An Observational Study of the Relationship between Cloud, Aerosol and Meteorology in Marine Stratus Regions

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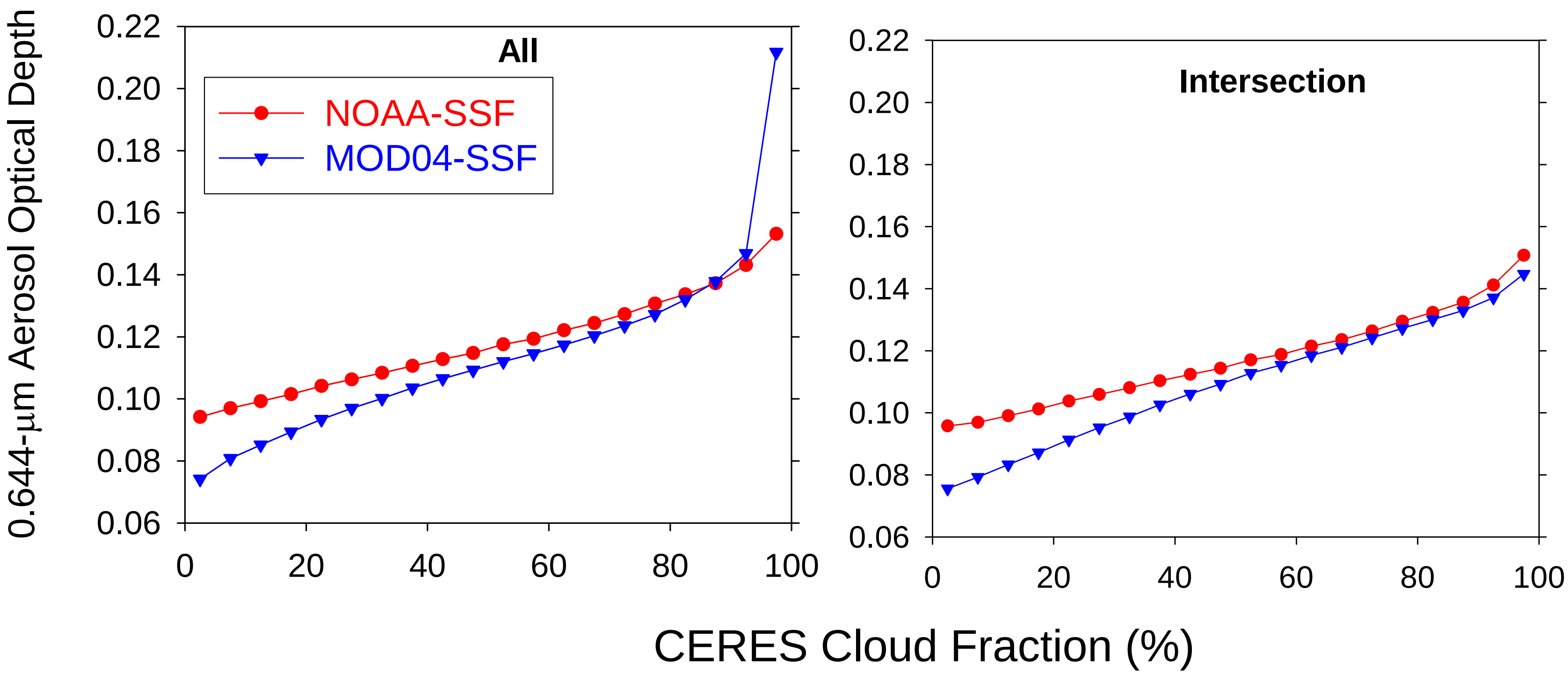
NPOESS Update

- **National Polar-orbiting Operational Environmental Satellite System (NPOESS) program was designed to provide the next generation of polar-orbiting satellite systems to collect and distribute data on Earth's atmosphere, oceans, land, and near-space environment.**
- **NPOESS was originally intended to serve as a converged civilian and military satellite weather system that would also supply state-of-the-art climate-quality data.**
- **Due to a variety of technical problems early in the program, NPOESS has seen staggering cost growths, from an initial price tag of $6.5B to well over $11B.**
- **Recent review of NPOESS resulted in significant scale-back of climate capabilities due to cost and schedule problems (e.g., OMPS Limb, TSIS, ERBS, ALT, APS).**
- **Two orbits and four spacecraft as opposed to the original plan of three orbits and six spacecraft.**
- **VIIRS imager: nowhere nearly as well calibrated as MODIS (they dropped most of the MODIS calibration system to save cost, mass, and power).**
- **Significant gap risk for solar irradiance and earth radiation budget records (=> gap in 30-year solar irradiance and 20+ year ERB records).**
- **Two aerosol polarimeter sensors dropped.**

