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Statistical Mechanics of the Geometric Control of Flow Topology in Two-Dimensional Turbulence

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We apply the principle of maximum entropy to two dimensional turbulence in a new fashion to predict the effect of geometry on flow topology. We consider two prototypical regimes of turbulence that lead to frequently observed self-organized coherent structures. Our theory predicts bistable behavior that exhibits hysteresis and large abrupt changes in flow topology in one regime; the other regime is predicted to exhibit monstable behavior with a continuous change of flow topology. The predictions are confirmed in fully nonlinear numerical simulations of the two-dimensional Navier-Stokes equation.

These results suggest an explanation of the low frequency regime transitions that have been observed in the non-equilibrium setting of this problem. Following further development in the non-equilibrium context, we expect that insights developed in this problem should be useful in developing a better understanding of the phenomenon of low frequency regime transitions that is a pervasive feature of the weather and climate systems. Familiar occurrences of this phenomenon—wherein extreme and abrupt qualitative changes occur, seemingly randomly, after very long periods of apparent stability—include blocking in the extra-tropical winter atmosphere, the bimodality of the Kuroshio extension system, the Dansgaard-Oeschger events, and the glacial-interglacial transitions.