Aerosol Indirect Climatic Effect Assessments using the NASA Global Modeling Initiative

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With acknowledgements to GMI core team: Jose Rodriguez, Susan Strahan, Jules Kouatchou, Bigyani Das, Bryan Duncan and others

GMI Science Team Meeting
Jan. 11-13, 2006
Atlanta, GA

Motivation

- Aerosol Radiative Effects on Climate
- GCMs - tools for assessment of aerosol climatic effects
- Values of first indirect aerosol forcing **-0.5 to -1.85** W m^{-2}
- Aerosol-cloud interaction - source of uncertainty
- How different parameters (i.e., meteo-fields, chemical mechanisms, emission scenarios, activation parameterizations) used in different GCMs can affect indirect aerosol forcing assessments

Global Modeling Initiative (GMI) Assessment Model

GODDARD SPACE FLIGHT CENTER

http://gmi.gsfc.nasa.gov/gmi.html

- 3-D chemistry-transport model (CTM)
- Multi-year assessment simulations
- Tropospheric, Stratospheric, and **Aerosol versions**
- Different modules (i.e., met fields, chemical mechanisms)
- Metrological inputs from GCMs (**GEOS-4 FVGCM** & **GISS-II'**) or data assimilation systems (NASA **DAO**)
- Any vertical resolution; horizontal resolutions of 2°x2.5°, or **4°x5°**
- Emission Scenarios (**UM**, **AEROCOM**)

GMI Aerosol Model

- Aerosol module (Liu & Penner, 2002) coupled to GMI advection core
- Emissions: SO_2, DMS, black carbon, organic matter, mineral dust, and sea salt
- Chemical production of sulfate, gravitational sedimentation, dry deposition, wet scavenging in and below clouds, and hygroscopic growth
- In cloud Liquid Water Content – (Hack, 1998)
- Stratiform and Convective cloud fractions – (Sundqvist et al., 1978; Xu and Krueger, 1991)
- Cloud drop effective radius (r_e)

  (Kiehl et al., 1998)

$$r_e = \begin{cases} 10\ \mu m & \text{Ocean} \\ 5 - 5\left(\frac{T+10}{20}\right)\ \mu m & -30^\circ C \le T \le -10^\circ C \quad \text{Land} \\ 5\ \mu m & T > -10^\circ C \end{cases}$$

- Optical depth, single scattering albedo, asymmetry factor – warm clouds

GMI Improvements

- Cloud droplet activation parameterizations
  - > Empirical Relationship (Boucher and Lohmann, 1995) **(BL)**
  - > Prognostic Relationship (Nenes and Seinfeld, 2003 Fountoukis and Nenes, 2005) **(NS)**

✓ Effective radius

$$r_e = k\sqrt[3]{\frac{3}{4}\cdot\frac{\rho_a q_l}{\pi\rho_w b N_d}}$$

k=1.143 Continental

k=1.077 Marine

(Martin et al., 1994)

✓ Cloud optical depth

$$\tau = \frac{3}{2}\int_{\text{cloud bottom}}^{\text{cloud top}} \frac{LWC}{\rho_w r_e} dz$$

(Seinfeld & Pandis, 1998)

✓ Cloud albedo

$$R_c = \frac{\tau}{\tau + 7.7}$$

✓ Indirect forcing

$$\Delta F_c = -\frac{1}{3} F_0 A_c T_a^2 \Delta R_c$$

$$\Delta R_c = \frac{1}{3} R_c (1 - R_c) \Delta \ln N_d \approx 0.075 \Delta \ln N_d$$

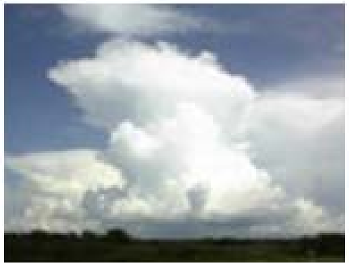
Empirical Relationship (BL)

$$CDNC = 10^{2.24+0.257\log(mSO4)}$$ (continents)

$$CDNC = 10^{2.06+0.48\log(mSO4)}$$ (ocean)

