Precipitation in extremely warm climates simulated with comprehensive GCMs

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What does precipitation look like in extremely warm climates?

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A conceptually convenient way to understand precipitation change is through the hydrological sensitivity η which is defined as:

$$\eta = \frac{\Delta \overline{P} / \overline{P}}{\Delta \overline{T}} \times 100,$$

where P is precipitation, T is surface temperature, and Δ is the change between two climate states.

Climate models suggest that the global-mean value of η falls somewhere between $1 - 2\,\%\,\mathrm{K}^{-1}$.

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Solved?

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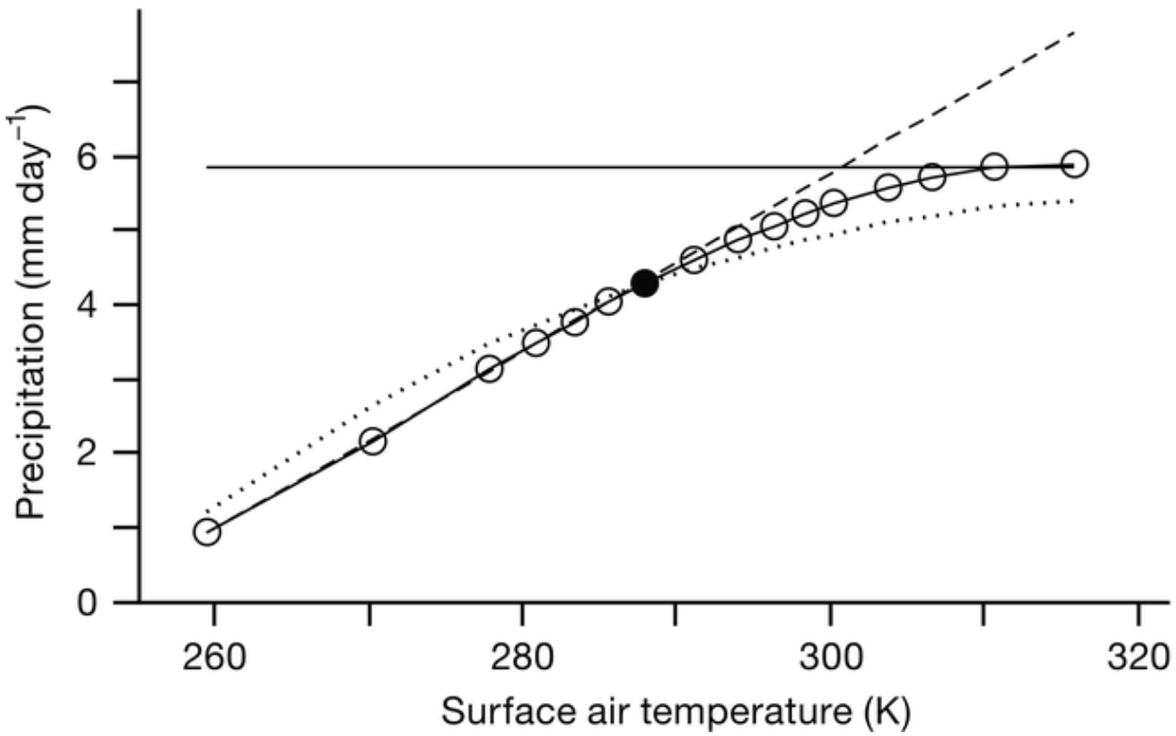
Precipitation in extremely warm climates simulated with an idealized GCM



- An idealized GCM suggests that global precipitation increases linearly with global surface temperature until approximately 300 K, where it saturates.

- This suggests much lower rates of global precipitation for the early Eocene (and other warm climate periods).

O'Gorman and Schneider, (2008)

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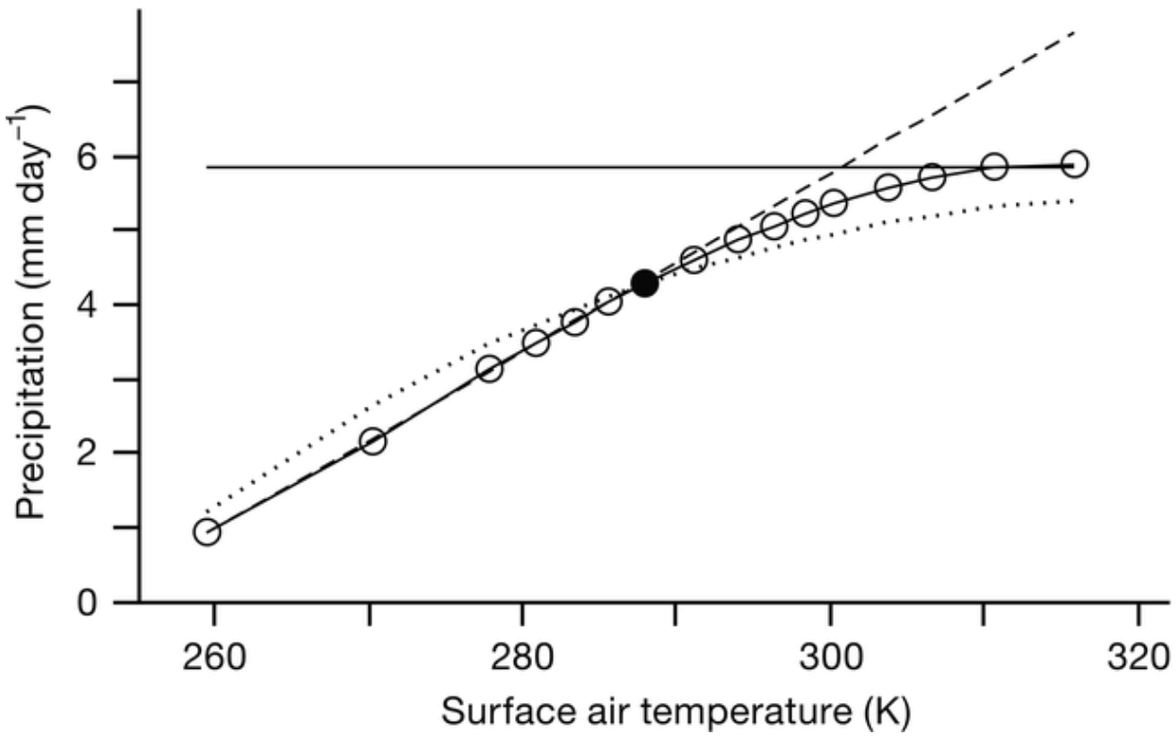

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- There are some caveats. These simulations were performed with:

    1. an aquaplanet configuration (no land);
    2. a gray-radiation scheme (radiative fluxes are a function of temperature alone);
    3. and no clouds or sea ice.

