The too-fast, too-frequent precipitation simulated in GCMs

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Introduction

Warm precipitation is of great hydrological and radiative importance in the climate system. **Process-level** investigation is required to identify the source of warm precipitation biases and fundamentally improve its model representation.

Motivation: To understand
- How precipitation behaves in GCMs?
- What biases exist in GCMs' precipitation microphysics?

Data and Models

Observational data:
CloudSat (radar reflectivity) and Aqua-MODIS (cloud droplet radius and optical depth).

Models:
GFDL_AM3 with CLUBB subgrid scheme (Guo et al., 2014), GFDL_AM4, ECHAM-HAM, MRI-CGCM, MIROC5.2, NICAM_Br (with Berry (1968) autoconversion), NICAM_KK (with Khairoutdinov and Kogan (2000) autoconversion)

Precipitation frequency

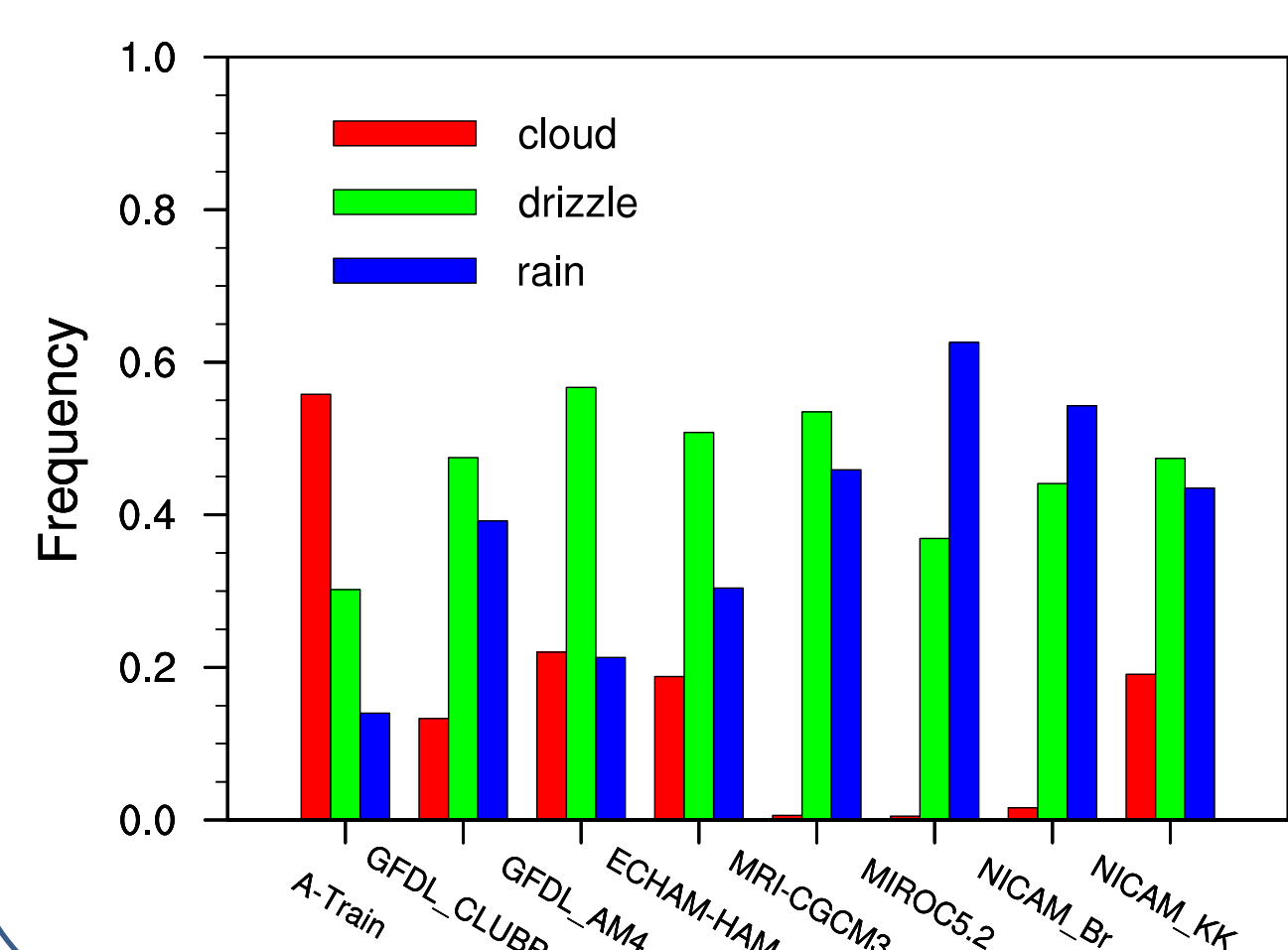Fig.1. Relative occurrence frequency of **cloud** ($-30 < Z_{max} < -15$ dBZ), **drizzle** ($-15 < Z_{max} < 0$ dBZ), and **rain** ($Z_{max} > 0$ dBZ). Z_{max} is column maximum radar reflectivity. Satellite simulators were used to simulate radar reflectivity for GCMs.

