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## ***Interactive comment on “Ocean modelling for aquaculture and fisheries in Irish waters” by T. Dabrowski et al.***

**T. Dabrowski et al.**

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Anonymous Referee #2 Received and published: 29 July 2015

Reviewer’s comment #1. The paper by Dabrowski et al. presents several oceanographic model products to support fisheries and aquaculture in Irish marine waters. The paper properly addresses the scope of the Ocean Science special issue on operational oceanography in support of blue and green growth. At the present stage, the paper seems to be a list of oceanographic model products, and does not give a comprehensive overview and discussion of the operational system they have implemented at the Marine Institute. Among the several products and model results presented, some appear mature and have already been published, whereas others look preliminary and need for a more detailed presentation and validation (see specific comments). Then, a

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summary table with the list of the products should be prepared. The table could contain the following information: 1. a short description of the products; 2. the models where the products are derived from; 3. the frequency and location/ resolution of products; 4. the level of reliability and the specific metrics used to validate the products; 5. the target users. The table should be presented in a discussion section that compares and reviews the presented products (see specific comments on the “conclusion” section.) Further, validation of operational products is an important step to guarantee a high level of confidence of model results that are used in support of blue growth decisions. The choice of the correct metrics (parametric vs non parametric statistics, contingency tables, expert judgment, GODAE/MERSE class metrics) for operational products is a presently debated issue. Given the richness of the products presented and the broad experience, the authors have the opportunity to contribute to the discussion about the most appropriate metrics for operational oceanography and about the level of reliability of the operational products serving the blue growth management. The authors have given some indications in the different sections of the paper, however a specific section dedicated to this topic, in which metrics and level of reliability of the products presented are compared and commented, would be strongly appreciated.

Authors' response to comment #1:

We would like to thank the reviewer for a thorough revision of our submission. Whilst we consider these suggestions and all questions raised in the Reviewer's comments to the Conclusion section below valid and important in the discussion on the readiness and fit for purpose of the operational oceanographic products for aquaculture and fisheries, the requested changes extend beyond our intended scope of this manuscript. This paper was submitted to the special issue and aims to give an overview of such modelling services in Ireland. Presented research is at the different stages of advancements and some products and services have already been published or being published, as indicated in the paper (e.g. shellfish growth, HAB warning), whereas other sections present results from preliminary research (e.g. offshore aquaculture), but still worth

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presenting in a special issue. The intention of the authors as regards the scope and relevance of this paper has been fully reflected in the comments from Referee #1 (“The introduction clearly frames the work. However, because the paper is rather descriptive of current ‘products’, the reader can wonder about the reasons for this work to be published. Authors should address this in the introduction, stating that this paper is part of a Special Issue (and briefly state the aims of the SI). I believe this will give the full credit and relevance to this paper.”). We included the following paragraph in the Introduction:

Authors’ changes in manuscript: “It should be noted that this paper is part of the Special Issue on operational oceanography in support of blue and green growth. Since the sustainable growth across various marine sectors requires timely delivery of high quality oceanographic products and services, the aim of this Special Issue is to inform the reader about the existing and ongoing developments in this regard. Within this context, the authors present the research results and the products and services that are at the different stages of advancements; some have already been published or being published, as indicated throughout the paper, whereas other are still preliminary.”

Reviewer’s comment #2 Other comments on the specific sections are reported below: 3.1-2 “Shellfish growth and carrying capacity” and “Shellfish microbial contamination” Page 1191 line 20-21: Are the North-East Atlantic biogeochemical model and the NE\_Atlantic model different? How? Which kind of coupling are they using? Some more details are needed.

Authors’ response: The North-East Atlantic is a standalone physical-biogeochemical model analogously set-up to the physical only NE\_Atlantic, but running at a coarser resolution for computational efficiency. The first paragraph of this section describing briefly the biogeochemical models and explaining the above has now been moved to section 2 (Description of the models) and reads as follows:

Authors’ changes in manuscript: “The Bantry Bay and North East Atlantic models contain the biogeochemical module, which is based on the nutrient-phytoplankton-

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zooplankton-detritus model developed by Fennel et al. (2006). The model governing equations remain the same as in Fennel et al. (2006), however, the rates of the following processes have been altered by the authors to achieve better model skill for Irish waters (see Dabrowski et al. (2014b)): zooplankton grazing, nitrification rate, coagulation rate of small detritus and phytoplankton, small detritus remineralization rate and vertical sinking velocities of small detritus, large detritus and phytoplankton. At the open boundaries of the Bantry Bay model, all biogeochemical model state variables are provided every 3 hours and are interpolated from the ‘parent’ North East Atlantic biogeochemical model. The ‘parent’ biogeochemical model is analogously set-up to the NE\_Atlantic model described above, but is of coarser resolution ( $\sim 5$  km) for the computational efficiency reasons. The physical-biogeochemical coupling is ‘online’, meaning it is a self-contained physical-biogeochemical model.”

