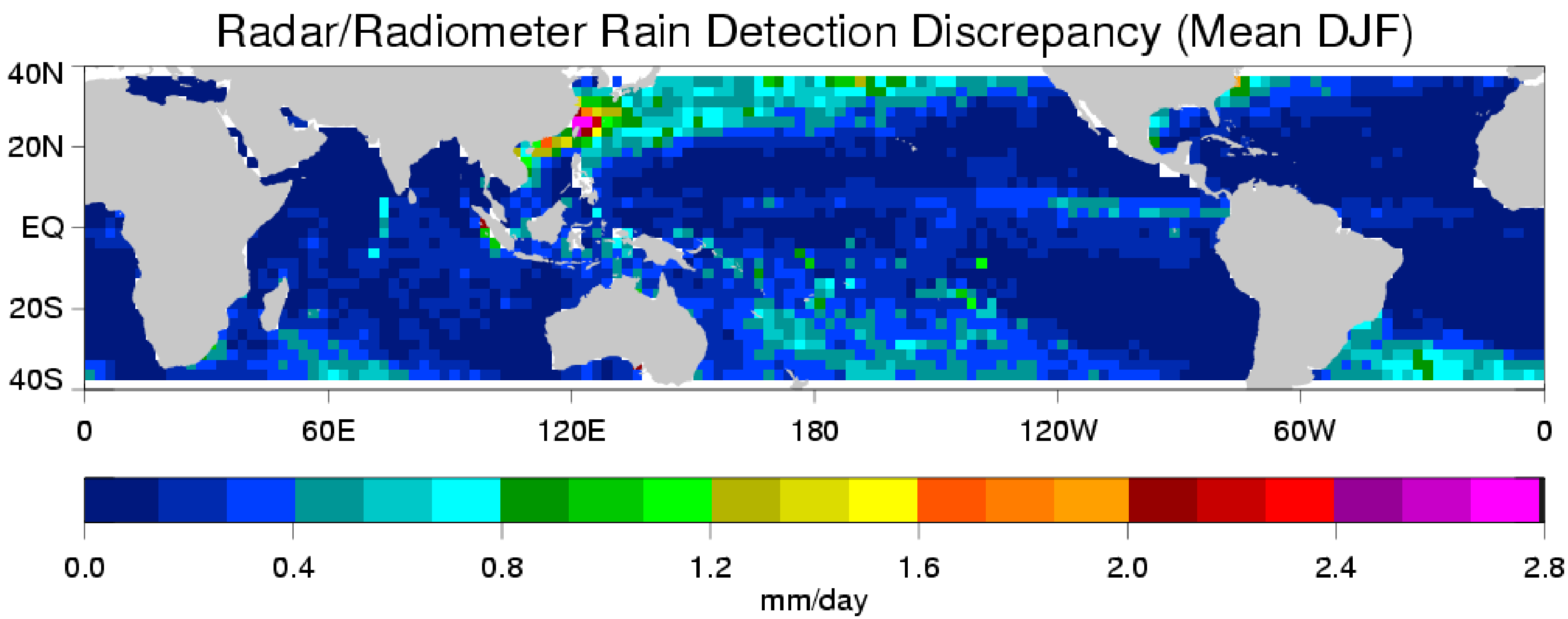
Relationship between Clouds, Aerosols, the environment and the onset of Precipitation

