An Aerosol Simulation with MODIS Terra, MODIS Aqua and MISR Assimilation

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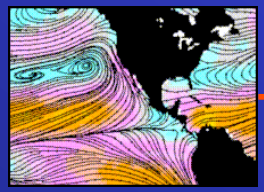
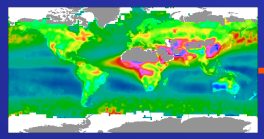
National Center for Atmospheric Research
Boulder, Colorado

CERES Science Team Meeting
May 3-5, 2005

Hybrid Models adjusted to Satellite Data





Chemical Transport Models

Aerosol mixing ratio q_i

Aerosol Optical Models

Optical depth τ_i, asymmetry g_i, ssa ω_i

Radiative Transfer Models

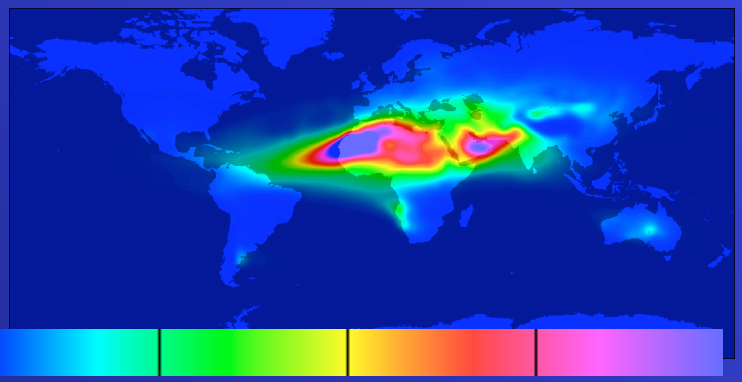
Radiative Forcing

Chemical Transport Models

$$\frac{\partial q_i}{\partial t} + \nabla \cdot (q_i \vec{v}) = S_{emis} + S_{chem} - S_{wet} - S_{dry} - S_{chem}$$

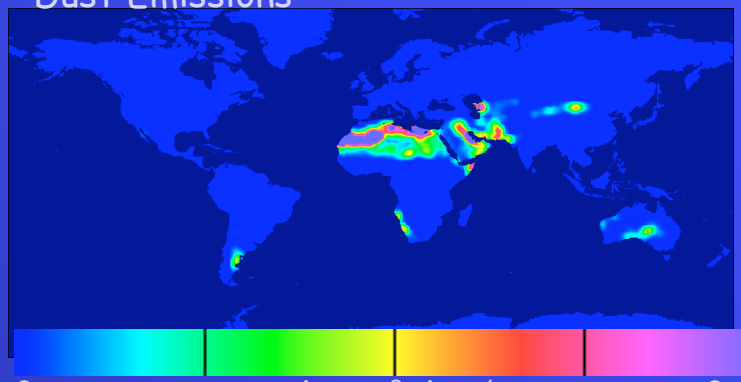
Sources | Sinks

Dust Mass



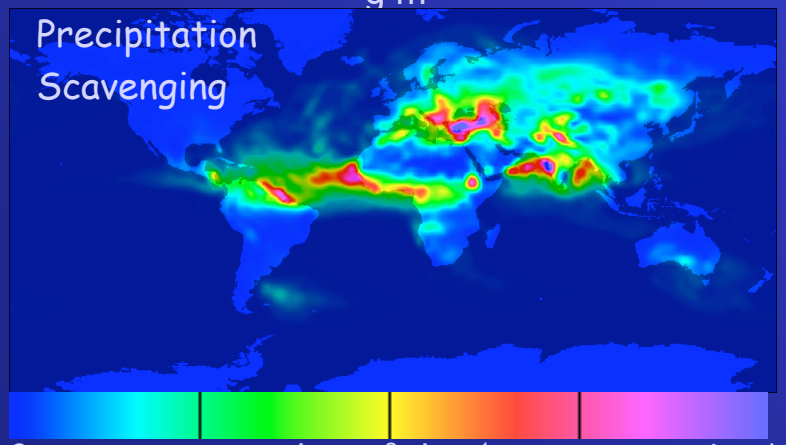
0 g m^{-2} 0.5

Dust Emissions



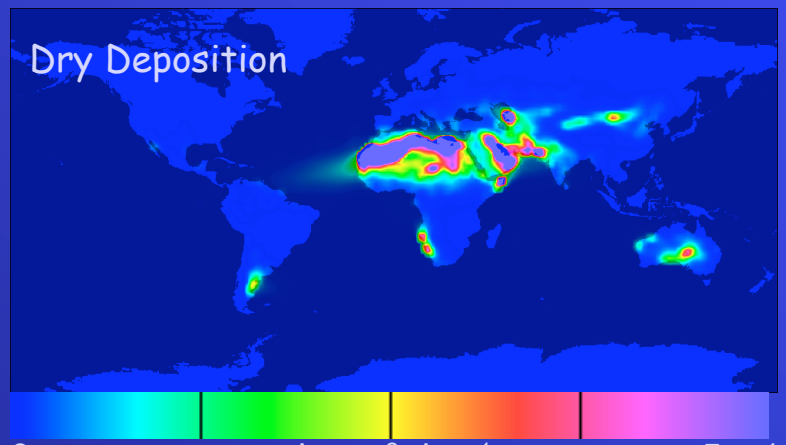
0 kg m^{-2} day^{-1} 3 x 10^{-4}

Precipitation Scavenging



0 kg m^{-2} day^{-1} 4 x 10^{-5}

Dry Deposition



0 kg m^{-2} day^{-1} 5 x 10^{-5}

AOD Assimilation
MODIS Moderate Resolution Imaging Spectrometer
AND/OR
MISR Multi-angle Imaging Spectrometer

AOD
l = 630 nm
OR 550 nm
Optimal Interpolation

1° by 1° gridded aerosol product
Stowe et al 1997
Kaufman et al 1998

Meteorological fields
NCEP/NCAR Reanalysis
resolution T62 ~ 1.9°, 28 levels
OR **NCEP Aviation Analysis**
resolution T126, 42 levels
OR **CAM** (NCAR Community Atmosphere Model)
resolution T42, 28 levels

MATCH
Model for Atmospheric Transport and Chemistry
Rasch et al 1997

SO_2/DMS/Carbon Aerosol Emission Inventories
monthly climatologies
Benkovitz et al 1996
Cooke et al 1999
Liousse et al 1996

MATCH Configuration

Sulfur Cycle/ Sulfate Aerosol
Gas phase/aqueous chemistry
Barth et al 2000
tracers DMS, SO_2, SO_4, H_2O_2
monthly climatologies for O_3, OH, HO_2, NO_3
from MOZART (Model for Ozone and its Precursors in the Troposphere)

Dust Aerosol
Mobilization and deposition
Zender et al 2003
Mahowald et al 2003
4 size categories
0.005 – 0.5 mm (radius), 0.5 – 1.25 mm, 1.25 – 2.5 mm, 2.5 – 5.0 mm