Reviewer’s comment #3. The list of open questions at the end of the two sections (page 1192 line 17-22 and page 1193 lines 16-20) remains unexplored in the paper. These could be moved in a discussion section, and the answers should be given on the basis of the potentiality of the presented products.

Authors’ response: The open questions at the end of the two sections are a form of concluding remarks pertaining to the services offered by these particular models. The authors believe that sufficient information is contained in the two sections for the reader to see that the presented models are capable of addressing these questions. Nevertheless, the last paragraph in section 3.1 has been revised and extended to include more detail on how the model can be used in the carrying capacity studies.

Authors’ changes in manuscript (last paragraph in section 3.1): “The presented model can thus answer two overarching questions: what is the spatial distribution of growth potential in the bay and what impacts on the ecosystem are exerted by the farms (e.g. depletion of phytoplankton, dissolved inorganic nitrogen enrichment). The above studies are therefore useful for the estimation of production and ecological carrying capacities enabling to make informed management decision by the authorities responsible

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for the aquaculture sector. The production and ecological carrying capacities are interlinked and concern the studies on maximum production that the environment can sustain. Since the presented model is implemented in 3D and includes ecological interactions, the carrying capacity issues can be addressed, for example, by running the experiments with alterations to standing stocks, relocation or removal of the existing farms, addition of new farms or change to farming practices (e.g. time of harvesting, rope vs. bottom cultures).”

Reviewer’s comment #4. Since Figures 2 and 3 are already published, the authors could decide whether to cite directly them or to modify them presenting some novel aspects.

Authors’ changes in manuscript: Figures 2 and 3 were removed and are now only cited in the manuscript.

Reviewer’s comment #5 3.3 “HAB warning” This section presents a well-developed set of products; however a more accurate presentation of the validation would be appreciated.

Authors’ response: The authors suggest that the following sentence is included in the manuscript: “Dabrowski et al. (accepted for publication) provides in-depth details on the validation of the Bantry Bay model that is deemed suitable for operational use in a nowcast/forecast system.” Dabrowski et al. (accepted for publication) already discusses in detail the validation of the Bantry Bay hydrodynamic model that is used in the Irish HAB nowcast / forecast system. Cusack et al. (accepted for publication) shows how this model is used in the HAB forecast and how the modelled products provide information on the likelihood that water exchange events will occur in Bantry Bay in the “toxic season”. The model is used alongside other data sources such as satellite data (SST and chlorophyll), biological (HABs) and chemical (biotoxins) data from the national monitoring programme. The table below shows the list of products that are used by local experts who prepare the weekly HAB forecast. Cusack et al.

also explain that the model does not predict the arrival of HABs in Bantry Bay, rather, the modelled products provide potential offshore-onshore transport pathways for HAB populations and the likelihood on the occurrence of large water exchange events. This information is then incorporated into the weekly Irish HAB bulletin and these products are used alongside other types of available datasets to help local scientists assess the risk of a HAB event for the following week. One of the important findings to date is that the current HAB forecast system is limited by a lack of an offshore ocean observing system to detect in-situ HAB populations.

Authors' changes in manuscript: The following sentences have been added to paragraph 1 of section 3.3 "Dabrowski et al. (accepted for publication) provides in-depth details on the validation of the Bantry Bay model that is deemed suitable for operational use in a nowcast/forecast system." "Cusack et al. (accepted for publication) shows how this model is used in the HAB forecast and how all of the above products provide information on the likelihood of HAB outbreaks in the bay. Table 1 summarizes the products that are currently used by local expert to generate the bulletin." The following sentence has been added at the end of section 3.3 following the sentence pointing to the requirement for the shelf observing system. "More detailed discussion can be found in Cusack et al. (accepted for publication)." Table 1 attached has been included in the manuscript. Tables numbering has been updated accordingly. Dabrowski et al. and Cusack et al. were added to the list of references.

