Direct Radiative Effect
of aerosols over clouds and clear skies determined using CALIPSO and the A-Train

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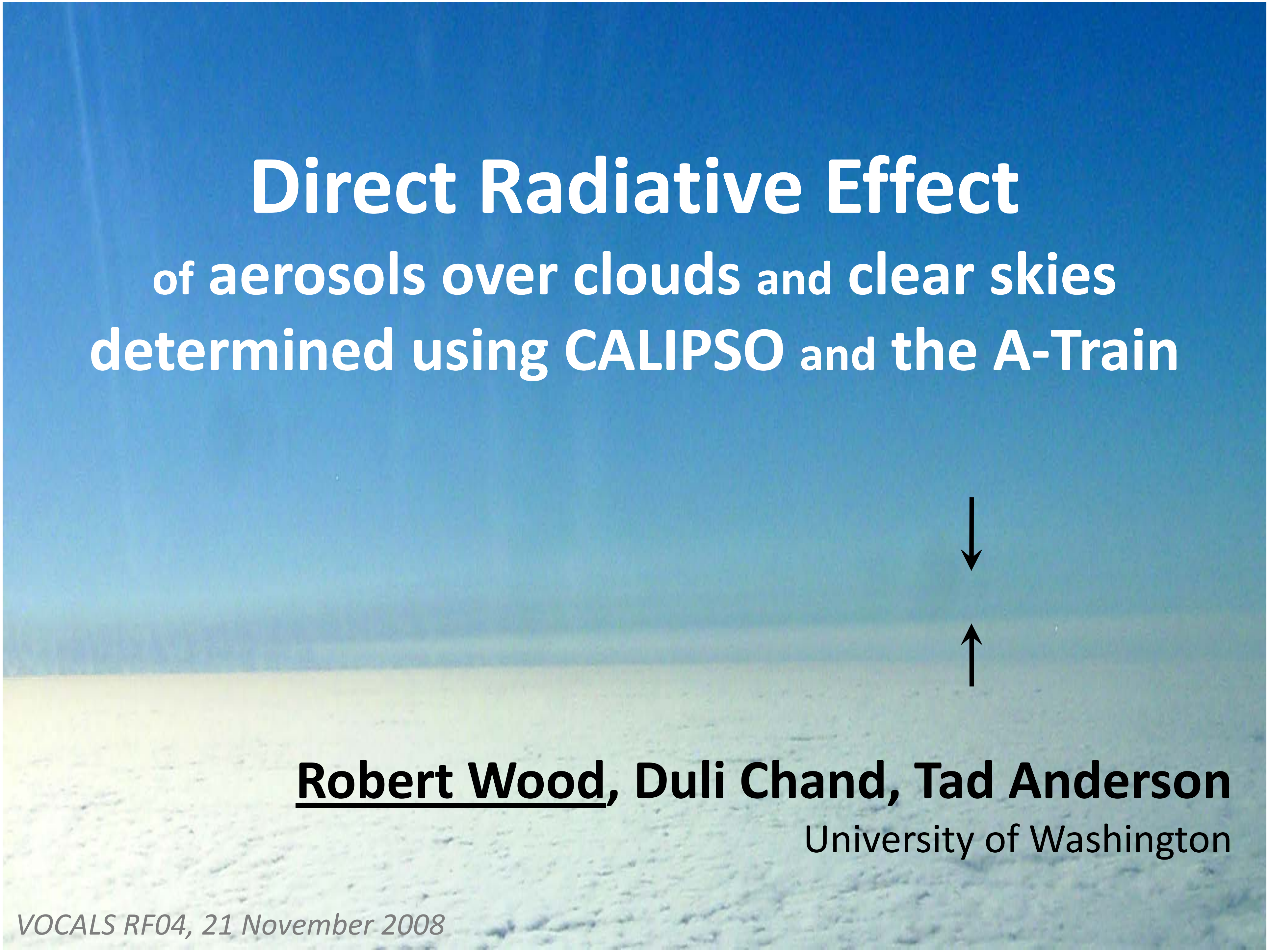
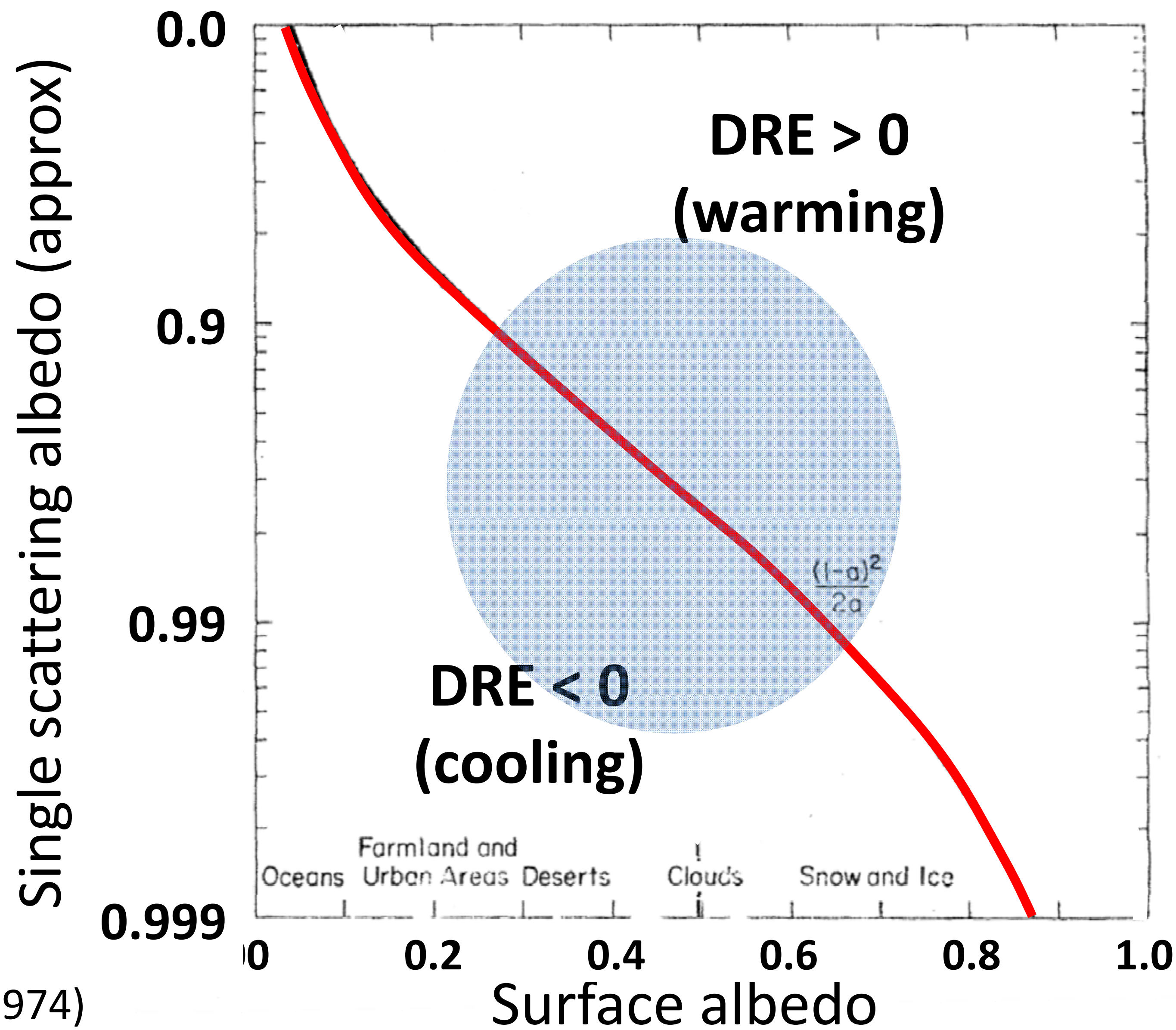
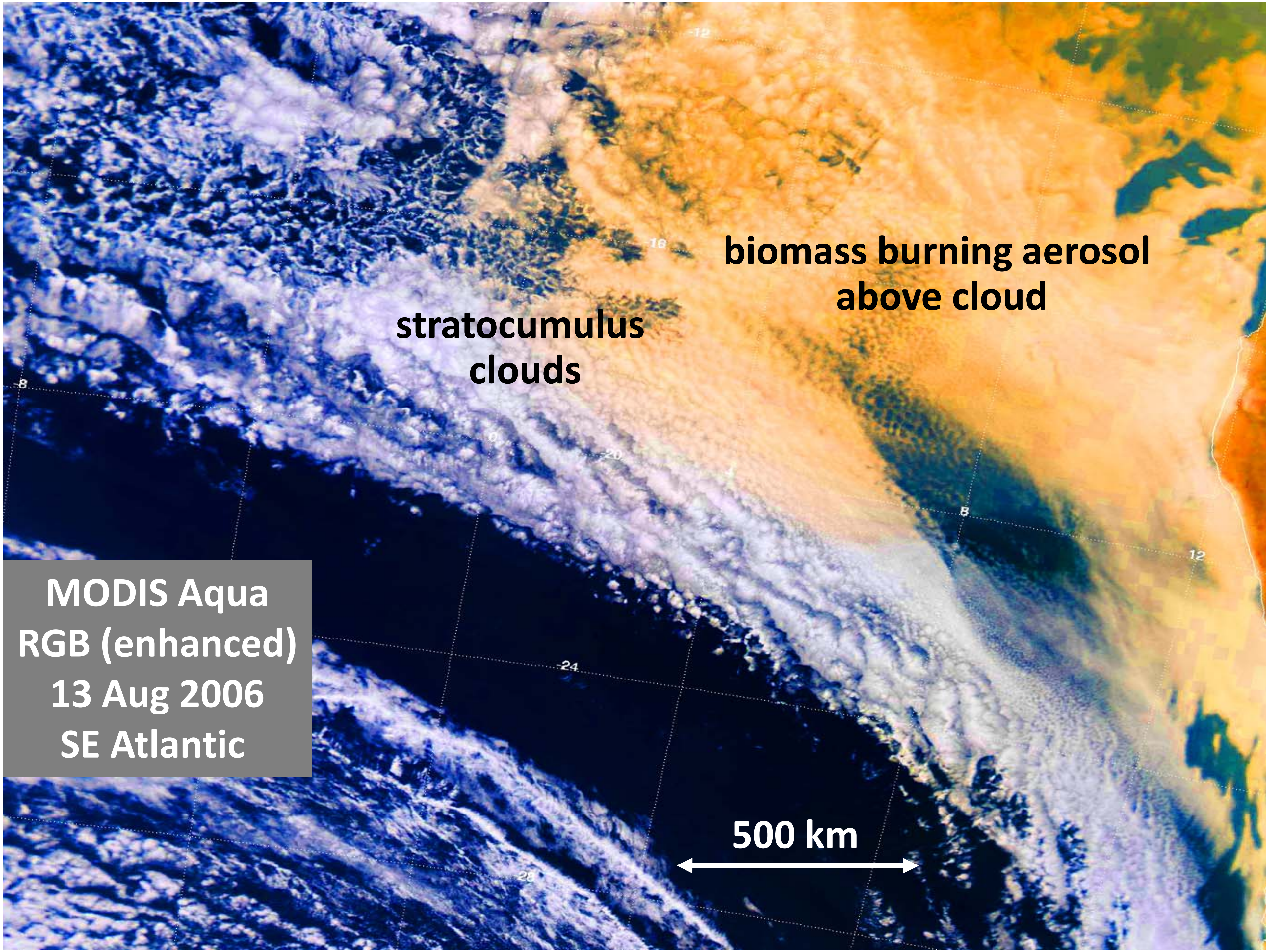


