Base state vs susceptibility: which is more important for ERFaci?

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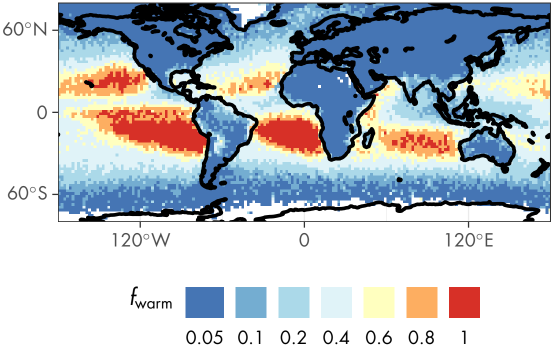
Motivation

- Constraints on state variables (cloud fraction, TOA fluxes, total precip) do not translate easily into constraints on sensitivity to anthropogenic perturbations

- This analysis uses process-oriented constraints instead to attempt to constrain parameterized warm rain processes in GCMs

Rain from pure liquid clouds ("warm rain") is very rare over the extratropical continents



f_{warm} is the temporal fractional occurrence of warm rain, normalized by the occurrence of any type of rain, at latitude ϕ and longitude λ:

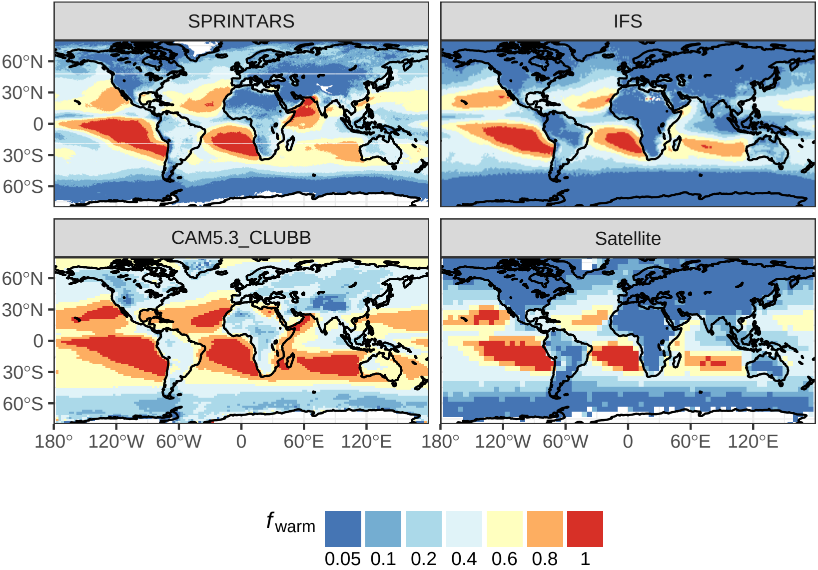
$$f_{warm}(\lambda, \phi) = [n_{warm\ rain}(\lambda, \phi)]/[n_{warm\ rain}(\lambda, \phi) + n_{cold\ rain}(\lambda, \phi)] \quad (1)$$

Mülmenstädt et al. (2015), *Geophys. Res. Lett.*; see also Field and Heymsfield (2015), *Geophys. Res. Lett.*

Warm rain fraction can serve as a process-based observational constraint on parameterized precipitation

- Warm rain fraction can be diagnosed in models
- Warm rain fraction means the same thing in models and satellite
- Warm rain fraction allows us to draw conclusions on precipitation processes active in the model and in reality
- Warm rain fraction has not been used as a model tuning target

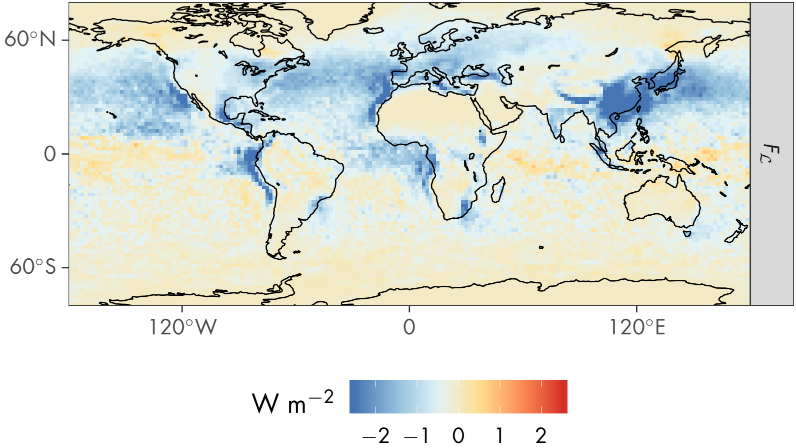
Modeled warm rain fraction is diverse



Hypothesis: warm-rain fraction can serve as an observational constraint on the cloud lifetime effect

