AtlantOS

Project	AtlantOS – 633211
Deliverable number	8.15
Deliverable title	Report AtlantOS fitness to Oil spill products
Description	Assessment of the observing system fitness for purpose for the hazard mapping
Work Package number	8
Work Package title	Societal benefits from observing/information systems
Lead beneficiary	UNIBO
Lead authors	Antonio Augusto Sepp Neves and Nadia Pinardi
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Submission data	05/04/2019
Due date	31/12/2018
Comments	The Web-based product had to be reworked because of some technical problems that arose. These problems lead to a delay in assessing the final product and submitting the deliverable in time.

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

Last updated: 05 April 2019

Stakeholder engagement relating to this task*

WHO are your most important stakeholders?	☐ Private company If yes, is it an SME ☐ or a large company ☐? ☐ National governmental body x International organization ☐ NGO ☐ others Please give the name(s) of the stakeholder(s): *European Maritime Safety Agency (EMSA)* *International Association of Oil and Gas Producers* *Oil Spill Response Limited*
WHERE is/are the company(ies) or organization(s) from?	☐ Your own country x Another country in the EU ☐ Another country outside the EU Please name the country(ies): Portugal and UK
Is this deliverable a success story? If yes, why? **If not, why?**	x Yes, because we could map the oil spill hazard at a national scale for all countries in the Atlantic basin. Additionally, it has been demonstrated that current operational ocean & atmospheric analyses and forecasts at the global scale cannot be used to give answers at the local scale (i.e. beach/town level where many end-users need information) ☐ No, because …..
Will this deliverable be used? **If yes, who will use it?** **If not, why will it not be used?**	x Yes, by users on our web portal that map the oil spill hazard in the global ocean. The deliverable will show the limitations of our products and guide future experiments. ☐ No, because …..

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Glossary

Name	Meaning
Use case	The AtlantOS Task 8.4 Oil spill hazard mapping targeted product
Upstream data	Input data for one or more Targeted products.
Targeted product	A product created according to the end-user specifications of production.
Fitness-for-use (FU)	FU is a combination of the quality elements determined in the Targeted Product and Upstream Data components of same name. Fitness-for-use only concern the Upstream Data.
Data Product Specification (DPS)	Precise technical description to build the desired product in terms of the requirements it will or may fulfil. The DPS contains both the specifications of the product and the specification of its quality evaluation.

Executive summary

The global ocean is exposed to a major threat: every year, about 600,000 tons of oil is spilled in the marine environment due to maritime casualties and operations. At present, we do not have a clear picture on where most oil spills take place and their potential impacts. This hinders monitoring and management policies at the international level.

The absence of observational data on oil spill occurrence and impacts impedes the assessment and management of the oil spill hazard. Numerical oil spill modelling is a widely tool to overcome the lack of observational data on spill trajectories and fate. Ensemble oil spill experiments allow us to address and quantify major uncertainties inherent to oil spills and the impact of these uncertainties in the oil spill hazard.

In this study, a large ensemble oil spill experiment was performed to depict the oil spill hazard distribution associated with maritime transportation in the Atlantic basin. The experiment results were used to generate three oil spill hazard products addressing documented end-user requirements. The oil spill hazard targeted products are:

- *OILHAZARD_1: Coastal oil spill hazard index for accidental spills in the Atlantic basin*
- *OILHAZARD_2: Cumulative oil spill trajectories for accidental events*
- *OILHAZARD_3: Coastal oil spill hazard map bulletin for accidental events*

The targeted products relied on up-to-date scientific methods and open and freely available data/information. The fitness-for-purpose and fitness-for-use were evaluated for the generated products and input datasets (i.e. upstream data), respectively. Results indicate that the pilot products qualitatively address the end-user requirements and are useful to depict the coastal oil spill hazard at the national/state level scale. The final products have the potential to support decision and policy making at the international level. The relatively coarse spatial resolution of the currently available global meteo-oceanographic fields hindered the description of oil spill hazard levels at the local (i.e. beach/town level) scale impacting the fitness-for-purpose of the designed products for local emergencies.

1.General scope of the oil spill hazard mapping

According to the National Research Council (2009) estimates, maritime transportation casualties (e.g. collisions, explosions) account for about 20% of oil inputs into the sea or 100,000 tons of oil/year. International and domestic regulations, in association with improvements on ship design, have contributed to an overall reduction in the volume of oil spilled in the ocean due to accidental spills (Musk, 2012), but, spill events still occur with significant social, economic and environmental impacts.

Hassler (2011) summarized a list of effective measures for oil spill risk reduction, highlighting the role played by monitoring strategies that complement international/domestic regulations. Effective monitoring and regulation of the sources of risk, depends on accurate mapping of the hazard at the desired spatial-temporal resolution and coverage. In other words, in order to properly manage the oil spill hazard, we must be able to map the hazard and risk at all scales.

Oil spill hazard (and risk) mapping methodologies have significantly progressed in recent decades. Price *et al.* (2003) inaugurated a new path in the field, addressing uncertainties, of meteo-oceanographic conditions defining the oil trajectory, inherent to oil spills employing ensemble oil spill simulations for the first time. This approach was also employed by Olita *et al.* (2012) who addressed the uncertainties due to seasonal variation of maritime traffic in the Strait of Bonifacio and meteo-oceanographic variability. Work by Sepp Neves *et al.* (2015, 2016) demonstrated that uncertainties in the employed ocean current fields, oil spill model setup and spill characteristics can modulate the oil spill hazard (and risk) in some areas, such as, Lebanon and The Algarve (Portugal).

Coordinated international efforts to sample the ocean at a reasonable spatial and temporal scale has facilitated the development of operational meteo-oceanographic systems. By ingesting and assimilating enormous amounts of observational data, such systems can deliver reliable and high-resolution sea-state analyses and forecasts. In the AtlantOS H2020 project, we developed of a suite of ocean products focused on

i) mapping coastal oil spill hazards in the Atlantic basin,
ii) estimating the most likely pathway of potential oil spills in coastal areas
iii) communicating the oil spill hazard to decision-makers.

The fitness-for-purpose of each product and the fitness-for-use of the data inputs that generated the product were evaluated using the MedSea Checkpoint methodology (http://www.emodnet-mediterranean.eu/).

This report follows the product development steps, and starts with the identification of the user requirements (Section 2), identification of the potential users (Section 3) and their needs (Section 4). Three products were specified (Section 5) and their prototypes implemented (Section 6). The quality of the prototypes were evaluated and weak points identified (Section 7). Finally, potential future product improvements are listed in Section 8.

2.User requirements identification

As described by several authors (Aven and Pitblado, 1998; Fischhoff, 1995), risk evaluation should be a participatory process . Therefore, oil spill risk assessments should ***involve a clear communication of the risk (and hazard)***. The literature available on oil spill risk communication is scarce. However, good insights are available from communities that have well developed risk assessment methodologies in place, such as health, meteorology and climate change. Firstly, it has been demonstrated that numerical illiteracy the end-users can compromise the correct understanding of the risk, especially for those cases where very small probabilities are involved. In this sense, visual communication of the risk should be prioritized over the simple numerical presentation of the results (Lipkus and Hollands, 1999). Recent publications have identified that the present challenge is ***to clearly communicate the risk and the uncertainties of the risk estimates*** while safeguarding the trust of the stakeholders involved.

