MERMAID

mermaidproject.eu

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D3.1 Energy resources

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EXECUTIVE SUMMARY

The FP7 Mermaid project deals with multi-use platforms to be located far offshore in European waters. The Mermaid project investigates the possibilities for multi-use platforms for renewable energies wind, wave, current and aquaculture. The current report provides an overview of the available potential resources of wind, wave and current in European Seas.

1. WIND RESOURCES

1.1 Background on wind resources in Europe

The ORECCA (Offshore Renewable Energy Conversion Platform Coordination Action) Project www.orecca.eu is an EU FP7 funded collaborative project in the offshore renewable energy sector.

Quotation:

> *The ORECCA project's principal aim is to overcome the fragmentation of know how available in Europe and its transfer amongst research organisations, industry stakeholders and policy makers stimulating these communities to take the necessary steps to foster the development of the offshore renewable energy sector in an environmentally sustainable way.*

Two of the important reports from ORECCA are the ORECCA European Offshore Renewables Energy Road Map (2011) at http://www.orecca.eu/c/document_library/get_file?uuid=0ad7e296-4f5c-443f-8ba7-490a7344d2da&groupId=10129 and the ORECCA Resource Data and GIS tool for Offshore Renewable Energy projects in Europe report (2012) at http://www.orecca.eu/c/document_library/get_file?uuid=757326c6-102f-4dd3-8790-916755694103&groupId=10129.

Furthermore, ORECCA provides an open GIS server where the European wind resource map can be retrieved at http://map.rse-web.it:8082/orecca/map.phtml *Figure 1* shows the mean wind speed map of Europe. This is based on 10 years of twice daily observations from the SeaWinds Scatterometer on-board the QuikSCAT satellite that operated from 1999 to 2009. It belongs to NASA, the National Aeronautics and Space Administration in the USA. The mean wind speed is valid at 10 m above sea level.

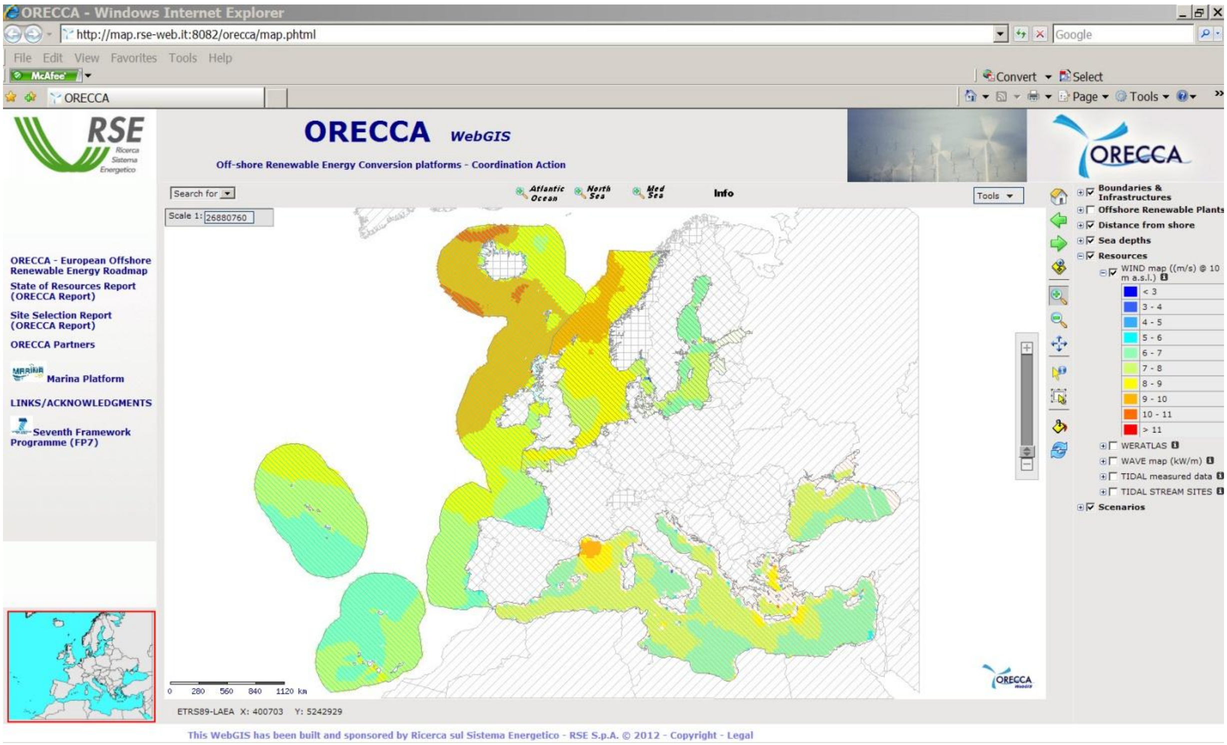


Figure 1 Mean wind speed map of Europe from OCECCA.

In the ORECCA report several regional offshore wind atlases are listed and some are also shown as maps. The overview of wind resources at the European scale is used to evaluate where to find promising wind farm areas. This process has been on-going for many years already and has resulted in an intense development of offshore wind farms primarily in the Northern European Seas. Currently around 4GW of installed offshore wind power capacity is installed and grid connected. The plan for year 2020 is around 40GW offshore wind power capacity and possibly 150 GW in 2030.

In comparison, the wave and tidal current energies do not yet include any commercial plant and the amount of capacity expected for year 2020 is around 2GW.

At the regional scale, wind resources in the Mediterranean Seas and Atlantic Sea (selected areas), and the Northern European Seas including the Baltic Sea, the North Sea and the Irish Sea have been mapped. The regional wind resource maps are superior to the pan-European map in Fig. 2.1 as more detail generally is provided, e.g. including winds at higher levels.

The overall picture of offshore wind resources at the European level is easily accessible. Also the offshore wind farm projects collocated on top of such map is available, see http://map.rse-web.it:8082/orecca/map.phtml. Another good source of information on offshore wind farm projects is http://www.4coffshore.com/offshorewind/ with a global map of offshore wind farm projects, and links to details on each project. It may be noted that meso-scale atmospheric flow models typically are used to assess the offshore wind resources. The calculation time and effort is very high. Even with modern supercomputers we talk months of calculations for an area like the North Sea at say 5 km by 5 km grid resolution.

One limitation of the pan-European and regional offshore wind resource maps is generally that comparison to high-quality offshore wind observations is very sparse. Thus the accuracy of the wind resource maps is not well-known. One reason for only sparse comparison analysis is the relatively few high-quality wind observations available. It is very costly to measure offshore for longer periods. Furthermore, in many cases the data collection of high-quality wind observations from tall offshore meteorological masts is performed within commercial projects. Therefore the data cannot be shared.

Satellite remote sensing of ocean winds has a long history. The continuous archive since 1987 of the passive microwave observations from the SSM/I series is legendary. The global data series include wind speed only but observed around 4 to 6 times per day. Later scatterometers are used operationally to map ocean wind vectors. QuikSCAT provided near-global coverage twice per day coverage for 10 years. At present two ASCAT scatterometers are in operation as well as OSCAT. The use of Synthetic Aperture Radar (SAR) on satellites for ocean wind mapping has been demonstrated during several years.

Specific examples of relevance for the Mermaid project are the maps produced by collaboration between DTU Wind Energy and CLS in the EU NORSEWiND project and publically available at http://soprano.cls.fr/ (Select: Winds/ Statistics (L3)/ Norsewind) shown in *Figure 2* to *Figure 4*. The spatial resolution is around 2 km by 2 km and it is winds at 10 m above mean sea level.

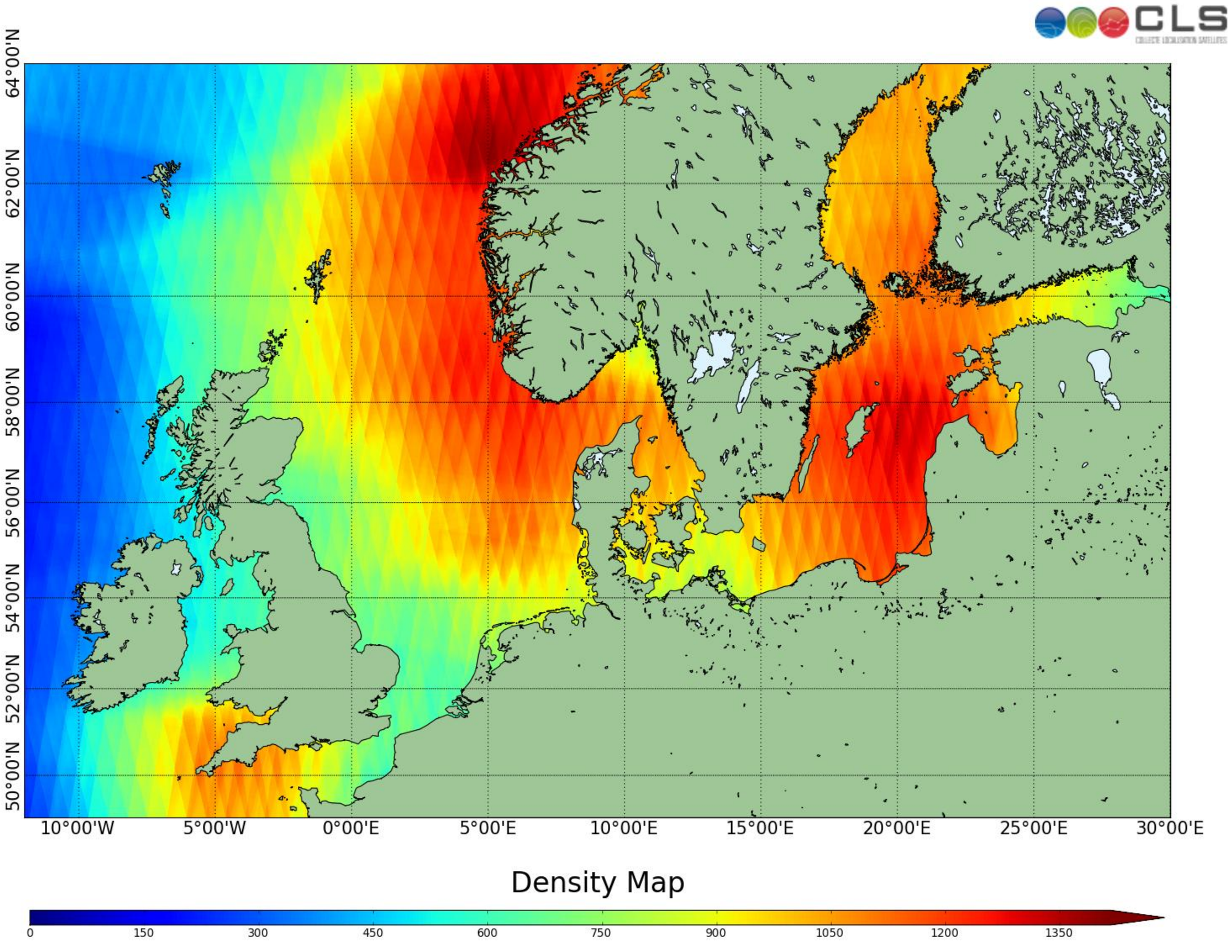


Figure 2 Number of wind overlapping wind maps based on Envisat ASAR of the Northern European Seas. Courtesy: CLS and DTU Wind Energy from the EU-NORSEWiND project.

