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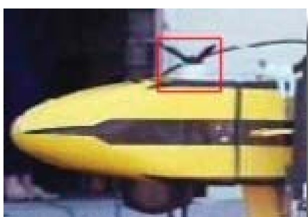
Application Note

ADVOcean Used in NPS AUV Research

Monterey, California, USA

The Naval Postgraduate School (NPS) Center for Autonomous Underwater Vehicle (AUV) Research, under the direction of Prof. Anthony Healey, has incorporated a SonTek ADVOcean into their research vehicle Phoenix. The Acoustic Doppler Velocimeter (ADV), fused together with Doppler velocity log (DVL) data, provides water particle velocity information to the vehicle's control systems. In addition, the ADV's installed optional compass provides a backup to the vehicle's Inertial Motion Package. The following photographs show the location of the ADVOcean on Phoenix.



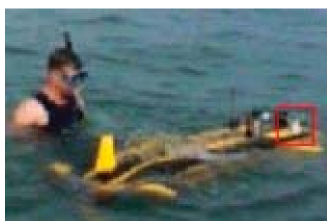


Figure 1. ADVOcean on AUV Phoenix
Figure 2. Phoenix and ADVOcean

These photographs were taken just before deployment for AUVFEST `98 in Gulfport, Mississippi. The AUVFEST was sponsored by the Naval Oceanographic Office in cooperation with the Office of Naval Research. The purpose of the event was to allow researchers such as NPS's Jeff Riedel and David Marco to demonstrate various vehicle capabilities and the direction of each group's research.

During a recent deployment, NPS demonstrated their vehicle's ability to gather data to be used for wave directional spectrum estimates. ADV data, integrated with DVL and vehicle motion data, are used to provide water particle velocity information. By integrating ADV, DVL, and vehicle motion information, the only correction that must be made to the data is to account for the Doppler shift or encounter frequency associated with the moving vehicle. This correction is made recursively during post-processing. The survey data below show the directional energy density plot (Figure 3) and wave directional spectrum estimates (Figure 4) after post-processing.

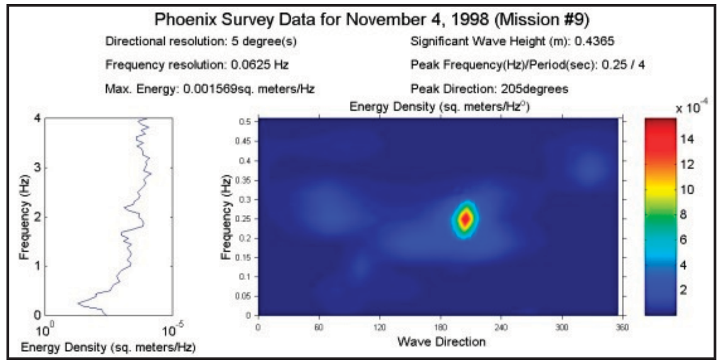


Figure 3. Directional Energy Density Plot

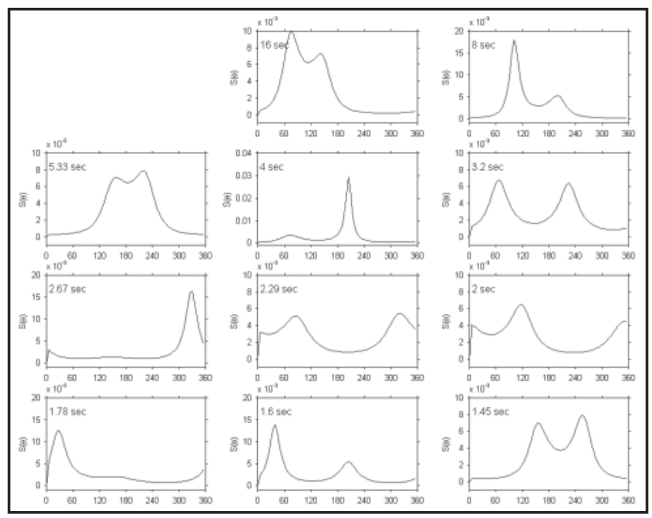


Figure 4. Wave Directional Spectrum Estimates

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ADV Laboratory Evaluation and Field Deployment in the Benthic Boundary Layer by WHOI

