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Transitioning Results From Recent ONR WESTPAC Field Programs to Operational Use

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LONG-TERM GOAL

The long-term goal is to enhance our understanding of coastal oceanography by means of applying simple dynamical theories to high-quality observations obtained in the field. My primary area of expertise is physical oceanography, but I also enjoy collaborating with biological, chemical, acoustical, and optical oceanographers to work on interdisciplinary problems. I collaborate frequently with numerical modelers to improve predictive skill for Navy-relevant parameters in the littoral zone.

OBJECTIVES

a) Continue analyzing recent data sets from the Western Pacific operating region (WESTPAC) and facilitate transitioning these basic research outcomes to operational use.

b) Improve our understanding of the circulation in the western Subtropical Countercurrent (STCC) and its impact on the neighboring boundary currents and downstream variability in the western North Pacific Ocean.

APPROACH

Over the past fifteen years, ONR has organized several major field efforts in the WESTPAC region. The PI has personally organized, participated in, and published results from several of these areas including the Japan Sea, the East China, the South China Sea, and the Luzon Straits. Ongoing work continues in the eastern and western South China Sea and the Philippine Sea. All of these programs have identified oceanographic features with sufficient strength, persistence and spatial extent to have identifiable impacts on acoustic propagation and therefore tactical ASW exploitation. Examples of such features include the Kuroshio current, mesoscale eddies, surface mixed layers of varying strength and extent, and high-frequency non-linear internal waves. Coincident modeling studies during the field efforts demonstrated that Navy models can reproduce these features with some degree of forecast skill, thus facilitating their inclusion in tactical planning via the NAVO ASW reach-back cell. This grant is to continue analyzing recent data sets and facilitate transitioning these basic research outcomes to operational use.

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WORK COMPLETED

A substantial effort in the grant is to work with the acoustics community (Peter Worcester, SIO; John Colosi, NPS; many others) analyzing the oceanographic data from several moorings deployed in the central Philippine Sea. The primary purpose of the program is to characterize and understand the acoustic propagation, but the hundreds of oceanographic instruments deployed also make the moorings conducive to basic ocean circulation studies. During April 2010-April 2011, seven moorings were deployed in a star pattern spanning roughly 17 – 23°N by 23 – 130°E (Figure 1). The six "transmit" moorings had an ADCP in the upper ocean spanning 260-360 m depth and many TSP instruments to 600 m depth. Additionally, the DVLA (receive) mooring observed current from 200-500 m and temperature to 4400 m depth. The data return was excellent with most instruments containing complete records for the duration of the experiment. The UNOLS vessels used to conduct the work operated hull-mounted ADCPs throughout the many cruises to the area. Several partner PIs (P. Worcester, SIO; J. Mercer, APL/UW; A Baggeroer, MIT) collected CTDs are part of their work. The satellite altimetry data, now easily available on the web (see for instance the Colorado Center for Astrodynamics Research, http://eddy.colorado.edu/ccar/data_viewer/index) have also been very helpful in establishing context for the field experiment. An array of Seagliders was also deployed which sampled the temperature and salinity (L. Van Uffelen, UH). We have devoted considerable effort during this funding cycle integrating all the physical oceanographic observations. The excellent spatial coverage of this array allows study of the highly-energetic STCC eddy field as well as the ambient water mass properties.

RESULTS

Some of the most exciting results noted to date include:

- The currents at the eastern moorings (T2, T3, T4, DVLA) resemble the flat-bottom deep ocean case in terms of the eddy energy (300 cm^2/s^2) and westward propagation (-10 cm/s).
- The western moorings however (T1, T5) exhibit strong boundary interactions and nonlinearity despite being over 200 km offshore. In this region topographic beta steers the eddies towards the southwest where they interact with other eddies incoming from the west. The data set additionally contains at least one clear eddy/Kuroshio interaction, and one example of a reflected "short" Rossby wave.
- Eddy/boundary current and eddy/eddy interactions increased the eddy energy at T1 and T5 to order 900 cm^2/s^2.
- The dominant length and time scales of the mesoscale variability (350 km and 60 days) are in general a poor fit for planetary waves and appear to be in the realm of geostrophic turbulence [Kobashi and Kawamura, 2001; Zang and Wunsch, 1999].
- Isotherm displacements in the eddy field are order 100 m and 2°C (Figure 2)
- The relative vorticity in the eddies is order 0.5*f*, which makes them similar in strength to Gulf Stream warm core rings [Olson et al., 1985] (Figure 3).
- There is no evidence of a mean eastward current in the STCC! The year-long mean currents at each mooring can be understood in terms of the dominant sign and position of the passing eddies.

