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# An interlinked coastal observatory network for Europe

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**Abstract :**

Existing coastal observatories in European waters are complex systems consisting of different observational components, providing crucial operational data for assessment, model validation and assimilation purposes. However, the geographical, structural, functional and operational heterogeneities that characterise them pose an enormous challenge to their efficient exploitation as information providers on a broader, cross-border, regional scale. To address this problem, the European Union (EU) Seventh Framework Programme (FP7) Towards a Joint European Research Infrastructure Network for Coastal Observatories (JERICO) project is creating a shared, pan-European framework for the networking of such observatories, promoting the identification and dissemination of best practices for their design, implementation and maintenance, as well as common data distribution and transnational access protocols to enhance their performance and sustainability. In doing so, the project is also laying down the foundation for the coastal element of the nascent European Ocean Observing System.

## Introduction

The European Union's current Integrated Maritime Policy (IMP) places ‘Blue Growth’ – harnessing the untapped potential of Europe's oceans, seas and coasts to stimulate long-term economic development and job creation - at the forefront of the agendas of Member States, regions, enterprises and civil society, in line with the objectives of the Europe 2020 strategy.1 Another cornerstone of the IMP is that there is an absolute need for better knowledge of Europe’s seas and oceans, which has been addressed through the adoption of the ‘Marine knowledge 2020’ initiative that aims to establish an integrated knowledge infrastructure capable of delivering accessible, compatible and timely data concerning the status of the marine environment.2 Concomitant efforts include the Common Information Sharing Environment for the surveillance of the European maritime domain3, the Marine Strategy Framework Directive4 aimed at achieving good environmental status, and programs such as Horizon 2020 that will be focusing partly on marine research and innovation.[5]

It is evident that the successful implementation of the IMP will require access to coastal marine observations, which are meaningful and qualified for use on the European scale. Currently, a number of coastal observatories dotted along Europe's coastlines deliver a wealth of information on the state of its seas. Although many of these observatories are maintained by leading scientific institutions, which employ them principally for carrying out research, their development has been driven mainly by national interests and priorities. Understanding the role that these observatories could play as a science and policy tool at the transnational level and as a driver for technological development in the marine services sector, a number of these institutions came together and launched a 4-year FP7 Infrastructure project entitled 'Towards a Joint European Research Infrastructure Network for Coastal Observatories' (JERICO, for short) in May 2011. JERICO is a partnership of 27 organizations, including 9 institutions with observing infrastructures located in the Mediterranean Sea (Fig 1). The project aims to create an operational pan-European network of coastal observatories - assemblages of distributed sensor systems covering extensive areas of Europe's coastal seas - capable of assuring timely, continuous and sustainable delivery of high-quality environmental data and information products for research, industry, and ecosystem health and resource management purposes. At the same time, it also intends to build a valid European platform, assembling state-of-the-art resources and hard-to-get expertise, for testing new technologies and methods impacting the marine and maritime sector.

