Aerosol Index Upgrades

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

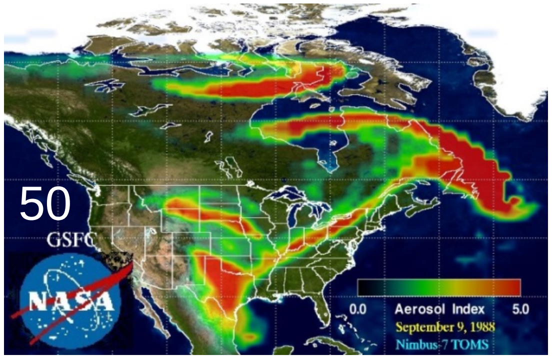
OMPS Science Team Meeting

02-26-2015

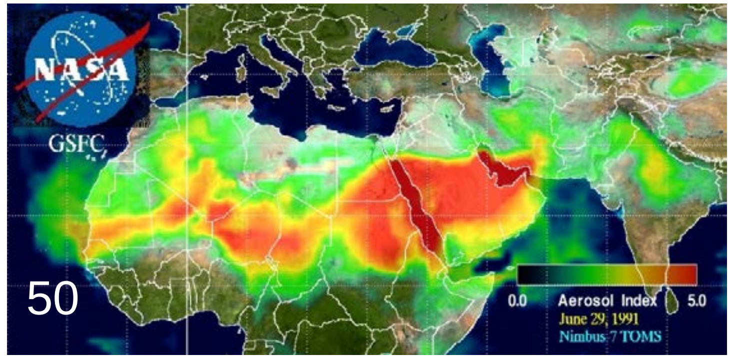
Absorbing Aerosol Index Record

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

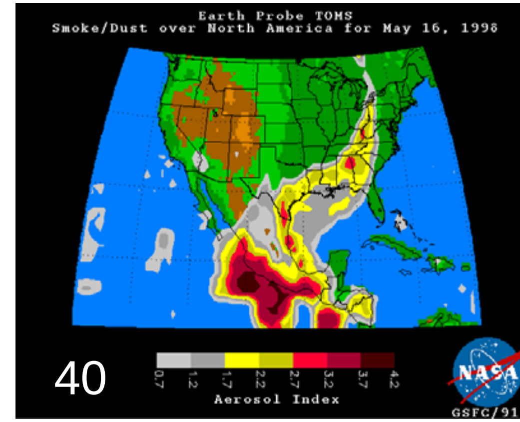
Nine sensors: N7-TOMS, M3-TOMS, EP-TOMS, AD-TOMS, GOME, OMI, GOME-2, SCIAMACHY, OMPS



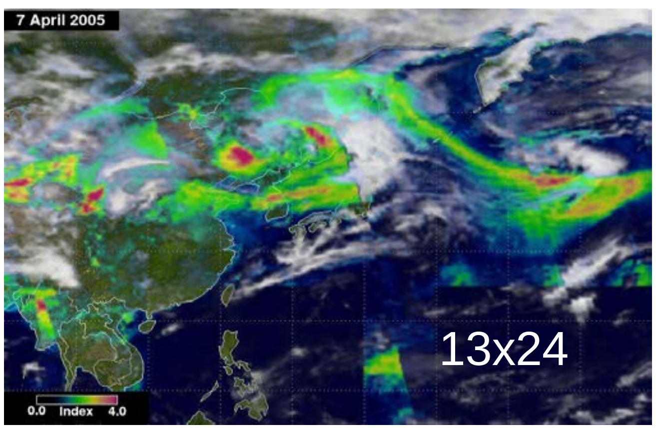
Yellowstone National Park Fires, Nimbus7-TOMS, Sept.9, 1988.



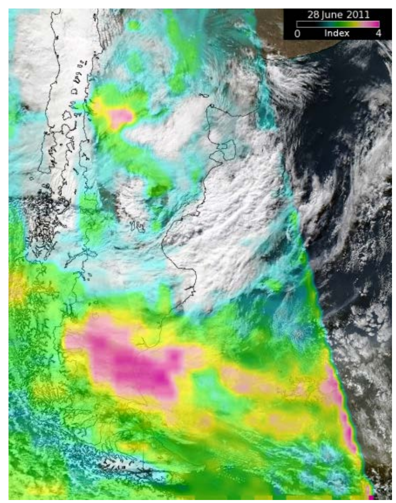
Kuwaiti Oil Fires Smoke layer as seen by Nimbus7-TOMS on June 29, 1991.