Christian Kummerow, Matt Lebsock and Katie Boyd

Colorado State University

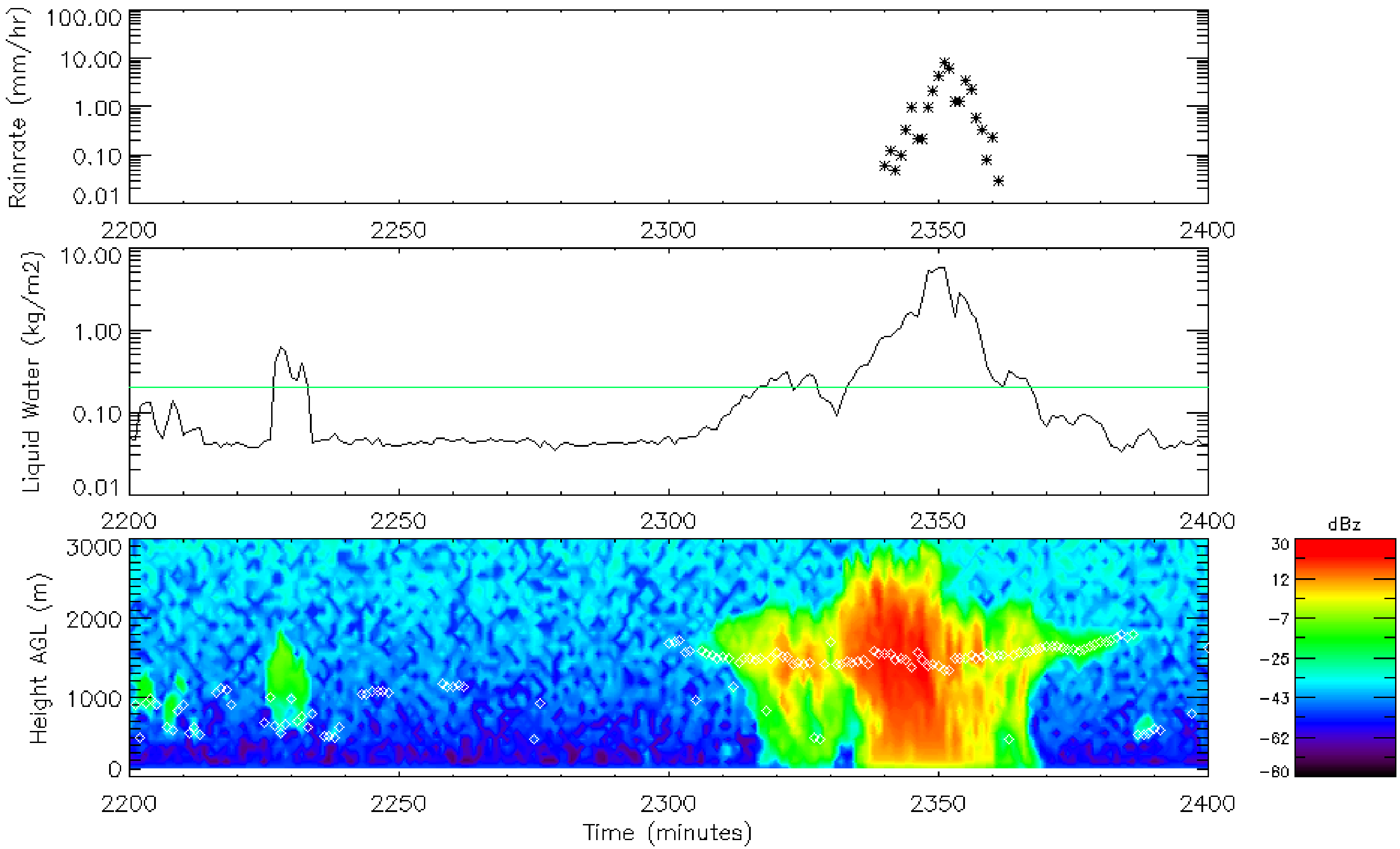
ASR Science Team Meeting
Boulder, CO
October 13-14, 2010

