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JERICO-S3 DELIVERABLE

Joint European Research Infrastructure for Coastal Observatories
Science, Services, Sustainability

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EXECUTIVE SUMMARY

JERICO's science strategy is based on the key scientific challenges, specific scientific challenges and research axes developed in previous JERICO projects (JERICO, JERICO-NEXT) and in particular in D1.1 of JERICO-S3. It emphasises the importance of an integrated, multi-platform approach at regional level, valorised by harmonisation and common practices at the pan-European level. The science strategy encompasses collaborations with existing RIs, technological innovations and experiments, as key pillars for maximising the impact of JERICO for science and society. Furthermore, the science strategy is the base on which JERICO services are built. It is also a means of implementing a strong bottom-up approach in a top-down strategic framework.

1.INTRODUCTION

1.1.Main objectives of the report

JERICO-S3 aims to establish a long-term, integrated research infrastructure across Europe dedicated to observing coastal marine systems. The primary goal is to enhance the understanding of how coastal marine environments respond to both natural and human-induced changes. Additionally, it addresses the urgent need for coordinated observations of these vital ecosystems. In this project, Work in WP1 aimed at re-defining **the science strategy** to converge into a common general scientific framework structured in **consolidated KSCs (Key Scientific Challenges) and SSCs (Specific Science Challenges) and a list of specific RA (Research Axes).** In WP3 and WP4, we demonstrate how the **scientific monitoring strategies** could be implemented both from the point of view of **experimentation (PSS, WP4)** and **networking** towards a coordinated pan-European dedicated research infrastructure (IRS, WP3), and including interfacing with other observing initiatives (WP2).

This report concludes the JERICO-S3 project and presents an updated version of the JERICO scientific strategy (WP1), on the basis of the thinking and experiments conducted during the projects. This strategic framework will contribute to maximising the impact of the Research Infrastructure (RI) with respect to scientific and societal/environmental challenges. The science strategy describes the design and implementation of innovative observing approaches of coastal processes and coastal regions, based on multiple, multidisciplinary and integrated platforms, and addressing key environmental challenges. .

2. Evolution and maturation of the JERICO science strategy since 2010

2.1. Evolution of the JERICO science strategy between 2011 and 2019

The evolution of the scientific strategy from the first JERICO INFRA-project (2011-2015 - hereafter named as FP7-JERICO) to the H2020 JERICO-NEXT (2015-2019) project reflects a maturation of the scientific strategy, moving from foundational efforts in network establishment and standardisation to advanced integration, technological innovation, expanded stakeholder engagement, regional implementation, and future planning. JERICO-NEXT builds upon the successes of its predecessor by enhancing the depth and breadth of coastal ocean observing, ensuring that the network is robust, inclusive, and forward-looking.

In the initial JERICO-FP7 project, the focus was on establishing a baseline for coastal observing by developing and deploying various observing technologies. The project aimed at creating a network of coastal observatories across Europe, standardising methodologies, and

enhancing data quality and accessibility. JERICO-NEXT builded upon this foundation by advancing the technological capabilities developed in the first project. It emphasises integrating innovative sensor technologies to fill gaps in existing observational capabilities and increase the Technology Readiness Levels (TRLs) of ocean observing systems. The strategy now includes developing key enabling technologies to optimise multidisciplinary data acquisition and processing. This shift signifies a move from establishing infrastructure to enhancing and optimising it for broader and more integrated use.

The first JERICO project focused on the initial integration of various observing systems and methodologies, aiming to create a more cohesive European coastal observatory network. It worked on harmonising observational procedures and promoting interoperability among different platforms. **JERICO-NEXT takes this integration further** by emphasising the harmonisation of observations to ensure full comparability across different locations and operators. It aims to demonstrate the benefits of full integration through Pilot Augmented Regional Infrastructures, which serve as models for comprehensive coastal monitoring. This approach highlights a deeper level of integration, focusing on multidisciplinary observations and the implementation of holistic monitoring strategies.

The first JERICO project laid the groundwork for a pan-European coastal observatory network, emphasising the need for regional cooperation and data sharing. JERICO-NEXT builds on this by focusing on regional implementation through Pilot Augmented Regional Infrastructures. These pilot actions are designed to tackle major scientific and societal questions in a multidisciplinary way, demonstrating the feasibility and benefits of regional approaches to coastal monitoring. This evolution highlights a strategic shift towards regionalization, ensuring that the unique characteristics and needs of different coastal areas are addressed.