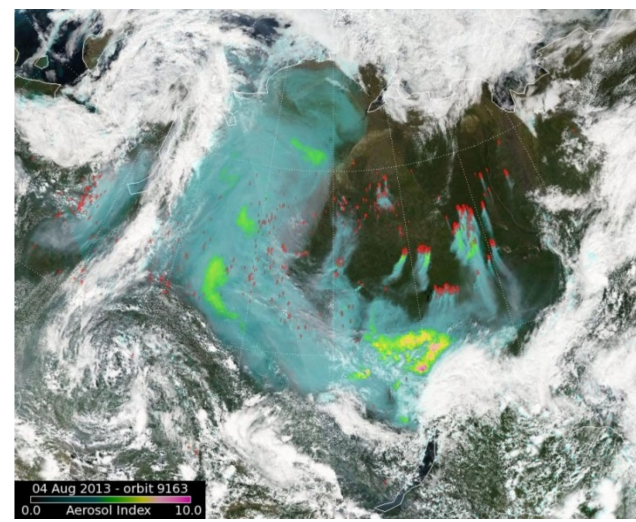
Smoke layer from fires in Mexico Earth Probe-TOMS, May 16,1998



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.

Calculated radiances must account for the presence of clouds.
Different approaches have historically been used for modeling the I_λ^{cal} terms:

- The Lambert Equivalent Reflector (LER) approximation
- The Modified LER (MLER) approximation

These two approaches are based on Rayleigh scattering calculations.

A third approach using Mie-Theory is being implemented.

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 $I^s_{\lambda_0}$, and a cloud term $I^c_{\lambda_0}$.

LER approximation

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

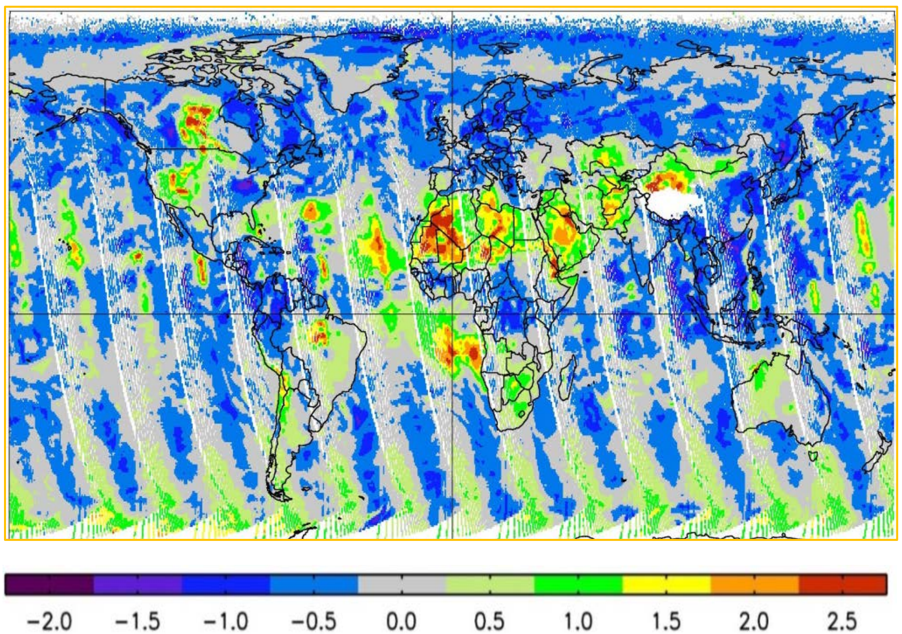
$$R_{\lambda_0} = \frac{I^*_{\lambda_0} - I^0_{\lambda_0}}{T_{\lambda_0} + S_{\lambda_0}(I^*_{\lambda_0} - I^0_{\lambda_0})} \qquad (3)$$

The resulting reflectivity is assumed to be *wavelength independent* and used back in equation (1) to find I_λ^{cal} at wavelengths other than λ_0.