VOCALS RF04, 21 November 2008

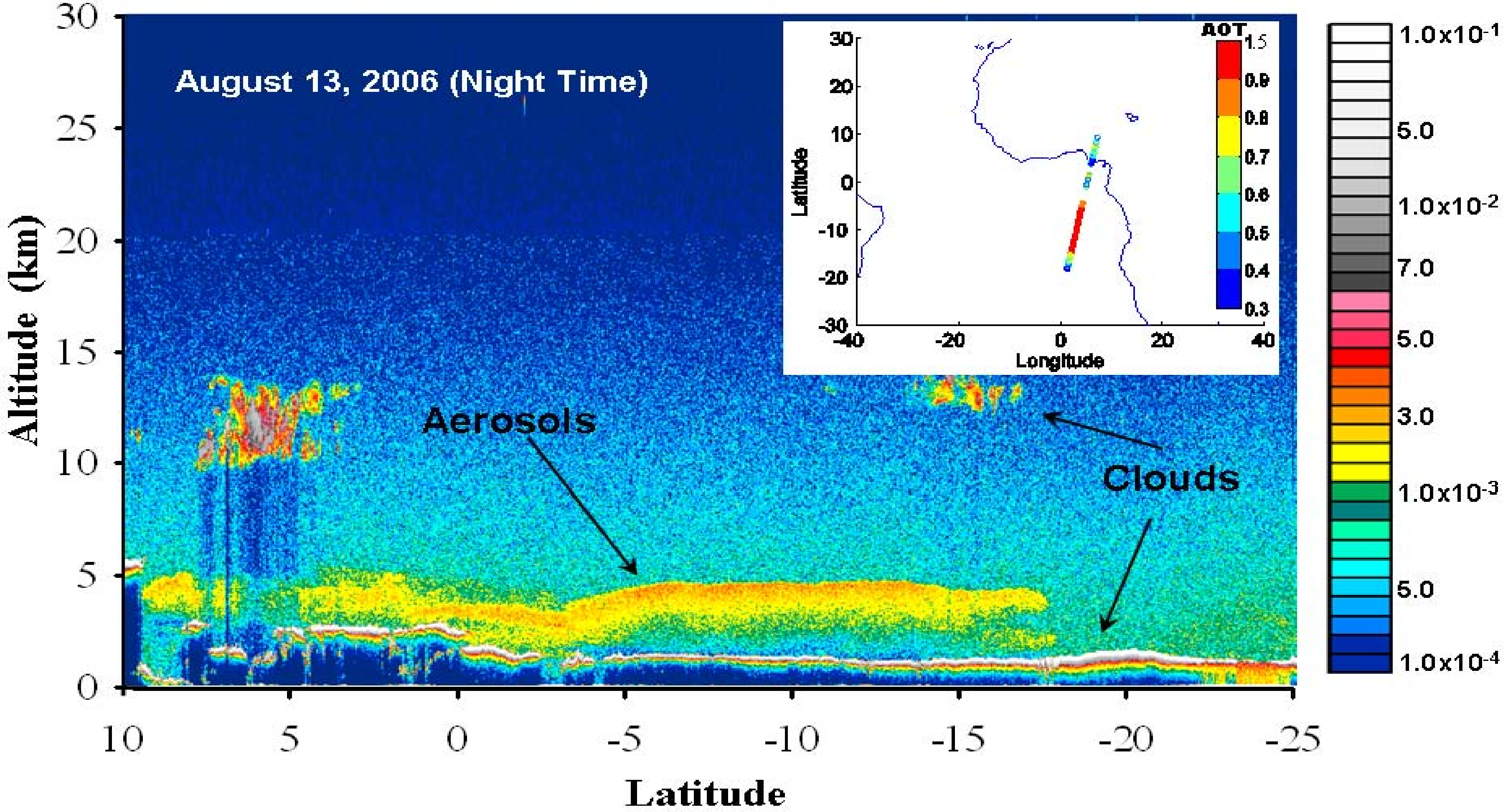
Effect of aerosol layer on TOA SW radiation



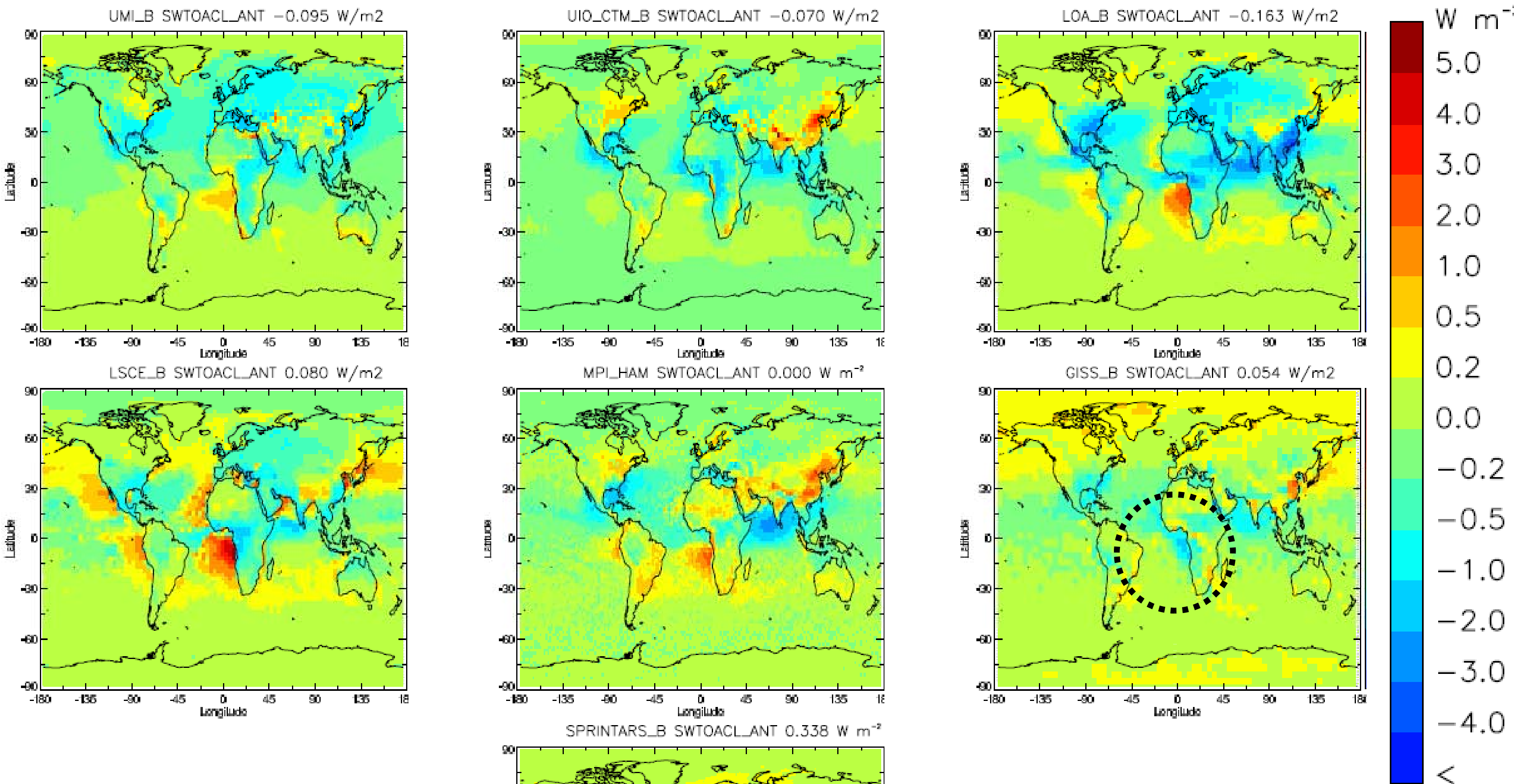
Coakley and Chylek (1974)

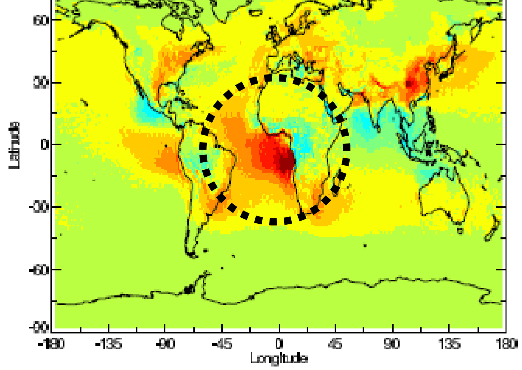

biomass burning aerosol
above cloud
stratocumulus
clouds
MODIS Aqua
RGB (enhanced)
13 Aug 2006
SE Atlantic
500 km

