Sophisticated wave models like SWAN (Simulating Waves Nearshore) are used to calculate extreme wave and water heights that may occur in the North Sea. Accuracy of these models and predictions rely strongly on validation by wave measurements. Current profilers offer perspectives for such measurement of waves in shallow waters. The accuracy of these is the subject of study at Rijkswaterstaat (The Dutch Ministry of Transport, Public Works and Water Management).

By Rinus Schroevers, National Institute for Coastal and Marine Management/RIKZ, Rijkswaterstaat, The Netherlands

Surface Wave Measurements by Current Profilers

Possible, but only within limits

Users and manufacturers of all brands of current profilers have shown that it is possible to derive wave information from the data produced by these instruments. But how accurate do we want wave parameters to be and how accurately can we measure them with current profilers? Two relatively simple questions to which I am still trying to find answers.

Need for Wave Measurement

In The Netherlands wave measurements in the North Sea have been performed for more than 25 years and the information used to assist vessels safely from and to our seaports. Another goal is to establish the wave climate of the North Sea; this way we can predict wave heights and wave periods, used in the design and maintenance of our coastal defences. However, a few years ago new insights showed our present wave modelling knowledge for estuaries and complex shallow water areas to be insufficient. The reliability of the safety levels of Dutch dikes and dunes became subject to debate. Moreover, the Wadden Sea, an extremely complex shallow water area, turned out to be a total blank in terms of available wave data for the validation of wave models.

Improving SWAN

To improve and validate SWAN, the wave model for shallow water, more knowledge is needed of waves propagating from the North Sea through tidal inlets onto the dikes. A ten-year measurement programme in a tidal inlet, the Ameland Inlet, was proposed (see Figure 1). The set-up of the in-

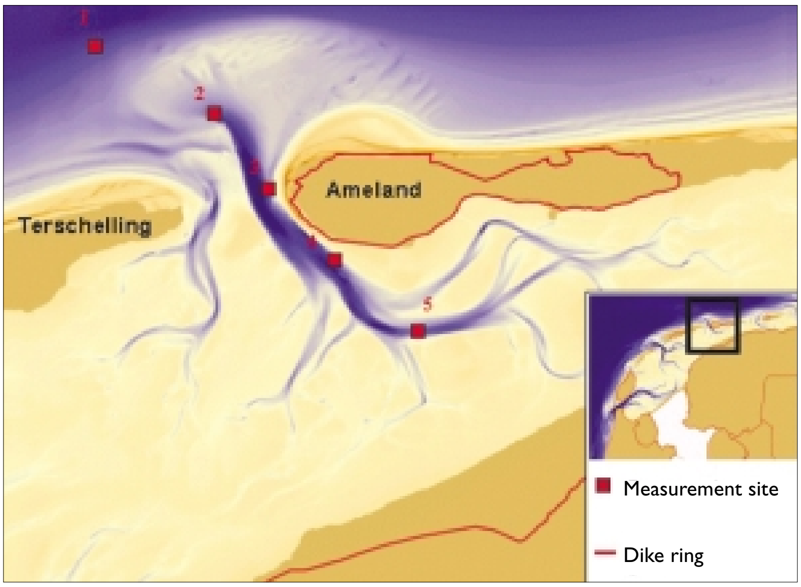

Figure 1: Proposed monitoring site in Wadden Sea: (red) locations of temporary Directional Wave-riders.

Figure 2: Example of a pole for measurements.