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

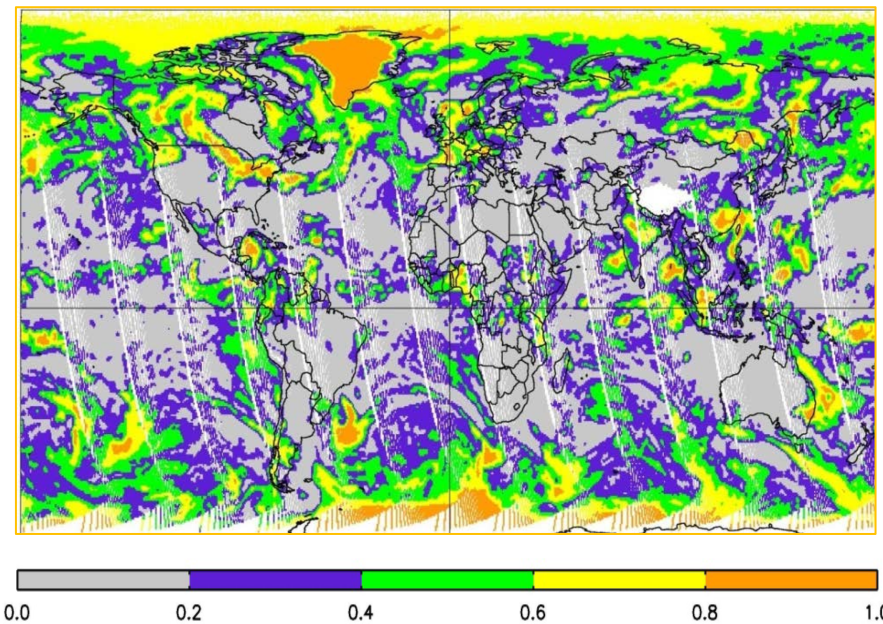
Application of LER approximation to OMI observations at 354 and 388 nm

Aug 20, 2007



Aerosol Index

-Clouds yield large negative values



LER (388 nm)

This approximation has only been used in non-operational applications for aerosol detection under cloud-free conditions.

MLER approximation

$I^{s}_{\lambda_0}$ is calculated for surface pressure and 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 LER method is applied

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

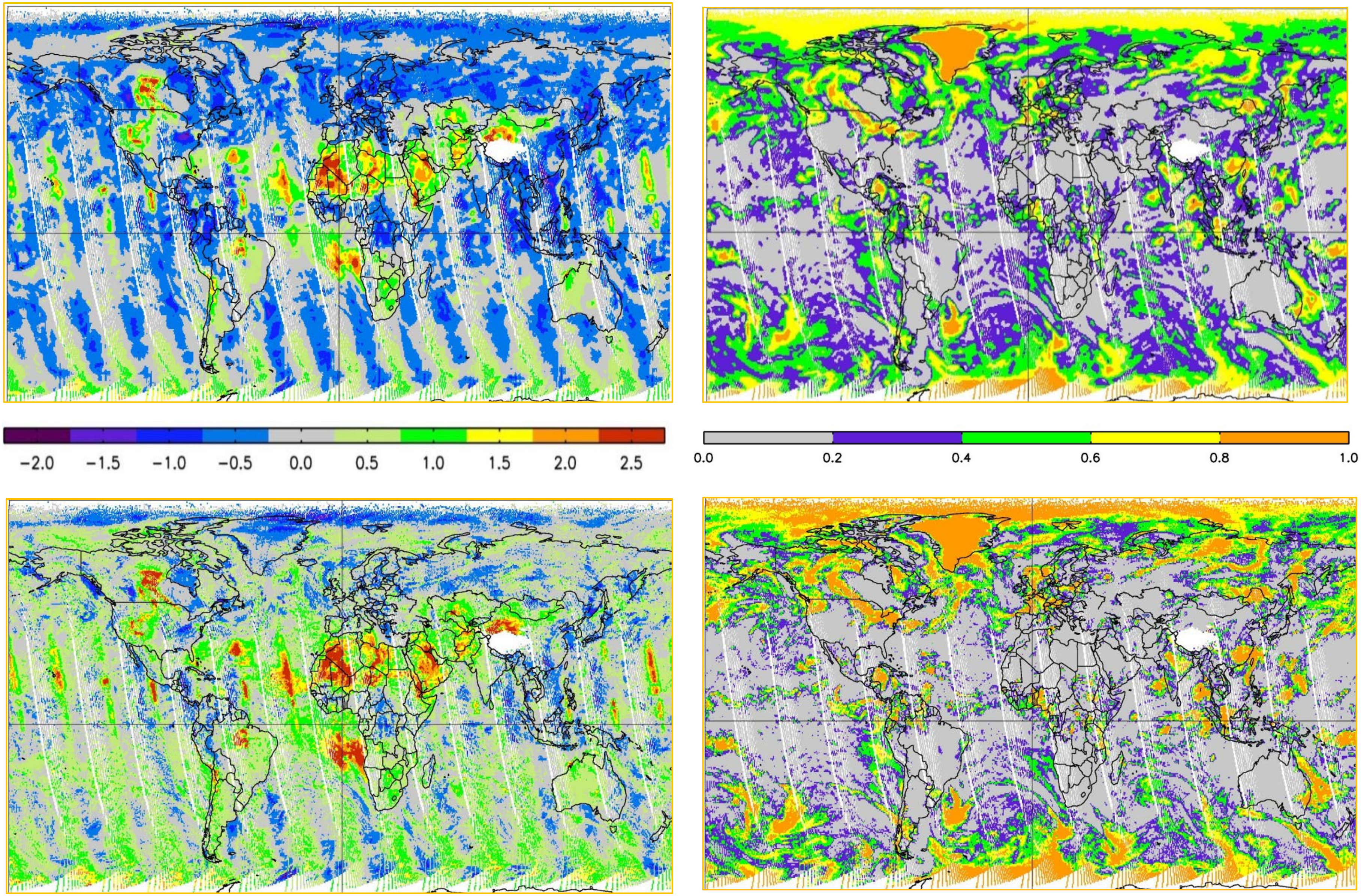
$$f = \frac{I^{*}_{\lambda_0} - I^{s}_{\lambda_0}}{I^{c}_{\lambda_0} - I^{s}_{\lambda_0}} \qquad (5)$$

