Use of satellite observations for constraining aerosol-cloud-precipitation* processes in global models

Kentaroh Suzuki (U. Tokyo)

Thanks to contributions from: X. Jing, H. Hotta, T. Michibata, H. Takahashi

EarthCARE Modeling Workshop @Online

February 16-18, 2022

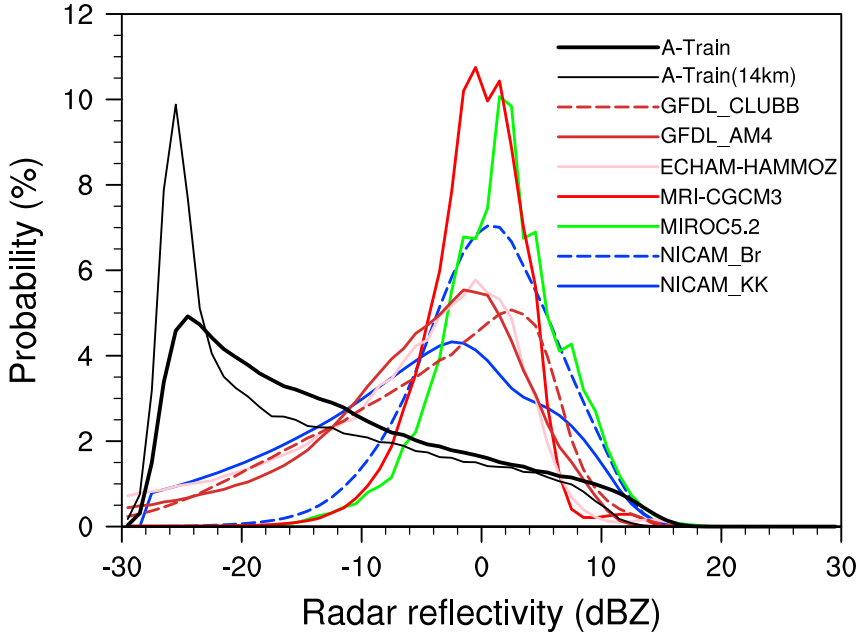
*Warm rain in this talk

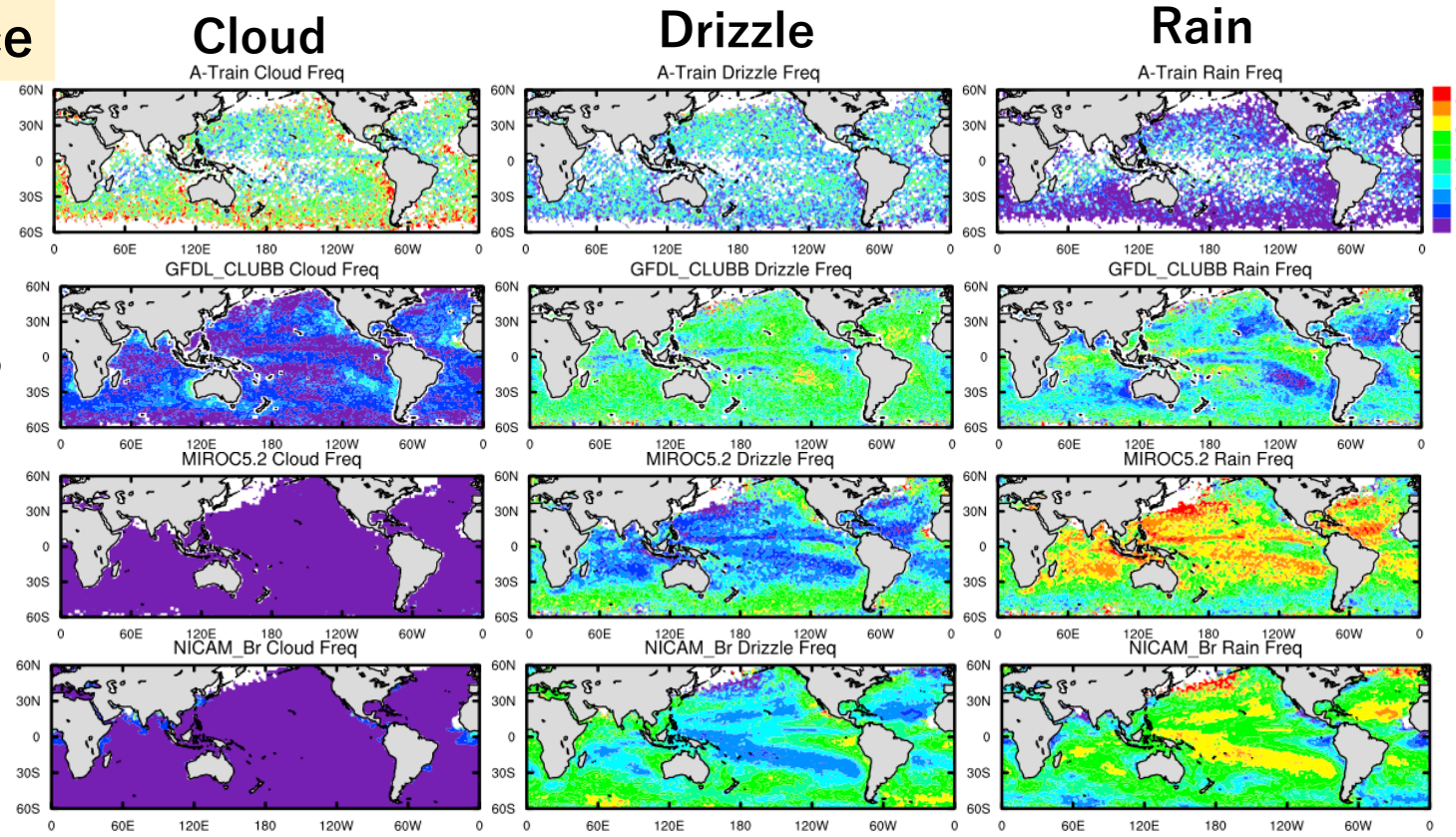
Questions

- How can process signatures of aerosol-cloud-precipitation interaction be identified in satellite observations?
  - What (combination of) observables? In what statistics?
  - How can the statistics serve as metrics for process “fingerprint”?
- How can these metrics be applied to evaluate/constrain global models (GCMs/GSRMs)?
