GOCART Model Study of Anthropogenic Aerosol Radiative Forcing

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NASA EOS Investigation

A global model analysis of anthropogenic aerosol radiative forcing using data from Terra and Aqua satellites, ground-based networks, and in-situ measurements

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Objectives

- Quantify aerosol composition, distribution, and properties inferred from the satellite data and constrained by atmospheric measurements
- Improve the sources, processes, and optical parameters in the model based on the multi-platform data
- Estimate anthropogenic aerosol forcing from industrial and biomass burning emissions and land-use modifications

GOCART Model

Goddard Chemistry Aerosol Radiation and Transport model

- A global atmospheric process model using assimilated meteorological fields from the Goddard Earth Observing System Data Assimilation System (GEOS DAS)
- Including major types of aerosols, sulfate, dust, BC, OC, and sea-salt, from both anthropogenic and natural sources
- Calculating aerosol composition, 4-D distributions, optical thickness, radiative forcing

Processes included in the GOCART model

- Emissions of aerosols and their precursors
- Transport (advection, convection, BL mixing)
- Chemistry (gas-to-particle conversion)
- Dry deposition and settling
- Wet deposition
- Hygroscopic growth and size distributions

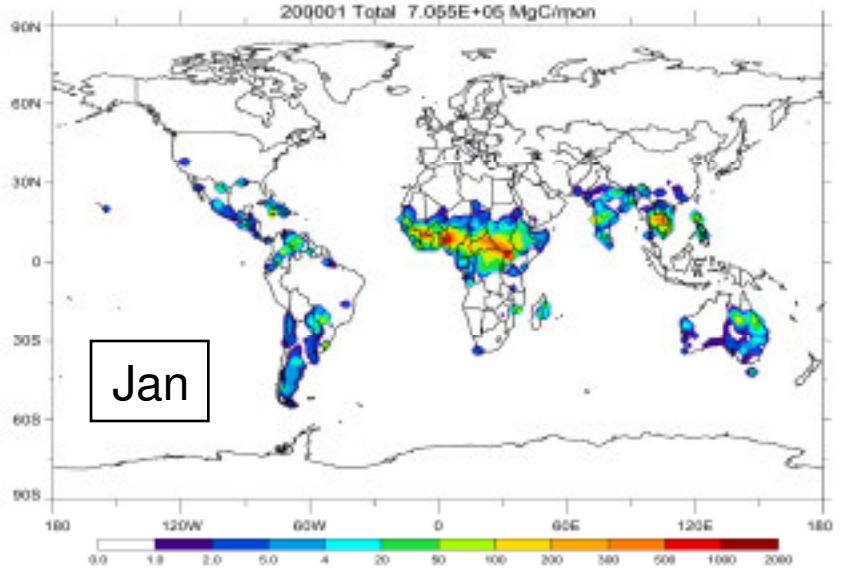
Task #1:

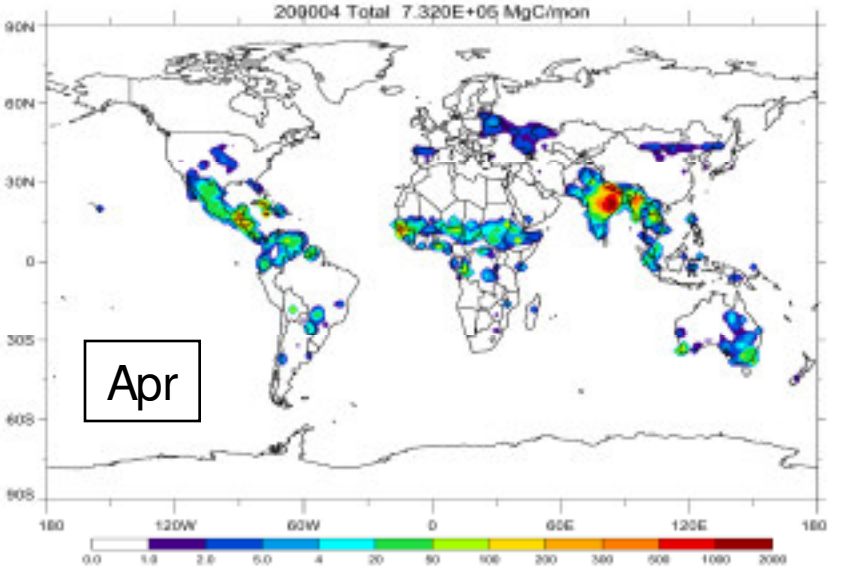
Using MODIS fire data to improve biomass burning emission

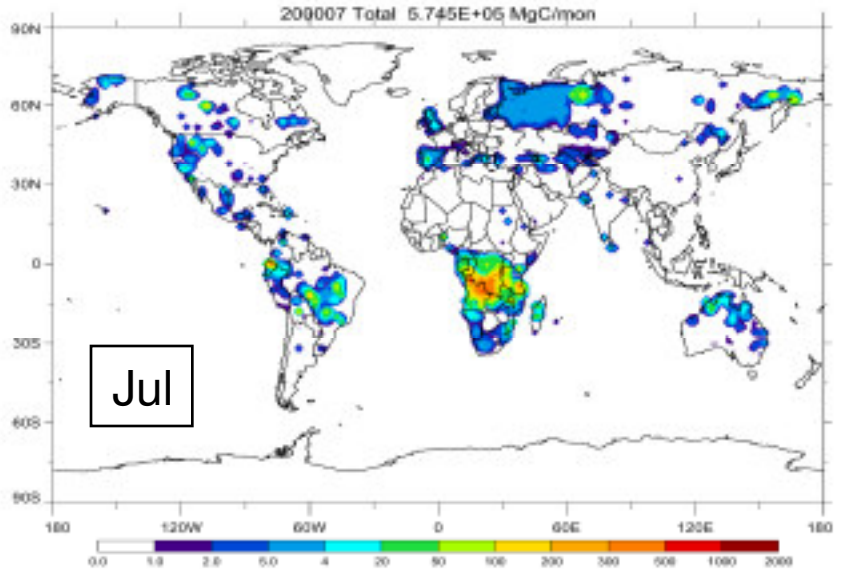
- Current biomass burning emission (SO_2, BC, OC):
  - (a) Duncan et al 2003: Monthly variations based on TOMS aerosol index, ATSR fire-count, and dry biomass burned estimations, 1980 - 2000
  - (b) van der Werf et al. 2004: Monthly variations based on TRMM and ATSR fire data and CASA biogochemical model, 1997 – 2002
- No daily variation available
- No near real time capability

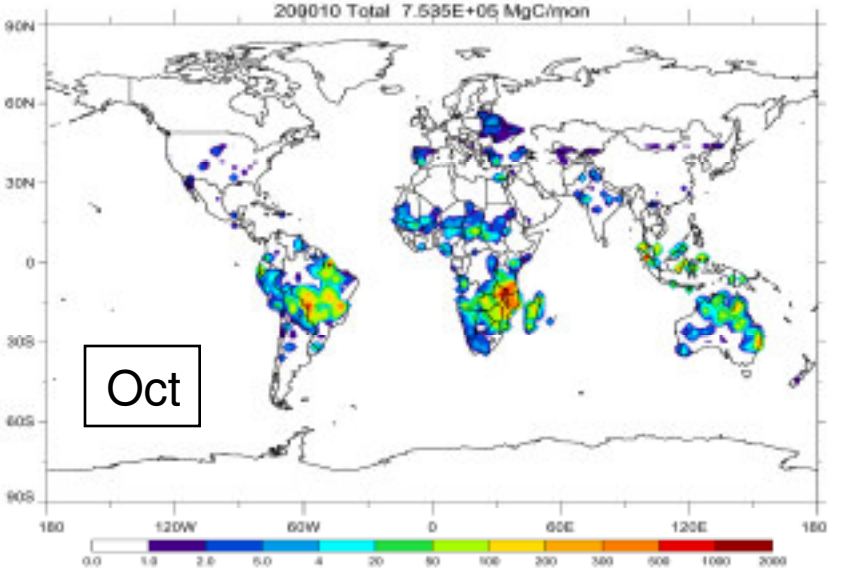
Biomass burning emission of BC in 2000

(Based on Duncan et al. 2003)





