Large Underwater Waves Observed with Towed ADCP

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Instruments

Overview

More than half of the world's population live in coastal areas. Thus many people worldwide need to reckon with coastal flooding due to severe storms and hurricanes. The subsequent extreme water discharges raise safety and health concerns. In quieter times, there is a need to monitor inshore waters affected by agricultural runoff and pollution by local industries. As a result, there is much interest in the mixing, exchange, and flushing of coastal waters and their contents.

Coastal oceanographers consider various mechanisms. One candidate is the turbulent mixing associated with large underwater "internal waves." Strong currents arise in these waves. Their shear can feed turbulent action that drives mixing in coastal waters. This process can be important for vertical exchange of water properties, from nutrients to pollutants.

Observational Discovery

In 2015, Canadian researchers were studying internal waves in the Saguenay Fjord in Quebec. Operating from a small research boat, they towed a Sentinel V ADCP for measuring currents to 50 m depth.

After crossing the boundary between two water masses, the team recorded an unusual event. It was the generation of large 10-m high, underwater waves. The passage of these large waves caused enhanced mixing due to an underwater wake of large swirls and severe turbulence.

The researchers found the cause for the large waves to be an intrusive horizontal plume whose currents disturbed density layers. Although such plumes are known in coastal seas, their role in generating large underwater waves was not previously recorded.

Instruments

Products:
TRDI Sentinel V ADCP

Application:
Towed measurements

Project:
Origin of large underwater waves

Organizations:
Institut des Sciences de la Mer de Rimouski (ISMER), Maurice-Lamontagne Institute (IML), Québec-Océan network

Contacts:
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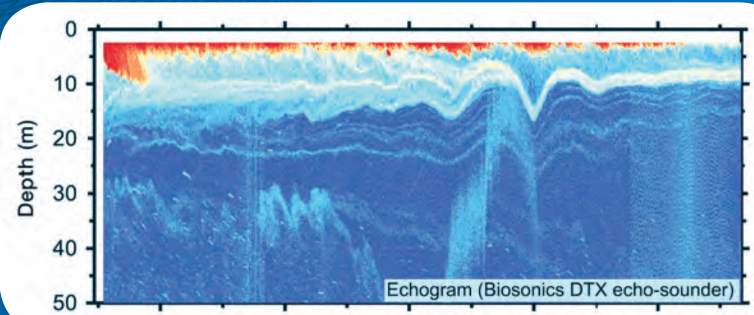
Peter S. Galbraith
Cédric Chavanne

Data Collection Date:
July 2015

Location:
Saguenay Fjord in Quebec, Canada

The team of Canadian researchers aboard their research boat that towed the Sentinel V ADCP.

Credit: D. Bourgault, P.S. Galbraith, and C. Chavanne



Echogram view of Internal Solitary Wave

Credit: D. Bourgault, P.S. Galbraith, and C. Chavanne

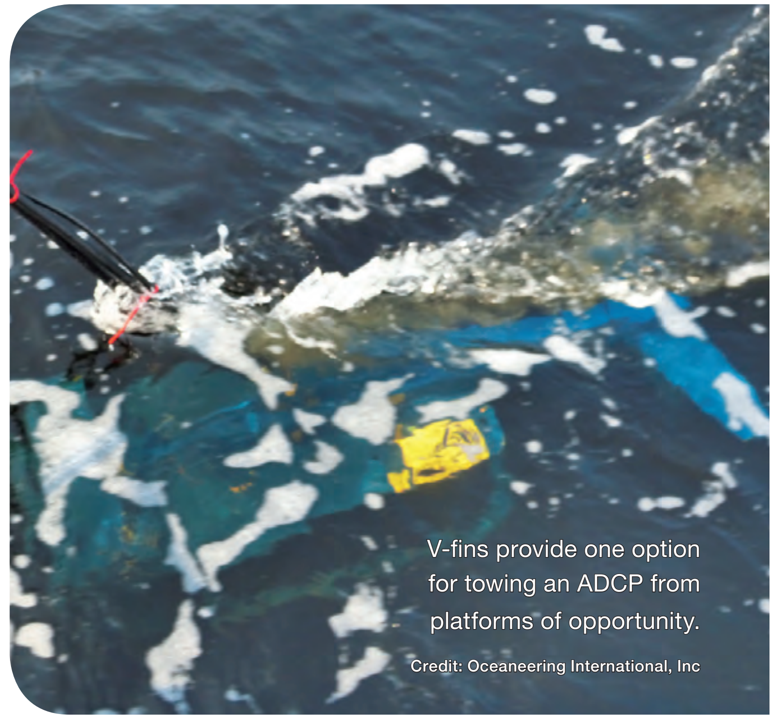
Situation

Ocean properties tend to persist in discernible layers. For example, salty waters lie below fresher waters. We are all familiar with waves moving along the water surface. Some waves, however, propagate within the water column. They travel along the interface between layers of different density. You've probably seen them inside a bottle holding layers of oil and water.

Internal Solitary Wave

Underwater waves can have large amplitude – tens of meters in coastal waters. One distinctive variant is the internal solitary wave. The descriptor solitary applies because these waves travel as a single isolated pulse. You've seen this waveform when you make a quick flick of a length of rope.

Various mechanisms can generate internal solitary waves. One candidate – the intrusive plume-- has been studied in theoretical work and lab-tank experiments. Yet this mechanism has rarely been observed.



V-fins provide one option for towing an ADCP from platforms of opportunity.

Credit: Oceaneering International, Inc

Observing Generation

Internal solitary waves populate Saguenay Fjord in Quebec though their cause was unknown. While studying these waves, a team of Canadian researchers towed a Sentinel V ADCP across a frontal region. This is where two water masses with different properties are adjoined. Because surface currents converge at these fronts, water sinks there too.