- How do the process signatures link to macroscopic/large-scale climate forcing?
- How can new capabilities of EarthCARE add information to these metrics for model constraints?

Statistic #1 - Frequency of CPR reflectivity

Fractional occurrence





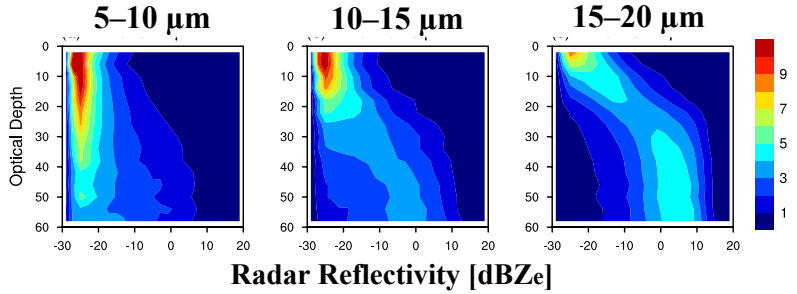
- Cloud: $Z_{max} < -15$dBZ
- Drizzle: $-15\text{dBZ} < Z_{max} < 0\text{dBZ}$
- Rain: $Z_{max} > 0$dBZ

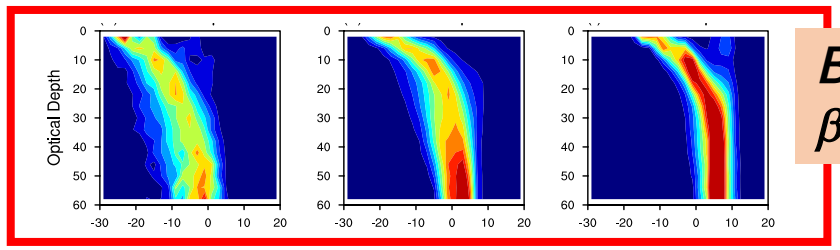
Z_{max}: column maximum reflectivity

Jing et al. (JGR '17)

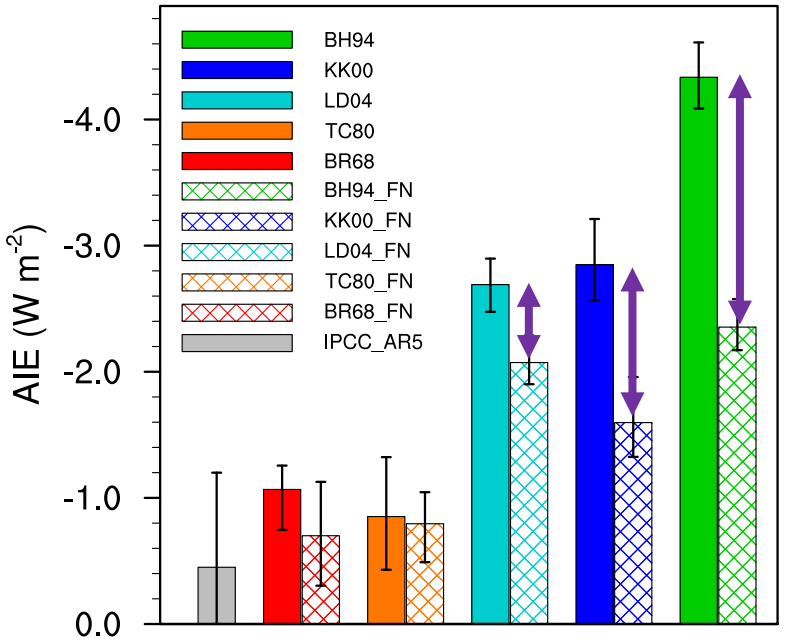
Statistic #2 - Radar profile combined with imager variables

Satellite





BR68:
***β* = -1.0**

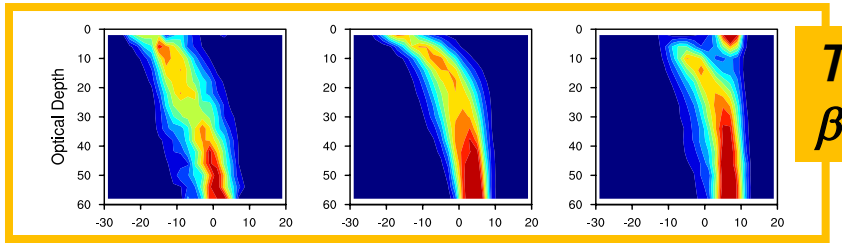


Wet scavenging effect

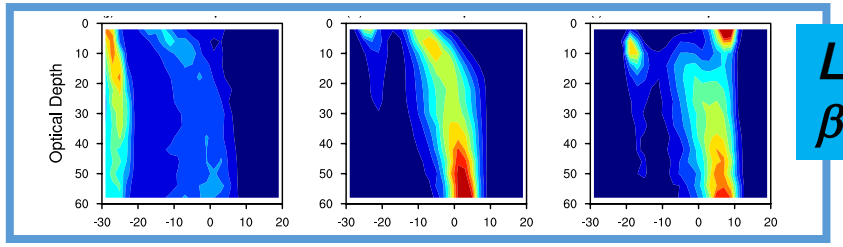
Jing et al. (JCLI '19)

