

Project	AtlantOS – 633211
Deliverable number	D8.8
Deliverable title	Aquaculture operation Bulletin: Weather window nowcast/forecast Bulletin tool for offshore aquaculture operators.
Description	<p>Use Case Title: Offshore aquaculture siting</p> <p>Environmental matrix of interest (Air, Ice, Mar. Water, etc.): Marine</p> <p>Study Regions: Shelf Seas in Norway, Ireland and Spain</p> <p>Dissemination Method: Web</p> <p>We will develop a weather window tool to give developers real-time access to observations and model forecasts of seas state to plan day to day operations</p>
Work Package number	8
Work Package title	Societal benefits from observing/information systems
Lead beneficiary	NIVA
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Contributors	
Submission data	All web based weather windows were available online before the 30 th March
Due date	30 th March
Comments	n/a



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement n° 633211.

Stakeholder engagement relating to this task*

<p>WHO are your most important stakeholders?</p>	<p>Private company (SMEs) National governmental body</p> <p>Please give the name(s) of the stakeholder(s): Fish farmers, shellfish harvesters, service vessel operators and scientific sampling teams</p>
<p>WHERE is/are the company(ies) or organization(s) from?</p>	<p>EU and Norway</p>
<p>Is this deliverable a success story? If yes, why?</p> <p>If not, why?</p>	<p>Yes</p> <p>This deliverable can be considered a success story because the aquaculture industry, on a daily basis, use and depend on the tool available in Norway. In the case of the Irish and Spanish applications developed in AtlantOS, we have shown that it is possible to provide a service with the potential of future enhancements. Continual improvement to the existing downstream service is possible and should be based on end-user feedback – an iterative process that has begun.</p>
<p>Will this deliverable be used?</p> <p>If yes, who will use it?</p> <p>If not, why will it not be used?</p>	<p>Yes, tests on its usefulness are currently underway by scientists, and the aquaculture industry.</p>

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1. Summary

The AtlantOS WP 8 “Societal benefits from observing/information systems” has an ambition to deliver a suite of new or improved products that are targeted at issues of societal concern in European Member States. The value and societal benefit of the existing observing system in the Atlantic will be demonstrated through seven pilot cases: HABs mapping, storm surge coastal hazard mapping, safe ship routing, oil spill hazards mapping, MSFD reporting, site selection for offshore aquaculture and forecast of North Atlantic albacore tuna populations. The WP 8 pilot cases are tangible outputs from the integration of Earth observation, *in-situ* data systems and model analyses, reanalysis and forecasts to form usable products.

As one of the seven AtlantOS pilot actions seeking to demonstrate the value and societal benefit of the existing observing system, Task 8.5 focuses on offshore aquaculture in the coastal waters off Norway, Ireland and Spain. Previously in this task, we carried out a GIS analysis where potential areas/sites suitable for offshore aquaculture production along the coast of Ireland, Norway and Spain were identified (Dale *et al.* 2017).

This report gives a brief description of the weather window tools developed for target areas in Ireland and Spain; how the tools are produced and instructions on how to use the weather window. The tools themselves are the formal requirements of D.8.8. Aquaculture operation Bulletin: Weather window nowcast/forecast Bulletin tool for offshore aquaculture operators, and they will be linked to the [AtlantOS webpage](#). For Norway, there is already such a tool in place (from May 2017), developed outside AtlantOS. The Norwegian tool can provide forecasts for offshore aquaculture operations and is described in this report.

2. Introduction and background

Aquaculture is the fastest growing food production system in the world. Over the past 30 years, this industry has grown steadily with 8 - 10 % per annum and this trend is set to continue. Today, nearly all global aquaculture is carried out inshore. Despite the fact that offshore aquaculture has been a topic of interest for decades commercial offshore aquaculture practice is still in its infancy. There are drivers both at local and global levels that incentivise aquaculture to move to the unprotected waters of the open sea. Among the drivers are competing claims on available space, water quality issues and negative public perception of aquaculture operations related to environmental and aesthetic impact concerns.

Moving aquaculture operations offshore will in most cases imply harsher met-ocean conditions, and longer travel times to and from the farms for vessels involved in routine day to day operations such as installation and maintenance. The way salmon farming is carried out along the Norwegian and Irish coasts there are several operations that depend on a suitable weather window lasting from hours to days depending of the operation in question (examples of operations are given in Table 1). In modern farms, most of these operations require the use of service motorised vessels of various types.

There are ongoing developments of farm designs aimed for more exposed and offshore sites. Some of these designs might require less maintenance and fewer operations than existing farm designs. It is, however, likely that several offshore farm operations will be weather and sea state dependent into the future. Based on information gathered from other industries, such as ocean wind farming, moving offshore is associated with increased costs (Gintautas & Dalsgaard Sørensen 2017). Tools that identify a suitable and safe “weather window” for the various types of farm operations undertaken are important, especially at the initial stages of site selection and for farm operation planning purposes at new sites.

