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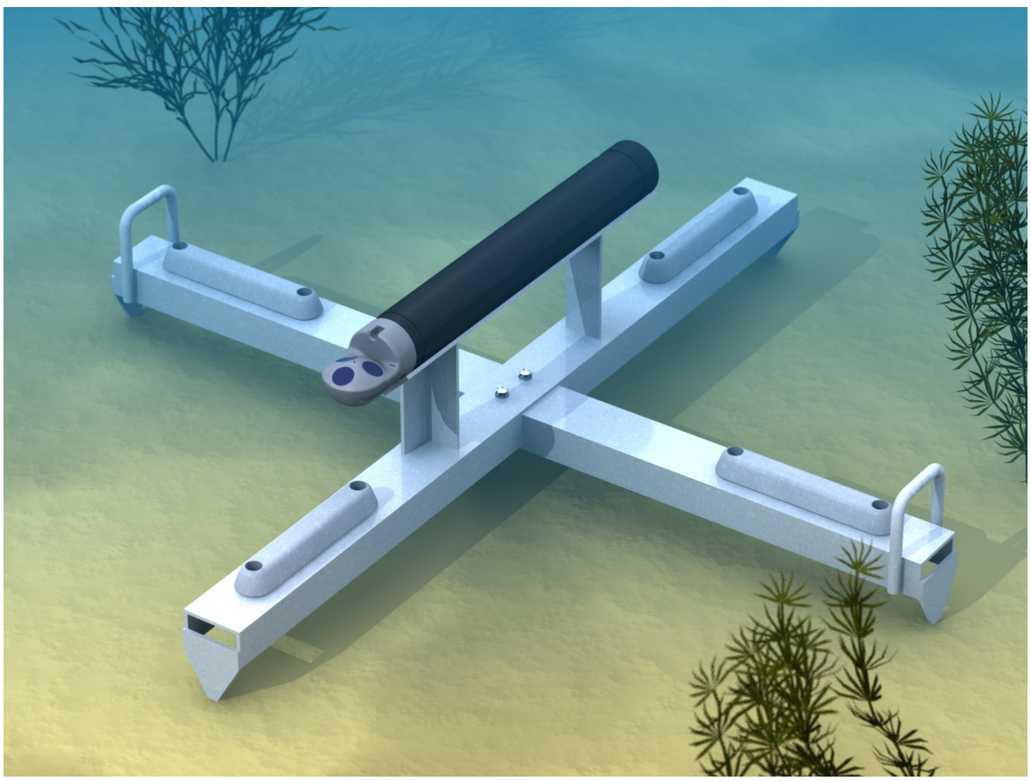
# Aquadopp HR Profiler: Extended Velocity Range Mode



## Introduction

Extended Velocity Range (EVR) is an ambiguity resolution scheme available on the Nortek Aquadopp HR Profiler. Instruments which use pulse coherent processing suffer from velocity ambiguities (phase wrapping) when the phase shift between the two pulses used for velocity measurement exceeds +/- π. Because of the constraints on the setup of pulse coherent instruments, such as the HR Profiler, with respect to pulse distance and the distance to a boundary, ambiguity issues are not resolvable by simply changing the velocity range. The EVR was developed to increase the velocity range of the HR Profiler and allow its use in higher energy environments such as the outer surf zone while also maintaining long enough pulse distances to avoid pulse interference.

## Basic Operating Principles

EVR is enabled in the Deployment Planning dialog by selecting the checkbox next to it in the lower right corner. The **Horizontal Velocity Range** and **Vertical Velocity Range** fields will increase by a factor of 3 when the **Extended Velocity Range** checkbox is enabled.