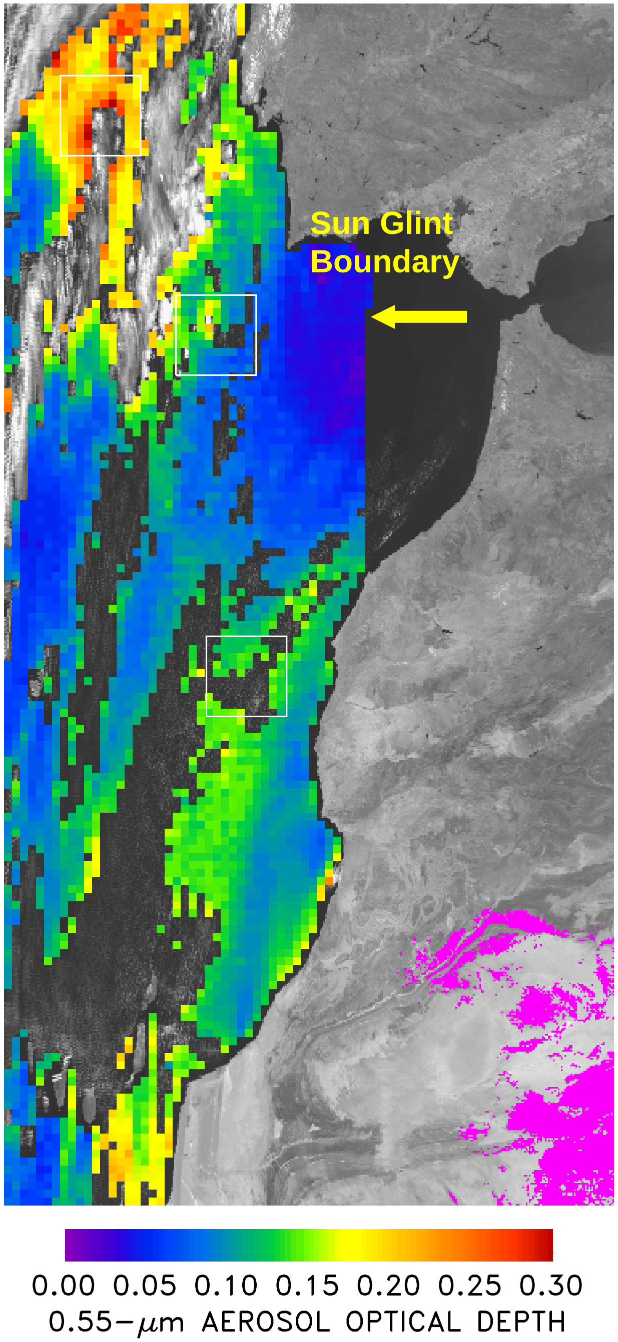
Introduction

- Recent satellite studies have shown correlations between aerosol optical depth and cloud cover (Ignatov et al. 2005; Loeb and Manalo-Smith 2005; Kaufman et al. 2005; Matheson et al. 2006).

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



Loeb & Manalo-Smith (JCL, 2005)



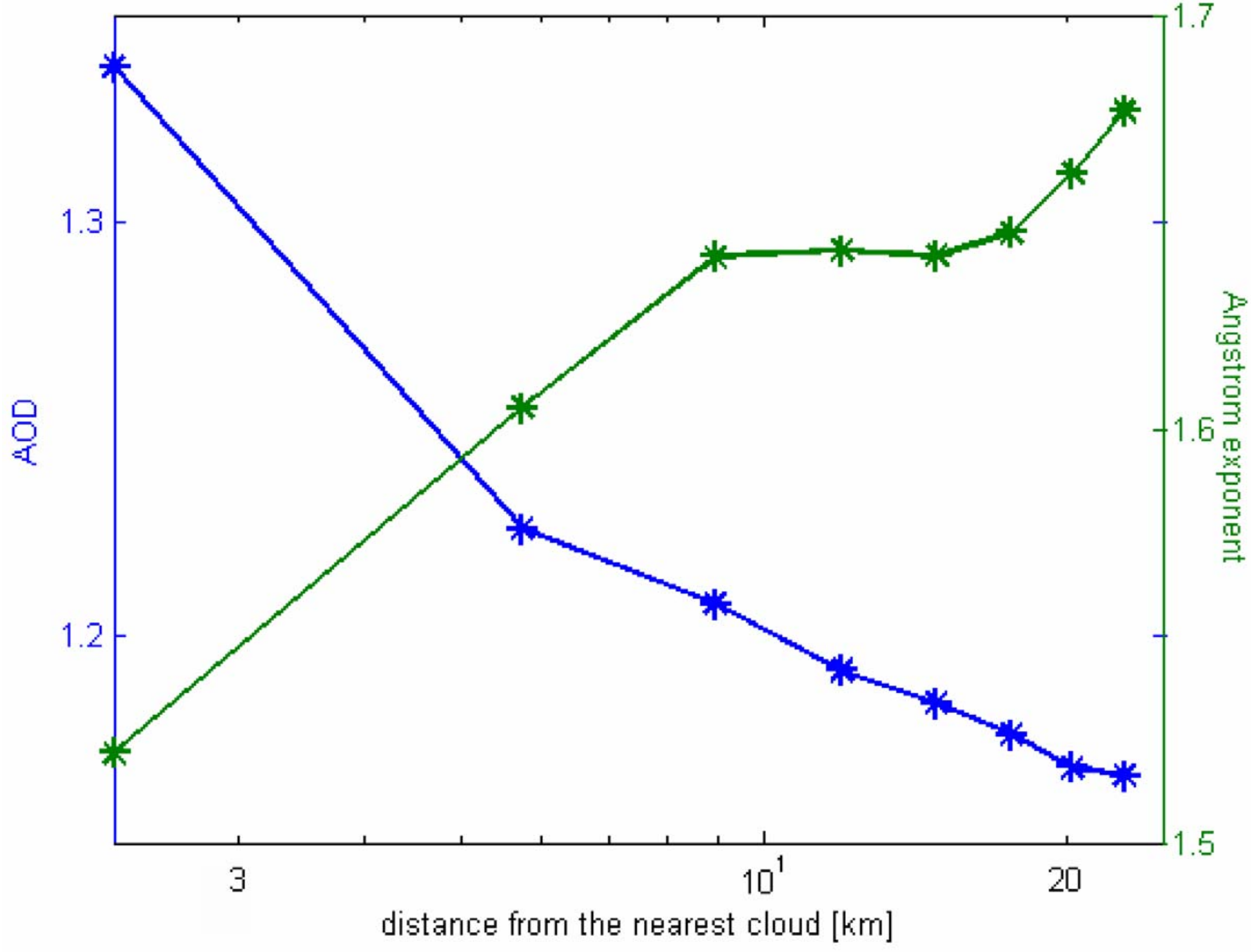
MODIS Aerosol Optical Depth and Cloud Cover

- **Aerosols grow in humid environments near clouds.**
- **Aerosols grow through in-cloud processing.**
- **New particle production in the vicinity of clouds.**
- **Illumination of particles enhanced by scattering of sunlight by clouds.**
- **Cloud contamination of the cloud-free pixels used to obtain aerosol properties.**
- **Aerosols are precursors to cloud formation.**

Clearly, what happens to aerosols in the vicinity of clouds needs to be understood.

