European Research Area for Climate Services

ECLISEA

European advances on CLImate Services for Coasts and SEAs

Catalogue of potential coastal climate indicators for a pan-European coastal climate service web tool

WP 1.3 Knowledge, research and identification of gaps

Work Package 1 - Deliverable D1.D

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1. Introduction

The deliverable D1.D is part of WP 1.3 “Knowledge, research and identification of gaps” in existing climate information of sea surface dynamics in European coastal areas. The objective of this deliverable is to develop a catalogue (table) of potential coastal climate indicators wich covers information needs of stakholders according to coastal climate and coastal climate change. This catalogue shall serve as a basis for a pan-European coastal climate service web tool, for which a prototype will be developed within ECLISEA (accepted ECLISEA project proposal, 2017).

The catalogue is mainly based on the results of the literature review about documented stakeholder needs for climate information, described in the deliverable D1.B of WP 1.2 “Climate information needs from multi-sector stakeholders” (see also chapter 2 for additional sources).

The term “climate information” is understood closely related to the broad meaning of the term “climate services” defined in the EC Roadmap for Climate Services document (European Commission, 2018). The term, if no other explanation is explicitly mentioned, includes both climate physical data and the transformation of climate-related data into general climate information and customized products.

The term “indicator”, as used in this report, refers to the information needs for coastal climate information expressed by stakeholders, in a summarized and categorized form. Indicators have been categorized in marine, atmospheric, inland, combined and context-based categories, and most of the indicators have been divided into several sub-indicators. The sub-indicators include on the one hand requested, physical climate variables, such as wave height, mean air temperature or wind speed, and, on the other hand, more generally formulated, complex, comprehensive and context-based information needs, referring for instance to requested regional climate adaptation strategies, such as technical climate change adaptation measures or beach management. It should be emphesized that the formulation of the sub-indicators is, where appropriate, based on the expressions and the wording used by stakeholders or the authors of the reports and articles. Thus, the sub-indicators reflect and show how detailed and specific the stakeholder needs for coastal climate information are described and documented in literature: either as physical climate variables, formulated in a quite specific manner (such as “significant wave height”, “wind direction”, “mean precipitation amount”) or in a very general manner (such as only “waves”, “currents”, “sea level”, which is described in the tables below as “general, without any further specification of stakeholders”), or as climate information, described in a more general and complex way and rather context-based without exactly expressed relations to physical data.

This report contains two different stages of a catalogue of climate indicators: a detailed inventory of potential indicators and a “short list”. Tables 1 to 5 in chapter 3 (the detailed inventory) show all potential coastal climate indicators that has been derived from the broad variety of documented stakeholder needs (for more information about the information basis of catalogue development see chapter 2). These tables include information needs (formulated as indicators) documented only for one country as well as information needs documented for two or more countries.

Based on these results, table 6 in chapter 4 eventually shows a "short list" of 20 potential coastal climate indicators that were documented in two ore more countries: **these 20 indicators form the final catalogue of potential coastal climate indicators for a pan-European coastal climate service web tool**.

Finally, the identified climate indicators of the short list have been compared with existing European datasets, described in deliverable D1.A (2018) "Climate datasets and related Coastal Exposure databases", as well as to additionally reviewed European datasets (see annex for more details), to see which data and knowledge is already available and to identify main gaps in the databases at European level (see chapter 5 and table 7 in the annex). The additionally reviewed datasets refer to variables which were not in the focus of the D1.A (2018) report, but were requested by stakeholders in the literature review (see annex for more details).

2. Data basis for catalogue development

The main source used for the development of coastal indicators are the documented stakeholder needs for climate information, reviewed and described in deliverable D1.B of WP1.2. This literature review includes scientific articles, project and workshop reports, policy papers, reports from companies, registered data queries from data bases, as well as information drawn from talks to researchers and experiences gained in previous projects of ECLISEA partners. The catalogue of indicators is the quintessence of the review findings with regard to stakeholder climate information needs. The review has been carried out in the four partner countries Germany, France, Spain and Greece with focus on the sectors tourism, offshore energy (in Germany only offshore wind energy), maritime navigation and ports, and risk insurance. Moreover, additional relevant sectors have been reviewed by Germany and Spain: coastal protection (Germany), municipalities and regional policy (Germany), water management (Spain), and a multi sectoral perspective (Spain).

Additionally, the members of the ECLISEA group in Germany are in contact with the project EXTREMENESS. EXTREMENESS fosters a science stakeholder collaboration forum composed of the scientific partners and 18 local stakeholders, risk managers and decision makers. The latter comprise authorities involved in coastal protection, disaster risk management, drainage management, and industry potentially affected by extremes. The forum has conducted several interactive workshops in which local stakeholder needs for sea level information from a risk management perspective were reviewed and prioritized. The top priorities identified comprise information on the height, intensity and duration of extreme storm tides together with information on mean sea level changes. From a risk management perspective information on storm tide clusters are particularly relevant.

3. Stakeholders' information needs on coastal climate

The catalogue of potential coastal climate indicators (detailed inventory) comprises of the following five main categories, each of them including several indicators. It does not only show potential indicators for sea surface dynamics (as focussed in ECLISEA), but also other needed information focussing additional marine, atmospheric and inland indicators as well as more complex, contextualised information needs. The broad variety of needed information illustrates the complexity of coastal climate in a natural and socio-economic environment and thus, broad and complex information needs.

1. Marine (see table 1):
    - Waves
    - Currents
    - Water levels
    - Water temperature
    - Salinity
    - Sea ice cover
    - Ocean acidification
    - Eutrophication

2. Atmospheric (see table 2):
    - Temperature
    - Wind
    - Pressure
    - Humidity
    - Precipitation
    - Solar radiation
    - Cloud cover

3. Inland (see table 3):
    - Surface water
    - Inland floods

4. Combined indicators from main categories marine, atmospheric (see table 4)
    - Marine
    - Atmospheric

5. Context-based information needs (see table 5):
    - Climate change impacts
    - Climate change adaptation

Most of these indicators encompass several sub-indicators. Additionally, tables 1 to 5 show further information, related to these sub-divisions, about spatial coverage and

time horizon, temporal resolution and spatial scales, requested formats and information channels, as well as the countries and sectors where the indicators have been requested for according to the literature review results and other sources (see tables 1-5 also for references). The climate indicators have been developed based on **documented** needs for "new" climate information and those information that already have been used by stakeholders, for instance in research projects or in companies' daily business (see D1.B, 2018). That also means that only those countries and sectors, where documented stakeholder climate information needs were available (in literature, talks to scientists, project experiences, see chapter 2), are included in the tables (column countries and sectors, see tables 1-5), and only these documented stakeholder needs have been used to develop (sub-)indicators of coastal climate.

As already mentioned, it should be noted that the catalogue of potential coastal climate indicators does not only comprise of physical climate data, such as "sea surface temperature" or "significant wave height" (as examples for sub-indicators, belonging to the indicators "water temperature" and "waves"), but also of rather complex, comprehensive and "context-based" information, such as "climate change impacts on ecosystems, ports or on society" or "regional and local climate change adaptation strategies". The literature review shows that stakeholders in many cases do not ask for information in data format (such as "significant wave height" or "wind speed") but quite often in very general termes (such as "more reliable climate scenarios needed" or "more information needed about climate change effects on the tourism sector"), especially, if stakeholders are not so much familiar with scientific work and terminology, or stakeholders are interested in regional and local information, measures and solutions with regard to climate change and adaptation (see D1.B, 2018). For that reason, an indicator catalogue containing only physical climate variables would not illustrate well the broad, complex and diverse information needs of stakeholders for climate information.

Table 1: Stakeholders' information needs: potential marine climate indicators (detailed inventory), based on documented stakeholder needs

Coastal climate indicators	Time horizon	Time resolution	Spatial scale	Format/Information channels	Countries and sectors	References
Waves						
General: (sub categories were not further specified by stakeholders)	recent decades (~30 years; since 1958), present, short term predictions, future	hourly	regional, local	raw data, processed and analysed data (e.g. scatter diagrams), websites, reports, maps, graphics, web-based tools and desktop applications, tailored to specific requirements, personal interviews	Germany, Spain, France: tourism, offshore energy, maritime navigation and ports, risk insurance, multi-sectoral perspective	ONERC, 2018; UC-IHC; López, Iago et al., 2013a, b; IHC Coastal Management and Engineering Research Group; Lecacheux et al., in press; Nicolae Lerma et al., in press; Wiese, 2008; Weisse et al., 2015; Ecologic Institute, 2014; Wöckner-Kluwe et al., n.n. www.coastdat.de; http://navclimate.pianc.org;
Significant wave height, Mean wave hight, Extreme wave hight	present, short term forecasts future	hourly	regional	raw data, in particular consistent and complete data sets, accurate and reliable data, processed and evaluated data analysed data (e.g. weather windows), user-friendly interfaces with elaborated filter functions	Germany: offshore wind energy, risk insurance, coastal protection, scientists	Eucleia project, n.n.: Itzehoer Insurance; Die Welt, 20th of January, 2012; Bülow et al., 2015; Weisse et al., 2015; Eschenbach, 2017; Ecologic Institute, 2014; Marx, 2010; www.coastdat.de
Wave direction	future	not addressed	regional	not addressed	Germany: coastal protection, scientists	Ecologic Institute, 2014
Wave period	future	not addressed	regional	raw data	Germany: offshore wind energy; scientists	Marx, 2010