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

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

In this approximation I^{s}_{λ} *is calculated assuming a wavelength independent surface albedo (0.08)*

AI (LER Model) OMI, Aug 20, 2007 LER (388 nm)



AI (MLER) Cloud Fraction

Mie-Theory-based Approach

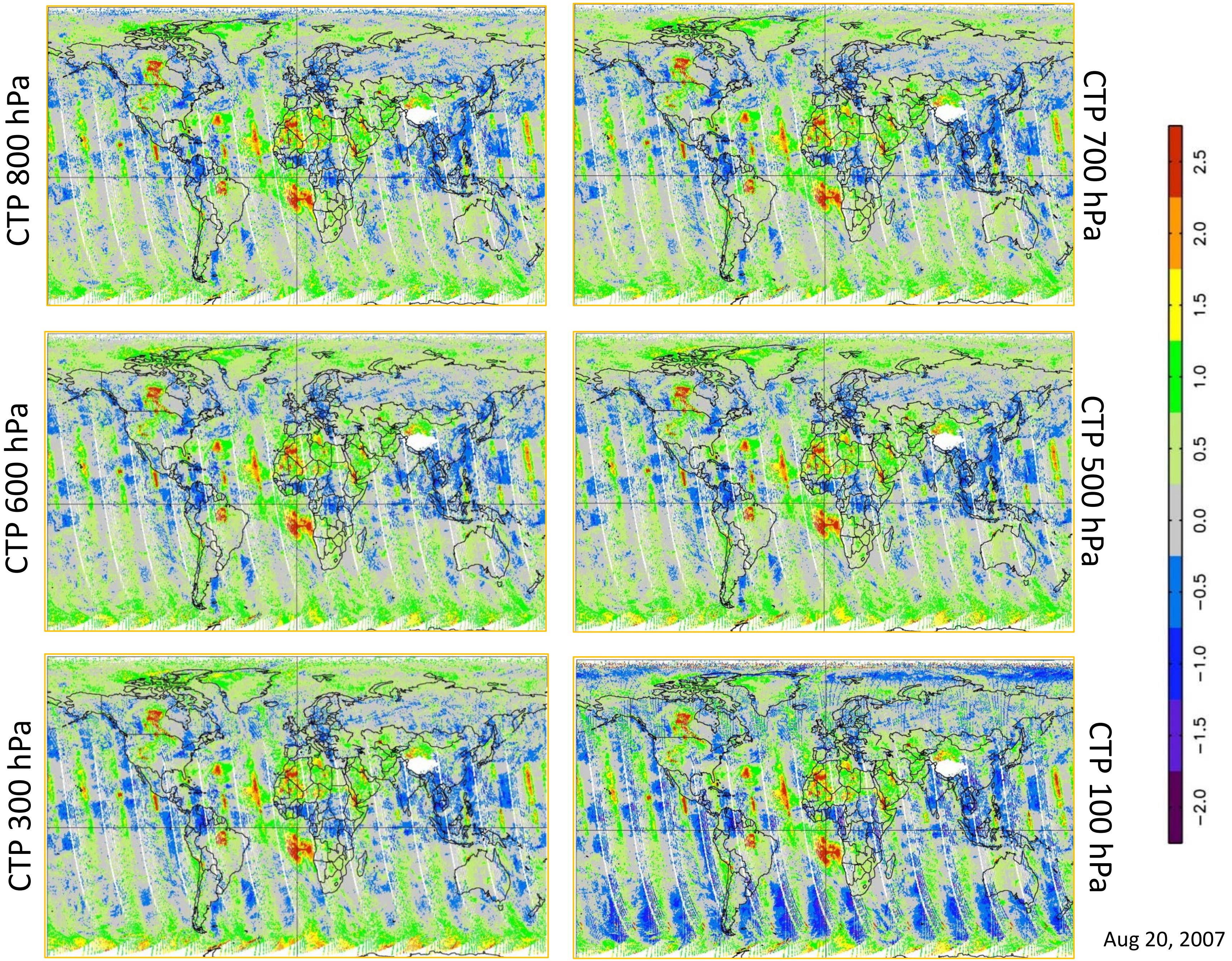
I_{λ}^{c} cloud terms are calculated using Mie scattering theory. A model representative of water clouds, at prescribed cloud top and bottom pressure levels. and cloud optical depth (COD) 10 is assumed.