The oil spill hazard mapping performed in AtlantOS Task 8.4 takes into consideration recent findings in communicating the hazard and its uncertainties. Additionally, the Targeted Products should support measures (monitoring and legislating)identified by Hassler (2011) which contribute to reducing the risk due to accidental spills such as remediation through investments in towing equipment, oil removal equipment and coast guard training.

3.Target Users for the AtlantOS oil spill hazard mapping

Three key target users identified by the oil spill hazard mapping Task are listed in Table 1.

Table 1 Target Users and their demands

<table>
<tr><th>Target User Name</th><th>URL of User</th><th>User needs (from previous work or literature)</th></tr>
<tr><td>European Maritime Safety Agency (EMSA) and similar agencies in other countries</td><td>www.emsa.europa.eu</td><td rowspan="3">• Identification of priority areas for oil spill monitoring;
• Allocation of resources for oil spill contingency and remediation (e.g. towing, booms, vessels);
• Identification of priority areas for protection.</td></tr>
<tr><td>International Association of Oil and Gas Producers</td><td>www.iogp.org</td></tr>
<tr><td>Oil Spill Response*</td><td>www.oilspillresponse.com</td></tr>
<tr><td>Oil Spill Response*</td><td>www.oilspillresponse.com</td><td>• Main areas impacted considering a given spill origin (coincident with an exploration area, pipelines or seaborne oil transportation)</td></tr>
</table>

** Oil Spill Response Limited (OSRL) is an international industry-funded cooperative that responds to oil spills on a global scale by providing preparedness, response and intervention services.*

4.Literature review of user needs

Specific literature on target user needs was not found. Information was, therefore, extracted from related documents especially those linked to oil spill risk assessments and to oil spill preparedness & response.

According to the Oil Spill Response Project (OSRP, 2016), there are crucial elements that "should be always considered" to guarantee oil spill preparedness. Elements listed by the OSRP that intersect with the aim of AtlantOS Oil spill hazard mapping are below listed:

- Understand the level of hazard
- Describe the oil fate and trajectory for the area of interest
- Identify coastal and marine areas which may be threatened
- Depict scenarios which robust contingency plans can rely on, including a "credible worst case"

The International Association of Oil & Gas Producers (2013) highlighted a few extra points that oil spill hazard and risk mapping should fulfil:

- support decision making related to alternative concepts/plans;
- support approval by regulatory authorities
- support stakeholder communication

5. Targeted Product Specification

The product development process started by identifying target users and their respective needs (Sections 2, 3 and 4). A suite of 3 potential products capable of addressing the observed user needs was specified. The names of the Targeted Products are listed in Table 2 and their specifications are listed in Tables 3, 4 and 5.

Table 2 List of Targeted products and short descriptions

Product	Extended name of Targeted Product	Short description
OILHAZARD_1	Coastal oil spill hazard index for accidental spills - Atlantic basin	Definition and computation of an index for the beached oil of national coastlines around the Atlantic basin
OILHAZARD_2	Cumulative oil spill trajectories for accidental events	Visual representation of oil trajectories distribution for a specified amount of time from a potential release point
OILHAZARD_3	Coastal oil spill hazard map bulletin for accidental events	Short overview of the methodology used and the hazard in different coastal areas of the North Atlantic published in pdf form

3.1 OILHAZARD_1: Coastal oil spill hazard index for accidental spills

The first conceptual end-user requested product had to address two identified elements considered important for oil spill preparedness:

- What is the distributed frequency and magnitude of coastal oil spills in all ice-free areas of the Atlantic?
- What coastal areas are most exposed to oil spill threats?

Answer to such questions must be given at the beach scale (~200 m) for the whole Atlantic ice-free basin, to support decision making at the municipal level. Significant seasonal variations of coastal hazard levels are reported in the literature due to meteo-oceanographic variability (e.g. see Sepp Neves *et al.*, 2016). Optimally, the developed product should allow end-users to consider seasonal variations of the hazard to inform the decision-making process. In order to cover as many meteo-oceanographic scenarios as possible and to generate reliable hazard estimates at the seasonal and annual scale, we established that the product should take into consideration past realistic situations in the last 10 years.

It is still not possible to state if small, but, frequent pollution events are more damaging than large rare events. Therefore, the oil spill hazard estimates should take into consideration both the magnitude and frequency of beach pollution events. To make the product usable for potentially non-scientific end users, the oil spill hazard spatial distribution should be graphically presented, preferentially in an interactive manner (e.g. GIS-layer). The product specification is summarized in Table 3.

Table 3 OILHAZARD_1 product specification summary -

Targeted Product Specification #1	
Product name	**OILHAZARD_1:** Coastal oil spill hazard index for accidental spills - Atlantic basin
Product description	An oil spill hazard index combining both the magnitude and frequency of beaching events in simulated accidental oil spill scenarios will be assigned to pre-defined coastal segments along the Atlantic coastline.
Geographic description	840,000km *Ice-free coastal areas in the Atlantic basin*
Horizontal extent	-60 to +60 latitude -100 to +30 in longitude

Horizontal resolution	200m (coastal segments)
Horizontal accuracy	100m
Vertical extent	0 (Shoreline)
Vertical resolution	Not applicable
Vertical accuracy	Not applicable
Temporal extent	10 years: 1st Jan, 2008 – 31st Dec, 2017
Temporal resolution	Seasonal
Temporal accuracy	1 Month
Spatial representation	The product will be mapped into a shapefile. The Atlantic coastline will be subdivided into segments and an oil spill hazard index will be assigned to each segment. Colours will be assigned to each index value, visually communicating the hazard.

3.2 OILHAZARD_2: Cumulative oil spill trajectories for accidental events

Our second conceptual end-user requested product should indicate *the most likely trajectory of a potential oil spill taking place at a given location*. Past events show that accidental oil spills can occur anywhere, at any time in the ocean and such uncertainties should be considered when developing the product. The most likely trajectories should be accurate enough to resolve the spatial variability at beach scale (25m resolution) and encompass seasonal flow field variability. Clearly, trajectories should be visually presented and should take into consideration “the most likely metocean scenarios at the area of interest”. We establish that at least 10 years of realistic atmospheric and ocean data fields should be included when estimating the most likely oil spill trajectories. The outputs should be graphically presented, preferentially in an interactive manner (e.g. GIS-layer). The product specification is summarized in Table 4.

Table 4 OILHAZARD_2 product specification summary

Targeted Product Specification #2	
Product name	**OILHAZARD_2:** Cumulative oil spill trajectories for accidental events (for each release point)
Product description	Cumulative plot of the accidental spill trajectories taking place within a pre-set time interval for a given release point
Geographic description	Marine areas in the Atlantic basin where a potential oil spill could reach coastal resources (between 30 and 130km away from the coast)
Horizontal extent	-60 to +60 latitude -100 to +30 in longitude
Horizontal resolution	25m (the grid should be able to resolve variability in a 200m scale – desired resolution of the coastal hazard index)
Horizontal accuracy	10m
Vertical extent	Sea surface
Vertical resolution	1
Vertical accuracy	0.5m
Temporal extent	10 years: 1st Jan, 2008 – 31st Dec, 2017
Temporal resolution	Seasonal
Temporal accuracy	1 month
Spatial representation	Geo-referenced plot showing the cumulative number of oil observations in a given area within a pre-set time interval.