Coastal climate indicators	Time horizon	Time resolution	Spatial scale	Format/Information channels	Countries and sectors	References
Currents						
General: (sub categories were not further specified by stakeholders)	recent decades (~30 years), present, short term predictions, future	hourly	regional, local	raw data consistent and complete data sets, accurate and reliable data processed and evaluated data; user-friendly interfaces with elaborated filter functions; freely available, with warranty; web-based tools and desktop applications, tailored to specific requirements, websites, reports, maps, personal interviews	Germany, Spain, France: offshore energy, maritime navigation and ports, tourism	ONERC, 2018; Eschenbach, 2017; UC-IHC; www.coastdat.de
Water levels						
Sea level						
General: (sub categories were not further specified by stakeholders)	recent decades (~30 years), present, short term predictions, future	not addressed	regional, local	raw data (observed and simulated)analyzed data (e.g. time-series); websites, internet platforms, reports, maps, graphics, web-based tools and desktop applications, tailored to specific requirements, meetings, personal interviews	Germany, Spain, France, Greece: offshore energy, maritime navigation and ports, risk insurance, coastal protection, water management, multi-sectoral perspective	Marx, 2010; Universidad de Cantabria (Department of science and techniques of water and environment), Environmental hydraulics Institute (IH Cantabria); Bárcena et al. (2017); Katopodis, T., NCSRD, PhD thesis (ongoing); Seiffert et al., 2014; BMVI, 2015; www.coastdat.de

Coastal climate indicators	Time horizon	Time resolution	Spatial scale	Format/Information channels	Countries and sectors	References
Mean sea level, Mean sea level rise	present, future (for the German North Sea region)	not addressed	regional and local	raw data, understandable information on sea level projections	Germany, France, Greece: tourism/ transportation, offshore energy, maritime navigation and ports, risk insurance, coastal protection, disaster risk management, scientists	Schuchardt & Wittig, 2012; Schuchardt et al., 2011; Seiffert et al., 2014; BMVI, 2015; Ecologic Institute, 2014; Wenzel & Treptow, 2013; Swiss Re, 2009; Weisse et al., 2012; ONERC, 2018; Ecologic Institute, 2014; EXTREMENESS stakeholder workshops (see chapter 2); http://navclimate.pianc.org; www.marinaproject.eu www.oceanography.ucy.ac.cy/mosep/
Storm surges						
General: (sub categories were not further specified by stakeholders)	recent decades, present, future	hourly	regional, local	raw data (measurements and simulations), consistent and complete data sets, accurate and reliable data; processed, evaluated and analyzed data (including early warning of extreme weather events), user-friendly interfaces with elaborated filter functions; websites, reports, maps; scientific information, translated into salient and credible (climate change) information	Germany, Spain, France, Greece: tourism, offshore (wind) energy, maritime navigation and ports, risk insurance, coastal protection, scientists	Eschenbach, 2017; Seiffert et al., 2014; BMVI, 2015; Swiss Re, 2009; Gaslikova et al., 2011; UC-ICH, IHC Hydrodynamics and Coastal Infrastructures Research Group; Juanes, JA et al., 2017; NCSRD: 3C's, Climate Change Consequences, 2011-2014; Lecacheux et al., in press; Nicolae Lerma et al., in press; Ecologic Institute, 2014; Wenzel & Treptow, 2013; Schwab et al., 2017; Schuchardt et al., 2011; Weisse et al., 2012; Osthorst et al., 2014; http://navclimate.pianc.org; www.marinaproject.eu www.oceanography.ucy.ac.cy/mosep/

Coastal climate indicators	Time horizon	Time resolution	Spatial scale	Format/Information channels	Countries and sectors	References
Storm surge heights	recent decades, present future,	hourly	regional, local;	raw data (observed and simulated), analysed data (e.g. return periods)	Germany: Offshore wind energy, risk insurance, coastal protection, disaster risk management	Swiss Re, 2003; Swiss Re, 2009; Gaslikova et al., 2011; Nibbe & Wittig, 2013; Schuchardt et al., 2011; Ecologic INstitute, 2014; www.coastdat.de; EXTREMENESS stakeholder workshops (see chapter 2)
Storm surge frequency	recent and present	hourly	local	analyzed and visualized data, user friendly interface	Germany: coastal protection, scientific users	Hamburg Authority for Environment and Energy, 2018b, c, EXTREMENESS stakeholder workshops (see chapter 2)
Storm surge intensity	recent and present	hourly	local	analyzed and visualized data, user friendly interfaces	Germany: coastal protection, disaster risk management, scientific users	Hamburg Authority for Environment and Energy, 2018b, c; EXTREMENESS stakeholder workshops (see chapter 2)
Storm surge duration	recent and present	hourly	local	analyzed and visualized data, user friendly interfaces)	Germany: risk insurance, disaster risk management	Swiss Re, 2003; EXTREMENESS stakeholder workshops (see chapter 2)
Tides						
General: (sub categories were not further specified by stakeholders)	future (German North Sea coast)	not addressed	regional, local	raw data; final information delivered through website, reports, maps and graphics	Germany, Spain: tourism, risk insurance, coastal protection, scientists	UC-IHC; López, Iago et al., 2013a, b; Eucleia project, n.n.: Itzehoer Insurance; Die Welt, 20th of January, 2012; Weisse et al., 2012; Schuchardt & Wittig, 2012; Schuchardt et al., 2011; Nibbe & Wittig, 2013;

Coastal climate indicators	Time horizon	Time resolution	Spatial scale	Format/Information channels	Countries and sectors	References
Mean high tide	present, future	not addressed	regional, local,	analyzed and visualized data, user friendly interfaces	Germany: tourism, coastal protection, scientists	Schuchardt et al., 2011; Hamburg Authority for Environment and Energy, 2018b,c
Mean low tide	not addressed	not addressed	local	analyzed and visualized data, user friendly interfaces	Germany: coastal protection	Hamburg Authority for Environment and Energy, 2018b,c
Mean amplitude of tides	not addressed	not addressed	local	analyzed and visualized data, user friendly interfaces	Germany: coastal protection	Hamburg Authority for Environment and Energy, 2018b,c
Number of subsequent tides	not addressed	hourly,	regional, local,	analyzed and visualized data, user friendly interfaces	Germany: coastal protection, disaster risk management	Hamburg Authority for Environment and Energy, 2018b,c; EXTREMENESS stakeholder workshops (see chapter 2)
Water temperature						
General: (sub categories were not further specified by stakeholders)	longer time scales (not further specified)	not addressed	regional	not addressed	Germany: tourism	Bülow et al., 2015
Sea surface temperature	future	not addressed	not addressed	raw data, analysed data; final information delivered through cloud, websites, reports, maps	Spain, France, Greece: tourism, scientists	ONERC, 2018; UC-IHC; Juanes, JA et al., 2017; NCSRD: 3C's, Climate Change Consequences, 2011-2014
Salinity						
	recent	not addressed	local	raw data and analysed data; reports, maps, meetings	Spain: water management	UC-IHC IHC Oceanography, Estuaries and Water Quality Reserach Group; Bárcena et al. (2017)

Coastal climate indicators	Time horizon	Time resolution	Spatial scale	Format/Information channels	Countries and sectors	References
Sea ice cover						
	future	not addressed	regional, local	raw data	Germany: maritime navigation and ports	Ecologic Institute, 2014; Wenzel & Treptow, 2013
Ocean acidification						
	future	not addressed	not addressed	not addressed	France: tourism	ONERC, 2018
Eutrophication						
	future	not addressed	not addressed	not addressed	France: tourism	ONERC, 2018

Table 2: Stakeholders' information needs: potential atmospheric climate indicators (detailed inventory), based on documented stakeholder needs

Coastal climate indicators	Time horizon	Time resolution	Spatial scale	Format/Information channels	Countries and sectors	References
Air temperature						
General: (sub categories were not further specified by stakeholders)	present, short and long term horizon	not addressed	regional	raw data, analysed data (including weather information); final information delivered through cloud, websites, reports, maps	Germany, Greece: tourism, offshore wind energy, scientists	Bülow et al., 2015; Fichter et al., 2013; NCSRD: 3C's, Climate Change Consequences, 2011-2014
Mean air temperature (2m temperature)	future	mean monthly and seasonal	national, regional, local	analysed data	Germany, France: tourism, maritime navigation and ports	Bülow et al., 2017; Ecologic Institute, 2014; Wenzel & Treptow, 2013; ONERC, 2018
Extreme air temperature (not further specified by stakeholders)	future	not addressed	not addressed	raw data	France, Greece: tourism, offshore energy, scientists	ONERC, 2018; www.marinaproject.eu www.oceanography.ucy.ac.cy/mosep/
Minimum air temperature (2m temperature)	not addressed	mean monthly	regional	analysed data	Germany: tourism	Bülow et al., 2017
Maximum air temperature (2m temperature)	not addressed	mean monthly	regional	analysed data	Germany: tourism	Bülow et al., 2017
Hot days, annual sum (Tmax ≥ 30°C)	not addressed	days per year	regional	analysed data	Germany: tourism, offshore wind energy	Bülow et al., 2017
Longest period of consecutive hot days (Tmax ≥ 30°C)	not addressed	days	regional	analysed data	Germany: tourism, offshore wind energy	Bülow et al., 2017

