AEROSOL INFLUENCE ON CLOUD OPTICAL DEPTH AND ALBEDO OVER THE NORTH ATLANTIC SHOWN BY SATELLITE MEASUREMENTS AND CHEMICAL TRANSPORT MODELING

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http://www.ecd.bnl.gov/steve/schwartz.html

AEROSOL INFLUENCES ON RADIATION BUDGET AND CLIMATE

Direct Effect (Clear sky)

Light scattering -- Cooling influence

Light absorption -- Warming influence, depending on surface

Indirect Effects (Aerosols influence cloud properties)

More droplets -- Brighter clouds (Twomey)

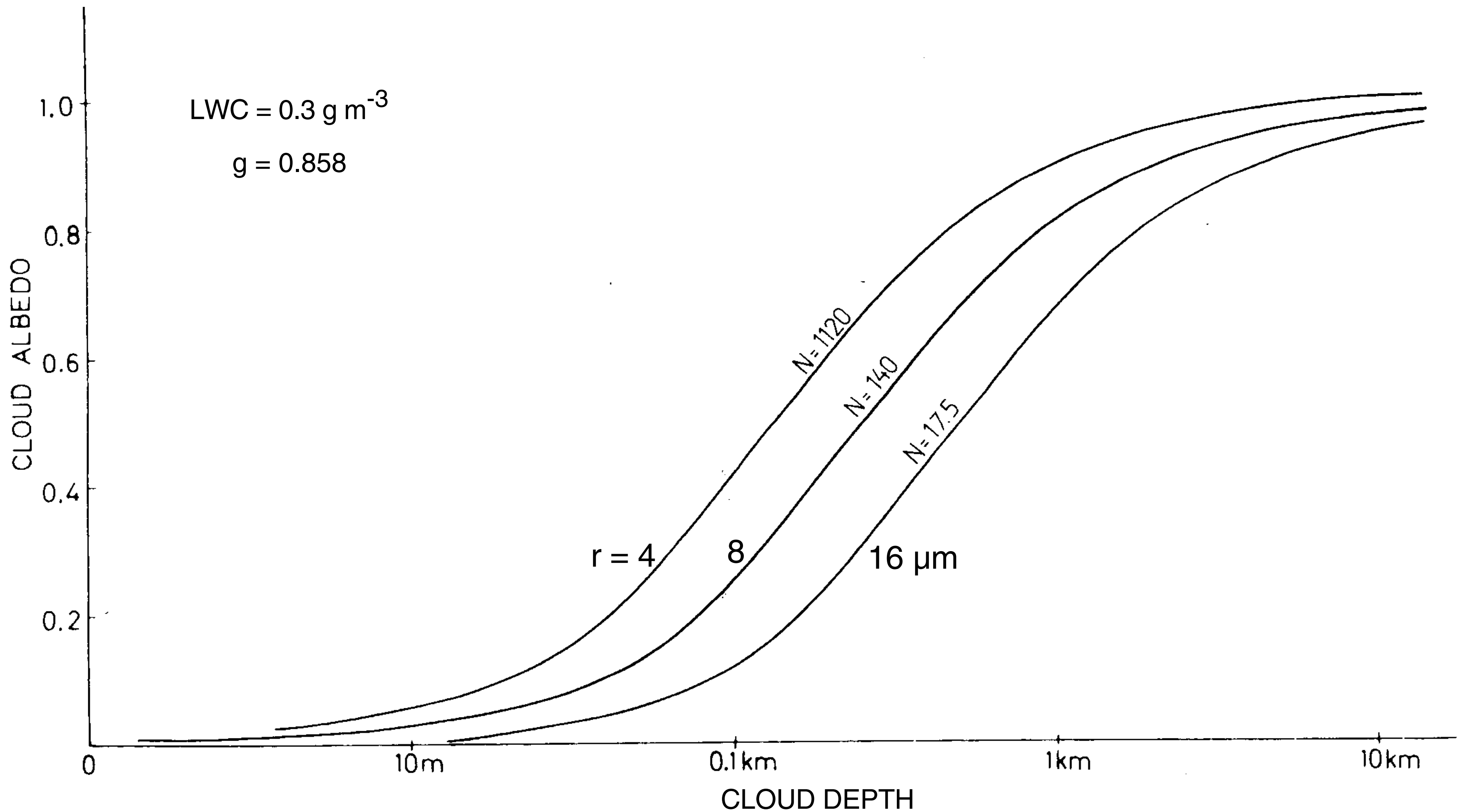
More droplets -- Enhanced cloud lifetime (Albrecht)

Semi-Direct Effect

Absorbing aerosol heats air and evaporates clouds

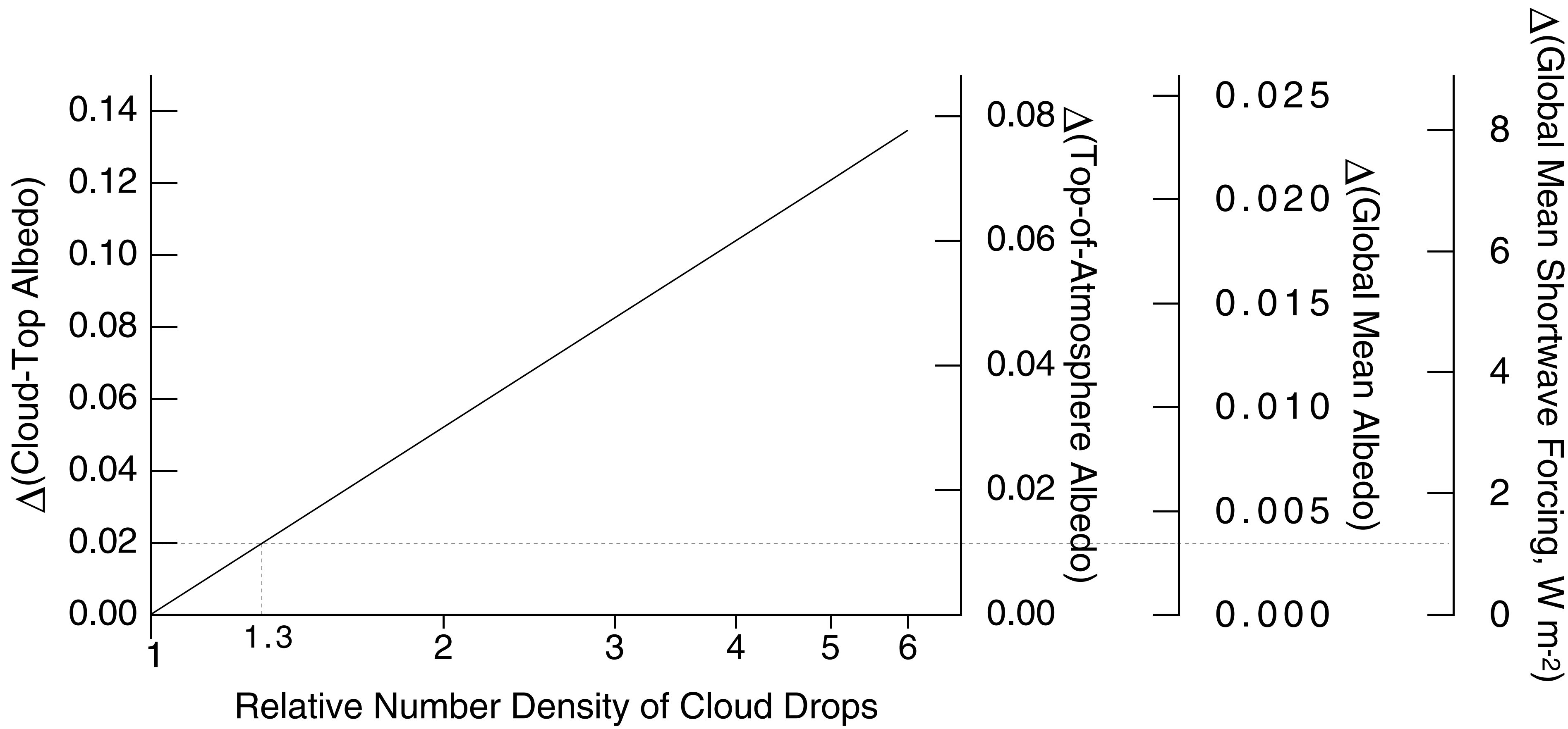
DEPENDENCE OF CLOUD ALBEDO ON CLOUD DEPTH

