AEROCOM -III
New York
December 1-3, 2004

Aerosol–Cloud Interactions detected by MODIS

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To find evidence for the first and second aerosol indirect effect using data from MODIS.

- **Clean versus Polluted Clouds**
- **Cold versus Warm Clouds**
- **1st and 2nd aerosol indirect effect**

Climate effects of aerosols

Aerosol effects on climate through:
direct, semi-direct, thermodynamical, indirect and associated feedbacks ranges from +0.8 to – 2.4 Wm^{-2}.

Value for the indirect effect is – 1 Wm^{-2}(ranges from – 0.5 to – 4.5 Wm^{-2})

Estimates due to aerosols are large compared to other forcings such as:

Greenhouse gases, Land-use, Solar activity, Volcanic aerosol effects, etc. that are ~ +3.35 Wm^{-2}.

Methodology

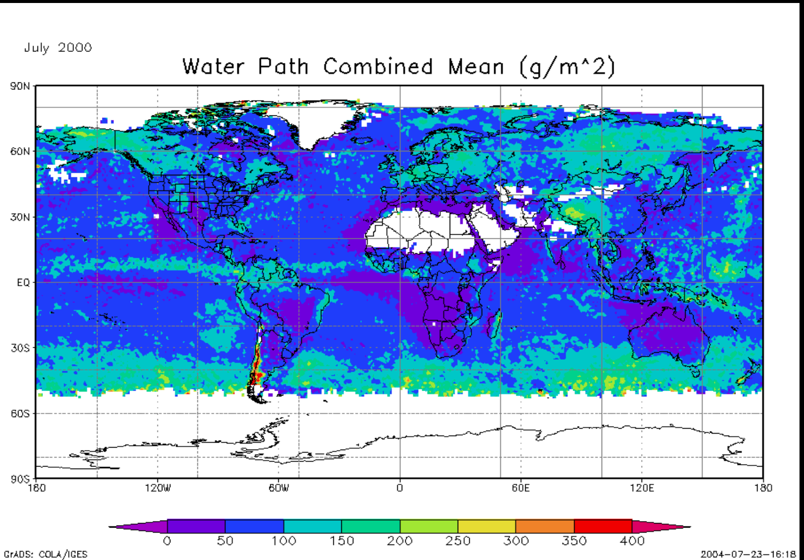
- 8 Variables were obtained from MODIS data
  - –Cloud Top Temperature (K) -CTT
  - –Cloud Top Pressure (hPa) -CTPP
  - –Cloud Droplet Number Concentration (cm^{-2}) -Nc
  - –Total Cloud Fraction
  - –Water Path ($g\ m^{-2}$)
  - –Cloud Effective Radius (microns) - Reff
  - –Cloud Optical Thickness - COT
  - –Aerosol Optical Thickness -AOT

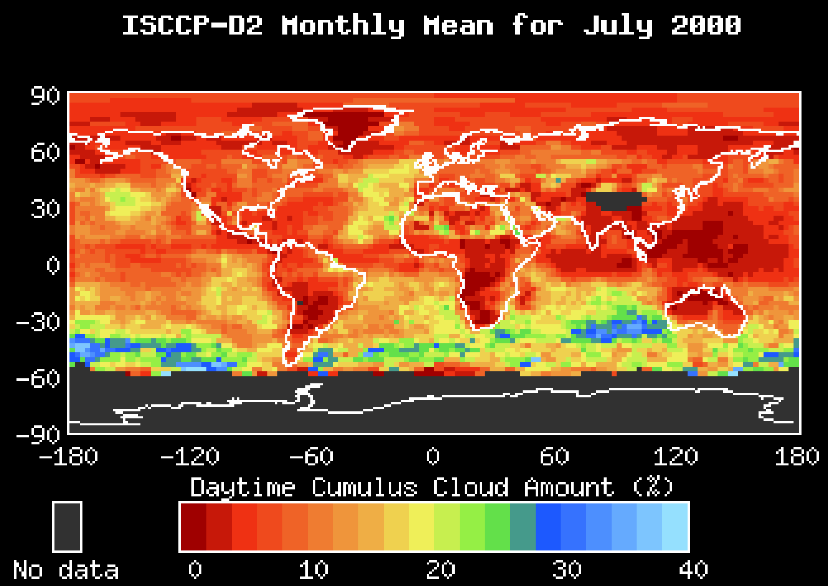
- July 2000 was chosen for this study

- The data is organized in a 1x1 degree global grid for each day

Methodology

- We selected 20 regions around the globe based on:
  - dominant stratus or convective clouds determined by ISCCP data (International Satellite Cloud Climatology Project)
  - consistent cloud top pressure, cloud top temperature, water path determined by MODIS
- Important so variation caused by water content, temperature, and pressure could be ignored and we could focus just on cloud properties related to AIE





