Supplementary

Development and Dynamics of Sediment Waves in a Complex Morphological and Tidal Dominant System: Southern Irish Sea: Supplementary Materials

Shauna Creane [1,2,3,*], Mark Coughlan [3,4,5], Michael O'Shea [1,2] and Jimmy Murphy [1,2]

[1] School of Civil and Environmental Engineering, University College Cork, College Road, T12 K8AF Cork, Ireland
[2] SFI Research Centre for Energy, Climate and Marine (MaREI), Beaufort Building, Environmental Research Institute, University College Cork, Ringaskiddy, P43 C573 Cork, Ireland
[3] Gavin and Doherty Geosolutions, Unit A2, Nutgrove Office Park, Rathfarnham, D14 X627 Dublin, Ireland
[4] School of Earth Sciences, Science Centre West, University College Dublin, Belfield, D04 N2E5 Dublin, Ireland
[5] SFI Research Centre for Applied Geosciences (iCRAG), O'Brien Centre for Science East, University College Dublin, D04 N2E5 Dublin, Ireland
* Correspondence: shauna.creane@ucc.ie

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1. Supplementary Material S1: Methodology—Sediment Wave Crest Delineation and Migration Direction and Rates

1.1. Crest Delineation

The methodology of Di Stefano and Mayer [1] for extracting sediment wave crests by geomorphon analysis [2] was adapted by this study. The r.geomorphon tool used in this method was originally developed for the terrestrial environment [2] but has since proven to be highly proficient at seabed characterisation [1]. This tool identifies the 10 most frequent landforms based on elevation differences between the central cell and its eight surrounding cells. These landforms consist of flat, summit, ridge, shoulder, spur, slope, hollow, footslope, valley and depression. The r.geomorphon tool was applied to each bathymetry dataset at each site. Runtime parameters were varied depending on the condition of each dataset. The resulting raster was reclassified to extract the classified 'summit' and 'ridge' (classifications 2 and 3 respectively) pixels as sediment wave crests. The resulting raster was thinned, filtered by length, and vectorised. Topological cleaning was carried out to remove any unwanted dangles and the sediment wave crests were smoothed to aid the next process of migration rate calculation, whilst ensuring the accuracy of the crest delineations were retained. Georeferenced polyline shapefiles were produced. These datasets were quality controlled (QC) in ArcGIS v.10.8 using slope and Terrain Ruggedness (VRM) tool in the Benthic Terrain Modeller.

1.2. Sand Wave Migration Calculation

The QGIS 'Points along the line' tool was applied to QC shapefiles to generate 10m spaced points along each crest, whereby the angle of the crest line at each point is calculated and presented in the point shapefile attribute table. All polyline and point shapefiles were taken into ArcGIS v10.8 where migration rate was calculated.

Taking two time-lapse datasets at a time and starting with the earlier time-stamp, several steps were taken to calculate migration rate and direction. Depending on the migration direction of the sediment wave (determined using the 'minus' tool or generating a Difference of DTM (DOD) whereby displacement direction of the wave crest is clearly identified) the angle from the crest to a perpendicular line was calculated in the point shapefile by either adding or subtracting 90° from the line angle at that point. The 'bearing distance to line' tool was used to generate a perpendicular line from each point on the crest using this newly calculated bearing angle, the x and y coordinate of each point, and an estimated fixed maximum extended distance. These lines were intersected with the crest of the next time-lapse dataset to generate a corresponding second point shapefile. Each corresponding a and b points were connected via a polyline shapefile whereby the length of each line corresponds to the perpendicular horizontal displacement of the sediment wave crest from one time-stamp to another. Annual migration rates are subsequently calculated based on the dates of each survey.