Sensitivity to parameterization in MIROC5

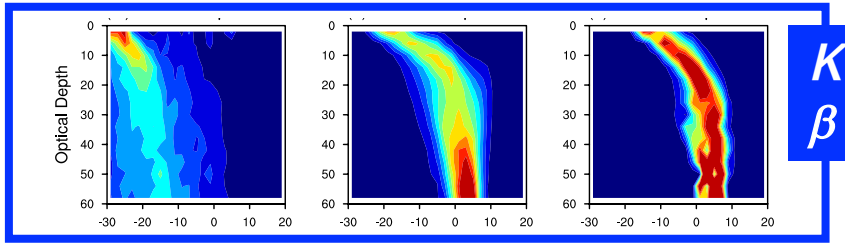
$$\left(\frac{\partial q_r}{\partial t}\right)_{auto} = C'_{auto}\, q_c^{\alpha}\, N_c^{\beta}$$



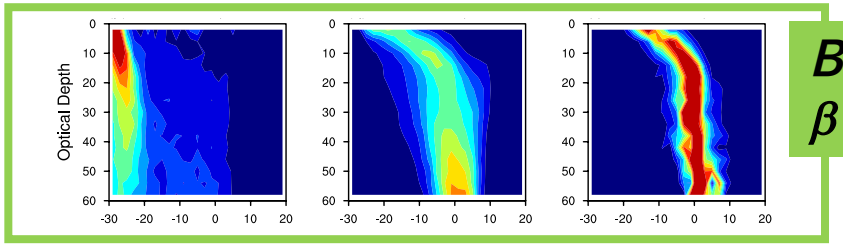
TC89:
***β* = -0.3**



LD04:
***β* = -1.0**



KK00:
***β* = -1.79**



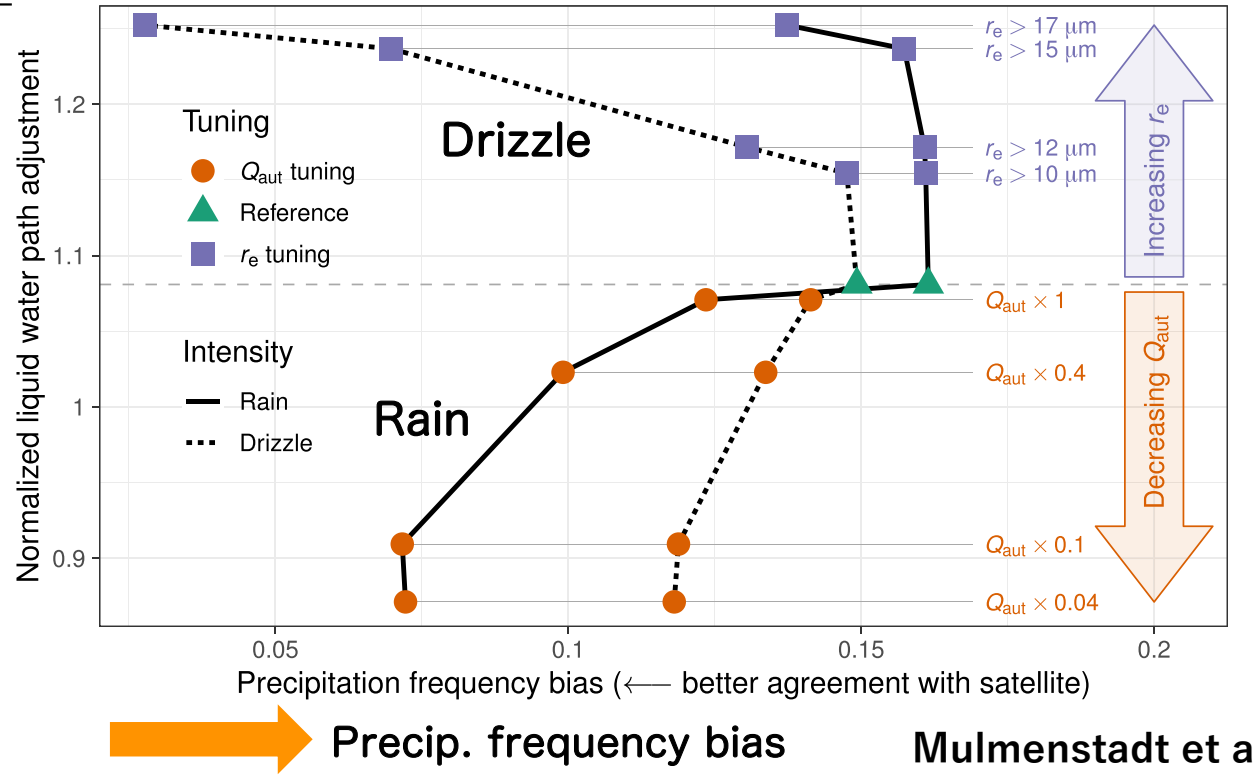
BH94:
***β* = -3.3**

Linkage of the process realism to climate forcing

Radiative forcing:

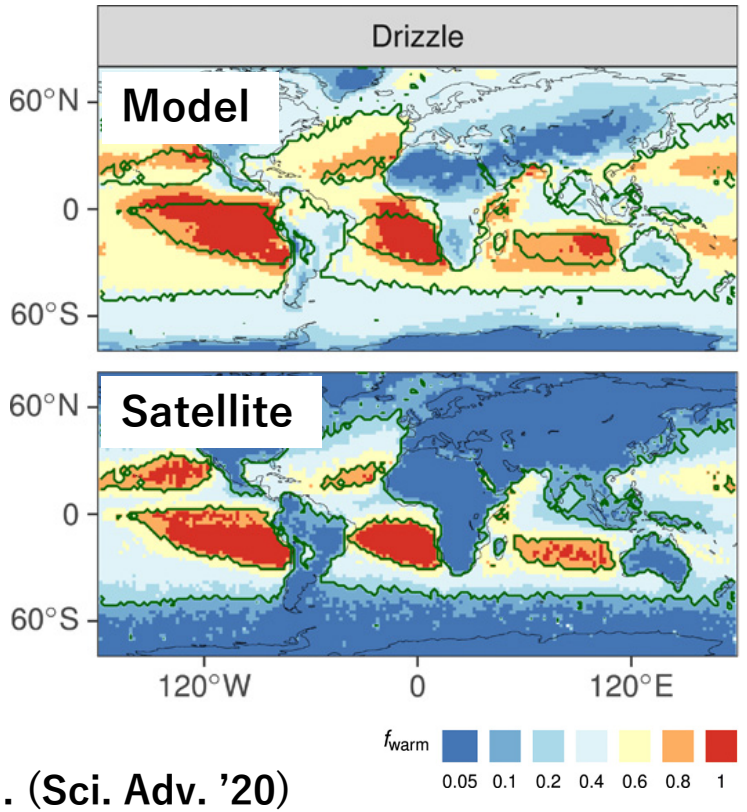
More cooling

Less cooling



Precip. frequency bias

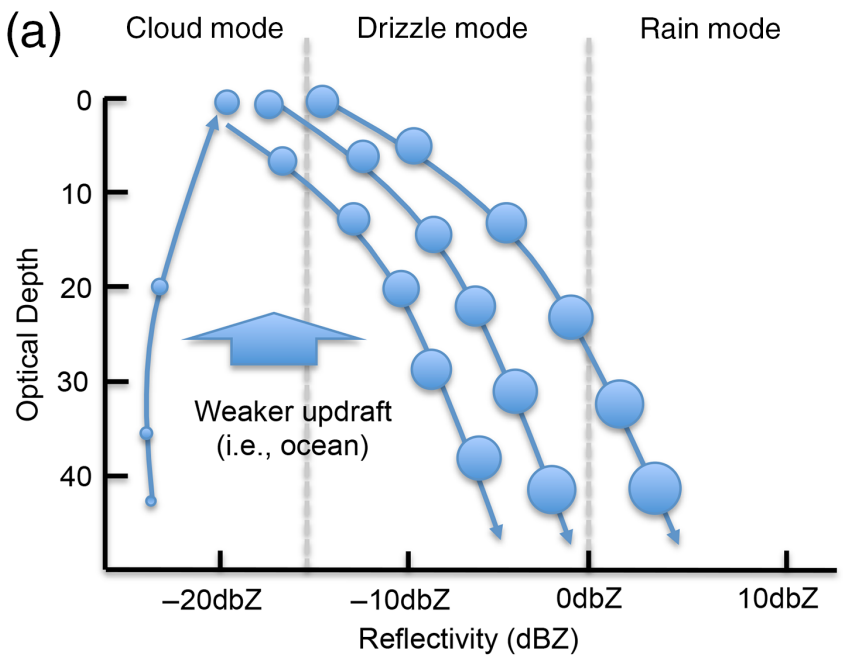
Warm rain fraction

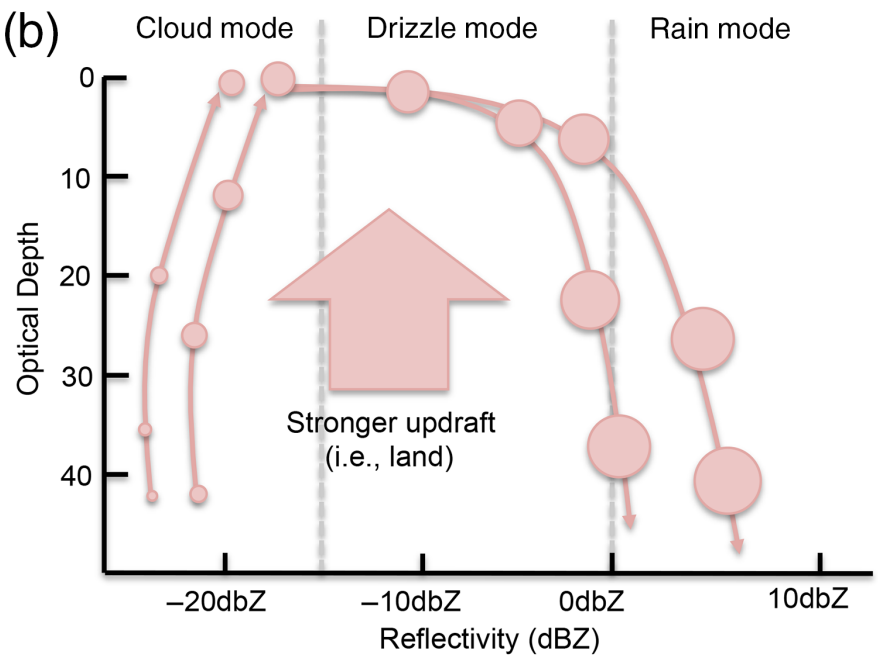


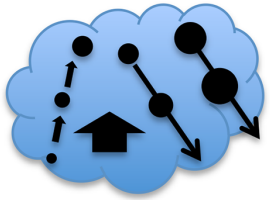
Mulmenstadt et al. (Sci. Adv. '20)

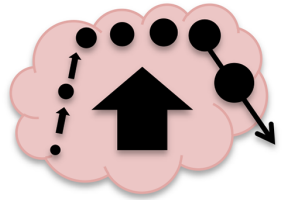
- Simultaneous measurement of rain/drizzle is critical for model precipitation processes
- Process-sensitive obs information is required for reliable estimates of radiative forcing
- How can EarthCARE Doppler add a "dynamical context" to this?

