Use of satellite observations for process-oriented evaluation of cloud microphysics in climate models

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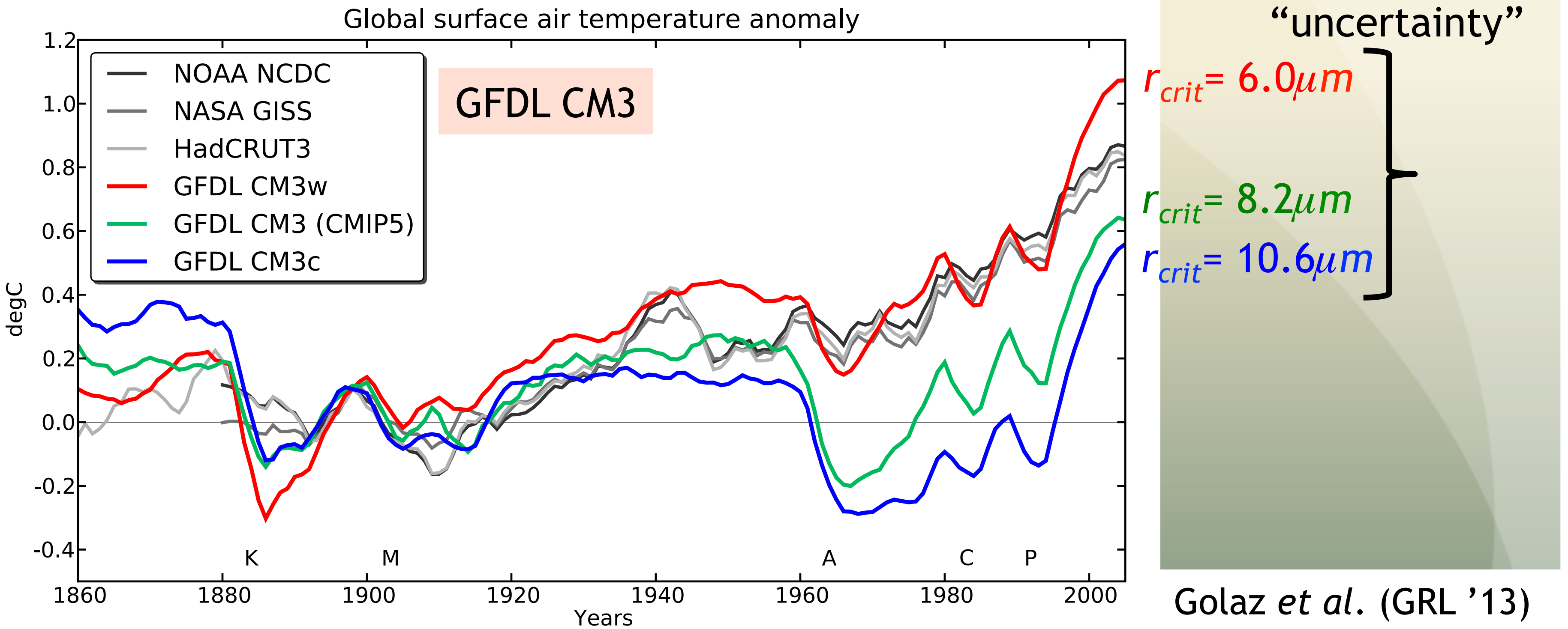
Impact of cloud μ-physics on climate projection