Crest perpendicular cross-sections over time-lapse data were extracted using various ArcGIS tools (Stack Profile) for further morphological and geomorphological analysis. This study uses a combination of the two-part geomorphological classification scheme developed by Dove et al [3] and the classification scheme adopted by Van Landeghem et al [4]. Digital Elevation Models (DEM) of difference (DOD) were calculated to quantify the volumetric change between successive bathymetric surveys and reveal geomorphic changes in a 3-dimensional (3D) surface. This aided the quantification of change in a 1-D, 2D and 3D manner allowing for a better understanding of bedform development on a regional scale and allow interpretation of trends in the wider hydrodynamic-morphodynamic system.

2. Supplementary Material S2: Results—Statistical Correlation between Sediment Wave Dimensions and Individual Environmental Parameters

The Pearson correlation coefficient is used to describe the strength of a relationship between independent variables and dependent variables. The interpretation of the strength of the correlation described by Evans [5] is adopted by this study (**Error! Reference source not found.**). **Error! Reference source not found.** to **Error! Reference source not found.** display the resultant relationships between sediment wave dimensions in the south-western Irish Sea and environmental parameters highlighted in section 4.3.1 of the main research paper, "Development and dynamics of sediment waves in a complex morphological and tidal dominant system: southern Irish Sea".

Table S1. Interpretation of Pearson correlation coefficient (r).

Correlation coefficient (r)	Strength
+ 1.00	Perfect positive
+ 0.8 to 1.0	Very strong positive
+ 0.6 to 0.8	Strong positive
+ 0.4 to 0.6	Moderate positive
+ 0.2 to 0.4	Weak positive
0.0 to + 0.2	Very weak positive/no association
0.0 to - 0.2	Very weak negative/no association
- 0.2 to - 0.4	Weak negative
- 0.4 to - 0.6	Moderate negative
- 0.6 to - 0.8	Strong negative
- 0.8 to - 1.0	Very strong negative
- 1.0	Perfect negative

Table S2. Relationship between sediment wave heights (H) and wavelengths (L) in the south-western Irish Sea. The Full dataset has been broken into three environments i.e. Southern Banks, Northern Banks and Independent Assemblages, and each individual study site.

Dataset	Power regression equation	r^2	Correlation coefficient (r)	Correlation description
Full dataset	$H_{mean} = 0.03L^{0.90}$	0.33	0.58	Moderate positive
Southern Banks	$H_{mean} = 0.05L^{0.77}$	0.27	0.52	Moderate positive
Northern Banks	$H_{mean} = 0.02L^{0.95}$	0.28	0.52	Moderate positive
Independent Banks	$H_{mean} = 0.03L^{0.96}$	0.50	0.71	Strong positive
8	$H_{mean} = 0.03L^{0.91}$	0.53	0.73	Strong positive

2F	$H_{mean} = 0.08L^{0.56}$	0.15	0.39	Weak positive
3C	$H_{mean} = 0.12L^{0.52}$	0.12	0.34	Weak positive
6	$H_{mean} = 0.04L^{0.92}$	0.48	0.69	Strong positive
5	$H_{mean} = 0.06L^{0.83}$	0.38	0.62	Strong positive
4	$H_{mean} = 0.29L^{0.13}$	0	0.07	Very weak positive/no association
1B	$H_{mean} = 0.08L^{0.78}$	0.30	0.55	Moderate positive
1C	$H_{mean} = 0.10L^{0.63}$	0.14	0.38	Weak positive
1A	$H_{mean} = 0.01L^{1.04}$	0.30	0.55	Moderate positive
3A & 3B	$H_{mean} = 0.06L^{0.64}$	0.13	0.36	Weak positive
2E	$H_{mean} = 0.11L^{0.63}$	0.31	0.56	Moderate positive
2D	$H_{mean} = 0.22L^{0.55}$	0.19	0.43	Moderate positive
2B & 2C	$H_{mean} = 0.11L^{0.71}$	0.31	0.56	Moderate positive
2A	$H_{mean} = 0.07L^{0.69}$	0.26	0.51	Moderate positive
7	$H_{mean} = 0.08L^{0.67}$	0.19	0.43	Moderate positive

Table S3. Relationship between sediment wave heights (H), wavelengths (L), and Sand Wave Index (SWI) with Rouse Number (P) in the south-western Irish Sea.