Aerosol layers over clouds seen with CALIPSO over SE Atlantic Ocean (13 Aug 2006)



AEROCOM Models
(Schulz et al. 2006)

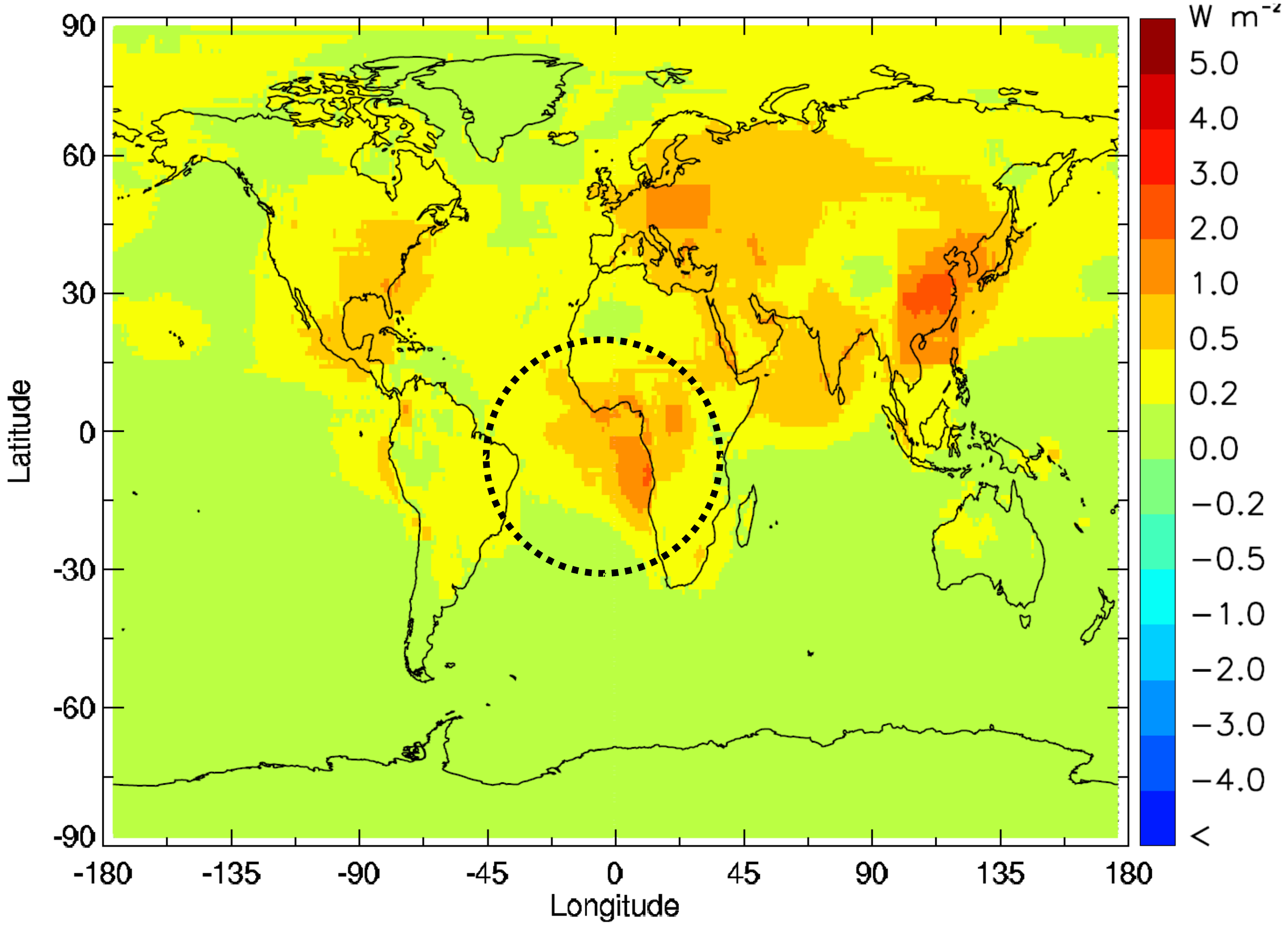




Direct radiative forcing for cloudy skies

Inter-model standard deviation of aerosol direct radiative forcing

(AEROCOM, Schulz et al. 2006)



Retrieval methodology

- CALIPSO data, integrated attenuated backscatter at 532 and 1064 nm (γ_{532} and γ_{1064})
- Determine color ratio $\chi_{\text{water}} = \gamma_{1064}/\gamma_{532}$ from layers classified as cloud (z < 3 km)
- Unobstructed liquid clouds should have χ = 1, and so deviations from this represent aerosols above clouds
- Use Beer-Lambert law to obtain AOD of aerosol layer:

$$\tau_{\text{top}} = \frac{1}{2} \ln\left(\frac{\chi_{\text{water}}}{\chi_{\text{water,unobstructed}}}\right) \frac{1}{(1 - 2^{-\mathring{a}})}$$