Motivation



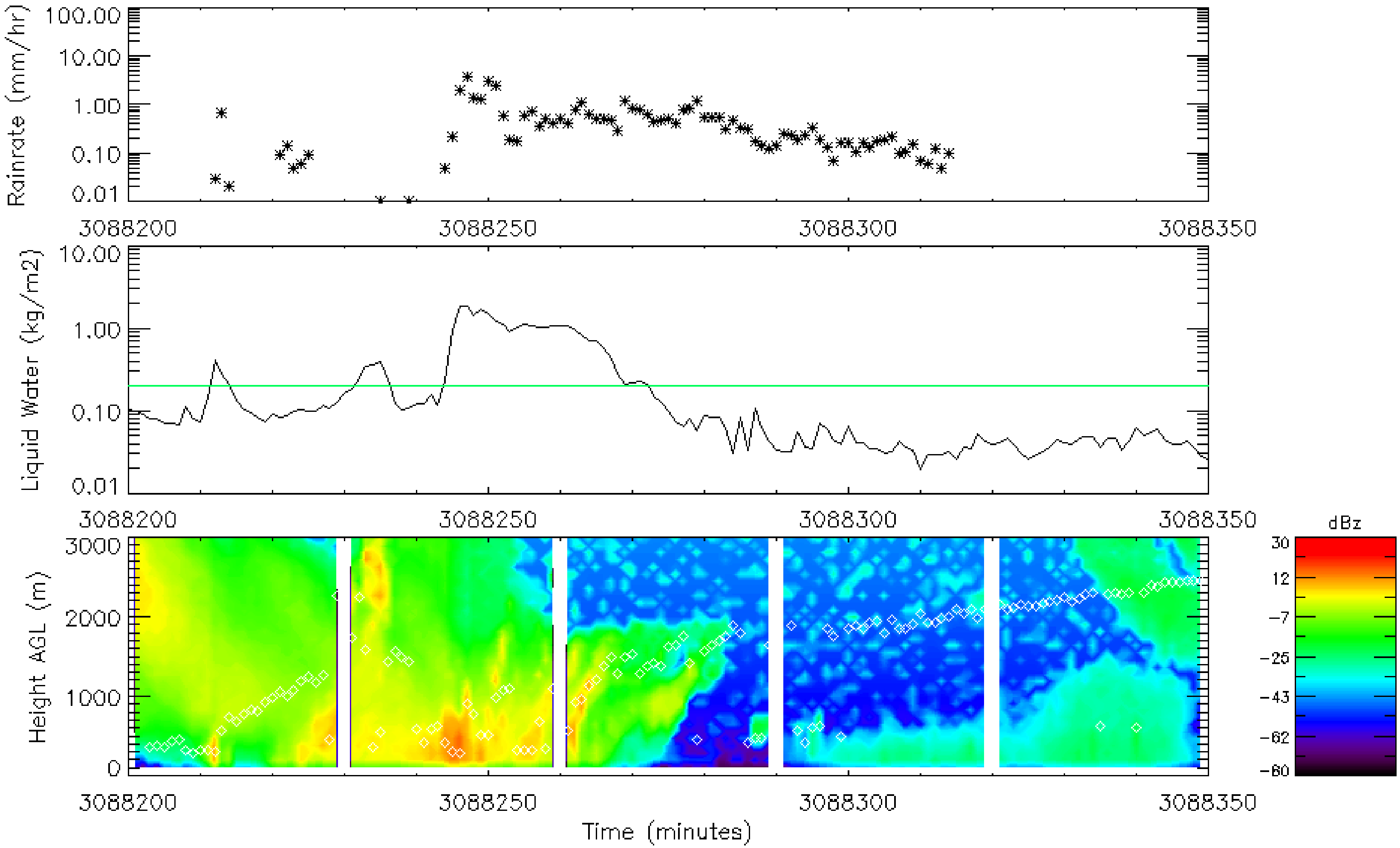
Paper by Berg, Kummerow et al., (2006) speculated that discrepancy in TRMM rainfall detection east of China was due to high aerosol concentrations increasing the liquid water content at which clouds begin to precipitate.

A straightforward example from Nauru



Surface rainfall (top), cloud liquid water (middle) and radar reflectivity (bottom) for 3 hours on 25 Nov. 1998.

A not so straightforward example from Nauru



Surface rainfall (top), cloud liquid water (middle) and radar reflectivity (bottom) for 3 hours on 07 Oct. 2004.

Objective

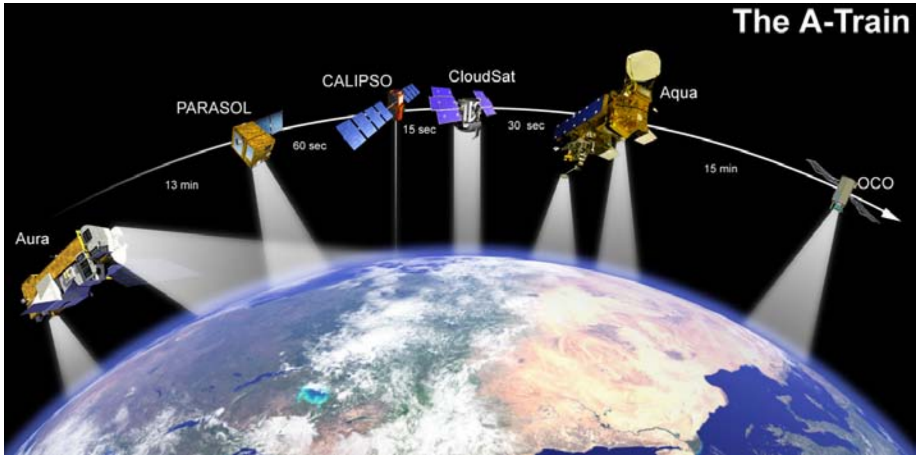
Determine if onset of precipitation can be parameterized as a function of relatively few thermodynamic and aerosol variables.

Procedure

- ☆ *Started with AMF/China campaign but radar data not available for robust statistics.*
- ☆ *Start with incomplete, but global satellite data and look for specific relationships*
- ☆ *Confirm these relationships using data from Arm permanent and Mobile Facility.*

