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Coastal Ocean Modeling & Dynamics - ESS

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LONG-TERM GOALS

The long-term goal of this research is to improve our ability to understand and predict environmental conditions in the coastal ocean.

OBJECTIVES

The central objective of the proposed research is to explore problems in coastal ocean modeling and dynamics, including Lagrangian trajectory analysis and the various roles played in coastal ocean predictability by basic physical elements of coastal ocean circulation. The research is being conducted by a graduate student, in collaboration with the PI.

APPROACH

The central activity of the proposed research is the development and analysis of a set of high-resolution numerical simulations of the Oregon coastal ocean that extend the recent work of Rivas and Samelson (2011), Kim et al. (2009), Kim et al. (2011), and Springer et al. (2009). The simulations and analysis are being carried out by graduate research assistant Rodrigo Duran. The research is currently focused primarily on describing and analyzing the dynamics of the poleward undercurrent (PUC). The PUC is a basic, persistent feature of eastern boundary current circulation regimes, but remains poorly understood and without an accepted dynamical explanation.

Research progress by Duran has included a nearly complete basic Eulerian and Lagrangian kinematic description of the undercurrent circulation in simulations for the year 2005, using an improved model configuration with smoothed bathymetry to prevent the development of spurious pressure gradients over the upper continental slope. To supplement the direct, Eulerian analysis of model mean poleward flow as a function of time and location, Duran has used forward integrations of conserved Lagrangian label and tracer fields, in order to obtain complementary and potentially more complete information on fluid parcel motion. Such techniques have been used successfully in some previous coastal simulations (e.g., Kuebel Cervantes et al., 2003, 2004; Springer et al., 2009) and offer the promise of a more complete representation and visualization of the complex patterns of Lagrangian motion in the coastal zone.

Duran's recent and current research under this project is focused on the dynamical analysis of these simulations, with particular attention to the model PUC regime.

WORK COMPLETED

The Eulerian and Lagrangian analysis of poleward mean flows in simulations for year 2005 has been essentially completed (R. Duran and R. Samelson, "Eulerian and Lagrangian kinematics of a model eastern-boundary poleward undercurrent," manuscript to be submitted). Work has begun on the dynamical analysis of these flows. Local momentum balances have been computed and various averages analyzed. Preliminary steps have been taken toward an analysis of the vorticity balances.

RESULTS

The analysis of local momentum balances showed the expected dominance of geostrophic balance for points in the undercurrent region. Away from surface and bottom boundary layers, both model-grid momentum-balance components are typically dominated by geostrophic terms, while the meridional momentum balance shows significant departures from geostrophy, typically asociated with advective or local acceleration contributions (Figure 1).

Pressure anomalies, computed as monthly-mean depth-averages of dynamic height anomaly, show a tendency for persistent high values in the southern part of the domain, and low values in the northern part of the domain, over depth ranges of 150-500 m and 500-1250 m (Figure 2). The implied south-to-north pressure gradient force is broadly consistent with the mean model Eulerian PUC flow (Figure 3). However, a local correspondence of mean northward flow and mean pressure-gradient force is not clearly evident. Moreover, the dynamics establishing the northward pressure gradient have not been identified. A full understanding of the model PUC dynamics is likely to require comprehensive analysis of the model vorticity balances.

IMPACT/APPLICATIONS

The results have impact and application for understanding of biological and any other related Lagrangian processes in the coastal zone, including dispersal of passive floating or submerged objects, and development of extreme biological conditions such as hypoxia or anoxia, and for the understanding of general eastern boundary current regimes.

RELATED PROJECTS

This project is generally related to the coupled physical-chemical Oregon coast modeling project "Modeling Coastal Oxygen production and carbon sequestration" (NSF, co-PIs R. Samelson and B. Hales, OSU), and to the coastal-zone ocean-atmosphere modeling elements of the project "Mesoscale Coupled Ocean-Atmosphere Interaction from Scatterometry and Coupled Models" (NASA, co-PIs D. Chelton, R. Samelson, and E. Skyllingstad, OSU).