=1

Angstrom exponent

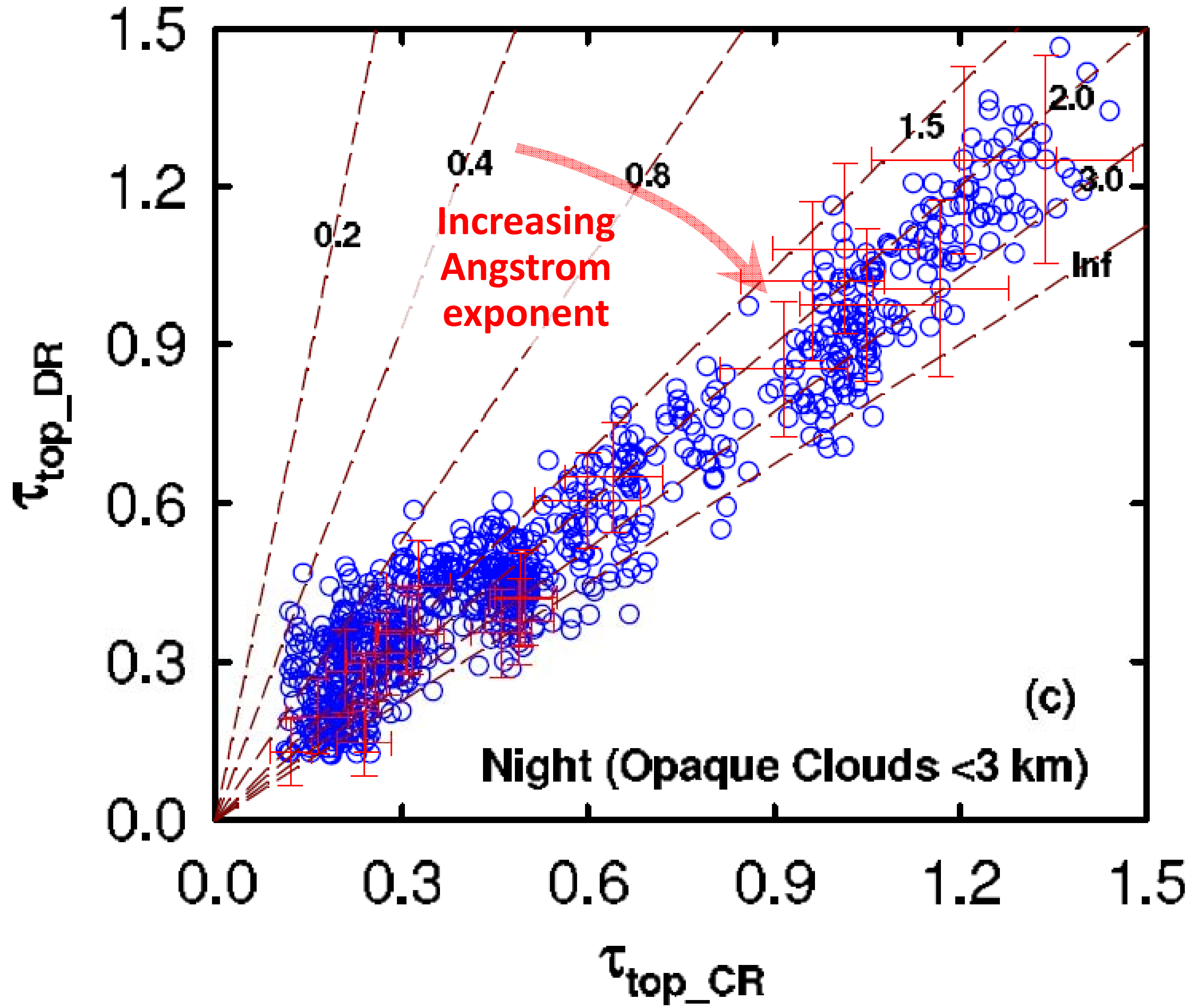
Depolarization ratio method
(Hu et al. 2007)

- Use depolarization δ of cloud layer, combined with its integrated attenuated backscatter γ, to derive AOD of overlying layer

$$\tau_{\text{top,DR}} = -\frac{1}{2}\ln\left(\frac{\gamma'_{\text{water}}}{\gamma'_{\text{water,SS,unobstructed}}}\left(\frac{1-\delta'_{\text{water}}}{1+\delta'_{\text{water}}}\right)^2\right)$$

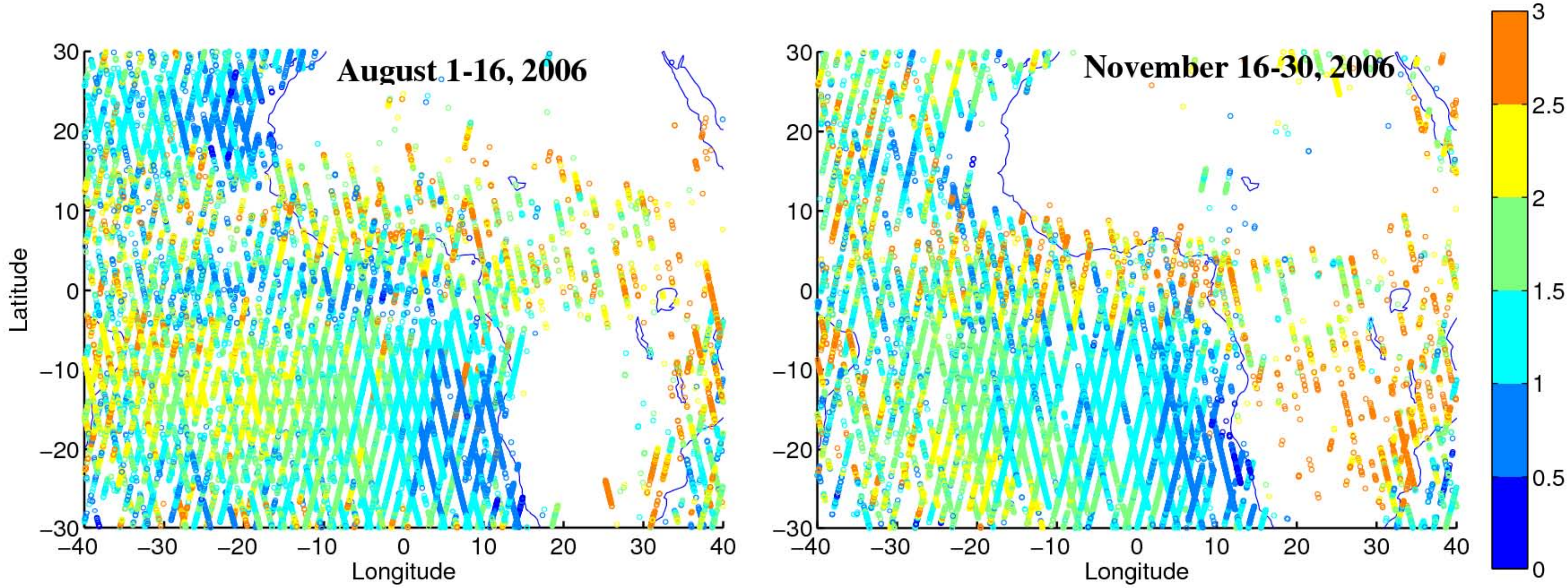
$$= -\frac{1}{2}\ln\left(2S_{\text{c}}\gamma'_{\text{water}}\left(\frac{1-\delta'_{\text{water}}}{1+\delta'_{\text{water}}}\right)^2\right)$$

Extinction to backscatter ratio for water clouds (19 sr)