How could dynamics-microphysics coupling be seen in satellite obs?







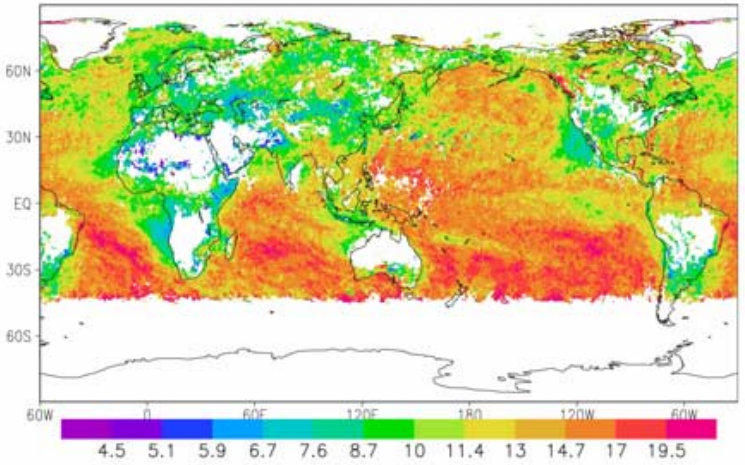


Takahashi et al. (QJRMS ’17)

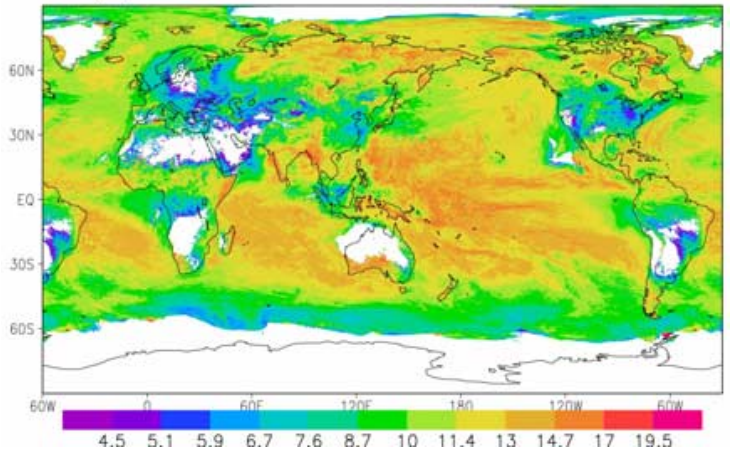
Can EarthCARE Doppler help test this?

Aerosol-Cloud Interaction in a global storm-resolving model

Cloud R_{eff} Satellite Obs.



NICAM-SPRINTARS Only 8 days

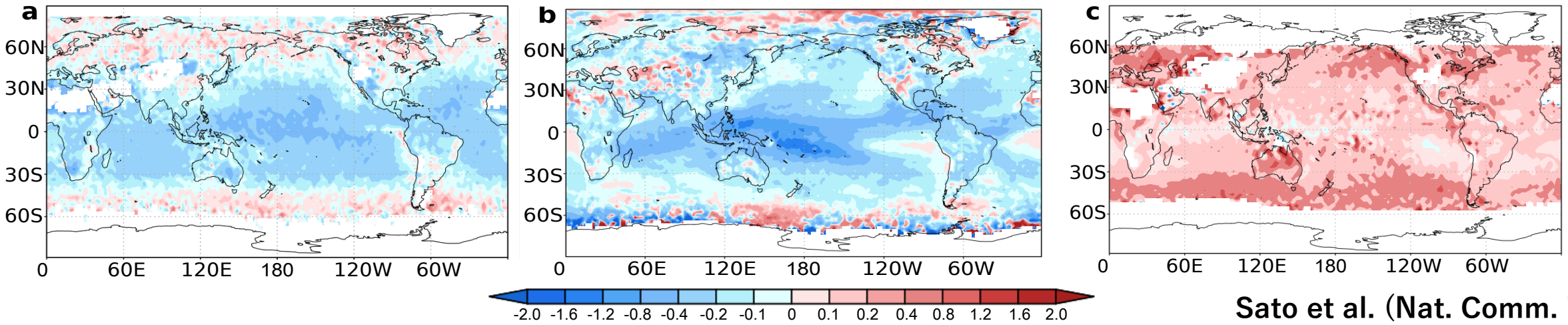


Suzuki et al. (GRL '08)