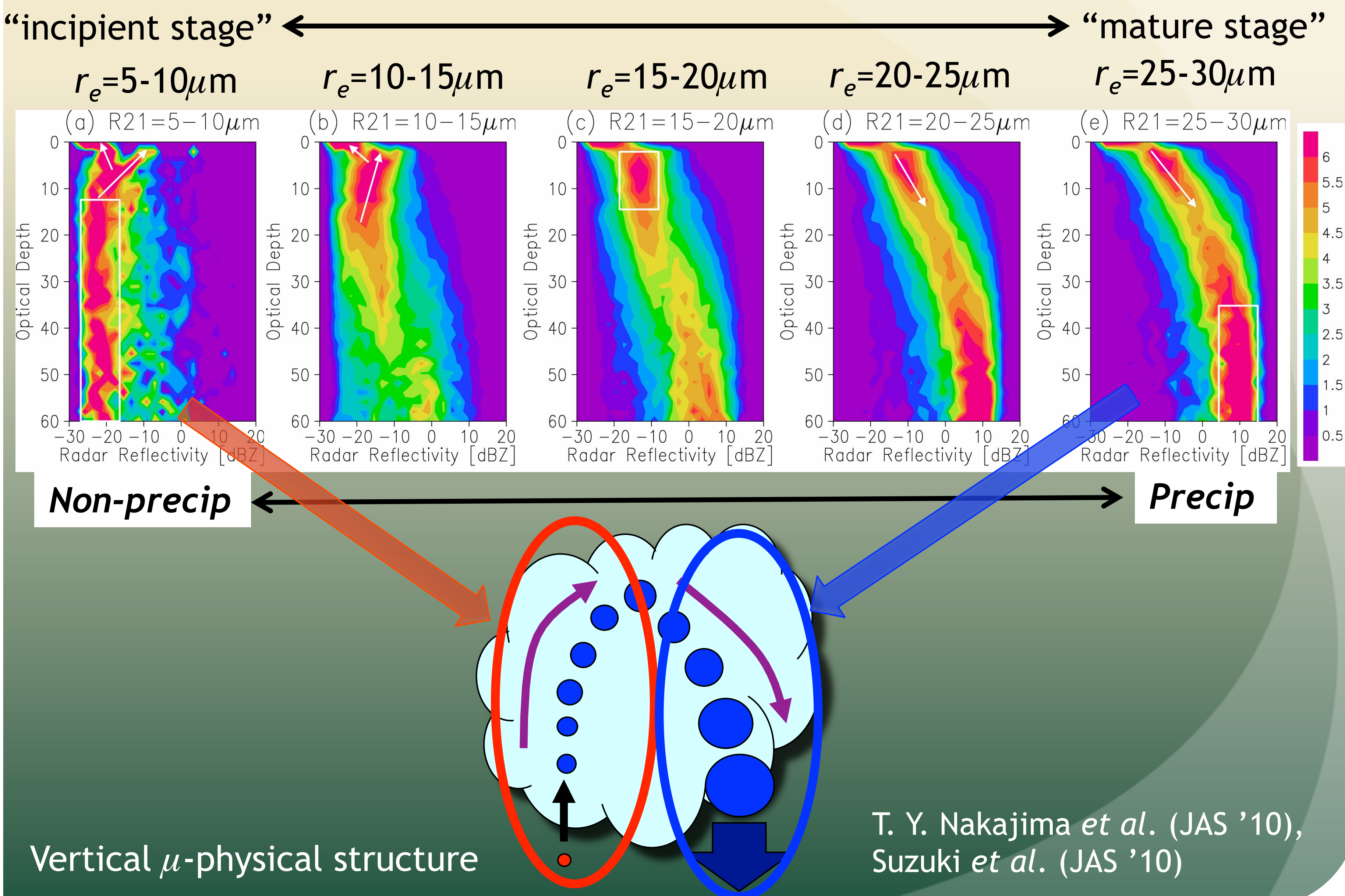


Golaz *et al.* (GRL '13)