Precipitation (drizzle and rain) occurs much more frequent in models compared with that in observations.

Precipitation & cloud properties (a) liquid water path (LWP)

The A-Train results demonstrate: 1) the cloud-to-precipitation transition occurs more readily with increasing LWP; 2) drizzle is responsible for most of the water transition over LWP below about 200 gm^{-2}, while rain becomes dominant with further increase in LWP.

However, too large occurrence of precipitation at small LWP are found for all the models. This means **precipitation is triggered to form too early when LWP is still small**.
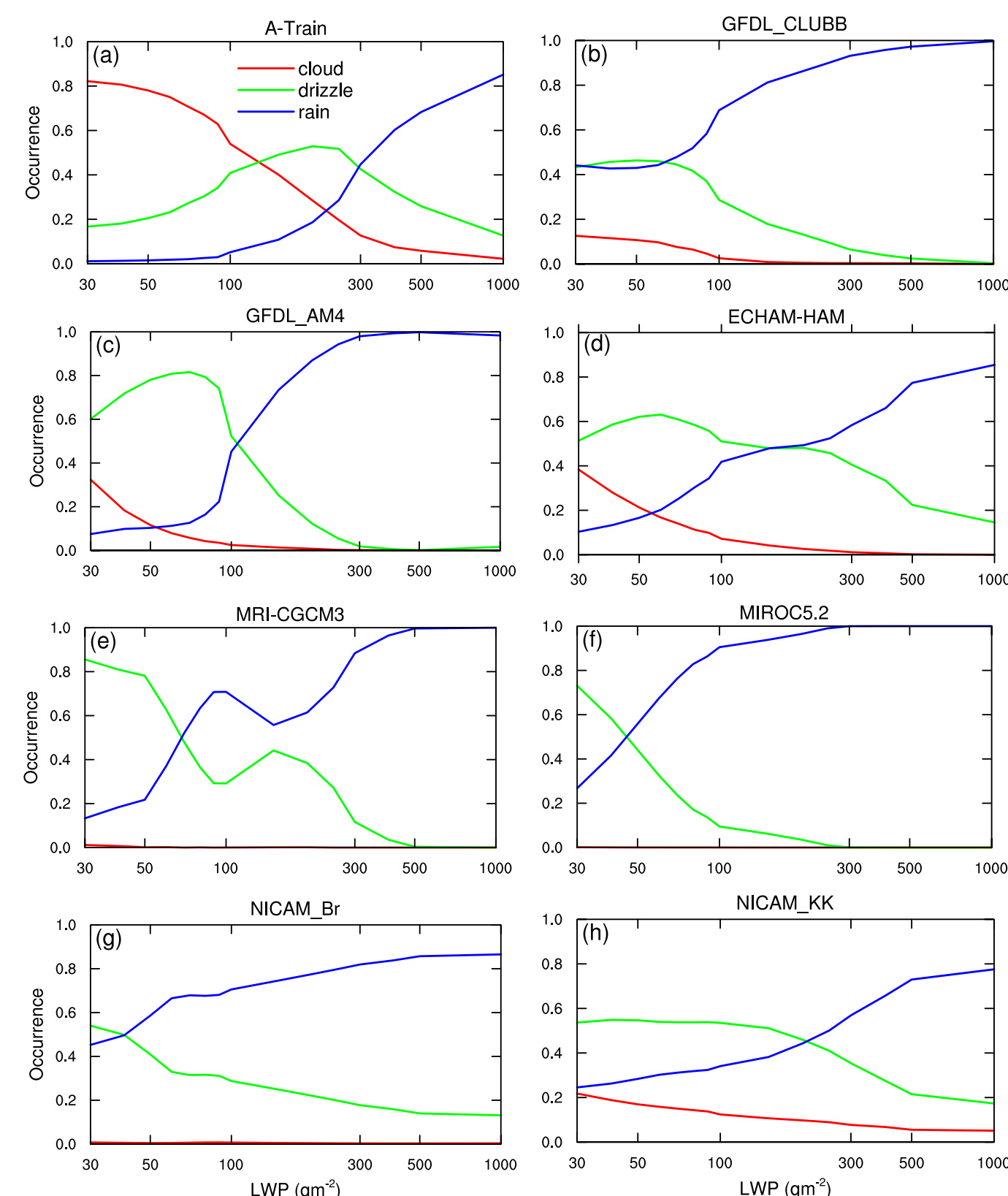

Fig.2. Fractional occurrence frequency of cloud (red), drizzle (green), and rain (blue) as a function of LWP.

