Strategies of Monitoring Aerosol Indirect Effect from Space

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What is the viable strategy for determining the indirect aerosol forcing and its changing by satellite observations?

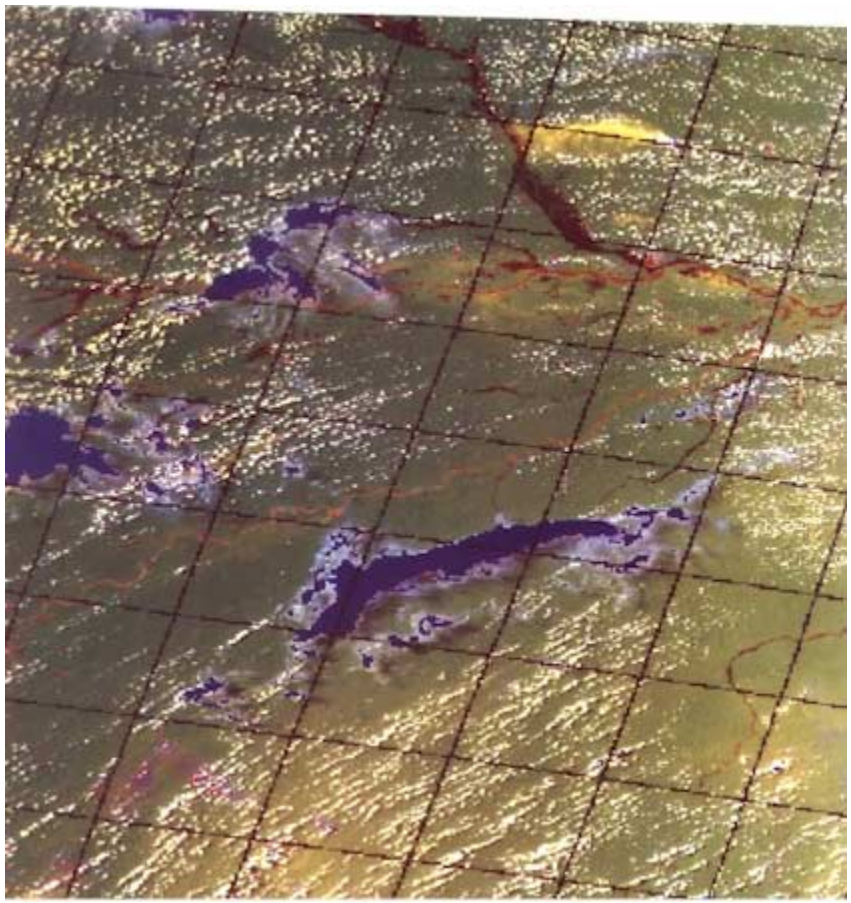
- Evidence and future research recommended by NRC 1996
- Progress since NRC 1996
  - New evidences
  - New observations
- Strategies

Evidences and Future Research Recommended by NRC 1996

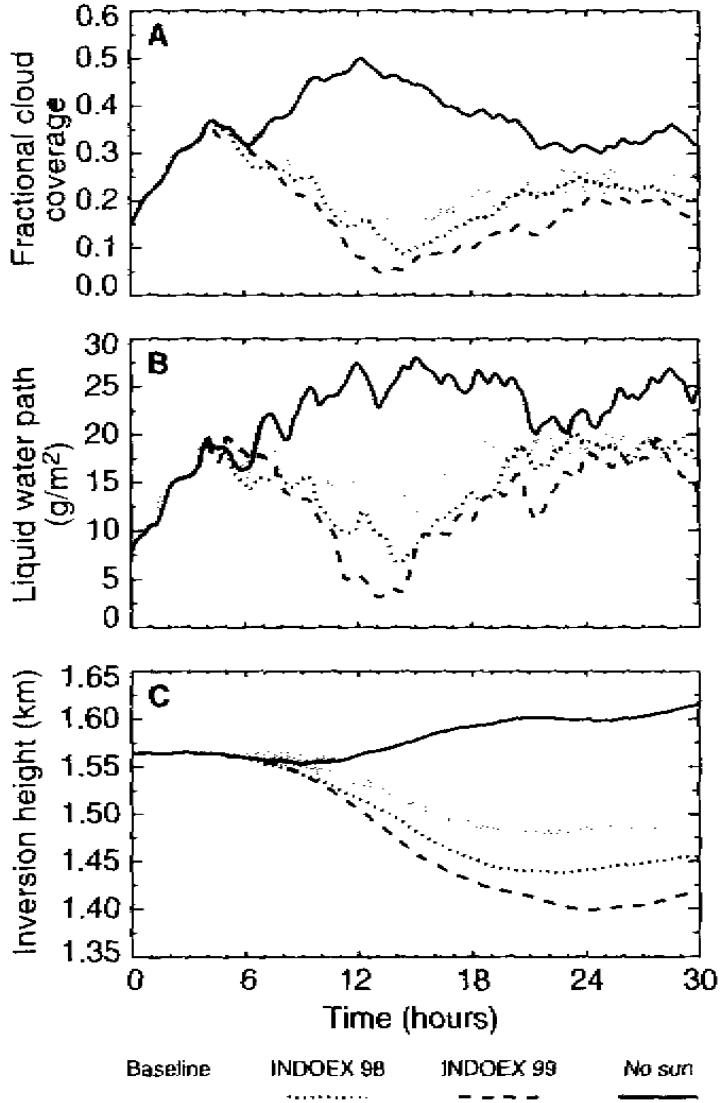
- **Evidences of Aerosol Indirect Effect**
  - Increased N_{aer} leads to increased N_{cld}
  - Decreased droplet size leads to increased albedo (Ship tracks)