As part of the Coastal Mixing and Optics Accelerated Research Initiative by the Office of Naval Research, Woods Hole Oceanographic Institute deployed three SonTek/YSI Acoustic Doppler Velocimeters (ADV) south of Martha's Vineyard on a tripod at 70-m depth to measure velocities just 35 cm above the seabed.

Prior to deployment, an extensive laboratory investigation was undertaken to evaluate the performance of the ADV*. Simultaneous flow measurements were obtained using the ADV and a Laser Doppler Velocimeter (LDV) for a range of flow conditions. The measured mean flows agreed within one percent. The difference was attributed to uncertainties in vertically aligning the two sensors. direct estimates of Reynolds stress were underestimated by only one percent by the ADV.

Special characteristics of the flow were used to examine the effect of sample volume size in turbulence spectra. It was found that at relatively low-boundary Reynolds numbers, the effect of viscous dissipation was more important than the effect of the sample volume size. Spatial filtering is a function of the Kolmogorov microscale (i.e., less attenuation at less turbulent flows) and is greater in the horizontal component than in the vertical. This, combined with the significantly lower noise levels, make the vertical component the best candidate for studies of the structure of turbulence.

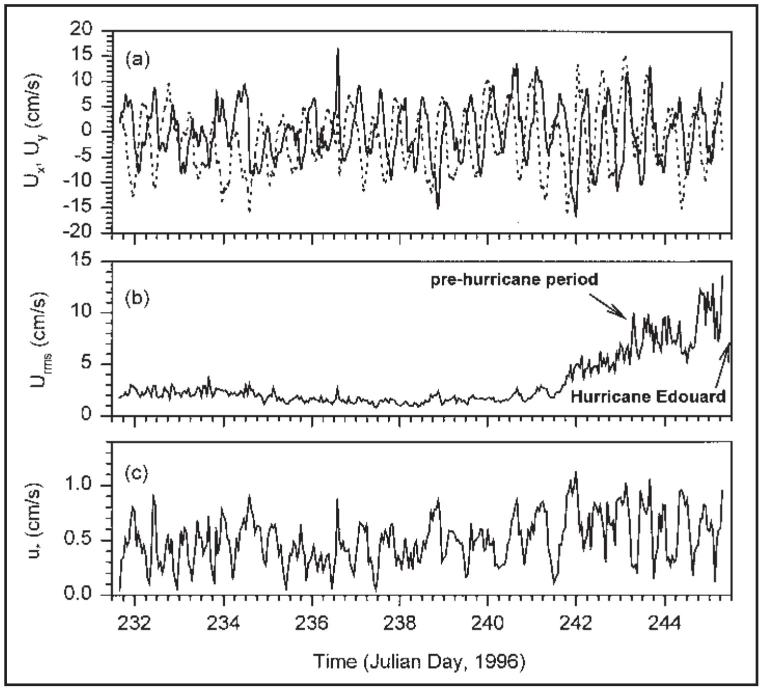

Figure 1. Time series of horizontal velocities (top), root mean squared velocity (center), and shear velocity (bottom) within the benthic boundary layer.

ADV time-series are shown in Figure 1 from the first field deployment in 1996 beginning on August 19, 1996 until Hurricane Edouard struck the east coast on September 1, 1996. Data consisted of velocity time-series sampled at 25 Hz for 9.5 minutes each hour per instrument. The diurnal tide dominates the mean horizontal velocities, while the relative phase difference indicates rotary flow at this depth. The variance of the horizontal flow was initially almost constant, but increased in response to the approach of Hurricane Edouard. The increase of the mean shear velocity due to the presence of the wave boundary layer can be seen just before the hurricane arrives.

