



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

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# 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

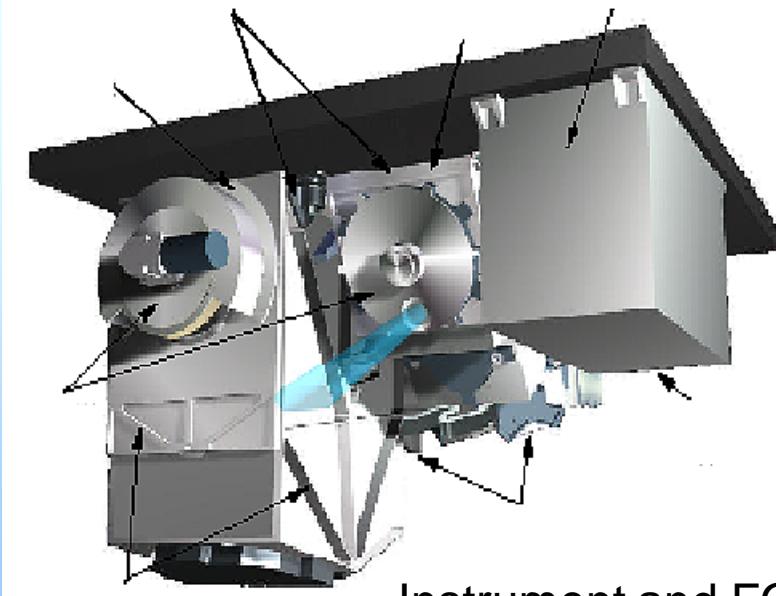
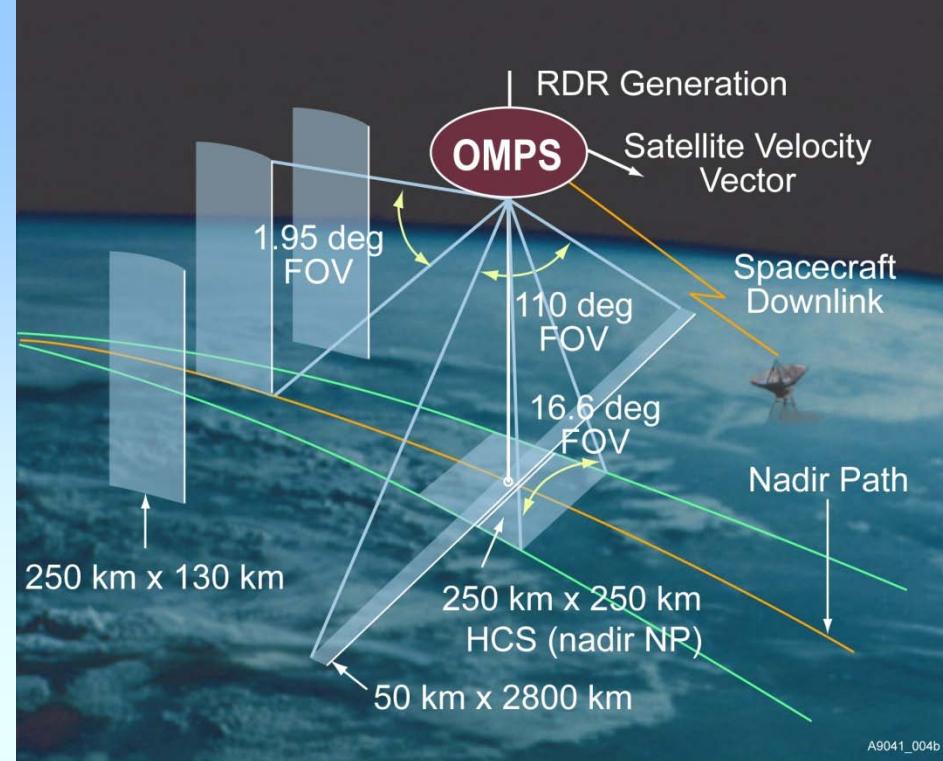
UV/Visible Limb Scatter, prism, 2-D CCD array

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.