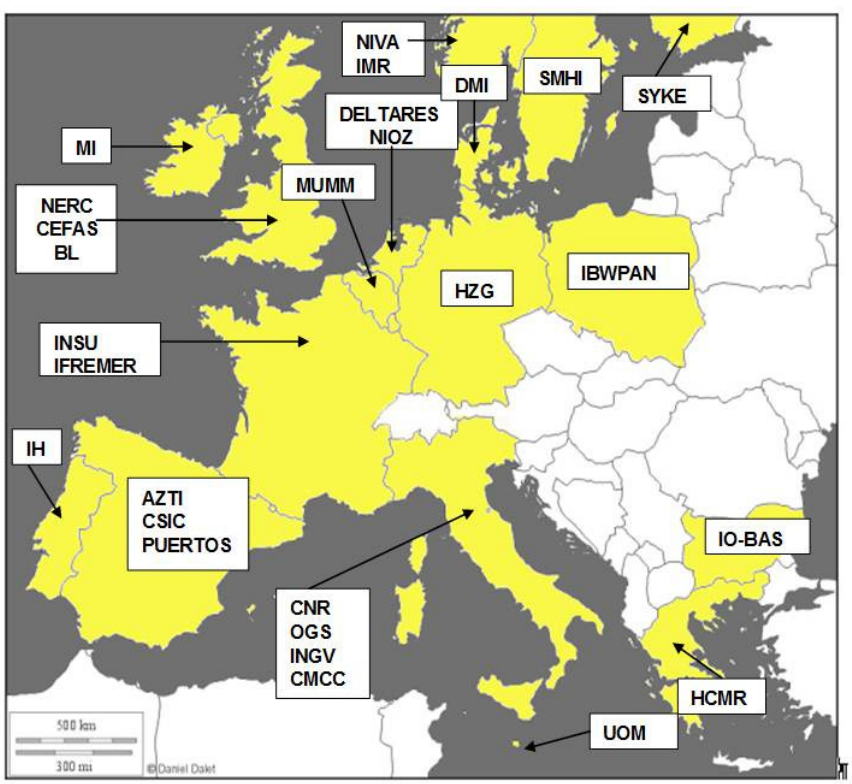



**Figure 1**. Geographical distribution of the JERICO consortium.

The present paper gives an overview of the JERICO project and its intended contribution as the coastal component of a European Ocean Observing System (EOOS).

## THE JERICO OBSERVING INFRASTRUCTURE

JERICO is geared towards ensuring continuous, timely access to coastal observations. There is thus an implicit focus on self-operating, automatic systems capable of providing data in real-time (RT) or near real-time (nRT). The current composition of the JERICO network of coastal observatories is summarized in Fig 2.

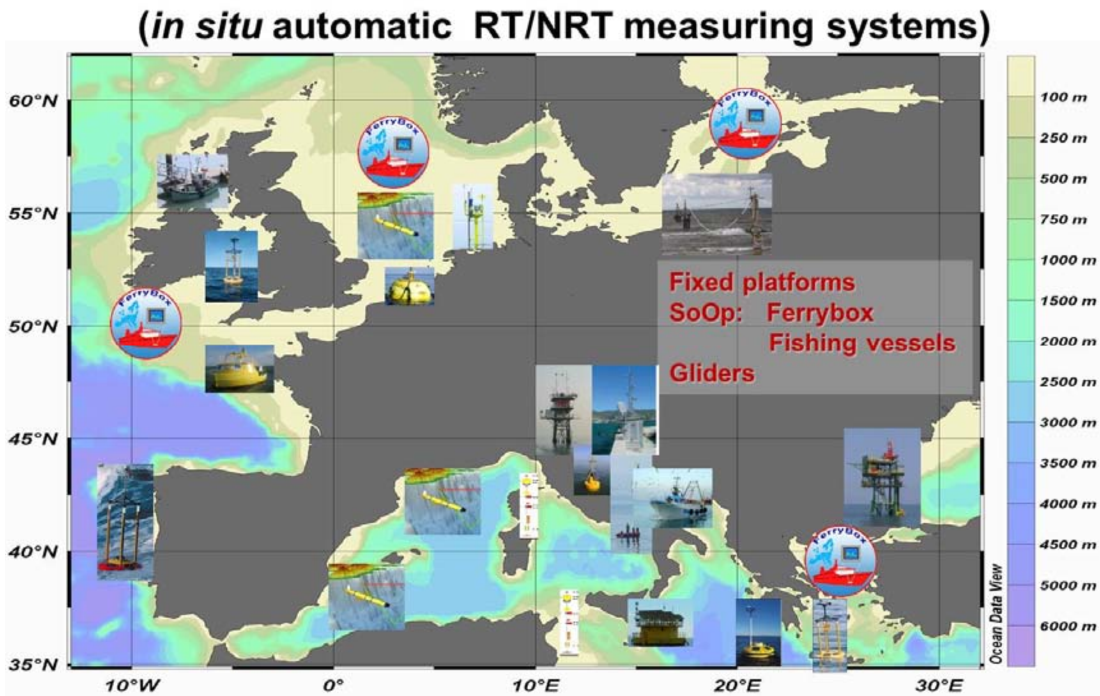



**Figure 2**. Current composition of the JERICO network of coastal observatories.

It is principally constituted by four main types of observing platforms: fixed or station-keeping structures, ferries carrying ferryboxes, fishing vessels equipped with sensors mounted on fishing gears, and instrumented gliders. This predominance is primarily because these platform types have so far been the ones most commonly employed within the marine research community for long-term deployments of RT (or nRT) measuring systems. In a number of cases, operators manage complex systems incorporating more than one platform, sometimes partly or fully interlinked to ensure a discrete level of holistic functionality. Some operators also maintain additional amenities such as laboratories and calibration facilities for managing their observing infrastructure/s.