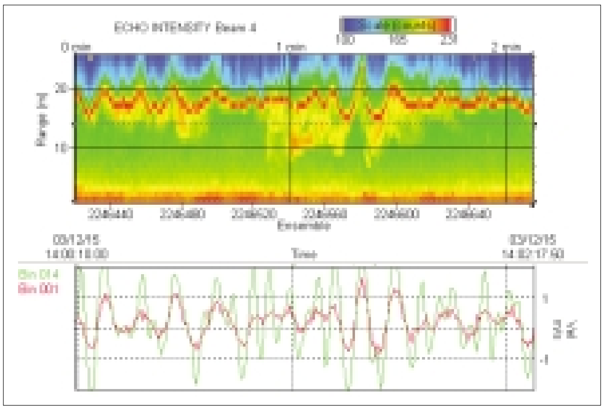

Figure 3: Two minutes of current profiler data. (Top) echo profile showing surface movement and entrainment of air (clouds of echo); bottom orbital velocities just below the surface and close to the seabed.

strumentation in this programme would have to be robust so that information could be gathered during occasional severe storms. Our experience teaches that such robustness cannot be met by deployment of frames and buoys in this sort of area; frames get towed away by fishermen or become buried beneath the sand, and buoys are at risk of being 'relocated' by ice-packs. So, the plan is to erect large, ice-resistant poles (see Figure 2) and mount them with all instruments needed to measure:

- wave height, wave period and wave direction
- current profile
- water level
- meteorological information such as temperature, wind speed and direction.

Current profilers can supply the wanted current information, as well as wave information. But the reliability of this wave information is scarcely documented, so we have to check the performance.

Principles of Acoustic Wave Measurements in a Nutshell

Current profilers measure waves using two acoustic techniques. A current profiler, placed on the bottom of the sea and looking upward can detect the surface by reflection of its acoustic pulses. Sampling the surface position at a high rate (2 to 4Hz) produces a time series usable for wave analysis. This technique is called 'surface tracking' and has been in use since the 1970s. The advantage of this method is the ability to measure both very long and short waves; a drawback is that the acoustic pulses are severely scattered and absorbed by bubbles when the surface is disturbed by strong winds and breaking waves. In such circumstances the surface is detected at the wrong place or not at all.

The second technique used by current profilers to measure waves is Doppler velocity measurement. Instead of measuring the surface elevation directly, current profilers measure orbital motion of the water, usually over a few meters of the water column. These orbital velocities are translated into wave heights, wave periods and wave directions. In contrast to the echo-ranging technique, the Doppler technique has not been seen to break down under severe wave conditions. However, reliability of the data during such conditions is still worthy of note. A disadvantage of the method is that the high-frequency range is limited.

The wave direction resolution of a current profiler is theoretically better than from a buoy, as it can resolve orbital motions (waves) coming from several angels at a time, which is only marginally the case with buoys. The NOWPHAS wave-monitoring network in Japan is at present the only network to incorporate a significant number of Doppler-type Directional Wave Meters (DWM).

Method Comparison

Current profiler performance in measuring waves is evaluated by a number of field experiments and review of processing techniques involved. The first field campaign we carried out was a comparison between Datawell directional wave rider buoys and Workhorse ADCPs from RD Instruments. In the winter of 2003-2004 we deployed a 1,200kHz current profiler in 12 metres of water, and a 600kHz current profiler in 18 metres of water. Two buoys were deployed next to the current profilers. The current profilers recorded full velocity profiles at 2Hz, logging 1GB of data per month, and were picked up every month. I must say, looking at raw 2Hz velocity and echo profiles is really amazing. You have a clear view of the waves damping as you get lower in the water column, and you can see air bubbles getting sucked down by the orbital motion (Figure 3). Wave heights, wave periods and wave direction were calculated from the current profilers velocity data with WavesMon processing software from RDI. The frequency interval used for the processing was 3 to 500mHz (for some of the results see Figures 4 and 5). The wave height and direction of the 1,200kHz current profiler compares reasonably well with the buoy, but the wave period is underestimated. The 600kHz data is clearly problematic, as can be seen in Figure 4; the source of the trouble lies in the processing of the current profilers velocity data. Spikes turn up in spectra in the region between 300 and 500mHz, leading to faulty values in wave heights and periods. Although the wave parameters derived from the 1,200kHz current profiler data show high correlation with buoy data it turns out that the phenomenon seen in the 600kHZ data is also present in the 1,200kHz data, but less obviously.