- Several moorings display strong sub-mesoscale variability. This variability appears from satellite MODIS SST images (not shown) to be filaments and instabilities around the edges of the eddies, but needs further investigation.

The array spanned a very sharp transition from El Nino to La Nina conditions in the western tropical Pacific. The eddies were stronger during spring 2010 than spring 2011 likely due to the ENSO cycle [Kashino et al., 2009]. This change dominated the seasonal variability reported by previous investigators [Qiu, 1999], which was not observed.

IMPACT/APPLICATION

This experiment is expected to break new ground in the field of blue-water deep-sea acoustic propagation. The array is also the first of its kind in region of the STCC, one of the most energetic mesoscale eddy regions of the world. Observing the eddy energetics and propagation speeds and directions will improve the quality of the oceanographic and acoustic nowcasts and forecasts for the region.

TRANSITIONS

Transitions are expected later in the funding cycle as the results are analyzed.

RELATED PROJECTS

Peter Worcester, Scripps Institution of Oceanography, project leader

John Colosi, Naval Postgraduate School, deep water acoustics, internal waves

Bruce Cornuelle, Scripps, mesoscale modeling

Brian Powell, University of Hawaii, mesoscale modeling

Brian Dushaw, APL/UW, internal waves

Lora Van Uffelen, UH, acoustic tomography from mobile nodes

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Ramp, S. R. J. A. Colosi, P. Worcester, and F. L. Bahr, "Quantifying the Mesoscale Variability in the Western Subtropical Countercurrent (STCC)." Presented at the 2012 ASA Meeting in Hong Kong, May 2012.

Colosi, J. A., S. R. Ramp, several others, presented by S. R. Ramp, "Observed sound speed structure during the PhilSea 2009 field year. Presented at the 2012 ASA Meeting in Hong Kong, May 2012.