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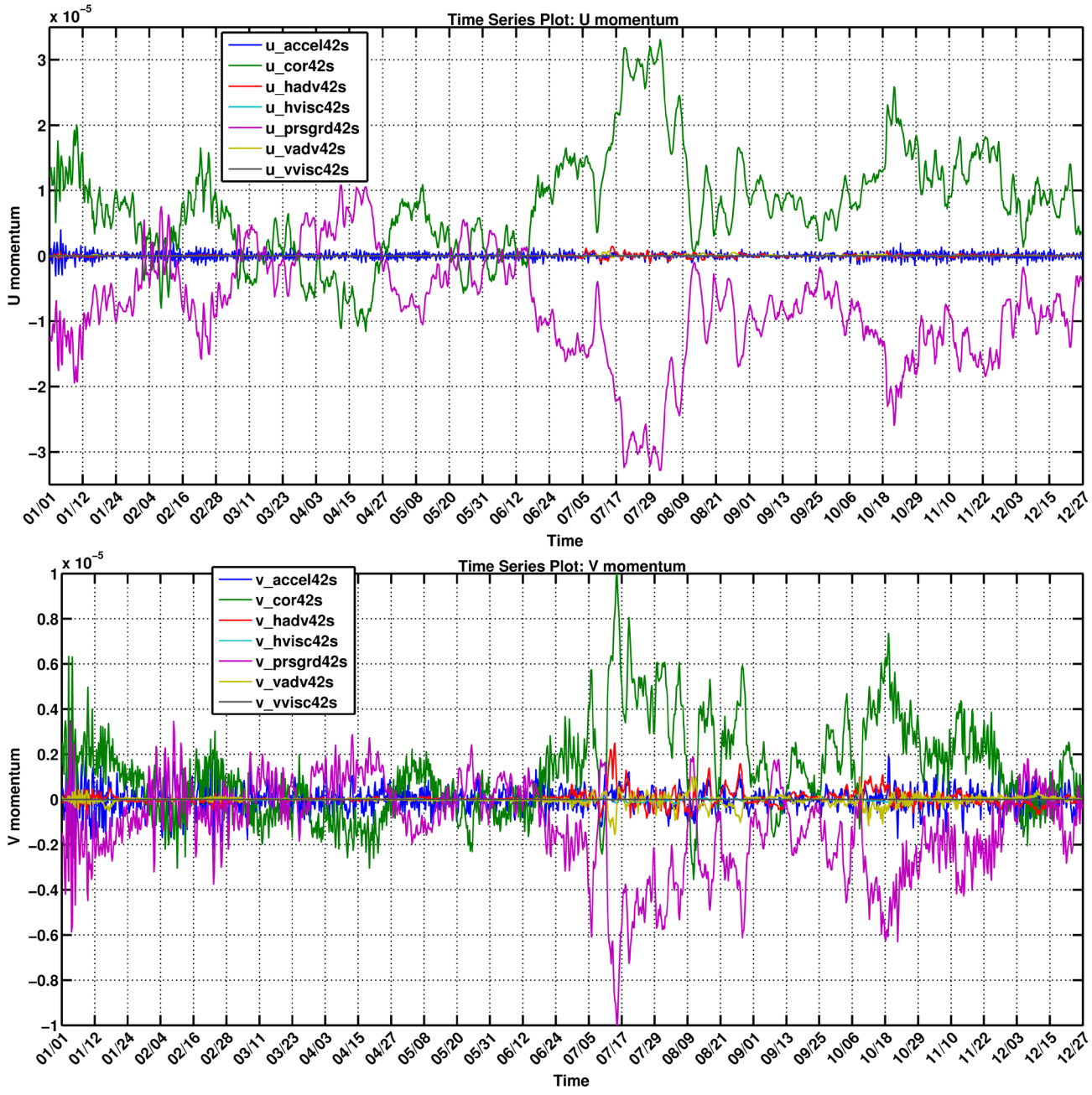

Figure 1. Time series of zonal (top) and meridional (bottom) momentum balance for a point within the undercurrent (-124.76^{o}W,42^{o}N,-250m) vs. month/day for year 2005. Both balances are geostrophic to first order. The meridional balance shows significant departures from geostrophic balance, with contributions from horizontal advection (red) and local acceleration (blue).

