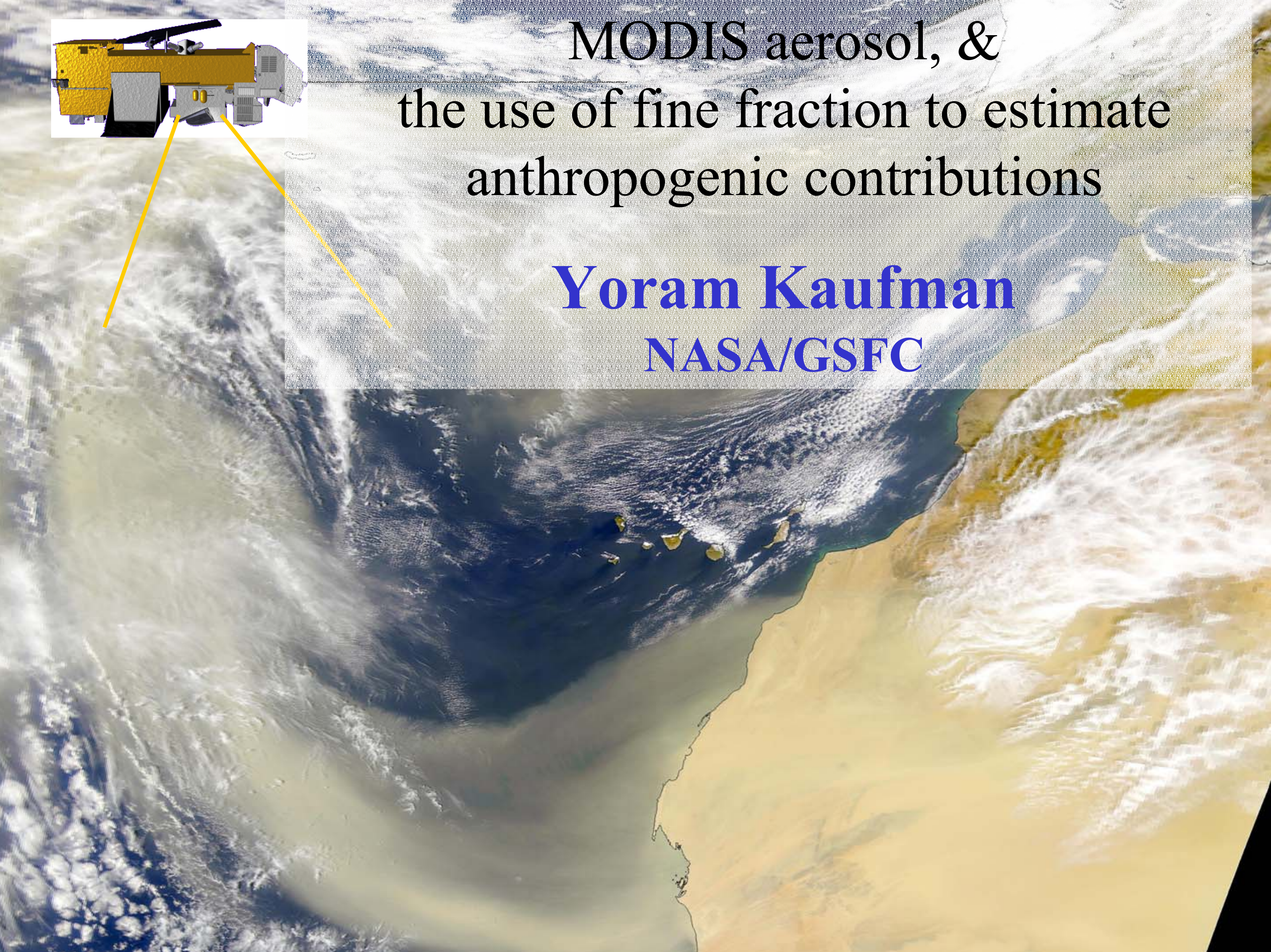


MODIS aerosol, & the use of fine fraction to estimate anthropogenic contributions

Yoram Kaufman
NASA/GSFC

MODIS:

- Spectral AOT, aerosol properties => solar reflected flux
- Fine fraction => classification of aerosol to anthropogenic, natural
- Cloud fraction and properties

- Aerosol radiative effect, forcing measured in cloud free conditions

MODELS:

- Compare to the MODIS measurements
- Estimate the effect of clouds on TOA flux/forcing
- Using AERONET SSA climatology estimate flux/forcing at the surface

2005

Feb-Apr Informal Review of Zero-Order Draft

May 2nd LA Meeting (China)

Note that literature to be cited will need to be published or available in draft form

Sep-Nov Expert Review of First-Order Draft

Nov 3rd LA Meeting (New Zealand)

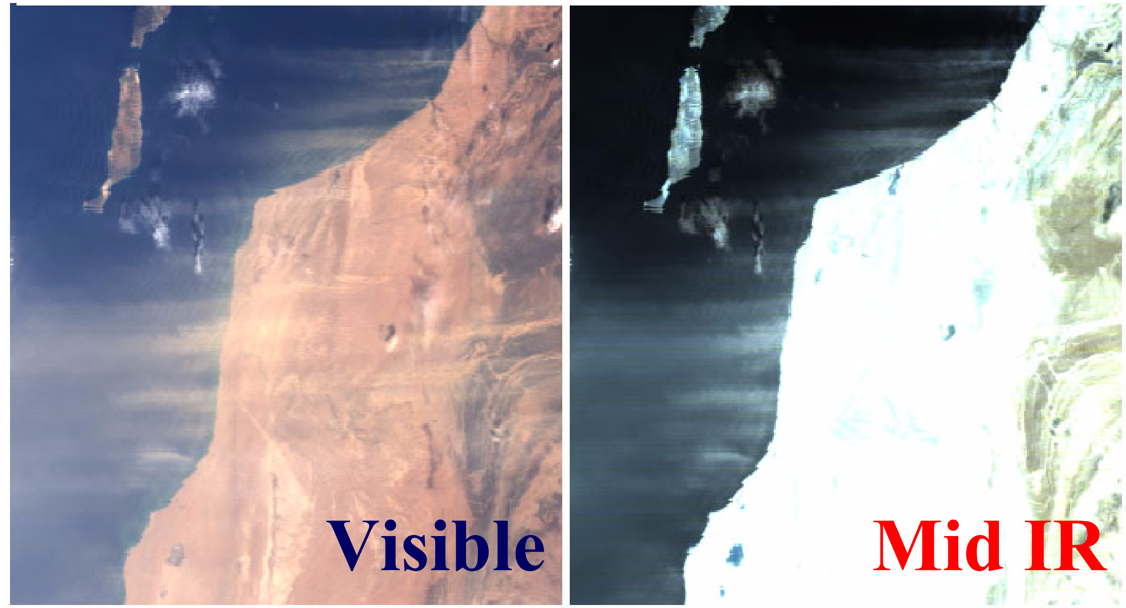
Note that literature to be cited will need to be published or in press

MODIS wide spectral range:

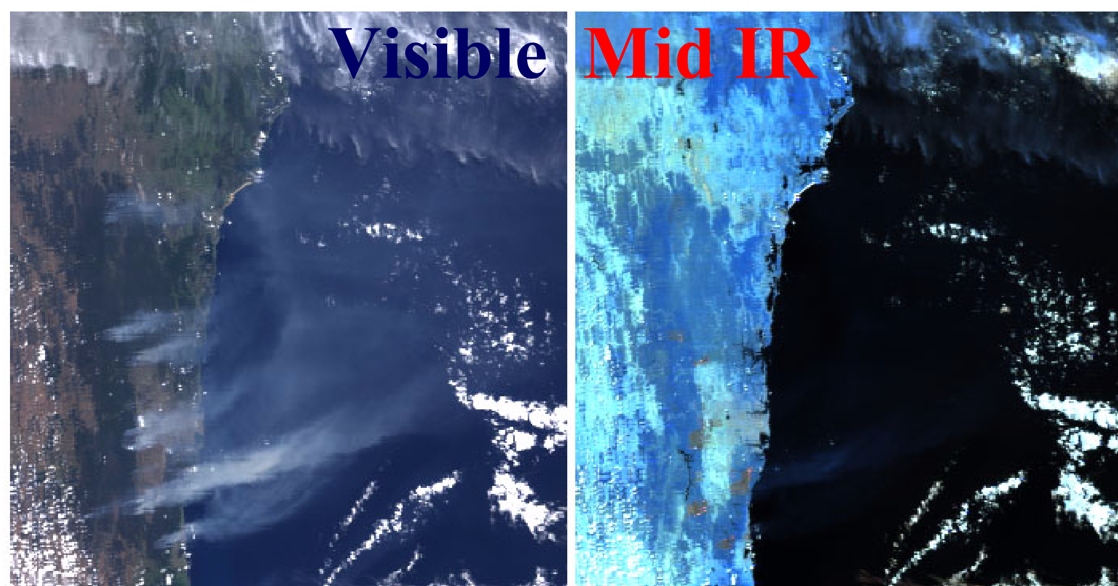
•Distinguish dust from smoke / pollution aerosol

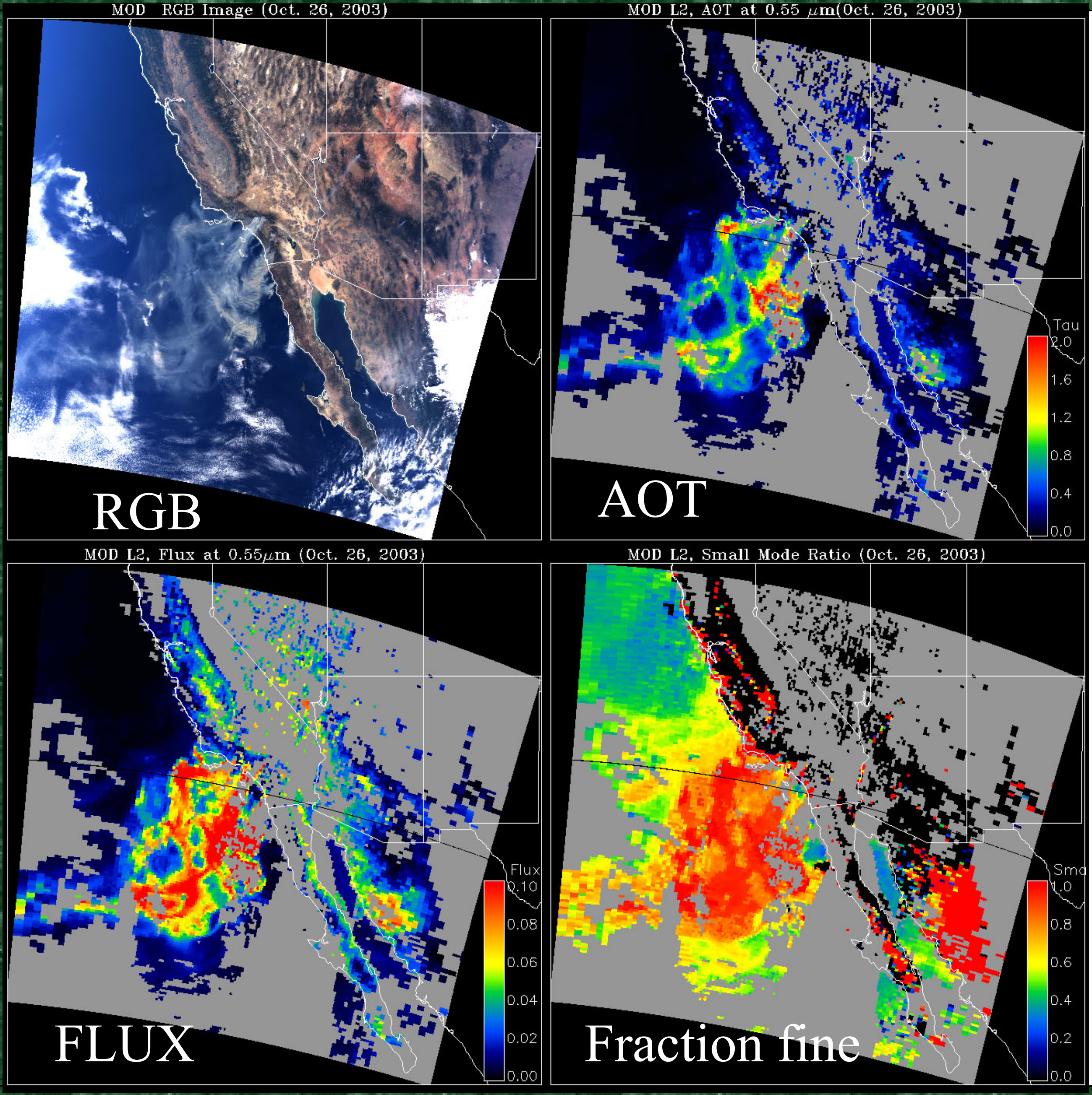
•Distinguish aerosol from land reflectance

