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***Abstract*— Telemac-2D/3D is used here to understand larval dispersal of mussels in the Irish Sea. Mussels (*mytilus edulis L.*) represent 40 to 50 % of the total gross turnover of Welsh shellfish industries and the industry has been operating sustainably for over 50 years in North Wales. In this context, it is in the interest for Mussels companies to understand where the larvae go in order to manage their stocks efficiently. We study the interactions between physical (e.g., tides, currents, temperature, weather conditions…) and biological (e.g., vertical migration, pelagic larval duration) processes experienced by the larvae. We created a variable mesh density for the Irish Sea: very fine scale at mussel seed source in the Menai Strait to coarser scale in the north and south Irish Sea. The aim was to simulate: 1) a range of larval dispersal under present-day natural variability (from a calm and cold year to a windy and warm year); and 2) dispersal patterns in the future (impact of sea-level rise and temperature warming). Telemac in baroclinic mode for the Irish Sea will be compared to existing data and models. A range of larval behavioural traits will also be simulated (e.g. passive vs. active swimmers). Model results will be fed back to the Mussel companies, who will then survey the likely settlement regions identified by the model, and so help validate the model.**

I. INTRODUCTION

The accuracy of an oceanographic model is the key to explain the best the impact of physical parameters (tide, wind, temperature…) on larvae dispersal. However, such model may be long to generate and/or to produce files which are too big. Furthermore, the creation of a model in a complex environment as the Irish Sea (shallow water vs deep water; stratified water or not…) can imply a variation of the particle dispersal from an area to another (Parker-Humphreys, 2004; Hill *et al.*, 1997).

The aim of this study is to model the mussel larvae dispersal in the Menai Strait and the Irish Sea. The TELEMAC-2D software was used to simulate the hydrodynamics and a Matlab program was used for the particle dispersion, modelling only the advection. A sensitivity analysis with regards to the time-step size and initial particle distribution was performed in order to determine optimal parameters for futures simulations.

II. MATERIAL AND METHODS

A. Mesh generation in Blue Kenue

A variable unstructured triangular mesh density, from 30 meters to 5000 meters, has been created for the Irish Sea on Blue Kenue. The finest scale (30 meters) is in the Menai Strait where mussel companies farm *Mytilus edulis*. The scale is getting coarser to the extreme south and north of the Irish Sea (5000 meters). Furthermore, several areas of interest, such as Morcambe Bay or Liverpool Bay, have a scale of 50 meters. Bathymetry has been downloaded from Digimap, changed into mean sea level (MSL) and mapped to the mesh (Fig. 1).

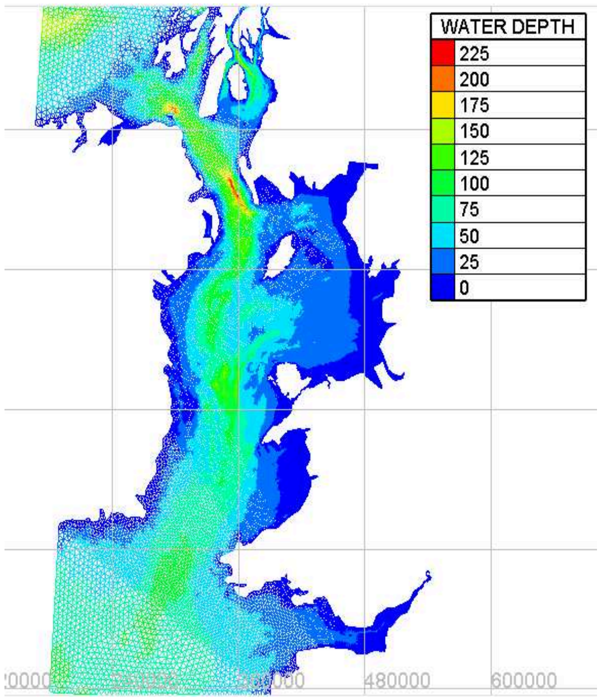

Figure 1. *Variable density of the two-dimensional unstructured triangular mesh of the Irish Sea with bathymetry*

