Top-of-Atmosphere Direct Radiative Effect of Aerosols over Global Oceans from Merged CERES and MODIS Observations

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Introduction

- Do models and observations provide consistent estimates of the total (natural+anthropogenic) direct radiative effect of aerosols (DREA) over clear ocean?

- **What are the uncertainties in the observations and how can they be reduced?**

- **What is the seasonal and interannual variability in the DREA over ocean?**

- What observations are needed to determine the natural and anthropogenic components of the total DREA?

Direct Radiative Effect of Aerosols (Natural+Anthropogenic)

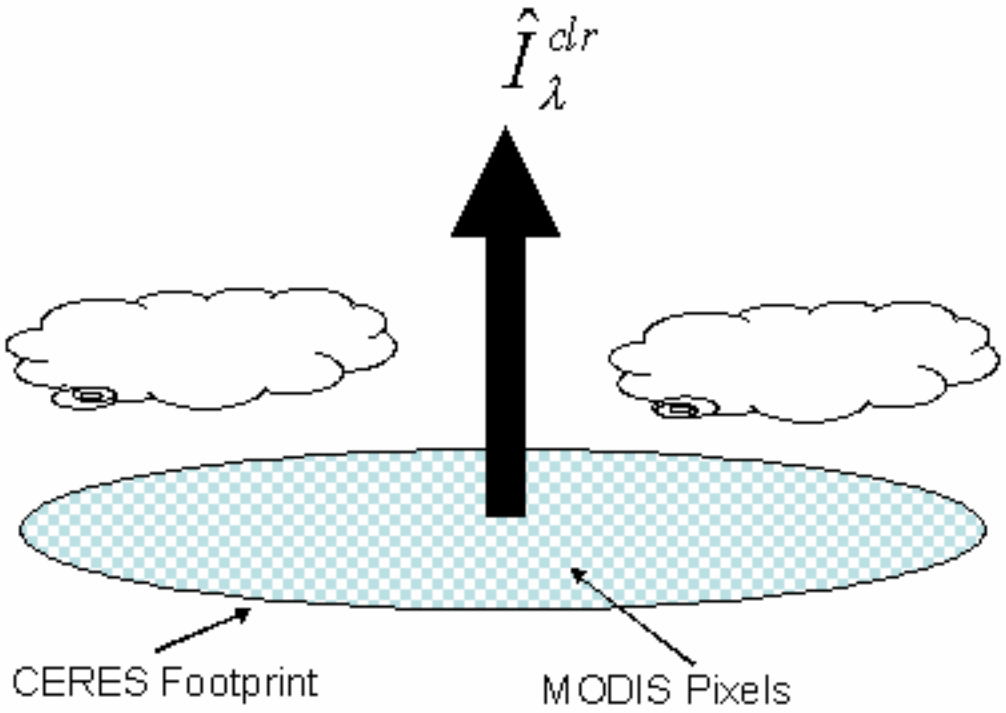
$$\Delta\overline{F}_{SW}^{clr}(\Theta,\Phi) = \overline{F}_{SW}^{na}(\Theta,\Phi) - \overline{F}_{SW}^{clr}(\Theta,\Phi)$$

$\overline{F}_{SW}^{clr}(\Theta,\Phi)$ = clear-sky SW TOA flux

$\overline{F}_{SW}^{na}(\Theta,\Phi)$ = clear-sky SW TOA flux (no aer)

	Spectral Resolution	Spatial Resolution
MODIS	Narrowband	**0.5 km**
CERES	**Broadband**	20 km

DIRECT RADIATIVE EFFECT OF AEROSOLS



$\hat{I}_{\lambda}^{clr}$

↓

Narrow-to-Broadband Conversion

↓

$\hat{I}_{SW}^{clr}$

↓

Angular Distribution Model

↓

$\hat{F}_{SW}^{clr}$

↓

$\hat{F}_{SW}^{na}$ → Temporal Averaging

↓

$\Delta\overline{F}_{SW}^{clr}$

NARROW-TO-BROADBAND REGRESSIONS

Data:

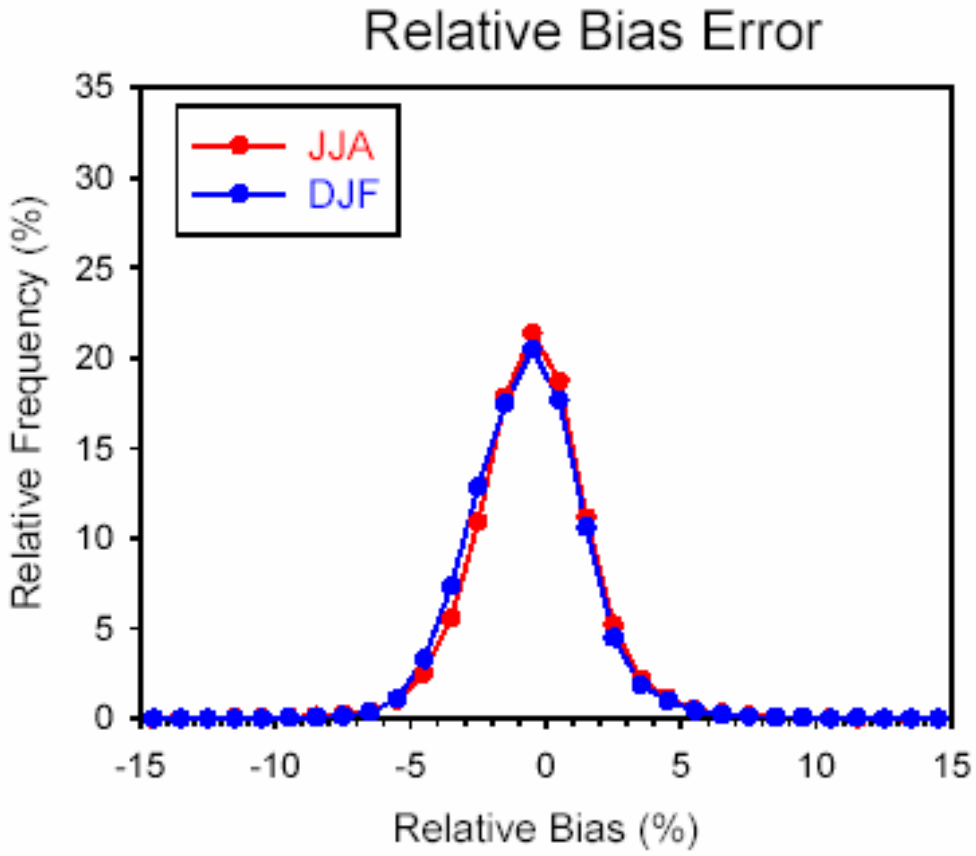
- CERES Single Scanner Footprint TOA/Surface Fluxes and Clouds (SSF)
- MODIS radiances at 0.644 μm, 0.858 μm, and 1.632 μm
- March 2000 - December 2003

