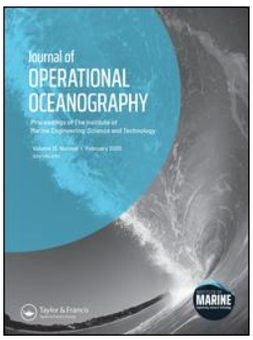

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SOCIB integrated multi-platform ocean observing and forecasting: from ocean data to sector-focused delivery of products and services

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ABSTRACT

In the last 10 years, new monitoring and modelling technologies have emerged allowing real-time observation and forecasting of the coastal ocean at regional and local scales. These technologies are at the core of multi-platform integrated observing and forecasting systems, such as the Balearic Islands Coastal Ocean Observing and Forecasting System (SOCIB). New capabilities to characterise the state of the ocean and its variability at finer spatial and temporal scales are emerging, supporting science and products for society.

SOCIB has a well-defined mission to deliver ocean observing for the benefit of science and society. From initiation in 2010, SOCIB has provided high-quality, free and open data. In order to increase our utility, we developed a Products and Services Strategy rooted in business best practice. Ten sectors – groups of users with common data needs – were identified, for which SOCIB has information and knowledge of high value. Dedicated products were developed in cooperation with the end-users: beach lifeguards/managers and sustainable marine resources managers. We illustrate an integrative approach, combining business concepts with collaborative software development methodologies and ocean observing science, to turn ocean observations and forecasts into products and services, with benefits for society in the sustainable blue economy era.

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1. Introduction

The ocean is linked to human livelihoods and quality of life in numerous ways. From its role in modulating the climate, to how it provides a variety of social, cultural and economic benefits, the ocean contributes significantly to human well-being. It influences weather and climate, impacting many sectors, such as agriculture, marine and coastal activities, marine ecosystems, tourism, and the hazard response to severe storms, coastal flooding or harmful algal blooms. Oceans and climate are inextricably linked and oceans play a fundamental role in mitigating climate change by serving as a major heat and carbon sink. Human induced climate change threatens coastal and marine ecosystems through, for example acidification, changes in weather patterns and water temperature. These changes impact the health of our oceans, marine species, ecosystems services and coastal communities. Today, the interrelationship between oceans and climate is recognised and increasingly incorporated into policies contributing to bridge the science-policy gap.

Observing the ocean is necessary to predict the climate evolution of our planet, to preserve healthy and sustainable oceans for future generations, and to support and strengthen a sustainable Blue Economy.[1] The Blue Economy is predicted by the OECD to reach $3 trillion by 2030, which is more than double its current contribution to the global value-added economy. It is part of the economic future of most countries with coastline resources, and for some, such as Small Island Developing States (SIDS), it is at the core of their economic future.

A better understanding of ocean variability and ecosystem response, as well as human impacts and vulnerabilities, requires the integration of ocean science and the coordination of a sustained system of ocean observations; at different scales, covering from the nearshore to open ocean, and across physical, biogeochemical and ecosystem variables.

We have seen an increasing number of assessments that place observations at the base of a value chain, stretching from ocean observation through to societal applications, for an example see the EU-H2020 Atlantic

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Observing System Project (AtlantOS) linking sustained ocean observations with societal benefit.[2] Ocean data portals (e.g. Copernicus Marine Services and EMODnet), with streams of high-quality data available for download, have developed to serve scientists, expert users and the developers of downstream services. Most of the European observing infrastructures (e.g. JERICO, EMSO-ERIC, EuroARGO ERIC) are also delivering their data through these portals. They are a valuable source of data for value creation but are less well known by the wide range of potential users that could benefit from the data and forecasts. How do we move beyond this and broaden the appeal of ocean data, knowledge and research outcomes? How do we better connect end-users into these data streams? How can we serve more and different users?

The community gathering these data is only now starting to identify how this wealth of multi-platform data can be turned into use for the benefit society beyond the traditional science and marine weather forecast applications. This is at least in part because users are not well identified or because the identification of the needs of users, except marine scientists, are only accounted for at the end of the process and not as a driving force.

SOCIB (ICTS SOCIB – Sistema d'observació i predicció costaner de les Illes Balears, Tintoré et al. 2013) is a multi-platform and integrated ocean observing and forecasting system, based in the Balearic Islands. SOCIB is a key European example of advanced operational ocean observing systems that are leading a new era of ocean observation, supporting key grand challenges that society is facing, in particular climate change, sustainable ocean resource and blue growth. SOCIB is an integrated facility of facilities that has evolved and continues to evolve, to promote the paradigm shift that has occurred in ocean observation and data availability (Delaney and Barga 2009; Tintoré et al. 2013): namely from the historical, single platform ship-based observation with delayed mode data availability to the current multi-platform, integrated and multidisciplinary observing systems (Figure 1). SOCIB provides streams of data, added value products and forecasting services from the coast to the open ocean.

The objective of this paper is to present the development of a sector-focused Products and Services Strategy at SOCIB, with the aim of increasing the use of data and knowledge developed from its observing and forecasting system.

2. SOCIB: responding to science and societal needs

SOCIB uses state-of-the-art and emerging technologies in order to better characterise ocean state and variability at different scales, from local to regional, and basin scales, in many cases in real time. A great challenge in this field for the next decade is the full integration of multi-platform/multidisciplinary ocean observations with ocean forecasting systems, to monitor the variability at small scales (e.g. mesoscale/weeks) in order to resolve the sub-basin/seasonal and inter-annual variability and

