A new Aerosol Index Algorithm Application to OMPS

O. Torres, P.K. Bhartia, C. Ahn

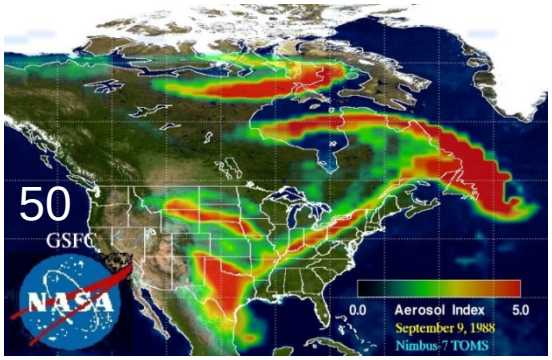
OMPS Science Team Meeting

03-31-2016

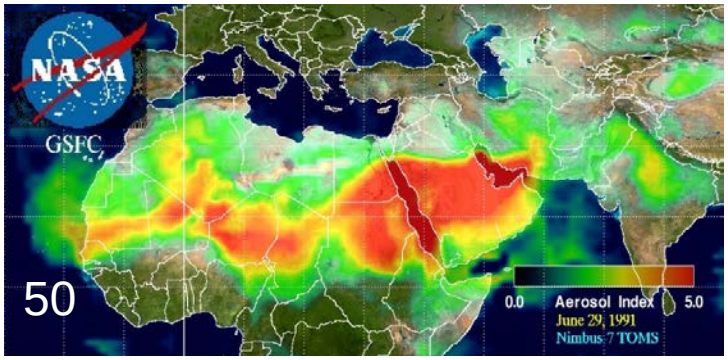
Absorbing Aerosol Index Record

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

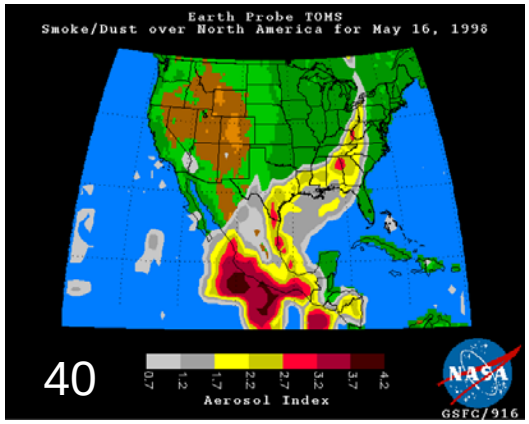
Nine sensors: N7-TOMS, M3-TOMS, EP-TOMS, AD-TOMS, GOME, OMI, GOME-2, SCIAMACHY, OMPS



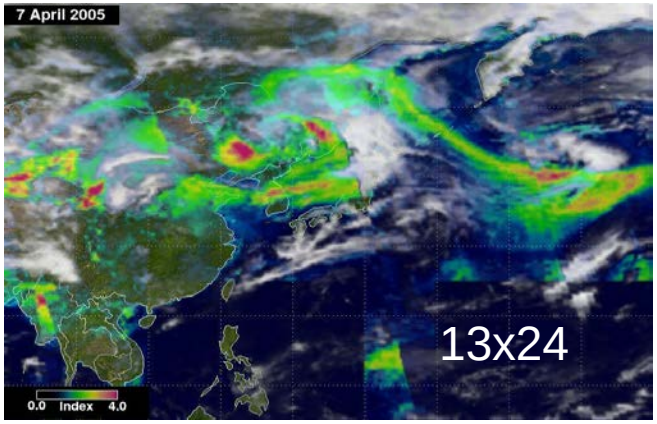
Yellowstone National Park Fires, Nimbus7-TOMS, Sept.9, 1988.



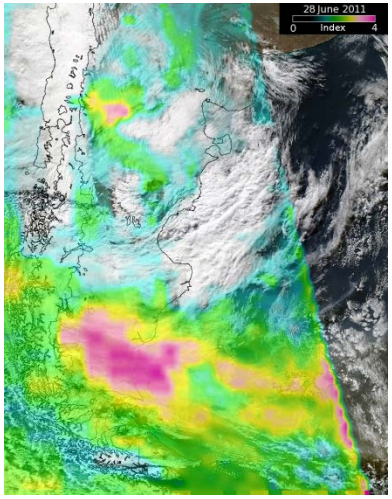
Kuwaiti Oil Fires Smoke layer as seen by Nimbus7-TOMS on June 29, 1991.