The platforms support measuring instruments and sensors, which differ widely in their number, kind, scope, and technical configuration from platform to platform, and from operator to operator. The sets of targeted parameters also vary considerably across the network in a similar way, though salinity, temperature and pressure (depth) are nearly always measured. Table 1 categorizes the chief parameters selected by JERICO for consideration in its networking effort.

**Table 1**. JERICO parameter list.

| | Parameter | Core | Optional |
|---|---|---|---|
| Physical | Salinity | ✓ | |
| | Temperature | ✓ | |
| | Turbidity | ✓ | |
| | Sea level | ✓ | |
| | Surface waves | ✓ | |
| | Surface currents | | ✓ |
| | Chlorophyll-a | ✓ | |
| | Turbidity | ✓ | |
| | Coloured Dissolved Organic Matter (CDOM) | | ✓ |
| | Noise Passive Acoustic Listener (PAL) | | ✓ |
| Chemical | Dissolved nutrients | | ✓ |
| | Dissolved oxygen | ✓ | |
| | CO2 partial pressure | ✓ | |
| | Contaminants | | ✓ |
| | pH or Alkalinity | | ✓ |

Being, for the greater part, science-oriented, the individual observatories making up the network are rarely supported institutionally, and tend to depend on the resourcefulness of operators in appropriating funds and manpower within the framework of research activities for their systematic upkeep and development. It is important to note that the JERICO network targets the coastal component of Europe's seas, a critical compartment that has not been specifically covered by any of the other ongoing European *in situ* observing infrastructure initiatives like $FixO_3$, EMSO, EuroArgo or Eurofleets. It, therefore, complements the fledgling idea of the EOOS, an integrated and sustained European system of systems for delivering high quality marine information and knowledge to underpin environmental policy and management that will help to build a truly integrated global ocean observing system.[6]

## TOWARDS OPERATIONAL INTEGRATION

All the coastal observatories forming the JERICO network share the same goal: to detect and investigate coastal processes in a timely fashion, and provide crucial operational data for planning, assessment, mitigation, and model validation and assimilation purposes. However, despite the common objective, the heterogeneity of the observatories from the perspectives of the kinds of parameters handled, the frequency and geographical coverage of measurements, equipment maintenance practices, and the quality assurance schemes employed for sensors and data is astonishing. This heterogeneity embodies a striking richness in the range and content of the observational resources on offer. Unfortunately, it also represents a serious challenge to cost-effectiveness, efficiency and utility on the wide, regional scale, particularly when cross-border integration of collected information is involved.

The JERICO project aims to unite the established coastal observatories constituting its network within a shared pan-European framework that will enhance their performance and sustainability at the transnational level. To achieve this union, a working plan based on a series of interlocked actions, articulated in singular work packages, was conceived and has been adopted. The plan is centered on the core observing elements of the network, namely: fixed platforms, ships-of-opportunity (ferries and fishing vessels), and gliders. The difficult task of network consolidation is addressed by working on bringing together these elements to a level of operational synergy that is able to satisfy coastal marine information needs on the European scale, and not just on local or limited regional scales. Integration is being actively pursued through the implementation of a common, consensual framework for dealing with the different indispensable functional aspects of running coastal observatories: policy, operations, data, engagement with users, and development. The framework is being realized through the coordinated activities of ten work packages (Fig 3).