Table 1 Examples of common maintenance operations in salmon farming where service vessels are required. The data are from Norwegian Fish farms. Compiled from Berge & Ramm 2017.

Type of operation	Frequency/Duration
Cleaning of nets	Frequency: depends on the site type (most frequent time this activity is carried out is in summer) Duration: Varies greatly and depends on weather conditions, the amount of fouling, and the size of the net average is three hours
Cleaning of floating collars	Frequency depends on the site type (most frequent time this activity is carried out is in summer) Duration: 2 - 3 hours per collar
Handling of moorings	Frequency: regularly Duration: around 2 days
Inspection of anchor lines	Frequency: every second year Duration: > 4 hours (depends on farm size)
Change of nets	Frequency: at the end of each production period when all fish are slaughtered Duration: 2-5 hours per net
Transportation of personnel	Frequency: depends on personnel working shift arrangement Duration: depends on distance from base
Parasite treatment of fish * There are several methods - in all methods the salmon are starved for a period prior to handling.	Frequency: depends on parasitic infestation rate that is highly variable and area dependent Duration: depends of farm size
*A very common operation in Norway and Ireland over the last 10 years. Might not be relevant for other areas.	

In Spain, shellfish harvesting is an activity of high socioeconomic importance. In the case of mussel farming, Galicia is one of the largest producers in Europe and in the world, with over 200,000 tonnes of mussel

production, generating over 8,000 jobs and incorporating 1,000 aquaculture support vessels. There is strong interest in the aquaculture community in getting reliable information and forecasts of sea conditions in order to plan operations.

3. The weather window tools

3.1. Ireland: Irish Wave Forecast “Weather Window” Demonstration

Product Link: <http://digitalocean.ie/Dashboard/WeatherWindow>

Product became available on-line: 7th March, 2018

About the service

The Irish Wave Forecast “Weather Window” demonstration service produces short-term forecasts of sea state conditions. It was developed for existing Irish finfish farms with the possibility of adding offshore sites as required. The reason existing sites were used in the demo was to facilitate the feedback loop on how to improve the downstream service in the future. The Irish Wave Forecast “Weather Window” can be applied to any site fully resolved by the East Atlantic wave model. New sites are easy to add and will be considered on a request basis and end-user feedback.

Physical model used to develop the product

East Atlantic SWAN Wave Model

The Marine Institute runs an operational wave model to simulate wave conditions for Irish waters. This model can reproduce wave parameters around the Irish coast with a good degree of skill. The wave model was developed using the open-source SWAN (Simulating Waves Nearshore) code. SWAN is a third-generation wave model that computes random, short-crested wind-generated waves in coastal regions (Booij *et al.*, 1999). The model domain encompasses Irish coastal waters from 20.0 to 0° W and 38.0 to 60.0° N at a horizontal resolution of 0.025 degrees. It uses wind forcing from NOAA’s GFS (Global Forecast System) atmospheric model. Wave data at the boundaries is provided by the Wave Watch III (WWIII) model developed by FNMOC (U.S. Navy Fleet Numerical Meteorology and Oceanography Centre; Tolman, 2009). The model has undergone extensive validation using wave data from a number of buoys around the coast. The wave model is run daily to produce a 6-day forecast and the data is published via the Marine Institute ERDDAP server and on the Marine Institute website.

Data source (URL): Marine Institute ERDAPP Server [<http://erddap.marine.ie/erddap/info>]

- http://erddap.marine.ie/erddap/griddap/IMI_EATL_WAVE.graph

Data Policy of the source: open and free

Product development

To create the wave weather window product, several existing Irish aquaculture sites in Atlantic waters were selected with the proviso that they are fully resolved by the East Atlantic wave model. A modelled time series at 30-minute resolution is output from the model for each selected aquaculture site. Wave related variables for the weather window product include:

1. Significant wave height (Hm0) (reported in metres)
2. Average wave period (Tm02) (reported in seconds)
3. Mean wave direction (Mdir) (reported with arrows pointed in the direction towards which the waves are moving)

The charts are created with Highcharts.js javascript library using SWAN wave model data stored on the Marine Institute's ERDDAP server. The weather window product is available on Ireland's Digital Ocean:

<http://digitalocean.ie/Dashboard/WeatherWindow>

Instructions on how to navigate the wave “weather window” webpage

1. Go to the [weather window webpage](#) (Fig. 1a).
2. “select a Bay” of interest (Fig. 1b).
3. Insert the “cut-off height in metres” value (Fig. 1c).

The value inserted is the significant wave height limit (m) determined by the user as a sea state that is safe to work – this will change depending on who the user is and what work activities are planned e.g. cleaning fish cages by divers, water sampling for environmental monitoring etc.

