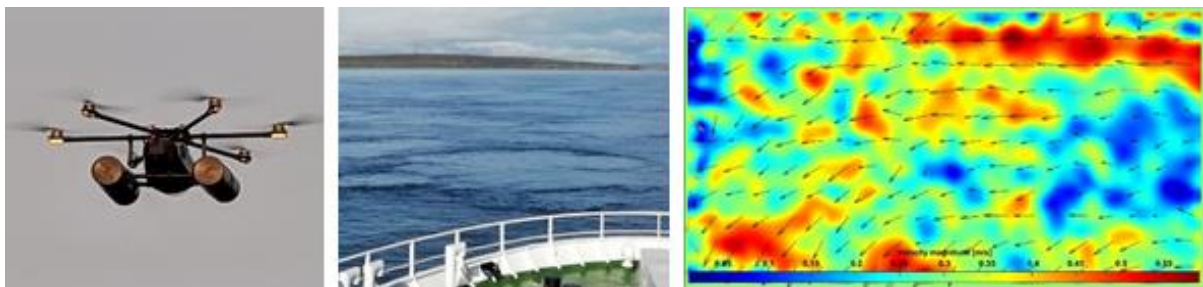


Validating Surface Currents at ORE Sites (V-SCORES)

The aim of V-SCORES was comprehensive validation of unmanned aerial vehicle (UAV) techniques for surface current spatial mapping, demonstrated at tidal stream sites.

Specific objectives were:

- Extend existing open-source surface current extraction algorithms to UAV measurements in tidal stream sites to assess uncertainty, accuracy, and capabilities compared to contemporaneous industry-standard GPS drifter measurements (**technique validation**).
- Quantify the relationship between surface (using UAVs, drifters and current meters) and water column (contemporaneous ADCP) currents, and how this varies with wind speed and direction (onshore meteorological station) (**relationship to water column currents**).
- Assess the impact on accuracy of measured currents between UAVs of different camera quality, station-keeping capability, and GPS accuracy (RTK), using UAVs of a range of costs (£1k-15k) to inform industry of likely capital costs (**device suitability**).
- Demonstrate applicability of UAV method under differing conditions at sites with contrasting depths, flow speeds and exposure (**synthesis and applicability**), developing practical guidelines on how to relate surface currents to currents in the water column.



1. Achievements

Current extraction algorithms (WP1) have been evaluated, further developed and applied across a number of different techniques to assess accuracy and suitability. Investigation has focused on quantification of errors and uncertainty, as well as the applicability to different conditions (e.g., sun glare / glint, discrimination of waves and ripples from underlying flow, performance with varying levels of natural tracers, sheltered / exposed sites, etc.).

Validation datasets have been collected in Scotland (**WP2**) and Wales (**WP3**) despite Covid-19. The data collection campaign covered a variety of different sites to build up a library e.g., sheltered conditions at META, through to the Menai Strait and Ramsey Sound (Wales) and St John's Point (Scotland), and finally sites with high wave exposure and turbulent conditions in the Inner Sound of the Pentland Firth (Scotland).

Relationships between surface and water column currents (WP4) have been investigated using a combination of co-collection of data (e.g., ADCPs, drifters) and established relationships for water-column profiles, including how this varies between sites. Wider collaboration with Jonathan Demmer

(Bangor University) via Co-I Matthew Lewis is facilitating investigation of wind-driven currents through examining drifters with drogues at different depths.

Synthesis and wider applicability (WP5) has compared drones of varying budgets (£1k - £15k) to allow comparisons of accuracy, as well as investigating differences between sites (conditions) and technology (RTK and non-RTK), providing an overall assessment of performance and wider application to inform recommendations for industry, e.g., modellers, ADCP users, ORE site developers.

We gratefully acknowledge the engagement and support of V-SCORES industry, government/policy and consultancy partners (*ANDRITZ HYDRO Hammerfest, SIMEC Atlantis Energy, Aquatera, ORE Catapult, Intertek, MarineSpace and Marine Scotland Science*) including through participation in V-SCORES workshops to guide the relevance and applicability of the techniques.