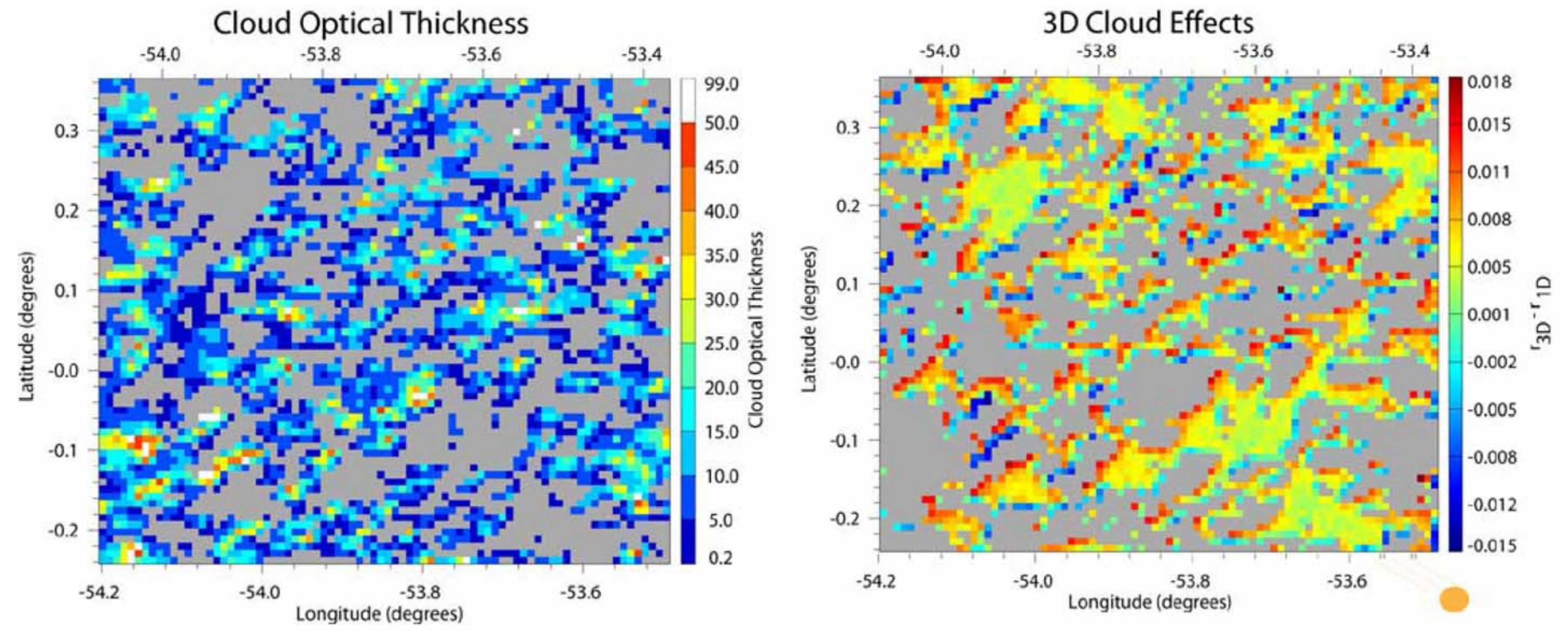
Jim Coakley (pers. comm.)

Aerosol Optical Depth and Angstrom Exponent vs Distance from Nearest Cloud (Aeronet data for Alta-Floresta biomass (dry) season 2000-2004)



Koren et al., GRL 2006 (submitted)

3D Radiative Effects of Cloud on Reflectance of Clear Pixels



3D radiative enhancement results in an overestimate of AOD of 0.04 in 1-D retrieval

Wen, Marshak, Cahalan 2006

OBJECTIVE

Study aerosol-cloud-radiation relationships with satellite data (CERES+MODIS Terra).

Attempt to minimize the influence of large-scale meteorological effects.

