

Kuroshio Transport East of Taiwan and the Effect of Mesoscale Eddies

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LONG-TERM GOALS

The long-term goal of this project is to improve understanding and predictability of the regional circulation in the western North Pacific.

OBJECTIVES

The objective of this project is to characterize variability in the Kuroshio east of Taiwan and to understand (1) how this variability is related to variability in the upstream region, where the North Equatorial Current bifurcates forming the northward-flowing Kuroshio and the southward-flowing Mindanao Current and (2) how westward-propagating mesoscale eddies that arrive east of Taiwan from the ocean interior affect Kuroshio variability. This will establish the advective versus the eddy-driven contributions to Kuroshio variability east of Taiwan.

APPROACH

To determine the time-varying Kuroshio transport and velocity structure east of Taiwan, in situ measurements will be collected with moorings deployed across the Kuroshio for at least 1 year. This work is being carried out in collaboration with Dr. Jan Sen from the National Taiwan University (NTU), whose companion project is funded by the Taiwanese National Science Council.

The field work will be carried out along the 200-km long KTV1-line at the Yaeyama Ridge (**Figure 1**). The Yaeyama Ridge is about 100 km south of the Ilan Ridge, which separates the Philippine Basin from the East China Sea. The field experiment will include shipboard and time series measurements. The deployment cruise is scheduled for November 2012 on the Taiwanese research vessel OR-1.

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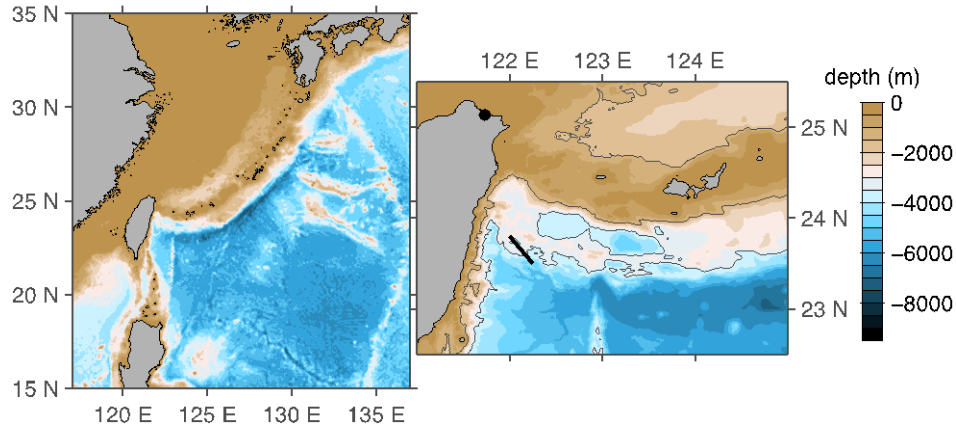


Figure 1. Map of the western North Pacific. Grey contours in the right panel show the 3500 m and 1500 m isobaths.

The KTV1-line will be equipped with 6 bottom-moored pressure-sensor-equipped inverted echo sounders (PIES) one of which will have an added current-sensor (CPIES). In addition, 3 tall moorings will be deployed along KTV-1, each instrumented with an upward-looking ADCP at 600 m depth and a deep RCM-8 current sensor (**Figure 2**). This combination of instruments will provide excellent horizontal and temporal resolution of the Kuroshio's time-varying position (including resolving a double-core structure when it is present) and will allow us to determine the full-water column transport time series without having to assume a level of no motion.

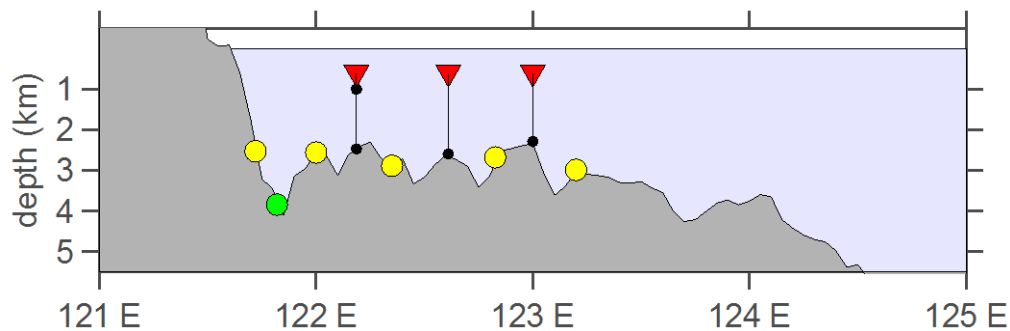


Figure 2. Cross-section along the Yaeyama Ridge showing the planned instrumentation for the KTV-1 line. Yellow circles indicate PIES, green circle CPIES, red triangles ADCP, black circles current meters.

WORK COMPLETED

In preparation for the field program, Vegan Mensah, a Ph.D. student from NTU, visited the Woods Hole Oceanographic Institution (WHOI) for two weeks in March 2012. M. Andres trained V. Mensah in the interpretation of acoustic travel time data collected by PIES. Using historical hydrography from the region, gravest empirical mode (GEM) lookup tables were constructed. These relate synthetic

acoustic travel time, calculated from an equation for the speed of sound in seawater (Del Grosso, 1974), to vertical profiles of temperature, salinity and density (Meinen, 2001).