Coastal climate indicators	Time horizon	Time resolution	Spatial scale	Format/Information channels	Countries and sectors	References
Summer days, annual sum (Tmax > 25°C)	not addressed	days per year	regional	analysed data	Germany: tourism	Bülow et al., 2017
Longest period of consecutive summer days (Tmax > 25°C)	not addressed	days	regional	analysed data	Germany: tourism	Bülow et al., 2017
Frost days, annual sum (Tmin < 0°C>)	not addressed	days per year	regional	analysed data	Germany: tourism, offshore wind energy	Bülow et al., 2017
Longest period of consecutive frost days (Tmin < 0°C)	not addressed	days	regional	analysed data	Germany: tourism, offshore wind energy	Bülow et al., 2017
Ice days, annual sum (Tmax < 0°C)	not addressed	days per year	regional	analysed data	Germany: tourism, offshore wind energy	Bülow et al., 2017
Longest period of consecutive ice days (Tmax < 0°C)	not addressed	days	regional	analysed data	Germany: tourism, offshore wind energy	Bülow et al., 2017
Tropical nights, annual sum (Tmin > 20°C)	not addressed	days per year	regional	analysed data	Germany: tourism	Bülow et al., 2017
Longest period of consecutive tropical nights (Tmin > 20°C)	not addressed	days	regional	analysed data	Germany: tourism	Bülow et al., 2017

Coastal climate indicators	Time horizon	Time resolution	Spatial scale	Format/Information channels	Countries and sectors	References
Wind						
General: (sub categories were not further specified by stakeholders)	recent decades (~30 years), present, short-term forecast, future	hourly	regional, local	raw data (observations and simulations), analysed, processed and evaluated data, visualized analyses (e.g. hazard maps); high quality data, consistent and complete data sets, accurate and reliable data; final developed information delivered to stakeholders in the form of data, web-based tools and desktop applications, tailored to specific requirements, internet platforms, websites, reports, maps, meetings and personal interviews; user-friendly interfaces with elaborated filter functions; freely available, with warranty	Germany, Spain, France, Greece: tourism, offshore (wind) energy, maritime navigation and ports, risk insurance, coastal protection, water management, scientists	UC-IHC; Katopodis, T., NCSRD, PhD thesis (ongoing); IHC Oceanography, Estuaries and Water Quality Reserach Group; Bárcena et al. (2017); Weisse et al., 2015; Gaslikova et al., 2011; Bülow et al., 2015; Von Storch & Claussen, 2011; Eschenbach, 2017; Seiffert et al., 2014; BMVI, 2015; Bülow et al., 2015; Deboudt, 2010; Le Cozannet et al., 2017; www.coastdat.de www.marinaproject.eu www.oceanography.ucy.ac.cy/mosep/ www.coastdat.de
Storm intensity (including gust speed, sustained wind speed)	recent, present, future	not addressed	national, regional	raw data, analysed data; final developed information is delivered to the stakeholders as data, report, maps, website publications	Germany, Spain: risk insurance, coastal protection, scientists	Swiss Re, 2003; Nibbe & Wittig, 2013; UC-IHC, Santander Meteorology Group
Storm frequency	recent, present, future	not addressed	national, regional	raw data, analysed data; final developed information is delivered to the stakeholders as data, report, maps, website publications	Germany, Spain: risk insurance, coastal protection, scientists	Eucleia project, n.n.: Itzehoer Insurance; Die Welt, 20th of January, 2012; Nibbe & Wittig, 2013; UC-IHC, Santander Meteorology Group

Coastal climate indicators	Time horizon	Time resolution	Spatial scale	Format/Information channels	Countries and sectors	References
Wind speed (including mean wind speed)	present, short-term forecasts future	hourly	regional, local	raw data, analysed data (including weather windows, current weather information, return periods)	Germany: offshore wind energy, maritime navigation and ports, risk insurance, coastal protection, scientists	Seiffert et al., 2014; Ecologic Institute, 2014; Wenzel & Treptow, 2013; Fichter et al., 2013; Schuchardt & Wittig, 2012; Schuchardt et al., 2011; Eschenbach, 2017; Eucleia project, n.n.: Itzehoer Insurance; Die Welt, 20th of January, 2012; Hamburg Authority for Environment and Energy, 2018b, c; Bülow et al., 2015; Bülow et al., 2017; Weisse et al., 2015; www.coastdat.de
Wind direction	present, future	not addressed	regional	raw data, analysed data	Germany: coastal protection, scientific users	Schuchardt et al., 2011
Wind duration	not addressed	not addressed	local, regional	analysed data	Germany: coastal protection	Hamburg Authority for Environment and Energy, 2018b, c
Days with strong winds (mean monthly sum, maximum wind speed/day ≥ 10,8 m/s)	not addressed	days	national,	analysed data	Germany: tourism, offshore wind energy, risk insurance, coastal protection	Bülow et al., 2017
Stormy days (mean monthly sum, maximum wind speed/day ≥ 20,8 m/s; wind speed > 17,2 m/s)	present, future	days	national, regional	raw data, analysed data	Germany: tourism, offshore wind energy, risk insurance, coastal protection, scientific users	Bülow et al., 2017; Schuchardt et al., 2011; KUNTIKUM, 2009;

Coastal climate indicators	Time horizon	Time resolution	Spatial scale	Format/Information channels	Countries and sectors	References
Air pressure						
not addressed	recent, future	not addressed	regional	raw data	Germany: offshore wind energy, risk insurance	Gaslikova et al., 2011; www.coastdat.de
Air humidity						
Air humidity	not addressed	not addressed	not addressed	analysed data	Germany: tourism, scientific users	Von Storch & Claussen, 2011
Foggy days (relative humidity ≥ 93%)	not addressed	not addressed	regional	analysed data	Germany: tourism, scientific users	Schuchardt et al., 2011; KUNTIKUM, 2009
Evaporation	not addressed	not addressed	local	raw data; final developed climate information is shown via data, reports, maps, graphics	Spain: water management	UC-IHC
Precipitation						
General: (sub categories were not further specified by stakeholders)	present, short term prediction, future	not addressed	regional, Spain: local	raw data, analysed data (including current weather information); final developed climate information is shown via data, cloud, websites, reports, maps, graphics	Germany, Spain, Greece: tourism, offshore energy, maritime navigation and ports, water management	Ecologic Institute, 2014; Wenzel & Treptow, 2013; Fichter et al., 2013; Von Storch & Claussen, 2011; UC-IHC; NCSRD: 3C's, Climate Change Consequences, 2011-2014; www.marinaproject.eu www.oceanography.ucy.ac.cy/mosep/
Mean precipitation amount	future	monthly, seasonal, annual	regional	raw data, analysed data	Germany, France: tourism, coastal protection	ONERC, 2018 Bülow et al., 2017
Maximum precipitation amount	not addressed	not addressed	national, regional	analysed data	Germany: coastal protection	Bülow et al., 2017

Coastal climate indicators	Time horizon	Time resolution	Spatial scale	Format/Information channels	Countries and sectors	References
Precipitation intensity	not addressed	not addressed	national, regional	analysed data	Germany: tourism, coastal protection	Bülow et al., 2017
Dry days (number of days withprecipitation ≤ 1mm)	not addressed	month, season, 6 months	national, regional,	analysed data	Germany: tourism, coastal protection, scientific users	Bülow et al., 2017; Schuchardt et al., 2011; KUNTIKUM, 2009
Days with precipitation (number of day with precipitation ≥ 1mm/10mm)	not addressed	month, season, 6 months	national, regional,	analysed data	Germany: tourism, offshore wind energy, coastal protection, scientists	Bülow et al., 2017; Schuchardt et al., 2011; KUNTIKUM, 2009
Days with extreme high precipitation (number of days with precipitation ≥ 20mm)	not addressed	season, 6 months	national, regional	analysed data	Germany: tourism, offshore wind energy, coastal protection, scientists	Bülow et al., 2017; Schuchardt et al., 2011
Days with snow cover	not addressed	not addressed	national, regional	analysed data	Germany: tourism, offshore wind energy, scientific users	Bülow et al., 2017; Von Storch & Claussen, 2011; KUNTIKUM, 2009
Drought index (precipitation deficite in % with regard to reference period and catchment area)	not addressed	3, 6 months	national	analysed data	Germany: coastal protection	Bülow et al., 2017
Range of vision	not addressed	not addressed	not addressed	analysed data	Germany: tourism, scientific users	Von Storch & Claussen, 2011

Coastal climate indicators	Time horizon	Time resolution	Spatial scale	Format/Information channels	Countries and sectors	References
Solar radiation						
Global radiation	not addressed	hourly basis	regional, local,	raw data, analysed data; final developed climate information is shown via data, reports, maps, graphics	Spain, Germany: offshore wind energy, water management, tourism	UC-IHC; Bülow et al., 2017; Weisse et al., 2015; www.coastdat.de
Ultraviolet radiation	not addressed	not addressed	not addressed	analysed data	Germany: tourism, scientific users	Von Storch & Claussen, 2011
Longwave radiation	not addressed	not addressed	not addressed	analysed data	Germany: tourism, scientific users	Von Storch & Claussen, 2011
Day length	not addressed	not addressed	not addressed	analysed data	Germany: tourism, scientific users	Von Storch & Claussen, 2011
Cloud cover						
Sunshine duration,	not addressed	not addressed	national, regional	analysed data	Germany: tourism, scientific users	Bülow et al., 2017; Von Storch & Claussen, 2011
Sunny days, days of clear sky	not addressed	not addressed	regional	analysed data	Germany: tourism, scientific users	Schuchardt et al., 2011; KUNTIKUM, 2009
Overcast days	not addressed	not addressed	national, regional	analysed data	Germany: tourism	Bülow et al., 2017
Cloud cover data	not addressed	not addressed	regional, local	raw data	Germany: offshore wind energy	Weisse et al., 2015; www.coastdat.de