- **Recommended process research**
  - Remote sensing the relation between cloud albedo and cloud droplet size distribution

Progress since NRC 1996 – New Evidences

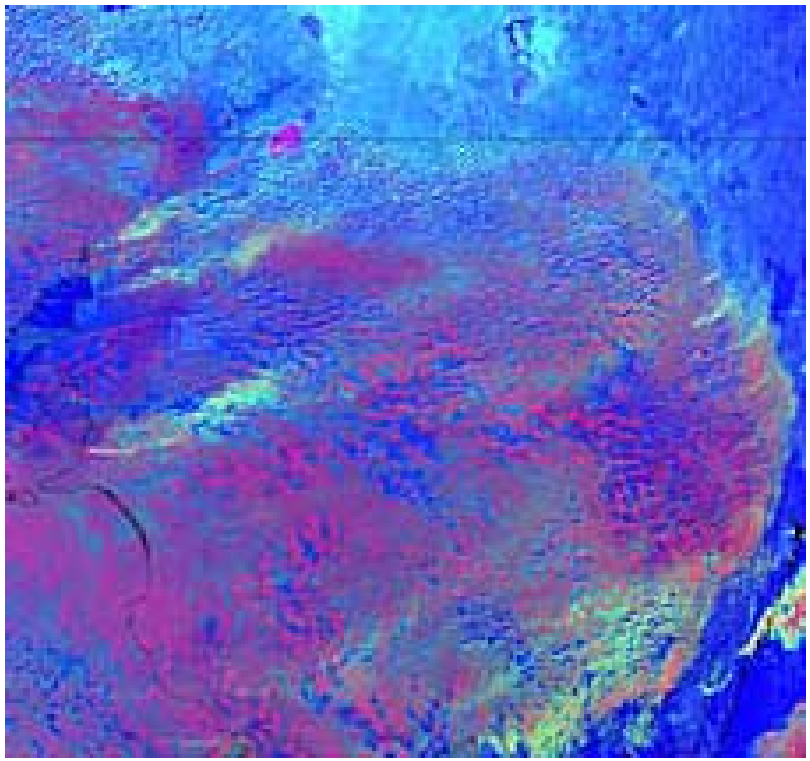


Increased N_{aer} →increased cloud albedo (Kaufman and Fraser, 1997)



Increased aerosol may decrease *LWP*, τ, & *f* (Ackerman et al., 2000)

Progress since NRC 1996 – New (and Old) Evidences



Aerosol inhibits precipitation (Rosenfeld 1999)