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.

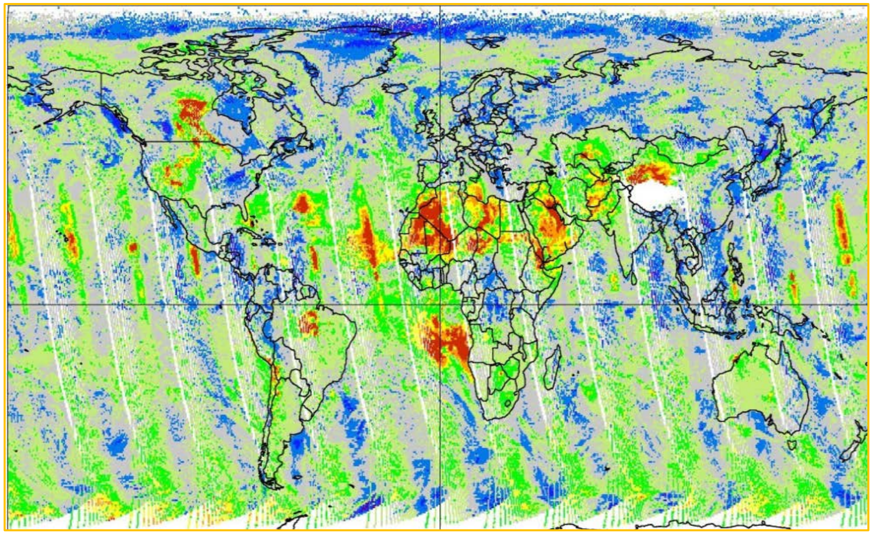
I_{λ}^{cal} values are calculated with equation (6)

