CERES/MODIS/MISR Synergy

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Data Fusion and CERES

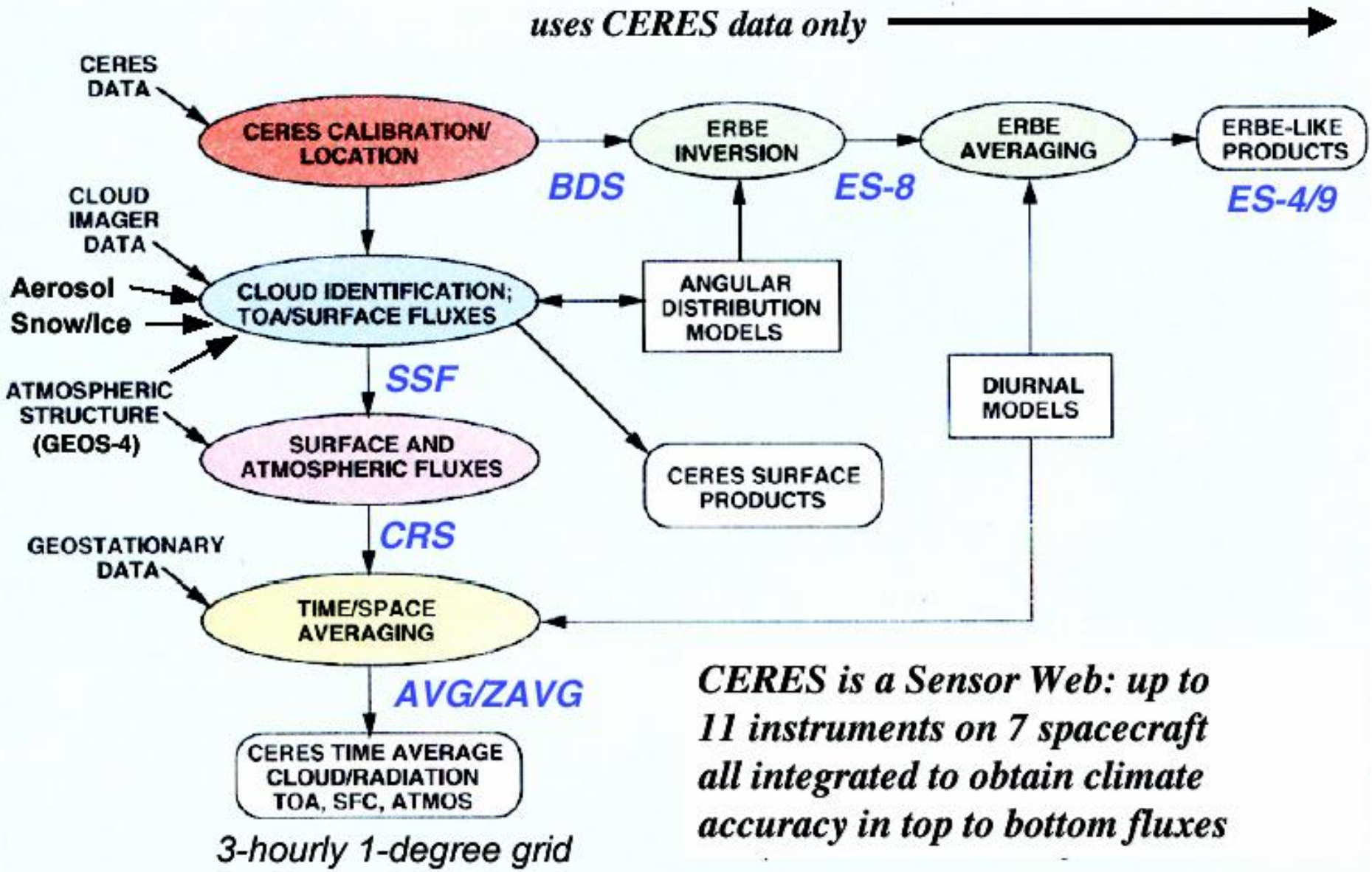
- **From the beginning of CERES, the need to merge data from multiple instruments was recognized.**

-> Development of improved Angular Distribution Models (ADMs) (CERES+MODIS+GMAO).

-> Model calculation of surface, within-atmosphere and top-of-atmosphere radiative fluxes (CERES+MODIS+GMAO+MATCH).

-> Time and space averages of CERES fluxes (CERES+MODIS+GMAO+GEO).

CERES DATA PROCESSING FLOW

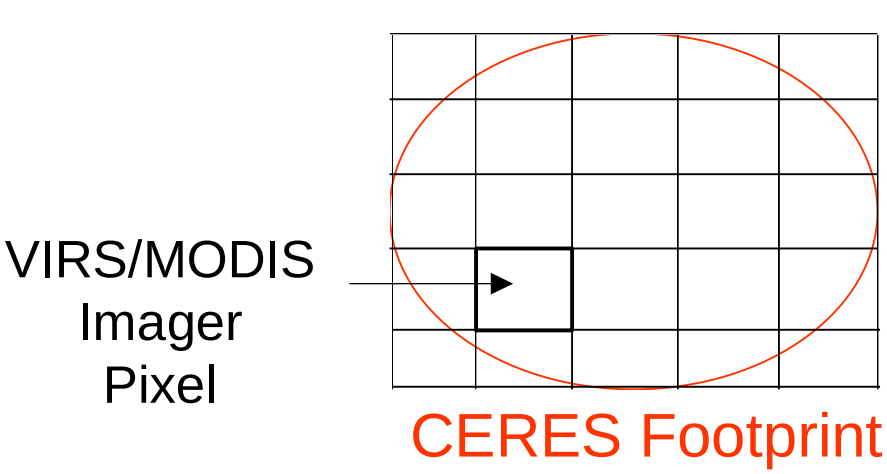


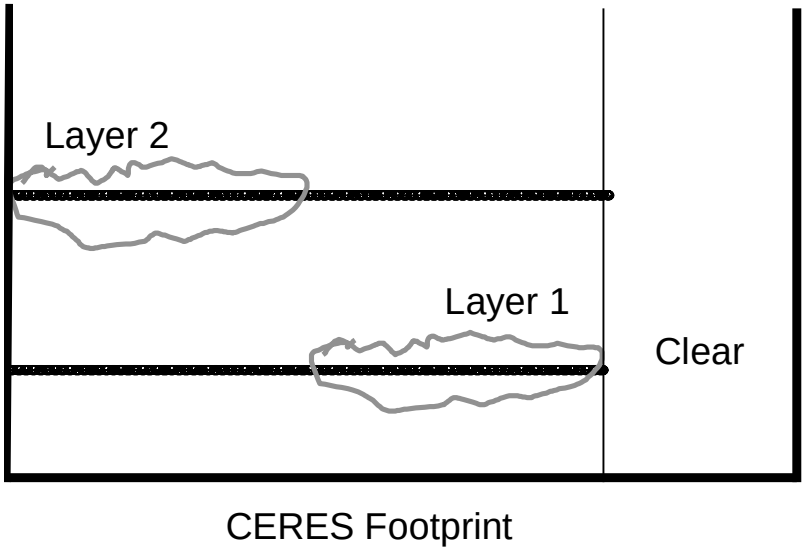
CERES is a Sensor Web: up to 11 instruments on 7 spacecraft all integrated to obtain climate accuracy in top to bottom fluxes

CERES Single Scanner Footprint (SSF) Product

- Coincident CERES radiances and imager-based cloud and aerosol properties (including MOD04 and NOAA-NESDIS aerosol products).
- Use VIRS (TRMM) or MODIS (Terra, Aqua) to determine the following parameters in up to 2 cloud layers over every CERES FOV:

Macrophysical: Fractional coverage, Height, Radiating Temperature, Pressure
Microphysical : Phase, Optical Depth, Particle Size, Water Path
Clear Area : Albedo, Skin Temperature, Aerosol optical depth, Emissivity





Selected Science Problems Involving CERES/MODIS/MISR Data Fusion

i) Development and validation of CERES Angular Distribution Models.

ii) Direct Radiative Effects of Aerosols – Ocean and Land.

iii) Cloud-Aerosol Interaction Studies.

