Extending Ozone Climate Data Records with the
Ozone Mapping and Profiler Suite

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Outline

- OMPS Nadir Ozone CDR Project Description
  - Instrument overview
  - Project description
  - Brief update on SBUV(/2) and OMPS Limb Profiler
- Production and QA Approach
- Applications
  - WMO Ozone Assessments
  - NCEP Stratospheric Bulletins (including Ozone Hole)
  - Ozone layer interactions with Climate Change
  - Surface UV and Health
  - Input for NWS Reanalysis
- Schedule & Issues

OMPS Instrument Design

Nadir Mapper

UV Backscatter, grating spectrometer, 2-D CCD

TOMS, SBUV(/2), GOME(-2), OMI

110 deg. cross track, 300 to 380 nm spectral, 1.1nm FWHM bandpass

Total Column Ozone, UV Effective Reflectivity, and Aerosol Index Daily Maps

Nadir Profiler

UV Backscatter, grating spectrometer, 2-D CCD
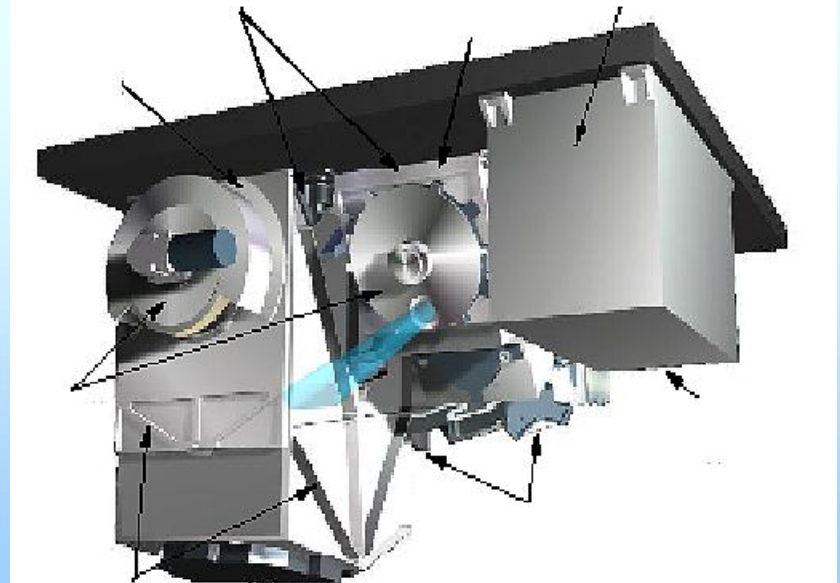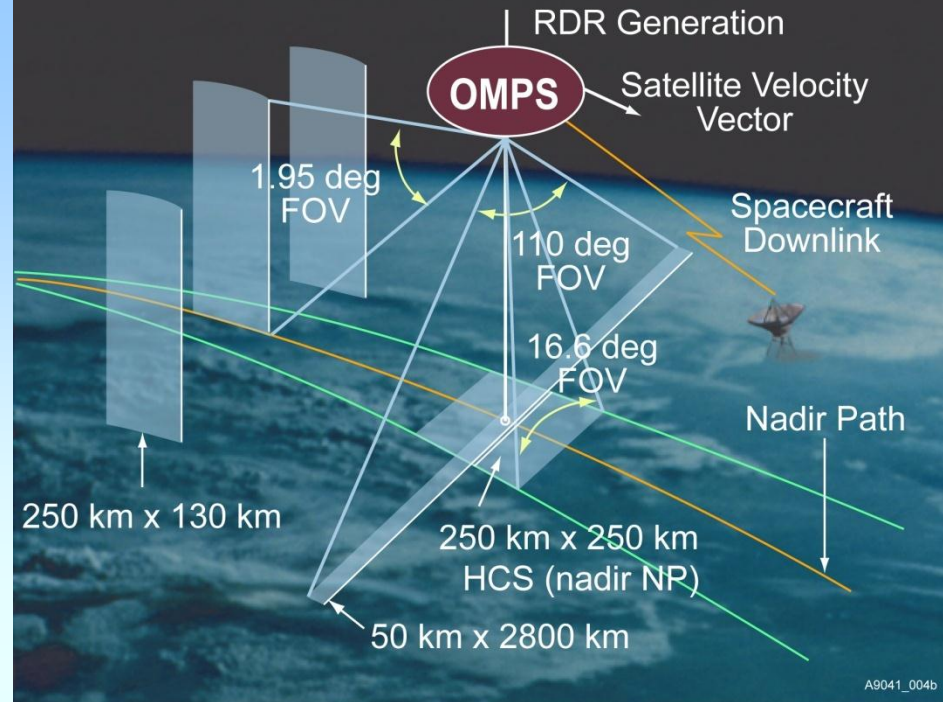
SBUV(/2), GOME(-2), OMI

Nadir view, 250 km cross track, 270 to 310 nm spectral, 1.1 nm FWHM bandpass

Ozone Vertical Profile, 7 to 10 KM resolution

Limb Profiler

UV/Visible Limb Scatter, prism, 2-D CCD array

SOLSE/LORE, OSIRIS, SAGE III, SCIAMACHY

Three 100-KM vertical slits, 290 to 1000 nm spectral

Ozone Vertical Profile, 3 KM vertical resolution

The calibration concepts use working and reference solar diffusers.

RDR Generation

OMPS

Satellite Velocity Vector

1.95 deg FOV

110 deg FOV

16.6 deg FOV

Spacecraft Downlink

Nadir Path

250 km x 130 km

250 km x 250 km HCS (nadir NP)

50 km x 2800 km

A9041_004b

Instrument and FOV Graphics from BATC

OMPS Fundamentals

NOAA, through the Joint Polar Satellite System (JPSS) program, in partnership with National Aeronautical Space Administration (NASA), launched the Suomi National Polar-orbiting Partnership (Suomi NPP) satellite on October 28, 2011. The Ozone Mapping and Profiler Suite (OMPS) consists of two telescopes feeding three detectors measuring solar radiance scattered by the Earth's atmosphere and solar irradiance by using diffusers. The measurements are used to generate estimates of total column ozone and vertical ozone profiles.

The nadir mapper (total column) sensor uses a single grating monochromator and a CCD array detector to make measurements every 0.42 nm from 300 nm to 380 nm with 1.0-nm resolution. It has a 110° cross-track FOV and 0.27° along-track slit width FOV. The measurements are currently combined into 35 cross-track bins: 3.35° (50 km) at nadir, and 2.84° at ±55°. The resolution is 50 km along-track at nadir, with a 7.6-second reporting period. The instrument is capable of making measurements with much better horizontal resolution.

The nadir profiler sensor uses a double monochromator and a CCD array detector to make measurements every 0.42 nm from 250 nm to 310 nm with 1.0-nm resolution. It has a 16.6° cross-track FOV, 0.26° along-track slit width. The current reporting period is 38 seconds giving it a 250 km x 250 km cell size collocated with the five central total column cells.

The limb profiler sensor is a prism spectrometer with spectral coverage from 290 nm to 1000 nm. It has three slits separated by 4.25° with a 19-second reporting period that equates to 125 km along-track motion. The slits have 112 km (1.95°) vertical FOVs equating to 0 to 60 km coverage at the limb, plus offsets for pointing uncertainty, orbital variation, and Earth oblateness. The CCD array detector provides measurements every 1.1 km with 2.1-km vertical resolution. The products for the Limb Profiler are discussed here very briefly.

OMPS Nadir Ozone CDR Project Description

- Implement the Level 1 (SDR) and the Version 8 (EDR) algorithms for OMPS Nadir Mapper and OMPS Nadir Profiler in a reprocessing system.
- Develop analysis tools and validation system to perform the cycle of … product evaluation (internal and external validation), instrument characterization (calibration, trending), reprocessing … over the OMPS missions (NPP 2011-2017, JPSS-1 2014-2021, JPSS-2 2020-2026)
- Primary products are Total Column Ozone (B-pair retrieval) and Ozone Vertical Profiles (optimal estimation retrieval) with Long-Term Stability (and other) performance specified in the JPSS Level 1 Requirements document.

BUV Ozone CDR Project Description

CDR(s) (Validated Outputs)	Period of Record	Spatial Resolution; Projection information	Time Step	Data format	Inputs	Uncertainty Estimates (in percent or error)	Collateral Products (unofficial and/or unvalidated)
Total Column Ozone	OMPS 2011 – 2026 (1970-preent)	Global sunlit	Daily	HDF/ NetCDF	NPP, J1, J2 OMPS Nadir Mapper (Nimbus-4 BUV; Nimbus-7 SBUV; NOAA-9,-11,-14,-16,-17,-18,-19 SBUV/2)	1% accuracy, 1%/decade long-term stability	UV Reflectivity, Aerosol Index
BUV Ozone Vertical Profiles	OMPS 2011-2026 (1979-present)	Global/orbit nadir sunlit	Daily	HDF/ NetCDF	NPP, J1, J2 OMPS (Nimbus-7 SBUV; NOAA-9,-11,-14,-16,-17,-18,-19 SBUV/2)	5% accuracy, 2%/decade long-term stability	Mg II Index, Solar UV Spectra

SBUV(/2) Update – Down the Up Spiral

A new version of the SBUV(/2) ozone vertical profile CDR covering 1979-2011 is ready for release. This product (V8 C7) has changes to reduce errors in the release in 2004 (V8 C1) including the following:

- Use of no-local-time-difference-latitude zonal means for intercalibration of overlapping SBUV/2 instruments

- Sequential Measurements
  - If not modeled, these create latitude-dependent biases
  - Procedure for interpolation along the orbital track (not yet published)

- Ozone Cross Sections
  - Use of Brion-Daumont-Malicet in place of Bass-Paur
    - Improvements in temperature dependence
    - Changes in relative absorption between channels
  - Many ground-based validation assets are still using the older cross-sections so new biases appear

- Morning/Afternoon stratospheric variations identified by MW
  - Recommendation to use ascending/afternoon periods for satellites with Nimbus-7 (11:00 AM) as an exception
  - Models to estimate diurnal variations are under development

