Acknowledgments:

IMPROVE data
MODIS data
NASA funding

Intercontinental Transport of Aerosols: Implications for Regional Air Quality

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Introduction

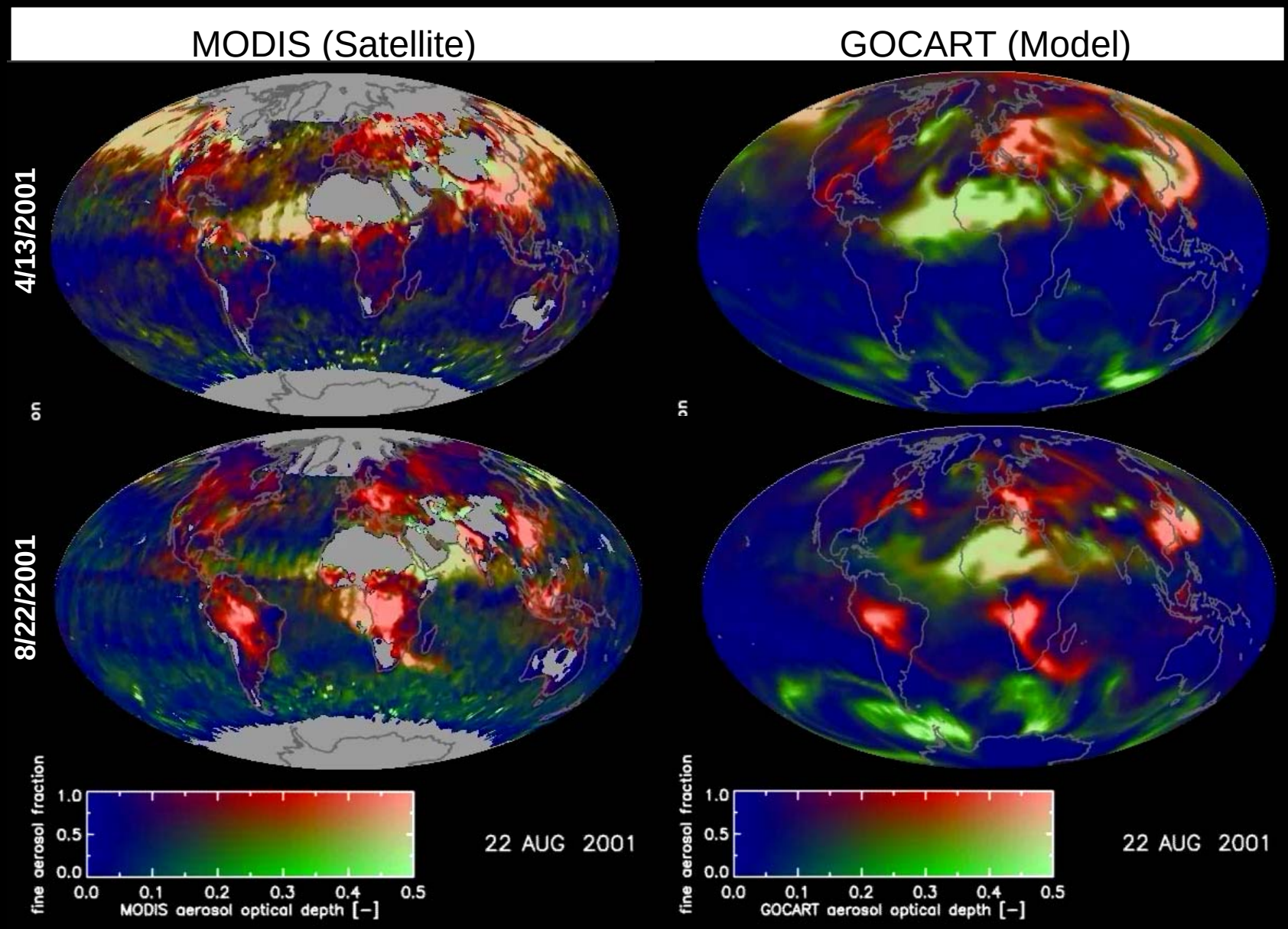
- Concentration of aerosol particles, also known as particulate matter (PM), is one of the major components that determine ambient air quality
- While local and regional emission sources are the main cause of air pollution problems, aerosols can be transported on a hemispheric or global scale
- Current US air quality standards for PM:

AQI values, categories, and pollutant concentration values for ozone, $PM_{2.5}$, and PM_{10} (source: EPA, http://www.epa.gov/airnow/aqibroch/aqi.html)

AQI	Air Quality	Color Scale	Ozone		$PM_{2.5}$	PM_{10}
			(8 hr ppb)	(1 hr ppb)	($\mu g\ m^{-3}$)	($\mu g\ m^{-3}$)
0 – 50	Good	Green	0 – 64	-	0 – 15	0 – 54
51 – 100	Moderate	Yellow	65 – 84	-	16 – 40	55 – 154
101 – 150	Unhealthy for sensitive groups	Orange	85 – 104	125 – 164	41 – 65	155 – 254
151 – 200	Unhealthy	Red	105 – 124	165 – 204	66 – 150	255 – 354
201 – 300	Very unhealthy	Purple	125 – 374	205 – 404	151 – 250	355 – 424

Long-range transport of aerosols

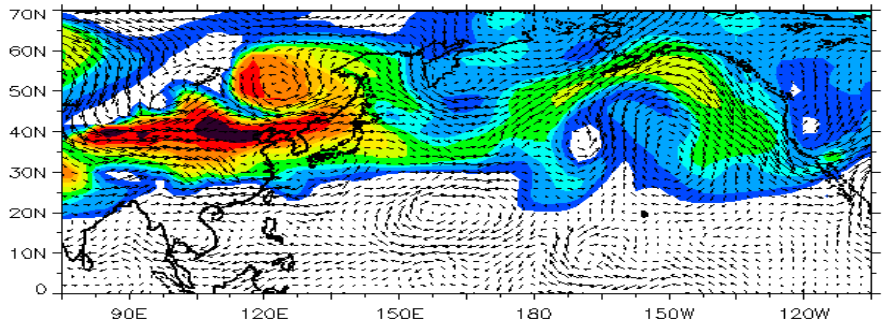
In memory of Yoram Kaufman



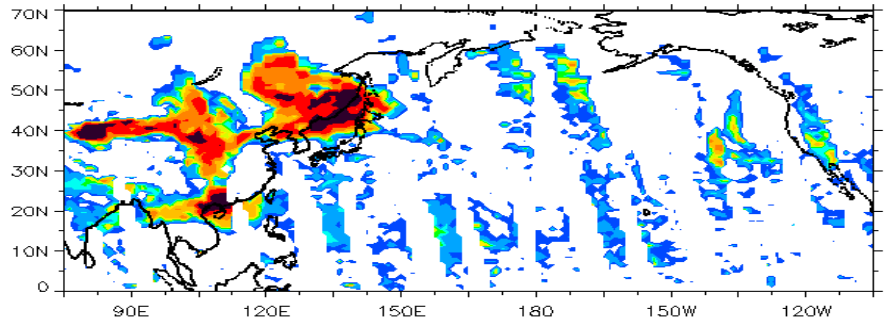
Trans-Pacific Transport of Dust

Simulated by GOCART (model) Observed by TOMS (satellite)