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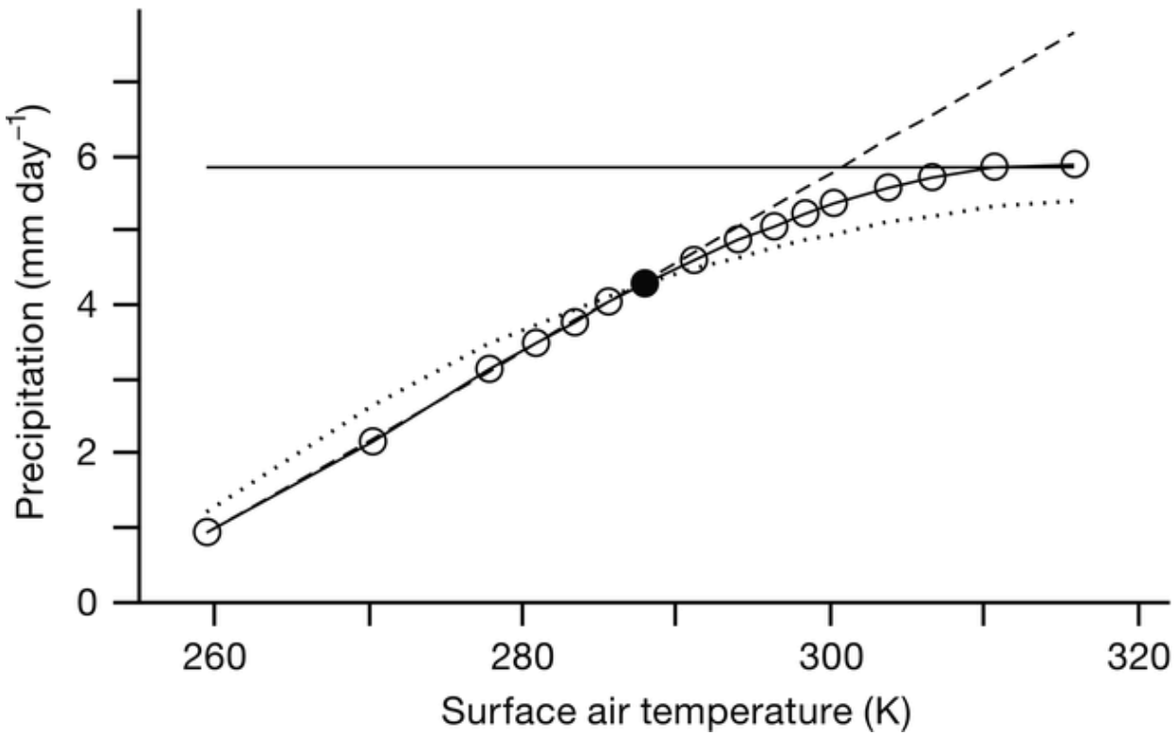
A surface energy budget perspective on global precipitation



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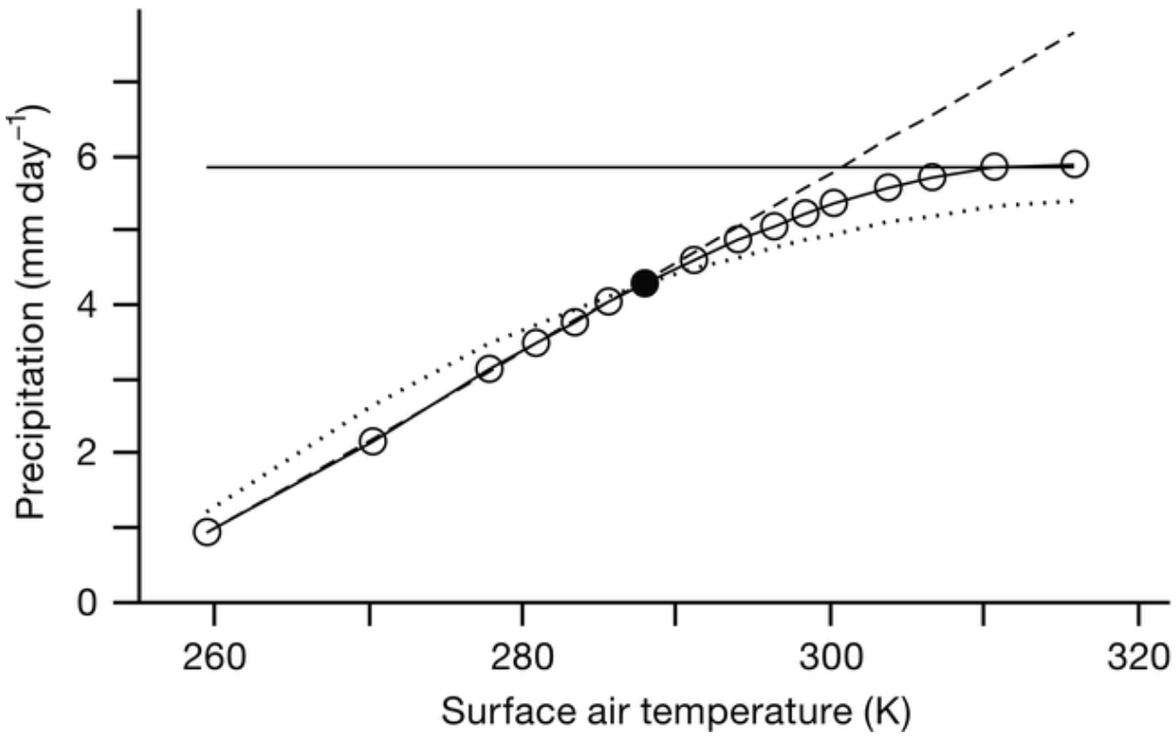

