GROWTH AND INNOVATION IN OCEAN ECONOMY

GAPS AND PRIORITIES IN SEA BASIN OBSERVATION AND DATA

D2.3.5 MedSea Checkpoint Challenge 1 (Wind Farm Siting): Description of Targeted Products, the methodology and the expert evaluation of fitness for purpose

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Glossary

CMCC - Centro Euro-Mediterraneo per i Cambiamenti Climatici S.c.a r.l. (IT)

CLS - Collecte Localisation Satellites (FR)

CLU - CLU s.r.l. (IT)

EDF EN (FR)

ENEA - Agenzia per le Nuove Tecnologie, l'Energia e lo Sviluppo Economico Sostenibile (IT)

FEM - France Energies Marines

HCMR - Hellenic Centre for Marine Research (GR)

IFREMER - Institut Français de Recherche pour l'Exploitation de la Mer (FR)

INGV - Istituto Nazionale di Geofisica e Vulcanologia (IT)

NKUA – National Kapodistrian University of Athens (GR)

OCEANS-CAT - OCEANS Catalonia International SL (ES)

SOCIB - Balearic Islands Coastal Observing and Forecasting System (ES)

UCY - University of Cyprus (CY)

FEM - Association de Préfiguration de l’IEED France Energies Marines (FR)

IH Cantabria - Fundación Instituto de Hidráulica Ambiental de Cantabria (ES)

Executive Summary

The primary aim of the wind farm siting challenge is to assess whether the currently available data on the Mediterranean Sea are appropriate for the preliminary assessment required to identify potential new farm sites. A variety of factors are considered to be important for wind farm siting. These factors include the natural resources data that can be used to define the energy potential of the area and the local climatic characteristics, and the intense anthropogenic activity, biodiversity, and sediment characteristics that may affect the installation of wind turbines in the area of interest. Useful information on the factors that might exert constraints can result in the site being classified as unsuitable for development.

To provide this information, three targeted products were defined as outputs of this challenge and are described in detail in the following pages:

- **MEDSEA_CH1_Product_1**: A wind and wave data set
- **MEDSEA_CH1_Product_2**: A suitability index for a wind farm in the NW Mediterranean based on the environmental resources
- **MEDSEA_CH1_Product_3**: A suitability index for a wind farm in the NW Med based on the environmental resources, natural barriers, human activities, Marine Protected Areas (MPA) and fisheries.

A broad range of data were identified, downloaded where possible and reviewed for the challenge. The discoverability and accessibility of the data and their format and usability varied a lot, depending on the online source, which included:

- National and Kapodistrian University of Athens, Department of Physics, Atmospheric Modeling and Weather Forecasting group
- Agence des Aires Marines Protegees
- SHOM
- GEBCO
- EMODnet

Targeted Products catalogue for this Challenge

Name of Targeted product	Short description	Format
MEDSEA_CH1_product_1	A wind-wave data set	SQL data base
MEDSEA_CH1_product_2	A suitability index of a wind farm in the NWMed based on the **environmental resources**	GIS shape files
MEDSEA_CH1_product_3	A suitability index of a wind farm in the NWMed based on the **natural resources**, natural barriers, human activities, MPA and fisheries.	GIS shape files

Description of Characteristics and Data sources used by Targeted products

MEDSEA_CH1_Product_1

Nb	Characteristics name (P02)	Environmental Matrix	Data source (URL)
1	EWSB	Zonal wind component/ESEWZZXX	forecast.uoa.gr
2	EWSB	Meridional wind component/ESNSZZXX	forecast.uoa.gr
3	CAPH	Air pressure/CAPHZZ01	forecast.uoa.gr
4	Not existing in P02	Air density	forecast.uoa.gr
5	CHUM	Specific humidity of the atmosphere /CHUMSS01	forecast.uoa.gr
6	CDTA	Air temperature/ATEMP2MM	forecast.uoa.gr
7	ASLV	Sea level/ASLVZZ01	forecast.uoa.gr
8	TEMP	Water temperature/TEMPPR01	forecast.uoa.gr
9	PSAL	Water salinity/ODSDM021	forecast.uoa.gr
10	RFVL	Water zonal velocity component/LCEWZZ01	forecast.uoa.gr
11	RFVL	Water meridional velocity component/LCNSZZ01	forecast.uoa.gr
12	WVSP	Two-dimensional Wave spectra over frequencies and directions model output	forecast.uoa.gr
13	WVST	Significant Wave Height model output	forecast.uoa.gr
14	GWDR	Mean wave direction model output	forecast.uoa.gr
15	WVST	Mean (Energy) wave period model output	forecast.uoa.gr
16	WVST	Peak wave period model output	forecast.uoa.gr
17	WVST	Swell wave height model output	forecast.uoa.gr
18	WVST	Maximum expected wave height model output	forecast.uoa.gr

MEDSEA_CH1_Product_2

Nb	Characteristics name (P02)	Environmental Matrix	Data source (URL)
1	EWSB	Zonal wind component/ESEWZZXX	forecast.uoa.gr
2	EWSB	Meridional wind component/ESNSZZXX	forecast.uoa.gr

MEDSEA_CH1_Product_3

Nb	Characteristics name (P02)	Environmental Matrix	Data source (URL)
1	EWSB	Zonal wind component/ESEWZZXX	forecast.uoa.gr
2	EWSB	Meridional wind component/ESNSZZXX	forecast.uoa.gr
3	BRDA	Birds: species	www.aires-marines.fr
4	BRDA	Birds: abundance	www.aires-marines.fr
5	GP088	Birds: migratory patterns	www.aires-marines.fr
6	GP04	Birds: reproduction area	www.aires-marines.fr
7	FABD	Marine mammals: species.	www.aires-marines.fr
8	FABD	Marine mammals: size.	www.aires-marines.fr
9	FABD	Marine mammals: migratory routes.	www.aires-marines.fr
10	FABD	Fishes: species.	www.aires-marines.fr
11	FAXT	Fishes: abundance	www.aires-marines.fr
12	FREP	Fishes: reproduction area	www.aires-marines.fr
13	MBAN	SDN P01 SFHTNPES Bathymetry	www.emodnet.eu
14	SSTR	SDN P01 SEDTYCAT Description of lithology of sediment by visual estimation	www.emodnet.eu

Description of methodology to produce the Targeted Products

MEDSEA_CH1_Product_1

A high-resolution database was developed, based on the outcomes of the FP7 MARINA Platform project (http://www.marina-platform.info/). The database covers a 10-year period (2001–2010) and contains hourly data on a wide range of atmospheric, wave and tidal information. The following parameters are provided:

1. *Zonal wind component*
2. *Meridional wind component*
3. *Air pressure*
4. *Air density*
5. *Specific atmospheric humidity*
6. *Air temperature*
7. *Water temperature*
8. *Water salinity*

9. *Water zonal velocity component*
10. *Water meridional velocity component*
11. *Dimensional wave height model output*
12. *Significant wave height model output*
13. *Mean wave direction model output*
14. *Mean (energy) wave period model output*
15. *Peak wave period model output*
16. *Swell wave height model output*
17. *Maximum expected wave height model output*

The atmospheric parameters are available at different vertical levels (10, 40, 80, 120 and 180 m). The database was developed under the framework of the European FP7 "Marina Renewable Integrated Application Platform", the main objective of which was to support the development of offshore structures to exploit wind, wave, tidal and ocean current energy around the European coastline. A 10-year re-analysis was performed, combining wind- and wave-induced motions. The regional atmospheric model, SKIRON (Kallos et al.,1997, 2006; Spyrou et al., 2010), was combined with the third-generation ocean wave model, WAM (Bidlot et al., 2007; Galanis et al., 2011; WAMDIG, 1988) and the global ocean circulation model, HYCOM (Hybrid Coordinate Ocean Model) (Chassignet et al., 2003).