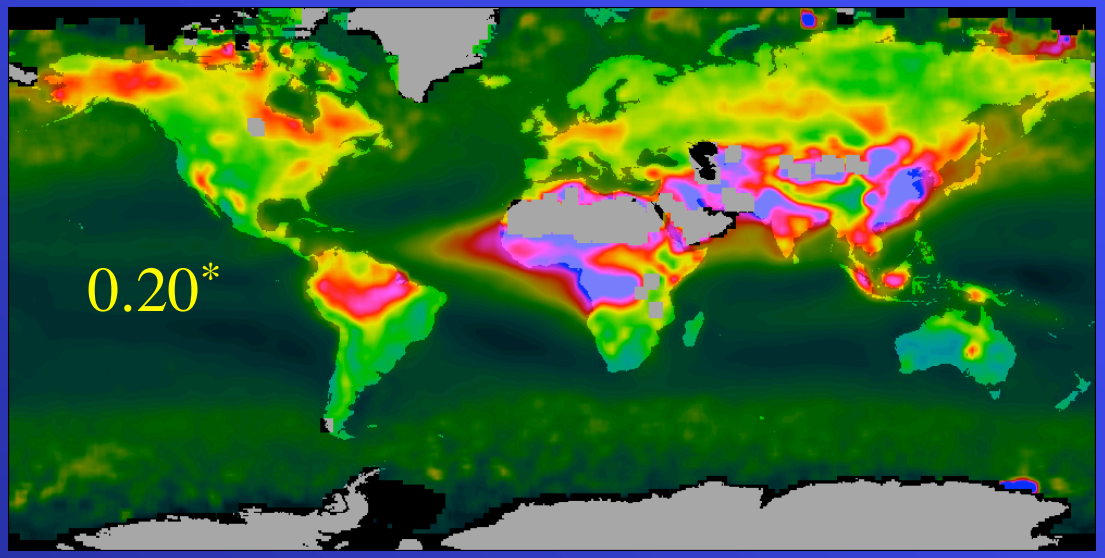
Diagnosed sea-salt aerosol
Blanchard and Woodcock 1980
No nitrate aerosol

Carbon Aerosol
Black Carbon (Soot)
Organic Carbon hydrophobic ⇨ hydrophilic
Cooke and Wilson 1996

Hydrological Cycle
Prognostic cloud water
Rasch and Kristjansson 1997
Vertical convection
Zhang and McFarlane 1995
Precipitation - bulk microphysical
Flatau 1989

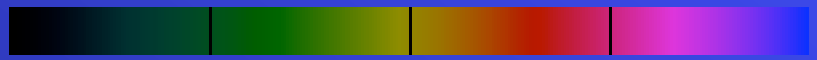
Aerosol Optics
Sea-Salt, Organic Carbon, Soot
Optical Properties of Aerosols and Clouds
Hess et al 1998
Dust
Zender et al 2003
Sulfate: Fillmore et al 2005 $(NH_4)_2SO_4$