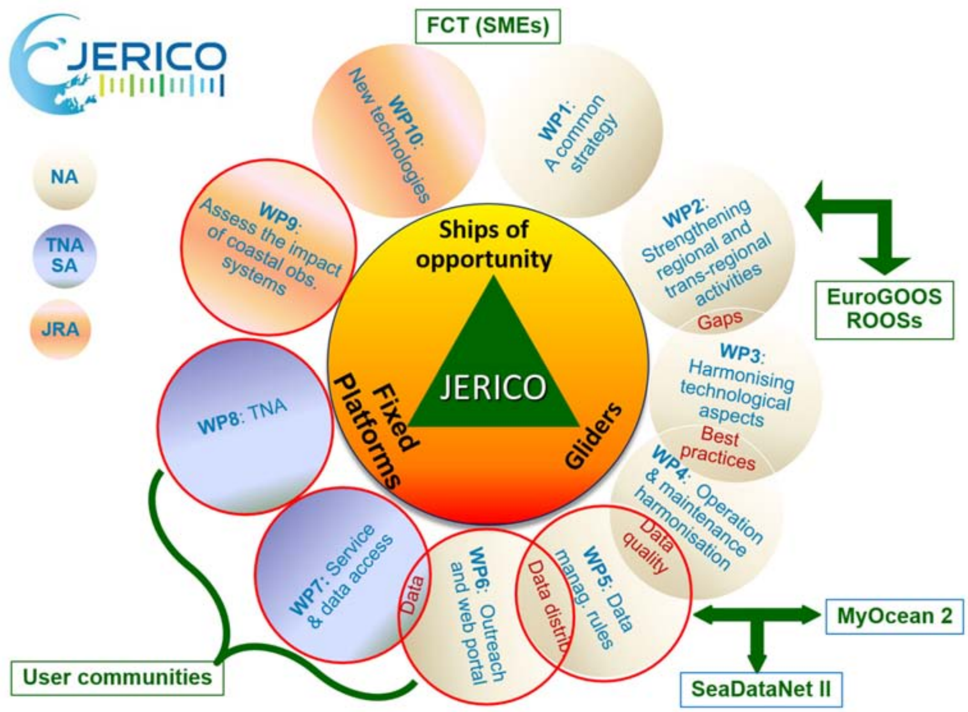



**Figure 3**. An overview of the JERICO work packages, highlighting their mutual interactions and relationships with Small and Medium Enterprises (SMEs) through the Forum for Coastal Technology (FCT) initiative, user communities, and other relevant organisations and projects.
Note: The underlying observing infrastructure constitutes the central pillar supporting the entire operating framework, which is based on the Integrated Infrastructure Initiative (I3) model that is constituted by Networking Activities (NA), Trans-national Access (TNA), Service Activities (SA) and Joint Research Activities (JRA).

Work Packages 1 and 2 are concerned with the general networking strategy. Work Packages 3 and 4 deal with technical and operational harmonization. Work Package 5 focuses on data handling. Work Packages 6, 7 and 8 address, in different ways, the necessary interface with the community of users, whereas Work Packages 9 and 10 contain state-of-the-art research initiatives as well as tasks directed towards the future development of the network. An additional work package, Work Package 11 (not shown), is also present, and is devoted to the overall management of the project.

The technology available within the network was mapped, and questionnaires dealing with different operational aspects of coastal observatories, including running costs, were carefully prepared and distributed amongst partners for their feedback. A number of meetings and workshops were held to facilitate the exchange of useful information and promote cooperation between the partners. Sensors and technology were discussed. , and elements of Best Practice for the design, implementation and maintenance of coastal observatories were identified and disseminated. A "Forum for Coastal Technology" was set up. The Forum constitutes a vehicle for bringing together users and sensor manufacturers, and fostering a mutually beneficial dialogue between them. A number of useful technical documents and reports have been produced, which are freely available on the project's website.[7]

## DATA MANAGEMENT

The JERICO network's approach to handling its data is strongly based on the principle of 'using what exist' through the creation of suitable partnerships with ongoing European data management initiatives so as to minimize possible duplication of efforts. Thus, there has been no development of a specific data management structure for JERICO. Instead, the use of, and integration with, already available data management infrastructure is being promoted.[8] This strategy is consistent with the policy behind SeaDataNet (SDN) and MyOcean (MyO), the major ongoing European initiatives for the establishment and coordination of infrastructures for the management and distribution of marine data and products.

Therefore, the JERICO data management framework for delayed-mode data uses the SDN infrastructure while real-time data are being handled through MyO. There is continuous interaction with SDN, MyO, EuroGOOS and EMODnet-PP to facilitate seamless integration with both these established infrastructures for managing the JERICO data stream.

The success of the networking activity in JERICO will depend on the reliability, accessibility and easy distribution of data coming from the participating observing systems. This necessarily implies the use of common standards and procedures for data management among Partners. To this end, two Data Management Handbooks, one for delayed-mode data[9] and the other for real-time data[10], have been prepared for providing practical advice on delivering data to the JERICO community. The documents take into account the lessons learned from SDN and MyO. The Handbooks contain all the references and links to the basic and most important online documents that data providers would need to successfully manage their data within JERICO. They also present the guidelines to be followed by Partners during the JERICO Service Data Access period that began in January 2013.

