MARINE-EO bridging innovative downstream earth observation and Copernicus enabled services for integrated maritime environment, surveillance, and security

Conference Paper · April 2018

DOI: 10.1117/12.2307066

CITATIONS
0

READS
58

13 authors, including:

Fábio A. Lourenço Vieira
Fundo Regional para a Ciência e Tecnologia
5 PUBLICATIONS **1** CITATION
SEE PROFILE

Stelios Thomopoulos
National Center for Scientific Research Demokritos
230 PUBLICATIONS **2,390** CITATIONS
SEE PROFILE

Alkis Astyakopoulos
Center for Security Studies (KEMEA)
11 PUBLICATIONS **48** CITATIONS
SEE PROFILE

Constantinos Rizogiannis
14 PUBLICATIONS **33** CITATIONS
SEE PROFILE

MARINE-EO bridging innovative downstream earth observation and Copernicus enabled services for integrated maritime environment, surveillance, and security

Stelios C. A. Thomopoulos, Alkis Astyakopoulos, Constantinos Rizogiannis, Marina Markellou, Dimitris M. Kyriazanos, et al.

Stelios C. A. Thomopoulos, Alkis Astyakopoulos, Constantinos Rizogiannis, Marina Markellou, Dimitris M. Kyriazanos, Anestis Trypitsidis, Alexia Tsouni, Haris Kontoes, Ioanna Varkitzi, Vasilios Lykousis, Beatriz Gómez Miguel, Fábio AL. Vieira , Ana Martins, "MARINE-EO bridging innovative downstream earth observation and Copernicus enabled services for integrated maritime environment, surveillance, and security," Proc. SPIE 10646, Signal Processing, Sensor/Information Fusion, and Target Recognition XXVII, 106460U (27 April 2018); doi: 10.1117/12.2307066

SPIE.

Event: SPIE Defense + Security, 2018, Orlando, Florida, United States

MARINE-EO bridging innovative downstream earth observation and Copernicus enabled services for integrated maritime environment, surveillance, and security

Stelios C. A. Thomopoulos[*a], Alkis Astyakopoulos[**a], Constantinos Rizogiannis[a], Marina Markellou[a], Dimitris M. Kyriazanos[a]
[a]National Center for Scientific Research "Demokritos", Institute of Informatics and Telecommunications, Integrated Systems Laboratory, Patriarchou Grigoriou and Neapoleos Str., GR-15310, Aghia Paraskevi, Attiki, Greece;

Anestis Trypitsidis[b], Alexia Tsouni[b], Haris Kontoes[b]
[b]National Observatory of Athens, Institute for Astronomy & Astrophysics, Space Applications and Remote Sensing, Metaxa & Vas. Pavlou, GR-15236 Athens, Greece;

Ioanna Varkitzi[c], Vasilios Lykousis[c]
[c]Hellenic Centre for Marine Research (HCMR), Institute of Oceanography, PO Box 712, Anavyssos GR-19013, Attica, Greece;

Beatriz Gómez Miguel[d]
[d]Technological Innovation Office, Dirección General de la Guardia Civil, C/ Guzmán el Bueno nº 110 28003 Madrid, Spain;

Fábio AL. Vieira[e], Ana Martins[e]
[e]Fundo Regional para a Ciência e Tecnologia (FRCT) Azores, Portugal;

ABSTRACT

Maritime "awareness" is currently a top priority for Europe in regards with the marine environment and climate change, as well as the maritime security, border control against irregular immigration and safety. MARINE-EO is the first European Earth Observation (EO) Pre-Commercial Procurement (PCP) project and aims at the following objectives: (i) Develop, test and validate two sets of demand-driven EO-based services, adopted on open standards, bringing incremental or radical innovations in the field of maritime awareness and leveraging on the existing Copernicus Services and other products from the Copernicus portfolio, (ii) Propose a set of "support" / "envelop" services which will better integrate the EO-based services to the operational logic and code of conduct, (iii) Strengthen transnational collaboration in maritime awareness sector by facilitating knowledge transfer and optimization of resources for the public authorities participating in the buyers group.

Keywords: Copernicus program, marine environment, maritime awareness, earth observation, integrated maritime surveillance and border security, Pre-Commercial Procurement, pollution and climate change, Common Information Sharing Environment (CISE).

1. INTRODUCTION

1.1 Copernicus program and ESA/EU activities

Copernicus, previously known as Global Monitoring for Environment and Security (GMES), is the European programme, coordinated and managed by the European Commission (EC), for the establishment of a European capacity

*scat@iit.demokritos.gr; phone 30 210 650-3154, fax 30 210 653-2175; https://www.iit.demokritos.gr/isl
**alastiak@iit.demokritos.gr; phone 30 210 650-3210, fax 30 210 653-2175

Signal Processing, Sensor/Information Fusion, and Target Recognition XXVII, edited by Ivan Kadar,
Proc. of SPIE Vol. 10646, 106460U · © 2018 SPIE · CCC code: 0277-786X/18/$18 · doi: 10.1117/12.2307066

for Earth Observation (EO). Copernicus consists of a complex set of systems, which collect data from multiple sources: earth observation satellites and in situ sensors such as ground stations, airborne and sea-borne sensors. It processes these data and provides End-Users with reliable and up-to-date information through a set of services related to environmental and security issues.

The main End-Users of Copernicus services are policymakers and public authorities. They need the information to develop environmental legislation and policies or to take critical decisions in the event of an emergency, such as a natural disaster or a humanitarian crisis. Based on the Copernicus services, on the data collected through the Sentinels and the contributing missions, many value-added services can be tailored to specific public or commercial needs, resulting in new business opportunities.

The development of the observation infrastructure is performed under the aegis of the European Space Agency (ESA) for the space component and of the European Environment Agency (EEA) and the Member States for the in situ component. The services provided by Copernicus are addressed in six thematic areas [4], namely, Atmosphere, Marine, Land, Climate, Emergency, and Security.

All data and services that are currently provided through the Copernicus Framework are being presented in Figure 1. Access to sentinel data is free, full and open for all user communities under the Copernicus Space Component Data Access (CSCDA), guide that supports users through all the processes (e.g. registration, access mechanisms etc.).

Figure 1. Copernicus Data and Services list [4]

1.2 The EU vision in earth observation

EC's vision aims at reaching a global, continuous, autonomous, high quality, wide range EO capacity, and thus providing accurate, timely and easily accessible information, serving the needs of the environment, to understand and mitigate the effects of climate change and ensure civil security. Therefore EC is putting much effort obtaining a comprehensive picture of Earth's "health" with the combination (fusion) of Copernicus satellites, air and ground stations (in-situ).

The above fundamental installation of infrastructures (e.g. satellites, in-situ, and ground stations) provides pure availability and accessibility - both legally and practically - of the plain raw data and some dedicated services. EC's vision is moving towards gaining extra value with the analysis, correlation and enrichment (and/or fusion) with other data sources, and turned into information and knowledge, thus fostering the users' uptake and creation of new businesses. Currently, EO Supply capacity is 200 - 300 times larger than levels of exploitation of current levels of service delivery.