The JERICO-NEXT project outlines a comprehensive scientific strategy aimed at enhancing coastal ocean observation through five key pillars (Figure 1). These pillars collectively address scientific, policy, and societal challenges, ensuring a holistic and integrated approach to monitoring the European Coastal Ocean: 1) developing innovative technologies by integrating new sensor technologies, improving readiness levels, and anticipating technological changes, 2) enhancing integrated monitoring by harmonising observations for comparability, promoting holistic approaches, and demonstrating integration benefits through pilot projects, 3) interfacing with other initiatives by strengthening cooperation with other European and global observation infrastructures, 4) fostering societal impact by expanding stakeholder involvement and tailoring observation products to their needs and finally 5) by regional implementation with conducting pilot actions to address regional scientific and societal questions and preparing for future infrastructure implementations. The strategy also considers the complexity of coastal oceans, experiences from other national networks (IOOS, IMOS, ONC), and lessons from previous JERICO projects. It aimed to balance integration at the European level with regional specificity, ensuring broad stakeholder engagement and effective interaction with various observation systems.

The first pillar focuses on developing innovative technologies for Coastal Ocean observing and modelling. This pillar emphasises the need to integrate cutting-edge sensor technologies to bridge the gaps in Technology Readiness Levels (TRLs) between various disciplines. By increasing the TRLs of existing ocean observing systems, the project aims to foster the development of multidisciplinary observing platforms capable of capturing a wide array of oceanographic data. Additionally, this pillar seeks to develop key enabling technologies that optimise the acquisition and processing of these observations, ensuring that data collection is both efficient and comprehensive. A crucial aspect of this pillar is the foresight into long-term technological advancements, allowing the project to anticipate and adapt to rapidly occurring changes in observation technologies.

The second pillar aims at enhancing integrated Coastal Ocean monitoring. It seeks to harmonise observations conducted by different operators, making them fully comparable across various locations. This harmonisation is essential for creating a cohesive and reliable dataset that supports a holistic understanding of the Coastal Ocean. By enhancing the accessibility of cutting-edge technologies, this pillar contributes to a comprehensive approach to Coastal Ocean Observing. Demonstrating the benefits of full integration, this pillar promotes the implementation of Pilot Augmented Regional Infrastructures, which serve as representative models of the European Coastal Ocean. These infrastructures showcase the advantages of integrated monitoring in selected regional areas, highlighting the potential for broader application.

The third pillar emphasises interfacing with other ocean observing initiatives operating at different spatiotemporal scales. By enhancing cooperation with European observing infrastructures and initiatives focused on the Open Ocean and riverine/terrestrial systems, this pillar fosters a collaborative approach to ocean observation. It encourages partnerships with world-class European ocean observing initiatives and engages with local observation providers and other contributors to Coastal Ocean observations. Additionally, this pillar seeks to collaborate with major non-European national ocean observing systems, thereby broadening the scope and impact of JERICO-NEXT's efforts.

The fourth pillar is dedicated to fostering societal impact for a larger community of stakeholders. It aims to expand the community of stakeholders involved in Coastal Ocean Observing, ensuring that a diverse range of perspectives and needs are considered. By deepening stakeholder involvement in the definition of observation-derived products, this pillar enhances the relevance and applicability of these products to address specific concerns. The goal is to make these products more suitable for assessing stakeholder issues, thereby increasing their utility and impact.

The fifth and final pillar focuses on establishing observing objectives, strategies, and implementation at the regional level. This pillar involves carrying out pilot actions designed to tackle major scientific and societal questions in a truly multidisciplinary manner. By implementing Pilot Augmented Regional Infrastructures in selected areas, this pillar demonstrates the feasibility and benefits of a regional approach to Coastal Ocean Observing. Furthermore, it prepares for the future implementation of additional Pilot Augmented Regional Infrastructures by initiating reflection and planning in other regional areas. This forward-thinking approach ensures that JERICO-NEXT remains adaptable and responsive to emerging challenges and opportunities.

Through these five pillars, **JERICO-NEXT aims to pave the way for the implementation of a future pan-European Coastal Ocean Observing infrastructure**. This integrated approach not only addresses current challenges but also anticipates future needs, ensuring a sustainable and impactful contribution to coastal ocean observation.

