Mullach Mor, Isle of Rum

Hydrodynamic Model Report

Mowi Scotland Ltd.

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QUALITY ASSURANCE

Mowi Scotland maintains a Quality Manual which defines the Quality and Environmental Policy of Mowi Scotland Farming Limited and includes an overview of its processes and acts as a signpost to key elements of its Quality Management System according to the requirements of BS EN ISO 9001, BS EN ISO 14001, GLOBALG.A.P. and British Retail Consortium Global Standard Food. Note the BRC standard is relevant to Blar Mhor processing plant only.

1. Introduction

This report has been prepared by Mowi Scotland Ltd. to meet the requirements of the Scottish Environment Protection Agency (SEPA) for an application to develop a new salmon farm site at Mullach Mor, Isle of Rum (**Error! Reference source not found.**). The application uses coupled hydrodynamic and particle tracking modelling to simulate the dispersion of bath medicine treatments, in order to determine EQS-compliant quantities for the current site biomass and equipment, and the regional dispersal of particulate wastes such as waste feed, faeces and in-feed medicines. This report describes the configuration, calibration and validation of the hydrodynamic model used in the application. The dispersion modelling for the site is described in a separate report (Mowi, 2026). The modelling procedure follows as far as possible guidance presented by SEPA in December 2023 (SEPA, 2023).

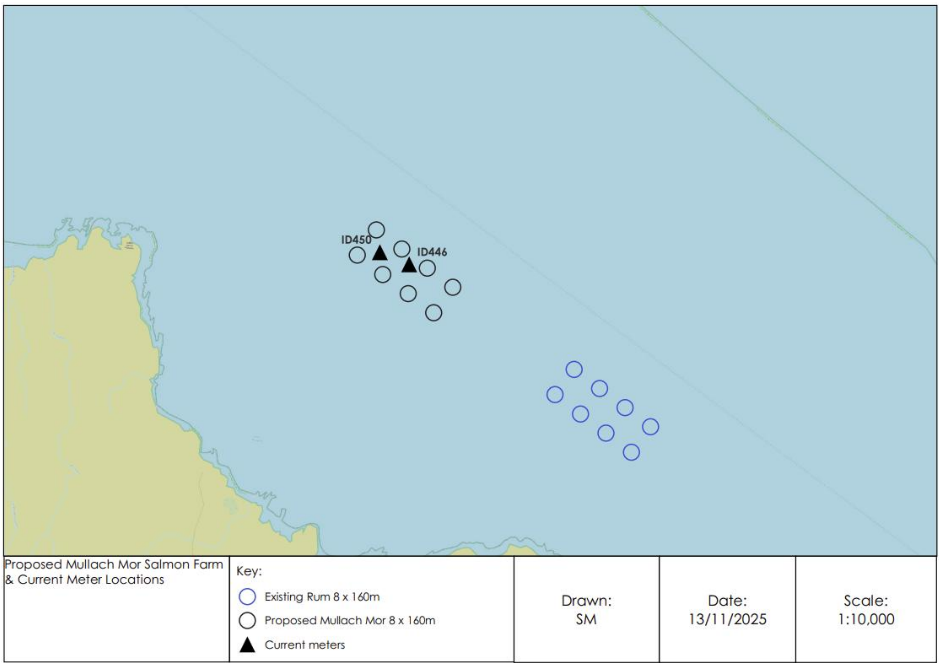

Figure 1. Pen locations (○) for the existing Rum site (blue) and proposed new Mullach Mor site (black). Current meter deployment locations are marked (▲).

1.1 Site Details

The proposed site is situated west of the existing Rum salmon farm (Figure 1). The receiving water is defined as open water. The proposed location at Mullach Mor is sited in a high wave exposure location (wave exposure index = 3.5).

1.2 Hydrographic Data

Hydrographic data at Mullach Mor were collected over two deployments in 2025 (ID446 and ID450, Figure 1). Because cumulative modelling is required, data from the existing Rum site, collected in 2018 (ID242), were utilised together with ID446 in the calibration and validation process. The hydrodynamic model was calibrated against current data and seabed pressure data, measured over the following deployment periods:

(i) Calibration: 14th February 2025 – 27th April 2025 (ID446, Mullach Mor)
(ii) Validation: 30th August 2018 – 22nd November 2018 (ID242, Rum)

The data are described in the relevant hydrographic reports. In total, the data extend over 120 days. The data were collected using Acoustic Doppler Current Profilers (ADCP). A summary of the data from the two deployments is provided in Table 1.