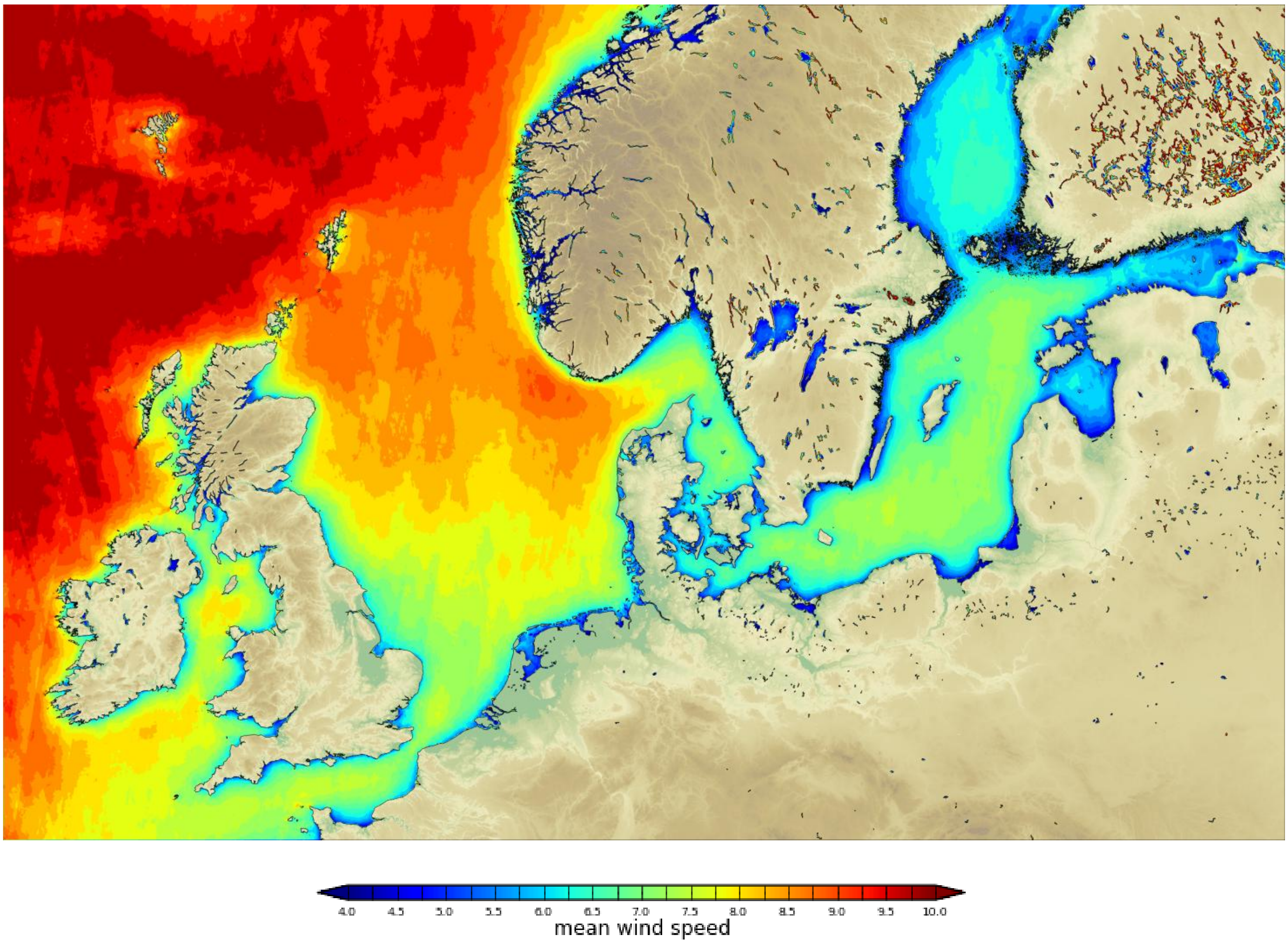


Figure 3 Mean wind speed based on Envisat ASAR of the Northern European Seas. Courtesy: DTU Wind Energy and CLS from the EU-NORSEWiND project.

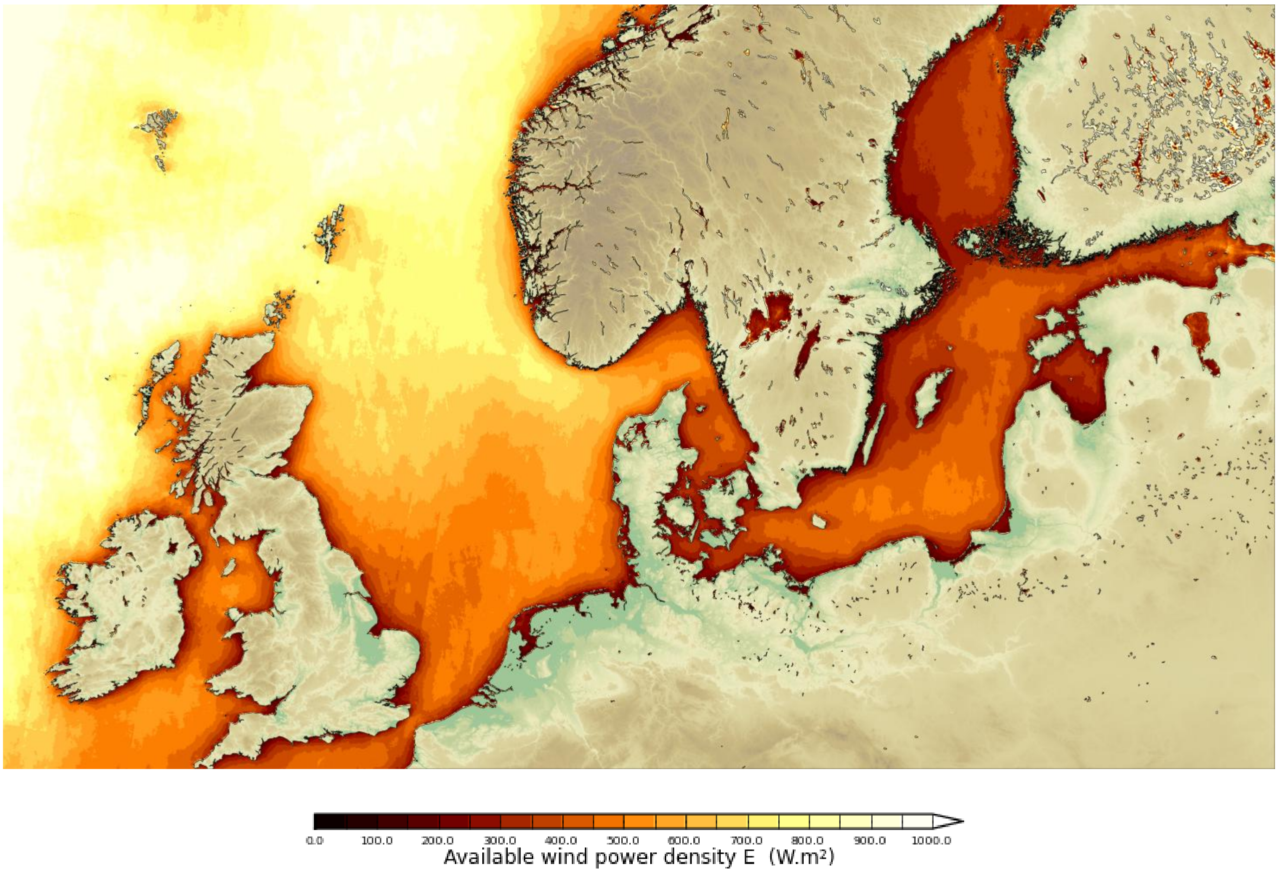


Figure 4 Energy density based on Envisat ASAR of the Northern European Seas. Courtesy: DTU Wind Energy and CLS from the EU-NORSEWiND project.

At the SOPRANO site http://soprano.cls.fr/ (Select: Winds/ Statistics (L3)/ Mediterrane Occidentale) maps from the Western part of the Mediterranean Sea and the Atlantic coast are shown in *Figure 5* to *Figure 6.*

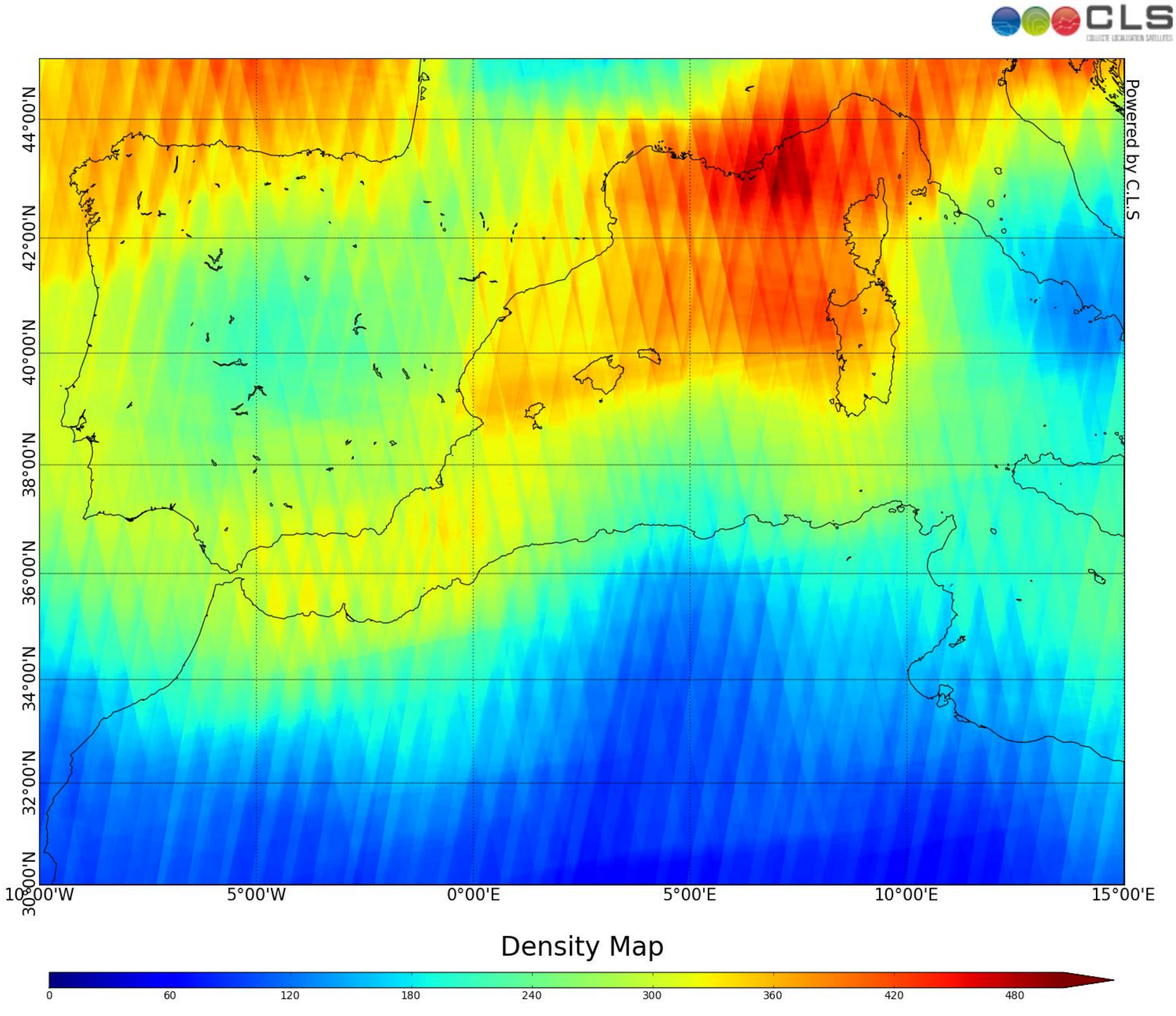


Figure 5 Number of wind overlapping wind maps based on Envisat ASAR of the Western part of the Mediterranean Sea and Atlantic coast. Courtesy: CLS.