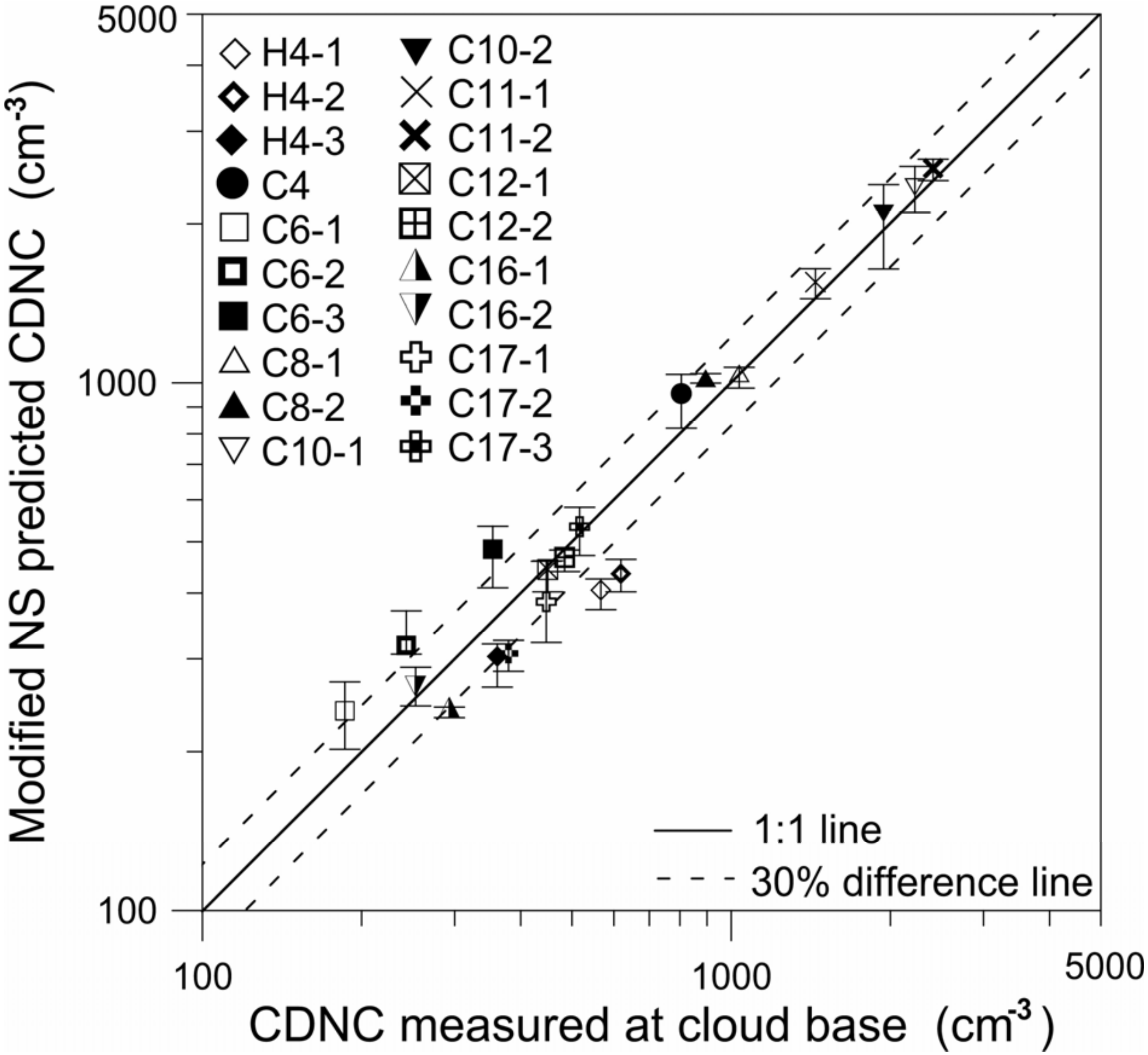
mSO_4 - in $\mu g\ SO_4\ m^{-3}$

> Specified from GMI
> Bypass complex physics of droplet formation



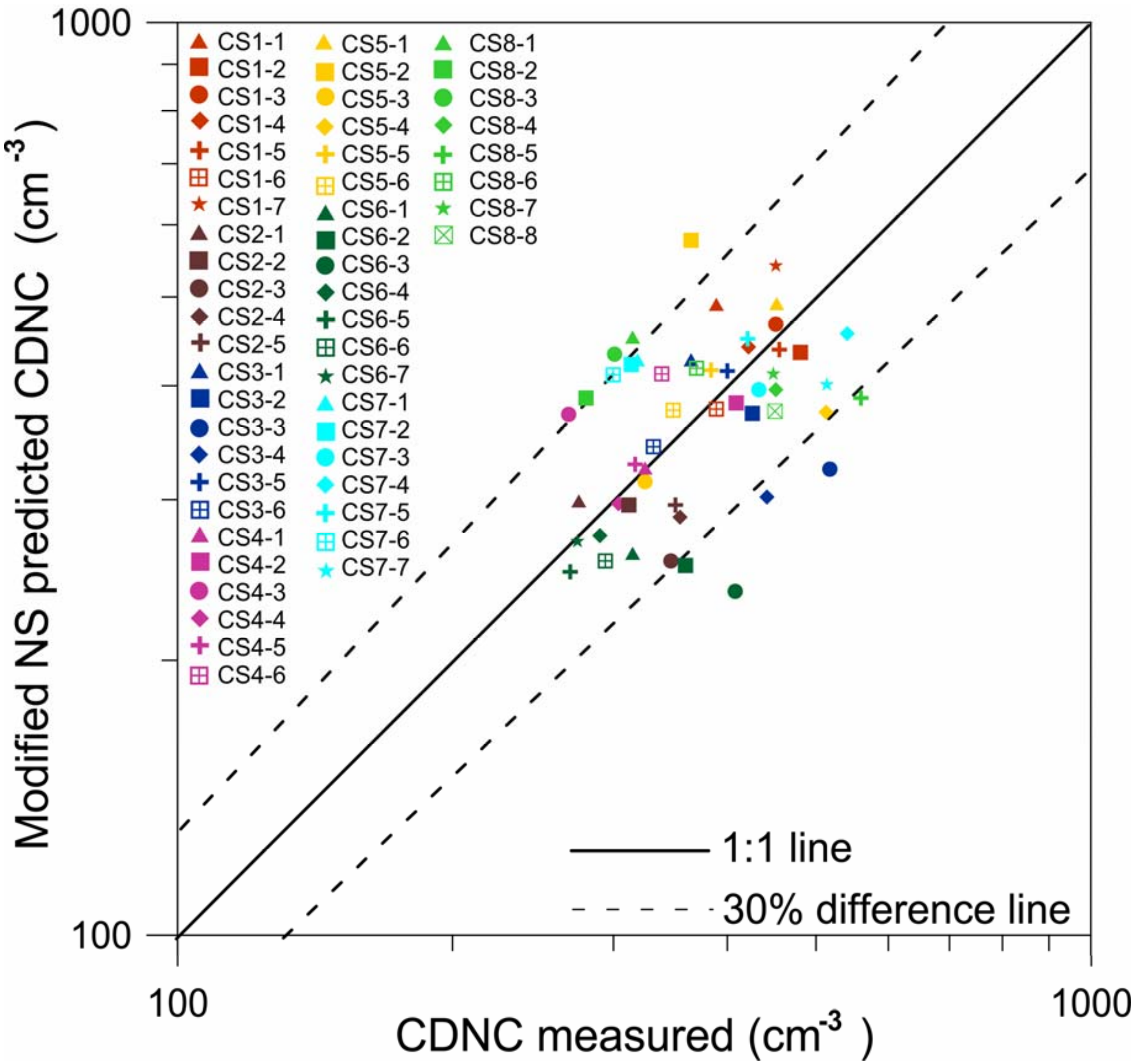
CRYSTAL-FACE

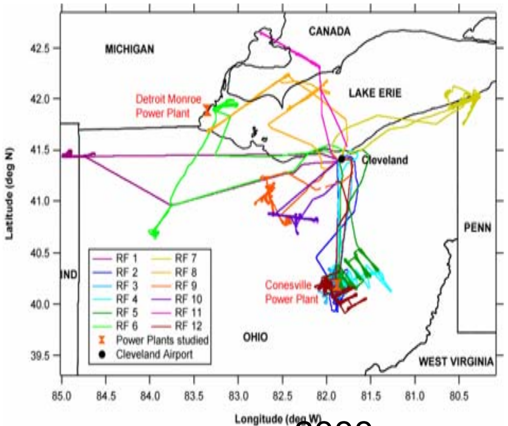
Cirrus Regional Study of Tropical Anvils and Cirrus Layers-Florida Area Cirrus Experiment



CSTRIPE

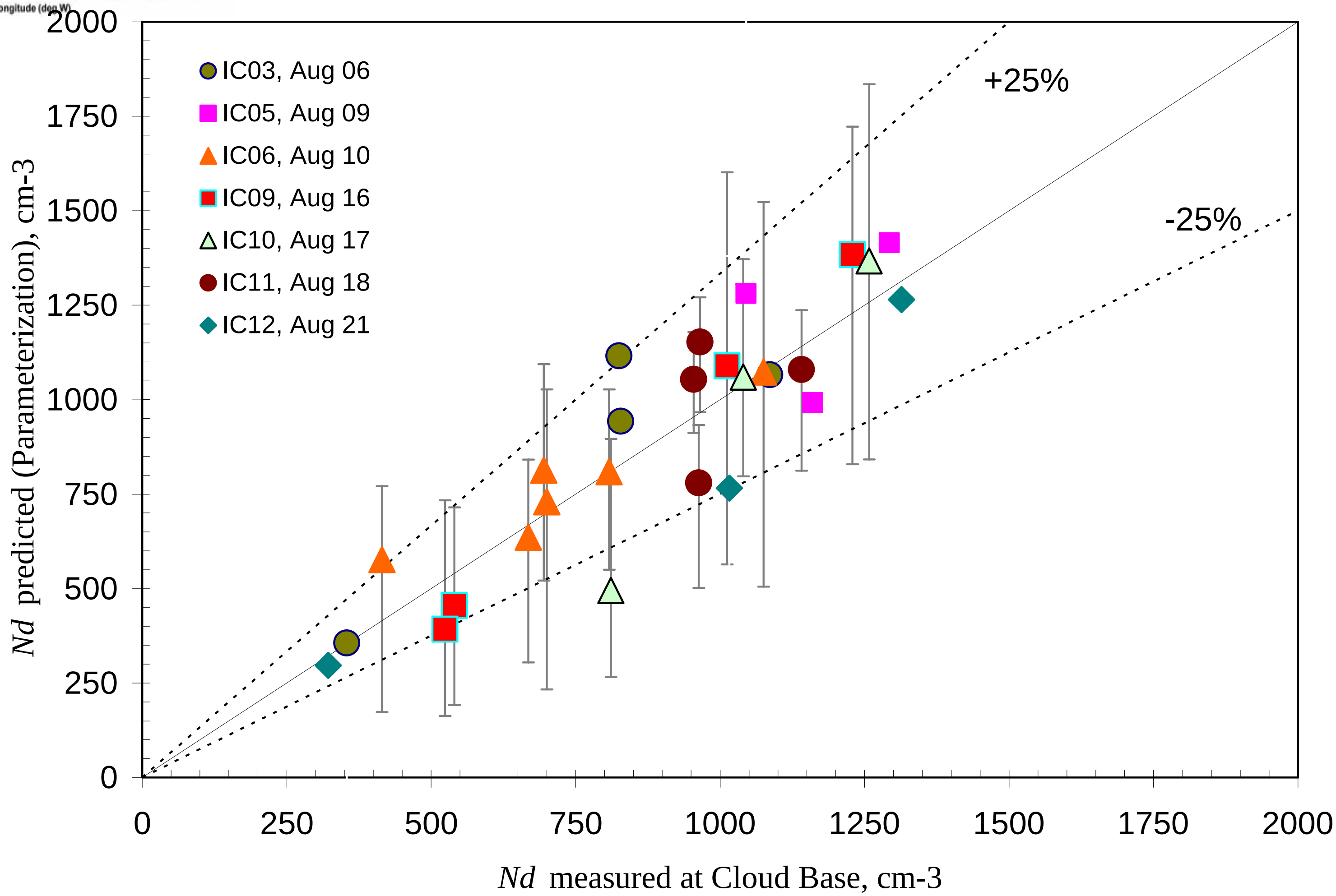
Coastal STRatocumulus Imposed Perturbation Experiment





ICARTT

International Consortium for Atmospheric Research on Transport and Transformation



Input parameters for NS

- Dry aerosol number concentration and size distribution
- Updraft velocity
- Aerosol chemical composition
- Water accommodation coefficient (0.042)
- Air temperature
- Atmospheric pressure

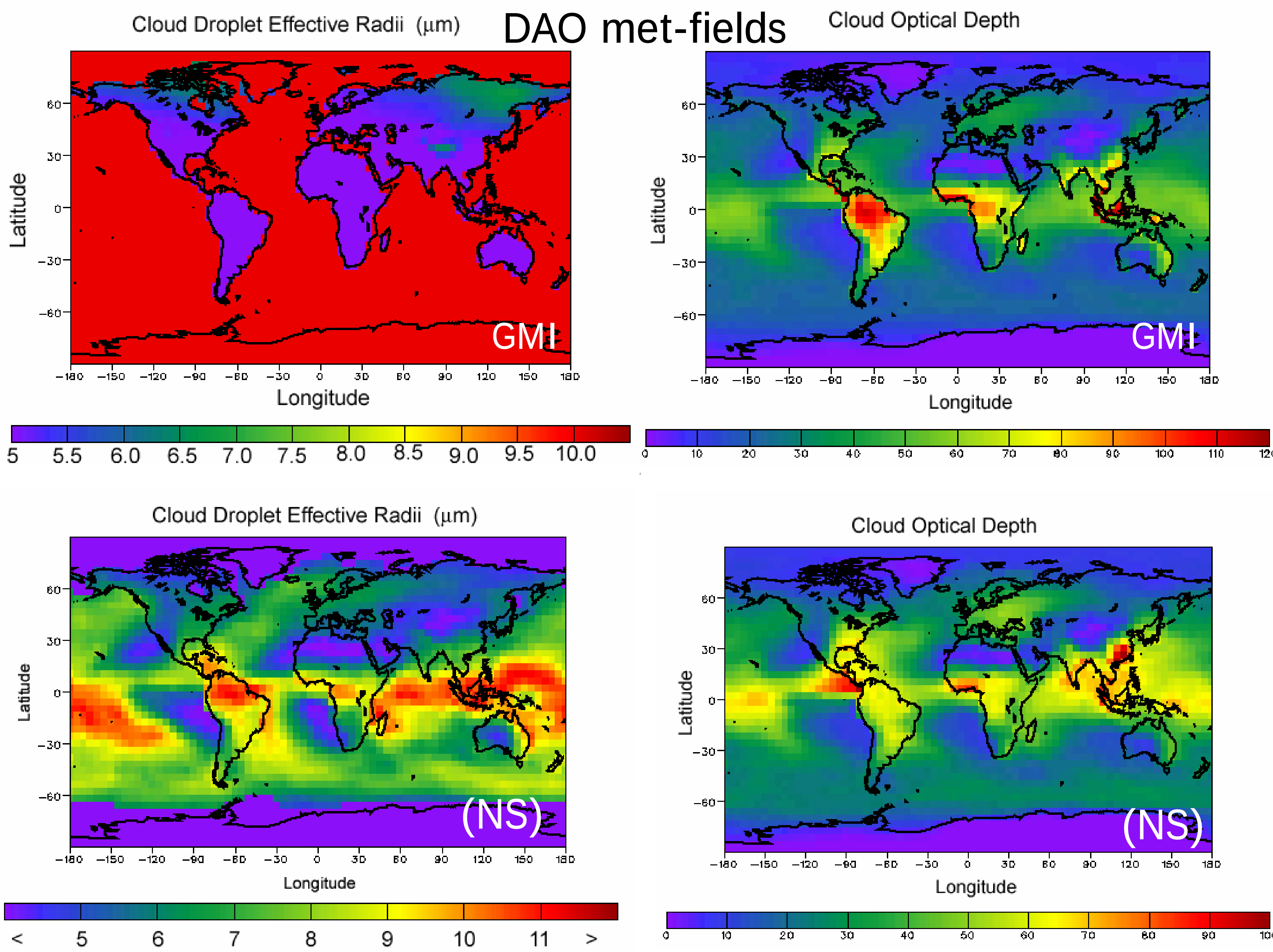
Input Parameters for NS parameterization