Not Yet Good Enough

The discrepancies between buoy data and current profilers velocity data are too large to implement the current profilers for wave measurements in its usual state. But having changed a few things in the processing, such as adapting a tide-removal algorithm, we reprocessed some data and the anomalies in the spectra disappeared, the parameters moving significantly closer to the buoy results.

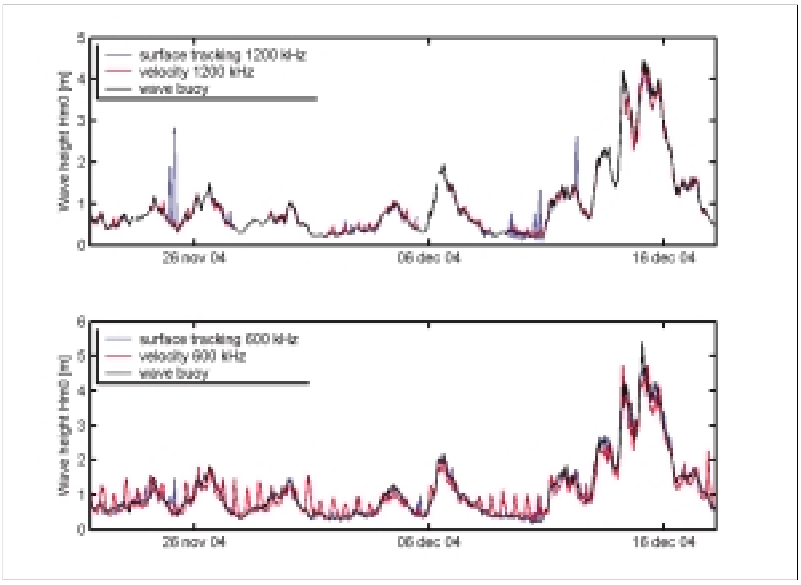

Figure 4: Time series of significant wave heights of a 1,200kHZ current profiler (top), a 600kHz current profiler (bottom) and reference buoys over a month.

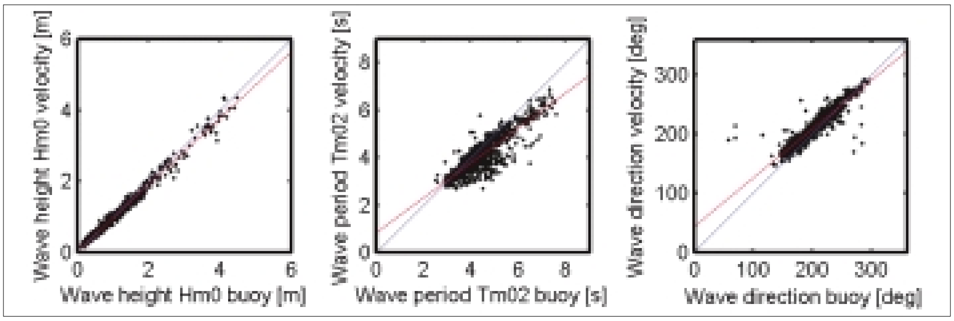

Figure 5: Correlation of wave heights, periods and direction of the 1,200kHz current profiler and a Datawell directional waverider buoy.

What Comes Next

The remaining data will be re-processed with the mentioned adaptations to see whether we get acceptable results over the whole period. If so, the next challenge is to measure at places in which we are really interested: shoals (0 to 10 metres depth). This will complicate acoustic measurements due to breaking waves and loads of suspended matter. Meanwhile, lack of alternatives led us to deploy buoys in the inlet anyway (see Figure 1). So far we have experienced few problems with fishery and there has been no significant amount of ice. So the option of using ice-resistant pole constructions might be abandoned.

Acknowledgements

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Biography

Rinus Schroevers holds a MSc degree in physics from Utrecht University. In 1997 he switched from nuclear particle physics to the more tangible world of water. He presently holds a position as project manager for innovation of monitoring at Rijkswaterstaat. Since 2002 he has acted as Dutch representative on the European committee for standardisation of hydrometric measurements. ■

E-mail: m.schroevers@rikz.rws.minvenw.nl