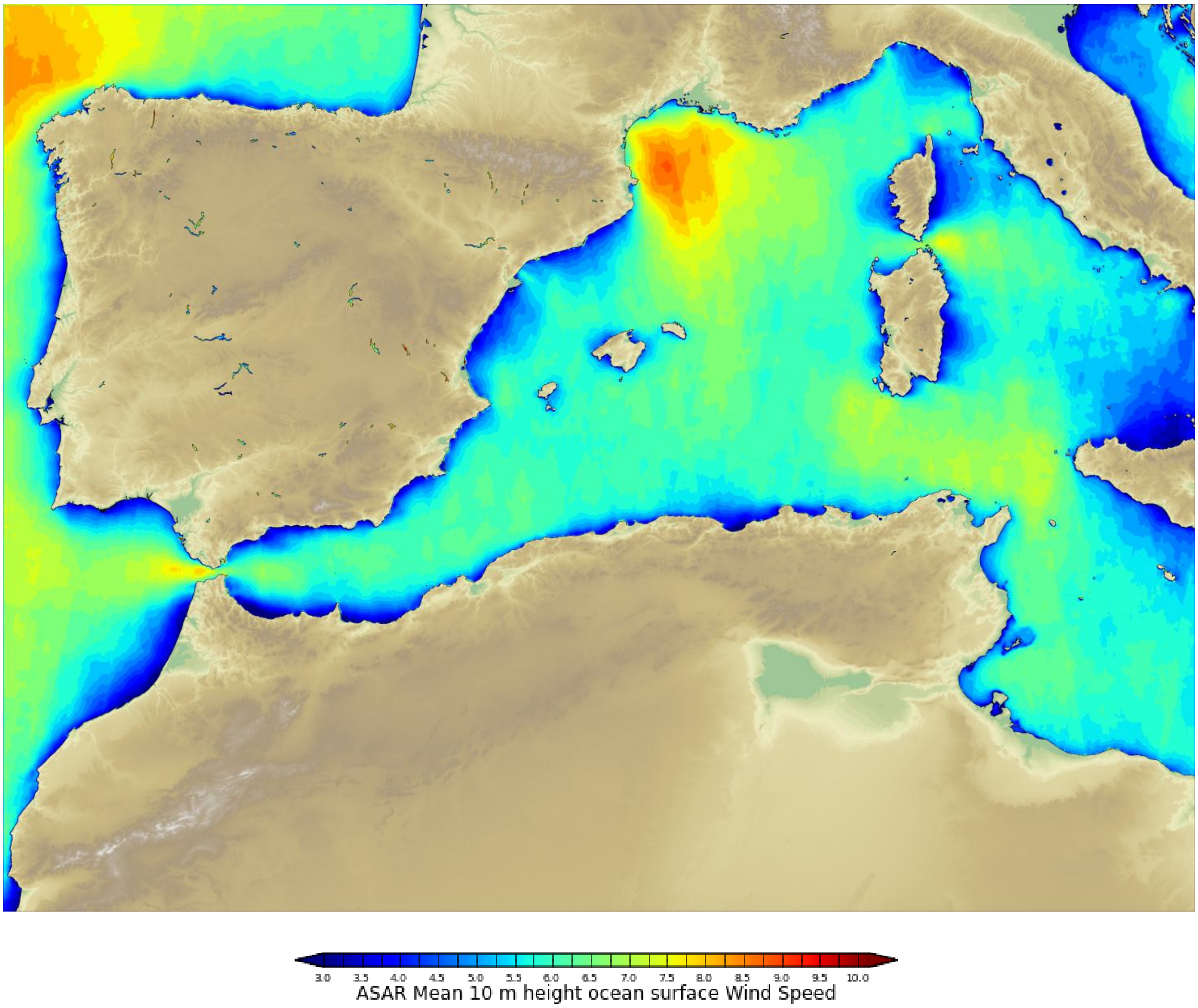


Figure 6 Mean wind speed based on Envisat ASAR of the Western part of the Mediterranean Sea and Atlantic coast. Courtesy: CLS.

In the Mermaid project the aim is not primarily to search for the ideal location for a wind farm. In fact, for three of the selected study sites in Mermaid there are already plans for new offshore wind farms. However, the final results of the Mermaid project may initiate a new type of renewable energy converters combined with other multi-use platforms (MUP). Therefore, the potential wind resource is one of several important factors, when mapping new potential sites for MUPs.

1.2 Wind map at European scale

The meteorological data was produced using the National Center for Atmospheric Research (NCAR) Weather Research and Forecasting (WRF) model (Wang *et al.* 2009). The version used is v3.2.1 that was released 18 August 2010. The model forecasts use 41 vertical levels from the surface to the top of the model located at 50 hPa; 12 of these levels are placed within 1000 m of the surface. The mean wind speed map in figure 7 is at the 100 m level and the spatial resolution is 30 km on a polar stereographic projection with center at 52.2°N, 10°E.

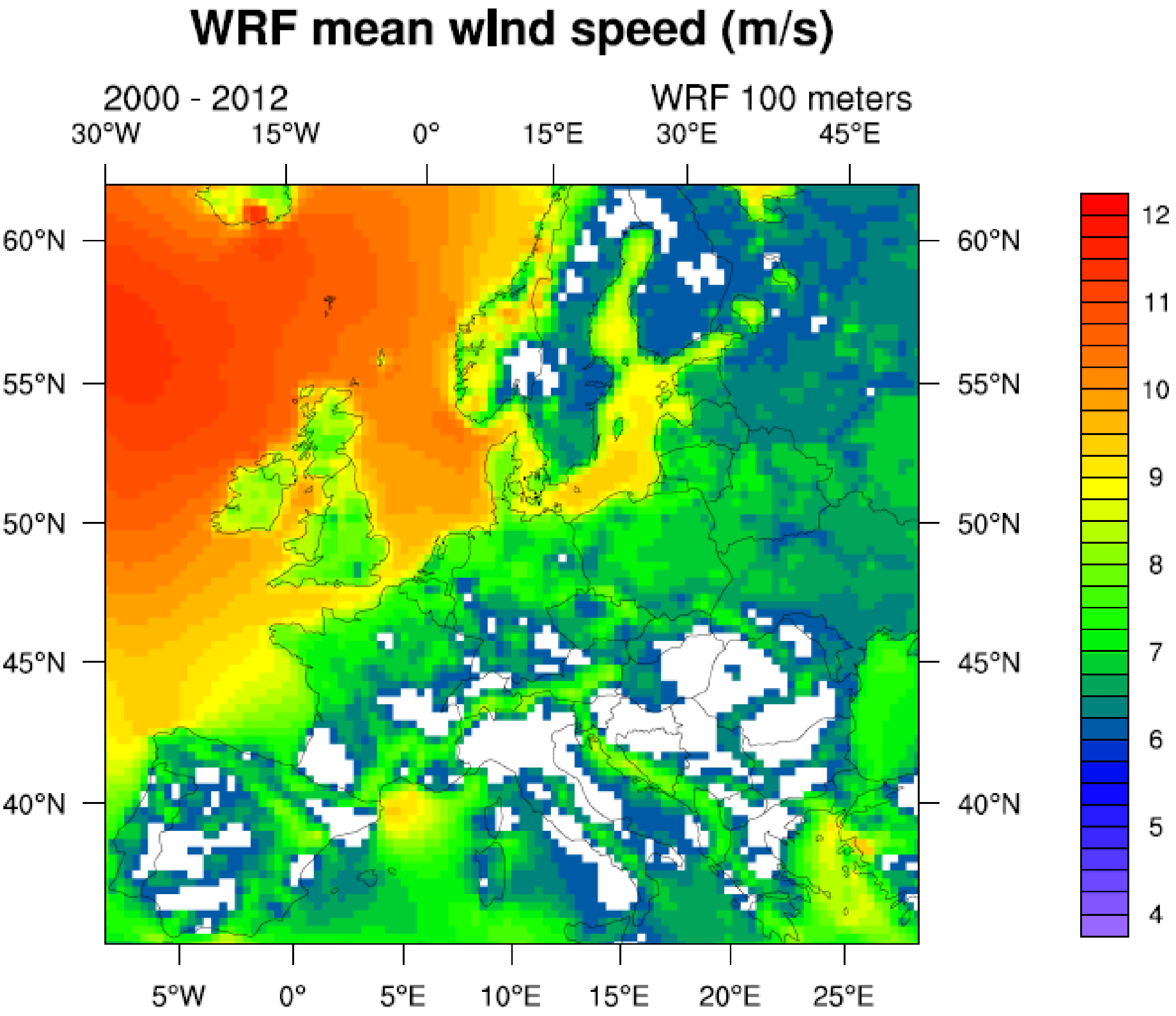


Figure 7 Mean wind speed at 100 m from WRF. Courtesy: Andrea Hahmann, DTU Wind Energy.

2. WAVE RESOURCES

2.1 Background on Wave Resources in Europe

The waves at the ocean surface create a movement of water particles. This requires a work and represents potential energy. In addition, the wave particles move, which represents kinetic energy. The waves travel across the ocean surface carrying their potential and kinetic energy with them. Therefore, the estimation of this energy transport -also called energy flux- characterizes the wave energy.

The generation and propagation of wind sea waves is a complex nonlinear process, in which energy is slowly exchanged between different components. The local behaviour of the waves is determined by the spectrum of the sea state that specifies how the wave energy, proportional to the variance of the surface elevation, is distributed in terms of frequency and direction. This spectrum is usually summarized by a small number of wave parameters, namely wave height, period and direction. Directional spectra and statistics of these wave parameters are the basic information currently used to characterize the wave energy resource, design wave power converters and forecast their performance by means of mathematical or numerical modelling.

Over the last decades, there has been an increasing interest in collecting wave climate information through instrumental devices such as buoys and satellite altimetry. Buoy measurements provide very accurate time series records but they are relatively short and are sparsely located in space, most of them in the Northern Hemisphere. In addition, they usually present interruptions due to disruptions on the normal use caused by buoy failure and maintenance activities. In contrast, satellite observations present a global coverage and also provide information with a high level of precision. However, this source of data is only available since 1992 and with a non-regular time resolution. Both sources of information, buoys and altimetry, do not configure a temporal and spatial homogeneous record of ocean wave climate variables for most of the purposes mentioned above. This issue has motivated an increasing interest in wind wave models, which allow obtaining spatially homogenous long-time series of wave climate parameters. In-situ measurements provide realistic data but are not widely available. Remote sensed data, namely satellite data, are becoming increasingly accurate and available. Numerical wind-wave models take as input wind fields over an ocean basin and compute directional spectra at the nodes of a grid extending over the considered basin(s). Although they cannot be considered as the truth, model results present advantages, namely their proven accuracy for extended oceanic areas and a very low ratio working costs/computational velocity. Measured data and model results show good complementarities. A common practice to improve the accuracy of these models is to calibrate their results against wave data, namely in-situ and satellite data.

The first attempt to assess the offshore European wave energy resource is the WERATLAS project, developed within a R&D European project (INETI et al., 1998, Pontes, 1998). A common methodology and homogeneous data sets was used to build this Atlas. Numerical wind-wave WAM model, run at ECMWF, as well as buoy data was used to get wave information for the North Sea, Norwegian Sea and Barents Sea. The basic resource statistic is the long-term annual value of wave power.