Influence of Cloud Drop Radius and Concentration



Twomey, *Atmospheric Aerosols*, 1977

SENSITIVITY OF ALBEDO AND FORCING TO CLOUD DROP CONCENTRATION

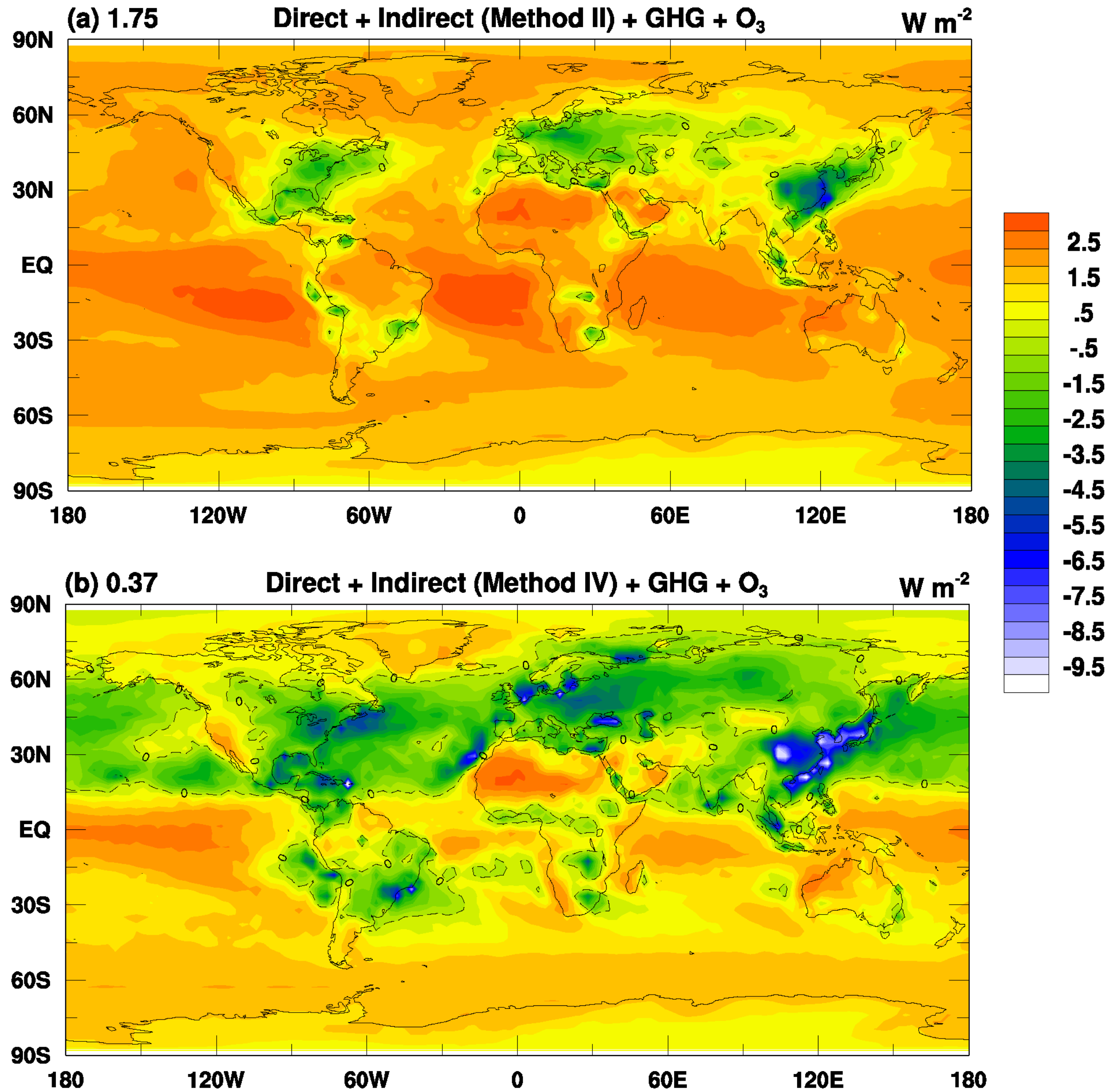


Schwartz and Slingo (1996)

