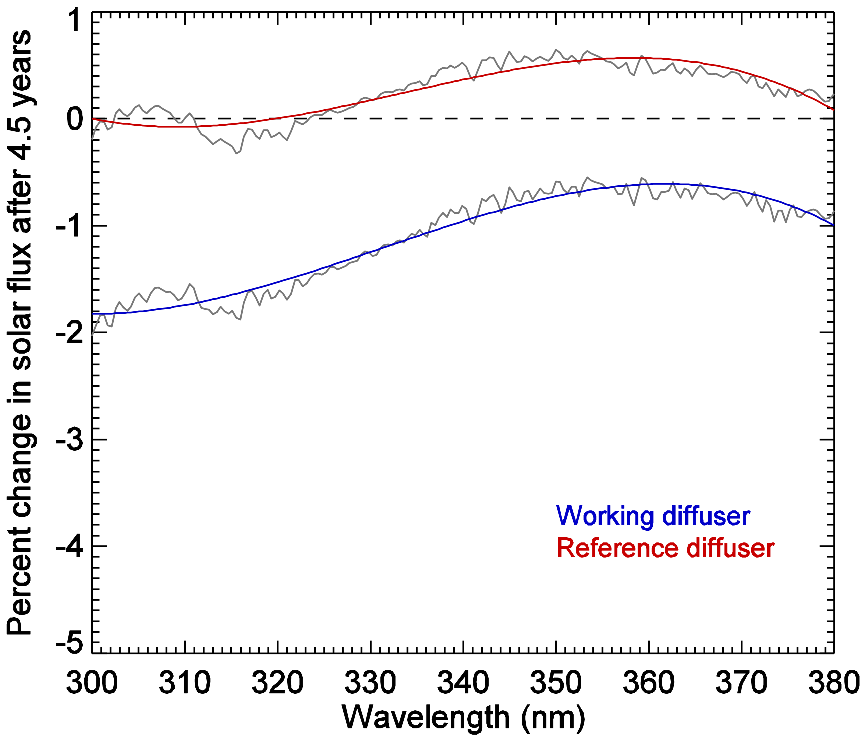


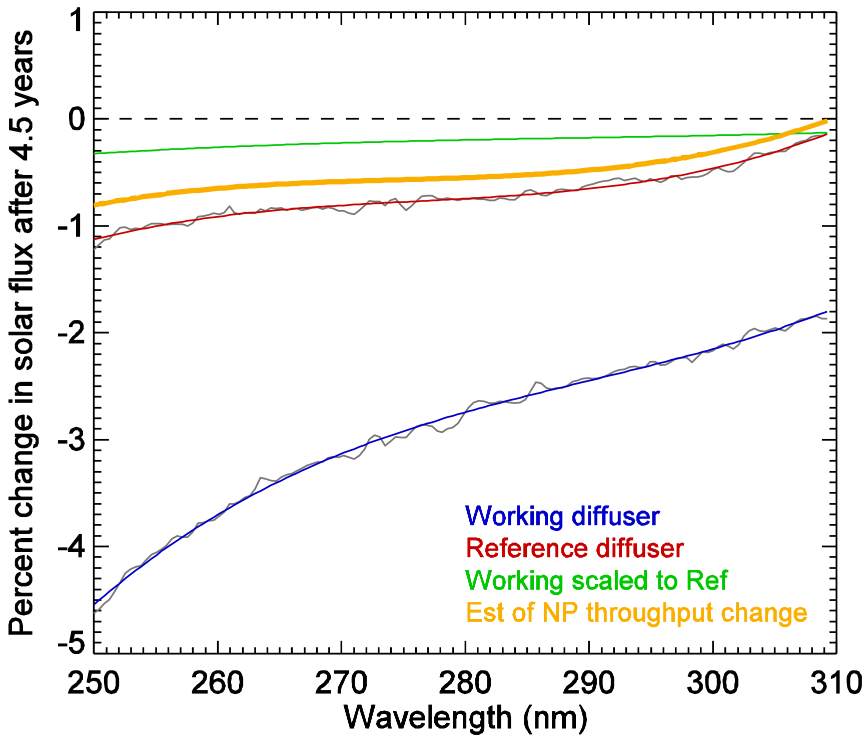
Change after taking into account wavelength shift, solar activity





How much of the change is due to actual sensor degradation?

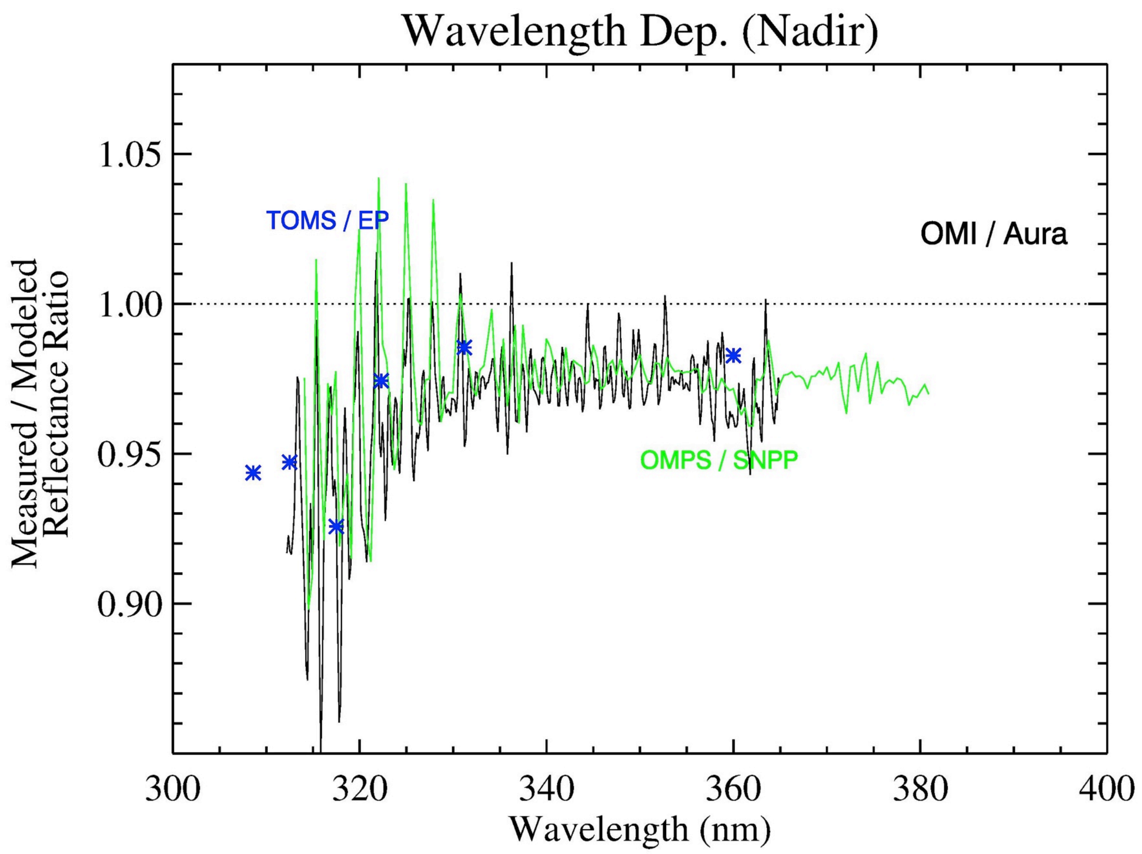




"Soft" Calibration

- Soft Calibration Designed to Account for Any Remaining Issues
  - Ice Radiance Used to Determine Absolute Adjustment for 331 nm at nadir
  - Mimimum sea surface reflectivity used to adjust absolute across the track
  - Comparisons of calculated to measured normalized radiances used to determine 317 nm adjustment
  - Residuals used to determine adjustments at other wavelengths

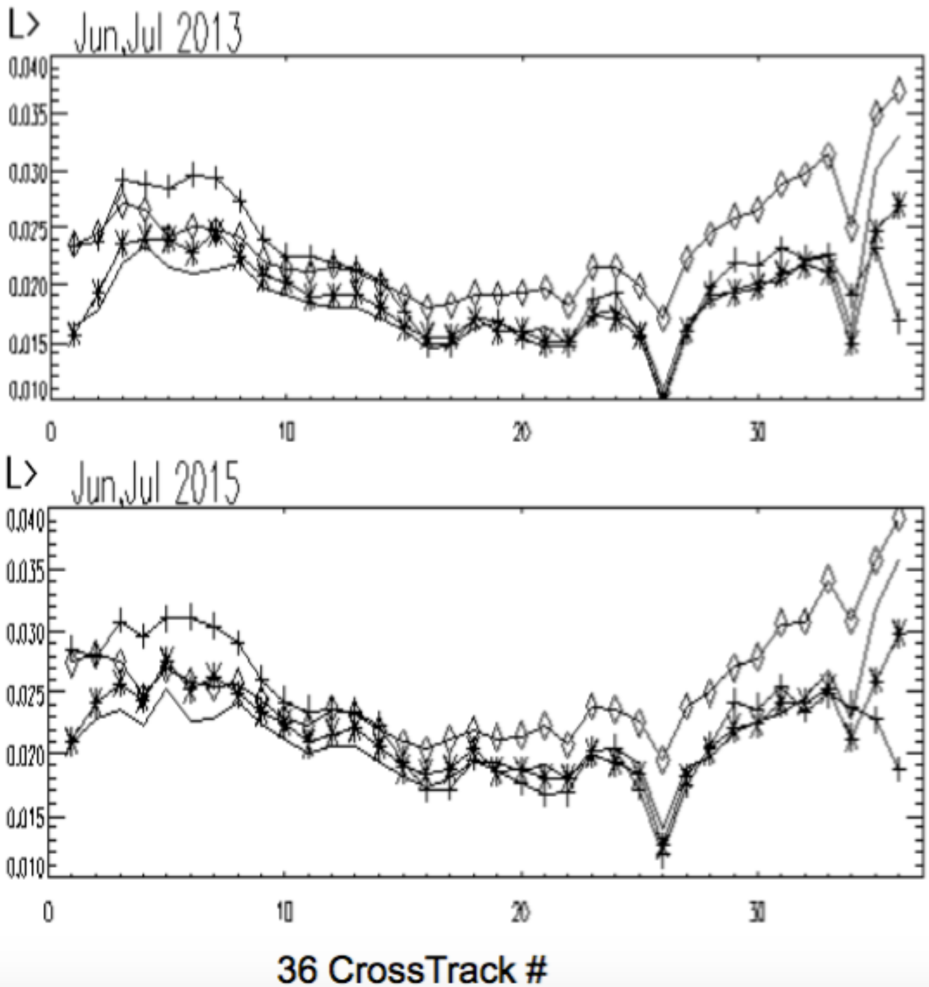
Ice Radiance Analysis



Minimum Reflectivity Analysis

Overview of Land Minimum Reflectivity for NMBUV OMPS 60004 non-absorbing channels

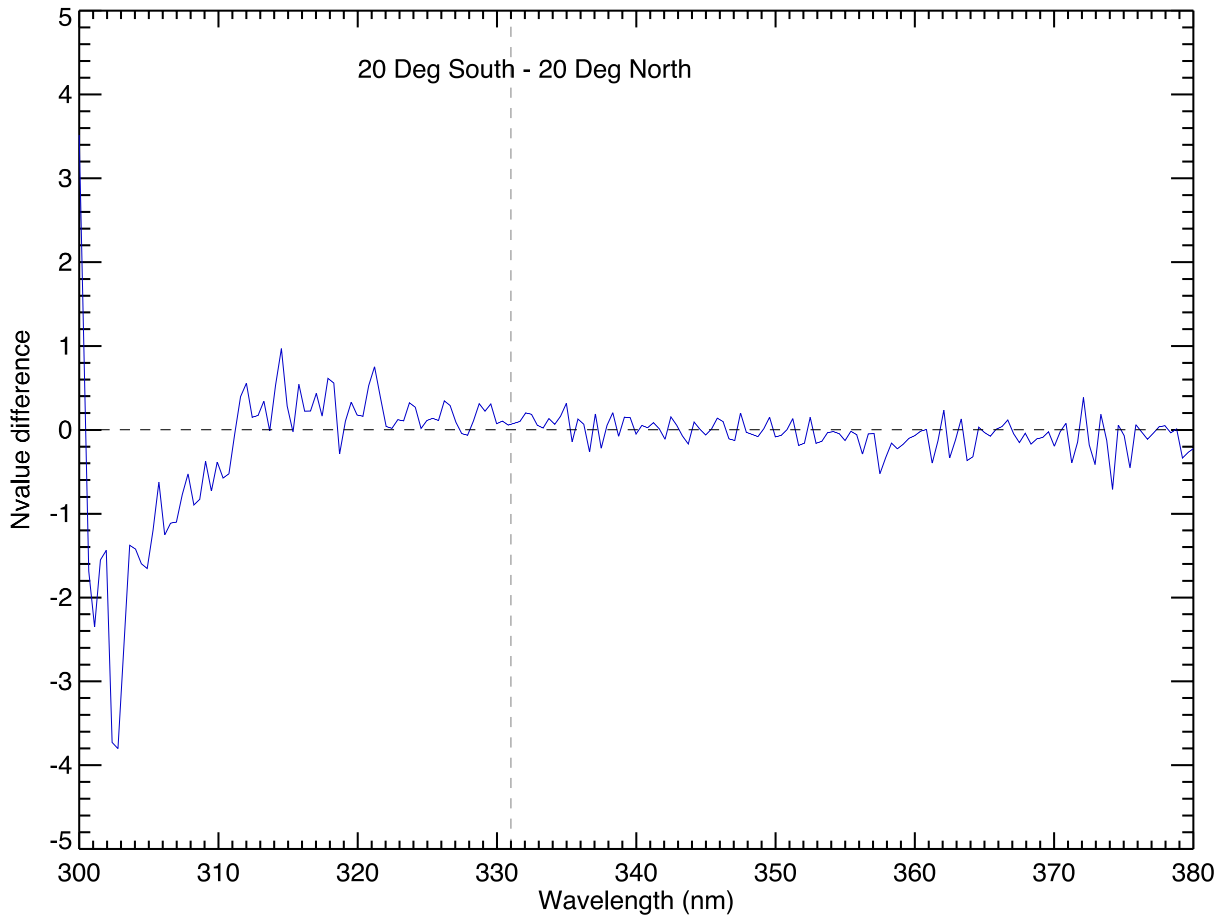
(+, *, -, <>) 313, 345, 360, 372



>> Overall relatively consistent pattern with time. Suggestion of a very slight upward drift

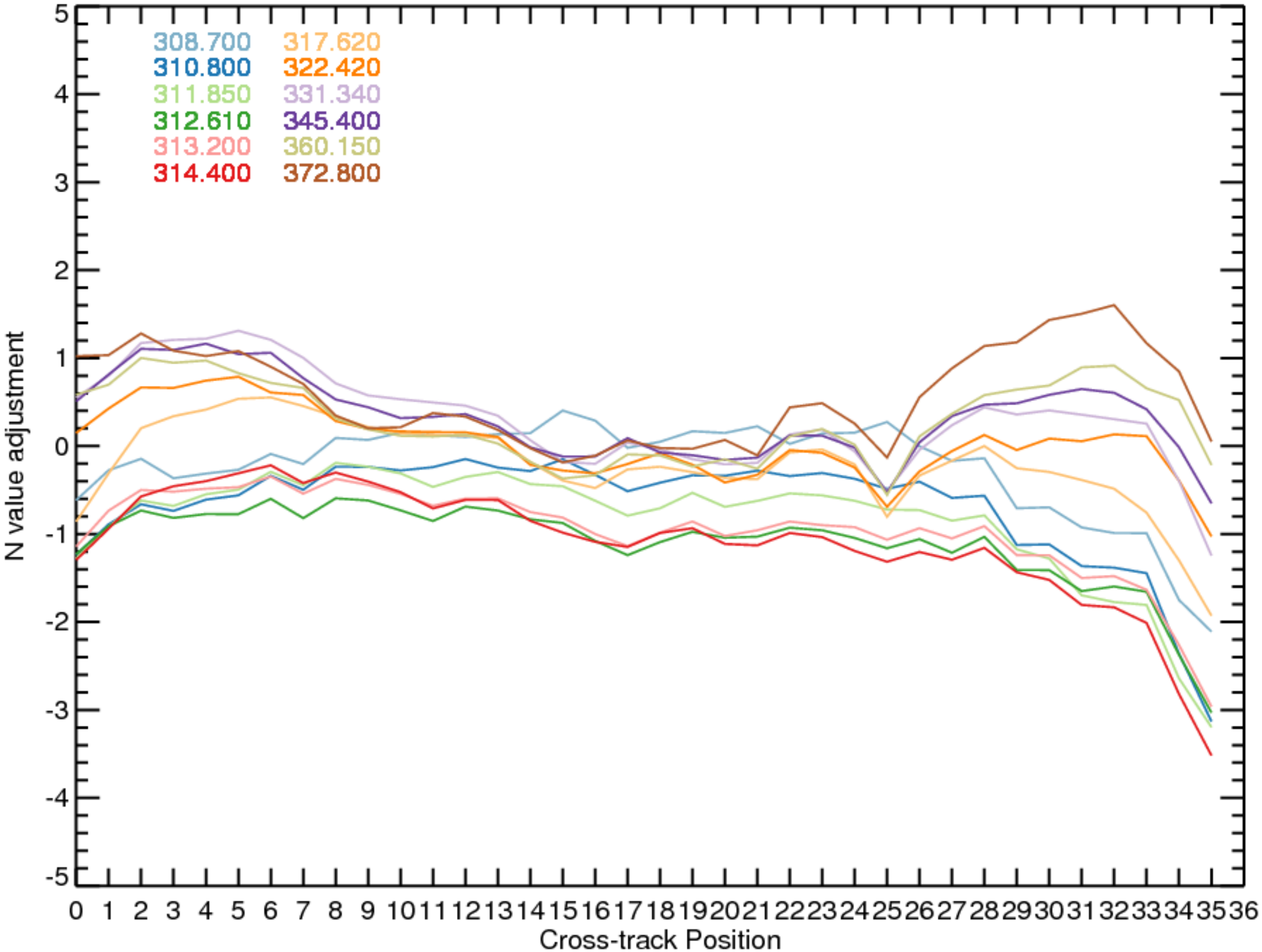
Comparison of Calculated to Measured Normalized Radiances

- NR calculated using:
  - Ozone climatology*
  - Temp climatology
  - Meas viewing cond
  - 331 nm reflectivity



*McPeters, R. D., G. J. Labow, and J. A. Logan (2007), Ozone climatological profiles for satellite retrieval algorithms, J. Geophys. Res., 112, D05308, doi: 10.1029/2005JD006823.

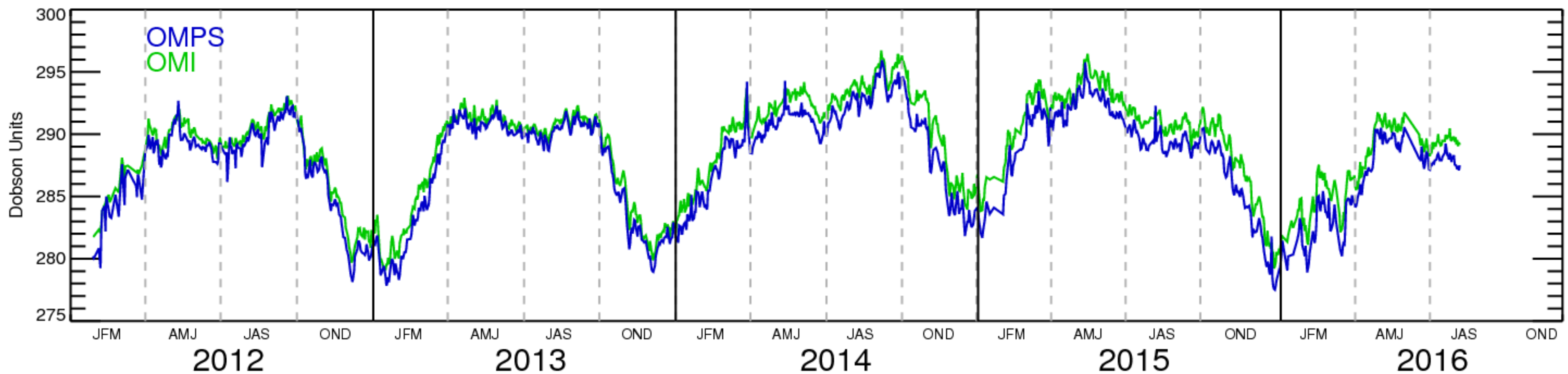
Residual Analysis

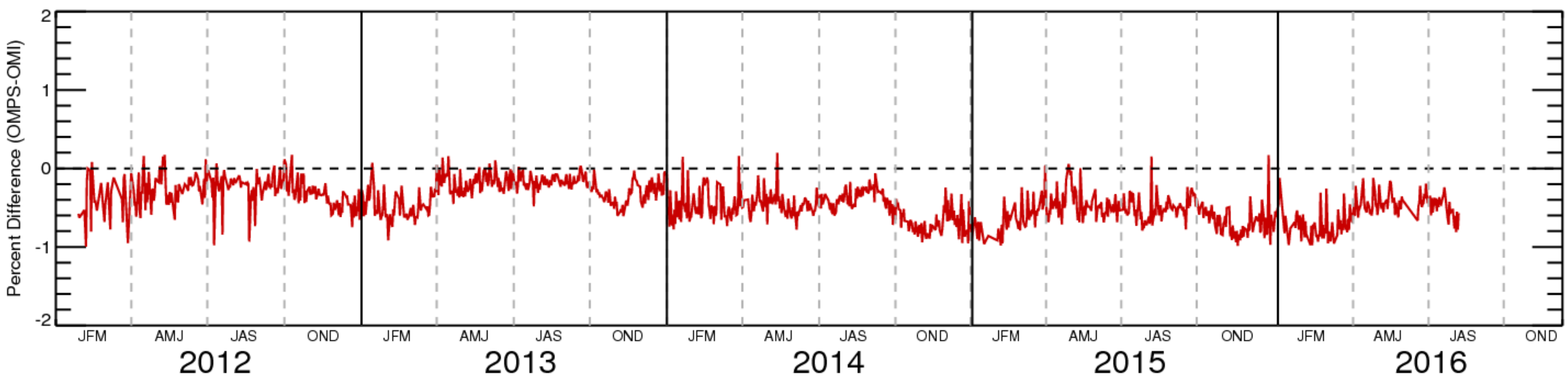


Comparison of OMPS to OMI total ozone

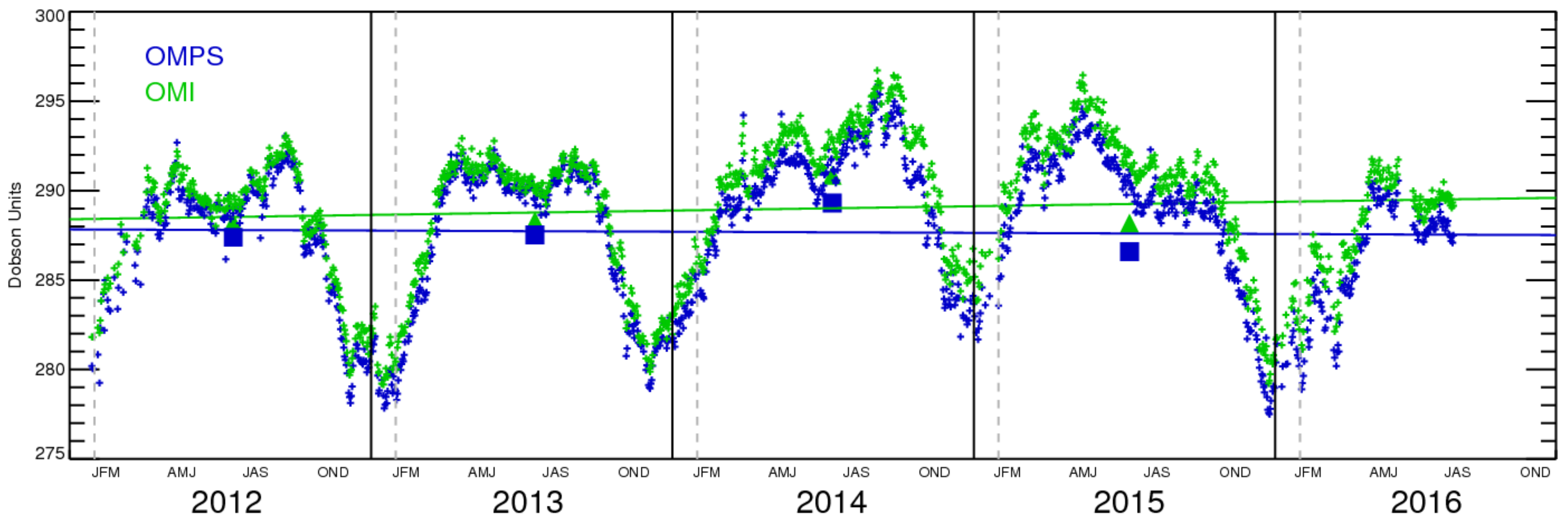
OMI / OMPS / Difference

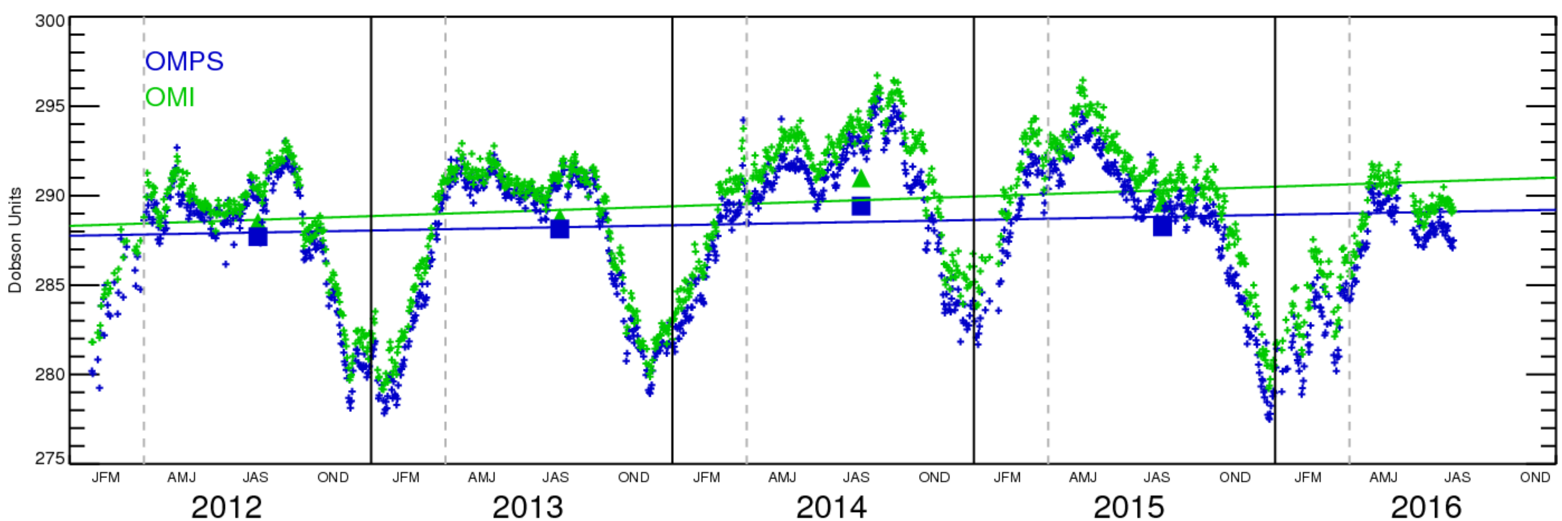
(Average total ozone from -60 to 60 degrees latitude)



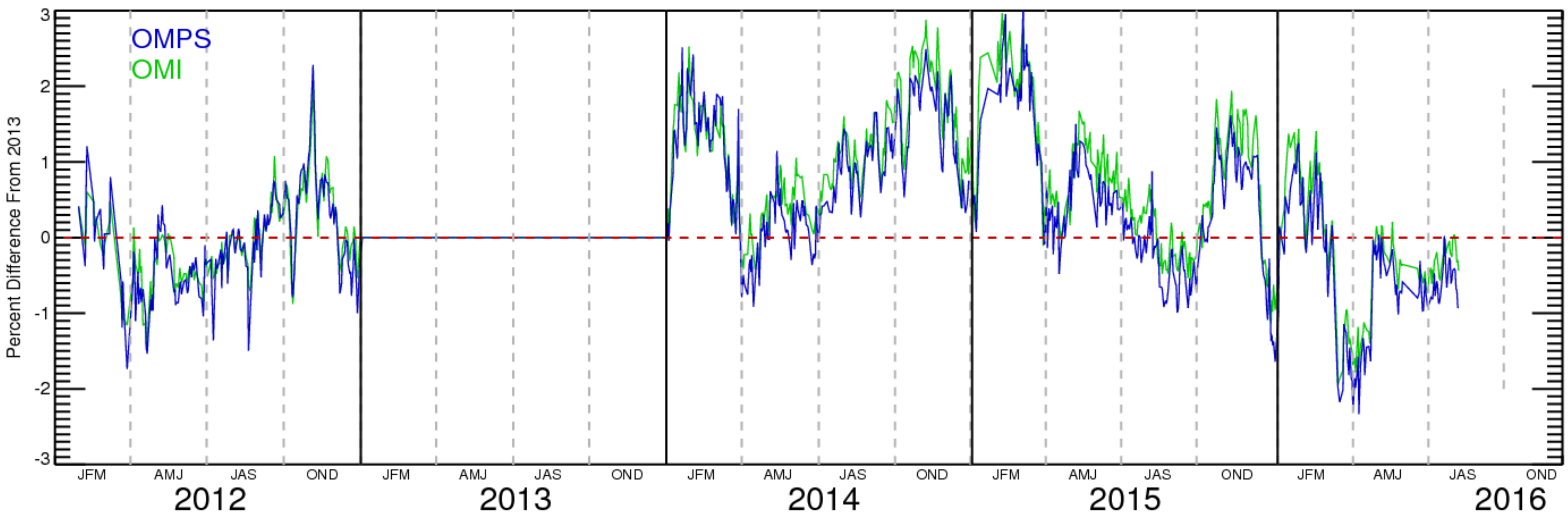


Comparisons of OMPS/OMI total ozone





Comparisons of OMPS/OMI total ozone to 2013



Summary

- OMPS nadir sensors met pre-launch specifications (for the most part)
  - NM outside spec for the shortest wavelengths (< 310 nm)
  - Correction for stray light now applied for both NM and NP sensors
- OMPS nadir sensors performing well post-launch
  - Wavelengths shifts understood, now corrected for
  - Sensor performance is linear over the entire signal range
  - Issues in dichroic "transition region" due to "unphysical" behavior of calibration coefficients, now minimized using coefficients corrected by assuming smooth behavior with wavelength
  - Dark current is changing as expected
    - Correction currently applied weekly, will move to daily correction
- Both NM and NP sensors stable, with little to no long-term change

OMPS SDR Validation via Forward Simulations

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Fuzhong Weng
Satellite Meteorology and Climatology Division (SMCD)
NOAA/NESDIS/Center for Satellite Applications and Research (STAR)

Outline

- Current issues in UV RT simulations
- Factors affecting the RT simulation
- OMPS simulation vs observations
- Summary and conclusions

Current RT Models for UV Simulations

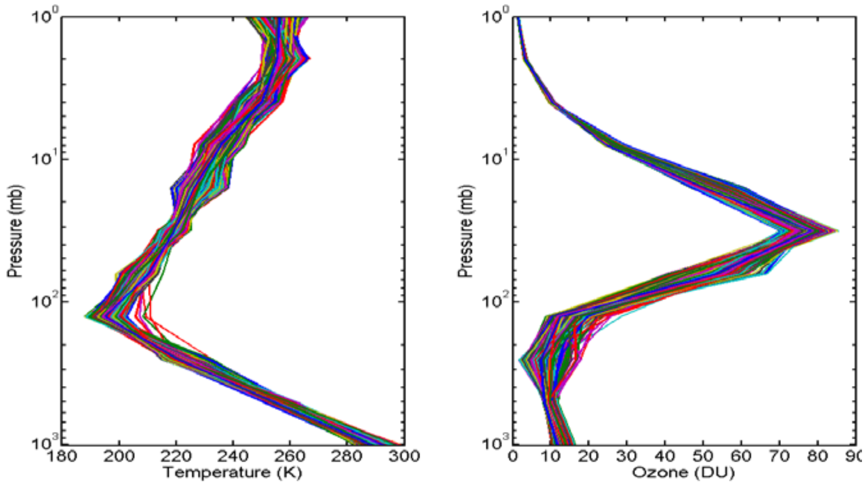
- **TOMRAD**: TOMS RADiative transfer model. The latest version: 2.24
  - Clear-sky, Rayleigh scattering and gases absorption (mainly Ozone) in UV band
- **UNL-VRTM**: UNified Linearized Vector Radiative Transfer Model *(Wang et al, 2014)*.
  - It is an integrated vector radiative transfer model. The core model is VLIDORT *(Spurr, 2008).* The latest version : 2.7
  - Including most of significant RT processes in atmosphere
- **SCIATRAN: (***Rozanov et al., 2014)*
  - An integrated model and the latest version: 3.6.9
  - Both Vector and Scalar model
  - Including all of significant RT processes in atmosphere and ocean
  - The Rotational Raman Scattering (RRS)

Data Used in RT Model

Collocated OMPS/MLS data generated at STAR using NASA algorithm

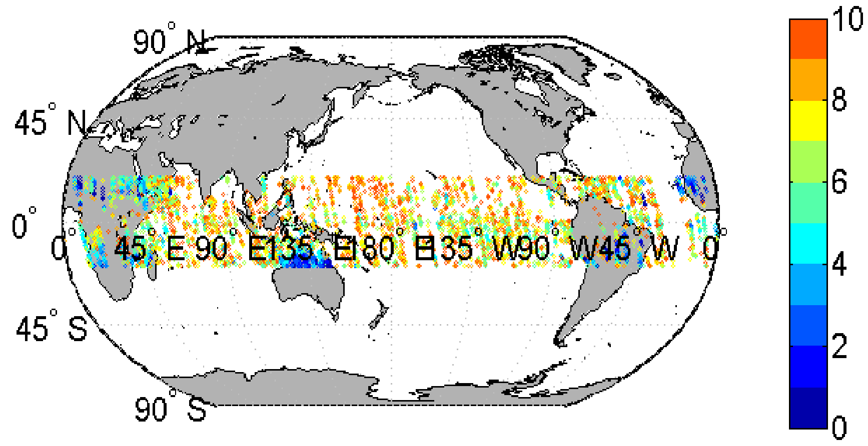
- OMPS wavelengths, solar and satellite viewing geometry, and surface albedo.
- MLS Ozone profiles
- Climatological temperature profiles

The number of profiles: 4478



Co-located OMPS/MLS Ozone Profiles (right) and Temperature (left)

Latitude: -20 to 20 degrees

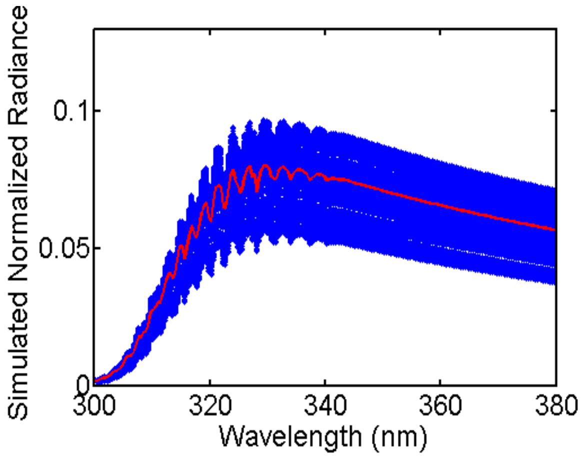


Surface Reflectivity at 331 nm

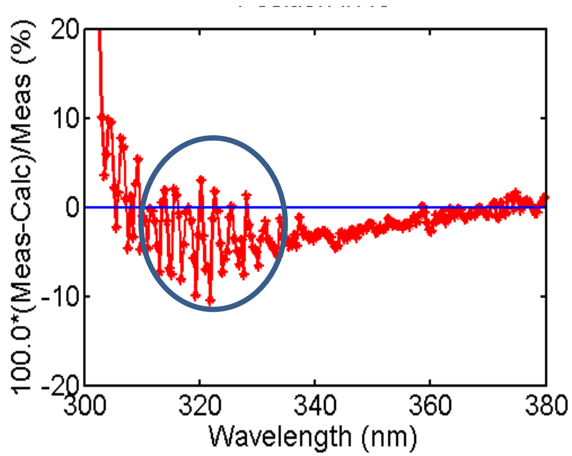
Current Issues in TOMRAD Simulations

Simulated Normalized Radiance at OMPS cross-track Position 19

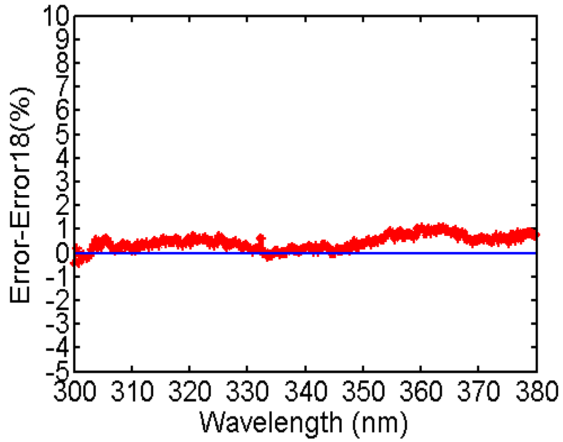
Simulated Normalized Radiance



Observation - Simulation (Obs-Sim)



$(Obs\text{-}Sim)_{19}$ - $(Obs\text{-}Sim)_{18}$

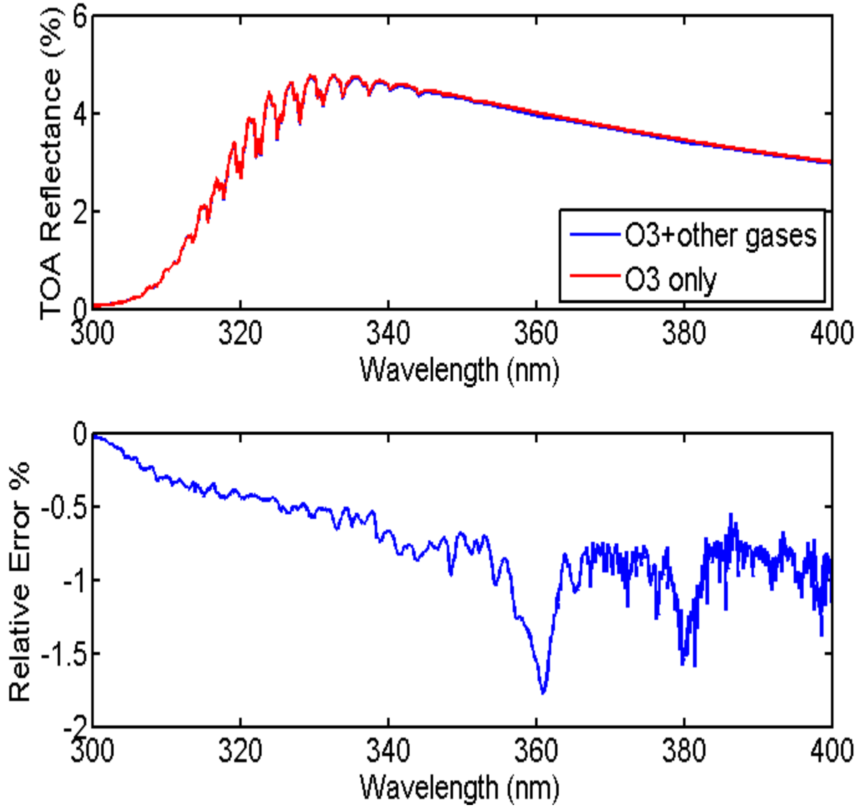


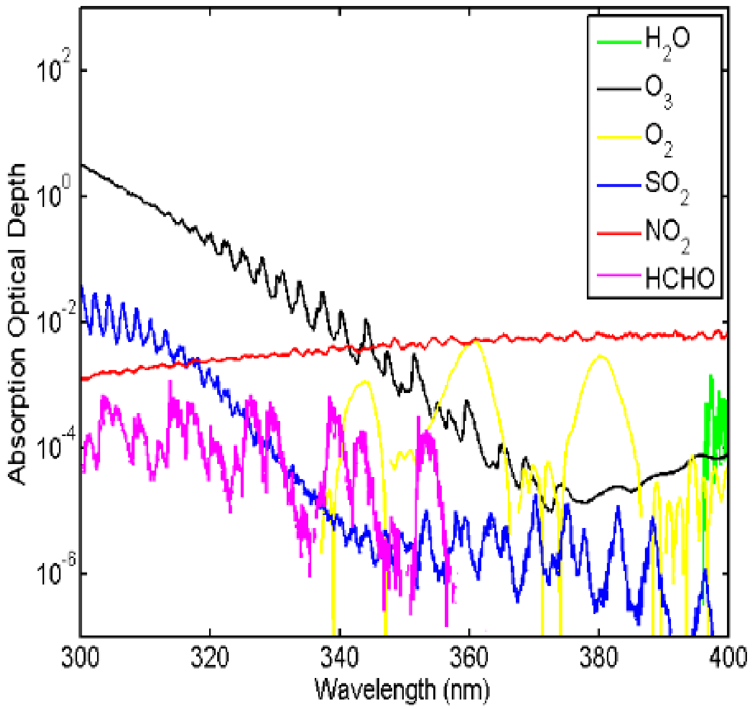
- Normalized Radiance (NR= radiance divided by solar flux)
- The simulated OMPS NR for position 19 (left); the averaged percentage difference (middle); the difference between position 19 and 18 (right).
- Large deviations between simulations and observations for wavelengths less than 340 nm.
- The large oscillation is not noise but physical effect not accounted for very well in the RT simulation.

Factors Influencing RT simulation in UV Region

- Absorption gases: Ozone and other absorption gases
- Surface reflectance
- Rayleigh scattering
- Rotational Raman Scattering

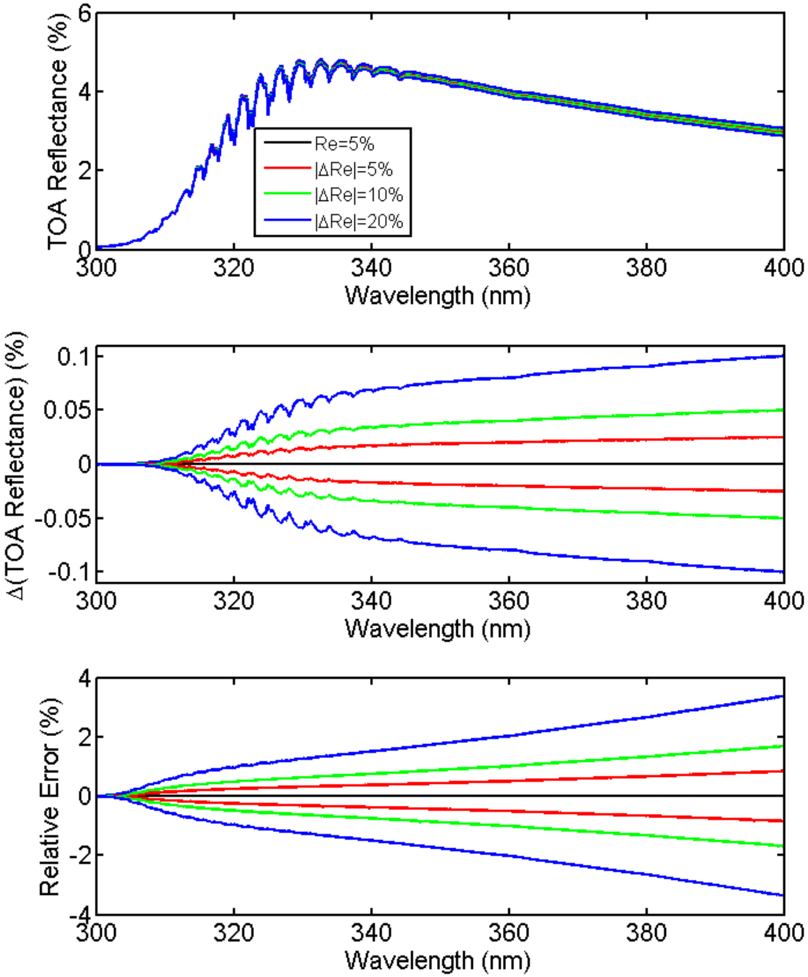
Simulations Including More Gaseous Components



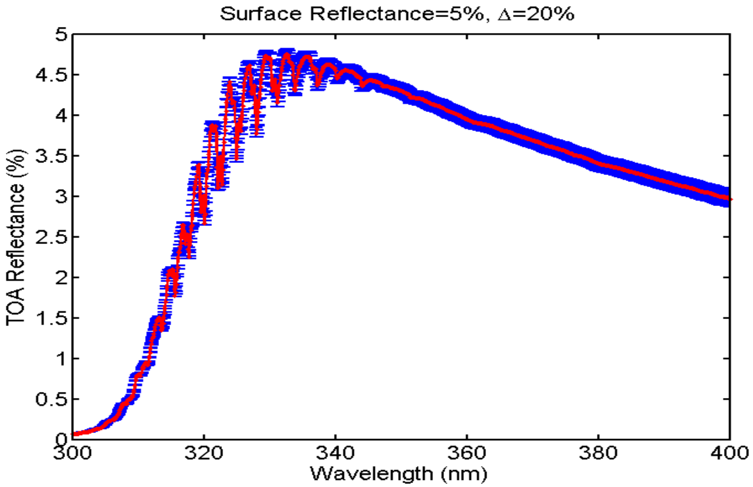


- In TOMRAD simulation, only ozone considered
- Two simulations, one is only ozone and the other more absorption gases are considered.
- **If only ozone is considered, the TOA reflected radiance can be overestimated** by up to 2% for wavelengths larger than 340 nm

Effects of Surface Reflectance



Error Bar for ΔRe=0.20



- Surface reflectance fixed to be 0.05 for all wavelengths
- A disturbance, 5%, 10%, and 20%, to the surface reflectance.
- The errors increase with increasing of wavelengths.
- In TOMRAD simulation, the OMPS surface reflectance at 331 nm is used for all wavelengths. **This assumption may cause significant errors to the TOA reflectance.**

Current Issues in TOMRAD Simulation

- In TOMRAD model, only Ozone absorption considered, and the Ozone absorption cross section data (from Bass and Paur (1985)) only covers a wavelength range from 241 nm to 342 nm.

- Fixed surface reflectance for all wavelengths

- Pre-calculated LUTs for Rayleigh scattering coefficient suggested by Bates (1984).

- Considering no Raman scattering

Our solutions

- Using UNL-VRTM model

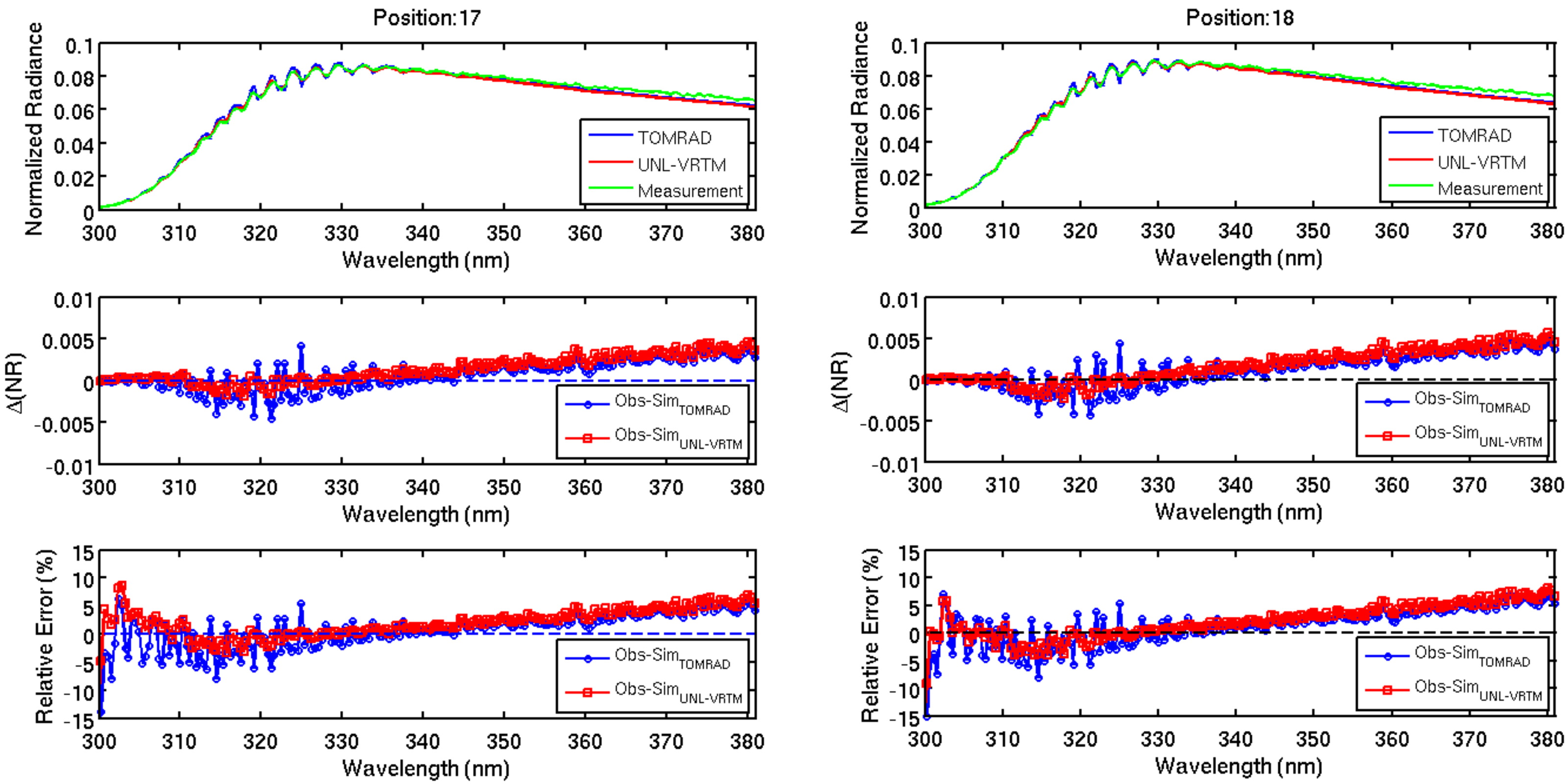
- Considering more absorption gases in UV band such as Ozone, NO2, SO2 etc. The Ozone absorption cross section data is from SAO (Smithsonian Astrophysical Observatory) and other gases absorption cross section is from the latest HITRAN2012 database.

- Rayleigh scattering optical depth and depolarization ratio are calculated accurately from a set of equations recommended by Bodhaine et al. (1999).

- Adjusting the surface albedo

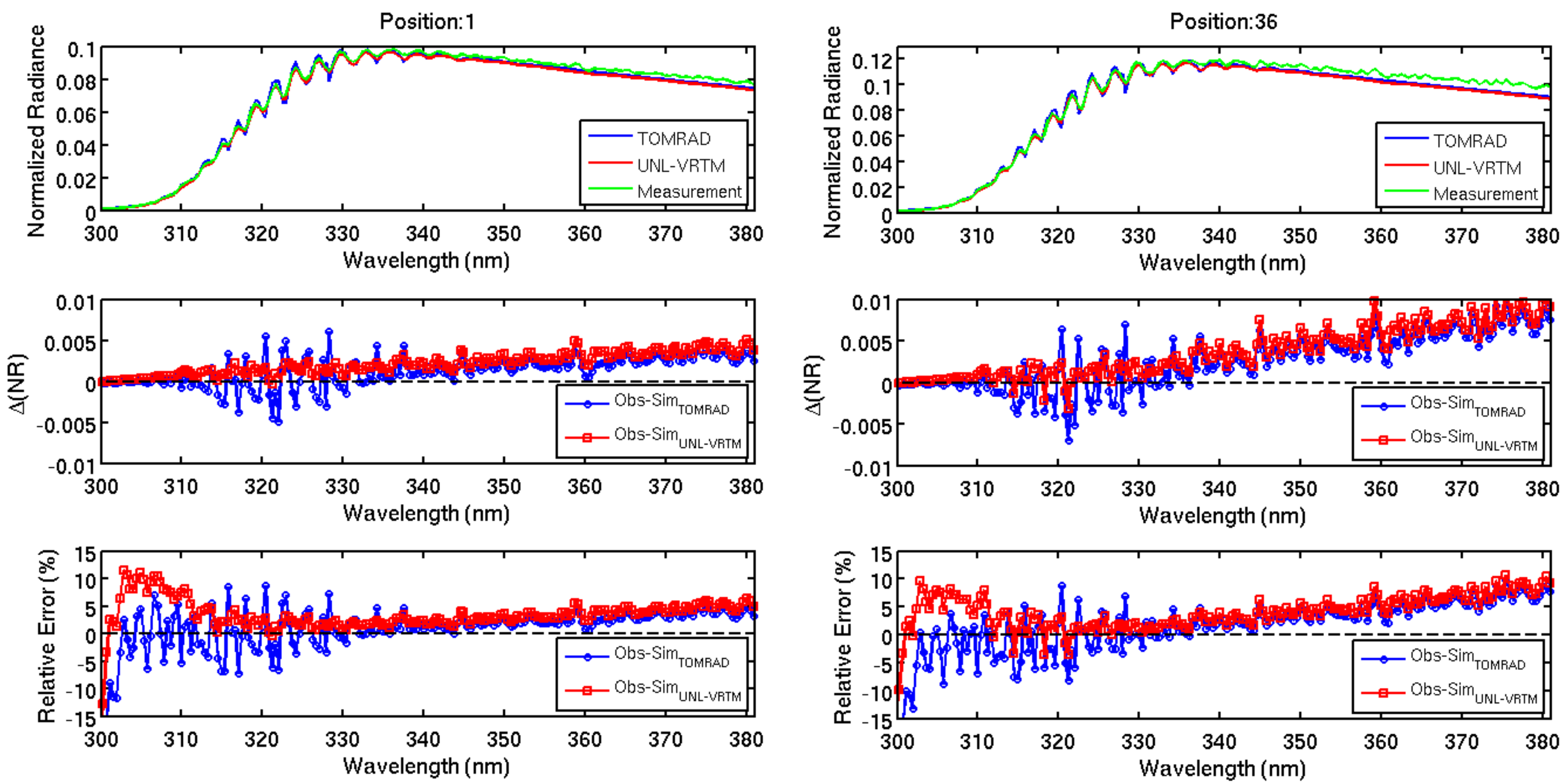
- Using SCIATRAN model to calculate the effect of rotational raman scattering (RRS)

Simulations vs. Measurements
Averaged for all Profiles at near Center Positions



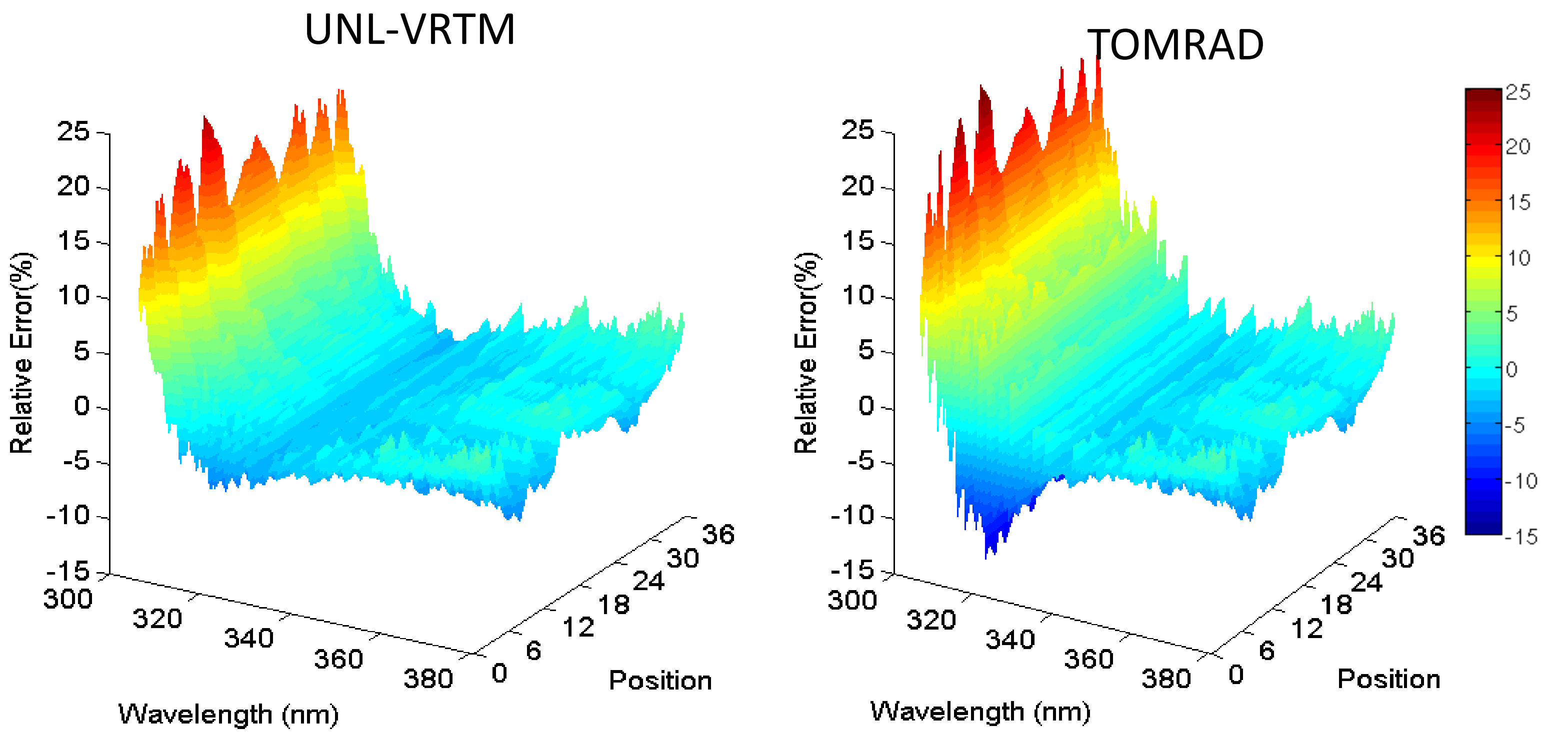
- Averaged simulation and measurement at two near center cross-track positions, 17 and 18
- Using the UNL-VRTM model, the large deviations at near center cross-track positions can be reduced

Simulations vs. Measurements
Averaged for all Profiles at Wing Positions



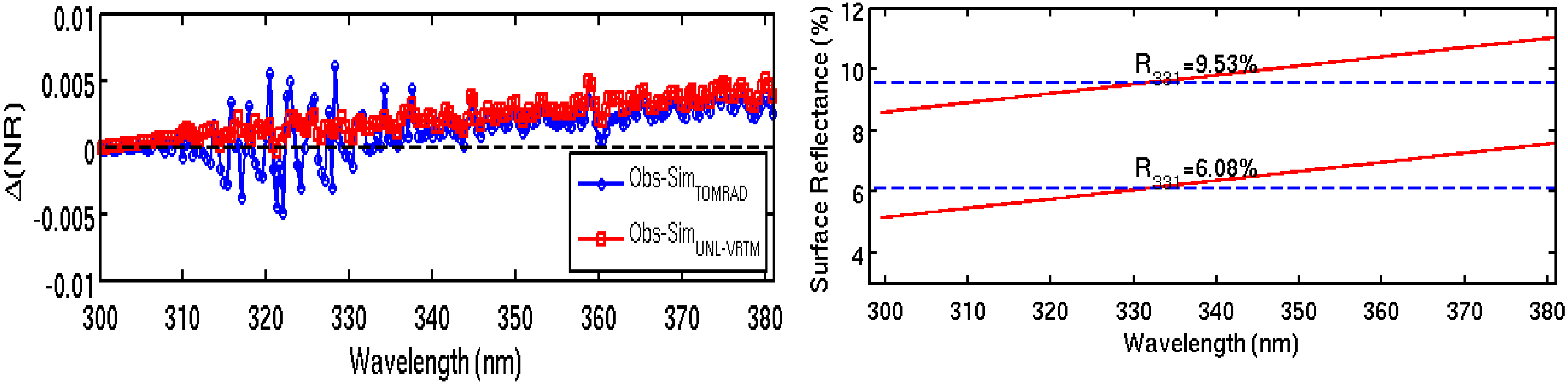
- Similar to the last slide, but for two wing positions of OMPS, 1 and 36
- Using the UNL-VRTM model, the large deviations at two wing positions can be reduced

Simulation vs. Measurement



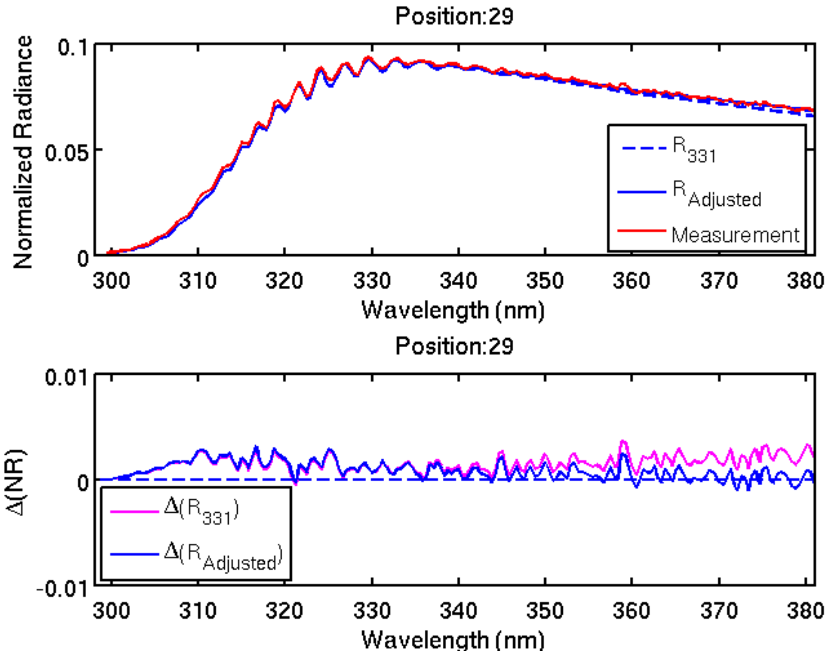
- The surface plot of percentage difference between simulation and measurement for all 36 cross-track positions at different wavelengths.
- Using the UNL-VRTM, with consider of more absorption gases, together with an accurate method to calculate Rayleigh scattering, The large deviations can be significantly reduced for all 36 cross-track positions at wavelengths of 310-340 nm

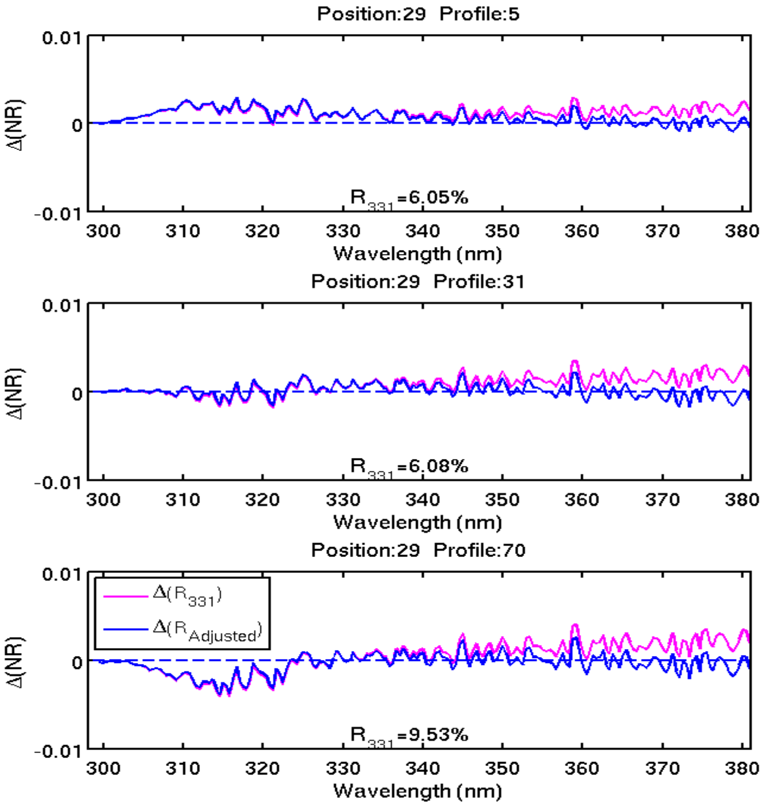
Adjusting the Surface Reflectance



- There is always a positive slope for the curve of NR difference between simulation and measurement.
- Based on the limited surface reflectance dataset, ASTER from NASA JPL, the reflectance increases with the increase of wavelength in UV band.
- In the simulation, the surface reflectance at 331 nm was used for all wavelengths.
- This may underestimate the reflectance for wavelength larger than 331 nm and overestimate it for wavelengths smaller than 331 nm.
- We adjusted the surface reflectance slightly based on the reflectance at 331 nm and suppose there is a positive slope of 0.0003.

Measurement vs. Simulations (Adjusted Surface Reflectance)

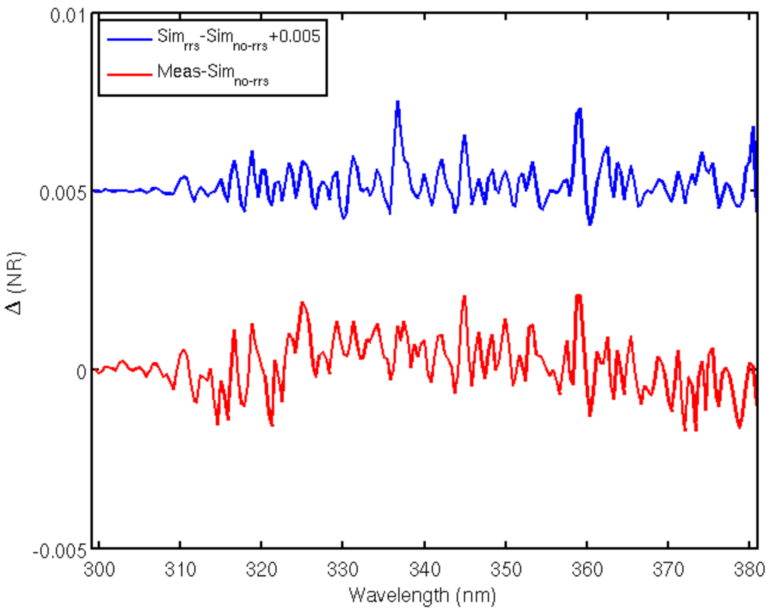


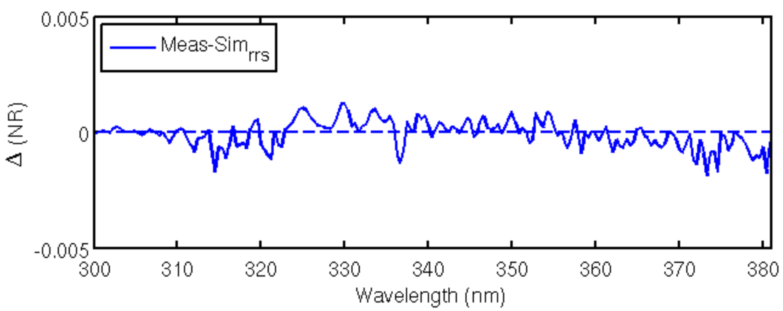


- The comparisons between OMPS measurements and simulation by using adjusted surface reflectance.
- The curve of difference between simulation and measurement becomes more horizontal (blue curve) for both individual profile (right) and average for all profiles (left).
- **There still have some small fluctuations. Carsed by raman scattering?**

The Effect of Raman Scatting

Position: 29 Profile: 31





- By using the SCIATRAN model, we simulated the effects of RRS. Blue curve is the difference between simulations with and without RRS considered. Red curve is the difference between measurements and simulations from UNL-VRTM.
- The peaks and valleys of two curves matched pretty well at most of the wavelengths.
- If the effect of RRS (blue) is removed from the difference between measurement and simulation (red), the difference will reduce and the curve of difference between measurement and simulation with RRS included becomes smoother.

Summary and Conclusions

- By using RTMs, we investigated the effects of different factors on TOA reflected radiance.
- The assumption that surface reflectance within UV region is a constant may cause significant errors to the TOA reflectance.
- By using UNL-VRTM, a vector RTM with consider more absorption gases and an accurate calculation of Rayleigh scattering optical depth, the large variations between measurements and simulations from TOMRAD were significantly reduced at the wavelengths 310-340 nm.
- By using SCIATRAN, a RTM with consider of RRS, the difference between measurements and simulations can be reduced greatly. If the effect of RRS removed, the curve of measurement-simulation difference can be smoothed to some extent, not completely but promising for most of the wavelengths larger than 310 nm.

Thank you!

2016 STAR JPSS Annual Science Team Meeting

Summary of JPSS-1/OMPS LEO&A Activities

T.J. Kelly, G.R. Jaross

2016-August-9

Some SNPP & J1 OMPS Comparisons

- Same instrument flight hardware design
  - No Limb Profiler (LP) on J1
  - Different diffusers:
    - SNPP: Aluminum
    - J1: QVD (diffuser features are much less)

    } **Compare on-orbit performance**
  - Bus rate upgrade
    - SNPP: 196.6 kb/s (shared among NM, NP & LP)
    - J1: 409.6 kb/s

    } **~2X increase**
  - Flight S/W
    - SNPP uses FSW v3.6
    - J1 uses FSW v6.0
      - Major instrument performance upgrades
        - » data compression: throughput upgrade . . . . **> ~2X increase**
        - » reduced-frame EV Timing Pattern: . . . . **optimizes efficiency**
      - **Effective, estimated data throughput = 800+ kb/s** . . . . **> ~4X overall increase**
- J1/EV_HI_RES capability to collect data at higher resolution:
  - Spatial: ~4X (from SNPP/BF=20 to J1/BF=5)
  - Temporal: ~6X (from SNPP/6 coadds to J1/no coadds)

J1 Mission Timeline & Opening the OMPS Door

- General Orbit Characteristics:
  - J1 *final* orbit is essentially the same as SNPP
    - J1 ~½ orbit ahead of SNPP (relative phasing)
- J1 Orbit Raising Campaign (ORC) is based upon SNPP ORC
  - SNPP ORC achieved final orbit by ~L+18
- ORC for J1:
  - First step: Get proper relative phasing of ½ orbit
    - Wait for right relative phase
      - Utilizes a ~10 km lower orbit for J1 *(safe distance from SNPP)*
      - Moves J1 relative phase ahead by ~13 s/orbit, or ~3 min/day
    - Minimizes fuel consumption
    - Range of Phasing Duration varies from ~3 to ~35 days
  - Second step: Execute J1's ORC
    - Best Case: 12 days
    - Worst Case: 24 days
- Effective range of OMPS door opening is from approximately L+38 to L+70
  - OMPS is powered on first, and opens its door last
  - Other instruments have sequences that have variable times to complete
- Reduce door open time prior to OAR & Operational Handover?

OMPS Notional Summary Timeline

Launch

Activation
(L + ~10)

Door Closed Phase

- SAA Transients: ≤ 6 Orbits/Day
- Nom. Door Closed Dark Cal Sequence: ≥ 1/Day
- Nom Door Closed LED Cal Sequence: ≥ 1/Day
- Diag Med-IT Dark (IMG/STO): Fills several orbits per day
- Nominal EV Orbits: ≥ 2/Day
- Pre-tests of NomOps CBM Activities
- Pre-tests of EV Low-Res & EV Med-Res

- Initial OMPS Table Upload L + ~10
- Nominal Flight Diffuser Wheel Mech Options Table ID 4 upload immediately prior to Door Opening
- Load CBM table with EV_MED_RES mated with Cal activities before L+90

Door Open Phase
(L + ~38 to 70)

- First High-Res EV Ozone
- Day-1 Solar Cals
- Extended SolEA Solar Cals
- Geo-Location
- EV ST & Date Rate Optimization
- Low-Res EV Science Data Collection
- Medium-Res EV Science Data Collection
- Dynamic Range & Full-Frame EV
- Solar Cals with S/C Maneuvers
- Storage Region Light Leak
- Lunar Opposition & Door Open Dark Cals

Orbit-Raising Campaign ends **(L + ~20 to ~62)**

- Operational Acceptance Review (OAR) at L + ~85
- Operational Handover at L + 90
  - NASA/JPSS → NOAA/OSPO
  - NASA/MOST → NOAA/MOT
- Time from start of Door Open Phase to OAR is ~ 52 down to 15 days

NomOps
(L + 90)

- EV_MED_RES: Default Activity (up to 15 Orbits/Day)
- Diag. Door Open Dark Cals: Default (≤ 15 Seq./Day)
- Nom. Door Closed Dark Cal Sequence: 1/Week
- LED Cal Sequence: Once every 4 Weeks
- Solar Working Cals: Once every 2 Weeks
- Solar Ref Cals: Semi-annually

Notes on *“Day-1”* Solar Cals

- No solar peeks planned during the Door Closed Phase
- *“Day-1”* Solar Cal:
  - If ORC not completed, then must wait for later Solar Cal to validate CBM timing
  - May need to work around the Orbit Raising Campaign
    - Similar to Inclination Adjustment Maneuver on SNPP & Solar Ref Cals in August of 2014
- Follow-up Solar Cals every 2 weeks, as occur on SNPP
  - TBD: Whether to use the 1-orbit or the 3-orbit Solar Cals?
  - 3-orbit = better SolEA coverage: ~16 images per Diff.Pos. covers most of Gon. SolEA
  - 1-orbit = fewer mech movements: 3 image per Diff.Pos.

Example of Consecutive Sequence of Initial Solar Cals			
Sequence begins between Orbits-of-the-Day 5 through 10, so nightside Door Closed Dark Cals are collected outside of the SAA			
Relative Orbit Number	**CBM Activity**	**Nightside Activity**	**Notes**
1, 2 & 3	**3orb_EV_WRK_SCAL**	**Door Closed & Open Dark Cals**	**~16 images/DiffPos**
4	**EV_WRK_SCAL**	**Door Closed Dark Cals**	**3 images/DiffPos**
5	**EV_ExtSCAL4_TC**	**Door Open Dark Cals**	**Extended SolEA=[-15°,15°] @ Diff.Pos. #4**
6	**EV_ExtSCAL_NP**	**Door Open Dark Cals**	**Same Extended SolEA Range**

Solar Cals with Spacecraft Yaw Mnvrs

- Desire is to measure Solar Cals at the angles used in the lab
  - Speak in terms of Solar Azimuth Angles instead of Solar Beta Angles
  - The 2 are very close during Solar Cals, where Solar Elevation Angle (SolEA) = ~0°
    - *SolarAz – SolarBeta = ~0.3°*
    - Need to check difference for J1 at SolEA = 0°
- Utilize 3-orbit Solar Cals with Working Diffuser
  - Covers most of Goniometric Solar Elevation Angles
- Exact *Reference Solar Azimuth Angle* is TBD
- Question: Collect 3-orbit Solar Cals with Reference Diffuser too? (at Ref.Azimuth Angle)

Example of Sequence of Solar Cals using Spacecraft Yaw Maneuvers

This sequence is very similar to the 5th Solar Reference Calibrations collected on SNPP/OMPS on 2014-March-4 that used a S/C Yaw Mnvr to the *Reference Azimuth Angle*

Relative Orbit Number	CBM Activity	Desired Goniometric Solar Azimuth Angle	Notes
1 – 3	3orb_EV_WRK_SCAL	Reference Az. Angle	Door Closed Dark Cals will occur 3 times here, and span a difference of 6 orbits from the 1st to the last, so at least 1 of the Door Closed Dark Cals will fall outside the SAA.
4 – 6	3orb_EV_WRK_SCAL	Min Gon. Az. Angle (12°)	
7 -9	3orb_EV_WRK_SCAL	Max Gon. Az. Angle (32°)	
10- 12	3orb_EV_REF_SCAL	Reference Az. Angle	May or may NOT be incluled

Notional Mission Timeline: Dark and LED Cals

Activity	Door Closed Phase	Door Open Phase (Early)	Door Open Phase (Later)
Door open Dark Cal	Frequent	Very frequently	Nearly every orbit
Door Closed Dark Cal	Daily	Transitioning	Once a week
LED Cal (Door Closed)	Daily	Transitioning	Once every 4 weeks
Note: Above Door Closed Dark and LED Cals follow EV Hi-Res data collection on the dayside			

Special EV CBM Activity Summary

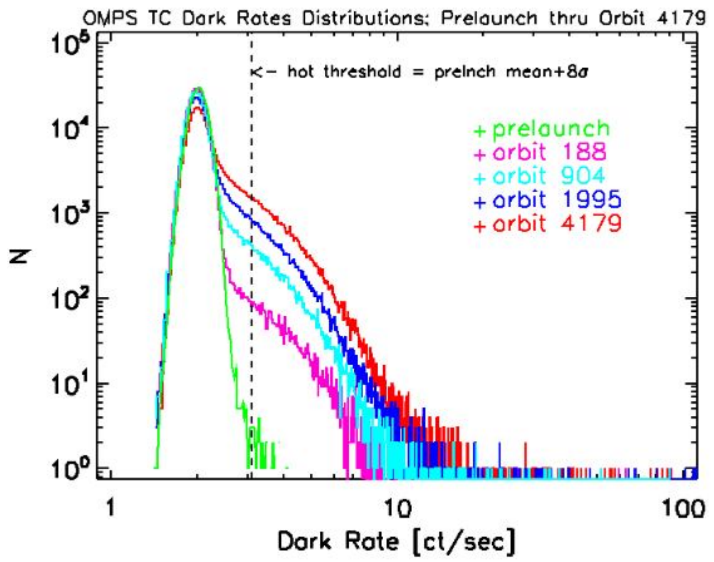
CBM Activity (PLT Tasks)	Coverage	Targets: Regions & Data
EV_GeoLoc (PLT-4 & 5)	Run for several days	Geo-Location: Cloud-free land Dynamic Range: Bright, cloudy scenes, usually over oceans & seas
EV_CoLoc	Run over land masses	Correlate NP EV imagery relative to NTC/NM EV imagery
EV_FF_TC	Run for entire day Weekly collection	To observe any spectral shifts through the orbits Monitor and λ shifts with orbital or seasonal dependence.
EV_FF_NP	Run for entire day Weekly collection	To observe any spectral shifts through the orbits Monitor and λ shifts with orbital or seasonal dependence.
EV_PRNU_NORTH **EV_PRNU_SOUTH**	Seasonal; run for part of the day	Pixel Response Non-Uniformity Greenland & Antarctica around Summer Solstices
EV_360	Run for entire day	Provide SolZA coverage >88° for all FOV in both Hemispheres.
EV_LOW_RES	Run for entire day	Required data collection.
EV_MED_RES	Run for entire day	Required data collection.
Note: EV_HI_RES is primary EV (Science Data) operating mode during the transition into NomOps.		

OMPS Post-Launch Tests (PLTs) & Operational Handover

- Demonstrate that the systems are ready for Operational Handover at L+90 days
  - Includes spacecraft & all instruments
  - Operational Acceptance Review (OAR) at L+85
  - Begin in Door Closed Phase:
    - OMPS Trending
    - OMPS Noise Characterization
  - Begin in Door Open Phase
    - OMPS Calibration
    - OMPS Geolocation/ Pointing Accuracy
    - OMPS Dynamic Range
    - OMPS Data Rate Characterization

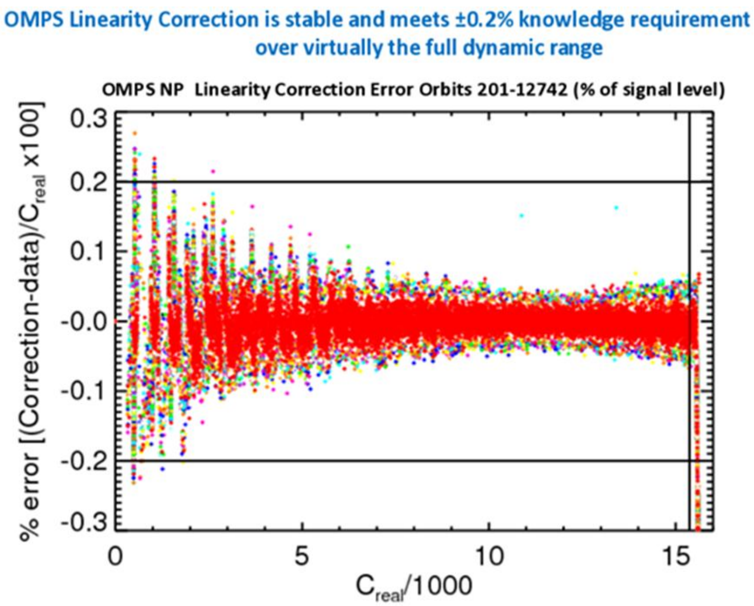
- Not an evaluation if systems meet requirements

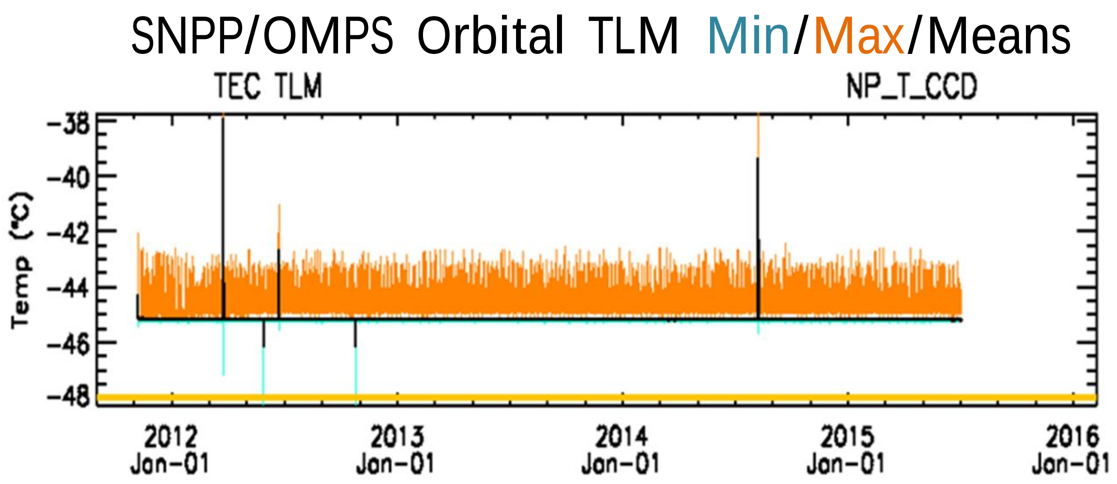
J1/OMPS Trending PLT



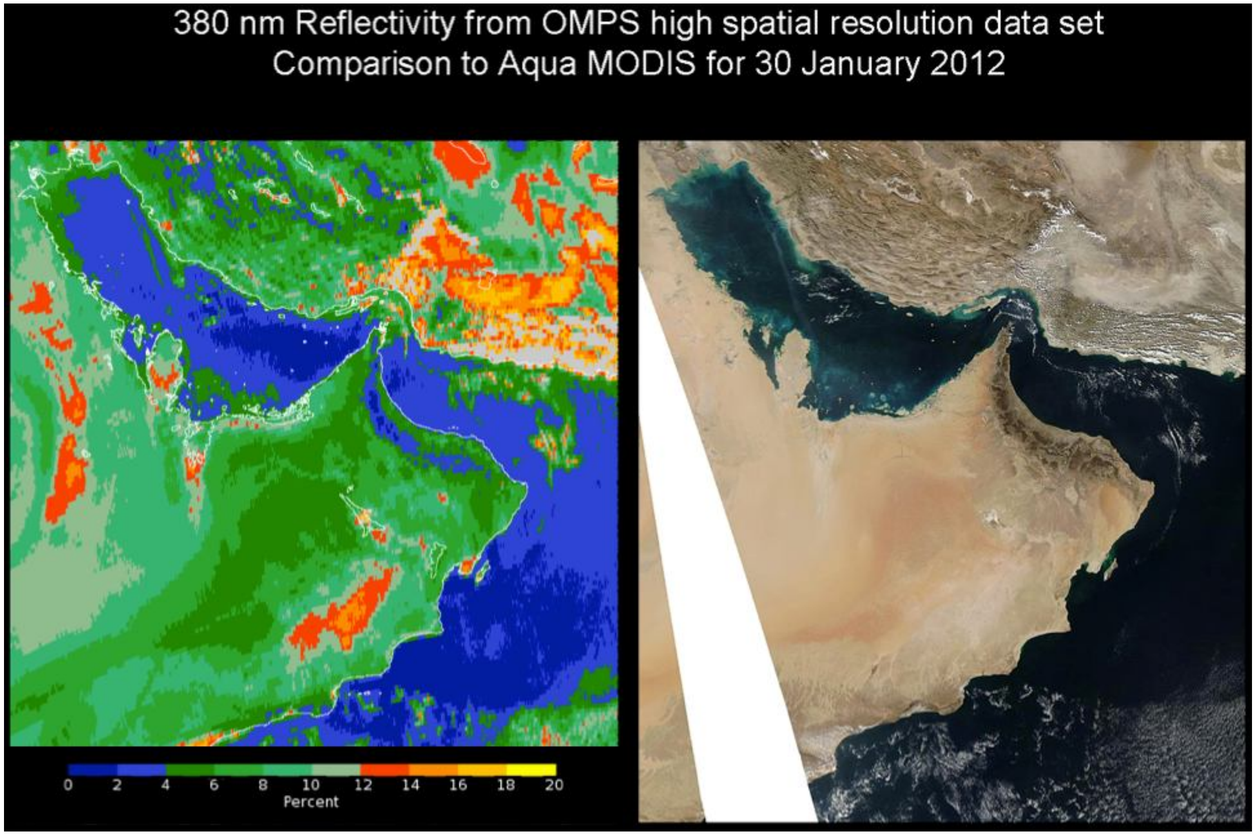
S-NPP/OMPS Examples of

- TC Dark Cal distributions,
- NP LED Linearity Cals performance, &
- instrument TLM Min/Max/Mean trending





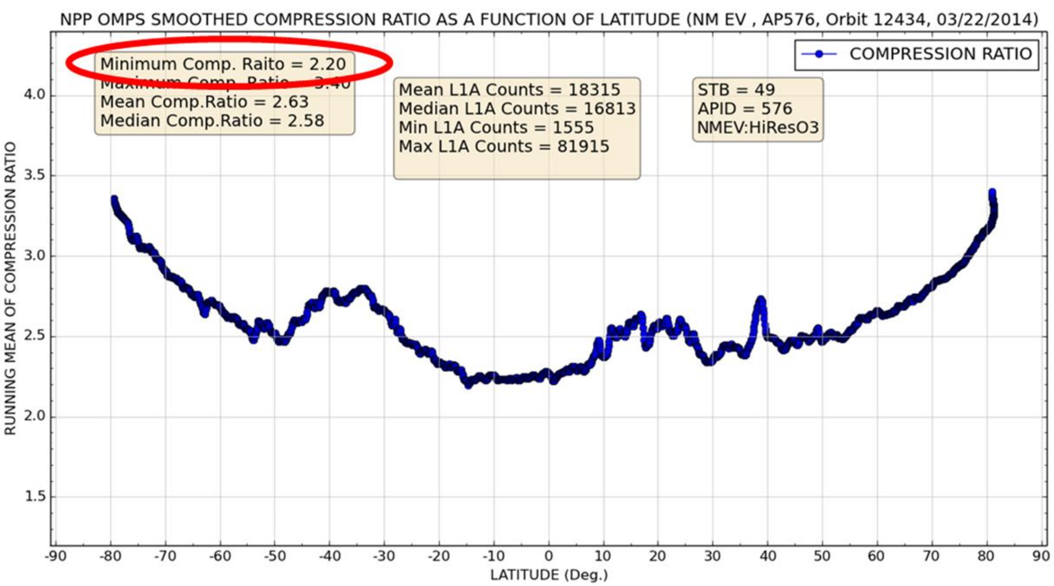
Example of J1/OMPS Geolocation



Geo-location Results of S-NPP/OMPS and MODIS images

- Figure shows S-NPP/OMPS geo-location results (left) and MODIS (right) images
- MODIS image shows clear water/land boundaries (plus some clouds, silt in the water, etc.)
- IDL s/w tools provide an outline of land edges (white)
- Agreement between expected land-edges locations and S-NPP/OMPS reflectivity is accurate to near the highest resolution (BinFactor = 1), well within the goals for this PLT.

J1/OMPS Data Rate Characterization PLT



An Example
of Data Compression
from S-NPP/OMPS
EV_HiResO3 Measurements

- Typical minimum compression found empirically ≈ 2.2X
  - EV_HiRes_O3 ST are sparse
- BATC assumed ~2X compression factor
  - Excludes BinFactor = 2 for aerosol λ's (~892 additional macro-pixels)
- Data Compression Fault halts current data stream.
  - Nightside activities will start nominally.
  - If a fault occurs, then, generally, it may be best to return to EV collection using the *baseline* NM EV ST, i.e., stop Secondary CSM and run Primary CSM.
  - Iterate to new version of *trial* NM EV ST and run on-orbit to test

J1/OMPS NomOps Summary @ L+90:
(Similar to SNPP/OMPS Overall)

Science Data : Default for All Orbits		
Orbits-of-the-Day	**Dayside**	**Dark Cals**
1 -14/15	**EV_MED_RES**	**Door Open**

Preliminary Calibration Schedule				Solar Ref Cals
Week 1	**Week 2**	**Week 3**	**Week 4**	**Semi-Annual**
Solar-Working		Solar-Working		Solar-Ref & Solar-Work
Door Closed Dark	Door Closed Dark	Door Closed Dark	Door Closed Dark	Door Closed Dark
	LED			

Potential Remaining Cal/Val Measurements:

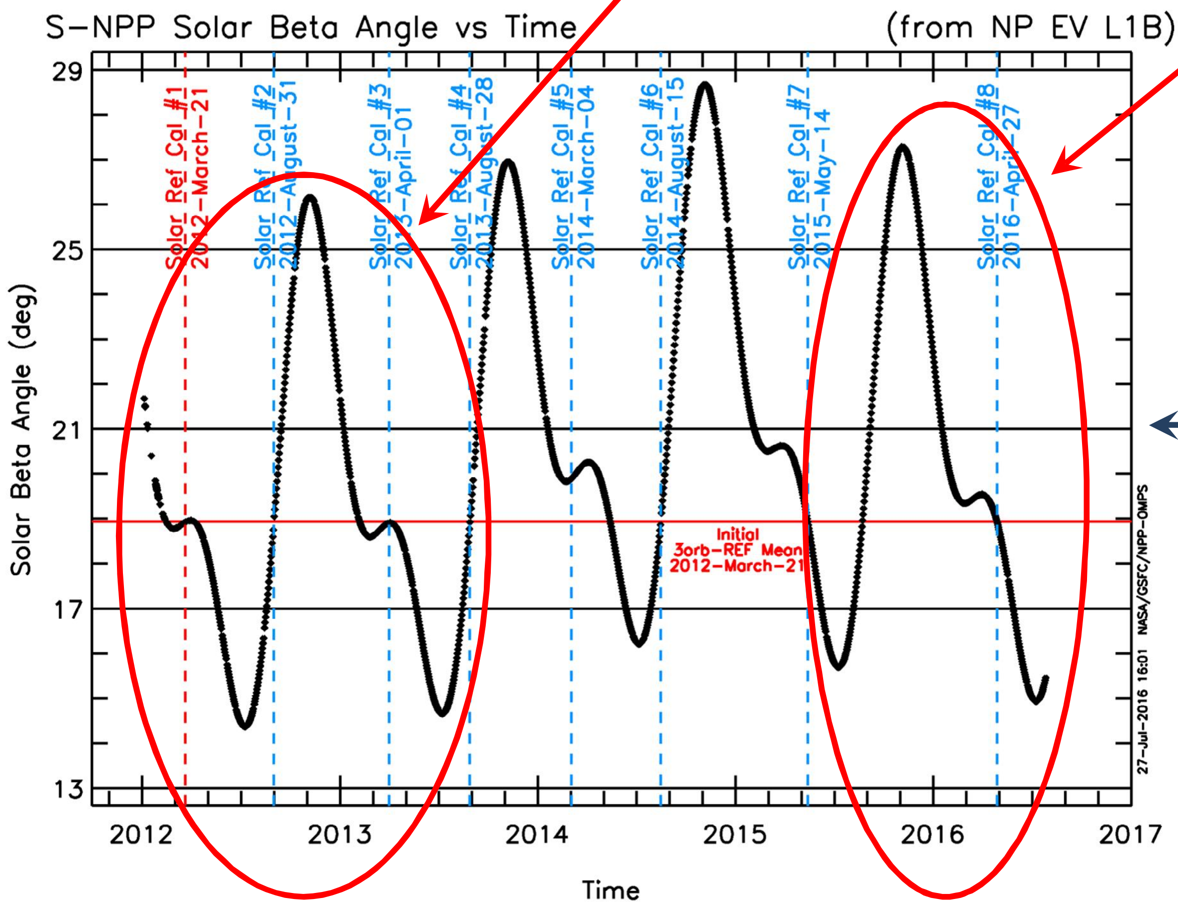
- Full-Frame EV Measurements to characterize orbital & seasonal variabilities: collected weekly/bi-weekly into 1st or 2nd year?
- EV Data Rate Optimization (seasonally dependent)
- PRNU (seasonally dependent: Solstice ±~6 weeks

Backup Slides

1. Expected range of J1 Solar Beta Angle
2. PLT Summary
3. J1/OMPS Calibration PLT Example
4. J1/OMPS Dynamic Range
5. Two Examples of J1/OMPS NomOps CBM

Expected J1 Solar Beta Angle Cycle

J1 Orbit Maintenance LTAN = 13:25 ± 1 min



Expected range of J1 Solar Beta Angle most like these 2 time periods

Goniometric Reference Azimuth Angle = 21.0° for SNPP & JPSS-1

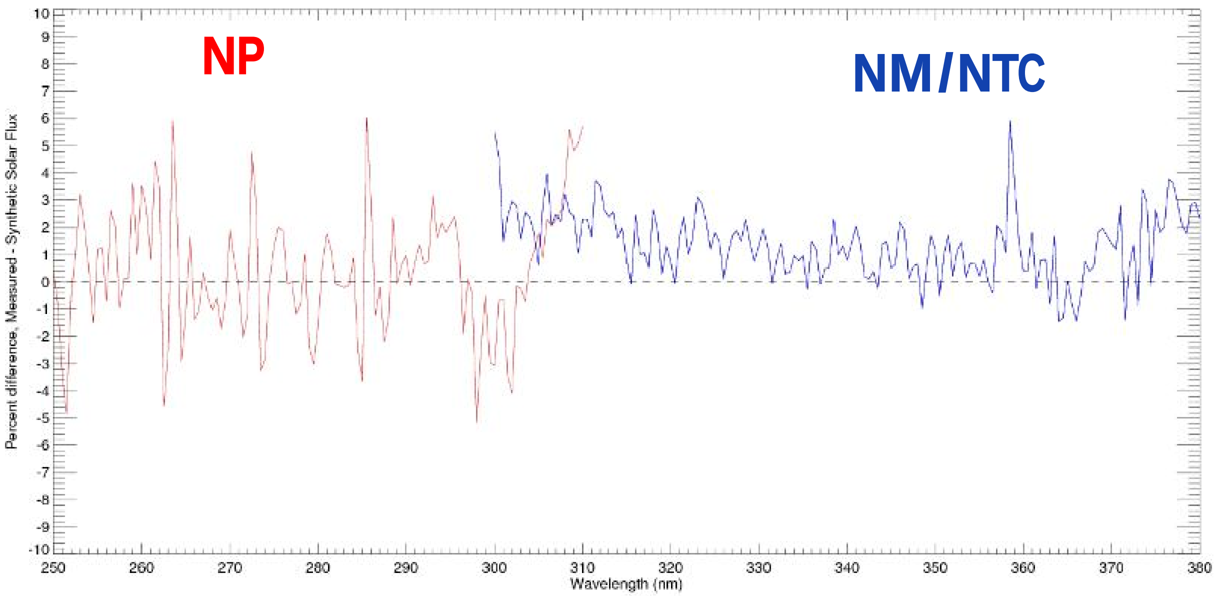
J1 Goniometric Azimuth Angle Range = [12.0, 32.0]

PLT Summary

#	PLT Name	Data	Description & Success Criteria
1	**OMPS Activation**	BATC/MOST activity	Instrument powered-on, runs functionality tests, and is approved as ready for operations
2	**OMPS Trending**	Dark & LED Cals, transient detection, TLM monitoring, etc.	1) TLM stays within its defined yellow (& red) limits, analyze data to understand why out-of-range violations occur. 2) Establish baselines & trends to characterize on-orbit behavior, including the LED and Dark Cals.
3	**OMPS Noise Characterization**	Estimate SNR from LED data	1) Measure LED signal variance in individual pixels relative to their neighbors in an attempt to estimate noise as a function of the signal level. 2) The theoretical SNR should not exceed the variance by more than 50%. Be aware of the location of the instruments relative to the SAA.
4	**OMPS Calibration**	Solar Cal & EV	1) Measured solar spectra agree with synthesized spectra to within ±5% over the full spectral range excluding 300-310 nm. Agreement at this level requires both good radiometric and wavelength calibration. The first validation will be performed with the Working Diffuser. 2) If a nearly coincident EV match-up occurs between J1 and OMI or SNPP, in both time & FOV, then can compare radiances, as has been done between SNPP & OMI.
5	**OMPS Geolocation/ Pointing Accuracy**	EV pixel radiances *match* calculated geo-locations	1) Check at various wavelengths w/BF=1: Limits & middle of image regions, VIIRS correlative λ's, etc. 2) Geographic feature mismatches should not exceed 1 ground pixel.
6	**OMPS Dynamic Range**	Max EV & Solar signals do not saturate any pixels	1) Assess EV dynamic range by observing sensor response over very bright scenes (i.e, clouds) at wavelengths of maximum signal response, & for max Solar Cal signals. 2) That at least 10% margin exists before saturation in the highest signal scenes.
7	**OMPS Data Rate Characterization**	Optimize NTC/NM EV High-Res ST	1) Test updated NM EV ST on-orbit; monitor compression margins through the ground processing. 2) Adjust NM EV ST and replace onboard table if necessary; continue iterating until ST is finalized, preserving a 10% margin & watching seasonal dependence.

J1/OMPS Calibration PLT

Comparison of Day 1 solar flux to Synthetic (KNMI) solar flux

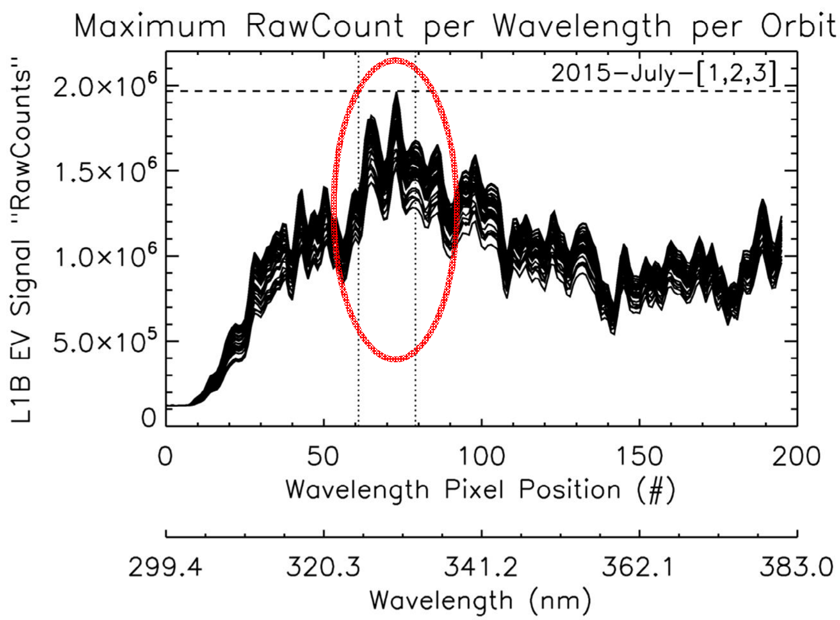


Differences of S-NPP/OMPS Day-1 Solar and Synthetic Spectra < ~6%

- Differences from both NP and NM are relatively small
  - Max differences are ~6%
  - Typical differences ~3%

J1/OMPS Dynamic Range

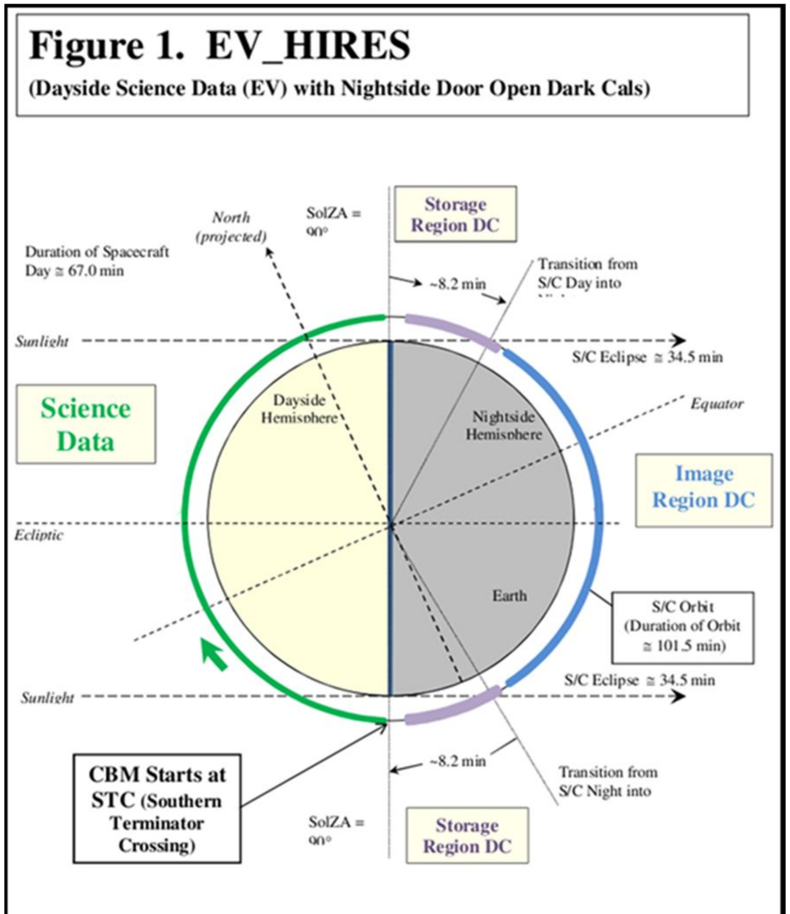
<u>SNPP/NM data review:</u>
Highest count levels across NM spectra: Approximate Wavelength-pixels:
65 ⇔ 326.4 nm
73 ⇔ 329.7 nm
(Due to higher instrument sensitivity and stronger radiances at those wavelengths.)



