JERICO-S3 INTEGRATED INNOVATIVE TECHNOLOGIES FOR COASTAL MONITORING

Eric Delory [1], Simone Marini [2], Jérôme Blandin [3], Catherine Boccadoro [4], Dominique Durand [7], Andrés Cianca [1], Joaquin Tintore [5], Jay Pearlman [6], Miguel Charcos [5], Miguel Ángel Alcalde [5], Juan Gabriel Fernandez [5], Laurent Delauney [3]

[1] Oceanic Platform of the Canary Islands (PLOCAN), Ctra de Taliarte s/n, TELDE 35200, Spain; eric.delory@plocan.eu

[2] CNR, Italy; Institute of Marine Sciences, Forte Santa Teresa, Pozzuolo di Lerici, LERICI 19032, simone.marini@sp.ismar.cnr.it

[3] IFREMER, France; 1625, Route de Sainte Anne, PLOUZANE 29280, jerome.blandin@ifremer.fr

[4] NORCE, Norway; Nygardscaten 112, BERGEN 5838, cabo@norceresearch.no

[5] SOCIB, Spain; Edificio Naorte S/N, Bloque A, planta 2, puerta 3, PALMA 07121, jtintore@socib.es

[6] IEEE, France; rue de la Tour, 14, PARIS, 75016, jay.pearlman@ieee.org

[7] COVARTEC AS, Norway, Bjørgefaret 22, FYLLINGSDALEN 5141, durand@covartec.eu

Abstract

JERICO RI, the Joint European Research Infrastructure for Coastal Observatories is an integrated pan-European multidisciplinary/multiplatform research infrastructure dedicated to an interdisciplinary appraisal of the coastal marine system environment. It is the coastal component of the future European Ocean Observing System. This Research Infrastructure is designing the future of coastal observation technology for harmonization and interoperability, advanced functionalities, cost efficiency and reliability. The technological developments of the JERICO-S3 EU project aim to strengthen and expand the infrastructure of the European network of coastal observatories. This objective will be achieved with new observing systems and platforms equipped with new technologies for interoperability, innovative sensor packages for multidisciplinary ecosystem monitoring, coupling physics, chemistry and biology. The planned technological developments consist in adapting interoperability standards, inter alia from the NeXOS and EMSODev European projects, developing on-board and on-server smart solutions for adaptive sampling, integrating technologies into dedicated sensor packages, further developing a capacity for high-frequency measurement of low trophic-level biological diversity and contaminants; hence filling critical gaps in the observation of the coastal ocean. An e-infrastructure is being developed and proof tested to integrate digital components (tools), best practices

and documentation, from observation data and data products, to methods and coastal observation services.

Keywords: Ocean, Sensors, Interoperability, Artificial Intelligence, Integration, Systems, Infrastructure, Coastal, Environment, Essential Ocean Variables, MSFD

1. Introduction

Recent updates in the definition of essential ocean variables (EOVs) and advances in technological solutions set new challenges and opportunities for coastal observations. Regional efforts are taking place at different paces throughout the world, using techniques ranging from ship-based sampling campaigns to autonomous systems, the resulting observations being then published with different degrees of interoperability, a requirement for seamless discovery, access and use of observations (a.k.a FAIRness principles). New solutions are addressed (section 2), with a particular focus on real-time services and a coastal generic instrumentation module (cEGIM), which in turn would enable so-called 'awareness', faster and more automated decision making based on observations (section 4). Improving our understanding of how marine ecosystems work, from micro to macro-organisms through finer spatio-temporal resolution or scales of observations, lead to the development of more autonomous acquisitions and processing capabilities, in response to the breadth and granularity of the problem. New sensor capabilities are a step towards this global objective (section 3). Section 5 addresses the integration of JERICO RI core virtual resources, from data to data products, training and best practices under a common environment.