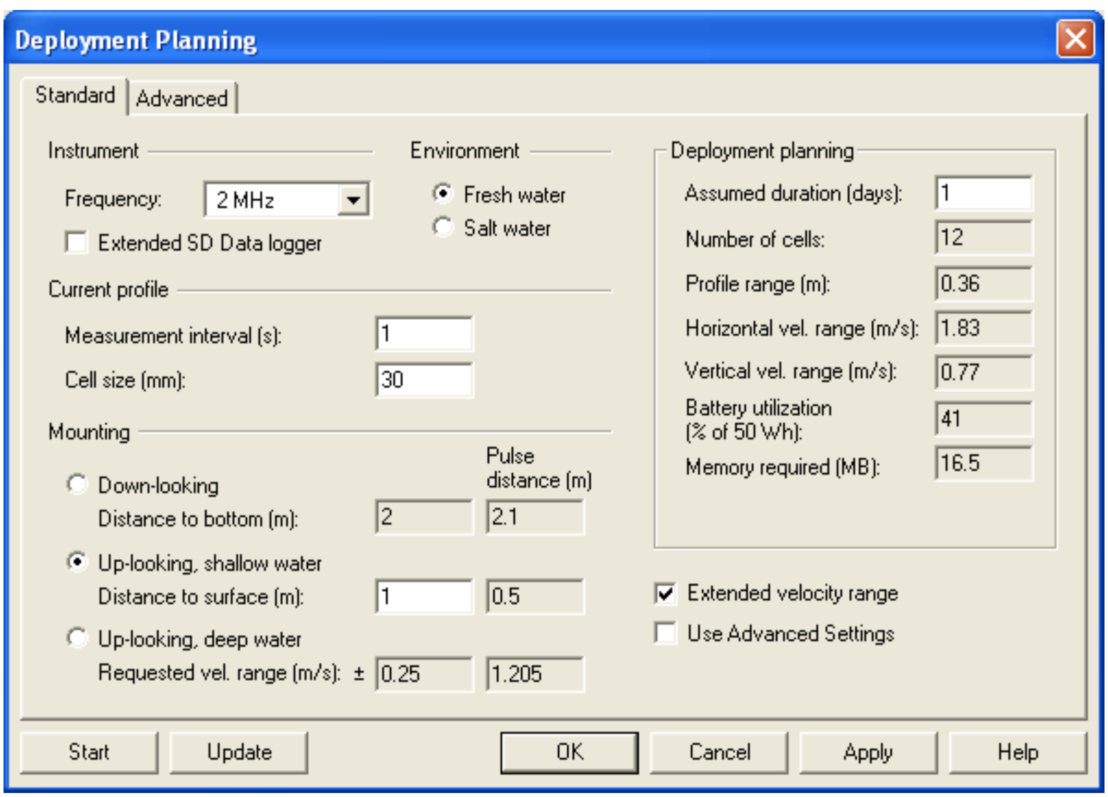



**Figure 1.** The Deployment Planning dialog from the Aquapro HR software. EVR has been enabled in this deployment.

EVR utilizes a single measurement cell located 1/3 of the distance into the profile with a pulse distance 1/3 of the lag shown in the **Pulse Distance** field. The data from this measurement cell is used for an initial estimate of the phase shift, which is then used to refine the standard pulse distance phase shift estimates by accounting for any phase wrapping (i.e. if the phase shifts from the two estimates don't agree, the standard pulse distance estimate is increased to match the EVR estimate). This adjustment is continued for all bins in the profile. The velocity-range product for EVR operation is 0.9 $m^2$/sec, compared to 0.5 $m^2$/sec for standard pulse coherent operation.

## An Example Dataset

An example region where EVR is useful is the surf zone. During the NortekUSA Training held in St. Augustine, FL in May 2009, an HR Profiler was deployed in the surf zone to demonstrate its capabilities. The HR Profiler was mounted on a bottom frame looking upward (Figure 2) and deployed in approximately 1 m of water.

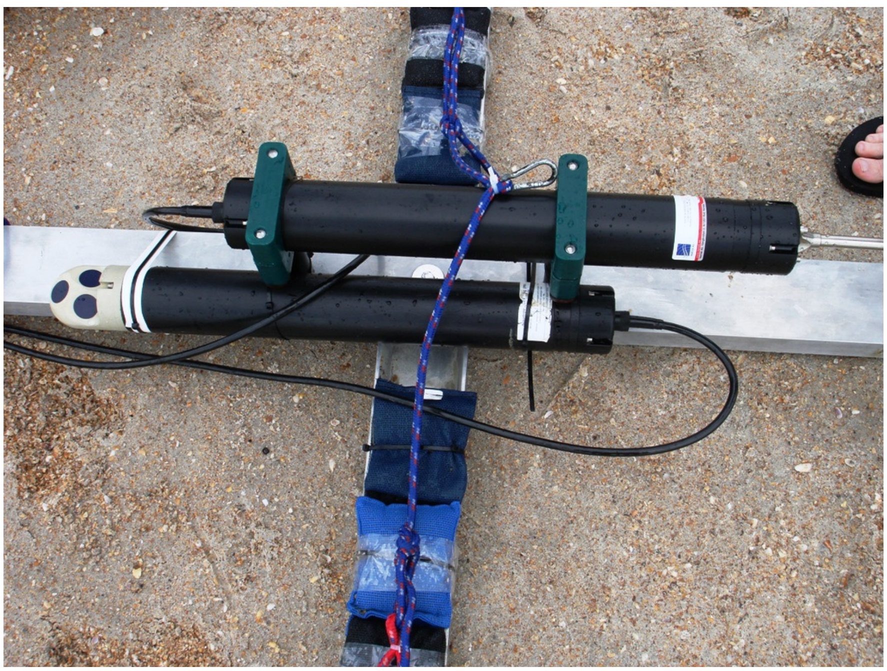


**Figure 2.** The Nortek Aquadopp HR Profiler mounted on a bottom frame (lower pressure case, head visible on the left). A Nortek Vector (upper pressure case, head out of frame to the right) was also mounted on the frame but not recorded. Both instruments were linked to shore via a radio telemetry system.