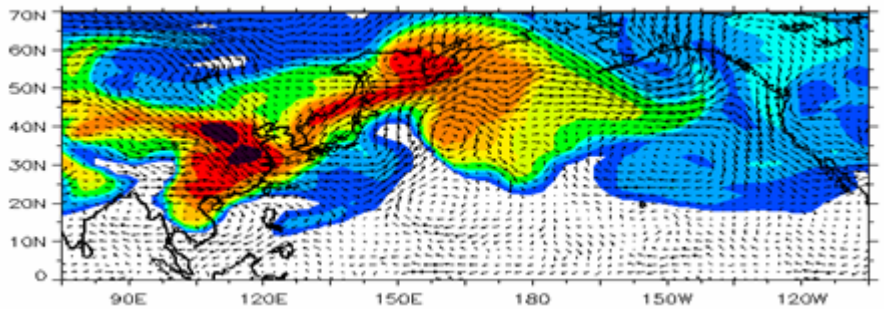
Dust AOT April 8, 2001 GOCART



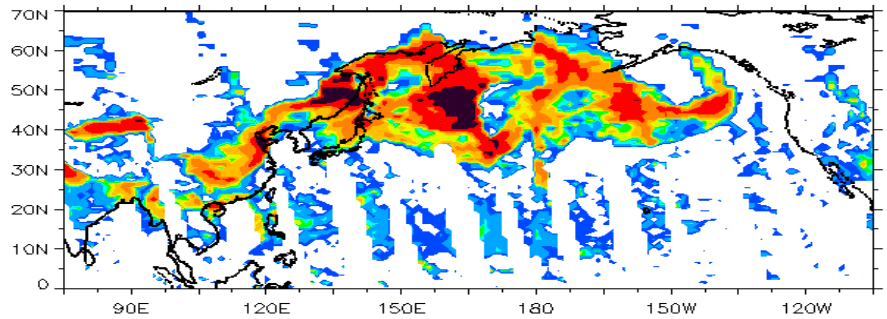
TOMS AI April 8, 2001



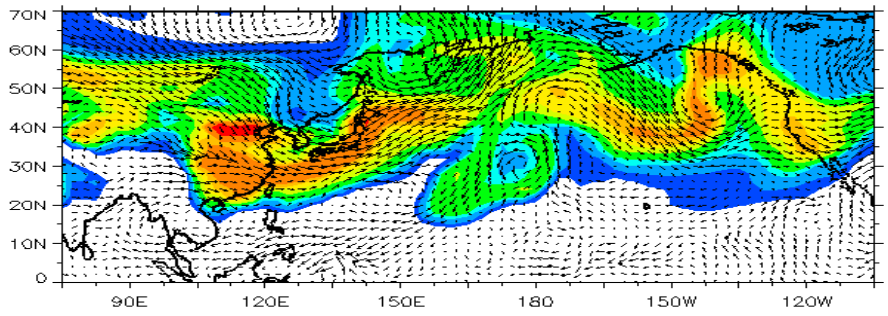
Dust AOT April 11, 2001 GOCART



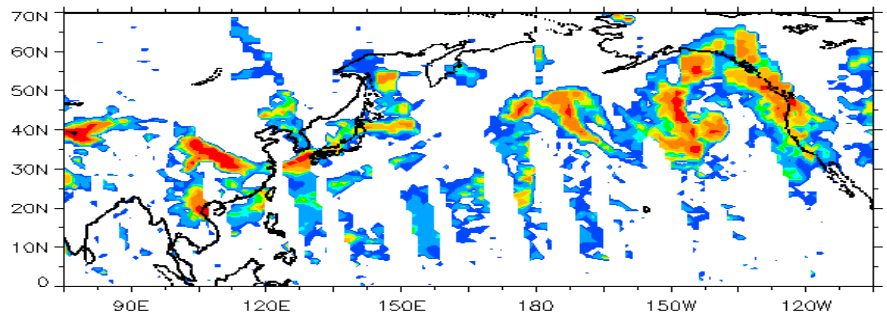
TOMS AI April 11, 2001

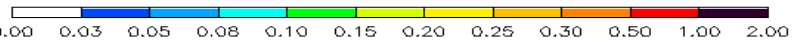


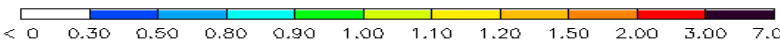
Dust AOT April 14, 2001 GOCART



TOMS AI April 14, 2001





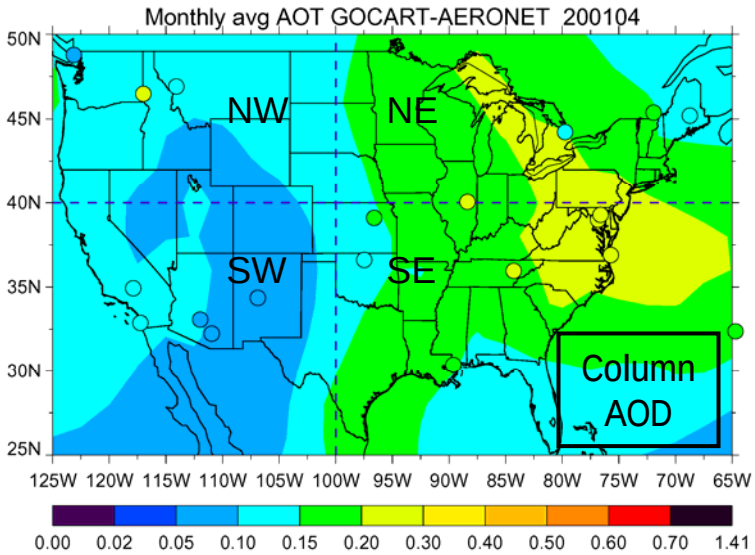


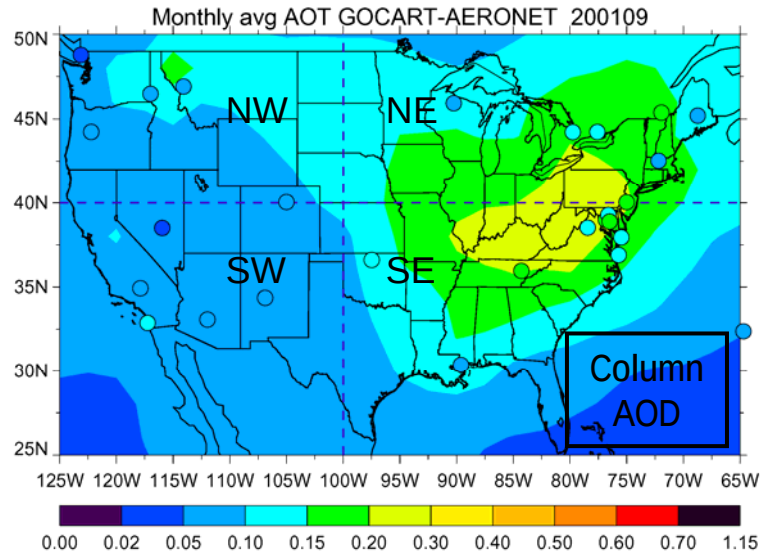
Introduction (2)

- We use the global model GOCART to answer the following questions:
  - What is the contribution of regional anthropogenic emission to the PM2.5 concentrations over the U.S.?
  - What is the contribution of long-range transport to the surface PM2.5 concentrations over the U.S.?
  - What is the seasonal variation of the "background" PM2.5?