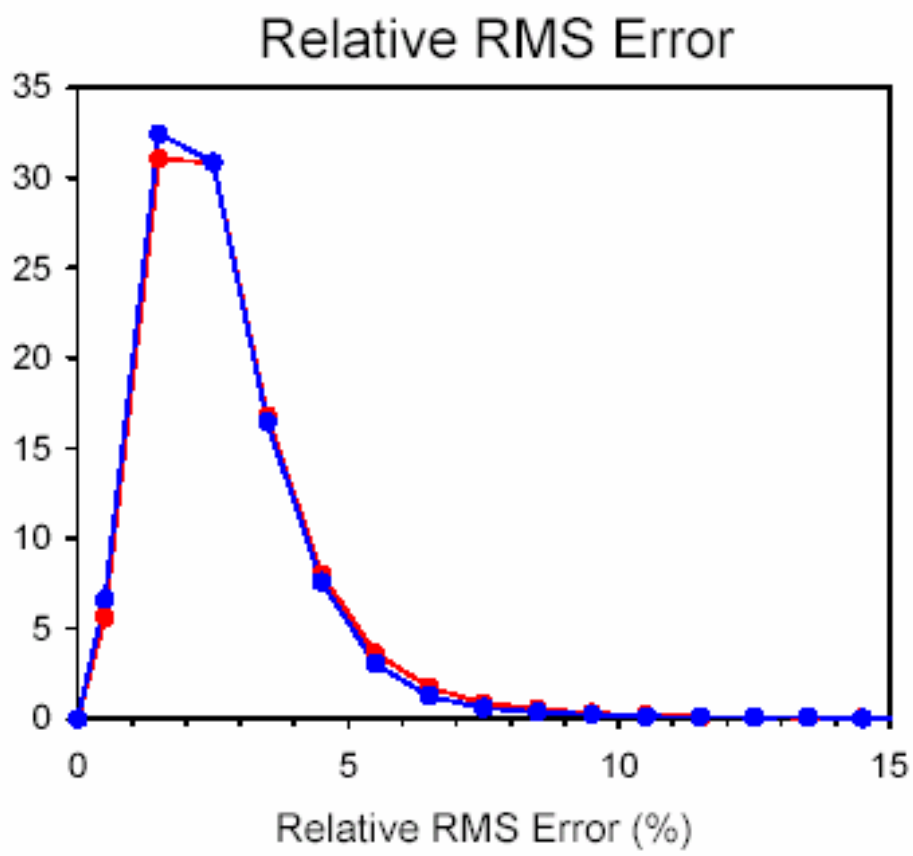
Multi-Channel Regression Fit:

$$\hat{I}_{SW}^{clr} = a_o + \sum_{i=1}^{N_\lambda} a_i I_i^{clr}$$

- I_i cloud-free MODIS radiance in ith channel
- Function of viewing geometry ($\Delta\theta_o$=10°; $\Delta\theta$=10°; $\Delta\phi$=20°)
- a_i's determined monthly using cloud-free CERES FOVs
- Avoid sunglint

1°x1° Regional Relative Bias and RMS Error in SW Radiance From Narrow-to-Broadband Regression