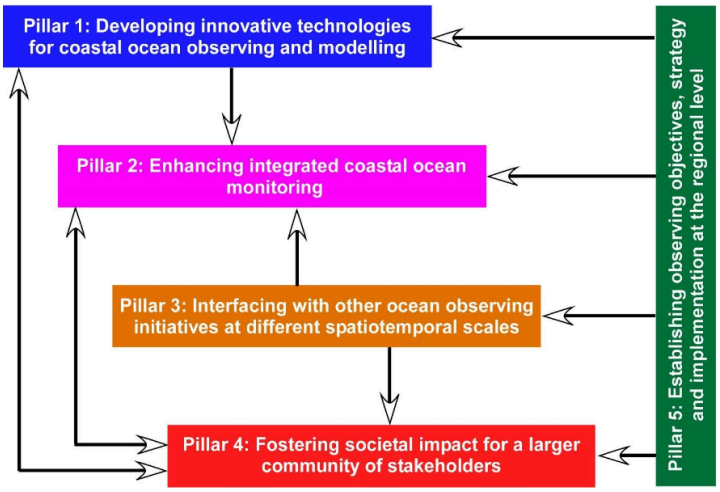

Figure 1: General structuration of JERICO science strategy showing its five main pillars together with their main interactions in 2015 (from Gremare et al., 2019)

The JERICO-NEXT D1.4 ("Roadmap for the Future") aimed to address both existing and emerging challenges in coastal ocean observing. It emphasises the need for a sustainable, integrated, and technologically advanced infrastructure capable of providing high-quality marine data and services. The roadmap begins by setting the context within the global and European frameworks, highlighting the importance of improved knowledge and understanding of key environmental changes such as ocean acidification, rising sea temperatures and levels, and pollution. It outlines JERICO's mission to **provide standardised, interoperable, and accessible data that supports research and innovation**. The values of the JERICO community should include scientific excellence, co-creation, effective collaboration, openness, prospectivity, and a service-oriented approach. The JERICO-NEXT D1.4 (Farcy et al., 2019) presents a forward-looking plan to enhance and sustain coastal ocean observation through technological innovation, integration, stakeholder engagement, and regional implementation. It aims to create a robust, adaptable, and comprehensive observing system that addresses both current and future challenges in marine science and policy.

2.2. Evolutions and maturation since 2019

In 2019, the JERICO community decided to apply the ESFRI roadmap. In preparing the proposal, major consolidation of the Science Strategy took place. The science strategy proposed in the JERICO ESFRI application built upon the one defined in JERICO-NEXT, sharing the vision and objectives but differing in their focus and depth of integration. While the JERICO-NEXT science strategy focuses on technological development, integration, and stakeholder engagement at a regional level, the JERICO ESFRI proposal expands these concepts into a comprehensive, multidisciplinary strategy with a strong emphasis on governance, sustainability, and integration across broader spatial and temporal scales.

1. **Depth of Integration:** The ESFRI proposal places a greater emphasis on comprehensive and multidisciplinary integration, ensuring that coastal observations are seamlessly linked with continental, atmospheric, and open ocean systems.
2. **Strategic Focus:** While both documents stress technological innovation, the ESFRI proposal provides a more detailed framework for achieving technological and operational excellence across the entire observation lifecycle.
3. **Governance and Sustainability:** The ESFRI proposal outlines a clear governance structure and sustainability plan, including financial feasibility, risk management, and political support, which is more detailed than the strategic outlines in JERICO-NEXT D1.4.

4. **Stakeholder Involvement:** Both documents recognize the importance of stakeholder engagement, but the ESFRI proposal integrates this engagement more deeply into the governance and operational frameworks, ensuring continuous and effective collaboration.

In the ESFRI proposal, the JERICO science strategy was structured around **three Key Scientific Challenges** (KSC): (KSC#1) of coastal marine systems under the combined influence of global and local drivers, (KSC#2) Assessing the impact of extreme events, and (KSC#3) Unravelling the impacts of natural and anthropogenic changes. The strategy for JERICO's development accounts for the main specificities of the coastal ocean. As such, a fundamental aspect is the integrative character of coastal ocean observations (integration of disciplines, technologies, observations, communities etc.). Enhancing the integration of the coastal ocean observation provided the **bedrock of JERICO Development strategy**, which is articulated around 3 Pillars: **i) Pillar #1: Fostering societal impact for a larger community of stakeholders, ii) Pillar #2: Developing innovative technologies for Coastal Ocean observing and modelling, iii) Pillar #3: Interfacing with other Ocean Observing Initiatives (Figure 2).**

Together with the three KSCs, the three development pillars provided a novel matrix architecture structuring the implementation of JERICO **at nested scales from single sites to regions and at the pan-European level.**

In JERICO-S3, the KSCs have been consolidated and the importance of the regional structuration of the RI has been demonstrated through different activities (eg. PSS and IRS)