A-Train

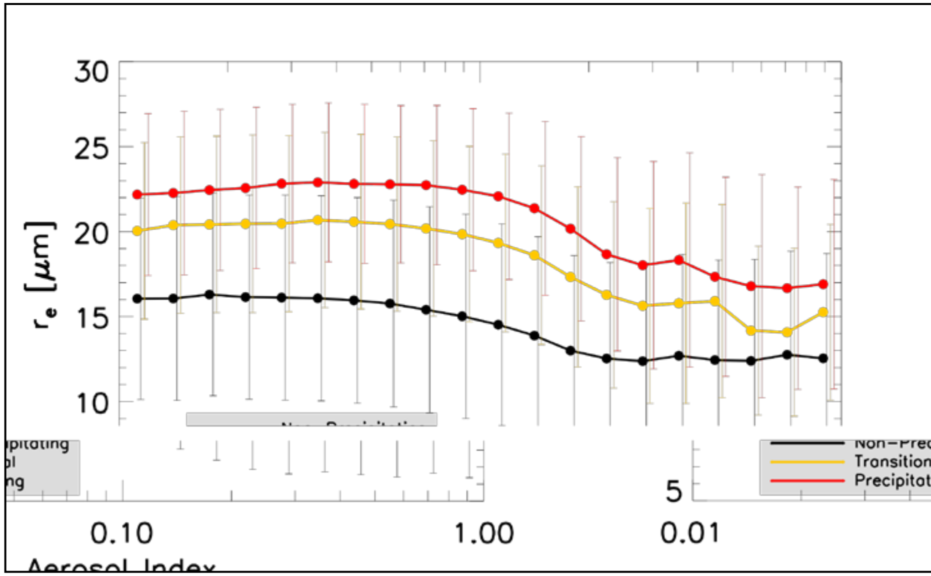
- State of the art remote sensing capabilities
- Formation flying provides spatially and temporally co-located observations
  1. CloudSat
  2. CERES
  3. MODIS
  4. AMSR-E
  5. AIRS

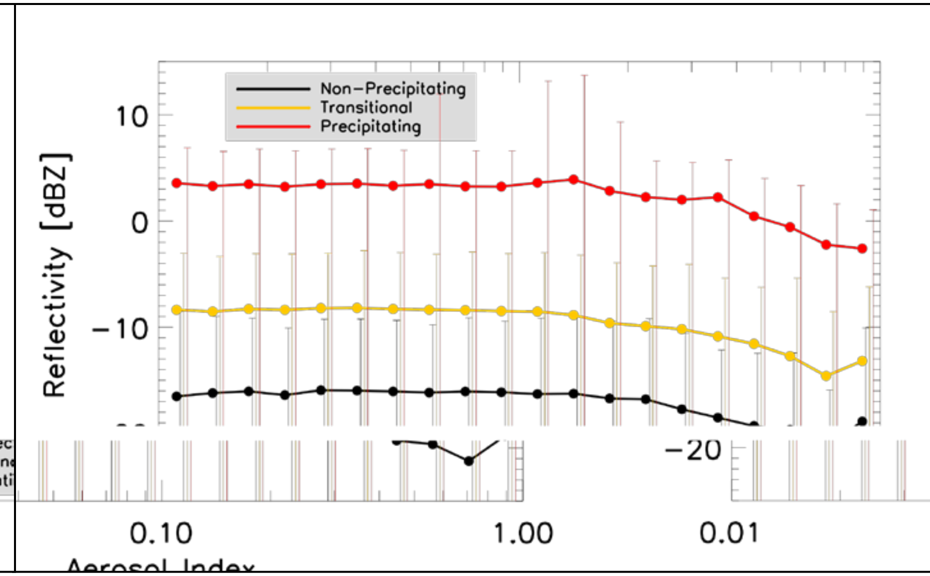


Precipitating Clouds
(2nd indirect effect)