B. Telemac modelisation and validation

The model has been run with TELEMAC-2D v7p2r2 with only the tide component. It ran during 4 days from the 1st of March 00:00:00 to 5th of March 00:00:00 during a neap tide. Only the time step has been modified in order to understand if there is an impact on the particle tracking model. The time steps tested are: 5, 10, 15, 30, 45, 60, 90, 120 and 180 minutes. The water elevation validation has been made using tide gauge data from the British Oceanographic Data Centre (BODC) on 14 sites scattered everywhere on the Irish Sea coasts. We also take into account the residuals on the validation results for each month of the year 2015 by calculating the Root Mean Square Error (RMSE). The residuals are the observed elevation of the water minus the predicted elevation of the water. Basically, the residuals are the effect of the weather on tides. In our case, we subtracted the residuals to the observed water elevation in order to validate our model only on tide effect on water elevation.

C. Particle tracking model (PTM)

The PTM has been run on Matlab for 5000 particles located between the Isle of Man and Llyn Peninsula for the north and the south boundary respectively (Fredj *et al.* 2016). The east and the west boundary are Anglesey (North wales) and Ireland coast respectively. Particles have been disposed either perpendicular or parallel to the flow (Fig. 2 and 3 respectively). The PTM was run only with the advection equations in order to minimize the random dispersal from the diffusion equations. We used a Lagrangian model and the same time-step for the PTM as the one in TELEMAC-2D.

Only the last position of each particle of the 5000 particles was recorded for all time steps. Then, we calculated the distance between the results from the 5 min time-step output (most accurate) and the other output by using Pythagoras theorem.

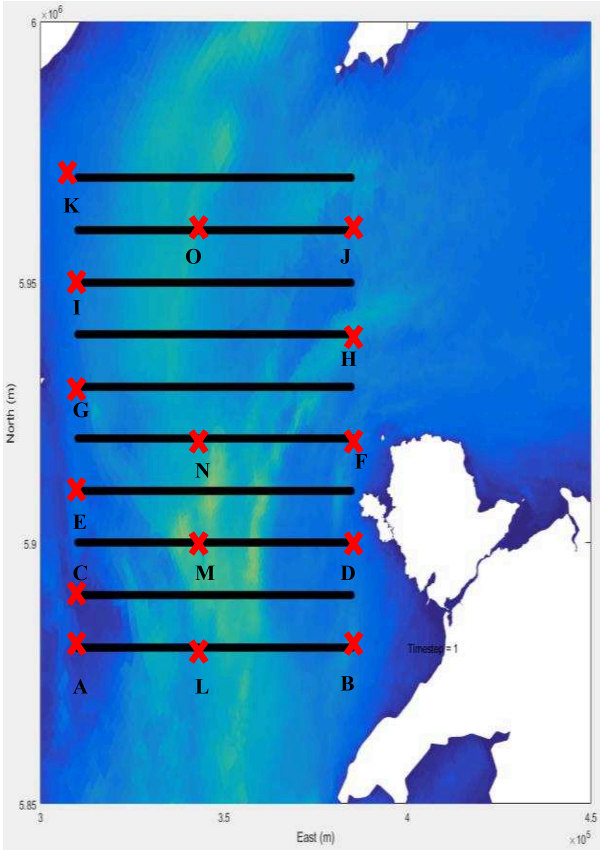

Figure 2. *Position of 5000 particles perpendicular to the flow, red crosses correspond to 15 individual particles of interest labelled from A to O.*