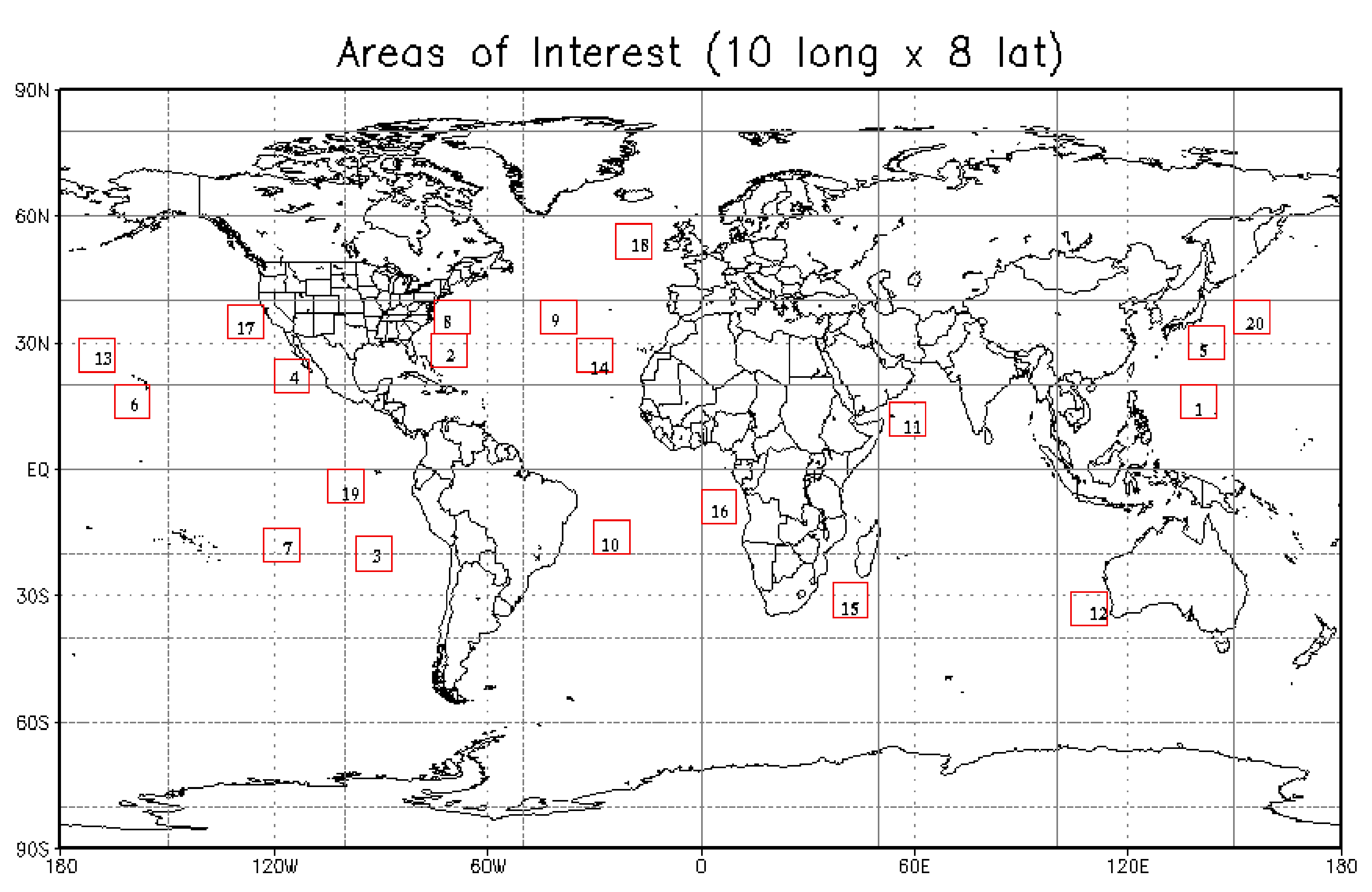
Methodology

- A correlation was found for each 1x1 degree grid point using the 31 points available for each point (each of the 31 days in July)