SKIRON uses 45 vertical levels and a time step of 15 seconds. The initial and lateral boundary conditions were prepared using the LAPS 3-D data assimilation model, based on ECMWF $0.5^{o}x0.5^{o}$ gridded fields and surface and upper air observations. The lateral conditions are updated every 3 hours. The geomorphological datasets used for the atmospheric and wave model were 30"x30" global elevation, 30"x30" land use and vegetation cover, 2'x2' soil classification and 1'x1' bathymetry. The SST fields were derived from NCEP with a resolution of 0.5°x0.5°. For ocean circulation, the results from the global model Hybrid Coordinate Ocean Model-HYCOM (Chassignet et al., 2003) were interpolated from the original $0.07^{o}x0.07^{o}$ grid to the model domain of SKIRON and WAM. The models operated at a high spatial resolution of 0.05°x0.05° latitude/longitude and the produced output is available for the 2001-2010 period on a daily base.

The configurations of the atmospheric model and the wave model are presented in Figures 1 and 2.

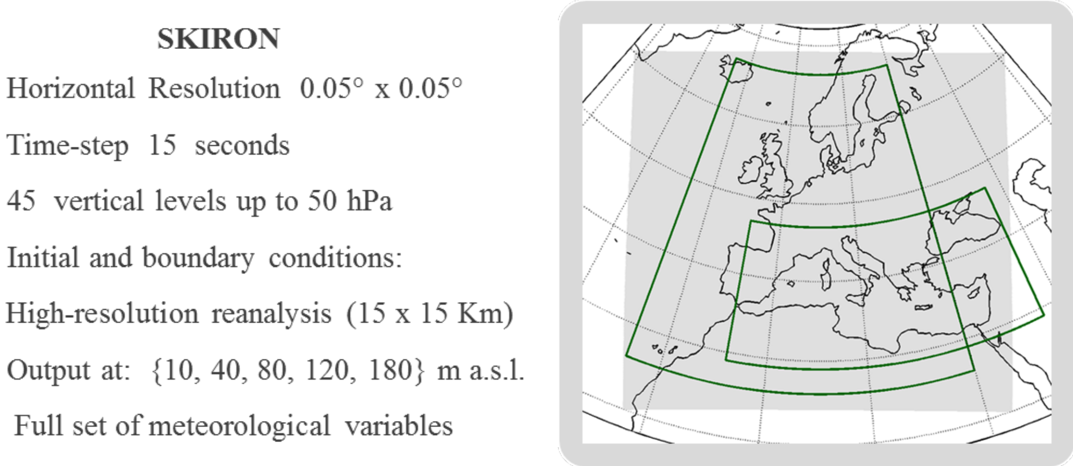

Figure 1 The set up and domains of the Skiron atmospheric model.

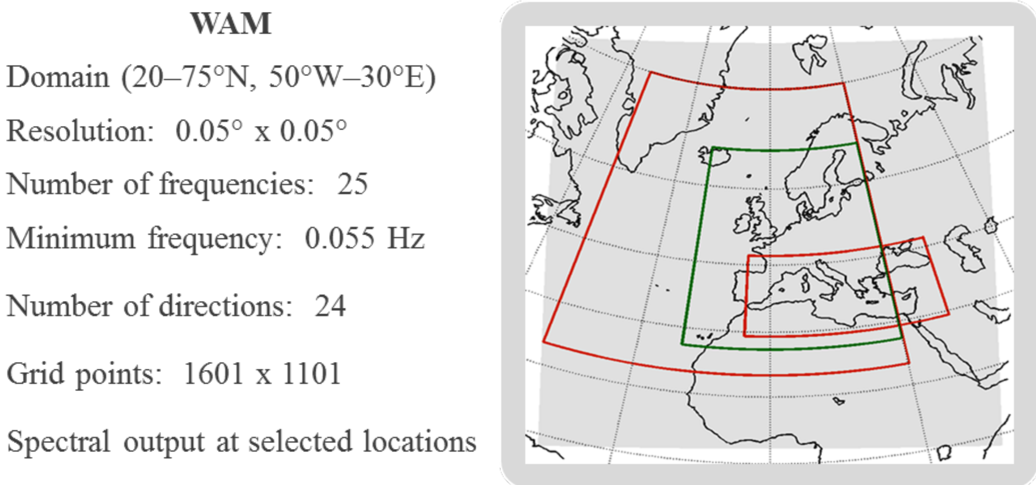

Figure 2 The set up and domains of the WAM wave model.

The modeling system operated in a reanalysis mode, thus exploiting the advantages of the data assimilation procedure using the available observations and measurements from the area (satellite records, meteorological observations, ship reports). This produced an optimum representation of the environmental parameters and a detailed wave climatology map of the area.

Spatial analysis

A number of statistical indices and measures were used for the statistical analysis.

- *Mean value* (μ): the mean is used as an indicator of the energy potential of the study area, and can be calculated as

$$\mu = \frac{1}{N}\sum_{\iota=1}^{N} x(i)$$

  where x denotes the parameter under study (wind speed, wind energy, significant wave height, etc.) and N is the size of the sample.

  For a more comprehensive analysis, a fundamental task is to describe the wind speed and wind energy probability distribution characteristics. This can be achieved using the skewness and kurtosis of the variable under study.

- *Skewness* (*g1*) is a measure of the symmetry/asymetry of the data and indicates whether higher values tend to be skewed to the right or left of the mean value. Skewness is calculated using the sample mean (μ) and standard deviation (σ):
$$g_1 = \frac{\frac{1}{N}\sum_{i=1}^{N}(x(i)-\mu)^3}{\sigma^3}$$
- *Kurtosis* (*g2*) is a measure of the peakedness and tail weight of the distribution:
$$g_2 = \frac{\frac{1}{N}\sum_{i=1}^{N}(x(i)-\mu)^4}{\sigma^4} - 3$$

The combination of these statistical indexes provides useful information about the occurrence and potential impact of non-frequent values in the wind park operation.

The variability of the produced energy is critical for the functionality of the electrical network. Therefore, a fourth statistical parameter, the *index of variation*, is introduced to depict the temporal variation of wind energy. The index of variation is equal to the standard deviation ($\sigma = \sqrt{1/_N \sum_{\iota=1}^{N}(x(\iota)-\mu)^2}$) divided by the sample mean, to obtain a dimensionless outcome.

The spatial analysis of the main parameters under study over the entire period is presented in Figures 3, 4, 5, 6, 7 and 8.

