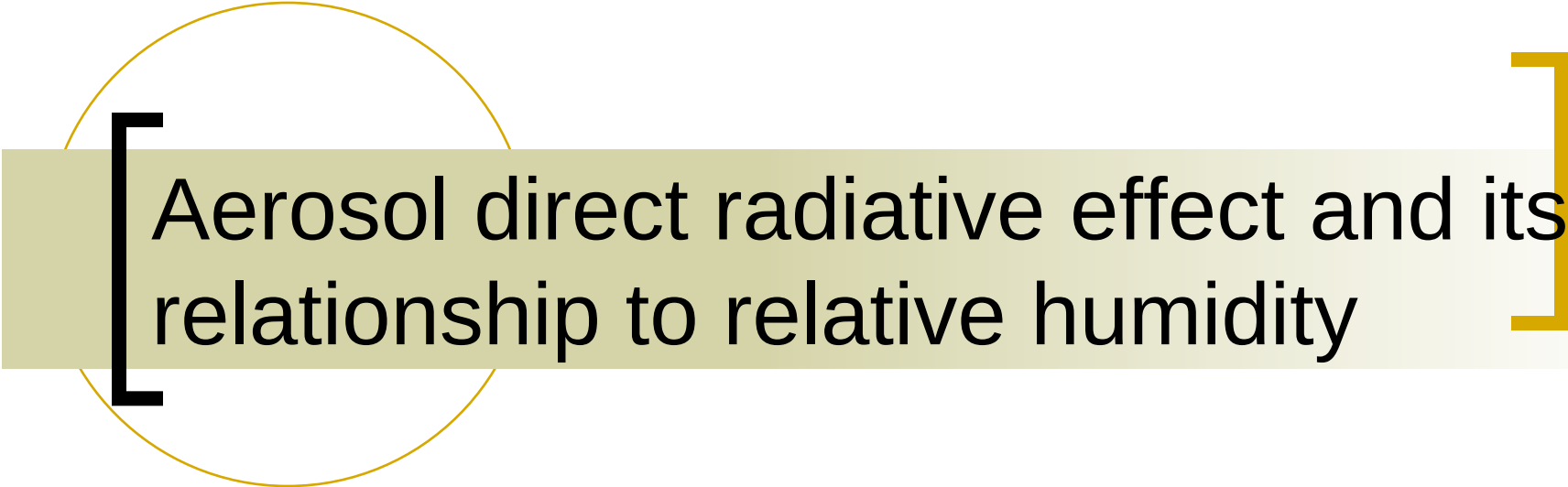




Aerosol direct radiative effect and its relationship to relative humidity

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Hongbin Yu, Joyce E. Penner, Susan Strahan

March 17-19, 2008
GMI workshop

Aerosol direct radiative effect (DRE)

- Radiative transfer model:
 - CLDRAD [Chou and Suarez, 1999]
 - Absorbers: O₃, CO₂, O₂, H₂O, and aerosols
Scatterers: clouds, aerosols, and gases
 - Solar spectrum (0.2-10 μ m) with 8 bands in UV/Vis and 3 in near IR
- Aerosol radiative properties:
 - AOT
 - single scattering albedo (ω)
 - asymmetry factor (g)
- Meteorological fields: GEOS4
 - temperature, specific humidity, cloud optical thickness, cloud fraction, and albedoes

Base case study:

2 (lat), 2.5 (lon), 42 layers to 0.01 mb

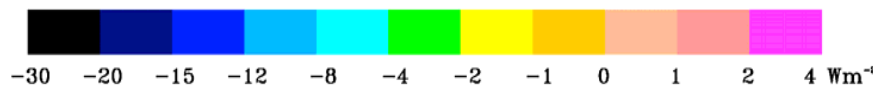
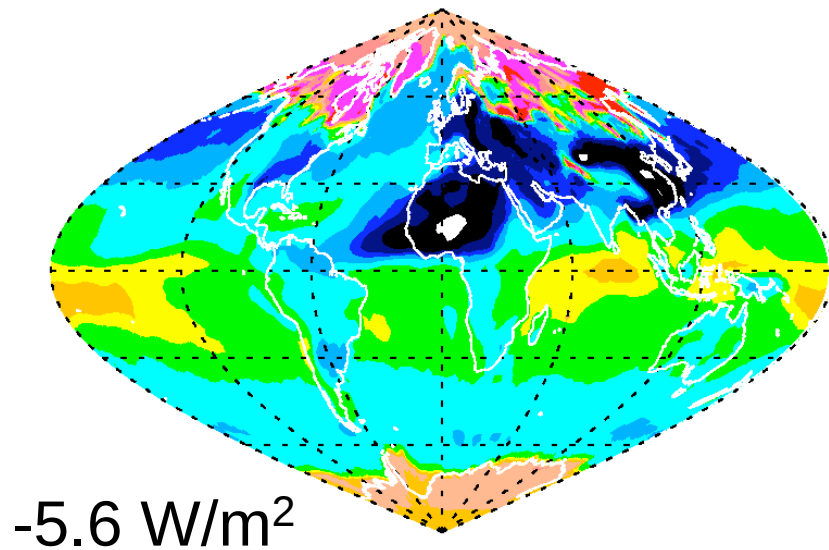
Meteorological field updated every 3 hours

Study for April 2001

Aerosol Direct Radiative Effect (DRE)

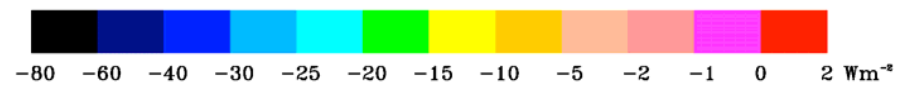
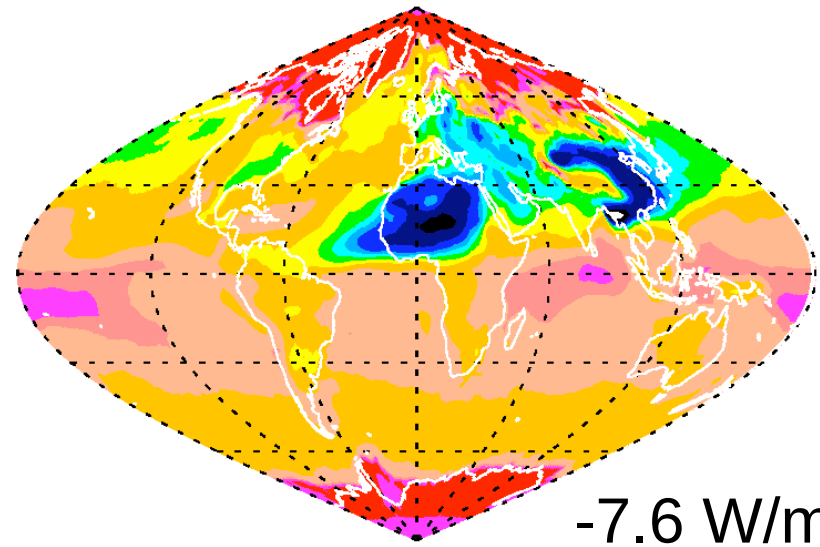
Clear-sky, total aerosols