Precipitation & cloud properties (b) cloud-top droplet radius (Reff)
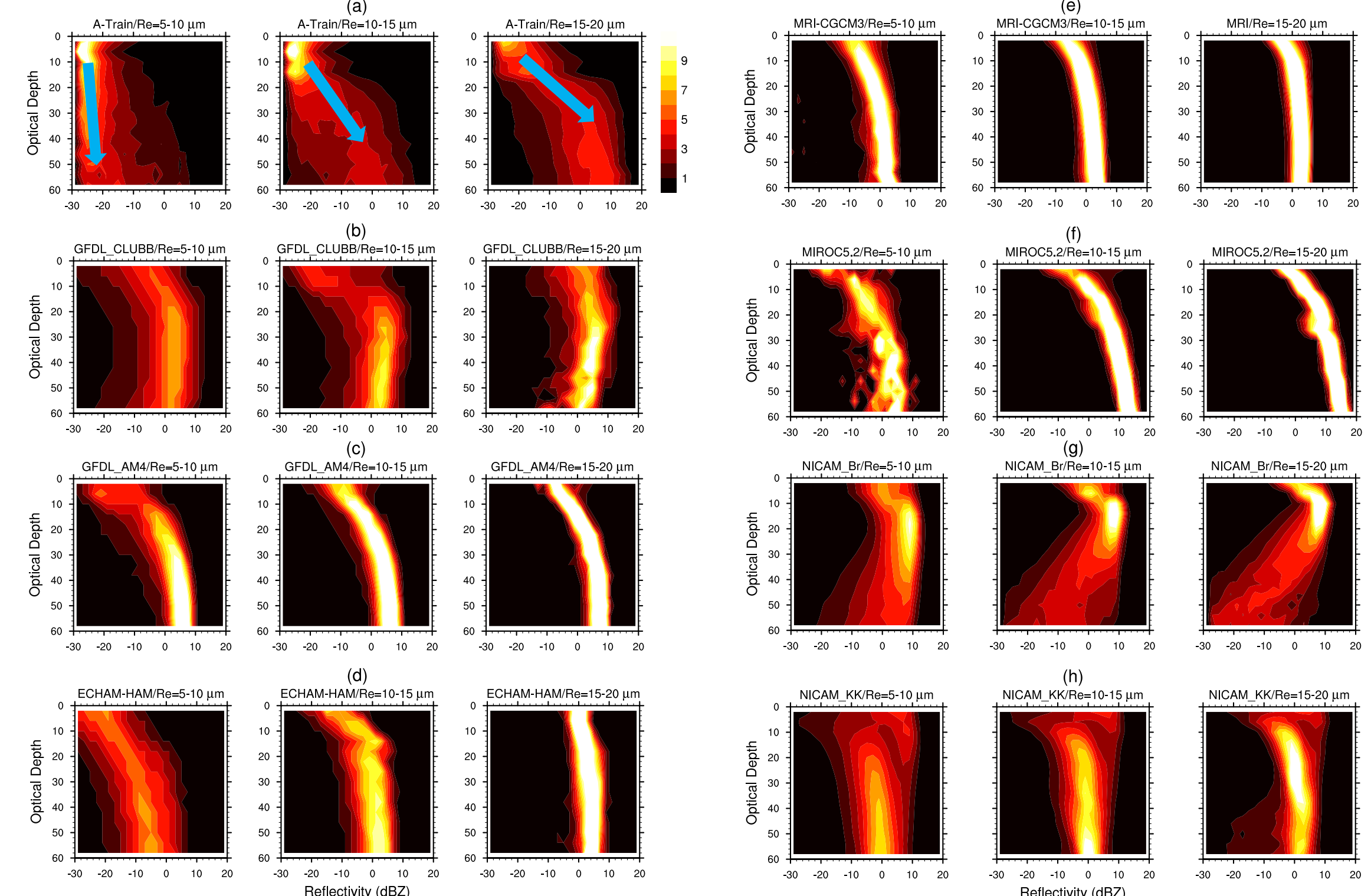

Fig.3. The probability function of radar reflectivity as a function of in-cloud optical depth (i.e. CFODDs), divided into Reff groups of 5-10, 10-15, and 15-20 μm.