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Application Note

Surf Zone Studies with ADV

San Diego, California, USA

Researchers from Scripps Institution of Oceanography prepare an ADV for measurements in the surf zone of a local San Diego beach. The ADV was deployed at low tide and left in place to study the near-bed velocities in the surf and swash zones with the changing tides. The ADV's sensor head is highlighted in the box to the left.

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Application Note

Open-Channel Flow Measurements at Water Treatment Facility

China

Figure 1. ADVOcean Custom Mounting for Water Treatment Facility

A major municipal water authority in China recently conducted a series of flow tests in a large treatment facility using a 5-MHz SonTek/YSI ADVOcean. They chose the ADVOcean because of its ability to measure precise 3-D currents at a focal point 18 cm from the transducer. The ADVOcean's heavy-duty construction made it ideal for this type of industrial application.

The ADVOcean was mounted on a stainless steel clamp (Figure 1), which was further supported on a pre-fabricated platform consisting of a trolley and winch system (Figure 2). The instrument was then lowered down at the clarifier outlet open-channel.

After obtaining the velocity profiles of the clarifier outlet open-channel, the water authority evaluated the total open-channel flow using the velocity-area method (ISO 748:1997 - Measurement of Liquid Flow in Open Channels -- Velocity-Area Methods). The results were then compared with the measurements made by the treatment plant's inlet dall-type flowmeter.

The open-channel was subdivided into 15 verticals. Three measurements were made in each vertical at depths of 0.2, 0.6, and 0.8 m. The flow rates derived from the tests were 438 Mld (megaliters per day) for the ADVOcean and 420 Mld for the inlet dall-type flowmeter. Given the dall-type flowmeter accuracy of 5%, this minor difference was considered acceptable in open-channel measurements for this field application. Figure 3 shows a flow profile in a cross section of the channel.

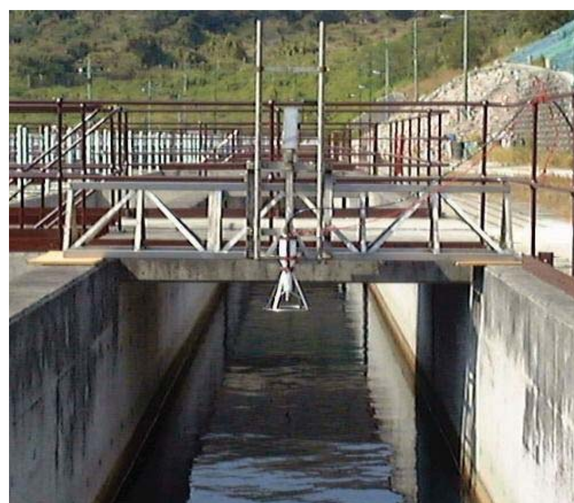

Figure 2. ADVOcean Mounting Platform at Water Treatment Facility

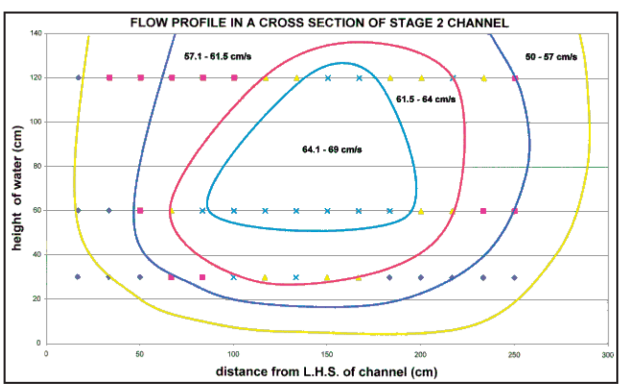

Figure 3. Flow Profile in a Cross Section of Channel

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Current Monitoring at Shinnecock Inlet