Reviewer's comment #6. A contingency table and an analysis of the factors causing the errors would help in understanding Figure 5.

Authors' response: It is unclear to us what the reviewer is looking for here. While the 3D physical Bantry Bay model accurately predicts upwelling and downwelling in the Bay (Dabrowski et al. accepted for publication in Journal of Harmful Algae), the arrival of a HAB event will depend on the cell levels of HAB populations in offshore waters. Cusack et al. (accepted for publication in Journal of Harmful Algae) show the example below with regards to predictions published in the Irish HAB alert system prior to the

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arrival of a Dinophysis bloom. As highlighted in the table attached as a supplement, the current HAB forecast system is limited by a lack of an offshore ocean observing system to detect in-situ HAB populations.

Reviewer's comment #7. Page 1195, line 26: how downwelling and upwelling events are defined?

Authors' response: These are defined by an analyst who views the daily volumetric flux images.

Reviewer's comment #8. Page 1196 lines 5-15: It is not clear what is generated by the present modeling system and what is from other sources. Please clarify.

Authors' response: Please refer to the HAB bulletin product list in Table 1 above – an integrated approach is taken to produce the HAB bulletins.

Reviewer's comment #9 3.4 "Offshore aquaculture". These products seem very preliminary. Authors should explore more in detail the potentiality of their suitability model for aquaculture site selection. The suitability model could be linked to a specific aquaculture industry; and new specific indexes (new specific layers of the GIS-based model) should be produced for different type of aquaculture industries. Results at the present stage look too generic and poorly informative. Further, the wave model is only briefly introduced in sec. 2; its results should be shown and validated. Finally, authors could draw the locations of existing off-shore aquaculture sites in Fig. 6-7 and discuss the level of agreement and the errors between model suitability and real data.

Authors' response: Although offshore aquaculture in Ireland dates back to mid-1980s, farming in offshore conditions has not developed to a great extent. The presented work has been stimulated by the ongoing discussions related to the development of this sector. The combination of modelling and mapping can make a meaningful contribution to the development of offshore aquaculture and the proposed methodology has been well received. The authors acknowledge that the results are preliminary, but are of

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the opinion, that still worth including considering the aims and scope of the paper and of this special issue. There are not any offshore aquaculture sites at present in the model domain; therefore, these could not be added to Fig. 6-7. Validation results of the wave model has been included on a new Figure 2 and are referred to in section 2 following the description of the wave model. They consist of scatter plots of model vs observation for significant wave height and wave period from the south of the domain (M3) and towards the north of the domain (Inner Belmullet).

Authors' changes in manuscript: The following text has been added at the end of section 2: "Figure 3 presents scatter plots of modelled and observed significant wave height (Hs) and wave period (Tz) from the south of the domain (M3) and towards the north of the domain (Inner Belmullet). Presented validation covers the time period January 2012 – February 2013 at one-hourly frequency. The observational data is available from the Marine Institute's ongoing operational observational programmes and can be accessed online (<http://data.marine.ie/>)." New Figure 3 has been added and Figures numbering updated accordingly.

Reviewer's comment #10 3.5 "Cross-contamination of farms" Some validation of the hydrodynamic Connemara model could be shown.

Authors' response: Authors included selected validation results for the Connemara model. Validation that is relevant for sea lice dispersion studies is concerned with the ability of the model to reproduce currents. Hence, the authors included comparison of the model-predicted currents against those recorded by ADCP at the deployment site within the model domain.

Authors' changes in manuscript: The following text has been added in section 2: "As regards the works presented herein, this model has been used in the studies related with the offshore aquaculture planning (section 3.4) and in the modelling of cross-contamination modelling between the aquaculture sites (section 3.5). Model outputs utilised in the above studies consist of predicted currents. Hence, Figure 2 presents

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relevant validation results. An Acoustic Doppler Current Profiler (ADCP) was deployed in October 2011 at the location shown in Figure 2a. Figure 2b presents a comparison of the depth integrated currents components in west-east (U velocity) and south-north (V velocity) directions between the model and ADCP.“ New Figure 2 has been added and Figures numbering updated accordingly.

Reviewer’s comment #11 It would be interesting to see some other examples (and validations) of this product other than that already shown by Jackson et al., 2012. In particular, has this model been used in any contamination events since 2012? Which were the results?