- Some instrument errors were accounted for and data was filtered out (e.g. contamination for AOT > 0.6)

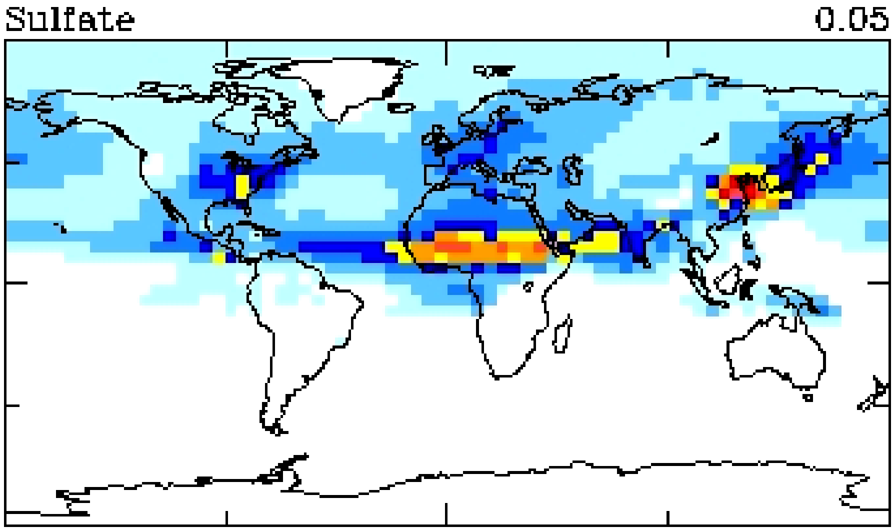
- If there were less than 5 valid points left for a grid point, then the correlation was marked as missing.