TOA



TOA: most useful metric
for global average
temperature

Surface

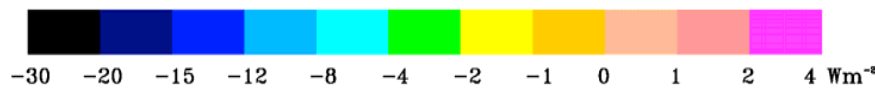
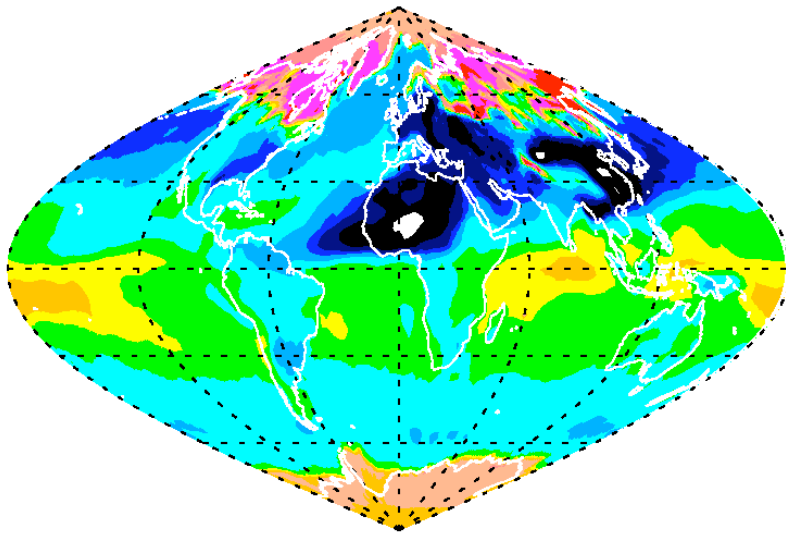


Surface: useful metric for
evaporation / changes to
hydrological cycle

Aerosol DRE

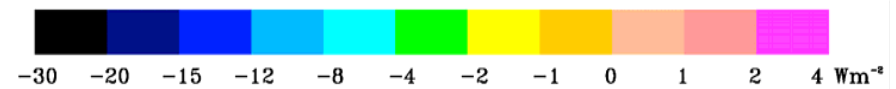
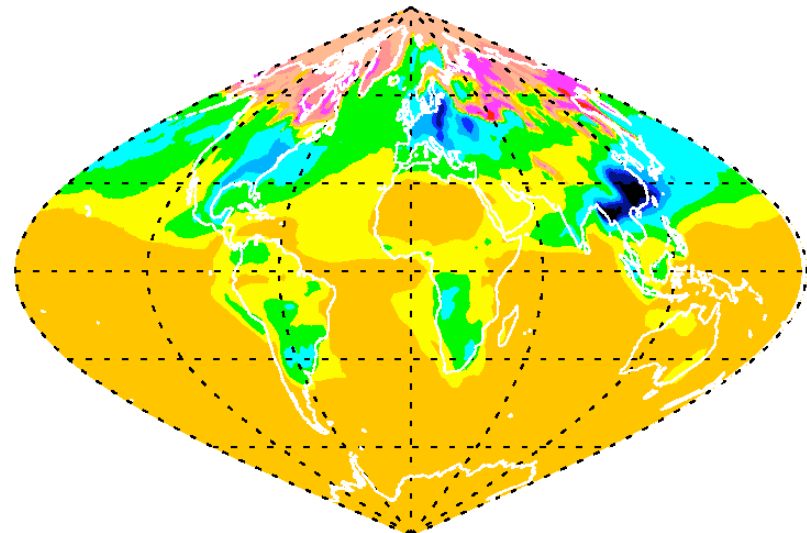
Clear-sky, TOA

Total aerosols



-4.4 -8.4 -5.6 W/m^2
Ocean land global

Anthropogenic aerosols



-1.3 -3.3 -1.9 W/m^2
Ocean land global

TOA aerosol DREs at different regions and atmospheric conditions

		Ocean	Land	Global
		2deg	2deg	2deg
clear sky	DRE (W/m ²)	-4.4	-8.4	-5.6
all sky	DRE (W/m ²)	-3.3	-6.9	-4.4

TOA aerosol DREs at different regions and atmospheric conditions

		Ocean	Land	Global
		2deg	2deg	2deg
clear sky	DRE (W/m ²)	-4.4	-8.4	-5.6
all sky	DRE (W/m ²)	-3.3	-6.9	-4.4

