# JERICO-DS DELIVERABLE

Joint European Research Infrastructure of Coastal Observatories - Design Study

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# EXECUTIVE SUMMARY


This report describes the **results of a gap analysis study** that was performed as part of the Technology Design work package of the JERICO Design Study project. The desired state of the future JERICO-RI, as described in the earlier Technology Outlook report (deliverable 2.1 of the JERICO Design Study project), is compared to the current situation as reported by JERICO nation representatives through a questionnaire. Furthermore, relevant results from earlier JERICO projects have been summarised: on the current **spatial and temporal resolution of JERICO observation**s and on the current **TRL-level of observation methods** for key JERICO variables that have been defined in the Technology Outlook report. Relevant results on gaps from the on-going JERICO-S3 projects and earlier gap analysis reports have been reviewed.

The information on current gaps in observation capacity from these different sources agreed on many overarching issues. The questionnaire results from nation representatives gave further insight into the reasons why current gaps in observation capacity and international harmonisation still exist.

While sensor observations of relevant physical variables are operational at high TRL-level in most countries associated to JERICO, **observations of biological, chemical and benthic variables are still in testing phase or developing phase**. Partly this is due to observation **methods** that are **still being developed**. A major reason why many variables are still observed at a **low TRL-level** is the **lack of sustained funding** for these observations. The **funding is currently nation-based or by European research projects**. These scattered funding sources hamper the prioritisation of international harmonisation efforts and the required maintenance, quality control and data management efforts to make observation data suitable and available for stakeholders in a FAIR way. **Stakeholders**, such as the EEA, Regional Sea Conventions and COPERNICUS have a high demand for such high-quality FAIR observation data, but they **don't fund the required efforts**.

These results indicate that there is a need for a **mature JERICO-RI**, as described in the Technology Outlook report, **based on international coordination and sustained funding**. Next, we will develop a roadmap describing how a mature JERICO-RI can be achieved within 10 years.

# 1. Introduction

## Background on JERICO Technology Design

JERICO started off as a series of EU projects on research and innovation in coastal observations: JERICO, JERICO-NEXT and JERICO-S3. The latter project is still on-going. In parallel the consortium involved in the JERICO projects collaborates in the development of a more permanent way of collaboration: as a European Research Infrastructure Consortium (ERIC): JERICO-RI. The current landscape of European Research Infrastructures (RI's) still lacks an RI on coastal waters, as a link between other RIs involved in Earth Observation, such as the more inland and near-shore oriented RI Danubius, the deep-sea oriented RI EMSO and the atmospheric RI ACTRIS. The JERICO Design Study project aims to elaborate the design of the proposed JERICO-RI: the Joint European Research Infrastructure for Coastal Observations. This includes many aspects, such as the strategy, governance, business plan, data management and the technology design.

This report is part of the development of the technology design work package, focusing on the required technologies for coastal observations and their use. It analyses the gaps between the current state of coastal observations in Europe and the desired state as described in the Technology Outlook report (deliverable 2.1 of JERICO Design Study). It also analyses the reasons why the desired state is not yet reached. The latter information is particularly relevant in the development of a roadmap to reach the desired state, as a next step in the development of the Technical Design of the JERICO-RI. Figure 1 below illustrates the relation between the Technology Outlook, the Gap Analysis and the Roadmap studies, as part of the Technology Design work package in the JERICO Design Study project.

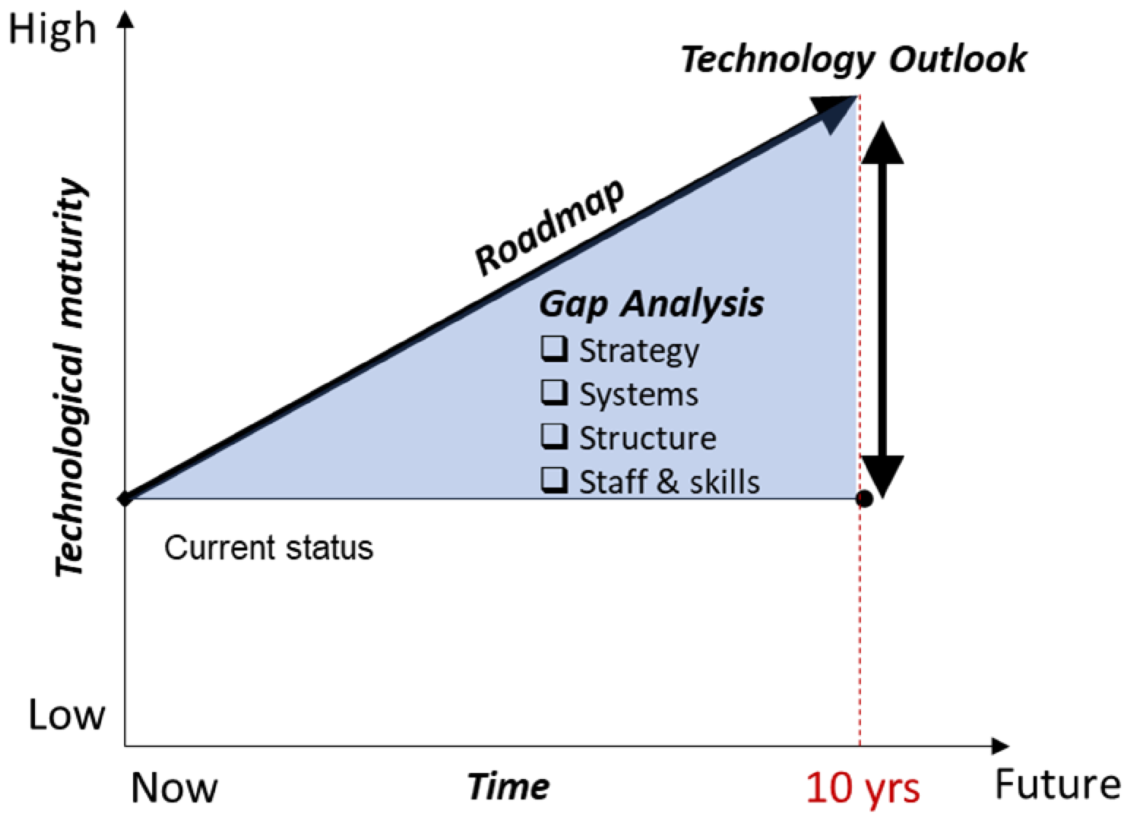


*Figure 1. Conceptual schematization of the role of the gap analysis in the development of the technical design of the Jerico-RI observational infrastructure*

## Desired state according to Technology Outlook

In the Technology Outlook report a set of variables is selected for which observation data is required to address the key scientific challenges (KSCs). Therefore, the observation methods should be at a sufficiently high Technology Readiness Level to make observations of high scientific quality. Also, the observations should have sufficient spatial and temporal resolution to address the KSCs. The key JERICO variables (within the circle in Figure 2) that need to be observed to address key scientific challenges include 4 different groups: physical variables, chemical variables, biological variables and benthic variables. Coastline observations are required to observe coastal erosion processes: both above and below water.

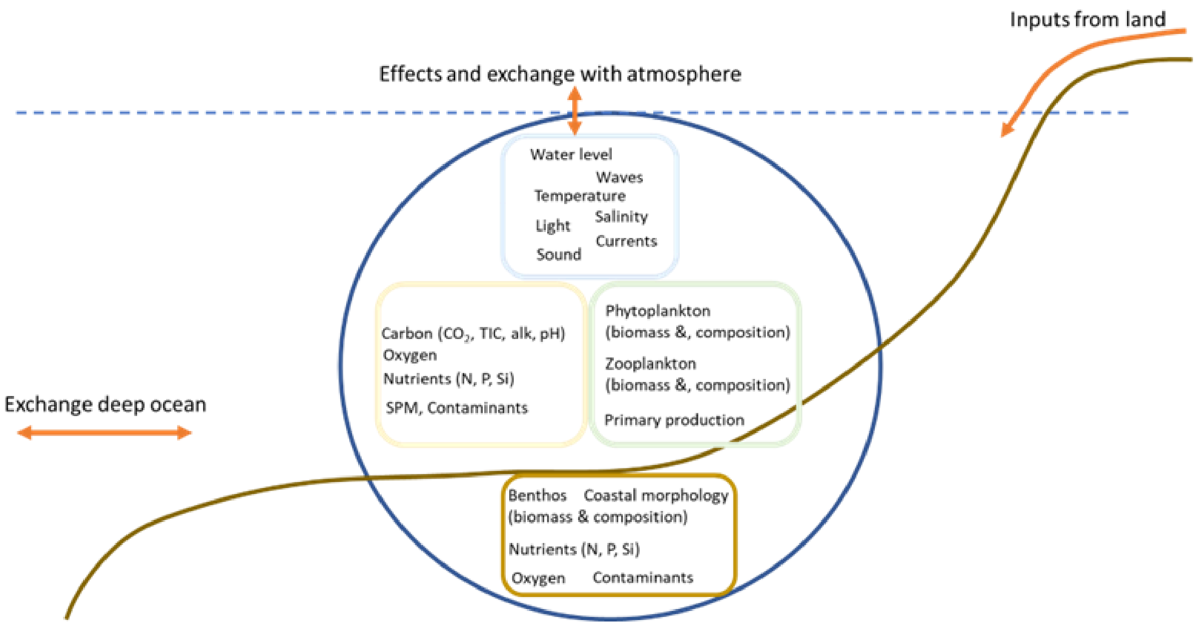


*Figure 2: Overview of variables required to be included in JERICO-RI in order to address Jerico key scientific challenges: within the blue circle. Squares in the circle represent subgroups of variables: physical variables (blue), chemical variables (yellow), biological variables (green) and benthic variables (brown).*

**Approach**

We make an overview for all variables proposed in the Technology outlook (D2.1) of their current data availability and technology readiness levels of sensors. Furthermore, we collated information on different aspects of the Technology Design, in a similar way as in the Technology Outlook study: the strategy, systems, structure, staff and skills, following the McKinsey 7S framework for gap analysis. Information on the current state of the JERICO observational infrastructure is derived from different sources:

- Information from a questionnaire filled out by nation representatives
- Review of existing gap analysis reports by European initiatives such as EUROGOOS and EEA.
- Information from the ongoing JERICO-S3 project (WP3 on Integrated Regional Sites: IRS and WP4 on Pilot Super Sites: PSS) and earlier JERICO reports.

Figure 3 gives a schematic overview of the information sources used in different phases of the technology design in JERICO Design Study.