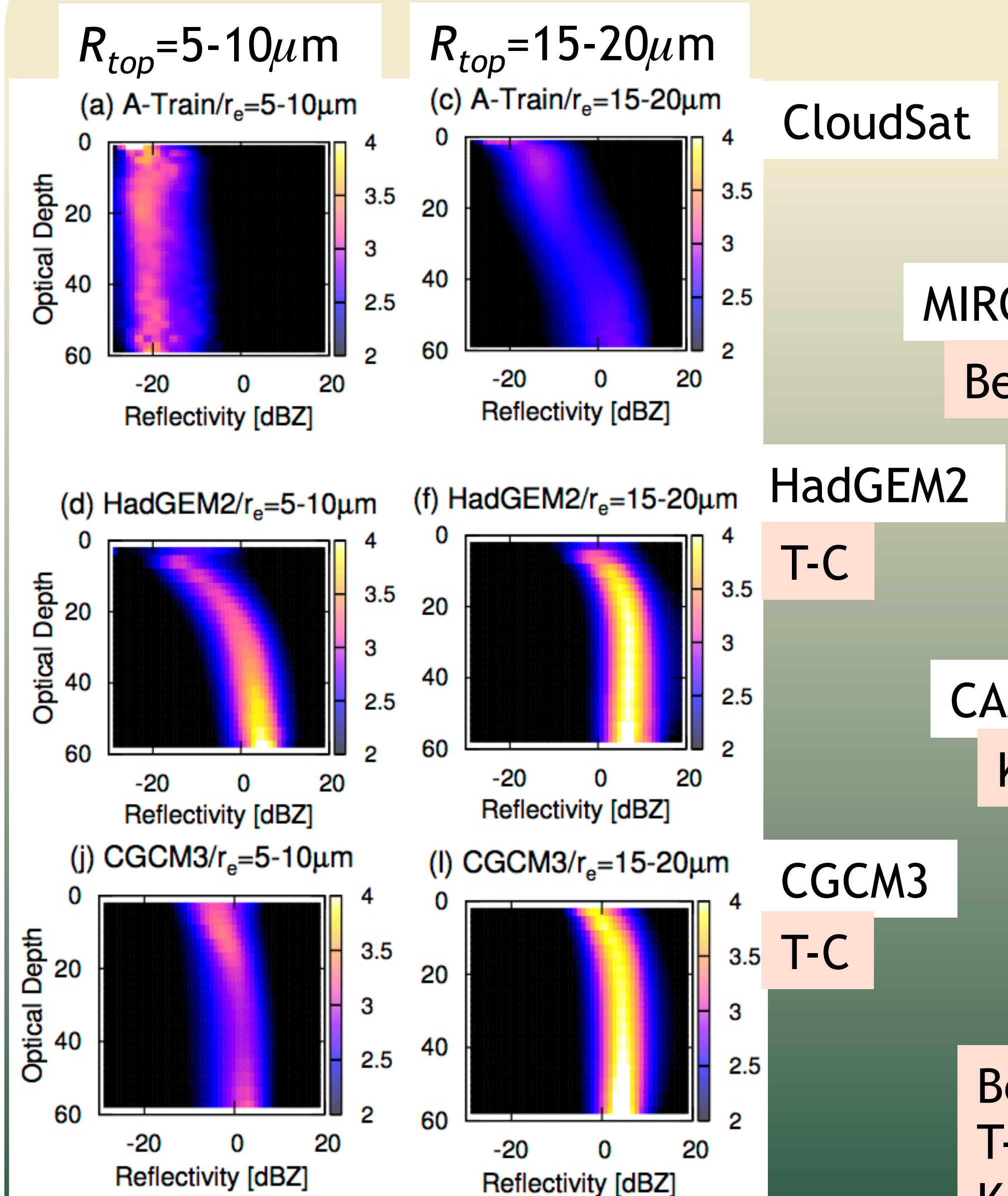
r_{crit}: Threshold particle radius for warm rain to occur

