Impact of microphysics on tropical precipitation extremes in a global storm-resolving model

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Summary

- Changes in microphysics influence tropical precipitation extremes in a global storm-resolving model.
- Hourly precipitation extremes are influenced dynamically through convective updraft speed, which depends on the raindrop terminal velocity.
- Daily precipitation extremes are more sensitive to the microphysical modulation on convective organization.

Experiments

We use a realistically configured global storm-resolving model ICON at a quasi-uniform horizontal mesh of 5 km to investigate the role of microphysics in tropical precipitation extremes.

The microphysical element we focus on is the terminal velocity of raindrops. We change the terminal velocity of raindrops by rescaling the original formula with a fixed rescaling coefficient .

Exp	Rescaling coefficient
Qt	0.25
Hf	0.5
Ct	1.0
Db	2.0

Response of tropical precipitation extremes

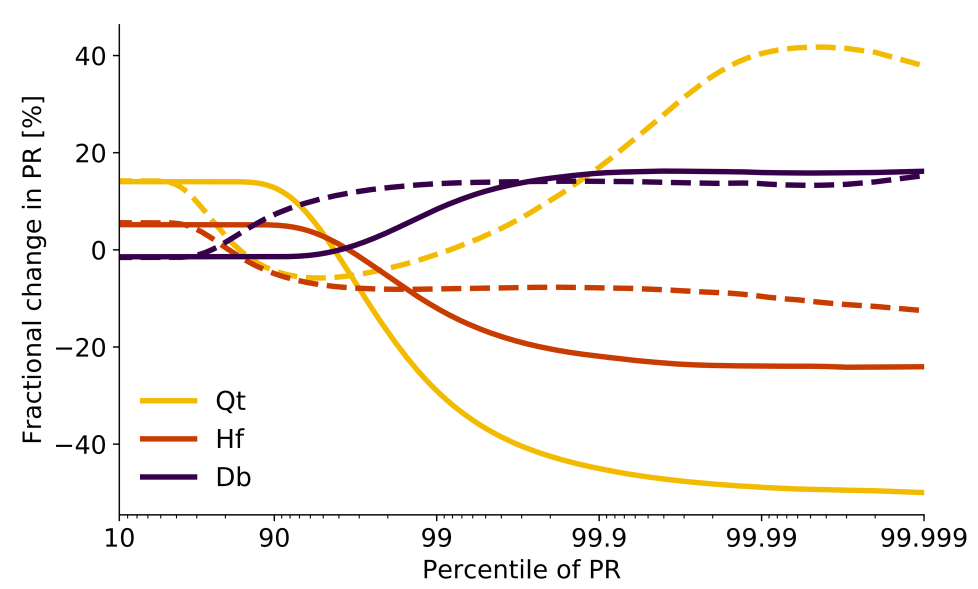

Fig.1 Fractional changes in precipitation (PR) relative to Ct as a function of PR percentile. Solid (dashed) lines represent hourly (daily) precipitation.

- At hourly time scales, extreme precipitation increases roughly linearly with the terminal velocity.
- Daily precipitation extremes do not seem to vary linearly with the terminal velocity. The highest daily extremes occur in the case with the slowest terminal velocity (Qt)

Extreme precipitation decomposition

Changes in extreme precipitation can be decomposed into a dynamical component (M) through changes in updraft velocity, a thermodynamic component (Γ_q) through changes in the moisture lapse rate, and a precipitation efficiency component (ϵ).

$$P_e \approx \epsilon M \Gamma_q$$

Thermodynamic $$\Gamma_q \approx -\frac{1}{M}\int_{p_s}^{p_t} \frac{\omega}{g}\frac{dq_s}{dp}\bigg|_{\theta_e^*} dp$$

Dynamic $$M = -\int_{p_s}^{p_t} \frac{\omega}{g}\, dp$$

Precipitation efficiency $$\epsilon = \frac{C}{P_e}$$

Hourly precipitation extremes

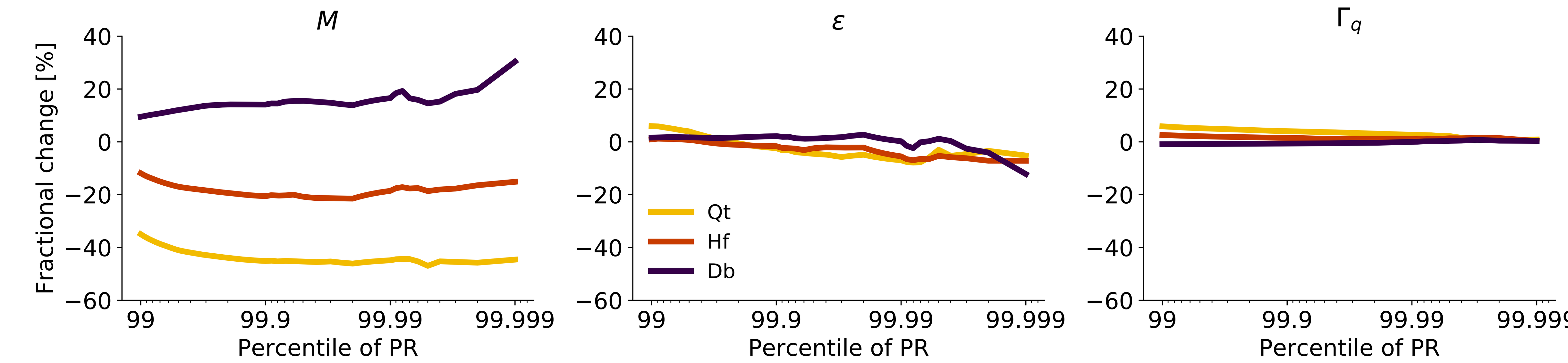

Fig.2 Fractional changes in the dynamical component (M), precipitation efficiency component (ϵ) and thermodynamic component (Γ_q) relative to Ct as a function of PR percentile.