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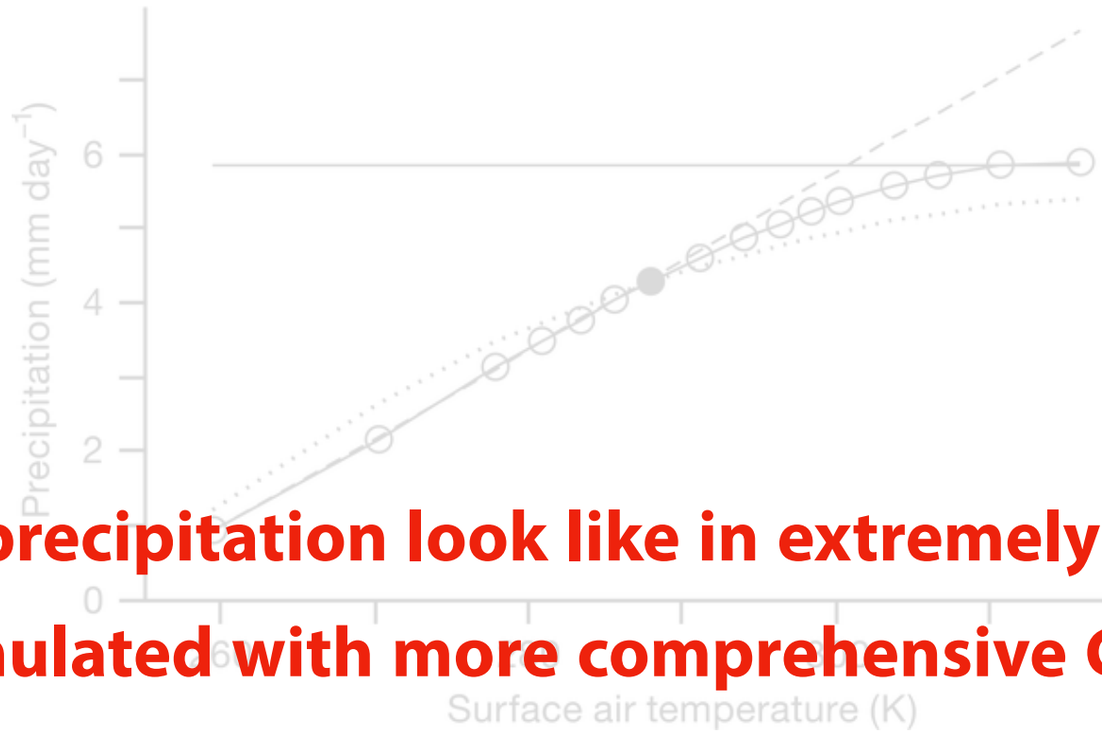

What does precipitation look like in extremely warm climates simulated with more comprehensive GCMs?

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Precipitation in extremely warm climates simulated with comprehensive GCMs

- Slab-ocean simulations with CAM4, CAM5, and CAM6

- Forced with 1xCO2, 2xCO2, 4xCO2, 8xCO2, 16xCO2, 32xCO2, 64xCO2, 128xCO2, and 256xCO2 (Zhu and Poulsen, 2020)

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This is wild and very unrealistic… 256xCO_2 is a CO_2 concentration of 71680 ppm.

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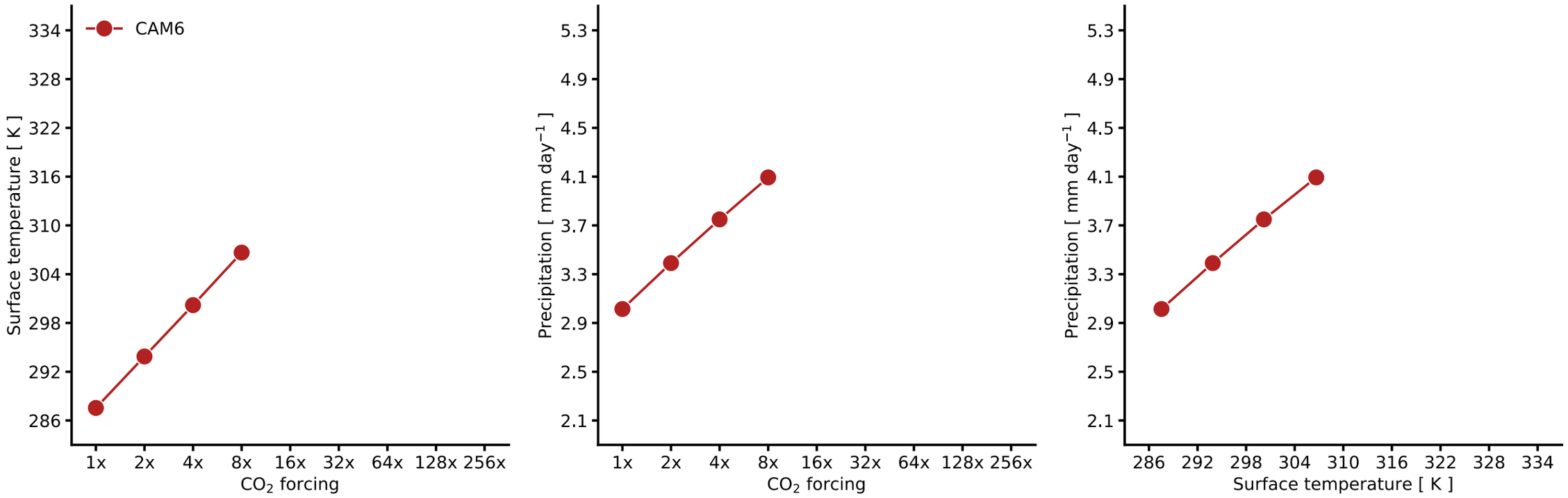

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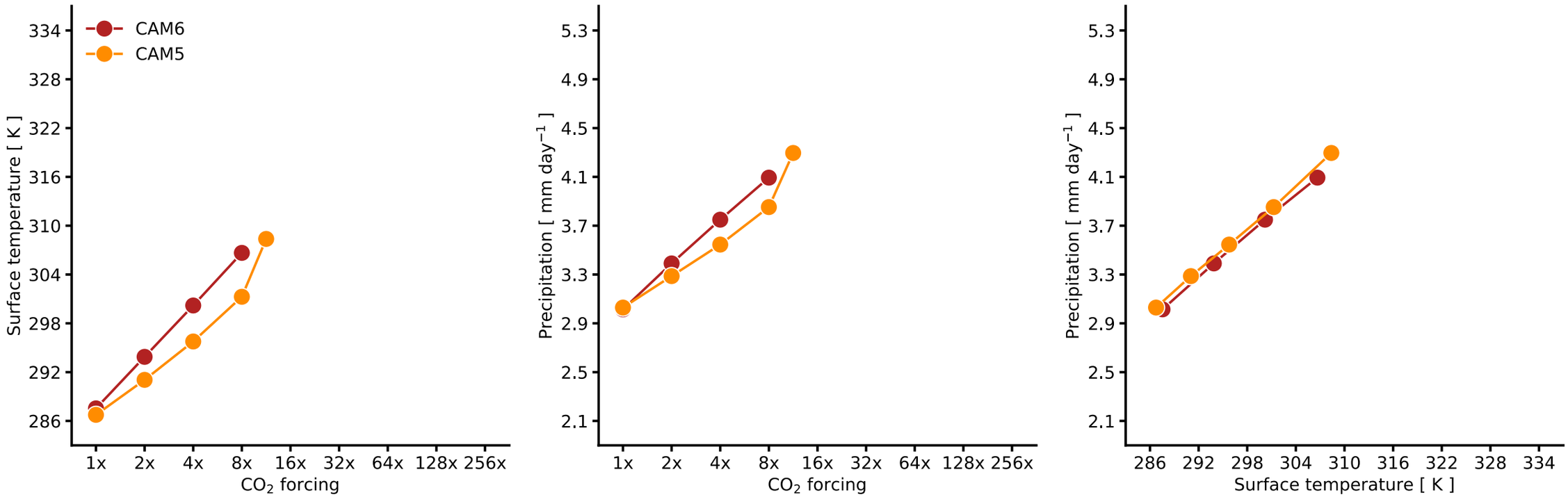