MODIS: Saharan dust, Jan. 2002



Fires in Australia, Dec 2001



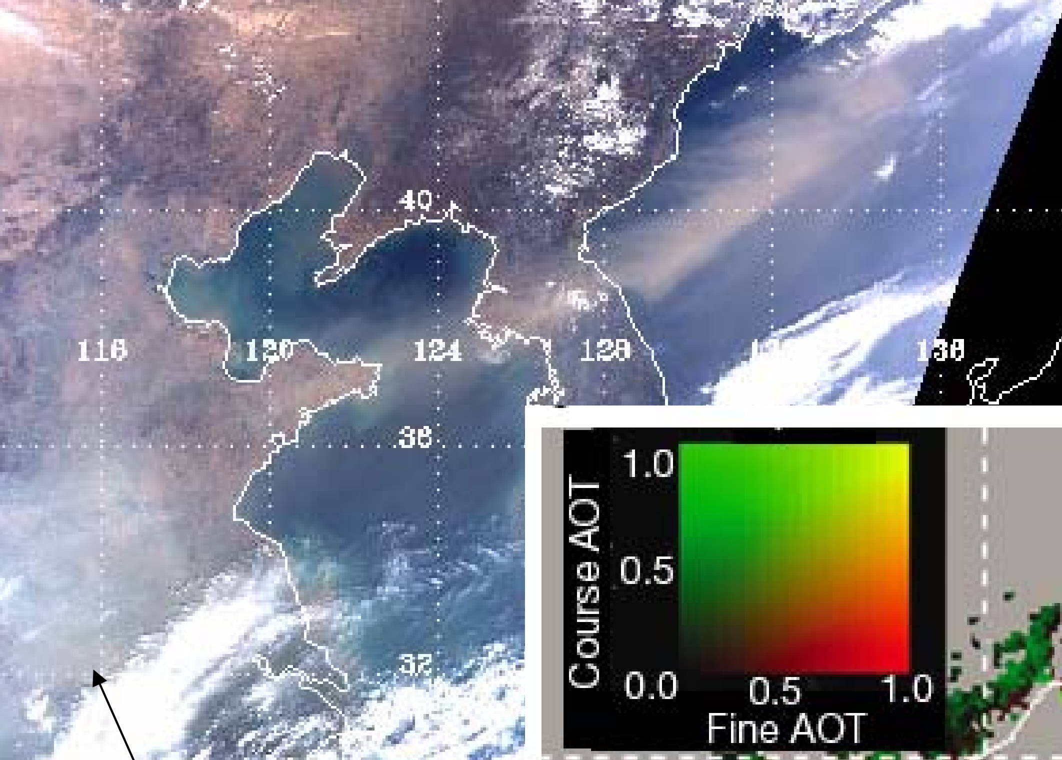


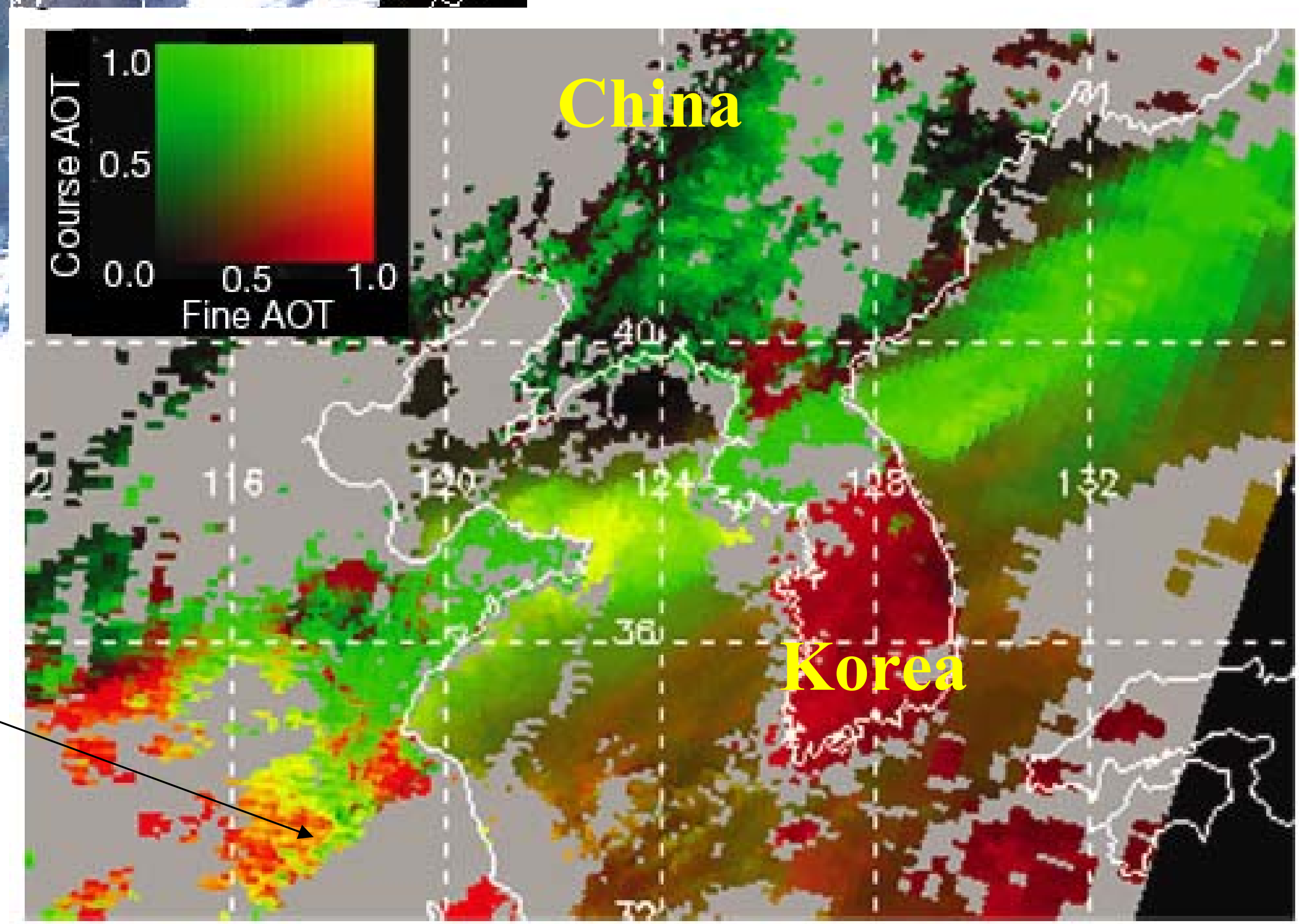
California Wildfires Oct. 26, 2003

From Terra-MODIS

Rong-Rong Li

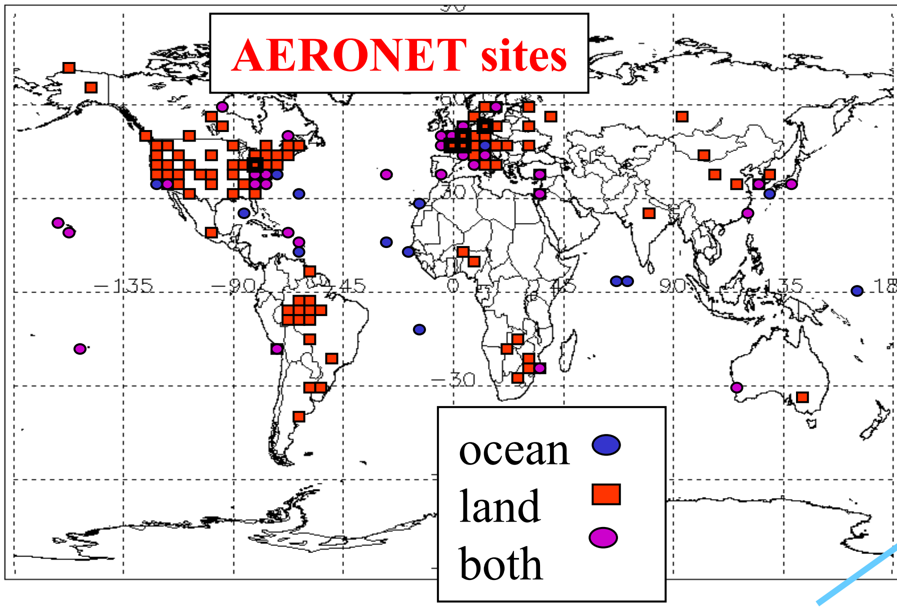
MODIS Aerosol optical thickness of coarse dust and fine pollution March 20, 2001

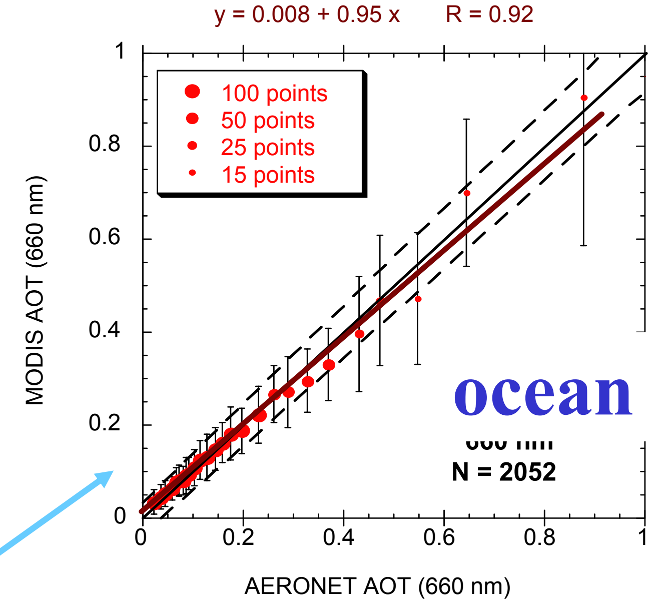




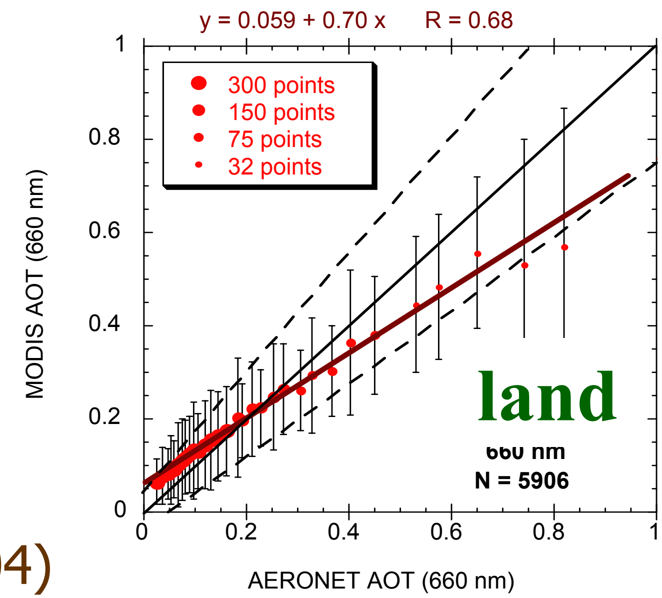
MODIS high spatial and spectral resolution distinguishes clouds from aerosol

MODIS aerosol validation 2000-2002





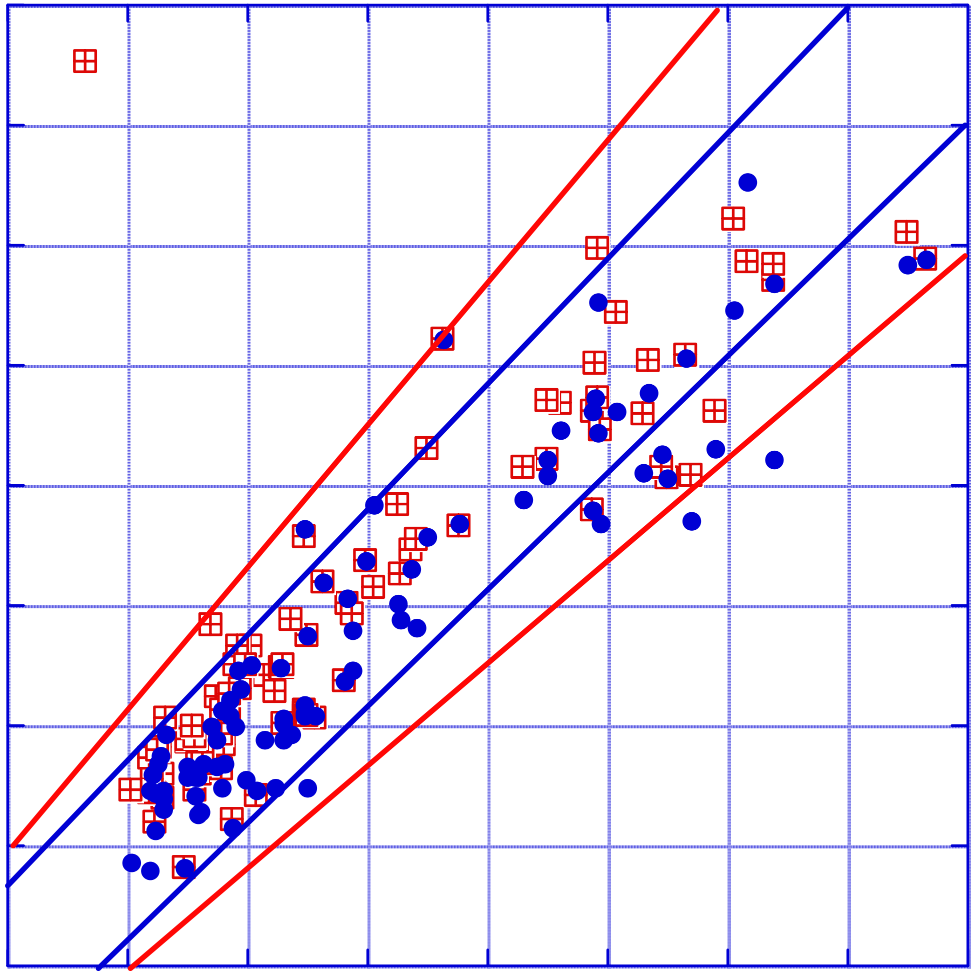
66% of MODIS aerosol retrievals
over ocean fall within expected uncertainty



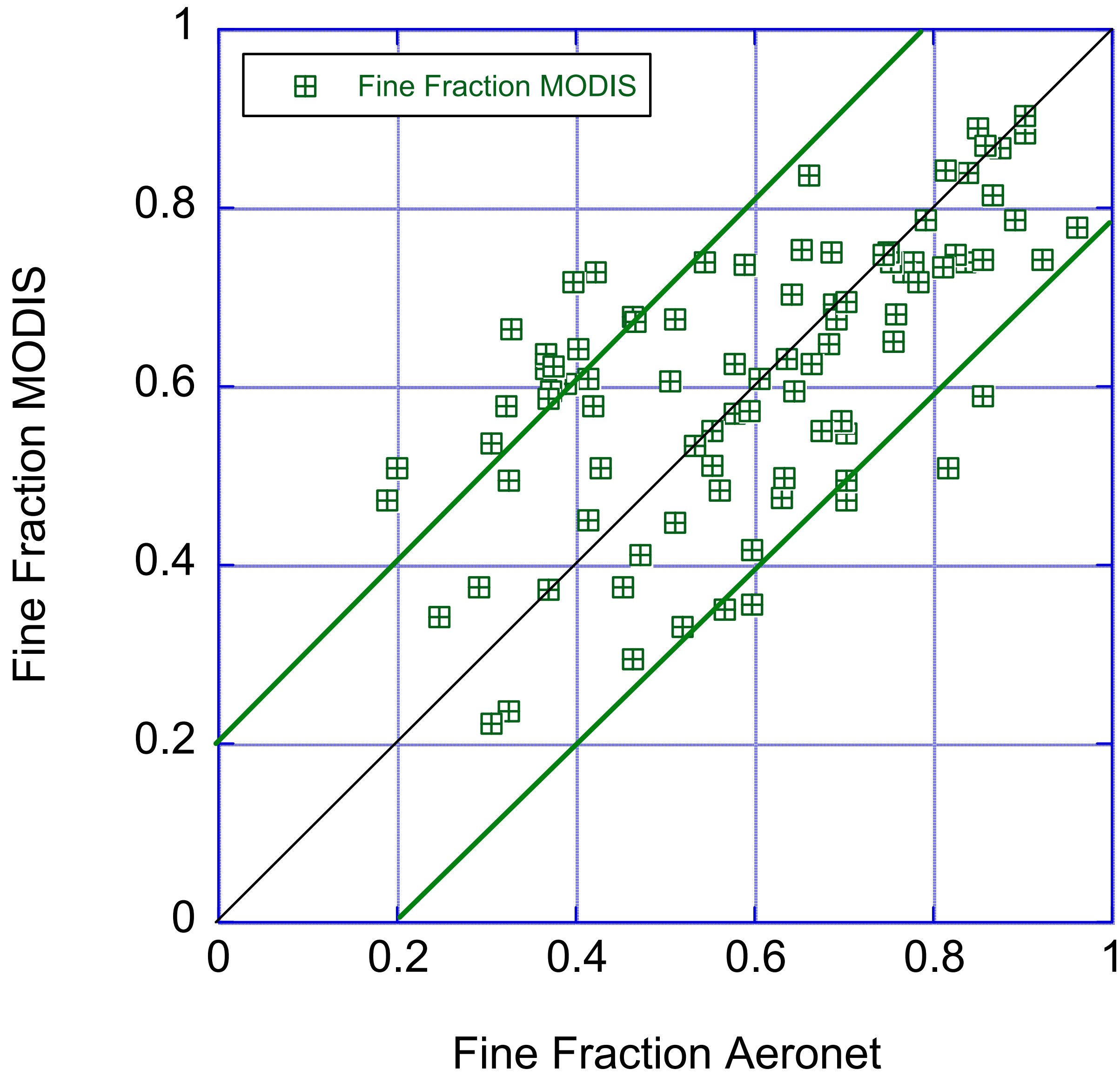
71% of MODIS aerosol retrievals
over land fall within expected uncertainty

Ichoku et al. 2002
Chu et al. 2002
Remer et al. 2002

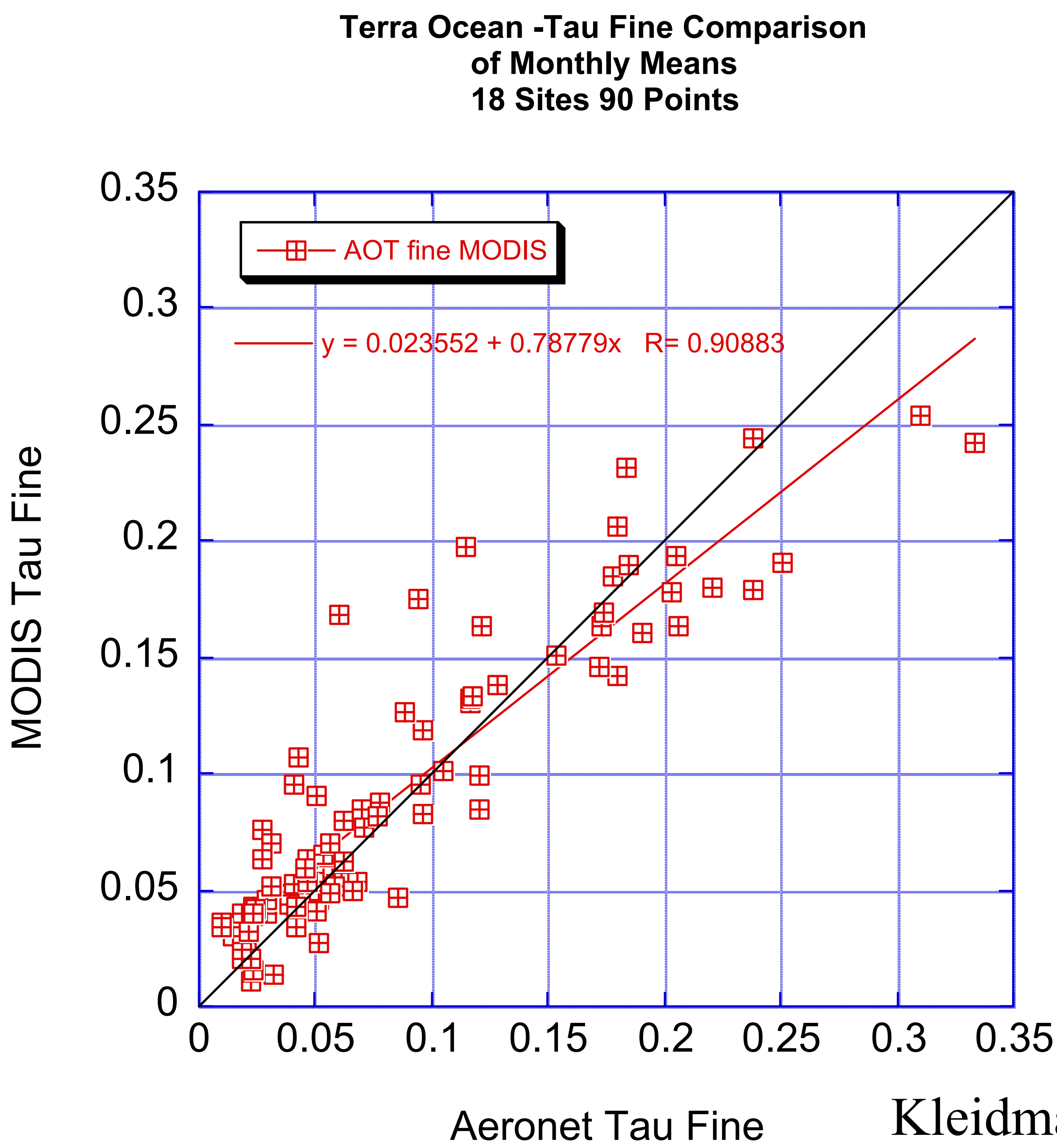
Remer et al. (2004)