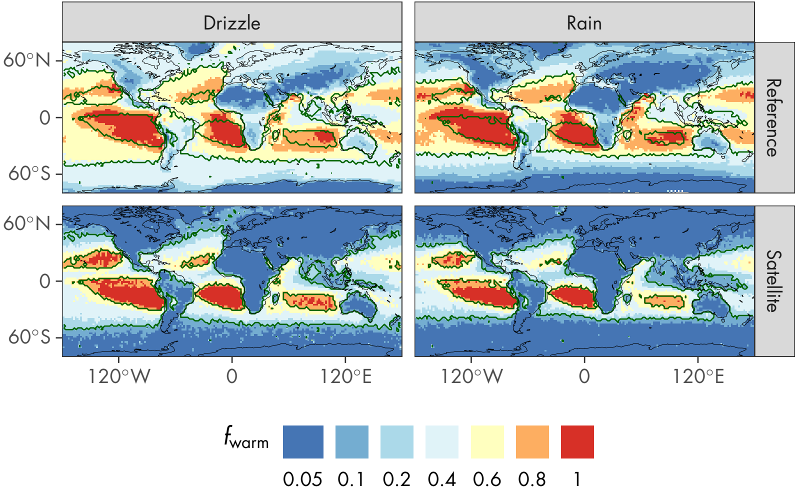
- The more precipitating warm clouds are simulated in a model, the more opportunity aerosols have to influence the precipitation microphysics
- Thus, even if the model's in-cloud precipitation susceptibility were perfect, the global-mean sensitivity would still be wrong
- Comparing warm-rain fraction in models against satellites may provide an observational constraint on the cloud lifetime effect
- This means precipitation base state biases, not just susceptibility to aerosols, affect the cloud lifetime effect

First, we need a method to decompose ERFaci

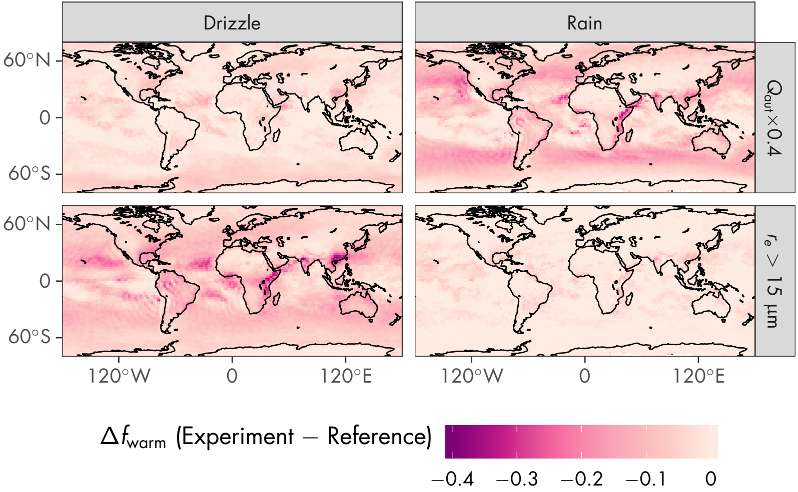


Mülmenstädt et al. (2019), ACP

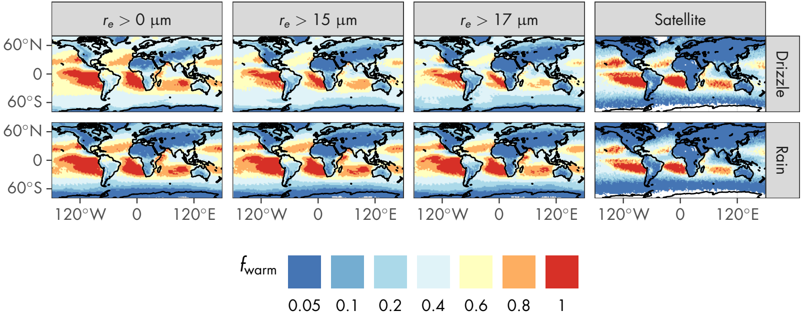
ECHAM–HAM is biased high in warm rain and drizzle