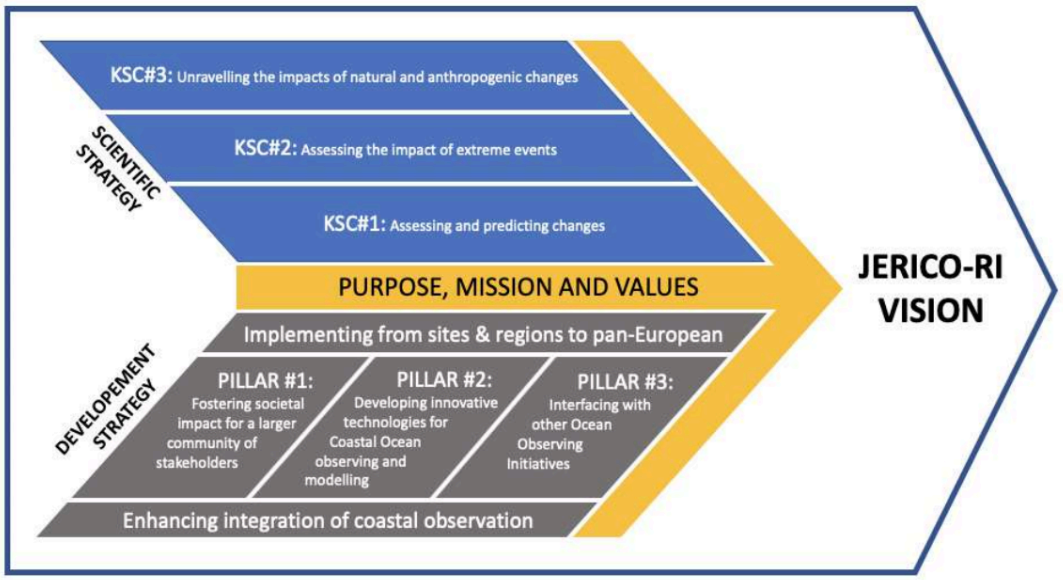

Figure 2: General architecture of JERICO with both scientific and development strategies showing the 3 Key Scientific Challenges and 3 Pillars.

The developments achieved within JERICO-S3 regarding the regional implementation rely on one of the strengths of the JERICO consortium, which consists in associating the elaboration of science strategy based on theoretical grounds (through networking activities) with practical experimentations (through joint research actions). **It clearly constitutes a major step forward compared to those accomplished during previous JERICO projects, which were mostly method/discipline oriented.**

3. Definition and implementation of the science strategy

3.1. The general scientific framework

Concerning the KSC, the main outcome has been to converge into a common general scientific framework structured in **KSC, SSC and a list of specific RA**. The undertaken actions have allowed consolidating the list of KSC and SCC. Stabilised KSC and SSC indeed constitute a strong backbone that can soundly structure the articulation of future integrated JERICO research actions. Besides, a living list of tackled RA has also been elaborated, which should be continuously updated through regular consultations of the JERICO consortium (J-S3 D1.1).

1. **Key Scientific Challenges (KSC):**
   - **KSC#1**: Understanding the coastal marine systems under combined global and local drivers.
   - **KSC#2**: Monitoring and predicting coastal ocean state and its variability.
   - **KSC#3**: Developing integrated and multi-disciplinary approaches for coastal observation and research.
2. **Specific Scientific Challenges (SSC):**
   - These challenges are aligned with societal needs and policy requirements, such as climate change adaptation, marine biodiversity protection, and sustainable resource management.
3. **Research Actions (RA):**
   - RAs are specific activities or projects aimed at addressing the KSC and SSC, including the development of new monitoring technologies, data integration strategies, and innovative research methodologies.

In the JERICO scientific framework**, KSC and SSC are permanent questions adapted to the marine coastal environment.** They are key components of the science strategy**. RA are more focused on variables and processes that can evolve according to new scientific questions, driven by societal needs.** In this concept, KSC and SSC contribute to the integrated observations (see D1.3).