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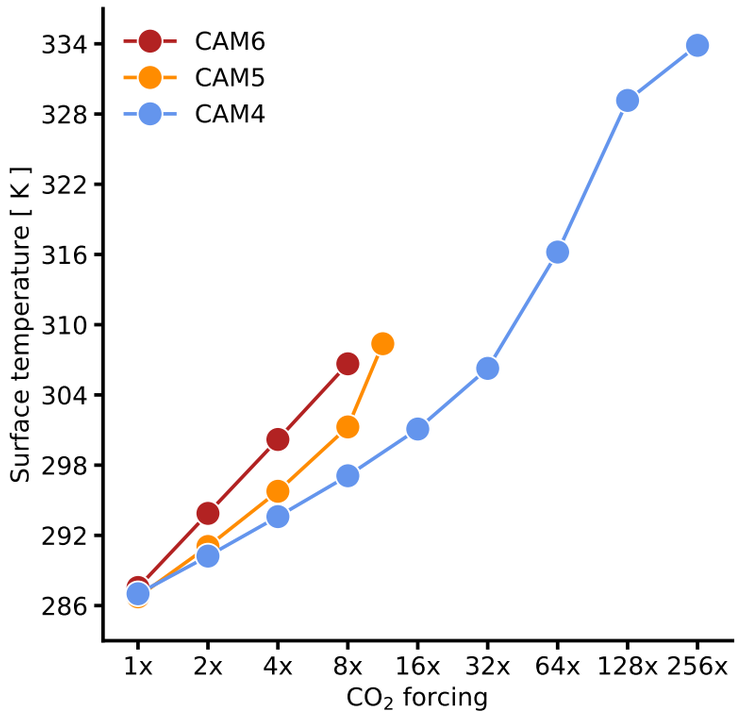