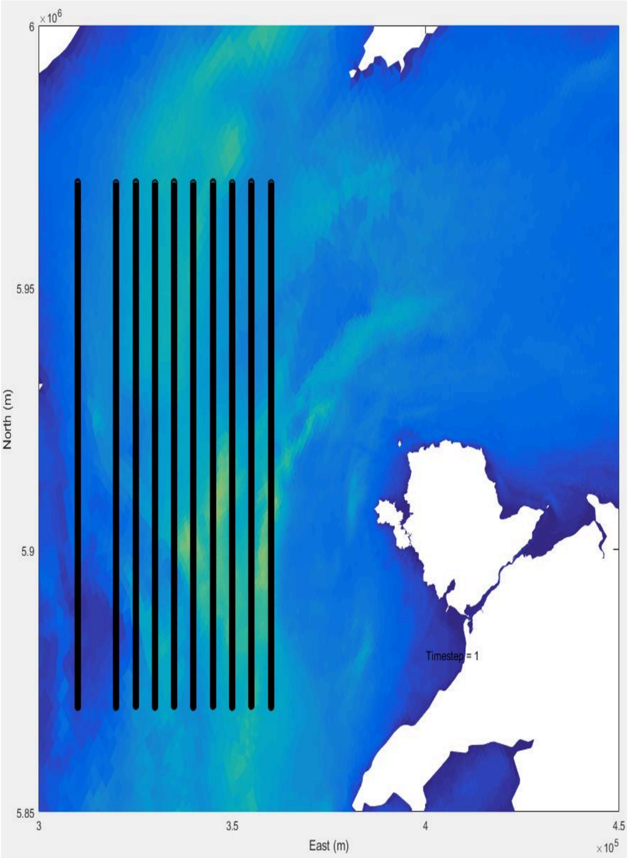

Figure 3. *Position of 5000 particles parallel to the main flow*

III. RESULTS

A. Validation results

The RMSE stays the same with a changing time step for each month. When the residuals were used for the water elevation validation, we observed an amelioration of the results. That means the value of the RMSE are more similar between the observed data and the model data. The summer and spring months were less impacted than the autumn and winter months by the residuals as we noticed an improvement of the validation results of 8.89 % and 32.99 % respectively (Tab. 1).

B. PTM results

The results showed that bigger is the time step and bigger is the distance with 5 min time step in average for both parallel and perpendicular situation (Fig. 4). However, the difference looked less important in average when particles are disposed parallel to the main flow. We also saw the emergence of a gyre in the south west of the Irish Sea as the time step is finer (Fig. 5).

By looking at individual particle, we noticed a difference of response between several areas (Fig. 2). We observed the biggest distance between the model run with a time step of 5 min and the time step of 180 min for the particle D and the smallest for the particle K (Tab. 2 and Fig. 6).

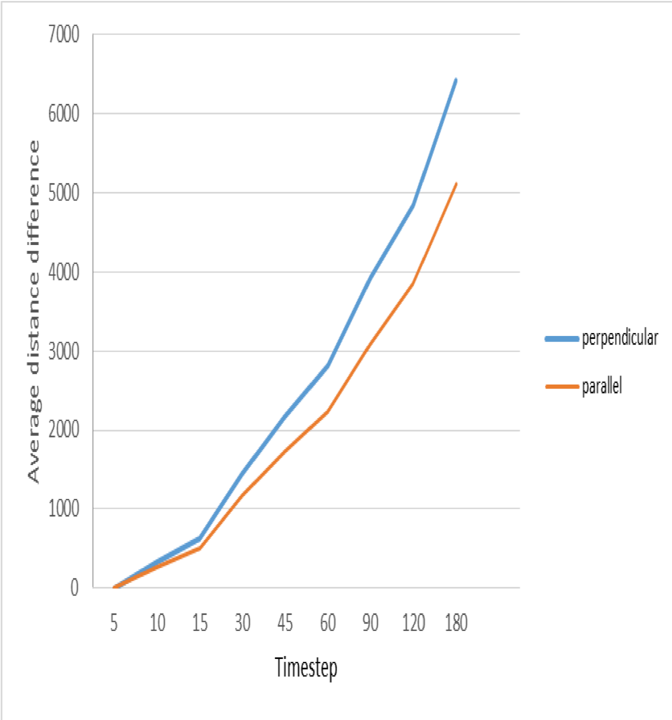

Figure 4. *Average difference distance for both situations when particles are parallel (orange curve) and perpendicular (blue curve) to the main flow.*