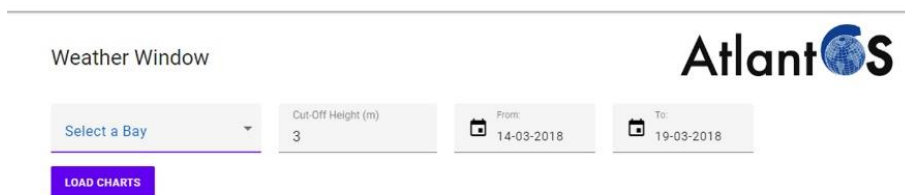
4. Select dates “from & “to” to view the forecast time period of interest (Fig. 2a). Note: the maximum forecast is ~ six days from today's date. Note: some web browsers are more compatible with the web tool. If you encounter errors please try Chrome or Firefox.
5. Click load charts (Fig. 2b).
6. Two charts appear (Fig. 2c).

Plot 1: The upper chart shows the “Significant Wave Height” at the site for the time period selected. Any period where the chart is highlighted in green is considered safe to work and is determined by the value inserted in the “cut-off height in metres” box. A horizontal red line appears if the selected.

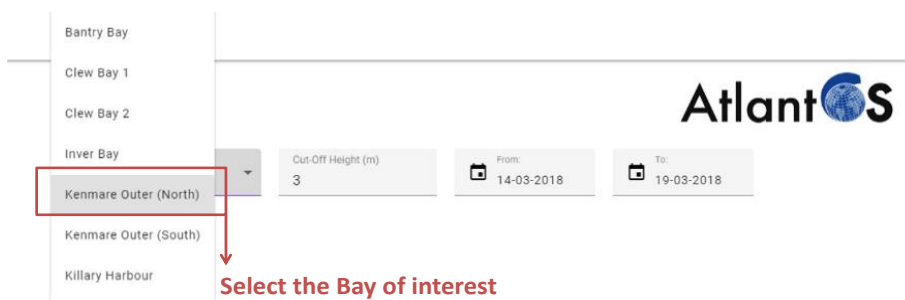
Plot 2: A chart with the forecast for “Average Wave Period” and arrows showing the direction the waves are predicted to go toward “Direction To”.

(a)

Page as displayed when you land on the website



(b)

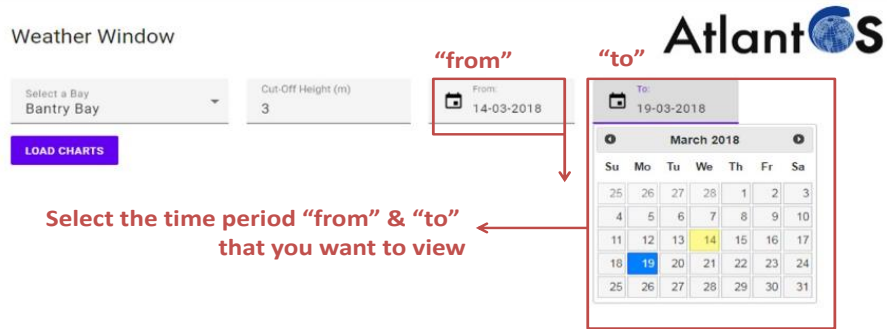


(c)

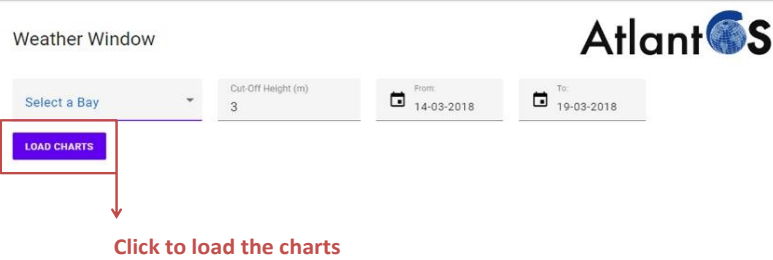


Figure 1. Visual weather window webpage display with highlighted sections and text in red are presented in this plot to guide the user when navigating the site. Where a = what to expect when the user lands on the webpage; b= where to select the Bay (site) of interest, and c = where to insert the users determined significant wave height limit (m).

(a)



(b)



(c)