Kleidman et al; 2004

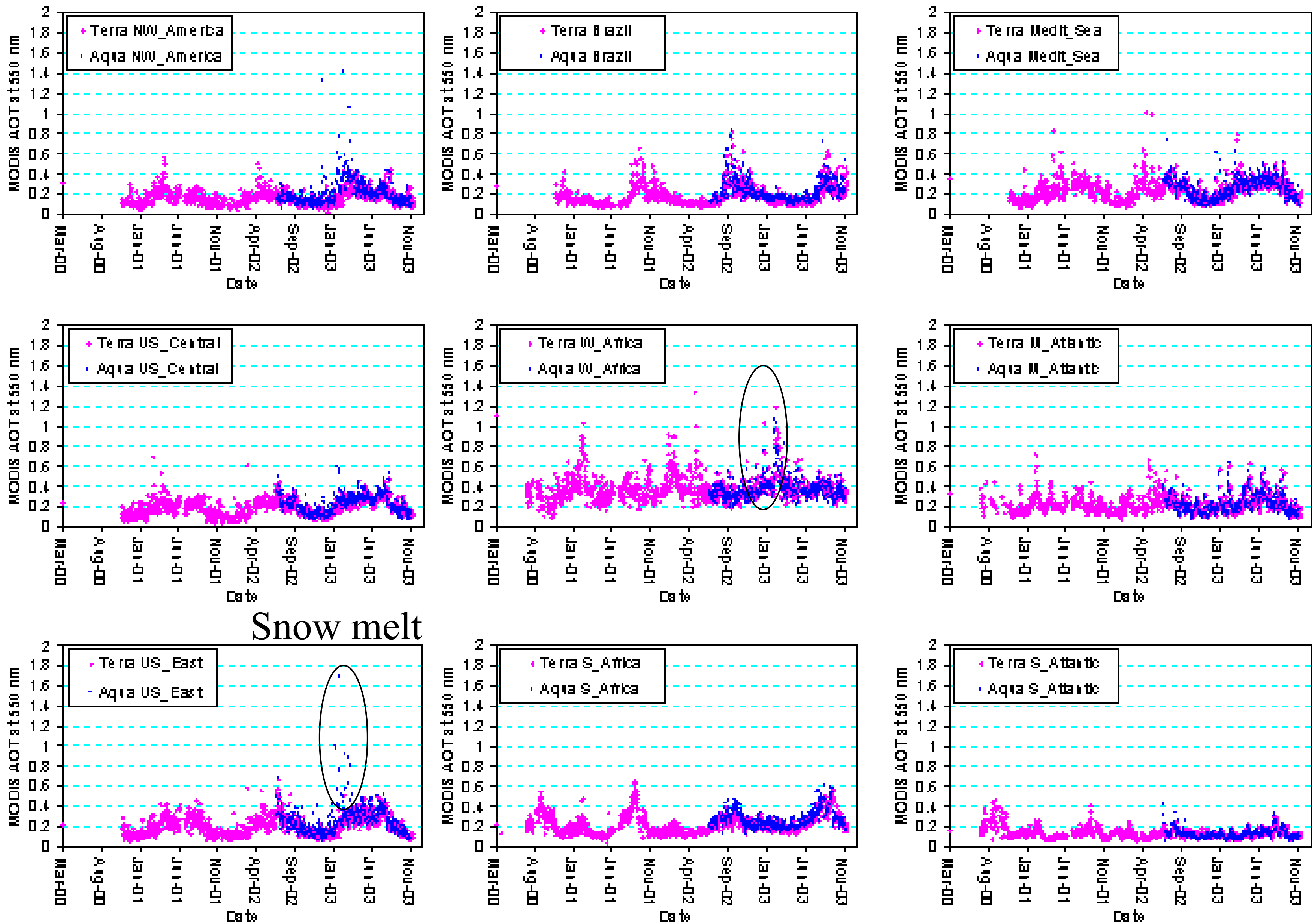


Kleidman et al; 2004



Kleidman et al; 2004

LAND LAND OCEAN



Ichoku et al 2004

Data: April 2000-till present Terra (10:30am, Aqua 1:30 pm)

- AOT spectral 0.47-2.1 μm (ocean)

- Fraction of AOT in the fine mode (at 0.55μm), selection of fine and coarse aerosol

- better over ocean than over land

- AOT increases in regions with clouds: global aerosol AOT over the ocean is 0.15, weighted by cloud free fraction it is 0.135

Monthly data 1°x1° at: http://lake.nascom.nasa.gov/movas/

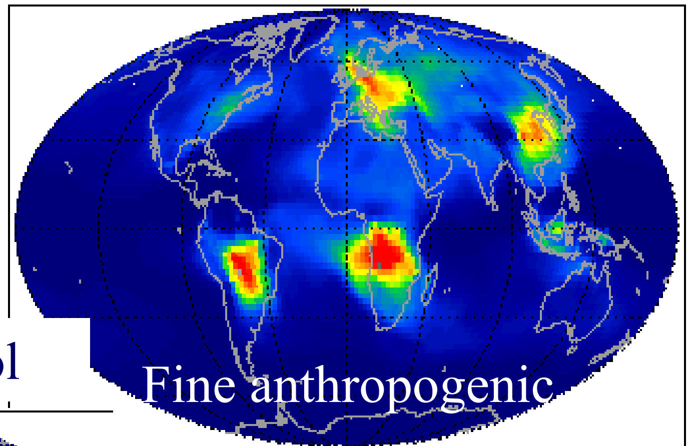
Problems, improvements:

- snow melt zone - high AOTs - mainly for Aqua
- next generation (V5) will have new cloud screening over the land
- cirrus with reflectance <0.01 at 1.37 μm may not be screened out

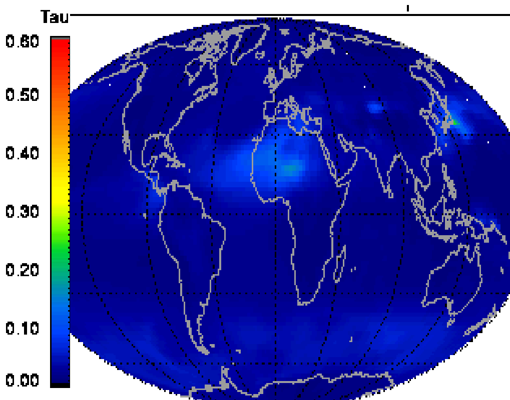
MODIS and model -> distinguish anthropogenic smoke and pollution aerosol from dust and sea salt

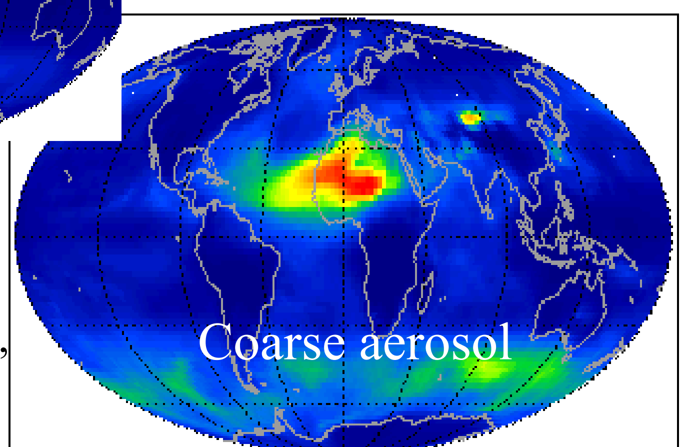
September 2000

GOCART Model

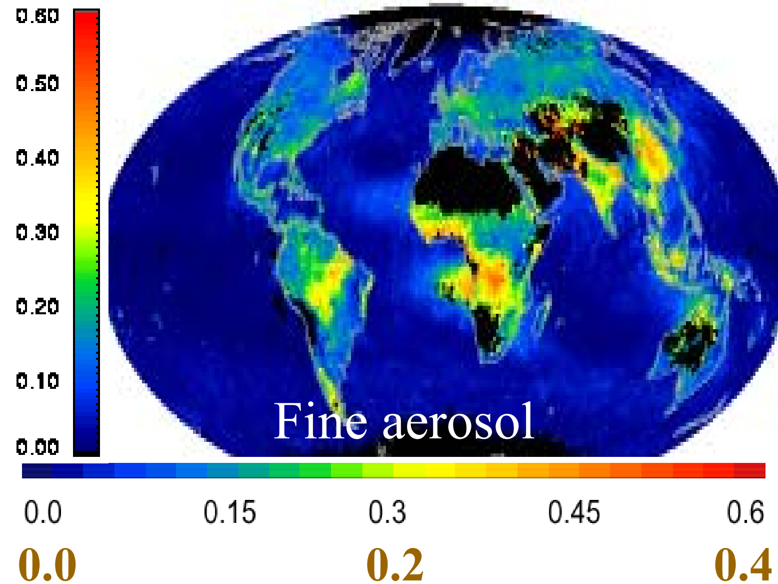


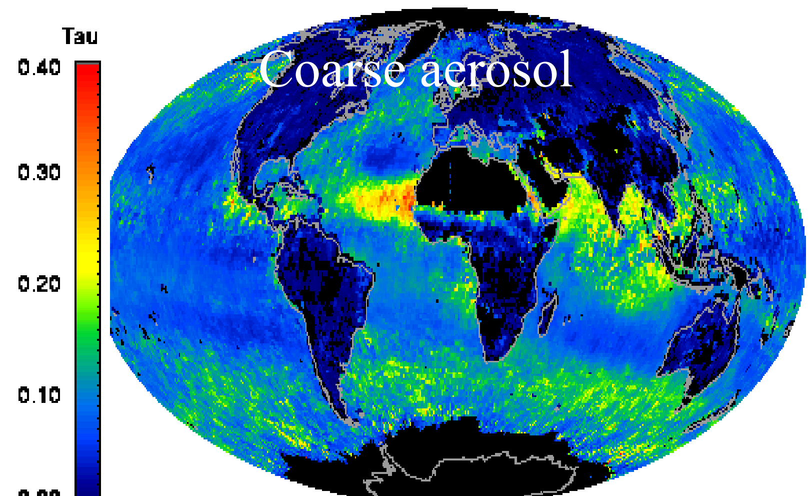
Natural fine aerosol





MODIS-Terra

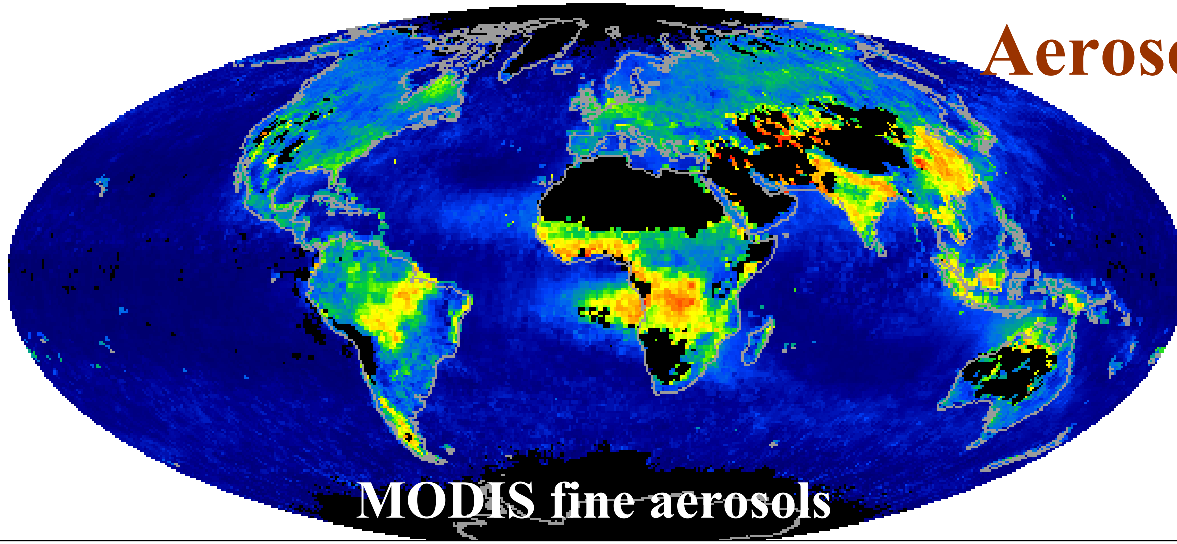




“A Satellite View of Aerosol in the Climate System” Kaufman et al., *Nature, Sept. 12, 2002*

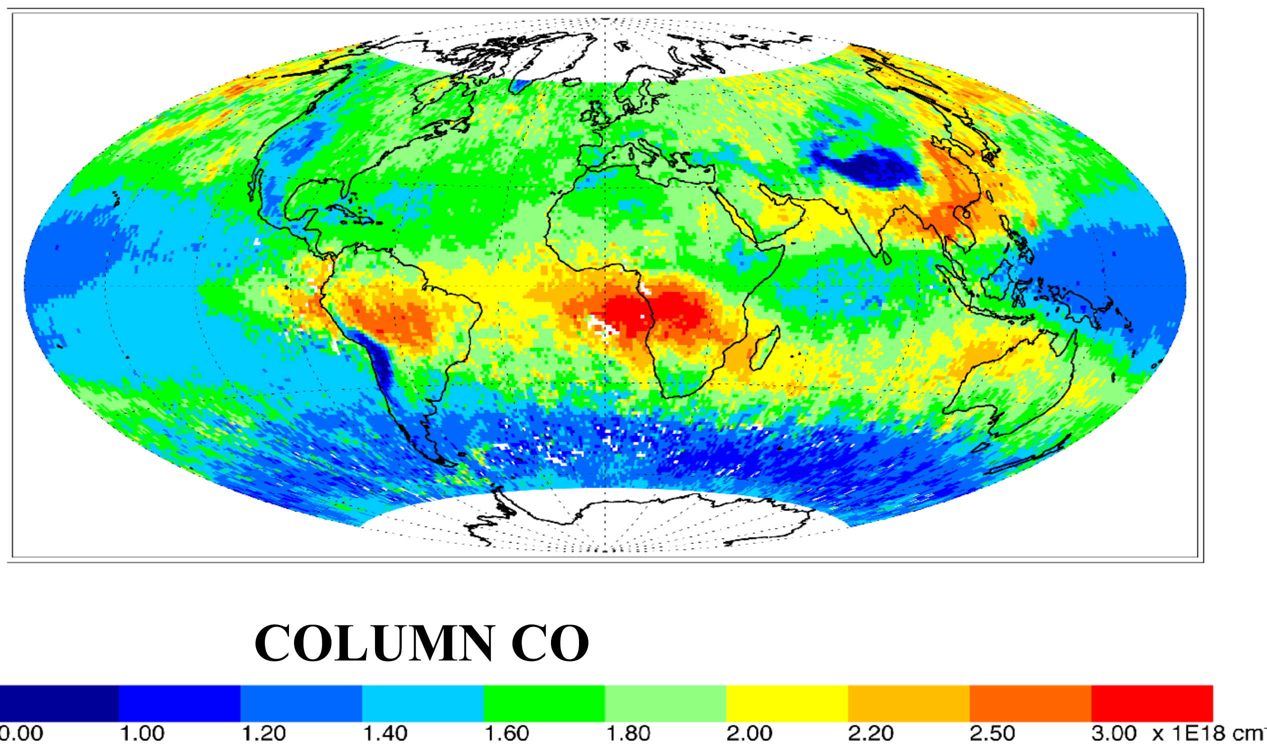
Aerosol <-> fires <-> CO

Sept. 2000



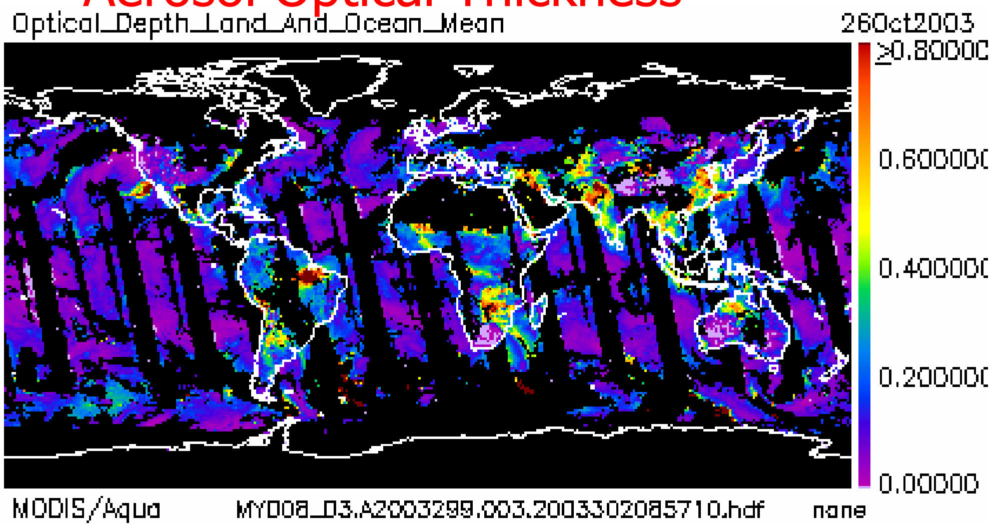
- Both CO and fine mode aerosol are produced by urban pollution, industrial combustion, and biomass burning