Development and Validation of CERES Angular Distribution Models

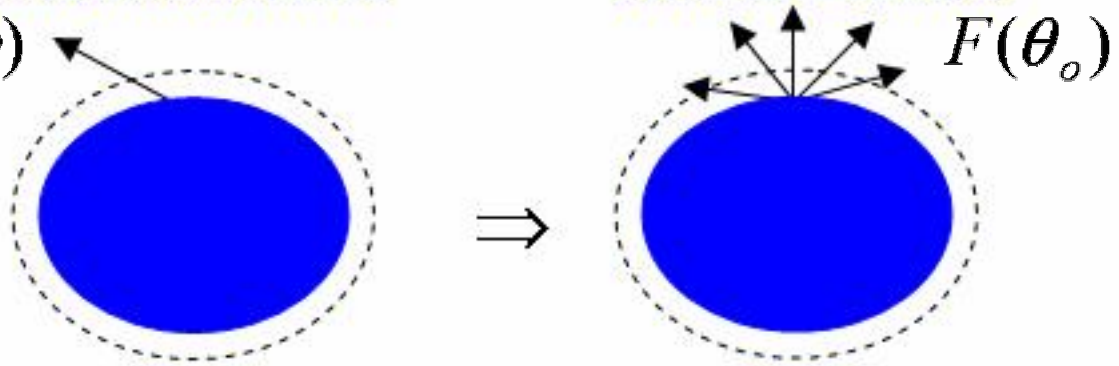
Instantaneous Fluxes at TOA and Angular Distribution Models

CERES Radiance Measurement

$L(\theta_o, \theta, \phi)$

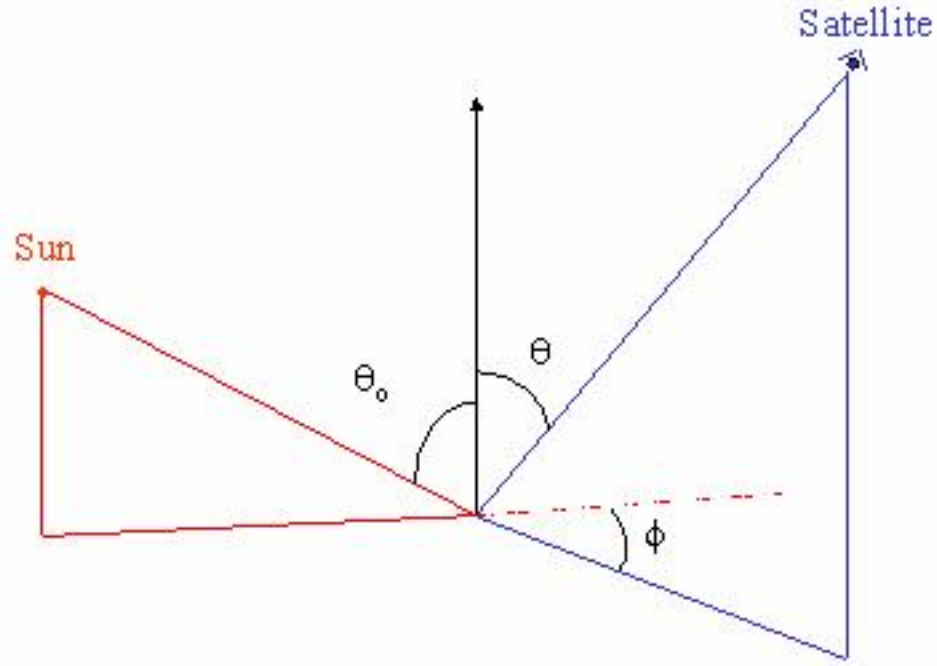
TOA Flux Estimate

$F(\theta_o)$



SW
LW
WN

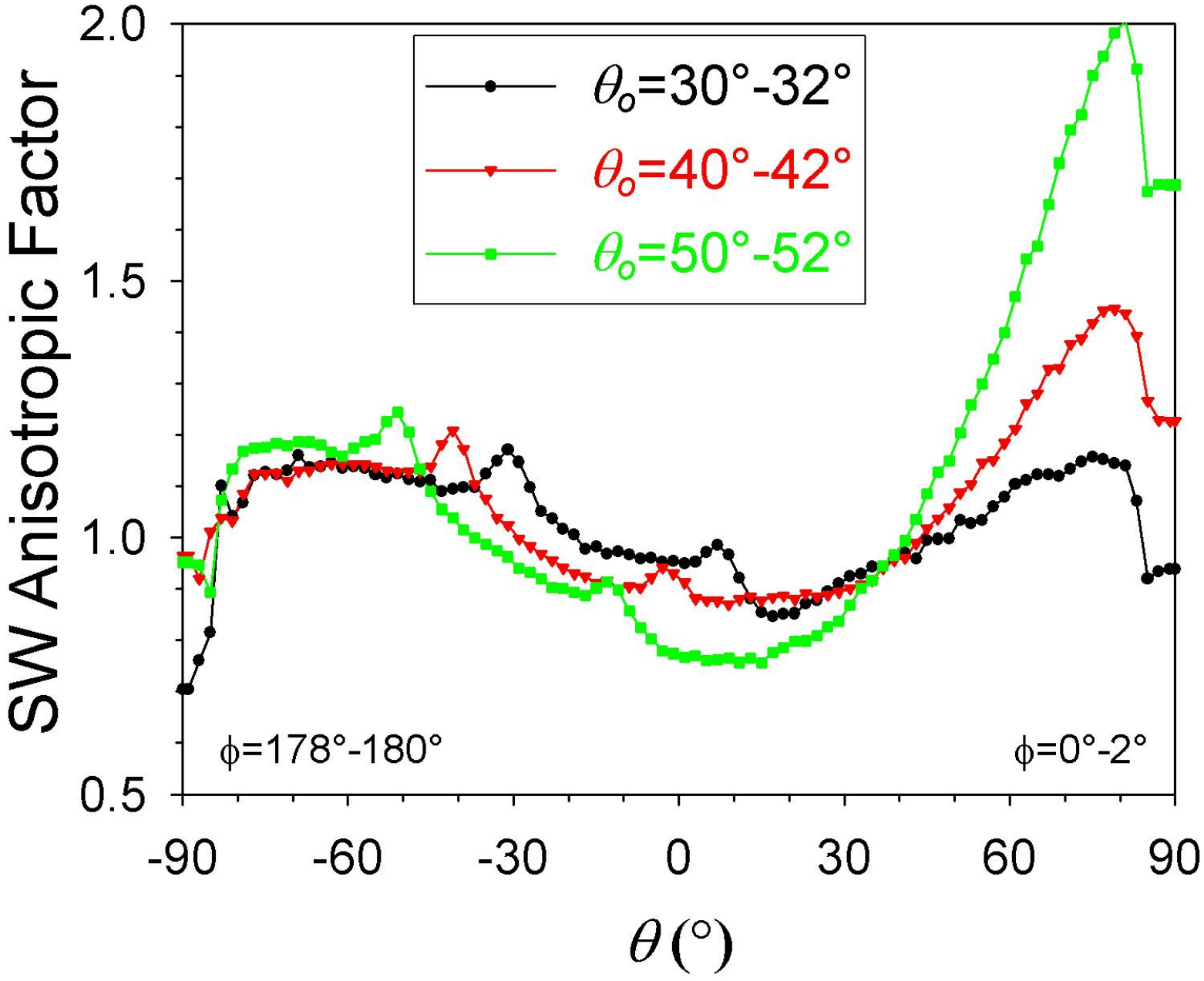
$$F(\theta_o) = \int_0^{2\pi} \int_0^{\frac{\pi}{2}} L(\theta_o, \theta, \phi) \cos\theta \sin\theta d\theta d\phi$$



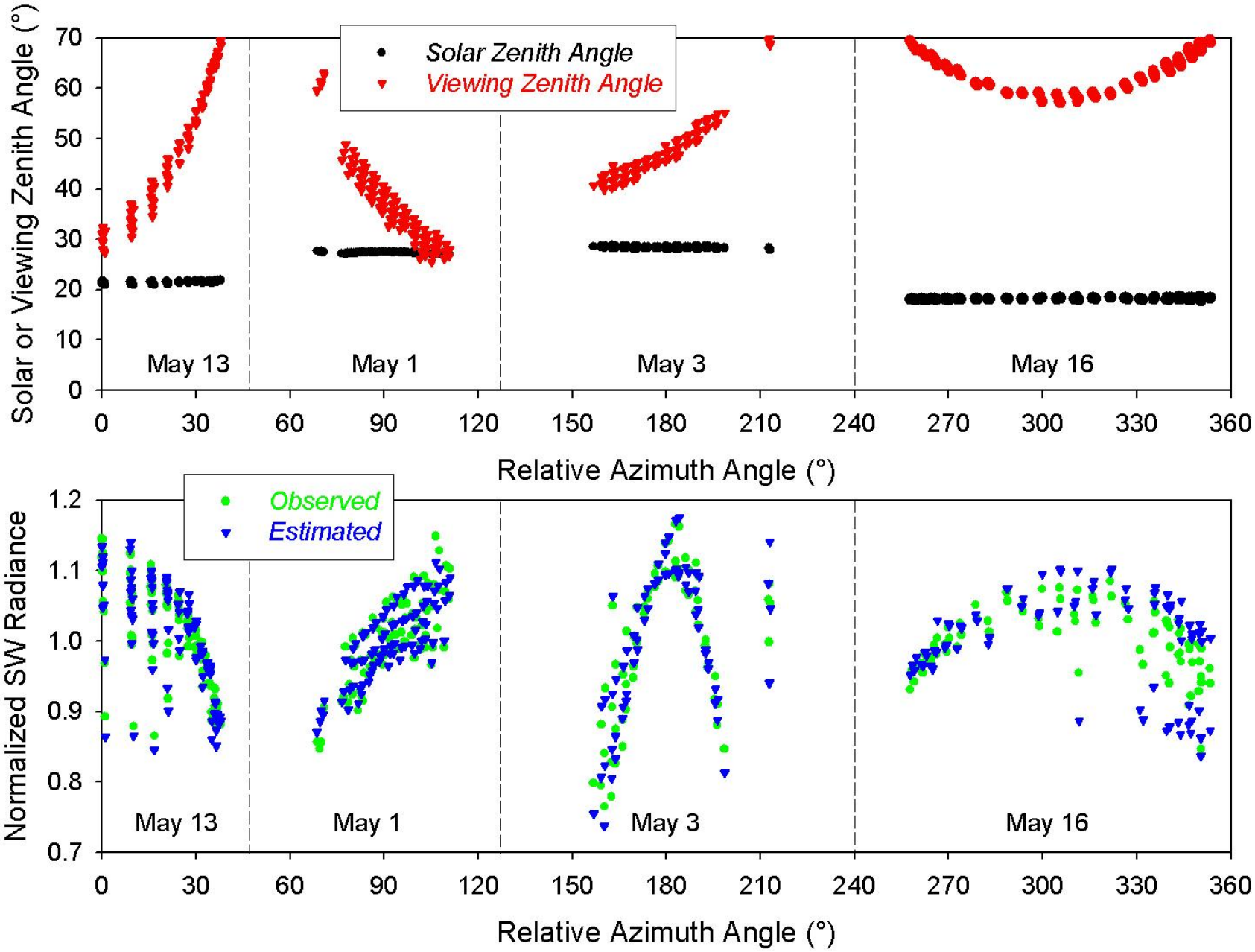
CERES/Terra Shortwave ADMs for Different Scene Types