OMPS/LP retrieved ozone profile Jan 10, 2012
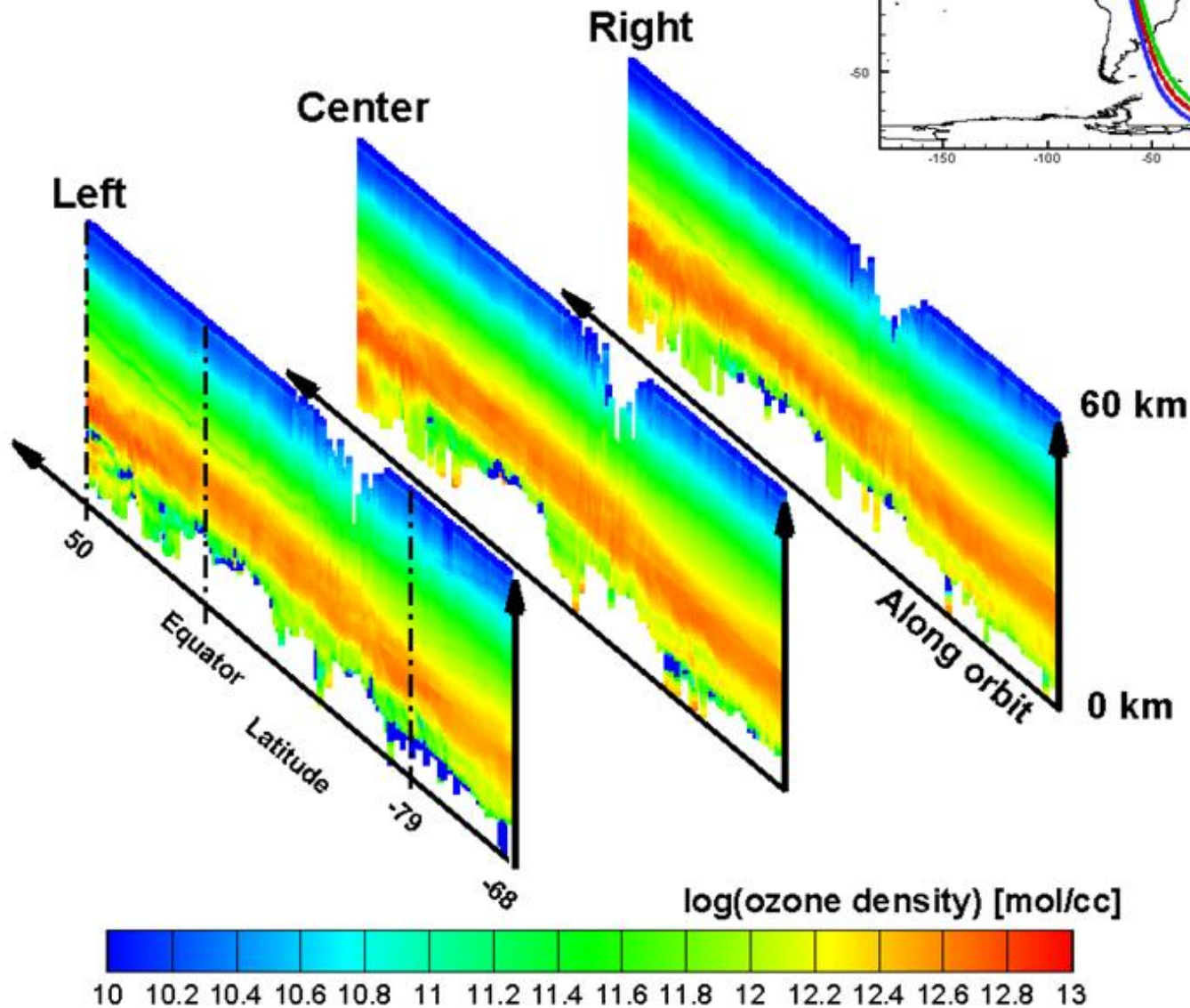
← OMPS Limb Profiler
These curtains represent the ozone profile in vertical slices through the atmosphere along the three paths shown above. They demonstrate the ability of the research retrieval algorithm for the OMPS Limb Profiler in use at the NASA Ozone PEATE. The gaps at the top in the middle of the plots occur when the satellite encounters charged particles as it passes through the South Atlantic Anomaly; these are consistent with the modeled effects.
The profiles regularly extend down below 15 KM in altitude.

log(ozone density) [mol/cc]

10 10.2 10.4 10.6 10.8 11 11.2 11.4 11.6 11.8 12 12.2 12.4 12.6 12.8 13

**D. Rault, NASA LaRC**

Production Approach

- RDR to SDR applies corrections and adjustments for instrument behavior (monitored by internal measurements)
  - dark current
  - non-linearity
  - Smear
- The basic measurements are ratios of Earth Radiance to Solar Irradiance
  - Relative throughput changes are tracked by using multiple diffusers and vicarious calibration methods (e.g., Antarctic ice reflectivity)
- Products are validated by comparisons to ozone total column and profile products from ground-based instruments in the Dobson, Brewer, and NDACC networks.
- Additional comparisons to contemporary products from other satellite instruments
- Specific challenges still to be addressed
  - Stray light corrections
  - Wavelength scale adjustments
  - Horizontal sampling flexibility

# How much data do you need? What can it tell you? How can you accentuate different effects?

- **Internal Measurements**
  - Dark Current and non-Linearity estimates, and Charged Particle effects
- **Single set of Solar measurements**
  - Goniometry, Irradiance Calibration, Wavelength Scale, SNR, Flat Fielding, Bandpass check (Comparisons to reference, contemporaneous, and high-resolution spectra)
- **Single Orbit of Earth-view data**
  - Wavelength Scale variations, SNR, Rough Radiance/Irradiance Calibration, Triplet/Pair consistency (Absorbing, reflectivity, and aerosol channels), Cross-track consistency
- **Single Day**
  - Total Ozone versus other mappers, Zonal Means, Stray Light (Profile Wavelengths), better orbital analysis, and start of performance monitoring
- **Single Week**
  - Cross-track consistency, Absolute calibration of reflectivity channels, calibration biases compared to other space-based mappers and profilers – transfer, and better daily analysis.
- **Single Month**
  - Ground based total ozone validation data points (assisted by transfer), Starting points for trending of instrument degradation and solar diffuser changes, and better weekly analysis – trending of consistency results.
- **Single Year**
  - Ground-based ozone profile validation, evaluation of long-term characterization, better monthly analysis, and start of ice radiance trending.