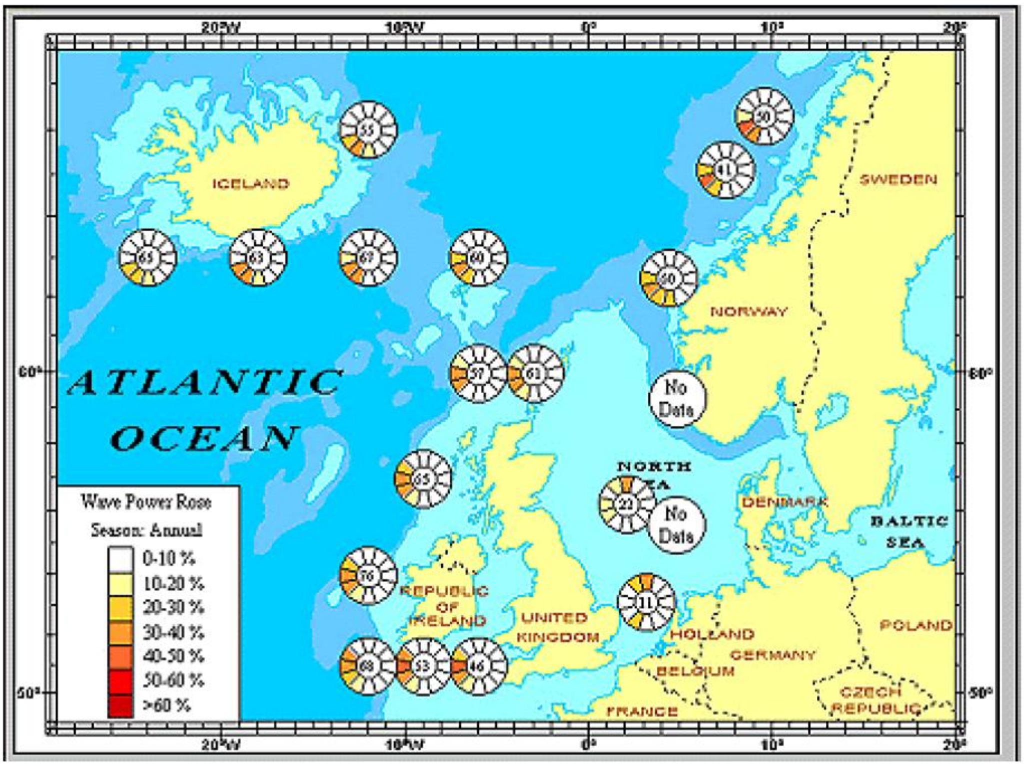


Figure 7 Annual wave power roses for the northern Europe covered by WERATLAS. The figure inside the rose represents the annual power level in kW/m.

During the last decade, various projects dealing with the derivation of wave and wind statistical information in coastal areas and in open sea, such as the EUROWAVES project (Barstow et al. 2001), WORLDWAVES project (Barstow et al., 2003a, 2003b) and MEDATLAS project (Athanassoulis et al., 2004) used numerical calibrated data or wave data from altimeters to derive the statistics for geographical areas of interest.

At regional scale, several authors have already carried out wave energy assessments during the last decade. Some of these works are developed for Ireland (E. E. service, 2005), United Kingdom (A. M. E. R. limited, 2008), Portugal (Pontes and O. P. H., 2005), California (Wilson & Beyene, 2007), Canada (D. Dunnett and W. J S, 2009), the Baltic Sea (Henfridsson et al., 2007), North-West Spanish coast (Iglesias and C. R, 2010) or the whole Spanish coastline (IH Cantabria, 2012, www.enola.ihcantabria.com)

2.2 Assessment of regional European Wave resource atlas

A methodology has been developed by IH Cantabria with the aim of providing a European wave resource atlas (see Figure 8). The methodology can be structured in three steps:

- Development of a Regional Wave Reanalysis (GOW).
- Calibration of GOW by using satellite data.
- Wave energy flux assessment.

The main requirement to characterize the wave energy resource is to get a homogeneous wave dataset. The dataset must have high temporal and spatial resolution and must be long enough to characterize wave climatologies. Therefore, a dynamic downscaling of historical waves, covering the European coast, is required. Historical global waves and ice-cover must be used as boundary conditions, whilst an appropriate bathymetry and historical regional wind fields as forcing. Because wave simulations sometimes do not accurately model the wave processes, a validation/calibration is required. Once regional wave data is validated/calibrated, wave energy resource is assessed.

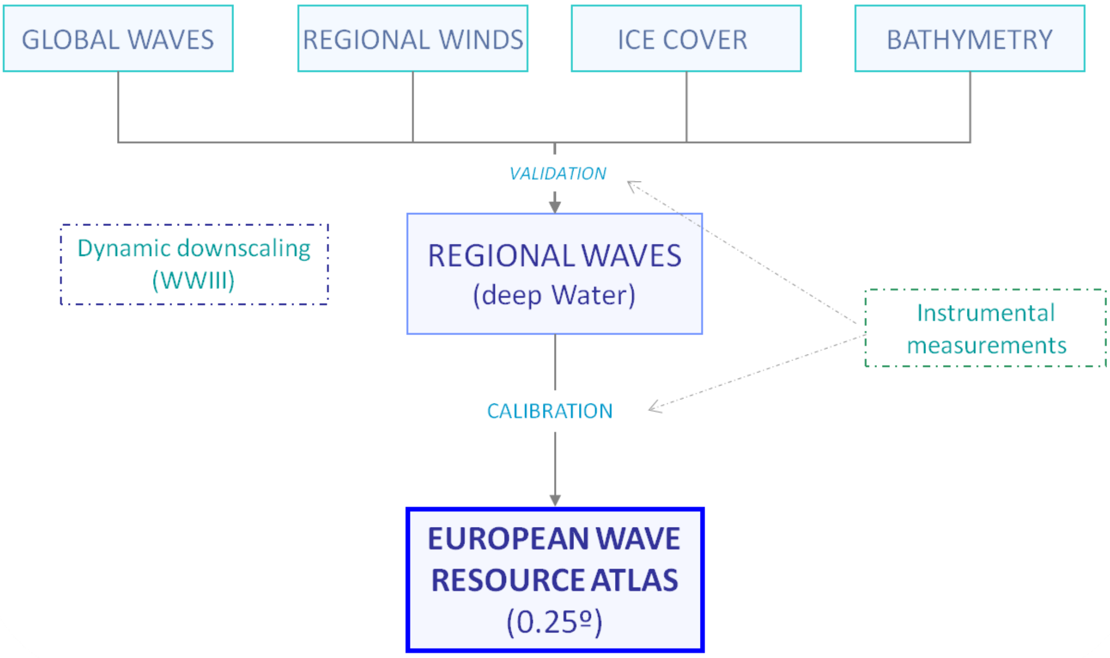


Figure 8 Diagram of the developed methodology to estimate a European wave resource atlas.

2.2.1 Development of a Regional Wave Reanalysis (GOW)

Ocean surface gravity waves are the result of an important exchange of energy and momentum at the ocean–atmosphere interface. Waves propagate through the ocean basins transporting the accumulated energy obtained from the wind. During wave propagation, some energy is dissipated through different processes. The knowledge about how energy from winds transfers into the seas and how this energy propagates and dissipates is of great importance.

The most advanced state-of-the-art wind wave models are the third generation wave models (Komen et al., 1994). Two of the most relevant and widely used within this group are the wave models WAM (Hasselman et al., 1998) and Wavewatch III (Tolman, 2002, 2009). Wind wave models are driven by wind fields and constrained by ocean basin, and the quality of the wave simulation depends upon the quality of wind forcing. The most recent model is Wavewatch III.

The GOW dataset (Global Ocean Waves) is a historical reconstruction of ocean waves developed by IH Cantabria. GOW has been generated from the spectral model WaveWatch III. Wavewatch III is a third generation wave model developed at NOAA-NCEP (Tolman, 2002; 2009). It solves the spectral action density balance equation for wave number direction spectra. The implicit assumption of this equation is that properties of the medium (water depth and current) as well as the wave field itself vary in time and space scales that are much larger than those of a single wave. The model can generally be applied to large spatial scales and outside the surf zone. Parameterizations of physical processes include wave growth and decay due to the actions of wind, nonlinear resonant interactions, dissipation (whitecapping) and bottom friction.

The wave spectra information from a global wave reanalysis (GOW dataset, more details in Reguero et al., 2012) are the boundary conditions for a regional European wave simulation. Global GOW was forcing with NCEP-NCAR R1 wind and ice fields and has a spatial resolution of 1x1.5º. A dynamical atmospheric downscaling of NCEP wind fields has been developed over the European region to be able to simulate relevant meso-scale atmospheric processes. The downscaled wind fields, named SeaWind (Menéndez et al., 2013), have been used as forcing on regional wave reanalysis. The SeaWind and regional GOW spatial domains are shown in Figure 9. The spatial resolution of the regional GOW is 0.25 degrees. Bathymetry data used for the simulation comes from the ETOPO dataset (NOAA, 2006). The minimum propagation time step used for the computation was 15 s and the spectral resolution covers 72 regularly spaced directions. Frequencies extend from 0.03679 hz with 25 frequency steps and a frequency increment factor of 1.1.

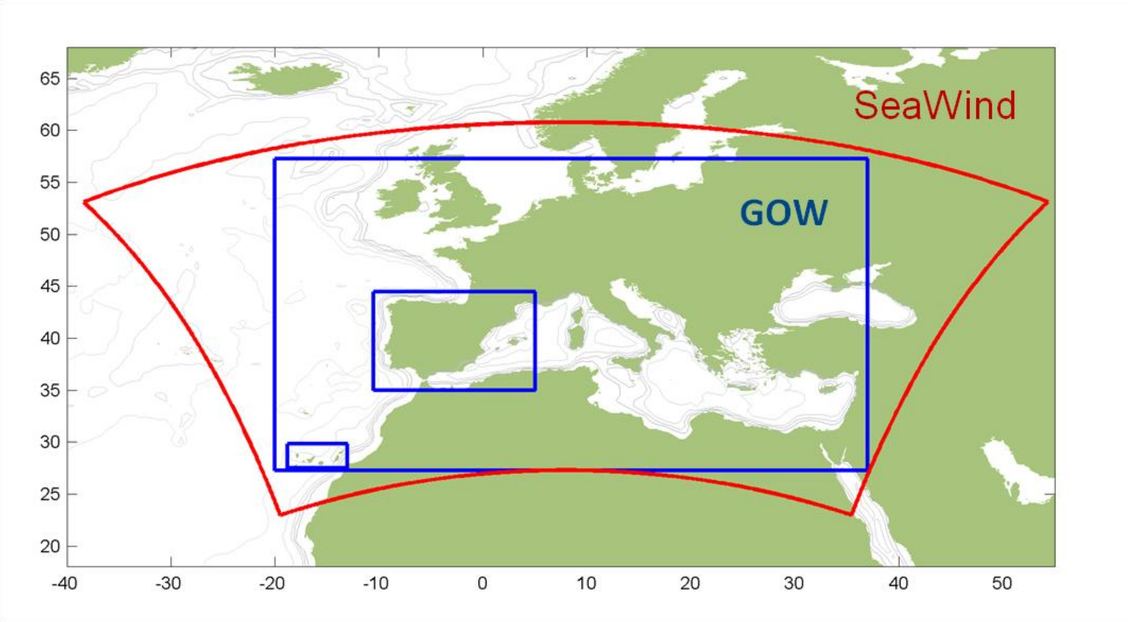


Figure 9 Spatial domain of the used high resolution wind fields (red) to downscaled European waves (blue).

The grid-points from this regional reanalysis covering the European coasts have been selected (Figure 10). 3344 locations were selected and the hourly sea state parameters recorded to assess the wave energy resource.

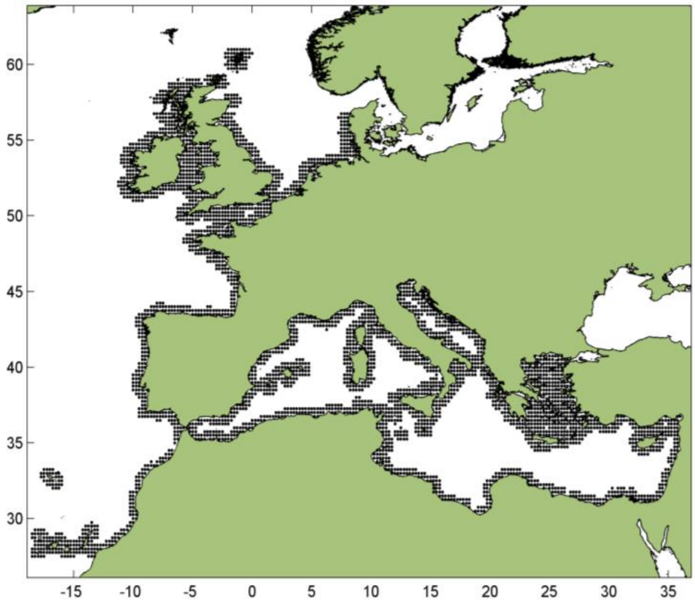


Figure 10 Selected locations to assess the European wave energy Atlas.