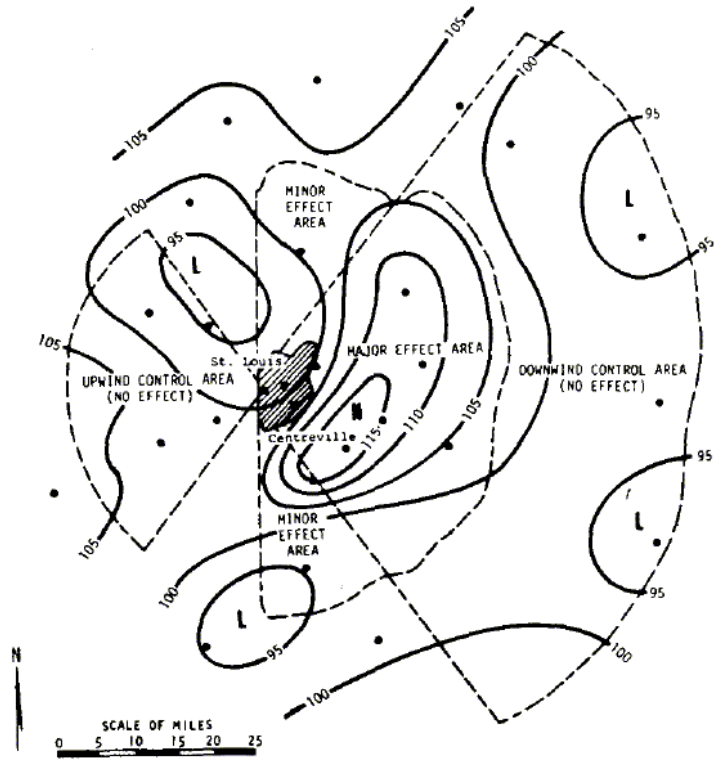
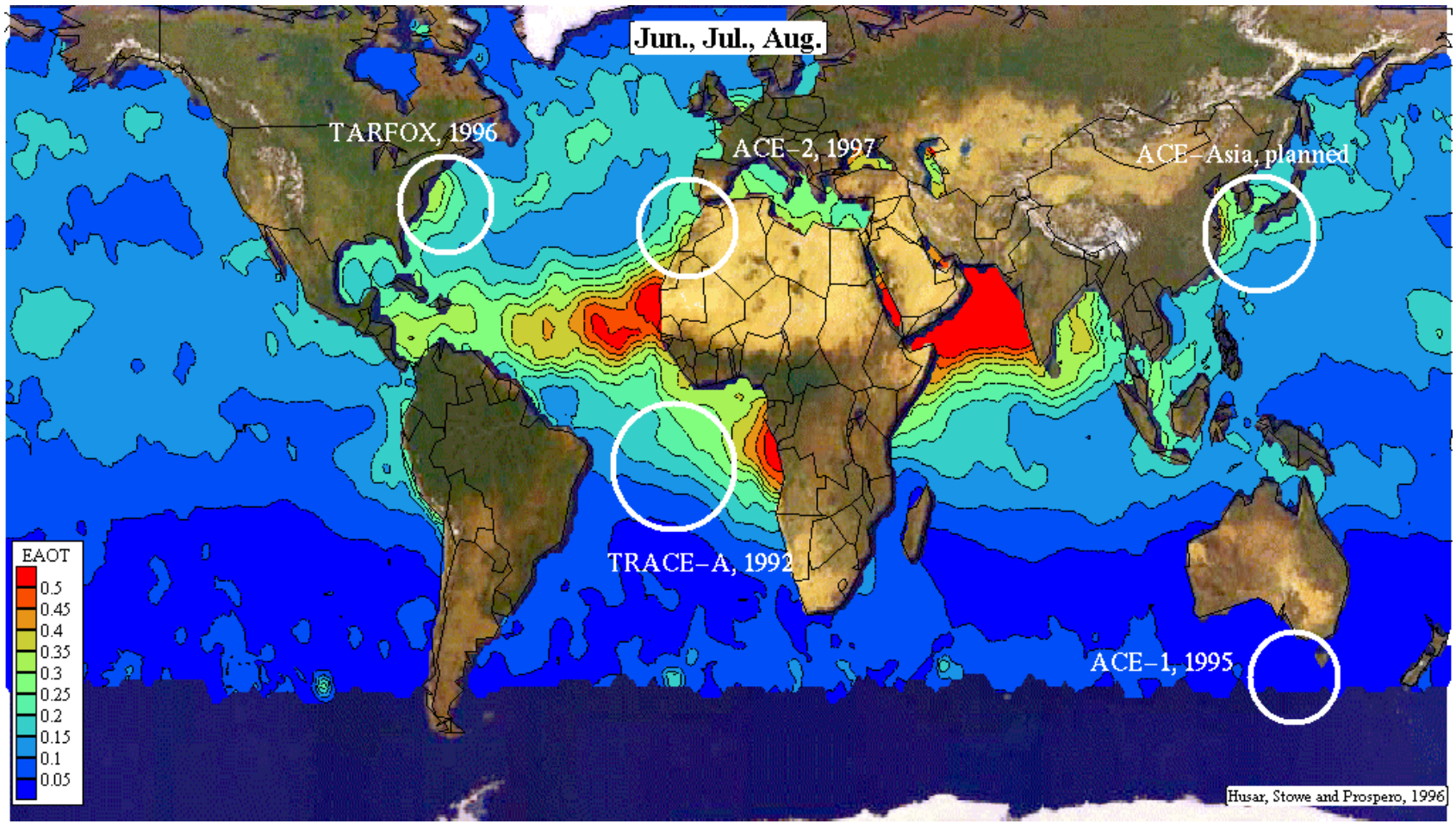


FIG. 1. Average rural/urban ratios of summer rainfall in St. Louis area, 1949–1968.

Urban aerosol increased rainfall, rain days (e.g., Ashworth, 1929; Kratzer, 1956; Stout, 1962; Lendsberg, 1956; Hobbs et al., 1970, Changnon et al., 1971, Mather, 1991).

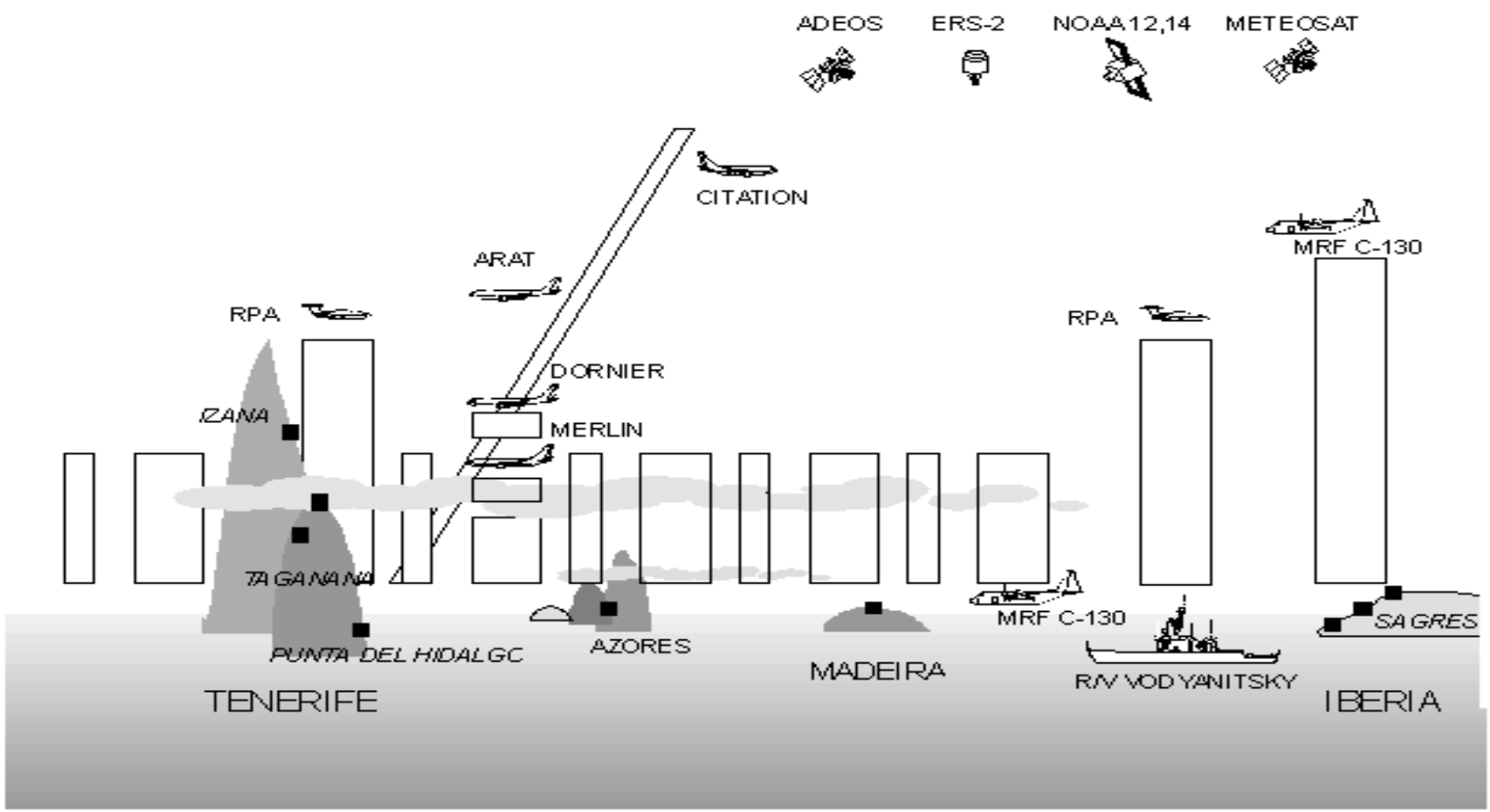
Progress since NRC 1996 –New Observations