The PIES and CPIES instruments were ordered this year. They have been built by the University of Rhode Island. The NTU instruments (3 PIES) were shipped to Taiwan in the beginning of September 2012 and have arrived at NTU. The WHOI instruments (2 PIES, 1 CPIES) were shipped to Taiwan at the end of September 2012.

Training for the deployment and recovery of PIES instruments has been scheduled for October 2012. M. Andres and Erran Sousa, an engineer from the University of Rhodes Island, will travel to Taipie, Taiwan to train the NTU technicians in advance of the November 2012 deployment cruise.

RESULTS

The analysis of historical hydrography (**Figure 3**) established that acoustic travel time can be used as a proxy for the vertical profiles of specific volume anomaly and temperature in the region east of Taiwan. The GEM lookup tables constructed from these data are critical for making use of acoustic travel time data to calculate vertical velocity shear. This will enable calculation of a timeseries of the Kuroshio's absolute geostrophic velocity along the KTV-1 line (Donohue et al., 2010) once the mooring data have been collected.

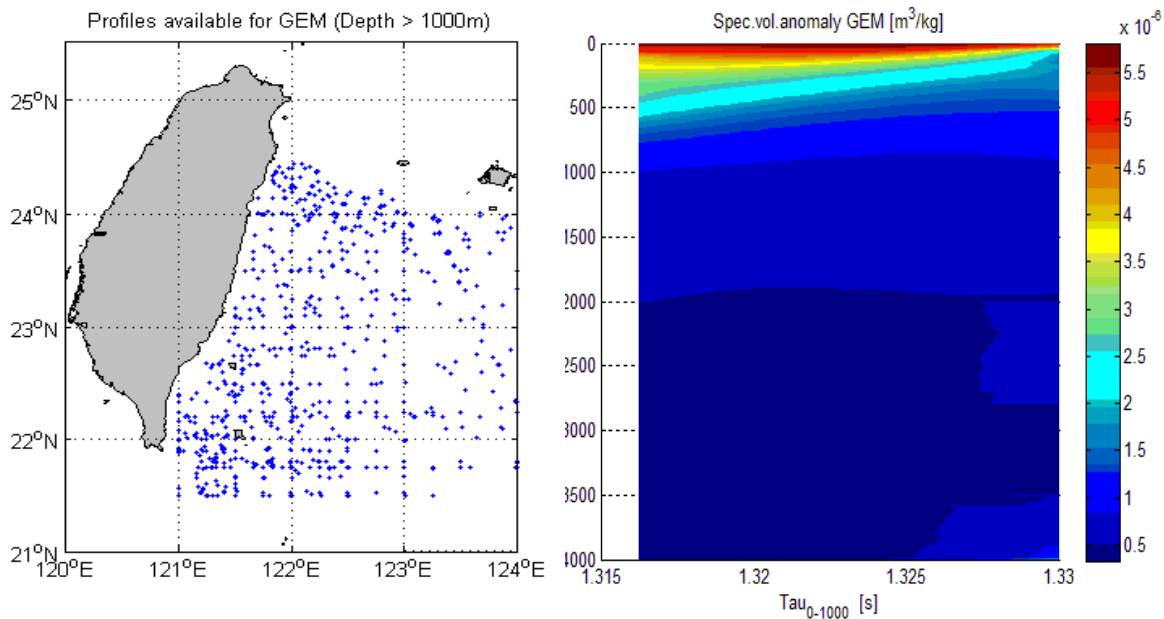


Figure 3. Left panel shows distribution of hydrography east of Taiwan used to calculate the GEM lookup tables. Right panel shows the lookup table for the vertical profiles specific volume anomaly as a function of acoustic travel time (figures courtesy of V. Mensah). A similar table has been calculated for temperature profiles (not shown).

IMPACT/APPLICATIONS

Understanding the variability of the Kuroshio east of Taiwan has implications for predictability in the downstream region where the Kuroshio sometimes intrudes onto the East China Sea shelf northeast of Taiwan. There is evidence that a weak Kuroshio corresponds with strong intrusions of the Kuroshio onto the East China Sea shelf (Gawarkiewicz et al., 2011). Understanding the Kuroshio interactions with the continental shelf is very important for forecasting acoustic propagation conditions in this region (Lermusiaux et al., 2011).

Determining the advective versus the eddy-driven contributions to Kuroshio variability east of Taiwan is relevant to understanding acoustic propagation in the Philippine Sea. Furthermore, this is an area where typhoons frequently pass, and the data collected here should provide some very interesting case studies for determining how the Kuroshio reacts to the passage of typhoons.