2. Progress in Interoperability and Modularity – the Coastal Egim

The EGIM (EMSO Generic Instrument Module, see Figure 1) concept was developed in the EMSOdev project to meet the requirement of measuring consistently and continuously the same set of Essential Ocean Variables (EOVs) in a number of open ocean locations (Lantéri *et al.*, 2019). Building on this concept, JERICO-S3 is developing a long-term observation module able to measure a set of common coastal EOVs on the one hand and to integrate different sensor packages adapted to particular fields of study (e.g. Plankton variability, BGC Eutrophication) on the other hand.

This module, named coastal EGIM or cEGIM, is adapted to the harsh coastal environment constraints. The module is based on the Communication and Storage Front-end (COSTOF2), a platform developed by Ifremer and able to accommodate twelve sensors by providing them controlled power, a common time base, large data storage capacity, communication channels with local or remote users as well as an active anti-biofouling protection. The platform is able to work in a very low power environment.

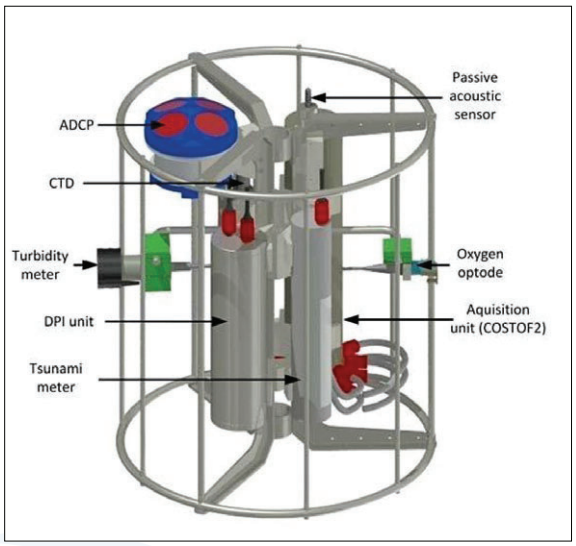

Fig.1. EMSO Generic Instrumentation Module (EGIM).

In the course of JERICO-S3, emphasis is given on the cEGIM ability to process sensor outputs in order to make appropriate decisions, such as triggering sensor acquisition (on or off), tuning acquisition parameters and sending alerts. The cEGIM will be first prototyped, tested then demonstrated in different representative environments. It will be operable up to 200 m water depth on the seabed, attached to a mooring line or aboard coastal surface buoys. Data will be delivered through a common format including Web Services based on open standards, and made accessible from the Jerico e-infrastructure. In the long run, it is hoped that a wide adoption of the same observation platform within the coastal observing community will favour interoperability.

3. Enabling Ecosystem Observing with new sensors

Coastal oceans are characterised by complex interactions and couplings between physical, chemical and biological processes. Such complex processes are often only investigated through dedicated short-term cruises, hence limiting the possibility to apprehend the high-frequency dynamics of the system. This is also limiting the current capability to appropriately model these coastal coupled processes and to catch and simulate their variabilities. In JERICO-S3, we have been mapping out recent sensor developments dedicated to biological diversity and pollutants, to be combined with well established sensor technologies into integrative multisensor packages focussing on the integration of crucial physical, chemical and biological data, and dedicated to continuously observing coastal variables in a way they provide consistent datasets on coastal processes and their natural and anthropogenic variability. Innovative

ecosystem sensors and sensor packages seek to integrate recent developments and novel technologies developed/tested in the course of the JERICO-Next project (2015 – 2019), as well as from Ocean-of-Tomorrow projects, into a common platform and data collection/analytics. Sensors are currently assessed in terms of their technology readiness level and requirements for integration into existing platforms and observing/sampling strategies. Several pelagic and benthic sensor packages adapted to specific environmental scientific and environmental questions are planned to be designed. One benthic multisensor package (ACOBS including video camera, SPI, oxygen microprofilers and eddy covariance system) is under development. One pelagic sensor package focussing on observing plankton dynamics (including hydrodynamic, hydrology, geochemistry and biology) will be integrated into the intelligent automated platform for data collections/analytics (cEGIM). To enable the integration of biological data for which sensors have not yet reached the required level of maturity or to be routinely integrated into *in situ* automated platforms, JERICO-S3 will develop a water sampling and preservation unit based on recent technologies, aiming at a future integration into sensor platforms and triggered through the cEGIM (see sections 2 & 4), to collect, filter and preserve diverse contaminants (heavy metal, plastics, pharmaceuticals) and the DNA from seawater samples for later laboratory analysis of microorganism communities (algae blooms, microbial species), and biological diversity (omics for targeted functional genes and molecular pathways, metabarcoding, eDNA).

