Seasonal behavior of the Hadley circulation: Role of continents and comparison with axisymmetric models

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A first-order understanding of the large-scale tropical circulation is often founded on the results from axisymmetric models. In these models, the Hadley circulation is driven by zonally-uniform atmospheric heating that is imposed by relaxing atmospheric temperatures to a specified radiative equilibrium temperature distribution. The seasonal behavior of the Hadley circulation is then explained in terms of the intensity of the resulting heating function, and the degree to which this heating is displaced off the equator. But an examination of the observed diabatic heating distribution indicates that the tropical heating is highly concentrated over the continents and western ocean basins, and is decidedly *not* zonally uniform. What are the implications of this lack of zonal symmetry for the seasonal behavior of the Hadley circulation?

Simulations with an AGCM and diagnosis of the NCEP reanalysis are used to argue that the physics of the seasonal behavior of the "real" Hadley circulation is not the same as predicted by an axisymmetric model. More specifically, the intensity of the Hadley circulation is not correlated with the latitude of maximum zonal heating, or even with the degree to which the heating is concentrated in latitude, in the NCEP reanalysis. The same is true of the Hadley circulation in the AGCM with one exception - the seasonality of the Hadley circulation in the AGCM occurs by the same physical processes as in the axisymmetric models when the AGCM has no continental surfaces and is forced with a zonally-uniform SST distribution that mimics the forcing imposed in the axisymmetric models.

Thus, these results suggest that the physical processes that are important for determining seasonal behavior of the MMC in the axisymmetric models are pre-determined by assumptions about shape of the heating function. We show that when the atmospheric heating has a pronounced peak in the tropics, the thermodynamics of vertical motion dominates the response of the circulation and produces the seasonal behavior simulated in axisymmetric models. However, the actual heating of the atmosphere over the continents is located much farther off the equator, and the resulting zonally-averaged heating is relatively across the tropics. This heating structure is associated with a more prominent role for the dynamics of the horizontal flow (and, thereby, friction) and horizontal temperature advection, and a different cause for the seasonal evolution of the Hadley circulation than that predicted by axisymmetric models.