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Surf Zone Observations with a Nortek Vector Velocimeter and a Sontek ADVO

Introduction

This report compares data collected with a Nortek Vector Velocimeter and a Sontek ADVO, both Acoustic Doppler Velocimeters. Data were collected during an experiment conducted by Northwest Research, Inc. (NWRA, www.nwra.com) on the open coast near Ocean Shores, WA. The experiment was a field test of a sensor package developed by NWRA and sponsored by the Office of Naval Research. The NWRA sensor package includes a Sontek ADVO. NWRA's sensor package, and its normal placement, are optimized to measure surface gravity wave directional spectra at frequencies below 0.05 Hz. The NWRA ADVO is configured to run in continuous mode and to accumulate data in the ADVO registers. The sensor package's imbedded computer reads and resets these registers based on timing generated by a precise ovenized clock. For more information on the NWRA sensor package hardware and software design, please refer to www.nwra.com/BPS_COSP.html. Since this report compares the Vector with the ADVO integrated into the NWRA sensor package, the NWRA sensor package will be referred to in the following as the ADVO.

Figure 1. The Vector (foreground) and the ADVO were deployed 2 m apart and measured velocity at an elevation of about 0.5 m above the sand.

Data were collected with both instruments partially buried in the sand and separated by a distance of about 2 m alongshore. At low tide, the sand was dry, and at high tide, the water level was about 2.2 m above the sand. The sampling volume for both instruments was about 0.5 m above the sand. During the experiment, the instruments were inundated by the tide five times, each time being under water for about 6 hours.

The Vector measured heading, pitch and roll and recorded velocity data in east, north and up coordinates. In post-processing, the direction was rotated 23.2° for the local magnetic declination. The beach was aligned within a degree or so of north-south so that east-west currents are nearly beach-normal and north-south currents are nearly parallel to the beach (onshore is east). The Vector recorded 13-minute bursts of 8 Hz data every hour. The Vector was set for a maximum vertical velocity of 0.6 m/s and horizontal velocity of 2.1 m/s (nominal range 1 m/s).
The ADVO data were collected in coordinates relative to the beach (beach-normal and beach-parallel), and were corrected for pitch and roll in post processing. The ADVO data were rotated by 180° for comparison with the Vector data.

ADVO data were collected continuously during each of the tidal inundations. The ADVOs were sampled at 2 Hz and 4 Hz during the first four inundations, and at 8 Hz during the fifth inundation. The detailed comparisons shown below all come from the fifth inundation (hours 10-15 on June 1, 2000). The ADVOs were set for a maximum vertical velocity of 0.75 m/s and horizontal velocity of 3 m/s (nominal range 2 m/s).