Observational Analysis

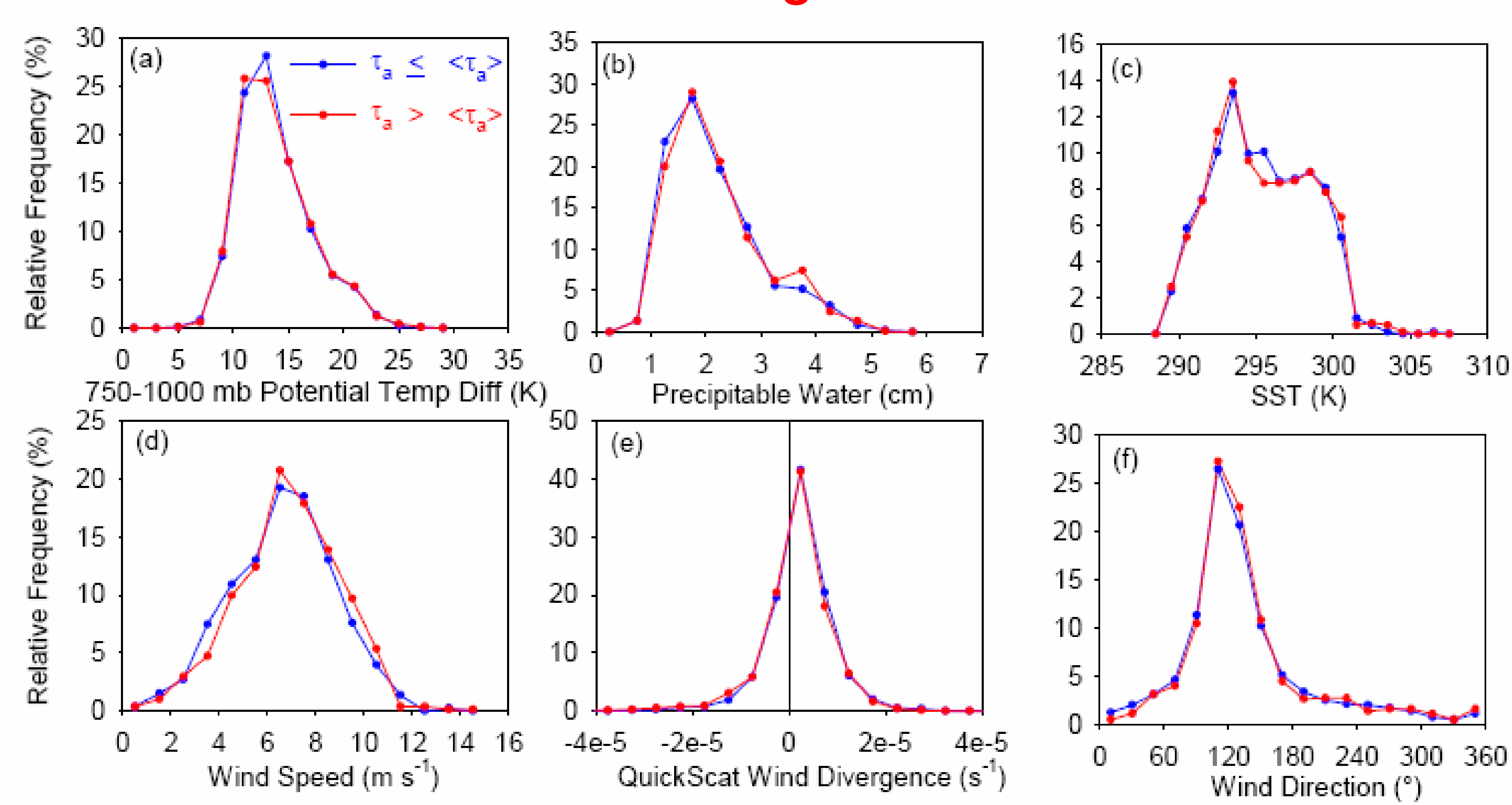
- Consider sulfate aerosols (according to MATCH) off African coast (0°S-30°S and 50°W-10°E) during September 2003.
- Consider only single-layer low clouds in 1°regions with both cloud and aerosol retrievals.
- Each day, cloud and aerosol retrievals in each 5°×5° region are separated into two distinct populations:

(I) 1° subregions with MODIS τ_a less than or equal to the mean 5°×5° value ($<\tau_a>$)

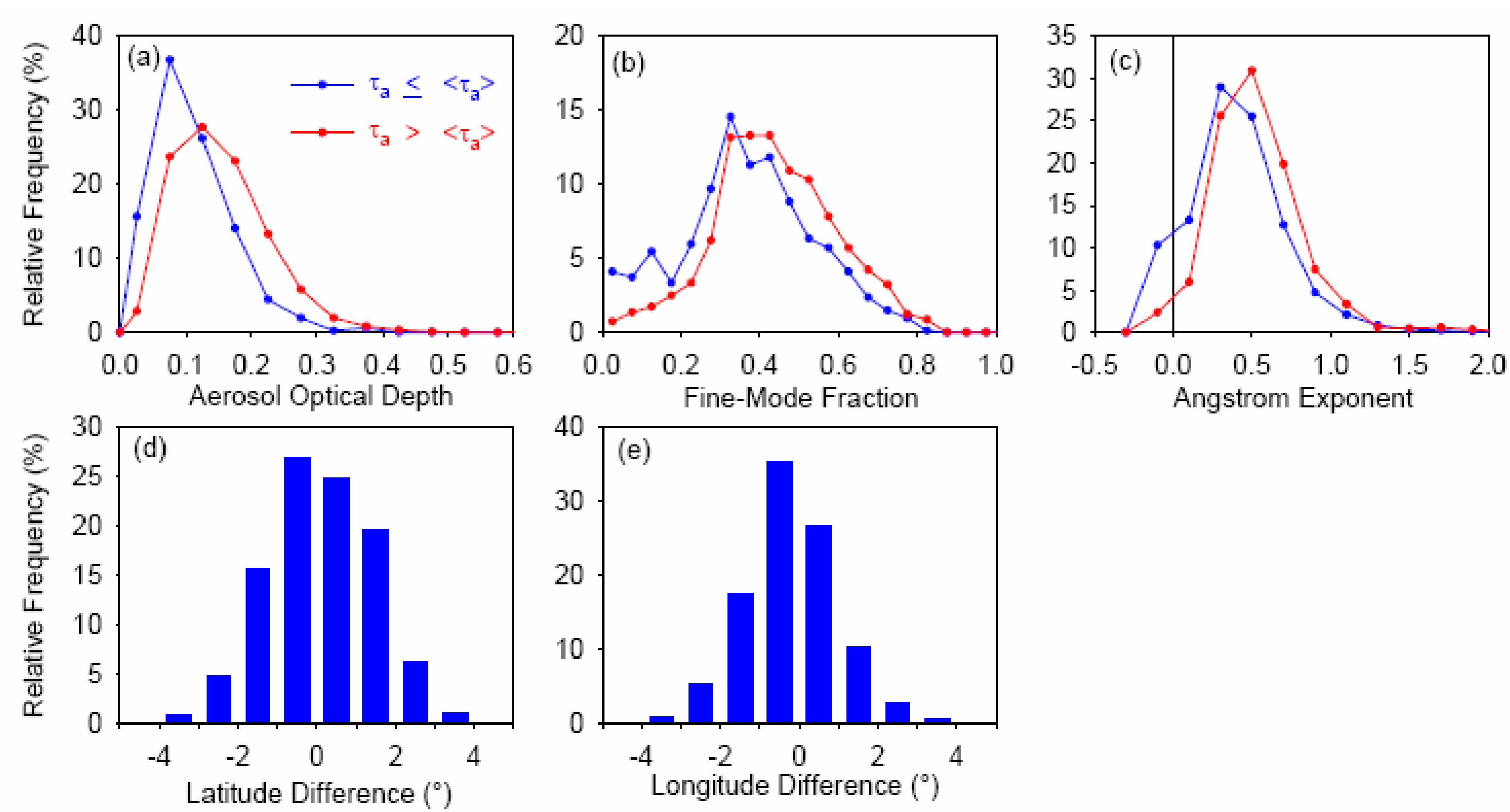
(II) 1° subregions with τ_a greater than $<\tau_a>$.

