Going Vertical with Sentinel V ADCPs

OVERVIEW

The versatility of the 4-beam design of the ADCP has enabled measuring many facets of water in motion—waves, tides, currents—even within a single deployment. Yet this design is optimized for measuring slowly varying currents that, for the most part, have a weak vertical signal. In response to clients wanting to measure high-frequency water motions that exhibit strong vertical motions with shorter spatial scales, a vertical beam was added to the Sentinel V ADCP. This new beam enables direct measurement of vertical currents and a more robust measurement of range to a boundary (e.g., sea surface, seabed); further, the new beam's perpendicular orientation to boundaries results in some secondary advantages as well.

SOLUTION

Studies of surface and internal waves are expected to see the most benefit from the Sentinel V's vertical beam. Advantages include (i) low-noise, high-resolution measurements of vertical motions, (ii) reliable, high-resolution tracking of the sea surface, and (iii) measurements closer to the surface. Clients calculating turbulence parameters will also gain from measuring vertical motions directly.

And all ADCP users will glean more information for explaining data features as well as save time during data analysis due to a clean definition of the sea surface.

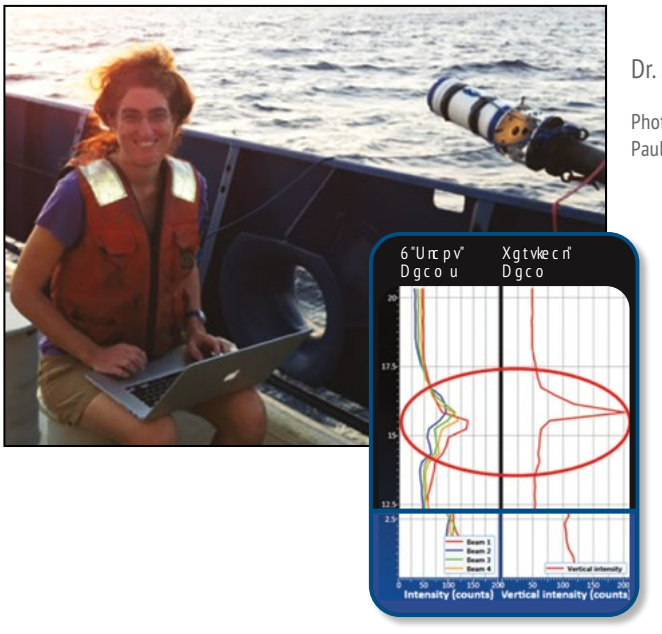
Products:
Sentinel V Acoustic Doppler Current Profiler (ADCP)

Application:
Improved Regional Ocean Models

Project:
Understanding internal waves and turbulence in the coastal ocean

Client:
Scripps Institution of Oceanography

Location:
San Diego, CA



Dr. Jen MacKinnon

Photos courtesy
Paul Chua

Single ping profiles of echo intensity from 5 beams of a Sentinel V ADCP

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For the Sentinel V ADCP data presented here, three notable improvements due to the vertical beam can be seen.

Data views of vertical motions show sharper features compared with 4-beam ADCP data. Because the beam measuring the vertical currents is aligned with the direction of motion, the resulting data quality (low noise, high resolution) is improved.

Surface echoes along the vertical beam have a sharper, more distinct signal; the resulting time series of water level therefore have improved precision and avoid drop-outs in fair-weather seas.

Data adjacent to a boundary can be used for vertical motions because acoustic returns along the vertical beam are not biased by side-lobe interference.

HIGHLIGHT:

- The Sentinel V ADCP fills a recognized need to measure high-frequency water motions that exhibit strong vertical motions with shorter spatial scales