The instrument recorded data at 4 Hz with 30 mm bins, 16 bins in the profile. The standard pulse distance was 0.5 m and EVR was enabled, resulting in velocity ranges of 1.83 m/s and 0.77 m/s for the horizontal and vertical velocities, respectively. The instrument measures initially in beam velocities and the vertical velocity range is the beam velocity range as well.

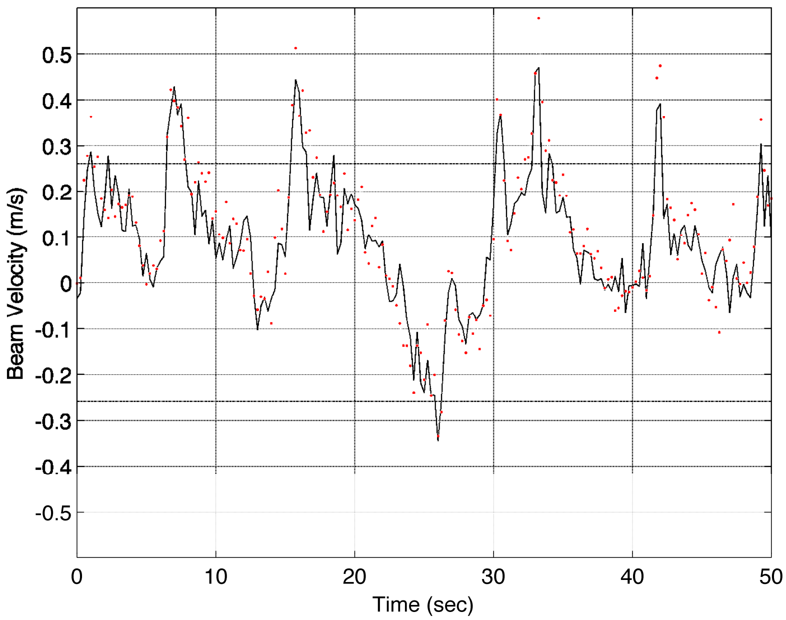



**Figure 3.** The EVR velocity cell data (—) and the profile velocity bin corresponding to the EVR measurement location (···•···). The standard (0.26 m/s) velocity range is indicated by (---), the EVR velocity range is 0.77 m/s and not shown.

Any ambiguity resolution should be done in beam coordinates, so beam velocities will be used when showing the effect of EVR. In Figure 3, velocities from Beam 1 of the HR Profiler are shown with the non-EVR velocity range indicated. With EVR enabled, the beam velocity range is extended to 0.77 m/s. There are many regions where the non-EVR velocity range is exceeded, but with EVR enabled these regions are automatically unwrapped and corrected.

To show the effect of EVR, the profile velocity data from Figure 3 has been artificially wrapped and plotted alongside the measured velocity in Figure 4. Too large or too small velocities (relative to the standard velocity range $V_{range}$ = 0.26 m/s) are converted to wrapped velocities via the formula $V_{wrapped} = V_{measured}$ +/- $2*V_{range}$, as appropriate.

While some regions of wrapping are very obvious (*t = 30 s*), other areas are not as easily identified without the EVR velocity trace for comparison (*t = 15 s*). EVR will be far more robust than a post-processing unwrapping scheme because it utilizes two measurements to identify phase wrapping.

A word of caution however, the EVR data is susceptible to phase wrapping since it utilizes the same pulse coherent processing for phase shift determination. If measured velocities are very close to the velocity range limits, the EVR velocity estimate can be verified by checking the data in the *.hr2 file produced during data export for phase wraps.