SBUV(/2) WOUDC Station Matchups
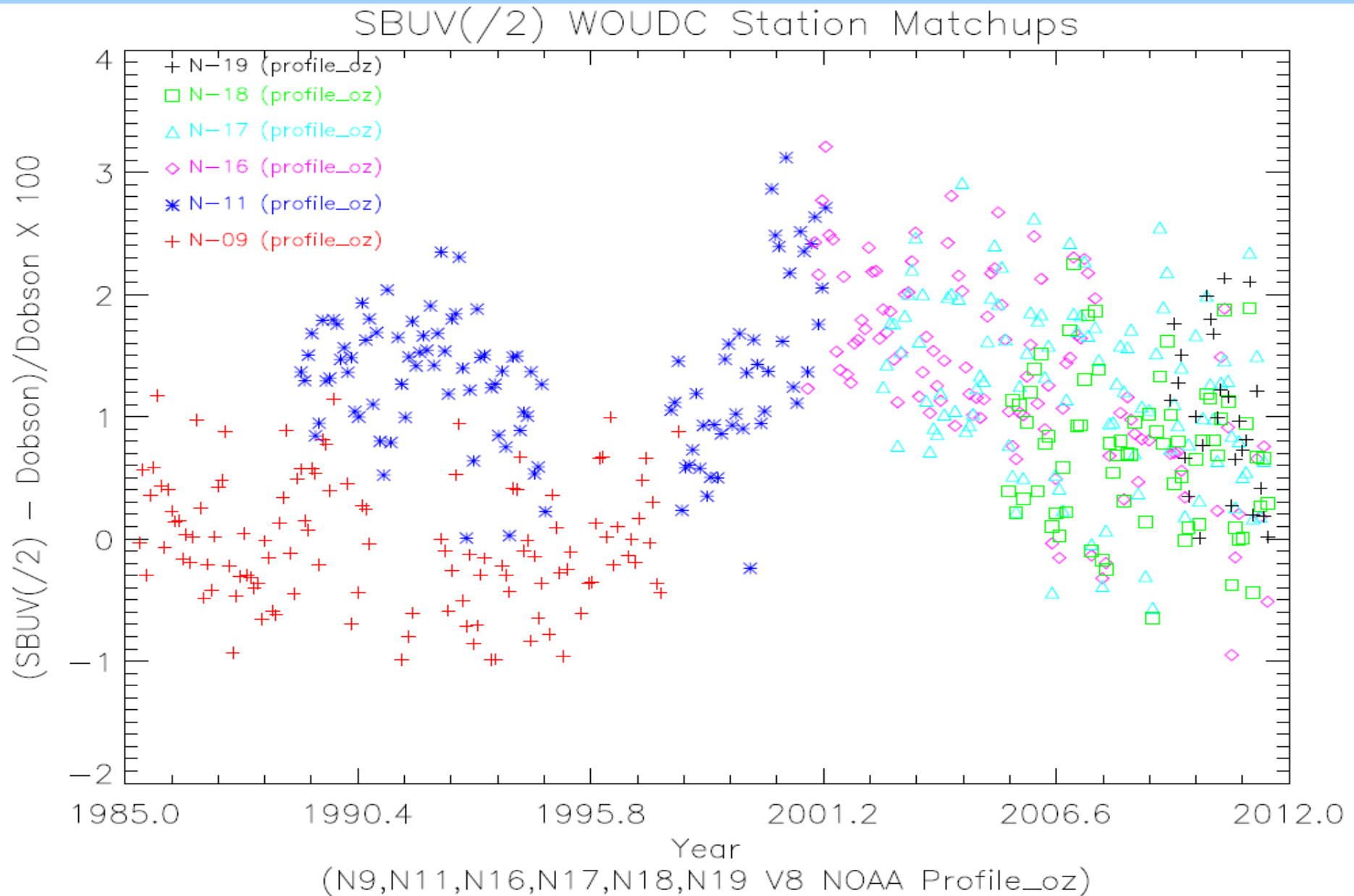
Time series of initial V8PRO residuals for OMPS NP February through June
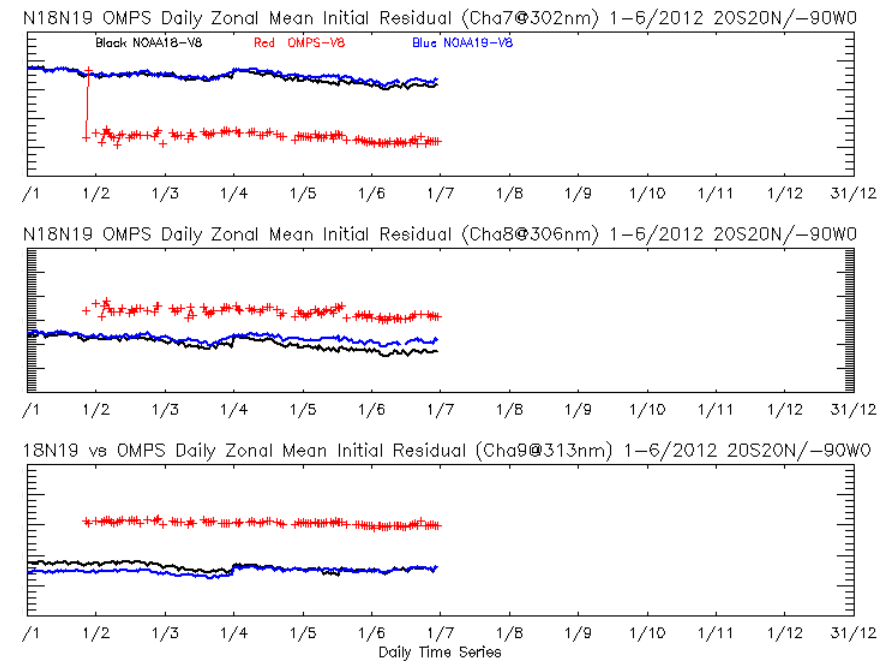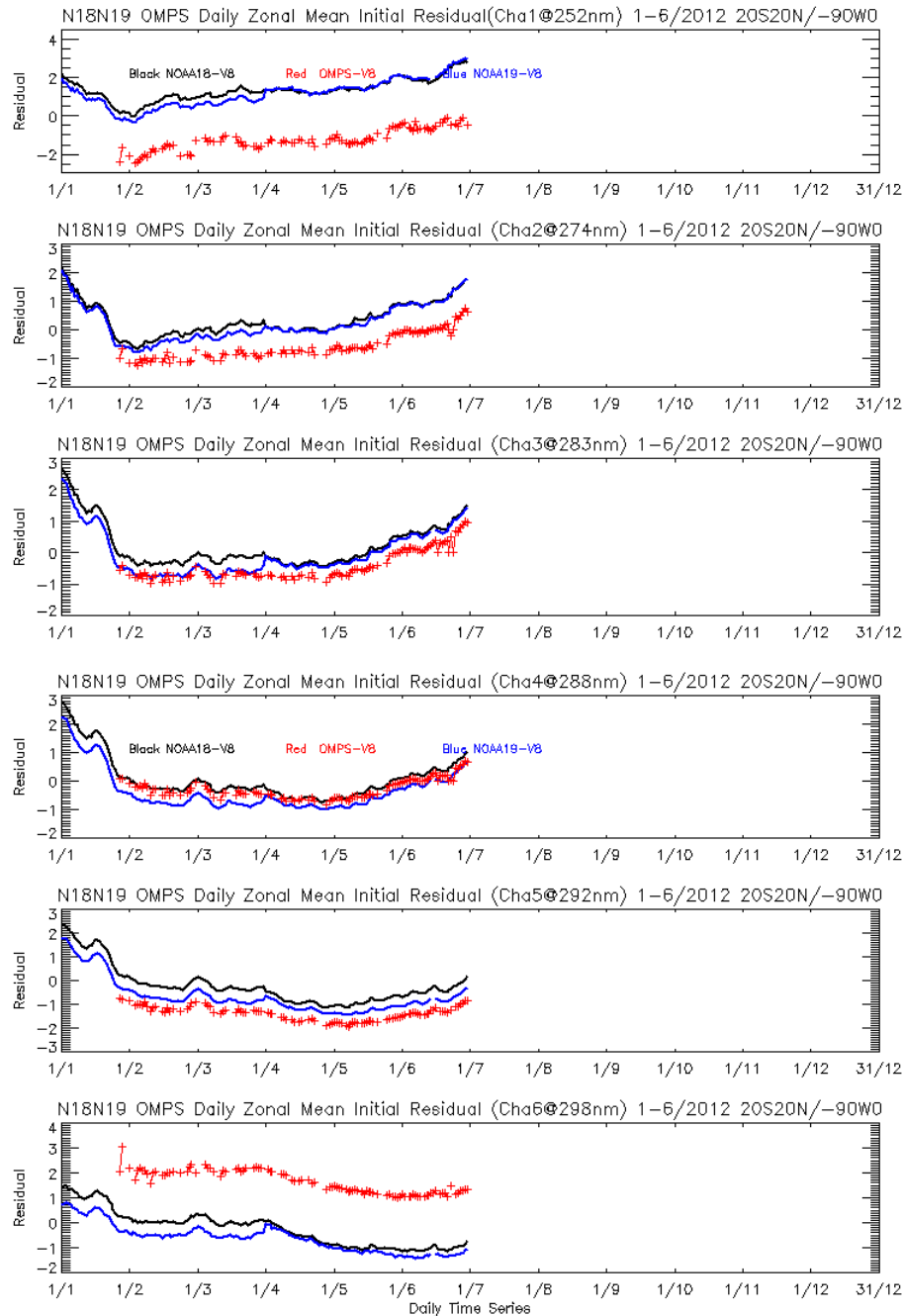
Initial Measurement Residuals for the OMPS NP V8 Profile Product: The nine figures show the initial residuals for profile wavelengths [252, 274, 283, 288, 292, 298, 302, 306 and 313 nm, (a) to (i), respectively] for the V8PRO product from **OMPS** compared to the same product for the operational **NOAA-18** and **NOAA-19** SBUV/2 for the equatorial daily zonal means (20N to 20S) with 0-90W removed to avoid the SAA. The residuals are in N-values (1 N ~ 2.3%). The time period is the first six months of this year (February to May for OMPS).

Notice that the residuals for OMPS, have maintained a persistent bias relative to the SBUV/2 residuals. Shifts in the operational residuals are not present in the reprocessed CDR products.

Applications

- WMO Ozone Assessments (See ref. #1 in notes.)
  - The Total Column Ozone and Vertical Profile CDRs (30+years) from the SBUV(/2) each form one of three key data sets for long-term monitoring of there respective products. The OMPS Nadir Mapper and Nadir Profiler will be used to extend these records.
  - High resolution ozone profiles from the OMPS Limb Profiler will help to extend the CDRs from previous limb instruments.
- Monitoring the Ozone Hole and Arctic Ozone Loss
  - The OMPS CDRs will extend the SBUV/2 record used in NCEP Stratospheric Bulletins (See ref. #2 in notes.)
- Long-Term UV Changes
  - Researchers use the long-term records of UV effective reflectivity and total column ozone to derive long-term records of changes in surface UV. (See refs. #3 & #4 in the notes.)
- Climate Change Studies
  - There are complex interactions expected for the ozone layer as climate change effects increase. (E.g., recent storms refs. #5 & #6 in notes.)
- Tropospheric Ozone Residuals
  - Ozone in the troposphere is a pollutant. Differences between total ozone and stratospheric column CDRs provide estimates of Tropospheric amounts to identify trends in air quality. (See ref. #7 in notes with additional TOR applications.)

Progress, Schedule & Issues

- Beta release of IDPS SDR (Level 1) OMPS Earth View products took place in March. Beta release of OMPS IDPS ozone products will take place in August. (Findings & ReadMe files at CLASS)

- Calibration SDR processing and trending is currently performed at the NASA PEATE. This work will transition to NOAA/NESDIS/STAR over the next two years.

- Plans to implement the V8 CDR algorithms as the operational product algorithms are proceeding subject to JPSS funding.

- ADL 4.0 is running at STAR with all IDPS OMPS algorithms. We have begun implementing the V8 total ozone algorithm in it.

- IDPS may transition to Linux-based processors in 2014

- The NPP Science Team has revised their plans for OMPS Limb Profiler algorithm development. This will delay the transition to NOAA STAR and NDE

- STAR is processing/reprocessing all OMPS Nadir Mapper and Nadir Profiler measurements with the V8 algorithms.

- The ICVS has expanded content to monitor OMPS products.
  - ➢ http://www.star.nesdis.noaa.gov/icvs/PROD/proOMPSbeta.php

(a)

(b)