In A-Train, the vertical structure shows a monotonic shift from non-precipitating profiles to precipitating profiles with increasing Reff. However, All models show precipitating profiles when Reff is in the smallest range. This means **precipitation is triggered to form too early when Reff is still small**.
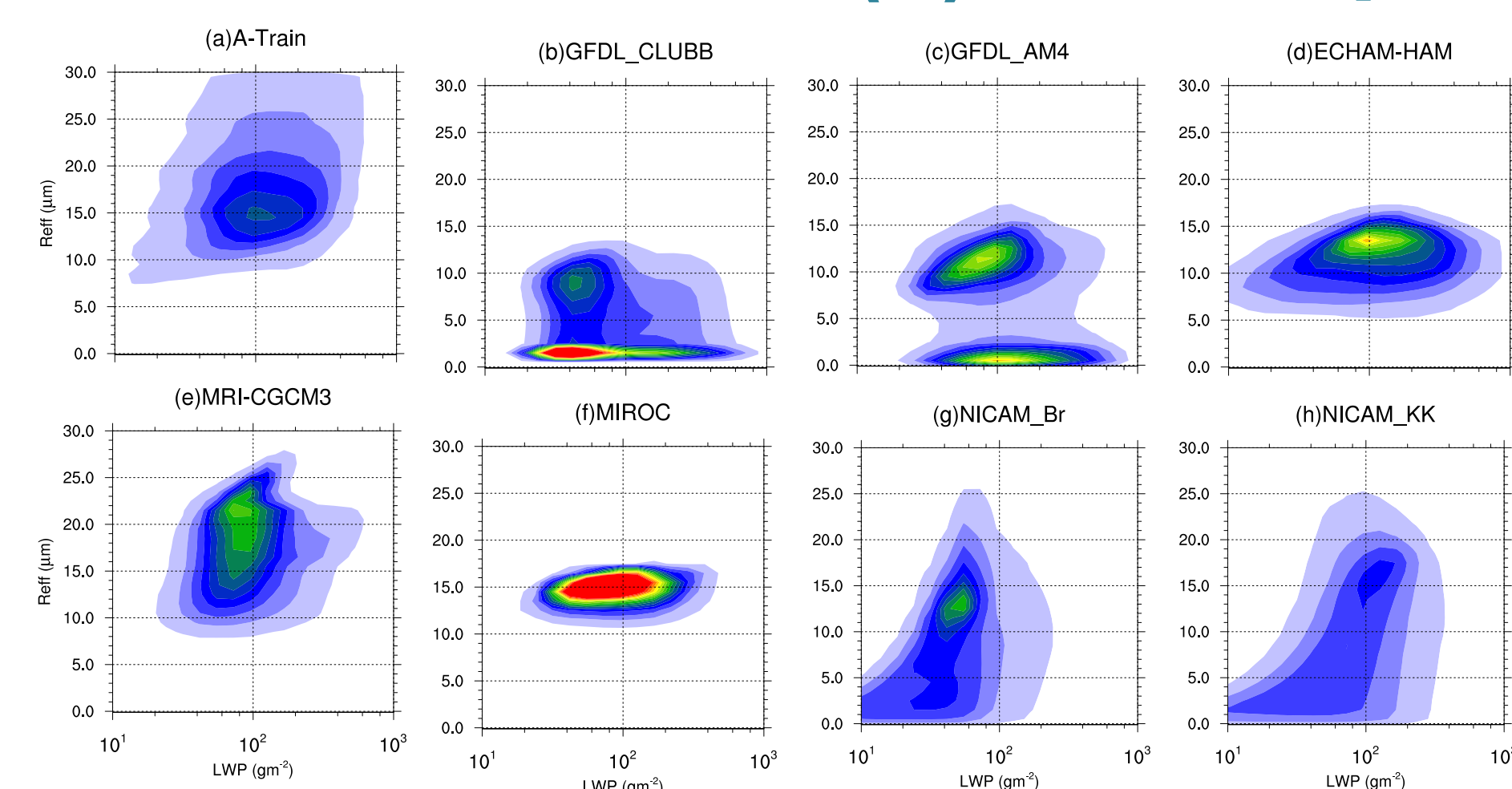
Biases (a): cloud properties

Fig.4. 2-Dimention PDF of cloud occurrence as a function of LWP and Reff.

