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Cost and value of multidisciplinary fixed-point ocean observatories

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ABSTRACT

Sustained ocean observations are crucial to understand both natural processes occurring in the ocean and human influence on the marine ecosystems. The information they provide increases our understanding and is therefore beneficial to the society as a whole because it contributes to a more efficient use and protection of the marine environment, upon which human livelihood depends. In addition the oceans, which occupy 73% of the planet surface and host 93% of the biosphere, play a massive role in controlling the climate. Eulerian or fixed-point observatories are an essential component of the global ocean observing system as they provide several unique features that cannot be found in other systems and are therefore complementary to them. In addition they provide a unique opportunity for multidisciplinary and interdisciplinary work, combining physical, chemical and biological observations on several time scales. The fixed-point open ocean observatory network (FixO3) integrates the 23 European open ocean fixed-point observatories in the Atlantic Ocean and in the Mediterranean Sea. The programme also seeks to improve access to key installations and the knowledge they provide for the wider community, from scientists, to businesses, to civil society. This paper summarises the rationale behind open ocean observatories monitoring the essential ocean variables. It also provides an estimate of the costs to operate a typical fixed-point observatory such as those included in the FixO3 network. Finally an assessment of the type of data and services provided by ocean observations and their value to society is also given.

1. Introduction

Sustained ocean observations are crucial for a variety of reasons, but their value is often not well recognized by the general public in comparison to, for example, meteorological observations. Unlike in meteorology, where requirements for data and services are largely driven by their contribution to protection of life and property, there is as yet no single big issue of immediate public concern to drive a variety of ocean observations in a sustained manner spanning multiple funding and political cycles [7]. This means that national governments see no compelling reason to invest sufficiently in observing the ocean, a global commons, and a large proportion of observations remains mostly funded through short-term research-driven programmes [14].

As the benefits of sustained ocean observations are often unclear because they seem not to produce products of direct relevance to society, the analysis of the benefits deriving from ocean observatories products is useful to clarify the value of these data and services. Ocean data are important via their contribution to increased forecast model skill and to the improvement and validation of forecast models. Among the applications are: ocean and climate prediction, prediction of tsunamis, storm surges and ocean waves, sea-ice monitoring and prediction, and future climatologies. Operational applications, on time scales of days to weeks, include coastal and offshore engineering design, ocean forecasting related to national defence and civilian protection, shelf and coastal predictions, information for maritime and off-shore industries, safety and search and rescue. Climate prediction involves understanding the links between ocean and atmosphere [7].

Cost-benefit analyses have been carried out for some ocean observing systems, e.g., Seawatch Europe, TOGA, the Integrated Sustained Ocean Observing System in the United States, and Ocean Network Canada, with the aim to discuss their value in relation to the services they provide or are planned to provide. The general

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conclusion of these reports is that the benefits of investing in sustained ocean observations are expected or proven to be higher than the costs, especially on the long-term and if the outcoming information is used by the largest number of end-users (Table 1).

The information synthesised by previous cost-benefit analyses however is limited. The benefits of a well-coordinated programme of ocean observations are widely accepted, but the ability to quantify these benefits remains a challenge [18]. Estimates of economic benefits from ocean observing activities to date have largely been based on simple assumptions about the improvement that better information may be able to generate in the aggregate level of economic value produced by commercial and recreational marine activities [11,12].

International efforts to establish and sustain continuous ocean observations started in the late 1980 s and comprise a variety of systems all contributing to the Global Ocean Observing System (GOOS).[1] GOOS is a permanent global system for observations and analysis of marine and ocean variables to support operational ocean services worldwide. It provides accurate descriptions of the present state of the oceans, including living resources, continuous forecasts of the future sea conditions, and the basis for forecasts of climate change and variability. GOOS is an international multipurpose initiative, providing the ocean part of the Global Climate Observing System (GCOS).[2]

Within GOOS, OceanSITES[3] is the worldwide system of long-term, open ocean reference stations monitoring the full depth of the ocean, from air-sea interface down to 5000 m. The network complements other in situ observation data by extending the dimensions of time and depth.