Lance et al., 2004; others

	Marine Aerosol			Continental Aerosol		
	Nuclei mode	Accumulation mode	Coarse mode	Nuclei mode	Accumulation mode	Coarse mode
N(# cm^{-3})	230	177	3.1	1000	800	0.72
Dp_g (μm)	0.02	0.092	0.58	0.016	0.067	0.93
σ_g	1.47	1.6	2.49	1.6	2.1	2.2
ρ_{sol}	1760	1760	1760	1760	1760	1760
ρ_{ins}	2100	2100	2100	2100	2100	2100
ε_{sol}	0.33	0.33	0.95	0.5	0.5	0.5
ε_{ins}	0.132	0.132	0.132	0.132	0.132	0.132
Vh	3.0	3.0	3.0	3.0	3.0	3.0
W (m s^{-1})	**0.35**			**1.0**		

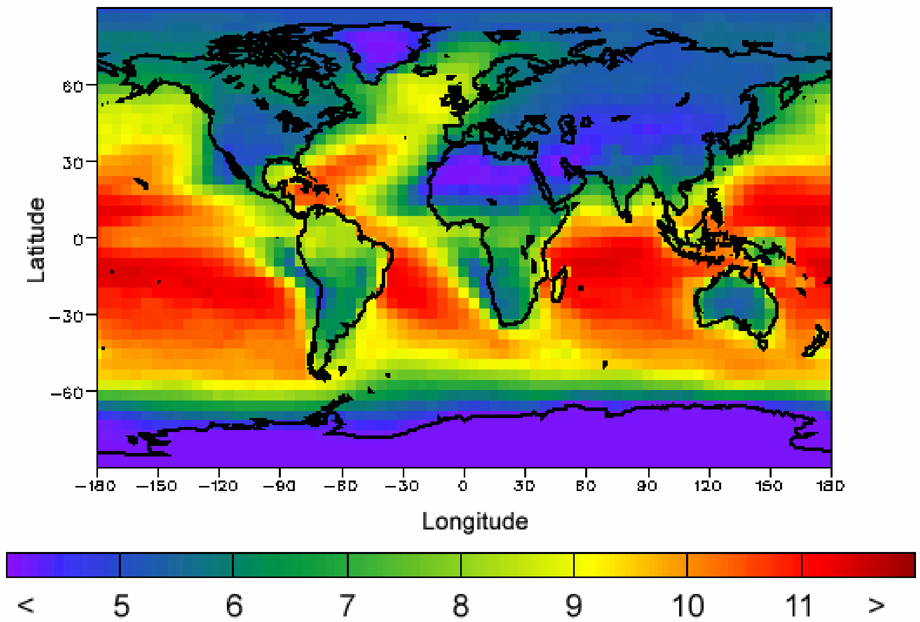
Scale N with sulfate

DAO met-fields

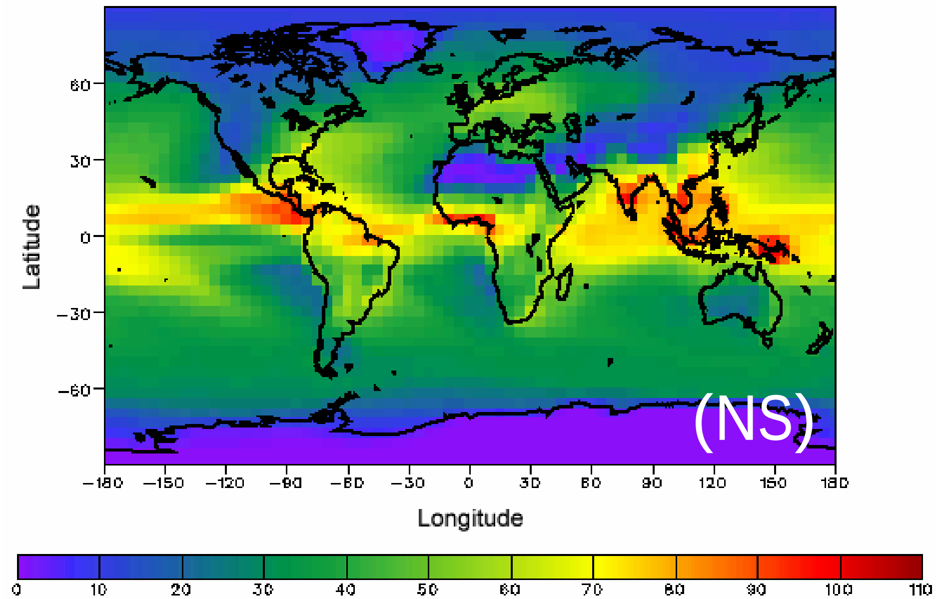


GEOS-4 met-fields

Cloud Droplet Effective Radii (µm)