For the development of scientific challenges, the KSC, SSC and RA encompass different scales to respond to dynamic and complex ecosystems where ecological processes and human interactions vary considerably over short distances. An **integrated multi-scale approach** is indeed essential for the effective management of these areas, enabling responses to local challenges while aligning efforts with regional and European strategies. This integration is crucial for addressing societal challenges related to the marine and coastal environment holistically and coordinately. Environmental management interventions, such as oil spill cleanups, habitat restoration, and the regulation of fishing activities, require precise and localised data to be effective. Small-scale observations allow for the precise targeting of risk areas and appropriate interventions. Sea level rise, ocean acidification, and extreme weather events disproportionately affect coastal zones. A multi-scale approach allows for monitoring these impacts and adapting policies accordingly, taking local specifics into account while coordinating efforts on a larger scale. To gain a comprehensive understanding of coastal processes, it is crucial to combine detailed local observations (small scale) with larger-scale analyses (regional or pan-European). For instance, regional climate models can benefit from precise local data to refine their forecasts and scenarios.

3.2. The concept of regions and integration

Regions in JERICO-S3, including IRSs and PSSs (WP3 and WP4), play a crucial role in the integration, harmonisation, and efficient operation of coastal observatories. They contribute significantly to the pan-European effort of monitoring and understanding coastal seas by aligning with the overarching JERICO-S3 science strategy while addressing specific regional challenges. These regions standardise data collection methods, deploy innovative technologies, and engage a diverse range of stakeholders, including researchers and policymakers. Actions taken by IRSs and PSSs aim to promote the use of their data and products in collaboration with other research infrastructures and in support of EU directives. Additionally, transnational and cross-regional **integration** is encouraged to extend regional activities to broader areas and jointly identify observational gaps.

Integration is the backbone of JERICO overall science strategy and is being achieved in a regional dimension, but also from the point of view of technological innovation and experimentation (D1.3). The aim of integration here is to be able to observe and understand complex processes acting on different scales of time and space, by integrating multiple scales of distributed marine observations into a single observation system and enabling these data to be provided free of charge to end users. This means being able to implement an infrastructure made up of platforms and science-based sensor systems that measure physical, chemical and biological properties and processes in coastal waters, from the open ocean to the land-sea interfaces.

In JERICO, there are two levels of integration: 1) the regional level in order to integrate disconnected, overlapping or neighbouring systems and to fill the gaps observed in the existing observations. This concept has been proposed and demonstrated (more or less) in the IRS/PSS, 2) a pan-European vision carried out with global harmonisation from JERICO governance, to ensure global coordination of coastal observations of the regions for worldwide needs. There is a clear need for a central structure to coordinate these regions. This idea has been developed in the governance strategies

The region's contributions to KSC and SSC are heterogeneous (Figure 3). There are some differences between IRS and PSS in terms of implementation and maturity. Inside the PSS the approach is different from region to region, depending on the region's history, scientific objectives, expertises engaged, technological innovations and connections between countries and existing RIs. In some regions, actions have a wide regional representativeness while in others experimentation is focused on small scale processes. The D1.3 stresses the importance of interregional and transnational integration, as well as interaction with other players, programmes and initiatives outside JERICO.

KSC	SSC	Pilote Super Sites					Integrated Regional Sites				
		North S.	EC	NWM	CS	BS/GF	BOB	NAS	IAM	K/S	Nor S
Assessing changes under the combined influence of global and local drivers	Land-Ocean continuum	✓		✓			✓		✓		✓
	Sea-atmosphere interface										
	Connectivity and transport			✓			✓		✓	✓	
	Biodiversity		✓				✓		✓		
	Primary productivity		✓		✓					✓	
	Ecosystem functionning	✓			✓	✓		✓		✓	
	Carbon budget and CO2 system	✓				✓				✓	
Assessing the impacts of extreme events	Extreme events & impacts on ecosystems			✓	✓	✓	✓	✓			
	Extreme events & coastal hazards						✓		✓		
	Harmful algal blooms		✓			✓				✓	✓
Unravelling and predicting the impacts of natural and anthropogenic changes	Climate change impacts					✓	✓		✓	✓	
	Eutrophication		✓	✓		✓					
	Impact of big cities			✓							
	Litter and plastic			✓			✓	✓	✓	✓	
	Contamination			✓					✓	✓	✓
	Unravalling impacts					✓	✓				✓

Figure 3: List of the 16 Specific Scientific Challenges addressed by the Pilot Super Sites and the Integrated Research Sites as identified during the JERICO-S3 and their further grouping in three Key Scientific Challenges (KSC). North S: North Sea, EC: English Channel, NWM: Northwestern Mediterranean, CS: Cretan Sea, BS/GF: Baltic Sea: Gulf of Finland, BOB: Bay of Biscay, NAS: Northern Adriatic Sea, IAM: Iberian Atlantic Margin, K/S: Kattegat/Skagerrak, Nor S: Norwegian Sea (table from D1.2)

3.3. Addressing the land-sea interface

The maturation of the thinking around the SSCs and RAs, together with increased expectation from the society, lead the JERICO community to consider addressing more explicitly the land-sea interface. It encompasses observations of e.g., coastal geomorphology and transport of mineral and organic compounds, impacts of land-originating punctual or diffuse discharges, extreme events at the coast (including heat wave, storm surge, habitat degradation, etc.), pelagic-benthic coupling.