MOPITT (day+night) Column: 20000901-20000930

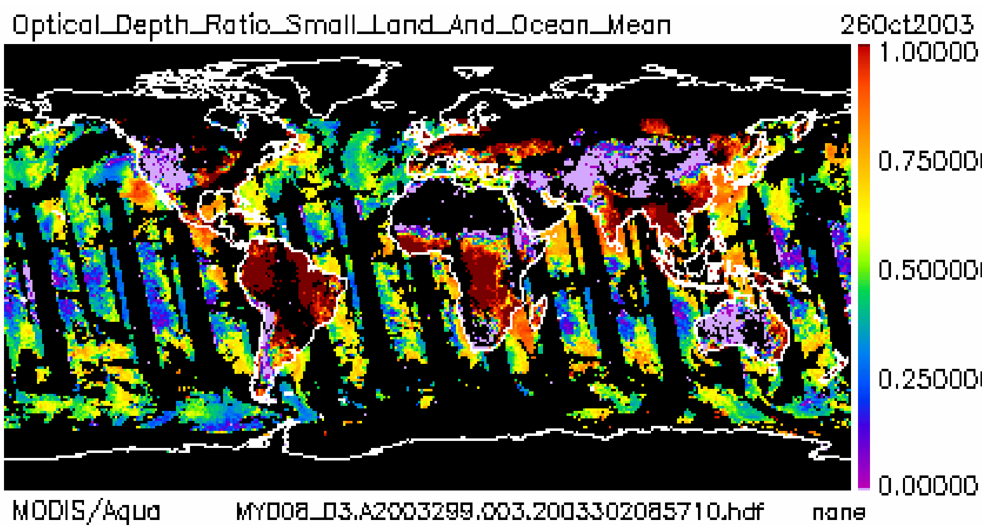


David Edwards, NCAR

Aerosol Optical Thickness



Fine mode fraction



The global aerosol

MOD08_D3

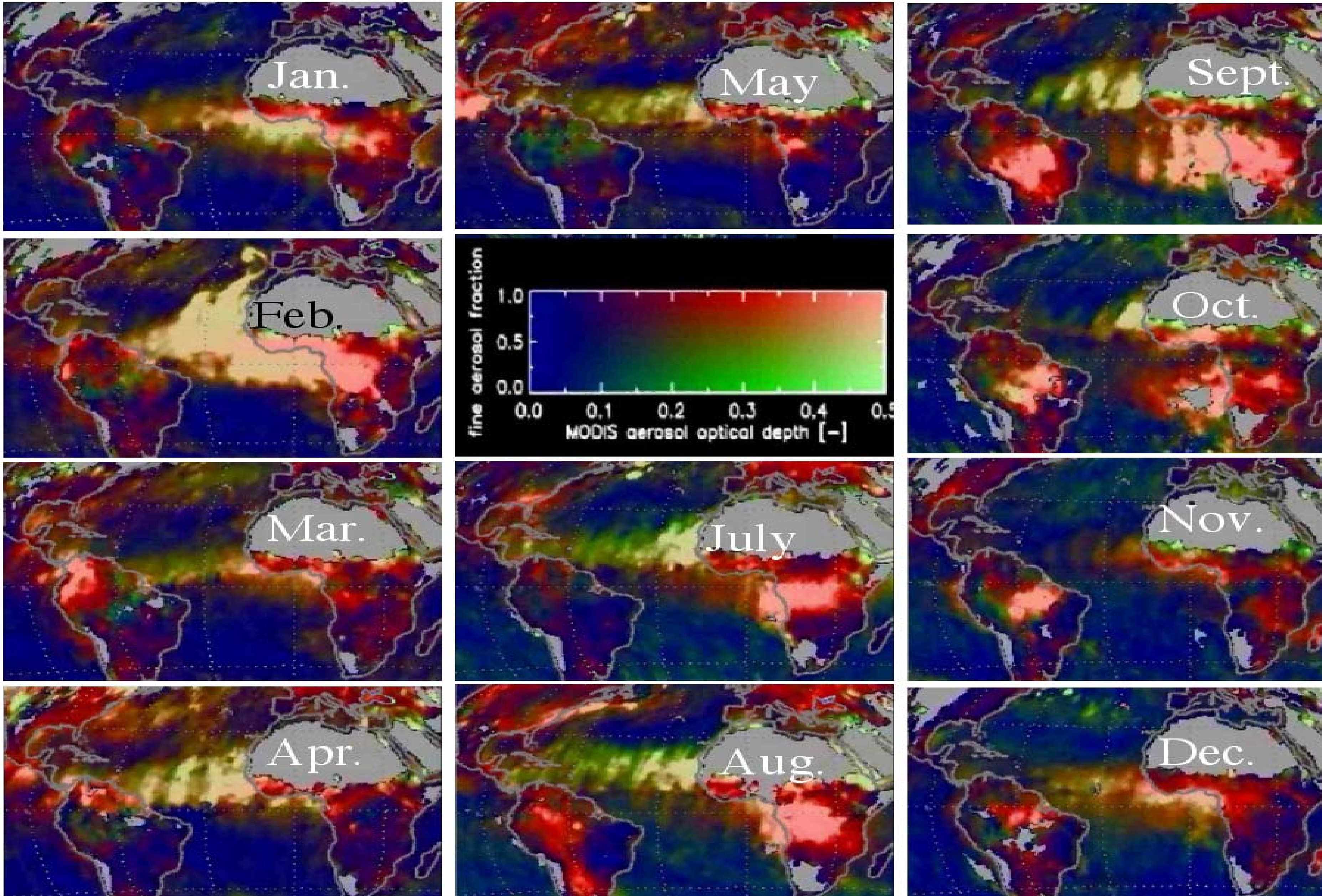
Daily Level 3
1 degree data

October 26, 2003

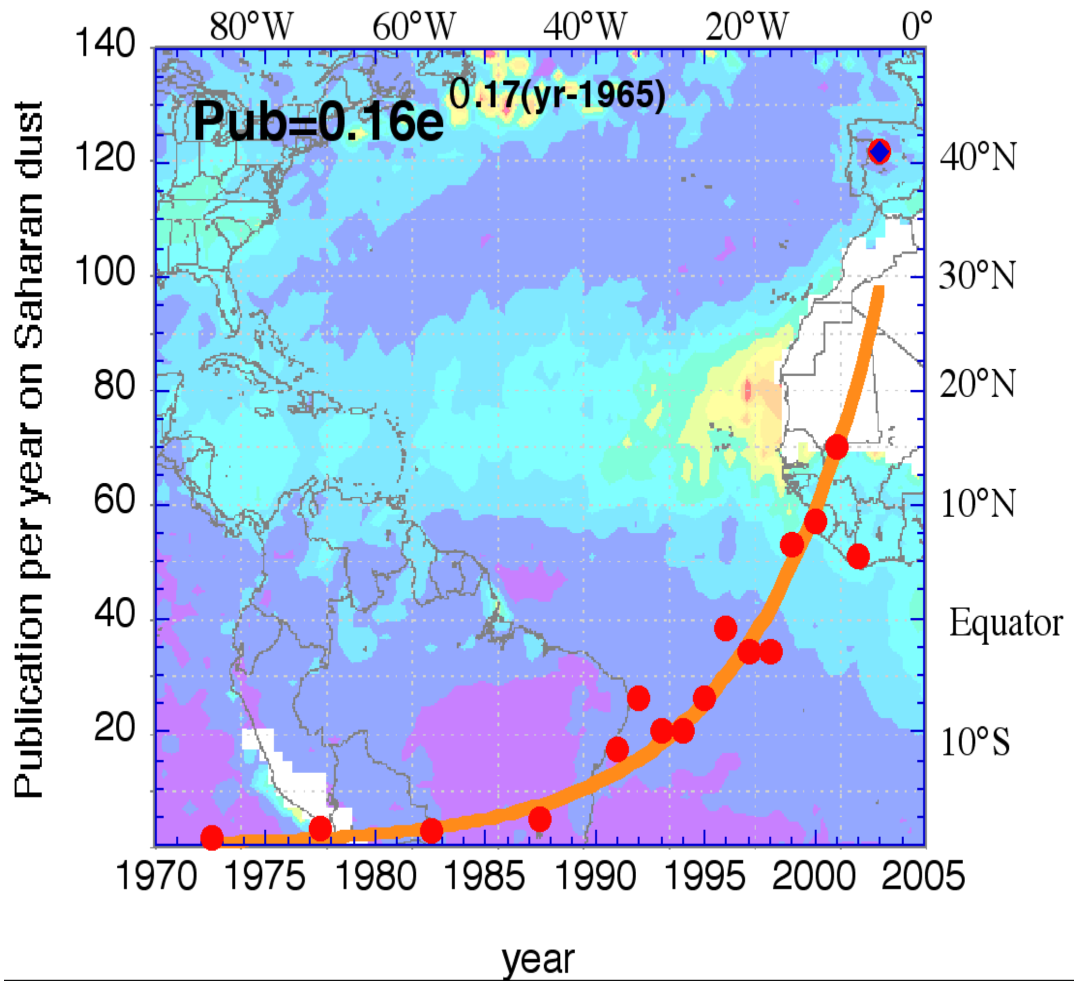
http//:modis-atmos.gsfc.nasa.gov

Paul Hubanks

Monthly evolution of dust (green) and smoke (red) from Africa



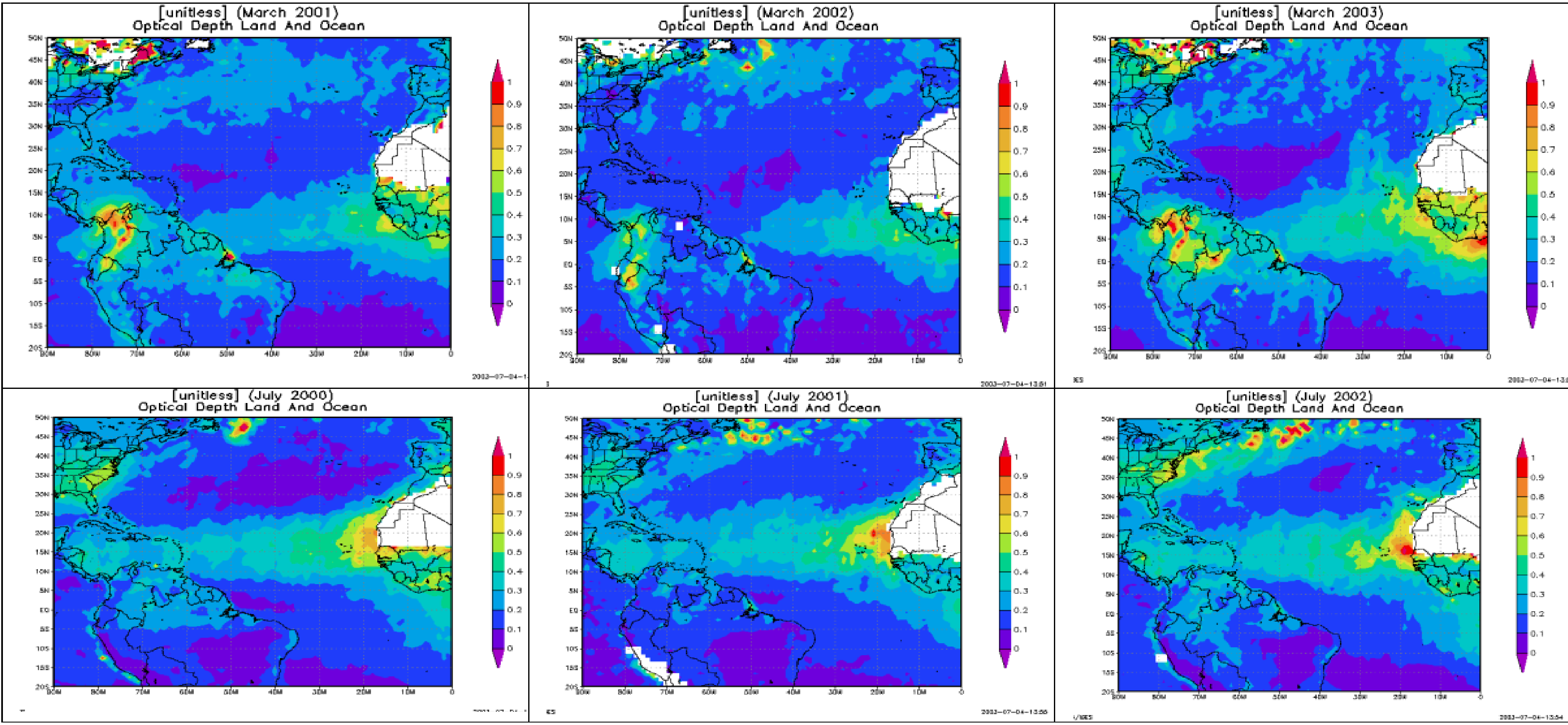
Dust transport and deposition observed from Terra-MODIS



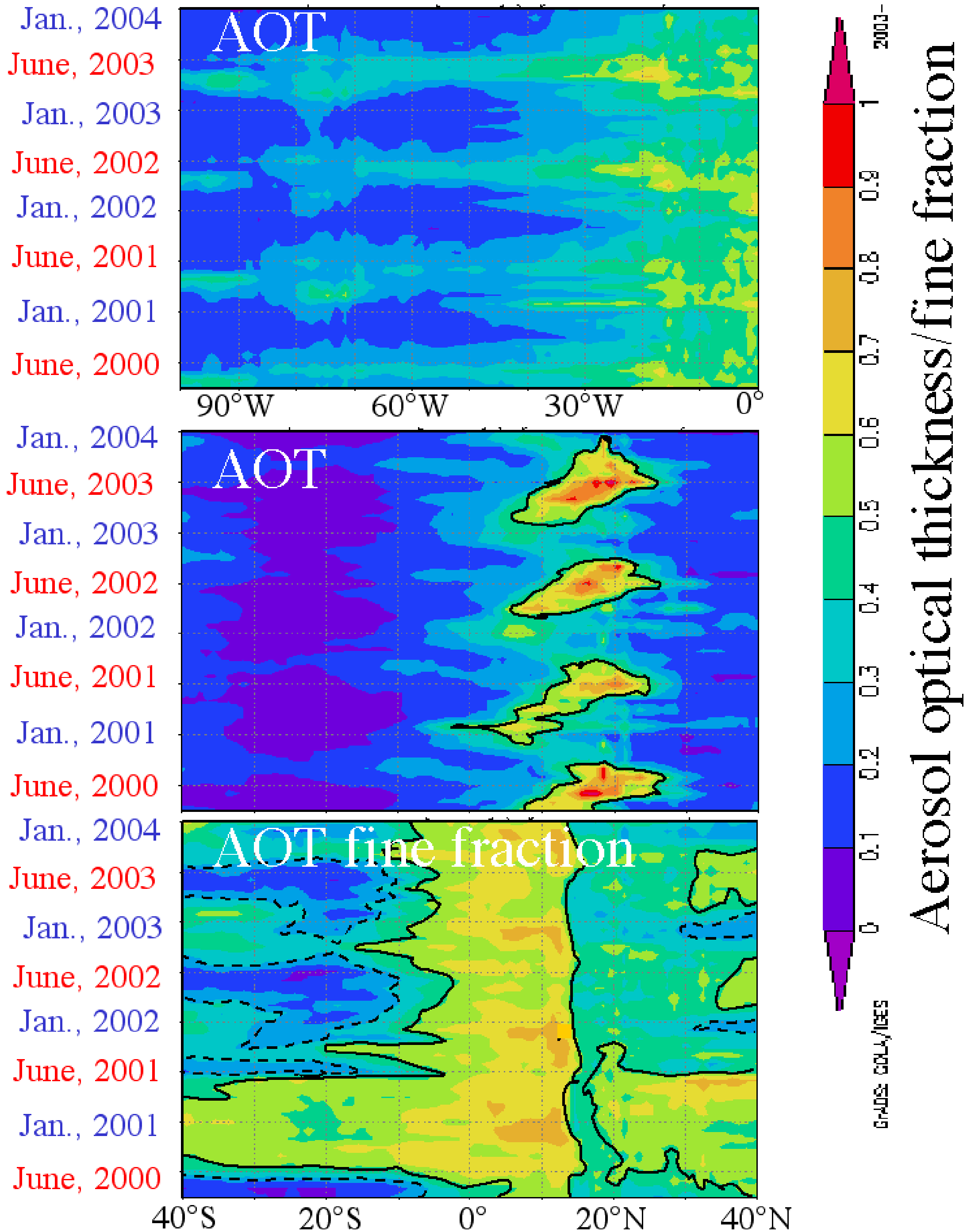
Back to African dust: Publication rate on Saharan dust - ISI citation index.

Background -MODIS aerosol optical thickness for July 2001.

Dust transport for March (top) and July (bottom) for three years



http://lake.nascom.nasa.gov/movas/



http://lake.nascom.nasa.gov/movas/

Dust depletion and deposition with its transport west

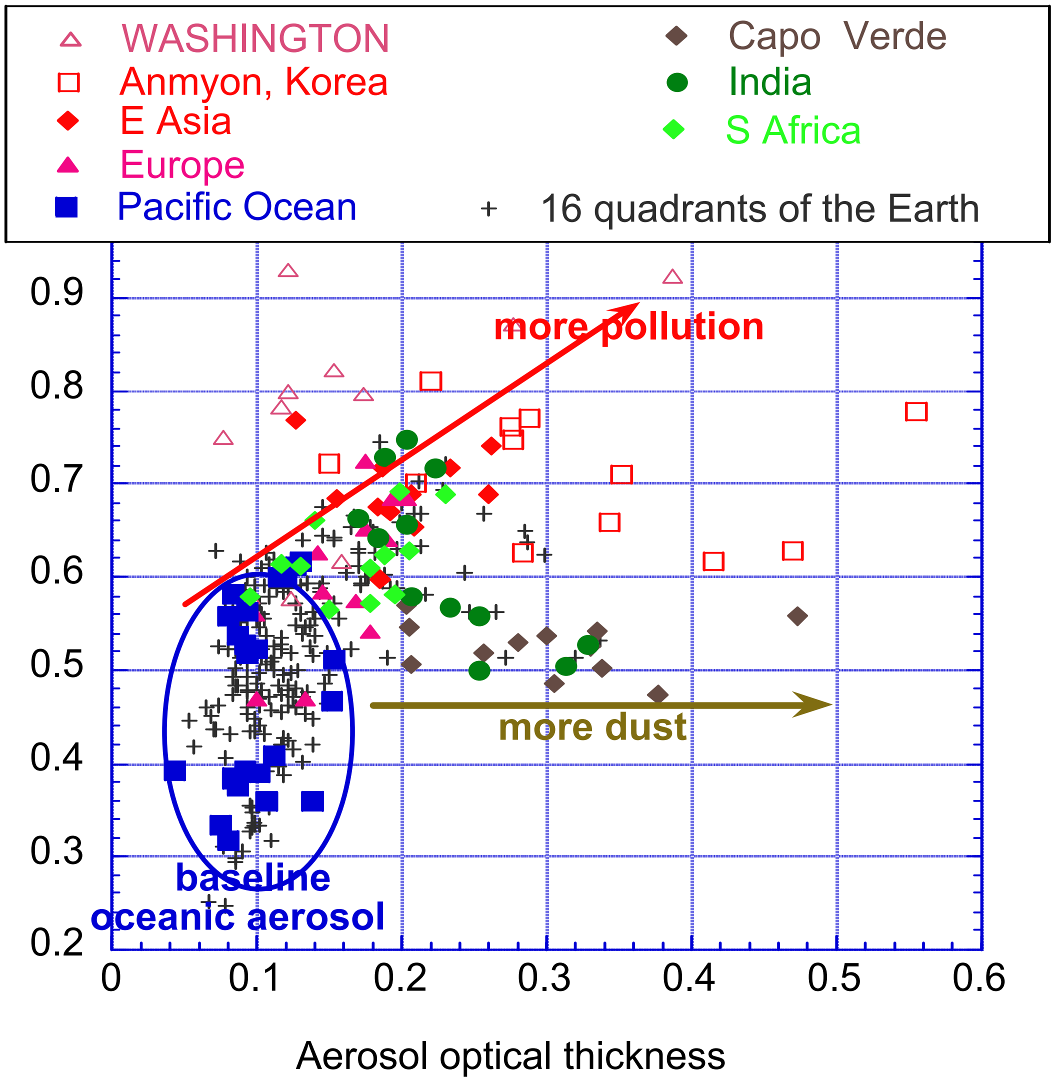
Multiyear variation of the dust maximum north from January to July.