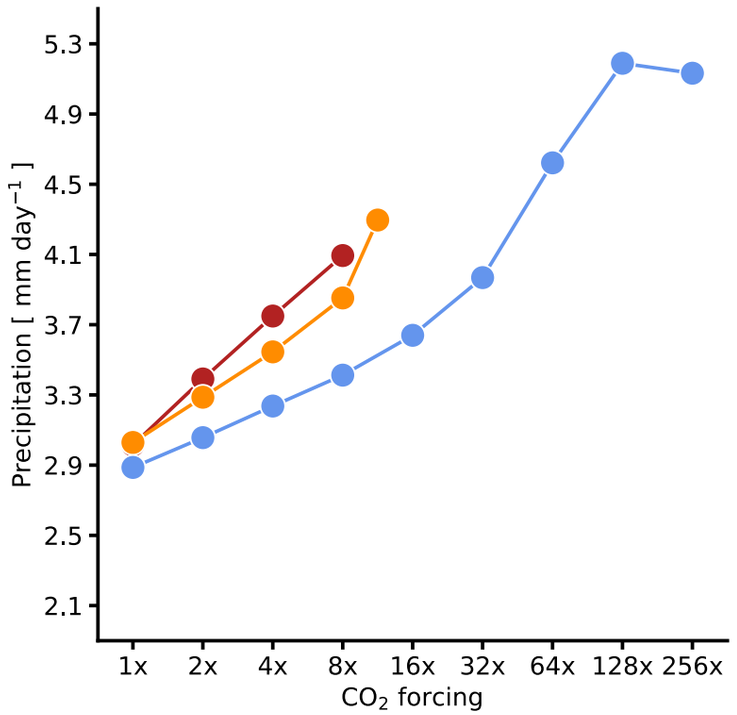

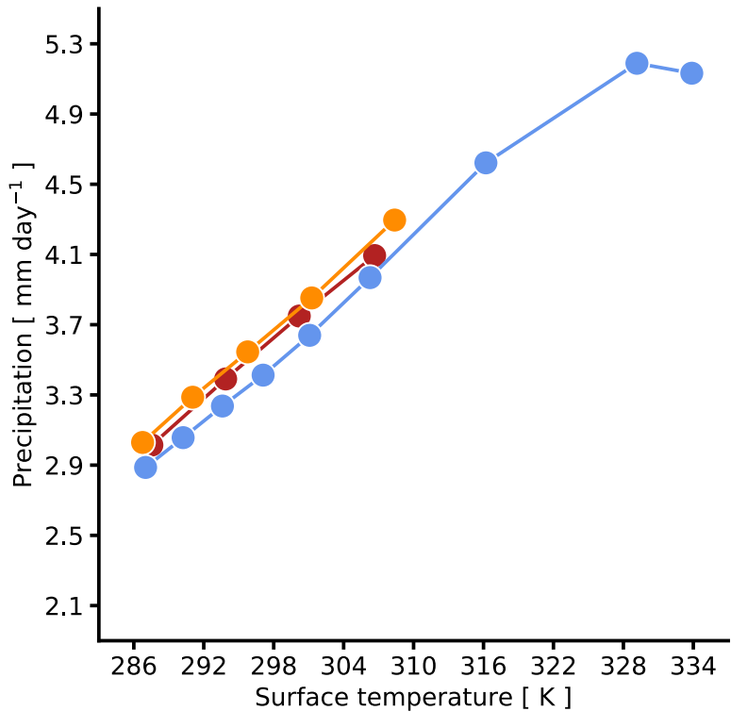

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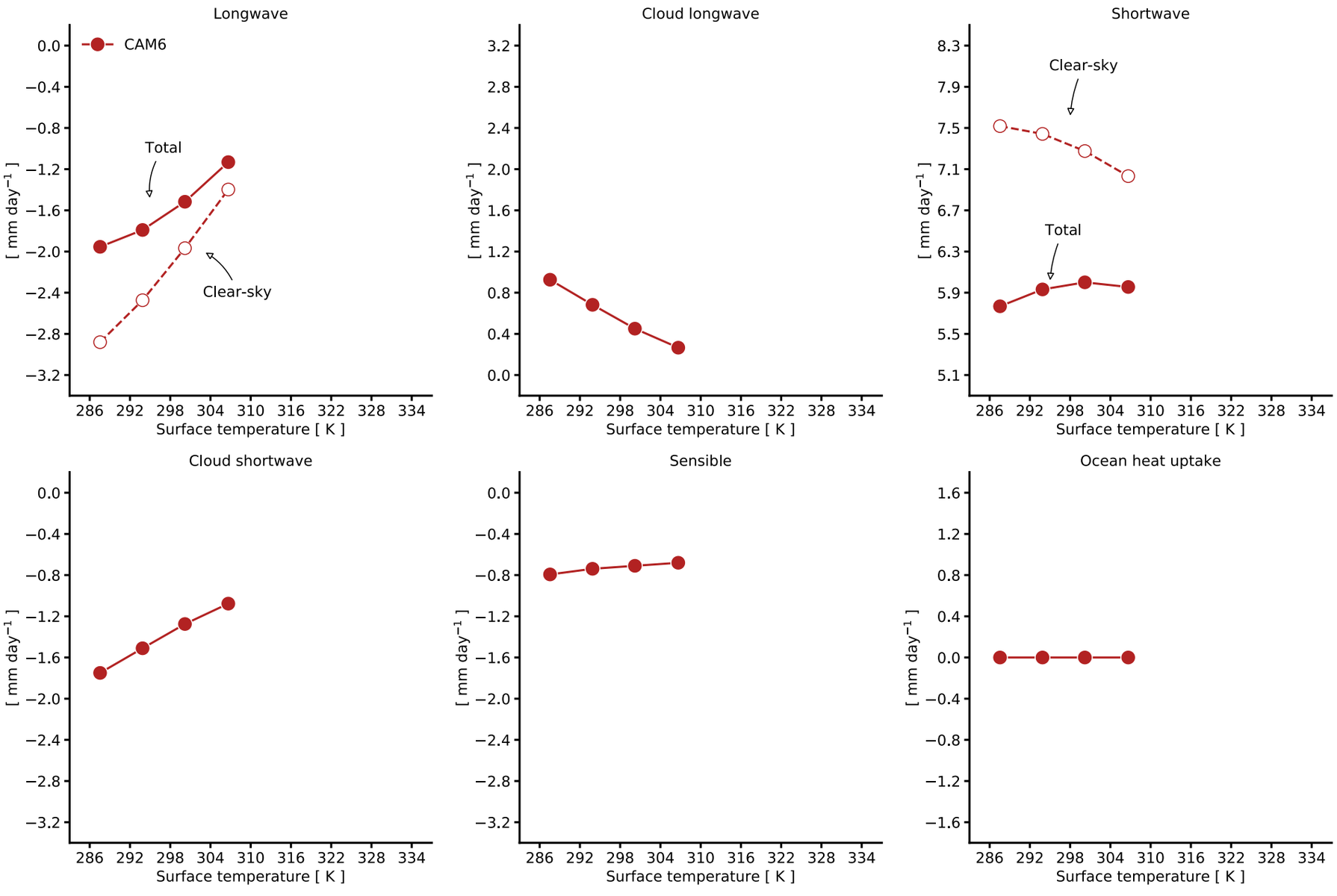

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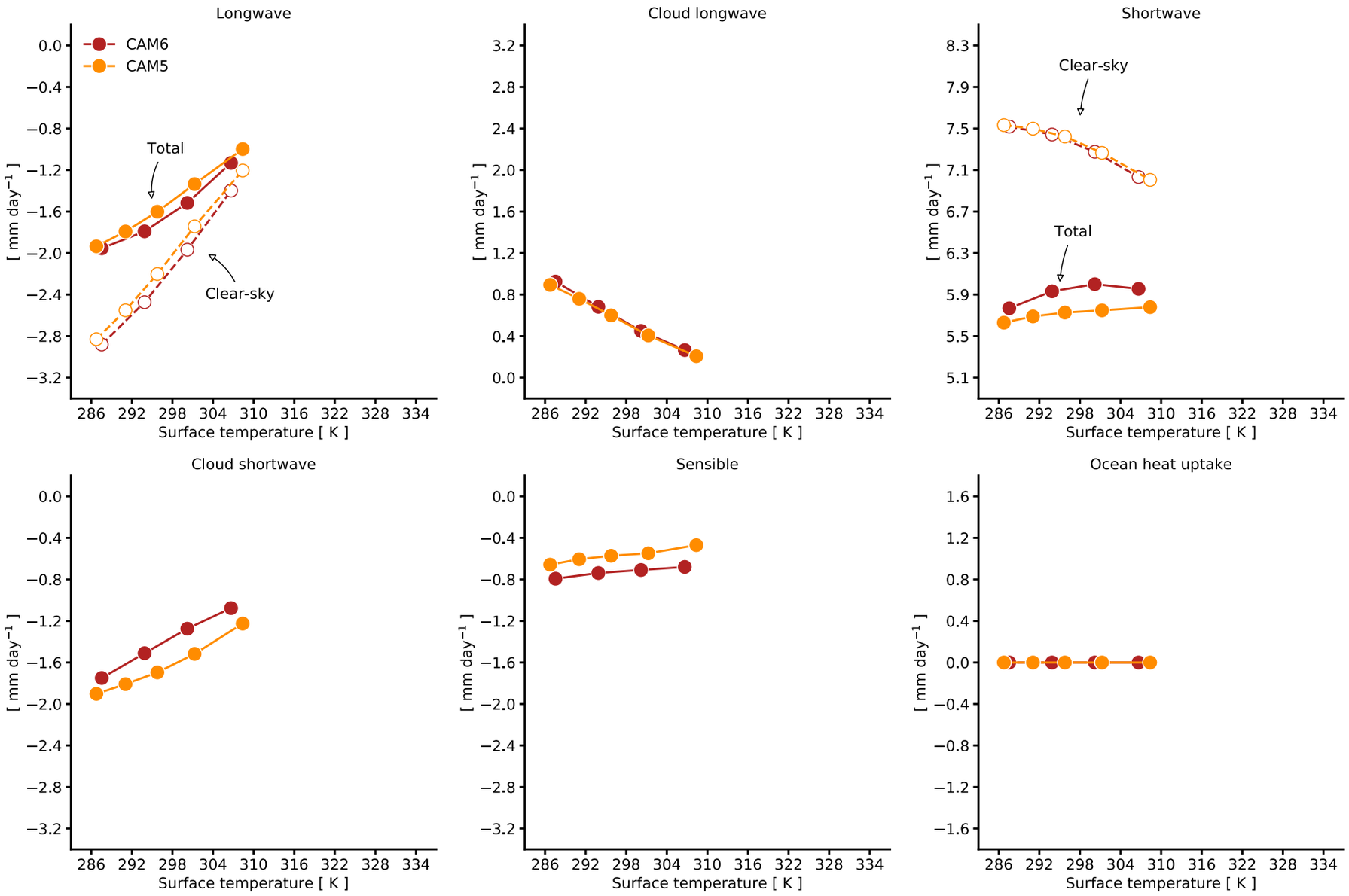