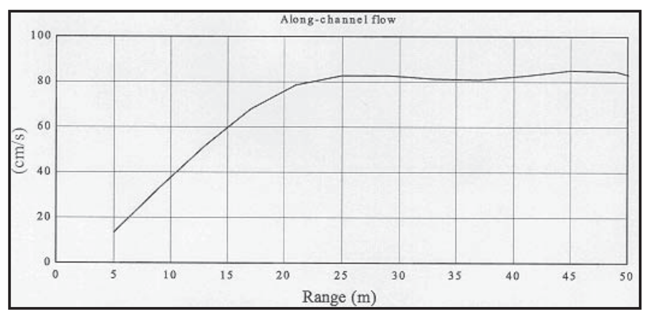
Long Island, New York

A 0.5-MHz Side-Looking Acoustic Doppler Profiler (ADP) is presently monitoring currents at Shinnecock Inlet on Long Island in New York. The project features an array of SonTek/YSI instruments, and is a cooperative partnership of the U.S. Army Corps of Engineers, the State of New York, SUNY Stony Brook, and Offshore and Coastal Technologies, Inc.

The ADP is mounted off the east jetty, and was chosen for this job to profile currents into the channel and determine the predominant flow patterns.

The large-diameter transducers in SonTek ADPs produce extremely narrow beams, offering distinct range advantages for horizontal profiling. Additionally, the use of a transducer shading technique minimizes side lobe interference, further increasing the maximum horizontal range of the system.

The graph shows the actual performance of the side-looking ADP. Note that when the instrument was deployed 1.2 m below the surface, it was able to accurately measure currents out to 50 m. This represents a phenomenal aspect ratio of over 40 (i.e., the SL-ADP achieved a horizontal range that was at least 40 times its distance to the nearer boundary). This suggests that placing the ADP at a depth of just 2-3 m may allow a 0.5-MHz side-looking ADP to achieve its full profiling range of 70 to 110 m.



This graph shows the actual performance of the side-looking ADP at Shinnecock Inlet, New York. Note that the main along-channel flow was reached at a distance of about 20 m from the ADP. What is astonishing here is that the ADP was submerged just 1.2 m below the surface and was able to accurately measure current data out to 50 m!

Live data from the Shinnecock Inlet project can be viewed at http://www.lishore.org/shinnecock/latest.htm.

In addition to the side-looking ADP, the Shinnecock Inlet Field Monitoring Project is also using the following SonTek systems for the listed purpose. The locations of these systems can be found at http://www.offshorecoastal.com/GaugeDescript.htm.

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Sediment Transport on Columbia River

Introduction

SonTek/YSI Acoustic Doppler Profiler (ADP) and Acoustic Doppler Velocimeter (ADV) integrated Hydra systems were deployed near the mouth of the Columbia River from August 18 through October 21, 1997 by researchers from the U.S. Army Corps of Engineers (USGS) Waterways Experiment Station (WES) and Oregon State University (OSU). The experiment was designed to measure movement of dredged material disposed off the mouth of the Columbia River. The data gathered are to be used for improvement of numerical model predictions of sediment transport.

Three tripods were deployed at different locations, each equipped with a Hydra and an ADP. All of the Hydras were outfitted with two optical backscatter sensors and a piezoelectric crystal pressure sensor. The ADPs incorporated a conductivity cell. WES investigators required simultaneous time stamping for the measurements made in the bottom boundary layer, and the Hydra was the SonTek solution.

Excellent data were retrieved from this deployment, and a few selected examples appear below. The velocity time series from the Hydra provide a means of estimating turbulence spectra, which are consistent with model predictions (Figure 1).