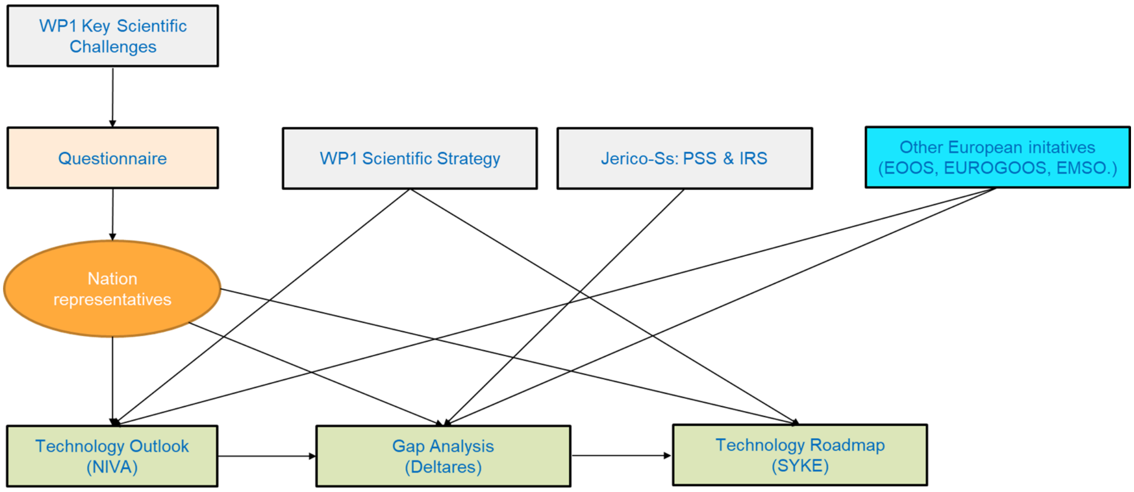


*Figure 3: Schematic overview of information sources used in different phases of the technology design in JERICO Design Study*

# 2. Main report

## 2.1 Gaps identified by JERICO nation representatives

### STRATEGY

This section of the questionnaire deals with the national actions that are under implementation or planned, to make sure that the technical/technological aspects of the national JERICO-RI infrastructure are compatible with the JERICO science strategy.

National coordination of coastal observation activities is currently limited in most countries. In five countries no national coordination is required because all observations are done by the same organisation within that country. In countries where some national coordination is present different approaches are used, as shown in Table 1. Three countries have regular meetings between national parties involved in coastal observations and three countries perform regular intercalibration activities between different organisations in the country. Three countries have a national strategy for coastal observations and one has a joint implementation plan. One country has a joint budget for different organisations involved in coastal observations. Several other countries are also thinking of applying these existing strategies mentioned above. Other ideas suggested to improve the national coordination are to organise a financial commitment, technical centres, a long term strategy, joint projects and a JERICO-RI node at a national level.

*Table 1. Overview of the number of countries that mentioned specific (categorised) answers to the question: "Describe any potential ongoing joint national activities in maintaining and operating national JERICO observations, and what could be done to improve national coordination?*

| Quoted approach | Now | Need to improve |
|---|---|---|
| | [number of countries quoted] | |
| One actor performing all observations | 5 | 1 |
| Joint budgets | 1 | 1 |
| Legal national JERICO node | | 2 |
| Joint projects | 1 | 2 |
| Long term strategy | 2 | 3 |
| Regular intercalibrations between organisations | 3 | 3 |
| Technical centres (national or international) | | 4 |
| Joint implementation of monitoring (planning, use & maintenance) | 1 | 4 |
| National strategy | 3 | 4 |
| Better communication/ meetings | 3 | 4 |
| National financial committment | 2 | 5 |

The technology transfer between science and policy applications is organised in different ways in different countries (Table 2). In most countries currently nothing is formally arranged to facilitate the technology transfer between science and policy applications and therefore the uptake of innovative methods is rather limited. Innovations are mostly planned and executed within research projects, by the scientists working on those projects. Informally, innovative technologies are discussed during meetings between scientists and policy makers or between national and international research organisations. In some countries the policy makers (for example at ministries) fund pilot studies or training and workshops. Two countries have a formal national research infrastructure for coastal observations (including national strategy) and one country has a national strategy for observations in coastal waters.

*Table 2. Overview of the number of counties that mentioned specific (categorised) answers to the question: "How is the transfer and implementation of new technologies and methods between research institutions and environmental management organised in your country?"*

| Comments made | Done | Lacking |
|---|---|---|
| Uptake of new methods is limited | | 6 |
| No structure for technology transfer between science and policy | | 5 |
| Scientists choose which technologies to implement | 8 | |
| Innovations are done in research projects | 8 | |
| National plan / strategy | 4 | 1 |
| Collaboration between organisations in projects | 4 | |
| Ministries fund pilots and comparisons | 4 | |
| Inspiration and information from international collaborators | 4 | |
| National research infrastructure | 4 | |
| Meetings between research and policy | 3 | |
| Meetings among national research organisations | 3 | |
| Environmental managers (biodiversity office) fund trainings & workshops | 1 | |

## SYSTEMS

This section deals with how the technology (platforms, sensors, supporting technology) is organised and implemented to meet the JERICO science strategy.

### How to improve the optimal use of currently available sensor technologies?

National representatives roughly classify observations of physical variables to be mature (TRL 8-9), biogeochemical observations as 'in pilot phase' (TRL 5-7) and biological observations as 'under development' (TRL < 5) (Table 3). Countries didn't use exactly the same ranges of TRL-levels. For the biogeochemical variables, countries classified variables differently. Variables with observation methods that were classified as mature by some countries (such as oxygen by Spain and Norway and chlorophyll-a by Norway), were classified as in pilot phase by other countries (Greece and Italy). It is yet unclear why different countries differ in their classification. Possible explanations could be a lack of experience in operating the sensors, lack of confidence in data precision or different ecosystems posing specific challenges for observing some variables. Ecosystem specific challenges are mentioned for example for measuring nutrient concentrations in oligotrophic waters and for measuring carbon variables in brackish waters. Other remaining issues for observing variables that are mentioned by countries are fouling issues on optical sensors, the need for proper quality checking procedures and a lack of competence in a specific country for operating the sensors. Four countries mentioned that they also observed meteorological variables at their platforms.

*Table 3. Classification of maturity of current observation methods for variables in scope for JERICO: number of countries that mentioned specific maturity levels for sensor-based observations of specific key JERICO variables. Colours indicate which variables are well-established (red: 6-11 times mentioned), which are tested in various countries (yellow/ orange: 2-5 times mentioned) and which are novel (green: mentioned only by one country).*

| | assessment of TRL- status [number of countries] | | |
|---|---|---|---|
| **Variable** | **Advanced (TRL 8-9)** | **pilot phase (TRL 5-7)** | **under development (TRL< 5)** |
| water temperature | 11 | | |
| salinity | 10 | | |
| sea level | 8 | | |
| wave height | 9 | | |
| currents | 7 | | |
| under water light/ transparency | | | |
| Sound/ Noise | 1 | 1 | 2 |
| oxygen | 3 | 4 | |
| Carbon (DIC, pCO2, pH, alkalinity) | | 6 | 1 |
| nutrients (N, P, Si) in water | | 4 | 3 |
| nutrients (N, P, Si) in sediment | | | 2 |
| particles / SPM | 1 | 3 | 2 |
| contaminants | | | 2 |
| phytoplankton biomass/ chlorophyll | 2 | 2 | 3 |
| phytoplankton diversity | | 1 | 3 |
| primary production | | 2 | 5 |
| zooplankton biomass | | | 6 |
| zooplankton diversity | | | 6 |
| benthic biomass | | | 3 |
| benthos composition | | | 3 |
| coastal morphology | 2 | | |

# STRUCTURE

This section deals with the focus areas for national observations, and how the observations and supporting actions are technically coordinated and implemented.

## Current use of multi-platform approaches

The application of a multi-platform approach to coastal observations is an important aspect of the Jerico technology outlook. Currently, the multi-platform approach is applied by several countries within the Jerico consortium, but for a limited number of variables (Table 4). Water temperature, salinity and phytoplankton biomass are the variables that are most commonly observed with a multi-platform approach and these are also observed with the highest number of platform types. The platform types used for multi-platform observations are shown in Table 5. Also, sea levels, currents, oxygen, carbon, nutrients and suspended particulate matter (SPM) are observed with a multi-platform approach in some countries. In Ireland only observations with fixed platforms are done. Observations that are only made with one platform type are not shown in Table 4.

*Table 4: Number of different types of platforms per country per key variable mentioned by nation representatives in response to the question: "Do you have national (or transnational) multiplatform approaches for some variables? If yes, please list the measured variables and explain why these have been selected." Observations that are only done with one platform type (such as wave buoys) are excluded from this table.*

| Variable | FR | Fi | ES | IT | NO | PT | GR | SE | NL | BE |
|---|---|---|---|---|---|---|---|---|---|---|
| water temperature | 3 | 5 | 5 | 6 | 3 | 2 | 4 | 3 | 3 | |
| salinity | 3 | 5 | 4 | 5 | 2 | | 4 | 3 | 3 | |
| sea level | | | | | | | | | | |
| wave height | 2 | | | 2 | | | | | | |
| currents | | | 3 | 3 | | 3 | | | | |
| under water light/ transparency | | | | | | | | | | |
| Sound/ Noise | | | | 2 | | | 2 | | | |
| oxygen | | 2 | 3 | 3 | 2 | | 4 | | | |
| Carbon (DIC, pCO2, pH, alkalinity) | | | | | 2 | | 3 | | | |
| nutrients (N, P, Si) in water | | 2 | | | | | | | | |
| nutrients (N, P, Si) in sediment | | | | | | | | | | |
| particles / SPM | | | | 2 | | | | 2 | 2 | 3 |
| contaminants | | | | 2 | | | | | | |
| phytoplankton biomass/ chlorophyll | | 5 | 2 | 3 | 3 | | 4 | 2 | 3 | 2 |
| phytoplankton diversity & HABs | | 5 | | 2 | | | | | | |
| primary production | | | | | | | | | | |
| zooplankton biomass | | | | | | | | | | |
| zooplankton diversity | | | | | | | | | | |
| benthic biomass | | | | | | | | | | |
| benthos composition | | | | | | | | | | |
| coastal morphology | 2 | | | | | | | | 2 | |

The platform types most commonly used are satellite data, research vessels, fixed platforms and FerryBoxes (Table 5). These platforms provide complementary data, since they cover different spatial and temporal scales on the same variables.