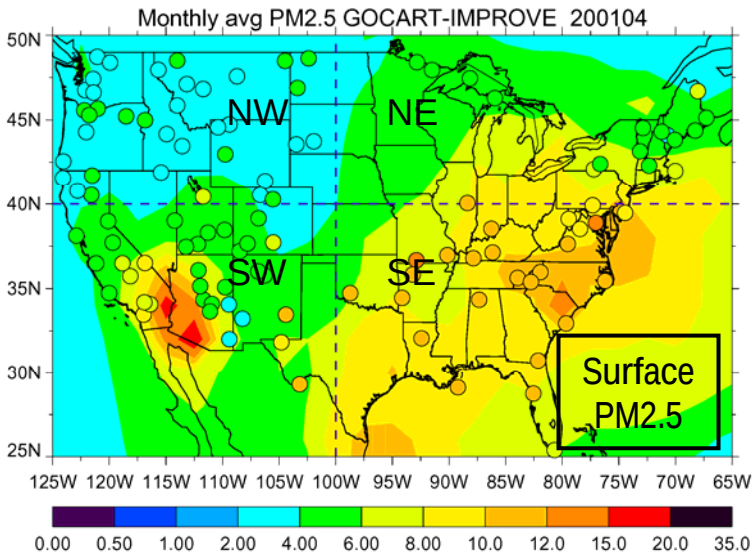
GOCART vs. AERONET & IMPROVE:

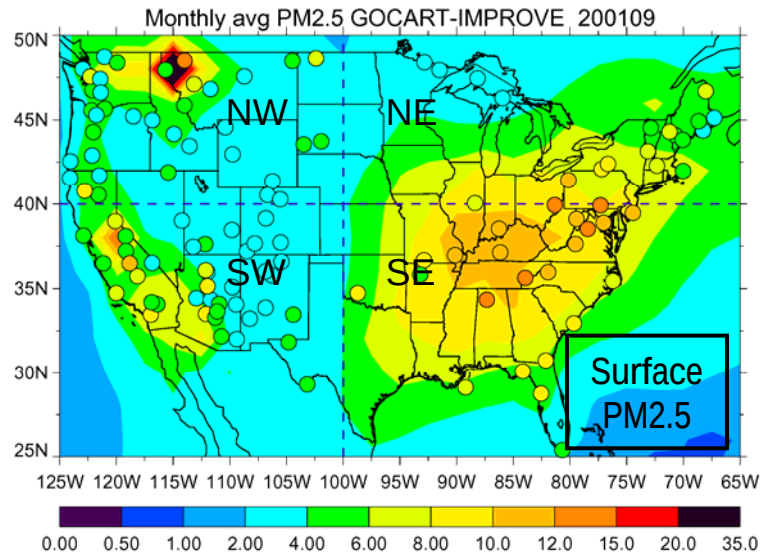
GOCART-AERONET





GOCART-IMPROVE

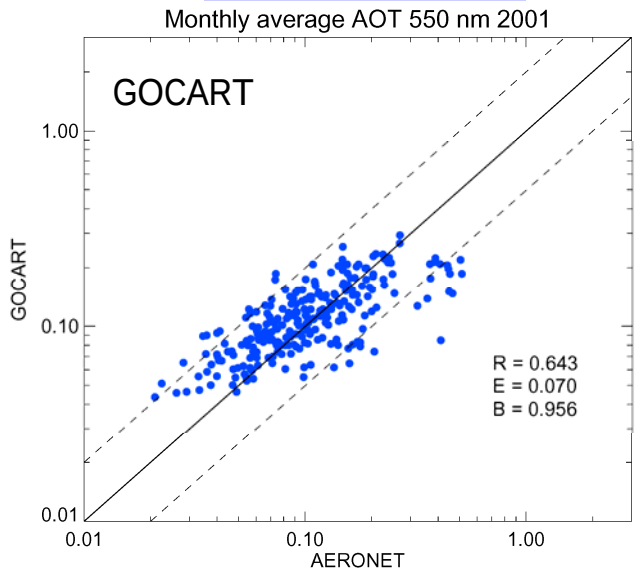




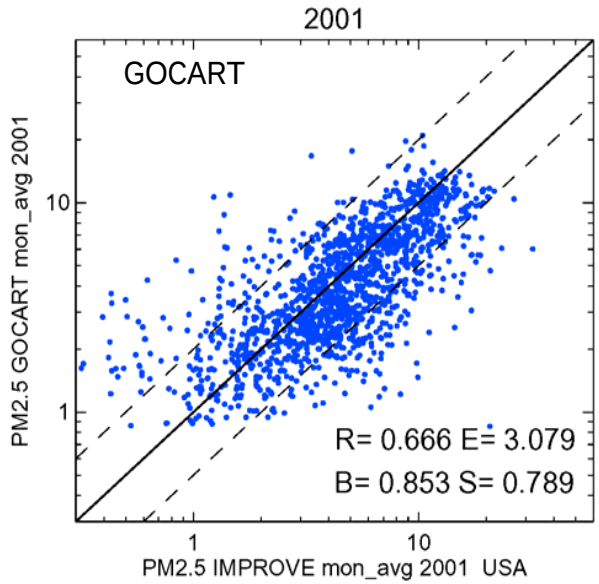
Overall comparison:

R = corr. coef.
E = RMSE
B = mean bias

Column AOD



Surface PM2.5



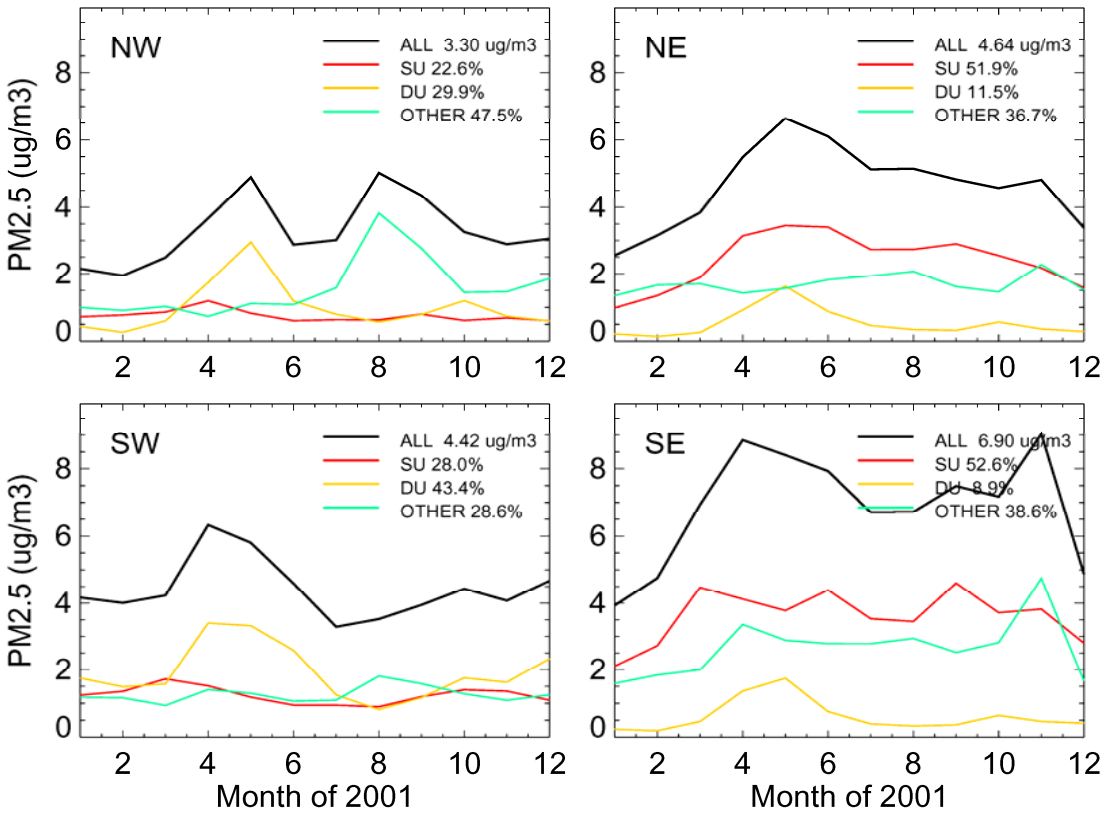
- Half glass empty: The don't agree very well.
- Half glass full: They agree to within a factor of 2 in most cases. At least the model and data show similar spatial distributions for both AOD and PM2.5.