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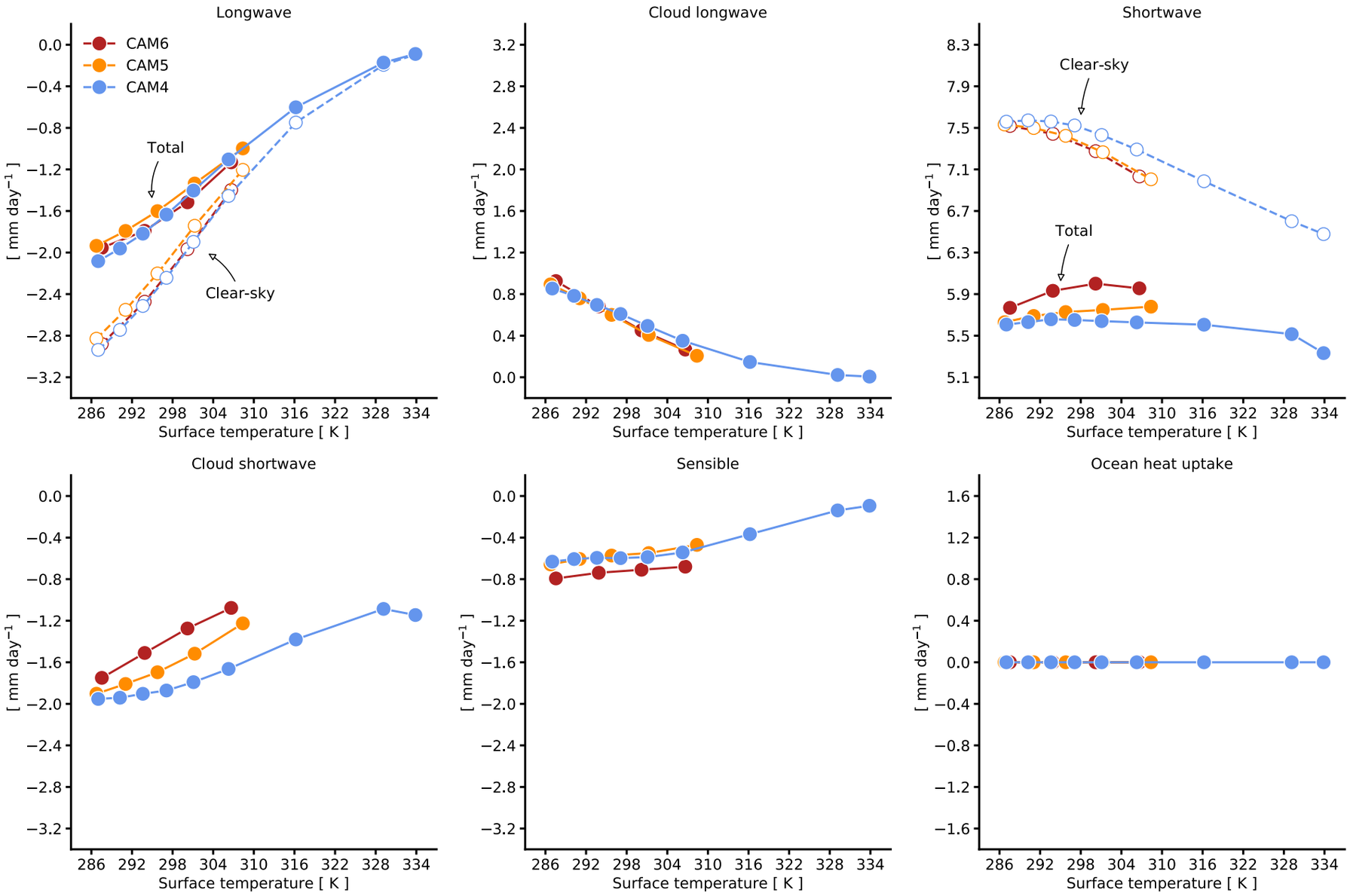
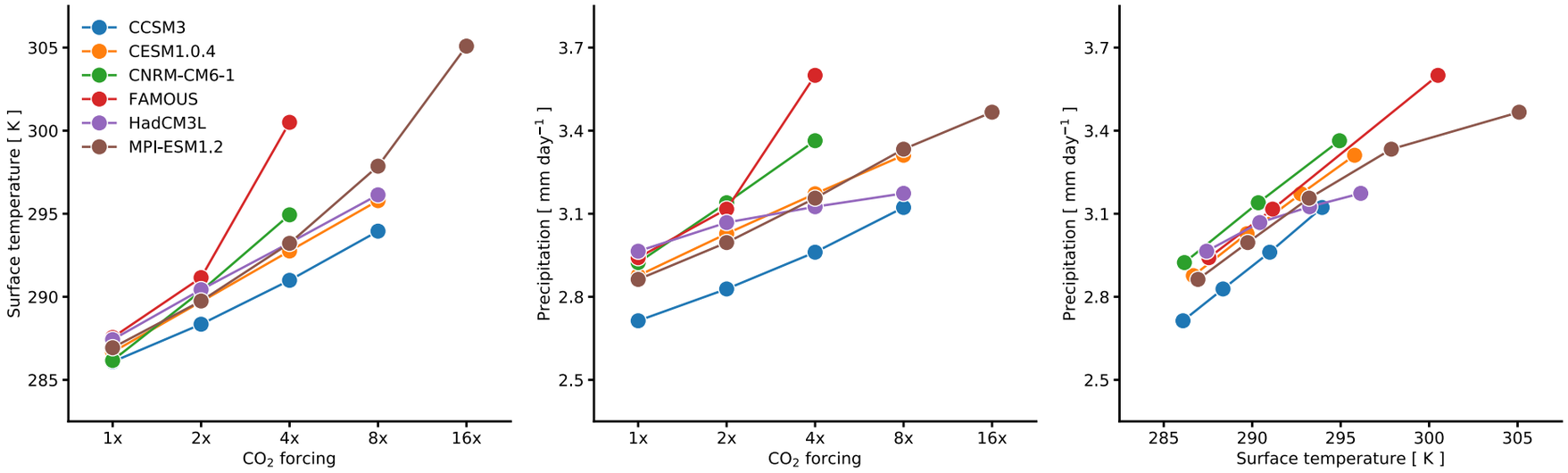


