Now ADCPs measure nearshore waves

The addition of wave data gathering capability while measuring water profiles has made ADCPs an even more versatile tool in support of dredging works and marine construction. A report by Brandon Strong and Paul Devine.

The value of the acoustic Doppler profiler (ADCP) for monitoring currents in support of dredging, marine civil engineering and port management is well known.

In dredging work it is often necessary to measure the extent of sediment plumes in environmentally sensitive areas. A knowledge of water movements is critical in planning long sea outfalls. In port management, real-time monitoring and telemetry of current data is a prime requirement to enable ships to enter narrow channels. All these activities are undertaken by ADCPs.

RD Instruments Inc., USA, (RDI) invented the ADCP is the early 1980s and has delivered more than 2400 of these versatile instruments to over 50 countries. That versatility has been still more enhanced by giving RDI ADCPs the capability to obtain wave data while measuring water profiles.

This new, patented, capability is available as an upgrade for RDI WorkHorse ADCPs and recent results demonstrate high quality output. In particular, ADCP wave data do not suffer from biases in significant wave height and direction that arise in traditional wave analyses that ignore wave interaction with strong tidal currents.

Directional resolution of the ADCP wave spectra is improved: wave packets of similar frequency from different directions are distinguished.

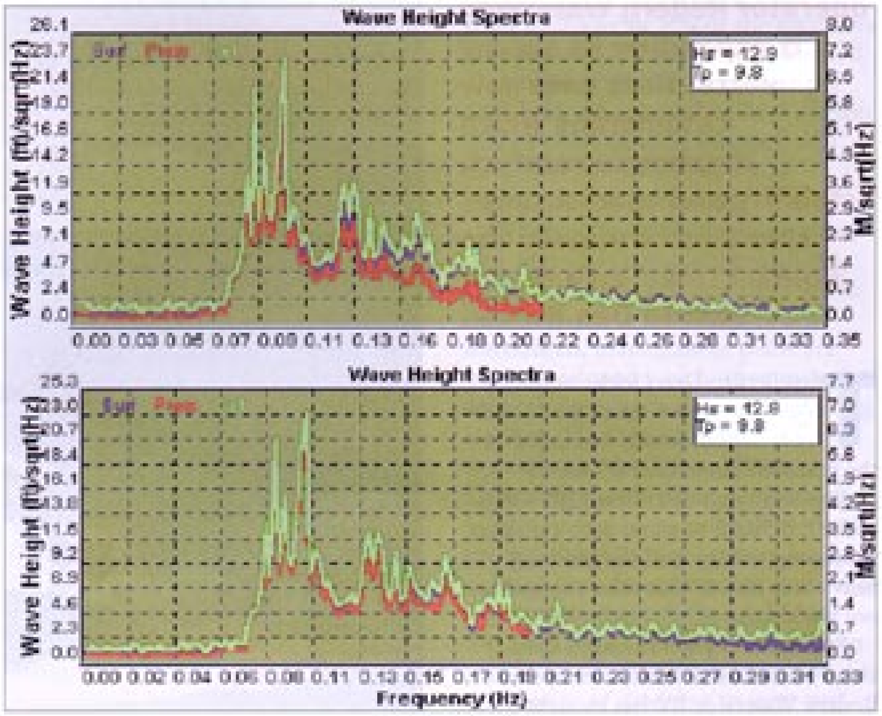

Fig 1: Three spectra for surface height derived from the independent data types measured by the ADCP. Results displayed in dark blue are from the surface tracking data, green are from orbital current fluctuations and pink are from the pressure sensor. The upper panel shows wave height inferred directly from pressure data without considering the effect of wave-tidal current interaction. The lower panel shows results that include the correction.

Because of its remote sampling capability and four acoustic beams the ADCP can be deployed safely on the bottom yet act as a surface and near-surface array to measure waves. The ADCP makes three independent types of measurements that independently confirm the wave analysis - surface variation, orbital currents and pressure record. Data show that the ADCP offers improved frequency response at high and low frequencies compared with traditional devices and can be operated through a much wider range of water depths.