Scene Type	Description
Clear Ocean	Function of wind speed; Correction for aerosol optical depth included.
Cloud Ocean	Function of cloud phase; Continuous function of cloud fraction and cloud optical depth (5-parameter sigmoid).
Land & Desert Clear	1° regional monthly ADMs using Analytical Function of TOA BRDF (Ahmad and Deering, 1992).
Land & Desert Cloud	Function of cloud phase; continuous function of cloud cover and cloud optical depth; uses 1°-regional clear-sky BRDFs to account for background albedo.
Permanent Snow	Cloud Fraction, Surface Brightness, cloud optical depth
Fresh Snow	Cloud Fraction, Surface Brightness, Snow Fraction, cloud optical depth
Sea-Ice	Cloud Fraction, Surface Brightness, Ice Fraction, cloud optical depth

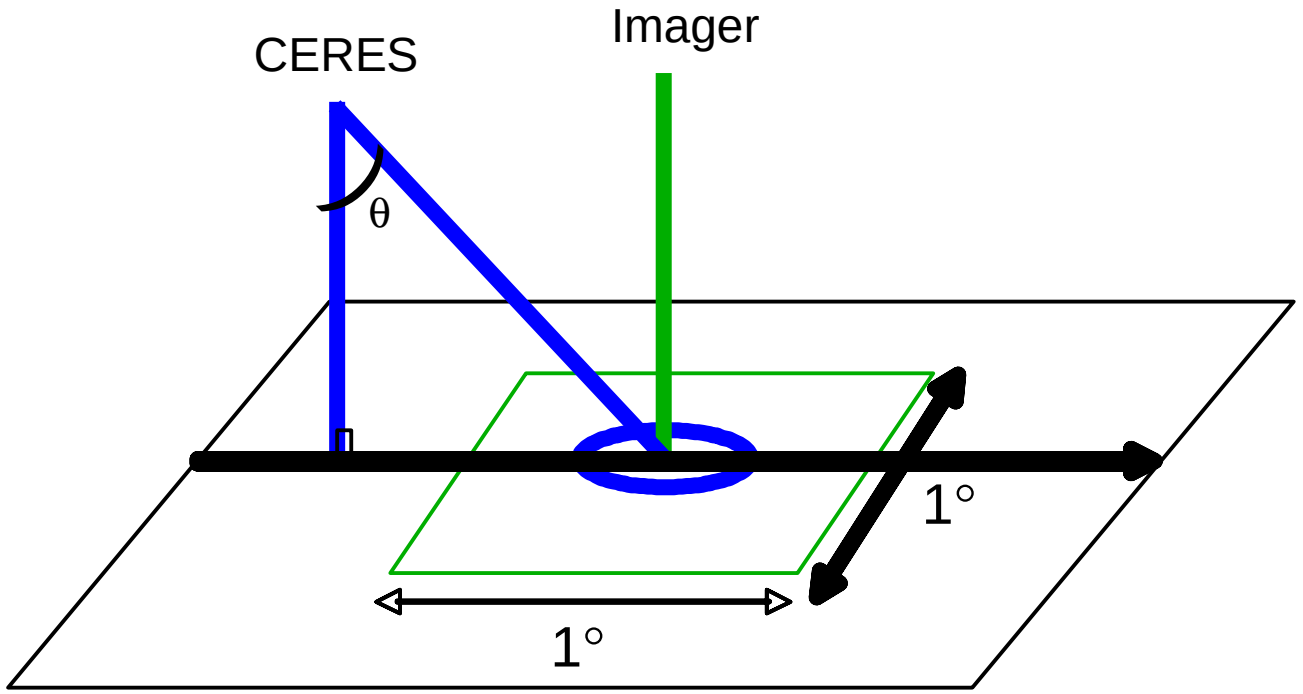
SW Anisotropy of Liquid Water Clouds from CERES *Terra*



Observed and ADM Anisotropy Over ARM SGP-Overcast



CERES-MODIS Instantaneous TOA Flux Consistency Tests



- **Convert imager nadir visible radiance to broadband flux**
- **Compare off-nadir CERES flux with nadir flux inferred from imager visible radiance**
- **79 global alongtrack days over 4 years**

CERES SW TOA Flux Consistency by Cloud Type
(RMS SW Flux Diff [F(θ=50-60) – F(Nadir)]

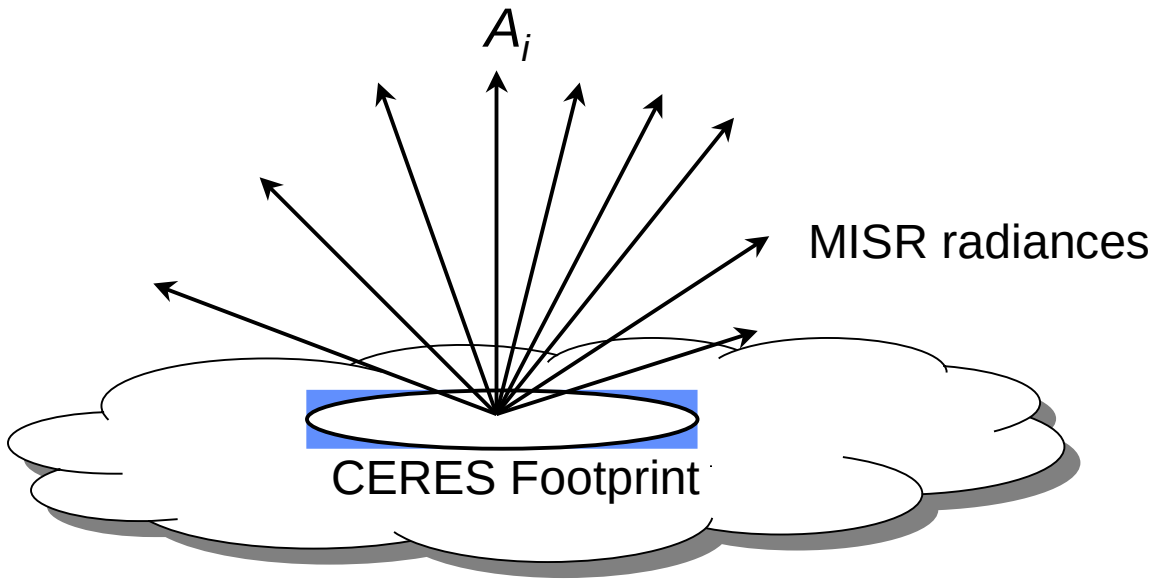
Ocean: (Overall 3.95%)

CLR		PCL			MCL			OVC		
4.53	High								4.59	2.83
	Mid								4.69	5.17
	Low	5.70	9.27		3.98	5.22			3.13	2.97
		Thin	Mod	Thick	Thin	Mod	Thick	Thin	Mod	Thick

Land and Desert: (Overall 4.16%)