Dataset	**Power Regression Equation**	r^2	**Correlation coefficient (r)**	***Correlation description***
Full	$SWI = 51.02P^{0.036}$	0.0019	0.043474	Very weak positive/no association
Independent sediment waves	$SWI = 44.57P^{-0.051}$	0.0063	0.079429	Very weak negative/no association
Northern Banks	$SWI = 47.91P^{0.078}$	0.0073	0.085545	Very weak positive/no association
Southern Banks	$SWI = 69.89P^{-0.072}$	0.0049	0.06976	Very weak negative/no association
Full	$L = 132.14P^{0.035}$	0.0028	0.05332	Very weak positive/no association
Independent sediment waves	$L = 167.48P^{-0.013}$	0.0004	0.0191	Very weak negative/no association
Northern Banks	$L = 117.59P^{0.072}$	0.01474	0.1214	Very weak positive/no association
Southern Banks	$L = 121.67P^{0.061}$	0.0057	0.0757	Very weak positive/no association
Full	$H = 2.59P^{-0.001}$	-4.62×10^{-6}	N/A	no association
Independent sediment waves	$H = 3.76P^{0.038}$	0.0017	0.0413	Very weak positive /no association
Northern Banks	$H = 2.45P^{-0.006}$	2.74×10^{-6}	0.001654	Very weak negative/no association
Southern Banks	$H = 1.74P^{0.132}$	0.01254	0.111982	Very weak positive/no association

Table S4. Relationship between sediment wave heights (H), wavelengths (L), and Sand Wave Index (SWI) with Water depth (D) in the south-western Irish Sea.

Dataset	**Power Regression Equation**	r^2	**Correlation coefficient (r)**	***Correlation description***
Full	$SWI = 382.32D^{-0.56}$	0.177	0.421	Moderate negative association
Independent sediment waves	$SWI = 539D^{-0.64}$	0.051	0.226	Weak negative association
Northern Banks	$SWI = 895.24D^{-0.83}$	0.1664	0.408	Moderate negative association
Southern Banks	$SWI = 639.79D^{-0.75}$	0.1503	0.388	Moderate negative association
Full	$L = 88.83D^{0.134}$	0.0157	0.125	Very weak/no association
Independent sediment waves	$L = 69.77D^{0.21}$	0.0052	0.072	Very weak/no association
Northern Banks	$L = 69.62D^{0.178}$	0.018	0.134	Very weak/no association

Southern Banks	$L = 153.05D^{-0.035}$	0.00054	0.0232	Very weak/no association
Full	$H = 0.232D^{0.71}$	0.1813	0.426	Moderate positive association
Independent sediment waves	$H = 0.129D^{0.85}$	0.045	0.213	Weak positive association
Northern Banks	$H = 0.078D^{1.01}$	0.1781	0.422	Moderate positive association
Southern Banks	$H = 0.239D^{0.711}$	0.1032	0.321	Weak positive association
7	$H_{mean} = 0D^{2.593}$	0.014	0.119	Very weak/no association
2A	$H_{mean} = 2.82D^{-0.092}$	0	0.018	Very weak/no association
2B & 2C	$H_{mean} = 0.315D^{0.747}$	0.108	0.328	Weak positive association
2D	$H_{mean} = 0.441D^{0.699}$	0.110	0.332	Weak positive association
2E	$H_{mean} = 1.971D^{0.075}$	0.001	0.032	Very weak/no association
3A & 3B	$H_{mean} = 0.071D^{0.965}$	0.137	0.370	Weak positive association
1A	$H_{mean} = 0.311D^{0.565}$	0.034	0.185	Very weak/no association
1C	$H_{mean} = 0.044D^{1.178}$	0.287	0.535	Moderate positive association
1B	$H_{mean} = 1.919D^{0.204}$	0.006	0.077	Very weak/no association
4	$H_{mean} = 0.001D^{1.874}$	0.003	0.057	Very weak/no association
5	$H_{mean} = 0.014D^{1.454}$	0.031	0.176	Very weak/no association
6	$H_{mean} = 0D^{2.156}$	0.051	0.227	Weak positive association
3C	$H_{mean} = 0.950D^{0.085}$	0.001	0.227	Weak positive association
2F	$H_{mean} = 0.024D^{1.672}$	0.084	0.290	Weak positive association
8	$H_{mean} = 221949.933D^{-2.853}$	0.203	0.451	Moderate positive association