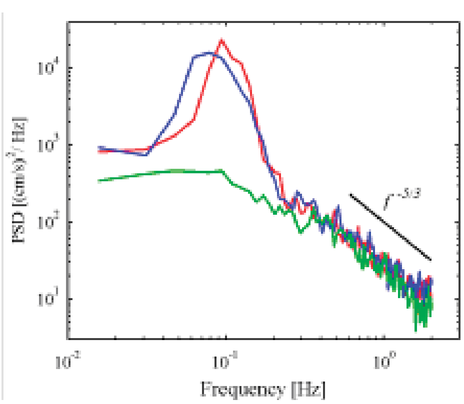

Figure 1. Turbulence Spectra

Combining measured orbital velocity with the pressure record allows calculation of a directional wave spectrum, at one point revealing dominant 11-s waves propagating from the North-East (Figure 2). Temperature and salinity show significant variability and reveal sharp fronts (Figure 3). The optical backscatter sensor provides insight on the distribution of suspended sediments. Acoustical and optical methods give generally similar results (Figure 4), though with some variation due to the inherent differences between the two methods.

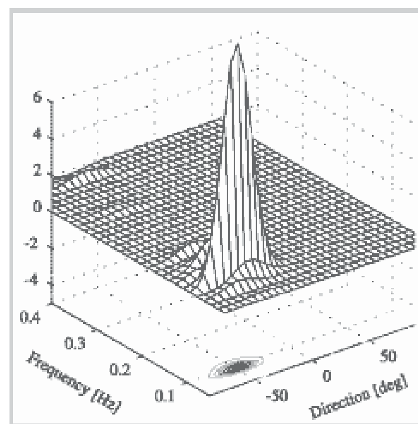

Figure 2. Directional Wave Spectrum

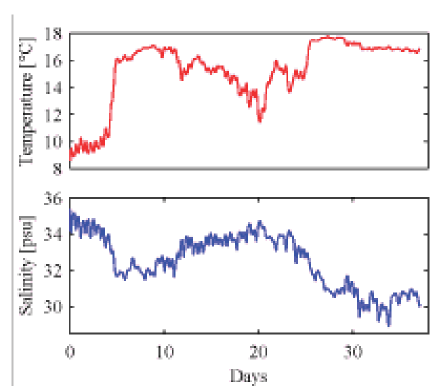

Figure 3. Temperature / Salinity

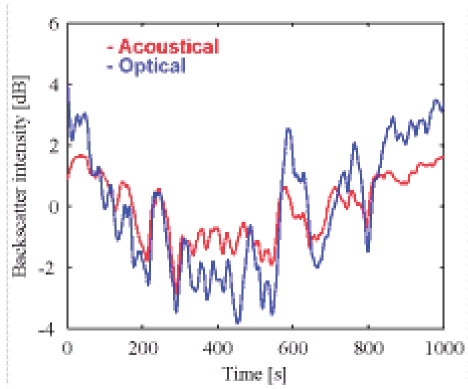

Figure 4. Sediment Distribution

These examples provide a good first look at the capabilities of the Hydra package. We are certain that additional exciting data will follow as more deployments are taking place at the Columbia River and other sites. On April 5, 1998, WES and OSU deployed another four Hydra and ADP-equipped tripods off the mouth of the Columbia River to continue monitoring dredged-material disposal sites in the presence of the spring discharge plume from the river.

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Fluid Mud Study in Canada's Petitcodiac River

New Brunswick, Canada

As part of a project aimed at understanding the influence of high-concentration suspensions of fine sediments (fluid muds) on flow, researchers from Boston College and the Bedford Institute of Oceanography recently deployed a SonTek Autonomous ADV (Hydra) in the Petitcodiac River, New Brunswick, Canada (pictured left).

The Petitcodiac was chosen because of consistently high suspended-sediment concentrations (0.5 to >200 g/L) and large tidal range (>4 m) producing strong current velocities (> 1.5 m/s). The Hydra was mounted on a tripod and lowered from a bridge into the Petitcodiac River obtaining flow and turbulence measurements within fluid muds and the overlying water column.

The Hydra was chosen for its robust configuration and ability to collect high-frequency (25 Hz) three-dimensional velocity data in a remote sampling volume. Additionally, it measures the distance to the boundary, which can be used to monitor morphological changes to the bottom. The resulting data set provides an excellent means to test threshold conditions regarding suppression of turbulence by sediment-induced stratification and the carrying capacity of turbulent flows.