TABLE 1. ELEVATION VALIDATION FOR THE YEAR 2015

Month		*January*	*February*	*March*	*April*	*May*	*June*	*July*	*August*	*September*	*October*	*November*	*December*
	No residuals	6,39	5,68	5,51	4,86	4,70	4,68	4,24	4,69	4,93	5,02	5,56	5,38
	With residuals	4,74	4,67	4,59	4,42	4,08	3,95	4,20	4,46	4,74	4,38	4,30	3,92
Amelioration (%)		34,78	21,60	20,10	9,84	15,07	18,54	0,91	5,17	3,87	14,47	29,50	37,22

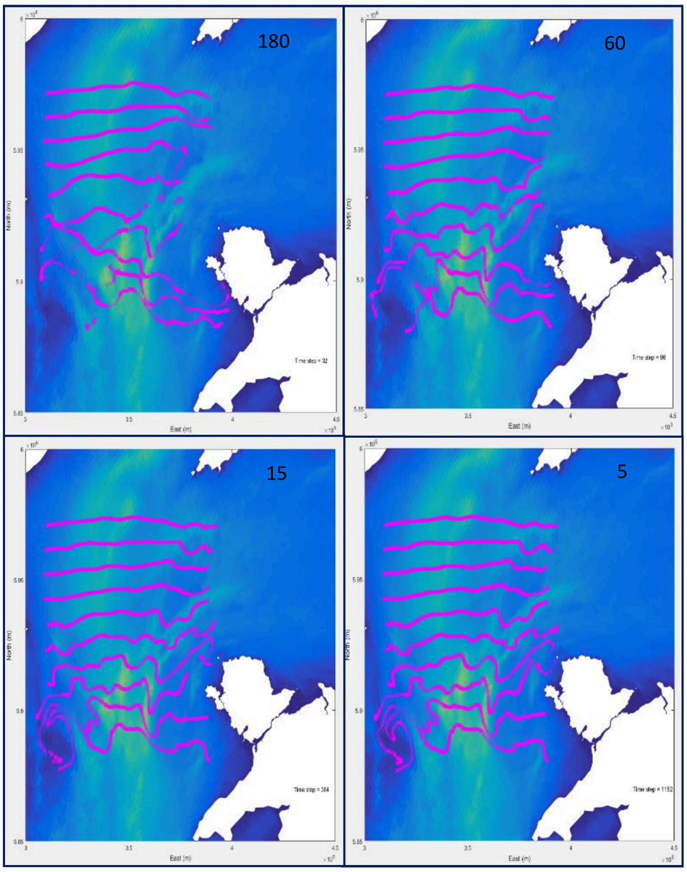

Figure 5. *Final position of 5000 particles distributed perpendicular to the main flow for 5, 15, 60 and 180 min time step after running a PTM.*

TABLE 2. DISTANCE BETWEEN THE 5 MINUTES TIME STEP OUTPUT AND 180 MINUTES TIME STEP OUTPUT FOR THE LAST POSITION OF 15 PARTICLES WITH IN RED THE BIGGEST DISTANCE AND IN BLUE THE SMALLEST DISTANCE.

Particle name	***Distance (m)***
A	15133,84
B	7002,60
C	22960,79
D	24676,39
E	4270,42
F	18503,45
G	867,31
H	11386,18
I	1371,81
J	2897,81
K	777,05
L	6192,52
M	3780,48
N	1787,28
O	1145,71