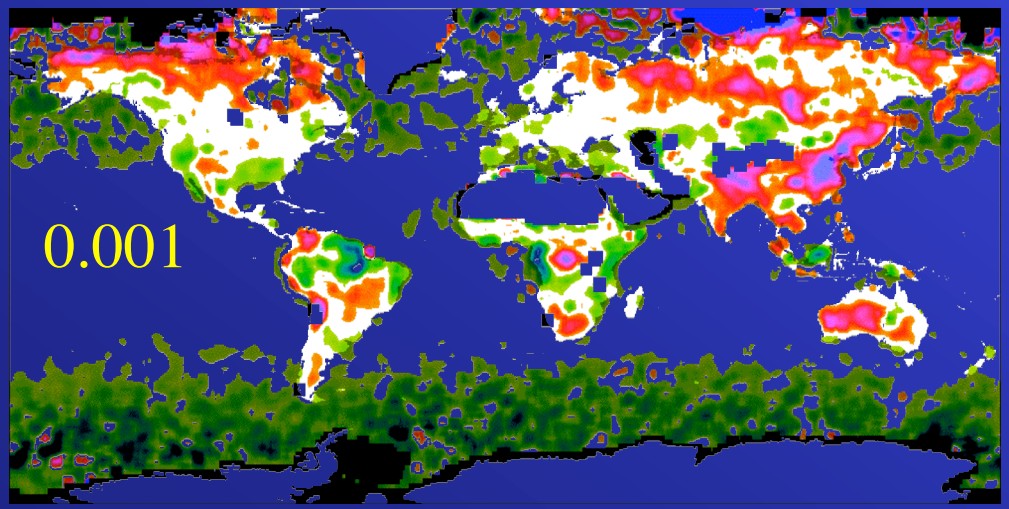
MODIS Terra Version 4



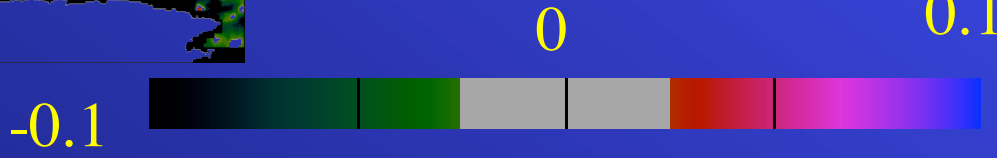
AOD 2003 - 2004
550 nm

* average does not include regions of missing data

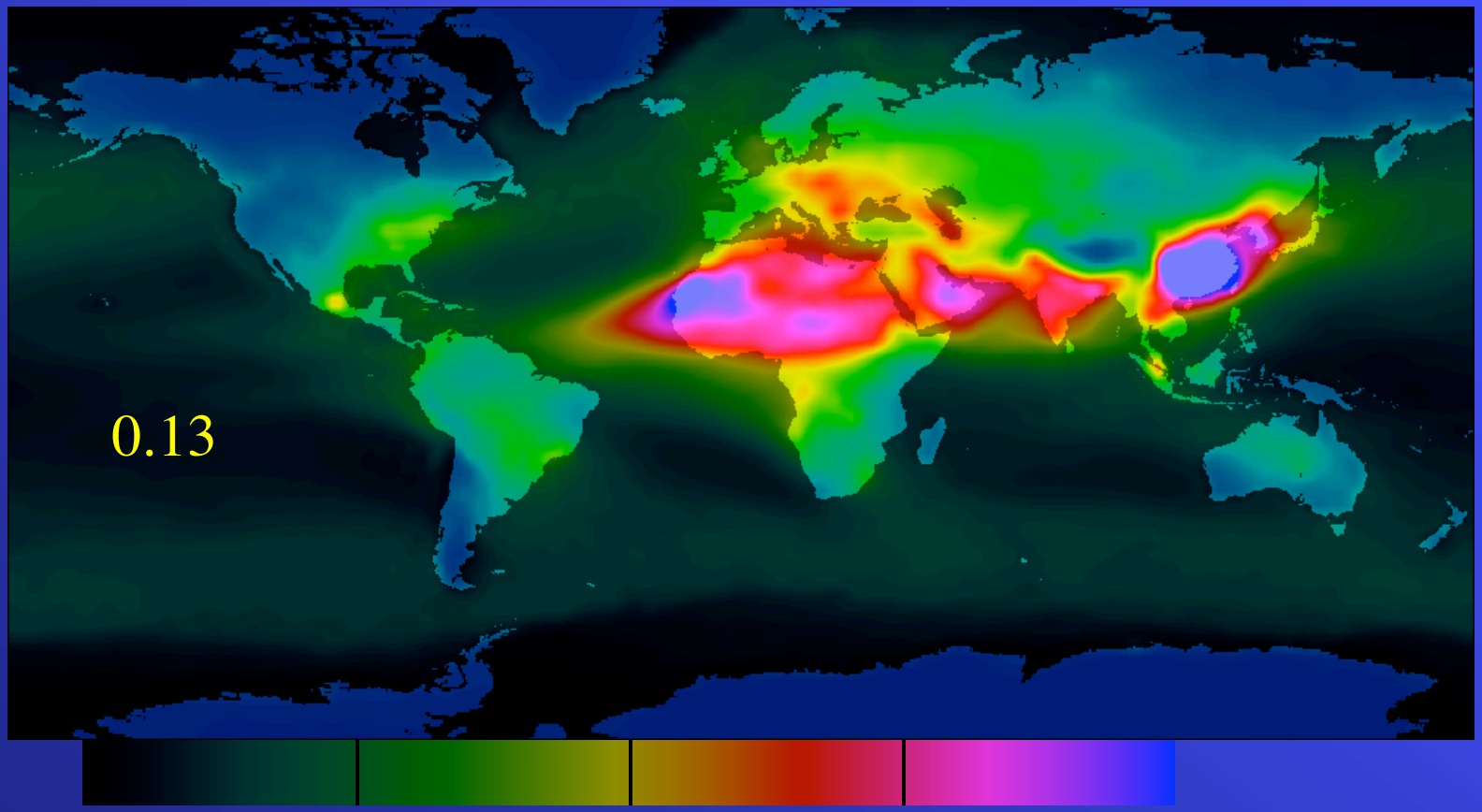


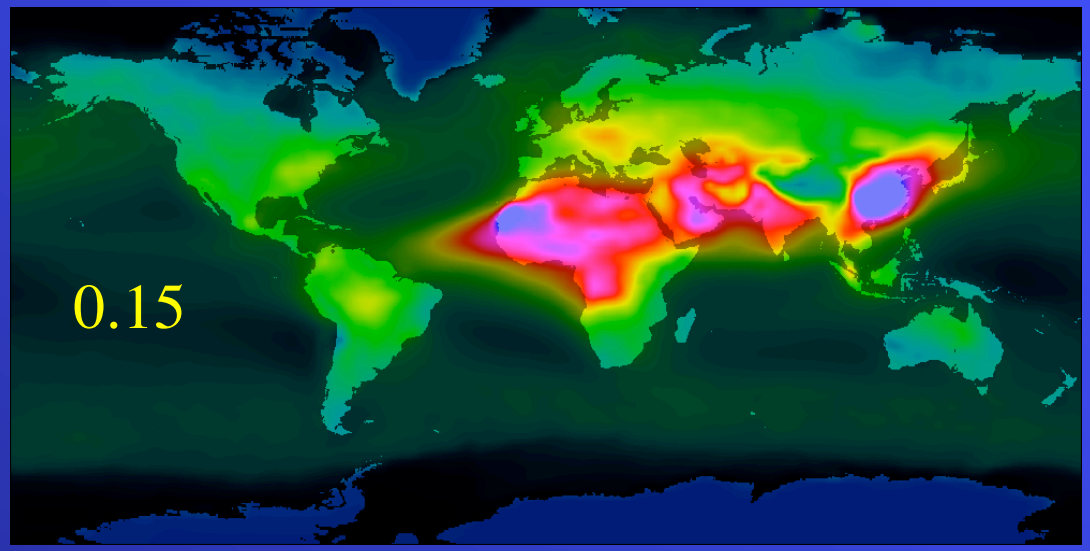


MODIS Aqua - Terra



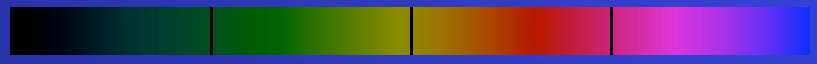
MATCH AOD 2003-2004 550 nm Control

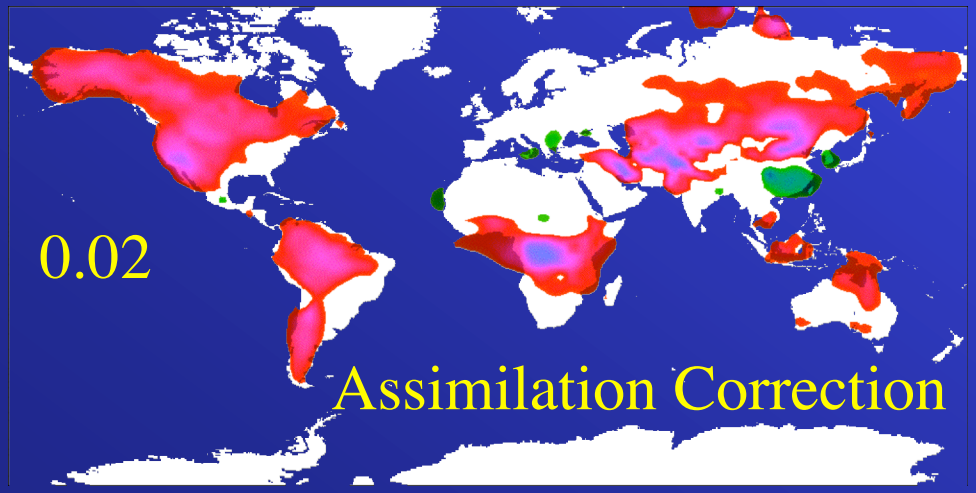




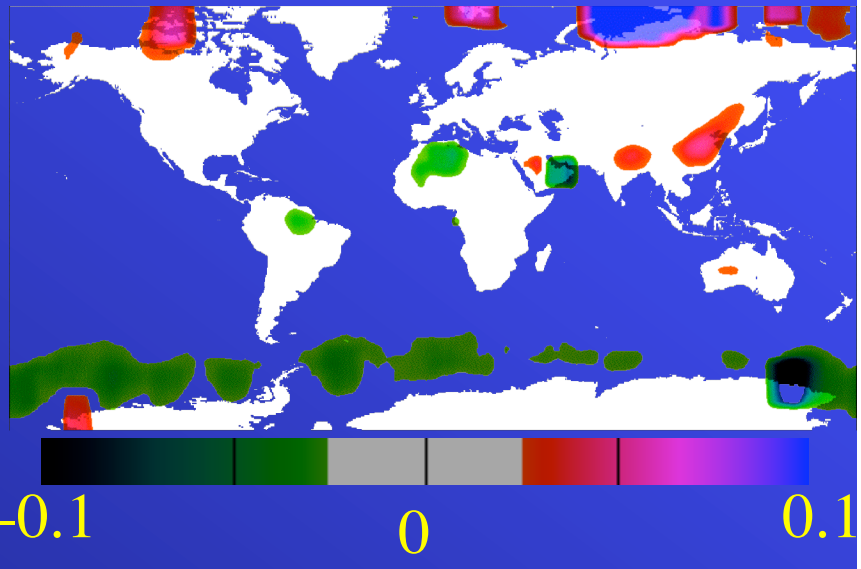
MATCH with
MODIS Terra/Aqua
Assimilation