Near the frontal region, the scientists observed that a downward plume of currents levelled out 10 m below the surface. From there, the plume intruded horizontally into ambient waters by moving along a density interface. Solitary internal waves formed at the plume's leading edge. These waves detached and propagated ahead of the plume along the same interface. In their wake, they left turbulent mixing.

Solution – Towed ADCP

Towing an ADCP offers an attractive option for working from smaller boats, rental vessels, and ships of opportunity. As well as being portable and easily deployed, the towed ADCP provides an affordable, efficient solution for survey work, and the setup simplifies system maintenance.

Highlights:

- Internal waves can travel along the interface between layers of different density
- Breaking internal waves act to homogenize the layered distribution of ocean properties
- A downward plume of currents levelled out at 10 m depth and then intruded horizontally into ambient waters
- Solitary internal waves formed at the plume's leading edge

Compared with using submerged vehicles, the towed approach allows speedier decision making. Notably, operators can react immediately when survey results arise. Typical examples include finding a jet of currents or a plume of particles.

Towed systems carry the ADCP aboard some type of fin, frame, or hydrodynamic body. For viewing data while underway, operators combine power and communications with the tow cable. As well as the ADCP, the towed body can carry other sensors. If available, the ADCP's bottom-tracking corrects observed water currents for motion of the towed body.

Some operators carry dual ADCPs oriented to look up and down. This enhances the flexibility and usefulness of the towed method. One example is for studying the surface layer and deeper currents at once.

For larger vessels moving at higher speeds, the towing setup is more complex. It typically includes a winch, shock cord, and cable fairing. The towed configuration for ADCPs avoids interfering bubble layers found below larger vessels. Yet any magnetic influence of the towed body (or ship's hull) on the ADCP's compass will need a calibration exercise.

Result

The field observations of the Canadian team show the generation of large-amplitude internal solitary waves. This work represents a rare case where internal wave generation is clearly observed at sea.

The Sentinel V ADCP used by the researchers provided high quality current measurements to 50 m depth with 0.5 m vertical resolution. This setup provided a useful blend of range and resolution.

Notably, the Sentinel V includes a vertical beam as well as the 4-beam Janus configuration. Up/down currents are a key signature of internal waves. The Sentinel V's fifth beam provides a low-noise measurement of vertical motions due to its being pointed straight along the direction of interest. These new data provide a sharper view of internal wave motions and can resolve fine-scale features.

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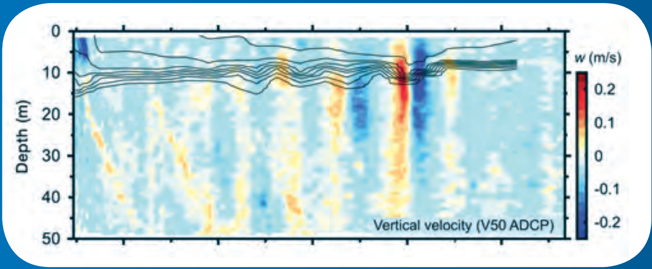
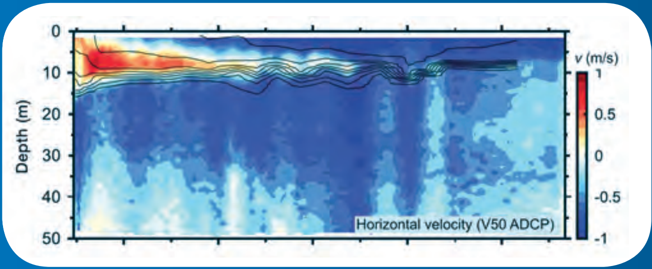
Highlights:

- Towed ADCPs offer an affordable, efficient solution for survey work
- As well as the ADCP, the towed body can carry other sensors
- Dual ADCPs oriented to look up and down enhance the flexibility of the towed method
- Towing an ADCP avoids interfering bubble layers found below larger vessels

Sentinel V ADCP. This newer ADCP includes a vertical beam in addition to the traditional 4-beam Janus configuration. This fifth beam measures up/down motions directly. One advantage is a sharper view of internal wave motions.



Contour view of vertical (up/down) currents along the measurement transect. Red colors indicate regions of upward flow whereas blue colors depict downward motion. To the right side of the panel are stronger motions associated with an internal solitary wave.



Contour view of horizontal (north/south) currents along the measurement transect. Red colors indicate regions of northward flows whereas blue colors depict flow moving in the opposite direction. At the left side above 10 m depth, you can see the intrusive plume.

Credit: D. Bourgault, P.S. Galbraith, and C. Chavanne

Highlights:

- The Sentinel V ADCP includes a vertical beam that crisply revealed up/down motions of internal waves
- The towed Sentinel V ADCP recorded the background currents as well as fine details in the wake of the internal solitary wave
- The different components of the ADCP currents revealed a detailed chronology for the generation of these internal waves

The data displays of the researchers provide a compelling story. In the first panel, you can clearly see sinking water at the frontal region. This is the blue patch of vertical velocity on the top left of the first panel.

Thereafter, in the second panel, you can see the intruding horizontal plume that is the red patch above 10 m depth.

Looking again to the first panel and farther to the right, you can see the vertical motions associated with the internal solitary waves. These are the distinct vertical patches of red and blue color. To advance the wave, water currents must raise density surfaces in front of a crest and lower them in front of a trough.

The towed Sentinel V ADCP provided a complete view to the researchers. They measured the background currents. Plus they could see the fine details of disturbances due to the passage of the large underwater waves.

For more of the story, see https://goo.gl/rhjJPP

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