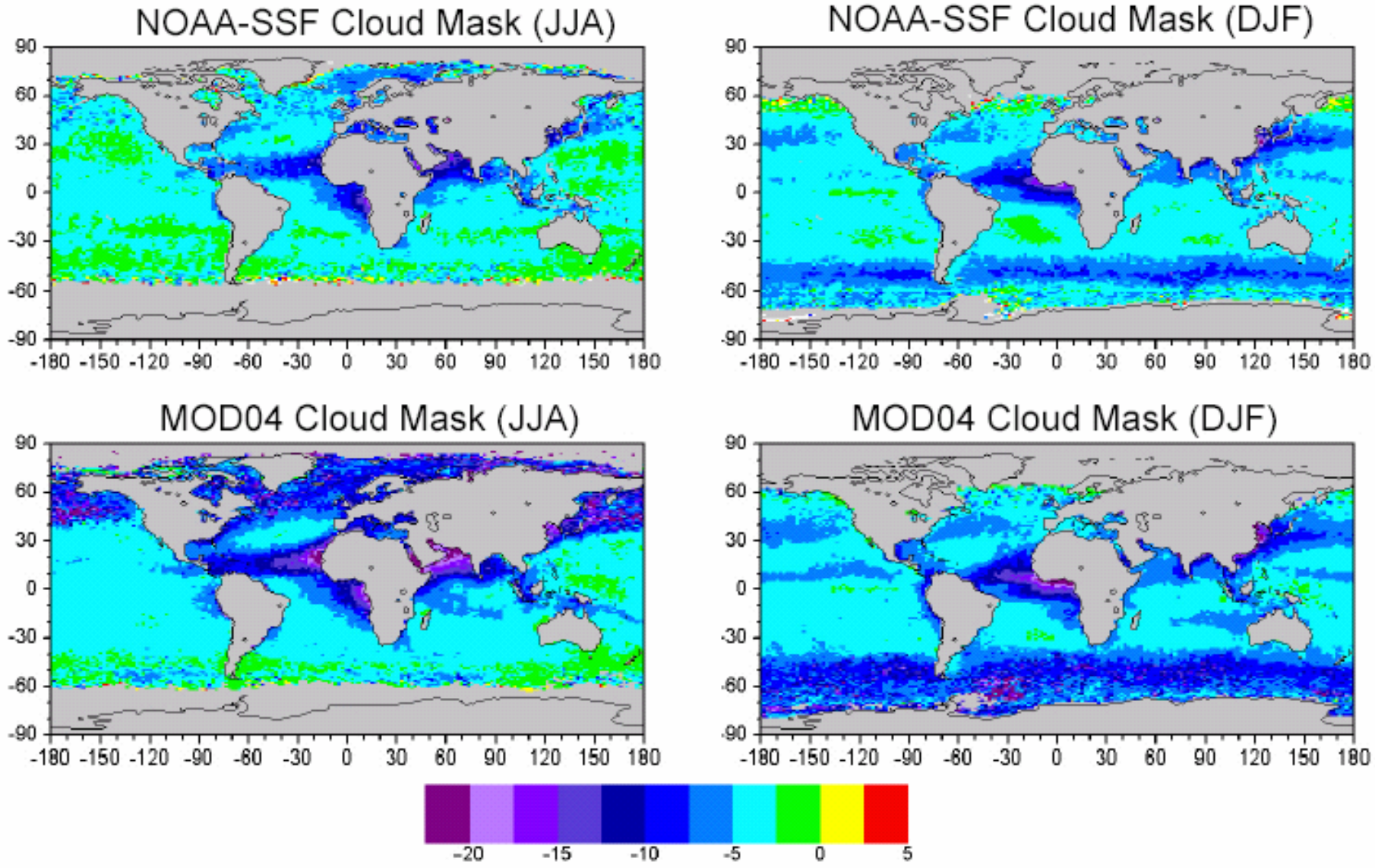




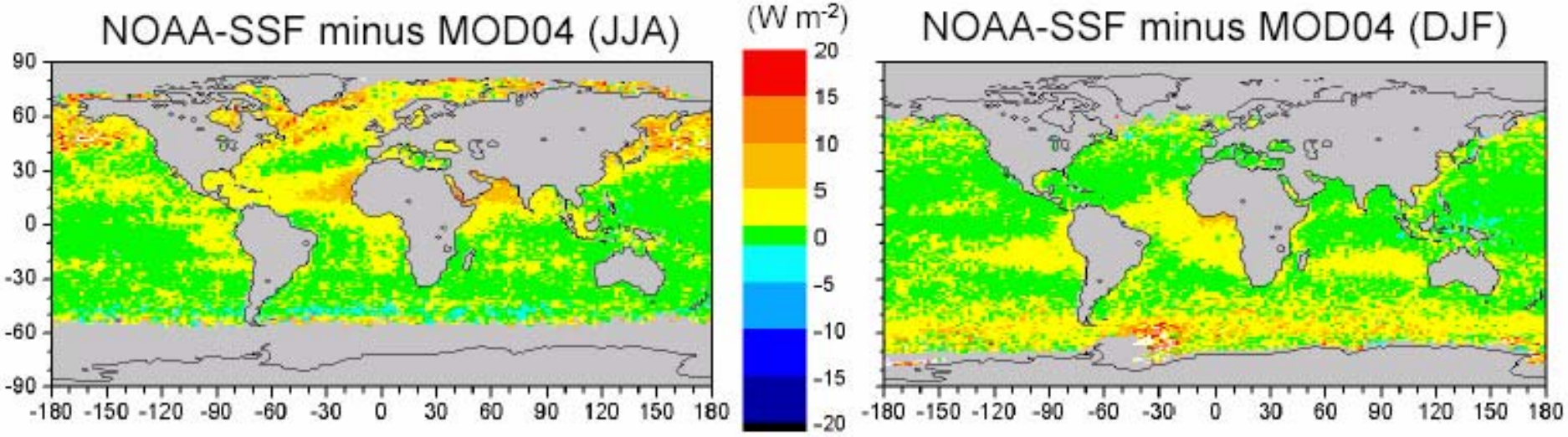
Avg relative bias error = -0.5%
(=> -0.2 W m^{-2} 24-h avg flux)

Avg relative RMS error = 2.75%
(=> 1 W m^{-2} 24-h avg flux)

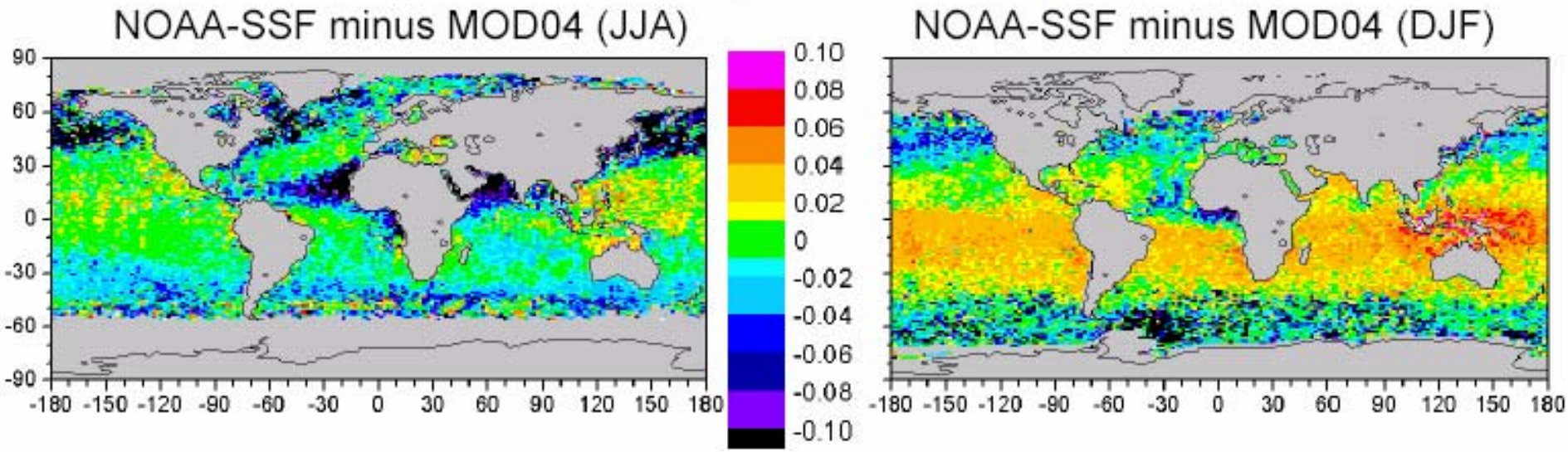
Clear-Sky SW Direct Radiative Rffect of Aerosols: Sensitivity to Cloud Mask