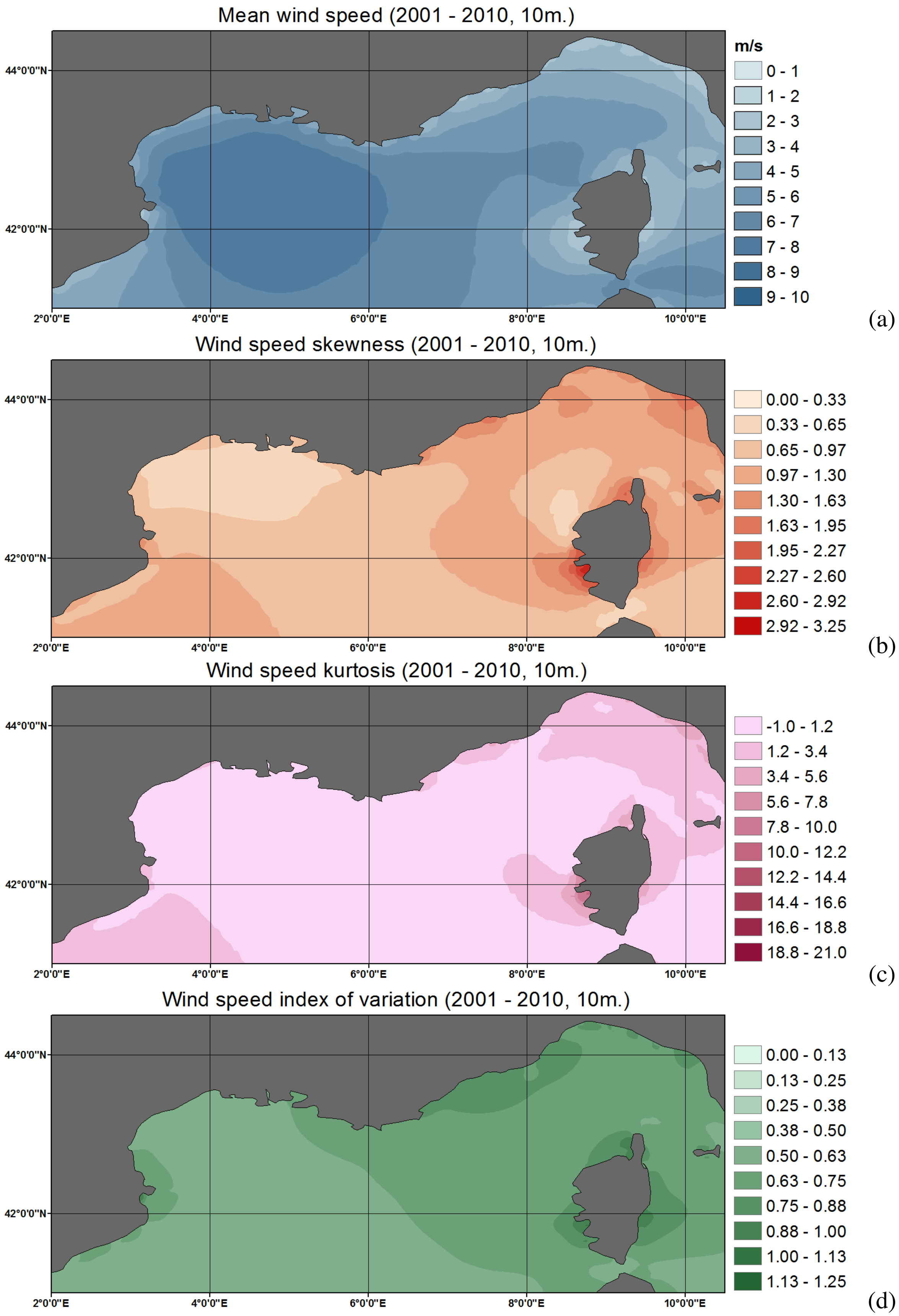

Figure 3 Wind speed statistics at 10 m computed over the 2001-2010 period: a) mean, b) skewness, c) kursotis, d) index of variation.

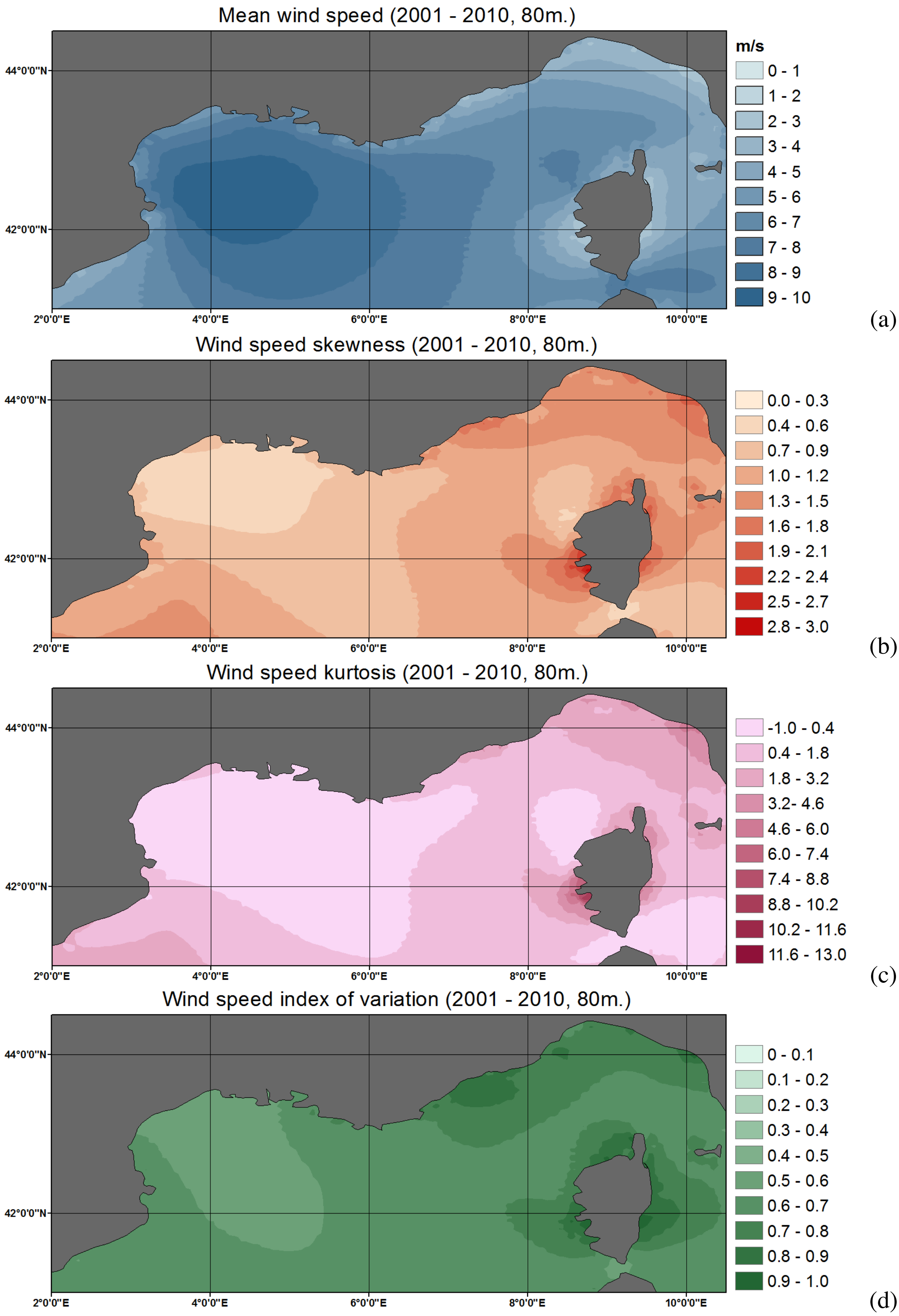

Figure 4 Wind speed statistics at 80 m computed over the 2001-2010 period: a) mean, b) skewness, c) kursotis, d) index of variation.