AOD 2003 - 2004
550 nm



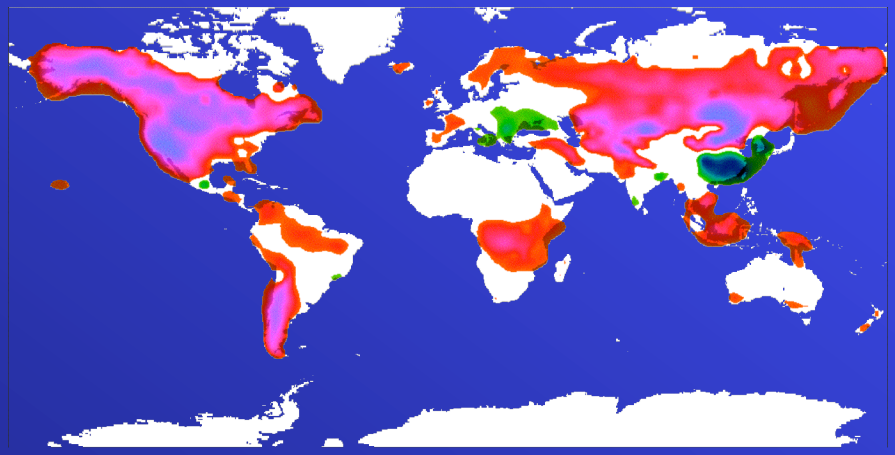


Aqua Assimilation - Terra Assimilation

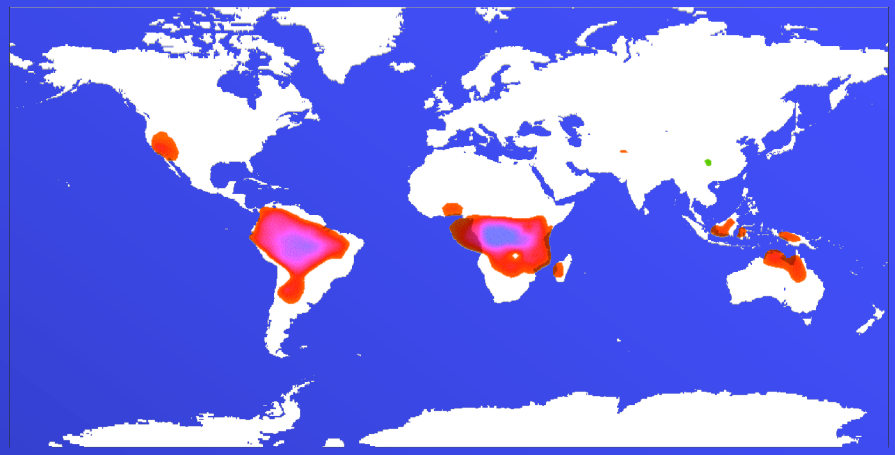


MODIS Assimilation Correction By Species

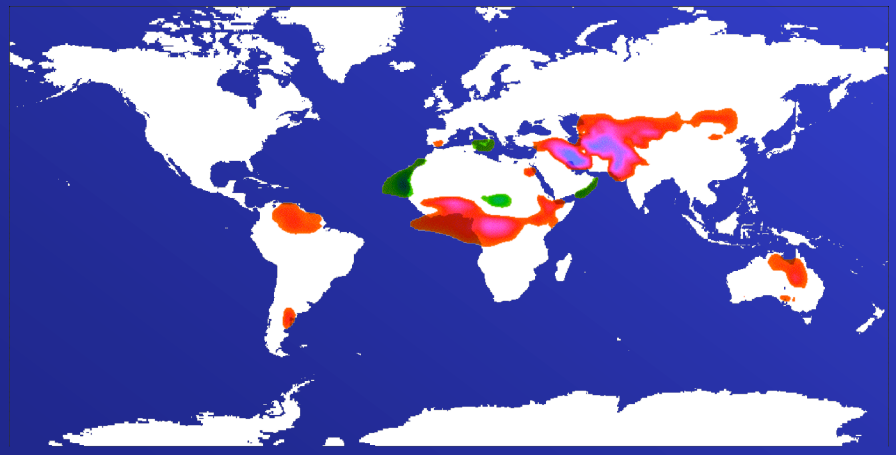
Sulfate



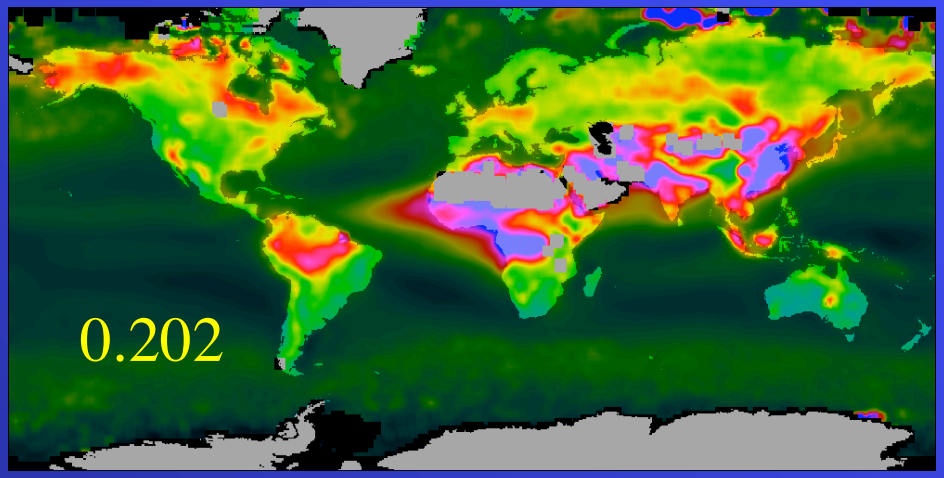
Carbon Aerosol



Dust

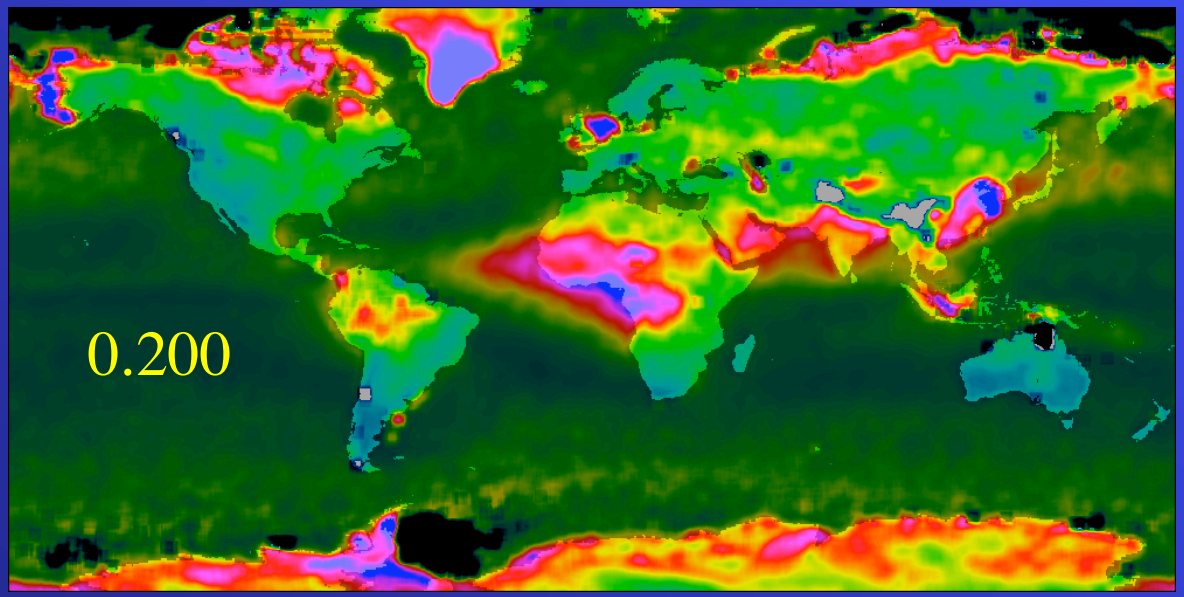


MODIS Terra/Aqua