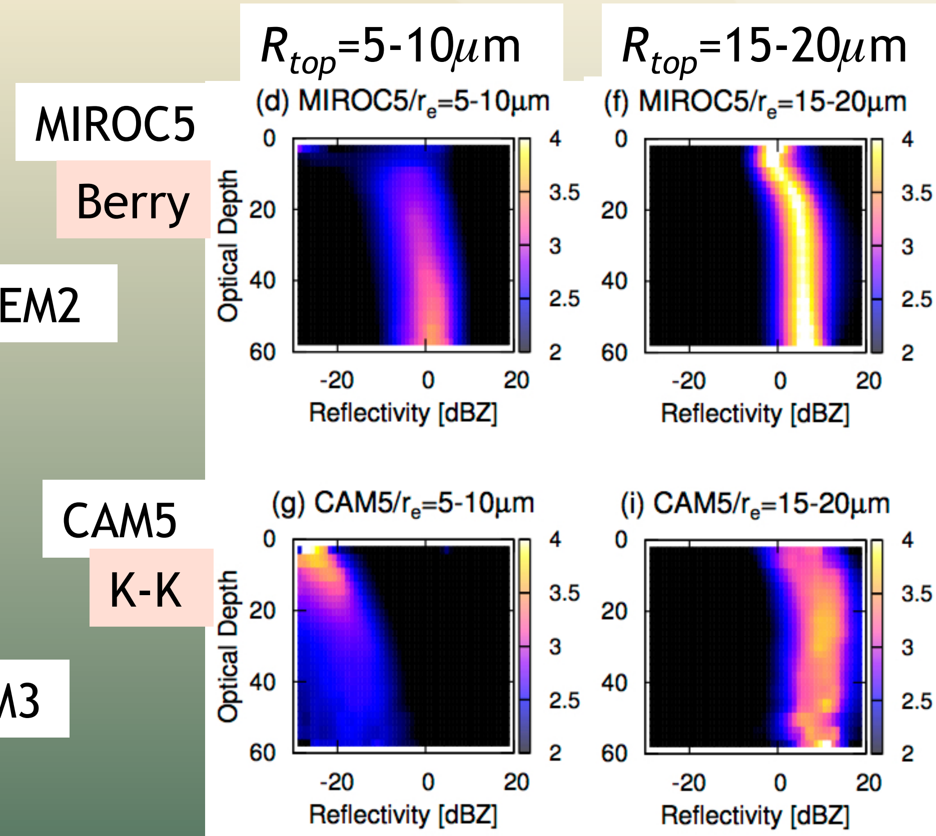
- Uncertain "tunable" parameter in climate models
- Modulates the magnitude of (2nd) aerosol indirect forcing, leading to severely different climate projections
- How could satellite observations be used to constrain this?

μ-physical processes depicted by satellite analysis



Evaluating climate models selected from CMIP5





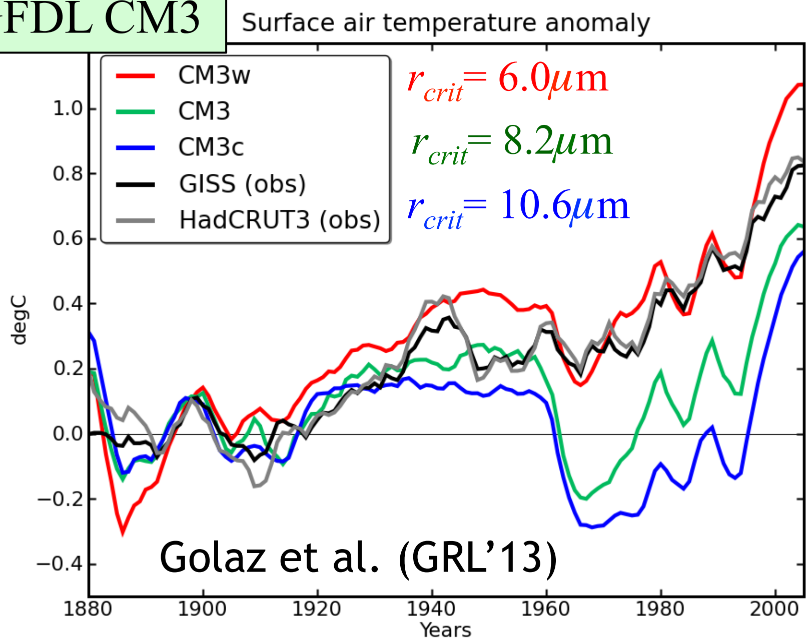
Berry: Berry ('67)
T-C: Tripoli and Cotton ('80)
K-K: Khairoutdinov and Kogan ('00)

