

FASTWATER

Investigators:

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Supported by: EMEC PROTEUS MARINE RENEWABLES ORE CATAPULT



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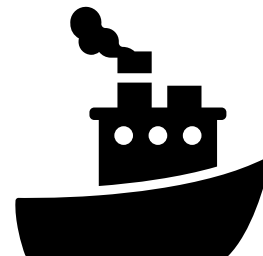
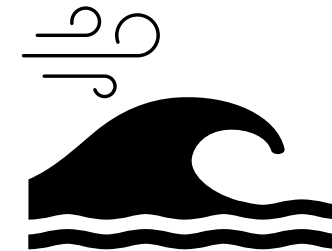
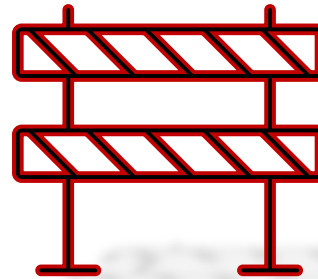
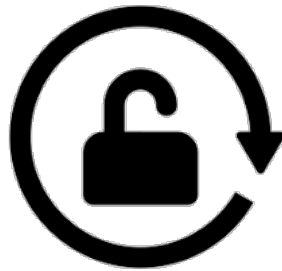
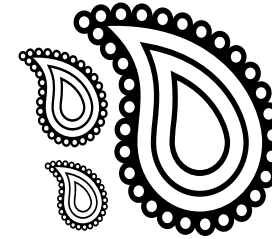
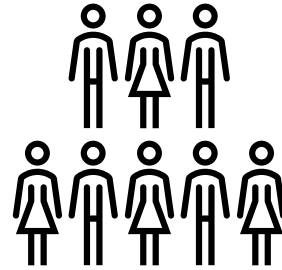
Dr Peter McCallum



Dr Brian Sellar

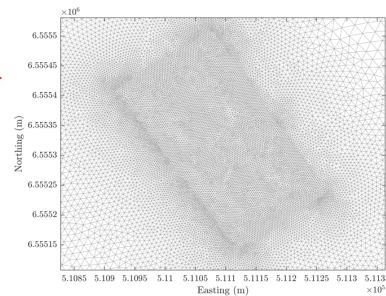
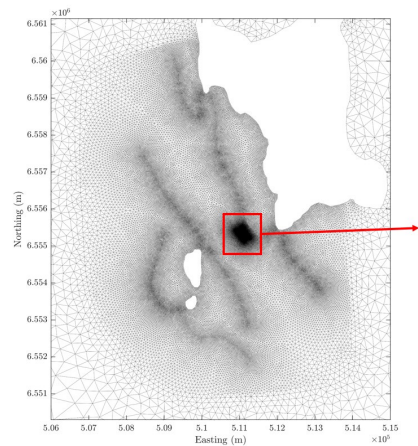
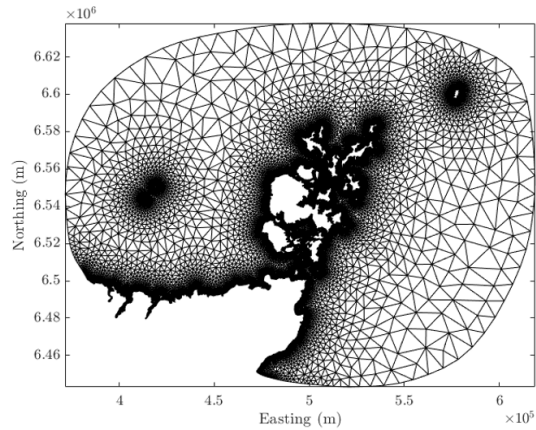
Funded by:

Barriers to the efficient exploitation of modelling tools to provide the right data at the right place at the right time for Tidal...



$$W = \int_{t_1}^{t_2} p(t) dt$$

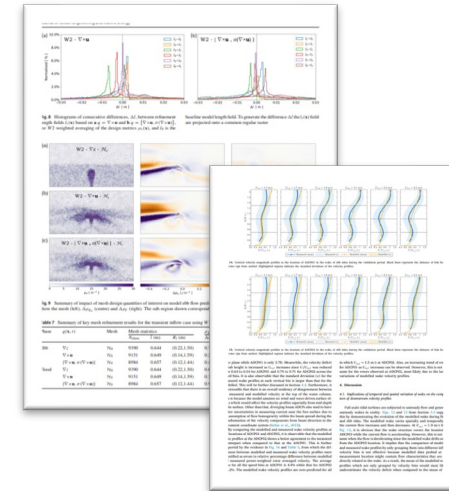
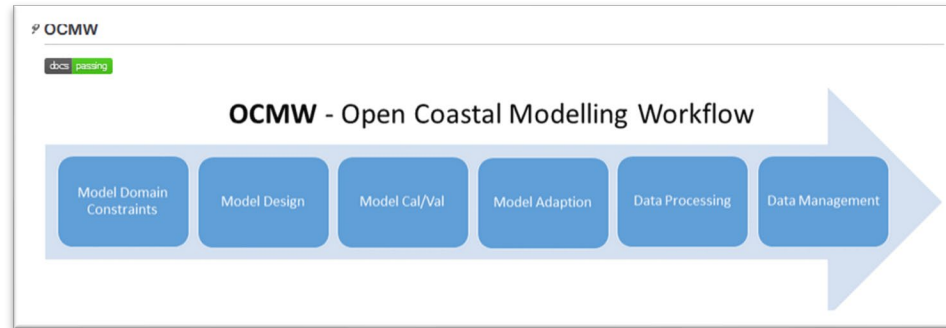
FASTWATER activities to reduce or remove some of these barriers...