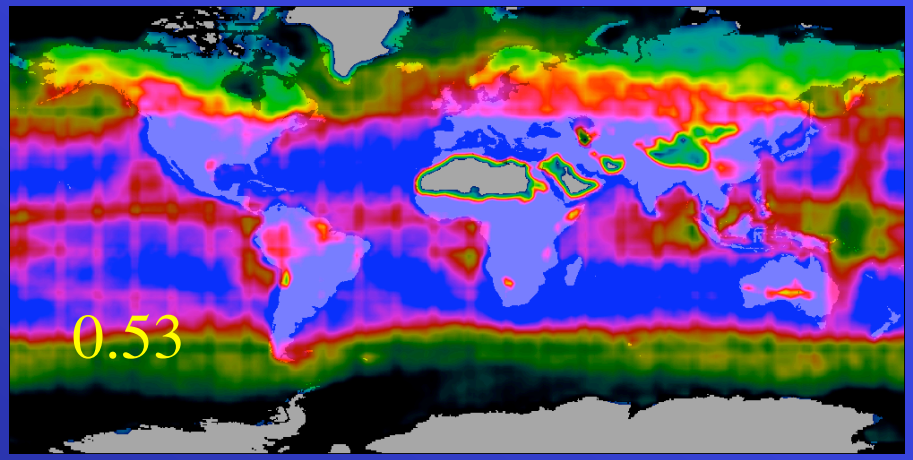


AOD 2003 - 2004
550 nm

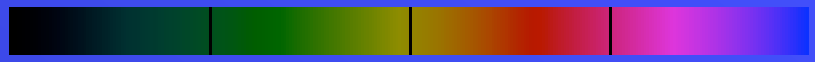
MISR
555 nm



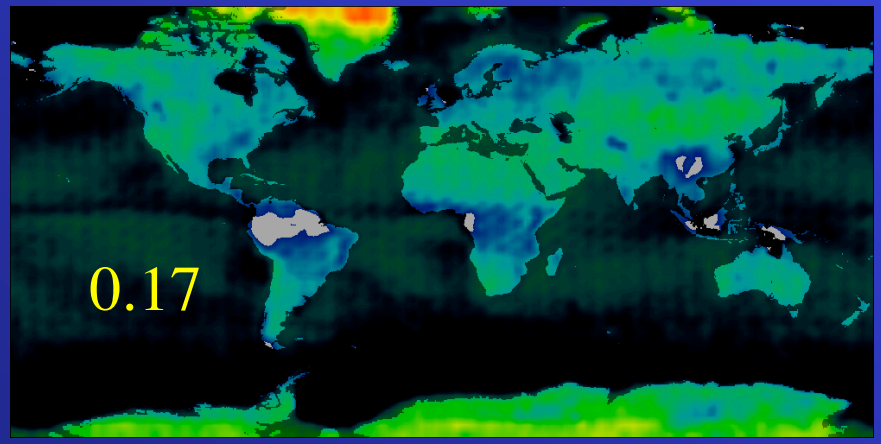
MODIS



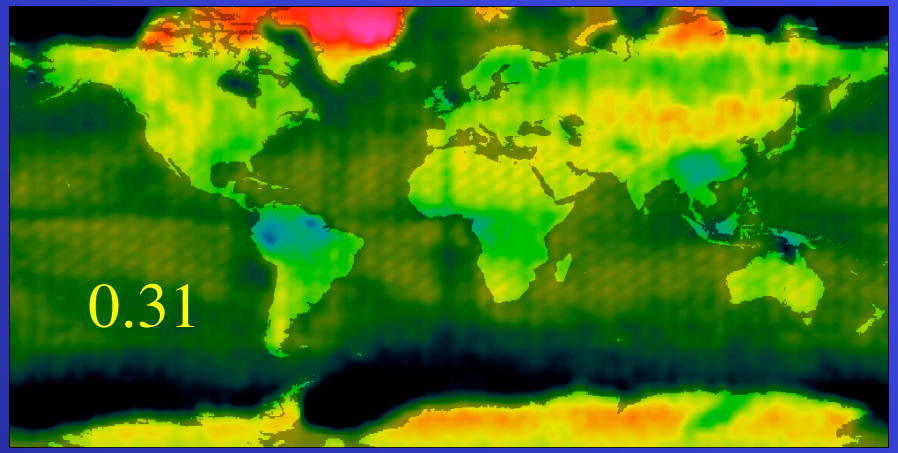
Daily Sampling Frequency

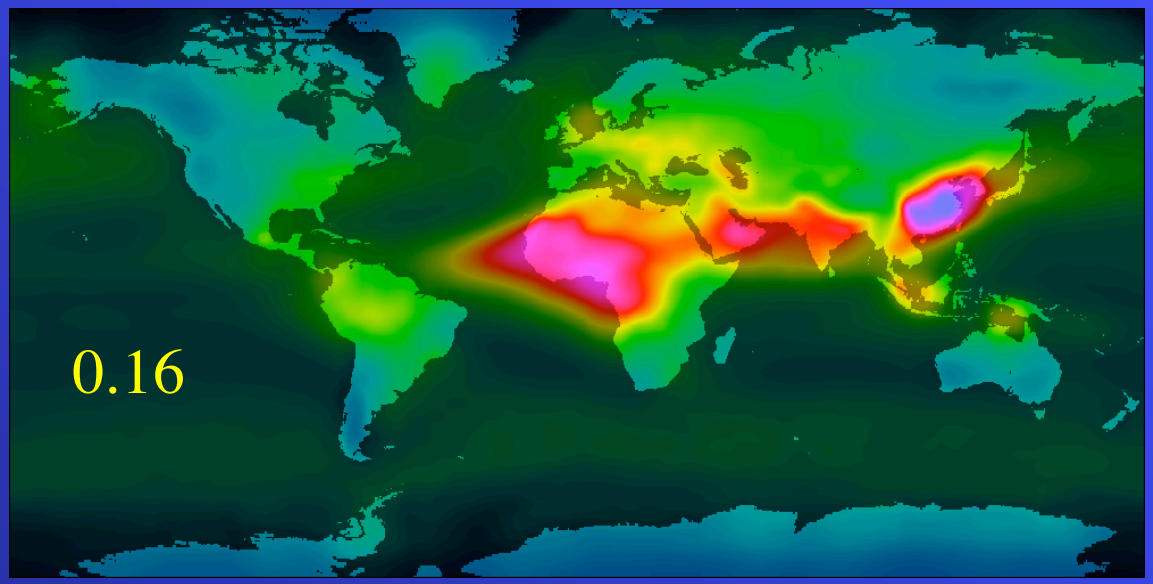


MISR



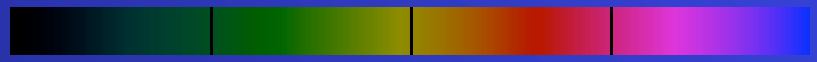
Effective MISR with increased spatial correlation coefficient