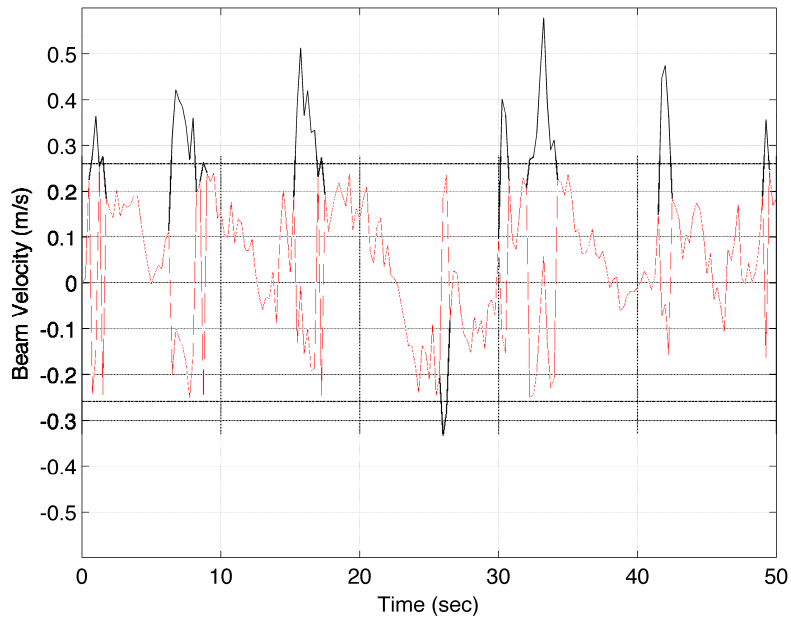



**Figure 4.** The measured (—) and artificially wrapped (—) velocities from the profile data shown in Figure 3. The standard velocity range is indicated by (---). Numerous phase wrappings would have occurred without EVR.

After basic screening (a low correlation threshold of 40%, adaptive Gaussian outlier removal), the beam velocities are transformed back to earth coordinate velocities (East, North, Up). A velocity contour of the East (onshore) component and the correlation data from Beam 1 are shown in Figure 5. A version of the velocity contour in Figure 5 with screened velocities replaced via a local median filter (applied to the east velocity data) is shown in Figure 6.

The HR Profiler measures a wide range of velocities in this short deployment and the only region in which there is a significant issue is near the surface when very steep waves pass (*t = 20, 50 s*). This results in low correlations (< 40%) in these two areas, likely caused by entrained air. Other than these two regions, the HR Profiler does an extremely good job measuring in this dynamic environment.

Extended Velocity Range is an extremely useful feature for the HR Profiler, allowing its use in much higher energy environments than pulse coherent profilers typically work in, while retaining the low noise and single ping accuracy pulse coherent processing is known for.