1.3 PCP methodology as a tool towards this scope

The maritime public authorities in the EU, as elsewhere in the world, are faced with important challenges in the area of maritime awareness which is related either with marine environment or security. These include modernising internal operations of public services aiming at customizing Copernicus information and stimulating the market to create sustainable supply chains for the delivery of innovative downstream EO-based services that will make them run more efficiently, as well as improving the reporting obligations of Member States and enabling informed decision-making.

Pre-Commercial Procurement (PCP) is the most preferable tool to tackle these challenges by procuring the R&D of those innovative solutions on behalf of the maritime authorities and involving different suppliers competing through different phases of development. Competitive development in phases is mainly the competitive approach used in PCP by procurers to buy the R&D from several competing R&D providers in parallel, and then compare and identify the best value for money solutions available to address the PCP challenges. R&D is split into phases (solution design,

prototyping, original development and validation/testing of the first products) with the number of competing R&D providers being reduced after each evaluation phase.

By acting as first buyers of new R&D with important technological needs, public procurers can drive innovation from the demand side. This enables EU maritime public authorities to innovate upon the provision of public services faster and create opportunities for companies in Europe to take international leadership within new markets of EO domain. Creating a strong European market for innovative products and services is an important step towards creating growth and jobs in quickly evolving markets such as EO and Copernicus.

2. THE MARINE-EO PROJECT

2.1 Project objectives

MARINE-EO teams up a group of 5 maritime authorities[1] (the buyers' group) and a group of 4 scientific and technical organizations[2] with experience in EO and maritime matters (the technical advisors) to achieve the following objectives:

- Objective 1: Develop, test and validate two set of demand-driven EO-based services, adopted on open standards, bringing incremental or radical innovations in the field of maritime awareness and leveraging on the existing Copernicus Services and other products from the Copernicus portfolio:
    - Thematic Area 1 – Marine Monitoring: The SATOCEAN service provides information about ocean parameters variability in time and space, best probable fishing areas, fish farm locations, and water quality. It also incorporates sea ice extent for safe navigation and maritime operations in the Arctic.
    - Thematic Area 2 – Copernicus Security: The SATSURVEILLANCE service contributes to the development of EUROSUR regulation, by providing services in response to Europe's security challenges in the domains of Border Security, as the monitoring of unusual/irregular activity around a Critical Infrastructure and the enhanced change detection for evidence of embarking or disembarking of irregular immigrants.
- Objective 2: Propose a set of "support" / "envelop" services which will better integrate the abovementioned EO and Copernicus-enabled services to the operational logic and code of conduct. Such services shall also bring "closer" the demand side with the EO data providers and EO data experts and analysts creating a dynamic environment for a single digital market to grow.
- Objective 3: Strengthen transnational collaboration in maritime awareness sector by facilitating knowledge transfer and optimization of resources for the public authorities participating in the buyers group. This shall bring together the supply and demand side in order to foster the development of innovative solutions in response to the increasing demand for strengthening EO and Copernicus capabilities.

2.2 Downstream EO-based services

The expected outcome under the two thematic areas is to provide five downstream service features as presented below.

1. SATOCEAN-UCS-1: Marine environmental status in hot spots (Areas of Interest (AoIs) e.g. Gulfs, Marine Protected Areas (MPAs) etc.).
2. SATOCEAN-UCS-2: Fish Farms, detection of Fish farms threats.
3. SATOCEAN-UCS-3: Detection of vessels and icebergs in Arctic areas.
4. SATSURVEILLANCE-UCS-1: Unusual/Irregular activity monitoring around a Critical Infrastructure.
5. SATSURVEILLANCE-UCS-2: Enhanced Change Detection.

2.3 Expected impacts

The expected impacts of the MARINE-EO project, in accordance with the priorities of the relevant topic are the following:

- The development and validation of future solutions experimenting in a real environment.

[1] Directorate General for Maritime Policy (Lead procurer), Guardia Civil, Hellenic Centre for Marine Research, Fundo Regional para a Ciência e Tecnologia, Kystverket.
[2] National Center for Scientific Research "Demokritos" (Project Coordinator), National Observatory of Athens, European Union Satellite Centre, Sintef Ocean

- The establishment of buyer groups for EO services.
- The establishment of sustainable supply chains for delivery of downstream EO-based services to public authorities.
- The fostering of the emergence of similar EO-based actions in smart specialization strategies.
- The development of Copernicus-enabled national, regional or local applications in support of public authorities.

3. USERS & DATA REQUIREMENTS AND REFERENCE ARCHITECTURE

3.1 MARINE-EO Generic requirements

Both thematic areas are aiming at developing a common platform as a single point of access where the MARINE-EO buyers group will be registered to request on demand services and accurate information.

3.2 Thematic Area 1 – Marine Monitoring: SATOCEAN service

SATOCEAN service provides information about ocean parameters variability in time and space, best probable fishing areas, fish farm locations, and water quality. It also incorporates sea ice extent for safe navigation and maritime operations in the Arctic. Indicative features of the service are the following: (i) Pelagic (particularly, tune) fisheries support information, (ii) Fish farm monitoring, (iii) Phytoplankton and harmful algal blooms (HABs) detection and mapping, (iv) Prediction of possible locations of jellyfish blooms, (v) Regular monitoring of MPAs, (vi) Information about oil spill events in the water and their development in time and space, (vii) Ocean biotic and abiotic parameters (e.g. wind, wave, Sea Surface Temperature (SST), chlorophyll *a*, etc.) climatological information and historical statistics, (viii) Detection of vessels and icebergs in Arctic areas, and (ix) Detection of open channels in the ice in the Arctic.

3.2.1 SATOCEAN-UCS-1: Marine environmental status in hot spots

Several problems have been identified for this service feature but they can be summarized in a broader common concept, concerning "the lack of a holistic approach". In such approach all required data from diverse sources (e.g. in-situ historical data from various national databases, long time series of buoy measurements, in-situ data collected during multidisciplinary oceanographic cruises, in-situ experiments for biological parameters) shall be combined in one single web application, serving needs of MARINE authorities at typical operating conditions. In addition, several times within a year, maritime authorities need to visit different portals to gather, download, and process the required information and then analyze and correlate it with information from other sources (e.g. in-situ, samples). This service feature will be connected with the European Marine Strategy Framework Directive (MSFD 56/2008 EC) and the environmental status assessment process. All Member States are currently in the process of MSFD implementation; they design monitoring plans and suggest programs of measures to stakeholders. In this context, MARINE-EO is a unique opportunity to use innovative tools, such as EO for environmental status assessment. Actually, this is a gap that has been considered in several gap analyses by other EU projects, e.g. DEVOTES, EcApRHA, Action-Med etc.