*Table 5: Type of platforms that are used in multi-platform approaches per key variable, as number of countries that mentioned these platforms in their country as part of multi platform observations in response to the question: "Do you have national (or transnational) multi platform approaches for some variables? If yes, please list the measured variables and explain why these have been selected."*

| JERICO key variable | benthic landers | satellite | vessel | buoy/ fixed platform | profiling buoy | Ferrybox | AUV | drifter | Hfradar | citizen |
|---|---|---|---|---|---|---|---|---|---|---|
| water temperature | | 2 | 8 | 9 | 4 | 5 | 4 | 2 | | |
| salinity | | 2 | 7 | 8 | 4 | 5 | 3 | | | |
| sea level | | | | 6 | | | | | | |
| wave height | | | | 6 | | | | | 2 | |
| currents | | | | 7 | 1 | | | 2 | 3 | |
| under water light/ transparency | | | | | | | | | | |
| Sound/ Noise | | | | 3 | | | 3 | | | |
| oxygen | | | 4 | 5 | 1 | 2 | 3 | | | |
| Carbon (DIC, pCO2, pH, alkalinity) | | | 3 | 4 | | 3 | | | | |
| nutrients (N, P, Si) in water | | | 6 | | | 1 | | | | |
| nutrients (N, P, Si) in sediment | | | 2 | | | | | | | |
| particles / SPM | 1 | 2 | 4 | 1 | | 2 | | | | |
| contaminants | | | 2 | 1 | | | | | | |
| phytoplankton biomass/ chlorophyll | | 4 | 8 | 5 | 1 | 6 | 4 | | | |
| phytoplankton diversity & HABs | | 1 | 4 | 2 | | 1 | | | | 1 |
| primary production | | | 2 | | | | | | | |
| zooplankton biomass | | | 4 | | | | | | | |
| zooplankton diversity | | | 4 | | | | | | | |
| benthic biomass | | | 2 | | | | | | | |
| benthos composition | | | 2 | | | | | | | |
| coastline | | 1 | | | | | | | | 2 |

## Future plans for multi-platform observations

Chlorophyll-a and the carbonate system were mentioned most often as variables that should be observed with multi-platform approaches. Also, several countries think that all key variables should be observed with multi-platform approaches. Many countries also stressed the importance of transboundary observations. Proposed methods to facilitate such transboundary or trans institutional collaboration are harmonisation of observation methods and data standards, sharing of platforms and data and data comparisons between platforms. Also, new multi-platform data analysis tools and models were proposed as an additional platform to integrate information with the other platforms.

## Key developing technologies and barriers for implementation

Key developing technologies that were mentioned by the nation representatives included both platforms, sensors and supporting tools. The most commonly named key developing platform technologies were gliders and in-situ profiling systems. Other promising platform technologies are: drones, smart observatories, integrated bottom modules, littoral monitoring systems and guard-one cameras with AI. Key developing sensor technologies are: fluorescence, primary production sensors, auto-samplers, e-DNA, standard multidisciplinary modules (such as EGIM), hydrophones, biogeochemical surface velocity programmes (SVPs) and biosensors. Key developing technologies with respect to supporting tools are: virtual research environments, IoT enabled AI and articulation between fixed platforms and AUVs (both above and below water).

The most important barrier for implementation of these key technologies is a lack of sustainable funding (mentioned by 8 countries). Some countries added that funding is specifically lacking for operationalisation and for technical supporting staff, which are typically not covered by research grants. Other barriers that were mentioned are: lack of staff, lack of technology pull by users, lack of collaboration and also unwillingness to change existing long time series by switching to new technologies. Additionally, in the Mediterranean Sea political issues around the definition of the EEZ borders hamper permissions for access to observation locations.

### Technical support structures

Technical support structures, such as calibration labs, sensor testing, best practices and maintenance labs are mostly organised at a national level: in 5 countries some kind of national coordination of technical support is reported. In 3 countries no national technical support structures are available. Some technical support structures are organised only within one institute. Only one case of international coordination of calibration was reported: on chlorophyll-a observations from FerryBox routes in the Baltic. In one country the technical support for HF radar systems is provided by the instrument supplier.

Figure 4 shows the current and future use of technical support structures per country and per key variable. This supports the conclusion that the use of technical support structures is currently very limited and could be much more widespread in the future, if the planned collaborations in JERICO-RI are realised.

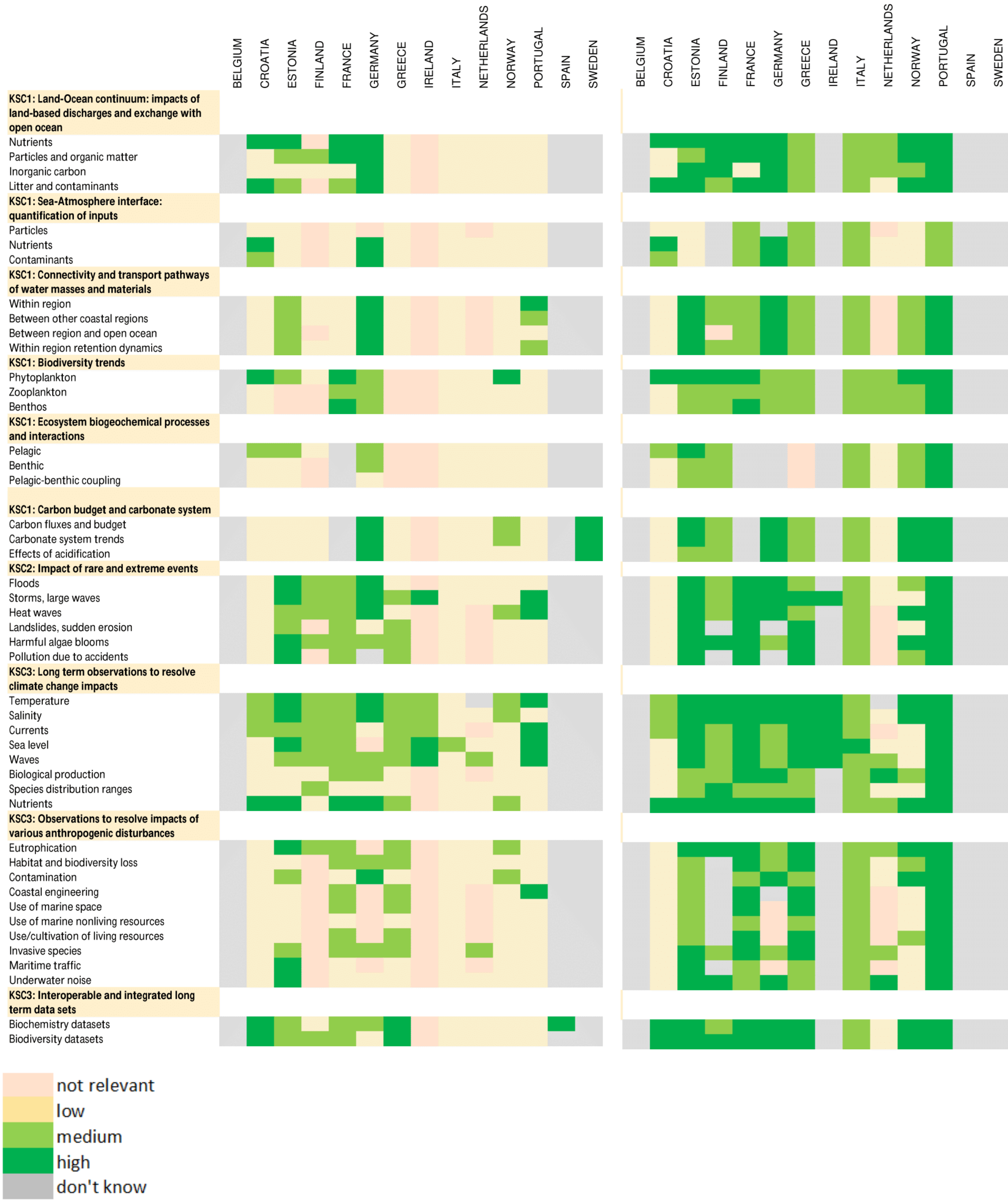


*Figure 4: Assessment of current (left) and feasible (right) use of technical support structures, such as intercalibration labs, per country and per KSC, by nation representatives*

## Staff and skills

This section deals with the available human resources and competences for the observation infrastructure.

We asked the nation representatives: "Is there a difference between the current and the foreseen technical competence needs in 10 yrs, and what are the plans to fill this gap?" A common gap in technical competence that was mentioned by 7 countries was the lack of qualified human resources for data processing, machine learning and AI. Several countries indicated that there is strong competition for such personnel by other sectors or countries with higher salaries. Other skills that were mentioned to have limited availability are general skills on working with autonomous platforms and sensors (mentioned by 5 countries), data management skills (2 countries), interdisciplinary skills (2 countries) and skills on specific technologies such as HF Radar and e-DNA.

The nation representatives were asked "to what degree the technical competence of personnel would be sufficient to address each KSCs". Figure 5 shows the difference between current technical competence of personnel per KSC, as assessed by the nation representatives and the potential future technical competence in 10 years if planned and desired activities in JERICO-RI are realized. For many cases where the current technical competence is assessed as 'low' the potential future level is medium or even high.