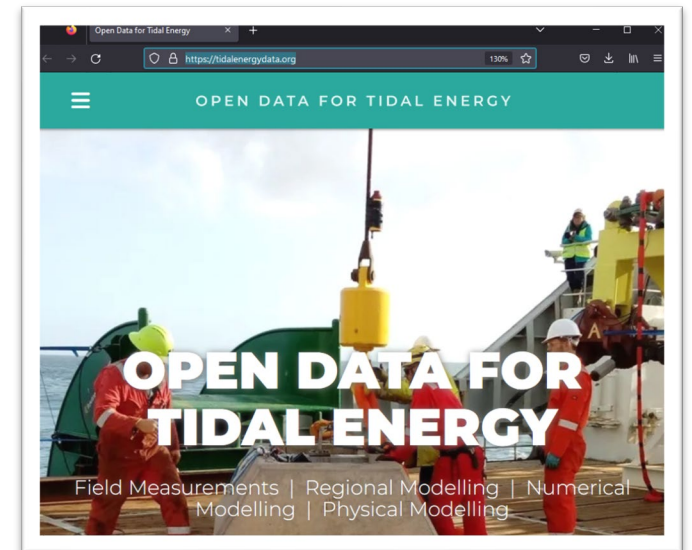
OPEN MODELS



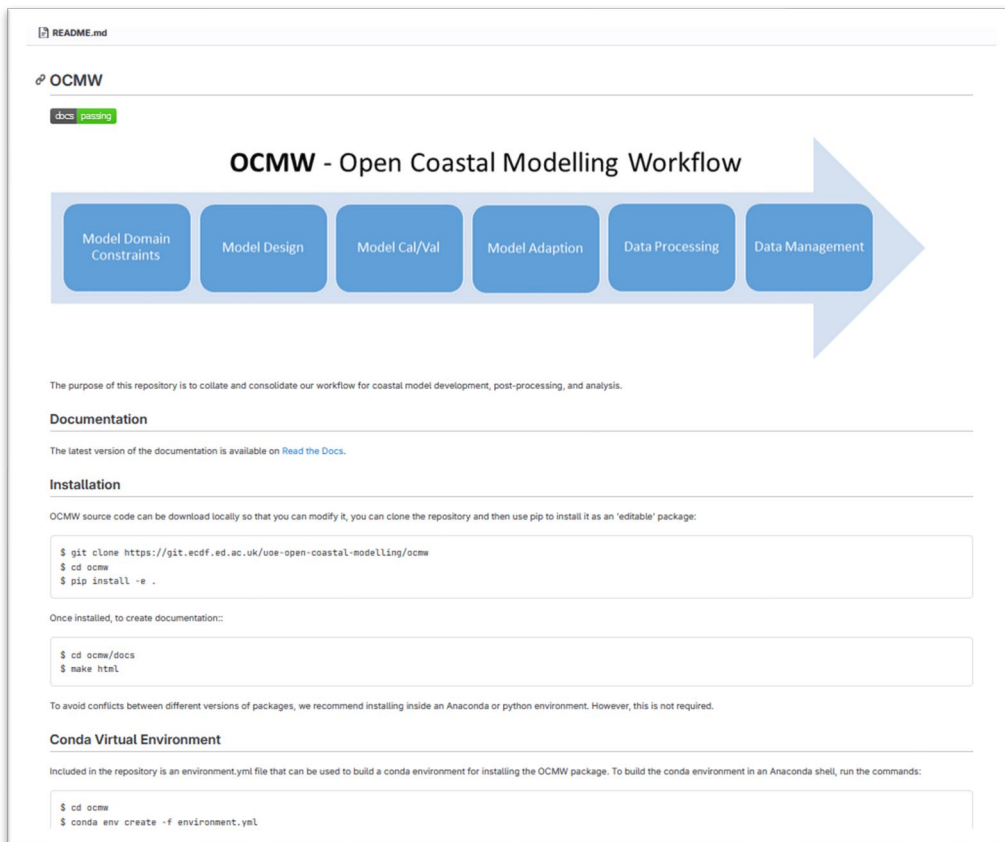
OPEN WORKFLOWS



OPEN PUBLICATIONS



OPEN DATA



The screenshot shows the README for the OCMW (Open Coastal Modelling Workflow) repository. At the top, it says 'OCMW' with a 'docs passing' badge. Below this is a large blue arrow graphic containing six boxes representing the workflow steps: Model Domain Constraints, Model Design, Model Cal/Val, Model Adaption, Data Processing, and Data Management. The text below the arrow states: 'The purpose of this repository is to collate and consolidate our workflow for coastal model development, post-processing, and analysis.' It then has sections for 'Documentation' (linking to Read the Docs), 'Installation' (with terminal commands for cloning, installing, and creating docs), and 'Conda Virtual Environment' (with terminal commands for creating the environment).

SPEC

- Python library of model design, cal/val, and post-processing tools.
<https://git.ecdf.ec.ac.uk/uoe-open-coastal-modelling/ocmw>
- On-line ReadTheDocs documentation.
<https://ocmw.readthedocs.io/en/latest/index.html>
- Core tools solver agnostic

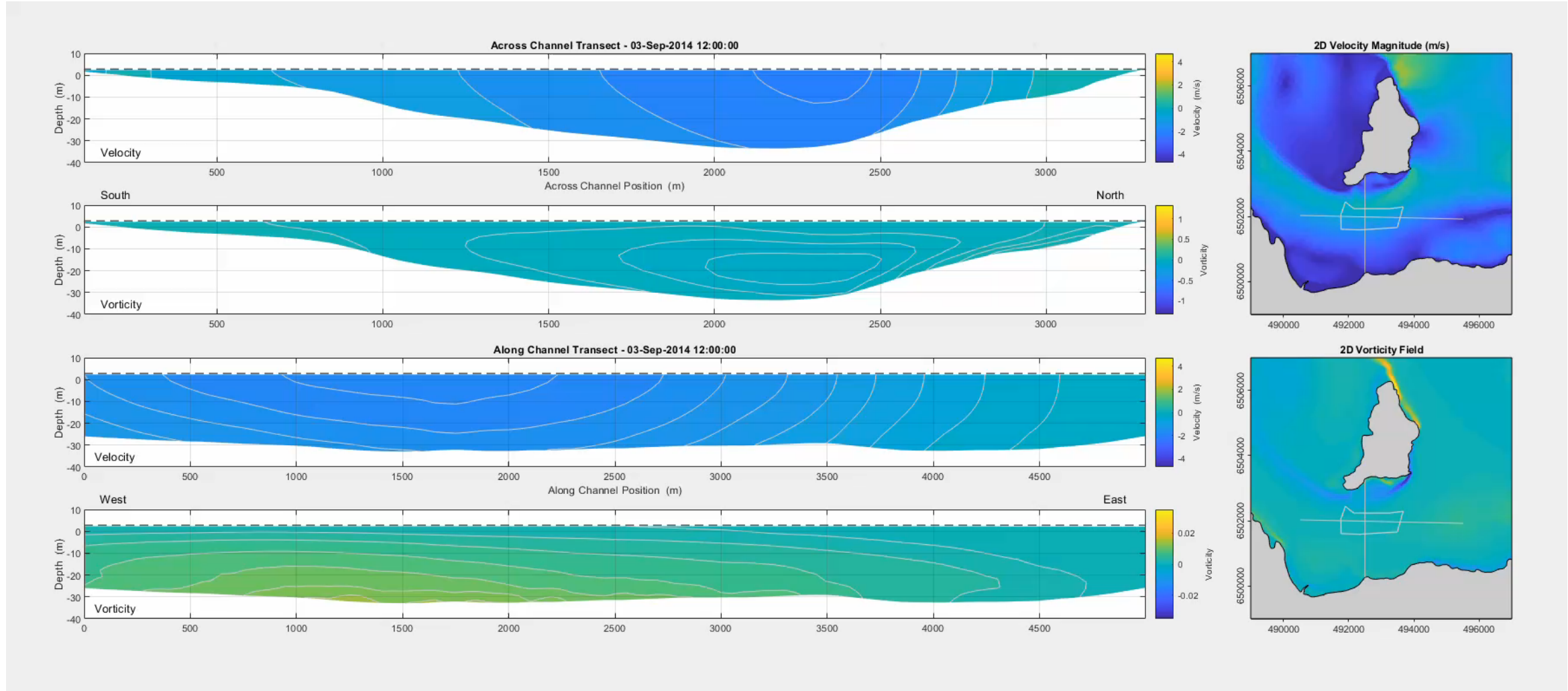
MESH

- Bathymetry manipulation and mapping tools.
- Mesh converters.
- Iterative mesh design (still ongoing)