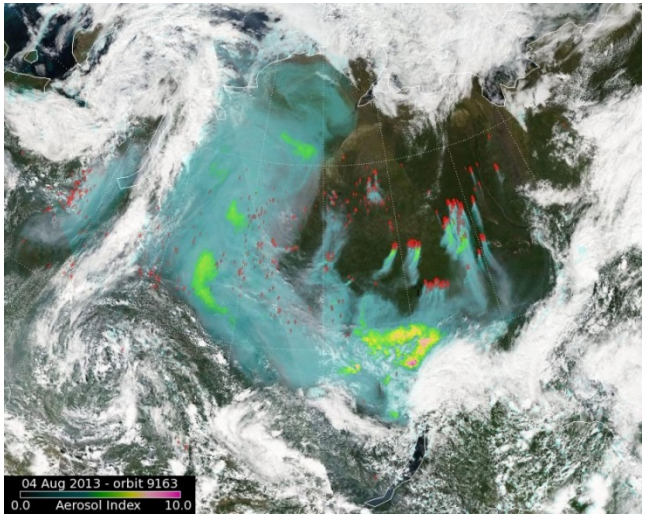
Smoke layer from fires in Mexico Earth Probe-TOMS, May 16,1998



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



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



OMPS view of wild fires over Russia on August 4, 2013

Aerosol Index Concept

Comparison of satellite *measured* I_λ^* and *calculated* I_λ^{cal} spectral contrast at any two wavelengths , λ and λ_0, in the range 330-390 nm where λ_0 is the reference wavelength. Generally, $\lambda_0 > \lambda$

$$AI = -100\left\{\log\left[\frac{I_\lambda^*}{I_{\lambda_0}^*}\right] - \log\left[\frac{I_\lambda^{cal}}{I_{\lambda_0}^{cal}}\right]\right\} \qquad (1)$$

AI should be zero when all radiative transfer processes are adequately accounted for in the radiative transfer calculations.

Properly accounting for clouds and surface effects facilitates the interpretation of the residue in terms of aerosols.

Different approaches have historically been used for modeling the I_λ^{cal} terms:

- Simple Lambert Equivalent Reflector (SLER) approximation
- Modified LER (MLER) approximation
- Mie-cloud Approximation

Governing Radiative Transfer Equation

$$I_\lambda(0,\mu,\varphi) = I_\lambda^0(0,\mu,\varphi) + \frac{R_\lambda T_\lambda(\tau^*,\mu,\varphi)}{(1-R_\lambda S_\lambda)} \qquad (2)$$

The measured radiance at the top of a purely molecular atmosphere is modeled as the combined effect of radiances originating from two pressure levels in the atmosphere: a surface term $I_{\lambda_0}^s$, and a cloud term $I_{\lambda_0}^c$.

SLER approximation

Surface reflectivity effects are not explicitly accounted for.
Clouds are assumed to be at the surface level.

For all values of $I_{\lambda_0}^*$ an effective reflectivity (also referred to as Lambert Equivalent Reflectivity or LER), is calculated by simply solving for *R* in equation (1) yielding

$$R_{\lambda_0} = \frac{I_{\lambda_0}^* - I_{\lambda_0}^0}{T_{\lambda_0} + S_{\lambda_0}(I_{\lambda_0}^* - I_{\lambda_0}^0)} \qquad (3)$$

The resulting reflectivity is assumed to be *wavelength independent* and used back in equation (1) to find I_λ^{cal} at wavelengths other than $\lambda_{0.}$

$$I_\lambda^{cal} = I_\lambda^0 + \frac{R_{\lambda_0} T_\lambda(\theta,\theta_0,p_0)}{1-R_{\lambda_0} S_\lambda(p_0)} \qquad (4)$$

MLER approximation

$I^{s}_{\lambda_0}$ is calculated for surface pressure and wavelength independent surface reflectivity (R_s) 0.08.

$I^{c}_{\lambda_0}$ is modeled as an opaque surface at pressure P_c (representing cloud top) and reflectivity (R_c) 0.80.

If $I^{*}_{\lambda_0} < I^{s}_{\lambda_0}$ or $I^{*}_{\lambda_0} > I^{c}_{\lambda_0}$ the SLER method is applied

If $I^{s}_{\lambda_0} \le I^{*}_{\lambda_0} \le I^{c}_{\lambda_0}$, an effective *wavelength independent* cloud fraction *f* is derived using

$$f = \frac{I^{*}_{\lambda_0} - I^{s}_{\lambda_0}}{I^{c}_{\lambda_0} - I^{s}_{\lambda_0}} \qquad (5)$$

The parameter *f* is used to calculate I^{cal}_{λ} as a linear combination of I^{s}_{λ} and I^{c}_{λ}

$$I^{cal}_{\lambda} = [1 - f]I^{s}_{\lambda} + fI^{c}_{\lambda} \qquad (6)$$

Mie-Theory-based Approach

I_λ^c cloud terms are calculated using Mie scattering theory.