Most of the JERICO partners already address these scientific questions at national level and have the infrastructures and long-term fundings to do so. It has therefore been seen as appropriate and as a small step to include these topics in the perimeter of JERICO. Furthermore, it provides a solid scientific basis for exploiting the complementarity between RIs, (i.e., DANUBIUS (river to coast), EMBRC and ICOS), and developing joint research actions and services. The memorandums of collaboration (MoC) established bilaterally with these RIs reflect this complementarity and common view (see D2.1).

3.4.Connections with existing RIs

The JERICO science strategy is based on a multi-scales and multidisciplinary approach to understand the complexity of the coastal environment. It builds upon multi-platforms integration and may be valorised through collaborations with other marine RIs that are already

established in the EU landscape (eg. EMSO, EMBRC, EURO-ARGO, ICOS, DANUBIUS…). Enhancing collaboration and interoperability with other RIs, is considered as an **important mechanism to maximise the value and impact of those RIs (including JERICO) to science and society, and to support EU policies**. A mapping of commonalities between RIs (Figure 4) has been the basis for establishing MoCs with those RIs.

Collaboration field	EMBRC	EMSO	EuroARGO	ICOS	DANUBIUS	eLTER	LifeWatch
Marine Biology	X	X			(X)	X	X
Ecology Research	X				X	X	X
DeepSea Platforms		X	X				
Subsurface Ocean Properties			X	Not yet			
Marine Carbon Cycle			X	X			
River-sea Continuum					X		
Ecosystem structure and functions						X	X
Near shore sites	X	X		X	X	X	
Biodiversity	X	X				X	X
Mesocosms							
Biogeochemistry		X	X	X	X	X	
Data	X	X	X	X	X	X	X
Services	X, access	X	X (data provision)	X	X	?	X (IT services)

Figure 4: Collaboration field proposed in the different MoC with others RIs (from D2.1)

In these collaborations, JERICO will provide solid expertise on coastal and shelf seas with access to platforms, FAIR data (EOVs with high quality control procedures),.. JERICO will also provide a strong expertise on the coastal processes characterising the domain in different regions (eg. water mass transport, acidification, phytoplankton distribution…).

DANUBIUS was identified as a high priority. For example, observations performed by DANUBIUS are important for JERICO, as river discharges have a strong influence on physical, biogeochemical and biological processes in coastal waters (eg. organic matter and nutrients fluxes, impact on salinity and total alkalinity, primary production …). Such collaborations will be demonstrated in the HORIZON-CL6-LandSeaLot project (grant #101134575) to seek better integration and collaboration between communities working in the land-sea interface, including the JERICO and DANUBIUS communities.

Collaborations with EMBRC will be based on the development of tools (and/or best practices) on imagery (plankton morphology) and DNA (plankton species), and their deployment on JERICO platforms as they reach a high level of maturity and performance (or TRL for sensors). In this context, JERICO will provide a long-term time series with a spatial coverage of oceanic data that will benefit to EMBRC to interpret and understand the distribution of plankton in the marine environment (eg. bio-regions, clustering…). Scientific collaboration around environmental issues such as HAB, invasive species, and conservation/restoration actions have already been envisioned by the two RIs.

Collaborations with EMSO & EURO-ARGO will be oriented towards (1) technological development of common interests (e.g., coastal profilers, cabled observatories, autonomous observing vehicles), and on ensuring an appropriate observing continuum between the coast

and the open ocean and deep ocean. JERICO will provide observations, expertise and understanding of processes occurring in coastal regions

For ICOS, there is a need to extend and improve observations of air-sea CO2 fluxes at the land-sea interface and in coastal regions. Since 2015, the JERICO community has been working on the observation of the carbonate system in coastal waters. Presently, it is performed from coastal fixed buoys and Ferrybox but, in the future, it could be based on autonomous platforms for which JERICO has solid expertise (e.g. gliders). Collaboration between ICOS and JERICO experts may accelerate the deployment of ad-hoc solutions towards a better understanding of the carbonate system, its variability and ecosystem impact in coastal regions. JERICO will provide e.g., the auxiliary variables necessary for ICOS to adjust and validate the carbonate variables whose accuracies in coastal waters will need to be adapted (e.g. accuracy of measurements for Total Alkalinity, Total Carbon and pH), and access to multiple platforms for deployment.

