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A unified perspective on the dynamics of axisymmetric monsoons and hurricanes

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Both monsoons and hurricanes have been idealized as circularly symmetric warm-core vortices on an f-plane. Yet, monsoons and hurricanes differ in various aspects, most notably ragarding their spatial scale and the strength of their surface winds. For both systems the highly nonlinear flow can be approximated in the nearly inviscid limit by semi-analytical theory. For the hurricane, this was achieved by K. Emanuel almost two decades ago, while for the monsoon this was done more recently by one of the authors. The latter work essentially modifies the ideas by I. Held, A. Hou, and A. Plumb regarding large-scale zonally symmetric circulations on a sphere, in order to apply them to circularly symmetric vortices on an f-plane.

The current work provides a unified perspective on the dynamics of hurricane- and monsoon-like vortices by identifying them as special limiting cases of a more general flow system. This more general system considers stationary axisymmetric balanced flow of a stably stratified dry non-Boussinesq atmosphere on an f-plane. Thermal forcing is implemented as relaxation towards a specified equilibrium temperature T_e. The flow is dissipated through surface friction, and it is assumed to be almost inviscid in the interior. The heating is assumed supercritical, which means that T_e does not allow a regular thermal equilibrium solution with zero surface wind, and which gives rise to a cross-vortex secondary circulation.

Essential properties of the primary circulation are controlled by the ratio between the forcing time scale and the dissipation time scale. This result is derived from a scale analysis, which is verified by numerical solutions spanning a wide range of the parameter space. When the forcing time scale is much shorter than the dissipation time scale, the temperature approximates T_e and the vortex shows properties which

can be associated with a hurricane including strong cyclonic surface winds. On the other hand, when the ratio of time scales is opposite, the secondary circulation keeps the temperature significantly away from T_e and the vortex shows properties which can be associated with a monsoon including near zero surface winds. It is shown how the semi-analytical theories for the two limiting cases fit into the more general system studied here. In the hurricane limit, balance and symmetric stability impose constraints on T_e which need to be satisfied in order for the vortex to be realizable.