Error assessment of acoustic velocimeters for large-scale non-obtrusive 3-D velocity sensing applications :Test tank results

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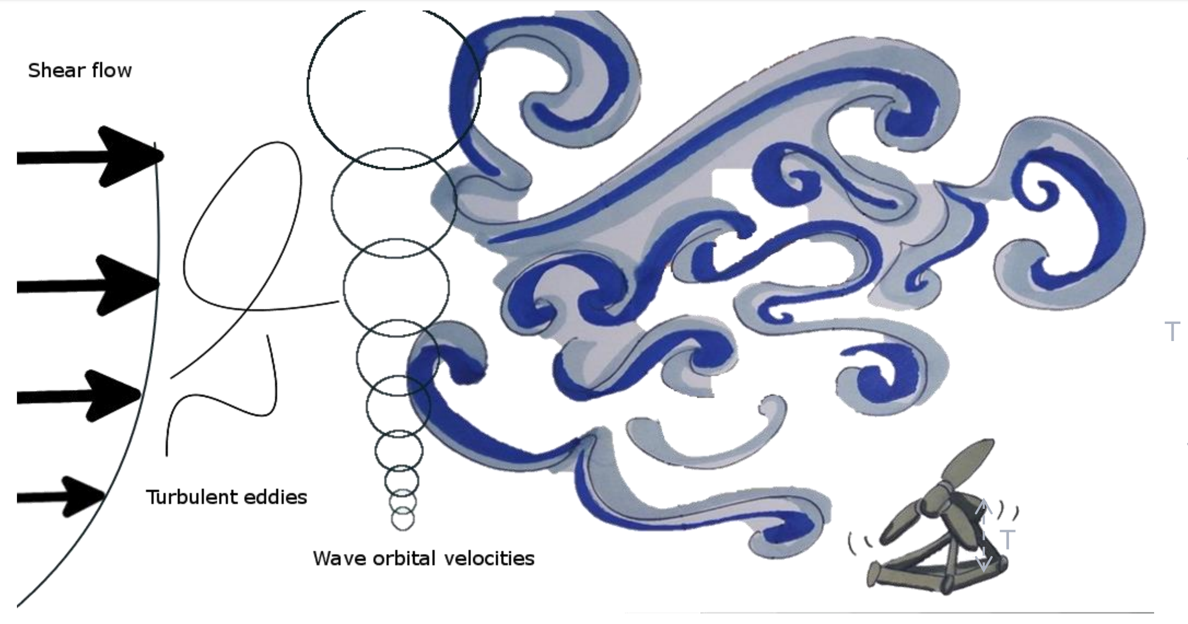
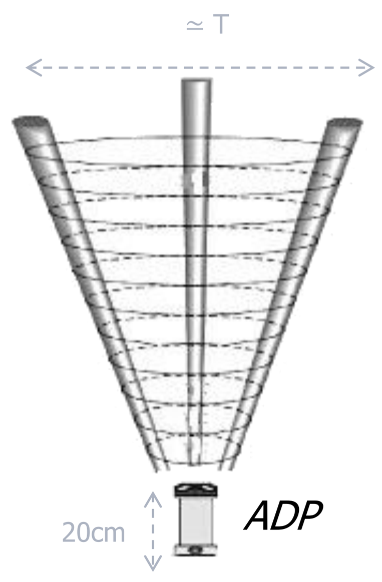
Background





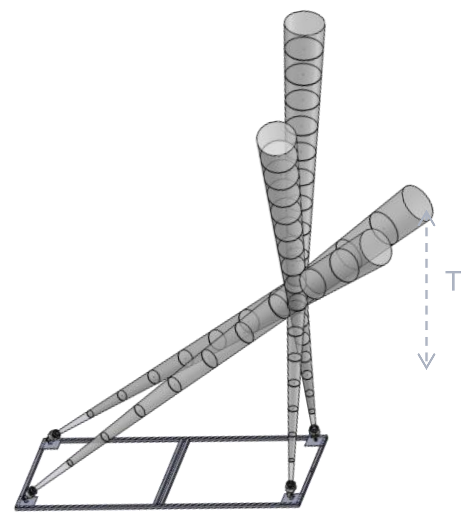
Tidal flow is highly complex and heterogeneous. It directly influences tidal turbine power conversion rates, blade loading and device reliability. As a result, tidal flow measurement and characterisation is necessary for the development of tidal technology. The instrument typically used to make flow measurements in the marine environment is the **Acoustic Doppler Profiler (ADP)**.

Motivation

Due to limitations in the ability of commercially available technologies to capture high resolution 3-D velocity in heterogeneous flow at turbine hub-height, U-Edin is developing, and deploying on international industrial-academic marine projects, a novel sensor prototype named the **Converging-ADP (C-ADP)** [1]. By focusing multiple velocity-profiling "acoustic beams" at a converged location from an array of multiple-sensors, 3-D velocities can be secured.

