TOWARDS A COST-EFFICIENCY DESIGN
of ocean observation and prediction infrastructures: examples of **knowledge-based support to decisions.**

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WHAT, WHERE, WHEN…and how much does it cost? We reflect on the relevance of introducing knowledge in support of cost-efficiency design of ocean observation and prediction infrastructures.

INTRODUCTION

Research Funding Organizations invest large part of their budget in **Research Infrastructures** (RI), whose maintenance and upgrades require a **careful evaluation of costs and impacts**, in order to guarantee their long-term sustainability. National efforts rarely can afford large-scale infrastructures. The European Union has successfully launched the ESFRI (European Strategy Forum on Research Infrastructures), adopted the ESFRI roadmap and carried out substantial work on the prioritization of support to ESFRI projects for implementation, which was acknowledged by the Council in May 2014. A system mainly based on national RIs (and nationally funded international RIs) is evolving into a truly European open system of RIs, used by European researchers and attractive for non-European users. Therefore, European strategies need for a systemic approach, which takes into account the overall landscape and different levels of governance and responsibilities. RIs success depends also on international benchmark, as several countries in the world are investing in new highly competitive facilities and technologies. By pooling efforts, European countries can achieve excellence in highly-demanding scientific fields, build the European Research Area (ERA), provide common and accessible services for boosting economy and for social needs.

Seas and Oceans address complex systems: **understanding and forecast of the dynamics are a difficult task**. The multi-scale and nonlinear nature of the ocean dynamics dramatically affects the spreading of matter, like pollutants, marine litter, etc., of physical and chemical seawater properties, and the biological connectivity inside and among different basins. Assessments of consequences on society and industrial sectors, and viceversa, are necessary for policy makers to manage human activities and the exploitation of resources. Local approaches are rarely effective and wider vision is needed, often implying international cooperation. Marine RIs aim therefore to be established on a global level, and capable to collect and analyze the huge amount of data they provide.

Data can definitely help in the description of this complexity, but the inference of laws and the accurate predictions struggle with the difficulty of identifying relevant variables (Lorenz, 1995, Boffetta et al. 2002, Cecconi et al. 2012). Too much information indeed tends to behave like very little information. The scientific method can be enriched by computer mining in immense databases, but not replaced by it (Calude, 2016).

Earth observing systems, in particular when dealing with seas and oceans, need essential variables to be identified, to complement the design of the appropriate geographical coverage, and the specifics for spatial and temporal resolution. Satellites, vessels, fixed buoys and automated unmanned vehicles with continuously development of sensors are therefore all contributing to data sampling, but funders and policy makers ask for a breakthrough able to avoid unnecessary duplications, increase cost-efficiency and provide usable information. **An intervention logic for the observing systems**, which can in turn result in a deluge of useless data, is urgently needed as a support to policy, as requested by the United Nations (SDGs), the G7 (Future of the Seas) and the EU recent international agreements (such as the Belem one) for an increased volume of data sampling in Seas and Oceans.

We reflect on the results of the analysis of available near-surface data sets (as from the European Earth Observation Programme Copernicus or the Global Drifter Program and the SeaDataNet hydrographic database) which has provided relevant clues in simplifying the complexity of ocean dispersion characteristics and mixing processes.

This can support observing effective strategies and suggest pathways for a closer cooperation between researcher, funders and policy-makers, in a shared value based on knowledge, feasibility and impact.

The economy of ocean observations

Huge efforts have been done (and are still needed) to develop networks for the Global Ocean Observing Systems as well as operational and monitoring frameworks all over the world. These systems should encompass activities related to the production and use of operational services and promote the visibility and recognition of the services with governmental agencies and private companies, also encouraging their integration at national, regional, European and global levels. They also address the development of downstream services aimed at supporting decision systems for sustainable use of marine space and resources. In particular, they should focus on the involvement of the non-EU countries, in seeking to reinforce trans-national cooperation. Network of observation and forecasting systems offer a wide range of products. Satellite, modeling, and in situ observations are the key components of such a framework, covering a wide range of platforms, sensors, and theoretical-based capacity.