Table 1. Summary of the sub-surface hydrographic data at Mullach Mor (ID446) and Rum

Hydrographic Summary	ID446	ID242
Deployment Date	Feb – Apr 2025	Aug – Nov 2018
Easting	140569	141338
Northing	803399	803238
Mean Speed (m/s)	0.100	0.132
Residual Speed (m/s)	0.022	0.042
Residual Direction (°G)	321	321
Tidal Amplitude Parallel (m/s)	0.154	0.206
Tidal Amplitude Normal (m/s)	0.051	0.065
Major Axis (°G)	315	315

2. Model Description

2.1 Hydrodynamic Model

The hydrodynamic modelling was performed using the RiCOM (River and Coastal Ocean Model; Walters and Casulli, 1998; Walters et al., 2010). The unstructured mesh used in the modelling (Figure 2) was adapted from the East Coast of Lewis and Harris (ECLH) sub-model of the Scottish Shelf Model (SSM; Marine Scotland, 2016). The model resolution was enhanced in the area around the proposed Mullach Mor and existing Rum sites (Figure 3). The spatial resolution of the model varied from 25m in some inshore waters and round the farm pens to 5 km along the open boundary. The model consisted of 88,329 nodes and 168,561 triangular elements.

2.2 Configuration and Boundary Forcing

Model bathymetry was taken from the European Marine Observation and Data Network (EMODnet, 2026) (Figure 4).

The model was run in 2D (depth-averaged) and was forced along its open boundary by eight tidal constituents (M_2, S_2, N_2, K_2, O_1, K_1, P_1 and Q_1) taken from the full Marine Scotland Scottish Shelf Model (Marine Scotland, 2016) using the MATLAB© tidal analysis routine t_tide (Pawlowicz et al., 2002). Spatially- and temporally-varying wind speed and direction were taken from the ERA5 global reanalysis dataset (European Centre for Medium-Range Weather Forecasts (ECMWF), 2021), with data interpolated onto the nodal locations of the model mesh.

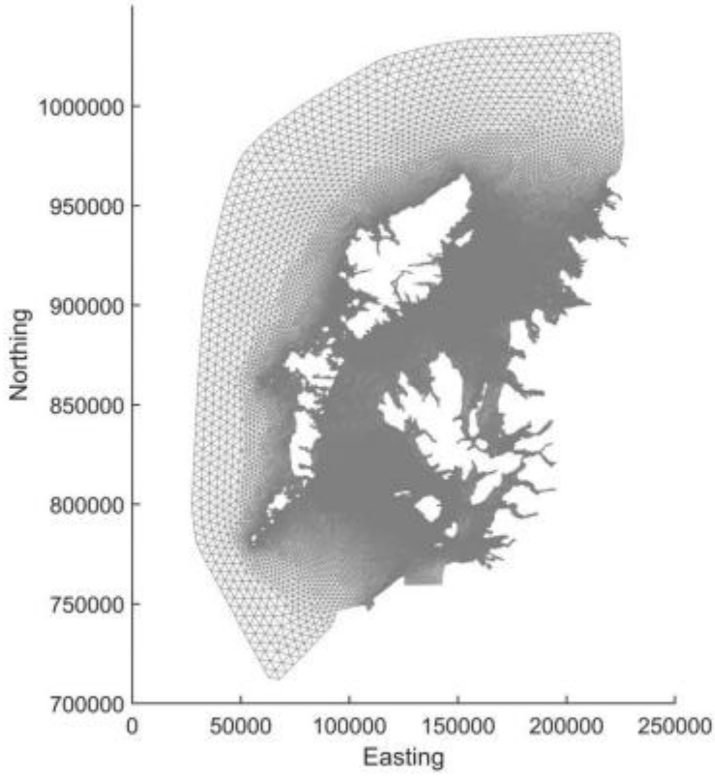

Figure 2. The ECLH mesh and domain of the modelling study.

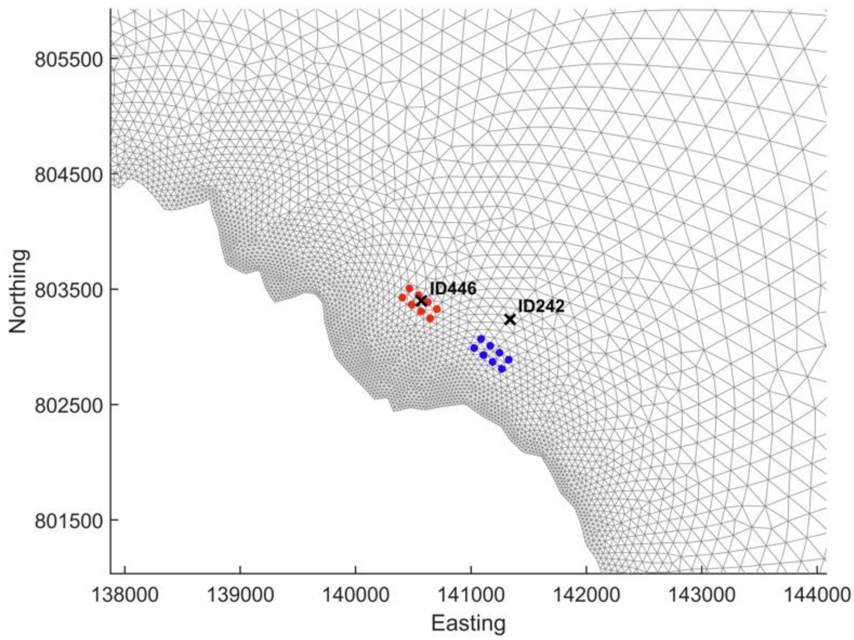

*Figure 3. The unstructured mesh around the Mullach Mor site in the modified model grid, with the proposed cage locations indicated (**o**) and the pens at the neighbouring Rum site also marked (**o**). Locations of ADCP deployments (**X**) are marked.*