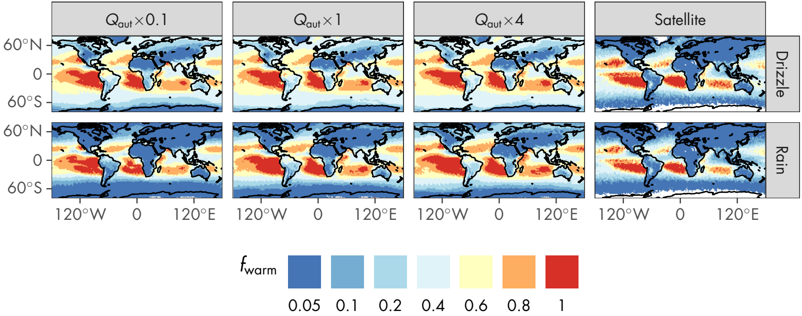
Bias can be reduced by scaling Q_{aut} or imposing r_e threshold



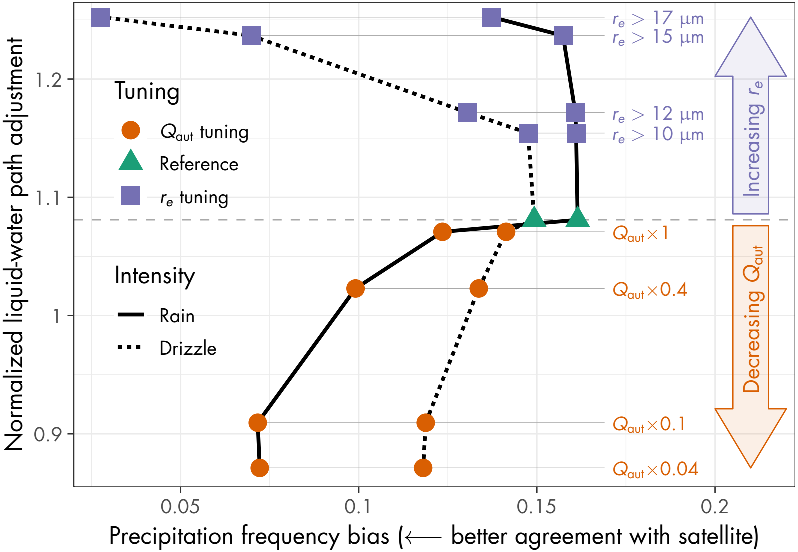
r_e mostly reduces warm drizzle. . .



... while Q_{aut} mostly reduces warm rain



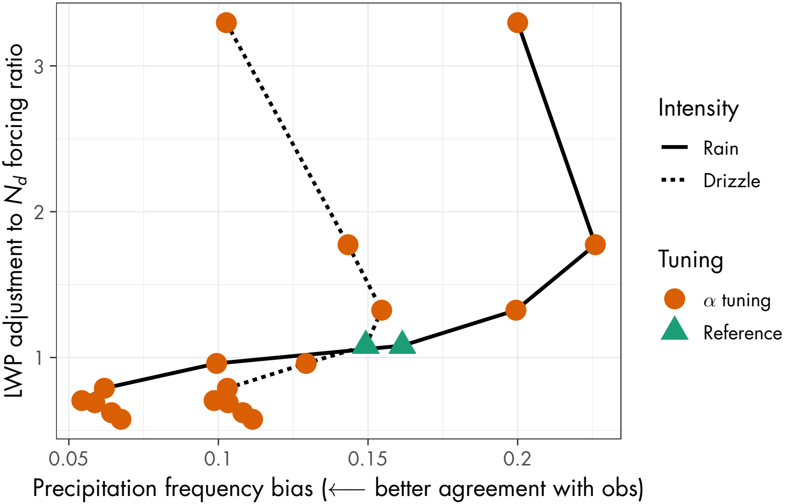
Opposing changes in LWP adjustment from reducing rain/drizzle bias