An important aspect within wave reanalyses is the validation process using instrumental information. For this particular issue, we compare wave model results with measurements from deep-water buoys at different locations and altimeter data. Figure 11 shows the scatter plots and several statistical indices on three different locations for the regional GOW against observations (buoy records and satellite information). For these three locations GOW shows very good agreements with respect to instrumental data.

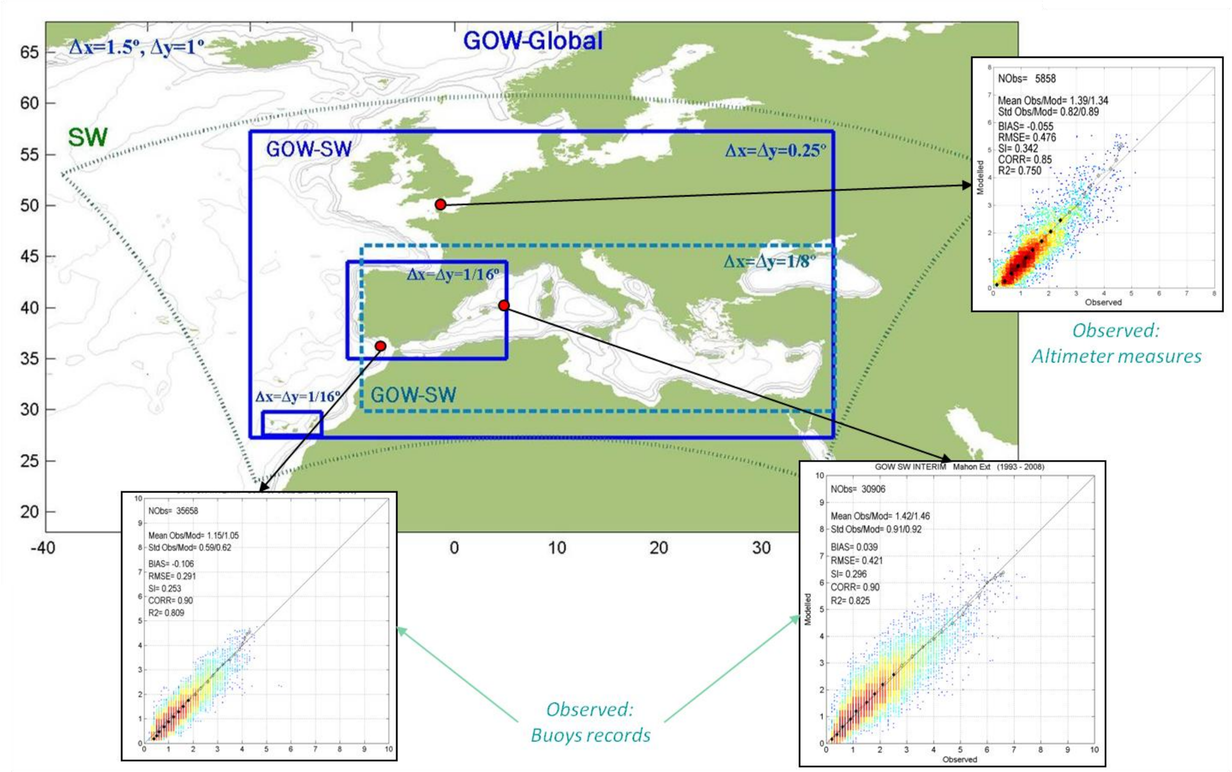


Figure 11 Validation of regional wave reanalysis at local sites from buoy records and satellite observations.

2.2.2 Calibration of GOW by using satellite data

In order to reduce possible discrepancies of numerical results with respect to the instrumental data, a calibration procedure using satellite info is applied to the GOW significant wave height. The discrepancies could be due to flaws in the wind fields, insufficient model resolution, unresolved island blocking, imperfect bathymetries, etc. The calibration of the GOW significant wave heights takes into account mean wave directions to embed satellite information. The calibration procedure is based on measurements taken during the satellite age and the correction is applied for the full period of wave hindcast.

Only satellite data from altimeters are considered and the corresponding data pairs of numerical and altimeter observations are used in the calibration procedure. The applied calibration technique is a parametric method based on a nonlinear regression problem.

Briefly, the correction parameters vary smoothly along the possible directions by means of cubic splines, allowing different corrections depending on the direction. Corrections are made on empirical quantile information on a Gumbel probability paper scale giving more relevance on the calibration procedure to the maximum data (Figure 12). A detailed description of the methodology can be found in Minguez et al., 2011.

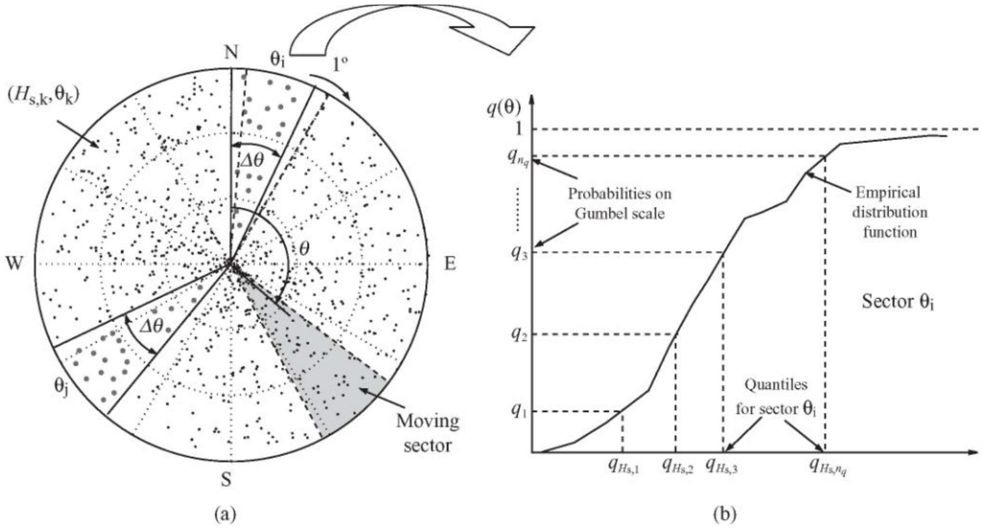
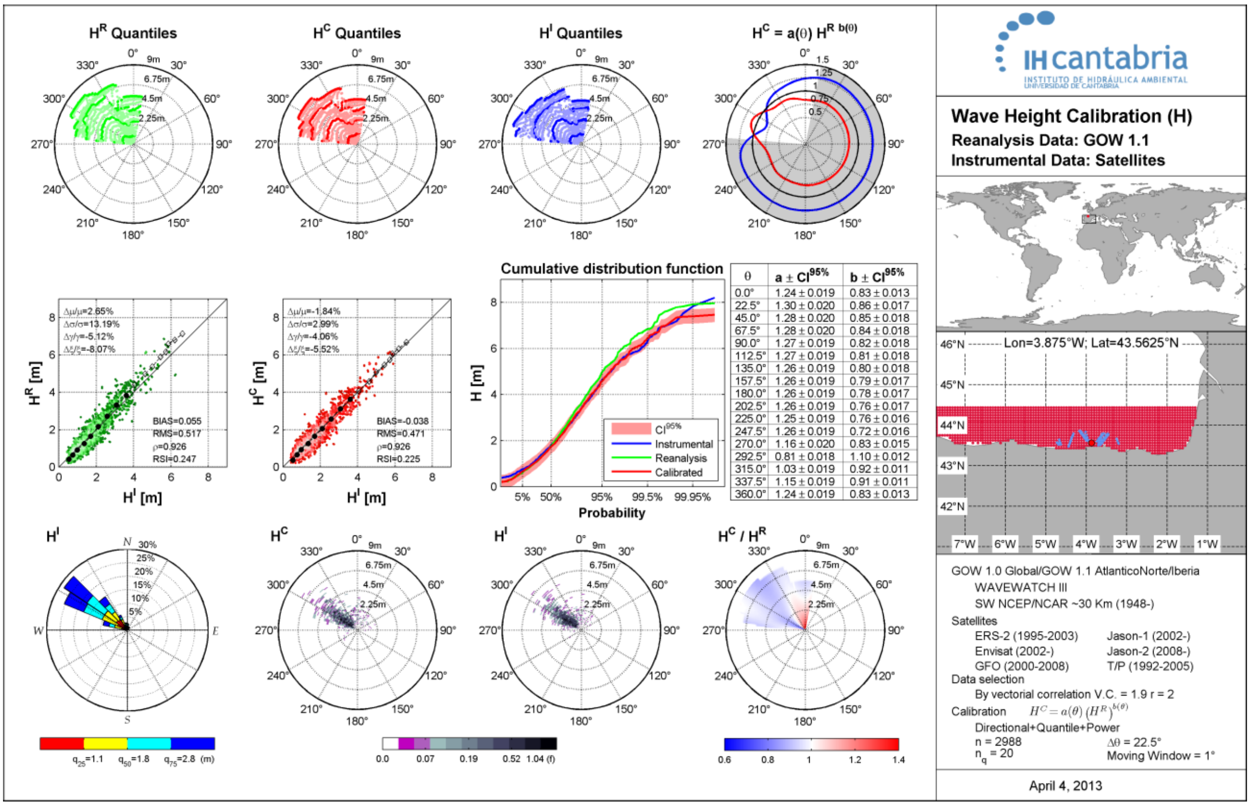


Figure 12 Data selection for the calibration procedure: (a) moving sector for smooth quantile evaluation and

The results of the calibration of the Spanish and Italian sites are shown in Figure 13 and Figure 14. The grid point and data pairs used for calibration are shown on the right of the figures. The quantile plots on a polar scale are shown on the top of the figures. Green colour means raw data from reanalysis (HsMOD), blue colour means the altimeter data (HsSAT) and red colour is the data after calibration procedure (HsModC). The scatter plots and CDF are shown in the middle of the figures. Classical rose, polar density functions of HsMOD and HsModC and changes due to parametric calibration are shown at the bottom of the figures. The estimated parameters of the calibration are also provided in the figures.