WHAT

Sensors, on board of platforms, provide a huge diversity of measurements, constituting the available dataset to be analyzed and interpreted. This brings to those environmental parameters and/or essential variables that feed a wide range of products: wave height, sea level, temperature, salinity, currents, biogeochemical (pH, chlorophyll, oxygen, etc.) and sedimentological tracers.

Their role is to recognize and monitor hotspots for biodiversity, marine connectivity and thermoaline balances, heat gradients and fluxes, heterogeneity of abiotic/biotic factors, and pollution. Those products are engaged in activities related to the production and use of operational services. From all this, the scientific community provides indicators and trends at different spatial and temporal scales. Further efforts should therefore focus on the harmonized and knowledge-based use of those systems, targeting those parameters, variables, and areas that are relevant for capturing WHAT is really need to fulfill end-users' needs.

Testing well-posed, knowledge-based hypotheses through ad hoc, localized (space- and/or timewise) measurements are able to reveal crucial dynamics, phenomena, and indicators that can be extend to broader scales. For instance, ad-hoc analyses of Temperature and Salinity profiles, collected over a specific areas (analysis of CTD casts, Artale et al., 2017), as well as the Lagrangian analysis of differential quantities (i.e., scale-dependent

separation rate of the adjacent tracers), performed over representative basin (analysis of NOAA GDP drifter data, Corrado et al., 2017), revel fundamental mechanism concerning mixing and diffusive properties at global scale. **Essential ocean variables can be therefore identified to describe specific dynamics common to all basins**.

WHERE

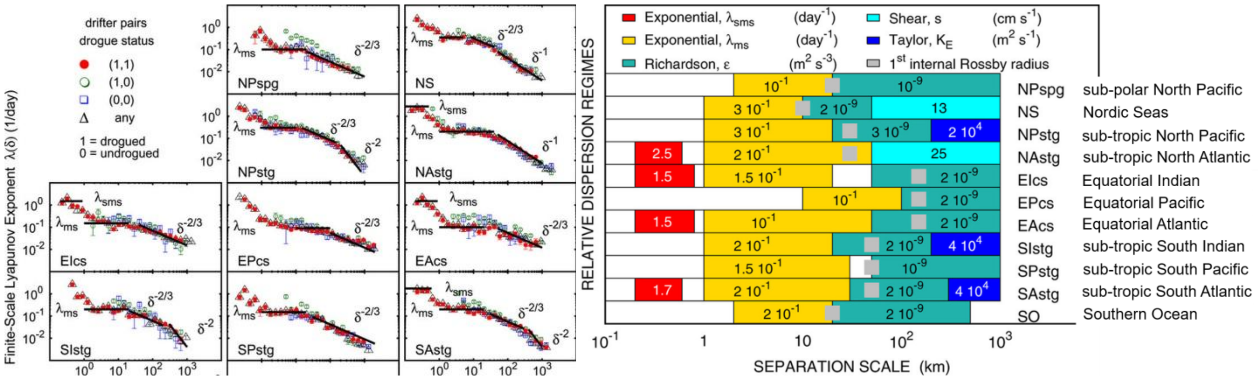
For the two case studies (Artale et al. 2017, Corrado et al. 2017), we consider: a) link between mixing processes of the abyssal Ionian Sea and the Mediterranean climate variability, b) general and universal characteristics of relative dispersion in the ocean.

The first case uses a well-posed hypothesis on local mixing due to bottom roughness in order to understand the deep thermohaline circulation at multi-decadal scale for the whole Mediterranean basin. Testing hypotheses that are based on theoretical knowledge, reveals fundamental mechanisms for a proper understanding of basin (or global) scale changes and hysteresis processes. **Knowledge can restrict the sampling areas and techniques**.