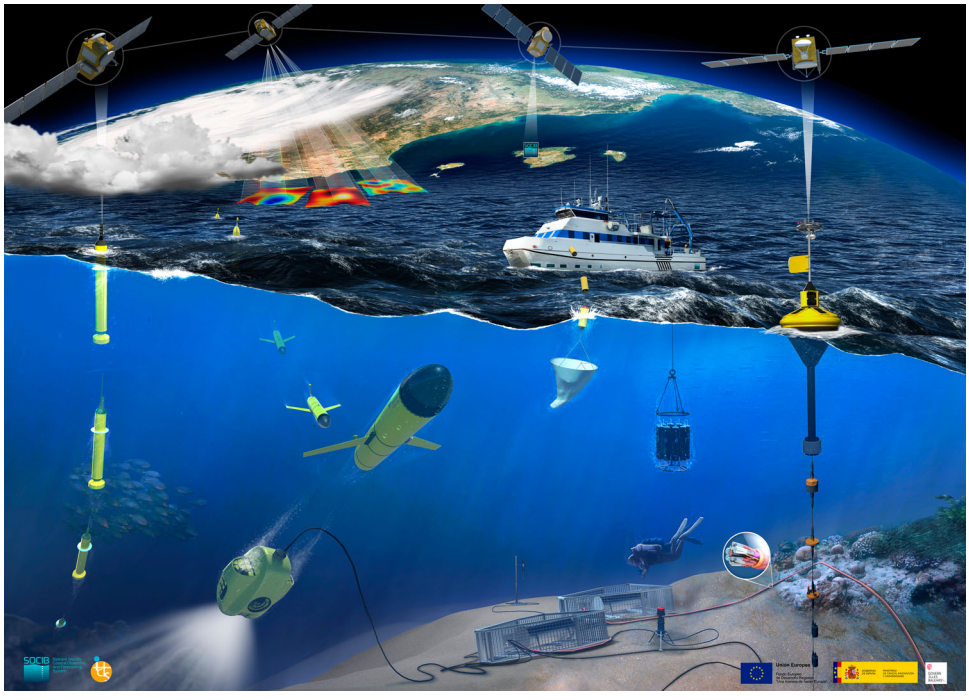


Figure 1. SOCIB a multi-platform observing and forecasting system.

through this establish the decadal variability, understand the associated biases and correct them. A major challenge is to advance from small to large scales, as observing and forecasting systems now enable this change of focus, from events to climate.

SOCIB is driven by three main priorities: scientific excellence, technological advancements and strategic societal priorities. SOCIB activities are well aligned with the Global Ocean Observing System (GOOS) that coordinates the delivery of global ocean observations around three themes: climate, ocean health and operational services. In Europe, we contribute, with its know-how, best practices and service-oriented approach, to JERICO-NEXT (the joint European Research Infrastructure for Coastal Observations), the European Multidisciplinary Seafloor and water-column Observatory (EMSO), Euro-Argo (the European contribution to the Argo program), and supports the future European Ocean Observing System (EOOS).

SOCIB operates a complex network of (1) observing platforms for long-term monitoring of physical and biogeochemical processes in the Western Mediterranean, (2) modelling and forecasting systems and (3) well-focused, intensive, process studies. The network of platforms includes surface and profiling drifters, fixed platforms (moorings, coastal stations), a research vessel, high-frequency radar, animal-borne instruments, autonomous underwater gliders and coastal monitoring stations and beach surveying campaigns. Continuously recorded multidisciplinary data are transmitted to the SOCIB Data Centre, and quality-controlled data are made available, freely and openly, for science, education, authorities, industry and the general public.

SOCIB focuses on scientific excellence with relevance to and impact on society. Since 2011, the team has contributed to 110 papers in peer-reviewed international journals, participated as a partner in 10 projects, including EU-FP7 (JERICO-FP7), EU-H2020 (PERSEUS, JERICO-NEXT), and other international projects such as Copernicus Marine INSTAC, EMODnet MedSea-Checkpoint and ODIP2. As an extension to its scientific and operational activities, SOCIB also undertakes significant outreach, providing visibility in the international landscape of new ocean observing systems and developing education materials. The SOCIB Outreach Service promotes ocean literacy and raises awareness on the impact of modern ocean observing systems on the advancement of knowledge, science-based management and the subsequent preservation of marine and coastal resources.

A summary of SOCIB outputs across the observing, forecasting, data centre facilities and outreach can be seen in Figure 2. The knowledge, data, operational forecasting

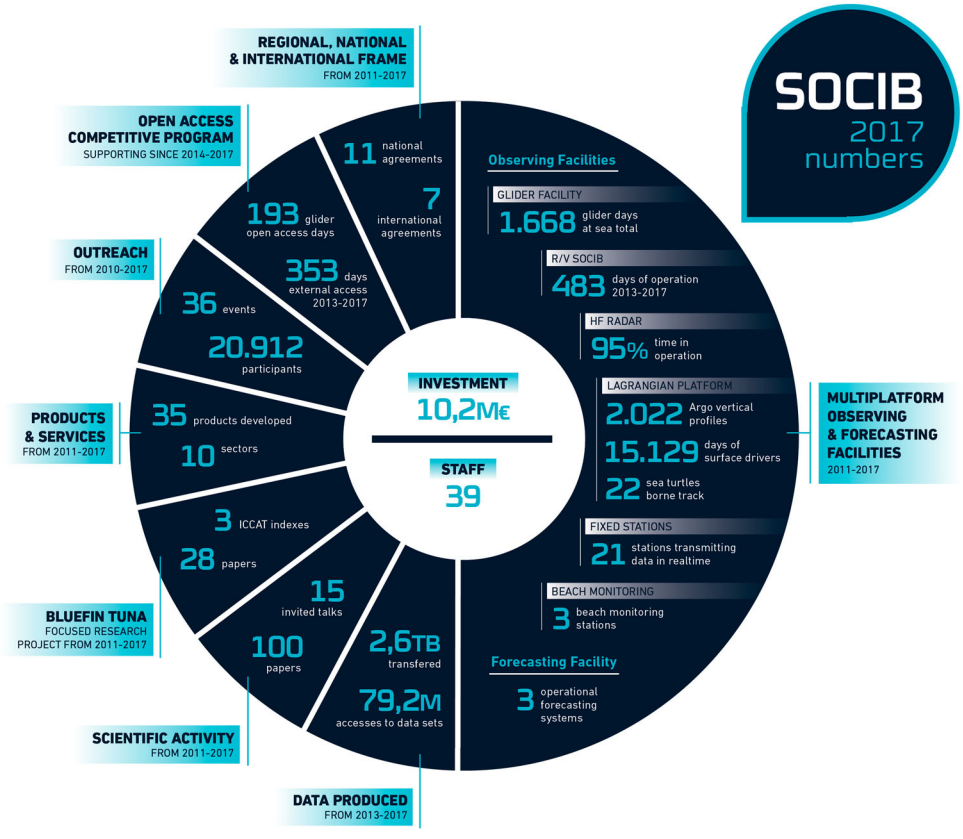


Figure 2. SOCIB by numbers 2018.

capabilities, tools and products developed to date are an indication of SOCIB achievements. Since 2015, SOCIB has also developed and implemented a sector-focused Products and Services Strategy, as presented in this article, in order to broaden the use of its data, forecasts and knowledge within societal end-users.