RELATED PROJECTS

This project is part of the Origins of the Kuroshio and Mindanao Currents (OKMC) program (<http://kirin.apl.washington.edu/okmc/>), funded by the Office of Naval Research and the Observations of Kuroshio Transports and Variabilities (OKTV) program (*Figure 4*), funded by the Taiwanese National Science Council. Instrumentation along the KTV-1 line is funded in part by this ONR proposal and in part by the OKTV program (Jan Sen, PI). Shiptime for instrument deployments and recoveries is provided through OKTV. Training for PIES deployments and recoveries is provided through this proposal. Data processing and analysis will be carried out collaboratively between NTU and WHOI.

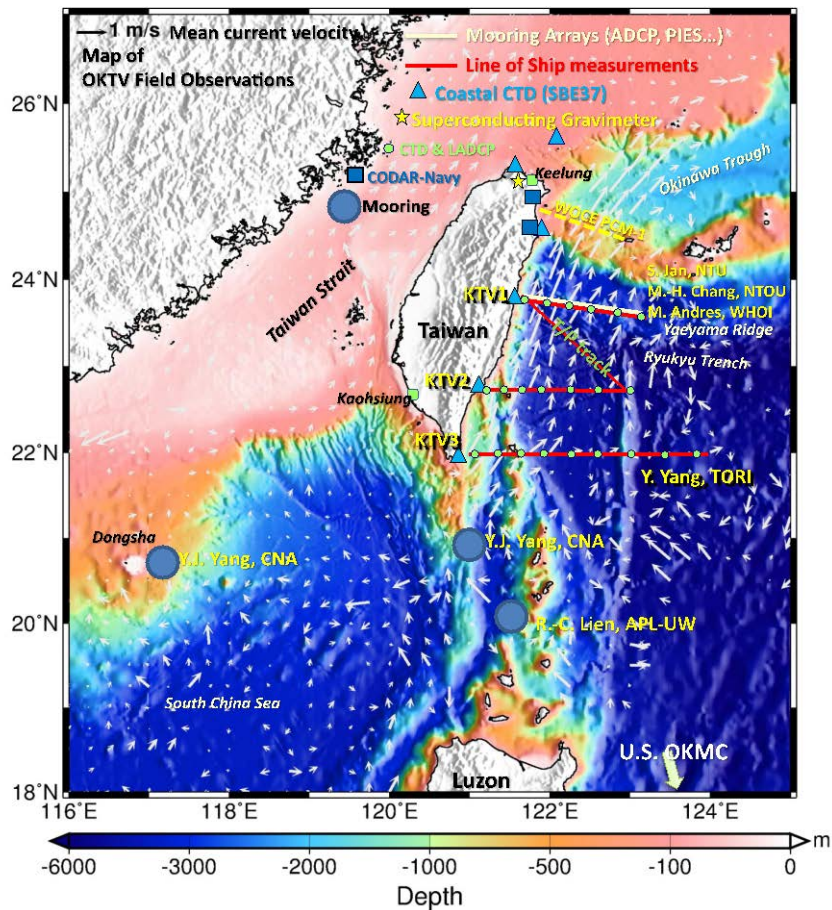


Figure 4. Map summarizing the planned elements of the Taiwanese OKTV field program. The ONR-funded efforts described in this annual report will complement the OKTV measurements along the KTV1-line. (Figure courtesy of Jan Sen.)

REFERENCES

- Del Grosso, V. A., 1974. New equation for the speed of sound in natural waters (with comparisons to other equations). *J. Acoust. Soc. Am.* **56**(4), 1084-1091.
- Donohue, K. A., D. R. Watts, K. L. Tracey, A. D. Greene and M. Kennelly, 2010. Mapping circulation in the Kuroshio Extension with an array of Current and Pressure recording Inverted Echo Sounders. *Journal of Atmospheric Oceanic Technology*, doi:10.1175/2009JTECHO686.1.
- Gawarkiewicz, G., S. Jan, P.F.J. Lermusiaux, J.L. McClean, L. Centurioni, K. Taylor, B. Cornuelle, T.F. Duda, J. Wang, Y.J. Yang, T. Sanford, R.-C. Lien, C. Lee, M.-A. Lee, W. Leslie, P.J. Haley Jr., P.P. Niiler, G. Gopalakrishnan, P. Velez-Belchi, D.-K. Lee, and Y.Y. Kim, 2011: Circulation and intrusions northeast of Taiwan: Chasing and predicting uncertainty in the cold dome, *Oceanography*, **24**(4):110–121, <http://dx.doi.org/10.5670/oceanog.2011.99>.
- Lermusiaux, P.F.J., J. Xu, C.F. Chen, S. Jan, L.Y. Chiu, and Y.-J. Yang, 2010: Coupled ocean-acoustic prediction of transmission loss in a continental shelfbreak region: Predictive skill, uncertainty quantification and dynamical sensitivities. *IEEE Journal of Oceanic Engineering*, **35**:895–916, <http://dx.doi.org/10.1109/JOE.2010.2068611>.

Meinen, C.S., 2001. Structure of the North Atlantic Current in stream-coordinates and the circulation in the Newfoundland Basin. *Deep Sea Res.*, **48**(7), 1553– 1580, doi:10.1016/S0967-0637(00)00103-5.