Furthermore, some concrete actions have been taken to help data providers in submitting data: dataset indexing procedures were developed to help ensure compatibility with MyO Thematic Assembly Center (TAC) requirements and assist non-NODC data providers in using the SDN infrastructure. A specific indexing and data distribution scheme was created. An appropriate tag (a JERICO index) was designed to easily recognize and select JERICO data from larger archives. This measure permits the clear identification of the JERICO contribution to the global marine observing system, and is consistent with the approach adopted in some other European projects dealing with marine data (for example, PERSEUS and $FixO_3$). Procedures using the OGC's SWE suite and SensorML format have been set up to implement descriptions of the different elements of the JERICO observing infrastructure in a standardized, accessible way. The descriptions can contain technical specifications of platforms and sensors, details of instrument settings, calibrations and performances, and some information on data processing procedures, all of which will be helpful to users. However, difficulties remain, especially in relation to parameters and data types that are not actually being considered in SDN and/or in MyO. The nRT data coming from partners involved in Work Package 7 (Services and Data Access) are being routed to the French CORIOLIS Data Assembly Center through the MyO *in situ* TACs.

Acknowledging the value of data to science, society and economy, JERICO is adopting an open access data policy (Fig 4), in line with relevant European policy. The flow of data from JERICO partners to the community of users is driven by a synergic action of three Work Packages: WP7 is collecting data from partners, WP5 defines the rules for data management and distribution, WP6 provides the platform for distribution of data and tools.