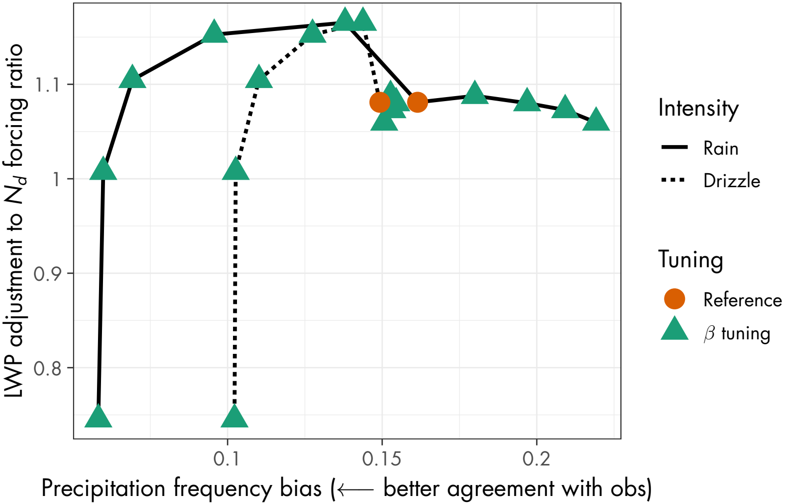
Base state vs susceptibility

$$Q_{aut} = \underbrace{1350\ \mathrm{s}^{-1} \times \gamma q_l^{\alpha}}_{\text{base state}} \underbrace{\left(\frac{N_d}{1\ \mathrm{cm}^{-3}}\right)^{-\beta}}_{\text{susceptibility}} \underbrace{\Theta\left(r_e - r_c\right)}_{\text{base state}} \quad (2)$$

Scanning α



Scanning β



Warm rain fraction as observational constraint: conclusions

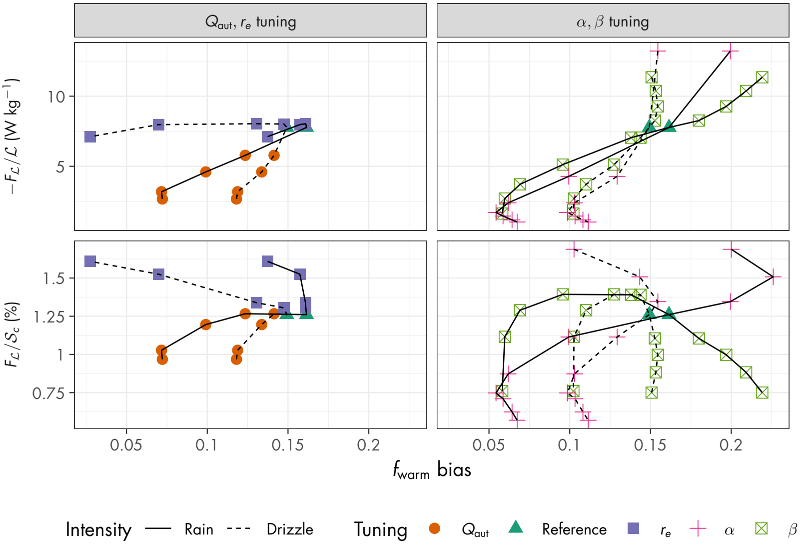
- A simple process-sensitive observable (are warm rain processes active or not at a given time and place?), but process-sensitive nonetheless

- Precipitation intensity matters

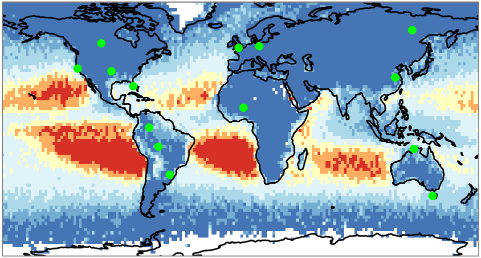
- Precipitation base state, not only susceptibility, has a large effect on ERFaci

- AeroCom Cloud MMPPE can provide a multimodel perspective on the base-state/susceptibility question