Peak signals in NM EV data, from S-NPP/OMPS

- Two signal peaks provide good sampling of max signal level
- Special NM EV ST uses 4 or 5 λ's to sample each peak, w/ BinFactor = 1.
  - Catches the brightest scenes without binning (i.e., averaging) from any adjacent pixels
- Plenty of room in Special ST for geo-location
  - Direct benefit from reduced-frame imaging and data compression
  - Still some room for Ozone too

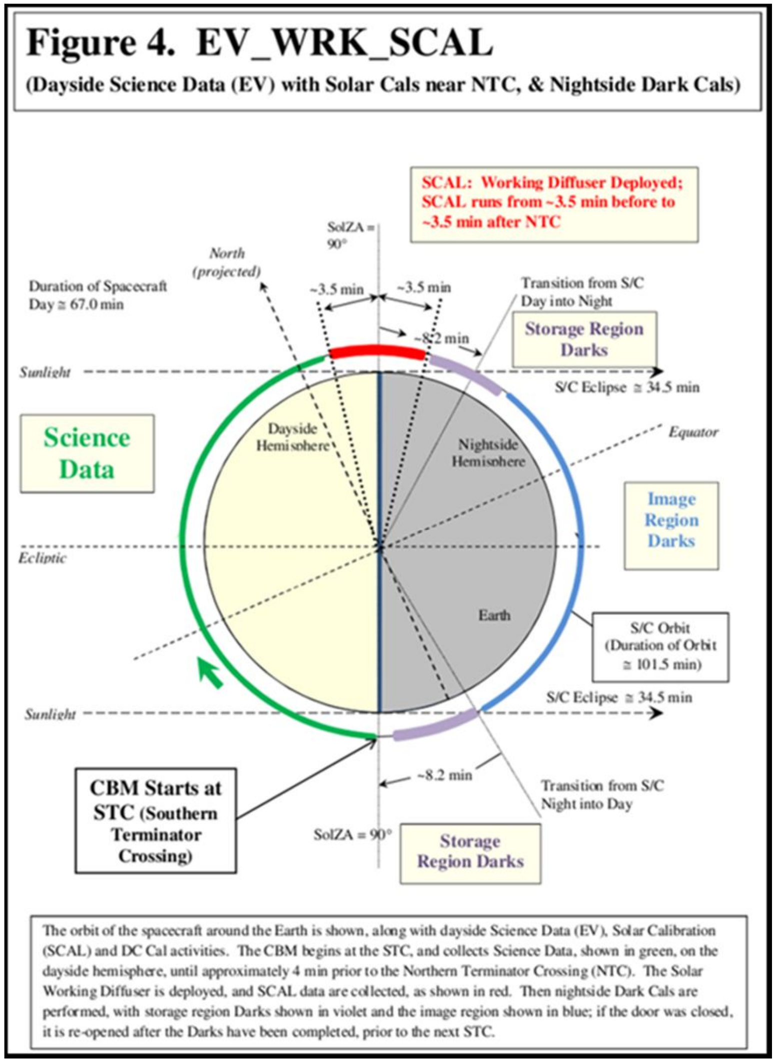
J1/OMPS NomOps: Science Data w/Dark & LED Cals



The orbit of the spacecraft around the Earth is shown, along with dayside Science Data (EV) and nightside Dark Cal (DC) activities, and with some orbital events identified. The Ascending Node of the orbit is on the dayside, so the direction of the orbit in the diagram is clockwise. The CBM begins at the STC, and collects Science Data, shown in green, on the dayside hemisphere as indicated, up to a SolZA=~88°. All Dark Cals are performed in the Nightside Hemisphere, with storage region Darks shown in violet and image region shown in blue.

- No LP on J01
- NomOps: **EV_HI_RES**
  - Default Science Data collection activity
  - Not "Extended-EV" past sub-satellite SolZA=88
    - Need to start ~75 sec prior to STC (2 EV-TPG *loops*)
    - Finish at NTC is similar
  - Open Door Dark Cals
    - Storage Region 2 sets of images in twilight
      - 5 images with IT = 30 sec
      - 5 images with IT = 10 sec
    - Image Region in S/C Night:
      - 41 images with IT = 30 sec
      - 21 images with IT = 10 sec
- Closed Door Cals:
  - Same dayside EV coverage **EV_CLOSED_DARK** is Closed Door version of above
  - **EV_CLOSED_LED:** Replace Dark w/LED Cals

J1/OMPS NomOps: Science Data w/Solar Cals



No LP instrument on JPSS-1/OMPS

NomOps:

- **3orb_EV_WRK_SCAL** or
- **EV_WRK_SCAL**
- New QVD Diffuser
  - Decreased diffuser features vs SNPP/OMPS
  - Evaluate on-orbit
- Differences are
  - EV_WRK_SCAL runs in single orbit
    - 3 Solar Measurements per 7 NM/TC Diffuser Positions
    - 9 per NP DiffPos
    - Closed Door Dark Cals
  - 3orb uses 3-orbits
    - 16 or 17 measurements per NM/TC DiffPos
    - Except 23 for TC4 and 16 for NP
    - Closed & Open Door Dark Cals
  - Similar image & Storage Dark Cals
  - Solar Cals take a bite out of EV near NTC

Integrated Cal/Val System (ICVS) for OMPS and SNPP OMPS SDR Data Reprocessing

Ding Liang, Chunhui Pan, Trevor Beck, Fuzhong Weng, Ninghai Sun

August 9, 2016

Outline

- OMPS performance monitoring at STAR ICVS
  - Calibration principle
  - Key performance parameters monitoring
    - Bias/Smear
    - Dark current/readout noise
    - Dark LUTs
    - Solar degradation monitoring
  - Instrument health and safety related parameters monitoring
  - Alerts
- STAR ICVS-beta website for S-NPP and J01
- S-NPP OMPS science SDR reprocessing

The NM/NP Calibration Principle

$$Q_{jk}^{c} = \frac{Q_{jk}^{ADC} - Q_0}{g\ m_{jk}} - Q_k^s - Q_{jk}^{dark} - Q_{jk}^{SL}$$

Q_{jk}^{ADC} : raw counts at the output of the analog-digital-converter

g : non-linearity of the electronics chain

Q_{jk}^{dark} : observed dark

Q_0 : zero input response

m_{jk} : relative pixel gain level

Q_{jk}^{SL} : stray light

Q_k^s : observed smear(contain the offset)

$$L_{jk}^{m} = \frac{Q_{jk}^{r} k_{jk}^{r}}{\tau_{jk}(t)}$$

L_{jk}^{m} : Observed earth radiance

Q_{jk}^{r} : corrected earth view counts

k_{jk}^{r} : radiance calibration coefficient

τ_{jk} : sensor response changes

$$E_{jk}^{m}(t) = \frac{Q_{jk}^{i} k_{jk}^{i}}{g_{jk}(\theta,\phi)\rho_{jk}(t)\tau_{jk}(t)}$$

E_{jk}^{m} : Observed solar irradiance

Q_{jk}^{i} : corrected solar view counts

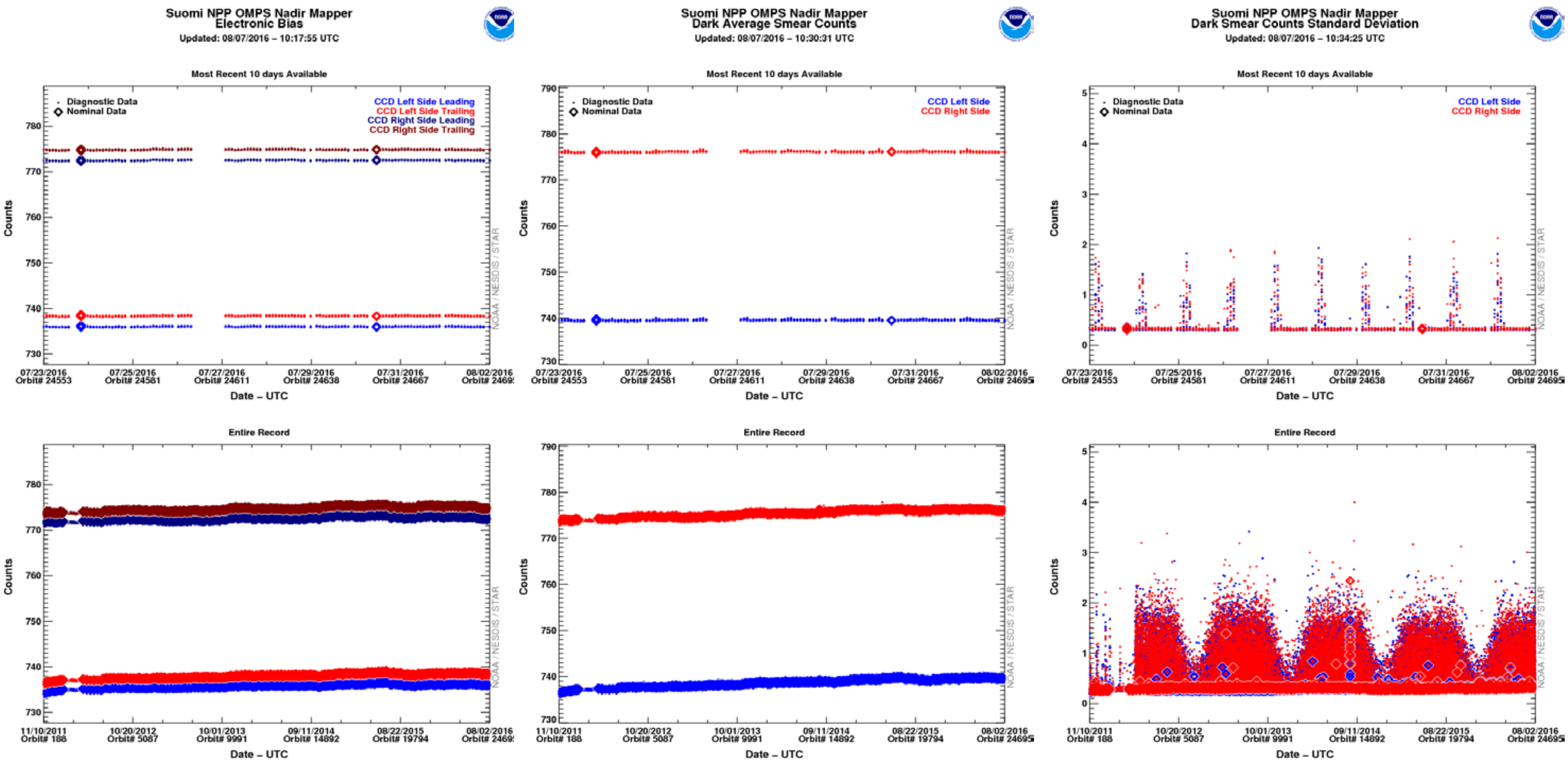
k_{jk}^{i} : irradiance calibration coefficient

g_{jk} : goniometric response

ρ_{jk} : long-term solar diffuser reflectivity changes

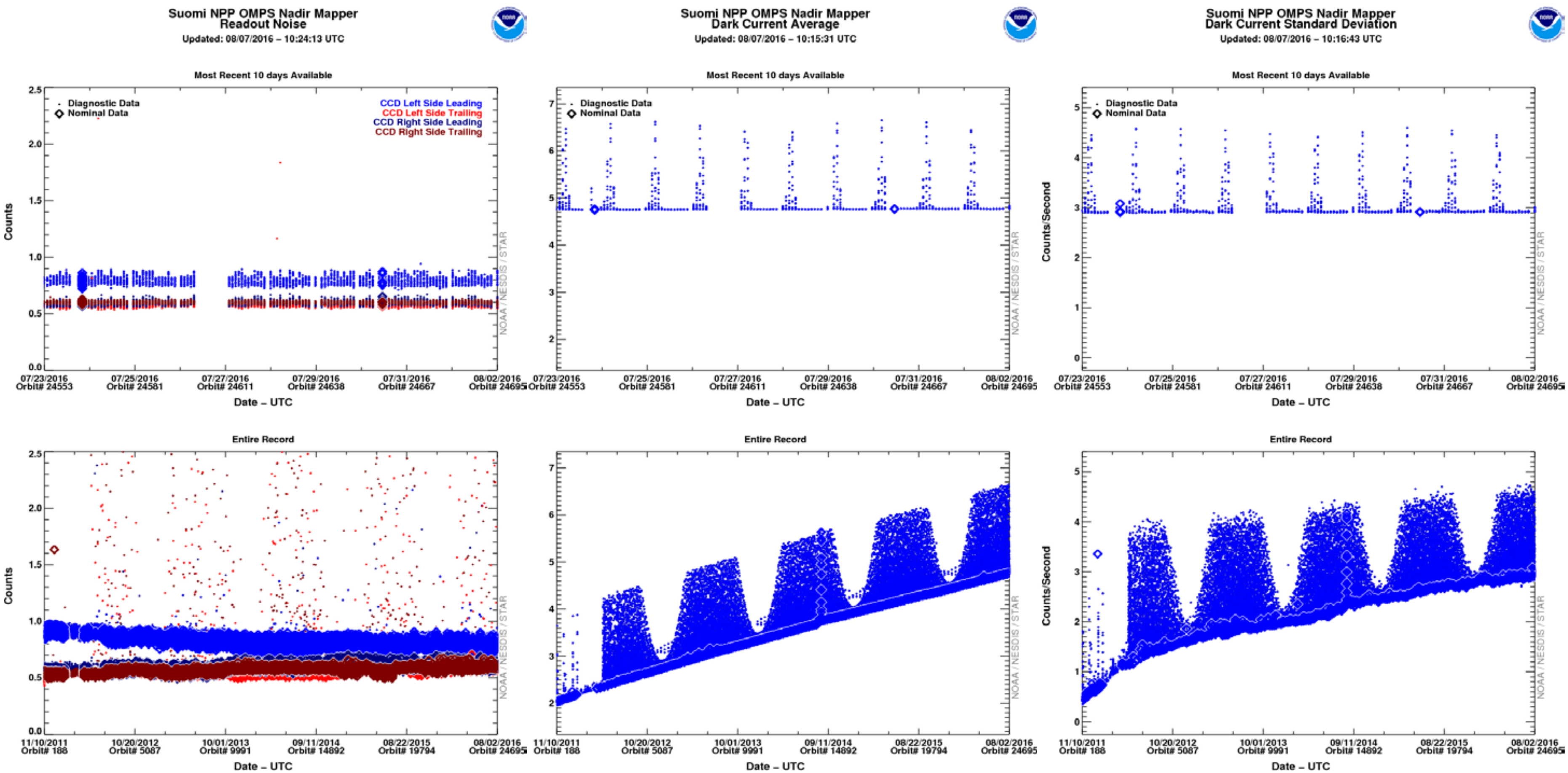
Key Performance Parameters

ICVS monitoring of electronic bias and mean value and standard deviation for smear



Key Performance Parameters

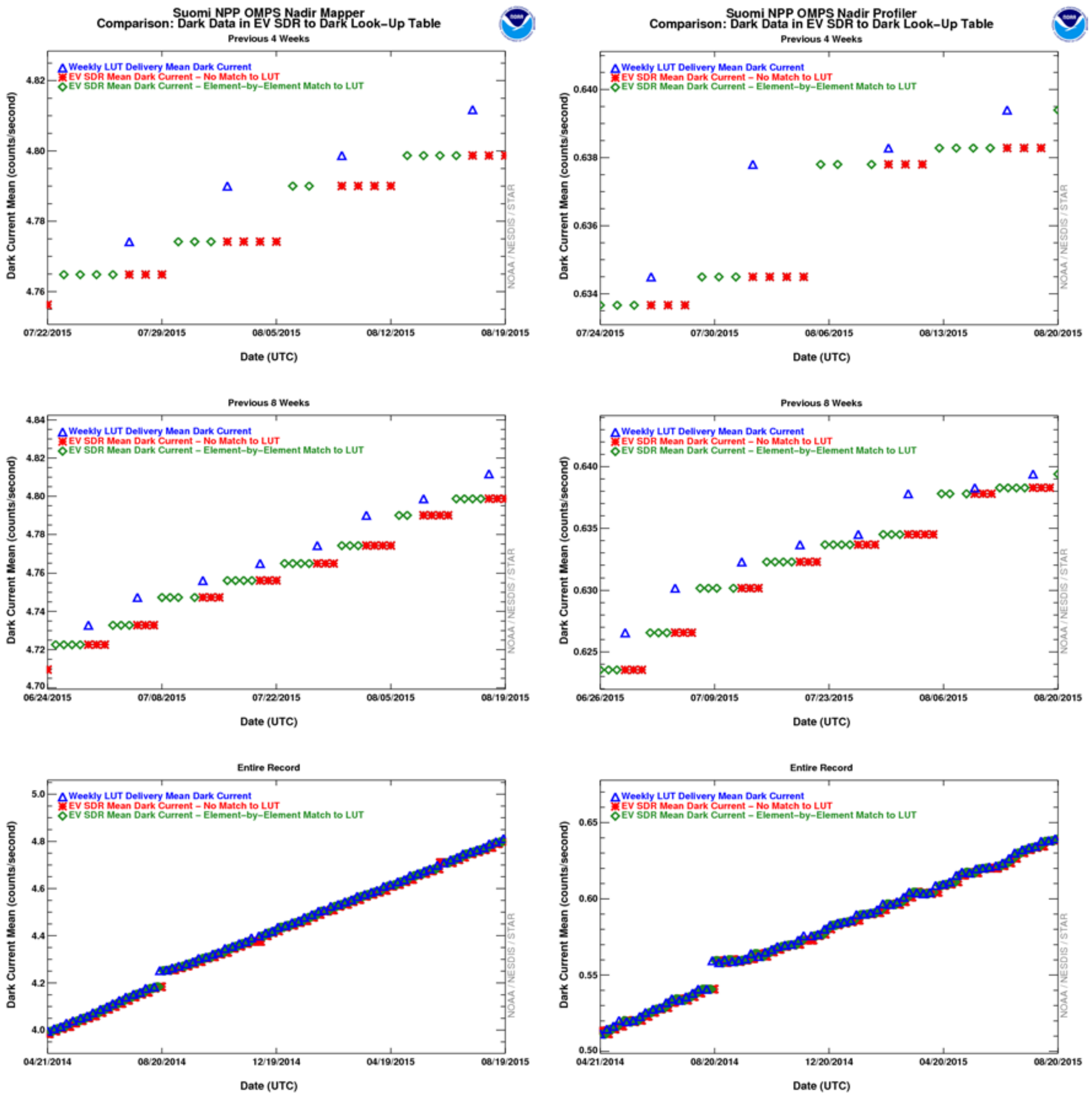
ICVS monitoring of readout noise and mean value and standard deviation for dark current



NM/NP Dark Current LUT Updates

ICVS monitoring of NM/NP dark current LUT updates:

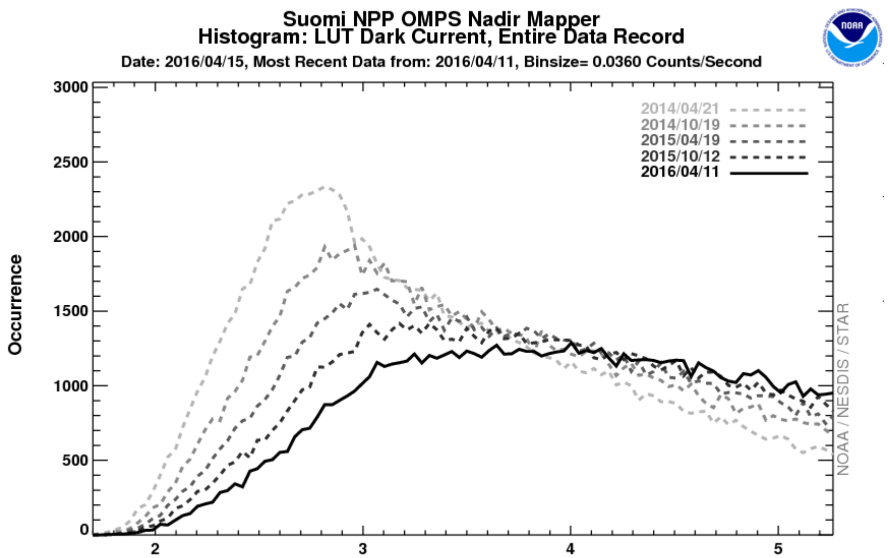
- Timely weekly updates of the dark current LUT for calibration
- Implementation of the weekly dark LUT (transition from red to green) into the Earthview SDR
- Expected steady increase of the dark current

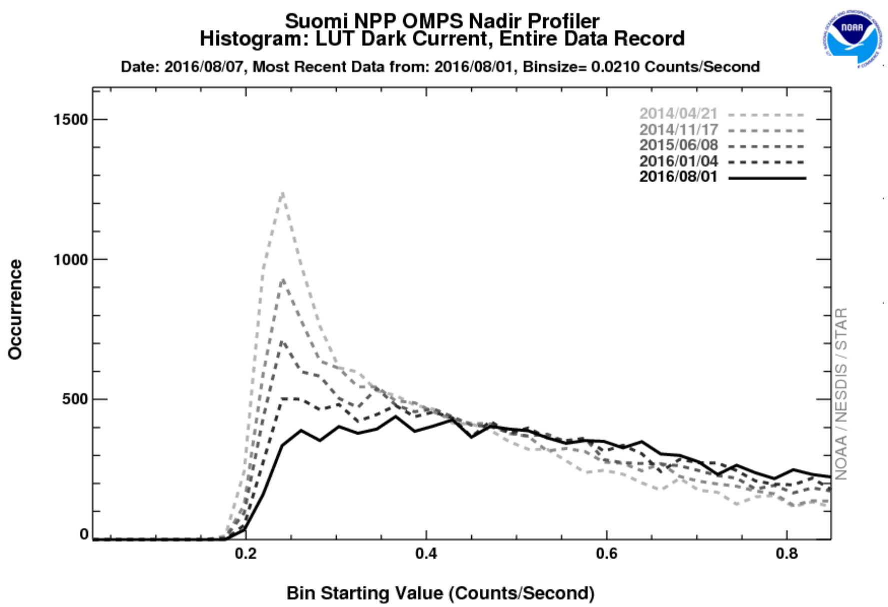


NM/NP Dark Current LUT Updates

ICVS monitoring of NM/NP dark current LUT updates:

•Statistical plots and histograms are also included



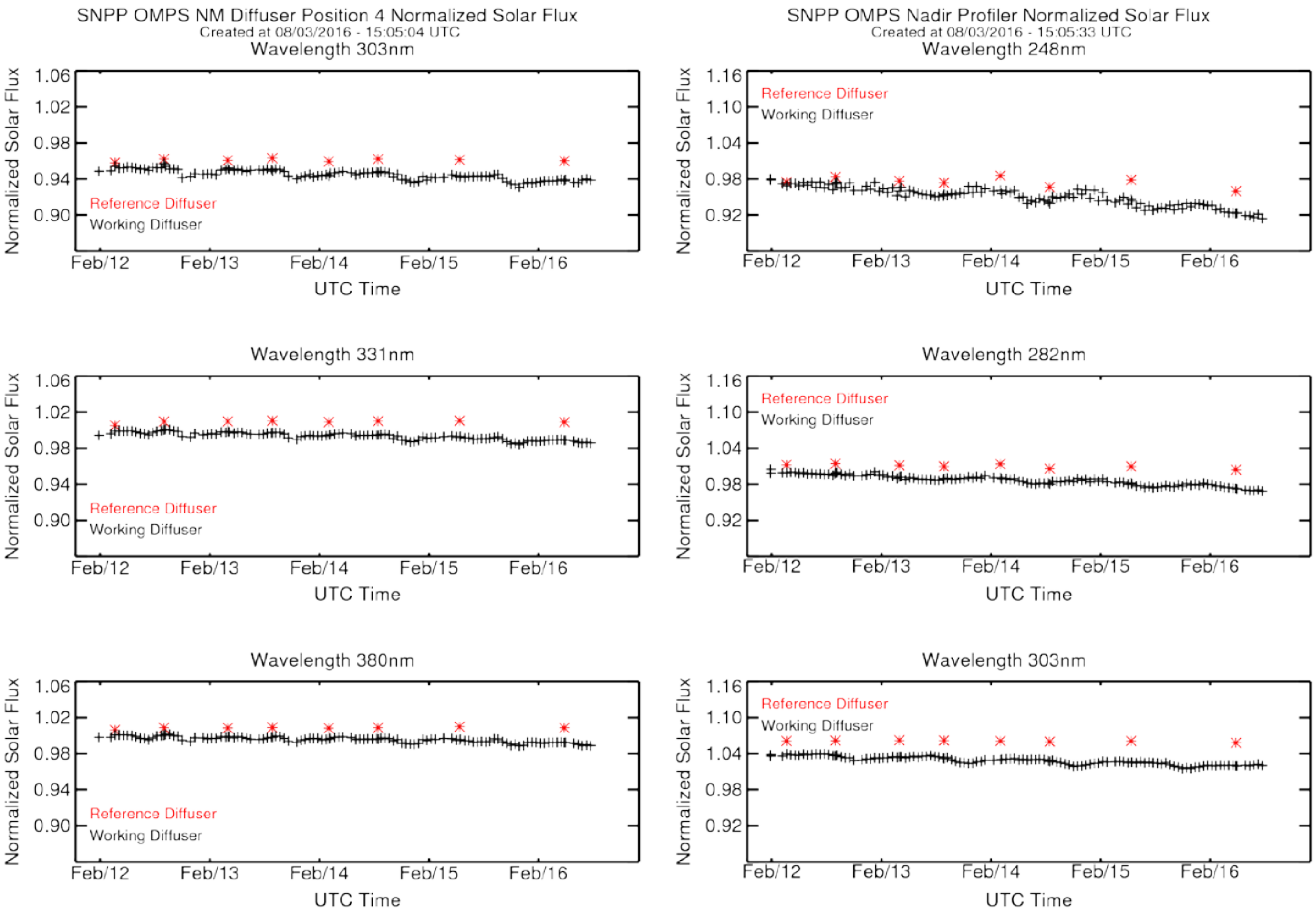


Normalized Solar Flux for NM and NP

- Solar flux time series are used to monitor diffuser degradation as well as sensor optical degradation

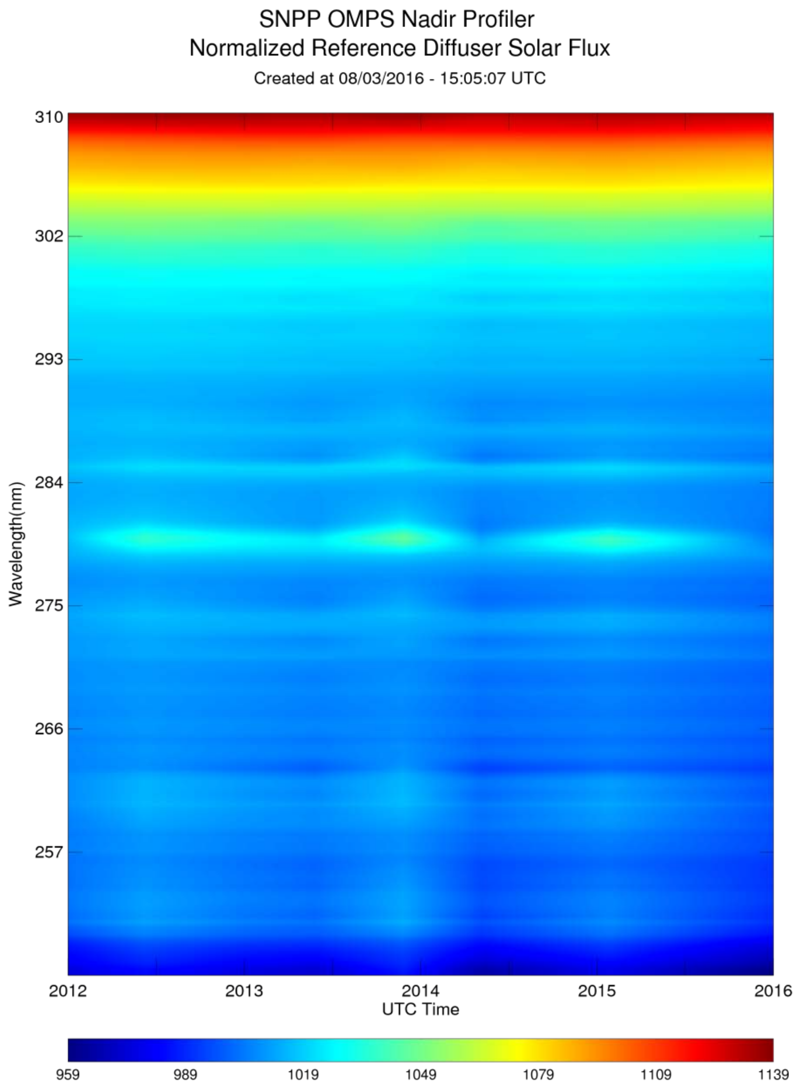
- Working diffuser data reflects both diffuser and optical degradation

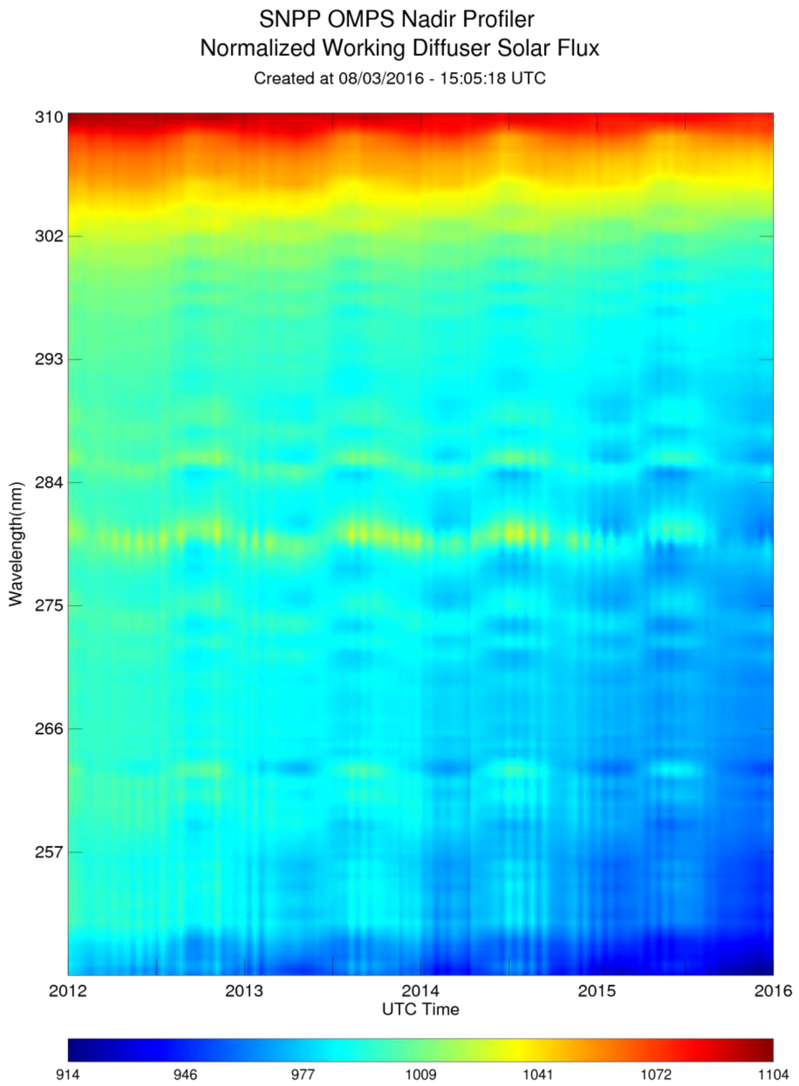
- Reference diffuser measurement is used to estimate optical degradation



Solar Flux value are normalized by the first day measurement. Solar Flux Measurements show minimal degradation in NM and NP.

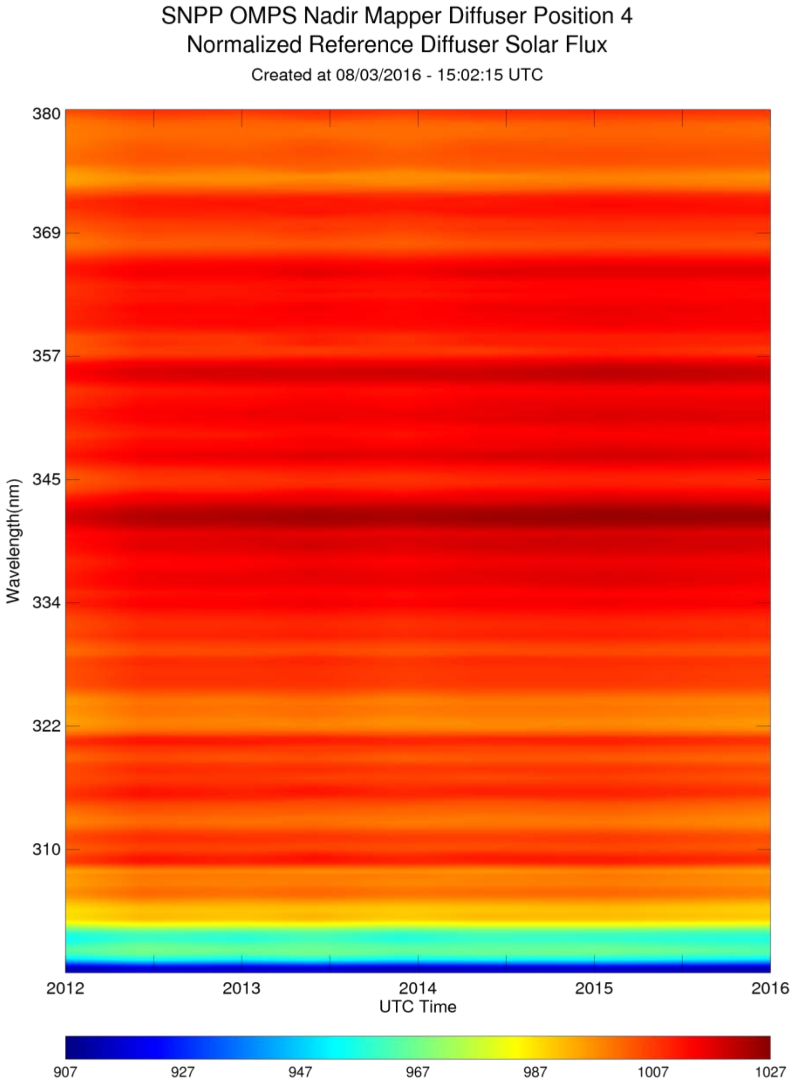
Normalized Solar Flux from NP Diffuser

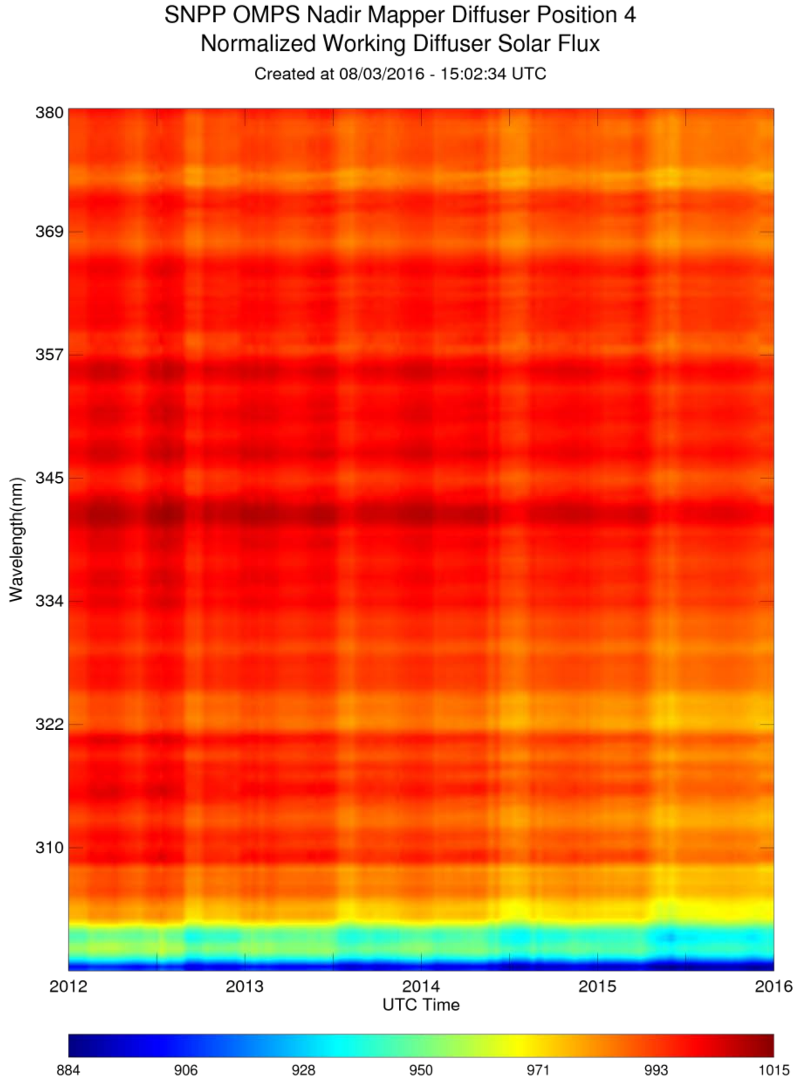




Solar Flux value are normalized by the first day measurement.

Normalized Solar Flux from NM Diffuser

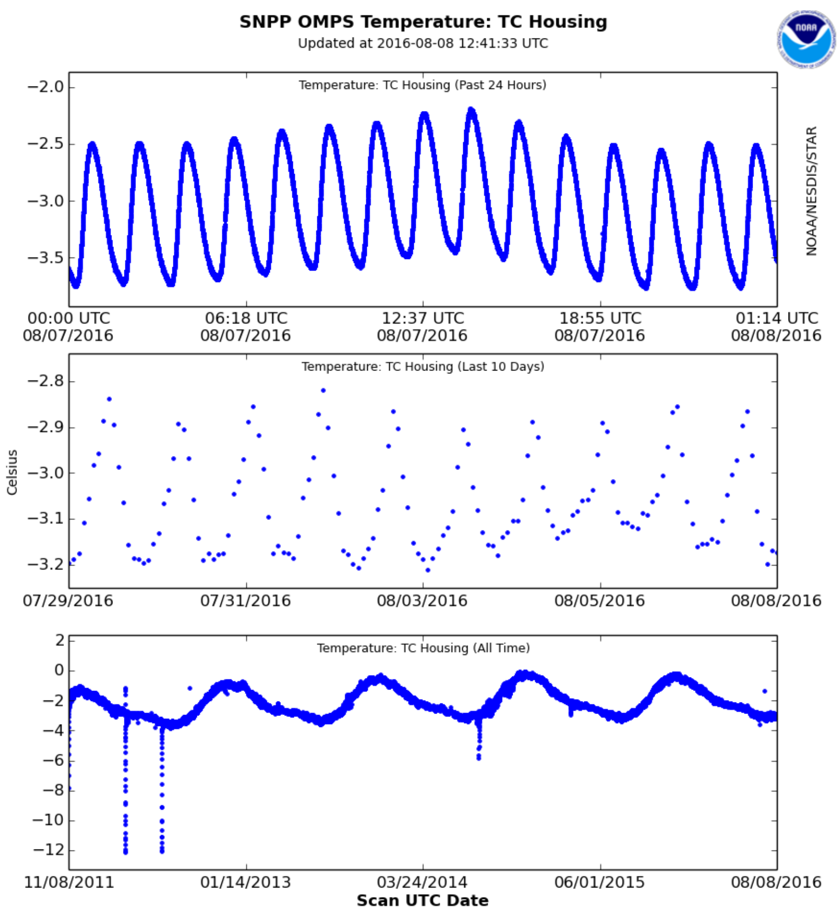


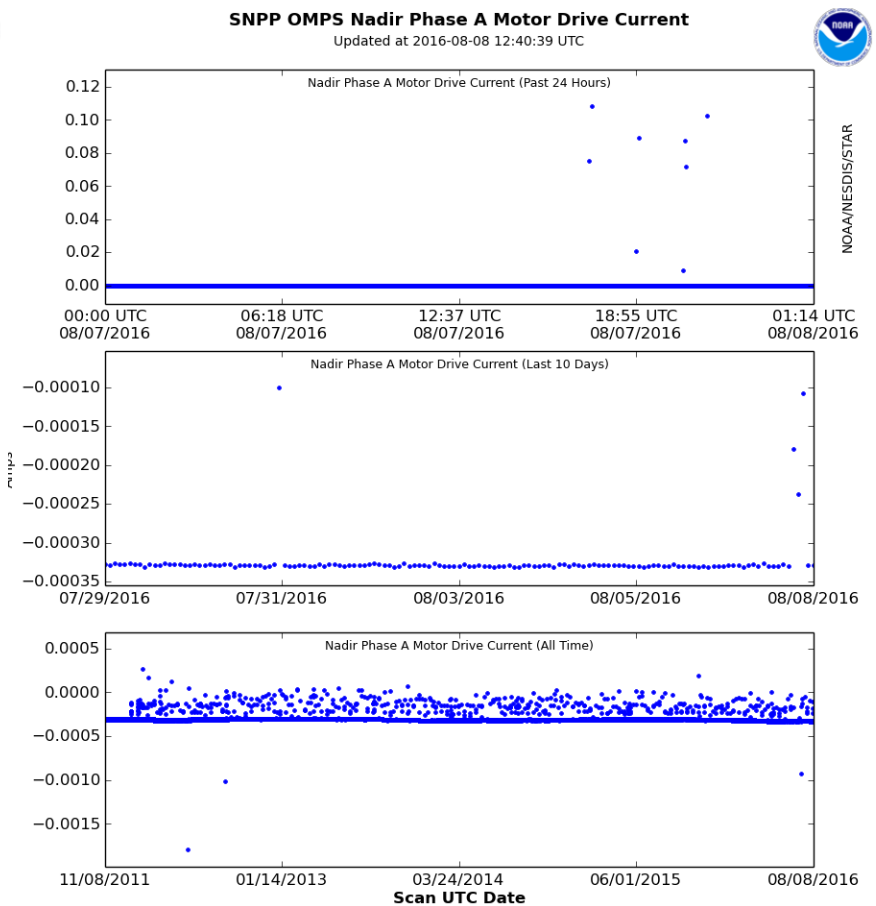


Solar Flux from NM diffuser position 1 and normalized by the first day measurement.

Senor Telemetry Monitoring

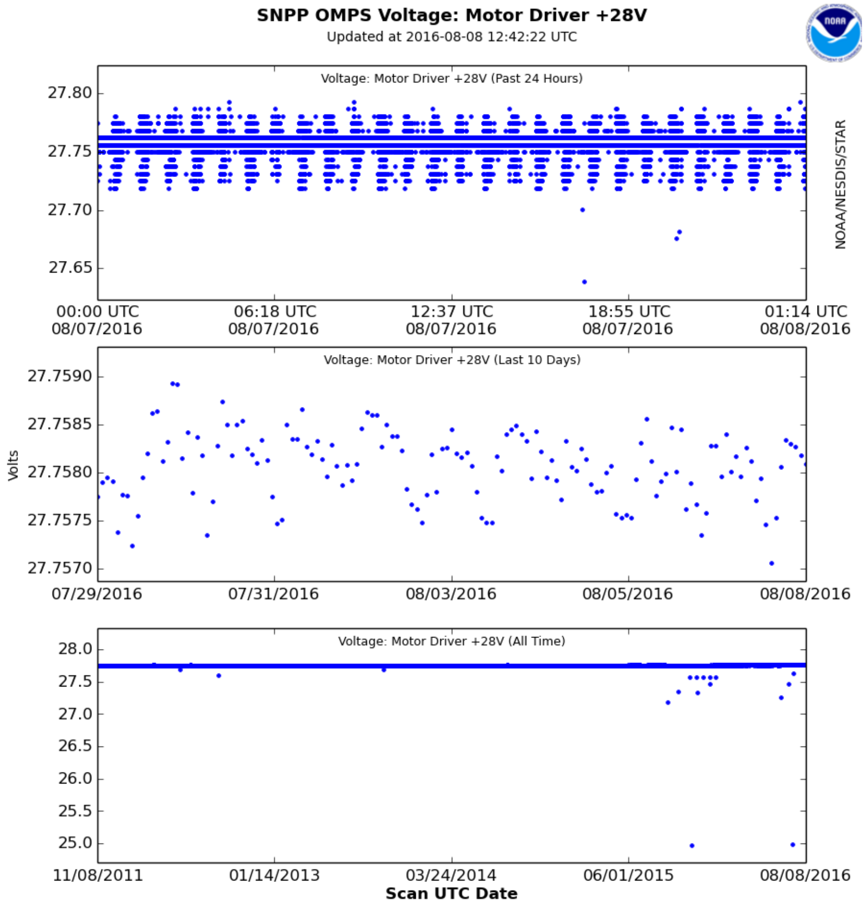
ICVS monitoring of parameters important to instrument health and safety, such as temperatures, electronic voltages and currents, and scan motor encoder output.

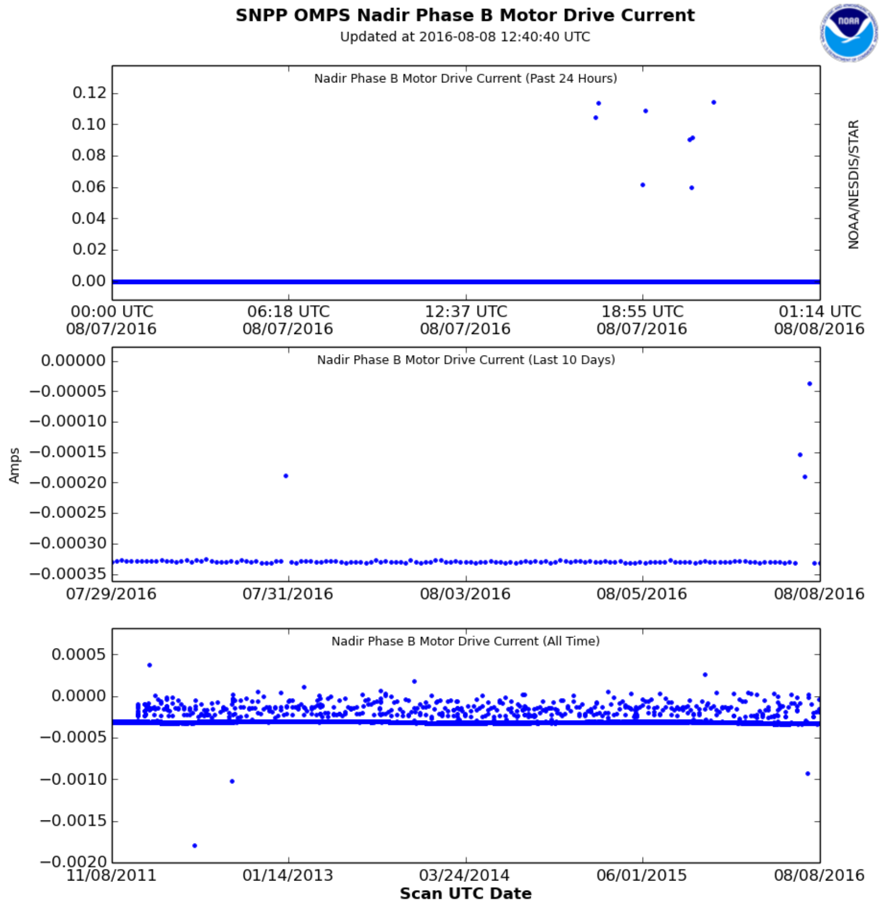




Senor Telemetry Monitoring

ICVS monitoring of parameters important to instrument health and safety, such as temperatures, electronic voltages and currents, and scan motor encoder output.





S-NPP OMPS Dark LUTs Anomaly

•Green symbols were missing since 3/31 indicating bad dark data. Incorrect version (LE) of the OMPS-TC-DARKS-GND-PI was delivered to OPS.

• IDPS reverted to table delivered on 3/21 and then re-used the old LUT back two weeks ago. (Fig. 2)

• A new function has been implemented in ICVS to send out email warnings when there is bad dark current in SDR

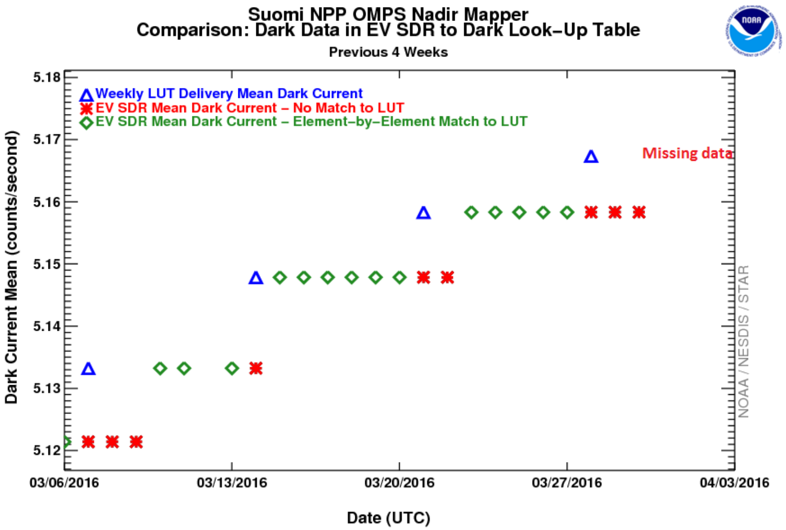


Fig. 1 Dark LUT mean plot on 4/4

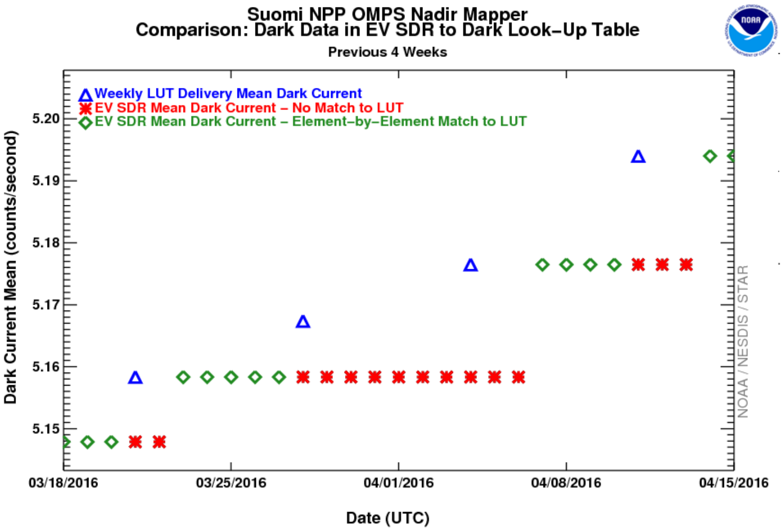
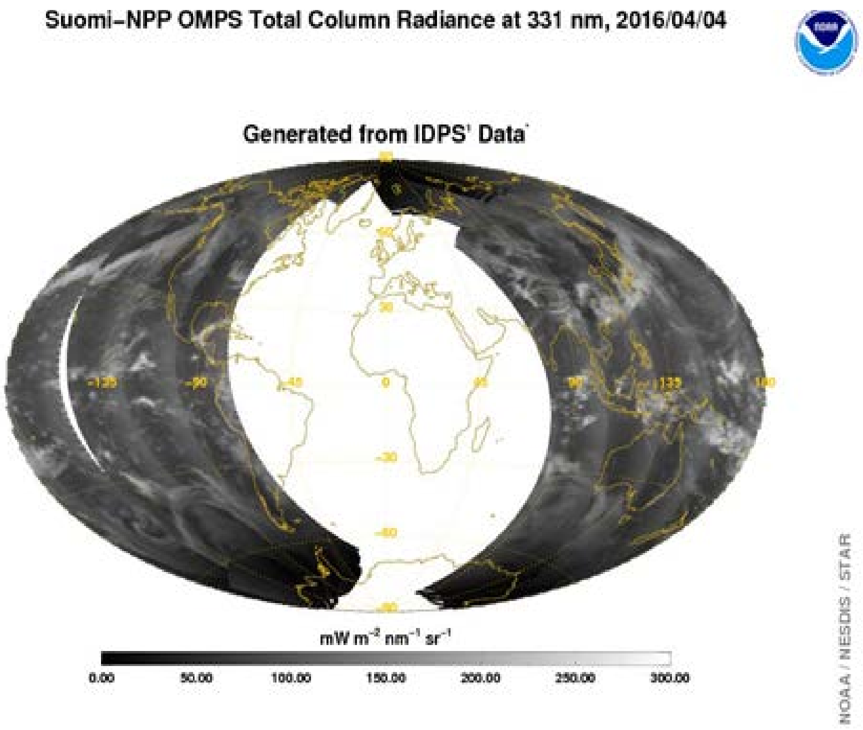


Fig. 2 Dark LUT mean plot on 4/15

OMPS EV Radiance Anomaly

• Anomalous EV radiance with many NAN values (blank in right map) was discovered on 4/4. The root cause is the little-endian TC dark LUT was accidently uploaded on 3/31.

•ICVS is implementing a near real-time monitoring algorithm to watch the quality of SDR products and send out email warnings when there is bad radiance in SDR



S-NPP OMPS TC "Missing" Scans

•ICVS is implementing a near real-time algorithm to monitor missing data, erroneous data and not-applicable data

•Filling value of -999.8 in radiance indicates missing data

•The granules with missing scans have none zero quality flag of N_Percent_Missing_Data

•Low latitude missing scan can be found in nearby granule

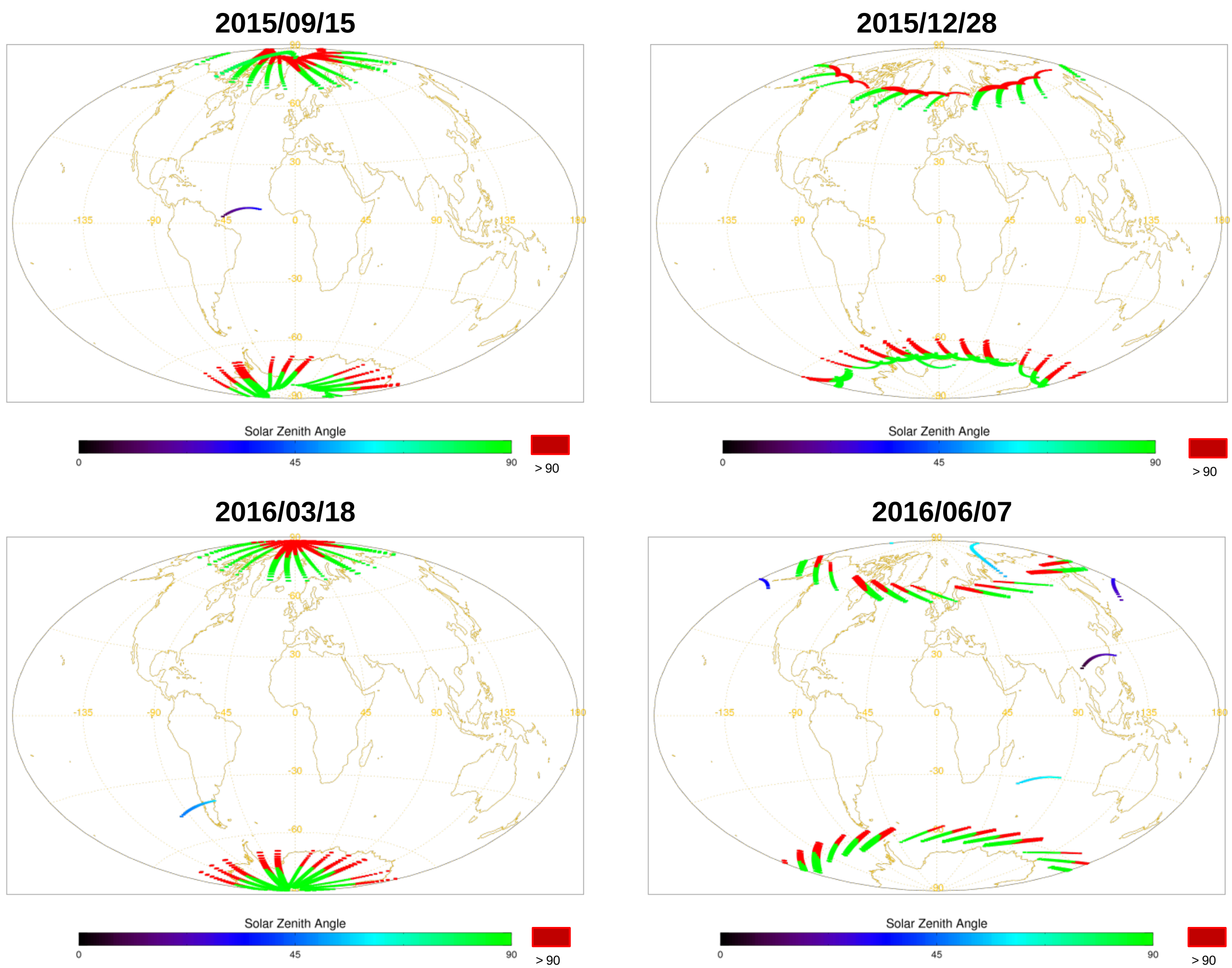
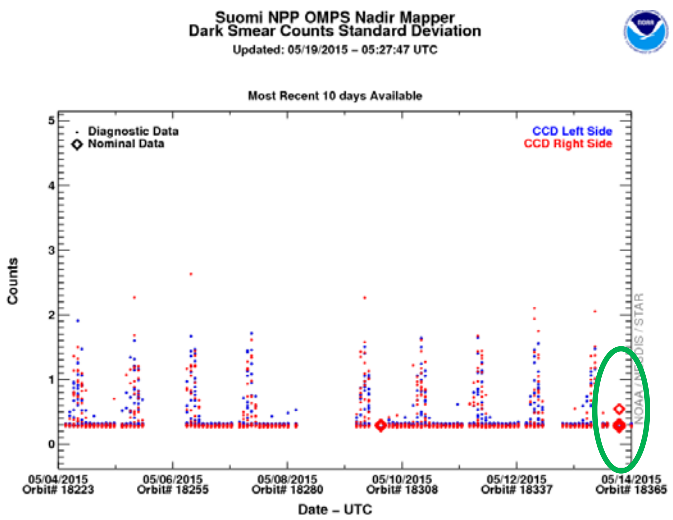


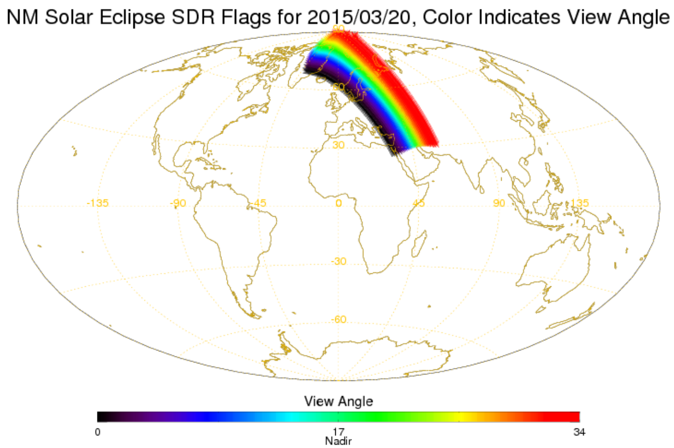
Fig 1. S-NPP OMPS TC missing scan color coded by solar zenith angle

Expected Anomaly Detection

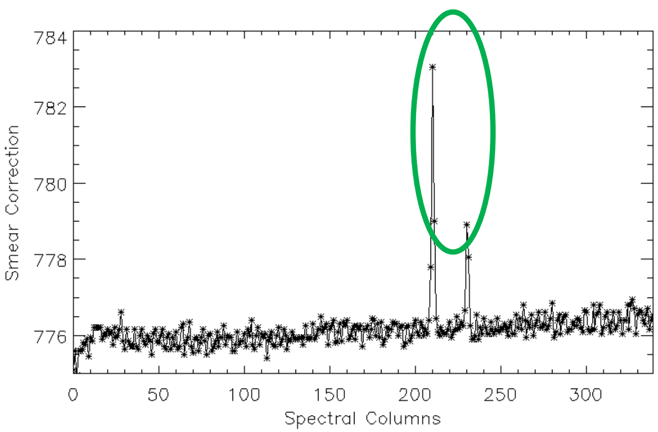
Automated anomaly detection and email warnings are established for radiance and key performance parameters



Time series of average OMPS NM dark smear counts for ten days



Solar eclipse as identified by OMPS eclipse flag



Transient in OMPS NP dark smear on orbit 18362 and image 24 for May 14, 2015

S-NPP Drag Maneuver

Many OMPS parameters exhibited atypical behavior during/after S-NPP drag maneuver on Aug. 8, 2014. For example, Fig. 1 shows the CCD temperature abnormal for both NP and NM on Aug. 10, 2014. Most parameters are back to normal after the S-NPP drag maneuver. However, dark current increases permanently for both NP and NM as show in Fig. 2.

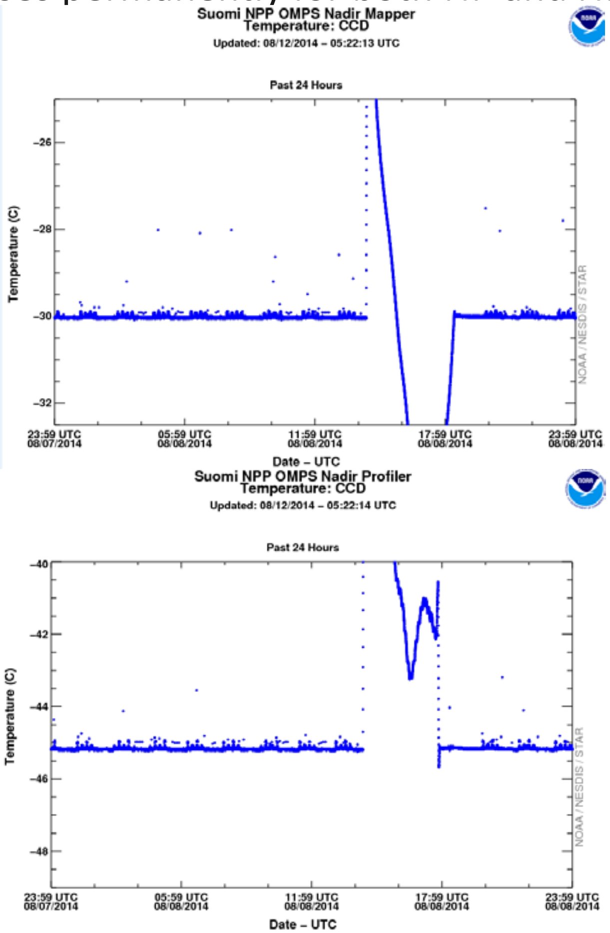


Figure 1. CCD temperature abnormal after Aug.10, 2014 S-NPP drag maneuver.

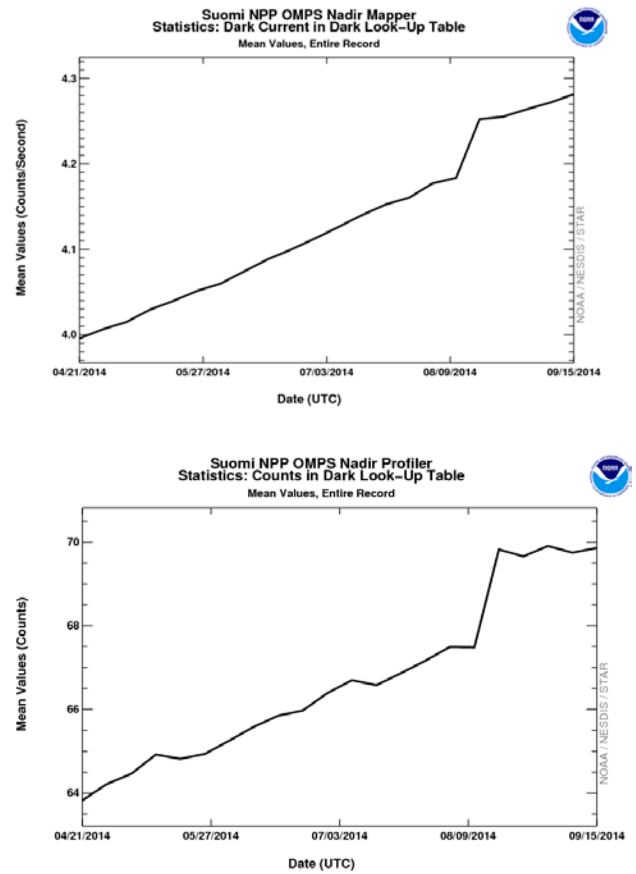
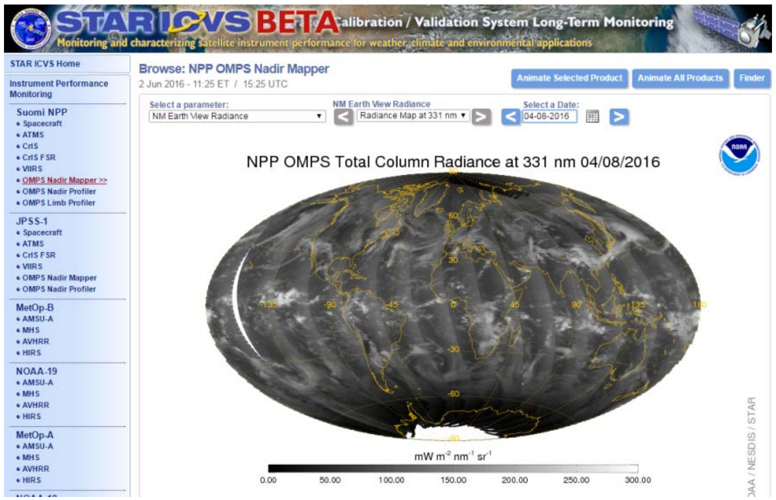
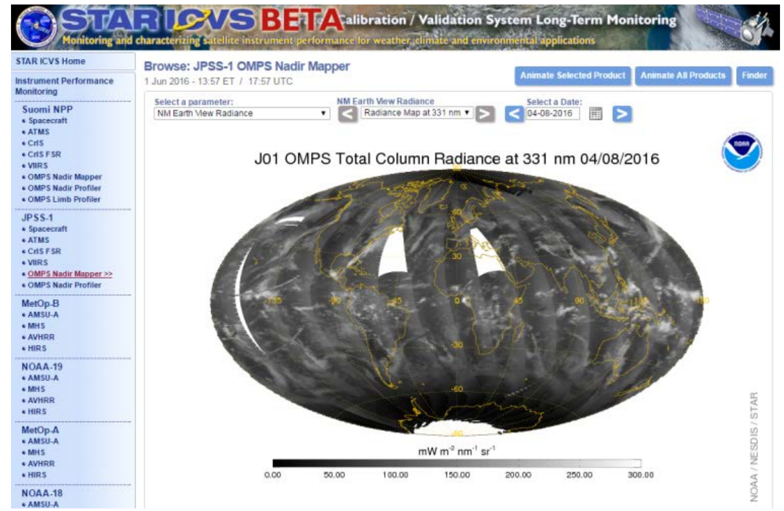


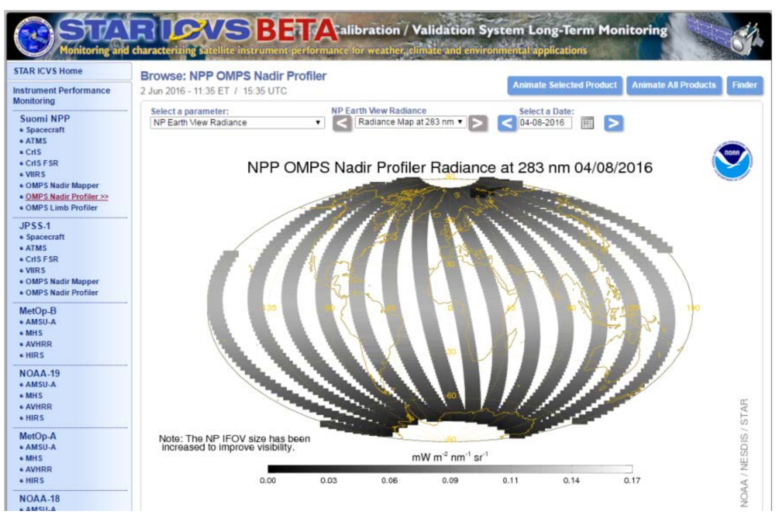
Figure 2. Dark current increases after Aug.10, 2014 S-NPP drag maneuver.

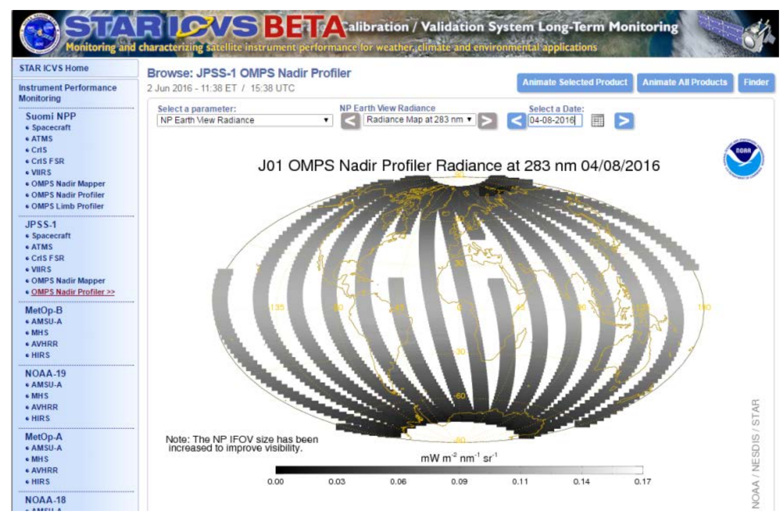
STAR ICVS BETA Website

SNPP, J01 OMPS TC and NP Radiance images at STAR ICVS BETA website:
http://www.star.nesdis.noaa.gov/icvs-beta/









OMPS Parameters Monitored by ICVS

Module	Parameters	Description
OMPS SDR	EV Radiance	Global radiance map
	Sensor Performance	Average and standard of Dark current, offset, smear
	Chasing Orbit Comparison	Reflectance comparison between SBUV/2 and OMPS
	SDR Quality Flags	solar eclipse events
	Dark Look-Up Table	Dark LUT statistics
	Linearity Calibration Reference LED	Reference LED counts statistics: left side, right side, earth view, full frame
	Solar Degradation	Solar flux Working diffuser and reference diffuse
OMPS RDR	SDR Data Flags	Linearity correction, gain correction, bin imager, reorder image
	Instrument Operational State	Fixed coadd count,
	SDR Table Version and ID	Gain correction, linearity correction, sample
	Instrument Temperatures	Housing, window, conduction bar, CCD
	Instrument Voltages	TEC error
	Instrument Currents	TEC, CCD output reset bias, CCD output drain bias
	OMPS Nadir System Operational State	Active Nadir Profile ID
	OMPS Nadir System Table Version and ID	Active timing pattern table version, timingpattern table ID
	OMPS Nadir System Temperatures	Signal board, timing board,telescope, calibration housing, diffuser motor
	OMPS Nadir System Voltages	CCD, signal board, timing board
	OMPS Nadir System Currents	Phase A motor drive, phase B motor drive
	OMPS Suite Software Version Control	Flight software version
	OMPS Suite Operational State	Calibration LED state, active main electronics box side
	OMPS Suite Temperatures	Motor driver board, SBC board, processor interface board
	OMPS Suite Voltages	TEC driver/reference, motor driver, CPE, motor/resolver electronics
	OMPS Suite Currents	Active calibration LED, CPE, TEC total

OMPS SDR Reprocessing

- ADL5.3
- Weekly updates of Dark LUTs
- Up-to-date static LUTs:

NP Table Name
OMPS-NP-OSOL-LUT
OMPS-NP-CALCONST-LUT
OMPS-NP-WAVELENGTH-GND-PI
OMPS-NP-BIAS-GND-PI
OMPS-NP-SDR-CC
OMPS-NP-CF-EARTH-GND-PI
OMPS-NP-STRAYLIGHT-LUT
OMPS-NP-LINEARITY-GND-PI
OMPS-NP-TIMING-PATTERN-GND-PI

TC Table Name
OMPS-TC-OSOL-LUT
OMPS-TC-CALCONST-LUT
OMPS-TC-WAVELENGTH-GND-PI
OMPS-TC-BIAS-GND-PI
OMPS-TC-SDR-CC
OMPS-TC-CF-EARTH-GND-PI
OMPS-TC-STRAYLIGHT-LUT
OMPS-TC-LINEARITY-GND-PI
OMPS-TC-TIMING-PATTERN-GND-PI

OMPS SDR Reprocessing Preliminary Results

- **Tested run ADL4.2 with up-to-date LUTs**
- **OMPS daily nadir view N-value trending**
  - ➢ **OMPS daily nadir view N-value over Tropical Pacific region (20S-20N,90W-180W).**

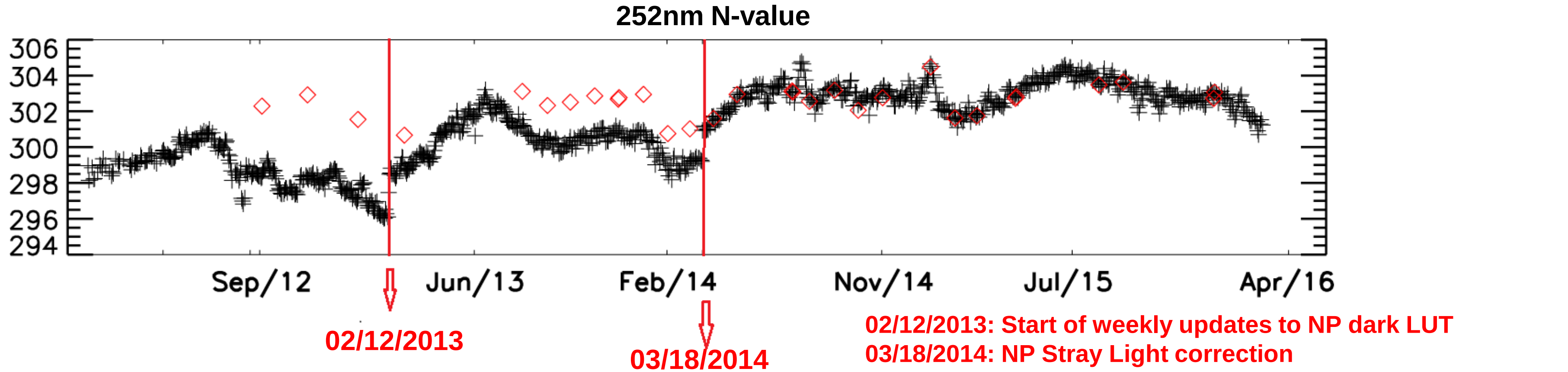


Fig. 1 OMPS NP daily nadir view N-value over Tropical Pacific region (20S-20N,90W-180W). Black: Operational; Red: Reprocessed

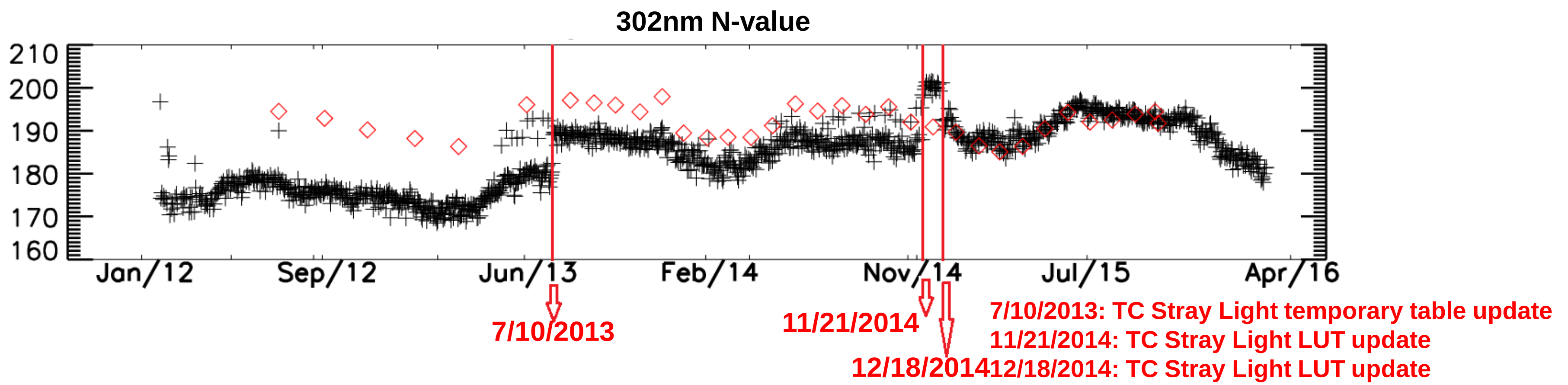


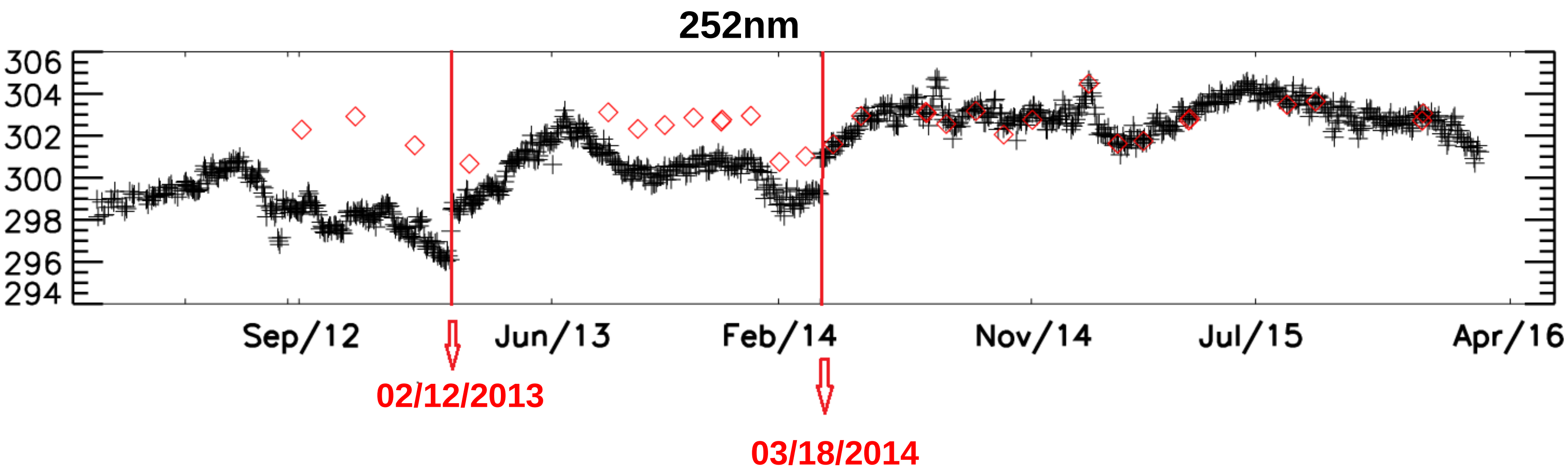
Fig. 2 OMPS TC daily nadir view N-value over Tropical Pacific region (20S-20N,90W-180W). Black: Operational; Red: Reprocessed

Summary and Future Plan

- Comprehensive near real time and long term instrument status and performance monitoring
- Real time support for sensor calibration activities
- Automated anomaly detection and email warnings are established for radiance and key performance parameters
- New parameters will be monitored according to requirements from OMPS SDR team
- S-NPP and J01 OMPS will be monitored at STAR ICVS-beta website
- ADL5.3 will be used in SNPP OMPS SDR Reprocessing

Impacts of OMPS NP SDR Algorithm Update on Data Quality

- Test run using ADL4.2 with up-to-date Look-Up-Tables.
- NP daily nadir view N-value over Tropical Pacific region
- N-value does not show obvious increasing with time after reprocessing.



02/12/2013: Start of weekly updates to NP dark LUT
03/18/2014: NP Stray Light correction

Fig. 1 OMPS NP daily nadir view N-value over Tropical Pacific region (20S-20N,90W-180W). Black: Operational; Red: Reprocessed

NP daily nadir view N-value over Tropical Pacific region

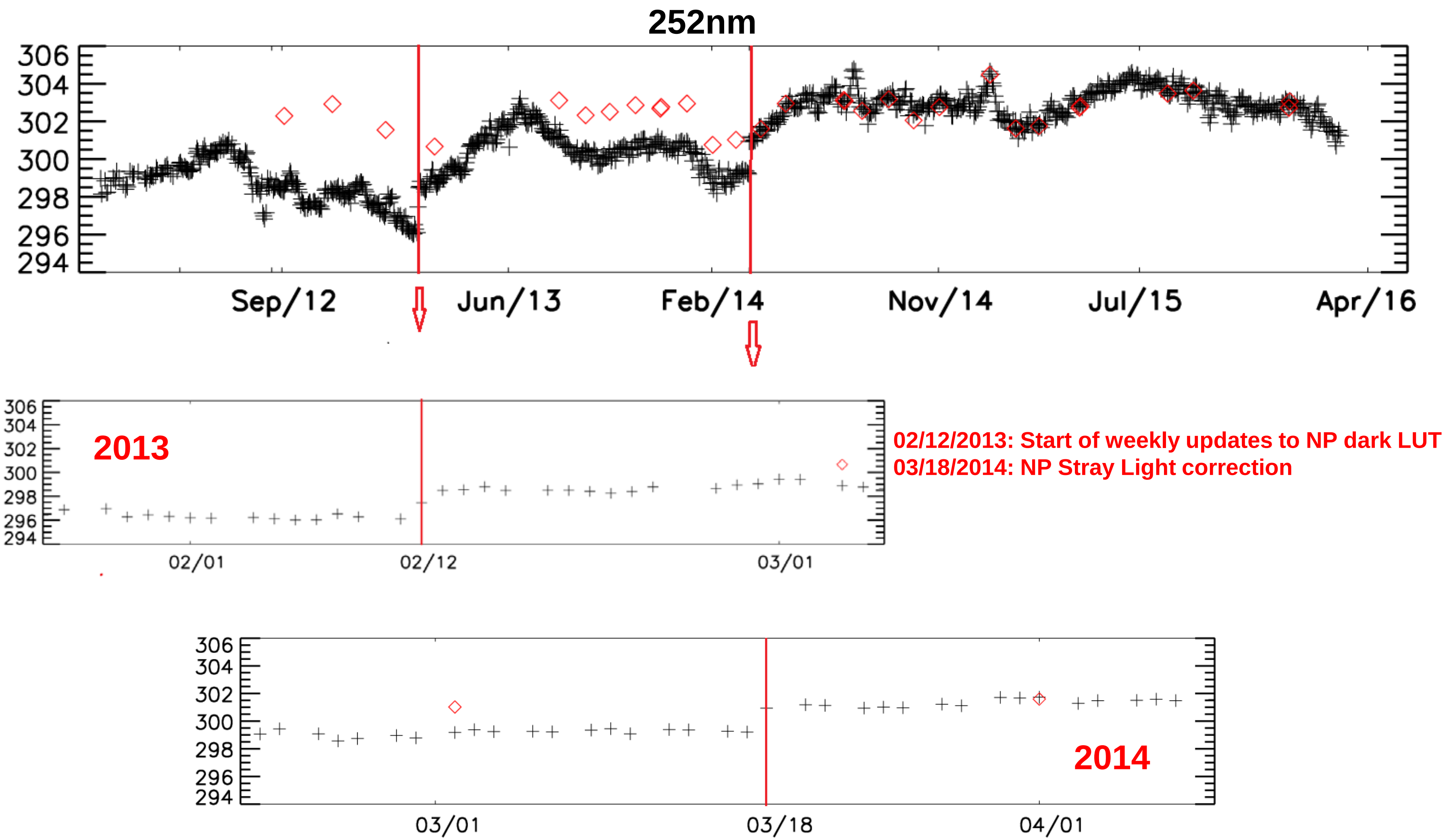
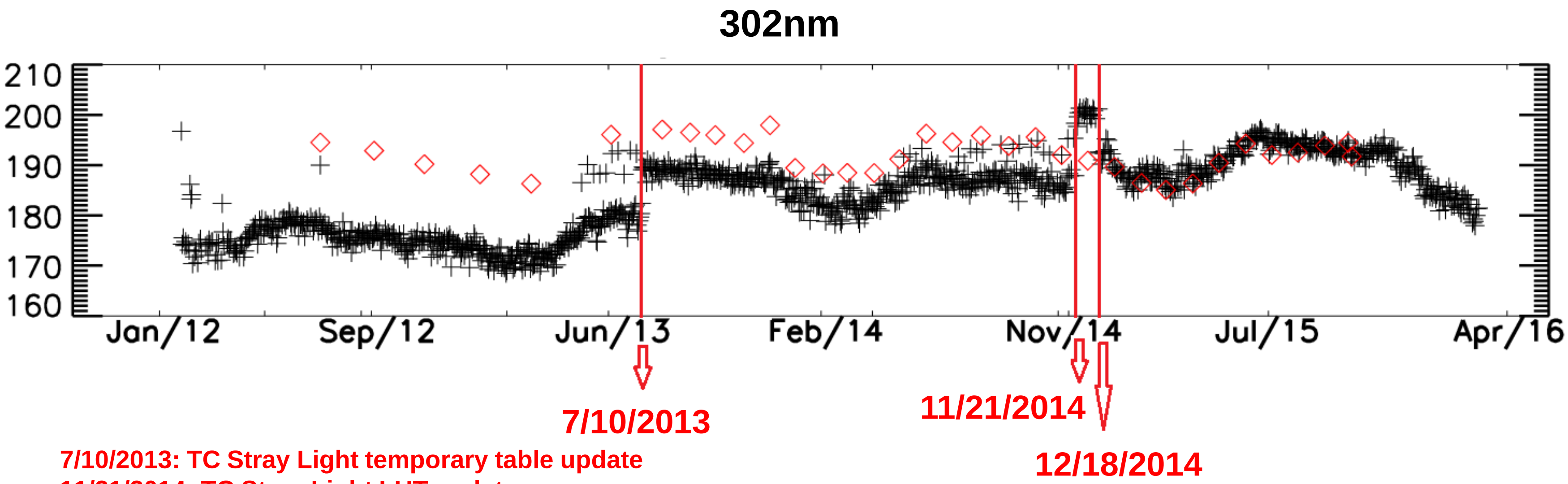


Fig. 1 OMPS NP daily nadir view N-value over Tropical Pacific region (20S-20N,90W-180W). Black: Operational; Red: Reprocessed

Impacts of OMPS TC SDR Algorithm Update on Data Quality

- Test run using ADL4.2 with up-to-date Look-Up-Tables
- TC daily nadir view N-value over Tropical Pacific region
- N-value does not show obvious increasing with time after reprocessing.



7/10/2013: TC Stray Light temporary table update
11/21/2014: TC Stray Light LUT update
12/18/2014: TC Stray Light LUT update

Fig. 2 OMPS TC daily nadir view N-value over Tropical Pacific region (20S-20N,90W-180W).
Black: Operational; Red: Reprocessed

TC daily nadir view N-value over Tropical Pacific region

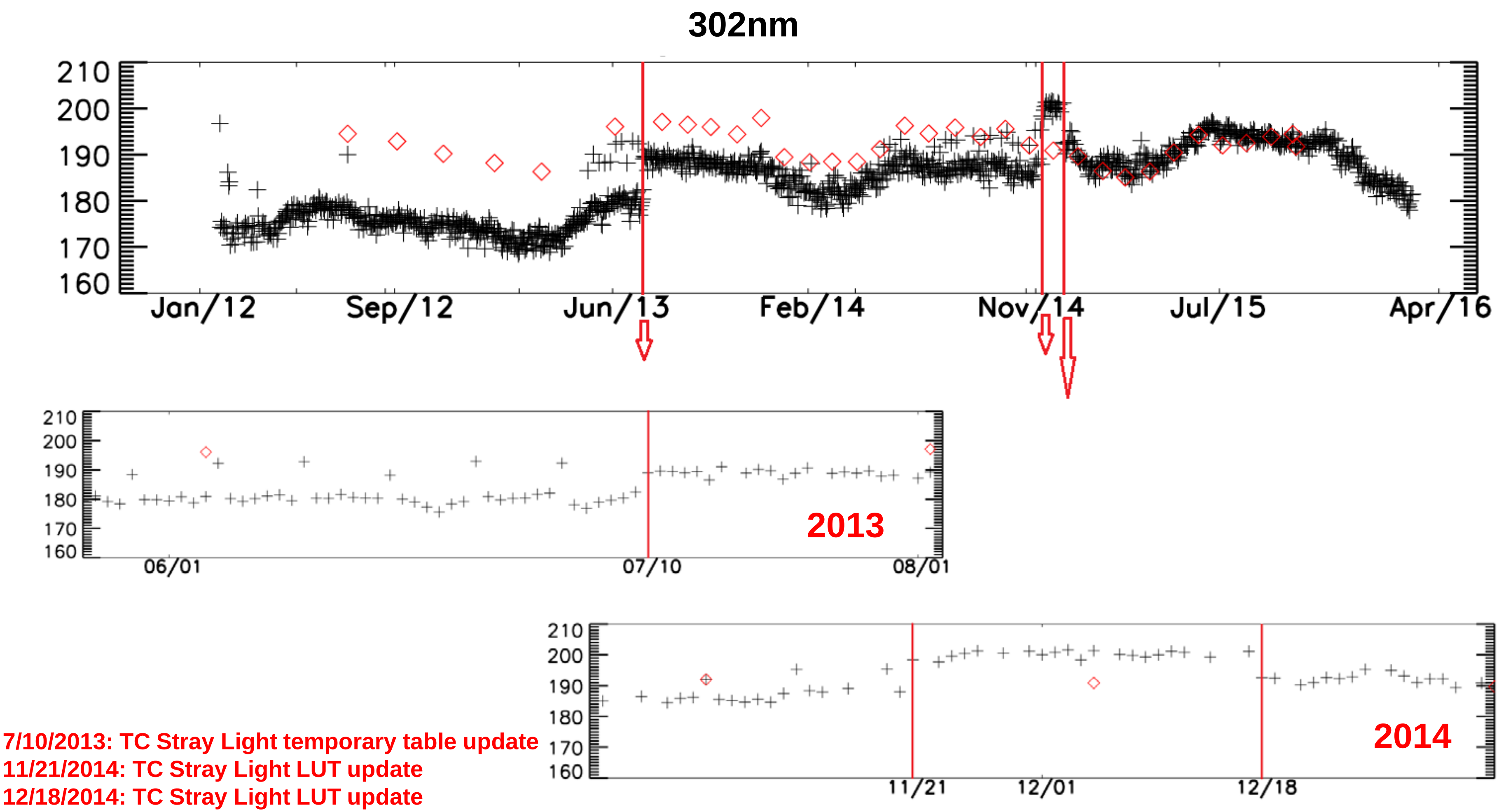
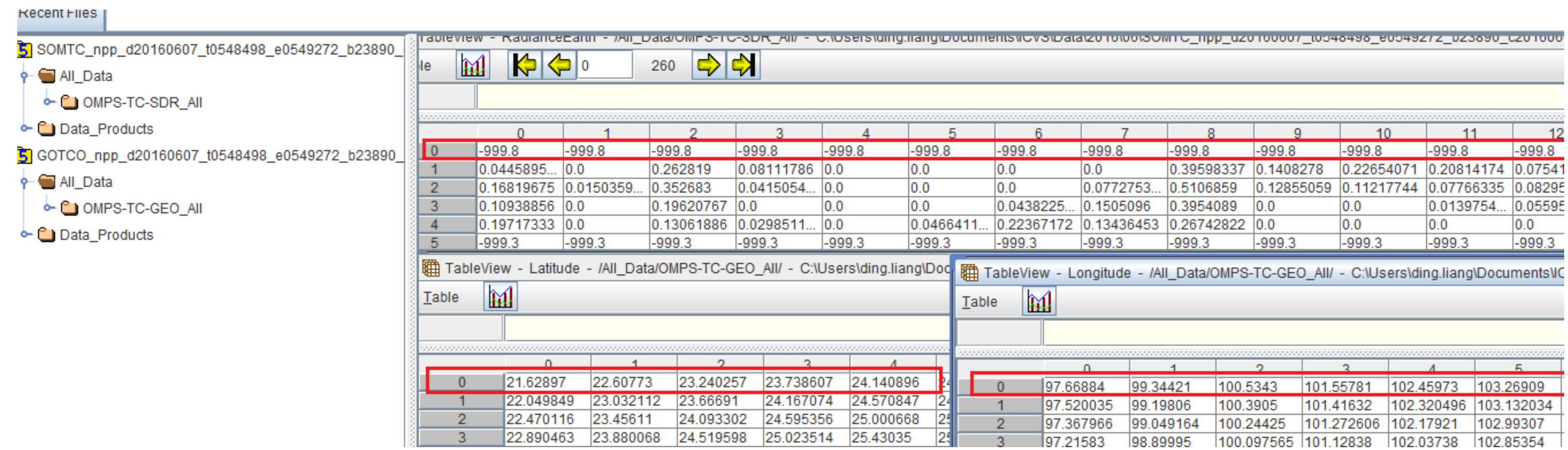


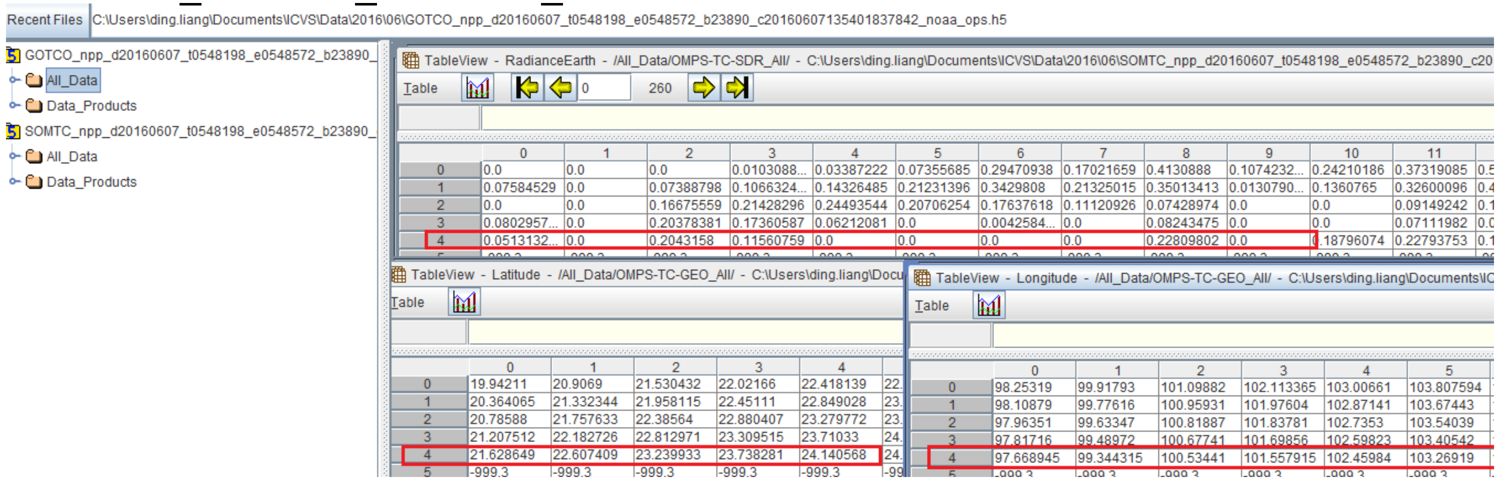
Fig. 2 OMPS TC daily nadir view N-value over Tropical Pacific region (20S-20N,90W-180W). Black: Operational; Red: Reprocessed

Some Missing Scan can be Found in nearby Granule

• Radiance and geolocation of a TC SDR granule with missing scan. Time stamp is d20160607_t0548498_e0549272_b23890



•The above missing scan can be found in a nearby granule. Time stamp is d20160607_t0548198_e0548572_b23890



JPSS Annual Science Meeting – August 9th 2016

OMPS Cal SDR Dark Automation

DOGS – Darks OMPS to GRAVITE Suite

Eve-Marie Seye, ERT, Inc for NOAA/NESDIS/STAR
Chunhui Pan, UMD for NOAA/NESDIS/STAR
Kristina Sprietzer, IMSG for NOAA/NESDIS/STAR/ASSIST
Bigyani Das, IMSG for NOAA/NESDIS/STAR/ASSIST
Wanchun Chen, ERT, Inc for NOAA/NESDIS/STAR
Richard Buss, Innovim Company for NASA/JPSS
Ryan Gerard, GVT, LLC for NASA/JPSS
M. K. Rama Varma Raja, SSAI for for NASA/Core Team and JPSS Team
Michael Haken, , SSAI for NASA/Core Team and JPSS Team
Thomas Kelly, SSAI for NASA/Core Team and JPSS Team
Glen Jaross, NASA
Laura Dunlap, JPSS/AMP

Talk Overview

- Teams Collaboration
- What is DOGS?
- DOGS Data and Execution flow
- Delivery Selection
- DOGS Implementation Status

Teams Collaboration

NASA SIPS

- Developed the original science APPs : L1A, L1B, DRKCAL, LUT_for_IDPS

STAR OMPS SDR

- Modified the code to make it gFortran and 64-bit friendly
- Developed a dynamic Interface to replicate the SIPS system functionalities in a stand-alone package following operations requirements (DOGS)

STAR ASSISTT

- Developed scripts to install libraries
- Testing & Instructions
- Packaged DOGS for GRAVITE

GRAVITE

- Integrate DOGS to GRAVITE system
- "Plug" to live data stream
- Run DOGS automatically for each orbit

DPES

- LUT Testing & Approval

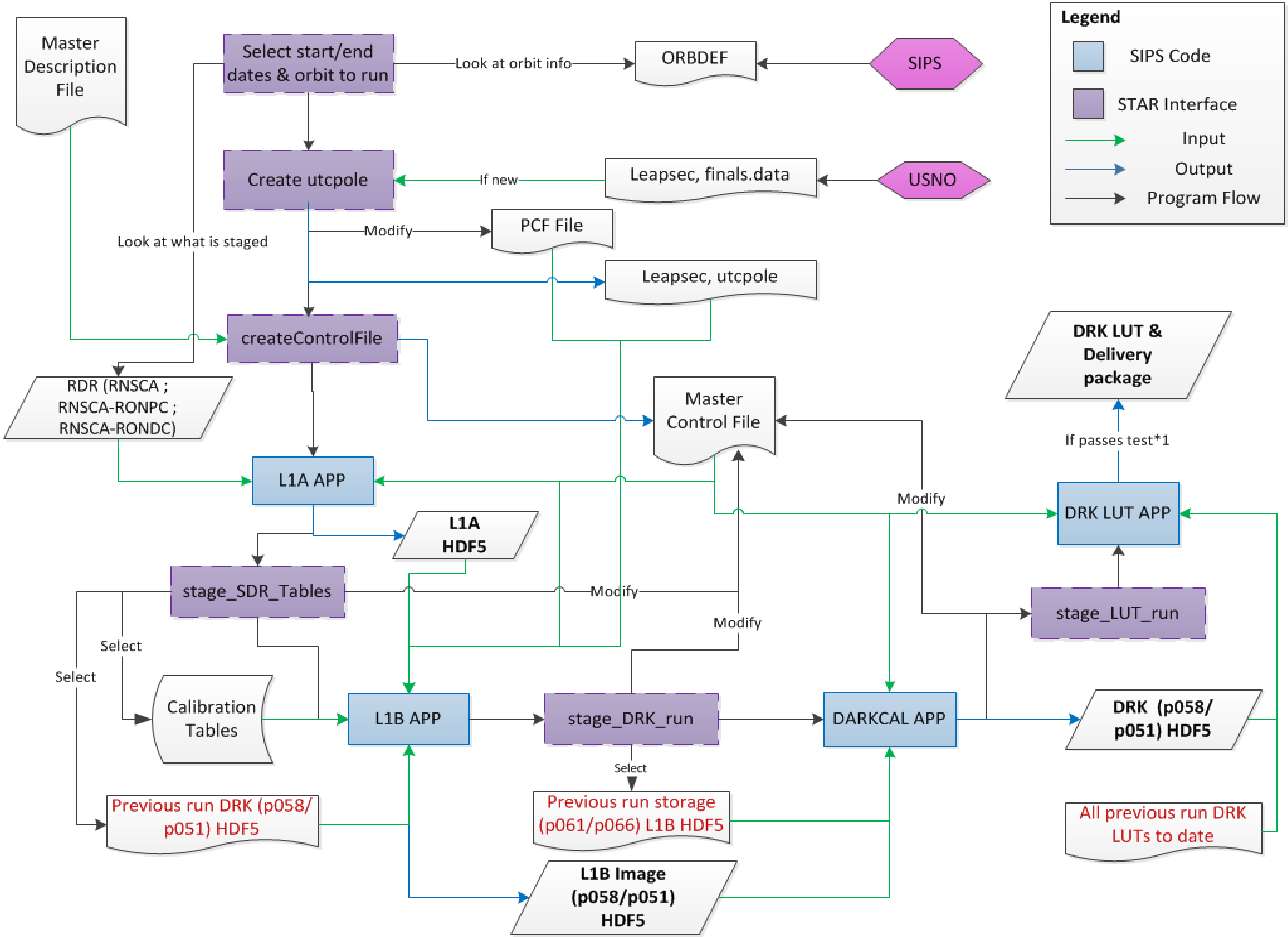
IDPS

- Archive
- Distribute to users

What is DOGS?

- DOGS – Darks OMPS to GRAVITE Suite
- Interface around the OMPS SIPS code so that the run could be executed all the way from the RDR to the DRK LUT (Lookup Table) for IDPS in one call and follow GRAVITE run requirements.
- Three Perl Packages were created:
  - STAR_OMPS_setup.pm: Holds the common variables to DOGS
  - STAR_OMPS.pm: Holds the main subroutines to DOGS
  - STAR_OMPS_subs.pm: Holds the common subroutines/utilities to DOGS
- One driver perl script : run_DRK_OMPS.pl
- Same code handle both Nadir Profiler and Nadir Mapper: only the setup differs

DOGS Data & Execution Flow (1/2)

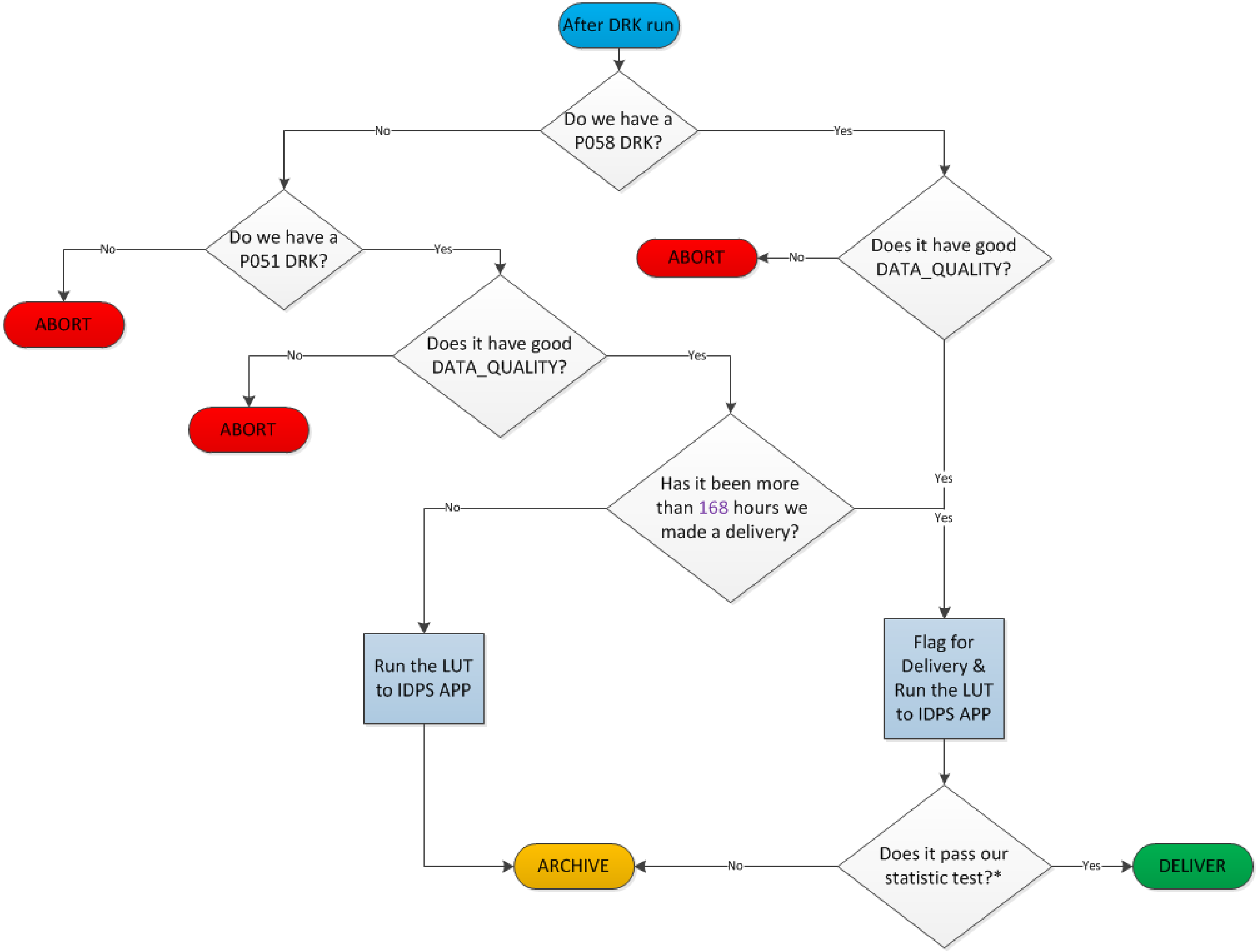


DOGS Data & Execution Flow (2/2)

- It will be run in GRAVITE for every orbit and delivery will be made once a week, if possible on door closed measurement (for each sensor)
- Additional testing:
  - DATA_QUALITY checks are added throughout the process at each step
  - criteria set for approval : CurrentWeekMean >= LowerLimit and CurrentWeekMean <= UpperLimit with:
    - LowerLimit = (NP_IDPS_Temporal_Mean_Diff - 3.0*NP_IDPS_STD)
    - UpperLimit = (NP_IDPS_Temporal_Mean_Diff + 3.0*NP_IDPS_STD)

    The mean difference and Standard deviation are calculated over the past delivered LUT that were delivered within a week of each other

Decision Tree for Delivery



Delivery Summary

	Currently (NASA processed)	When DOGS is in GRAVITE
Delivery	Deliver only on door closed measurement	Deliver only on door closed measurement unless door closed has bad data -> deliver on door open measurement
If DRK mean test fails…	Still deliver bad data – only indicates in the approval letter that it is not falling within the criteria set for approval and further investigation is needed	Won't deliver the failed run ; will pick a good run on door open in the next 12 hours
Delivery Frequency	Update possible only once a week	Running for every orbit ; could deliver more often

DOGS Implementation Status

- We show absolutely no difference between the DOGS produced DRK LUT and the NASA/SIPS one (given the same inputs)
- GRAVITE successfully tested the library installations and the official unit test version for NP on their test system (also showing no difference at all)
- Live data stream outlined and implemented – available after the next GRAVITE update provided the development team conducts a successful test on their final system
- Official NP "live" version delivered to STAR/ASSISTT last week and successfully tested by STAR/ASSISTT along with documentation and PGE Integration Form
- TC "live" version just implemented and tested at STAR/OMPS SDR – delivery to ASSISTT later this week
- Ongoing discussion with IDPS & DPES to plan for test period and ultimately aiming to simplify the delivery process to IDPS
- Block 2.0 compatible (with flag)

Thank You....

