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Bi-stability in turbulent, rotating spherical Couette flow

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Flow between concentric spheres of radius ratio $\eta = r_\mathrm{i}/r_\mathrm{o} = 0.35$ is studied in a 3 m outer diameter experiment. We have measured the torques required to maintain constant boundary speeds as well as localized wall shear stress, velocity, and pressure. At low Ekman number $E = 2.1\times10^{-7}$ and modest Rossby number $0.07 < Ro < 3.4$, the resulting flow is highly turbulent, with a Reynolds number ($Re=Ro/E$) exceeding fifteen million. Several turbulent flow regimes are evident as Ro is varied for fixed E. We focus our attention on one flow transition in particular, between $Ro = 1.8$ and $Ro = 2.6$, where the flow shows bistable behavior. For Ro within this range, the flow undergoes intermittent transitions between the states observed alone at adjacent Ro outside the switching range. The two states are clearly distinguished in all measured flow quantities, including a striking reduction in torque demanded from the inner sphere by the state lying at higher Ro. The reduced angular momentum transport appears to be associated with the development of a fast zonal circulation near the experiment core. The lower torque state exhibits waves, one of which is similar to an inertial mode known for a full sphere, and another which appears to be a strongly advected Rossby-type wave. These results represent a new laboratory example of the overlapping existence of distinct flow states in high Reynolds number flow. Turbulent multiple stability and the resilience of transport barriers associated with zonal flows are important topics in geophysical and astrophysical contexts.

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