A cloud model representative of liquid water clouds (C1 model) is assumed.
Cloud Optical Depth (COD) = 10
Prescribed cloud top and bottom pressure levels:
-700 and 800 hPa for sea level conditions
-430 and 508 hPa for 600 hPa terrain pressure

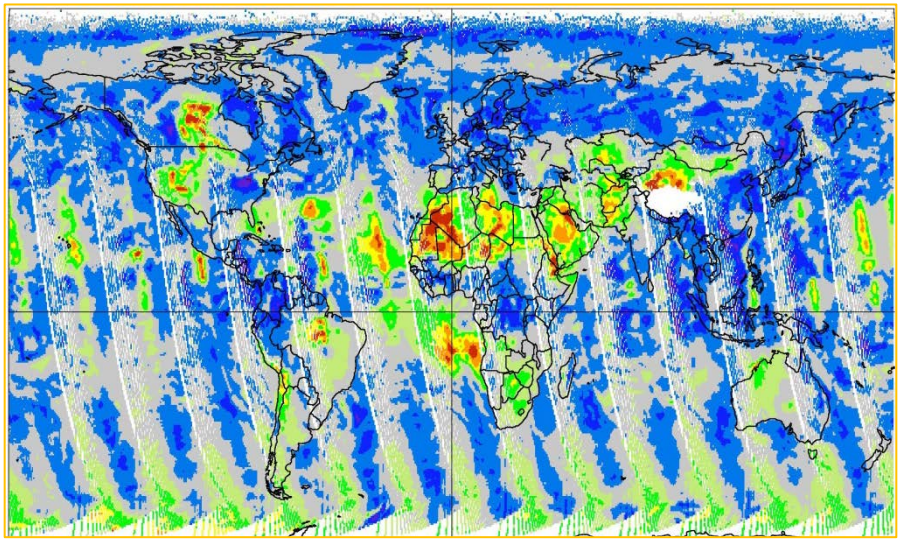
I_λ^s terms are calculated using wavelength-dependent, climatology-based values of surface albedo.

As in the MLER method a *wavelength independent* cloud fraction is calculated for all values of $I_{\lambda_0}^*$ as in equation (5).

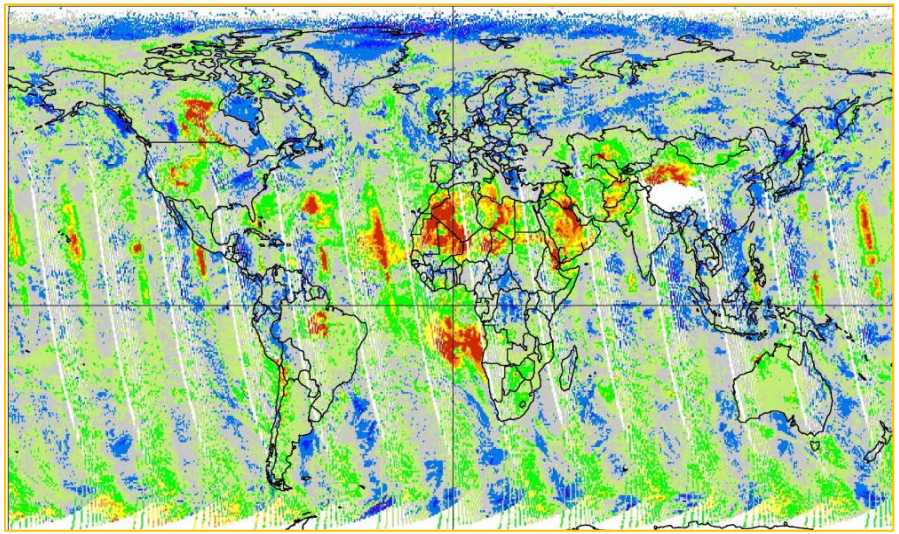
If $f > 1.0$, overcast sky conditions are assumed (i.e., $f = 1.0$), and a COD that matches the observed $I_{\lambda_0}^*$ is derived.