Note: Stratifying each 5°×5° region each day into two groups ensures that both groups are influenced by the same large-scale meteorological influences.

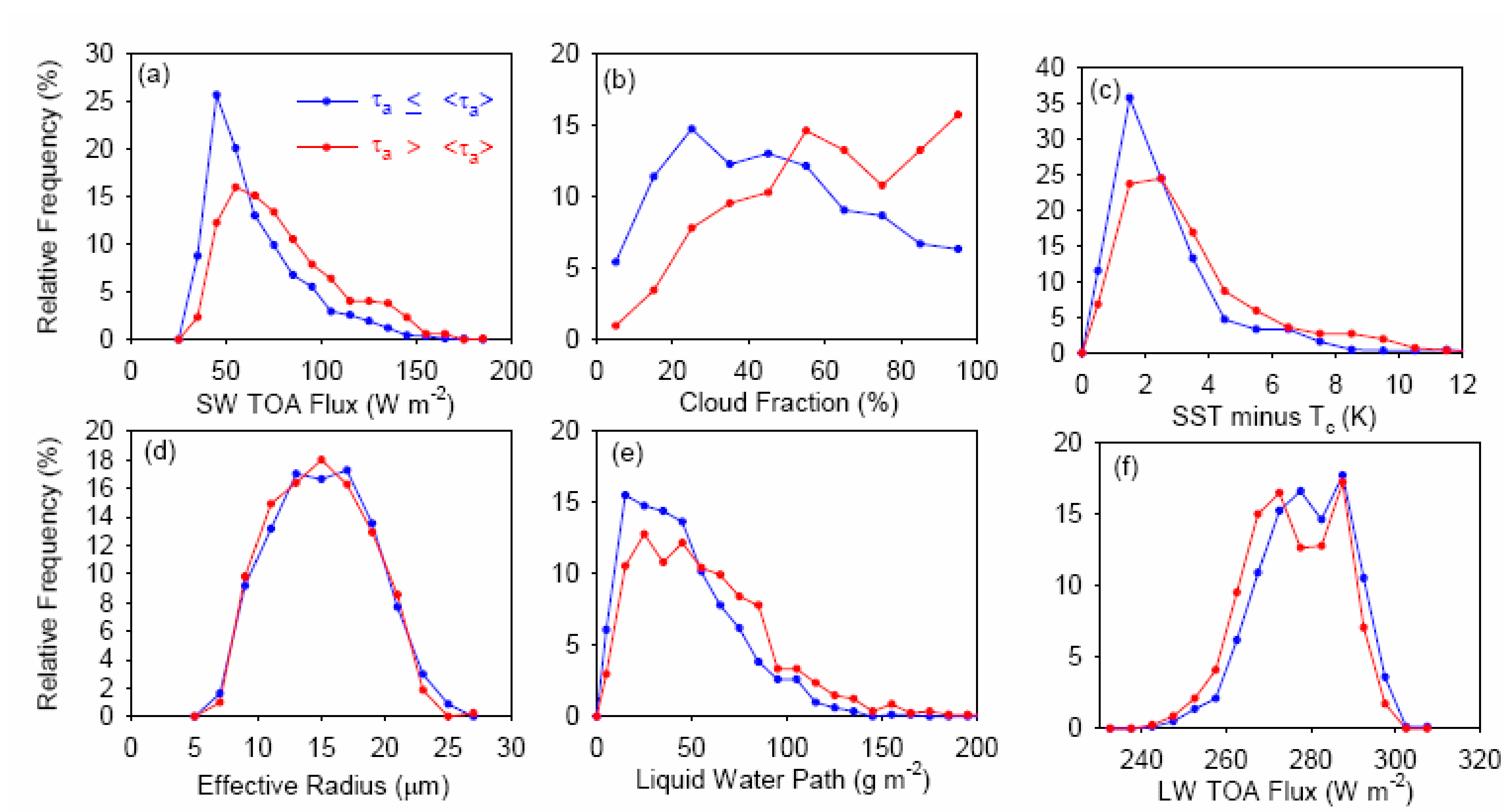
PDFs of Meteorological Parameters



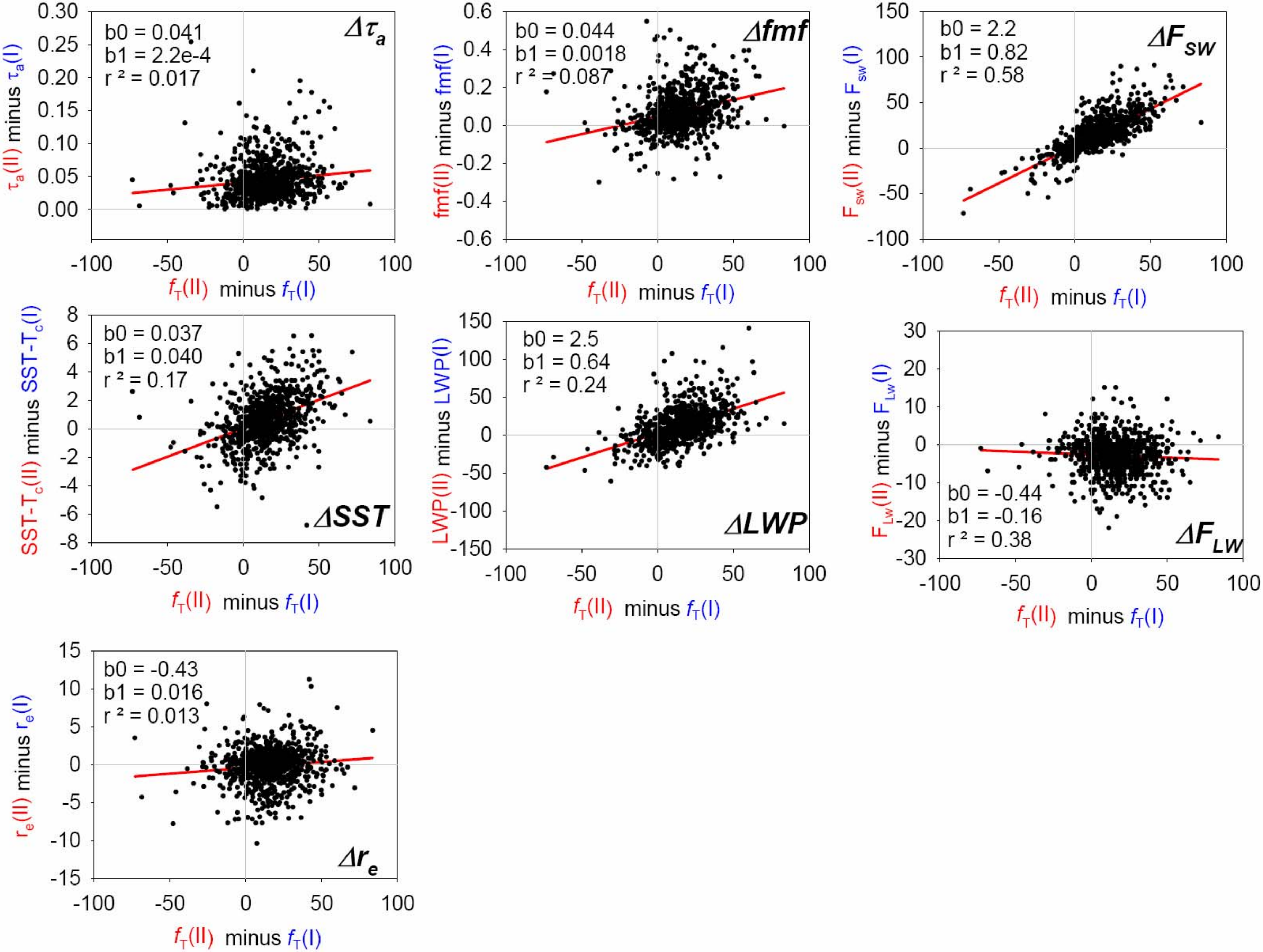
PDFs of Aerosl Parameters



PDFs of Cloud and Radiation Parameters



Variable	Mean		Mean Diff (Δ)	Δ/σ_{95}
	$\tau_a \leq \langle\tau_a\rangle$	$\tau_a > \langle\tau_a\rangle$		
τ_a	0.11	0.15	$4.4\times10^{-2} \pm 1.2\times10^{-2}$	**3.5**
η_a	0.37	0.43	$6.7\times10^{-2} \pm 3.2\times10^{-2}$	**2.1**
α	0.42	0.62	$-2.1\times10^{-1} \pm 7.0\times10^{-2}$	**3.0**
p_w	2.2	2.3	$4.3\times10^{-2} \pm 2.2\times10^{-1}$	0.19
w_s	6.4	6.6	0.2 ± 0.6	0.38
wind direc	125	125	$3.0\times10^{-2} \pm 2.5\times10^{1}$	0
wind_div	2.6×10^{-6}	1.9×10^{-6}	$-6.8\times10^{-7} \pm 8.5\times10^{-7}$	-0.80
θ_{750}-θ_{1000}	13.6	13.6	$-2.5\times10^{-2} \pm 6.1\times10^{-1}$	-0.04
SST	295	295	$6.0\times10^{-2} \pm 5.3\times10^{-1}$	0.1
SST-T_c	2.6	3.4	$8.1\times10^{-1} \pm 3.5\times10^{-1}$	**2.3**
F_{sw}	64	78	14 ± 4	**3.3**
F_{LW}	279	276	$-2.8\times10^{1} \pm 2.0\times10^{1}$	**-1.4**
f (%)	45	59	14 ± 5	**3.1**
r_e (μm)	15	15	-0.2 ± 0.8	-0.23
LWP (gm^{-2})	42	53	12 ± 7	**1.7**