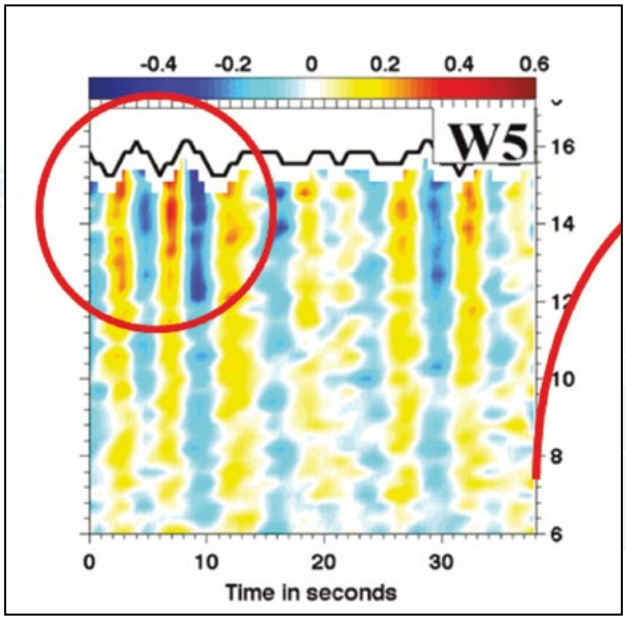
RESULTS

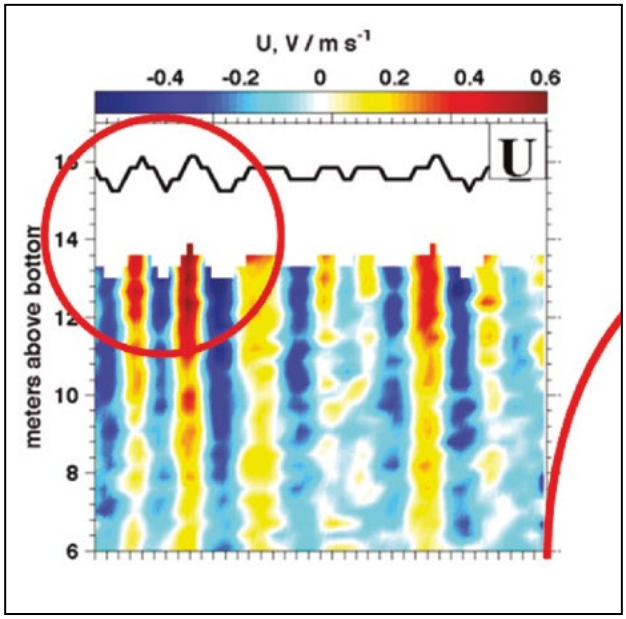
Following are some examples of Sentinel V ADCP data that show waves, tides, and currents. Data views are generously provided courtesy of Dr. Jen MacKinnon of Scripps Institution of Oceanography. The deployment was off San Diego, California.

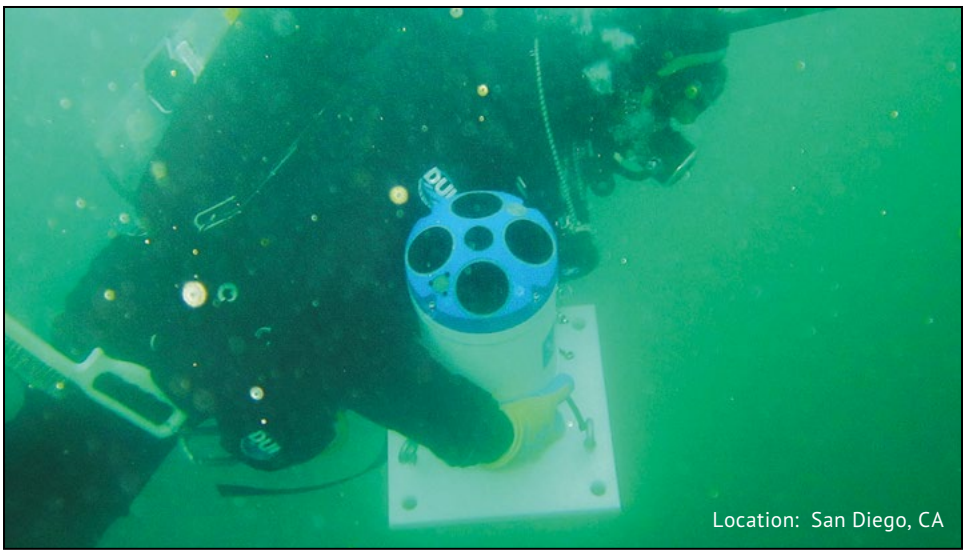
SURFACE GRAVITY WAVES

Orbital patterns: The top view to the right provides an impressive example of textbook orbital motions during the passing of a wave; specifically the water moves upward (+) in front of an approaching crest and then downward (-) in front of the following trough. And vertical motions vanish in the crest and trough where water moves forward (+), i.e., with the wave, in a crest and backwards (-) in a trough. Thus horizontal motions follow a similar pattern to vertical motions though delayed in phase by 90 degrees.

Vertical Decay: Similarly, this view shows how a wave's orbital motions diminish rapidly away from the water surface: from textbook formulas we can expect an exponential decay with depth that scales with the distance between crests. For the data views here, we can see 8 waves in 40 s duration. For this wave period, wavelengths are 35-40 m. Thus you can expect a 3-fold change in currents when depth levels differ by 6 m.







HIGHLIGHT:

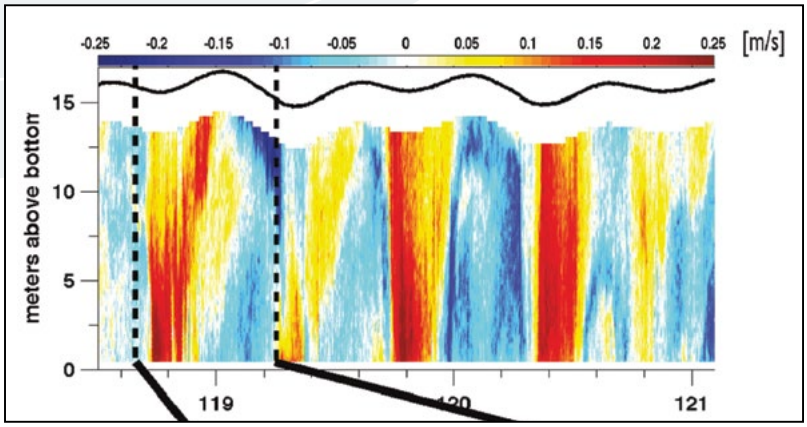
- Sentinel V data shows an impressive example of textbook orbital motions during the passing of a wave

TIDES AND INTERNAL WAVES

Like the wave motions, simple tidal variation can have predictable relationships between currents and water levels. Zooming into the early days of a 7-d view, we see a consistent pattern in which inflow (+) and outflow (-) deliver and then extract the water on either side of the high water mark. Some intriguing changes in vertical structure are also apparent in which the deeper currents noticeably precede the near-surface currents during the first couple of tidal cycles yet the timing of currents becomes far more depth-independent in later days.