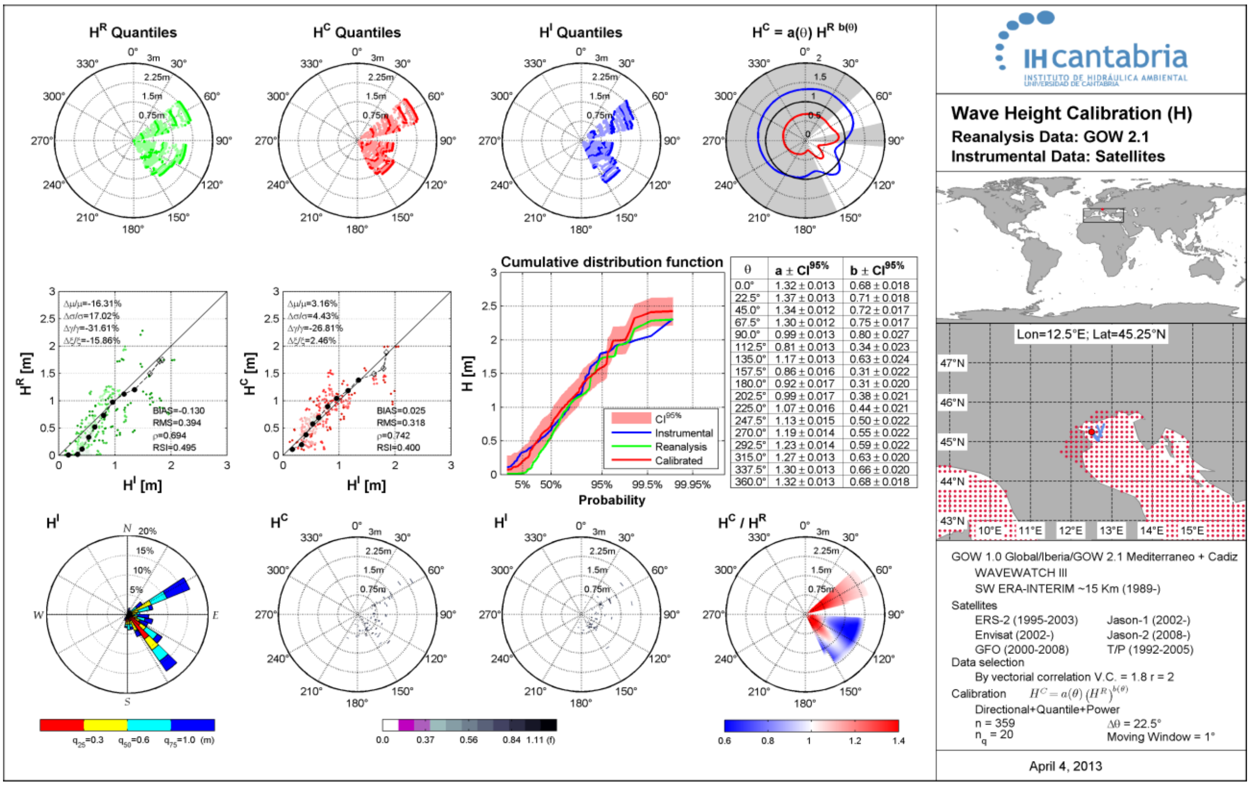
Wave Height Calibration (H)
Reanalysis Data: GOW 1.1
Instrumental Data: Satellites

θ	a ± $CI^{95\%}$	b ± $CI^{95\%}$
0.0°	1.24 ± 0.019	0.83 ± 0.013
22.5°	1.30 ± 0.020	0.86 ± 0.017
45.0°	1.28 ± 0.020	0.85 ± 0.018
67.5°	1.28 ± 0.020	0.84 ± 0.018
90.0°	1.27 ± 0.019	0.82 ± 0.018
112.5°	1.27 ± 0.019	0.81 ± 0.018
135.0°	1.26 ± 0.019	0.80 ± 0.018
157.5°	1.26 ± 0.019	0.79 ± 0.017
180.0°	1.26 ± 0.019	0.78 ± 0.017
202.5°	1.26 ± 0.019	0.76 ± 0.017
225.0°	1.25 ± 0.019	0.76 ± 0.016
247.5°	1.26 ± 0.019	0.72 ± 0.016
270.0°	1.16 ± 0.020	0.83 ± 0.015
292.5°	0.81 ± 0.018	1.10 ± 0.012
315.0°	1.03 ± 0.019	0.92 ± 0.011
337.5°	1.15 ± 0.019	0.91 ± 0.011
360.0°	1.24 ± 0.019	0.83 ± 0.013

GOW 1.0 Global/GOW 1.1 AtlanticoNorte/Iberia
WAVEWATCH III
SW NCEP/NCAR ~30 Km (1948-)
Satellites
ERS-2 (1995-2003) Jason-1 (2002-)
Envisat (2002-) Jason-2 (2008-)
GFO (2000-2008) T/P (1992-2005)
Data selection
By vectorial correlation V.C. = 1.9 r = 2
Calibration $H^C = a(\theta)\,(H^R)^{b(\theta)}$
Directional+Quantile+Power
n = 2988 Δθ = 22.5°
n_q = 20 Moving Window = 1°

April 4, 2013

Figure 13 Calibration card of wave heights at the Spanish-Atlantic Site.



θ	a ± CI$^{95\%}$	b ± CI$^{95\%}$
0.0°	1.32 ± 0.013	0.68 ± 0.018
22.5°	1.37 ± 0.013	0.71 ± 0.018
45.0°	1.34 ± 0.012	0.72 ± 0.017
67.5°	1.30 ± 0.012	0.75 ± 0.017
90.0°	0.99 ± 0.013	0.80 ± 0.027
112.5°	0.81 ± 0.013	0.34 ± 0.023
135.0°	1.17 ± 0.013	0.63 ± 0.024
157.5°	0.86 ± 0.016	0.31 ± 0.022
180.0°	0.92 ± 0.017	0.31 ± 0.020
202.5°	0.99 ± 0.017	0.38 ± 0.021
225.0°	1.07 ± 0.016	0.44 ± 0.021
247.5°	1.13 ± 0.015	0.50 ± 0.022
270.0°	1.19 ± 0.014	0.55 ± 0.022
292.5°	1.23 ± 0.014	0.59 ± 0.022
315.0°	1.27 ± 0.013	0.63 ± 0.020
337.5°	1.30 ± 0.013	0.66 ± 0.020
360.0°	1.32 ± 0.013	0.68 ± 0.018

GOW 1.0 Global/Iberia/GOW 2.1 Mediterraneo + Cadiz
WAVEWATCH III
SW ERA-INTERIM ~15 Km (1989-)
Satellites
ERS-2 (1995-2003) Jason-1 (2002-)
Envisat (2002-) Jason-2 (2008-)
GFO (2000-2008) T/P (1992-2005)
Data selection
By vectorial correlation V.C. = 1.8 r = 2
Calibration $H^C = a(\theta)\ (H^R)^{b(\theta)}$
Directional+Quantile+Power
n = 359 $\Delta\theta$ = 22.5°
n_q = 20 Moving Window = 1°

April 4, 2013

Figure 14 Calibration card of wave heights at the Italian-Mediterranean study site.

2.2.3 Wave energy flux assessment

The hourly wave energy flux has been assessed for the 3.344 selected grid–points along the European coastline. The wave energy is proportional to the square of the wave height and dependent of the group celerity of the waves and water density. The wave energy power is estimated at annual and seasonal time scales.

Figure 15 shows the atlas of the annual wave energy power. Highest energies can be found in the west coast of Ireland and northwest coast of Scotland, high wave energy values are also found along the Portuguese coast, NorthWestern Spanish coast and Bretagne region of France. In contrast, the North Sea and Mediterranean Sea has not high wave energy potential.

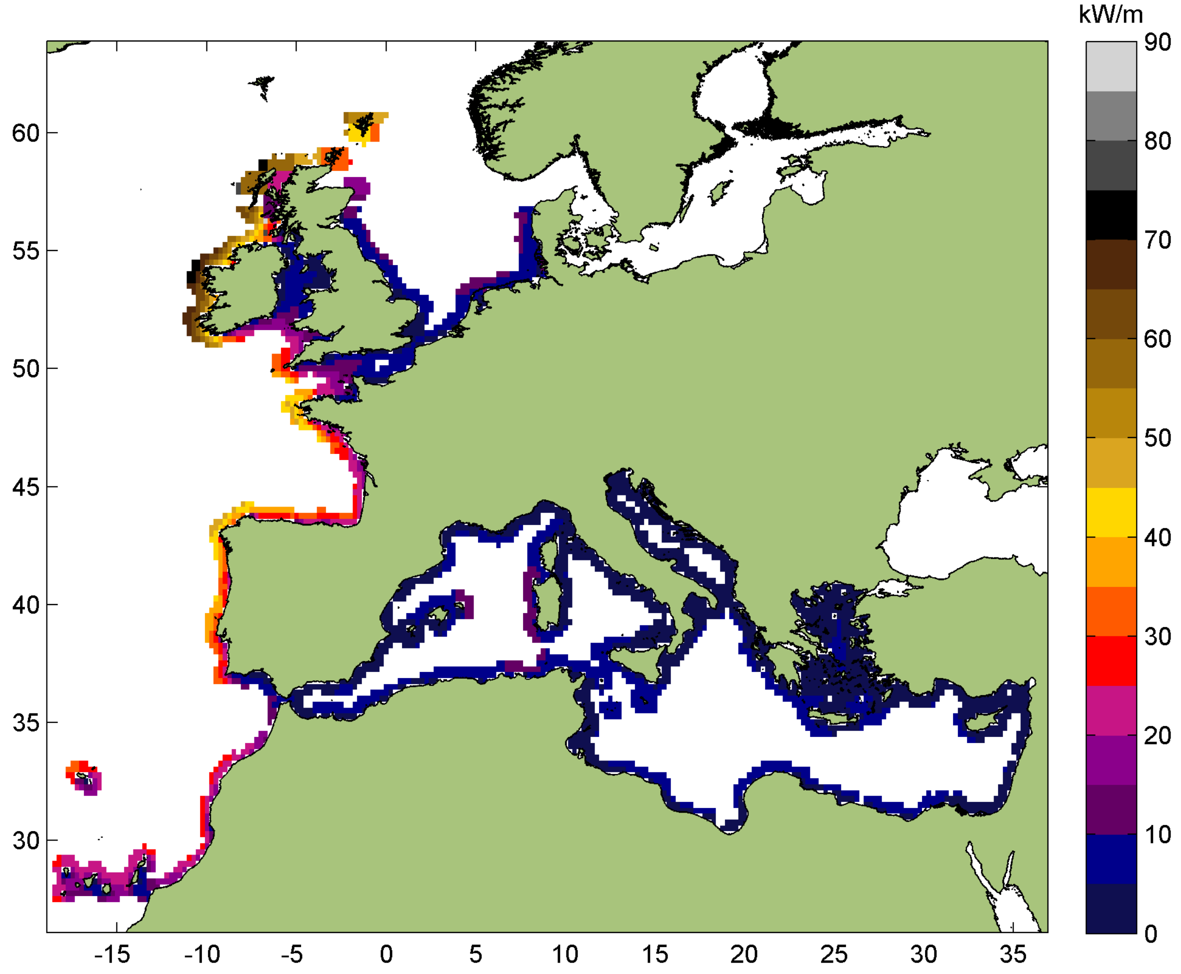


Figure 15 Annual wave energy.

The seasonal wave energy power atlases have been also estimated (Figure 16). Seasonal variability shows that the Atlantic European coast and North-western North Sea are the potential regions for wave energy extraction.