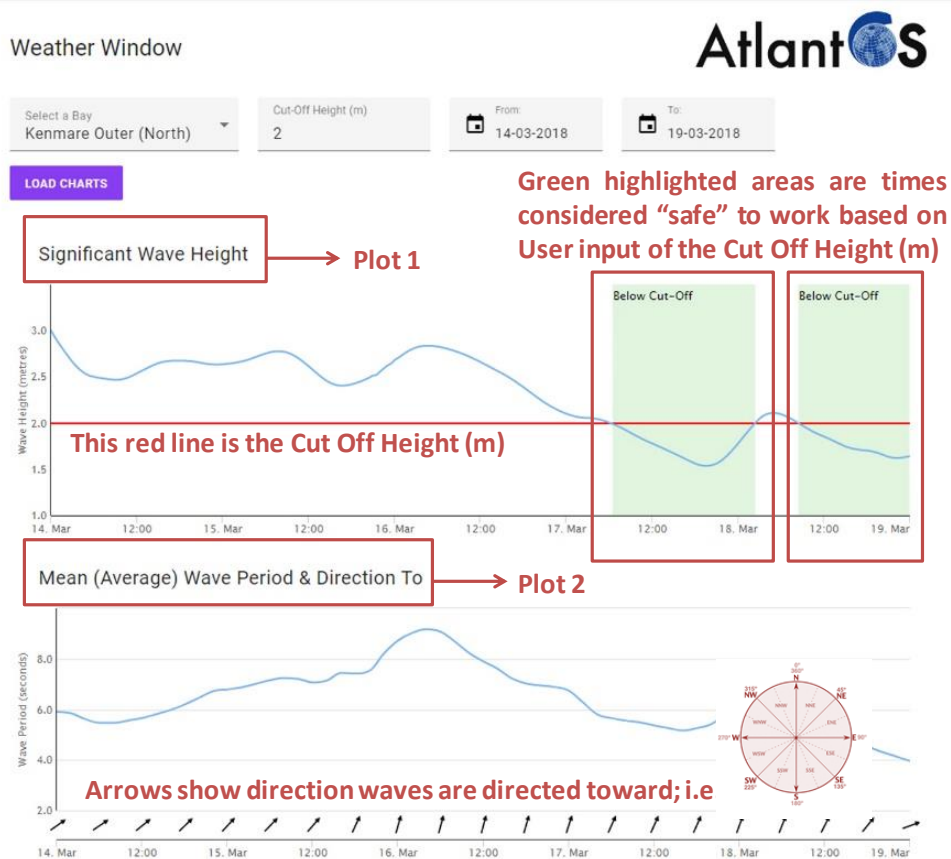


Figure 2. Visual weather window webpage display with highlighted sections and text in red are presented in this plot to guide the user when navigating the site. Where a = where to select the dates of interest; b= button to click to load charts and c = 6 day wave weather window forecast for significant wave height, mean wave period and direction of the waves.

Stakeholder engagement

The weather window is currently under review by two different end-user groups

1. Scientists who sample at fish farms
2. Fish farmers who are on station daily

The end-users are currently testing out the new tool and are expected to provide feedback on the following questions:

- a) Do the generated charts help you to plan daily sampling activities / farm operations?
- b) What are the significant wave height thresholds (sea state condition limits) for the different activities you carry out while on site? e.g. it's only safe to go out sampling on a boat when the significant wave height is <3 metres (this is the current default). Is there a threshold level for feeding fish? Is there a threshold level for cleaning cages? Is there a threshold level for diving activities? Other activities?
- c) Have you any suggestions on how to improve the user experience of the AtlantOS wave weather window product?

3.2. Spain: “Weather Window” Demonstration for Shellfish harvesters

Product Link: www.indicedeafloramiento.ieo.es/batinfo

Product became available on-line: 16th February, 2018

About the service

The weather window demonstration in Galicia (Spain) is intended to give service to shellfish harvesters in the Galician coast. The main activity is mussel farming in rafts (bateas) but there are also areas where bivalve harvesting is done on foot (pie), on boat (bote) or diving (buceo). Location of mussel raft polygons and harvesting areas is regulated and administrative layers can be obtained from Xunta de Galicia.

The ATLANTOS weather window demonstration is based on the developments of viewers oriented for marine services performed during projects related to RAI A observatory (<http://www.marnararia.org>, INTERREG 0313-RAIA-1-E, 0520-RAIA-CO-1-E) and ASIMUTH (Fp7-SPACE-261860), which were reviewed by Ruiz-Villarreal *et al.* 2016. Web services were developed for different uses: temperature and weather conditions in beaches (<http://playas.ieo.es>, Otero *et al.* 2016), location of eddies and fronts, etc. During ATLANTOS, the viewer was upgraded and adapted to show environmental conditions, including wave data, in shellfish harvesting areas.

By clicking in shellfish harvesting areas, results of temperature, salinity, wave height, wave direction and chlorophyll are shown.