Fine fraction, f:

f_{dust}=0.5±0.05

$f_{maritime}$ =0.3±0.1

$f_{anthrop}$ =0.9±0.1



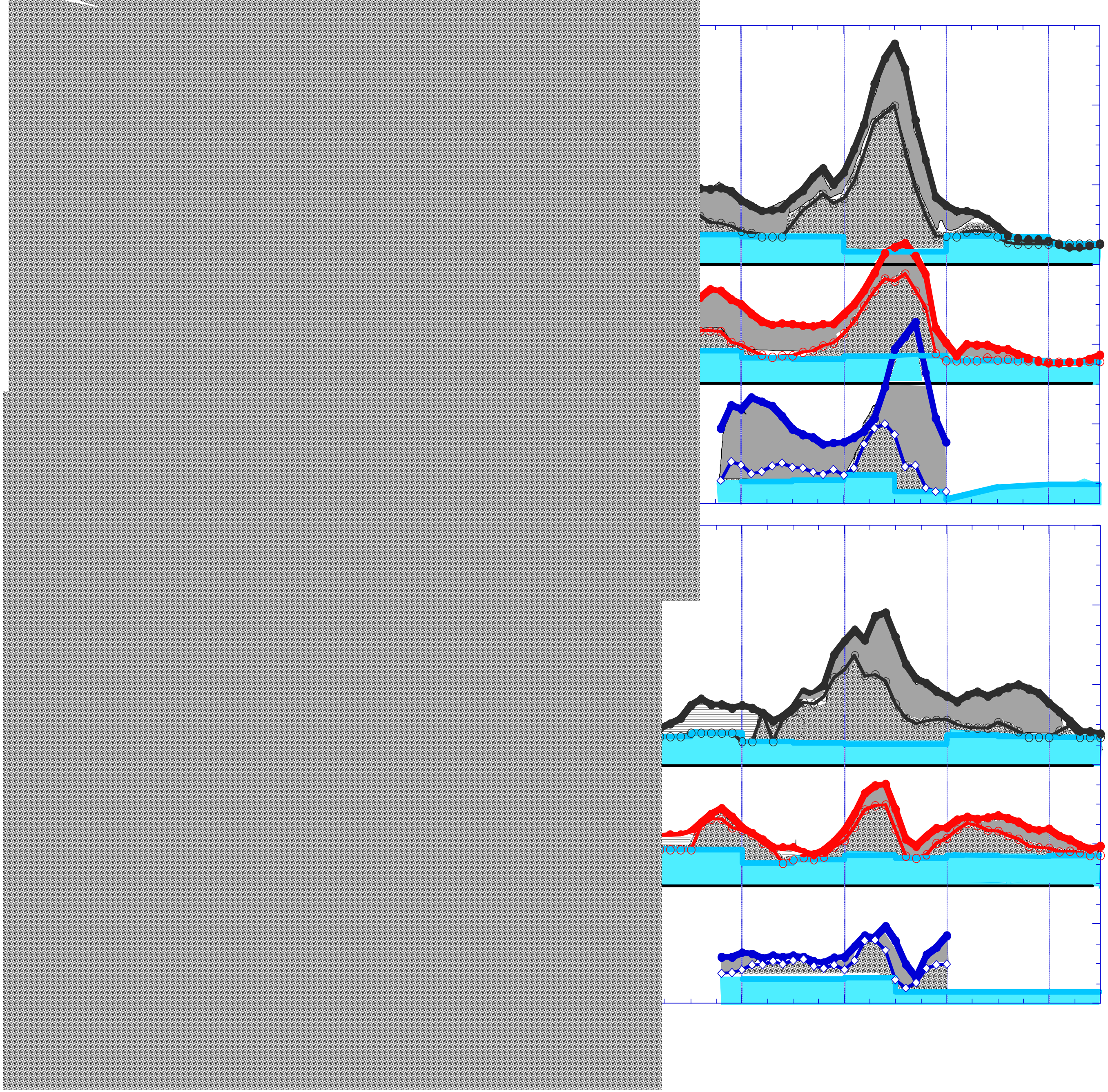
Fine fraction, f:

f_{dust}=0.5±0.05

$f_{maritime}$ =0.3±0.1

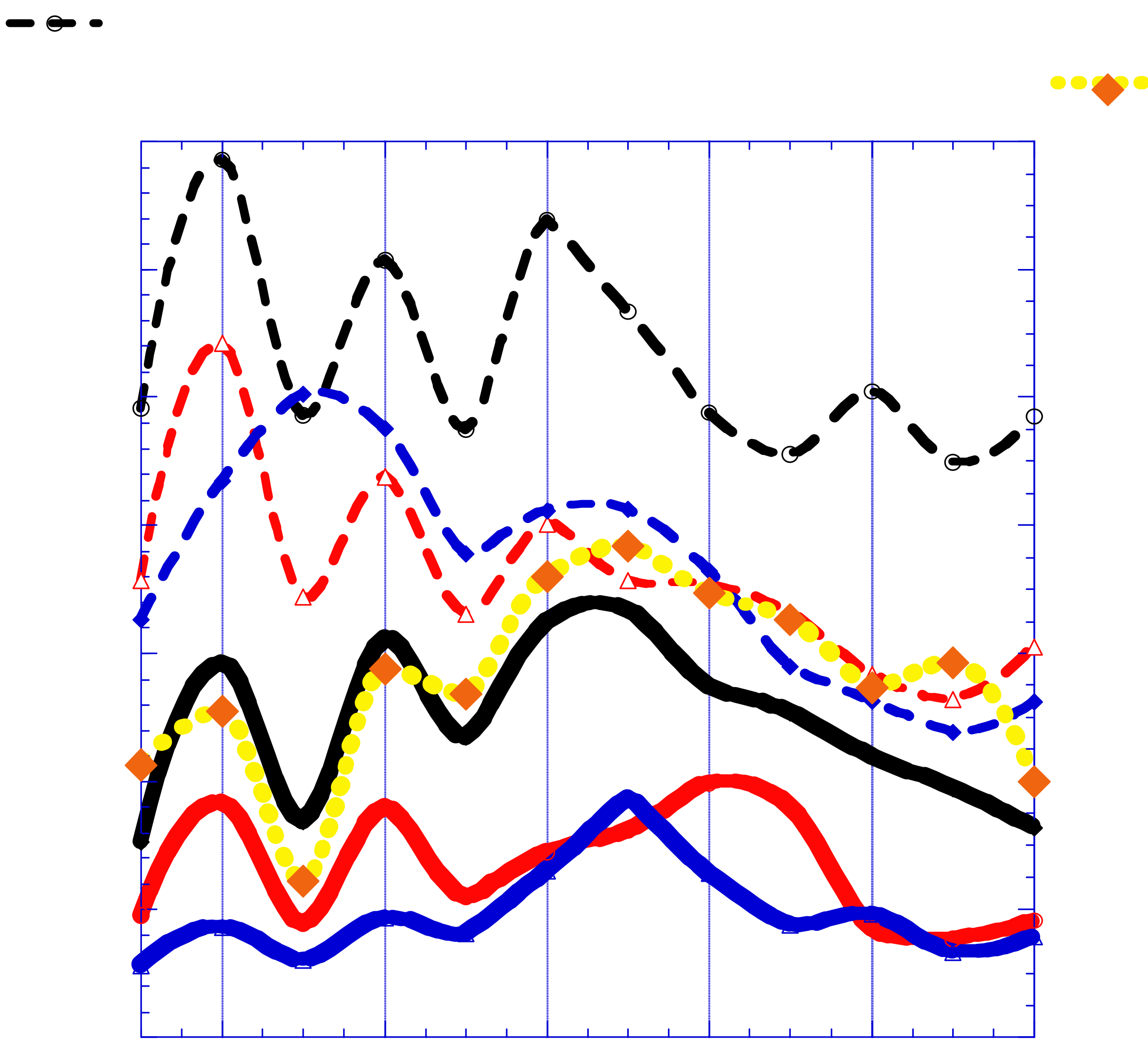
$f_{anthrop}$ =0.9±0.1

Separating dust from pollution/maritime aerosol

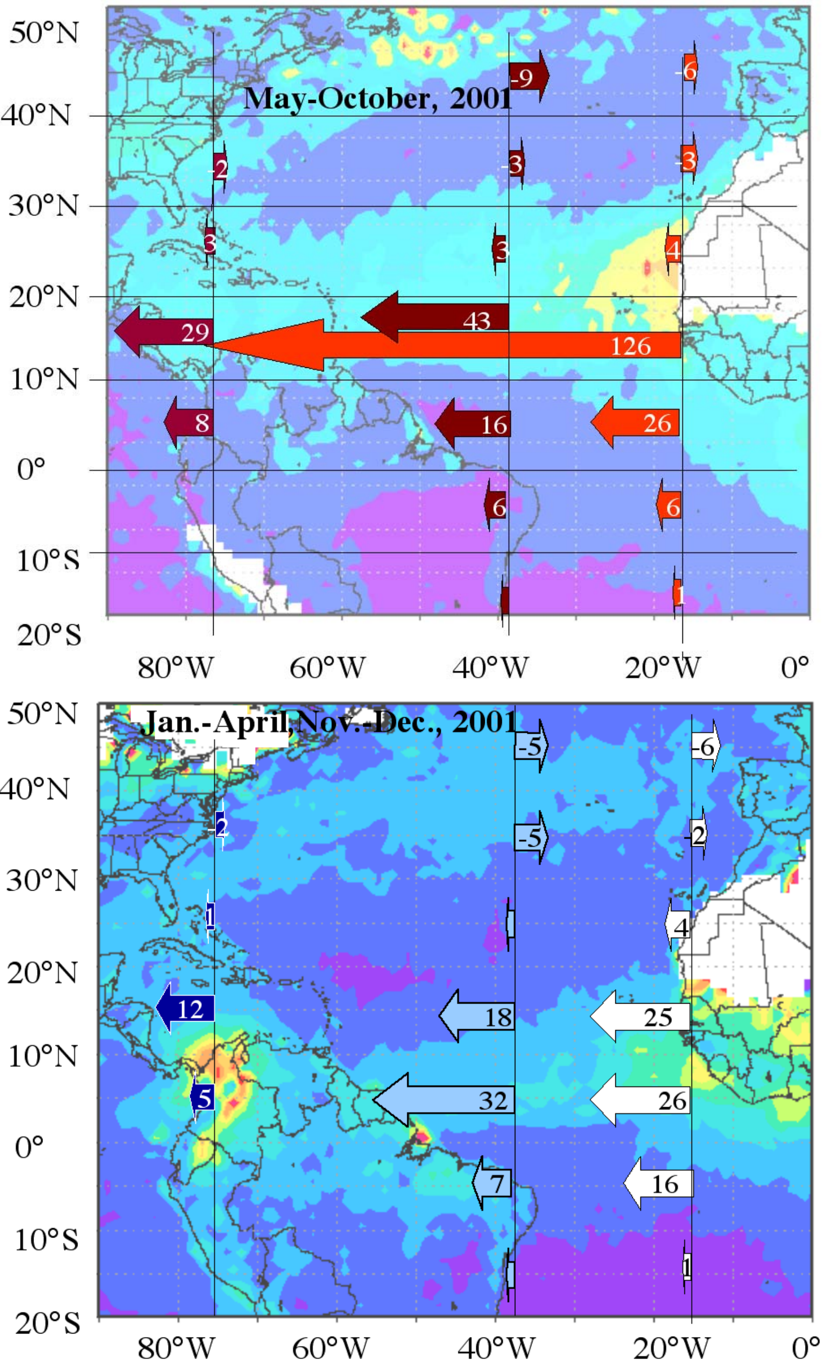


Dust, smoke/pollution and maritime components of the aerosol as a function of latitude.

Maritime AOT based on wind speed 0.02+0.007W



The dust component of the optical thickness correlates well with the wind speed - r= 80%. The correlation with total optical thickness is 25%.

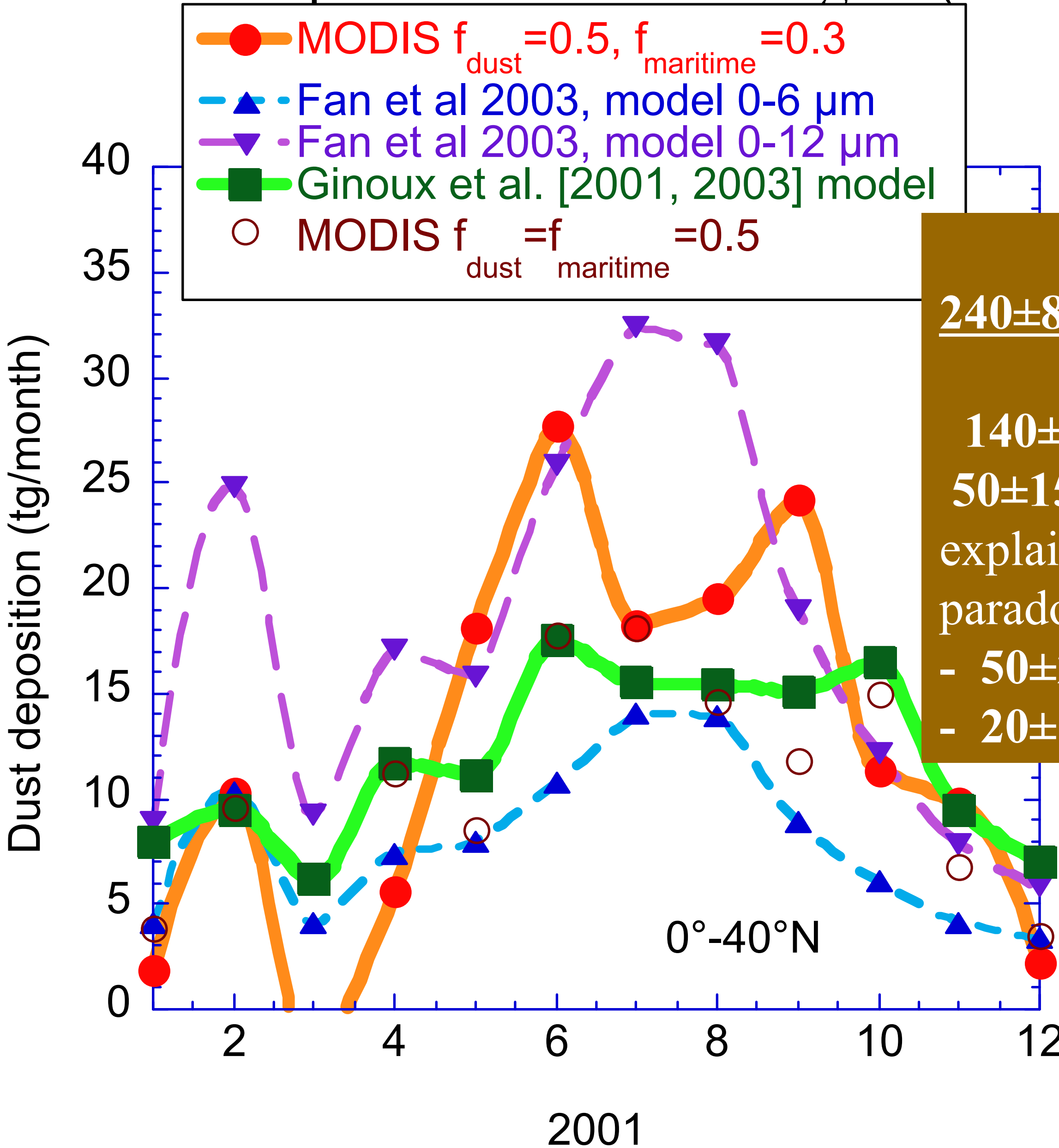


Dust transport (tg) across the Atlantic Ocean

May-September background - MODIS image from July 2001

October-April background - MODIS image from March 2001

Dust deposition rates (tg/month) in 2001: MODIS measurements and chemical transport models for the region (0°-40°N).