SHORTWAVE FORCING, ANNUAL AVERAGE

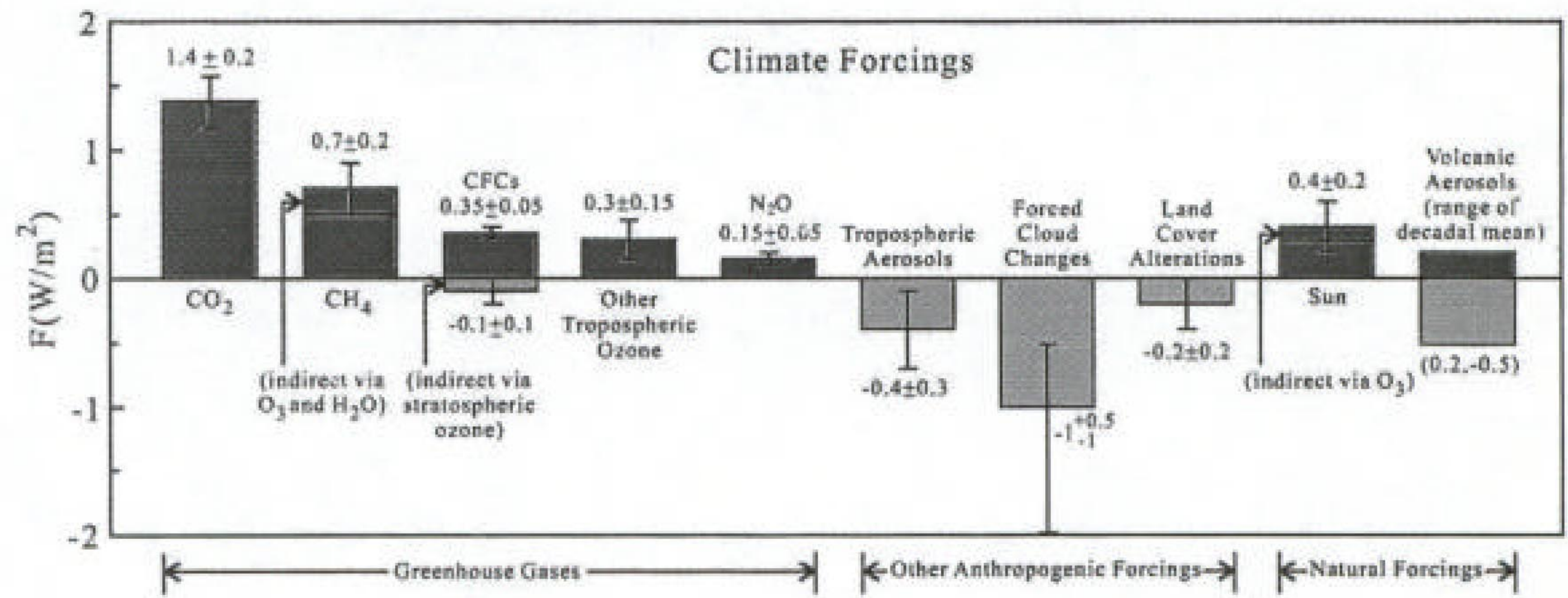
GHG's + O_3 + Sulfate (Direct and Indirect)

Two Formulations of Cloud Droplet Concentration



Kiehl et al., JGR, 2000

CLIMATE FORCING COMPONENTS OVER THE INDUSTRIAL PERIOD



CLIMATE CHANGE SCIENCE

AN ANALYSIS OF SOME KEY QUESTIONS

Committee on the Science of Climate Change
National Research Council
June 6, 2001

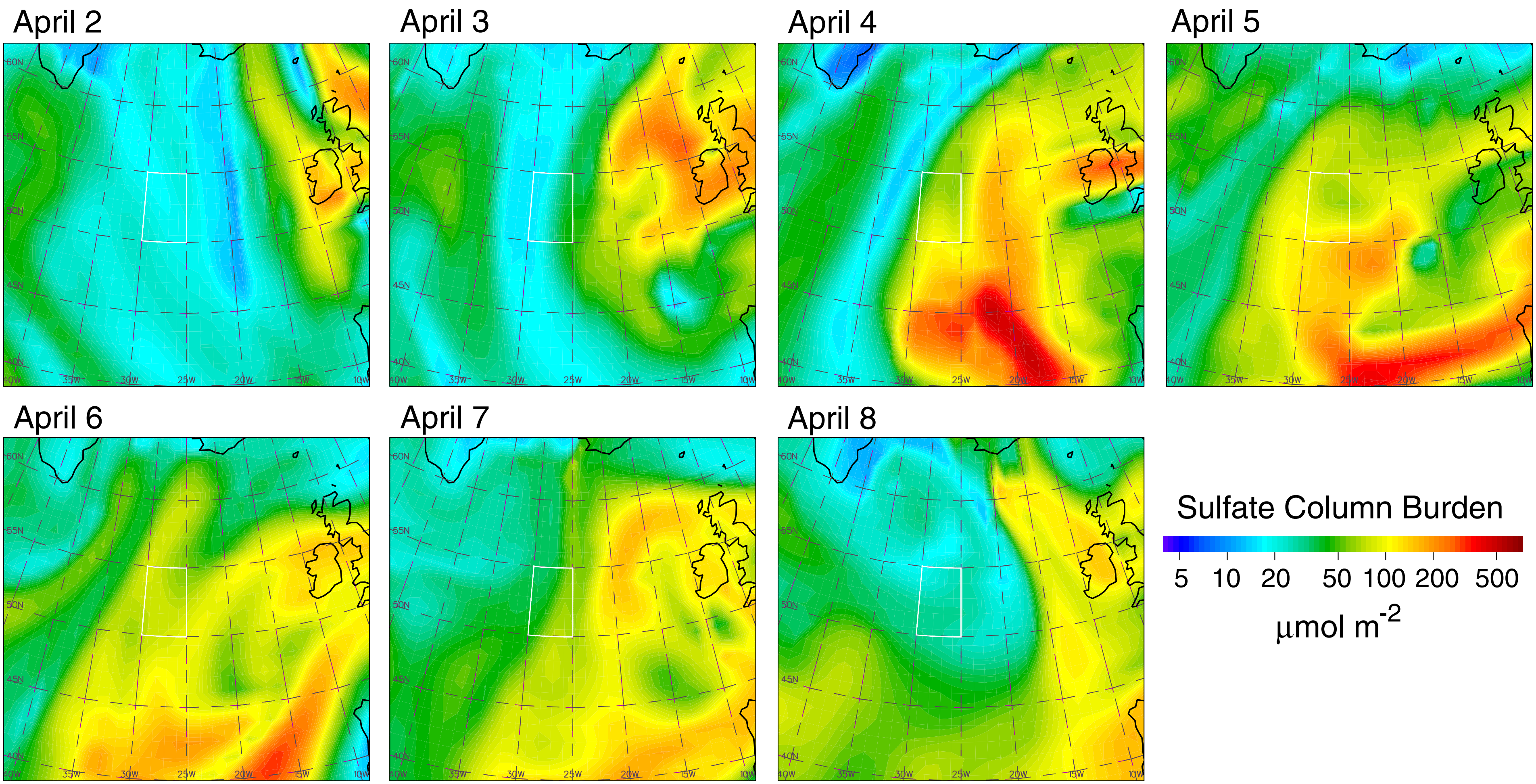
THIS STUDY

- Uses a ***chemical transport and transformation model*** to identify a situation where a strong aerosol influence on cloud albedo might be expected.
- ***Examines for this signal in satellite data*** in two one-week episodes in which the model indicates transport of anthropogenic sulfate from Europe or North America to mid North Atlantic.
- Finds a strong signal in cloud drop radius.
- Does ***not*** find an immediate strong signal in cloud albedo: ***Why?***
- Offers an explanation: ***Inherent variability in cloud liquid water path on a given day and from day to day***.
- ***Quantifies the perturbation in cloud albedo***.