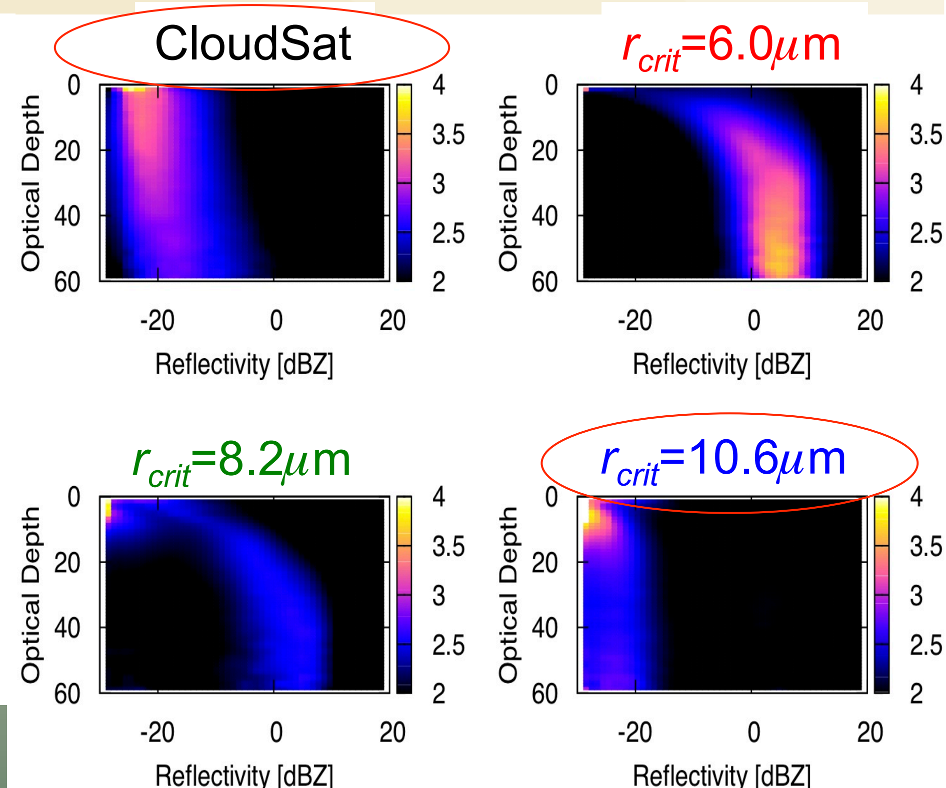
Is the cloud "tuning" correct?

Suzuki, Golaz and Stephens (GRL '13)