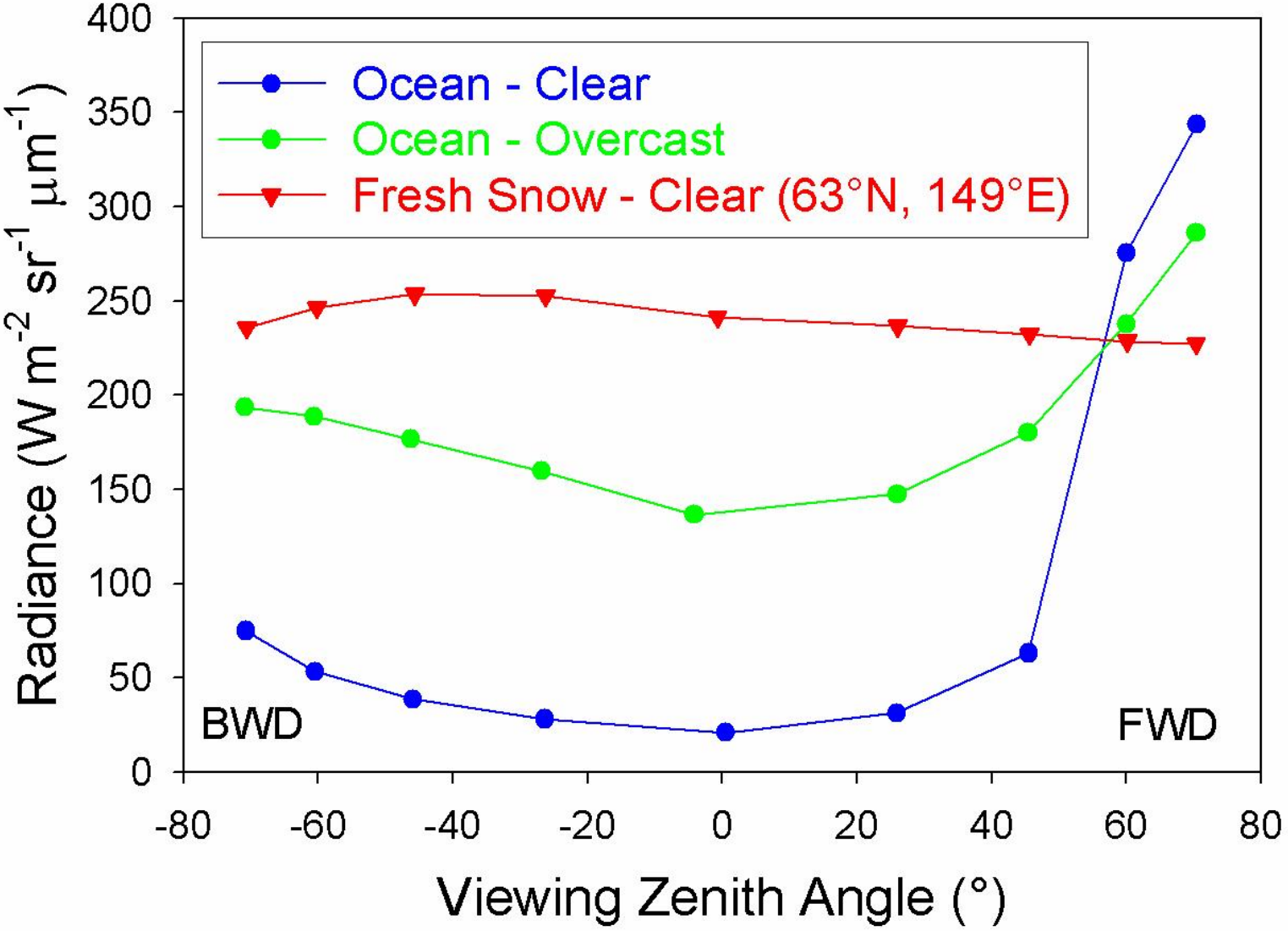
CLR		PCL			MCL			OVC		
3.65	High								7.70	4.23
	Mid					6.60				3.35
	Low	9.78	7.99			5.77			2.92	4.61
		Thin	Mod	Thick	Thin	Mod	Thick	Thin	Mod	Thick

CERES-MISR Albedo Comparison

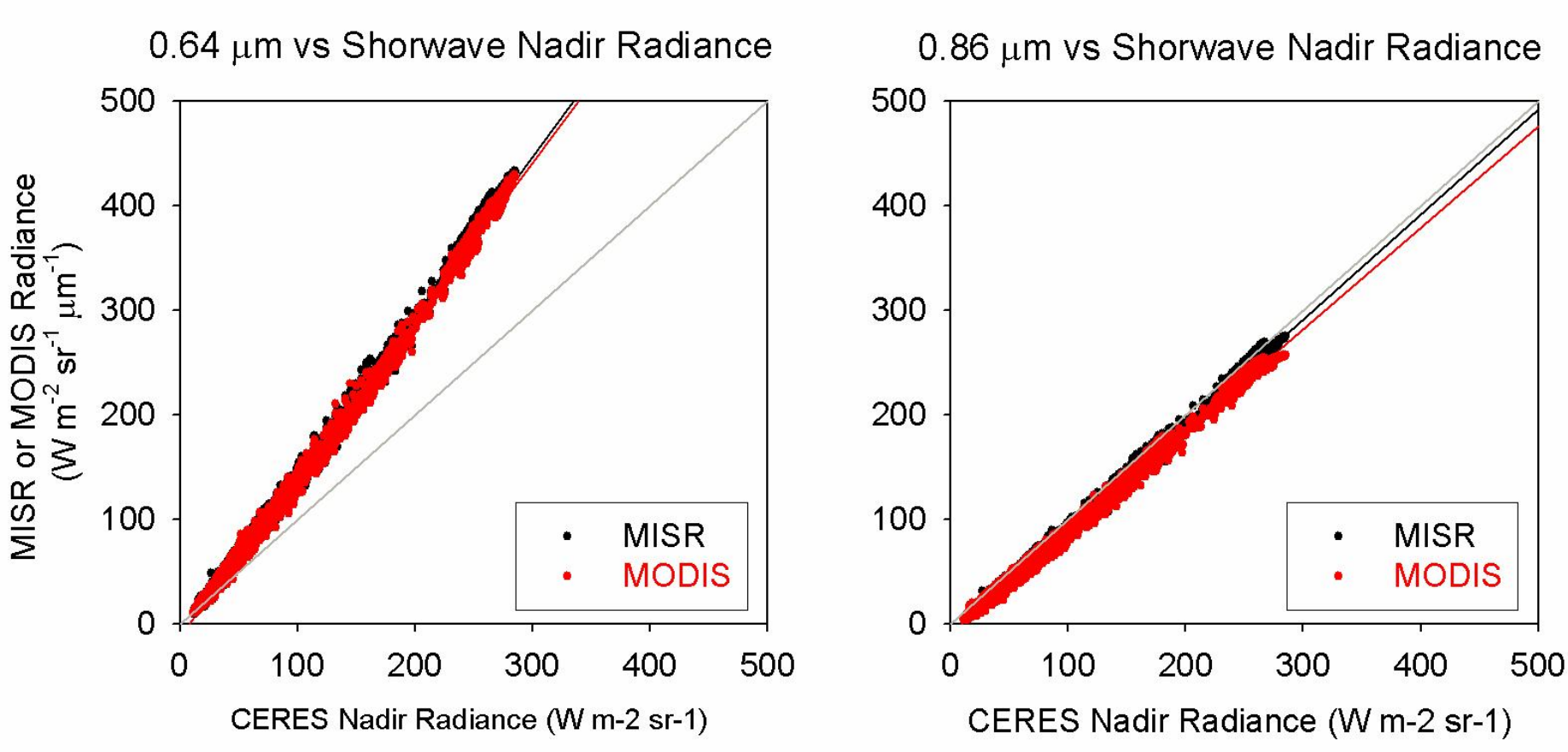


- **Convert MISR radiances and albedos to broadband SW.**
- **Are CERES and MISR albedos consistent?**
- **Infer TOA albedo from every MISR angle using CERES ADMs**
- **Are albedos from different angles consistent?**
- **How do differences depend upon cloud type and degree of anisotropy and inhomogeneity?**

0.558 μm MISR Anisotropy Over CERES Footprints (θ_o=54°; 20° off Principal Plane; April 12, 2000)



CERES, MODIS and MISR Radiance Comparison



Direct Radiative Effects of Aerosols

Direct Radiative Effect of Aerosols (Natural+Anthropogenic)

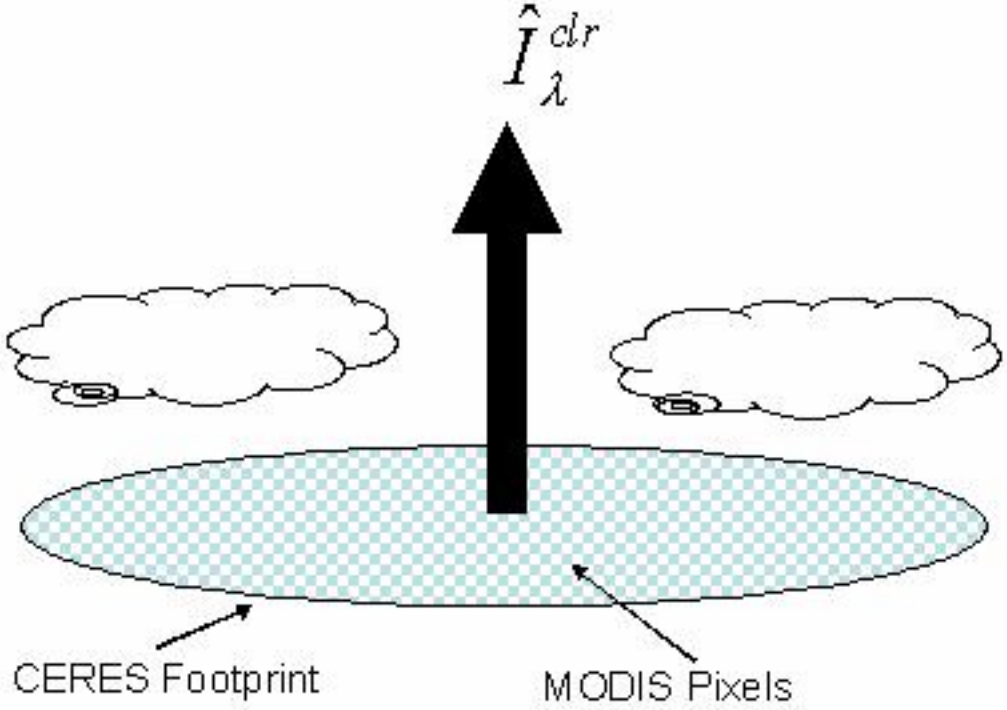
$$\Delta\overline{F}_{SW}^{clr}(\Theta,\Phi) = \overline{F}_{SW}^{na}(\Theta,\Phi) - \overline{F}_{SW}^{clr}(\Theta,\Phi)$$