Any Questions?...

LOGISTICS

Agenda

1300 - Logistics, agenda, tour of the table — Larry Flynn

1305 - Introduction to OMPS Products and Validation Plans — Larry Flynn

1315 - OMPS Limb Profiler aerosol extinction profile measurements in the stratosphere — G. Taha

1330 - Ozone profile products from the Suomi NPP OMPS Limb Profiler: overview of the quality of version 2.0 and a path for the updated version 2.5 — N. Kramarova

1345 - Limb ozone data assimilation in GEOS-5: MLS and OMPS-LP — K. Wargan

1400 - TOAST total ozone maps using CrIS and OMPS LP ozone profiles — J. Niu

1415 - Validation of OMPS ozone products with ground-based Dobson network — I. Petropavlovskikh

1430 - NASA OMPS Nadir Science Team products, validation and applications — C. Seftor

1445 - Version 8 algorithm products and ICVS monitoring — Z. Zhang

1500 - Break

1515 - Ozone Applications and CDRs — C. Long

1530 - Small Field of View Products from OMPS — T. Beck

1545 - Validation of V8Pro and V8TOz products — L. Flynn

1600 – Discussion — L. Flynn

General

- Introductions
- Remote attendance

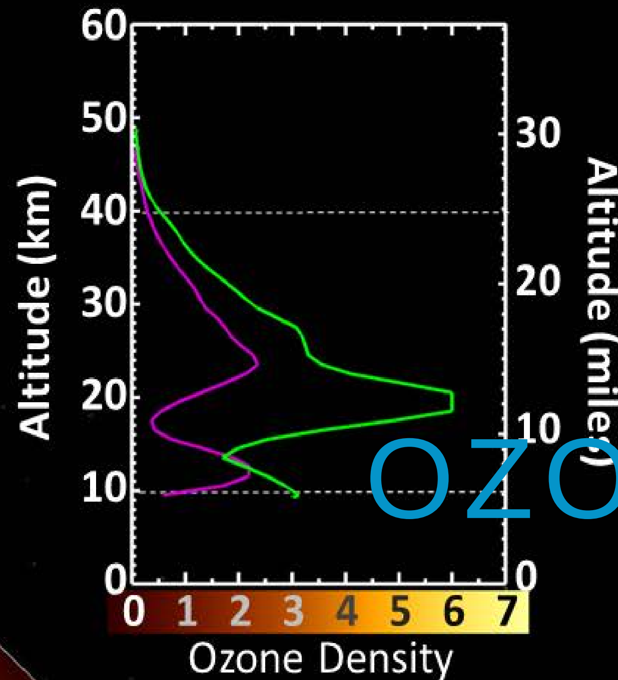
- Copies of the presentations
  - Please provide final copies of presentations for general release by Monday

- Breaks
  - We will have one break at 3:00

Introduction to OMPS Products and Validation Plans

L. Flynn, C.T. Beck, C. Long, and
I. Petropavlovskikh
Lawrence.E.Flynn@noaa.gov

OZONE



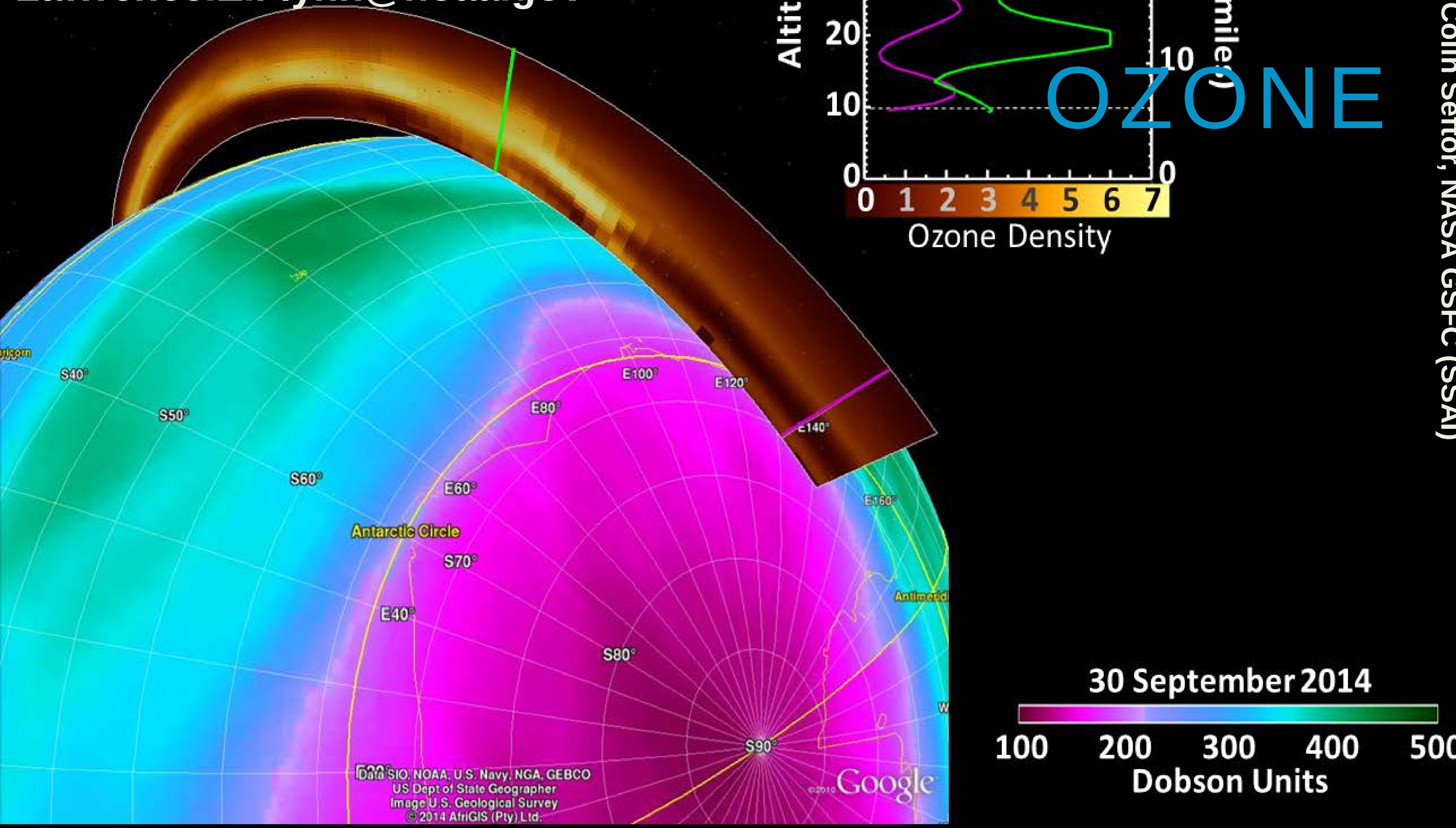


Figure provided by Colin Seftor, NASA GSFC (SSAI)

Outline

- Cal/Val Team Members
- Sensor/Algorithm Overviews
  - Sensor overview
  - Algorithm overview
- S-NPP Products Overview
- JPSS-1 Readiness
- Summary and Path Forward

Ozone Cal/Val/Alg Team Membership

EDR	Name	Organization	Tasks and Responsibilities
Lead	Lawrence Flynn	NOAA/NESDIS/STAR	Ozone EDR Team
Sub-Lead	Irina Petropavlovskikh	NOAA/ESRL/CIRES	Ground-based Validation
Sub-Lead	Craig Long	NOAA/NWS/NCEP	Product Applications
Sub-Lead	Trevor Beck	NOAA/NESDIS/STAR	Algorithm development and reprocessing
Member	Jianguo Niu	STAR/IMSG/SRG	Algorithm development, trouble shooting, Limb Profiler science
Member	Eric Beach	STAR/IMSG	Validation, ICVS/Monitoring, Data management
Member	Zhihua Zhang	STAR/IMSG	V8 Algorithms implementation and modification
Member	Eve-Marie Devaliere	STAR/ERT	Limb Profiler algorithms
JAM	Laura Dunlap	JPSS/Aerospace	Coordination
Adjunct	Bigyani Das	STAR/AIT	Deliveries
Ozone PAL	Vaishali Kapoor	OSDPD	Ozone Product Area Lead

Measurement Overview

Nadir Mapper (NM)

Grating spectrometer, 2-D CCD
110 deg. cross track,
300 nm to 380 nm spectral,
1.1nm FWHM bandpass

Nadir Profiler (NP)

Grating spectrometer, 2-D CCD
Nadir view, 250 km cross track,
250 nm to 310 nm spectral,
1.1 nm FWHM bandpass

Limb Profiler (LP)

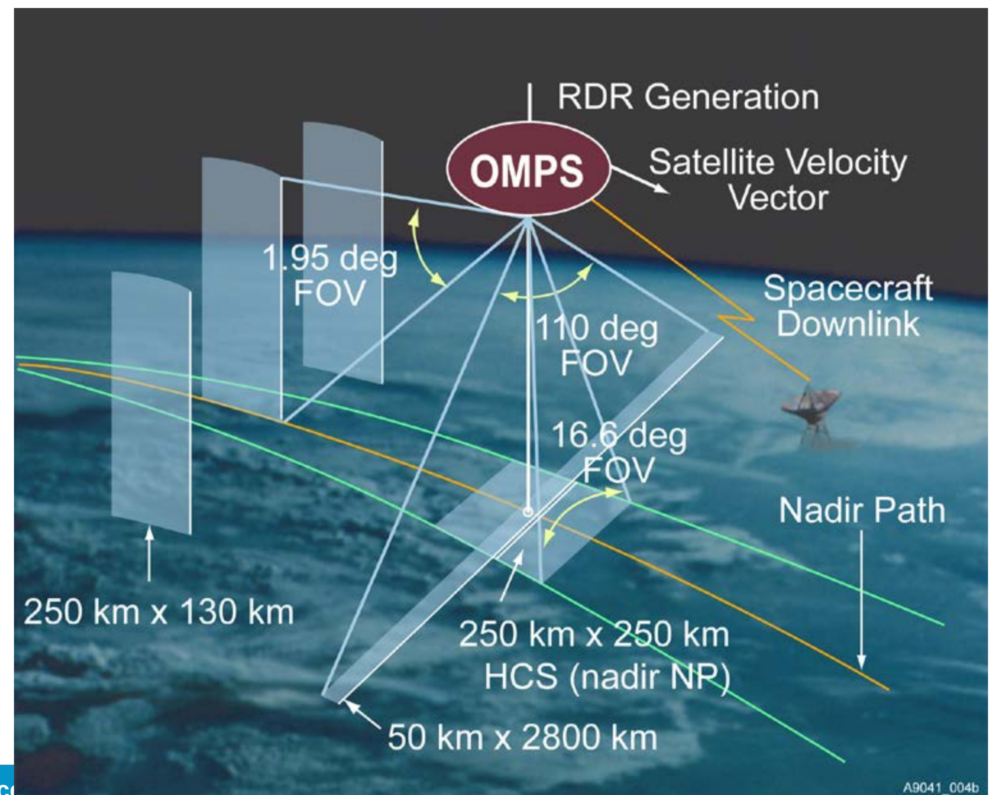
Prism spectrometer, 2-D CCD
Three vertical slits, -20 to 80 km,
290 nm to 1000 nm

The calibration systems use pairs of working and reference solar diffusers.

Ozone Mapping & Profiler Suite

Global daily monitoring of the three dimensional distribution of ozone and other atmospheric constituents.

Continues the NOAA SBUV/2, EOS-AURA OMI and SOLSE/LORE records.



OMPS Version 8 Total Ozone EDR Requirements

- JPSS Level 1 Requirements Document (L1RD) Supplement for the OMPS Ozone Total Column Environmental Data Records (EDRs)

Table 5.2.11 - Ozone Total Column (O

EDR Attribute	Threshold
Ozone TC Applicable Conditions: 1. Threshold requirements only apply under daytime conditions with Solar Zenith Angles (SZA) up to 80 degrees. 2. The EDR shall be delivered for all SZA	
a. Horizontal Cell Size	50 x 50 km² @ nadir
b. Vertical Cell Size	0 - 60 km
c. Mapping Uncertainty, 1 Sigma	5 km at Nadir
d. Measurement Range	50 - 650 milli-atm-cm
e. Measurement Precision	
1. X < 0.25 atm-cm	6.0 milli-atm-cm
2. 0.25 < X < 0.45 atm-cm	7.7 milli-atm-cm
3. X > 0.45 atm-cm	2.8 milli-atm-cm + 1.1% ~2%
f. Measurement Accuracy	
1. X < 0.25 atm-cm	9.5 milli-atm-cm
2. 0.25 < X < 0.45 atm-cm	13.0 milli-atm-cm
3. X > 0.45 atm-cm	16.0 milli-atm-cm ~3%
g. Refresh	At least 90% coverage of the globe every 24 hours (monthly average)

Verification of Performance:

a. 20-Pixel Aggregation and 7-S along track integration.
b. 318 nm channel BUV comes from the surface to top of atmosphere. Standard profiles in tables account for full range.
c. Confirmed by coastlines and comparison to 750x750 m^2 VIIRS.
d. Confirmed by standard profiles and four years of processing and ground-based matchup scatter.
e. Precision estimates from Nearest Neighbor analysis. Use of 1512 Latitude/Month/TOz profiles.
f. Accuracy is adjusted by soft calibration and checked by zonal mean and overpass statistics.
g. 105° cross-track swath provides full daily coverage.

OMPS Version 8 Ozone Profile EDR Requirements

Ozone Nadir Profile (OMPS-NP) (3)	
Attribute	**Threshold**
a. Horizontal Cell Size	250 x 250 km^2 (1)
b. Vertical Cell Size	3 km reporting
1. Below 30 hPa (~ < 25 km)	10 -20 km
2. 30 -1 hPa (~ 25 -50 km)	7 -10 km
3. Above 1 hPa (~ > 50 km)	10 -20 km
c. Mapping Uncertainty, 1 Sigma	< 25 km
d. Measurement Range 0-60 km	0.1-15.0 ppmv
e. Measurement Precision (2)	
1. Below 30 hPa (~ < 25 km)	Greater of 20 % or 0.1 ppmv
2. 30 -1 hPa (~ 25 -50 km)	5% -10%
3. Above 1 hPa (~ > 50 km)	Greater of 10% or 0.1 ppmv
f. Measurement Accuracy (2)	
1. Below 30 hPa (~ < 25 km)	Greater of 10 % or 0.1 ppmv
2. 30 -1 hPa (~ 25 -50 km)	5% -10%
3. Above 1 hPa (~ > 50 km)	Greater of 10 % or 0.1 ppmv
g. Refresh	At least 60% coverage of the globe every 7 days (monthly average) (2,3)

Notes: 1. SDRs will go to 50x50 km^2 for J-01. 2. The OMPS Nadir Profiler performance is expected to degrade in the area of the South Atlantic Anomaly (SAA) due to the impact of periodic charged particle effects in this region. 3. All OMPS measurements require sunlight, so there is no coverage in polar night areas.

Verification of Performance:

a. 93-Pixel Aggregation and 37.5-S along track integration.
b. Version 8 Algorithms Averaging Kernels
c. Confirmed by to Nadir Mapper and Pixel size.
d. Confirmed by four years of processing and ground-based matchup scatter.
e. Precision estimates from SNR and Version 8 performance.
f. Accuracy is adjusted by soft calibration and checked by zonal mean statistics and Version 8 measurement functions and a priori profiles
g. Suborbital track and precession of orbits.

OMPS Total Ozone Products Algorithm Status and Approach

- Current status of algorithms being considered in your project
  - The Version 8 total ozone algorithm (V8TOz) and Linear Fit SO_2 (LFSO2) algorithm were developed by NASA OMI Science Team.
  - Versions of the total ozone algorithm have been in use at NOAA for operational processing of SBUV/2 and GOME-2 measurements and for offline processing of the OMPS NM measurements.
- Overview of technical approach of the algorithm and its implementation
  - The V8TOz will be implemented on a granule processing to create an EDR. The algorithm combines radiance/irradiance ratios at 12 channels with climatological information and radiative transfer tables for standard ozone profiles to compute estimates of total column ozone, effective reflectivity and aerosols.
  - The algorithm will process up to 105 cross-track by 15 along-track FOVs/granule.
  - The LFSO2 algorithm uses the measurement residuals from the V8TOz retrievals to estimate the SO_2 using three sensitive channels and adjusts the final ozone estimate for the SO_2 absorption effects.
  - The algorithm uses the OMPS NM SDR and GEO products, climatological ancillary data, and radiative transfer look-up tables. We expect to refine the ancillary data in the future, e.g., to use daily snow/ice tiles in place of climatology.
  - Need to change output from EOS HDF5 to NetCDF4
  - Concept of operations
    - Obtain operational NRT OMPS NM SDR and GEO from IDPS at NDE
    - Process SDRs to EDRs granule by granule
    - Process 15 EDR granules at a time to produce the final SO_2 /O_3 estimates.
    - The algorithm uses a set of soft calibration adjustments that will be updated infrequently.
  - Will be implemented in NDE 2.1

OMPS Total Ozone Products Algorithm Status and Approach (Cont.)

- Briefly describe the validation concept
  - Validation is concentrating on comparisons to total ozone retrievals from other total ozone mapping satellite instruments (e.g., SBUV/2, OMI, and GOME-2) and to ground-based records from Dobson and Brewer station.
  - The NOAA JPSS Ozone Team and NASA S-NPP Science Team validated V8TOz products for the first four years of S-NPP data. OMPS LFSO2 products are in use at the European VAAC from the FMI Fast Delivery direct broadcast system.

OMPS Nadir Ozone Profile Products Algorithm Status and Approach

- Current status of algorithms being considered in your project
  - NASA developed the Version 8 nadir ozone profile algorithm (V8Pro) ten years ago, which has been in use for the NOAA SBUV/2 program.
- Overview of technical approach of the algorithm and its implementation
  - The V8Pro will be implemented as granule processing to create an EDR. The algorithm combines radiance/irradiance ratios at 12 channels with climatological information and radiative transfer tables for standard ozone profiles to compute maximum likelihood estimates of ozone vertical profiles, effective reflectivity and aerosols.
  - The algorithm is designed for producing retrievals for Nadir centered FOVs.
  - The algorithm uses the OMPS NM and NP SDR and GEO products, climatological ancillary data, and radiative transfer look-up tables. We expect to refine the ancillary data in the future, e.g., use daily snow/ice tiles in place of climatology.
  - Changing output from EOS HDF5 to NetCDF4
  - Concept of operations
    - Obtain OMPS NM and NP SDR and GEO from IDPS
    - Process SDRs to EDRs granule by granule.
    - The algorithm uses a set of soft calibration adjustments that will be updated infrequently.
  - Will be integrated in NDE 2.1

OMPS Nadir Ozone Profile Products Algorithm Status and Approach (Cont.)

- Briefly describe the validation concept
  - Validation is concentrating on comparisons to ozone retrievals from other ozone profile instruments (e.g., SBUV/2) and to ground-based records from Umkehr and Ozonesonde stations.
  - The NOAA JPSS Ozone Team and NASA S-NPP Science Team validated V8Pro products for the first four years of S-NPP data.

S-NPP Product Overview (1/2)

- List of Products
  - Total Column Ozone (O_3, SO_2, reflectivity, Absorbing aerosol index)
    - V7MTTOz (IDPS)
    - V8TOZ (NDE) (Enterprise/Heritage Algorithm)
    - LFSO2 (NDE) (No SO_2 exclusion for J-01)
  - Nadir Ozone Profile
    - V8Pro (IDPS Mx8.11, NDE) (Enterprise/Heritage Algorithm)
  - Limb Ozone Profile (high vertical resolution)
    - Limb V2.0 (NDE)
  - TOAST (CrIS Ozone with OMPS Ozone)
  - BUFR products in development with user input.

S-NPP Product Overview (2/2)

- Reprocessing as better SDRs are provided
  - Total Column Ozone (O_3, SO_2, reflectivity, Absorbing aerosol index)
    - V8TOZ/LFSO2
  - Nadir Ozone Profile
    - V8Pro
  - Limb Ozone Profile will be reprocessed by NASA
    - Limb V2.5 (NASA PEATE in research)
- S-NPP Cal/Val Status
  - Finalizing V8 soft calibration adjustments
- ICVS pages are in transition from Demonstration to Permanent

www.star.nesdis.noaa.gov/smcd/spb/OMPSDemo/index.php

www.star.nesdis.noaa.gov/jpss/EDRs/products_ozone.php

JPSS-1 Readiness – Algorithms

- Major Accomplishments and Highlights Moving Towards J-01
  - V8Pro was implemented in IDPS Mx8.11
  - Delivered V8TOz single granule package with medium FOV capability to NDE
  - Delivered 15-granule moving-window version of the LFSO2 Code to NDE
  - Ready to deliver V8Pro single granule package with medium FOV capability to NDE
  - Working with NASA on early operations and Cal/Val Plan test timelines
- J1 Algorithm Summary
  - LFSO2/V8TOz for 17x17 km^2 FOV

The V8TOZ has been implemented on LINUX systems with NetCDF output. The LFSO2/V8TOz has been adapted to run on 15-granule sequences on the STAR LINUX system using the first-run V8TOz EDR as input. Both algorithms have been delivered with the capability to handle large and medium FOV SDR products, and they will be integrated into NDE following the October 2016 NDE Block 2.0 ORR.

  - V8Pro for medium FOV

The V8Pro has been implemented in IDPS. We have developed a new glue-ware aggregator to create 50x250 km^2 FOV EDR product from the full range of large and medium FOV SDR products. The algorithm will be delivered after completion of the code reviews, and it will be integrated into NDE following the October 2016 ORR.

JPSS-1 Readiness – Cal/Val

- J1 Cal/Val Overview
  - Pre-Launch Calibration/Validation Plans
    - Ozone Cal/Val Plan Completed January 2016
    - Demonstrating V8Pro and V8TOz soft calibration capabilities with S-NPP
    - Working to develop and test all analysis programs as described in the plan with new medium FOV data sets.
  - Post-Launch Calibration/Validation Plans
    - "Beta" ten days after activation and doors open (launch plus 60 days).
      - Geolocation, product range and reporting
    - "Provisional" L+120 days.
      - Precision and first iteration of soft calibration
    - "Validated 1" after ICV (L+210 days)
      - Accuracy and stability from six months of data
    - “Validated 3” After 1 year of measurements (L+410 days)
      - Accuracy and stability over one annual cycle

JPSS-1 Readiness – Issues & Applications

- Issues / Mitigation
  - Program guidance on platform for OMPS products – NDE Transition
    - Products in NetCDF4 (+ changes for downstream)
    - Details for product deliveries to Users (BUFR) , STAR and CLASS
    - New system for maintenance and table deliveries
  - Small FOV preparations / Using diagnostic test data sets, CCR Requesting upgrade for S-NPP OMPS to Flight Software 6.0
  - Uneven records (moving targets) / Develop better initial tables and reprocessing capabilities
    - Product validation analysis has to be repeated or adjusted as new algorithms and SDR resolution improvements and calibration corrections enter the system.
  - NP Degradation, wavelength scale, solar activity and bandpass / Working with SDR team to implement and demonstrate improvements for S-NPP OMPS.

- Users' Readiness
  - We are upgrading the BUFR products to be created from the OMPS V8 algorithm products and parameters. V8 algorithm BUFR products are already in use.
  - We are working on soft calibration to homogenize the suite of ozone products from OMPS, SBUV/2, OMI and GOME.
  - We are working with users of aerosol, SO_2 and O_3 products to prepare them for the higher spatial resolution products.

Summary

- Heritage/Enterprise Version 8 algorithms are ready for implementation at NDE and provide the capability to process medium FOV J-01 data.
- The products will meet the program requirements.
- OMPS Limb Profiler products will also be made operationally at NDE.

FY17 OMPS EDR Milestones/Deliverables

Task Category	Task/Description	Start	Finish	Deliverable
Development (D)	Deferred algorithm improvements (EOFs, Solar, Wavelengths, Bandpasses]	Present	Q3	Code modification
Integration & Testing (I)	Final V8Pro, LFSO2, and V2LP algorithm deliveries to NDE	Present	Q1, Q2	Code logic and output changes
Calibration & Validation (C)	Final RT Tables for J-01 Evaluation/validation of S-NPP V8 products including SO2 Prepare, demonstrate and exercise tools for J-01 Soft Calibration for J-01	Present	Q2 Q1,Q2 Q2, Q3 Q4	New Tables Report and statistics on C/V C/V Plan RR and execution Adjustment LUT
Maintenance	Monitor performance and resolve anomalies	Ongoing	Ongoing	New DRs and CCRs as needed
LTM & Anomaly Resolution (L)	Continue and expand ICVS Monitoring Trending of ground-based comparisons	Ongoing Ongoing	Ongoing Q4	New ICVS content Report for S-NPP and J-01

Path Forward (FY-18 thru FY-21)
High Priority Ozone Tasks/Milestones

	S-NPP	JPSS-1	JPSS-2
FY18	**Sustainment, monitoring, maintenance** **Develop Cloud Optical Centroid and DOAS NO_2 and SO_2 Retrievals**	**Provide feedback to SDR Team** **Complete Validation of Ozone Profile, Total Column Ozone, Aerosol Index, and Total Column SO_2 per Cal/Val Plan**	**Review FM3 performance and evaluate impact of any waivers etc.**
FY19	**Sustainment, monitoring, maintenance, reprocessing**	**Complete coordination with users for applications** **Sustainment, monitoring, maintenance**	**J-02 product algorithm review including Limb Profiler**
FY20		**Sustainment, monitoring, maintenance**	**Deliveries for J-02 tables and code specifics**
FY21		**Sustainment, monitoring, maintenance, reprocessing**	**Prepare resources and analysis tools to execute Cal/Val Plan**

OMPS NP EDR Performance Characteristics

Table 4.2.4 - Ozone Nadir Profile (OMPS-NP)

Attribute	Threshold	Objective
Ozone NP Applicable Conditions: 1. daytime only (3)		
a. Horizontal Cell Size	250 X 50 km^2 (1)	50 x 50 km^2
b. Vertical Cell Size	3 km reporting	
1. Below 30 hPa (~ < 25 km)	10 -20 km	3 km (0 -Th)
2. 30 -1 hPa (~ 25 -50 km)	7 -10 km	1 km (TH -25 km)
3. Above 1 hPa (~ > 50 km)	10 -20 km	3 km (25 -60 km)
c. Mapping Uncertainty, 1 Sigma	< 25 km	5 km
d. Measurement Range		
Nadir Profile, 0 - 60 km	0.1-15 ppmv	0.01 -3 ppmv (0-TH) 0.1-15 ppmv (TH-60 km)
e. Measurement Precision (2)		
1. Below 30 hPa (~ < 25 km)	Greater of 20 % or 0.1 ppmv	10% (0 -TH)
2. At 30 hPa (~ 25 km)	Greater of 10 % or 0.1 ppmv	3%
3. 30 -1 hPa (~ 25 -50 km)	5% -10%	1%
4. Above 1 hPa (~ > 50 km)	Greater of 10% or 0.1 ppmv	3%
f. Measurement Accuracy (2)		
1. Below 30 hPa (~ < 25 km)	Greater of 10 % or 0.1 ppmv	10% (0 -15 km)
2. 30 -1 hPa (~ 25 -50 km)	5% -10%	5% (15 -60 km)
3. At 1 hPa (~ 50 km)	Greater of 10 % or 0.1 ppmv	5% (15 -60 km)
4. Above 1 hPa (~ > 50 km)	Greater of 10 % or 0.1 ppmv	5% (15 -60 km)
g. Refresh	At least 60% coverage of the globe every 7 days (monthly average) (2,3)	24 hrs. (2,3)

Notes: 1. The SBUV/2 has a 180 km X 180 km cross-track by along -track FOV. It makes its 12 measurements over 24 Samples (160 km of along-track motion). The OMPS Nadir Profiler is designed to be operated in a mode that is able to subsample the required HCS. 2. The OMPS Nadir Profiler performance is expected to degrade in the area of the South Atlantic Anomaly (SAA) due to the impact of periodic charged particle effects in this region. 3. All OMPS measurements require sunlight, so there is no coverage in polar night areas.

23

OMPS TC EDR Performance Characteristics

	Threshold	Objective
Ozone TC Applicable Conditions 1, 2.		
a. Horizontal Cell Size	50 x 50 km2 @ nadir	10 x 10 km2
b. Vertical Cell Size	0 - 60 km	0 - 60 km
c. Mapping Uncertainty, 1 Sigma	5 km at Nadir	5 km
d. Measurement Range	50 - 650 milli-atm-cm	50-650 milli-atm-cm
e. Measurement Precision	.	.
1. X < 0.25 atm-cm	6.0 milli-atm-cm	1.0 milli-atm-cm
2. 0.25 < X < 0.45 atm-cm	7.7 milli-atm-cm	1.0 milli-atm-cm
3. X > 0.45 atm-cm	2.8 milli-atm-cm + 1.1%	1.0 milli-atm-cm
f. Measurement Accuracy	.	.
1. X < 0.25 atm-cm	9.5 milli-atm-cm	5.0 milli-atm-cm
2. 0.25 < X < 0.45 atm-cm	13.0 milli-atm-cm	5.0 milli-atm-cm
3. X > 0.45 atm-cm	16.0 milli-atm-cm	5.0 milli-atm-cm
g. Latency	90 min.	15 min.
h. Refresh	At least 90% coverage of the globe Every 24 hours (monthly average)	24 hrs.
i. Long-term Stability	1% over 7 years	0.5 % over 7 years
1. Threshold requirements only apply under daytime conditions with Solar Zenith Angles (SZA) up to 80 degrees. 2. The EDR shall be delivered for all SZA. 3. SO2 exclusion removed.		

OMPS LP EDR Performance Characteristics

Table 3.3.1 - Ozone Limb Profile (OMPS-L)		
Attribute	**Threshold**	**Objective**
Ozone LP Applicable Conditions	SZA < 80 degrees	SZA < 88 degrees
a. Horizontal Attributes		
1. Horizontal Cell Size	250 km	125 km
2. Horizontal Reporting	125 km	50 km
b. Vertical Attributes		
1. Vertical Coverage	TH to 60 km	0 km to 60 km
2. Vertical Reporting	1 km	1 km
3. Vertical Resolution		
i. 0 to TH (1)	N/A	3 km
ii. TH to 25	5 km	1 km
iii. 25 km to 60 km	5 km	3 km
c. Mapping Uncertainty, 1 Sigma	< 25 km	< 5 km
d. Measurement Range		
1. 0 to TH (1)	N/A	0.01 to 3 ppmv
2. Th - 60 km	0.1 to 15 ppmv	0.1 to 15 ppmv
e. Measurement Precision		
1. 0 to TH (1)	N/A	10%
2. TH to 15 km	Greater of 10 % or 0.1 ppmv	3%
3. 15 to 50 km	Greater of 3 % or 0.05 ppmv	1%
4. 50 to 60 km	Greater of 10% or 0.1 ppmv	3%
f. Measurement Accuracy		
1. 0 to TH (1)	N/A	10%
2. TH to 15 km	Greater of 20 % or 0.1 ppmv	10%
3. 15 to 60 km	Greater of 10 % or 0.1 ppmv	5%
g. Latency	90 minutes	15 minutes
g. Refresh	At least 75% coverage of the globe every 4 days (monthly average) (2)	24 hrs (2)
h. Long-term Stability	2% over 7 years	1% over 7 years
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.		

OMPS LP aerosol extinction profile measurements in the stratosphere

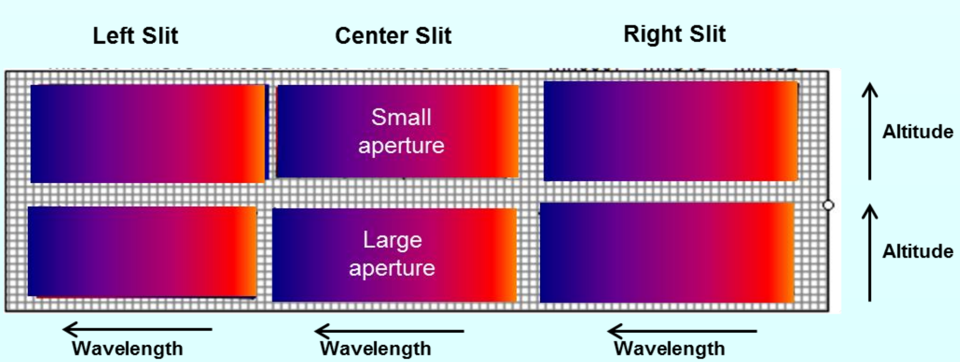
Ghassan Taha[1,2], P.K. Bhartia[2], Philippe Xu[2,3], Robert Loughman[4], and Glen Jaross[2]

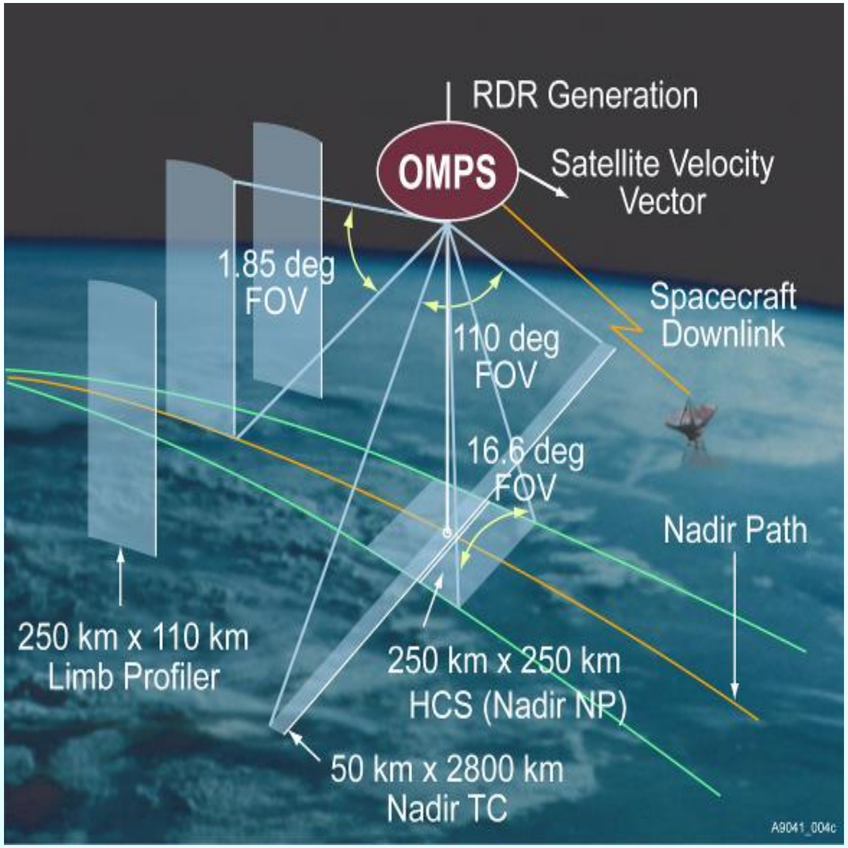
[1]Universities Space Research Association, [2]NASA GSFC, [3]SAIC, [4]Hampton University

OMPS Limb sensor

Limb Profiler

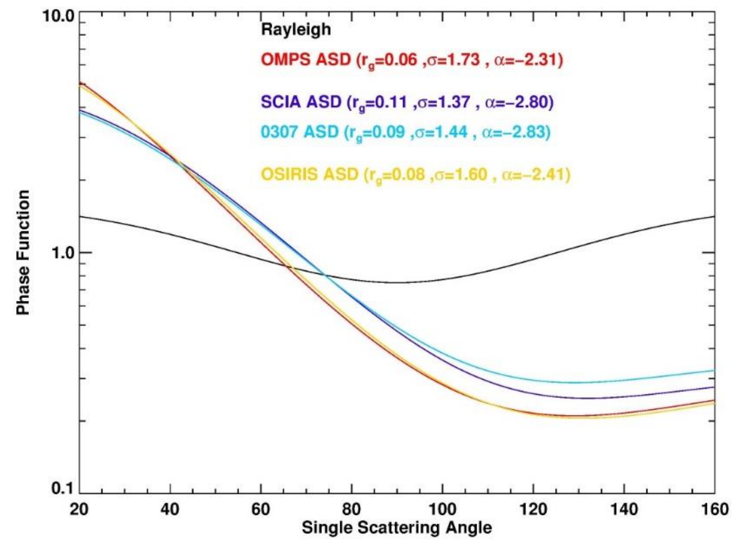
- **Heritage:** SOLSE / LORE, SAGE III, OSIRIS, SCIAMACHY, GOMOS
- **Wavelength:** 280 –1000 nm
- **Vertical range:** 105 km (5 - 80 km consistently)
- **Vertical Sampling:** 1 km
- **Vertical resolution:** ~1.8 km
- **Along-track sampling:** 125 km
- **Detector:** 0.25 megapixel CCD at -45 ^{o}C





Aerosol retrieval algorithm

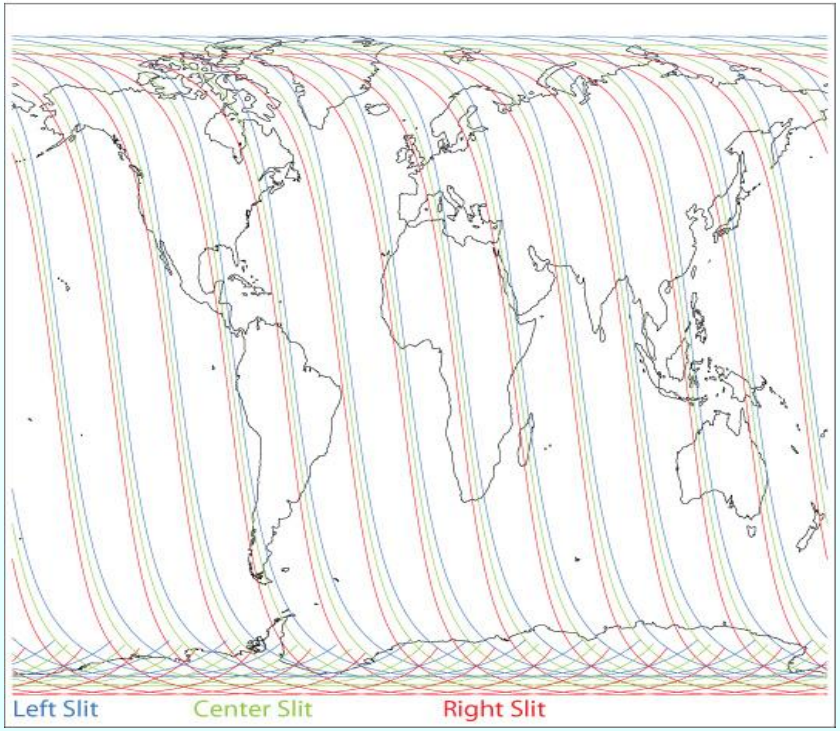
- **OMPS LP current aerosol retrieval algorithm uses Chahine's non-linear relaxation method**
- **Uses 675 nm Rayleigh-corrected radiances $(I-I_0)/I_0$**
  - **– I_0 is calculated using MERRA data assuming no aerosols and 45.5 km reflectivity**
- **Aerosol phase function determined by aerosol size distribution, refractive index and shape**
  - **Use a constant aerosol size distribution (ASD), single-mode log-normal, with no altitude variation: (r_0, σ) = (0.06 µm, 1.73)**
  - **Current data Version 0.5**
- **Data are screened for clouds using Chen et al. [2016]**



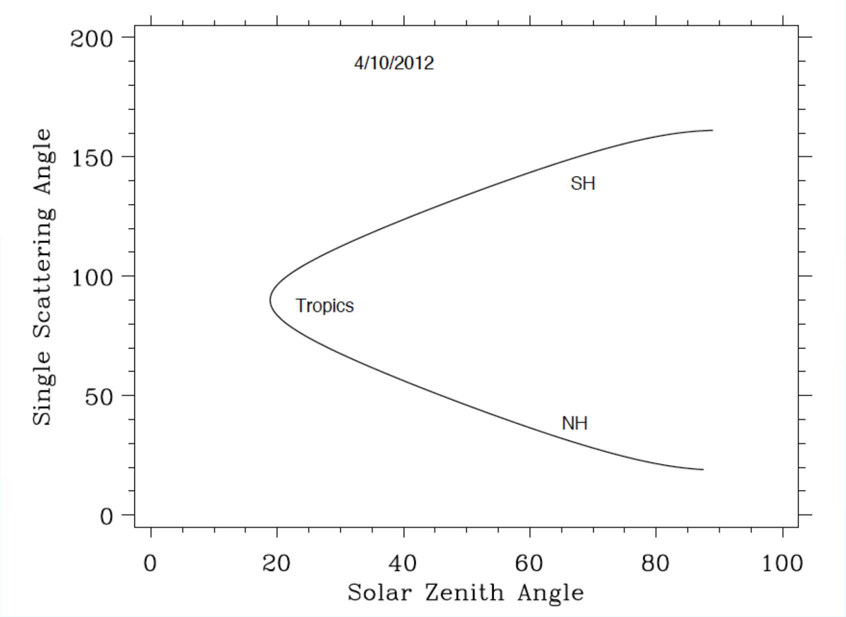
Phase Function at λ=0.674 µm, α (0.674/0.750) µm, *m= 1.448 – i0*

**Deshler 2006/05/06* *Deshler 2003/07/28*

OMPS LP daily coverage



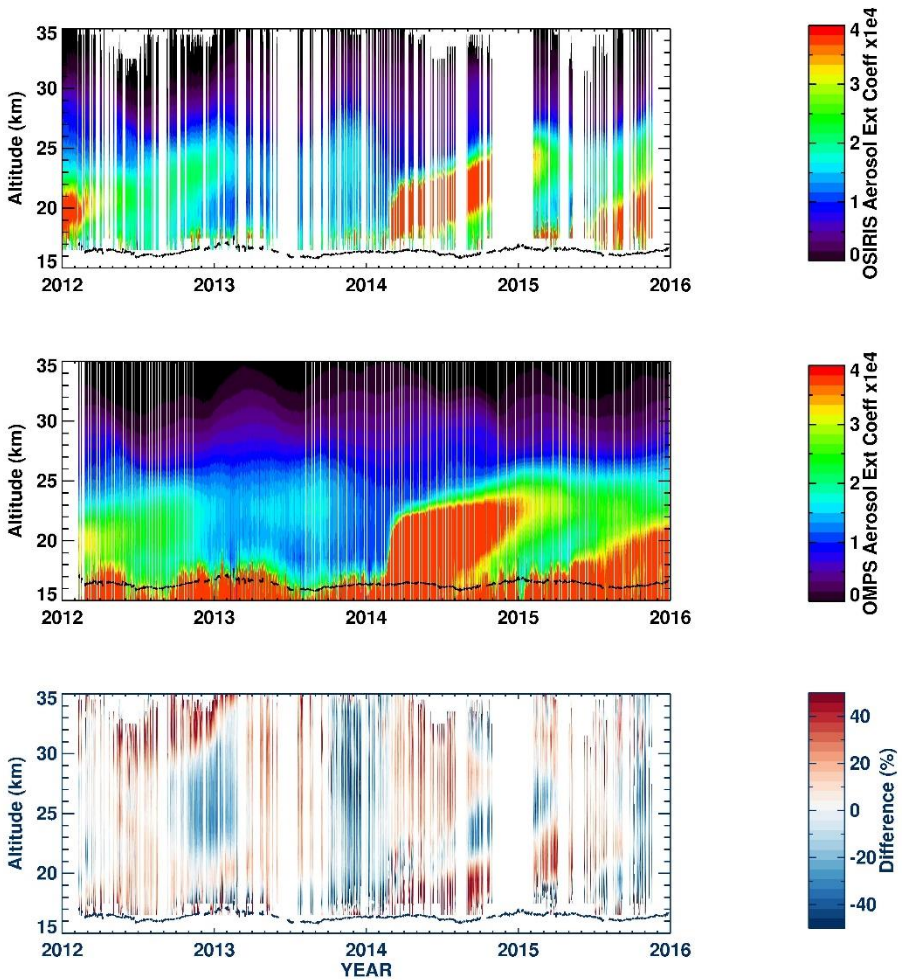
Variation of OMPS LP SSA



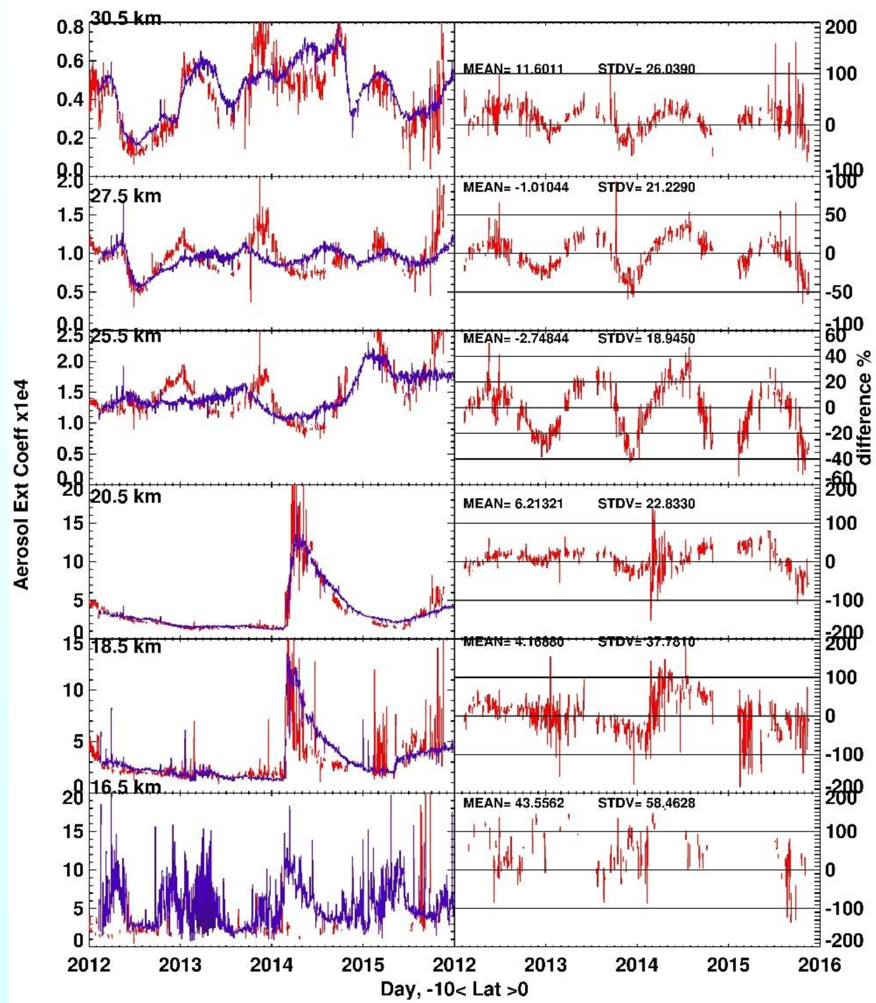
3 slits, 14-15 orbits each day, 160 events, ~7200 measurement daily

OMPS & OSIRIS daily zonal mean comparison Latitude 10S - 0

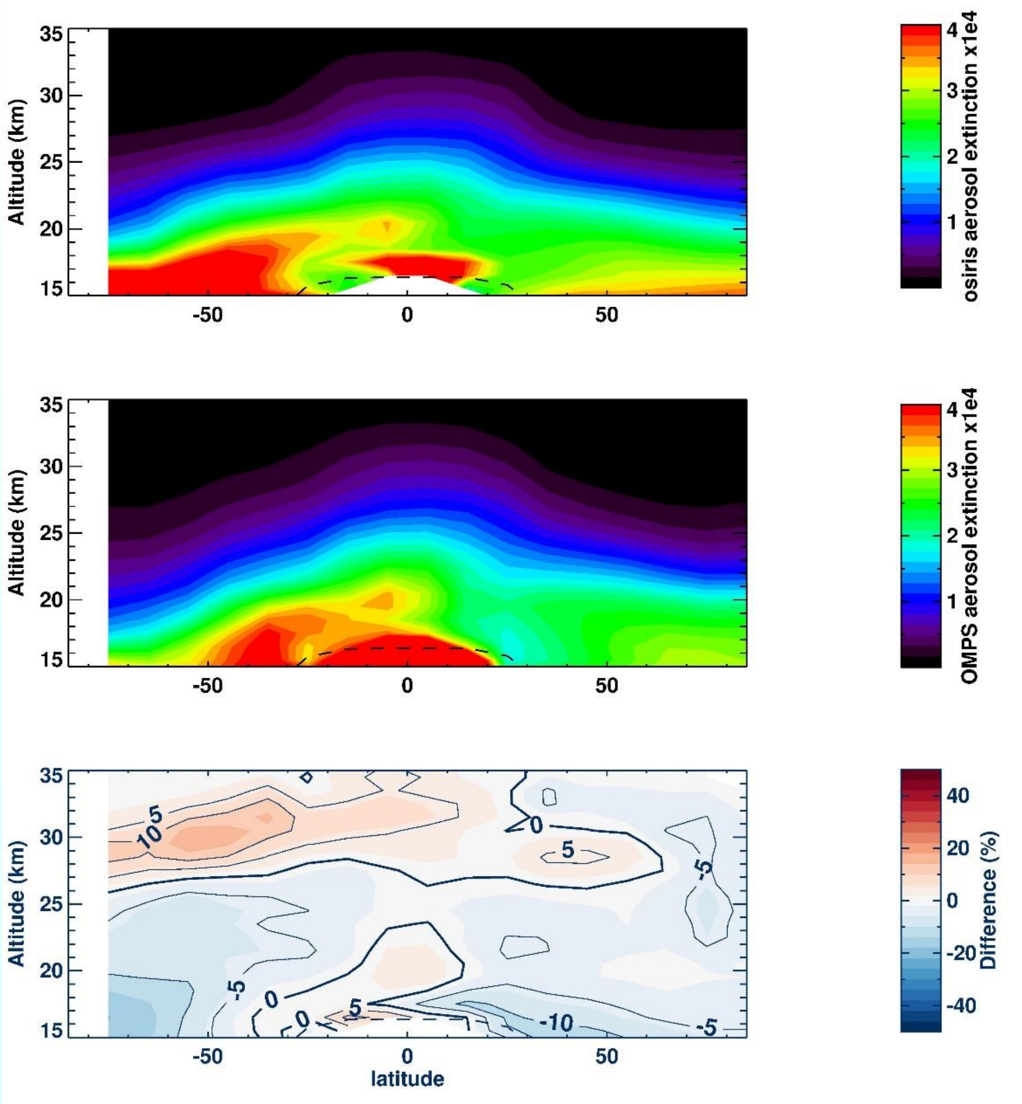
-10< Lat >0



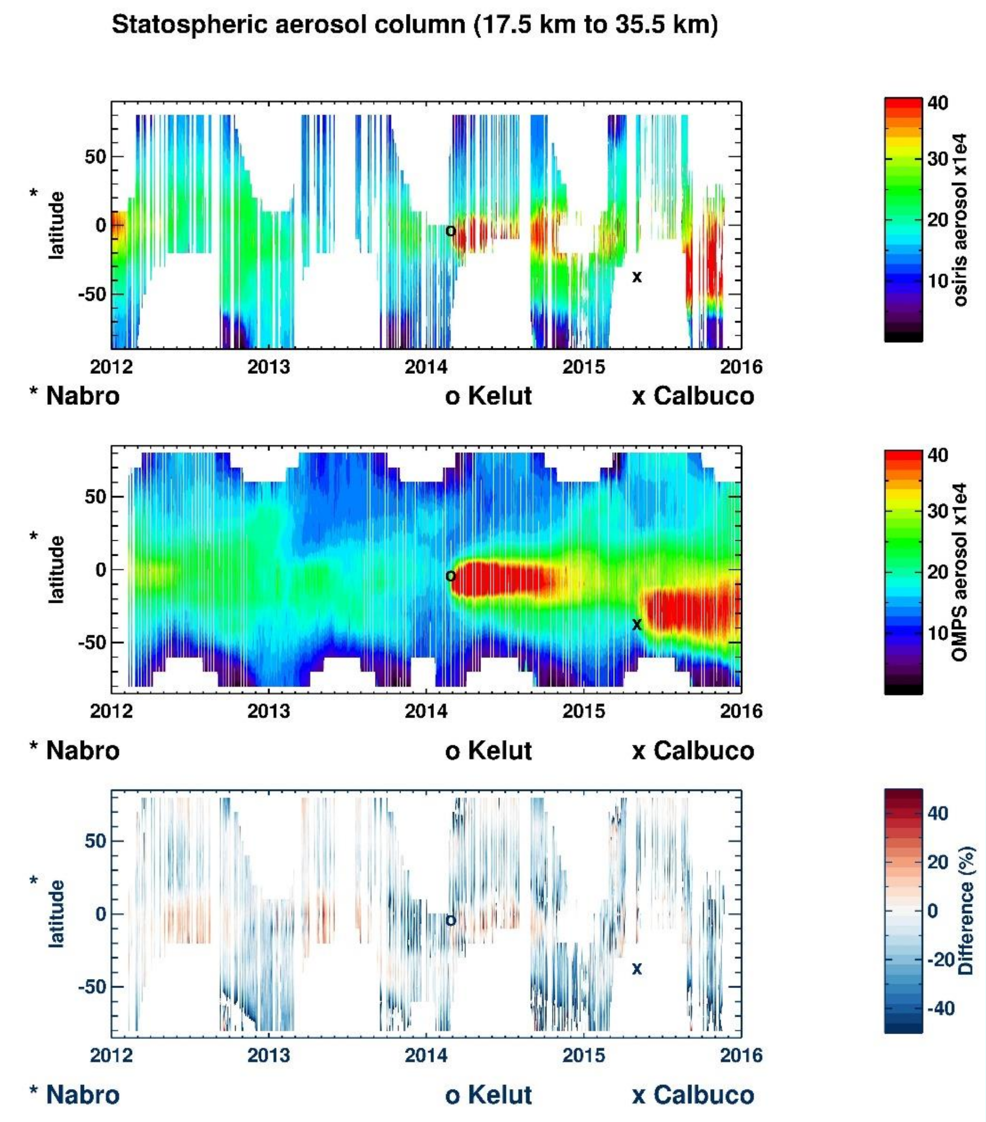
OMPS - OSIRIS %



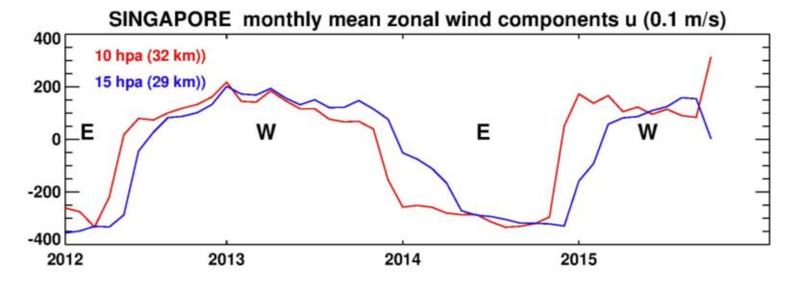
OMPS vs. OSIRIS global zonal mean comparison



OMPS vs. OSIRIS stratospheric column

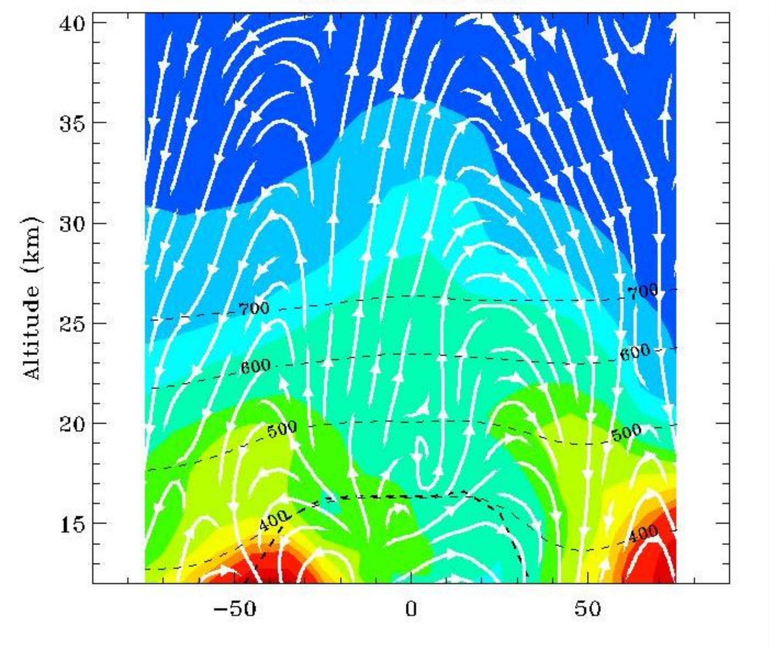


Quasi-Biennial Oscillation (QBO) signature

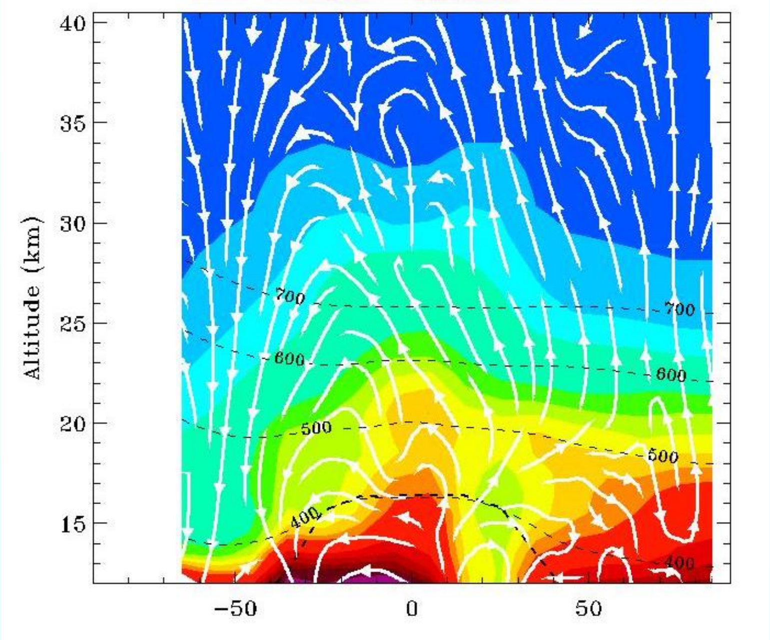


Enhanced tropical aerosol extinction values during easterlies (upward lofting) and drop in aerosol values during westerlies (downward descent).

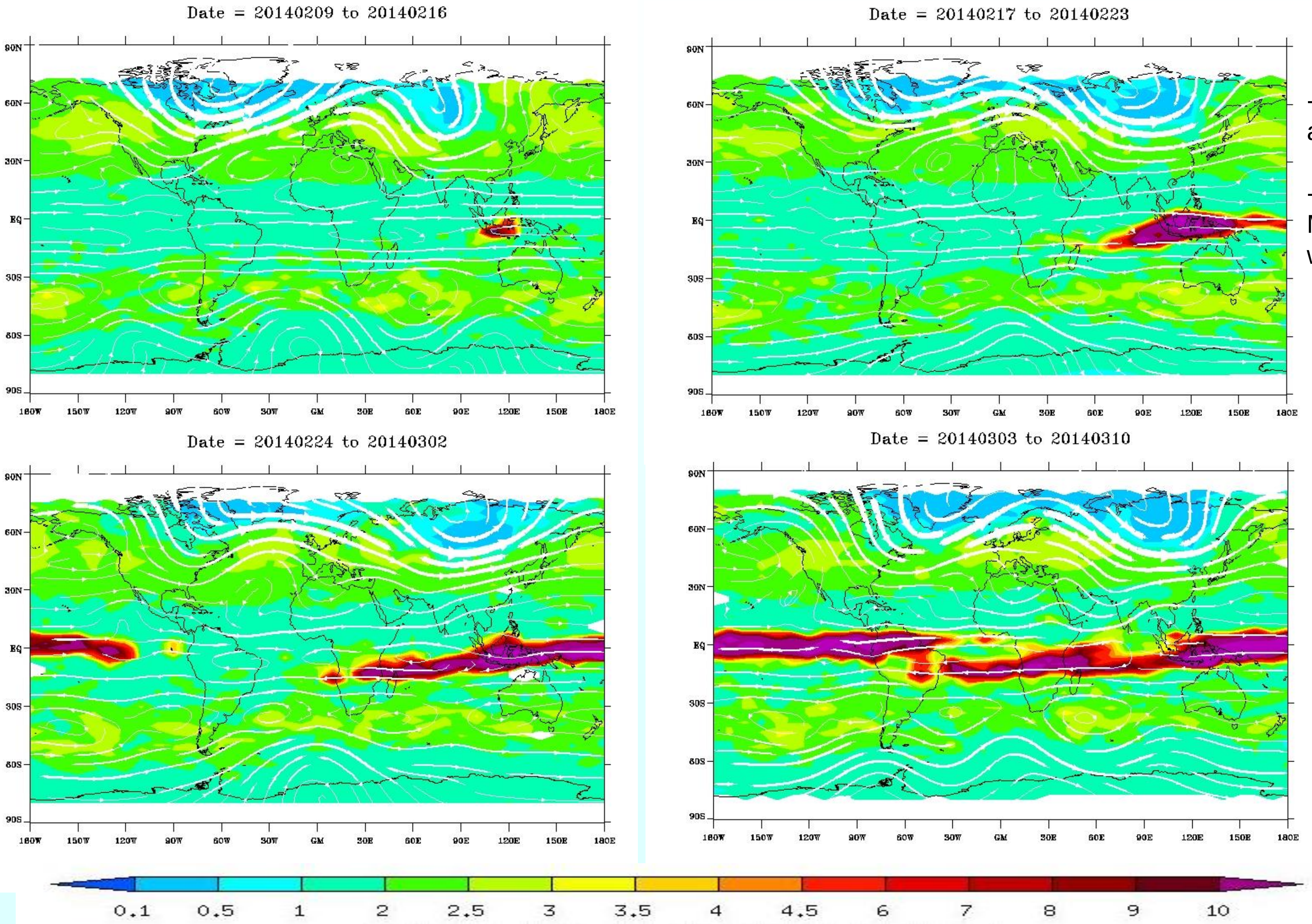
February 2012 (Easterly phase)



May 2012 (Westerly phase)



Tracking Kelut volcanic eruption –first month

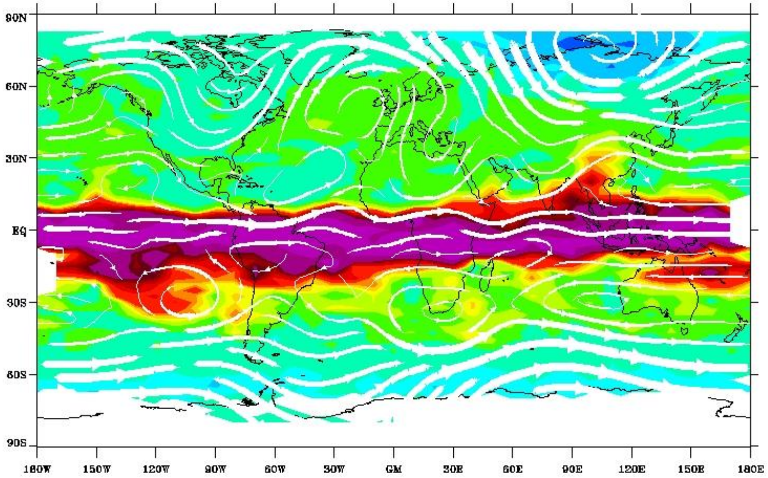


x 10^4 km^{-1}

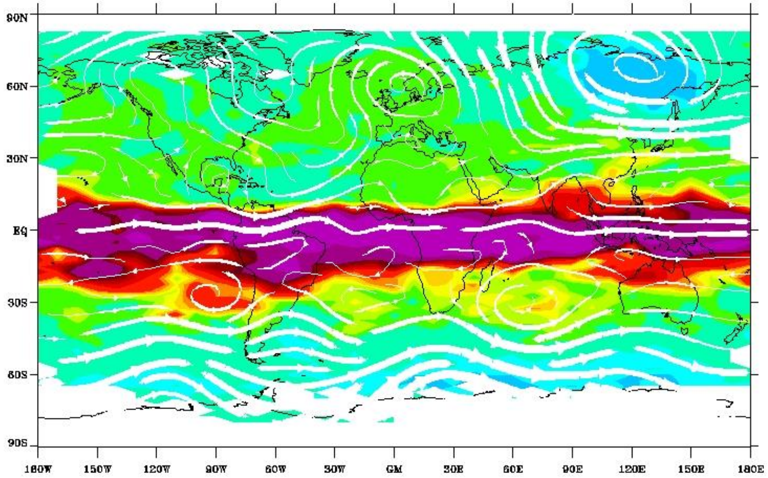
- -Weekly maps at 20.5 km
- -Superimposed MERRA zonal winds

Tracking Kelut volcanic aerosol

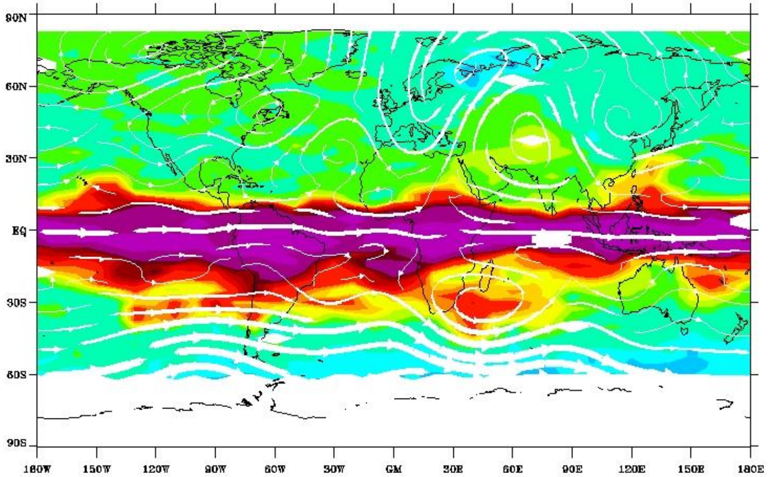
Date = 20140410 to 20140416



Date = 20140417 to 20140423

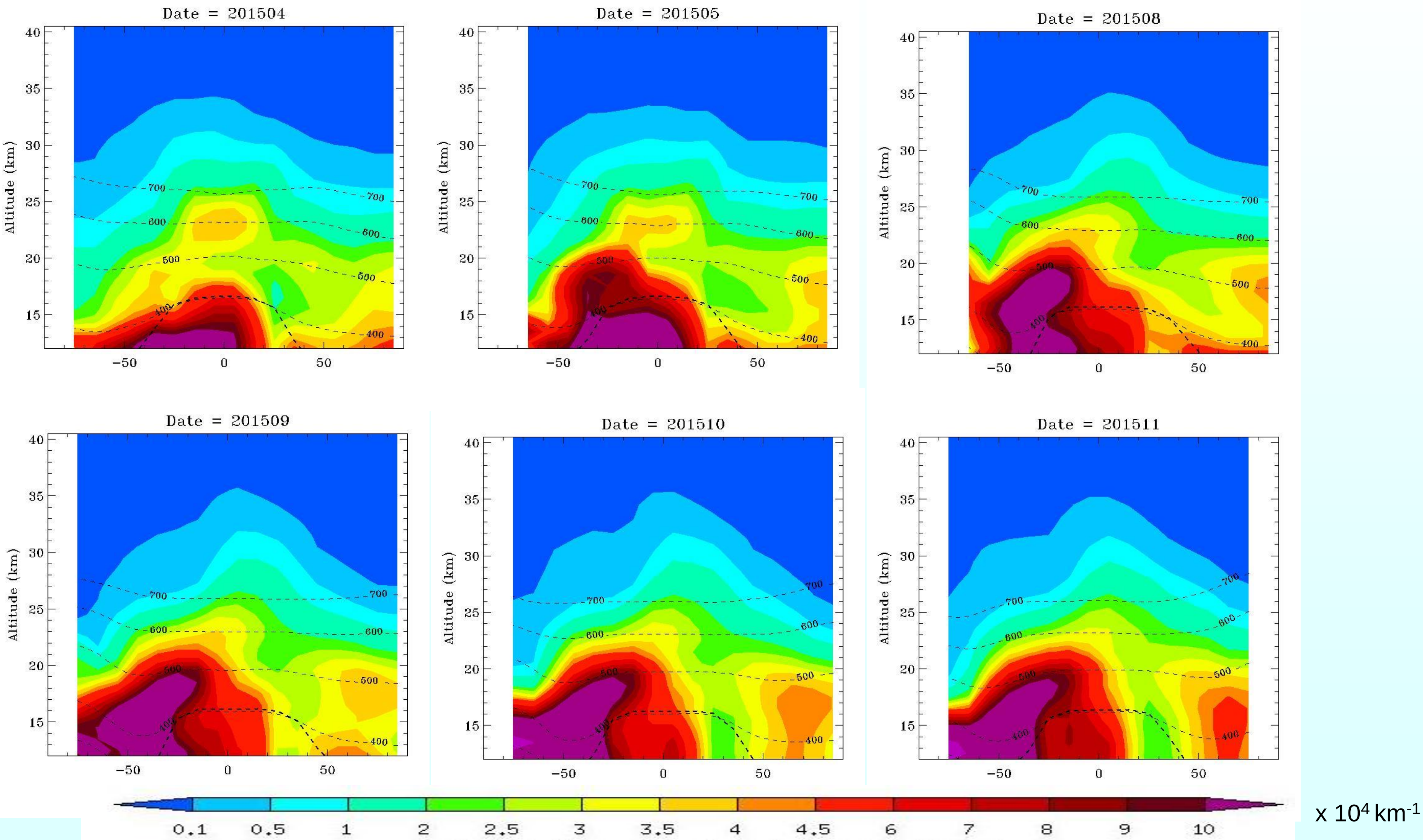


Date = 20140502 to 20140508



- Aerosol transport poleward in synoptic scale tongue of air
- Aerosol transport via anticyclone poleward and trapped inside for weeks.

Injection of Calbuco aerosol in the polar vortex



Future plans

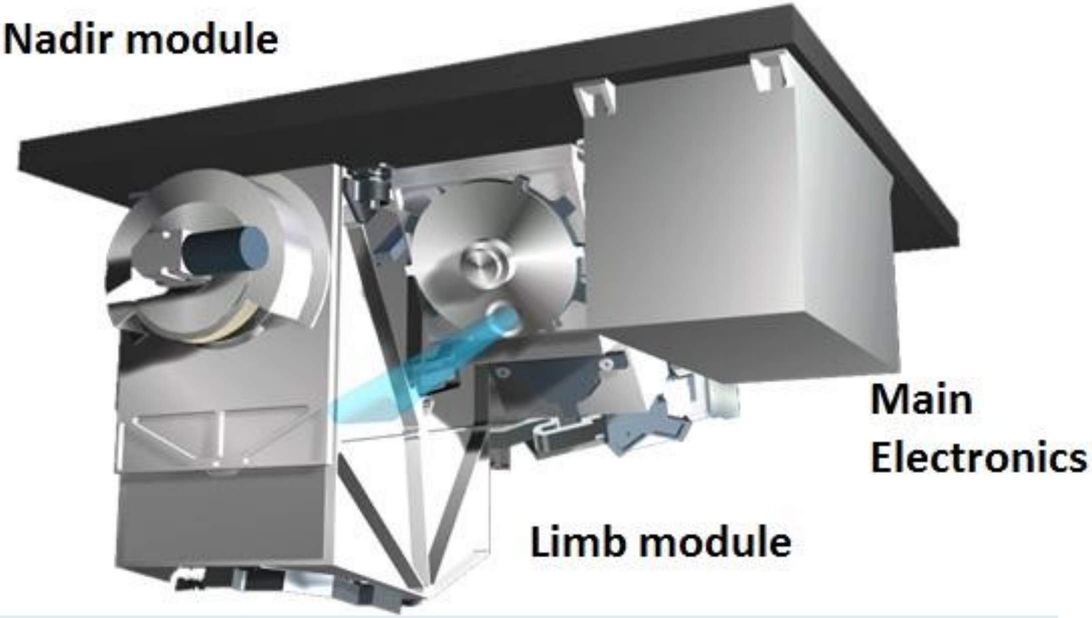
- New V1.0 aerosol data in Sept 2016
  - Improved straylight correction results in better agreement between 3 slits, and improved retrieval in polar region
  - New bimodal lognormal size distribution model with coarse mode fraction of 0.003. Only minor change in aerosol extinction
  - Provides residuals at 8 wavelengths for diagnostics and future improvements.
- Validate OPMS LP V1.0 with OSIRIS, CALIPSO and Models
- Use CALIPSO and CATS polarization measurements to validate and improve the cloud detection algorithm
- Investigate the use of longer wavelength (867 nm) to improve the retrieval at lower altitudes.
- Validate OMPS LP with SAGE III solar and limb measurements (after launch) and utilize SAGE III multi-wavelength and aerosol size information

Ozone profile products from the Suomi NPP OMPS Limb Profiler: overview of the quality of version 2.0 and a path for the updated version 2.5

Natalya Kramarova, P.K. Bhartia, Philippe Xu, Zhong Chen, Leslie Moy, Ghassan Taha, Robert Loughman, Glen Jaross and Matthew DeLand

2016 STAR JPSS Annual Science Team Meeting

Suomi NPP OMPS Limb Profiler



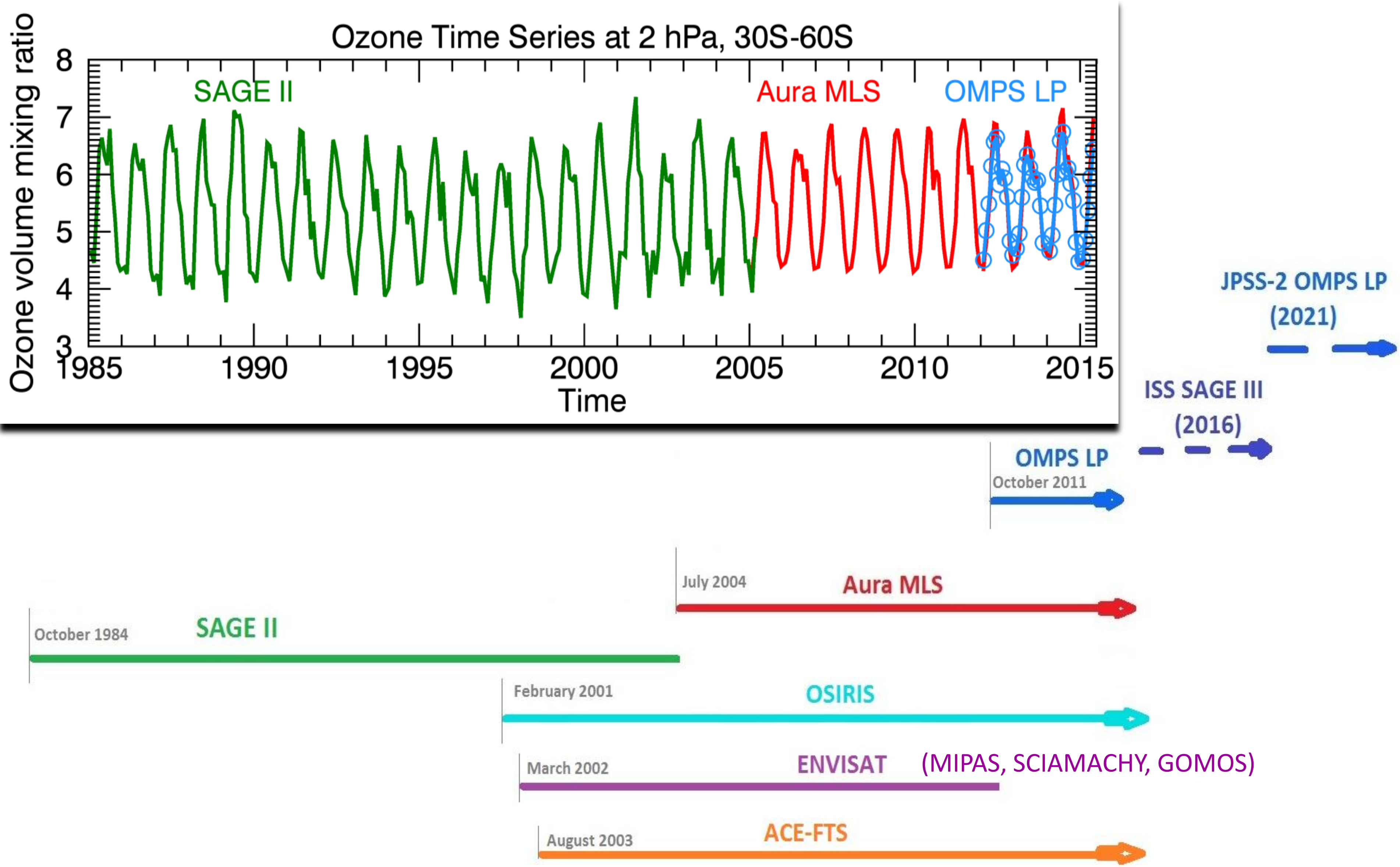
- ➢LP measures limb scattered radiation in the wavelength range 290-1000 nm, with variable resolution (1-25 nm);
- ➢LP has three slits separated horizontally by 4.25 (about 250 km) to expand the sensor cross-track coverage;
- ➢Altitude range: 0-80 km with 1 km sampling and ~ 2 km vertical resolution;
- ➢LP collects radiance spectrum simultaneously from all altitudes;
- ➢LP makes about 160–180 measurements per orbit (~1° latitude sampling) with 14 orbits per day.

OMPS LP ozone vertical profiles version 2.0

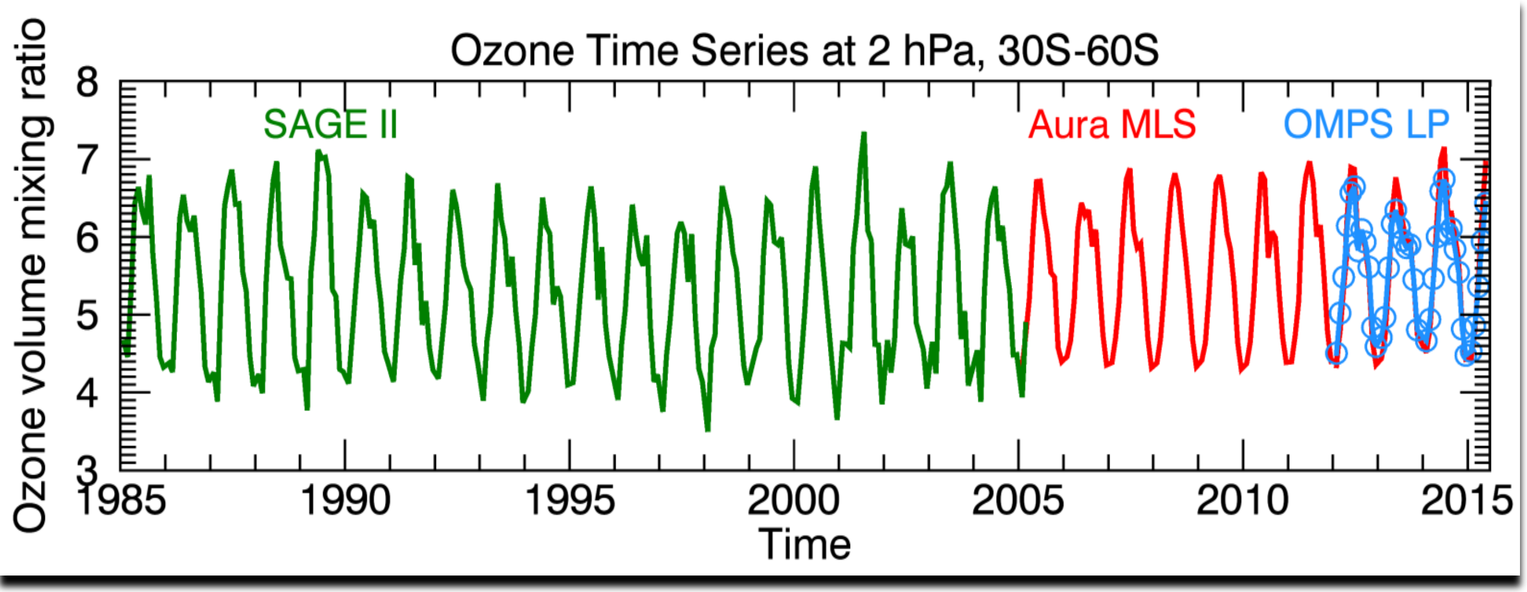
- ▪O3 profiles are independently retrieved from UV and VIS spectral ranges;
- ▪43 UV pairs and 17 VIS triplets;
- ▪ measurements are normalized at 65 km for UV and 45 km for VIS ranges;
- ▪Optimal Estimation technique + Tikhonov regulization;
- ▪The aerosol correction module is turned off.

[D. Rault and R. Loughman, 2013]

Continuation of the ozone climate record



Continuation of the ozone climate record

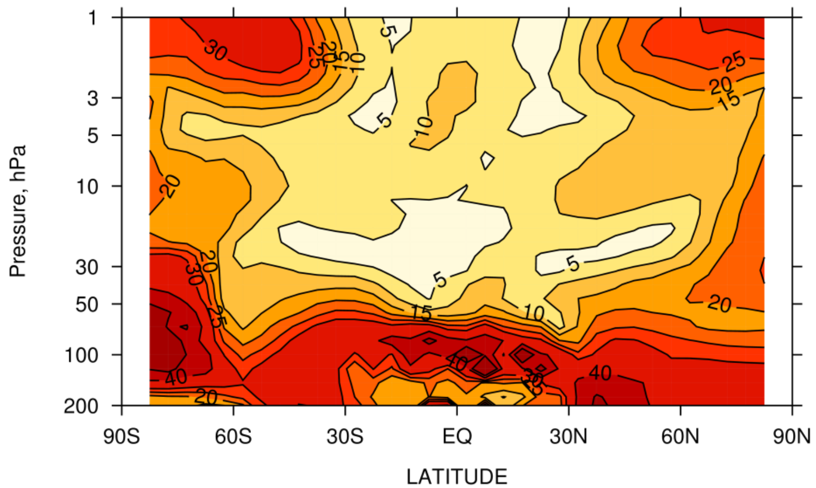


Stability of LP measurements: altitude (or tangent height) registration error is the main source of uncertainties in limb measurements. In addition to the star tracker readings, two methods for the altitude registration - RSAS and ARRM – have been tested and applied. By combining these two methods we can detect the tangent height **with ±200 m uncertainties**. The ARRM method detected a 100m shift in altitude registration in April 2013, later confirmed by the star tracker system. This 100m shift in April 2013 will be corrected in the version 2.5 processing of Level 1 data.

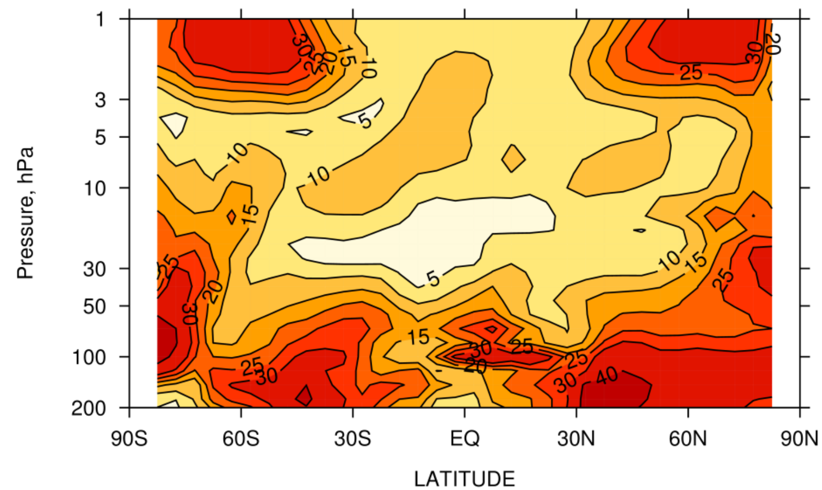
[*Moy et al., Atmos. Meas. Tech. Discuss., doi:10.5194/amt-2016-103, 2016*]

Ozone seasonal cycle: Aura MLS, MIPAS and OMPS LP

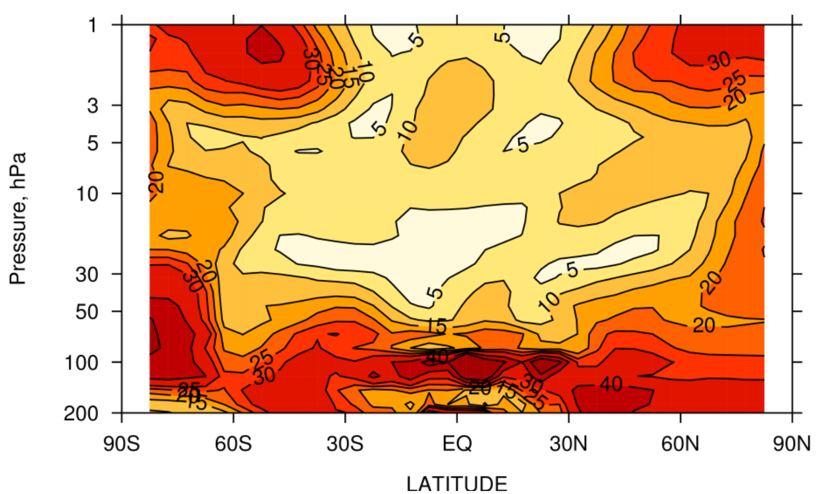
Amplitude of the Seasonal cycle MIPAS, nd(%)



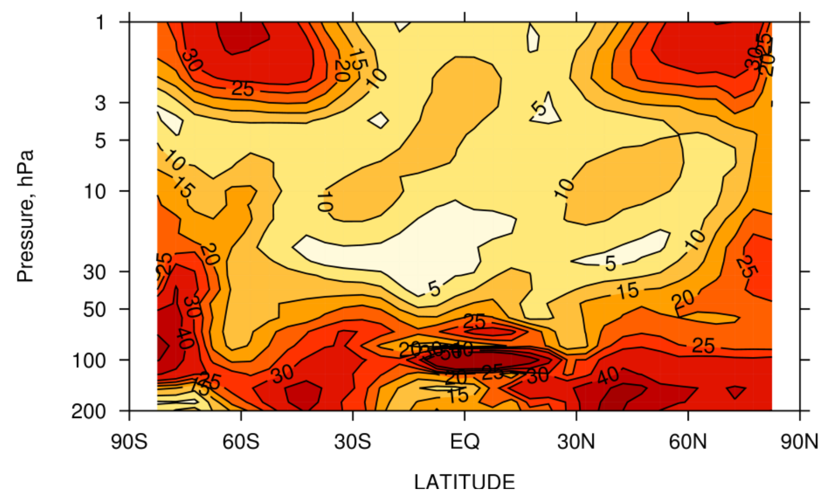
Amplitude of the Seasonal cycle LP, nd(%)



Amplitude of the Seasonal cycle MLS, nd(%)

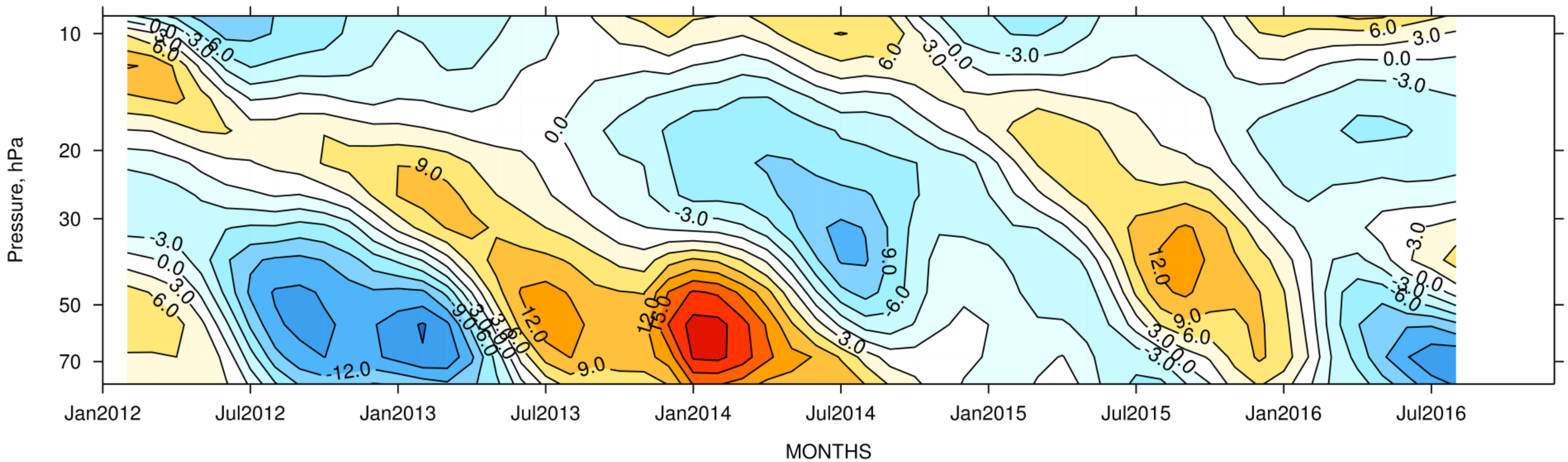


Amplitude of the Seasonal cycle MLS, nd(%)

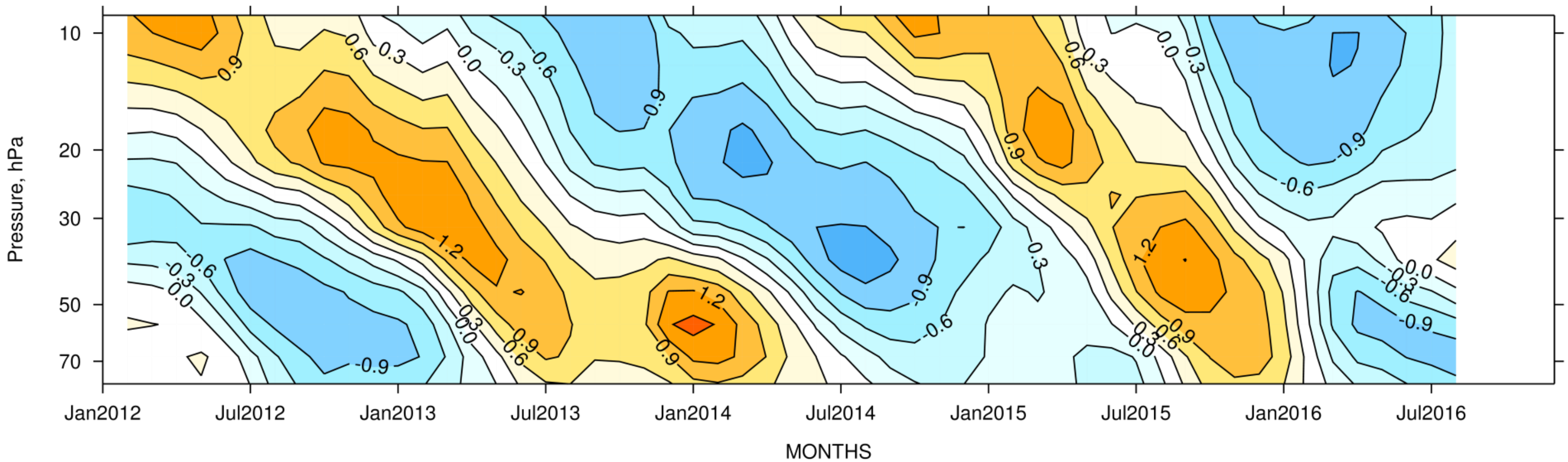


Quasi-Biennial Oscillation in the equatorial stratosphere

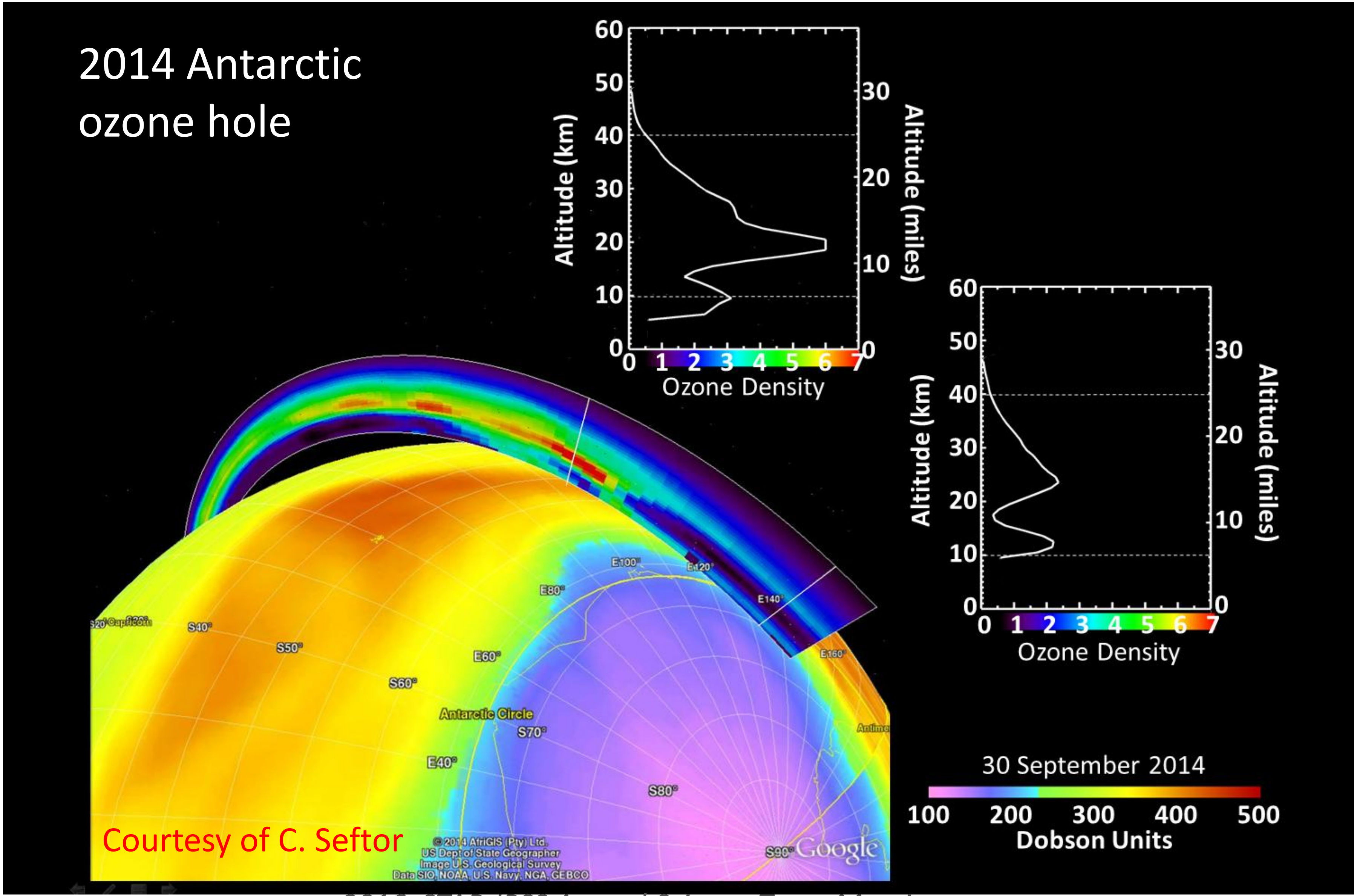
mzm ozone deseasonalized, OMPS LP (%), 5S-5N



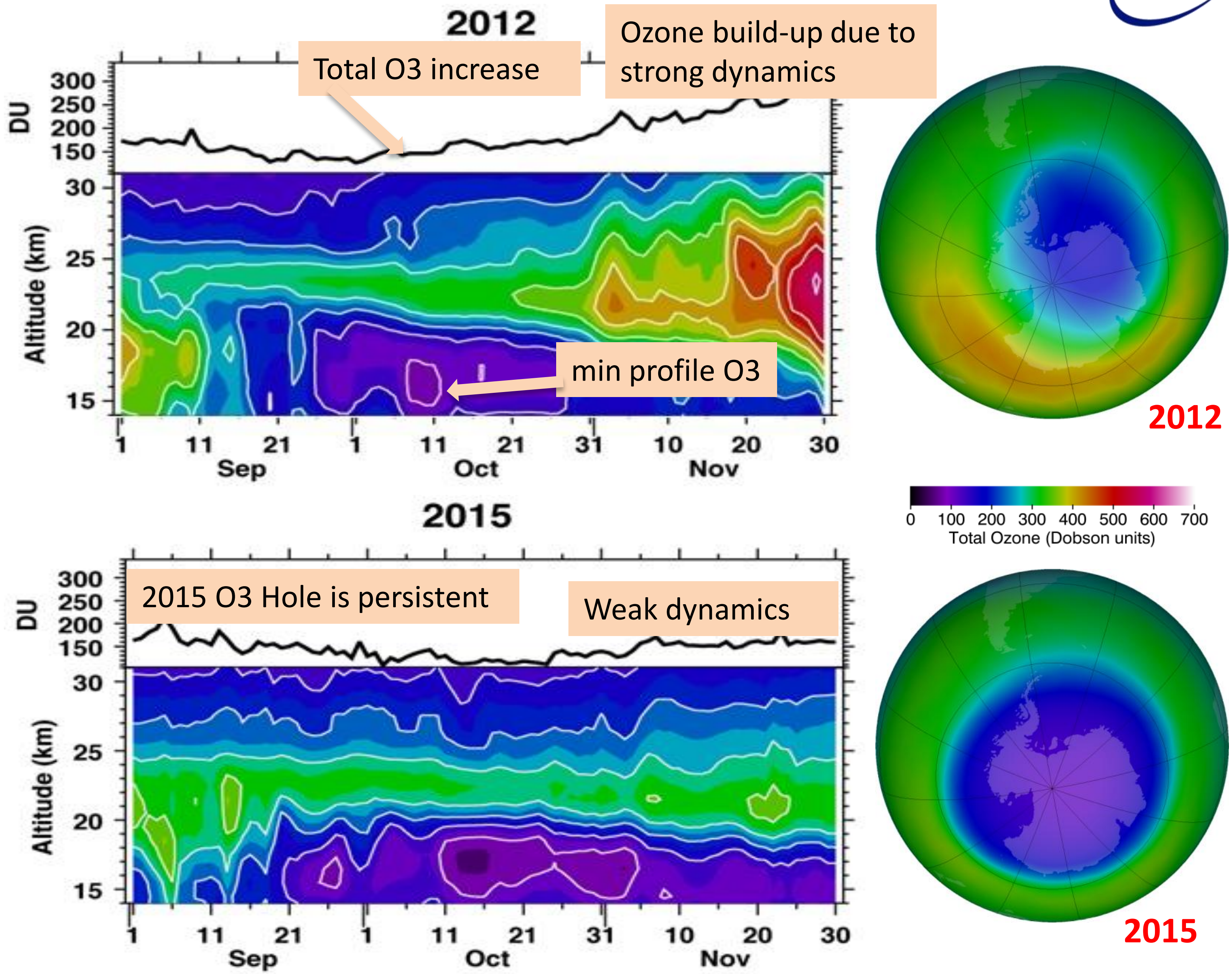
mzm MERRA T deseasonalized (%), 5S-5N



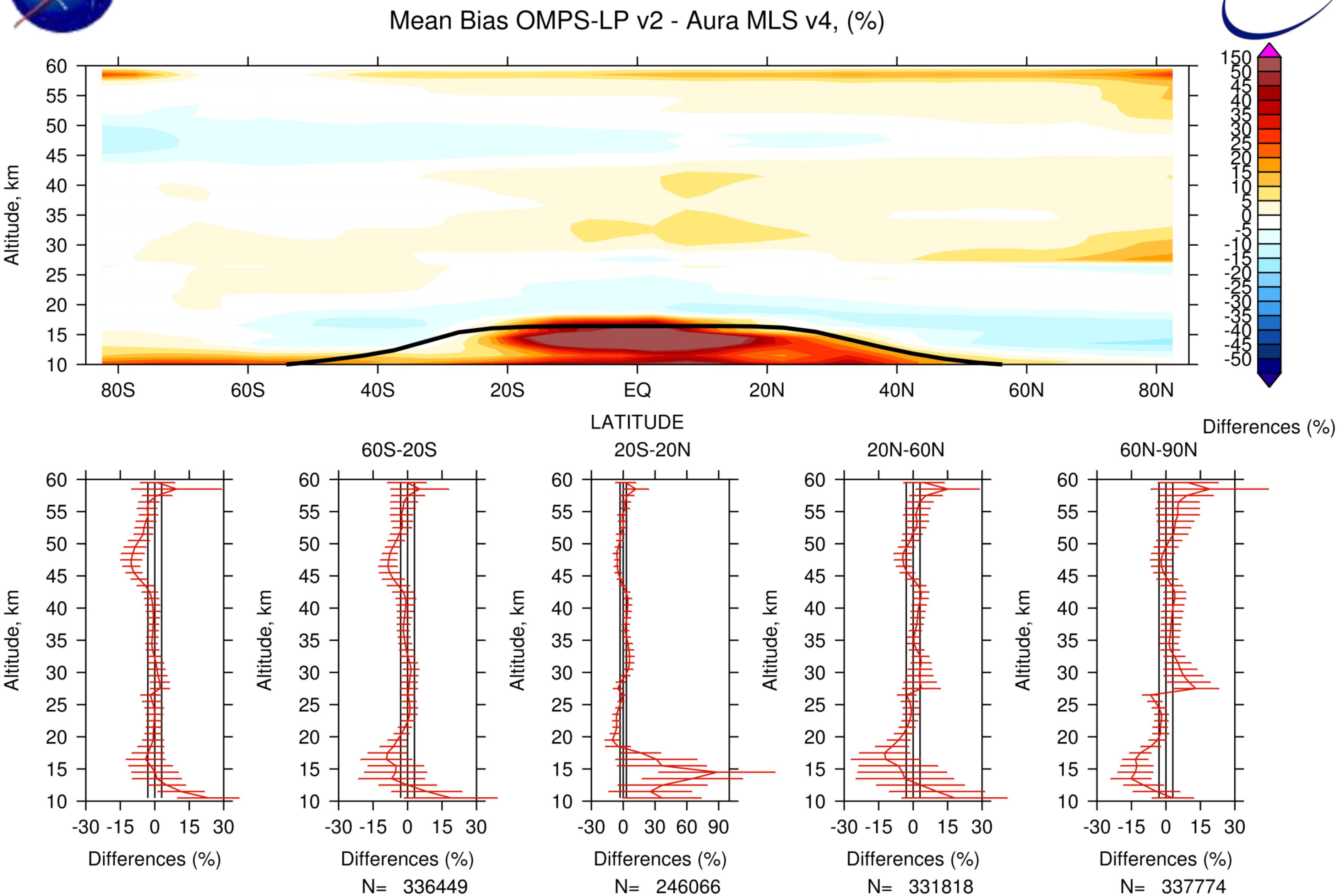
Antarctic ozone measurements with OMPS: synergy between nadir and limb modules



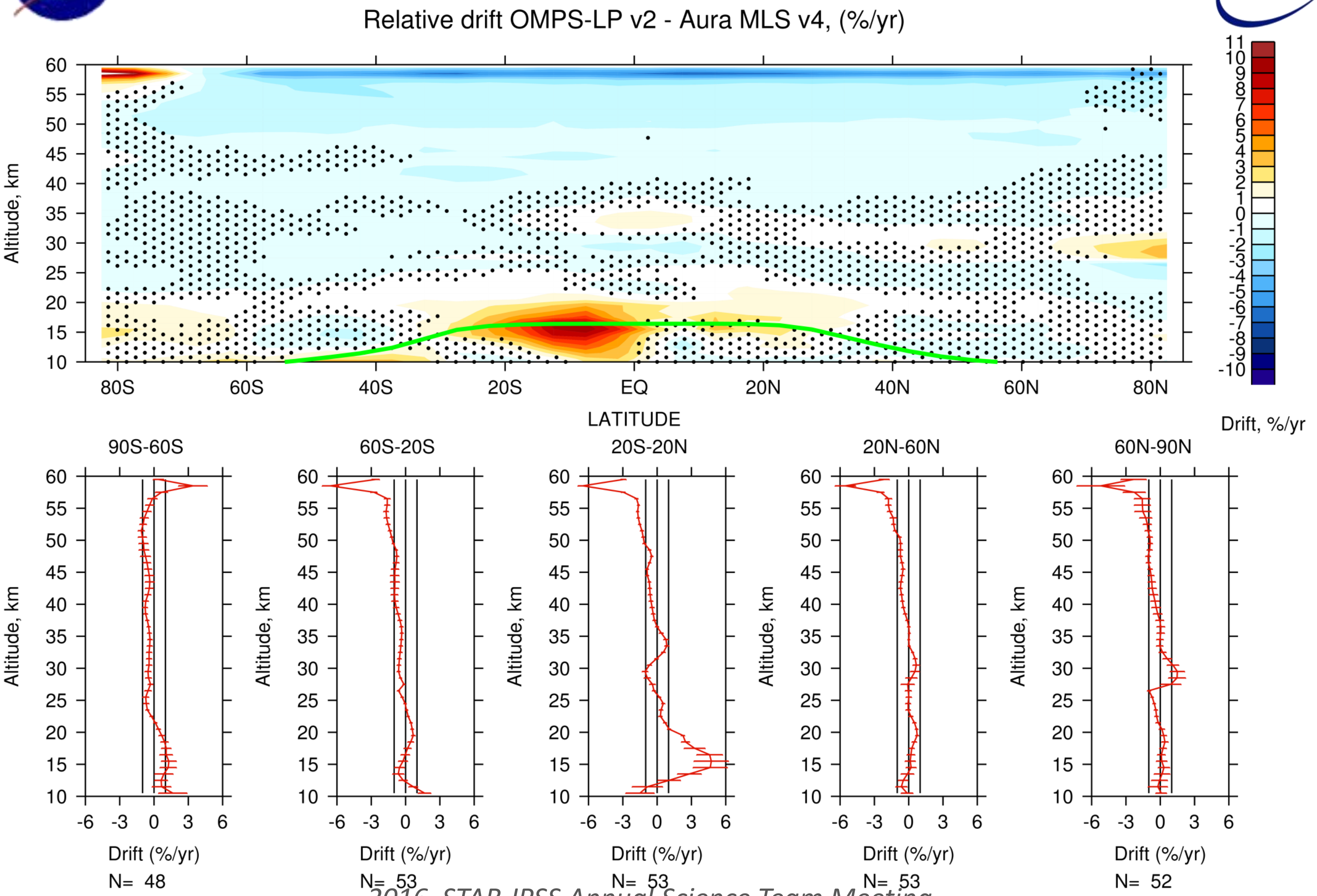
Look inside the ozone hole with OMPS



Quality assessment of OMPS LP v2



Quality assessment of OMPS LP v2



A path toward the version 2.5

- **The stray light correction for the VIS wavelengths will be implemented in version 2.5;**
- **A 100 m shift in the altitude registration detected in April 2013 will be corrected;**
- **TH shifts between 3 slits will be removed (expect better agreement between slits);**
- **A new cloud height detection algorithm will be integrated in version 2.5 [Chen et al., AMT, 2016].**

OMPS-LP v2 algorithm

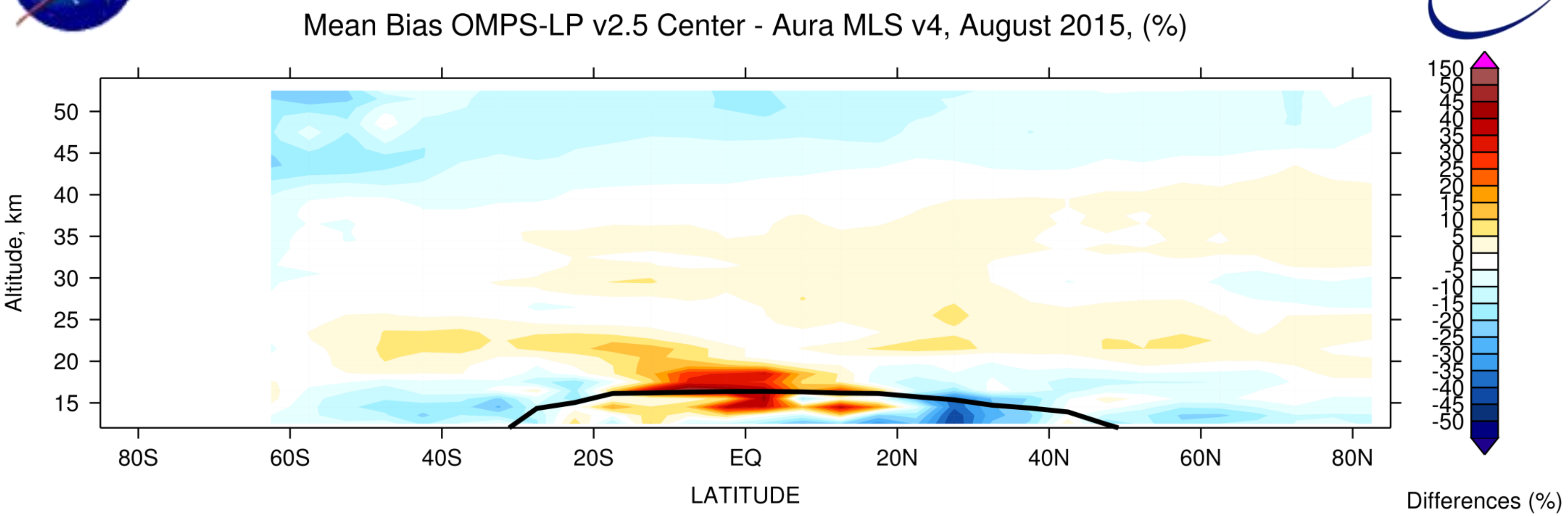
- 43 UV pairs and 17 VIS triplets;
- radiances are normalized at 65 km for UV and 45 km for VIS ranges;
- The aerosol correction module is turned off

→

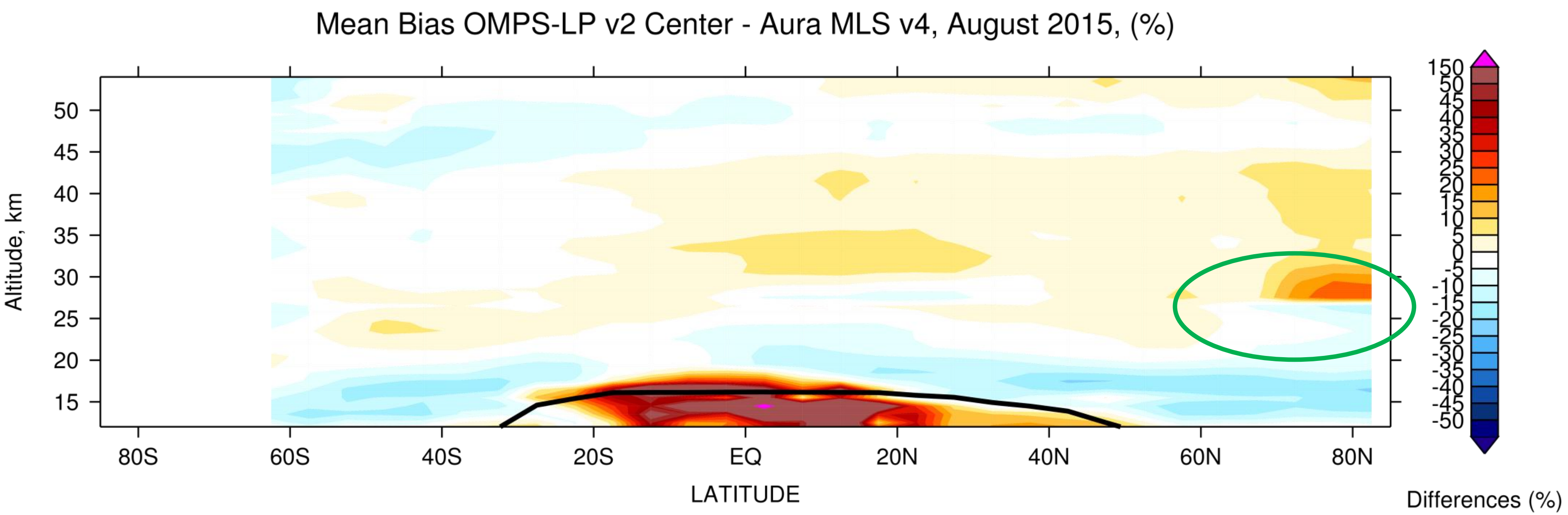
OMPS-LP v2.5 algorithm

- 3 UV pairs and 1 VIS triplets;
- radiances are normalized at 55 km for UV and 40 km for VIS ranges;
- Include the explicit aerosol correction by using LP aerosol v1

Version 2.5



Mean Bias OMPS-LP v2.5 Center - Aura MLS v4, August 2015, (%)
Altitude, km
LATITUDE
80S
60S
40S
20S
EQ
20N
40N
60N
80N
Differences (%)



Mean Bias OMPS-LP v2 Center - Aura MLS v4, August 2015, (%)
Altitude, km
LATITUDE
80S
60S
40S
20S
EQ
20N
40N
60N
80N
Differences (%)

Future plans

- Account for horizontal inhomogeneity (2D effects) along the line of sight :

  ✓ 1. Near-term: apply the horizontal contribution function of the measurement vector to the retrieved profiles;

  ✓ 2. Long-term: collaborate with GMAO in assimilating cloud and aerosol corrected LP radiances using 2D RT model.
- Temperature profiles in the mesosphere and upper stratosphere can be retrieved from the LP measurements.