3. A SOCIB products and services strategy

SOCIB's mission, to serve both science and society, initiated the need to develop a more comprehensive strategy for its data products and services. With multi-platform observations, high-resolution modelling and a data centre SOCIB is a 'complete' observing system on a regional scale and therefore an ideal laboratory to understand how to make the last link in the observing data value chain, from data to regional societal end-users. And in doing so create more value from the investment in ocean observations and forecast.

There are examples of ocean observatories successfully creating great value for end-users in focused projects, e.g. Irish Marine Institute for regional aquaculture (Dabrowski et al., 2016), SOCIB Bluefin Tuna project for ICCAT (Alvarez-Berastegui et al., 2016, Reglero et al., 2018), IOOS MARACOOS for butterfish population modelling,[3] Prooceano using gliders to monitor deep eddies that impact oil field operations[4] and the observing system response to the Deepwater Horizon oil spill. These are excellent examples, but in a sense are based on existing science norms, research or rapid response projects with key outcomes. How do we now move beyond this and broaden the appeal of data, knowledge and research outcomes? How can greater value be created from the increasing wealth of ocean data and knowledge that is being collected and developed for the benefit of science and society?

These questions were raised at SOCIB, where despite developing a broad range of high-quality freely available datasets, and having developed dedicated applications for visualising data, after 2 years of operational capacity (2013–2015) there was no clear evidence of widespread use of the data beyond the regional scientific community. Although many of the scientists were using SOCIB data for societally relevant investigations, there was a belief at SOCIB that the data could additionally offer more direct and real-time benefits to end-users.

To understand how to deliver more to more societal end-users, SOCIB developed a Products and Services Strategy. To do this we took an innovative approach, combining business best practice, innovation and science. The business best practice follows new market and start-up development concepts (e.g. Crossing the Chasm, Geoffrey Moore, 1991), and mainstream business strategy concepts (e.g. What is Strategy? Michael Porter, HBR The Essentials, 2011). The start-up concepts are also useful here as although there are some existing ocean data products and great potential, they are not yet in mainstream use. The strategy implementation used complimentary methodology and concepts from Agile software development.[5]

The Products and Services Strategy encompassed four general stages:

1. Defining aims, guiding principles and a goal
2. Review of internal and external factors
3. Identification key sectors, priorities and product ideas
4. Strategy implementation: existing products and new product development.

Stages 1, 2 and 3 were undertaken during 2015 and 2016, and stage 4 was initiated in 2017, following the delivery of the Products and Services Strategy. Below we outline these stages as a potential reference for similar initiatives.

3.1. Defining the aims, guiding principles and a goal

The aims and guiding principles were discussed early in the strategy process, and as strategy is an iterative process, were modified as awareness of the ocean services area developed. They guided the development and implementation.

The aims of the P&S Strategy were defined as follows:

- gain more users
- collect/create once, use multiple ways
- increase utility to science and society
- deliver more knowledge/Intellectual Property (IP) to users
- communicate what we provide in a coherent way
- guide development and resource allocation
- speed/enhance our capacity to innovate
- coordinate activities, and thereby increase internal efficiency and external impact
- educate on value of ocean data/SOCIB observing system
- demonstrate effective use of public funds to government (regional/national)
- enhance end-user experience.

The accompanying guiding principles were defined as:

- use SOCIB competency, knowledge and IP
- innovate and avoid duplication, particularly with commercial sector
- design carefully and well
- support the blue economy in a sustainable manner

- open access and open source, where relevant develop transferable technology
- evolve as new needs identified and new knowledge developed.

Our goal was articulated as: to create smart ocean products from our observing system and intellectual property that add value to decision making and are actively used by target scientific and societal customers.

In order to deliver on these aims, a user-based approach is required. In brief, the business logic behind this approach is, if you do not have a sector or a defined set of users for your products, with common needs that you can fulfil, then you cannot communicate effectively or guarantee that you have something to offer, and so have very little control over a successful outcome. It is possible to leave it to chance in the hope that your product will, for example, go viral. However, that is a gamble and companies in general do not gamble, if they want a product to go viral they work at it. At the same time, this end-user focus needs to be balanced against the organisations resources and core competencies, in order to select a 'sweet spot' between market demand, ability to deliver and value/benefit to society.

Putting end-users at the core of the SOCIB Products and Services strategy, in combination with a clear understanding of our abilities and value (externally and internally driven), was needed and this concept informed the next steps.

3.2. Review of internal and external factors

To inform the strategy development, a review of internal and external factors was undertaken; through web-based research, publication review, discussions with thought leaders, participation in workshops,[6] attendance to trade exhibitions (e.g. Oceanology International held in 2016 (https://www.oceanologyinternational.com/Oi-News/Press-releases-/OCEANOLOGY-INTERNATIONAL-2016--LOOKING-BACK/)), and meetings with SOCIB Facilities and Projects. The following questions were addressed:

External:

- What users do other ocean observing systems have, how do they serve them?
- What information is there on the value of ocean data (observations and forecast)?
- What potential users of our ocean data are there in the Balearic Islands, Western Mediterranean region?

Internal:

- What data products do we have, how do they function and who uses them?
- What data are currently being used and do we have any contact with end-users around any specific data?
- What knowledge, intellectual property or product ideas do we have that could be useful for users?

From this review, major 'global' societal benefit areas for ocean data were defined. We then looked at these with reference to a series of criteria; the users in the Balearic region, the economic value of ocean data/knowledge that was required, our ability to deliver and the potential for engagement with end-users, in order to assess the following:

- the type of data required,
- user importance (regionally, but also at national/global level), size,
- societal benefit/value,
- whether SOCIB had data of relevance and value of this data,
- existence of current users (a clear indicator of value),
- whether SOCIB had developed products to address the users, and whether SOCIB had additional data or knowledge to offer,
- if we were in contact with or could effectively contact end-users.