(c)
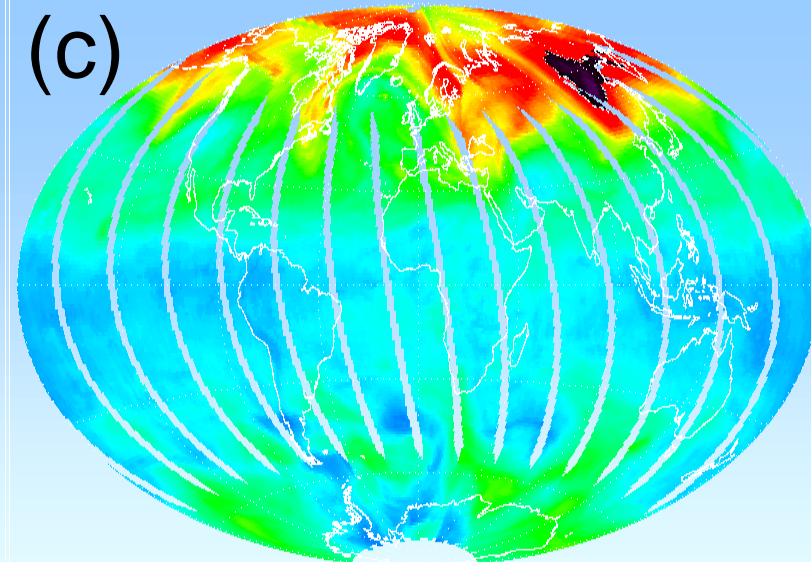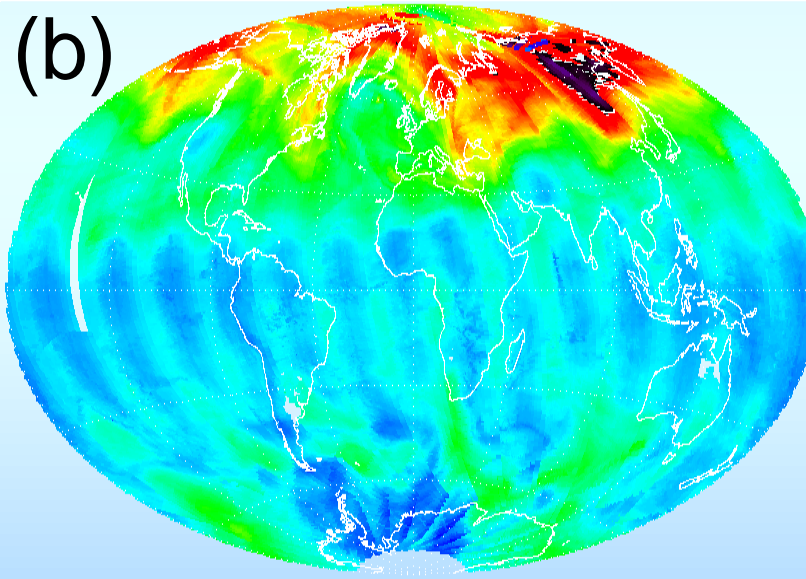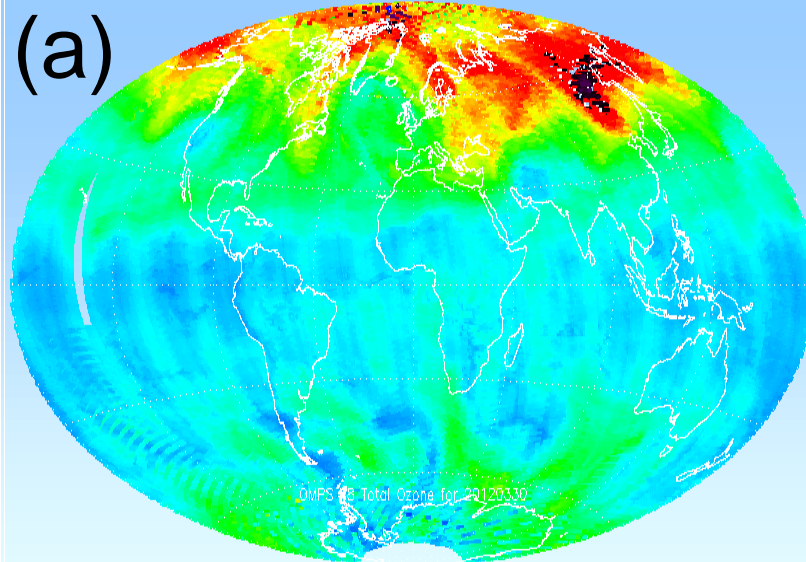
Daily Total Column Ozone map comparisons between (a) IDPS OMPS First Guess Multiple Triplet product, (b) NOAA OMPS V8 product, and (c) NASA OMI V8.6 product for March 30, 2012. Cross-track features in OMPS products are related to the use of preliminary calibration values.

DU 100   300   500

Backup, including material from past years' presentations

OMPS NP Solar Flux Measurements
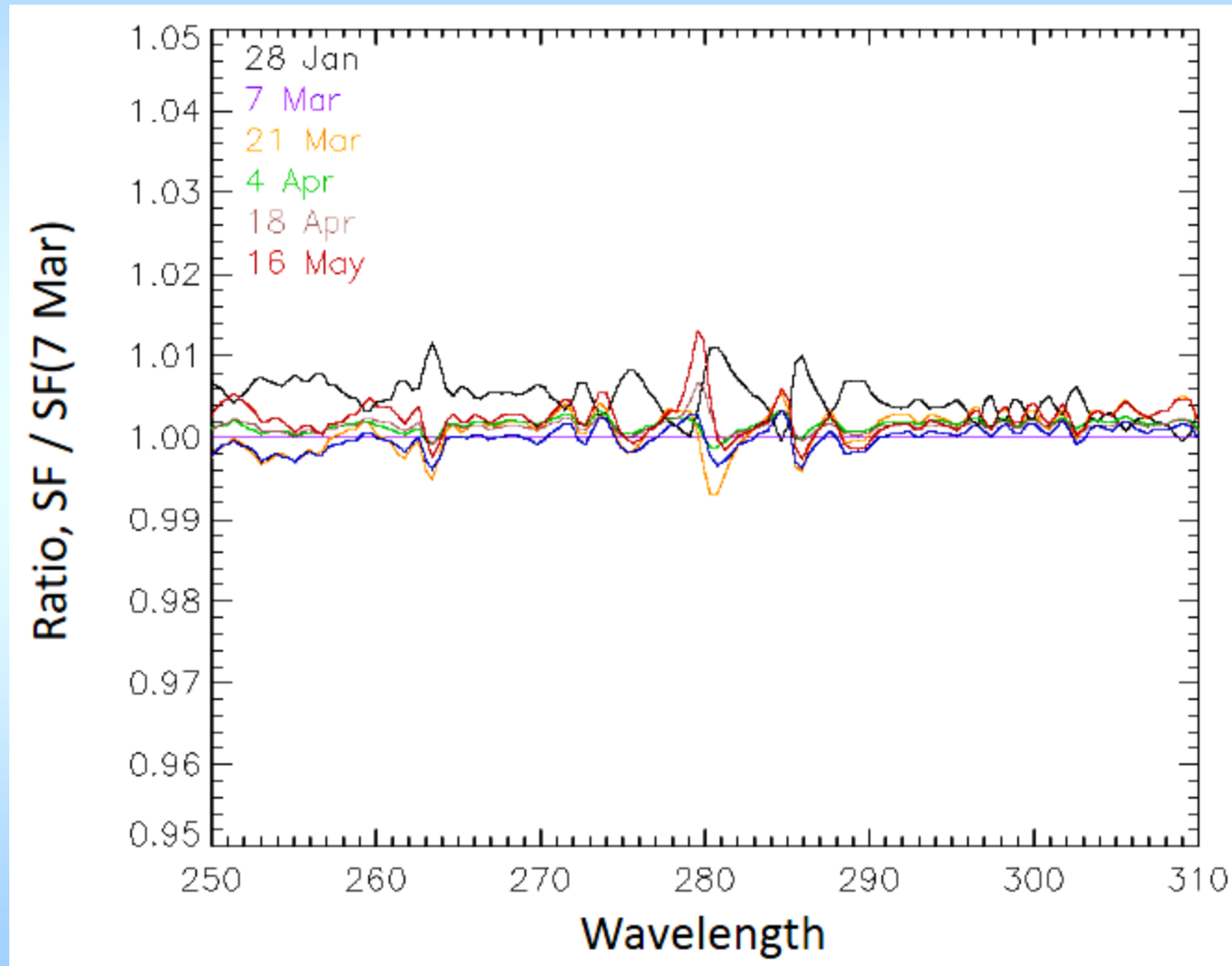
Benefit to the Science Community

- The existing satellite-based total ozone and ozone profile CDRs are part of the foundation of the WMO Scientific Assessments of Ozone Depletion. The OMPS-extended records will continue that support. Question 20 in the 2010 assessment is "How is ozone expected to change in the coming decades?" The uncertainties in the near-term projections will be removed by the CDRs extended by OMPS ozone products. http://ozone.unep.org/Assessment_Panels/SAP/Scientific_Assessment_2010/

- The NOAA annual stratospheric summary Bulletins are based on SBUV(/2) records. The OMPS records will provide continuity for that analysis.

http://www.cpc.ncep.noaa.gov/products/stratosphere/winter_bulletins/sh_10/

Benefit to Society

- In the coming decade, we expect to see extensive evidence of the recovery of the ozone layer in reduced ozone hole sizes and reduced ozone loss at mid-latitudes. These improvements will provide tangible evidence of our ability as a global society to recognize, confront and avert a major ecological and health catastrophe (See, "What would have happened to the ozone layer if CFCs had not been regulated," Newman et al., Atmos. Chem. Phys. 9(6), 2113-28, 2009.)

- The satellite measurements of ozone provide global to local views of our changing atmosphere. This project allows us to form continuous records of ozone amounts tracing back to 1979 with algorithms and instruments sharing similar heritage. These consistent long-term records can be used to estimate historical UV Index values for studies on human health.

- Educating the public on scientific studies of our world. See the NOAA Science on a Sphere and webinar (explaining ozone's slow recovery) recorded at

www.amnh.org/sciencebulletins/?sid=e.v.ozone2010.20110124#

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Thematic Benefits to Society

- ## Health
    - Public awareness of the danger or overexposure to UV radiance is leading to healthier lifestyles. One Australian researcher opined that this increased attention (reduced exposure, use of sunscreen and hats) would lead to lower skin cancer rates over recent years even as surface UV increased due to ozone depletion. Daily UV forecasts and accurate historical records allow better planning by individuals and communities.

- ## Agriculture/Ecosystems
    - Increases in surface UV levels are tied to ecological damage affecting a range of biota from crops to amphibians to ocean plankton. Accurate monitoring and prediction of ozone changes help to evaluate the level of these threats and allow more efficient distribution of research resources.

- ## Climate
    - The Montreal Protocol and the onset of ozone recovery are both a cautionary tale and a success story for global atmospheric change. On the one hand we have a dramatic demonstration of humankind's ability to alter the atmosphere all over the world; Antarctica is not a source of CFCs and yet the ozone hole is there. On the other hand we have a profound example of our ability to defeat a major threat to the stability of the our atmosphere through international cooperation on chemical releases and industry development of replacement technologies.

Overview: Create a system to reprocess OMPS measurements to extend atmospheric ozone CDRs

- Measurements: OMPS Nadir Mapper, Nadir Profiler, and Limb Profiler RDRs of scatter solar radiances
- Deliverables
  - OMPS Nadir Reprocessing system
    - IDPS OMPS NM and NP RDR to SDR algorithms (via ADL)
    - Version 8 total ozone (V8TOz) and ozone profile (V8Pro) algorithms
  - OMPS Limb Reprocessing system
    - NPP Science Team RDR to SDR algorithm
    - NPP Science Team ozone profile algorithm
- ECVs
  - Total Column Ozone CDRs
  - Ozone Vertical Profile CDRs (Nadir)
  - Ozone Vertical Profile Research CDRs (Limb)
- Project Product Description matrix is valid

Results/Accomplishments (1)

- Linux Implementation of V8Pro with OMPS NP/NM SDR demonstrated on synthetic SDRs

- Hosting of ADL 3.0 Beta on STAR Linux. Test runs of OMPS NP/NM SDR algorithms. (Major change in project approach)

- Added to ICVS content for GOME-2; will transition to OMPS NM

- SAA spike filter tested on OMI and GOME-2 spectra

- Working with NASA/GSFC on methods for intercalibration including no-local-time difference comparisons

- SBUV(/2) V8.6 Collection 7 will be released soon

- The Version 8 ozone profile algorithm paper is in preparation with P.K. Bhartia as lead author

- NPP ST OMPS Limb SDR algorithm running at NASA PEATE; ATBD provided: http://ozoneaq.gsfc.nasa.gov/documents.md

- NPP ST OMPS Limb EDR algorithm stabilized

- WMO Workshops
  - Past changes in vertical distribution of O3 (data etc. for 2014 assessment)
  - Absorption cross sections of O3

Results/Accomplishments (2) V8Pro Implementation Milestone

- The Version 8 SBUV/2 ozone profile retrieval algorithm has been adapted to perform retrievals from the OMPS Nadir Mapper and Nadir Profiler measurements. It has been tested on synthetic SDR data sets #3 and #4 provided by the JPSS program.