The next generation C-ADP is currently being designed. It will feature actuation of the multiple **single-beam ADPs (SB-ADPs)** which constitute the C-ADP, enabling variation of the focal point location.

The SB-ADPs are bespoke profiling instruments which sample at relatively high frequencies, enabling their use in test tank facilities.



C-ADP comprising four single-beam ADPs [2]

However, understanding the measurement error and uncertainty of a new measurement tool is essential to interpret and exploit the recorded data

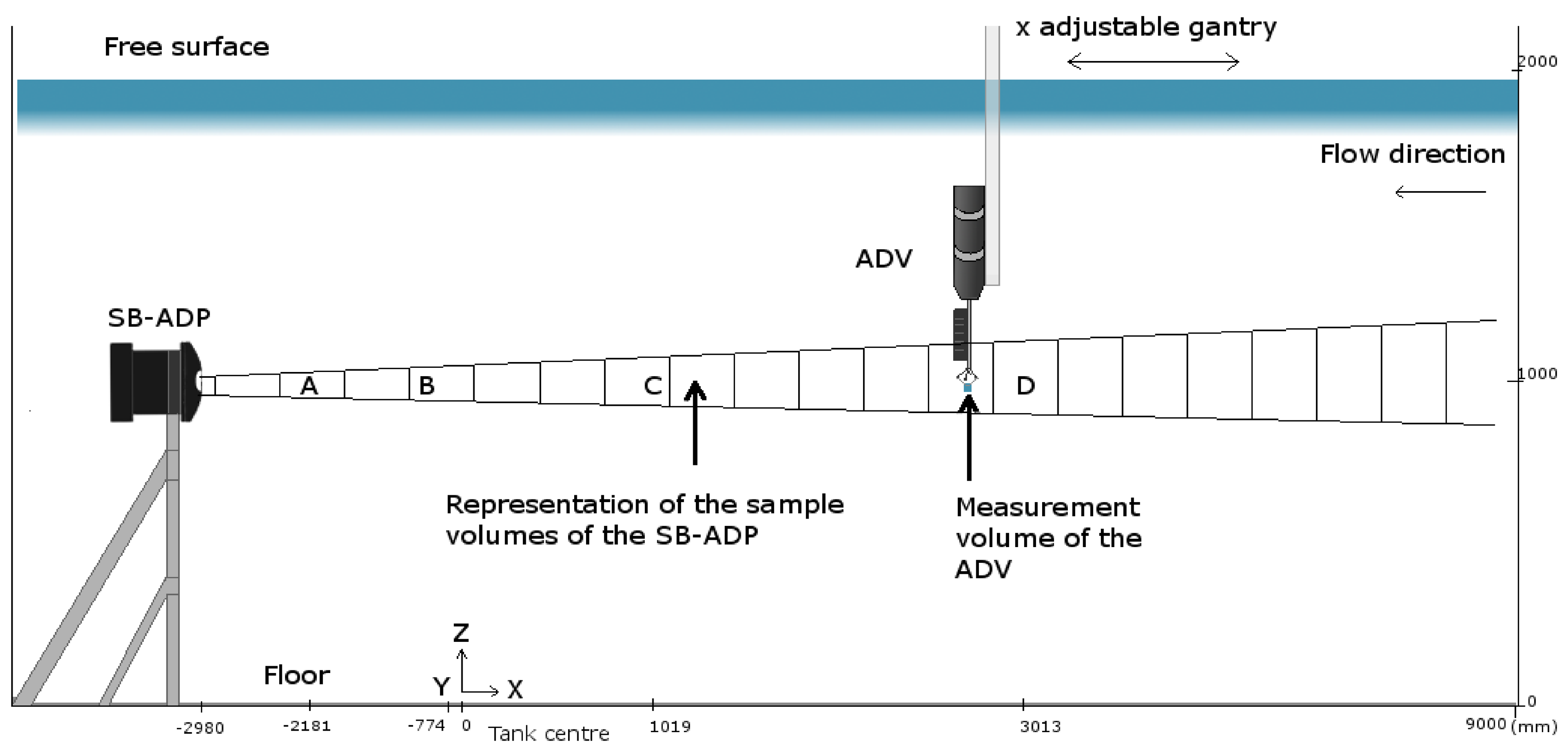
Work to date

A **component level study** of the U-Edin SB-ADP, the underlying sensor technology[1], has been carried out. The aim of this work was to investigate the effect, on measurement error and uncertainty, of the flow velocity and sensor profiling range. Experimental testing has been performed in a controlled laboratory test tank environment : the circular FloWave ocean energy research facility, a state of the art combined wave and current circular tank.

