Does the Earth have a meso scale water vapour iris?

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Clouds and water vapour are strong regulators of the energy budget in the tropics. Tropical clouds are associated with convection, vertical motions arising from instability, and can be restricted to the lowest few kilometers within the atmosphere, or rise all the way to the 12-15km, in the form of thunderstorms similar to those that develop over Europe during the summer. In the tropics, these thunderstorms are concentrated in a region known as the inter-tropical convergence zone (ITCZ), situated over the warmest sea surface temperatures and over tropical continents around local summer time.

In this presentation, I will discuss the link between thunderstorms and the water vapour field. In a time mean sense, the tropics are often viewed as characterised by a moist, convective ITCZ surrounded by dry subsidence zones across the sub-tropics on scales of 1000km or more, with convective storms within the ITCZ locally moistening the environment and drying the atmosphere at larger distances through subsidence. As water vapour is the strongest greenhouse gas, these dry zones are very effective at allowing energy emitted from the earth’s surface to escape to space. However, this time-mean picture hides variations on the meso scale, which, with a typical scale of around 100 km, is also the typical size of a climate model grid box. I will show that in high-resolution models that can resolve convective storm motions run in very idealized configurations (cloud-resolving models), convective storms can spontaneously transition from a state where convection is randomly distributed to a state where convection is aggregated into clusters. This results in very strong local gradients of water vapor and a drier mean state, with more cooling to space even on these small spatial scales. Observations support the existence of strong relationships between convection, water vapor and sea surface temperatures and provide evidence of both random and clustered states at these scales in the tropics, with very sharp gradients in humidity within the deep moist zones.

That the degree of convection aggregation and clustering might depend on sea surface temperatures has strong implications for global climate, as it could act either as an iris effect or an inverse iris effect, respectively stabilising or destabilising the climate response to greenhouse gas perturbations. However, while global climate models with “parameterized” convection agree on a tendency for the width of the ITCZ to narrow in future climates (an iris effect), cloud-resolving models reveal a strong sensitivity of the onset and nature of convective clustering to different representations of moist physics and diffusion parametrisations, and there is little consensus between models. I will conclude with a personal perspective on how to leverage idealized models and new observations to make progress on this pressing challenge in climate science.

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ISTA Campus Raiffeisen Lecture Hall

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