Authors’ response A very similar approach has been used by the authors in a project Aquaplan that brought together key stakeholders from the aquaculture industry and state agencies in Ireland, and which aimed at providing the basis for the development and implementation of a Strategic Plan for Fish Health Management in Ireland. The authors conducted similar disease connectivity modelling for the total of 23 sites in the west of Ireland and developed the cross-contamination matrix. The report from the project has been published in 2015 (Ruane et al., 2015).

Authors’ changes in manuscript: The above paragraph has been included at the end of section 3.5 and the reference to Ruane et al. included in the list of references.

Reviewer’s comment #12 Page 1198, line 16: why 14 days?

Authors’ response: This is explained in Jackson et al. (2012) to which the reader is referred to. Relevant excerpt from Jackson et al. (2012): “The larvae do not feed in the plankton and all energetic requirements for planktonic development to the infective stage are provided by the female during vitellogenesis and pre-fertilization maturation of the egg. The free-swimming nauplius I moults into a nauplius II and then moults again into the infective planktonic copepodid stage. At a water temperature of 10 °C it takes approximately 15 days; 5 days to become a copepodid which can then survive for up to 10 days (Boxaspen, 2006). This is critical to the distance the salmon louse can

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migrate or drift to find a host. Planktonic sea lice must find a host or they will die.”

Reviewer’s comment #13 3.6 “Products for fisheries. “ O’Sullivan et al., 2014, and Casal et al., 2015 are not ISI publications. Some more details on these products should be shown, as well as their validation.

Authors’ response: The reference to O’Sullivan et al. 2014 has been changed to O’Sullivan et al. 2015, which has been published recently and is a peer-reviewed ISI publication. The authors included a validation of monthly satellite SST against in-situ surface temperatures from the Irish National Weather Buoy Network (M1-M6) and one buoy from the Wave Buoy Network (Belmullet) operated by the Marine Institute.

Authors’ changes in manuscript: The following sentence has been added to section 3.6:

“Validation of monthly SST derived from the above product against monthly in-situ temperatures from the buoy networks operated by the Marine Institute around Ireland is presented in Figure 9.”

Figure 9 has been added and Figures numbering updated accordingly.

Reviewer’s comment #14 4 “Conclusion section” Page 1201, line 8-14. The feedback and continuous improvement of the HAB product is not shown. Please provide a description of the process of participation of users (how are their feedbacks gathered? and how are new features implemented after that?). This looks like a very interesting aspect of the use of products for blue growth management.

Authors’ response: On 20 February 2013, stakeholders (see list below) present at the Irish Shellfish Safety Workshop were given the opportunity to provide feedback on the content of the Irish HAB bulletin. Since then the bulletin has continued to evolve.

The text below comes from an ASIMUTH project report called “The Final user requirements report” written by Julie Maguire (project co-ordinator) 25 November 2013

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The report presents the results of both the initial and final users' requirements survey. Initially, fish farmers expressed a desire for a HAB forecast to help in decision-making so as to minimize mortalities and financial impacts on their farms. When the forecast was published 80% of farmers who filled out the questionnaire were already using the information presented in the bulletin. 93% of respondents felt that the bulletin contained enough information to make it a useful tool. 88% felt that the ideal forecast would be between three days and one week. In general the forecast was very well received with 67% of respondents giving it a "good" or "very good" ranking with the remainder scoring it as "excellent".

The bulletins are discussed by members of the Molluscan Shellfish Safety Committee, a food safety forum for industry, scientists and regulators ([https://www.fsai.ie/about\\_us/industry\\_fora/mssc.html](https://www.fsai.ie/about_us/industry_fora/mssc.html)).

For example: Below is some text taken from Minutes of the Molluscan Shellfish Safety Committee - 9 June 2015. . . "3a. Improving the impact of Phytoplankton Warnings . . . CD noted that producers planning to harvest should consider the phytoplankton warnings and results in conjunction along with other information such as biotoxin results and their own local knowledge, in advance of harvesting. CD noted that the Weekly HAB Bulletins, which follow on from the Azimuth Project, are available on the MI website. RF noted that the bulletins are a great resource and that he had put the link on Twitter recently."

