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Nota

In the following pages, the European Coastal Research Infrastructure will be named JERICO-RI, the project funded in the framework of the FP7 JERICO-FP7 (2011-2015) and the project funded within H2020 JERICO-NEXT (2015-2019)

1. Executive summary

This document reports on the science strategy required to answer the targeted scientific questions, policy requirements, and societal challenges linked with the observation of the European Coastal Ocean as elaborated within the framework of the **WP 1** of the JERICO-NEXT project.

The structuration of JERICO-RI science strategy is in line with the scientific strategies put forward by current major international initiatives regarding the observation of the ocean (i.e., GOOS, EOOS and EUROGOOS). The main elements of those general strategies are: (1) technological innovation, (2) the enhancement of integration/coordination, (3) the developments of interactions between observation initiatives acting over different spatiotemporal scales, (4) the optimisation of the benefit of coastal observing for the society, and (5) the major importance of the regional level in structuring ocean observation. These elements constitute the basis of the **five pillars** of JERICO-RI science strategy, which consist in:

1. **Developing innovative technologies for Coastal Ocean Observing and modelling,**
2. **Enhancing integrated Coastal Ocean monitoring,**
3. **Interfacing with other ocean observing initiatives operating at different spatiotemporal scales,**
4. **Fostering societal impact for a larger community of stakeholders**, and
5. **Establishing observing objectives, strategy and implementation at regional level.**

JERICO-RI science strategy also includes a set of strategic elements accounting for: (1) Coastal Ocean specificities, (2) experiences gained from the implementation of major non-European national observation networks (i.e., IOOS, IMOS and ONC), and (3) the main elements of the scientific strategy already elaborated within JERICO-FP7 and the experience gained within JERICO-NEXT itself.

The main inputs from these different sources first refer to the complexity (i.e. the spatial heterogeneity, the temporal dynamics, the importance of biological compartments and biogeochemical processes, and the strong interactions between systems compartments and processes) of the Coastal Ocean, which induces the necessity of deploying a truly holistic approach, and achieving sound spatio-temporal upscaling; both aspects having major consequences on the technological developments (including modelling) to be achieved. The Coastal Ocean is clearly affected by global change. However, one of its key characteristics is the importance and the diversity of its use by the large (and constantly increasing) human population living nearby, which generate both environmental disturbances and expectations from a large variety of local stakeholders. Coastal Ocean Observing should clearly address the duality of these two issues over the whole range of associated spatio-temporal scales. This has major consequences on:

1. The best **balance** to be reached **between integration** (i.e., at the level of a whole pan-European network) **and regionalization**,
2. The nature of the **interactions** to be developed **with stakeholders**, and more largely
3. The **interactions** to be developed **with** other **external partners** including other observation initiatives acting on different compartments/systems and/or over different spatio-temporal scales.

A last important point is the discrepancies between the geographical limits of the large European Coastal Ocean functioning systems and European political boarder, which clearly pleas for the structuration of a pan-European coastal observing infrastructure as a network of regional subsystems, each coordinating national (and subnational) observing initiatives.

The contents of the five pillars of JERICO-RI science strategy have been fine-tuned based on this set of rationales. For **pillar 1** (**"Developing innovative technologies for Coastal Ocean Observing and modelling"**), this mainly consists of:

1. **Integrating innovative sensor technology** to reduce discrepancies in Technology Readiness Levels between disciplines,
2. Increasing current Technology Readiness Levels of ocean observing systems in view of **developing multidisciplinary observing platforms**,
3. Developing key enabling technologies to **optimize the acquisition and process of multidisciplinary observations**, and
4. Achieving a **long-term technological foresight** to anticipate quickly occurring changes.

For **pillar 2** (**"Enhancing integrated Coastal Ocean monitoring"**), this mainly consists of:

1. Enhancing the **harmonization of observations** achieved by different operators so that they become fully comparable,
2. Contributing to an **holistic approach of Coastal Ocean Observing** by enhancing the accessibility of cutting-edge technologies, and
3. Demonstrating the benefits of **full integration in a limited number of Pilot Augmented Regional Infrastructures** representative of the European Coastal Ocean.

For **pillar 3** (**"Interfacing with other ocean observing initiatives operating at different spatiotemporal scales"**), this mainly consists of enhancing cooperation with:

1. **European** observing **infrastructures/initiatives on Open Ocean and riverine/terrestrial systems**,
2. Other **European world-class ocean observing infrastructures/initiatives**,
3. **Local observation** providers **and other providers of Coastal Ocean observations** and
4. **Major non-European national ocean observing national systems**.

For **pillar 4** (**"Fostering societal impact for a larger community of stakeholders"**), this maily consists of:

1. **Enlarging the community of stakeholders** of Coastal Ocean Observing,
2. **Deepening their involvement** in the definition of observation derived products, and
3. **Enhancing the suitability of** these **products** to assess stakeholder concerns.

For **pillar 5** (**"Establishing observing objectives, strategy and implementation at regional level"),** this mainly consists of:

1. Carrying out pilot actions designed to tackle major scientific/societal questions at the regional level in a truly multidisciplinary way through the **implementation of Pilot Augmented Regional Infrastructures in a limited set of selected areas**, and
2. **Preparing** for **the implementation of future Pilot Augmented regional Infrastructures** by initiating a reflexion **for several other regional areas**.

Through all these components/actions, JERICO-RI science strategy intends to pave the way for the implementation of a future pan-European Coastal Ocean Observing infrastructure.

2. Introduction and general structuration of JERICO-RI science strategy

2.1. Introduction

The JERICO-RI is a long-term framework providing high-quality marine data, expertise and infrastructures for Europe's coastal seas. The data are multidisciplinary, standardised, quality controlled, sustained, interoperable and free to access and use. JERICO-RI vision is to improve and innovate the cooperation in coastal observatories in Europe by implementing the coastal part of a European Ocean Observing System, to cooperate with other European initiatives to contribute in providing services to the research community and the society.

In the continuity of JERICO (FP7) and JERICO-NEXT (H2020), JERICO-RI science stragegy aims in strengthening and enlarging a solid and transparent European network in providing operational services for the timely, continuous and sustainable delivery of high quality environmental data and information products related to marine environment in European coastal seas. JERICO-RI will support European coastal research communities, enable free and open access to data and enhance the readiness of new observing platform networks.

The JERICO-RI science strategy is in line with the general scientific strategies put forward by current major international initiatives regarding the observation of the ocean (e.g. GOOS, EOOS and EUROGOOS) (
Figure 1).

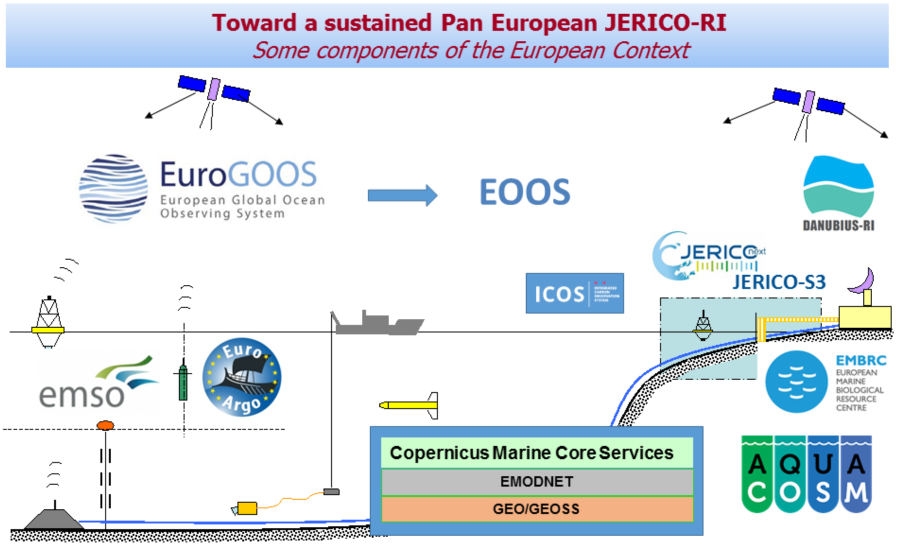

***Figure 1**: Positioning of JERICO-RI in relation with current European observing initiatives regarding the Open Ocean and terrestrial systems.*

JERICO-RI science strategy includes several key element specifically suited to the observation of the European Coastal Ocean. These elements are mainly based on:

1. The **main specificities of the Coastal Ocean** (i.e., its spatial heterogeneity and strong temporal dynamics both over a large range of nested spatiotemporal scales, the occurrence of strong interaction between physical, chemical and biological compartments/processes of different kinds, the major importance of biology, and the high number of ecosystem services and the diversity of their uses by humans).
2. **Experiences gained from the implementation of non-European national observation networks** (i.e., IOOS in the US, ONC in Canada and IMOS in Australia).

3. The **scientific strategy elaborated within JERICO-FP7** and the **experience gained within JERICO-NEXT** through the harmonization of existing observations using various platforms, the development of new technologies and the deployments of six topical pilot Joint Research Activity Projects (JRAPs).

This overall process is shown in **Figure 2**.

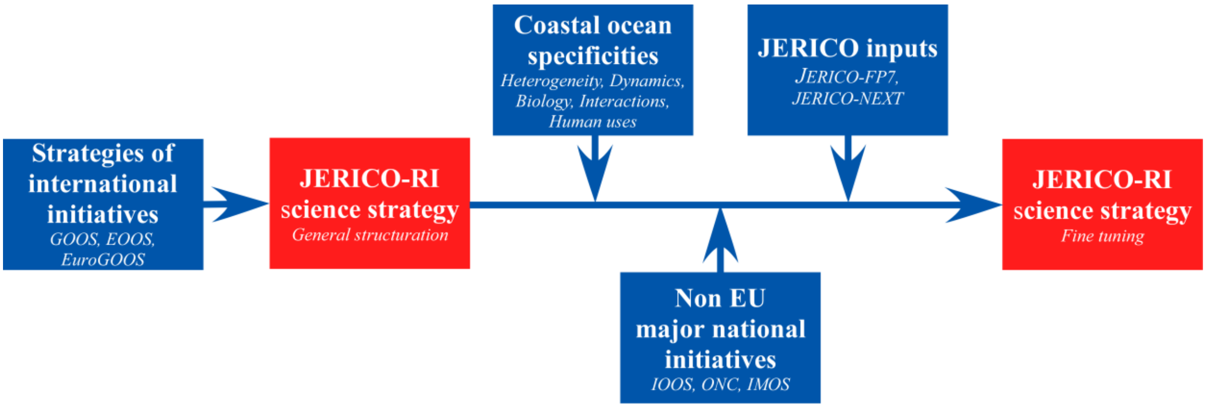

***Figure 2**: Main sources and steps taken into account during the elaboration of JERICO-RI science strategy.*

2.2. The general structuration of JERICO-RI science strategy

The followed approach allowed to identify a large set of potential coastal observing concerns/expectations associated with a wide range of spatio-temporal scales. It also showed that these concerns/expectations largely differ between and even within regional areas. This resulted in the structuration of JERICO-RI science strategy in four main pillars, respectively aiming at:

1. **Developing innovative technologies for Coastal Ocean Observing and modelling**
2. **Enhancing integrated Coastal Ocean monitoring**
3. **Interfacing with other ocean observing initiatives operating at different spatiotemporal scales**
4. **Fostering societal impact for a larger community of stakeholders**

Moreover, an originality of the approach followed by the JERICO community during JERICO-NEXT has been the setup of pilot actions to test for the implementation of the main elements of its science strategy. This resulted in the implementation of six JRAPs, which allowed to tackle scientific problematics tightly associated with Marine Strategy Framework Directive descriptors and key environmental challenges, and to test some emerging technological developments.
While answering well to the topical questions, JRAPs had shortages in spatial coverage and lack of multidisciplinary integration between topics. Therefore, JERICO-RI science strategy now intends to push this "integrative" approach one-step forward by developing a set of multidisciplinary pilot actions at a broader regional level. The aim is to implement transnational, harmonized and jointly steered **Augmented Regional Infrastructures** for integrated Coastal Ocean Observing, and improve their dialog with stakeholders. These pilot actions are also aiming at enhancing regular performance evaluation and constitute a key element of a fifth (transversal) pillar of JERICO-RI science strategy:

5. **Establishing observing objectives, strategy and implementation at the regional level**

The resulting overall general structuration of JERICO-RI science strategy is shown in **Figure 3**.