MODIS Effective Radius

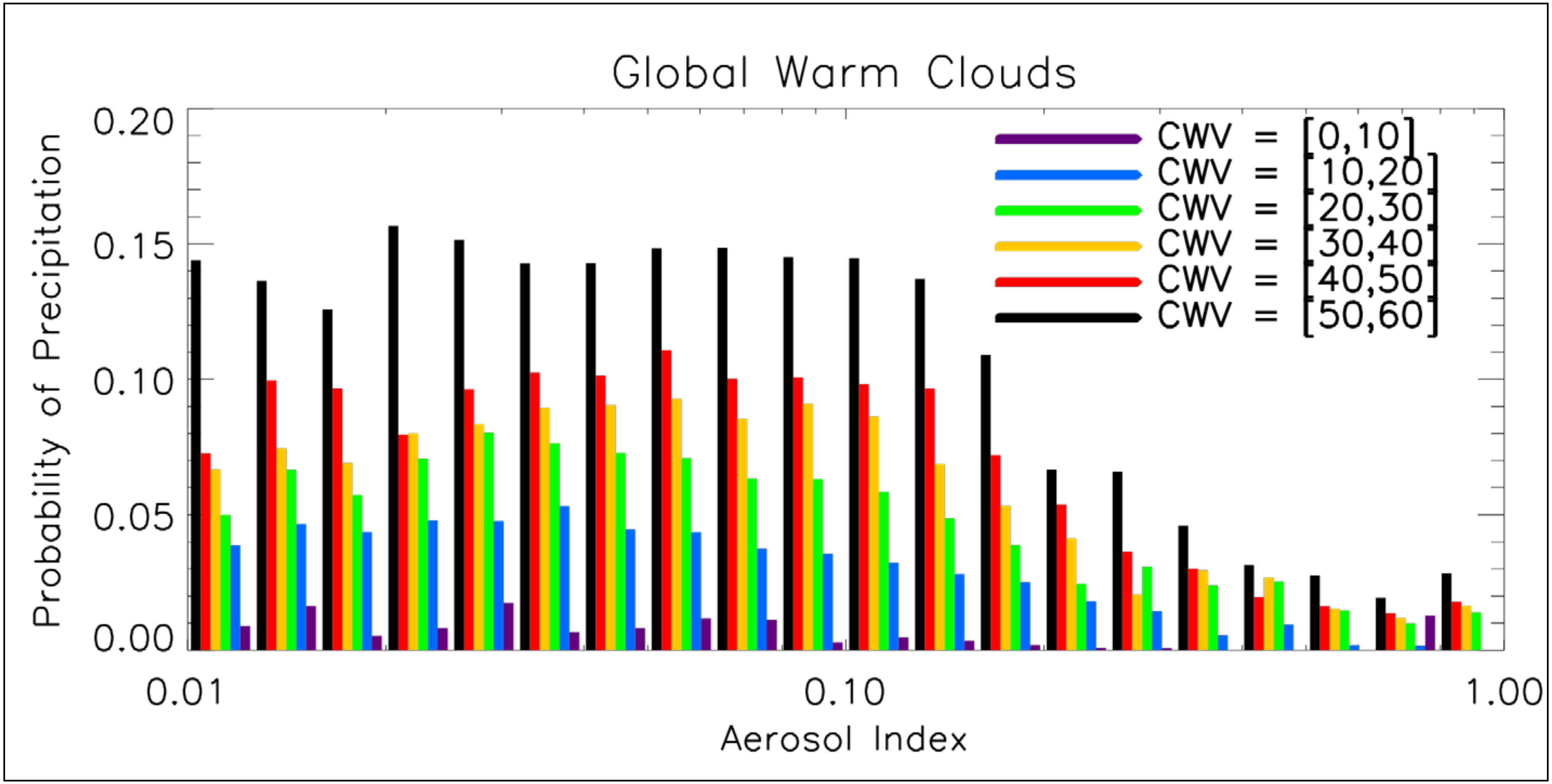
CloudSat Mean Reflectivity





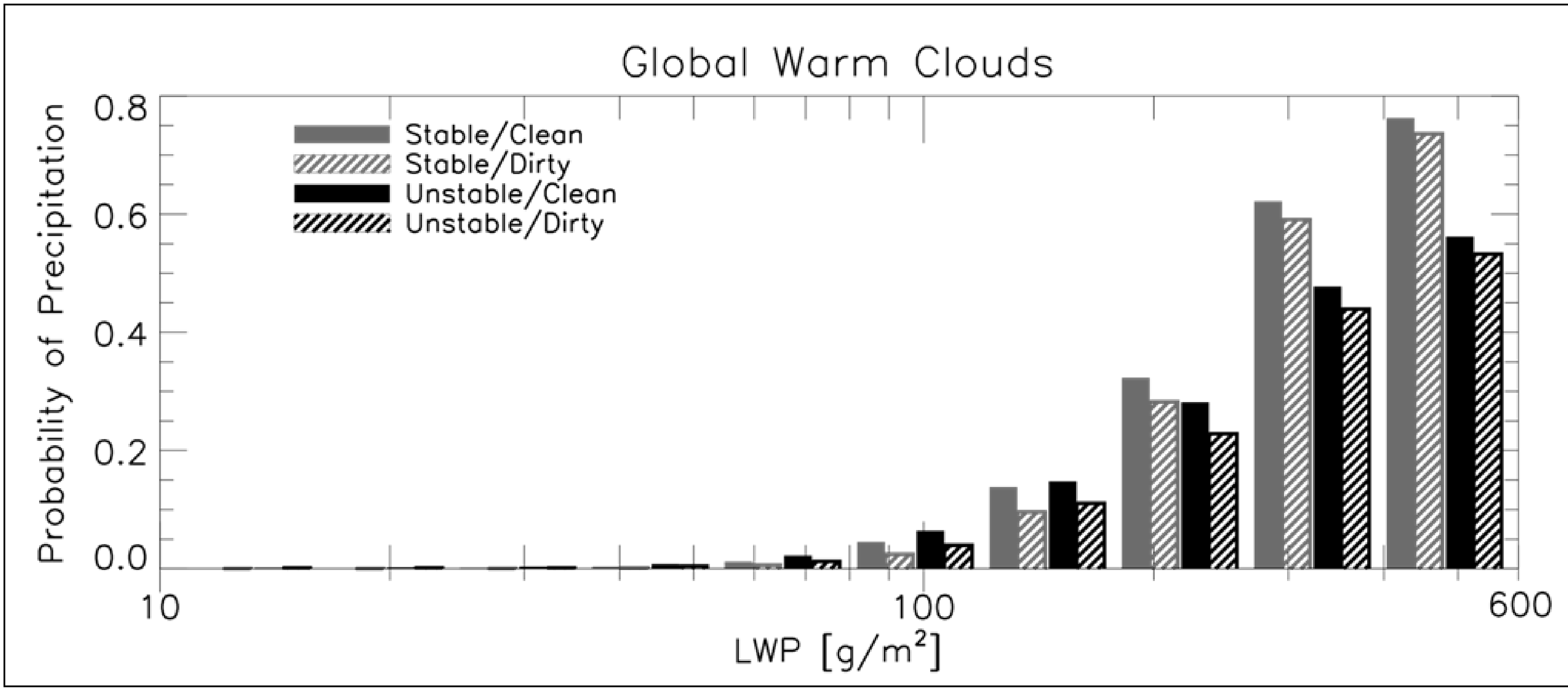
Evidence for decreased droplet/drop sizes in high CCN air for raining and non-raining clouds from A-train observations