4. Enabling Self-Assessment through artificial intelligence

Underwater observatories are a remarkable case of data-rich environments, as a consequence data science and artificial intelligence approaches are gaining a growing consensus in the marine science and technology community. Autonomous platforms will create an important increase in the production of data (European Marine Board, 2020) and the need for novel and effective technologies, creating a paradigm shift from the traditional vessel-assisted, time-consuming and high-cost sampling surveys (Farcy 2019, Aguzzi 2019). Data science and artificial intelligence methodologies studied in JERICO-S3 are aimed at improving the observing capabilities of the infrastructure by defining and implementing both a set of intelligent services for the coastal EGIM, and a set of data processing tools accessible or deployed on the JERICO-S3 virtual access eInfrastructure. The intelligent services may be executed on board the coastal EGIM or in a land laboratory after the data have transferred from the module. The coastal EGIM will be equipped with an embedded processing unit allowing for the onboard execution of specifically developed data processing algorithms that will be the basis for the automated intelligent services. According to the observed environmental conditions, the proposed services will identify and select relevant information from the acquired data and, based on the analysis of such information, will be capable of activating sensors and samplers, and adaptively change their configurations (e.g. sampling frequency, resolution). The effectiveness of such services will be demonstrated in an application context mainly dealing with plankton dynamics. Algorithms for multivariate time series analysis (e.g. gap filling, change point

detection, feature detection, multivariate modeling), will be combined with algorithms for cytometry, active and passive fluorimetry data analysis.

5. Integrating virtual resources under a common environment: eJERICO / JERICO CORE

e-JERICO expands the capabilities of JERICO by providing a comprehensive catalog of inter-related coastal resources to facilitate web access to a wide range of data, tools, software, BP and documentation. This coastal observing resource environment is critical to provide the different users and stakeholders with the appropriate information and tools for their needs. The conceptual design of e-JERICO accounts for the current scenario of JERICO where resources are distributed among partners and non-JERICO systems. The core of the system, illustrated in Figure 2, is built on adaptation of the EPOS operating system adapted for the coastal marine infrastructure and resources.

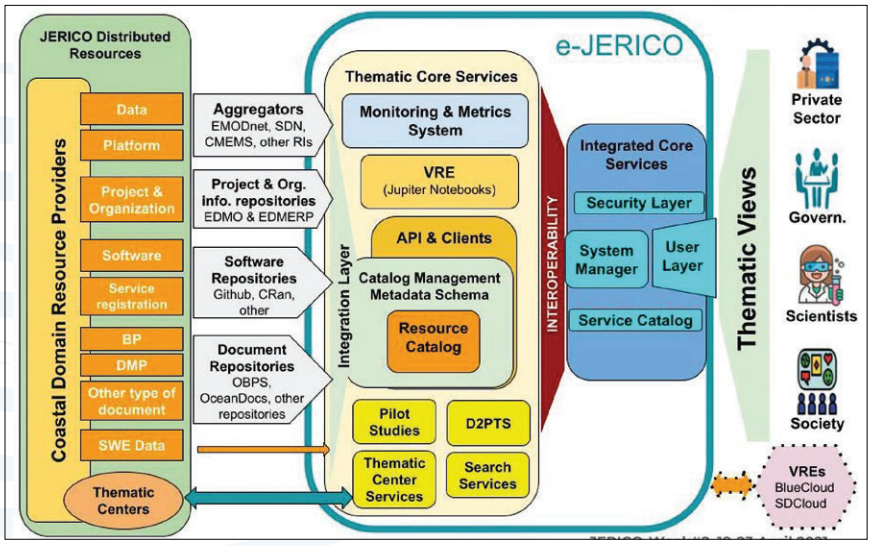

Fig. 2. e-JERICO conceptual design.