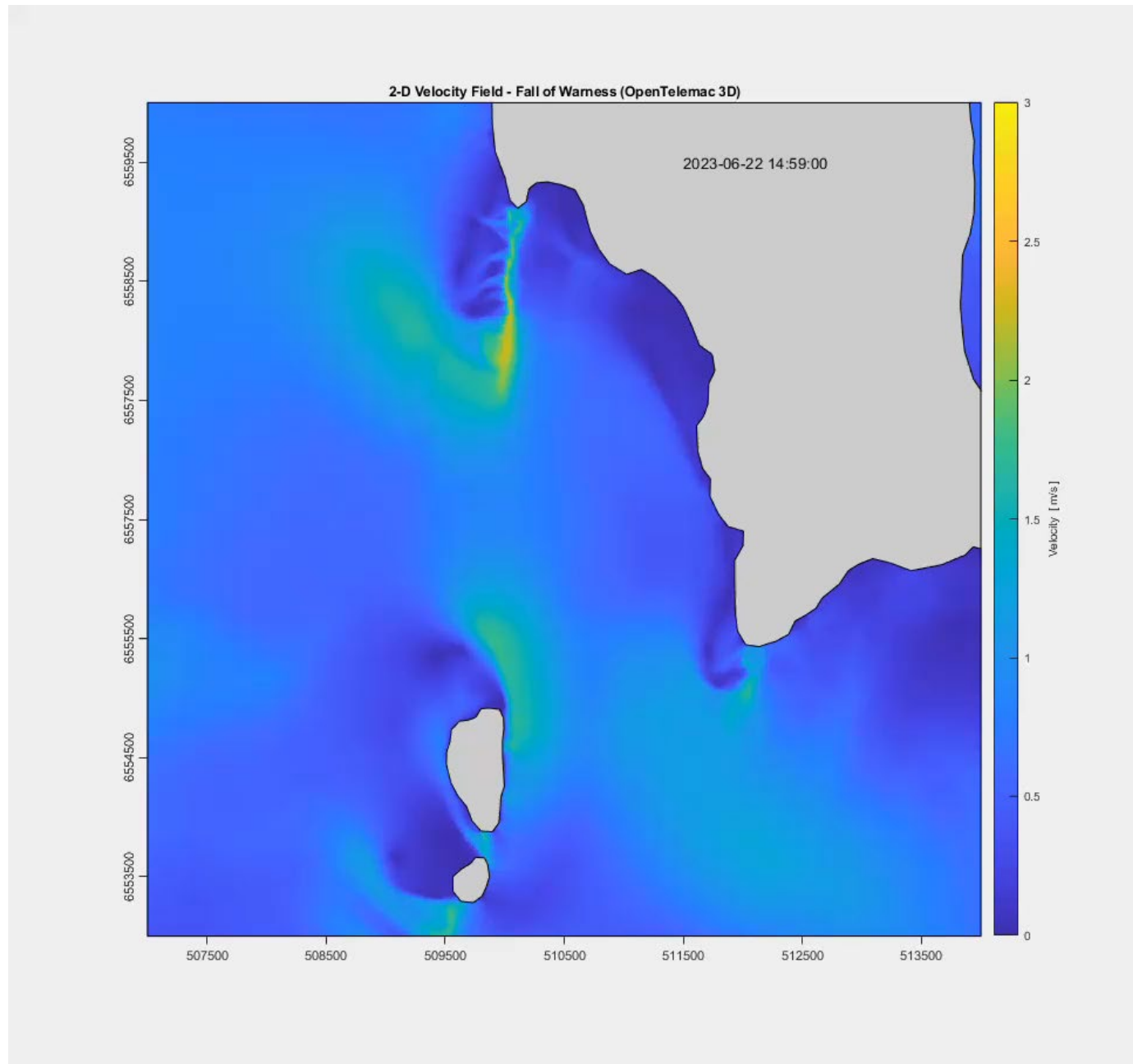
POST PROCESS

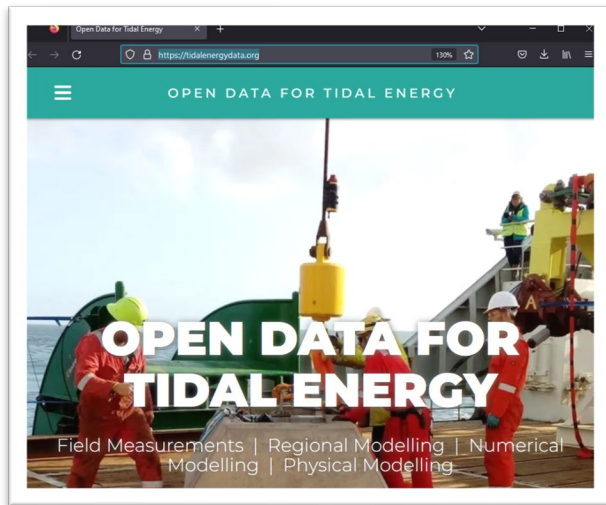
- Standard processing application scripts (e.g. data extraction by location, transect, polygon)
- Example post-processing scripts
 - flow characterisation,
 - parameter calcs,
 - tidal energy calcs,
 - tidal analysis,
 - field mapping,
 - cal/val against ADCP data,
 - etc.