The content of the bulletin continues to improve with time . . . Recent enhancements to the bulletin include infographics on "Ireland: Current Conditions, Shellfish biotoxin report (last week)" and "Ireland: Historic Conditions" that were reported as text in the past. New modelled products for the west coast of Ireland have also been included in the bulletin in 2015. <http://www.marine.ie/Home/site-area/data-services/interactive-maps/weekly-hab-bulletin>. Currently, HAB bulletins are generated manually by MI scientists. Future plans include a more automated system that generates all charts for the HAB bulletins, with the most recent results displayed as soon as they become available.

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Stakeholders include members from the Department of Agriculture, Food & the Marine, the Food Safety Authority Ireland, Bord Iascaigh Mhara (Irish Sea Fisheries Board) the Irish Farmers Association Aquaculture, the Irish Shellfish Association, the Marine institute, the Molluscan Shellfish Safety Committee, the Sea-Fisheries Protection Authority and the Shellfish aquaculture industry.

Reviewer's comment #15 Page 1201 line 21: ERDDAP is only mentioned. A description of this potentially useful tool would be appreciated.

Authors' response: ERDDAP (Simons, 2015) is a data server that gives a simple consistent way to download subsets of gridded and tabular scientific datasets in common file formats and make graphs and maps.

Authors' changes in manuscript: The above sentence has been included in section 3.6. The reference to Simons (2015) has been included in the list of references.

Reviewer's comment #16 Page 1201 from lines 22- to the end. This part looks like a too generic dissertation. The paper lacks a discussion about the presented list of products. As commented earlier, a discussion section is needed. Some possible questions that could find answer in this discussion section could be: Which is the level of reliability of the presented products? Which products are already mature for supporting blue growth policies, and which are not? Why? What is missing? Which are the main requests raised by the Irish aquaculture and fisheries users/industry that the present models can answer and which are not? Which observing systems/modeling systems/ modeling crossvalidation activities are needed to provide high-quality operational oceanographic services and products in the Irish (eventually European) marine systems? Which validation techniques are the most appropriate for the different type of products?

Finally, the conclusions are missing a clear take home message matured from the many model products, applications and derived services described in the paper.

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Authors' response: Please see also our response to Reviewer's comment #1. Whilst these are all valid and important questions, the authors' are of the opinion that they are beyond the intended scope of this paper. The authors are of the opinion that answers to the above questions could be formulated in a separate discussion paper. Such discussion paper would actually form a good opening paper for this special issue, in our view.

The authors would like to thank the Reviewer for a thorough review of the manuscript and useful comments.

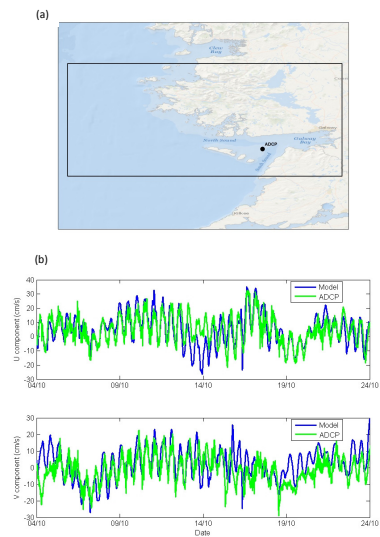
Please also note the supplement to this comment:

<http://www.ocean-sci-discuss.net/12/C1033/2015/osd-12-C1033-2015-supplement.pdf>

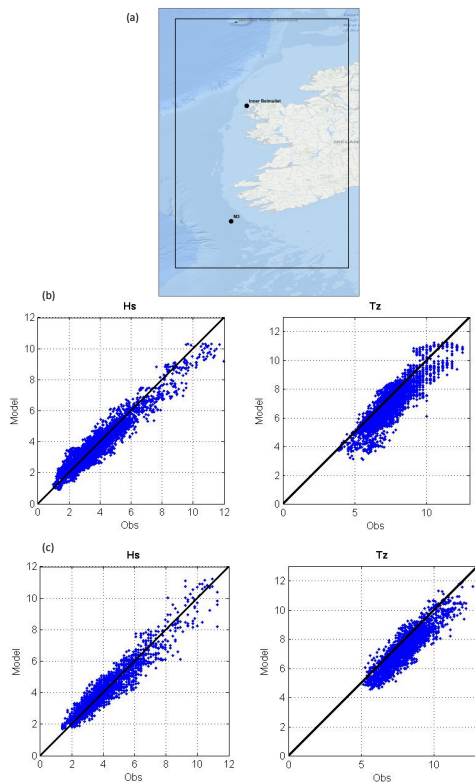
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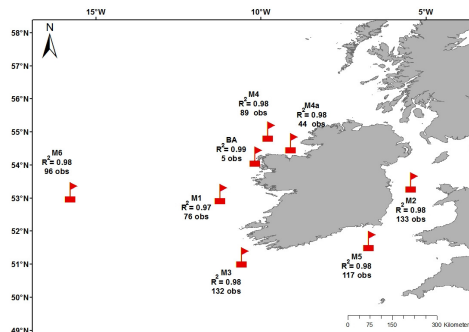
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**Fig. 1.** Figure 2. Results from the validation of the Connemara model: (a) location of ADCP, (b) comparison of modelled and observed depth integrated U and V velocity components.



