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Influence of Continental Geometry on the Onset and Spatial Distribution of Monsoonal Precipitation

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Idealized modeling studies have provided the basis for significant progress on our conceptual and theoretical understanding of the fundamental dynamics of monsoons. For instance, aquaplanet simulations have shown how monsoon onset occurs as the tropical meridional overturning circulation transitions from an equinox, eddy-driven regime, to a monsoon, angular momentum conserving regime. This transition is mediated by internal dynamical feedbacks and can occur on an homogeneous lower boundary with low thermal inertia.

Here, we study monsoons over idealized zonally symmetric, fully saturated continents: The lower boundary is a slab ocean, with land and ocean differing only by the mixed-layer depth of the slab ocean, which is two orders of magnitude smaller over land than over ocean. The model is run with different zonally symmetric configurations of Northern Hemispheric land that extend poleward from southern boundaries at various latitudes. We find that the development of a monsoon with a rapid onset is seen only in simulations with a continent extending to tropical latitudes. For continents with more poleward southern boundaries and weaker hemispheric asymmetry, the main precipitation zone remains over the ocean, moving gradually into the summer hemisphere. A decrease in hemispheric asymmetry prevents the establishment of a reversed meridional gradient in lower-level moist static energy and, with it, of an angular-momentum cross-equatorial monsoonal circulation with a subtropical convergence zone. This suggests that in order to have the rapid onset of monsoonal precipitation, tropical regions of low thermal inertia may be necessary to facilitate the transition of the tropical circulation into a dynamical regime that restricts the degree to which eddy momentum fluxes influence the circulation strength and allows the cell to grow rapidly in strength and poleward extent. Implications for observed monsoons are discussed.