Limb ozone data assimilation in GEOS-5: MLS and OMPS-LP

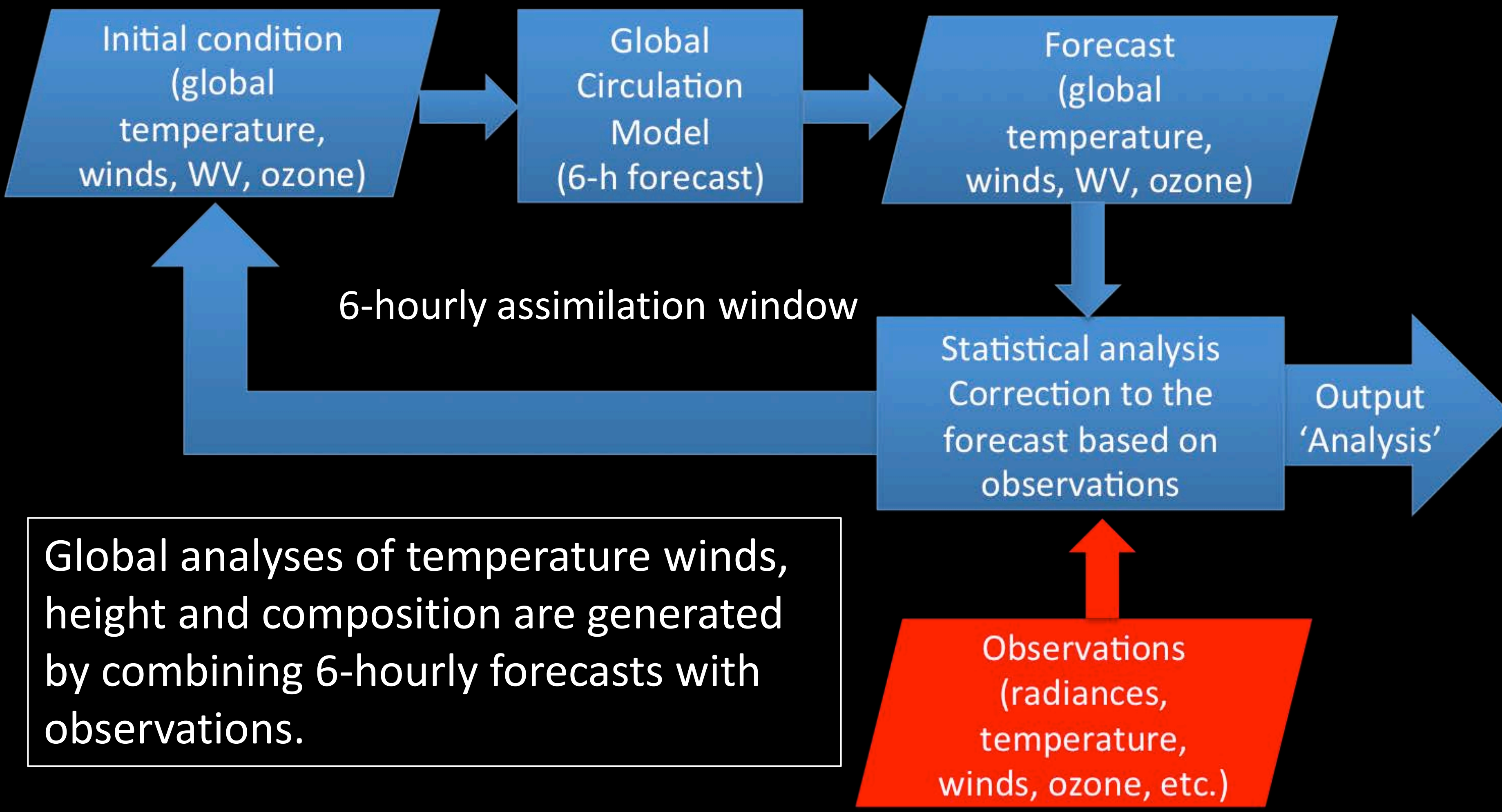
K. Wargan, S. Pawson, N. Livesey and N. Kramarova

Outline

Recent developments and results with limb ozone data assimilation

- MLS assimilation: MERRA-2
- OMPS-LP assimilation, early results: representation of vertical and horizontal structures

GEOS-5 Data Assimilation System
(a very simplified picture)



Global analyses of temperature winds, height and composition are generated by combining 6-hourly forecasts with observations.

Assimilated limb ozone data

Microwave Limb Sounder

- Ozone profiles retrieved from measured microwave emissions – day and night coverage.
- 261 hPa –mesosphere
- Vertical resolution: 2.5-6 km
- Longitudinal separation: 10°-20°
- On the EOS Aura satellite, 2004 – present
- Version 4.2
- Used in GMAO's operational analyses

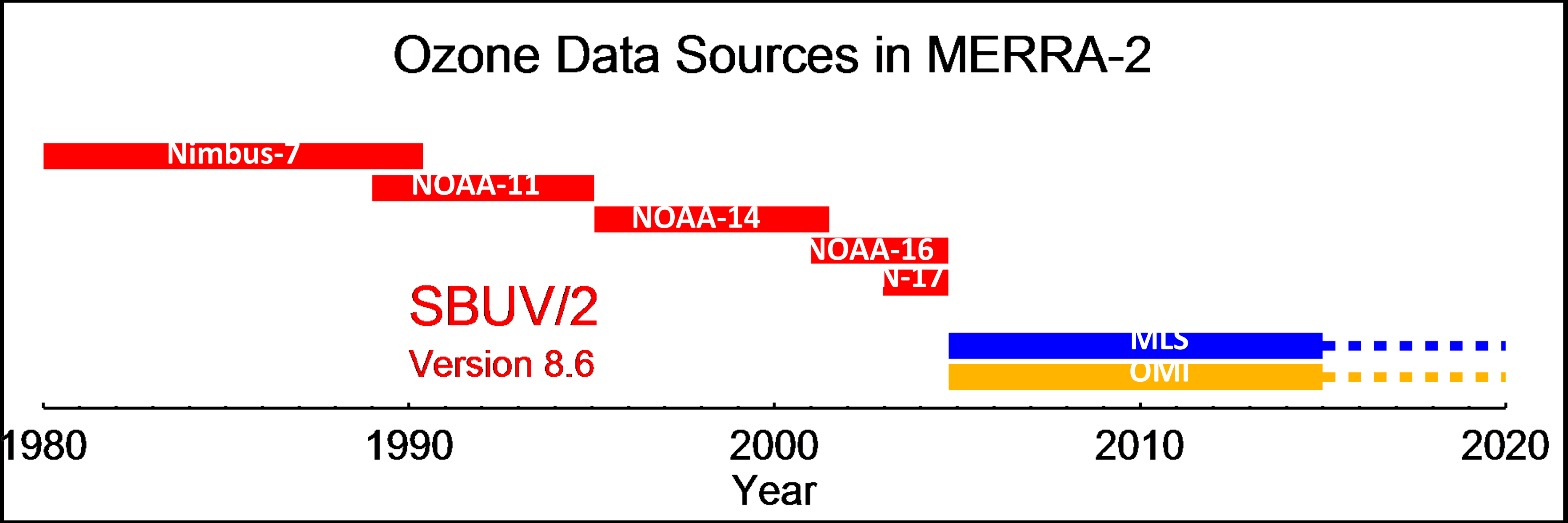
Ozone Mapping and Profiler Suite - Limb Profiler

- Ozone profiles from backscattered UV (above 32 km) and visible radiation – daylight only
- 240 hPa – mesosphere
- Vertical resolution: ~1.8 km
- Three slits with 4.25° separation provide more cross-track coverage
- On Suomi-NPP, 2011 – present
- Version 2.x

Very different principles of measurement!

ASSIMILATION OF MLS OZONE: MERRA-2

Modern Era Retrospective Analysis for Research and Applications - 2



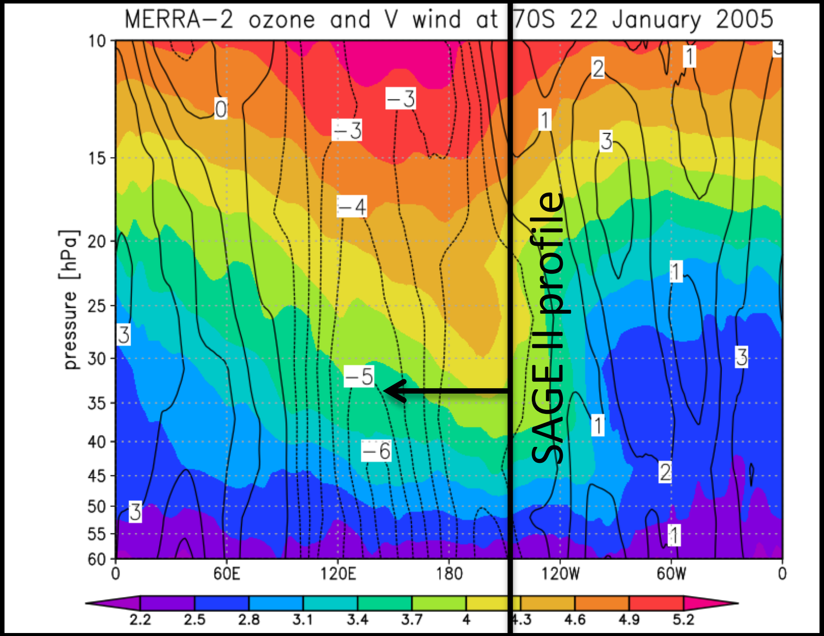
- New GMAO reanalysis, 1980 – present
- 3-hourly global fields at 0.625°×0.5° horizontal resolution, 72 levels, surface to 0.01 hPa
- Stratospheric ozone constrained by MLS data, Oct. 2004-present

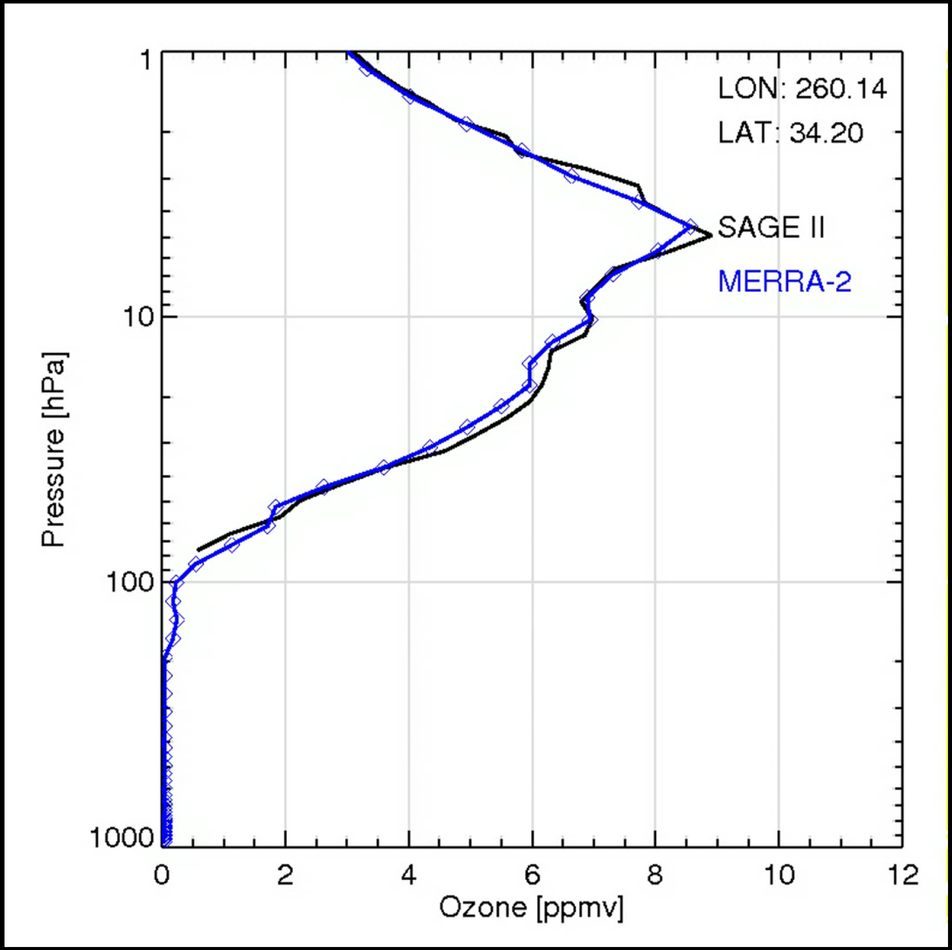
The record of limb ozone observations is limited. We need to develop a better way to assimilate nadir data! Averaging kernels, correct error specification,…

Verification of MERRA-2 ozone profiles against Stratospheric Aerosol and Gas Experiment II (SAGE II)

Collocated MERRA-2 and consecutive SAGE II ozone profiles for several days in January 2005.

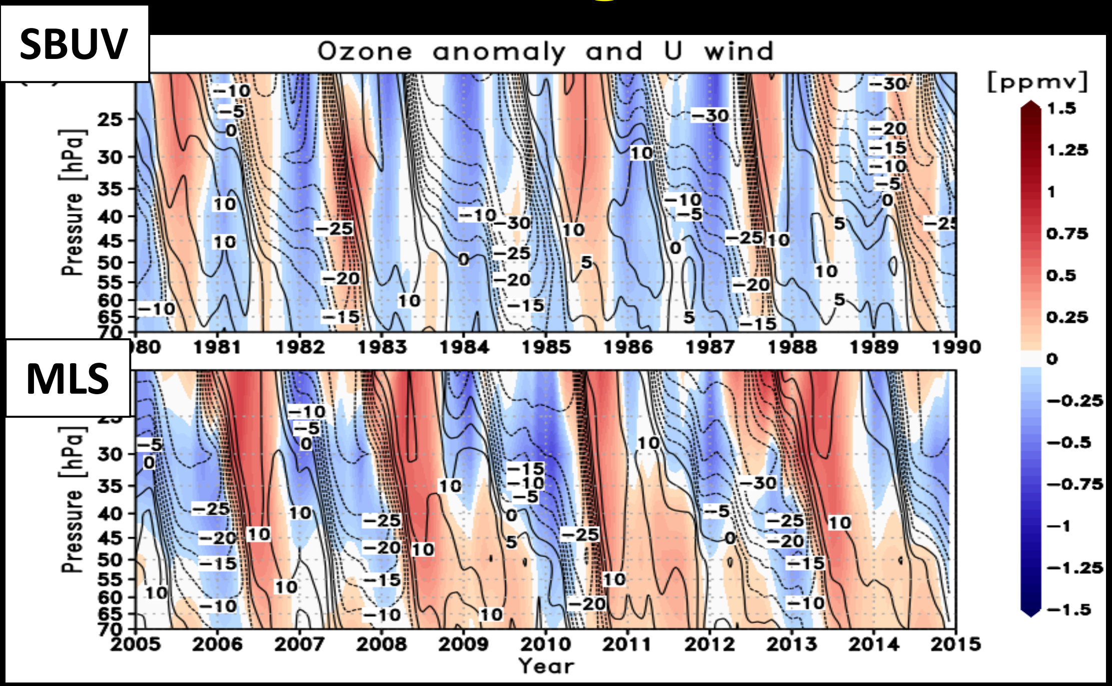
MERRA-2 assimilates MLS but NOT SAGE II

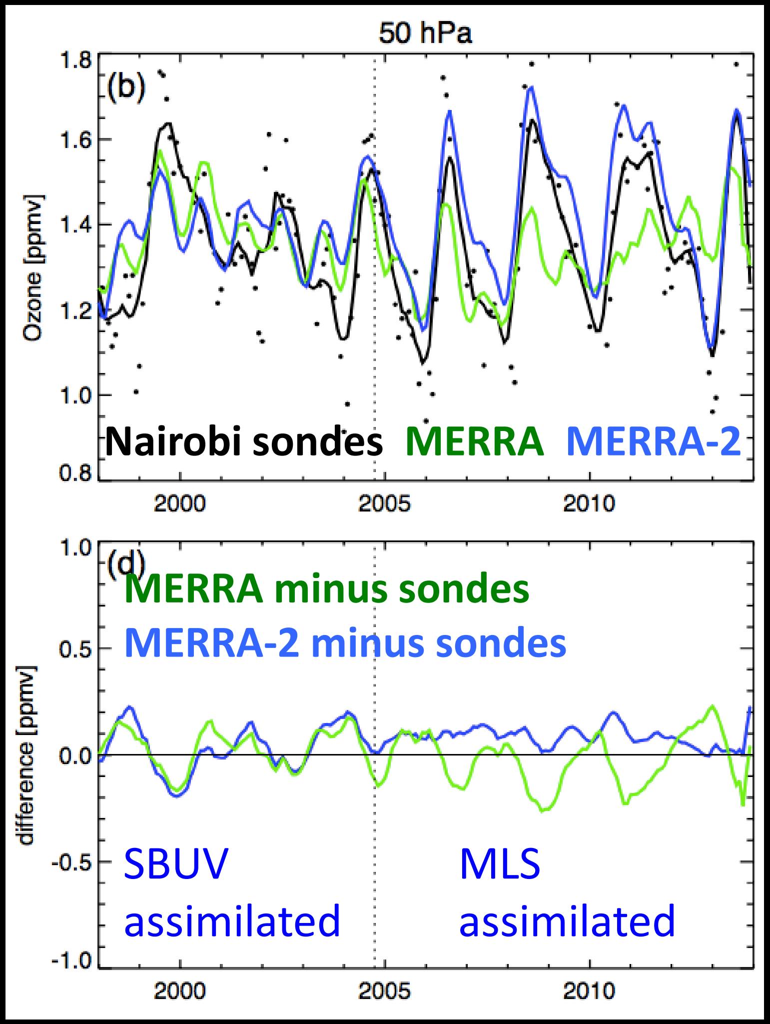




Profile variability is very well represented in MERRA-2

QBO signature in MERRA-2 ozone





Coy et al., 2016

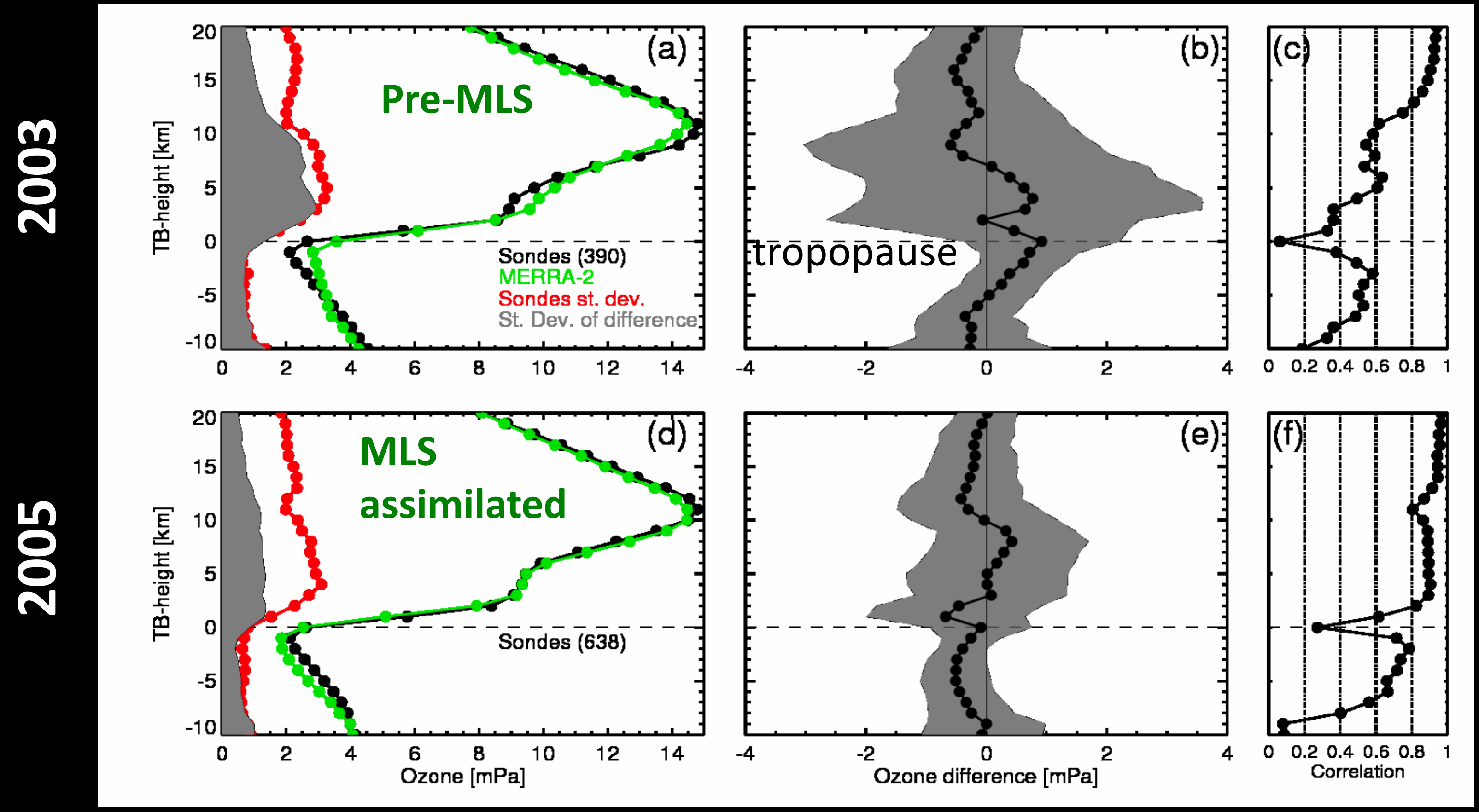
When MLS is assimilated in MERRA-2 the QBO signal in ozone shows more realistic phase propagation

- Consistent with the zonal wind
- In agreement with ozonesondes

SBUV has large vertical smoothing errors [*Kramarova et al., 2013*]

<u>The right lesson to draw</u>: We have to do a better job assimilating SBUV ozone : use averaging kernels and better error specifications

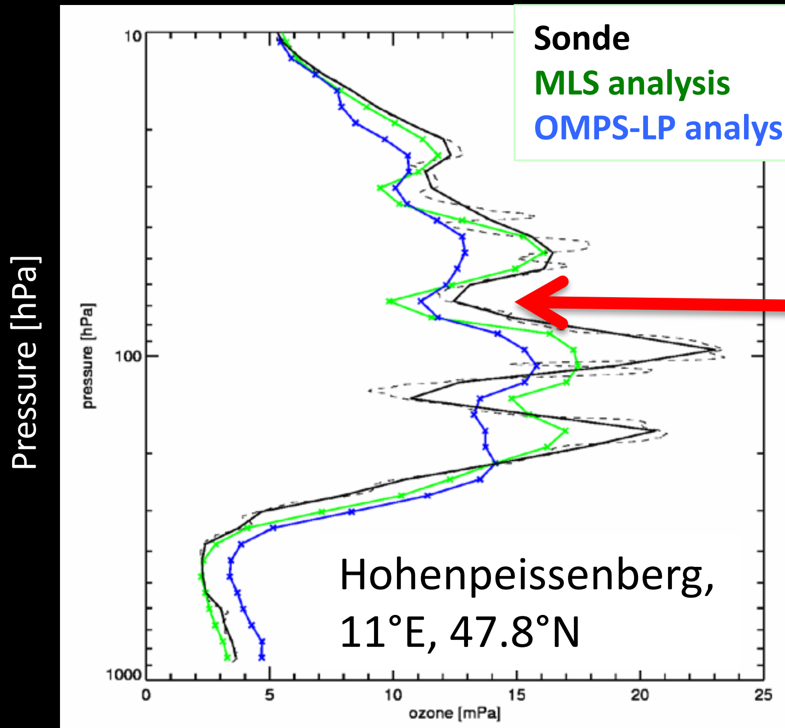
Ozonesondes: upper troposphere – lower stratosphere, Europe, March-May

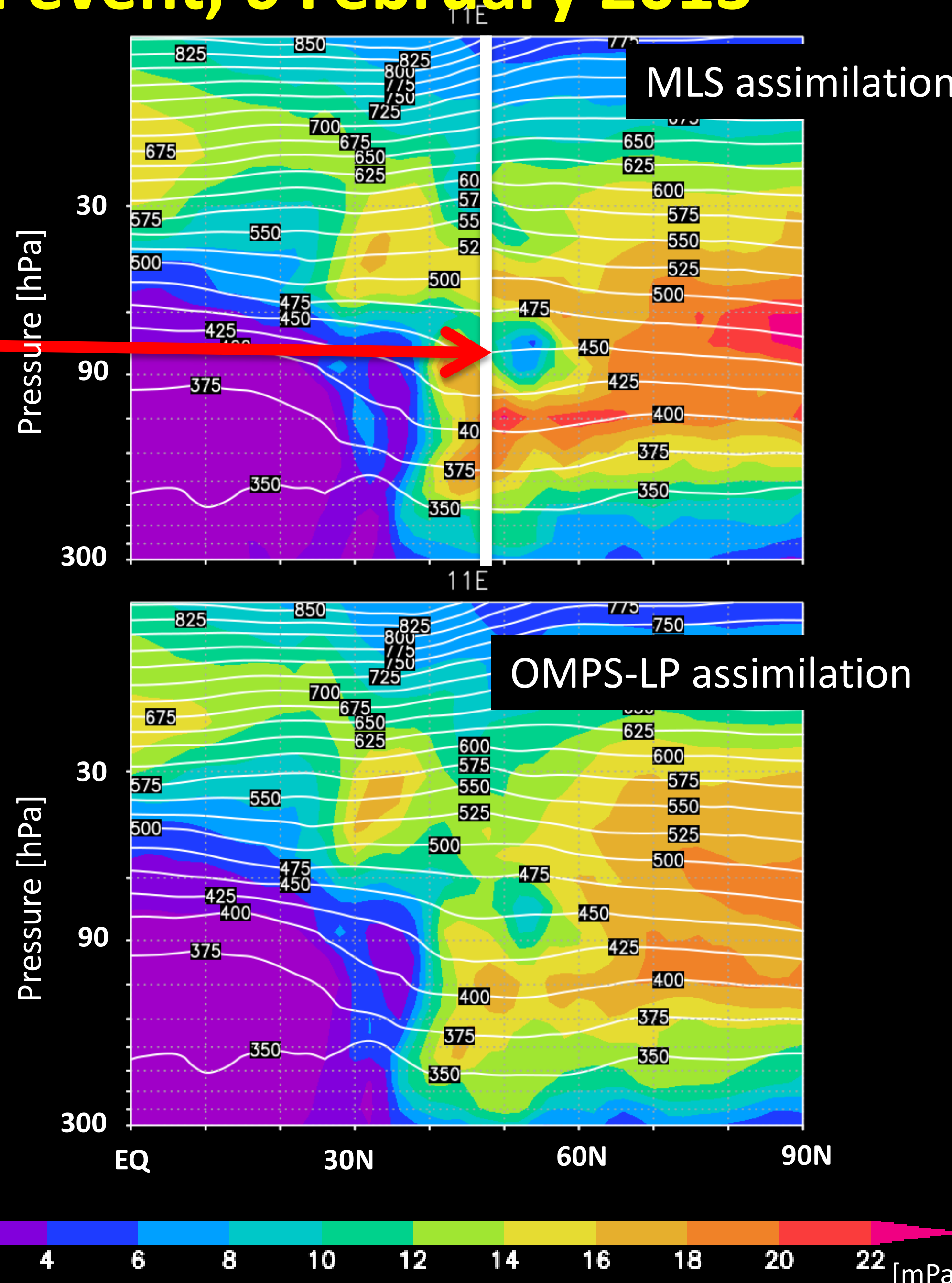


- Good agreement of MERRA-2 with ozonesondes in the UTLS
- **In the MLS assimilation period:**
  - Smaller difference standard deviations
  - Higher correlations in the LS
  - Sharper gradient across the tropopause

PRELIMINARY RESULTS WITH OMPS-LP: VERTICAL STRUCTURES

A low ozone lamina event, 6 February 2013

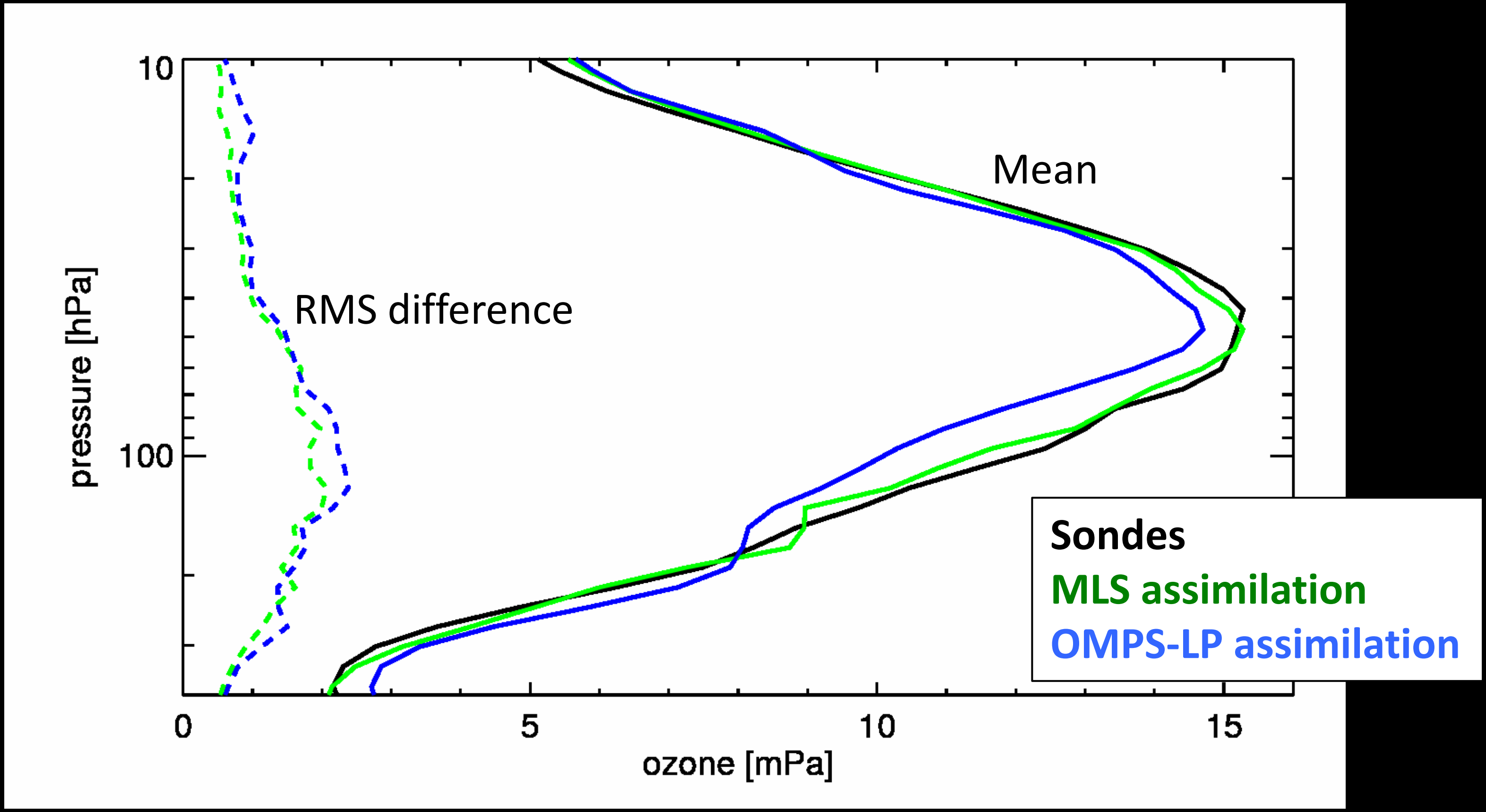




- A complex profile structure over Hohenpeissenberg is reproduced (to some degree) by both analyses
- A low ozone lamina at ~70 hPa is seen in both experiments

The same morphology in both analyses

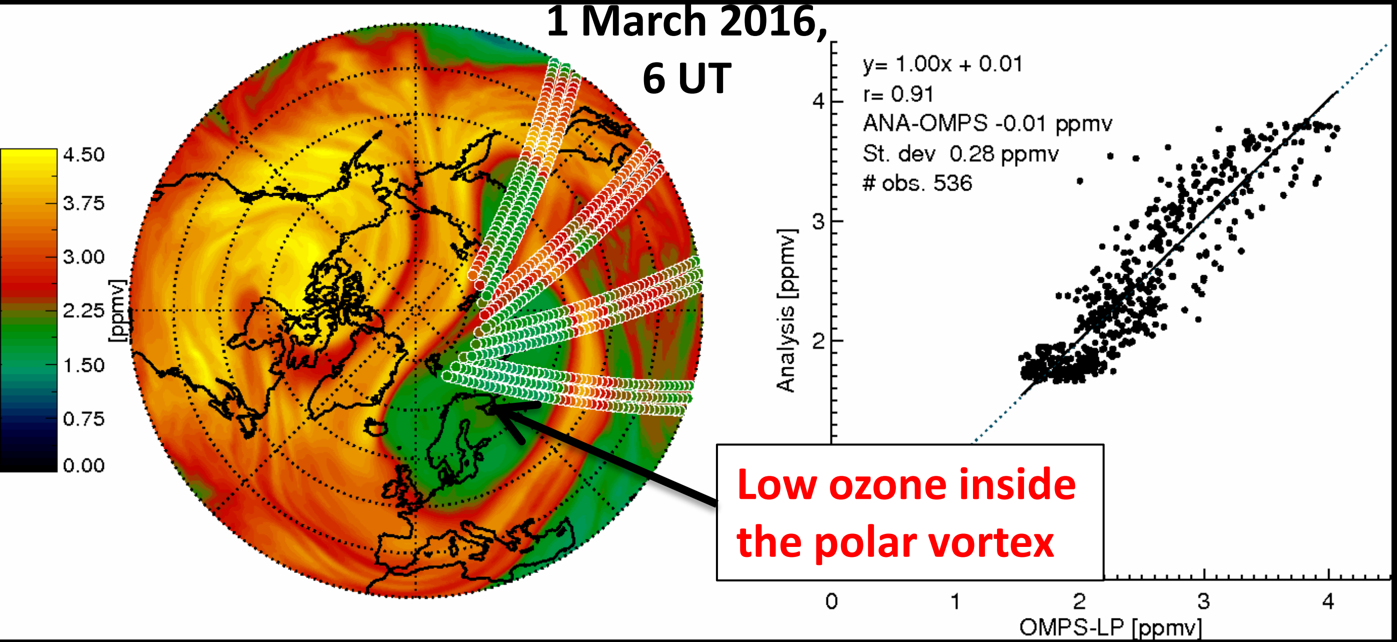
Comparison with ozonesondes 45°N-90°N in DJF 2012/2013

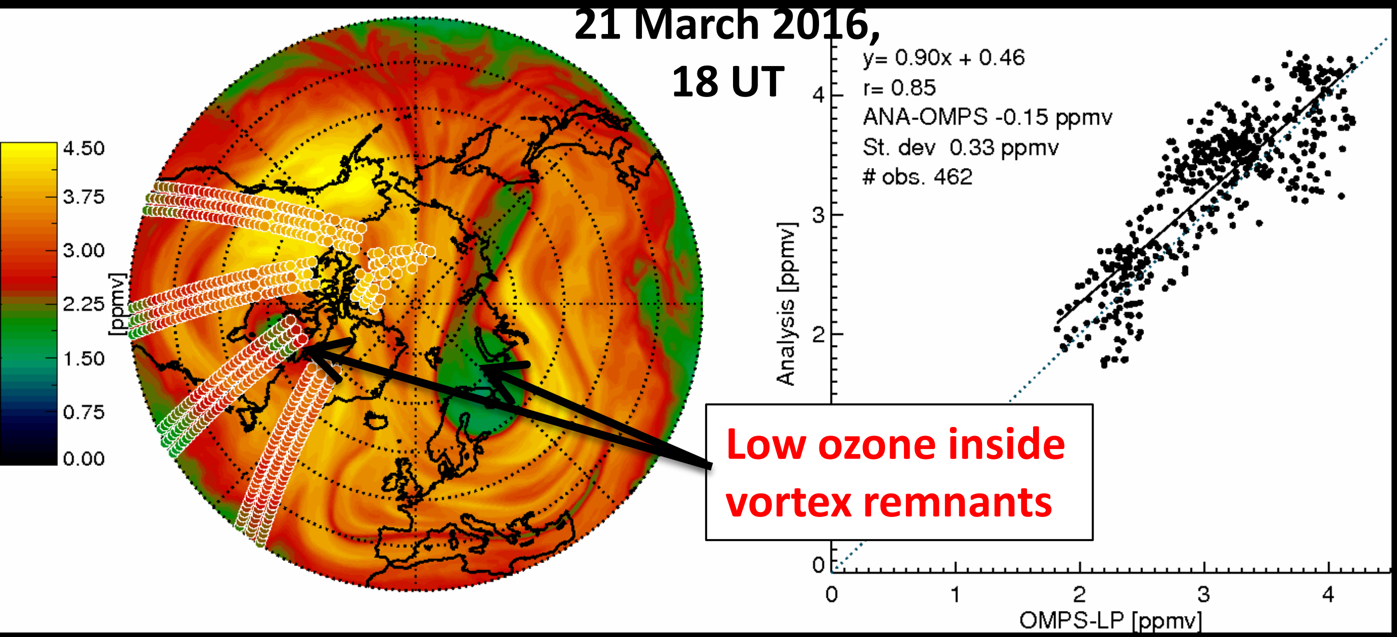


- Some systematic differences: The MLS analysis is slightly closer to the sondes
- The RMS differences are close: both analyses reproduce the variability about equally

PRELIMINARY RESULTS WITH OMPS-LP: HORIZONTAL STRUCTURES

MLS assimilation & OMPS-LP data : horizontal structures



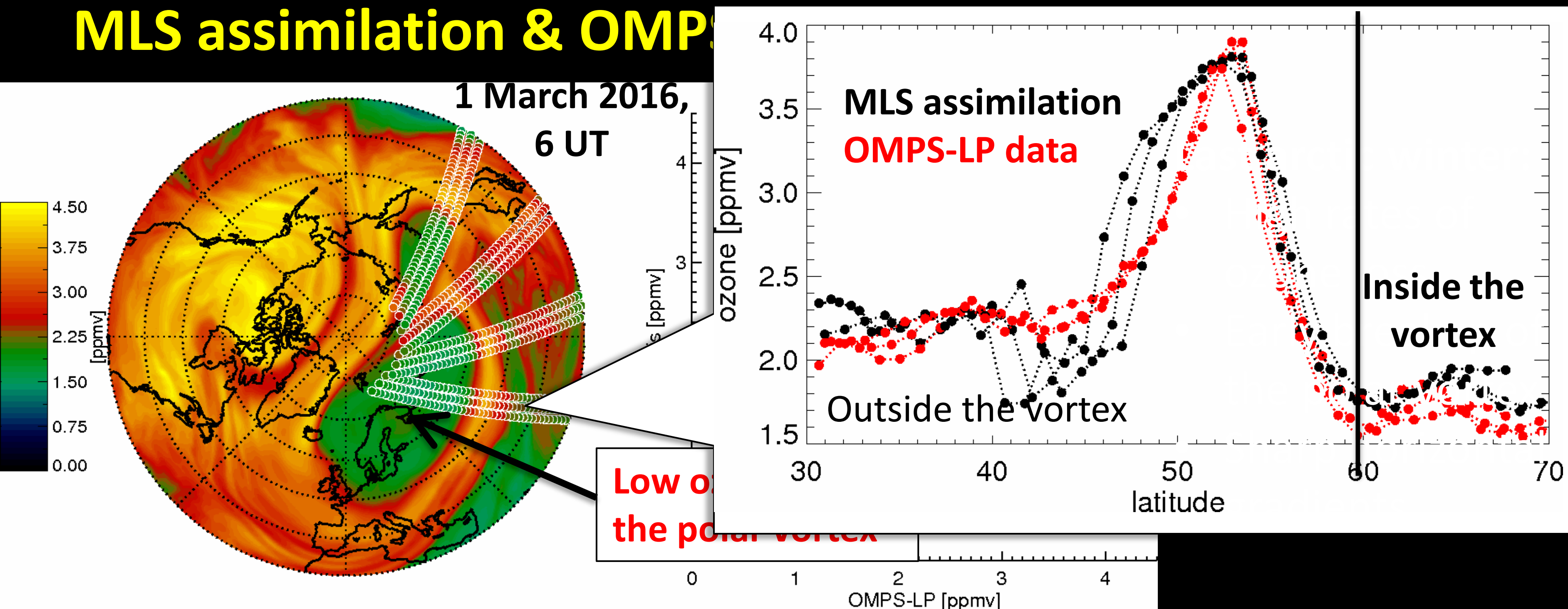


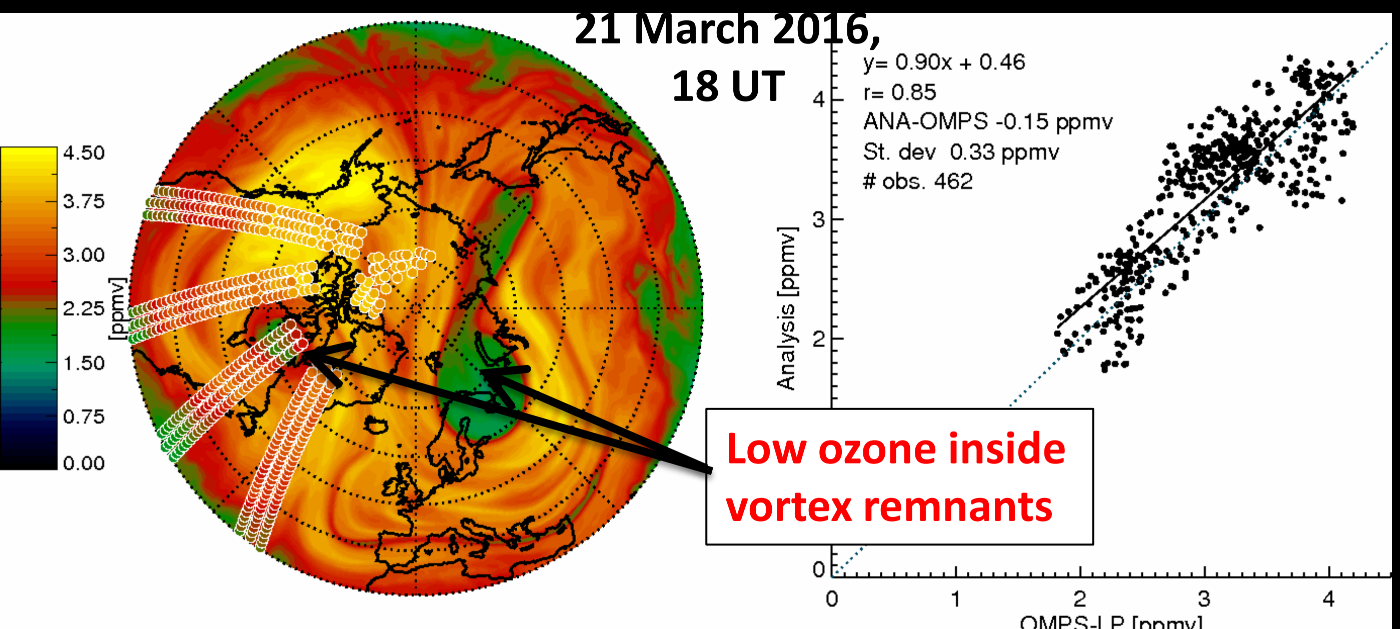
2015/2016 Arctic winter:

- High rates of ozone loss
- Early breakup of the polar vortex
- Sharp horizontal gradients

OMPS-LP picks up horizontal structures and gradients across the vortex edge

MLS assimilation & OMPS





OMPS-LP picks up horizontal structures and gradients across the vortex edge

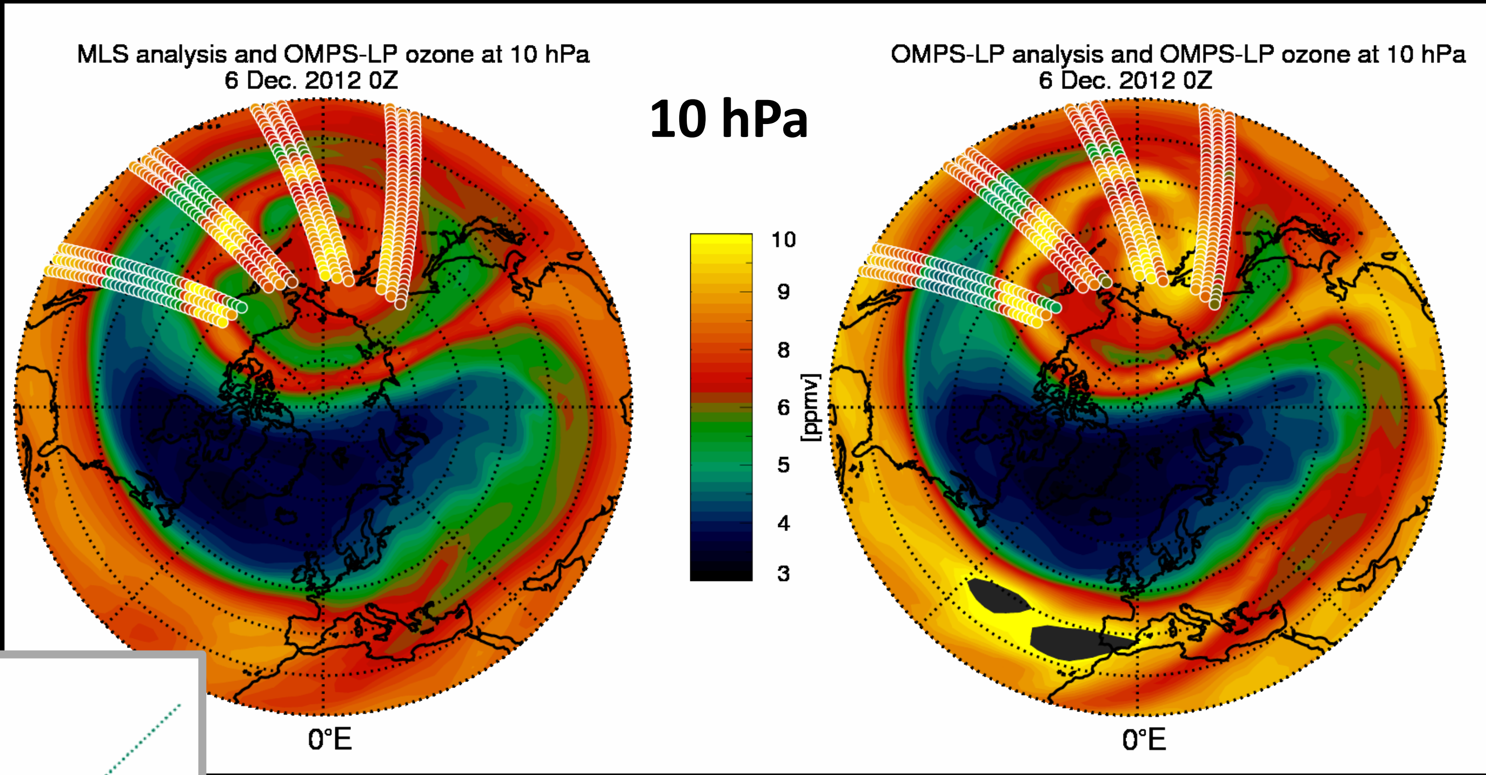
Summary

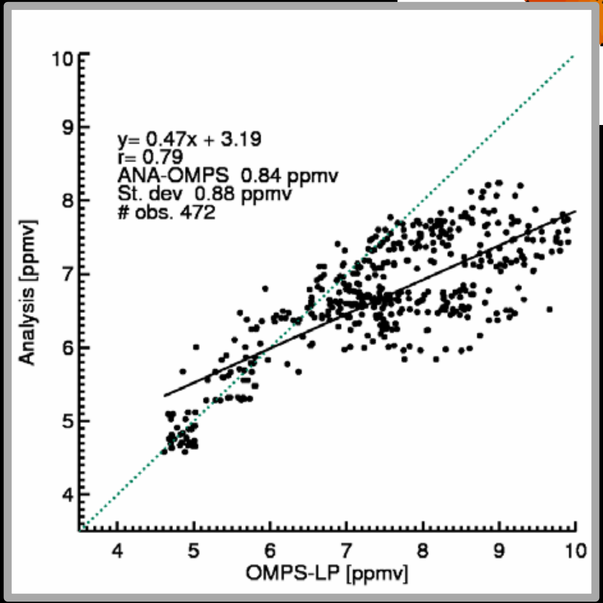
- MERRA-2 uses MLS ozone data from late 2004 onward
  - Good representation of stratospheric profiles
  - Realistic ozone response to QBO
  - Faithful representation of the lower stratosphere O_3
- Early results with OMPS-LP
  - Vertical structures and variability comparable to MLS assimilation
  - Capability to resolve horizontal O_3 gradients
  - Some systematic offsets relative to MLS assimilation
- Potential future directions
  - Assimilation of aerosols from OMPS-LP
  - Assimilation of OMPS-LP radiances
  - Better ways to assimilate nadir ozone data

backup

MLS & OMPS-LP assimilation reproduce a transport event

Ozone-rich tropical air wrapped around the Aleutian anticyclone





- OMPS-LP observations at 10 hPa are biased high with respect to MLS analysis but show the same filamentary structures
- Assimilated OMPS-LP produces the same ozone field morphology

TOAST total ozone maps using CrIS and OMPS LP profiles

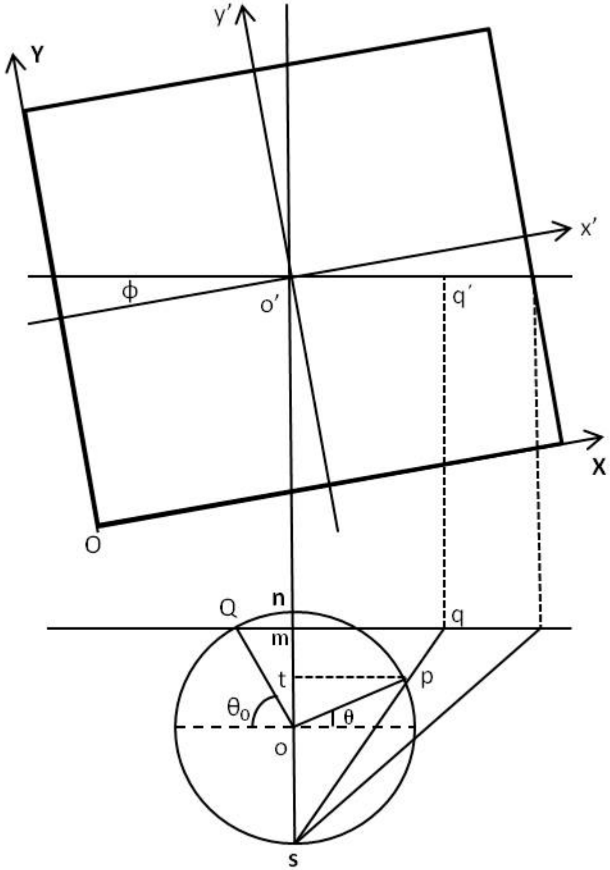
Jianguo Niu
System Research Group@NOAA/NESDIS/STAR

Larry Flynn,
NOAA/NESDIS/STAR

STAR JPSS Annual Science Team Meeting
August 9, 2016

TOAST objective analysis

- **Basic consideration:**
  1. IR obs. possess higher sensitivity to tropospheric ozone
  2. UV obs. possess higher sensitivity to stratospheric ozone
  3. Mix the IR and UV retrieved O_3 may increase O_3 accuracy
  4. Fill in the UV observation gaps
- **Basic procedures:**
  1. Convert IR and UV O_3 pressure scale into same pressure scales.
  2. Transform coordinate from geographic into stereographic.
  3. Objective analysis.
  4. Analyzed global ozone data are transformed back to the geographic coordinate with $1^\circ \times 1^\circ$ resolution.



$$X = \cos\theta \cdot \cos\phi \cdot \frac{\sin\theta_0 + 1}{\sin\theta + 1} \cdot \frac{\mathrm{Re}}{mesh} + \frac{N-1}{2} \qquad (1)$$

$$Y = \cos\theta \cdot \sin\phi \cdot \frac{\sin\theta_0 + 1}{\sin\theta + 1} \cdot \frac{\mathrm{Re}}{mesh} + \frac{N-1}{2} \qquad (2)$$

mesh=24,384/(N-1) km, θ_0=60˚; N is mesh grid number;
For CrIS N=245; for OMPS N=65

Fig 1. coordinate transformation from geographic to Stereographic.

$$C = WE \qquad (3)$$

$$W = \frac{R^2 - d^2}{R^2 + d^2} \qquad (4)$$

Any initial value on the grid within radius R and the origin point A determined circle will be corrected by the sum of the initial value with correction value C , where E is the difference between observation and the initial value at A, W is a weighting factor.

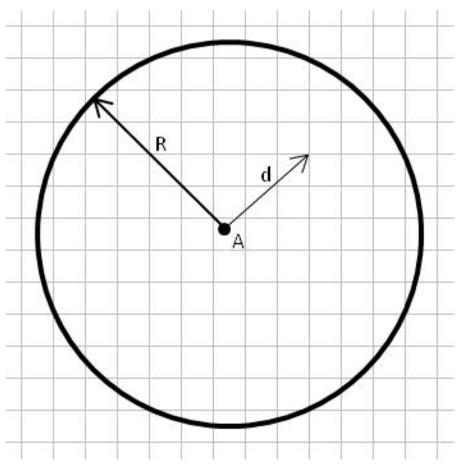


Fig 2. scheme of objective analysis

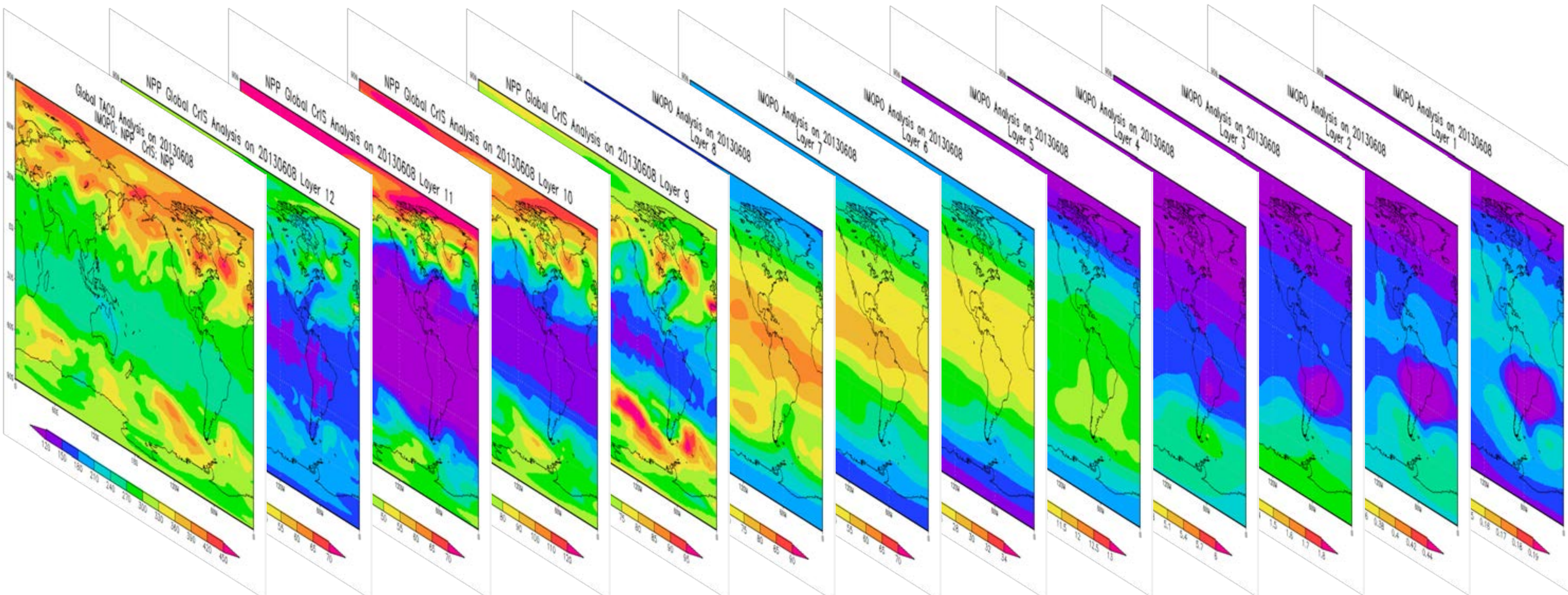
S-NPP provides following ozone sensors

- CrIS IR full global day and night profiles
- OMPS NP nadir view vertical profiler
- OMPS NM full daily total ozone for sunlit Earth
- OMPS LP limb view vertical profiles

The current TOAST was developed in 2014

- **T**otal **O**zone from **A**nalysis of CrIS and SBUV2 in **S**tratosphere and **T**roposphere
- ***TOAST*** will use CrIS + OMPS NP when OMPS NP is at NDE.
- ***TOAST*** will use CrIS + OMPS LP when OMPS LP is at NDE.

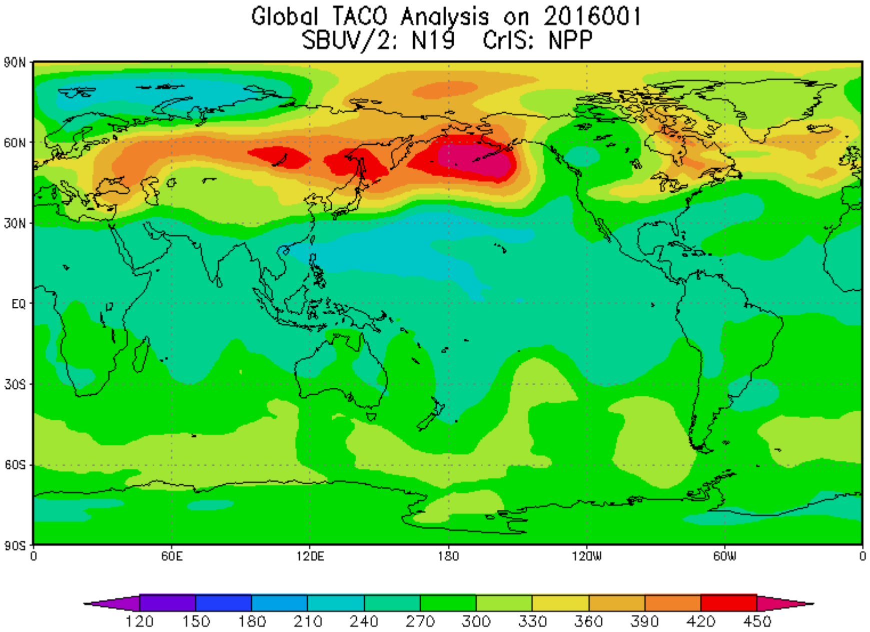
Current operational TOAST using CrIS and SBUV-2 (06-08-2013)

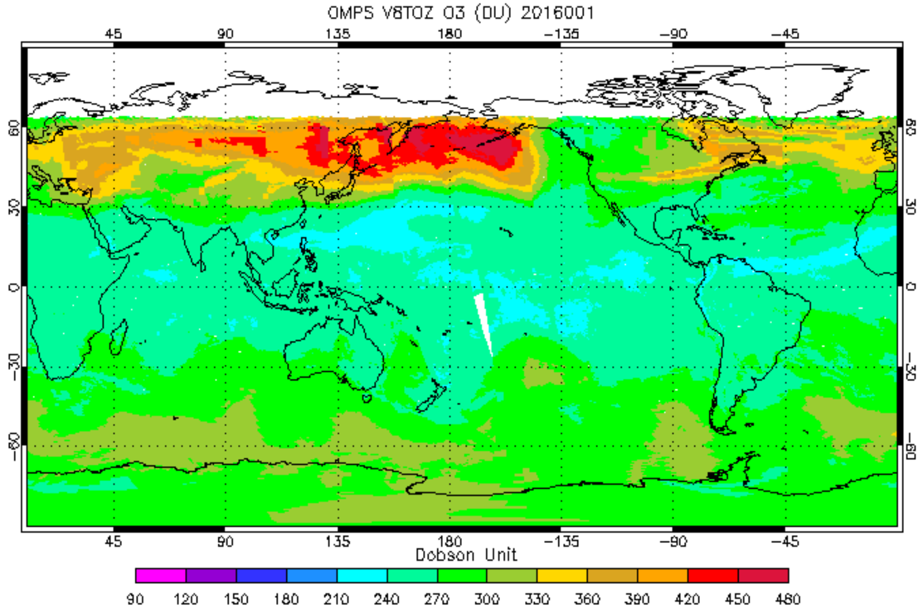


TACO total amount 1013 253 127 63.3 31.7 15.8 7.93 3.96 1.98 0.99 0.5 0.25 mb

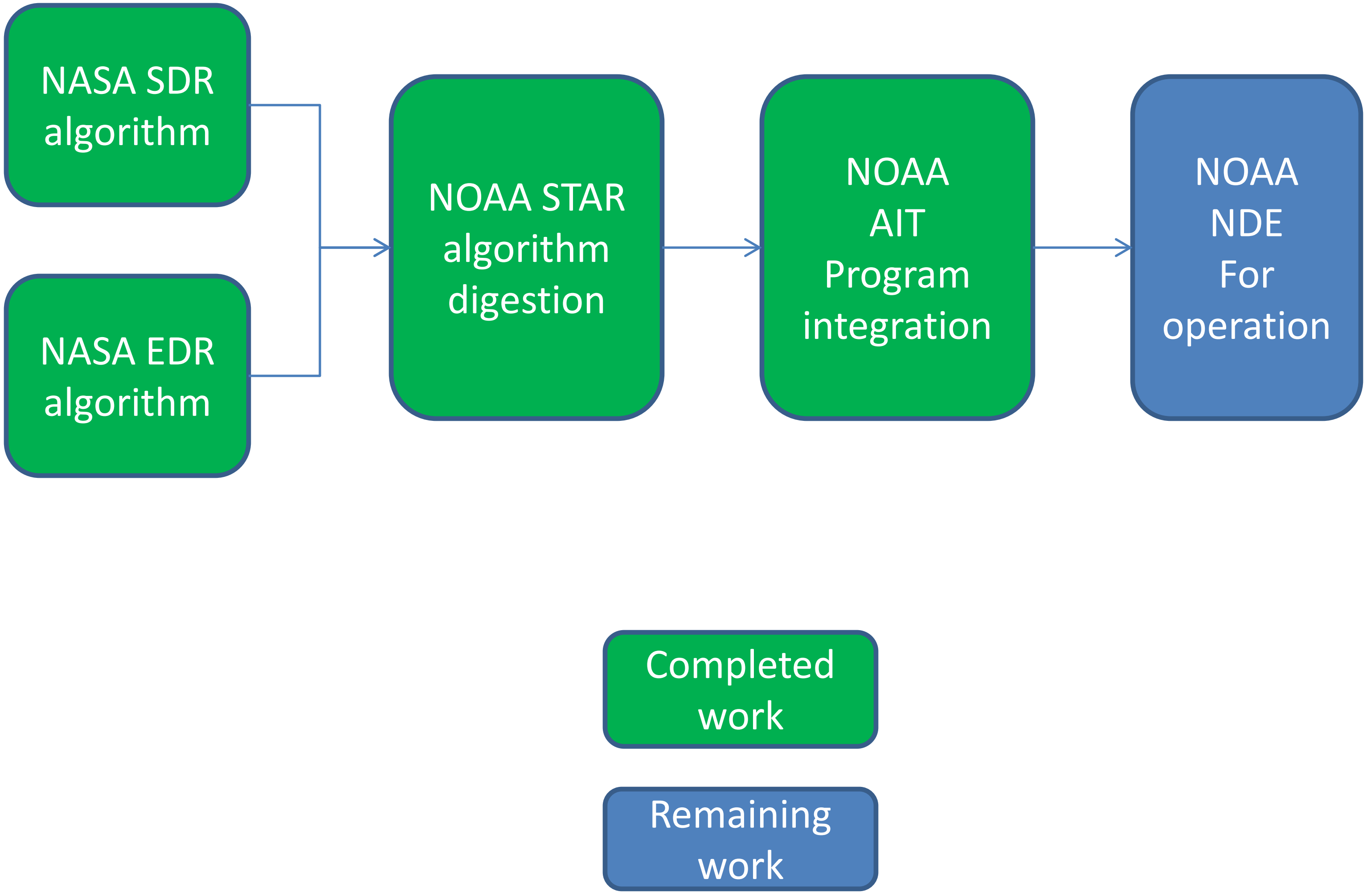
TOAST = ***CrIS*** ***+*** ***SBUV***

2016 Total column density of ozone from current TOAST and V8TOZ

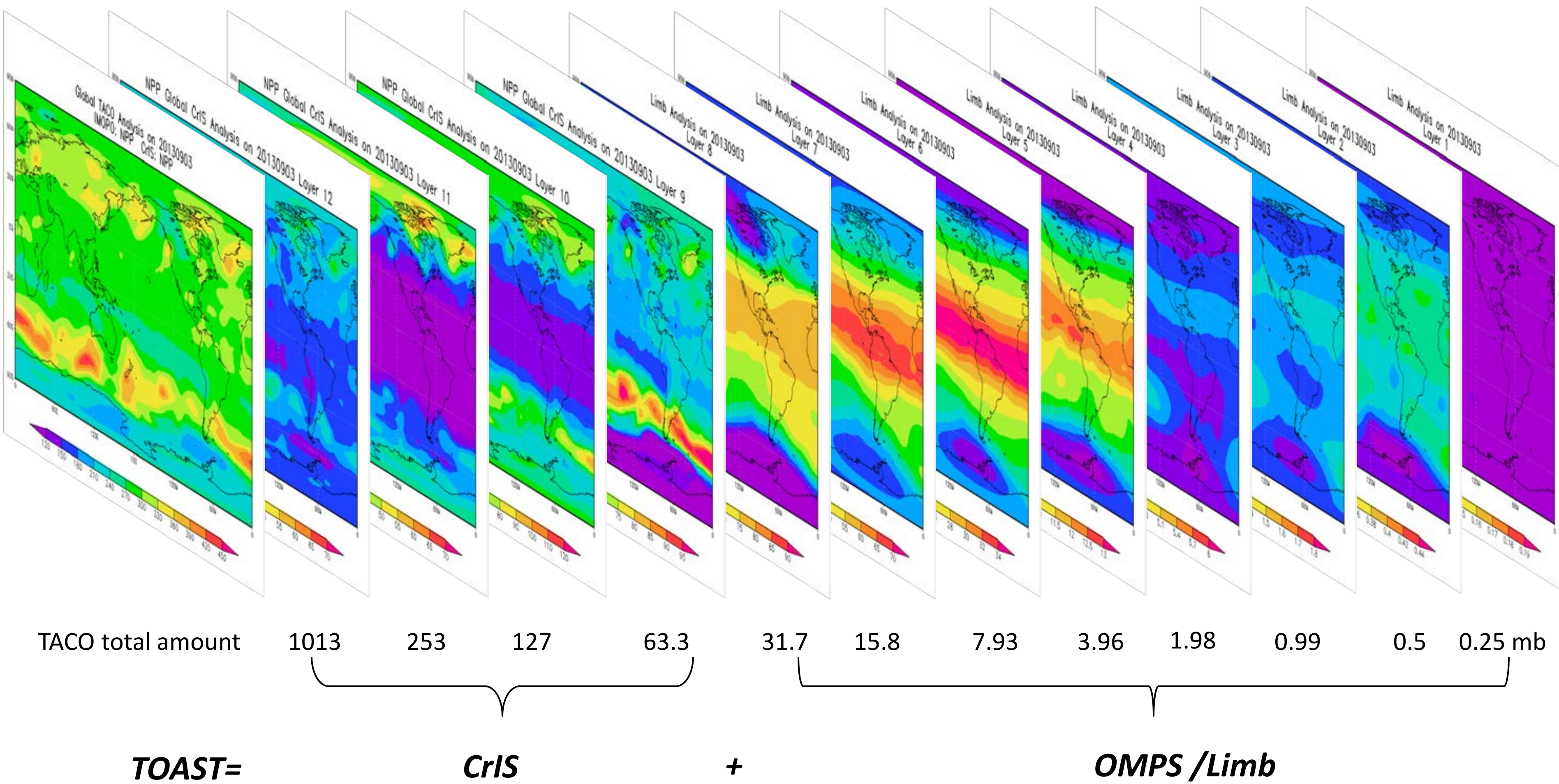




Limb processing algorithm status

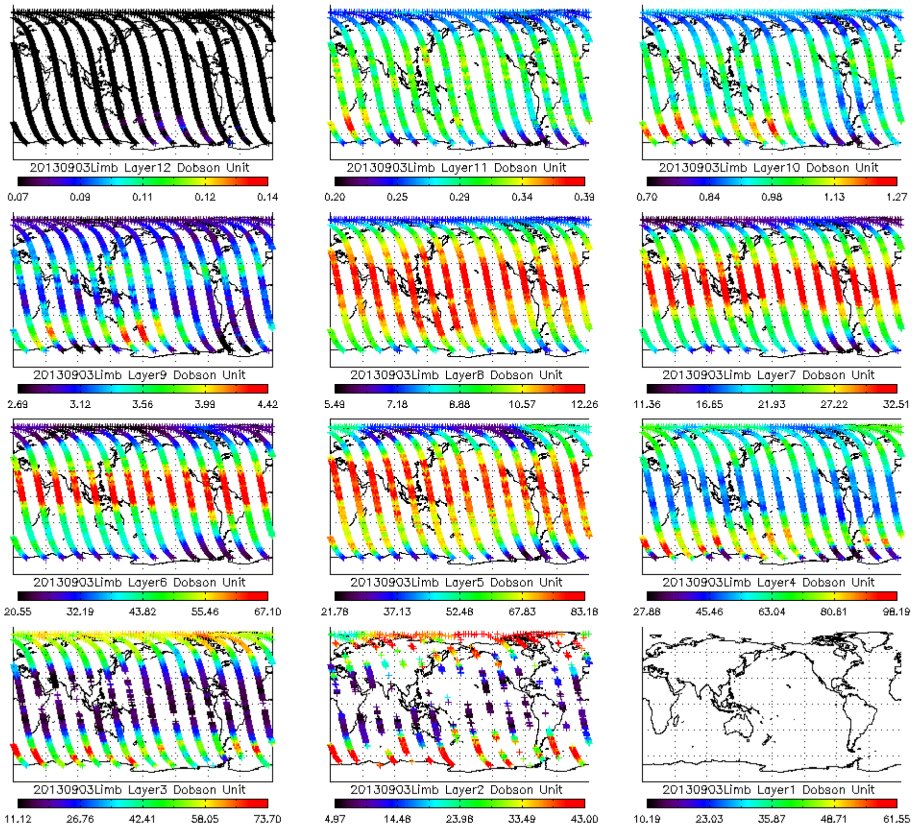


Last year demonstrated:
TOAST using CrIS and Limb (09-03-2013)

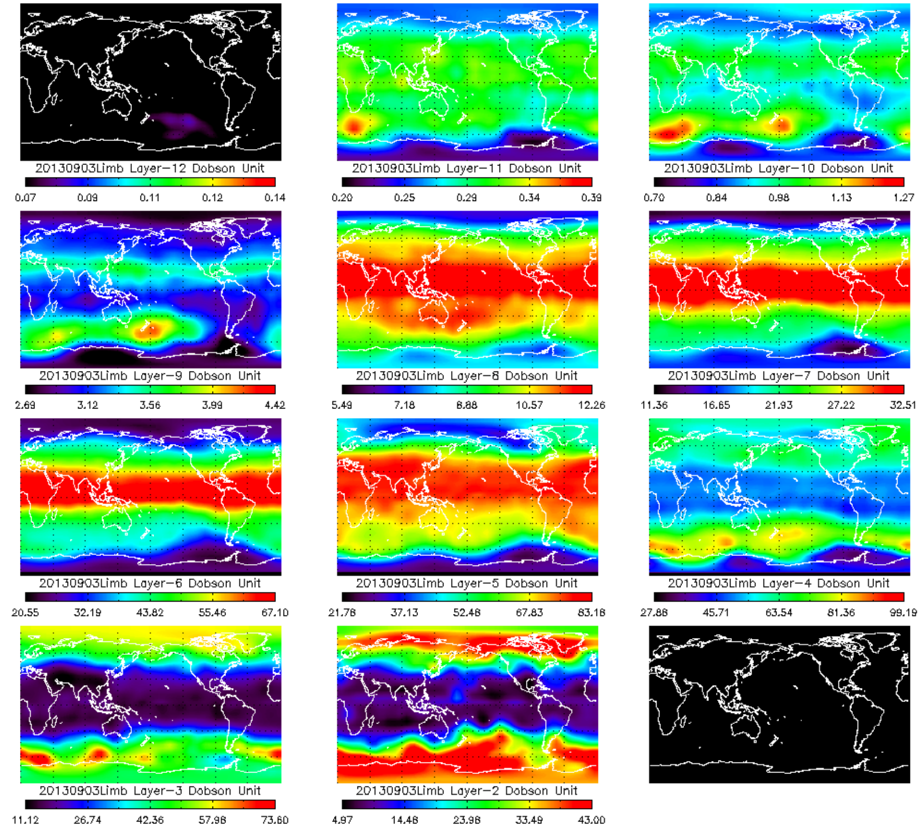


Last year demonstrated:
Limb Layer reformed vs. analyzed (09-03-2013)

Layer reformed Limb input

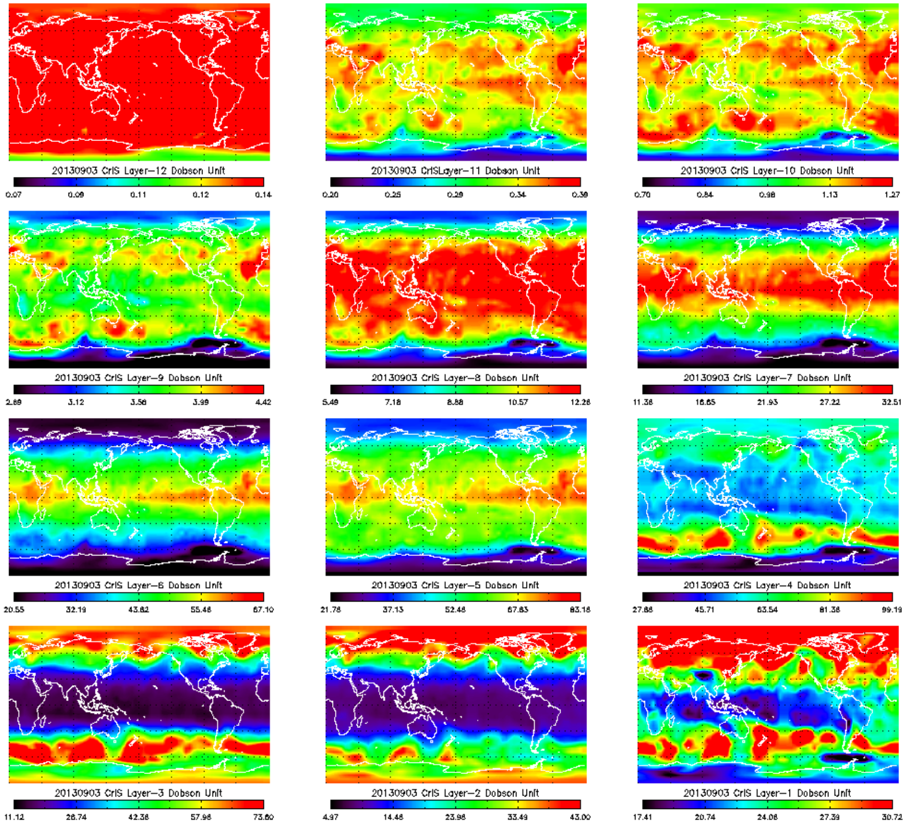


Limb TOAST analyzed

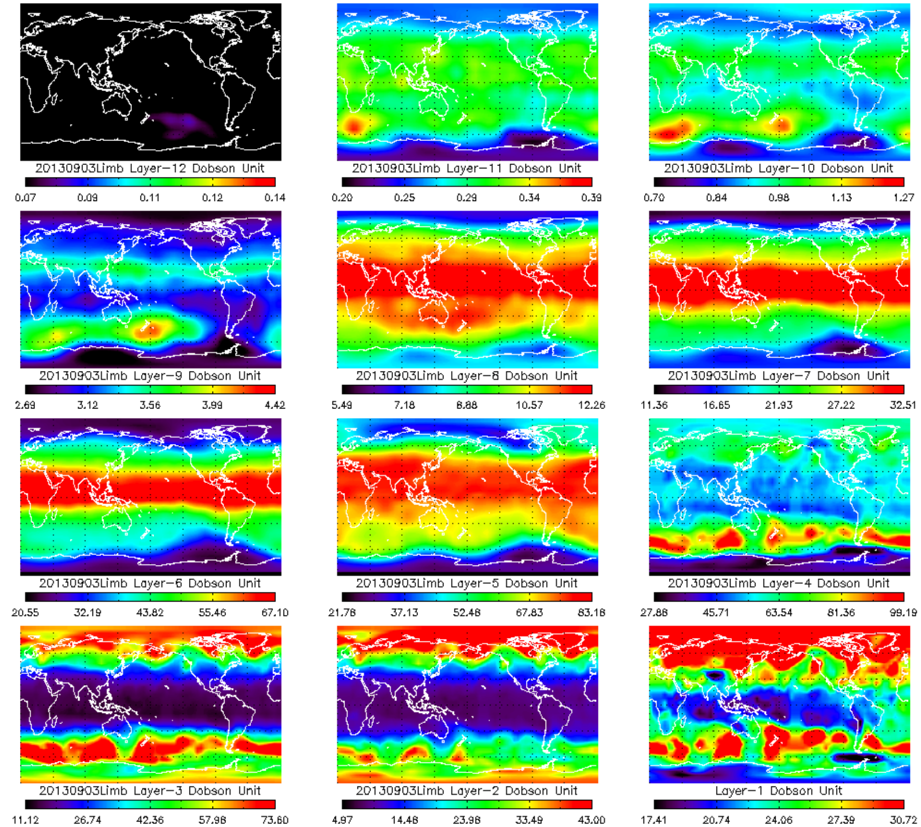


Last year demonstrated:
Analyzed 12 Umkehr O_3 layers (09-03-2013)

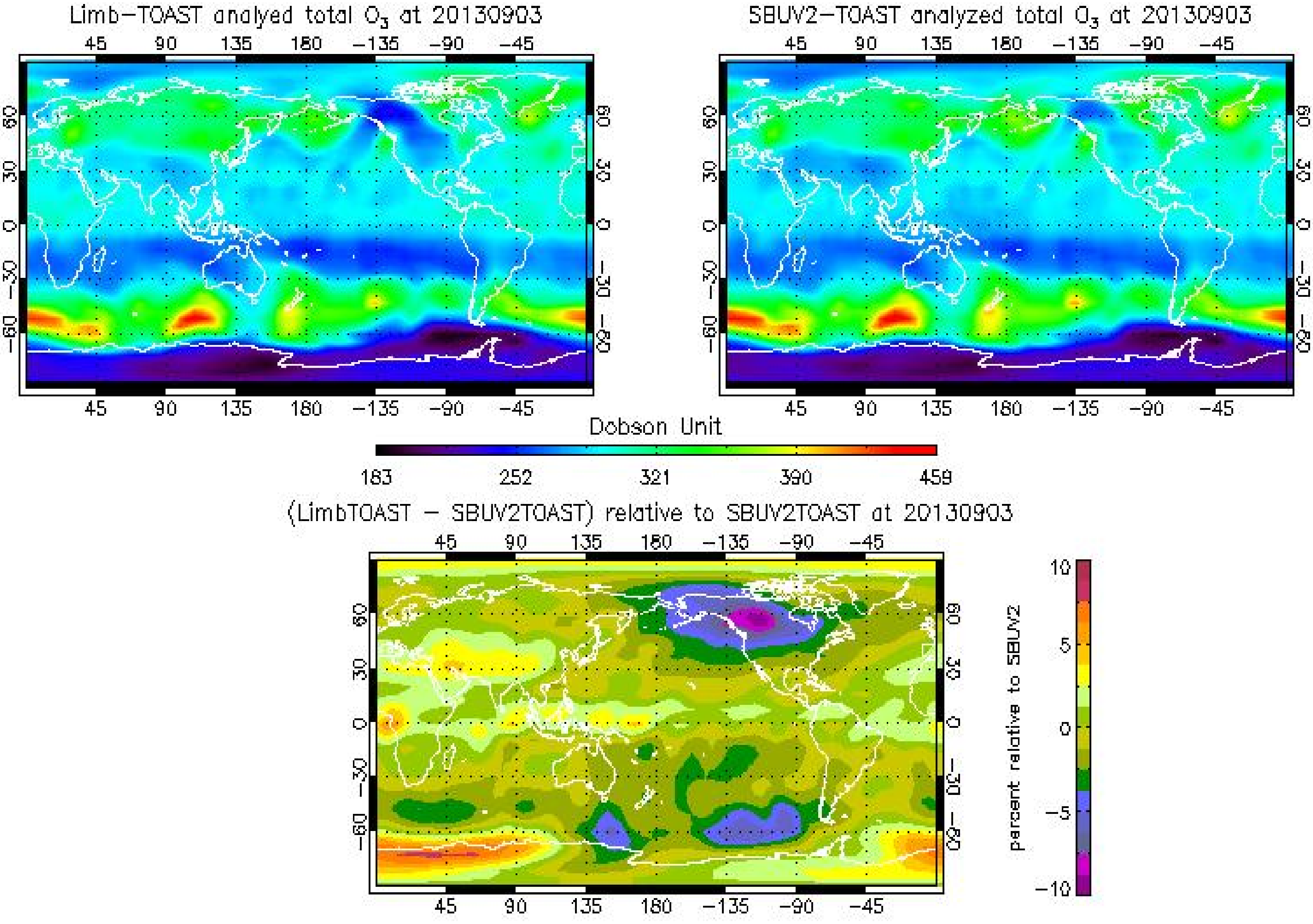
CrIS



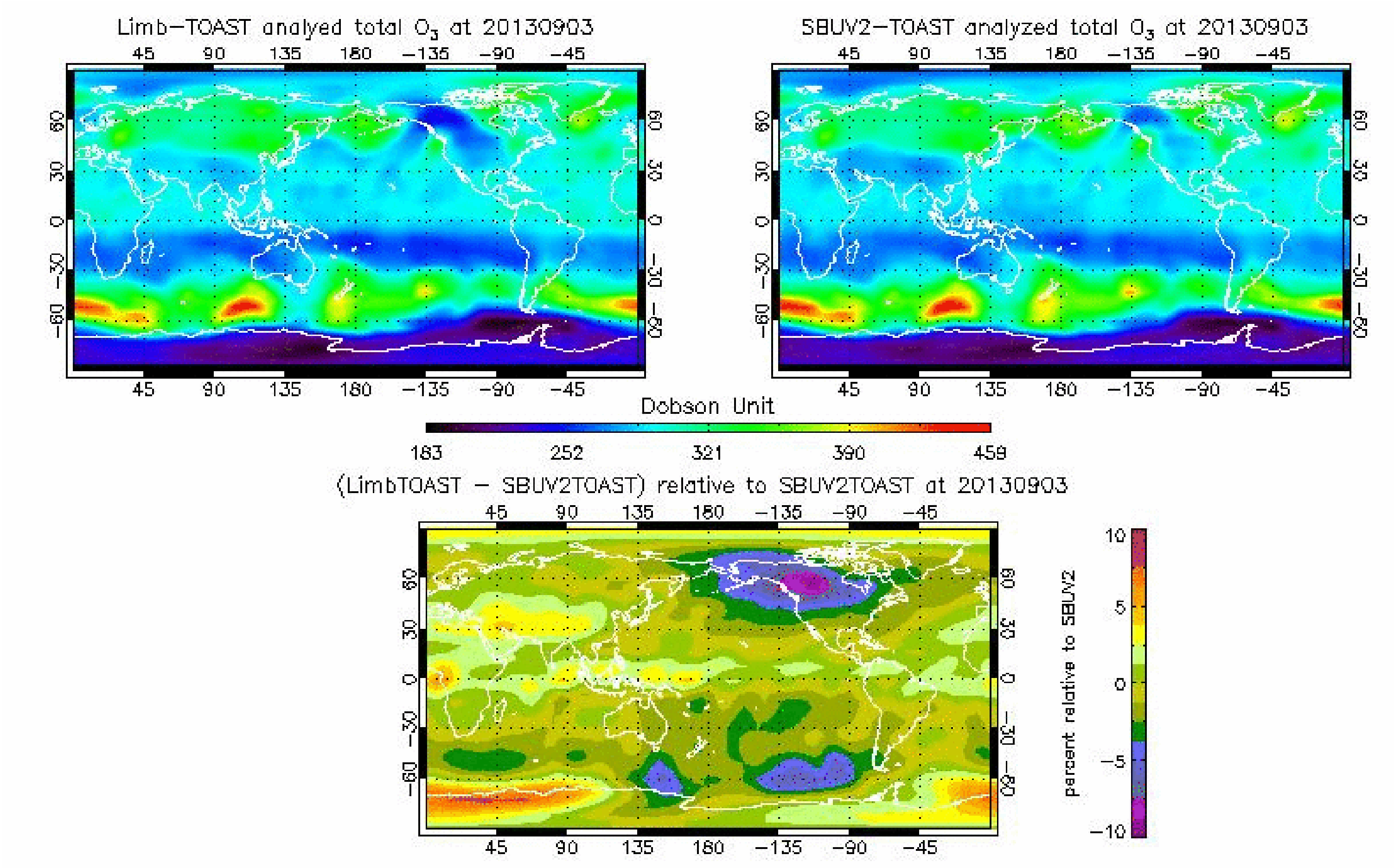
CrIS + Limb



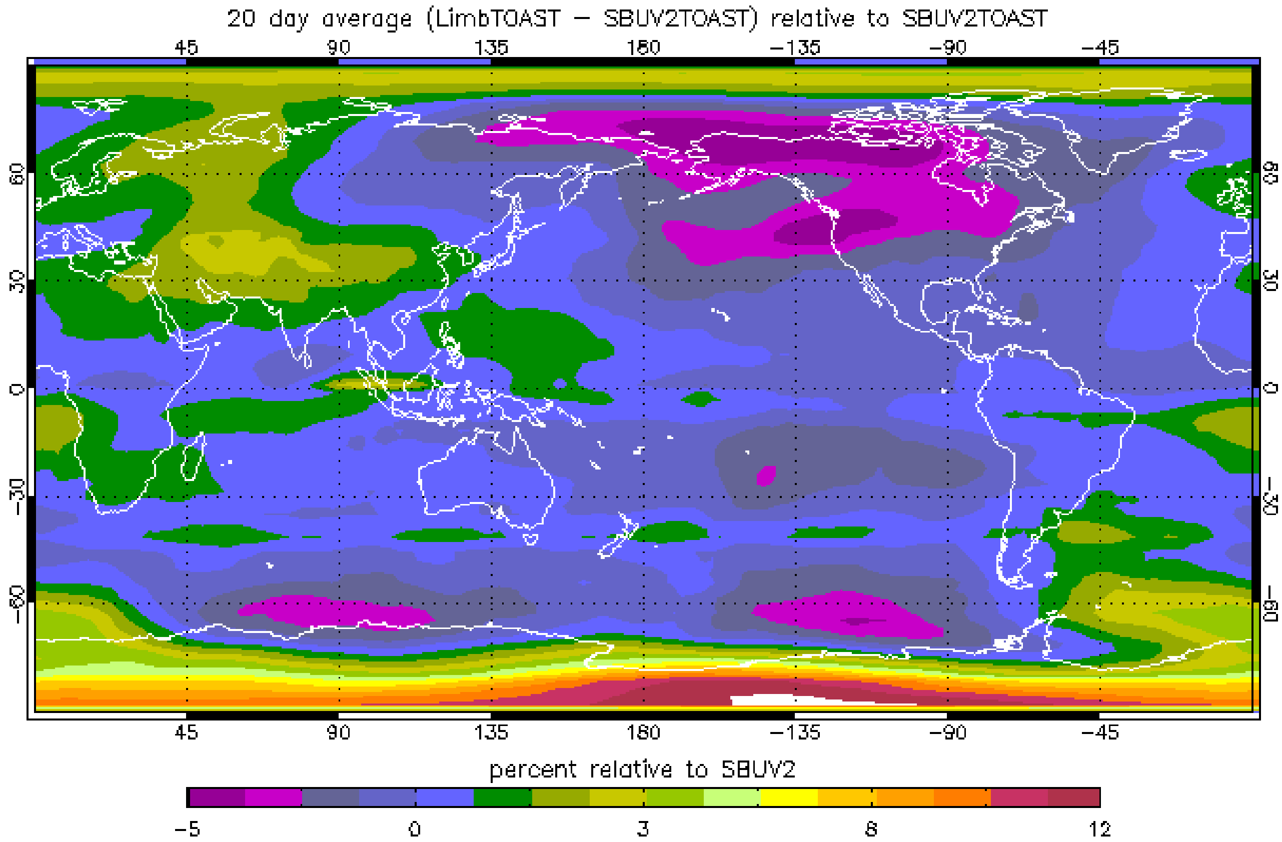
Last year demonstrated:



Last year demonstrated:
20 days analyzed maps and the relative differences.