PM2.5 annual cycle in the U.S.

- PM2.5 composition
  - Sulfate
  - Fine mode dust
  - Other (BC, OC, Fine mode sea-salt)

NW:
- About 30% of PM2.5 is dust, max. in spring
- About 47% is carbonaceous, max. in late summer/early fall

SW:
- About 43% of PM2.5 is dust, dominating in spring



Eastern:
- About 10% of PM2.5 is dust
- Maximum in spring

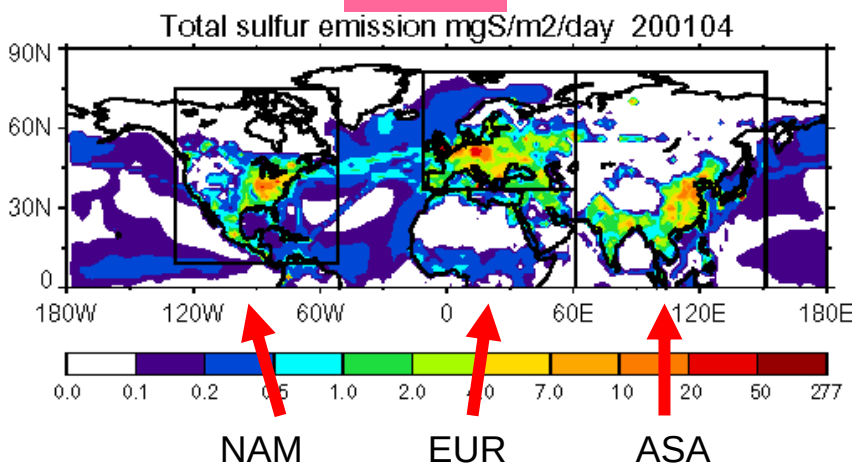
Monthly average surface PM2.5 concentrations in 2001 from the GOCART model. Annual average concentrations and contributions from different components are shown.

Model Experiments
(for US air quality study)

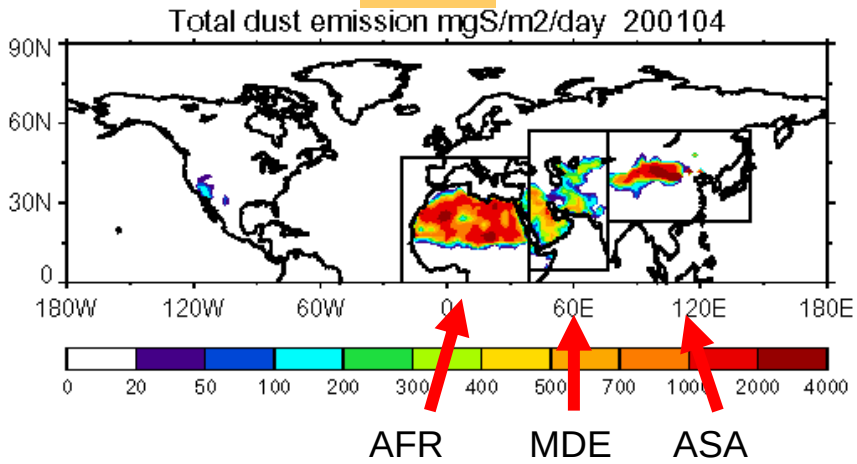
	Exp.	Definition	Model setup
	ALL	PM2.5 from all sources, including anthropogenic, biomass burning, and natural emissions	Standard model run
	BKG	Background PM2.5 – from sources we cannot control, e.g. dust, volcanoes, trees, long-range transport from other regions	Model run without North America anthropogenic emissions
	NAT	PM2.5 from natural sources only	Model run without all anthropogenic emission
SU BC OC	NAM ASA EUR	Pollution aerosols from North America (NAM), Asia (ASA), or Europe (EUR) anthropogenic emissions	Differences between standard run and the run without anthropogenic emissions in a selected region
DU	AFR ASA MDE	Dust aerosol from Africa (AFR), Asia (ASA), or Middle East (MDE)	Differences between standard run and the run without emissions in a selected region

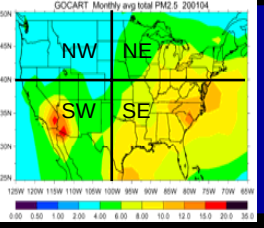
Major Aerosol Source Regions

Sulfur



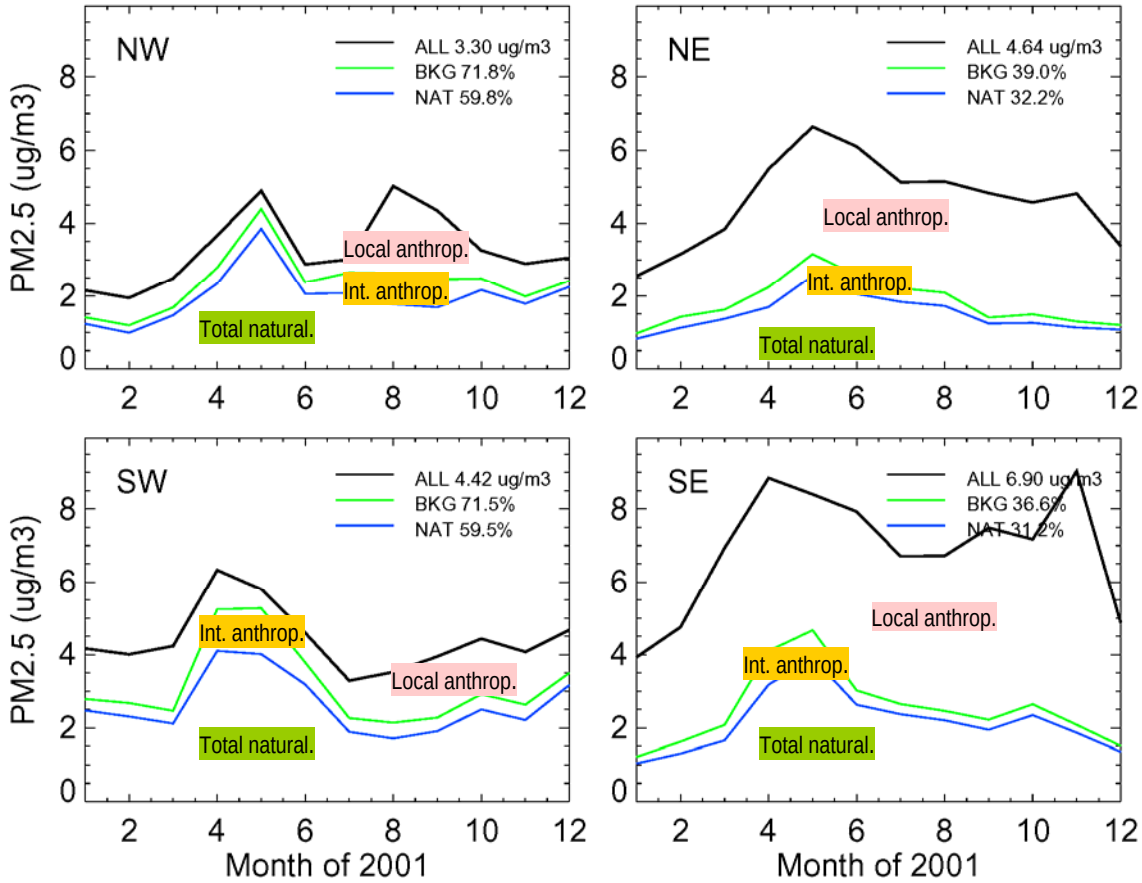
Dust





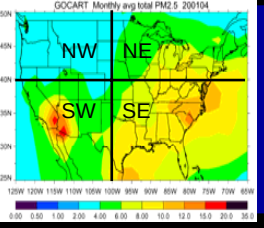
Surface PM2.5 Concentrations

Western:
- About 70% PM2.5 is "background"
- Nearly 60% is "natural" (dust, biogenic aerosols)