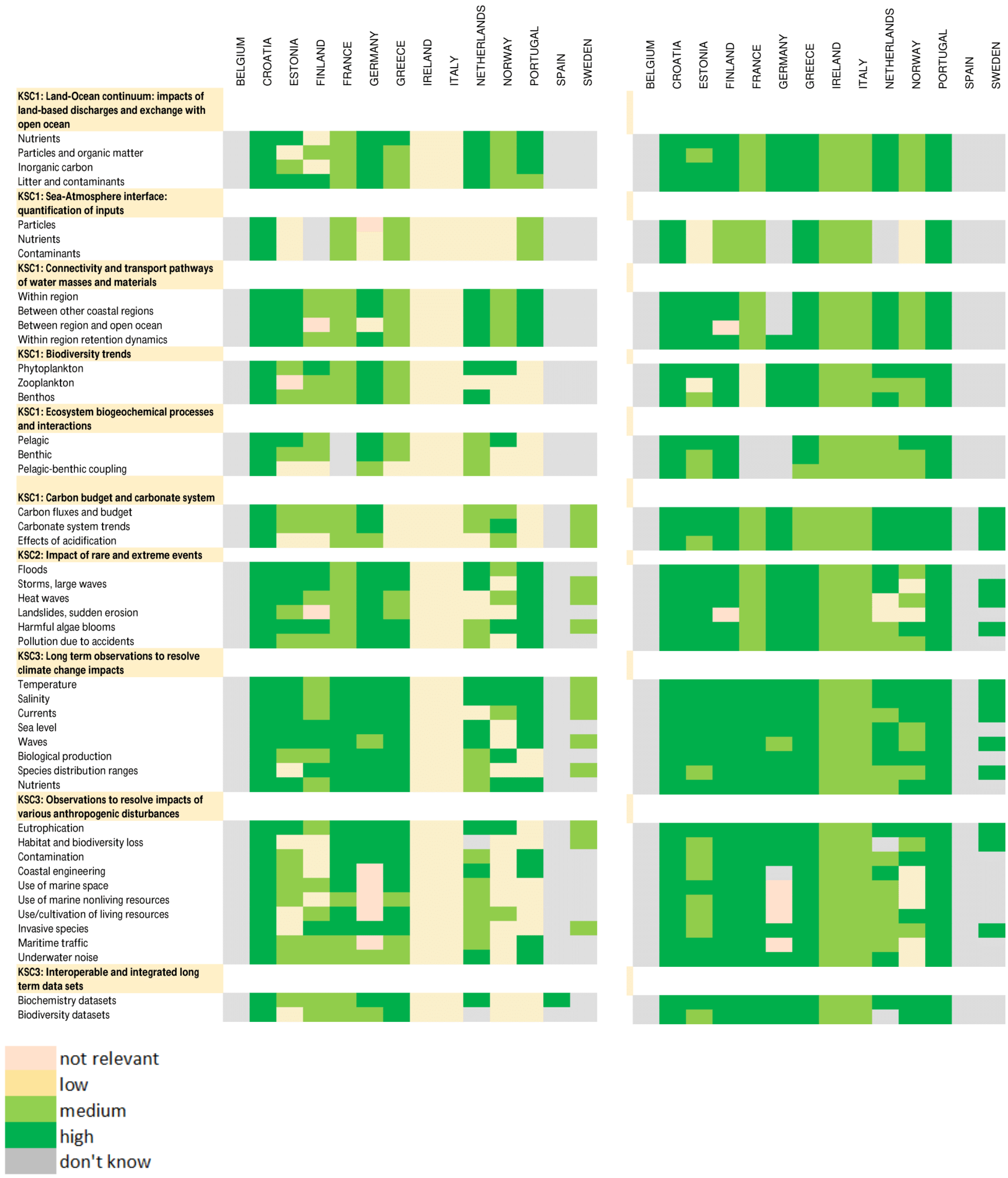


*Figure 5: Assessment of current (left) and feasible (right) technical competence of personnel per country and per KSC, by nation representatives*

## 2.2 Review of existing gap analysis reports

### EUROGOOS perspective

Relevant white papers and policy notes of EuroGOOS, as well as contributions to H2020 projects, were screened to extract European level gaps in operational areas (observing networks, technologies, variables, standards, methods). The EuroGOOS vision is to support a seamless coastal forecasting service[1], therefore they regularly identify technology gaps that obstruct that seamless transition towards the coast. European Ocean Observing System (EOOS) organises the Technology Forum (latest in March 2022) where the current technological landscape is discussed, as well as the ways on how to achieve a distributed embedded, multi-parameter ocean network and how to establish a systematic and robust data value chain. The Technology Forum is therefore also dedicated to technological gap analysis. Moreover, Task 1.1 of the EOOS Implementation plan stresses the need for mapping existing ocean observing infrastructure and capabilities to ensure an inclusive approach and fit for purpose measurements for different stakeholders. Nevertheless, this EOOS mapping exercise is an ongoing activity.

Table 6 below describes high level European technology gaps and issues in operational observing. Several overarching issues can be identified that are mentioned:

- **Observation gaps:** A prominent issue is the insufficient number of coastal observations in terms of spatial coverage (e.g. near-coast versus open ocean), vertical description (extending to the whole water column especially in the river mouths, estuaries, and (semi-enclosed basins), variables (e.g. lack of biogeochemical or biological observations) and temporal frequency;
- **Technology gaps:** These include (1) integrating of existing non-operational, multi-source observations, (2) coordinated and cost-effective deployment of multiplatform infrastructure at regional level (also the focus of JERICO-RI);
- **Standardization and interoperability:** best practices and harmonization for the whole range of observing networks, real-time quality control protocols, implementing GEOSS philosophy, homogenous biogeochemical monitoring network in Europe, standardizing technological modules for continuous, affordable and efficient monitoring systems;
- **Technological barriers:** tedious efforts for maintenance including calibration and quality assessment, especially for biogeochemical and optical sensors due to biofouling issues in productive coastal waters, or uptake of innovative sensors such as pCO2, pH, algal composition, and potential toxic species.

[1] model resolution ranging from hundreds of metres to kilometres; high-resolution measurements from HF radar, FerryBox, buoys, and gliders assimilated; the model system shall resolve challenging processes and features in coastal waters such as currents–sea level–wave–ice interaction, inter-basin and inter-sub-basin exchange, strong density gradients in estuaries, and transport of momentum, heat, and sediment in very shallow waters. Combining modelling and monitoring tools: assimilating; advantages of high-performance computing are drawn for high-resolution climate simulations.

*Table 6: Overview of European level gaps and priorities in operational areas (observing networks, technologies, variables, standards, methods) from: EuroGOOS Science Advisory Working group - Developing European operational oceanography for Blue Growth, climate change adaptation and mitigation, and ecosystem-based management (2016)*

| **Gaps / priorities** |
| --- |
| • **Integrated ocean observing systems**<br>○ *reducing observation gaps*: integrating existing non-operational, multi-source observations at regional level to ensure more timely access, delivery, and usage of observations for analysis/forecasting and regular ocean state estimation; integrating new observations into the existing operational data flow, promoting the historical data gathering in coordination with EMODnet (in particular for biogeochemical variables); widening the usage of innovative cost-effective monitoring technology, e.g. FerryBox, HF radar and Bio-Argo, in operational monitoring.<br>○ *Coordinated use of marine infrastructures at regional level*<br>○ *Testing the effectiveness of existing (semi)automated sensors for chemical and biological observations.*<br>○ *Data processing: further development of real-time quality control protocols;*<br>○ *Integration of observations from the research community and private sectors*<br>○ *Coordinated and cost-effective deployment of multiplatform infrastructure at regional level,*<br>○ *Interoperability:* moving from the file transfer-based, data exchange technology to the GEOSS philosophy based on interoperable web services.<br><br>• **Operational oceanography in coastal waters**<br>○ *Integration of project-oriented observations into operational data flow for forecasting;*<br>○ *Generation of new knowledge from the high-resolution observations in the coastal waters (e.g. morphology, water mass properties, dynamic features)*<br>○ *Vertical stratification in coastal areas especially in the river mouths, estuaries, and (semi-)enclosed basins*<br>○ *Improved understanding of coastal sea-level forcing mechanisms and coupling with the regional variability in climate*<br>○ *methods and diagnostics to evaluate the climate change predictability of the ocean circulation, biogeochemistry and marine ecosystems at basin scale and coastal scale to provide a theoretical basis for the long term prediction*<br><br>• **Operational ecology**<br>○ *increasing the amount of biogeochemical data which can be used for validation and assimilation, through enhanced data sharing, shortening the delivery time and making new observations via innovative instruments; extension of existing monitoring capabilities from primary production to plankton.*<br>○ *Tailored provision of operational products in addition to standard (water temperature, salinity, ice, waves, mixing features, residence time, Chl a, oxygen, pH, nutrients, light, plankton biomass) in support of predictive habitat forecasts, for ecological status and fisheries modelling and risk assessment (e.g. invasive species, HABs).*<br>○ *a more homogenous biogeochemical monitoring network in Europe; improved methodologies for supplying operational information on sources of nutrients and pollution/chemicals to the oceans (e.g. CDOM, underwater noise, and plastic/paraffin)* |

The need for further sensor development for bio-geochemical variables and the need to extend the capabilities to perform biological measurements was also pointed out by the Ferrybox community (EuroGOOS Ferrybox Whitebook, 2017). It was highlighted that mature and suitable bio-geochemical sensors for unattended long-term operation are commercially available for some variables (e.g. chlorophyll-a fluorescence, dissolved oxygen, pCO2 and pH) but some still suffer from long-term instabilities and tedious efforts for maintenance including calibration and quality assessment (e.g. nutrients). Although a further extension with new sensors is underway such as pCO2, pH, algal composition, and potential toxic species, there is still a need to further extend the capabilities to perform biological measurements. New sensor development should focus on (coastal) oceanographic observations for measuring phytoplankton biomass and species composition, nutrients, carbonate system, microplastics and contaminants, as well as circulation and physical oceanography.

## AtlantOS perspective

An inventory of current coastal observation is presented based on the **AtlantOS - Gap analysis of links between coastal and open ocean networks (2018) report**. It should be noted that the AtlantOS gap analysis only focused on the Ireland-Biscay-Iberia and North-West Shelf regions. Their definition of coast is the zone shallower than 200m. The analysis included a range of stationary and non-stationary platforms (profiling floats, moorings, drifting buoys, CTD, Tesac, FerryBox, Thermosalinograph, mini logger on Fishery Observing Systems, gliders, XBT or XCTD). These platforms are depicted in Figure 6 below based on their first occurrence within the defined region during 2017. Table 8 shows the type of platforms that were used to make the observations included in this analysis. Moorings are the most commonly used platforms and temperature and salinity are observed with the widest range of platforms.

*Table 7. Overview of European level gaps and priorities in operational areas (observing networks, technologies, variables, standards, methods), from: AtlantOS - Gap analysis of links between coastal and open ocean networks (2018)*

- **Observing networks**
  - an insufficient spatial coverage clearly appears between the near-coast and open ocean observing systems
  - most of the moorings are located near-shore and the number of deeper moorings are limited
  - mini loggers (particularly fishery observing systems) play an important role as shelf and shelf-break observing platforms.
  - in coastal regions most of the observing networks cover surface layers, and moorings extending to the whole water column remains scarce
  - insufficient spatial coverage (for most of the variables) leads to a general lack of shelf break and shelf sampling
  - Continuous monitoring of the shelf waters is crucial supporting the continuity and success of active operational numerical forecast models
  - there is an urgent need for coastal data (especially near-real-time) for assimilation and validation purposes
  - lack of biogeochemical or biological observations and data: Mature observing technologies to observe oxygen, nutrients, Chlorophyll-a, carbon or pH observations exist, but they are not extensively deployed
  - best practices and harmonization actions need to be extended to the whole range of observing networks (particularly diverse in coastal area)

- **Data availability**
  - Non-open data policies limiting the release of data, datasets obtained by private companies not being available, holding back data due to publishing strategy or data not released for lack of Quality Control are some of many reasons that limit the open and free access to marine data
  - coastal data availability remains more limited because coastal observing systems are supported at national levels. Furthermore, some initiatives on data are not extended at European or international level (e.g. data remains stored on national databases not connected with European data portals)

- **Sustainability**
  - Sustainability issues for different observing platforms are very heterogeneous as they rely on a wide range of different funding mechanisms depending on the particular networks or systems (HF radars, moorings, ships etc..). Both in-situ ocean observations funds in coastal or open ocean are based on infrastructures mainly supported by national agencies or time-limited research projects.