I_λ^{cal} values are calculated with equation (6)

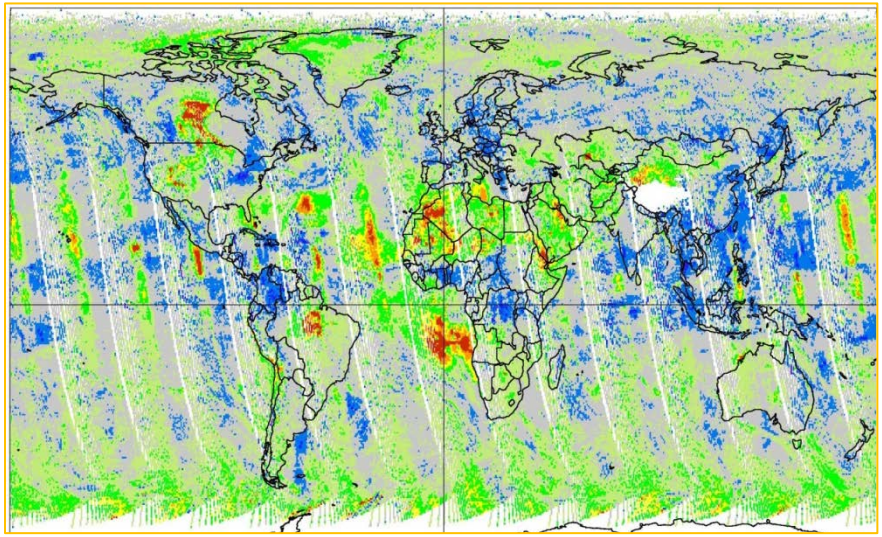
Comparison of AI methods applied to OMI 354 and 388 nm observations



AI (SLER Model)



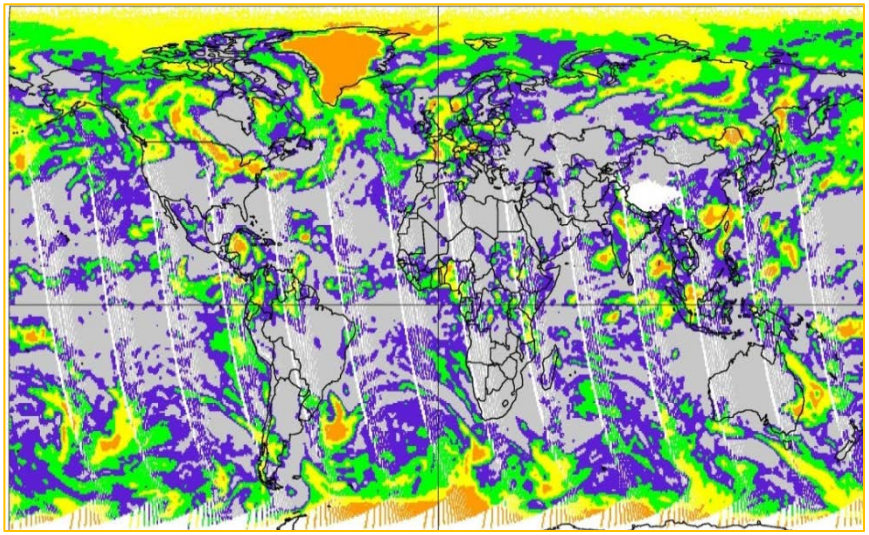
AI (MLER)



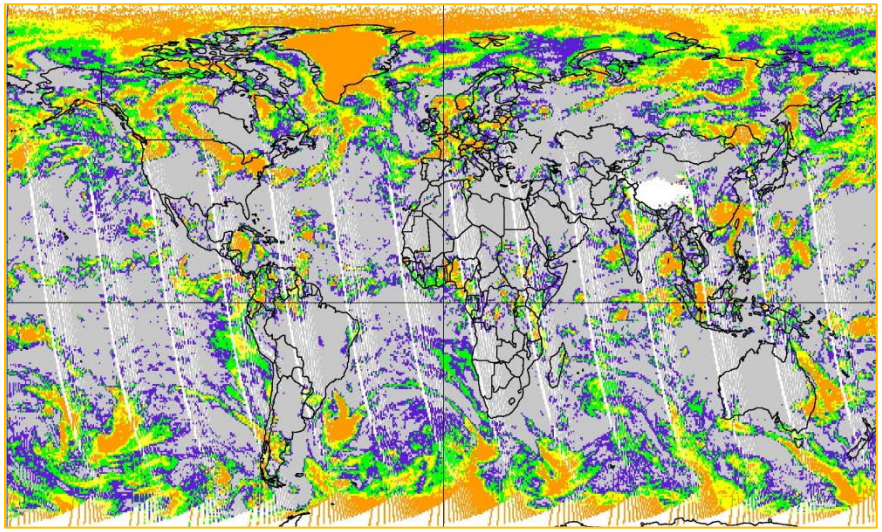
AI (Mie-Theory based)