4. The role of JERICO in the development of EU DTO capabilities

The DTO aims at providing a capability for simulating and forecasting marine environments in support of both the need for ecosystem conservation/restoration and the development of a sustainable blue economy. By their nature, coastal regions are known to be the most impacted by anthropogenic stresses, and where populations live, giving them a central importance on the expectations from DTOs.

The JERICO science strategy will significantly contribute to the maturation of the Digital Twin of Ocean (DTO) by enhancing the **quality, reliability, and integration** of oceanographic data across European seas. JERICO will provide continuous, high-quality observational data and process-focussed datasets. This comprehensive data collection is essential for the DTO, which relies on accurate and extensive datasets to create detailed and robust digital replicas of ocean environments, not least supporting the emerging of AI-based solutions. By leveraging JERICO's observational infrastructure, the DTO can improve its predictive models, leading to better-informed decision-making processes concerning marine and coastal management.

The impact of JERICO on the DTO extends to **enhancing data interoperability and standardisation**. The JERICO strategy emphasises harmonising data collection methodologies and integrating various data sources, ensuring that information from different observatories can be seamlessly combined. This standardisation is vital for the DTO, as it aims to synthesise diverse datasets into a coherent digital framework. With JERICO's commitment to data quality and consistency, the DTO can achieve higher precision in simulating oceanic processes and dynamics, thereby offering more accurate and actionable insights.

Coordination at the EU level is imperative to maintain and improve the **high-quality data flow to the DTO**. Effective EU coordination can ensure that resources are allocated efficiently, avoiding duplication of efforts and fostering collaboration among member states. This collaboration is crucial for addressing the complex and transboundary nature of oceanographic data, as the marine environment does not adhere to national borders. An EU-coordinated approach can also facilitate the sharing of best practices, technological advancements, and innovative solutions, further enhancing the capabilities of both JERICO and the DTO.

To boost this coordination, it is essential to develop **robust governance frameworks** that oversee data management, sharing protocols, and long-term sustainability of the observatories. These frameworks should promote transparency, data accessibility, and open science principles, encouraging broader participation from the scientific community and

stakeholders. Additionally, investment in advanced technologies, such as autonomous sensors and real-time data transmission systems, can enhance the efficiency and reach of data collection efforts, ensuring that the DTO is continuously updated with the latest observations.

Propositions to enhance the impact of the JERICO strategy on the DTO include establishing dedicated funding streams for collaborative research projects that bridge observational data with digital twin technologies. Creating multidisciplinary platforms where scientists, technologists, and policymakers can interact and exchange knowledge will foster innovation and address emerging challenges in marine science. Furthermore, **integrating citizen science initiatives can expand data collection capabilities** and promote public engagement, enhancing the societal relevance of the DTO. In this context, JERICO will provide EOVs from coastal waters to the DTO, which will improve simulations of dynamic and complex processes in this field, where **societal needs are significant**. In a way, **JERICO will enable the DTO to offer products with high added value for the public and decision-makers, making JERICO a key player in the EU marine infrastructure landscape.**

Currently, there are still barriers to the use and visibility of JERICO data in EU dataset aggregators, which will then be used for the development of DTO products. The systematic implementation of **DOIs in JERICO datasets** should contribute to greater visibility and traceability, while providing a technology for the delivery of all such data (e.g. ERDDAP). In addition, the move from FAIR FAIR-2 principles to Facilities for AI-Ready data/datasets will be necessary for JERICO (and other IRs) in order to adapt datasets to new **machine learning** tools such as neural networks capable of predicting data not directly measured but necessary for understanding marine coastal systems. This transition from FAIR to FAIR-2 data will therefore facilitate the integration of in situ observations into the models used for the DTO and future CMEMS synthetic products.

By prioritising these strategic initiatives, the EU can ensure that JERICO's observational prowess is effectively harnessed to support the DTO, ultimately contributing to a deeper understanding of marine environments and fostering sustainable management practices. The synergistic relationship between JERICO and the DTO, underpinned by strong EU coordination, will pave the way for groundbreaking advancements in oceanography and environmental stewardship.

5. Key elements of the science strategy into the JERICO services and governance

The services to be provided by JERICO are based on the JERICO science strategy, and are designed to answer scientific and societal needs by enhancing the **capabilities of coastal observatories and providing critical support to a wide range of marine research and management activities**. These services are rooted in the integration of advanced observational technologies, development of sophisticated analytical tools, and provision of expert knowledge and access to research platforms.