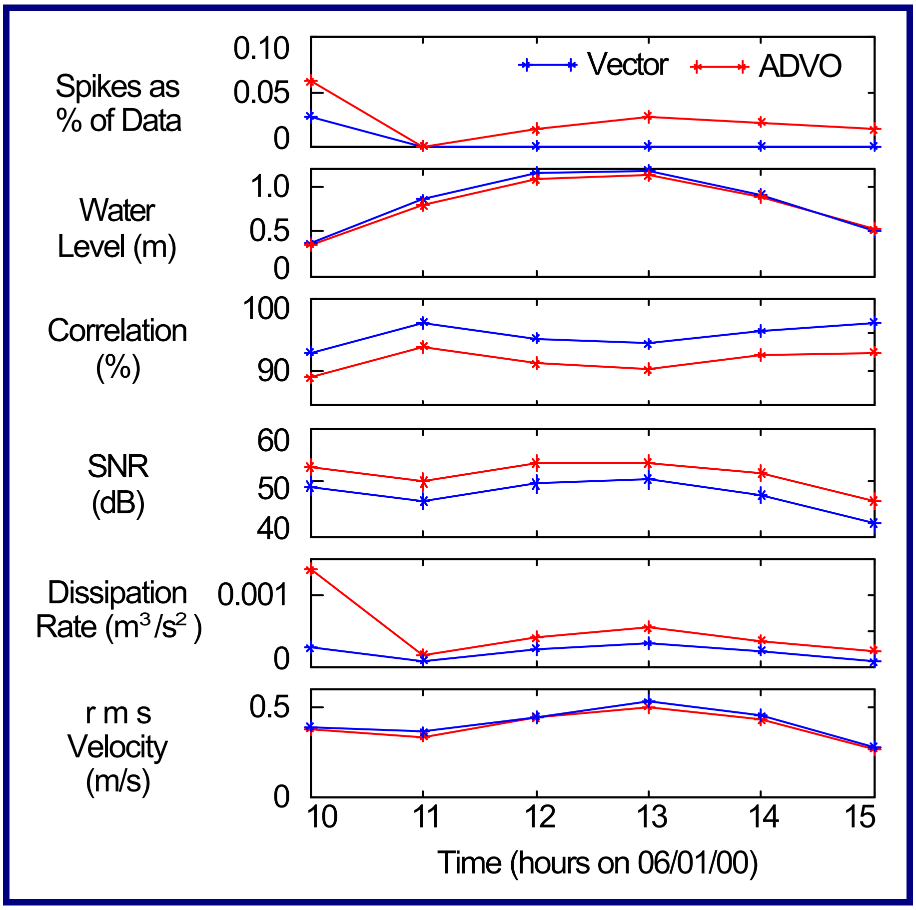

Figure 2. Computed and recorded parameters, which have a bearing on data quality and performance. Water level is relative to the measurement volume. SNR is an approximate signal/noise ratio, obtained by subtracting in-air signal strength, then scaling to dB. Dissipation rate is a measure of the turbulent intensity in the inertial subrange. The rms velocity includes contributions at all frequencies including the mean. Data were computed using exactly overlapping time series.

Data

Data processing consisted of aligning the data in time and identifying and removing data spikes. Time alignment was necessary because the clocks were independent of each other and because no effort was made to synchronize them. Velocimeter data commonly has spikes. Spikes were removed by taking the first difference in the velocity data, and iteratively rejecting outliers exceeding 6 standard deviations (Alex Hay, personal communication). Resulting gaps were filled by interpolation.

Figure 2 presents parameters that bear on the instruments' performance. Spikes were plotted as a percentage of the number of data points. The instruments were more likely to produce spikes when the water was shallow than when it was deep. In this data set, both instruments have relatively little spike noise. In contrast, it is not uncommon for Velocimeter data to produce data in which more than 1% of the data are spikes. Velocity spikes can in general be reduced by increasing the maximum velocity (Gordon and Cox, 2000). All else being equal, the Vector should have seen more spikes than the ADVO because its maximum velocity was smaller. Instead, it saw less.

The correlation is a predictor of velocity uncertainty—higher correlation predicts lower uncertainty. The average correlation for the data covered by Figure 2 was 95% for the Vector and 91% for the ADVO.

The differences in the SNR reflect differences in system frequency and internal signal processing. In general, as long as SNR is above around 20 dB, SNR plays little role in data quality.
Dissipation and *rms* velocity are included in Figure 2 because both play a role in measurement uncertainty (Voulgaris and Trowbridge, 1998). The plotted *rms* velocity was a combination of both horizontal velocity components:

$$V_{rms} = (<U_x^2> + <U_y^2>)^{0.5}$$

Where U_x and U_y are the x- and y-components of velocity, and brackets < > represent the average.

Dissipation was computed following Lumley and Terray (1983), using an equation specifically for surface waves:

$$\epsilon = (2\pi\ c/U)\ S_{uu}^{3/2}\ F^{5/2}$$

where:

- ϵ = energy dissipation per unit mass (m^2s^{-3})
- c = 1.9
- U = *rms* wave velocity for one horizontal component (m/s)
- S_{uu} = power spectrum of the same velocity component ($m^2s^{-2}Hz^{-1}$)
- F = frequency (Hz)

Dissipation was computed in the turbulent inertial subrange in which the spectrum falls as $f^{-5/3}$. The inertial subrange in these data typically began in the range 1-2 Hz—all estimates of dissipation in Figure 2 were computed using the frequency range 2-3.5 Hz.

