Chasing clouds: Determining tropical cirrus origin and their radiative effects in a cloud-resolving model

Blaž Gasparini, Rachel Atlas, Martina Krämer, Aiko Voigt, Peter Blossey

The processes controlling tropical cirrus clouds are poorly understood, contributing to large uncertainty in estimating how clouds respond to global warming. A major challenge is distinguishing between cirrus formed by deep convective outflow (anvils) and those originating from in situ ice nucleation at temperatures below -40°C (in situ cirrus). These two cloud types are governed by different processes that may respond differently to warming, so distinguishing between them is important.

We implement passive tracers in the cloud-resolving model SAM used in a tropical channel setup to track the 3D evolution of cirrus from two different perspectives:

1. A detrainment perspective, useful for tracking the evolution of anvil clouds.
2. An ice nucleation perspective, useful for following the evolution of in situ cirrus.

The detrainment tracer shows that anvil cirrus rapidly lose ice crystals and become optically thinner as they age. The ice nucleation tracer highlights the formation of in situ cirrus in the very cold upper troposphere and shows a gradual decline in ice number over time.

Tracers provide insights into cirrus climatology. We find that at T<-65°C in situ cirrus dominate, making up over 70% of total tropical cirrus. While individual in situ cirrus have weaker radiative effects than anvils, their high frequency leads to a top-of-atmosphere radiative effect of around 3 W m^{-2} in both shortwave and longwave part of the spectrum, or about 7% of the total cloud radiative effects of tropical clouds. These results help clarify the distinct roles of anvil and in situ cirrus in shaping the tropical cloud radiative budget and improve our understanding of their potential climate feedbacks.