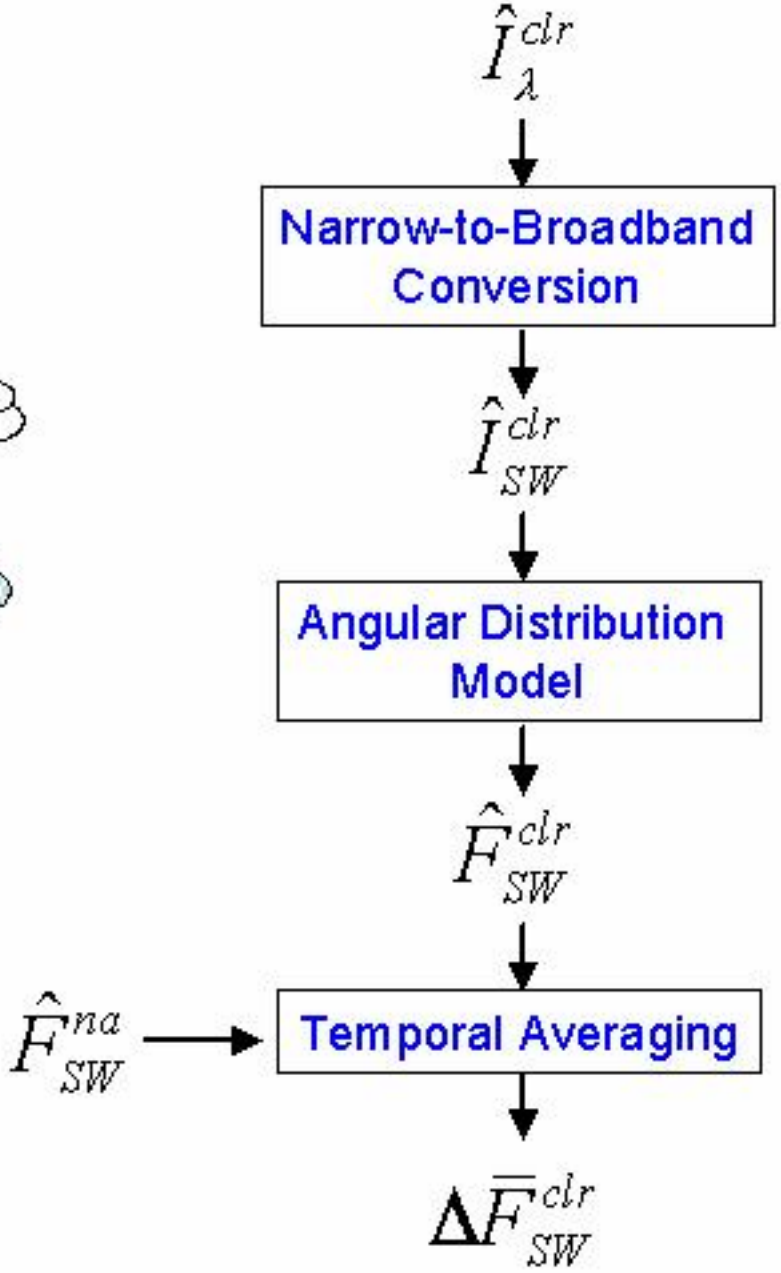
$\overline{F}_{SW}^{clr}(\Theta,\Phi)$ = clear-sky SW TOA flux

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

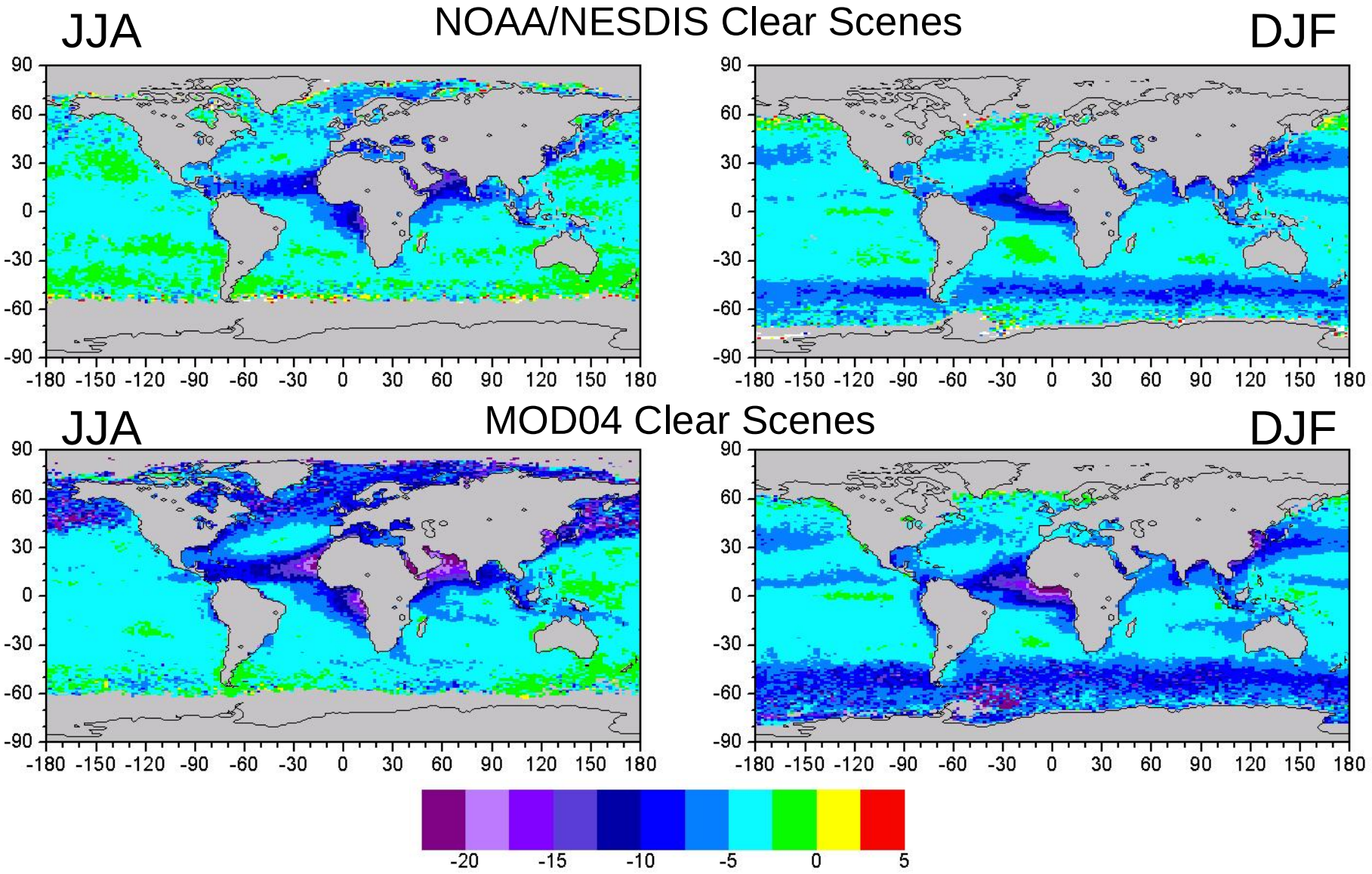
	Spectral Resolution	Spatial Resolution
MODIS	Narrowband	**0.5 km**
CERES	**Broadband**	20 km

