CASTS Talk

The Wind-Driven Ocean Circulation: Bifurcations, Simulations and Observations

2012 - 09 - 14 (Fri.)
15:00 - 16:00
308, Mathematics Research Center Building (ori. New Math. Bldg.)

The large-scale, near-surface flow of the mid-latitude oceans is dominated by the presence of a larger, anticyclonic and a smaller, cyclonic gyre. The two gyres share the eastward extension of western boundary currents, such as the Gulf Stream or Kuroshio, and are induced by the shear in the winds that cross the respective ocean basins. The boundary currents and eastward jets carry substantial amounts of heat and momentum; the jets also contribute to mixing in the oceans by their "whiplashing" oscillations and the detachment of eddies from them. We study the low-frequency variability of the wind-driven, double-gyre circulation in mid-latitude ocean basins, subject to time-constant or purely periodic wind stress. Both analytical and numerical methods of nonlinear dynamics are applied in this study. Symmetry-breaking bifurcations occur, from steady to periodic and aperiodic flows, as wind stress increases or dissipation decreases. The first bifurcation is of pitchfork or perturbed-pitchfork type, depending on the model's degree of realism. Oscillatory instabilities arise by supercritical Hopf bifurcation, with periods from a few months to a few years. Numerical evidence points to homoclinic orbits that connect high- and low-energy branches of steady-state solutions and induce interdecadal variability. These results are shown to be robust across a full hierarchy of models — quasi-geostrophic, shallow-water, and primitive-equation ones — including multi-layer and eddy-resolving ocean models. Coupled ocean– atmosphere models show the basin-scale variability to be still dominated by the intrinsic ocean variability. High resolution is necessary in the atmospheric component of these models in order to allow for proper coupling of the intraseasonal variability with the interannual one. Given such resolution, we obtain a promising explanation of the North Atlantic Oscillation. The results are compared with decade-long in situ and more recent, satellite observations of three ocean basins, the North and South Atlantic, and the North Pacific. Based on this comparison, we discuss what is and isn't known about the role of the oceans in climate variability. This talk reflects collaborative work with a large and still increasing number of people.

Please visit http://www.atmos.ucla.edu/tcd/ for their names, affiliations, and respective contributions.

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