All the above information will be converted into tangible and more precise necessities/requirements derived from a combination of users' feedback and state-of-the-art solutions that are currently being used in gathering vital ocean parameters. Specifically, the requirements are being composed by:

Data Requirements: mainly raw Sentinels data, Copernicus - Marine environment monitoring service (CMEMS) data and products/services and in-situ data will be used. In more detail, the service feature will: i) extract essential parameters such as wind direction, wind speed, speed wave direction and wavelength, chlorophyll-a concentration, suspended matter concentration etc.; ii) make of use of long-term time series at the finest available spatial resolution; iii) store in-situ data via ship cruises data whenever such information is available from MARINE-EO end-users; iv) design tailored data model storing different temporal, spatial resolution along with error analysis information for each product; v) provide additional parameters such as turbidity and primary production that that are currently missing and/or not having the appropriate resolution and accuracy from Med-CMEMS; vi) separate information layers for Particulate Inorganic Carbon (PIC), Particulate Organic Carbon (POC), Colored Dissolved Organic Matter (CDOM); vii) guarantee access to other climatological data from ECMWF, NOAA-NCEP & satellite products from SeaWind (NOAA) that could contribute in enhancing spatial and temporal resolution of datasets/parameters.

Accuracy/Reliability: i) solutions to enhance both spatial (1x1 km pixel size) and temporal resolution of all ocean biotic and abiotic parameters (e.g. SST, Salinity, chlorophyll-a, suspended matter, turbidity, transparency, reflectance and primary production); ii) Very high resolution data shall be used on demand from contributing satellite missions (DWH), in order to provide the predefined parameters in higher resolution (i.e. in smaller AoIs); iii) be tested and validated in

four different AoIs, covering all countries; iv) each dataset/parameter the level of trust (reliability) and performance in terms of availability of dataset.

Interfaces & Functionalities: i) scalable of the service feature allowing users to request another area of interest; ii) use of Sentinel missions and contributing missions data in order to cover areas such as Azores (North Atlantic), where the CMEMS data and products do not provide the required resolution; iii) error analysis information for each product/service; iv) methodology for gathering and exposing information (parameters and data that are abovementioned) related to environmental status; v) methodology and workflow illustrating detected changes; vi) content based search mechanism via a semantic image retrieval, storage and management of the extracted metadata both coming from data and products; vii) user friendly interface for non-gridded data (currently provided via ftp) and provide a solution for the temporal extend of those files; viii) incorporation of functionalities that are currently provided from NASA's Giovanni portal and Ocean color products; ix) new data extraction mechanism/interface based on a specified temporal and spatial frame that will include both archival and processing services along with all information.

3.2.2 SATOCEAN-UCS-2: Fish Farms, detection of fish farms threats

Even though there is a lot of information related to ocean and sea parameters freely accessible by many sources (e.g. CMEMS), there are quite few paradigms (e.g. mostly related to EC Research Funds) of applying this critical information to a dedicated sector such as fish farming which is a fast-growing market[3] and fish farmers are not aware of the availability of such information.

This service feature is going to focus on specific fish farms identified by the end-users (e.g. allocated zones for aquaculture, fjord), serving /addressing the detection of fish farms threats (e.g. HABs) and the prediction of fish farm threats based on environmental data from different sources (e.g. CMEMS, Sentinel, in-situ).

Information of fish farm status and detection of threats can be provided as data services to aqua farming companies, associations of aqua farmers, environmental Agencies in Ministries and Prefecture units, fish farming control related Agencies, other marine authorities, administration services, decision makers, policy makers, Marine Spatial Planners, law-enforcement authorities that are interested (e.g. awareness and illegal activities in fish farm areas), environmental and urban engineering companies, scientific community in Research and Academia, NGOs etc.

All the above information will be integrated in the common platform that will be self-sustained on operational activities and lead to an increase of the efficiency and sustainability of fish farming activity by: (i) incorporating satellite and geospatial data from various satellite missions (different modes of Sentinel 1-2-3) and data repositories (e.g. CMEMS, C-TEP) for increasing the spatial and temporal resolution, (ii) combining information on SST, harmful algal blooms, fish diseases or anomalies from information extracted by using systematically EO and in-situ measurements through well adapted algorithms / modeling / automated workflow or machine learning techniques.

This service feature aims to be sustainable on an operational basis, following specific standards that are applicable and transferable to other AoIs at regional level. Specifically, the requirements are being composed by:

Data Requirements: i) incorporate satellite and geospatial data from various satellite missions (different modes of Sentinel 1-2-3) and data repositories (e.g. CMEMS, C-TEP) increasing the spatial and temporal resolution; ii) continuity of all-weather capability of C-band SAR data from Sentinel-1; iii) use high-spatial resolution optical images from Sentinel-2 & 3A for the environmental monitoring of fish farms (e.g. Ocean Land Colour Instrument and Sea Land Surface Temperature Radiometer); iv) use the available CMEMS products; v) use of Contributing Missions data with an efficient and cost effective use for the fish farm monitoring and to develop on demand request functionality of very high resolution data.

Accuracy/Reliability: i) on a daily basis, horizontal maps indicating marine pollution/threats together with all the available parameters either coming from in-situ measurements or from EO data with spatial resolution below 1 km; ii) leverage on methods applied in "Marine environmental status" feature service, related to the enhancement of both spatial and temporal resolution; iii) sustainable solution on an operational basis, following specific standards

Interfaces & Functionalities: i) build upon CMEMS available products, such as biogeochemical data and forecast for global and regional seas. Oceanographic parameters including SST and ocean currents; ii) build upon existing solutions and tools that are currently available (open source and/or proprietary) for fish farm monitoring that can provide critical

[3] http://www.worldwatch.org/node/5444

information for managing the risk of spreading diseases; iii) easy online access to data services related to aquaculture facilities (fish farms); iv) Service validation in selected countries; v) monitor water quality of fish farms and an early warning functionality to the end-users (fish farmers) about any threats, either coming from pollution or from HABs, followed by corresponding (ocean colour) maps that prove and illustrate the problem; vi) solution leveraging on in-situ measurements (e.g. multidisciplinary oceanographic cruises, inspections, data directly coming from fish farmers); vii) Knowledge on fusing in-situ data with EO data, as well as long-term time series of in-situ records, enhancing the scale and the resolution of the products in terms of mapping scale and timeliness; viii) Long term assessment of fish farms activities; ix) interface that will provide in NRT (near real time) the status of existing fish farms; x) alerting mechanism for extreme weather forecasts and/or changes based on long time series of historical data.

3.2.3 SATOCEAN-UCS-3: Detection of vessels and icebergs in Artic area

This service feature is proposed to serve the needs of various bodies such as: The Norwegian authorities including the "Norwegian Coastal Administration - NCA"; the "Search and Rescue – SAR"; the "Fisheries"; the "Customs"; etc., as well as the ships navigator on board the ship, shipping industries (ship owners from all countries with interest in the Arctic operations), the offshore industries, and the R&D institutions. It should be assured that this service is replicable and thus can serve the needs for other maritime authorities and other areas. The service aims to provide a solution capable of enhancing the level of trust for vessel and iceberg detection and providing reliable information on ice status and on forecast models near the AoI. The information shall be accessible or shall be able to be sent digitally on demand to all types of users, including the navigator on board the ship.