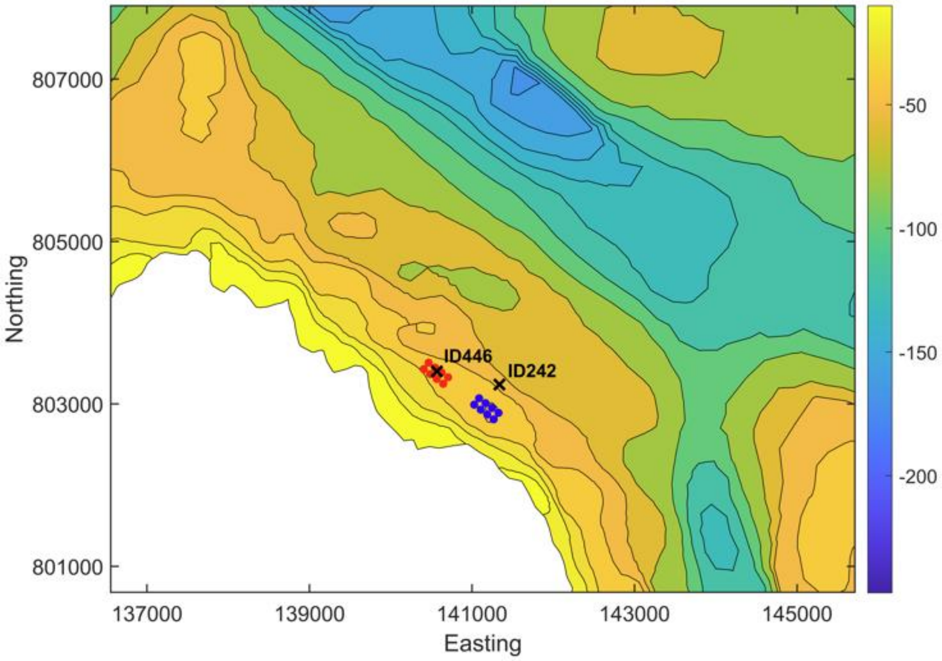

*Figure 4. Model water depths (m) in the area around the proposed salmon farm. The proposed cage locations indicated (○) and the neighbouring existing Rum site (○). ADCP deployment locations are indicated (**X**).*

3. Model Calibration and Validation

For the current study, the model was further calibrated against hydrographic data collected in the region of the farm site in February 2025 (Figure 3, Figure 4). The data are described in the relevant hydrographic reports. The ADCP deployments provided both current velocity and seabed pressure data, which were used to calibrate and validate modelled velocity and sea surface height. The model was calibrated initially against data from February – April 2025 at Mullach Mor (ID446) and then validated against the data from August – November 2018 at Rum (ID242).

For each simulation, the model was “spun-up” for three days with boundary forcing ramped up from zero over a period of 48 hours. The model state at the end of the 72-hour spin-up period was stored, and the main simulations “hot-started” from this state.

The following main simulations were performed, corresponding with the dates of the ADCP deployments:

(iii) Calibration: 14th February 2025 – 27th April 2025 (ID446)
(iv) Validation: 30th August 2018 – 22nd November 2018 (ID242)

[Note that the dates above refer to the main simulations and that the spin-up simulations ran for three days prior to the start dates given above.]

Model performance was assessed using three metrics: the mean absolute error (MAE), the root-mean-square error (RMSE) and the model skill (d_2). The first two are standard measures of model accuracy; the third, d_2, is taken from Willmott et al. (1985) and lies in the range $0 \le d_2 \le 1$, with $d_2 = 0$ implying zero model skill and $d_2 = 1$ indicating perfect skill.

3.1 Calibration: February - April 2025, ID446

The calibration used observed depth and current velocity from the ADCP location to compare with modelled sea surface height (SSH) and velocity. Calibration was performed in a standard fashion, with the model bed friction adjusted using the drag coefficient, C_D, in the 2D simulations to obtain the best fit against the sea surface height and current data. Once the best comparison with the calibration data was achieved, the parameter set was tested (validated) without further adjustment against the second (validation) dataset. The chosen values for key parameters are given in Table 2.

Table 2. Parameter values chosen for the RiCOM model from the calibration simulations.

