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Do tropical islands warm or cool the troposphere?

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Tropical islands are commonly seen as hot spots that heat the troposphere, since during the day, they typically become warmer than the ocean. However, at the same time, they also become dryer (in terms of relative humidity), due to the soil's resistance to evaporate. The surface warm and dry anomaly is then propagated upwards into the troposphere by thunderstorms (deep convection) that frequently form over the islands. The vertical propagation of the anomaly happens because the warmer surface over land tends to push the induced diurnal convection towards a warmer moist adiabat. However, the drying of the land surface also pulls the clouds towards a colder moist adiabat, as more initial lifting along the dry adiabat is needed until saturation is reached. In other words, a dryer island leads to a more elevated cloud base, and thus, to convection at a colder moist adiabat. The formation of convective clouds over land results in a local density anomaly that is then communicated to the island's surroundings by gravity waves since the tropical atmosphere cannot sustain strong horizontal density gradients (WTG theory). Together these ideas allow formulating the hypothesis that surface temperature and humidity anomalies emerging over islands project onto the large-scale temperature profile of the troposphere. Who wins in influencing the troposphere, the surface warming or the drying? Or put differently, do islands heat or cool the troposphere?

We assess this hypothesis using a six-member ensemble of double-periodic convection-resolving Radiative-Convective Equilibrium (RCE) simulations (1006x1006x74 grid points), containing an archipelago of flat islands obtained from the Maritime Continent. In contrast to previous RCE simulations, the islands are represented by a land-surface scheme and are thus capable of representing not only the daytime anomaly in temperature but also that in relative humidity. We find that during episodes when precipitation occurs more frequently over land, the domain-mean (virtual) temperature in the mid-troposphere becomes colder. We also find that the drying (i.e, cooling) effect becomes pronounced for larger islands, and thus, removing a large island from the simulation also leads to a systematically colder domain-mean (virtual) temperature profile. The results suggest that islands may rather cool than warm the troposphere and that the inability of evaporation over land to keep up with the daytime surface warming is of key relevance for the temperature profile in the Maritime Continent.