Precipitation in extremely warm climates simulated with comprehensive GCMs

- LongRunMIP fully-coupled simulations with 1xCO2, 2xCO2, 4xCO2, 8xCO2, and 16xCO2 (Rugenstein et al., 2019)

- Time-average of years 970-1000 after abrupt CO2 forcing (quasi-equilibrium)



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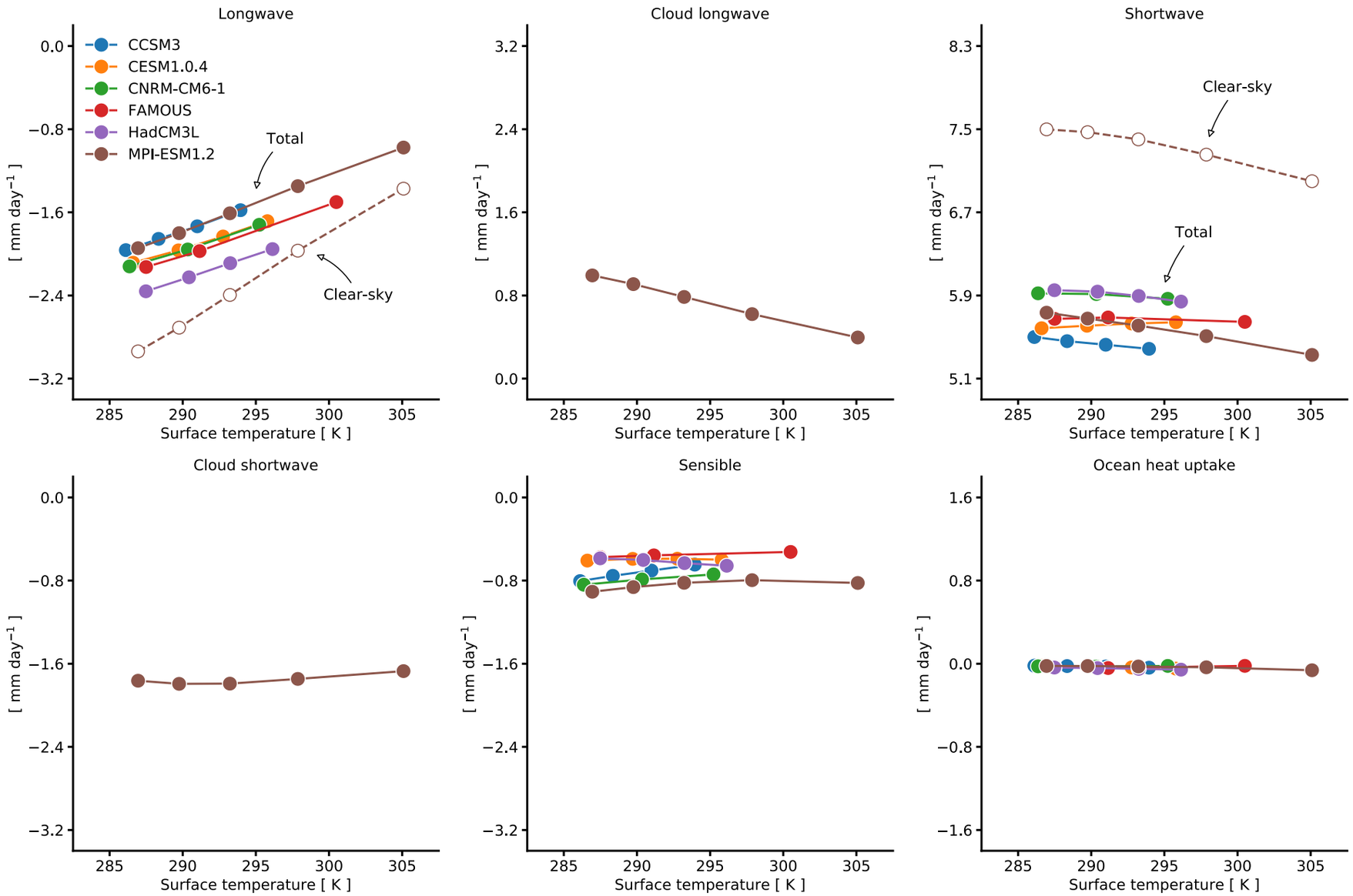


Summary

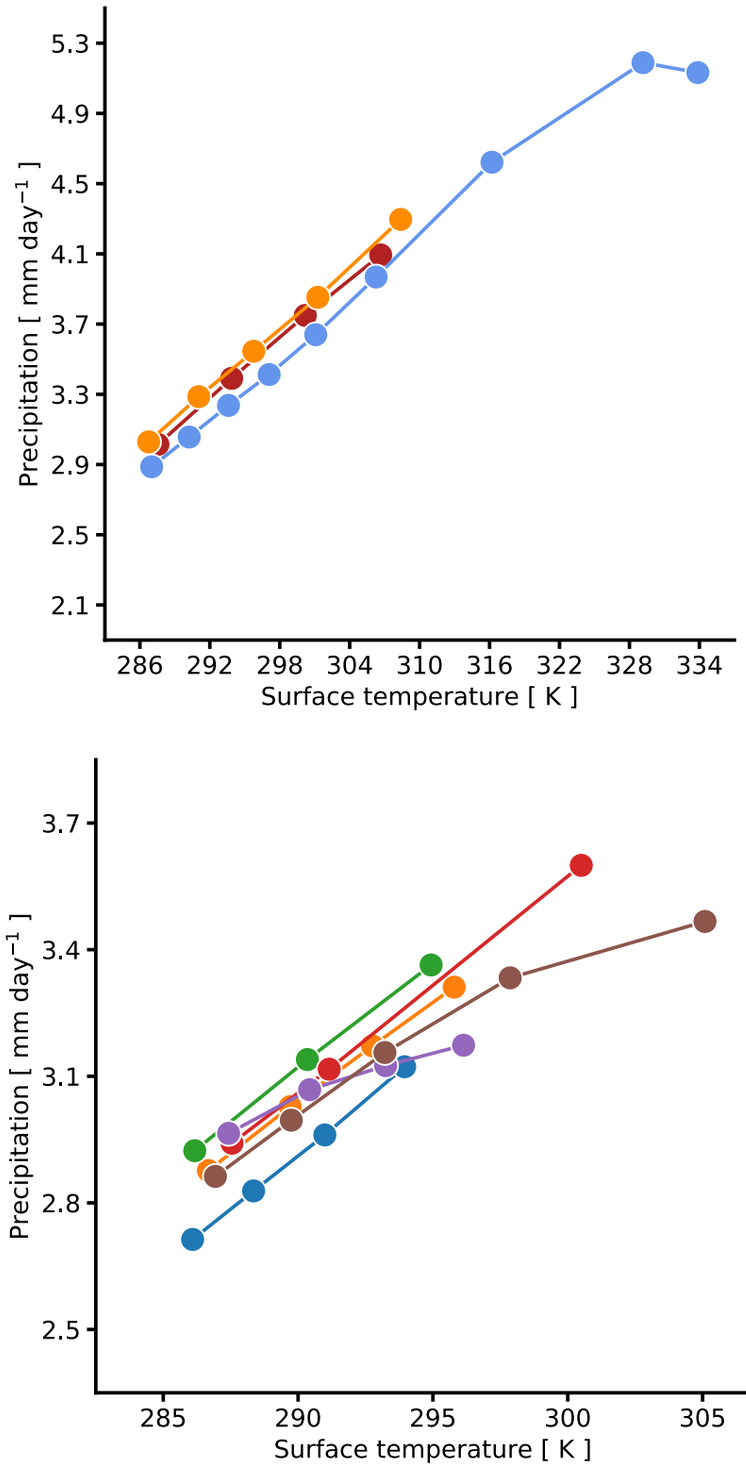
- Global precipitation increases linearly with global surface temperature for warming of about 10 K relative to today's climate.

