Lab researchers develop models to analyze mixing in the ocean

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Many scientists expect that carbon emitted from the burning of greenhouse gases and its accompanying heat will be predominantly sequestered within the deep ocean instead of the atmosphere. Understanding the mechanisms and quantifying the rate and variability of this sequestration has profound implications for predicting the rate of atmospheric warming over the next century. Los Alamos researchers created models to quantify the horizontal and vertical structure of mixing in the ocean and its dependence upon eddy velocities. Understanding the processes driving mixing is vital for ocean and climate modeling.

Significance of the research

Deep ocean heat and carbon storage are dependent on heat transfers driven by mesoscale eddy mixing. Ocean mesoscale eddies are the “weather” of the ocean, with typical horizontal scales of less than 100 km and timescales on the order of a month. Mesoscale ocean eddies are currents which flow in a roughly circular motion around the center of the eddy. Oceanic eddies are usually composed of water masses that are different from those outside of the eddy. The water within an eddy usually has different temperature and salinity characteristics compared with the water outside of the eddy. Eddies carry heat, carbon, and other biogeochemical tracers into the deep ocean, aiding carbon and heat sequestration. The eddies also supply nutrients to coastal zones and the surface ocean where plankton blooms may result. Transport and mixing regulates the global climate and the distribution of natural marine resources.

Global climate simulations are just beginning to be able to resolve the largest of these key scales. However, some mixing due to eddies is lost in current simulations because the small scales are not adequately resolved. The models that the Laboratory researchers developed for ocean model mixing lead to an improved understanding of mesoscale eddy mixing. This information increases global climate simulation accuracy through better representation of deep ocean heat and carbon fluxes. Knowledge of dominant scales associated with mesoscale eddies enables a better understanding of the resolution requirements for the Coupled Model Intercomparison Project, the framework used for comparison of global coupled ocean-atmosphere general circulation models.

Research achievements

The Laboratory team developed models to analyze mixing in the ocean. The Model for Prediction Across Scales-Ocean (MPAS-O) is a global, multiscale, ocean code that simulates spatial and temporal scales ranging from coastal dynamics to basin-wide circulations. The researchers created the Lagrangian In-situ Global High-performance particle Tracking (LIGHT) analysis module within the Model for Prediction Across Scales Ocean for rapid calculations. The scientists conducted ocean simulations in an idealized mid-latitude ocean basin to Simulate Mesoscale Ocean Activity (SOMA) and eddy mixing. Los Alamos researchers designed the SOMA model to investigate equilibrium mesoscale activity in a setting similar to the way that ocean climate models are deployed. The researchers performed simulations at eddy resolving 4, 8, 16 and 32 km resolution.

The simulations revealed that recirculation, with minimal mixing, occurs on the continental shelf. Wind drives a strengthened subtropical gyre (large-scale rotating ocean current) with respect to a subpolar gyre in the interior basin. These gyres form western boundary currents, which coalesce and separate to form a meandering, eastward zonal jet. Three-dimensional spatial structure calculations indicate that diffusivities (calculated from particle dispersions) are greatest near the ocean surface and attenuate at depth. The results highlight the capability of LIGHT to compute the horizontal and vertical structure of diffusivity within the high performance computing Model for Prediction Across Scales Ocean framework.

The research team

Lab researchers include Phillip J. Wolfram, Todd D. Ringler, Mathew E. Maltrud and Douglas W. Jacobsen of the Fluid Dynamics and Solid Mechanics group; and Mark R. Petersen of Computational Physics and Methods.

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Caption for image below: *Simulation shows gyres and an area of intense mixing. Lat is latitude, and Lon is longitude.*