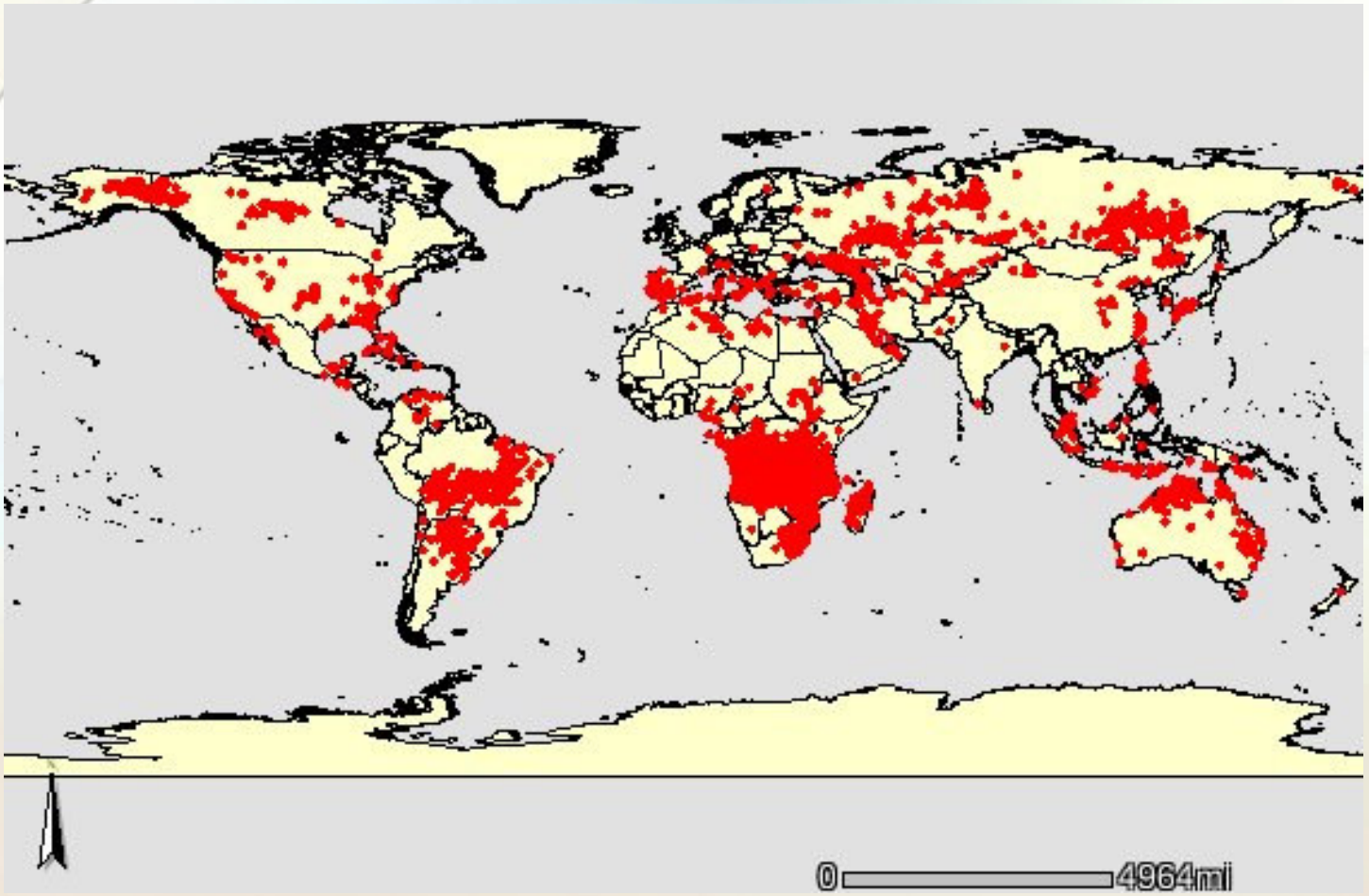




Use MODIS fire data

- **Purpose:**
  - **For continuous input for estimating biomass burning emission**
  - **Hope to get daily or sub-monthly data**
- **MODIS fire data:**
  - **Fire counts: Readily available, but quantitative relationship between fire counts and dry mass burned is very uncertain**
  - **Fire energy: Potentially could be directly used to estimate dry mass burned, but is not available yet.**

Example of MODIS fire map



From MODIS Fire website:

0.25 Degree Climate Modeling Grid Fire Products

Daily and monthly gridded summaries of fire pixels intended for use in regional and global modeling. These products will be released in late 2003 or early 2004.

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Task #2:

Using MODIS land cover and VI data to improve dust source

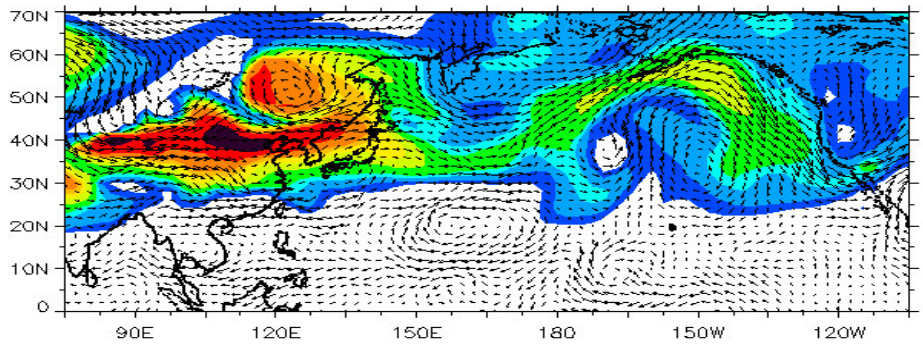
- Current dust source:
  - Ginoux et al 2001: Location of dust source at topographically depressed area with bare soil
  - Vegetation cover based on 1994 AVHRR that do not reflect recent desertification regions

Example from ACE-Asia study

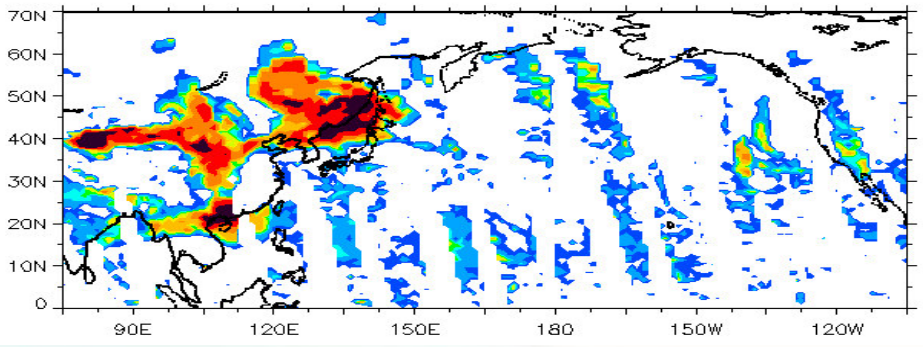
- During ACE-Asia field experiement (spring 2001), the model provided aerosol forecast for flight planning
- The model forecast missed the high concentration of boundary layer dust over the Yellow Sea