Field Experiments



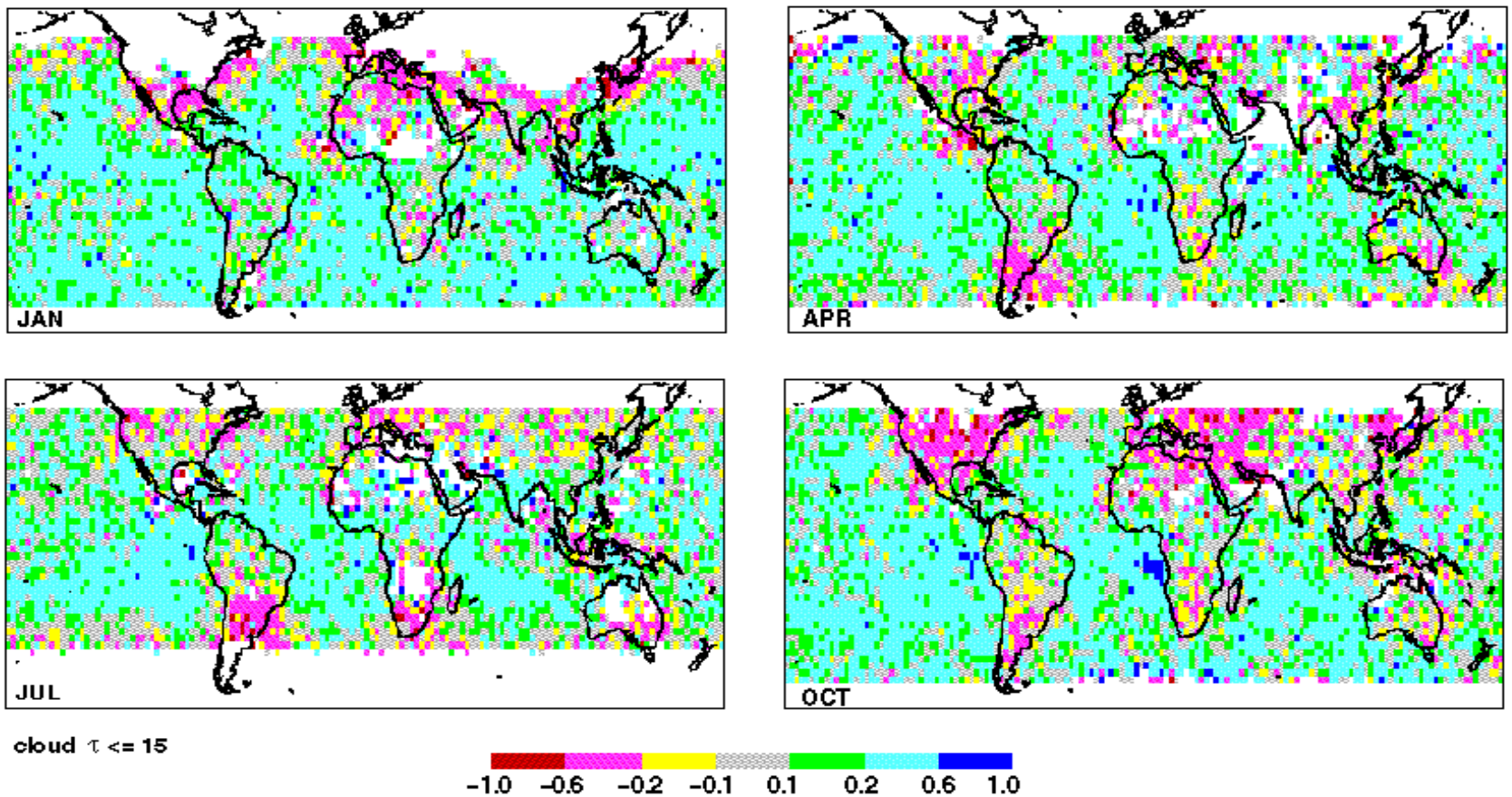
Progress since NRC 1996 –New Observations