The ADVO produced higher dissipation than the Vector (consistent with the spectra in Figure 6). The difference between the ADVO and the Vector dissipation rates appears to be correlated with the spikes. The largest difference in dissipation occurs at hour 10, associated with the largest number of data spikes. The smallest difference is at hour 11 when there were no spikes. It is likely that the spikes increase apparent dissipation, rather than the reverse (dissipation increasing spikes). Spikes are in general associated with increased velocity noise, which raises and flattens the spectrum. The higher spectrum appears as a larger dissipation rate.

Time series from the ADVO and Vector (Figures 3 and 4), show that both instruments measured nearly the same current velocities. Small differences are likely the result of the 2 m separation.

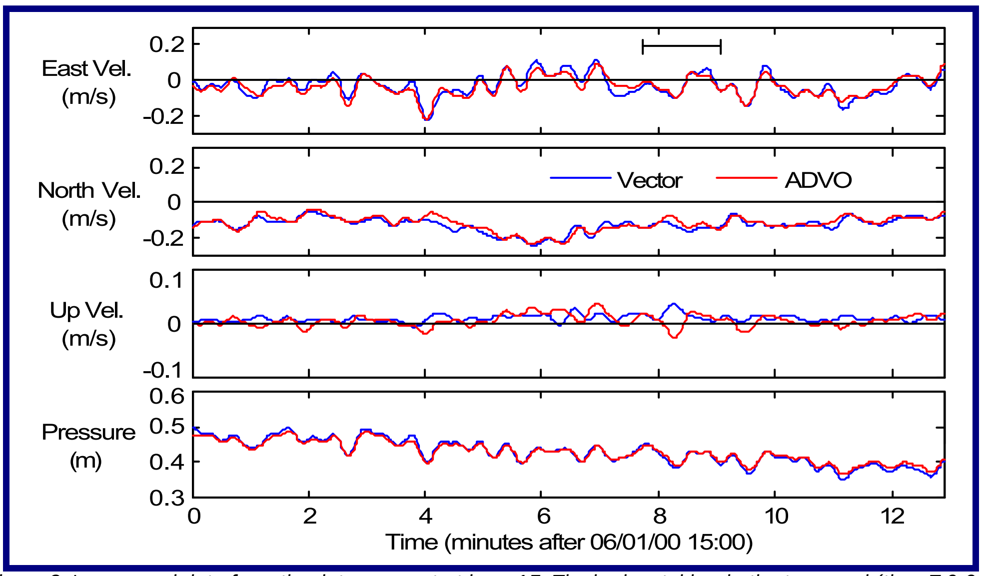

Figure 3. Low-passed data from the data segment at hour 15. The horizontal bar in the top panel (time 7.9-9 minutes) indicates the detail data segment plotted in Figure 4. The low-pass filter cutoff is 0.07 Hz.