2D & 3D MODELS



2D & 3D MODELS





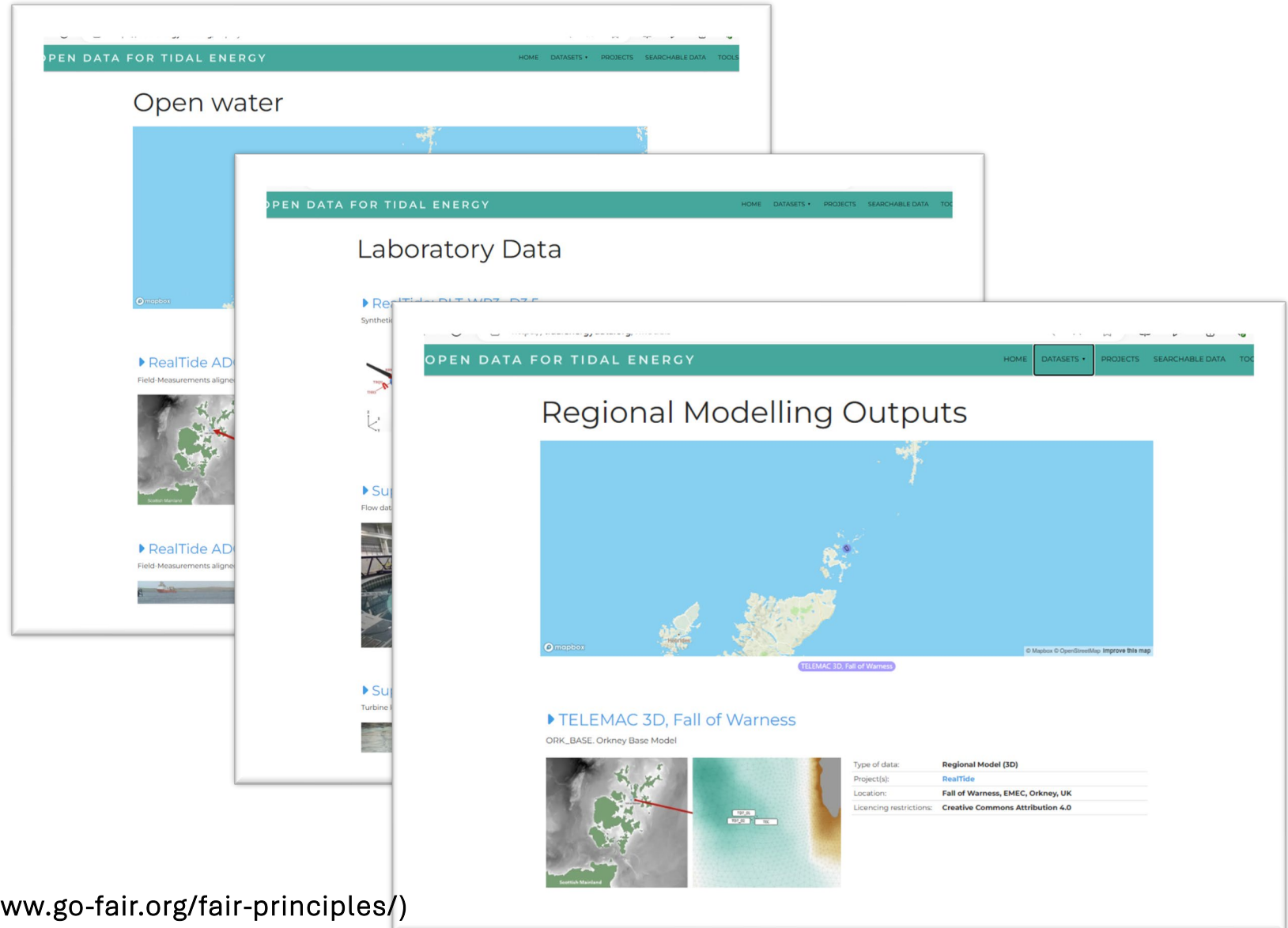
<https://tidalenergydata.org>
(Moving to *eng.ed.ac.uk* Q2 2024)

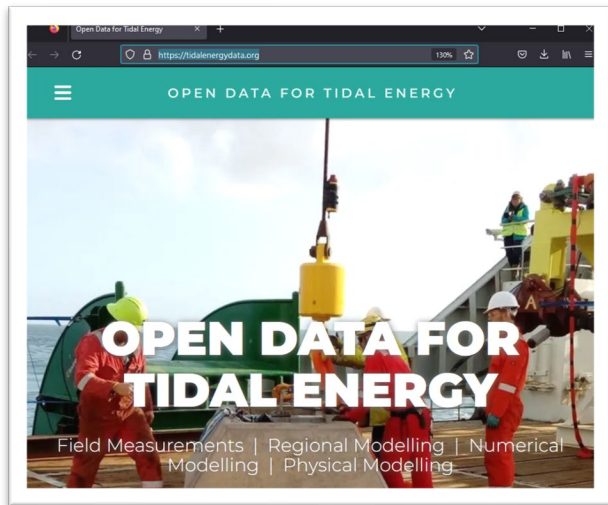
Collate and serve open data sets:

- in situ* measurements,
- physical models,
- numerical simulations

Standard data formats + metadata

Aim to meet FAIR data principles (<https://www.go-fair.org/fair-principles/>)



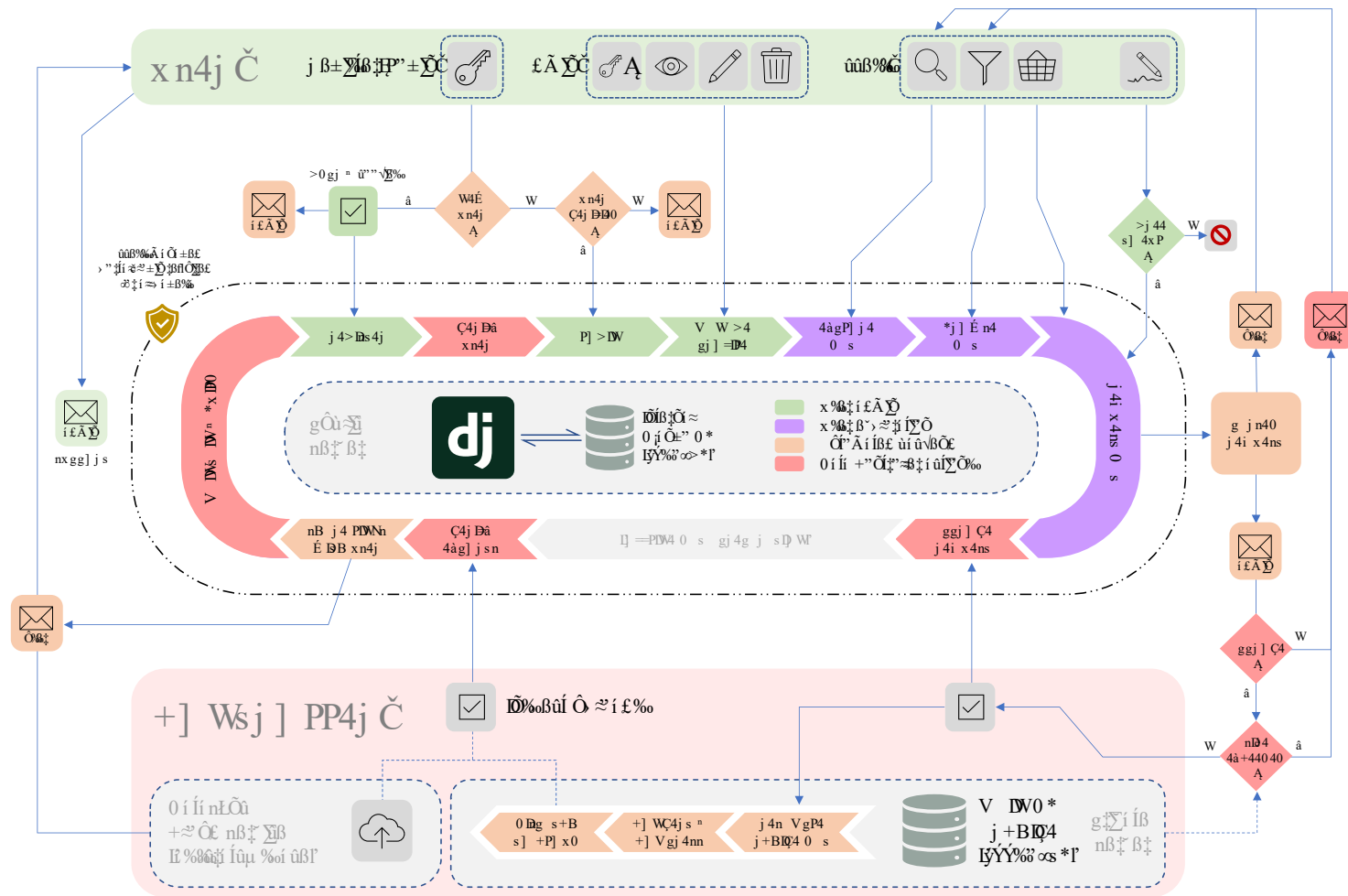


Searchable Data “is hard”...