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Application Note

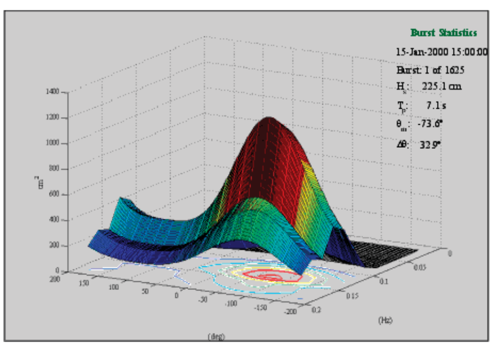
Directional Wave Measurements

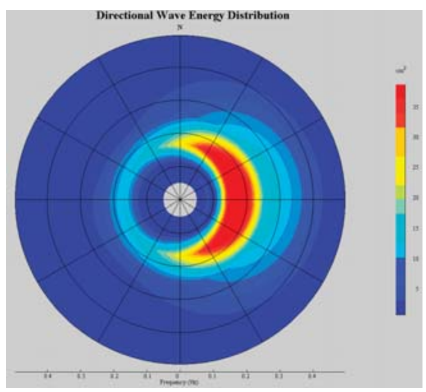
Our SonWave-Pro wave spectra software package uses the proven PUV method for directional wave measurement. This method requires accurate measurement of pressure (P) and horizontal velocities (UV) at data rates high enough to resolve wave energy (typically 2 Hz or higher).

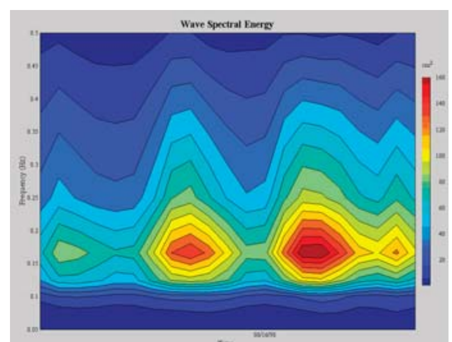
Most of our instruments (ADP, ADV, Hydra, PC-ADP, Triton-ADV) allow you to collect the data needed for directional wave measurements. In some cases, upgrading the capabilities of an existing system is fairly simple and does not require the return of the system to SonTek.

Directional Wave System Requirements

ADV, Hydra, PCADP	These instruments are already capable of the appropriate measurement rates. As long as the system has a pressure sensor, all that is needed is the PUV software package.
ADP	To gather accurate velocity data at rates sufficient for directional wave analysis, the SonTek ADP uses a modified measurement strategy. Burst sampling of highly accurate short-range measurements for waves is interspersed with the standard current profiles. Frequently Asked Questions about Directional Waves for ADPs/ADCPs
Triton-ADV	The Triton-ADV is a directional wave, tide, and current measurement system that combines the power of SonTek's ADV technology with the proven PUV wave method. The Triton-ADV is the most value-packed system available for currents, directional waves, and tides.







The SonWave-Pro software package offers flexible processing schemes, custom plots (surface, polar, mesh), time-series displays, spectral displays, and wave statistics. The software can create publication quality graphics. Most of our instruments (ADP, ADV, Hydra, PC-ADP, Triton-ADV) allow you to collect the data needed for directional wave measurements.

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Acoustic Doppler Velocimeters Making Waves in Nearshore Research

San Diego, California, USA

Understanding wave behavior has huge implications, from the most casual surfer to the most rugged Navy special-ops warrior and plenty of people in between. Surfers are looking for a beautiful curl and a long ride; Navy SEALs are careful to avoid dangerous currents, but want enough wave action to hide them from enemy radar. Then there are zoning authorities looking for guidance on beachfront development, park commissioners trying to determine whether to site a public beach on a strip of shoreline, and health agencies hoping to predict where – and how quickly – a toxic spill will travel along the coast.