Table 3: Stakeholders' information needs: potential inland climate indicators (detailed inventory), based on documented stakeholder needs

Coastal climate indicators	Time horizon	Time resolution	Spatial scale	Format/Information channels	Countries and sectors	References
Surface water						
Run-off	recent, present, future	not addressed	local, regional	raw data (observations), analysed data (e.g. return periods); information should be prepared and tailored to the interest groups' needs; overview maps or maps with 1km-grids	Germany, France: maritime navigation and ports, risk insurance, coastal protection	Munich Re, 2005; Swiss Re, 2003; Seiffert et al., 2014; BMVI, 2015; Schlünzen & Linde, 2014;
Continental water flow	not addressed	not addressed	local	raw data (observations, analysed data; reports, maps, graphics	Spain: water management	UC-IHC
Inland floods						
River floods, flash floods: maximum water levels, flow velocity, quantities of bed-load, flood duration	not addressed	not addressed	not addressed	raw data (observations), analysed data	Germany: risk insurance	Swiss Re, 2003

Table 4: Stakeholders' information needs: potential combined marine, atmospheric climate indicators (detailed inventory), based on documented stakeholder needs

Coastal climate indicators	Time horizon	Time resolution	Spatial scale	Format/Information channels	Countries and sectors	References
Marine						
Waves and breakers that influence coastal processes	future	not addressed	local	raw data	Germany: coastal protection	Weisse et al., 2012
Atmospheric						
Hot and humid summer days, annual sum (Tmax > 25°C, relative air humidity > 80%)	not addressed	days per year	national, regional	analysed data	Germany: tourism	Bülow et al., 2017
Longest period of consecutive hot and humid summer days (Tmax > 25°C, relative air humidity > 80%)	not addressed	days	national, regional	analysed data	Germany: tourism	Bülow et al., 2017
Heat stress (PET > 35°C)	not addressed	days	regional	analysed data	Germany: tourism, scientific users	Schuchardt et al., 2011; KUNTIKUM, 2009
Days with cold stress, annual sum (PET < 0°C; Tmin < 0°C, relative air humidity > 80%, wind > 5m/s)	not addressed	days per year	regional	analysed data	Germany: tourism, scientific users	Schuchardt et al., 2011; KUNTIKUM, 2009; Bülow et al., 2017
Longest period of consecutive days with cold stress (Tmin < 0°C, relative air humidity > 80%, wind > 5m/s)	not addressed	days	regional	analysed data	Germany: tourism, scientific users	Bülow et al., 2017
Thermal suitability (18°C< PET <29°C)	not addressed	days	regional	analysed data	Germany: tourism, scientific users	Schuchardt et al., 2011

Table 5: Stakeholders' information needs: potential context based climate information (detailed inventory), based on documented stakeholder needs

Coastal climate indicators	Time horizon	Time resolution	Spatial scale	Format/Information channels	Countries and sectors	References
Climate change impacts						
Climate change impacts on ports: Regional climate change and its effects (e.g. of storm surges, sea level rise) on ports and their infrastructure (e.g. traffic areas, depots, quay walls, irrigation and drainage systems), technical adaptation measures	future	not addressed	regional, local	climate impact information (format not further spezified); target-group specific preparation of current and relevant information, suitably presented; more application-oriented and comprehensible information about impacts of climate change and possible adaptation measures necessary, targeted dissemination of information; used information channels: professional events, networks, talks	Germany, France: maritime navigation and ports, research	Von Storch et al., 2017; Schröder & Hirschfeld, 2014; Schröder et al., 2013 Ecologic Institute, 2014; ONERC, 2011
Climate change impacts on flood-prone areas: Flooding and shoreline change; flood-prone areas (e.g. during storm surges) and existing values within these areas	future	not addressed	regional, local	analysed data; hazard and risk maps, vulnerable area maps; scientific information should have a close connection to the community's own situation; elaboration of concrete concepts and proposed solutions desired; reliable scientific statements desired; tailored information needed according to the needs of different types of stakeholders and with special attention to specific topics and sectors	Germany, France: risk insurance, coastal protection, municipalities and regional policy	Koerth & Sterr, 2012; González-Riancho et al., 2017; Deboudt, 2010; Le Cozannet et al., 2013; Le Cozannet et al., 2017; ONERC, 2011
Climate change impacts on ecosystems and beaches: Effects of sea level rise/change, sea surface temperature, ocean warming, acidification, pollution and dredging on beaches, biodiversity and ecosystems	future	not addressed	regional, local,	analysed data	France: tourism, maritime navigation and ports, research	ONERC, 2018; Individual interviews; Budoc, 2018

Coastal climate indicators	Time horizon	Time resolution	Spatial scale	Format/Information channels	Countries and sectors	References
Climate change impacts on coastal and estuarine morphology: Interactions between sea level rise and morphological changes (e.g. growing mudflads); sediment transport parallel to the coastline, lee side erosion, wave set-up at the coast	future	not addressed	regional,	raw data and analysed data	Germany: maritime navigation and ports, coastal protection, research	Seiffert et al., 2014; BMVI, 2015; Schuchardt & Wittig, 2012; Schuchardt et al., 2011; Ecologic Institute, 2014
Climate change impacts on technical systems: Effects of stronger wind, more storms on technical and economical wind energy potentials; effects of rising water levels on pumping stations and drainage	not addressed	not addressed	regional, local,	raw data	Germany: offshore wind energy, coastal protection	Knoblauch et al., 2012; Ecologic Institute, 2013; Ecologic Institute, 2014; RADOST poster
Climate change impacts on socio-economical systems: Consequences of climate change for society, options for action; social and economic impacts of storm surge events	not addressed	not addressed	regional	tailored information needed according to the needs of different types of stakeholders and with special attention to specific topics and sectors; information sources on climate change issues: media (print, radio and TV) are most important, only about 4% use scientific information services	Germany: coastal protection, municipalities and regional policy	Meinke, 2017; González-Riancho et al., 2015; González-Riancho et al., 2017
Climate change impacts on sectors in general: Climate change effects on coastal tourism sector	not addressed	not addressed	regional, local,	raw data and analysed data; information exchange, networking, dialogues, discussions, platforms, print media; information tailored to stakeholders' needs; compact, comprehensible and easily understandable	Germany: tourism	Knoblauch et al., 2012; Schumacher et al., 2010a+b; Schumacher et al., 2010c; Schumacher et al., 2012; Stelljes, 2012; Filies, 2012
Air quality	not addressed	not addressed	not addressed	analysed data	Germany: tourism, scientific users	Von Storch & Claussen, 2011

Coastal climate indicators	Time horizon	Time resolution	Spatial scale	Format/Information channels	Countries and sectors	References
Climate change adaptation						
Technical climate change adaptation: Reference values/rated values for construction standards and for safeguarding the port infrastructure, climate-adapted transport logistics	not addressed	not addressed	regional, local,	not addressed	Germany, France: maritime navigation and ports	ONERC, 2011; Osthorst et al., 2014
Beach management: Solutions for handling with growing amounts of seaweed at beaches needed	not addressed	not addressed	local	scientific information should have a close connection to the community's own situation, elaboration of concrete concepts and proposed solutions desired, reliable scientific statements desired;	Germany: municipalities and regional policy	Koerth & Sterr, 2012
General: Climate change adaptation strategies, measures and options for action	not addressed	not addressed	regional, local	information exchange, networking, dialogues, discussions, platforms, print media; general recommendations and specific measures; information and project results prepared and tailored to stakeholders' needs (e.g. range of outcomes for the planning sector, extreme events and frequencies for political decision makers); compact, comprehensible and easily understandable; overview map or maps with 1km-grids	Germany: tourism, maritime navigation and ports	Knoblauch et al., 2012; Schumacher et al., 2010a+b; Schumacher et al., 2010c; Schumacher et al., 2012; Stelljes, 2012; Schlünzen & Linde, 2014

4. Potential indicators of a pan-European service web tool on coastal climate

One objective of ECLISEA is to develop a prototype for a pan-European coastal climate service web tool for stakeholders from different sectors at European coasts. For this reason, it was examined which of the indicators/sub-indicators listed in the tables 1 to 5 in chapter 3 were in demand in at least two countries (on the basis of documented stakeholder needs in literature, projects and experiences on ECLISEA-partner level). This criterion has been used as a filter function to develop the **final catalogue of potential coastal climate indicators for a pan-European service web tool, the short list** (see table 6). It was also checked for which of these sub-indicators internet-based information channels/formats like "web-based tools", "user-friendly interfaces" or "internet platforms" were used or requested explicitely. This might be an indication of the extent to which web tools could also be used by stakeholders in the future, or how openly stakeholders are in using web tools when searching for climate information. In cases where the more general term "websites" were mentioned, it was included in the table as well, as "websites" could also include "web tools".