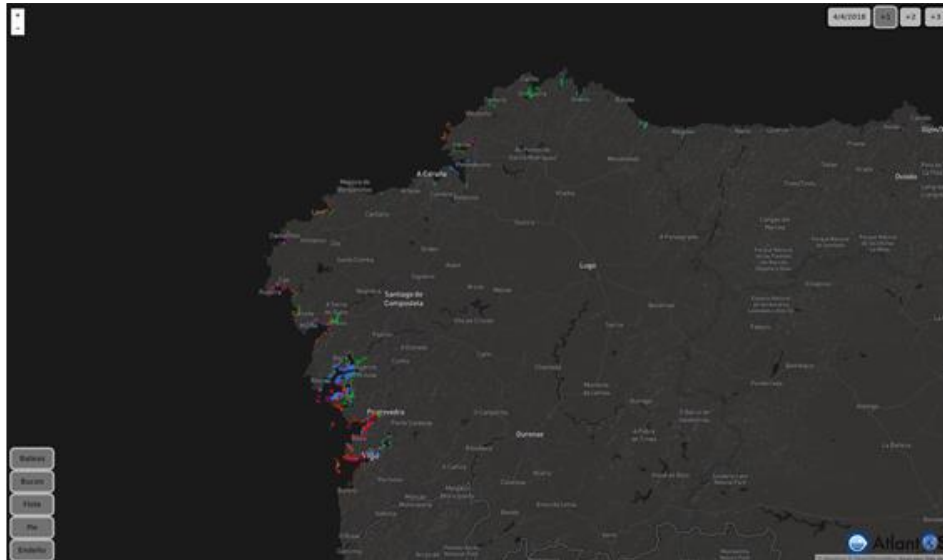


Figure 3: Weather window viewer for predictions in shellfish harvesting areas. Bottom left-hand side: the user can select areas where harvesting is done in rafts (bateas), diving (buceo), on boat (flote) or on foot (pie or endeño). Top right-hand side: the user can select the preferred date: current day or next 3 days(+1,+2,+3)

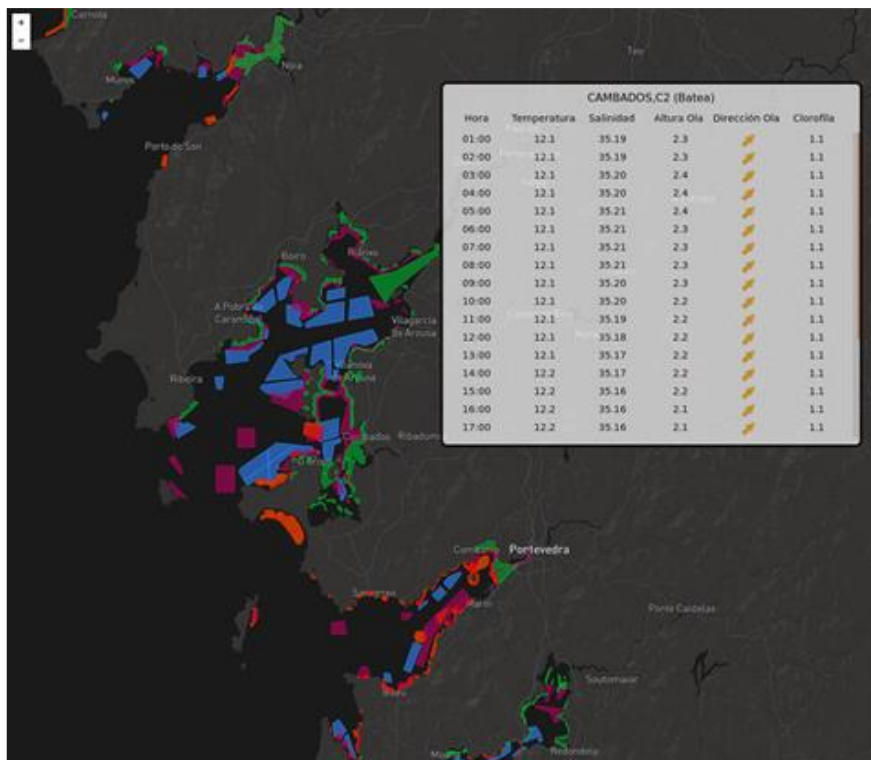


Figure 4. Display of the weather variables after clicking in a raft polygon. Results of temperature, salinity, wave height, wave direction and chlorophyll are available.

Data sources

The viewer is coded in HTML5 +JavaScript (Jquery). Maps are visualised using Mapbox and Leaflet. Everything is designed to use geo-referenced products available in OGC (Open Geospatial Consortium) servers.

Information on shellfish harvesting polygons is stored in JSON files that are loaded when the page is initiated. Every polygon has name, mean longitude and latitude, coordinates and type of polygon as features.

Information displayed on the viewer is available in Thematic Real-time Environmental Distributed Data Services (THREDDS) data servers. Queries to the servers for getting variables in polygons is made using WMS protocol.

Clicking on every polygon performs a query to the THREDDS data server where data are available.

Wave model data is obtained from the MeteoGalicia THREDDS data server (http://www.meteogalicia.gal/web/modelos/threddsIndex.action?request_locale=en).

where model output from the SWAN model forecasts run by MeteoGalicia is available. Model SWAN runs operationally once a day initialized at 12UTC and is forced by MeteoGalicia operational Wave Watch III (WWIII) model that runs in a domain covering the Galician adjacent ocean. Forecasting lead time is 84 hours to provide 3 days forecast and two higher resolution domains are used to forecast Artabro and Rias Baixas geographical regions.