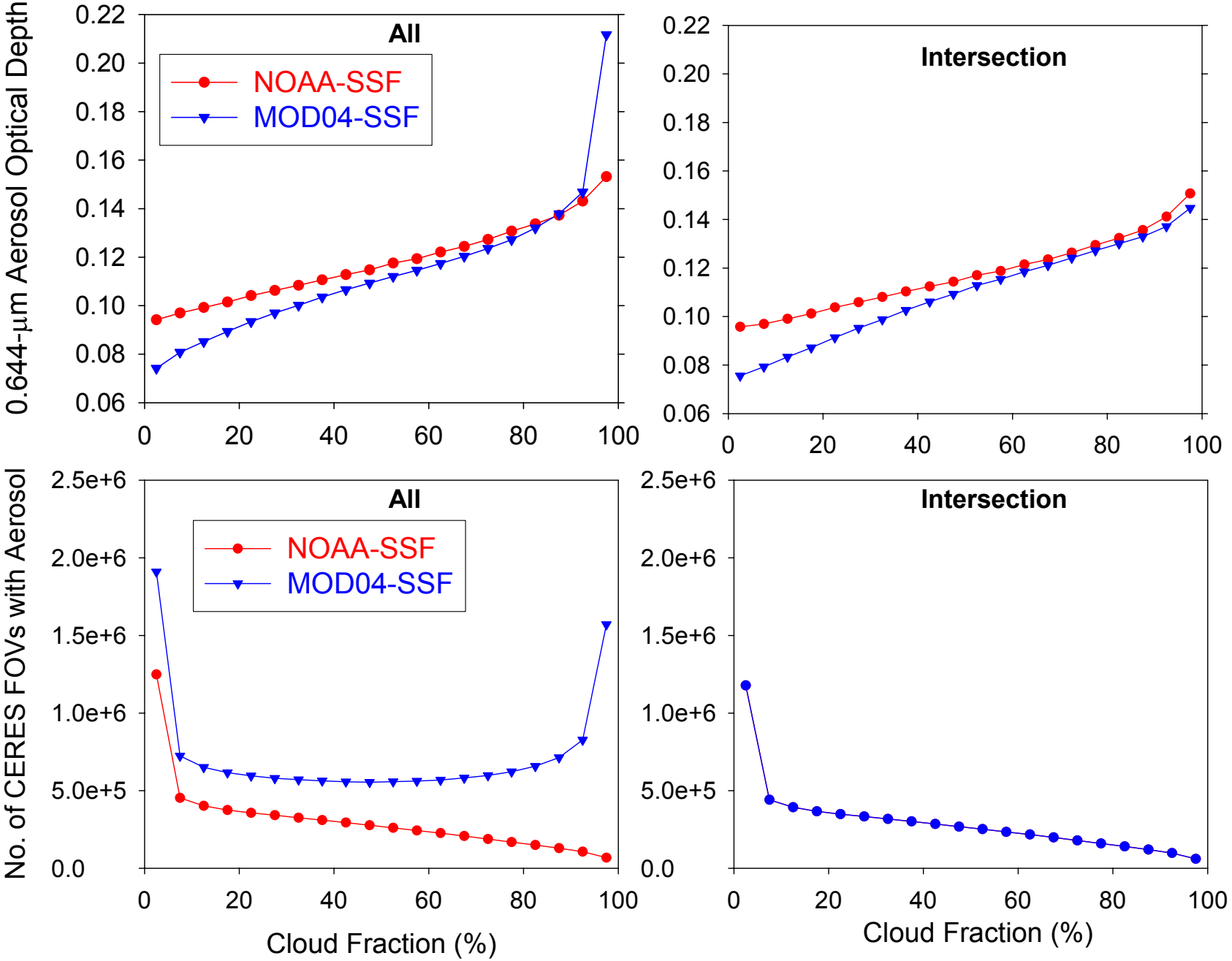
Difference in Clear-Sky SW Direct Radiative Effect



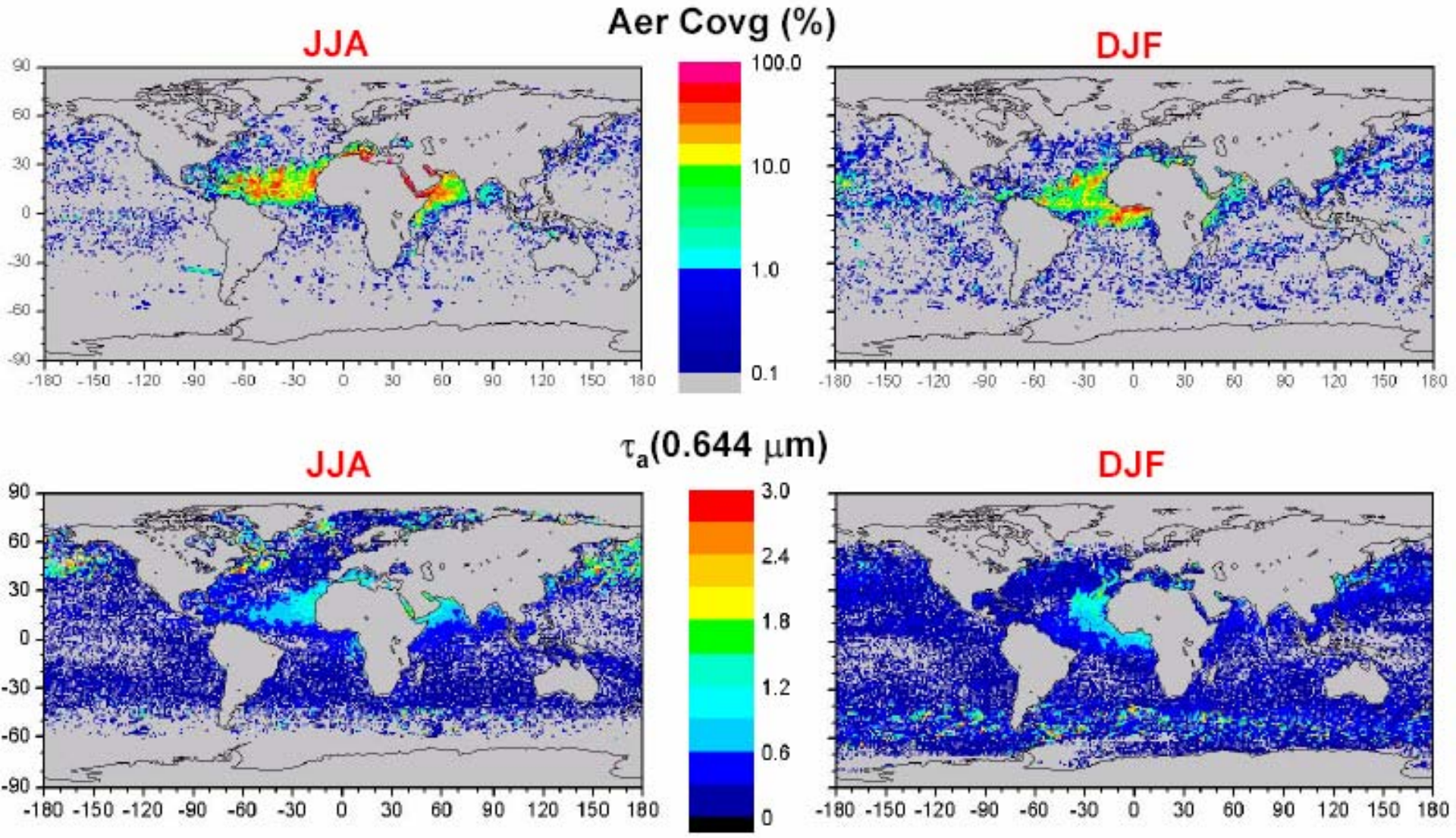
Difference in 0.644-μm Aerosol Optical Depth



