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Facets of the Tropical High-Cloud Feedback

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Tropical high clouds are the cloud type contributing most to the uncertainty in climate sensitivity since their feedback on global warming remains poorly constrained.

Part of the reason for this is that global circulation models do not resolve what is at the core of the high-cloud radiative effect: the balance between thin, warming, and thick, cooling clouds. We investigate how high clouds with different thicknesses contribute to the total feedback with a set of storm-resolving simulations that resolve individual high clouds. We conduct three aquaplanet simulations with prescribed sea surface temperatures: control, 2 K and 4 K uniform warming. We use ice water path, the total amount of cloud ice within a column, as a measure for cloud thickness. This allows us to decompose the total high-cloud radiative effect into the cloud radiative effect of each ice water path and its frequency of occurrence.

Previous studies came to the conclusion that the high-cloud area should decrease with warming, yielding a negative feedback. However, we find that while high clouds do decrease with warming, this affects warming and cooling clouds similarly, resulting in a near-neutral feedback. In addition to this change in high-cloud frequency, their cloud radiative effect also changes with warming. The positive longwave effect of all high clouds increases with warming, since high-cloud temperatures remain approximately fixed as the surface warms. This causes a positive feedback of $0.33\,W\,m^{-2}K^{-1}(+2\,K)$ and $0.25\,W\,m^{-2}K^{-1}$ $(+4\,K)$. The shortwave radiative effect of deep convective clouds becomes less negative with warming due to changes in the daily cycle of deep convection. Deep convective clouds become less likely to occur at daytime as the surface warms and hence reflect less sunlight, which decreases their shortwave radiative effect. This results in a positive feedback of $0.31\,W\,m^{-2}K^{-1}$ $(+2\,K)$ and $0.16\,W\,m^{-2}K^{-1}$ $(+4\,K)$. By resolving cloud thickness, our storm-resolving simulations show that heterogeneous high-cloud responses to warming combine to yield a positive total feedback.