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Ramp, Steven R.

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Submarine Sand Dunes on the Continental Slope in the South China Sea and Their Impact on Internal Wave Transformation and Acoustic Propagation

Steven R. Ramp
Soliton Ocean Services, Inc.
691 Country Club Drive
Monterey, CA 93924
phone: (831) 659-2230 fax: none email: sramp@solitonocean.com

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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

- Conduct a field program in the South China Sea to determine the combined impact of large submarine sand dunes (hereafter "dunes") and large amplitude nonlinear internal waves (hereafter "waves") on sound transmission over the Chinese continental slope near Taiwan
- Determine how the nonlinear internal waves (NLIW) and tides interact with the seafloor to form and maintain the dunes
- Study how enhanced bottom roughness in the dune field affects energy dissipation in the NLIWs and tides as they shoal over the upper continental slope

APPROACH

The approach is to characterize the space and time scales of the dune field via repeated multibeam bottom surveys. The dunes are nominally 10-20 m tall with 350 m between crests, in water roughly 250 m – 600 m deep [Reeder et al., 2011]. Their migration rate and formation mechanism is unknown. Acoustic travel times will be observed both along and across the dune crests, both with and without the presence of large-amplitude nonlinear internal waves shoaling into the region. The energetics will be observed ahead of, central to, and just past the dune field to observe how the dunes impact energy dissipation in the internal waves and tides. The methodology is to use shipboard surveys during the 2013 pilot study and augment these results with a moored array and much more extensive shipboard surveys during the intensive operation period (IOP) during spring 2014. There will be greater emphasis on observing the near-bottom currents and stratification than during previous field experiments. Innovative instruments and techniques are required to cope with a difficult, unpredictable, high-energy environment.

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WORK COMPLETED

The pilot study was a two-ship operation during May 8-14, 2013 with the Taiwanese R/V OCEAN RESEARCHER 5 doing the MBES, moorings and environmental surveys and the R/V OCEAN RESEARCHER 2 doing the towed source and additional MBES work. Two moorings were deployed, one testing a new system to place a recoverable package on the sea floor to obtain observations in the bottom boundary layer. This mooring used a rope canister to deploy a line to the surface which could then be used to haul back the entire package. Both moorings supported a simple hydrophone receiving unit (SHRU) and minimal environmental sensors to minimize possible losses. Both moorings were deployed at the beginning of the cruise and recovered as designed at the end. The utility of the bottom design for longer deployments remains contingent on determining the stability of the bottom dune field. This will be determined by comparing the MBES data from these two cruises with the bottom maps from earlier cruises and planned subsequent cruises.

While the moorings were in the water, three 24-hour time series stations were conducted at a "smooth" location, a high-dunes location, and a high-dunes, shallower water location. The package contained a CTD, LADCP, transmissometer, dissolved oxygen (DO) sensor, and acoustic current meter/turbulence sensor (MAVS). All sensors on this package worked well. One day of internal wave "hopscotching" was also planned, assuming a suitable wave could be observed and tracked. The plan was to position the ship in front of an advancing wave with the package deployed near the sea floor to observe the bottom interactions, let the wave pass, and then reposition further up the continental shelf and repeat. In fact no suitable wave ever appeared (see results) so this day was used for additional MBES and time series work.

RESULTS

The new Atlas MBES on OR5 worked extremely well, producing bottom maps with phenomenal detail. These maps will be essential for locating assets during the main field program during spring 2014.

The oceanographic results were very different from previous springs: During ASIAEX (May 2001) [Ramp et al., 2004] and WISE/VANS (May 2005 and 2006) [Ramp et al., 2010] which were located close by, very large solitons were always observed at this time of year. Large solitons were also observed at the sand dunes site during previous dune reconnaissance cruises during 2010 and 2011. During May 2013 however, despite the observations being made during a spring tide, no solitons were observed. The waves were sometimes observed in the MODIS images, which were received in real-time, but they would then disappear before they reached the ship on the upper continental slope in around 350-400 m water depth. What was observed instead was rather weak but very clear mode-2 internal tides (Figure 1) which were supported by anomalous temperature, salinity, and stratification conditions. Relative to historical WISE/VANS data from June 2005, there was a deeper mixed layer and a weaker thermocline (Figure 2). There was also more Kuroshio water present than is normal during May, with a stronger salinity maximum near 150 m and stronger salinity minimum at depth. It seems the ocean was still in the winter condition due to an anomalously late onset of the summer (southwest) monsoon. This condition was also observed by other cruises on the R/V REVELLE in the area [L. St. Laurent and K. Shearman, personal communication]. The deep surface mixed layer, weak stratification, and double thermocline structures above and below the salinity maximum, were conducive to mode-2 internal tides but not able to support incoming mode-1 NLIW from the deep basin. While these conditions were highly anomalous on an inter-annual basis, we are nevertheless planning to conduct the main field program later in the year to head off this situation. For the acoustics team, the conditions were favorable, since they were able to observe the no-wave condition this year, and will observe the "with waves" condition next year.