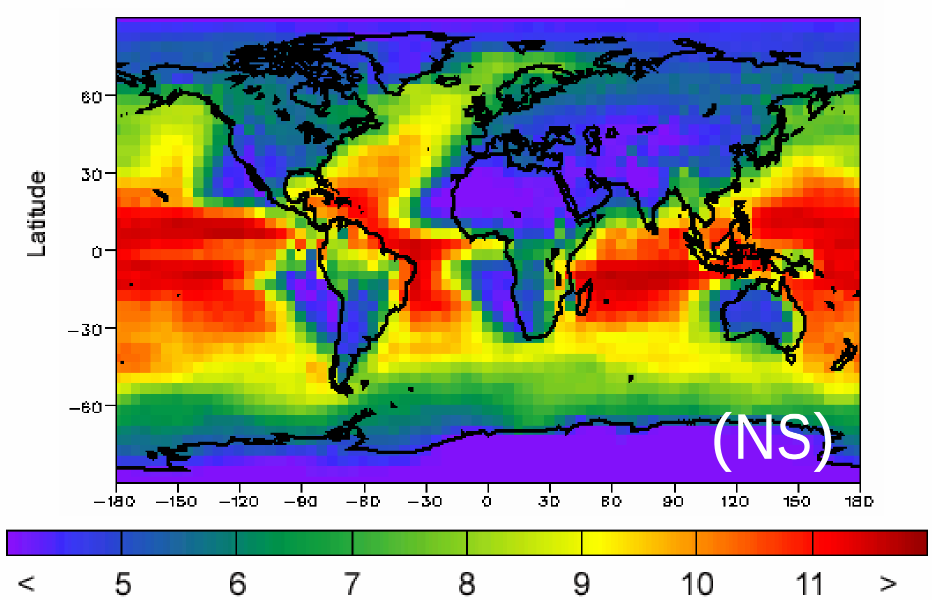


Cloud Optical Depth

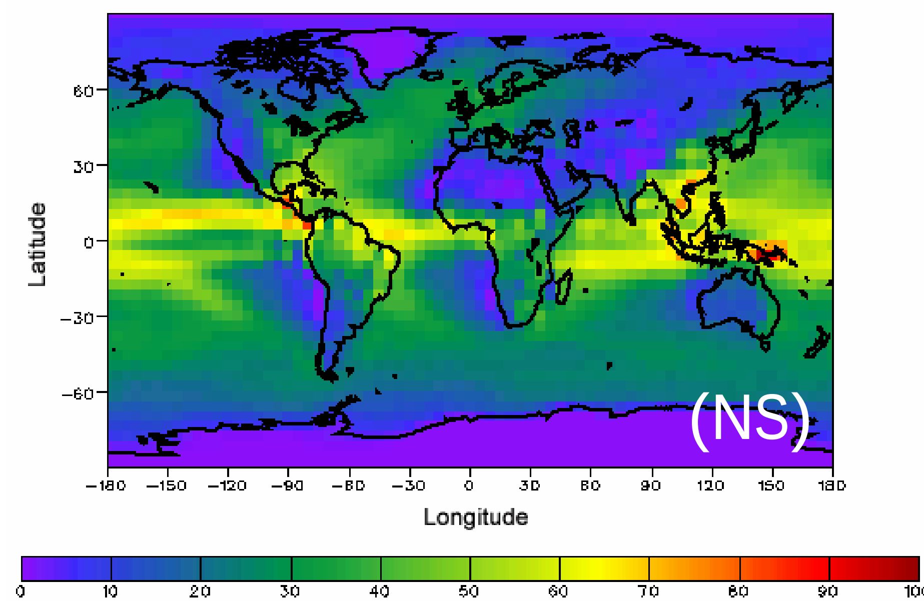


GISS-II' met-fields

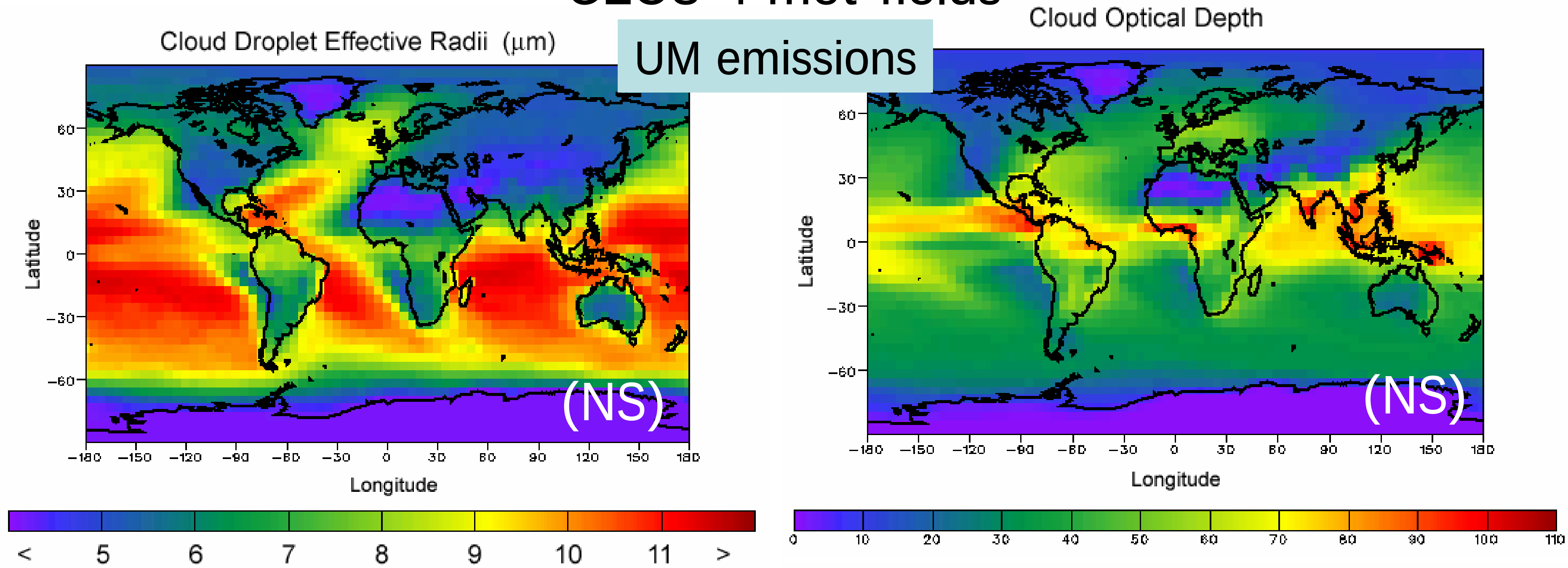
Cloud Droplet Effective Radii (µm)

