Variability of the Kuroshio in the East China Sea, and its Relationship to the Ryukyu Current

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LONG-TERM GOALS

To characterize and understand (with our Korean and Japanese colleagues) the dynamics of the time varying structure and transport of the Western Boundary Current (WBC) system at 26^{O}–28^{O}N in the northwest Pacific Ocean, in particular the Kuroshio in the East China Sea (ECS), and the Ryukyu Current.

OBJECTIVES

On time scales ranging from two days to two years, our main objectives are the following:

(1) To observe the WBC variations near Okinawa on all relevant timescales, and, with ancillary information on wind forcing and arrival of offshore eddies, address a comprehensive set of hypotheses that have been proposed to account for the WBC structure and variability:
- that the combined WBC mean transport balances the average Sverdrup transport;
- that the phasing of the annual cycle in transport is lagged in a predictable manner from the seasonally varying Sverdrup transport, by the propagation of wind-generated Rossby waves from offshore;
- that variability in how the Kuroshio bifurcates upstream (off Taiwan) governs the proportion of transport that enters either the ECS Kuroshio or the Ryukyu Current;
- that eddies arriving at this WBC system from the ocean interior affect the upstream bifurcation and—as a result—the strength of these two currents.

(2) To measure the characteristic periods and phase speeds of Kuroshio meanders in the ECS and relate them to the strength of the transport.

(3) To investigate the relationship between the transports of the ECS Kuroshio and the Tsushima Current.

APPROACH

By deploying an array of inverted echo sounders (with additional sensors) in the Okinawa Trough, we expect to measure the time-varying current and temperature structure in the region, over a two-year time period simultaneous with similar measurements in the Ryukyu Current being made by Japanese scientists at the Japan Agency for Marine-Earth Science and Technology Center, Frontier Observational Research System for Global Change (JAMSTEC). Also, by deploying ADCP's on the continental shelf near our array, Korea Ocean Research & Development Institute (KORDI) scientists (with NICOP support) are measuring the flow over the outer shelf.

To determine temperature and specific-velocity-anomaly profiles from the inverted-echo-sounder measurements, we use the Gravest Empirical Mode (GEM) technique (Meinen and Watts, 2000) similar to that which has been successfully applied to the Kuroshio 700 km further downstream (Book et al., 2002).

Satellite altimeter data will be used to observe Ryukyu Current variations independently of the JAMSTEC measurements and to track eddies arriving in the region from the ocean interior.

WORK COMPLETED

Under ONR (DURIP) support, we first modified our inverted echo sounder design to incorporate the Aanderaa 3820R current measuring head. Then, after successful field testing, we constructed 12 CPIES instruments (current-and-pressure-sensor-equipped inverted echo sounders). In December 2002, six of these, together with five PIES instruments (pressure-sensor-equipped inverted echo sounders) belonging to NRL, were deployed in two lines north of Okinawa, each line being near and parallel to the PN-line (along which Japanese oceanographers take regular hydrographic sections). This deployment was carried out in conjunction with Dr. Hiroshi Ichikawa and his associates from JAMSTEC on their ship, *R/V Yokosuka*. On the same cruise our JAMSTEC colleagues deployed a similar array under the Ryukyu Current, on the opposite side of the Ryukyu Island chain. We took hydrocasts at all deployment sites after the instruments were deployed.

During 2004, Magdalena Andres, a doctoral student supported on this grant, has been assembling historical hydrographic data from the region and using them to compute suitable GEM's. These GEM's will be used to interpret the CPIES and PIES measurements after those instruments are recovered later this year. She has computed various types of GEM's including standard, SLACTS-deseasoned, residual, and multi-index. The best of these seems to be a multi-index GEM in which the GEM field is parameterized by sea-surface temperature (SST) in addition to acoustic travel time. In application, SST will be obtained from measurements by the radiometers aboard the Tropical Rainfall Measuring Mission (TRMM) and Advanced Microwave Scanning Radiometer for EOS (AMSR-E) satellites. These measurements, unlike infrared observations, can determine SST through non-precipitating clouds. Figure 1 shows the form of the resulting temperature GEM field. A specific-volume-anomaly GEM has also been computed.