6. Demonstration Objectives

In situ demonstrations will bring the developments described in the above sections to an end-to-end field demonstration. The demonstration plan initially performs several tests which will take place at PLOCAN facilities in the Canary Islands (Spain). PLOCAN will perform on-shore and coastal tests of the cEGIM before engaging in costly and more risky field operations. System functionalities will first be tested in a seawater

tank, then in the waters of Taliarte Port, connected by cable (estimated test duration is about a week). The cEGIM will then be moved to PLOCAN marine test site, moored in 50 m depth (estimated deployment time is one month). Interoperability, new sensors and methods (automated sampling), and the coupling of multi-compartment measurements (physics, biogeochemistry, biology) will be tested. Once the cEGIM has been functionally tested at PLOCAN facilities, it will be moved to a regional site, as selected for the demonstration according to scientific and technical criteria (e.g. impact and logistics). Results of the demonstration will be made accessible from the eJERICO infrastructure (Section 5).

7. Summary

The coastal marine environment is complex. Yet many resources for human well being come from the coast as well as risks for coastal communities. JERICO RI is focused on providing a foundation for applications and informed policy and decision making. Advances in observation technology and access to data and information are key to provide a comprehensive and trusted resource. This paper addressed steps evolving under the JERICO-S3 project, from sensor and data interoperability, addressing the biological dimension from autonomous sensors and adaptive sampling, and the integration of all resources to advance knowledge under a common environment, connected with external data brokers, services, and users.

Acknowledgements

JERICO-RI is the European coastal observing research infrastructure established and structured through JERICO-FP7 and JERICO-NEXT, JERICO-S3 and JERICO-DS projects. JERICO-FP7 is the European 7th framework project named JERICO under Grant Agreement N° 262584.
JERICO-NEXT is a European Horizon-2020 project under Grant Agreement N°. 654410.
JERICO-S3 is a European Horizon-2020 project under Grant Agreement N°. 871153.
JERICO-DS is a European Horizon-2020 project under Grant Agreement N°. 951799.
EMSOdev is a European Horizon-2020 project under Grant Agreement N°. 676555.
NeXOS is a European FP7 project funded under Grant Agreement N°. 614102.

References

Aguzzi, J., Chatzievangelou, D., Marini, S., Fanelli, E., Danovaro, R., Flögel, S., Lebris, N., Juanes, F., De Leo, F.C., del Rio, J., Thomsen, L., Costa, C., Riccobene, G., Tamburini, C., Lefevre, D., Gojak, C., Poulain, P.-M., Favali, P., Griffa, A., Purser, A., Cline, D., Edgington, D., Navarro, J., Stefanni, S., D'Hondt, S., Priede, I.G., Rountree, R., Company, J.B. (2019) New High-Tech Flexible Networks for the Monitoring of Deep-Sea Ecosystems. *Environmental Science and Technology*, 53 (12), pp. 6616-6631

European Marine Board – Working Group on Big Data in Marine Science (2020). Big Data in Marine Science. *European Marine Board IVZW Future Science Brief 6*, April 2020. https://www.marineboard.eu/publications/big-data-marine-science

Farcy, P., Durand, D., Charria, G., Painting, S.J., Tamminem, T., Collingridge, K., Grémare, A.J., Delauney, L., Puillat, I. (2019) Toward a European coastal observing network to provide better answers to science and to societal challenges; the JERICO research infrastructure. *Frontiers in Marine Science*, 6 (SEP), art. no. 529

Lantéri N., Legrand J., Ruhl H., Blandin J., Cannat M., del Rio Fernandez J., Gates A., Lagadec J.R., Moreau B., Pagonis P., Sarradin P.M. (2019) The EGIM, EMSO Generic Instrument Module, step towards standardization. E*uropean Geosciences Union General Assembly*, 7-12 April 2019, Vienna, Austria.