There are several areas in which the combined wave- and current-measuring capabilities of ADCPs are put to use in the nearshore zone and in ports and harbours.

• **Beaches** are in a delicate balance because they are highly susceptible to rapid changes caused by waves and the long-shore currents they drive. Variations in beaches are both natural due to winter storms and summer accretion and man-made due to intervention in the nearshore zone. This intervention often changes the state of balance for a beach by altering the erosion, deposition, and redistribution of beach materials. Long-term measurements of waves and currents by instruments mounted safely on the seabed help establish patterns and thus enable predictions of erosion and accretion to be made.

• **Navigation** is aided by anticipating sea conditions.

• **Coastal engineering** must plan and design for expected wave regimes and wave climate. While protecting their structures, coastal engineers must avoid unintended effects that, at times, have worsened the problem the structures were intended to solve.

Improved technique

Standard techniques for measuring waves use arrays of sensors, surface following devices and single-point subsurface devices. These traditional methods have complementary advantages and disadvantages and generally the sacrifice for improving data quality is more complex logistics. However, an ADCP changes this picture by providing the power of an array, the quality of a surface-tracking device and the simplicity of a single point instrument.

• **Power of an array:** The ADCP provides the powerful method of a beamforming array for directional wave analysis. The array can be visualised by viewing from above the ADCP's four beams and depth cells along each beam. In the analysis, the current fluctuations observed in depth cells are transformed to the surface via linear wave theory. Together with the beam data at the surface, they emulate a grid of independent sensors recording the incident wave field.

• **Quality of a surface-tracking device:** The ADCP directly tracks the water surface variation along each of four beams; this allows high frequency wave information, even in deeper water.

• **Simplicity of a single point instrument:** The ADCP allows the simple logistics of a single point instrument because it is compact, easy to install and is bottom mounted.

• **More secure deployments:** The security of the ADCP and its dataset are improved thanks to the instrument's capability to measure remotely. It sees the surface and near surface variability from a fixed bottom mounting to 40m depth. This remote measurement allows the ADCP system to measure the same wave field as a pressure gauge or surface following device but from a safer location—well outside the surf zone and on the sea bottom!

More versatile deployment choices More generally, this remote measurement capability enables the same ADCP directional wave gauge to operate across a wide range of water depths.

Performance

Users of the ADCP directional wave gauge can compare statistics from three independent data types measured simultaneously.

The *first* data type is direct tracking of the water surface variation along each of four beams.

But how does the wave-field analysis avoid spatial aliasing caused by wide beam separation at the surface?

The *second* data type measured by the ADCP provides the answer: orbital current fluctuations. These fluctuations are measured with each beam at 3-5 depths near the water surface. Once these data are transformed to the surface using linear wave theory, the array has at least 16 elements spaced at longer beam-to-beam lags and shorter bin-to-bin lags, which avoids the potential aliasing referred to above. This combination produces directional information across a wide bandwidth, including high frequency waves in deeper water, (e.g. measuring 4-second waves in 40m of water!).

The *third* data type is obtained via a pressure sensor. The pressure sensor is used first to establish the depth of the ADCP below the water surface, from which the separation of the ADCP array elements is determined. So the extra benefit of these pressure data is a third independent measurement of waves. Fig 1 shows how all three factors allow dire* comparison with results derived from traditional wave sensors that rely completely on pressure data for their results.

An important result comes from data that clearly reveal the bias error in pressure-based wave results when the wave interaction with a strong current field is not considered. By including the simultaneous current profiles in the wave analysis, the ADCP wave results do not suffer from biases in significant wave height and direction that arise in traditional wave analyses. There is also the improved directional resolution of the ADCP wave spectra, distinguishing wave packets of similar frequency from different directions.

In summary, data show that for situations where the performance of other wave gauges is limited, the ADCP Directional Wave Gauge continues to measure waves accurately. In particular the ADCP has been demonstrated to have an impressive bandwidth from short local seas to long swells, eclipsing the performance of other common choices for wave gauges. ▲