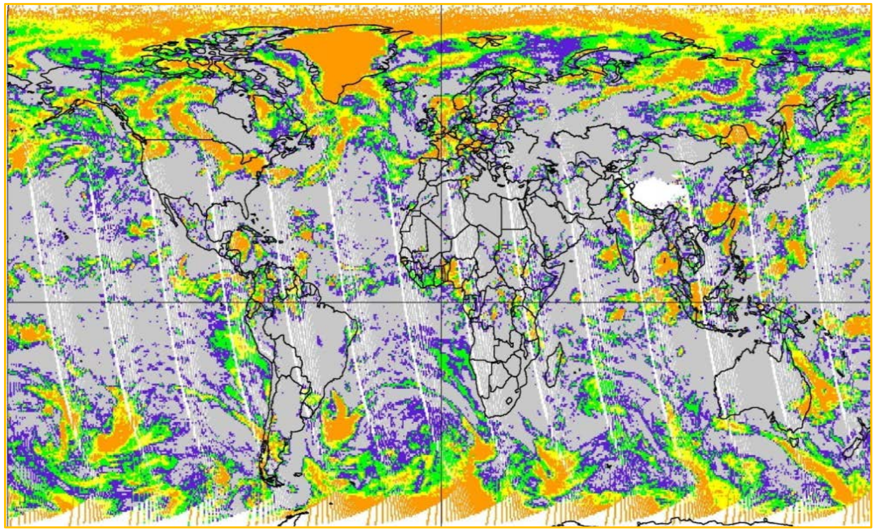

CTP 800 hPa
CTP 700 hPa
CTP 600 hPa
CTP 500 hPa
CTP 300 hPa
CTP 100 hPa
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
−2.0
Aug 20, 2007

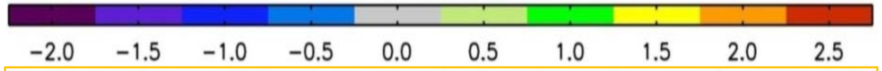
AI (MLER Model)

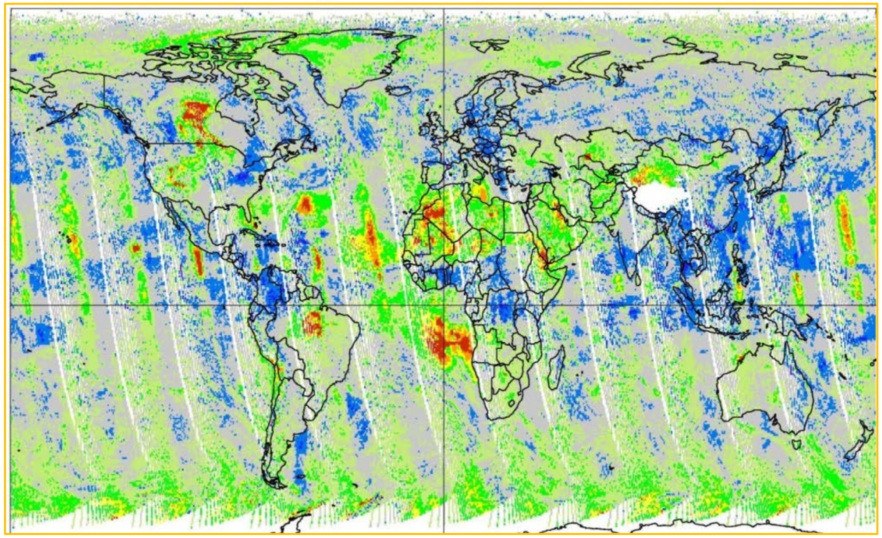
OMI, Aug 20, 2007

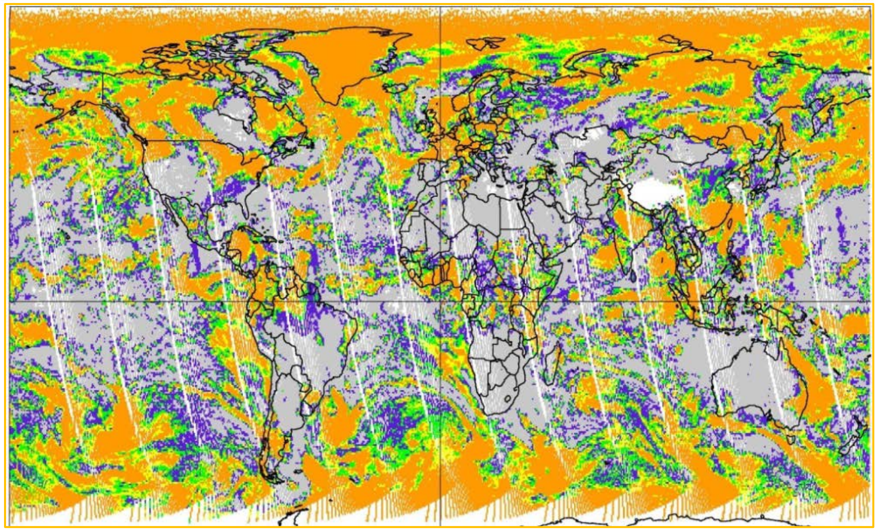
Cloud Fraction (MLER)