LWP susceptibility

1 full year

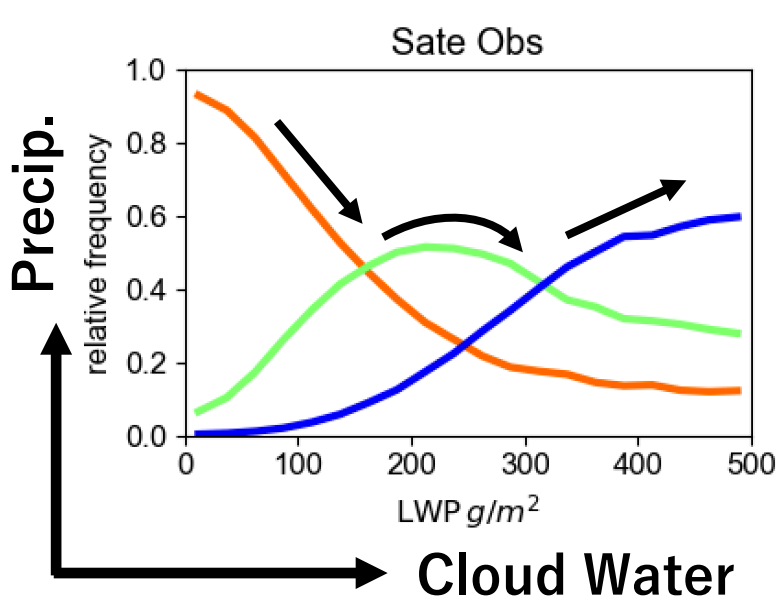
MIROC-SPRINTARS

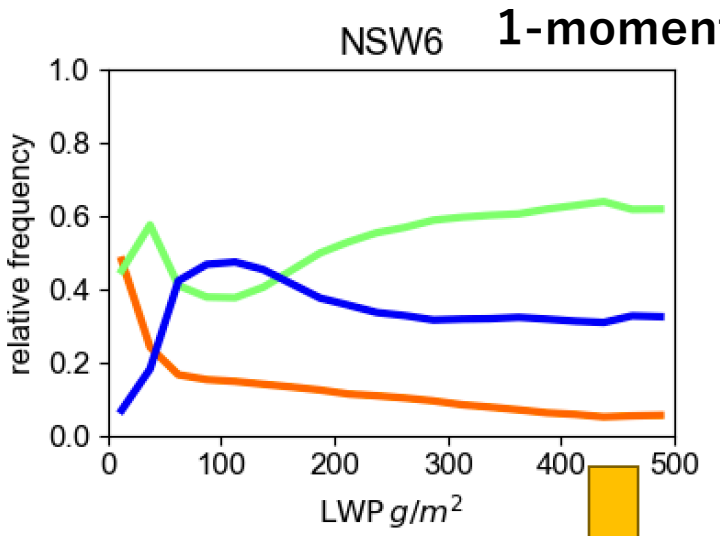


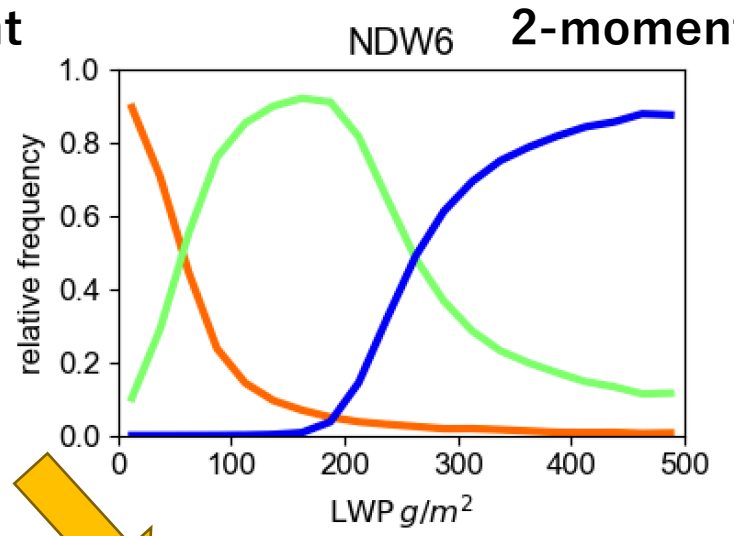
Sato et al. (Nat. Comm. '18)

■ How realistic are key process representations in NICAM?

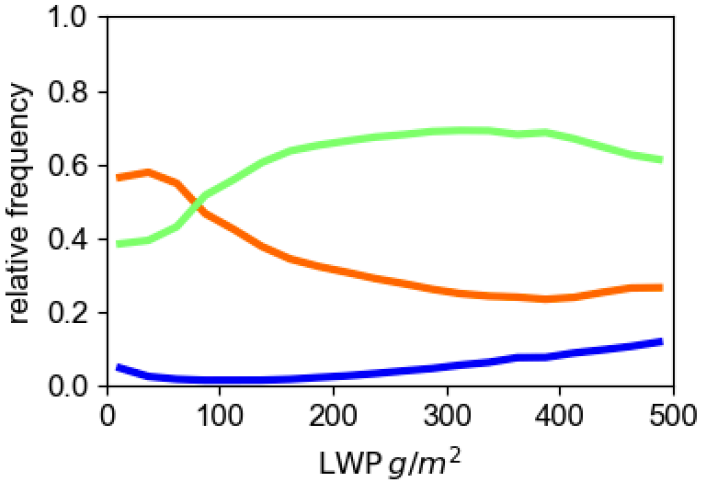
The rain process realism in NICAM – Statistic #3