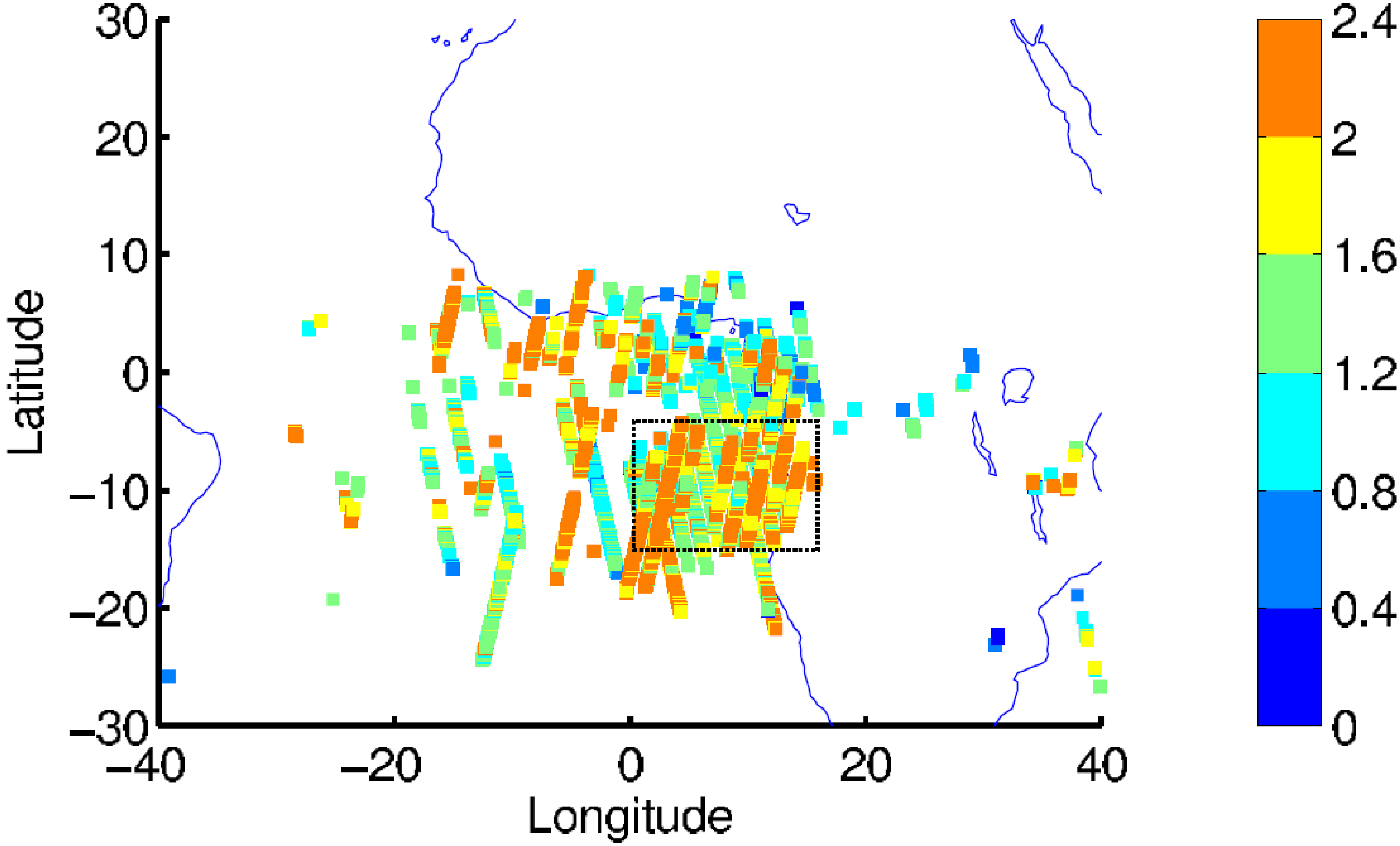


1.5
1.2
0.9
0.6
0.3
0.0
0.0
0.3
0.6
0.9
1.2
1.5
τtop_DR
τtop_CR
0.2
0.4
0.8
1.5
2.0
3.0
Inf
Increasing
Angstrom
exponent
(c)
Night (Opaque Clouds <3 km)