Parameter Description	Value
Drag coefficient, C_D	0.0025
Number of vertical levels	1
Model time step (s)	36

The results of the calibration exercise are presented in Figure 5 – Figure 8 and Table 3. At the ADCP location, the sea surface height was reasonably accurately modelled, with model skill of 0.99. The mean absolute error (MAE) and root-mean-square error (RMSE) values of 0.16 m and 0.19 m (Table 3) are about 3.2% and 3.8% of the spring tide range (5 m) respectively.

For the calibration period, the model skill scores, RMSE and MAE for the East and North components of velocity are shown in Table 4 and Figure 6. The scatter plots and histograms demonstrate that the modelled current had broadly the same magnitude and direction characteristics as the observed data (Figure 7 and Figure 8).

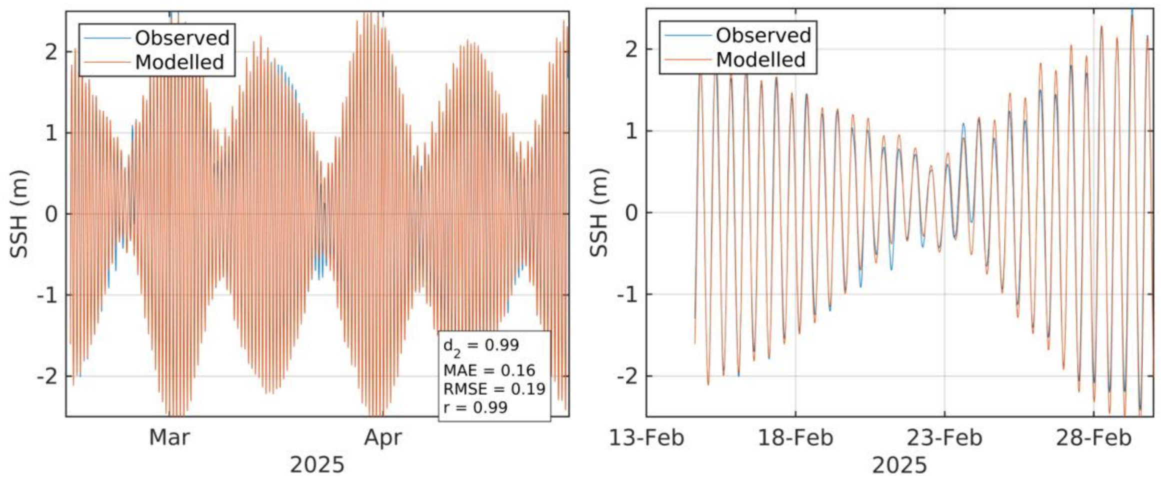

Figure 5. Comparison between observed and modelled sea surface height from March – May 2018 (ADCP deployment ID208) using model parameter values from Table 2. Both the full record (left) and a subset of 15 days (right) are shown. Observed data are in blue, model results in red.

Table 3. Model performance for SSH at the ADCP location from February – April 2025 (ID446).

	SSH
Model skill, d^2	0.99
Mean Absolute Error (MAE) (m/s)	0.16
Root-Mean-Square Error (RMSE) (m/s)	0.19

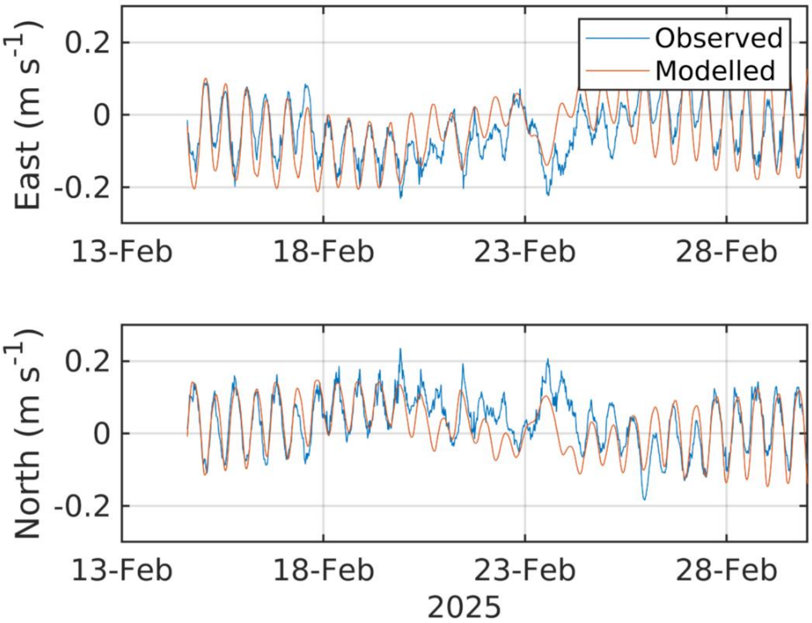

Figure 6. Comparison between observed and modelled East (top) and North (bottom) components of velocity at the ADCP location for 15 days in February 2025 (ID446). Observed data are in blue, model results in red.