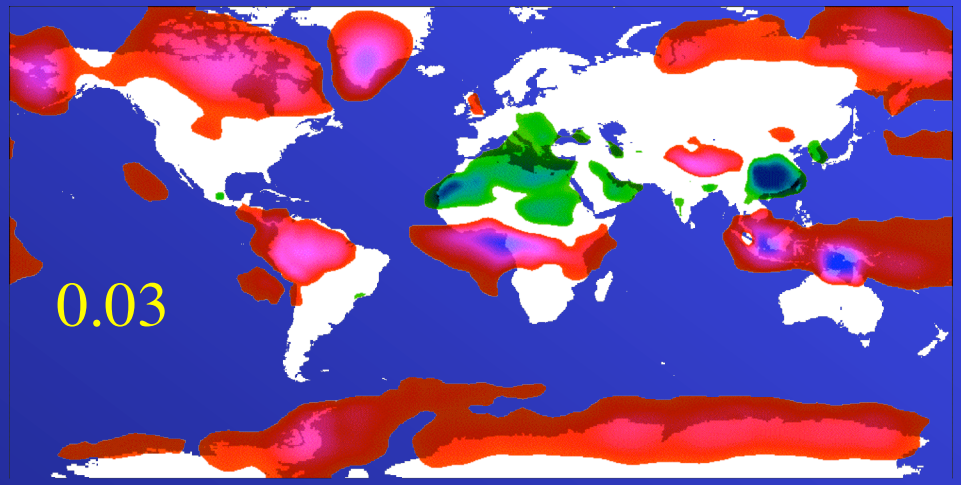
MATCH with MISR(only) Assimilation

AOD 2003-2004 550 nm



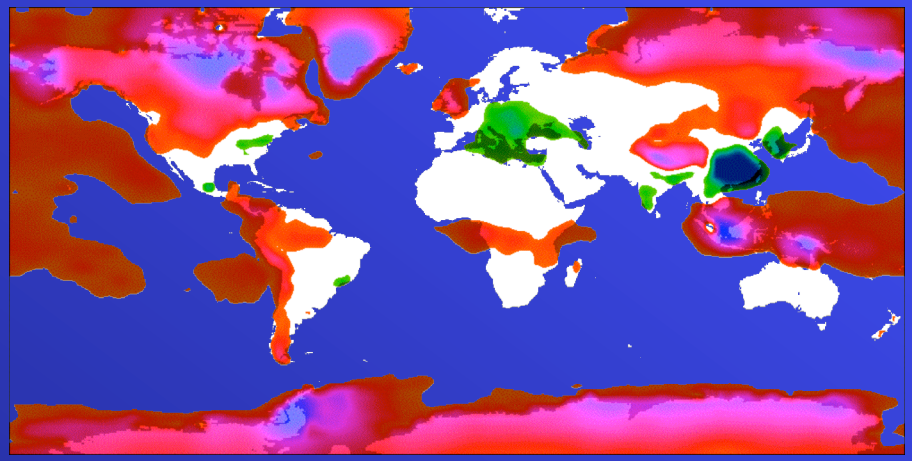
0.0 0.3 0.6

Assimilation Correction

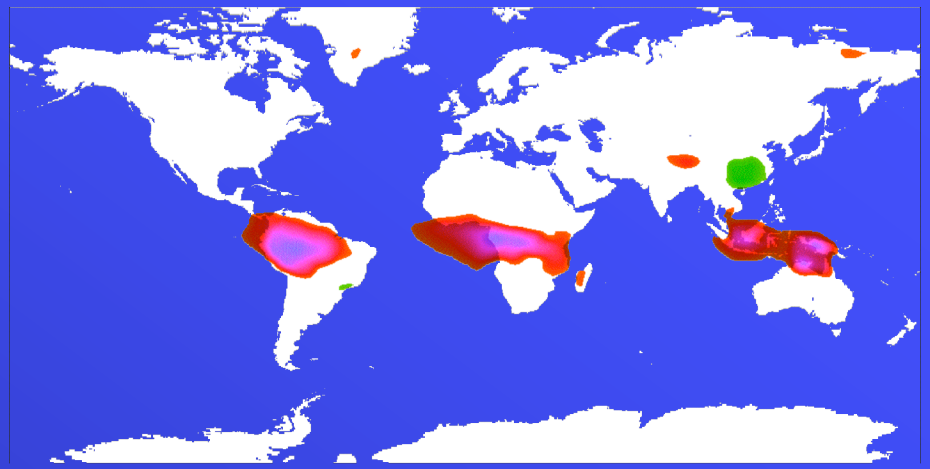


-0.2 0 0.2

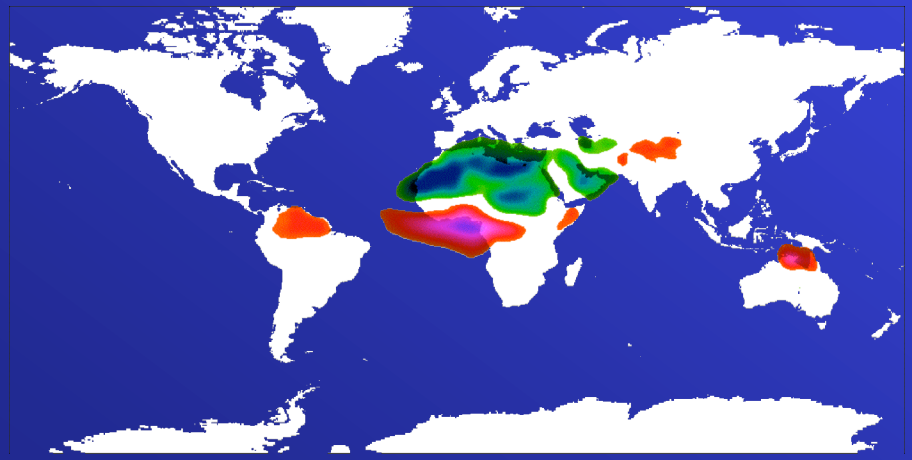
Sulfate



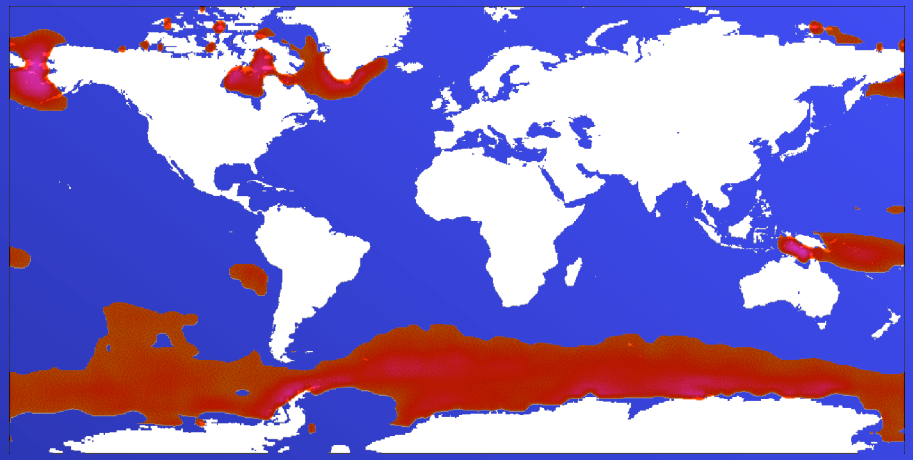
Carbon Aerosol



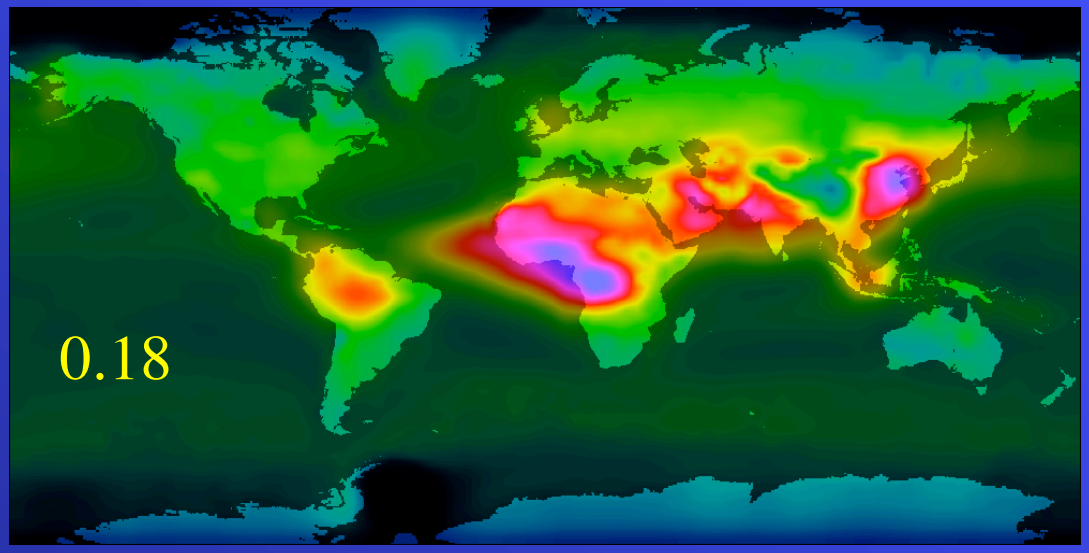
Dust