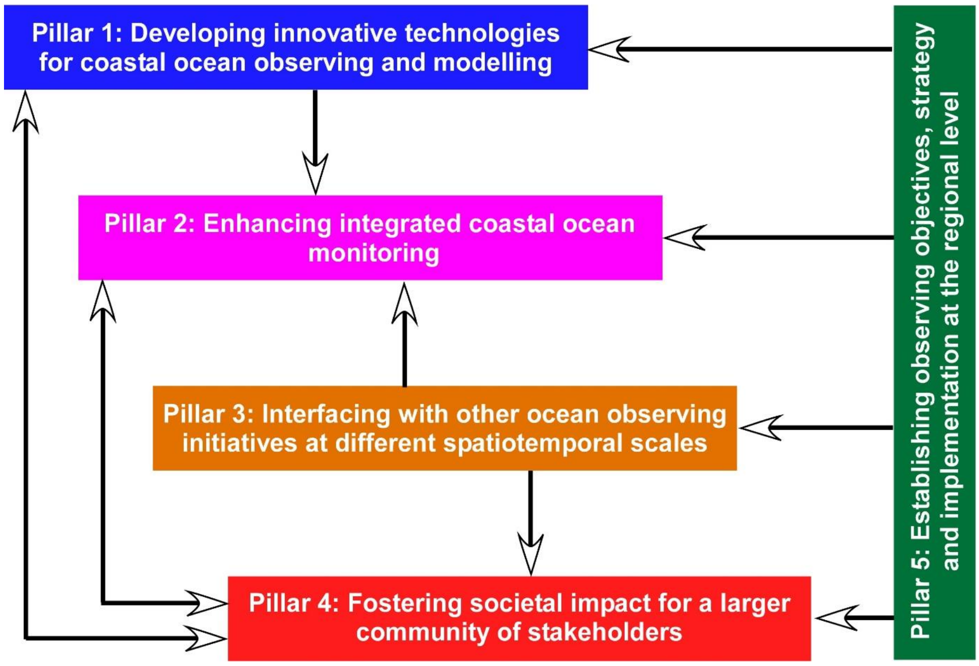

***Figure 3**: General structuration of JERICO-RI science strategy showing its five main pillars together with their main interactions.*

3. JERICO-RI Science strategy

This section presents the JERICO-RI science strategy *per se*. Following the GOOS 2030 and the EOOS strategy documents, JERICO-RI strategy encompasses two main levels of structuration: (1) a higher level, which correspond to the five pillars identified in **section 2 "Introduction and general structuration of JERICO-RI science strategy**", and (2) a lower level with more specific objectives associated with each of these pillars. The section below is dedicated to each pillar. It will show how specific objectives have been defined based on inputs from the other elements of the above presented background (see **section 4** "**Background elements of JERICO-RI science strategy**").The links between each pillar and the main elements of the strategies of current major international ocean observing initiatives will be detailed in **Figures 4-8**.

3.1. Pillar 1: Developing innovative technologies for Coastal Ocean observations

Context and issues. Major users and applications of ocean observing data require a multidisciplinary integrative approach for observations. This is for example the case of marine European policies, which either involves multidisciplinary observations (e.g. WFD) or are themselves based on a holistic approach including functional aspects (e.g., MSFD). Following an integrative approach is also essential for developing sound products, derived from observations, when stakeholder concerns/expectations are linked to biological/biogeochemical compartments/processes, since those are most often cued through physical-chemical-biological interactions. The integrative approach is of major importance as well in acquiring fundamental knowledge on the structuration and functioning of the ocean in view of predicting some of its changes in response to global and anthropogenic pressures, which are acting at different spatio-temporal scales.

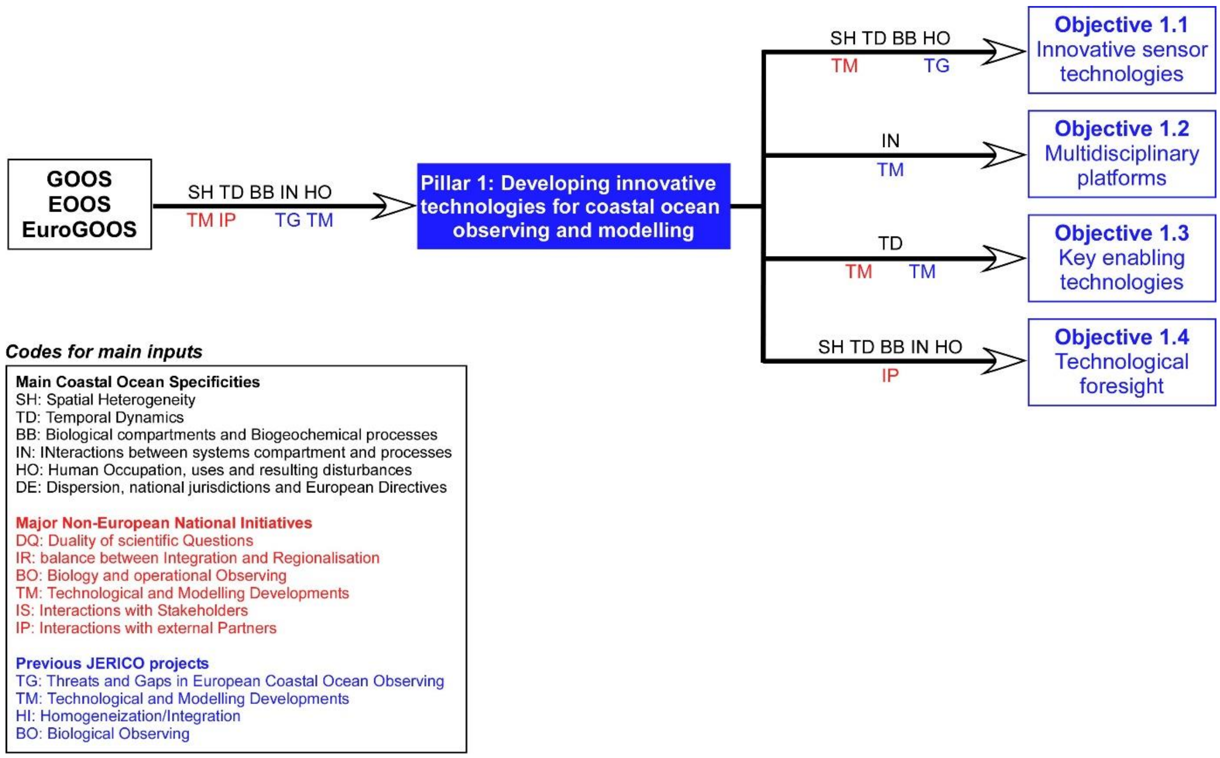

***Figure 4**: Major inputs to the structuration of **pillar 1** (**"Developing innovative technologies for Coastal Ocean Observing and modelling**") of JERICO-RI science strategy (see **section 4 "Background elements of JERICO-RI science strategy"** for further details).*

EOOS has identified the adoption of an integrated ecosystem approach as one key elements of its 2018-2022 strategy. JERICO-RI science strategy underlines that the interest/necessity of adopting such an approach for Coastal Ocean Observing is even stronger due to the major social relevance of biological/biogeochemical compartments/processes; and the complexity of the interactions between compartments, which are often cued by physical processes (e.g. the modalities of benthic-pelagic coupling, which largely result from local hydrodynamics). There is thus a crucial need to improve the coordination and integration of biological, physical and chemical observing of the Coastal Ocean. From a technological standpoint, the set-up of a multidisciplinary integrative approach is still facing several challenges:

1. Several sensors for biogeochemical studies at still at the early phases of the development and their Technology Readiness Levels may be low;
2. Current national, regional and European ocean observation monitoring initiatives are most often limited by their disciplinary scope, which results in a lack of platforms encompassing large sets of sensors allowing for integrative multidisciplinary measurements;
3. Technologies to pilot the acquisition of large heterogeneous data sets resulting from multidisciplinary observing are still largely lacking; and
4. Technology is a fast evolving field in terms of observation acquisition, handling and processing, which requires developing a mid-term prospective foresight to adapt/prepare a future European Coastal Ocean Observing infrastructure to foreseen changes.

JERICO-RI will tackle these issues by:

1. **Integrating innovative sensor technology**,
2. **Increasing current Technology Readyness Levels** (TRLs) of ocean observing systems in view of developing multidisciplinary observing platforms,
3. **Developing key enabling technologies** to optimize the acquisition and process of multidisciplinary observations, and
4. **Achieving** a **long-term technological foresight** for European coastal observing to pave the way for the implementation of a future infrastructure dedicated to the observation of the European Coastal Ocean.

Objective 1.1: ***JERICO-RI will contribute to a step change in observing system performances by integrating innovative sensor technologies***. JERICO-RI will identify state-of-the-art and novel sensors that can appropriately measure the set of variables at the appropriate frequency required for sound Coastal Ocean Observing. This is will allow for gap identification in terms of variables and automation potential. JERICO-RI will for example further develop and test innovative technologies for high frequency monitoring of contaminants and biodiversity. (e.g. phytoplankton) in cooperation with European SMEs. It will also contribute to the enhancement of non-real time high frequency measurements of contaminants, biogeochemical (e.g. nutrients) and biological (e.g. DNA sequencing, metabarcoding and gene expression) parameters through the development of a specific sampling and preservation device for the collection of water samples. By doing so, JERICO-RI is clearly aiming at inducing a paradigm shift in the frequency of observation of several crucial parameters for the understanding of marine coastal ecosystems.

Objective 1.2: JERICO-RI will improve TRLs in view of enhancing multidisciplinary platforms. The actions conducted in this field should meet two distinct requirements related to the necessity of harmonizing and insuring cost-effectiveness of observation acquisition at the pan European level, and carrying out specific developments for better balancing the disciplinary scope of automated observations and for enlarging the spectrum of scientific and environmental questions to be addressed. JERICO-RI will for example contribute to the harmonization and the cost-effectiveness of future multidisciplinary platforms by developing and testing a novel Interoperable Instrument Module hosting a core set of observing devices. This new equipment will be based on the EMSO Generic Instrument Module and customized for Coastal Ocean constraints (e.g. strong hydrodynamics and reinforced antifouling capabilities as compared to deep sea). Its stand-alone and cabled configurations will be tested for interoperability and data delivery in real-time and delayed mode. JERICO-RI will also develop smart multisensor packages for multidisciplinary observation of dedicated processes pertaining the pelagic and benthic compartments and their interactions. This will include specific technological developments achieved within

JERICO-FP7 and JERICO-NEXT. As an example, surface and sediment profile imaging will be integrated together with electrode microprofiling in a novel Autonomous Coastal Observing Benthic Station.

Objective 1.3: *JERICO-RI will contribute to the emergence of key enabling technologies for data acquisition and processing.* The temporal dynamics of environmental conditions is especially strong in the Coastal Ocean so that major components of a large variety of biogeochemical fluxes (e.g. riverine inputs of particles and associated compounds) occur during transient intensive events (e.g. floods). The optimization of observation acquisition thus clearly requires the sampling strategy (i.e., the sampling frequency) to be flexible. JERICO-RI will for example develop and test appropriate technologies for triggering acquisition by sensors/samplers in response to changes in key environmental parameters (e.g. Suspended Particulate Matter in the above example).

As stressed above (**Objective 1.1**), the development of innovative sensors constitutes a key challenge for Coastal Ocean Observing and more specifically for biological/biogeochemical compartments and processes. As for biology, innovative sensors are often based on imaging technologies, which are producing large data sets suffering from a lack of standards in terms of formats and automated processing. A specific challenge still consists in reaching the best possible threshold between the automation of the processing of the complex information produced at high-flow rates by these sensors (which be beneficial in reducing processing time and cost, enhancing operational observing and coupling with physico-chemical observations, and harmonizing data processing); and the quality/resolution of the derived information as compared to classical (non operational) biological approaches. JERICO-RI will tackle this issue by developing novel methodologies based on evolutionary computing and deep learning, primarily to exploit the information derived from flow cytometry and visible images in view of assessing the diversity of biological compartments.

The strong spatial heterogeneity and temporal dynamics are key natural characteristics of the Coastal Ocean, which are even reinforced by the fact that, although increasing, the panel of variables that can be assessed in a global comprehensive way (e.g., through remote sensing) for the Coastal Ocean remains still limited. The question of the representativity and the upscaling of observations thus constitutes a major challenge for Coastal Ocean Observing. Modelling is fundamental in this context by providing links between individual observations, and providing description or even predictions for processes taking place over defined spatial and temporal scales. There is currently a clear lack of multidisciplinary, coupled models applicable at the right spatial and temporal scales to the high diversity of Coastal Ocean problematics. Moreover, the state of the art in modelling developments strongly differ between disciplines, being more advanced for physics than for biogeochemistry and even more for biology. JERICO-RI will tackle this issue by achieving: (1) a review of available modelling methodologies and of their potential application to coastal ecosystem monitoring, and (2) new developments including the comparison with ground truth for the modeling of time series combining environmental, physical, biogeochemical and biological data.

Objective 1.4: *JERICO-RI will achieve a long-term technological foresight.* JERICO-RI will review the potential of emerging technologies for Coastal Ocean Observing to anticipate and prepare for future changes. JERICO-RI will investigate how disruptive innovations, emerging technologies are likely to provide appropriate responses to current and long-lasting environmental challenges and lead to a paradigm shift in the way European Coastal Ocean will be observed in the future. JERICO-RI will review the latest progress and engage with relevant innovation providers for identifying innovations of high relevance either for measuring variables of high importance but not currently addressed at the appropriate spatial and temporal scales because of technological limitations, or for significantly improving the present capability for integrative observation of complex coupled coastal processes.

3.2. Pillar 2: Enhancing Coastal Ocean integrated observing

Context and issues. The modalities of the issues linked to the integration of Coastal Ocean Observing first refers to the nature of tackled scientific questions. When considering large-scale long-term scientific questions (see **section 4.3 *"Main inputs from major non-European national initiatives"***), a major issue regarding Coastal

Ocean integrated observing consists in enhancing the harmonization of observations achieved by different operators at various locations so that they become comparable. A way forward then consists in defining best practices procedures allowing reaching satisfactory quality standards. This approach has been, for example, initiated by IOOS through its interaction with ACT. It was started by the JERICO community through dedicated Networking activities within both JERICO-FP7 and JERICO-NEXT. **JERICO-RI will further contribute to harmonize observing procedures by focussing on less advanced disciplinary fields and the implementation of multidisciplinary observations.**

Multidisciplinarity also constitutes a fundamental element of integrated observing due to the complexity of interactions between compartments and processes taking place in the Coastal Ocean. In practice, one of the limitations of its implementation is the lack of availability of sensors/technologies for the operational observing of some major compartments/processes. The JERICO community has started to fill this gap by achieving technological developments within both JERICO-FP7 and JERICO-NEXT. Corresponding pieces of equipment remain restricted to a limited number of laboratories. Enhancing the accessibility to technologies thus constitute a key point in enhancing the implementation of multidisciplinary observing in different locations of the European Coastal Ocean. The JERICO community contributed to this aim through the Trans National Access components of both JERICO-FP7 and JERICO-NEXT. **JERICO-RI will extend technology availability to a larger set of technologies**.