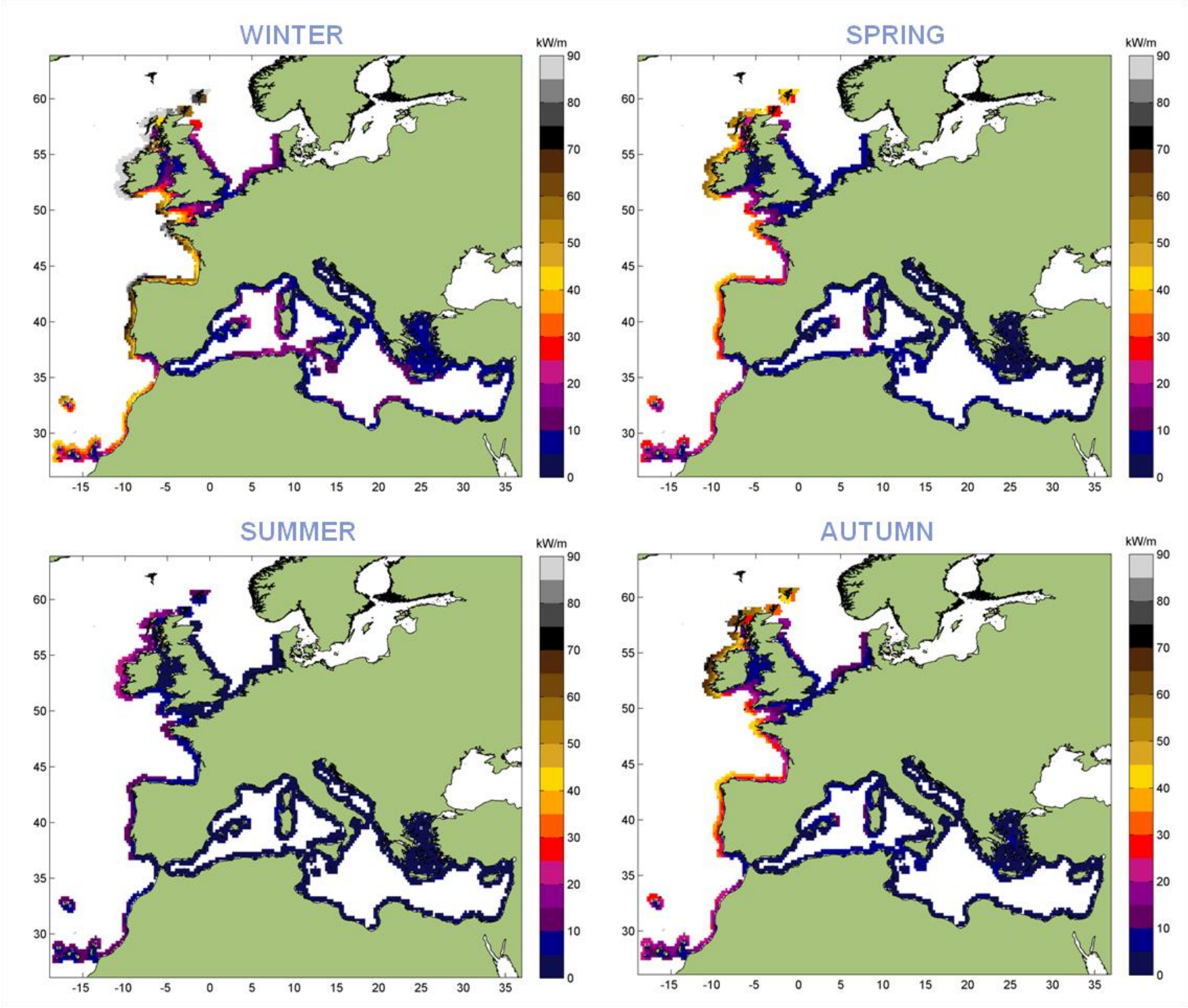


Figure 16 Seasonal wave energy.

3. CURRENTS RESOURCES

In order to characterize the potential current energy resource it would be desirable to rely completely on measured data and do not utilize model results. However, measurements are rarely available. Usually the nearest buoy is located some kilometres from the objective point, not being representative of the local climate. Even when such records are available, they usually present missing data and time series are not sufficiently long to correctly define the long-term distribution of the currents. Therefore, the use of numerical models is needed to quantify current resources. Nowadays, results of ocean tides are available from several global models based on satellite altimeter. In this work, results from TPXO global tidal model (TPXO7.2, Oregon State University TOPEX/Poseidon global inverse solution) have been used. This model provides tides as complex amplitudes of earth-relative sea-surface elevation for eight primary (M2, S2, N2, K2, K1, O1, P1, Q1), two long period (Mf,Mm) and 3 non-linear (M4, MS4, MN4) harmonic constituents in a global grid at low resolution (0.25ºx0.25º). Surface elevation and currents can be estimated from these data through a harmonic prediction. Figure 18 shows the tidal amplitude for the M2 component estimated with TPXO model.

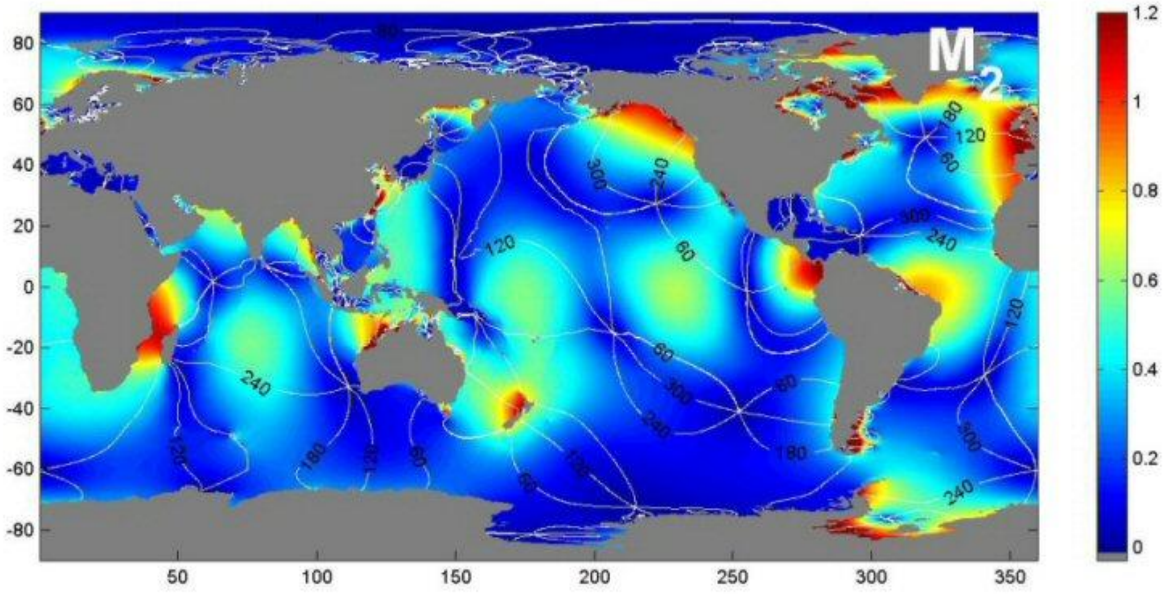


Figure 18 Map of the M2 component estimated with TPXO model.

Source: http://volkov.oce.orst.edu/tides/global.html

3.1 Methodology in the Atlantic study site

To assess tidal current resources in the Atlantic sea, the information produced by TPXO model was propagated to shallow waters increasing the spatial resolution (downscaling). This higher resolution allows taking into account a more detailed bathymetry and also the geometry of the coast. Therefore an accurate estimation of the tidal current resources was obtained.

The model employed in the downscaling process was the Regional Oceanic Modeling System (ROMS), a free surface terrain following three dimensional ocean model. ROMS solves the Primitive Equations in a rotating environment, based on the Boussinesq approximation and hydrostatic vertical momentum balance [Shchepetkin and Mcwilliams, 2005; Haidvogel et al., 2008]. Results from TPXO global tidal model were used to impose the harmonically predicted tidal elevation and currents at the open boundaries of the grid. The grid used in the tide propagation (Figure 19) has a horizontal resolution of 1 nautical mile (~1.85 km). ROMS model was run for a representative year (2001). As a result of the numerical modelling, hourly tidal currents (magnitude and direction) were obtained for the entire year 2001.

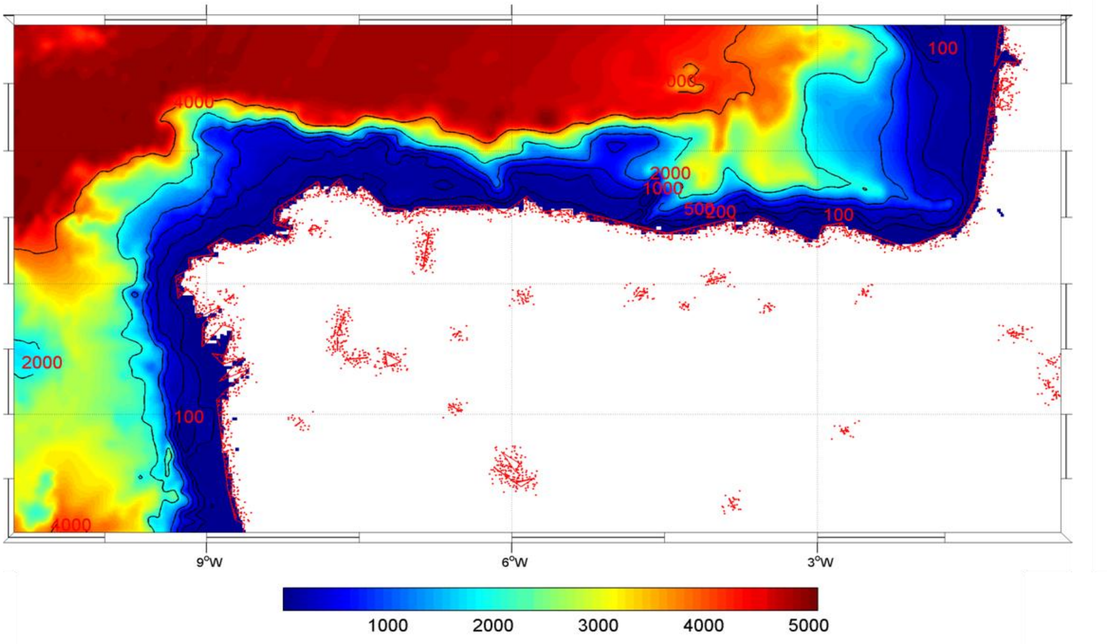


Figure 19 Grid domain used in the tide propagation for the Atlantic Study Site.

3.2 Results

Tidal currents for Baltic Sea, North Sea, Mediterranean Sea and Atlantic Sea study sites were calculated using TPXO7.2 database. An example of the astronomical tidal currents obtained with TPXO is shown in Figure 20. Data are plotted, at each study site, at the instant where maximum velocities were reached for the year 2001. As can be seen, the North Sea study site is where the maximum currents were found, with values up to 0.7 m/s. On the other side, the Baltic Sea and Mediterranean Sea study sites show the lowest velocities, with values around 0.01 and 0.05 m/s, respectively. The Atlantic study site will be studied deeply through the results of the dynamical downscaling.

