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

Potential Use of OMPS Nadir Mapper to provide aerosol information

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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)

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Particle Scattering Theory

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-Scattering, Absorption and Extinction coefficients

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

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

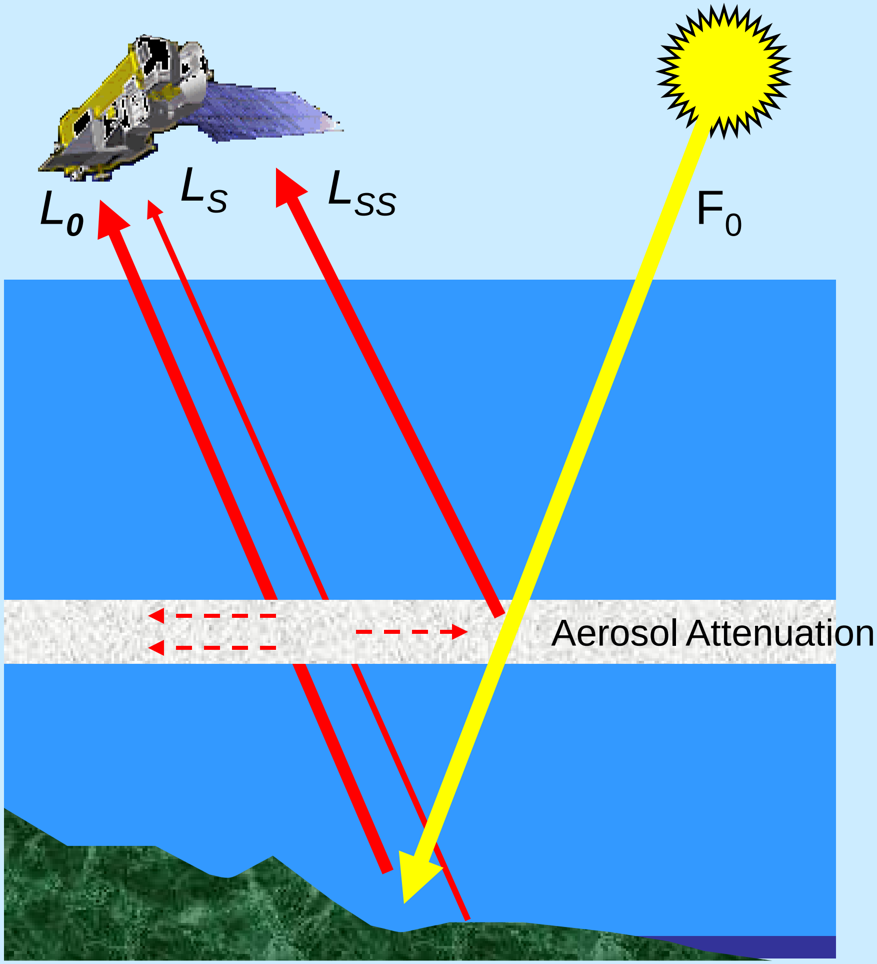
↓

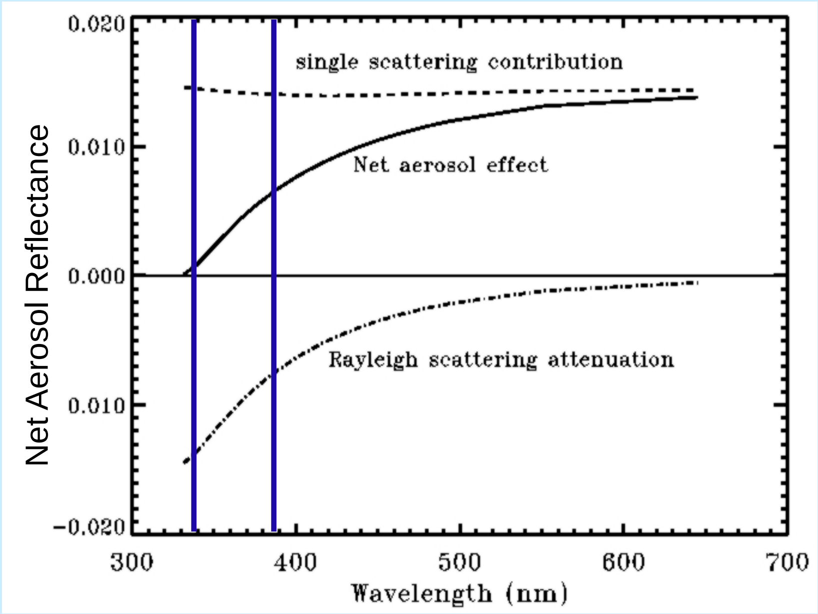
-Column Integrated Properties

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)