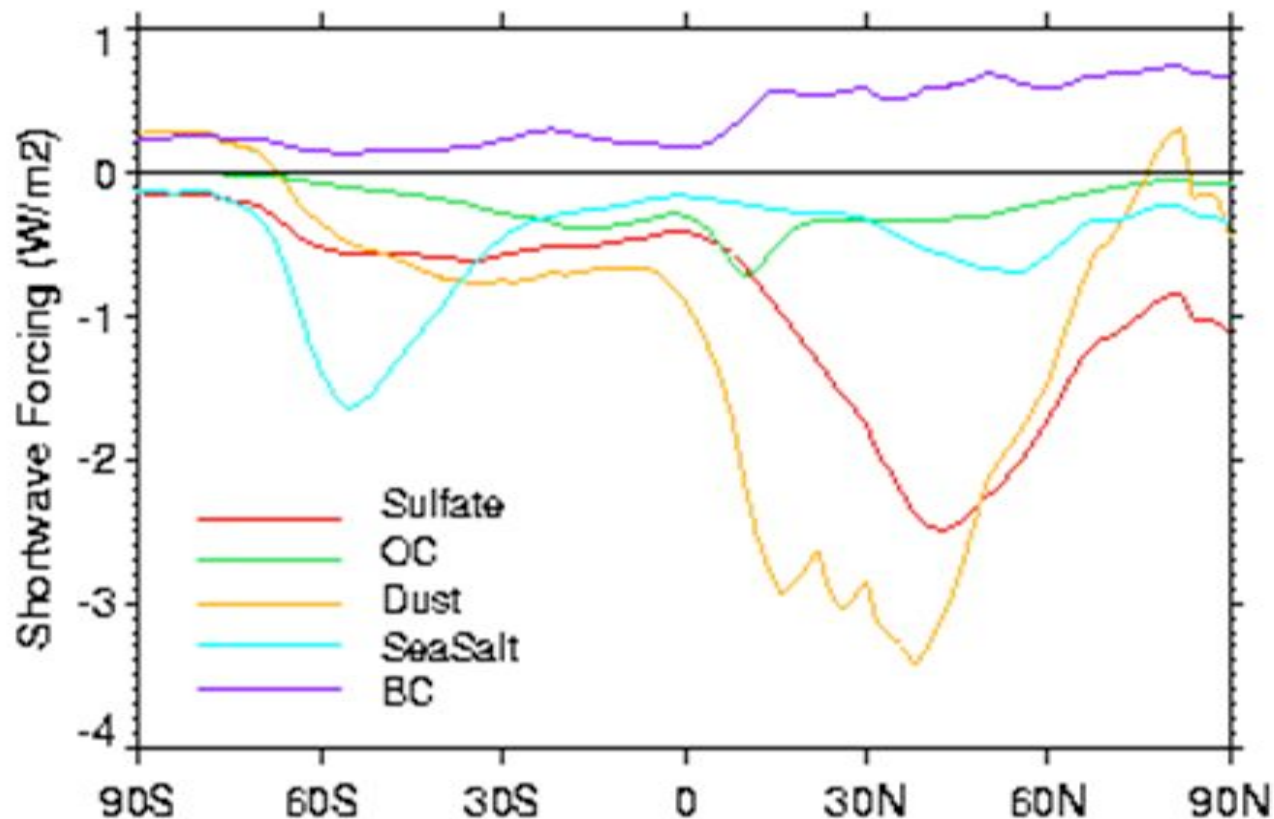
Ocean: - 4.1 ~ - 5.9 W/m² (Yu et al., 2006, Zhang et al., 2005)

1/3 as sea salt, 1/3 as anthropogenic, 8% as dust, and the rest as the other natural aerosols

Land: - 4.1 ~ - 6.2 W/m² (Yu et al., 2006, Patadia et al., 2008)