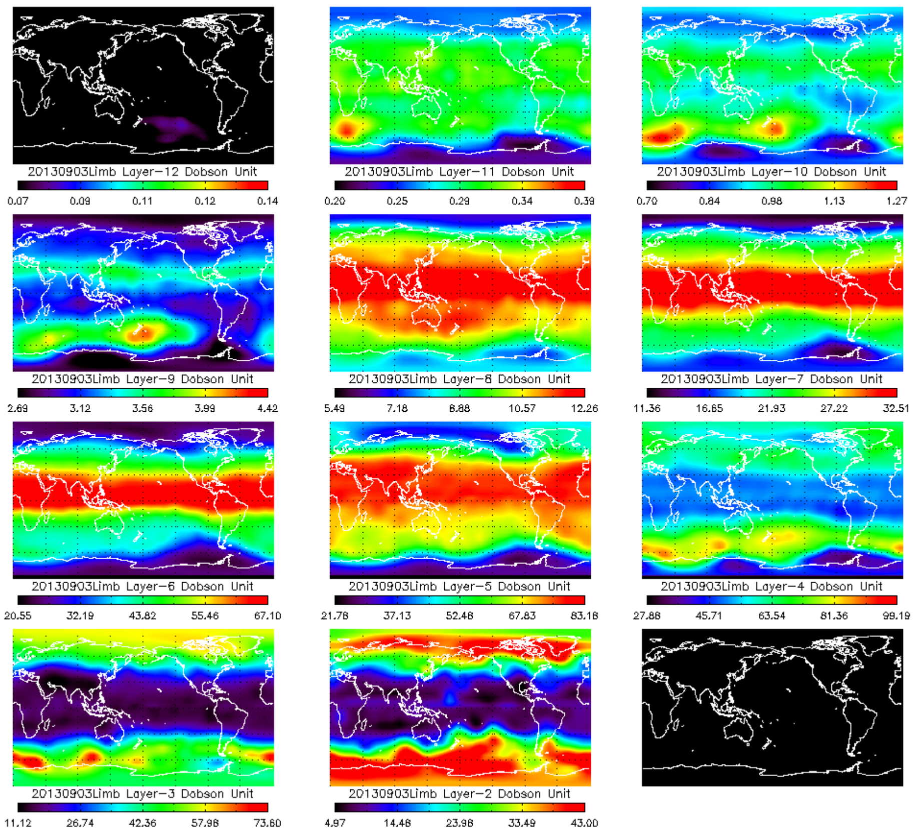


Last year demonstrated:
20 day average of the relative differences to current version
from 09-03-2013 to 09-22-2013

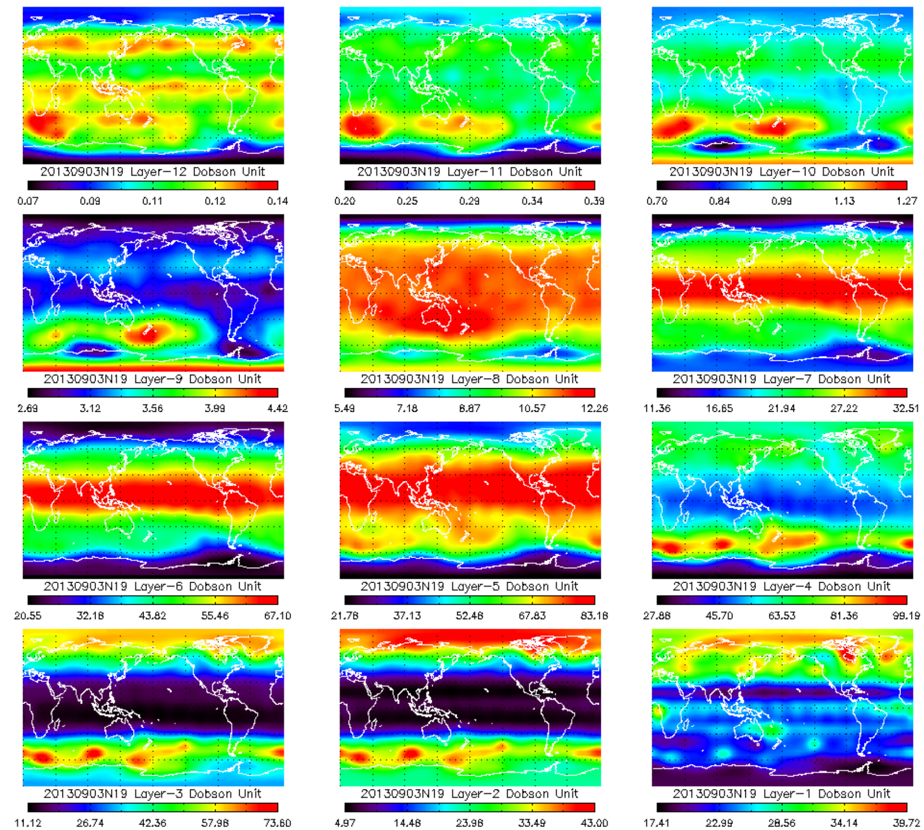


Analyzed 12 Umkehr O_3 layers 09-03-2013

Limb



SBUV



What we have achieved

- OMPS Limb TOAST and SBUV/2 TOAST show similar global patterns and values in the upper layers (comparison need to introduce retrieval averaging kernels)
- Limb analysis algorithm functions well from the comparison of the EDR input and analyzed figures
- 20 days of total column Ozone analysis have been conducted
- The averaged relative differences shows Limb TOAST total amount analysis has ±5% differences relative to current operational version (SBUV/2 TOAST).

The upcoming TOAST (CrIS + OMPS/Limb)

Baseline products:

- 12 layers global 1˚ × 1˚ layer VCD O_3 maps
- Eight layers of Limb global 1˚ × 1˚ layer VCD maps at pressure level of 31.7, 15.8, 7.93, 3.96, 1.98, 0.99, 0.50, 0.25 mb
- Four layers of CrIS global 1˚ × 1˚ layer VCD maps at pressure level of 1013, 253, 127, 63.3 mb.

Based on operational request we could:

- Provide 21 layer (V8 layers ~3km) the same analyzed maps
- Provide 61 Limb layers of analyzed maps

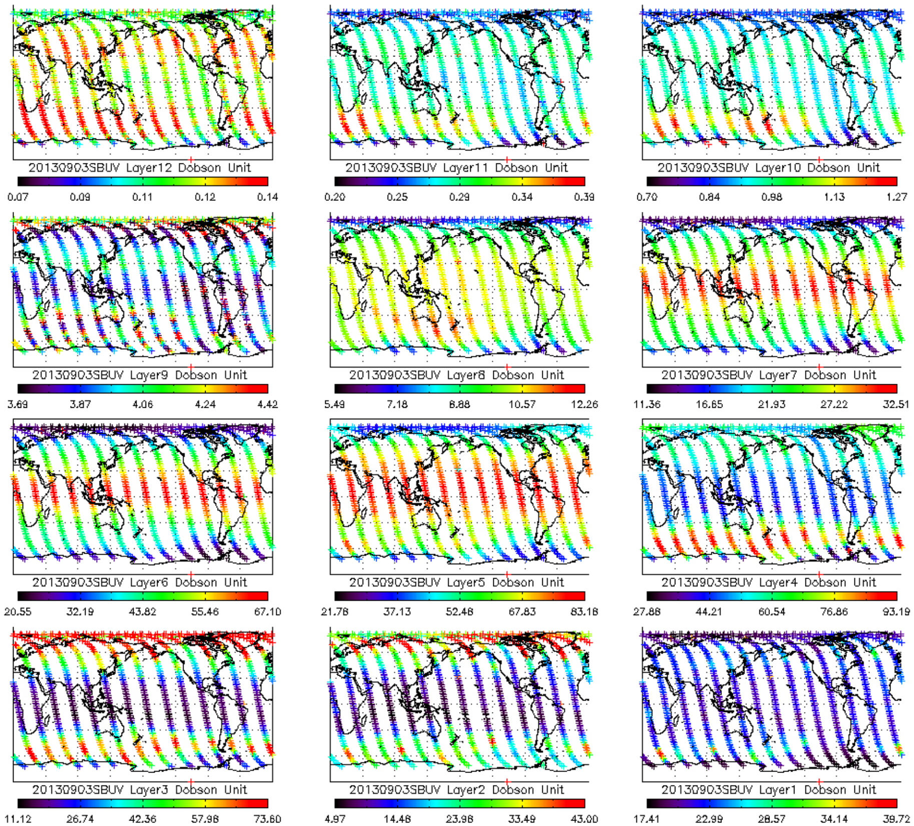
Summary

- The TOAST algorithm for CrIS + Limb has been developed and tested using NUCAPS and NASA Limb Profiler daily data products.
- The OMSP Limb Profiler SDR and EDR processing algorithms have been successfully transferred from NASA to NOAA, and have completed code and security review, they are ready for implementation the next builds at NDE.

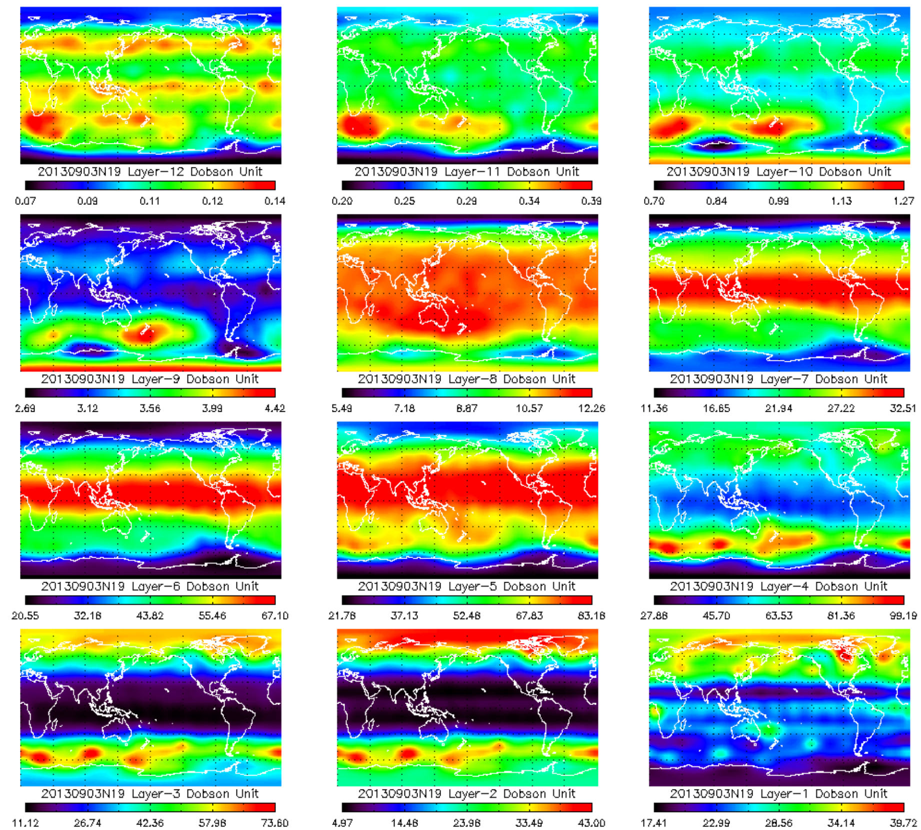
THANKS

SBUV 12-layer vs. analyzed 09-03-2013

SBUV-2 input



TOAST SBUV-2 analyzed



Validation of the NPP-Suomi OMPS ozone products with NOAA ground-based Dobson network.

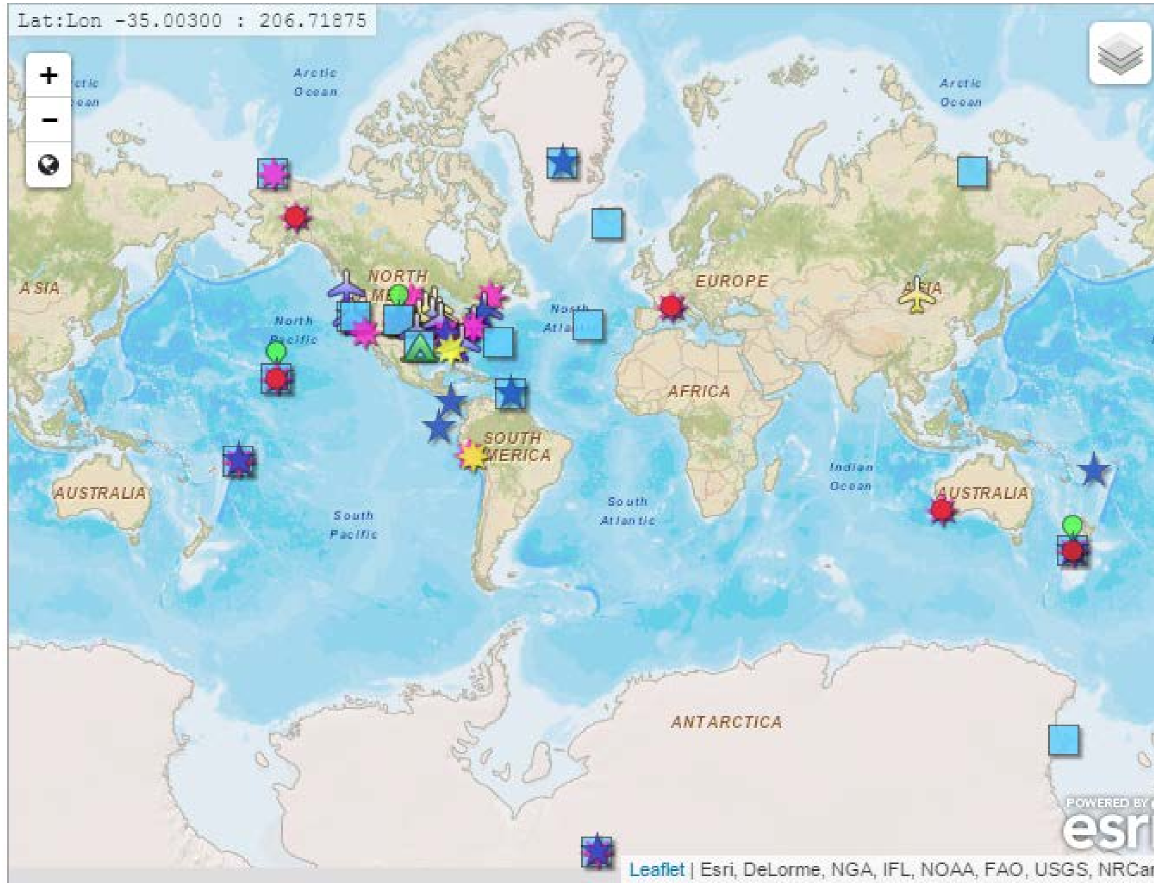
By I. Petropavlovskikh[1,2], K. Miyagawa[2], B. Evans[1,2], G. McConville[1,2], A. McClure[1,2], E. Beach[3], L. E. Flynn[4]

1 Cooperative Institute for research in Environmental Sciences, U. of Colorado, Boulder, CO
2 Global Monitoring Division, NOAA/ESRL, Boulder, CO
3 IMSG, Inc. @ Center for Satellite Applications and Research, NOAA/NESDIS, College Park, MD
4 Center for Satellite Applications and Research, NOAA/NESDIS, College Park, MD

CIRES

Cooperative Institute for Research in Environmental Sciences
UNIVERSITY OF COLORADO BOULDER and NOAA

Introduction to NOAA’s Ozone Network



NOAA GMD ozone and water vapor group maintains long-term records of total column and ozone profiles at 20+ unique locations around the globe.

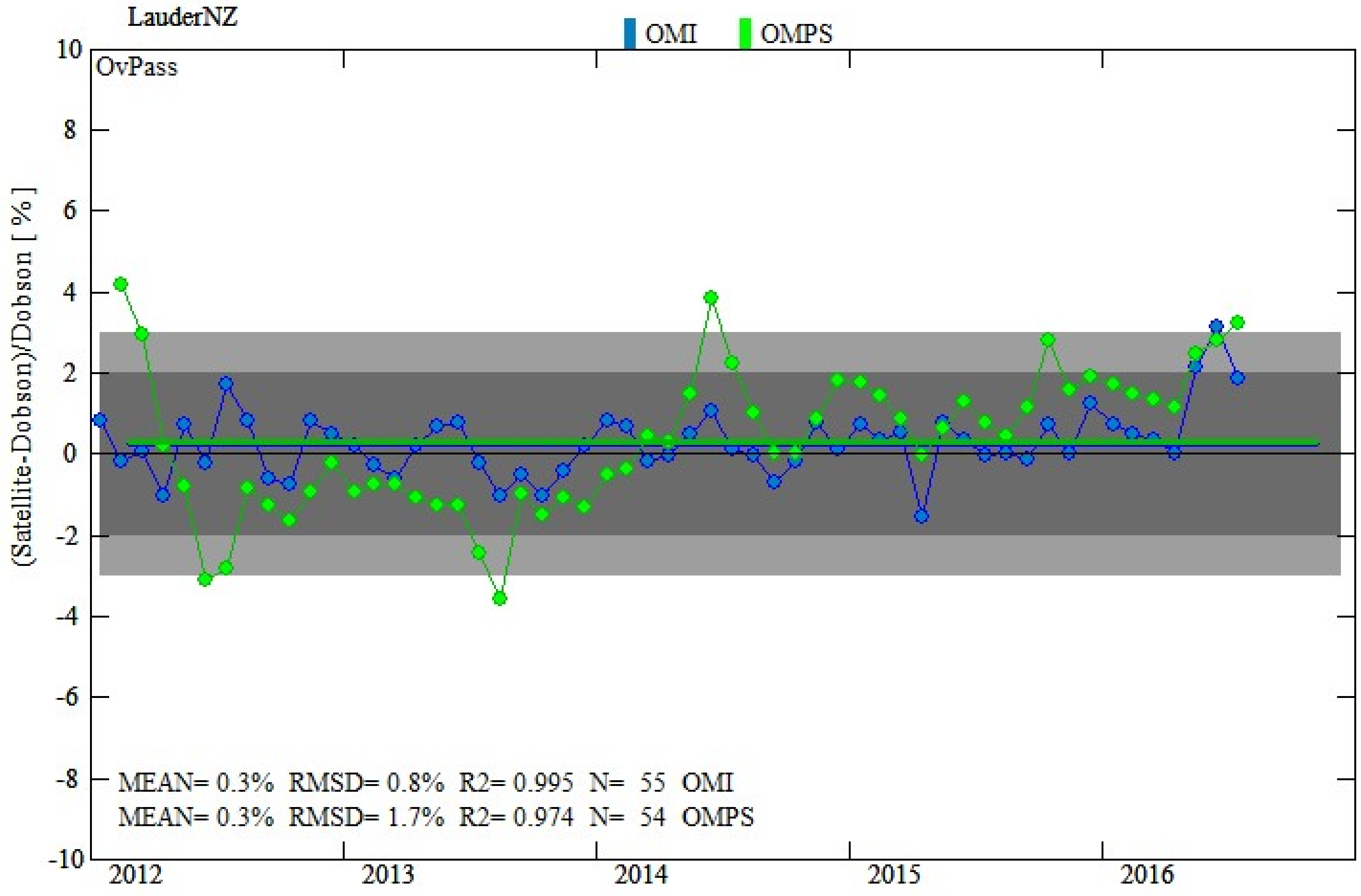
Spatial and temporal variability and its impact on Dobson comparisons

- Size of the footprint

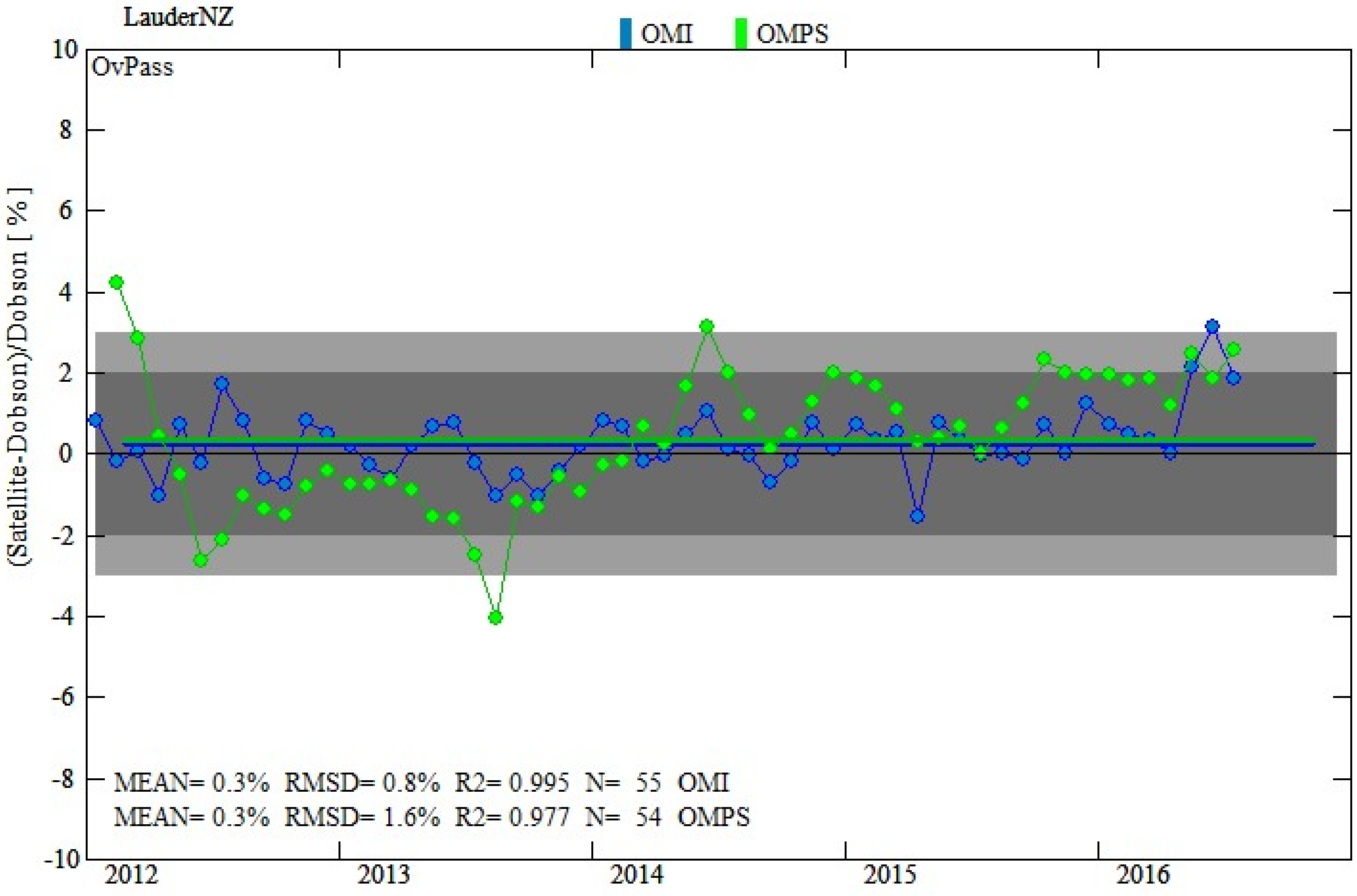
OMI -13x24 , OMPS – 50x50 , SBUV -180x180 km2

- Separation in space
- Separation in time (jet stream meandering)
- Clouds – ozone amount below the cloud, averaging of ozone field with partial clouds
- Surface pressure
- Temperature sensitivity in ozone x-sections

Match ADDS OMPS_NOAA (TOZ; Closest_Dist)

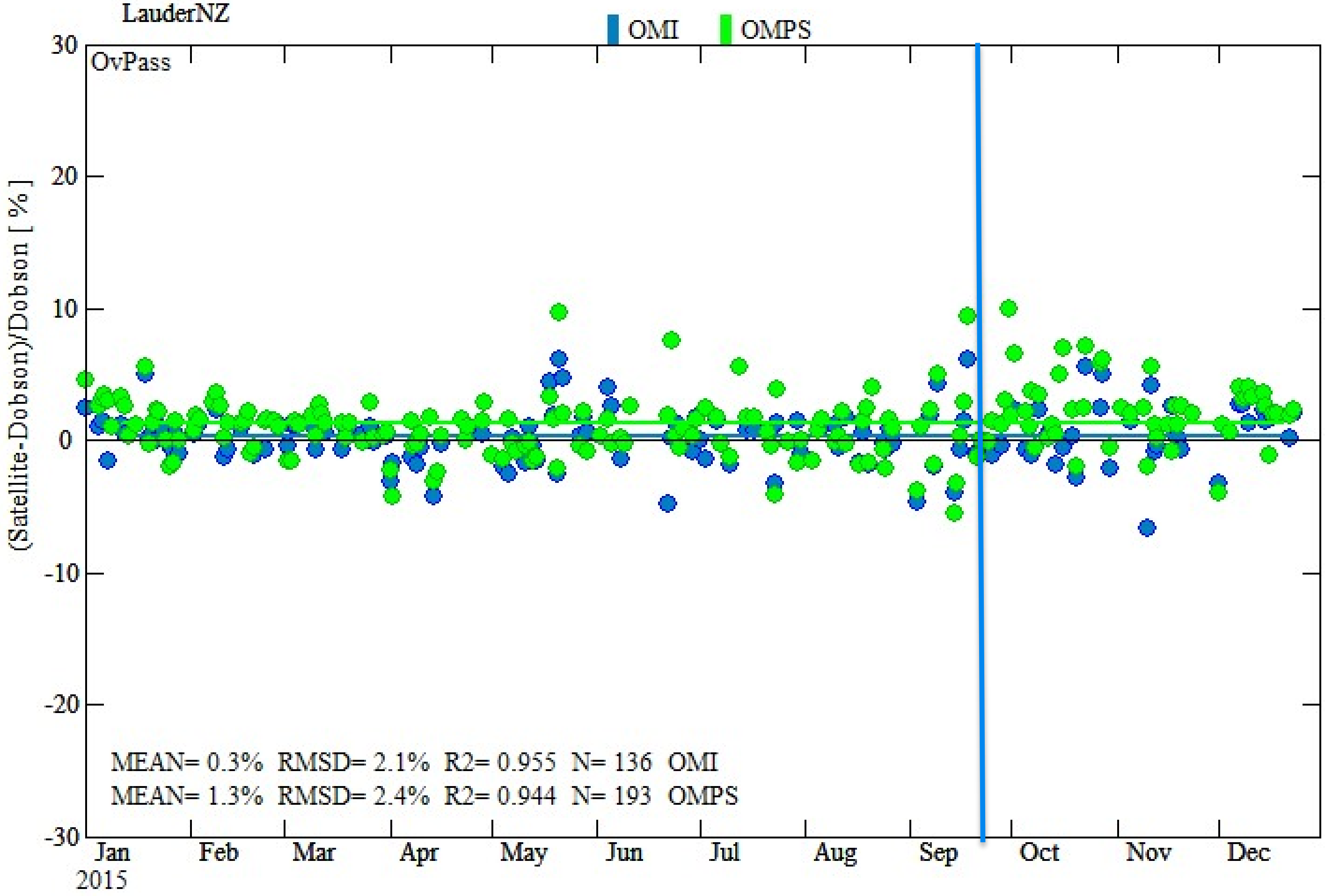


Match ADDS OMPS_NOAA (TOZavg)

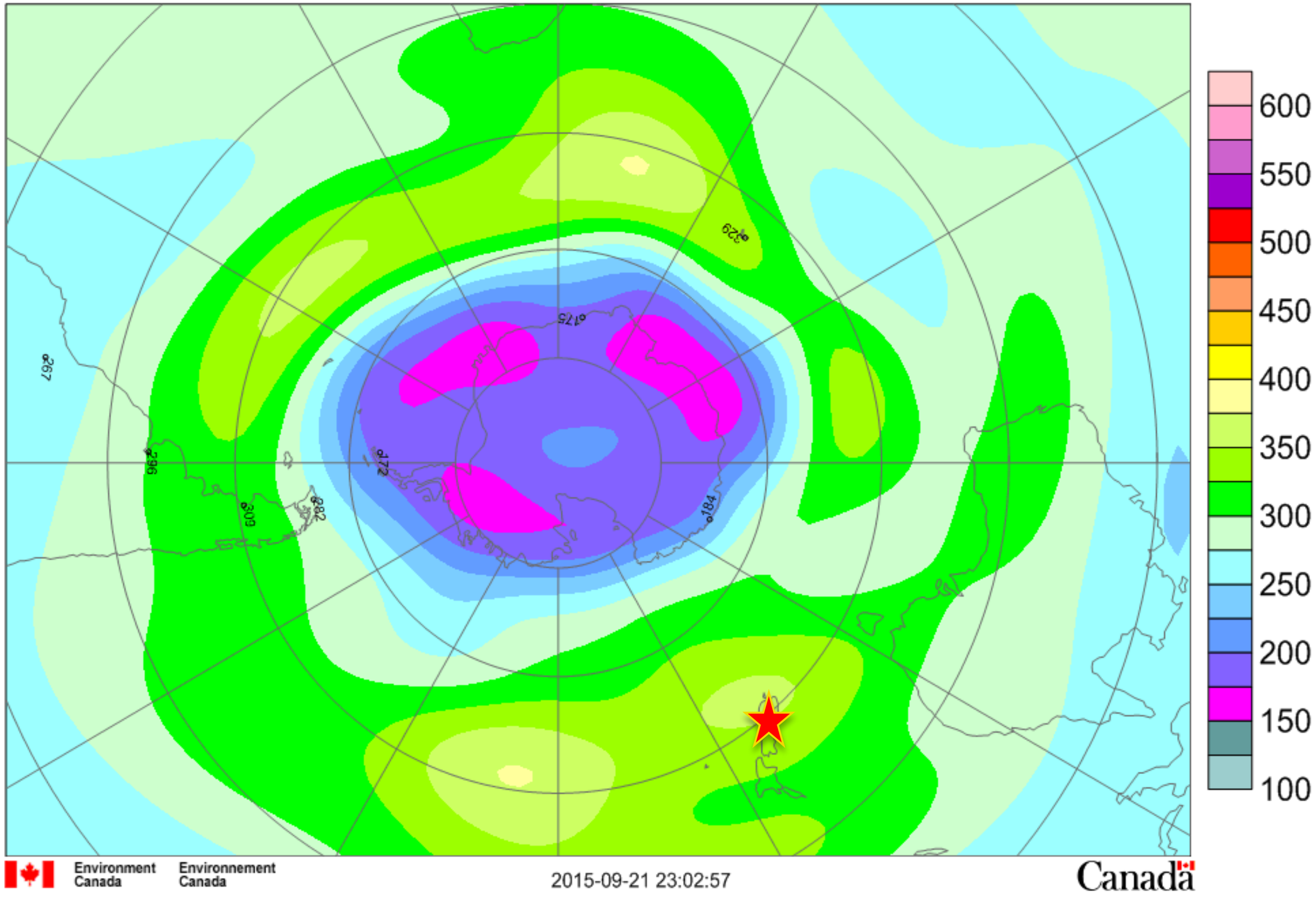


Match ADDS OMPS_NOAA (TOZ; Closest_Dist)

September 19, 2015 Wavelength, Solar, Calibration NM NP CCR 15-2549 15-2548

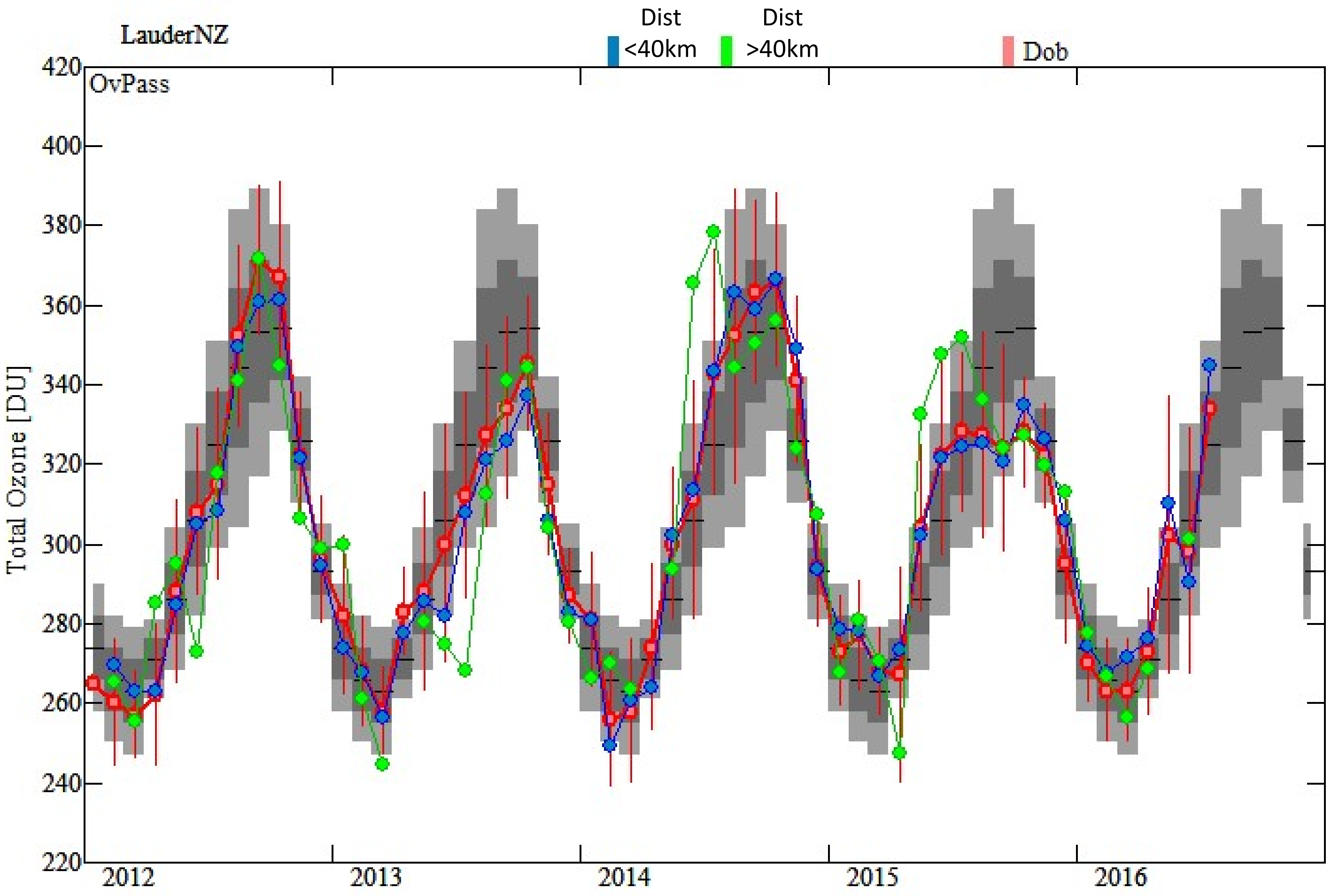


Total ozone (DU) / Ozone total (UD), 2015/09/18



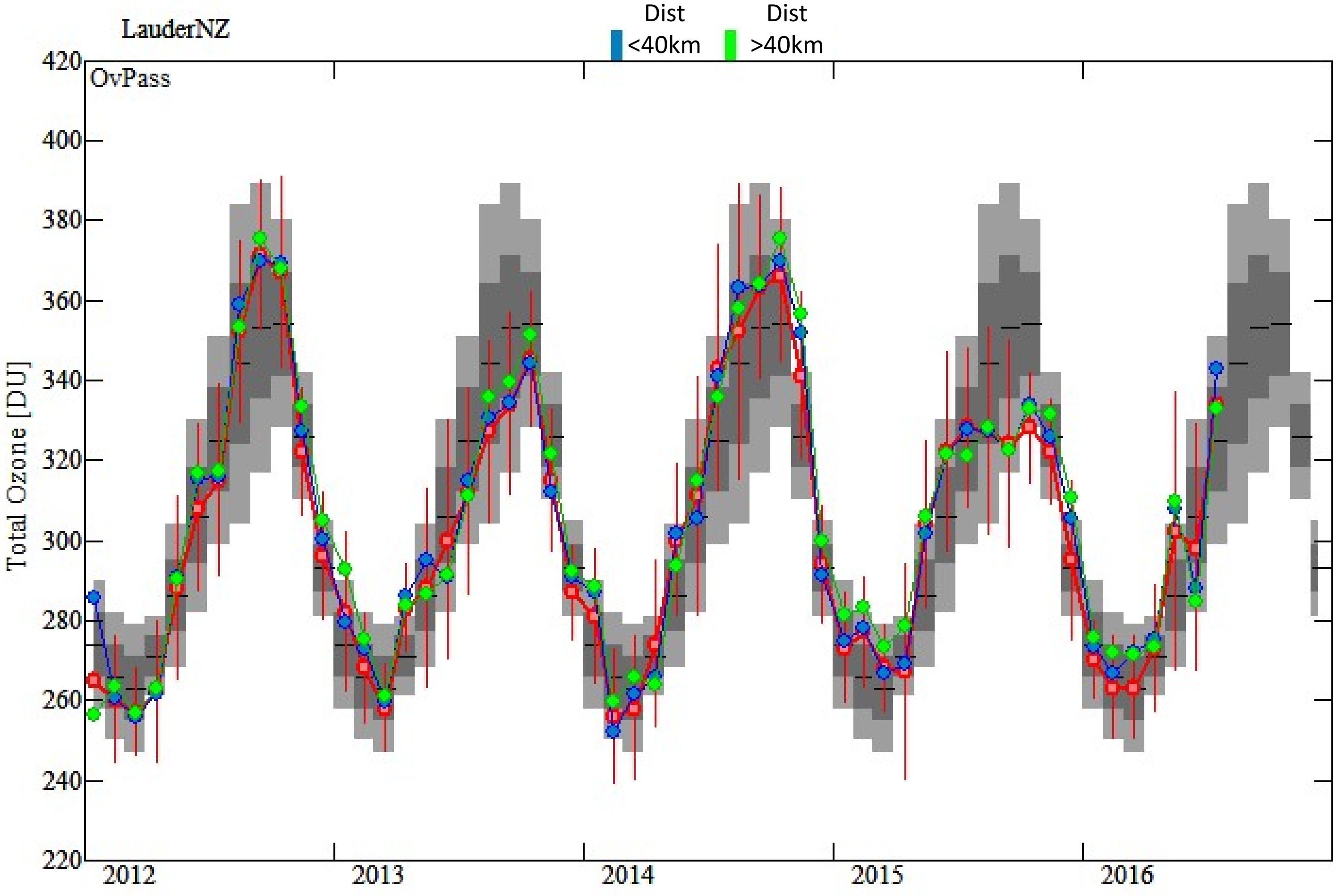
LDR

Matched ADDS OMPS_NOAA

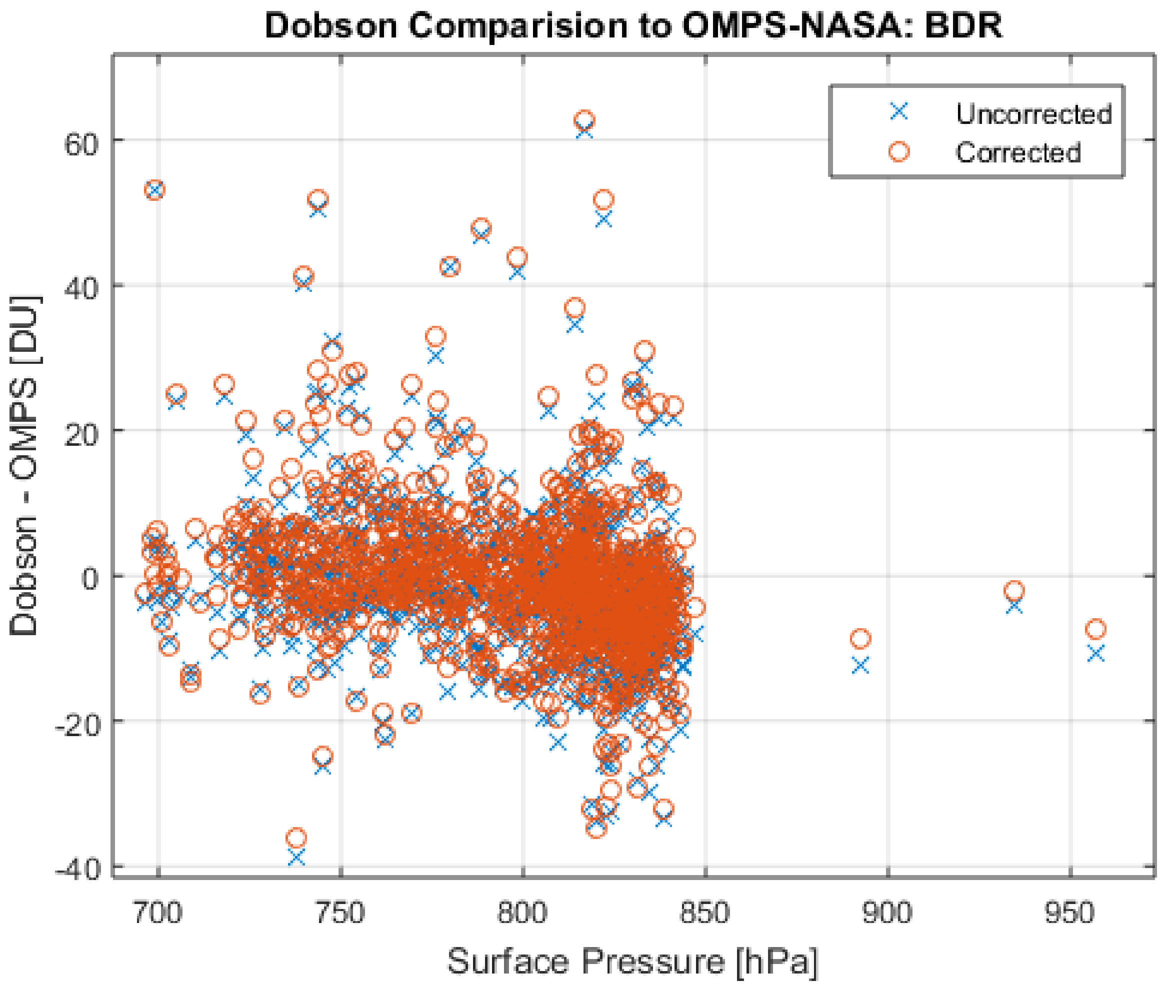


LDR

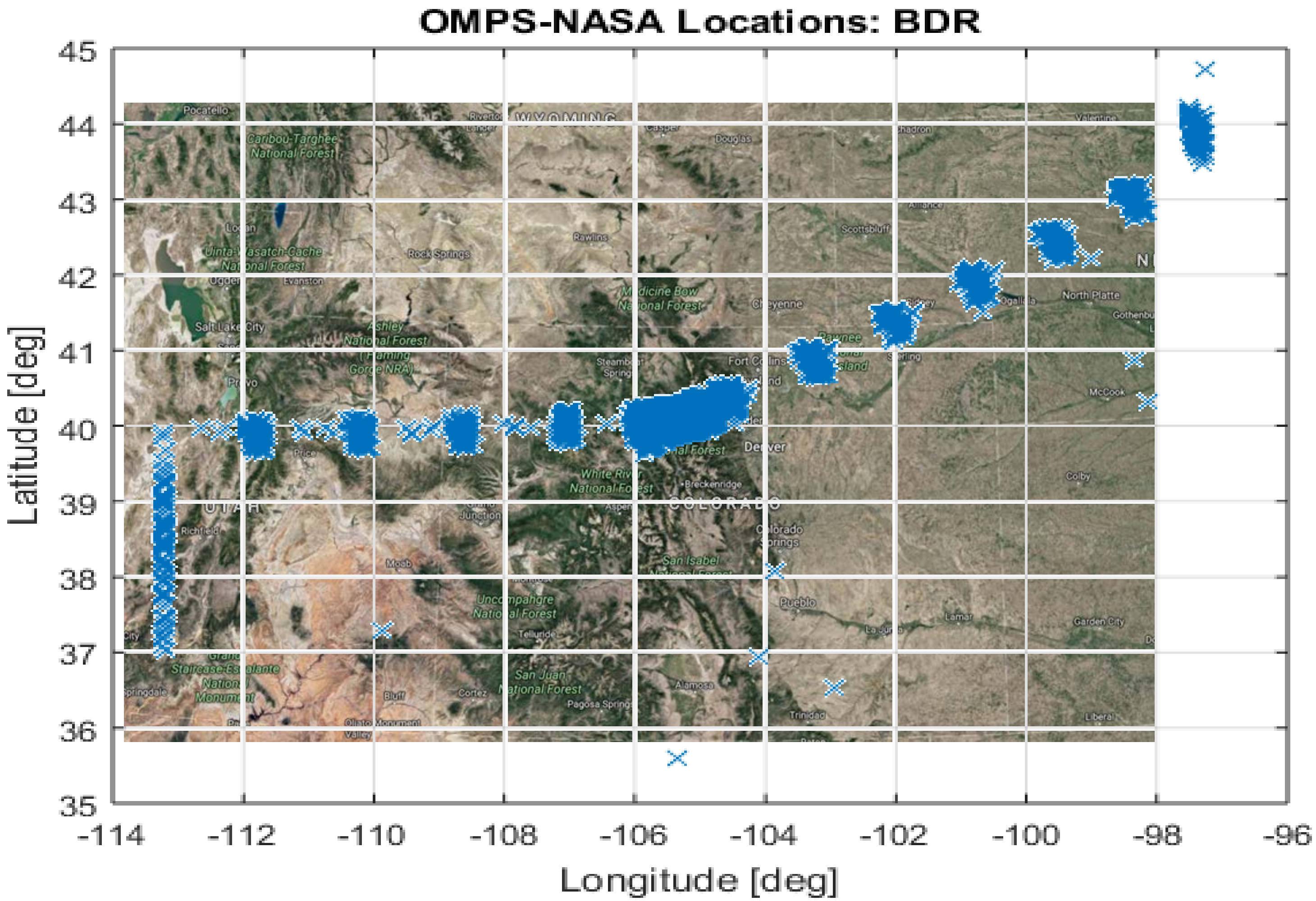
Matched ADDS OMPS_NASA



Screening of the overpass data



Matching criteria for the "closest"



Tracking OMPS SDR changes

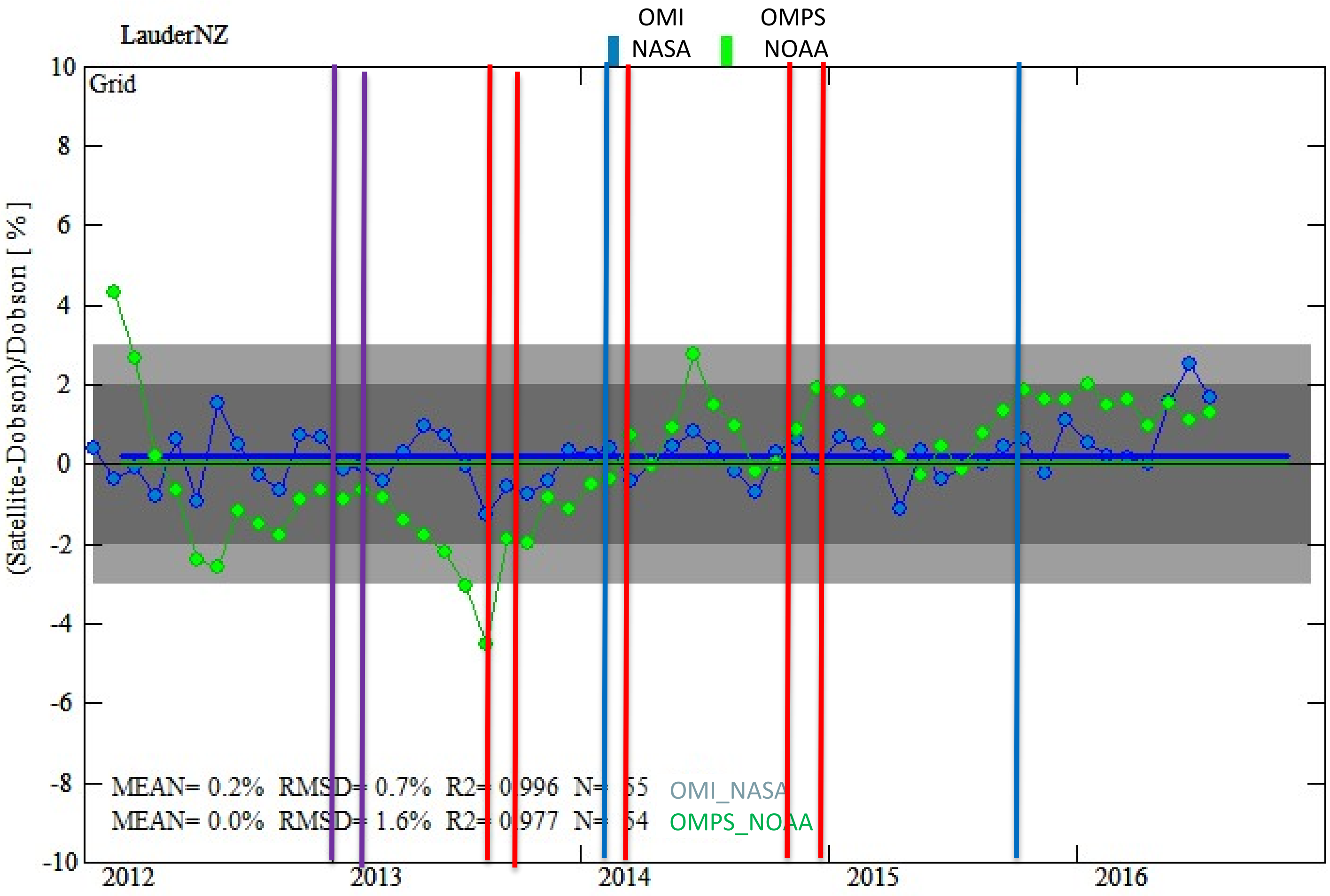
- 1. Wavelength scale changes.
- 2. Day 1 Solar changes
- 3. Changes in stray light corrections
- 4. Calibration constant changes.
- 5. Start of weekly dark update
- 6. Wavelength shift adjustment

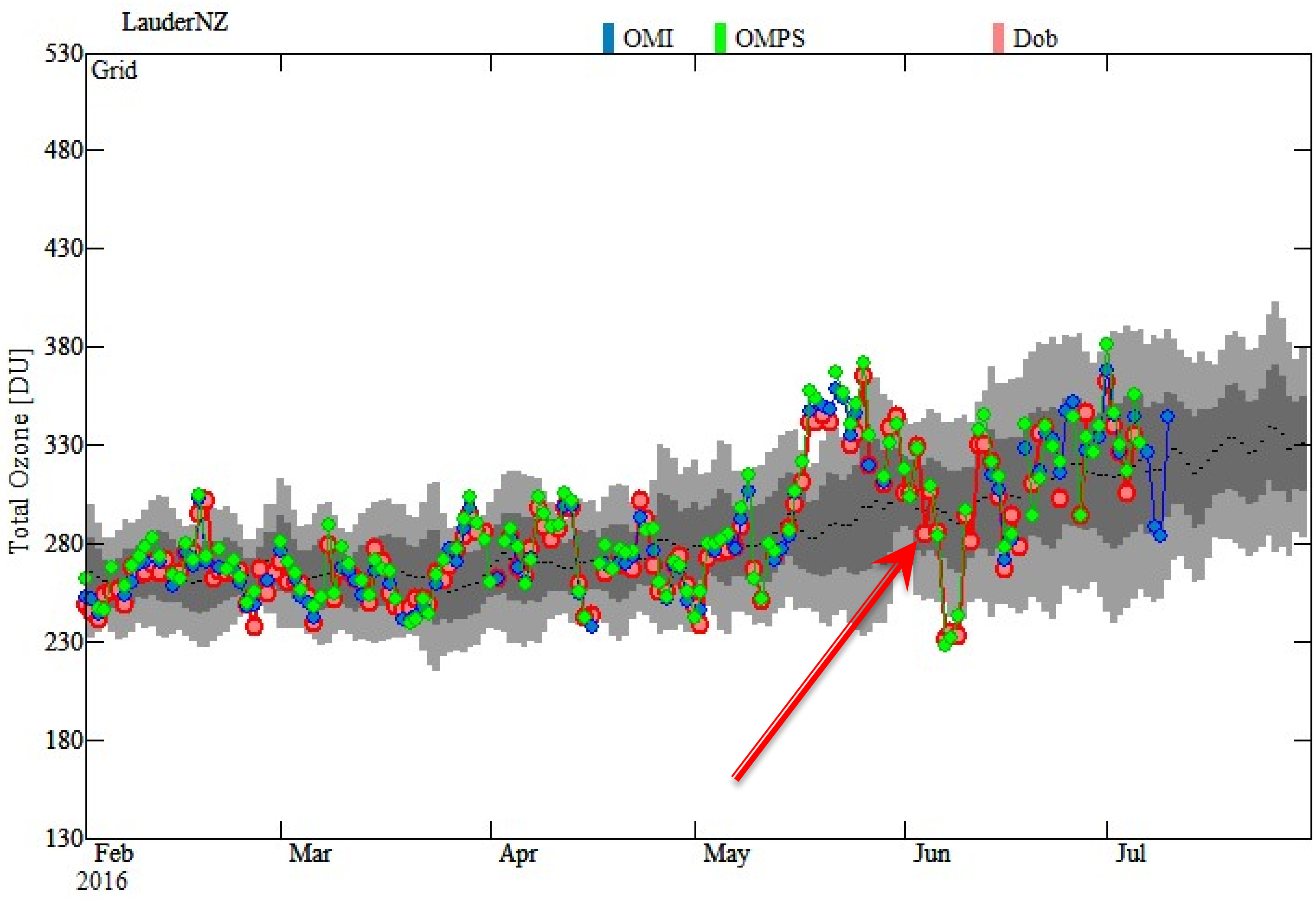
Timeline OMPS SDR changes

- February 2012 Problem with wavelength scales for both NM and NP - SDRs were reprocessed.
- May 7, 2012 Wavelength scales for NM and NP CCR 389
- June 11, 2012 Day 1 Solar for NM CCR 411
- July 17, 2012 Day 1 Solar for NP CCR 458
- **December 21, 2012 Dark Update NM CCR 12-776**
- **February 6, 2013 Dark Update NP CCR 13-801**
- **July 10, 2013 Stray Light Correction NM CCR 13-1115**
- **August 21 2013 Stray Light Correction NM CCR 13-0883**
- **February 20, 2014 Wavelength Shift Adjustment CCR 13-1192**
- **March 18, 2014 Stray Light Correction NP CCR 13-1249**
- October 23, 2014 Wavelength Scale NP CCR 14-2053
- November 13, 2014 Day 1 Solar and Wavelength Scale NM CCR 14-2052
- **November 21, 2014 Stray Light Correction NM CCR 14-1879**
- **December 18, 2014 Stray Light Correction NM CCR 14-2100**
- **September 19, 2015 Wavelength, Solar, Calibration NM NP CCR 15-2549 15-2548**

Lauder, NZ

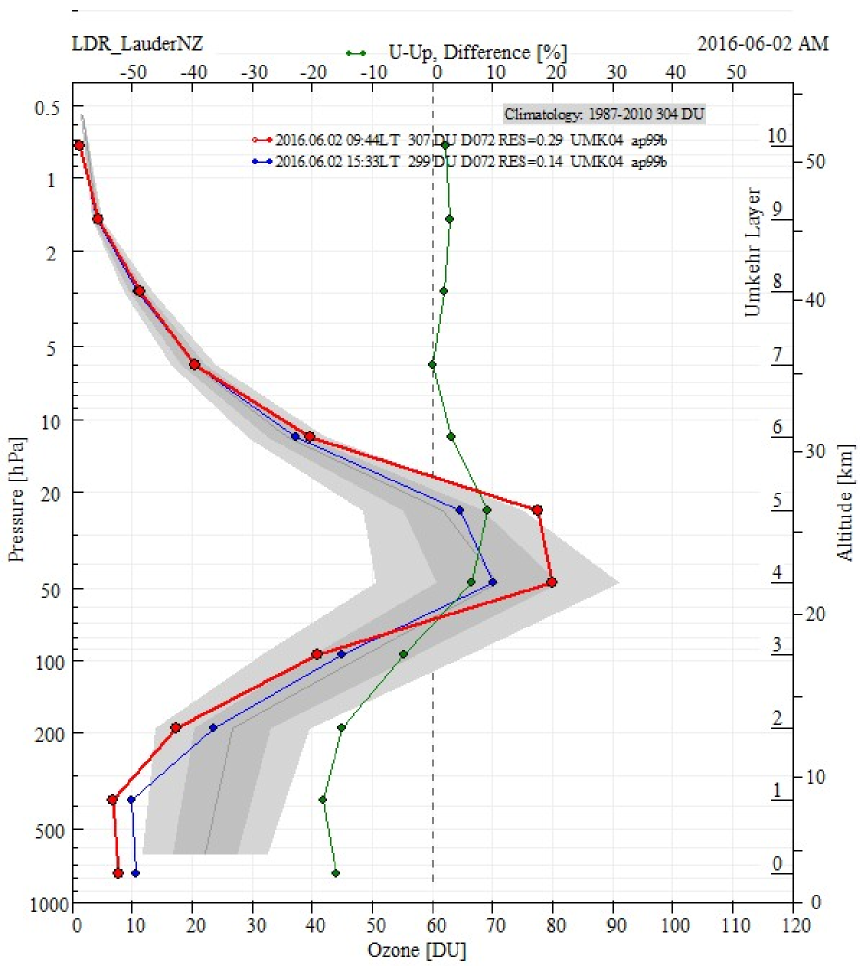
Matched ADDS   Gridded Data



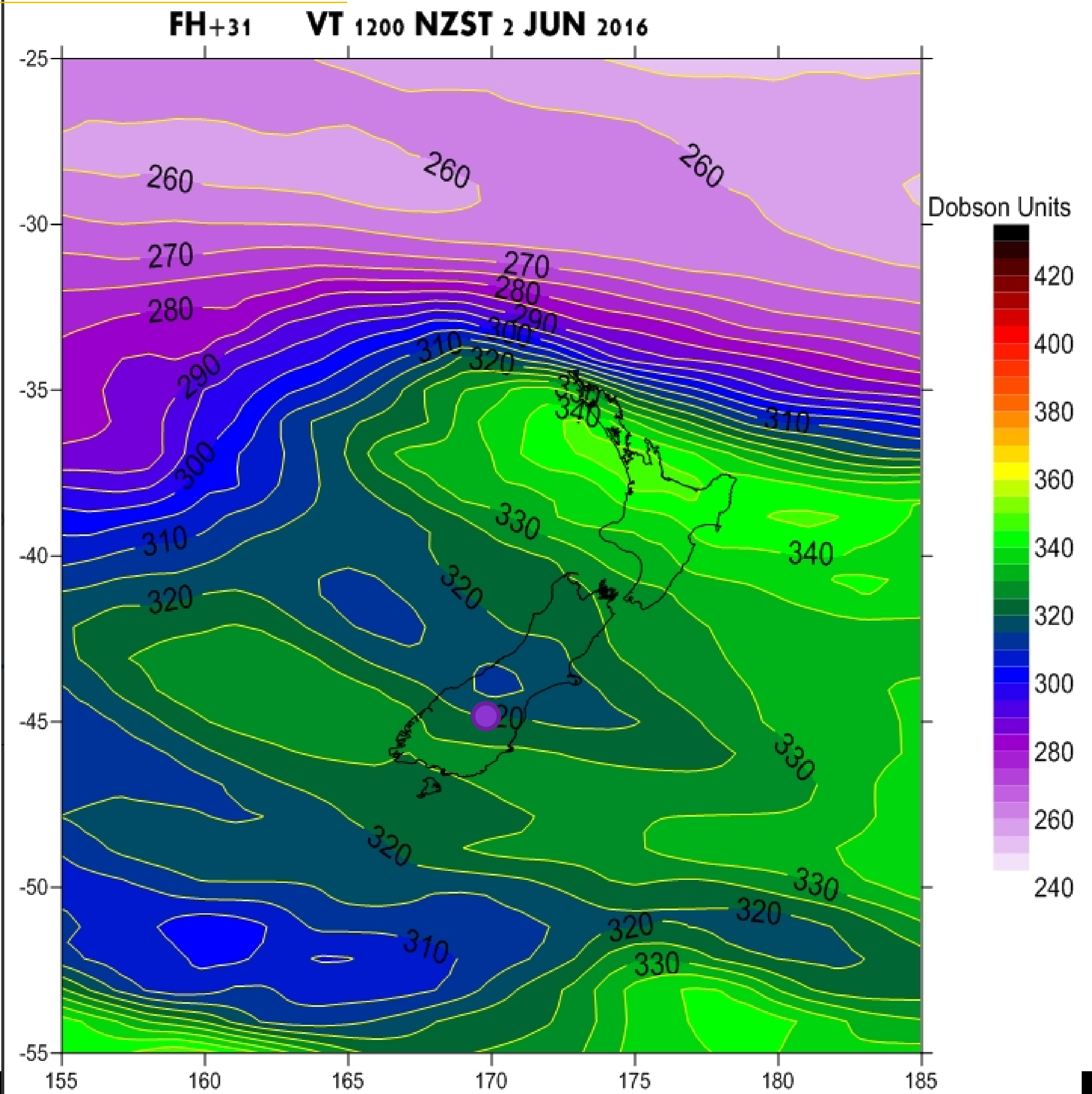


LauderNZ
OMI
OMPS
Dob
Grid
530
480
430
380
330
280
230
180
130
Total Ozone [DU]
Feb
2016
Mar
Apr
May
Jun
Jul

Umkehr AM and PM



https://www.niwa.co.nz/our-services/online-services/uv-ozone



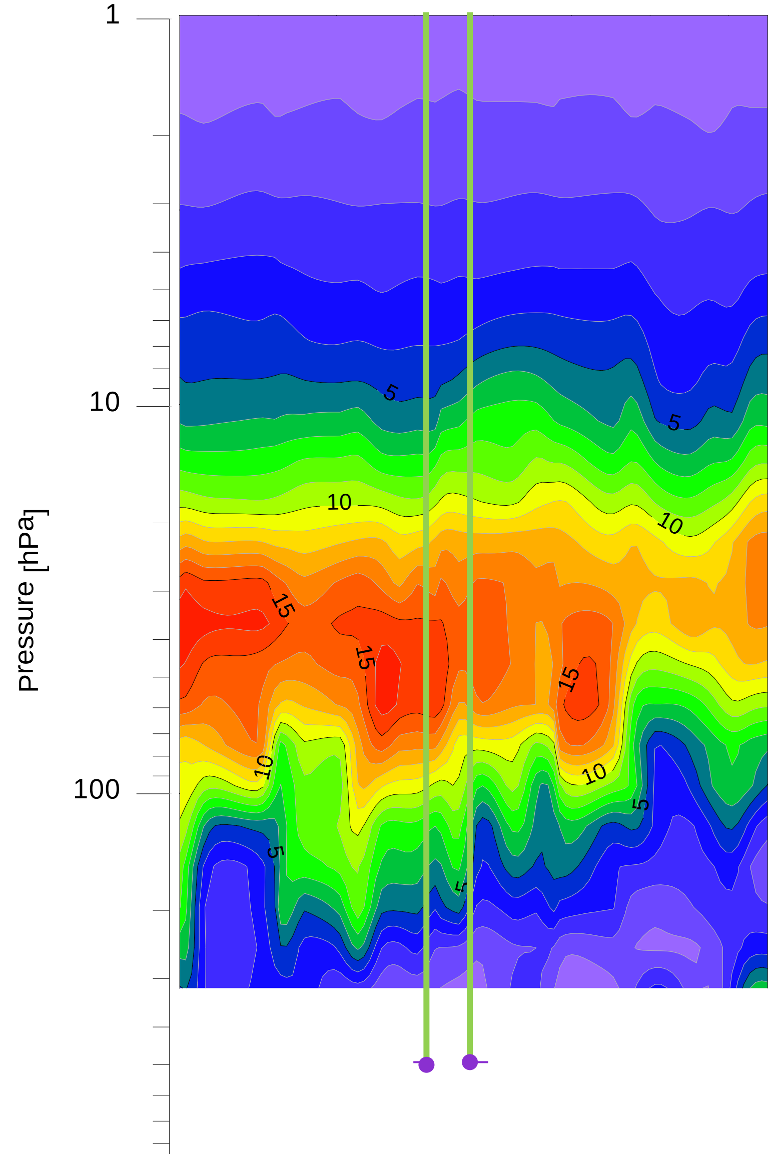
Ozone Map For Today

https://www.niwa.co.nz/our-services/online-services/uv-ozone

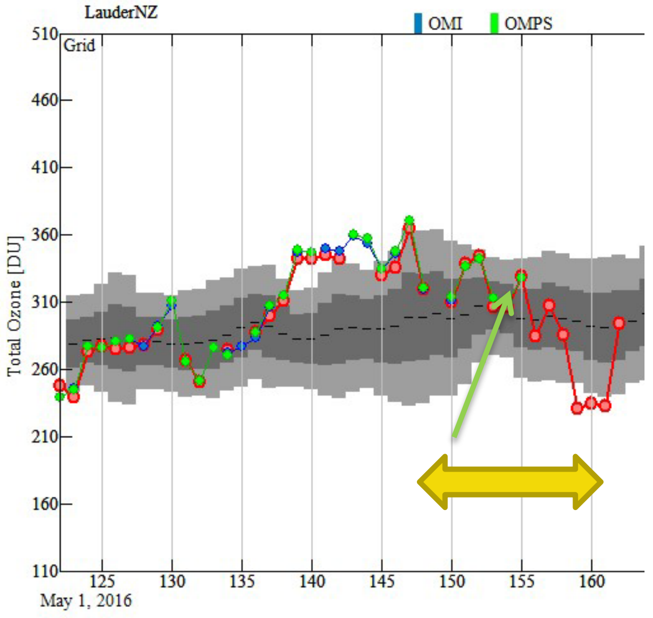
New Zealand ozone maps for noon (12:00NZST, 0:00GMT)

CIRES

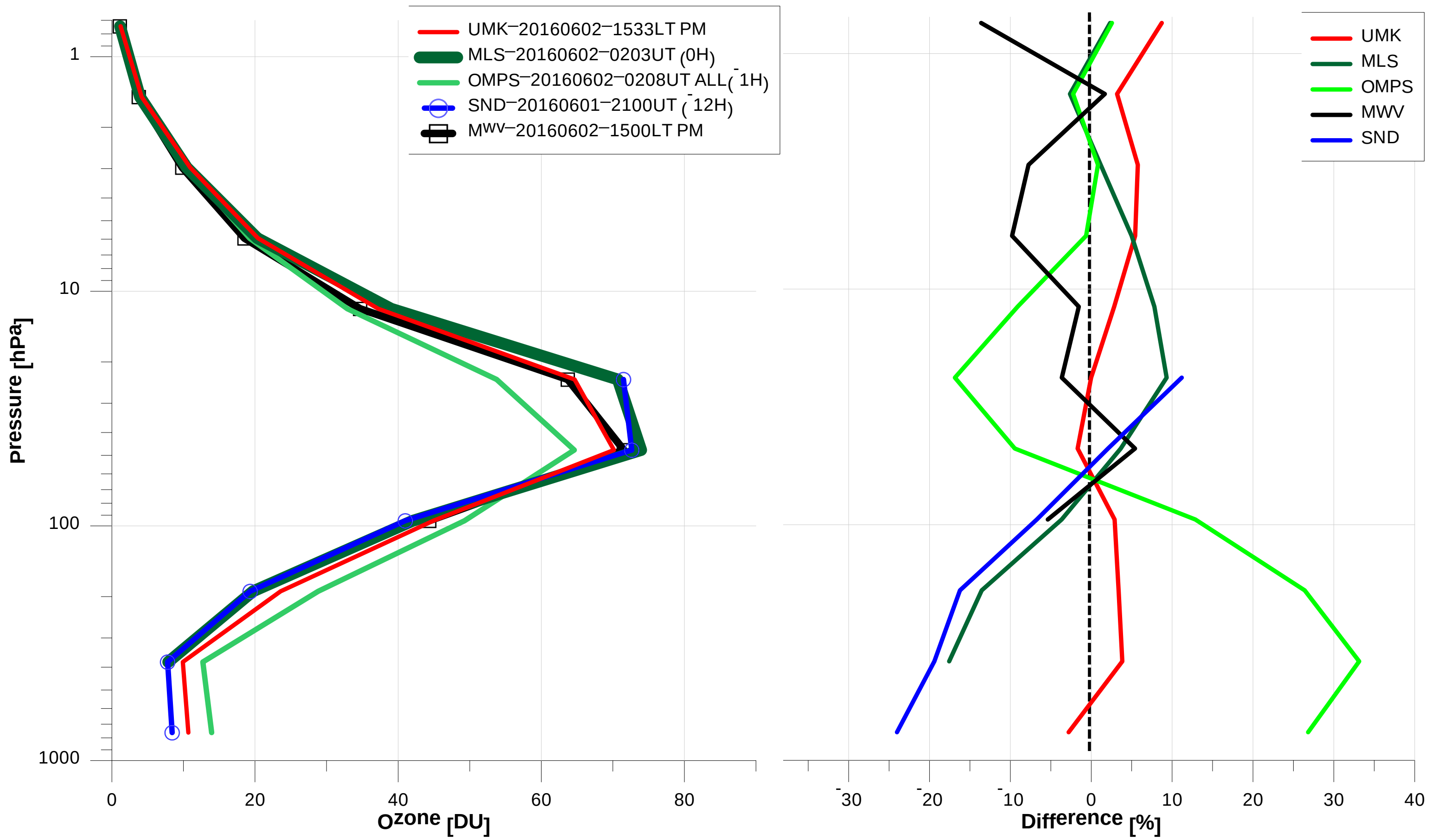
MLS



1
10
100
pressure [hPa]
5
10
15



LauderNZ
OMI
OMPS
Grid
Total Ozone [DU]
510
460
410
360
310
260
210
160
110
125
130
135
140
145
150
155
160
May 1, 2016



UMK–20160602–1533LT PM
MLS–20160602–0203UT (0H)
OMPS–20160602–0208UT ALL(-1H)
SND–20160601–2100UT (-12H)
MWV–20160602–1500LT PM
pressure [hPa]
Ozone [DU]
Difference [%]
UMK
MLS
OMPS
MWV
SND

Boulder Dobson/SBUV Comparison (1992 – 2015)

Brandon Noirot, CIRES/NOAA

Introduction

Problem:
Dobson Total Column Ozone exhibits seasonal error associated with current operational processing of the data using the constant stratospheric temperature. This creates the known bias from other Ozone-measuring methods.

Purpose:
To develop and validate the seasonal cycle correction method for Dobson Total Column Ozone record in Boulder (initially).

Ozone-Temperature Datasets Used to Test Correction:

~ Ozonesondes

~ Solar Backscatter UltraViolet (SBUV)

http://www.star.nesdis.noaa.gov/smcd/spb/ozone/Version8AlgorithmDesc.php

~ Ozone Mapping Profiler Suite (OMPS)

http://npp.gsfc.nasa.gov/omps.html

~ Global Modeling Initiative (GMI) (Susan Strahan, Goddard/USRA)

http://gmi.gsfc.nasa.gov/index.php?section=7

Equations: Effective Temperature

Generic Effective Temperature (Ozone-Weighted Temperature) [2]:

$$T_{effective} = \frac{\int_0^{top} (T(Z) * O_3(Z))dZ}{\int_0^{top} O_3(Z)dZ} = \frac{\sum_{i=1}^{N_{top}} [T(i) * O_3(i)]}{\sum_{j=1}^{N_{top}} O_3(j)} \qquad (1)$$

Effective Temperature for Ozonesonde (Ozone-Weighted Temperature) [4]:

$$T_{effective} = \frac{\sum_{i=1}^{N_{top}} [T(i) * O_3(i)]}{\sum_{j=1}^{N_{top}} O_3(j)} + \frac{O_{3,top} * \frac{(T_{top}+T_{ref})}{2}}{TOC} \qquad (2)$$

T_{ref} is the reference temperature at a certain altitude using the 1976 Standard Atmosphere.
T_{ref} = -2.5°C for a Geopotential Height of 50km.

TOC is the Total Ozone Column (in DU).

T_{top} is the temperature at the burst.

Equations: TOC

Total Ozone Column Calculation (in DU):

$$O_{3,column} = \frac{1}{2} 0.7898 ln(\frac{P_i}{P_{i+1}})(VMR_i * P_i + VMR_{i+1} * P_{i+1}) \qquad (3)$$

VMR is the Volumetric Mixing Ratio in ppmv.
p is pressure in hPa.

$10 * RT_0 / g_0 p_0 = 0.7898$

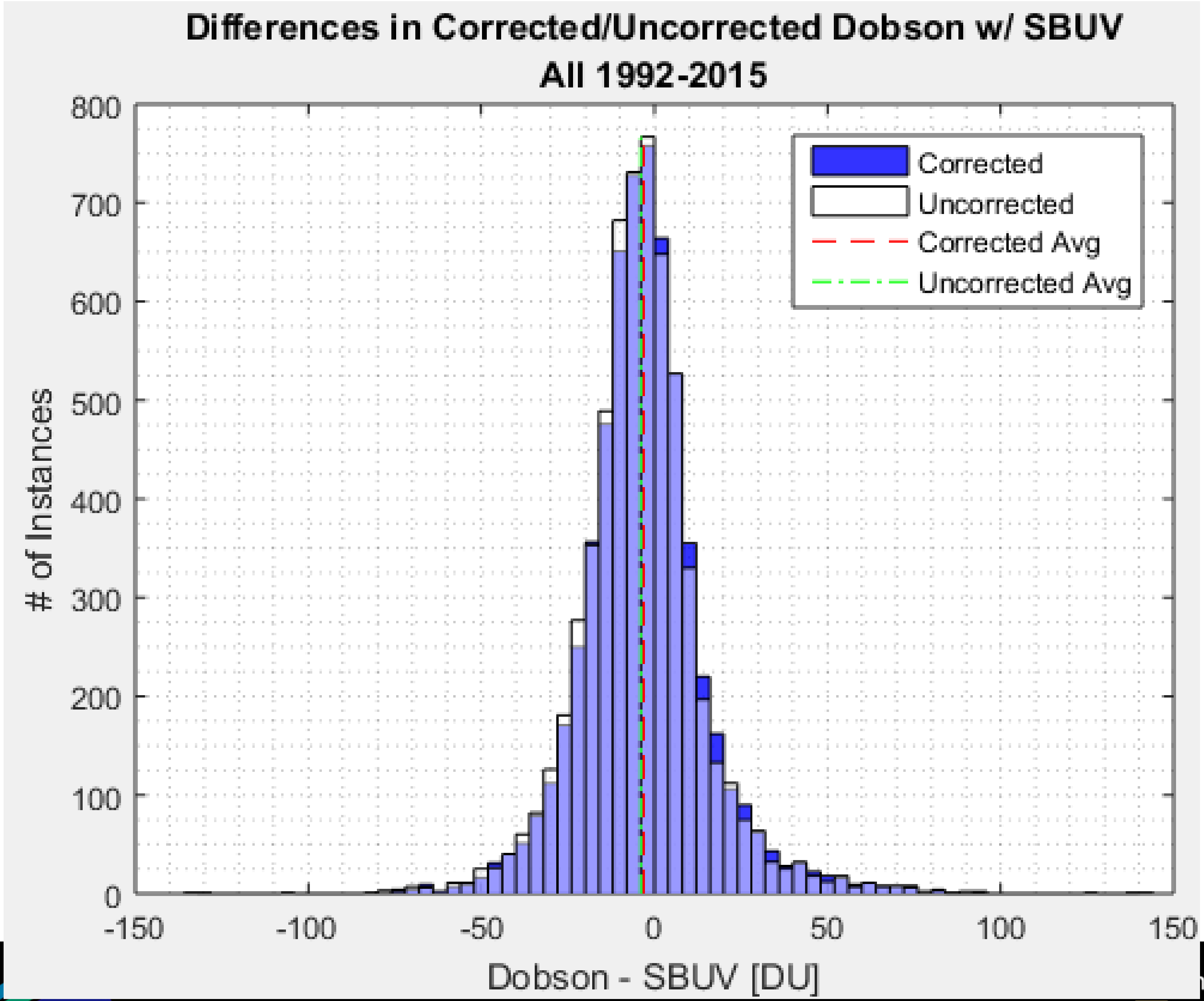
Effective Temperature Adjusted Total Ozone Column (in DU) [2]:

-46.5^{o}C (Note: Dobson reference temperature is -46.3^{o}C)

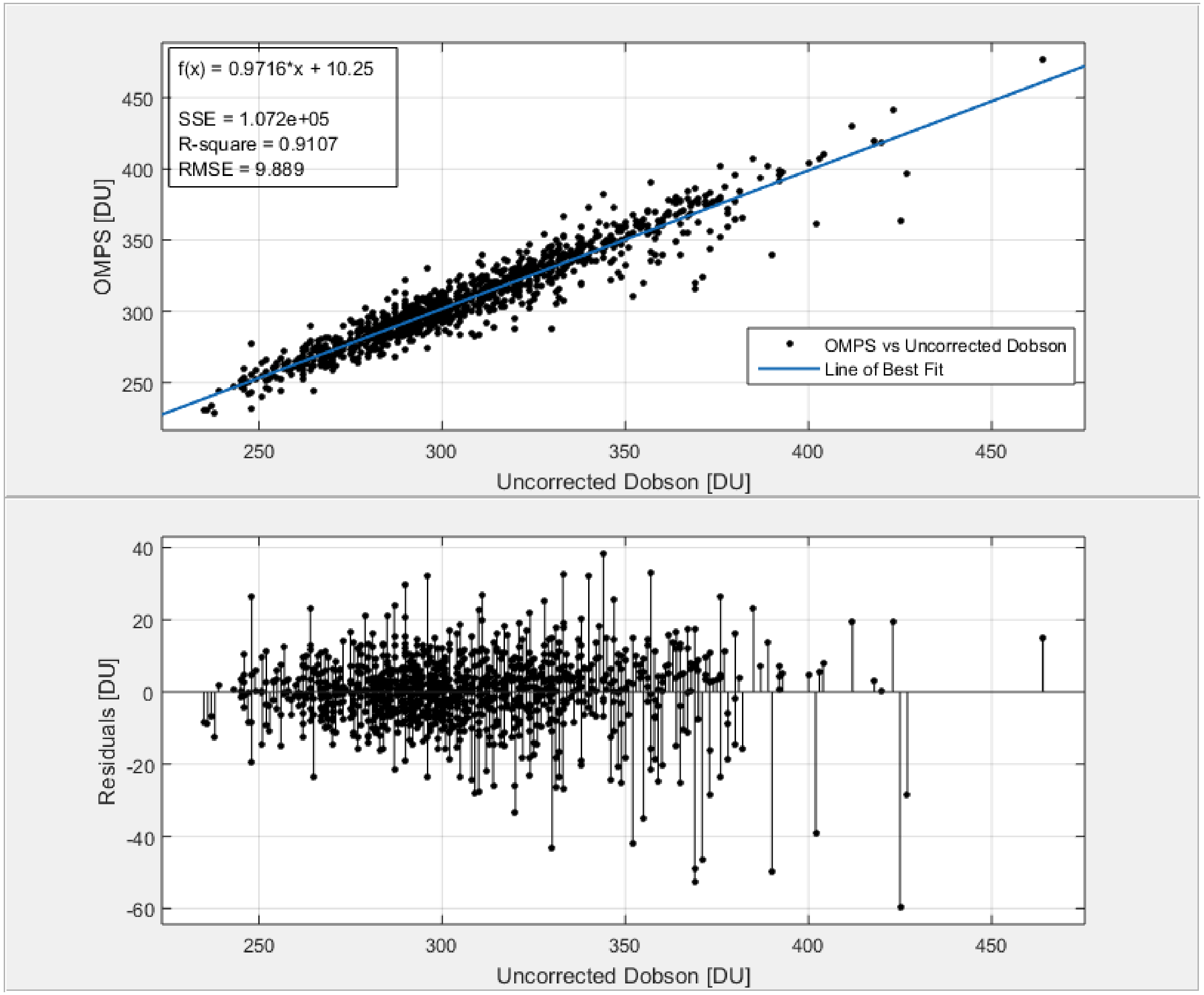
$$TOC_{new} = TOC_{old} * [1 - 0.0013 * (T_{effective} - 226.7)] \qquad (4)$$

In Kelvin

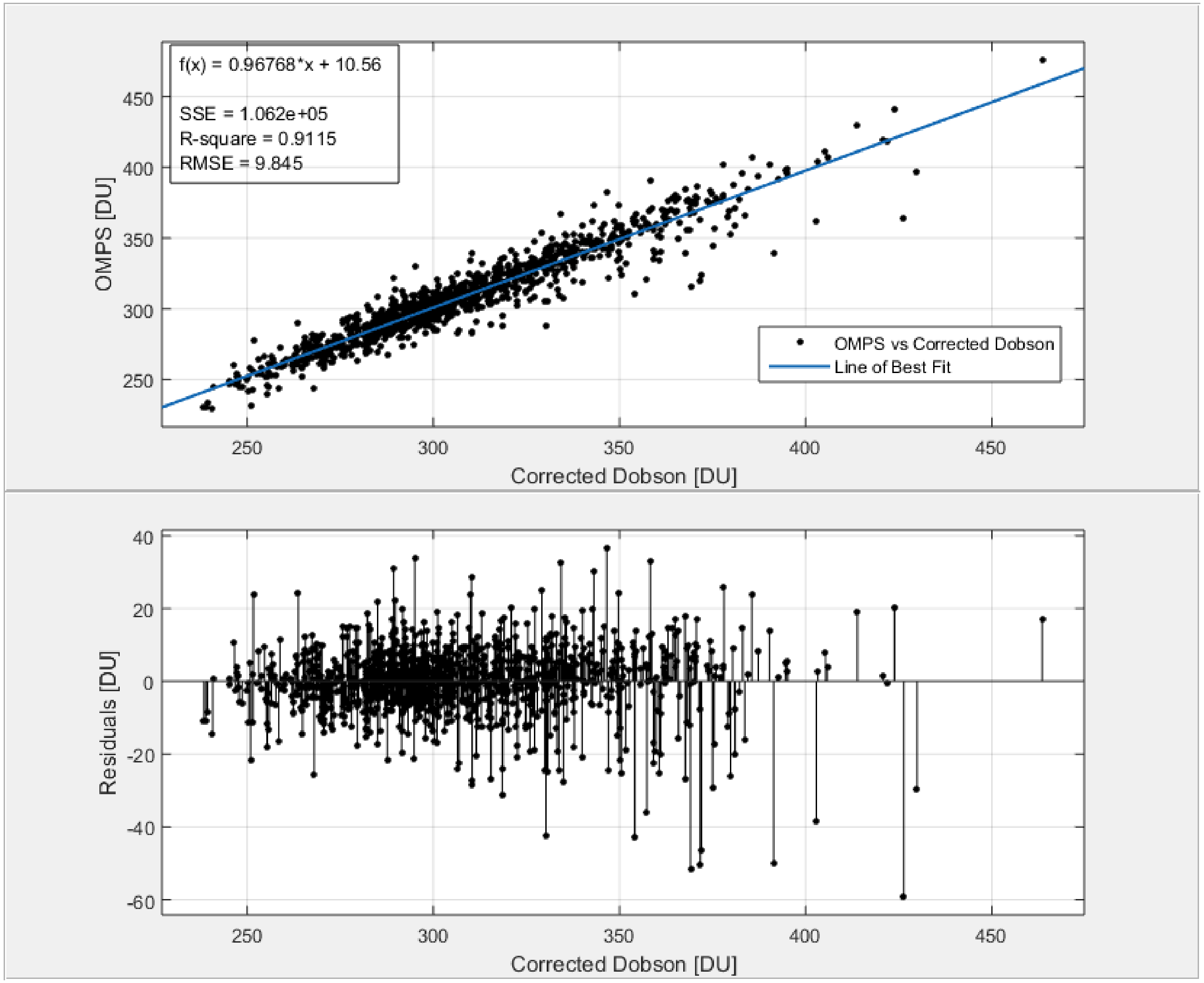
*Dobson Spectrophotometer correction


Differences in Corrected/Uncorrected Dobson w/ SBUV
All 1992-2015
# of Instances
Dobson - SBUV [DU]
Corrected
Uncorrected
Corrected Avg
Uncorrected Avg
0
100
200
300
400
500
600
700
800
-150
-100
-50
0
50
100
150

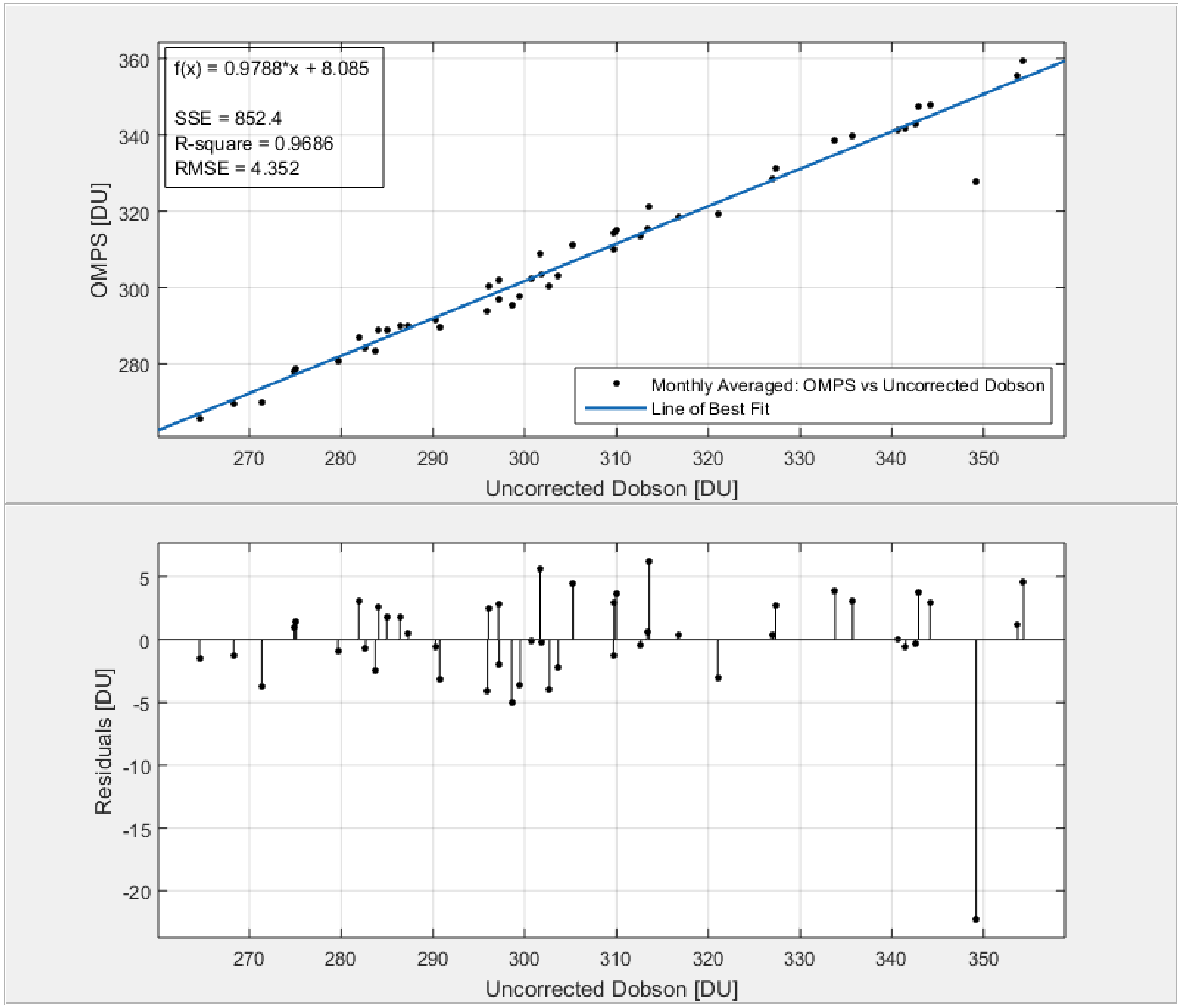
Daily: Uncorrected Dobson



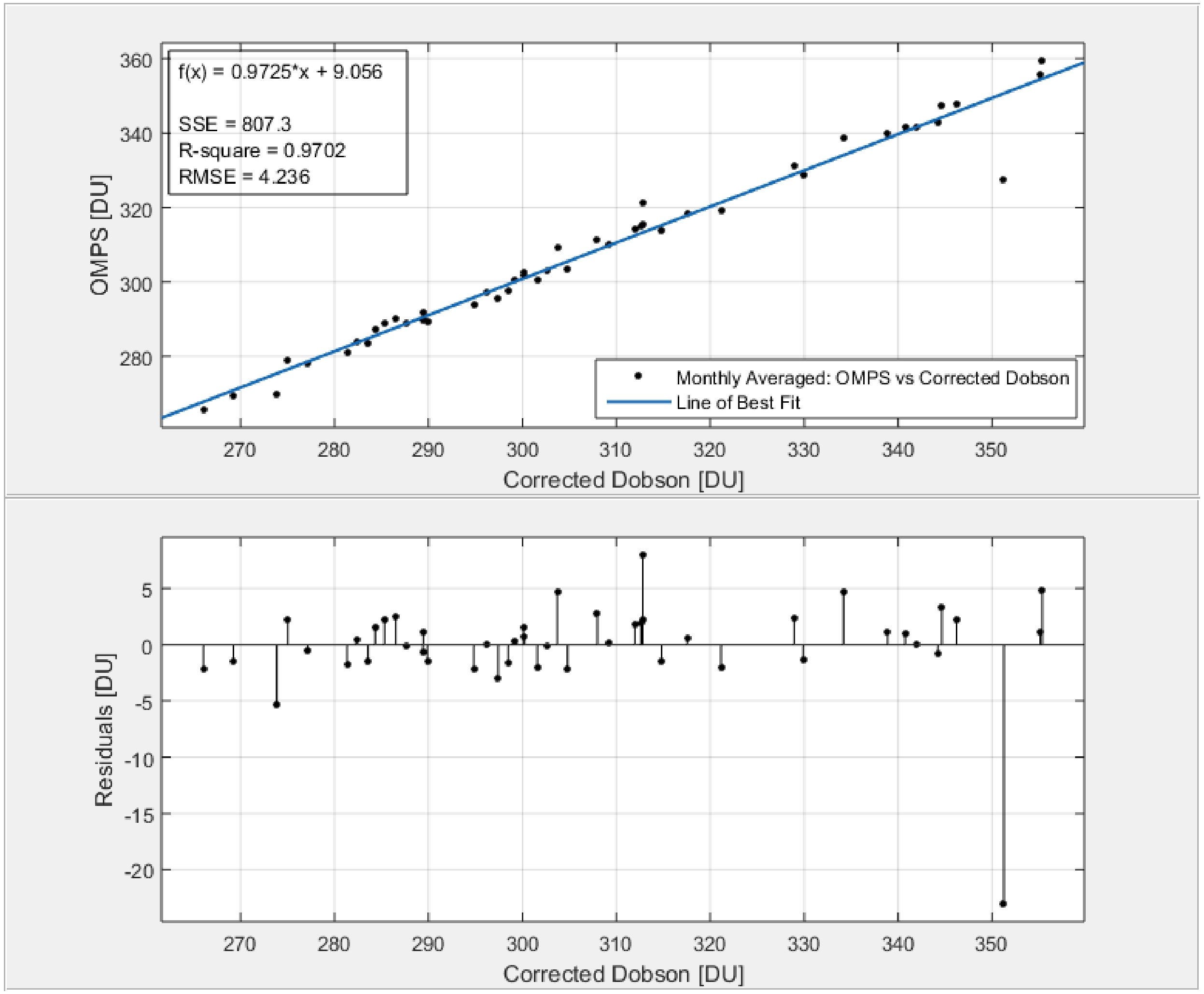
Daily Averages: Corrected Dobson



Monthly Averages: Uncorrected Dobson



Monthly Averages: Corrected Dobson



Correlation Matrix: R^2

	Dobson	GMI	Sonde	SBUV	OMPS
Dobson	1.0000	0.9174	0.7575	0.9111	0.9313
GMI	0.9174	1.0000	0.6806	0.8366	0.8700
Sonde	0.7575	0.6806	1.0000	0.8550	0.7543
SBUV	0.9111	0.8366	0.8550	1.0000	0.8736
OMPS	0.9313	0.8700	0.7543	0.8736	1.0000

NASA OMPS Nadir Science Team Products, Validation and Applications

Colin Seftor[1], Rich McPeters[2], Glen Jaross[2],
Jason Li[1], Jeremy Warner[1],

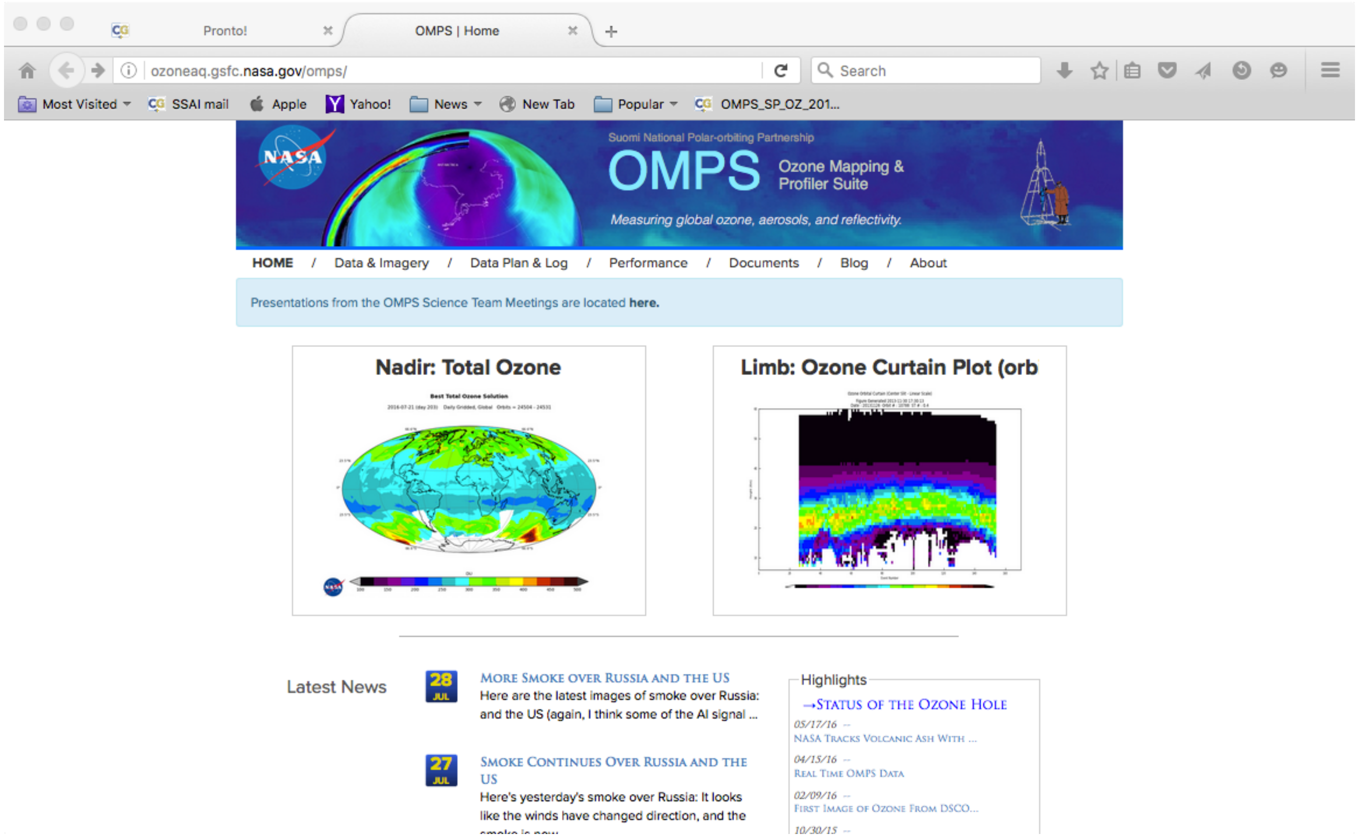
[1]Science Systems and Applications, Inc
[2]NASA Goddard Space Flight Center

NASA OMPS Science Team / SIPS

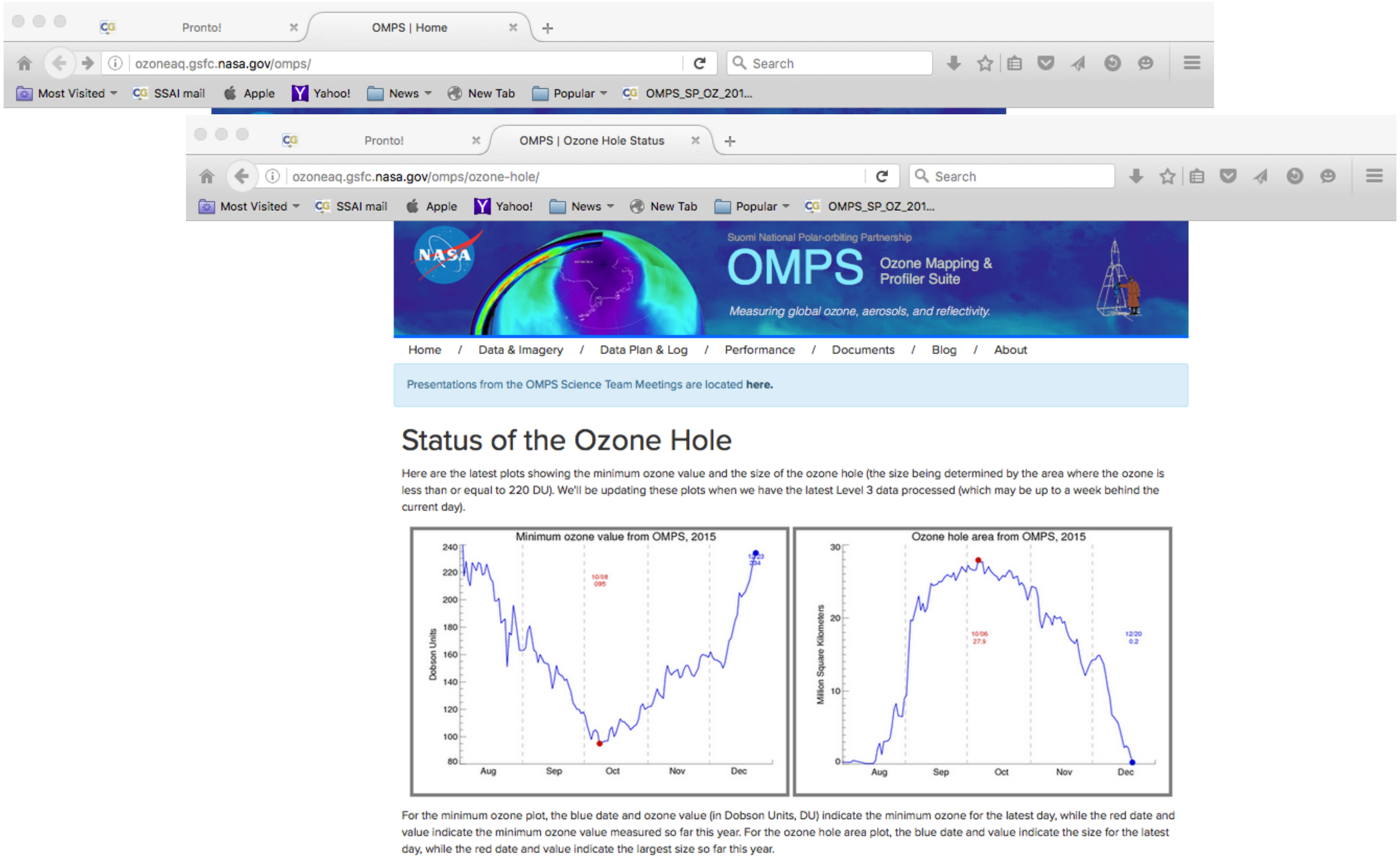
Summary

- NASA Science Team and SIPS recently completed reprocessing of OMPS NM and NP data
  - Designated V2
  - Will be first version archived at the GSFC DISC
  - Uses NASA convention - L1A (not RDR), L1B (not SDR), L2 (not EDR), L3
  - Current L2 based on V8 SBUV/2 algorithm for NP, V8.6 algorithm for NM
    - New NM L2 using V9 algorithm planned for next year
- Dataset is currently being validated
  - Will present some initial assessments
- "Forward" processing of V2 dataset currently taking place
  - L3 data (both HDF5 and ASCII format) / images available from
  - http://ozoneaq.gsfc.nasa.gov/omps
    - Special "ozone hole" page will be set up and available
- Near real-time and real-time applications of V2 in development
  - Based on V1 "pathfinders"

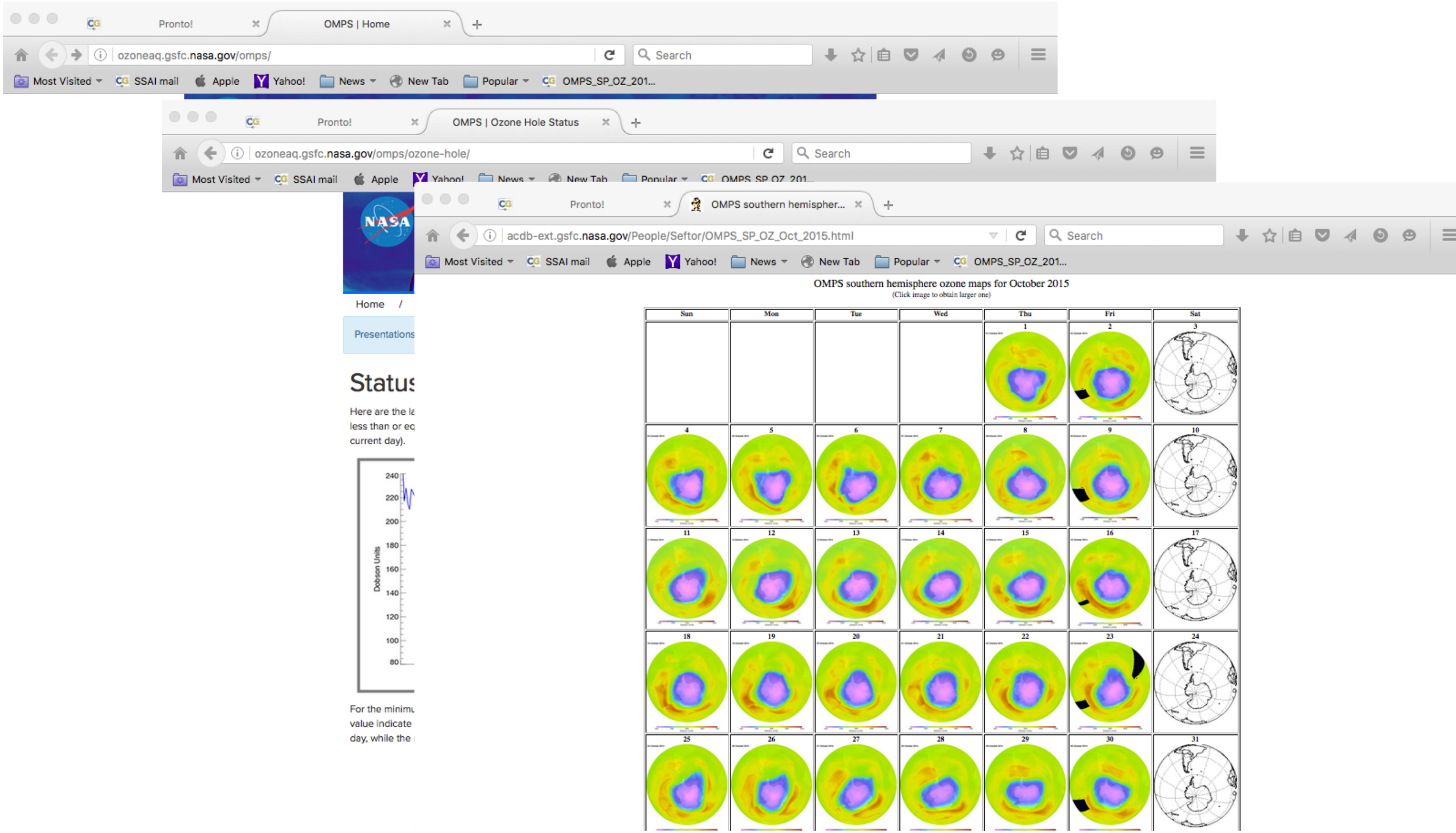
Ozone Hole Page at http://ozoneaq.gsfc.nasa.gov/omps