- **Technology**
  - there is a need for standardizing technological modules for continuous, affordable and efficient monitoring systems, particularly for the coastal ocean.
  - Biofouling issues in productive coastal waters impose the use of efficient biofouling protection and more frequent operations at sea. More frequent maintenance is required for biogeochemical and optical sensors.

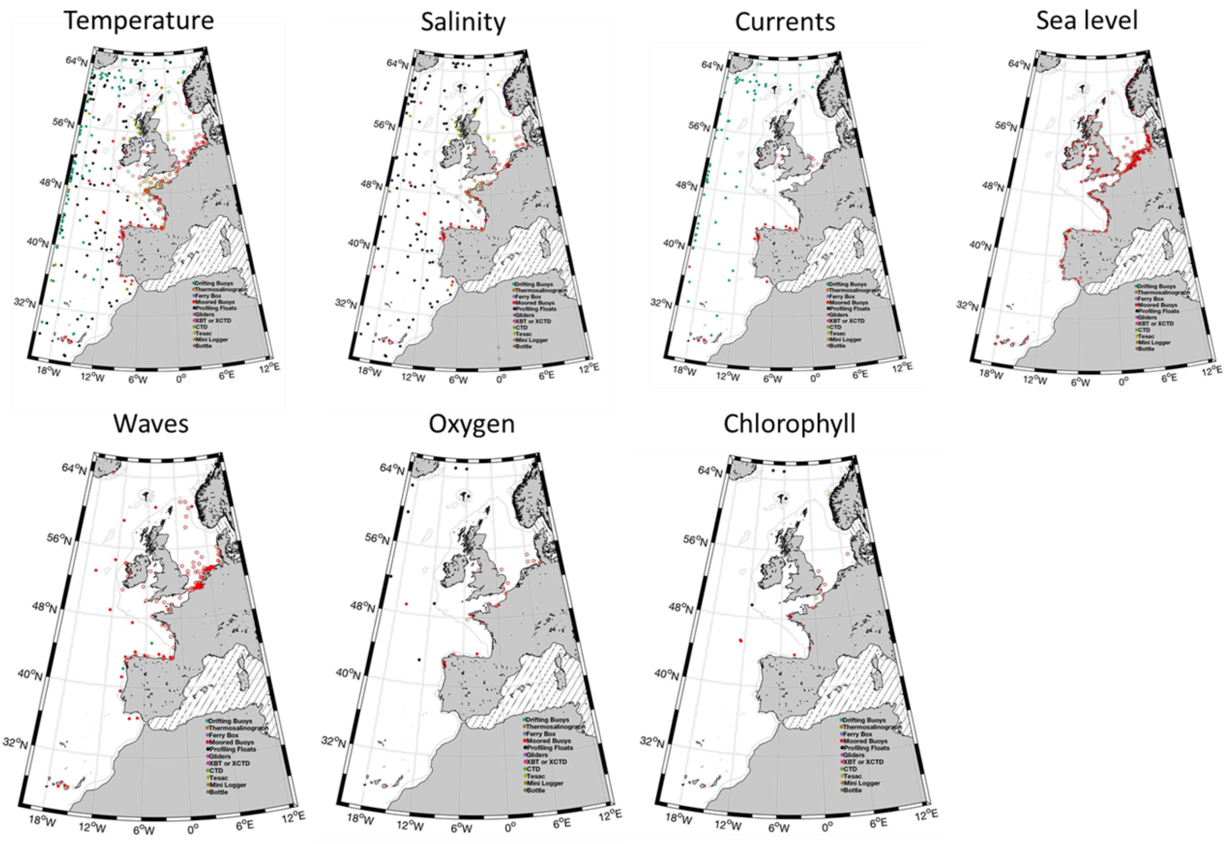


*Figure 6: Distribution of in-situ platforms (both offshore and coastal) measuring temperature, salinity currents, sea level, waves, oxygen, chlorophyll, during 2017. The light grey line represents the 200m depth isobath considered as a limit between coastal and open ocean waters. The figure is an adaptation of Figures 2-8 from the AtlantOS report*

*Table 8: Type of platforms that are used for the observations of variables shown in Figure 6.*

| Platform\ Variable | Temperature | Salinity | Currents | Sea level | Waves | Oxygen | Chlorophyll |
|---|---|---|---|---|---|---|---|
| Profiling Floats | 3 | 3 | | | | | |
| Moorings | 94 | 39 | 15 | 223 | 121 | 28 | 10 |
| Drifting Buoys | 10 | | 5 | | 2 | | |
| CTD | 3 | 2 | | | | | 1 |
| Tesac | 19 | 19 | | | | | |
| FerryBox | 8 | 2 | 13 | | | 1 | 2 |
| Thermosalinograph | 9 | 10 | | | | | |
| Mini Logger used on Fishery Observing Systems | 40 | 17 | | | | 1 | 1 |
| Glider | 1 | 1 | | | | | 1 |
| XBT or XCTD | 2 | 2 | | | | | |

## Perspective of regional sea conventions and data portals

Within the framework of the EEA contract 'Support to Copernicus In Situ Data Coordination' (COINS), reports have been prepared to inventory existing European Biogeochemical observations: COINS report on Inventory of existing European Biogeochemical observations (2021).

This report presents important gaps in coastal biogeochemical observations that should be considered for the scoping of JERICO-RI. These regional inconsistencies, technological and data gaps can potentially be filled by JERICO-RI, which will provide a strong boost to EU and national policy implementation.

The JERICO-RI sites cover most European Regional Seas (Figure 7), except the Black Sea, which is included in the Danubius-RI. The Regional Sea Conventions perform joint assessments of the State of the Environment (SoE) in their sea basin, in order to support their contracting parties in the implementation of the Marine Strategy Framework Directive (MSFD). For these assessments they use data gathered by member states across the different thematics. The data update frequency is irregular (not near-real time) since it is mostly coupled to the preparation of State of the Environment reports.

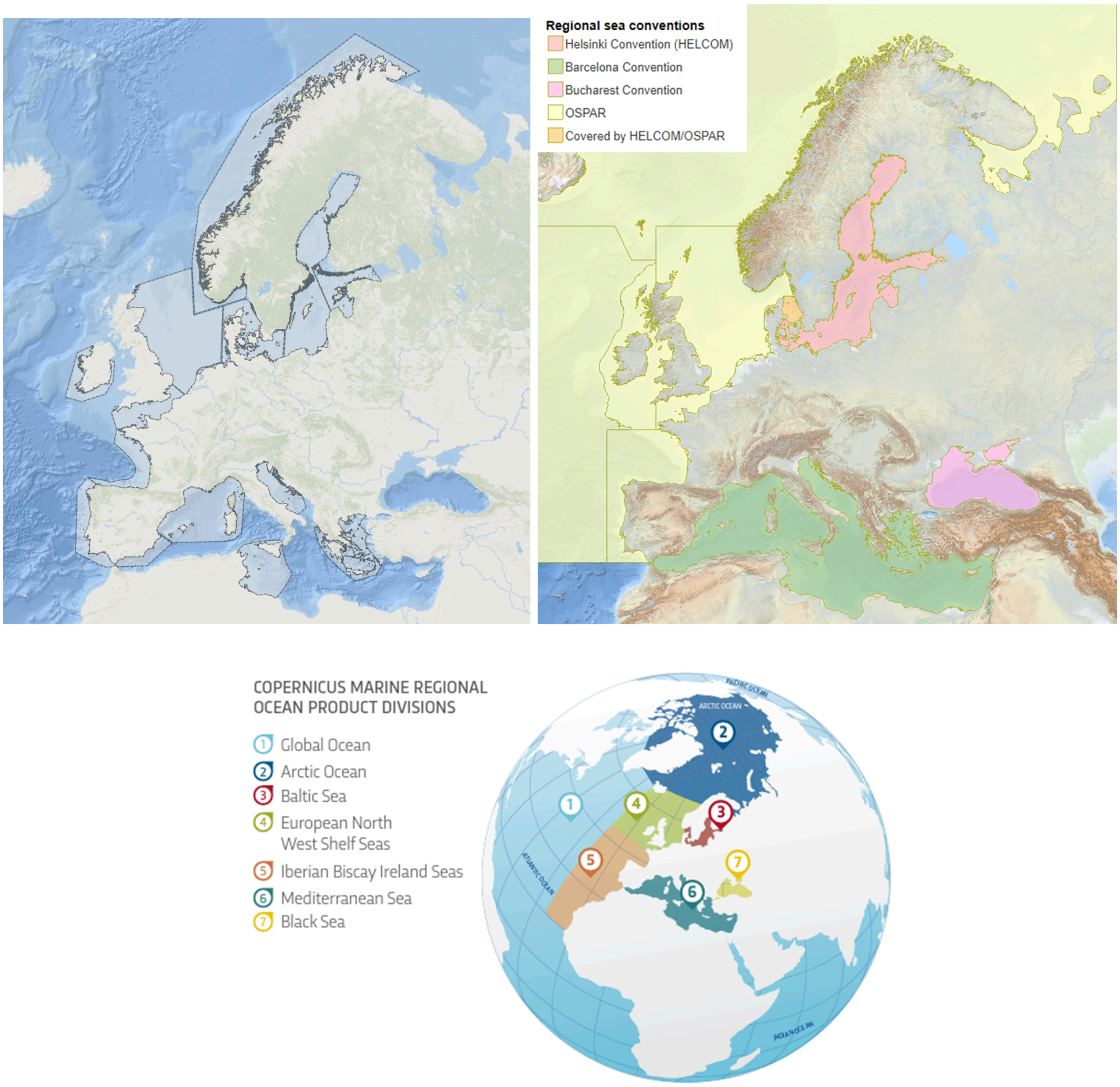


*Figure 7: JERICO IRS and PSS regions[2] [version 2020-08-04] (top left) and Regional Sea Conventions[3] (top right), CMEMS Monitoring and Forecasting Centers[4] (lower panel)*

Specific needs of Regional Sea Conventions are reflected in their selected indicators. JERICO-RI can help to provide consistent and standardised measurements for part of those indicators.