In practice, this was a working spreadsheet with a series rows for the 'global' user sectors and a series of columns with metrics for the sector analysis, e.g. potential users in the region, sector size/importance to the region, what data do they require, types of use of data/applications, economic/socio-economic benefit, SOCIB data/knowledge available now/future, current SOCIB products for the sector, any future developments underway, do we have contact/can we contact these end-users, do user requirements match SOCIB core competence. The working spreadsheet was revised as information became available, however, it formed the basis for the analysis to define target sectors, priorities and the potential development projects. We looked at how current SOCIB products were used (science and anecdotal societal use) and were on the lookout for ideas for products, especially those that had developed through contact with user groups.

The review identified the following issues with the existing SOCIB product offer, as developed from 2011 to 2015:

- development was led by observing facility and generally platform based;
- availability not well communicated, products could be difficult to find and not always intuitive to use;
- many products were not developed with a specific user group in mind;
- important regional user groups were not supported by any products.

3.3. Identification regional sectors, priorities and product ideas

Following the review, SOCIB defined 10 target user sectors, as listed in Table 1. The sectors represent groups of users with common data needs, for which SOCIB could provide data/knowledge/IP, and that are important, economically, societally, in number of users or in terms of regional impact.

From these 10 sectors, 3 were identified as already having a number of useful products, namely Marine and Coastal Research, Coastal Protection, Planning and Governance, and Education and Kids, Maritime Safety was identified as being supported through a third party developed application (the Environmental Data Server (EDS) developed by RPS). The other sectors were prioritised against their ability to fulfil the aims of the strategy, namely:

- economic value of data;
- uniqueness of SOCIB contribution;
- readiness of technology/development capability;
- no existing 'commercial' products for this sector.

This resulted in the selection of three user group targeted products for development, two of which were initiated in 2017, as described in Section 4.

3.4. Strategy implementation: existing products and new product development

The characterisation of end-user groups/sectors enabled SOCIB to initiate an implementation plan to fulfil the aims laid out at the start of the process, for both the existing products and for new, user group targeted, product development.

Table 1. SOCIB sectors and users list.

	Sectors	Users
1	Marine and Coastal Research	Academia, government, NGOs
2	Marine Sports	Divers, recreational sailing, sports sailing/regattas, surfers
3	Beach, Coastal Communities & Tourists	Citizens, coastal communities, beach users, tourists
4	Coastal Protection, Planning and Governance	Local, regional and Balearic government environmental and emergency response managers, beach and coastal planners
5	Sustainable Marine Ecosystems	Fisheries managers, fisheries scientists, sustainability managers, commercial fishermen, recreational fishermen
6	Integrated Coastal Zone and ocean Management (ICZM)	ICOM managers, MPA managers, marine managers other, water quality
7	Ports and Shipping	Port managers, port pilots, ferry companies/captains, shipping companies/captains, cruise companies/captains
8	Sustainability of Islands and Climatic Change	Sustainability managers, environmental sensitivity managers
9	Maritime Safety	Air sea search and rescue, coastguard, pollution/oil spill and other maritime emergency managers
10	Education and kids	School kids and teachers, higher education, kids and teachers

3.4.1. Existing products

The existing products were grouped for easy communication and uptake by the targeted end-user sectors (see Figure 3). The new SOCIB web design, due for release in 2019, will include a new products catalogue, where users can search for relevant tools and browse tool descriptions, plus sector-focused pages with relevant grouping of products and user stories/case studies. This will also support the use of analysis statistics (Google Analytics) to give insight into user interaction with products through the web interface.

3.4.2 New product development

The development of new products for target user groups is a challenge that addresses both cross-platform integration and the development of an 'end-to-end' observing system. The two product ideas selected as the initial development projects were:

1. A tool for the Sustainable Marine Resources sector; an oceanography exploration tool, using experience, knowledge and contacts developed through the SOCIB-Spanish Institute of Oceanography (IEO) Bluefin Tuna Project focused around sustainable fisheries management
2. An interface for the Beach, Coastal Communities & Tourism sector; focused around beach lifeguards that require specific ocean and meteorological data every day of the beach monitoring season (spring through to autumn).

Both product ideas filled gaps in SOCIB delivery to the target sectors had identified 'early adopter' users,[7] with needs that matched high economic value data (forecasts and derived variables). The two ideas also matched the SOCIB product and services guiding principles, in that existing technology could be reused, they were innovative and leading edge, they supported the blue economy in a sustainable manner and used existing SOCIB knowledge to enhance utility, visualisation and/or user experience.

To guide the development of these products, SOCIB utilised 'Agile development' methodologies, from commercial software development, and new market development methods from 'Crossing the Chasm' (Geoffrey Moore, 1991). Agile development methodologies are used for early delivery, adaptive planning and continuous improvement, they develop through cross-discipline teams and iterative face-to-face communications

