Shipboard LADCP/χpod Profiling of Internal Wave Structure and Dissipation in the Luzon Strait

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Award #: N00014-09-1-0281
http://mixing.coas.oregonstate.edu/

LONG-TERM GOALS

We seek a more complete and fundamental understanding of the hierarchy of processes which transfer energy and momentum from large scales, feed the internal wavefield, and ultimately dissipate through turbulence. This cascade impacts the acoustic, optical, and biogeochemical properties of the water column, and feeds back to alter the larger scale circulation. Studies within the **Ocean Mixing Group** at OSU emphasize observations, innovative sensor / instrumentation development and integration, and process-oriented internal wave and turbulence modeling for interpretation.

OBJECTIVES

Luzon Strait represents a major source of internal tides and NLIWs in the SCS. However, unlike other regions of strong internal wave generation (i.e., Hawaii), Luzon Strait is believed to be highly dissipative. We seek to understand the character of this enhanced nonlinearity and turbulence, and how it affects internal wave generation and transmission. Specifically, we intend to:

- identify hotspots of generation and dissipation,
- quantify the structure and variability of wave energy, its flux and dissipation at the generation site.
- link the broader spatial structure, temporal content, and energetics of the internal wave field to the topography, forcing, and mesoscale influences (i.e., Kuroshio).

APPROACH

Much of the turbulent dissipation in Luzon Strait was anticipated to be deep, outside the range of tethered microstructure profilers, and evolving too rapidly for autonomous profilers. As a result we chose to obtain rapid profiles into the abyssal ocean using the shipboard CTD, augmented with ADCPs, turbulence sensors, and a motion package. These allow us to systematically obtain 36-h yo-yo timeseries, from which energy generation, energy fluxes, and energy dissipation can be directly measured.

Report Documentation Page

Report Documentation Page	*Form Approved* *OMB No. 0704-0188*

1. REPORT DATE **2010**	2. REPORT TYPE	3. DATES COVERED **00-00-2010 to 00-00-2010**

4. TITLE AND SUBTITLE **Shipboard LADCP/χpod Profiling of Internal Wave Structure and Dissipation in the Luzon Strait**	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Oregon State University,College of Oceanic and Atmospheric Sciences,104 COAS Admin Bldg,Corvallis,OR,97331-5503**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**4**	

WORK COMPLETED

Through this award, we have developed a self-contained microstructure package that can be lowered on a standard shipboard CTD to measure full water column turbulence. χpod-CTD is a deep version of our equatorial-moored χpod (Moum and Nash, 2009), with two fast-response thermistors, a full motion package and 3000-m depth rating. It is installed on a the ship's CTD rosette, which is vaned to set χpod's orientation into the flow. With the addition of 2-300 kHz ADCPs, this system measures full-water column velocity, density, and temperature microstructure, permitting dissipation rates of temperature variance (χ) and TKE (ε) to be computed.

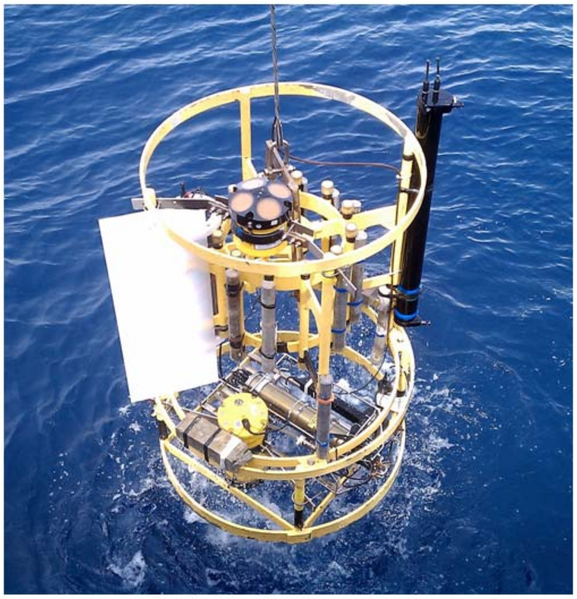

Figure 1: Revelle's CTD as modified during the IWISE pilot to measure full-depth velocity and dissipation rates. 2 ADCPS, a white vane for stabilization, and black χpod are each visible

This system was used for turbulence profiling during the 2010 IWISE pilot, and will also be deployed during the main 2011 experiment to investigate the generation of internal waves, NLIWs, bores and their associated dissipation within Luzon Strait. In addition, a full water-column mooring will be deployed at the central ridge crest to help ground the larger experiment.

RESULTS

Initial results from the pilot are spectacular. From an instrumentation standpoint, χpod/LADCP returned uncontaminated temperature and its gradient on all upcasts. These have enabled the dissipation rates of temperature variance (χ) and TKE (ε) to be computed to 3000-m depths. A comparison of station-mean dissipation rates from χpod and from Thorpe-scale estimates (figure 2) is highly encouraging. At abyssal depths, dissipation estimates are consistent in their time-means, but differ in the details (since they are computed from stages of turbulent-billow evolution). In the higher stratification surface waters, Thorpe estimates are biased low due to sensor resolution issues.