- The algorithm has been upgraded to match current SBUV(/2) CDR applications with improved ozone cross sections for the radiative transfer look-up tables and a new, UV-based, cloud optical centroid pressure climatology

- Tasks are continuing to generate algorithm documents and develop a robust system for reprocessing OMPS SDRs and EDRs.

Test Retrieval from Data Set #4
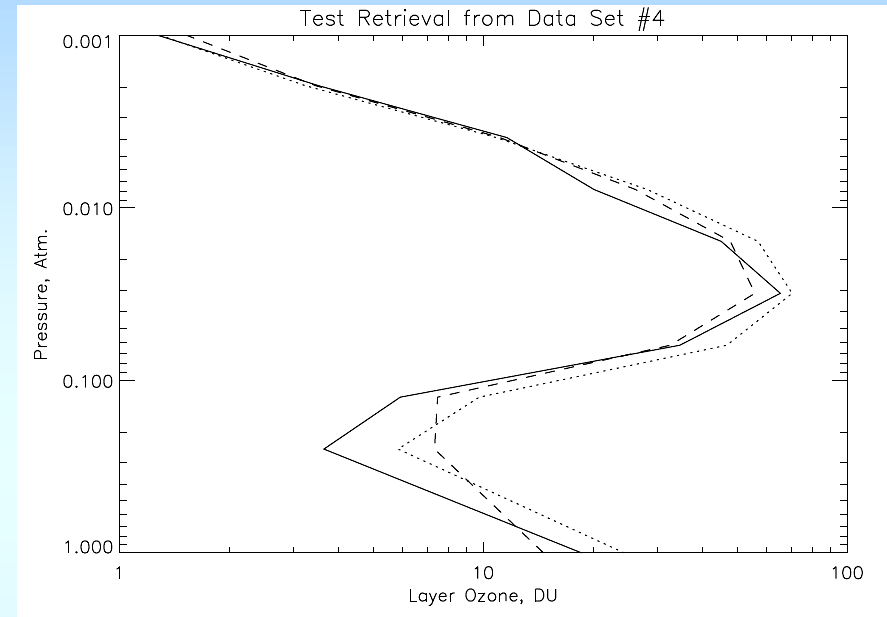
Sample result for V8pro Applied to Synthetic Test Data Set #4. The solid line is the V8 ozone profile retrieval, the dotted line is the A Priori ozone profile retrieval, and the dashed line is the truth ozone profile. There are two significant differences between the raditative transfer used to create the V8 tables and the one used for the synthetic data; the synthetic data uses an older set of ozone absorption cross sections and it does not include Ring effects in the forward model.

Significance: The OMPS instruments will provide the measurements to continue monitoring atmospheric ozone.

Results/Accomplishments (3)
# Hosting of SDR under ADL

- Two Algorithm Development Library versions (ADL 2.0 and ADL 3.0 Beta) have been hosted on STAR Linux workstations

- Tests runs of OMPS NP/NM SDR algorithms match IDPS generated samples

- Some coding errors have been identified and reported back to the JPSS program

- OMPS SDR algorithms will be exercised in ADL as part of Cal/Val rehearsal Part II
  - We will attempt to acquire the necessary inputs to produce SDRs matching the flow from IDPS during NCT-4

Validation Strategy/Results (1)

- The OMPS Nadir SDR algorithms are identical to the operational ones at IDPS and will be validated by the JPSS OMPS SDR Team

- The OMPS Limb SDRs and EDRs will be validated by the NPP ST

- The V8TOz and V8Pro are an integral part of the OMPS Nadir product Cal/Val plan
  - Test OMPS_E8 V8TOz Internal Consistency
  - Test OMPS_E9 V8Pro Internal Consistency
  - Test OMPS_E10 EDR consistency & residuals
  - Test OMPS_E11 Compare V8TOz and IDPS MT EDR
  - Test OMPS_E12 Compare V8Pro and IDPS V6 EDR
  - Test OMPS_E13 Evaluate Performance in the Pacific Box
  - Test OMPS_E14 Satellite Intercomparisons (OMI, GOME-2, SBUV/2, MLS, CrIS)

- The OMPS SDR and EDR validation (and reports) will form the first step in the CDR creation/validation

Validation Strategy/Results (2)

- Existing/expanding satellite Integrate Calibration/Validation System analysis for GOME-2 and SBUV/2 will be applied to OMPS
    - http://www.star.nesdis.noaa.gov/smcd/spb/icvs/proSBUV2operational.php
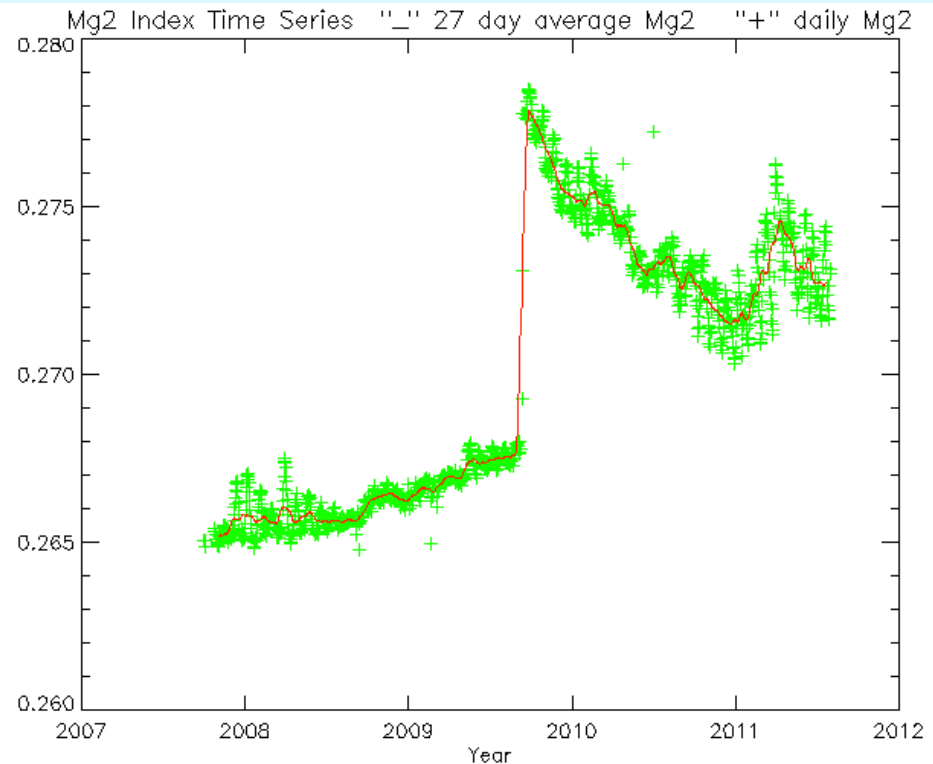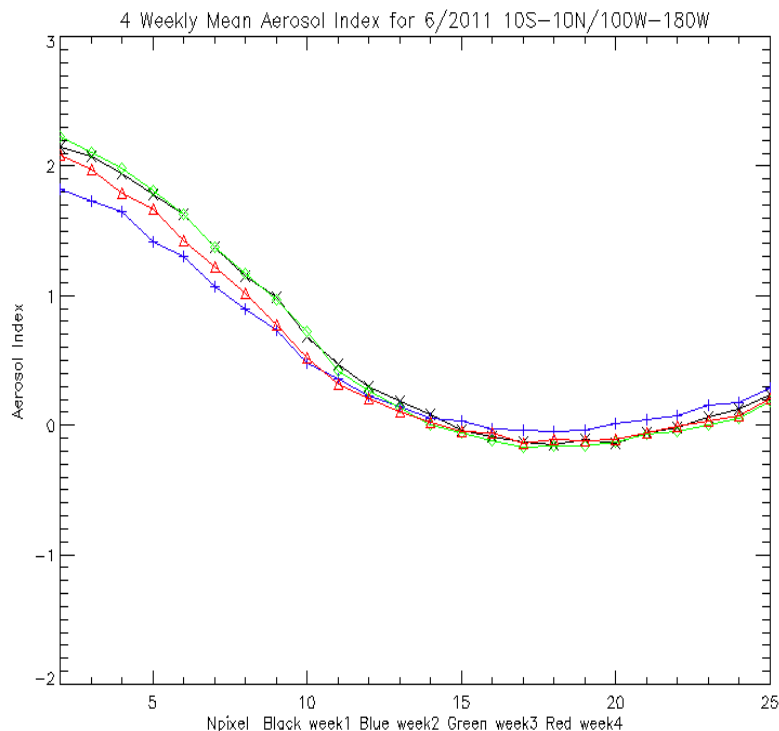
Algorithm/Product Maturity
NPP ST OMPS Limb EDR

▪ The NPP ST OMPS Limb EDR algorithm has been stabilized

OMPS Limb Profiler EDR status updated in email 6/27/2011 from D. Rault:

Hello, Larry,

I wanted to let you know that we have completed the series of comprehensive testing on the EDR code a few weeks ago and have tagged the latest version as our "official version". That version will go all the way to launch, with no more changes. We have shown that version to be very stable (tested on over 100,000 LS events) and on three different platforms (PC/windows, Linux, SuperComputer). It gives retrievals of ozone and aerosol products at the level of a few percent for ozone and 30% for aerosol and consistently identify/correct height registration offsets. While we are still continuing further development on a parallel branch, this at-launch version is now ready for your use/analysis.