OMI, Aug. 20, 2007

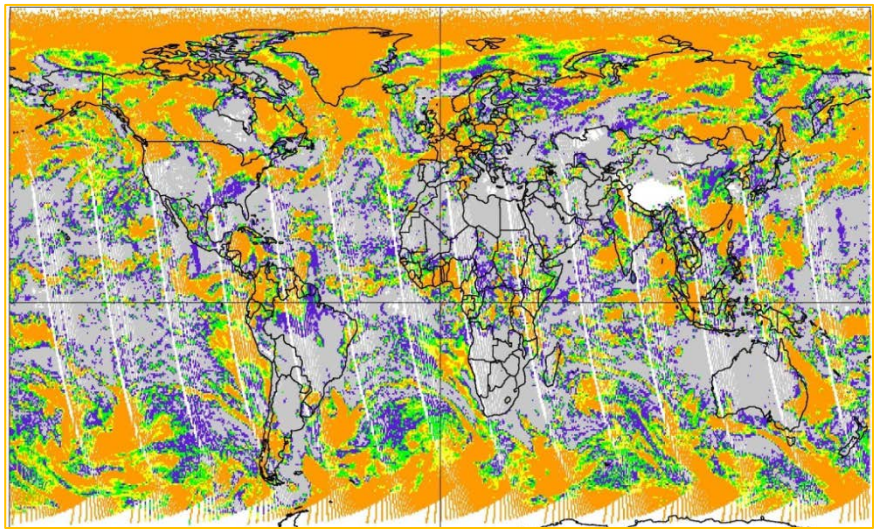
Comparison of AI methods applied to OMI 354 and 388 nm observations (continued)



SLER Reflectivity (388 nm)