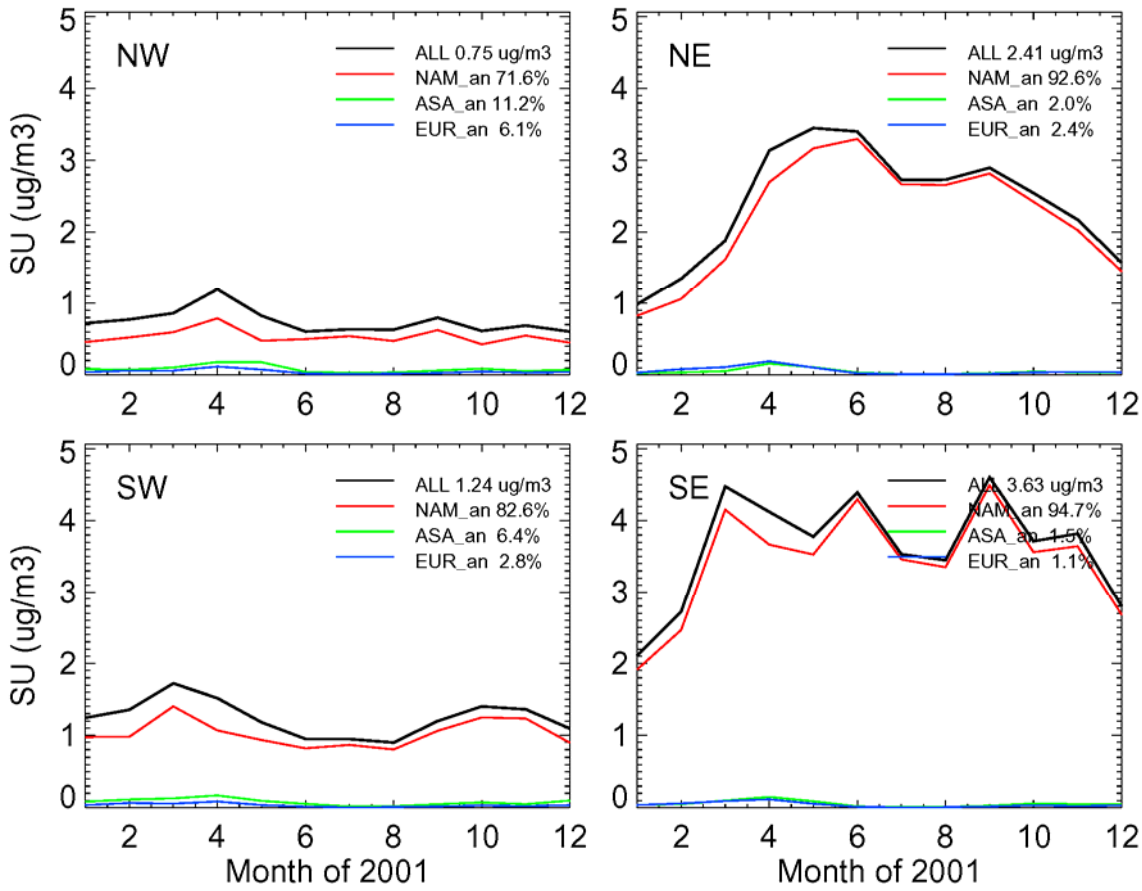
Eastern:
- Less than 40% PM2.5 is "background"
- Nearly 1/3 is "natural" (dust, biogenic aerosols)

Monthly average surface layer PM2.5 concentrations in 2001 from the GOCART model (see earlier pages for experiment definition). Annual average concentrations and contributions from different sources are shown.
ALL – BKG = NAM pollution
BKG – NAT = pollution from other regions



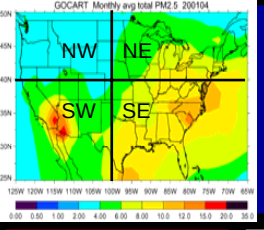
Surface Sulfate Concentrations

Western:
- 70 – 80% sulfate is from NAM local/ regional pollution



Eastern:
- More than 90% sulfate is from NAM local/ regional pollution

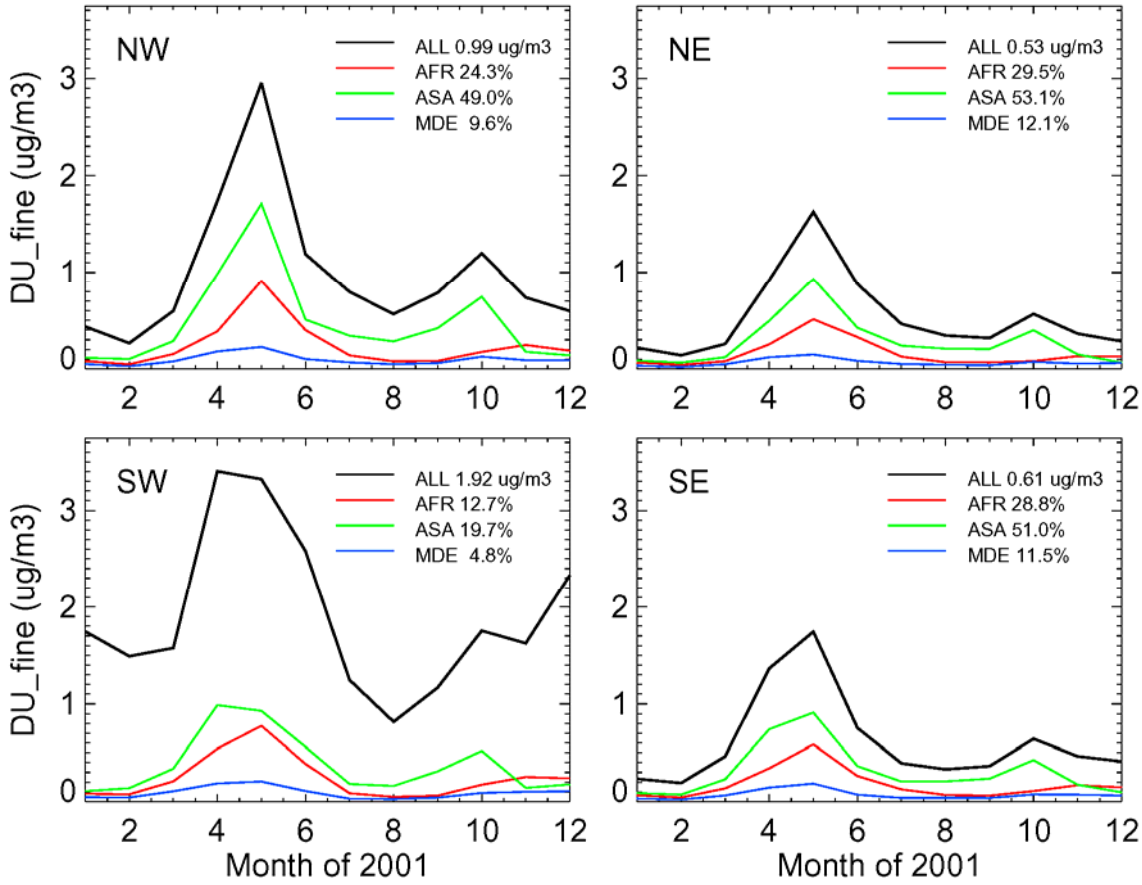
Monthly average surface layer sulfate concentrations in 2001 from the GOCART model (see earlier pages for experiment definition). Annual average concentrations and contributions from different sources are shown.