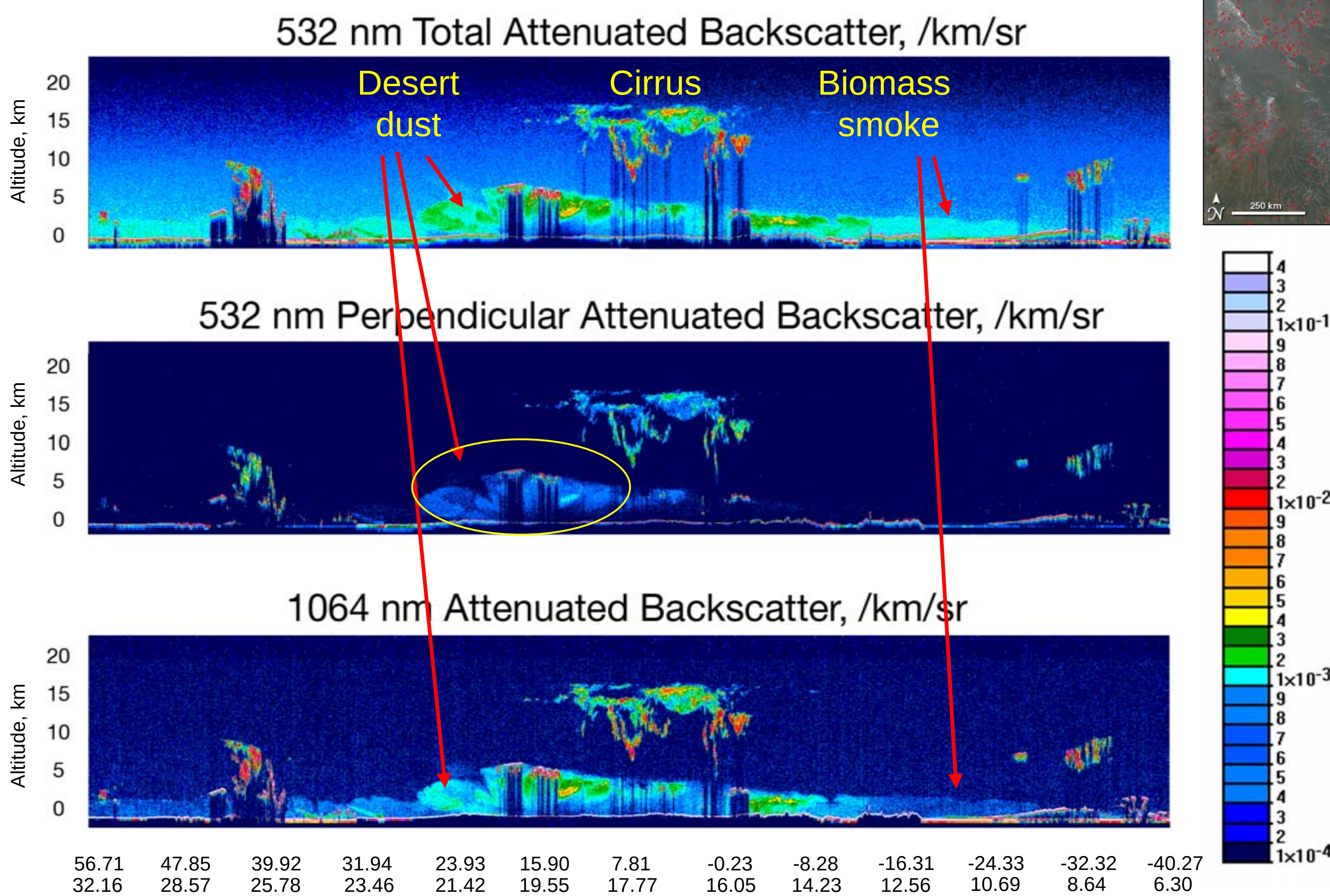
b0 = 0.041
b1 = 2.2e-4
r ² = 0.017
Δτa
τa(II) minus τa(I)
fT(II) minus fT(I)
b0 = 0.044
b1 = 0.0018
r ² = 0.087
Δfmf
fmf(II) minus fmf(I)
fT(II) minus fT(I)
b0 = 2.2
b1 = 0.82
r ² = 0.58
ΔFSW
Fsw(II) minus Fsw(I)
fT(II) minus fT(I)
b0 = 0.037
b1 = 0.040
r ² = 0.17
ΔSST
SST-Tc(II) minus SST-Tc(I)
fT(II) minus fT(I)
b0 = 2.5
b1 = 0.64
r ² = 0.24
ΔLWP
LWP(II) minus LWP(I)
fT(II) minus fT(I)
b0 = -0.44
b1 = -0.16
r ² = 0.38
ΔFLW
FLw(II) minus FLw(I)
fT(II) minus fT(I)
b0 = -0.43
b1 = 0.016
r ² = 0.013
Δre
re(II) minus re(I)
fT(II) minus fT(I)