Besides technological aspects, the implementation of integrated Coastal Ocean Observing also requires an *a priori* reflexion on the sampling/deployment strategy. Due to differences in spatiotemporal scales between monitored compartments and processes, an efficient coupling of observations of heterogeneous sets of parameters indeed require an *a priori* in depth thinking of data acquisition and processing schemes, which is far from trivial and here again is clearly depending on tackled questions, which vary both between and within regions. The JERICO community started addressing these sources of variability by setting up pilot experimentations through the six JERICO-NEXT JRAPs. Although highly valuable, this experience proved the need to progress in terms of multidisciplinarity/integration as expected. **The JERICO-RI now intends to move one-step further through the implementation of Pilot Augmented Infrastructures in a limited number of regional areas representative of the European Coastal Ocean**.

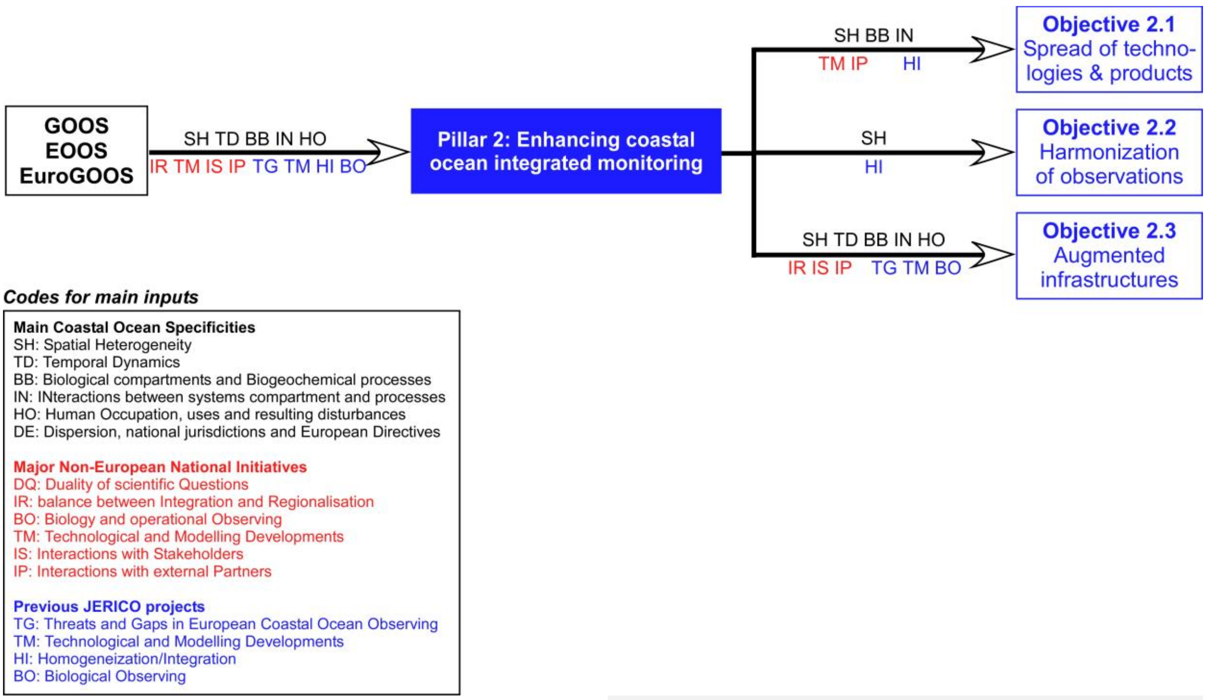

***Figure 5:** Major inputs to the structuration of **pillar 2** (**"Enhancing multidisciplinary approaches to achieve Coastal Ocean monitoring in a fully integrated way**") of JERICO-RI science strategy (see **section 4 "Background elements of JERICO-RI science strategy"** for further details).*

Objective 2.1. *JERICO-RI will enhance the spread of technologies and products for Coastal Ocean Observing.* The JERICO community has started enhancing the access to mature observation technologies through the Trans-national Access components of both JERICO-FP7 and JERICO-NEXT. In line with the international collaborative projects achieved by ONC, this approach was found of major importance for: (1) testing and enhancing technological developments, (2) improving the homogeneity of ocean observing between locations within JERICO-RI, and (3) contributing to the spread of best practices within JERICO-RI (see the section regarding **Objective 2.2**). The last two items are key elements of **pillar 2** ("**Enhancing integrated Coastal Ocean monitoring"**) of JERICO-RI science strategy. JERICO-RI intends to continue to favour the spread of Coastal Ocean Observing technologies and to apply it to a larger set of fields. This will include the access to: (1) multi-disciplinary multi-platform coastal observing systems, and (2) data management and processing tools allowing for the elaboration of innovative products based on observations *per se*. The general objective will be to provide smooth and efficient access to JERICO-RI mature technologies and infrastructures for both academy and industry research teams. This will allow promoting innovation and transfers of expertise in the coastal marine sector that offers rich promise for the future and build long-term collaborations between end-users and JERICO-RI.

Objective 2.2. *JERICO-RI will strengthen the European network of coastal observatories by harmonizing observation procedures*. Highly significant progresses have been achieved in recent years through both major non-European initiatives (e.g. by IOOS through ACT) and within the framework of both JERICO-FP7 and JERICO-NEXT. JERICO-RI first intends to carry on with the harmonization, update and actualisation of existing documentations regarding mature coastal observing platforms (including *inter alia* HF Radar, Glider, Ferrybox, Fixed Platform) primarily based on the outputs of JERICO-FP7, JERICO-NEXT and other initiatives. This will result in the production of an interactive electronic handbook that will be continuously actualized and will allow for the enhancement of the joint management of the main issues on observing platforms operations. Nevertheless, the availability of current best practice recommendations is clearly depending on the maturity of the observing technology and there are still significant gaps in the coverage, harmonization and implementation of best practices in some fields including biogeochemistry (e.g., carbonate system variables, oxygen, nutrients) and biology (e.g.

biodiversity assessments). Corresponding recommendations are thus clearly needed. Within this context, JERICO-RI will primarily focus on 3 main fields, namely:

1. Elaborating recommendations related to the implementation of near real-time biogeochemical observations on platforms (e.g. FerryBoxes, gliders, coastal profiling systems, fixed platforms and coastal cable observatories),
2. Producing Standard Operating Protocols for automated coastal water sampling and preservation of target molecules (barcodes) for DNA based biodiversity measurements, and
3. Defining best practices on the implementation/deployment of biological automated sensors with a focus on phytoplankton functional diversity using flow cytometry and multispectral fluorometer as well as zooplankton diversity using flow and *in situ* imaging.

Overall, this will contribute to the better integration of biological/biogeochemical observations in European Coastal Ocean Observing.

Objective 2.3. JERICO-RI will establish observing strategies and implement a limited number of augmented regional infrastructures, in form of hierarchical coastal observatory network representatives of the main hydrodynamical regimes of the Coastal European Ocean (see the detailed presentation in the sections below regarding **objectives 5.1** and **5.2**).

3.3. Pillar 3: Interfacing with other ocean observing initiatives at different spatiotemporal scales

Context and issues. The structuration and the functioning of the Coastal Ocean are partly depending on processes originating from the continent (e.g. freshwater and particle inputs from large rivers), the Open Ocean (e.g. major storms affecting hydro-sedimentary processes and biological compartments) and the atmosphere (e.g. carbon flux, weather). **Achieving a sound comprehension** of their effects clearly **requires the tight coupling of the observations achieved on the Coastal Ocean *per se* and on** these **adjacent systems**. The structuration and the functioning of the Coastal Ocean is also largely resulting from a complex interplay between internal compartments and processes. Adopting a holistic approach for Coastal Ocean Observing is therefore of major importance. This requires achieving observations on a large set of compartments/processes differing by their nature and dynamics. In Europe, these observations are currently carried out through different top-class observation infrastructures/initiatives, which raises the issue of their articulation with JERICO-RI observations.

Processes controlling Coastal Ocean structuration are associated with a large range of nested spatiotemporal scales. This results in strong spatial heterogeneity and strong temporal dynamics, which complicates the observation of the Coastal Ocean. A significant proportion of stakeholder requirements are associated with small spatial and temporal scales, which are impossible to cover in a fully integrated way but are often monitored through local observation initiatives. **JERICO-RI intends to enhance the integration of** such **local observations** in a pan European network, which implies to:

1. Insure that the quality of the data they produced meets relevant standards,
2. Optimize data acquisition designs, and
3. Enhance observation durability.

Overall, setting up integrated Coastal Ocean Observing over a large spatial scale certainly constitutes an ambitious objective that several major non-European countries have started tackling through the developments of their national ocean observing systems. These initiatives have been empirically facing challenges linked with Coastal Ocean Observing and have gained highly valuable experience regarding these challenges. It is therefore essential to further develop interactions with them through continuous real time exchanges regarding scientific questions *per se*; technological expertise and developments; and (3) interactions with partners including stakeholders. JERICO-RI will tackle those issues by **enhancing cooperation with**:

1. **European observing infrastructures/initiatives on Open Ocean and riverine/terrestrial systems,**
2. **Other European world-class ocean observing infrastructures/initiatives,**
3. **Local observation providers,**
4. **Other providers of Coastal Ocean observations, and**
5. **Major non-European national ocean observing systems.**

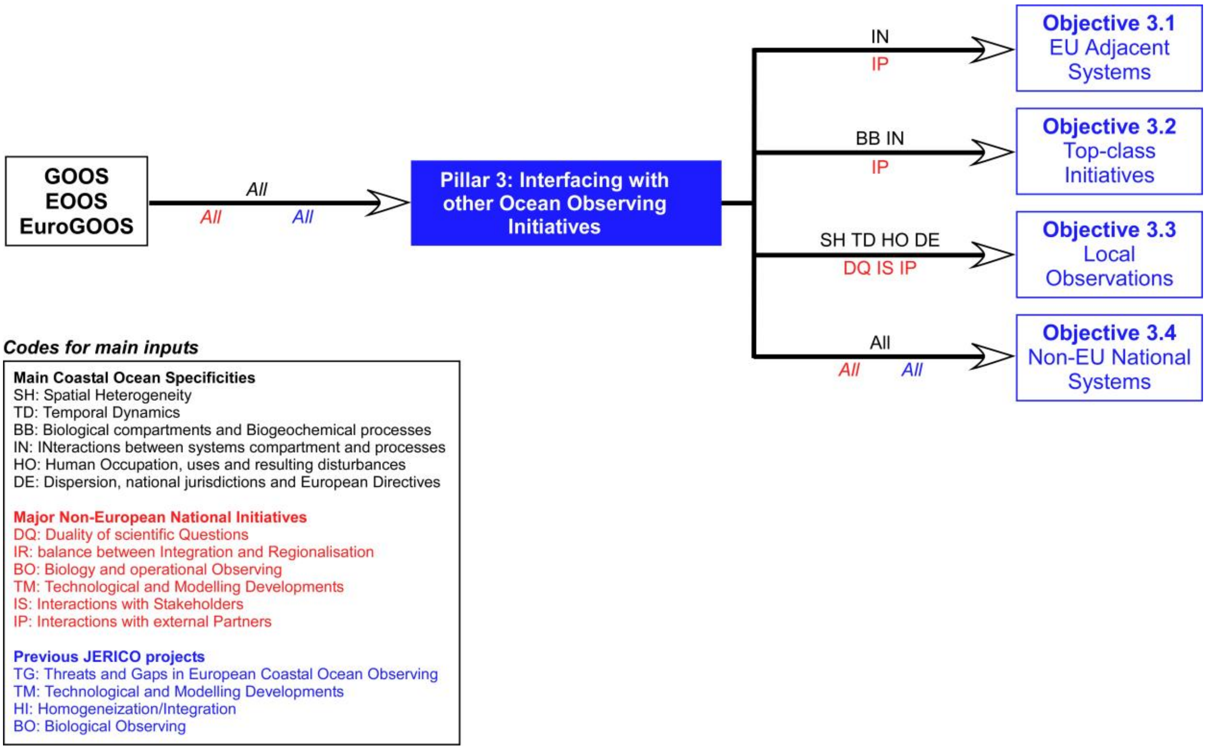

***Figure 6**: Major inputs to the structuration of **pillar 3 ("Interfacing with other ocean observing initiatives at different spatiotemporal scales")** of JERICO-RI science strategy (see **section 4 "Background elements of JERICO-RI science strategy"** for further details).*

Objective 3.1: JERICO-RI will enhance cooperation with observing infrastructures/initiatives on systems adjacent to the European Coastal Ocean. JERICO-RI will develop collaborations with Open Ocean (e.g. EMSO, EUROARGO…) and River-Sea (e.g. DANUBIUS) observing infrastructures. Interactions will be achieved at high level with the ultimate aim of signing Memorandum of Understandings. Joint collaborations will also be explored at the regional and sub-regional levels within both a limited number of Augmented Regional Infrastructures (see also the section dedicated to **pillar 5** (**"Establishing observing objectives, strategy and implementation at the regional level"**) of JERICO-RI strategy). The objective is to make a major contribution in optimizing the articulation between observing systems in terms of monitored parameters, sampling designs, data interoperability and use. This will ensure that observations on adjacent systems are suitable to parametrize some of the main external variables to be considered in Coastal Ocean modelling.

Objective 3.2. *JERICO-RI will enhance cooperation with other European top-class ocean observing infrastructures/initiatives.* JERICO-RI will strengthen its links with other major European initiatives on Coastal Ocean Observing. This *inter alia* will include ERICs such as EMBRC (biology) and ICOS (carbonate systems) as well as other relevant infrastructures such as AQUACOSM (*in situ* experimentation). The aim here is clearly to optimize the combination of the outputs of all complementary infrastructures in order to provide joint and many-sided (i.e., observation/experimentation/modelling) answers to Grand Environmental Challenges. JERICO-RI will also interact with major current EU initiatives regarding data storing and processing. JERICO-RI will interact with EMODnet by providing coastal data to EMODNET data management systems, through SeaDataNet and SeaDataCloud. In the same way, it will provide data and products to the Copernicus marine service CMEMS.