Dust migration

240±80 tg left Africa at 0°-30°N

Deposition:

140±40 tg in the Atlantic Ocean,

50±15 tg in the Amazon Basin - explaining the Amazon fertilization paradox

- **50±25** tg arrive to the Caribbean.
- **20±10** tg return to Africa & Europe

Summary points:

- MODIS measures spectral AOT (0.47-2.1μm), fine fraction identifies fine and coarse aerosol for consistent flux calculations

- better over ocean than land

- aerosol forcing measured in cloud free conditions - models should supplement the effect of clouds on direct forcing

- simultaneous measurements of water vapor and cloud properties: ice/water, droplet size, top temperature spatial structure

Measurement based assessment of aerosol radiative forcing

MODIS level 3 (1°x1°) daily, monthly, measures:
- aot (550 nm)
- distribution of the AOT among 8 models:

R_{eff}= 0.10, 0.15, 0.20, 0.25 μm - fine aerosol
R_{eff}= 1.0, 1.5, 2.0 μm for sea salt
R_{eff}= 1.5, 2.5 μm for dust

} Consistent calculations of solar reflected flux at TOA

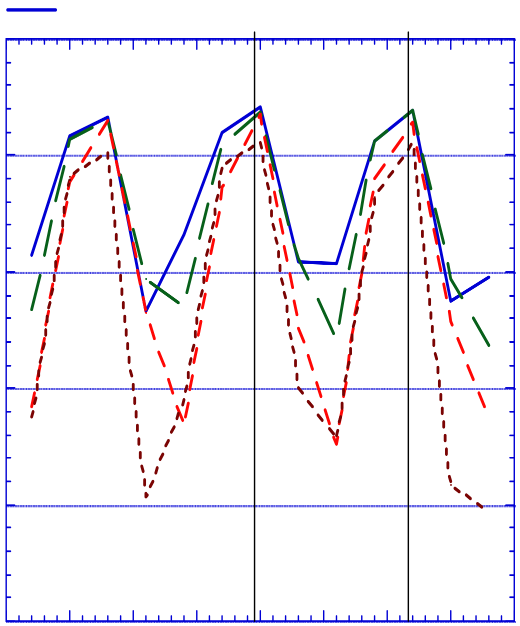
Aerosol Models_”Didier2”

Small particles:

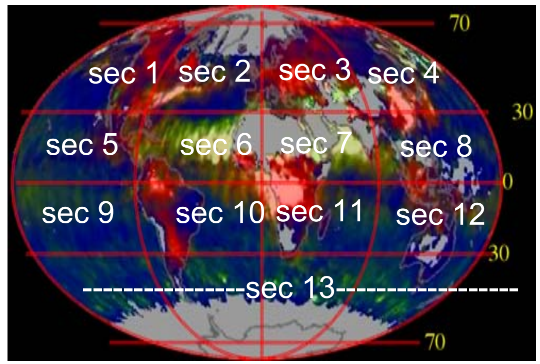
	l=0.47-->0.86mm	l=1.24mm	l=1.64mm	l=2.13mm	r_g	s	r_{eff}	comments
1	1.45-0.0035i	1.45-0.0035i	1.43-0.01i	1.40-0.005i	0.07	0.40	0.10	Wet Water Soluble type
2	1.45-0.0035i	1.45-0.0035i	1.43-0.01i	1.40-0.005i	0.06	0.60	0.15	Wet Water Soluble type
3	1.40-0.0020i	1.40-0.0020i	1.39-0.005i	1.36-0.003i	0.08	0.60	0.20	Water Soluble with humidity
4	1.40-0.0020i	1.40-0.0020i	1.39-0.005i	1.36-0.003i	0.10	0.60	0.25	Water Soluble with humidity

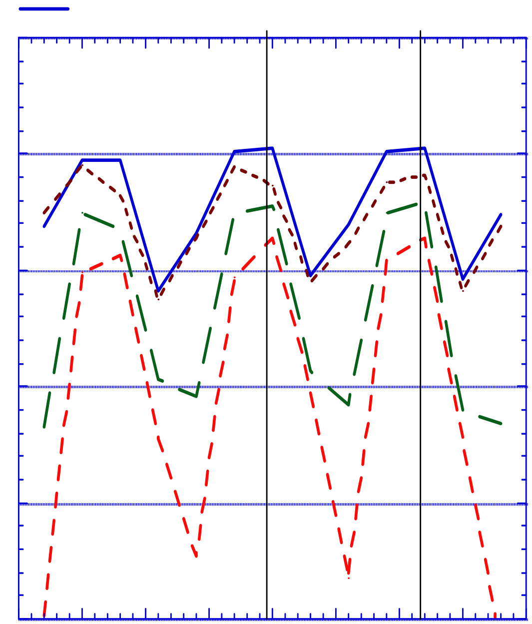
Large particles:

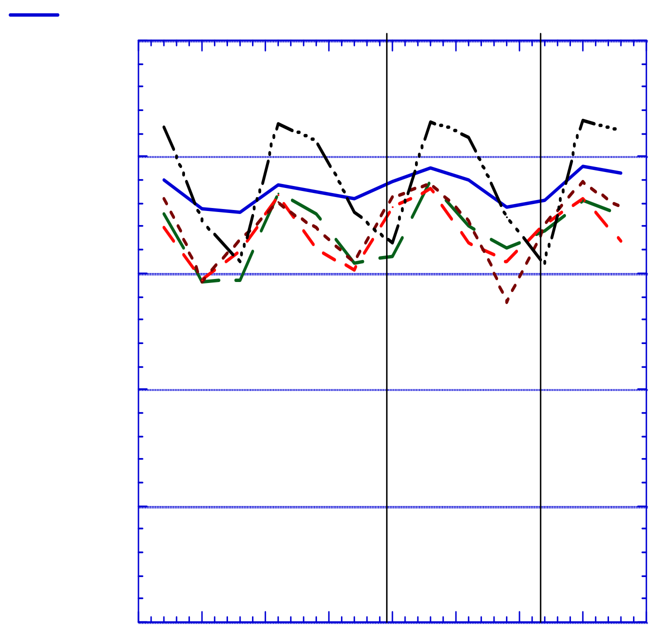
	l=0.47-->0.86mm	l=1.24mm	l=1.64mm	l=2.13mm	r_g	s	r_{eff}	comments
5	1.45-0.0035i	1.45-0.0035i	1.43-0.0035i	1.43-0.0035i	0.40	0.60	0.98	Wet Sea salt type
6	1.45-0.0035i	1.45-0.0035i	1.43-0.0035i	1.43-0.0035i	0.60	0.60	1.48	Wet Sea salt type
7	1.45-0.0035i	1.45-0.0035i	1.43-0.0035i	1.43-0.0035i	0.80	0.60	1.98	Wet Sea salt type
8	1.53-0.003i (0.47) 1.53-0.001i (0.55) 1.53-0.000i (0.66) 1.53-0.000i (0.86)	1.46-0.000i	1.46-0.001i	1.46-0.000i	0.60	0.60	1.48	Dust-like type
9	1.53-0.003i (0.47) 1.53-0.001i (0.55) 1.53-0.000i (0.66) 1.53-0.000i (0.86)	1.46-0.000i	1.46-0.001i	1.46-0.000i	0.50	0.80	2.50	Dust-like type



Radiative effect over the oceans from MODIS



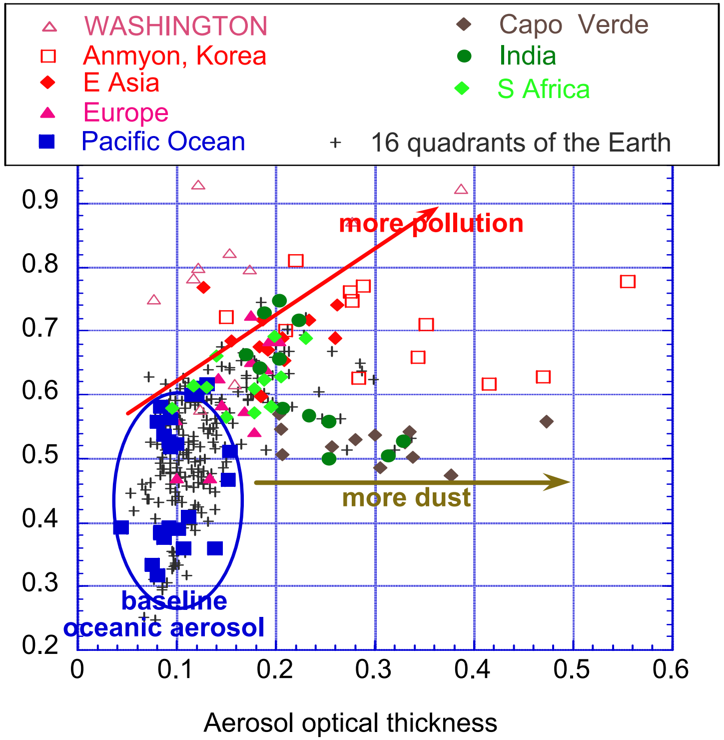




Seasonal aerosol Radiative effect at TOA
Remer et al., 2004

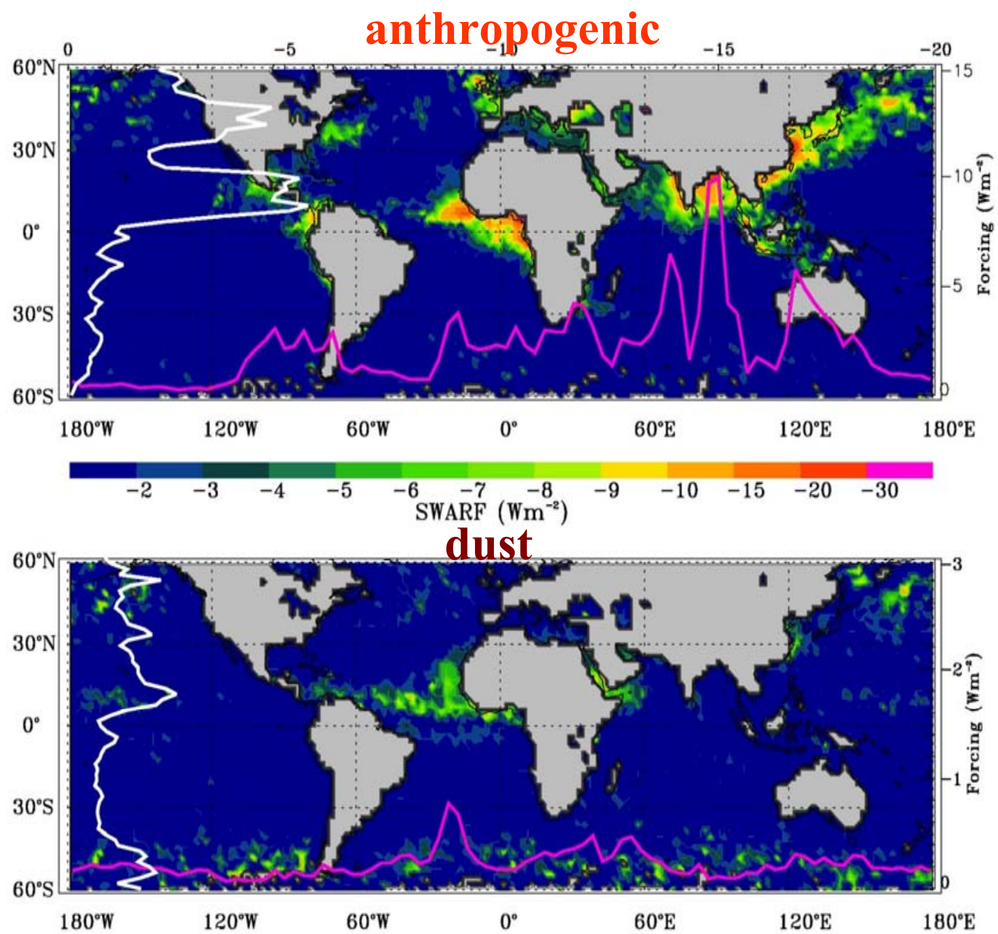
Aerosol direct radiative forcing

Classification of aerosol to natural and anthropogenic



Kaufman et al 2004 ?

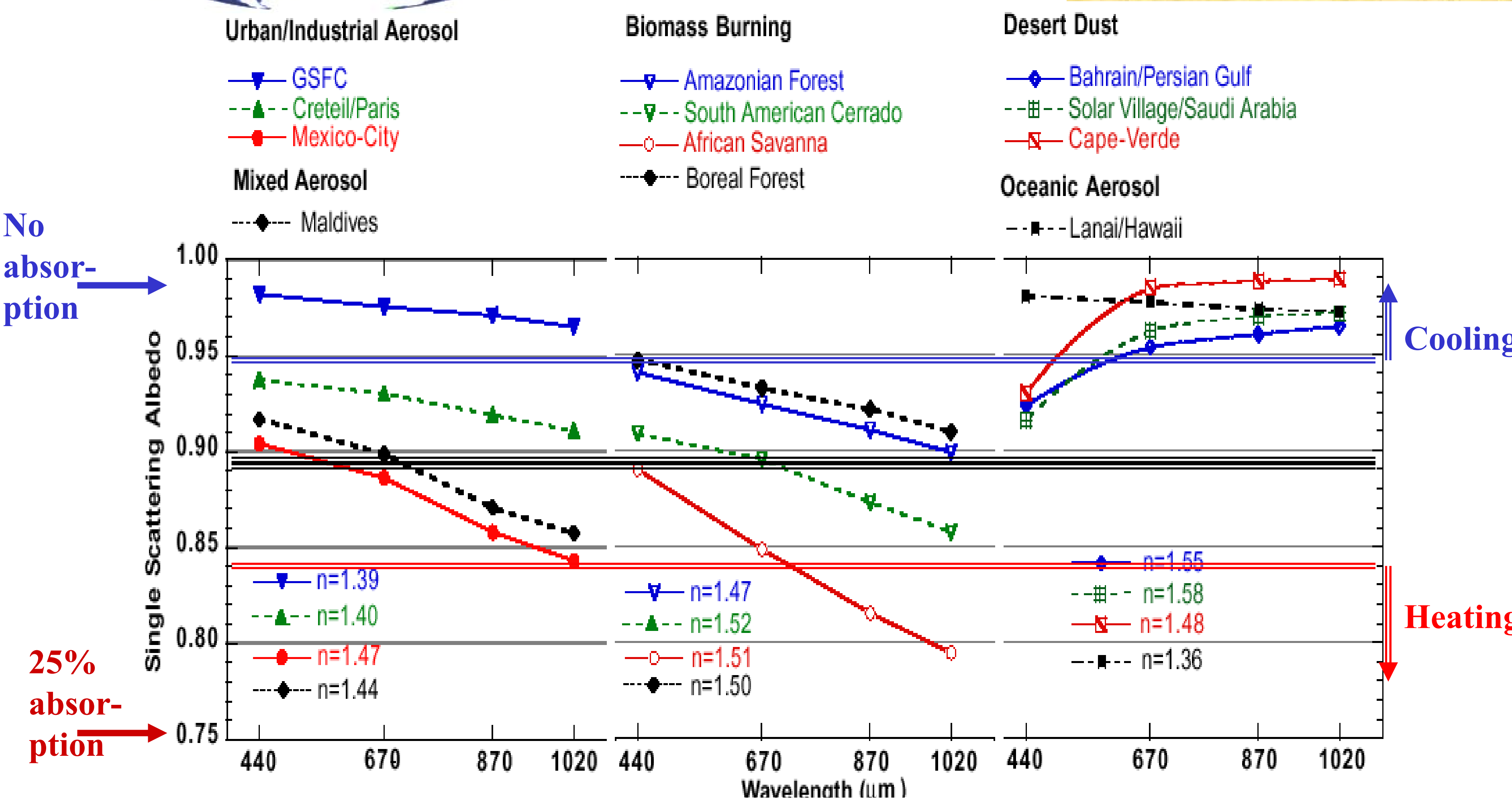
Instantaneous aerosol anthropogenic forcing and dust radiative effect