"incipient stage": R_e=6-10μm

GFDL CM3

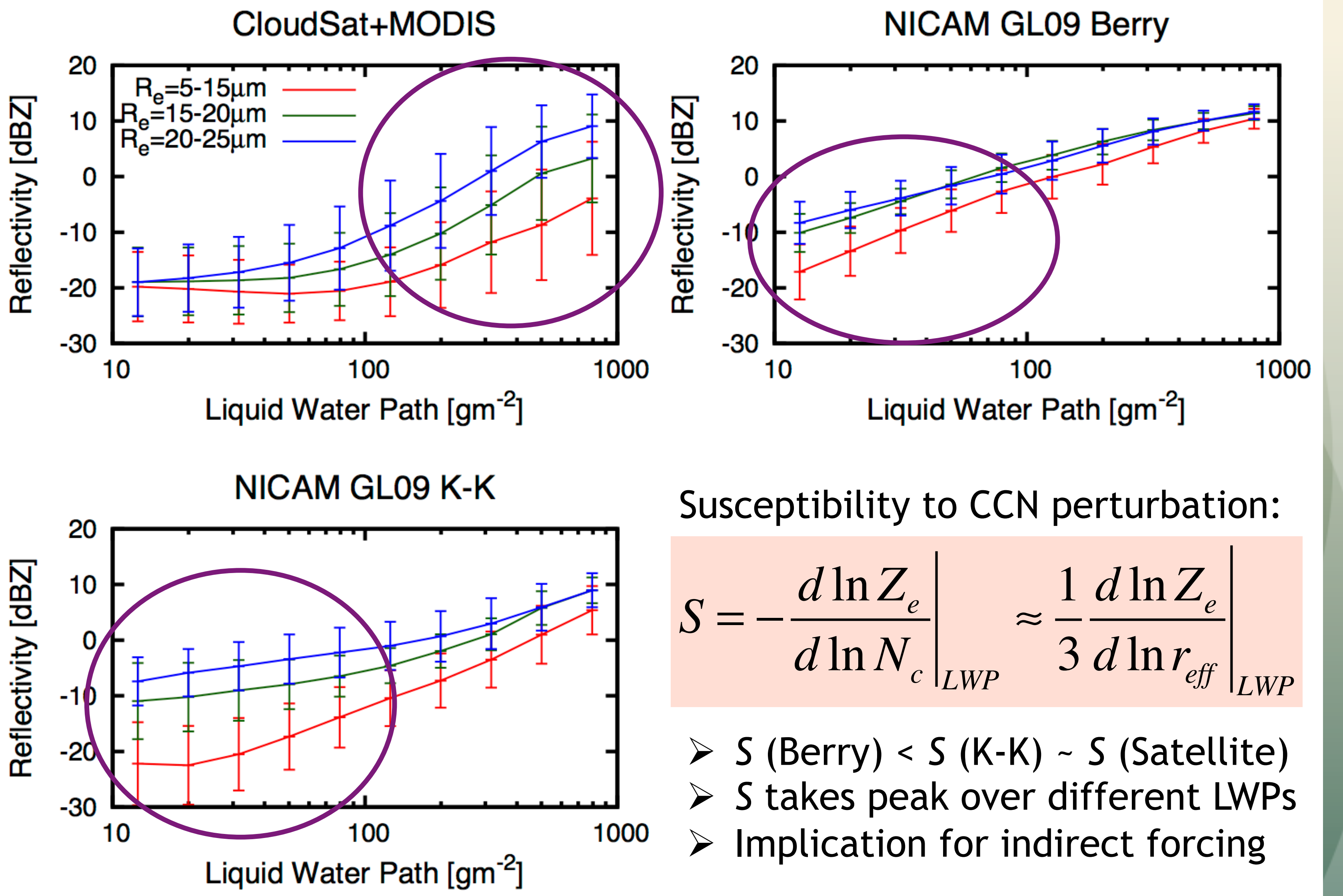




r_{crit}: threshold radius for rain to occur

- 20th century temperature trend is best simulated by r_{crit}=6.0μm
- CloudSat provides a process-based constraint on this: r_{crit}=10.6μm
- Dichotomy: compensating errors in the model at a fundamental level?
- What causes this problem?: Resolution vs Physics?

Cloud-to-precipitation process in NICAM



Susceptibility to CCN perturbation:

$$S = -\left.\frac{d\ln Z_e}{d\ln N_c}\right|_{LWP} \approx \frac{1}{3}\left.\frac{d\ln Z_e}{d\ln r_{eff}}\right|_{LWP}$$

- *S* (Berry) < *S* (K-K) ~ *S* (Satellite)
- *S* takes peak over different LWPs
- Implication for indirect forcing

Summary

- A particular statistic of satellite observations "fingerprints" signatures of warm rain processes
  - Cloud lifecycle is depicted in the statistic
- The statistic is used as a metric to evaluate the warm rain process in climate models.
  - Some models produce warm rain too fast
  - "Tunable" cloud parameter is constrained with satellite
- The process-based constraint contradicts the "top-down" temperature reproducibility in a climate model
- Global cloud-resolving model also exposes biases in rain formation process depending on microphysics schemes