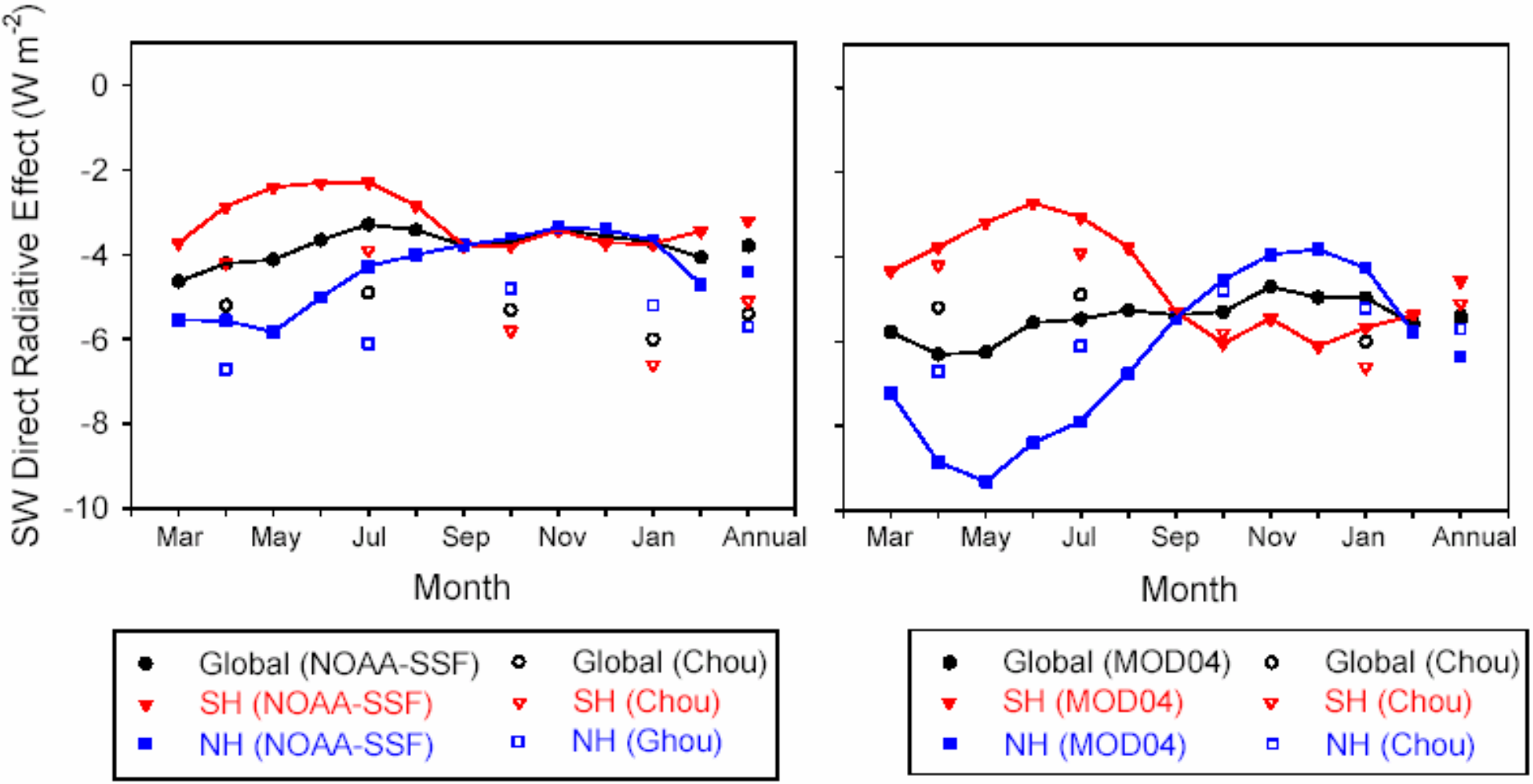
0.644-μm Aerosol Optical Depth vs Cloud Fraction (JJA 2000)



MOD04 Aerosol Coverage & 0.644-μm Aerosol Optical Depth in "Overcast" CERES Footprints Identified by CERES Cloud Mask