Sea-Salt

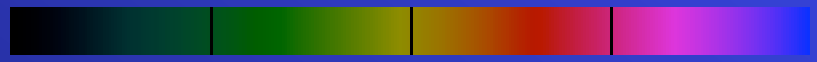


-0.1 0 0.1



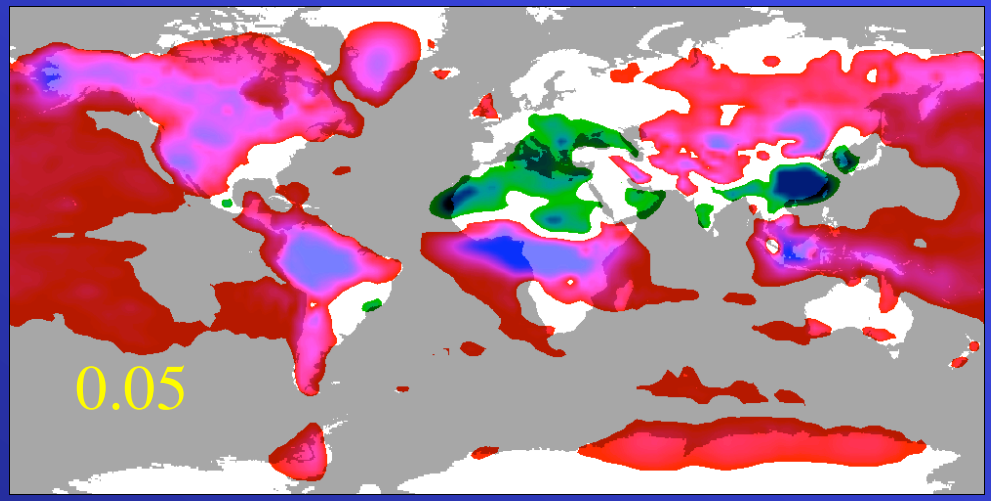
MATCH with
MODIS/MISR
Assimilation

AOD 2003-2004
550 nm



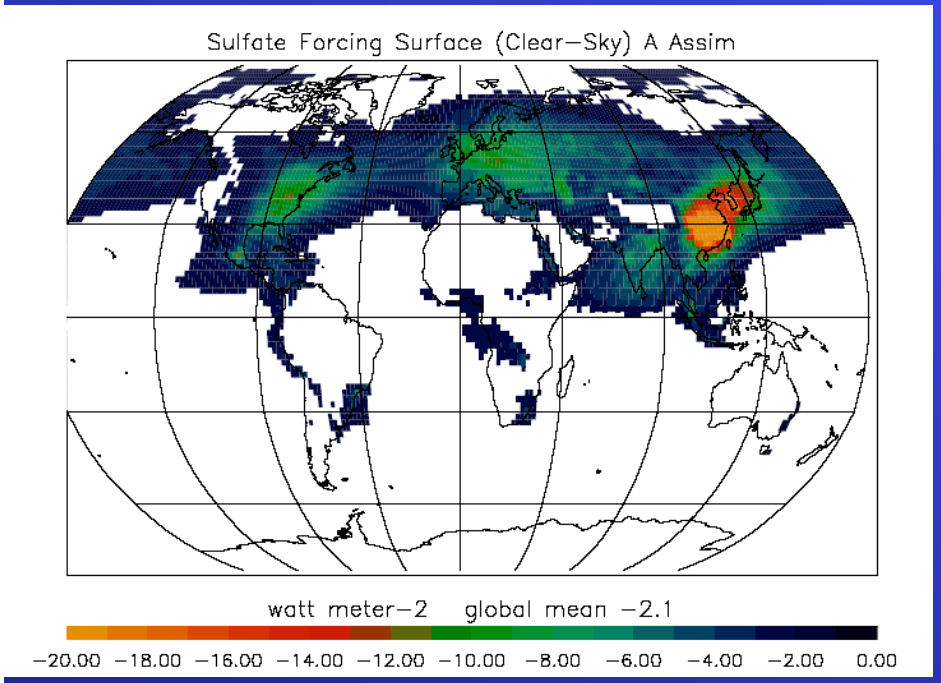
0.0 0.3 0.6

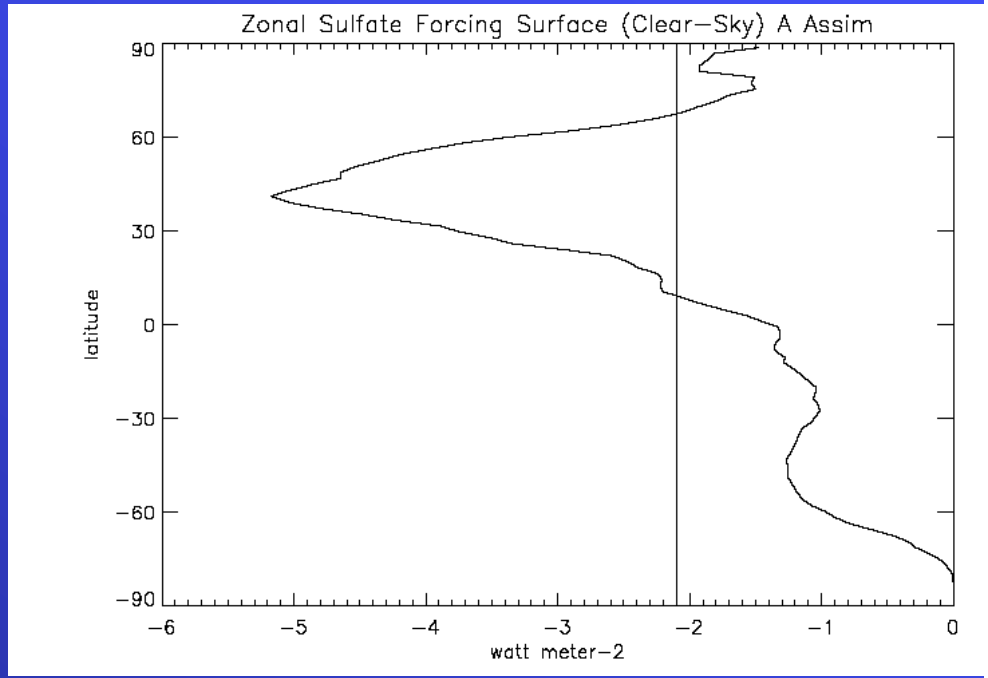
Assimilation
Correction



-0.2 0 0.2

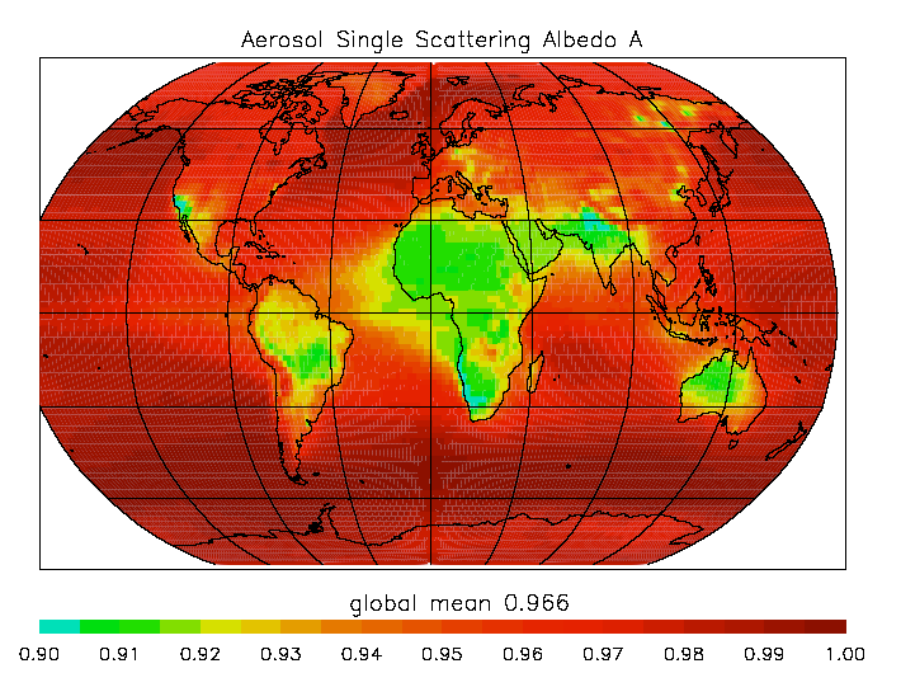
Sulfate Forcing at Surface, Clear-Sky (3/2000 – 2/2003)