Objective 3.3: *JERICO-RI will develop bilateral interactions with local observation providers.* Processes of relevance for Coastal Ocean Observing are taking place over a large range of nested (spatial) scales from local to pan-European. Most users are primarily concerned by issues associated to small spatial scales. A challenge for a pan-European observing network is to provide relevant information/products at small spatial scales. Through its *objective 1.3*, JERICO-RI will contribute to meet this objective by developing innovative modelling approaches of multidisciplinary time-series. An integrated infrastructure, such as JERICO-RI, will however certainly prove unable to provide a comprehensive set of local observations for covering the whole European Coastal Ocean. Observation of these kinds are currently achieved through a multiplicity of initiatives conducted by a large variety of entities including public bodies and private companies. The existence of this reservoir should not be ignored although its collection currently suffers from a lack of harmonization and for most of them are not secured over the long term. JERICO-RI is aiming at contributing to the enhancement of the quality and the durability of local observations and their better use in developing new scientific knowledge and specific products for stakeholders. In order to do so, JERICO-RI will develop tight interactions with local observation initiatives including the setup of synergies and partnership models with private sector observing activities. Anticipated interactions are clearly bilateral. On the one hand, JERICO-RI will enhance the quality and the durability of local observations by providing advices/labelling. On the other hand, JERICO-RI will collect and make use of the data produced by local observing initiatives. By doing so, JERICO-RI will contribute to the densification and the diversification of the observations regarding the European Coastal Ocean.

Objective 3.4: *JERICO-RI will enhance its collaboration with major non-European ocean observing national initiatives.* JERICO-RI intends to enhance its interactions with major non-European operational oceanographic systems by building on links with major non-European ocean observing national systems as already started within JERICO-NEXT with US IOOS, ONC Canada and IMOS Australia. This will facilitate new collaborations around common issues of technological and societal concern,and help in better defining key elements of a future pan-European Coastal Ocean Observing infrastructure. A practical action will consist a workshop on best practices, innovative monitoring and technological developments in cooperation with US ACT. At this occasion, JERICO-RI will exchange with its American partners on the opportunity to build a European equivalent to ACT. Links with developing oceanographic systems in adjacent regions including the Black Sea and North Africa will also be strengthened by sharing existing and promising technologies as well as deployment strategies.

3.4. Pillar 4: Fostering societal impact for a larger community of stakeholders

Context and issues. Current international initiatives regarding ocean observations (e.g. GOOS, EOOS and EUROGOOS) all stress that observations and derived products should be set up in tight interactions with stakeholders on a fit-for-purpose basis and that they have necessarily to be sustained on the long term. The widening of its stakeholder community clearly constitutes a key element in enhancing the visibility and the sustainability of ocean observing. Ocean observing stakeholders mostly include scientists and users of data, products and services. This last community is especially diverse in the case of the Coastal Ocean and even more in its littoral component due to the large diversity of uses of ecological services made by humans and resulting socio-economic concerns. The JERICO community has started to gather stakeholders by creating a user committee. It is however clear that this community can further be enlarged and its involvement in Coastal Ocean Observing improved. This requires that the **stakeholder community** is **further enlarged and deeper involved in the definition of** the **products** derived from JERICO-RI observation; **so that** derived **products are better suited in tackling stakeholder concerns**.

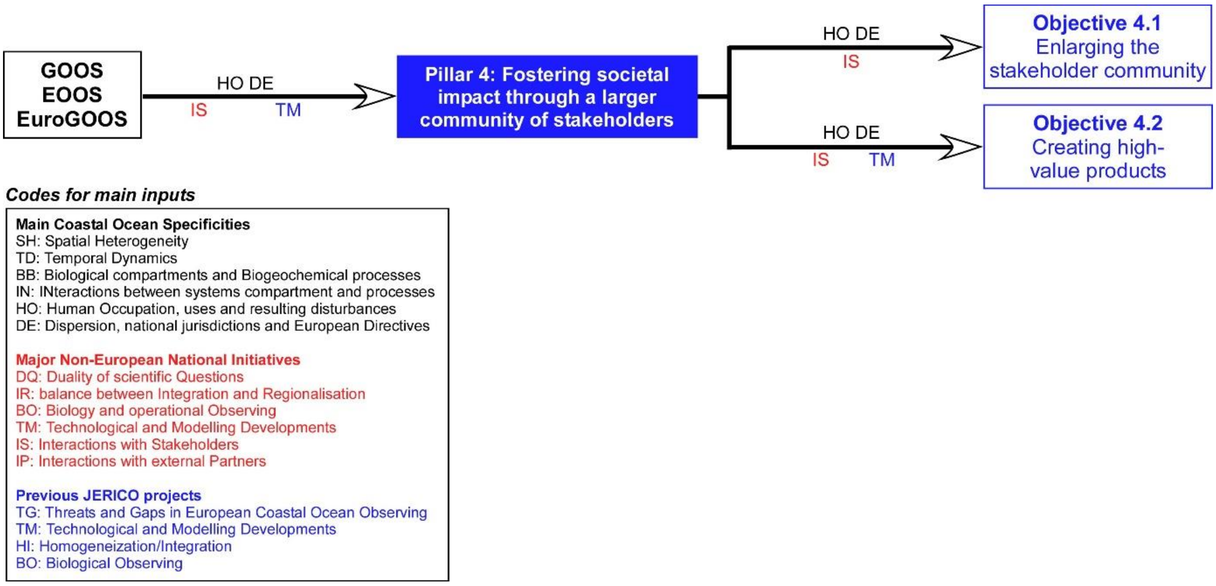

***Figure 7**: Major inputs to the structuration of **pillar 4** (**"Fostering societal impact for a larger community of stakeholders"**) of JERICO-RI science strategy (see **section 4 "Background elements of JERICO-RI science strategy"** for further details).*

Objective 4.1: JERICO-RI will contribute to enlarge and deepen the involvement of the Coastal Ocean Observing stakeholder community by: mapping this community and better identifying its needs through active interactions; and comparing these needs with currently available products/services. These two actions will be achieved over a large range of spatial scales from global to local with a particular emphasis put on the regional and sub-regional levels. By so doing JERICO-RI will enlarge its current user committee and better interact with its members. JERICO-RI will for example achieve an analysis of expectations from the policy realm versus products derived from coastal observing. It will identify the needs from EU directives and Regional Sea Conventions in relation to current monitoring programs and identify products that can contribute to meeting these needs. A similar approach will be developped for the actors of the private sector.

Objective 4.2: JERICO-RI will support the emergence of new high added-value products to coastal and shelf seas marine and maritime socio-economical actors. This will be achieved by:

1. Adapting observations to the assessment of key processes,
2. Developing novel data science methodologies,
3. Reinforcing cooperation with COPERNICUS (ESA, CMEMS), EMODNet and coastal modelling experts, and
4. Developing partnerships with public, private and participating organisations that provide relevant environmental and socio-economic observations and expertise.

Items 1 and 2 have been detailed in the section dedicated to **pillar 1** (**"Developing innovative technologies for Coastal Ocean observations"**) of JERICO-RI strategy. JERICO-RI will enhance its production of coastal data to EMODnet and its production of data and products to the Copernicus marine service CMEMS. JERICO-RI will further explore mutual interests and promote its own observations and expertise for developing novel joint products including *inter alia* the calibration/validation of satellite observations. JERICO-RI will also foster cooperation/synergies with non-RI providers of coastal observations including national, regional and sub-regional monitoring programs (see also the sections dedicated to **pillars 3** "**Interfacing with other ocean observing initiatives at different spatiotemporal scales**" and **5** "**Establishing observing objectives, strategy and implementation at the regional level**") and private sector organizations performing observing activities.

3.5. Pillar 5: Establishing observing objectives, strategy and implementation at regional level

Context and issues. Most non-EU national initiatives consist of networks of regional subsystems. This is also the case of EuroGOOS, which is organized in Regional Ocean Observing Systems. The main rationale for this is the existence of functional links mainly due to boundary currents and to the structuration of biological communities at this particular scale. Such items constitute the basis of the delimitation of the five IMOS coastal nodes, whereas the eleven IOOS regional observation systems largely result from political considerations. As for the European coastal Ocean, regionalization can therefore constitute a significant benefit by coordinating transnational efforts in observing the different components of functionally connected systems. Another rationale for defining observing objectives and strategies at regional level is linked to the diversity of specific (i.e., short-term, small-scale) issues and the willingness of enlarging the community of end-users of Coastal Ocean observations and derived products, which benefit from initiatives at a spatial scale small enough to:

1. Account for regional specificities,
2. Allow for an extensive mapping of potential end-users, and
3. Allow for frequent interactions with identified end-users.

One of the specificities of the JERICO-RI lies in the fact that it has already implemented several pilot actions to tackle some of the complex issues associated with Coastal Ocean Observing. Within JERICO-NEXT, this was achieved through six JRAPs, which were mostly discipline oriented. Although JRAPs succeeded in addressing the main scientific questions formulated according to the specific disciplines, they suffered from a restricted implementation of multidisciplinarity, which was identified as a clear point to progress upon within JERICO-NEXT deliverable **D4.5**. Moreover, some of these actions (i.e., all but **JRAP 3** and **5**) consisted of a juxtaposition of local actions with a limited geographical coverage. The *a posteriori* effort to coordinate and synchronise the actions across the JRAPs carried out in different regional areas (JERICO-NEXT deliverable **D4.4**) generated major results and led to interesting prospectives for the future. It however, showed limitations in terms of the identification of major questions to be tackled and associated potential stakeholders; and of the implementation of pluridsciplinarity. One major reason for this is that these items should be *a priori* planned and taken care off in the design of Coastal Ocean Observing strategies. A main lesson learned is that societal challenges and priorities at the regional level are important elements for the structuration of a coastal observing system.

Therefore, a key objective for the future is to **improve regionalisation** of the observatories **for a better understanding of region-specific processes and an improved fit-for-purpose** of the JERICO-RI. Furthermore, the **observatories need to be consolidated in terms of performance, reliability and variables to optimally address and answer key regional and pan-European environmental challenges**. The two above-mentioned aspects are the integration challenge that **JERICO-RI will tackle by implementing a regional structuration** based upon**:**

1. Harmonizing observations and sampling strategies at regionally relevant
2. Fulfilling regional needs for consistent data and coordination of observations
3. Establishing multipurpose/multidicisplinary sites serving pan-European needs to study grand environmental challenges
4. Using these sites for piloting the connection with other RI, industry and other coastal stakeholders.

The proposed **actions** requires regional Coastal Ocean Observing systems that have reached an appropriate level of maturity. In addition, actions for **peparing** less mature systems **for future implementations of Augmented Regional coastal observatory network** must be conducted, through **progressing on hierarchical coastal observing networks**.

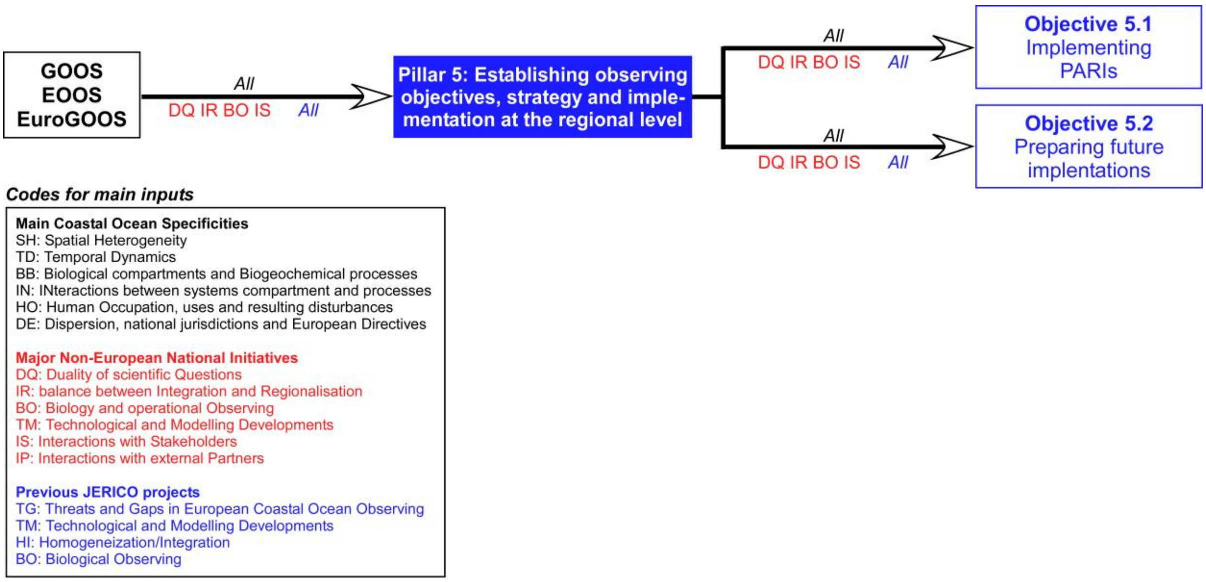

***Figure 8**: Major inputs to the structuration of **pillar 5** (**"Establishing observing objectives, strategy and implementation at the regional level"**) of JERICO-RI science strategy (see **section 4** "**Background elements of JERICO-RI science strategy**" for further details).* ARCOs: Augmented Regional coastal observatory network.