1/3 as anthropogenic, 1/2 as dust, 3% as sea salt, and the rest as other natural aerosols

Annual zonal average aerosol SW effect at TOA for *all-sky* from GEOS-1 in 1990, not separated by land and ocean

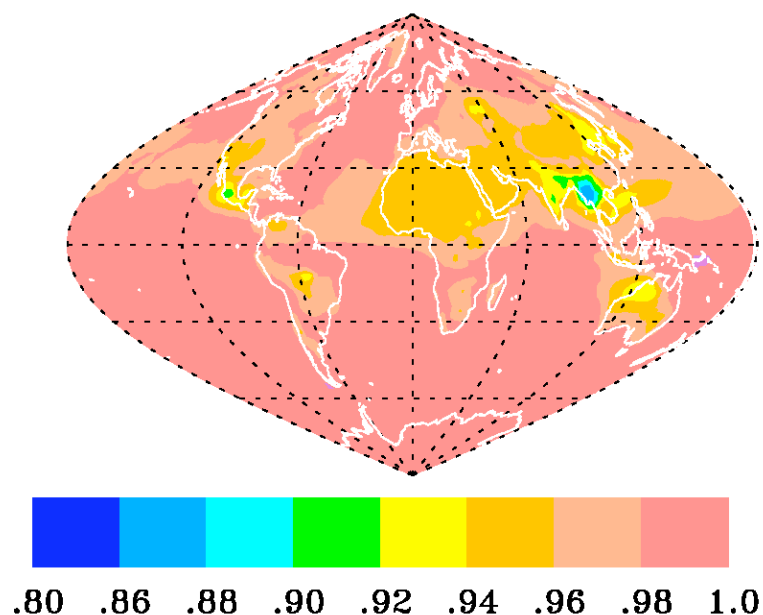


GEOS-4 GOCART Dust *all-sky* TOA DRE (W/m^2)
ocean (- 0.25), land (- 3.5), global (-1.2)