$F_{\mathcal{L}}$ metrics



Compare satellite climatology to CMIP5 cfSites



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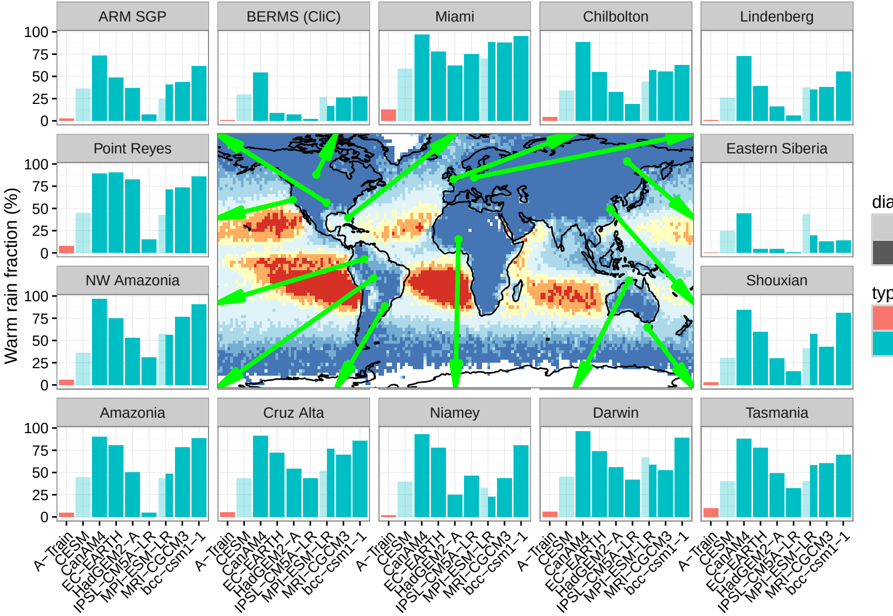

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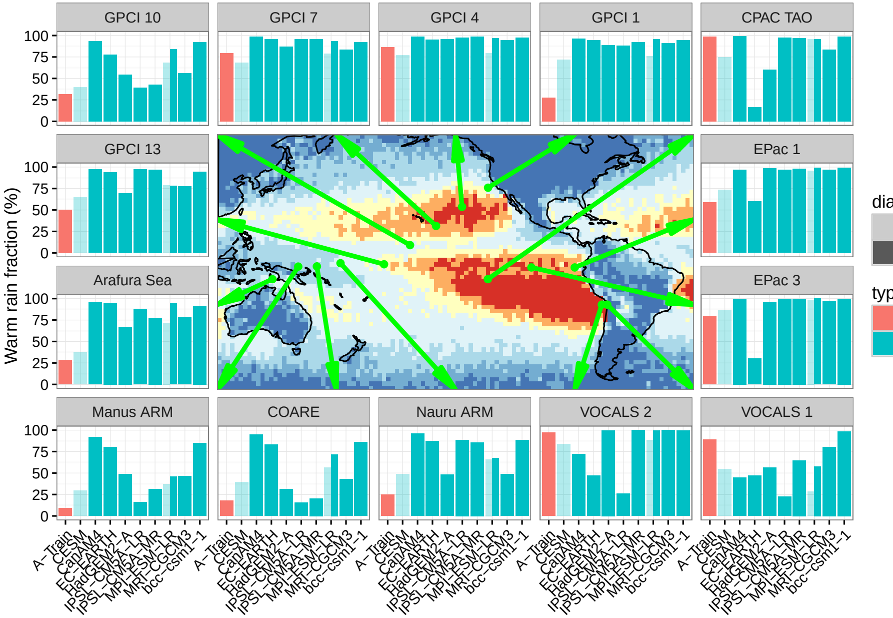
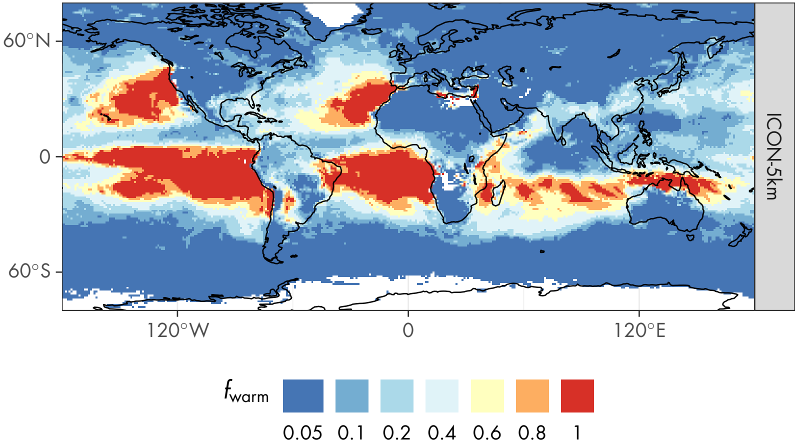


CRM instead of GCM



Effect of turning off parameterized convection