Table S5. Relationship between sediment wave heights (H), wavelengths (L), and Sand Wave Index (SWI) with median grain size (D_{50}) in the south-western Irish Sea.

Dataset	Power Regression Equation	r^2	Correlation coefficient (r)	*Correlation description*
Full dataset	$SWI = 55.41{D_{50}}^{0.041}$	0.0021	0.046	Very weak positive/no association
Independent sediment waves	$SWI = 39.93{D_{50}}^{-0.056}$	0.0051	0.072	Very weak negative/no association
Northern Banks	$SWI = 57.82{D_{50}}^{0.094}$	0.011	0.104	Very weak positive/no association
Southern Banks	$SWI = 59.91{D_{50}}^{-0.045}$	0.00172	0.0415	Very weak negative/no association
Full dataset	$L = 142.82{D_{50}}^{0.037}$	0.0273	0.0523	Very weak positive/no association
Independent sediment waves	$L = 158.23{D_{50}}^{-0.061}$	0.006	0.0755	Very weak negative/no association
Northern Banks	$L = 137.71{D_{50}}^{0.072}$	0.072	0.015	Very weak positive/no association
Southern Banks	$L = 139.25{D_{50}}^{0.053}$	0.004	0.064	Very weak positive/no association
Full dataset	$H = 2.58{D_{50}}^{-0.0043}$	8.77×10^{-6}	0.002962	Very weak negative/no association
Independent sediment waves	$H = 3.96{D_{50}}^{-0.0057}$	-4.61×10^{-6}	N/A	no association
Northern Banks	$H = 2.38{D_{50}}^{-0.022}$	0.00041	0.02	Very weak negative/no association
Southern Banks	$H = 2.32{D_{50}}^{0.098}$	0.0063	0.079	Very weak negative/no association

Table S6. Relationship between sediment wave heights (H), wavelengths (L), and Sand Wave Index (SWI) with maximum current speed ($U_{c_{max}}$) in the south-western Irish Sea.

Dataset	Power Regression Equation	r^2	Correlation coefficient (r)	*Correlation description*
Full dataset	$SWI = 56.39{U_{c_{max}}}^{-0.23}$	0.005	0.0729	Very weak negative/no association
Independent sediment waves	$SWI = 40.1{U_{c_{max}}}^{0.09}$	0.0017	0.0418	Very weak positive/no association

Northern Banks	$SWI = 48.19 U_{c_{max}}{}^{0.51}$	0.0063	0.079	Very weak positive/no association
Southern Banks	$SWI = 59.9 U_{c_{max}}{}^{0.12}$	0.0011	0.033	Very weak positive/no association
Full dataset	$L = 139.26 U_{c_{max}}{}^{0.033}$	0.00018	0.0134	Very weak negative/no association
Independent sediment waves	$L = 182.83 U_{c_{max}}{}^{-0.32}$	0.0213	0.146	Very weak negative/no association
Northern Banks	$L = 119.65 U_{c_{max}}{}^{0.40}$	0.009	0.095	Very weak negative/no association
Southern Banks	$L = 138.86 U_{c_{max}}{}^{-0.12}$	0.0018	0.042	Very weak negative/no association
Full dataset	$H = 2.47 U_{c_{max}}{}^{0.26}$	0.0047	0.069	Very weak positive/no association
Independent sediment waves	$H = 4.56 U_{c_{max}}{}^{-0.403}$	0.0188	0.137	Very weak negative/no association
Northern Banks	$H = 2.48 U_{c_{max}}{}^{-0.1121}$	0.00019	0.0139	Very weak negative/no association
Southern Banks	$H = 2.32 U_{c_{max}}{}^{-0.2327}$	0.00331	0.058	Very weak negative/no association