MODELED SULFATE COLUMN BURDEN

$$\int [SO_4^{2-}]\,dz$$

April 2-8, 1987

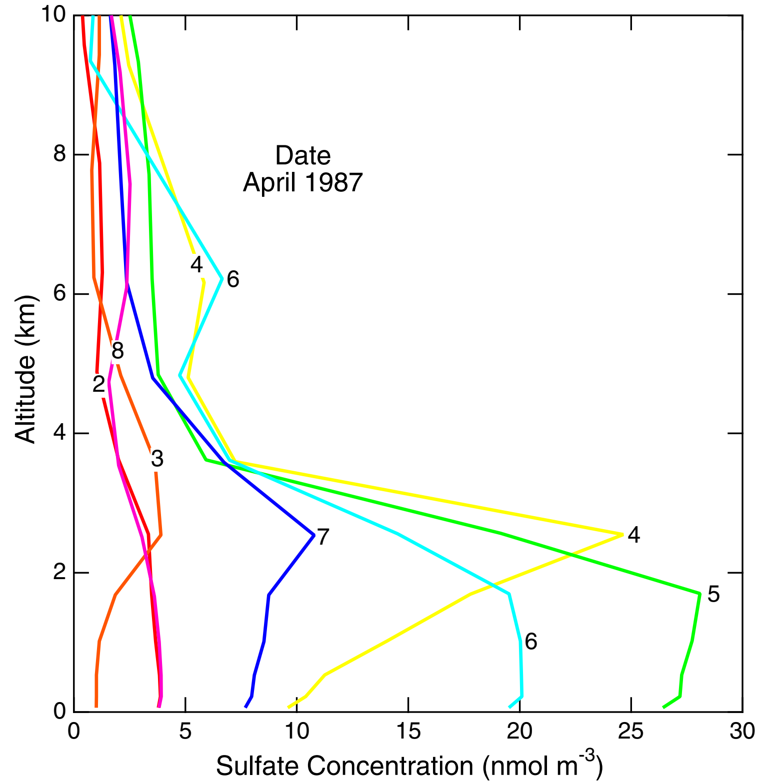


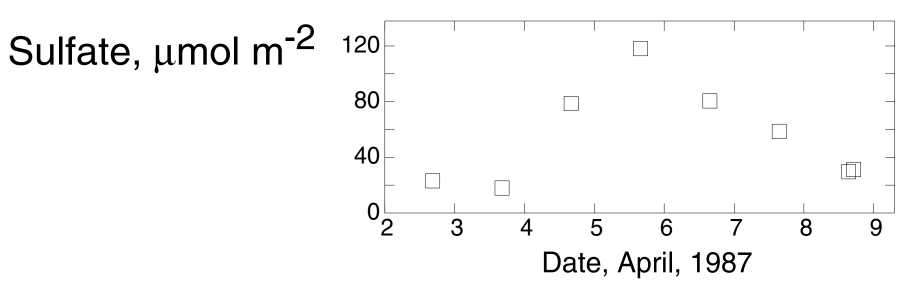
Benkovitz et al., *Geochem. Geophys. Geosyst.* **2** (2001)

http://g-cubed.org/publicationsfinal/articles/2000GC000129/fs2000GC000129.html

MODELED SULFATE CONCENTRATION PROFILE AND COLUMN BURDEN ($\int [SO_4^{2-}]dz$)