Objective 5.1: JERICO-RI, through pilot initiatives, will implement a set of Augmented Regional coastal observatory network. The JERICO community will provide a proof of concept by implementing several Pilot network (ARCOs), which will consist of regional, spatially dense networks of observing platforms that will jointly perform multidisciplinary observations over a range of nested spatial scales from local to regional. This will provide first-hand experience on how to operate transnational and multiplatform observatories, how they are best connected to other local, regional and European networks and how the practical aspects of observations and data flows are best organised at different sites. The overall aim will be to improve the cost-efficiency, innovative use, and scientific and societal impact of multiple coastal observations. The key feature of ARCOs will be the production of synoptic, interoperable, and openly available biological, biogeochemical, and physical data together with derived products/services.

Based on an entire overview of coastal observatories operating in respective regions outside the JERICO-RI community, ARCOs will include the definition of key societal information needs regarding regional marine environments and of current scientific gaps in observing regional coastal systems. Their implementation will thus also significantly contribute to **Pillars 3 ("Interfacing with other ocean observing initiatives at different spatiotemporal scales"**) and **4 ("Fostering societal impact for a larger community of stakeholders"**) of the JERICO-RI science strategy. Augmented Regional coastal observatory network will also constitute a key element supporting JERICO-RI integration process (**Pillar 2 "Enhancing coastal integrated observing"** of JERICO-RI science strategy) by exploring how to:

1. Transnationally share and manage platforms/equipments and plan joint missions,
2. Jointly manage the whole data lifecycle, following the FAIR principles,
3. Increase the societal and scientific value of observations through data fusion and integration, and

4. Transfer knowledge within and between regions, and between research infrastructures.

At last, ARCOs will clearly be of major importance for testing coordinated deployments of the new technological developments achieved within **Pillar 1 ("Developping innovative technologies for coastal observations"** of JERICO-RI science strategy. The implementation of ARCOs therefore constitutes a key transversal component of JERICO-RI science strategy, which will contribute to feed the four other pillars.

Within its **D4.4**, JERICO-NEXT has achieved a preliminary assessment of the current level of maturity of costal ocean observing systems in major European regional areas. This analysis clearly showed that the current levels of maturity of regional Coastal Ocean Observing systems largely differ between areas with only a few of them suitable for the implementation of ARCOs, namely:

1. the Gulf of Finland and Baltic Sea,
2. the North-West Mediterranean,
3. the North Sea and English Channel, and
4. the Cretan sea.

These four areas feature different set of physico-chemical and biogeochemical environments. They are also submitted to different anthropogenic pressures generating different major socio-economical issues. The implementation of these four ARCOs by JERICO-RI will demonstrate the benefits of integrated, state-of-the-art multidisciplinary and multiplatform observation capabilities. It will *inter alia* show how:

1. Transnational and multiplatform should be optimally operated when studying complex coastal challenges in an integrated approach,
2. Interactions with other environmental observing networks can be regionally organised,
3. Interactions with modelling and satellite remote sensing communities can be regionally implemented, and
4. To upgrade harmonised and sustained observations and products that are usable for various societal and scientific needs.

Overall, the implementation of ARCOs will allow for the development of innovative hierarchical monitoring concepts for coastal seas; and for the creation of coastal collaboration platforms for other European environmental research infrastructures, maritime industries, and regional environmental management of coastal ecosystems. By doing so, it will allow to gather highly relevant experience in view of building up a future pan European Coastal Ocean Observing infrastructure consisting in a network of regional subsystems.

Objective 5.2: JERICO-RI will prepare less mature regional areas for future implementations. Because of the low number of identified ARCOs, the coordination and optimisation of a pan European network of regional subsystems, clearly requires the integration of European regional areas that are not yet mature enough. The action achieved by JERICO-RI to reach this objective will consist of pure networking activities, as it will not include any new implementation of additional observing platforms and/or programs under JERICO funding. It will consist of coordinating and developing region-specific observational strategies and approaches, promoting cooperation, integration, and development between countries adjacent to coastal observing regions, as well as providing the cooperational framework for regional data management and accessibility.

Based on the outputs of JERICO-NEXT **D4.4**, JERICO-RI will primarily work toward these objectives in five areas, namely:

1. the Northern Adriatic Sea,
2. the Iberian Atlantic Margin,
3. the Bay of Biscay,
4. the Skagerrak-Kattegat, and
5. the Norwegian Sea.

JERICO-RI will organize, harmonize, and integrate existing coastal observing activities and initiatives in order to address both pre-identified region-specific and pan-European scientific and socio-economic challenges (i.e., based on an initial analysis of the main characteristics of each of the above-mentioned areas and tight interactions with regional/national stakeholders, industry, users, and policy makers). JERICO-RI will develop observational strategies and propose roadmaps (including implementation as well as business and sustainability plans) for the coordination of regional activities in order to maximise efficiency and effectiveness of Coastal Ocean observations in relation to other observing initiatives operating over different spatial and temporal scales. JERICO-RI will devote a particular attention to the coordination and the harmonization of data/handling/delivery at the regional level.

4. Background elements of JERICO-RI science strategy

This section presents the general background of JERICO-RI science strategy. More specifically, it shows how it is linked to the main constitutive elements of the strategies of current global ocean observing initiatives; and fine-tuned by considering the main specificities of the Coastal Ocean, inputs from major non-European National Ocean observing initiatives and experience gained by the JERICO community during previous projects (i.e., JERICO-FP7 and JERICO-NEXT).

4.1. Constitutive elements of the strategies of current global ocean observing initiatives.

The main elements put forward by the major current ocean observing international initiatives are shown in **Figure 9** together with their links with the five pillars of JERICO-RI science strategy. The three major international initiatives regarding ocean observing are GOOS, EOOS and EuroGOOS. Their current overall strategies are detailed in the GOOS 2030 strategy[1], the EOOS Strategy 2018-2022[2], and in the EuroGOOS AISBL STRATEGY 2014-2020[3]. Besides differences in their overall structuration and considered timeframe, common elements in the strategies of these three initiatives were identified as following:

Technological innovation. This element first refers to data acquisition *per se* (e.g., GOOS specifically mentions the necessity of achieving "innovation in observing technologies", while EOOS underlines the importance of a transition from platform-specific to multiplatform observing" in relation with the adoption of an integrated ecosystem approach). It also includes data handling as put forward by GOOS, which identifies "innovation in observing networks" as a specific objective. At last, EuroGOOS emphasizes the importance of co-production in enhancing the "Specialization of products derived from (operational) observations".

Integration/coordination. This first corresponds to the necessity of adopting an holistic approach for ocean observing. This is explicitely stated by EOOS, which underlines the major importance of adopting an "integrated ecosystem approach" and by GOOS, which recommends setting-up such an approach for reaching a better "understanding human impact" on the ocean. This element however also refers to the necessity of a better coordination in implementing ocean observing. This point is clearly apparent in many of the items put forward by GOOS (e.g. "Observation coordination", "Guidance for implementing integrated observing"…) and EOOS, which underlines the interest in defining a set of core variables to be commonly measured (e.g. "EOVs and EBVs", "Priorities for wider ocean variables").

Links with other observation initiatives acting over different spatiotemporal scales. EOOS notices that, in spite of significant investments at the European, national and subnational levels, the connexion between the full diversity of ocean observations is still insufficient. Together with GOOS "Spreading end-user applications at the local level", it stresses the importance of taking in consideration the local scale in ocean observing. More specifically, EOOS underlines the interest of "connecting with stakeholders measuring additional parameters" and thereby to develop links with the large variety of ocean observers collecting data over small spatiotemporal scales. The absolute necessity of better coordinating national initiatives is also clearly apparent in EOOS (see above) and EuroGOOS strategies (e.g. "Foster cooperation with national initiatives"). EuroGOOS also stresses the necessity of enhancing its interactions with other European and international networks of marine and environmental sciences (e.g. EOOS, EMODnet, EEA Copernicus…)

Maximizing the benefit of coastal observing for the society. All three initiatives clearly identify the enhancement of societal impact of ocean observing as a major element of their strategies especially in terms of long-term sustainability. They all stress the necessity of changing the nature of the interactions with a larger set of stakeholders (e.g. GOOS "Widening the range of stakeholders", EOOS "Connexion of stakeholders", EuroGOOS

[1] https://www.jcomm.info/index.php?option=com_oe&task=viewDocumentRecord&docID=21868
[2] http://www.eoos-ocean.eu/download/EOOS_Strategy_2018-2022_October2018.pdf
[3] http://eurogoos.eu/download/reference_documents_/EuroGOOS-Strategy-2014-2020.pdf

"Interaction with stakeholders"). This necessitates better involving stakeholders in the definition of their requirements including those associated with the local level, developing innovative products covering those requirements and improving the visibility/accessibility of those products.

These four elements constitute the basis of the first four pillars of JERICO-RI science strategy. In addition, the GOOS, EOOS and EuroGOOS strategies clearly mention the necessity for Coastal Ocean Observing to take in consideration a large variety of processes taking place over a wide range of spatial (i.e., from local to global) and temporal scales (i.e., from the short time period associated to extreme events to the long one suitable to assess the effects of climate change), and the interest in achieving "Regular performance evaluation" (GOOS). Together with the current structuration of EuroGOOS in five ROOS, of IOOS in eleven Regional Associations, and of IMOS in six nodes (see below), this contributed to the introduction of a ***fifth pillar*** entitled ***Establishing observing objectives, strategy and implementation at the regional level*** in JERICO-RI science strategy.

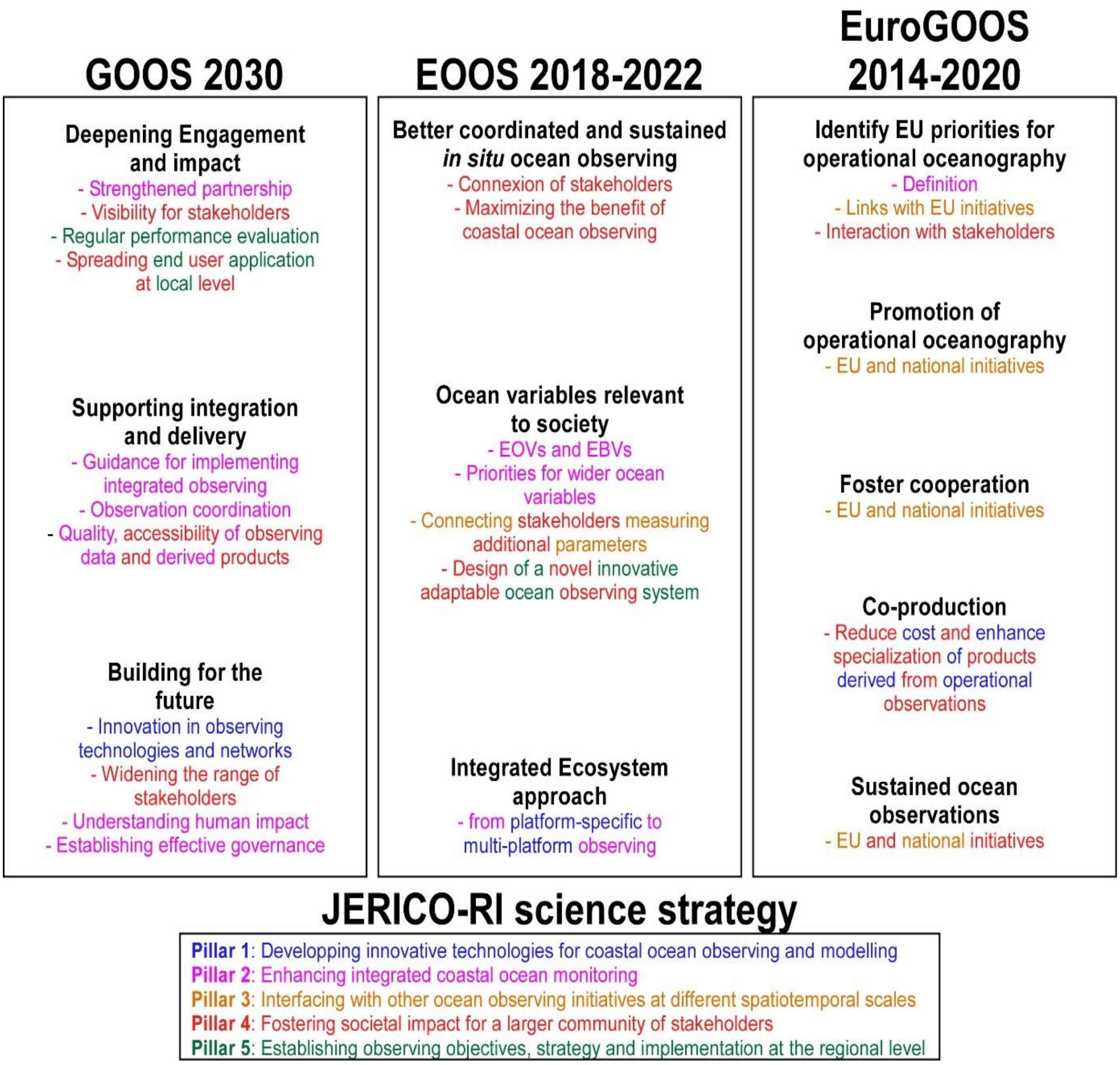

Figure 9: *Main elements constitutive of the GOOS 2030, EOOS 2018-2022 and EuroGOOS 2014-2020 strategies and links with the five pillars of JERICO-RI science strategy. The color code refers to each of these five pillars.*

4.2. Coastal ocean specificities: stakes, issues and complexity

As compared to GOOS, EOOS and EuroGOOS, JERICO-RI presents the originality of being specifically dedicated to the observation of the (European) Coastal Ocean. Its scientific strategy must therefore be suited to the main specificities of this component of the world ocean. The most important ones have been identified as follows:

Spatial heterogeneity. The Coastal Ocean is composed of components that are showing very different environmental conditions. These differences refer to a large set of nested spatial scales from large (e.g. between open and closed basins) to local ones (e.g. between exposed and sheltered areas, rocky and sandy shores, areas influenced or not by freshwater inputs…). Spatial heterogeneity thus constitutes a fundamental characteristic of the Coastal Ocean, which clearly complicates its observing since approaches allowing for synoptic spatial measurements (e.g., remote sensing) are still of limited use in coastal areas. A challenge for Coastal Ocean Observing thus consists in soundly upscaling spatially limited observations. This can be achieved through: (1) technological developments allowing for a better spatial coverage during data acquisition, and (2) modelling. Both aspects are part of **pillar 1** ("**Developing innovative technologies for Coastal Ocean Observing and modelling**") of JERICO-RI science strategy.