Issues/Risks & Work-Off Plans

- **JPSS funding deficits**
  - May impact V8Pro implementation at IDPS
  - May impact R2O transition of OMPS Limb
- **OMPS Calibration SDR algorithm choices**
  - IDPS implemented algorithm
  - NPP ST PEATE developed algorithm
- **SDR algorithms under ADL and C-RDRs**
  - Need to become Beta testers for C-RDRs
- **Ring effect improvements will be tracked**
- **South Atlantic Anomaly for NP**
  - Filter data with EOF and Nearest Neighbors
  - Adjust zonal means as necessary

Limb Issues/Risks & Work-Off Plans

- **Limb algorithm development and performance**
  - NPP Science Team
- **Limb Research to Operations Project**
- **Limb Pointing Errors**
  - RSAS and Nadir Profiler Registration
  - Orbital statistics and comparisons
- **Stray Light**
  - Evaluate errors and apply corrections

Schedule

- 10/2011 V8TOz and V8Pro output to NetCDF4
- 12/2011 Create documents for as-implemented V8Pro and V8TOz
  - C-ATBD
  - Interface Control Document
  - System Description Document
  - Maintenance Manual
- 2/2012 OMPS Limb on PEATE clone
- NPP-Launch + 6 Validation and Evaluation of OMPS Nadir SDRs
- NPP-L + 12 Validation and Evaluation of OMPS Nadir V8 products
- NPP-L + 24 Validation and Evaluation of OMPS Limb products (Beyond current project)

Research-to-Operations or Delivery Plan

- V8 Profile algorithm will be implemented in IDPS under other funding

- OMPS NM and NP SDR algorithms will be maintained and updated at IDPS and update in ADL

- OMPS LP SDR and EDR algorithms will be implemented and maintained at NDE under other funding

- Reprocessing capability on Linux workstations is created by this project

Transition Plan

- DOCUMENTATION (Estimated date of delivery)
  - Climate Algorithm Theoretical Basis Document (C-ATBD)
    - V8TOz (12/2011)
    - V8Pro (1/2012)
    - OMPS Limb Profile Algorithm (12/2012)
  - Data Flow Chart and Maturity Matrix
    - Need guidance on OMPS as new component of CDR and missing sensors
    - Records concentrate on US satellite instruments
- DATA SETS
  - OMPS RDR and SDRs in HDF-5 with good metatdata
  - OMPS Nadir Mapper and Nadir Profiler CDRs will be converted to NetCDF-4
  - OMPS Limb SDRs and EDRs in HDF-5
- SOURCE CODE
  - Well-documented
  - FORTRAN-90 and C++
- CONCERNS (Risks)
  - JPSS and other NOAA funding for Limb R20 and V8Pro implementation at IDPS may be in jeopardy
  - OMPS SDR algorithms require substantial coordination of ancillary data set and calibration tables

CDR Maturity Matrix TOZ

Level	Sensor Use	Code Stability	Metadata & QA	Documentation	Validation	Public Release	Science & Applications	IV&V
1	Research Mission	Significant changes likely	Incomplete	Draft ATBD	Minimal	Limited data availability to develop familiarity	Little or none	
2	Research Mission	Some changes expected	Research grade (extensive)	ATBD Version 1+	Uncertainty estimated for select locations/times	Data available but of unknown accuracy; caveats required for use.	Limited or ongoing	ATBD Review
3	Research Missions	Minimal changes expected	Research grade (extensive); Meets international standards	Public ATBD; Peer-reviewed algorithm and product descriptions	Uncertainty estimated over widely distribute times/location by multiple investigators; Differences understood.	Data available but of unknown accuracy; caveats required for use.	Provisionally used in applications and assessments demonstrating positive value.	NOAA Operations Review
4	Operational Mission	Minimal changes expected	Stable, Allows provenance tracking and reproducibility; Meets international standards	Public ATBD; Draft Operational Algorithm Description (OAD); Peer-reviewed algorithm and product descriptions	Uncertainty estimated over widely distribute times/location by multiple investigators; Differences understood.	Source code released; Data available but of unknown accuracy; caveats required for use.	Provisionally used in applications and assessments demonstrating positive value.	
5	All relevant research and operational missions; unified and coherent record demonstrated across different sensors	Stable and reproducible	Stable, Allows provenance tracking and reproducibility; Meeting international standards	Public ATBD, Operational Algorithm Description (OAD) and Validation Plan; Peer-reviewed algorithm, product and validation articles	Consistent uncertainties estimated over most environmental conditions by multiple investigators	Source code portable and released; Multi-mission record is publicly available with associated uncertainty estimate	Used in various published applications and assessments by different investigators	CDR Certification Review
6	All relevant research and operational missions; unified and coherent record over complete series; record is considered scientifically irrefutable following extensive scrutiny	Stable and reproducible; homogeneous and published error budget	Stable, Allows provenance tracking and reproducibility; Meeting international standards	Product, algorithm, validation, processing and metadata described in peer-reviewed literature	Observation strategy designed to reveal systematic errors through independent cross-checks, open inspection, and continuous interrogation	Source code portable and released; Multi-mission record is publicly available from Long-Term archive	Used in various published applications and assessments by different investigators	

CDR Maturity Matrix Nadir Profile

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2	Research Mission	Some changes expected	Research grade (extensive)	ATBD Version 1+	Uncertainty estimated for select locations/times	Data available but of unknown accuracy; caveats required for use.	Limited or ongoing	ATBD Review
3	Research Missions	Minimal changes expected	Research grade (extensive); Meets international standards	Public ATBD; Peer-reviewed algorithm and product descriptions	Uncertainty estimated over widely distribute times/location by multiple investigators; Differences understood.	Data available but of unknown accuracy; caveats required for use.	Provisionally used in applications and assessments demonstrating positive value.	NOAA Operations Review
4	Operational Mission	Minimal changes expected	Stable, Allows provenance tracking and reproducibility; Meets international standards	Public ATBD; Draft Operational Algorithm Description (OAD); Peer-reviewed algorithm and product descriptions	Uncertainty estimated over widely distribute times/location by multiple investigators; Differences understood.	Source code released; Data available but of unknown accuracy; caveats required for use.	Provisionally used in applications and assessments demonstrating positive value.	
5	All relevant research and operational missions; unified and coherent record demonstrated across different sensors	Stable and reproducible	Stable, Allows provenance tracking and reproducibility; Meeting international standards	Public ATBD, Operational Algorithm Description (OAD) and Validation Plan; Peer-reviewed algorithm, product and validation articles	Consistent uncertainties estimated over most environmental conditions by multiple investigators	Source code portable and released; Multi-mission record is publicly available with associated uncertainty estimate	Used in various published applications and assessments by different investigators	CDR Certification Review
6	All relevant research and operational missions; unified and coherent record over complete series; record is considered scientifically irrefutable following extensive scrutiny	Stable and reproducible; homogeneous and published error budget	Stable, Allows provenance tracking and reproducibility; Meeting international standards	Product, algorithm, validation, processing and metadata described in peer-reviewed literature	Observation strategy designed to reveal systematic errors through independent cross-checks, open inspection, and continuous interrogation	Source code portable and released; Multi-mission record is publicly available from Long-Term archive	Used in various published applications and assessments by different investigators	

CDR Maturity Matrix Limb Profile

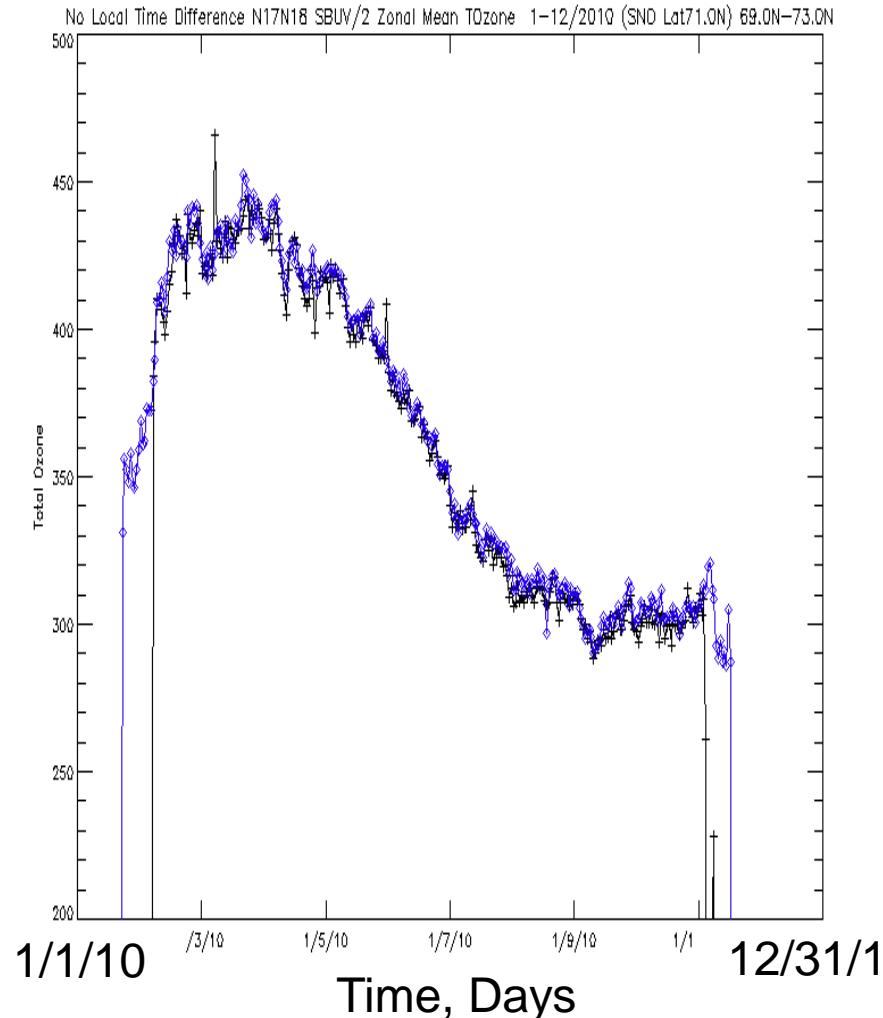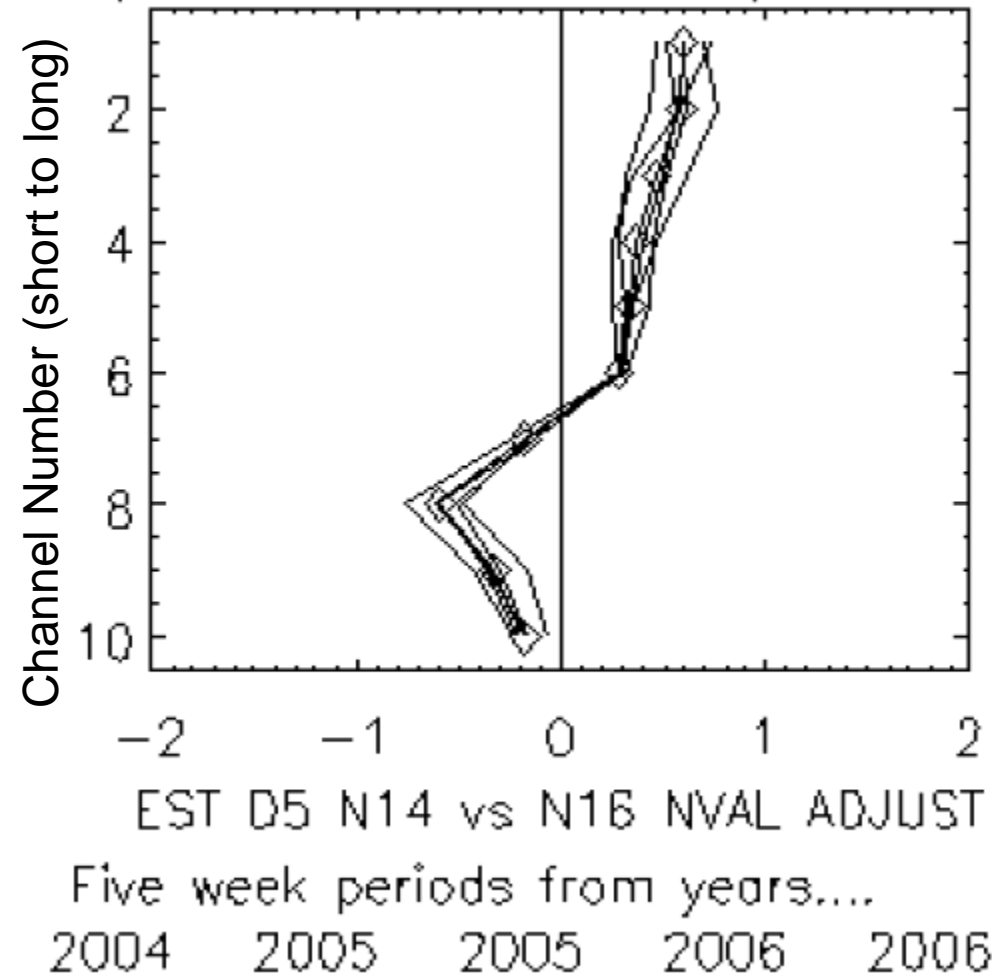| Level	Sensor Use	Code Stability	Metadata & QA	Documentation	Validation	Public Release	Science & Applications	IV&V
1	Research Mission	Significant changes likely	Incomplete	Draft ATBD	Minimal	Limited data availability to develop familiarity	Little or none	
2	Research Mission	Some changes expected	Research grade (extensive)	ATBD Version 1+	Uncertainty estimated for select locations/times	Data available but of unknown accuracy; caveats required for use.	Limited or ongoing	ATBD Review
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Resources