Ship's navigators in the Arctic Sea need to operate in effective ways. Such requirement could mean choosing optimum routes prior and during their voyage. Thus, compilation satellite images as well as other types of information such as weather and wave height forecast are critical.

To achieve safety, security, and efficiency, and the reduction of emission to air, the service feature needs to provide to the user on demand, a mean for communication and digital information sharing or information retrieval of the processed data, taking into consideration the challenges of communication and broadband limitations in the Arctic remote area.

All the above information is being converted into tangible and more precise necessities/requirements derived from a combination of users' feedback and state-of-the-art solutions that are currently being used. Specifically, the requirements are being composed by:

Data Requirements: i) base the service feature on data and products from CMEMS and more precisely the Arctic Ocean-SAR Sea Ice Berg Concentration service, the Arctic Ocean–Sea Ice Concentration Charts-Svalbard service, and the Arctic Ocean–Sea Ice Charts-Greenland service; ii) output shall be provided from the Arctic Ocean Physics Analysis and Forecast service using the operational TOPAZ4 system and the HYCOM model to provide 10 days forecast of the 3D physical ocean, including sea ice; iii) the vessels detection shall be followed by a timestamp (location, time), classification of reporting or non-reporting, type of vessel and any other information that can be provided by the AIS system (e.g. ship type and size, ship's polar code, Speed, direction); iv) the iceberg detection shall be accompanied with the status of the iceberg – forecast drift: remote sensing methods for forecasting and routine monitoring of combined risk of waves and ice, considering the marginal ice zone, ice forms, ice deformation, ice types, ice movement, ice strength, ice classification, ice cycle, ice concentration color, ice distribution factors, ice drift and routing; v) use of SAR and optical data (e.g. Sentinel-1, Modis, Sentinel-2).

Accuracy/Reliability: i) provide positioning (vessel/objects and icebergs) (lon, lat) accuracy 100m; along with the type of object (vessels, offshore mobile drilling units, ocean structure and/ or iceberg) shall provide also the reliability figure for the detection (high, medium, low).

Interfaces & Functionalities: i) define a solution that it increases the accuracy based on the combination of data (e.g. AIS, Satellite data); ii) use of TOPAZ4 system and the HYCOM model to provide 10 days forecast of the 3D physical ocean, including sea ice; iii) methodology that will inform the end-users whether an object is a vessel or an iceberg, the position of the object and the ice situation close to the object; iv) methodology for automatic and more accurate object recognition of vessels and icebergs together with the level of trust; v) provide information on detected vessel and icebergs 24x7. Quality controlled analysis shall be delivered within 1 hour from satellite overpass. When the data is available and retrieved from the Copernicus DWH, the delivery time shall be as soon as possible, and within 1 hour; vi) optimum route suggestions product for Arctic going vessels on demand, based on compiled data and processed information regarding the vessel, the weather and wave conditions, and the ice conditions; vii) enable the delivery of

product digitally to the end-users upon request and based on the user delivery selection mode; viii) provide a stable and secure data communication and broadband coverage capacity to deliver the product digitally to the end-users and Arctic going vessels on demand.

3.3 Thematic Area 2 – Security: SATSURVEILLANCE service

The MARINE-EO SATSURVEILLANCE service features are intended to provide added value to maritime authorities entrusted with security responsibilities. User needs in this area drive the development of the services, while other actors in the security domain may also take advantage of the information that will be created and shared.

The maritime authorities look for continuous improvement in their surveillance capabilities. Part of their efforts is intended to identify gaps and analyze accessible data sources, possible technological transfers and cooperation to fulfill as much as possible those gaps. In complex environments, like maritime surveillance for security [1], maritime authorities have to deal with huge areas that are borders, but at the same time, they can be communication and transport routes, protected areas, tourist spots, fishing zones, critical infrastructures or public places.

To tackle the challenge, the most effective analysis involves technological developments matching their needs and customized for their purposes. The maritime authorities have to perform a thorough operational requirement analysis, participate in the development phase and jointly design the operational validation procedure that will evaluate the usefulness of the produced results. That is exactly what MARINE-EO intends to do.

Regarding the operational requirement analysis, apart from identifying user needs, data and information inputs to the services are key points. MARINE-EO core sources of information are EO data and current services provided by Copernicus [4], [5]. On these sources, others considered as ancillary data will be merged to get the most valuable outcome.

On the other hand, scenarios covering functionalities required by the participating maritime authorities on a daily basis are the main parameters in the operational validation. The following two main scenarios of interest have been identified at a preliminary stage:

3.3.1 SATSURVEILLANCE-UCS-1: Unusual/Irregular activity monitoring around a Critical Infrastructure

This service feature will support the risk analysis and the risk management of a particular Critical Infrastructure identifying threats by characteristics, behavior, origin-destination, etc.; monitoring threats during a specified timeframe and evaluating threats, the risk of incident occurrence and possible impact.

The operational approach for unusual/irregular activity monitoring around a critical infrastructure is based on the setup of buffers around the critical infrastructure (e.g. 50NM, 25 NM, 5NM), a monitoring period, a group of possible abnormal behavior patterns depending on areas (i.e. revisits during monitoring period, meetings, stops, crossing, etc.), and a schema of alert or event triggering (Figure 2). Alert handling includes the possibility of specific surveillance plans to be launched covering smaller areas. For that new surveillance plans higher performance data in terms of spatial resolution and/or revisit time are foreseen.

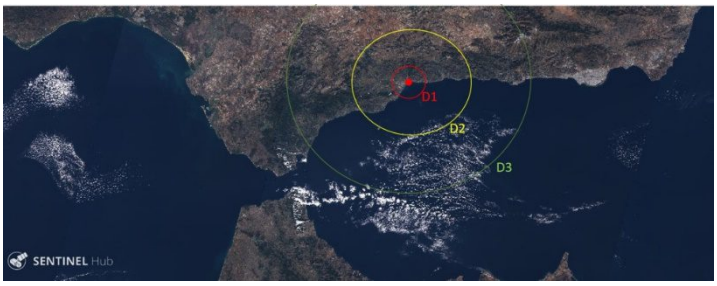


Figure 2. Example of unusual/irregular activity monitoring around a critical infrastructure buffering

The service feature requires the management of AoIs processed independently and then information is merged to extract global analysis. Non-collaborative vessels detection, features extraction and behavior analysis based on EO data and other auxiliary data, for instance AIS (spoofing, shutdown), are included in output information levels. The same as suspicious vessel back-tracking in time series of images or periodic reporting based on intelligence analysis.

