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Bistability and hysteresis of the large-scale tropical circulation in idealized GCM simulations

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The potential impact of tipping points for climate dynamics is now widely recognized. Furthermore, paleoclimate records suggest that abrupt climate changes have indeed occurred in Earth's past, potentially on timescales which do not exceed a decade. Several tipping elements, involving various components of the climate system, such as the ocean circulation, sea-ice, continental ice sheets, vegetation, and their couplings, have been suggested. Yet, it remains virtually unknown whether the large-scale atmospheric circulation, the component of the climate system with shortest response time, may undergo bifurcations that could trigger abrupt climate change.

In this talk I will discuss the possibility of abrupt transitions of the large-scale circulation in the tropics. Specifically, I will consider potential reversals of the mean zonal winds, from the weak easterlies observed in current climate to a "superrotation" state with prevailing westerly winds. The superrotating state exhibits a strongly reduced Hadley circulation.

I will discuss positive feedback mechanisms and their relevance for the Earth across a hierarchy of models of increasing complexity. A low-dimensional model based on Rossby wave resonance exhibits bistability, and provides a simple criterion for the region of parameter space where this regime exists. We then study the nature of the transition to superrotation in a dry dynamical core, forced in an idealized manner. The main result is that there exists a parameter regime where the dry primitive equations support two coexisting states, with and without an equatorial jet. We will discuss the role of parameters such as the meridional temperature gradient and the boundary layer friction on the existence of this bifurcation.