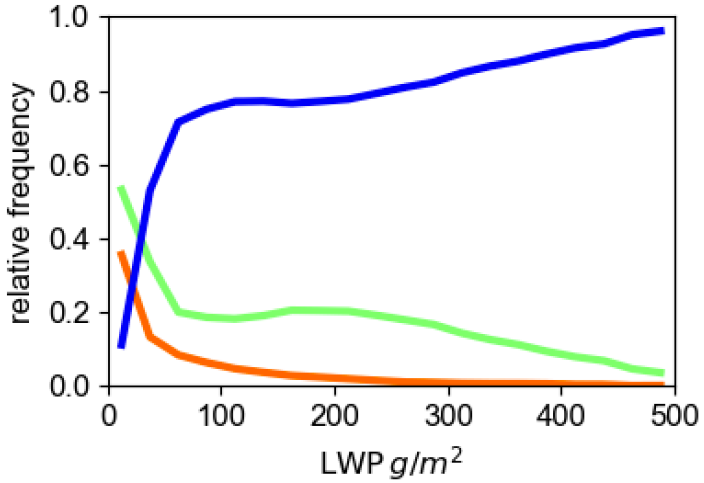






Sensitivity of NSW6 to some parameters





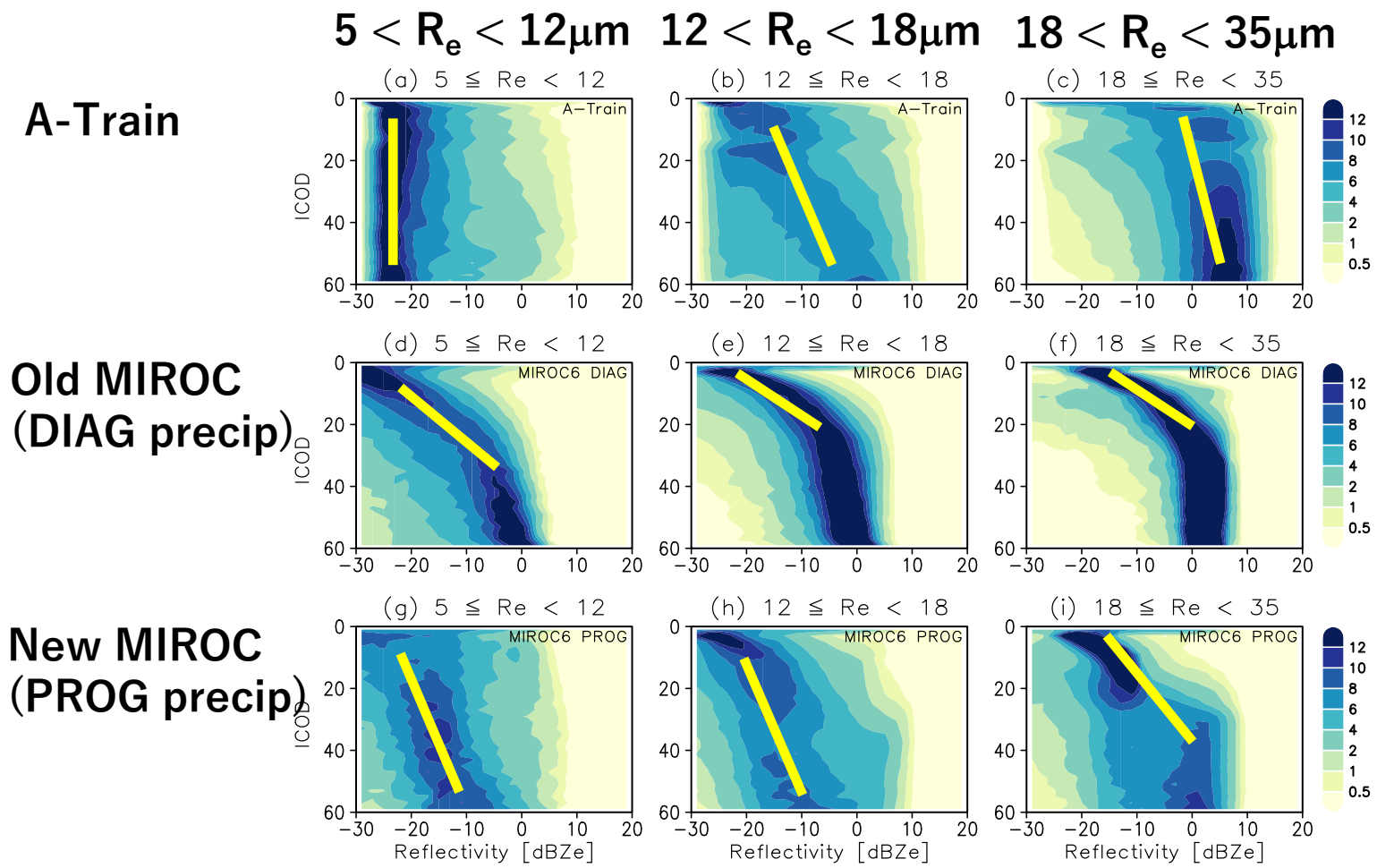
No precipitation: Z < -15dBZ
Drizzle: -15dBZ < Z < 0dBZ
Rain: Z > 0dBZ