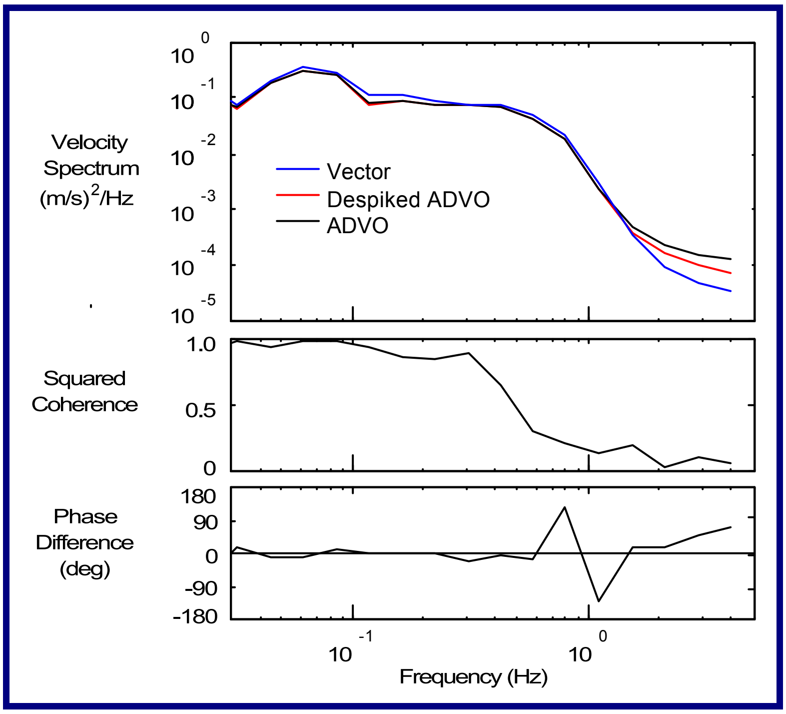

Figure 5. Velocity spectra and coherence computed from hour 15. Spectra were computed using complex velocities (u +iv). Coherence compares the Vector data with the despiked ADVO data. The Vector data had no spikes.

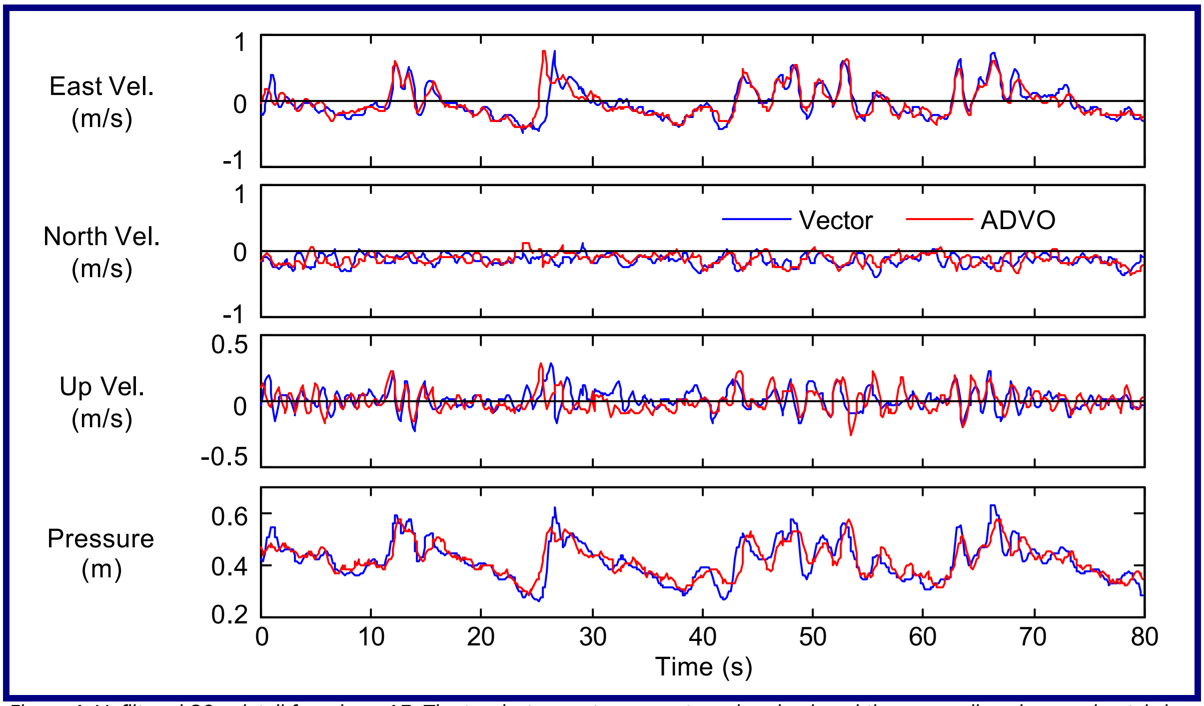

Figure 4. Unfiltered 80-s detail from hour 15. The two instruments were not synchronized, and they were aligned approximately in time by eye.

Spectra and Coherence

Figure 5 shows that the Vector and ADVO produced nearly identical spectra over most of the frequency band. Below about 0.5 Hz, the data were highly coherent with a constant phase near zero (keep in mind that the date were not synchronized and that they were aligned in time by eye).

At the beginning and end of the tidal inundations when the water is shallowest, a broad peak appears in the frequency range 0.03-0.10 Hz (see Figure 6). Coherence between the Vector and ADVO is particularly high in these peaks. In hour 15 in the band 0.03-0.10 Hz, the mean coherence is 0.97. This peak is associated with infragravity waves.

