STAR JPSS Annual Science Team Meeting
Session 5e: Ozone EDR

Potential Use of OMPS Nadir Mapper to provide aerosol information

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May 14, 2014

Importance of global measurements of aerosol absorption

Climate Effects:

Aerosol absorption contributes to the current levels of uncertainty associated with the direct and indirect effects of aerosols.

Aerosol absorption is THE ONLY FACTOR responsible for the current level of uncertainty of the semi-direct effect ('burning' of clouds).

In addition to the radiative impact, aerosol absorption is also associated with perturbations to the hydrological cycle as recently shown by research results (Lau et al, GRL,2006; Koren et al Science, 2004).

Aerosol absorption has also important non-climate effects:

-Attenuation of harmful surface UV-A and UV-B radiation
-Local, regional, and global air pollution
-Fertilization of the global ocean (Iron flux from desert dust and other sources)
-Heterogeneous tropospheric chemistry and photochemistry
-Interference in trace gas retrieval

Aerosol Absorption Parameters

Complex refractive index (composition)
$m = n - ik$ (wavelength dependent)

↓

Particle Scattering Theory

↓

-Scattering, Absorption and Extinction coefficients

σ_{sca} , σ_{abs}, $\sigma_{ext} = \sigma_{sca} + \sigma_{abs}$

-Single Scattering Albedo $\omega_0 = \sigma_{sca} / (\sigma_{sca} + \sigma_{abs})$

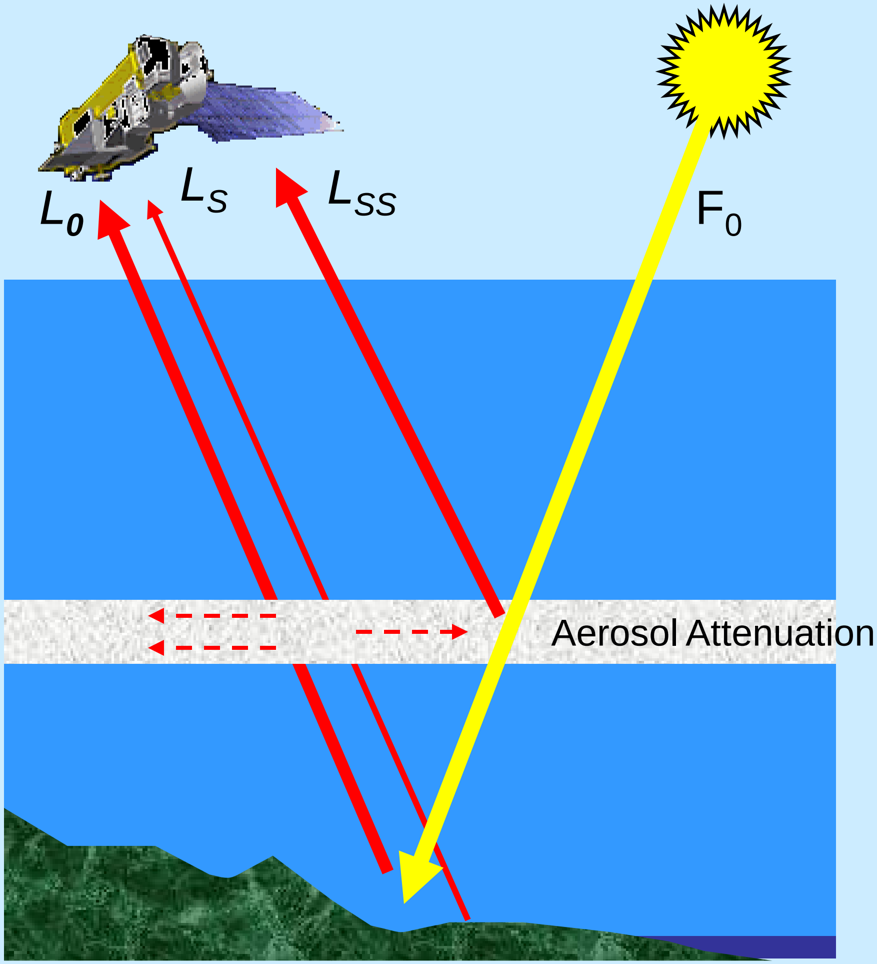
↓

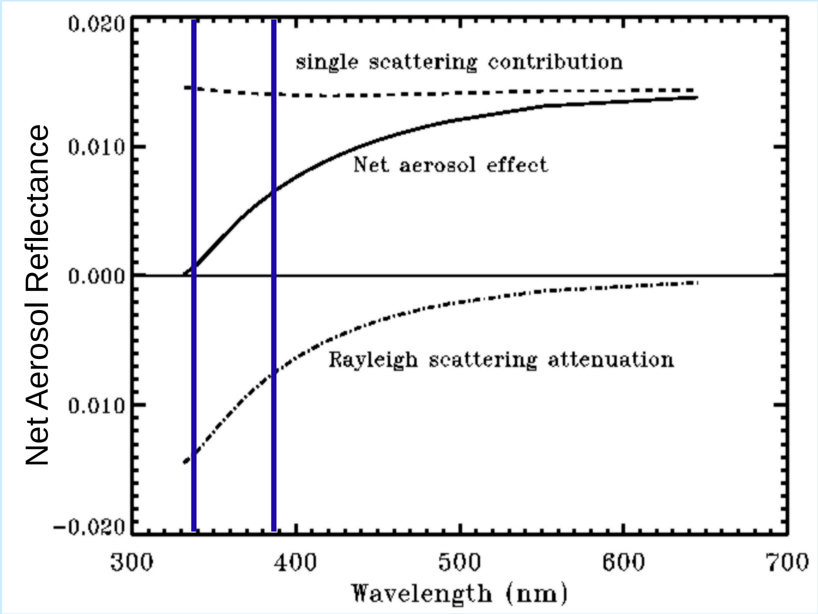
-Column Integrated Properties

Extinction Optical Depth, τ_{ext}

Absorption Optical Depth, $\tau_{abs} = \tau_{ext}(1-\omega_0)$

Measuring Aerosol Absorption from space: The near-UV method





Sensitivity to Aerosol Absorption

$$L_{aer} \approx \frac{\omega_0 P(\Theta)\pi F_0}{4\pi}\frac{\mu_0}{\mu_0+\mu}[1-e^{-\tau(1/\mu+1/\mu_0)}]+[L_0+L_s][e^{-(1-w_0)\tau(1/\mu+1/\mu_0)}-1]+......$$

Rayleigh scattering attenuation by particle absorption is the physical basis of aerosol absorption remote sensing in the UV

Absorbing Aerosol Index Calculation

For a given viewing geometry, measurements at two wavelengths in the range 330-390 nm are used in the near UV aerosol absorption algorithm:

Step 1: Use satellite measurements at longer wavelength (λ_0) to calculate scene Lambert Equivalent Reflectivity

$$R_{\lambda_0} = \frac{L_{\lambda_0}^{meas} - L_{\lambda_0}^{atm}}{T_{\lambda_0} + S_{\lambda_0}[L_{\lambda_0}^{meas} - L_{\lambda_0}^{atm}]}$$

T (*two-way atmospheric transmittance*) and *S* (*spherical albedo*)are obtained from Rayleigh scattering radiative transfer calculations.

Step 2: Assume R is wavelength independent to calculate L_λ at shorter wavelength

$$L_\lambda = L_\lambda^{atm} + \frac{R_{\lambda_0} T_\lambda}{1 - S_\lambda R_{\lambda_0}}$$

Step 3: Use measured L_λ to calculate the residual quantity

$$r_\lambda = -100 \left\{ \log \left[\frac{L_\lambda}{L_{\lambda_0}} \right]_{meas} - \log \left[\frac{L_\lambda(R_{\lambda_0})}{L_{\lambda_0}(R_{\lambda_0})} \right]_{calc} \right\} = -100 \log \left\{ \frac{[L_\lambda]_{meas}}{[L_\lambda(R_{\lambda_0})]_{calc}} \right\}$$

Generally, *λ= 340 nm and λ_0 = 380 nm*

Absorbing Aerosol Index Properties

For a well calibrated sensor the residual quantity r_λ is a measure of the observed change in spectral dependence with respect to that of a purely molecular atmosphere.

Observed non-zero residuals are due to geophysical effects such as:

-Aerosol absorption and scattering
-Ocean color effects (pure water absorption, Chlorophyll and CDOM absorption)
-Sun glint effects (specular reflection)
-Wavelength-dependent surface albedo

Because most of the observed residuals are associated with aerosol effects, r_λ is commonly referred to as Aerosol Index (AI)

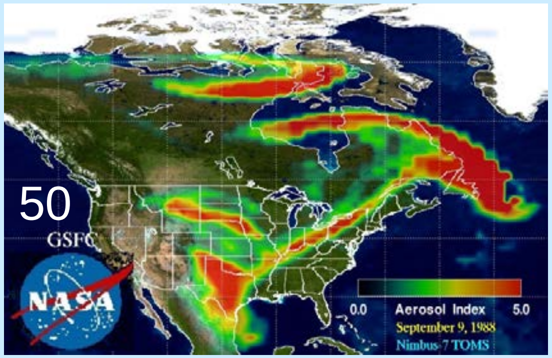
- The magnitude of AI depends mainly on aerosol optical depth (AOD), aerosol single scattering albedo (SSA), and aerosol layer height (ALH).
- The AI is a unique Identifier of absorbing aerosols: smoke plumes, desert dust, volcanic ash
- Works over all land and ocean surfaces (even over deserts).
- Detects absorbing aerosols mixed with and above clouds
- Detects absorbing aerosols above ice and snow

The AI's coarse spatial resolution (20 to 50 km) limits its quantitative interpretation in terms of physically meaningful parameters.

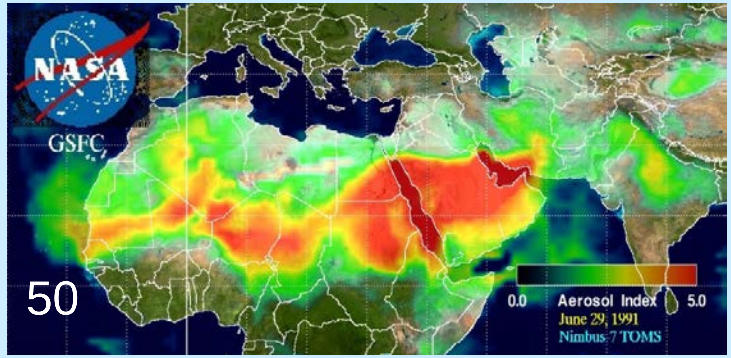
Absorbing Aerosol Index Record

Thirty five years (1979 – present, a few gaps)

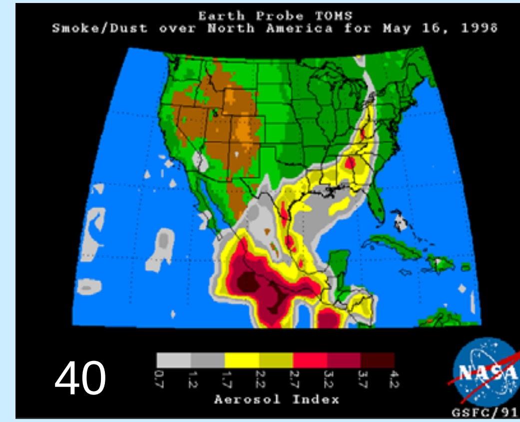
Nine sensors: N7-TOMS, M3-TOMS, EP-TOMS, AD-TOMS, GOME, OMI, GOME-2, SCIAMACHY, OMPS



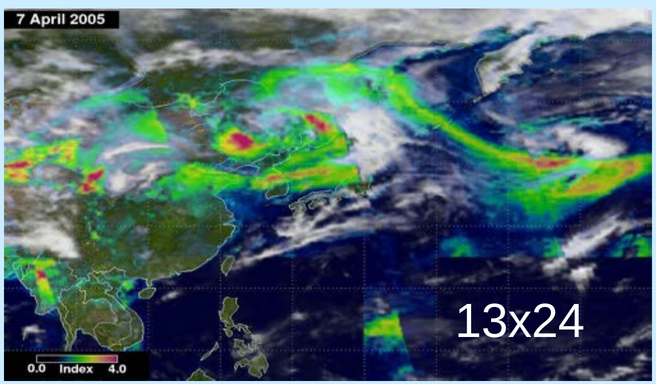
Yellowstone National Park Fires, Nimbus7-TOMS, Sept.9, 1988.



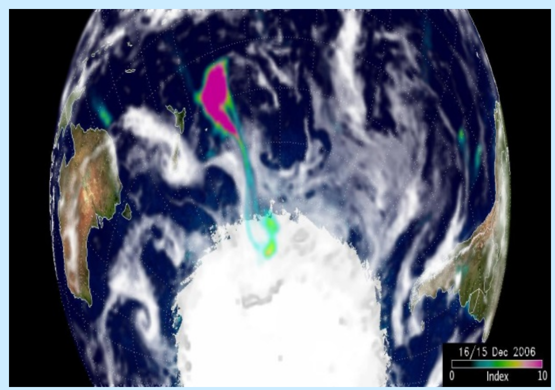
Kuwaiti Oil Fires Smoke layer as seen by Nimbus7-TOMS on June 29, 1991.



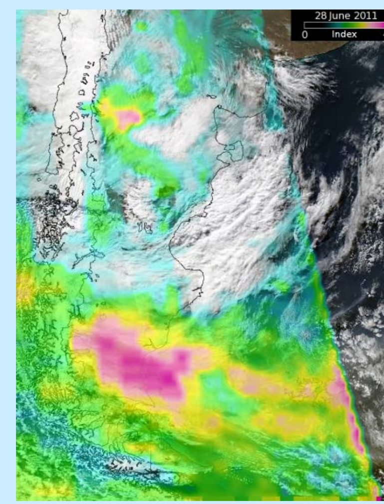
Smoke layer from fires in Mexico Earth Probe-TOMS, May 16,1998



OMI detection of long-range transport of Asian desert dust (April 7, 2005).



OMI image of high altitude smoke plume from Australian brush fires on Dec 15/16, 2006.



Ash layer, Puyehue eruption. OMI, June 28, 2011

OMPS UV Aerosol Index

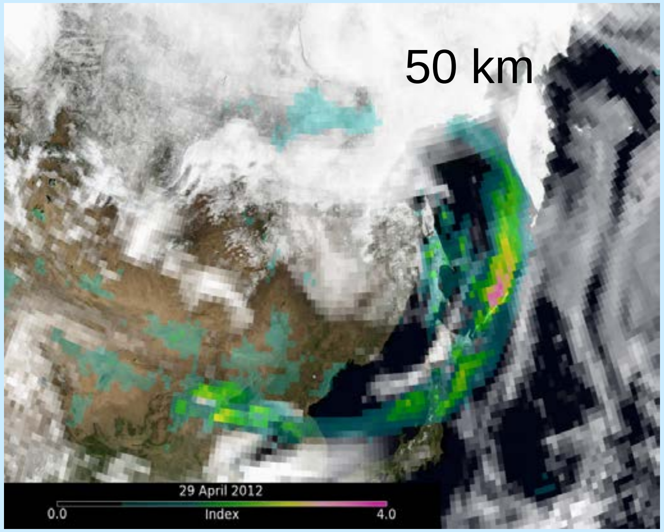
-OMPS native pixel size at nadir is about 3km across track and 12 km along track.

-Onboard averaging takes place to produce 50X50 km macro-pixels.

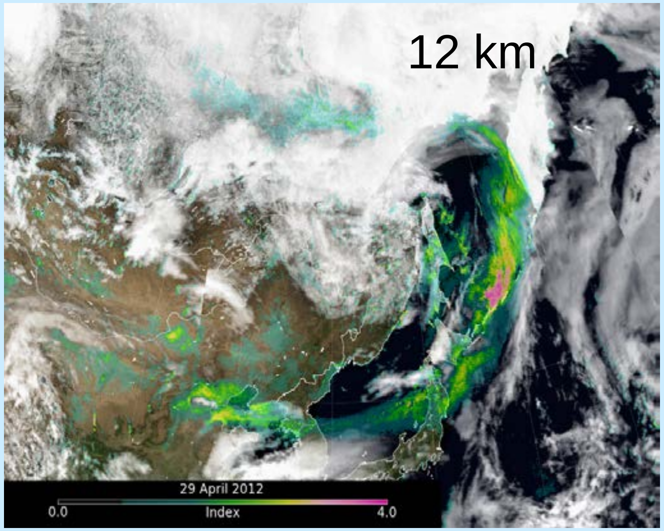
-Currently, observations at selected wavelengths (including 340, 380 nm) are brought down at native resolution once-per week.

Aerosol Index is currently available (50x50 km) from OMPS measurements as a by-product of the Total Ozone EDR.

Asian desert dust above clouds, April 20, 2012



50 km Standard OMPS resolution

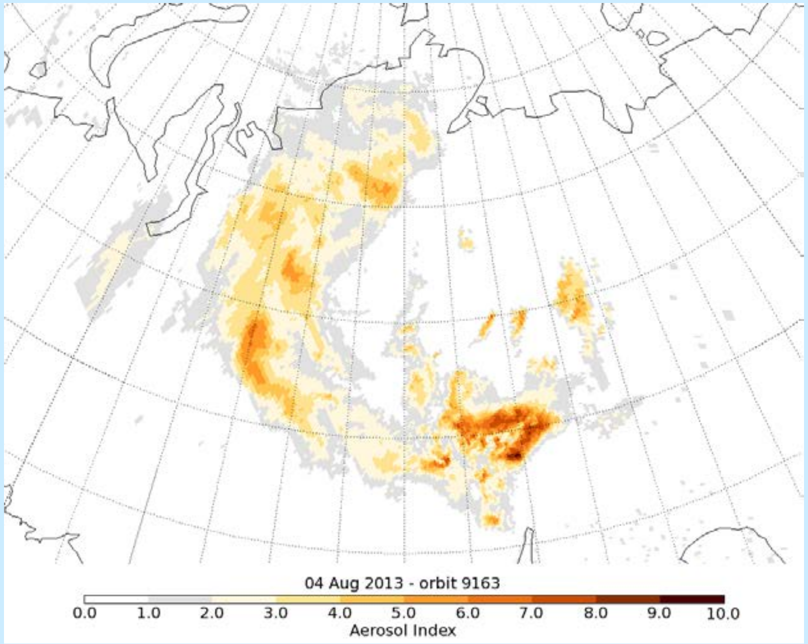


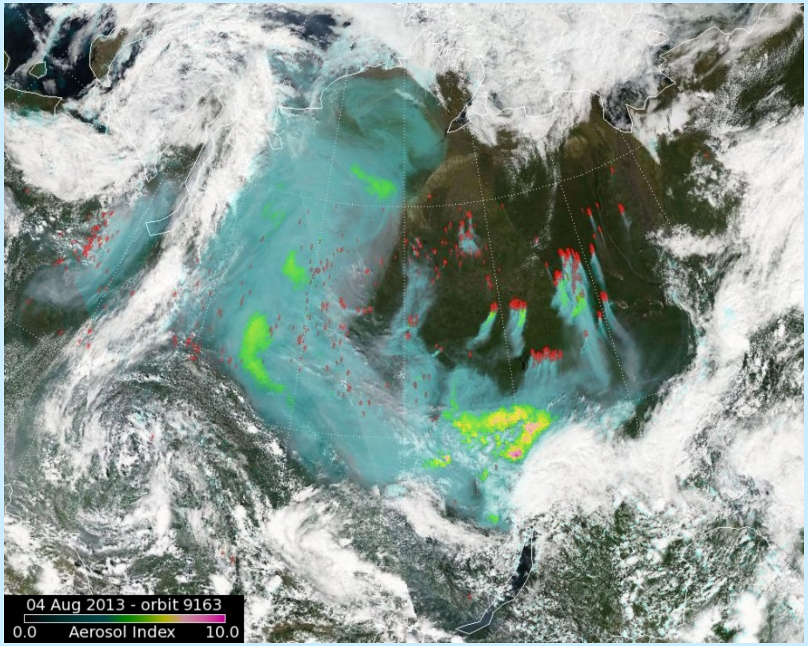
12 km once-a-week, product

Courtesy of Colin Seftor/SSAI

High Resolution OMPS Aerosol Index

Wild fires over Russia on August 4, 2013





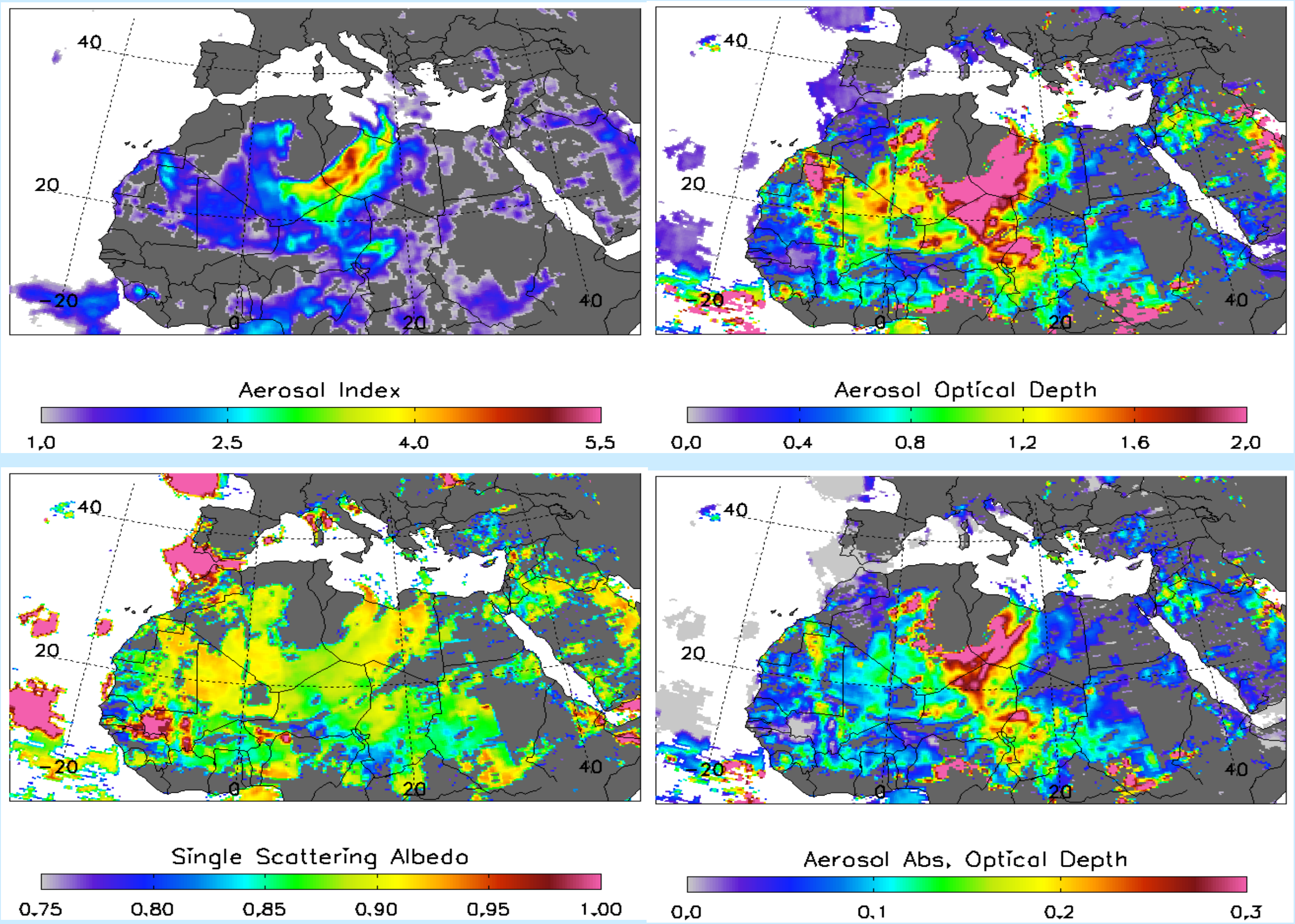
- Never seen before level of detail in AI imagery
- Individual smoke plumes can be resolved
- It would facilitate quantitative interpretation (AAOD, SSA)

Courtesy of Colin Seftor/SSAI

From qualitative to quantitative aerosol absorption information

Aerosol Single Scattering Albedo and Optical Depth can be simultaneously retrieved.

(Height of absorbing aerosol layer must be prescribed)



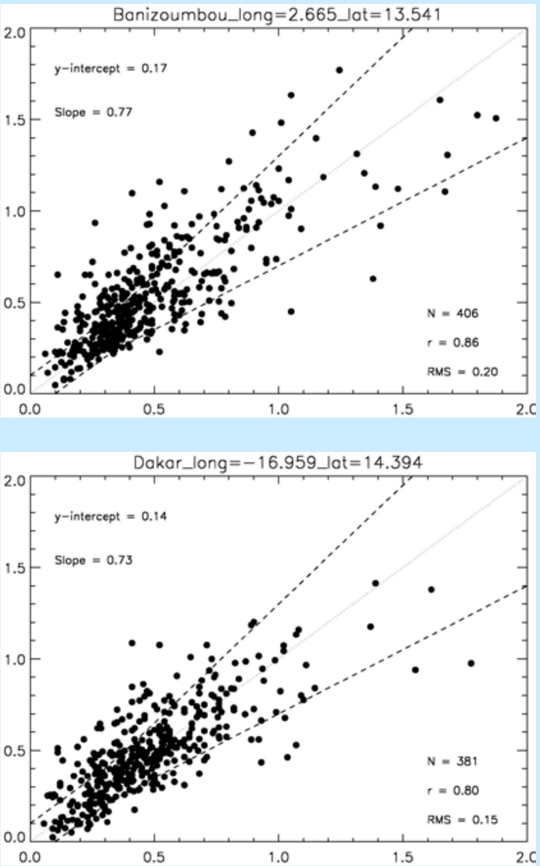
OMI Retrieved Dust Properties (March 9-2007)

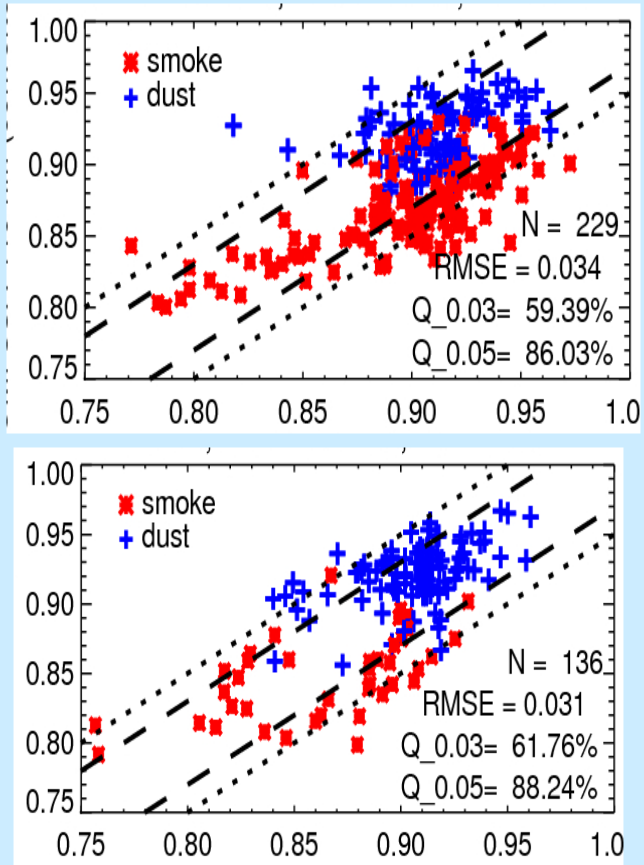
Assessment of OMI Aerosol Retrievals

Aerosol Optical Depth

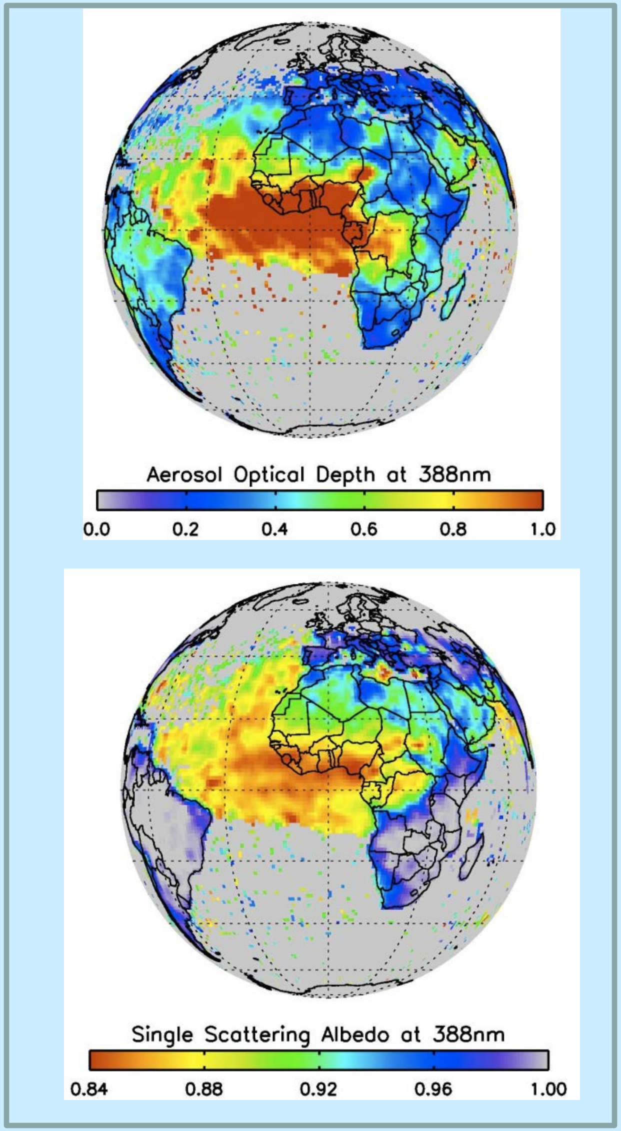
Single Scattering Albedo

OMI Retrieval





AERONET Measurement

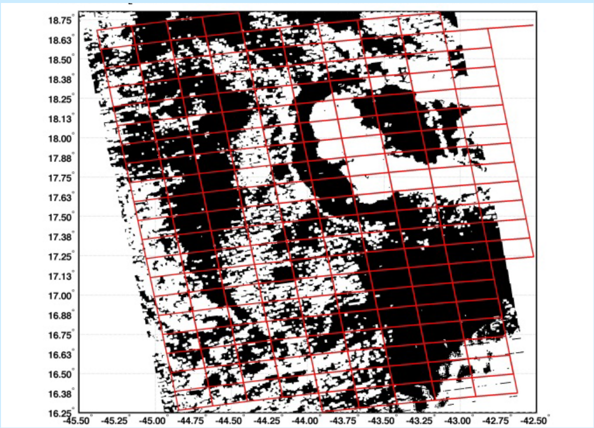


January 2007, Monthly Mean

Aerosol Characterization Combining near UV and Visible Satellite Observations

-For the first time near UV (OMPS) and high resolution visible and near IR observations (VIIRS) are available from the same platform.

-VIIRS high resolution observations can provide information on sub-pixel cloud presence in the larger OMPS field of view.



Aqua-MODIS cloud mask overlaid on OMI pixels (red rectangles)

-VIIRS derived AOD can be used as input to an OMPS near UV algorithm to derive SSA and ALH.

-A retrieval algorithm using near UV and visible radiances Can be developed (large difference in pixel size is a problem

-Work on the combined use of Aqua-MODIS and OMI observations is underway.

-A proposal on the combined use of VIIRS and OMPS has been submitted to the recent SNPP Science Team call.

Conclusions and Recommendations

- OMPS Near-UV observations can be used to extend the long term AI record.

- Daily Aerosol Index and retrieved AOD and SSA can be obtained from OMPS at a higher spatial resolution than currently done.

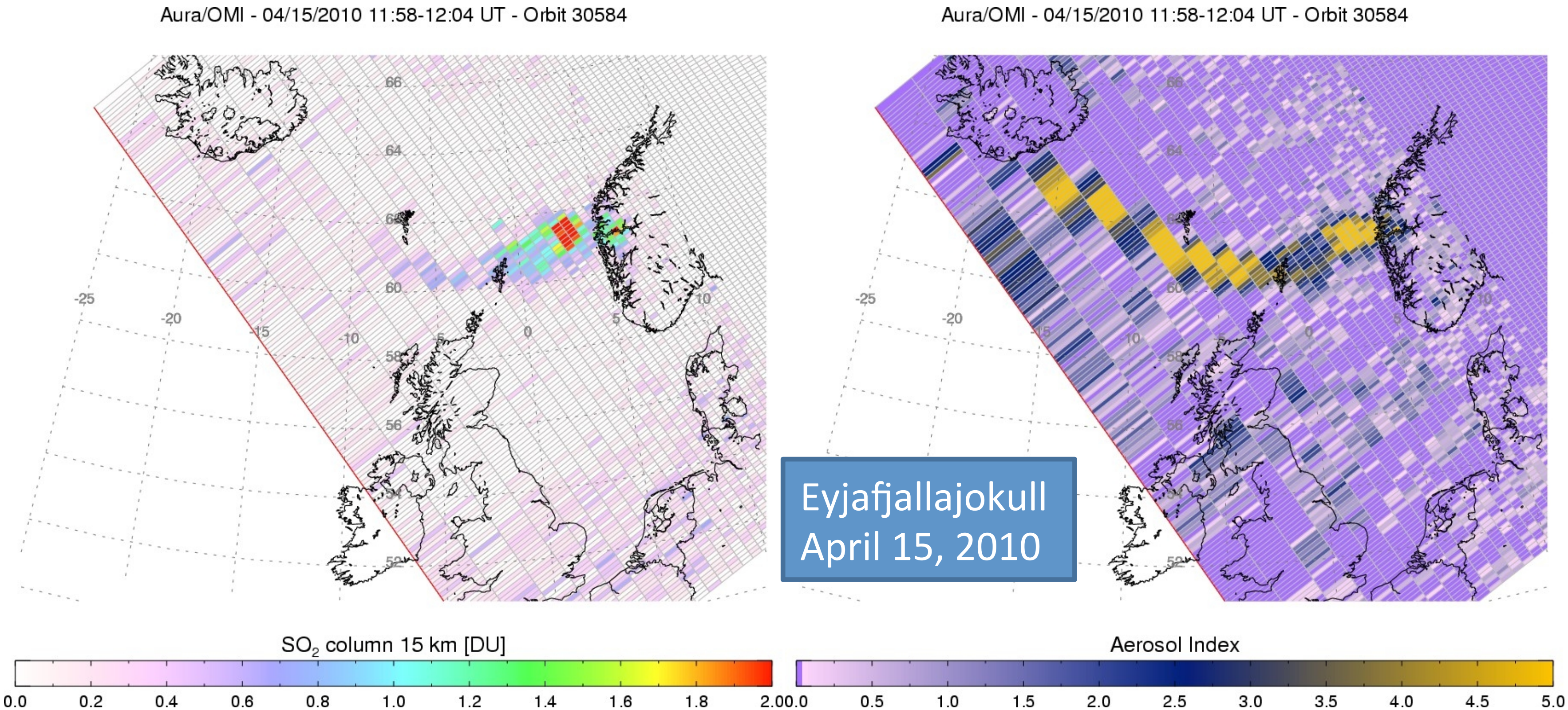
- A 3X12 km spatial resolution at two near-UV channels is recommended for retrieval of aerosol properties from OMPS observations.