The **final catalogue** now contains **20 (sub-)indicators** of coastal climate information from four main catagories (marine, atmospheric, inland, context-based) that were requested by stakeholders from two ore more countries, which indicates a broad interest and need of these kind of information.

These 20 (sub-)indicators belong to the following main indicators (see table 6 for more details):

Marine

- Waves
- Currents
- Water levels
- Water temperature

Atmospheric

- Air temperature
- Wind
- Precipitation
- Global radiation

Inland

- Surface water

Context-based:

- Climate change impacts on ports
- Climate change impacts on flood-prone areas
- Technical climate change adaptation

The final catalogue contains, compared to the detailed inventory of potential climate indicators (tables 1-5, chapter 3), many generally formulated (sub-)indicators, such as “waves”, “currents”, “storm surges” and “tides”, but only a few more specificly formulated sub-indicators, e.g. “mean sea level”, “sea surface temperature” or “mean air temperature at 2m”. The reasons lay in the very general documentation of stakeholder needs in literature and, thus, in the literature review as an insufficient method for analysing and deriving stakeholder needs on coastal climate information. Therefore, the specific stakeholder needs remain quite vague, and the final catalogue of coastal climate indicators may rather function as a general suggestion for topics to be included in the service web tool than as a profound and specific basis for the web tool (see also discussion in chapter 6).

With regard to the requested format of information, table 6 shows that not for all of the 20 (sub-)indicators web-based formats or information channels (such as web tools) have been requested explicitely (only for the (sub)-indicators waves, currents, sea level, storm surges and wind). This could indicate that web tools are either only one needed information channel/format among others, or other formats/information channels are much more important and web tools have not been used so much up to now to seek for coastal climate related information. This should be taken into account when introducing new ECLISEA climate service formats to stakeholders.

Table 6: Catalogue of potential indicators/sub-indicators for a pan-European coastal climate service web tool (short list)
Selection based on sub-indicators requested in two or more countries.
Time resolution: a = annual, s = seasonal, m = monthly, d = daily, h = hourly.
Empty fields: no specific requests by stakeholders documented.

Coastal climate indicators	Countries	Regional/local information requested	Time horizon				Time resolution					Web-based tools/interfaces
			Recent	Present	Near future	Future (2100)	a	s	m	d	h	
Marine												
Waves												
General (not further specified by stakeholders)	Germany, Spain, France	x	x	x	x	x					x	x
Currents												
General (not further specified by stakeholders)	Germany, Spain, France	x	x	x	x	x					x	x
Water levels												
Sea level												
General (not further specified by stakeholders)	Germany, Spain, France, Greece	x	x	x	x	x						x
Mean sea level, Mean sea lvel rise	Germany, France, Greece	x		x		x						

Coastal climate indicators	Countries	Regional/local information requested	Time horizon				Time resolution					Web-based tools/interfaces
			Recent	Present	Near future	Future (2100)	a	s	m	d	h	
Storm surges												
General (not further specified by stakeholders)	Germany, France, Spain, Greece	x	x	x	x	x					x	x
Tides												
General (not further specified by stakeholders)	Germany, Spain	x				x						websites
Water temperature												
Sea surface temperature	Spain, France, Greece	not addressed				x						websites
Atmospheric												
Air temperature												
General (not further specified by stakeholders)	Germany, Greece	x		x	x	x						websites
Mean air temperature (2m temperature)	Germany, France	x				x		x	x			
Extreme air temperature	France, Greece	not addressed				x						

Coastal climate indicators	Countries	Regional/local information requested	Time horizon				Time resolution					Web-based tools/interfaces
			Recent	Pre-sent	Near future	Future (2100)	a	s	m	d	h	
Wind												
General (not further specified by stakeholders)	Germany, Spain, Greece, France	x	x	x	x	x					x	x
Storm intensity (including gust speed, sustained wind speed)	Germany, Spain	x (and national)	x	x		x						websites
Storm frequency	Germany, Spain	x (and national)	x	x		x						websites
Precipitation												
General (not further specified by stakeholders))	Germany, Spain, Greece	x		x	x	x						websites
Mean precipitation amount	Germany, France	national				x	x	x	x			
Solar radiation												
Global radiation	Germany, Spain	x									x	
Inland												
Surface water												
Run-off	Germany, France	x	x	x		x						

Coastal climate indicators	Countries	Regional/local information requested	Time horizon				Time resolution					Web-based tools/interfaces
			Recent	Pre-sent	Near future	Future (2100)	a	s	m	d	h	
Context-based												
Climate change impacts												
Climate change impacts on ports (e.g. of storm surges, sea level rise)	Germany, France	x				x						
Climate change impacts on flood-prone areas (e.g. during storm surges)	Germany, France	x				x						
Climate change adaptation												
Technical climate change adaptation (e.g. reference values for constructions and port infrastructure, climate-adapted transport logistics)	Germany, France	x										

5. Identification of main gaps in the databases at European level

In order to identify main gaps in existing climate information of sea surface dynamics along the European coasts and seas, the sub-indicators of the short list of the catalogue were compared, as far as possible, with available European met-ocean surface datasets and related coastal exposure databases, listed and described in deliverable D1.A "Climate datasets and related Coastal Exposure databases" (2018) (see table 7 in the annex). This report concentrates on available sea surface datasets and coastal exposure databases mainly including data about wind, waves, storm surges, sea and water levels, currents and air temperature. Additionally, further European databases and datasets have been reviewed with regard to other potential coastal climate indicators listed in the catalogue. Those databases and datasets that could be allocated to sub-indicators in the catalogue (by comparing the variables included in the datasets/databases with the sub-indicators), are listed and shortly described in the annex.

For all indicators and sub-indicators in table 7 one or more datasets or databases could be allocated. These datasets are climate observational datasets (in-situ records from buoys and tide gauges, remote observations like wave height altimeter measurements and sea level data from satellite), historical climate datasets (sea level datasets, wave hindcasts, atmospheric datasets), and climate projections datasets (about mean sea level rise, regional wave climate, storm surges and compounded water levels) (see deliverable D1.A Climate datasets and related Coastal Exposure databases). Additionally reviewed datasets containing variables like air temperature, wind, precipitation, solar radiation and water runoff could also be allocated within the catalogue.

The following overview about knowledge gaps was developed by comparing the indicators and sub-indicators of the short list (including the spatial coverage, spatial and time resolution and time horizon requested by stakeholders) with available European databases and datasets (reviewed in deliverable D1.A and additionally searched datasets). It should be noted that this can only be a rough overview, because detailed climate data needs of stakeholders could not be documented in many cases through the literature review (see deliverable D1.B). Especially, possible gaps referring to spatial coverage, spatial and temporal resolution of the sub-indicators are difficult to identify, because the needs for climate variables have not been expressed that specificely by stakeholders in many cases. Nevertheless, in general terms, the ***need for much more regional and local climate data and information, for recent and present time horizons as well as for future scenarios,*** has been documented, which the available datasets often cannot fulfil (for further details see table 7 for the comparism and a short description of relevant datasets in the annex).

On the basis of stakeholders' documented climate information requests and available European datasets, the following main gaps could be defined:

Waves

- Localised data (apart from buoy measures) for recent and present time horizons for the German, Spanish and French coastal areas

Currents

- Present data and future scenarios for the Atlantic Ocean and the Mediterranean Sea
- Localised data (recent, present) for the German, Spanish, French and Greek coastal areas

Sea level

- Localised data for past and present time horizons at the coastal areas of all four countries
- Local and regional sea level rise scenarios for the coastal areas of all four countries

Storm surges

- Recent and present localised for the coastal areas of all four countries
- Localised storm surge projections for French, Spanish and Greek coasts along the Mediterranean Sea and North Atlantic Ocean
- Local storm surge projections for the North Sea coasts

Tides

- Localised tidal projections for the German and Spanish coasts

Sea surface temperature

- Future scenarios for the Spanish, French and Greek coastal areas

Air temperature

- Localised data (present and future) for German, French and Greek coastal areas

Wind

- Localised data (recent, present, future) for the coastal areas of all four countries

Precipitation

- Localised data (present, future) at German, Spanish and Greek coastal areas

Solar radiation

- Localised data with hourly time resolution for German and Spanish coastal areas

Run-off

- Localised data for a past and present time horizon for German coasts
- Future scenarios for German and French coastal areas

Climate change impacts and climate change adaptation

- Localised storm surge, sea level rise and extreme wind projections for German and French coastal areas
- Localised data about storm surges, sea level rise and storms for the German North Sea and French coastal areas

6. Summary and conclusions

This report contains a detailed inventory of potential coastal climate indicators/sub-indicators (tables 1 to 5 in chapter 3) and a "short list" of 20 indicators/subindicators (table 6 in chapter 4), that are mainly based on documented stakeholder needs found in literature, projects and experiences of ECLISEA project partners in Germany, France, Spain and Greece. The indicators and sub-indicators can be devided into five main categories: marine, atmospheric, inland, combined as well as complex and context-based. The short list was extracted from the detailed inventory and contains only those (sub-)indicators requested by stakeholders in at least two countries, to develop an indicator list of broad (pan-european) interest.