Dust Evolution and Trans-Pacific Transport 4/8 – 4/14/01

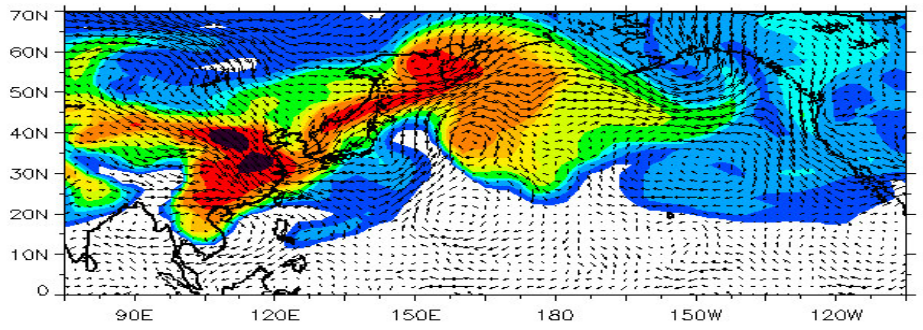
Dust AOT April 8, 2001 GOCART



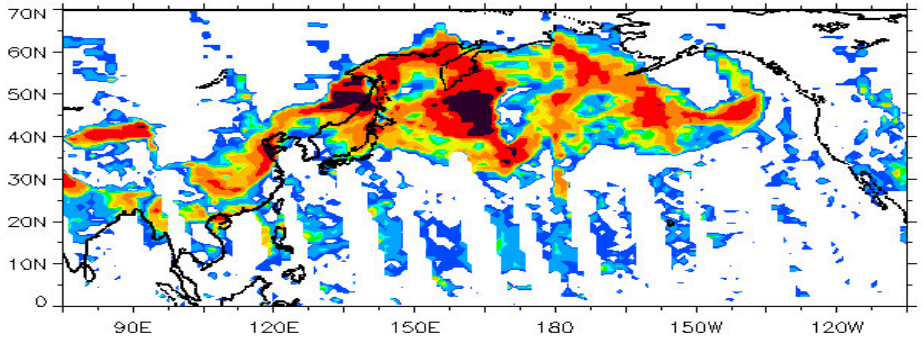
TOMS AI April 8, 2001



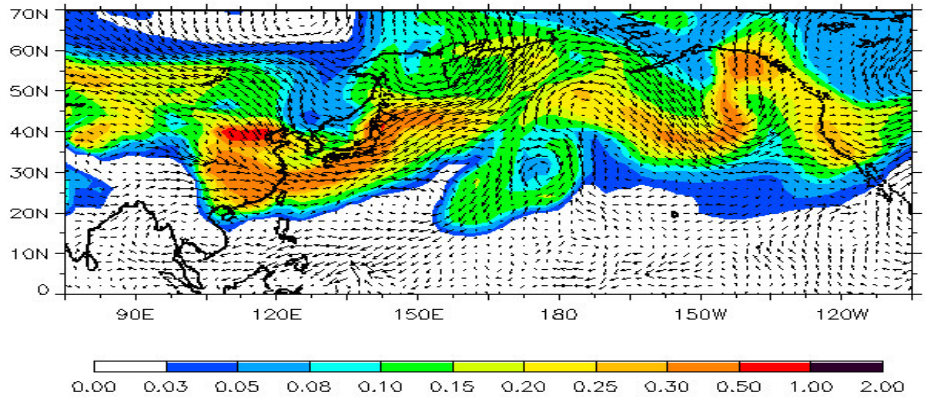
Dust AOT April 11, 2001 GOCART



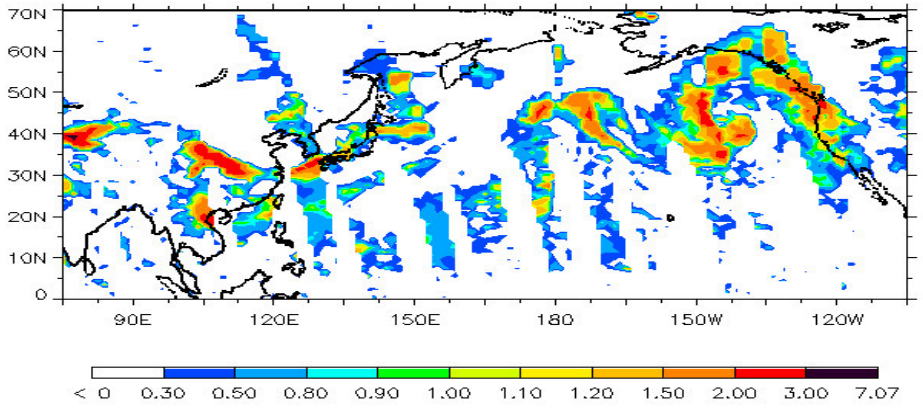
TOMS AI April 11, 2001



Dust AOT April 14, 2001 GOCART

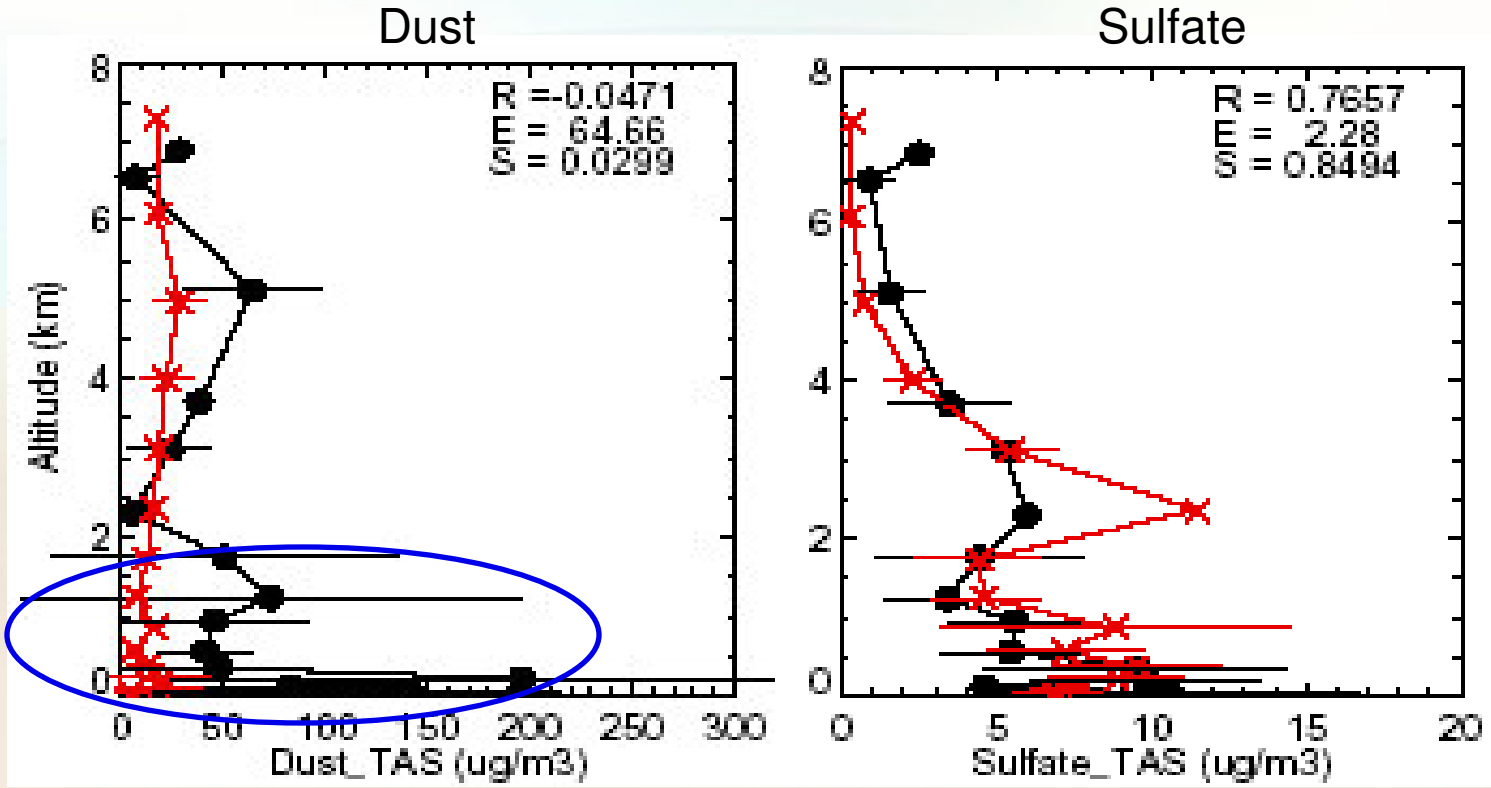


TOMS AI April 14, 2001



Over the Yellow Sea …