3.3 OILHAZARD _3: Coastal oil spill hazard map bulletin for accidental events

The third conceptual end-user requested product focuses on integrating and communicating the results of products 1 and 2. The product should support stakeholder communication and decision-making, potentially facilitating discussions with regulatory authorities. The process should be interactive, allowing the end-users to fetch the desired information to build a customized document. It should be shaped as a document and include graphic descriptions of the oil spill hazard, an objective estimate of the oil spill hazard level and the most likely trajectories for potential release points surrounding the area of interest. Finally, the product should be web-based and available on an open and free basis. The product specification is shown in Table 5.

Table 5 - OILHAZARD_3 product specification summary

Targeted Product Specification #3	
Product name	OILHAZARD_3: Coastal oil spill hazard map bulletin for accidental events
Product description	Text document summarizing targeted (site and time specific) hazard maps for the end user and cumulative spill trajectories for the desired release points.
Geographic description	Ice-free coastal areas in the Atlantic basin
Horizontal extent	-60 to +60 latitude -100 to +30 in longitude
Horizontal resolution	200m for the hazard index and 25m for the cumulative trajectories
Horizontal accuracy	100m for the hazard index and 10m for the cumulative trajectories
Vertical extent	Shoreline (hazard index) and sea surface (cumulative trajectories)
Vertical resolution	Not applicable
Vertical accuracy	Not applicable
Temporal extent	10 years: 1st Jan, 2008 – 31st Dec, 2017
Temporal resolution	Seasonal
Temporal accuracy	1 month
Spatial representation	PDF file containing geo-referenced trajectory plots and hazard index distribution for a desired area.

6.Targeted Products description

The targeted products specifications of Section 5 represent our “ideal products” and potential limitations in the available information or technology were not taken into consideration at that phase.

The next step in the product development process consists of searching for available methodologies, technologies and input data necessary to fulfil the specifications listed above for the “ideal products”. The Targeted Product prototypes, built using available sources, are described in the following subsections.

6.1 OILHAZARD_1: Coastal oil spill hazard index for accidental spills

The oil spill hazard mapping method applied is founded on the work developed by Sepp Neves et al. (2015) and later improved by Sepp Neves et al. (2016). The methodology, named IT-OSRA, is aligned with standardised concepts of risk (ISO 31000 – Risk management principles) critically adapted to the oil spill case. The theoretical concepts behind the IT-OSRA method can be found in Sepp Neves et al. (2015).

The oil spill hazard estimation in IT-OSRA relies on outputs generated by ensemble oil spill modelling experiments. As many as necessary spill scenarios are simulated with different spill site locations, meteo-oceanographic conditions and oil spill model configurations addressing uncertainties on where, when and how a spill might happen (e.g. spilled volume, type of oil, etc.). The larger is the number of simulated scenarios, the more comprehensive the experiment and the more uncertainties one can address. However, more simulated scenarios also mean increased computational time. Consequently, important simplifications and assumptions were applied to the IT-OSRA methodology for the AtlantOS experiment.

The simplifications and assumptions applied to the AtlantOS experiment aimed to reduce the computational time involved in each simulation and the overall number of scenarios. To address uncertainties regarding “where” the spill might happen, 9,648 potential release points were defined covering marine areas between 30 to 130 km away from the coastline (Figure 1). The simplification was founded on the qualitative assessment of global maritime traffic density maps, where most of the traffic is confined to coastal areas. A fixed distance of approximately 25 km between neighbouring release points (i.e. release grid spatial resolution) was defined based on previous experiments on the statistical independence of beaching events.

Uncertainties about "when" the spill will happen (i.e. the meteo-oceanographic conditions during the spill event) were regarded by simulating 37 realistic spill scenarios. The procedure was repeated for every release point using sampled ocean current and wind fields in 2013. Undoubtedly, 37 scenarios cannot fully capture the meteo-oceanographic variability, but, this provides an idea of how the oil spill hazard is distributed at the large scale. Uncertainties regarding spill characteristics (i.e. spill volume, oil type, spill duration) were not addressed in the AtlantOS experiment although part of the IT-OSRA methodology. A "typical-spill" of 10,000 tons of relatively light oil (API 38) was assumed in accordance with the literature (Sepp Neves *et al.*, 2016). Finally, oil spill simulations were limited to 240 hours, enough time for spills taking place at the farthest release point to reach coastal resources. In total, about 300,000 oil spill scenarios were simulated with the MEDSLIK-II oil spill model.

Oil spill simulations were performed using MEDSLIK-II. MEDSLIK-II is a Lagrangian oil spill model that can reproduce the oil transport and oil weathering in the marine environment by ingesting realistic ocean and atmospheric fields (Dominicis *et al.*, 2013a). For the current experiment, MEDSLIK-II was fed with global ocean currents and temperature fields (GLOBAL_ANALYSIS_FORECAST_PHY_001_024) available from Copernicus Marine Environment Monitoring Service (http://marine.copernicus.eu/). As a first approach, wind-driven oil transport was neglected, although ECMWF ERA-Interim Reanalysis wind fields (https://www.ecmwf.int/en/forecasts/datasets/archive-datasets/reanalysis-datasets/era-interim) were used to compute oil evaporation rates at sea. The Atlantic bathymetry field ingested in MEDSLIK-II was extracted from the global GEBCO 30'' bathymetry (https://www.gebco.net/). Twenty-five thousand parcels (i.e. modelled particles representing a set volume of oil) were used to simulate the oil spills.

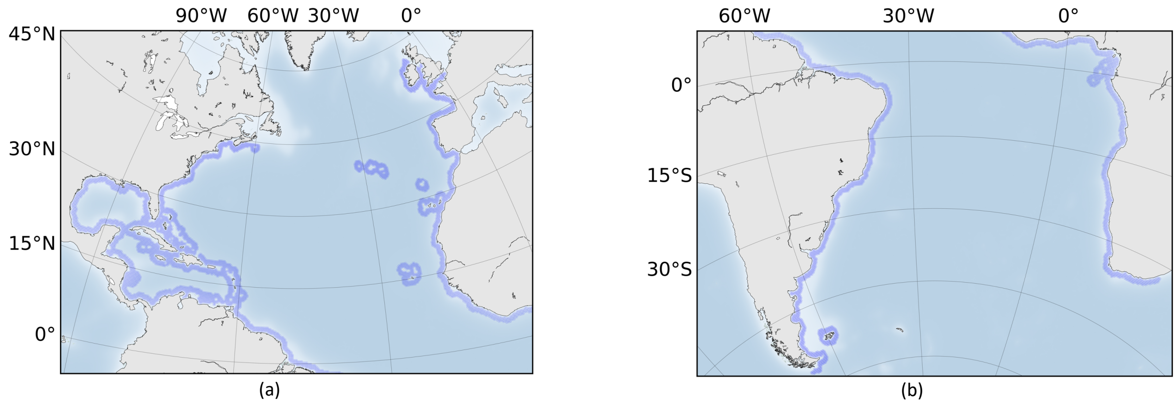

Figure 1 Release points (blue dots) used in the ensemble experiment at the (a) Northern and (b) Southern hemispheres.