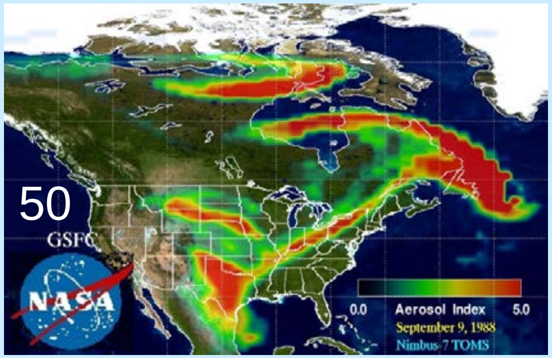
- The magnitude of AI depends mainly on aerosol optical depth (AOD), aerosol single scattering albedo (SSA), and aerosol layer height (ALH).
- The AI is a unique Identifier of absorbing aerosols: smoke plumes, desert dust, volcanic ash
- Works over all land and ocean surfaces (even over deserts).
- Detects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

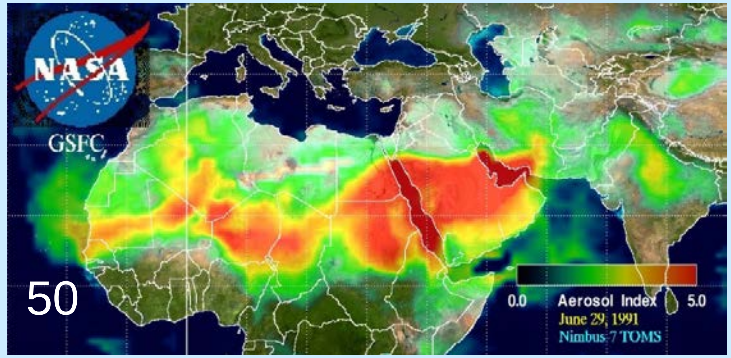
Absorbing Aerosol Index Record

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

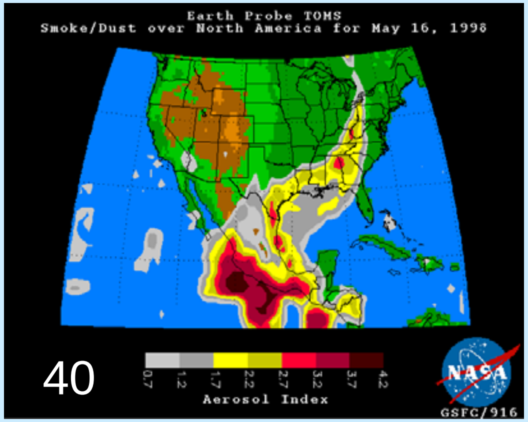
Nine sensors: N7-TOMS, M3-TOMS, EP-TOMS, AD-TOMS, GOME, OMI, GOME-2, SCIAMACHY, OMPS



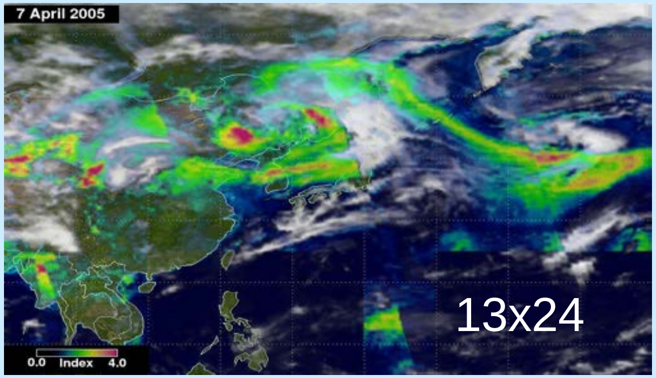
Yellowstone National Park Fires, Nimbus7-TOMS, Sept.9, 1988.