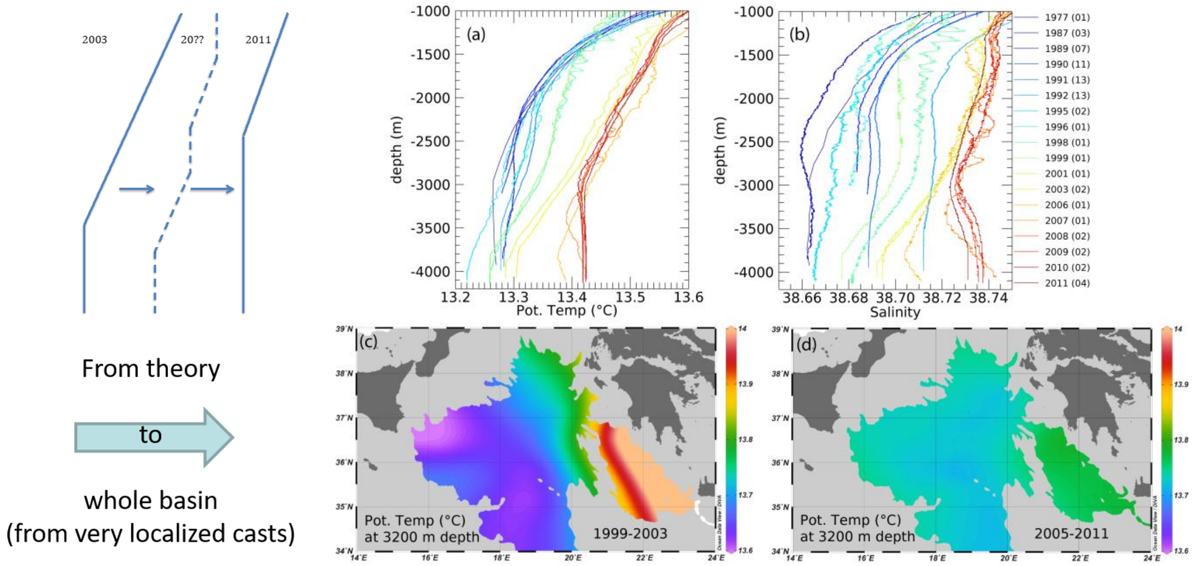
The second case explore ocean surface Lagrangian dynamics, by measuring differential quantities (i.e., separation rate of two adjacent tracers, computed on the Global Drifter Program data set subdivided in eleven ocean basins).

It results that separation rates have a quasi-universal character for every ocean sub-system.

Basic indicators of relative dispersion have similar values (i.e. same order of magnitude) everywhere and the dispersion regimes display only a few fundamental scaling laws.



Separation rate of two adjacent tracers, computed on the Global Drifter Program data-set subdivided in ocean basins (Corrado et al.**)**



One station can represent the behavior of the whole basin: the case of Mediterranean (Artale et. al)

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CONCLUSIONS

In times of fiscal constraints, the need of avoiding the fragmentation of investments has often suggested to concentrate resources on a smaller number of world class RIs, capable of impacting on knowledge advances and socio-economic system. Indeed, the **design of RIs is crucial in their economic sustainability and to fulfill the expected results**.

For this reason, the analysis of what effectively an infrastructure has asked to offer is mandatory to identify the most effective and efficient design. Since technologies and sensors continuously evolve, relevant aspects to be addressed need to be carefully selected in a long-term perspective. For ocean observations, **essential ocean variables are definitely to be addressed**.

We presented scientific results for different examples: our analysis demonstrates 1) that, despite the large variety of flow features present in the ocean, relative dispersion can ultimately be described **by a few parameters common to all ocean sub-basins**, and 2) the inherited link between local mixing processes and the whole basin climate variability.

What we present can constitute a case study on **how scientific evidence and knowledge can support policy decisions** in terms of strategies for the implementation of research infrastructures, also in the view of cost-savings and effectiveness of products. Taking into account that the majority of EU Programmes for Earth Observations (as Copernicus) involve EU Commission, Member States, ESA, EU Agencies and national stakeholders, we propose a coordination of efforts, also through JPI Oceans, to support and promote the trans-national dialogue and cooperation between researchers, funding organizations and policy makers, in order to make **scientific results to be translated into responsible advice for high-level decisions and facilitate the design of future needs for national, EU and global ocean infrastructures**.