The oil spill hazard was computed at the national level for all the Atlantic countries situated in ice-free areas. Hazard levels were assigned at the state/province level in Brazil, USA and Argentina due to their large territories. As established in the product specification, the oil spill hazard index depends on both the magnitude (i.e. concentration) and frequency of simulated beaching events evaluated at pre-defined political units (i.e. country of state).

Beached oil concentrations, value in tons/km, were registered at pre-defined coastal segments (Wessel and Smith, 1996) after each simulation. The procedure was repeated for each release point and for the 37 meteo-oceanographic scenarios. The histograms of beached oil concentrations found in every country/state were successfully fitted by a Weibull distribution (Figure 2). The Weibull survival function was used as a proxy of the oil spill hazard, OSH:

$$OSH = 1 - F(x_C)$$

where $F(x_C)$ is the cumulative distribution function at a concentration x_C. In other words, the oil spill hazard index applied in our experiment represents the probability of observing a beaching event with magnitude above a concentration threshold x_C. For the AtlantOS experiment, an arbitrary concentration of 50 tons of oil per km of coastline was applied for the sake of demonstration since such values should be defined by the end-users.

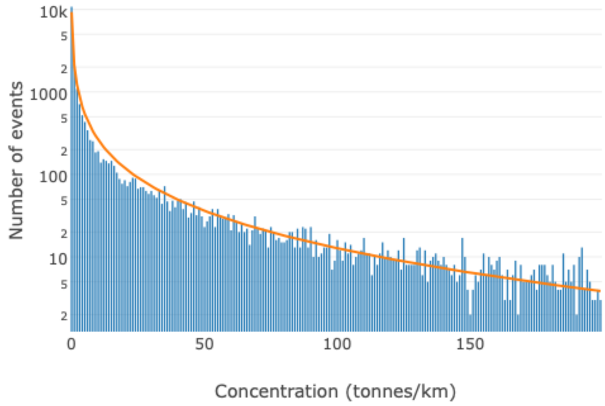

Figure 2 Example of histogram and fit for beaching events concentration in Cuba, Central America.

The final OSH result for national coastlines around the Atlantic basin are displayed below in Table 6.

Table 6 Atlantic oil spill hazard ranking

Rank	Political unit	OSH	Rank	Political unit	OSH
1	France	0.72	**42**	Honduras	0.10
2	United Kingdom	0.61	**43**	Sierra Leone	0.10
3	Trinidad and Tobago	0.37	**44**	Costa Rica	0.10
4	Guinea	0.31	**45**	Bahia	0.09
5	Madeira	0.27	**46**	The Guianas	0.09
6	Guinea Bissau	0.25	**47**	Rio Grande do Norte	0.09
7	Mississippi	0.22	**48**	Jamaica	0.08
8	Colombia	0.19	**49**	Liberia	0.08
9	Turks islands	0.19	**50**	Pernambuco	0.08
10	Nicaragua	0.19	**51**	Sao Paulo	0.07
11	US Gulf coast	0.18	**52**	Angola	0.07
12	Bahamas	0.18	**53**	Rio de Janeiro	0.07
13	Maine	0.18	**54**	Ivory Coast	0.07
14	Cayman Islands	0.18	**55**	Nigeria	0.07
15	Ireland	0.18	**56**	Paraiba	0.06
16	Falklands	0.17	**57**	Benin	0.06
17	Dominican Republic	0.17	**58**	North Carolina	0.06
18	Canary islands	0.17	**59**	US Central coast	0.05
19	Venezuela	0.16	**60**	South Africa	0.05
20	US North coast	0.16	**61**	Espirito Santo	0.05
21	Leeward Caribbean islands	0.16	**62**	Texas	0.05
22	Chubut	0.15	**63**	Alagoas	0.05
23	Puerto Rico	0.15	**64**	Ghana	0.04
24	Morocco	0.15	**65**	Equatorial Guinea	0.02
25	Belize	0.14	**66**	Sergipe	0.02
26	Uruguay	0.14	**67**	Namibia	0.02
27	Haiti	0.14	**68**	Buenos Aires	0.02

28	Massachusetts	0.14	**69**	Congo and Belize	0.01
29	Cape Verde	0.14	**70**	Western Sahara	0.01
30	Ushuaia	0.13	**71**	Santa Cruz	0.01
31	Mexico	0.13	**72**	Santa Catarina	0.01
32	Louisiana	0.13	**73**	Togo	0.00
33	Mauritania	0.13	**74**	Rio Negro	0.00
34	Panama	0.13	**75**	Rio Grande do Sul	0.00
35	Spain	0.13	**76**	Parana	0.00
36	Portugal	0.12	**77**	South Carolina	0.00
37	Cuba	0.12	**78**	Virginia	0.00
38	Cameroon	0.12	**79**	New Jersey	0.00
39	Florida	0.11	**80**	New York	0.00
40	Senegal	0.11	**81**	Guatemala	0.00
41	Gabon	0.10			

A summary of the actual OILHAZARD_1 quality indices is presented in Table 7.

Table 7 OILHAZARD_1 Targeted product final configuration

Targeted Product #1	
Product name	OILHAZARD_1: Coastal oil spill hazard index for accidental spills - Atlantic basin
Product description	An oil spill hazard index combining both the magnitude and frequency of beaching events in simulated accidental oil spill scenarios will be assigned to pre-defined coastal segments along the Atlantic coastline.
Geographic description	Ice-free coastal areas in the Atlantic basin
Horizontal extent	-60 to +60 latitude -100 to +30 in longitude
Horizontal resolution	Results mapped at the national level (hundreds of km)
Horizontal accuracy	100m
Vertical extent	0 (Shoreline)
Vertical resolution	Not applicable
Vertical accuracy	Not applicable
Temporal extent	1 year: 1st Jan, 2013 – 31st Dec, 2013
Temporal resolution	Yearly
Temporal accuracy	Yearly
Spatial representation	The product was mapped into a shapefile. The Atlantic coastline will be subdivided into segments and an oil spill hazard index will be assigned to each segment. Colours will be assigned to each index value, visually communicating the hazard.

6.2 OILHAZARD_2: Cumulative oil spill trajectories for accidental events

The second product developed, relied on the ensemble experiment presented in ATLANTOS_UC4_Product_1. For each of the 9,648 release points, the cumulative spill trajectory was computed as an indication of the most likely spill displacement. The cumulative trajectory was calculated by counting the number of oil parcels found within pre-defined grid cells. The frequency-map was updated with hourly parcel positions information and for the 37 meteo-oceanography scenarios (Figure 3). The final frequency map differentiates between the most frequently contaminated areas at the sea surface from areas with sparse or no oil observations. For each release point, one cumulative trajectory map was generated and is valid for the year 2013 (Figure 4).

The horizontal grid used to compute the cumulative frequencies has a 150m spatial resolution as recommended by Dominicis *et al.* (2013a). The sensitivity experiment carried out by Dominicis *et al.* (2013b) used a 150m grid resolution for optimal results to reproduce the shape and spatial distribution of oil spills at sea. Modelled slicks were compared with *in-situ* observations in the Mediterranean Sea. Please note, the oil spill integration grid resolution is finer than the spatial resolution of the input ocean fields.