Surface Fine Mode Dust Concentrations

NW:
- 1/2 fine mode dust is from Asia, 1/4 from Africa

SW:
- About 60% fine mode dust is “local” (20% Asia, 13% Africa, 5% Middle East



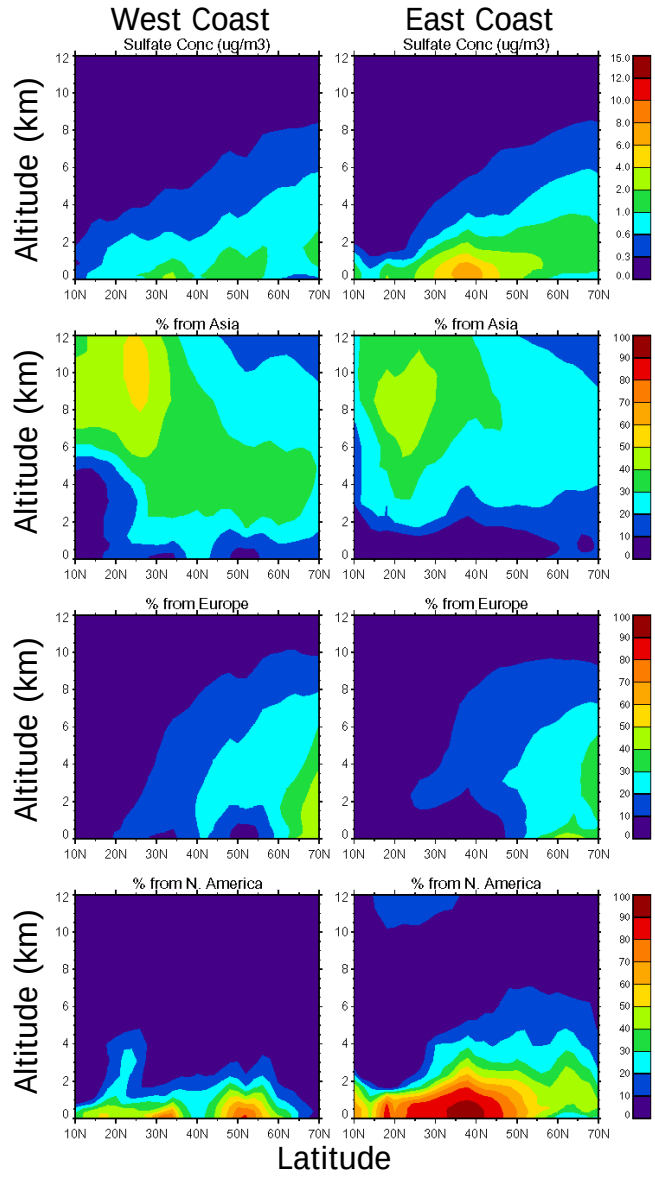
Eastern:
- About 1/2 fine mode dust is from Asia
- Nearly 30% fine mode dust is from Africa

Monthly average surface layer find mode dust concentrations in 2001 from the GOCART model (see earlier pages for experiment definition). Annual average concentrations and contributions from different sources are shown.

Hemispheric Transport – How do the "foreign sources" affect US air quality? (April 2001 as an example)

Sulfate Over North America:

- Most sulfate stays in the boundary layer
- Pollution from Asia can travel around the hemisphere at higher altitudes above BL
- European pollution makes its way over N. America at higher latitudes
- In the BL over North America, most sulfate is from is own regional source