Several services will be useful and should be aligned with the science strategy: expertise in integrated observations (e.g. acquisition frequency, spatial coverage, etc.), technology watch and the development of analysis tools to improve data visibility (e.g. indicators, products, etc.). As regards the technological aspects, the science strategy could contribute its expertise to the implementation of a new coastal observation system, access to and integration of new sensors on coastal platforms and the recommendation of certain devices to limit pressure on the coastal environment.

One of the primary services emerging from the JERICO science strategy is the concept and implementation of **integrated observations**. This involves deploying a network of interconnected coastal observatories that work synergistically to provide comprehensive data on various marine parameters. Such integrated observations enable the continuous monitoring of coastal ecosystems, facilitating the collection of high-resolution, real-time data. These data are crucial for understanding complex marine processes, detecting environmental changes, and informing sustainable management practices.

Technological innovations are another key service offered through JERICO. These innovations encompass the development and deployment of state-of-the-art sensors and autonomous systems that enhance data accuracy and reliability. For example, advanced technologies, such as coastal autonomous underwater vehicles (gliders, micro-AUV), are employed to cover large spatial areas and difficult-to-reach regions, thereby expanding the observational capabilities of coastal observatories. These technological advancements ensure that the data collected are both comprehensive and precise, supporting various research and operational needs.

In addition to observational technologies, JERICO also focuses on the development of **analytical tools** that facilitate the processing, interpretation and application of collected data. These tools include software for detecting trends and anomalies in environmental data, which are essential for identifying changes in marine ecosystems. The development of such tools allows researchers and policymakers to build products such as environmental indicators, maps, and models that provide valuable insights into the health and dynamics of coastal waters. For instance, trend analysis tools can help track long-term changes in water quality, while anomaly detection tools can alert stakeholders to sudden shifts or unusual events that may require immediate attention.

The JERICO science strategy also emphasises providing **expertise and access to research platforms**. This includes offering specialised knowledge on coastal water dynamics, which encompasses understanding the influences of biofouling, waves, tides, winds, and contaminants on marine ecosystems. Access to well-equipped platforms, such as research vessels and fixed coastal stations, allows researchers to conduct experiments and collect data under various environmental conditions. These platforms serve as ideal locations for testing new technologies and methodologies, particularly in understanding and mitigating coastal water constraints like biofouling, which can significantly impact sensor performance and data quality.

Moreover, JERICO's commitment to building a robust and sustainable research infrastructure ensures that these services are continuously refined and updated in response to emerging science and technological needs. The collaborative nature of JERICO, involving multiple European research infrastructures, fosters the sharing of **best practices and innovations**, further enhancing the quality and impact of the services provided.

6.CONCLUSIONS

The JERICO-S3 project has consolidated the science strategy of the JERICO RI. The perimeter of actions has been made more precise through the KSC and SSC. Flexibility has been incorporated in the form of RAs that can be easily adapted for answering observational needs arising from emerging scientific questions. The objectives of the science strategy is fostering the implementation of the JERICO RI through a structuration at (1) local to regional (e.g., sea basin) scale and (2) a coordination and harmonisation at a pan-European scale. In practice, the project has advanced the integration and harmonisation of coastal observatories through demonstrations conducted in European coastal regions. By aligning regional efforts

with a unified science strategy, the project pushed to standardise data collection methods, deployed innovative technologies, and engaged diverse stakeholders. The science strategy, based on well defined scientific challenges, emphasised the development and implementation of cutting-edge sensor technologies and multidisciplinary integrated observation platforms. These innovations have bridged gaps in existing observational capabilities, enabling more accurate and efficient data collection. The science strategy of JERICO has fostered extensive collaboration with other research infrastructures, enhancing data interoperability and standardisation to maximise the value and impact of those RIs (including JERICO) to science and society, and to support EU policies. By anticipating future challenges and technological advancements, JERICO ensures that Europe remains at the forefront of coastal observation and marine environmental management. JERICO's efforts as a contribution to the DTO will further enhance the impact of marine coastal data for decision-making and policy development. Through its dual focus on regional integration and pan-European coordination, JERICO has demonstrated the importance of addressing both localised and global environmental challenges. The science strategy is highlighting the necessity of a central coordinating structure to manage regional contributions and ensure global harmonisation of coastal observations. This approach not only fills observational gaps but also supports EU directives, international marine policies, and a sustainable blue economy.

7. ANNEXES AND REFERENCES

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