Assuming flow stationarity over the 2 minutes measurement period, velocity measurements from the SB-ADP profiling technique have been statistically compared with co-located measurements from a reference instrument, the Acoustic Doppler Velocimeter[2] (ADV).

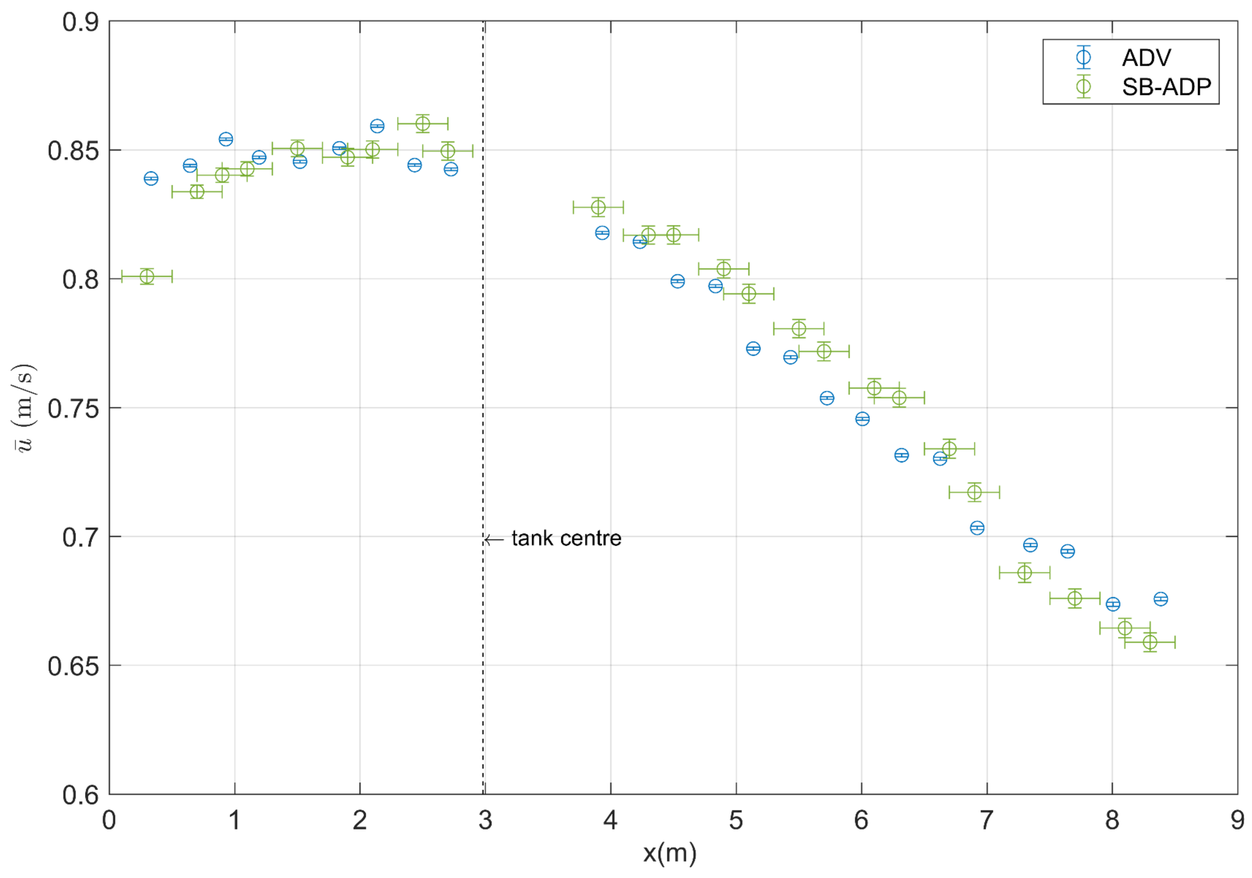
A full 9 meter measurement profile was compared at a tank nominal velocity of 0.8 m/s, with a partial profile study (locations A-D) at velocities of 0.6 m/s, 1.0 m/s and 1.2 m/s.