Probability of Precipitation and Aerosol



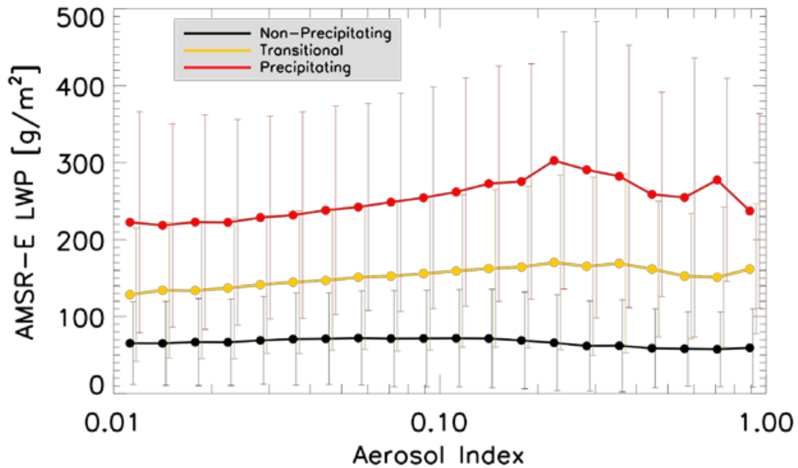
POP decreases by as much as 10% with large aerosol burden

Probability of Precipitation and Water Path



- Dependence on thermodynamic stability greater than that of aerosol
- POP decreased by ~5% in dirty air regardless of LWP