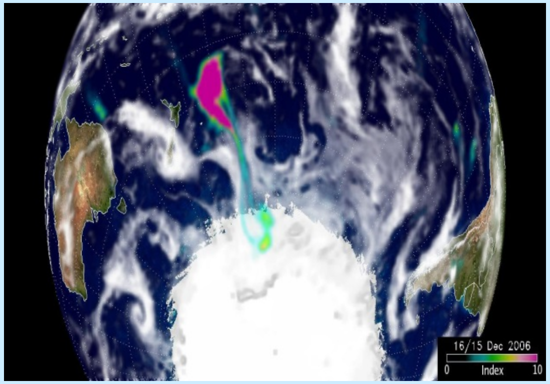
Kuwaiti Oil Fires Smoke layer as seen by Nimbus7-TOMS on June 29, 1991.



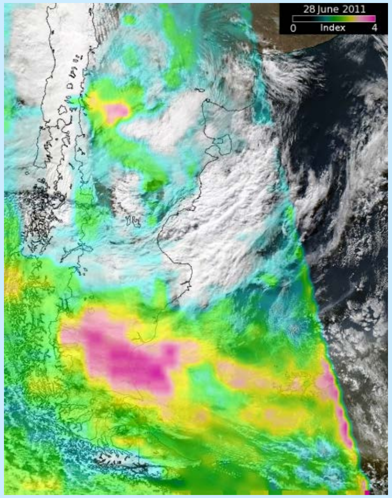
Smoke layer from fires in Mexico Earth Probe-TOMS, May 16,1998



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

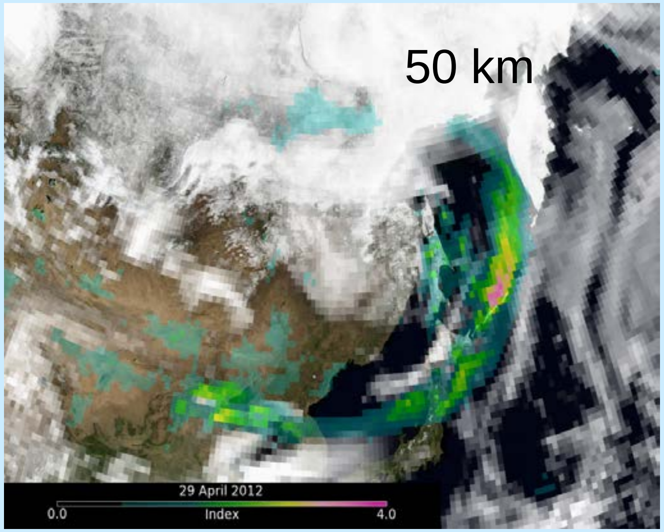
-OMPS native pixel size at nadir is about 3km across track and 12 km along track.

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

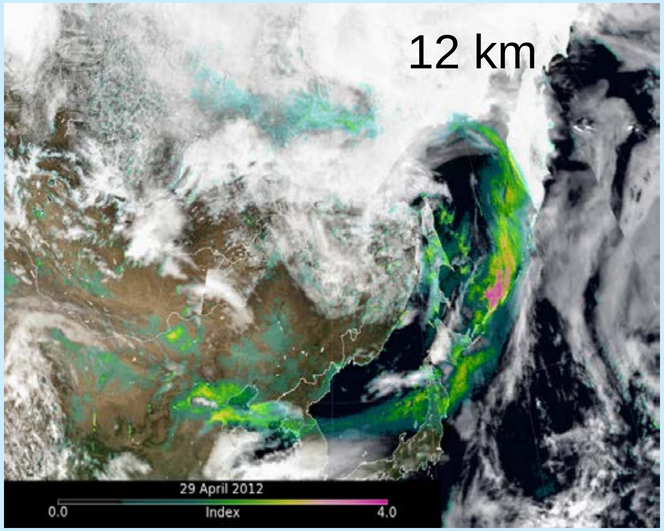
-Currently, observations at selected wavelengths (including 340, 380 nm) are brought down at native resolution once-per week.