Temperature and salinity forecasts are obtained from the ROMS2km operational model run by MeteoGalicia, which provides 72 h forecasts of currents, temperature and salinity in a grid covering the Galician coast and available in MeteoGalicia THREDDS server

(<http://mandeo.meteogalicia.es/thredds/catalog/roms/fmrc/files/catalog.html>)

Surface Chlorophyll-a data on the day the web is accessed is obtained from the CMEMS ocean colour product [dataset-oc-atl-chl-multi-l4-oi_1km_daily-rt-v02](http://cmems-oc.isac.cnr.it/thredds/cmems/V3.3/oc/atl/OCEANCOLOUR_ATL_CHL_L4_NRT_OBSERVATIONS_009_037.html?dataset=dataset-oc-atl-chl-multi-l4-oi_1km_daily-rt-v02)http://cmems-oc.isac.cnr.it/thredds/cmems/V3.3/oc/atl/OCEANCOLOUR_ATL_CHL_L4_NRT_OBSERVATIONS_009_037.html?dataset=dataset-oc-atl-chl-multi-l4-oi_1km_daily-rt-v02

Functioning of the web page

When the webpage is visited

1. Preferred layer of the navigator is detected and loaded (Spanish, Galician and English available)
2. Information of shellfish harvesting polygons is loaded and represented on the map
3. Time and type of polygon controls are displayed:
 - Time control: Date for querying data servers
 - Polygon type control: Polygons of different types:rafts (bateas), on foot (pie), on boat (bote) or diving (buceo) can be viewed or hidden
4. When clicking on a polygon:
 - Time and polygon type controls are hidden for easing visualization, especially in smartphones
 - Servers are queried for asynchronous data using mean latitude and longitude of the polygon. The data are represented when received. If no data is available, value is set to “-”
5. When clicking outside a polygon:
 - Data display window is closed
 - Time and polygon type controls are displayed again

Stakeholder engagement

Stakeholders consider very important security in the availability of forecasts, therefore they have recommended the addition of alternate sources of model data to fall back on and guarantee the service in the eventuality that any of the data sources is not available. Other suggested improvements to the service include the addition of wind data and precipitation from the WRF operational model by

MeteogaliciaMeteoGalicia available in the THREDDS server:

http://mandeo.meteogalicia.es/thredds/catalogos/WRF/catalog_1km.html

http://mandeo.meteogalicia.es/thredds/catalog/wrf_2d_04km/fmrc/files/catalog.html and also

3.3. Norway: The BarentsWatch

About the service

The example from Norway benefits from an existing tool. In the following, we illustrate that it provides a weather window service to aquaculture operations in exposed areas making use of meteo-ocean data . Forecasts for waves and currents have been available on the Norwegian Coastal Administration and Yr websites for several years. From May 2017, the now user-friendly service covers the entire Norwegian coast. The meteo-ocean service is displayed as an interactive map solution on the website of [BarentsWatch](http://www.barentswatch.no) www.barentswatch.no. The forecast application is smart phone-tablet compatible. The next development step underway is to relay information directly onto ships' chart plotters. The forecasts come in an open standard format. This opens for digitalization of work processes for the end user, where wave and current information are relevant for efficient and safe operations (information compiled from <https://www.barentswatch.no/en/services/Wave-forecasts/> and http://www.kystverket.no/en/EN_Maritime-Services/Reporting-and-Information-Services/Wave-and-current-warnings)

The Norwegian service was primarily developed for coastal traffic safety. Targeted end-users include operators of ferries and high-speed passenger boats, yachts and other marine vessels. Since the aquaculture industry use service vessels for a range of daily operations (transport of feeds/fish and personnel, cleaning of nets, salmon lice treatment etc.), the service is very useful to this marine sector. The transport of live fish is carried out with large well boats, and transport can be done either with open or closed tanks. Open tanks are healthier for fish welfare due to constant water renewal, but can only be used if the threat of disease and parasites is low along the planned transport route. The BarentsWatch interactive on-line map includes up to date information on disease and parasite levels. Therefore the site is a "one-stop-shop" for farm operation related information.

How the forecast is made

Ten ministries and 29 administrative agencies and research institutes are partners in BarentsWatch. The wave forecast and coastal forecasts are produced by a company called Polytec (<https://polytec.no/services/oceanography-meteorology-metocean/computer-modeling/wave-modeling/>) who refine the marine weather forecasts from the Norwegian Meteorological Institute and the U.S. National Weather Service to suit user needs. The coastal models are based on the STWAVE, from the U.S. Army Corps of Engineers, and the map data are supplied by the Hydrographic Service of the Norwegian Mapping Authority. The methodology is partly inspired by work performed by SINTEF Marine Technology and Statoil. The models are validated over several years in Norwegian Waters (information compiled from

<https://www.barentswatch.no/en/services/Wave-forecasts/>). Forecasts are at three-hour intervals up to 72 hours in advance.

Instructions on how to navigate the BarentWatch webpage

1. Open the following link <https://www.barentswatch.no/>
2. Choose a language e.g. English (Norwegian is the default language).
3. Click on the “Wave forecast” window.