Ozone Hole Page at http://ozoneaq.gsfc.nasa.gov/omps



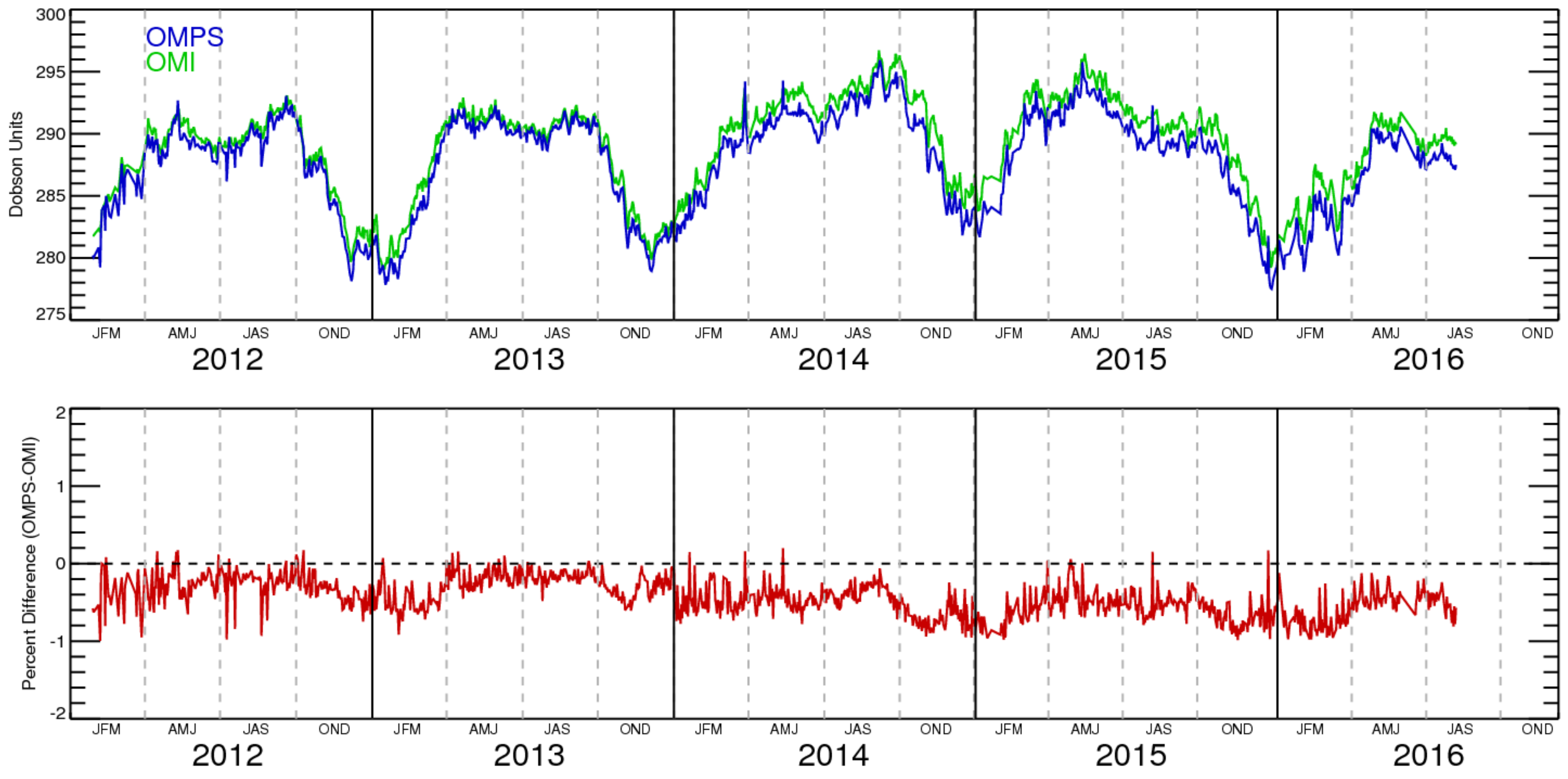
Ozone Hole Page at http://ozoneaq.gsfc.nasa.gov/omps



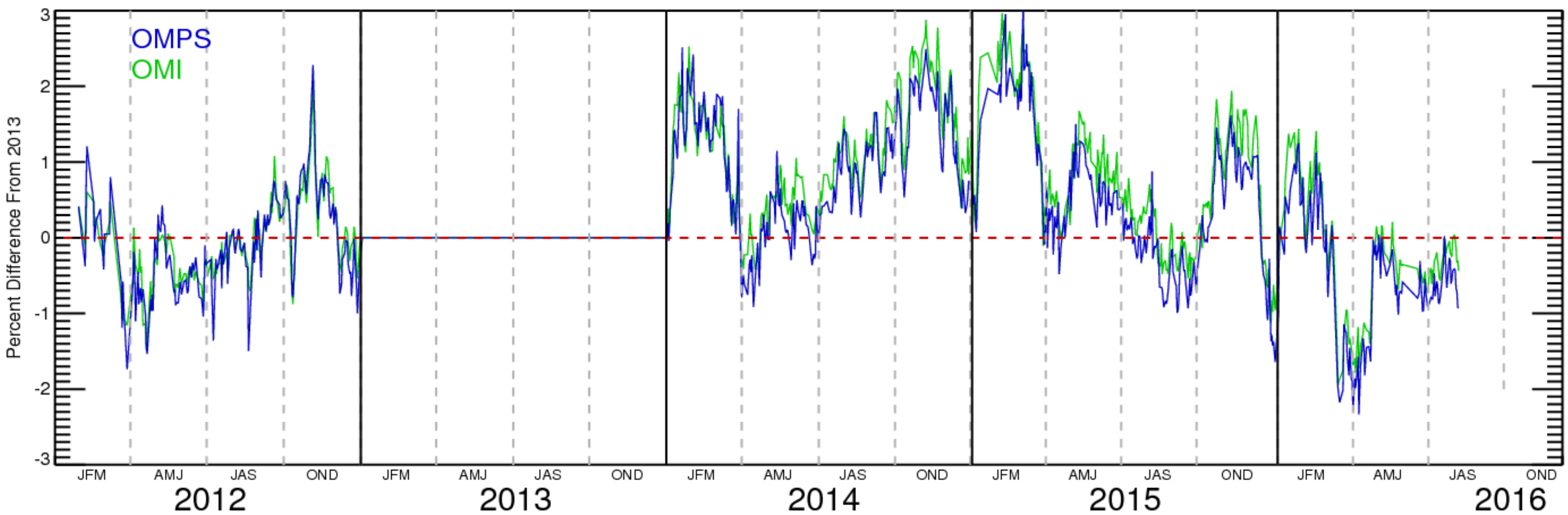
Comparison of OMPS to OMI total ozone

OMI / OMPS / Difference

(Average total ozone from -60 to 60 degrees latitude)

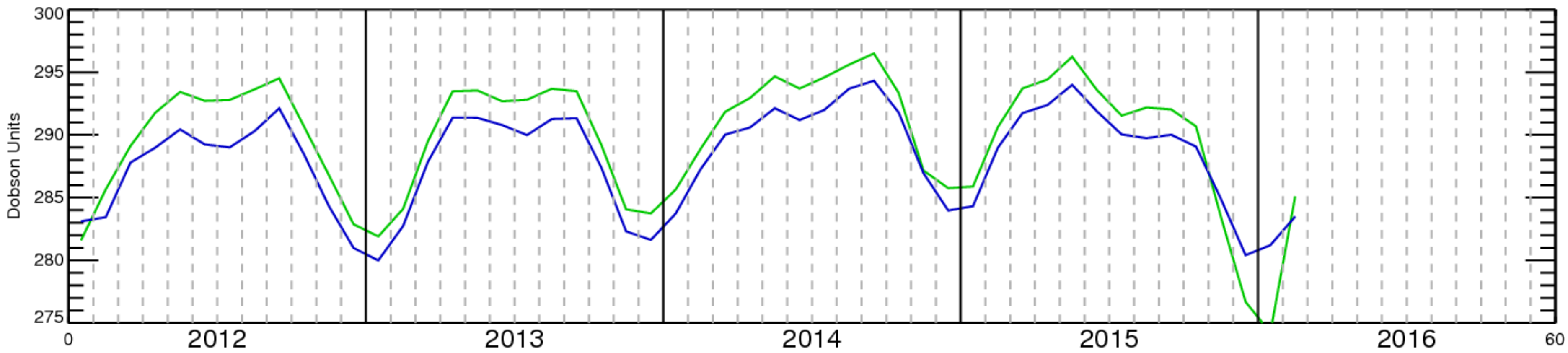


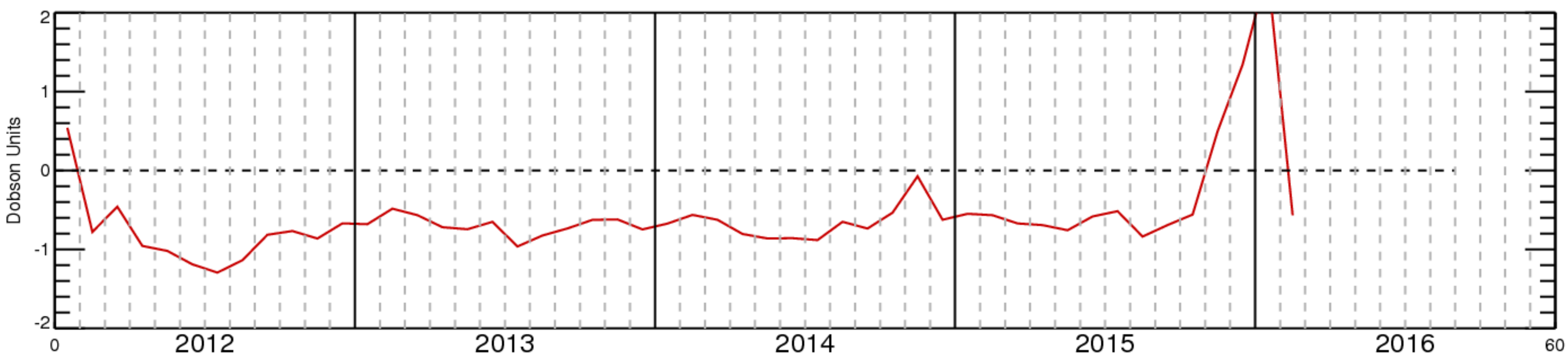
Comparisons of OMPS/OMI total ozone to 2013



Comparisons of OMPS to NASA's MOD (Merged Ozone Dataset – 60S to 60N)

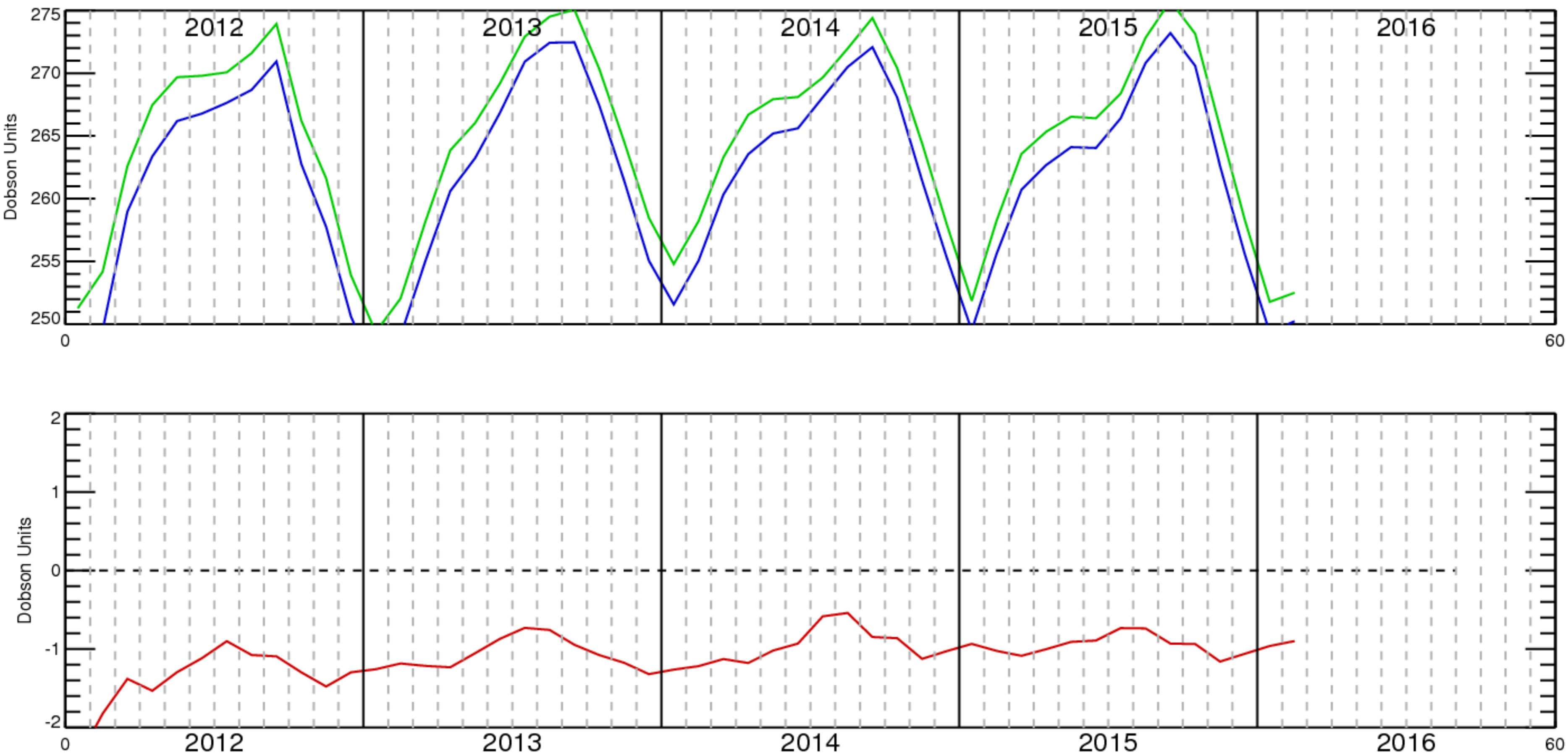
MOD is a monthly-mean zonal and gridded average products constructed by merging individual SBUV/SBUV/2 (total and profile ozone) data sets





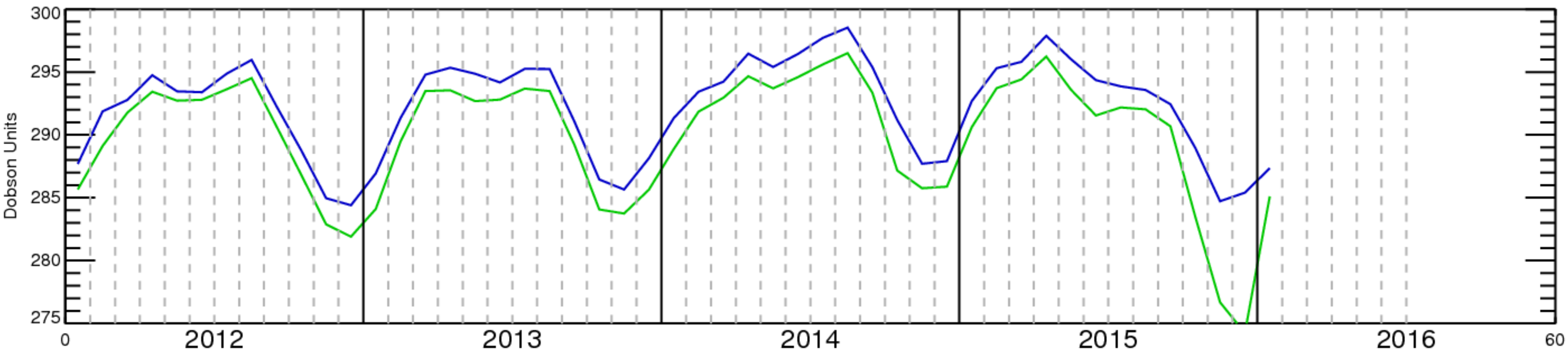
Comparisons of OMPS to NASA's MOD (Merged Ozone Dataset – 30S to 30 N)

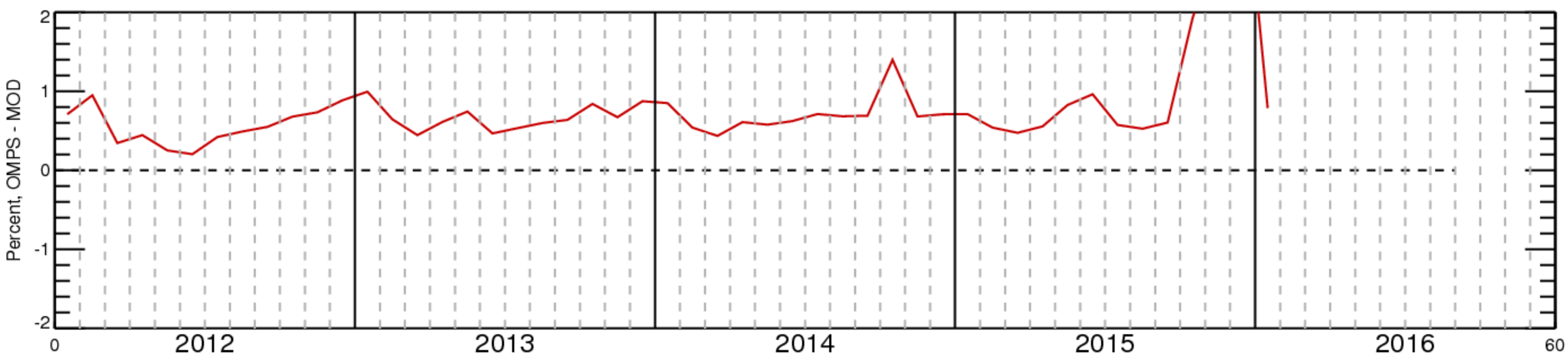
MOD is a monthly-mean zonal and gridded average products constructed by merging individual SBUV/SBUV/2 (total and profile ozone) data sets



Comparisons of OMPS NP to MOD (Merged Ozone Dataset – 60S to 60N)

Total Ozone = Sum of Ozone Profile





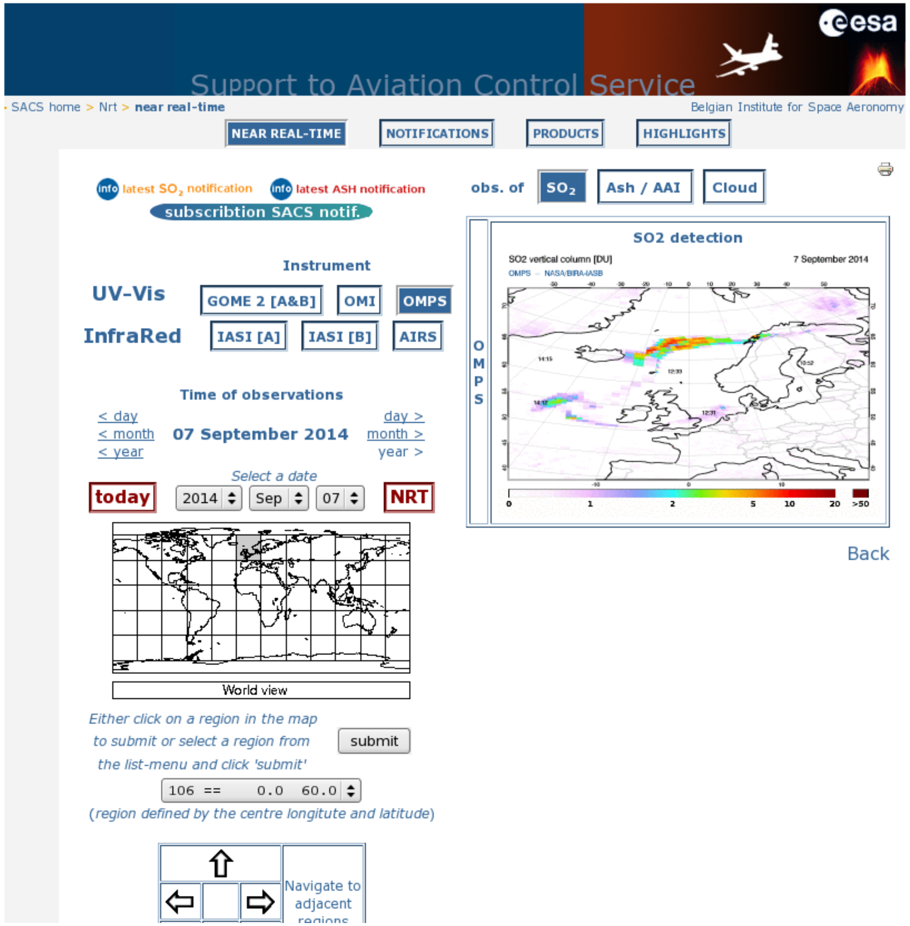
Near Real-Time OMPS data

- The OMPS Science Team and SIPS are working on incorporating the following products in the Land, Atmosphere Near real-time Capability for EOS (LANCE) system by the end of this year
  - SO_2
    - Monitoring of volcanic eruptions
    - Mapping of volcanic ash clouds hazardous to aviation
  - Aerosol Index
    - Monitoring of volcanic eruptions
    - Mapping of volcanic ash clouds hazardous to aviation
    - Dust / Smoke monitoring and forecast
  - Ozone
    - "Identification of stratospheric air intrusions leading to rapid cyclogenisis and hurricane force winds"
    - Mapping of high ozone areas for aircraft to avoid
      - Can adversely affect crew/passenger health
- Access through LANCE will facilitate their availability and use through
  - Worldview (https://worldview.earthdata.nasa.gov/)
  - GIBS (Global Image Browse Services)
  - Access via ftp (need to register with urs.earthdata.nasa.gov)

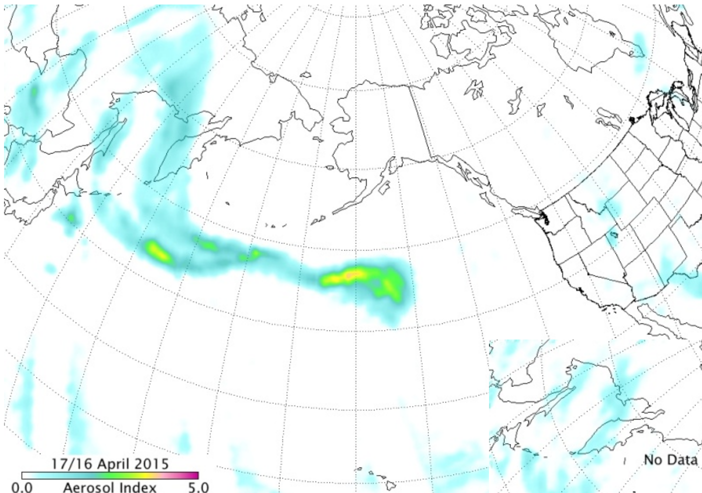
Volcanic Eruption Monitoring

OMPS currently supports the ESA's Support to Aviation Control Service (SACS)
With near-real time SO_2 and AI data

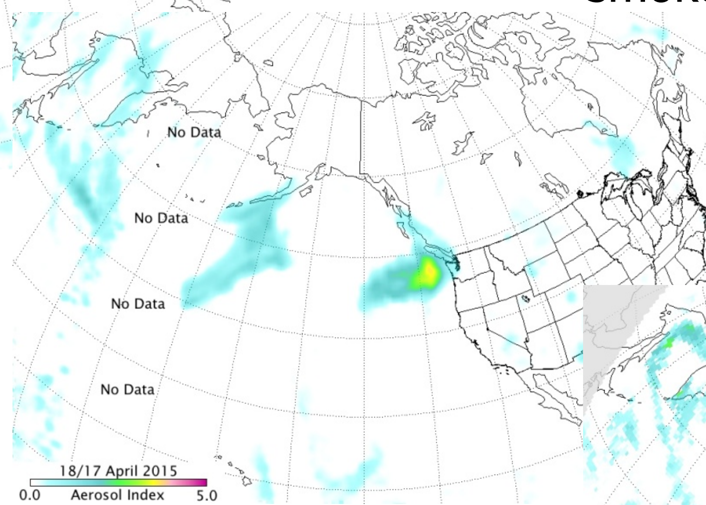
Example from last year showing eruption of Bardarbunga / Holuhraun

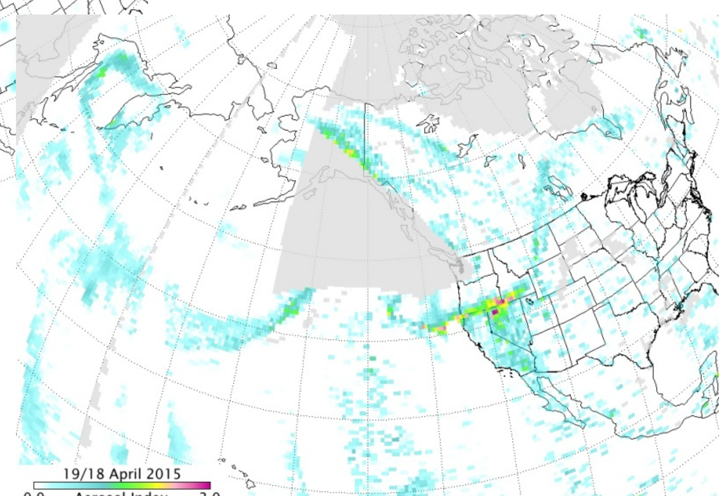


Smoke / Dust Monitoring



The HMS (Hazard Mapping Service) group of NOAA's Satellite Analysis Branch wants a near real-time OMPS AI product to map and forecast both smoke and dust events

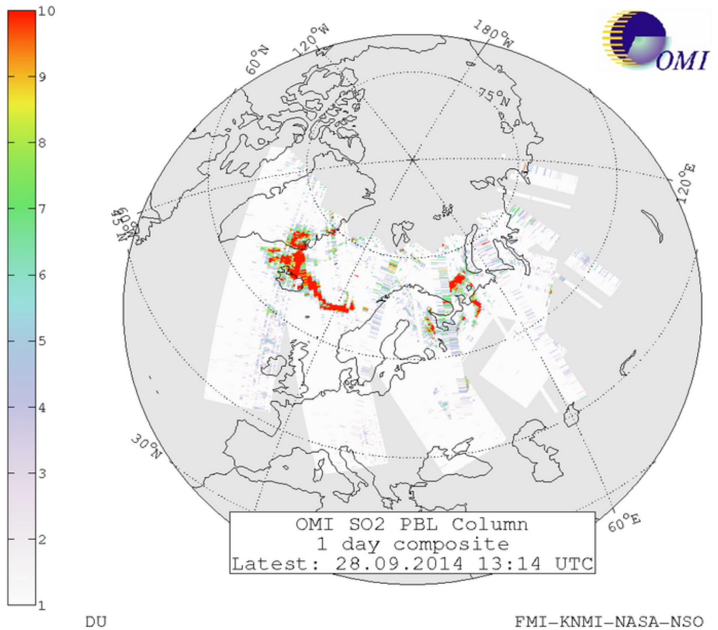


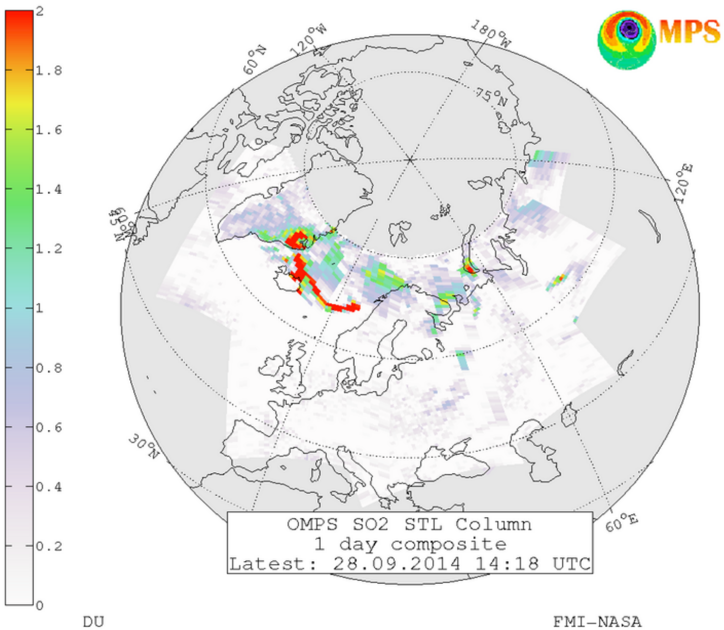


Smoke from Siberian fires travelled across the Pacific to North America this week

Real-Time Suomi NPP OMPS Data Processing Being Performed

- S-NPP OMPS Science Team and GSFC DRL incorporated OMPS processing package to provide real-time OMPS data similar to OMI
  - Package uses NASA's algorithms, provides continuity with OMI
  - FMI, GINA (and ESA's SACS) provide warning to VAACs, pilots, airlines, etc



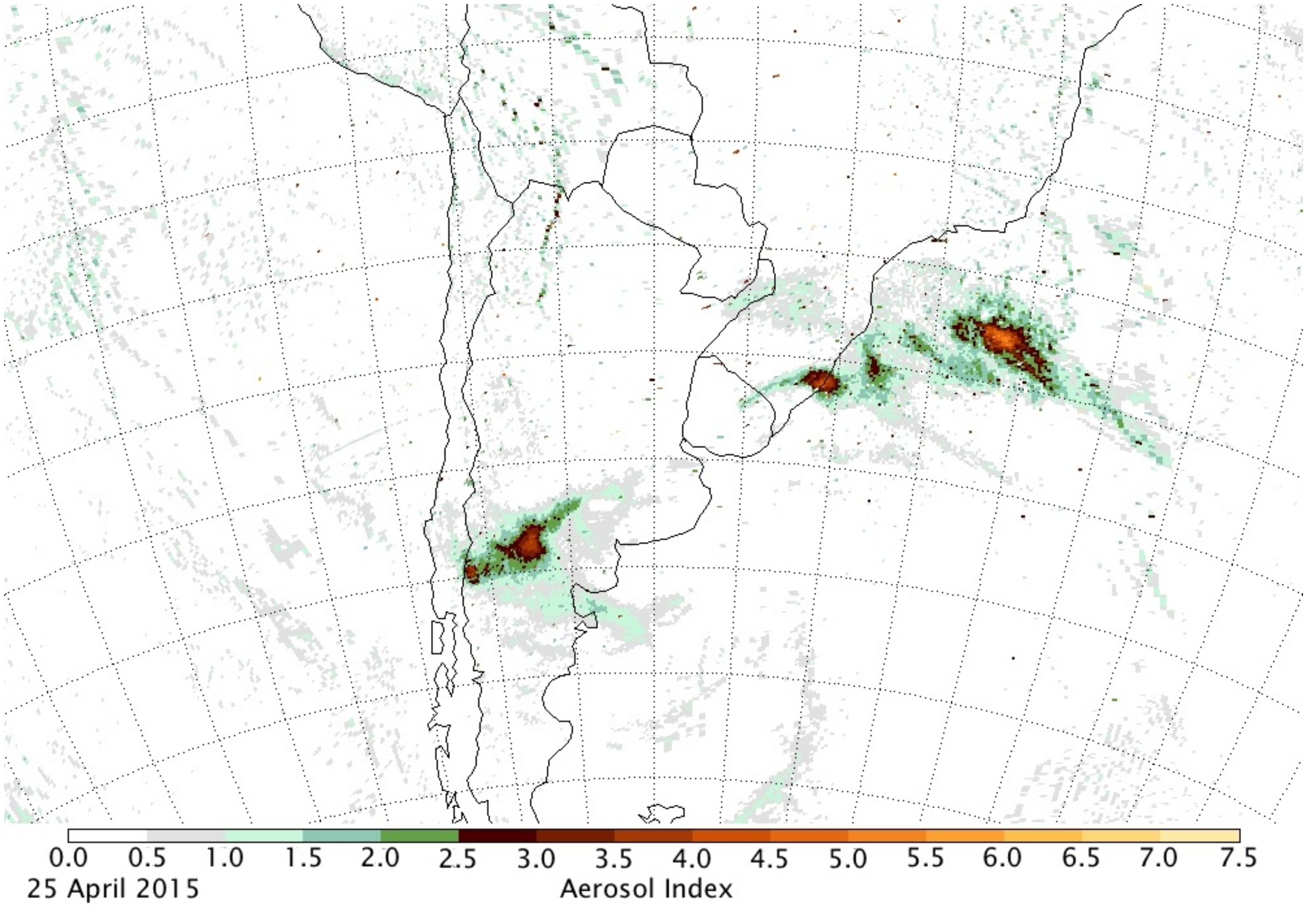


FMI monitoring of Bardarbunga / Holuhraun eruption (from http://sampo.fmi.fi)

Real-Time Data Processing from Suomi NPP OMPS Useful Globally

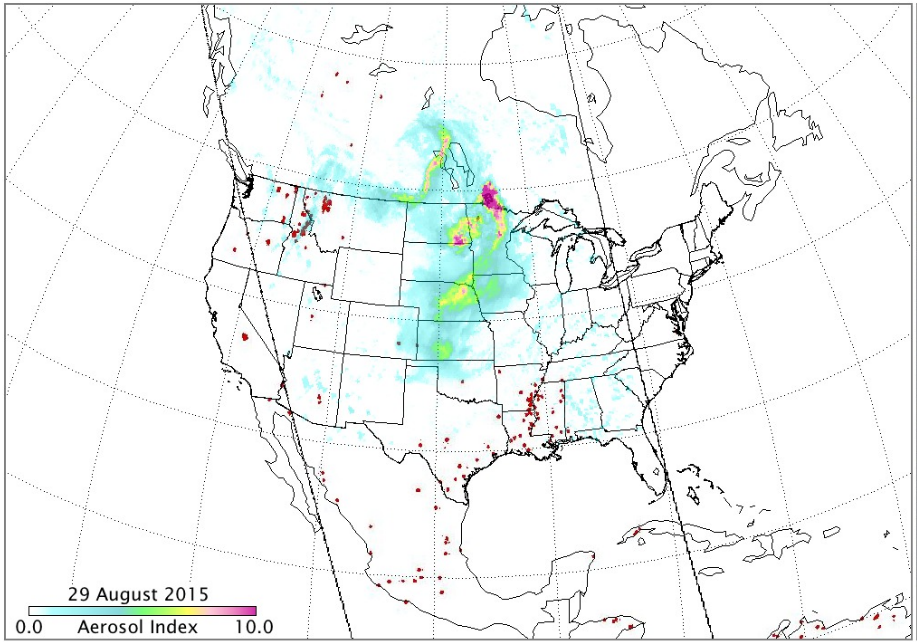
- As part of IPOPP, OMPS SO_2 and Aerosol Index information will be available to the entire DB community

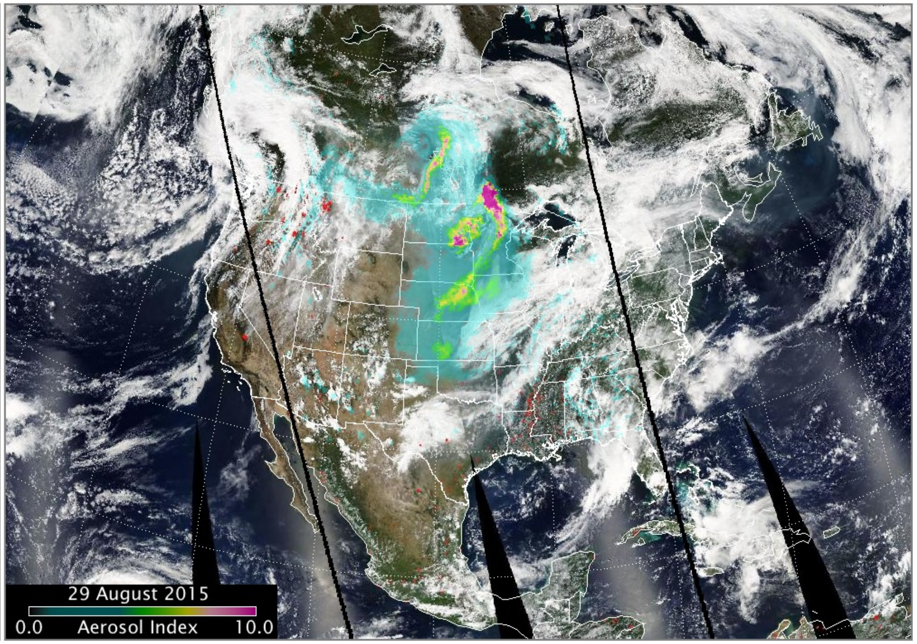
Volcanic Ash from the eruption of Calbuco
25 April 2015
OMPS Aerosol Index
(High resolution mode)



OMPS Real-Time Aerosol Index Data Also Useful for Other Purposes

- Real-time processing of OMPS data may also provide valuable information on smoke and dust transport, air quality forecasts, validation/verification of PyroCb events





OMPS Aerosol Index over MODIS hotpot

OMPS Aerosol Index over MODIS RGB

For more examples, see http://ozoneaq.gsfc.nasa.gov/omps/blog

V8 Total Ozone Algorithm on NDE and ICVS Monitoring

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Trevor Beck, NOAA/STAR
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Aug. 9, 2016

OUTLINE

- Introduction to V8TOz Algorithm
- J1 Implementation of V8TOz on NDE
- Soft Calibration Adjustments
- Products and Applications
- ICVS Monitoring
  - -- OMPS Product Demo Site URL
  - -- SBUV/2 V8 Operational Performance
  - -- GOME-2 V8 (Metop A/B)
  - -- V8 OMPS, GOME-2, and OMI Maps
  - -- OMPS V8 Total Ozone
  - -- OMPS V8 Profile Product
  - -- New OMPS EDR Site Features
- Conclusion

Introduction to V8TOz Algorithm

The Version 8 total O3 algorithm (V8TOZ), developed by NASA Ozone Science Team, is the most recent version of a series of BUV (backscattered ultraviolet) total O_3 algorithms

V8TOz is currently used to generate operational products for SBUV/2 , GOME-2, OMI, OMPS and TOMS at NOAA and NASA

The V8TOz makes retrievals of total column ozone, reflectivity, volcanic sulfur dioxide, aerosol index, and the output file includes error flags and retrieval efficiencies, residuals and sensitivities, and other parameters.

Introduction to V8TOz Algorithm

Three steps in V8TOz Algorithm:

Step 1:

Using a pair of wavelengths to derive reflectivity from 331 nm and ozone from 318nm by using radiative transfer look-up tables. (Given an initial guess ozone, through an iterative process, to make the measured radiances equal to or close to the calculated ones for the estimates)

Step 2:

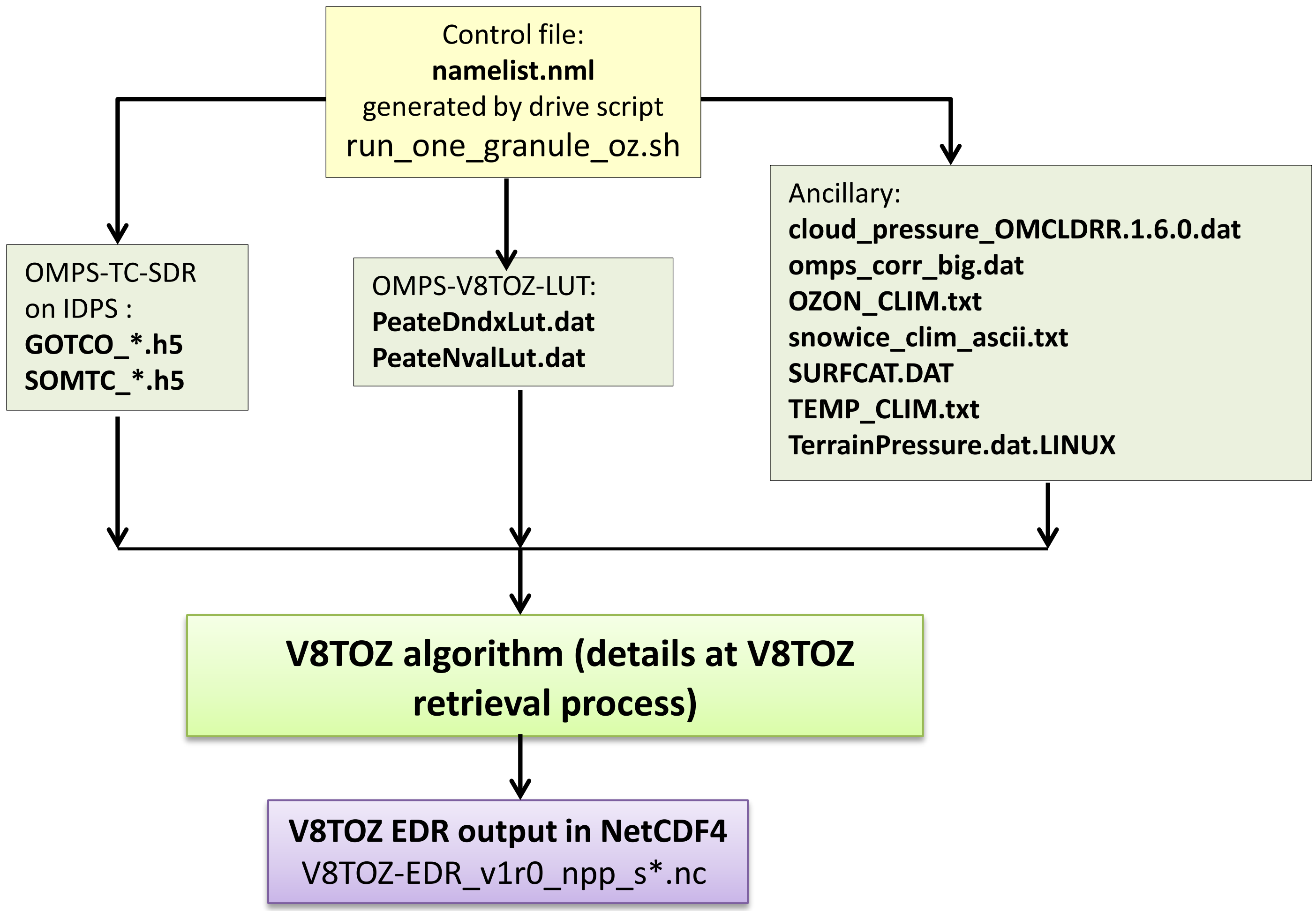
Ozone and temperature climatologies are applied at all levels to account for seasonal and latitudinal variations in profile shape.

Step 3:

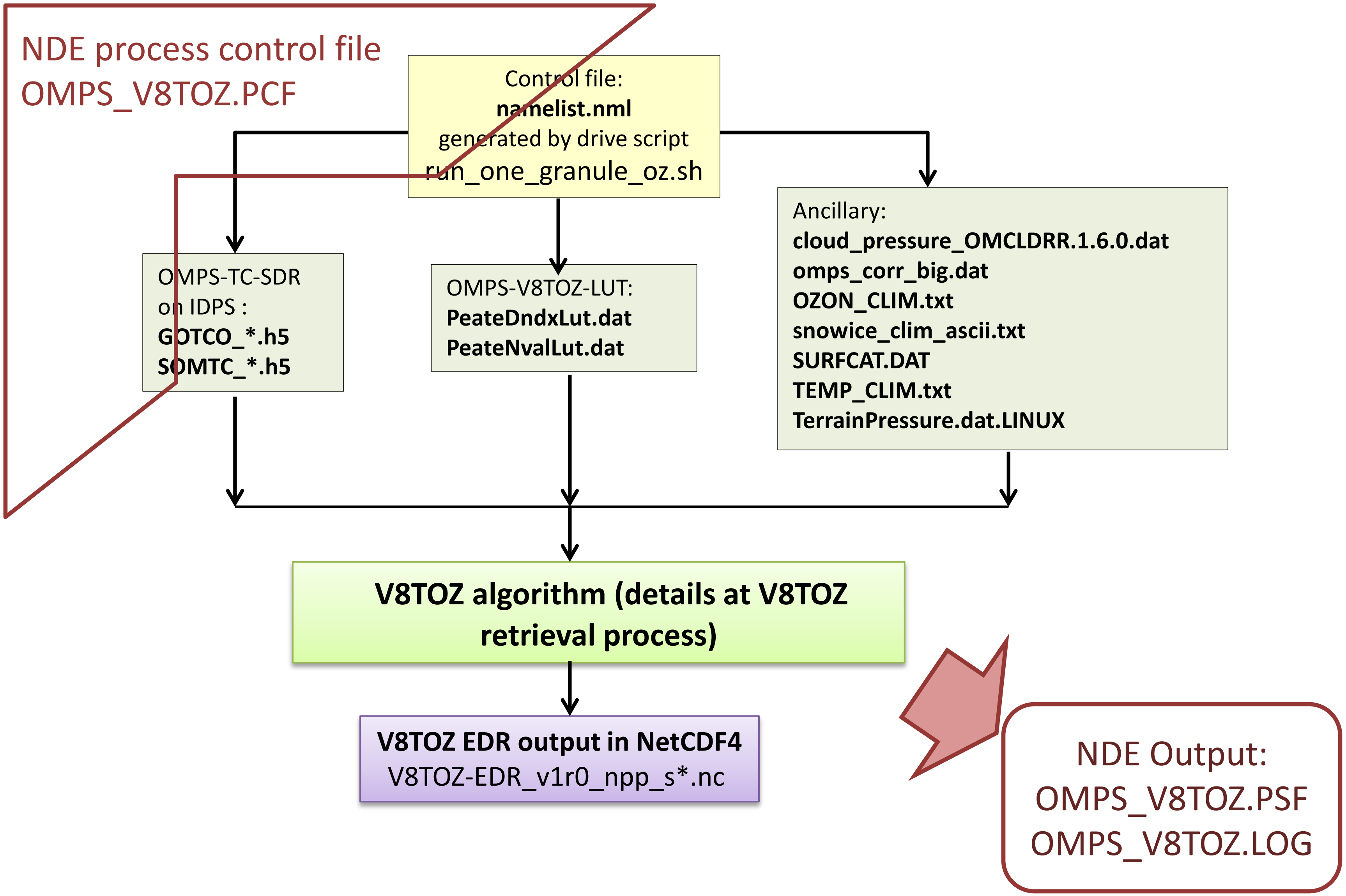
Correct step 2 ozone for wavelength dependence effects, such as tropospheric aerosol, sun glint, and local upper level profile shape effects.

J1 Implementation of V8TOz on NDE

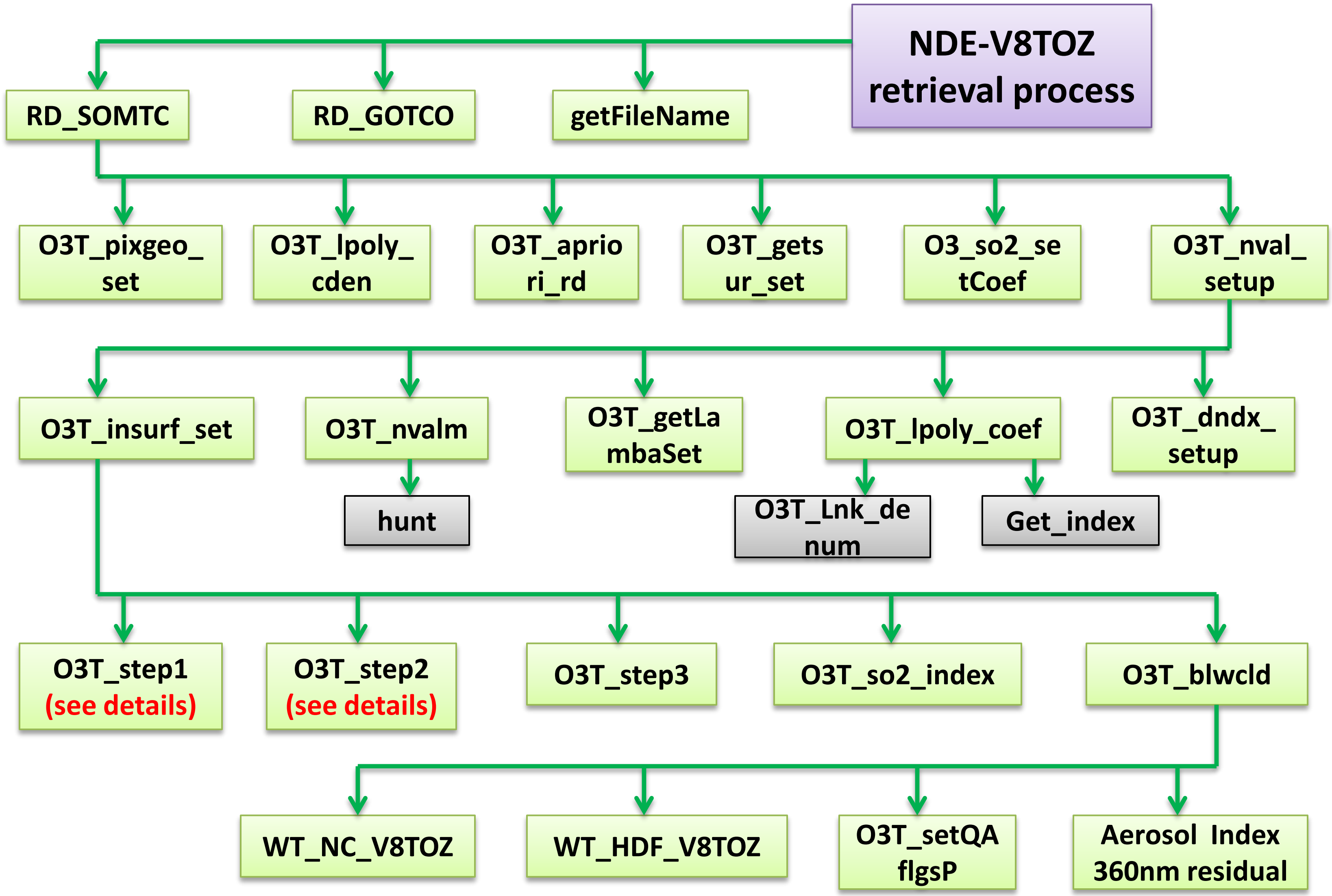
---- Deliver entire package of V8TOz to NDE



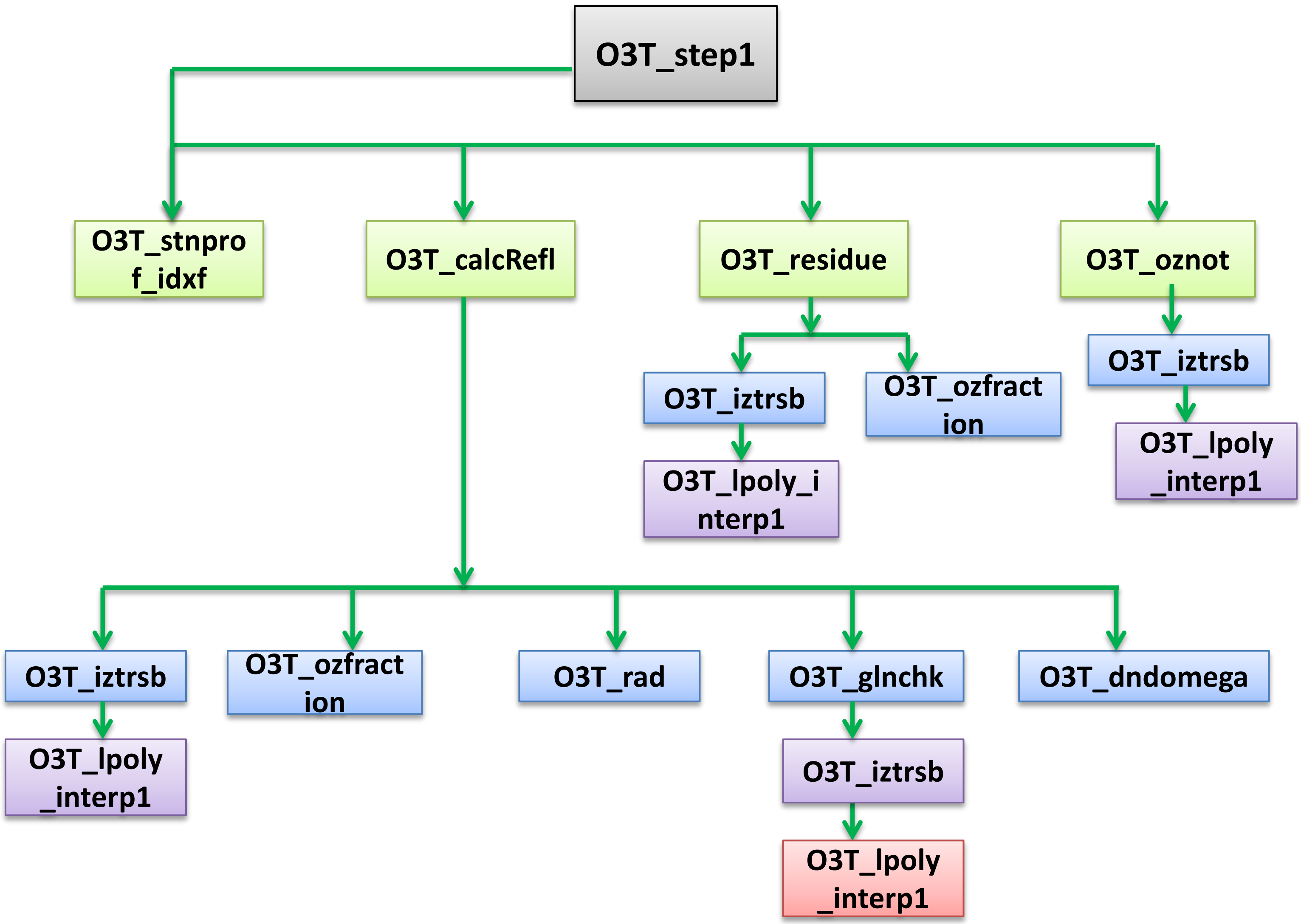
J1 Implementation of V8TOz on NDE



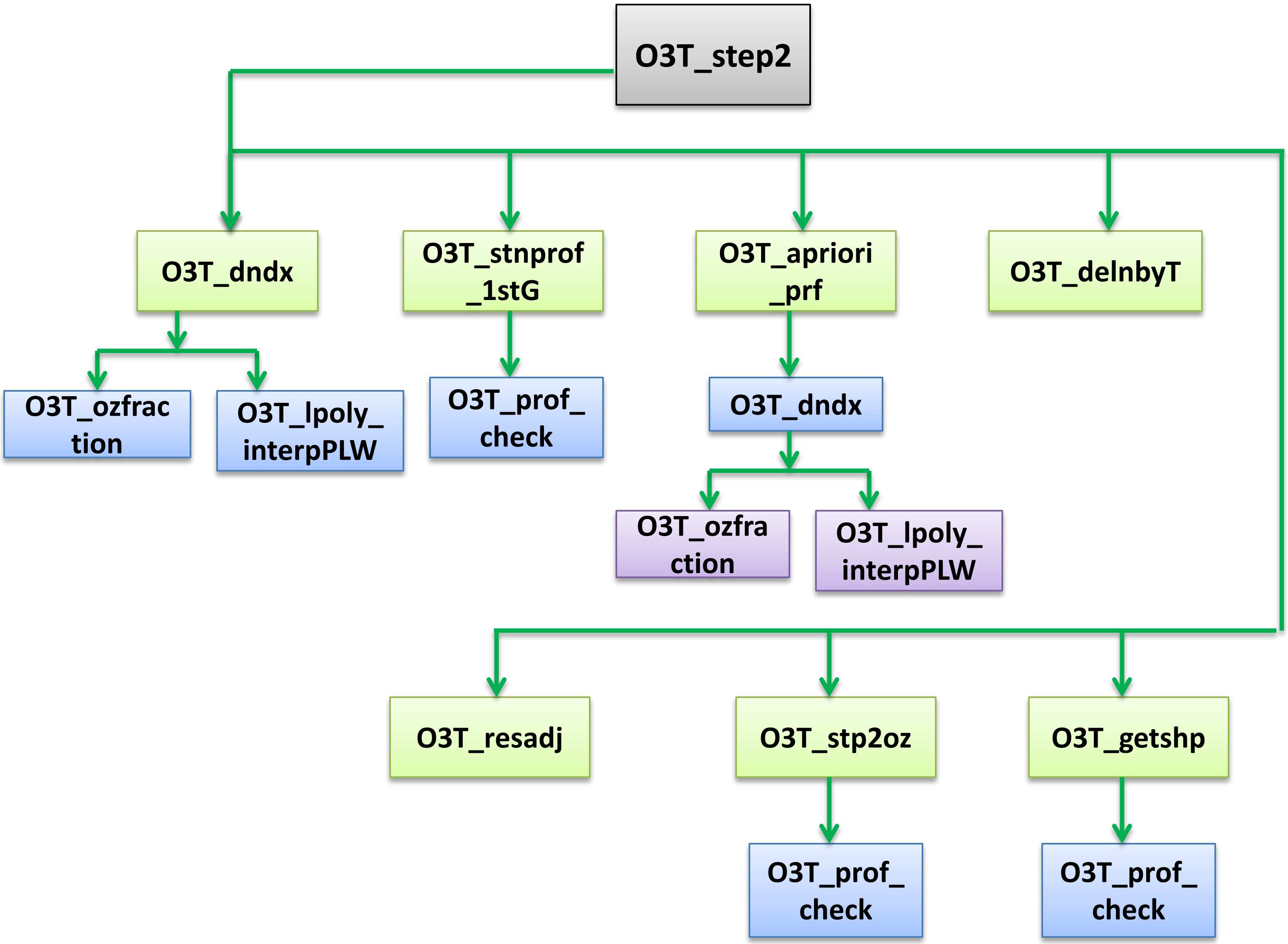
J1 Implementation of V8TOz on NDE



J1 Implementation of V8TOz on NDE



J1 Implementation of V8TOz on NDE



Soft Calibration Adjustments

The main purpose of soft-calibration:

- Remove bias between the retrieved total ozone and a "truth" data set.
- Remove the systematic cross-track bias in ozone, reflectivity and aerosol index.

The procedure of soft-calibration:

1) Determine ΔΩ and ΔR, the bias of retrieved total ozone and reflectivity related to cross-track positions
2) Calculate N-Value adjustments for ozone(318nm) and reflectivity(331nm), using N-Value sensitivity to ozone and reflectivity

$$\Delta N_{(318)} = \Delta R * dN_{(318)}/dR + \Delta\Omega * dN_{(318)}/d\Omega$$
$$\Delta N_{(331)} = \Delta R * dN_{(331)}/dR + \Delta\Omega * dN_{(331)}/d\Omega$$

3) For the rest of 10 channels, calculate the N-Value adjustments by averaging the adjusted step2 residuals from ΔΩ and ΔR

$$\Delta N_{(wl)} = \mathrm{mean}(Step2Res_{(wl)} - \Delta R * dN_{(wl)}/dR - \Delta\Omega * dN_{(wl)}/d\Omega)$$

Soft Calibration Adjustments

The data used for soft-calibration:

Jan. 11, 2016 to Jan. 19, 2016 OMPS V8TOz retrievals

(choosing 9 day's data because OMPS orbits will go back close to the same position after 9 day's run)

Region,

[lat(0N ~ 30N), lon(-180w ~ -45w)], [lat(0N ~ 30N), lon(45E ~ 180E)]

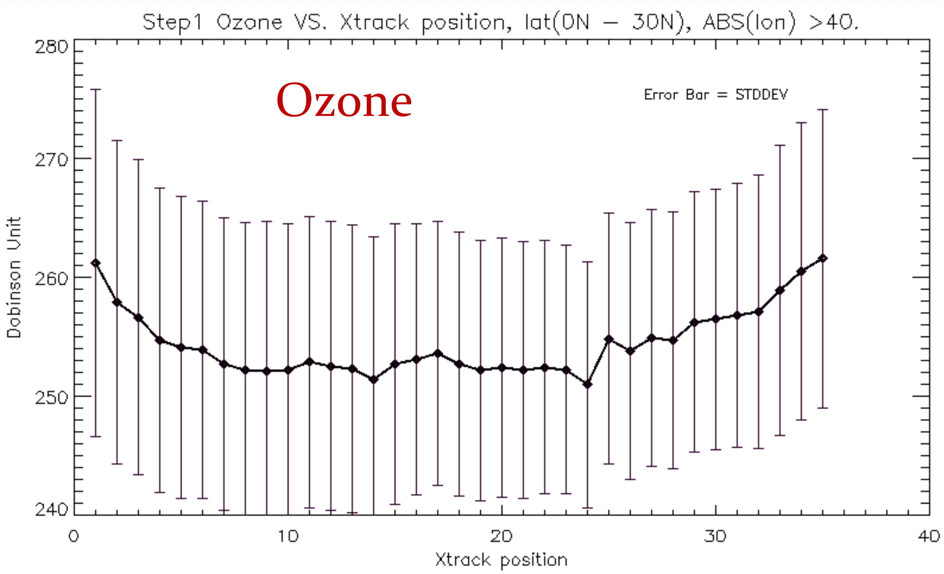
(to avoid potential contamination from sun glint and Sahara dust loading)

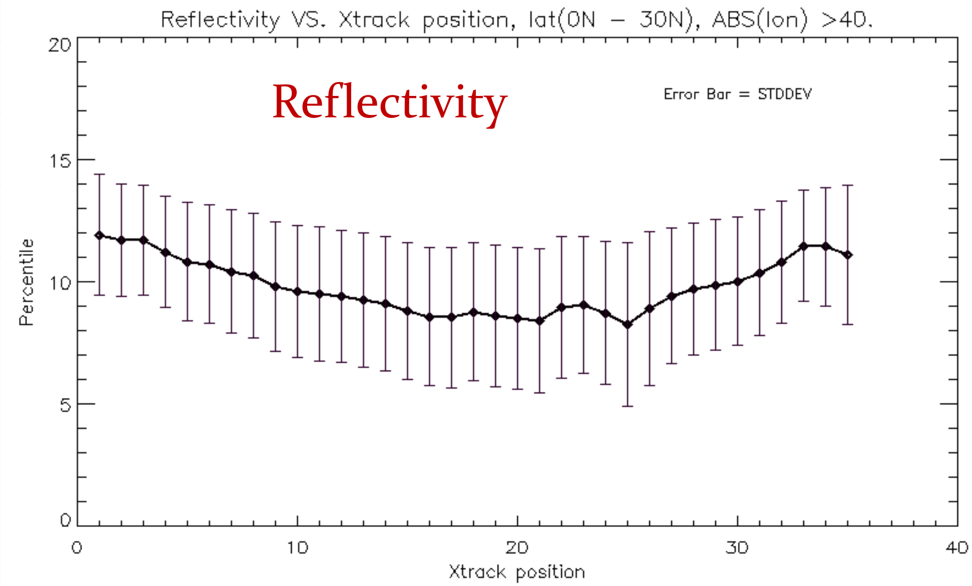
Pixels, cloud fraction < 0.1

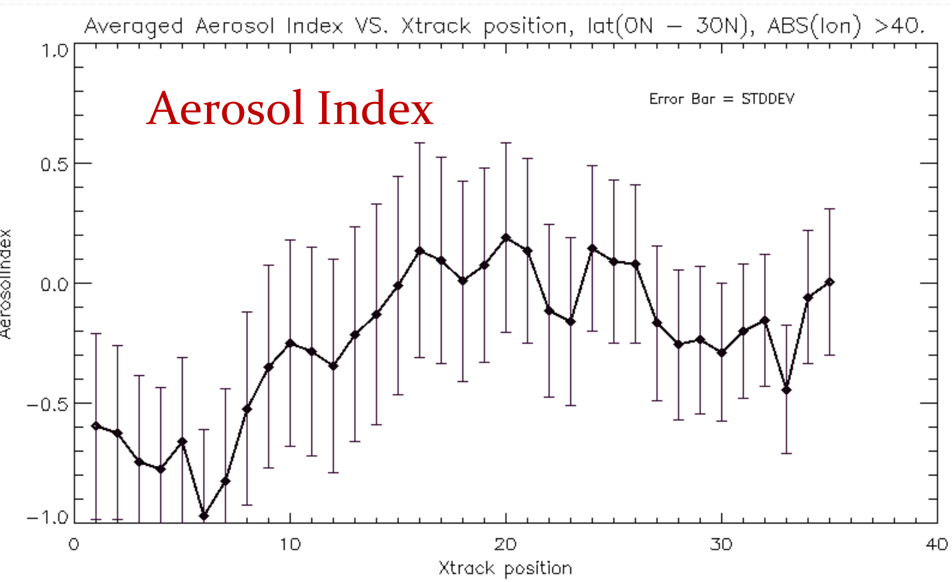
(to avoid potential contamination from cloud)

Soft Calibration Adjustments(before)

Averaged Ozone, Reflectivity and Aerosol Index (01/11/2016-01/19/2016)



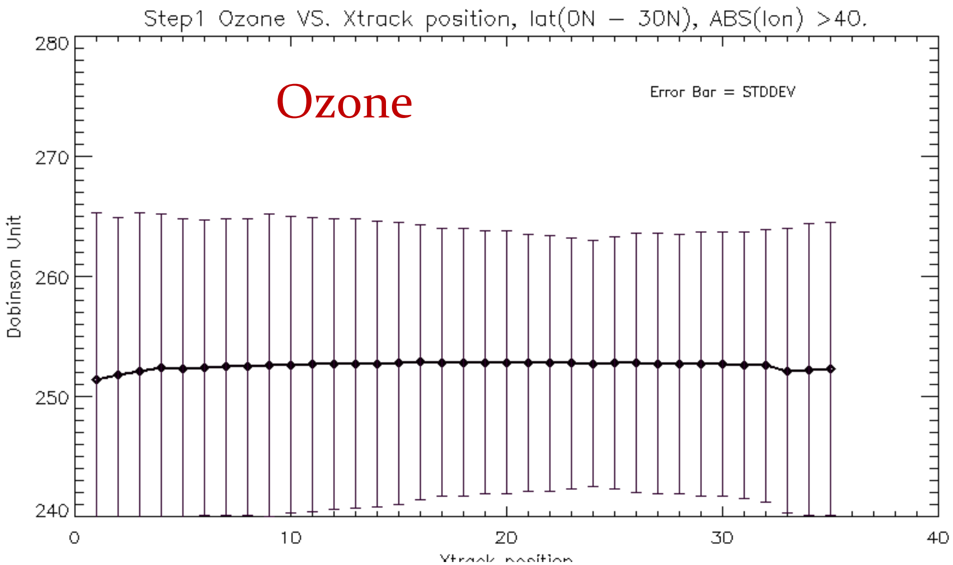


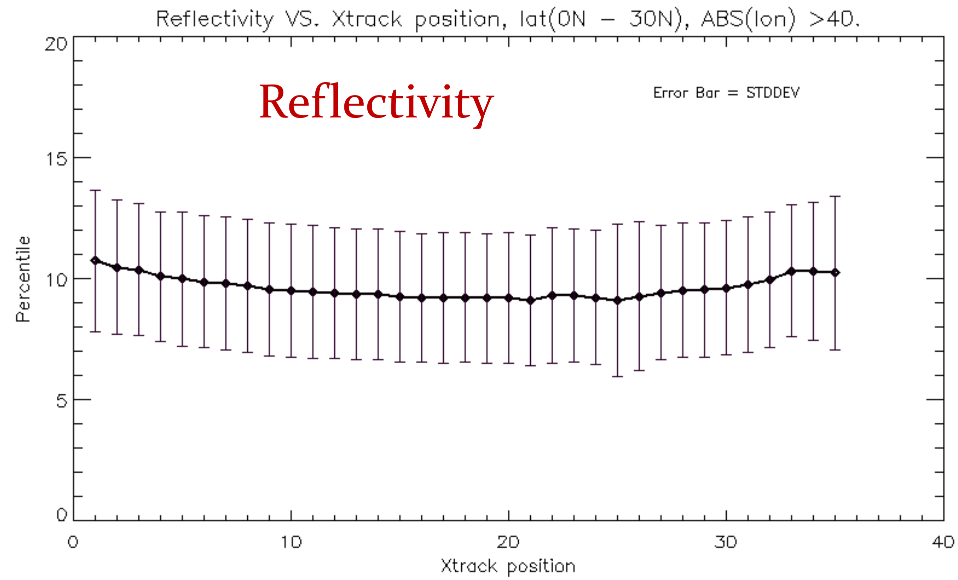


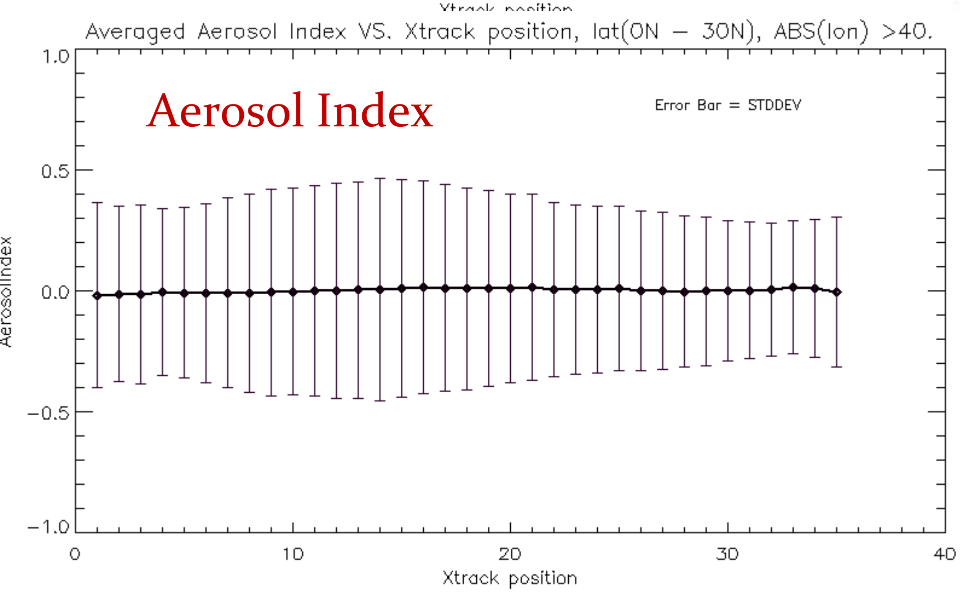
These cross-track bias are from:
instrument
measurements
models
...

Soft Calibration Adjustments(after)

Averaged Ozone, Reflectivity and Aerosol Index (01/11/2016-01/19/2016)



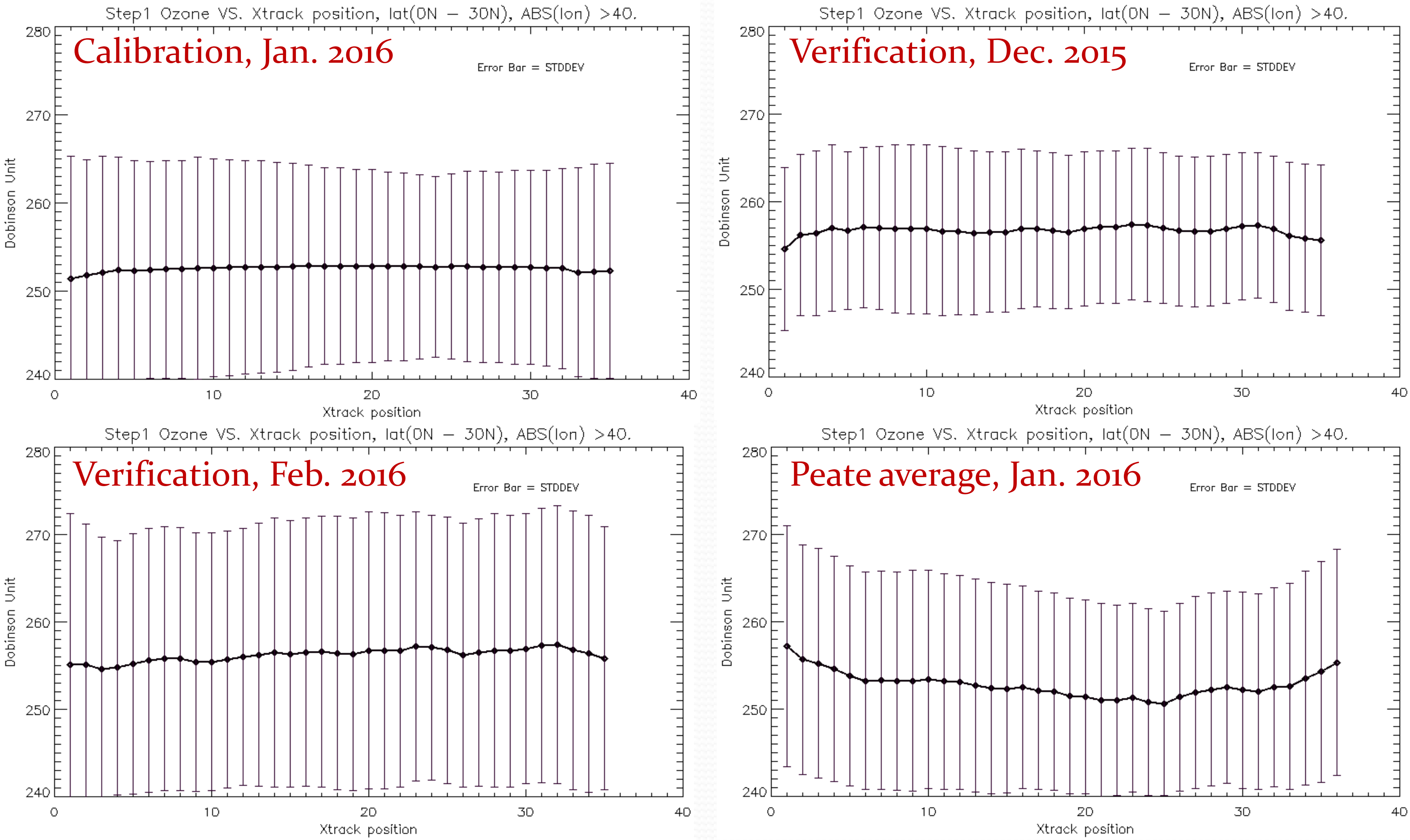




Cross-track bias are mostly removed from our first adjustment, we can make even flatted through second or third calibration…

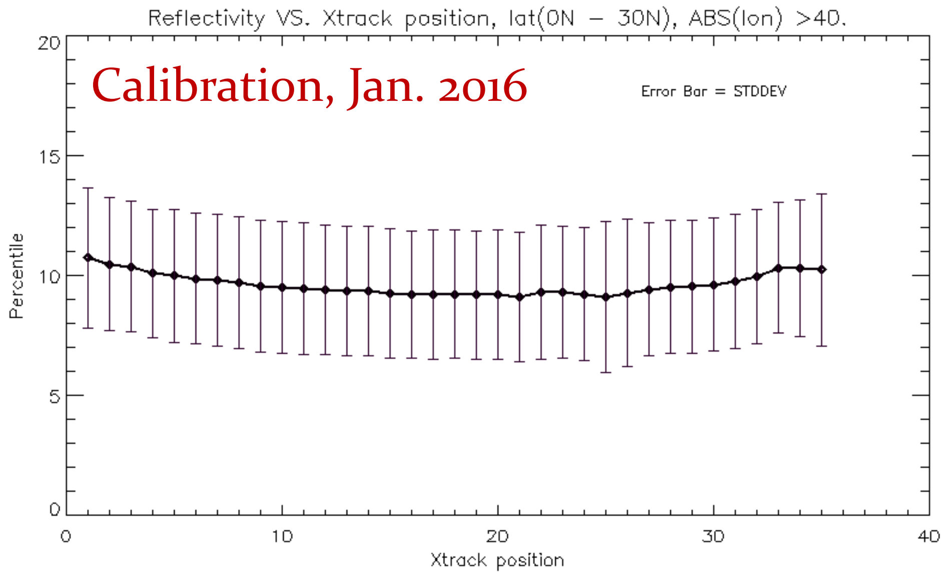
Soft Calibration Adjustments

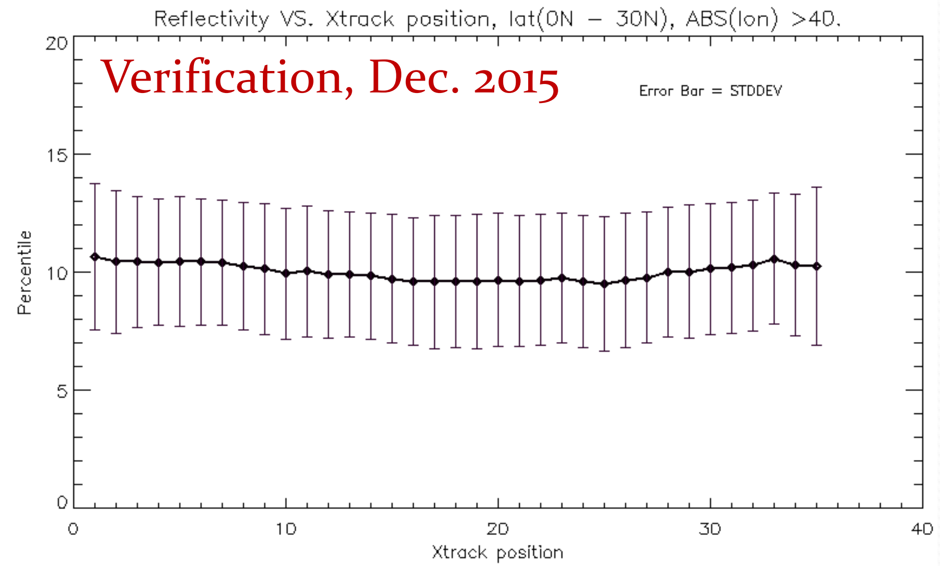
Independent verification and comparison (step1 ozone)

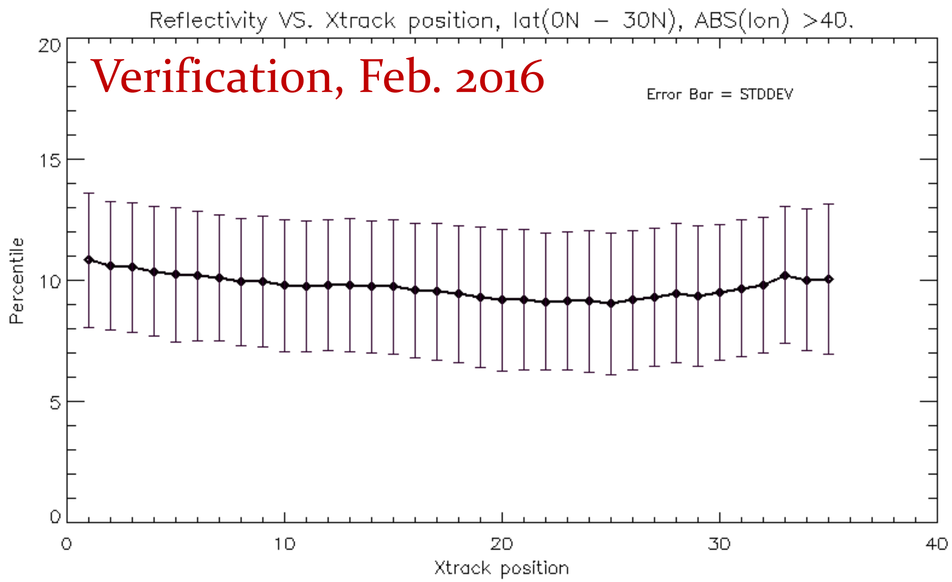


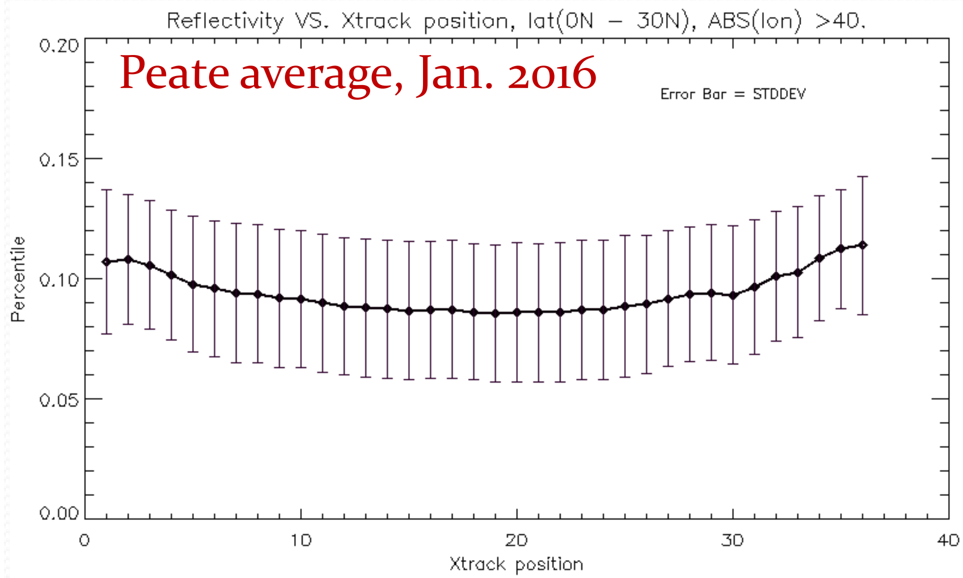
Soft Calibration Adjustments

Independent verification and comparison (reflectivity)



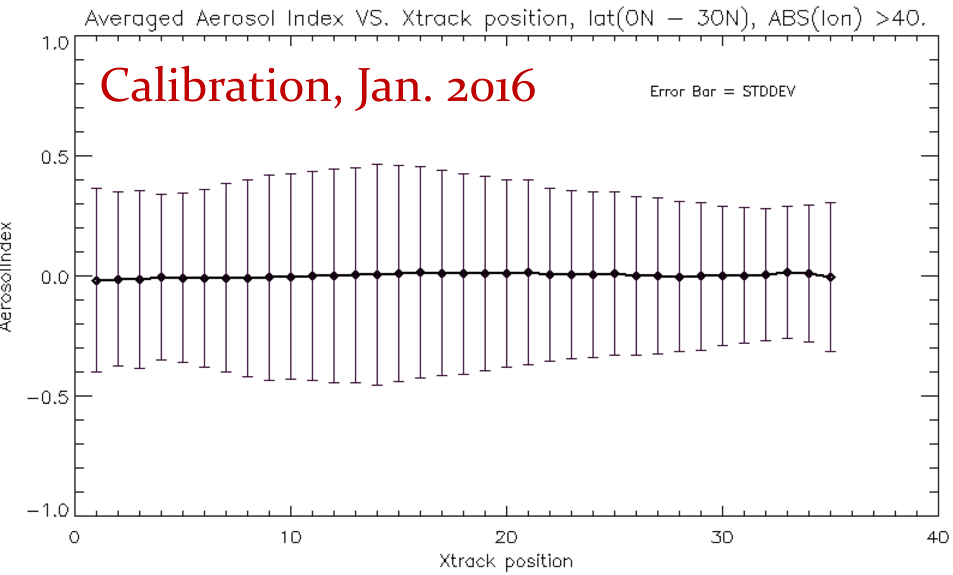


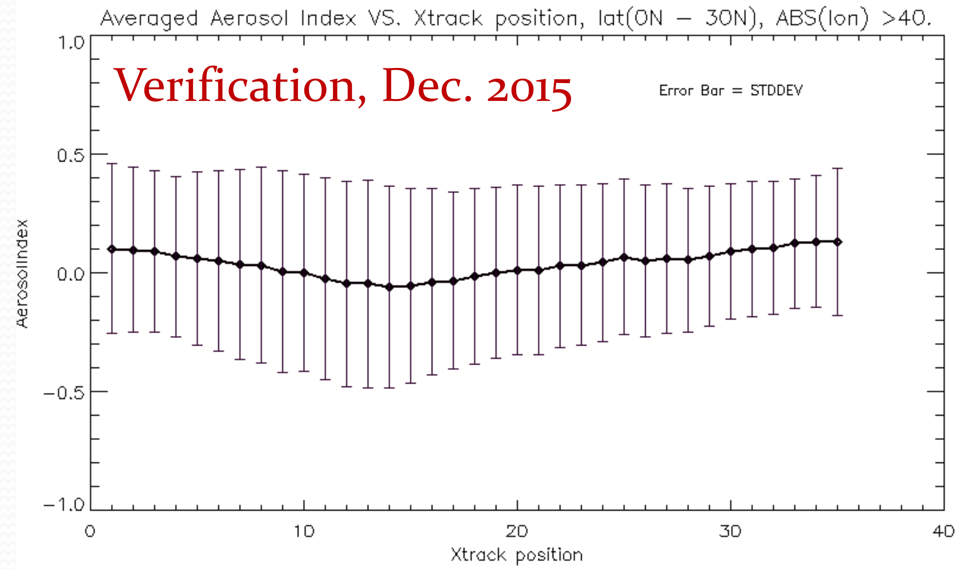


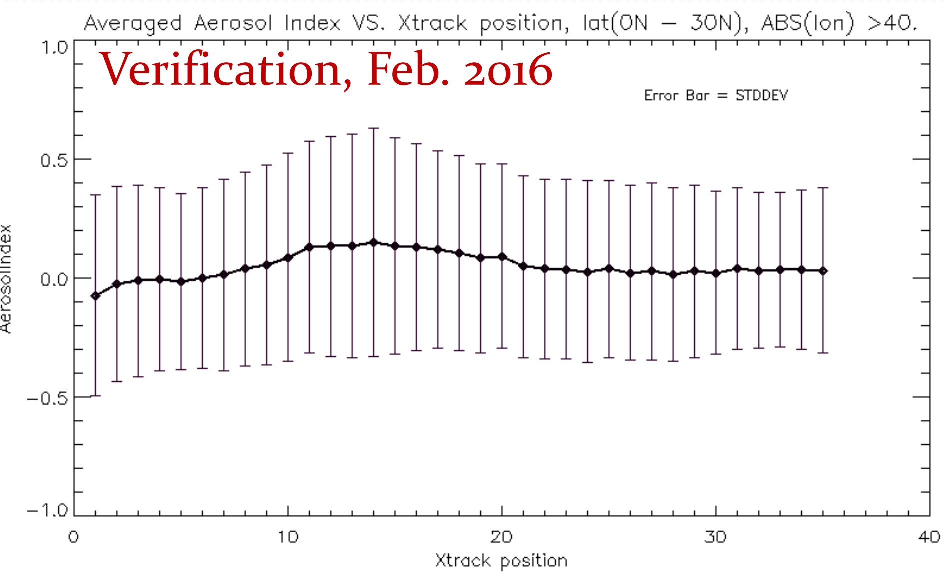


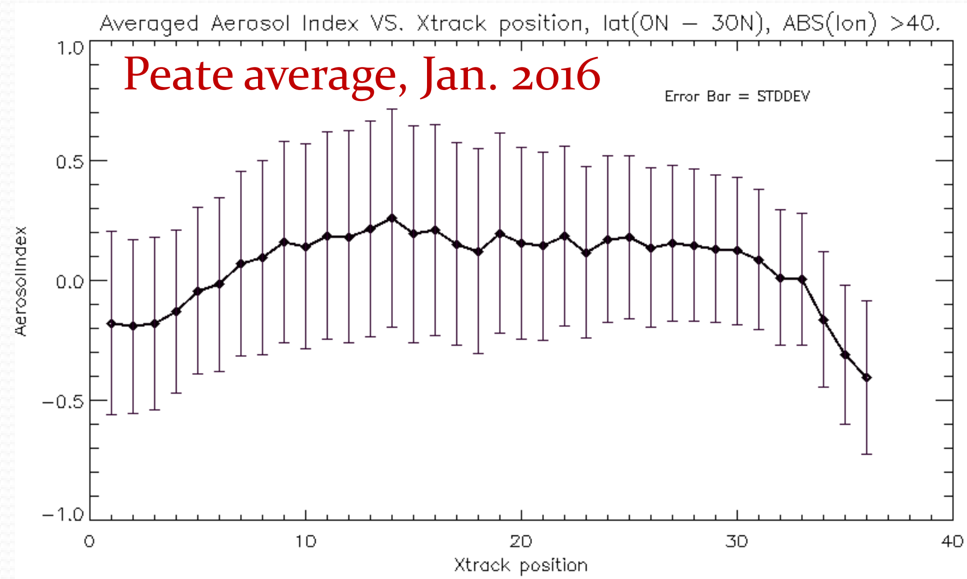
Soft Calibration Adjustments

Independent verification and comparison (Aerosol Index)

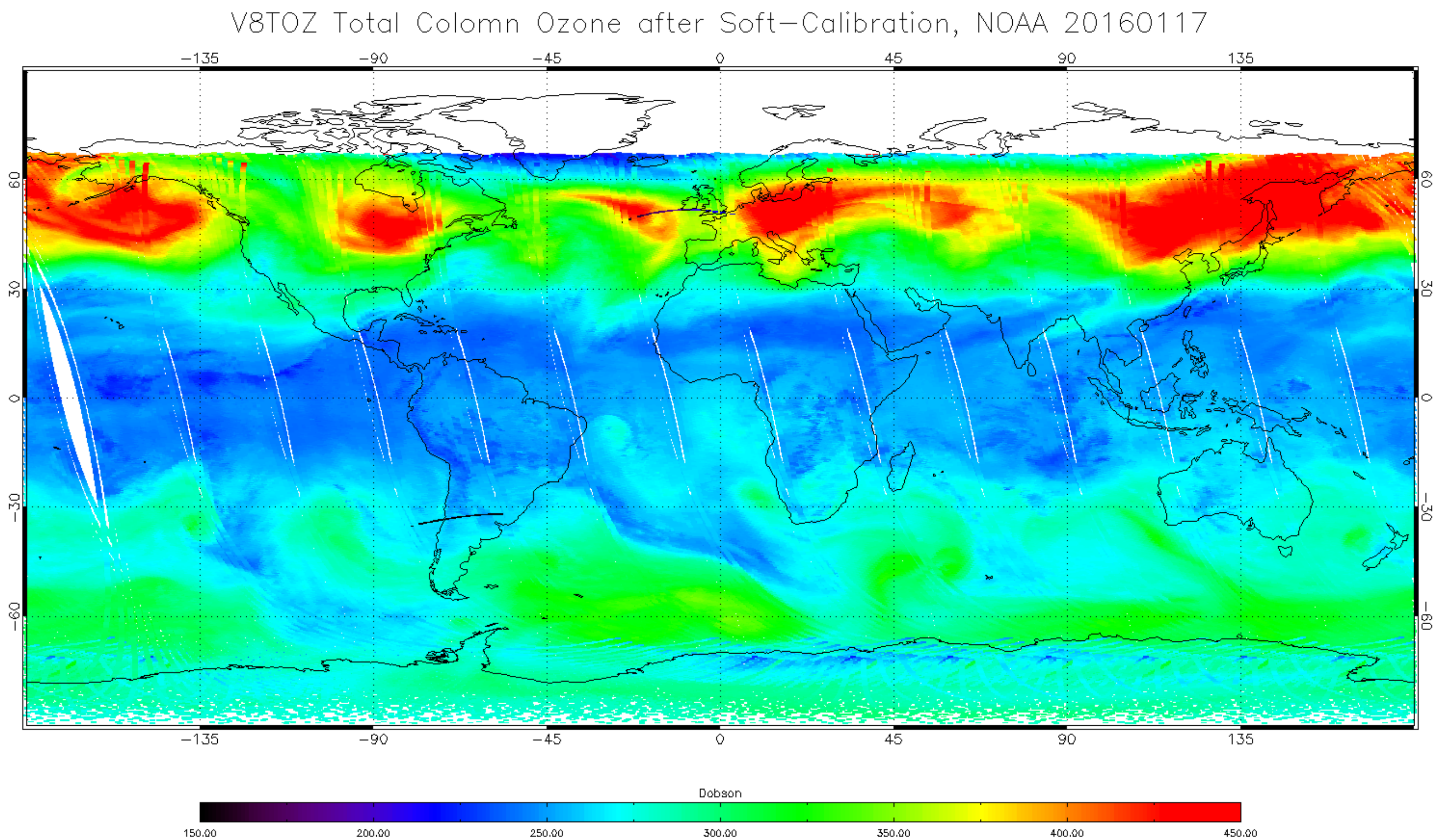






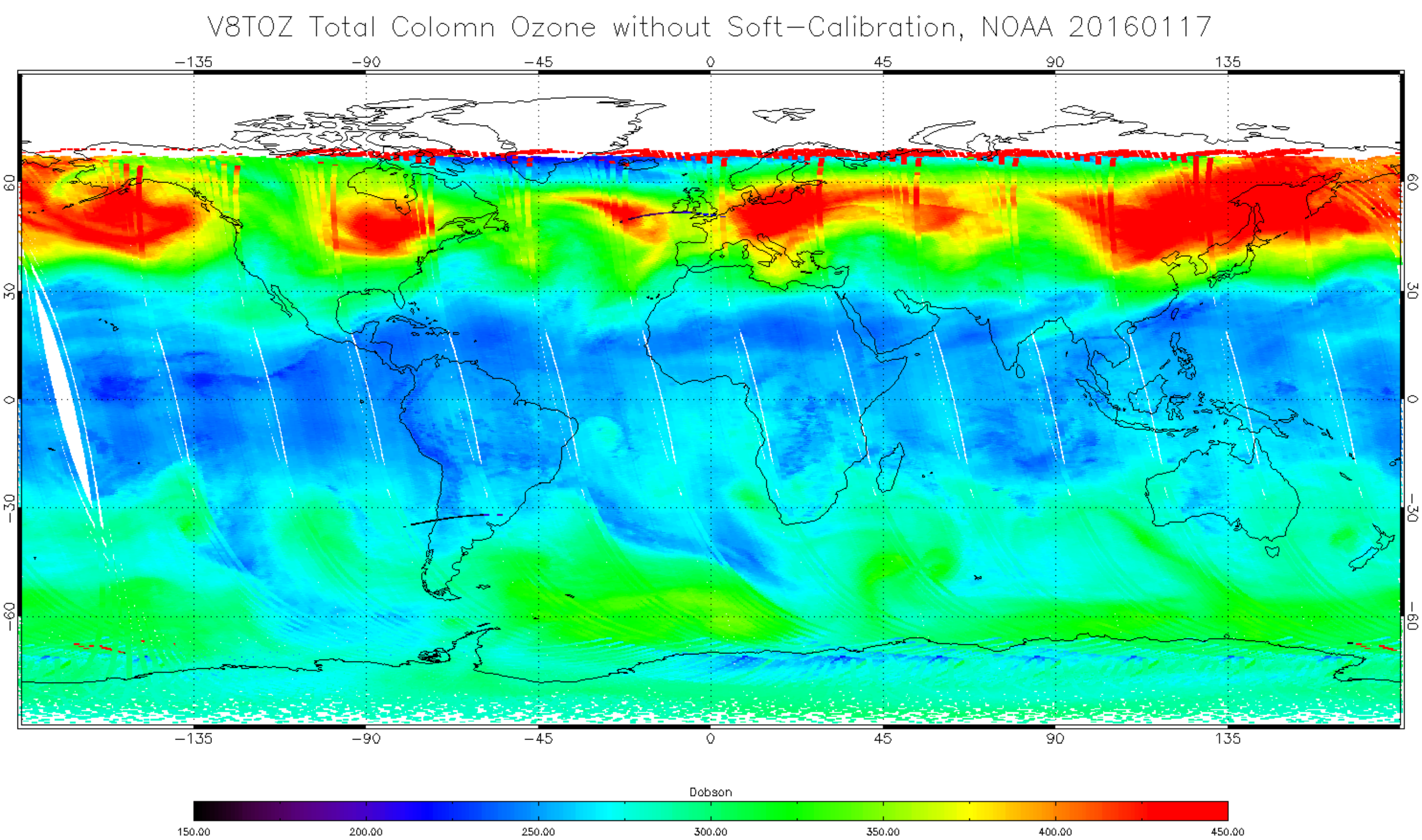


Products and Applications



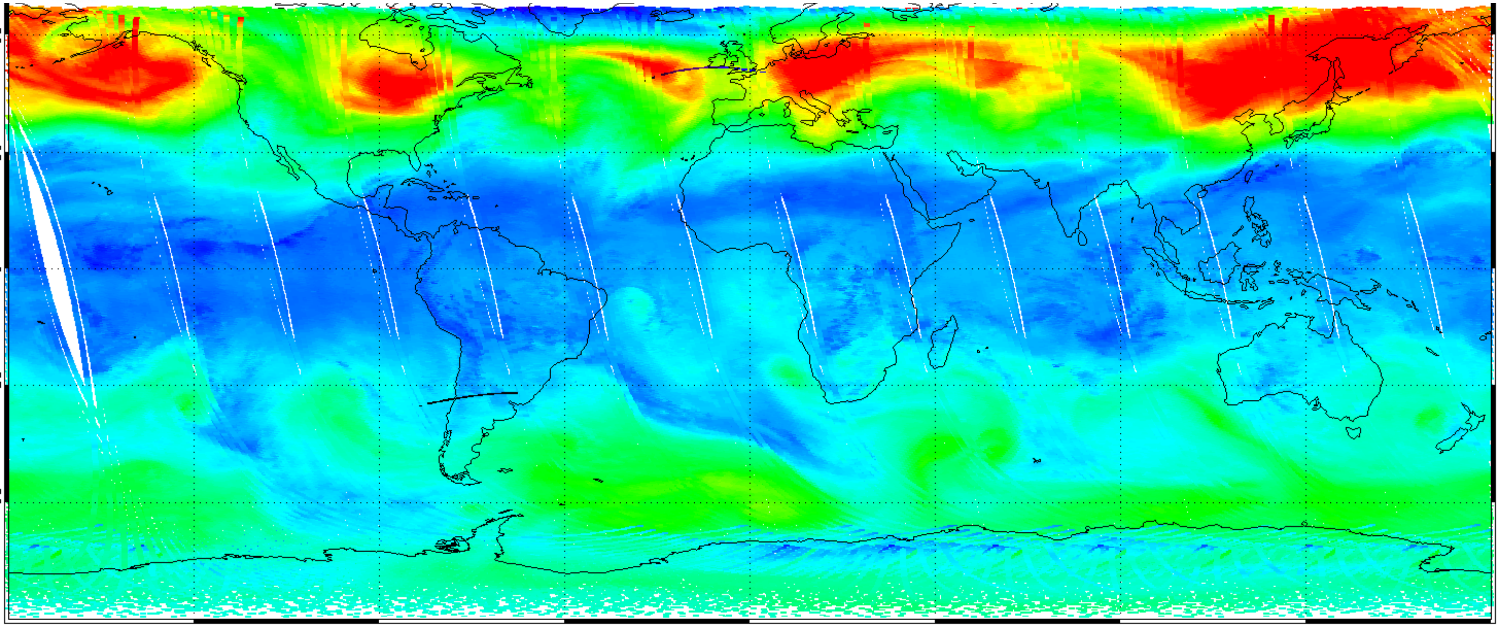
Retrieved Total Column Ozone after Soft-Calibration

Products and Applications

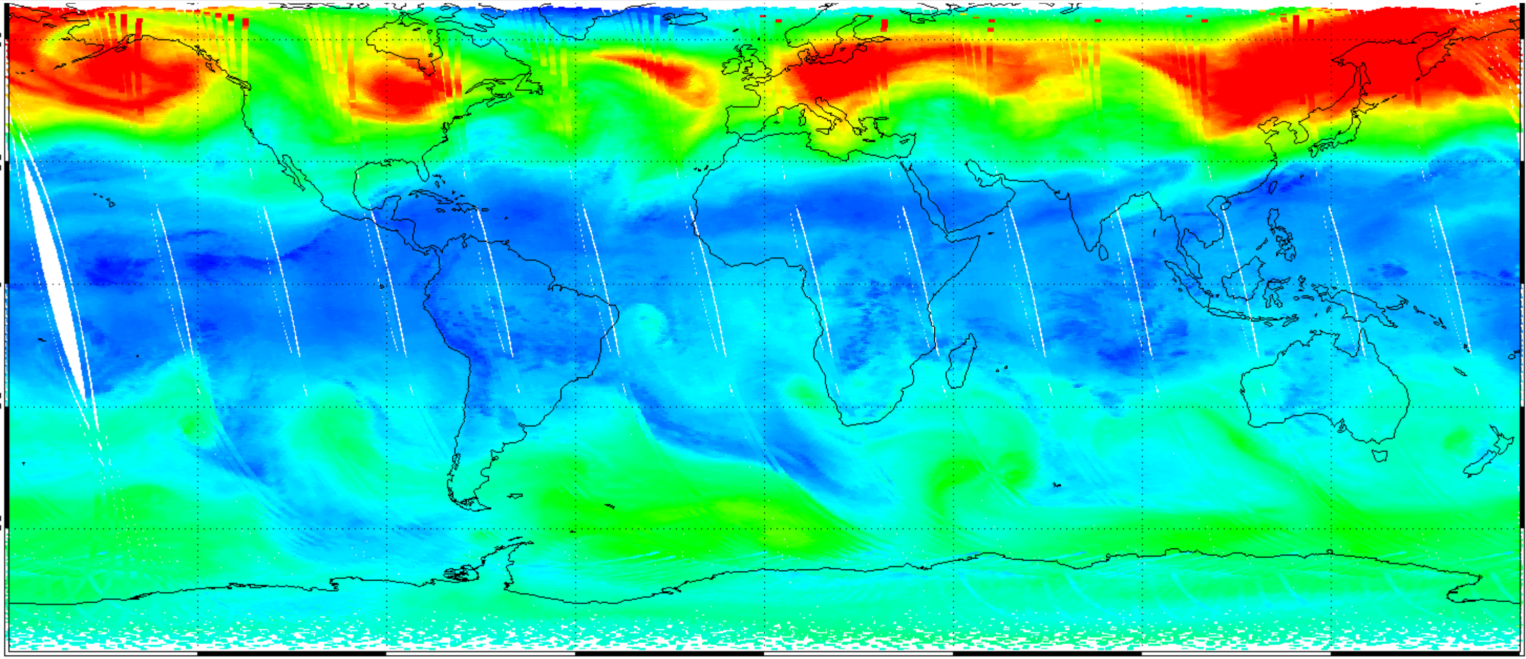


Retrieved Total Column Ozone without Soft-Calibration

Products and Applications

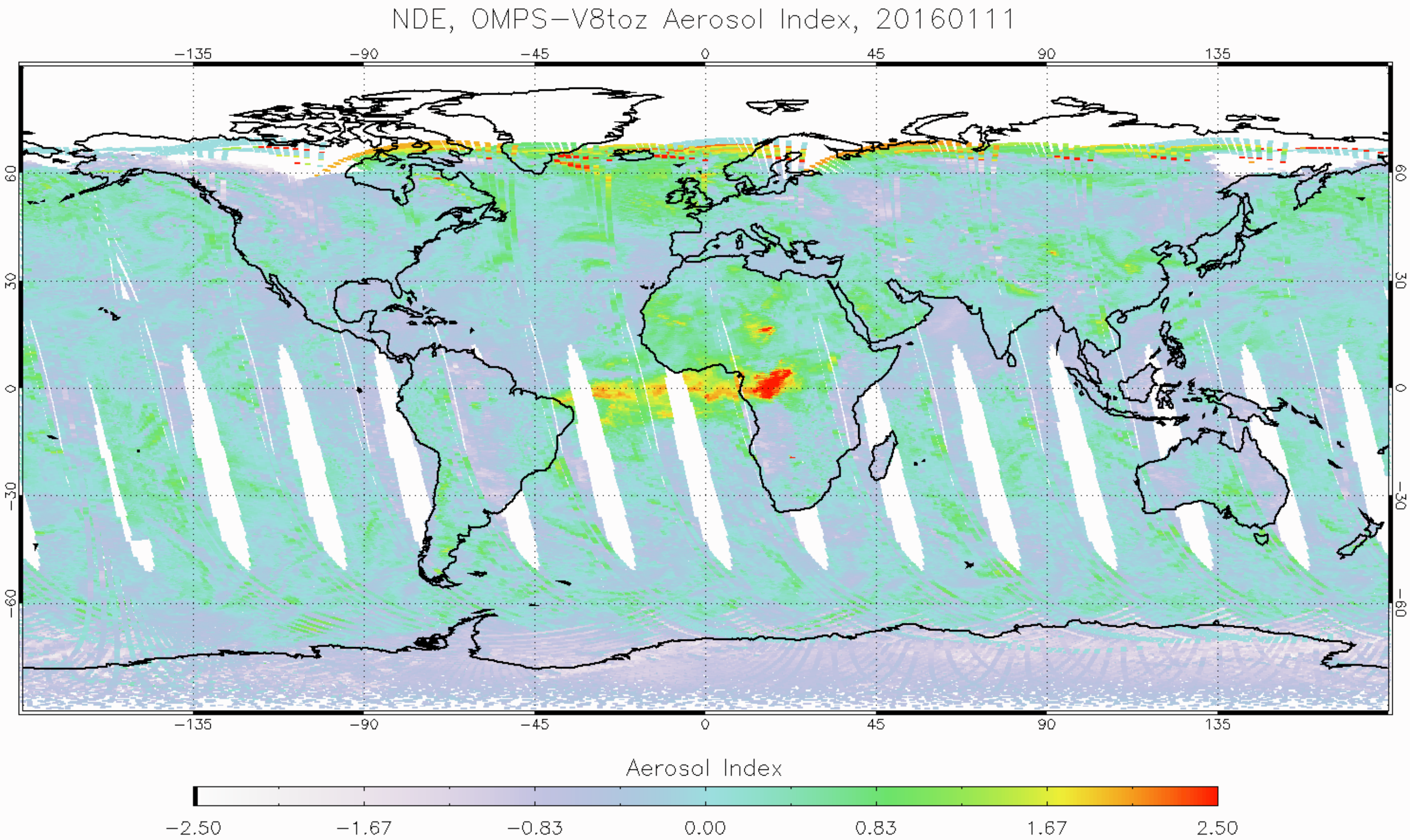


NDE OMPS
OZONE



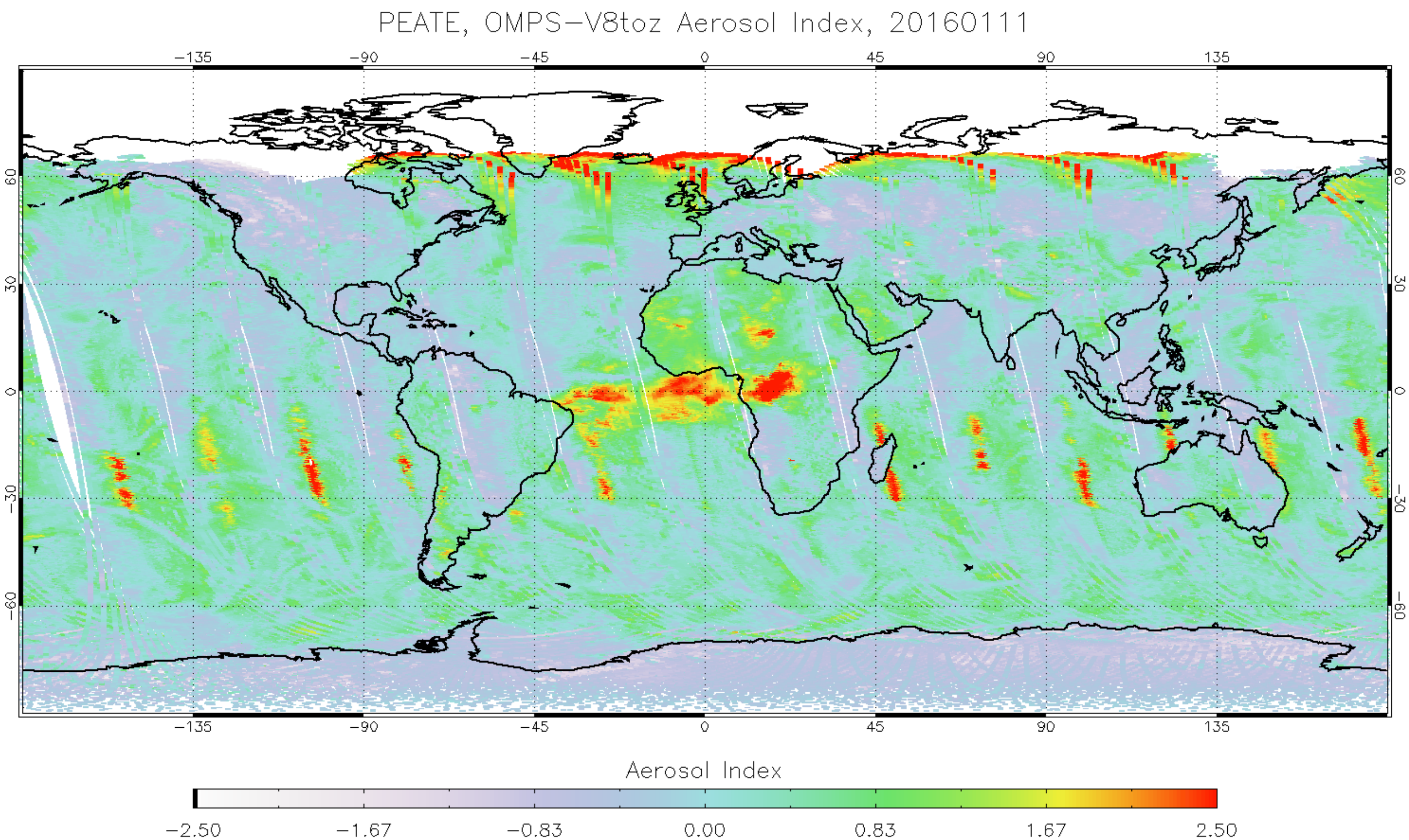
PEATE OMPS
OZONE

Products and Applications



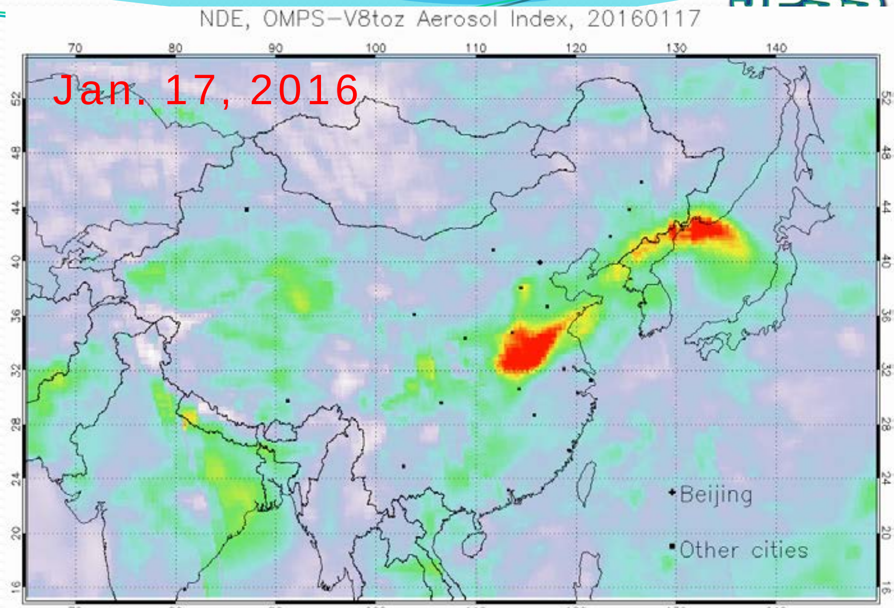
Daily Retrieved Aerosol Index from NDE OMPS