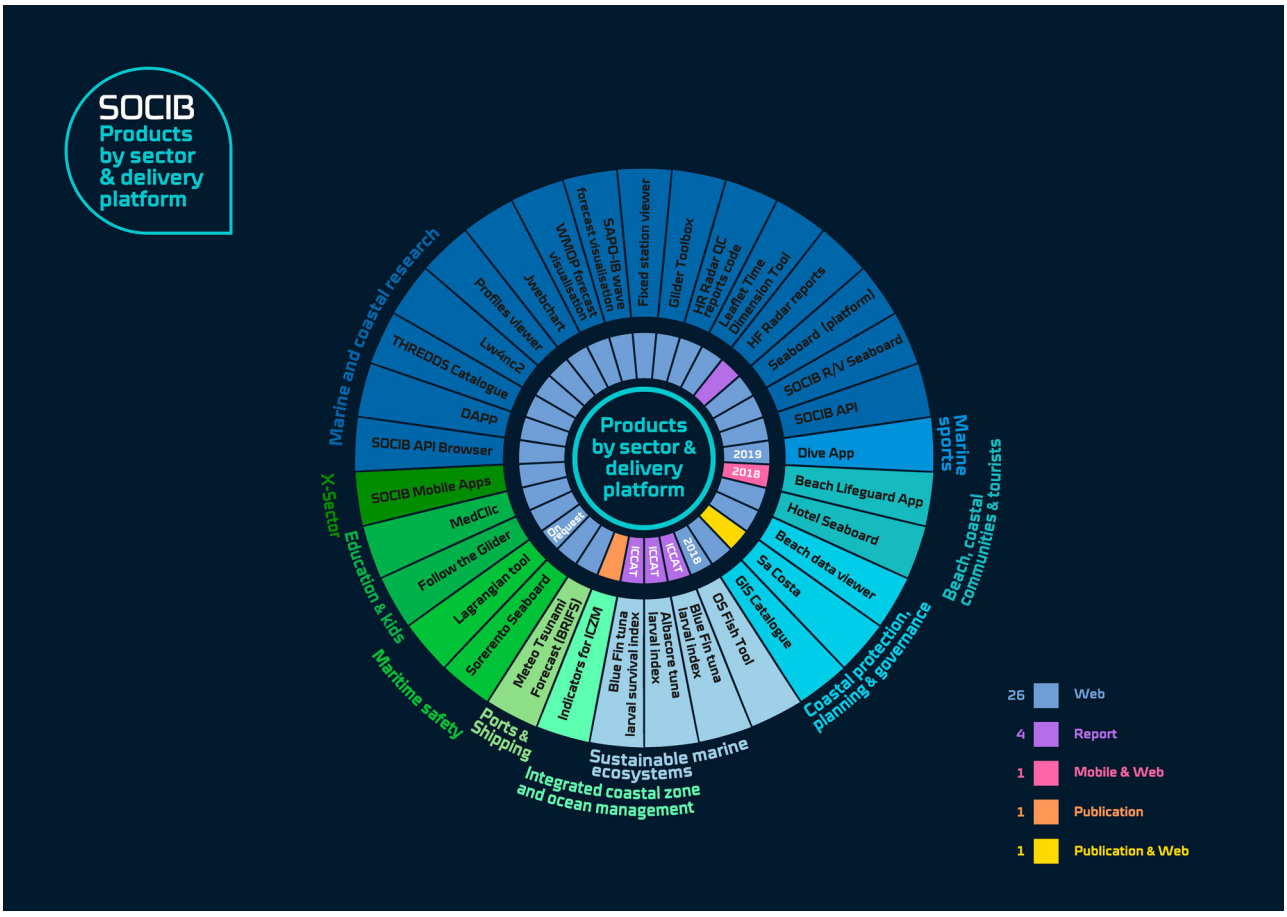


Figure 3. Sectors and Products infogram, where current and future products are shown by sector and product type, this enables end-users to quickly identify products that could provide data to support decision making in their work areas. Note some products were developed with support from key partners such as Agencia Estatal de Meteorología (AEMET) and Puertos del Estado.

(Figure 4). A cross-disciplinary team was developed for each product that harnessed knowledge across the Modelling Facility, Data Centre Facility, Observing Facilities, Outreach and key external experts.

A final component of the development thinking was the careful use of scarce resources, through using existing SOCIB interface developments, open source technology and selective outsourcing, where competitive and beyond our core competence, to meet defined user needs.

4. New product development details

4.1. The Oceanography Exploration Tool – for marine resource management

The Oceanography Exploration Tool is a planning and analysis tool that responds to drivers and gaps identified in the sustainable management of marine resources.

The application of operational oceanography to incorporate environmental variability into fisheries assessment

Figure 4. Typical development loops of the Agile methodology, by Appinventiv, 2018, https://appinventiv.com/blog/reasons-why-we-trust-agile-for-our-mobile-app-development-process.

is a new pathway to advance towards a more ecosystem and variability based approach for fisheries management (Reglero et al., 2017). This has strong potential to reduce uncertainty for fish abundance indices (Manderson et al. 2011, Ingram et al. 2017) and also opens up the possibility of implementing new, more effective and real-time marine spatial planning capability (Hobday et al. 2010). Nevertheless, the effective implementation of operational oceanography products in fisheries assessment and management processes still needs to resolve several important gaps and issues (Alvarez-Berastegui et al. 2018; Berx et al. 2011). These gaps are related to:

1. the design of operational oceanography data products,
2. the data delivery process,
3. the technical background of the fisheries management community and
4. the techniques used in fisheries assessment (population models).

SOCIB worked with the IEO, as a key external collaborator, to understand and look at how to bridge these gaps within the SOCIB-IEO Bluefin Tuna Project (Alvarez-Berastegui et al., 2016). The tool is designed to facilitate fisheries researchers and managers in accessing time series and real-time data for key oceanographic variables driving species ecology. Thus helping bridge the gap for the exploration of oceanographic physical–biological scenarios, enabling access and analysis of multiple datasets, and easing the integration of environmental variability into the design of field sampling and fisheries assessment processes.

A series of meetings were held between SOCIB and IEO, and within SOCIB, in order to develop the initial idea, define the team and define a minimum viable product (MVP). The initial MVP was created and tested through a structured feedback session with a group of end-users in 2017 (see Figure 5). This test group has experts working in regional sustainable marine resources science, mainly, but not exclusively, from fisheries. The feedback from this face-to-face session was very positive and provided clear end-user consensus on requirements for the next stage, giving the team vital guidance around development needs for interface and functionality of the Tool. The user session identified 2 key needs lacking in the initial MVP, the ability to (i) save user searched data and time series selections and (ii) deliver data at a range of depths. The first need was easily met with the existing interface design and technology, the second requirement contributes to the visualisation of ocean data but requires additional development of the selected THREDDS technology.

The MVP interface that was tested can be found on the following link: http://apps.socib.es/oceanography-exploration/.

4.2. The Beach Lifeguards Product – metocean data for beach lifeguards and managers

The Beach Lifeguards ('socorristas' in Spanish) Product displays in user-friendly panels specific meteorological and oceanographic variables that are critical to ensure safety on beaches, providing benefits to the operators in terms of:

- easing daily reporting: centralised access point to needed data sources (meteo, hydrodynamics, waves, etc.),
- unifying criteria: common data reference for all lifeguards to face decision making,
- improved resource allocation (beach opening/closure based on best available forecasts).