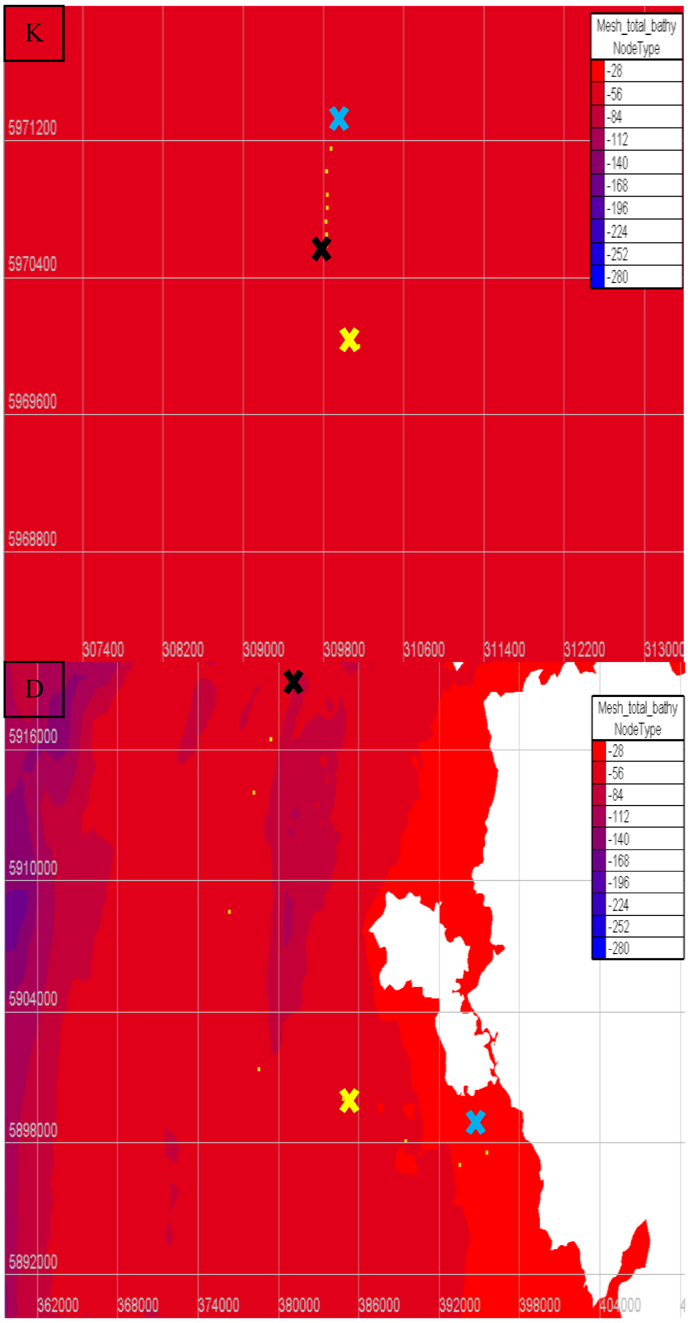

Figure 6. *Representation of the dispersion of particle D and K. The initial position (yellow crosses) and the last positon for 5 minutes output (black crosses) and 180 minutes output (blue crosses) are represented.*

IV. DISCUSSION

The difference in results between particles distributed parallel and perpendicular to the flow (20.27 % in average) could be explained by the absence of particle around Anglesey which is on area of high dispersal due to the velocity of the current as shown in Fig. 6.

As shown in the Fig. 5, it seems that variation of time step impact more the south part of the Irish Sea than the north part. This could be explained by in the west part of the Irish Sea by the gyre formation which occurs every year during the spring and the summer (Hill *et al.,* 1997) and in the east part by the current velocity and/or direction along the north coast of Anglesey (Borthwick *et al.*, 2013). The next step would be to study the residuals to consolidate those results. The evaluation of the model accuracy will be done by different kind of surveys 1) by the mussel company by recording observations like date and places of spawning and settlement during spring/summer period (data are already available) and 2) by water sampling of different areas around Anglesey and in the Menai strait to identify the larvae present in the water.

V. Conclusion

This paper showed the difficulty to run a particle tracking model in a variable environment such as the Irish Sea. The creation of a varying time step model depending on the physical marine conditions (velocity, water depth and/or seasonal effect) could be a solution to avoid both heavy files problematic and wrong results interpretation.

VI. Acknowledgments

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VII. References

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