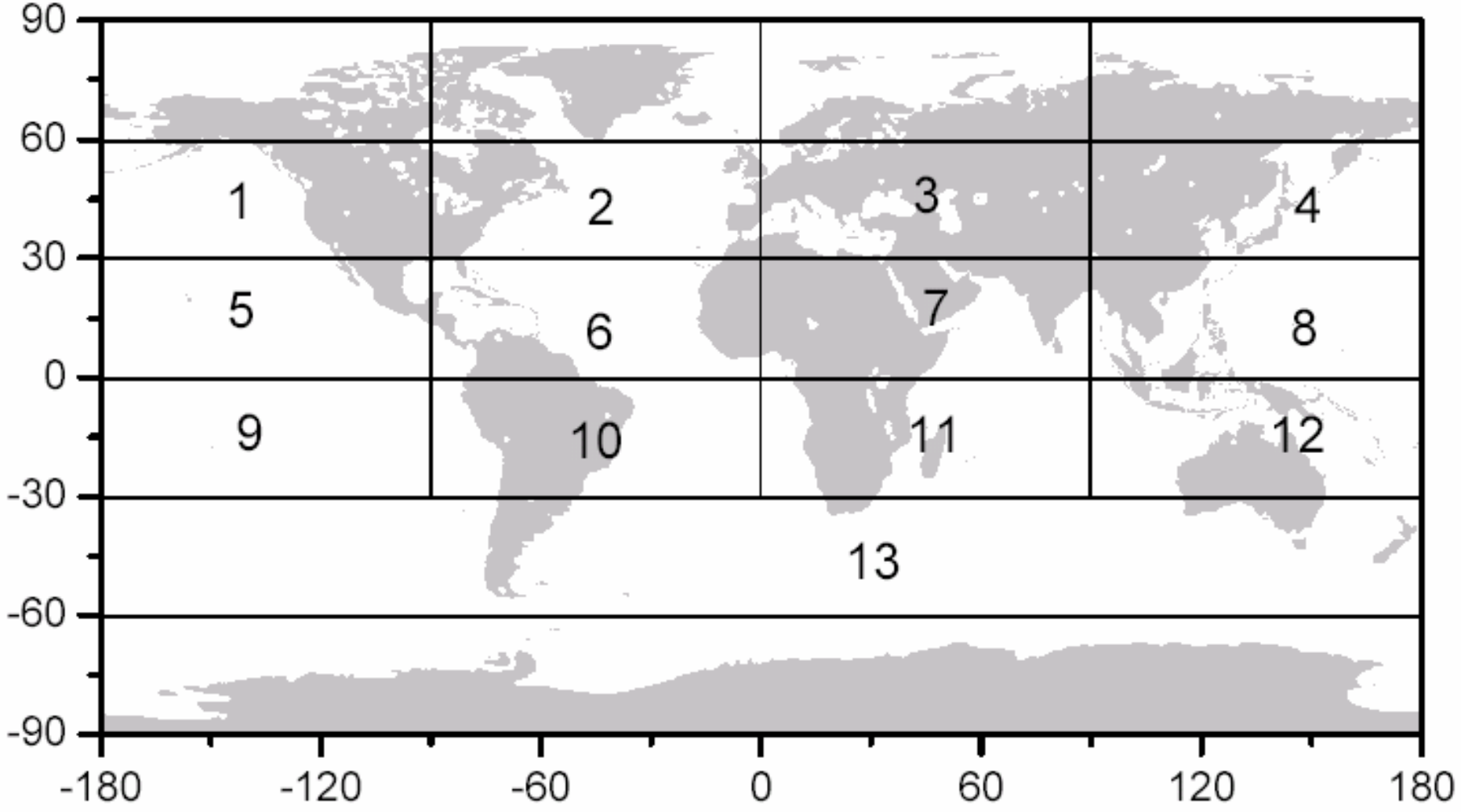
Clear-Sky SW Direct Radiative Effect: Comparison with Chou et al. (2002)

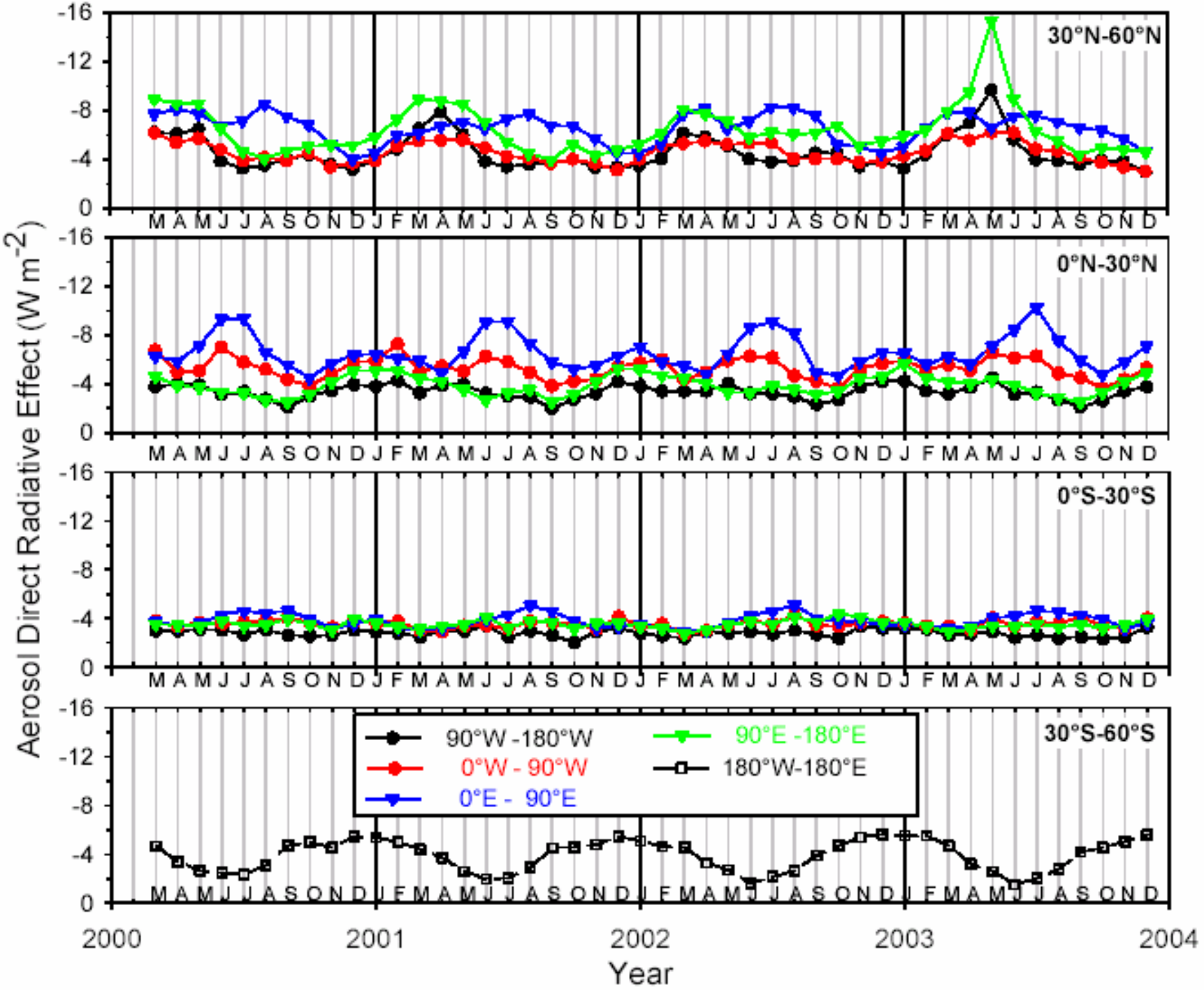


Annual Average Clear-Sky SW Direct Radiative Effect: Comparison with Chou et al. (2002)

	SW Direct Effect of Aerosols (W m^{-2})		
	NOAA-SSF	MOD04	Chou_2002
Global	-3.8	-5.5	-5.4
SH	-3.2	-4.6	-5.1
NH	-4.4	-6.4	-5.7

Stratification by Region




30°N-60°N
0°N-30°N
0°S-30°S
30°S-60°S
90°W -180°W
0°W - 90°W
0°E - 90°E
90°E -180°E
180°W-180°E
Aerosol Direct Radiative Effect (W m-2)
Year
2000
2001
2002
2003
2004