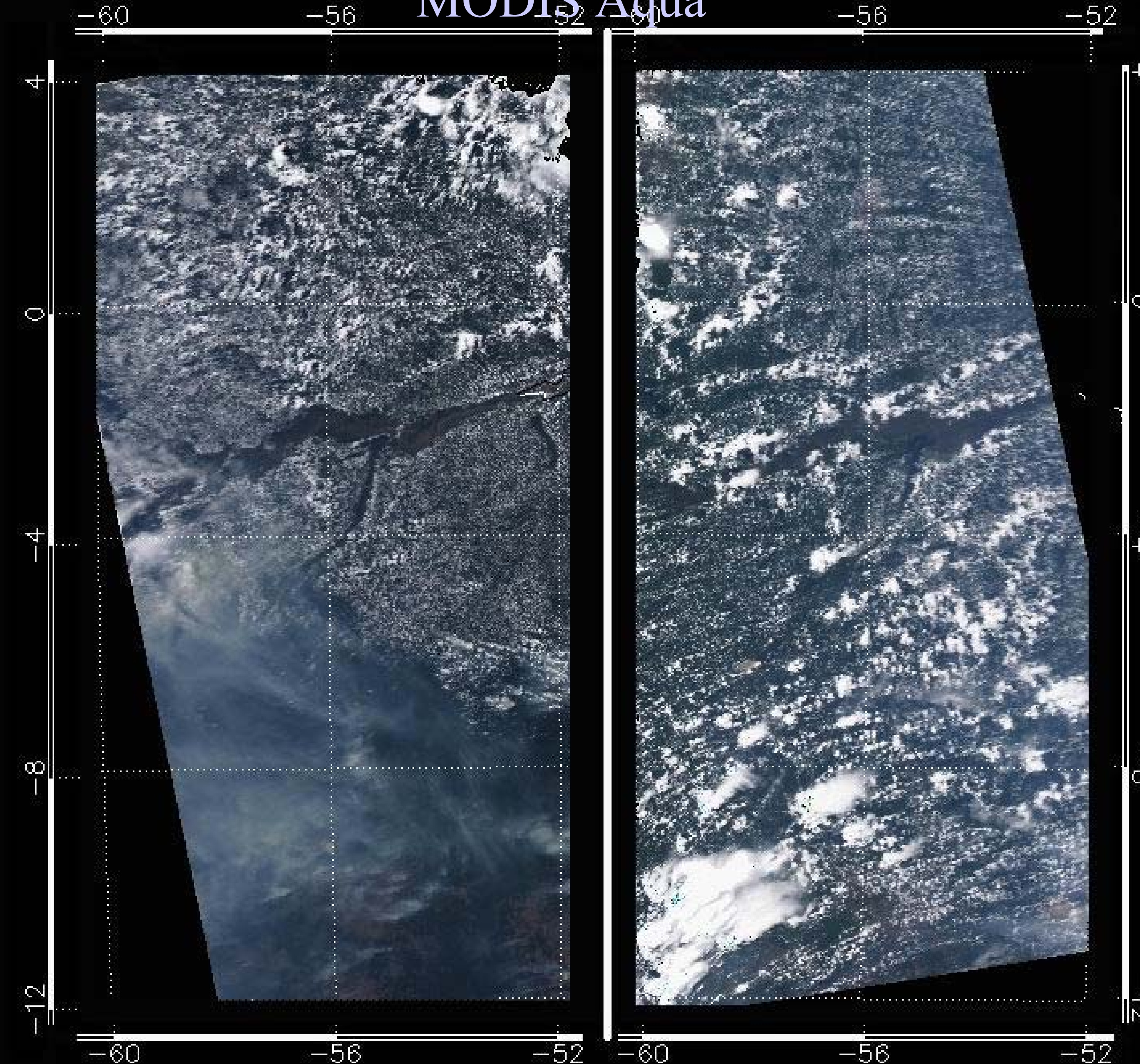
Christopher et al 2004

Opportunity from AERONET

Dubovik et al.,2002

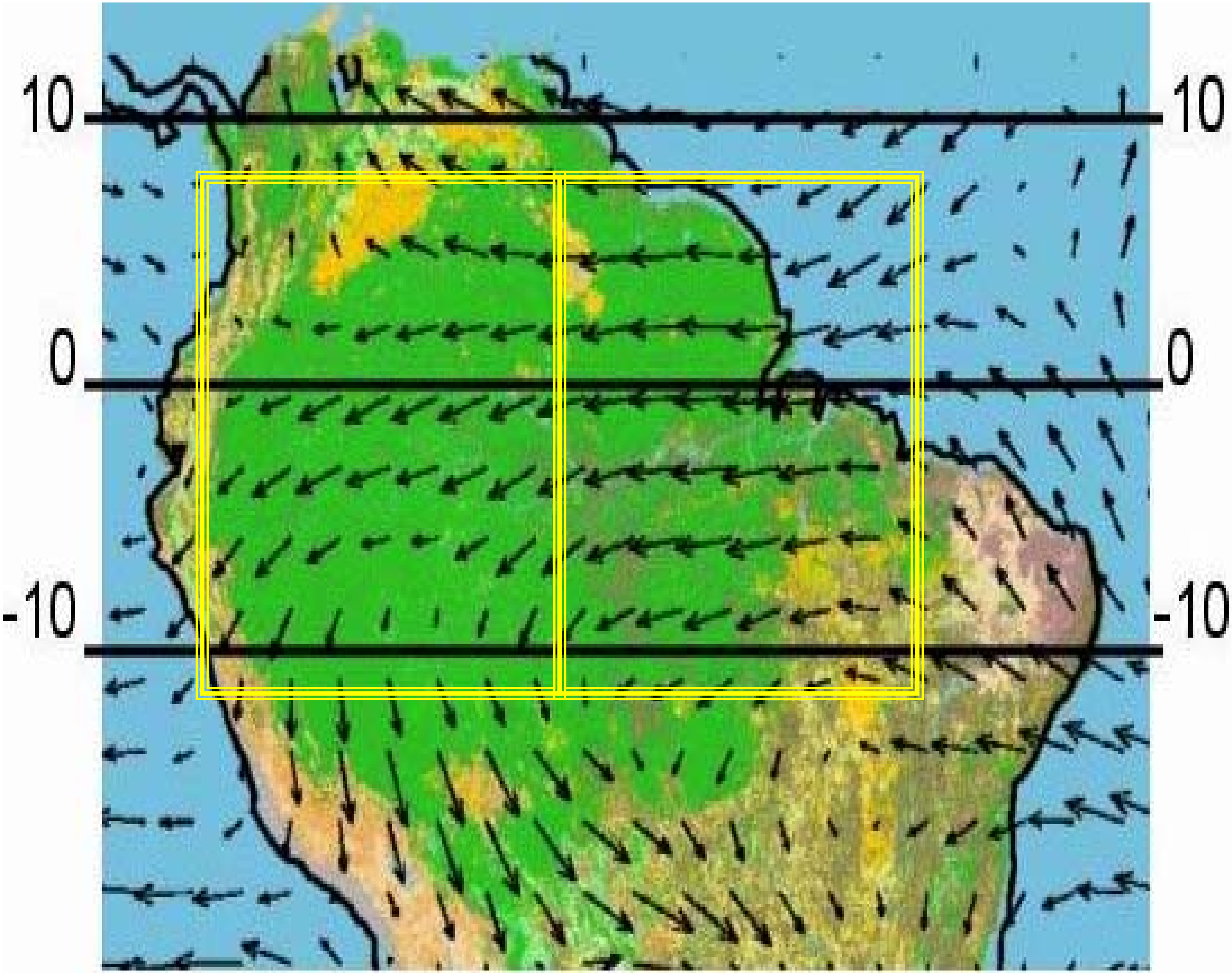


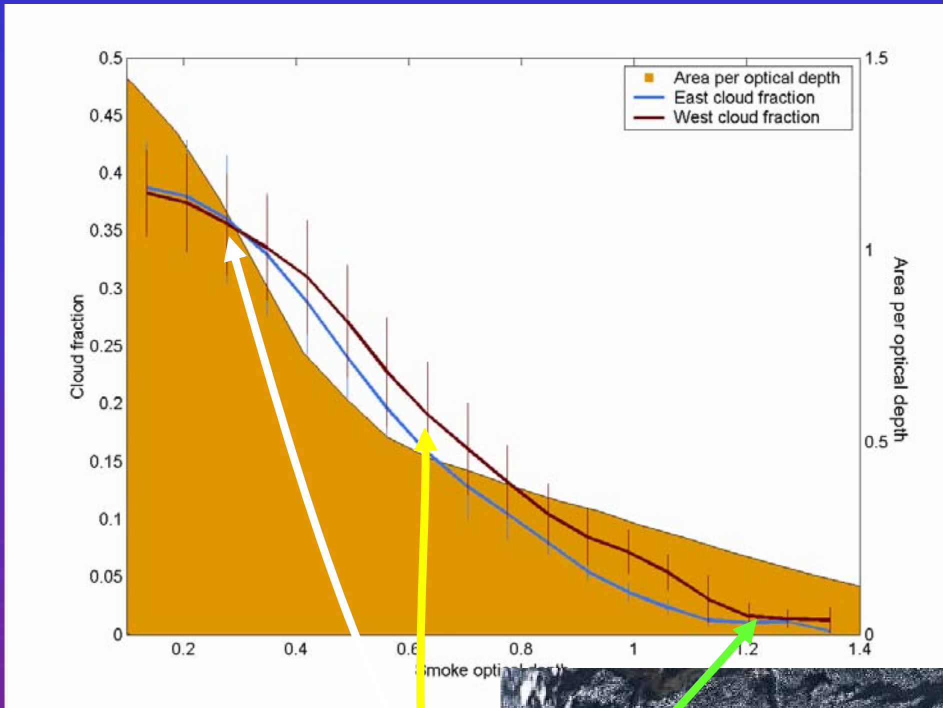
MODIS Aqua



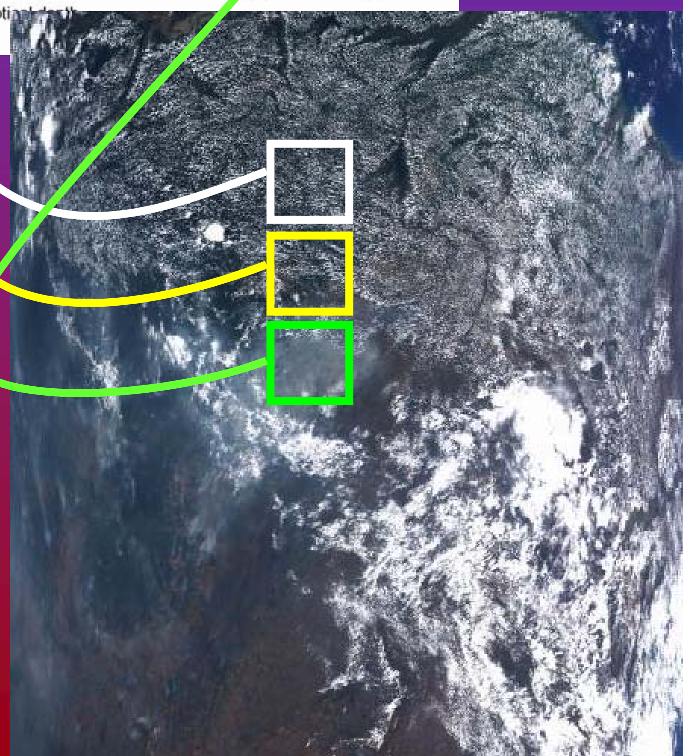
Aerosol Semi-direct effect - Koren et al 2004

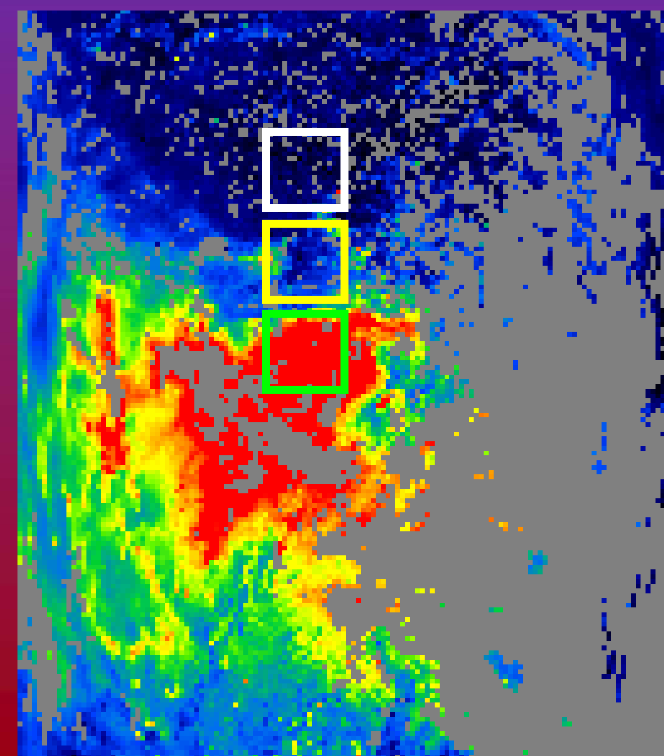
Selection of meteorological conditions



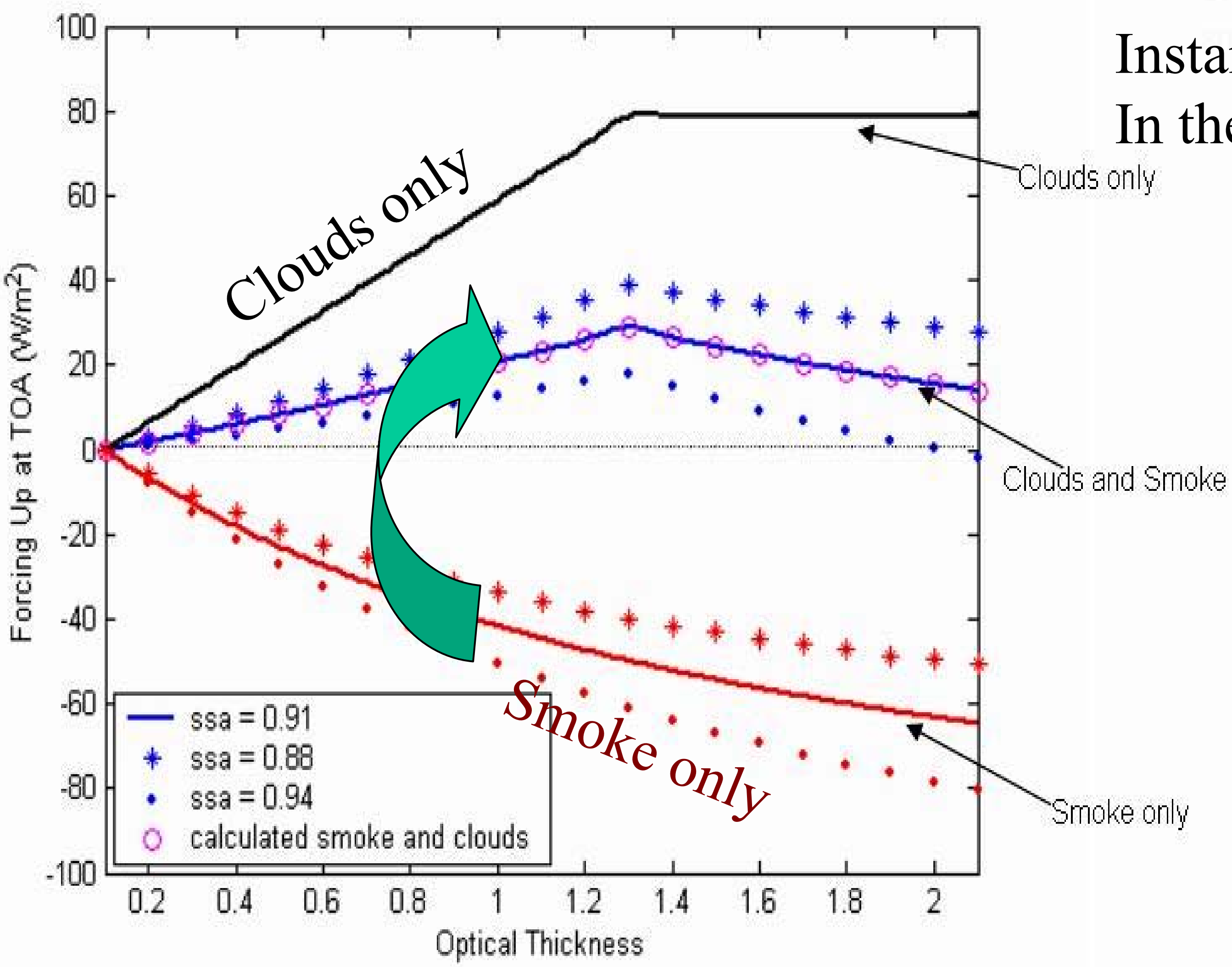


Cloud fraction as function of aerosol optical depth (OD). The cloud fraction decreases almost linearly with increasing OD.