**Fig. 2.** Figure 3. Results from the validation of the wave model: (a) model domain and locations of buoys, (b) and (c) scatter plots of modelled vs. observed significant wave height and wave period at Inner Be

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**Fig. 3.** Figure 9. Coefficients of determination for monthly satellite SST against in-situ SST at the locations of the buoys operated by the Marine Institute.

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Table 1. List of products used to generate weekly HAB bulletin.

Product	Description
Current conditions and Predictions	<p>Harmful and/or Toxic Algal bloom and biotoxins national monitoring programme data is presented.</p> <p>The products include:</p> <ol style="list-style-type: none"> <li>Biotoxin report for the last week [whole tissue long-line mussels and oysters].</li> <li>HAB report for the last week.</li> <li>Ireland HISTORIC TRENDS; What happened this week over the past ten years? 2003-2012 Harvesting closures (biotoxins above regulatory levels).</li> <li>Biotoxin prediction for the current week; includes a rationale.</li> <li>Biotoxin and HAB distribution maps of importance for the last 3 weeks are presented.</li> <li>Data is also plotted on a weekly basis from week 1 to the current week to allow the user view upward and downward trends in the national dataset.</li> </ol>
Satellite observations	<p>The most up-to-date daily satellite map is presented to provide large spatial scale information on surface phytoplankton blooms (Chl <i>a</i> measurements) and sea surface temperature (SST). <i>Karenia mikimotoi</i> cell densities from the national dataset are overlaid on a weekly Chl <i>a</i> anomaly map. The composition of near shore phytoplankton communities are described in detail with some highlights for the most recent week. <i>In-situ</i> national weather buoy network data SST for the week in question (includes the weekly anomaly from a 10 year mean) is presented alongside the satellite SST maps.</p>
Bantry Bay model	<p>Bantry Bay model is a hydrodynamic model of the shelf sea off southwest Ireland with horizontal resolution of 200 – 250m and 20 levels in vertical. It is an application of a widely used primitive equation, free surface, hydrostatic ROMS model and its prognostic variables consist of surface elevation, potential temperature, salinity and water velocities. Number of ASIMUTH-aioered products are derived from the model:</p> <ol style="list-style-type: none"> <li>prediction of lagrangian water transport from the Mizen Head (south of Bantry Bay) and the Bantry Bay mouth transects based on particles released at surface, 20 m and at bottom</li> <li>prediction of eulerian water transport at the Bantry Bay mouth and inner Bantry Bay transects</li> <li>cross-section through water temperature, salinity and density at Bantry Bay mouth</li> <li>current total volumetric inflow of water into Bantry Bay through cross-section at the mouth and in inner Bantry Bay</li> </ol>
North East Atlantic model	<p>The North-East Atlantic model encompasses all of Ireland's territorial waters and beyond. It became operational in 2008, and, similarly to the Bantry Bay model is an implementation of ROMS. The model domain covers a significant portion of the North-West European continental shelf and also the Porcupine and Rockall Banks and the Rockall Trough at a variable horizontal resolution, ranging from 1.1-1.6 km in Irish coastal waters to 3.5 km in the south of the domain. There are 40 sigma-coordinate levels in the vertical with a concentration of levels at the surface and the bottom.</p> <p>Within ASIMUTH, the model is primarily used as the boundary conditions provider for the Bantry Bay model and for predicting the transport of <i>Dinophysis</i> spp. blooms by water currents across the region based on particle tracking (including the inter-regional transport).</p>

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Fig. 4. Table 1. List of products used to generate weekly HAB bulletin.