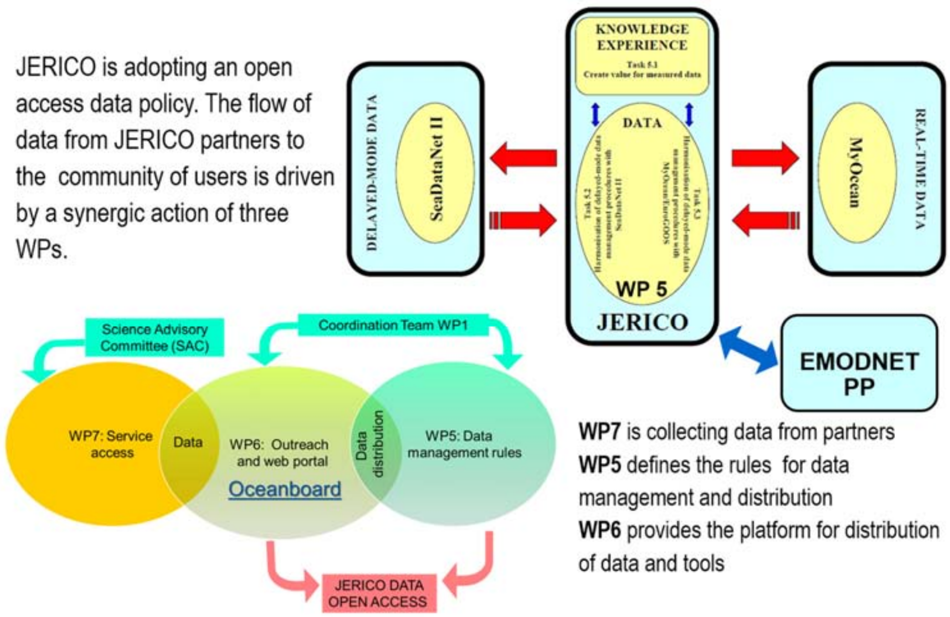


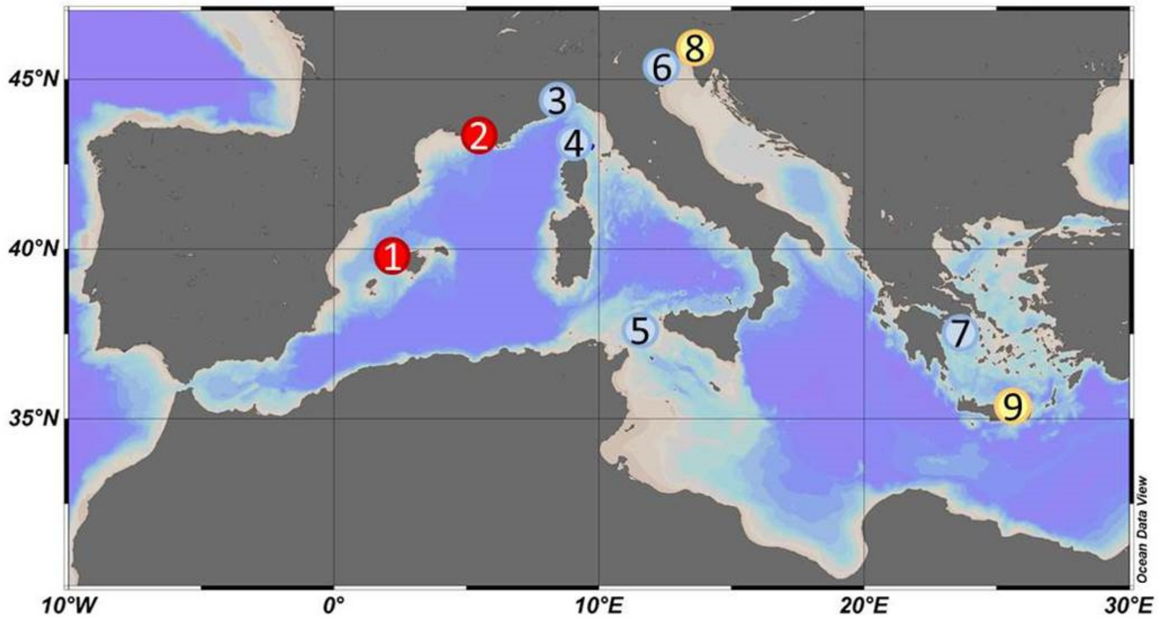

**Figure 4**. Outline of the JERICO data-management scheme, featuring the driving actions and main information flows.

## TRANSNATIONAL ACCESSIBILITY

The JERICO network has offered users free access to a selected number of its facilities for international research and technological development via the JERICO Trans National Access (TNA) program.

Three TNA calls have been organized and closed, involving four kinds of facilities: ferryboxes, fixed platforms, gliders, and calibration laboratories. The submitted proposals were evaluated by an independent panel of international experts each time, and those that passed were implemented with the logistical, technological and scientific assistance of the participating facility operators.

The JERICO TNA program was particularly successful in the Mediterranean Sea. Nine infrastructure elements were involved (Fig 5), which received twenty applications for access. Sixteen of these applications were supported by JERICO with free access and financial contributions to users for covering their costs relating to travel, subsistence and the shipping of equipment.




| Map | Infrastructure | Location | Operator | N. applications |
|---|---|---|---|---|
| 1 | SOCIB glider facility | Palma / Esporles (Mallorca) | CSIC/IMEDEA, SOCIB Spain | 3 |
| 2 | Glider National Facility | La Seyne sur Mer | CNRS/INSU France | 3 |
| 3 | Experimental Marine Station | Genoa harbor | CNR ISMAR Italy | 1 |
| 4 | Corsica Channel Observatory | Corsica Channel | | 1 |
| 5 | Sicily Channel Observatory | Sicily Channel | | 3 |
| 6 | Acqua Alta Oceanograhic Tower | Gulf of Venice | | 4 |
| 7 | Saronikos buoy | Saronikos Gulf | HCMR Greece | 1 |
| 8 | Poseidon Calibration Lab | Heraklion, Crete | | 4 |
| 9 | Oceanographic Calibration Centre | Sgonico (Trieste) | OGS Italy | 1 |

**Figure 5**. Map showing the geographical distribution of the infrastructure elements in the Mediterranean Sea participating in the JERICO TNA programme. Note: The numbered dots mark the locations of the various elements, which are concisely described in the table underneath. The colour of the dots represents the type of facility: red for glider laboratories, blue for fixed platforms and yellow for calibration laboratories. The last column in the table shows the number of applications for access time received by each facility. One user group applied to two infrastructure elements in the same proposal.

The JERICO TNA program has been an opportunity for the members of the Consortium to widen the reach of their existing coastal infrastructures beyond national borders, build long-term collaborations with new users, and promote innovation and the transfer of know-how. The Program has helped to evidence the major existing client communities of the network, their scientific and technological needs, and also the most attractive services amongst those offered by the network at present. Most of the JERICO TNA user groups were from academia (universities or research institutes), or belonged to the general community of marine scientists. However, it is worth noting that one user group was from industry, and another one was from the materials science field. These are examples of key uncustomary sectors which JERICO can, and should, cultivate in future.

## NEW METHODS TO ASSESS THE IMPACT OF COASTAL OBSERVING SYSTEMS: THE EXAMPLE OF DISTRIBUTED TEMPERATURE DATA IN THE ADRIATIC SEA

In order to optimize the returns on investments in coastal observing systems, JERICO is evaluating the influence of individual observing platforms on the effective ability to monitor processes in the coastal seas so that the sites and numbers of observations can be trimmed down to the bare essentials while keeping the information content as high and as multi-purpose as possible. This is being done through Observing System Experiments (OSE) and Observing System Simulation Experiments (OSSE), which respectively estimate the impacts of existing and planned observational systems by combining the information from observations with modelled dynamics.