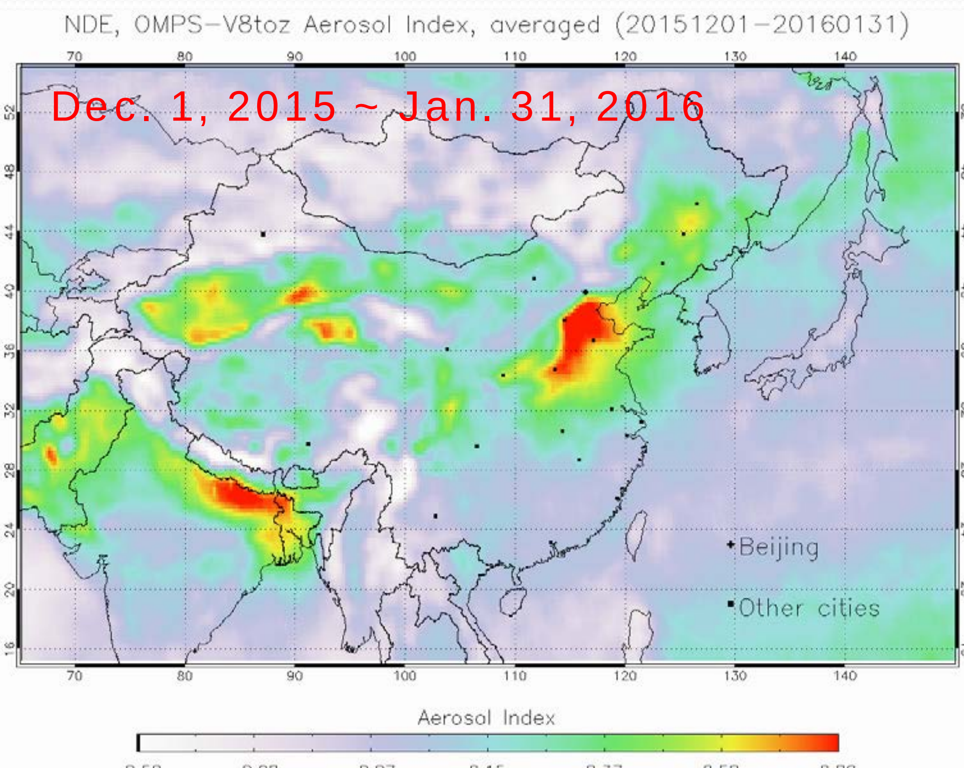
Products and Applications

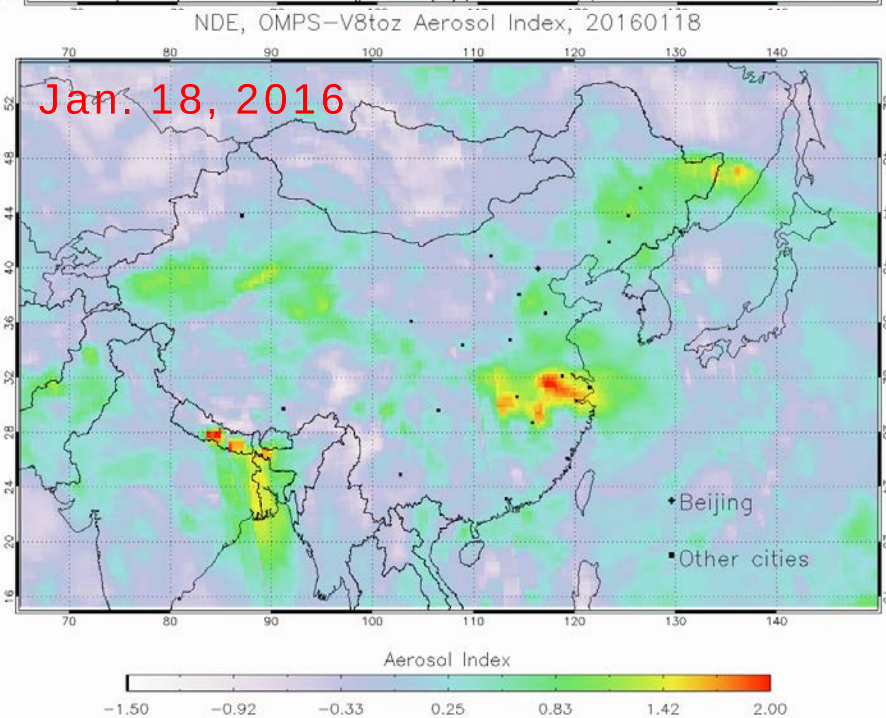


Daily Retrieved Aerosol Index from PEATE OMPS

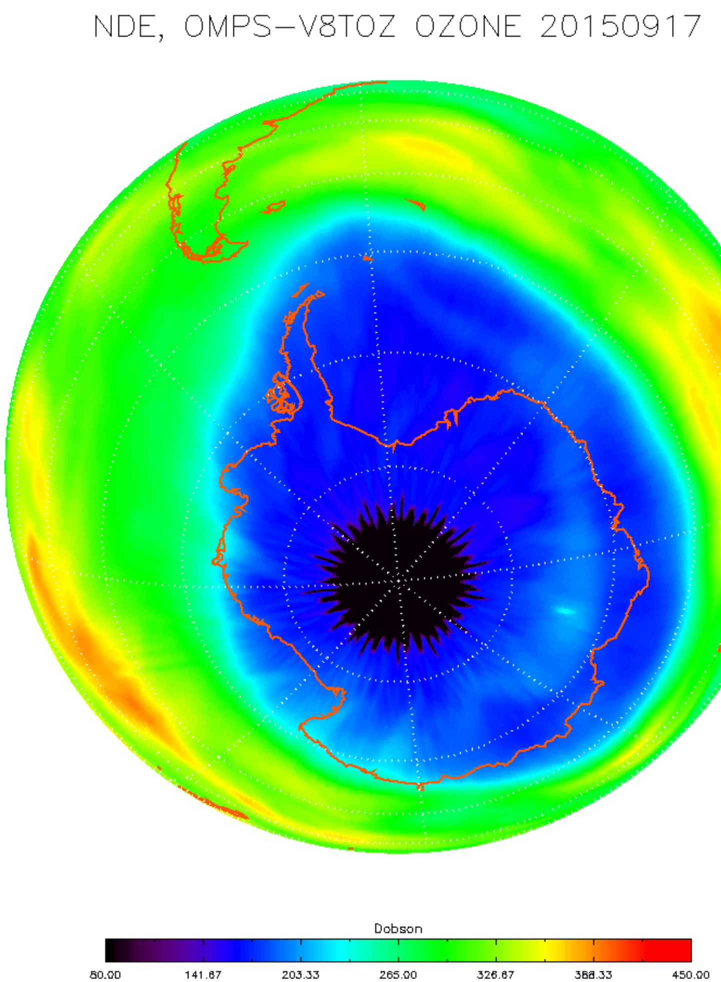
Products and Applications

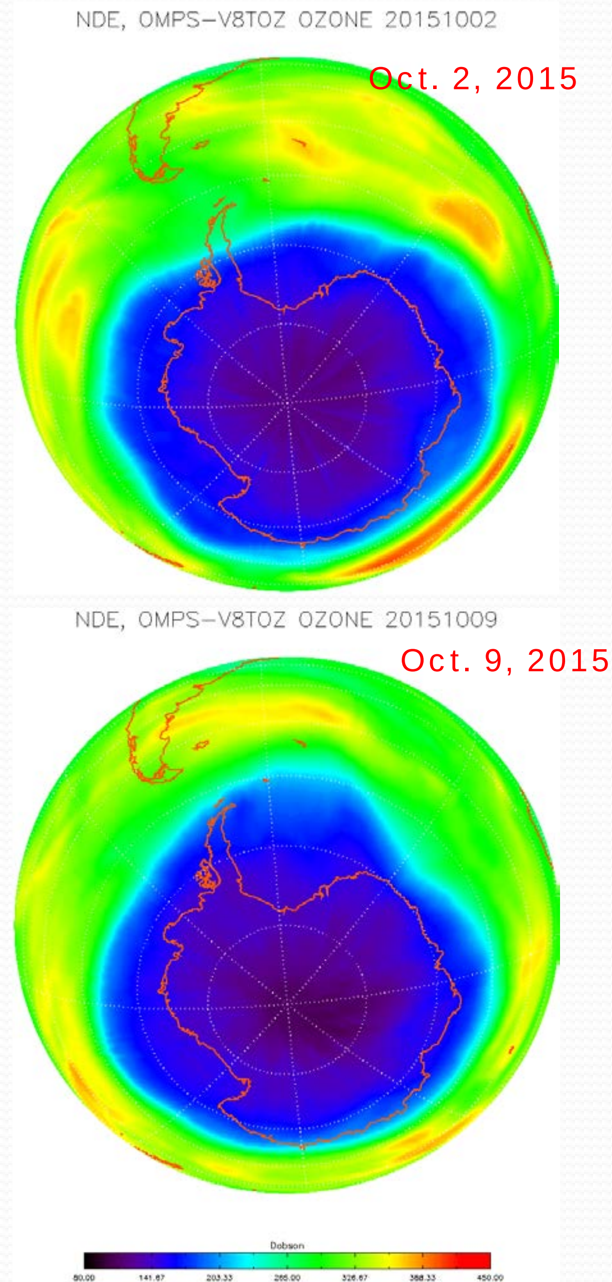






Products and Applications





Daily Ozone Hole Changes in 2015

OMPS Product Monitoring at the ICVS

OMPS Product Demonstration Site

Eric Beach, IMSG@NOAA/STAR
Zhihua Zhang, IMSG@NOAA/STAR
Lawrence Flynn, NOAA/STAR

Aug. 9, 2016

OMPS Product Demo Site URL:

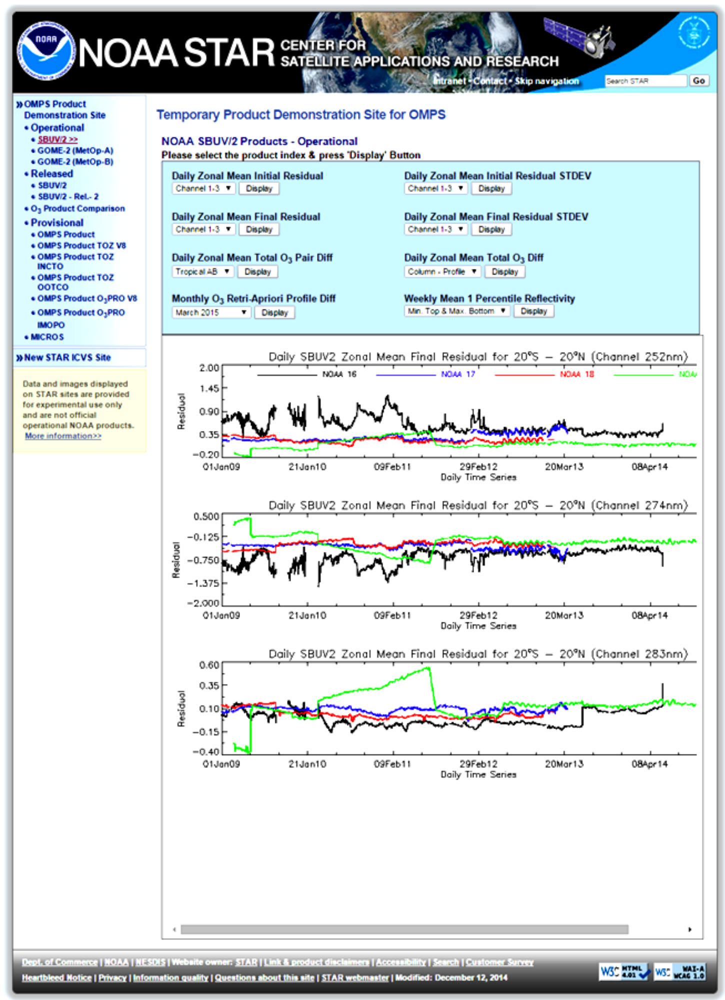
http://www.star.nesdis.noaa.gov/icvs/prodDemos/index.php

General Characteristics of site:

- Depicts performance of OMPS, GOME-2 and SBUV/2 instruments.
- Updated daily, weekly, or monthly depending upon the type of plot.
- Navigable via menu on left side of page. Pull down menus are available for most plot types to select previous time periods.
- Site is in process of being redesigned and relocated.

SBUV/2 V8 Operational Performance

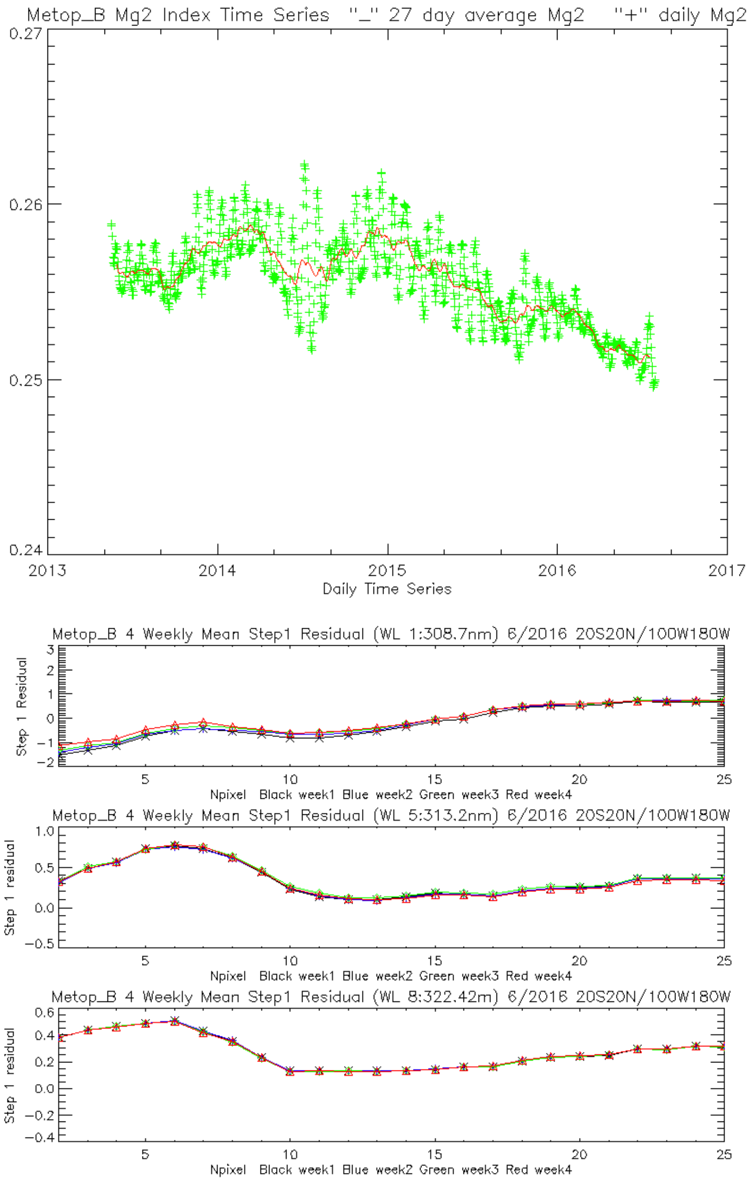
- SBUV/2 data products are monitored long term
- Parameters plotted include:
  - Daily zonal mean initial/final residual
  - Daily zonal mean initial/final residual standard deviation
  - Daily zonal mean total ozone pair difference
  - Monthly ozone retrieved a priori profile difference
  - Weekly mean 1-percentile reflectivity



GOME-2 V8 (Metop A/B)

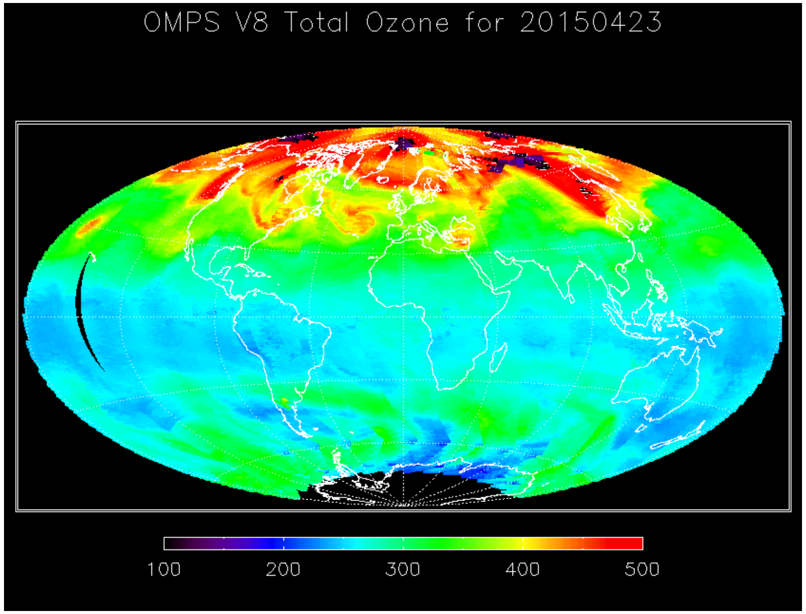
Parameters plotted include:

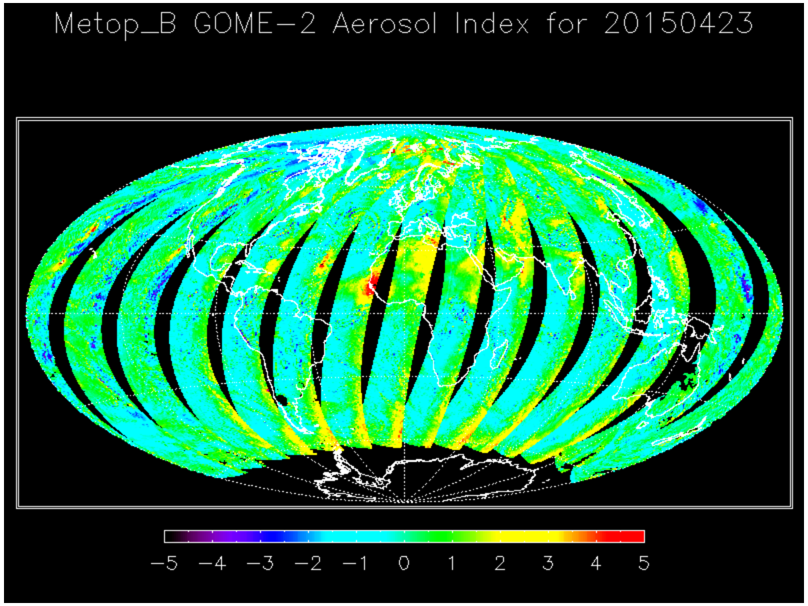
- Mg-II index
- Daily zonal mean total ozone, aerosol index, reflectivity, step 1 residual
- 4-Weekly mean total ozone, reflectivity, aerosol index, step 1 residual



V8 OMPS, GOME-2, and OMI Maps

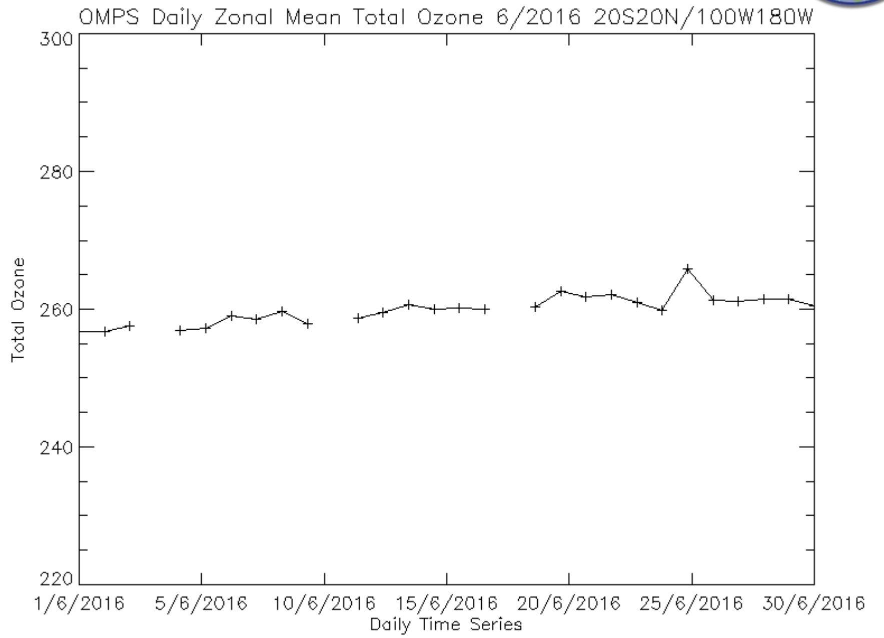
- Daily “postage stamp” images depicting total ozone, reflectivity, and aerosol index
- OMPS V8, INCTO, OOTCO, METOP A/B GOME-2, and OMI products are available

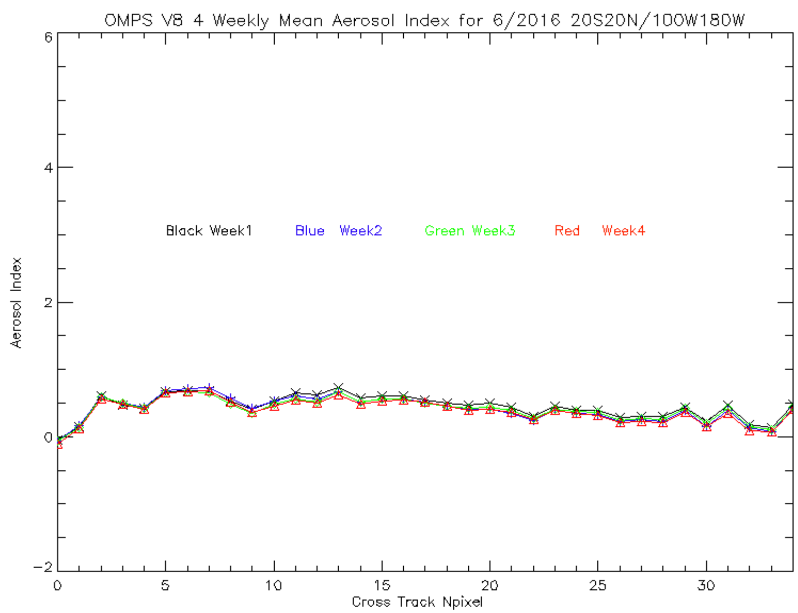




OMPS V8 Total Ozone

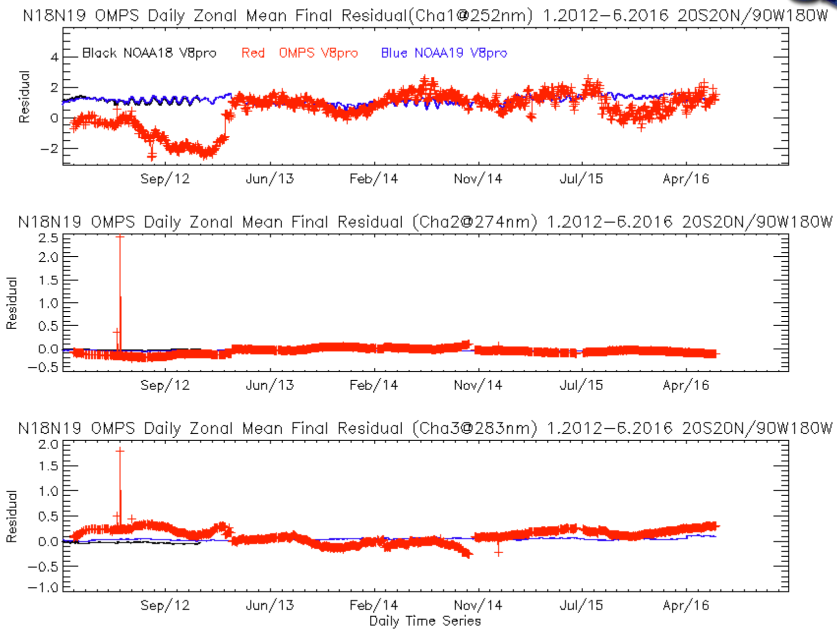
- Monitor the performance of the V8 ozone, reflectivity, and aerosol products
- Daily zonal mean and 4 weekly mean plots are available for each product

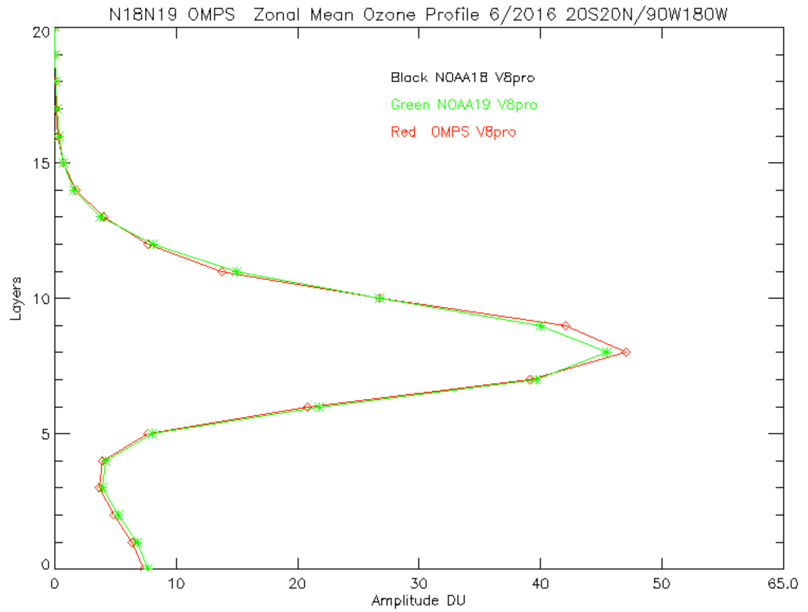




OMPS V8 Profile Product

- Monitor the performance of the V8 profile product
- Plots produced:
  - Daily zonal mean initial/final residual
  - Zonal mean total column O3 – profile O3
  - Retrieved – A priori plots





New OMPS EDR Site Features

- Plots and images will have consistent projections, labels, fonts, and sizes
- Navigation improvements will include:
  - Parameters selected via pull down menu
  - Selectable dates or products via forward or reverse buttons. Also enable date selection via a calendar interface
  - For daily image products, animations can be produced

Conclusion

- V8TOz is a trusted algorithm for J1 instrument
- The delivery of V8TOz to NDE for J1 was successful
- V8TOz products have great value in environmental monitoring and research
- ICVS is a useful tool to monitor our ozone instruments and products

Thanks!

Ozone Applications and CDRs

Craig Long & Jeannette Wild*

NOAA/NWS/NCEP

Climate Prediction Center

**Innovim*

Applications of Ozone Data

- Monitoring the health of the stratospheric ozone layer
  - Global ozone depletion through 1990’s
  - Annual Antarctic ozone hole and occasional Arctic ozone depletion
  - Montreal Protocol impacts to cease depletion and start recovery
  - Detection of recovery :where, what altitudes
- Assimilation into weather and climate models and reanalyses
  - Needed for proper radiation computations
  - Needed for model to separate out ozone effects in IR channels
  - Ozone forecasts used to generate UV Index forecasts
  - Boundary conditions for AQ models
  - Stratospheric intrusions : AQ in passenger planes / surface

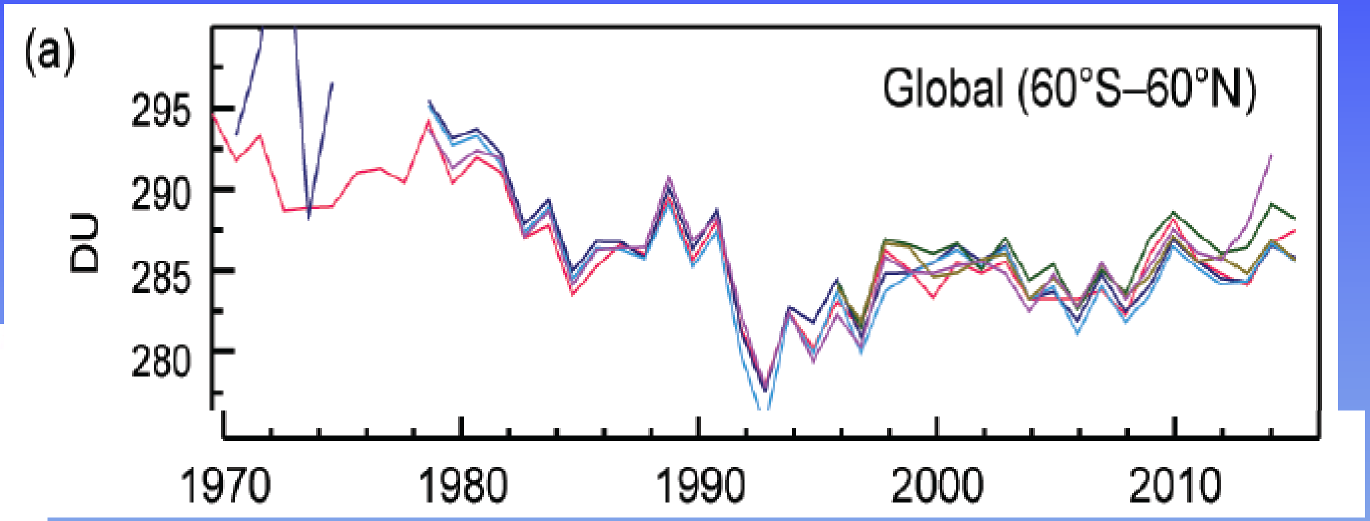
Monitoring

- Short term monitoring
  - Ozone depletion over Antarctica and Arctic during winter/spring months
  - CPC monitoring ozone via SBUV/2, OMPS-NM & NP, LP coming soon
  - CPC provides dynamical context for ozone monitoring
- Multiple long term ozone data sets
  - WOUDC – ground based; Brewer, Dobson, SAOZ, and filter spectrometers
  - SBUV v8.6 – NASA & NOAA - Nadir
  - GOME / SCIAMACHY / GOME-2 – Univ of Bremen & ESA/DLR - Nadir
  - GOZCARDS – occultation and limb
  - SAGE II + OSIRIS– occultation and limb
- Total and Profile trends published in recent papers.
- WMO Ozone Assessments
- 2015 State of the Climate: Stratospheric Ozone (Weber et al)

Continued monitoring

- Where should we be looking for changes in climate and ozone recovery?
  - In a changing climate it is expected that tropical upwelling will increase and thus ozone will continue to decline (Zubov et al. 2013; WMO 2014).
  - The most recent ozone assessment (WMO 2014) and studies (Nair et al. 2015; Harris et al. 2015) indicate that the clearest signs of significant ozone increases should occur in the upper stratosphere (2%–4% decade−1 at ~2 hPa or 40 km)
- Proper trend analysis needs to be preformed with an auto-regressive model taking into account the effects of atmospheric and solar oscillations:
  - Solar cycle
  - QBO
  - ENSO
  - Arctic Oscillation / Antarctic Oscillation

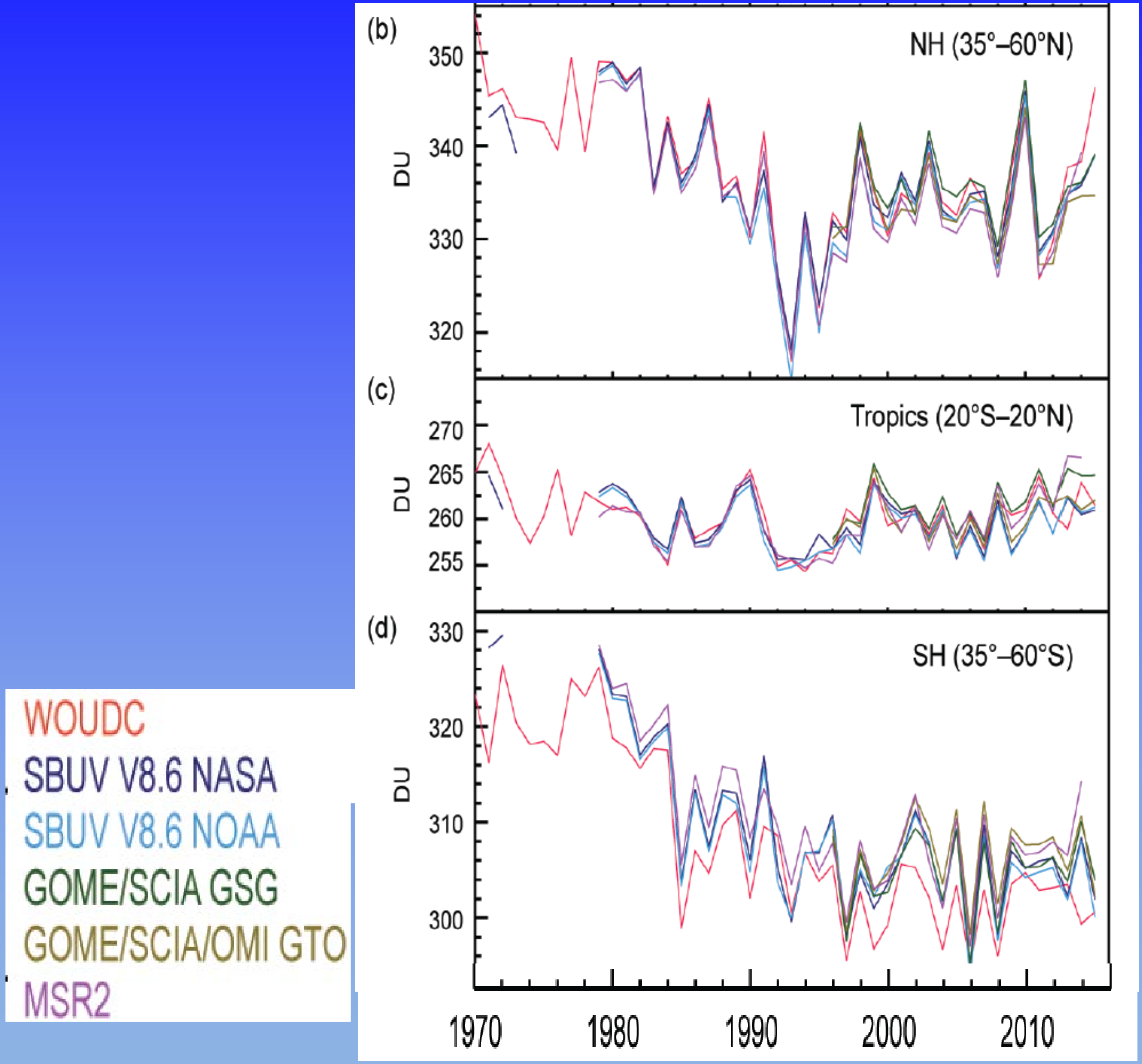
Global Total Ozone



From State of the Climate, 2015

Very good agreement among data sets except for last couple years

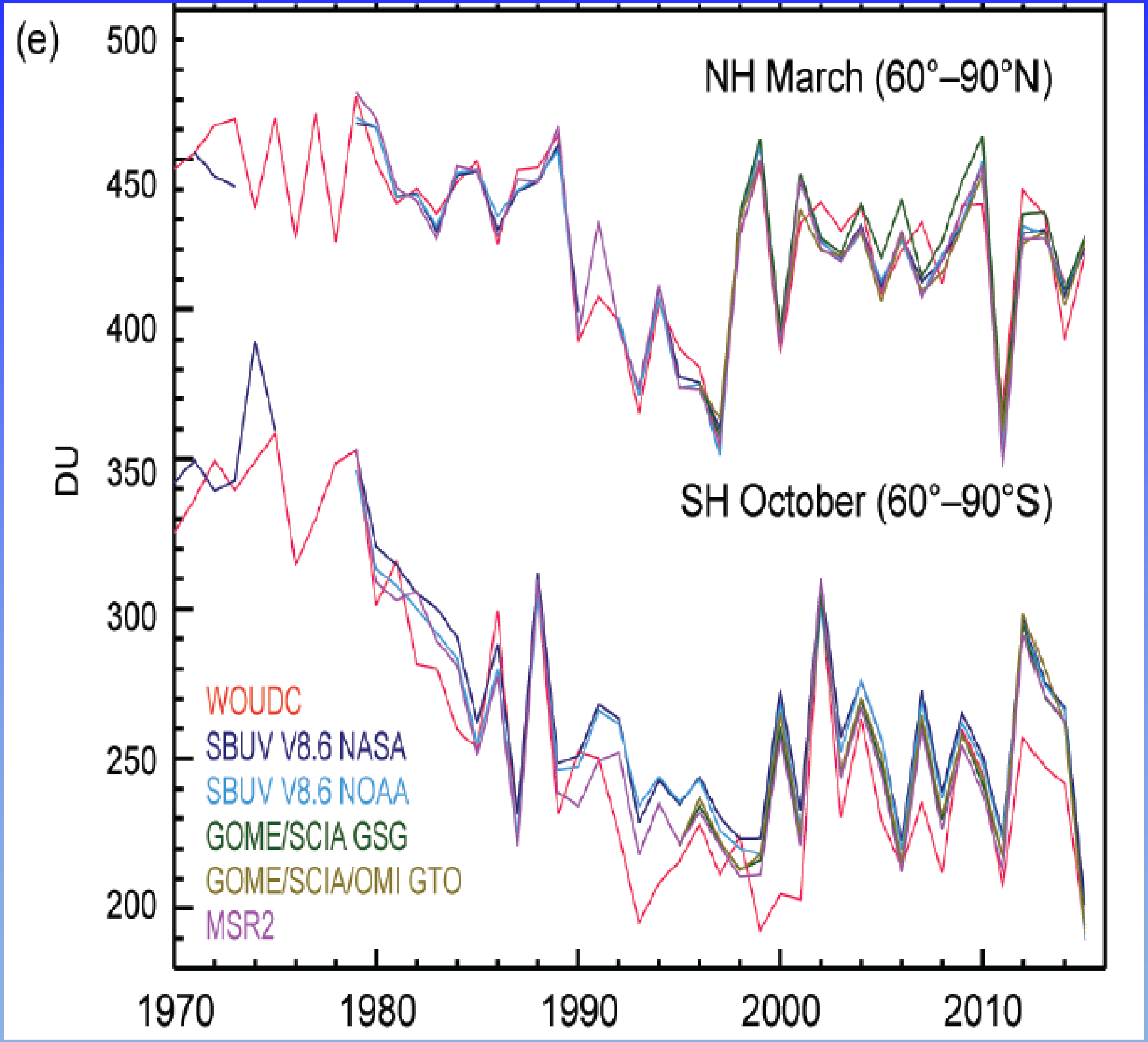
Total Ozone – NH, Tropics, SH



Very good agreement among data sets in NH and Tropics except for last couple years.
SH has greater disagreement especially with WOUDC. Could be do to sparse observation sites.

From State of the Climate, 2015

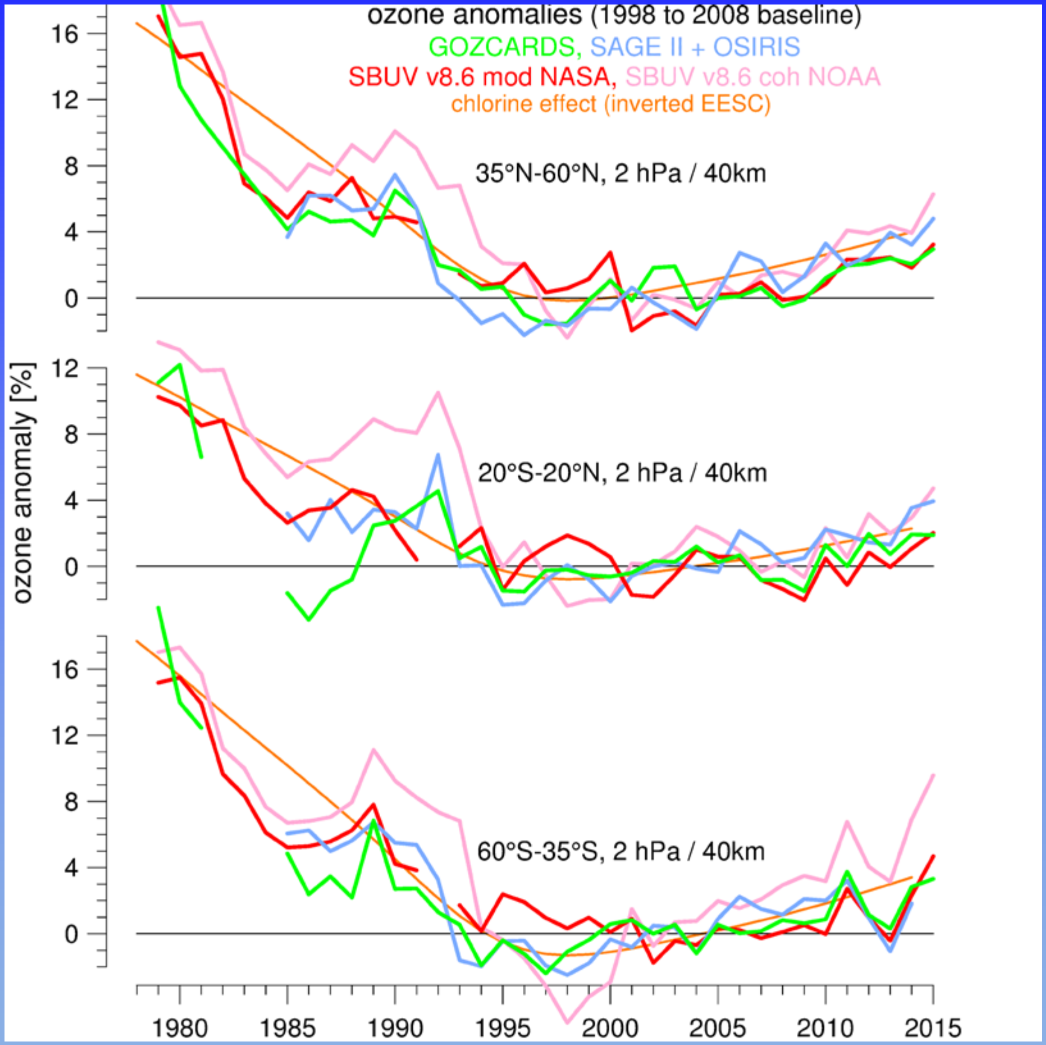
Total Ozone – NH,SH Polar Latitudes



NH March shows period in the 1990's of repeated low ozone years due to cold (noWarmings) conditions. 2010/2011 cold winter also shows up.
SH October shows monthly mean drop from 350 to 220 DU from 1970 to late 1990's. High ozone years of 1986, 88, 02, 12-14 are seen. But large variability since 1999.

From State of the Climate, 2015

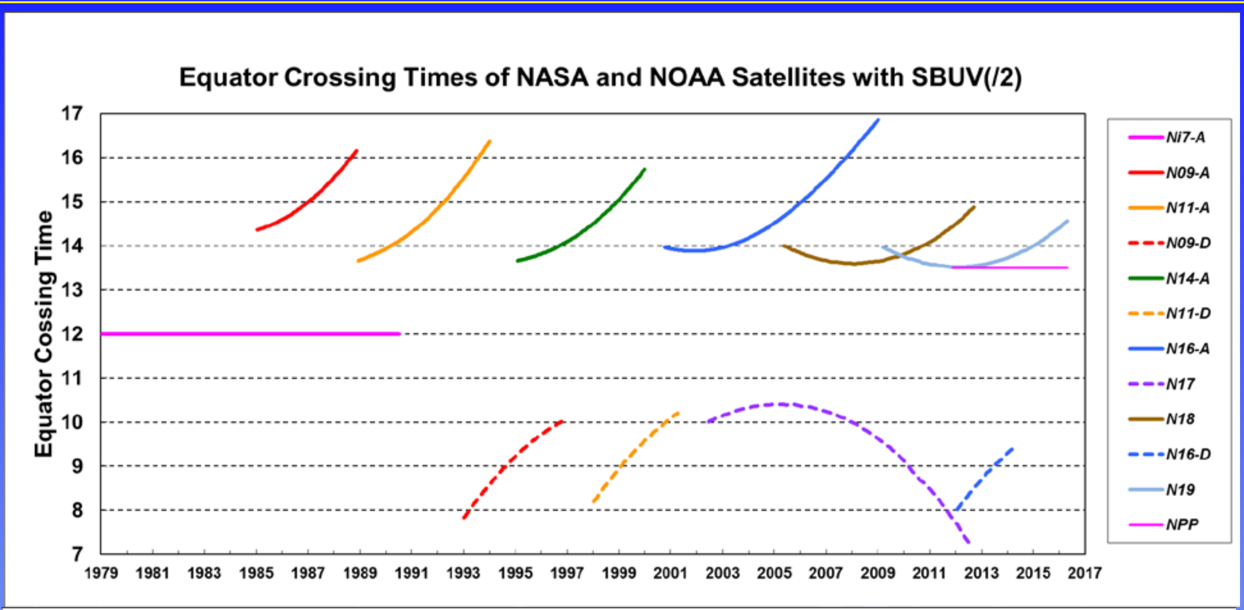
2 hPa Ozone Anomalies

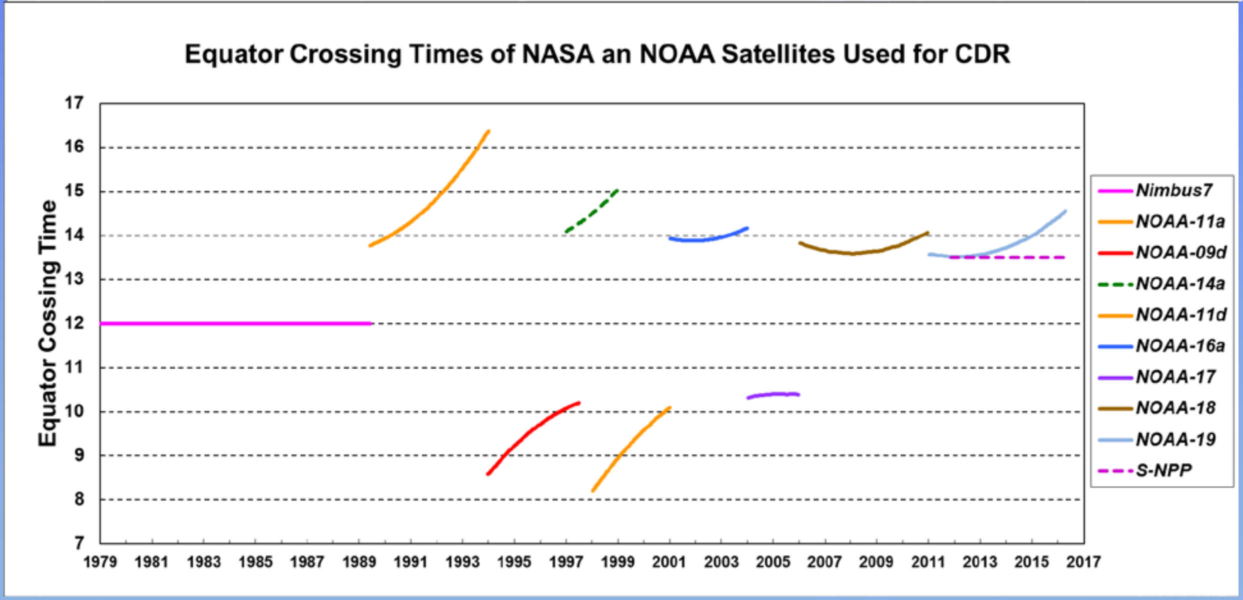


Plots of various ozone profile data sets from 1980-2015 at 2 hPa for NH mid lats, Tropics, and SH mid lats.
Inverted EESC curve is added to show expected effective chlorine levels.
NH and Tropics data set trends somewhat agree with EESC upward trend since 2000. SH mid lat data set trends appear to be flatter than EESC trend.
A new version of the SBUV v8.6 Coh NOAA has been released.

From State of the Climate, 2015

NOAA Cohesive SBUV v8.6 CDR

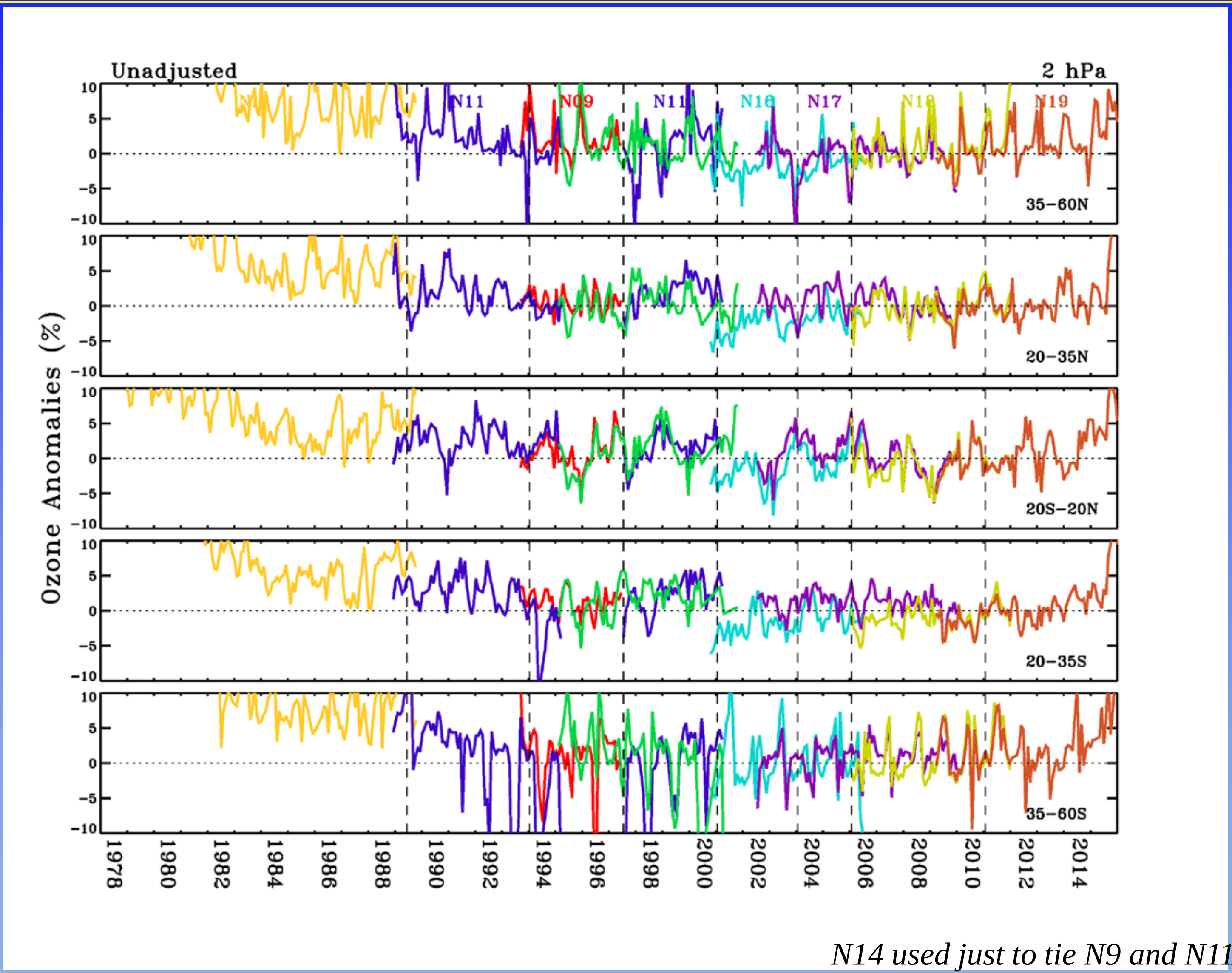




Upper graph shows equator crossing times for all available SBUV(/2) observations. Note that N19 is precessing towards later Equator crossing times. NPP and JPSS satellites will have stable Eq crossing times.

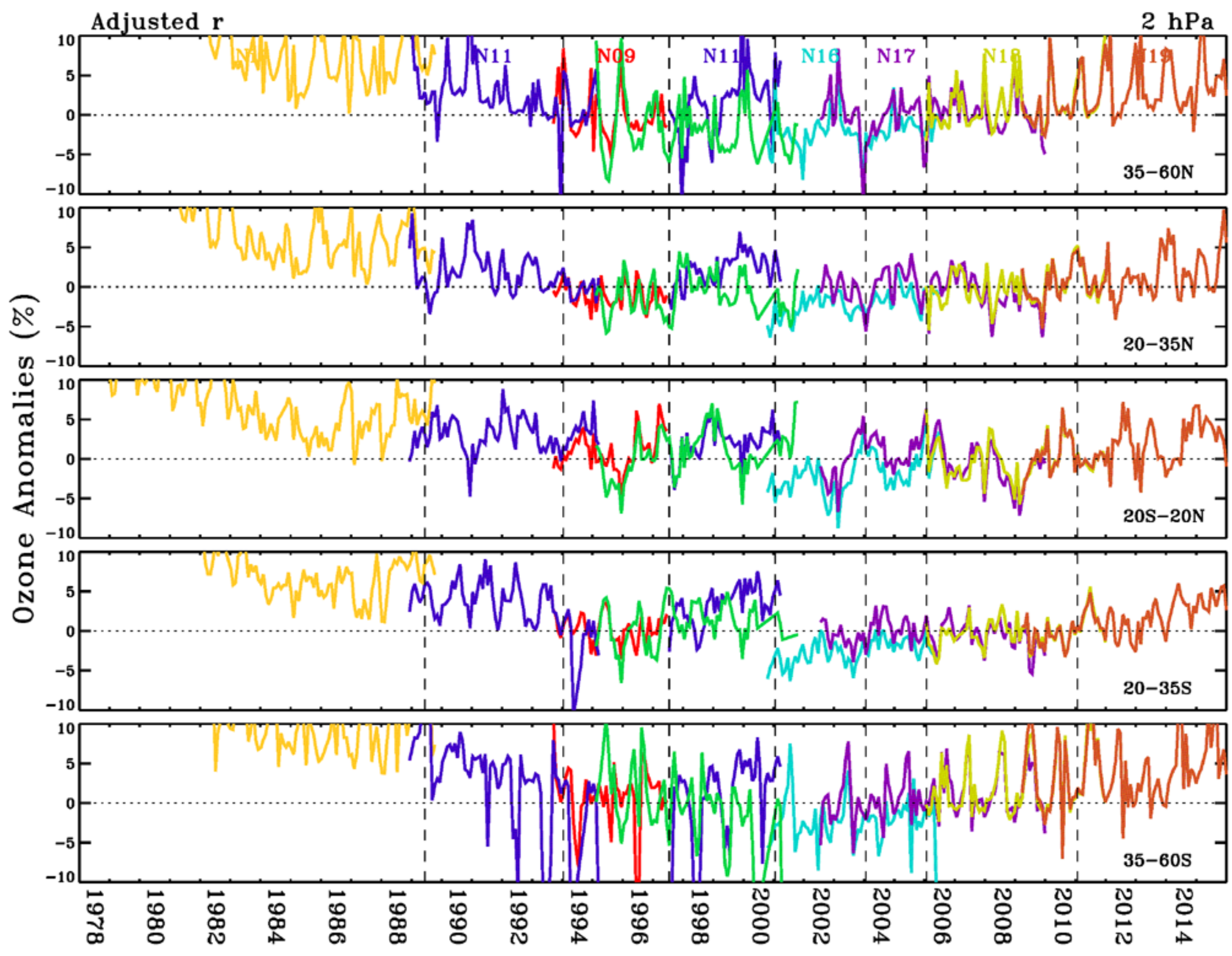
Lower graph shows satellites and time periods used for the latest version of v8.6 Coh. N14 is only used to bridge N9 and N11. N17 is minimally used to keep diurnal diff to a minimum.

2 hPa Unadjusted



N14 used just to tie N9 and N11
No attempt to match N11 and N16

2 hPa Adjusted



Adjustments provide better transition between satellites.

Summary

- Satellite ozone observations are used for multiple applications
  - Primarily for monitoring and assimilation into weather/climate models
- Several types of ozone observing satellites have extensive data spans so long term Climate Data Records can be created and used for trend detection
  - Adds assurance that any one type is observing the ozone trends correctly
- Ozone satellite missions need to be continued to extend these CDRs
  - Where used to monitor the ozone decline
  - Needed to monitor the longer term recovery
  - Complicated by climate change
- NOAA Cohesive SBUV v8.6 CDR adjustments have been finalized
  - Much improved over earlier versions
  - Sent to NCEI for distribution
- OMPS NP (LP) needs to be used to extend the SBUV v8.6 data record
  - N19 drifting away
  - NPP and JPSS have stable orbits

OMPS Small Field of View Products

OMPS-TC-EDR and OMPS-NP-EDR

Trevor Beck
NOAA/NESDIS/STAR

August 9, 2016

Outline

- S-NPP/J01 IDPS capable of producing OMPS SDR MedRes NP and NM (BLK2.0 PSAT21 and later)
- Medium Resolution EDR total ozone products from NDE
- 5x5 EDR ozone profile enhancements
- Status of NDE Implementation and MedRes capability

* *S-NPP someday also will make measurements at medium and high resolution(upgrade to FSW6).*

Expected J01 SDR Measurements

J01 SDR NM expected to be either of two configurations:

1) NM LowRes, 35 xtrack and 5 scans per granule
2) NM MedRes, 103 xtrack and 15 scans per granule

NP MedRes,   5x5, 5 scans per granule X 5 xtracks. 400 scans per orbit. Wavelength dimension ~150 measurements from 250nm to 310nm.

Images shown in this presentation are J01 Proxy data derived from NPP and NPP diagnostic, from off-line ADL runs at NOAA by the OMPS STAR SDR team.

These are SDR formats. the NadirMapper RDR measurements can be made at different spatial and spectral measurements. The IDPS system will aggregate pixels to produce either 35x5 or 103x15.

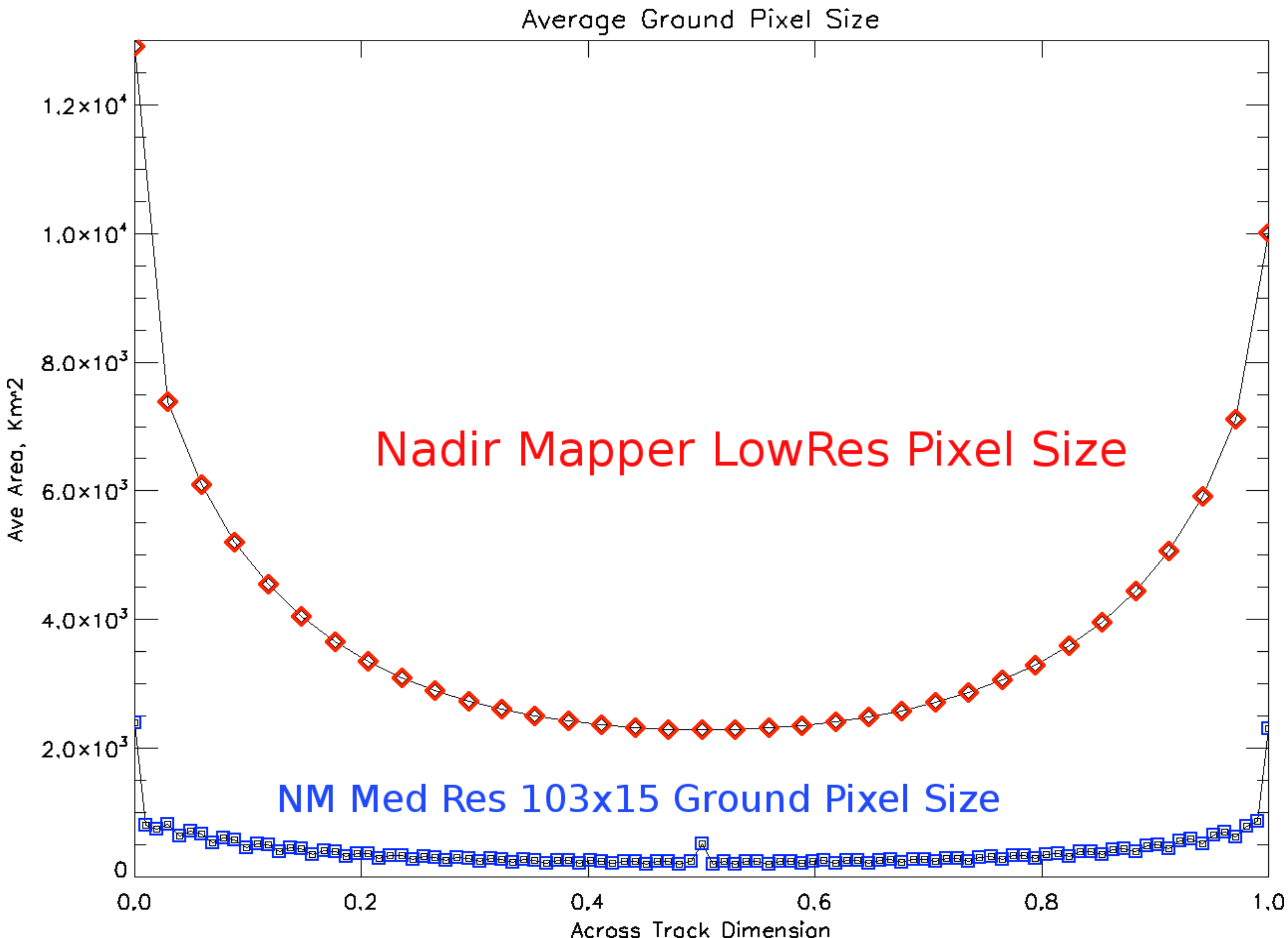
NM Low Res SDR Format

- Same number of ground pixels as current nominal NPP SDR. 35X5.
- This is the expected nominal SDR format from L+3 months to L+9 months
- Approximate same wavelength dimensions and coverage as NPP 35x5.
- J01 RDR measurements will be made at higher spatial resolutions, the IDPS will aggregate to 35x5.

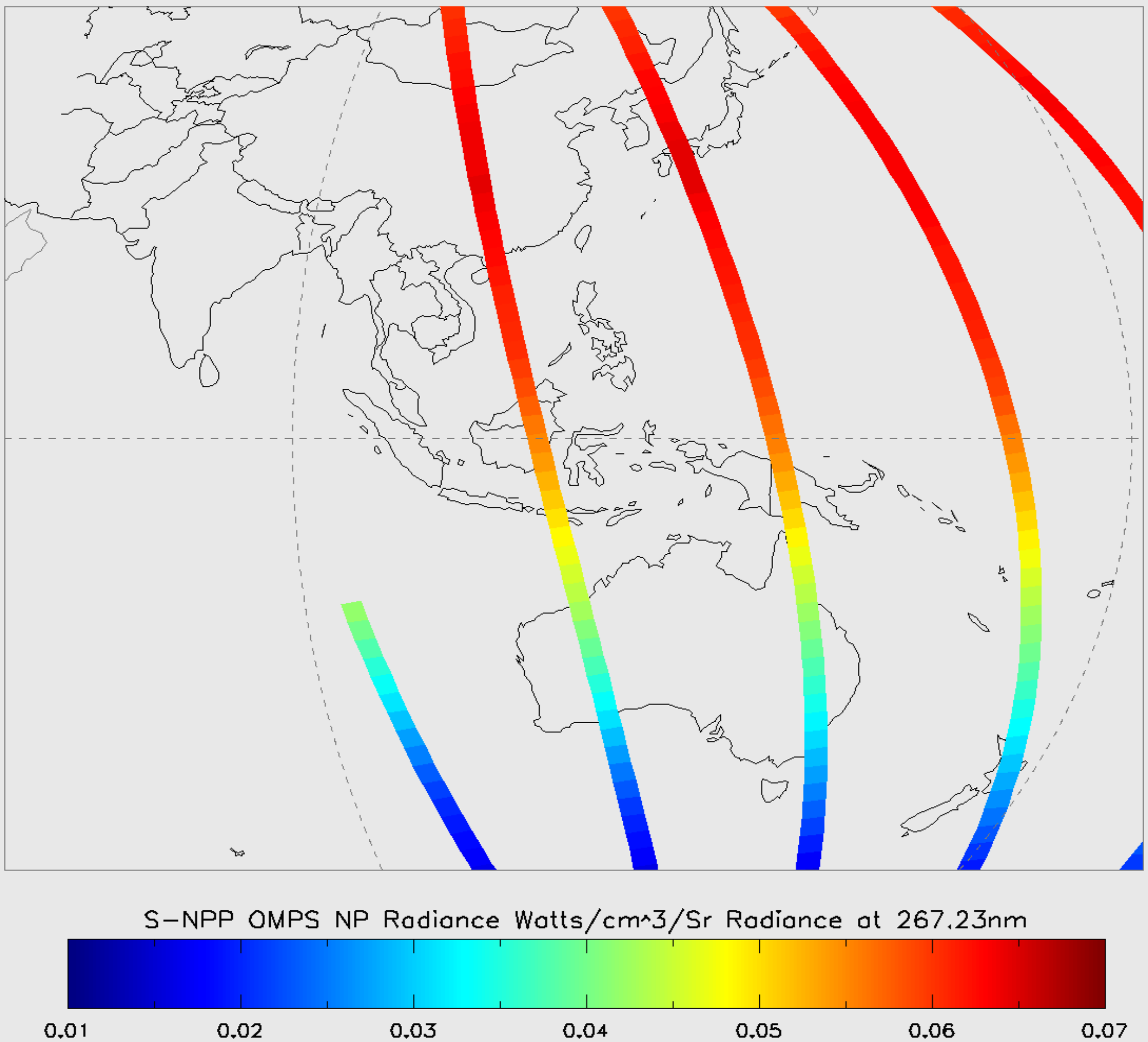
NM Med Res SDR Format

- This is the expected nominal SDR format from L+9 months onward
- 15 scans per granule, 103 xtrack pixels
- Approximate same wavelength dimensions and coverage as current NPP NM.
- RDR measurements will be made at higher spatial resolutions, the IDPS will aggregate to 103x15.

NM Ground Pixel Sizes



J01 and S-NPP NP SDR



S-NPP Configuration

Ground pixel size:
250Km . 250Km

80 ground pixels per orbit

Viewing Zenith Angle
Approximately zero°

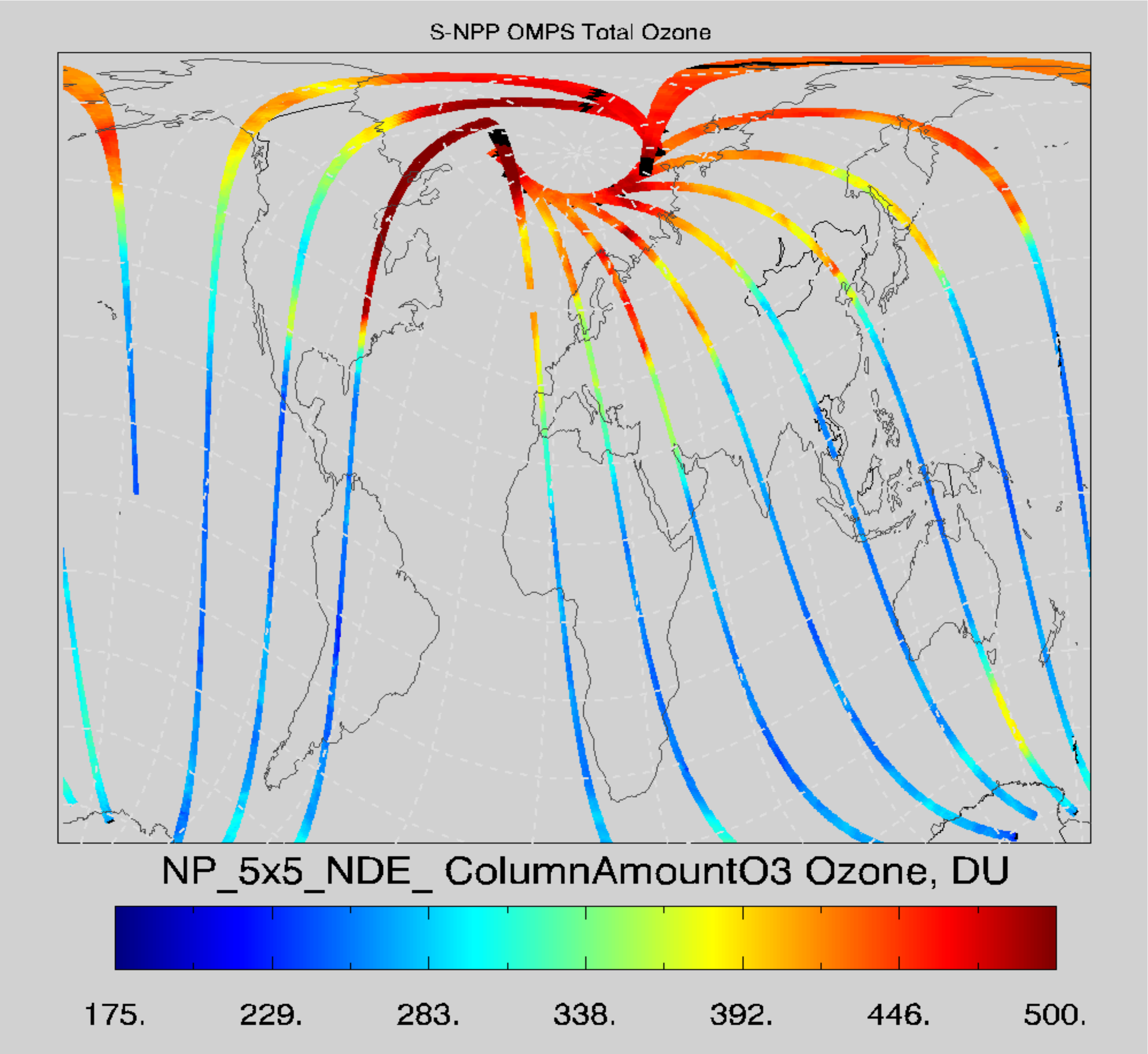
J01 Configuration

J01 Ground Pixel size:
50Km . 50Km

2000 pixels per
orbit=80*5*5

Viewing Zenith Angle
ranges from -7.5° to 7.5°

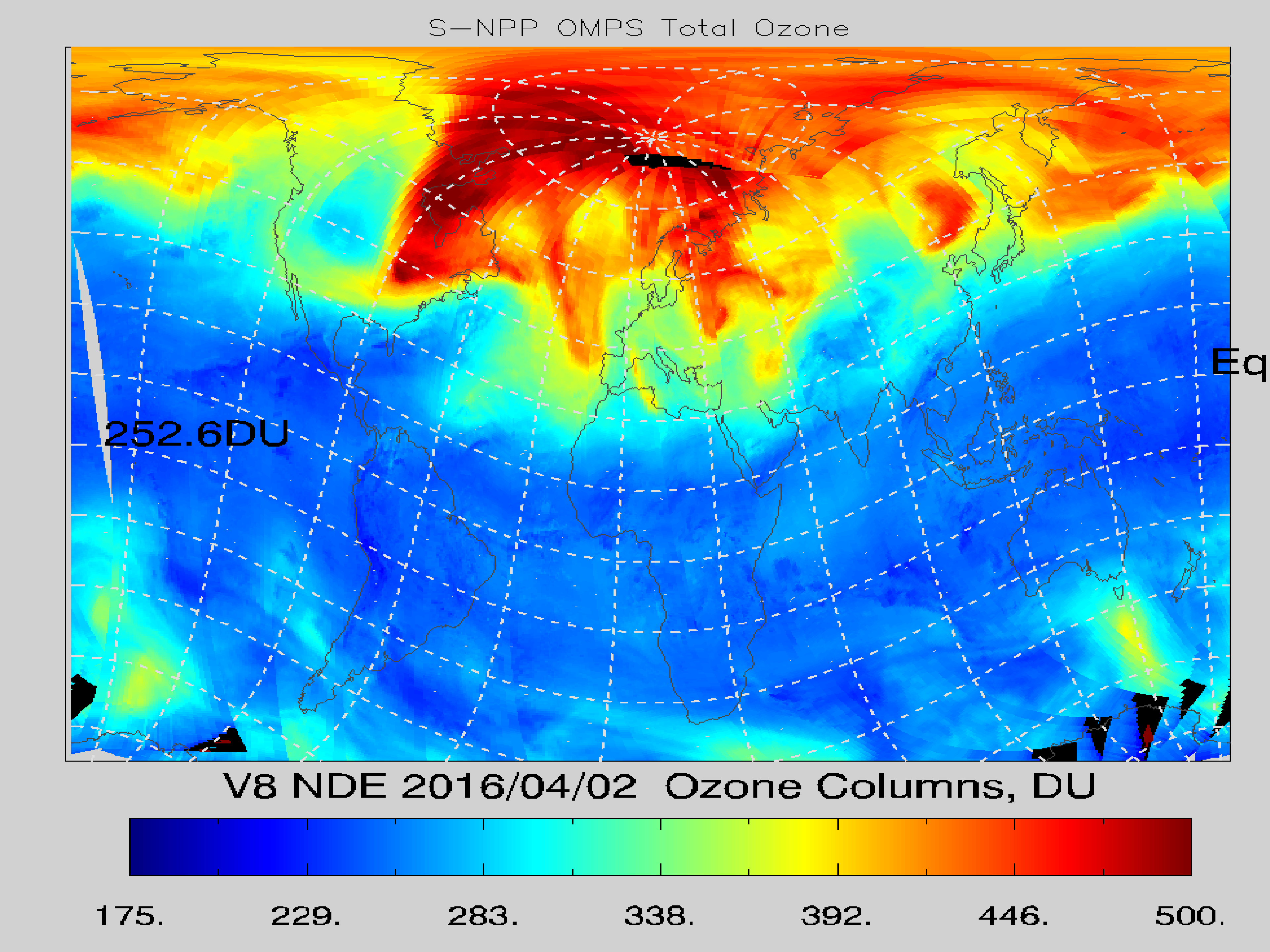
5x5 Ozone Retrieval NP



5x5 Ozone retrieval Example.

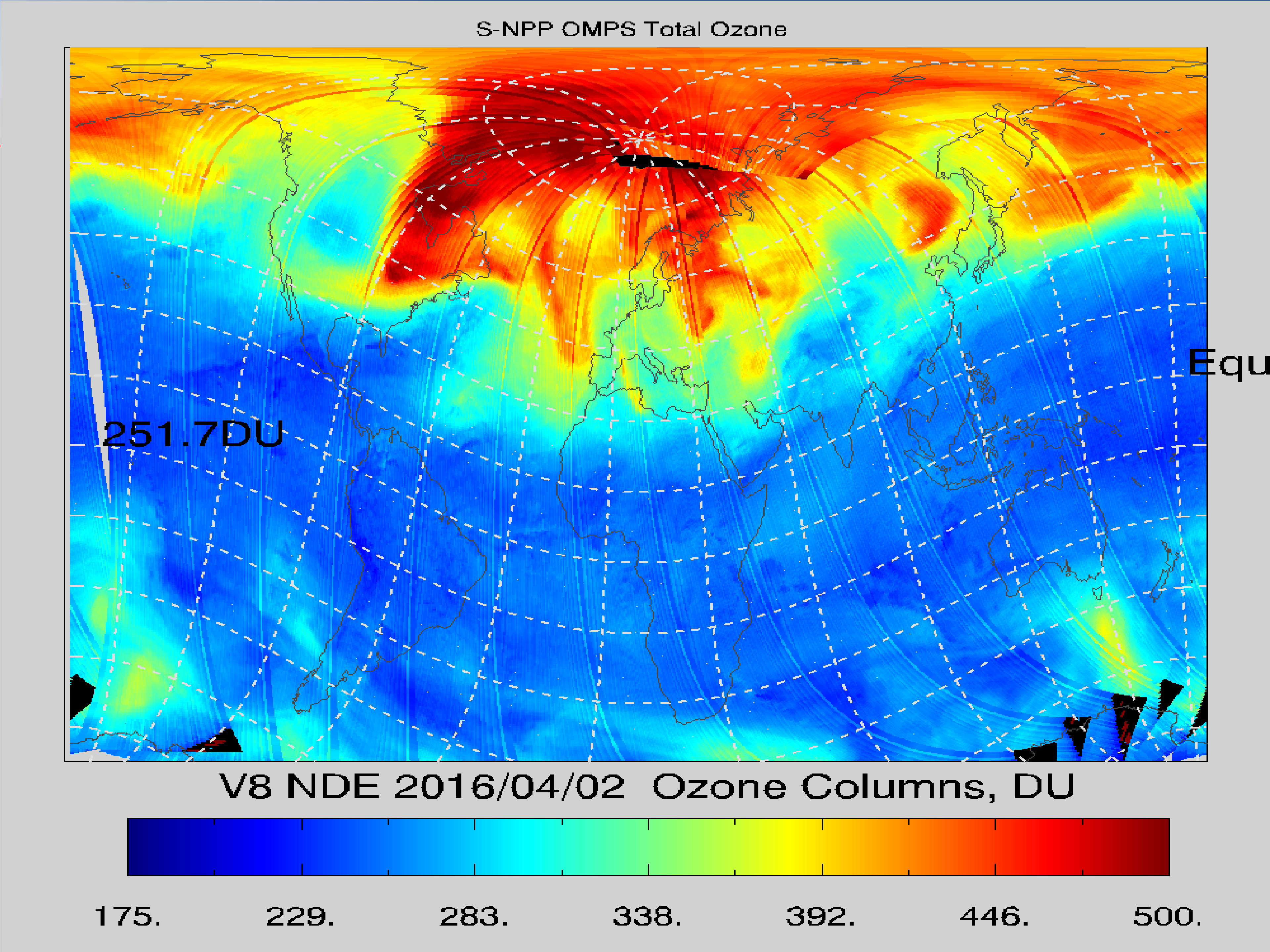
We took S-NPP diagnostic data and converted to Nominal. Then it is processed through ADL BLK2.0 to SDR level.

The image is created by the NDE V8Pro ozone profile retrieval code. This science code is currently undergoing security code review at NDE.


S-NPP OMPS Total Ozone
252.6DU
Eq
V8 NDE 2016/04/02 Ozone Columns, DU
175.
229.
283.
338.
392.
446.
500.

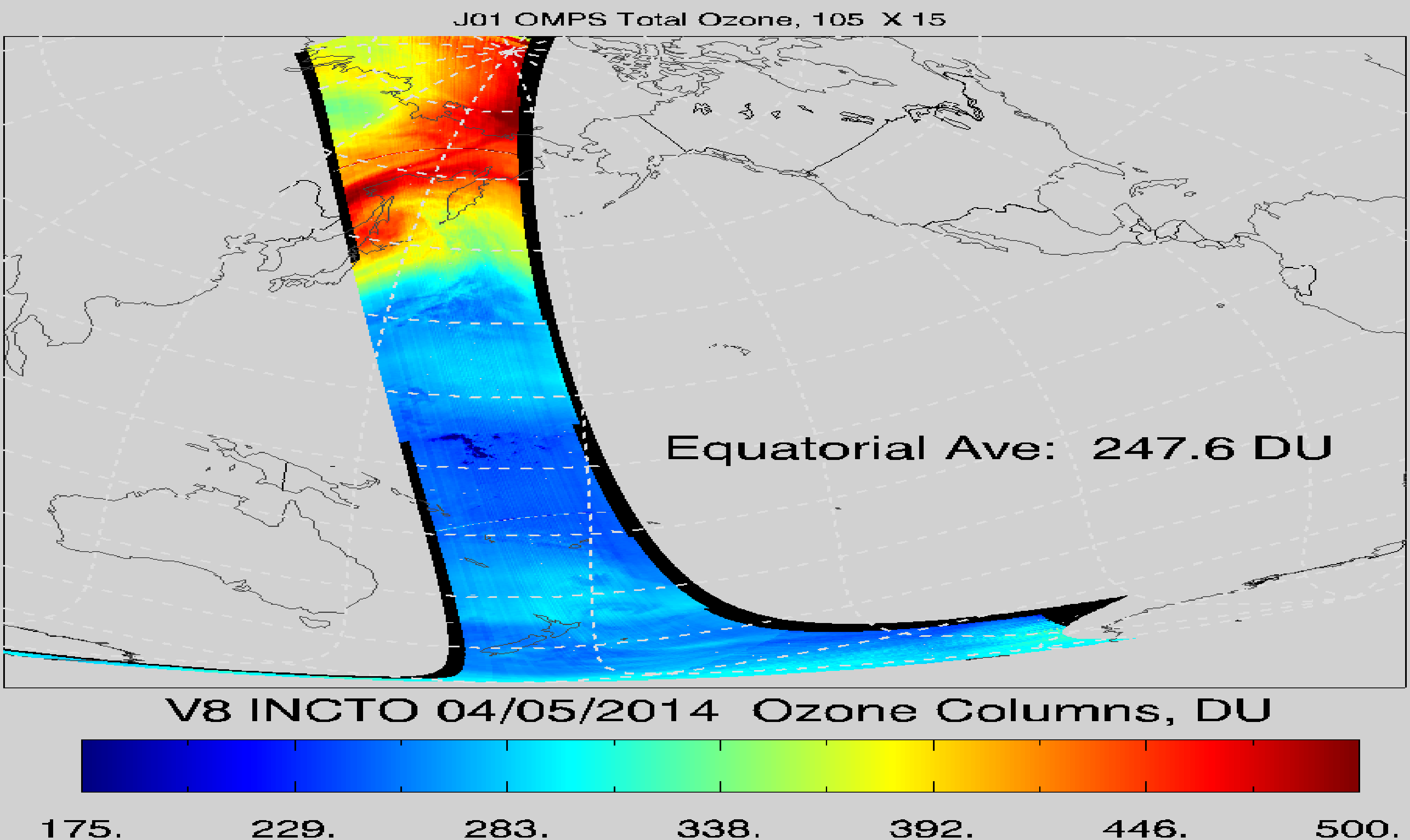
MedRes TC Ozone Retrieval

- The Following page shows 103x5 ozone
- Image is upsampled version of a 35x5 measurement.
- There are striping problems.
- This is a good EDR test dataset because we understand the 35x5 SDR inputs. The upsampled 103x5 have the same characteristics.


S-NPP OMPS Total Ozone
Equ
251.7DU
V8 NDE 2016/04/02 Ozone Columns, DU
175.
229.
283.
338.
392.
446.
500.

OMPS 43A Proxy Data

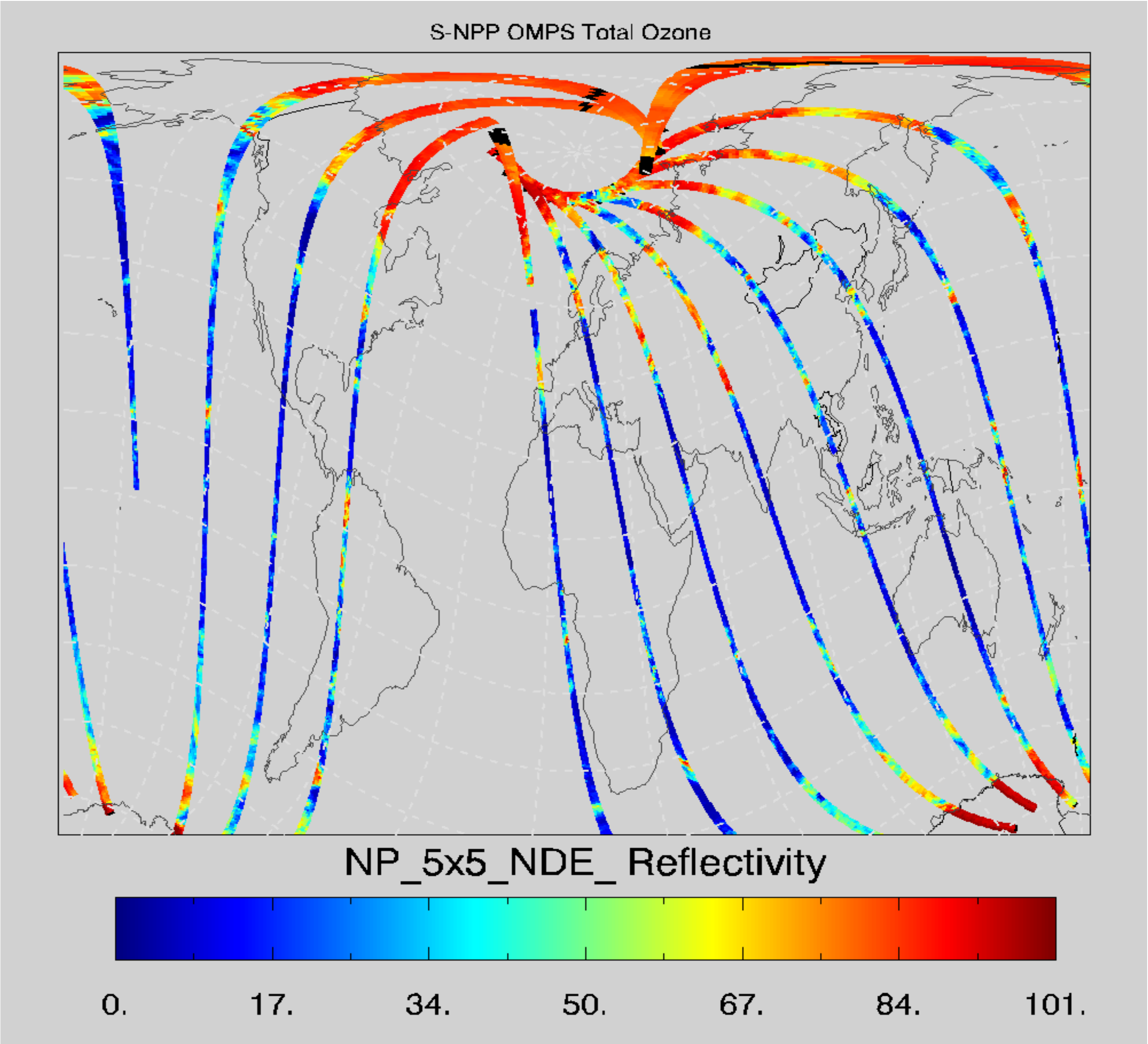
Our Current best SDR test dataset for EDR testing is based on 2016/04/02 35x5nm 5x5np.



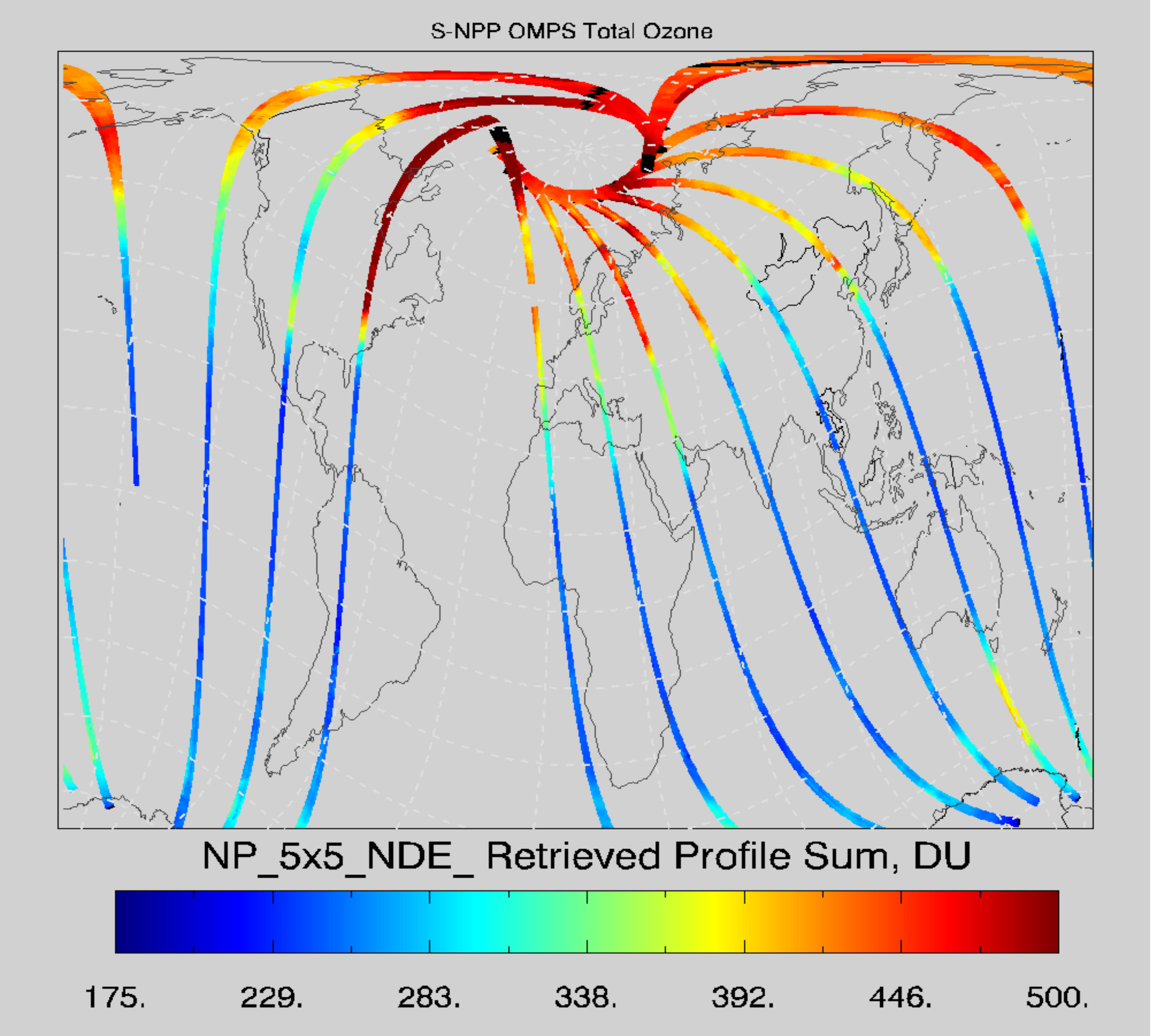
Currently Delivered NDE V8PRO

- Based on the V8SBUV version 8.
- Sized to 5x5 output, netcdf-4.
- 2000 profiles per orbit.
- RT lookup tables include VZA index. Total ozone computation uses VZA,RAZA.
- Profile single scatter RT code uses modified path length: assume we are looking Nadir but a longer path length: $1/\cos(VZA) + 1/\cos(SZA)$.
- Reasonable approximation, max VZA is ±7.5°
- Our implementation relaxes some SBUV/2 specific constraints in the V8SBUV code: grating drive, 12 monochromator & 12 photometer paired measurements, nadir only. There was a major rewrite done to the SBUV/2 code.
- We can account for separate viewing geometries in the NM, NP SDR inputs. This was developed using OMI inputs: UV1,UV2 differences.

Reflectivity V8pro 2016/04/02



Retrieved Column 2016/04/02
Sum of Retrieved 21 layer profile



Conclusion

- The V8 total ozone 103 X 15 algorithm had been put into the NDE system.
- A 5x5 capable ozone profile retrieval code is under review for inclusion in the NDE processing system for JPSS-1.
- The NP 5x5 total ozone parameters are as expected(2% bias).
- We haven't gotten the results from the V8PRO ozone profiles that we would like(wavelength problem).
- NOAA STAR is on track for 5x5 NP EDR ozone profiles based on the legacy V8SBUV retrieval for J01 OMPS.
- NOAA STAR made significant enhancements to the SBUV/2 Version 8 ozone profile algorithm based on OMI and OMPS experiences.

Version 8 Ozone EDR Validation

Lawrence Flynn with input from NOAA and NASA OMPS Teams

August 9, 2016

Context

- The algorithms to generate the Total Column Ozone and Nadir Ozone Profile EDR estimates from the OMPS instruments are in the process of a migration from the IDPS system to the NDE system. As part of this transition, we are switching from the Multiple Triplet Algorithm (MTTOz) to the Enterprise Version 8 Total Ozone Algorithm (V8TOz).
- We have been making the OMPS V8TOz and OMPS V8Pro products offline for the last four years and tracking their performance as the OMPS Nadir Mapper and Nadir Profiler SDR processing has introduced improvements and new calibration characterizations. See www.star.nesdis.noaa.gov/smcd/spb/OMPSDemo/proOMPSbeta.TOZ_V8.php
- We work with the NASA OMPS Science Team, the OMPS SDR Team, and ozone researchers at NCEP and ESRL.
- The Total Ozone and Nadir Ozone Profile EDRs are part of the suite of data products from the JPSS system. These particular products are used to monitor the ozone layer and as input to NWMs. In particular, the UV Index forecast product requires good quality maps of total column ozone.
- JPSS has been providing funding for all aspects of this work including product validation and code transition. Funding was provided by NCDC for the initial implementation of the V8TOz and V8Pro for OMPS at NOAA.

Challenges

- The SDR advances and improvements have presented a moving target for validation. We do not have sufficient resources for full SDR reprocessing after each change, so new comparisons must be generated over time following major SDR changes.
- The V8TOz was delivered last year for implementation at IDPS but the program redirected the implementation to NDE. We completed the S-NPP V8TOz ARR and DAP last month and are nearing completion of a refinement for J-01 processing to address degradation in the retrievals due to elevated atmospheric SO_2 levels.
- The V8Pro has been delivered and implemented at IDPS but we have been instructed to move it to NDE as well. The code is awaiting a security review and will be delivered after we hold an Algorithm Readiness Review.
- Estimates of precision require characterization of uncertainties in the retrievals due to profile shapes and ozone below clouds. The truth conditions are difficult to verify for individual measurements due to matchup and validation data set uncertainties. We have used various difference techniques to use the data itself to estimate these uncertainties.

Actions

- The V8TOz and V8Pro algorithms are well-designed with excellent suites of measurement residuals and response efficiencies to relate uncertainties in products to uncertainties in measurements or intermediate products.
- The content has been refined and exercised over the last 40 years by a sequence of NASA Science Teams. They have empirically-tuned adjustments for UV absorbing aerosols, sun glint and profile shape variations and improved RT model information on inelastic scattering.
- The algorithms use extensive sets of satellite and ground-based measurements to provide standard and a priori ozone and temperature profiles and cloud top pressure for use with UV measurements.

Results

- The V8TOz DAP has been delivered to NDE. The V8Pro is awaiting code and algorithm readiness reviews. The implementation at NDE will be this fall after the end of the Block 2.0 ORR freeze. The V8TOz and V8Pro operate on single granules of OMPS NM and NP SDR and GEO.
- The V8TOz is used to generate the NOAA Operational GOME-2 total ozone products and the NASA EOS Aura OMI total ozone product.
- The V8Pro is used to generate the NOAA Operational SBUV/2 ozone profile products.
- Papers in JGR on OMPS SDR and EDRs
  - Seftor et al. [2014] doi:10.1002/2013JD020472
  - Wu et al. [2014] doi:10.1002/2013JD020484
  - Flynn et al. [2014] doi:10.1002/2013JD020467
  - Jaross et al. [2014] doi:10.1002/2013JD020482
- Other References
  - Bhartia et al., (2013) SBUV total ozone and profile algorithm; doi:10.5194/amt-6-2533-2013.
  - Wellemeyer, C. G., et al., (1997), A correction for total ozone mapping spectrometer profile shape errors at high latitude, J. Geophys. Res., 102(D7), 9029–9038, doi:10.1029/96JD03965.

Future Plans

- We will evaluate the V8TOz and V8Pro products once they are at NDE and make sure that they show the same performance as our offline products. We will use them to populate the ICVS monitoring pages instead of the offline products currently monitored there.
- A presentation will be given to the SPSRB when the products are ready for operational distribution from NDE.
- We are providing our ICVS product monitoring tools to OSPO. They will use some of these and also replicate their existing SBUV/2 and GOME-2 monitoring.
- The exclusion for elevated SO_2 amounts (> 6 DU) goes away for J-01. We are preparing to hold a delta Algorithm Readiness Review and deliver the $LFSO_2$ algorithm to NDE. This algorithm uses the V8TOz measurement residuals to make an estimate of the atmospheric SO_2, and then uses this SO_2 estimate to correct the total column ozone estimate.
- The codes delivered to NDE are ready to process the medium resolution OMPS SDRs planned for the JPSS-01 operations.

OMPS Total Ozone Product Requirements

- JPSS Level 1 Requirements Document (L1RD) Supplement for the OMPS Ozone Total Column Environmental Data Records (EDRs)

Table 5.2.11 - Ozone Total Column (O

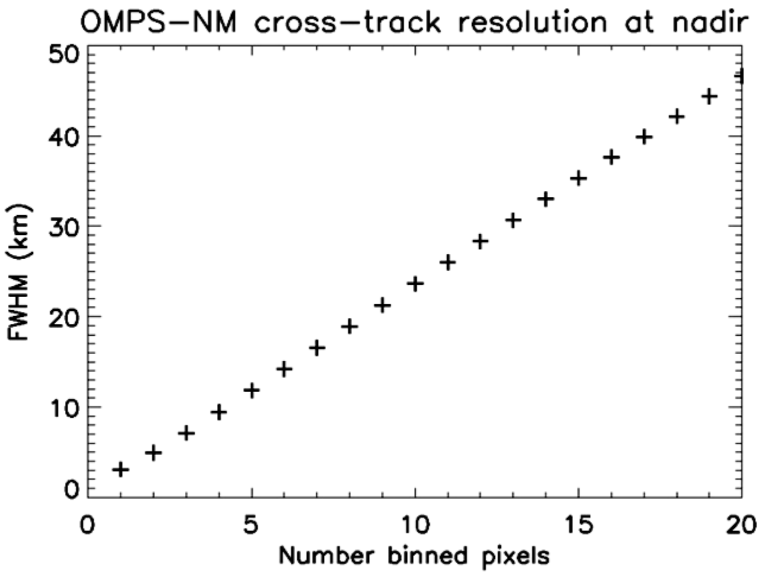
EDR Attribute	Threshold
Ozone TC Applicable Conditions: 1. Threshold requirements only apply under daytime conditions with Solar Zenith Angles (SZA) up to 80 degrees. 2. The EDR shall be delivered for all SZA	
a. Horizontal Cell Size	50 x 50 km² @ nadir
b. Vertical Cell Size	0 - 60 km
c. Mapping Uncertainty, 1 Sigma	5 km at Nadir
d. Measurement Range	50 - 650 milli-atm-cm
e. Measurement Precision	
1. X < 0.25 atm-cm	6.0 milli-atm-cm
2. 0.25 < X < 0.45 atm-cm	7.7 milli-atm-cm ~2%
3. X > 0.45 atm-cm	2.8 milli-atm-cm + 1.1%
f. Measurement Accuracy	
1. X < 0.25 atm-cm	9.5 milli-atm-cm
2. 0.25 < X < 0.45 atm-cm	13.0 milli-atm-cm ~3%
3. X > 0.45 atm-cm	16.0 milli-atm-cm
g. Refresh	At least 90% coverage of the globe every 24 hours (monthly average)

Verification of Performance:

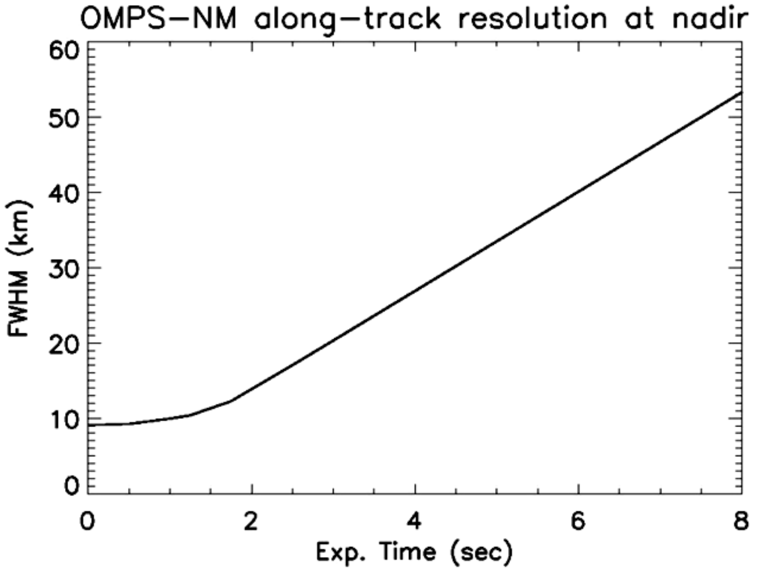
a. 20-Pixel Aggregation and 7-S along track integration.
b. 318 nm channel BUV comes from the surface to top of atmosphere. Standard profiles in tables account for full range.
c. Confirmed by coastlines and comparison to 750x750 m^2 VIIRS.
d. Confirmed by standard profiles and four years of processing and ground-based matchup scatter.
e. Precision estimates from Nearest Neighbor analysis. Use of 1512 Latitude/Month/TOz profiles.
f. Accuracy is adjusted by soft calibration and checked by zonal mean and overpass statistics.
g. 105° cross-track swath provides full daily coverage.