- At hourly time scales, changes in precipitation extremes are almost entirely due to the dynamical component.
- The convective updraft speed is influenced by the raindrop terminal velocity through the condensate loading effect.

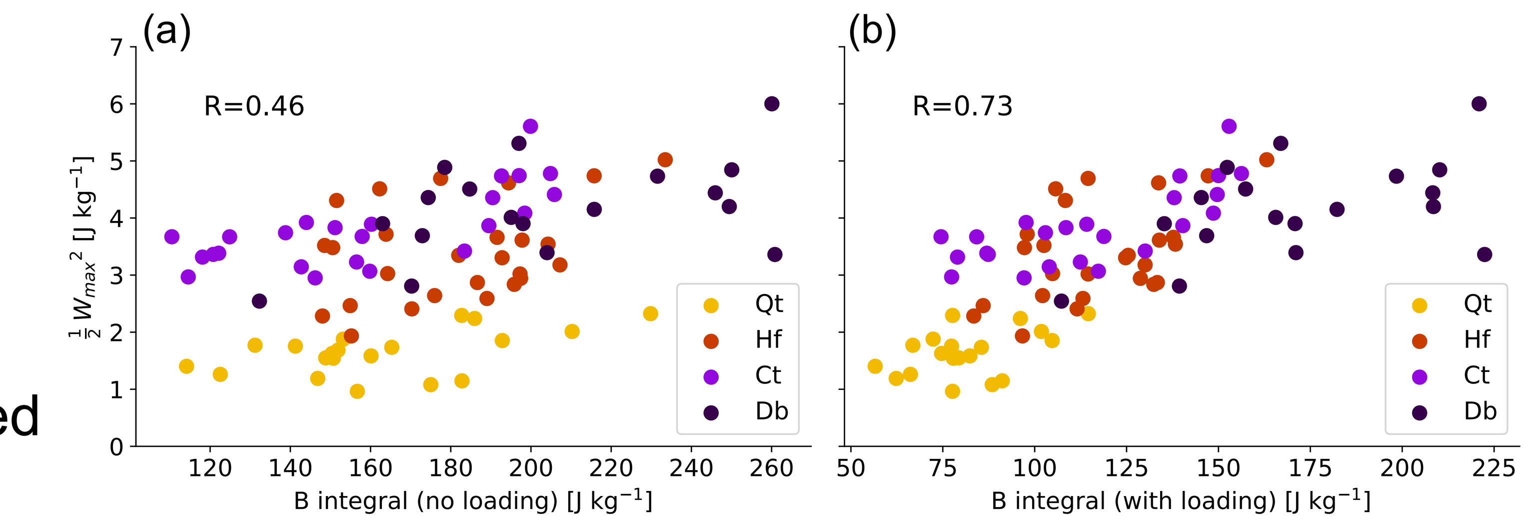

Fig.3 Peak kinetic energy ($W_{max}^2/2$) vs. vertical integrated buoyancy (B) calculated without the loading effect (a) and with the loading effect (b).

Daily precipitation extremes

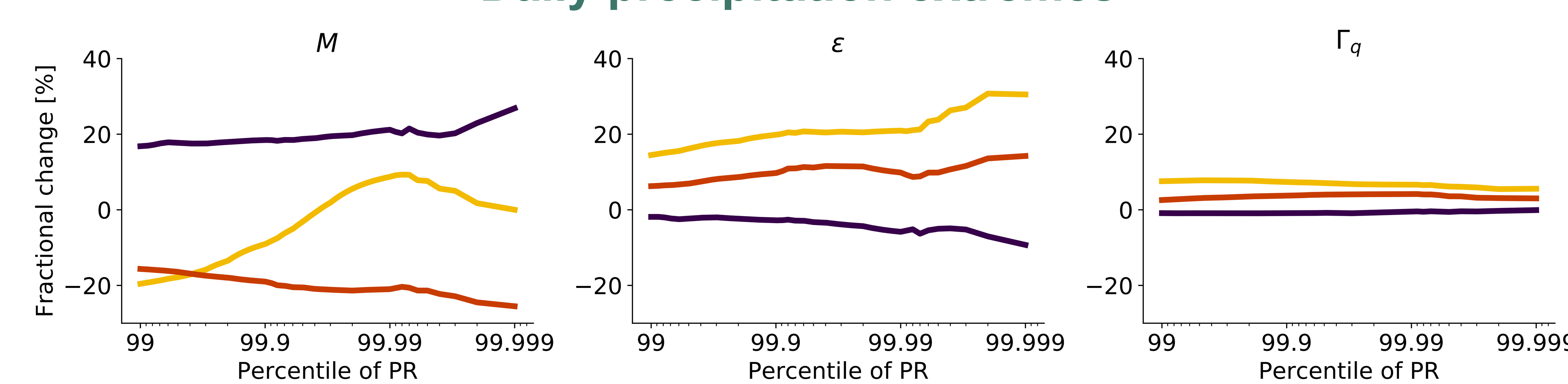

Fig.4 Fractional changes in the dynamical component (M), precipitation efficiency component (ϵ) and thermodynamic component (Γ_q) relative to Ct as a function of PR percentile.

- At daily time scales, both the dynamical component and the precipitation efficiency are important.
- The degree of convective organization plays a role (mainly through precipitation efficiency) in the daily precipitation extremes.
- Precipitation efficiency is higher in more organised states (larger Iorg).

Exp	Iorg
Qt	0.939
Hf	0.861
Ct	0.834
Db	0.829

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