Associated with this period showing marked vertical structure is the following 30-minute snapshot of the currents. These more-detailed data provide a great example of the advantage of the Sentinel V's vertical beam for measuring internal waves.

The horizontal currents show the arrival of an impressive two-layer structure in which the interface descends about 10 m in 10 minutes. Vertical currents during this period are consistent in size and direction with this change. More interesting are the subsequent patterns in the vertical currents that show strong heaving up and down, likely associated with internal waves propagating along the mid-column interface. From these data, it seems the wave period is about 3 minutes. You can see how the vertical motions measured with the vertical beam appear with sharper resolution in depth and time compared with slant beam data.



Contour plot showing 2.5 days of north-south water currents. Data were measured with a Sentinel V ADCP deployed at 16 m depth off San Diego, California. Duration of the series is about 20 minutes. Call-outs identify where data were taken for Surface Waves (left) and Internal Waves (above).

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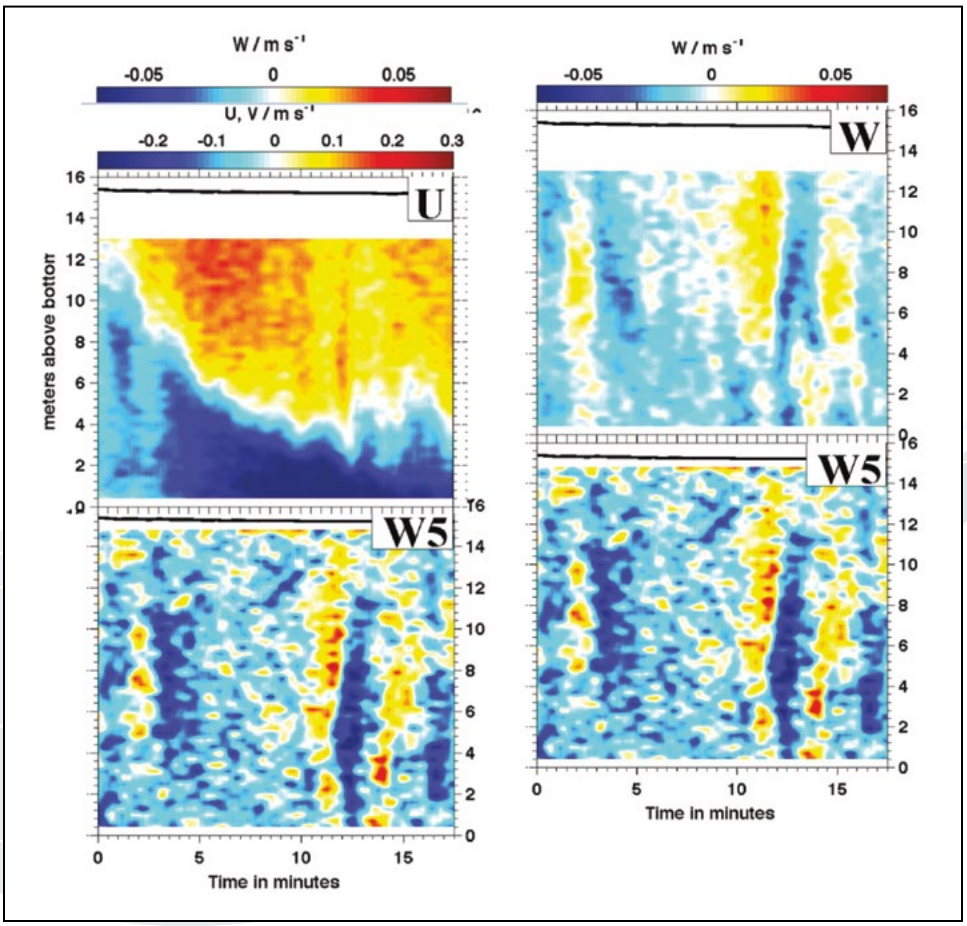

HIGHLIGHT:

- A 30-minute snapshot of the currents shows more detailed data that provides a great example of the advantages of the Sentinel V's vertical beam for measuring internal waves

SUMMARY

In summary, the Sentinel V ADCP includes a vertical beam that measures vertical currents directly. Studies of high frequency features will benefit from much sharper images of vertical motions as well as more robust measurements of range to surface. And thanks to that unambiguous definition of the water's top edge, all ADCP users will save time during data analysis.

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