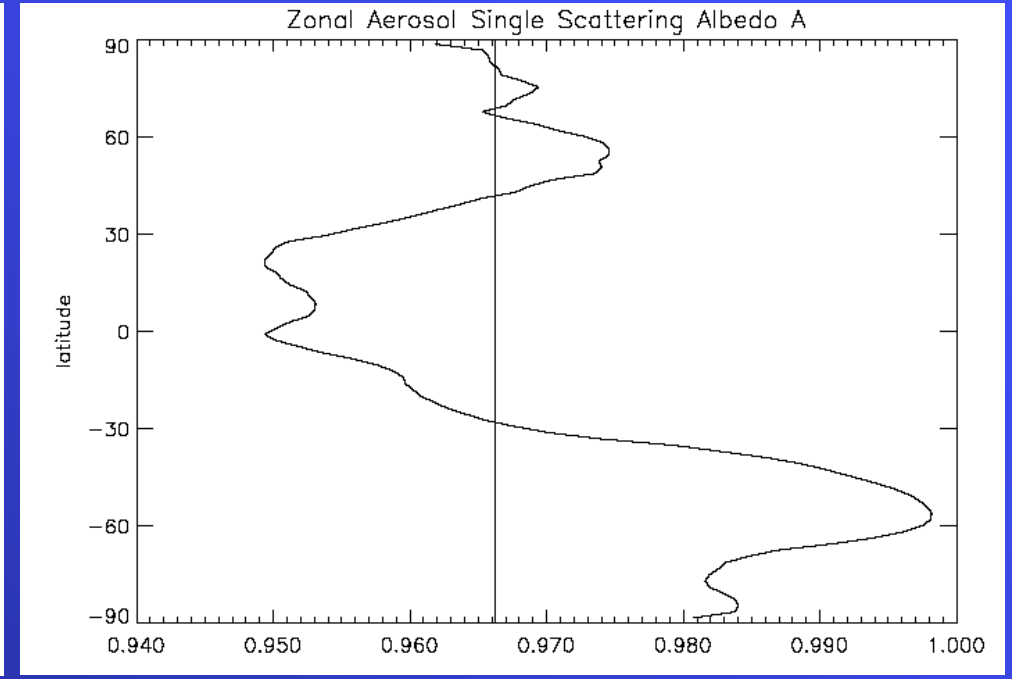




Fillmore, 2005; Fillmore et al, 2005

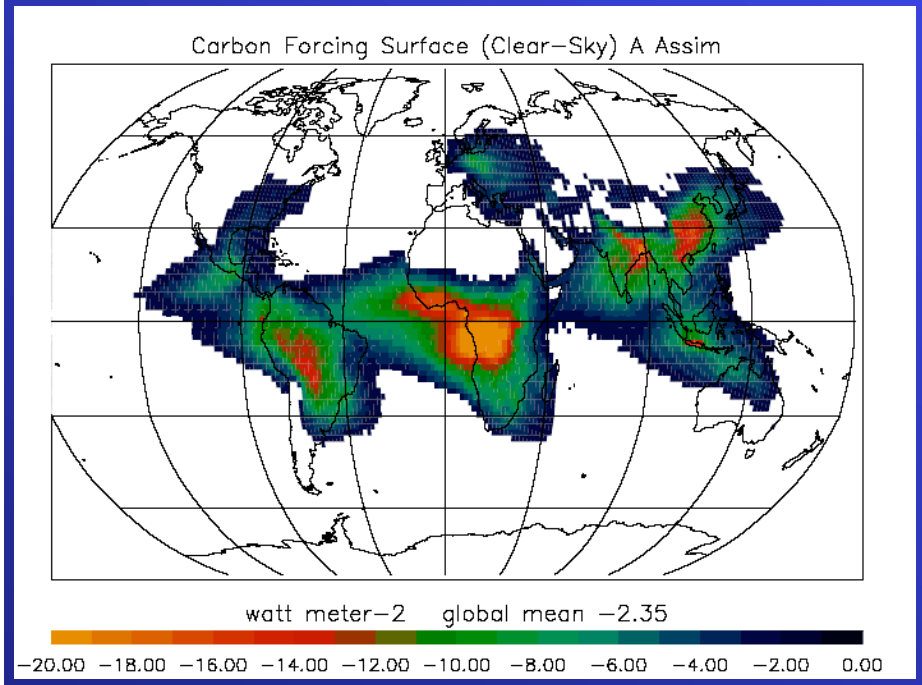
Carbon Aerosol Single Scatter Albedo 3/2000 – 2/2003

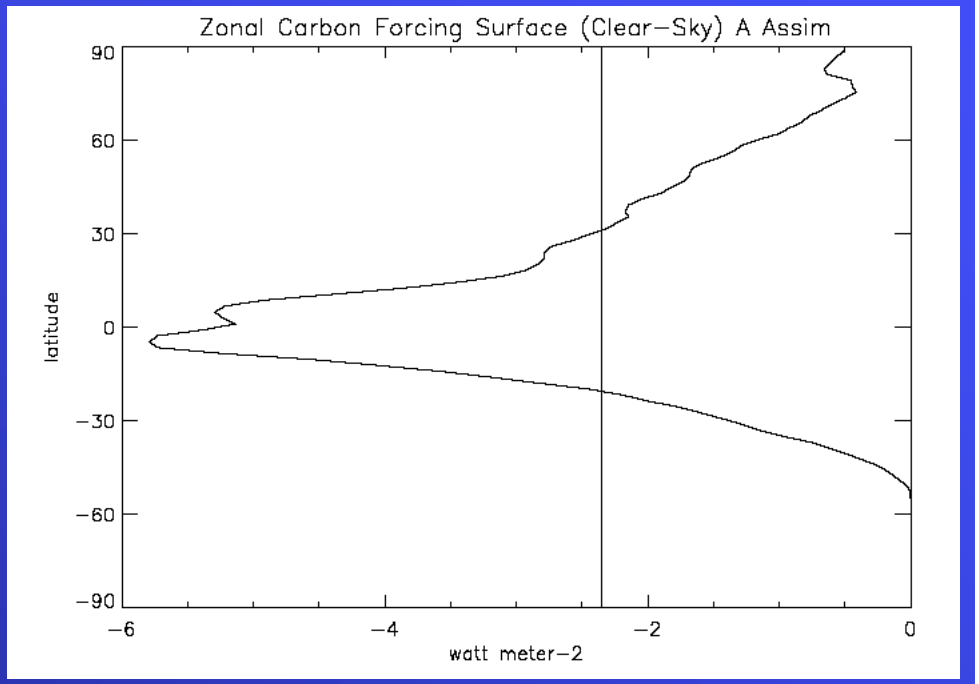




Fillmore, 2005; Fillmore et al, 2005

Carbon Aerosol Forcing at Surface, Clear-Sky (3/2000 – 2/2003)





Fillmore, 2005; Fillmore et al, 2005

Next Steps

- Provision of Aqua/Terra assimilation for 2000-2005 to CERES SARB
- Error analysis of AOD, etc from AERONET (Kinne et al, 2005)
- Sensitivity of results to uncertainties in sulfate and black/organic carbon emissions
- Error analysis of aerosol TOA forcing (all-no aerosols) using CERES estimates?