The Adriatic Sea in the Eastern Mediterranean basin is one of the areas where Observational System Experiments (OSEs) are being performed in JERICO. Here, for the first time, the impact of *in situ* temperature observations collected with instruments installed on fishing nets on state estimates provided by the NEMO set-up[11,12] is being investigated.

Depth-referenced temperature data for the year 2007 have been extracted from a huge data set initiated in 2003 under the MFSTEP project, when an extensive observational program in the Adriatic Sea based on the Fishery Observing System (FOS)13 - that consisted of instrumentation installed on fishing nets - was begun. This subset was chosen because of its exceptional coverage of the area of study. In 2007, FOS data were available for a large area of the Northern Adriatic all year round (Fig 6). The measured variables were temperature and depth. Star Oddi probes with declared accuracies of ±0.1 C for temperature and ±0.4% of the full-scale range for depth were used. The data were subjected to a quality check to remove spurious and anomalous values prior to assimilation.

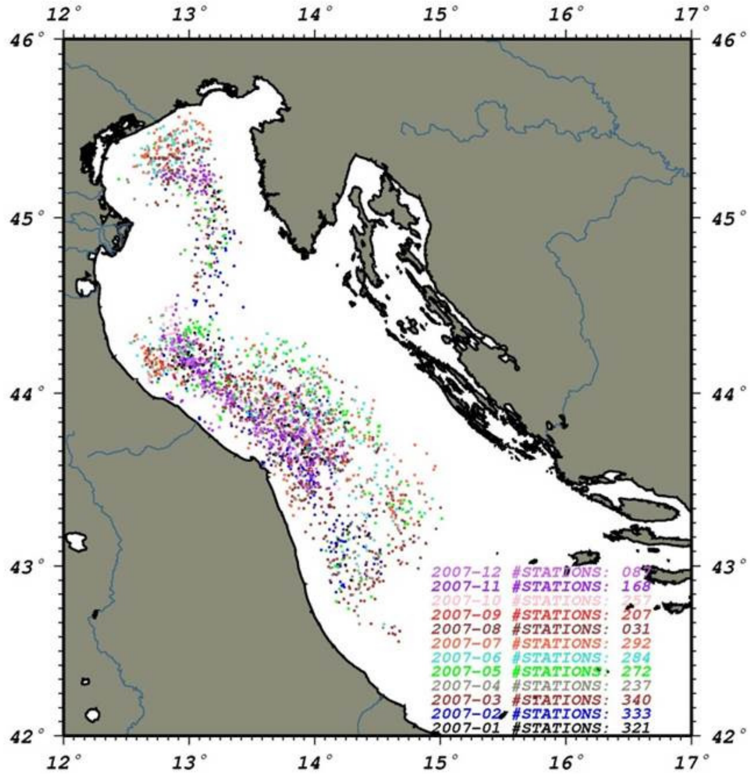



**Figure 6**. Positions of temperature observations made by fishing vessels in 2007 (each colour represents a different month).

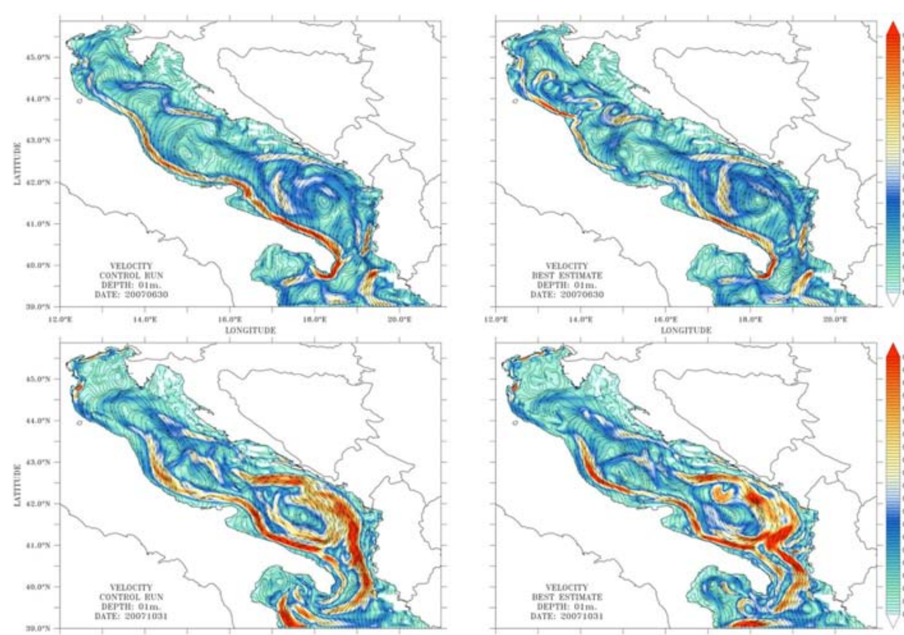



**Figure 7**. Intensity (m/s) and direction of surface currents in the Adriatic Sea in the control experiment (left) and the continuous assimilation experiment (right), estimated on 30 June (top) and 31 October (bottom) 2007.