Table S7. Relationship between sediment wave heights (H), wavelengths (L), and Sand Wave Index (SWI) with residual current speed ($U_{c_{res}}$) in the south-western Irish Sea.

Dataset	Power Regression Equation	r^2	Correlation coefficient (r)	*Correlation description*
Full dataset	$SWI = 72.52 U_{c_{res}}{}^{0.87}$	0.0094	0.097	Very weak positive/no association
Independent sediment waves	$SWI = 30.88 U_{c_{res}}{}^{-0.07}$	0.0051	0.071	Very weak negative/no association
Northern Banks	$SWI = 33.3 U_{c_{res}}{}^{-0.159}$	0.0099	0.099	Very weak negative/no association
Southern Banks	$SWI = 66.03 U_{c_{res}}{}^{0.026}$	0.0006	0.025	Very weak positive/no association
Full dataset	$L = 123.61 U_{c_{res}}{}^{-0.037}$	0.0028	0.053	Very weak negative/no association
Independent sediment waves	$L = 412.82 U_{c_{res}}{}^{0.22}$	0.048	0.22	Weak positive
Northern Banks	$L = 104.09 U_{c_{res}}{}^{-0.072}$	0.0048	0.069	Very weak negative/no association
Southern Banks	$L = 158.64 U_{c_{res}}{}^{0.045}$	0.0031	0.056	Very weak positive/no association
Full dataset	$H = 1.7 U_{c_{res}}{}^{-0.12}$	0.013	0.114	Very weak negative/no association
Independent sediment waves	$H = 13.37 U_{c_{res}}{}^{0.294}$	0.045	0.212	Weak positive
Northern Banks	$H = 3.17 U_{c_{res}}{}^{0.87}$	0.0021	0.046	Very weak positive/no association
Southern Banks	$H = 2.4 U_{c_{res}}{}^{0.02}$	0.0003	0.016	Very weak positive/no association

Table S8. Relationship between sediment wave heights (H), wavelengths (L), and Sand Wave Index (SWI) with mean current speed ($U_{c_{mean}}$) in the south-western Irish Sea.

Dataset	Power Regression Equation	r^2	Correlation coefficient (r)	*Correlation description*
Independent sediment waves	$SWI = 45.28 U_{c_{mean}}{}^{0.2}$	0.0043	0.065	Very weak positive/no association
Northern Banks	$SWI = 94.14 U_{c_{mean}}{}^{0.97}$	0.011	0.105	Very weak positive/no association
Southern Banks	$SWI = 69.48 U_{c_{mean}}{}^{0.22}$	0.0034	0.058	Very weak positive/no association
Independent sediment waves	$L = 134.67 U_{c_{mean}}{}^{-0.43}$	0.018	0.135	Very weak negative/no association
Northern Banks	$L = 168.92 U_{c_{mean}}{}^{0.46}$	0.006	0.077	Very weak positive/no association
Southern Banks	$L = 129.61 U_{c_{mean}}{}^{-0.09}$	0.00093	0.031	Very weak negative/no association
Independent sediment waves	$H = 2.97 U_{c_{mean}}{}^{-0.63}$	0.021	0.15	Very weak negative/no association
Northern Banks	$H = 1.79 U_{c_{mean}}{}^{-0.51}$	0.0022	0.047	Very weak negative/no association
Southern Banks	$H = 1.87 U_{c_{mean}}{}^{-0.31}$	0.0051	0.071	Very weak negative/no association

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