3.3.2 SATSURVEILLANCE-UCS-1: Enhanced Change Detection

This service feature aims at detecting evidence to support the hypothesis that certain irregular activity is taking place in specific AoIs, e.g. beaches/coasts are (or were) used for embarking/ disembarking migrants, pre-frontier areas, etc. It includes detection/no detection of vessels at possible departure sites (beaches, ports, etc.) taking into account specified targets of interest, trace/evidence's identification based on change detection analysis by using a group of EO products properly selected and scheduled along with target(s) tracking estimation from EO data analysis.

3.3.3 SATSURVEILLANCE service overall concept

MARINE-EO outcomes will fit current infrastructures and operational framework. Enhanced and new capabilities will be covered by functional modules' developments and by proper input data selection. They will embed a set of operational workflows, including data collection planning, product interpretation and analysis and report production, among others. MARINE-EO platform shall ensure confidentiality, integrity and security along the entire process.

The new service features are intended to be part of maritime authorities' infrastructures as depicted in Figure 3. This will to be taken into account in several aspects:

- Regarding integration, service features will be interoperable with different legacy systems and national-transnational current infrastructures. That is, they will be accessible through current communication networks, deployed at maritime authorities' premises and compatible with models/formats agreed by user communities, particularly with Data and Service CISE model [2].
- Operationally, MARINE-EO services shall be merged with other data/services in order the users to get a complete picture at once. Likewise, MARINE-EO data and services could be inputs for specific products and services provided within a national authority environment. On a daily basis, monitoring, alert management and intelligence are handled. Suitability of space-based sensors, in general, and Copernicus in particular, have to be considered for any type of surveillance. On the other hand, legal, security and timing, constraints are critical.

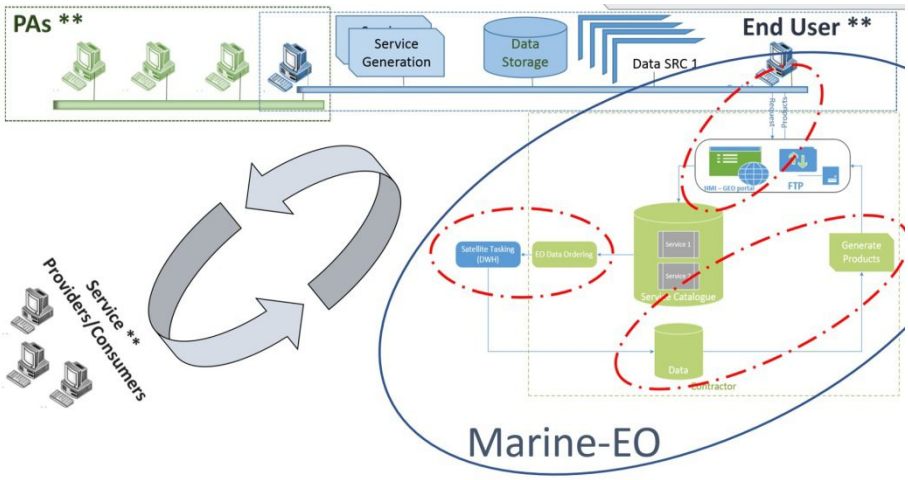


Figure 3. Marine EO platform deployment in maritime public authorities' environment

In terms of input data versus capabilities, the main goal will be Sentinels data processing optimization in detection and target feature extraction. It includes performance dependencies, for instance, weather conditions, movement, etc. In addition, a planning tool will allow putting requests for data and services taking into account type of surveillance, targets of interest, cost, revisit time, weather forecast, etc.

It is mandatory research and innovation in optimization of performance through cutting-edge algorithms implementation mainly intended to maximize detection and target feature extraction on Sentinels data. Secondly, it is necessary to develop support tools matched to Copernicus missions planning and to end user's needs, that is, tools covering request to delivery.

Moreover, delivery time minimization is a key point in security. The complete service is made up of several outputs. Outputs that could require different processing refinements and data fusion at different levels. Ideally, first results (intermediate services, such as vessel detections) should never be longer than 15 minutes for areas of about 250x250 km^2 and 5 minutes for areas of about 10x10 km. The idea is to provide valuable information as soon as possible. The same information can be delivered several times, each time associated to a reliability coefficient.

Operational requirements: Remote sensing is inherently associated to data fusion [11]. In MARINE-EO case, it includes multilevel and heterogeneous fusion to get a complete picture of the monitored area status. EO data sources registration is mandatory. Registration covers multisource and non-homogeneous sources, in terms of missions, bands, time, geometry, product channels, dimensions and level of processing [12]. This stage is intended to image interpretation support. Redundancy, complementarity and cooperativity is exploited to improve accuracy and knowledge. Regarding EO products information extraction capabilities (many times closely linked) can be summarized as follows: i) Detection of targets at sea, on beaches and in ports (mainly), ii) Target features extraction, such as, size, movement, material and other like masts, cranes, color, etc., iii) Target classification based on groups of maritime targets established, iv) Pattern recognition in images and in time series of images, v) Rules of behavior related to location, movement, objects around, vi) Statistics on targets over time, and areas, vii) Objects appearance or disappearance, viii) Human settlements and movement (routes, traffic) evidences, ix) Infrastructures development, damages or discontinuities

A second level of information generation is the result of fusion of outputs from these capabilities with ancillary data. The aim can be improvements in accuracy or reliability, added value information extraction, final product completeness, etc. Sources of information such as reference maps, sea status, currents, maritime traffic information, maritime protected areas, fishing grounds, diving areas or tourist attractions can be helpful concerning EO product information extraction.

In maritime environment, AIS or other positioning information are commonly used as source of valuable information. In MARINE-EO, AIS supports information extraction in false positives determination or suspicious behavior identification (possible spoofing when AIS position but not vessel in images, vessel in images but not AIS, routes tracking over time periods of analysis, rules of behavior, etc.).

Several levels of data and information fusion can be implemented and included in processing flows. It is important to point out that the human machine interface is by itself a data and information fusion stage [9]. Operation flexibility in terms of data acquisition, processing flows, outputs and delivery schema has been traced to service definition requirements. Service definition is included in the GUI-tool. The rationale behind service definition is the automatic provision of options by default based on spatial and temporal coverage, weather forecast (if available) and required outputs. On this base, the operator can modify the request step by step:

Time and place: AoIs defined as polygons are managed by user. They can be created and/or loaded from a previous definition. A monitoring period, part of the day and required revisit are input parameters. Different periods of time can be chosen, (i.e. one in the past, two in the future).

EO and ancillary data: EO products are selected based on time and place definition or ancillary data when available (weather, sea conditions, etc.) that help the operator to choose the type of data. By default, the AoI matches the coverage of the EO basic product. The size of the standard product should match the size of the AoI as much as possible. The user can always modify the default selection, in terms of one of several EO basic product dismissing, source of the data or product changes. The operator is responsible for input data request. That is, in one area of around 100x100 km^2 would be matched by products of equivalent coverage, and an optical product could be a selection by default, but the user could update the selection to a radar product with a bigger coverage or to an optical product with better resolution, for example. Ancillary data to support service generation depend on the algorithm workflow and requested outputs.