- The combination of OMPS and VIIRS observations present a great opportunity for more accurate retrieval of aerosol properties (AOD and SSA).

Linear Fit SO_2 Retrieval Algorithm with TOMS V8 Total O_3

Kai Yang UMCP

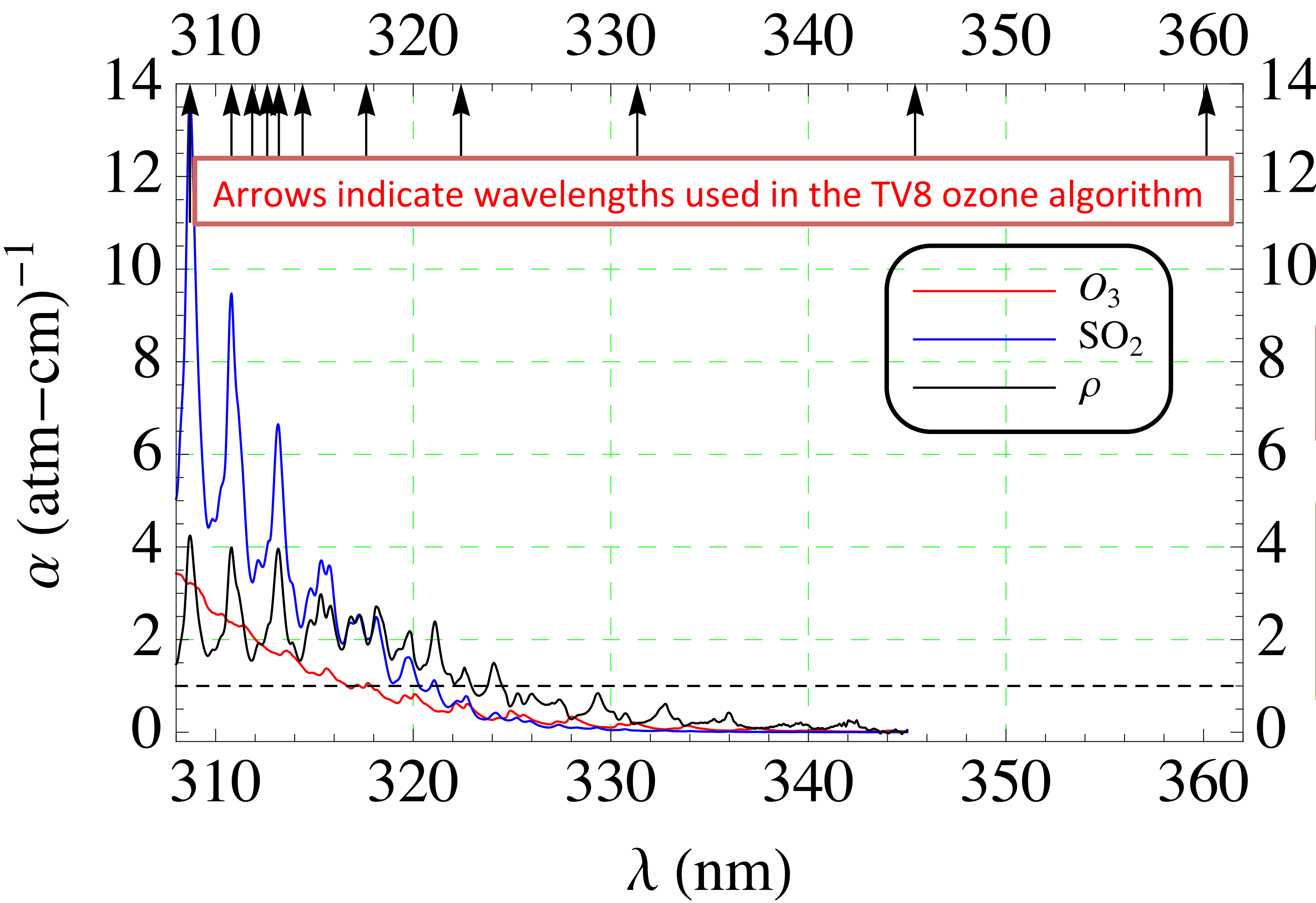
Simon Carn MTU



Outline

- Algorithm Basis
- V8 Total O_3 and Linear Fit (LF) SO_2 Retrieval
- SO_2 Retrieval Sensitivity
- Limitation and Mitigation
- Radiance Residual Correction
- OMPS LF SO_2
- Unexpected achievements from OMPS

O_3 and SO_2 Absorptions in UV



$\rho=\alpha_{so2}/\alpha_{o3}$

@ 317.62 nm
1 DU SO_2 ->
~ 2 DU O_3 Error

Linear Fit SO_2 Algorithm

Basic idea: Minimization between measured (I_{obs}) and modeled (I) radiance measurements.

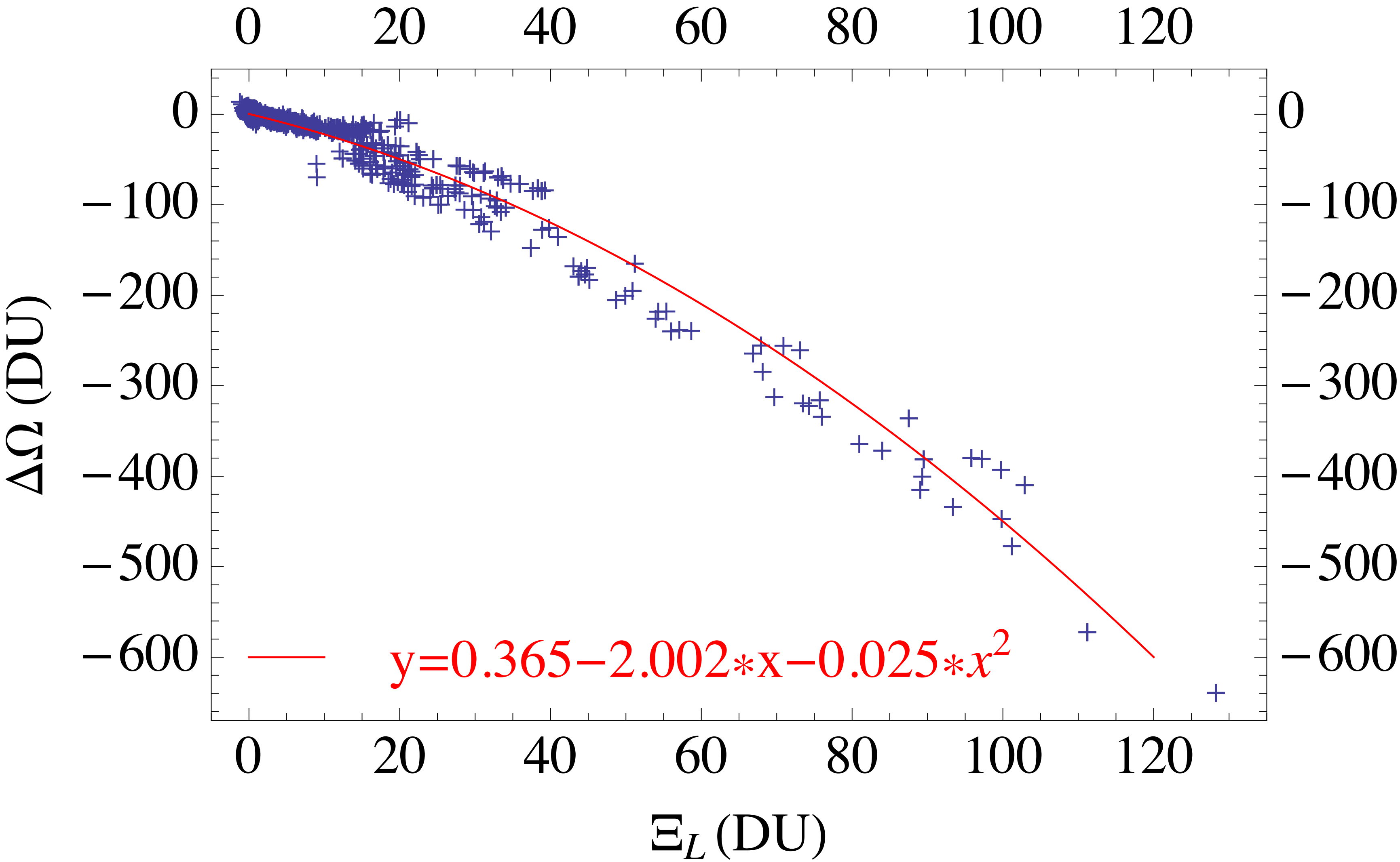
Algorithm Steps:

- Linearization: TOMS V8 total O_3, reflectivity, climatology cloud pressure, no SO_2
- Linear equations: each for one spectral band (λ)

$$\ln I_{obs} - \ln I = \Delta\Omega \frac{\partial \ln I}{\partial \Omega} + \Delta\Xi \frac{\partial \ln I}{\partial \Xi} + \left(\Delta R + \sum_{i=1}^{N} c_i (\lambda - \lambda_0)^i \right) \frac{\partial \ln I}{\partial R} + \varepsilon$$

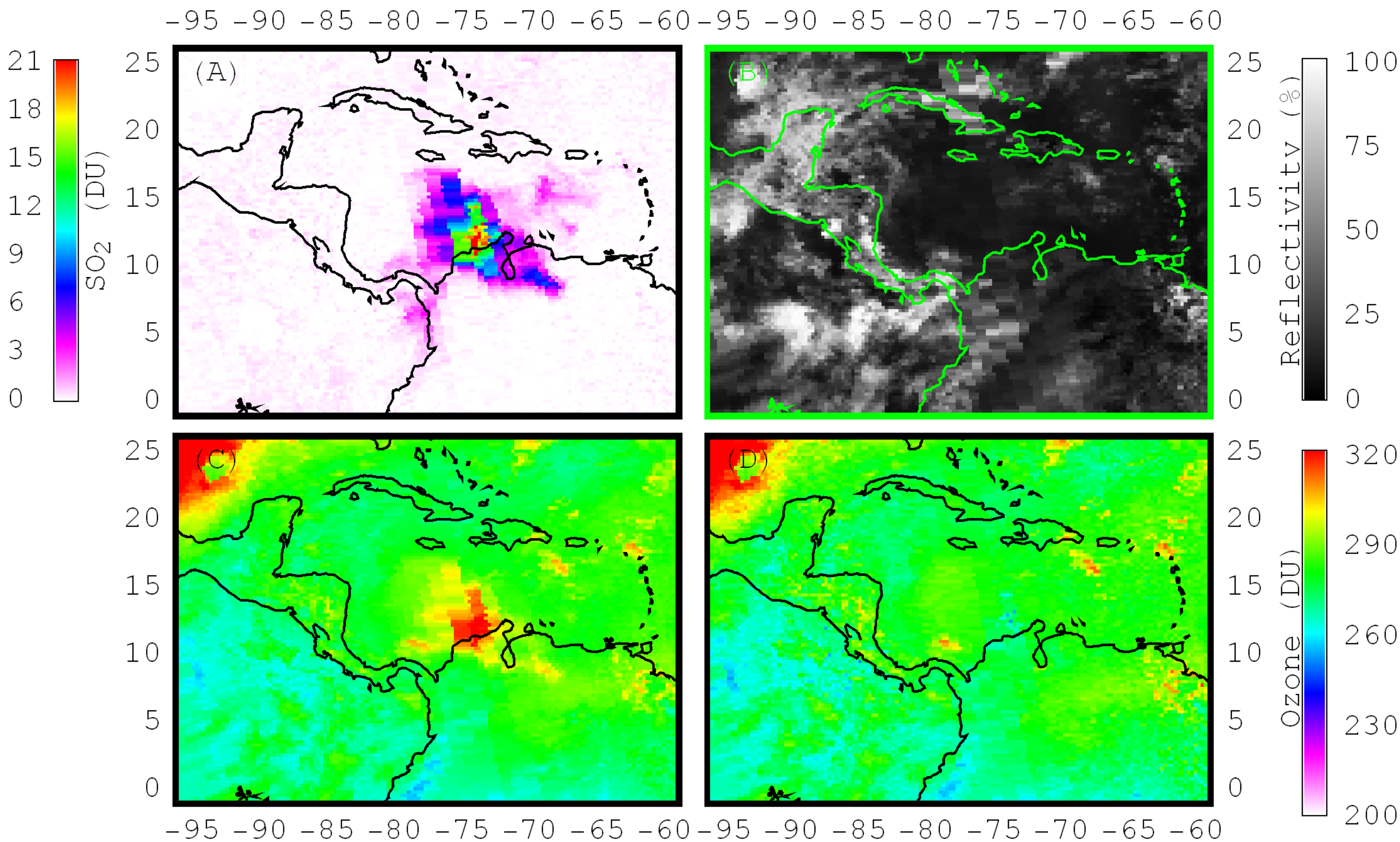
- Least square fit of weighting functions: determine adjustments to ozone (Ω) , SO_2 (Ξ), surface reflectivity (R) or cloud fraction (fc), and AI (c_1).

O_3 adjustments vs. LF SO_2

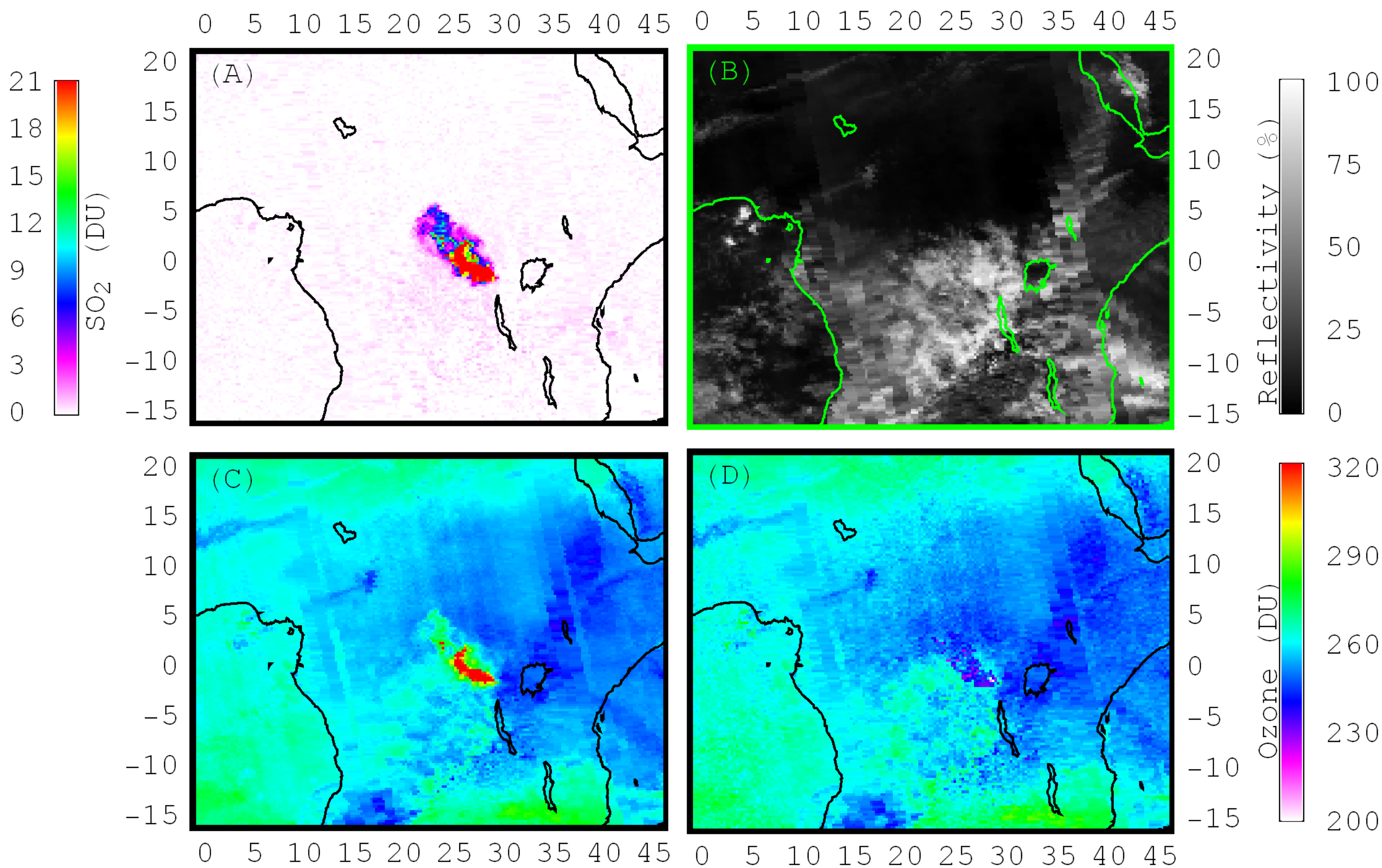


LF Sample Results: OMI

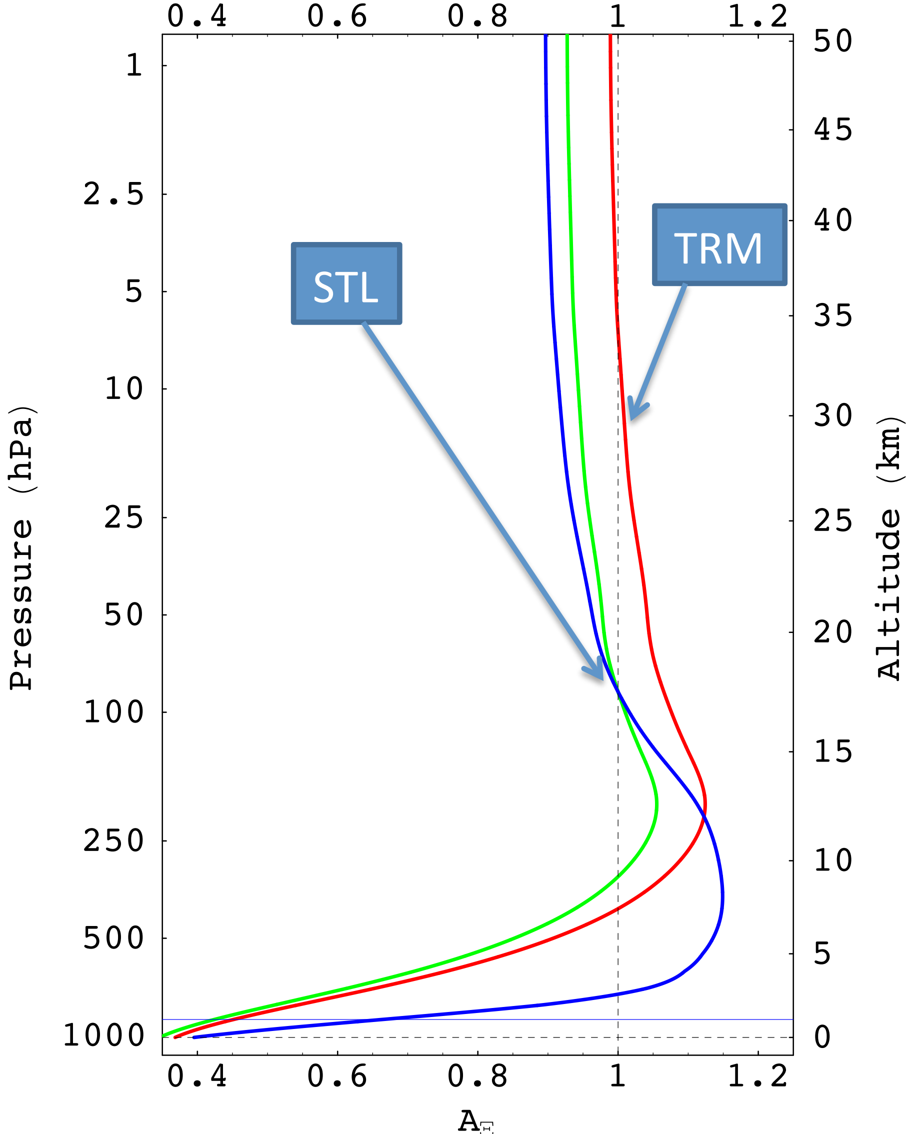
Soufriere Hills Volcano 05/21/2006



LF Sample Results: OMI
Nyamulagira Volcano 11/28/2006



SO_2 Retrieval Sensitivity: LF Averaging Kernels



Three LF products:

- Lower Troposphere (TRL) : 0 – 5 km, pollution and volcanic degassing SO_2
- Middle Troposphere (TRM) : 5 – 10 km, volcanic degassing and eruption SO_2
- Lower stratosphere (STL) : 15 – 20 km, volcanic eruption SO_2

Limitation and Mitigation

Limitation

- Non-linear effect leads to LF underestimation of large SO_2 columns (> 100 DU)

Mitigation

- Use only longer wavelengths (>= 315 nm, weaker absorption) for LF SO_2 retrieval
- Use improved algorithm: Iterative Spectral Fitting

Radiance Residual Correction

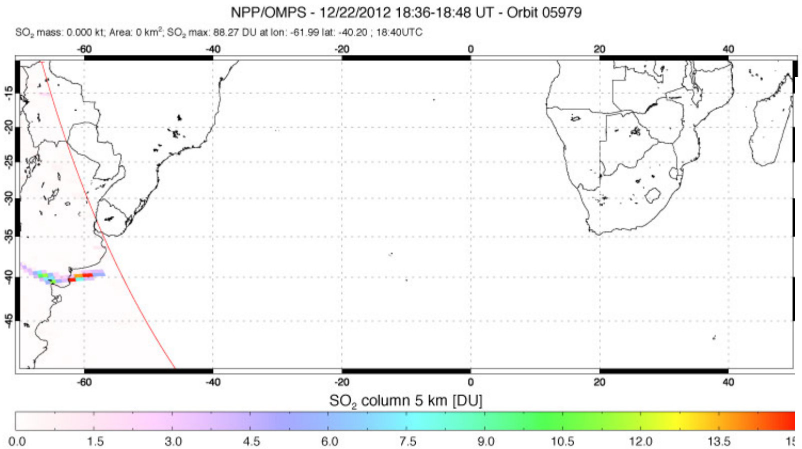
LF Retrieval are severely impacted by systematic errors:

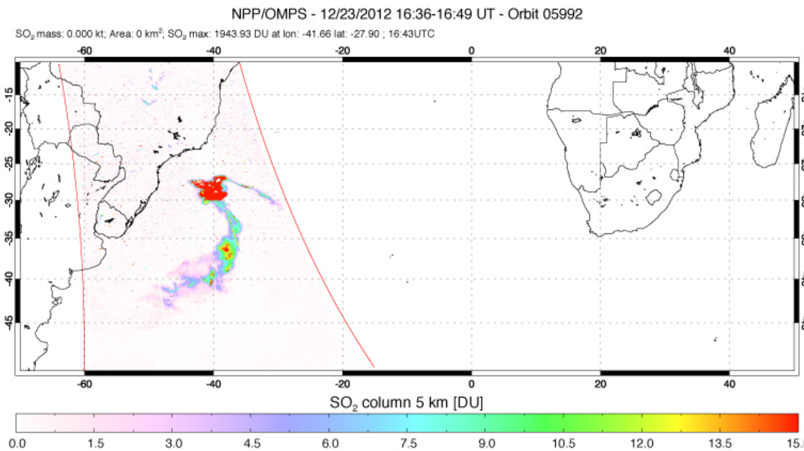
- Additive radiance errors, ozone retrieval error, forward model error, etc …

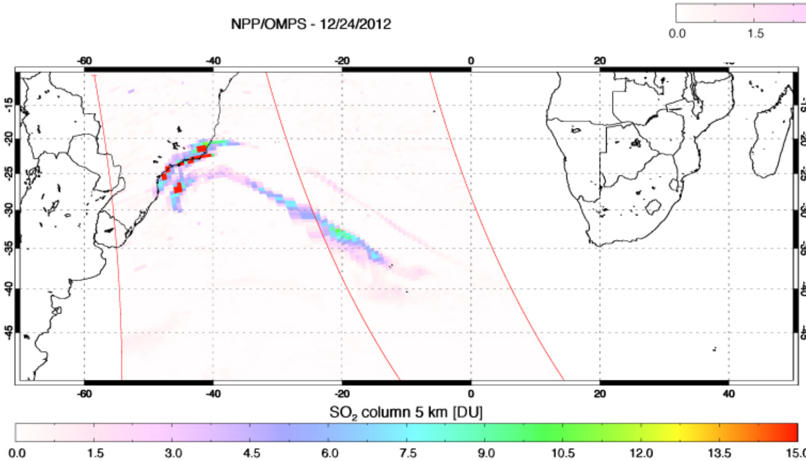
Radiance residuals errors are corrected for LF Retrieval

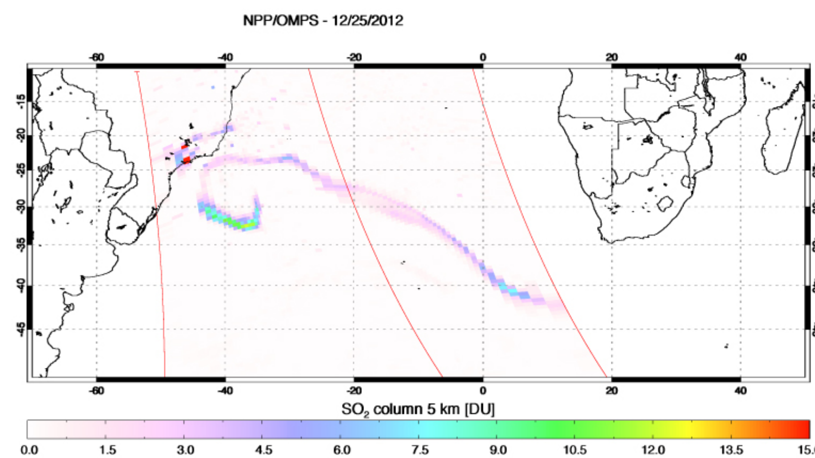
- Each cross-track position has its own correction
- Full orbit data: sliding median
- Partial orbit data: latitude-band (~10°, smaller is OK) average

S-NPP OMPS LF SO_2: Copahue (Chile & Argentina), Dec 2012

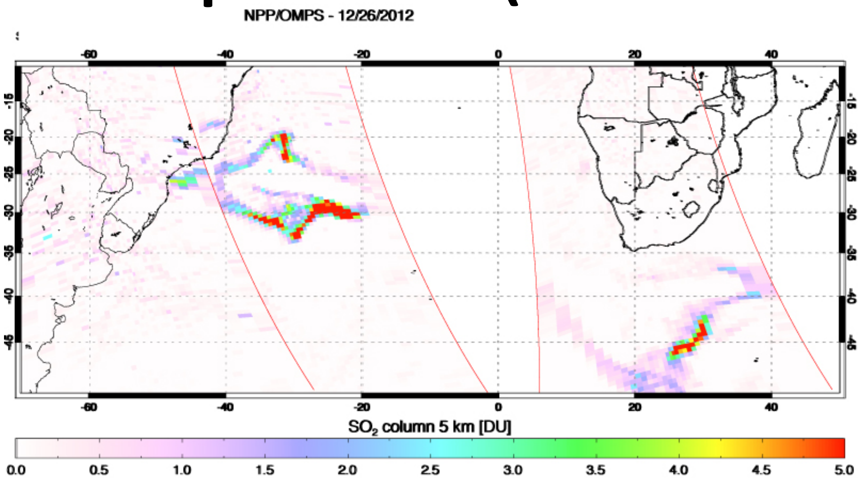


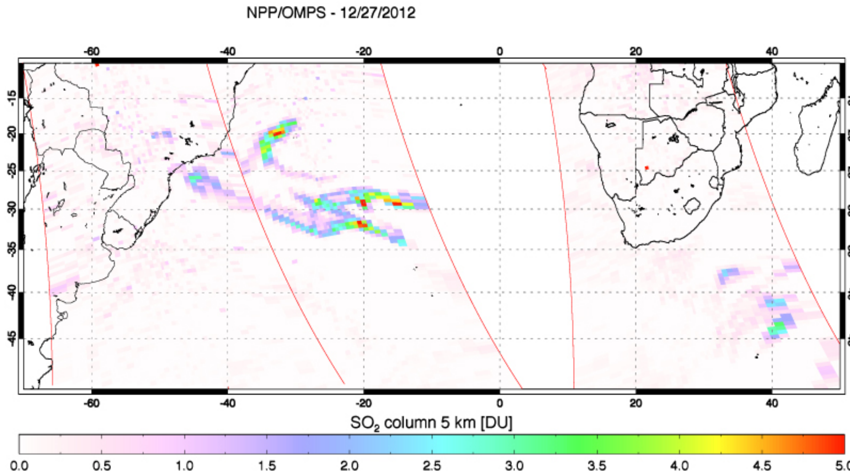


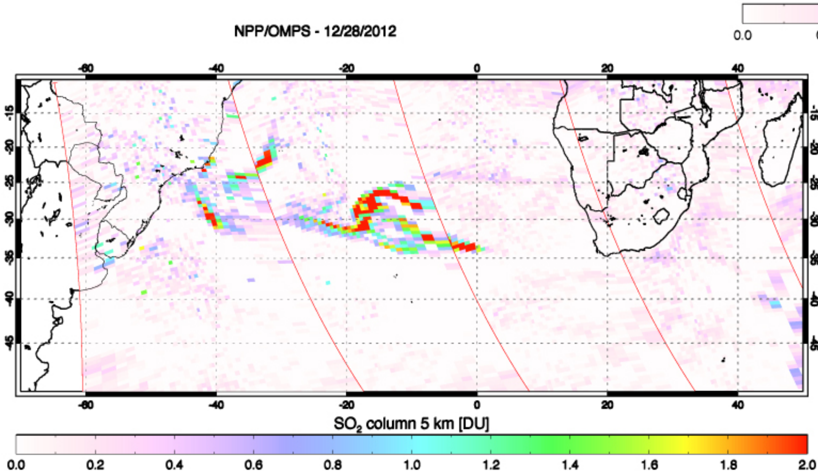


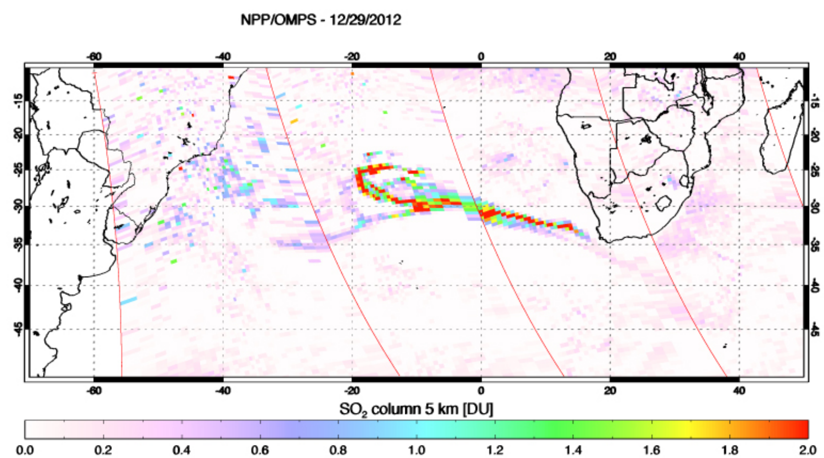


S-NPP OMPS LF SO_2: Copahue (Chile & Argentina), Dec 2012









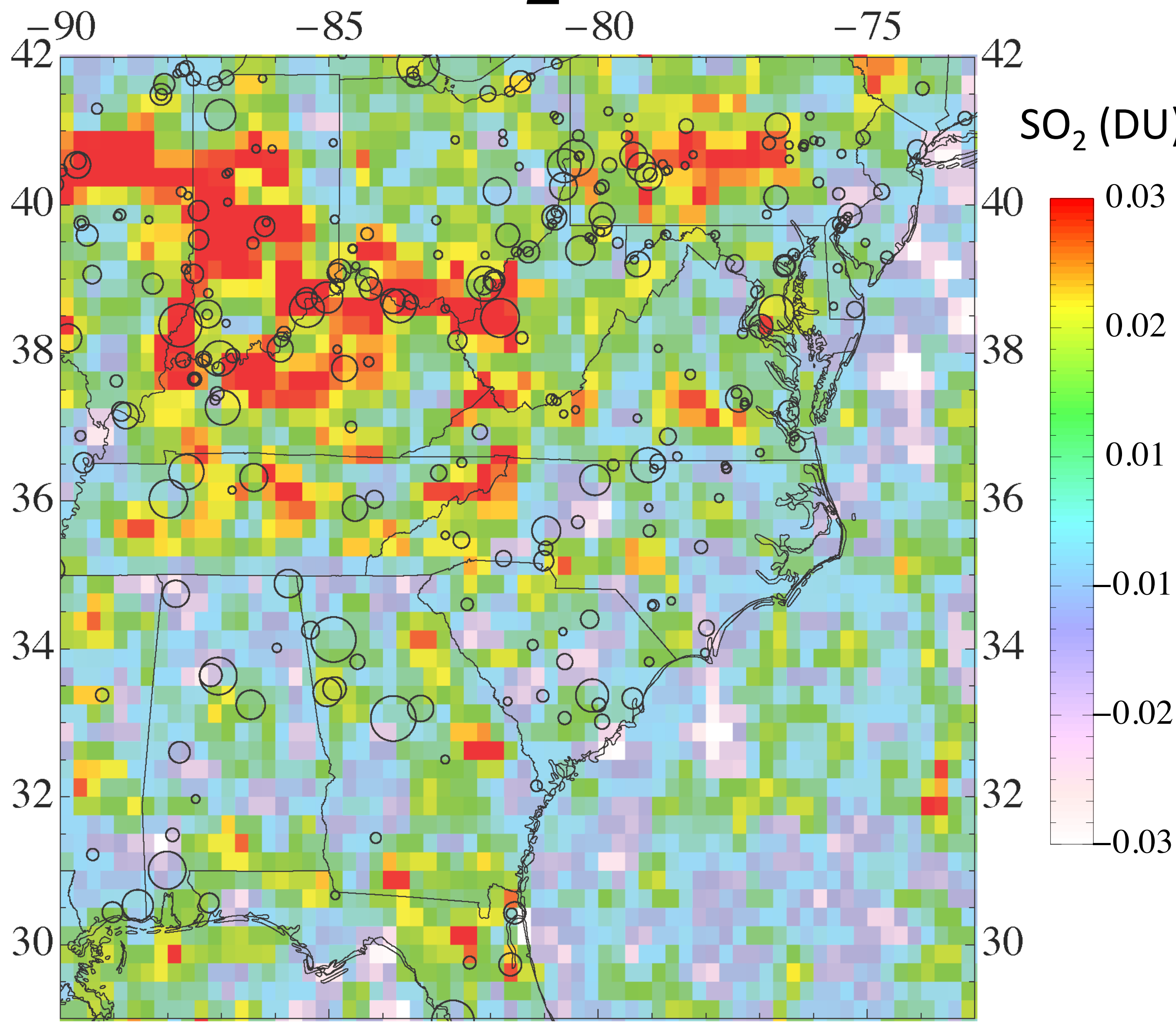
Unexpected results from OMPS Achieved with Algorithm Advances