The whole catalogue (tables 1 to 6) contains generally formulated sub-indicators (e.g. "waves", "currents", "storm surges"), more specifically formulated sub-indicators (physical climate variables like mean sea level, mean air temperature at 2m) as well as more complex and context-based climate information needs (e.g. climate change impacts on ports) which are also often documented in a very general and unspecific manner. This reflects the broad and differentiated needs of stakeholders for coastal climate information: on the one hand there exists a need for specific physical climate data (in many cases expressed by scientists and science-related stakeholders), on the other hand for more customer-oriented and prepaired information of different complexity, such as with regard to local climate change impacts in different fields or regional and local solutions for climate adaptation challenges.

However, those sub-indicators requested by at least two countries are often formulated very generally in literature, and thus, the short list of climate indicators (see table 6) contains many unspecifically formulated sub-indicators, compared to the detailed inventory. One reason could be that specific stakeholder needs have not been surveyed or documented exactly and detailed enough in many cases, and the range and existence of the respective literature varied very much among the countries (see also deliverable D1.B, 2018).

Specificly expressed physical parameters for waves or storm surges etc. were found in the reviewed literature often in only one country, if at all, although the need is probably present also in the other countries. Thus, the amount of requested information in the form of sub-indicators also varies quite a lot between the countries. This means that, if the tables 1-5 in chapter 3 list only one country behind a specific sub-indicator, the conclusion that stakeholders of the other countries do not use or request this specific climate information is misleading, which shows a weakness of the selection criterium itself resulting from insufficient data basis. In fact, the short list of potential climate indicators could be much longer and much more precise. This indicates that a literature review is an isufficient method to describe and analyse stakeholder climate information needs, because the documentation remains incomplete. Actually, there exist only few studies with explicit focus on stakeholder climate information needs (see deliverable D1.B, 2018). Therefore, the specific stakeholder needs remain quite vague.

As a conclusion, the (sub-)indicators of the short list (e.g. waves, currents, sea level, storm surges, tides, etc.) could rather serve as a content-related basis or as general

suggestions for topic fields than as a detailed and specific indicator catalogue to be integrated in a web tool. General formulated information could be developed for a web tool, on the basis of the available (sub-)indicators, e.g. about wave climate, because the specific stakeholders needs are unknown. Moreover, stakeholders' interests in climate information with regard to the indicators in the short list probably differ between and within countries, regions and sectors, as well as the issues connected with these indicators and the reasons why the information has been requested for (see also deliverable D1.B, 2018). This underlines the necessity to explicitly identify stakeholders' specific information needs (for instance with workshops or surveys tailored to different stakeholder groups in different sectors and regions in the four partner countries).

One objective of WP 1.3 of the ECLISEA project is to define main gaps in European datasets with regard to stakeholder climate information needs. For that reason, the variables provided by the datasets as well as the connected information about their spatial scale, time horizon and time resolution were compared to the sub-indicators (see chapter 5 and table 7 in annex). Generally formulated, a need for much more local and regional climate data and information (recent and present as well as future scenarios) could be determined which the available databases cannot fulfill in many cases. This raises the question whether the great request for localised information is primarily focussed on local data in the sence of "high spatial resolution" as a data-technical format or whether these requests rather underline a strong need for contextualised information with relation to the situation of the own locality and community, beyond technically possible spatial resolutions. However, the columns about requested formats and information channels (see tables 1-5) indicate both, a need for "technical" data, as well as for context-based information, target-group specific, application-oriented and comprehensible, tailored to the local situation and presented for instance in reports, maps, graphics or during meetings.

Nevertheless, as stakeholder information needs were not expressed and documented that specifically in many cases (with regard to spatial scale etc.), the definition of gaps could have been done only very roughly and has to remain incomplete. Further research with focus on different stakeholder groups and their specific information needs would be necessary in order to better be able to define knowledge gaps.

Finally, with regard to the catalogue of potential coastal climate indicators it should be discussed very briefly the main deficiencies in the way climate information is provided to stakeholders. The catalogue shows that climate information in the form of data is only one way of information transfer which has been requested and/or used by stakeholders. Other requested ways of climate information provision are for instance through reports, maps, graphics, websites, meetings or personal contact.

In some cases, especially with regard to the context-based indicators "Climate change impacts" and "Climate change adaptation", stakeholders expressed their needs for advice and for climate information, which is easily to understand and tailored to their specific needs and localities. These indicators show the needs of many stakeholders for coastal climate information that go far beyond the supply of climate data and even beyond scientific information provision in general maps or graphics or via a service web tool.

Instead, personal contacts, advice and, in some cases, cooperation between scientists and practitioners in projects or workshops with focus on their specific questions and situations (such as to conduct site-specific vulnerability studies with regard to the local impacts of climate change, e.g. on ports), would be a more appropriate way of providing climate information to stakeholders.

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Offshore energy

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2 MOSEP: http://www.oceanography.ucy.ac.cy/mosep/

8. Annex

Table 7: Catalogue of potential indicators/sub-indicators for a pan-European coastal climate service web tool (short list), compared with available European datasets and databases (gap analysis)

Selection based on sub-indicators requested in two or more countries; for more details about datasets see annex below and deliverable D1.A, 2018.
Spatial scale of datasets: As orientation framework the regional scale was defined 50 km^2 and below.
Time resolution: a = annual, s = seasonal, m = monthly, d = daily, h = hourly. In some colums: w = weekly.
Empty fields: no specific requests by stakeholders, datasets do not provide data with these features.

Coastal climate indicators	Examples of European data availability	Countries/ Spatial coverage of datasets	Regional/local information requested	Regional spatial scale of datasets	Time horizon				Time resolution				
					Recent	Pre-sent	Near future	Future (2100)	a	s	m	d	h
Marine													
Waves													
General (not further specified by stakeholders)		Germany, Spain, France	x		x	x	x	x					x
	MARNET: buoy records	German North Sea and Baltic Sea		points	?	x							x
	Spanish buoy network	Spanish coastal and deep waters: Atlantic Ocean, Mediterranean Sea		points	?	x							x

Coastal climate indicators	Examples of European data availability	Countries/ Spatial coverage of datasets	Regional/local information requested	Regional spatial scale of datasets	Time horizon				Time resolution				
					Recent	Pre-sent	Near future	Future (2100)	a	s	m	d	h
	Météo France: buoy records	French deep waters: Bay of Biscay, Mediterranean Sea		points	x	x							x
	CANDHIS: buoy records	French coastal regions: Bay of Biscay, English Channel, Mediterranean Sea		points	?	x							x
	Global altimeter SWH: wave height altimeter measurements	Global		irregular	x				irregular				
	AVISO+: wave height altimeter measurements	Global		1x1°	x	x						x	
	GOW: wave hindcasts	Europe		x	x								x
	coastDat: wave hindcasts	North Sea, Baltic Sea		x	x								x
	Bobwa-h: wave hindcasts	English Channel, Bay of Biscay		x	x								6h
	Marinadb Wave Parameters	Europe		x	x								x
	IH-GOW Regional Projections: regional wave climate projections	Europe		x	x	x	x	x				x	
	coastDat: regional wave climate projections	North Sea, Baltic Sea		x	x	x	x	x					x
	Bobwa: regional wave climate projections	English Channel, Bay of Biscay		x	x	x	x	x					6h

Coastal climate indicators	Examples of European data availability	Countries/ Spatial coverage of datasets	Regional/local information requested	Regionalspatial scale of datasets	Time horizon				Time resolution				
					Recent	Pre-sent	Near future	Future (2100)	a	s	m	d	h
Currents													
General (not further specified by stakeholders)		Germany, Spain, France	x		x	x	x	x					x
	coastDat: historical climate data set, sea level dataset	(Southern, South-Eastern) North Sea		x	x								x
	coastDat: current and storm surge projections	North Sea and Baltic Sea		x	x	x	x	x					x
	NCEP Climate Forecast System Reanalysis	global		0.3°-2.5°	x								1h 6h
Water levels													
Sea level													
General (not further specified by stakeholders)		Germany, Spain, France, Greece	x		x	x	x	x					
Mean sea level, Mean sea level rise		Germany, France, Greece	x			x		x					
	Permanent Service for Mean Sea Level (PSMSL): tide gauge records	global, Europe (including Germany, France, Spain, Greece)		points	x	x			x		x		
	Global Sea Level Observing System (GLOSS): tide gauge records	global (including Germany, France, Spain)		points	x	x			x		x	x	x

Coastal climate indicators	Examples of European data availability	Countries/ Spatial coverage of datasets	Regional/local information requested	Regional spatial scale of datasets	Time horizon				Time resolution				
					Recent	Pre-sent	Near future	Future (2100)	a	s	m	d	h
	GESLA-2 (Global Extreme Sea Level Analysis): tide gauge records	global, (including Germany, France, Spain, Greece)		points	x	x							x
	Global Ocean Gridded L4: Sea level data from satellite	Global		x	x							x	
	Mediterranean Sea Gridded L4: Sea level data from satellite	Mediterranian Sea		x	x							x	
	SL_cci ECV v2.0: Sea level data from satellite	Global		x	x						x		
	RADS: Sea level data from satellite	Global		irregular	x				irregular				
	Global Ocean Along-Track L3: Sea level data from satellite	Global		x	x				irregular				
	coastDat: historical sea level dataset	(Southern, South-Eastern) North Sea, Baltic Sea		x	x								x
	Baltic Sea Physics Reanalysis from SMHI: historical sea level dataset	Baltic Sea		x	x						x	x	x
	GOST: historical sea level dataset	Europe		x	x								x
	Mediterranean Sea Physics Reanalysis: historical sea level dataset	Mediterranean Sea		x	x						x	x	
	LEGOS Sea level reconstruction and historical sea level hindcast	(Quasi) global		1x1°	x				x		x		
	AWI sea level reconstruction	Global		1x1°	x						x		
	CSIRO sea level reconstruction, GECCO2, ORA-S4	(Quasi) global		1x1°	x						x		
	CCAR sea level reconstruction	Quasi global		x	x						w		