Information layers: A service is made up of different information layers. These layers can handle different type of information or perform different deliveries of the same information. Main layers are EO data (images at different processing levels and/or fusion), entities information such as, vessels detections (velocity, position, physical features), entities behavior associated to warnings and alerts [13], etc. The operator can select some of them and the input parameters associated. Examples could be vessel detection in a time series of images, a warning when a crossing of one AoI by a specific vessel, and an alert if more of than one vessel in the AoI.

Processing workflows and intermediate result deliveries determine the outputs the user handles and those available to be merged with other user's resources. Sets of algorithms with similar capabilities can be included due to the variability on EO product characteristics (missions, type of sensors, channels, resolution, coverage) and the availability of ancillary

data or the required outputs (target detection, identification of specific targets, behavior, changes, statistics, etc.). A selection of processing flows among possible ones has to be done. This selection is part of the product definition.

At several steps valuable EO products and/or information are generated. The user can select these intermediate outputs as deliveries. In this way, operator knowledge can be fully exploited or these deliveries can be used as inputs for other fusion procedures out of the scope of MARINE-EO. One example can be the integration of a vessel detection implemented by MARINE-EO with intelligence data. Other can be one visual analysis of detected target in images, were the skill of the operator can be crucial.

Other intermediate outputs are those generated as quick responses. Better outputs in terms of performance are provided when all the information is available.

Reliability according to uncertainty associated to data, processing and information sources shall be included in MARINE-EO services. It can be made up of different contributions in order the user identify the meaning in the service output.

Data requirements: From an operational point of view, several constraints are applicable. Coverage area depends on the type of surveillance, monitoring surveillance or targeted surveillance. In monitoring case, larger areas are usually involved and EO product resolution is bigger. On the contrary, in general, when a new surveillance plan is generated after one alert, products with better resolution but less coverage area are required.

In the security thematic area, Gulf of Cadiz and Alboran Sea and North Coast of Africa are considered as test areas. All over these big area, specific scenarios will be operationally validated (i.e. Malaga Port). Different test levels and environments will be handled: (i) simulation to carry out specific evaluations on planning and service performance (detection, identification, behavior capabilities), (ii) real time simulation where data and results are known and time line is equivalent to actual operation, (iii) finally, real trials should validate how daily work can be supported by MARINE-EO.

Regarding EO data, Copernicus portfolio characteristics are described in [5]. Missions and data characteristics are summarized in Table 1 for Synthetic Aperture Radar (SAR) and Optical missions. For security services, only Very High Resolution (VHR) and High Resolution (HR) products are considered (VHR1 (res ≤ 1m), VHR2 (1m ≤ res ≤ 4m), HR1 (4m ≤ res ≤ 10m) and HR2 (10m ≤ res ≤ 30m)).

Table 1. Optical and SAR missions in Copernicus Portal [3].

Optical sensor missions		
• Deimos-1, Deimos-2 • Dubaisat-2 • GeoEye-1 • IRS-P5 CartoSat • Ikonos-2 • Kompsat-2, Kompsat-3	• Landsat-5, Landsat-7, Landsat-8 • Pleiades-1A/1B • Proba • QuickBird-2 • RapidEye Constellation • ResourceSat-1, ResourceSat-2	• Sentinel-2 • SPOT-4, SPOT-5, SPOT-6, SPOT-7 • TH constellation • Uk-DMC2 • WorldView-1, WorldView-2, WorldView-3, WorldView-4
SAR missions		
• ALOS-PALSAR • COSMO-SkyMed • Kompsat-5	• PAZ • RADARSAT-2 • RISAT-1	• Sentinel-1 • TerraSAR-X , TanDEM-X

Regarding EO services a description can be found in [4]. Data needs can be organized according to service definition:

Regarding coverage of AoIs defined by users, data requirement key points are monitoring or targeted surveillance. A general approach is the use of products with a standard size similar to the area. Larger AoIs are usually intended to monitoring purposes and less quality are requested in terms of resolution. Only in specific cases higher resolution product could be selected to cover large AoIs.

Regarding revisit, requirements are driven by operational needs and requested capabilities. Surveillance aims at establishment of the number of required acquisitions over a period of time. On the other hand, some capabilities could

require a group of acquisitions over a short period. In this case, data request should take the advantage of missions with passes around the same time.

Regarding sea and weather conditions, the usefulness of EO data will be imposed by the capabilities of a type of sensor to extract valuable information (e.g. cloudy weather).

Regarding capabilities in feature extraction, heterogeneous data sources have to be handled. All the variability of EO products accessible from Copernicus portal [5] (missions, geometries, frequency bands, optical, infrared or radar sensors, processing levels, etc.) should be combined for performance optimization. A huge number of algorithms to cover Marine-EO capabilities are available for optical, infrared and synthetic aperture radar sensors [1], [6], [8]. These algorithms are intended to be used with specific EO input data covering all the possible products available through Copernicus portal.

Regarding Sentinel1 and Sentinel2 use optimization, the selection of data from these two missions is preferential. It is foreseen that these sensors are part of any monitoring plan. Both are owned by Copernicus Program. In MARINE-EO, cost optimization is carried out through algorithms optimization when Sentinel1 and/or Sentinel2 data product are handled.

In general, it is important that input data possibilities are fully exploited (e.g. spectral bands and polarizations). The same applies to any processing level product and service (CMEMS, IMS). It is necessary a comprehensive understanding of data input and algorithm dependencies versus output performance.

3.4 Reference Architecture

The overall system design comprises the practical basis for establishing and applying the set of downstream services that will be served to MARINE-EO end-users. With reference to the previous requirements defined above and according to information gathered from the Request for Information (RFI)[4] and Prior Information Notice (PIN)[5] concerning of applying two different lots, two distinct web based platforms shall be developed having, to the extent possible, a common Human Machine Interface (HMI) where the end user should be able to register and make use of the Downstream services and/or also to request further EO-based services. Thus, the reference architecture envisaged for what concerns the MARINE-EO downstream and support services is based on the consensus to both meet current/forthcoming activities, trends and fulfill the requirements that have been identified.

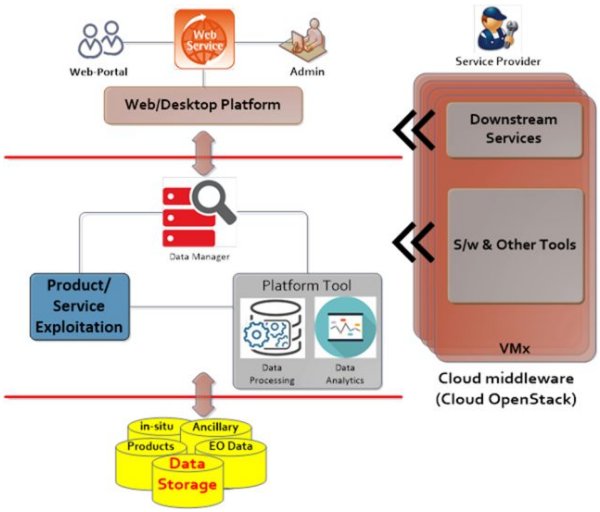


Figure 4. High Level Architecture of MARINE-EO

High Level Architecture (Figure 4) will be designed to function as a service to intermediates and end-users, for i) providing capabilities and methods to transparently query, visualize and access products and sub-products of heterogeneous datasets via MARINE-EO system and ii) allowing intermediate service providers to apply additional services, on end-users/market request.

