Studies of the Origins of the Kuroshio and Mindanao Currents with EM-APEX Floats and HPIES

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LONG-TERM GOALS

Improving observations and understanding of major oceanographic features and phenomena. We emphasize motionally induced electric fields for measuring ocean velocities.

OBJECTIVES

The primary objectives of this observational program are to quantify the origin of the Kuroshio and Mindanao currents at their origin and as they evolve downstream.

APPROACH

The use of bottom-mounted horizontal electric field sensors combined with inverted echo sounder units complements the ADCP moorings in the Kuroshio near the NE tip of Luzon, the Philippines. The new instrument is denoted as HPIES, an abbreviation of Horizontal EF, Pressure and Inverted Echo Sounder. The HEF measures the barotropic horizontal velocity. The pressure and IES data determine baroclinic velocity when operated in a horizontal array. Three complete HPIES exist from the original NSF development support. Two new HPIES are built using existing PIES and new HEF units.

Five HPIES were deployed around upper ocean ADCP moorings by Ren-Chieh Lien. The ADCP is moored at 600-m level and upward looking. The HPIES will provide the depth-averaged velocity. Thus, the combination provides both upper-ocean Kuroshio transport and total-water transport. The moorings and the HPIES are installed at NE of Luzon. The HPIES and ADCP array are centered at the Kuroshio stream .

Nine EM-APEX float are deployed along of 135°E between 13° N and 22°N. Floats drift at a parking depth (~200m) that moves with the westward component of North Equatorial Current (NEC) but profile to 1,000 m to acquire velocity and density profiles.

WORK COMPLETED

Field observation plan was presented at the ONR OKMC workshop in Kaohsiung, Taiwan in April 2012.

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R/V *Revelle* RR-1205 cruise was conducted on 6/3 - 6/16 2012 for HPIES and ADCP moorings deployment, shipboard CTD/ADCP observation and bathymetry survey (Fig. 1 & 2). The yearlong deployment of HPIES and ADCP moorings will be recovered in the summer of 2013. The HPIES were deployed using a newly designed three-poles quick release mechanism. All five HPIES were deployed successfully (Fig. 3). The absolute velocity profiles from the HPIES will be calculated from the gravest empirical mode (GEM) field. For the GEM technique to work, there must be sufficient hydrography within the study region to characterize the mesoscale variability [*Meinen et al.*, 2002]. Sixty-one shipboard CTD casts were made along the HPIES array during the RR-1205 cruise (Fig. 4). These stations will be used to prepare a GEM model for the interpretation of IES signals in terms of profiles of water properties, such as density. More CTD survey will be conducted during the recovery cruise next year (Fig. 5).

Nine EM-APEX floats were deployed by the KORDI R/V *Onnuri* in June 2012 (Fig. 6). The deployments have been delayed after float #4906 was deployed to allow Typhoon *Guchol* to pass. The deployment started around 20°N, 133°E and ended at 13°N, 136°E. All the floats are profiling every half inertial period which has ranges from 35 h at 20°N to 53 hr at 13°N. As of September 28, 2012, two float, #4915 and #4908, have reached near the 128°E (Fig. 7). These float are expected to enter the KC-MC bifurcation zone in October 2012.

RESULTS

The Kuroshio transport at 18.8°N is estimated at about 10 SV from the shipboard ADCP survey (Fig. 5). The value is comparable with further upstream survey (18.35°N) from Arnold Gordon's Lamon Bay cruise. Current efforts are on the navigation of the EM-APEX floats, computation of absolute velocity profiles and NEC transport based on the EM-APEX density and velocity from the surface to 800 dbar. Also, the CTD stations along the mooring/HPIES lines are being studied to compose a GEM model for the interpretation of the IES observations on the HPIES lander.