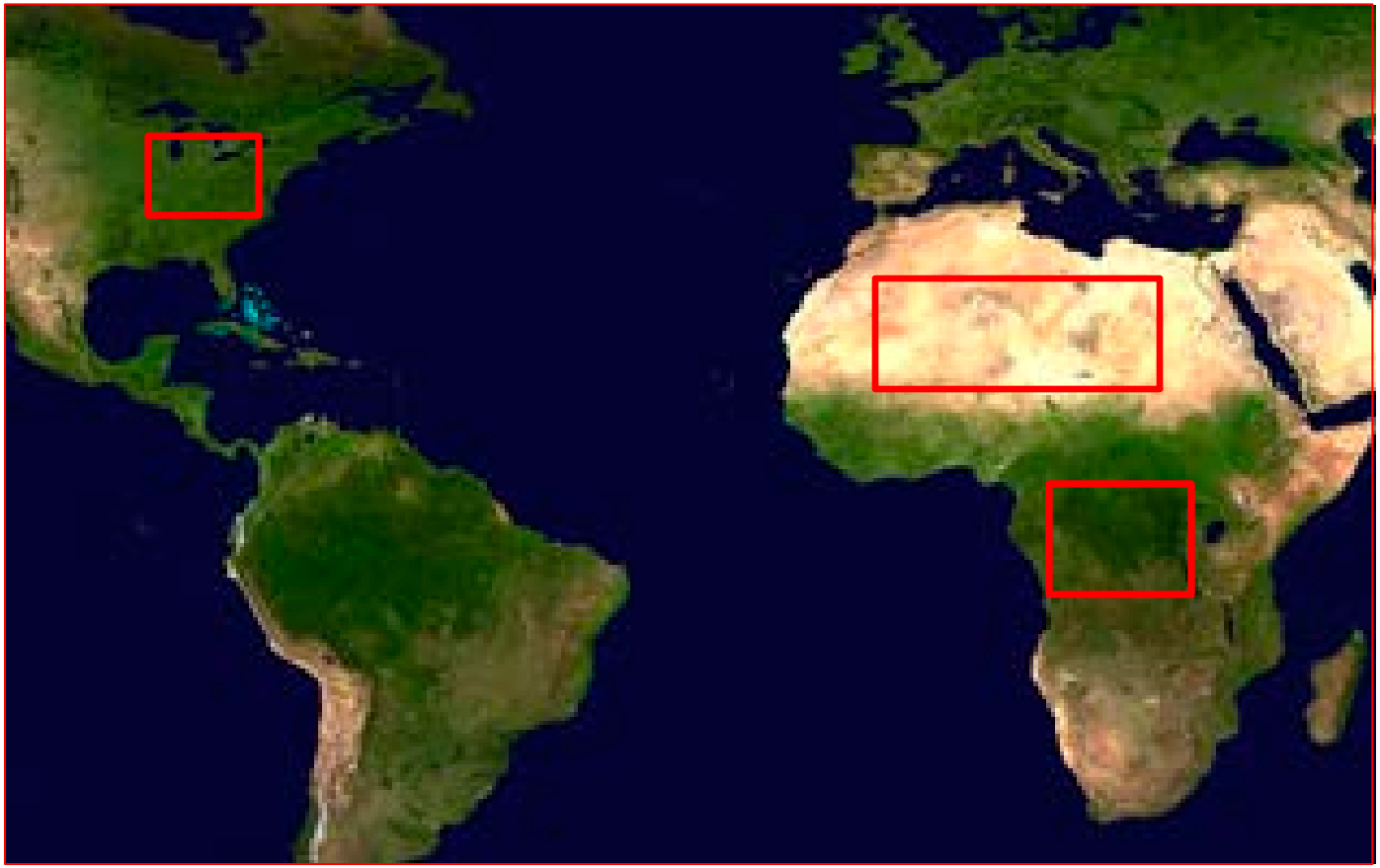
MLER Cloud Fraction



Mie Theory Cloud Fraction

OMI, Aug. 20, 2007

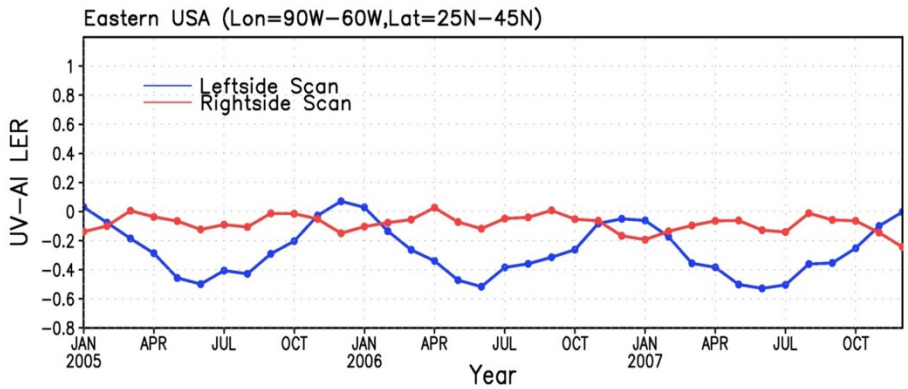
Analysis of AI scan angle dependence

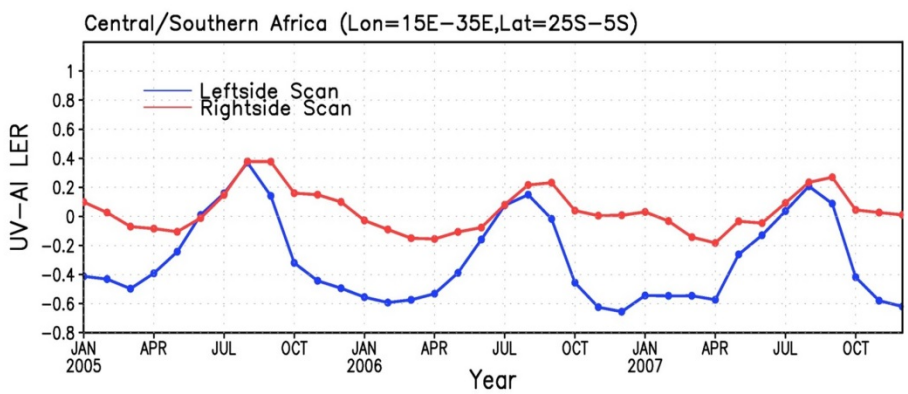


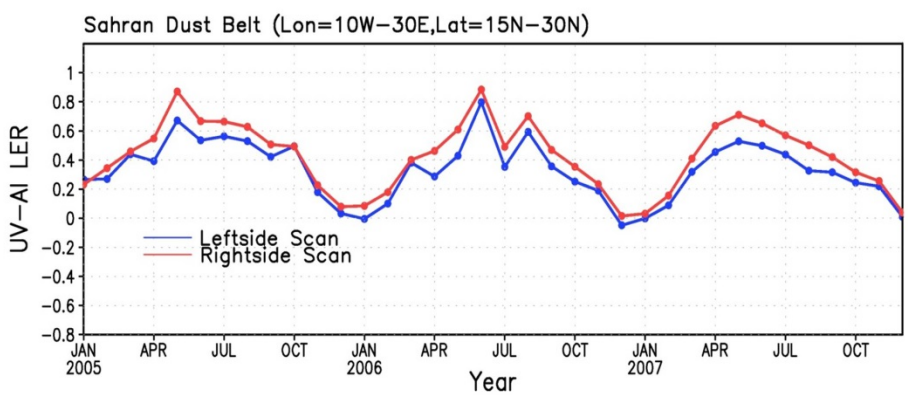
Compare monthly AI averages using separately OMI positions 1-30 and 31-60
During 2005-2007 for the regions above.