The Lifeguards management authority (Direcció General d'Emergències, Servei de Platges Direccion General de Costas) played a key role as collaborator to test and provide feedback during the development of the product. The aim of the product is to support the completion of the daily lifeguard reports, previously lifeguards were using several different portals to access different variables as a workaround solution, and to enable managers to review incidents in relation to marine conditions. The Beach Lifeguard product is designed to be used in the field (beaches), thus a mobile interface was selected.

The initial MVP was created and tested in 2017 with eight representatives from the beach lifeguards and management team. The feedback from this face-to-face session was extremely fruitful, again providing consensus on requirements, functionalities and target platforms. Following this user testing, two apps were developed under this product heading, the (i) 'Beach Lifeguards Seaboard' – a web-based application built in Django and having features useful to the management authority and (ii) SocorristaIB, a mobile app for Android. Both of them with common look, feel and features, see Figure 6.

The Android mobile platform is not a core competency of SOCIB, so the implementation for this was outsourced to a mobile application development partner – Apploading S.L.

The products enable the user to:

- browse through the 353 monitored beaches through a select menu and input search;
- access through a select menu and input search to past (calendar selection), present (default view) and future (48 h) metocean data, such as sea temperature, waves (height, direction, period), winds (direction, intensity), rain, pressure;
- relative scales (Beaufort scale and Douglas scale) are provided, as requested, to better address end-user data norms. This enables the lifeguards to more easily foresee dangerous scenarios and thus supports hazard mitigation (decision support tool) and improved planning.