Unprecedented SO_2 Sensitivity

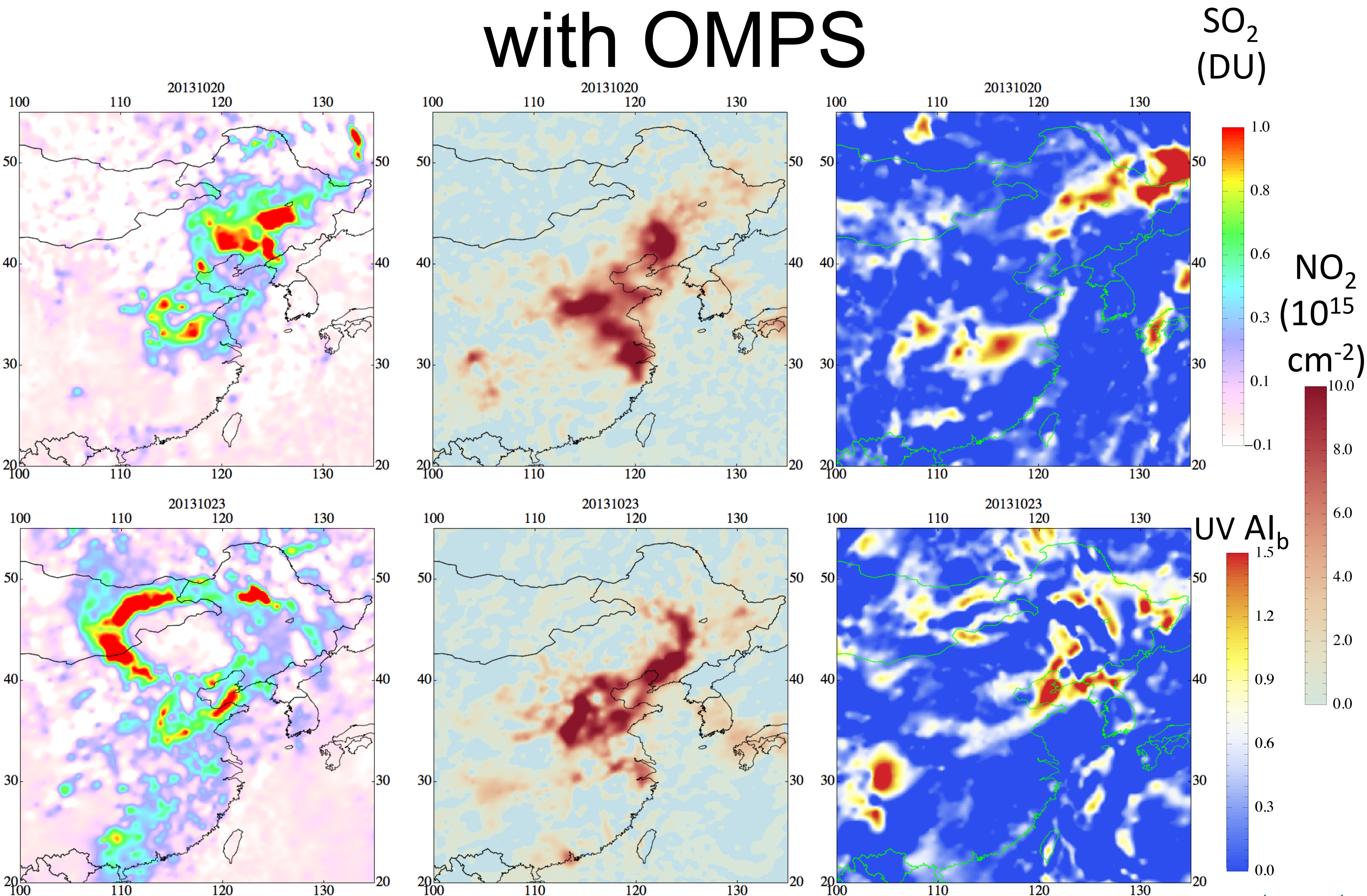
October 2013
Monthly Mean
ISF Algorithm

ISF sensitivity is an order of magnitude higher than other existing algorithms for boundary layer retrievals:

- 20 to 30 times > BRD
- 5 to 10 times > PCA
- 5 to 10 times > LF



Daily Global Pollution Monitoring with OMPS



TOAST versions, improvements and validation

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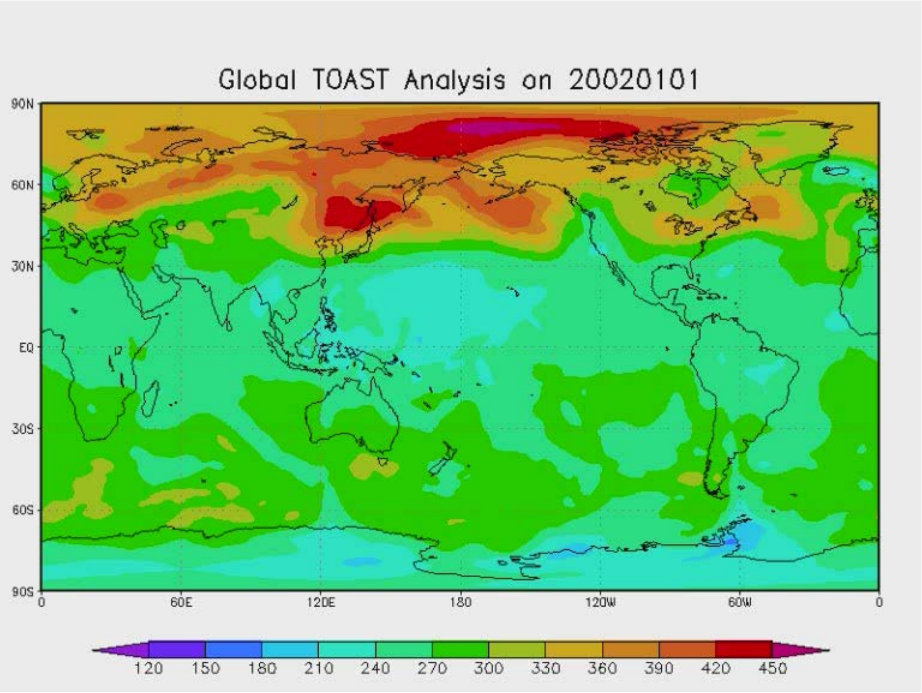
STAR JPSS Annual Science Team Meeting May 14, 2014

TOAST : Total Ozone Analysis using SBUV/2 and TOVS

- purpose: combining IR ozone at lower atmosphere with the UV ozone at higher atmosphere to derive a new ozone product better than the product from a single sensor.
- Reason:
  1. UV observations are sensitive to the ozone variations in the upper atmosphere.
  2. IR observations are sensitive to ozone variations in the lower atmosphere

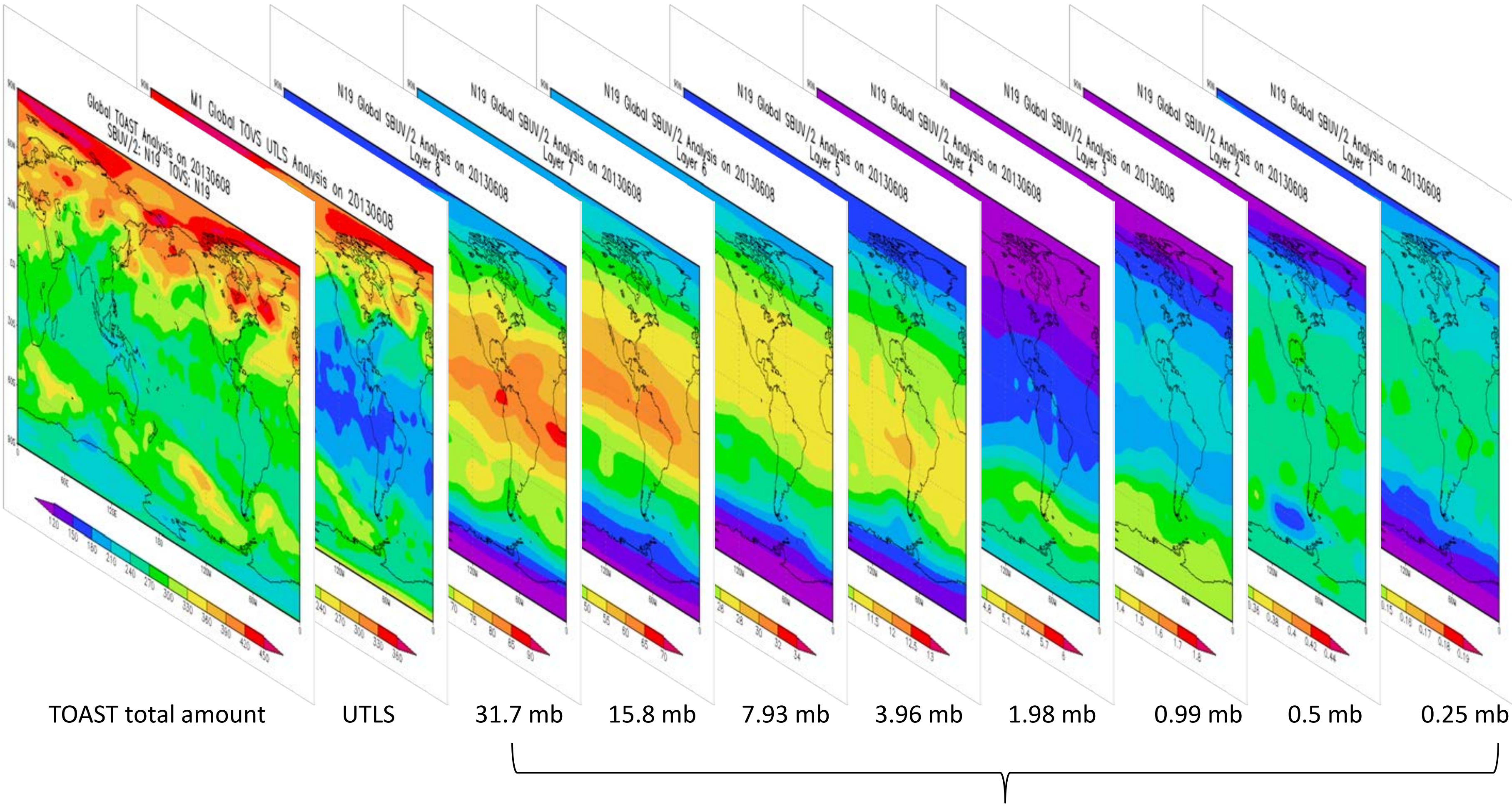
TOAST : Total Ozone Analysis using SBUV/2 and TOVS



2002 → 2003 → 2004 → 2005 → 2006 → 2007 → 2008 → 2009 → 2010 → 2012 → 2013 → 2014 → ....

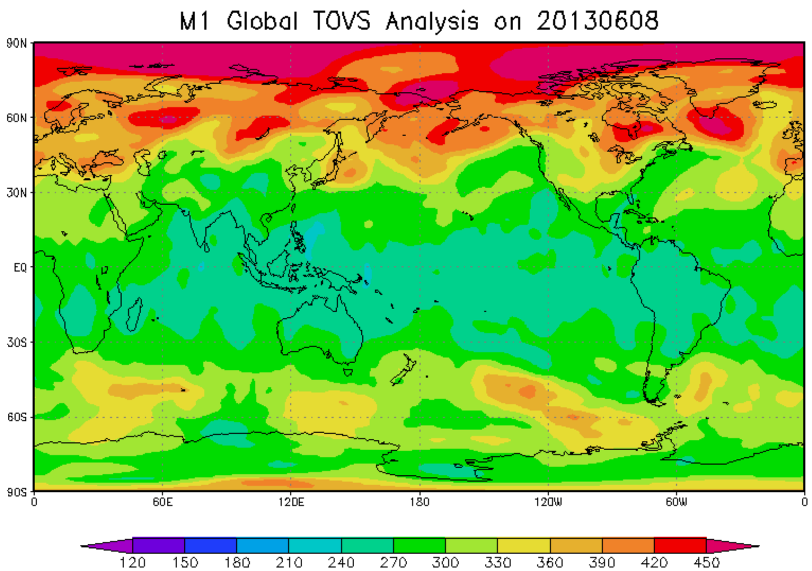
- Started from 01/01/2002 and has accumulated 11$^+$ years data.
- Provide global 1˚ × 1˚ total O_3
- Provide global 1˚ × 1˚ for eight Umkehr layer O_3 at 31.7, 15.8, 7.93, 3.96, 1.98, 0.99, 0.50, 0.25 mb.

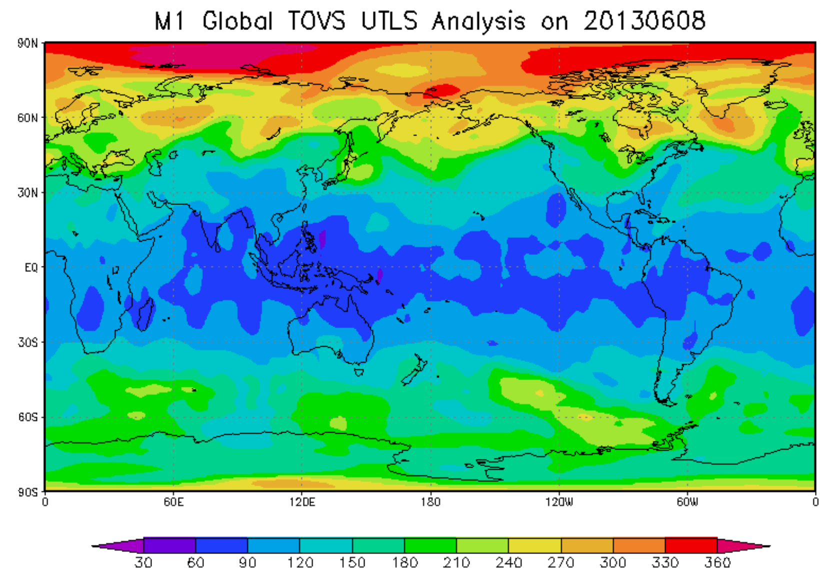
Composition of TOAST total ozone product



TOAST = TOVS + SBUV-2

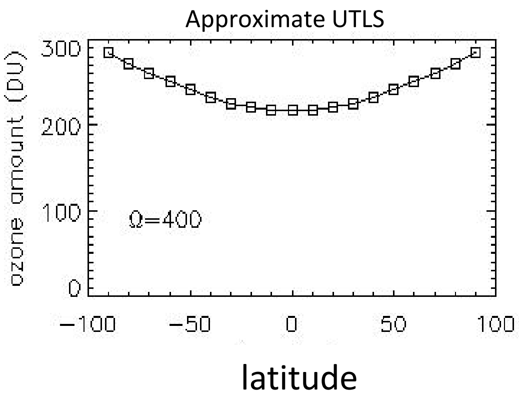
TOAST UTLS: upper troposphere lower stratosphere O_3





$$UTLS = [0.85 + 0.05 \times (0.9 + 1.1 \times \cos\theta)] \times \Omega - 81.6 \times (0.9 + 1.1 \times \cos\theta)$$

θ : Latitude; Ω : total amount of ozone



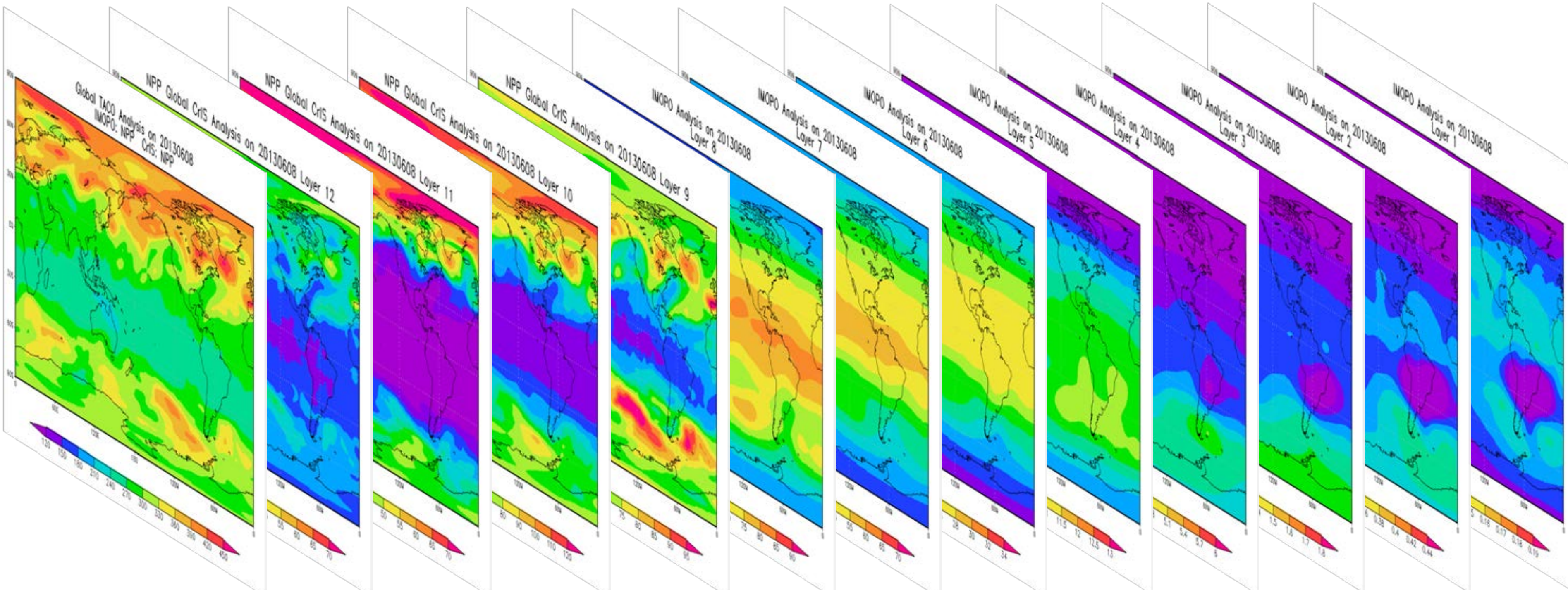
TOAST data sources

	SBUV/2	TOVS/HIRS
Jan. 1, 2002	N16	N16
Dec. 16, 2006	N16, N17	N16
Dec. 4, 2007	N16, N17	M2 (MetOp-A)
July 30, 2008	N16, N17, N18	M2 (MetOp-A)
Oct. 20, 2008	N17, N18	M2 (MetOp-A)
Dec. 19, 2012	N17, N18, N19	M2 (MetOp-A)
Feb. 5, 2013	N17, N19	M2 (MetOp-A)
Apr. 11, 2013	N19	M2 (MetOp-A)
Apr. 22, 2013	N19	M1 (MetOp-B)
Now in test running	N19	CrIS
After OMPS validated	OMPS/NP	CrIS

TACO: a new version of the TOAST

- ***TACO***: Total ozone Analysis of CrIS and OMPS
- Provide global 1˚ × 1˚ total O_3
- Provide global 1˚ × 1˚ O_3 maps of eight Umkehr layers at 31.7, 15.8, 7.93, 3.96, 1.98, 0.99, 0.50, 0.25 mb from OMPS NP (or SBUV/2) observation
- Provide global 1˚ × 1˚ O_3 maps of four Umkehr layers at 1013, 253, 127, 63.3 mb derived from CrIS NUCAPS product.

Composition of TACO total ozone product



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

TACO = CrIS + OMPS or SBUV-2

TACO objective analysis

- **Basic consideration:**
  IR measurement is sensitive to the ozone variation in the lower atmosphere and UV is sensitive to the ozone variation in the upper atmosphere.
- **Basic procedures:**

  1. convert CrIS O_3 pressure scale into OMPS Umkehr scale.
  2. coordinate transform from geographic into stereographic.
  3. improve an initial ozone distribution by incorporating the currently available satellite measurements.
  4. analyzed global ozone data are transformed back to the geographic coordinate with 1˚× 1˚ resolution.

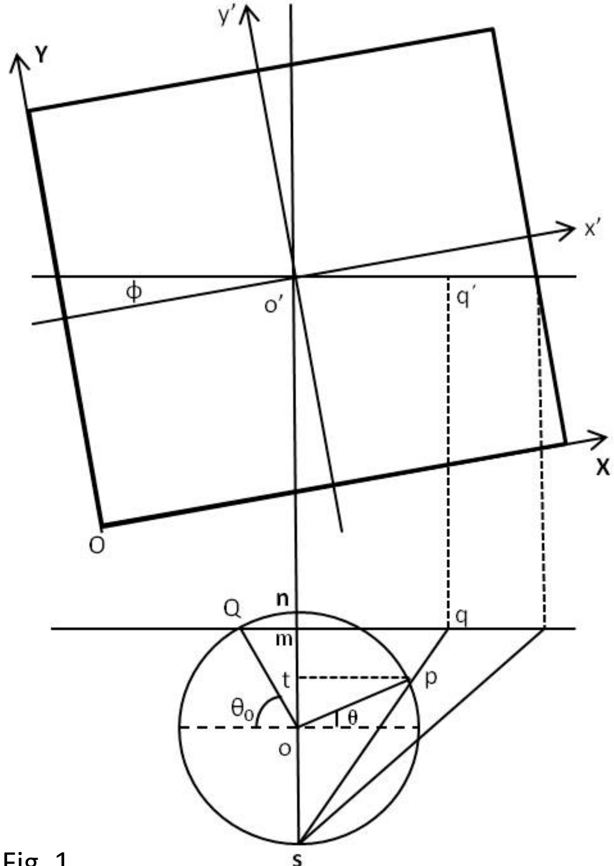


Fig. 1

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

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

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 correction value C , where E is the difference between observation and the initial value, W is a weighting factor.

Fig. 2

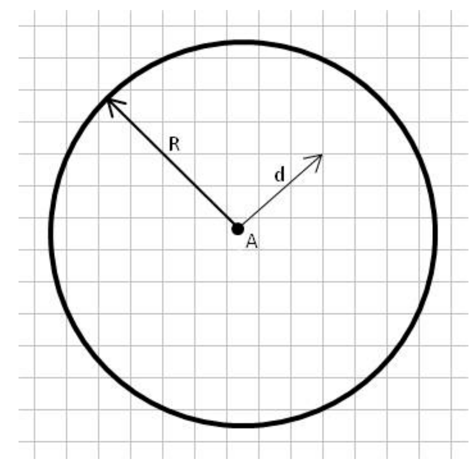
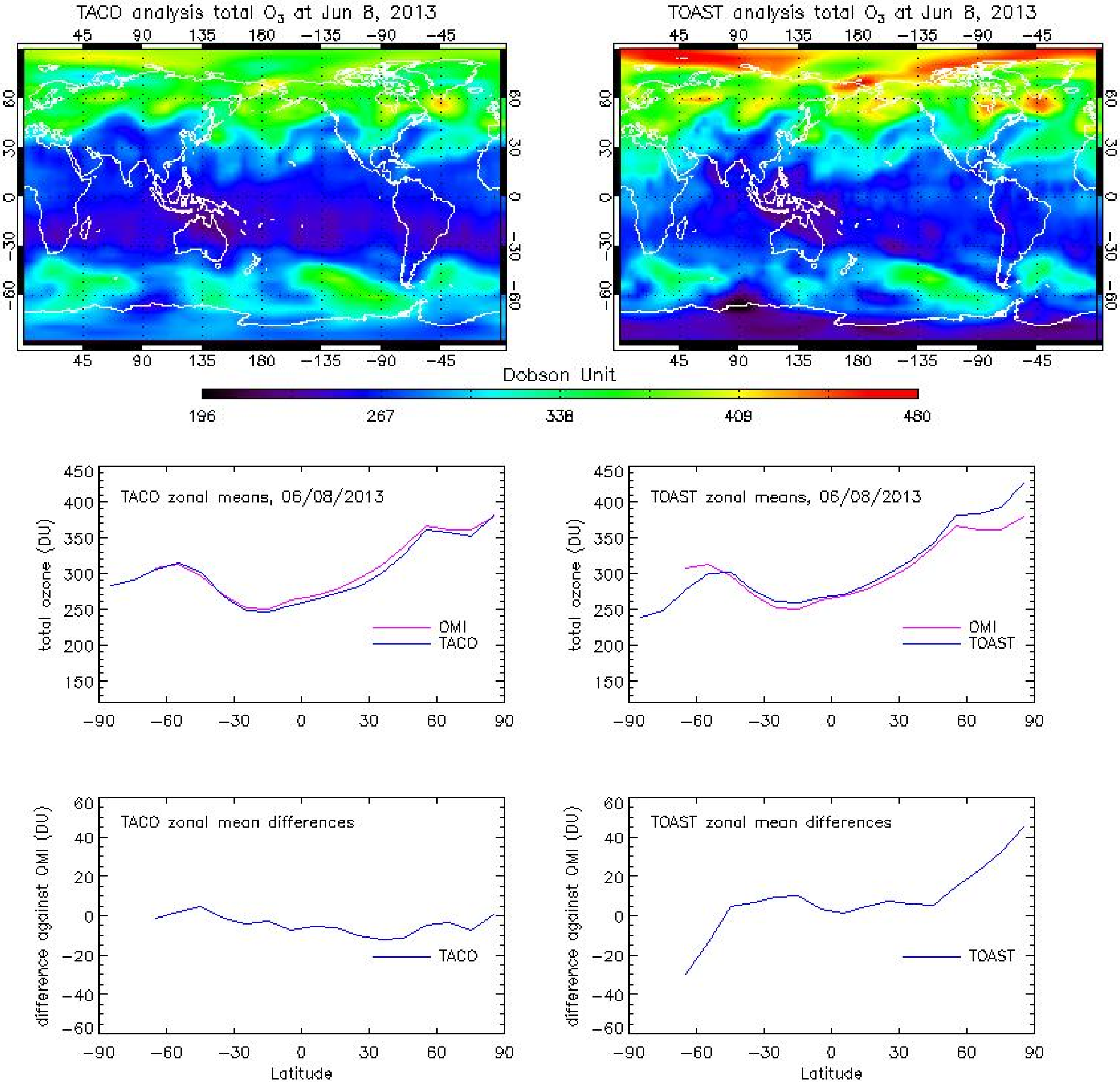
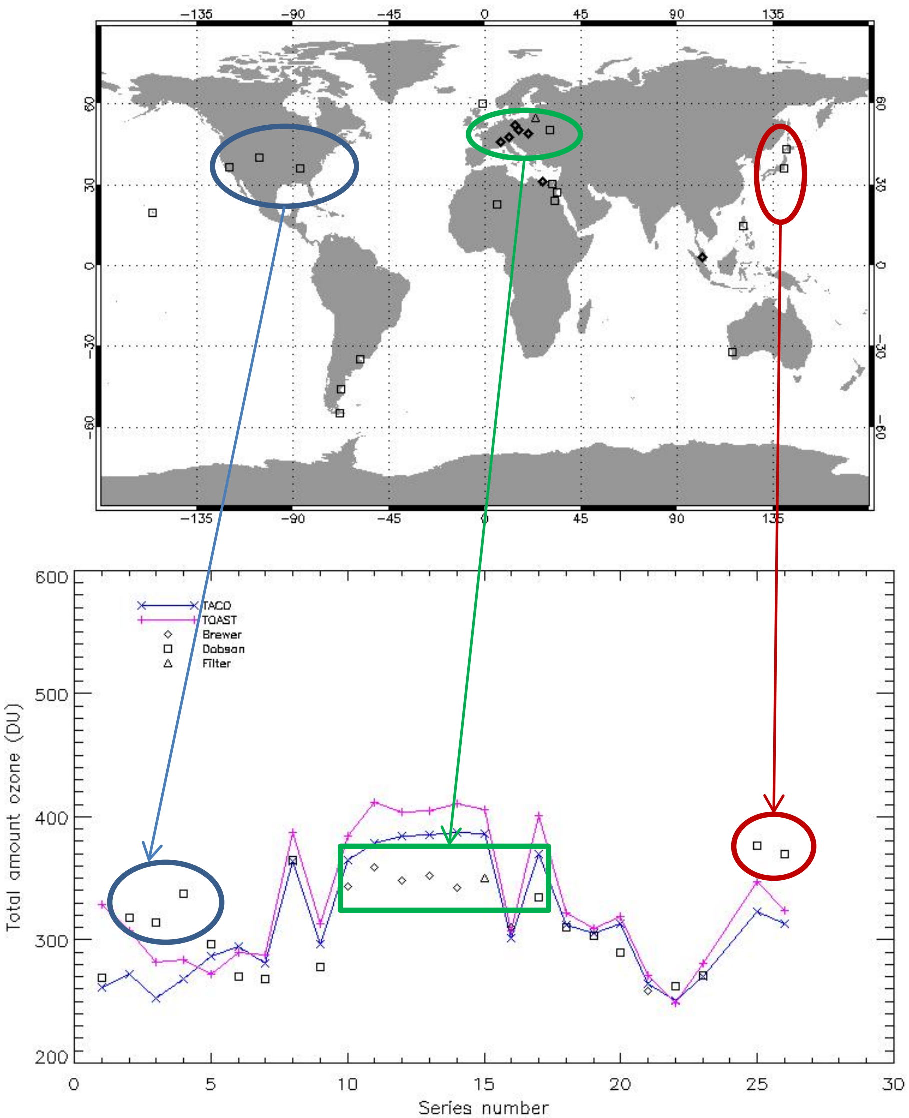


Fig 2. scheme of objective analysis


TACO analysis total O_3 at Jun 8, 2013
TOAST analysis total O_3 at Jun 8, 2013
45 90 135 180 −135 −90 −45
60 30 0 −30 −60
Dobson Unit
196 267 338 409 480
TACO zonal means, 06/08/2013
TOAST zonal means, 06/08/2013
total ozone (DU)
450 400 350 300 250 200 150
OMI
TACO
TOAST
−90 −60 −30 0 30 60 90
TACO zonal mean differences
TOAST zonal mean differences
difference against OMI (DU)
60 40 20 0 −20 −40 −60
Latitude

Comparison with ground based station on June 8, 2013



Along the longitude

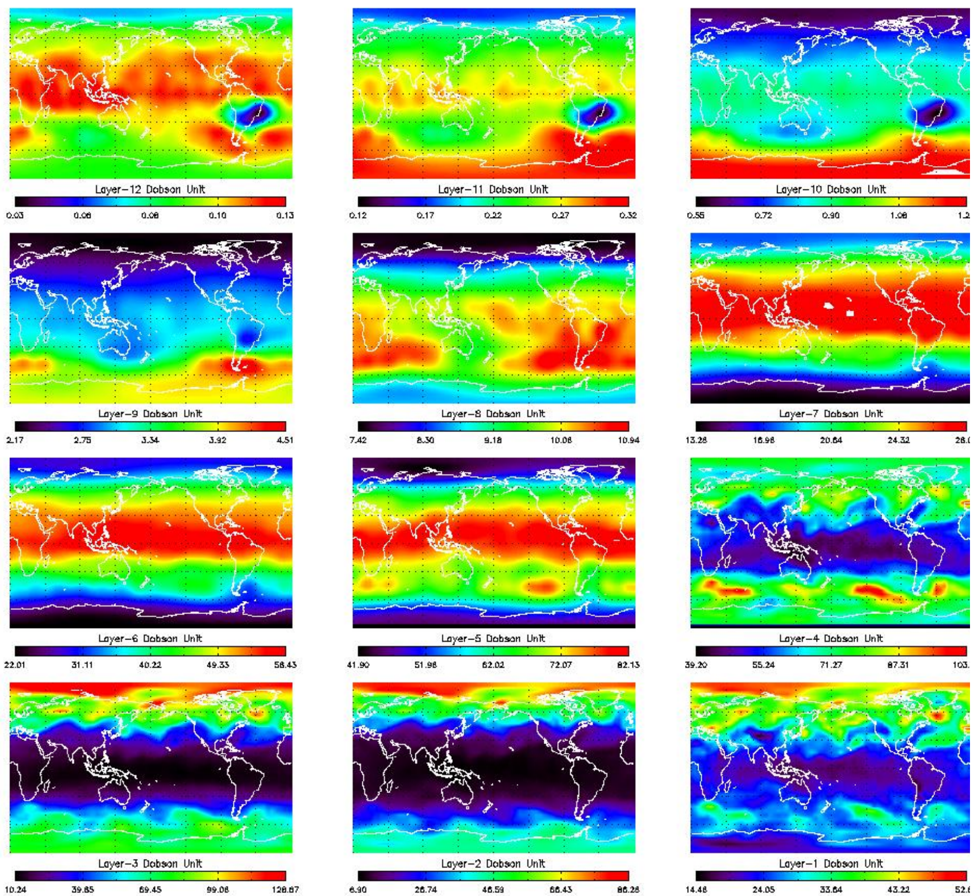
1. Differences of TACO relative to the ground station are mostly less than 10% , and have only 4 locations larger than 15%.