GOCART model forecast – The model severely underestimated dust especially in the boundary layer!



Red: model. Black: C-130 observations

What was the problem in the model?

- Recent desertification areas in the Inner Mongolia Province were not included in the model during forecast (they were “grassland” in the 1994 AVHRR map)
- These sources apparently are the major contributors to the heavy dust in the boundary layer off the East Asia coast

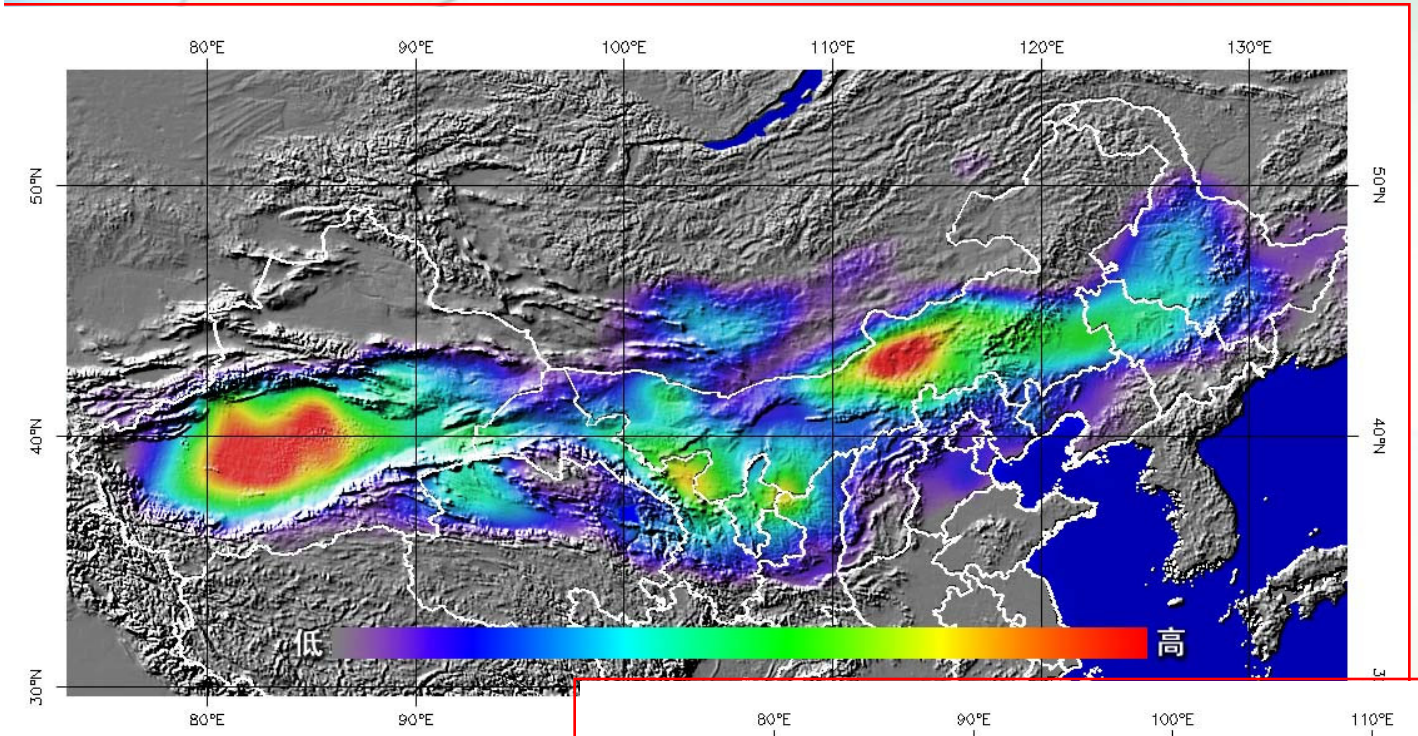
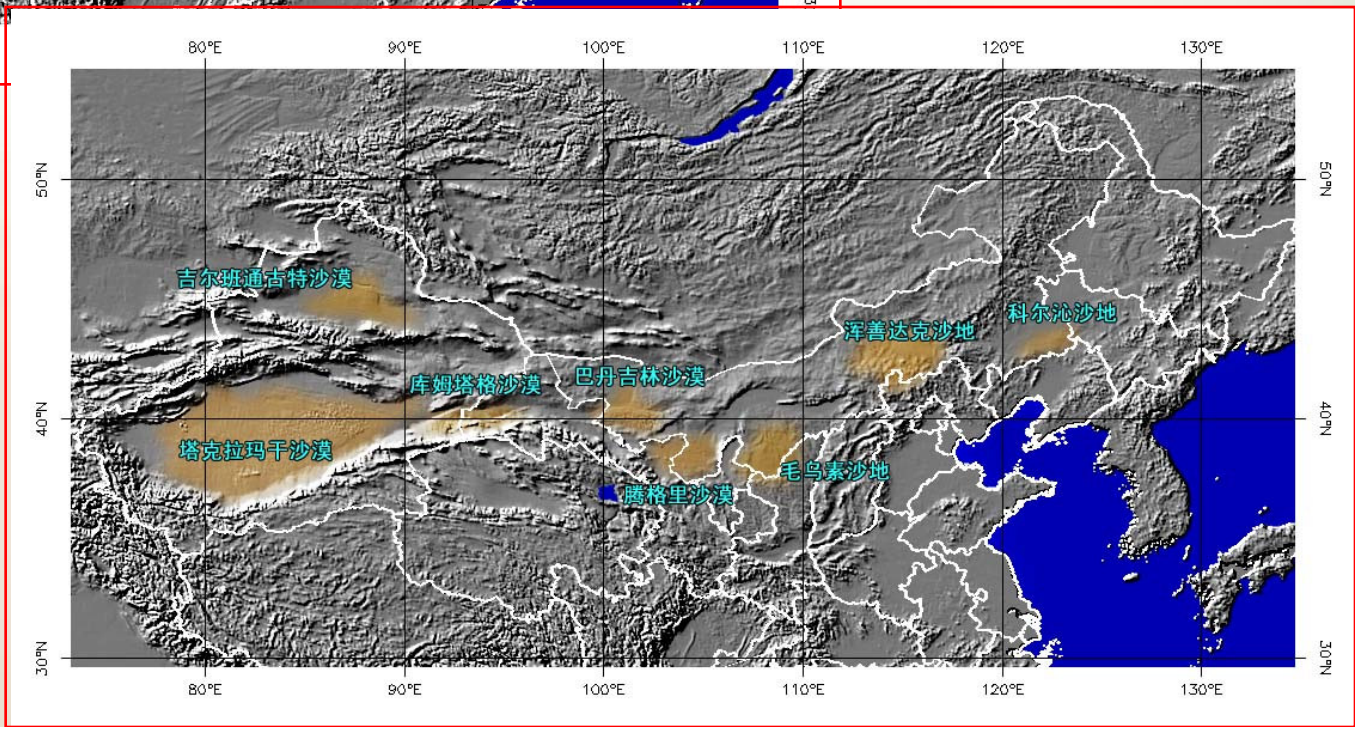