DIRECT RADIATIVE EFFECT OF AEROSOLS

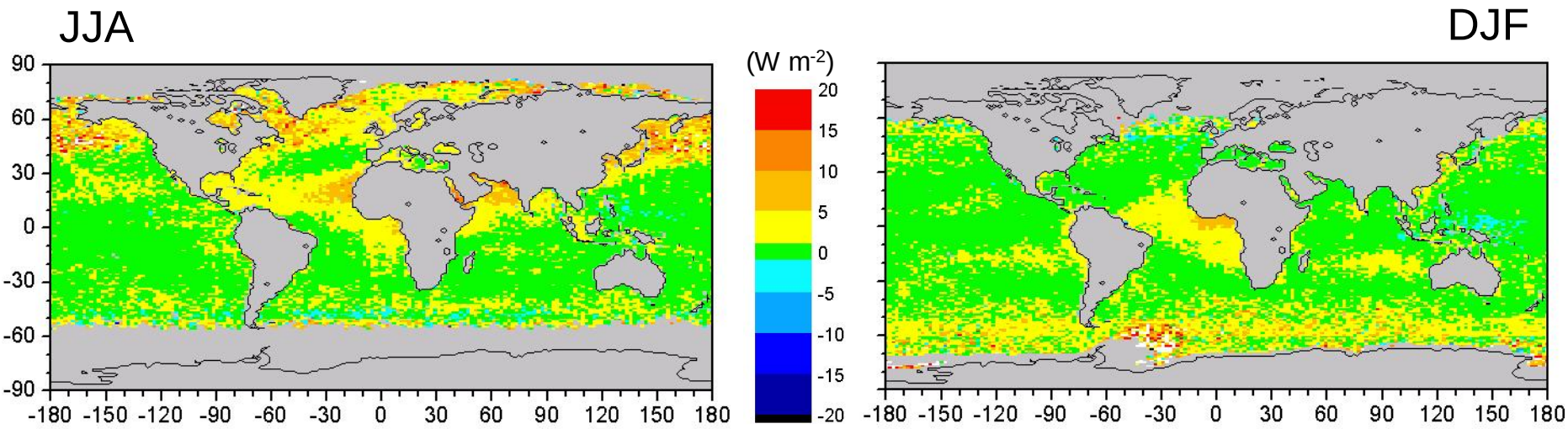




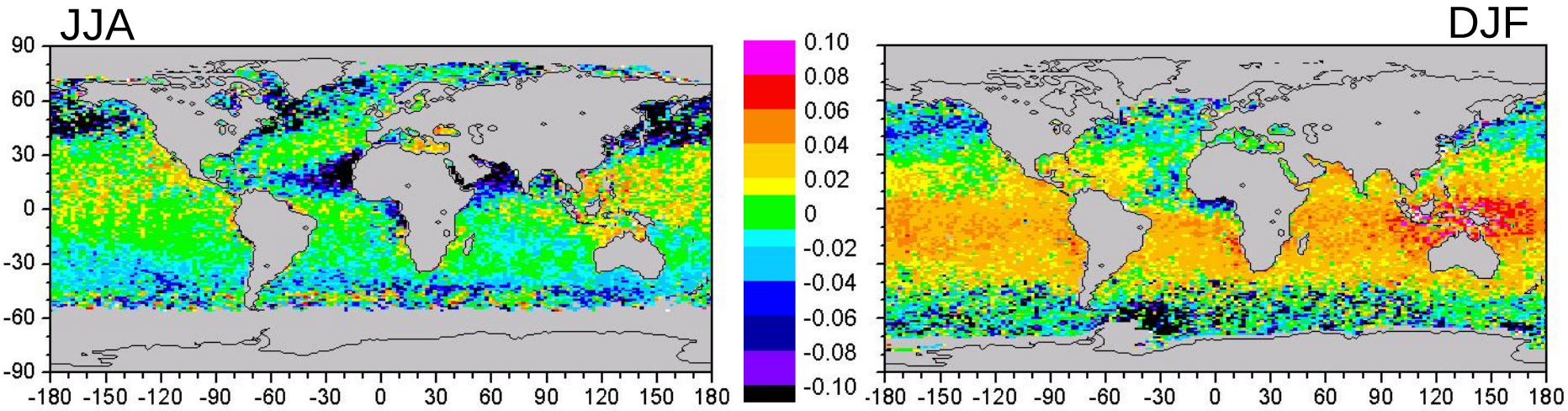
Direct Radiative Effect of Aerosols Inferred from MODIS Clear-Sky Radiances



Difference in Direct Radiative Effect Due to Sampling of Clear Scenes



Difference in Aerosol Optical Depth from MODIS: NOAA/NESDIS – MOD04



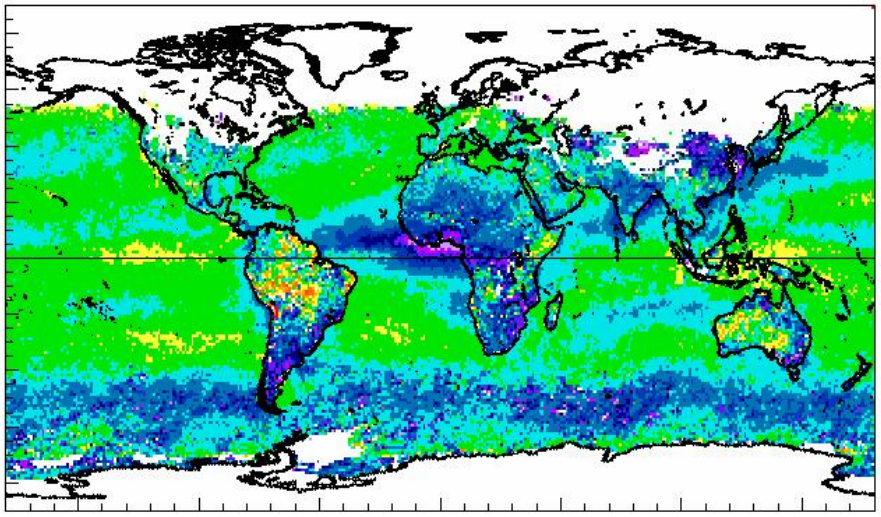
Global Average Direct Radiative Effect of Aerosols & AOT Over Ocean

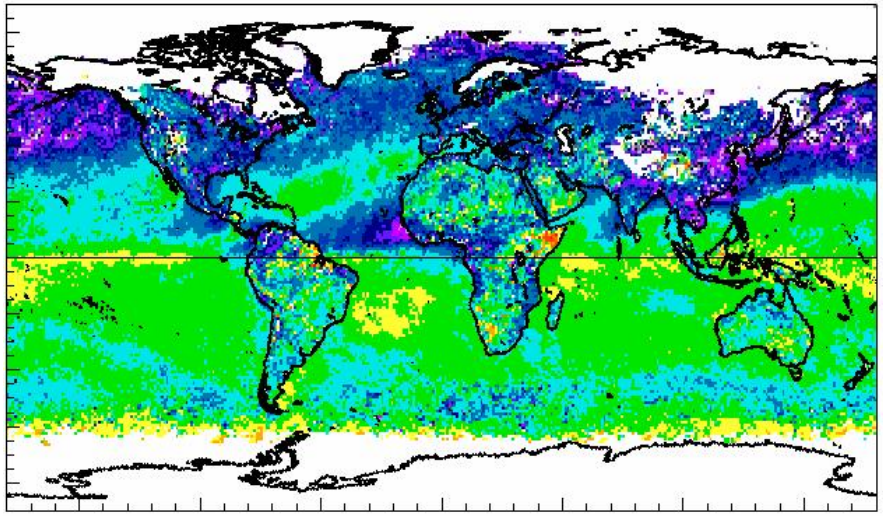
	JJA		DJF	
	NOAA Clear	MOD04 Clear	NOAA Clear	MOD04 Clear
Direct Effect ($W\ m^{-2}$)	-3.54	-5.48	-3.95	-5.23
0.65 μm AOT	0.112	0.139	0.131	0.127

Global Direct Radiative Effect of Aerosols (CERES+MOD04+MOD43)