Prototype process being implemented on Eleanor Cloud service.

Based on linked Public (frontend web service) and Private (backend data processing) VMs.

Django webservice data request passed to background process that extracts and serves up time-limited password protected data to user.



ACCESS HI-RES DATA (>0.5HZ)

APPLY FILTER

CLEAR FILTERS

Dataset

ADCPTD7_Dep1 ▾

Starting from (UTC)

18/09/2014 × 00:00 ×

Elapsed time

88 ▾ hours ▾ mins ▾

Speed, tidal stream

Min. ▾ — Max. ▾ m/s Drop nulls

Flood & Ebb | Flood Ebb

Tidal energy converter power

Min. ▾ — Max. ▾ kW Drop nulls

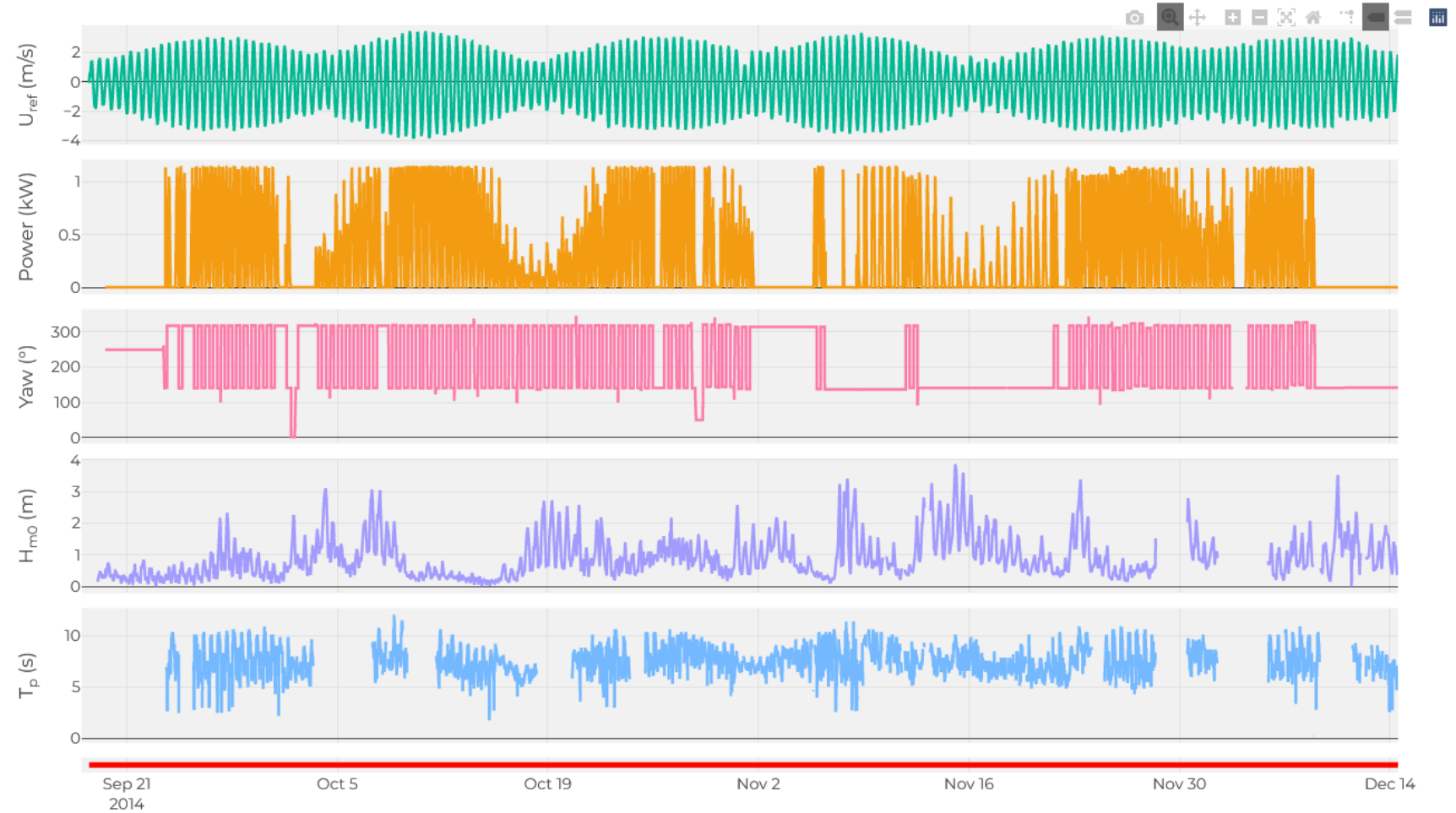
Significant wave height (H_{m0})

Min. ▾ — Max. ▾ m Drop nulls

Wave period (T_p)

Min. ▾ — Max. ▾ s Drop nulls

SEARCHABLE DATA (BETA)



ACCESS HI-RES DATA (>0.5HZ)

APPLY FILTER

CLEAR FILTERS

Dataset

ADCPTD7_Dep1 ▾

Starting from (UTC)