Conclusions

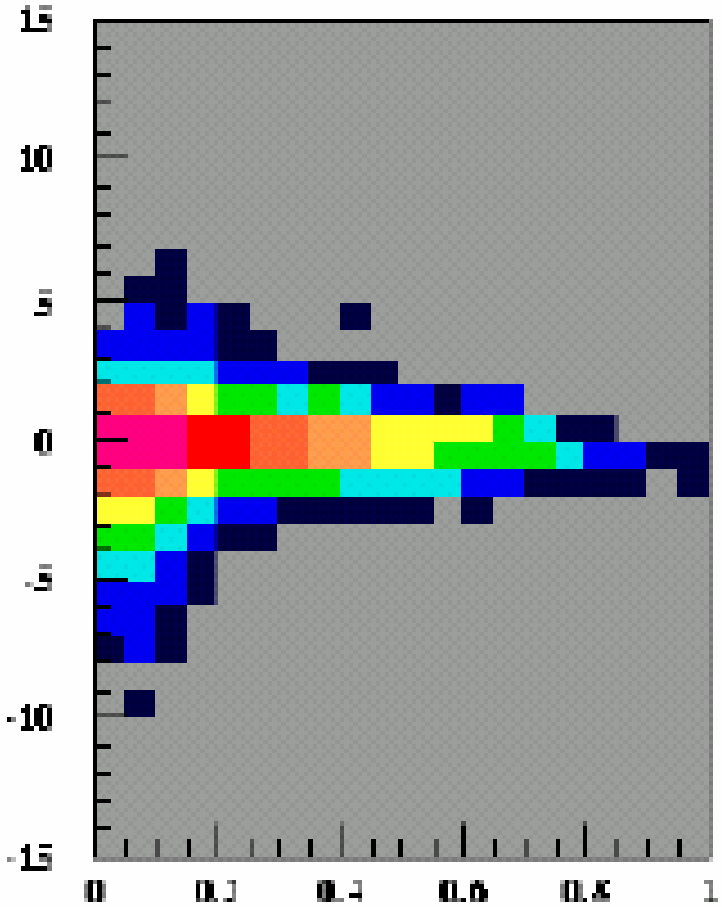
- Global ocean clear-sky SW direct radiative effect of aerosols estimated to be -5.5 W m^{-2} (MOD04) and -3.8 W m^{-2} (NOAA-SSF).

- Large regional and global uncertainty due to cloud mask differences, especially near desert regions.
  -> CALIPSO should help with this.

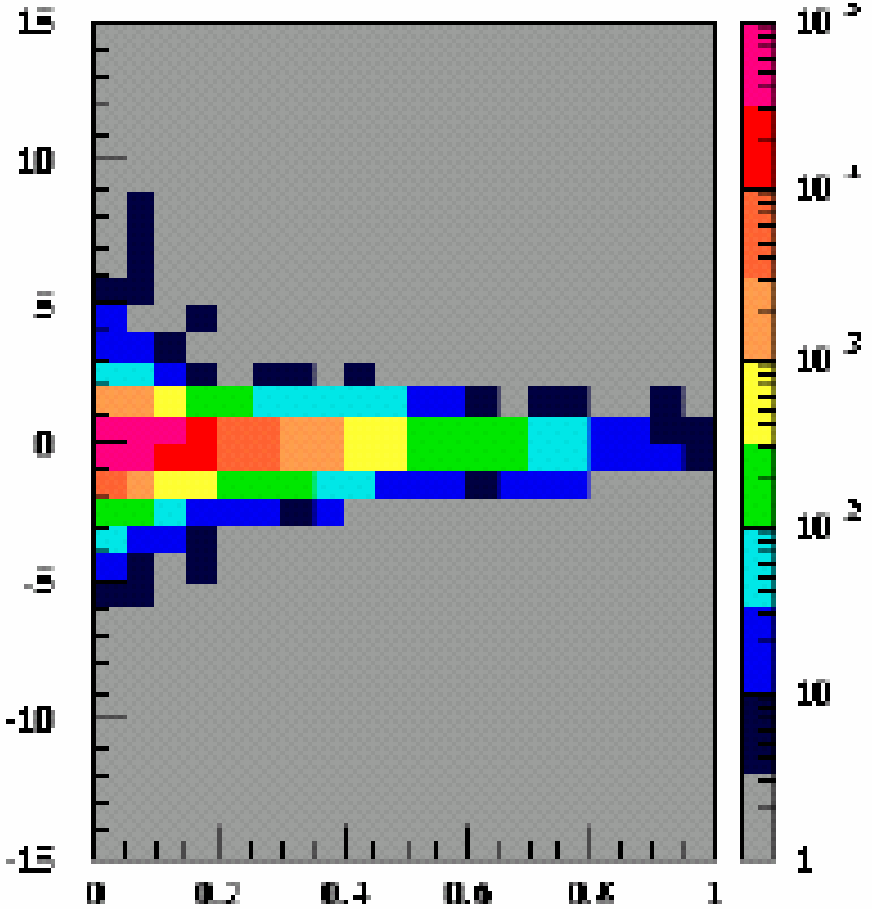
- The DREA has pronounced seasonal cycle in the Northern Hemisphere and large year-to-year fluctuations between 30°-60°N.

- No systematic trend in deseasonalized anomalies of the DREA is observed over the 46-month time series considered