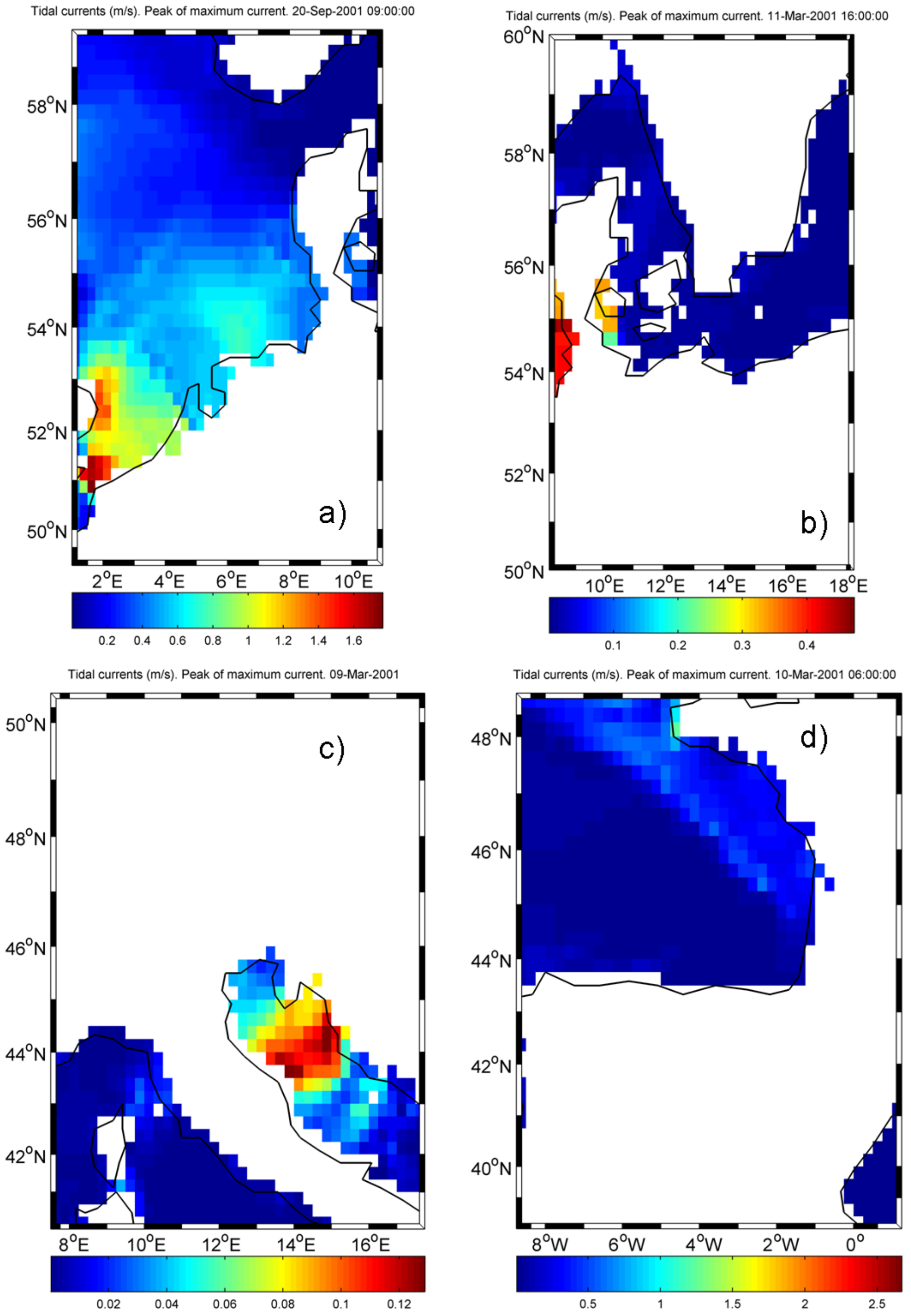


Figure 20 Instant of maximum velocities (m/s) at each study site. a) North Sea b) Baltic Sea c) Mediterranean Sea d) Atlantic Sea.

At the Atlantic study site, hourly results from the numerical downscaling were post-processed to obtain representative indicators of the current resource.

Next figures show the magnitude of the current associated with different tidal states. Figure 21 and Figure 22 display the peak of the tidal current for the equinoctial spring tide and for the lowest neap tide, respectively. Figure 23 and Figure 24 present the mean values for all the peaks during spring and neap tides, respectively. As can be seen in these figures, rather strong spatial variations are present during spring tides, with values ranging from 0.01 to 0.1 m/s. In neap tides, tidal currents are more homogenous, with values of around 0.01 - 0.05 m/s. As expected, maximum values were obtained during equinoctial spring tides, period where the maximum tide range takes place. Lowest values were obtained at the lowest neap tide, were the minimum tide range occurs.

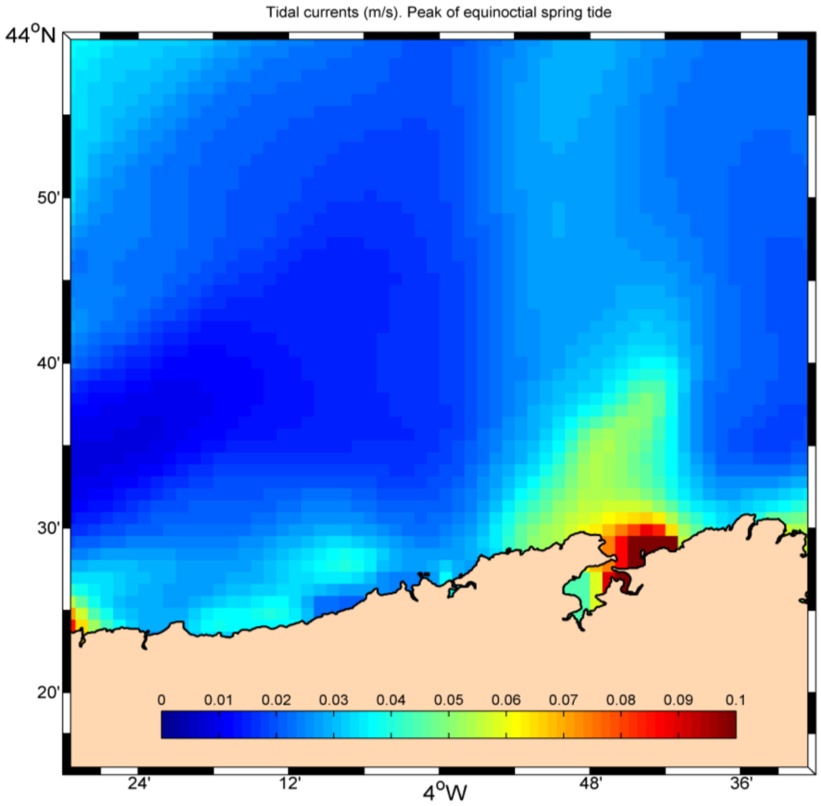


Figure 21 Peak of tidal current for the equinoctial spring tide (m/s)

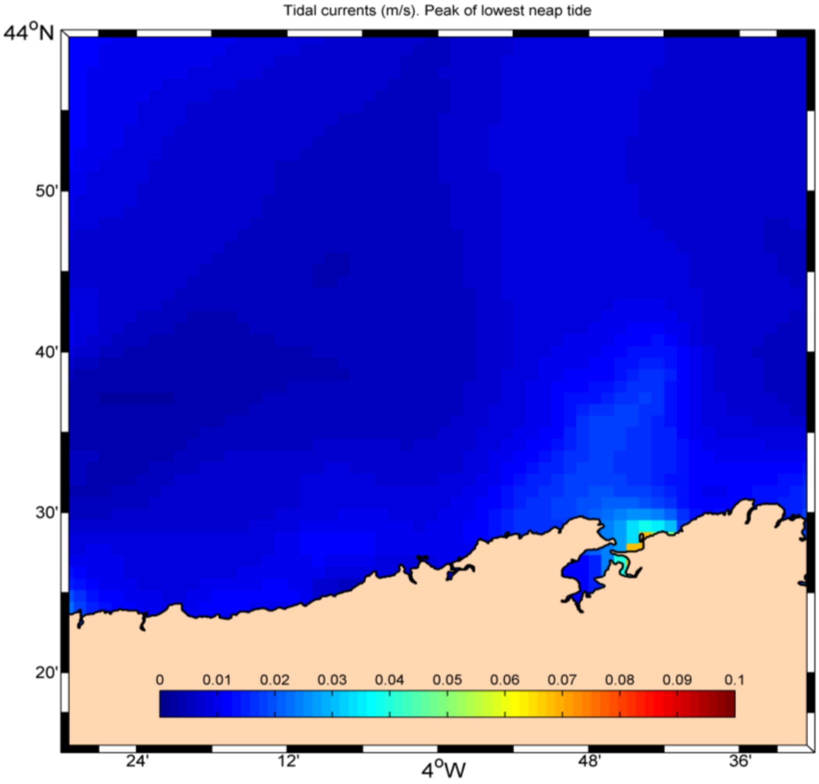


Figure 22 Peak of tidal current for the lowest neap tide (m/s)

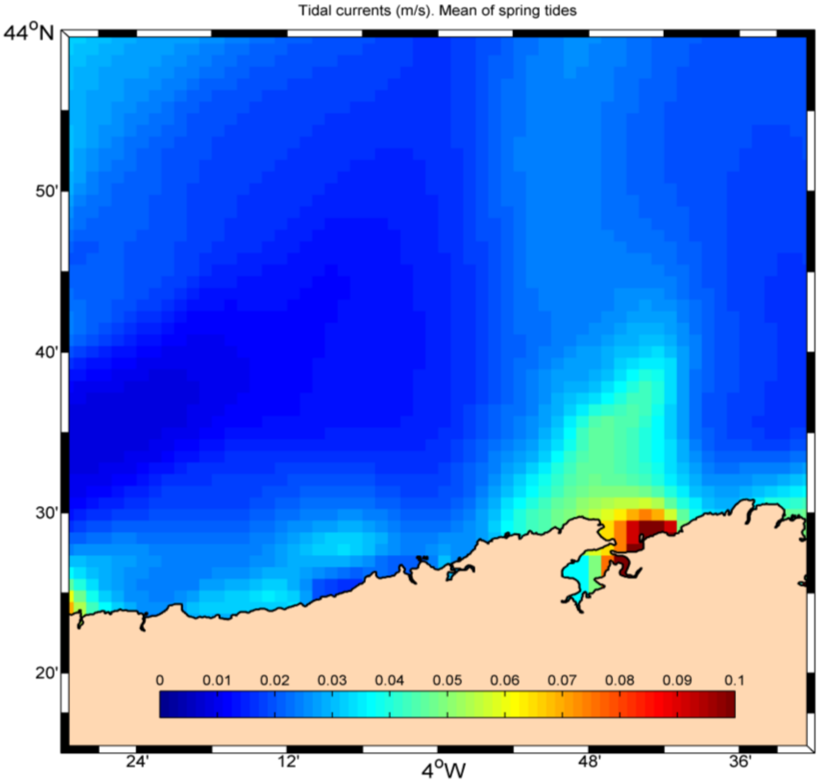


Figure 23 Mean values of peaks in spring tides (m/s).

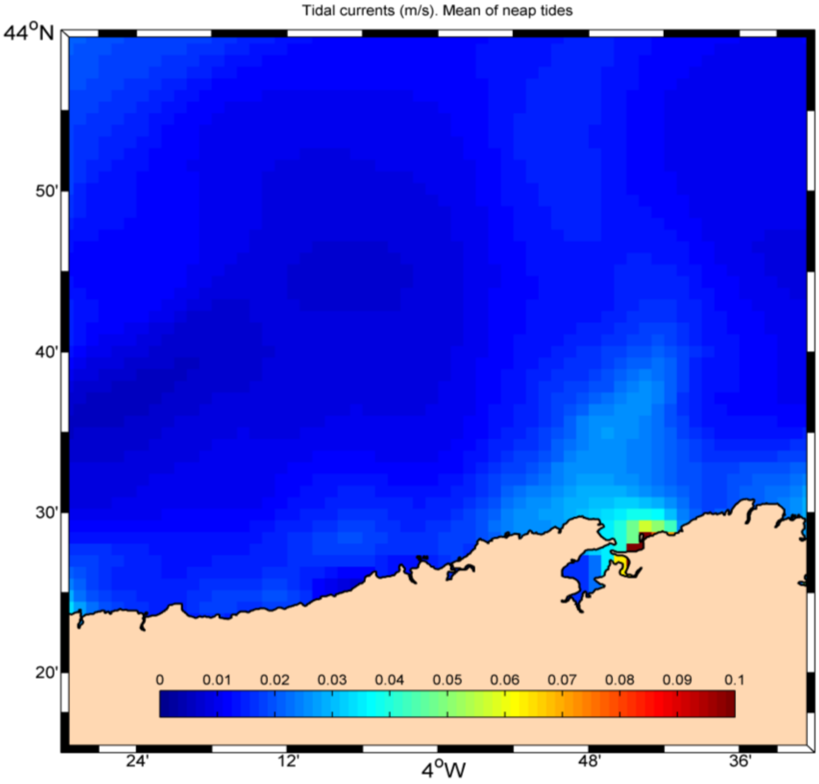


Figure 24 Mean values of peaks in neap tides (m/s).

4. CONCLUSIONS

The general wind climate of European waters is quite well known from several modelling and observational studies including satellite data. Specific offshore wind climate details at a wide range of sites observed near existing or planned offshore wind farms is generally of confidential nature. Therefore the model results are not easily evaluated due to limited access to high quality wind data. In the Mermaid project there are two aims of characterising wind resources. One is as a general broad overview at European scale given in this report. The other is more specific site dependent on the four selected Mermaid sites. This information will be given in Deliverable 5.1.

Similarly the wave and current resources in Europe are given as overview in the present report, and more detailed in a following report.

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