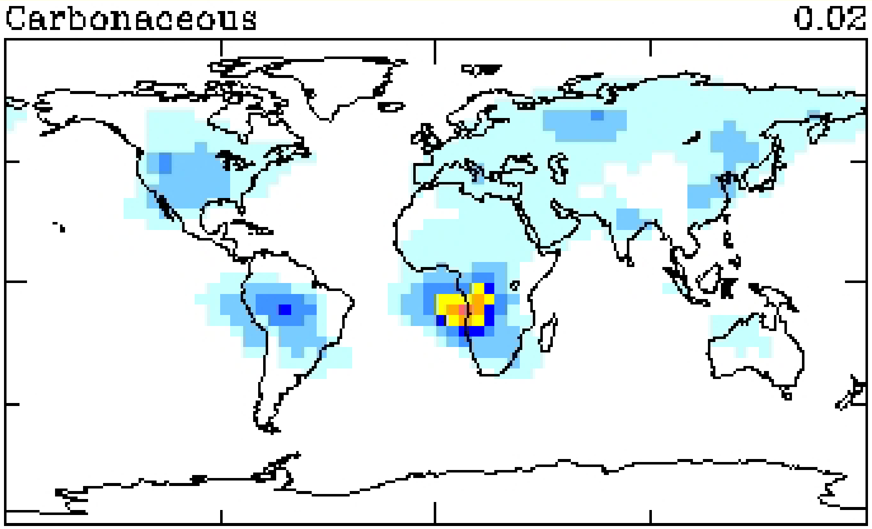
Area of Interest

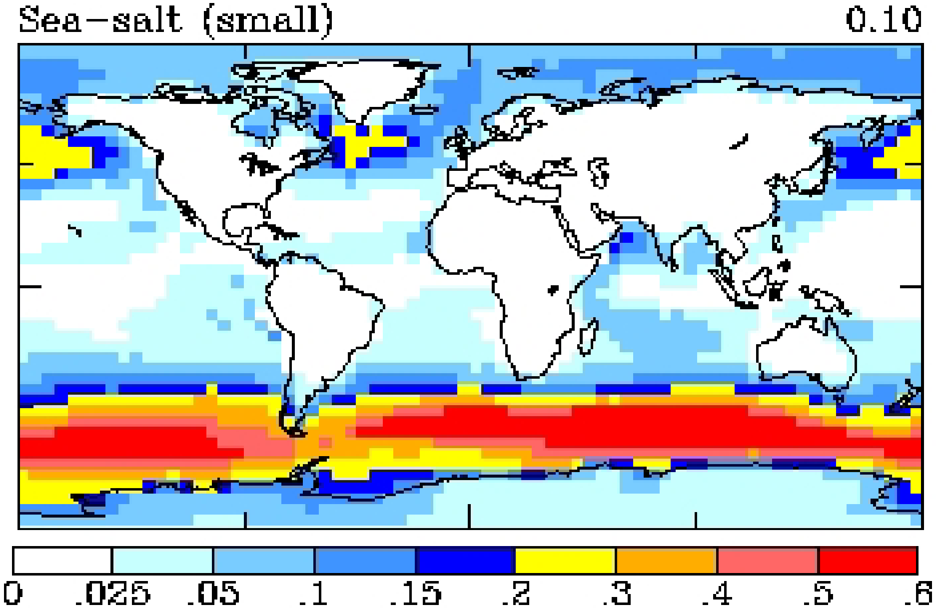


From Chmura and Menon, 2004

GISS Aerosol Optical thickness for Jun-Jul-Aug 2000







Based on AEROCOM-B Emissions

Future Work

- Identify specific dynamic regimes using reanalysis data and look for similar statistical relationships between aerosols and cloud microphysics under these regimes.

- Use GISS GCM to identify the type of aerosols present in each region and the different relationships between aerosol optical thickness and cloud properties for the 20 regions as observed in MODIS data.

Climate effects of aerosols in the GISS GCM

Using AEROCOM-B emissions we evaluate direct and indirect aerosol effects on climate in terms of:

Climate sensitivity to carbonaceous aerosols
Heating effects of black carbon
Aerosol-convective cloud effects

Forcings due to aerosols in the GISS GCM

Case	Sulfate Total	OC (fossil/bio-fuel/biomass)	BC (fossil/bio-fuel)	BC (biomass)	Total
Direct forcing (W m-2)	–0.29	–0.13	0.18	0.06	–0.18
Forcing efficiency (W g-1)	–103	–106	1385	857	NA

(From Menon and Del Genio, 2004)

Forcings due to aerosols in the GISS GCM

Case	Sulfate Total	OC (fossil & bio-fuel)	OC (biomass & terpene)	BC (fossil & bio-fuel)	BC (biomass)	Net Cloud forcing (W m^{-2})
M02	2.66/0.42	1.57/0.14		-	-	–4.36
	5.03/1.05	2.46/0.27		-	-	–2.41
Exp A	2.96/0.15	0.98/0.57	1.61/0.80	0.13/0.0	0.12/0.06	–0.65
Exp A_S	4.34/0.14	0.96/0.55	1.63/0.15	0.12/0.0	0.12/0.01	–1.03

(From Menon and Del Genio, 2004)

Simulations to determine aerosol climate sensitivity

Simulation	Type
Exp A	**Standard run with both indirect effects**
Exp NBC	**Like Exp A but without fossil/bio-fuel Black Carbon**
Exp 2BC	**Like Exp A but with twice fossil/bio-fuel Black Carbon**

Δ : denotes differences between simulations with present-day aerosol emissions (AEROCOM) and pre-industrial aerosols (terpenes, DMS, volcanic, some portion of biomass, sea-salt and dust).

Climate sensitivity

Climate sensitivity is determined from ratio of surface temperature change to forcing.

Climate sensitivity for:

ΔExp A	**0.12 K W^{-1} m^2**
Δ Exp NBC	**0.097 K W^{-1} m^2**
Δ Exp 2BC	**1.14 K W^{-1} m^2**

Sensitivity in same model coupled to a mixed ocean slab model for:

2xCO_2	**0.66 K W^{-1} m^2**

(From Menon and Del Genio, 2004)

Climate sensitivity

In an atmosphere only model (Hadley Center climate model) with **4 times as much fossil fuel Black Carbon as in Exp A:**

Annual mean surface temperature change is ~ 0.436K

Climate sensitivity = **0.56 K W^{-1} m^2**

(Roberts and Jones, 2004).

Effects of Black Carbon on cloud properties not considered.

Within the same model the climate sensitivity to doubled CO_2 is ~ **0.91 K W^{-1} m^2.**

Change in climate due to varying black carbon induced heating

Indian Ocean (Jan-Mar) (0-20N, 40-100E)	TOA (Wm^{-2})	Surface (Wm^{-2})	Atmosphere (Wm^{-2})	Precipitation (mm/d)
Δ Exp A	-2.97	-7.33	4.36	0.35
Δ Exp NBC	-2.07	-3.52	1.45	-0.08
Δ Exp 2BC	-2.06	-5.71	3.65	0.01

(From Menon and Del Genio, 2004)

Change in climate due to aerosol-convective clouds effects