- Programmer/analysts 2.5 for next 17 Months
- Equipment
  - V8 algorithms on LINUX workstation cluster
  - OMPS NM & NP SDR on ADL (Scalable/hostable)
  - OMPS LP on PEATE Clone (Scalable LINUX workstations)
- Collaborating Projects
  - NASA NPP ST OMPS LP Development (D. Rault)
  - NASA Ozone Measures (R. McPeters)
  - NPP OMPS LP R2O (L. Flynn)
  - JPSS OMPS SDR Cal/Val (X. Wu)
  - JPSS OMPS Product Cal/Val (L. Flynn)
  - NOAA/NESDIS/STAR ICVS (F. Weng)
- NOAA POCs
  - NOAA/NWS/NCEP C. Long
  - NOAA/ERSL I. Petropavlovskikh
- Target NOAA Data Center – NCDC/CLASS

Backup

ABS(N14 TOTAL — N16 TOTAL) < 2.5DU

Channel Number (short to long)

EST D5 N14 vs N16 NVAL ADJUST

Five week periods from years....
2004   2005   2005   2006   2006

No Local Time Difference N17N18 SBUV/2 Zonal Mean TOzone 1–12/2010 (SNO Lat71.0N) 69.0N–73.0N

Total Ozone

1/1/10   12/31/1

Time, Days
Black N-17 SBUV/2
Blue N-18 SBUV/2

Can be combined with measurement contribution functions to return expected ozone profile differences. Figure from S. Taylor SSAI.

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Nadir Mapper & Profiler
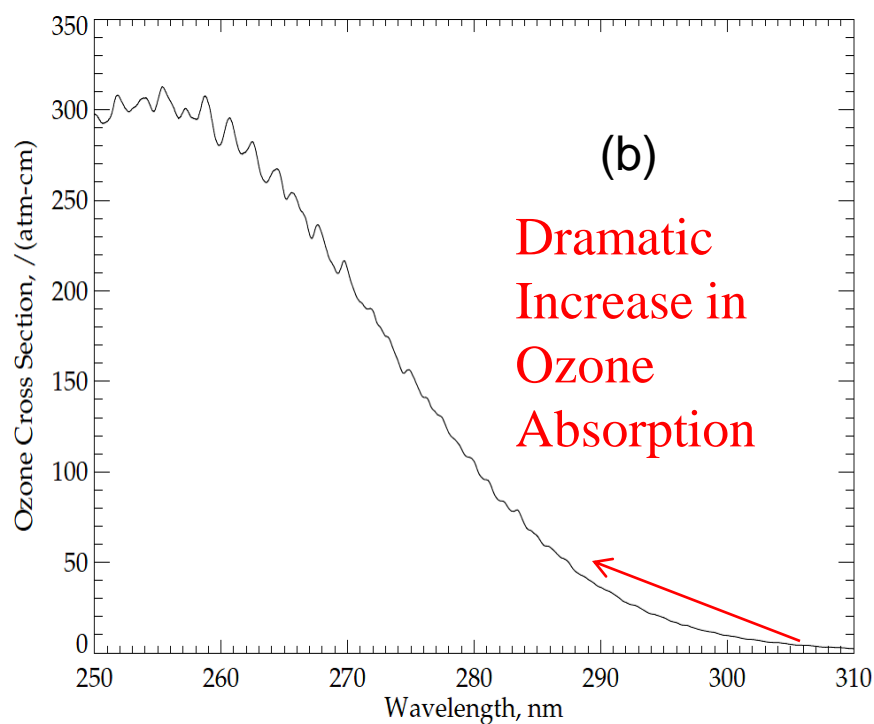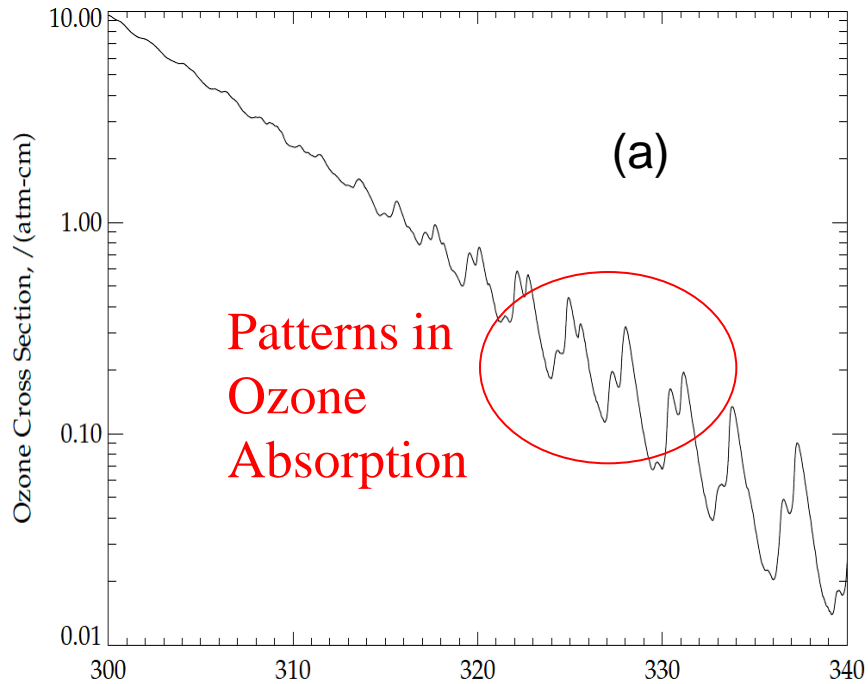
Main Electronics

Limb Profiler
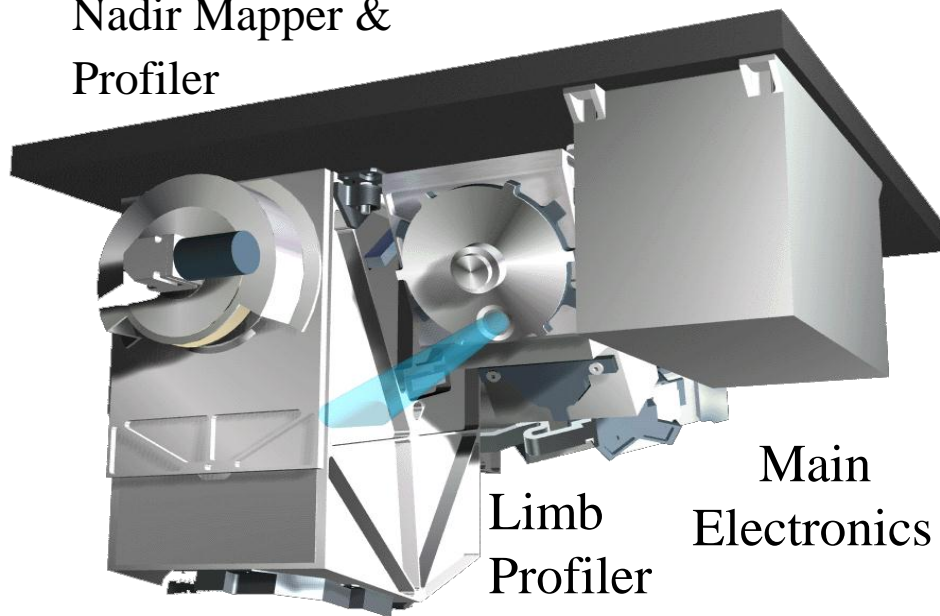
Diagram from Ball Aerospace and Technology Corporation
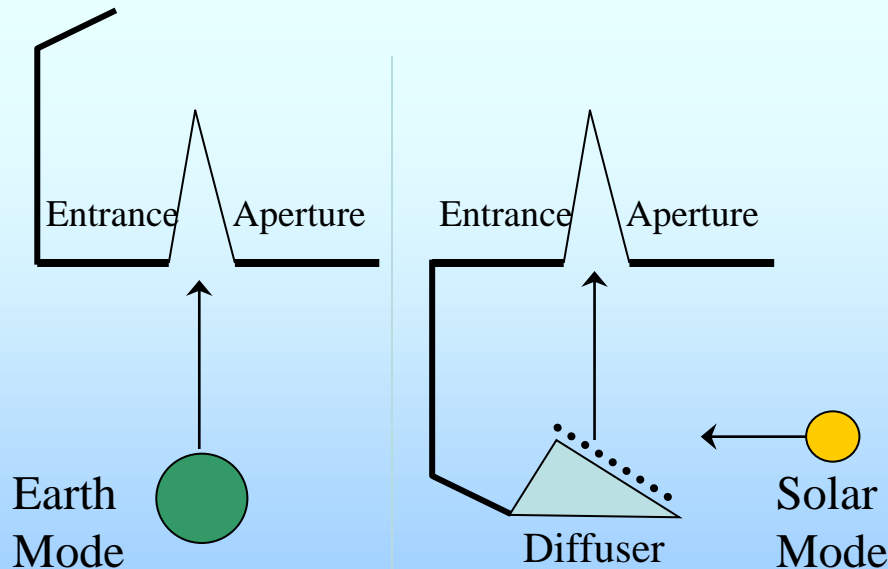
The instruments measure radiance scattered from the Earth's atmosphere and surface. They also make solar measurements using pairs of diffusers. Judicious operation of working and reference diffusers allows analysts to track the diffuser degradation. The solar measurements also provide checks on the wavelength scale and bandpass. The instruments have completed multiple passes through their internal dark and nonlinearity calibration sequences and are beginning to make regular solar measurements.