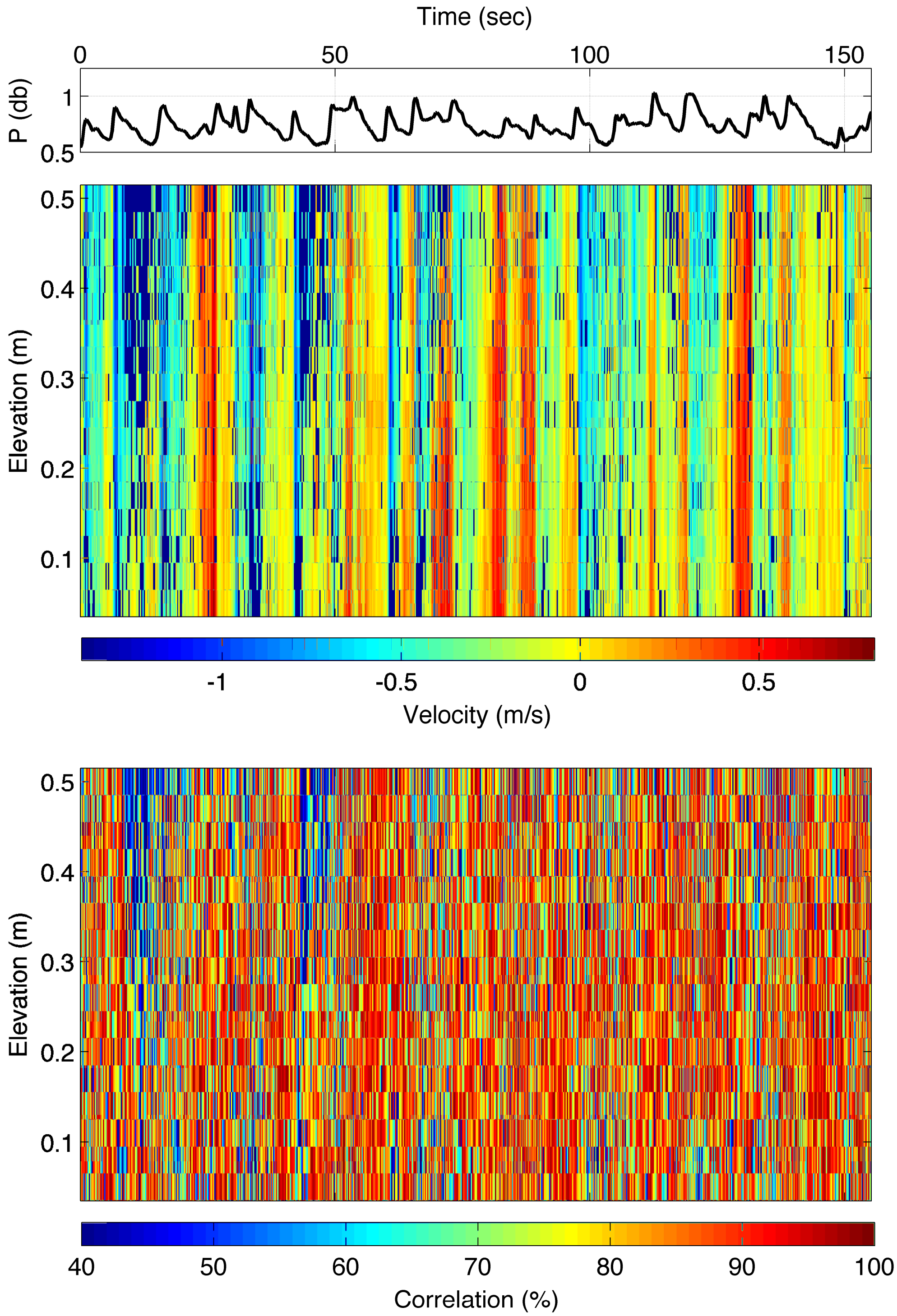



Figure 5. The pressure sensor time series, east velocity contour, and Beam 1 correlation contour for the St. Augustine deployment. With EVR enabled, the HR Profiler does a very good job of measuring velocities in the surf zone. Low correlations occur primarily when the water surface is at minimums (t = 20, 50 sec), likely due to entrained air creating bubbles.

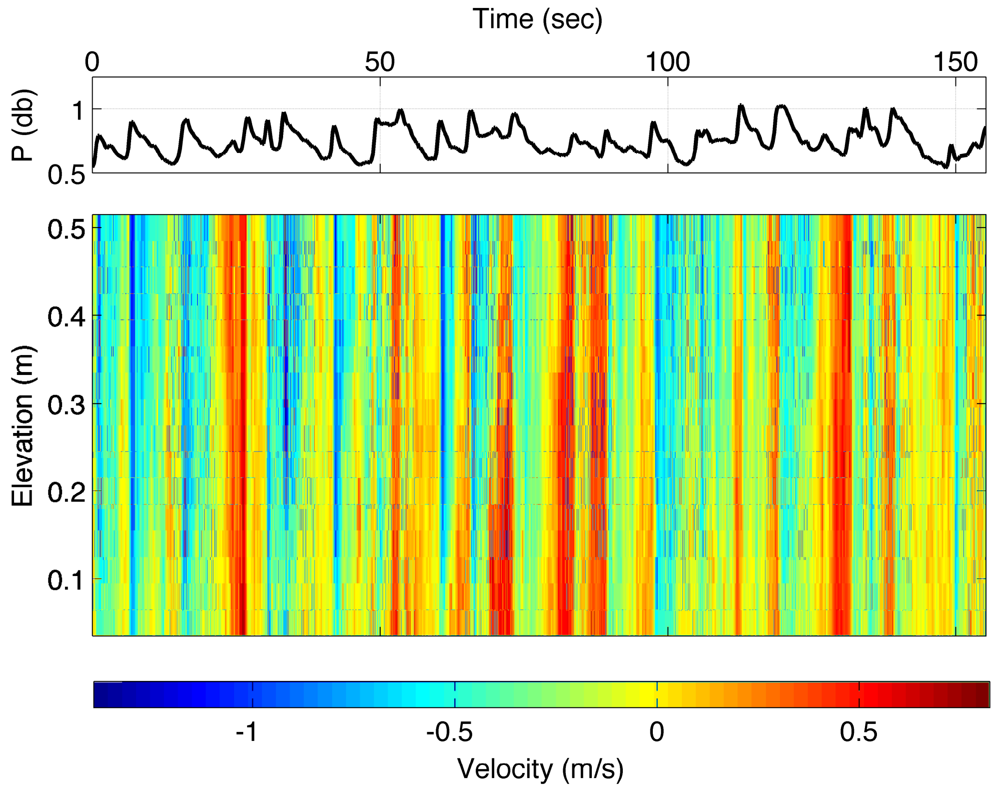



**Figure 6.** The velocity contour from Figure 5, with screened data replaced by a local median filter.