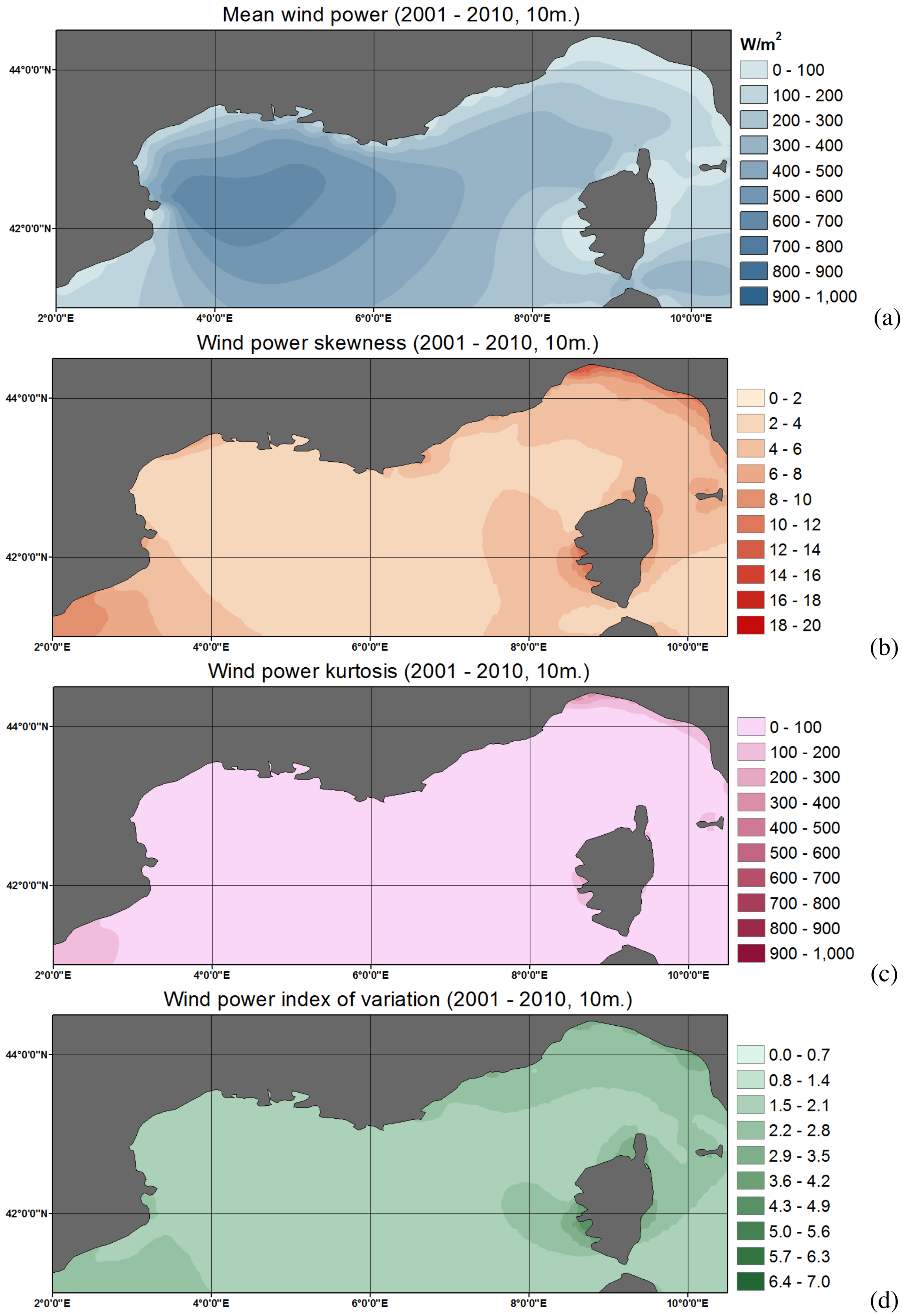

Figure 5 Wind power statistics at 10 m computed over the 2001-2010 period: a) mean, b) skewness, c) kursotis, d) index of variation.

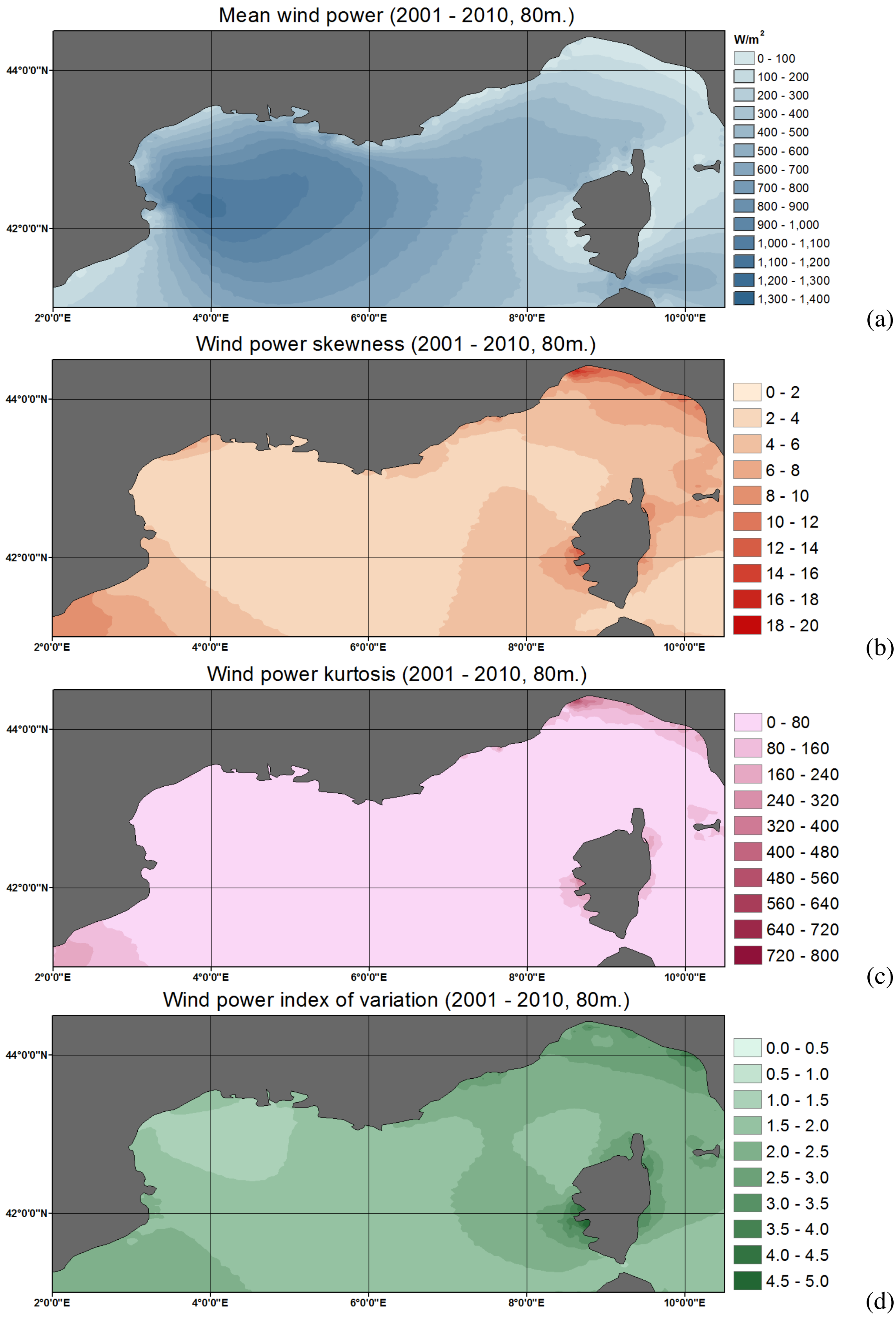

Figure 6 Wind power statistics at 10 m computed over the 2001-2010 period: a) mean, b) skewness, c) kursotis, d) index of variation.