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[2] https://www.jerico-ri.eu/jerico-ri-catalogue/#/map
[3] https://ec.europa.eu/maritimeaffairs/atlas/maritime_atlas/
[4] https://marine.copernicus.eu/about/producers

*Table 9: Indicators of Regional Sea Conventions (RSCs). Highlighted (in red) indicators are part of JERICO*

| RSCs | Thematics | Indicator (groups) |
|---|---|---|
| **OSPAR** | Biological Diversity and Ecosystems, Environmental Impacts of Human Activity, Hazardous Substances, Eutrophication, Offshore Industry, Radioactive Substances | • Marine Mammal Common Indicators<br>• Seabird Common Indicators<br>• Fish Community Common Indicators<br>• **Benthic Habitat Common Indicators**<br>• **Pelagic Habitat Common Indicators**<br>• Food Web Common Indicators<br>• Non-Indigenous Species Common Indicators<br>• Marine Litter Common Indicators<br>• Underwater Noise Common Indicators<br>• **Eutrophication Common Indicators**<br>• **Hazardous Substances Common Indicators**<br>• Other Indicator-Related OSPAR Publications and Resources |
| **HELCOM** | Biodiversity, Eutrophication, Hazardous substances, Pollution loads, Maritime activities | • Abundance of coastal key fish species<br>• Abundance of coastal fish key functional groups<br>• Abundance of salmon spawners and smolt<br>• Radioactive substances: Cesium-137 in fish and seawater<br>• Distribution of Baltic seals<br>• Population trends and abundance of seals<br>• Abundance of waterbirds in the wintering season<br>• Abundance of waterbirds in the breeding season<br>• Number of drowned mammals and waterbirds in fishing gear<br>• Trends in arrival of new non-indigenous species<br>• **Zooplankton mean size and total stock (MSTS)**<br>• Hexabromocyclododecane (HBCDD)<br>• Perfluorooctane sulphonate (PFOS)<br>• **Metals (lead, cadmium and mercury)**<br>• White-tailed eagle productivity<br>• Nutritional status of seals<br>• Reproductive status of seals<br>• Polybrominated diphenyl ethers (PBDEs)<br>• **Dissolved inorganic nitrogen (DIN)**<br>• **Dissolved inorganic phosphorus (DIP)**<br>• **Chlorophyll-a**<br>• **Water clarity**<br>• **Oxygen debt**<br>• Abundance of sea trout spawners and parr<br>• Oil-spills affecting the marine environment<br>• State of the soft-bottom macrofauna community<br>• **Polyaromatic hydrocarbons (PAHs) and their metabolites**<br>• **Polychlorinated biphenyls (PCBs), dioxins and furans**<br>• TBT and imposex<br>• Reproductive disorders: malformed embryos of amphipods<br>• **Total nitrogen (TN)**<br>• **Total phosphorus (TP)**<br>• **Cyanobacterial bloom index**<br>• **Diatom/Dinoflagellate index**<br>• **Inputs of nitrogen and phosphorous to the basins**<br>• Diclofenac<br>• **Seasonal succession of phytoplankton groups** |
| **Barcelona Convention** | marine and coastal environmental state, drivers of environmental degradation, pressures exerted on ecosystems and impacts, pollution loads, interactions between environment and development | • **Biodiversity indicators**<br>• Non-indigenous species indicators<br>• Harvest of commercially exploited fish and shellfish<br>• **Marine food webs indicators**<br>• **Eutrophication indicators**<br>• Sea-floor integrity indicators<br>• Hydrography indicators<br>• Coastal ecosystems and landscapes indicators<br>• **Pollution indicators**<br>• Marine litter indicators<br>• Energy including underwater noise indicators |

**Gaps in data management practices of Regional Sea Conventions**

Regional Sea Conventions have quality control and standardisation practices in place but they follow heterogenous approaches for data management with varying levels of maturity. While their efforts for sharing the data underlying their assessment reports are very useful, public accessibility is not guaranteed in Regional Sea Conventions that involve non-EU Contracting Parties. Presently, the databases of Regional Sea Conventions (used for assessment reports) are not always ingested through EU data aggregators. Currently Member states share their data twice, first to the Regional Sea Conventions and then to data aggregators (parallel track). This is partly due to the fact that member states have legal obligations to share their data with Regional Sea Conventions but not with data aggregators. Moreover, Regional Sea Conventions have less complex data management requirements.

JERICO-RI can ensure good data management practices therefore enhancing interoperability and data sharing between Regional Sea Conventions and data aggregators. In this way, data from member states are shared directly with data aggregators, which are then used by the Regional Sea Conventions (instead of a parallel track). This would help to assure FAIR (Findable, Accessible, Interoperable, Reusable) data, as advocated by Tanhua et al (2019), and Trustable data repositories, which is currently a clear gap.

**Gaps in data availability based on screening of data portals**

After screening ~50 data portals (note that many overlaps identified) the following generic conclusions were made in the COINS report.

- **More biogeochemical observations needed:** BGC data availability is still lagging behind physics data availability, which hinders the validation and further improvement of (coastal) biogeochemical models. Moreover, BGC products are still predominantly chemistry focused, carbon-focused in many cases (e.g. SOCAT and GLODAP). Consequently, there is an urgent need to expand BGC data availability and data management practices in general, but especially beyond chemical variables towards biological elements (e.g. phytoplankton biomass or diversity). The first point is already being addressed with the BGC-Argo float system in the open ocean but for coastal areas, initiatives such as JERICO-RI and other European research infrastructures, or other national monitoring programmes can play an important role.
- **Distorted picture on data availability:** (1) due to the appearance of a single data source in many platforms, (2) and due to the fact that is actually more observed data than is available through the data aggregators. The European BGC observation network relies on national and international programmes and research campaigns/projects that feed into national data portals. These are in most cases integrated and aggregated to regional observatories, such as the EuroGOOS ROOS, which then feed into the main European in situ data portals CMEMS, EMODnet, and SeaDataNet. Not even mentioning the downstream applications, which harvest their data from these aggregators and display it in various web-viewers. While the appearance of a single data source in many platforms is positive for the data accessibility, it does not further increase the data coverage. At the same time, despite all their efforts, data aggregators are not able to incorporate all observed data and therefore some of this data remains "sleeping data" that is not actively being used or processed.

- **Coastal data labelling:** An issue while preparing coastal data inventory is the representation of coastal observations (compared to open ocean observations). Most data platforms in this report use a classification based on regions (e.g. European regional seas), thematic (e.g. chemistry or biology), and parameters. Only few of the portals allow the selection of coastal BGC in situ data, also noting that the scientific definition of "coastal zone" is still very much debated.
- **Spatial gaps:** The coverage of BGC in situ data is still heterogeneous with major gaps in transitional and coastal areas and in certain parts of regional seas. The coastal zones of the southern North West Shelf region, or certain parts of the Northern Mediterranean region (e.g. Spanish, French, Italian coast) are well covered, while others have major coastal observation gaps, such as the Southern Mediterranean, Arctic Ocean or the eastern Black Sea. An identification of coastal observation gaps and their prioritisation should therefore be conducted, based on the ecosystem and socio-economic importance of the coastal zones.
- **Data accessibility** was in most cases satisfactory, via online instant access, although there are several platforms where registration is necessary, or data is granted upon request via email. Even these minor data restrictions should be eliminated to further promote data sharing. The data management of BGC in situ data on European level seems to be well harmonised thanks to the EuroGOOS Task Teams, the CMEMS INSTAC, EMODnet, SeaDataNet, which maintain standard formats and quality control for the BGC EOVs. Timeliness of BGC data in data aggregator portals such as EMODnet or SeaDataNet should be improved as it is currently accessible in delay mode (with a delay of more than 6-12 months in some cases). Moreover,

## COPERNICUS perspective

Within the framework of the EEA contract 'Support to Copernicus In Situ Data Coordination' (COINS), another report has been prepared to inventory Copernicus BGC in situ requirements. The COINS report on Copernicus BGC in situ requirements (October 2021) conducted a survey amongst CMEMS MFCs to identify their in-situ data needs to improve coastal modelling capacities. This report presents future requirements of CMEMS MFCs that should be considered for the scoping of JERICO-RI.

The following conclusions were drawn:

- **Focus on the coast:** improving and validating the forecasting skills of CMEMS MFCs in coastal areas (fine scale processes and strong gradients) require concentrated effort on the coast, especially near mouths of major rivers. Currently, the main BGC data source is BGC Argo floats, which cover the open ocean rather than coastal areas  Consequently, more BGC in-situ data sources are needed in the coastal area;
- **Profiles required for vertical validation:** Apart from operational in-situ fixed platforms, such as moorings or surface Ferry Boxes in ships of opportunity, periodic missions that also provide profiles (e.g., gliders) are also crucial to allow vertical validation of the biogeochemical models.

- **Providing in-situ observations of turbidity and phytoplankton biomass**, which are currently not used or only used to a limited extent, may be an enabling factor towards improved BGC modelling capacity in the coastal regions;
- **Variables for data assimilation:** future requirements indicate that the MFCs wish to improve their data assimilation systems including chlorophyll-a, dissolved oxygen, $pCO_2$, particulate matter, and pH. Measuring these BGC variables should be prioritized;
- **Improved data update frequency:** BGC in-situ observations are mostly required with weekly update frequency for product monitoring or even less frequently (monthly and six-monthly) to serve interim production and reanalysis purposes. Nevertheless, improved timeliness in data delivery is required to ensure data assimilation needs for coastal models, prioritizing near real time delivery (less than one day) for chlorophyll-a, dissolved oxygen, $pCO_2$, particulate matter, and pH (see recommendation above);
- **Heterogenous spatial resolution and coverage requirements** of MFCs call for regional (covering entire basins) and local (e.g., river outlets) monitoring programmes to fill the existing data gaps. New mechanisms need to be set up between the EU and member states to address the major gaps in coastal biogeochemical observations in areas of interest (e.g., Arctic region or Black Sea);
- **bias and uncertainty estimates** of BGC in-situ data should be provided to CMEMS MFCs.

## 2.3 Input from JERICO projects

This section summarizes information collected from JERICO research projects: JERICO, JERICO-NEXT and JERICO-S3.

### Key variables addressed by JERICO research projects

Tabel 11 below shows which key JERICO variables have been addressed by Jerico research projects. This provides information on the extent to which current Jerico partners have experience with each key variable. It shows that 11 out of 22 variables have been addressed in all 3 Jerico projects. So, on these variables the JERICO partners have already collaborated and gained experience. Two of the variables (sound and coastline) have not yet been addressed in JERICO projects. This does not necessarily mean that current Jerico partners have no experience with these variables. The questionnaire results show that some JERICO partners already make observations of sound in coastal waters. But there is no experience yet on collaborating on these variables. For these variables the gap between the current situation and harmonised high-quality observations within JERICO is relatively large. Also on chemical contamination and benthic observations (biomass, composition and nutrient concentrations) there is relatively little experience among Jerico partners. The biological observations of phytoplankton diversity, primary production and zooplankton are subject of joint research by JERICO since the JERICO-next project.