Cloud layer top heights

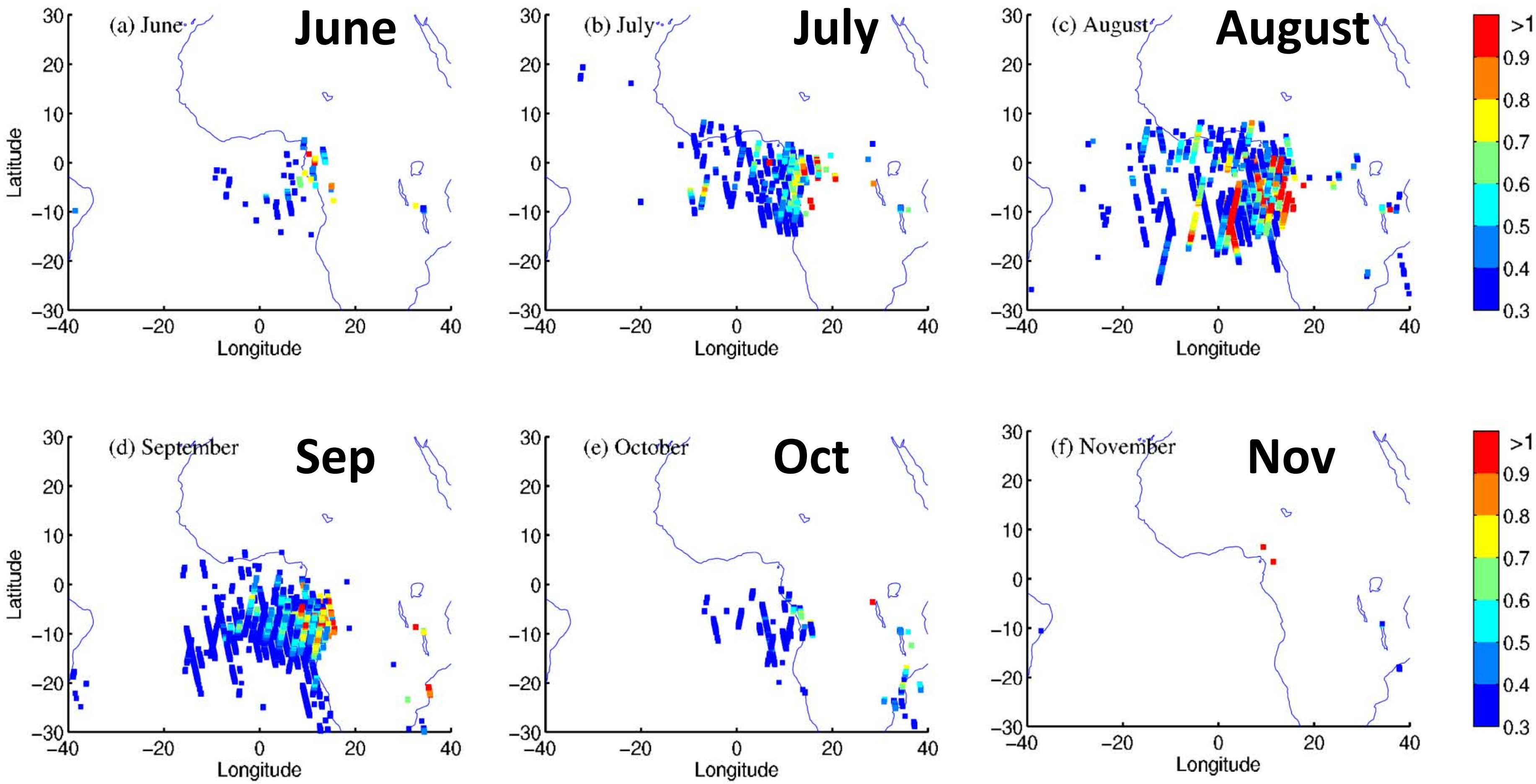


Angstrom exponent for layers above cloud

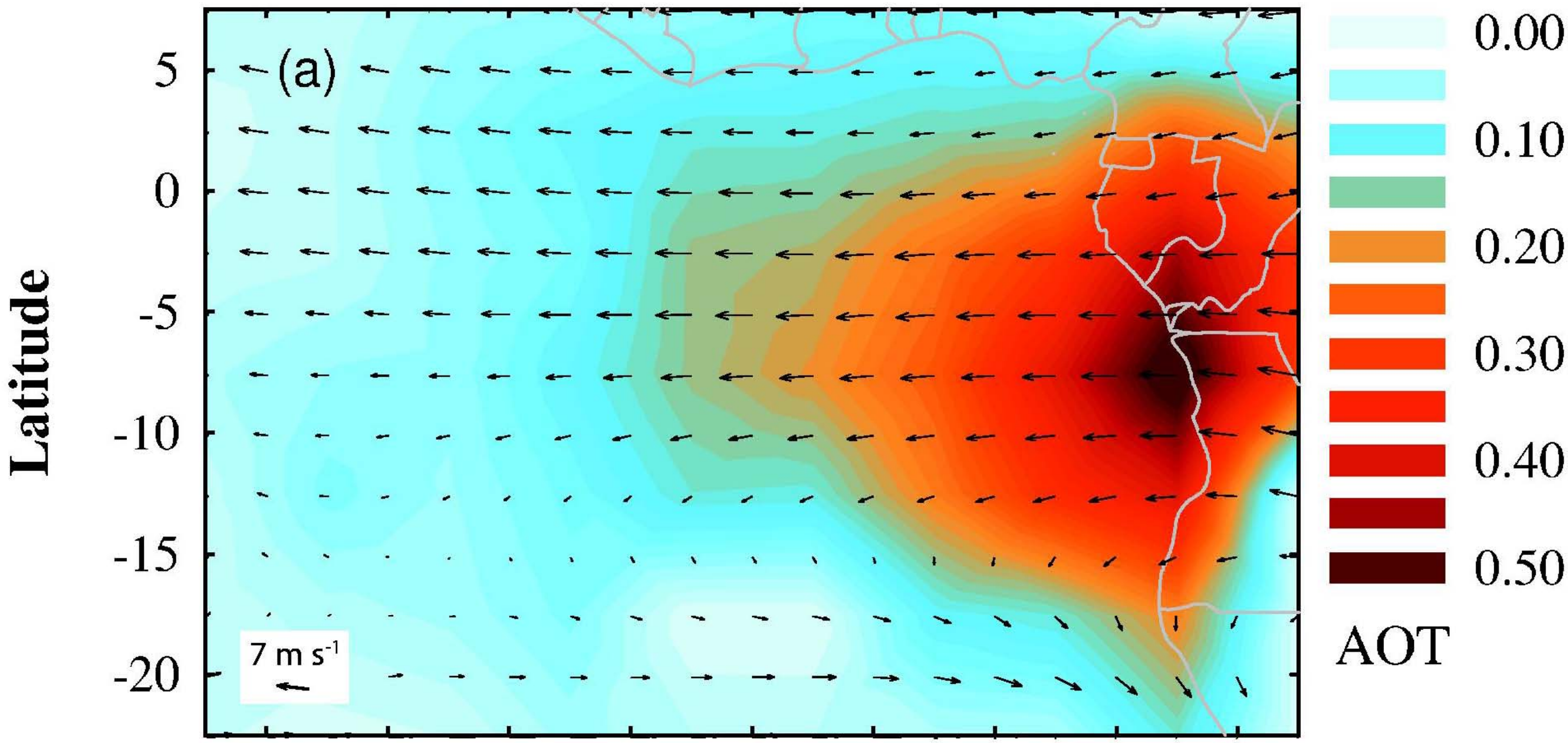


Aerosol optical depth for layers above cloud

(by month 2006)