Temporal dynamics. The Coastal Ocean is also showing strong temporal dynamics. Extreme events constitute major actors in controlling the structuration and the functioning of costal (eco)systems. Major floods are for example largely responsible for the export of particles by rivers. At another level, hydrodynamics is a key factor in controlling sandy beach erosion and sandy bottom benthic fauna composition Understanding the structuration and the functioning of the Coastal Ocean thus requires collecting observations over the right time-period and at the appropriate time-frequency to capture the impact of intense episodic events. This is still a challenge in terms of technological developments since the conditions at sea during these events are often incompatible with data collection. This will also be addressed within **pillar 1** (**"Developping innovative technologies for Coastal Ocean Observing and modelling**") of JERICO-RI science strategy through technological and modelling developments.

Importance of biological compartments and biogeochemical processes. The Coastal Ocean is the most productive part of the world ocean due to: (1) continental nutrient inputs, and (2) upwellings resulting from the interaction between winds, marine currents and coastlines. The Coastal Ocean therefore constitutes a significant source of living resources for humans. The dynamics of these resources are resulting from a complex interplay between "natural" and anthropogenic (e.g. overexploitation, loss of habitats, contamination…) processes. Unravelling these two types of effects on the structuration and the functioning of the Coastal Ocean constitutes a major scientific challenge since it is essential to reach a full understanding of the factors/processes controlling the spatiotemporal dynamics of living resources in view of insuring the durability of their exploitation. Biological productivity in coastal waters result from complex interactions between physical and biogeochemical processes (e.g., the regeneration of nutrients through organic matter mineralisation). This reinforces the necessity of adopting an integrated approach forc. Sustained observations of biological variables should therefore be coupled with observations of potentially controlling physical and biogeochemical variables to better understand their interactions and the long-term impact of wider global environmental changes on coastal marine ecosystems. This will be addressed within **pillar 2** ("**Enhancing integrated Coastal Ocean monitoring**") of JERICO-RI science strategy.

Interactions between systems, compartments and processes. The Coastal Ocean is the component of the world ocean located at the interface between the continent and the Open Ocean. As such, its structuration and functioning are strongly affected by processes originating from these two adjacent systems. Inputs by major rivers for example create Regions Of Freshwater Influence (ROFI), which are largely differing from the surrounding ocean regarding their physics (stratified inversed circulation), biogeochemistry (potential importance of mineralization and burial of organic matter) and biology (importance and lack of seasonality in primary production). The structuration and the functioning of the Coastal Ocean are also affected by processes originating from the Open Ocean. A clear example is given by the temporal dynamics of the Peru-Chile upwelling, which is fuelling the most important fishery in the world and whose temporal dynamics is tightly cued by the El Nino Southern Oscillation, which is resulting from meteorogically-induced physical processes taking place at the scale of the whole Pacific

Ocean. Overall, such continental and Open Ocean driven processes can be considered as external forcing factors influencing the Coastal Ocean. As such, it is essential to coordinate their observation with Coastal Ocean Observing *per se*. This will be addressed within **pillar 3** ("**Interfacing with other ocean observing initiatives at different spatiotemporal scales**") of JERICO-RI science strategy.

The benthic and pelagic components of the Coastal Ocean are strongly interacting. The degree of complexity of benthic/pelagic coupling is by far more complex in the coastal than in the Open Ocean. One major difference is the retroaction of benthos on pelagos in coastal systems. The mineralization of organic matter at the water sediment interface and the resulting flow of nutrients into the water column are for example clearly critical for the control of pelagic primary production is coastal areas featuring long water residence times. This process accounts for the persistence of eutrophication in some coastal areas (e.g., the Baltic) in spite of remediation measures adopted to decrease the nutrient loads of freshwater inputs. This clearly pleas for the adoption of an integrated approach for Coastal Ocean Observing (see also above), and for a better balance between technological developments covering the monitoring of benthos and pelagos as well as of the biogeochemical fluxes linking these two compartments. These points will be addressed respectively within **pillar 2** ("**Enhancing integrated Coastal Ocean monitoring**"), and **pillar 1** (**"Developing innovative technologies for Coastal Ocean Observing and modelling**") of JERICO-RI science strategy.

Human occupation, uses and resulting disturbances. More than 40% of the world population lives within two hundreds kilometers of the ocean. This proportion is currently increasing, since more and more people are leaving near the coasts. The densification of human populations and the intensification of their activities close to the coast is a process known as "littoralisation". It is partly resulting from the large diversity of resources/services provided to humans by the Coastal Ocean, which includes: (1) transportation, (2) availability and access to raw materials and resources for industry, (3) living resources (fishing and aquaculture), (4) repository and dilution of contaminants, and (5) leisure resources. One of the specificities of Coastal Ocean stakeholders is therefore the dominance and the diversity of end-users. One first objective of Coastal Ocean Observing is to provide better services to these stakeholders by developing a set of innovative products more suited to their proximal needs in terms of addressed compartment/processes and spatial/temporal scales. This will be addressed within **pillar 4** ("**Fostering societal impact for a larger community of stakeholders**") of JERICO-RI science strategy.

Littoralisation induces major socio-ecological risks including the degradation of fragile ecosystems, which can place the resources, and services they provide at risk. Directly in contact with human populations/activities, the Coastal Ocean is most affected by anthropogenic disturbances compared to other ocean regions. Insuring the durability of the exploitation of the resources/services it provides requires reaching a sound comprehension of the factors controlling its structuration and functioning. Because of the occurrence of strong interactions taking place in the Coastal Ocean, developing an integrated monitoring approach together with coupled modelling is essential to reach such a comprehension. This will be addressed in **pillar 2** ("**Enhancing integrated Coastal Ocean monitoring**") and in **pillar 1** (**"Developing innovative technologies for Coastal Ocean Observing and modelling**") of JERICO-RI science strategy.

Dispersion, National jurisdictions and European directives. The ocean is an ultra-dispersive medium due to its general circulation and to the physical characteristics of seawater. As for the European Coastal Ocean and together with physiography, marine currents define sub- (regional) systems that are functionally linked. Understanding the structuration and the functioning of these systems clearly requires developing an observation strategy at this regional level. This will be specifically addressed within **pillar 5** ("**Establishing observing objectives, strategy and implementation at the regional level**") of JERICO-RI science strategy.

Moreover, the geographical delimitations of these regional subsystems are independent of political boarders. This discrepancy is important for coastal observing since the waters of most of the European Coastal Ocean are under national jurisdiction and as such currently monitored through national initiatives. Achieving a sound Coastal Ocean Observing at a pan European scale thus clearly requires a strong coordination between national ocean observing initiatives, which will be addressed both within **pillar 3** ("**Interfacing with other ocean observing initiatives at**

different spatiotemporal scales") and **pillar 5** ("**Establishing observing objectives, strategy and implementation at the regional level**") of JERICO-RI science strategy.

The European Coastal Ocean is currently the object of several major European directives that are aiming at insuring that coastal marine ecosystems as a whole reach and then maintain a good health. The most recent and comprehensive of these directives is the Marine Strategy Framework Directive, which is using eleven descriptors monitored at the national level to characterize the Ecological Quality status of a set of (sub)regional coastal areas through a scientifically challenging holistic approach. Fulfilling MSFD requirements was at the heart of the JERICO-NEXT project and still has major consequences on JERICO-RI science strategy in terms of: (1) regionalisation (**pillar 5** "**Establishing observing objectives, strategy and implementation at the regional level**"), (2) coordination (**pillar 3** "**Interfacing with other ocean observing initiatives at different spatiotemporal scales**"), (3) integration (**pillar 2** "**Enhancing integrated Coastal Ocean monitoring"**), and (4) developments of new technologies and products derived from Coastal Ocean Observing (**pillars 1 "Developing innovative technologies for Coastal Ocean Observing and modelling**" and **4** "**Fostering societal impact for a larger community of stakeholders**" of JERICO-RI science strategy).

4.3. Main inputs from JERICO projects to JERICO-RI science strategy.

The JERICO community has been supported by EU since 2011 through two Integrated Infrastructure Initiative (I3): JERICO-FP7 (2011-2015) and JERICO-NEXT (2015-2019). Both projects aimed at developing an integrated infrastructure dedicated to Coastal Ocean Observing at a pan European scale. They have resulted in significant progress in various fields. Their main contributions to JERICO-RI science strategy deal with:

1. The identification of main environmental threats and gaps in current European Coastal Ocean Observing,
2. Technological and modelling developments,
3. The integration, and
4. The coupling between geophysical and biological observations.

4.3.1. Main environmental threats and Gaps in current European Coastal Ocean Observing

JERICO-NEXT Deliverable **D1.1** summarises the outcome of a review of environmental threats in European waters as a 2017 status, as well as gaps in programmes for monitoring these threats. The approach included a summary of recent studies, and a questionnaire completed by national representatives within JERICO-NEXT and other European relevant communities. Participation in the JERICO-NEXT questionnaire was not exhaustive. However, responses provided new insights into the gaps between the environmental pressures or threats and their impacts, and associated monitoring.

The most commonly identified threats to the marine environment were: (1) marine litter, (2) shipping, (3) contaminants, (4) organic enrichment and (5) fishing. Regime shift and ocean acidification were noted as pressures with large potential for widespread harm. More than 70% of respondents identified habitat loss or destruction, underwater noise and contamination with harmful substances as an impact of human activities on the marine environment, with more than 50% identifying undesirable disturbances, changes in sediment and substrate composition, changes in community composition, harmful microorganisms and invasive species as key impacts. Linkages between threats and impacts were considered as complex due to cumulative effects of multiple pressures.

JERICO-NEXT Deliverable **D1.1** also summarises gaps in programmes for monitoring environmental threats in European waters. The report supported the main conclusions from the Dobris Assessment (EEA 1995) and more recent studies (EEA, 2008a, b and the DEVOTES EU project, 2012-2016) in highlighting the need for improved monitoring of environmental threats in European coastal environment.

The main policy drivers of monitoring in the European Coastal Ocean were identified as the EU MSFD, WFD. Although policy drivers change over time, their overall purposes remain similar. Regional Seas conventions

(OSPAR and HELCOM) were also identified as key policy drivers of monitoring programmes. Only 12% of the respondents to the questionnaire considered monitoring programmes to be adequate in terms of providing the information required to monitor and address environmental threats, while one quarter (26%) of respondents considered monitoring programmes to be inadequate. The greatest proportion (62%) of respondents to the questionnaire considered monitoring programmes to be partly adequate for addressing environmental threats.

The questionnaire included the possibility to make comments, to enable respondents to give details on their views and responses. Relatively little detail was given in these free text boxes, but the range of views that were given showed that a broad spectrum of participants responded to the questionnaire, and that their comments reflected different experiences in their areas of expertise and in their different countries. The majority of responses were related to spatial and/or temporal scales at which monitoring takes place, and inadequate monitoring of parameters.

A number of suggestions for improved monitoring programmes were highlighted. They focussed on improved design, increased monitoring effort and better linkages with research and new technologies. It was noted that these monitoring programmes should be designed to fulfil the requirements of policy end-users, but should also underpin longer-term scientific objectives, which cut across policy and other drivers, and consider cumulative effects of multiple pressures.

The suggestions for improving monitoring programmes considered to be only partly adequate or not adequate are given below:

- To develop monitoring programmes that are fit-for-purpose and meet policy needs
- To meet requirements for spatial representativeness of data.
- To develop coordinated and integrated monitoring programmes.
- To assess benthic habitats in the wider environment (beyond Marine Protected Areas).
- To take into account new offshore activities such as renewables industries
- To take into account regional or national specificities, and high-risk areas.
- To assess availability of information in relation to pressures.
- To make better use of low-cost biochemical sensors on low-cost platforms.
- To increase observations in time and in space, and include parameters that provide information on ecosystem function.
- To monitor marine waters extending beyond the coastal zone and adding more biological such as zooplankton, microbes, marine mammals (Mediterranean Sea).
- To increase effort to improve monitoring for biodiversity components not yet monitored, poorly covered habitats (beaches sometimes), small plankton.
- To systematically monitor marine litter (microplastics), noise and other chemicals not already included in certain areas (phosphorous-based flame-retardants)
- To implement systematic monitoring based on rigid baseline ecological assessment (at small local scales, e.g. Mediterranean Sea).
- To have consistent and routine fixed-point monitoring (e.g. Malta island).
- To develop a limited number of long-term monitoring sites in remote areas to monitor changes in baseline conditions (chemistry, ecotoxicology, and ecosystem structure) in response to climate change/acidification, and diffuse inputs.
- To include flexible research/investigative monitoring to increase knowledge of specific impacts likely to cause harm to or changes in biota.

This whole set of recommendations is addressed within **all five pillars** of the JERICO RI science strategy.