*Table 10: Overview of which variables have been addressed in which JERICO project.*

| Variable | JERICO | JERICO-NEXT | JERICO-S3 |
|---|---|---|---|
| water temperature | ■ | ■ | ■ |
| salinity | ■ | ■ | ■ |
| sea level | ■ | ■ | ■ |
| wave height | ■ | ■ | ■ |
| currents | ■ | ■ | ■ |
| Light | ■ | ■ | ■ |
| Sound/ Noise | | | |
| oxygen | ■ | ■ | ■ |
| Carbon (DIC, $pCO_2$, pH, alkalinity) | ■ | ■ | ■ |
| nutrients (N, P, Si) in water | ■ | ■ | ■ |
| nutrients (N, P, Si) in sediment | | ■ | |
| particles / SPM | ■ | ■ | ■ |
| contaminants | | ■ | |
| phytoplankton biomass | ■ | ■ | ■ |
| phytoplankton diversity | | ■ | ■ |
| primary production | | ■ | ■ |
| zooplankton biomass | | ■ | ■ |
| zooplankton diversity | | ■ | ■ |
| benthic biomass | | ■ | |
| benthos composition | | ■ | |
| coastal morphology | | | |

## Spatial coverage of observations

In the first JERICO project an overview was made of available coastal observations from fixed platforms (JERICO deliverable 2.5, 2015). It showed a good spatial coverage of observations of physical variables (particularly water levels and water temperature) and a very limited spatial coverage of biogeochemical observations (Figure 8).

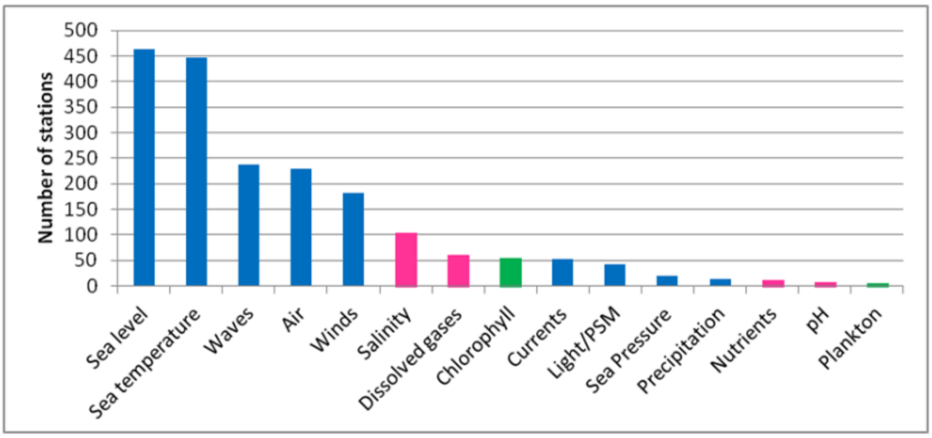


*Figure 8: Number of monitoring locations for a range of variables (blue: physical variables, pink: chemical variables and green: biological variables)*

## Technological maturity of sensor observations

Technological maturity of sensor observations extracted from JERICO-NEXT D2.2 (Petersen and Möller, 2017).

*Table 11: Technological maturity of sensor observations extracted from JERICO-NEXT D2.2.*

| Jerico key variable | sensor type | TRL | remaining issues |
|---|---|---|---|
| nutrients | submersible nutrient analyser | 9 | frequent maintenance and recalibration needed, due to clogging, reagens precipitation, breakdown and memory saturation |
| | portable nutrient analyser | - | only applicable in stationary systems due to size and time resolution |
| | biosensors | ? | new method, little experience |
| | water samplers | - | none, commercially available |
| phytoplankton biomass | LED fluorometry | 8-9 | fluorescence data flowing into different databases stay incomparable as long as there is no traceable calibration. |
| | spectral fluorescence | 8-9 | traceable calibration is lacking. It is difficult to assess the TRL for taxonomic separation of phytoplankton pigmentary groups |
| phytoplankton composition | fluorescence induction | 9 | accessories for flow-through systems are rather recent and with lower TRL |
| | Spectral absorption | 5 | it is expected that TR-level will increase to a successful tested prototype (TRL 6) |
| | Spectral reflectance | ? | less reliable at the edges of the measured spectrum, difficult to achieve ideal measuring conditions |
| | Turbidity and scattering | 9 | no significant issues |
| | scanning flow cytometry | 9 (?) | significance of abundance estimation (data reliability) |
| carbonate system | $pCO_2$ sensors | 7-9 | relatively high power requirements, require calibration gases |
| | pH sensors | 8-9 | (bio)fouling, reliability of an auxiliary pump system, correction algorithm |
| | total alkalinity sensors | 9 | the instrument is better suited for operation in coastal regions, turbid samples require filtration before AT measurements |
| vertical profiles | autonomous profilers | 9 | main risk is the vulnerability linked to the coastal area, deployment should not last too long (~1 year) |
| | surface-buoy based profilers | 9 (?) | no significant issues |
| | bottom tethered profilers | 4-7 | conductivity sensor is subject to drifts and fouling |
| | fishing vessel based profilers | 8-9 | optimal conditions for the usage of the sensors is important |

## Lessons learnt from JERICO-S3 Integrated Regional sites

Within the JERICO-S3 project, five Integrated Regional Sites (IRS) and four Pilot Super Sites (PSS) have been developed (see Figure 9).

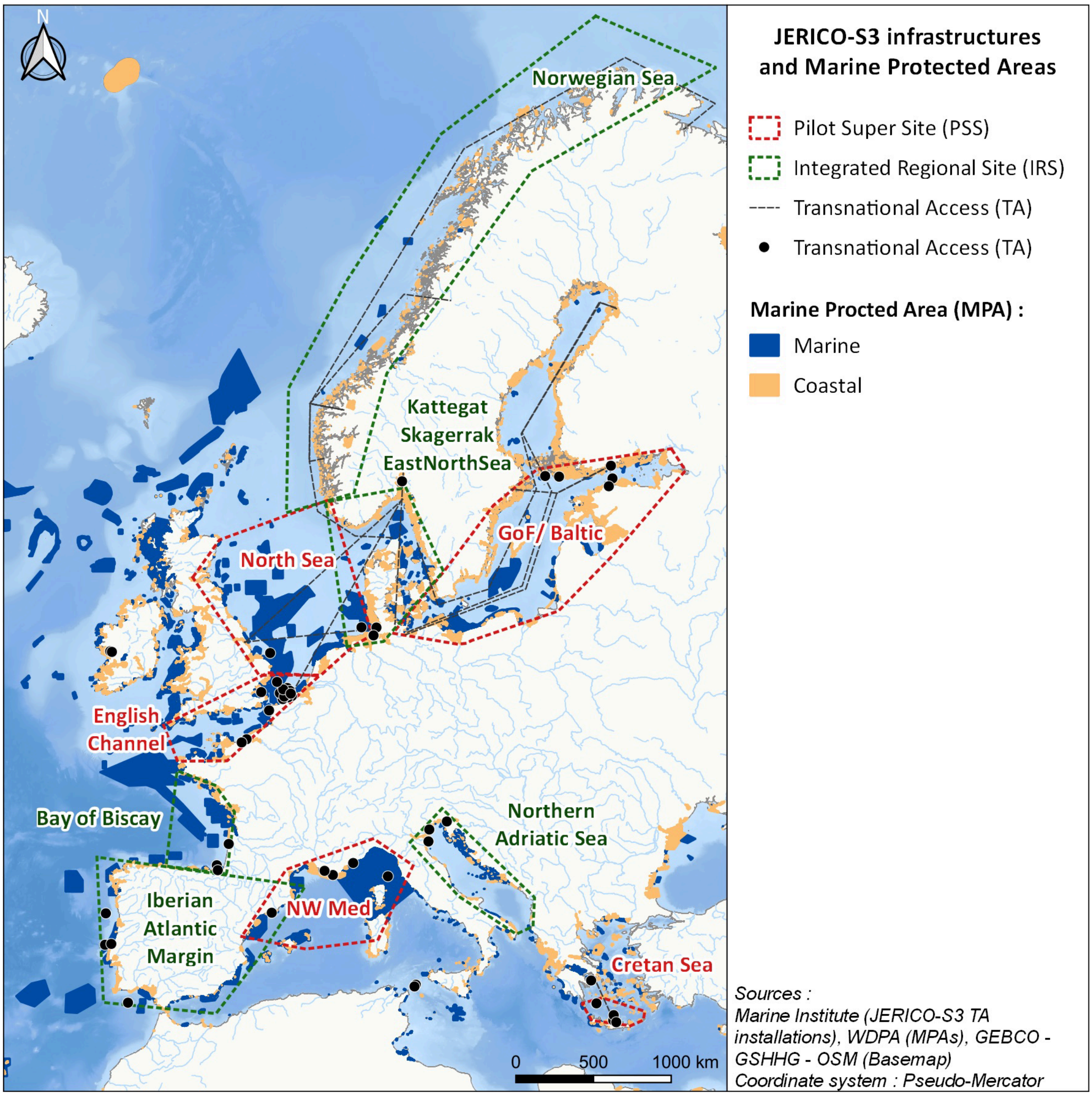


*Figure 9: Definition of Pilot Super Sites (PSS) and Integrated Regional Sites (IRS) in the JERICO-S3 project.*

The IRS sites have been developed to promote harmonisation and integration within defined multi-national coastal ocean regions. While there is not an explicit focus on technology development, IRSs have developed regional strategies based on the JERICO-RI KSC framework. As highlighted in Figure 4 for the national level, there is some degree of specificity with regards to which KSCs are targeted and/or relevant for each IRS. This is due to the relative heterogeneity in pressing or important issues that are high on national agendas and therefore receive financial support either at a national or institutional level. That is, each region has a focus on a different subset of KSCs which is balanced between the ecosystem importance/relevance of a KSC, and various external requirements and forces at play. A primary objective of structuring JERICO-RI by region is to precisely target this issue - how can each country with their own national agenda(s) and strategies align with other countries in the region that are adjacent to the same coastal ocean region with common KSCs? The outcome, thus far, is that this is a challenging task that remains unresolved. The primary gaps are the following:

- For the most part, institutional or national coastal observing efforts are not financially-sustained in the long-term. This means that partners are, rightfully so, first focused on how to sustain their observing programs at the national level. A multi-national approach has a somewhat lower priority, despite the fact that a strong multi-national approach might contribute significantly towards addressing national funding issues.
- Related to the first gap, while there is a will to organise and cooperate between nations, each nation has its own specific funding and political systems. Coordinating between IRS partners and their respective national funding systems is difficult.
- There are various non-JERICO entities that play an important role in coastal observation. Efforts have been made at the IRS level to explore how to include all relevant non-JERICO entities to a regional approach. This is also crucial in some cases when considering how to align with national priorities.