RELATED PROJECTS

Study of Kuroshio Intrusion and Transport using Moorings, HPIES and EM-APEX Floats (N00014-08-1-0558) as a part of QPE DRI: The primary objectives of this observational program are 1) to quantify and to understand the dynamics of the Kuroshio intrusion and its migration into the southern East China Sea (SECS), 2) to identify the generation mechanisms of the cold dome often found on the SECS, 3) to quantify the internal tidal energy flux and budgets on the SECS and study the effects of the Kuroshio front on the internal tidal energy flux, 4) to quantify NLIWs and provide statistical properties of NLIWs on the SECS , and 5) to provide our results to acoustic investigators to assess the uncertainty in the acoustic prediction. Results of this DRI program will help understand oceanic physical processes on the southern East China Sea, e.g., the cold dome. Typhoons may modulate the Kuroshio, the Kuroshio intrusion, and other oceanic processes and result in cold pools on the continental shelf of the SECS.

Process Study of Oceanic Responses to Typhoons using Arrays of EM-APEX Floats and Moorings (N00014-08-1-0560) as a part of the ITOP DRI. Fourteen EM-APEX floats were air-deployed into two W. Pacific typhoons. *T. Fanapi* was a category 1 tropical cyclone. Seven floats were deployed about a day in front of *Fanapi* in mid-September 2010. Similarly, 7 floats were deployed in front of Super Typhoon Megi in mid-October. All floats survived the deployment and reported profiles. We

are studying the characteristics and dynamics of the oceanic response to and recovery from tropical cyclones in the western Pacific Ocean

Quantify Lateral Dispersion and Turbulent Mixing by Spatial Array of χ-EM-APEX Floats (N00014-09-1-0193) as part of the LatMix DRI. A suite of twenty-one EM-APEX floats, 10 with Chi turbulence sensors, was used in three experiments SE of Cape Hatteras, NC in June 2011. This was the first time a number of EM-APEX has been choreographed to profile simultaneously. For most of the time, the RMS differences on arrival at the surface as less than 1 minute. Only a single float was lost during the experiment, a result that partly was achieved by the development and use of a situation awareness system developed at APL for this experiment. Assets in the water were displayed on a dedicated screen on the bridge of each of the three research vessels. More than 8,000 CTD and velocity profiles were obtained in the three experiments. The data are being processed for distribution by 1 January 2012.

REFERENCES

Meinen, C. S., D. S. Luther, D. R. Watts, K. L. Tracey, A. D. Chave, and J. Richman (2002), Combining inverted echo sounder and horizontal electric field recorder measurements to obtain absolute velocity profiles, *J Atmos Ocean Tech*, *19*(10), 1653-1664.

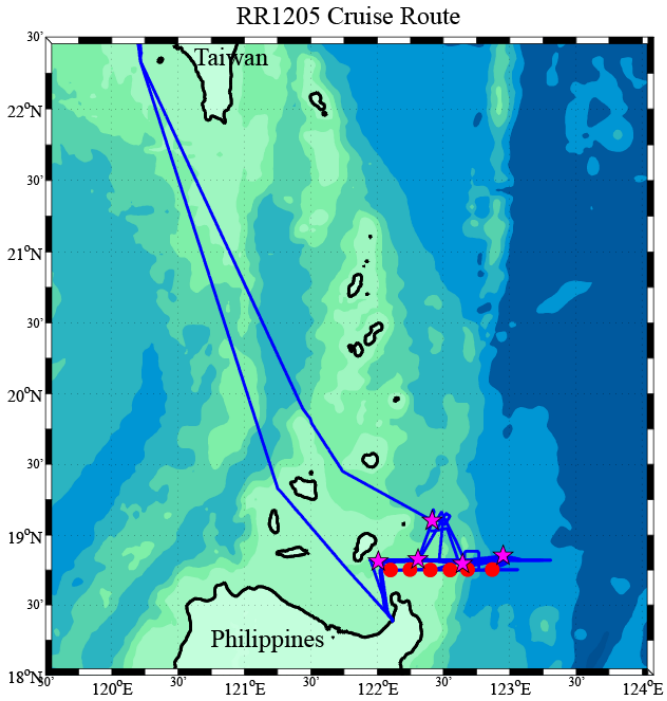

Figure 1. RR1205 cruise track (blue line) with HPIES (magenta stars) and mooring (red circles).