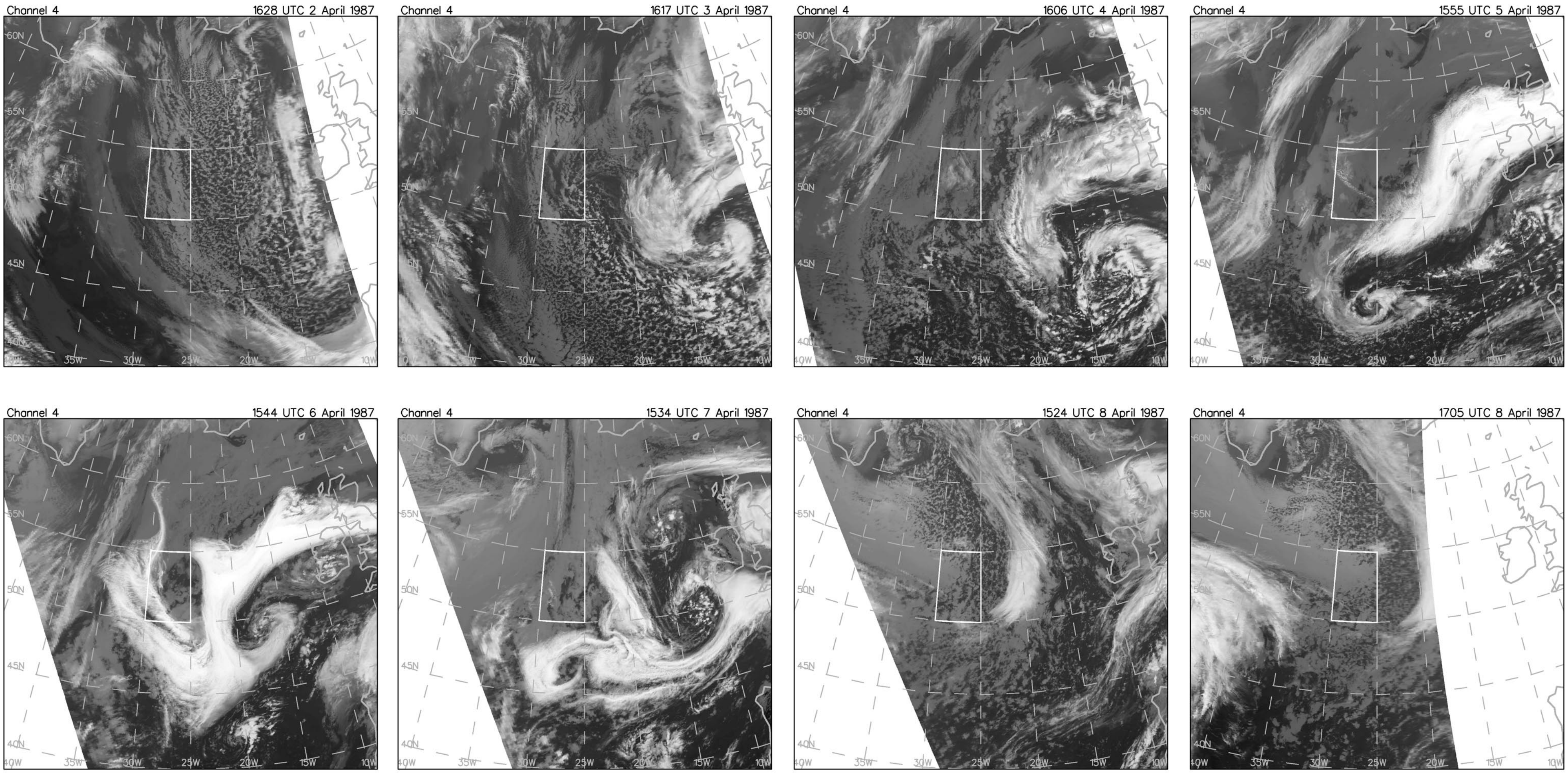
25°-30°W, 50°-55°N, April 2-8, 1987





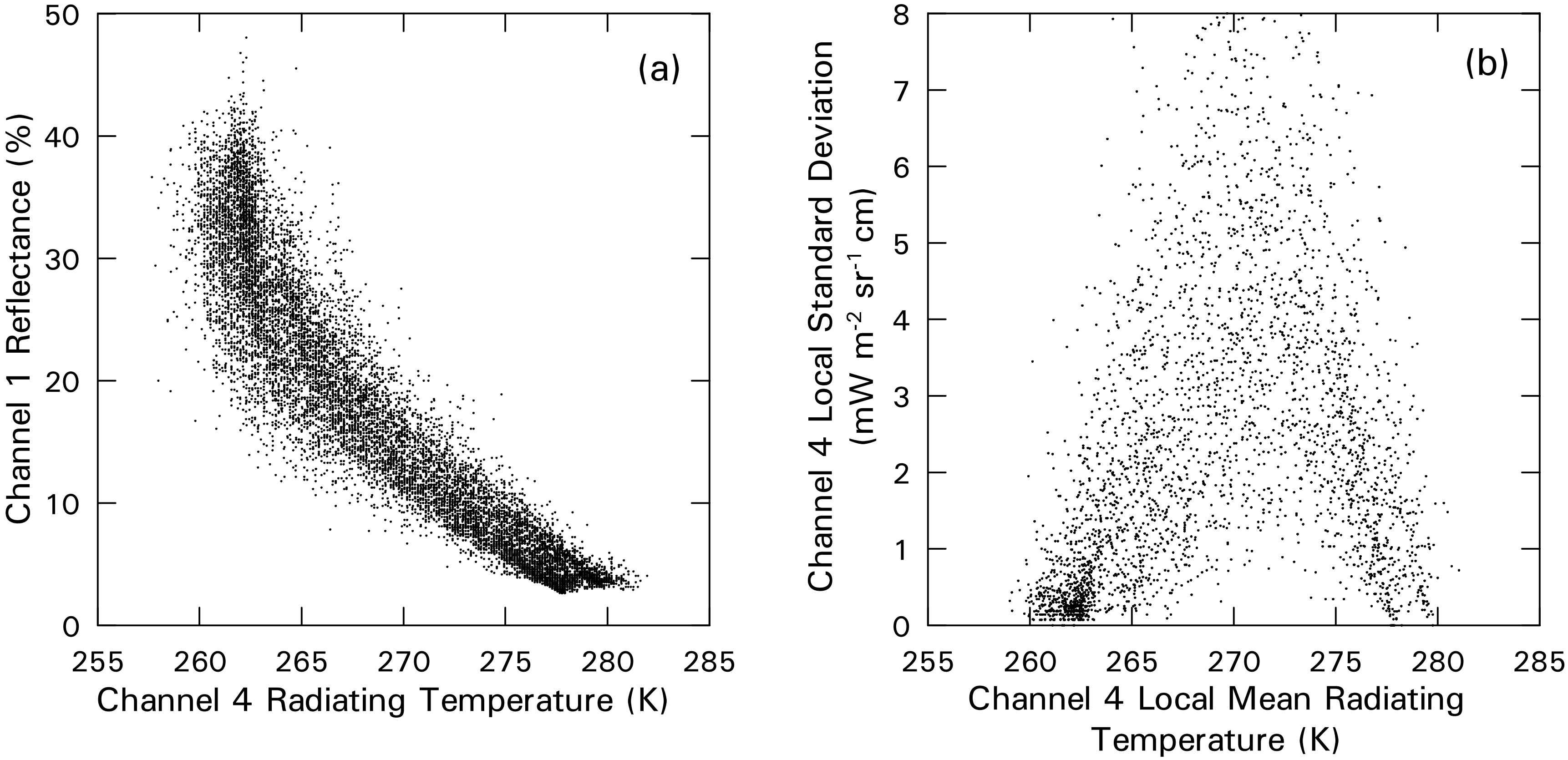
AVHRR IMAGES APRIL 2-8, 1987

Channel 4, Thermal IR, 10.3-11.3 µm



AVHRR DATA
Screening for Spatial Coherence

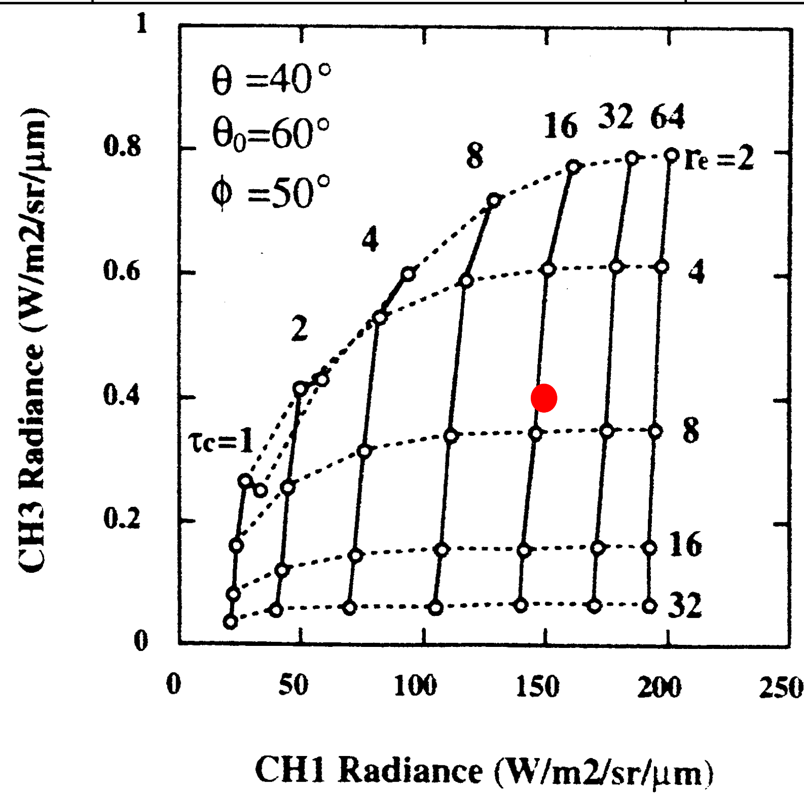
April 2, 1987 50-55N/25-30W 1628 UTC



Harshvardhan, Schwartz, Benkovitz & Guo, J. Atmos. Sci, submitted, 2000

DETERMINING CLOUD OPTICAL THICKNESS AND EFFECTIVE DROP RADIUS FROM SATELLITE RADIANCE MEASUREMENTS

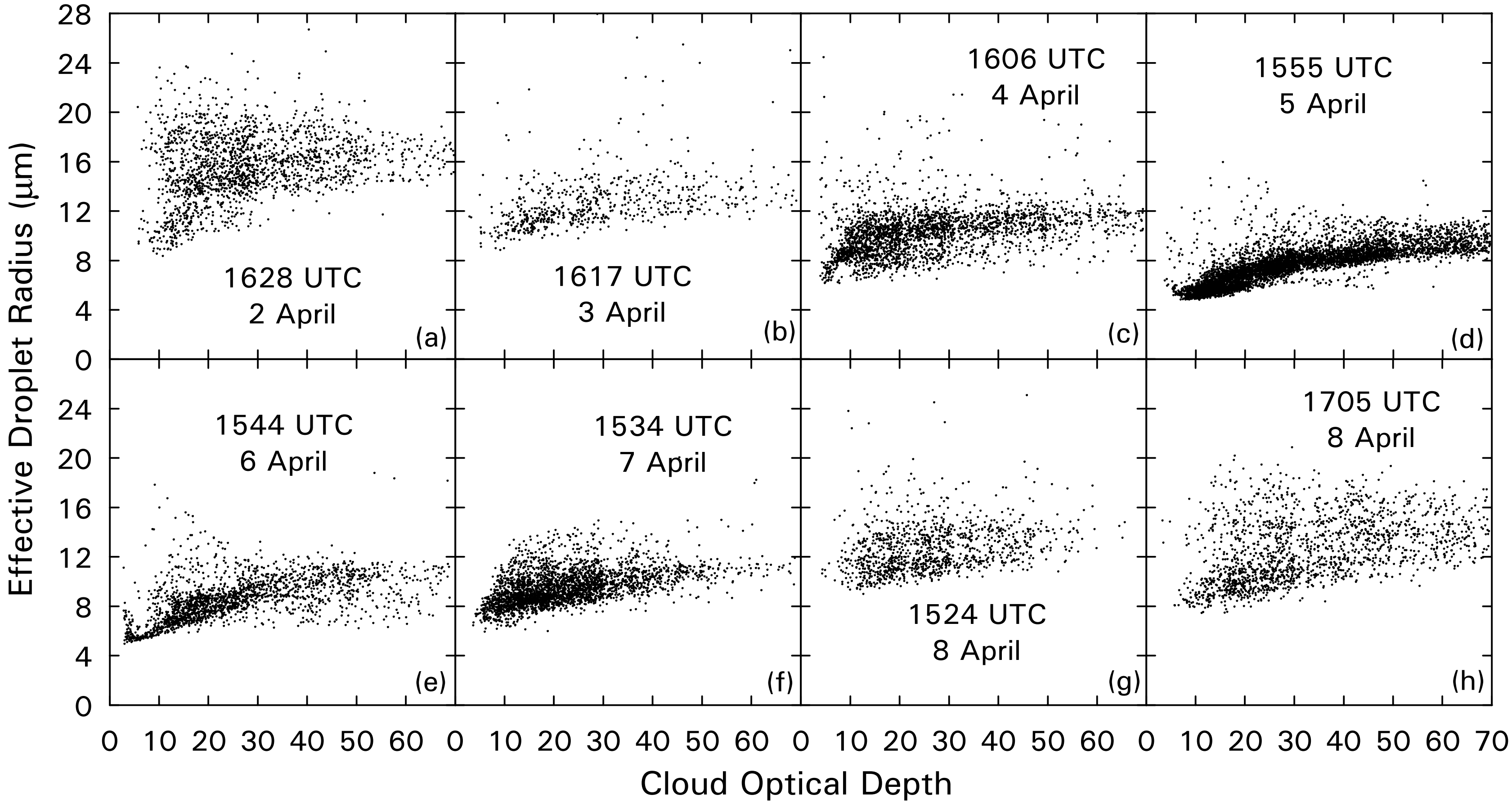
IN	LOOK-UP TABLE	OUT
Visible and IR radiance Channel 1 (0.58-0.68 μm) Channel 3 (3.6-3.9 μm)	Based on Radiative Transfer Calculations $f(\theta_0, \theta, \phi)$ ⟶	Cloud optical thickness (0.63 μm) τ_c Effective radius $r_e = \mu_3/\mu_2$