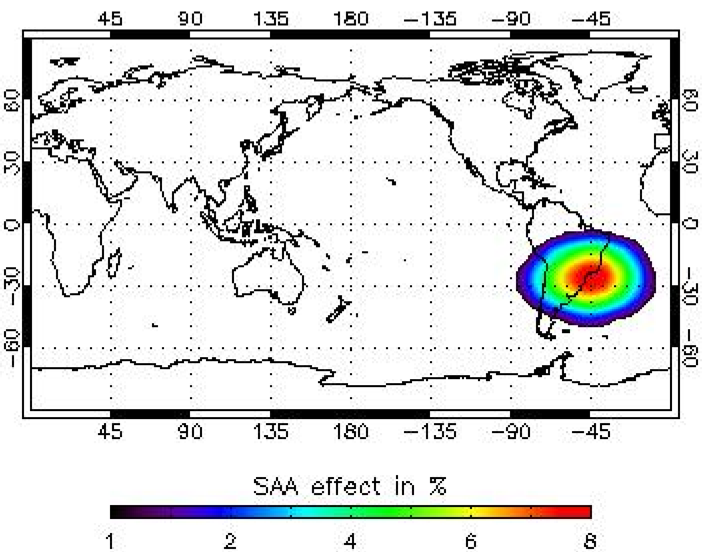
2. The average difference is 7.8%

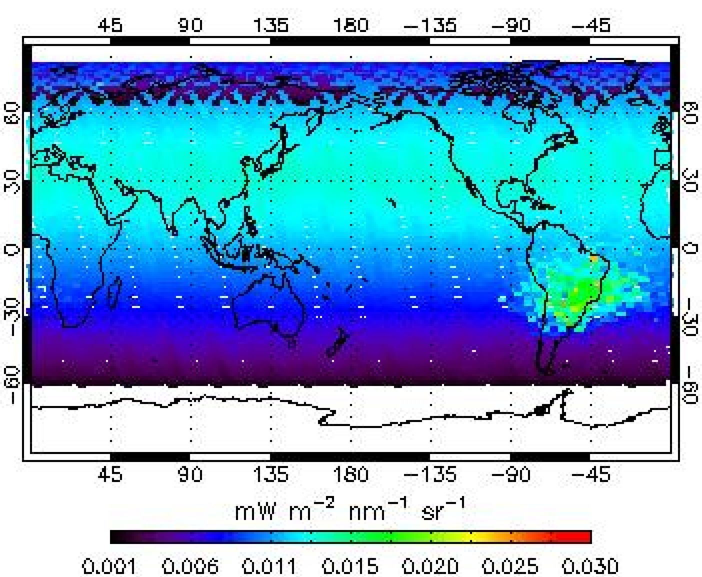
Total ozone and validation

- TACO and TOAST give similar O_3 global pattern.
- TACO zonal mean are similar to OMI's
- TACO gives improve estimates for the high latitude regions in both southern and northern hemisphere.
- TACO replaced approximate estimation of UTLS ozone by using CrIS layer products

12 layers TACO analysis on June 8, 2013

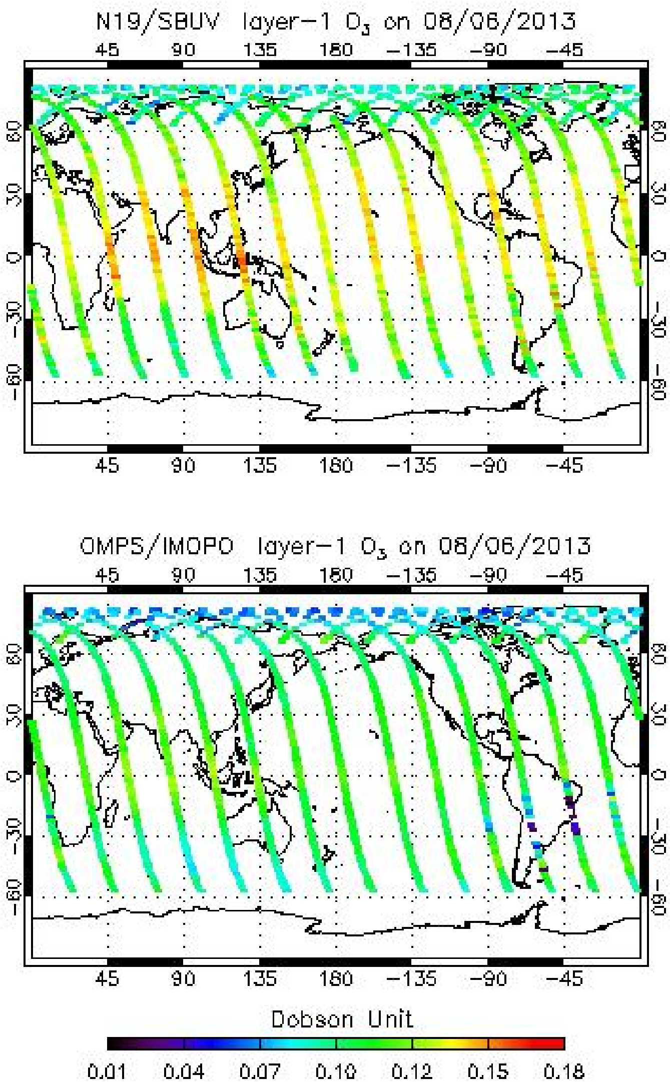






South **A**tlantic **A**nomaly

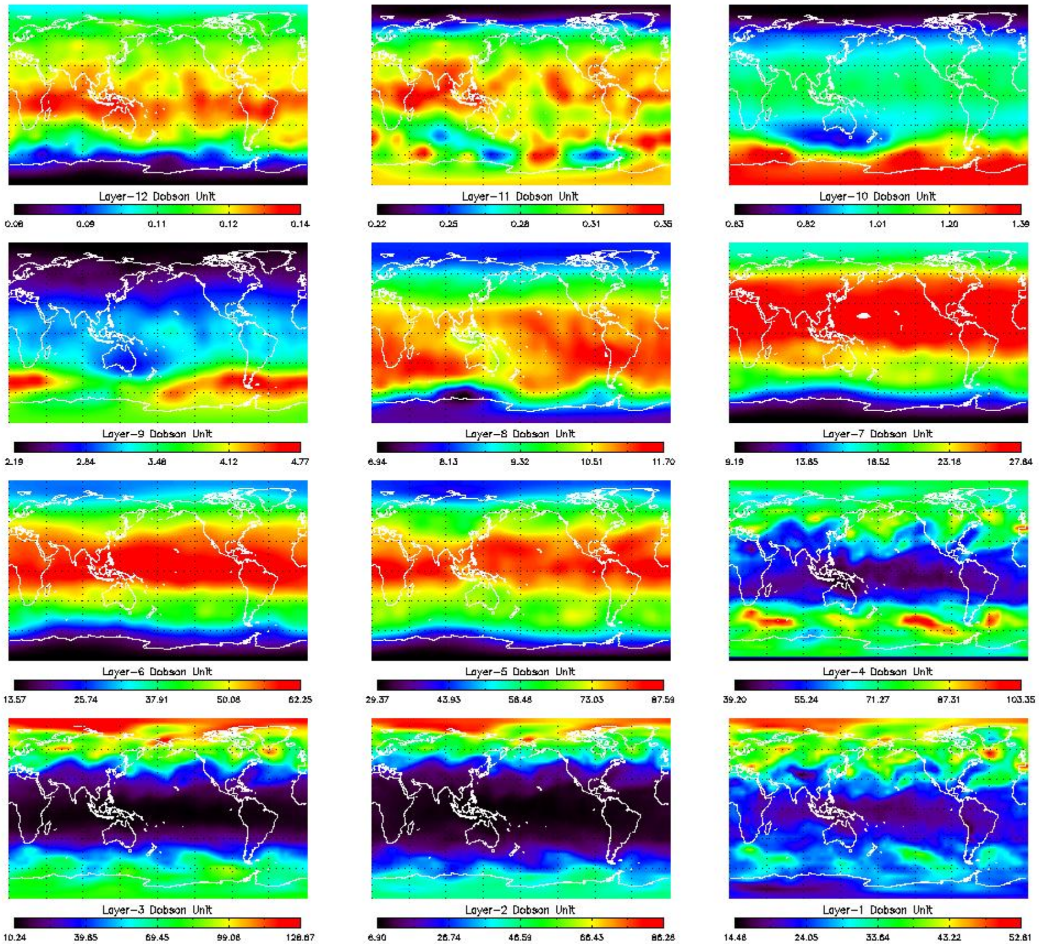
Current OMPS/NP retrievals are systematic lower than SBUV/2



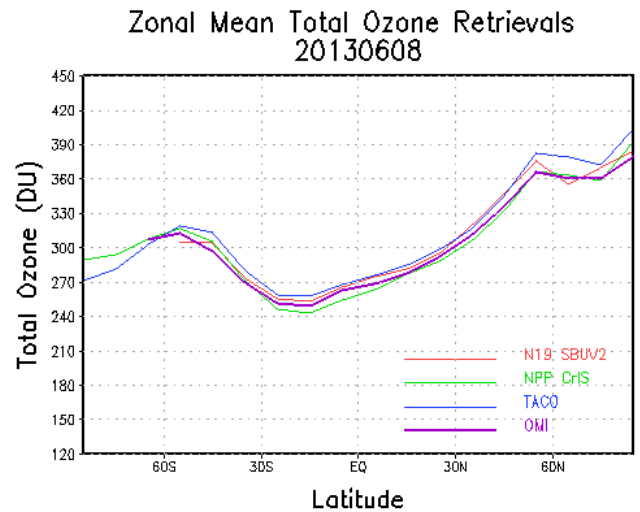
- TACO provide 12 layer ozone maps.
- Current NP retrieval values are systematic lower than SBUV/2 at higher layers
- This can be corrected by soft calibration.
- SAA effect has not been eliminated.
- Elimination of SAA effects are expected on the future hardware improvement.

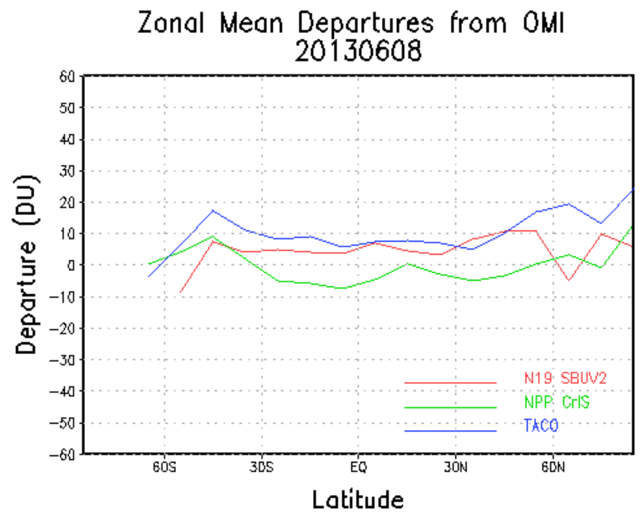
TACO intermediate version: SBUV/2 + CrIS

SBUV/2 + CrIS



Comparison with OMI





Conclusion

- TOAST has provided global one by one degree total ozone product for 11^+ years.
- TACO, as a new version, will continue the contribution by using new IR and UV instruments.
- New CrIS sensor provide better estimation of the tropospheric and lower stratospheric ozone values.
- Prior to the OMPS nadir profiler advancing to validated maturity, TACO will be created from (SBUV/2 + CrIS) intermediate version by OSPO.

Future work:

- More validation work are expected.
- We planed to replace OMPS SAA ozone values by a zonal mean average.
- It is possible to run TACO algorithm in near real time manner combining the real time OMPS and CrIS profile orbitally to create products with less latency.
- We are investigating using the OMPS profile analysis fields as CrIS a priori profiles for NUCAPS retrieval. This may improve the CrIS retrieval accuracy in upper layers.
- There is a proposed project in NASA to create retrievals using the OMPS and CrIS measurements together as have been developed for use with OMI and TES.

THANKS

O3ProV8 Implementation with ADL

Trevor Beck
Zhihua Zhang

Alter existing code as little as possible

- Add on to existing V6 IMOPO-INPAK code.
- 4 xml files lengthened
- 5 existing Fortran files altered(as little as possible)
- 45 New Fortran 90 Files
- 2 Cxx files altered: glueware file and c++ caller.
- Output file: 30 additional Fields in group /All_Data/OMPS-NP-IP_All

Allow for future improvements

- Information concentration
- Outlier removal
- Increased number of channels
- Off-Nadir Viewing geometry

New Output Fields

/All_Data/OMPS-NP-IP_All/Step1O3_v8
/All_Data/OMPS-NP-IP_All/Step2O3_v8
/All_Data/OMPS-NP-IP_All/aerind_v8
/All_Data/OMPS-NP-IP_All/algflag_v8
/All_Data/OMPS-NP-IP_All/averaging_kernel_v8
/All_Data/OMPS-NP-IP_All/bestozone_v8
/All_Data/OMPS-NP-IP_All/cloudfrac_v8
/All_Data/OMPS-NP-IP_All/cloudpress_v8
/All_Data/OMPS-NP-IP_All/dn360_v8
/All_Data/OMPS-NP-IP_All/dndr_v8
/All_Data/OMPS-NP-IP_All/efficiency_v8
/All_Data/OMPS-NP-IP_All/errflag_v8
/All_Data/OMPS-NP-IP_All/groundpres_v8
/All_Data/OMPS-NP-IP_All/mixing_ratio_press_v8
/All_Data/OMPS-NP-IP_All/mixing_ratio_v8
/All_Data/OMPS-NP-IP_All/niteration_v8
/All_Data/OMPS-NP-IP_All/ozcloud_v8
/All_Data/OMPS-NP-IP_All/profile_apriori_v8
/All_Data/OMPS-NP-IP_All/profile_code_v8
/All_Data/OMPS-NP-IP_All/profile_firstguess_v8
/All_Data/OMPS-NP-IP_All/profile_temperature_v8
/All_Data/OMPS-NP-IP_All/ref331_v8
/All_Data/OMPS-NP-IP_All/ref360_v8
/All_Data/OMPS-NP-IP_All/residual0_v8
/All_Data/OMPS-NP-IP_All/residual_v8
/All_Data/OMPS-NP-IP_All/resn_v8
/All_Data/OMPS-NP-IP_All/resqc_v8
/All_Data/OMPS-NP-IP_All/sens_v8
/All_Data/OMPS-NP-IP_All/toz_apprf_v8
/All_Data/OMPS-NP-IP_All/tozpro_v8

Output file size increases about 85%

Old size 201K
new: 377K

**ADL sizes including Geolocation and INPAK*

Per day size of GONPO-IMOPO-INPAK V8: 410MB, 1100 HDF5 files.

Code Improvements

Based on earlier work for OMI Version 8 ozone profile.

Code has machinery to use more than 13 wavelengths it currently uses.

Single scatter channels and multiple scatter channels handled separately.

Eliminated all SBUV Instrument specific code(N07, NOAA14)

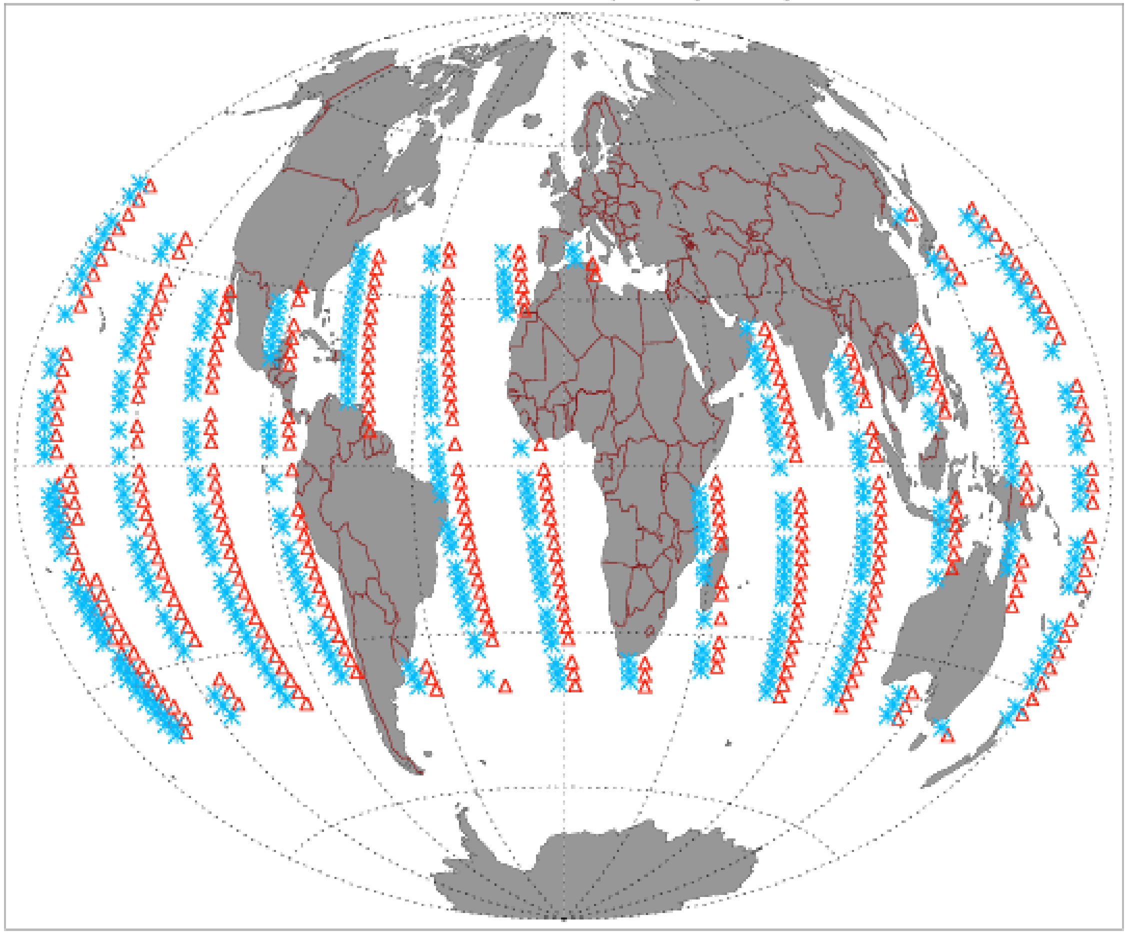
Edited code to use Fortran90 features where possible.

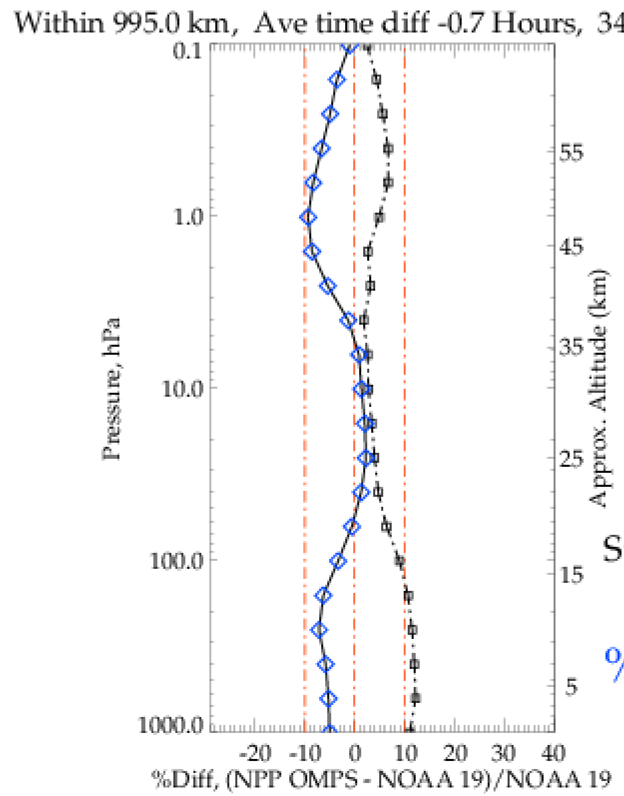
- Indenting
- intent statements
- strongly typed, real some_var becomes real(KIND=SP) :: some_var
- F90 Comment style
- continuation character
- Tested on multiple compilers: sunf95, intel, gfortran, Portland

Most time consuming task was I/O. Input files were opened and read in numerous files. Input files were in different formats. All input needed to be consolidated and put in flat binary input. The existing OMPS-NP-LUT file has about 10 MB data appended to it.

Validation Results.

NPP OMPS and NOAA 19 for 1 Days, Beginning on 2013/10/22



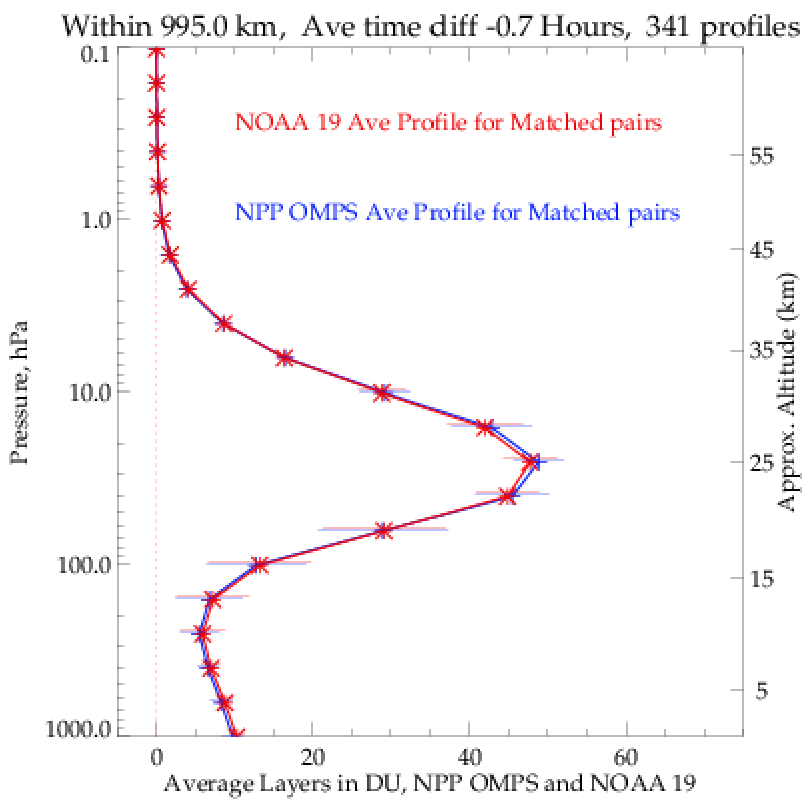


StdDev, BLACK

%Diff,BLUE

Ave SZA for NPP OMPS = 33.85°

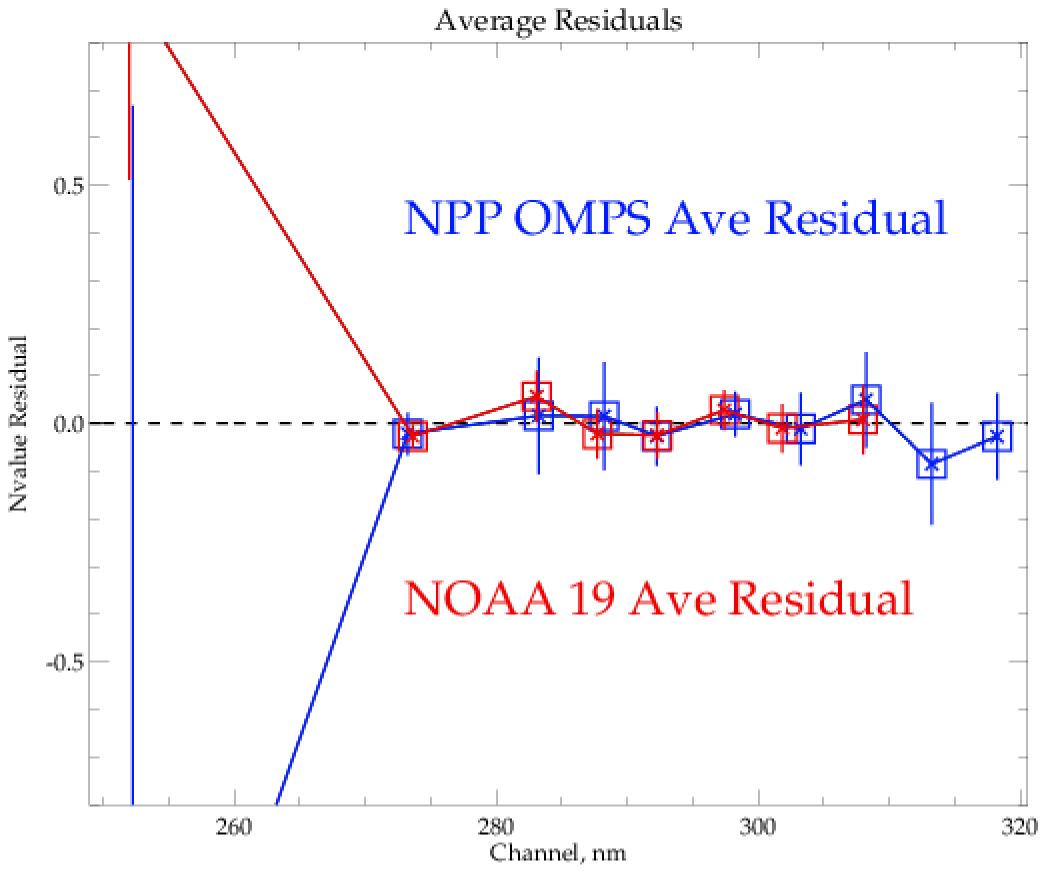
Ave SZA for NOAA 19 = 36.95°



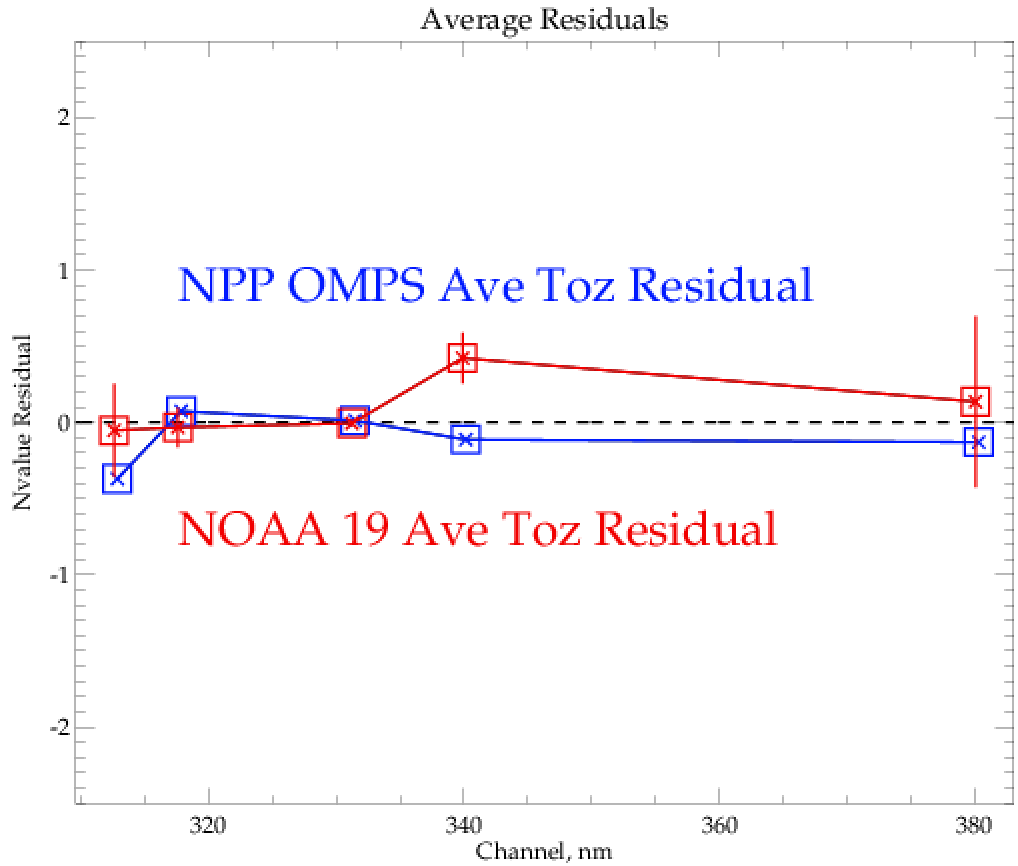
276.7 DU, Column sum for NPP OMPS

277.1 DU, Column sum for NOAA 19

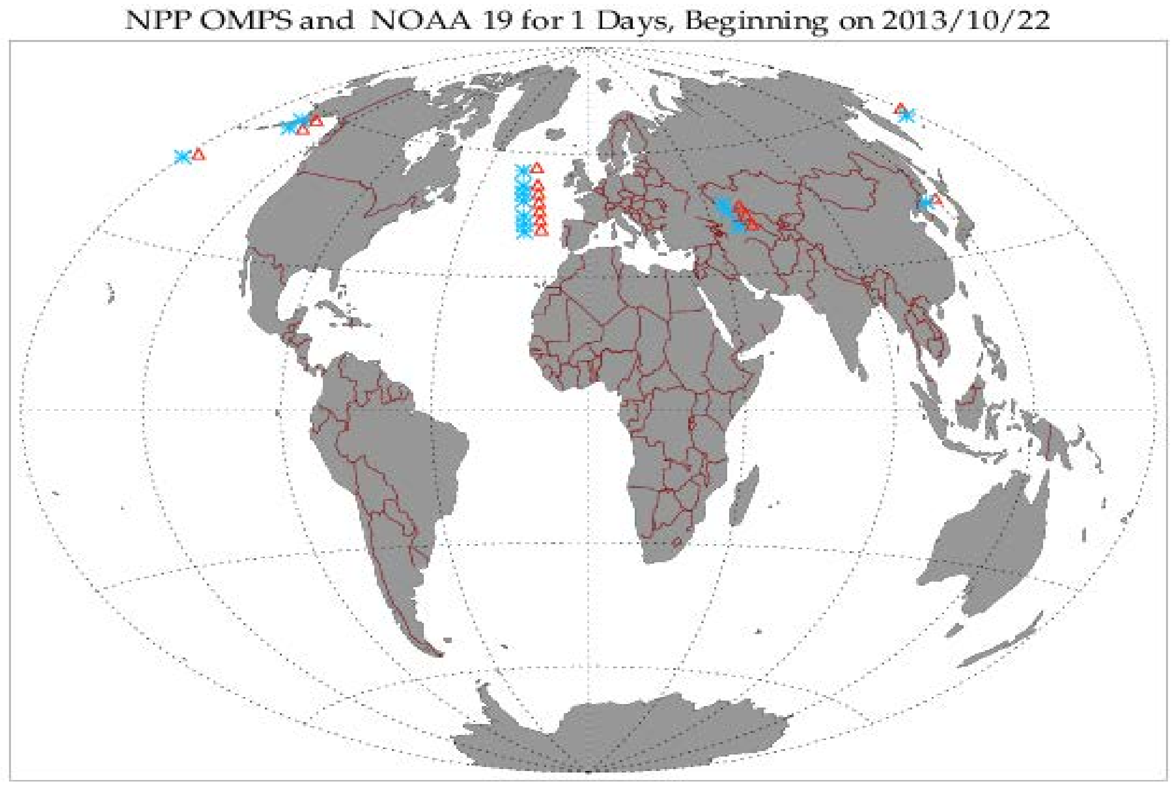
-0.1 %Diff in Column sum: NPP OMPS - NOAA 19

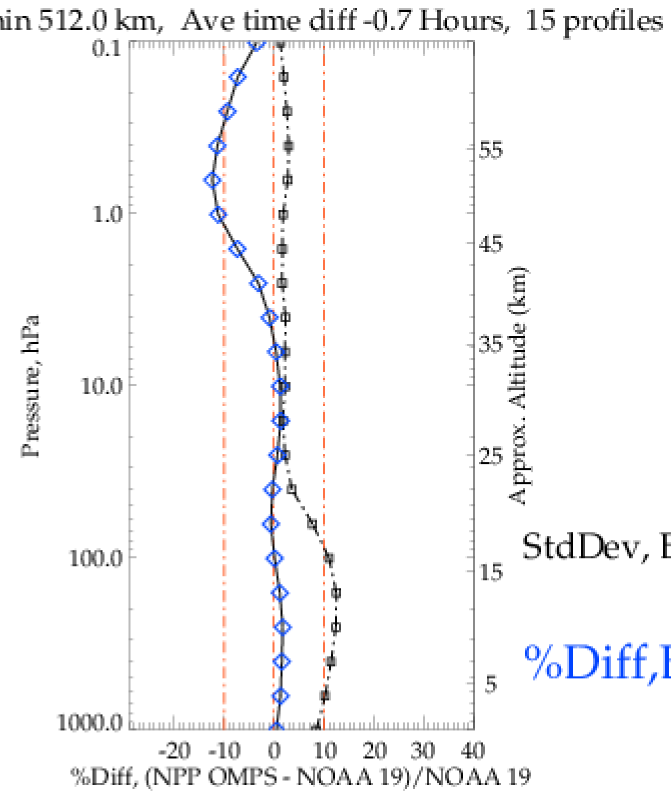


Average Residuals
NPP OMPS Ave Residual
NOAA 19 Ave Residual
Nvalue Residual
0.5
0.0
-0.5
260
280
300
320
Channel, nm


Average Residuals
NPP OMPS Ave Toz Residual
NOAA 19 Ave Toz Residual
Nvalue Residual
2
1
0
-1
-2
320
340
360
380
Channel, nm

Mid Lat case



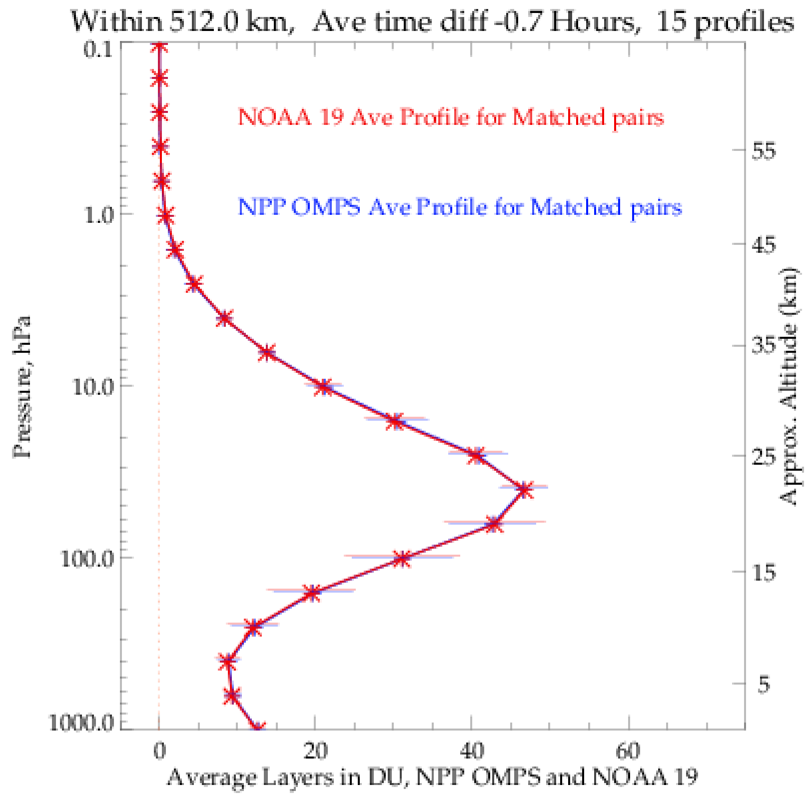


StdDev, BLACK

%Diff,BLUE

Ave SZA for NPP OMPS = 61.15°

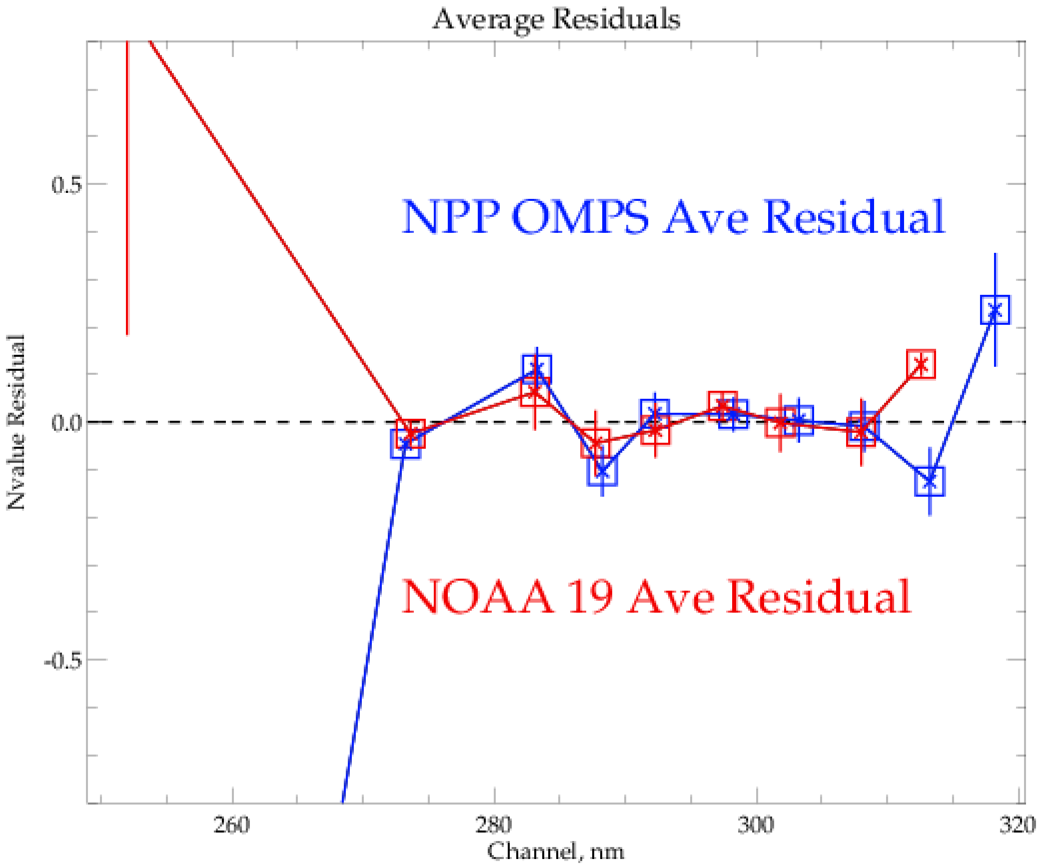
Ave SZA for NOAA 19 = 61.58°



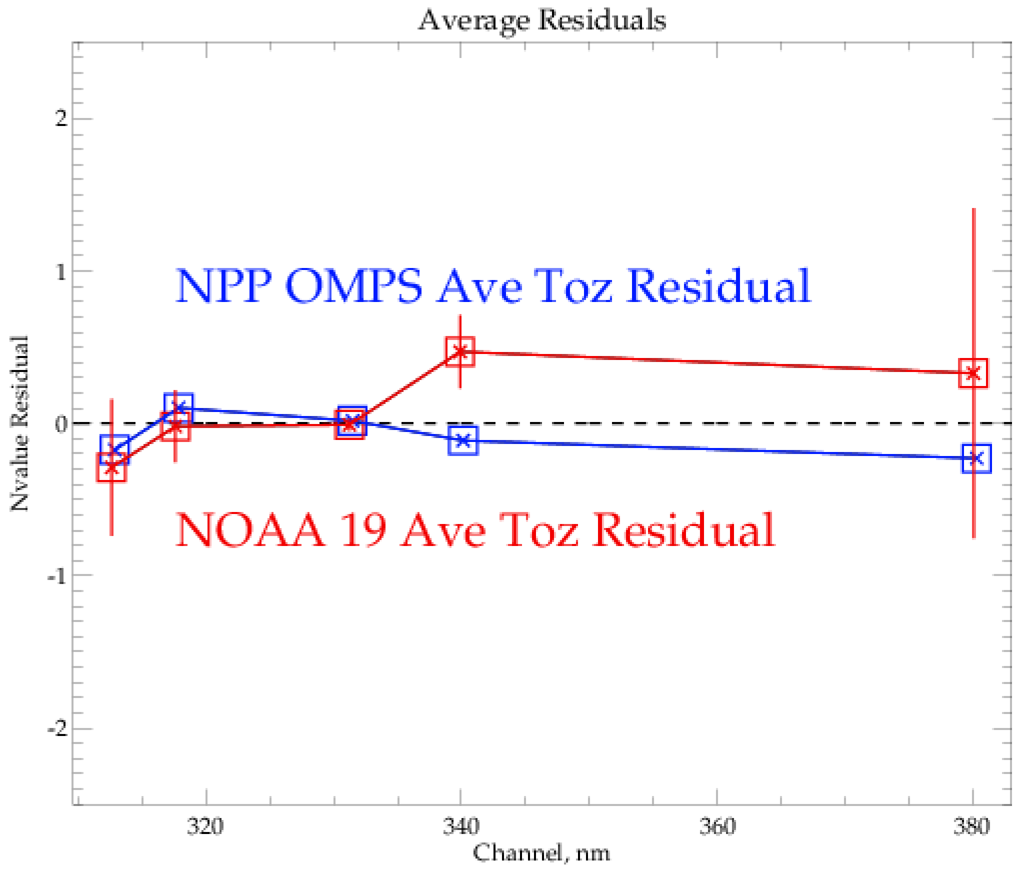
305.4 DU, Column sum for NPP OMPS

304.5 DU, Column sum for NOAA 19

0.3 %Diff in Column sum: NPP OMPS - NOAA 19



Average Residuals
NPP OMPS Ave Residual
NOAA 19 Ave Residual
Nvalue Residual
0.5
0.0
-0.5
260
280
300
320
Channel, nm