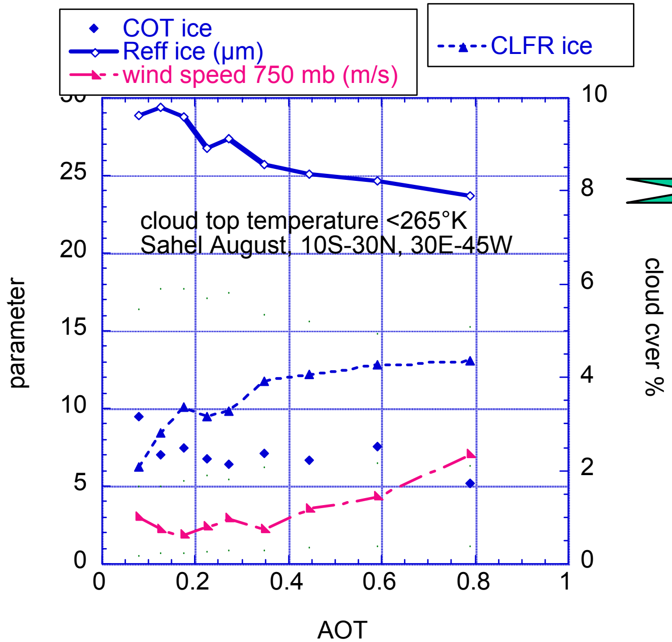


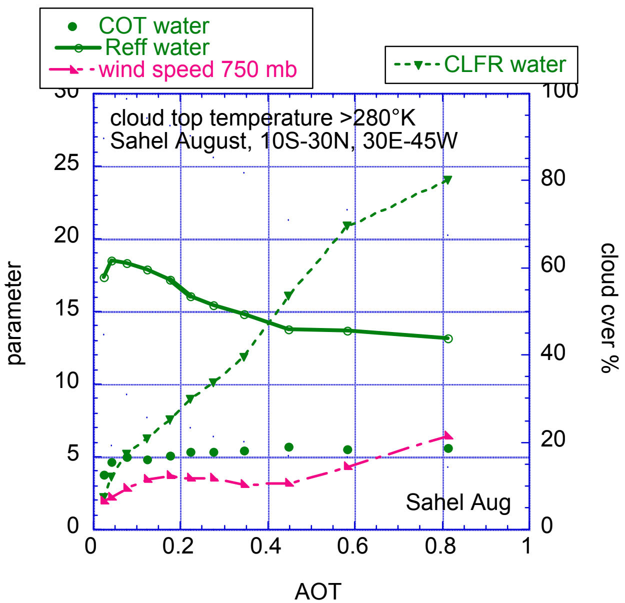
Instantaneous forcing
In the afternoon

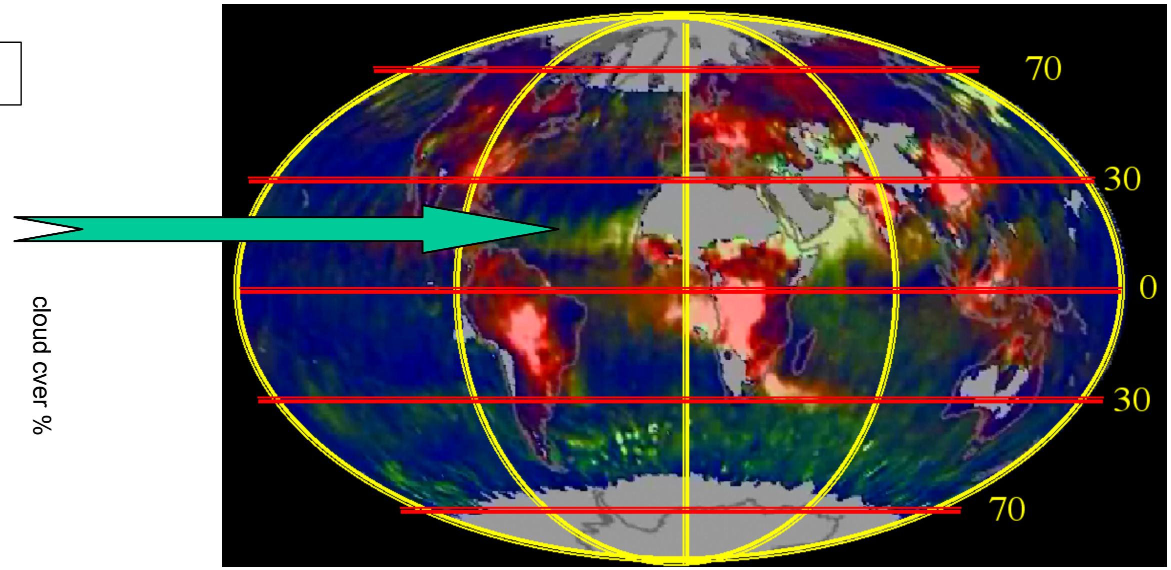


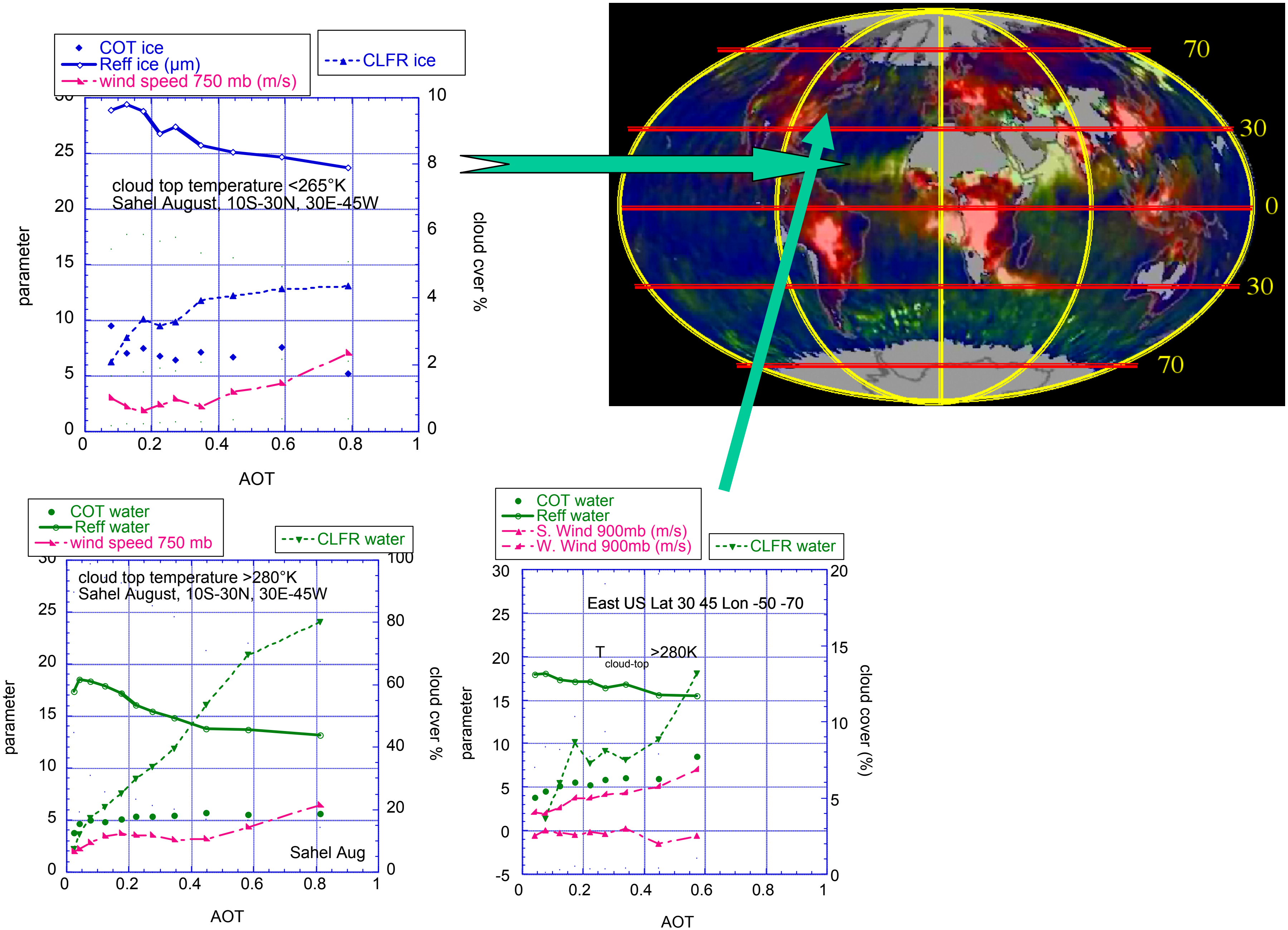
Impacts:

- slowing Greenhouse warming of the surface
- warmer, higher, more stable boundary layer
- smaller boundary layer cloud fraction

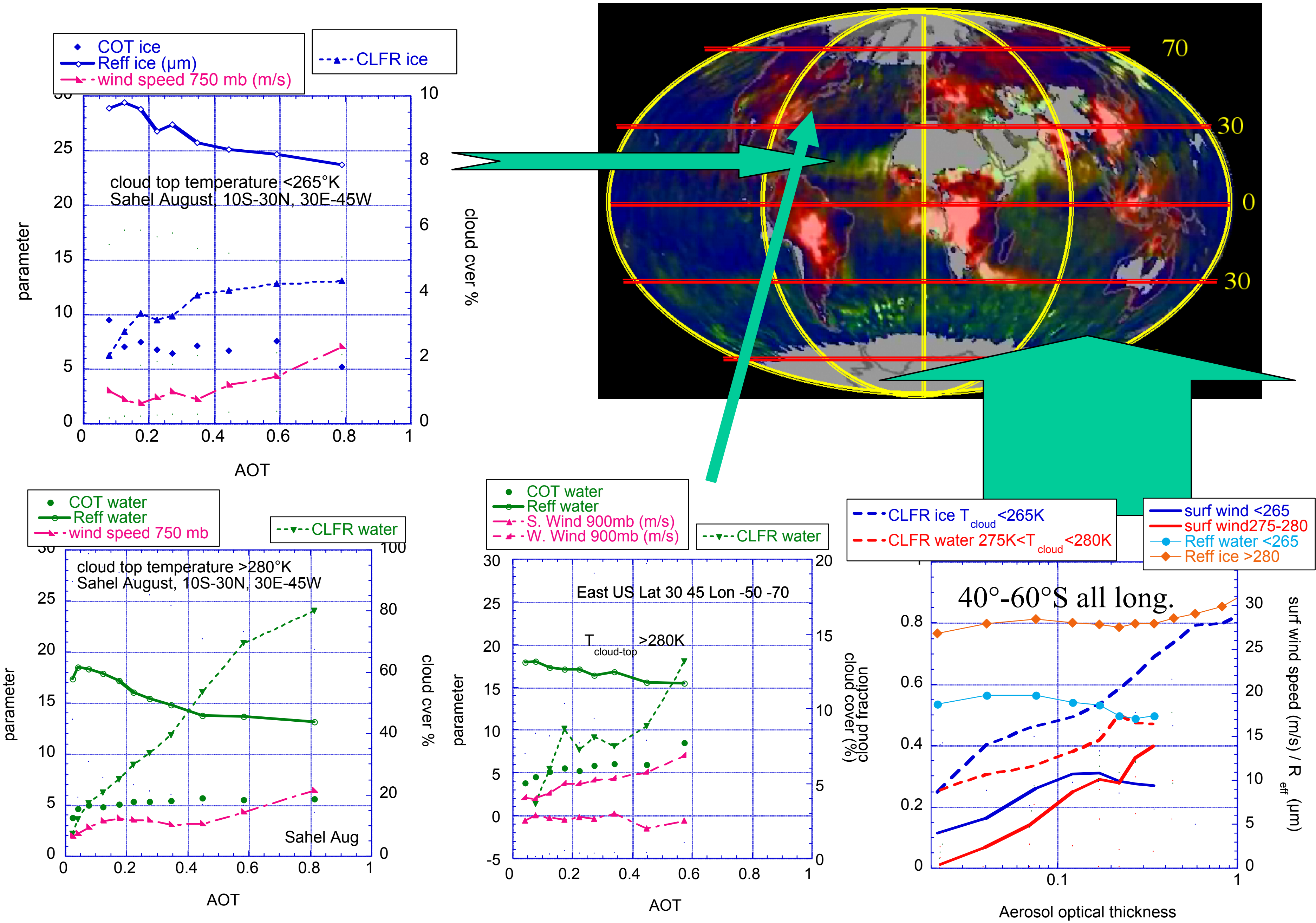

COT ice
Reff ice (μm)
wind speed 750 mb (m/s)
CLFR ice
cloud top temperature <265°K
Sahel August, 10S-30N, 30E-45W
parameter
cloud cver %
AOT
0
5
10
15
20
25
0.2
0.4
0.6
0.8
1
2
4
6
8


COT water
Reff water
wind speed 750 mb
CLFR water
cloud top temperature >280°K
Sahel August, 10S-30N, 30E-45W
Sahel Aug
parameter
cloud cver %
AOT
0
5
10
15
20
25
0.2
0.4
0.6
0.8
1
40
60
80
100


70
30
0
30
70



COT ice
Reff ice (µm)
wind speed 750 mb (m/s)
CLFR ice
cloud top temperature <265°K
Sahel August, 10S-30N, 30E-45W
parameter
cloud cver %
AOT
70
30
0
30
70
COT water
Reff water
wind speed 750 mb
CLFR water
cloud top temperature >280°K
Sahel August, 10S-30N, 30E-45W
Sahel Aug
parameter
cloud cver %
AOT
COT water
Reff water
S. Wind 900mb (m/s)
W. Wind 900mb (m/s)
CLFR water
East US Lat 30 45 Lon -50 -70
T cloud-top >280K
parameter
cloud cover (%)
AOT

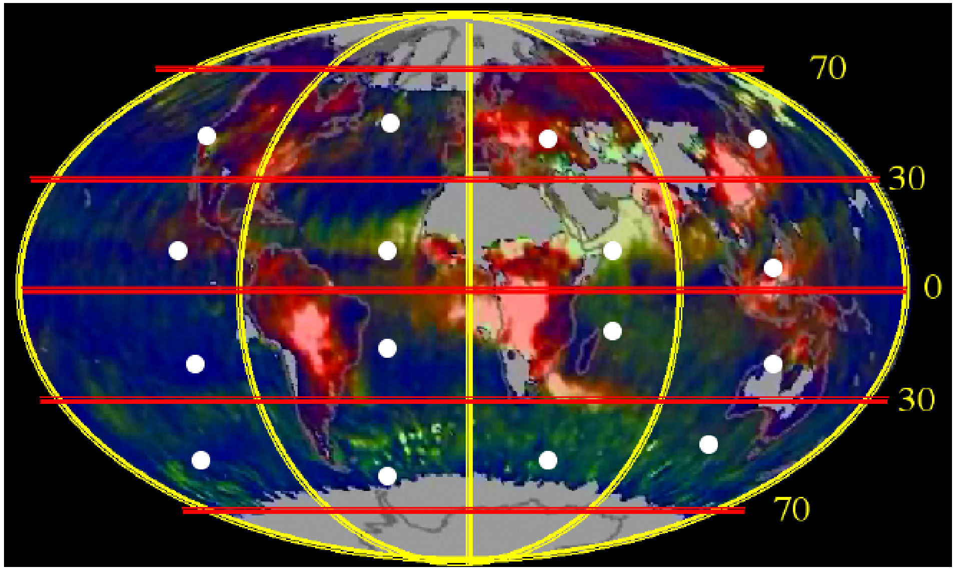


COT ice
Reff ice (μm)
wind speed 750 mb (m/s)
CLFR ice
cloud top temperature <265°K
Sahel August, 10S-30N, 30E-45W
parameter
cloud cver %
AOT
70
30
0
30
COT water
Reff water
wind speed 750 mb
CLFR water
cloud top temperature >280°K
Sahel August, 10S-30N, 30E-45W
Sahel Aug
cloud cver %
AOT
COT water
Reff water
S. Wind 900mb (m/s)
W. Wind 900mb (m/s)
CLFR water
East US Lat 30 45 Lon -50 -70
T cloud-top >280K
cloud fraction cloud cover (%)
AOT
CLFR ice T cloud <265K
CLFR water 275K<T cloud <280K
surf wind <265
surf wind275-280
Reff water <265
Reff ice >280
40°-60°S all long.
surf wind speed (m/s) / R eff (μm)
Aerosol optical thickness

Ocean - August 2003

AOT

0.15	0.18	0.20	0.23
0.11	0.23	0.42	0.11
0.09	0.13	0.17	0.11
0.10	0.12	0.13	0.11



Broken Cloud fraction

0.52	0.47	0.34	0.49
0.42	0.40	0.52	0.39
0.34	0.44	0.43	0.38
0.54	0.56	0.58	0.55

Correlations with aerosol AOT

CORRELATION of ice cloud cover

<265	0.84	0.87	0.96	0.80
0.8	0.91	0.57	0.64	0.73
	0.90	0.85	0.49	0.80
	0.90	0.90	0.94	0.94

CORRELATION Reff ice cloud

<265	0.75	0.79	-0.24	-0.92
-0.1	-0.81	-0.96	-0.94	-0.94
	0.84	-0.88	-0.93	-0.54
	0.92	0.82	0.37	0.65

CORRELATION of water cloud cover

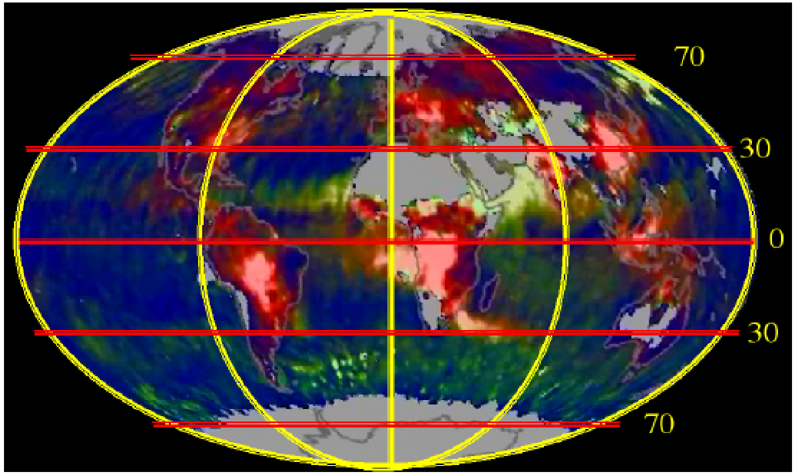
>280	0.71	0.89	0.86	0.63
0.9	0.98	0.98	0.99	0.99
	0.99	0.99	0.98	0.81
	0.96	0.95	0.96	0.97

CORRELATION Reff water cloud

>280	-0.78	-0.83	0.26	-0.60
-0.5	-0.76	-0.97	-0.93	-0.93
	0.83	-0.85	-0.92	-0.95
	0.64	-0.87	-0.97	0.87

Correlation of 0.2 is 95% significant, 0.55 is 99% significant

Change in cloud properties for a change in AOT from background (0.06) to the average value



Range of cloud top temperature (K)

↓

<265	Aerosol OT			
0.19	0.23	0.24	0.22	0.25
	0.16	0.26	0.35	0.14
	0.13	0.15	0.18	0.13
	0.15	0.16	0.18	0.15

<265	% change in ice cloud OT			
0.5	0	5	-2	2
	5	-7	17	-1
	1	7	7	-4
	-5	-4	-5	-6

>280	Aerosol OT			
0.15	0.09	0.16	0.22	0.2
	0.1	0.22	0.47	0.09
	0.08	0.13	0.17	0.11
	0.09	0.1	0.11	0.08

>280	% change in water cloud O			
2.6	2	5	-4	6
	2	3	2	2
	4	1	3	4
	4	5	1	3

<265	% change in Reff ice cloud			
-1.1	2	1	0	-1
	-1	-4	-8	-1
	2	-3	-5	-1
	1	1	0	1

<265	% change in ice water			
-0.6	1	6	-3	1
	4	-11	9	-2
	2	4	2	-5
	-5	-3	-5	-5

>280	% change in Reff water clo			
-2.9	-2	-2	0	-3
	0	-4	-18	-1
	0	-4	-6	-2
	0	-3	-3	1

>280	% change in liquid water			
-0.3	0	3	-4	3
	2	-2	-16	1
	4	-3	-3	2
	4	2	-2	4

Correlation between the aerosol effect on cloud ice size and optical thickness for 0-70°N Oct. 2003