Nakajima and Nakajima, J. Atmos. Sci. (1995)

EFFECTIVE RADIUS VS. CLOUD OPTICAL DEPTH

AVHRR Data: 50-55°N, 25-30°W, 2-8 April, 1987



Harshvardhan, Schwartz, Benkovitz & Guo, J. Atmos. Sci., ~~submitted, 2000~~ 2002

DERIVED MICROPHYSICAL QUANTITIES

Primary measured quantities:

Effective radius at top of cloud r_e

Cloud optical depth τ_c

Derived quantities:

Liquid water path $$W = \frac{2\rho_w \tau_c \overline{r_e}}{3}$$

where $\overline{r_e}$ is mean drop radius in cloud, taken as $(5/6)r_e$, and

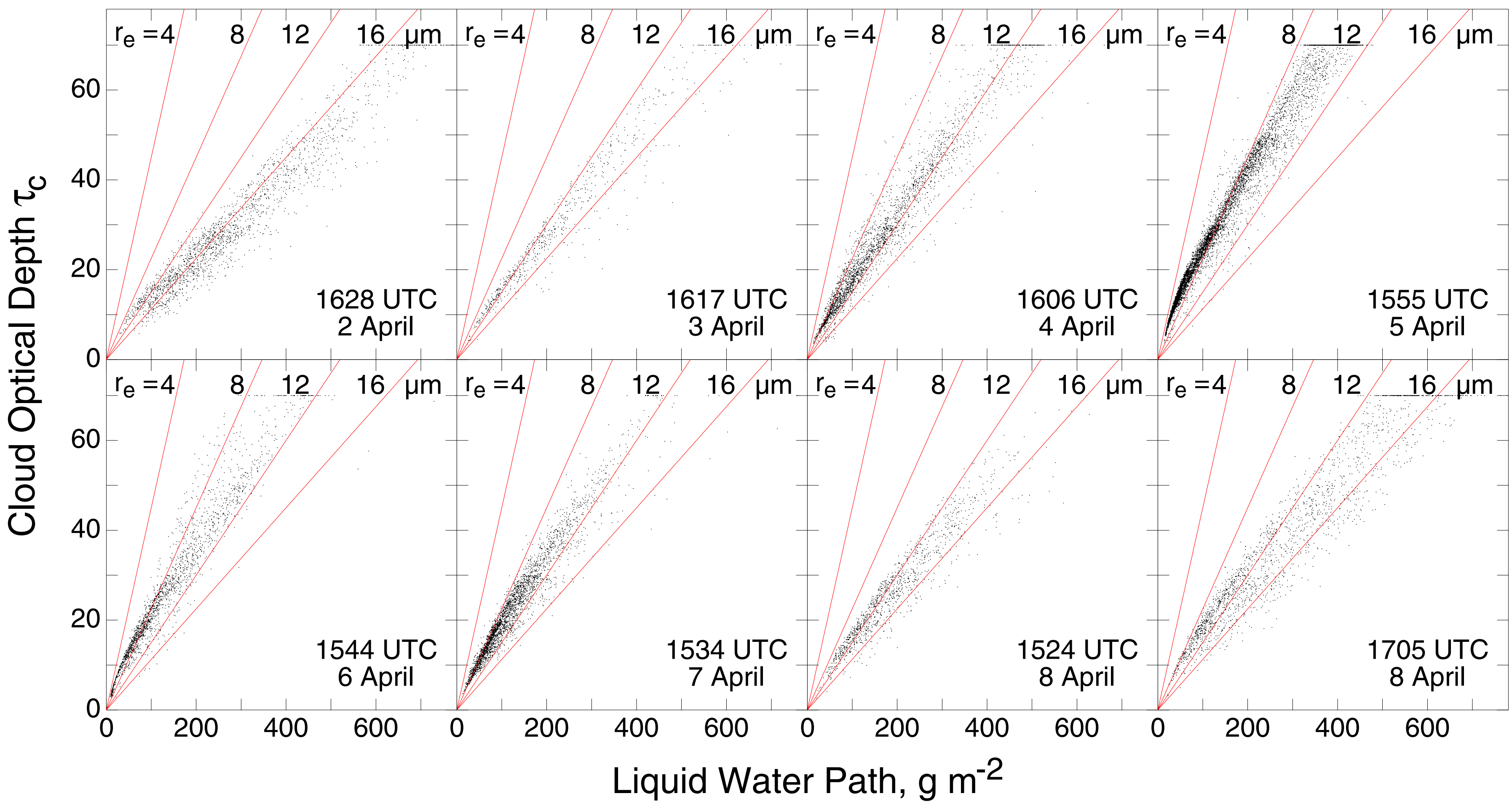
Cloud spherical albedo $$\alpha_{\mathrm{sph}} \approx \frac{\tau_{\mathrm{c}}(1-g)+0.097}{\tau_{\mathrm{c}}(1-g)+1.43}$$