"Ideally, we'd like to start with weather predictions, then take that all the way to the beach," says Steve Elgar of the Woods Hole Oceanographic Institution (WHOI) in Woods Hole, Massachusetts, who studies waves on coastlines around the world. "It would be nice if we could measure waves offshore, in deep water, and understand how they go from deep water to the beach."

One of the most intriguing environments for studying the effects of seafloor topography on waves is the California coast north of San Diego, where Scripps and La Jolla canyons rip chasms almost all the way to the shore, and offshore islands create "shadows" in the surf. As a result, parents teach their young children to swim in the peaceful shallows just yards from famous surfing spots like Black's Beach, which serves up dramatic surf as some waves bounce off canyon walls to reverse course and smash into oncoming tides, while others are refracted, or bent, by traveling along the canyons.

Along that coastline, Elgar and his wife and lab partner, Britt Raubenheimer, joined researchers from a dozen institutions in the Nearshore Canyon Experiment (NCEX) in 2003.

NCEX, funded by the U.S. Navy's Office of Naval Research and the National Science Foundation brought together an array of sensing technologies – from multi-channel video recorders and satellite cameras to a suite of wave and current measuring instruments – to research the complicated effects of undersea canyons on waves. When all the data have been analyzed, the experiment should yield a comprehensive model that includes modules on waves, circulation and sediment transport – vital tools for important decisions along coastlines around the world.

ADV Technology Proves Itself

Elgar deployed about two dozen instruments to study wave height, current and water depth for NCEX. With instruments in the water – often in punishing conditions – and streams of data flowing in almost continuously, he was looking for durability and reliability, and he found both in a line of acoustic Doppler-based technologies from SonTek/YSI.

SonTek Acoustic Doppler velocimeters (ADVs) play a key role in surf zone wave research of Steve Elgar and Britt Raubenheimer – not just because they can provide extremely accurate current, pressure and level data, but also because they can withstand the punishing conditions of the surf zone.

First, Elgar had to prove to himself that acoustic Doppler velocimeters would excel in ocean conditions. "Edie Gallagher, a grad student of mine, developed an acoustic altimeter dedicated to find the bottom," he recalls. "Then we started using the SonTek equipment and realized that it does the same thing. We compared our fancy sonar altimeter with the SonTek equipment and realized that we were getting two-for-one from the SonTek – the ADVOcean and Triton-ADV probes find the bottom and measure current and pressure in one instrument."

Similarly, he tested SonTek's acoustic current meter against the electromagnetic sensors he previously used. "We used to use electromagnetic current meters, but we were constantly correcting for an offset," Elgar says. "The electromagnetic sensors are temperature-sensitive, so they drift. Also, when electromagnetic sensors get a little biofouled, they quit. I've had SonTek equipment completely covered – one was buried for 10 months under a meter of sand – and they still collected data. We have made acoustic current meters work as well as or better than electromagnetic current meters, and their offsets are perfect."

Elgar adds that the multiple-sensor equipment has really earned its stripes in the field. "On one of my instruments in a study in the Gulf of Mexico, the pressure gauge got plugged the first day, but we got enough information from the current meter that we salvaged the data," he notes.

ADV technology also proved itself on the beach in Raubenheimer's study of the swash zone. Raubenheimer mounted her acoustic current meters 2 cm, 5 cm and 8 cm above the sand, supported on sturdy tripods. The meters measure wave action through a cylindrical sampling area 0.5 cm in diameter and 2 cm high. The swash comes through as a mass of bubbles, which Elgar says can present a challenge. "Rather than getting one nice, clean return, we get a mess," he notes. "But we've learned how to post-process the data to clean it up so it works great for waves. Actually, the bubbles make great reflectors."

Huge tripods position acoustic Doppler velocimeters (ADVs) at precise heights in the swash zone above San Diego, Calif. in Woods Hole Oceanographic Institution researcher Britt Raubenheimer's study of current and sediment movement.

