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Canonical Transfer and Multiscale Energetic Processes in Complex Ocean Circulations

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We here summarize the recent development of a portable self-contained system to unravel the intricate multiscale energetic processes from real ocean and atmosphere flows, which are in nature highly nonlinear and intermittent in space and time. Of particular focus are the interactions among large-scale, meso-scale, and sub-mesoscale processes. We first introduce the concept of scale window, and a new mathematical apparatus called multiscale window transform (MWT) by Liang and Anderson (SIAM J. MMS 6, 437-467, 2007). Established on MWT is a rigorous formalism of multiscale transport, canonical energy transfer, and multiscale conversion, which makes a new methodology, localized multiscale energy and vorticity analysis (MS-EVA). A direct application of the MS-EVA is the development of a novel localized instability analysis, generalizing the classical notion of hydrodynamic instability to finite amplitude processes on irregular variable domains. The theory is consistent with the analytical solutions of Eady's model and Kuo's model, the bechmark models of baroclinic instability and barotropic instability; it is further validated with a vortex shedding control problem. We have put it to application with a variety of real ocean problems, which would be otherwise very difficult, if not impossible, to study. As an example, we will see how the complex circulation in Monterey Bay can be driven by winds through nonlinear instability, and how winds may excite the ocean via an avenue which is distinctly different from the classical paradigms.