$SO_4^=$ µg m^{-3}

% from Asia

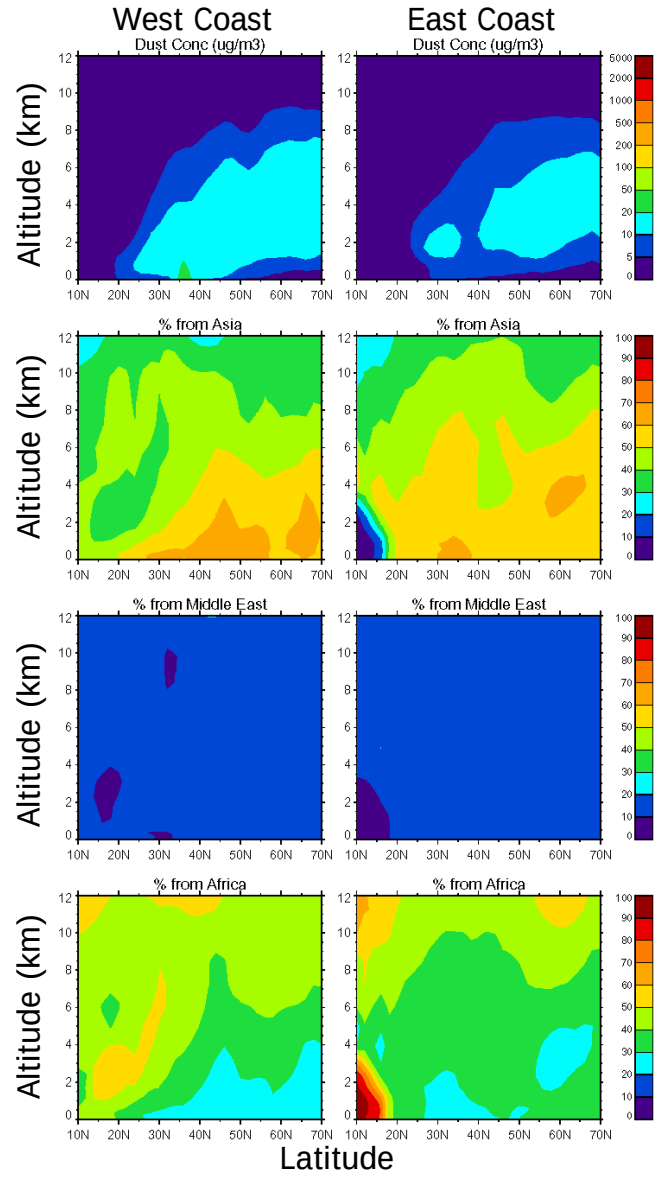
% from Europe

% from N America

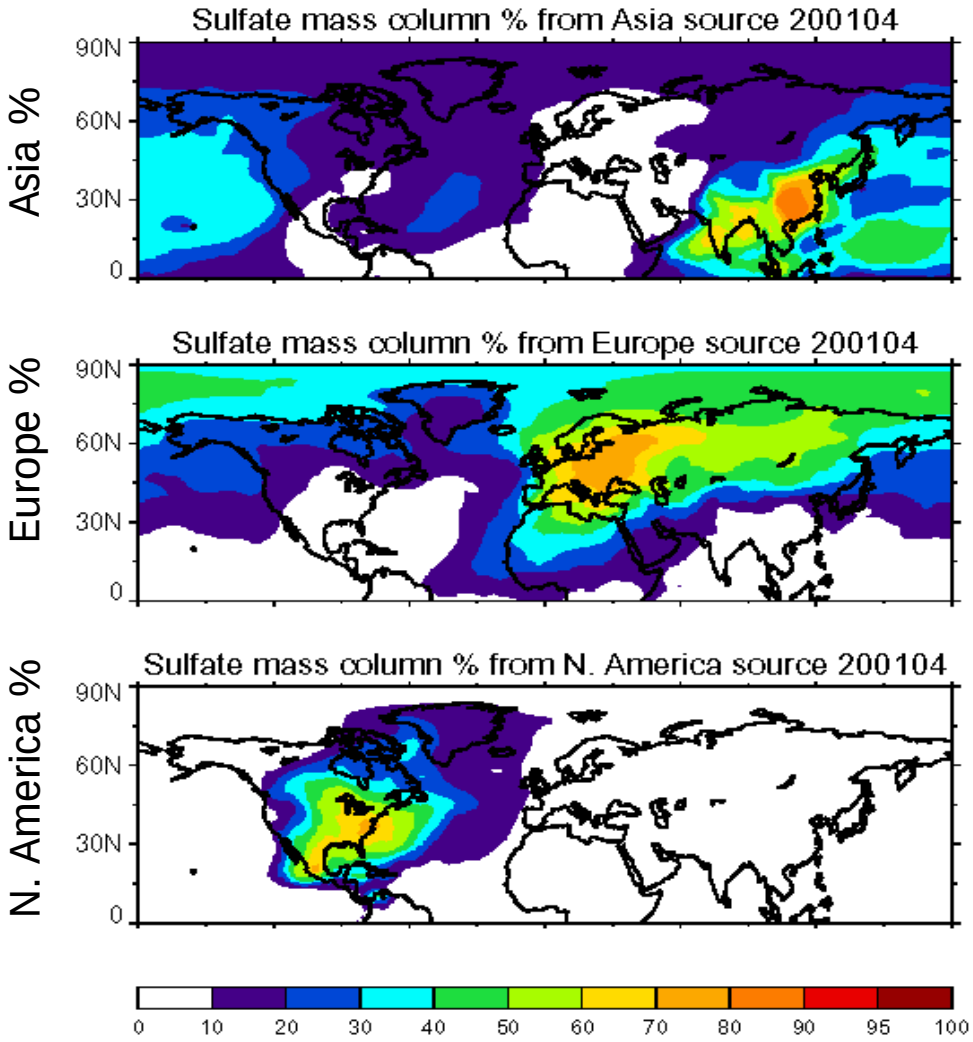
Hemispheric Transport – How do the "foreign sources" affect US air quality? (April 2001 as an example)

Dust Over North America:

- Dust plume has broad vertical extension above the BL
- Most dust below 6 – 7 km is from Asia
- Dust from the Middle East contributes to about 10% dust loading
- African dust is an important contributor to the dust level in the tropics and at high altitudes above 6 – 7 km



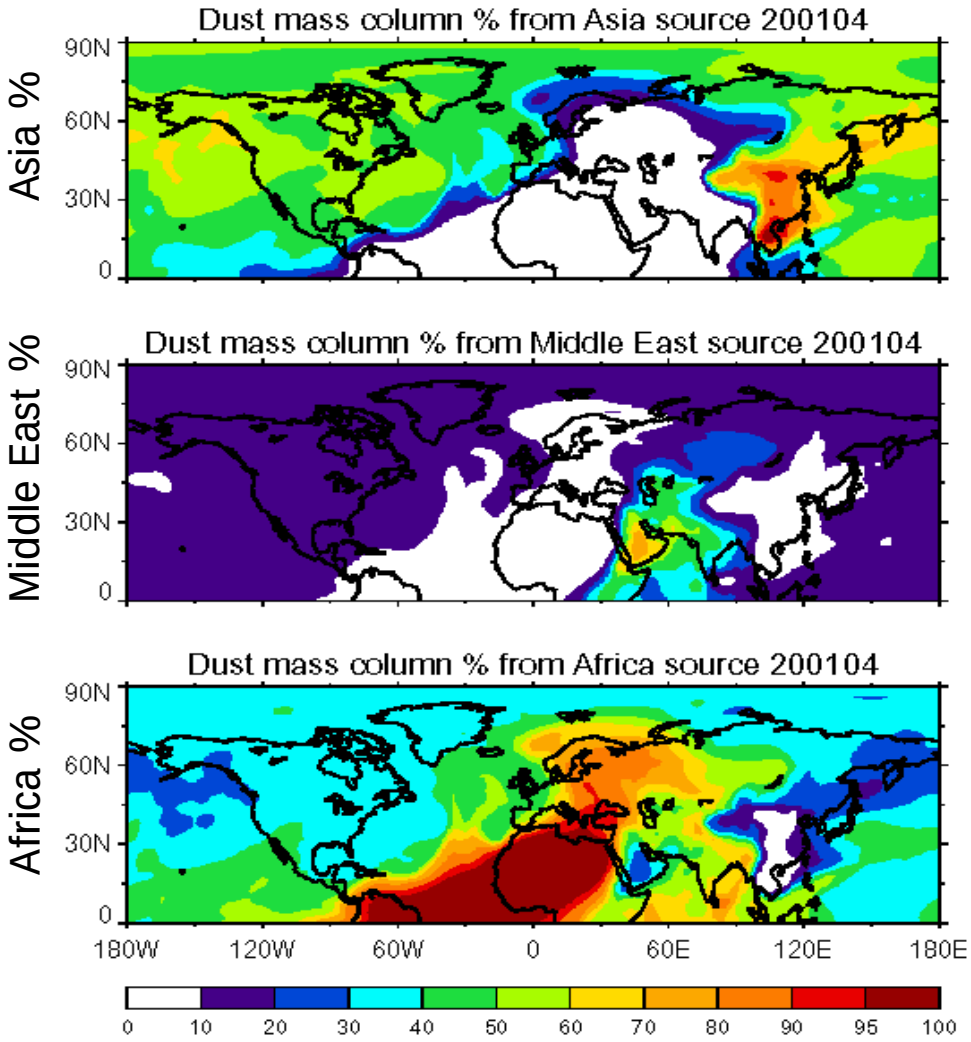
Contributions of pollution (sulfate) aerosols from different source regions



Total column:

- Asia source dominates sulfate over Asia (south of 40N) and contributes 30-50% over the Pacific
- European source dominates sulfate over Europe, Eurasia, and Arctic
- North America source controls sulfate over North America and western North Atlantic