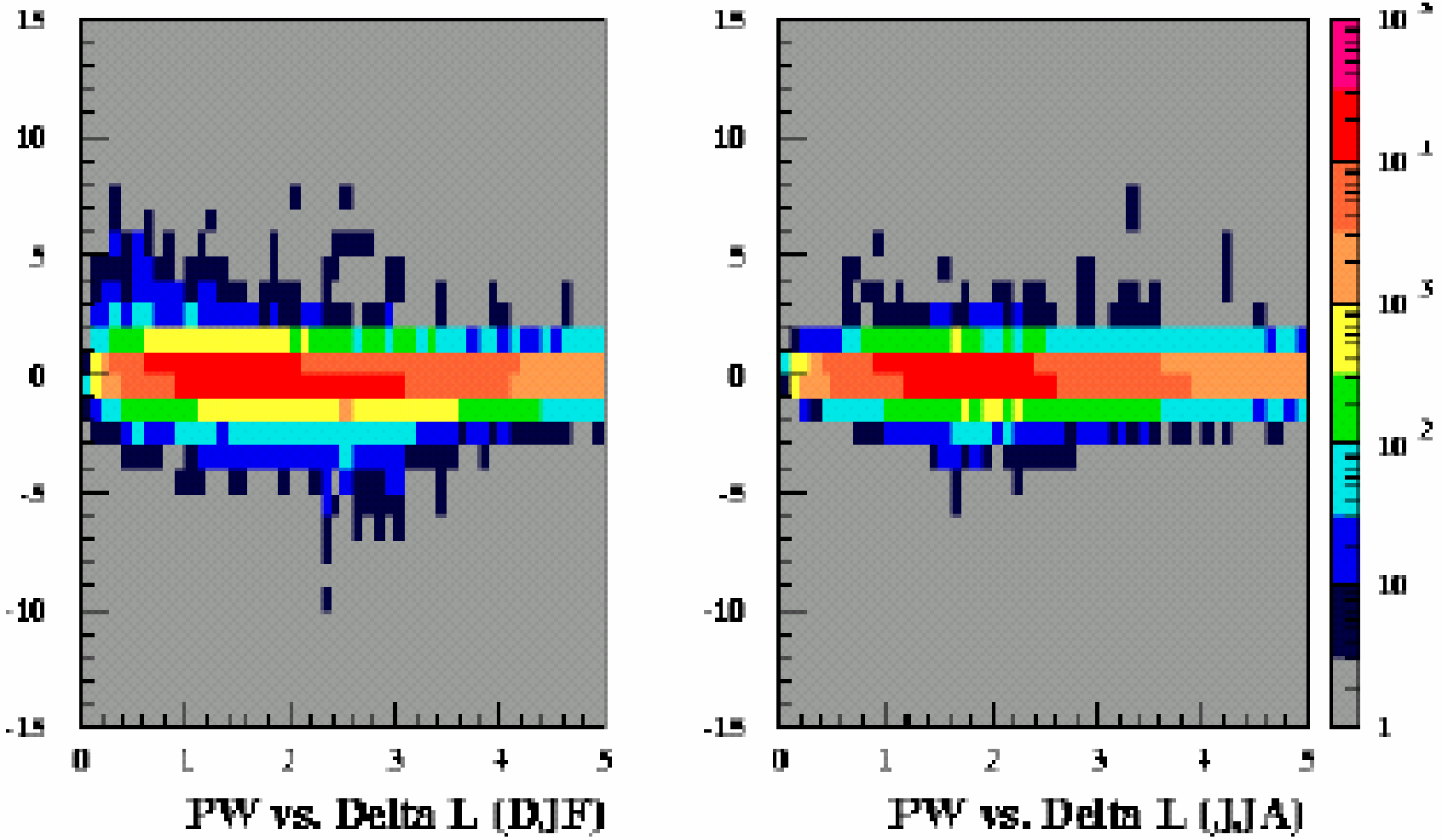
- Next: Extend analysis to land



Tau vs. Delta L (DJF)

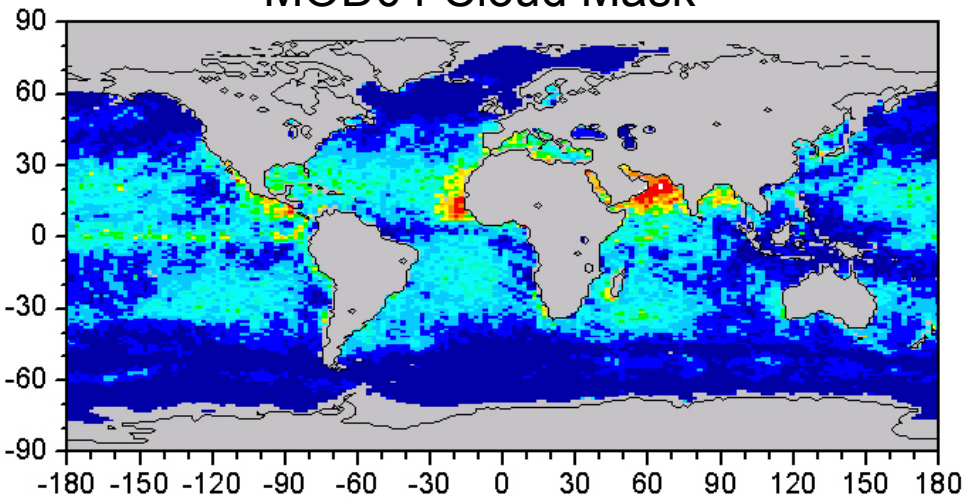


Tau vs. Delta L (JJA)


15
10
5
0
-5
-10
-15
0
1
2
3
4
5
PW vs. Delta L (DJF)
PW vs. Delta L (JJA)

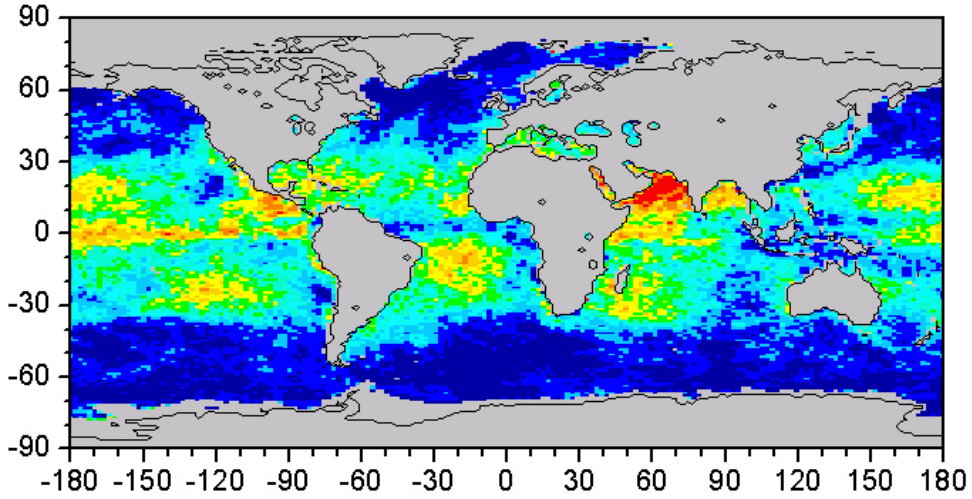
Clear Fraction (March 2000)

MOD04 Cloud Mask

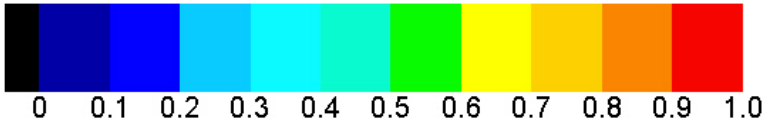


Global Avg
0.21

CERES Cloud Mask



Global Avg
0.32



Clear Fraction