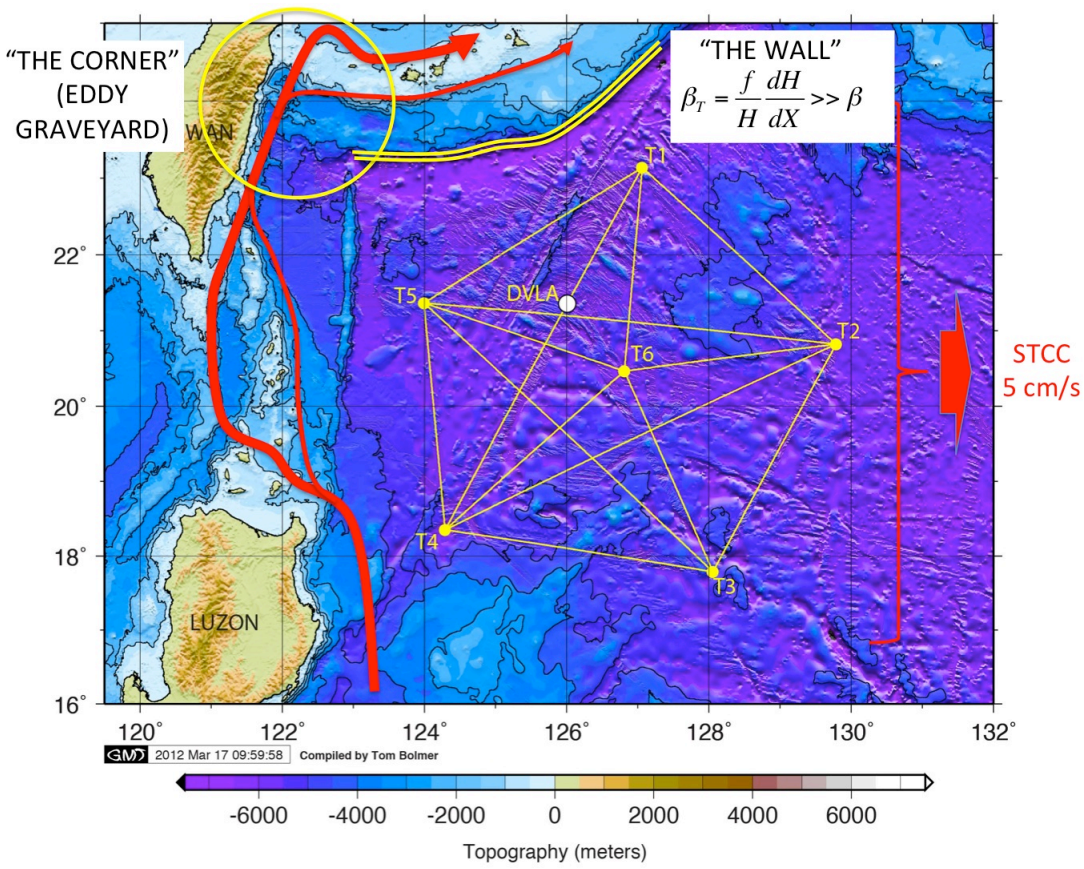

Figure 1. Map of the PhilSea 2010 moored array as deployed, with cartoon annotation of the dominant oceanographic features. Sites T1-T6 were source moorings and DVLA was the receiving mooring. All the moorings except T6 were heavily instrumented with oceanographic sensors. Most of the Kuroshio transport flows inside the Batan and Ryukyu Island chains (heavy red line), but there is some offshore transport as well (thinner red line). The supposed mean flow in the STCC is order 5 cm/s eastward. Eddies entering "The Corner" are re-absorbed by the Kuroshio or dissipated on topography and are never seen again. Eddies move southwest along "The Wall" where topographic beta dominates planetary beta. (Base map courtesy of the NPAL PhilSea 2010 web site)