Coastal climate indicators	Examples of European data availability	Countries/ Spatial coverage of datasets	Regional/local information requested	Regional spatial scale of datasets	Time horizon				Time resolution				
					Recent	Pre-sent	Near future	Future (2100)	a	s	m	d	h
	Soda2.1.6: historical sea level dataset	Global		x	x						x		
	GLOBAL OCEAN PHYSICS REANALYSIS GLORYS2V4: historical sea level dataset	Global		x	x						x	x	
	IPCC-AR5: climate projections dataset: mean sea level rise projections	Global		1x1°	x	x	x	x	x				
	LISTCoAsT: water level projections	Europe, along European coastlines		≤ 1.5°	x	x	x	x	8 return periods				
Storm surges													
General (not further specified by stakeholders)		Germany, France, Spain, Greece	x		x	x	x	x					x
	GOST: historical sea level dataset	Europe		x	x								x
	coastDat: storm surge projections	North Sea, Baltic Sea		x	x	x	x	x					x
	IH-DAC Regional Projections: storm surge projections	North Atlantic Ocean		2°				x				x	
	LISCoAsT: storm surge projections	Europe, along European coastlines		x	x	x	x	x	8 return periods				
Tides													
General (not further specified by stakeholders)		Germany, Spain	x					x					

Coastal climate indicators	Examples of European data availability	Countries/ Spatial coverage of datasets	Regional/local information requested	Regional spatial scale of datasets	Time horizon				Time resolution				
					Recent	Pre-sent	Near future	Future (2100)	a	s	m	d	h
	Permanent Service for Mean Sea Level (PSMSL): tide gauge records	global, Europe (including Germany, France, Spain, Greece)		points	x	x			x		x		
	Global Sea Level Observing System (GLOSS): tide gauge records	global (including Germany, France, Spain)		points	x	x			x		x	x	x
	GESLA-2 (Global Extreme Sea Level Analysis): tide gauge records	global, (including Germany, France, Spain, Greece)		points	x	x							x
	GOST: historical sea level dataset	Europe		x	x								x
Water temperature													
Sea surface temperature		Spain, France, Greece	not addressed					x					
	NCEP Climate Forecast System Reanalysis	global		0.3°-2.5°	x								1h 6h
	HOAPS: satellite data	global		x	x						x		
	GECCO2: water temperature data etc., historical climate dataset	global		1x1°	x						x		
	Soda2.1.6: water temperature data etc., historical dataset	global		x	x						x	x	
	Global Ocean Physics Reanalysis GLORYS2V4: water temperature data etc., historical climate dataset	global		x	x						x	x	
	Mediterranean Sea Physics Reanalysis: water temperature data etc., historical climate dataset	Mediterranean Sea		x	x						x	x	

	EPER NCSRD: atmospheric dataset, hindcast	Europe – Mediterranean Basin		x	x								6h
	Baltic Sea Physics Reanalysis from SMHI: water temperature data etc., historical climate dataset	Baltic Sea		x	x						x	x	x
Atmospheric													
Air temperature													
General (not further specified by stakeholders)		Germany, Greece	x			x	x	x					
Mean air temperature (2m temperature)		Germany, France	x					x		x	x		
Extreme air temperature		France, Greece	not addressed					x					
	NCEP Climate Forecast System Reanalysis: atmospheric data set	Global		0.3°-2.5°	x								1h 6h
	ERA: atmospheric data set	Global		0.75°	x							x	6h
	MPI-ESM: historical and emission scenarios	Global		0.4°/ 1.5°	x	x	x	x			x		
	EPER NCSRD: atmospheric dataset, hindcast	Europe – Mediterranean Basin		x	x								6h

Coastal climate indicators	Examples of European data availability	Countries/ Spatial coverage of datasets	Regional/local information requested	Regional spatial scale of datasets	Time horizon				Time resolution				
					Recent	Pre-sent	Near future	Future (2100)	a	s	m	d	h
Wind and storms													
General (not further specified by stakeholders)		Germany, Spain, Greece, France	x		x	x	x	x					x
Storm intensity (including gust speed, sustained wind speed)		Germany, Spain	x (and national)		x	x		x					
Storm frequency		Germany, Spain	x (and national)		x	x		x					
	SeaWind II: atmospheric dataset, hindcast	Europe		x	x								x
	MARINAdb Atmospheric Parameters: reanalysis	Europe		x	x								x
	EPER NCSRD: atmospheric dataset, hindcast	Europe – Mediterranean Basin		x	x								6h
	NCEP Climate Forecast System Reanalysis: atmospheric data set	Global		0.3°-2.5°	x								1h 6h
	MPI-ESM: historical and emission scenarios	Global		0.4°/ 1.5°	x	x	x	x			x		
	HOAPS: satellite data	Global		x	x						x		
	ERA-Interim: atmospheric reanalysis	Global		0.75x0.75	x	x							6x
	CFS Hourly products, CFSv2 Hourly products: climate forecast system reanalysis	Global		x	x	x							x

Coastal climate indicators	Examples of European data availability	Countries/ Spatial coverage of datasets	Regional/local information requested	Regional spatial scale of datasets	Time horizon				Time resolution				
					Recent	Pre-sent	Near future	Future (2100)	a	s	m	d	h
Precipitation													
General (not further specified by stakeholders))		Germany, Spain, Greece	x			x	x	x					
Mean precipitation amount		Germany, France	national					x	x	x	x		
	MPI-ESM: historical and emission scenarios	global		0.4°/ 1.5°	x	x	x	x			x		
	NCEP Climate Forecast System Reanalysis: atmospheric data set	global		0.3°-2.5°	x								1h 6h
	ERA: atmospheric data set	global		0.75°	x							x	6h
	HOAPS: satellite data	global		x	x						x		
	CPC Merged Analysis of Precipitation (CMAP)	global		2.5°	x	x					x		
Solar radiation													
Global radiation		Germany, Spain	x										x
	MPI-ESM: historical and emission scenarios	global		0.4°/ 1.5°	x	x	x	x			x		
	ERA: atmospheric data set	global		0.75°	x							x	6h

Coastal climate indicators	Examples of European data availability	Countries/ Spatial coverage of datasets	Regional/local information requested	Regional spatial scale of datasets	Time horizon				Time resolution				
					Recent	Pre-sent	Near future	Future (2100)	a	s	m	d	h
Inland													
Surface water													
Run-off		Germany, France	x		x	x		x					
	NCEP Climate Forecast System Reanalysis	global		0.3°-2.5°	x								1h 6h
	Global Runoff Data Base (GRDC): gauging stations	global		points	x	x					x		
Context-based													
Climate change impacts													
Climate change impacts on ports (e.g. of storm surges, sea level rise)		Germany, France	x		x	x		x					
Climate change impacts on flood-prone areas (e.g. during storm surges)		Germany, France	x		x	x		x					
	See all datasets above assigned under sea level and storm surges.												

Coastal climate indicators	Examples of European data availability	Countries/ Spatial coverage of datasets	Regional/local information requested	Regional spatial scale of datasets	Time horizon				Time resolution				
					Recent	Pre-sent	Near future	Future (2100)	a	s	m	d	h
Climate change adaptation													
Technical climate change adaptation (e.g. reference values for constructions and port infrastructure, climate-adapted transport logistics)		Germany, France	x										
	See all datasets above assigned under sea leve, storm surges and wind.												
	It should be noted that for the context-based indicators climate change impacts and climate change adaptation much more data than mentioned in the table and climate information in other formats as well as for instance vulnerability and technical studies or cooperation between science and practitioners would be necessary.												