4.3.2. Technological and modelling developments.

The JERICO community has long acknowledged the necessity of achieving significant technological developments for Coastal Ocean Observing. It identified two major fields (i.e., technology and modelling), which were addressed through dedicated work packages during both JERICO-FP7 and JERICO-NEXT. Technological developments included the development of new tools and sensors allowing for: (1) measuring new set of parameters (including biological ones), (2) improving the accuracy and precision of already available measurements (e.g., in relation with the monitoring of rising threats such as ocean acidification), and (3) the automation of measurements allowing for operating at higher frequencies and over wider geographical scales. The commitment of the JERICO community resulted in significant technological developments in various disciplinary fields including physics (e.g. HF radar deployments and methodology during JERICO-NEXT), biogeochemistry (e.g. pH measurement during JERICO-FP7, combined sensors for carbonate systems and equipment dedicated to benthic O_2 flux measurements during JERICO-NEXT) and biology (e.g. benthos and phytoplankton diversity in relation with ecosystem services during JERICO-NEXT). Moreover, the setup of six JRAPs during JERICO-NEXT allowed for successful tests of some of those technologies (e.g. first coupling of remote sensing and glider data for the assessment of hydrography and transport; increase of spatial monitoring resolution by deployment of low cost coastal profiling systems…).

4.3.2.1. Physics

During JERICO-FP7 and JERICO-NEXT a key issue dealt with the use and development of platforms (e.g. emerging coastal profiling technology, gliders and ships of opportunity allowing for optimal sensor deployments. During JERICO-NEXT, a low-cost coastal 1D system (MASTODON) was upgraded to a 2D version with thermistor chains and tested at sea, the MASTODON-2D. MASTODON-2D moorings represent a cost divided by ten compared to conventional moorings. The Etoile campaign in the SE Bay of Biscay enabled the deployment and recovery after 3 weeks of 6 MASTODON-2D moorings and revealed the existence of solitons of about 20m amplitude on the continental shelf. Four other moorings were deployed in Mediterranean Sea and revealed in great details the birth and relaxation of a coastal upwelling. In addition, several methodologies/tools (e.g. advanced QA/QC and processing, gap-filling, Lagrangian methods) were applied to HF radar surface current data for different study areas. They allowed an improved application of this powerful technology to solve different scientific questions related to the ocean surface transport and processes. Moreover, through the combined use of observation and models, it was demonstrated the high value of HF radars, gliders, fixed moorings and FerryBox data to evaluate models (identifying their main limitations and areas of improvement) and understand Coastal Ocean variability over a broad range of scales in different European coastal environments. Finally, models with data assimilation allowed to quantify the impact of HF radar, gliders, moorings and FerryBox in conjunction with complementary observations from CTDs and satellites on the improvement of Coastal Ocean forecasts.

OSE and OSSE. The JERICO community also acknowledged the strong spatial heterogeneity and temporal dynamics of coastal (eco)systems. It thus identified the establishment of a sound implementation strategy (including the sets of parameters to be monitored, key sites where monitoring should take place, and temporal sampling strategy) as a key issue for long-term coastal observatories. During JERICO-FP7 and then JERICO-NEXT, this was mostly tackled using Observing System Experiment/Observing System Simulation Experiment (OSE/OSSE) technology and mostly focussing on physical parameters. This resulted in significant progresses now allowing for the use of OSEs and OSSEs to objectively propose optimization in existing coastal physical observing network in some European areas.The JERICO community now intends to focus on the developments of multidisciplinary integrated models, which will be addressed within **pillar 1** (**"Developing innovative technologies for Coastal Ocean Observing and modelling**") of JERICO-RI science strategy.

4.3.2.2. Biogeochemistry

JERICO-NEXT addressed specific developments to improve the accuracy and the precision of measurements involved in the monitoring of carbonate systems. Very promising instruments were developed and test at sea on fix and mobile platforms (e.g. FerryBox). Developing combined sensors for measuring two carbonate system variables at the same time, is an important step towards improving observations and hence bettering our understanding of the coastal carbon cycle. While each development encountered issues, promising progress has been made.

JERICO-NEXT developed/tested several tools to monitor the mineralization of sedimentary organics. This included the Unisense® MP7 micro-profiler, which allows monitoring the main biogeochemical parameters (i.e. O_2, pH, H_2S) during repeated observation periods covered within a single deployment. This equipment allows monitoring O_2 benthic diffusive fluxes and assessing their micro-spatial heterogeneity. The duration of deployment is now up to 4 days and can be increased if necessary up to 20 days. The profiler has also been interfaced with several autonomous loggers for a full monitoring of environmental characteristics of bottom water during deployment. A reference O_2 optode enables to achieve a real-time calibration of O_2 microelectrode throughout the deployment and to adjust the frequency of profiling sequences with the O_2 level in the bottom water, which is essential, for instance, in coastal systems affected by deoxygenation events. Two developments to assess benthic total O_2 fluxes (TOU) were also achieved within JERICO-NEXT. A new set of benthic chambers was developed and tested. Numerous tests in the laboratory and at sea have been achieved to get a functional version. Promising results have been obtained and it is now essential to increase field application at sea, reliability and the accuracy of TOU measurements. An Eddy Correlation (EC) system was also tested during JERICO-NEXT. *In situ* tests confirmed the capability of EC systems for short-term (i.e., a few hours) deployments. Results show the ability of EC to detect major trends in TOU (i.e., decrease with decreasing temperature and higher values over seagrass beds than bare muddy sediments). It is now essential to combine these technologies together with some previously developed within JERICO-FP7 (i.e., sediment imaging) within an Autonomous Coastal Observing Benthic Station to allow for a more holistic monitoring of the sediment-water interface. This will be addressed within **pillar 1** (**"Developing innovative technologies for Coastal Ocean Observing and modelling**") of JERICO-RI science strategy.

4.3.2.3. Biology

JERICO-FP7 explored potentials methodologies as a basis for the development of new biological sensors based on:

1. Potential indicator value,
2. Possibility of deployments on different platforms,
3. Type of delivered data,
4. Spatial coverage,
5. Operationality,
6. Cost, and
7. Width of application spectrum.

It underlined the high potential of optical methods. Environmental genomics was further included in this list during JERICO-NEXT, which proved fully coherent with the analysis later achieved by IOOS (see above).

Harmful algal blooms and pollutants. JERICO-NEXT developed and tested innovative methods for the molecular detection of harmful algal blooms and pollutants through their effect on microbial communities. This included the development of novel molecular sensors for the detection, quantification and identification of organisms, microbial markers of pollutant exposure or toxin concentrations in marine coastal waters. Bacterial species and genes that can be used as markers of high nutrient load or hydrocarbon contamination were identified through bacterial community analyses in contaminated environment and literature reviews. Assays using quantitative Polymerase Chain Reaction (qPCR) for the quantification of these organisms were developed and tested through environmental sampling campaigns and laboratory exposure studies. The most promising markers and assays were selected for further study in conjunction with other biological and chemical sensors, and tested within JERICO-NEXT JRAP 3. Complementary technologies were developed to monitor toxic algae, combining the detection of: (1) organisms through an autonomous sensor, and (2) toxins using a probe. The fully automated sensor module for autonomous monitoring of toxic algae includes a remote-controlled automated filtration system coupled to a semi-automated nucleic acid biosensor based on specific molecule binding In parallel, for the direct detection of algae toxins, the capabilities of an *in situ* optical biosensor were extended. This was achieved to reduce the device size, increase its efficiency, and extend its performance to detect more than domoic acid, which was the toxin that the sensor was initially designed for. The sensor was successfully redesigned and tested in laboratory conditions prior to deployment at sea.

Biodiversity. The JERICO community achieved several developments on the use of optical methods for assessing both benthic and pelagic biodiversity. For the benthos this included both a new platform for image acquisition and specific software for image analysis. A new towed underwater video system called 'Pagure-2' was developed during JERICO-NEXT. It was tested to investigate areas negatively affected by an invasive species (e.g., *Crepidula fornicata*) within the JRAP dedicated to benthic diversity and proved to be a relevant imagery tool to get comprehensive insights into the integrity of benthic habitats of European coastal areas. The images acquired with 'Pagure-2' can be semi-automatically analysed using the aviExplore software developed within JERICO FP7. Another specific software development within JERICO-FP7 was dedicated to the analysis of sediment profile imagery.

Automated platforms for the observation of Phytoplankton diversity were developed within JERICO-NEXT, which resulted in promising capabilities to address phytoplankton dynamics in several European coastal and shelf seas, at high resolution and in (near) real-time. The focus was on innovative sensors and associated classification/discrimination to better characterize phytoplankton diversity. Three types of "bio" data were addressed: (1) images of cells or colonies (imaging in flow and *in situ*), (2) single-cell (or colony) optical signature (flow cytometry), and (3) bulk optical signals (single and multi-wavelength fluorometry, single and multi-wavelength absorption). Several software and packages produced during previous projects including JERICO-FP7 were improved during JERICO-NEXT to facilitate their use, which makes them especially adapted to deal with the high amounts of data provided by autonomous or semi-autonomous platforms in the frame of integrated coastal observatories. The potential of rDNA meta barcoding methods for assessing phytoplankton diversity was also evaluated during JERICO-NEXT. Results showed that metabarcoding reveals a much higher diversity compared to classical microscopy. However, it only gives results on the relative abundances of Operational Taxonomical Units and does not provides any information on biomass. Overall, the methods addressed by the JERICO community to assess phytoplankton diversity (functional groups, size classes, taxa when possible) and biomass appear reliable. The Jerico community stresses that they should be considered as complementary of classicall sampling methods and analyses. Operating the equipment and analysing raw signals, however still requires both knowledge and time. Even though some operational procedures can be established, the standardization of analytical and data processing as well as data management need more development. This will be addressed within both **pillar 1** (**"Developing innovative technologies for Coastal Ocean Observing and modelling**") and **pillar 2** ("**Enhancing integrated Coastal Ocean monitoring"**) of JERICO-RI science strategy.

4.3.3. <u>Homogenisation/integration</u>

JERICO-FP7 acknowledged the fact that in Europe, most of the observations of the Coastal Ocean are achieved at national or subnational levels and stated that major efforts at the pan European level should be dedicated to integration. JERICO-FP7 and then JERICO-NEXT enhanced the spread of the use of innovative technologies through their Trans National Access components. Both projects also contributed to the homogenisation of data quality through the definition and dissemination of good practices. From a spatial standpoint, JERICO FP7 recommended to achieve ocean-observing integration at the level of EuroGOOS Regional Ocean Oberving Systems (ROOS), while JERICO-NEXTfocused on Coastal Ocean Observing in response to specific MSFD requirements in several EU regions.

A significant difficulty in structuring any networked ocean observing network at the pan European level is the heterogeneity in the technological capacity of the different components of such an infrastructure. In its strategy document, JERICO-FP7 made a clear distinction between observatories monitoring only core parameters and those also assessing "secondary or good to have parameters". One way of reaching an equilibrium between the two kind of observatories and thus to improve homogenisation/integration at the level of the whole network is to promote the spread of cutting-edge techniques. This was initiated by the JERICO community through the Trans National Access components of both JERICO-FP7 and JERICO-NEXT. The JERICO community intends to pursue with this process, which will be further addressed within **pillar 2** ("**Enhancing integrated Coastal Ocean monitoring"**) of JERICO-RI science strategy.

JERICO-FP7 and JERICO-NEXT also enhanced coastal observing homogenisation/integration through the better dissemination of sound maintenance and operational designs. JERICO-FP7 produced two reports defining the best practices associated with: (1) calibration (**D4.2** [4]), and (2) conducting operations and maintenance (**D4.4** [5]). JERICO-FP7 project also pinpointed the major importance of sound data management procedures, from acquisition to long term archiving and open access in defining a coastal observing system. For that purpose, a clear distinction was made between real time, near real time and delayed data. Finally, JERICO-FP7 proposed the creation of a JERICO label acknowledging a set of criteria ensuring that "some standardisation and interoperability, and the quality of data for coastal observatories are set". These different points all contributed to insure good data quality within a whole complex heterogeneous infrastructure. They were deepened within JERICO-NEXT and will be further assessed within **pillar 2** ("**Enhancing integrated Coastal Ocean monitoring"**) of JERICO-RI science strategy.

JERICO-NEXT set up six pilot Joined Research Activity Projects (JRAPs) to first tackle the complex issues associated with the implementation of multidisciplinary Coastal Ocean Observing over a wide range of spatiotemporal scales. Those JRAPs dealt with the following scientific questions (most of them in direct relation with MSFD descriptors):

1. **JRAP 1**: Biodiversity of plankton, harmful algal blooms and eutrophication,
2. **JRAP 2**: Monitoring changes in microbenthic biodiversity, assessing potential environmental controls and functional consequences
3. **JRAP 3**: Occurrence of contaminants in Northern coastal waters and biological responses
4. **JRAP 4**: 4D characterization of trans-boundary hydrography and transport
5. **JRAP 5**: Coastal carbon fluxes and biogeochemical cycling
6. **JRAP 6**: Operational oceanography and forecasting

All JRAPs evolved and got to include a multidisciplinary component (e.g. between physics and biology in **JRAPs 1** and **2**, chemistry and biology in **JRAP 3**, physics and chemistry in **JRAP 4**, biogeochemistry and biology in **JRAP 5**, physics and biogeochemistry in **JRAP 6**). Except for JRAP 3, JRAPs partners expressed challenges to achieve these coupling due to different reasons including:

1. Difficulties in interacting with non JERICO-RI partners in charge of hydrosedimentary modelling within the time frame of the project (**JRAP 2**),
2. Lack of consistency in the spatiotemporal resolution/coverage of observations (**JRAPs 4** and **5**), or the lack of resources (e.g. numerical models) for joint data analysis (**JRAP 4**), and
3. Lack of maturity of biogeochemical models (**JRAP 6**).

The setup of integrated Coastal Ocean Observing observation thus still constitutes a major challenge that will be further addressed within **pillar 5** ("**Establishing observing objectives, strategy and implementation at the regional level**") of JERICO-RI science strategy.