AMSR-E Water Path

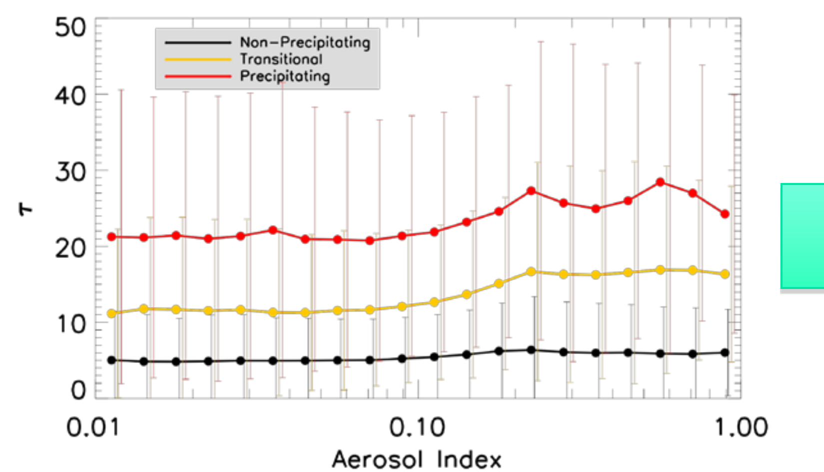


The water path effect for precipitating clouds dominates the radius effect

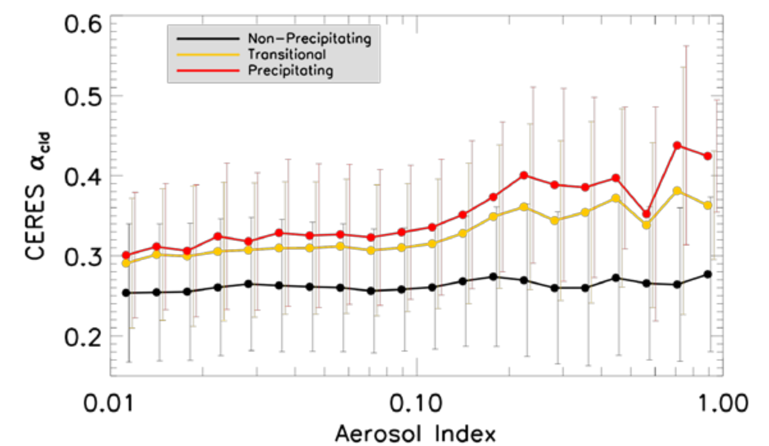
$$\tau = \frac{3\text{LWP}}{2\rho_l r_e}$$

$$\alpha_{cld} \approx F(\tau) = F(r_e, \text{LWP})$$

MODIS Optical Depth



CERES Cloud Albedo



Summary: Precipitating Clouds

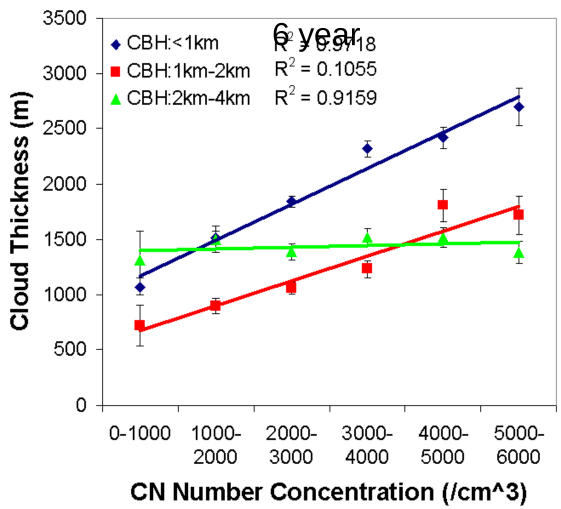
- r_e and mean cloud Z_e tend to decrease in precipitating clouds
  - Implies decreased autoconversion rates

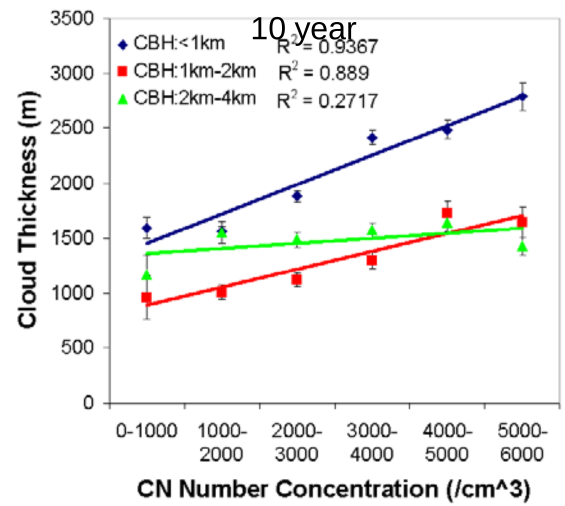
Stability has a greater impact on POP than aerosol concentration

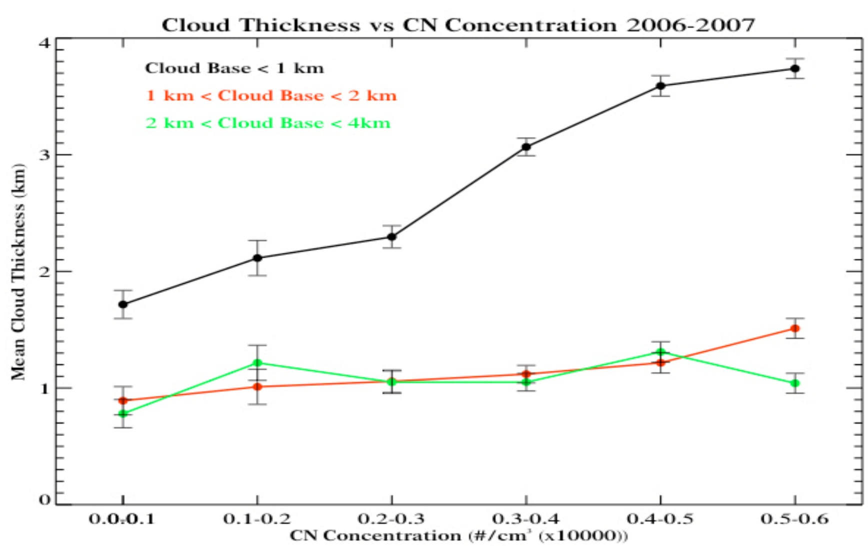
- For a given LWP, POP decreases by ~5% from clean to polluted state.
  - Independent of thermodynamic environment

- $/_{cld}$ and α_{cld} response in precipitating clouds is dominated by the water path effect.