Table 4. Model performance statistics for East and North velocity at the ADCP location from February – April 2025 (ID446).

	East	North
Model skill, d^2	0.87	0.89
Mean Absolute Error (MAE) (m/s)	0.04	0.04
Root-Mean-Square Error (RMSE) (m/s)	0.05	0.05

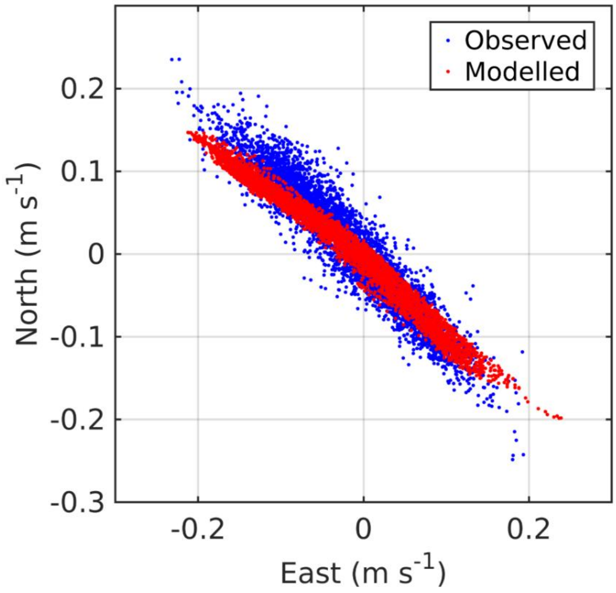

Figure 7. Scatter plot of observed and modelled velocity at the ADCP location from February – April 2025 (ID446). Observed data are in blue, model results in red.

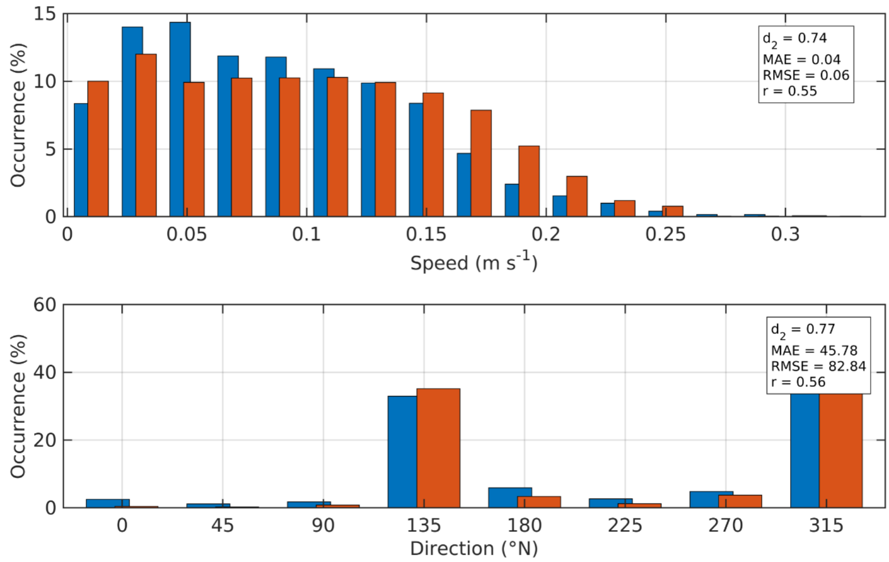

Figure 8. Histograms of observed and modelled speed (left) and direction (right) at the ADCP location from February – April 2025 (ID446). Observed data are in blue, model results in red.

3.2 Validation: August - November 2018, ID242

At the ADCP location, the sea surface height was reasonably accurately modelled, with model skill of 0.99 (Figure 9, Table 5). The mean absolute error (MAE) and root-mean-square error (RMSE) values of 0.17 m and 0.20 m are about 3.4% and 4.0% of the spring tide range (5 m) respectively.

For the calibration period, the skill scores, RMSE and MAE for the modelled East and North components of velocity (Figure 10) are shown in Table 6. The scatter plots and histograms demonstrate that the modelled current had broadly the same magnitude and direction characteristics as the observed data (Figure 11 and Figure 12).