Field Experiment: ACE-2 (6/16-7/24, 1997) (Brenguier, 2000)



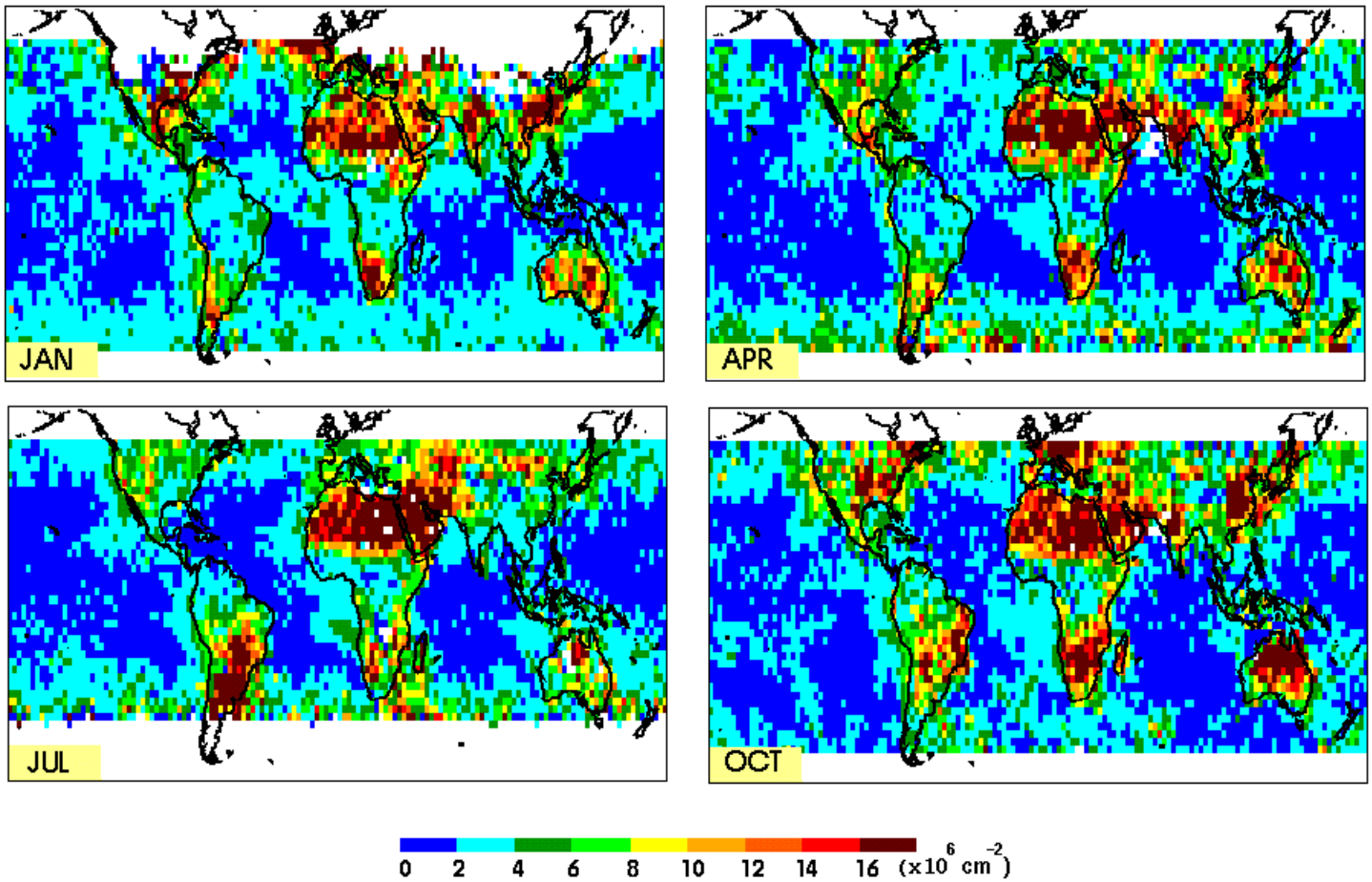
Progress since NRC 1996 –New Observations

Correlation between cloud albedo and droplet size (Han et al., 1998a)