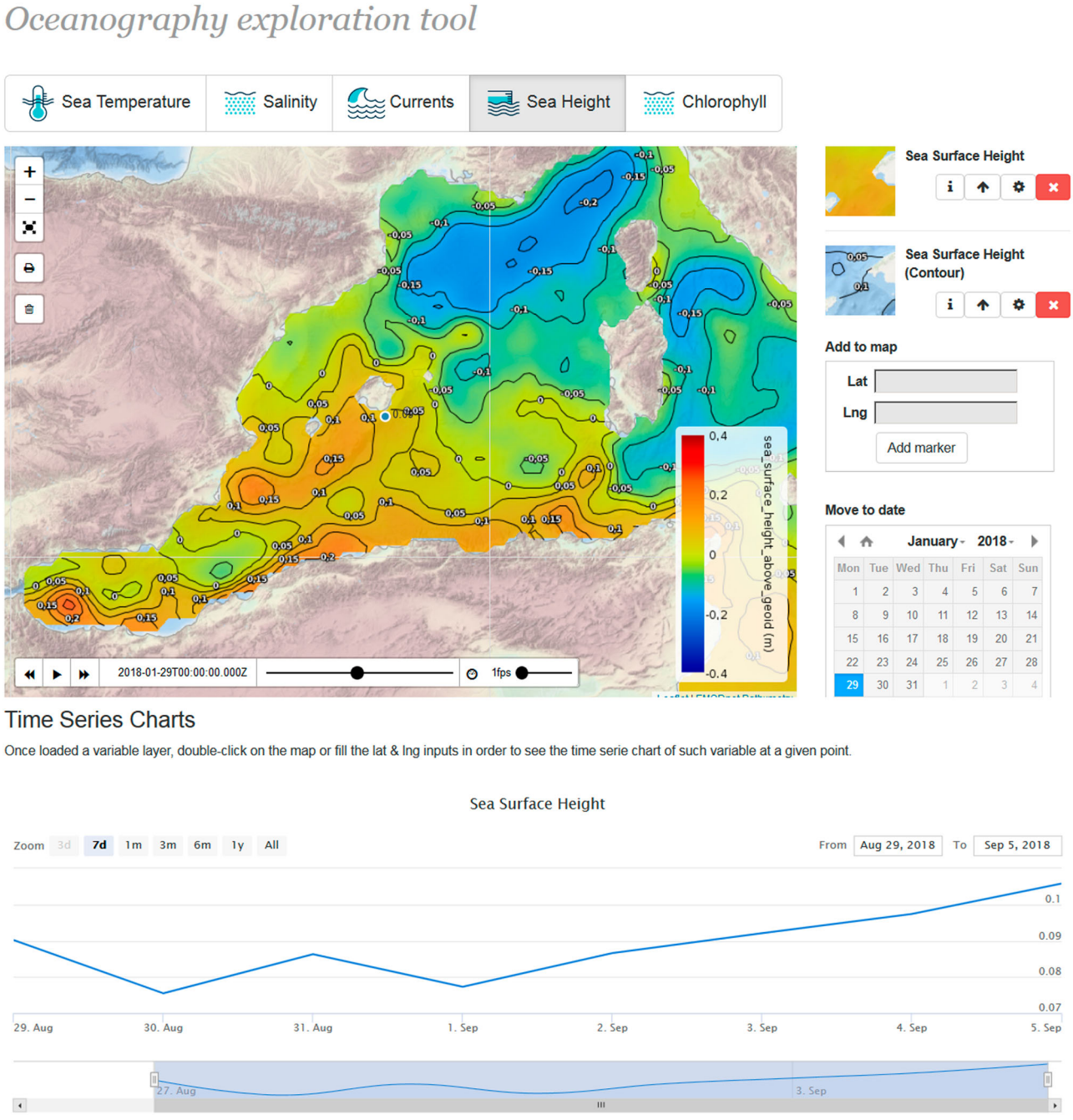


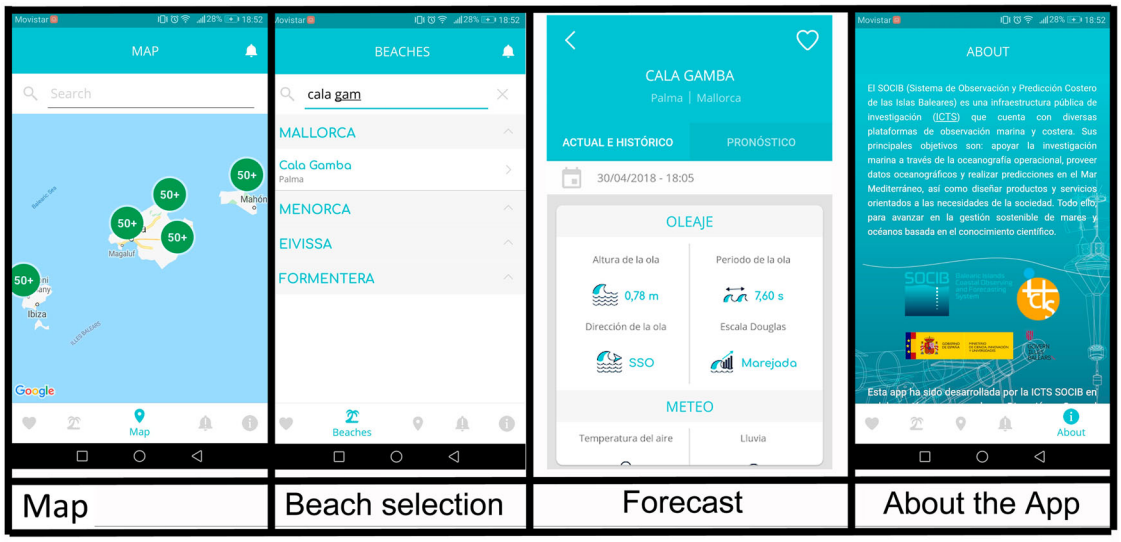
Figure 5. Prototype of the Oceanography Exploration Tool showing the interactive viewing window with variable selection; time series location (point) selection; calendar selection; visualisation settings. Below is a time series at user selected location points and time ranges.

Following input from the end-user meetings, the Mobile App platform provides the following additional features:

- browse through up to 353 beaches through a *map*,
- create *favourites* (shortcuts for a quick access to certain beaches),
- create *alarms* over a set of variables for any beach (e.g. wave height > 0.5 m at Cala Millor),
- receive *notifications* and check them whenever needed.

The product – SocorristaIB – was launched in May 2018 and can be downloaded from Google Play Store: https://play.google.com/store/apps/details?id=com.socib.lifeguards. The web interface can be explored on this link: http://seaboard.socib.es/lifeguard.

Although designed for the 'socorristas', the data provided within the tool are also useful to any beachgoer that would like to check metocean conditions at their favourite beach, and so has broader application potential.



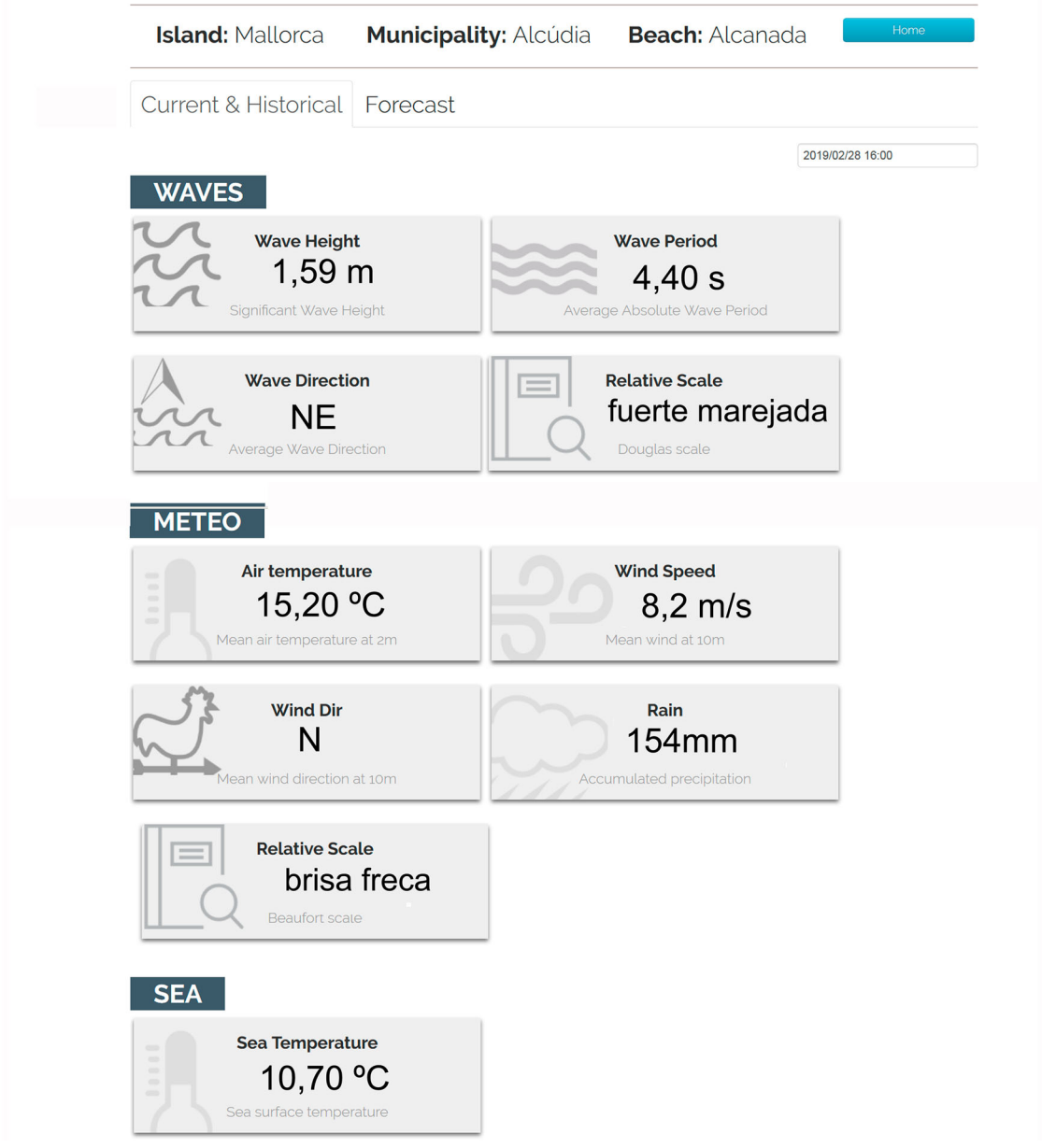


Figure 6. The interface for the Socorristas app (SocorristaIB) for Android, and below an example of the web interface.