The Right Tool

Matching the right equipment to the assignment was also extremely important. In the surf zone component of NCEX, Elgar anchored SonTek ADVOcean probes in 1 and 2.5 meters of water. The steel-housed ADVOcean probes delivered three-dimensional data on current, wave height, and turbulent flow patterns, and transmitted the information via cable in near-real-time to dataloggers on shore. "We like the Ocean probe because it can blast through the bubbles pretty nicely," Elgar says. "In Boundary mode, it can blast through the sediment to give us a good reading of the bottom, too."

Beyond the surf zone, at a depth of 5 meters, Elgar positioned SonTek Triton-ADV systems to measure current, wave direction and tidal action; one of his students flanked the canyon with a pair of Triton-ADVs in 15 meters of water a mile from shore. Elgar points out that the Triton-ADVs' on-board memory were vital – instead of spooling a mile of cable to the beach, he and his student simply downloaded the data on bi-weekly battery-changing visits.

Elgar adds that he's had great success with Triton-ADVs in the Gulf of Mexico, where deploying sensors in muddy conditions is especially challenging. "We do most of our work with divers, so things have to be simple – in the mud, it's totally black, so you have to be able to do it with your eyes closed," he notes. "For the Tritons, you just have to have a single pipe jetted in the sand. You don't need a tripod and cables – you just slip the current meter over the pipe and you're done. Then we have a little team that goes out to change batteries every two weeks."

In other field programs, Elgar also used eight SonTek Hydra systems, which have the capacity to add plenty of power, as well as external ancillary sensors. "Hydras have so much room for batteries that we can put in two or three extra batteries, so they can run a long time – even with CTD [a Conductivity-Temperature-Depth sensor that can be added via serial port] and OBS [Optical Backscatter, for studying turbidity] sensors plugged in," he notes. The downside is that the extra battery cases require mounting pipes of their own, Elgar points out, but the long battery life can make a compelling tradeoff.

Reliability is Paramount

"It's expensive to put a current meter in the water," Elgar notes. That's why reliability and service are vital to a successful experiment. It also helps that the SonTek equipment includes easy-to-use software that makes the instruments virtually plug-and-play easy.

Elgar admits that he's a tough customer. "No-one is as demanding on equipment as I am," he says. "I am the customer from Hell and I know it. But I used to tell the guys at SonTek, 'if you can satisfy me, you'll have a great instrument.' And they did.

"The service from SonTek has also been super," Elgar adds. "They understand that you're in the field, and things can't wait a month."

From the manufacturer's point of view, Elgar and Raubenheimer have been invaluable in helping SonTek develop versatile and rugged instruments. "Steve and Britt use our equipment with tremendous creativity and outstanding results," notes Chris Ward, Director of Global Marketing for SonTek. "They expect a lot from their tools, but they have also provided perspective from the field that has helped us create instruments that deliver under even the most punishing conditions they can dream up."

Answering a pressing question for Naval operations planners, Steve Elgar and Britt Raubenheimer of the Woods Hole Oceanographic Institution deployed seven SonTek acoustic Doppler velocimeters (ADVs) in a 35-foot-wide hole – designed to approximate a crater caused by an explosion on the beach – to study the behavior of waves and sand in mine-studded landing zones.

Testing the Models

Comparing data from the Nearshore Canyon Experiment is yielding great insight on wave behavior in areas with complex bathymetry, and helping modelers get significantly more accurate. Ultimately, accurate models will provide an outstanding tool for planners.

"We've got 25 current meters, but they've got 25,000 dots on their maps," Elgar notes. "Everybody thinks they know the beach, but anyone who wants to operate on the coast wants a good, reliable computer model. It's pretty preliminary, but I'd say the models have a lot of skill. They certainly predict rip currents where we see rip currents."

That means, someday, using current meters and models, authorities can predict whether their beaches will wash away, or whether they need to plan on tripling the dredging budget for their proposed park. Naval officers can look at data from a secret sensor in the surf and decide whether to send in a SEAL team. And surfers will go online and figure out whether, that day, they'll get the ride of their lives.

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