If you want a weather window for a site

4. Use the cursor to select the area of interest and zoom into your site (Fig. 5a).
5. “Marinogram” opens (Fig. 5b).

If you want a weather window for a fairway

6. Use the cursor in the map and click on chosen fairway (Fig. 6a).
7. A page opens that shows you route from start to end- with significant wave height, maximum wave height and crossing waves along the route (Fig. 6b).

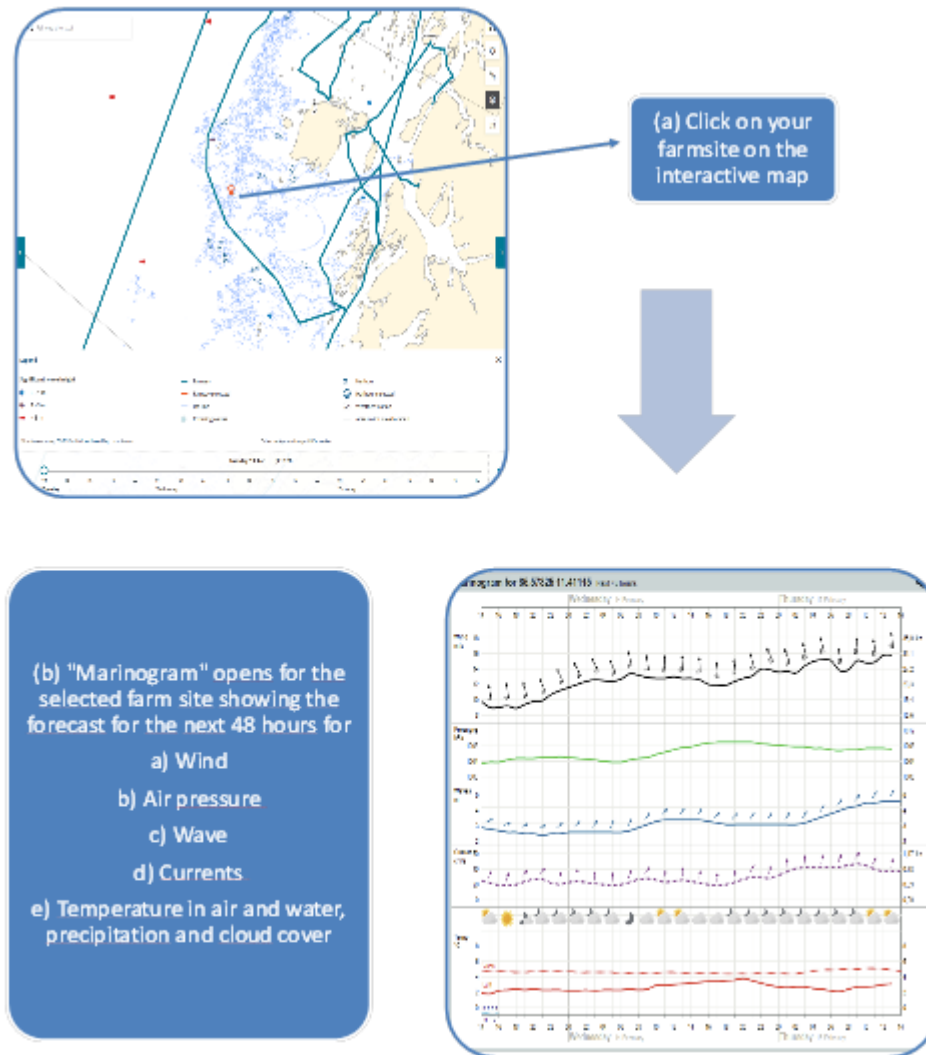


Figure 5. Screen shots from the Norwegian wave forecast web page <https://www.barentswatch.no/> where, 5a shows a chosen site and 5b shows the weather window with variables of interest to the end-user.