Average Residuals
NPP OMPS Ave Toz Residual
NOAA 19 Ave Toz Residual
Nvalue Residual
2
1
0
-1
-2
320
340
360
380
Channel, nm

Future Work for V8Pro

Information Concentration

Outlier Detection

More Wavelengths

Off-nadir geometry

Glueware source code file must change for J1

Development and Application of Hyperspectral Infrared Ozone Retrieval Products for Operational Meteorology

Emily Berndt[1], Bradley Zavodsky[2], Gary Jedlovec[2]

[1]NASA Postdoctoral Program Marshall Space Flight Center, Huntsville, Alabama
[2]Short-term Prediction Research and Transition Center NASA/MSFC, Huntsville, Alabama

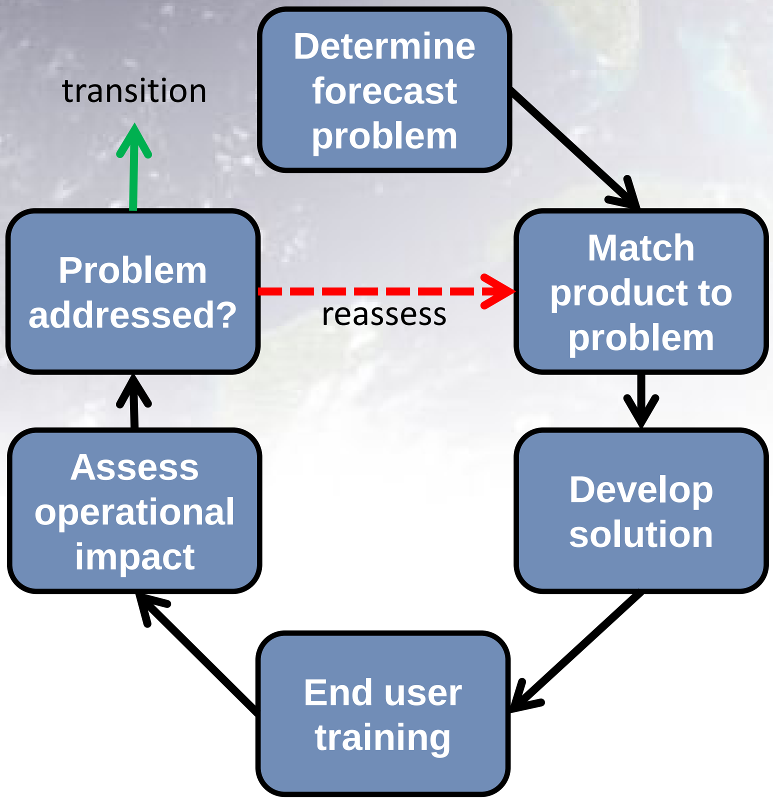
STAR JPSS Annual Science Team Meeting
Ozone EDR Breakout 5e
14 May 2014

Outline

- SPoRT Paradigm/Overview
- Forecast Challenge & Ozone Retrievals
- Ozone Products
- Transition to National Centers
- New Product Development & Future Goals

Transitioning unique data and research technologies to operations

SPoRT Mission and Paradigm



Test-Bed Environment

- *Apply satellite measurement systems and unique Earth science research to improve the accuracy of short-term weather prediction at the regional and local scale*
- Bridge the "Valley of Death"
- Can't just "throw data over the fence"
  - Maintain interactive partnerships with help of specific advocates or "satellite champions"
  - Integrate into user decision support tools
  - Create forecaster training on product utility
  - Perform targeted product assessments with close collaborating partners
- Concept has been used to successfully transition a variety of satellite datasets to operational users for nearly 10 years

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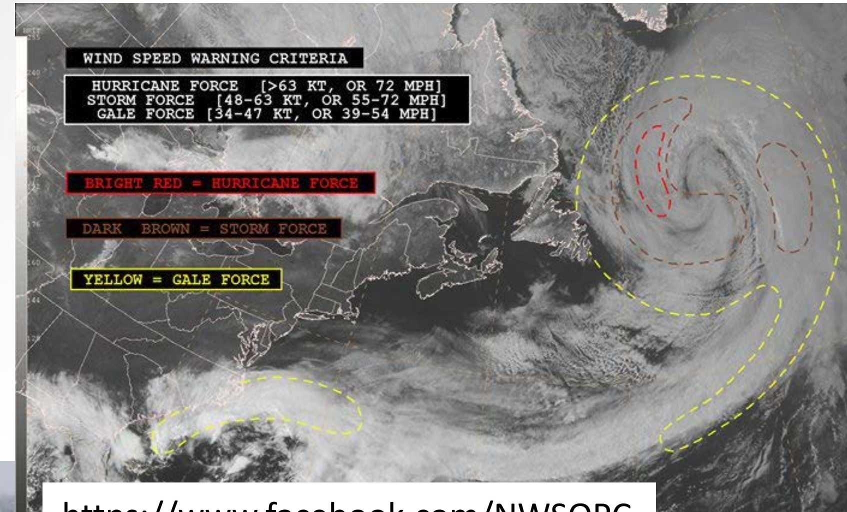
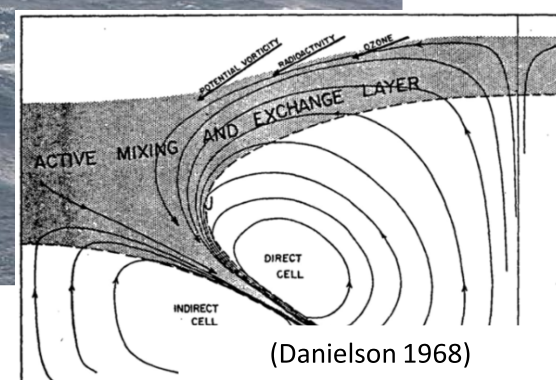
The Forecast Challenge and Ozone Retrievals

- The National Centers (WPC/OPC/SAB) are tasked with providing outlooks that involve forecasting the development of synoptic scale systems and associated severe weather
- OPC especially focuses on forecasting cyclogenesis and the development of hurricane-force winds in the North Pacific and Atlantic oceans
- Identifying regions of stratospheric air and the potential for tropopause folding can enhance forecaster situational awareness of impending cyclogenesis and high wind events
- Stratospheric air can be identified by potential vorticity and warm, dry, ozone rich air

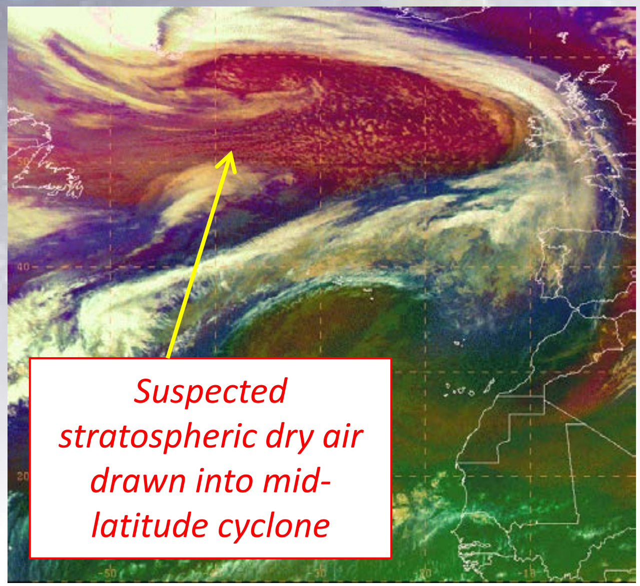


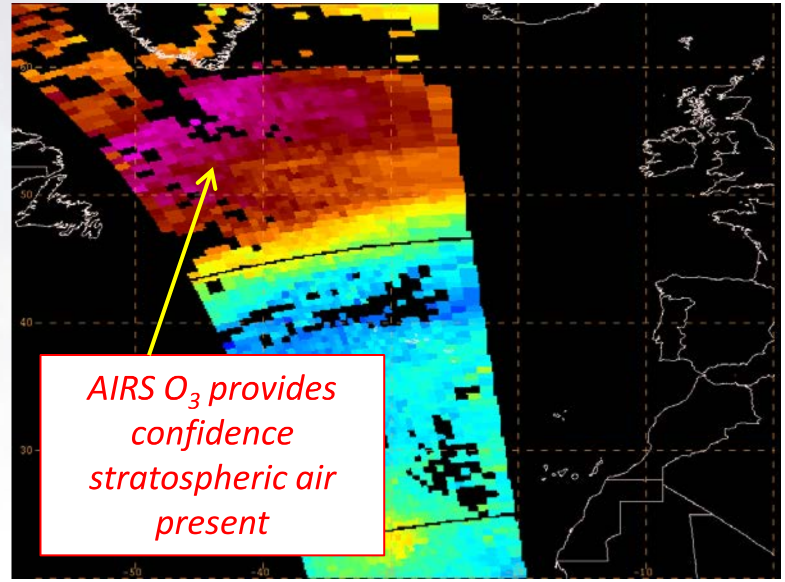
https://www.facebook.com/NWSOPC



(Danielson 1968)

The Forecast Challenge and Ozone Retrievals





- SPoRT has worked closely with the GOES-R and JPSS Proving Grounds to develop and transition ozone products in N-AWIPS format to OPC
- OPC has used the Air Mass RGB product to identify stratospheric air, however uncertainty exists about interpreting the new qualitative product
- Legacy AIRS ozone retrievals can be used to increase forecaster confidence in the Air Mass RGB and enhance interpretation

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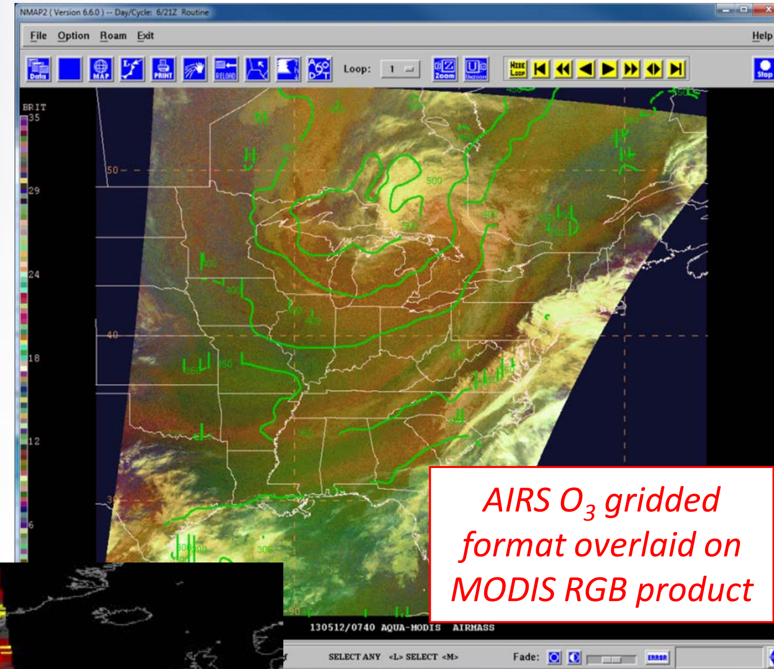
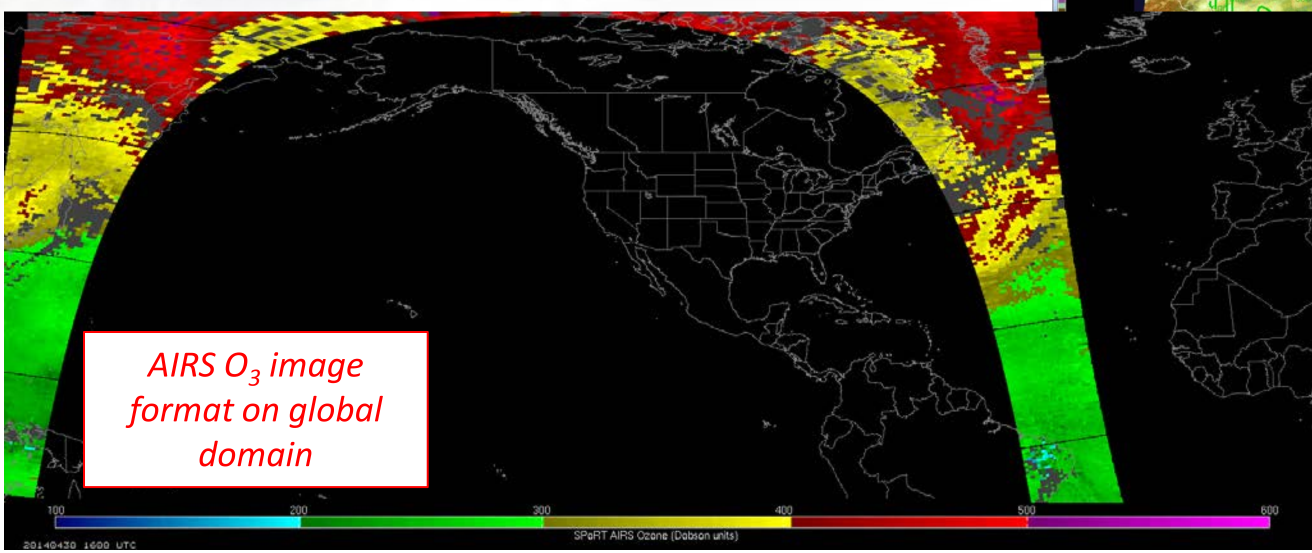
What products does SPoRT create?

- SPoRT produces 2 products in image and gridded format:
  - Total Column Ozone
  - Ozone Anomaly
- AIRS data obtained from NASA Land Atmosphere Near Real-time Capability for EOS (LANCE) with latency between 60 and 200 minutes



AIRS O_3 gridded format overlaid on MODIS RGB product

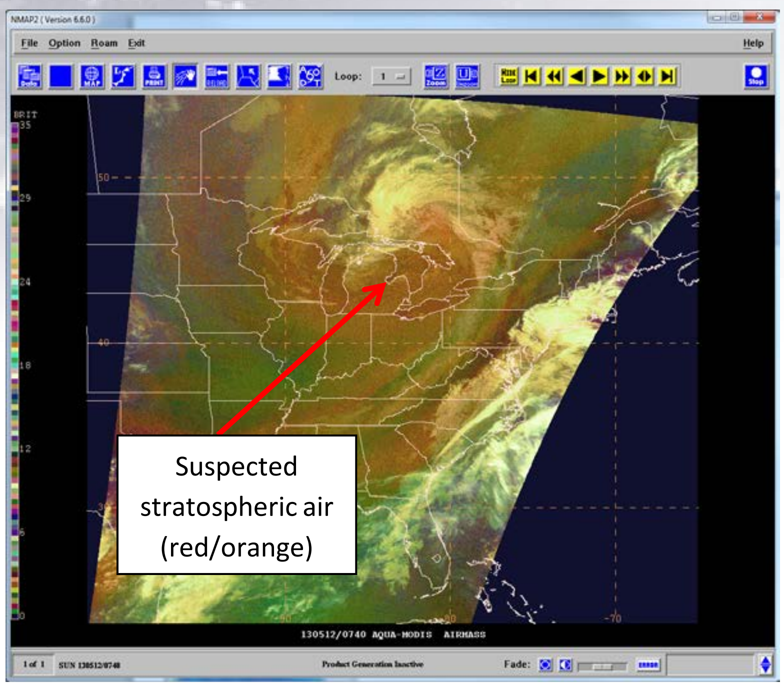


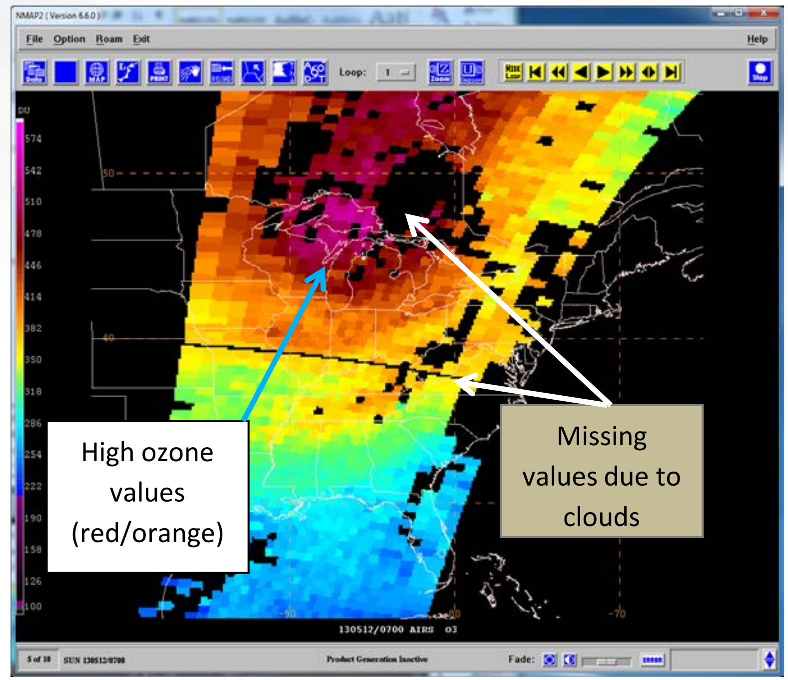
AIRS O_3 image format on global domain

- Product is provided in hourly swaths:
  - Products have a 4-hour latency to utilize all granules
  - Advantage is hemispheric coverage for OPC's domain

Example 12 May 2013

- SPoRT MODIS RGB Air Mass Image show a region of red/orange coloring surrounding the low pressure center
- AIRS Total Column Ozone confirms there are high zone values in the region

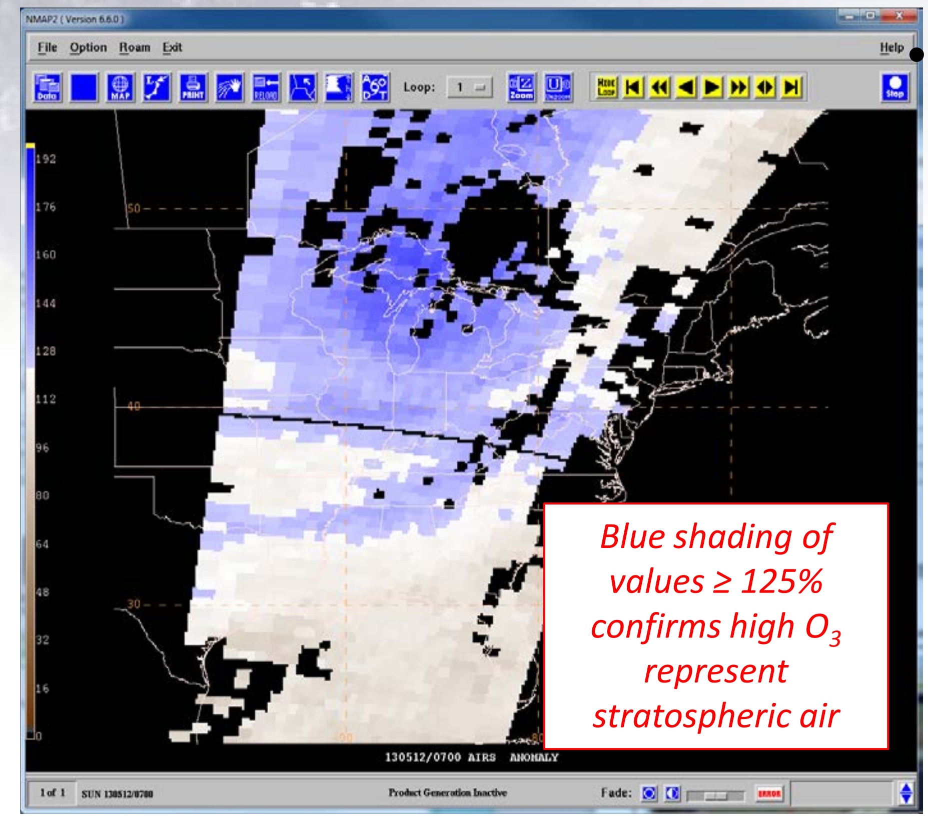




- How do we know if these high ozone values represent stratospheric air or are within the climatological range?

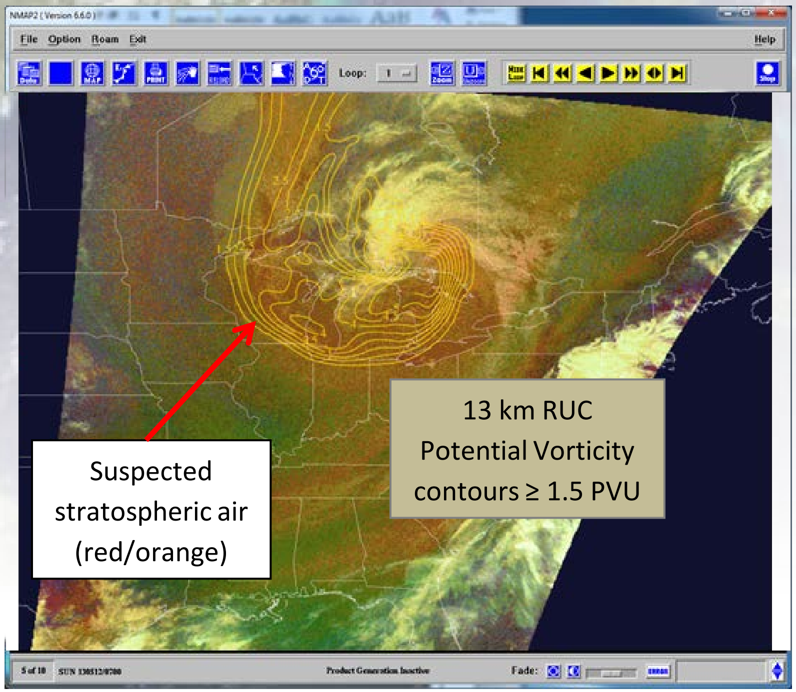
Ozone Anomaly Product

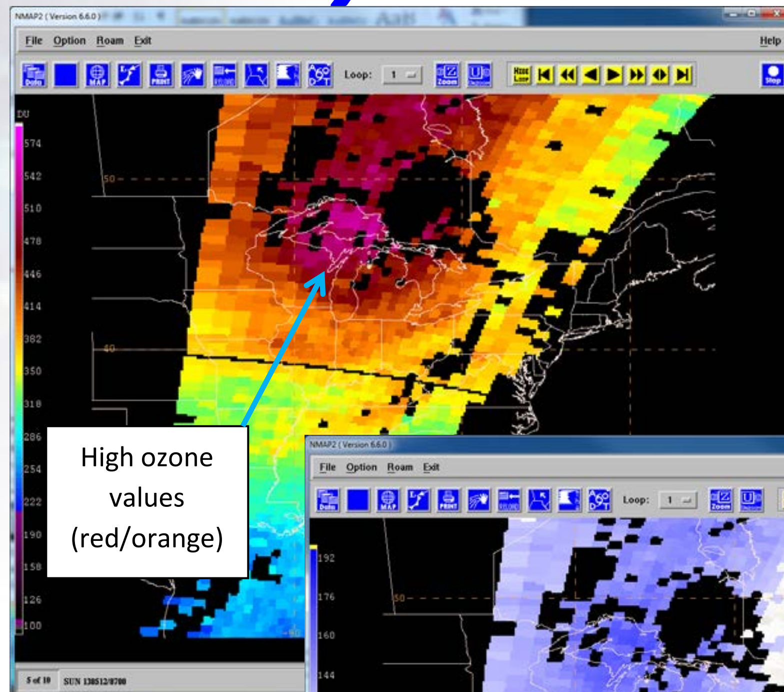
- Identification of stratospheric air based on high ozone values could lead to misinterpretation if the values actually range within climatology since the mean varies seasonally and spatially

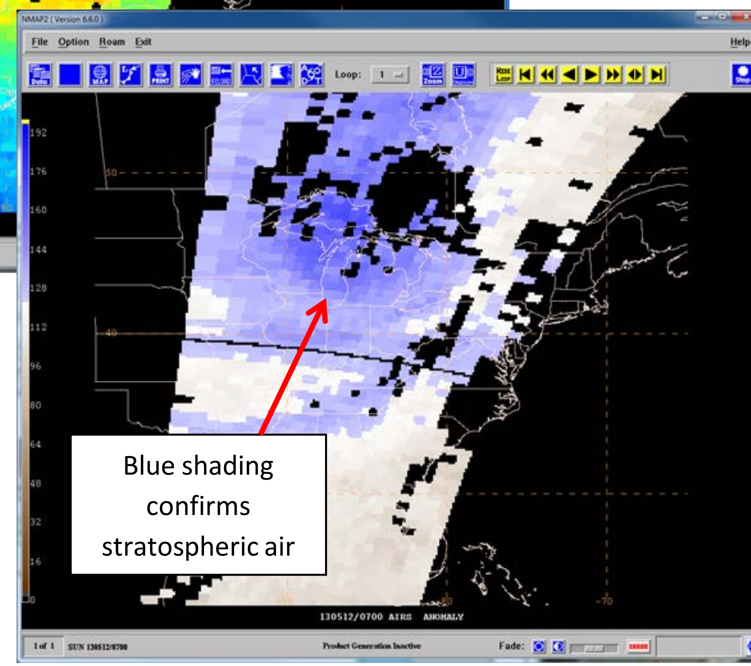


- The AIRS Ozone Anomaly product clarifies the presence of stratospheric air based on:
  - Stratospheric air has ozone values at least 25% larger than the climatological mean (Van Haver et al. 1996)
  - Global and zonal monthly mean climatology of stratospheric ozone derived from the NASA Microwave Limb Sounder (Ziemke et al. 2011)

Example 12 May 2013







- SPoRT AIRS Ozone Anomaly product created as a percent of normal (0-200%)

$$PON = \frac{TCO}{climo} \; x \; 100$$

- Shades of blue represent stratospheric air (ozone values ≥ 125%)

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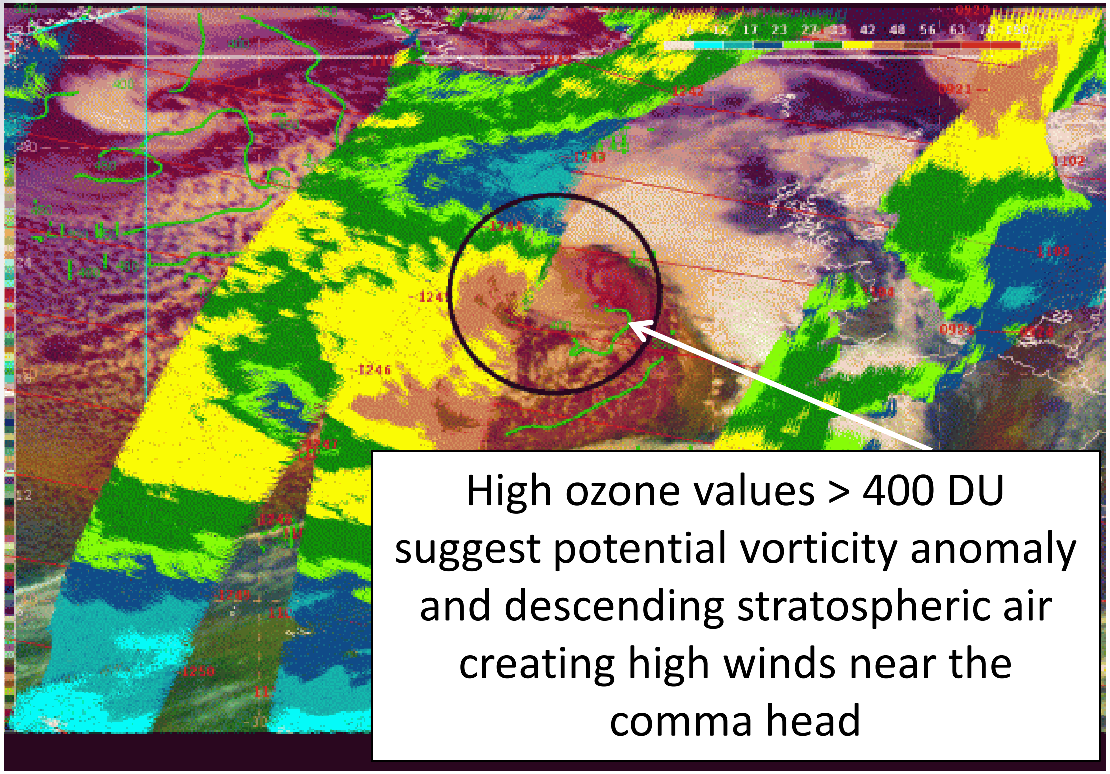
Transition to National Centers

- Ozone products evaluated at OPC, WPC, SAB winter 2014
- Forecaster Feedback
  - "Reinforce the evidence from RGB of the descent of stratospheric air with tropopause folding."
  - "This has allowed me to have confidence in assessing the RGB Airmass product and also in conjunction with gridded GFS output that a perceived PV anomaly is real or not."



SEVIRI RGB Air Mass image, AIRS Total Column Ozone (green contours), and ASCAT winds valid at 1400 UTC on 12/18/13. The black circle highlights the descending stratospheric intrusion near the comma-head/bent back front. Image courtesy of Michael Folmer Satellite Liaison at NOAA/NWS WPC/OPC/TAFB and NOAA/NESDIS SAB

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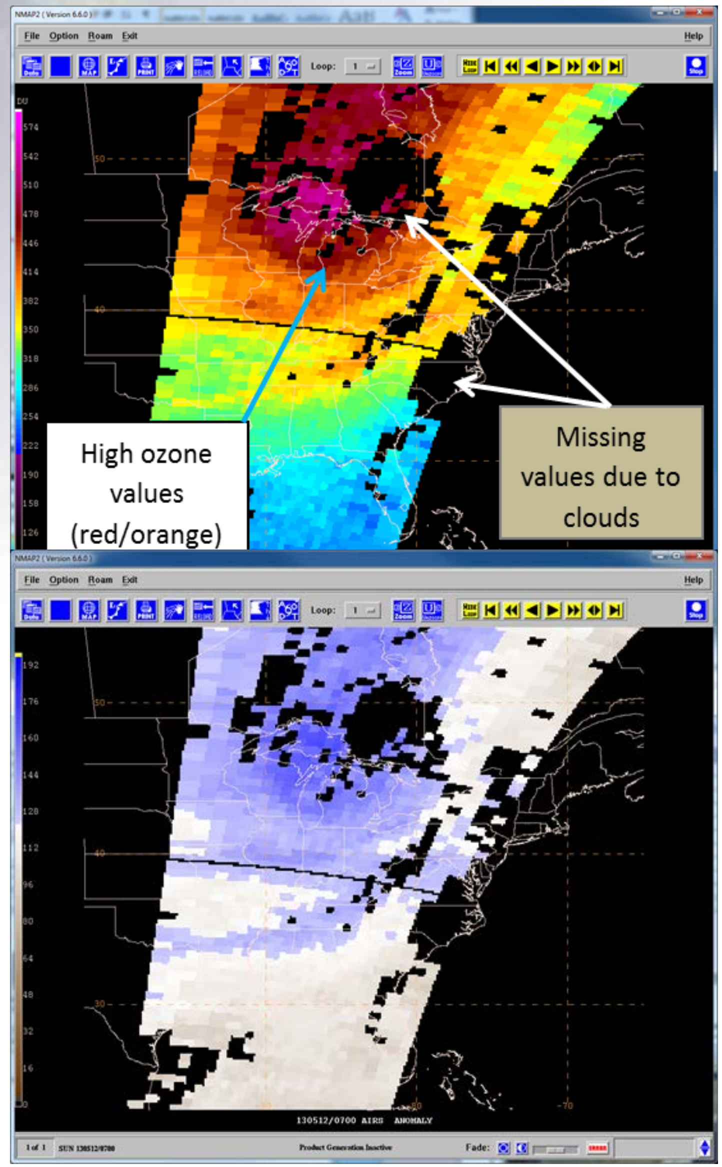
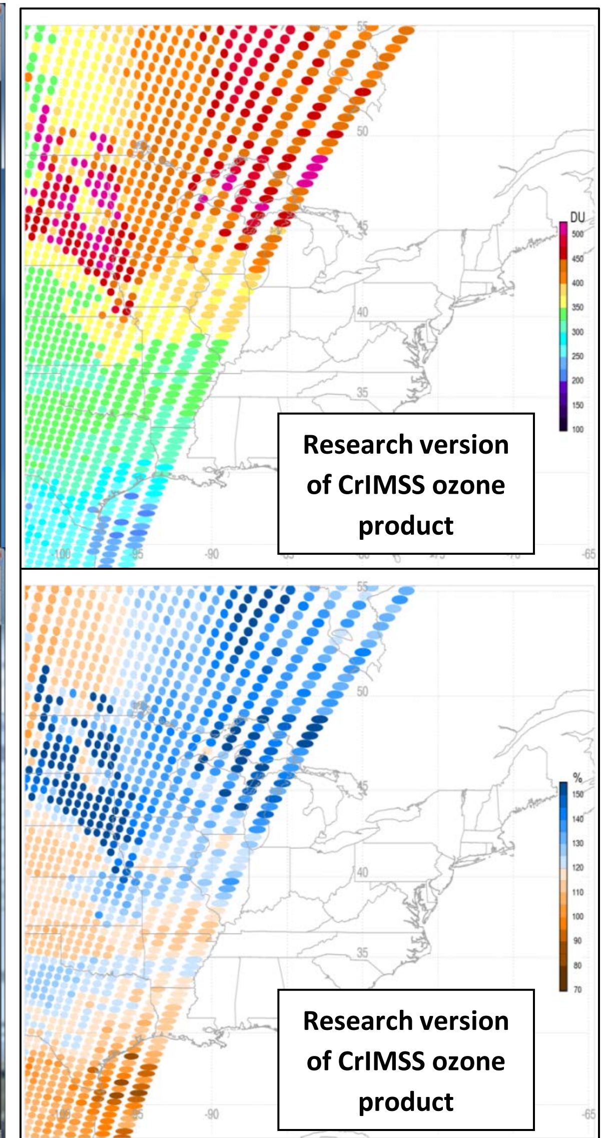
CrIMSS Ozone Products

- Expanding suite of ozone products to include CrIS
- Initial use of CrIMSS until NUCAPS CrIS is available
- Data obtained from SSEC PEATE server at an 8-hour latency to produce hourly swaths on a hemispheric domain
- NUCAPS CrIS ozone retrievals will hopefully be transitioned to OPC Fall 2014





Future Goals

- Currently training includes a quick guide
  - expand forecaster training to include a short module
- Make the products available in AWIPS-II
  - Currently funded joint SPoRT/CIRA/CIMSS GOES-R visiting scientist project to explore products in National Centers Perspective AWIPS-II

"There may have been 1 occasion where 1 pass did line up over the US with the spot I was interested in. In that case, it was helpful in reaffirming my suspicions on whether stratospheric air was present. Otherwise, the passes were few and far between and not particularly timely. If there was greater coverage of passes and not as much of a lag, it would certainly be useful."

near the Great Lakes in the Air Mass RGB Imagery (top left) indicate stratospheric air and high potential vorticity near a jet streak. High potential vorticity values at 0800 UTC in the 500-300 mb layer correlate with the stratospheric air on the Air Mass RGB Imagery. The top right diagram shows high values of ozone over the Great Lakes region at 0700 UTC. The Ozone Anomaly product (bottom left) shows the high ozone values are a significant enough deviation from climatology to be considered stratospheric air. Non-convective high winds tend to occur under the region of stratospheric air. ASCAT measured winds ranging from 52-64 knots (27-33 m/s) over western Lake Erie and 33-52 knots (17-33 m/s) over Lake Huron (bottom right).