A summary of the actual OILHAZARD_2 quality indices is presented in Table 8.

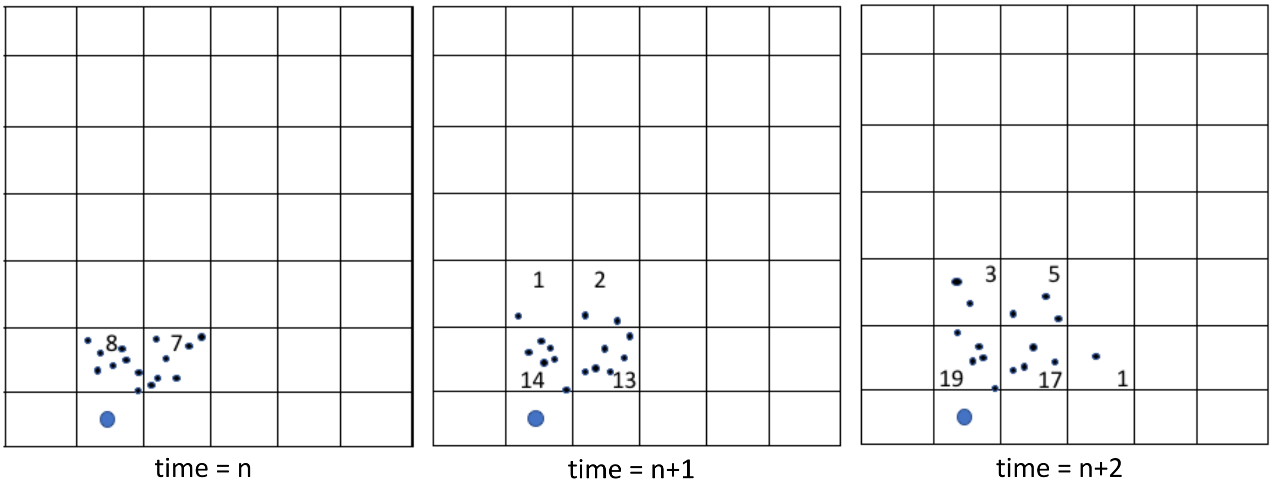

Figure 3 Schematic of cumulative oil trajectories computed for a 3h time window. Blue circle represents the spill origin, black small dots represent oil parcels, black squares represent the oil spill model grid and the numbers represent the cumulative frequencies in each grid cell.

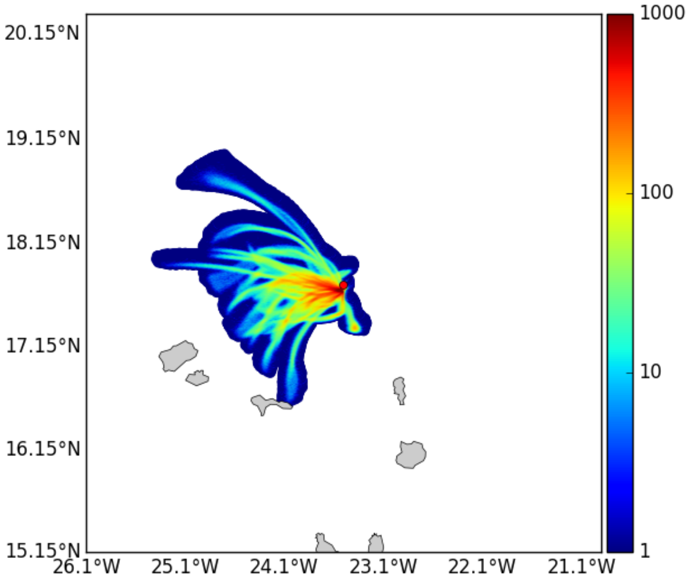

Figure 4 Cumulative oil spill trajectory map. Spill origin is represented by a red circle. Colours represent the number of observations.

Table 8 OILHAZARD_2 Targeted product final configuration

Targeted Product #2	
Product name	OILHAZARD_2: Cumulative oil spill trajectories for accidental events (for each release point)
Product description	Cumulative plot of the accidental spill trajectories taking place within a pre-set time interval for a given release point
Geographic description	Marine areas in the Atlantic basin where a potential oil spill could reach coastal resources (between 30 and 130km away from the coast)
Horizontal extent	-60 to +60 latitude -100 to +30 in longitude
Horizontal resolution	150m
Horizontal accuracy	75m
Vertical extent	Sea surface
Vertical resolution	1
Vertical accuracy	0.5m
Temporal extent	1 year: 1st Jan, 2013 – 31st Dec, 2013
Temporal resolution	Yearly
Temporal accuracy	Yearly
Spatial representation	Geo-referenced plots showing the cumulative trajectory for each release point. Colour gradients should be used to display the frequency maps.

6.3 OILHAZARD_3: Coastal oil spill hazard map bulletin for accidental events

A web-GIS interface was built to allow end-users to interact with the ensemble experiment post-processed outputs (https://glamor.sincem.unibo.it/, Figures 5 and 6). Detailed information on the website structure and functionalities are reported in the AtlantOS Deliverable 8.4 (https://www.atlantos-h2020.eu/download/AtlantOS_D8.4.pdf).

The "Bulletin" was designed to provide overview information of the beached oil hazard for each national coastline and two Bulletins were produced for demonstration purposes. The demonstration first is for the Canary Islands (Figure 7) and the second for the Brazilian coastlines (Figure 8).

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ATLANTOS OIL SPILL HAZARD BULLETIN
CANARY ISLANDS, SPAIN

The bulletin users are invited to visit our website (https://glamor.sincem.unibo.it) to know more about the methodology and vocabulary used.

FOREWORD

The bulletin was designed to support the national and international policy makers and practitioners of oil spill emergency management. Its structure is simple: first, we depict the overall surface circulation in the area of interest (i.e. Canary Islands), which will give the environmental sea condition awareness from the advanced analysis system of Copernicus Marine Environment Monitoring Service. Finally, we describe the oil spill hazard at the coasts as represented by a number of release points near the coasts simulating potential oil spills from maritime traffic routes.

ON THE CANARY ISLANDS

Currently, about 2,100,000 people live in the Canary Archipelago, located off the African coast (Figure 1) and with strong connections to the sea mainly by the tourism industry. The archipelago is exposed to heavy maritime traffic (Figure 2), which might represent a threat to the coasts.

Figure 1 Canary archipelago and bathymetry of surrounding areas

Figure 2 Maritime traffic density for the year of 2017. Extracted from www.marinetraffic.com

AtlantOS

Figure 5 Cover page of an oil spill hazard bulletin prepared for the Canary Islands, Spain. The PDF file can be retrieved at the GLAMOR portal.

A summary of the actual OILHAZARD_3 quality indices is presented in Table 9.