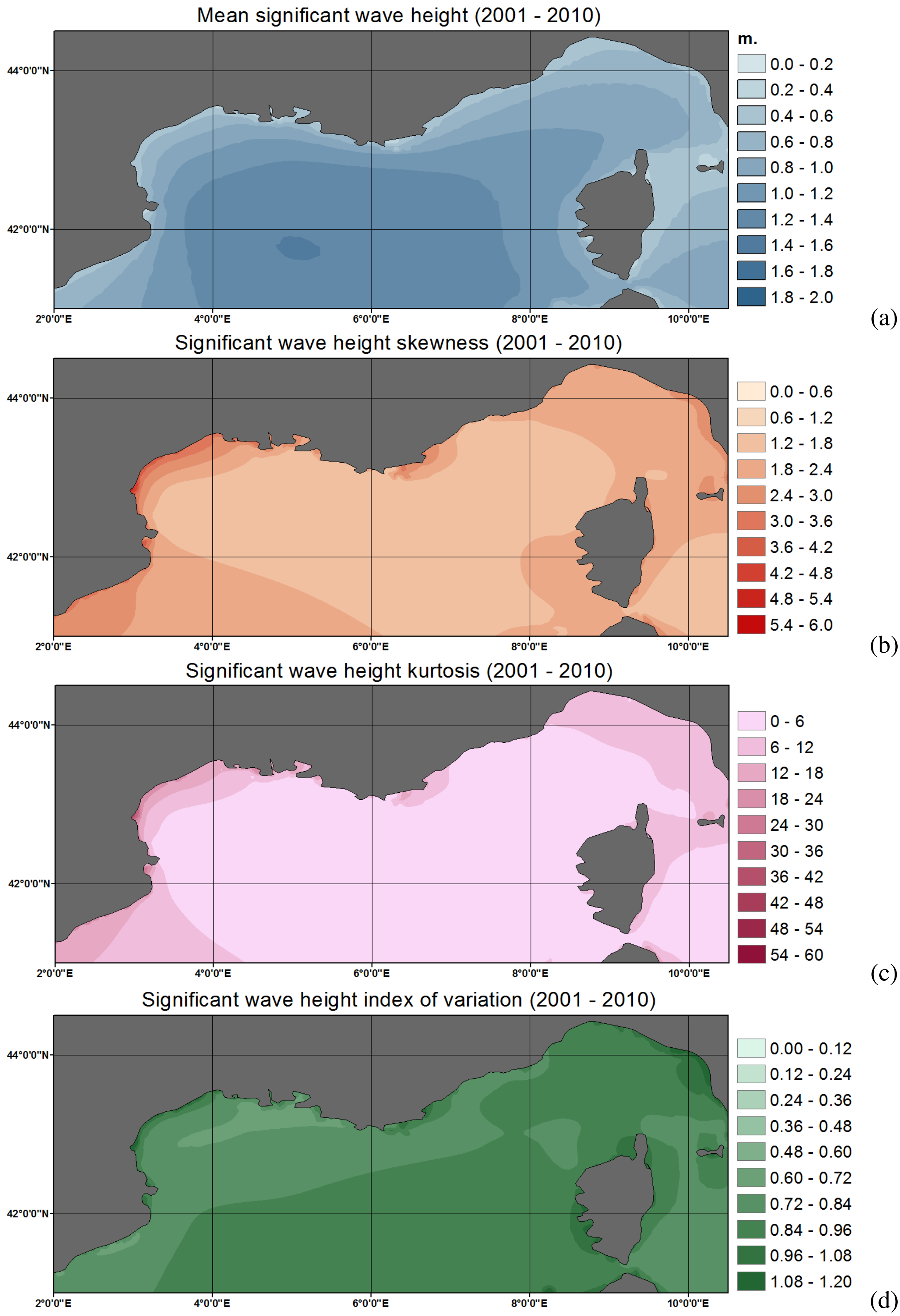

Figure 7 Significant wave height statistics computed over the 2001-2010 period: a) mean, b) skewness, c) kursotis, d) index of variation.

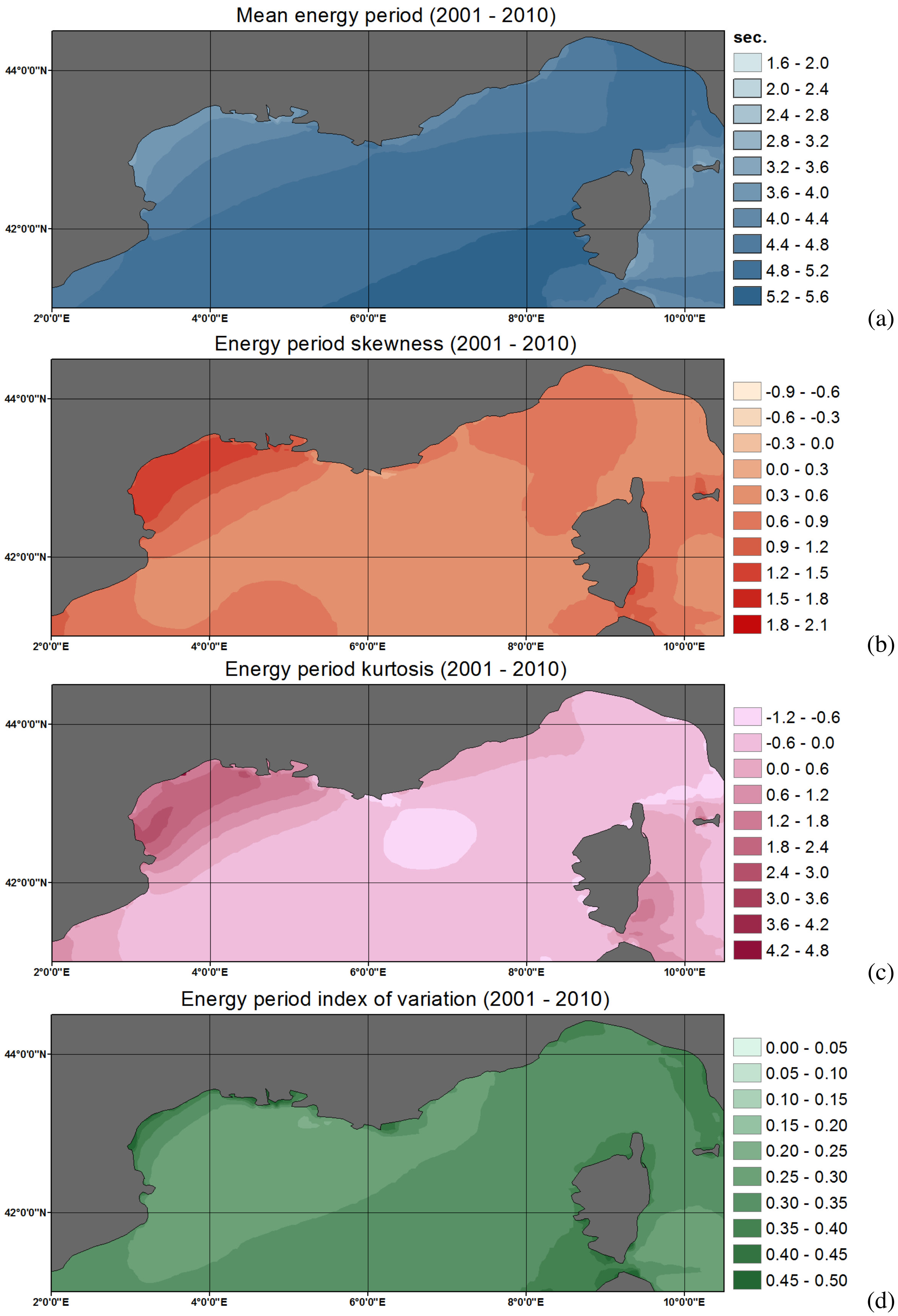

Figure 8 Wave energy period statistics computed over the 2001-2010 period: a) mean, b) skewness, c) kursotis, d) index of variation.