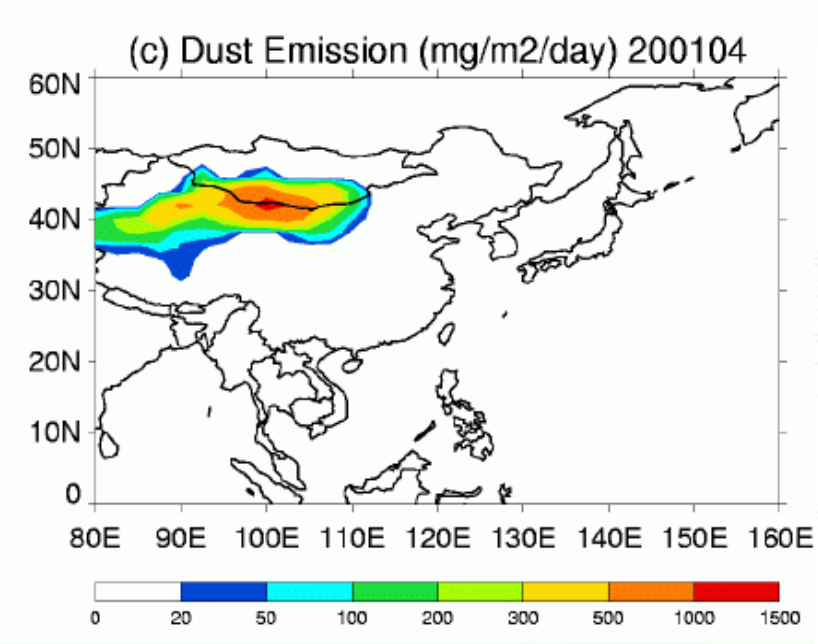
Figure from Chinese Meteorological Administration

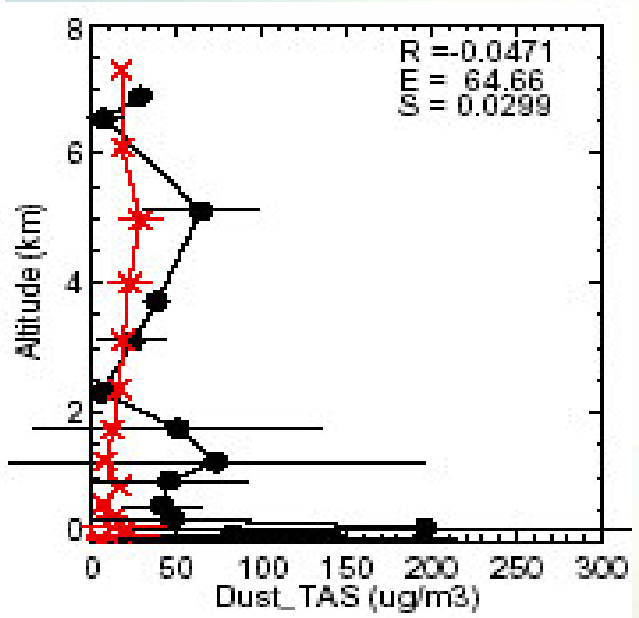
Occurrence frequency of all dust storm in 2001