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

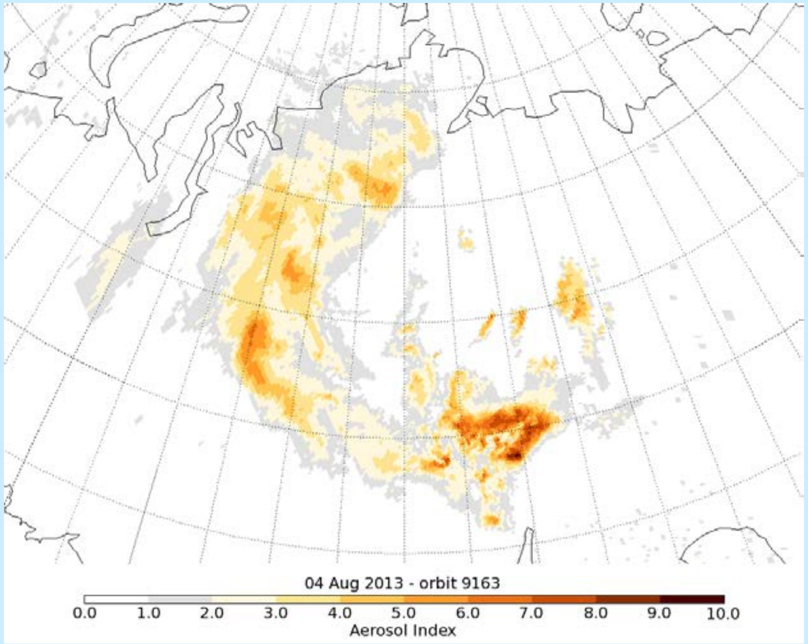


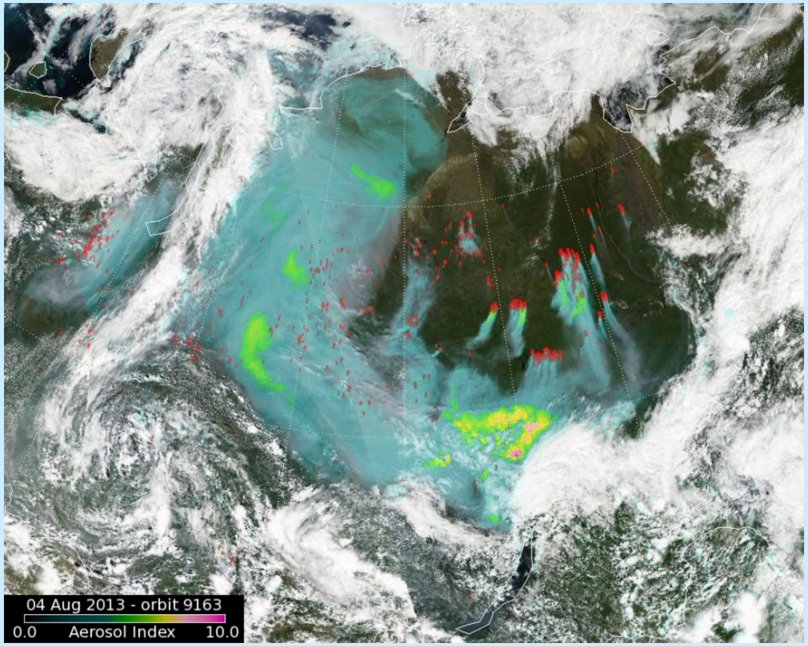
12 km once-a-week, product

Courtesy of Colin Seftor/SSAI

High Resolution OMPS Aerosol Index

Wild fires over Russia on August 4, 2013





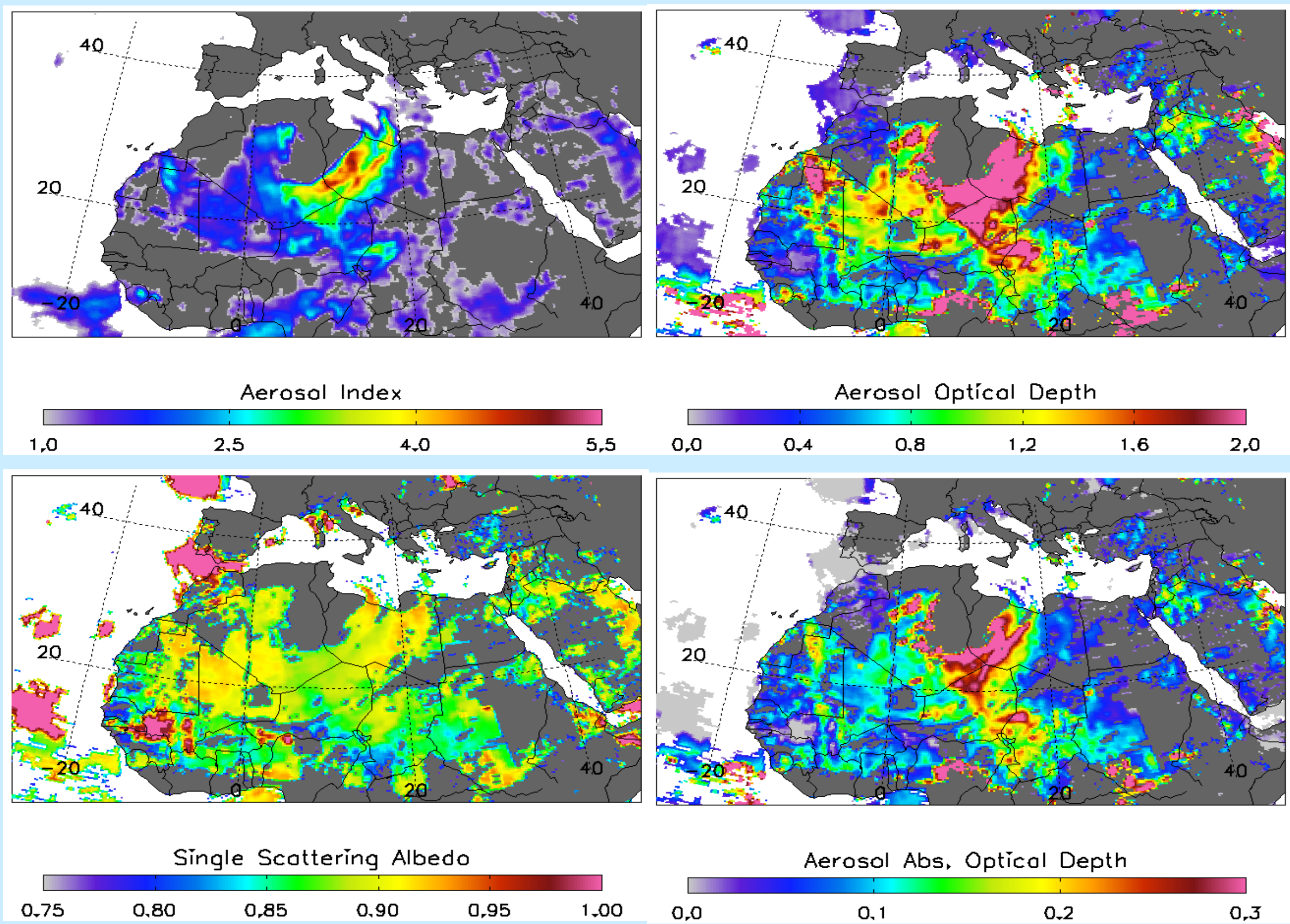