- Adjust product according to forecaster feedback after the winter demonstration at OPC
- Expand the ozone products to other instruments
  - IASI
  - Suomi NPP instruments such as CrIS and OMPS
  - Explore a single product with AIRS, IASI, CrIS retrievals once NUCAPS is available

Questions & Comments

Email any additional feedback or comments

emily.b.berndt@nasa.gov

OMPS Limb Profiler – Level 2 Products Update

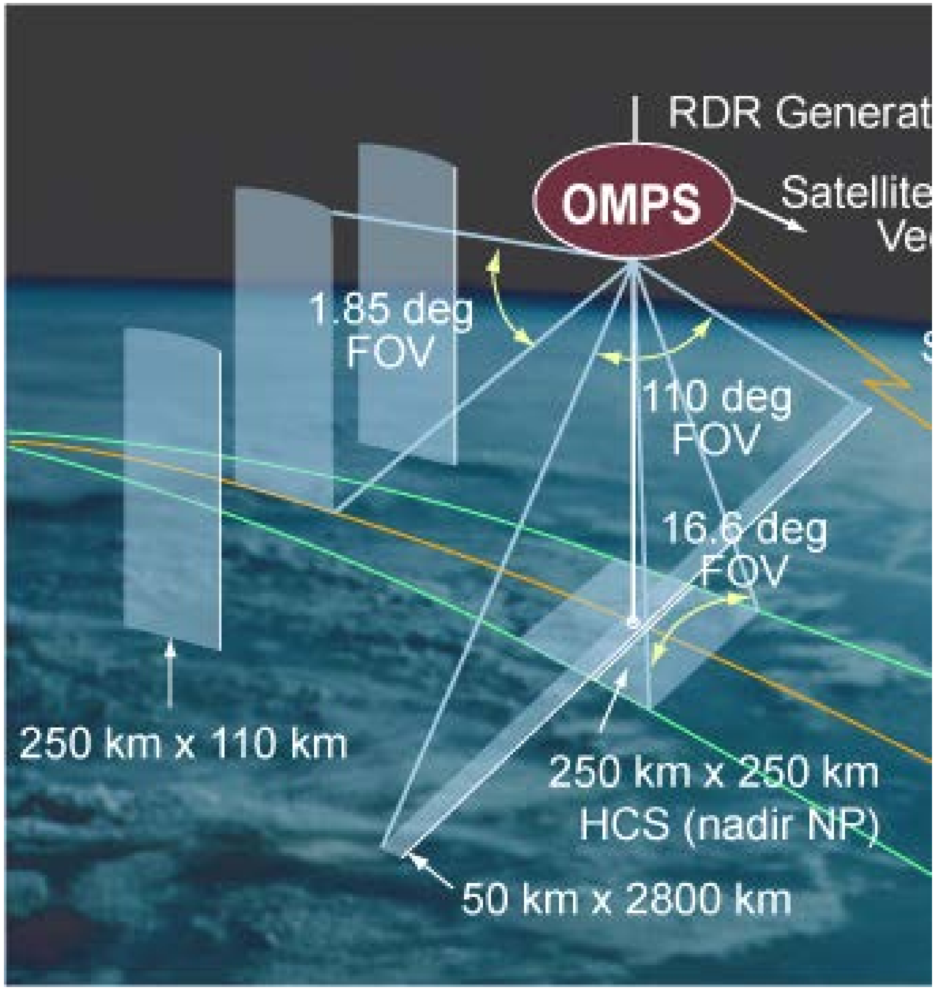
Matthew DeLand (SSAI)
P. K. Bhartia (NASA/GSFC)
+ contributions from Ghassan Taha, Didier Rault, Philippe Xu, Natalya Kramarova, and other team members

STAR JPSS Science Team Meeting

College Park, MD 14 May 2014

LP Instrument Review

- LP makes limb scattering measurements viewing backwards along orbit.
- Wavelength range = 290-1000 nm, with variable resolution (1-25 nm).
- Altitude range = 0-80 km, 1 km sampling.
- Collect radiance spectrum simultaneously at each altitude.
- Specify (programmable) sample table of CCD pixels that are downloaded to meet data rate limits.



Major LP Data Products

- Gridded radiances (Level 1)
  - L1B pixels have variable wavelength, altitude sampling across CCD.
  - Interpolate radiances to regular grid for use in L2 retrievals.
- Ozone profile (UV wavelengths)
  - Retrieved profile covers stratosphere and lower mesosphere (28-60 km).
- Ozone profile (visible wavelengths)
  - Retrieved profile covers lower stratosphere (cloud top to 30-35 km).
- Aerosol extinction coefficient (visible, near-IR wavelengths)
  - Retrieve profiles at 5 wavelengths between 514-865 nm.

Processing Status

- Release 1 products (L1G radiances, center slit ozone profiles) initially released October 2012.
- Release 2 L1G processing completed (up to present) April 2014.
- Ozone reprocessing completed 12 May 2014. Evaluation in progress to support archival of data set at DAAC for public release.
- Aerosol reprocessing now in progress. Estimate completion by end of May 2014.

L1 Changes from Release 1

- Implement intra-orbit “dynamic” tangent height adjustment through OPF. Also implement additional 500 m “static” adjustment.
- Revise wavelength gridding in L1G product to use fixed grid for all events.
- Revise reference wavelength scale to use better data set.
- Implement intra-orbit and seasonal wavelength scale adjustments for each event.
- Eliminate merging of multiple gain/aperture values for determining radiance at each pixel.
- Prioritize data selection to use high gain sample for $\lambda < 500$ nm, low gain sample for $\lambda > 500$ nm.
- Revise ancillary data selection to use GMAO products for temperature, pressure, density. Profiles extended to 80 km with constant temperature lapse rate.

L2 Changes from Rel. 1 [1]

- Implement new ozone *a priori* data set created from 2012 MLS data.
- Implement SUSIM data for UV portion of high-resolution solar irradiance spectrum.
- Exclude OH emission wavelengths (306.5-311 nm) from UV ozone profile retrieval.
- Add 1% instrument error term to SNR noise term for retrieval.
- Modify VIS retrieval to use 510 nm and 673 nm as "guard" wavelengths for triplet formation, 549-633 nm as range to sample Chappuis band.
- Turn off explicit aerosol correction in ozone retrieval.

L2 Changes from Rel. 1 [2]

- Provide ozone retrieval data from all three slits.
- Limit altitude range of ozone product to z_{max} = 60.5 km.
- Report UV and VIS ozone retrieval results as separate products, in addition to combined profile.
- Combined ozone profile uses UV retrieval values from 60.5 km down to 27.5 km, uses VIS retrieval values from 26.5 km down to retrieval cutoff.
- Create mixing ratio ozone profile product on regular pressure grid for every event.
- Generate separate aerosol product data set using current retrieval algorithm.

Evaluation of GMAO vs. MLS

- LP retrieval algorithm uses GMAO FP-IT Np profiles for temperature and pressure (derived from geopotential height), interpolated to event location and time, as ancillary data.
- Compare zonal mean products with MLS data for selected days to evaluate accuracy and variability.
- Temperature profiles generally agree to ±5 K between 10-60 km.
- Pressure profiles generally agree to ±2% between 10-60 km.

GMAO vs. MLS – Temperature

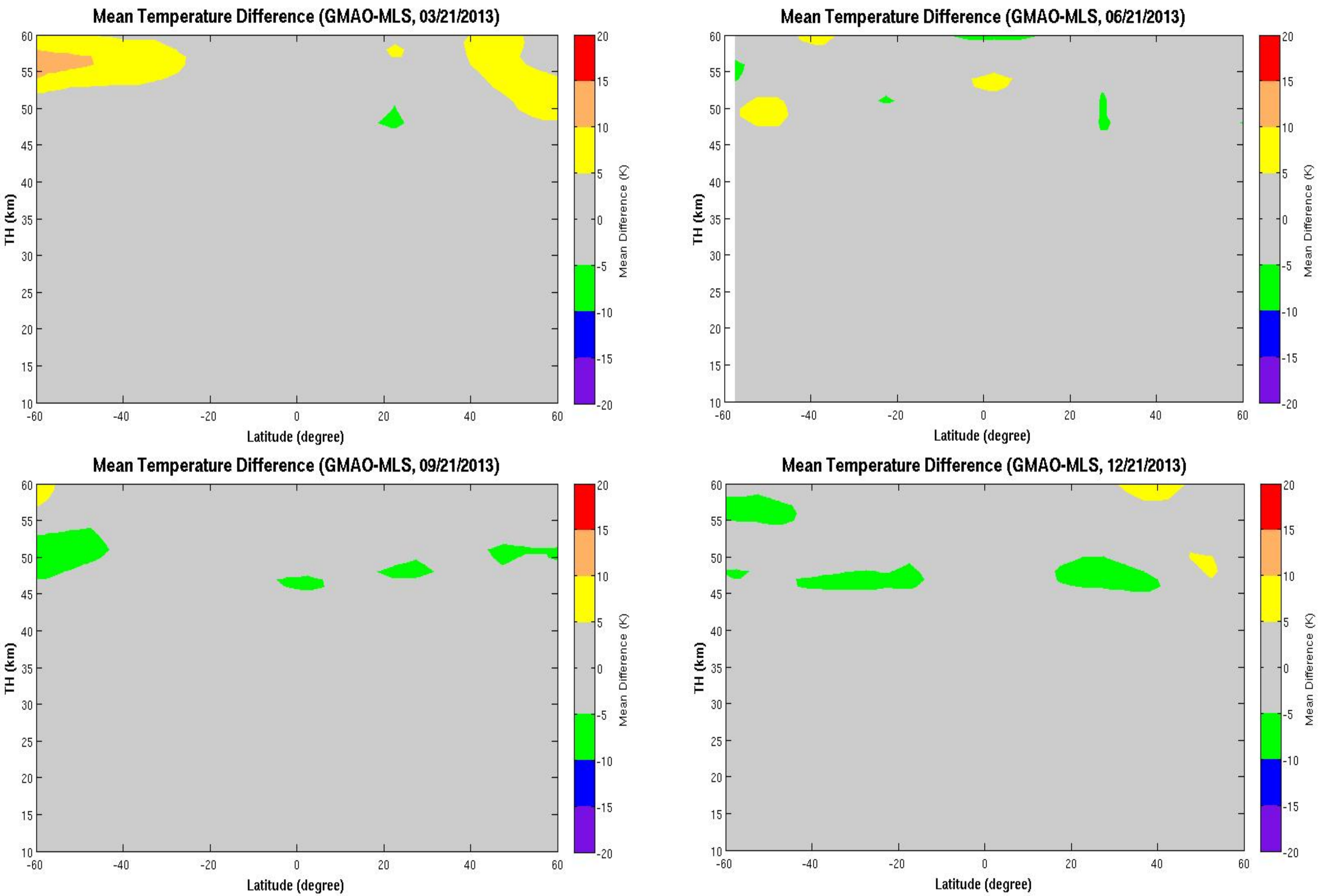


Figure courtesy of Philippe Xu

GMAO vs. MLS – Pressure

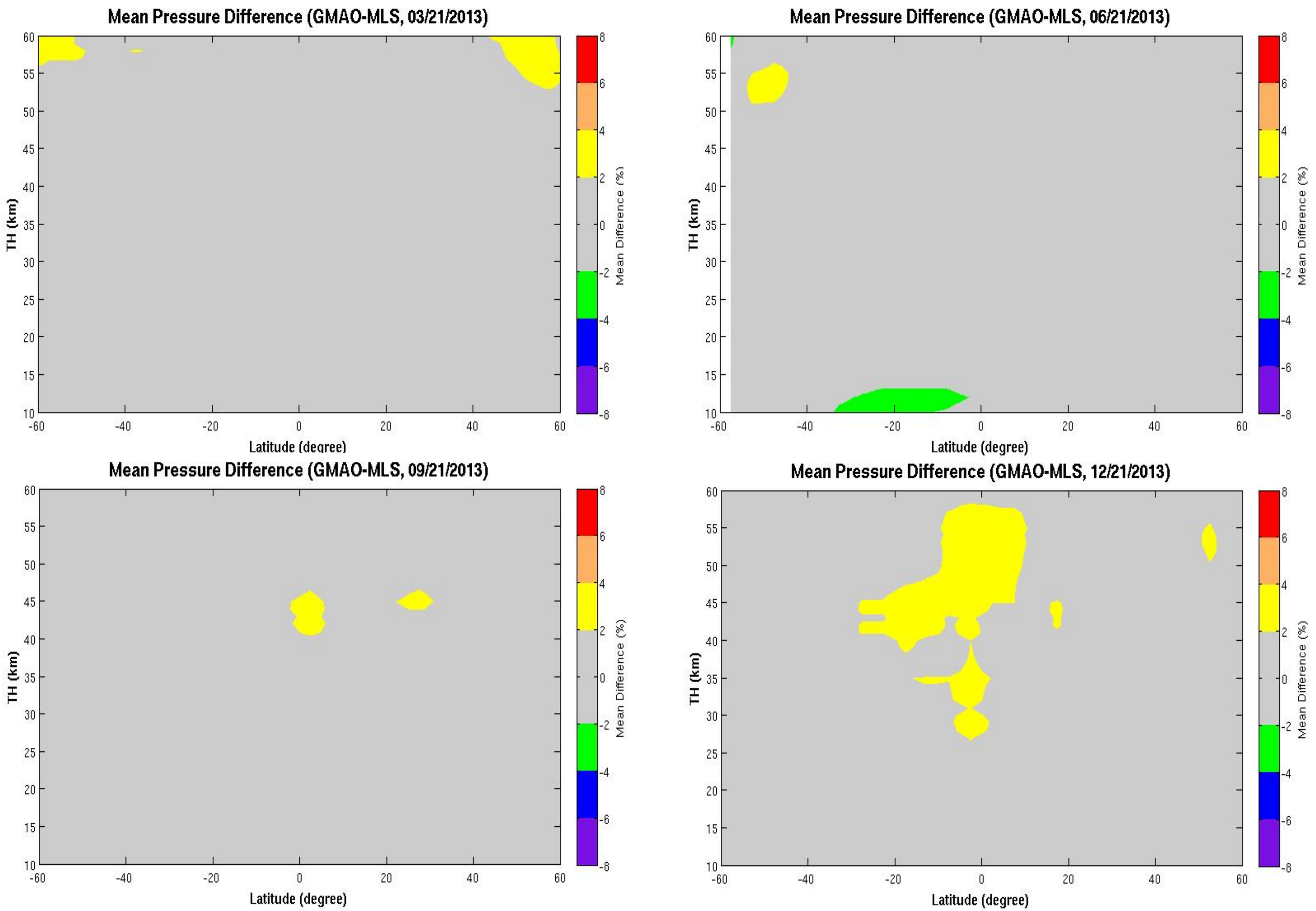
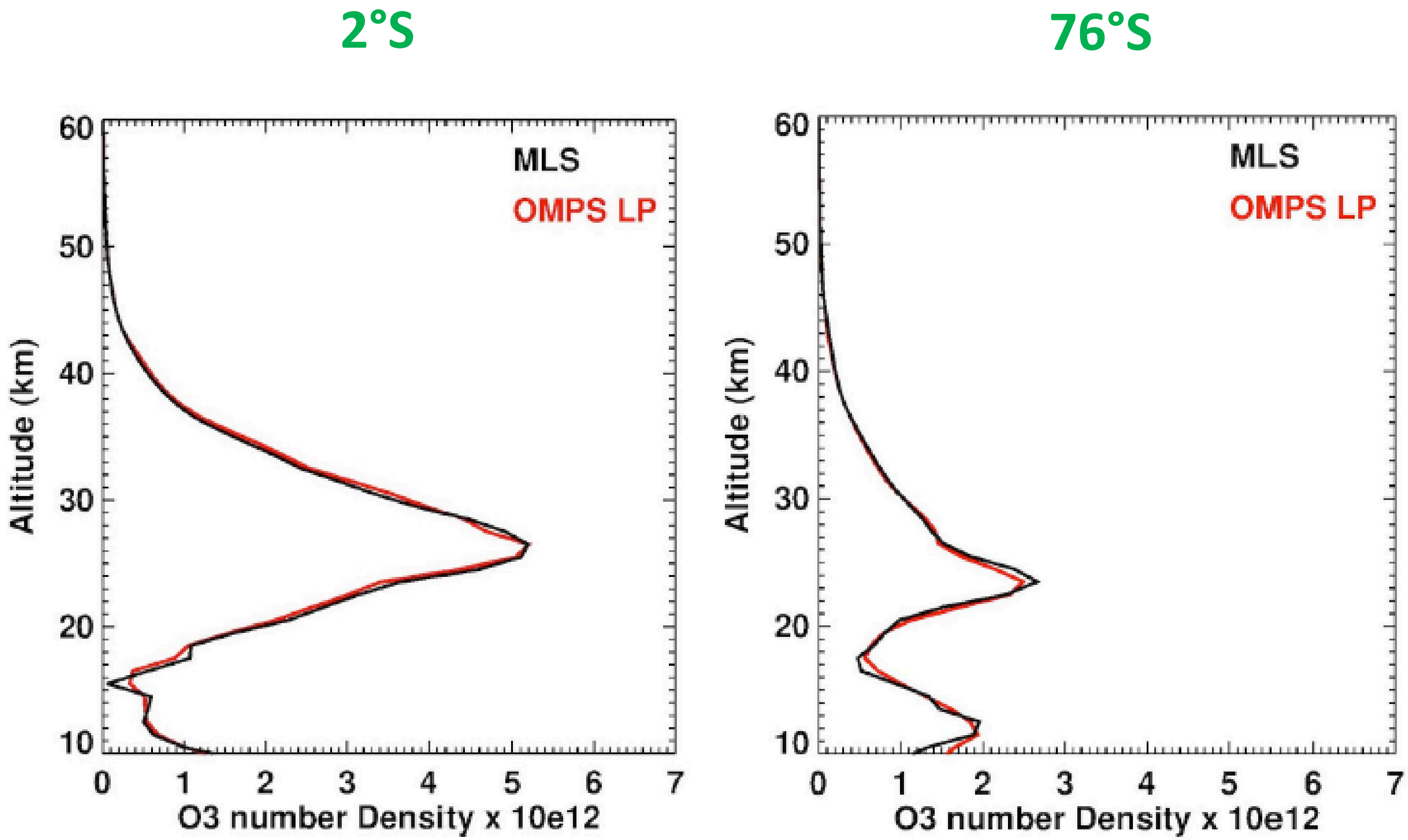


Figure courtesy of Philippe Xu

Ozone Products

- Combined ozone density profile uses visible ozone retrieval for cloud top-27 km, UV retrieval for 28-60 km. No merging or adjustment at transition altitude.
- Mixing ratio profiles also created for user convenience.
- Development testing results shown here utilized set of 38 “golden days” during April-December 2012, where NPP orbit is closely aligned with Aura satellite (and MLS instrument).

Sample LP Profiles vs. MLS



LP vs. MLS - All Sample Orbits

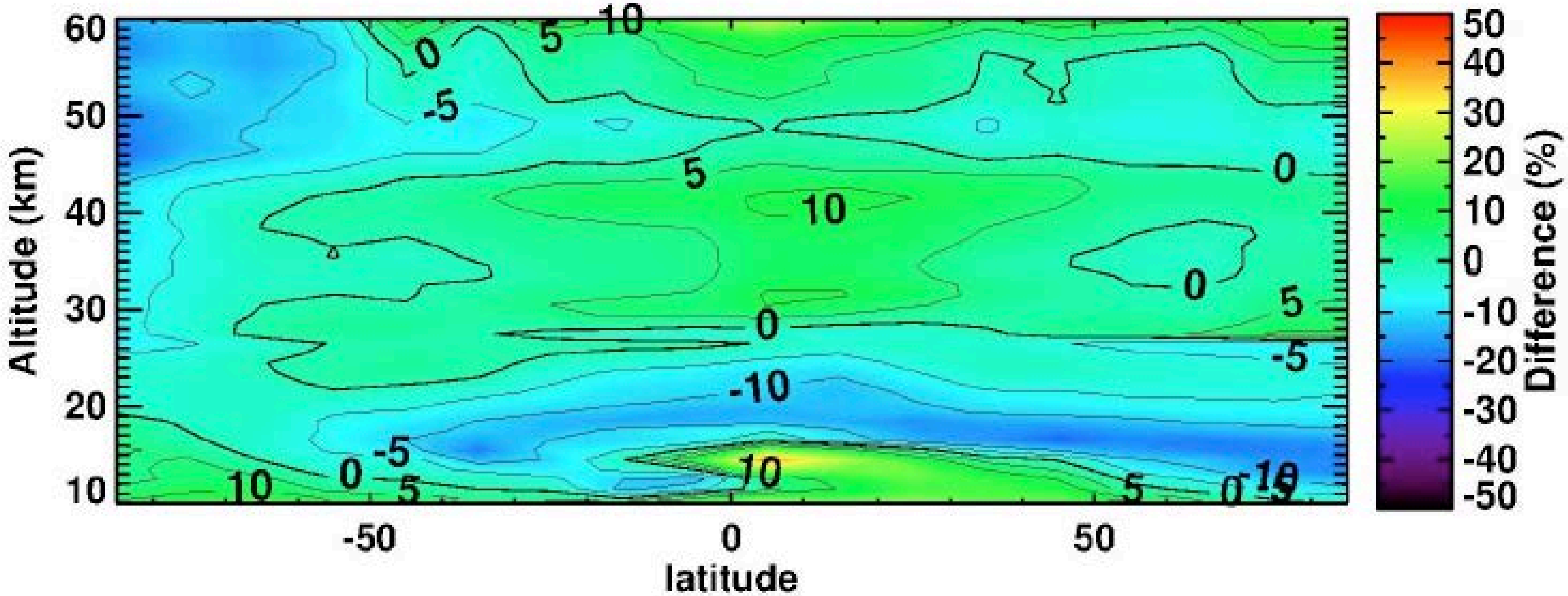
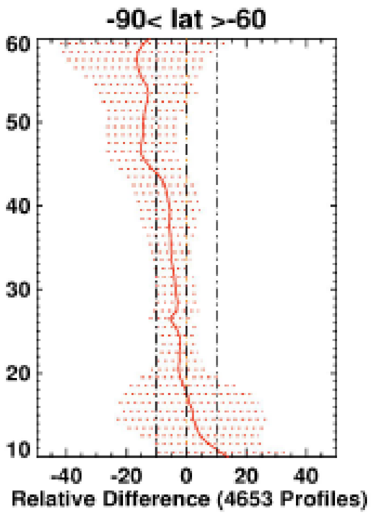
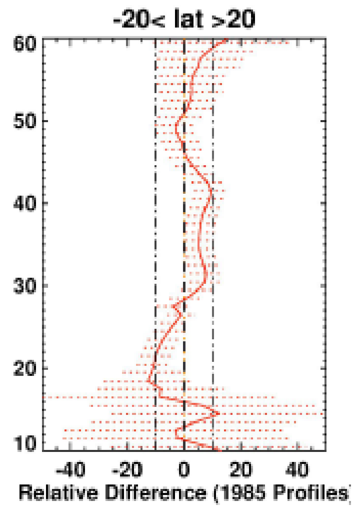
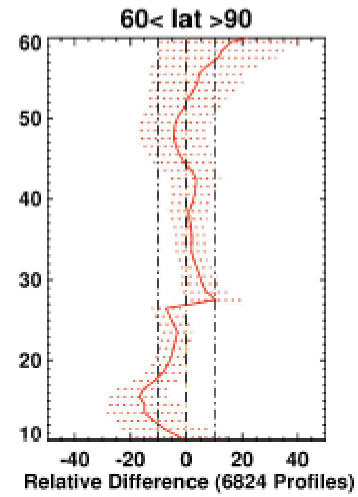


Figure courtesy of Ghassan Taha

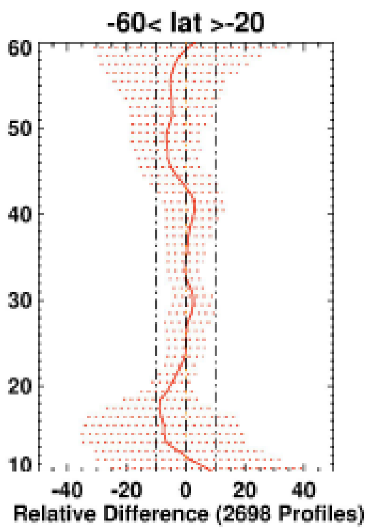
LP vs. MLS – Zonal Means

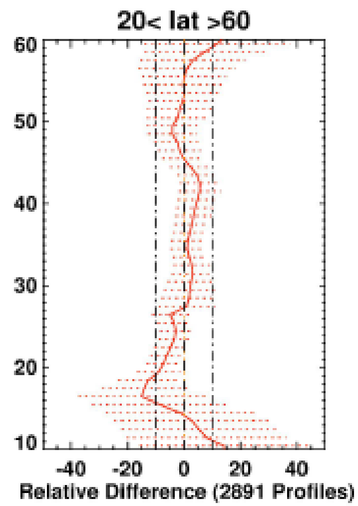






Southern Hemisphere

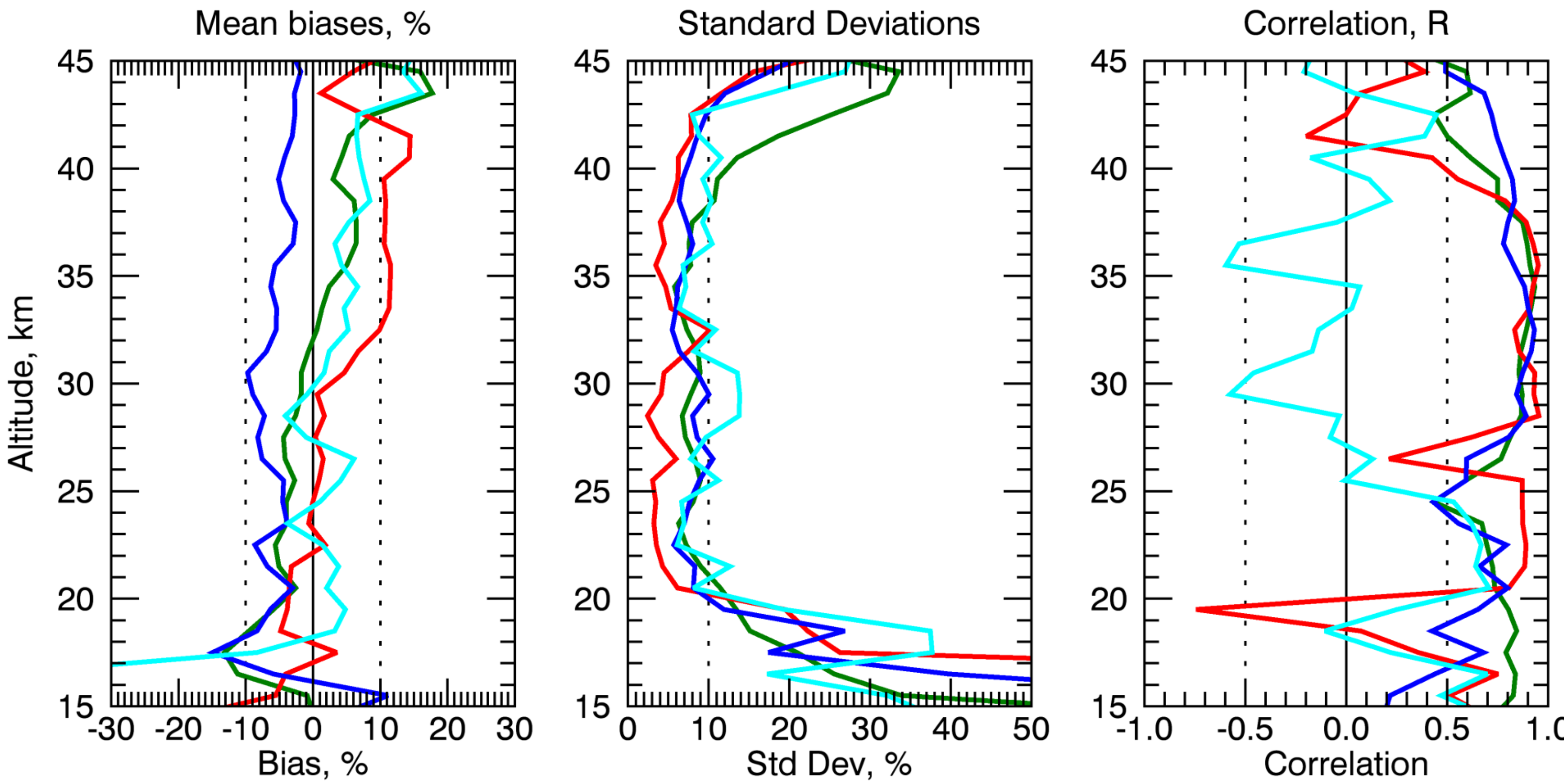




Northern Hemisphere

Figure courtesy Ghassan Taha

LP vs. Lidar - Overpass



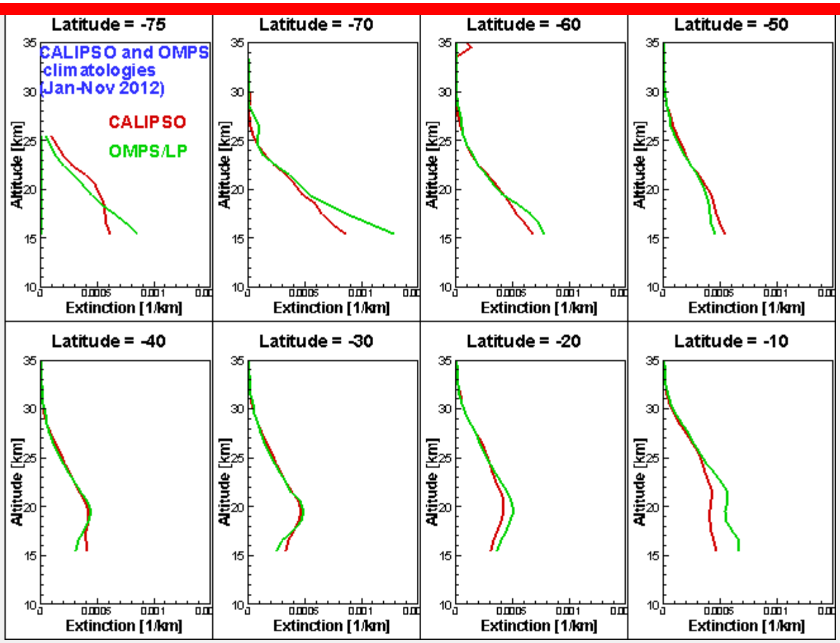
Haute Provence 31 Mauna Loa 10 Hohenpeissenberg 23 TableMount 13

[44N,5.7E]; [20N, 155W]; [48N,11E]; [34N, 118W]