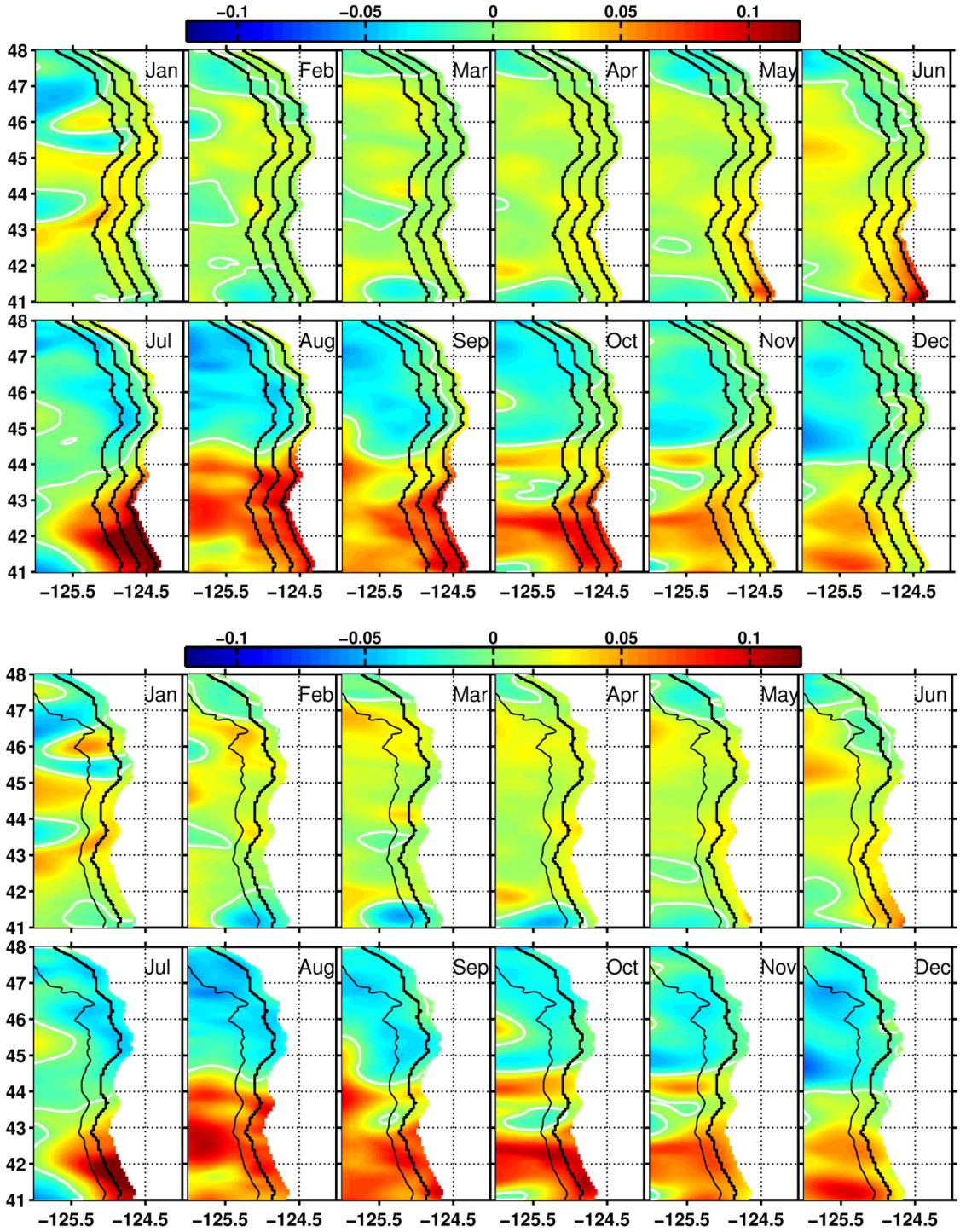

Figure 2. Monthly-mean depth-averaged dynamic height anomaly (m) for depths 150-500 m (upper panels) and 500-1250 m (lower panels) vs. longitude and latitude. The zero contour is indicated (white). The 200-m isobath and the longitude points 36 km west of the 200-m isobath (approximately the 850-m isobath) are also indicated (outer black contours), along with the points midway between these at constant latitude (central black contour).