- However, in extremely warm climates, precipitation saturates (and can actually decrease) despite increasing surface temperatures.

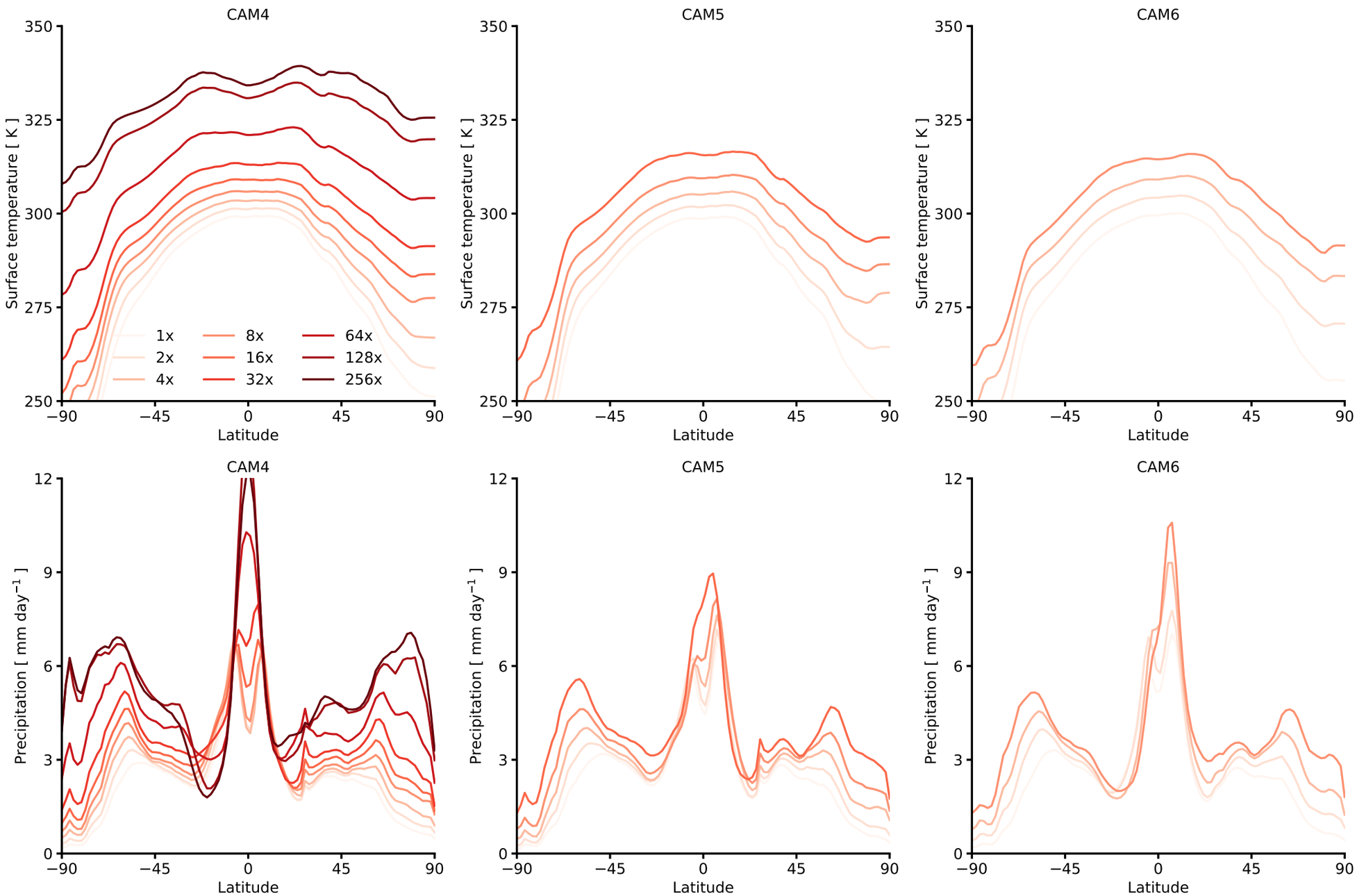
- This occurs because as the atmosphere becomes more optically thick, the net longwave radiative flux and sensible heat flux go to zero, and precipitation is balanced by the net shortwave radiative flux.

- As the atmosphere warms, water vapor increases, causing more absorption of shortwave radiation in the atmosphere, and less at the surface.

- Clouds are extremely weird at high CO2 concentrations and change this story greatly. We need better more simulations in extremely warm climates from a broader suite of GCMs.



Regional precipitation in extremely warm climates



$$P\left(x,y\right) = S\left(x,y\right) + L\left(x,y\right) + \nabla \cdot F_{\mathrm{dry}}\left(x,y\right) - H\left(x,y\right)$$

Muller and O'Gorman, (2011)

Questions?

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www.davebonan.com

- D.B. Bonan, T. Schneider, J. Zhu, and T. Mauritsen (in preparation): **Global and regional precipitation in extremely warm climates simulated with comprehensive GCMs.**