JAN, 2001

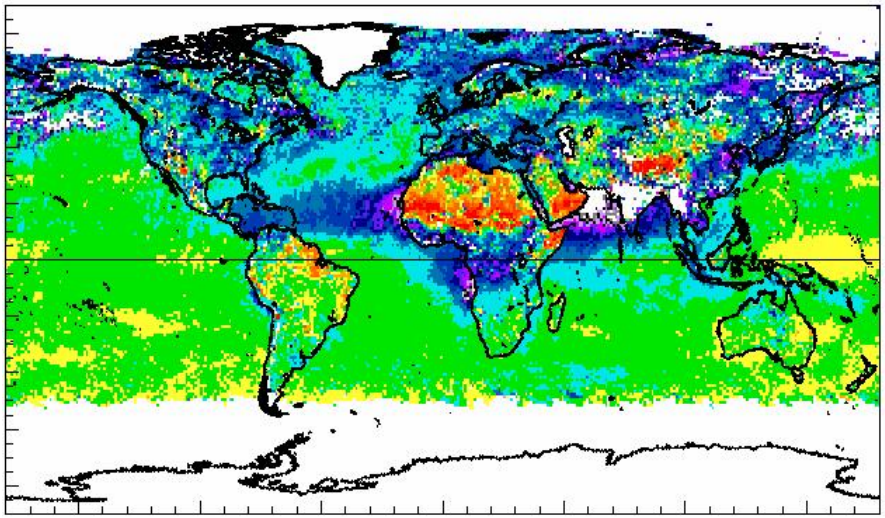
APR, 2001

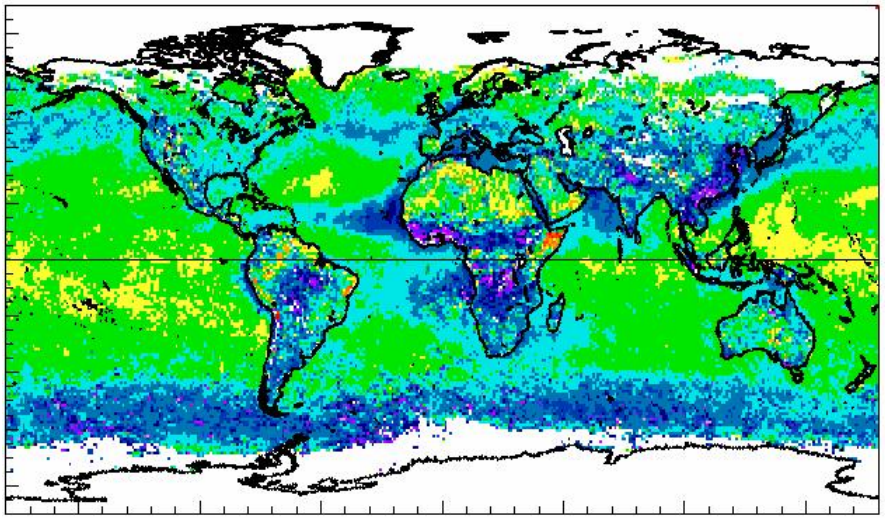


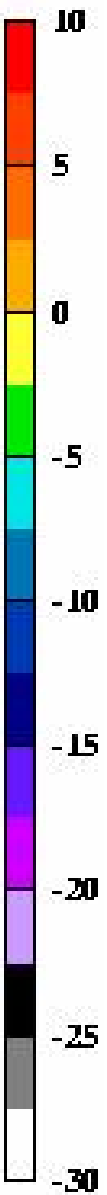


JUL, 2001

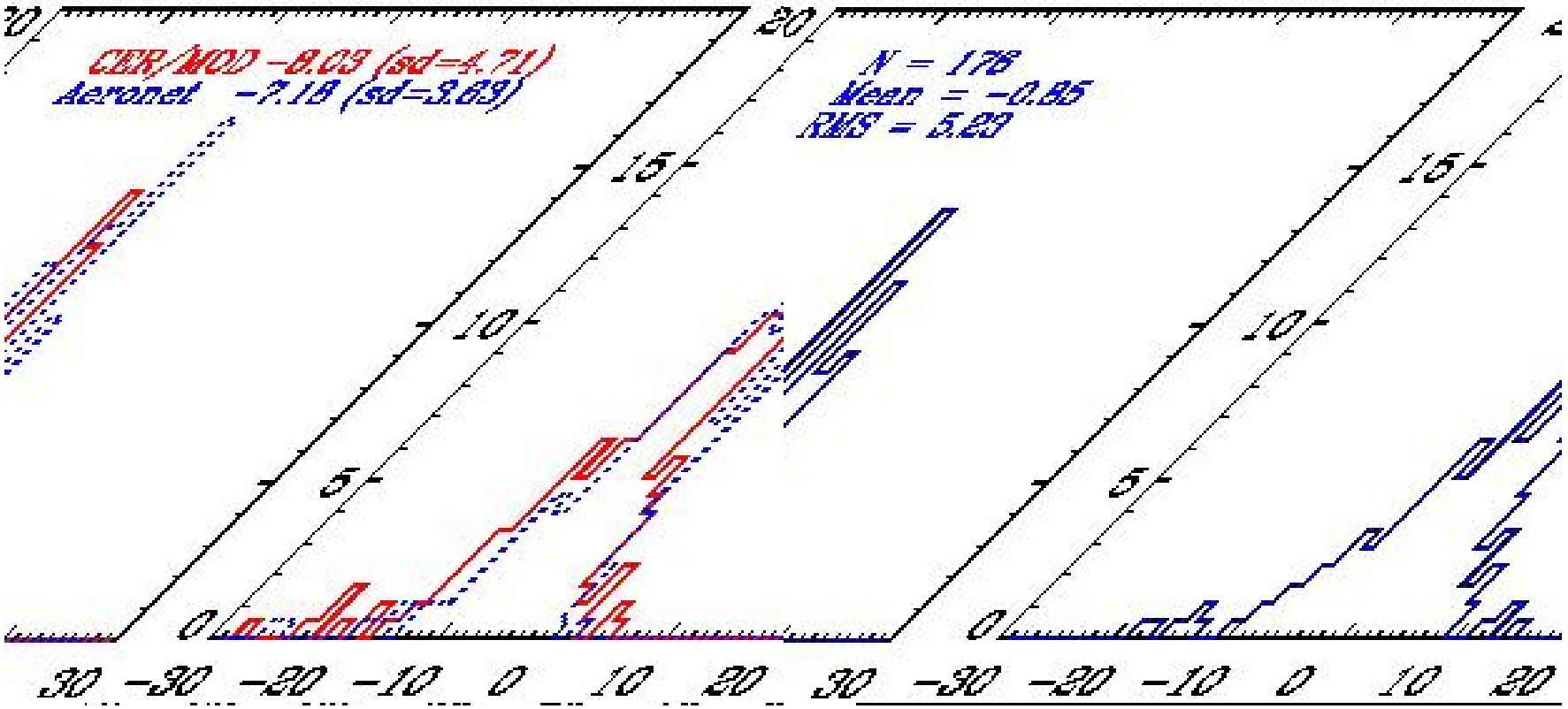
OCT, 2001







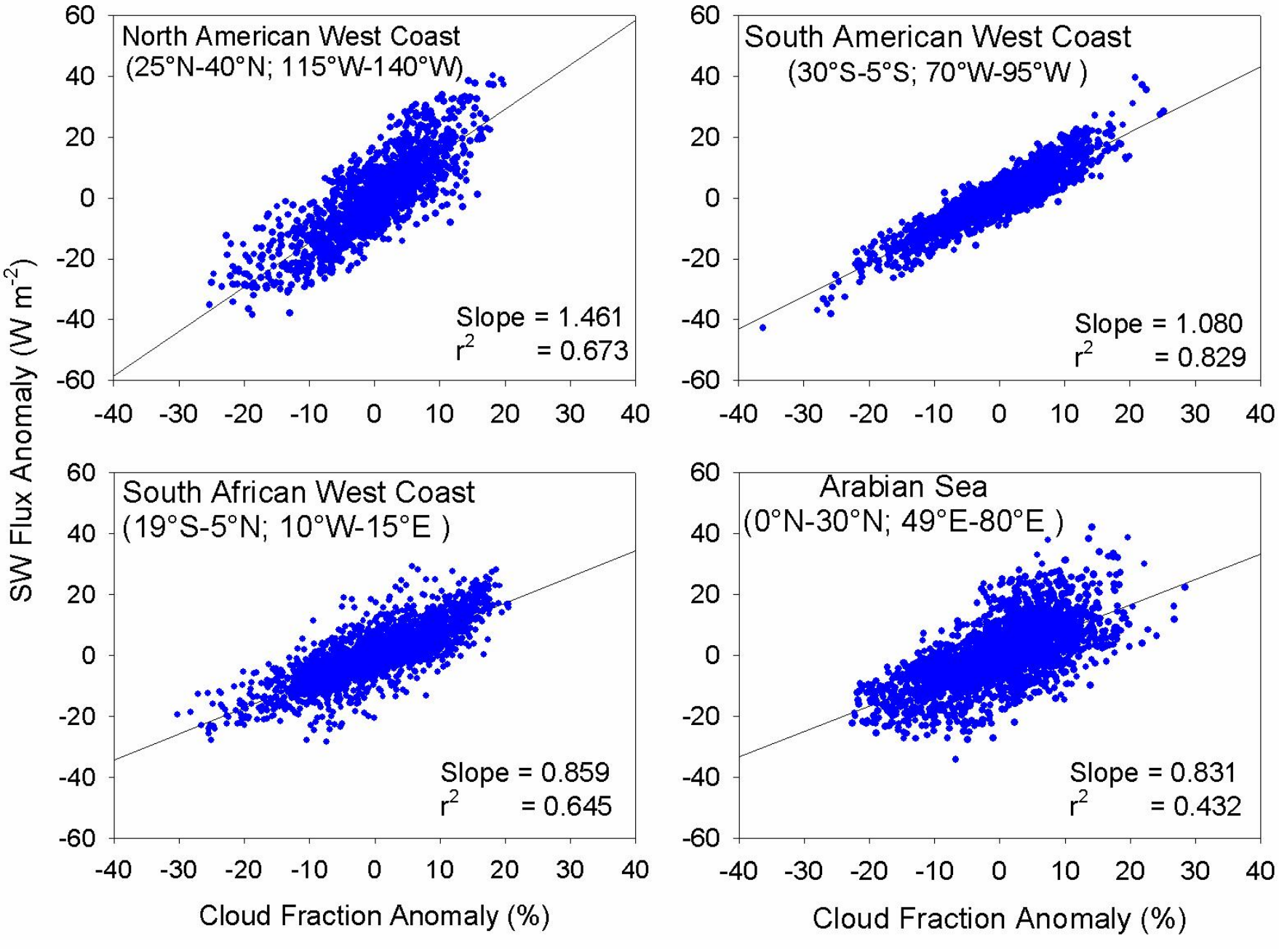
Direct Radiative Effect of Aerosols Over Land (Comparison with Aeronet-Derived Values)