# Outline

- Brief Project Overview
- Approach
- Results/Accomplishments
- Validation Strategy/Results
- Algorithm/Product Maturity
- Issues/Risks & Work-Off Plans
- Schedule
- Transition Plan
- Societal Benefits
- Resources

# 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

# Approach

- OMPS Nadir Mapper & Nadir Profiler
  - Linux ADL implementation of IDPS SDR algorithms
  - Linux Implementation of Version 8 total ozone and ozone profile algorithms
- OMPS Limb Profiler
  - Linux implementation of NPP SDR algorithms
  - Linux implementation of NPP ozone profile algorithms

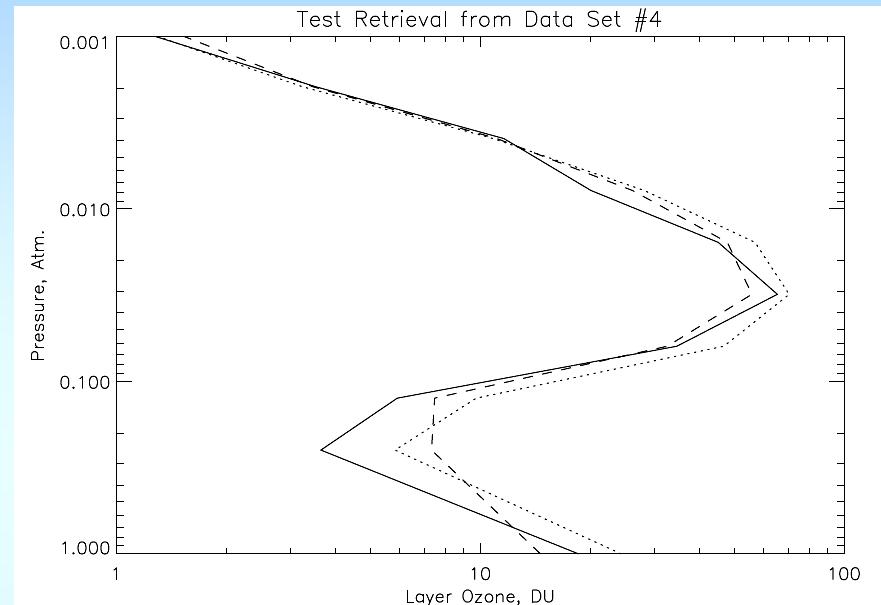
# Results/Accomplishments (1)

- 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.



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 radiative 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