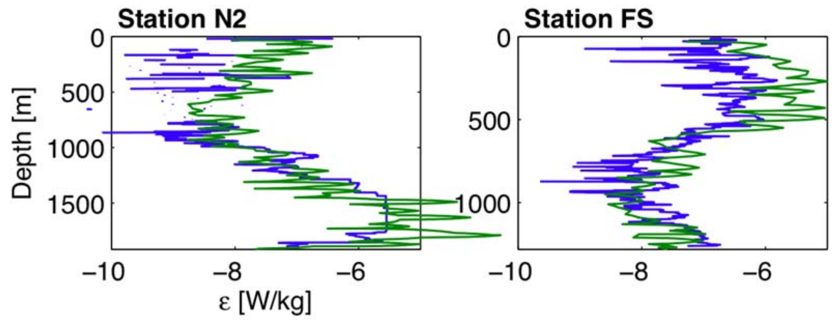

Figure 2: TKE dissipation rate from from LADCP/χpods (green) and Thorpe analyses (blue) at two of the most energetic stations observed during the Luzon Strait pilot. These represent the first direct measurements of abyssal turbulence from shipboard CTD/LADCP.

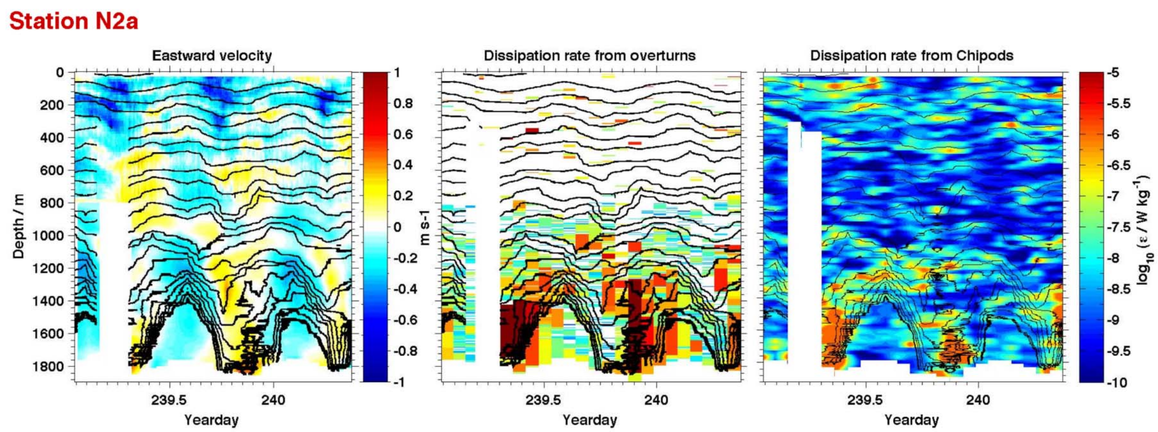

Figure 3: Timeseries of velocity (left) and TKE dissipation from Thorpe overturns (middle) and from χ (right) for the first occupation of station N2. This was one of the more energetic stations, with vertical displacements and overturns exceeding 500 m, as illustrated by density contours (black).

During the IWISE pilot, internal wave vertical displacements exceeded 500 m and TKE dissipation rates were among the largest recorded in the abyssal ocean, exceeding 3×10^{-6} W/kg as the newly-generated internal tide interacts with the Western ridge at 1200-1800 m water depths (figure 3). In the upper water column, differences between dissipation rates computed from Thorpe-scales (Fig 3, center), and chipods are due to Thorpe-estimate resolution; however, deep in the water column, these differences are real and provide important clues as to the mechanism and evolution of the turbulent overturns. At the southern ridge (figure 4), dissipation rates and vertical displacements were slightly weaker. However, both ridges appear to have significantly more nonlinearity and dissipation than other sites of strong internal tide generation, such as the Hawaiian Ridge system (Nash et al 2006; Klymak et al, 2006).

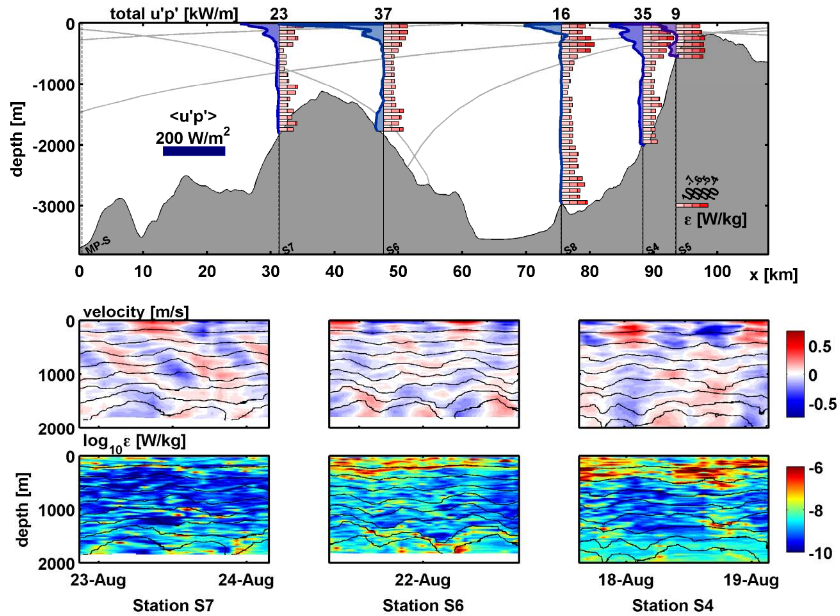

Figure 4: Summary of energy flux and TKE dissipation across the southern line, computed from five 36-h χpod/LADCP stations during the 2010 IWISE pilot. These show intense dissipation at the generation site (S4, right), which decays with distance from the ridge (S6 & S7).

RELATED PROJECTS

Profiling and moored operations are being coordinated with M Alford (UW); analysis of turbulence data are being conducted in conjunction with J MacKinnon (UCSD) and H Simmons. (UAF)

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