The mean wind speed is usually much lower close to the shore due to the wind shadow effect of the land. There is high spatial and slightly lower temporal variability. The effect of the wind speed spatial distribution is evident in the maps that depict wind power, which show similar behavior.
The mean wind power values at 10 and 80 m in the Gulf of Lions and the Spanish-French waters show rather increased mean values, comparing to other regions of the NW Mediterranean Sea, associated with low variability . The low skewness values indicate that the data are quite symmetric. The corresponding mean wind speed values are between 4-7 m/sec, which, combined with the relatively low variation and asymmetry values, further highlights the suitability of the area for wind farm development.
In the sea area between French-Italian waters, the wind power values show limited potential at both heights of interest. The mean wind speed is less than 4 m/sec, associated with non trivial variation and kurtosis values. These values characterize the area as unstable in general and with increased uncertainty in the wind speed values, compared with other regions of the NW Mediterranean Sea. However, higher index of variation values are observed where the mean wind speed is generally lower.
The wave height estimations, both in terms of mean and variability, do not pose important restrictions on the development of wind farm structures. Moreover, extreme wave height values, as measured by kurtosis, do not have a critical effect on the general distribution. This behavior is stable for all parameters across the 10 years of available data.

In situ analysis

In addition to the spatial analysis, an in situ study was performed in two selected locations in French-Spanish and French-Italian waters. The analysis involved a directional study of wind speed at 10 m and a Weibull distribution fit. The Weibull distribution was chosen as it is considered to represent wind speed and other left-skewed data sets well. The Weibull distribution probability density function (PDF) is positive only for positive values of x, and zero otherwise, and is given by

$$f(x) = \frac{b}{a}\left(\frac{x}{a}\right)^{b-1} e^{-(x/a)^b}$$

The shape parameter (b) and the scale parameter (a) are estimated using the maximum likelihood method.

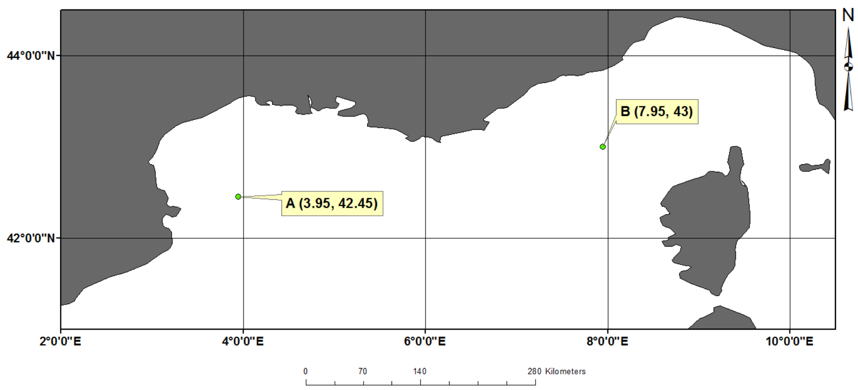

Figure 9 Locations of study sites A and B.

The distribution of wind speed in the French-Spanish waters is a 2-parameter Weibull with a shape parameter of 1.80 and scale of 8.92, and the main direction is NW (Figure 10). The distribution of wind speed in the French-Spanish waters is a 2-parameter Weibull with a shape parameter of 1.54 and scale of 6.68, and the main directions are NE and SW (Figure 11).

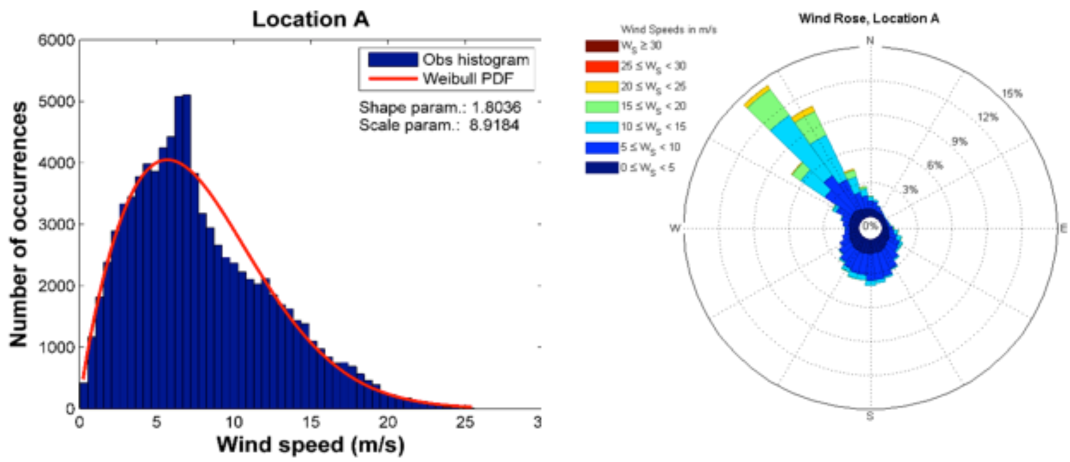

Figure 10 (Left) Wind speed distribution and (right) wind rose plot at site A, as shown in Figure 9.

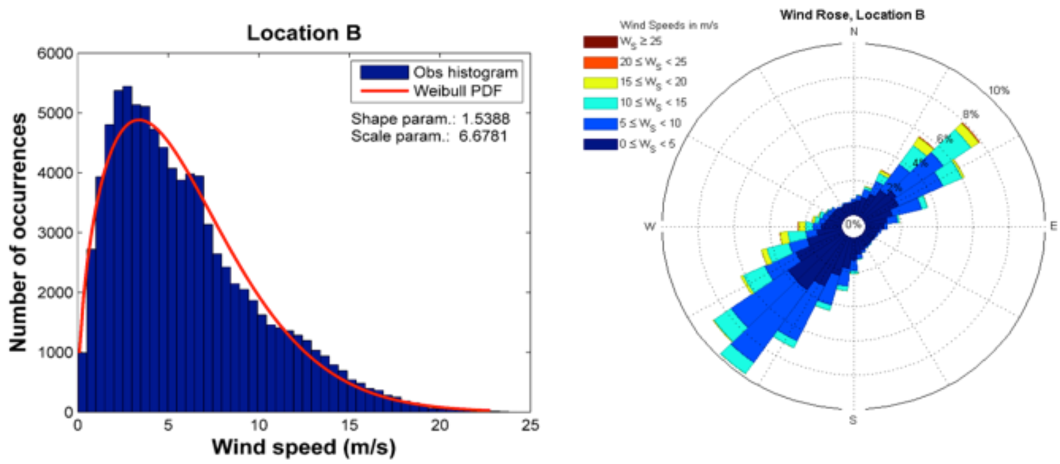

Figure 11 (Left) Wind speed distribution and (right) wind rose plot at site B, as shown in Figure 9.

The Gulf of Lion is highly affected by two local winds, the Marin and the Mistral. The Marin is a strong SE wind that is usually accompanied by warm, cloudy weather and rain. The Mistral blows from the N/NW and can last up to a couple of days with speeds reaching 100 km/h. It occurs when a depression is centered over NW Italy and a ridge of high pressure extends northeastward across the Bay of Biscay. The latter is in agreement with the intensity of the annual and 10-year mean wind speed and the wind direction observed in the wind rose of location A. The main wind directions over location B are NE and SW, due to the channeling between Corsica and NW Italy/NE France alongside the depression centered over northwest Italy.

MEDSEA_CH1_Product_2

The method used for the windfarm siting challenge is based on the approach used by HR Wallingford in commercial projects to help companies select potential wind farm locations.

The main aim of the study is to assess whether a site is a suitable location for a wind farm. The approach classifies data according to their level of suitability, ranging from grade 5 for exclusion zones, to a grade 1 for areas deemed appropriate for wind farm development. This suitability scale is described in detail in Tab. 1.