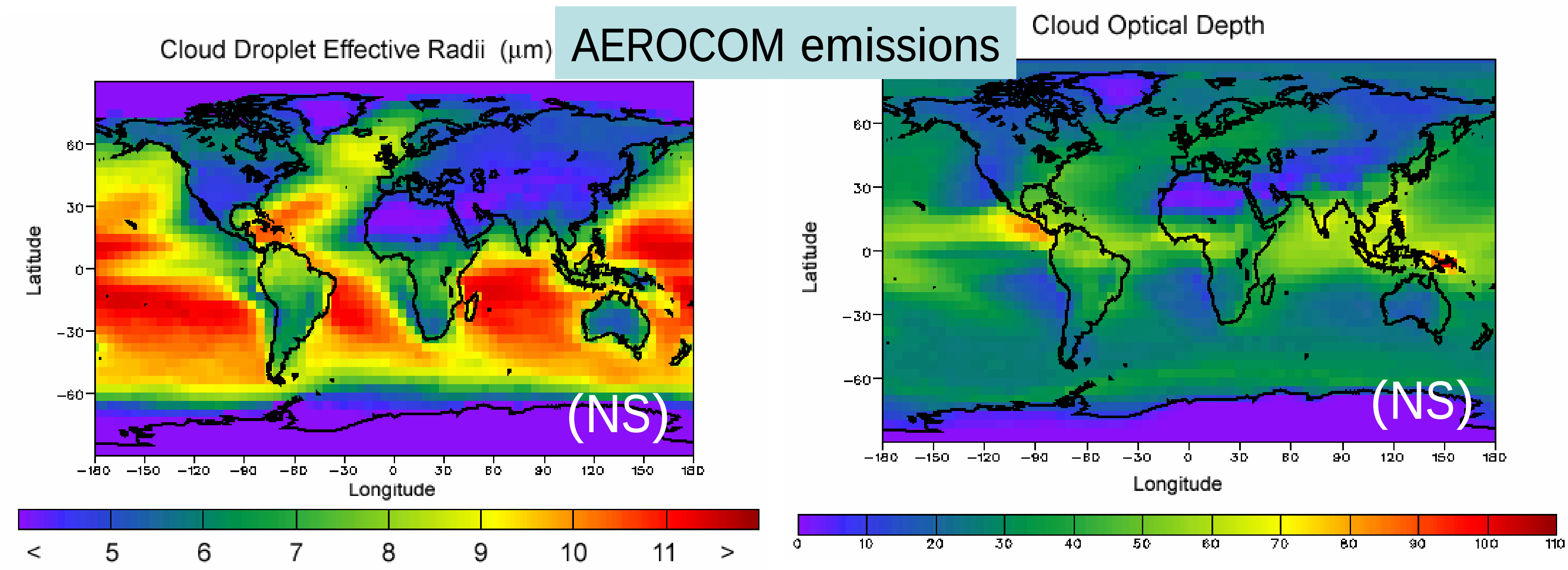


Cloud Optical Depth

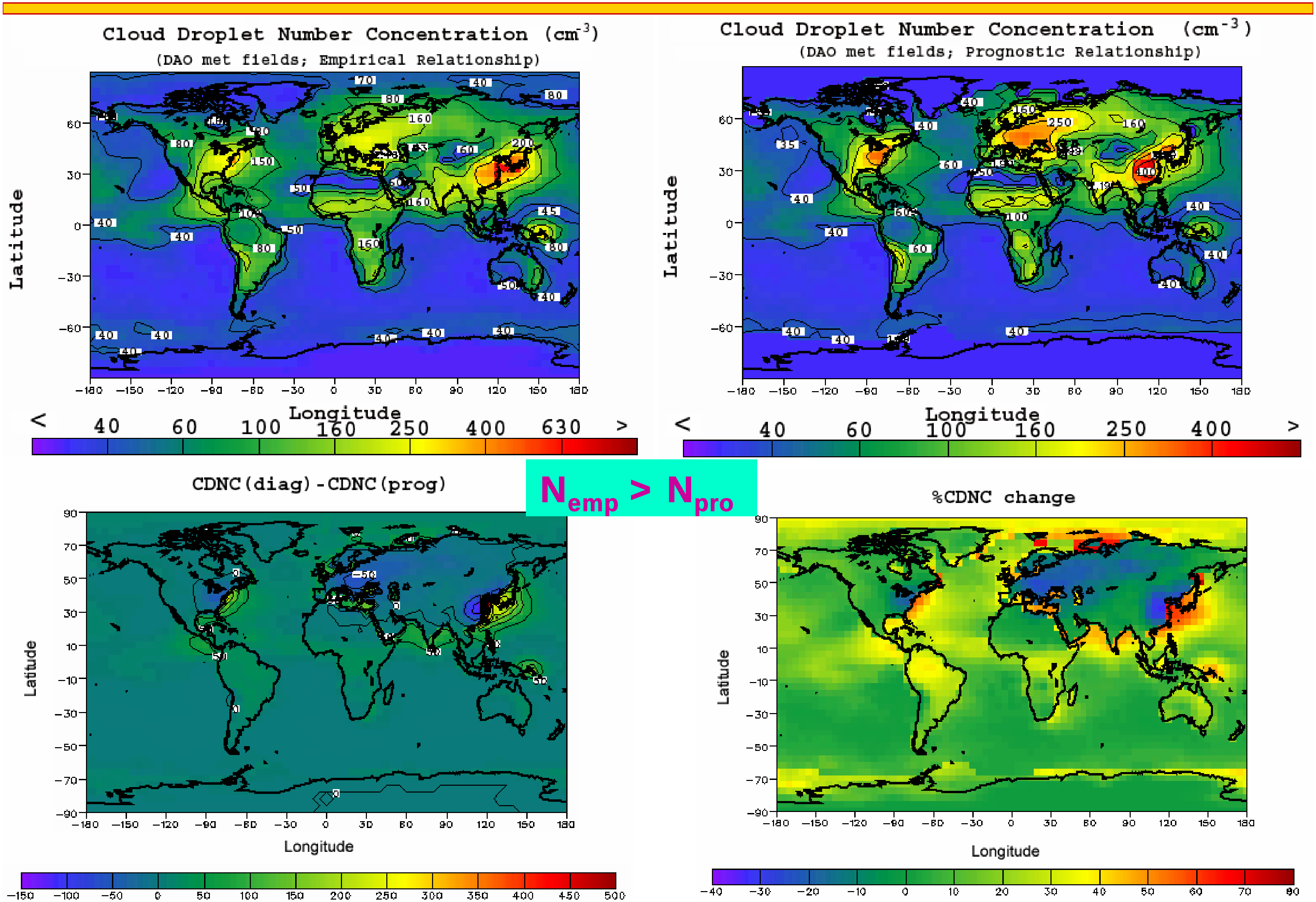


GEOS-4 met-fields

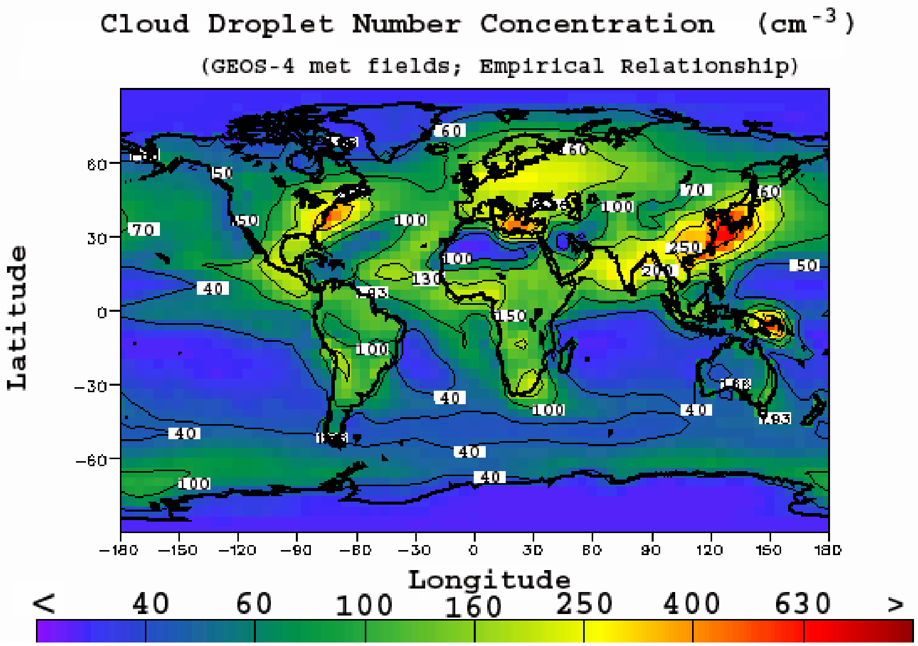


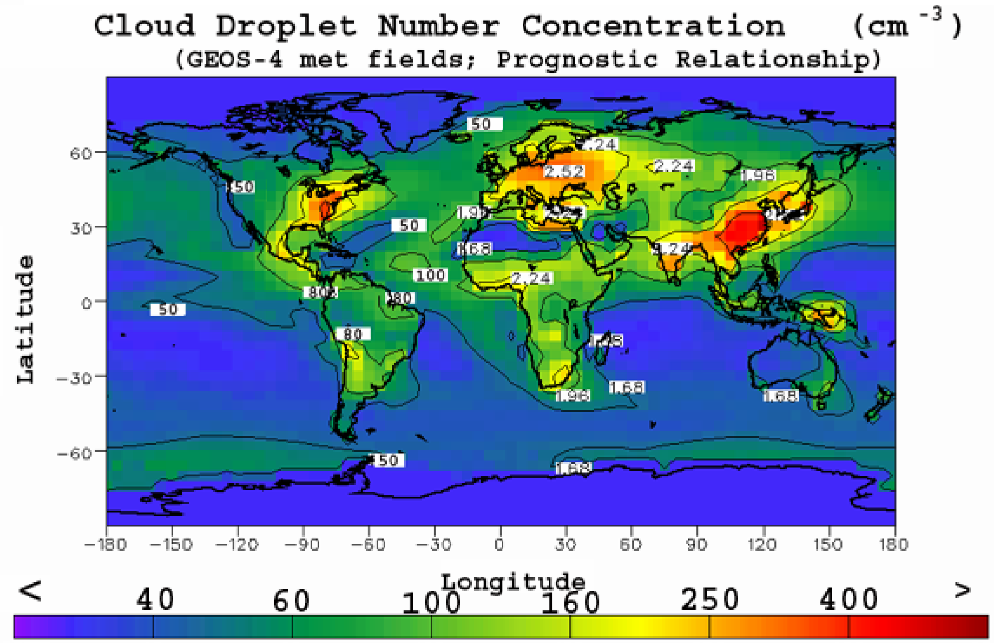


Yearly Averaged Cloud Droplet Number Concentration

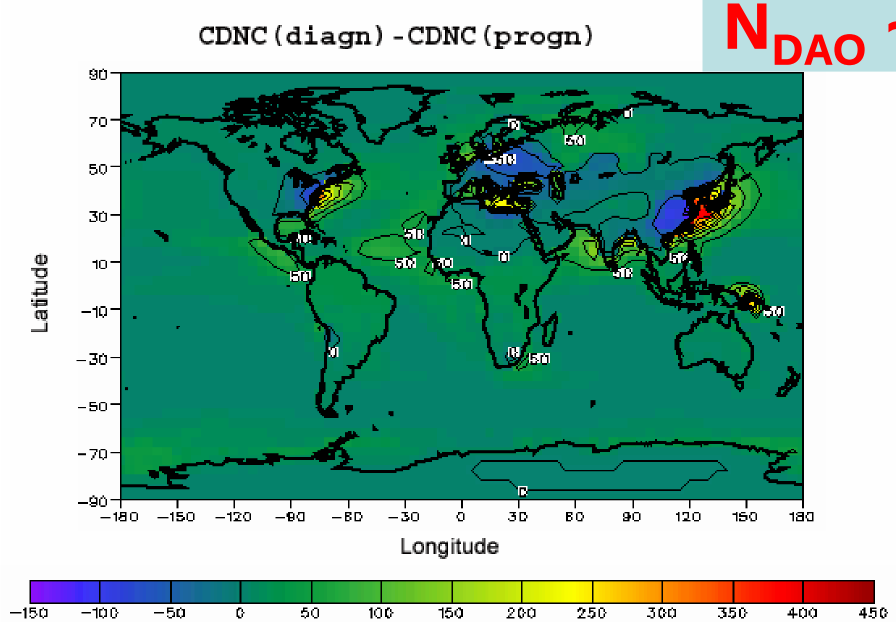


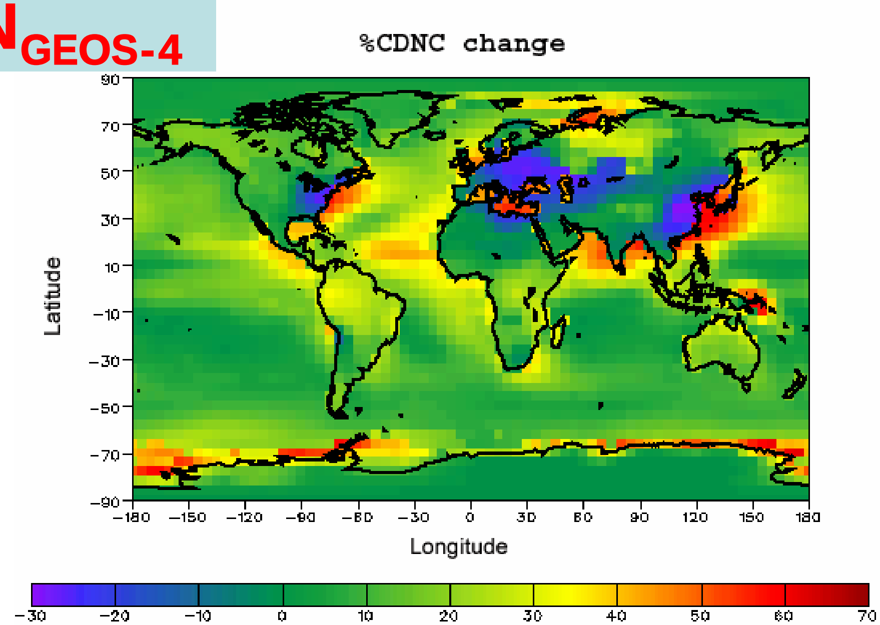
Yearly Averaged Cloud Droplet Number Concentration