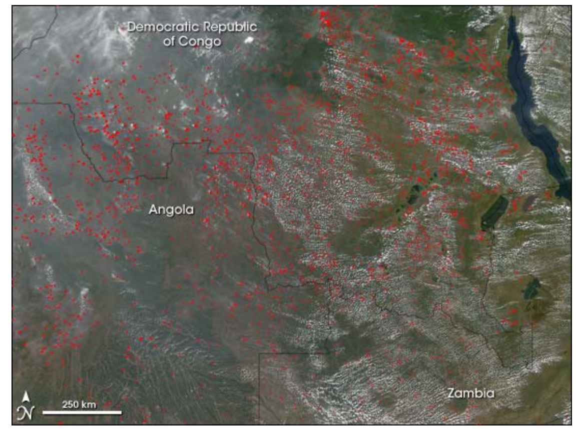
Influence of Cloud Contamination

- Compare MODIS Aqua and CALIPSO cloud/clear-sky masks

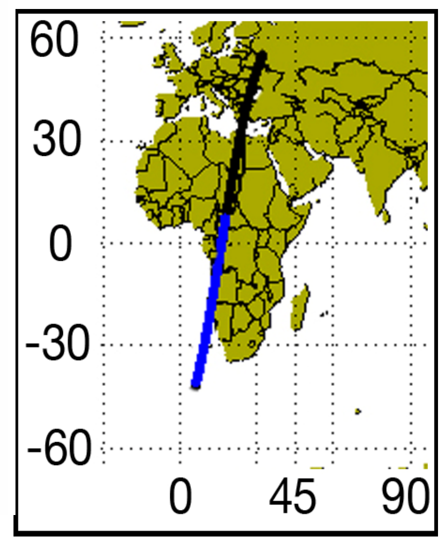
CALIPSO First-Light Observations

(All 3 Lidar Channels)
9 June 2006

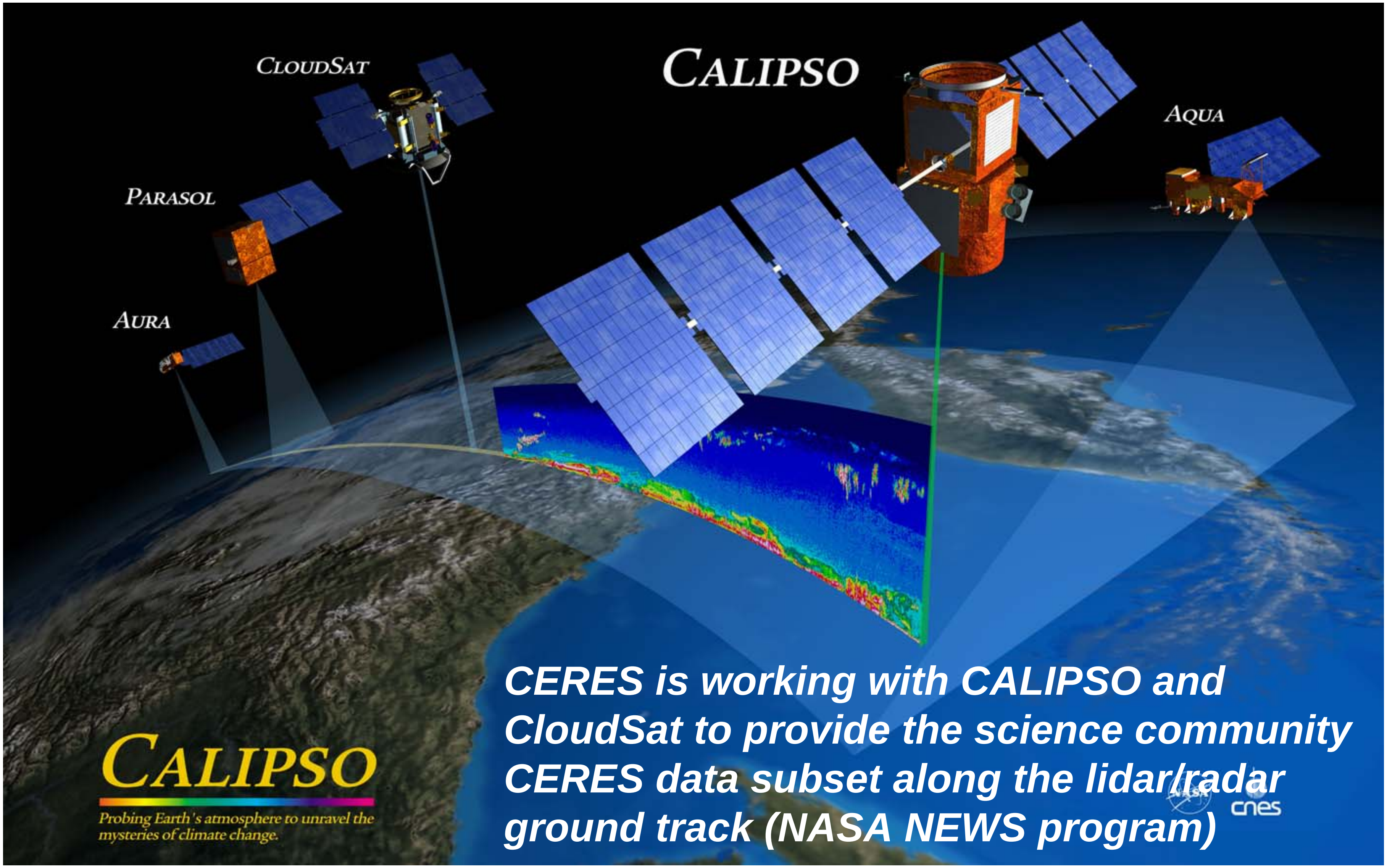




Fire locations in southern Africa from MODIS, 6/10/06



"A-Train" Formation for Aerosol and Cloud Vertical Profiles Atmospheric State => Aerosol/Cloud => Radiative Heating



Summary

- Early satellite results suggest impressive aerosol-cloud correlations:
  - Cloud cover increases with aerosol optical depth and fine-mode fraction.
  - Need to assess role of cloud contamination in aerosol retrievals.
  - 3D cloud effects can also a significant role.

- No apparent dependence on large-scale meteorological conditions.
  - Need higher-resolution meteo. data to verify this (especially relative humidity).

- Plan to conduct similar analysis using CRMs to isolate influence of changes in thermodynamics and dynamics vs real indirect effect of aerosols.