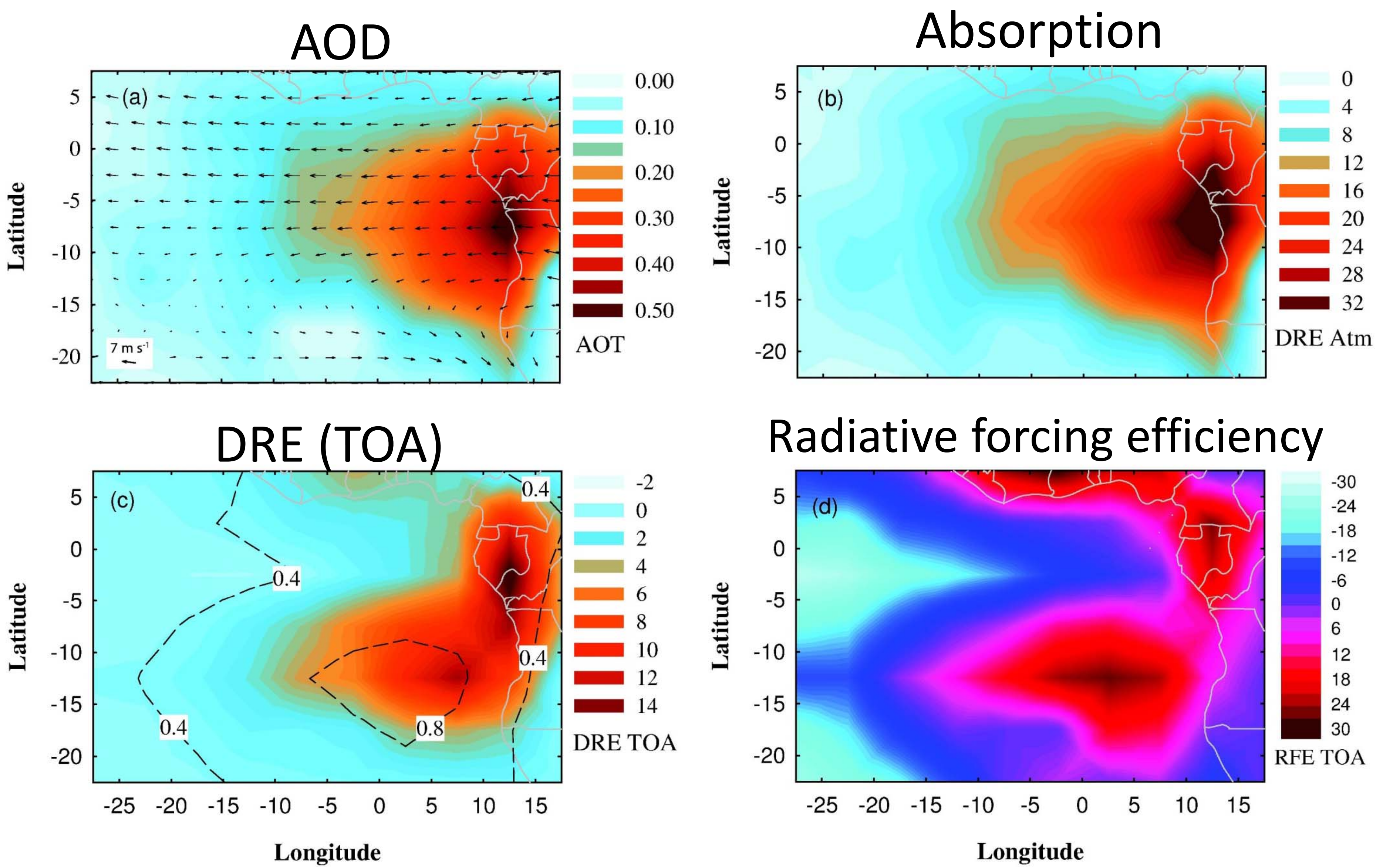
AOD and winds at 600 hPa



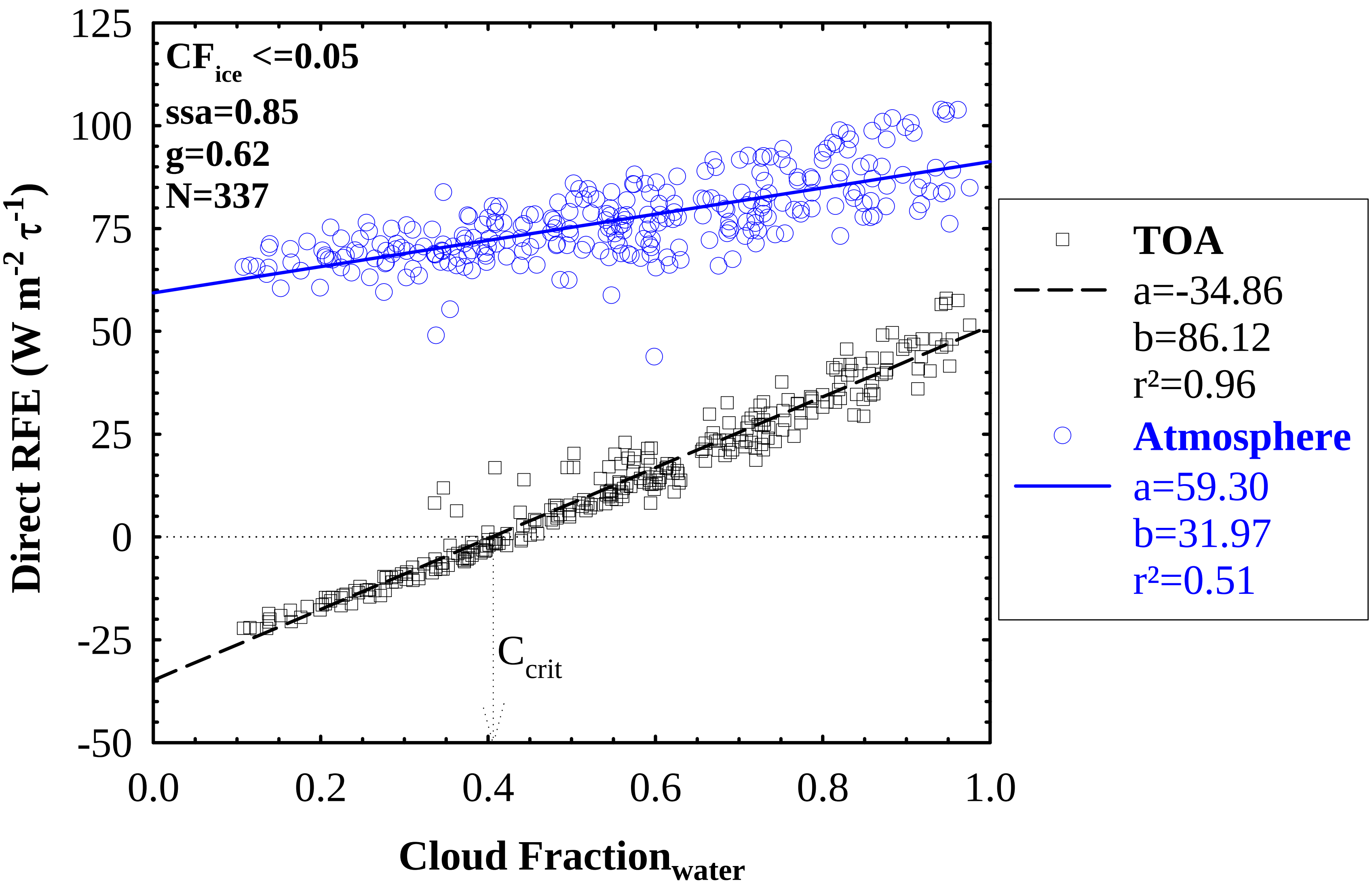
Radiative transfer model

- DISORT radiative transfer model
- Aerosol properties needed are **AOD** (from CALIPSO), **single scattering albedo** (ω=0.85, Leahy et al. 2006), **Angstrom exponent** (CALIPSO), **asymmetry factor** (g = 0.62)
- Cloud properties are **cloud optical depth** and **cloud effective radius** (MODIS), and **cloud fraction**
- Ocean surface albedo = 0.06
- **Determine aerosol radiative effect for clear sky, cloudy sky, and all-sky (Jul-Oct 2006/2007)**

Effect of aerosol upon radiative fluxes



RFE is determined primarily by cloud cover



Questions

- To what extent is inter-model variation in aerosol radiative forcing explained by variation in model cloud cover and thickness?
- Can we determine the regional/global mean effects of aerosols above cloud using CALIPSO/DISORT, and can this be used to constrain models?
- Passive remote sensing of aerosols above clouds using MODIS?