The solution will support the deployment of the service features either on cloud using the Copernicus Data and Information Access Services Operations (DIAS)[6] or other resources or locally on user premises (for the security service feature). MARINE-EO platform will ensure the proper integration of third-party products that could be added after the end of the project. The concept is not to develop and test only some services serving current needs but to ensure that other service providers shall be able to use the existing enablers, add new ones and create other marine related services, like applications, in a simple and intuitive technical approach. In this context, a schema for a role-based access control system will be integrated to the platform.

[4] https://www.marine-eo.eu/request-information-rfi
[5] https://marine-eo.eu/article/prior-information-notice-pin-just-published
[6] http://copernicus.eu/news/upcoming-copernicus-data-and-information-access-services-dias

The platform will consist of the following components:

1. Three interfaces are provided towards the users: i) Web Portal, providing access to different applications, data and related documentation via a simple Web browser, ii) Web Services, according to standardized or widely used interfaces, are provided to invoke MARINE-EO services, iii) Appropriate admin interface for managing on demand requests,
2. An appropriate data management solution for big data analysis deemed necessary,
3. Tools to easily deploy scalable processing and data analytics, accessing the complete data archive (discover and access) on the platform,
4. OpenStack or similar private cloud for service deployment.

The platform will be scalable enough to store and process large data-sets, whilst allowing analytics on large time series of data.

3.5 Verification and Validation strategy

The purpose of the verification and validation strategy is to generate sets of guidelines for MARINE-EO platform solutions' evaluation process. Guidelines have been defined per PCP phase, where assessment methods have been selected and will be adjusted during the implementation of the project to fit each phase specific characteristics. Appropriate metrics have been also selected for the evaluation of each PCP Stage based on the above requirements. The verification and validation will take place in different MARINE-EO's PCP phases, as have been defined in Section 1.3.

3.5.1 Verification and Validation (V&V) process

The whole V&V process has been determined by answering the following question: *Which outputs do End-users and decision-makers expect from the Verification and Validation process?* Therefore, V&V process provides measures and evidence of the level of compliance per each MARINE-EO solution, per service and per PCP phase. To this respect, the acceptance, per phase through suitability covering functional, operational, maturity and cost aspects, needs to be determined by the end-users. In MARINE-EO's case we considered each service as a high-level Key Performance Area (KPA) in MARINE-EO V&V process. Then each KPA will be measured in all the aspects. In SATOCEAN and in SATSURVEILLANCE service we can identify four and three KPAs respectively, and four aspects per PCP phase.

V&V strategy will take place in different PCP stages: Design stage (5 months); Prototyping stage (9 months); & Development stage (13 months). Thus, the strategy creates a guide that will help and ease the process of evaluation. For the second and third stage, verification and validation process is respectively assigned.

3.5.2 Design Process

"Design Process" checks whether the proposed solutions cover needs that have been identified. Specifically, the process exams if the development of a platform is being envisaged, if all services have been included and if R&D activities of each service feature are clearly defined. Additionally, the design process for each service, checks for the solution readiness level, if appropriate algorithms and workflows have been used, if a group of general requirements have been addressed, and if the architecture concept is in line with user requirements.

3.5.3 Verification processes strategy

Verification strategy is supported by: i) Verification plans proposed by procurers and agreed with the consortium; ii) Verification procedures and reports generated by procurers in PCP stage 2 and agreed with the consortium; iii) Monitoring reviews planned by the consortium.

The "Verification Process" shall check whether the prototype is performing to a satisfactory level. Thus, through pre-defined scripts and areas, all components and functionalities will be checked. During verification stage, minimum requirements should be met for passing in next PCP phase. During validation stage, the user requirement will be evaluated for their efficiency with scoring scale 0-5.Additionally, at this stage there are also minimum criteria that should be met in order a contractor to pass in the following PCP phase.

3.5.4 Validation procedure

The contractors that reach the final PCP stage (stage 3), they will be challenged to operate their developed service features in real operations for a minimum duration of two months. As a first approach, pending for further confirmation and negotiation with the responsible authorities, different operational areas are contemplated as potential options. This

characterization shall include, among others, items like mission description, operational areas, targets of interest, mission tasks and user profiles, operational environment, the concept of operations, C2 relationship structure, policies, reporting scheme, rules of engagement, etc. The validation procedures are based on the scenarios, requirements and information defined within above information (requirements and architecture) and most prominently those will be adjusted from the contractors after the first 2 PCP phases.

The validation procedure is, sustained on a validation taxonomy built upon aggregated measures which addresses the effectiveness of the developed solutions [10]. These are namely included in the following tables:

Table 2. KPAs tree in SATOCEAN

Service / Aspect	**SATOCEAN Service 1** **MARINE environmental status in hot spots**	**SATOCEAN Service 2** **Detection of Fish farms threats**	**SATOCEAN Service 3** **Detection of vessels and icebergs in Arctic areas**	**Management tool** **User/admin Sat Surveillance services management**
Functional	Service 1 definition Detection capabilities Behaviour analysis capabilities Analysis of irregularities	Service 2 definition Detection capabilities Behaviour analysis capabilities Detection of threats	Service 3 definition Detection capabilities Behaviour analysis capabilities	HMI-GeoPortal Acquisition Planning User Request Product delivery AoIs management
Operational	Use cases Service continuity (acquisitions, revisit, etc.) scenarios	Use cases Service continuity (acquisitions, revisit, etc.) scenarios	Use cases Service continuity (acquisitions, revisit, etc.) scenarios	Timing Workflow monitoring Service output UI Service Integrity Service confidentiality
Maturity	Service 1 Interoperability Test trials incidences Fault recovery Continuity	Service 2 Interoperability Test trials incidences Fault recovery Continuity	Service 3 Interoperability Test trials incidences Fault recovery Continuity	Interoperability Test trials incidences Fault recovery Continuity
Cost	Licensing cost Equipment cost Deployment cost	Licensing cost Equipment cost Deployment cost	Licensing cost Equipment cost Deployment cost	Licensing cost Equipment cost Deployment cost