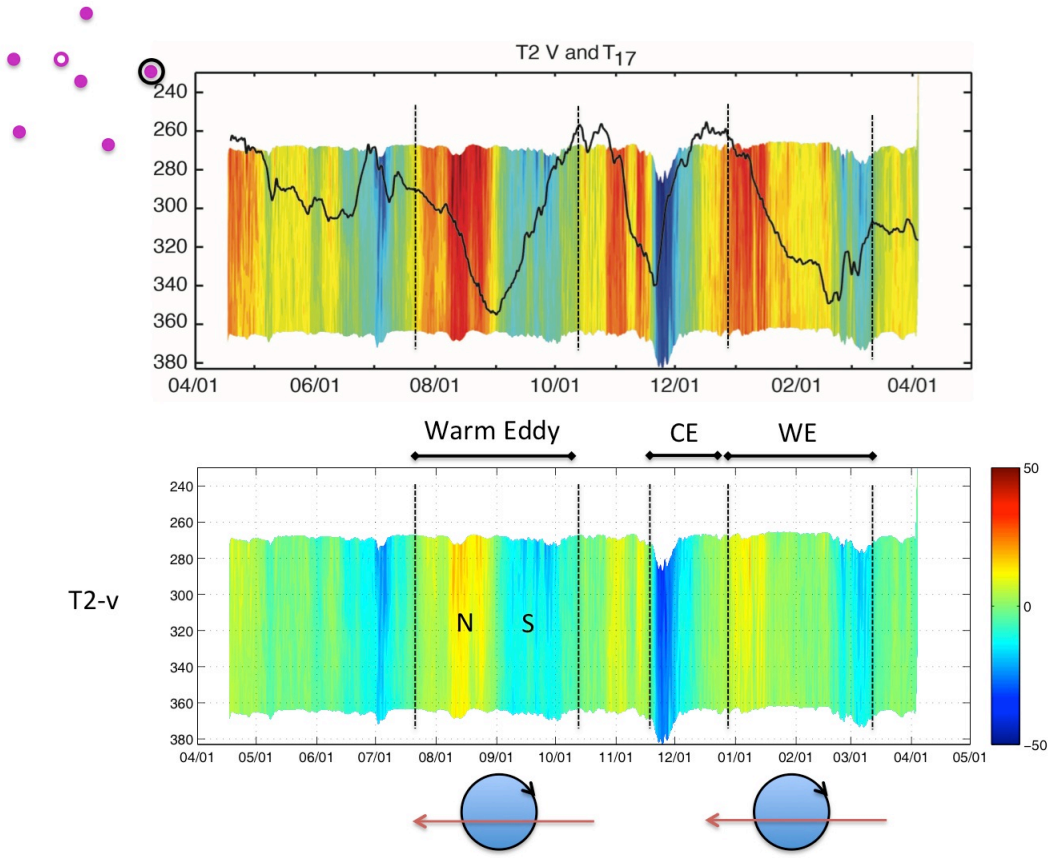

Figure 2. (top) The depth of the 17°C isotherm (black) plotted over the north-south component of velocity (color) at mooring T2. The location of T2 on the east side of the array is indicated in the cartoon in the upper left corner. (bottom) Also the v-component on a slightly different color scale, with the position of passing eddies which drive the observed currents noted. The eddy positions were determined from the surface altimetric data.

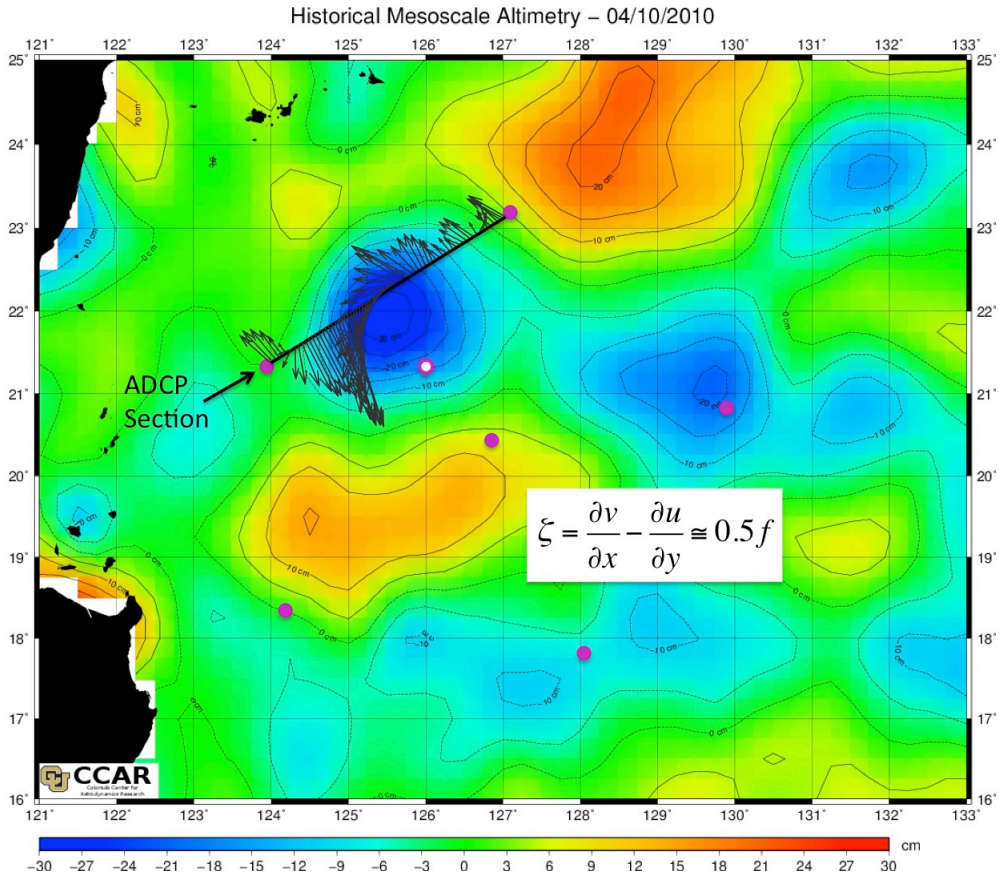

Figure 3. Hull-mounted ADCP data from the R/V ROGER REVELLE overlaid on the sea surface altimetry data from April 10, 2010. The scale of the longest vector is 1.25 m/s. Blue eddies are cyclonic (low, cold) and red are anticyclonic (high, warm). The agreement of the ADCP vector positions with the altimetric data in this and other cases was remarkable.