Table 9 OILHAZARD_3 Targeted product final configuration

Targeted Product #3	
Product name	OILHAZARD_3: Coastal oil spill hazard map bulletin for accidental events
Product description	Text document summarizing targeted (site and time specific) hazard maps for the end user and cumulative spill trajectories for the desired release points.
Geographic description	Ice-free coastal areas in the Atlantic basin
Horizontal extent	-60 to +60 latitude -100 to +30 in longitude
Horizontal resolution	Hazard is mapped at the national level (hundreds of km) and 150m resolution for the cumulative trajectory maps.
Horizontal accuracy	100m for the hazard index and 75m for the cumulative trajectories
Vertical extent	Shoreline (hazard index) and sea surface (cumulative trajectories)
Vertical resolution	Not applicable
Vertical accuracy	Not applicable
Temporal extent	1 year: 1st Jan, 2013 – 31st Dec, 2013
Temporal resolution	Yearly
Temporal accuracy	Yearly
Spatial representation	PDF file containing geo-referenced trajectory plots and hazard index distribution for a desired area.

7. Upstream Data

In order to produce the three targeted products, defined and generated as described in the previous two sections, five upstream or input data sets were used. The upstream input data sources are defined in Table 10 below. The input data characteristics are defined, together with their data originator and the data policy of the source.

Table 10 Targeted products and their input data characteristics

Number	Input data characteristics (*)	Environmental Matrix (*)	Data originator (URL)	Data Policy of the sources
1	Global numerical model output – u and v ocean current velocity components – employed vertical layers	Marine waters	www.marine.copernicus.eu	Open and free
2	Global numerical model output – sea surface temperature	Marine waters	www.marine.copernicus.eu	Open and free
3	Global numerical model output – u and v 10m winds	Marine waters	http://apps.ecmwf.int/datasets/data/interim-full-daily/levtype=sfc/	Open and free
4	High resolution coastline - points	Seabed/Riverbed	https://www.ngdc.noaa.gov/mgg/shorelines/gshhs.html	Open and free
5	High resolution bathymetry	Seabed/Riverbed	https://www.gebco.net/	Open and free

8. Targeted products and input data adequacy

In the following subsections, targeted products and upstream data had their fitness-for-purpose and fitness-for-use respectively evaluated using the MedSea EMODnet Checkpoint methodology (Pinardi *et al.*, 2017). The methodology to assess the fitness-for-purpose consists of a comparison between the "desired" product specifications and the actual developed product characteristics in terms of quality elements adapted from ISO 9000. For the fitness-for-use of the upstream data sets the same methodology is used, but, the comparison is between the specification and the input data set quality element. An expert evaluation is carried out addressing six points and an overall score is attributed to the product (Table 11).

Table 11 Expert evaluation table and scoring system

EVALUATION GUIDELINES	
Assign an overall product quality score with respect to scope (fitness for purpose) and explain why	
Most important characteristics for the Targeted product quality	
Quality element of the most important characteristics (variables) that affects the Targeted Product	
Limitations of the quality of the targeted products due to input dataset	
Characteristics that fail to meet the scope of the targeted product	
Expert judgement of the most important gaps in the input data sets for the Targeted Product	
SCORE	**MEANING**
1	EXCELLENT: completely meets the scope of the Targeted product
2	VERY GOOD: meets more than 70% of the scope of the Targeted product
3	GOOD: meets less than 50% of the scope of the Targeted product
4	SUFFICIENT: does not adequately meet the scope but is a starting point
5	INADEQUATE: does not fulfill the scope and is not usable

8.1 Data and product adequacy for OILHAZARD_1

As requested, hazard values combining both the magnitude and frequency of beaching events were computed for pre-defined ice-free coastal areas in the Atlantic. The hazard levels were assigned at the shoreline vertical level and within the desired horizontal accuracy. In general terms, the developed product achieved 6 of the 11 requirements (54%) and awarded a product quality score of 3 = "good" according to the expert evaluation guidelines (Table 11 and 12).

Table 12 Expert evaluation table - OILHAZARD_1

Assign an overall product quality score with respect to scope (fitness for purpose) and explain why	Good
Most important characteristics for the Targeted product quality	• ocean fields • wind fields
Quality element of the most important characteristics (variables) that affects the Targeted Product	• horizontal spatial resolution • temporal resolution and extent • accuracy
Limitations of the quality of the targeted products due to input dataset	• horizontal spatial resolution
Characteristics that fail to meet the scope of the targeted product	• ocean fields spatial resolution • wind fields spatial resolution
Expert judgement of the most important gaps in the input data sets for the Targeted Product	• meteo-oceanographic fields spatial resolution • maritime traffic density maps are proprietary • data on coastal types were not found at the Atlantic scale

The targeted product deviated in three aspects from the product specification: horizontal spatial resolution and temporal resolution, extent and accuracy (Table 13). The coarse spatial resolution found in the ocean (9x9km) and atmospheric fields (80x80km) limited the final product horizontal resolution (~500km, Table 13. Current available meteo-oceanographic fields are unable to resolve events at the beach scale and are ranked as the major contributor to the low quality score awarded.

Temporal extent and resolution of meteo-oceanographic input datasets were satisfactory. Bathymetry and coastline geometry datasets fully satisfied the product requirements (Table 14). The low temporal resolution, extent and accuracy found in the produced product are not linked to the input dataset characteristics, rather they are a result of simplifications applied to the ensemble experiment to reduce the number of simulated scenarios.

It has been identified that all the maritime traffic density datasets available online are proprietary and were unavailable to optimally establish the release points grid. Data on coastal types (e.g. sand, breakwater, cliffs, etc.) are important to reproduce oil spill beach landing processes. Unfortunately, coastal types were not accessible at the Atlantic scale and, therefore, not included during product development.

Table 13 Targeted product evaluation summary - OILHAZARD_1. Table cells marked in green indicate Targeted Product quality elements that satisfied the product specification. Cells marked in red indicate Upstream data quality elements that did not satisfy the product specification.

Targeted Product #1		
Product name	OILHAZARD_1: Coastal oil spill hazard index for accidental spills - Atlantic basin	
Product description	An oil spill hazard index combining both the magnitude and frequency of beaching events in simulated accidental oil spill scenarios will be assigned to pre-defined coastal segments along the Atlantic coastline.	
	Product	**Specification**
Geographic description	Ice-free coastal areas in the Atlantic basin	Ice-free coastal areas in the Atlantic basin
Horizontal extent	-60 to +60 latitude -100 to +30 in longitude	-60 to +60 latitude -100 to +30 in longitude
Horizontal resolution	Results mapped at the national level (hundreds of km – 500km)	200m (coastal segments)
Horizontal accuracy	100m	100m
Vertical extent	0 (Shoreline)	0 (Shoreline)
Vertical resolution	Not applicable	Not applicable
Vertical accuracy	Not applicable	Not applicable
Temporal extent	1 year: 1st Jan, 2013 – 31st Dec, 2013	10 years: 1st Jan, 2008 – 31st Dec, 2017
Temporal resolution	Yearly	Seasonal
Temporal accuracy	Yearly	1 Month
Spatial representation	The product was mapped into a shapefile. The Atlantic coastline was subdivided into segments and an oil spill hazard index was assigned to each segment. Colours were assigned to each index value, visually communicating the hazard.	The product will be mapped into a shapefile. The Atlantic coastline was in countries/states/provinces and an oil spill hazard index was assigned to each political unit. Colours were assigned to each index value, visually communicating the hazard.