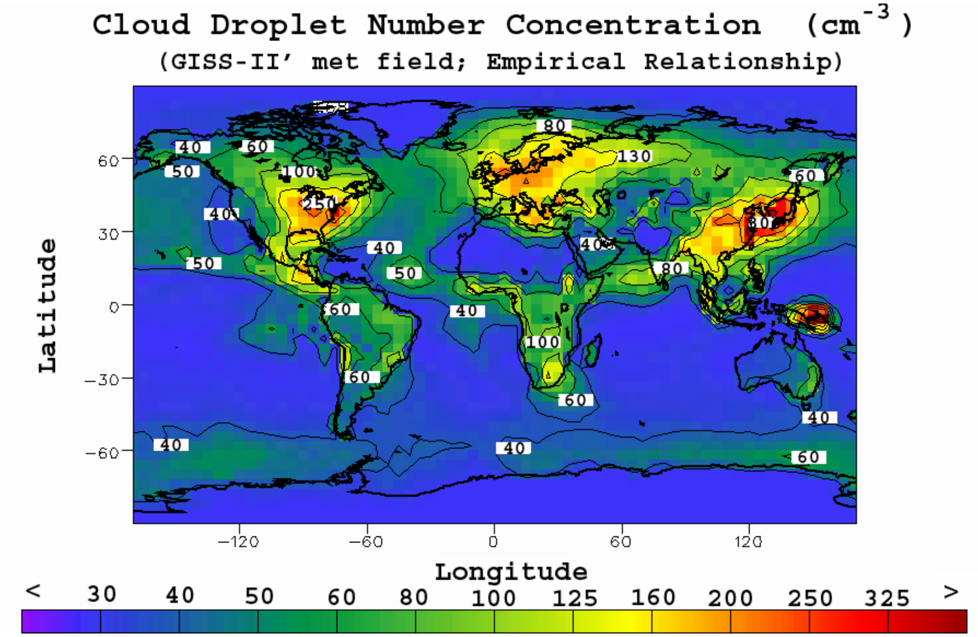


$N_{DAO} \sim N_{GEOS-4}$

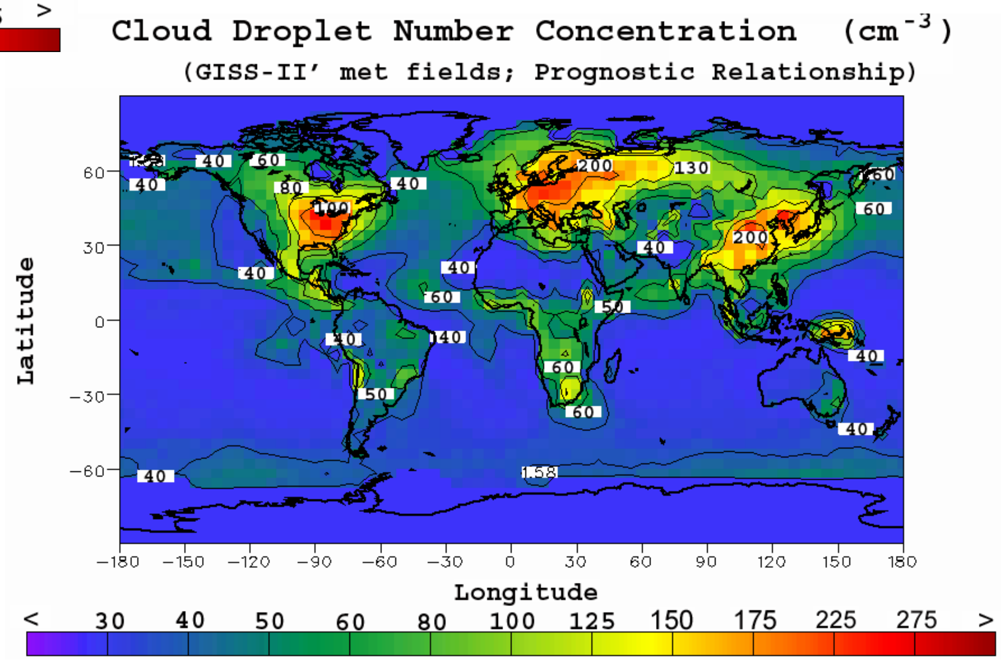




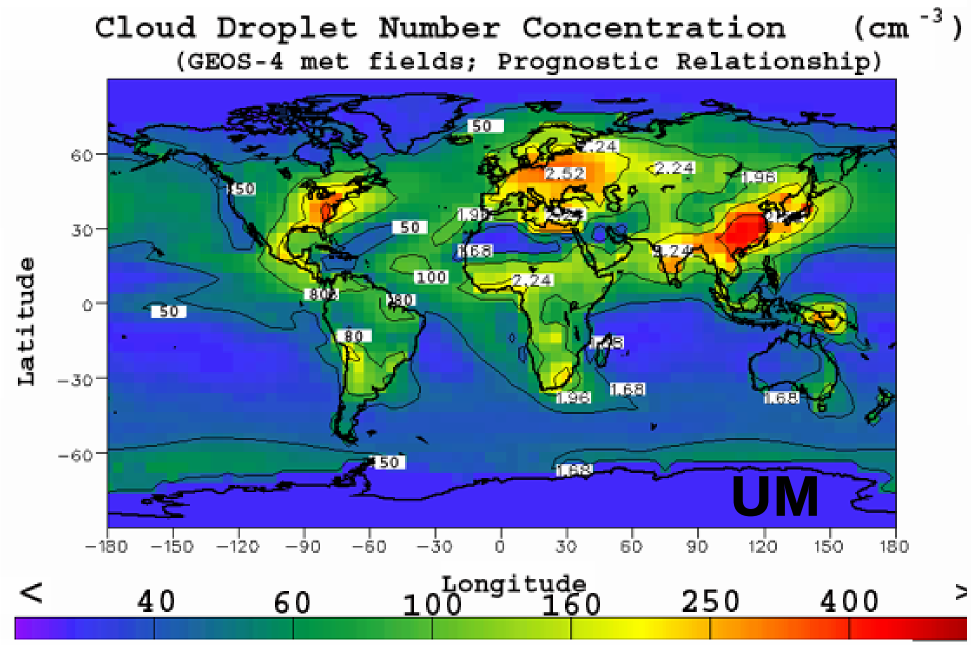
Yearly Averaged Cloud Droplet Number Concentration