Several OSE experiments have been performed[14], and the results are promising. For example, Fig 7 shows the comparison between estimates of surface currents in the Adriatic Sea obtained from a control experiment (no fishing vessel observations were assimilated) and a continuous assimilation experiment (fishing vessel observations were assimilated continuously throughout the year). It is clear that the assimilation of the new temperature data improves the estimate of the circulation patterns at the surface significantly, not just in the northern part where data exist but also in the south. At the beginning of the stratification season (Fig. 7, top), the intensification of southern Adriatic gyre is better represented by the assimilation run. In addition, the separation between the north and mid-western Adriatic currents in the summer is an observed phenomenon[15] and reproduced well compared to the free simulation. In autumn (Fig. 7, bottom), there is an intensification of estimated velocities along the western Adriatic current along the Italian coastline. Moreover, the south Adriatic gyre weakens more and south-eastern Adriatic current starts to detach, describing a regime that is closer to real conditions in the area in the period concerned.

## CONCLUSIONS

The EU JERICO project is coalescing Europe's currently fragmented coastal observatory community into a broad and inter-linked pan-European network, capable of offering a comprehensive operational service for the timely, continuous and sustainable delivery of high quality, comparable, coastal marine environmental data. In doing this, it is also defining the roadmap for the implementation and deployment of operational coastal observatories in the future EOOS. Most importantly, the Project is supporting transnational access to its networked facilities, thereby offering a cohesive European platform for the promotion of scientific and technological research and innovation in the marine and maritime sector.

## ACKNOWLEDGEMENTS

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**NOMENCLATURE AND ACRONYMS**

CORIOLIS - French data center handling *in situ* oceanographic data, http://www.coriolis.eu.org/

EMODnet PP - EMODnet Physics, portal for providing access to physical data and metadata included in the European Marine Observation and Data Network, http://www.emodnet-physics.eu/Portal

EMSO - European Multidisciplinary Seafloor Observatory, a large-scale European Research Infrastructure, http://www.emso-eu.org/

EOOS - European Ocean Observing System

EuroArgo - European Research Infrastructure contributing to the ARGO International Program, http://www.euro-argo.eu/

Eurofleets - Towards an Alliance of European Research Fleets, FP6&7 project, http://www.eurofleets.eu

EuroGOOS - European Global Ocean Observing System – an International Not for Profit Organisation (INPO) of governmental agencies and research organisations, http://eurogoos.eu/

FixO3 - Fixed-point Open Ocean Observatories, FP7 project, http://www.fixo3.eu/

FOS - Fishery Observing System, Italian initiative for equipping commercial fishing vessels in the Adriatic sea with oceanographic sensors and electronic logbooks.

FP7 - Framework Programme 7

IMP - Integrated Maritime Policy

JERICO - Towards a Joint European Research Infrastructure Network for Coastal Observatories, FP7 project, http://www.jerico-fp7.eu/

MFSTEP - Mediterranean Forecasting System Towards Environmental Predictions, FP5 project, http://mfstep.bo.ingv.it

MyO (MyOcean) - Ocean monitoring and forecasting, FP7 project providing products and services for all marine applications, www.myocean.eu.org

MyO TAC - MyOcean Thematic Assembly Center

NEMO - Nucleus for European Modelling of the Ocean, http://www.nemo-ocean.eu/

NODC - National Oceanographic Data Center

nRT - near real-time

OGC - Open Geospatial Consortium

OSE - Observing System Experiments

OSSE - Observing System Simulation Experiments

PERSEUS - Policy-oriented marine Environmental Research for the Southern European Seas, FP7 project, http://www.perseus-net.eu/

RT - real-time

SDN (SeaDataNet ) - Pan-European infrastructure for ocean & marine data management, FP6&7 project, http://www.seadatanet.org/

SensorML - Sensor Model Language

SWE - Sensor Web Enablement

TNA -Trans National Access