IMPACT/APPLICATION

Bottom scattering conditions are expected to be quite different from previously observed regions outside the dune field. Intensive near-bottom observations beneath the NLIWs is new and should provide new information on if/how these wave resuspend and redistribute bottom sediment over the continental slope. The new observations should also expand understanding of how much energy is dissipated on the continental slope over varying bottom strata.

TRANSITIONS

The project is just getting started and there are no transitions yet.

RELATED PROJECTS

The acoustics side of the project is funded by ONR 321OA. See related annual reports by C.-S. Chiu and D. B. Reeder, Naval Postgraduate School. The project is jointly funded by the National Science Council of Taiwan under grants to National Taiwan University (NTU) and National Sun Yat-sen University (NSYSU). The principal invesigators are Profs. Y. J. Yang and C. Chen (NTU) and Prof. Linus Chiu (NSYSU).

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PUBLICATIONS

Ramp, S. R., C.-S. Chiu, and D. B. Reeder, 2013: Preliminary cruise report: Research Vessel OCEAN RESEARCHER V, May 8-14, 2013: The David Tang cruise.

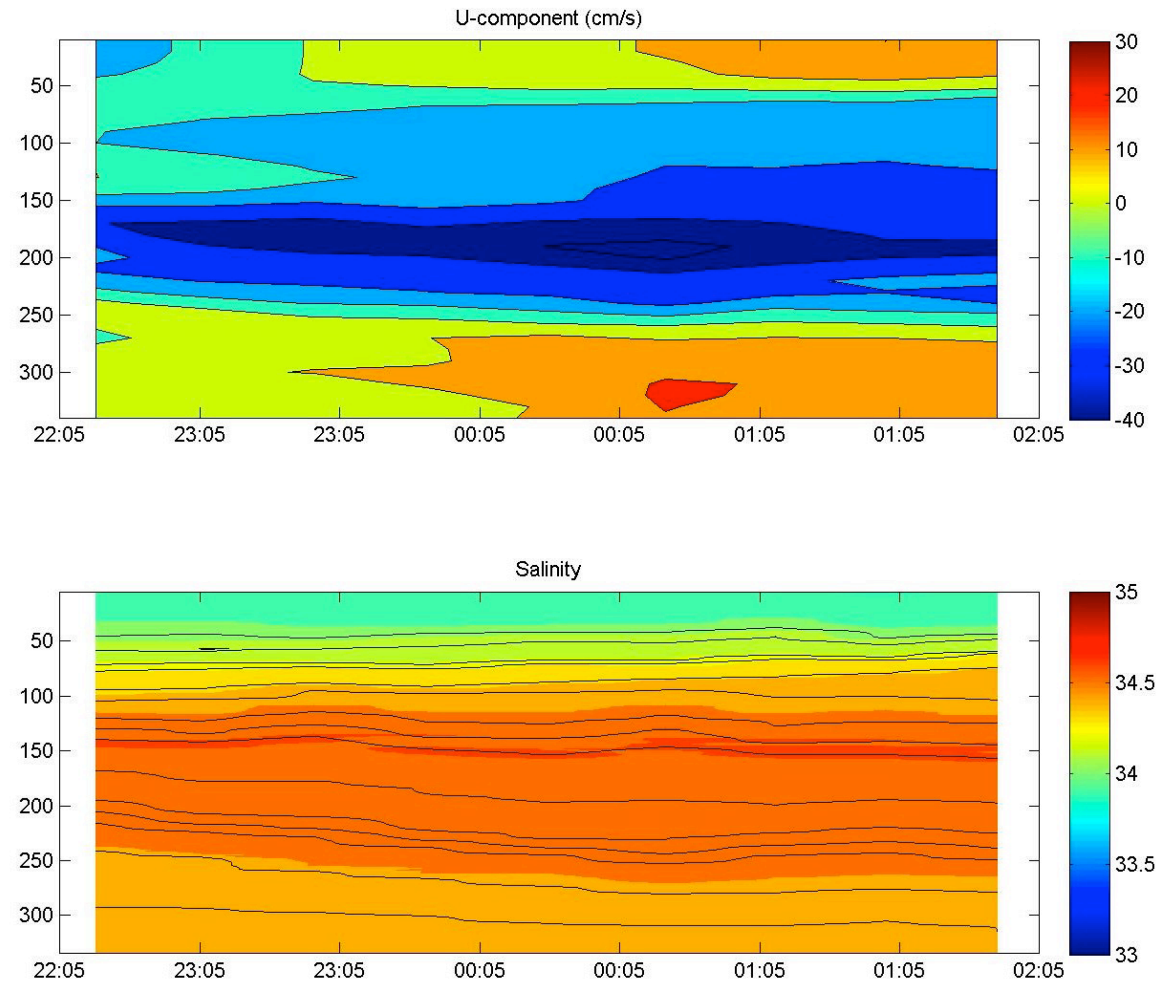

Figure 1. (top) The east/west component of velocity obtained using the LADCP package for a time series station in the dune field. (bottom) The temperature (contours) plotted on top of salinity (color bar) for the same station. Note mid-depth bulge in both T and S associated with the westward core velocity of the mode-2 internal tide. Note also the 50 m mixed layer depth, double thermocline structure (100-150 m and 200-250 m), and mid-depth thermostad.

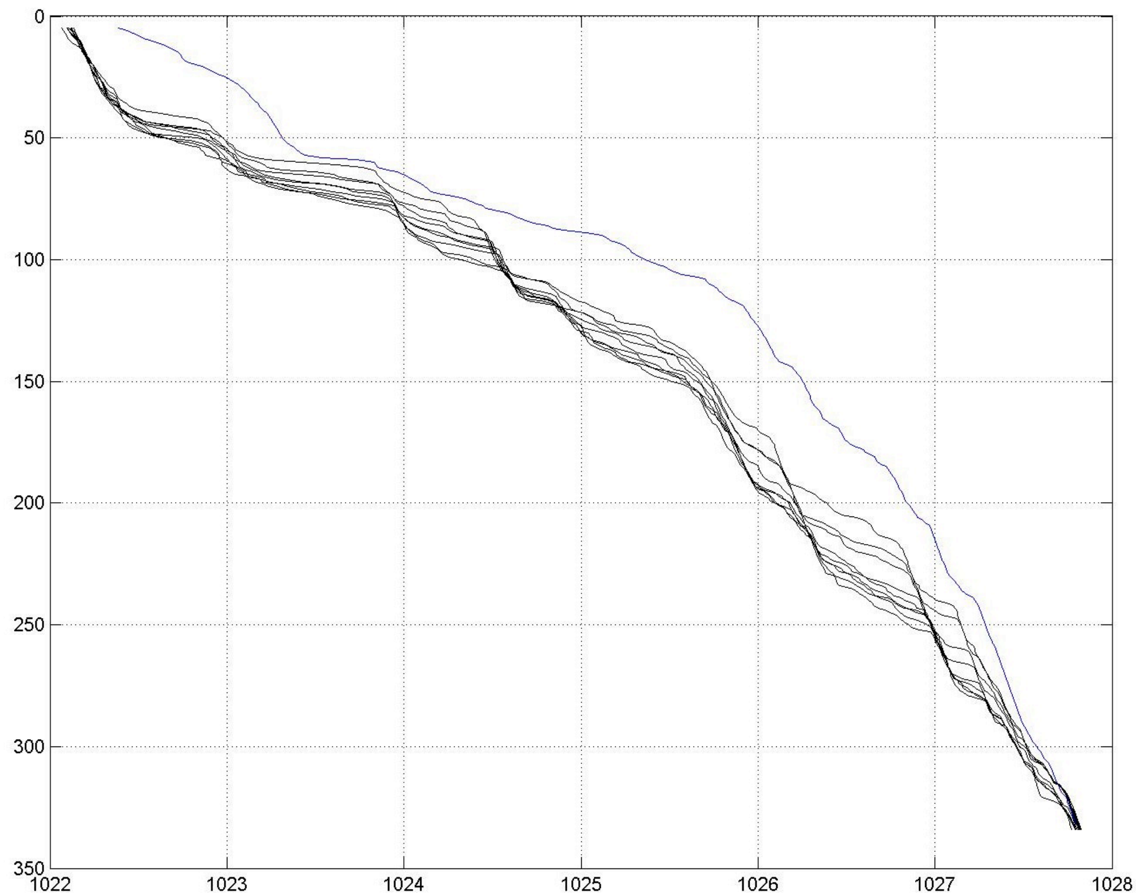

Figure 2. Density structure from the sand waves May 2013 cruise (many black lines) vs. WISE/VANS data from June 2005 (blue single line). Note the deeper mixed layer and weaker stratification during May 2013.