The Fixed-point Open Ocean Observatory Network (FixO3)[4] is the European contribution to OceanSITES. The network integrates 23 fixed-point ocean observatories in the Atlantic Ocean and the Mediterranean Sea providing a quantity of multidisciplinary marine measurements. The network includes all the European fixed-point observatories that provide multidisciplinary observations on long term in the open ocean and that represent well the surrounding area. The project is an international collaboration of 29 partners funded by the European Commission over four years started in September 2013. The main objectives of the programme are: (1) to provide high-quality ocean data open to the public, (2) to improve access to these infrastructures and data products and (3) to research better ways to make observations and link these to data from other observing systems.

Recognizing that a full estimate of the cost incurred for operating a fixed-point ocean observatory is difficult, as is an assessment of the economic benefits deriving from Eulerian observations, this paper wants to:

1. Emphasise the rationale behind Eulerian time series monitoring essential ocean variables (EOVs).
2. Provide an estimate of the costs for a typical open ocean observatory of the kind of those included in the FixO3 network.
3. Examine the services and products derived from Eulerian ocean observations such as those provided by observatories within the FixO3 Network.

The paper is directed at the European Commission (as the FixO3 project funding entity), as well as to governments of countries supporting sustained ocean observations and policy-makers in general.

The structure of the paper follows its objectives. In the next section the EOVs are defined and the unique benefits of Eulerian observations are emphasised.

The third section gives an estimate of the running costs of a typical fixed-point observatory such as those included in FixO3. An approximate evaluation of the annual cost for the whole network is also provided in comparison to the financial contribution from the European Commission.

The fourth section provides an assessment of the data products and services provided by ocean observations to examine the purpose of using this kind of ocean observation, who are the end-users of the outcoming information, and what type of benefits ocean observations provide.

The fifth and last section summarises the paper's conclusions and recommendations.

2. Rationale for Eulerian observations

Long-term observations of the chemical, biological and physical properties, circulation intensity and patterns, and of the exchange of heat, freshwater, and momentum between the ocean and the atmosphere are essential to understand the ocean's role in the global climate. The GCOS established a list of the Essential Climate Variables (ECVs) that are both currently feasible for global implementation and have a high impact on the requirements of forecasting climate change. For the oceans these are listed in Table 2 as provided in the Second Report on the Adequacy of the Global Observing System for Climate in support of the UNFCCC [26].

More recently the Framework for Ocean Observing (2009) supported a refinement of observing requirements that respond to societal needs for ocean information in the context of: 1) climate (e.g. ocean temperature for warming, carbonate system for CO_2 uptake); 2) biodiversity (e.g. bio-optics for algal taxa); 3) fisheries (e.g. ocean circulation, temperature, salinity and oxygen for larvae dispersion and development); and 4) private sector activities (e.g. sea floor mapping for resource extraction, storm surge statistics for offshore installations, low oxygen occurrences for offshore aquaculture).

Within GOOS, three panels provide advice on EOVs for physics, biogeochemistry and biology and ecology, respectively. While the physical variables have been defined over a period of more than 20 years since before the initiation of GOOS and GCOS, the EOVs for biology and ecosystems are still under discussion aiming to have a similarly developed list as for physics in 2019. The increased attention to ocean health, biodiversity and human interactions with the marine environment suggest an increasing role in the future for multidisciplinary observatories similar to those operated in FixO3.

EOVs are monitored in a variety of ways and with a variety of instruments, including satellites, gliders, floats, ships and fixed point (Eulerian) observatories.

Eulerian observatories are unmanned platforms which incorporate sensors for in situ measurements of water and sediment properties or for monitoring of processes. They may also collect samples of water, fauna or solids. This has the advantage of shared logistics and possibility for interdisciplinary observations such as on the relationship between physical, chemical and biological properties. Eulerian observatories provide a direct means to examine the complex interrelations between processes and properties at various scales. They allow for a more comprehensive understanding of the properties of different components of a system that vary in time to gain insight into the interactions between the different components, and therefore of how the system functions as a whole. They also help determine if the system is changing on a longer time scale, which may be related to anthropogenic activity [13].

[1] http://www.ioc-goos.org/.
[2] http://www.wmo.int/pages/prog/gcos/index.php.
[3] http://www.oceansites.org/.
[4] http://www.fixo3.eu/.