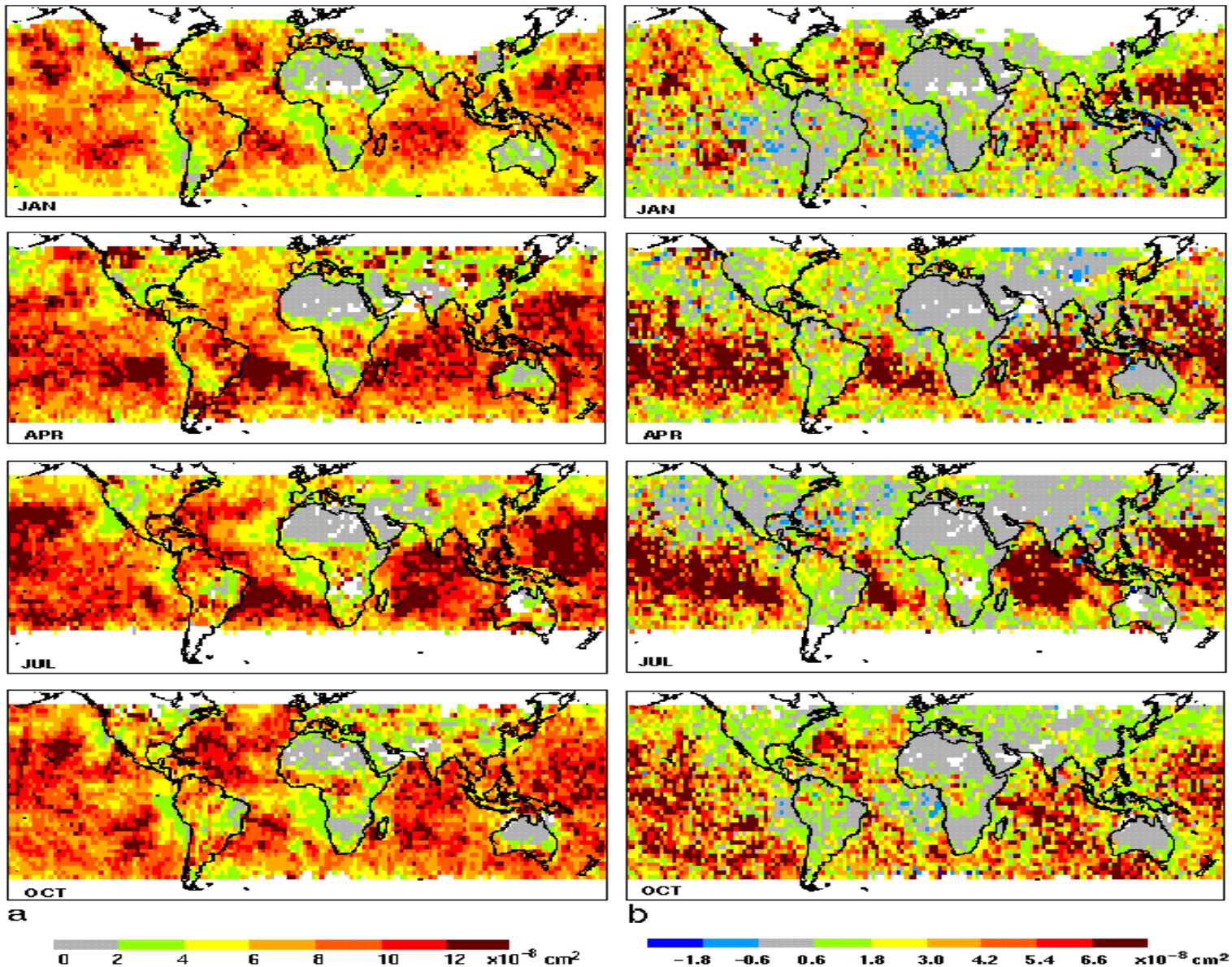
Progress since NRC 1996 –New Observations

Cloud column number concentration N_c (Han et al., 1998b)



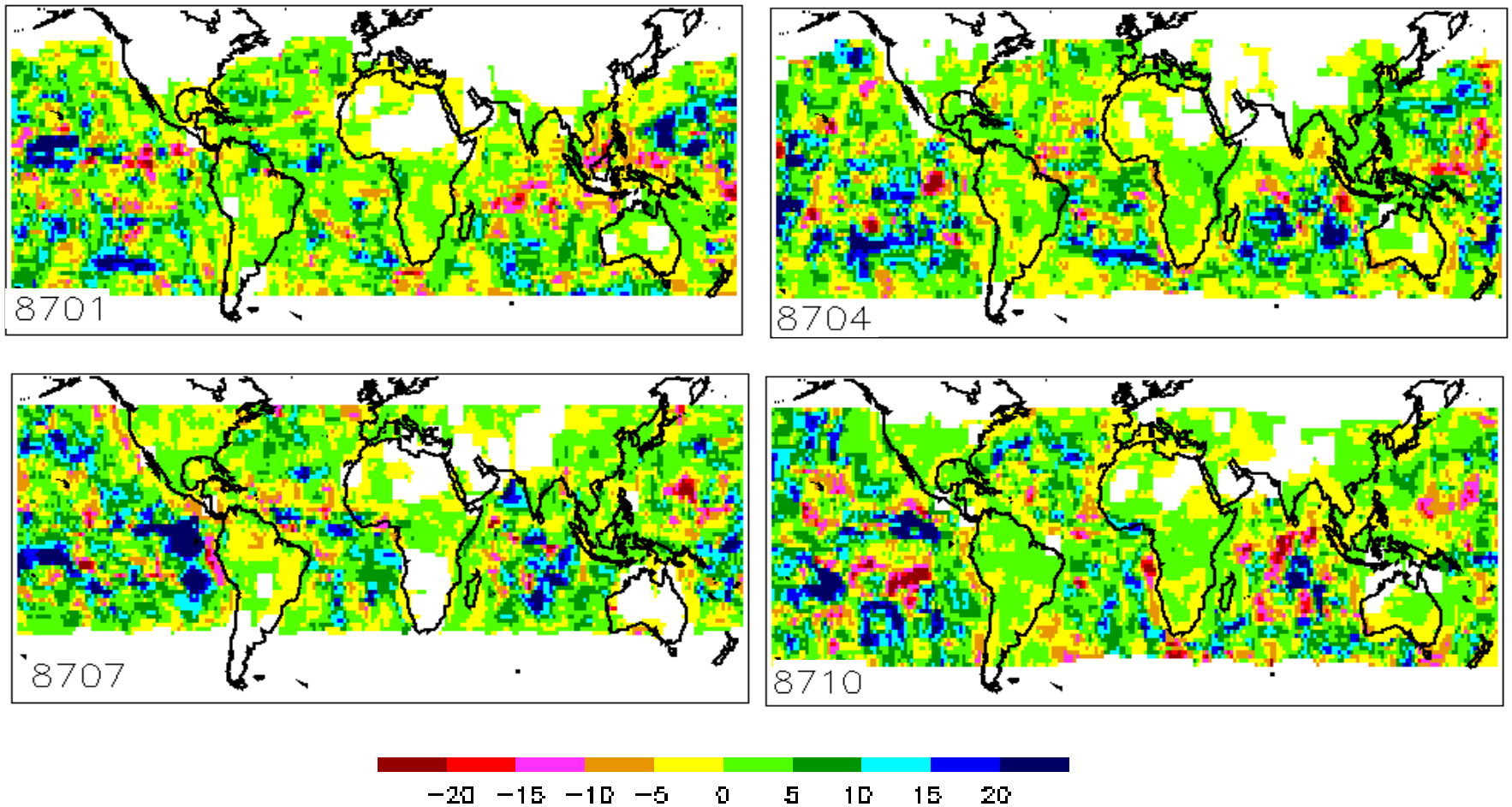
Progress since NRC 1996 –New Observations

