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Non-equilibrium statistical mechanics of geophysical flows

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We describe the dynamics of two-dimensional and quasi-geostrophic flows with stochastic forces. It exhibits extremely long correlations times, related to multiscale dynamics, and collective behaviors such as bistability and multistability. We show that in regimes of weak forces and dissipation, dominated by the large-scale inertial dynamics, equilibrium statistical mechanics provides extremely precise predictions for the self-organized large-scale flows. This is true for a range of parameters much larger than could be expected, explaining a renewed interest for statistical mechanics approaches. Non-equilibrium theory, based on kinetic theories (or equivalently Mori-Zwanzig projections), gives explicit predictions for algebraic correlations of the velocity field, and for the large-scale mean flow. We also describe briefly recent applications to ocean jets and vortices, explaining the detailed structure of inertial mid-basin jets and both the structure, and westward and poleward drifts of oceans rings and eddies.

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