Analysis of AI scan angle dependence (continued)

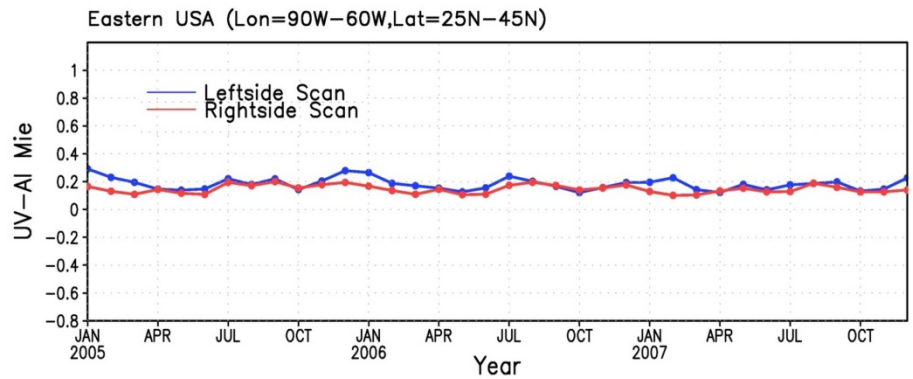
SLER

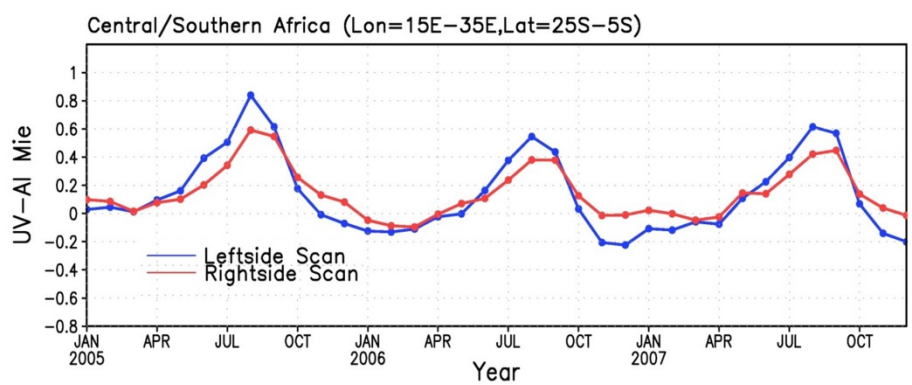


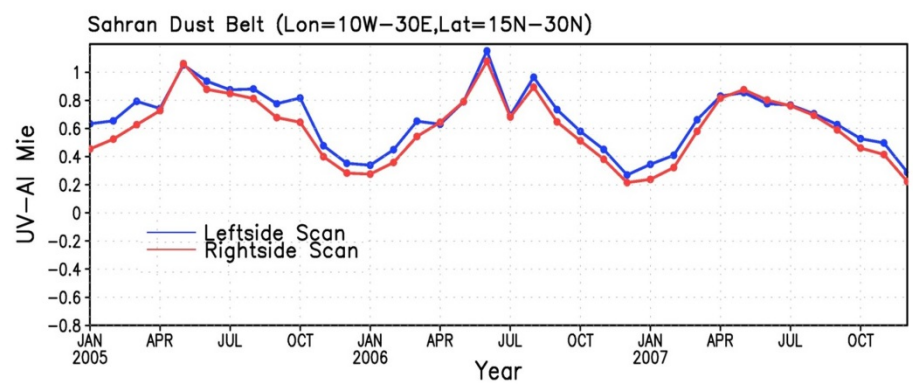




Mie Theory







Application to OMPS observations

-An OMPS beta algorithm (NMAERUV) to calculate AI using the Mie-Theory approach has been developed and delivered to SIPS.