Site availability	Category	Symbol	Description
Very low	**5**		The presence of a variable that makes the area unsuitable for wind farm development
Low	**4**		The suitability of the area under study for wind farm development is low due to nearby receptors or marine activities
Medium	**3**		The installation and presence of a wind farm may adversely affect the marine activity or sensitive receptor, although the site may be suitable for development
High	**2**		The site is suitable for development and only minor adverse impacts on the sensitive receptor or marine activity are anticipated
Very high	**1**		The site is suitable for development and no adverse impacts on the sensitive receptor or marine activity are anticipated

Tab. 1 Levels of suitability for wind farm siting used to classify the area under investigation.

The mean wind speed and direction values and the associated variability were used to compute a **suitability index of sites only** in terms of **environmental resources**. The applied methodology is described in Tab. 2.

Figure 12 shows a map of the suitability of the area for wind energy platform development based on environmental resources only.

Mean wind speed (m/s)	Wind speed index of variation	Category	Site availability
0 - 3	-	5	Very low
3 - 3.25	>70%	5	Very low
3 - 3.25	<70%	4	Low
3.25 - 5	-	4	Low
5 - 5.25	>70%	4	Low
5 - 5.25	<70%	3	Medium
5.25 - 7	-	3	Medium
7 - 7.25	>70%	3	Medium
7 - 7.25	<70%	2	High
7.25 - 9	-	2	High
9 - 9.25	>70%	2	High
9 - 9.25	<70%	1	Very High
9.25 - ...	-	1	Very High

Tab. 2 Site suitability scoring index based on environmental resources only.

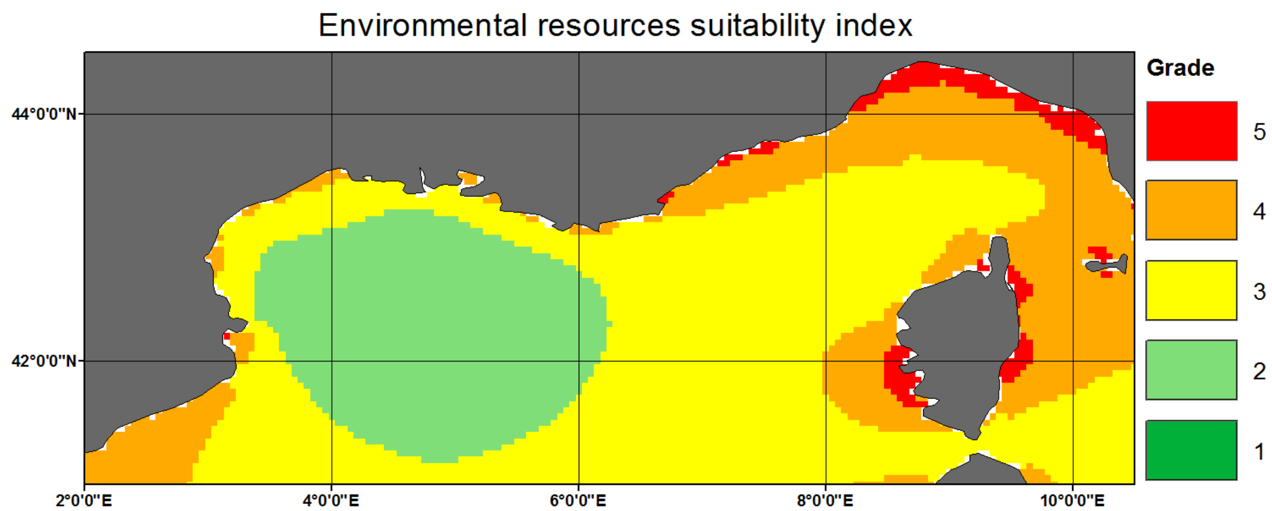

Figure 12 Suitability index map based on environmental resources only.

MEDSEA_CH1_Product_3

In addition to the environmental considerations, intense anthropogenic activity, biodiversity and sediment characteristics may lead to several constraints on the installation of wind turbines in the area of interest. A second suitability index was therefore developed, which combines the available environmental resources with the potential constraints set by local activities and natural characteristics.

As the available information and data were accessed in various formats, a GIS tool was used for the quantitative analysis. The estimations that were used were based on:

1. Sea depth

2. Distance from the shore
3. Seabed characterization
4. Marine Protected Areas

The data were prepared using the WGS84 World Reference system and the area characteristics are described in Table 3.

Table 3 Site availability for wind farm siting in terms of water depth range, distance from shore, Marine Protected Areas and Seabed characterization.

Site availability	Water depth range (m)	Distance from shore (km)	Marine Protected Areas	Seabed characterization
Very low	>500	>200 or <25	Included in the Natura 2000 Habitats and Birds Directive	Protected Seagrass: posidonia oceanica
Low	200-500	150-200		Coral presence, Hard substrate, Rock fragment, Seagrass
Medium	60-200	100-150		Silt, clay
High	25-60	50-100		Mud, gravelly sediment
Very high	0-25	25-50	-	Sand, Sediment

The results are illustrated in Figures 13 and 14. As a final concluding remark, one should emphasize the high suitability of the area between French and Spanish waters for wind farm platform development.

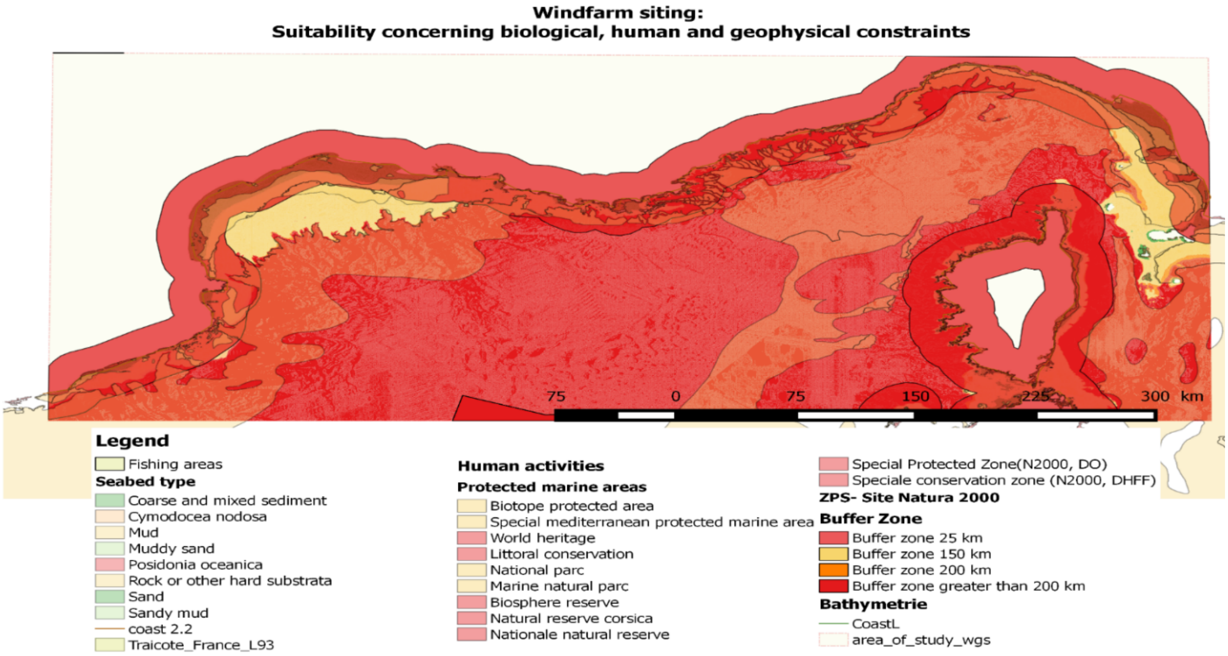

Figure 13 Suitability index based on biological, human and geophysical constraints.