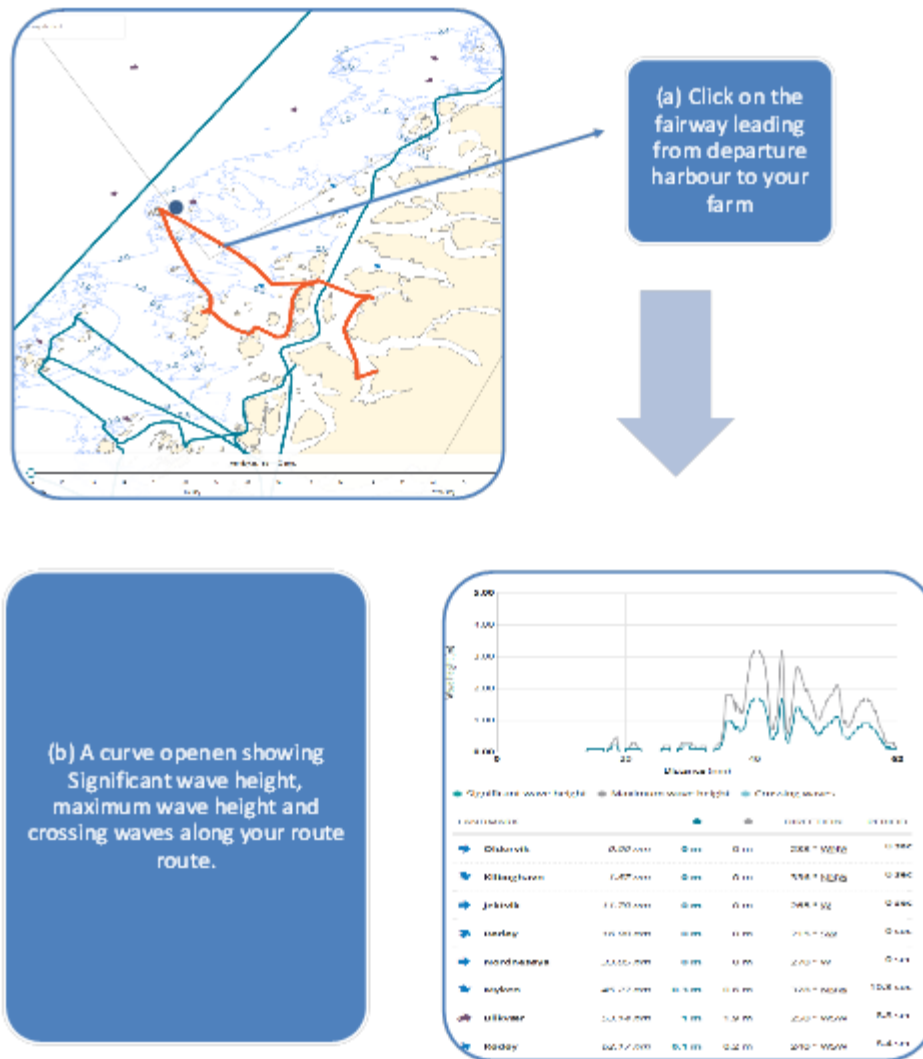



Figure 6. Screen shots from the Norwegian wave forecast web page www.barentswatch.no where (a) shows how to select a fairway and (b) shows wave conditions in the region of interest.

Stakeholder engagement

The Barents Watch has operated for several years, and the services has expanded to cover new areas. We contacted them and asked about users. Google Analytics shows that the service has ~20,000 users and ~150,000 page views per month. About 90 % of the users are Norwegian. At the bottom of all pages there is a feedback button to click and user feedback is used continuously to improve the service.



BarentsWatch do user-driven, agile development. In order for our services to be useful and user friendly, we would like feedback from you as a user. It can be in the form of complaints or compliments, questions, ideas, and other issues of relevance. We greatly appreciate your help.

Feedback

References

- Booij, N., Ris, R.C. and Holthuijsen, L.H. (1999). A third-generation wave model for coastal regions 1. Model description and validation. *Journal of Geophysical Research* 104(C4), 7649-7666.
- Dale, T., Cusack, C., Ruiz-Villarreal, M., Rune Selvik, J., Hjermann, D., Dabrowski, T., Lyons, K., Carr, R. and O'Rourke, E. (2017). Aquaculture site selection Report on potential, selected sites for offshore aquaculture along the Spanish, Norwegian and Irish Atlantic coasts. AtlantOS Deliverable, D8.2 . AtlantOS, 39 pp. DOI 10.3289/AtlantOS_D8.2
http://oceanrep.geomar.de/39456/1/D.8.2_AtlantOS.pdf
- Gintautas, T. and Sørensen, J.D. (2017). Improved Methodology of Weather Window Prediction for Offshore Operations Based on Probabilities of Operation Failure. *Journal of Marine Science and Engineering*, 5(2), 20.
- Otero, P., González-Nuevo, G., Tel, E., Ruiz Villarreal, M. and Cabanas, J.M. (2016). Insights from the development of a downstream web-service to visualize ocean and meteorological forecast data at Iberian Atlantic beaches. *Bollettino di Geofisica*. 57 - SUPPLEMENT, 234 - 237. OGS. ISSN 0006-6729
- Ramm, H.T. and Berge, A.W. (2017). Fleet Scheduling of Service Vessels used in a more exposed Norwegian Aquaculture Industry. Master Thesis, NTNU, Trondheim, Norway, 121 pp.
- Ruiz-Villarreal, M., García García, L.M., Cobas García, M., Otero, P., González-Nuevo, G., Reguera, B., Cabanas, J.M. (2016). ASIMUTH: a Copernicus marine downstream service for HAB forecasts in the Galician region. In: *Operational Oceanography for Sustainable Blue Growth*. 545-554. Ed: EuroGOOS, Brussels (Belgium). ISBN: 978-2-9601883-1-8. Available at <http://eurogoos.eu/download/publications/EuroGOOS-2014-Conference-Proceedings.pdf>
- Tolman, H.L. (2009). User manual and system documentation of WAVEWATCH III version 3.14, *NOAA/NWS/NCEP/MMAB Technical Note 276*, 194 pp.