The spatial scales addressed by JRAPs were highly variable but always remained sub-regional except for **the cases using** Ferryboxes, which allowed for a synoptic sampling over large areas. For many JRAPs, the structuration consisted in the juxtaposition of sites representative of a set of conditions (e.g., environmental disturbances for **JRAP 2**, or hydrodynamical regimes for **JRAPs 4** and **6**). The spatial delimitation of each of these individual sites resulted both from the spatial extension of the entity under study (i.e., the tackled scientific question)

[4] http://www.jerico-ri.eu/download/filebase/jerico_fp7/deliverables/D4_2_Report%20on%20Calibration%20best%20practices_v1-3rev.pdf

[5] http://www.jerico-ri.eu/download/filebase/jerico_fp7/deliverables/D4.4_Report%20on%20best%20practices%20in%20conductiong%20operations%20and%20maintaining.pdf

and from the coverage of spatial observatories (i.e., observation availability), making the overall sampling not optimal in most regions. The organization of Coastal Ocean Observing at regional levels will be addressed within **pillar 5** (“**Establishing observing objectives, strategy and implementation at the regional level**”) of JERICO-RI science strategy.

4.3.4. Integrating biological observing

JERICO-FP7 acknowledged the importance of biology in coastal observing. It also recognized specificities in monitoring biological variables, which led to the elaboration of a specific document dedicated to the monitoring of biodiversity [6]. This document stressed the strong inadequacy between the platforms/sensors approach and classical biodiversity assessments. It clearly acknowledged that actual standardized measurements of marine biodiversity at various levels over larger temporal and spatial scales could not be achieved within an operational observing framework. JERICO-FP7 carried out a literature review of the potential proxies for biodiversity in line with a platforms/sensors approach (i.e. temperature, salinity, chlorophyll *a*, turbidity, dissolved oxygen, pCO_2, and nutrients). Overall, this relevance was considered as weak and it appeared that data collected using this kind of sensors could at best be used to define species potential boundary limits. JERICO-FP7 proposed a strategy based on the concepts of potential and realized biodiversity. This strategy consisted in coupling the monitoring of a large spatial grid using automated geophysical platforms/sensors to infer potential diversity based on the above-defined boundary limits with a series of in depth biodiversity measurements achieved along a tractable number of transects to infer realized diversity. The ratio between realized and potential biodiversity could then be used as an indicator of the environmental quality status of considered areas. Conversely, JERICO-FP7 did not elaborate on the tuning of sampling strategies for optimizing the direct crossing of geophysical and biological data, which are collected following different spatial and temporal patterns and are associated with different integration scales. This issue was tackled within JERICO-NEXT JRAPs; which specifically considered the interaction between couples of individual geophysical and biological parameters (see the **“Homogenisation/integration”** section above for the list of these interactions). The extension of the ambitious challenge of coupling of physical, chemical and biological observations will be further tackled within **pillar 5** (“**Establishing observing objectives, strategy and implementation at the regional level**”) of JERICO-RI science strategy.

4.4. How we can take advantages from the major non-European national initiatives

The three major Non-European national ocean monitoring initiatives considered in the present section are: (1) the US “Integrated Ocean Observing System” (IOOS), the Canadian “Ocean Networks Canada” (ONC) and the Australian “Inegrated Marine Observing System” (IMOS). The main skills originating from these initiatives are derived from: (1) the analysis of their structuration and production and (2) visits to the IOOS-NANOOS (Northwest Association of Networked Ocean Observing Systems) regional observing system and to the Victoria ONC centre. They are mosly dealing with the following items:

The duality of scientific questions. Conversely to IMOS, the (scientific) questions tackled by IOOS and ONC observation systems are clearly dual with global (i.e., long-term, large-scale) on one side and specific (i.e., short-term, small-scale) issues on another side. This duality largely coincides with the littoral/coastal gradient as apparent in: (1) the location and the scientific questions tackled by the VENUS and NEPTUNE ONC observatories in NE Pacific, and (2) by the geographical zonation of IOOS-NANOOS structuration (i.e., Coastal Ocean, inland basin, coastal estuaries, shorelines and major rivers). With the full spectrum of end-users of the Coastal , these questions therefore constitutes a key feature for the good accomplishment of the objectives of **pillar 4** (“**Fostering societal impact for a larger community of stakeholders**”) of JERICO-RI science strategy.

[6] http://www.jerico-ri.eu/previous-project/deliverables/d1-9-definition-strategy-and-interfaces-with-the-monitoring-of-marine-biodiversity/

The balance between integration and regionalisation. Regionalisation is the basis of the structuration of IOOS and IMOS. IOOS is a network of eleven regional observation systems, whereas IMOS is composed of six nodes with five coastal regional ones identified considering factors such as topography, boundary currents - shelf interactions and marine bioregions. In IOOS, each regional observation system is designed to tackle specific environmental issues in relation with main identified stakeholder requirements. The resulting heterogeneity does not constitute an issue for IOOS provided that data quality is insured. This is largely achieved by the Alliance for Coastal technologies (ACT[7]), which is committed to providing the information required to select the most appropriate tools for studying and monitoring coastal environments. It therefore constitutes a key organisation in good practice dissemination and harmonization within IOOS. An important consequence of the acknowledgement of the specificities of IOOS regional observing systems is that all data do not necessarily have to be integrated/homogenised at the level of the whole IOOS. One could therefore make a clear distinction between two types of observations: (1) those collected in all regional ocean observing systems in order to tackle global environmental issues; and (2) those specific to a restricted number of regional ocean observing systems, in relation with local/regional issues. This is explicitly stated in the report of the March 2018 ACT "Coastal ecosystem mooring workshop" which clearly recommends to consider both "a backbone of core measurements" and "subsets of additional measurements based on regional needs and requirements" (see also [8] below). The necessary balance between integration and regionalisation will be addressed within several pillars of JERICO-RI science strategy: **pillar 2** ("**Enhancing integrated Coastal Ocean monitoring"**), **pillars 4** ("**Fostering societal impact for a larger community of stakeholders**") **and pillar 5** ("**Establishing observing objectives, strategy and implementation at the regional level**").

Biology and operational observing. IOOS and IMOS have initially put a clear emphasis on operational observing through the acquisition of sensor-derived measurements that can be processed and used (e.g. for data assimilation) in near real-time. This is well suited for geophysical data because of the existence of automated sensors and efficient models. This approach is however likely to prove limited for Coastal Ocean Observing due to the importance and complexity of biological/biogeochemical compartments and processes (see **"The main specificities of the Coastal Ocean and their consequences on Coastal Ocean Observing"** section above). The implementation of biological monitoring and its coordination with other observation sources therefore now constitutes a major objective for IOOS, which acknowledged that, "so far, the data integration effort has focused on geophysical variables such as temperature, salinity, and ocean currents…" This raises the issue of how the acquisition of additional biological and geophysical variables should/could be harmonized. An important conclusion of the 2018 ACT workshop on "National coastal ecosystem moorings"[8] was that ocean observing strategies must exploit the advantages of all types of observing sources including moorings, mobile platforms, dedicated cruises and remote sensing. Along the same line, IMOS has recently produced the "Plankton 2015: State of the Australia's Ocean" report[9]), which is based on: (new biological data collected between 2007 and 2015, and historical data (both collected all around Australia). IMOS has made use of these data to tackle several environmental issues based on stakeholder's requirements including:

(1) Climate change (range shifts), (2) Ocean acidification, (3) Biodiversity, (4) Productivity supporting fish, (4) Ecosystem health, and (5) Management applications.

Such an approach for producing and exploiting biological observations in a non-operational way is extremely interesting even though the content of the plankton 2015 report reflects the difficulty in achieving synoptic biological observations, and in coupling biological and geophysical observation at such a large scale. The question of the coupling of observations differing in their nature and acquisition strategy will be addressed within **pillars 2** ("**Enhancing integrated Coastal Ocean monitoring"**), **3** ("**Interfacing with other ocean observing initiatives at different spatiotemporal scales**") and **5** ("**Establishing observing objectives, strategy and implementation at the regional level**") of JERICO-RI science strategy.

[7] http://www.act-us.info/

[8] http://www.act-us.info/Download/Workshops/2018/Ecosystem_Mooring_Workshop_Report.pdf

[9] http://imos.org.au/fileadmin/user_upload/shared/Data_Tools/15-00245_OA_Plankton2015_20ppBrochure_WEB_151116.pdf

Technological and modelling developments. IOOS is achieving technological developments in various fields (e.g., carriers, samplers, sensors…) and disciplines (e.g. geophysics and biology) through the internal funding of individual projects. It is tightly interacting with the alliance for Coastal technology (ACT [7]) both upstream and downstream of this process through: (1) the analysis of the state of the art and the definition of requirements, and (2) the tests of newly developed technologies. Conversely, ONC is running its own technological division, which put a strong emphasis on the deployment of modular cabled systems allowing for integrated ocean observing. ONC have long paid a specific attention to biological observations with a focus on benthic ecosystems. This is not the case of IOOS, which nevertheless is now putting an emphasis on ecosystem observing (see the "***Biology, and operational observing" section above)***, which resulted in the organization of the 2018 ACT workshop on "National coastal ecosystem moorings". During this workshop, imaging systems and genomics have been identified as the two most promising fields for the development of new biological sensors. As for imaging systems, the emphasis was put on the necessity of developing common standards and new image analysis procedures allowing for the processing of the huge amount of generated information. As for genomics, IOOS is currently achieving developments and tests of eDNA methods within the framework of the US Marine Biodiversity Observation Network. These include the development of specific field samplers/processors that could be suitable for long-term field deployments. Technological developments will be addressed within **pillar 1** (**"Developing innovative technologies for Coastal Ocean Observing and modelling**") of JERICO-RI science strategy.
Developments in biological observing and integrated modelling will be both specifically addressed within **pillar 1** (**"Developing innovative technologies for Coastal Ocean Observing and modelling**") of JERICO-RI science strategy.

Interacting with stakeholders. IOOS, IMOS and ONC are all putting a clear emphasis on their interactions with stakeholders. These interactions are especially strong in IOOS, which is developing a large variety of fit for purpose products in tight collaboration with user products committees gathering local stakeholders. In IOOS-NANOOS, stakeholders are involved during all steps of product developments from the expression of their requirements to the test of prototypes and the implementation of the infrastructure allowing for the elaboration of final products. Such products can be either associated to a regional (e.g., Tuna fish probability presence maps for fishery) or a local (e.g. prediction of short-term changes in seawater temperature and salinity for aquaculture). The large diversity of stakeholders and products derived from Coastal Ocean Observing is further illustrated by some of the productions of: (1) IMOS, which derived both fundamental (climate change, ocean acidification and biodiversity) and practical (productivity supporting fish, ecosystem health, and management applications) information from the "Plankton 2015: State of the Australia's Ocean" survey (see above the section **"Biology and operational observing"**), and (2) ONC which is *inter alia* aiming at developing a real time tsunami alert system based on signal transmission of a network of offshore marine seismometers. The development of interactions with stakeholder will be specifically addressed within **pillar 4** ("**Fostering societal impact for a larger community of stakeholders**") of JERICO-RI science strategy.

Interacting with external partners. IOOS and ONC have developed significant interactions with external partners through two different pathways. IOOS integrates information originating from different organizations (e.g., the US Geological Survey for river monitoring). A similar approach will be looked for in **pillar 3** ("**Interfacing with other ocean observing initiatives at different spatiotemporal scales**") of JERICO-RI science strategy. ONC is favouring the use of its technology by external users/partners, which allows for: (1) the widening of the panel of observations achieved at dedicated sites, and (2) the enrichment of ONC technological expertise. This second approach is somehow comparable to the Trans National Access components put in place by JERICO-FP7 and JERICO-NEXT (see below). The JERICO community intends to further explore and experiment on these two (i.e., those of IOOS and ONC) ways of interacting with external partners. This will be addressed within **pillars 2** ("**Enhancing integrated Coastal Ocean monitoring"**), **3** ("**Interfacing with other ocean observing initiatives at different spatiotemporal scales**") and **5** ("**Establishing observing objectives, strategy and implementation at the regional level**") of JERICO-RI science strategy.

Annex I: List of abreviations

ACT: Alliance for Costal Technologies
AQUACOSM: Mesocosms facilities for research on marine and freshwater ecosystems
ARCO: Augmented Regional Coastal Observatory network
Copernicus: Europe's eyes on Earth
CMEMS: Copernicus Marine Environment Monitoring Service
D: Deliverable
EBV: Essential Biodiversity Variable
EC: Eddy Correlation
EEA: European Environment Agency
EMBRC: European Marine Biological Resource Center
EMODNET: European Marine Observation and Data Network
EMSO: European Multidisciplinary Seafloor and water column Observatory
EOOS: European Ocean Observing System
EOV: Essential Ocean Variable
ERIC: European Research Infrastructure Consortium
EU: European Union
EURO-ARGO: European Contribution to Argo program
EUROGOOS: European Global Ocean Observing System
GOOS: Global Ocean Observing System
HELCOM: Baltic Environmental Protection Commission
HF: High Frequency
ICOS: integrated Carbon Observation System
IMOS: Integrated Marine Observing System
IOOS: Integrated Ocean Observing System
JRAP: Joint Research Activity Project
MASTODON: Mapping of Seabed Temperature and Observation of Downwelling
MSFD: Marine Strategy Framework Directive
ONC: Ocean Networks Canada
OSPAR: Oslo Paris Commission
QA/QC: Quality Assurance/Quality Control
qPCR: quantitative Polymerase Chain Reaction
ROFI: Region Of Freshwater Influence
ROOS: Regional Operational Observing Systems
SeaDataNet/SeaDataCloud: Pan-European infrastructure for ocean and marine data management
SME: Small and Medium Enterprise
TOU: Total Oxygen Uptake
TRL: Technology Readiness Level
WFD: Water Framework Directive
WP: Work Package