Nonlinear Scale Interactions and Energy Pathways in the Ocean

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currents and eddies pervade the ocean and play a prime role in the general cir-
culation and climate. The coupling between scales ranging from \( O(10^4) \) km down 
to \( O(1) \) mm presents a major difficulty in understanding, modeling, and predicting 
oceanic circulation and mixing, where the energy budget is uncertain within a factor 
possibly as large as ten. Identifying the energy sources and sinks at various scales 
can reduce such uncertainty and yield insight into new parameterizations. To this 
end, we refine a novel coarse-graining framework to directly analyze the coupling 
between scales. The approach is very general, allows for probing the dynamics si-
multaneously in scale and in space, and is not restricted by usual assumptions of 
homogeneity or isotropy. We apply these tools to study the energy pathways from 
high-resolution ocean simulations using LANL’s Parallel Ocean Program. We ex-
amine the extent to which the traditional paradigm for such pathways is valid at 
various locations such as in western boundary currents, near the equator, and in the 
deep ocean. We investigate the contribution of various nonlinear mechanisms to the 
transfer of energy across scales such as baroclinic and barotropic instabilities.