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Internal tide generation and propagation in a strong, sheared current

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LONG-TERM GOALS

To understand the generation, propagation and dissipation of large amplitude internal tides.

OBJECTIVES

To obtain time series and spatial structure of internal tidal propagation and evolution westward from the ridges in Luzon Strait during the Internal Waves in Straits Experiment (IWISE).

APPROACH

Since writing our proposal, our approach has changed considerably due to limited ship time. *Spray* gliders 33 and 35 are acting as relocatable virtual moorings from June–August 2011 in the South China Sea for a spring-neap cycle before relocating. Both *Sprays* are equipped with an acoustic Doppler profiler (ADP) to measure currents directly. The gliders were modified to dive at 30° instead of the usual 17° to complete a dive cycle from 0–500 m and back to the surface in 1.5 hours, which better resolves the semidiurnal tides.

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MacKinnon has contributed moored profilers from her faculty startup package to the mooring array in Luzon Strait for the main experiment and participated in the pilot experiment in August–September 2010. A separate report for this work will be done.

WORK COMPLETED

The gliders were deployed during Matthew Alford's (UW/APL) mooring deployment cruise by Amy Waterhouse (SIO postdoc with MacKinnon) and are scheduled to be picked by Luc Rainville (UW/APL) on the mooring recovery cruise in early August. As of the writing of this report, the gliders are still in the water.

Spray 35 is occupying three stations for a spring-neap cycle along 20.6°N at 120.05°E, 119.90°E, and 119.75°E from June–August 2011 (Figure 1). *Spray* 33 occupied two additional stations at 120.5°E and 120.35°E. At the last station, the mean current has been greater than 0.25 m s^{-1} and so *Spray* 33 has been swept northward but is still measuring internal tidal signals (Figure 2). *Spray* 35 has held station within $\sim$10 km most of the time. *Spray* 33, which is closer to the Kuroshio, has been swept around by the currents much more, but this path may eventually contribute to a better 3D understanding of the generation and propagation of large internal tides.

RESULTS

The gliders are still in the water and are measuring vigorous internal tidal with velocities reaching 1.5 m s^{-1} and displacements exceeding 50 m (Figures 1–2).

IMPACT/APPLICATIONS

Using a glider as a virtual mooring which can be relocated is a novel approach. Future work will use this approach to study internal waves and tides.

RELATED PROJECTS

Internal waves and mixing in the SW Indian Ocean. *PIs: MacKinnon, Johnston, and Pinkel.* This NSF-funded project is recently completed and was designed to study intense mixing near the SW Indian Ridge over two cruises in 2007–2008. Some evidence suggests that elevated mixing in a deep jet is due to breaking internal waves at critical levels in the strong mean vertical shear of the jet (*MacKinnon et al.*, 2008). These data are used in the next project.

Turbulence from internal-wave beams in the upper ocean. *PIs: Sarkar, Johnston, Rudnick, MacKinnon, Pinkel, and Klymak.* In this recently funded ONR project, models and existing observations from the Hawaii Ocean Mixing Experiment (*Martin and Rudnick*, 2007; *Cole et al.*, 2009), the SW Indian Ridge, and AESOP (*Johnston et al.*, 2011a) will examine turbulence in internal wave beams reflecting from the surface.

Experiment on internal tidal scattering (EXITS) *PI: Johnston.* Three cruises in 2010–2011 examined possible dissipation of low-mode internal tides due to scattering from the Line Islands Ridge using moored profilers and ship-based LADCP stations. Preliminary results of this NSF work show the incident mode-1 tide diminishes across the ridge with increasing mode-2 energy fluxes south of the ridge.

Assessing the effectiveness of submesoscale ocean parameterizations (AESOP) *PIs: Johnston and Rudnick.* For this completed ONR project, a microstructure instrument mounted on SeaSoar measured moderately elevated mixing in internal tidal beams (*Johnston et al.*, 2011a). Also elevated mixing was found on the cyclonic, dense side of the front and its spatial distribution resembled that of lateral strain which acts to trap near-inertial internal waves (*Johnston et al.*, 2011b). An exhaustive examination of frontal dynamics was made (*Pallàs-Sanz et al.*, 2010a,b).

Origins of the Kuroshio and Mindanao Currents (OKMC) *PI: Rudnick.* For this ONR project, gliders are being deployed from Palau to do repeated sections across the North Equatorial Current and the Mindanao Current. Continuous observations have been going for two years. Initial objectives of observing variability in these two major currents are being achieved. Data will soon be assimilated into a regional model for predictability studies.