Global survey of cloud column susceptibility (Han et al., 2000)



Progress since NRC 1996 –New Observations

Global survey of cloud fraction susceptibility $\Delta f/\Delta N_c$ (Han et al., 2000)



Cloud cover may be increased or decreased for increasing cloud column number concentrations

Strategies

What do we need for monitoring the aerosol indirect effect from space?

$\Delta\alpha_{cld}/\Delta N_{aer}$; $\Delta f/\Delta N_{aer}$; $\Delta R/\Delta N_{aer}$

- *Approach I: Direct correlations between instantaneous cloud properties and neighboring aerosol properties (Snapshot Approach)*

Problem: 1) No temporal interactions between aerosols and clouds

2) Only data with coexistence of aerosol and cloud can be used

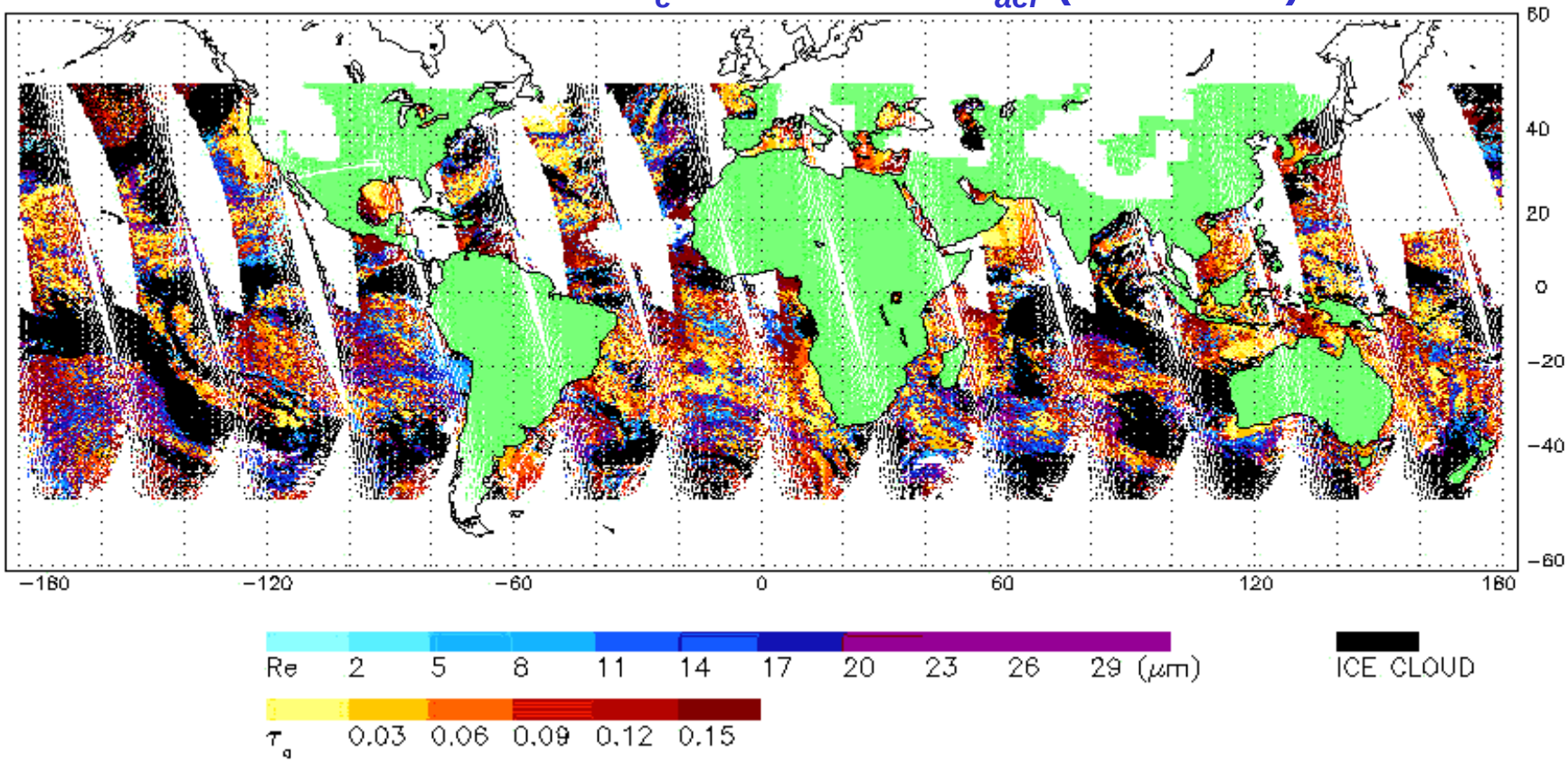
- *Approach II: Correlating cloud and aerosol properties in the same region during a month.*