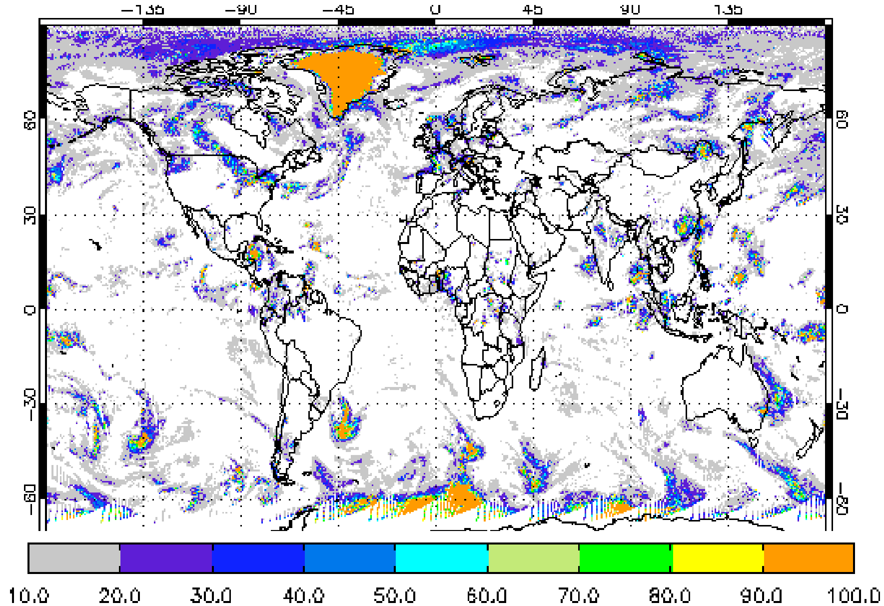




AI (Mie-Theory based)

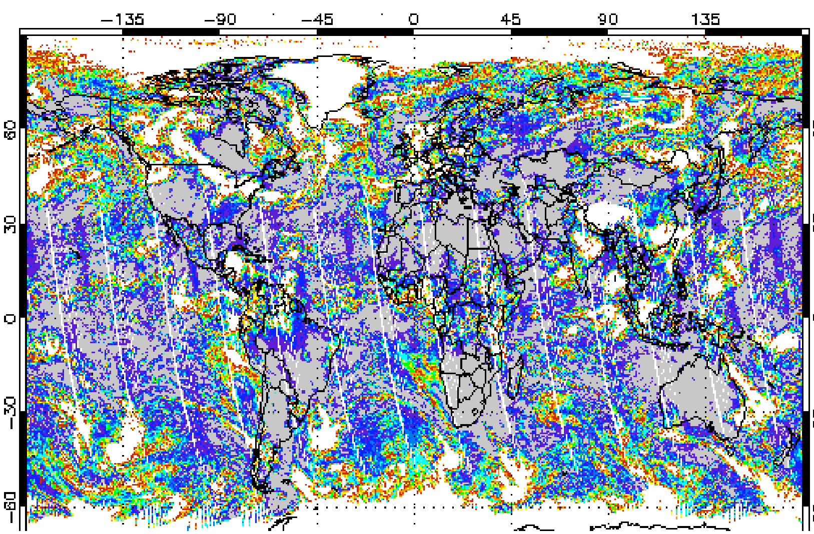
Cloud Fraction (Mie-Theory)