Table 14 Upstream data evaluation summary - OILHAZARD_1. Table cells marked in green indicate Upstream data quality elements that satisfied the product specification. Cells marked in red indicate Upstream data quality elements that did not satisfy the product specification.

Measure	Current fields	Wind fields	SST	Coastline	Bathymetry	DPS value
Horizontal extent	840000 km^2 *Ice-free Atlantic basin*	840000 km^2 *Ice-free Atlantic basin*	840000 km^2 *Ice-free Atlantic basin*	*Not applicable*	840000 km^2 *Ice-free Atlantic basin*	840000 km^2
Temporal extent	3650 days *From 2007 onwards*	3650 days *From 1979 onwards*	3650 days *From 2007 onwards*	*Not applicable*	*Not applicable*	3650 days *From 2007 onwards*
Vertical extent	*Surface ocean fields are delivered (at 0.4m)*	*Wind fields at sea surface/shoreline are given (10m winds)*	*Temperature at the sea surface are given (0.4m)*	*All countries bordering the Atlantic had their coastlines (0m) included in the dataset.*	1 *Bathymetry dataset covers sea-land interface.*	
Number of Characteristics	*1 - Horizontal current components*	*1 - Horizontal 10m wind components*	*1 - sea surface temperature*	*1 - coastline*	*1 - Bathymetry*	5
Horizontal resolution	9000 meters *Global CMEMS Mercator fields.*	80000 meters *ERA-Interim spatial resolution.*	9000 meters *Global CMEMS Mercator fields*	180 meters *Average length of coastal segments in the NOAA GSHHS dataset*	30 meters *GEBCO spatial resolution: 30''*	200 meters
Vertical resolution	*Not applicable*	*Not applicable*	*Not applicable*	*Not applicable*	*Not applicable*	*Not applicable*
Temporal resolution	1 day *Daily*	0.25 day *6hourly fields*	1 day *Daily*	*Not applicable*	*Not applicable*	90 days
Temporal validity	1 day *Ocean fields are updated every one day.*	0.25 day *Winds fields are updated every 6 hours*	1 day *Water temperature fields are updated every day*	*Not applicable.*	*Not applicable*	90 days

8.2 Data and product adequacy for OILHAZARD_2

The specified objective of *computing cumulative oil spill trajectories for accidental spills* was qualitatively addressed by the targeted product. Through expert evaluation, the developed product achieved 5 out of the 11 (45%) requirements and awarded a product quality score of 3 = "good" according to the expert evaluation guidelines (Tables 11 and 15).

Table 15 Expert evaluation table - OILHAZARD_2

Assign an overall product quality score with respect to scope (fitness for purpose) and explain why	Good
Most important characteristics for the Targeted product quality	• ocean fields • wind fields
Quality element of the most important characteristics (variables) that affects the Targeted Product	• horizontal spatial resolution • temporal resolution and extent • accuracy
Limitations of the quality of the targeted products due to input dataset	• horizontal spatial resolution
Characteristics that fail to meet the scope of the targeted product	• ocean fields: spatial resolution • wind fields: spatial resolution
Expert judgement of the most important gaps in the input data sets for the Targeted Product	• meteo-oceanographic fields spatial resolution

Large spatial coverage and the ability to deliver results at the sea surface layer positively contributed to the fitness-for-purpose of the targeted product (Table 16). The coarse spatial and temporal resolutions of the targeted product, in addition to its limited temporal extent, were the main factors affecting the assigned targeted product quality score (Table 16).

Table 16 Targeted product evaluation summary - OILHAZARD_2. Table cells marked in green indicate Targeted Product quality elements which satisfied the product specification. Cells marked in red indicate Upstream data quality elements that did not satisfy the product specification.

Targeted Product #2		
Product name	OILHAZARD_2: Cumulative oil spill trajectories for accidental events (for each release point)	
Product description	Cumulative plot of the accidental spill trajectories taking place within a pre-set time interval for a given release point	
	Product	**Specification**
Geographic description	Marine areas in the Atlantic basin where a potential oil spill could reach coastal resources (between 30 and 130km away from the coast)	Marine areas in the Atlantic basin where a potential oil spill could reach coastal resources (between 30 and 130km away from the coast)
Horizontal extent	-60 to +60 latitude -100 to +30 in longitude	-60 to +60 latitude -100 to +30 in longitude
Horizontal resolution	150m	25m (the grid should be able to resolve variability in a 200m scale – desired resolution of the coastal hazard index)
Horizontal accuracy	75m	10m
Vertical extent	Sea surface	Sea surface
Vertical resolution	1	1
Vertical accuracy	0.5m	0.5m
Temporal extent	1 year: 1st Jan, 2013 – 31s Dec t, 2013	10 years: 1st Jan, 2008 – 31st Dec, 2017
Temporal resolution	Yearly	Seasonal
Temporal accuracy	Yearly	1 month
Spatial representation	Geo-referenced plots showing the cumulative trajectory for each release point. Colour gradients are used to display the frequency maps.	Geo-referenced plots showing the cumulative trajectory for each release point. Colour gradients should be used to display the frequency maps.

The ocean and atmospheric fields used in the product development hindered the delivery of cumulative trajectories at the desired horizontal resolution (Table 17). The GEBCO 30'' bathymetry field was suitable. As for OILHAZARD_1, the temporal extent offered by the meteo-oceanographic operational programs was satisfactory. The product limited temporal extent is a consequence of our attempts to limit the computational time taken by the experiment by reducing the number of ensemble members.

Table 17 Upstream data evaluation summary - OILHAZARD_2. Table cells marked in green indicate Upstream data quality elements which satisfied the product specification. Cells marked in red indicate Upstream data quality elements that did not satisfy the product specification.

Measure	Current fields	Wind fields	SST	Coastline	Bathymetry	DPS value
Horizontal extent	840000 km^2 *Ice-free Atlantic basin*	840000 km^2 *Ice-free Atlantic basin*	840000 km^2 *Ice-free Atlantic basin*	*Not applicable*	840000 km^2 *Ice-free Atlantic basin*	840000 km^2
Temporal extent	3650 days *From 2007 onwards*	3650 days *From 1979 onwards*	3650 days *From 2007 onwards*	*Not applicable*	*Not applicable*	3650 days *From 2007 onwards*
Vertical extent	1 *Surface ocean fields are delivered (at 0.4m)*	1 *Wind fields at sea surface/shoreline are given (10m winds)*	1 *Temperature at the sea surface are given (0.4m)*	58 *All countries bordering the Atlantic had their coastlines (0m) included in the dataset.*	1 *Bathymetry dataset covers sea-land interface.*	
Number of Characteristics	*1 - Horizontal current components*	*1 - Horizontal 10m wind components*	*1 - sea surface temperature*	*1 - coastline*	*1 - Bathymetry*	5
Horizontal resolution	9000 meters *Global CMEMS Mercator fields.*	80000 meters *ERA-Interim spatial resolution.*	9000 meters *Global CMEMS Mercator fields*	180 meters *Average length of coastal segments in the NOAA GSHHS dataset*	30 meters *GEBCO spatial resolution: 30''*	25 meters

Vertical resolution	*Not applicable*	*Not applicable*	*Not applicable*	*Not applicable*	*Not applicable*	*Not applicable*
Temporal resolution	1 day *Daily*	0.25 day *6hourly fields*	1 day *Daily*	*Not applicable*	*Not applicable*	90 days
Temporal validity	1 day *Ocean fields are updated every one day.*	0.25 day *Winds fields are updated every 6 hours*	1 day *Water temperature fields are updated every day*	*Not applicable.*	*Not applicable*	90 days

8.3 Data and product adequacy for OILHAZARD_3

The GLAMOR portal provides the necessary information and infrastructure to produce oil spill hazard bulletins. The identified user requirements were qualitatively satisfied. According to the expert evaluation template, the OILHAZARD_3 fitness-for-purpose was considered "good" (Table 18). Coarse spatial resolution of the cumulative trajectory maps and oil spill hazard index products (Table 19) compromised the product score.

