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Kuroshio Large Meander Evolution simulated by an Eddy-Resolving Ocean Model

N. Schneider (1,2), B. Qiu (1) and H. Sasaki (3)

(1) Department of Oceanography, University of Hawaii, Honolulu, Hawaii, USA, (2) International Pacific Research Center, Honolulu, Hawaii, USA, (3) Earth Simulator Center, JAMSTEC, Yokohama, Japan, (nschneid@hawaii.edu, Fax-Nr. 1-808-956-9425)

The Kuroshio-Large Meander south of Japan is a prime example of interannual and decadal variability controlled by ocean intrinsic dynamics. Here, we examine the Large Meander evolution in a 1950-2003 hindcast of the Ocean Model for the Earth Simulator (OFES) in a near global domain with 0.1 degree spatial resolution, 54 levels in the vertical, and forced by observed surface fluxes.

This OFES simulation produces variance of sea level, temperature in the thermocline, ocean pressure in the region to the south of Japan that indicate vigorous variability of the Kuroshio Path. The vertical structure appears equivalent barotropic, and trapped in and above the thermocline. A complex empirical orthogonal function (CEOF) decomposition of anomalies of sea level or geostrophic stream function yields a leading mode that accounts for 63% of the variance in this area, and serves as an index for the large meander evolution. The phase of the principal component decreases at nearly monotonically in concert with systematic variations of the magnitude. The implied time scale is irregular, but covers several years to a decade.

The phase of the CEOF is used to derive composite states of the Kuroshio path. These show that when in the Large Meander state, the simulated Kuroshio detaches from the coast at Tokara Strait and returns to the coast just west of Izu Ridge. During the non-large meander state the Kuroshio follows the coast and departs at Kii peninsular to loop around the northern part of Izu Ridge. The preferred state of OFES is a large meander with the straight path occupied only 1/10 part of the time. These detachment of the Kuroshio at Tokara Strait and preponderance of the large meander are not in accordance with observations, and pose an exciting challenge to understand the model's

physics and dependence on parameters as to enhance its realism.

The systematic evolution of the leading principal component is used to determine the composite evolution of the Large Meander. Starting from a straight path, a meander forms close to Izu ridge. Over the course of several years, this meander grows and retrogrades until the Large Meander is established. The system then collapses very rapidly in a few months back to a straight path. This evolution is independent of upstream anomalies of the Kuroshio. Rather, it is associated with a build up of low potential vorticity (PV) in the anticyclonic recirculation on the southern side of the Kuroshio. Inside the large meander high potential vorticity is found to stream from small topographic features, a process that can only be simulated thanks to the high resolution of OFES. Overall, this suggests that lateral mixing in OFES is insufficient to increase the low potential vorticity water supplied by the Kuroshio from low latitudes to ambient values. Thus, the low PV water accumulates, until the system becomes unstable and resets.