26/09/2014 × 00:00 ×

Elapsed time

3 hours mins

Speed, tidal stream

Min. — Max. m/s Drop nulls

Flood & Ebb Flood Ebb

Tidal energy converter power

Min. — Max. kW Drop nulls

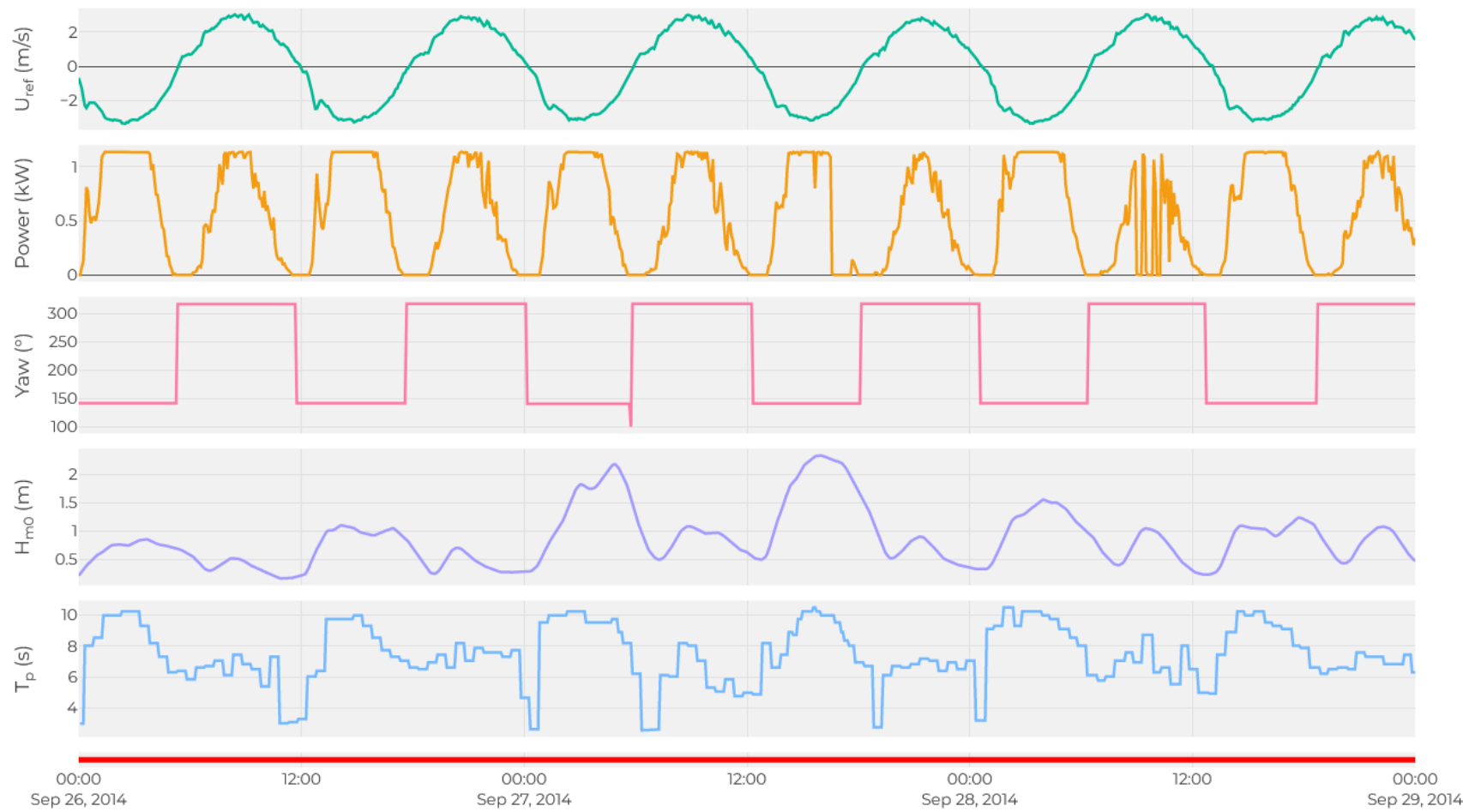
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Min. — Max. m Drop nulls

Wave period (T_p)

Min. — Max. s Drop nulls

SEARCHABLE DATA (BETA)



ACCESS HI-RES DATA (>0.5HZ)

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ADCPTD7_Dep1 ▾

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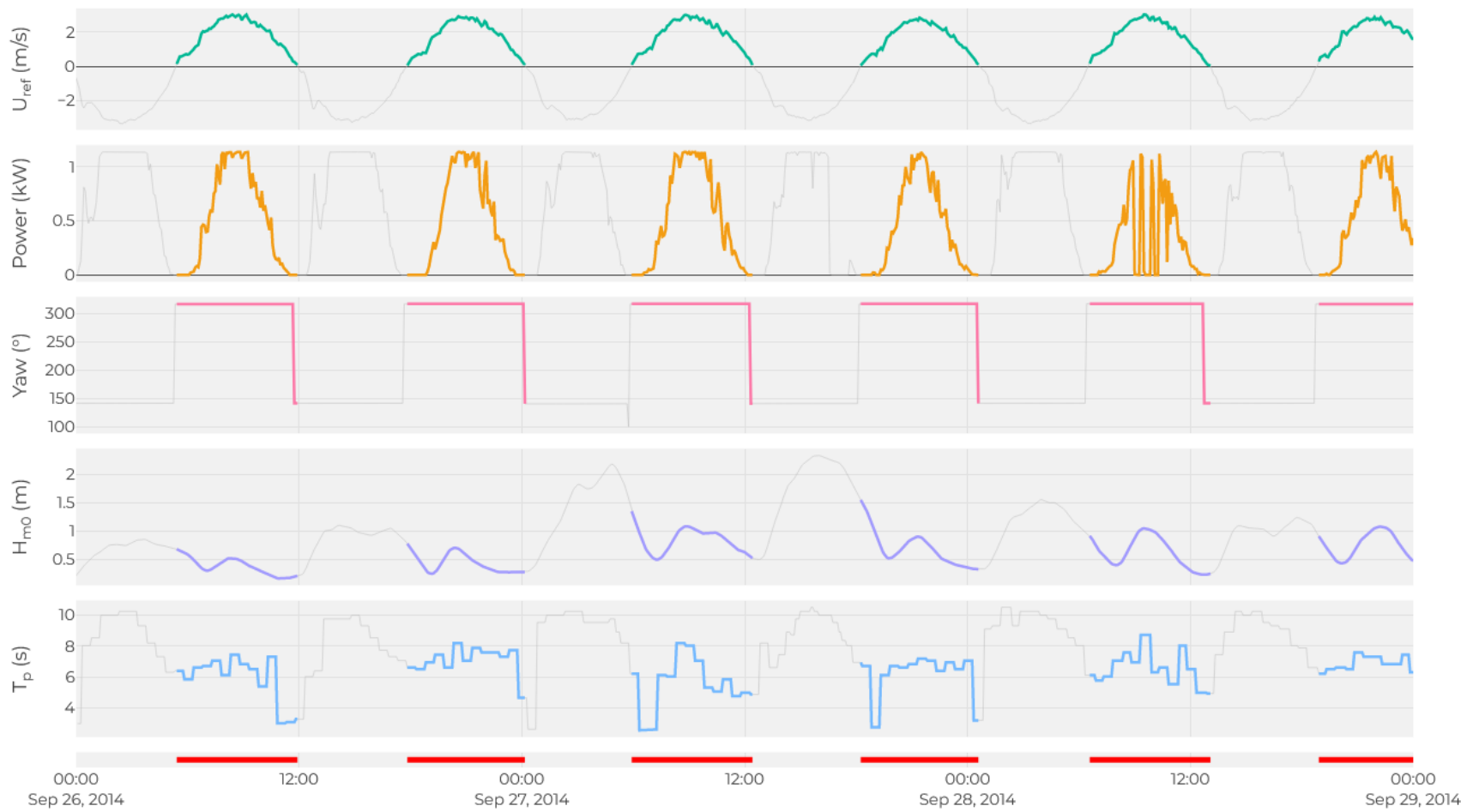
Significant wave height (H_{m0})