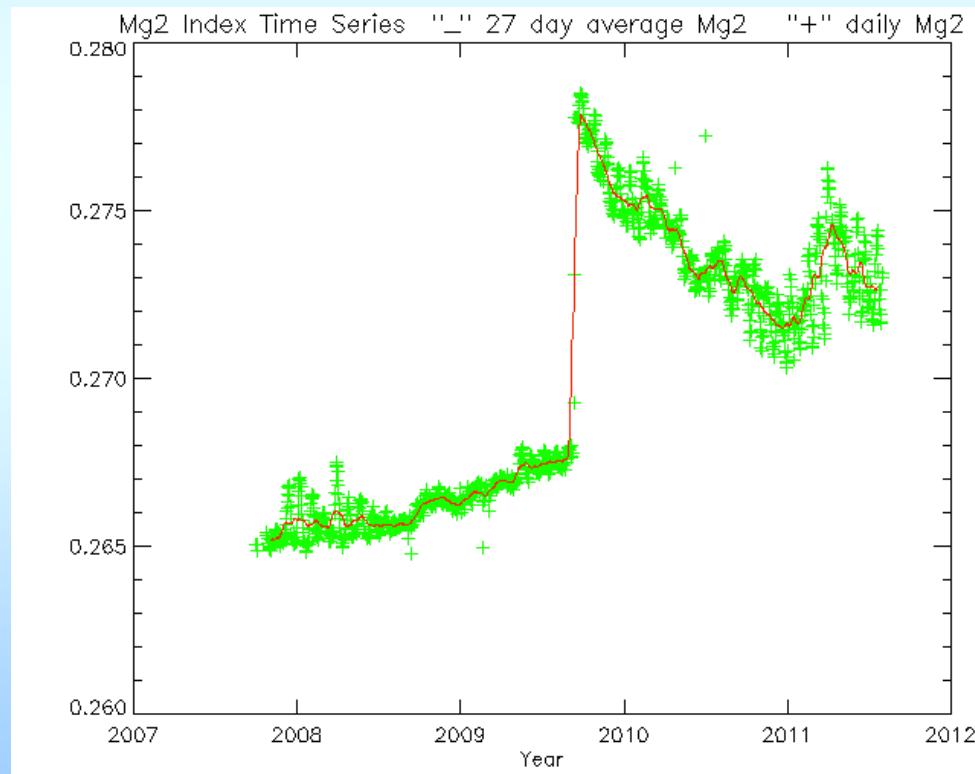
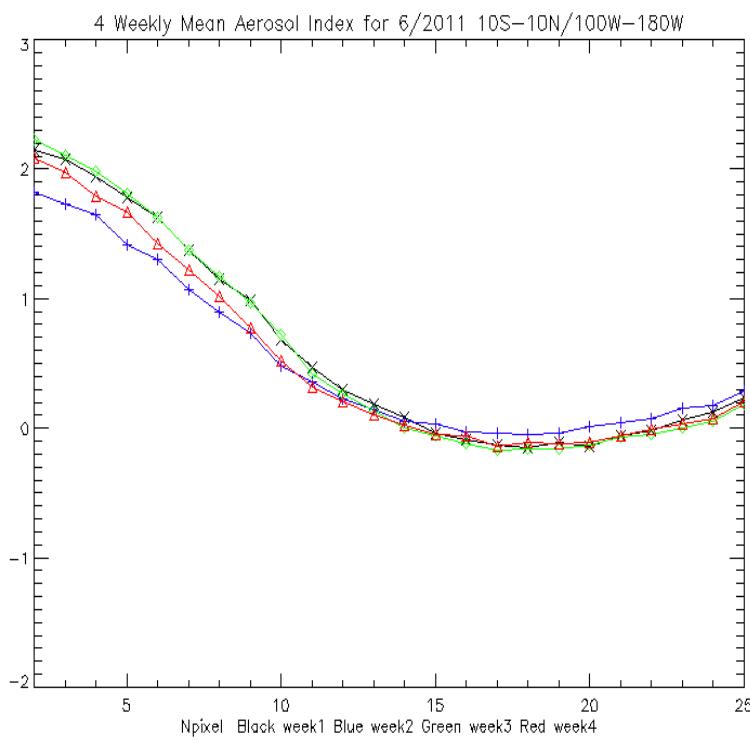
- Two Algorithm Development Library versions (ADL 2.0 and ADL 3.0 Beta) have been hosted on STAR Linux workstations
- Tests runs of OMPS NP/NM SDR algorithms match IDPS generated samples
- Some coding errors have been identified and reported back to the JPSS program
- OMPS SDR algorithms will be exercised 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 metadata
  - 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
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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

Level	Sensor Use	Code Stability	Metadata & QA	Documentation	Validation	Public Release	Science & Applications	IV&V
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# CDR Maturity Matrix Limb Profile

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# 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/](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/](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