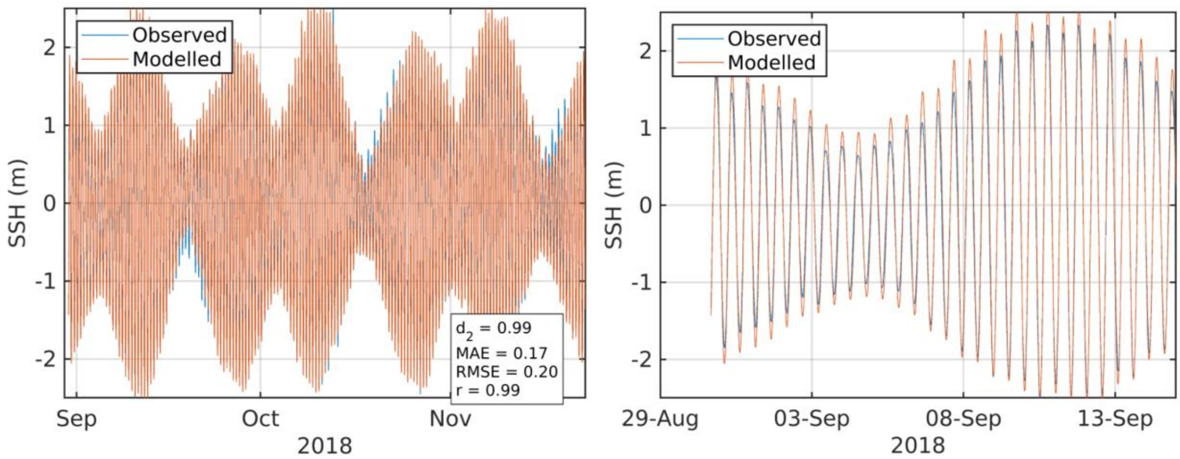

Figure 9. Comparison between observed and modelled sea surface height from August - November 2018 (ADCP deployment ID242) using model parameter values from Table 2. Both the full record (left) and a subset of 15 days (right) are shown. Observed data are in blue, model results in red.

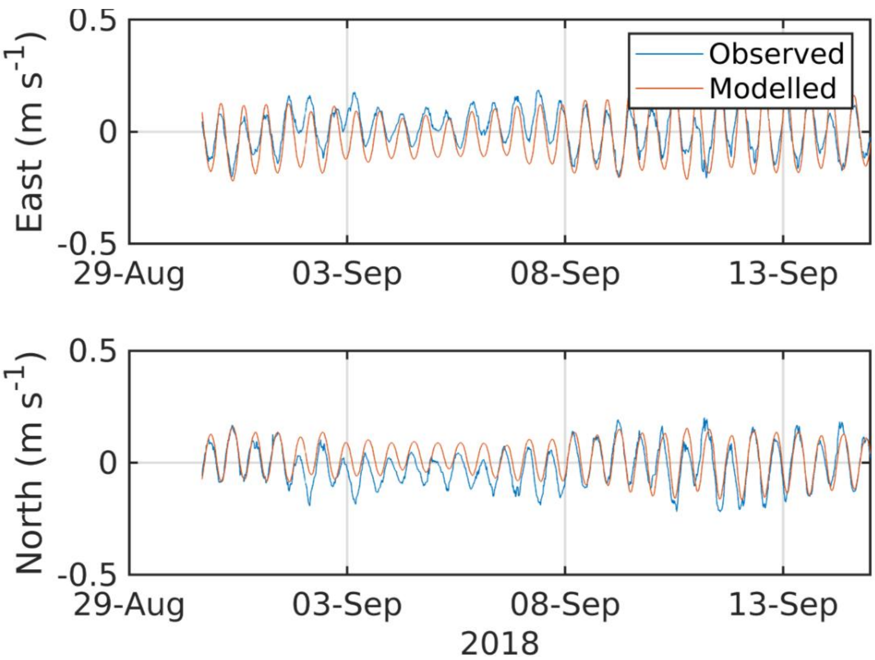

Figure 10. Comparison between observed and modelled East (top) and North (bottom) components of velocity at the ADCP location for 15 days in August - November 2018 (ID242). Observed data are in blue, model results in red.

Table 5. Model performance for SSH at the ADCP location from May – August 2018 (ID242).

	SSH
Model skill, d^2	0.99
Mean Absolute Error (MAE) (m/s)	0.17
Root-Mean-Square Error (RMSE) (m/s)	0.20

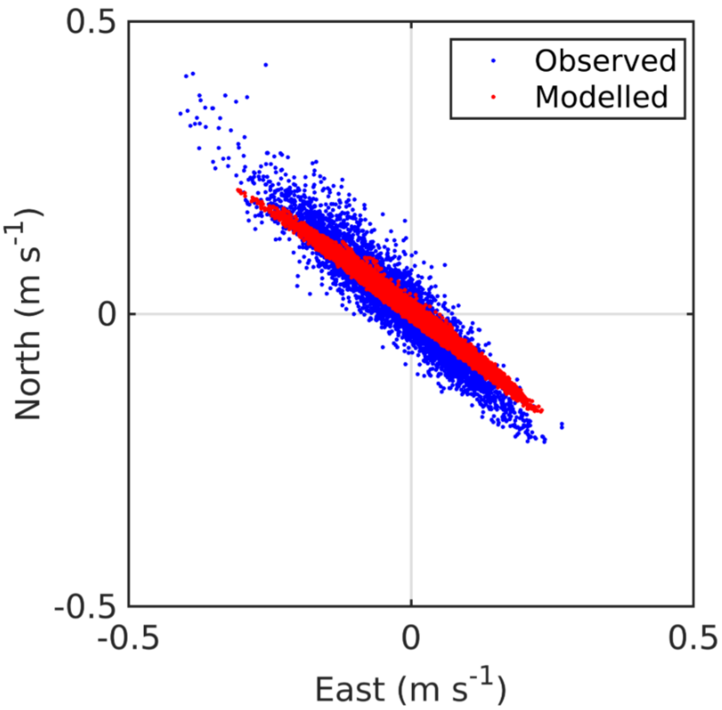

Figure 11. Scatter plot of observed and modelled velocity at the ADCP location from August - November 2018 (ID242). Observed data are in blue, model results in red.

