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The Influence of Nonlinear Mesoscale Eddies on Oceanic Chlorophyll

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High-resolution sea-surface height fields have revealed that features previously interpreted as linear Rossby waves are in fact nonlinear mesoscale eddies. We analyze 10 years of satellite measurements of sea-surface height and concurrent upper-ocean chlorophyll concentration to show that these nonlinear eddies exert a strong influence on oceanic biology, thus requiring reassessment of the underlying mechanisms that have previously been used to explain the observed covariability of sea surface height and chlorophyll. Globally, the dominant mechanism is shown to be eddy-induced horizontal stirring of the ambient chlorophyll field. In some regions, highly nonlinear mesoscale eddies are observed not only to stir the ambient chlorophyll field, but also to trap chlorophyll within their cores.

In order to understand the nature of the eddy influence on chlorophyll observed by spaceborne sensors, a $1\frac{1}{2}$-layer nonlinear quasigeostrophic model is seeded with random Gaussian eddies with statistical distributions of amplitude, scale and frequency of occurrence of the eddies observed in high-resolution sea-surface height fields. The model eddies propagate through an ambient tracer field that varies meridionally and zonally similar to the observed distribution of chlorophyll and with a relaxation time scale intended to mimic that observed in marine phytoplankton blooms. The sensitivity of the chlorophyll response to mesoscale eddies is investigated by varying the degree of nonlinearity of the eddies and the geographical distribution and relaxation time scale of the ambient chlorophyll field. Although the model does not include any active biology, it is able to reproduce many aspects of the observed influence of mesoscale eddies on chlorophyll. This suggests that active biology plays a secondary role in the mesoscale distribution of chlorophyll variability. Exceptions to this abiotic response are documented from case studies of the satellite observations.