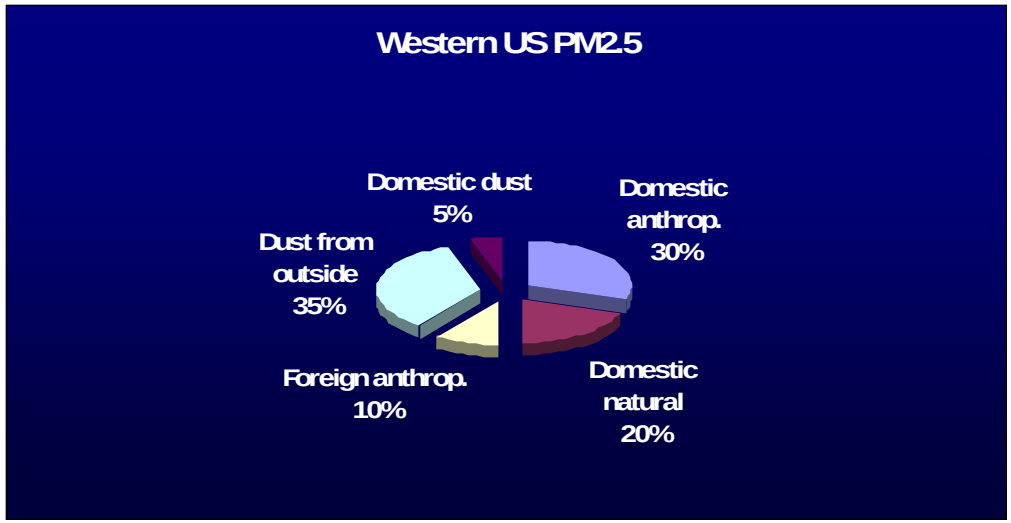
Contributions of dust aerosols from different source regions



Total column:

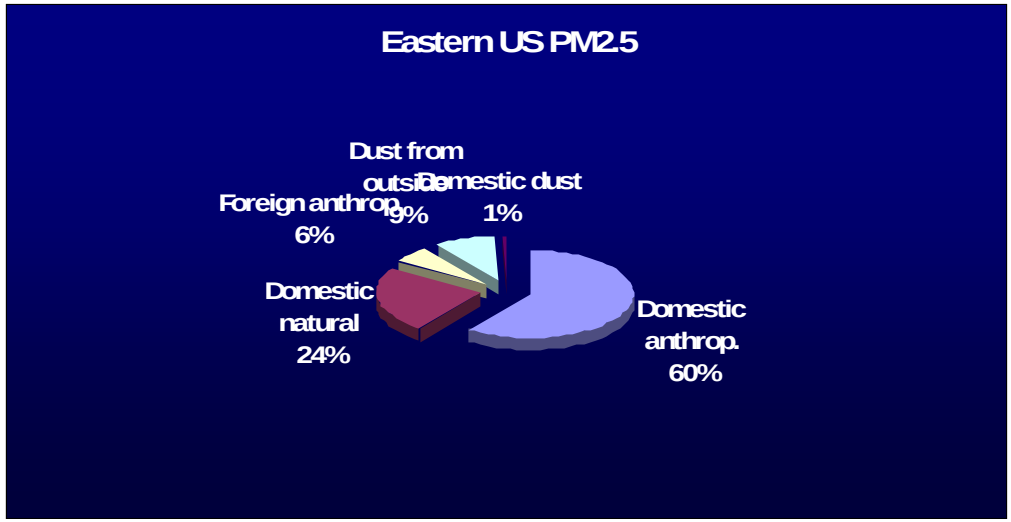
- Asia source dominates dust over eastern Asia, North Pacific, North America, and extra tropical North Atlantic
- Middle East source is important mostly over its own region
- Africa source controls dust loading over Africa, Europe, western Asia, and tropical oceans

Conclusions



Western US PM2.5:
Annual average 3.3 -4.4 μg m^{-3}
North America source 55%
From other regions 45%

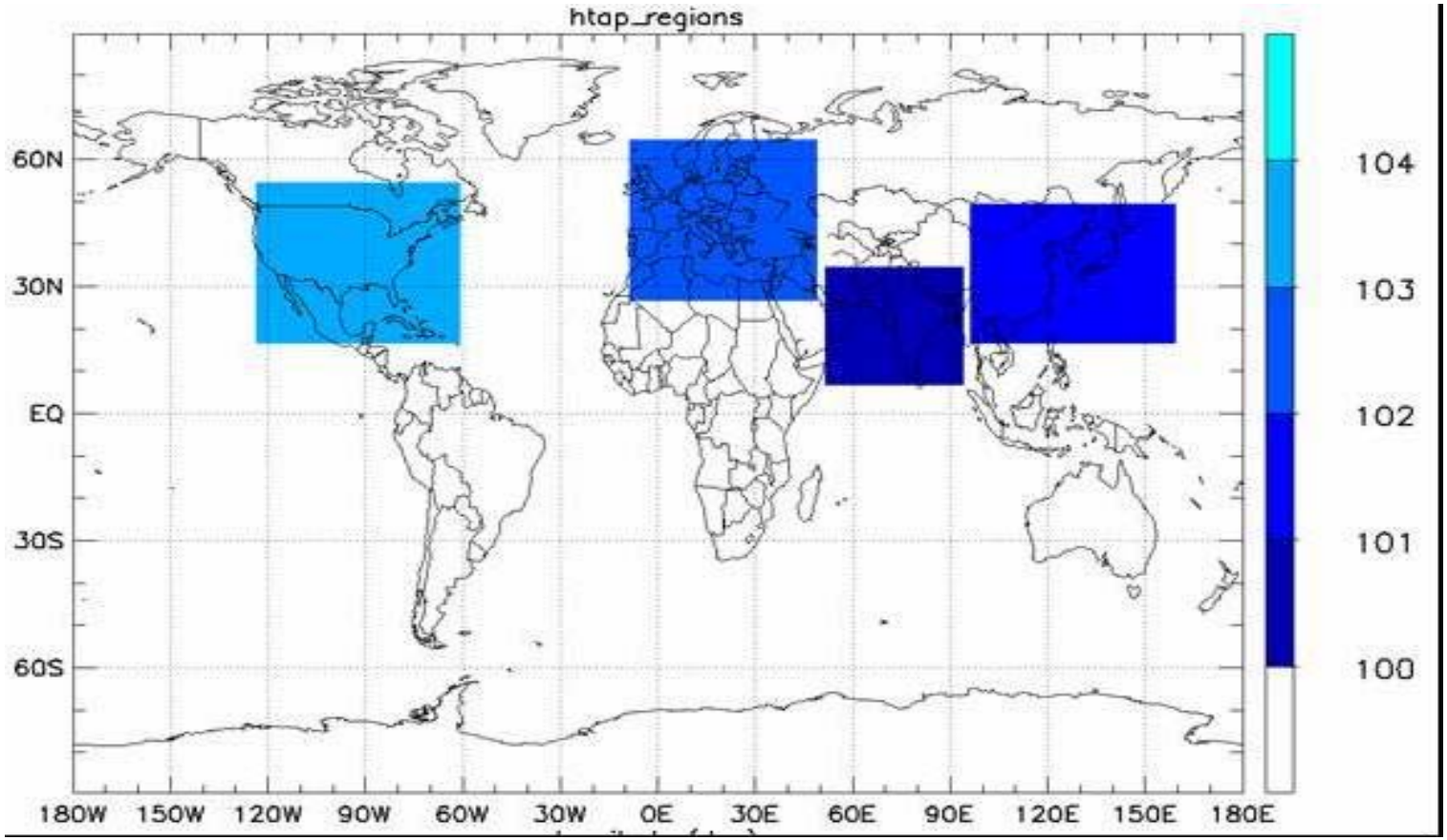
Eastern US PM2.5:
Annual average 4.6 -6.9 μg m^{-3}
North America source 85%
From other regions 15%



Conclusions (2)

- Surface sulfate:
  - Western:
    - 70-80% domestic anthropogenic
  - Eastern:
    - 90% domestic anthropogenic
- Surface fine mode dust:
  - Southwestern:
    - 60% from local desert
  - Other regions:
    - 50% from Asia
    - 25-30% from Africa

HTAP


htap_regions
60N
30N
EQ
30S
60S
180W
150W
120W
90W
60W
30W
0E
30E
60E
90E
120E
150E
180E
104
103
102
101
100