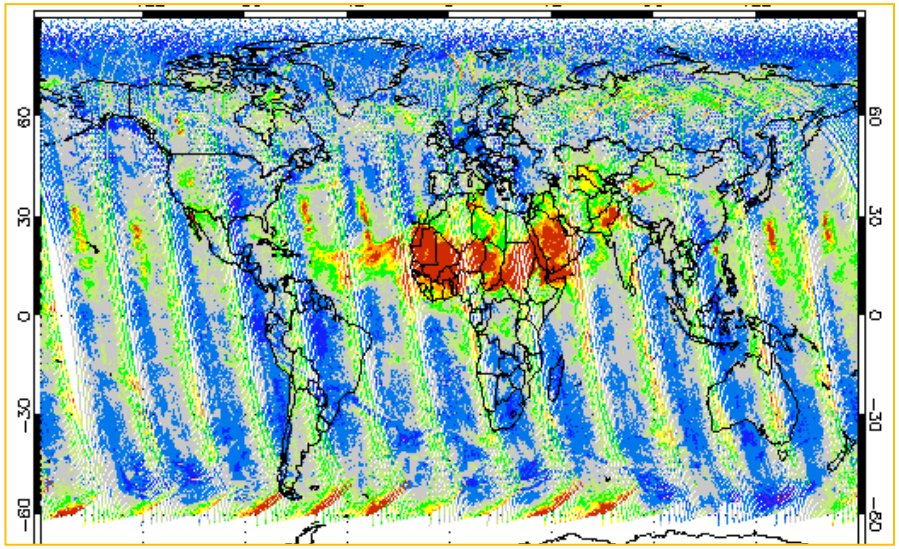
-Input: radiance measurements at 340 and 378.5 nm (NMEV-L1B V1.8)

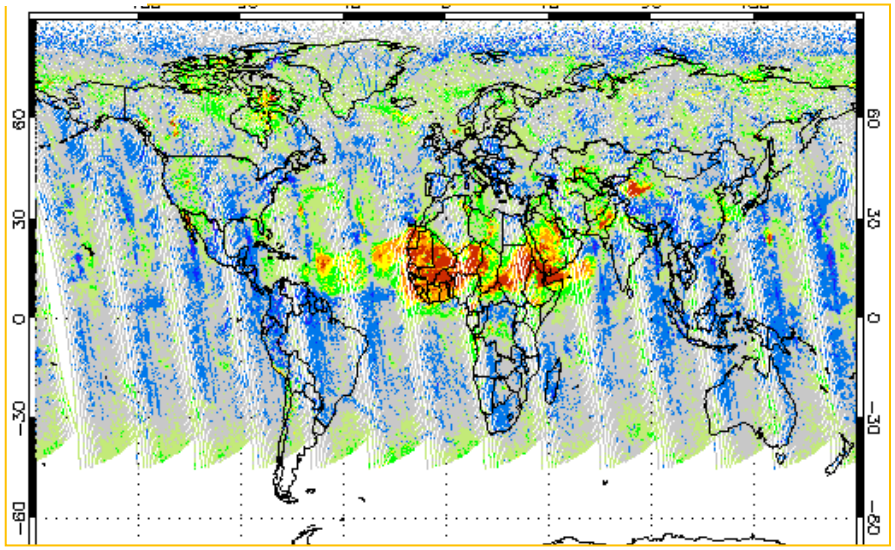
-Climatology of TOMS-based long-term surface reflectivity (340, 380 nm)

- Entire record of both standard and high resolution data have been processed.

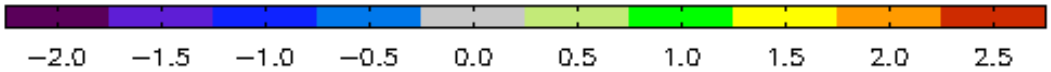
Application to OMPS observations

NMTO3 (V 2.1) AI **Jun 12, 2015** NMAERUV (V 0.1.7) AI





/omps/live/dd/85605/NMTO3-L2/2015/06/12/ /omps/live/dd/60000/NMAERUV/2015/06/12/



- Both products use the same L1B input (NMEV-L1B V1.8).
- No soft calibration was applied to NMAERUV.
- SZA threshold (< 70°) was applied to NMAERUV.
- NMTO3 uses TOMSV8 AI definition (360 and 331 nm)

Summary

Two important upgrades have been implemented in the AI calculation:

- The use of Mie Theory to account for the presence of clouds.
- Climatology-based values of wavelength dependent surface albedo.

The Mie-based AI reduces the occurrence of negative values (w.r.t. MLER) in the presence of clouds.

It shifts the mode AI closer to zero.

It is more physically-based than the MLER approach and, therefore, easier to explain.

The use of climatology-based surface albedo data eliminates *false* AI features associated with surface features.

An OMPS beta algorithm (NMAERUV) to calculate AI using the Mie-Theory approach has been developed and delivered to SIPS.

The Mie-based AI approach is currently being applied to the MEaSUREs TOMS, OMI and OMPS records.