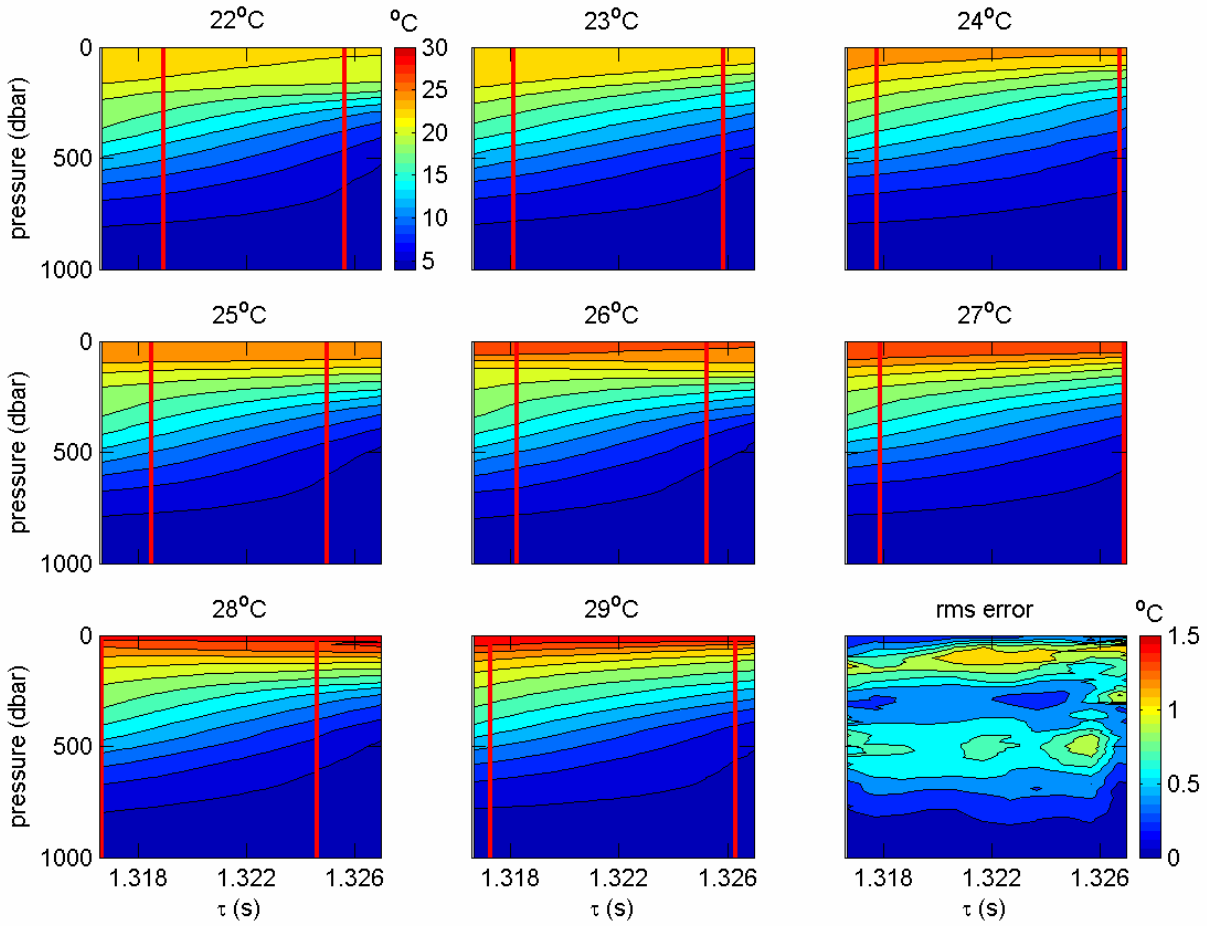

Figure 1. Multi-index temperature GEM for the East China Sea. Headings of first 8 panels indicate the lower bound of the corresponding SST bin. τ is 0-1000 dbar acoustic travel time. Lowest contour is 6˚C; interval is 2˚C. Vertical red lines show τ bounds of the hydrographic data in each case. 9th panel shows distribution of rms error associated with the GEM.

RESULTS

In November 2004, the CPIES and PIES instruments will be recovered using the Japanese ship *T/V Kagoshimamaru* (belonging to Kagoshima University). The data recorded by these instruments will not be available until after that time.

IMPACT/APPLICATIONS

The results from this study should lead to advances in our understanding of WBC dynamics, in particular the dynamics associated with spatiotemporal variability of meanders and bifurcations. This knowledge should be applicable to the Kuroshio at other latitudes, and also to other WBC's.

TRANSITIONS

Since our CPIES and PIES instruments (with their internally recorded data) have not yet been recovered, others are not yet able to make use of our work on this project.

RELATED PROJECTS

(1) The Korea Ocean Research and Development Institute (KORDI) is supported by ONR/NICOP to deploy ADCPs on the outer continental shelf near the PN-line in a project titled "Kuroshio Variability on the Shelf in the East China Sea." These instruments are recording the part of the Kuroshio transport which flows over the shelf. Dr. Kyung-Il Chang of KORDI deployed ADCP's at two sites during Oct–Nov 2003 and Nov 2003 – May 2004. The final deployment (May – Nov 2004) is currently in operation. During each of the first two deployments, one ADCP provided good data and the other did not.
(2) The JAMSTEC "Kuroshio Observation Project" (KOP) focuses on understanding the barotropic and baroclinic components of the WBC on either side of Okinawa, in the Ryukyu Island Chain. The JAMSTEC array is on the southeastern side of Okinawa, under the Ryukyu Current. Our array is on the northwestern side in the ECS Kuroshio. The JAMSTEC group has been experiencing difficulties in recovering some of the instruments in their array.
(3) Dr. Kuh Kim of Seoul National University, Korea has calibrated the voltage measured on a cable across the Korea/Tsushima Strait and is thus able to measure the time varying Tsushima Current transport while our array is deployed.

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