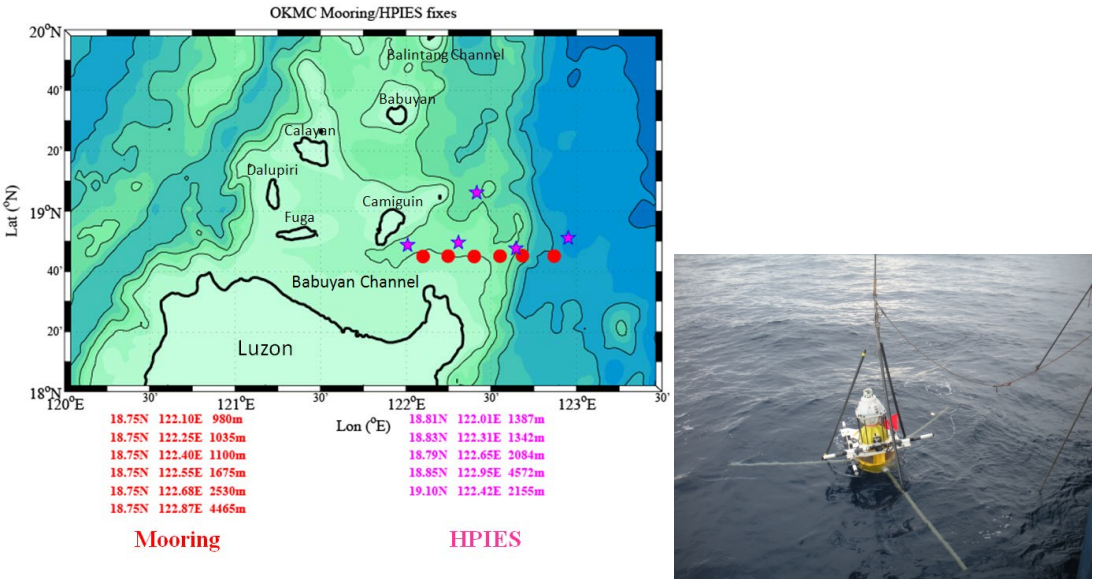

Figure 2. The RR-1205 HPIES and mooring location. The HPIES are deployed

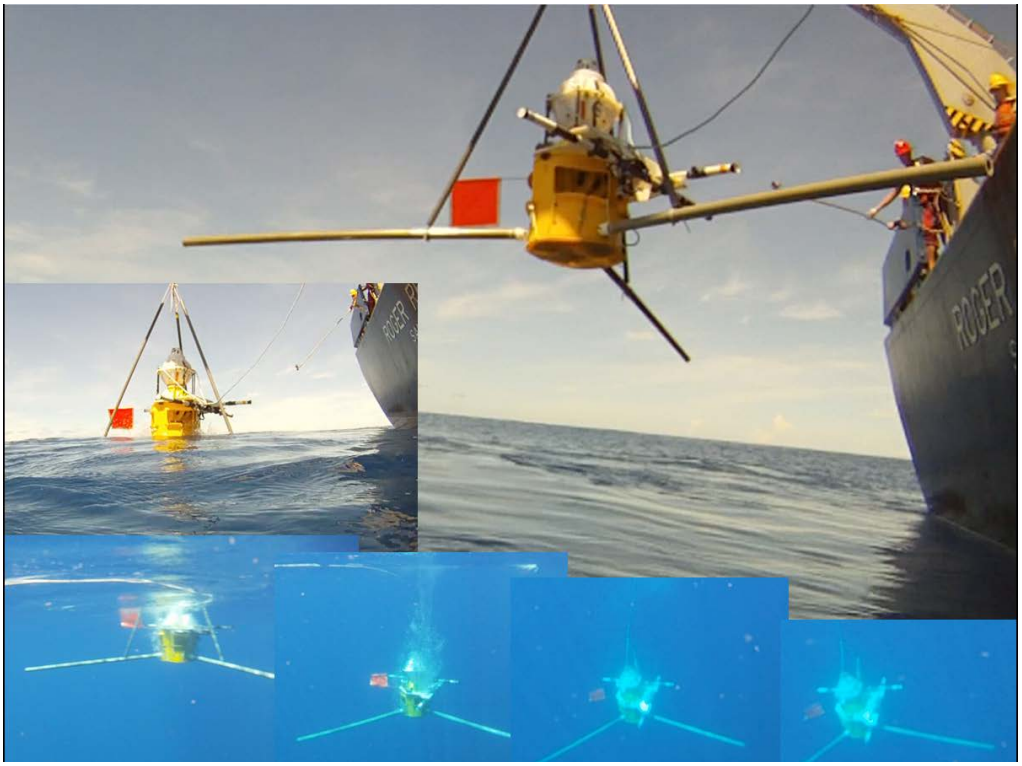

***Figure 3. The deployment of HPIES#4 (PIES 177/ HEF03) at H4 station on June 9, 2012.The photo sequence shows the HPIES descending