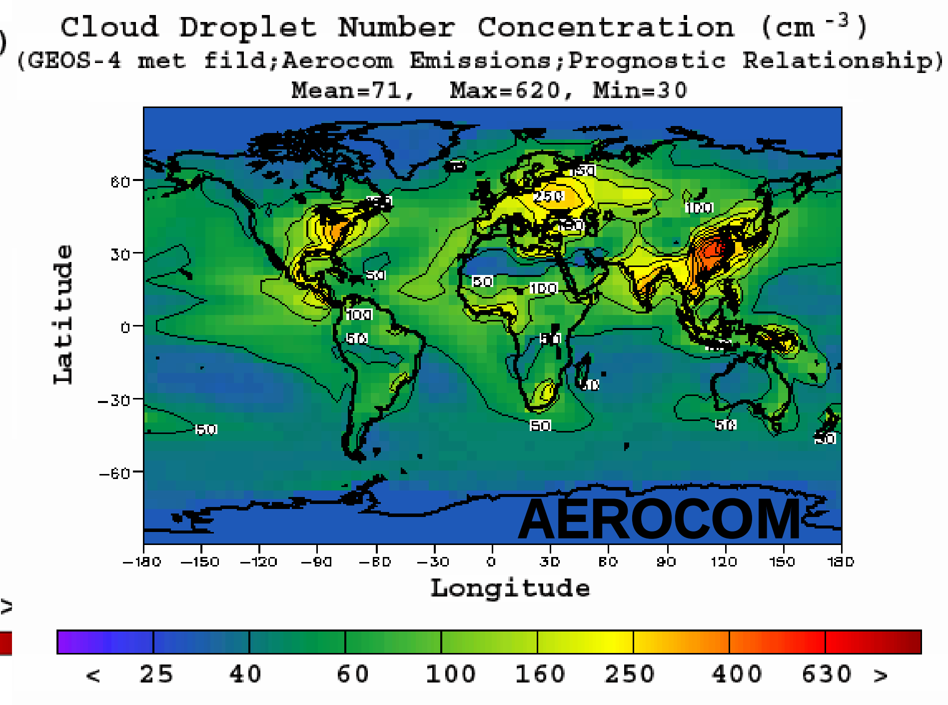


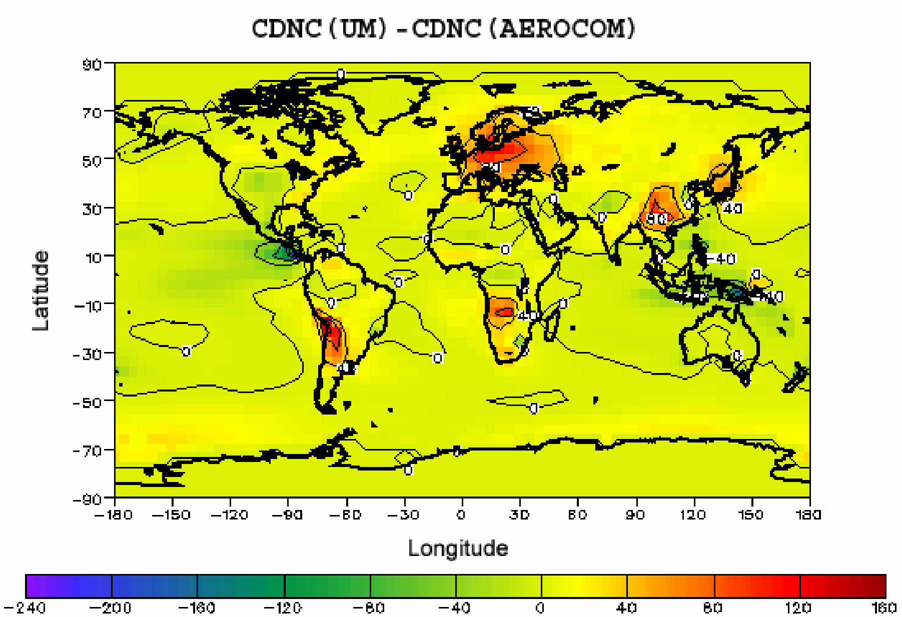
$N_{GISS-II'} < N_{DAO}$ or N_{GEOS-4}

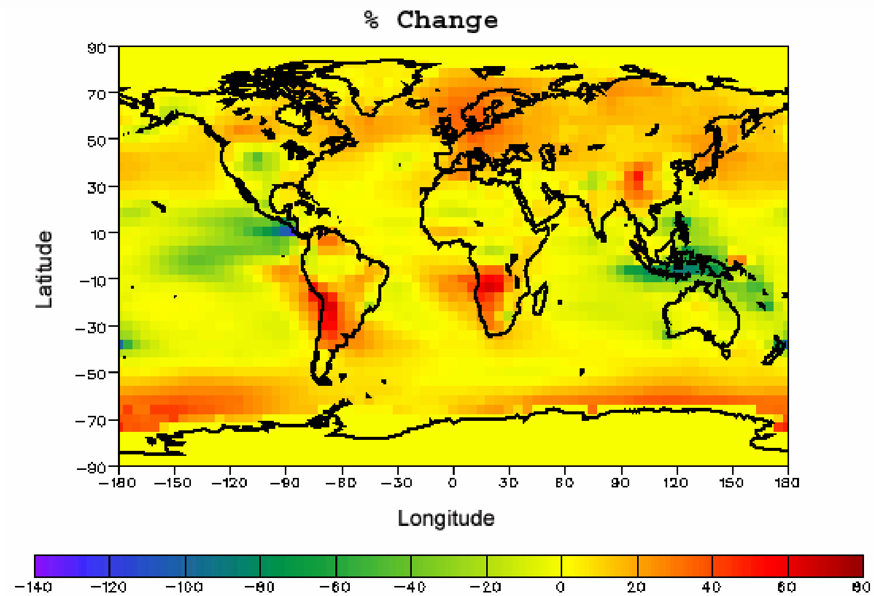


Yearly Averaged Cloud Droplet Number Concentration



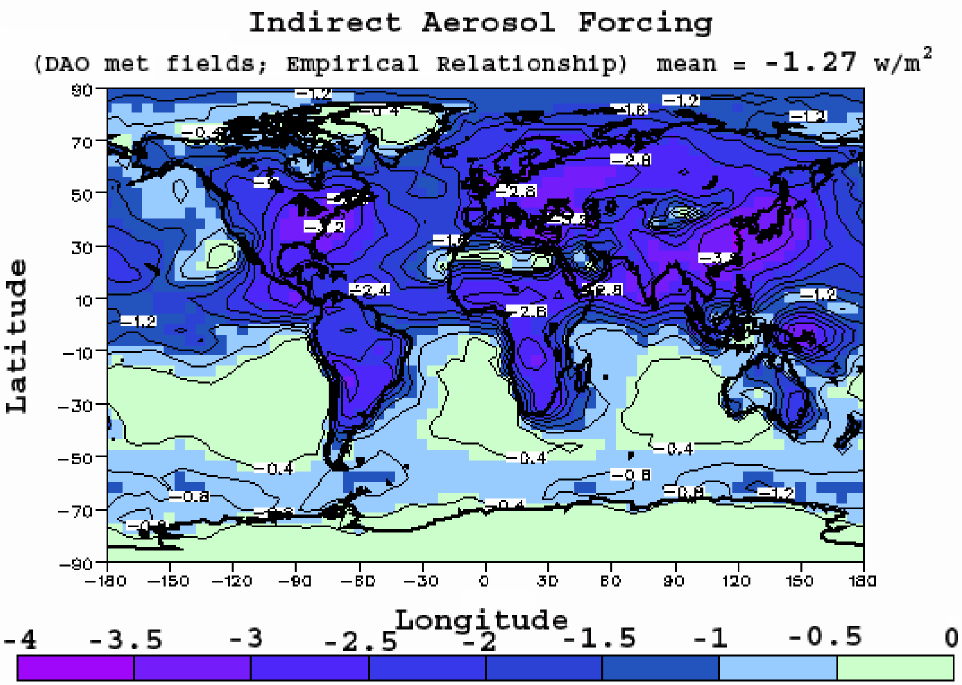


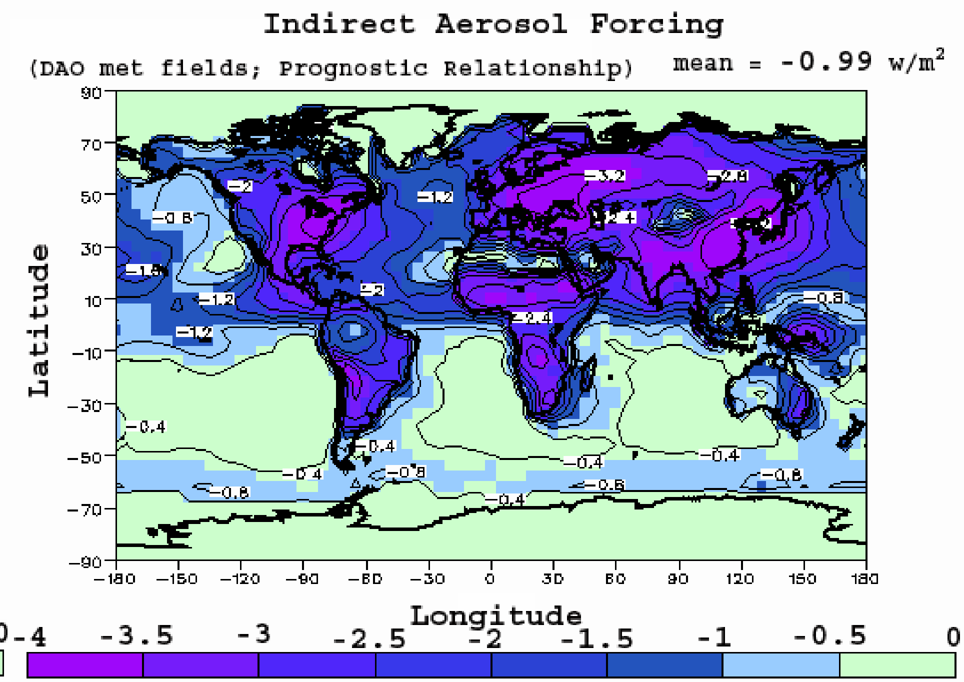


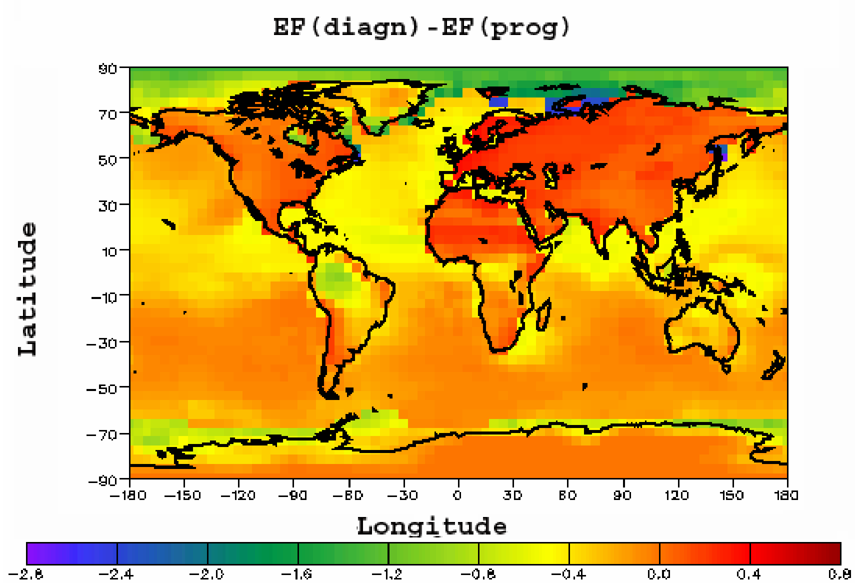


Yearly Averaged Indirect Aerosol Forcing

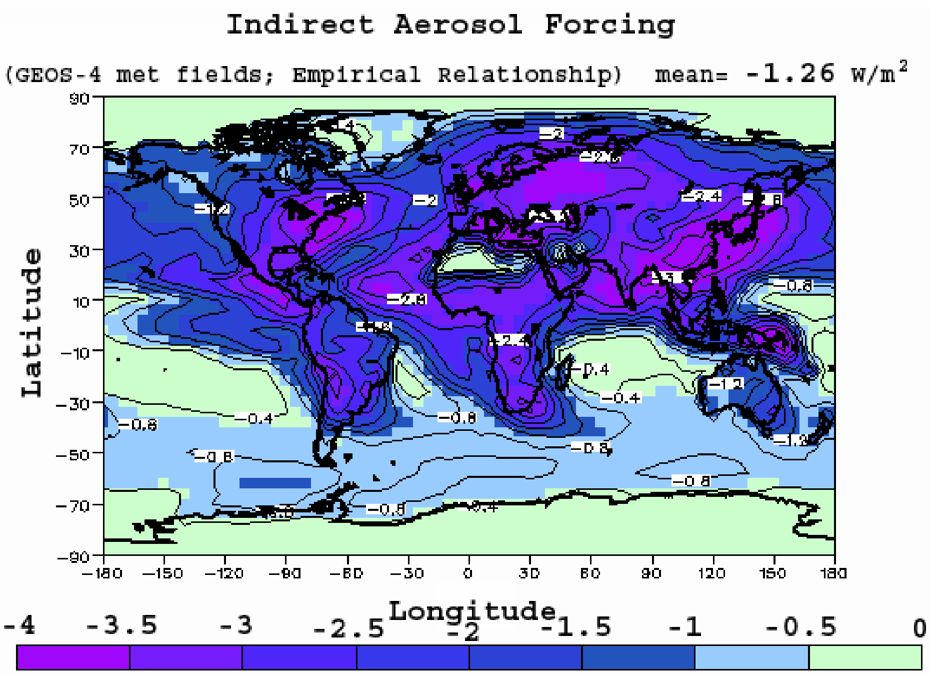
emp > prog







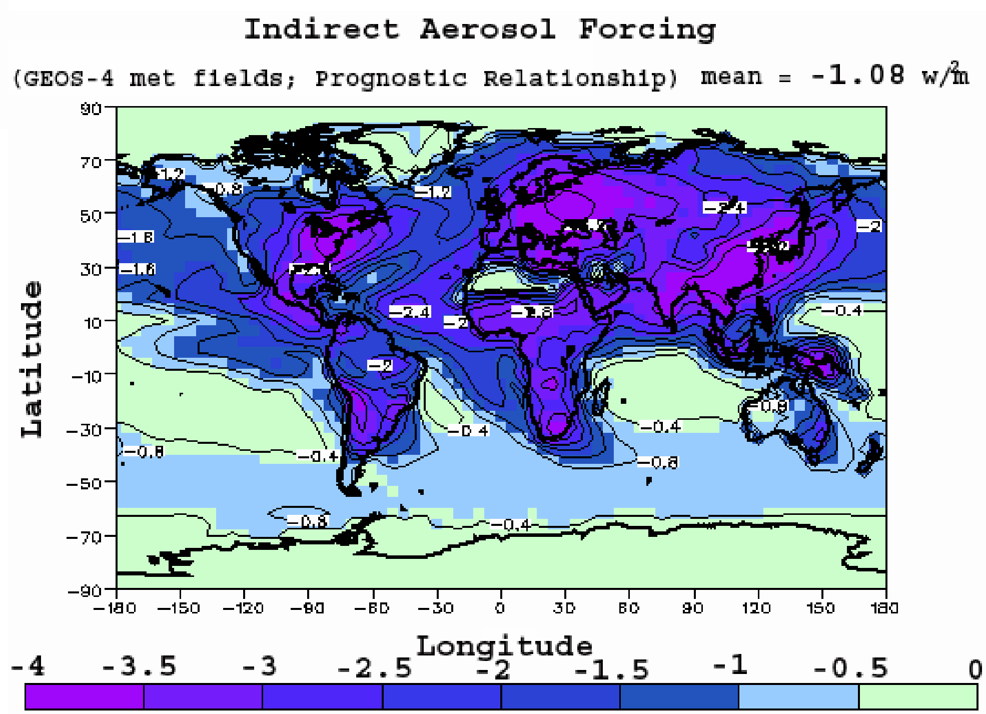
Yearly averaged Indirect Aerosol Forcing