Figure 6 compares spectra from the Vector and ADVO from the six data segments during the last tidal inundation. The water is shallowest during hours 10 and 15, and deepest at hour 13. Both the wind wave spectra (0.05 - 0.5 Hz) and turbulent spectra (above 1 Hz) are weakest when the water is shallow (hours 10 and 15). At these times, the ADVO data appear to be limited by a noise floor, while the Vector spectra continue to fall. When the water level is higher, the turbulent spectra appear to stay above the ADVO's noise level. Note that the ADVO's nominal maximum velocity was set for 2 m/s and the Vector's nominal maximum velocity was set for 1 m/s (the maximum horizontal velocities for the two instruments are 3.0 m/s for the ADVO and 2.1 m/s for the Vector).

The expected Doppler noise floor for the two instruments is well below the observed spectra. The predicted Doppler noise levels are 1.5×10^{-5} $m^2/s^2/Hz$ for the ADVO, and 9×10^{-6} $m^2/s^2/Hz$ for the Vector (based on a standard deviation of 1% of the nominal velocity range at a sample rate of 25 Hz). The ADVO data appear to reach a noise floor near 1×10^{-4} $m^2/s^2/Hz$, or about 7 times the expected value. The Vector spectra fall to as low as 3×10^{-5} $m^2/s^2/Hz$ (hour 15), but do not appear to reach a noise floor.

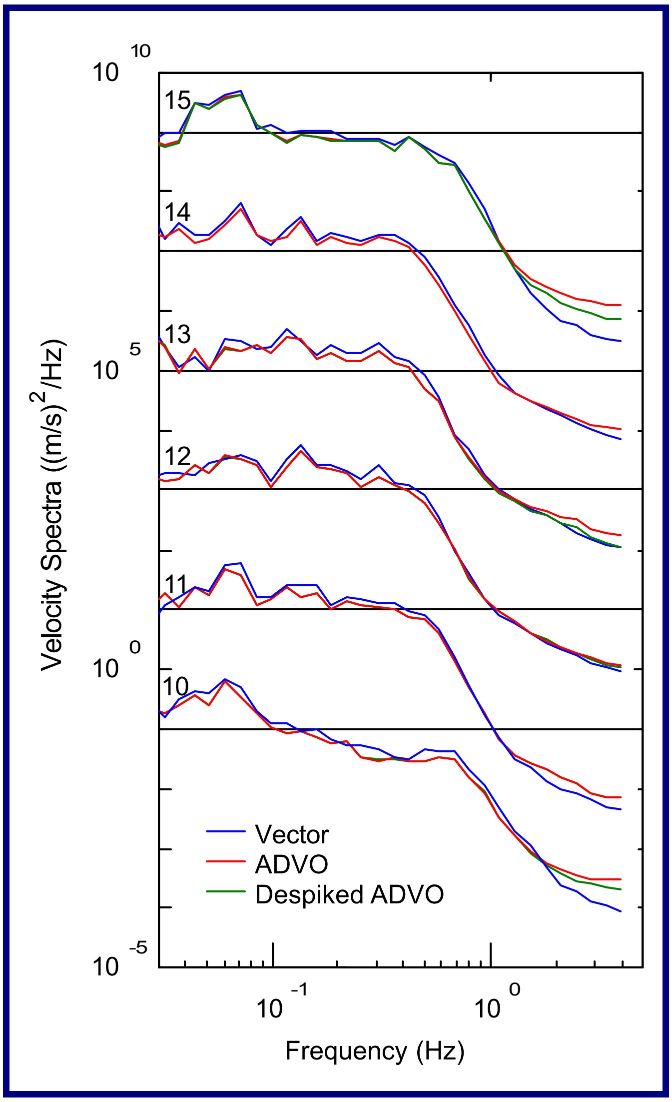

Figure 6. Detail showing hourly comparisons of spectra from the ADVO and Vector. Spectra are successively offset by 10^2.

Conclusions

Both the Vector and ADVO collected nearly identical data. The Vector data had fewer spikes and a lower noise floor. It does not appear that the spikes and noise affect the data at frequencies below around 1 Hz.

References

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