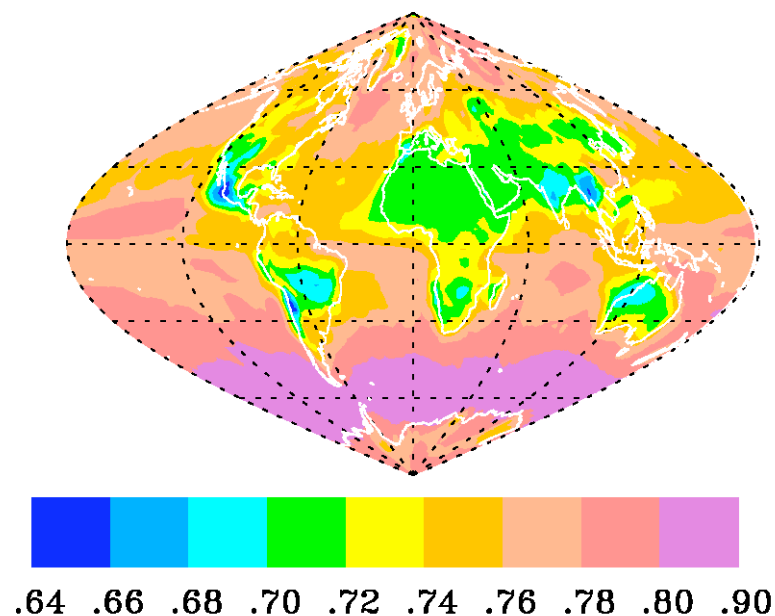
Mian Chin

Total Aerosol Single-scattering albedo and Asymmetry factor

Single-scattering Albedo
April 2001

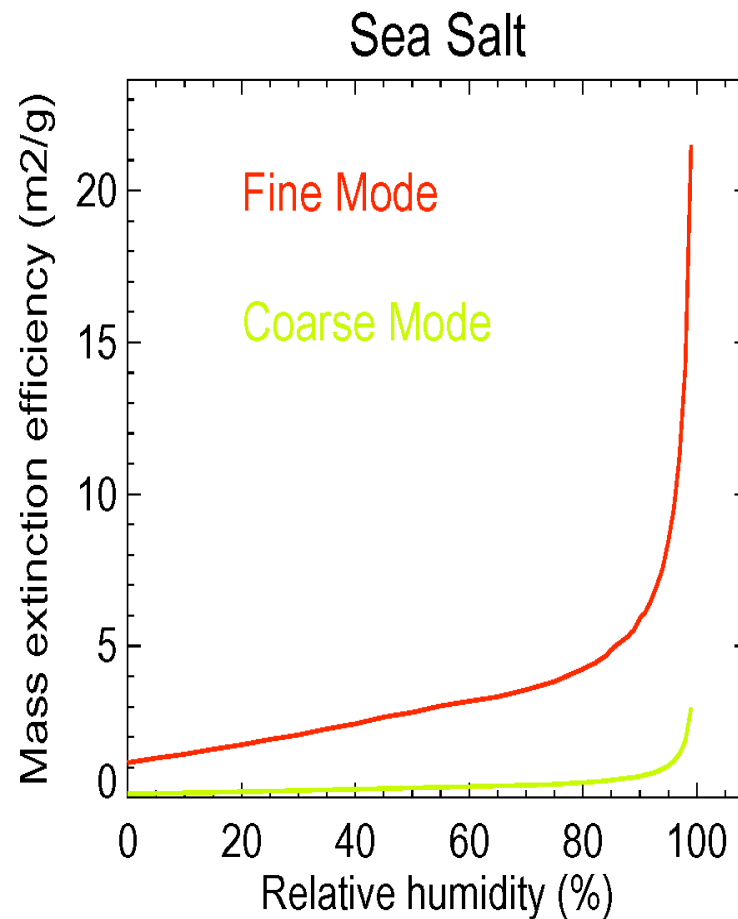


Asymmetry Factor
April 2001



Is SSA too high ?

Mass Extinction Efficiency (MEE) vs Relative Humidity (RH)



$$\text{AOT} = \text{dry_mass} \times \text{MEE (RH)}$$

Change of RH horizontal resolutions

Base case: 2° (lat) x 2.5° (lon)

Control case: 1° (lat) x 1.25° (lon)