smoothly to the bottom. The HPIES is deployed using a* custom designed three-pole, quick-release mechanism.**

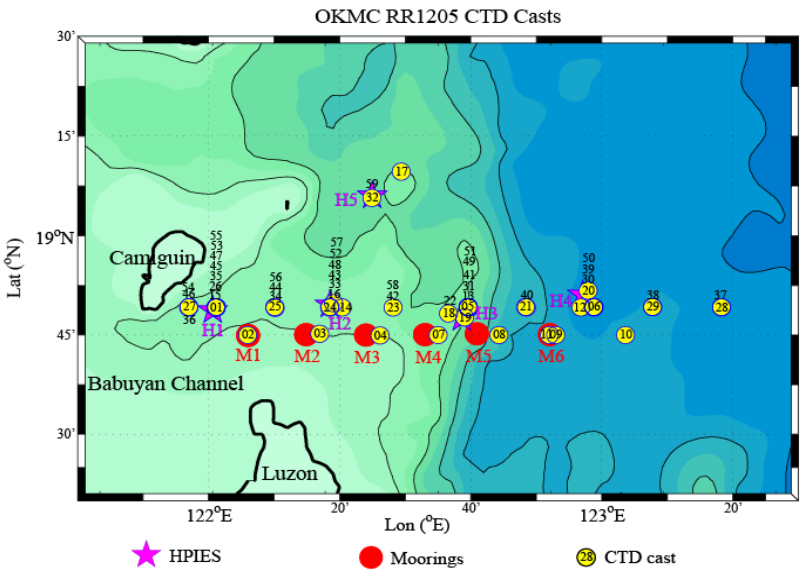

Figure 4. RR1205 CTD stations and cast number. 59 station and 61 casts have been made during the cruise. Gravest Empirical Mode analysis .