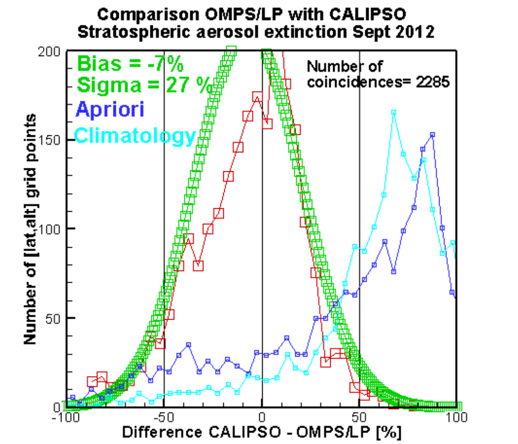
Figure courtesy Natalya Kramarova

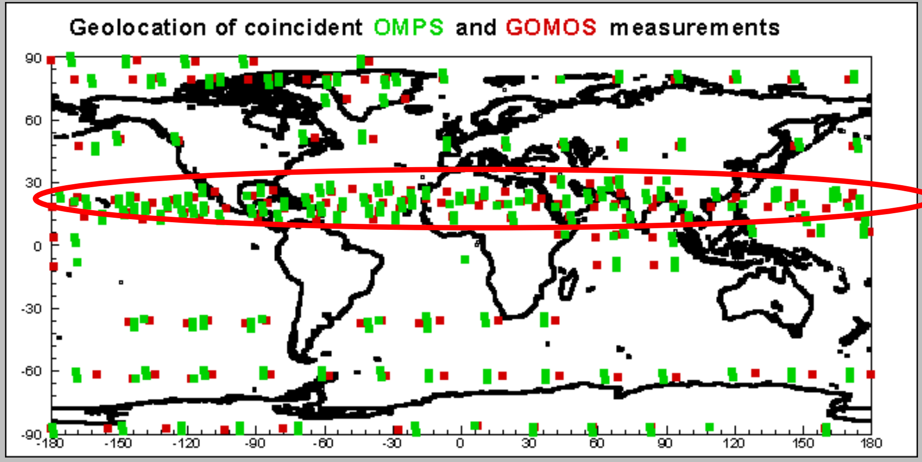
LP Aerosol Product

Comparison with CALIPSO and GOMOS



Comparison with CALIPSO
Bias < 7%, Variance = 27 %





Comparison with GOMOS
Bias < 10%, Variance = 30 %

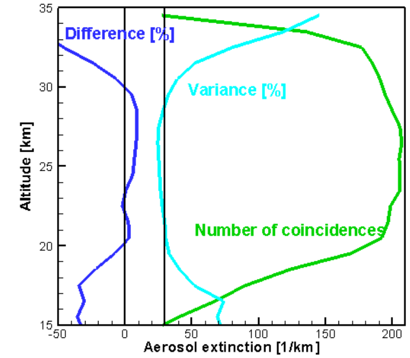


Figure courtesy Didier Rault

LP Aerosol Product

Evolution over NPP mission

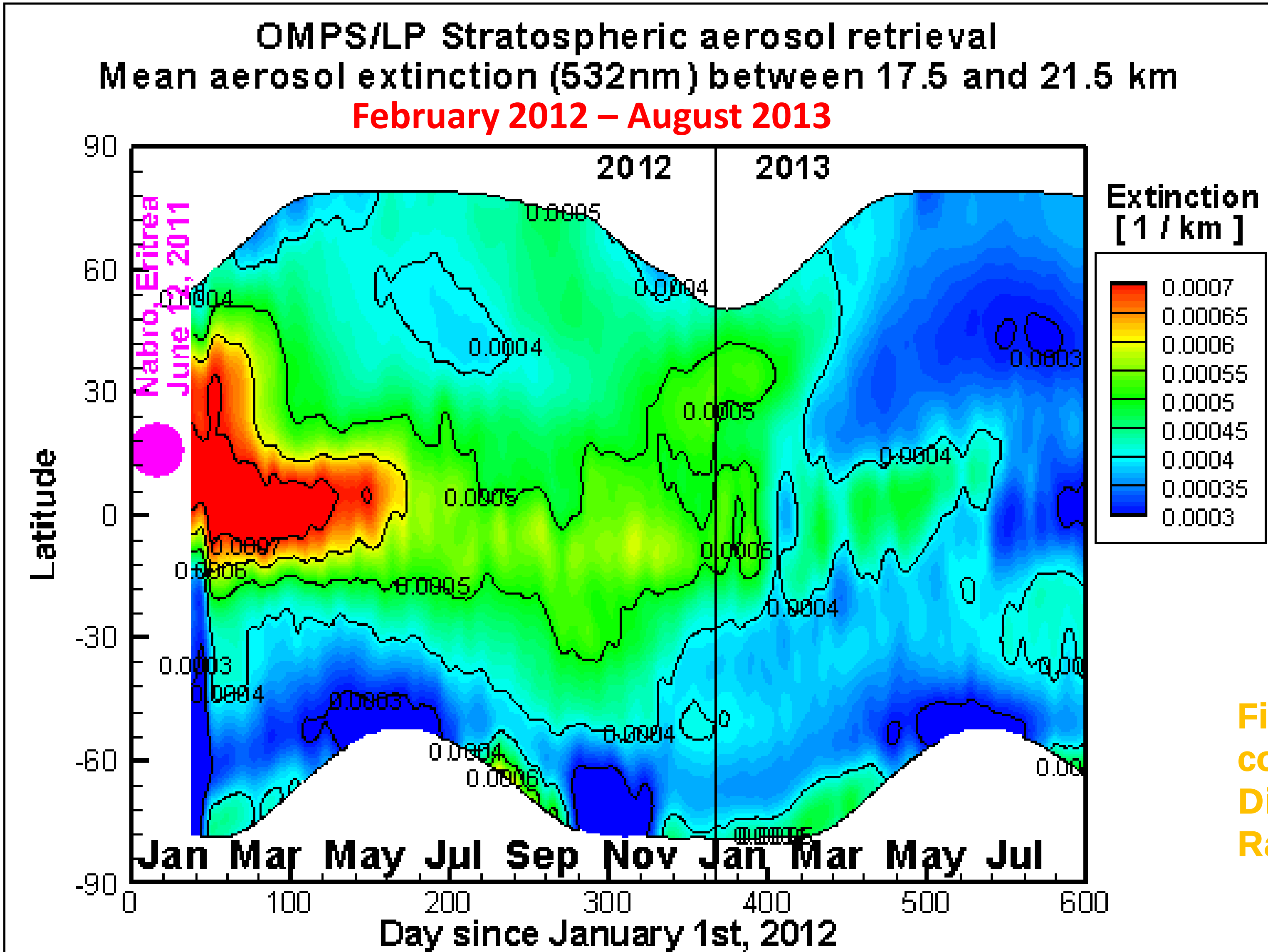
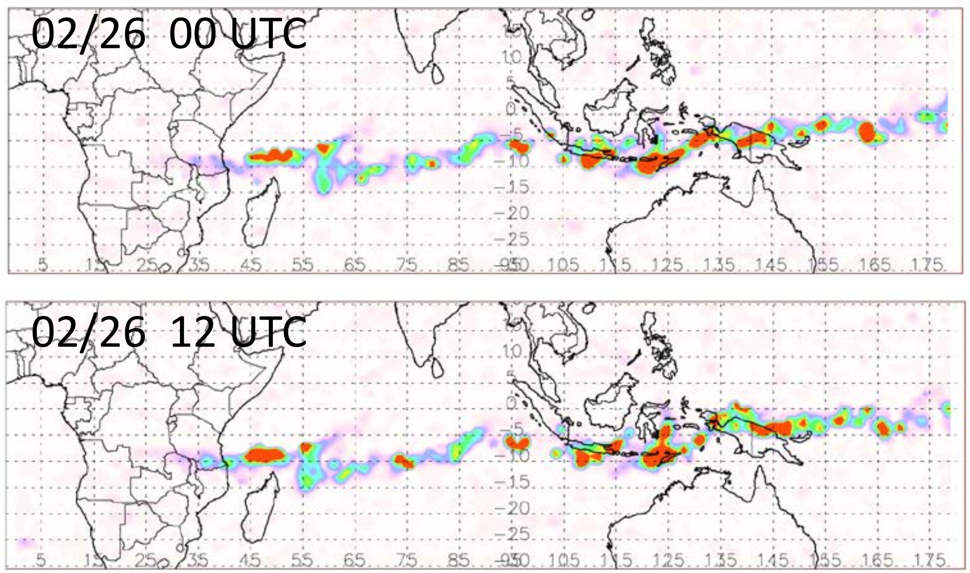


Figure courtesy Didier Rault

LP Aerosol – Kelut Volcano

LaRC Forecast 26 Feb 2014 (Duncan Fairlie)



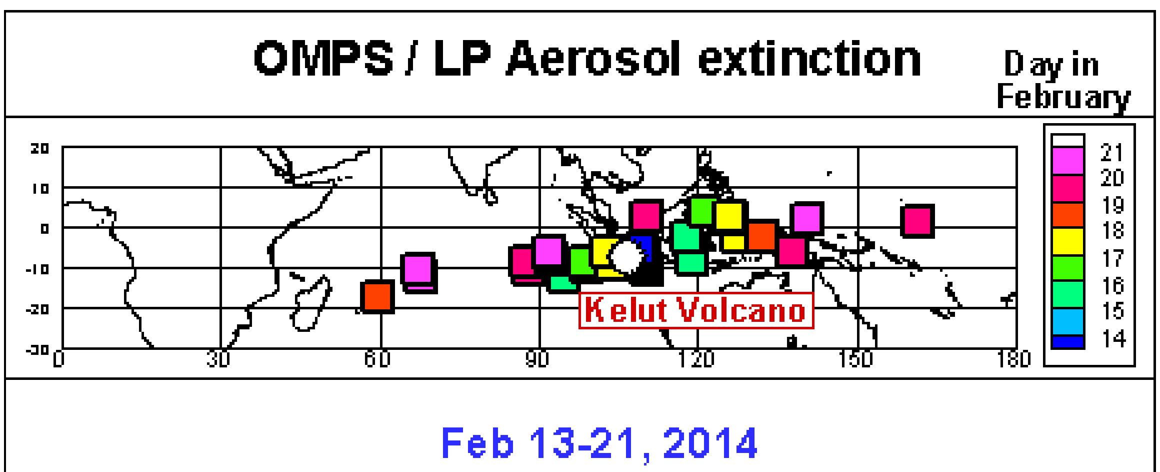
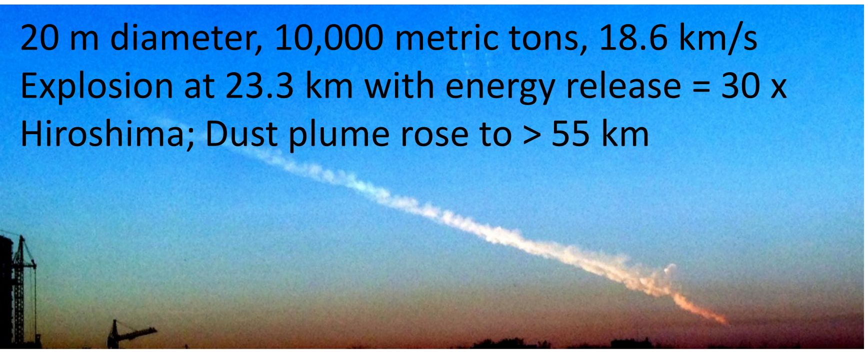


Figure courtesy Didier Rault

LP Aerosol – Chelyabinsk bolide

20 m diameter, 10,000 metric tons, 18.6 km/s
Explosion at 23.3 km with energy release = 30 x Hiroshima; Dust plume rose to > 55 km



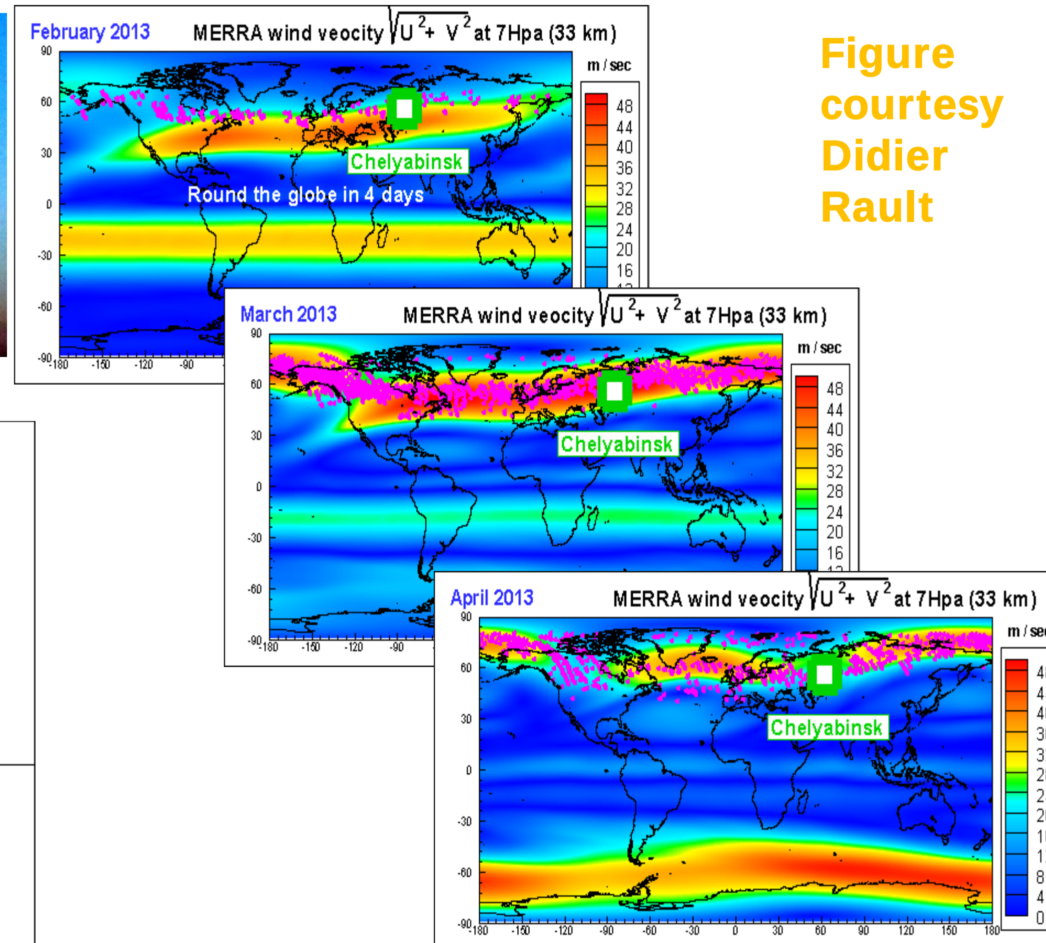
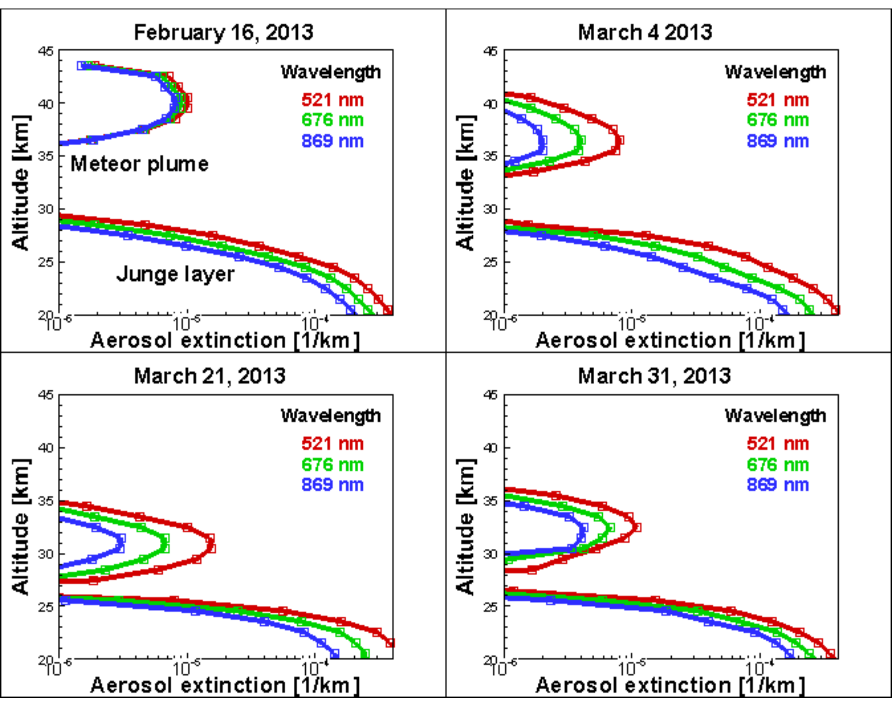


Figure courtesy Didier Rault



"New stratospheric dust belt due to the Chelyabinsk bolide", Gorkavyi, Rault, Newman, da Silva, Dudorov, *GRL*, doi:10.1002/grl.50788 (5 Sep 2013)

Unresolved Issues

- Accuracy of geopotential height profiles in mesosphere (60-80 km)
  - GMAO data currently extrapolated to 80 km with linear lapse rate for ancillary data.
  - MLS team claims 400 m uncertainty in both MLS and GMAO products at this altitude.
- Tangent height registration error along orbit
  - Stratospheric radiance values are very sensitive to tangent height location ($dI/dz \approx -14\%/\text{km}$).
  - Current analysis suggests remaining errors are ±300 m or less, but results from different techniques are not yet consistent.

Future Work

- Aerosol correction
  - Need to be consistent with current “clean” environment, accommodate local variability.
  - Need capability to handle future change in conditions.
- Polar mesospheric cloud (PMC) correction
  - Layers of ice crystals at 80-85 km during polar summer.
  - Affects radiance signal at lower altitudes due to LP viewing geometry.
  - Flagging approach in place for Release 2. Correction will be more complex to develop.
- Extend retrieved ozone profiles into troposphere.
- Derive improvements to GMAO profiles above 40 km using LP data.

Big and Little Pictures

L. Flynn

May 14, 2014

NOAA STAR JPSS Science Meeting

What do we need to do and when, where, how, and why?

- OMPS Nadir Profiler
  - V8Pro to Operations
  - Consistent with NOAA-19 SBUV/2
  - Products in BUFR
- OMPS Nadir Mapper
  - V8TOz to Operations
  - Consistent with OMI and GOME and SBUV/2
  - Add table profile and efficiencies
  - Add SO_2 products (Linear Fit)
- OMPS Limb Profile
  - V2 to Operations (NDE)

Table 4.2.4 - Ozone Nadir Profile (OMPS-NP)		
Attribute	**Threshold**	**Objective**
Ozone NP Applicable Conditions: 1. Clear, daytime only (3)		
a. Horizontal Cell Size	250 X 250 km (1)	50 x 50 km2
b. Vertical Cell Size	5 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)
	(16.7° FOV)	v2,0, 9/22/12

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.

Path Forward (Solution Key: DONE, READY, KNOWN APPROACH, UNKNOWN, *FUTURE WORK*)

A. OMPS NP Ozone Profile

A.i. Turn on the 253 nm channel in the retrieval algorithm -- DONE.

A.ii. First version of the stray light correction. – March 17 in Mx8.3 DONE.

A.iii. Improved/tuned stray light correction table -- April (SDR Table Tuning) Analysis shows there is room for improvement. Which channels are the best proxies?

A.iv. New Day 1 Solar irradiance spectrum and wavelength scale – May (SDR Table Tuning)

I recommend that this be a simple -0.115 nm shift relative to Day 0. We would revisit with annual wavelength scale variations and wavelength dependent shifts in the future.

(Should this also adjust the radiometric coefficients for the shift/dichroic? Should the solar activity level be picked for the current Mg II 27-day average state?)

A.v. Proper matchup for Nadir Mapper and Nadir Profiler FOVs – TTO May 19 in Mx8.4 (EDR only).

A.vi. Error in smear subtraction creating offset bias error – Correct code (in Mx8.5), Change Input Bias to 742 counts.

A.vii. Soft Calibration adjustments including dichroic to Day 1 Solar or CF Earth -- May (SDR Table Tuning).

A.viii. Annual variations in the wavelength scale correlated with temperature gradients. SDR. Need to include dichroic interaction with wavelength and calibration factors.

A.ix. Adjustments to Day 1 Solar for solar activity. SDR.

Why "I could have had a V8Pro"?

The V8Pro algorithm is in use for the operational and CDRs for the SBUV(/2). It improves on the Version 6 SBUV(/2) algorithm described in Bhartia et al. (1996) as follows:

The V8Pro has a new set of a priori profiles varying by month and latitude, leading to better estimates in the troposphere (where SBUV/2 lacks retrieval information) and allowing simplified comparisons of SBUV/2 results to other measurement systems (in particular, to Umkehr ground-based ozone profile retrievals which use the same a priori data set).

The V8Pro has a true separation of the a priori and first guess. This simplifies averaging kernel analysis. Examples and further information are provided at http://www.star.nesdis.noaa.gov/smcd/spb/ozone/Version8AlgorithmDesc.php

The V8Pro has improved multiple scattering and cloud and reflectivity modeling. These corrections are updated as the algorithm iterates toward a solution.

Some errors present in the V6Pro are reduced. These include the elimination of errors on the order of 0.5% by improved fidelity in the bandpass modeling.

The V8Pro incorporates several ad hoc Version 6 algorithm improvements directly. These include better modeling of the effects of the gravity gradient, better representation of atmospheric temperature influences on ozone absorption, and better corrections for wavelength scale errors.

The algorithm uses improved terrain height information and gives profiles relative to a climatological or forecast surface pressure.

The V8Pro is also designed to allow the use of more accurate external and climatological data and allow simpler adjustments for changes in wavelength selection.

Finally, the V8Pro is designed for expansion to perform retrievals for hyperspectral instruments, such as the Ozone Monitoring Instrument (OMI), the Global Ozone Monitoring Experiment (GOME-2) and the Nadir Profiler in the Ozone Mapping and Profiler Suite (OMPS).

V8Pro Algorithm Paths Forward

OMPS NP V8Pro (Creates NRT and CDR ozone profiles for SBUV/2)

- A.i. Provide 12 soft calibration adjustments
- A.ii. Change to work with smaller FOVs (just along track)
- A.iii. Put in N-value fitting (Noise reduction, outlier identification and removal, and information concentration)
- A.iv. Add Solar Activity / Scale Factors
- A.v. Off-nadir retrievals
- A.vi. SO_2 profile retrieval

What about future refinements for V8Pro?

- Solar Activity and Wavelength Scales in the SDR or when SDR is read in.
  - The daily Mg II Index values from GOME-2 can be used to adjust the Day 1 solar by using scale factors.
  - The day of year values can be used to give the expected wavelength scale from intra-annual variations. The can be used to adjust the Day 1 solar and its wavelength scale. (The V8Pro can accommodate small variations in the wavelength scale about some mean values. There is also a need to adjust the calibration factors for the dichroic throughput interactions with the wavelength shift. This can be done by modifying the Day 1 Solar but that is not a conceptually appealing idea.)
- Information concentration / Noise reduction and Outlier Detection and Removal
  - Information concentration can be performed at the same step as the N-value creation, either in the input stage of the V6Pro or the input stage of the V8Pro (if the latter is working directly from SDRs). SONPO would maintain spectral coverage for smaller FOVs.
- Smaller FOVs
  - Under the current plan, these products would not flow from IDPS starting points for SDRs or EDRs as those would use an aggregator.
  - Recommend that the “aggregator” have a “non-aggregator” switch and we develop smaller FOV capabilities as part of V8Pro implementation.
  - Glueware (NM/NP Matchups) modifications on the appropriate system would be needed to handle new cases of FOVs.
- New ancillary Input
  - All three systems can access better data for snow/ice and surface pressure for use in the V8Pro processing

Recommendations for V8Pro

- OMPS ozone profile products should be made by using the V8Pro code as implemented for the SBUV/2.
  - This will require a flow of OMPS SDRs and GEOs.
  - Is this a long-term solution?
- The operational products should be the first step in CDR generation.
- Smaller FOVs should be accommodated by changes in the matchup glueware. Output products should be dynamically sized.
- Information concentration (noise reduction), outlier detection, solar activity adjustments, and intra-annual wavelength shifts should be implemented in the OMPS data input module for the V8Pro.
- Can the V8Pro in ADL jumpstart the IDPS.

Table 2.1.3 - Ozone Total Column		
EDR Attribute	**Threshold (1,2)**	**Objective**
a. Horizontal Cell Size	50 x 50 km^2 @ nadir (10)	10 x 10 km^2 (10)
b. Vertical Cell Size	0 - 60 km	0 - 60 km
c. Mapping Uncertainty, 1 Sigma (3)	5 km at Nadir (3)	5 km
d. Measurement Range	50 - 650 milli-atm-cm	50-650 milli-atm-cm
e. Measurement Precision (4)		
1. X < 0.25 atm-cm	6.0 milli-atm-cm (4,5)	1.0 milli-atm-cm
2. 0.25 < X < 0.45 atm-cm	7.7 milli-atm-cm (4,5) ~ 2%	1.0 milli-atm-cm
3. X > 0.45 atm-cm	2.8 milli-atm-cm + 1.1% (4,5)	1.0 milli-atm-cm
f. Measurement Accuracy (6)		
1. X < 0.25 atm-cm	9.5 milli-atm-cm (6,5)	5.0 milli-atm-cm
2. 0.25 < X < 0.45 atm-cm	13.0 milli-atm-cm (6,5) ~ 3%	5.0 milli-atm-cm
3. X > 0.45 atm-cm	16.0 milli-atm-cm (6,5)	5.0 milli-atm-cm
g. Latency	120 min. (7)	15 min
h. Refresh	At least 90% coverage of the globe every 24 hours (monthly average) (8)	24 hrs. (8)
i. Long-term Stability (9)	1% over 7 years	0.5% over 7 years
		v1.4.2, 7/29/11

Notes:

1. The OMPS Limb Profiler instrument does not fly on JPSS-1. Thus, only the Ozone Total Column elements are shown in this Table.
2. The loss of the OMPS Limb Profiler has had a small effect on the total column performance as the estimates of the profile shape and the tropospheric ozone are poorer, so the corrections are also poorer. There is new information that the OMPS algorithm use of the IR cloud top pressures will lead to errors as the IR values tend to be higher than the UV ones that should be used. A Discrepancy Report has

Path Forward (Solution Key: DONE, READY, KNOWN APPROACH, UNKNOWN, *FUTURE WORK*)

B. OMPS NM Total Column Ozone

B.i. Measurement-based wavelength scale adjustments – February 19 Mx8.1. DONE. *Need to include dichroic interaction with wavelength and calibration factors.*

B.ii. Revised profile mixing fraction logic – March 17 in Mx8.3 (EDR only) DONE

B.iii. First version of OOR Table for the stray light correction -- May (SDR Table Tuning and Code Change)

New Table received. OOR cross-track dependence requires code change.

CCR to proceed with this for the Mx8.5 build. It is a change to the code and table dimensions. Minor ATBD and OAD and CDFCB changes.

B.iv. New Day 1 Solar irradiance spectra and wavelength scales. Should be set to middle of orbital scale variation. Cross-track dependence is complex. – May (SDR Table Tuning)

B.v. Soft Calibration adjustments to Day 1 Solar or CF Earth -- May (SDR Table Tuning)

B.vi. *Check flagging and logic for total ozone out of range and fill for triplet retrievals. (EDR)*

B.vii. *Possible bandpass changes -- ground to flight, intra-orbit.*

Why V8TOz instead of MTTOz?

- Provides a set of products consistent with the TOz CDR from the TOMS/SBUV(/2)/OMI record. This also means it can serve as the first step in the CDR cycle of evaluation and reprocessing.
- Versions of the algorithm are currently used in OSDPD to make the NOAA GOME-2 NRT TOz products and SBUV/2 TOz products. It is planned for use in making OMPS V8Pro TOz products.
- The fundamental ozone estimates are from a single pair of channels simplifying validation studies, calibration adjustments, and anomaly resolution. The MTTOz requires soft calibration of 22 channels.
- The V8TOz uses the 313 nm residual to adjust for profile shape variations. The MTTOz was going to use the Limb Profile to do this adjustment.
- The V8TOz is synergistic with the Linear Fit SO2 Retrieval algorithm.

What about future refinements for V8TOz?

Path to upgrades

Information concentration

Information concentration can be performed at the same step as the N-value creation, either in the input stage of the MTTOz or the input stage of the V8TOz (if the latter is working from SDRs).

Additional channels for SO2 and NO2

These would be best implemented as stand-alone processes/products, although one of the SO2 options can work directly from the V8TOz residuals

Smaller FOVs

Under the current plan, these products would not flow from IDPS starting points for SDRs or EDRs as those would use an aggregator.

The bookkeeping for retrieving total ozone for smaller fields of view from an SDR is simple but the output products would have to be resized or be dynamically sized whether for the MTTOz or V8TOz.

New ancillary Input

IDPS can access better data for snow/ice and surface pressure and use these in the V8TOz processing

So can NDE and OSDPD

We have removed most of the dependencies on VIIRS and CrIS EDRs.

OMPS LP Performance Requirements

The OMPS Limb Profiler provides global ozone observations at high vertical resolution (< 3 km). This EDR provides a measurement of ozone concentration within a specified volume.

Requirements are TBD per L1RDS V2.9 Action: Insert OMPS Limb Profiler SDR Performance Characteristics – Deferred until S-NPP Ozone Limb Profile performance is sufficiently validated to constrain the JPSS-2 instrument acquisition.

Table 3.3.1 - Ozone Limb Profile

Attribute	Threshold (1)	Objective
a. Horizontal Cell Size	250 km	100 km (7)
b. Vertical Cell Size		
1. 0 to TH (2)	N/A	3 km
2. Th to 25 km	5 km	1 km
3. 25 to 60 km)	5 km	3 km
c. Mapping Uncertainty, 1 Sigma (3)	< 25 km	25 km
d. Measurement Range		
1. 0 to TH (2)	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 (2)	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 (2)	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	120 min. (4)	15 min
h. Refresh	At least 75% coverage of the globe every 4 days (monthly average) (5)	24 hrs (5)
i. Long-term Stability (6)	2% over 7 years	1% over 7 years
		v1.4.2, 7/29/11

Notes:

OMPS LP Path Forward

- Migrate V2 algorithm to STAR and then to NDE
- Design and create NetCDF and BUFR versions of the output.
- Arrange/coordinate dark table updates
- Validate products.

Sulfur Dioxide (SO2) Total Column EDR Description & Requirements Table – CCR in preparation

The Sulfur Dioxide Total Column EDR (also called Atmospheric SO_2) is defined as the amount of SO2 in a vertical column of the atmosphere measured in Dobson Units (milli-atm-cm). SO_2 absorption in the 305 nm to 315 nm region influence OMPS Nadir Mapper measurements of backscattered Ultraviolet radiances. Estimates of atmospheric SO_2 are obtained for three or more assumed heights for the amounts within the column averaged over the FOV from measurement residuals calculated by the OMPS total column ozone EDR algorithm. This product will continue the heritage SO_2 Index provided in the NOAA POES SBUV/2 operational Product Master File and the Atmospheric SO_2 products currently provided in NRT products from the NASA EOS Aura OMI.

Note: J1 will not have an SO_2 performance exclusion, so improved information on amounts and corrections to the ozone product will be required.

OMPS Nadir Mapper Atmospheric SO_2 Column Amount in DU*

	Threshold	Objective
a. Horizontal Cell Size:	25x25 KM^2	10X10 KM^2
b. Vertical Reporting NA	Column amount*	
c. Mapping Uncertainty, 3 Sigma	5 KM	2 KM
d. Measurement Precision	2 DU	0.5 DU
e. Measurement Accuracy	3 DU	1 DU
f. Measurement Uncertainty		
g. Latency	80 Minutes	30 Minutes
h. Refresh		

Daily global sunlit Earth** (multiple coverage at high latitudes)

* SO_2 column amounts will be reported as calculated for three heights as appropriate for their occurrence -- local pollution, transported pollution, volcanic eruption.

** SO_2 is not sensed below clouds

CCR needs SO_2 Users

- **VAACs: The SO_2 products are used to track volcanic eruptions for aviation hazards. This is the most important NRT application.**
- **EPA & ARL: Air Quality forecasts and monitoring (SO_2 amounts, aerosol classification)**
- **USGS/AID: Passive volcanic outgassing**
- **Atmospheric chemistry and climate change research**
- **MACC II ECMWF**

OMPS Team Challenges

- How to be a climate sensor in an operational program?
- Users and NRT Users (Chicken and Egg for Applications)
- Soft Calibration
  Determination and implementation of soft calibration is a moving target as SDR improvements move into the system
- Validation
  Product validation analyses has to be repeated or adjusted as improvements and corrections enter the system.

OMPS Team Challenges

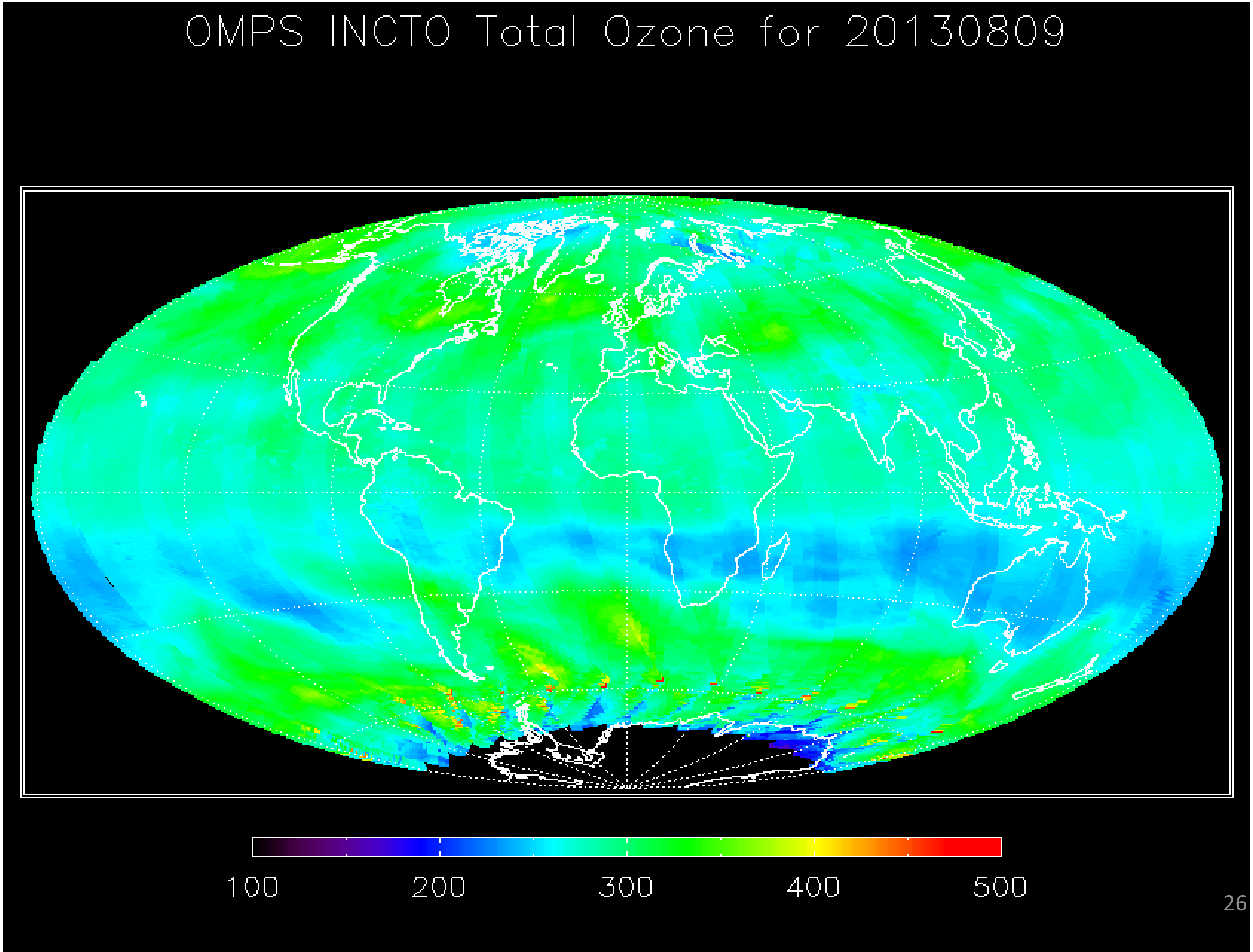
- Performance versus Schedule issues
  - V8TOz implementation schedule is in competition with V8TOz improvements – SO_2 Linear Fit Algorithm module, small FOVs, Efficiency Factors, Outlier Detection / Information Concentration
  - V8Pro implementation schedule is in competition with V8Pro improvements – Small FOVs, Solar Activity, Outlier Detection / Information Concentration
  - V2Limb implementation requires choices on aerosol products. We will need to see how NDE accommodates processing intensity.