Precipitation is parameterized with droplet size and water content. Fig.4 shows underestimated Reff and LWP for most models. **These biases in cloud properties compensate partly for the too early formation bias.**

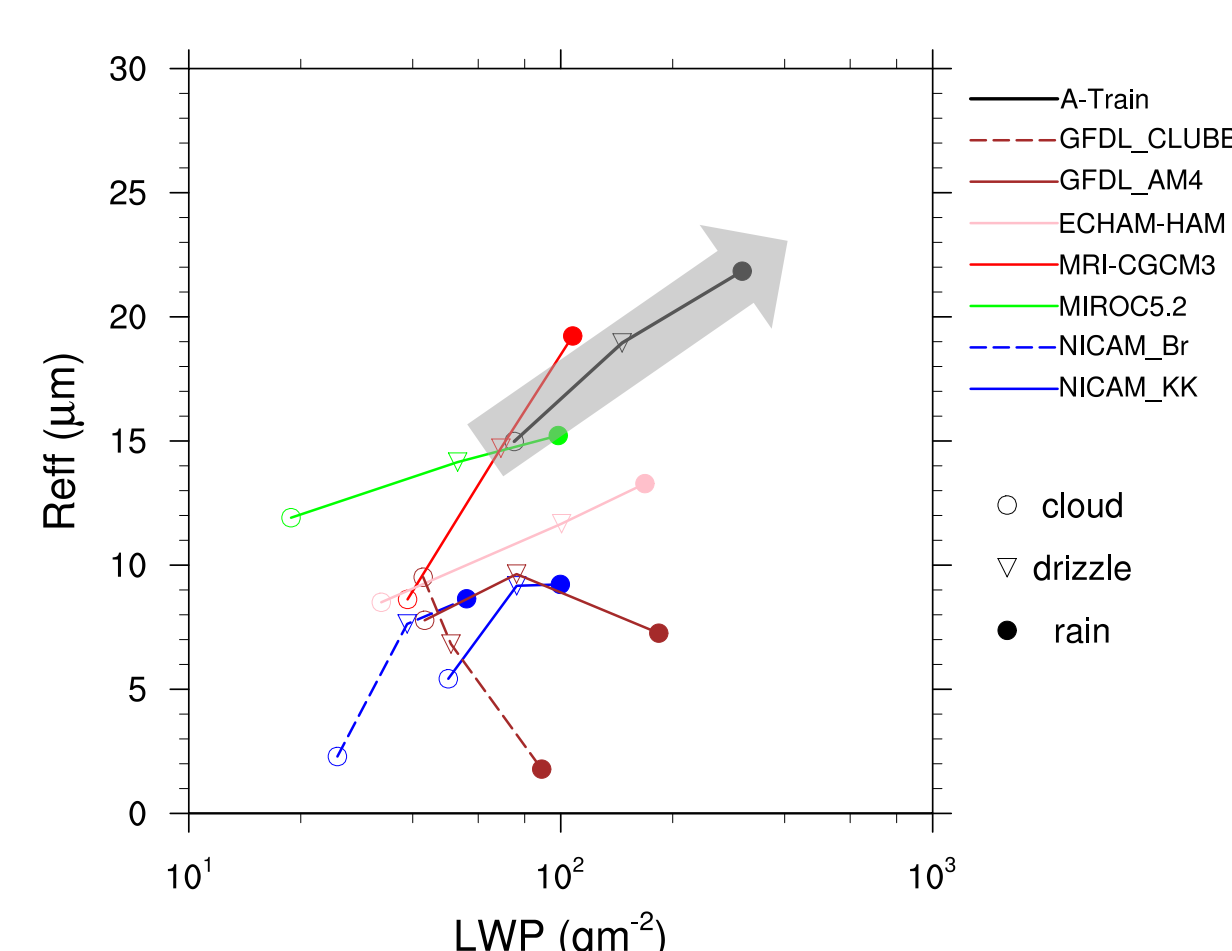## Biases (b): precipitation evolution

Fig.5. Evolution of cloud properties with the precipitation process. Each mark represents the typical (median) position of the cloud/drizzle/rain category.

In A-Train observations, the enhancement of precipitation is associated with increasing LWP and Reff (gray arrow). Although some models captured this relationship, others show decreasing Reff with the enhancement of precipitation. This implies too efficient depletion of cloud water by precipitation. Thus **precipitation happens too fast compared with observation.**

Highlights

Note Two problems in precipitation process :

Triggering problem ⟷ Too-frequent

Evolution problem ⟷ Too-fast

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