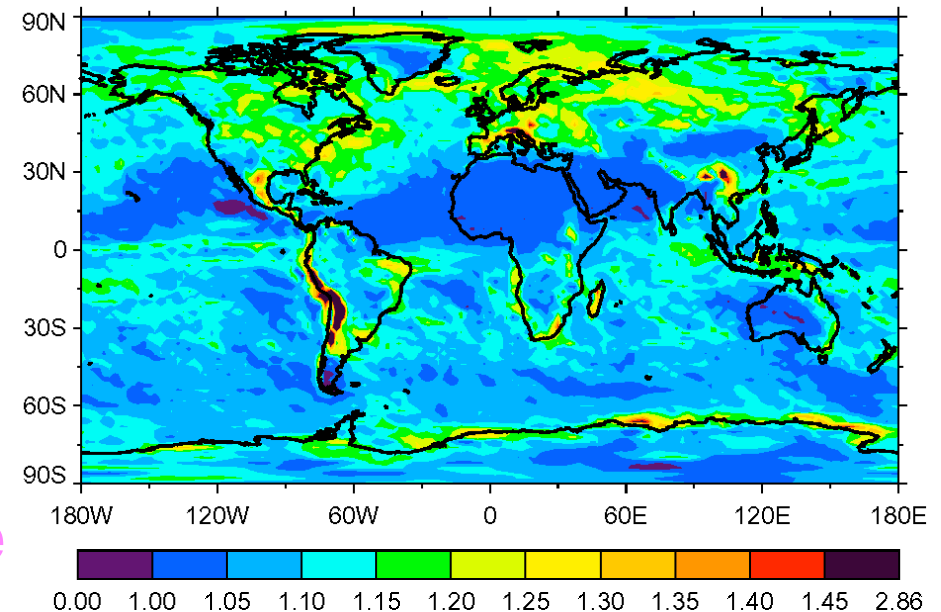
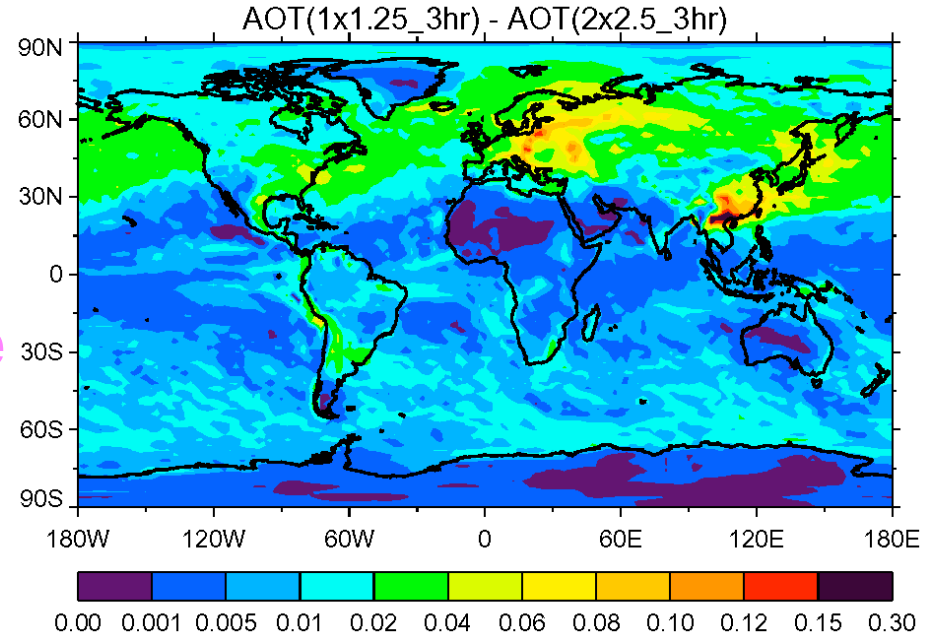
AOT(1x1.25_3hr) vs AOT(2x2.5_3hr)

Absolute
Difference

High difference occurs over:

1. high hygroscopic aerosol areas
2. large RH gradient regions

Relative
Difference



TOA aerosol DREs and their changes with the change of RH horizontal resolution

		Ocean		Land		Global	
		2deg	1deg	2deg	1deg	2deg	1deg
clear sky	DRE (W/m ²)	-4.4	-4.8	-8.4	-9.1	-5.6	-6.1
	dDRE* (%)		8.9		8.0		8.4
all sky	DRE (W/m ²)	-3.3	-3.6	-6.9	-7.4	-4.4	-4.8
	dDRE (%)		9.3		7.7		8.5

* $dDRE = [DRE(1deg) - DRE(2deg)] / DRE(2deg)$

Total aerosol vs *Anthropogenic* aerosol

The changes of aerosol TOA DREs with the change of RH horizontal resolution

		Ocean		Land		Global	
		Ant	Total	Ant	Total	Ant	Total
clear sky	dDRE* (%)	12.7	8.9	15.6	8.0	14.9	8.4
all sky	dDRE (%)	13.7	9.3	16.9	7.7	15.1	8.5