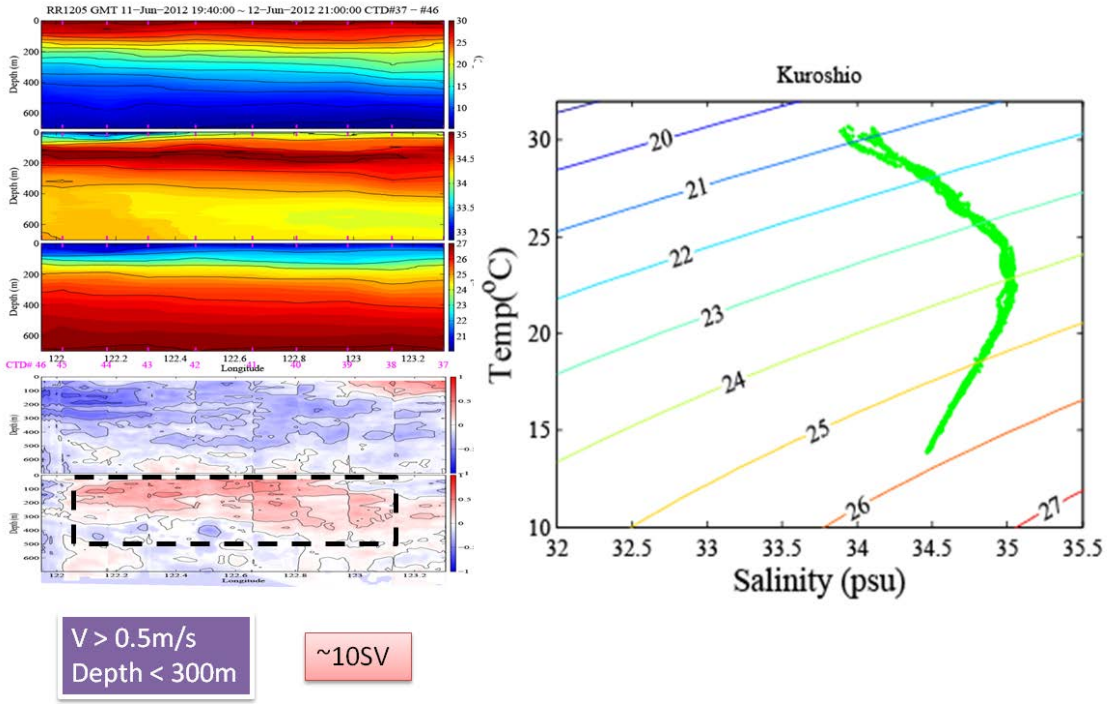

Figure 5. The possible upstream Kuroshio T-S property identified by meridional velocity greater than 0.5 m/s.

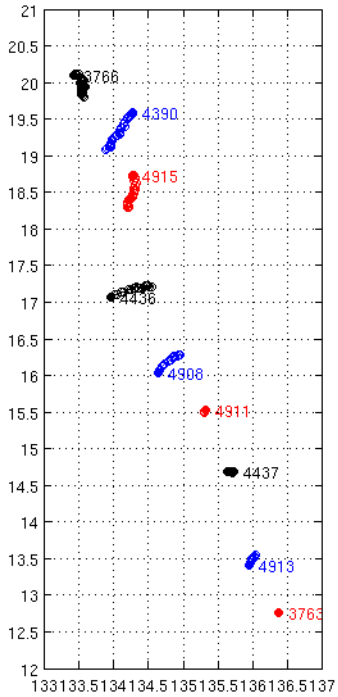

Figure 6. Nine EM-APEX floats have been deployed by KORDI R/V Onnuri in June 2012.

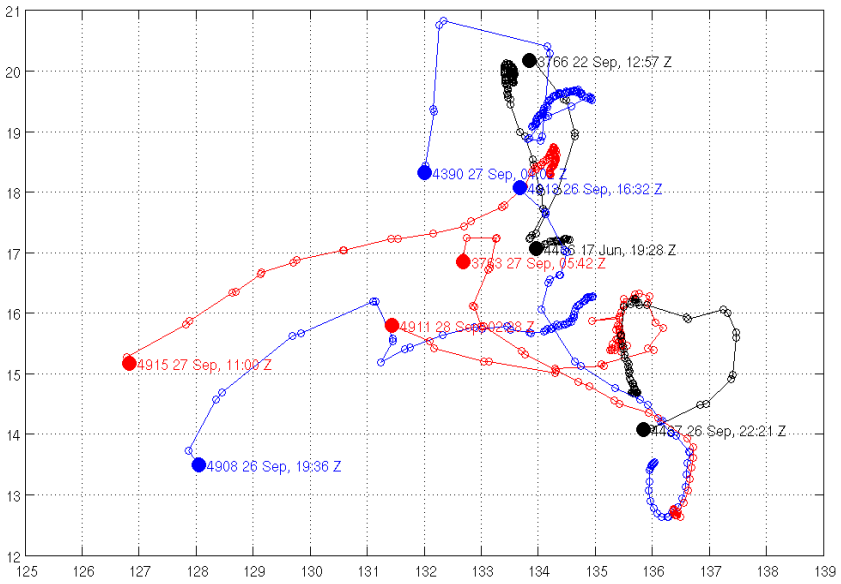

Figure 6. Tracks of the EM-APEX floats as they conduct half-inertial period profiles every 10 days. Their park depth for 10 days is 200 m. As of September 28, 2012 nearly all of the EM-APEX floats have moved West from their initial deployment sites. Two EM-APEX floats have reached near the 127°E. These are expected to enter the bifurcation zone in October, 2012.