The following European datasets and databases could be matched to some of the sub-indicators of the catalogue (see table 7 above) and are described here very shortly (for more details regarding the databases and datasets see deliverable D1.A, 2018):

Marine datasets:

Climate observational datasets

- In-situ records

  Buoys

  Spanish buoy network of Spanish Port Authority: wave sea state parameters, hourly resolution, Spanish coastal and deep waters, buoy records, txt data format, starting dates of measurements: 1993-2006, real time records available

  Météo-France in French deep waters: wave parameters, hourly resolution, buoy records, txt data format, longest recording period: 1990-2018, historical records available

  CANDHIS in French coastal regions: wave parameters, hourly resolution, buoy records, txt data format, real time records available

  POSEIDON marine monitoring network in Greek waters: wave parameters, 3 hours resolution, buoy records, txt data format, longest recording period: 2000-2017, real time records available

  MARNET monitoring network in the German North Sea and Baltic Sea: wave parameters, hourly resolution, buoy records and measuring stations, txt data format, real time records (available), historical (but not available on website)

  Tide gauges

  Permanent Service for Mean Sea Level (PSMSL): variables: water level, application: global and regional sea level rise and variability, long term changes during the last two centuries, tide gauge record (since 1998, some before), monthly/annual data frequency, txt data format, data sets available for all four countries

  Global Sea Level Observing System (GLOSS): global and regional long term sea level monitoring, tide gauge record, hourly/daily/monthly/annual data frequency (last data after 2005), txt data format, data sets available for Germany, France, Spain

  GESLA-2 (Global Extreme Sea Level Analysis): changes in frequency and magnitude of extreme sea levels, global, tide gauge records, hourly frequency, txt data format, data sets available for all four countries

- Remote observations

  Wave height altimeter measurements

  Global altimeter SWH data set and AVISO+ gridded wave products: variables: significant wave height, global, satellite altimeters, NetCDF data format; AVISO: spatial resolution 1x1 degree, time resolution daily, 2009-ongoing, SWH: spatial and time resolution irregular, 1991-2017

Sea level data from satellite

Global Ocean gridded L4 Sea surface heights and derived variables reprocessed, Mediterranean Sea gridded L4 Sea surface heights and derived variables reprocessed, SL_cci ECV v2.0, RADS, Global Ocean Along-Track L3 Sea surface heights reprocessed: variables: Sea Level Anomalies, satellite altimeters, Mediterranian Sea and global, spatial resolution: 0,125x0,125 degree, 0,25x0,25 degree, 7x7 km, irregular, time resolution: daily, monthly, irregular, longest period: 1991-2017

Historical climate datasets

- Wave hindcasts

  GOW, coastDat, Bobwa-h, Marinadb Wave Parameters: wave hindcasts, variables: significant wave height, mean wave period, wave peak period, (mean) wave direction, wave peak direction, maximum wave height; Europe, North Sea, Baltic sea, English Channel, Bay of Biscay, spatial resolution: several, from 0,125x0,125 degree to 0,05x0,05 degree, time resolution: hourly, 3-h, 6-h, period: several, earliest start time 1949, latest end time 2017, model data in NetCDF format

- Sea level datasets

  coastDat: (southern, south-eastern) North Sea, Baltic Sea, variables: currents, historical climate data sets, sea level datasets, spatial resolution: 1.6-12.8 km, time resolution: hourly, longest period: 1948-2015, model data, simulation based in NetCDF format

  GOST: historical climate dataset, variables: sea level (storm surge + astronomical tide elevations), Europe, horoizontal resolution: 3.5 to 11 km, time resolution: hourly, period: 1979-2014 or 2017 (?), model data in NetCDF format

  LEGOS sea level reconstruction, LEGOS historical sea level hindcast, AWI/CSIRO/CCAR sea level reconstructions, GECCO2, ORA-S4, SODA 2.1.6, Global ocean physics reanalysis GLORYS2V4, Baltis Sea physics reanalysis from SMHI, Mediterranean Sea physics reanalysis (1955-2015/1987-2015): several datasets, variables: Sea Level Anomalies, mean sea level, sea surface height, global, Baltic Sea, Meditarranian Sea, spatial resolution: 1x1 degree, 0,5x0,5 degree, 0,25x0,25 degree, 0,065x0,063 degree, 5,5x5,5 km, time resolution: weekly, monthly, hourly/daily/ monthly mean, annual, longest period: 1900-2015, hybrid and statistical models, ensemble of model output, model data, NetCDF format and matlab files

Further variables: water temperature (not included in D1.A, 2018)

GECCO2: global; variables: water temperature, salinity, sea ice (area, thickness, velocity), spatial resolution: 1×1degree; period: 1948-2016; time resolution: monthly

Soda2.1.6: global; variables: water temperature, salinity, spatial resolution: 0.5×0.5 degree; period: 1960-2008; time resolution: daily, monthly

Global Ocean Physics Reanalysis GLORYS2V4: global; variables: water temperature, salinity, sea ice (area, thickness, velocity), spatial resolution: 0.25×0.25 degree; period: 1993-2015; time resolution: daily, monthly

Baltic Sea Physics Reanalysis From SMHI: Baltic Sea; variables: water temperature, salinity, spatial resolution: 5.5×5.5km; period: 1989-2015; time resolution: hourly, daily, monthly

Mediterranean Sea Physics Reanalysis*:* Mediterranean Sea; variables: water temperature, salinity, spatial resolution: 1/16×1/16 degree (ca. 6-7km); period: 1987-2016; time resolution: daily, monthly

Climate projections datasets

- Mean sea level rise projections

  IPCC-AR5: climate projections datasets, variables: mean sea level rise projections, global, spacial resolution: 1x1 degree, time resolution: anual, period: 2007-2100, model and ensemble data, NetCDF and txt format

- Regional wave climate projections

  IH-GOW Regional Projections: variables: significant wave hight, mean wave period, wave energy flux; Europe, spatial resolution: Atlantic Ocean 0.5^{o}x0.5^{o}, European coastline at 0.125^{o}x0.125^{o}, time horizon 2010-2099, time resolution: daily, model based statistical downscaling.

  CoastDat: variables: significant wave hight, North Sea and Baltic Sea, spatial resolution: North Sea 0.05 x 0.1, 0.05 x 0.075 degree, Baltic Sea 0.05 x 0.075 degree, time horizon: 1961-2100, time resolution: hourly, model data.

  Bobwa: variables: significant wave height, mean wave period, mean wave direction; English Channel, Bay of Biscay; spatial resolution: North Atlantic Ocean of 0.5°, Bay of Biscay 0.1°, time horizon: 1961-2000, 2061-2100, time resolution: 6-hourly. model data.

- Storm surge projections

  CoastDat: storm surge projections, variables: storm surge and currents, North Sea and Baltic Sea, spatial resolution: North Sea (12.8 km), Baltic Sea (from 1.6 to 12.8 km), time resolution: hourly, longest period: 2001-2100, model data, NetCFD format

  IH-DAC Regional Projections: storm surge projections, North Atlantic Ocean, variables: daily maximum surge level, spatial resolution: 2 degree, time resolution: daily, period: 21st century, statistical downscaled data, NetCFD format

  LISCoAsT: storm surge projections, Europe, variables: extreme storm surge level, spatial resolution: along European coastline (every 25 km), time resolution: 8 return periods, longest period: 2001-2100, model data, NetCFD format

- Compounded water level projections
  LISTCoAsT: water level projections, Europe, variables: total water level (simulation of mean sea level, tides, storm surges, waves), extreme sea level, spatial resolution: along European coastline, 1.5 degree and less, time resolution: 8 return periods, period: 2009-2099, model data, NetCFD format

Atmospheric datasets:

- Historical climate datasets
  EPER NCSRD: atmospheric dataset, hindcast, Europe-Mediterranean basin, variables: wind speed and direction at 10m height, sea surface temperature, temperature at 2m, surface pressure, spatial resolution: 0,2x0,2 degree, time resolution: 6-hourly, period: 1980-2009, model data in NetCDF format
  MARINAdb Atmospheric Parameters: atmospheric datasets, variables: air pressure, air density and others, Europe, spatial resolution: 0,05x0,05 degree, time resolution: hourly, period: 1996-2015, model data in Ascii format
  SeaWind II, ERA-Interim, CFS Hourly products, CFSv2 Hourly products: variables: wind speed and direction at 10m height, zonal and meridonial wind components, other atmospheric variables; global, Europe; spatial resolution: several, from 0,05x0,05 degree to 0,312x0,312 degree, time resolution: hourly, 6-hourly, longest period: 1979-ongoing, model data in NetCDF and Ascii format

  Further variables: temperature, precipitation, solar radiation, precipitation (not included in D1.A, 2018)
  MPI-ESM*:* climate projections dataset, historical and emission scenarios, global; variables: air temperature, air pressure, precipitation, evaporation, solar radiation, wind, spatial resolution: 1.5degree, 0.4degree; period: 1850-2100; time resolution: monthly
  ERA*:* global; variables: air temperature, sea level pressure, precipitation, solar radiation, sunshine duration, spatial resolution: 0.75degree; period: 1979-2017; time resolution: 6-hourly, daily
  NCEP Climate Forecast System Reanalysis (CFSR)*:* global; variables: air temperature, sea level pressure, precipitation, runoff, ice depth/thickness, sea ice motion, water temperature, salinity, wind, currents, etc., spatial resolution: 0.3, 0.5, 1.0, 1.9, and 2.5 degree; period: 1979-2010; time resolution: hourly, 6-hourly
  Hamburg Ocean Atmosphere Parameters and Fluxes from Satellite Data (HOAPS)*:* remote ovservation, global; variables: wind speed, evaporation, evaporation-precipitation, precipitation, radiation, specific humidity, latent & sensible heat flux, precipitable water, sea surface temperature, spatial resolution: 0.5 degree; period: 1987-2008; time resolution: monthly

CPC Merged Analysis of Precipitation (CMAP)*:* climate observation (satellite estimates and gauge data), global; variables: precipitation, spatial resolution: 2.5 degree; period: 1979-present; time resolution: monthly

Inland datasets:

Further variables: River run-off (not included in D1.A, 2018)
Global Runoff Data Base (GRDC) distributed by BfG*:* global; 9500+ gauging stations; variables: runoff data, period: time span depends; time resolution: monthly