2. Impact and dissemination

- Project kick-off **press release** ([link](#)) widely covered in the media including BBC ([link](#)), internationally including CNBC ([link](#)), radio interviews and industry news websites.
- Invited **presentation** at the Supergen ORE Hub Annual Assembly 18-22 January 2021 in the session 'Tackling the research challenges: resource and environment characterisation & survivability, reliability and design' to build collaborations with the Hub, and a **poster** from Iain Fairley on the potential and challenges of using drones to measure surface currents at tidal stream sites, with details of initial image pre-conditioning work.
- Engagement with **STEM outreach** for MRE in Clevedon via Frazer Nash Consultancy in February 2021.
- Invited presentation to the EU Project TIGER Survey Network Group 5 February 2021 to explore opportunities for application of V-SCORES techniques at wider ORE sites.
- Participation in the **cross-hub workshop** between the Supergen ORE Hub and the Offshore Robotics for Certification of Assets (ORCA) Hub on 23 February 2021 to develop collaborations beyond the V-SCORES Flexible Fund project.
- Engagement with the UKCEH / University of Hull International Surface Velocimetry **workshop** (4-6 May 2021).
- Presentation "*Novel validation of high-fidelity Lagrangian Particle Tracking Models*" at AMEMR: Advances in Marine Ecosystem Modelling Research **symposium**, July 2021, Plymouth.
- V-SCORES material as a **case study** to the Supergen Net Zero conference (1 September 2021) via Co-Director Professor Beth Scott.
- Presentation of V-SCORES methodology and results at the EWTEC **conference** (6-9 September 2021), Plymouth.
- Invited **presentation** at the Supergen ORE Hub Annual Assembly 18-20 January 2022 in the session 'Tackling the research challenges: resource and environment characterisation, and environmental and ecosystem' to present the outputs of the V-SCORES project.
- **Presentation** on "Environmental science to support offshore renewables" at the Scottish Parliament 24 March, including underpinning techniques of drone measurements.

- A **presentation** at PRIMaRE 2022 “*Surface velocimetry for tidal stream resource assessment: a comparison of two methods at a range of sites*”.
- A **presentation** accepted at ICOE2022 “*An overview of the use of drones for current measurements at tidal stream sites*”.
- A **presentation** accepted at Challenger 150: The Challenger Society Conference 2022 “*Pushing the limits in autonomous oceanography in a net zero carbon world measuring hydrodynamics with videos from low-cost drones*”.
- V-SCORES closing **webinar** recorded to increase dissemination and access, recommended for publication on the Supergen ORE Hub V-SCORES project page.

3. Publications

The initial outputs from V-SCORES have been published:

- I. Fairley, B.J. Williamson, J. McIlvenny, N. King, I. Masters, M. Lewis, S. Neill, D. Glasby, D. Coles, B. Powell, K. Naylor, M. Robinson, D. Reeve (2022). *Drone-based large-scale particle image velocimetry applied to tidal stream energy resource assessment*. Renewable Energy. <http://doi.org/10.1016/j.renene.2022.07.030>
- J. McIlvenny, B.J. Williamson, I. Fairley, M. Lewis, S. Neill, I. Masters, D. Reeve. Comparison of dense optical flow and PIV techniques for mapping surface current flow in tidal stream energy sites. International Journal of Energy and Environmental Engineering. <http://doi.org/10.1007/s40095-022-00519-z>

V-SCORES investigators co-authored a paper in Proceedings of the Royal Society A, 2021, titled “*A review of the UK and British Channel Islands practical tidal stream energy resource*” ([link](#)) which continues to establish the context and opportunity for tidal stream energy in the UK, and opportunities for future application of V-SCORES techniques.

V-SCORES investigators co-authored a paper in Frontiers in Marine Science, 2022, titled “*Using Unmanned Aerial Vehicle (UAV) Imagery to Characterise Pursuit-Diving Seabird Association With Tidal Stream Hydrodynamic Habitat Features*” ([link](#)) which demonstrates the potential for concurrent collection of ecological and hydrodynamic habitat data concurrently with surface velocimetry for site characterisation using V-SCORES techniques.

The user-interface development to enable concurrent collection of ecological and hydrodynamic habitat data is in review with the International Marine Energy Journal titled “*The bigger picture: developing a graphical user interface to process UAV imagery of tidal stream environments*”.

Further V-SCORES related papers are in preparation / in review, including:

- Moriarty et al. (in review) *Salmon lice infestation pressure from fish farms: Where is knowledge lacking and how can this be rectified?*
- Neill et al. (in prep) *META site characterisation*

4. Follow on opportunities

Collaborations are being developed with further partners, including test sites (EMEC, META), with other academics (e.g., Imperial College London) and industry sectors (e.g., aquaculture, Kelson Marine) both nationally and internationally to extend the applicability and impact of V-SCORES outputs, and including STEM outreach to schools.

Follow on opportunities are being explored to build on V-SCORES. This includes continued development of the software techniques following validation in V-SCORES, with applicability to mapping fine-scale site heterogeneity, model validation and wake measurements. Wider applications include rapid low-cost ORE site selection and sift, understanding biophysical interactions through co-collection of ecological and hydrodynamic data from drones, to applications in the aquaculture sector, or investigating larvae dispersion and connectivity of offshore wind. Beyond offshore renewables, there are wider applications including measuring the distribution and movement of marine plastic litter, with opportunities for concurrent measurement of surface flows and plastic litter debris (e.g., TISPLALI project).

Additional funding has been secured with opportunities to apply the techniques from V-SCORES to other offshore sectors, e.g., £233k PhD studentship secured for particle tracking modelling to inform nuclear decommissioning at ERI UHI, and two MRes studentships secured at Bangor University on wind-driven flows as a MRE resource, and Lagrangian dispersal modelling, 2*£17.75k.