Table 6. Model performance statistics for East and North velocity at the ADCP location from August - November 2018 (ID242).

	East	North
Model skill, d^2	0.87	0.86
Mean Absolute Error (MAE) (m/s)	0.06	0.05
Root-Mean-Square Error (RMSE) (m/s)	0.07	0.06

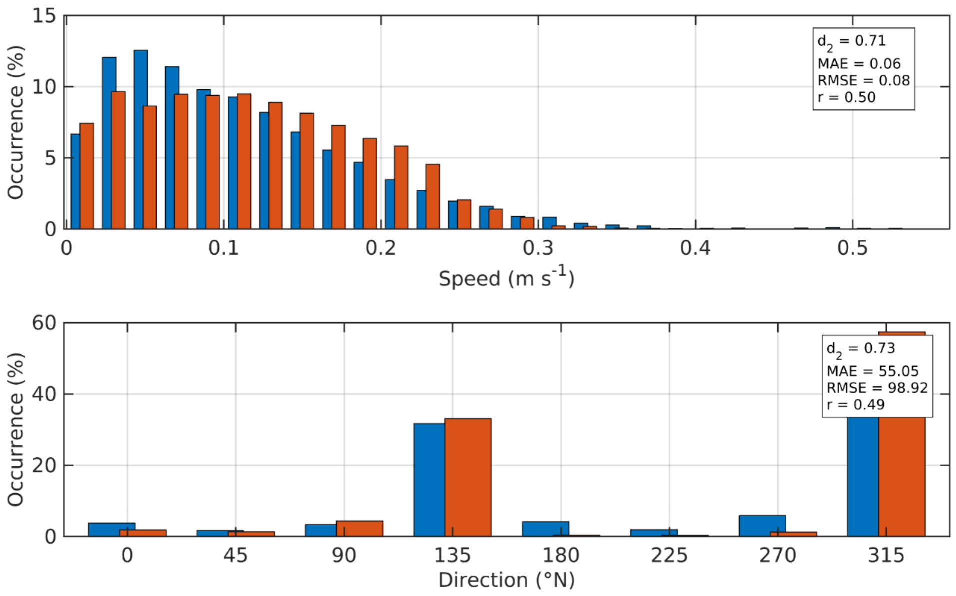

Figure 12. Histograms of observed and modelled current speed (top) and direction (bottom) at the ADCP location from August - November 2018 (ID242). Observed data are in blue, model results in red.

4. Modelled Flow Fields (ID446)

Modelled flood and ebb velocity vectors at spring tides are illustrated in Figure 13 and mean (residual) flows are shown in Figure 14. The proposed Mullach Mor site is subjected to strong bidirectional currents, predominantly oriented north-westwards with significant secondary flows to the south-east. The mean currents are strongly to the north-west (Figure 14).