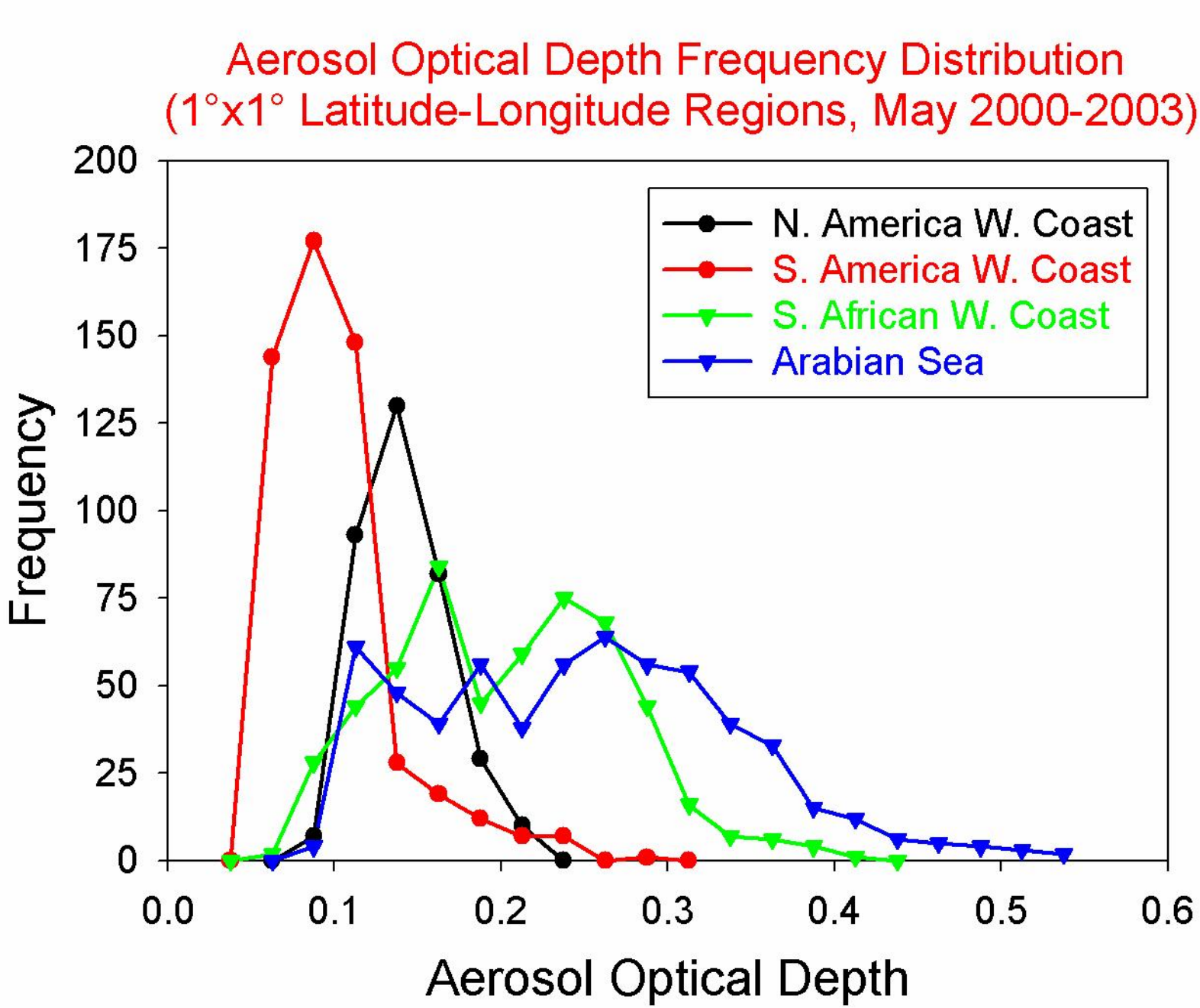


Aeronet-derived DREA provided by Stefan Kinne

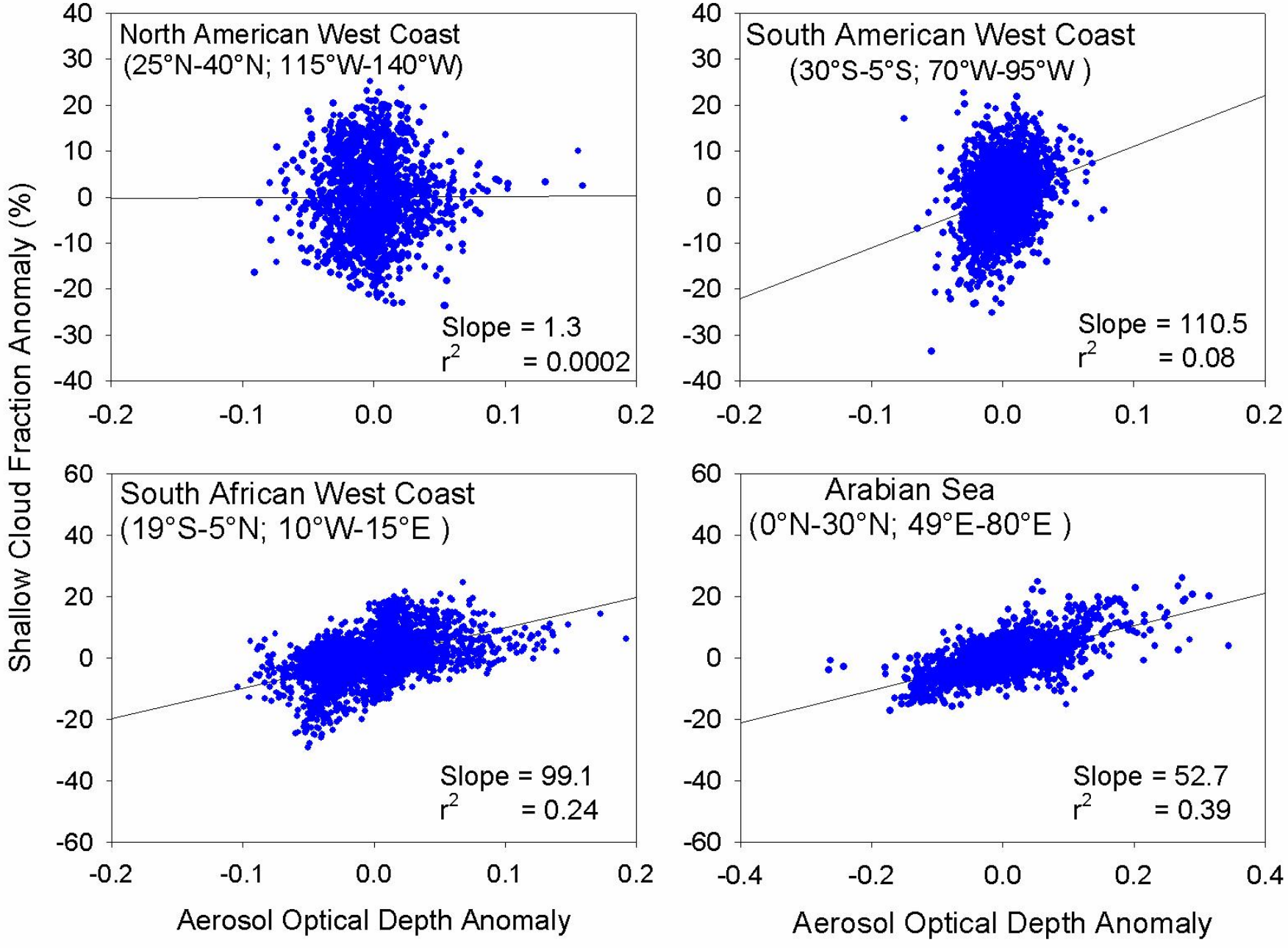
Cloud-Aerosol Interaction Studies

SW Flux Anomaly vs Cloud Fraction Anomaly (May, 2000-2003)




Aerosol Optical Depth Frequency Distribution
(1°x1° Latitude-Longitude Regions, May 2000-2003)
Frequency
200
175
150
125
100
75
50
25
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
Aerosol Optical Depth
N. America W. Coast
S. America W. Coast
S. African W. Coast
Arabian Sea

Shallow Cloud Fraction Anomaly vs Aerosol Opt. Depth Anomaly (May, 2000-2003)



Summary

- **CERES merges data from several sources to produce accurate cloud-aerosol-radiation datasets.**
- **However, a lot more can be done: CERES, MODIS & MISR instruments provide complementary information (broadband, spectral and multiangle).**

-> MODIS+MISR surface BRDF

-> MODIS+MISR aerosols

-> CERES+MISR+MODIS cloud-radiation in polar regions.

-> CERES+MISR+MODIS high-resolution cloud radiative forcing