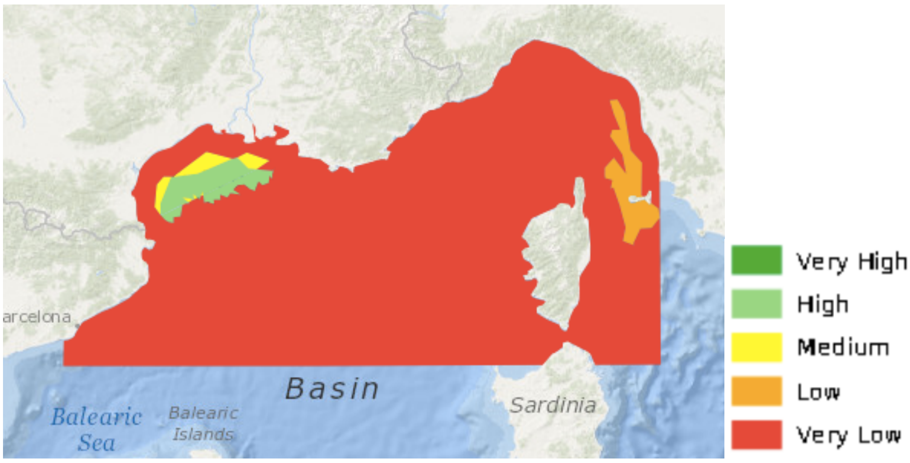

Figure 14 Suitability index of wind farm locations in the NWMed based on environmental resources, natural barriers, human activities, MPA and fisheries.

Expert evaluation of Targeted Product quality and gaps in the input data sets

The objective is to provide an expert evaluation of the "fitness for purpose and use" for each Targeted Product. The coordinator asked the challenge teams to provide the following information.

1. Assign an overall product quality score with respect to scope (fitness for purpose) and explain why, according to the scale in Table **A**.
2. Identify the most important characteristic(s) for the Targeted Product quality (if all characteristics are important, please say so).
3. Identify which quality element(s) (see Annex 1) of the most important characteristic(s) affects the Targeted Product quality.
4. Identify the limitations of the quality of the Targeted products due to the input data set used.
5. Explain which of the characteristics "most fails" to meet the scope of the Targeted Product.
6. Provide an expert judgement of the most important **gaps in the input data sets** for each 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

Table A Targeted Products quality scores and their meaning.

MEDSEA_CH1_Product_1

1. The product quality score is **excellent** (1). The developed wind/wave database and the associated statistical analysis meet the targets set by the project for a complete assessment of wind farm siting. A wide range of environmental parameters (beyond the classic wind/wave information) were considered, over an area that extends the borders of the predefined region under study. The data were analyzed using a variety of conventional and advanced statistical tools that provide critical information on the data and their impact on wind farm siting.
2. All of the input characteristics contribute to the product quality. However, the wind components (zonal and meridional) are critical for estimating the available wind power.
3. The **spatial and temporal extent and resolution** combined with the **accuracy** of the data are the most important quality elements that influence the analysis used to define the optimal areas for wind farm development.
4. The product's quality is limited by the vertical and horizontal resolution of the wind data, which does not resolve the sub-scale phenomena, especially horizontally.
5. All of the characteristics contribute to the analysis, but the 2-dimensional wave spectra fail the most to meet the scope of the product because the data are limited to specific preselected grid points. In particular, while the other atmospheric and wave parameter data are in one-dimensional time series, the wave spectra are in 2-dimensional matrices that could not be stored in full due to storage limitations. Therefore, only the wave spectra for

specific pre-defined points were stored in the data base. Nevertheless, these points are indicative for the coastline of interest.

6. There are no serious gaps in the input data sets, but as mentioned above, the 2-dimensional wave spectra data are only available for fixed pre-selected points rather than the whole domain under study, which creates some restrictions.

MEDSEA_CH1_Product_2

1. The product's quality score is **excellent** (1). The suitability index developed for wind farm siting is complete and detailed because it combines statistical indexes and provides mean values and variability.
2. Wind (zonal and meridional components) is the most important characteristic because it defines the available wind power potential.
3. The spatial (5 km) and temporal (hourly) resolutions guarantee a detailed and accurate analysis of the suitability of an area for wind farm development.
4. The product's quality is limited by the vertical and horizontal resolution of the wind data, which although high, do not resolve the sub-scale phenomena, especially horizontally.
5. All the characteristics contribute to the analysis and none of them fails to meet the scope of the product.
6. There were no serious gaps in the input data sets.

MEDSEA_CH1_Product_3

1. The product's quality score is **very good** (2). It covers the most important resources available in and constraints on the targeted area. It provides crucial information regarding the suitability of the targeted area for wind farm siting.
2. All of the input characteristics contribute to the product quality; however, the presence of a national reserve or protected area prevents any wind farm deployment.
3. The spatial extent and resolution, together with the accuracy and completeness, have the greatest impact on the product quality.
4. As we have very accurate and complete information on the sea depth and distance from shore (with a spatial resolution less than 1 km), the product's quality is mainly driven by the biological or sediment dataset and the main concerns are their spatial accuracy and completeness. This would require updating the dataset as often as possible.
5. All of the characteristics contribute to the analysis and meet the scope of the product. The biological data (marine protected areas and sediments) have the greatest potential for time and space evolution and, as stated above, their databases need to be updated as often as possible.
6. Individual biological species distributions are available, but not readily useable in a database and their presence is taken into account in the marine protected areas maps. Other characteristics could be important, but information on them was not available, either due to their real-time or non-free nature, such as commercial shipping routes, or due to data policy reasons, particularly regarding military areas.

TP	CH1
1	1
2	1
3	2

Table B Summary of the quality scores associated with each Targeted Product according to the experts' evaluations and the evaluation scheme presented in Table A.

Annex 1: Definitions

We extracted the following definitions from the MedSea Literature Survey:

Characteristic

In this document, a "characteristic" is a distinguishing feature that refers

1. either to a variable derived from the observation, the measurement, or the numerical model output of a phenomenon or of an object property in the environment; or
2. to the geographical representation of an object on a map (i.e., a layer such as a protected area, a coastline or wreck) by a set of vectors (polygon, curve, point) or a raster (a spatial data model that defines space as an array of equally sized cells such as a grid or an image).

Environmental matrices

This concept is introduced to avoid ambiguities when using a characteristic name such as "temperature". The environment matrix is the environment to which a characteristic is related, which we define as

1. Air
2. Marine Water
3. Fresh Water
4. Biota/Biology
5. Seabed
6. Human activities.

Quality principles

- ✓ ***Spatial extent***
  Box or geographic region bounding the datasets.
- ✓ ***Spatial resolution***
  Size of the smallest object that can be resolved on the ground. In a raster dataset, the resolution is limited by the cell size.
- ✓ ***Spatial accuracy***
  Requested closeness of coordinate values to values accepted as or being true e.g. on the base of the instrument used.
- ✓ ***Time extent***
  Time interval represented by the dataset or by the collection.
- ✓ ***Time resolution***
  Size of the smallest interval of time that can be resolved.
- ✓ ***Time accuracy***
  Requested closeness of temporal values to the values that are accepted as or are true.
- ✓ ***Usability***
  The extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use.
- ✓ ***Completeness***
  Amount of missing data in a dataset.
- ✓ ***Logical consistency***
  Degree of adherence to the required format.
- ✓ ***Thematic accuracy***
  Requested closeness of characteristic values to the values that are accepted as or are true (the so-called attribute of a data entity, e.g., "wave height"). It includes the correctness of the classification of features or their associations.

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