where g is asymmetry parameter ranging from 0.834 for r_e = 6 μm to 0.872 for r_e = 19 μm.

CLOUD OPTICAL DEPTH

Dependence on Liquid Water Path

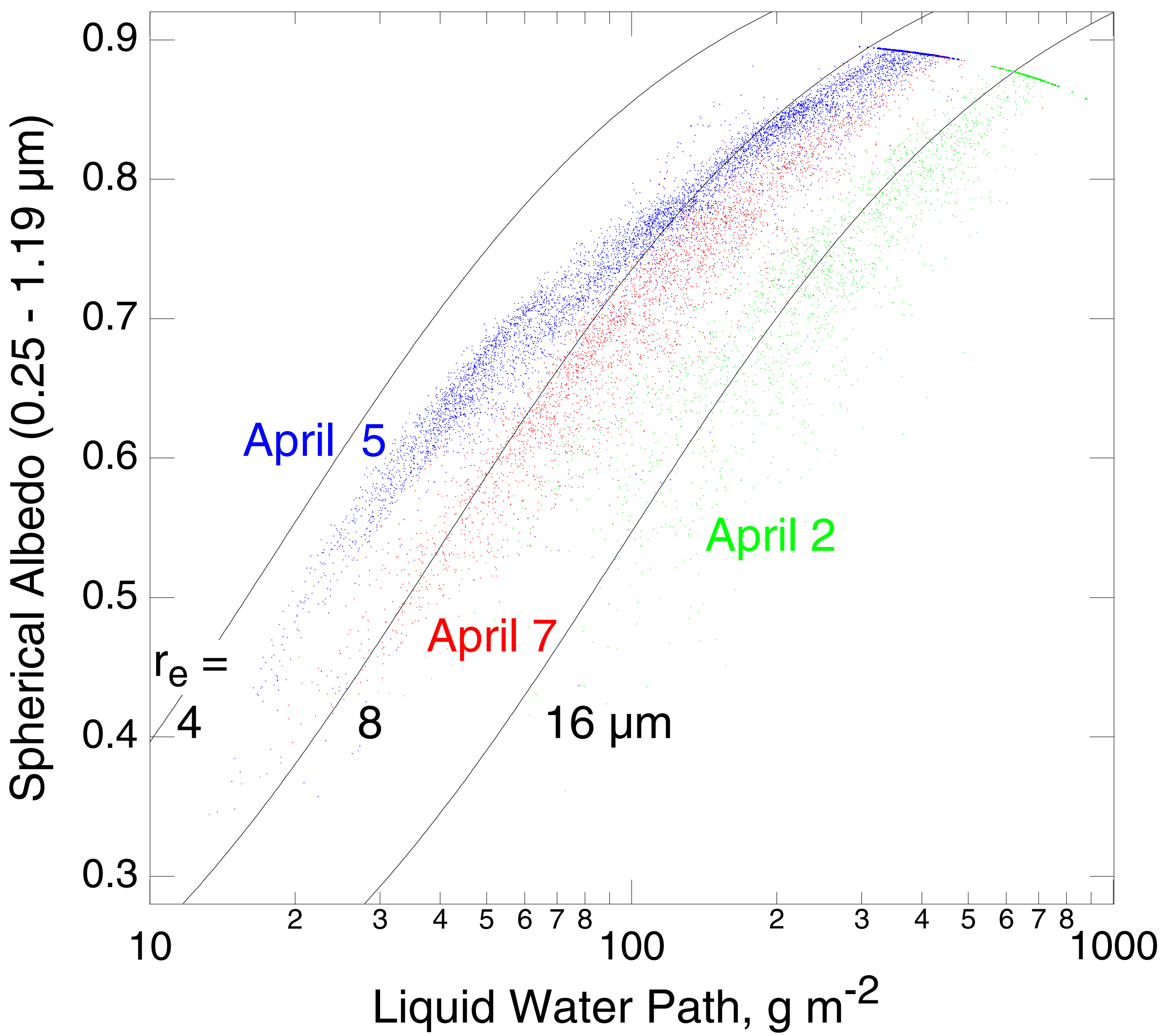
25°-30°W, 50°-55°N April 2-8, 1987



CLOUD-TOP ALBEDO

Dependence on Liquid Water Path

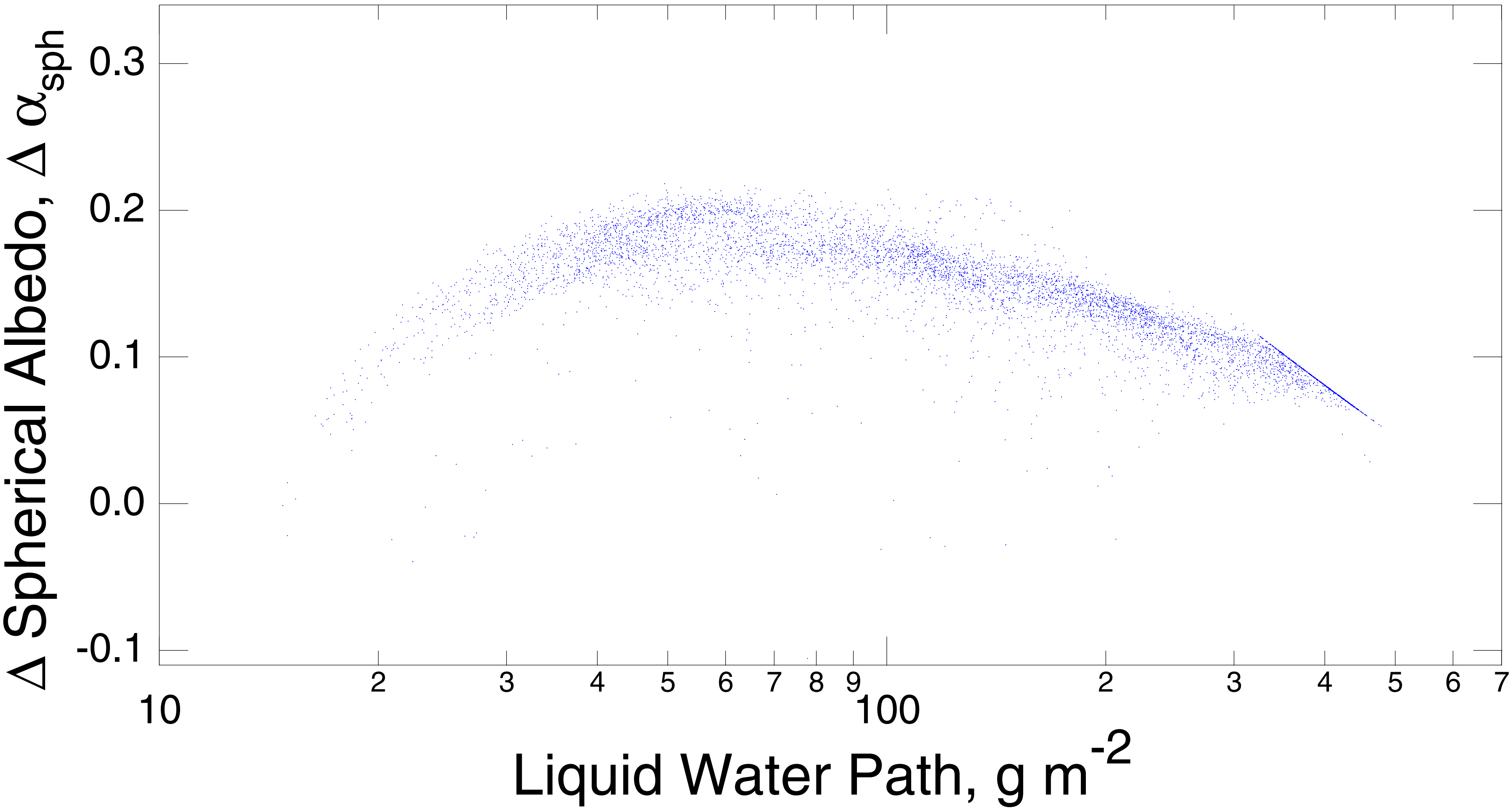
25°-30°W, 50°-55°N   April 2, 5 and 7,1987



CLOUD-TOP ALBEDO DIFFERENCE

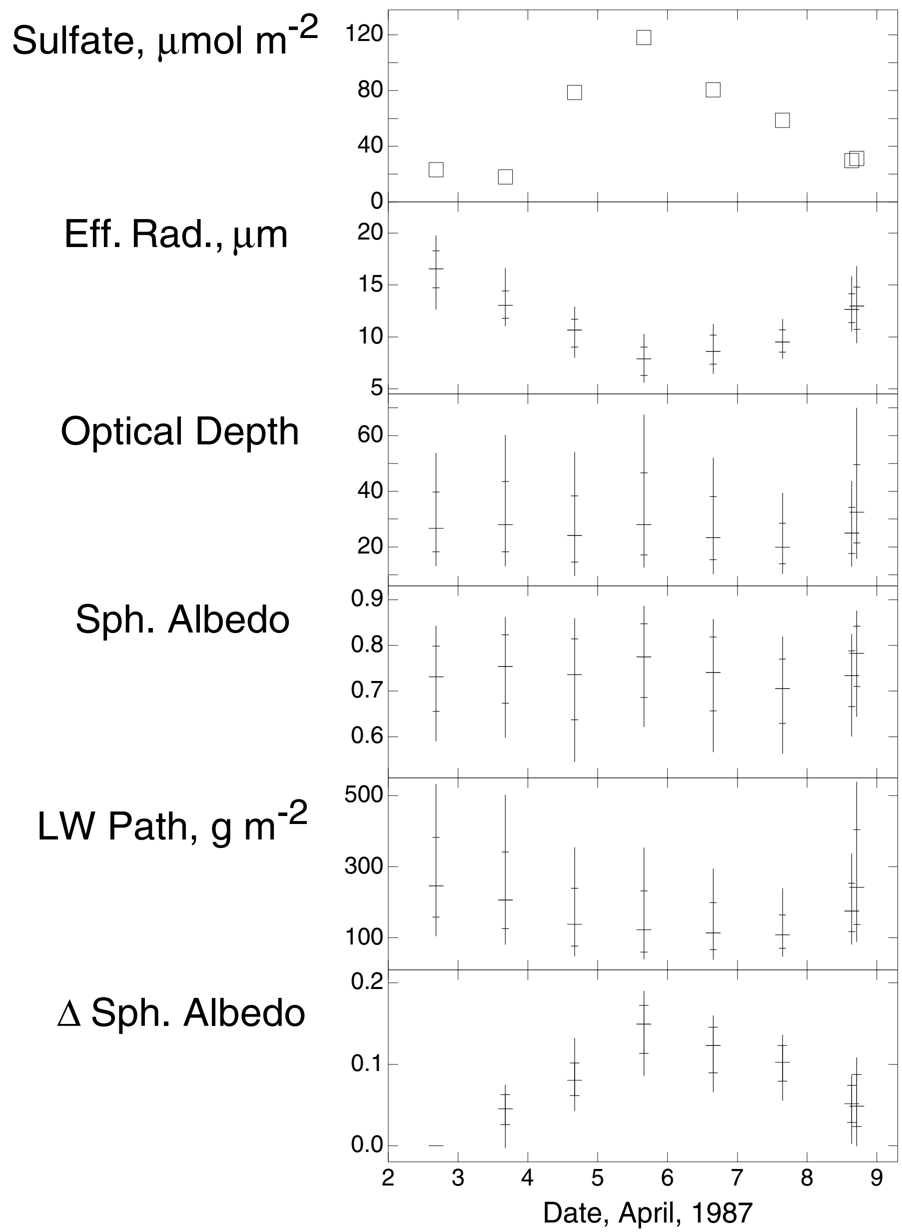
April 5 relative to April 2, 1987

Evaluated for LWP of April 5 Data



CLOUD PROPERTIES AND SULFATE COLUMN BURDEN

25°-30°W, 50°-55°N, April 2-8, 1987



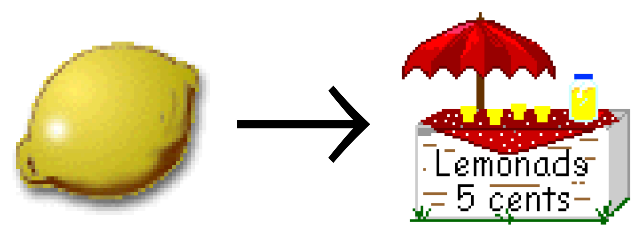
CONCLUSIONS

- Satellite-derived cloud microphysical properties are correlated with modeled sulfate loading.

- ***Aerosol exerts substantial influence*** on cloud optical depth and albedo.

- Approach relies on ability to ***simultaneously determine liquid water path and optical depth***.

  - Takes advantage of variability in LWP.



- This approach may be ***broadly applicable*** to examining aerosol influences on cloud microphysical properties and radiative forcing.