Table 18 Expert evaluation table - OILHAZARD_3

Assign an overall product quality score with respect to scope (fitness for purpose) and explain why	Good
Most important characteristics for the Targeted product quality	• ocean fields • wind fields
Quality element of the most important characteristics (variables) that affects the Targeted Product	• horizontal spatial resolution • temporal resolution and extent • accuracy
Limitations of the quality of the targeted products due to input dataset	• horizontal spatial resolution
Characteristics that fail to meet the scope of the targeted product	• ocean fields: spatial resolution • wind fields: spatial resolution
Expert judgement of the most important gaps in the input data sets for the Targeted Product	• meteo-oceanographic fields spatial resolution

The web-portal allows end-users to retrieve site-specific hazard maps and cumulative spill trajectories for the desired release points. It is currently impossible to obtain seasonal hazard maps or cumulative trajectories due to limitations in the ensemble experiment temporal extent (Table 19).
As discussed in the previous subsections, wind and current fields spatial resolution is a major barrier to the development of fine-scale oil spill hazard products (Table 20).

Table 19 Targeted product evaluation summary - OILHAZARD_3. Table cells marked in green indicate Targeted Product quality elements which satisfied the product specification. Cells marked in red indicate Upstream data quality elements that did not satisfy the product specification.

Targeted Product #3		
Product name	OILHAZARD_3: Coastal oil spill hazard map bulletin for accidental events	
Product description	Web interface able to retrieve targeted maps to the end user, their respective uncertainties and cumulative spill trajectories for the desired release points.	
	Product	**Specification**
Geographic description	Ice-free coastal areas in the Atlantic basin	Ice-free coastal areas in the Atlantic basin
Horizontal extent	-60 to +60 latitude -100 to +30 in longitude	-60 to +60 latitude -100 to +30 in longitude
Horizontal resolution	Hazard map: hundreds of km	200m
	Cumulative trajectories: 150m	Cumulative trajectories: 25m
Horizontal accuracy	Hazard map: 100m	Hazard map: 100m
	Cumulative trajectories: 75m	Cumulative trajectories: 10m
Vertical extent	Hazard map: shoreline (0m)	0m
	Cumulative trajectories: sea surface	Sea surface
Vertical resolution	1	1
Vertical accuracy	0.5	0.5

Temporal extent	1 year: 1st Jan, 2013 – 31st Dec, 2013	10 years: 1st Jan, 2008 – 31st Dec, 2017
Temporal resolution	Yearly	Seasonal
Temporal accuracy	Yearly	1 month
Spatial representation	PDF file containing geo-referenced trajectory plots and hazard index distribution for a given area.	PDF file containing geo-referenced trajectory plots and hazard index distribution for a given area.

Table 20 Upstream data evaluation summary - OILHAZARD_3. Table cells marked in green indicate Upstream data quality elements which satisfied the product specification. Cells marked in red indicate Upstream data quality elements that did not satisfy the product specification.

Measure	Current fields	Wind fields	SST	Coastline	Bathymetry	DPS value
Horizontal extent	840000 km^2 *Ice-free Atlantic basin*	840000 km^2 *Ice-free Atlantic basin*	840000 km^2 *Ice-free Atlantic basin*	*Not applicable*	840000 km^2 *Ice-free Atlantic basin*	840000 km^2
Temporal extent	3650 days *From 2007 onwards*	3650 days *From 1979 onwards*	3650 days *From 2007 onwards*	*Not applicable*	*Not applicable*	3650 days *From 2007 onwards*
Vertical extent	1 *Surface ocean fields are delivered (at 0.4m)*	1 *Wind fields at sea surface/shoreline are given (10m winds)*	1 *Temperature at the sea surface are given (0.4m)*	58 *All countries bordering the Atlantic had their coastlines (0m) included in the dataset.*	1 *Bathymetry dataset covers sea-land interface.*	
Number of Characteristics	*1 - Horizontal current components*	*1 - Horizontal 10m wind components*	*1 - sea surface temperature*	*1 - coastline*	*1 - Bathymetry*	5
Horizontal resolution	9000 meters *Global CMEMS Mercator fields.*	80000 meters *ERA-Interim spatial resolution.*	9000 meters *Global CMEMS Mercator fields*	180 meters *Average length of coastal segments in the NOAA GSHHS dataset*	30 meters *GEBCO spatial resolution: 30''*	25 meters
Vertical resolution	*Not applicable*	*Not applicable*	*Not applicable*	*Not applicable*	*Not applicable*	*Not applicable*
Temporal resolution	1 day *Daily*	0.25 day *6hourly fields*	1 day *Daily*	*Not applicable*	*Not applicable*	90 days
Temporal validity	1 day *Ocean fields are updated every one day.*	0.25 day *Winds fields are updated every 6 hours*	1 day *Water temperature fields are updated every day*	*Not applicable.*	*Not applicable*	90 days

9. Recommendations for system improvements

In general, the three targeted products produced in this AtlantOS task addressed more than half of the specified purposes and user requirements. Spatial and temporal resolutions were the main factors responsible for the lower product quality scores. It is possible to resolve the low scoresby:

1. Using high resolution meteo-oceanographic fields able to resolve the ocean and atmospheric dynamics at the appropriate scale (i.e. hundreds of meters);
2. Enlarging the number of simulated scenarios, especially regarding uncertainties due to meteo-oceanographic variability (i.e. increase temporal extent).

Currently, there is no global operational oceanographic system that can deliver very high resolution ocean fields with global coverage. Some improvement could be reached by employing existing regional operational system (e.g., Iberian shelf, Mediterranean Sea) outputs, with higher spatial resolution, in the products generated. However, local systems produce limited spatial coverage and high resolution simulations are still necessary to describe the oil spill hazard at the beach scale.

Although the Oil Spill Hazard Targeted products suite were unable to estimate the hazard at the fine scale, they can still support policy making at the international scale. As identified in point (2), covering more meteo-oceanographic scenarios would result in an increased product quality and reliability, and unveil seasonal variations in the hazard map.

Uncertainties on spill characteristics and oil spill model setup were not taken into consideration in the Oil Spill Hazard Targeted products. If included in the oil spill experiment, scenarios regarding different spill characteristics and model setup can help to modulate the hazard levels and improve the hazard estimates. Access to maritime traffic density data, currently restricted data, would help to optimize the release grid coverage and potentially reduce the number of simulations required to achieve “excellent” oil spill hazard maps.

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