- Never seen before level of detail in AI imagery
- Individual smoke plumes can be resolved
- It would facilitate quantitative interpretation (AAOD, SSA)

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)

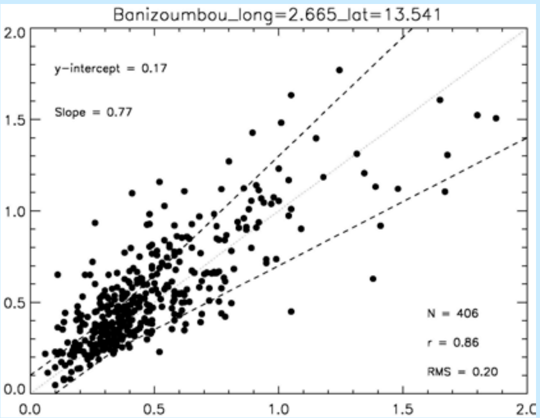


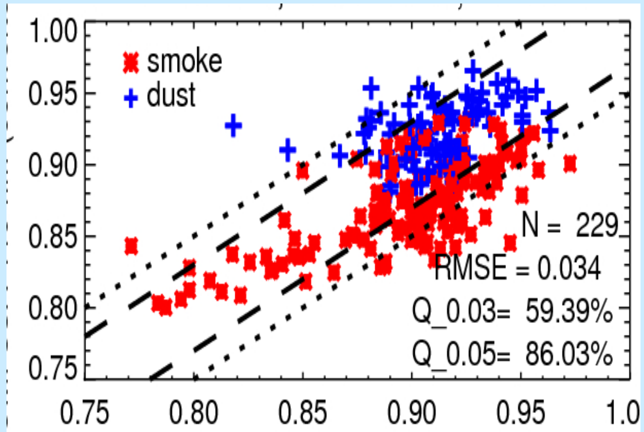
OMI Retrieved Dust Properties (March 9-2007)