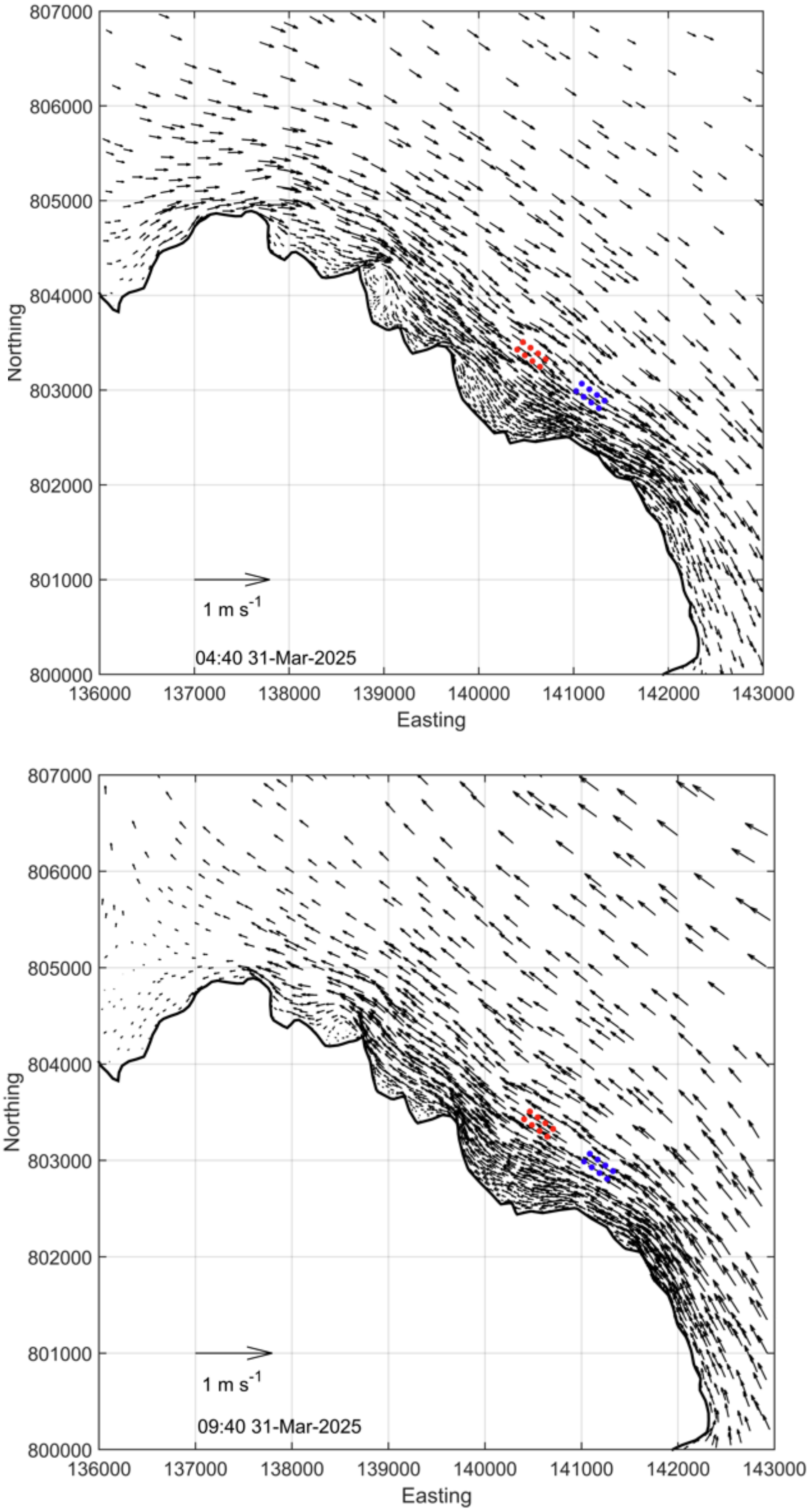

Figure 13. Modelled flood (top) and ebb (bottom) surface current vectors during spring tides on 31st March 2025 (ID446). For clarity, only 25% of the model current vectors are shown. The proposed Mullach Mor indicated in red and the existing Rum site is in blue.

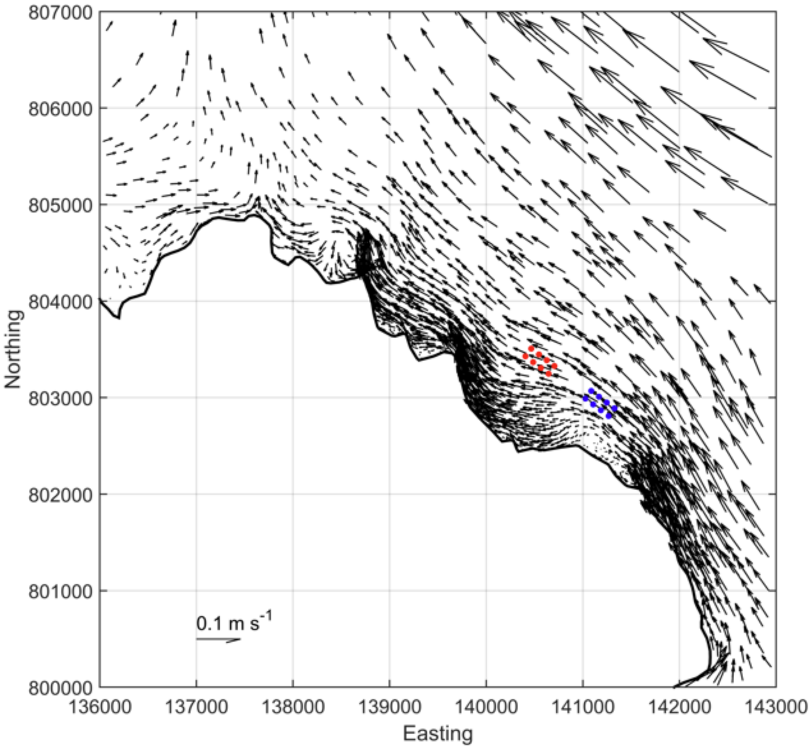

Figure 14. Modelled vector plot for the mean currents around Mullach Mor (red) and Rum (blue).

5. References

European Centre for Medium-Range Weather Forecasts ERA5 reanalysis product (ECMWF, 2026) (https://www.ecmwf.int/en/forecasts/datasets/reanalysis-datasets/era5)

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