Tasmanian tidal dissipation experiment (TTIDE) *PIs: Pinkel, Alford, Johnston, MacKinnon, Nash, Rainville, Rudnick, and Simmons.* TTIDE's hypothesis is that significant tidal dissipation takes place where propagating low-mode internal tides impinge on steep continental slopes. Slope geometry affects wave reflection, transmission, scattering, and breaking, which in turn determine the spatial distribution of mixing. We were recently notified that NSF will fund this proposal.

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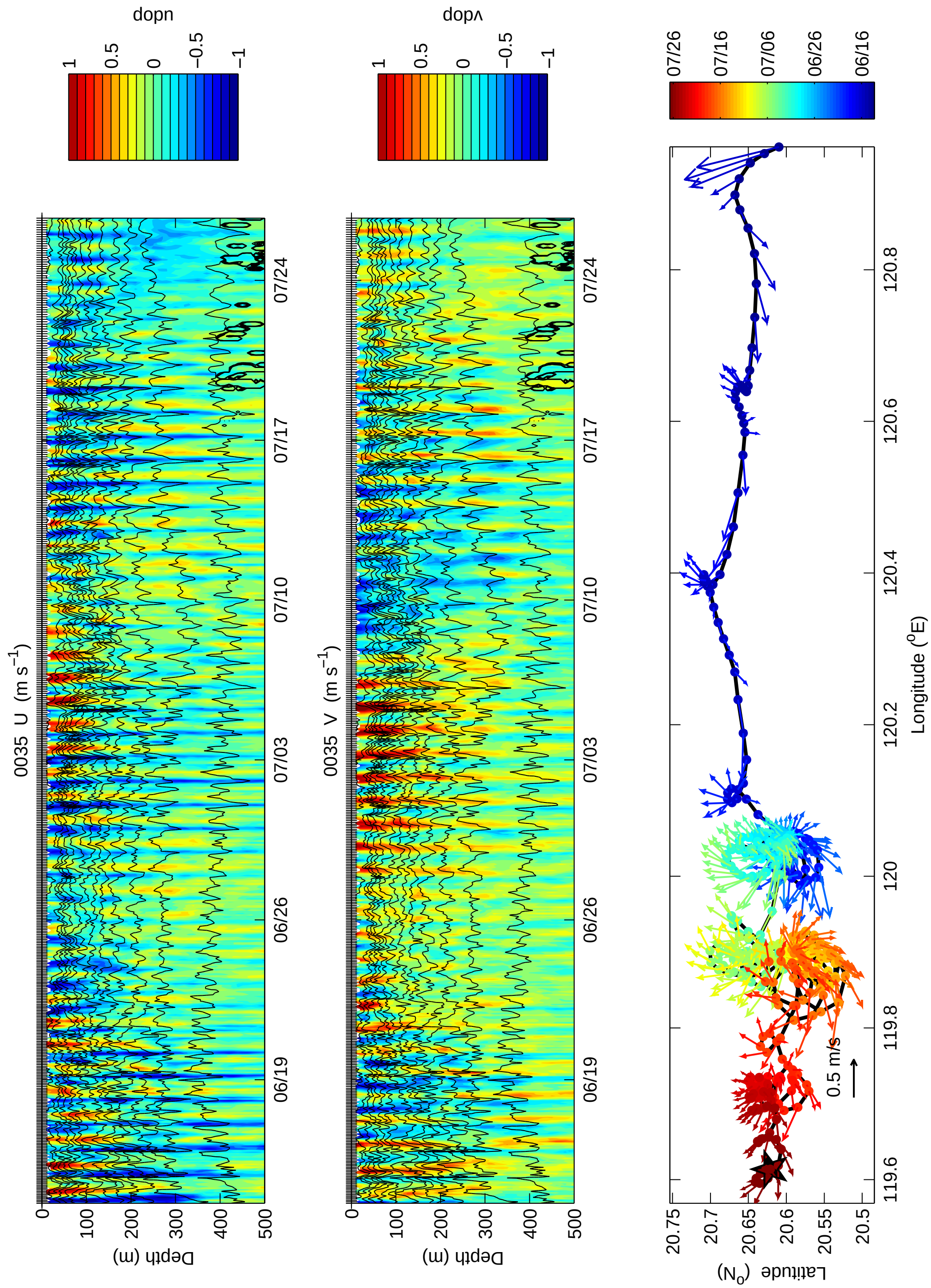