e.g., $\Delta\alpha_{cld}/\Delta N_{aer} = \Delta\alpha_{cld}/\Delta N_c * \Delta N_c/\Delta N_{aer} = S_c * \Delta N_c/\Delta n_{aer}$

$\Delta f/\Delta N_{aer} = \Delta f//\Delta N_c * \Delta N_c/\Delta N_{aer}$

With N_c and S_c retrieved, the focus is on the relation of ΔN_c *and* ΔN_{aer}

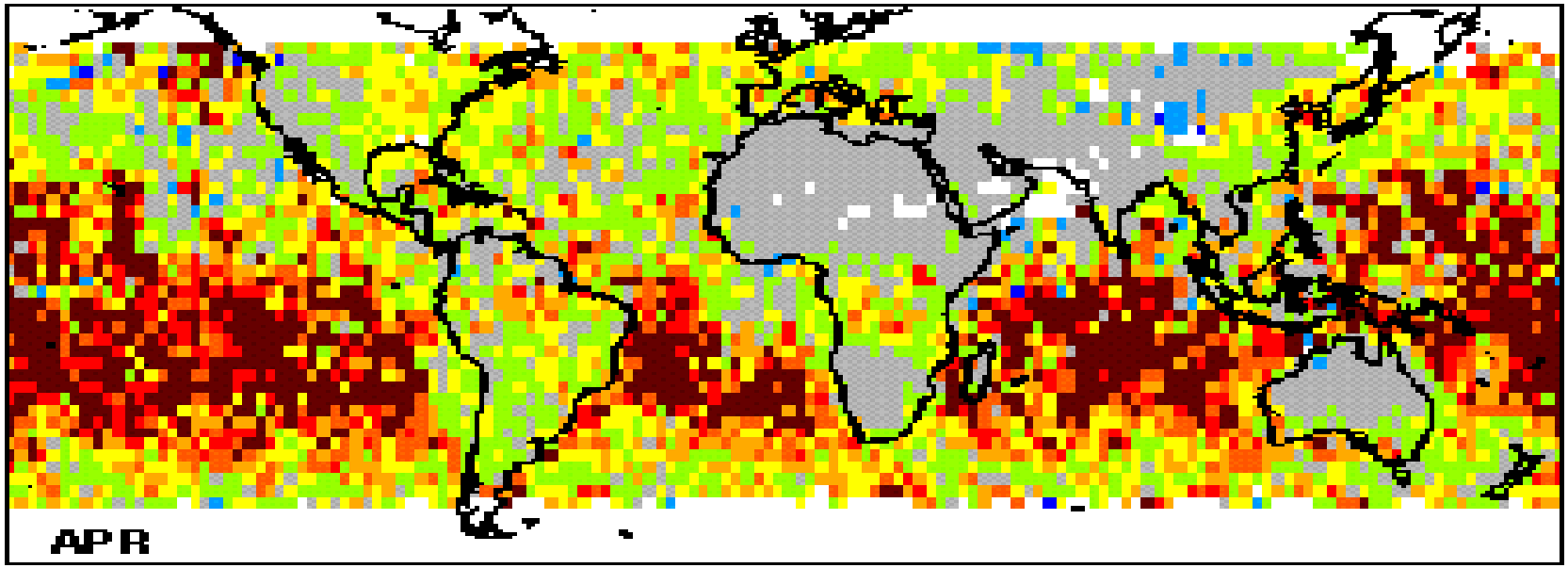
Retrieved cloud r_e and aerosol τ_{aer} (4/20/1987)



Approach I: Direct correlations between cloud & aerosol properties

1) No simultaneous retrieval of cloud AND aerosol properties for the same pixel
2) At cloud edges, which is cloud, which is aerosol?
3) When cloud and aerosol are horizontally separated, they may not interact
4) What is the wind direction? Which side of the cloud is interacting with aerosols?
5) Aerosols may be not interacting with clouds at different altitudes

Cloud Column Susceptibility $S_c = \Delta\alpha/\Delta N_c$ (Apr 1987)



Approach II: Study Cloud Column Susceptibility $\Delta\alpha/\Delta N_c$ and $\Delta N_c/\Delta N_{aer}$

1) With cloud AND aerosol properties for the same region
2) Problems of cloud property change and aerosol screen are separated
3) Analogue to study continent-maritime cloud contrasts

Conclusions

- **More complete view of the aerosol indirect effect**
  - Regional studies show that the aerosol indirect effect
    - may increase or decrease cloud water and cover
    - may inhibit or promote precipitation
  - Global observations show that
    - Cloud albedo increases with increasing r_e for $\tau<15$
    - Cloud column susceptibility may be negative
    - Cloud fractional cover may increase or decrease
- **Strategies**
  - **Snapshot data correlation technique**
  - **One-month data regression technique**