These gaps are presently on the agenda for all IRSs to address - each IRS has some potential actions delineated in roadmap tools that were developed as part of JERICO-S3 D3.1 and D3.2. Another aspect of IRSs in JERICO-S3 is that while there are specific IRS tasks and actions that are needed, there are important common issues across all five IRSs that are addressed. For example, the structure and system aspects of each IRS, despite different KSC foci, could be formed on the same template. And technologies used within each IRS could also be commonly used in two or more IRSs. Whether the common approach for integration is needed at a national level (e.g., JERICO-DS approach) or regional level (e.g., JERICO-S3 approach), or both, is an open question.

## Lessons learnt from JERICO-S3 Pilot Supersites

JERICO-S3 Pilot Supersites (PSS) provide a proof of concept for future JERICO-RI Supersites and aim to demonstrate the added value of integrated, state-of-the-art multidisciplinary and multiplatform observation capabilities. PSSs aim to improve national, regional and pan-European collaboration for consistent observations while working on solutions and best practices for organisational challenges. Four PSSs have been working with predefined topics, so-called Actions, linked to the JERICO-RI KSC framework. The objective of these PSS Actions, besides advancing the coastal science, is the elaboration of organisational challenges, helping to understand the technical, administrative, legal and cultural aspects that need to be assessed and adapted while integrating pan-European coastal observations.

While some topics have been addressed in many PSSs, there is quite some diversity on Actions between PSSs, reflecting partly regional specificities and focus areas, partly regional maturity in study topics, but also providing a wider range of addressed topics. Thus, already the initial selection of PSS Actions may reflect which observational, or technical, gaps were identified when planning PSS actions.

Elaborating from PSS planning and implementation, we may list the following technology related gaps in PSS observations and data provision, based on the definition of PSS Actions to address these gaps:

- Lack of knowledge, expertise (partly due to lack of funding). Some PSS Actions have focused on exemplifying how to transfer knowledge and sharing resources through collaboration between partners within the PSS or between PSSs to improve the regional capacity for observations.
- Technological difficulties, lack of harmonisation. To fill this gap, national and regional actions are first needed, but driven by hierarchical needs for EU-level harmonisation. PSSs have actions to share experiences in technologies and to harmonise practices, providing examples for regional integration.
- Low level of sensor/system TRL. As some observations are limited by overall lack of technology, some observational deficiencies are due to low capacities in adopting new technologies. The first gap, lack of technology, has been addressed in PSSs by working with industries developing new technologies and by disseminating knowledge within PSSs. The second gap, low capacity in adopting technologies, (much related to the first item in the list) can be approached by sharing technologies and data, by peer support in transfer of knowledge, or by smart specialisation between partners, as not everyone needs to do all.
- Non-optimal structuration of observation capacity. This gap has been addressed by several PSS actions, while collecting data from existing observations. Of course, PSS funds do not allow restructuring observations, but understanding who are the relevant actors and which are the existing political, economical, societal and cultural drivers behind non-optimal structuration is a starting point.
- Some observation programmes are outdated (or not fit-for purpose) and do not match expectations of all current users. Some PSSs Actions have identified that while existing observations may have been planned for some very specific uses, they do not necessarily support optimally the Actions (not to speak about other uses). Making integrated and synergistic observations, supporting various uses optimally is hard to perform, but is actually the central idea of JERICO-RI Supersites, providing high quality, intensive and flexible observation capacities.
- Not adopting FAIR principles or adequate QA/QC. For those PSS Actions working with well-established technologies, FAIR data flows and QC/QA routines have been typically in place. However, many variables, often BGC or biological, lack adopting FAIR principles, partly as best practices and vocabularies have not been established. To fill this gap is not a task for the JERICO-RI community only, but must involve all the expertise in the regions.

While the PSS implementation period took two years (2021-2022), and reporting is ongoing, some further gaps have been identified:

- Harmonisation of observations and sharing of Best Practices and SOPs is often slow. While there are certainly case-by-case differences, likely the most common reason is related to lack of resources and tardiness in changing organisational practices. The game changer to close this gap may be finding efficient incentives to perform such organisational shifts. JERICO-RI may help to solve this issue.
- Adopting new technologies has various bottlenecks. While various PSSs deal with new technologies, their operationality (and data provision) is often lacking. It is a large amount of work, across the data value chain, to make new technologies operational, and typically this requires a joint and coordinated work from various actors. JERICO-RI Supersites may have a key role in providing such critical mass for goal-oriented developments.

- Merging transnational and multiplatform data is a complex task. As many PSSs have noted, glueing data together for joint use from different platforms and sensor types is not easy, even if they all are submitted in common portals. Without joint planning of sampling strategies, QA/QC and technical specificities in data collection, merging various datasets may not be optimal. Again, a key gap for JERICO-RI to close.
- Connections to modelling and ocean colour communities are not always fluent. As noted in various PSSs, again, data collection is often not planned to match the needs of these communities and products are not fit-for-purpose. Improvements in connecting these communities and providing the data for their needs can be done by co-designing l modifications to sampling strategies and involved technologies, and need to be considered in JERICO-RI technology roadmap.
- Suboptimal collaboration with other RIs. PSSs had regional connections to other RIs and these practical experiences proved that some of the KSC require combining JERICO observations with other data sources (like river loads) or approaches (like experiments). For JERICO-RI technology design, interfacing with other RIs need to be taken into account.
- Limited use of new products by stakeholders. PSSs have been working with novel sensors and products, which may be scientifically sound, but not yet adopted by stakeholders. Reliability of operational observations, compared to traditional sampling, needs to be improved in the factual metrological level but needs to be also communicated appropriately (including appropriate information on uncertainties).

Overall, filling the gaps noted above requires a lot of regional and pan-European attention from the European coastal observation community, driven by JERICO-RI. But it also requires flexibility and willingness from national and regional counterparts (institutes, ministries, regional conventions) to adopt new sampling strategies, technologies and ways of working. And it requires sufficient and consistent funding and strategic planning of human resources, starting from the educational sector.

# 3. Outreach, dissemination and communication activities

The proposed approach for this gap analysis study has been shared and discussed with Jerico partners during the online Jerico workshop in March 2022. The preliminary results have been discussed with JERICO Design Study project partners during the JERICO Design Study GA in Delft in October 2022. The results of this draft report on the perspective of nation representatives are checked and reviewed by nation representatives before final submission.

# 4. Conclusion and next steps

## Synthesis of results

From the perspectives of nation representatives, JERICO projects and existing gap analysis reports a few overarching conclusions arise on current gaps in coastal observation capacity and causes of these gaps:

- Observation of physical JERICO key variables (sea surface temperature, salinity, sea levels, waves) is operational at high TRL level in many countries involved in

JERICO-RI. Biochemical observations for some variables (phytoplankton biomass, oxygen, turbidity) are also operational at high TRL levels in a limited number of countries. However, harmonisation and implementation of joint QA/QC procedures for phytoplankton biomass observations still needs more work, to make the results useful for stakeholders and compatible with other observations from satellites and samples. Other chemical, biological and benthic key variables are still observed at lower TRL levels: in some countries in pilot phase (TRL 5-7) and in other countries still under development (TRL < 5). Biological observations are in the development stage in most countries.

- Reasons why chemical, biological and benthic observations are in lower TRL-levels are partly that observation methods are still being developed or defined and partly a lack of sustained funding for maintenance, QA/QC, international harmonisation and data management. Lack of sustainable funding is a major cause for the gap between technology development and operational use of innovative methods. Particularly, the last phase of development (from TRL8 to TRL9) lacks funding since research programmes aim at lower TRL levels. Best practices and harmonisation actions are currently applied heterogeneously and these need to be extended to the whole range of observing networks (particularly diverse in coastal areas). Due to lack of funding JERICO partners prioritise continuation of national infrastructure above cross-border collaboration.
- Prominent issues in most gap analysis reports are the insufficient number of coastal observations in terms of spatial coverage (e.g. near-coast versus open ocean), vertical description (extending to the whole water column especially in the river mouths, estuaries, and (semi-enclosed basins), variables (e.g. lack of biogeochemical or biological observations) and temporal frequency;
- Stakeholders are insufficiently investing in making innovative technologies useful for them. The key Jerico variables as identified in the Technology Outlook report show strong overlap with indicators defined by all regional sea conventions. Currently there are important gaps in spatial coverage of observations in coastal waters, particularly for biological variables. Also the data accessibility and interoperability is identified as a gap, so not all observations that are done in coastal waters are available for use by the Regional Sea Conventions.
- Copernicus Marine Service MFCs expressed various BGC in-situ data needs for their operational modelling activities. These needs largely reflect the above-mentioned gaps identified by other sources. Nevertheless, their requirements provide further specification of those gaps. For instance, coastal gaps (river outlets, Artic, Black Sea, Southern Mediterranean), priority variables (turbidity and phytoplankton biomass), and specific temporal frequency (weekly update frequency for product monitoring, monthly and six-monthly to serve interim production and reanalysis purposes, and near real time delivery (less than one day) for chlorophyll-a, dissolved oxygen, pCO2, particulate matter, and pH).

## Challenges and opportunities

An important challenge to reach the desired maturity of coastal observation systems across Europe is the lack of sustainable funding, leading to lack of qualified personnel to sustain the observations and slow innovation. Separate funding mechanisms between countries limit the possibilities for international collaboration of data collection and processing. Also, strengthening the collaboration with stakeholders of coastal observations, such as Regional Sea Conventions and COPERNICUS is required to improve the use and usability of coastal observations. A joint effort by European countries, through JERICO-RI, to provide the required funding and technology pull would be a great opportunity to obtain the observations required to address the key scientific challenges for coastal waters. This is much needed with the current trends:

- to use coastal waters more and more intensively, leading to conflicting interests and scarcity of resources.
- the threats of climate change and biodiversity loss, leading to risks to human safety, human health and ecosystem health.

## What is next?

The above challenges and opportunities can be jointly addressed by the development of a future JERICO-RI by member states. Next, the results for this gap analysis study will be used to develop a roadmap on how to reach the desired maturity of the JERICO-RI in 10 years.

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