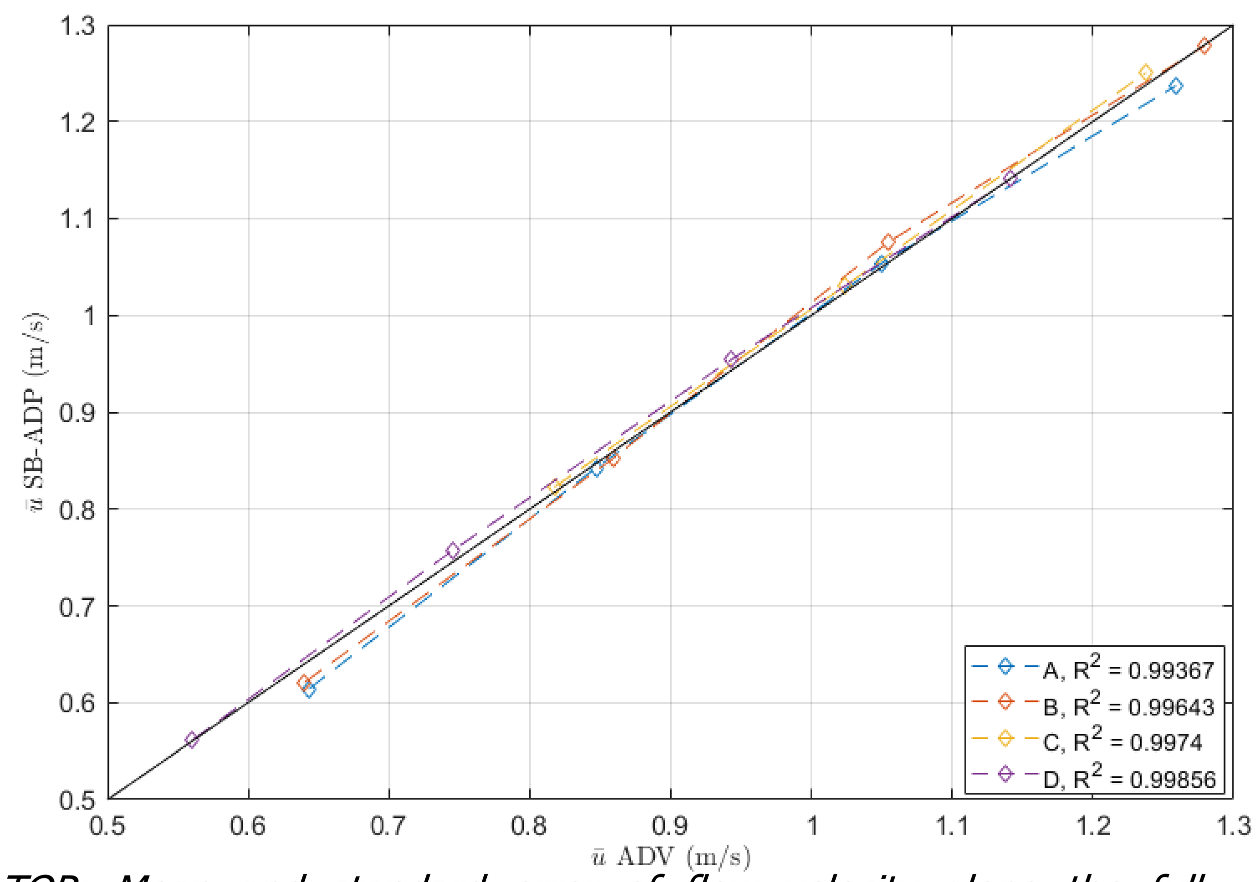
1 - Based on single-transducer Nortek 1MHz *Signature 1000* hardware, 2 - Nortek *Vectrino*



Experimental set up: the SB-ADP pointed into the flow, measuring near-simultaneous velocity within each sample volume along the profile. The ADV is mounted on a gantry that is moved (between tests) along the x-axis to capture successive point measurements within the sample volumes of the SB-ADP. Measurements were performed individually to avoid interference: the ADV was out of the water when the SB-ADP was measuring

Results





TOP: Mean and standard error of flow velocity along the full measurement profile, for a nominal tank velocity of 0.8 m/s. Horizontal lines represent the measurement cell width.

BOTTOM: Comparison (1:1 plot) of velocities measured by the SB-ADP and those measured by the ADV at locations A, B, C and D.

Future work

Component level study

- Spectral analysis for determination of SB-ADP noise floor
- Assessment of acoustic side lobes
- Phased introduction of multiple-sensors

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System level study

- Theoretical assessment of the constraints on the beams focal point location
- Estimate of Doppler noise bias in turbulent parameters estimation
- Model for estimation of error associated with the ensemble geometry : including angles and distances between the SB-ADPs
- Study of uncertainty associated with system sample volumes

Conclusions

- The SB-ADP performed well in a confined tank testing
- Complex interference happening at low velocities around the tank centre location are being investigated
- The error between the SB-ADP and reference velocity, as measured by the ADV, has been estimated to be < 4%

References

[1] B. Sellar, S. Harding, and M. Richmond, High-resolution velocimetry in energetic tidal currents using a convergent-beam acoustic Doppler profiler," Measurement Science and Technology, vol. 26, no. 8, 2015.

[2] S. Harding, B. Sellar, and M. Dorward, "Implications of asymmetric beam geometry for convergent acoustic Doppler profilers," in 2019 IEEE/OES/CWTM 12th Working Conference on Current, Waves, Turbulence Measurement and Applications, CWTMA 1, 2019.