# 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**

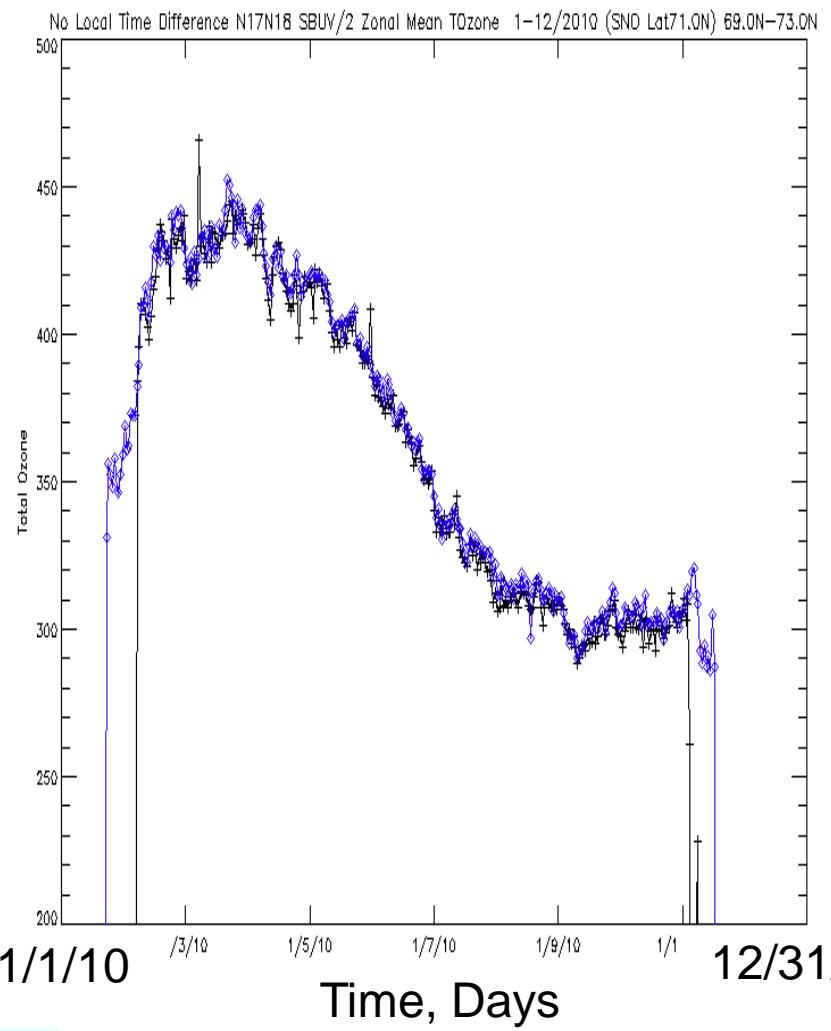
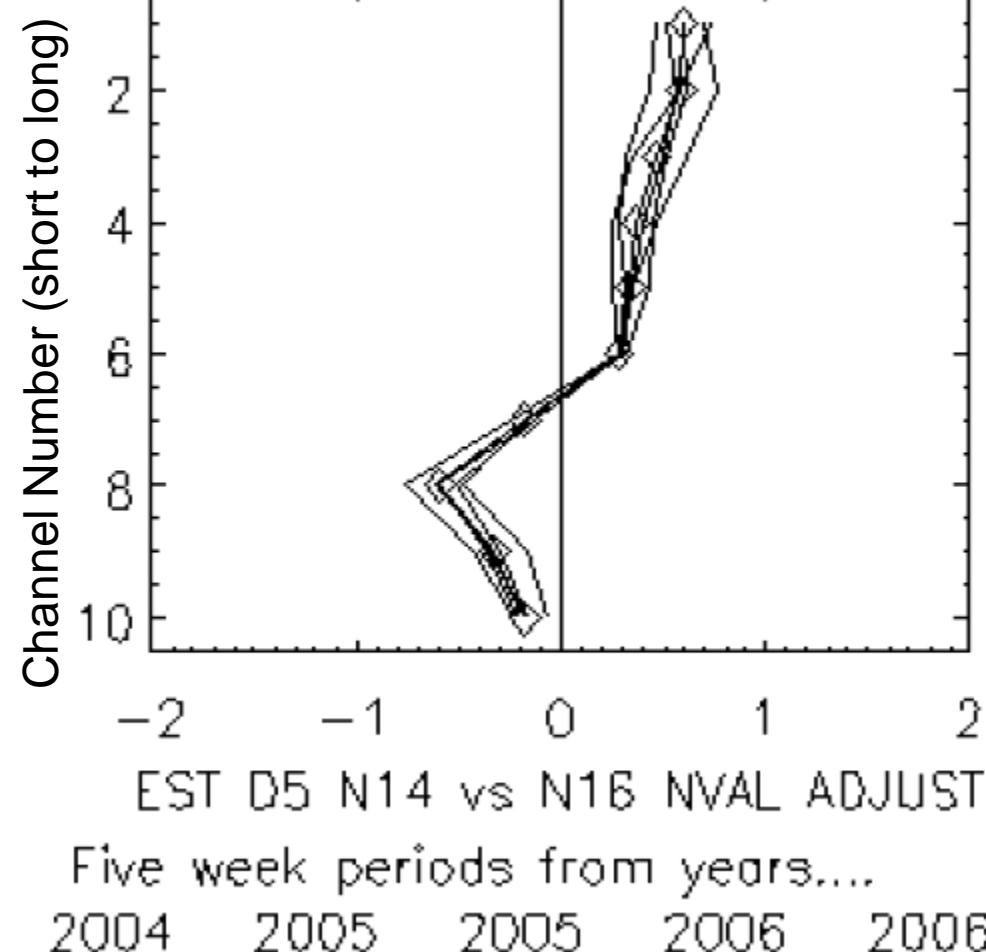
- The Montreal Protocol and the onset of ozone recovery are both a cautionary tale and a success story for global atmospheric change. On the one hand we have a dramatic demonstration of humankind's ability to alter the atmosphere all over the world; Antarctica is not a source of CFCs and yet the ozone 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.

# 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

$\text{ABS}(\text{N14 TOTAL} - \text{N16 TOTAL}) < 2.5\text{DU}$



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.