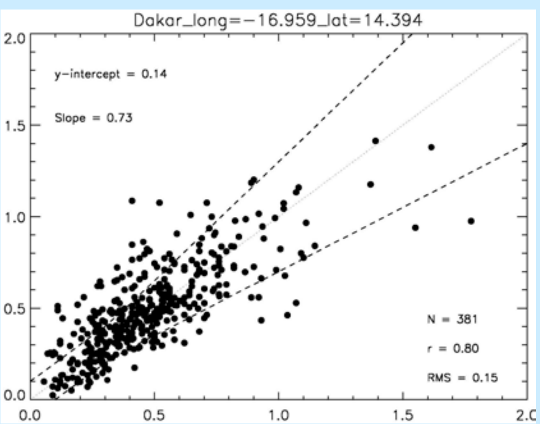
Assessment of OMI Aerosol Retrievals

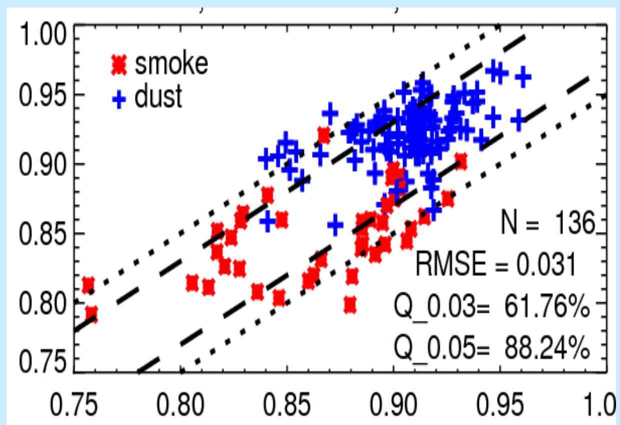
Aerosol Optical Depth

Single Scattering Albedo



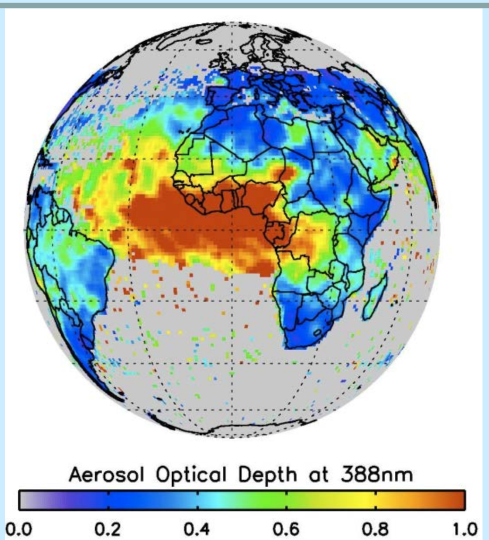


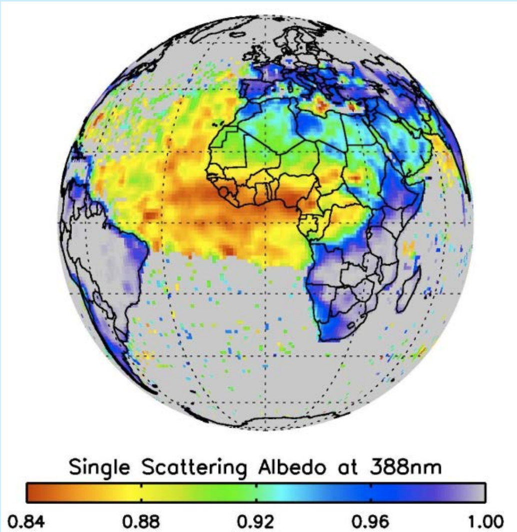




OMI Retrieval

AERONET Measurement



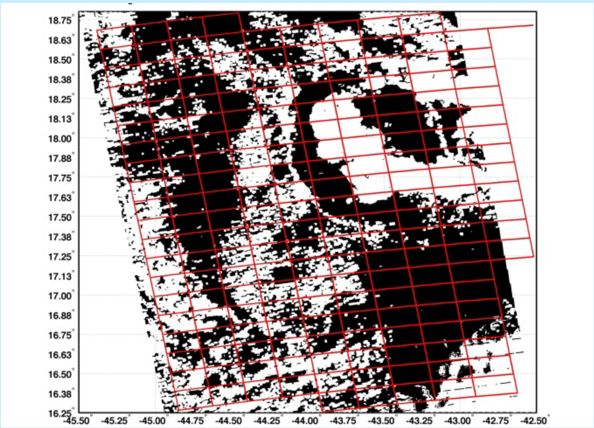


January 2007, Monthly Mean

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).