Figure 1: Currents from **Spray** ***35. ADP-measured a) eastward and b) northward currents reach 1.5 m s^{-1} and show a spring-neap cycle with strong semidiurnal and diurnal internal tides. Isopycnals (black lines) are plotted every 0.5 kg m^{-3} and show tidal excursions exceeding 50 m. c) Mean currents from 0–500 m (vectors) trace tidal ellipses. Gliders are occupying three stations along 20.6°N at 120.05°E, 119.9°E, and 119.75 °E (coloured dots also indicate date). Black star denotes latest position on 26 July 2011. Vertical lines on top axis indicate 520 glider profiles to date.***

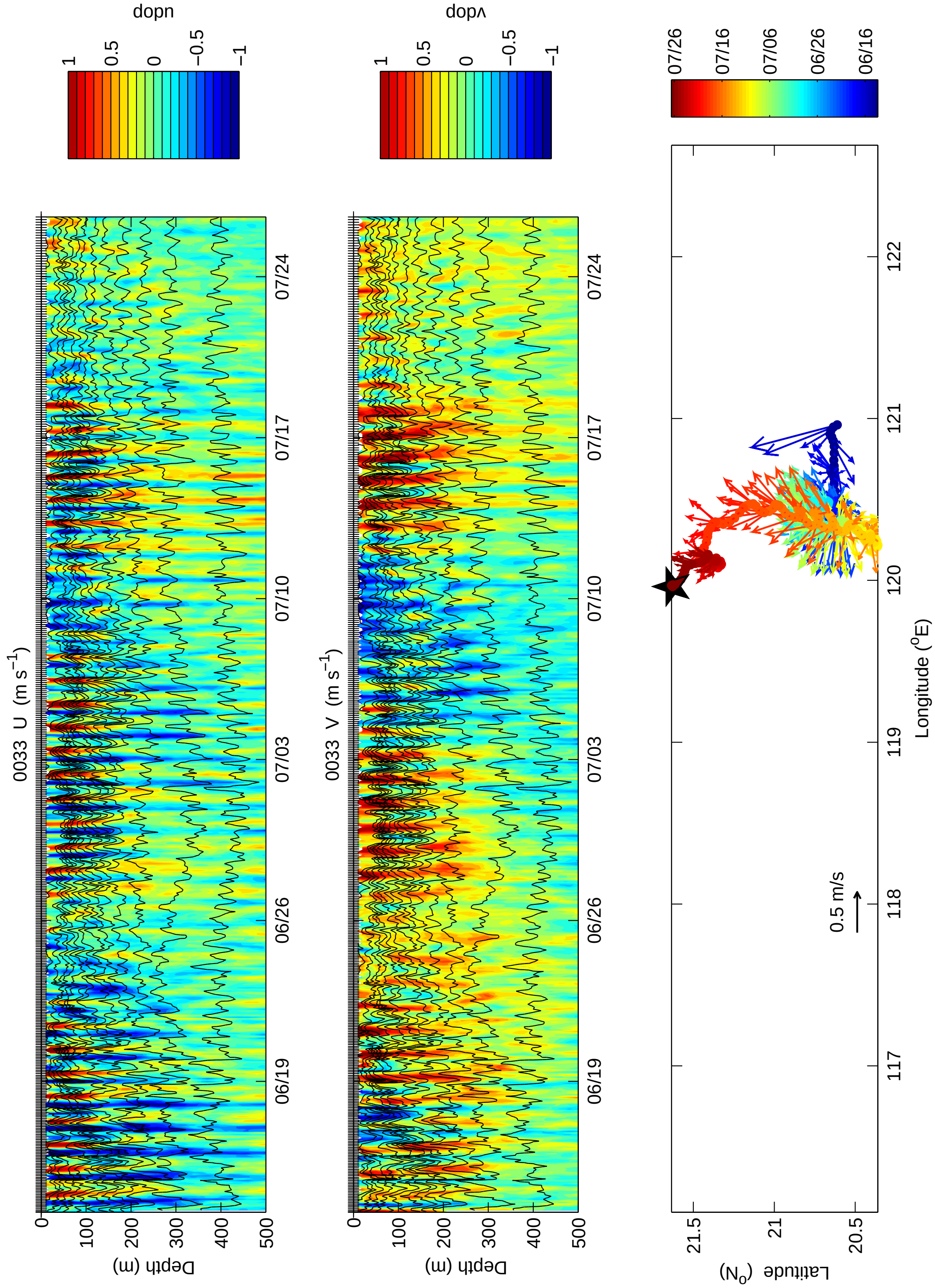

Figure 2: As in Figure 1, but for **Spray** ***33 which is obtaining profiles along 20.6°N and 120.25°E.***