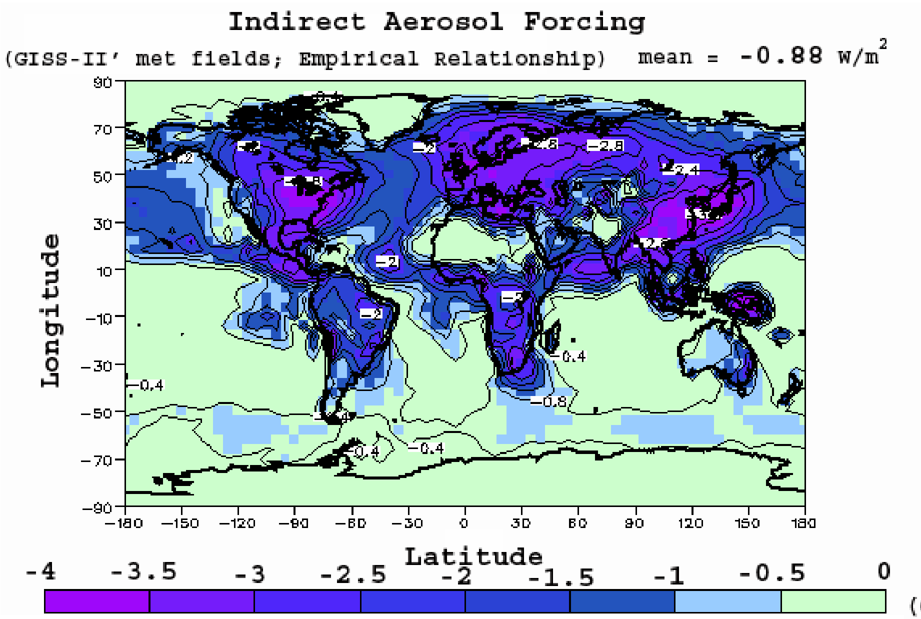
DAO ~ GEOS-4

Forcing = -1.08 W/m^2

Forcing = -1.26 W/m^2



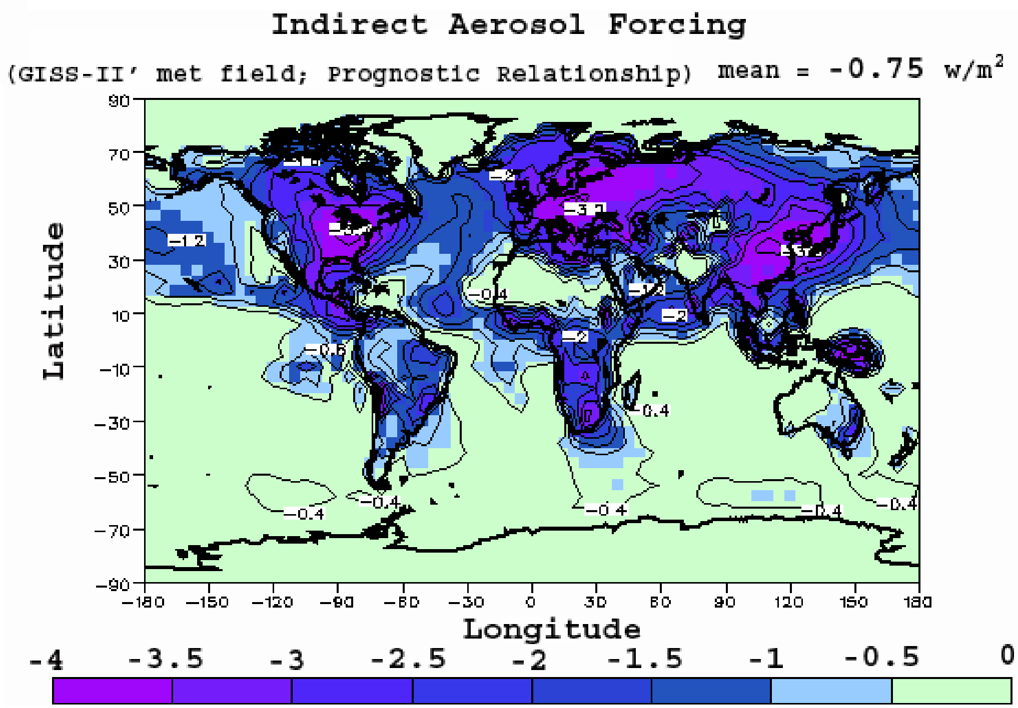
Yearly averaged Indirect Aerosol Forcing



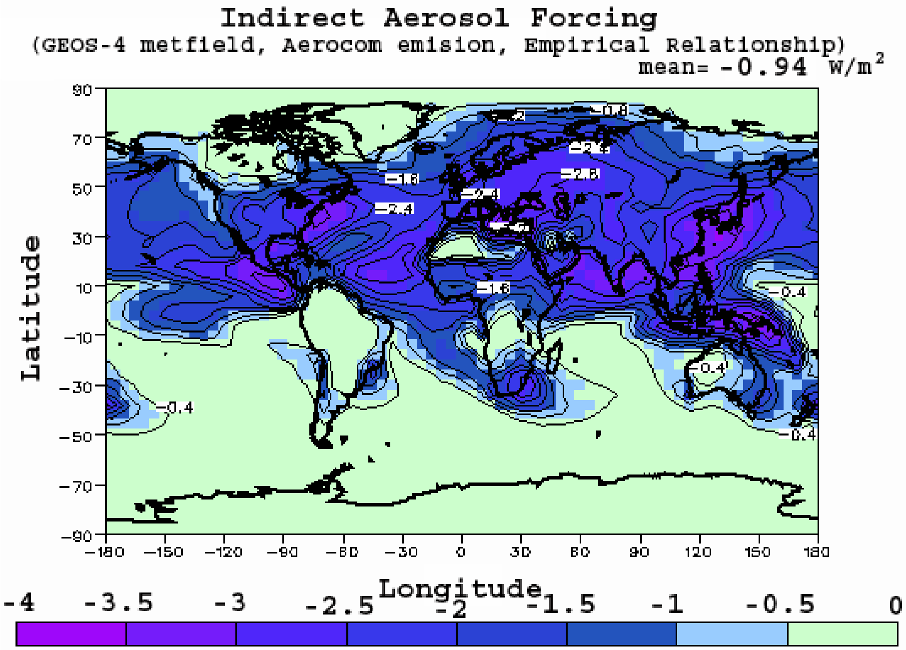
GISS-II' < DAO, GEOS-4

Forcing = -0.75 W/m^2

Forcing = -0.88 W/m^2



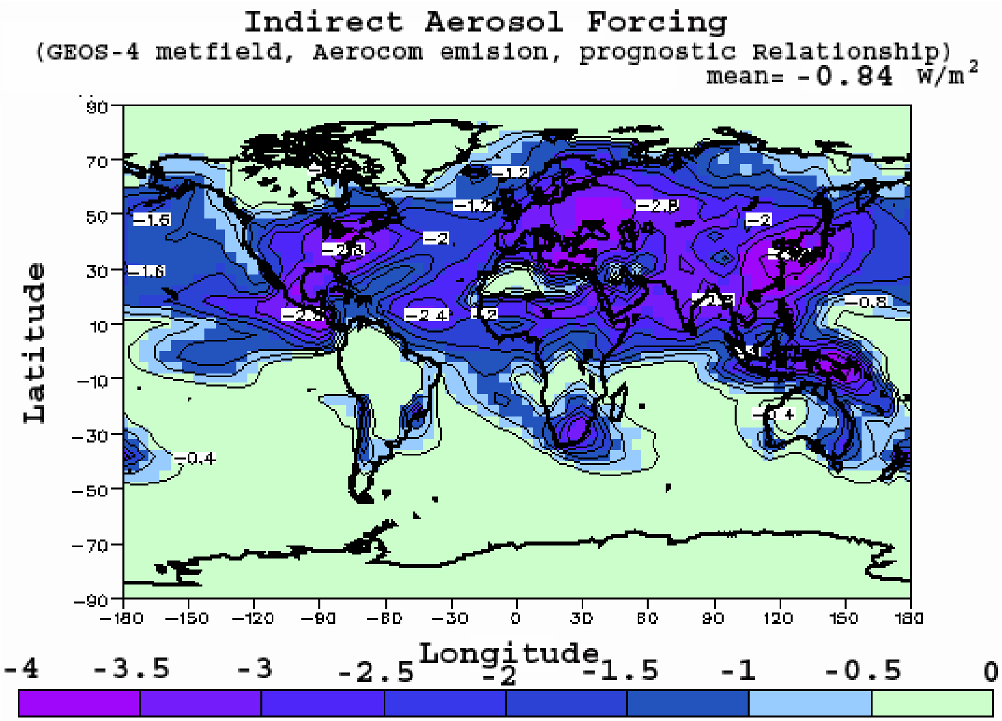
Yearly averaged Indirect Aerosol Forcing



AEROCOM < Michigan

Forcing = -0.84 W/m^2

Forcing = -0.94 W/m^2



Conclusions

- GMI- ideal testbed for assessing the effect of different parameters (i.e., emission scenarios, met fields, chemical modules) on Aerosol Indirect Forcing

- Calculated global yearly averaged indirect aerosol forcing for different met fields and droplet activation parameterizations

-0.75 W/m^2 to -1.27 W/m^2

- Different met fields lead up to **30%** (Global average) variability in indirect forcing calculations

- Diagnostic and empirical parameterizations up to **20%** (Global average) difference

- Different emission scenarios lead up to **20%** (Global average) difference

Thank you !