Backup

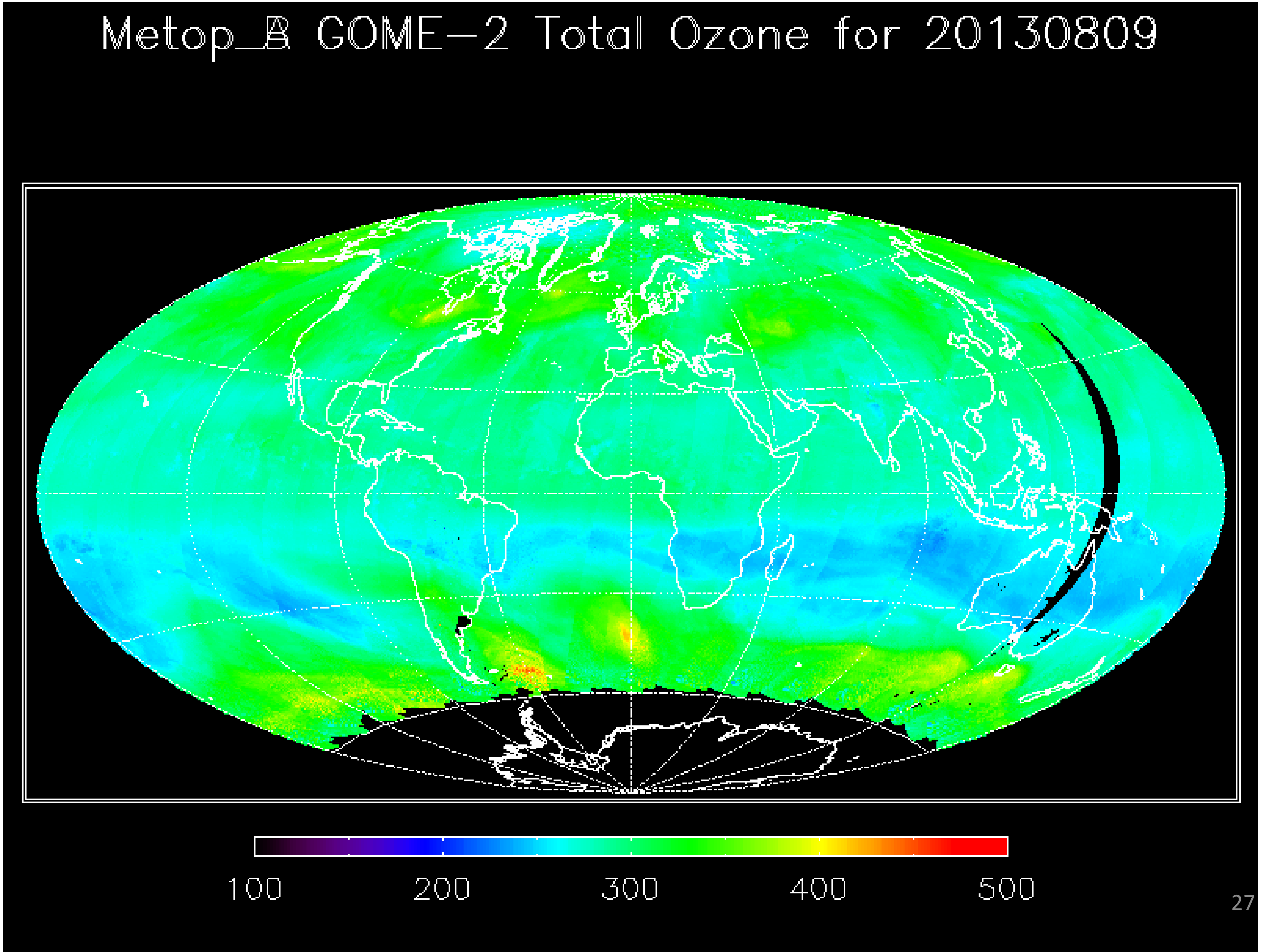
Categories of products

- In operations
  - Total column O_3, Nadir UV O_3 Profile, Aerosol Index, SO_2 Index
  - TOAST combined UV/IR analysis map
  - NUCAPS (CrIS/ATMS) trace gases (O_3, CO, CH_4, CO_2, N_2O, HNO_3, SO_2)
- Planned products
  - Limb O_3 Profile, Limb aerosol profile
- Likely future products
  - Total column SO_2
- Research products
  - Total Column NO_2
  - Combined UV/IR retrieval
  - UV absorbing aerosol optical depth, combined UV/Vis
  - UV cloud optical centroid (inelastic scattering – Ring effect)

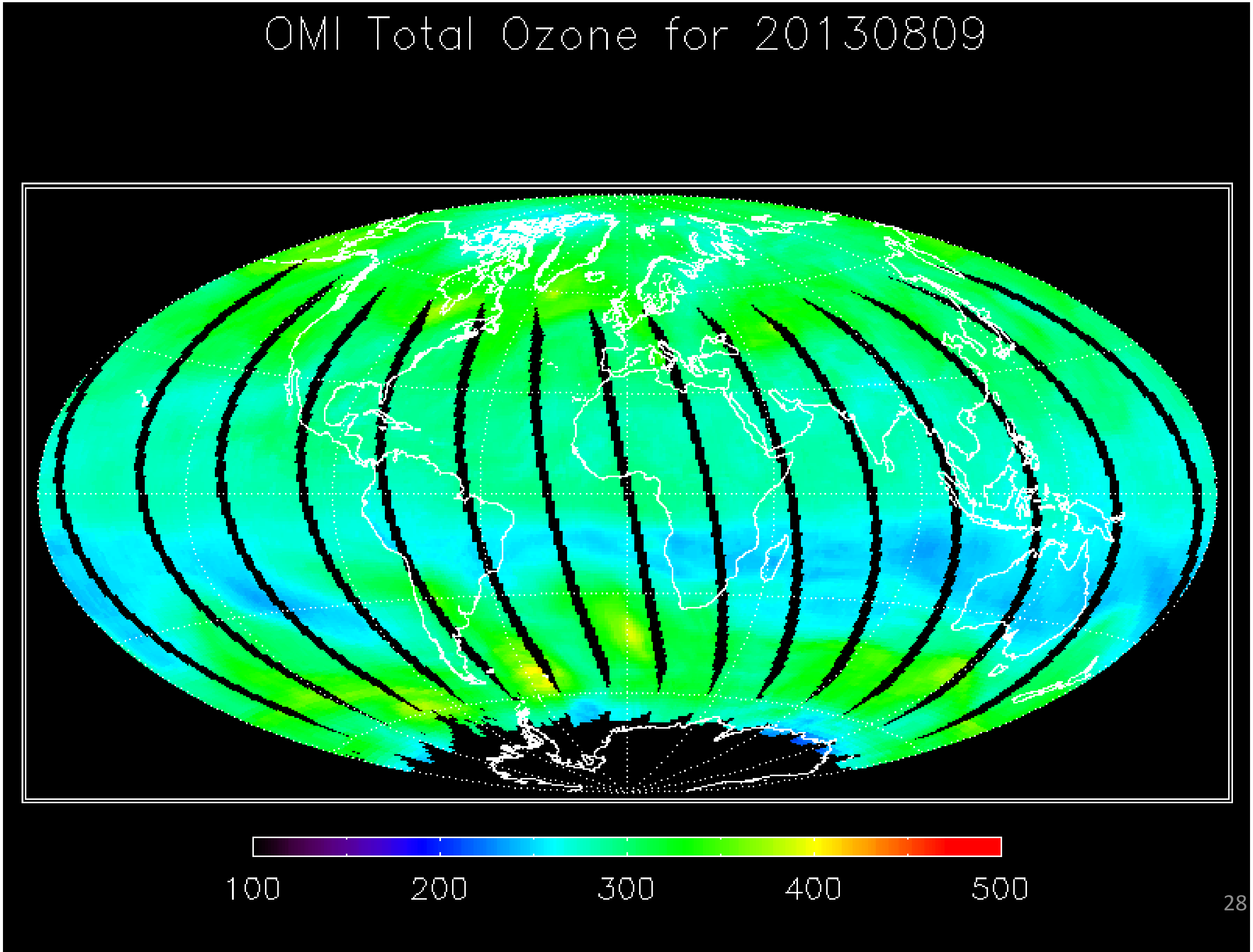
Sample OMPS INCTO Total Ozone Map



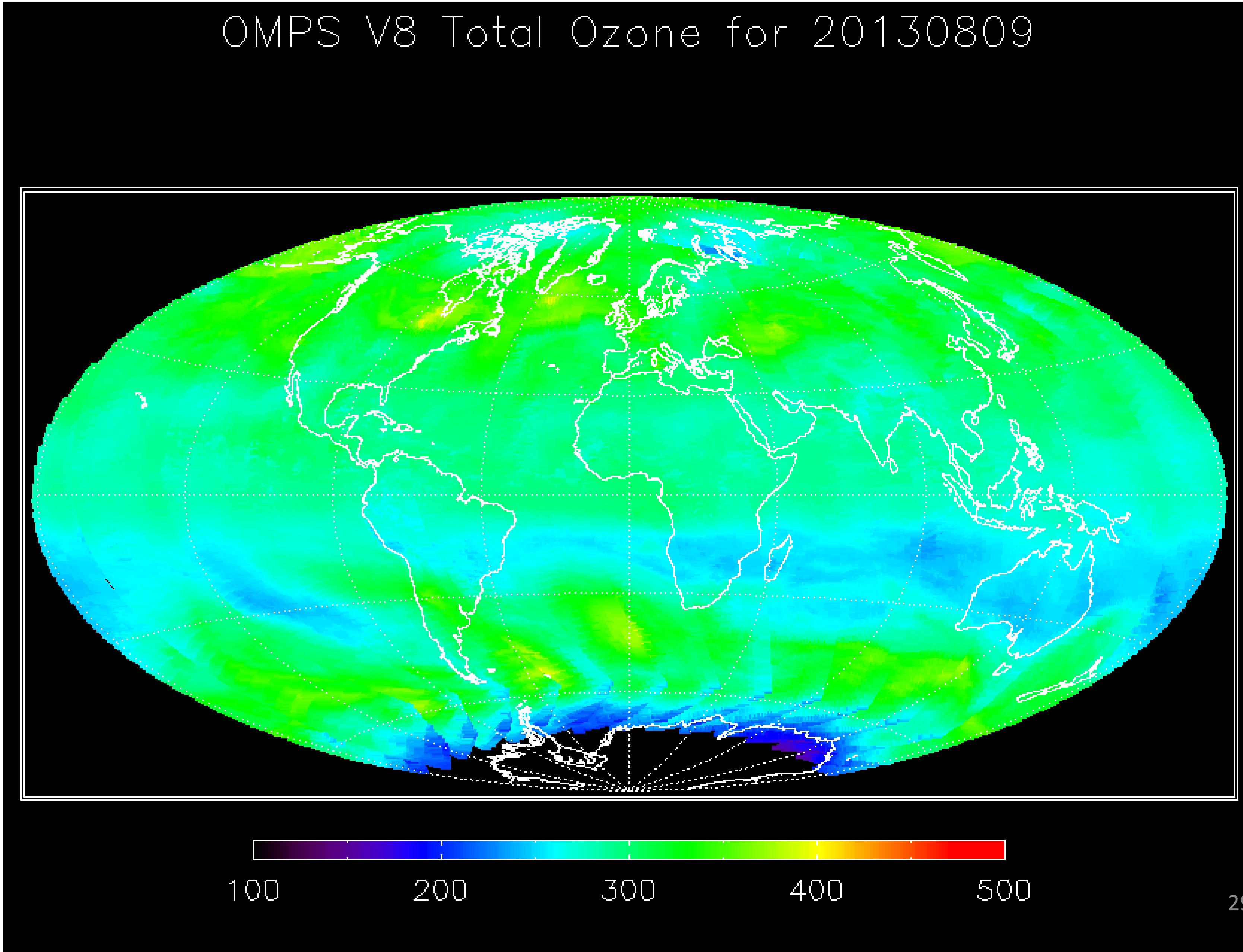
Sample MetOp-A+B GOME-2 V8 Total Ozone Map



Sample EOS Aura OMI Total Ozone Map



Sample OMPS V8TOZ Total Ozone Map



Lines of Code for V8TOz

- 1) To prepare LUT: 1252 lines
- 2) To generate files and prepare SDR and GEO for processing: 920 lines
- 3) The algorithm source codes: 19828 lines

Total lines: 22000 lines.

Options for Basic Implementation of V8TOz

- IDPS (Need to introduce new Process, LUTs and output)
  - Implement as a follow-on process to the MTTOz. Make use of the INCTO input/output as input. INCTO still run in IDPS, or
  - Replace MTTOz with V8TOz as PRO.
    - Minor changes to select 12 channels from the current 22, add/remove some input tables and output parameters.
- NDE
  - Implement as a new process
    - Transition V8TOz implementation for OMPS on LINUX in use at STAR. Only SDRs and GEOs continue in IDPS.
    - Need OMPS NM SDRs (SOMPS) and GEOs (GOTCO) delivered to the NDE system
- OSPO/POES
  - Implement as another "GOME-2" with existing V8TOz processing code
    - Reader in use at STAR can provide V8TOz with GEO and 12 channels. Only SDRs and GEOs continue in IDPS.
    - Need OMPS NM SDRs (SOMPS) and GEOs (GOTCO) delivered to the POES system

Options for Basic Implementation of V8Pro

- IDPS (Need to introduce new content and format for LUTs and output in addition to new PRO components)
  - Implement as a companion process to the V6Pro. Make use of the V6Pro input/output as input. V6Pro still runs in IDPS. (Tested in ADL at STAR.), or
  - Replace V6Pro with V8Pro as the Program part of IPO.
- NDE (Need to implement as a new process with new output)
  - From IMOPO – no new glueware, V6Pro still runs in IDPS, or
    - Need flow of IMOPO to NDE
  - From SONPS/GONPO & SOMTC/GOTCO – New glueware (in use at STAR), Only SDRs and GEOs in IDPS
    - Need flow of SDRs and GEOs to NDE
- OSPO/POES (Need to implement as another "SBUV/2" with existing V8 processing code)
  - From IMOPO – no new glueware, V6Pro still runs in IDPS, or
    - Need flow of IMOPO to POES processing system
  - From SONPS/GONPO & SOMTC/GOTCO – New glueware (in use at STAR), Only SDRs and GEOs in IDPS
    - Need flow of SDRs and GEOs to POES processing system

Lines of Code for V8Pro at STAR

- 1) To prepare LUT: 1253 lines
- 2) To generate orbit files, match up FOVs, and prepare SDRs and GEOs for processing: 1228 lines
- 3) Algorithm source codes: 15319 lines

Total lines: 17800 lines.

Application of OMPS Ozone Products

Craig Long, Jeannette Wild, Shuntai Zhou, SK Yang

NOAA/NWS/NCEP/CPC & Innovim

Larry Flynn, Eric Beach

NOAA/NESDIS/STAR & IMSG

NESDIS/STAR JPSS Annual Review – May 12-16, 2014

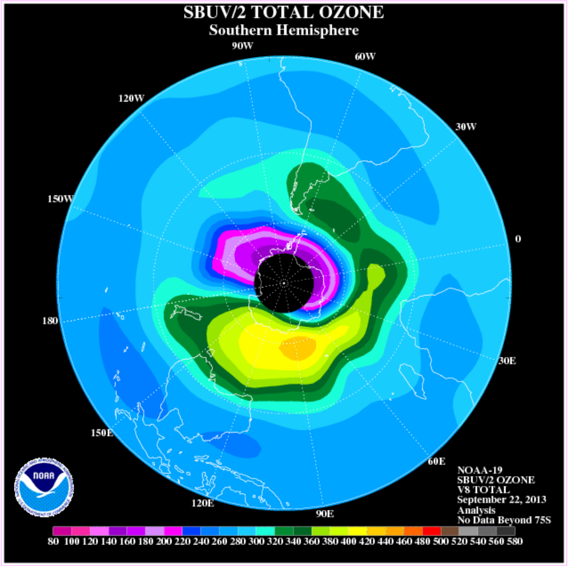
Continuity of Ozone Monitoring

- OMPS NP will allow CPC to continue its ozone monitoring into the future.
  - Replicating everything CPC has done using the SBUV/2
- OMPS TC & LP provide additional tools to work with.
  - TC gives CPC higher horizontal resolution than analysis of NP
  - LP gives CPC higher vertical resolution than NP

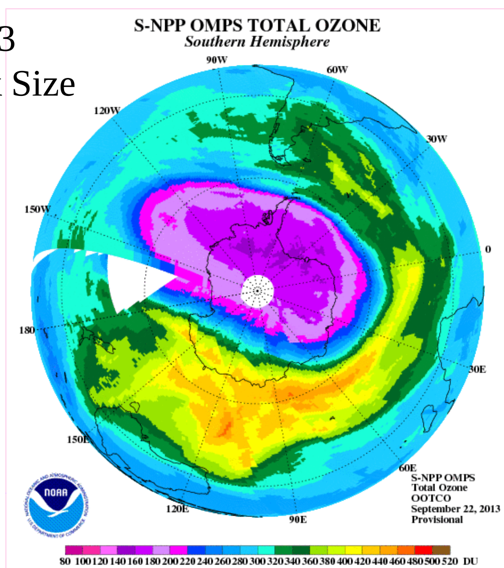
Various Time Scales of Ozone Monitoring

- Short (day to day)
  - Antarctic /Arctic Ozone Hole monitoring
- Seasonal
  - Relationship of profile and TC to phase of QBO
    - QBO dictates the strength of the BD circulation
    - Dictates the anomalous amount of ozone in the winter hemisphere
  - Impacts of winters with Stratospheric Warmings
- Inter-annual to Decadal
  - Creation of cohesive data sets for long term trend detection
  - TC and Profile
  - Hockey Stick regression analysis
    - Depletion trend
    - Recovery trend

Day-to-Day Time Scales

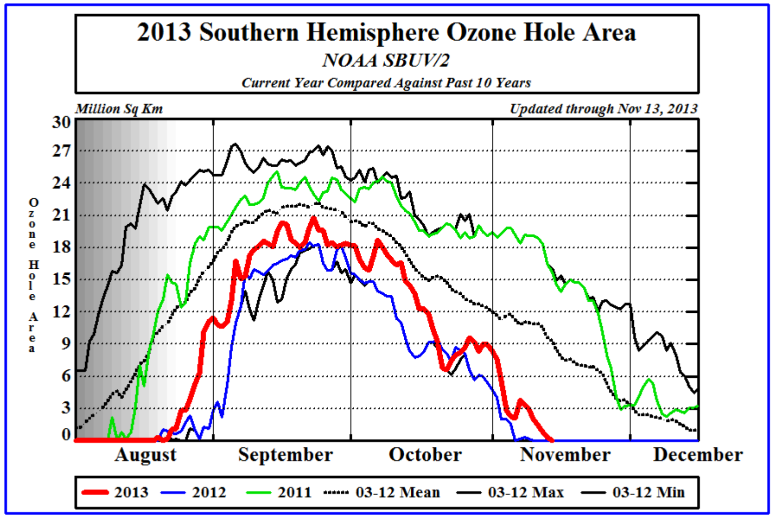


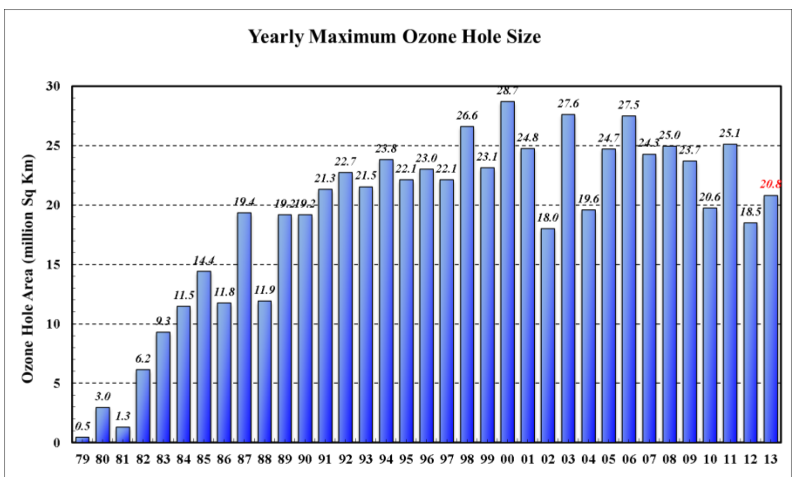
Sept 22, 2013
Date of Peak Size



- Using the SBUV/2 nadir observations, CPC uses a Cressman Scheme to make a polar stereographic analysis of the Total Column Ozone. (top)
  - Smoothes out or misses fine features
- OMPS TC provides full global coverage.
  - Heritage: TOMS and OMI
  - Currently is providing 35 scan positions
  - Has potential of ~100 scan positions with out compromise to S/N ratio
- www.cpc.ncep.noaa.gov/products/stratosphere/sbuv2to/
- www.cpc.ncep.noaa.gov/products/stratosphere/omps/

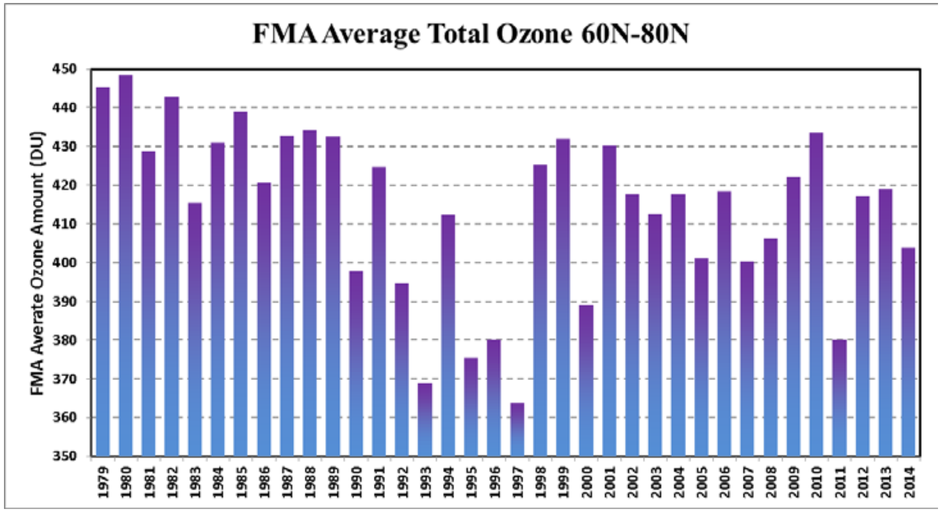
Day-to-Day Time Scales





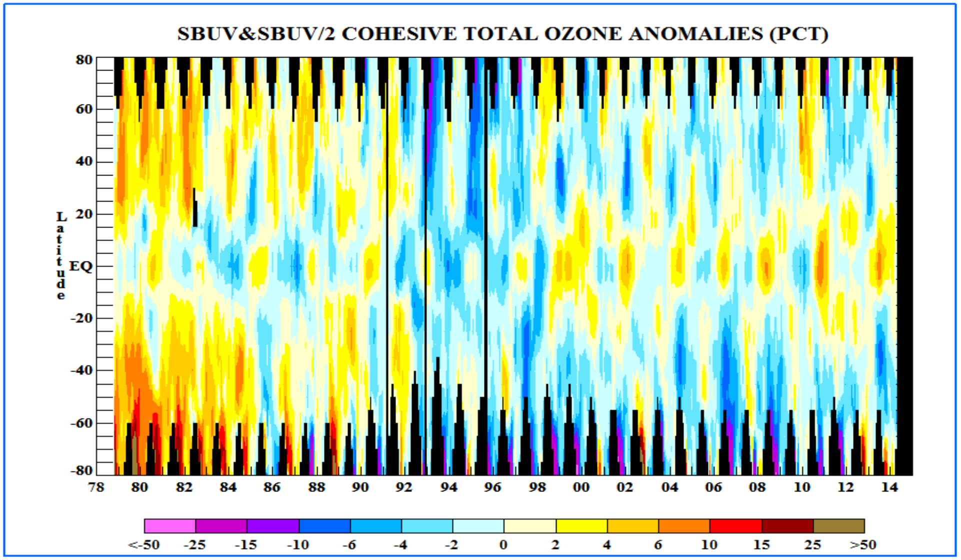
- Daily Analyses are used to determine the Area of Total Column < 220 DU
- OMPS TC needs to be put into a grid
  - 1/2x1/2 degree
- TC usually has observations closer to pole than NP
  - Will decrease uncertainty of early September ozone hole size estimates
- From daily areas the maximum ozone hole size is determined
  - Usually occurs in latter third of September
- Monitor the life cycle of the ozone hole.

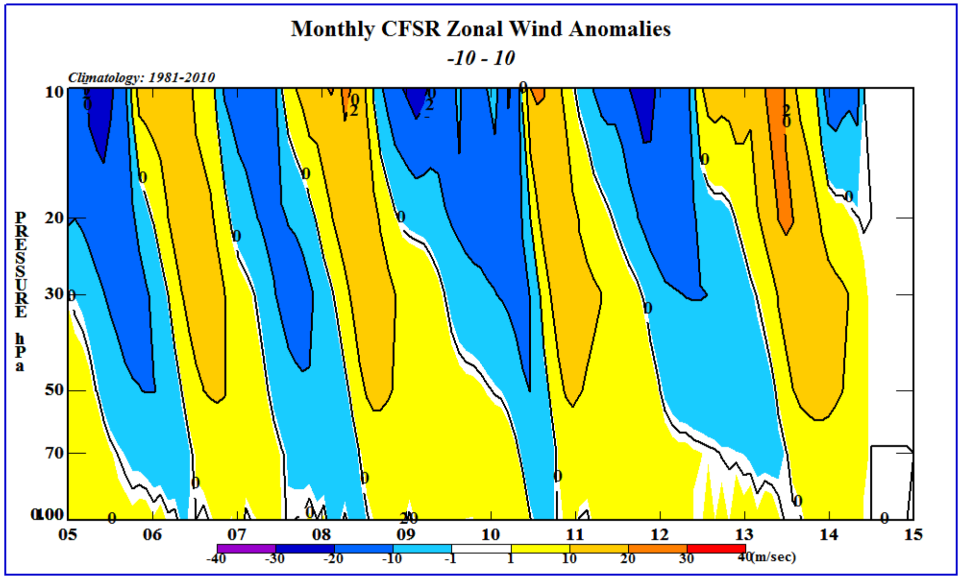
Seasonal Time Scales



- Comparison of mean ozone amounts during a particular season versus previous years
  - Average of Feb-Mar-Apr
  - Period in NH of maximum ozone amounts
  - Cold winters have low FMA ozone
    - ‘90, ‘92, ‘93, ‘95, ‘96, ‘97, 2000, 2011
  - Warm winters have higher FMA amounts

Seasonal Time Scales

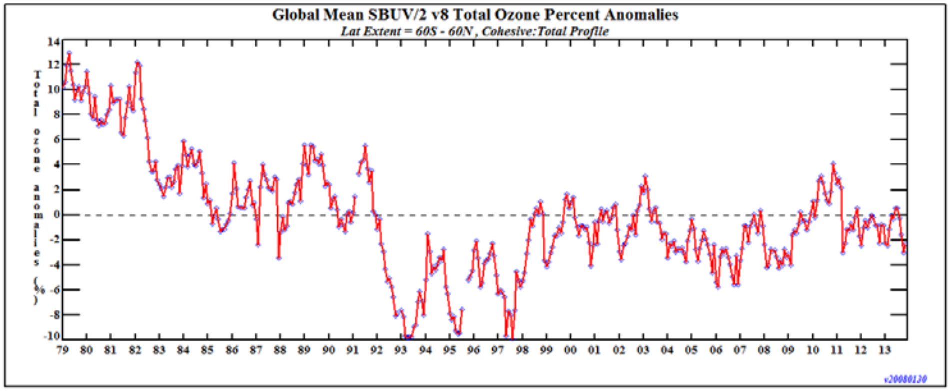




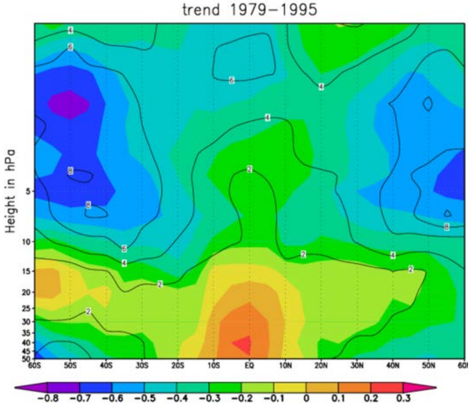
- Zonal mean total ozone anomaly time series illustrates the role the QBO has on the total ozone variability.
- Descending westerlies slows down the BD Circulation
  - Positive anomalies in tropics
  - Negative anomalies in winter polar lat
- 2011:
  - Descending Westerlies
  - no stratospheric warming
  - large negative anomalies in FMA
  - photochemical ozone depletion

Inter-Annual to Decadal Time Scales

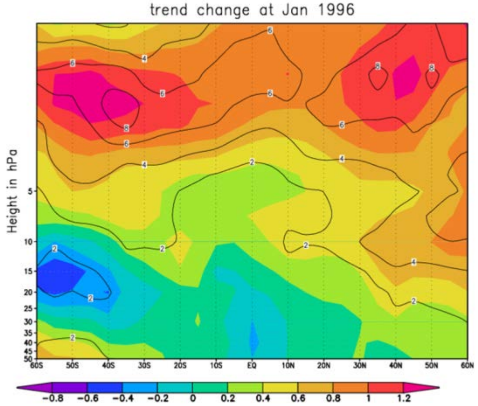
60N-60S Ozone Anomalies (%)



Trend 1



Trend change

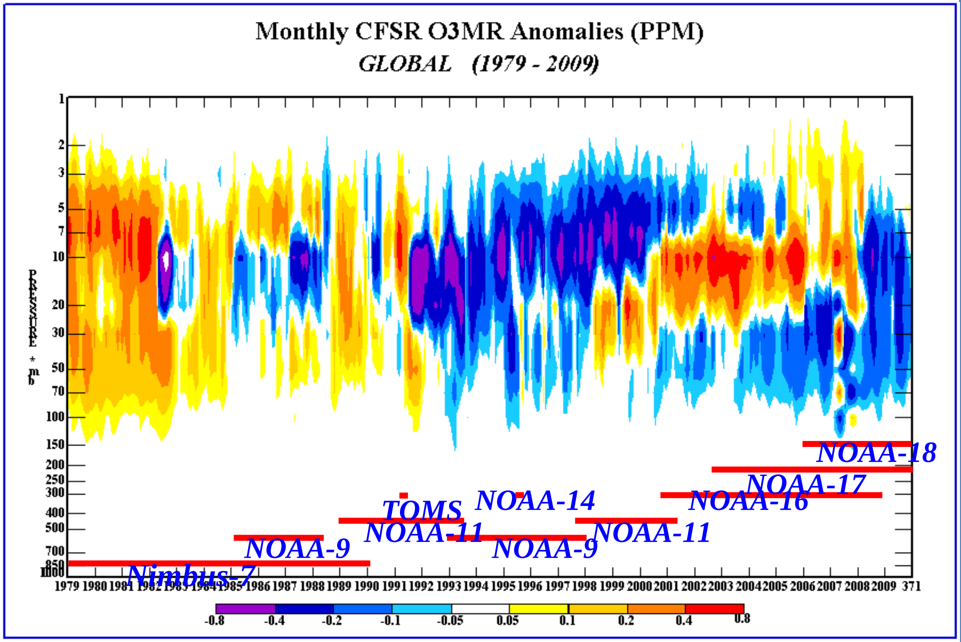


- On multi-annual to decadal time scales trends can be determined.
- Requires creation of a cohesive total and profile ozone data set.
- Start with v8.6
- Apply Wild method to adjust for biases and satellite trends
- Then can apply “hockey stick” regression analysis to determine depletion trend and trend change
- Remove AO, AAO, QBO, and solar cycles

Assimilation into Weather Forecast Models and Climate Reanalyses

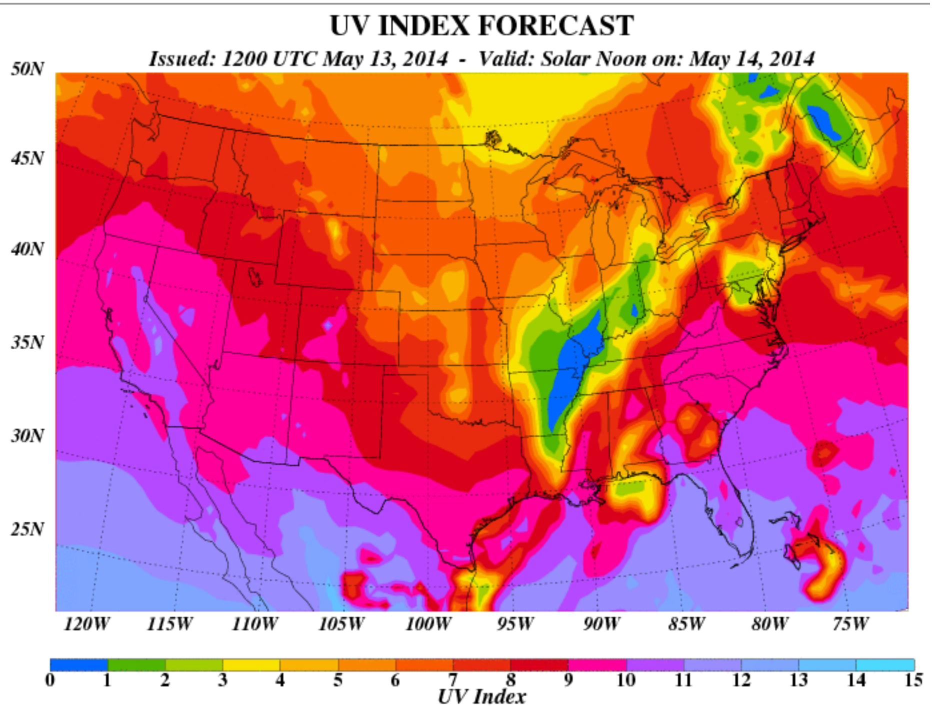
- Ozone is important in NWP
  - Radiation scheme relies on it
    - Heating/cooling in stratosphere
  - Needed for IR channels that are ozone sensitive
- NCEP assimilates SBUV/2 profile and OMI total ozone
  - Other centers also assimilate: GOME-2, MLS
  - NCEP needs resources and priority to assimilate OMPS NP and TC
- OMPS v6 profile and total column are made into BUFR
  - WMO requirement for data assimilation
- BUFR table for OMPS-LP?

Assimilation into Weather Forecast Models and Climate Reanalyses



- Next set of reanalyses will use SBUV(/2) v8.6
  - NESDIS/STAR is putting v8.6 into BUFR for international community
- Will OMPS NP be addition to SBUV(/2) data set?

UV Index Forecasts Rely Upon Good Ozone Forecasts



- Primary step in UV forecasting is relating the total ozone and SZA to surface erythemal UV-B.
- NWP models are increasing in horizontal resolution
- Higher resolution OMPS-TC would be good addition

Summary

- 2 out of 3 isn't bad:
  - Transition / extension of SBUV/2 to OMPS NP have no issues to date
  - TC and LP will enhance CPC's monitoring capabilities
  - Work needs to be done at NCEP/EMC and JCSDA to bring in OMPS NP, TC, and LP obs