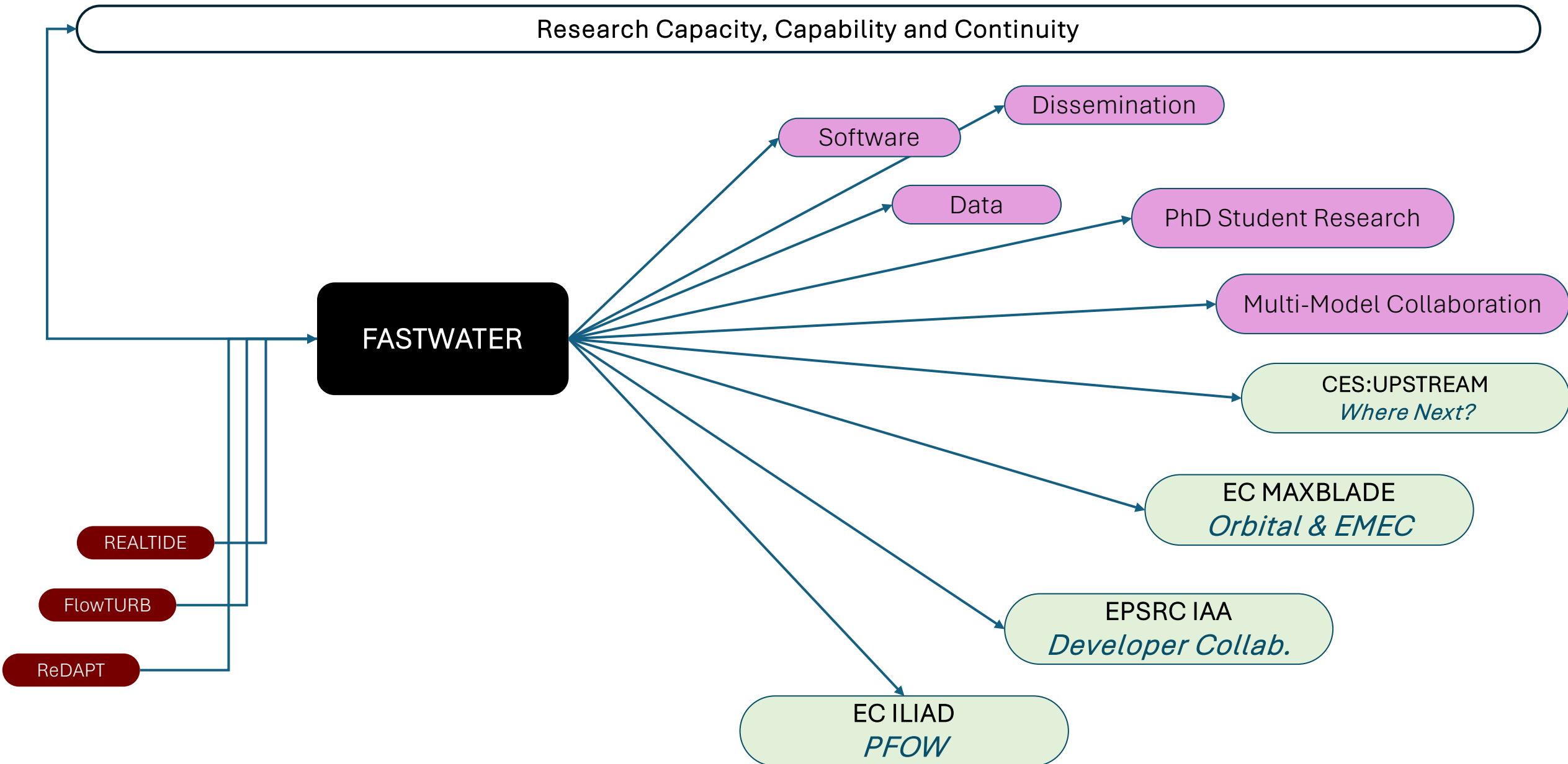
Min. Max. m Drop nulls

Wave period (T_p)

Min. Max. s Drop nulls

SEARCHABLE DATA (BETA)





OPEN
PUBLICATIONS

Underpinning
techniques

Journal of Ocean Engineering and Marine Energy
https://doi.org/10.1007/s40722-024-00314-4

RESEARCH

Iterative dynamics-based mesh discretisation for multi-scale coastal ocean modelling

Chris Old¹ · Brian Sellar¹ · Athanasios Angeloudis¹

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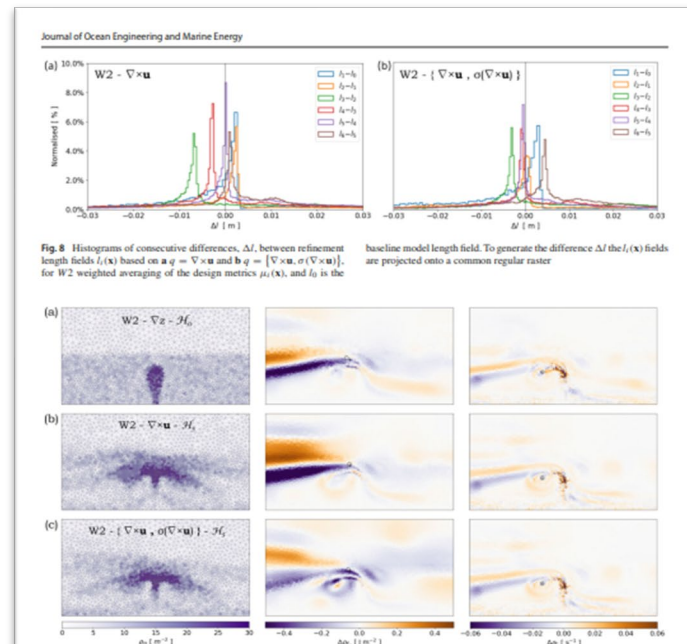


Fig. 8 Histograms of consecutive differences, Δf , between refinement length fields $l_i(\mathbf{x})$ based on $\mathbf{a} = \nabla \times \mathbf{u}$ and $\mathbf{b} = [\nabla \times \mathbf{u}, \sigma(\nabla \times \mathbf{u})]$, for W2 weighted averaging of the design metrics $\mu_i(\mathbf{x})$, and l_0 is the baseline model length field. To generate the difference $\Delta f_i(\mathbf{x})$ fields are projected onto a common regular raster

Table 7 Summary of key mesh refinement results for the transient inflow case using W2 metric weighting