Entrance   Aperture

Entrance   Aperture

Earth Mode

Diffuser

Solar Mode

Each instrument can view the Earth or either of two solar diffusers; a working and a reference.

(a) Patterns in Ozone Absorption

(b) Dramatic Increase in Ozone Absorption

Ozone Absorption Cross Sections: Ozone has four main absorption bands in the ultraviolet, visible and near-infrared as follows: the Hartley bands from 200 nm to 310 nm, the Huggins bands from 310 nm to 380 nm, the Chappuis bands from 400 nm to 650 nm, and the Wulf bands from 600 nm to 1100 nm. The OMPS nadir telescope directs photons to two spectrometers, one with a wide, cross-track field-of-view (FOV) and spectral coverage in the Huggins ozone absorption bands, and the other with a smaller, nadir FOV and spectral coverage in the Hartley ozone absorption bands. Figures (a) and (b) show the ozone absorption cross-sections at a nominal atmospheric temperature for parts of these bands. These cross-sections are for -50ºC as estimated from a quadratic fit in temperature of the Brion-Daumont-Malicet data set.

OMPS Nadir Mapper Spectra

- The plot at the top of the following slide shows a sample OMPS Nadir Mapper solar spectrum measured in January. The initial calibration, goniometry and wavelengths scales have been applied. Notice the Fraunhofer lines, e.g., a deep one near 360 nm.

- The plot in the middle shows a sample spectrum for the Earth View data for the nadir field-of view.

- The plot on the bottom shows the ratio of the first two spectra. Notice that much of the structure in the solar spectrum cancels out in the ration. Also notice the variations between 320 and 330 nm produced by differential ozone absorption with wavelength as illustrated in the Figure (a) from two slides earlier.

Typical spectra from 310 to 380 nm for OMPS Nadir Mapper
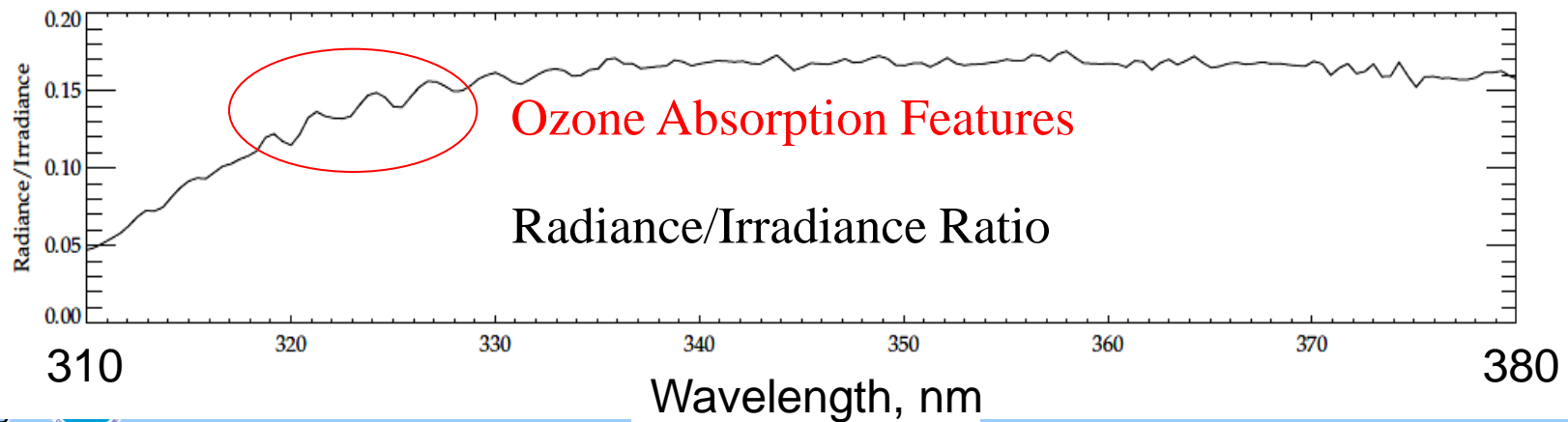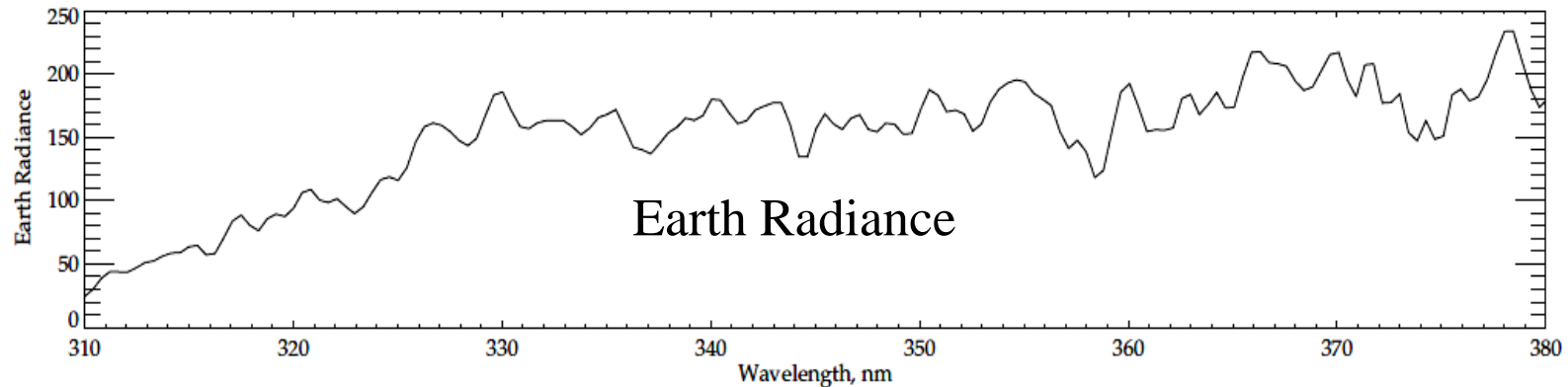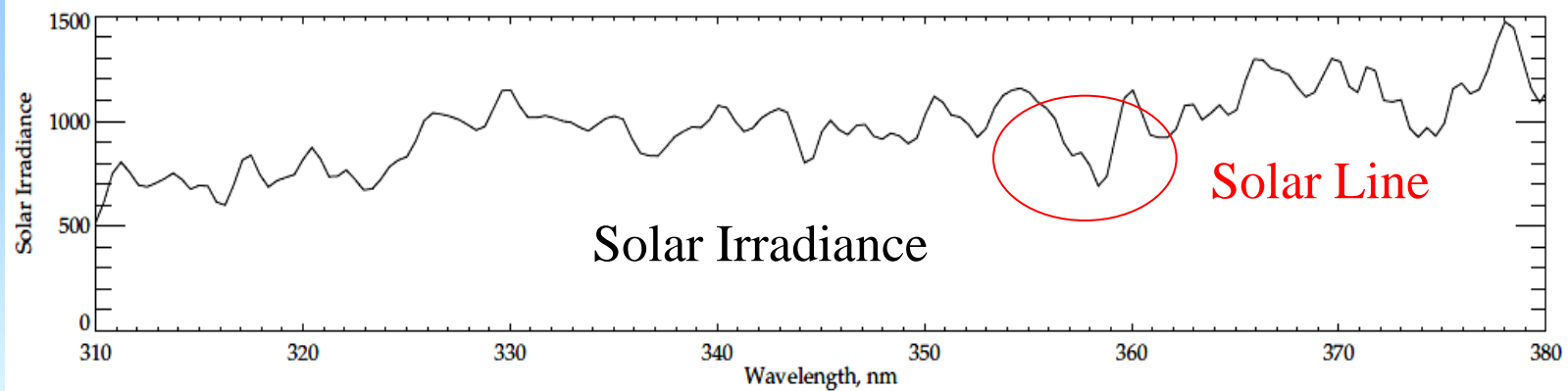
OMPS Nadir Profiler Spectra

- The plot at the top of the following slide shows a synthetic OMPS Nadir Profiler solar spectrum measured currently in use. The spectrum was created by combining the laboratory bandpass characterization with a high spectral resolution reference solar spectrum. Notice the Fraunhofer lines, e.g., a deep Mg one near 280 nm.

- The plot in the middle shows a sample spectrum for the Earth View data. The initial calibration, goniometry and wavelengths scales have been applied.

- The plot on the bottom shows the ratio of the first two spectra. Notice that much of the structure in the solar spectrum cancels out in the ration. Also notice the rapid drop in albedo from 310 nm to 290 nm produced by differential ozone absorption with wavelength as illustrated in the Figure (b) from four slides earlier.

Typical spectra from 250 to 310 nm for OMPS Nadir Profiler