2001□□□□□□□□□□□□

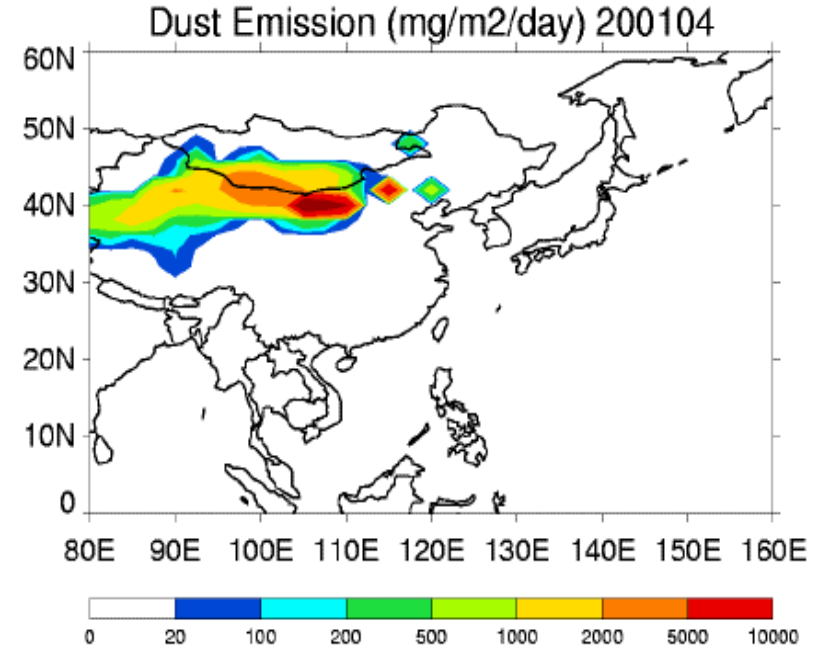


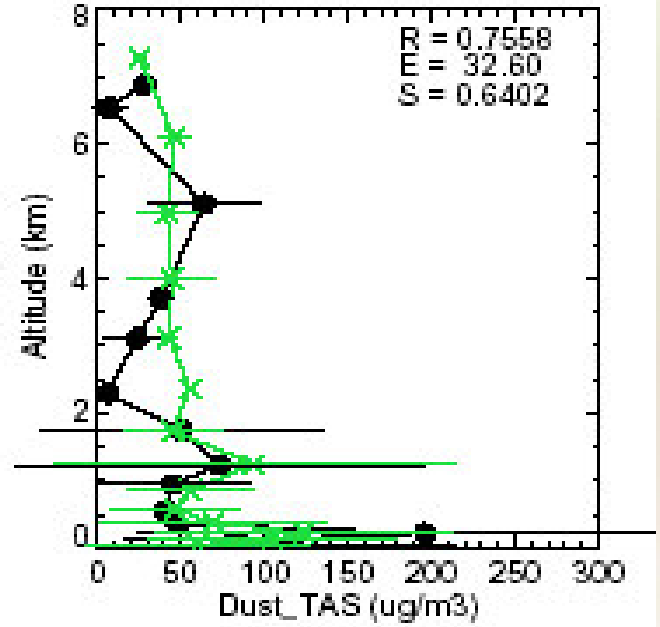
Before …



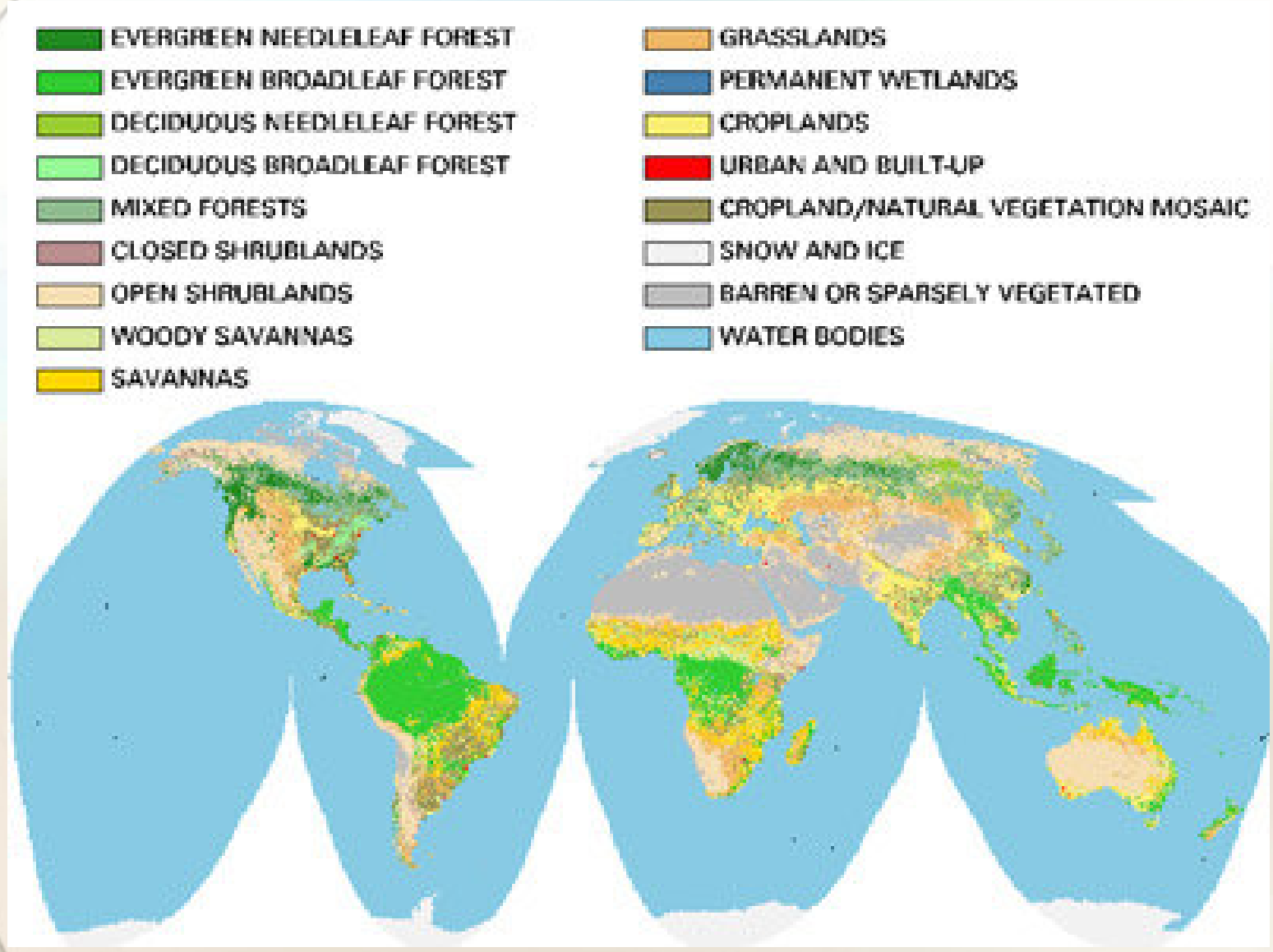


After …

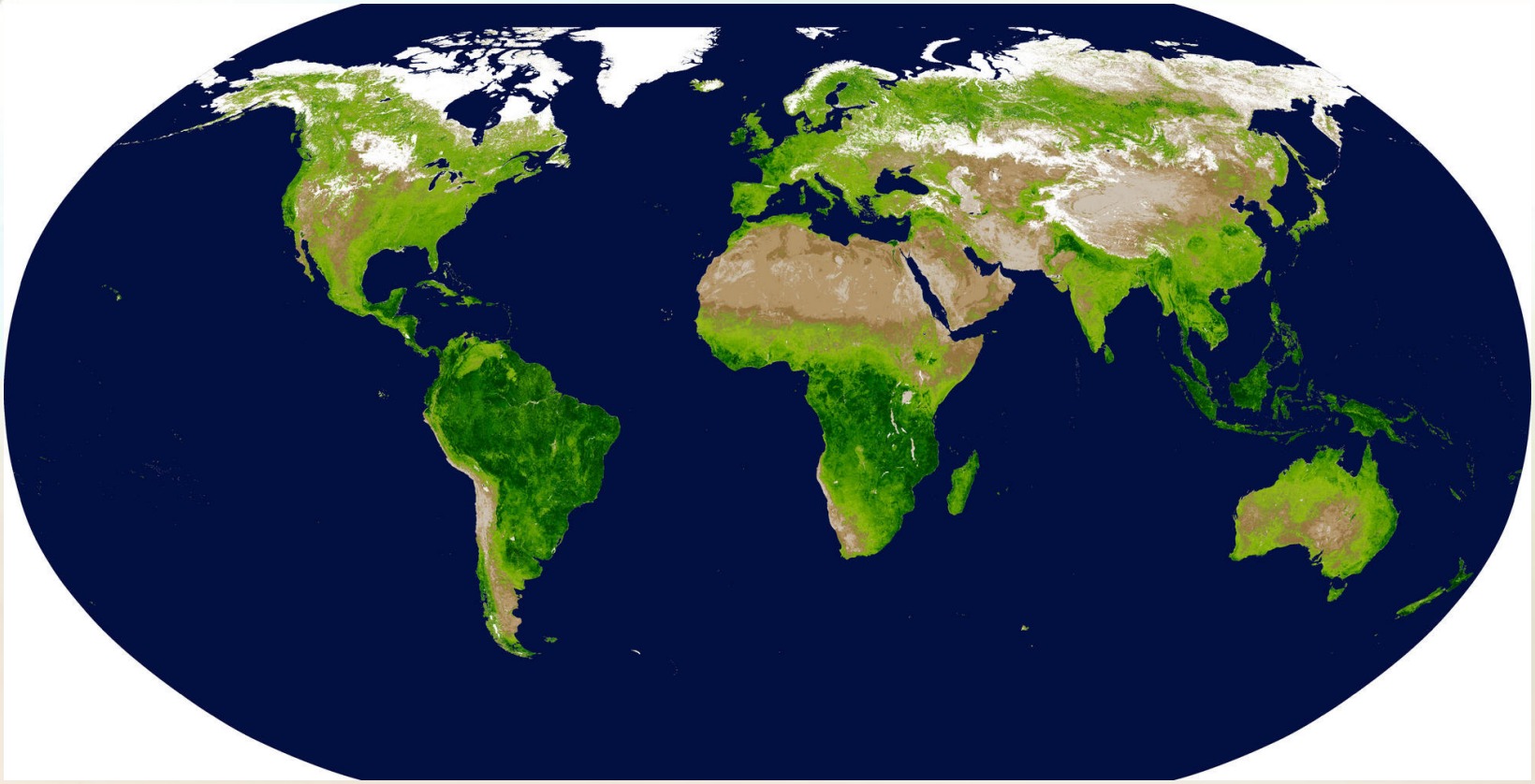




MODIS land cover data

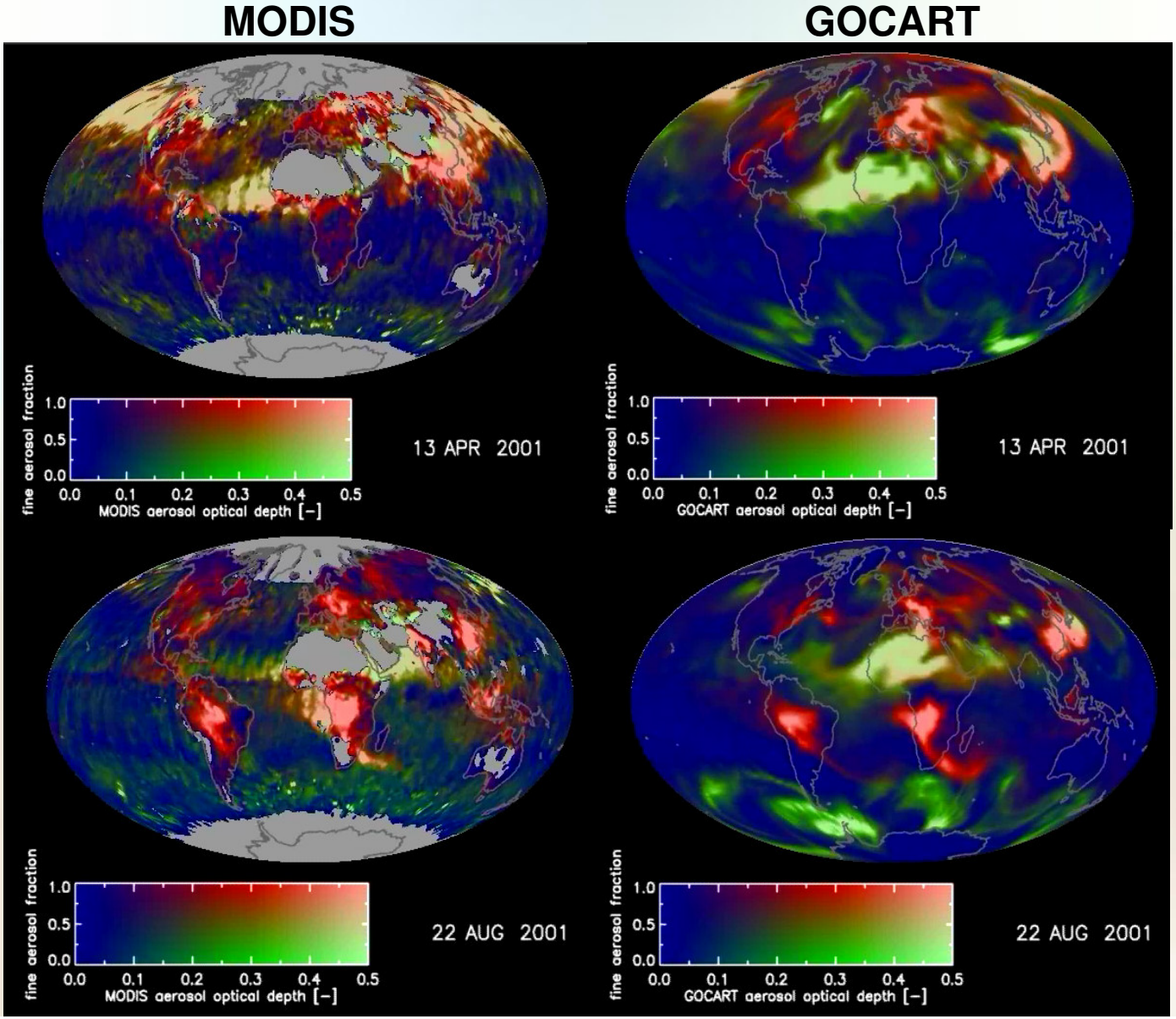


MODIS NDVI data

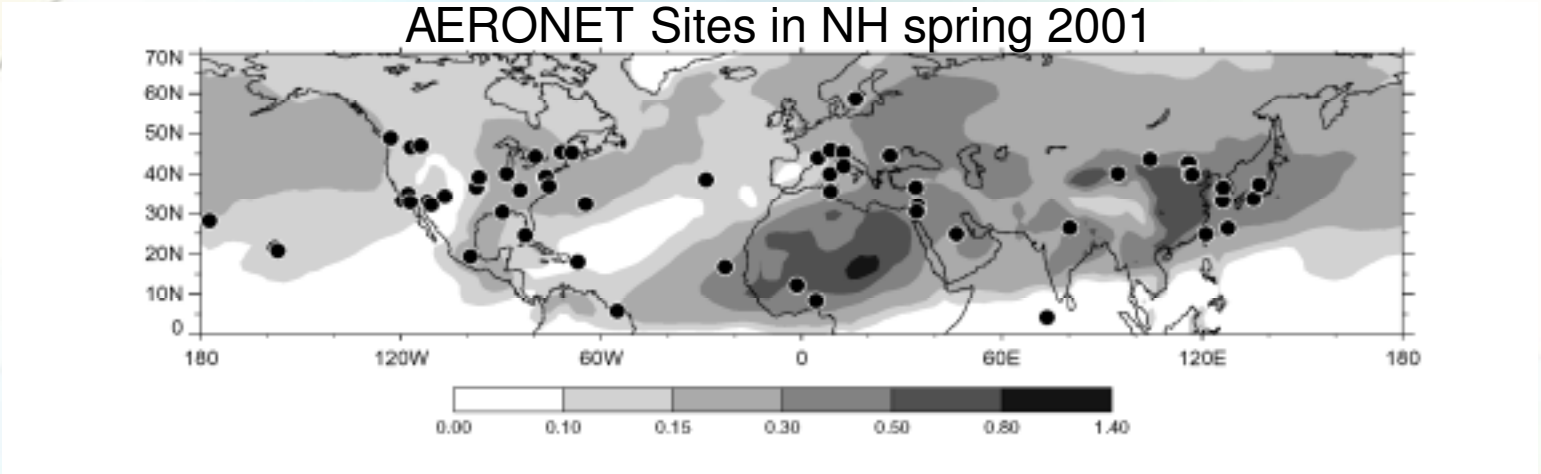


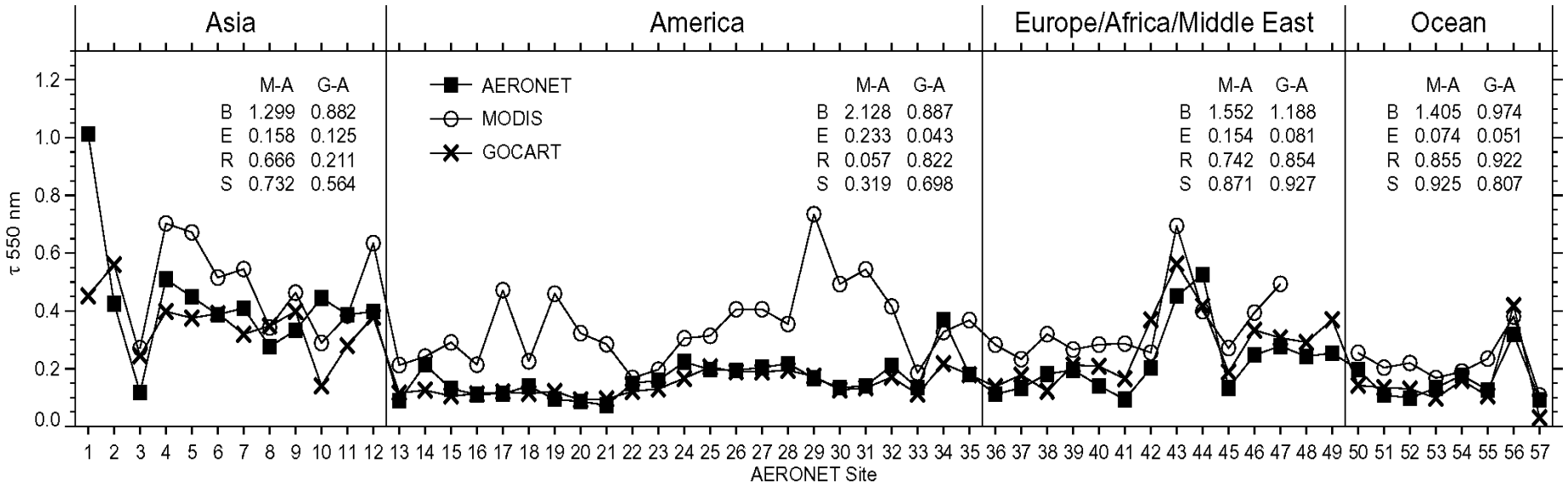
Task #3:

Comparing aerosol distributions with MODIS and other data



Comparisons between MODIS, AERONET, GOCART





All sites - M-A: B=1.642 E=0.185 R=0.596 S=0.765 G-A: B=0.966 E=0.075 R=0.800 S=0.896

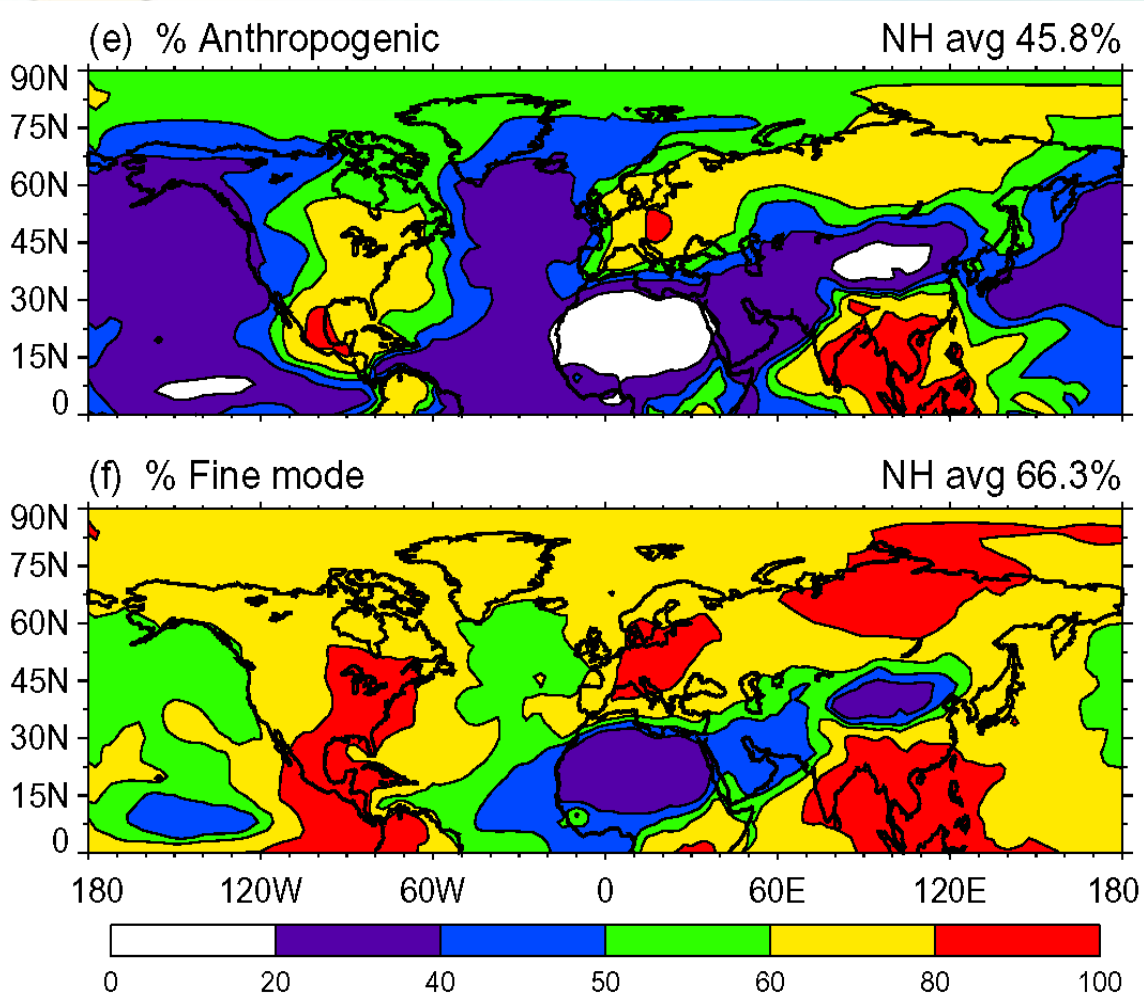
A few conclusions (problems) from April 2001 study:

- MODIS over land retrieval needs to improve on
  - Removing snow/ice interference
  - Better dealing with surface reflectance
- Model needs to improve on
  - Dust sources and emissions over Asia (inferred from comparison with AERONET)
  - Understanding "missing source" at tropical ocean

Chin et al., submitted to JGR, 2004

Fine mode vs. anthropogenic fractions

% of AOT 550 nm April 2001



Not all fine mode aerosols are anthropogenic:

•In the N.H. April 2001, about 20% of AOT are from fine mode natural sulfate, OC, fine mode dust and sea-salt

• Assuming all fine mode aerosols are anthropogenic will overestimate the anthropogenic contribution

Summary

- We will use the MODIS land data to improve biomass burning and dust emissions
- MODIS aerosol data and model can help each other to identify problems and improve data quality and model processes
- AERONET and other in-situ measurements provide important reference
- At lease 3 independent efforts have been made within one year on MODIS-GOCART aerosol assimilation (Georgia Tech, U. Maryland, Colorado State), and several more are in progress. Therefore, improvements of both MODIS and GOCART will have large implications

Schematic of EOS investigation