Phase	$q(\mathbf{x}, t)$	Mesh	Mesh statistics			R_f (m)	ρ_{R_f} (J m^{-2})	$\Delta \rho_{R_f}$ (Kp) (%)	ρ_f (s^{-1})	$\Delta \rho_f$ (m)	$\Delta \rho_f^2$ (K) (%)
			N_{elem}	l (m)	R_f (m)						
Ebb	∇_z	7e_6	9390	0.644	(0.22, 1.50)	0.78	-6.45	0.10	-7.99		
	$\nabla \times \mathbf{u}$	7e_5	9151	0.649	(0.14, 1.59)	0.24	-4.78	0.05	-4.69		
	$[\nabla \times \mathbf{u}, \sigma(\nabla \times \mathbf{u})]$	7e_5	8984	0.657	(0.12, 1.44)	0.48	-9.03	0.52	-3.21		
Flood	∇_z	7e_6	9390	0.644	(0.22, 1.50)	0.60	-11.94	0.11	-17.97		
	$\nabla \times \mathbf{u}$	7e_5	9151	0.649	(0.14, 1.59)	0.31	-11.33	0.22	-4.41		
	$[\nabla \times \mathbf{u}, \sigma(\nabla \times \mathbf{u})]$	7e_5	8984	0.657	(0.12, 1.44)	0.99	-16.66	0.44	-23.29		

Fig. 9 Summary of impact of mesh design quantities of interest on model ebb flow predictions of \overline{u}_{fz} and \overline{u}_f , where $\Delta \rho = \overline{u}_f - \overline{u}_{\text{BEM}}$. The panels show the mesh (left), $\Delta \rho_{fz}$ (centre) and $\Delta \rho_f$ (right). The sub-region shown corresponds to the RoI indicated in Fig. 2

Contents lists available at ScienceDirect

Ocean Engineering

Journal homepage: www.elsevier.com/locate/oceaneng

Validation of tidal turbine wake simulations using an open regional-scale 3D model against 1MW machine and site measurements

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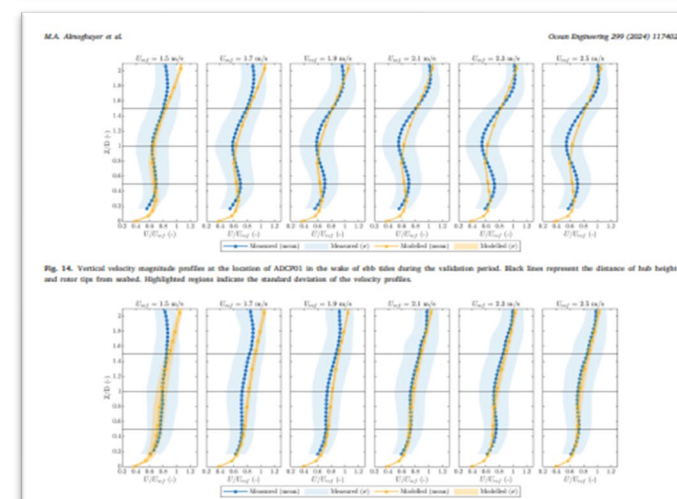


Fig. 14 Vertical velocity magnitude profiles at the location of ADCP01 in the wake of ebb tides during the validation period. Black lines represent the distance of hub height and rotor tips from wake. Highlighted regions indicate the standard deviation of the velocity profiles.

Fig. 15 Vertical velocity magnitude profiles at the location of ADCP02 in the wake of ebb tides during the validation period. Black lines represent the distance of hub height and rotor tips from wake. Highlighted regions indicate the standard deviation of the velocity profiles.

rotor plane while ADCP01 is only 3.7D. Meanwhile, the velocity deficit at hub height is increased as U_{ref} increases since U/U_{ref} was reduced from 0.63 to 0.54 for ADCP01 and 0.79 to 0.71 for ADCP02 across the speed bins. It is also observable that the standard deviation (σ) for the measured wake profiles at each vertical bin is larger than that for the modelled. This will be further discussed in Section 4.2. Furthermore, it is noticeable that there is an overall tendency of disagreement between the measured and modelled velocity at the top of the water column. This is because the model assumes no wind and wave-driven surface effects which would affect the velocity profiles especially from mid-depth to the surface. Other than that, diverging-beam ADCPs also tend to have higher uncertainties in measuring current near the free surface due to the assumption of flow homogeneity within the beam spread during the transformation of the velocity components from beam direction to the instrument coordinate system (Sellar et al., 2015).

By comparing the modelled and measured wake velocity profiles at the locations of ADCP01 and ADCP02, it is observable that the modelled wake profiles at the ADCP02 shows a better agreement to the measured counterpart when compared to that at the ADCP01. This is further supported by the evidence in Fig. 16 and Table 5, from which the differences between modelled and measured wake velocity profiles were quantified as errors in relative percentage difference between modelled and measured power-weighted rotor averaged velocity. The average error for all the speed bins at ADCP01 is 4.4% while that for ADCP02 is 5.2%. The modelled wake velocity profiles are over-predicted for all the cases across the speed bins and the two locations except for the one in which $U_{ref} = 1.5$ m/s at ADCP02. Also, an increasing trend of errors for ADCP01 as U_{ref} increases can be observed. However, this is not the same for the errors observed at ADCP02, most likely due to the larger variations of modelled wake velocity profiles.

4. Discussion

4.1. Implications of temporal and spatial variation of wake on the comparison of downstream velocity profiles

Full-scale tidal turbines are subjected to unsteady flow and generate unsteady wakes in reality. Figs. 12 and 13 from Section 3.3 support this by demonstrating the evolution of the modelled wake during flood and ebb tides. The modelled wake varies spatially and temporally as the current flow increases and then decreases. At $U_{ref} = 1.9$ m/s from Fig. 13, it is obvious that the wake structure covers the location of ADCP03 while the current flow is accelerating. However, this is not the same when the flow is decelerating since the modelled wake drifts away from the ADCP03 location. It implies that the comparison of modelled and measured wake profiles by only grouping them into different inflow velocity bins is not effective because modelled data probed at the measurement location might contain flow characteristics that are not directly related to the wake. As a result, the mean of the modelled wake profiles which are only grouped by velocity bins would most likely underestimate the velocity deficit when compared to the mean of the measured wake profiles. Therefore, it is important to filter modelled

Full-scale
applications

Open Data Access

- High resolution bathymetry related to CES lease sites
- In situ measurements (EMEC, CES – current, waves, acoustic)
- 2-D / 3-D models for Scottish waters (constructs + simulation data)

Searchable Model Data

- Prototype Cloud service to be extended to include model data requests.
- Link frontend web service with backend implementation of OCMW toolbox.
- Model based resource assessment and site characterisation
- Turbine-based yield estimated using Cal/Val 2-D/3-D model data

Array Modelling

- 2-D / 3-D embedded turbine array hydrodynamic models
- Array-Array interaction assessment (relates to changes in site lease model)

CES:UPSTREAM – Targeted Workshops Coming Soon Q2 & Q3 2024...

CES-UP : STREAM

**Crown Estate Scotland – University of Edinburgh Partnership:
SUPPORTING TIDAL RESOURCE, ENERGY-YIELD & ARRAY MODELLING**

An Interdisciplinary Team ...