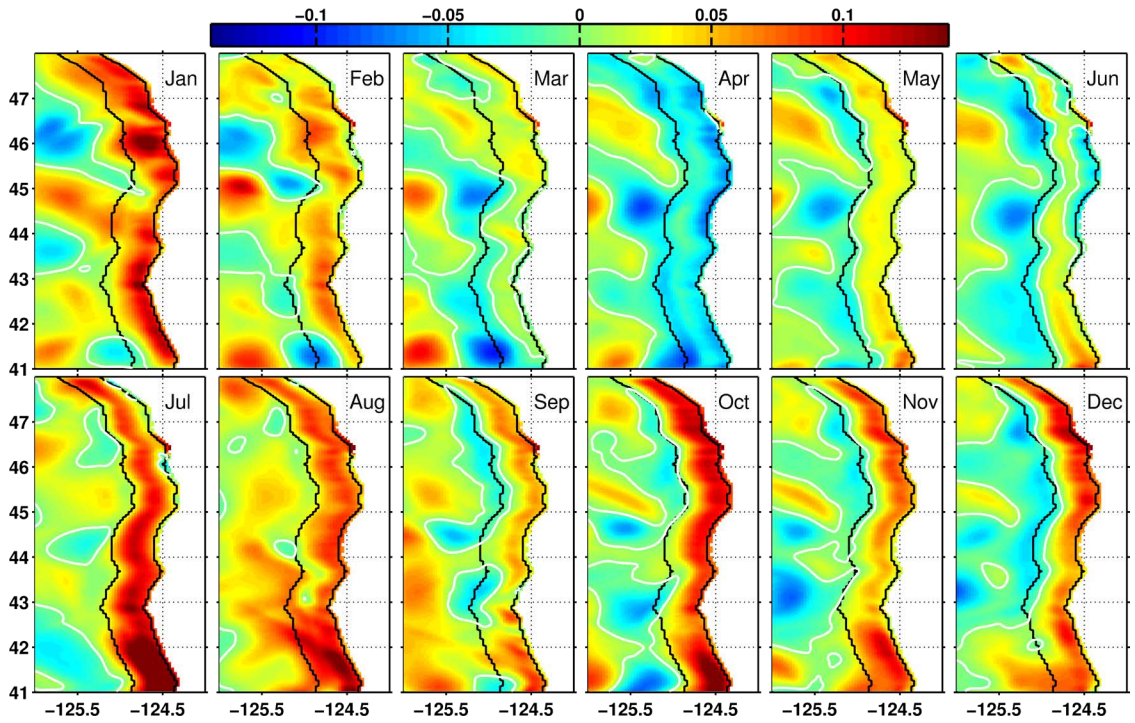

Figure 3. Monthly Eulerian-mean meridional velocity (m s^{-1}), averaged over the depth range 150 - 500 m (or the bottom, in depths less than 500 m). The zero contour is indicated (white). The 200-m isobath and the longitude points 36 km west of the 200-m isobath (approximately the 850-m isobath) are indicated (black contours). In white is the zero-velocity contour.