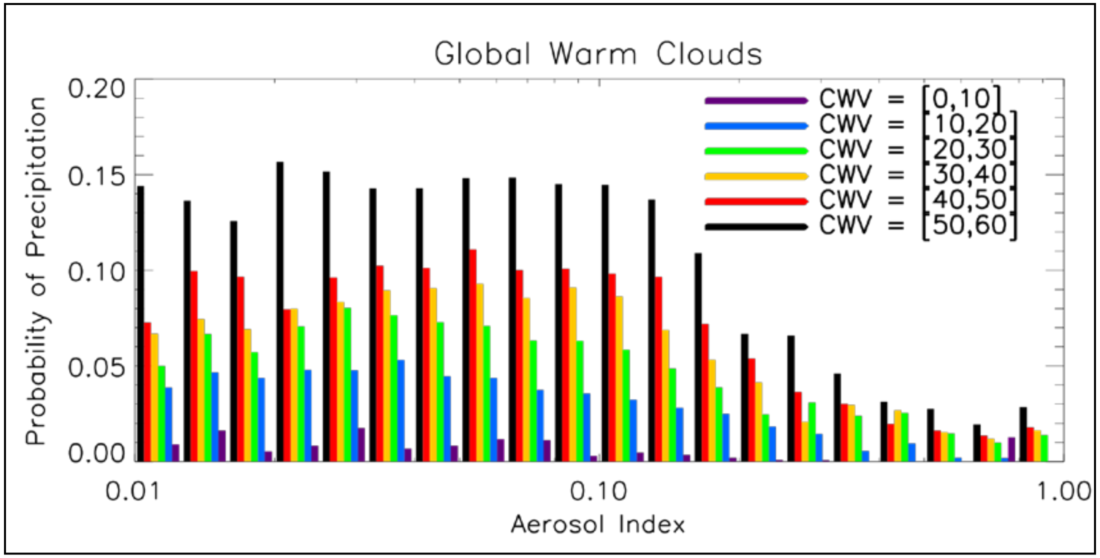
Back to ARM Data



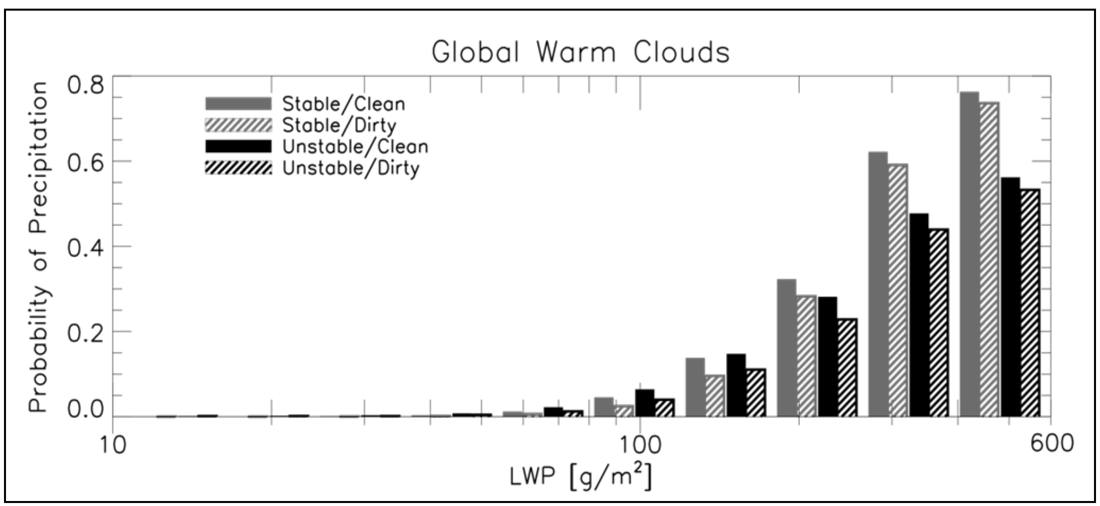




Next Steps



Use SGP, Nauru and China AMF, Azores deployment with observed aerosol concentrations and precipitation from ground radar (Z > -15 dBZ) to verify satellite inference.



Use SGP, Nauru and China AMF, Azores deployment with observed microwave LWP & LWC, in situ aerosols, radar precipitation and in-situ measurements of stability to verify satellite inference.

Aerosol Indirect Effects

(How we think they work)