(a) Horizontal Cell Size
Flight Parameters and Lab MTF

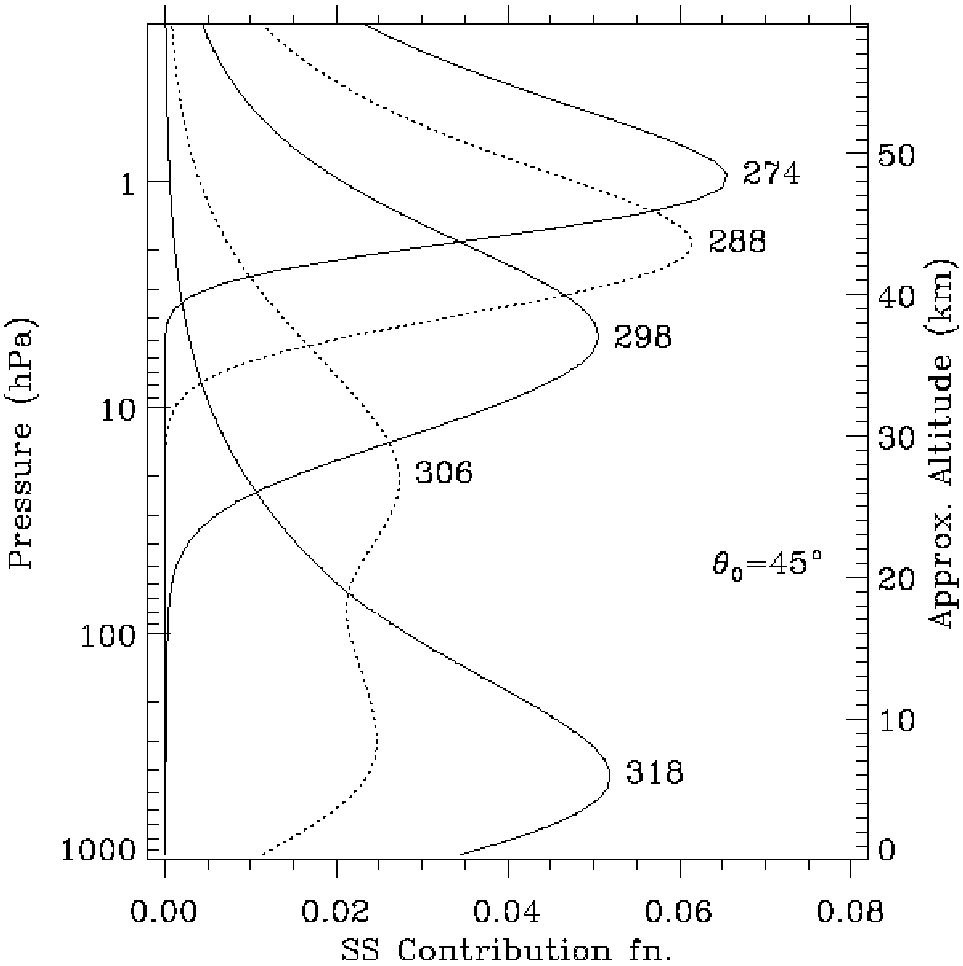
- Across-Track
  - 20 pixels at 2.5 km/pixel
  - = 50 km

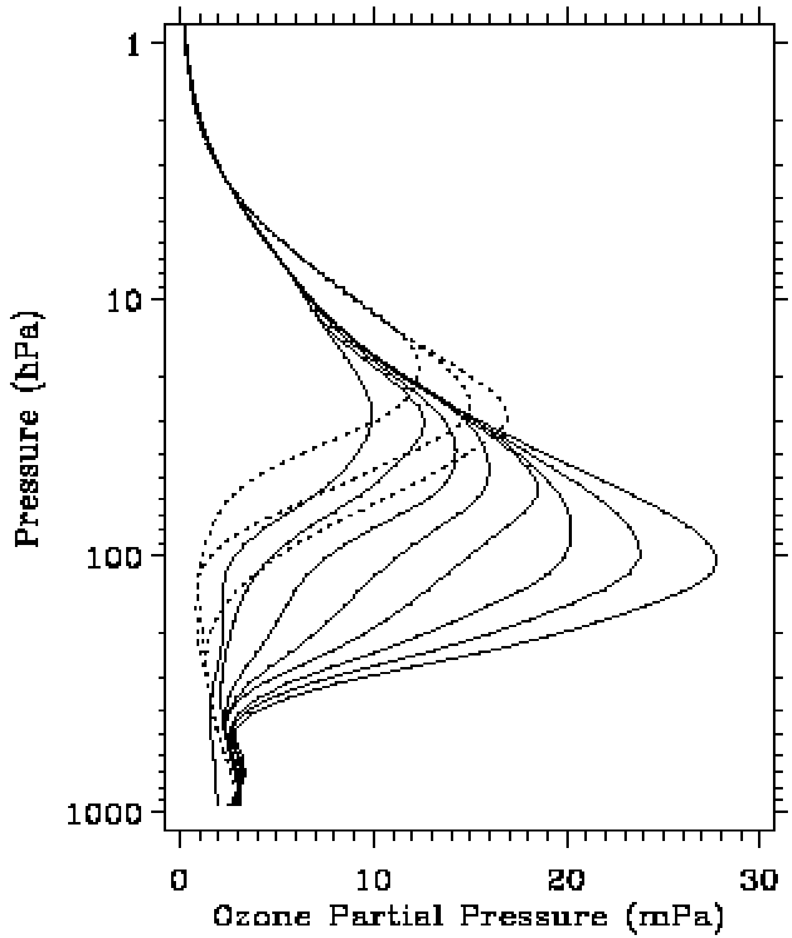


- Along-Track
  - 7.5 S integration at 6.56 km/S
  - = 49.2 km motion

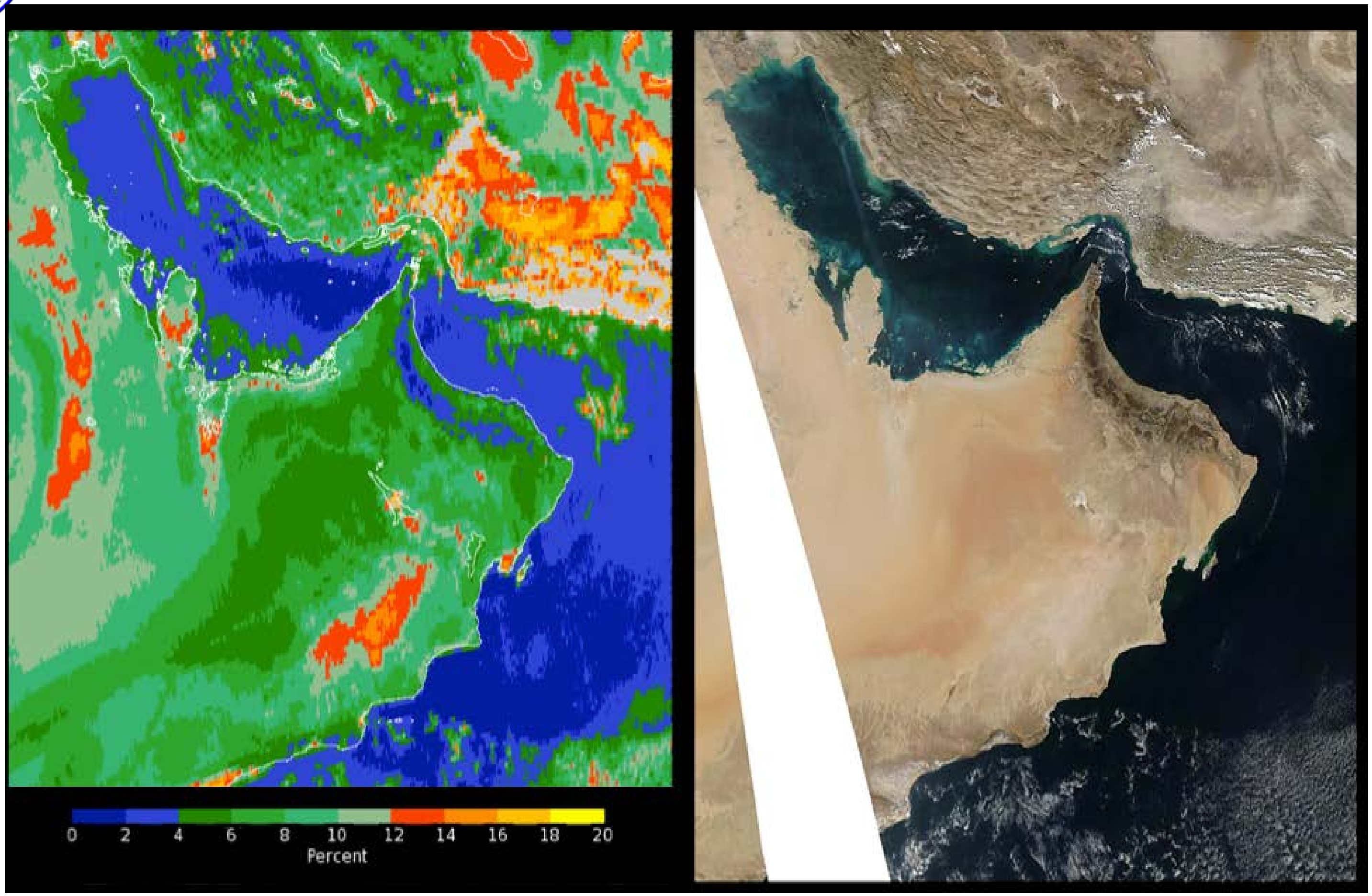


(b) 318 nm Contribution Function and Standard Ozone Profiles

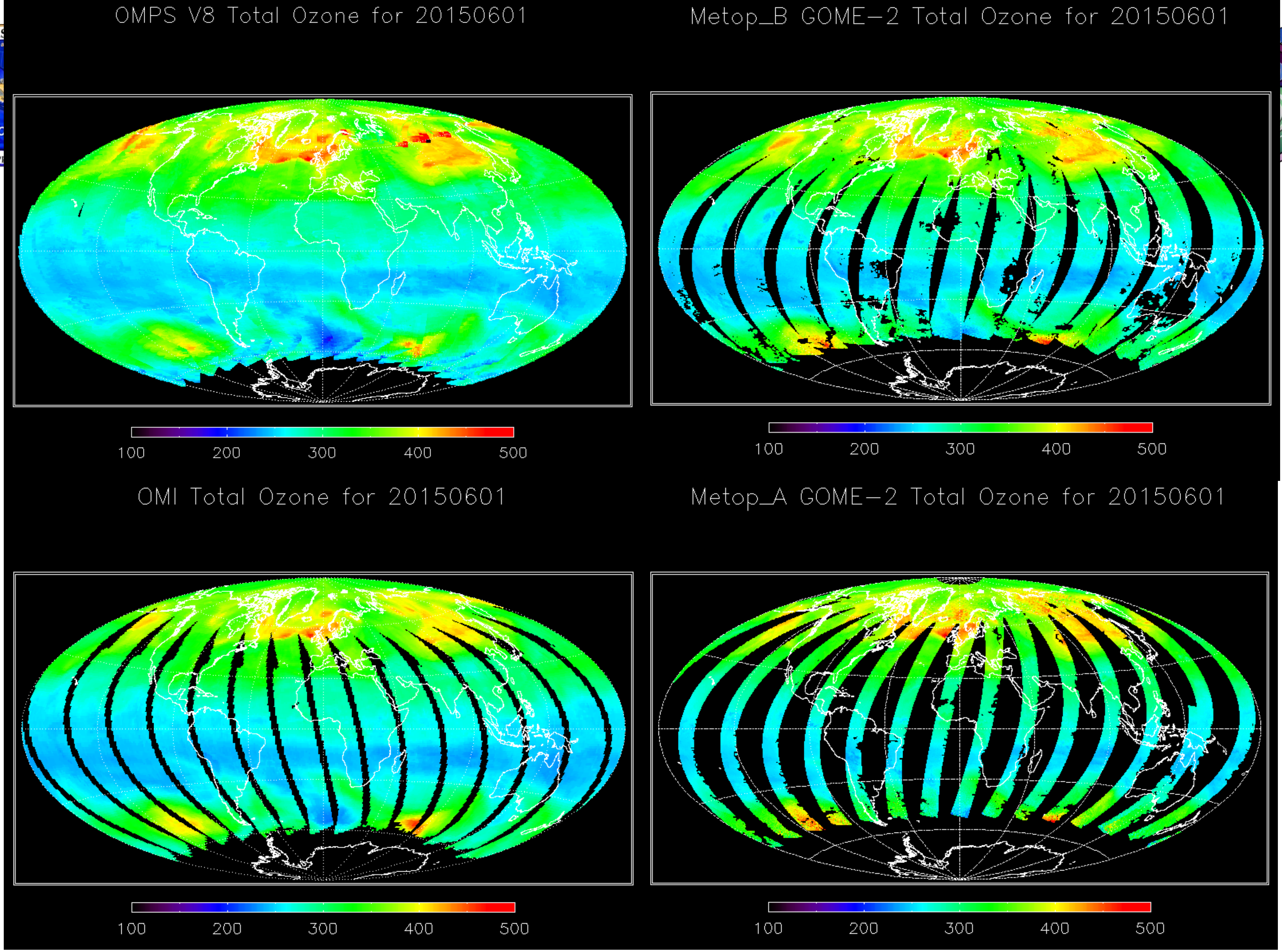




(c) Geolocation Uncertainty

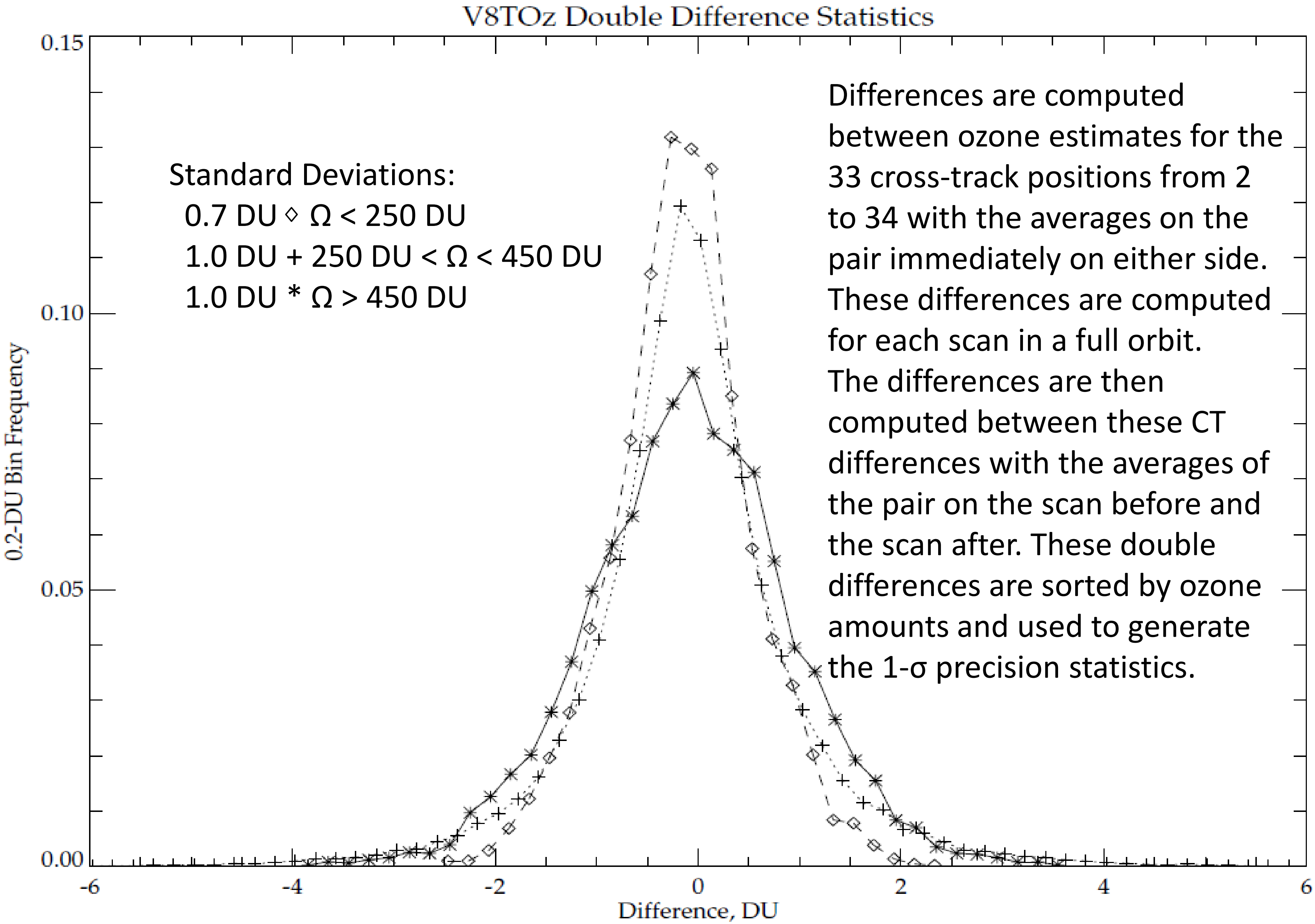


High-Spatial-Resolution for Geolocation. The image on the left shows a false color map of the OMPS effective reflectivity (from a single Ultraviolet channel at 380 nm) over the Arabian Peninsula region for January 30, 2012 when the instrument was making a set of high-spatial-resolution measurements with 5×10 km^2 FOVs at nadir. The color scale intervals range from 0 to 2% in dark blue to 18 to 20% in yellow. The image on the right is an Aqua Moderate Resolution Imaging Spectroradiometer (MODIS) Red-Green-Blue image for the same day. (Provided by C. Seftor, SSAI.)



(g) Refresh, (d) Range and (f) Accuracy from Daily maps of total column ozone.
The false color maps show the total column ozone in Dobson Units for June 1, 2015 for the V8TOz algorithm applied to S-NPP OMPS (Top Left), Metop-B GOME-2 (Top Right), EOS Aura (Bottom Left) and Metop-A GOME-2 (Bottom Right).

(e) Measurement Precision



Differences are computed between ozone estimates for the 33 cross-track positions from 2 to 34 with the averages on the pair immediately on either side. These differences are computed for each scan in a full orbit. The differences are then computed between these CT differences with the averages of the pair on the scan before and the scan after. These double differences are sorted by ozone amounts and used to generate the 1-σ precision statistics.

These provide conservative estimates of instrument noise contributions to precision.

Using V8TOz dN/dR and dN/dO3 to determine soft calibration adjustments

The V8TOz output contains a variety of useful parameters in addition to the total column ozone estimates. In particular, the retrieval sensitivities, dy/dx can be used to give soft calibration estimates of the N-value changes to remove reflectivity and ozone bias. If you want to increase the effective reflectivity, R, and the total column ozone, Ω, by ΔR and ΔΩ then you should increase the N-values by

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

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

where dNw/dR is the rate of change of the N-value, Nw, for wavelength, w, with respect to changes in the effective reflectivity, R, and dNw/dΩ is the rate of change of the N-value, Nw, for wavelength, w, with respect to changes in the total column ozone, Ω.

Conversely, if you increase the N values by C1=ΔN318 and C2=ΔN331, then the retrieved R and Ω increase by

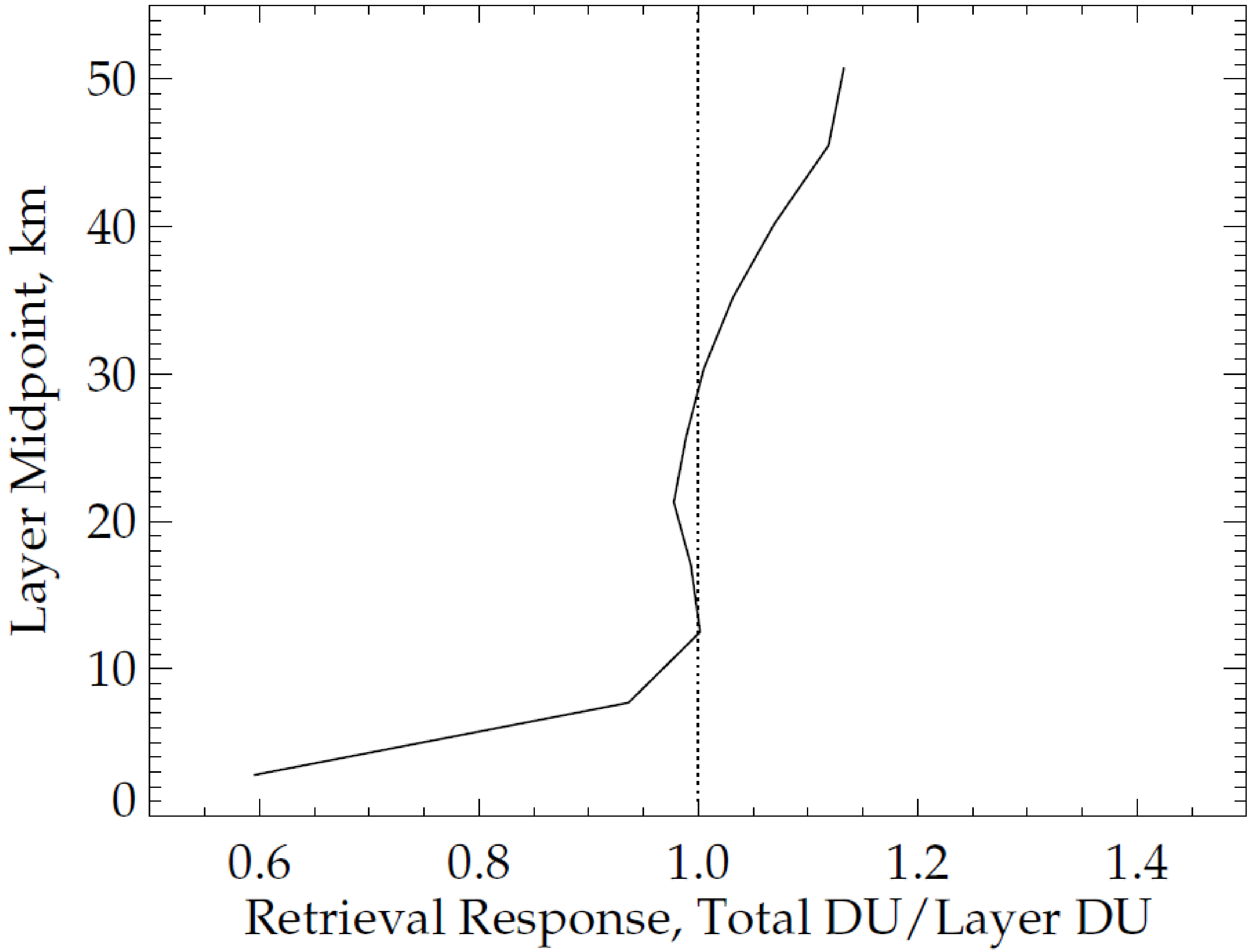
$$\Delta R = [C1 * dN331/d\Omega - C2 * dN318/d\Omega] / D$$

$$\Delta\Omega = -[C1 * dN331/dR, - C2 * dN318/dR] / D$$

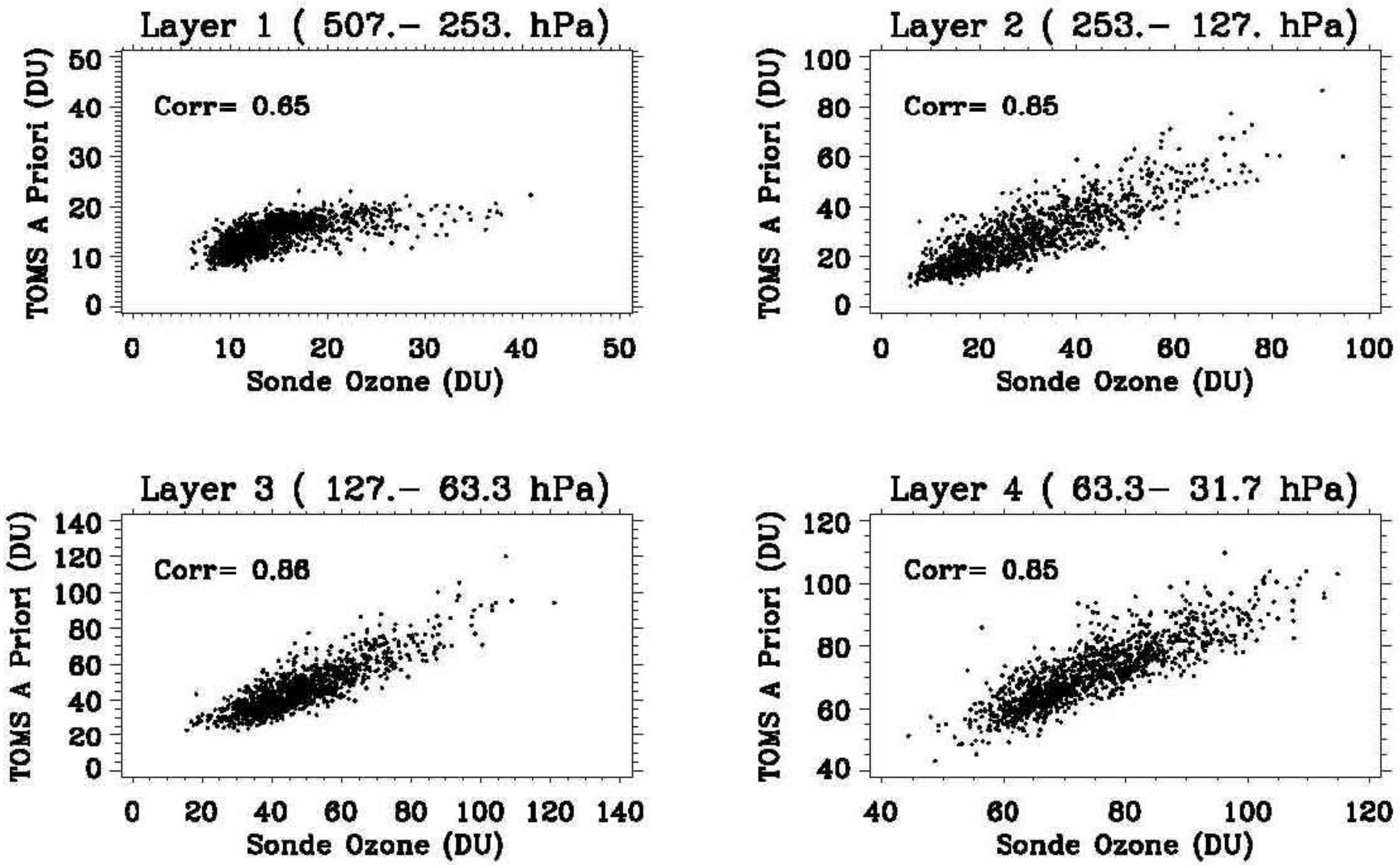
$$D = [dN318/dR * dN331/d\Omega - dN331/dR * dN318/d\Omega]$$

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

Total Ozone Retrieval Efficiency



Errors from Tropospheric Variations



Comparisons between Hohenpeissenberg ozonesonde layer amounts and the 96 standard profiles in the 3-dimensional set used at its latitude.

Comparison of *A Priori* profiles with ozonesonde and SAGE

Layer (No.)	Layer midpoint (~km)	Hohenpeissenberg		SAGE @50°N	
		Variance reduction (%)	Residual std dev (DU)	Variance reduction (%)	Residual std dev (DU)
0	2.8	41	2.9	-	-
1	7.7	42	3.8	-	-
2	12.5	73	7.6	75	9.7
3	17.0	74	7.4	83	8.9
4	21.3	73	6.0	77	6.4
5	25.8	24	5.5	29	5.3
6	30.4	42	3.5	35	4.3
7	35.2	-	-	39	1.9
8	40.2	-	-	28	1.0
9	45.5	-	-	40	0.5

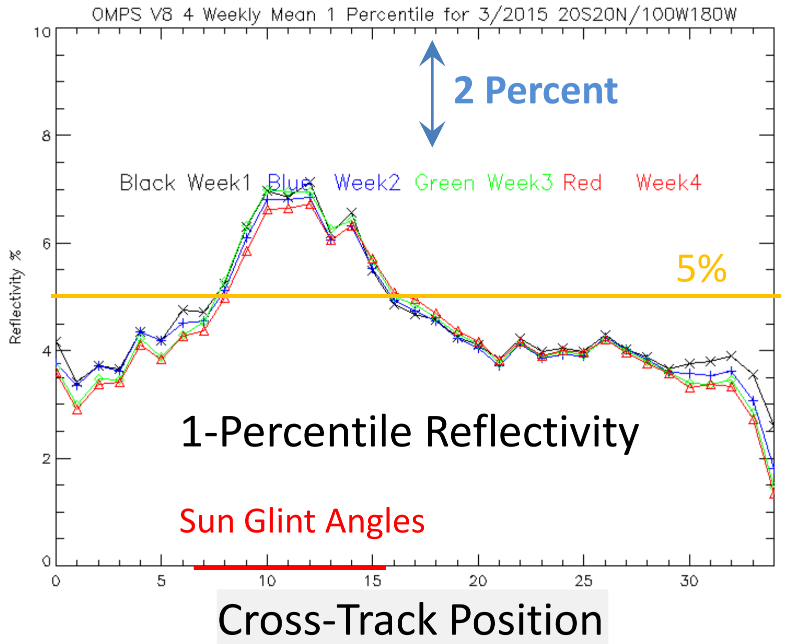
Offline Processing at STAR

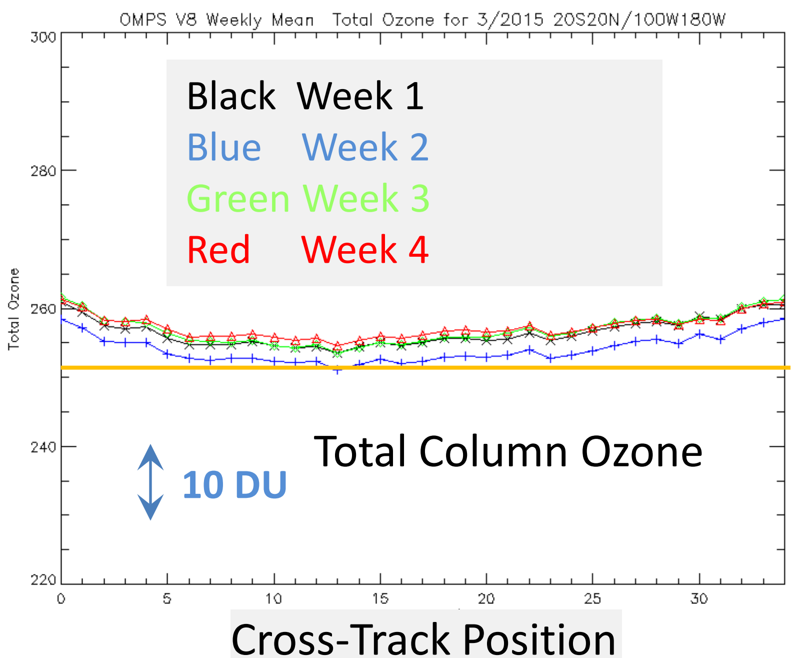
- The V8TOz has been used to process the first four years of OMPS NM SDRs to produce full daily global maps on the LINUX system at STAR.
- The products from this processing have been monitored and validated with a suite of analysis and comparison figures available at

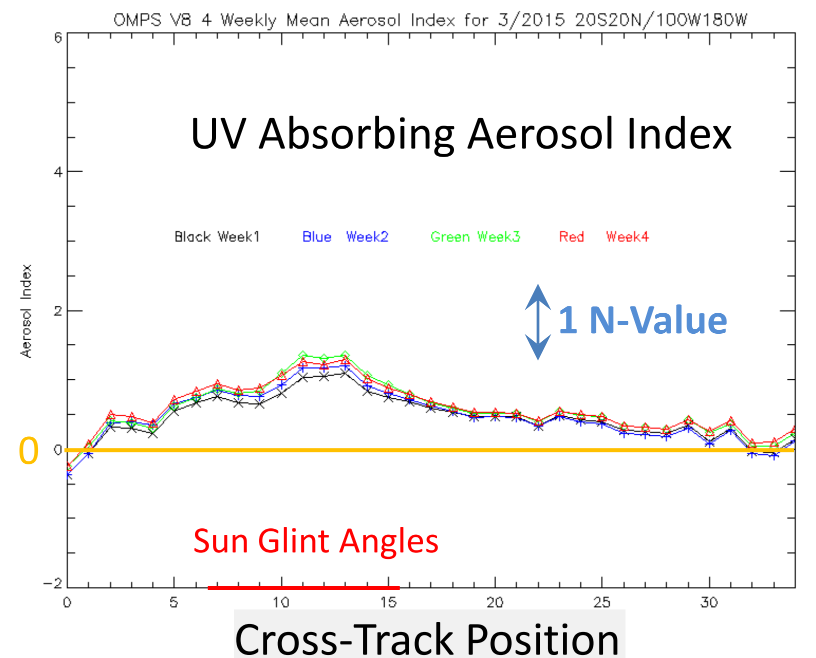
  www.star.nesdis.noaa.gov/smcd/spb/OMPSDemo/proOMPSbeta.TOZ_V8.php
- Select figures and results are presented in the following slides

Internal Consistency

Weekly Total Ozone, 1-percentile Effective Reflectivity and Aerosol Index values, for March 2015 for a latitude / longitude box in the Equatorial Pacific versus cross-track pixel. Internal Consistency and Vicarious Calibration / Validation Generation of soft calibration coefficients (CFE) – Can use Minimum Reflectivity = 4.5%, no aerosols, no SO2, and Ozone set to EOS OMI mean.



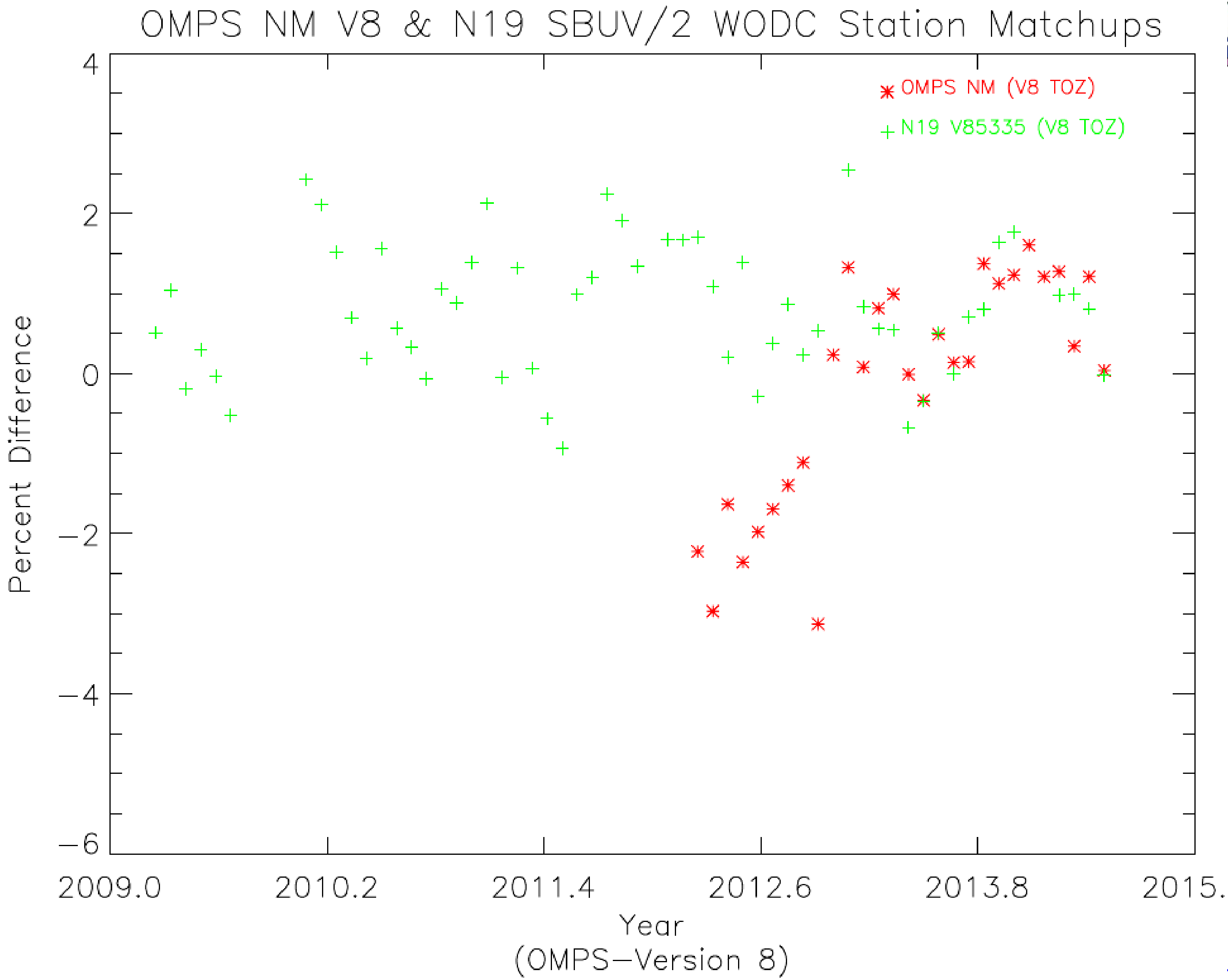




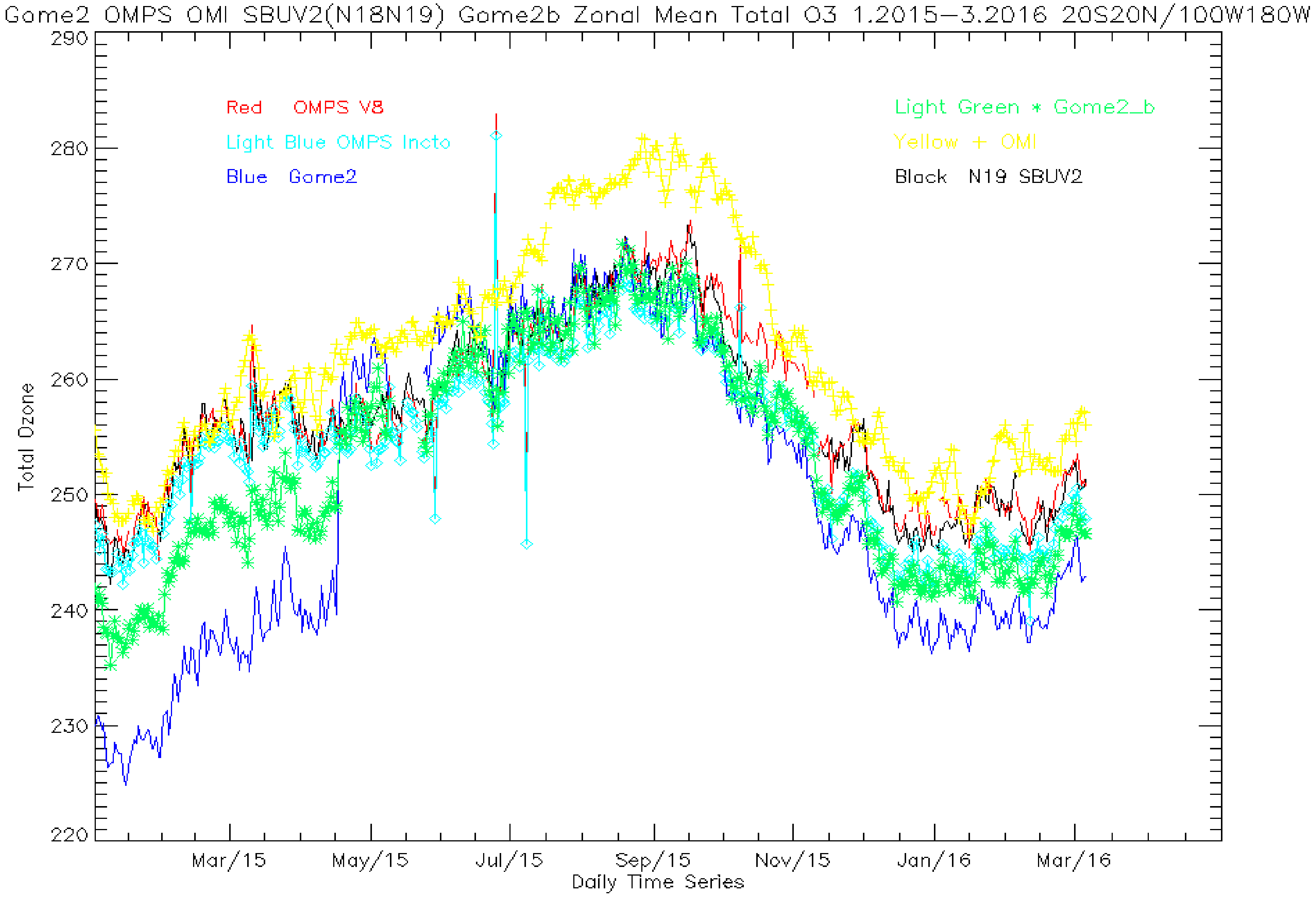
(f) Validation Data Sets

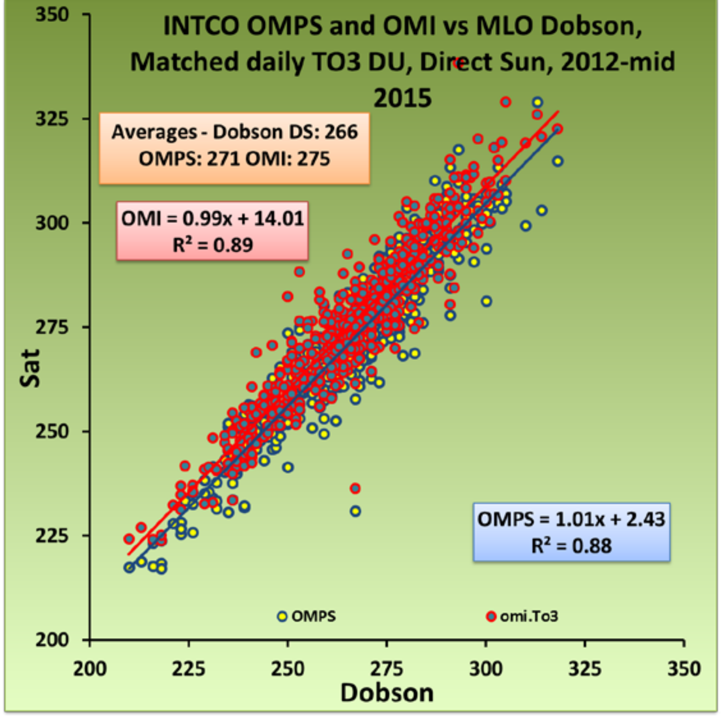
- Satellite Ozone Products
  - OMI V8TOz
  - GOME-2 V8TOz
  - MLS Ozone Profiles
- Ground-based
  - Dobson Stations total ozone
  - Umkehr Stations ozone profiles
  - Balloon sondes

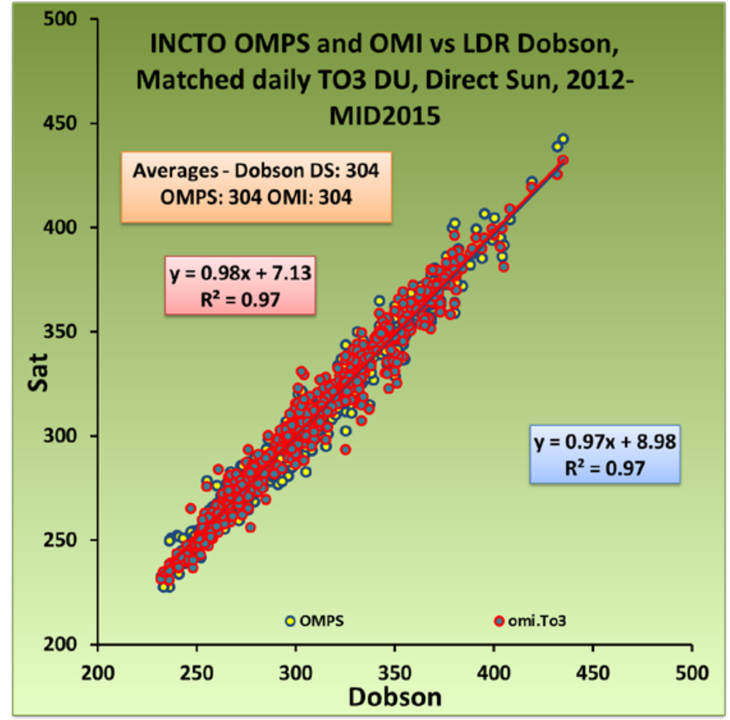
(f) Comparison to 23 Dobson Stations

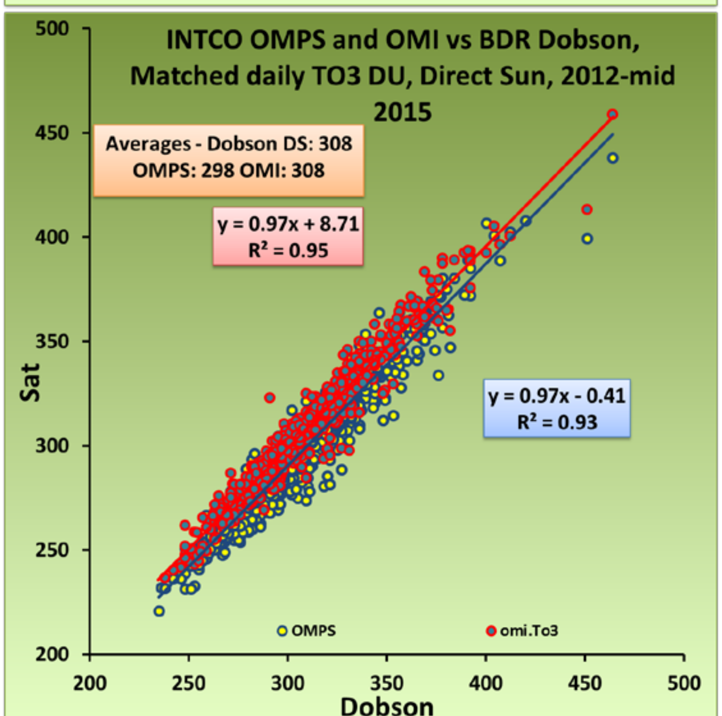


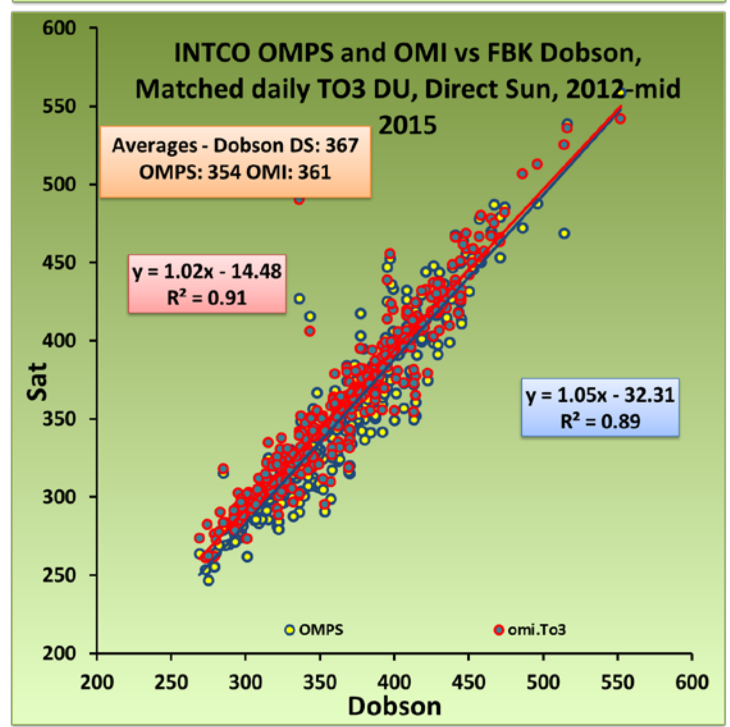
(f) Comparisons to other Satellites




INTCO OMPS and OMI vs MLO Dobson, Matched daily TO3 DU, Direct Sun, 2012-mid 2015
Averages - Dobson DS: 266
OMPS: 271 OMI: 275
OMI = 0.99x + 14.01
R² = 0.89
OMPS = 1.01x + 2.43
R² = 0.88
OMPS
omi.To3
Sat
Dobson
200
225
250
275
300
325
350


INCTO OMPS and OMI vs LDR Dobson, Matched daily TO3 DU, Direct Sun, 2012-MID2015
Averages - Dobson DS: 304
OMPS: 304 OMI: 304
y = 0.98x + 7.13
R² = 0.97
y = 0.97x + 8.98
R² = 0.97
OMPS
omi.To3
Sat
Dobson
200
250
300
350
400
450
500


INTCO OMPS and OMI vs BDR Dobson, Matched daily TO3 DU, Direct Sun, 2012-mid 2015
Averages - Dobson DS: 308
OMPS: 298 OMI: 308
y = 0.97x + 8.71
R² = 0.95
y = 0.97x - 0.41
R² = 0.93
OMPS
omi.To3
Sat
Dobson
200
250
300
350
400
450
500


INTCO OMPS and OMI vs FBK Dobson, Matched daily TO3 DU, Direct Sun, 2012-mid 2015
Averages - Dobson DS: 367
OMPS: 354 OMI: 361
y = 1.02x - 14.48
R² = 0.91
y = 1.05x - 32.31
R² = 0.89
OMPS
omi.To3
Sat
Dobson
200
250
300
350
400
450
500
550
600

V8 Total Ozone Summary

- The heritage, enterprise Version 8 Total Ozone algorithm has been delivered for implementation at NDE as part of the redirected EDR processing for JPSS.
- The EDRs from the algorithm meet the required performance levels for the Total Column Ozone when applied to the validated OMPS NM SDRs.

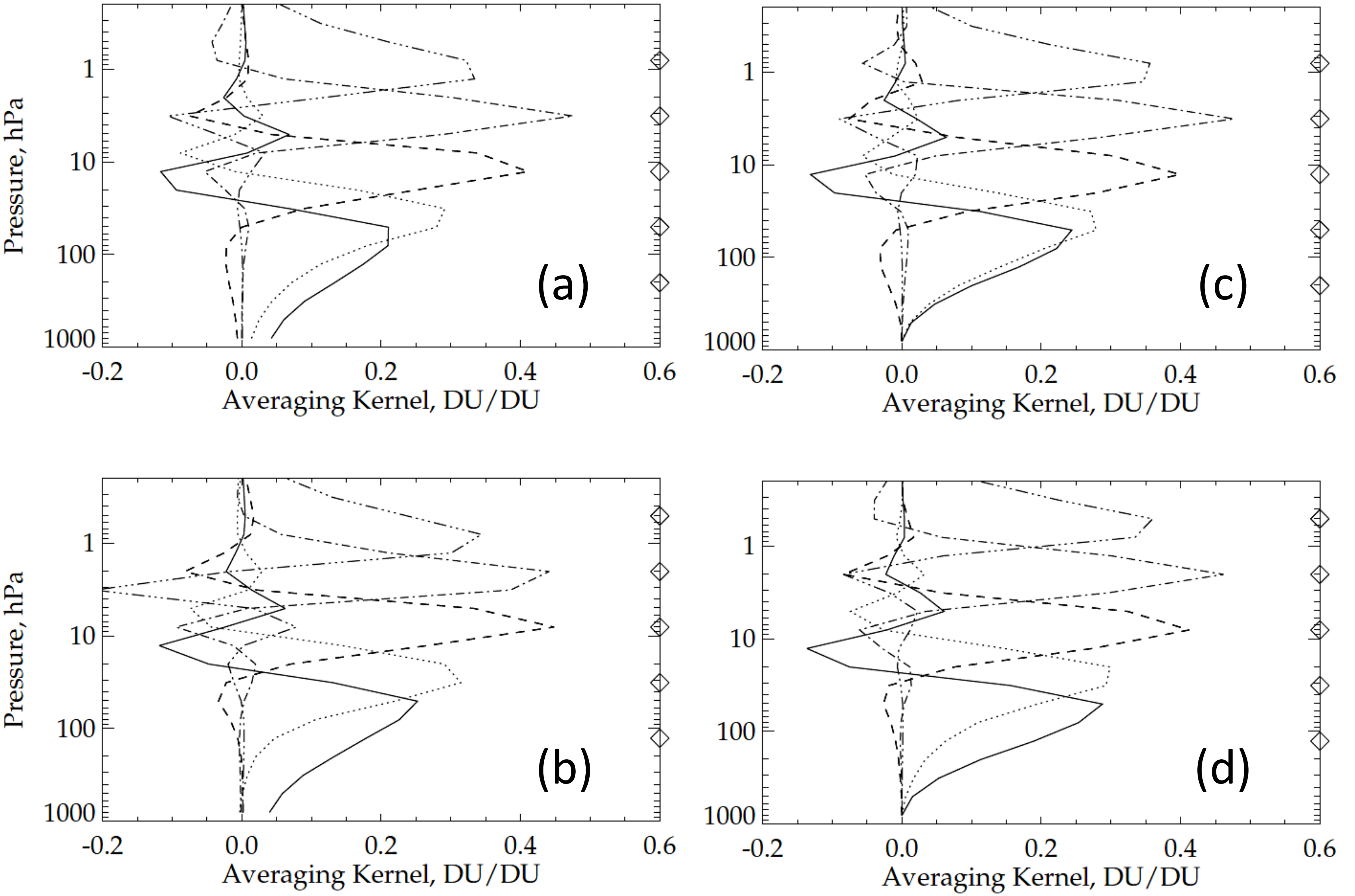
OMPS Version 8 Ozone Profile EDR Requirements

Ozone Nadir Profile (OMPS-NP) (3)	
Attribute	**Threshold**
a. Horizontal Cell Size	250 x 250 km^2 (1)
b. Vertical Cell Size	3 km reporting
1. Below 30 hPa (~ < 25 km)	10 -20 km
2. 30 -1 hPa (~ 25 -50 km)	7 -10 km
3. Above 1 hPa (~ > 50 km)	10 -20 km
c. Mapping Uncertainty, 1 Sigma	< 25 km
d. Measurement Range 0-60 km	0.1-15.0 ppmv
e. Measurement Precision (2)	
1. Below 30 hPa (~ < 25 km)	Greater of 20 % or 0.1 ppmv
2. 30 -1 hPa (~ 25 -50 km)	5% -10%
3. Above 1 hPa (~ > 50 km)	Greater of 10% or 0.1 ppmv
f. Measurement Accuracy (2)	
1. Below 30 hPa (~ < 25 km)	Greater of 10 % or 0.1 ppmv
2. 30 -1 hPa (~ 25 -50 km)	5% -10%
3. Above 1 hPa (~ > 50 km)	Greater of 10 % or 0.1 ppmv
g. Refresh	At least 60% coverage of the globe every 7 days (monthly average) (2,3)

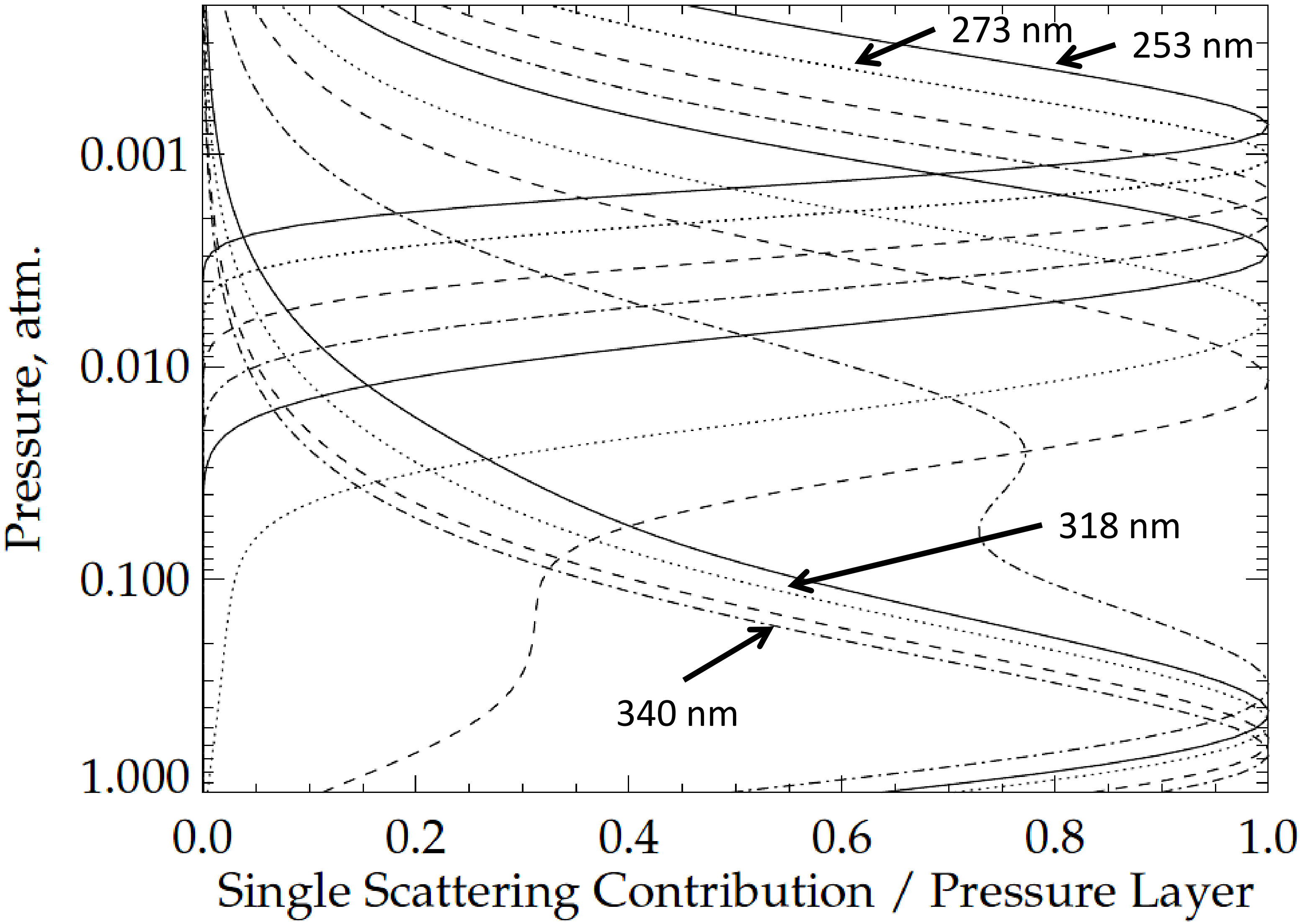
Notes: 1. SDRs will go to 50x50 km^2 for J-01. 2. The OMPS Nadir Profiler performance is expected to degrade in the area of the South Atlantic Anomaly (SAA) due to the impact of periodic charged particle effects in this region. 3. All OMPS measurements require sunlight, so there is no coverage in polar night areas.

Verification of Performance:

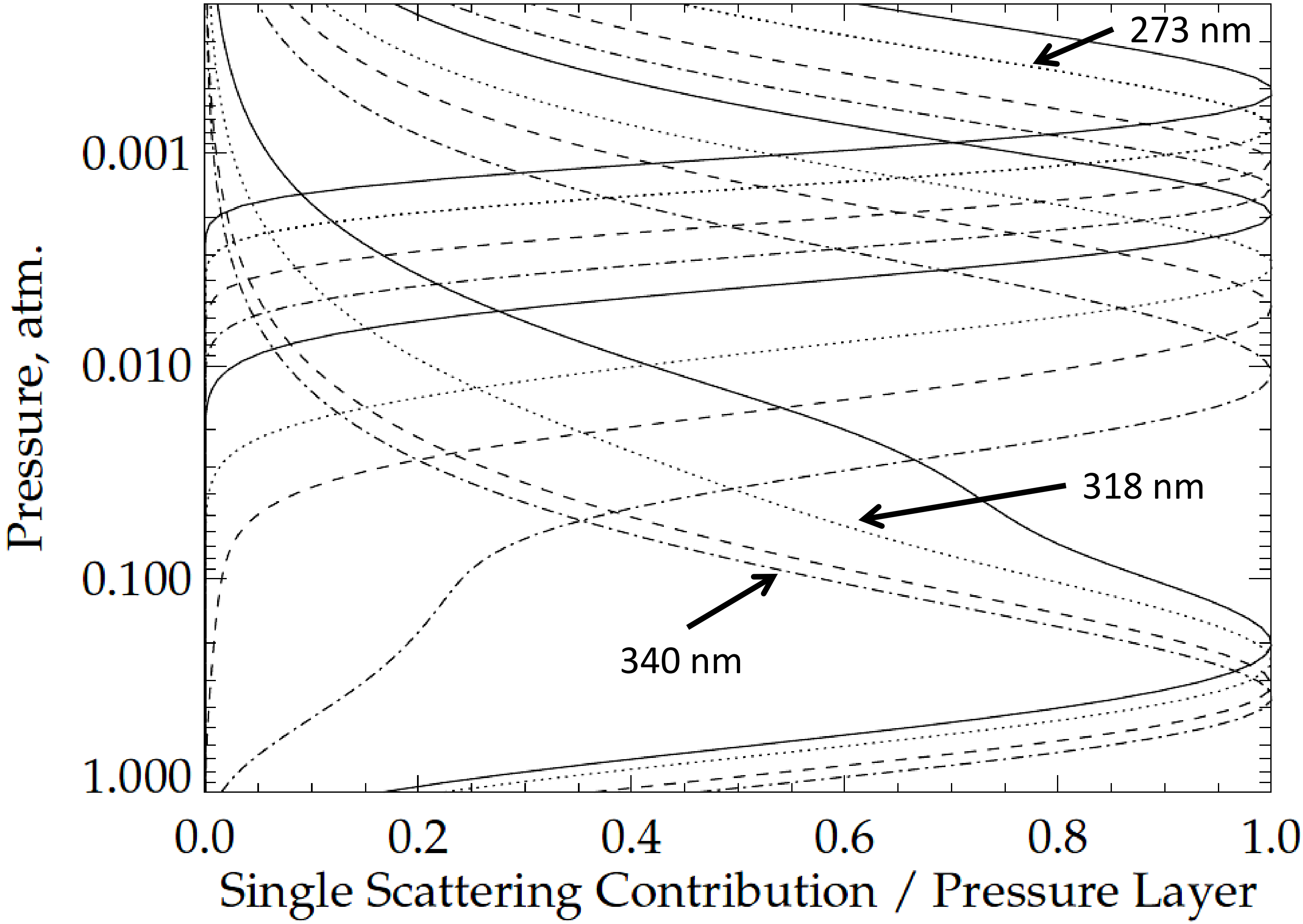
a. 93-Pixel cross-track aggregation and 37.5-S along track integration.
b. Version 8 Algorithms Averaging Kernels
c. Confirmed by to Nadir Mapper, Pixel size, and co-alignment.
d. Confirmed by four years of processing and ground-based matchup scatter.
e. Precision estimates from SNR and Version 8 measurement contribution functions, and along-track differences
f. Accuracy is adjusted by soft calibration and checked by zonal mean statistics, chasing orbits, and Version 8 a priori profiles
g. Suborbital track and precession of orbits.



b. OMPS V8Pro Averaging Kernels for selected layers for two retrievals on December 20, 2015: (a) and (b) are for a retrieval at 49°S, 143°E, with 45° SZA, *R*=0.22 and 294 DU total column ozone; (c) and (d) are for a retrieval at 48°N, 170°E, with 75° SZA, *R*=0.76 and 325 DU total column ozone. The Diamond symbols show the altitudes of the perturbed layers.

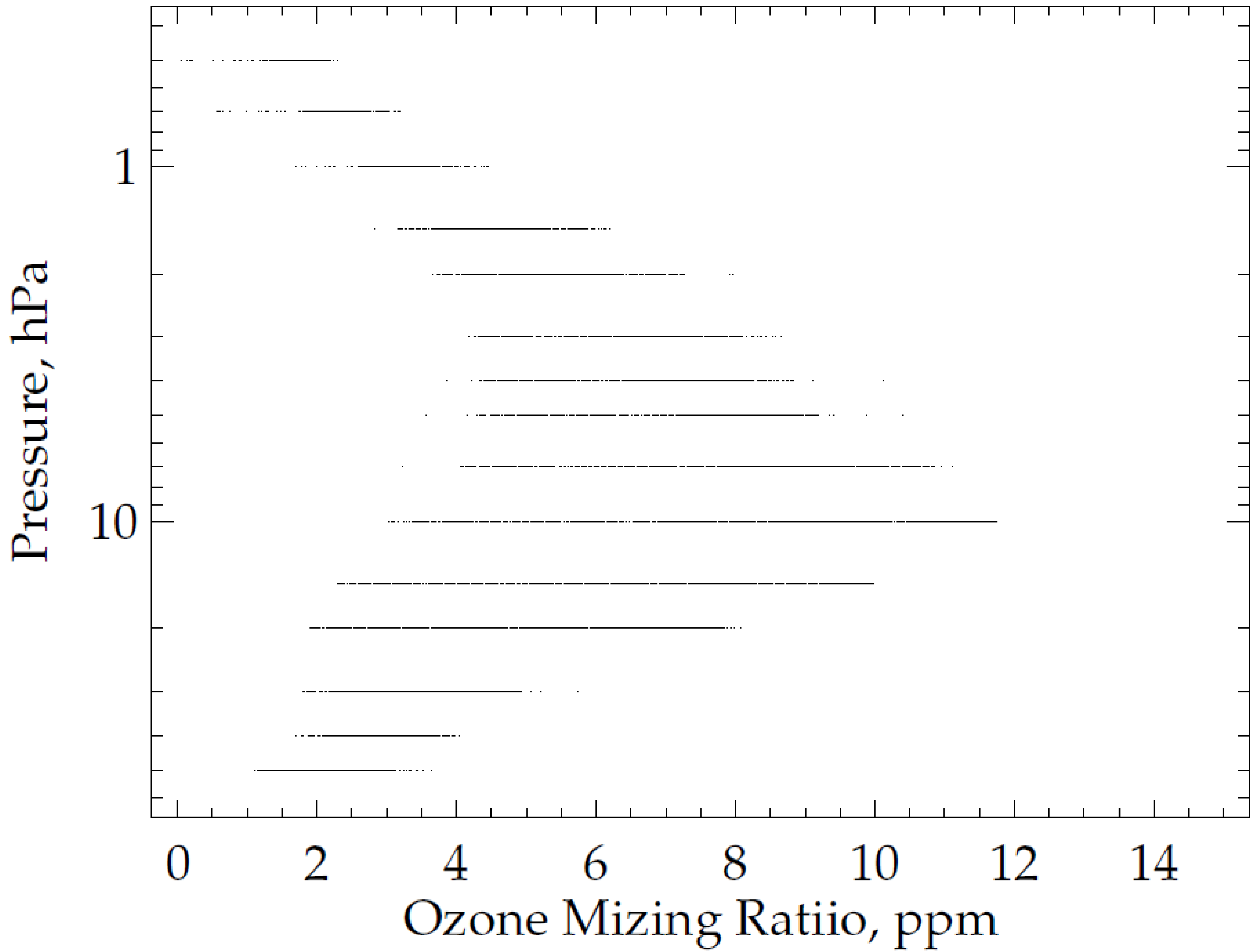


d. Normalized Single Scattering Contribution Functions for 12 wavelengths at [253,273,283,288,292,297,302,306,313,318,331,340] nm for a 325 DU total column ozone profile for Solar Zenith Angle θ_0 = 30°.



d. Normalized Single Scattering Contribution Functions for 12 wavelengths at [253,273,283,288,292,297,302,306,313,318,331,340] nm for a 325 DU total column ozone profile for Solar Zenith Angle θ_0 = 70°.

d. Mixing Ratios for August 25, 2015



d. Measurement range of mixing ratios versus pressure for one day including SAA.

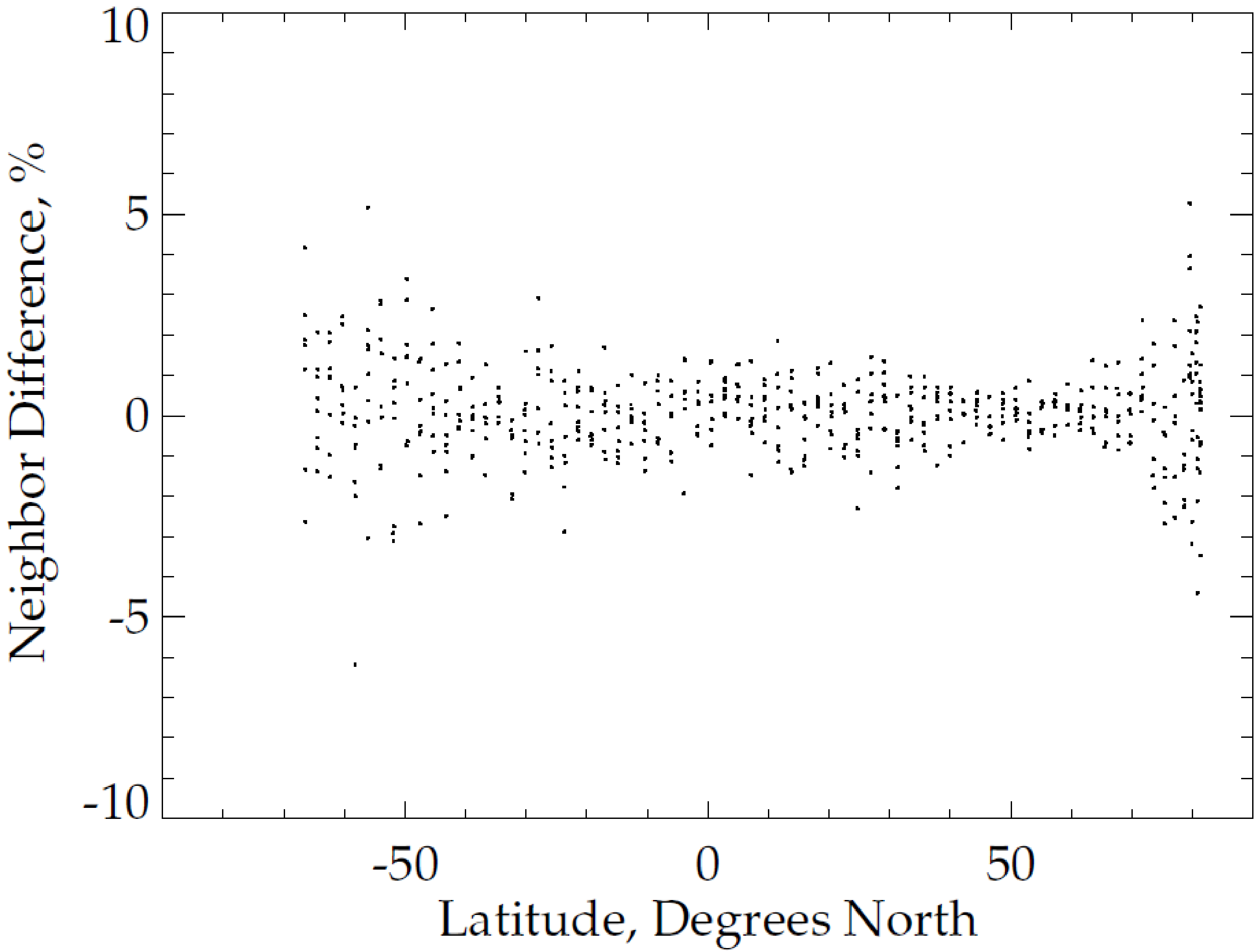
e. SDR Error Impacts on Precision/Accuracy

The sensitivity of the ozone retrievals to radiance/irradiance ratio errors is approximately 1.6%::1%

- Wavelength scale produces radiance variations of ±1%
  - 1.6%/1% x 1% = 1.6% O3 effects

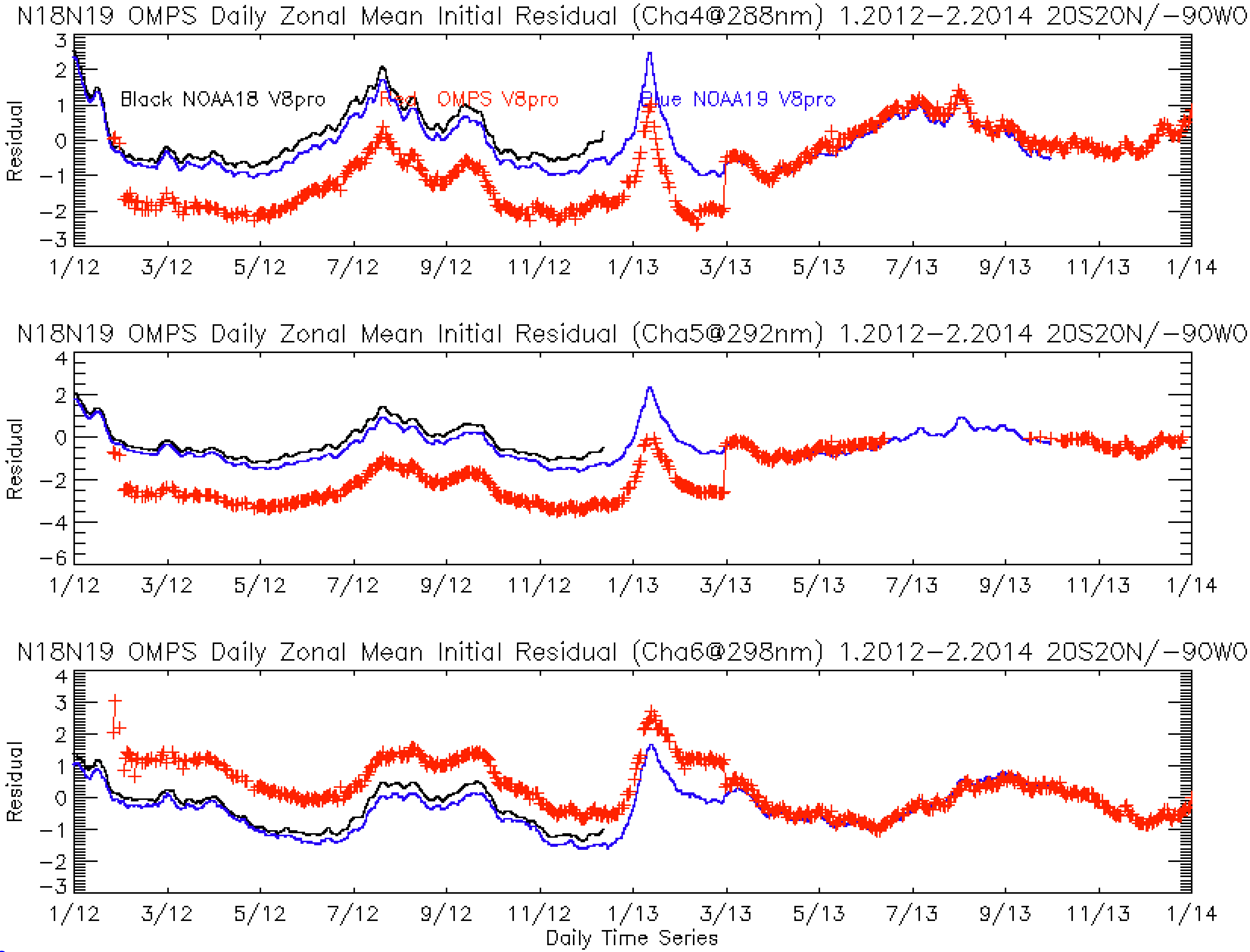
  and ozone cross-section, alpha, of ±0.4 %,
  - 0.02 nm x 100%/5 nm x 1%/1% = 0.4% O3 effects
- Solar activity produces irradiance variations of ±1%
  - 1.6%/1% x 1% = 1.6% O3 effects
- Instrument degradation is -0.5%/year at 253 nm
  - 1.6%/1% x 0.5%/year = 0.8%/year O3 effects (annual update to CFE)
- Stray light errors are now approximately 1/3 of the original errors with radiance variations of ±1%
  - 1.6%/1% x 1% = 1.6% O3 effects

e. Along-Track Differences for August 25, 2015



e. Layer ozone difference with averages of adjacent retrievals for Layer 11 of 21 for August 25, 2016. Daily RMS values for layers 2 to 20 are 5.0, 5.5, 5.9, 5.8, 5. 3, 4.3, 2.6, 2.8, 3.2, 2.3, 1.3, 1.2, 1.4, 1.2, 0.9, 1.3, 1.5, 1.5, 1.3 %

f. Initial Residual Biases before/after adjustments



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:

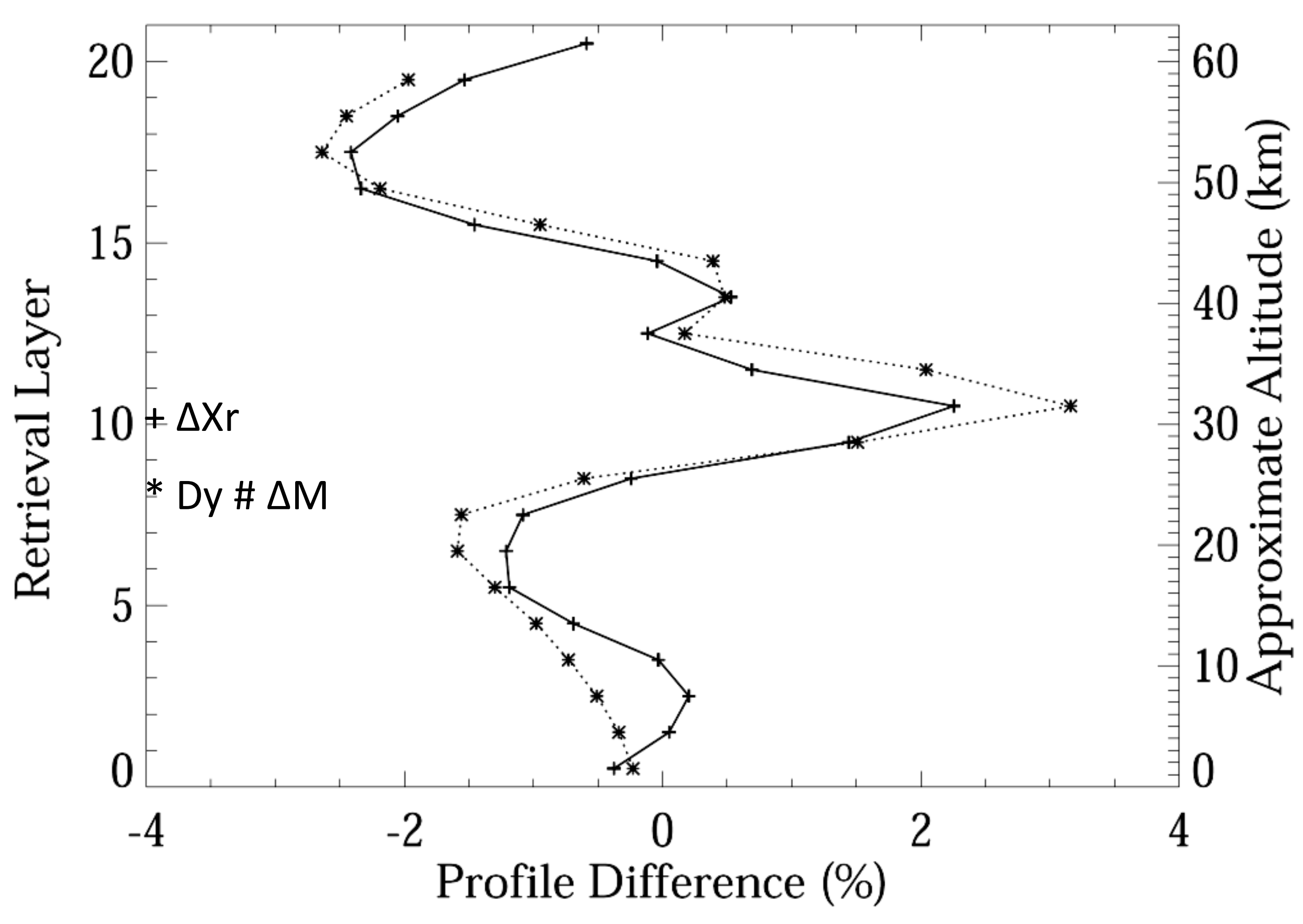
$$Xr = Xa + A \# [Xt - Xa]$$

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

$$\Delta M = K \# \Delta X$$

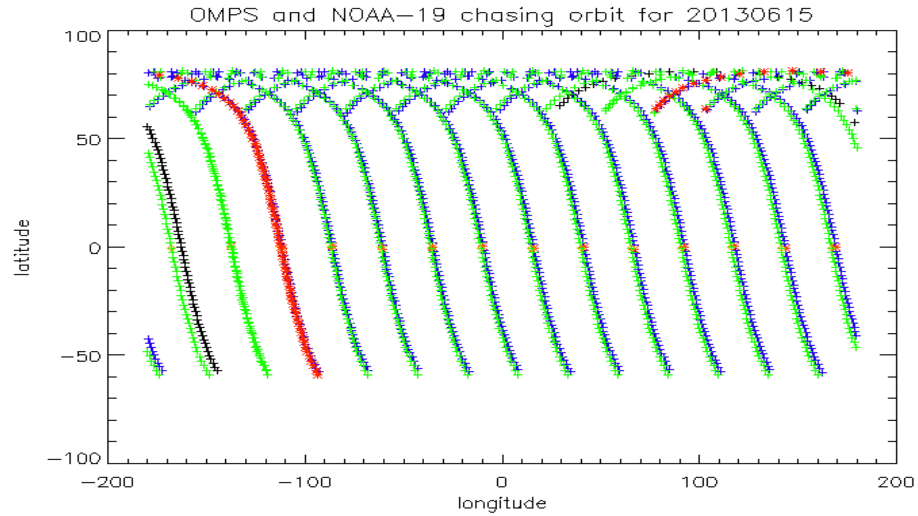
The retrieval change, ΔXr, is the contribution function times a measurement change, ΔM:

$$\Delta Xr = Dy \# \Delta M$$



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 their differences in their initial residuals. The "+" symbols are Δ**Xr** computed directly from the ozone retrievals and the * symbols are **Dy** Δ**M** with Δ**M** computed from the initial residuals. We can produce vary homogeneous Climate Data Records by determining the Δ**M** values.

f. Chasing Orbit Comparisons to SBUV/2



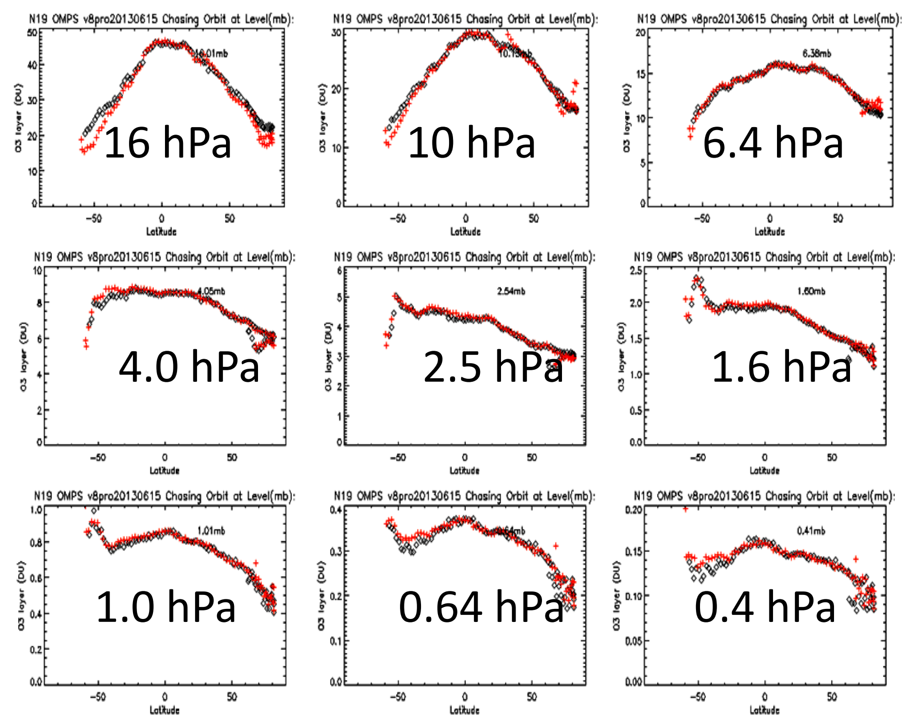
Approximately every 12 days, the orbital tracks for the NOAA-19 and S-NPP spacecrafts align and allow comparisons of products for similar locations with small viewing time differences. The top figure shows convergence of the orbital paths.

Products and residuals from the same retrieval algorithms for SBUV/2 and OMPS NP can be compared directly. The bottom figures shows ozone amounts for nine layers for the two Version 8 retrievals with the top left for the lowest layer and the bottom right for the highest layer.

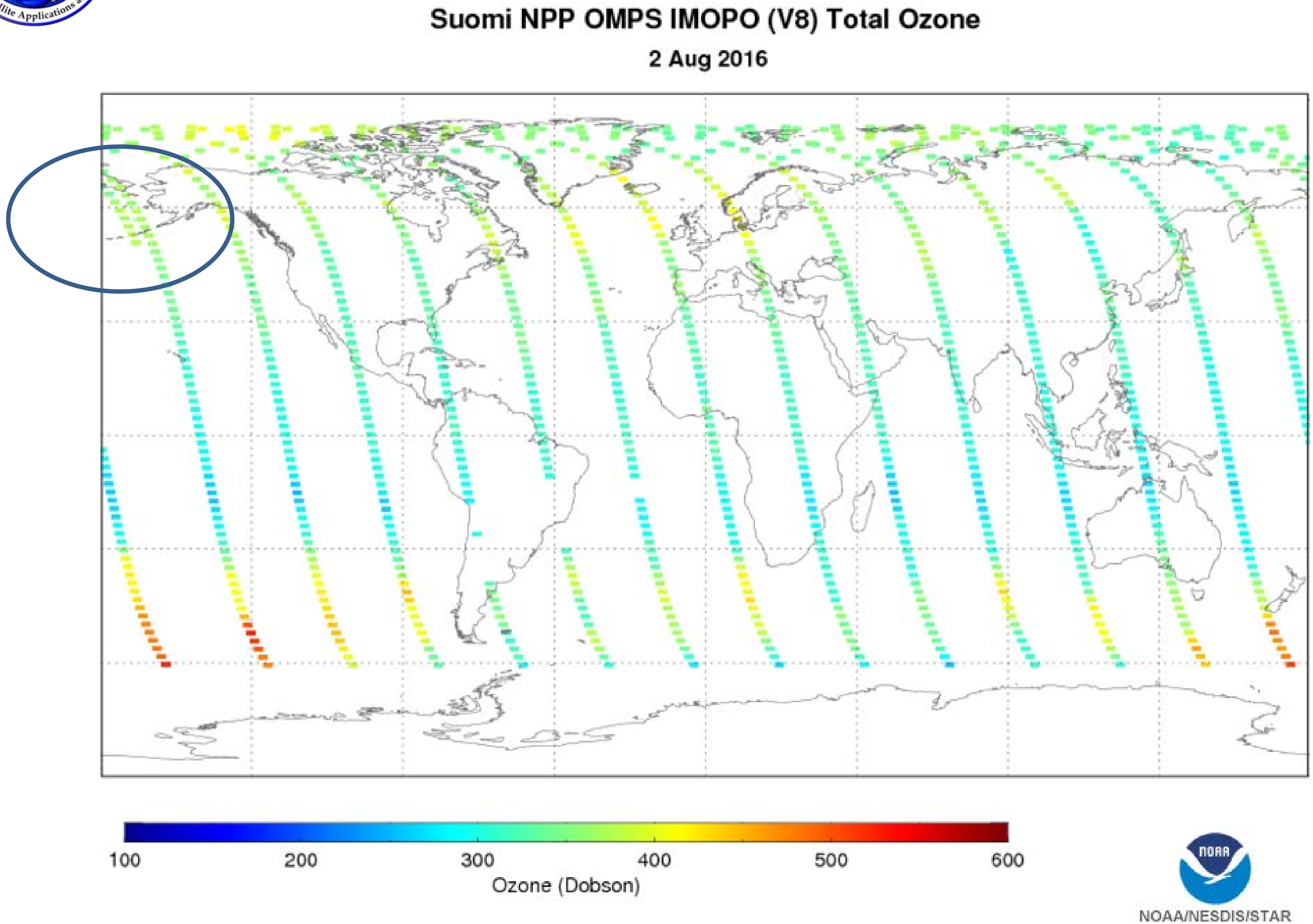
Additional monitoring plots provided at

http://www.star.nesdis.noaa.gov/icvs/prodDemos/proOMPSbeta.O3PRO_V8.php

show that the ozone profile differences are consistent with the initial measurement residuals computed relative to the first guess profiles.



Daily Coverage for Nadir Ozone Profile



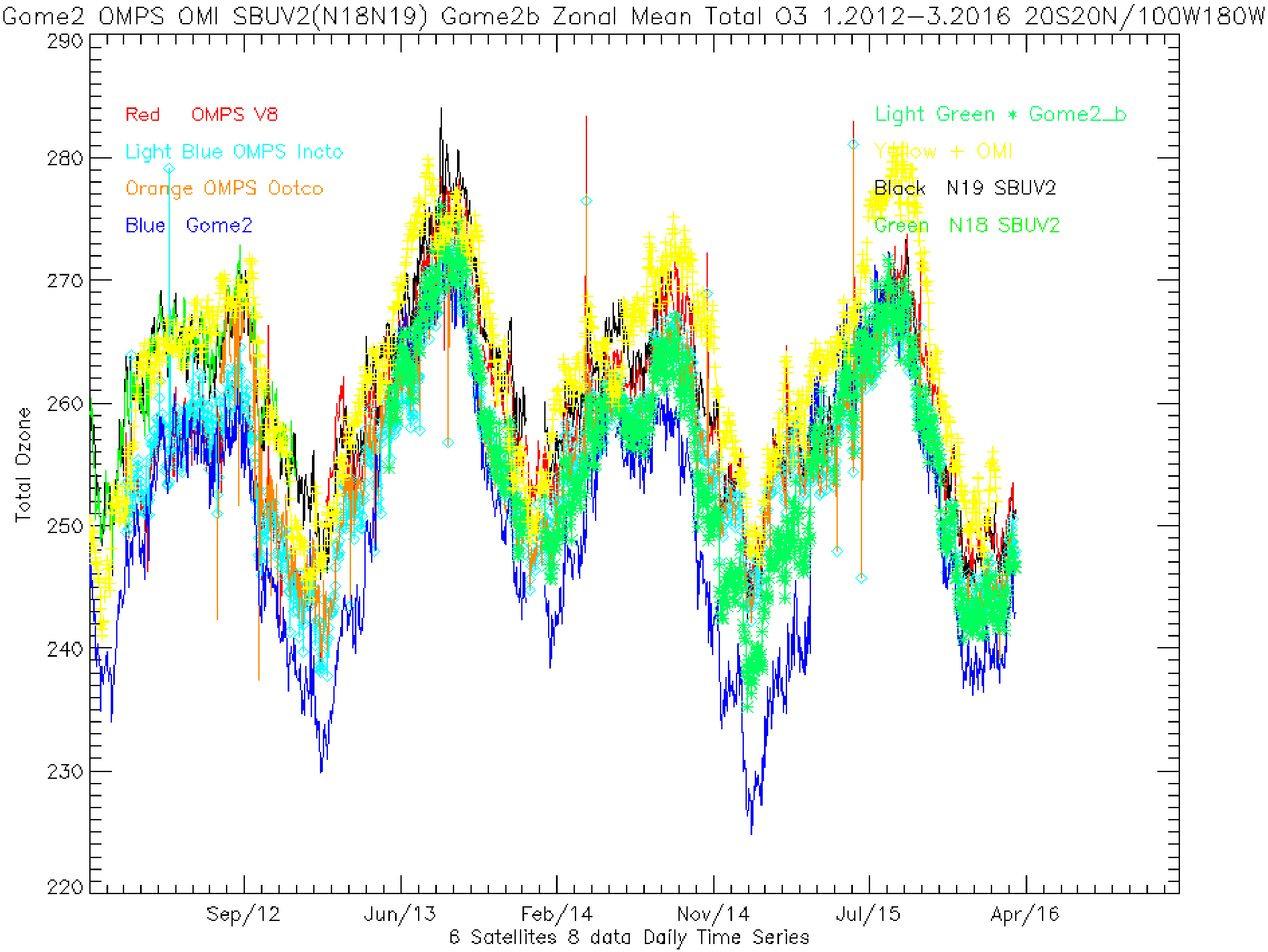
g. Daily coverage of OMPS Nadir Ozone Profile EDR. Note the precession of the orbits in the upper left corner.

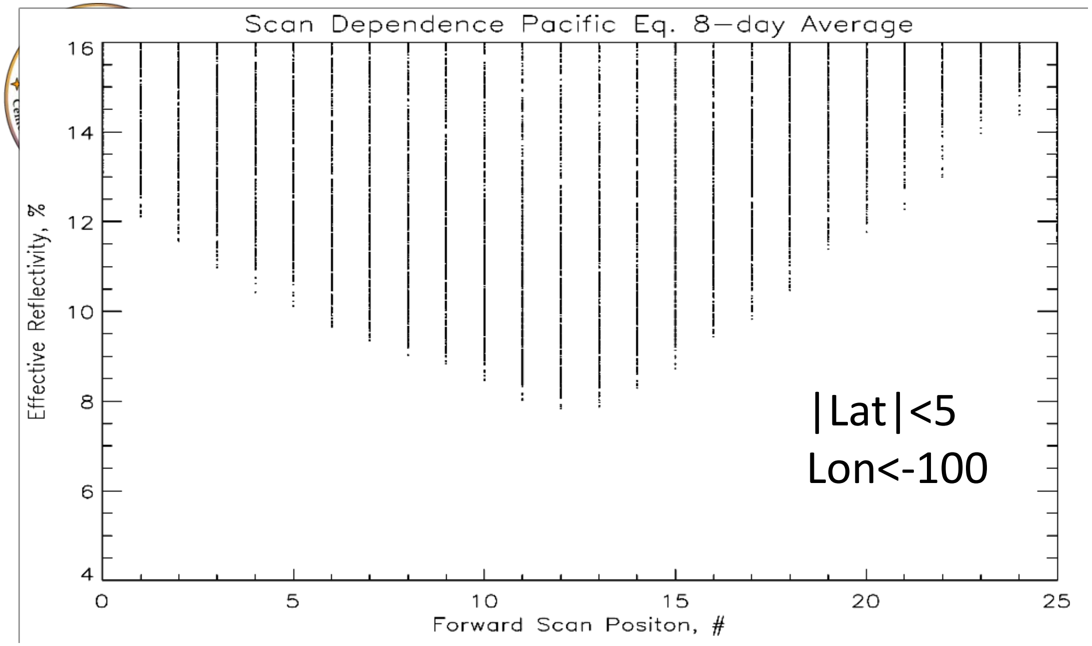
V8 Nadir Ozone Profile Summary

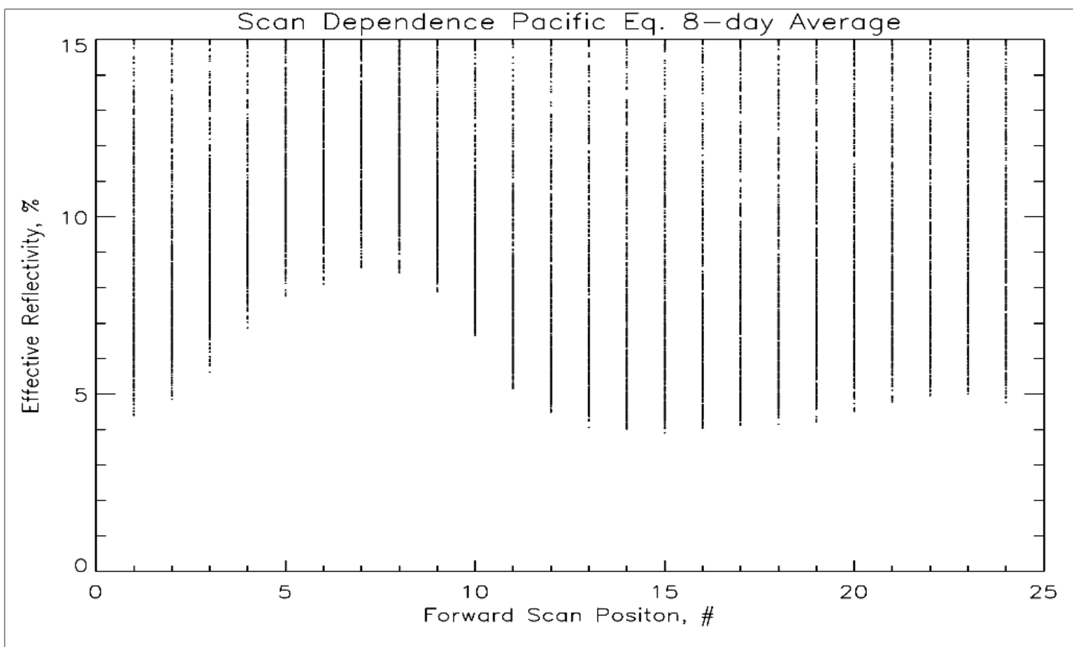
- The heritage, enterprise Version 8 Ozone Profile algorithm is ready for implementation at NDE as part of the redirected EDR processing for JPSS.
- The EDRs from the algorithm meet the required performance levels for the Nadir Ozone Profiles when applied to the validated OMPS NP and NM SDRs.

Backup

(f) Comparisons to other Satellites





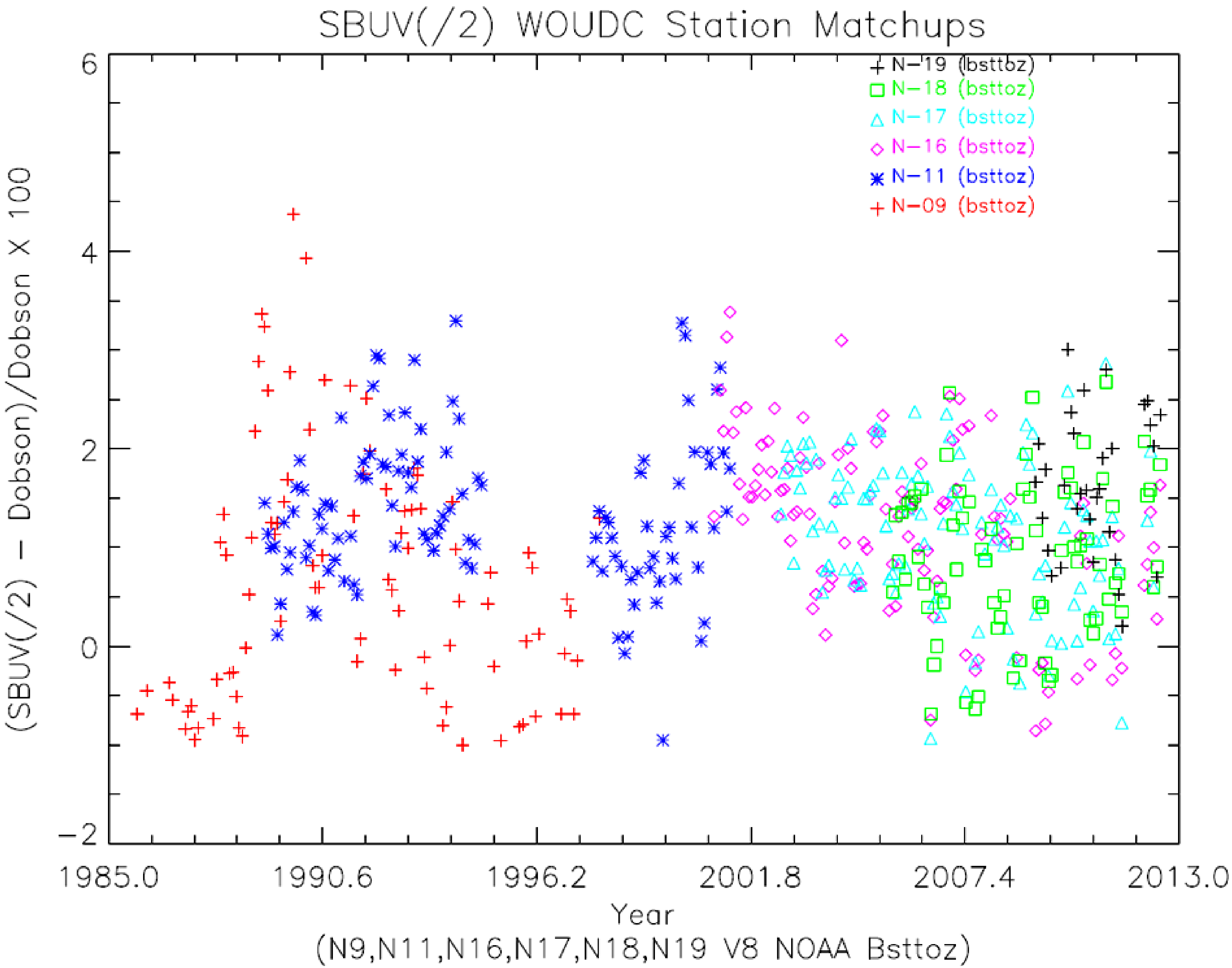


EAST WEST

Metop-A GOME-2 Version 8 331-nm Reflectivity for a box in the Equatorial Pacific.

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) WOUDC Station Matchups
N-19 (bsttoz)
N-18 (bsttoz)
N-17 (bsttoz)
N-16 (bsttoz)
N-11 (bsttoz)
N-09 (bsttoz)
(SBUV(/2) − Dobson)/Dobson X 100
6
4
2
0
−2
1985.0
1990.6
1996.2
2001.8
2007.4
2013.0
Year
(N9,N11,N16,N17,N18,N19 V8 NOAA Bsttoz)