Derived COD when Fc =1.0

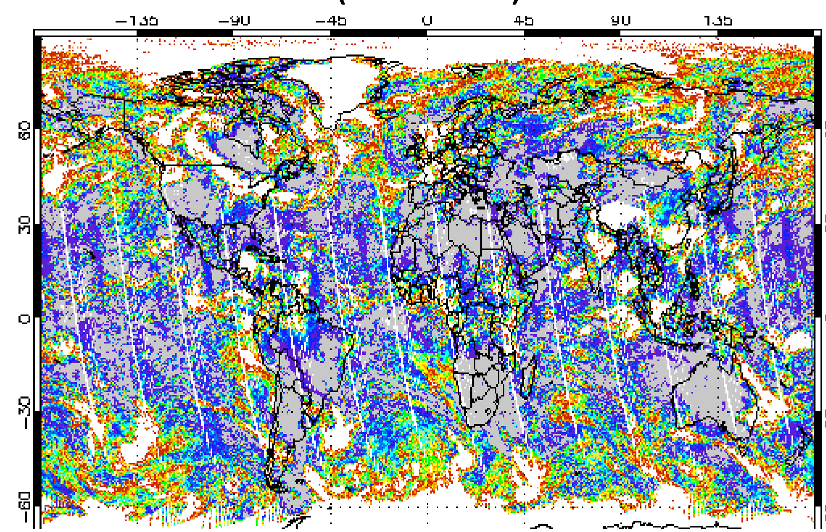


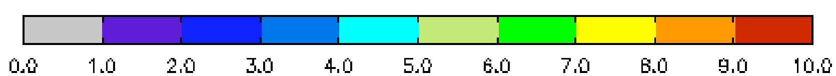
August 20, 2007

Derived COD when Fc ≤ 1.0

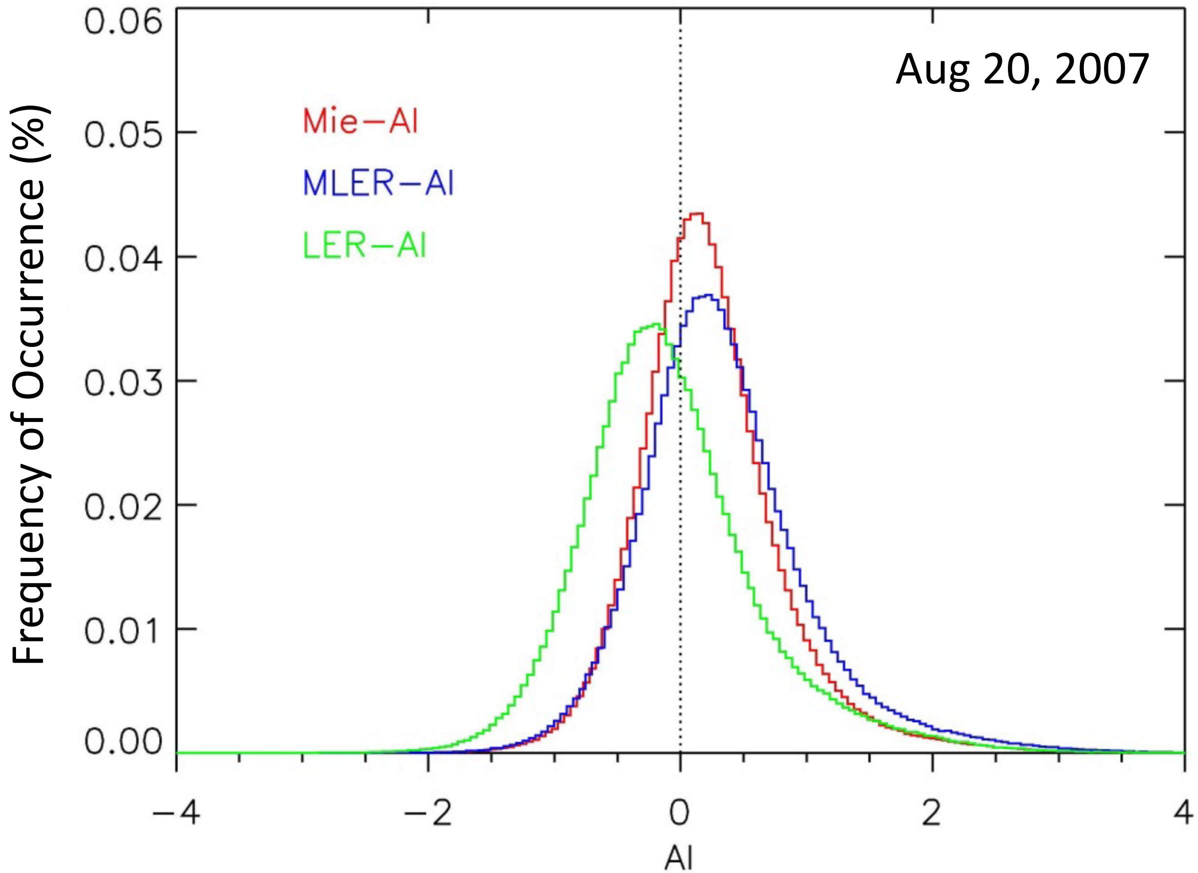


Calculated COD (10.0* Fc) when Fc ≤ 1.0





Some Statistics



	Mean	Std. Dev.	Mode
Mie - AI	0.23	0.59	0.13
MLER - AI	0.34	0.68	0.20
LER - AI	-0.08	0.72	-0.22

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.

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

It is recommended that the Mie approach be applied to the OMPS data for consistency of the long-term record.