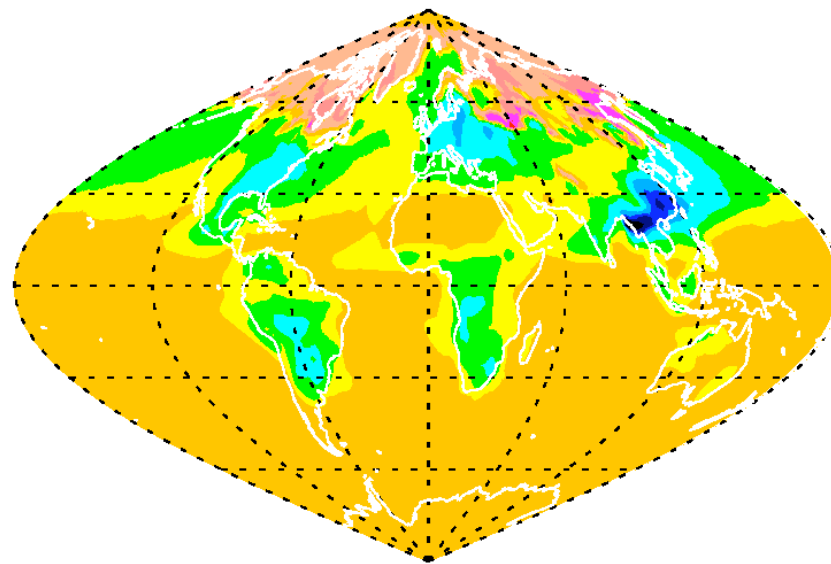
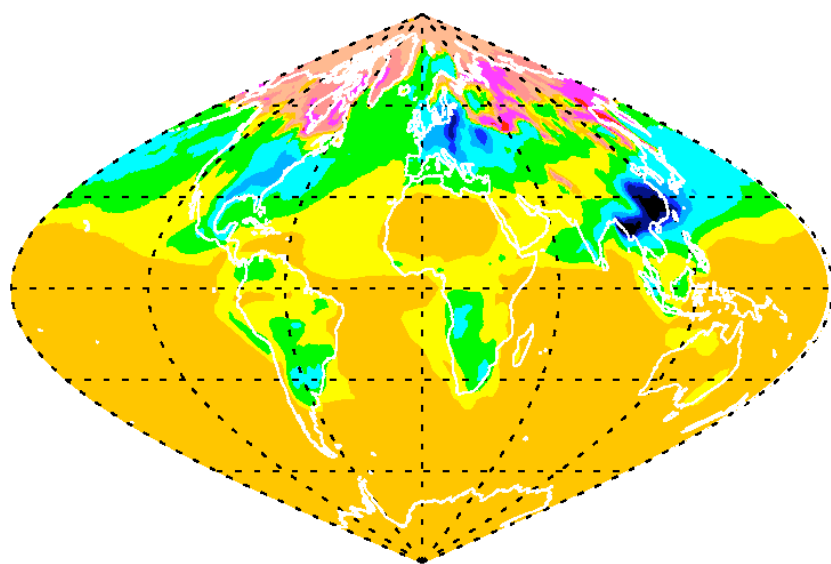
The sensitivity of MEE to RH is much higher for anthropogenic aerosol than for other aerosols including sea-salt.

Anthropogenic Aerosol TOA DRE

Clear-sky, TOA, April 2001

Michigan

GOCART



Ocean: -1.26 (Michigan), -0.72 (GOCART)

Land: -3.3 (Michigan), -2.9 (GOCART)

Conclusions

In the base case study:

- Clear sky total aerosol DREs are estimated to be **-5.6** W/m² at TOA and **-7.6** W/m² at surface. These values are reduced by 20-25% in all sky condition.
- Anthropogenic aerosols contribute about **1/3** of total aerosol DRE at TOA.

When change resolutions:

- Total aerosol TOA DRE in clear sky increases by **8-9%** globally while using RH in spatial resolution 1° by 1.25° instead of 2° by 2.5°. Correspondingly, the DRE changes by **15%** if only anthropogenic aerosol is accounted.
- If RH temporal resolution is changed from 3 hours to 6 hours, the TOA DRE is reduced by about **3%**.