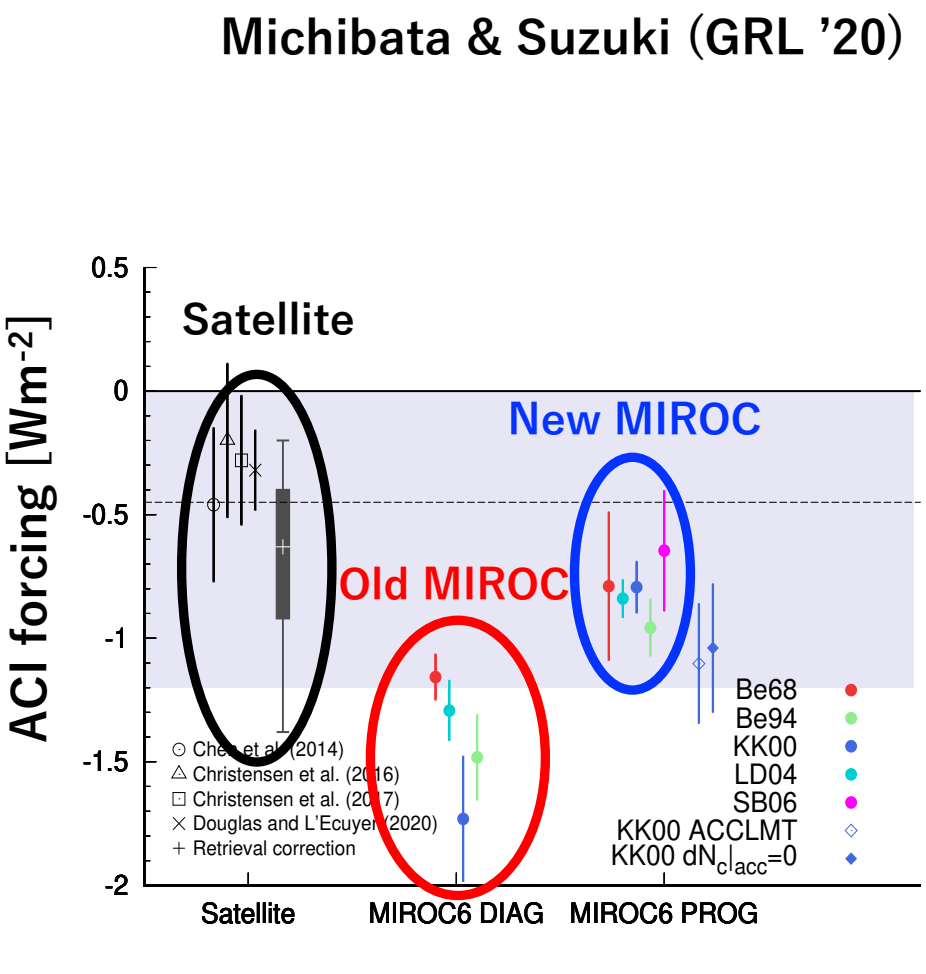
Hotta & Suzuki (in prep.)

Summary & Some thoughts for EarthCARE

- There exist some metrics that can “probe” some aspects of key cloud-precipitation processes
- The process realism depicted in them is found to correlate with ACI radiative forcing
- The dynamical context would be added by ECARE with Doppler capability to the existing metrics
  - How can we do this specifically?
- How about HSRL?
  - Distinguishing aerosols of differing colors (absorbing/scattering)
  - Detailed characterization of hydrometeors (ice crystal habits)
- How to exploit new ECARE capabilities for extending the existing metrics and devising new ones?

Metrics based on CPR reflectivity 2 - Vertical profiles

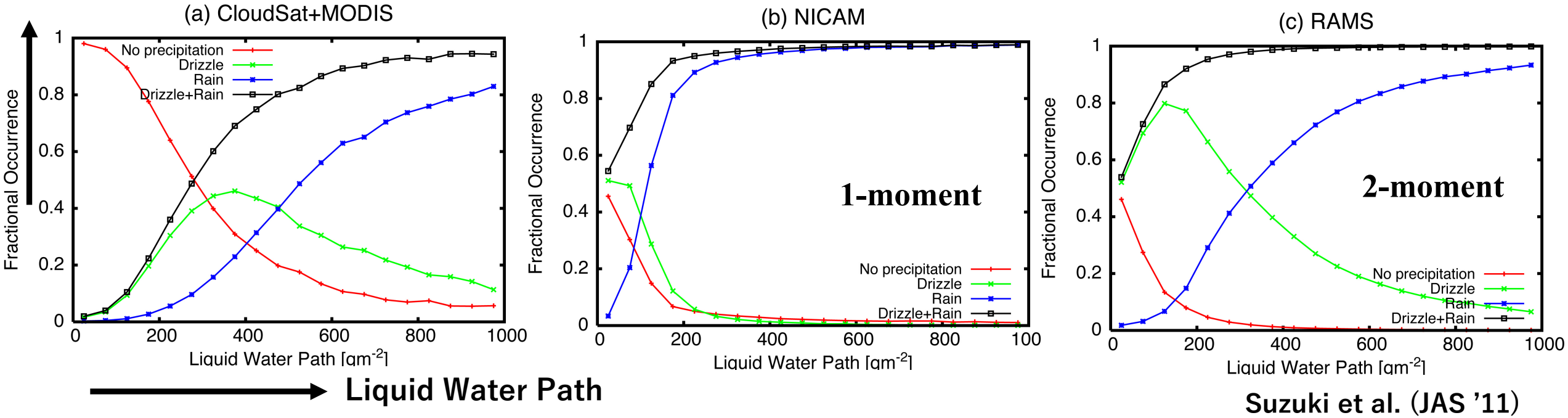




- A particular statistics of CloudSat+MODIS "fingerprints" the rain formation process
- This offers a direct constraint on model cloud physics, which is linked to ACI forcing
- Recent MIROC development was guided by this to produce new estimates of ACI forcing

Evaluation of water conversion process

Probability of Precipitation



Suzuki et al. (JAS '11)

Precipitation Category:

Non-precip: $Z_{sfc} < -15dBZ$

Drizzle: $-15dBZ < Z_{sfc} < 0dBZ$

Rain: $0dBZ < Z_{sfc}$

Z_{sfc}: Surface radar reflectivity

- NICAM forms rain too fast
  - Common bias with GCMs
  - Not solved by resolution alone
- Issue of cloud physics