4.3. Current status

The SocorristaIB product was released in April 2018 for critical field testing with the lifeguards during the spring–summer season. The Balearic Islands Directorate for Emergencies, the local authority coordinating the Balearic Islands lifeguards, encouraged product use and feedback to ensure the needs of the teams deployed in every municipality were being met. For example, the local Calvia team has been using it daily during the spring–summer season across 28 beaches and providing feedback, thus far there are approximately 50 active users of the app. The next steps for this product will be:

- formally engage with other lifeguard municipalities (apart from Calvia) to obtain further feedback on its performance across the Balearics;
- continue upgrading based on the lifeguard feedback;
- promote it to the general public in 2019, after proving robustness for lifeguards.

The Oceanographic Exploration Tool is in *standby* or *latency*, waiting for allocation of resources to complete the development process, in a manner similar to the lifeguard product.

5. Innovation and marine research infrastructures

In this paper, we have focused on the presentation of a regional ocean observing system and more specifically described the development and implementation of SOCIB Products & Services Strategy that lead to the development of two new integrated and end-user group targeted products. In other words, we have described an innovation process within a marine research infrastructure, which is fully in line with well-established business practices and with the recent ideas around a 'mission oriented' innovation approach adopted by the EU (Mazzucato, 2018).

In this section, we expand on the concept of innovation in oceanography and discuss the importance of research infrastructures, key actors of the research and innovation system, in bridging the gap between scientific excellence and impact on society.

Following the Oslo Manual (2018), we refer to innovation as the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organisational method in business practices, workplace organisation or external relations. Innovation is not limited to technological innovation.[8] It is now increasingly evident that there are many different types of innovation and that there can be relevant innovation without new knowledge, through combining knowledge that previously existed in new ways to serve new needs.

Since SOCIB is an ocean observing system, focusing on multi-platform observation, it is interesting to try to understand the innovation process in oceanography. In particular, Curtin and Belcher (2008) studied innovation in oceanographic instrumentation and showed that whenever a new instrument appeared, new fundamental scientific findings also appeared. This result is aligned with the well-known technology pull of innovation. These authors analysed the development of the glider platform, a major innovation in ocean observation. They showed that gliders have been a disruptive innovation, an integration of well-developed components (pressure housing, pumps, bladders, sensors, batteries, etc.) with an incubation time that was half that of the usual instrument incubation time in oceanography. They studied the conditions for this and identified three key decision centres: scientist, engineer and Science and Technology Investor working together, that integrated towards a common goal and for a sustained period of more than 10 years to achieve this.

The process for innovation described in this paper also follows a similar approach to that described above, in that it integrated across the SOCIB 3 main drivers, namely science, technology and society. It was guided by business best practice, in taking a user centric approach, with awareness of SOCIB core competencies and unique value or intellectual property, and in harnessing the creative forces of a multidisciplinary development team, in this case a mix of scientists, data engineers and business experts.

In other words, SOCIB and similar leading research infrastructures worldwide, with a multidisciplinary, integrated and targeted approach, are capable of establishing new symbiotic ecosystems that facilitate mission-oriented innovation. Furthermore, regional observing systems have a role to play in bringing the benefit of the observing system to end-users, and thereby increasing connection to regional stakeholders and supporting blue growth activities associated with coastal areas.

Although marine infrastructures can innovate in this area, as demonstrated here, it will not be possible for government to fund the development of all the potential products and services for all the potential users. We believe that the commercial sector can also leverage the market potential of marine data and play a bigger role in exploiting the wealth of this resource, and that user sectors can also fund development of tools and services. To aid this process, SOCIB will try to 'seed' the market by bringing these examples of focused products, with documented users and associated development partners, to marine industry forums, exhibitions and innovation

fairs, to demonstrate the value that has been created and the relatively low threshold of the additional development cost for product development. Most of the cost of development has already been invested, in taking the observations, running the forecast models, managing quality control and the open access interfaces to these valuable data and forecasts.

6. Conclusion

SOCIB cannot yet offer definitive user numbers for the new products, however, operational use has been requested for the Oceanography Exploration Tool, and the feedback has been positive and the SocorristaIB App is in its first year of 'field' trials, again with initial positive feedback.

SOCIB is a resource limited infrastructure and, although we have a clear mission to deliver value to society, we can only support a limited number of well-targeted products. Through adopting this approach to innovation, SOCIB identified key user sectors and product ideas that had a greater chance of success and capitalised on our scarce resources.

Through EU initiatives such as JERICO-NEXT, ODIPS2 and/or CMEMS, SOCIB promotes its approach to innovation in the ocean products and services area, reaching a broader European audience and advocating for the benefit of open, free-of-charge data and well-targeted product development, to support sustainable blue growth.

Notes

1. The Blue Economy is marine-based economic development that aims for improved human well-being, while significantly reducing environmental risks and ecological scarcities and, "The Blue Economy is a knowledge-based economy looking to the sea, not really for extraction of natural goods but for data to address societal challenges and inspire solutions" – Chief Scientist, NOAA, EOS, August 1, 2016.
2. See AtlantOS Deliverable D1.1, value chain as adapted from the G7 Ocean Expert Group think piece, May 2016.
3. https://www.scribd.com/document/110776633/IOOS-Hurricanes-Fish-Oh-My.
4. http://prooceano.com.br/site/.
5. Agile software development refers to a group of software development methodologies based on iterative development, where requirements and solutions evolve through collaboration between self-organising cross-functional teams. Agile methods or Agile processes generally promote a disciplined project management process that encourages frequent inspection and adaptation, a leadership philosophy that encourages teamwork, self-organization and accountability, a set of engineering best practices intended to allow for rapid delivery of high-quality software, and a business approach that aligns development with customer needs and company goals – https://www.cprime.com/resources/what-is-agile-what-is-scrum/.
6. AtlantOS/OECD Ocean Economy Group Scoping Workshop: Exploring the Economic Potential of Data from Ocean Observatories, May 2016.
7. 'early adopter' users a concept from Crossing The Chasm (Geoffrey Moore, 1991).
8. From OECD definition: technological innovations comprise new products and processes and significant technological changes of products and processes. An innovation has been implemented if it has been introduced on the market (product innovation).

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No potential conflict of interest was reported by the authors.

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