Table 3. KPAs tree in SATSURVEILLANCE

Service / Aspect	**Sat Surveillance 1** **Unusual/Irregular activity around a Critical Infrastructure**	**Sat Surveillance 2** **Enhanced Change detection**	**Management tool** **User/admin Sat Surveillance services management**
Functional	Service 1 definition Detection capabilities Behaviour analysis capabilities Position estimation capabilities	Service 2 definition Change detection in harbours Change detection in coastal areas	HMI-GeoPortal Acquisition Planning User Request Product delivery AoIs management
Operational	Use cases Service continuity (acquisitions, revisit, etc.) scenarios	Use cases Service continuity (acquisitions, revisit, etc.) scenarios	Timing Workflow monitoring Service output UI Service Integrity Service confidentiality
Maturity	Service 1 Interoperability Test trials incidences Fault recovery Continuity	Service 2 Interoperability Test trials incidences Fault recovery Continuity	Interoperability Test trials incidences Fault recovery Continuity
Cost	Licensing cost Equipment cost Deployment cost	Licensing cost Equipment cost Deployment cost	Licensing cost Equipment cost Deployment cost

KPIs will be defined per each item identified in the above tables. KPI definition includes assessment method, measures to be carried out and score/acceptance criteria. In this framework, V&V process objective is to gather measurement collections that provide KPIs score per KPA. The score is computed according to criteria, and then an acceptance analysis covering items identified in the above tables will be carried out. Last but not least for each service feature from both thematic areas a mission description has been created. Namely, a narrative description; operational areas; user profiles; Operational environment; & Mission tasks and corresponding KPI's.

4. OPEN MARKET CONSULTATION

4.1 The need of an open market consultation

The Industry Day (Open Market Consultation) was organized in July 2017, with the intention to inform the industry about the PCP procedure of the project and the requirements needed for the implementation phase of the project.

The specific objectives of this event consisted to collect the insights of the industries, implement a broad dissemination of the project, and clarify the PCP process and how companies can benefit from it.

The main outputs achieved through this event were: the consortium was able to fine-tune the procurement with the suggestions and comments of the industries; verification of the latest developments in the industry, including current projects and technical solutions that are deployed in the market; and the dissemination of the procurement process, phases and technical procedures for the potential applicants.

4.2 Feedback from the industry

Over 60 participants, from all over Europe, attended the Open Market Consultation event, including industry leaders, SME's, Start-up companies, Research Centers and Academia, NGO's and Government authorities/entities. The event was composed of seven sessions regarding the project presentation, one specific session for Q&A (moderated by the Project Coordinator and Lead Procurer), and 14 presentations from Industries and SME's for their project ideas and competences.

During this event, some questions/issues were raised by the Industries/company's, which were particularly important for the Procurement stage, being these answered by the buyers group and the coordinator of the project, namely:

- A clear approach of what is expected after the PCP phase 3. The Consortium will analyze the opportunities to implement a PPI project, assuring a market deployment of the PCP results;
- The industries also emphasized the importance of identifying the role of the buyers as potential users of the services. It is expected that the buyers group, and other public procurers across Europe, will use the newly developed services. It is also clear that the buyers group will be actively involved in the whole process, especially focusing on phase 3 of the PCP, in order to assure a combination of their needs and the final services presented;
- The industry also highlighted the importance to define rapidly the exclusion criteria in the PCP. The project has worked on this issue and the criteria have been thoroughly defined in the tender documents;
- The industry also showed some concerns about the required services, regarding what is already available in the market and if they should be integrated in a coherent way. The Consortium objective is to build and leverage upon existing services and in continuation provide these services to the end users;
- A critical issue for the industries was regarding the budget for each phase. All efforts have been made to assure a fair distribution between lots and PCP phases;
- The R&D Centers showed some concerns regarding the access to previous existing data. It was clarified that the biding budgets should comprise all the financial needs to operationalize their projects;
- It is also important, for both the public procurers and the companies to assure a clear ownership of the results. The Consortium foresees the implementation of the H2020 basic guidelines for that purpose;

Having in consideration all the above questions, the tender process assures a clear explanation of the operational and financial aspects of the procurement, in order to avoid any misunderstandings during the implementation process. This is important in order to assure a smooth implementation of the project and usage of the services by the participating maritime authorities.

4.3 Results

The several sessions, and especially the Q&A, helped to understand better what the EU and the public procurers aim at MARINE-EO project, in order to align needs and capacities of public and private entities in a common goal - deliver innovative EO downstream services in the areas of Maritime Environment and Security. The final part of this event, which comprised the companies' presentations (together with the available matchmaking tool), boosted the formation of a potential Consortium to bid for the Procurement.

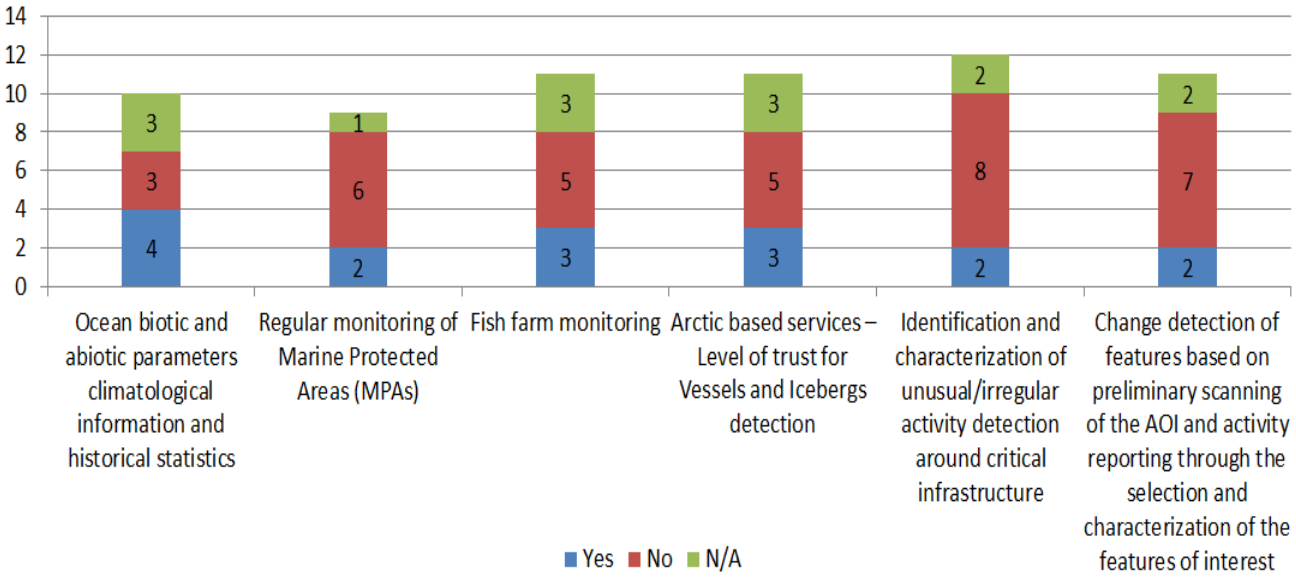
The OMC event helped to finalize the services that were request, leading to a better sort of service features for both SATOCEAN and SATSURVEILLANCE groups. Additionally, the outcome had a high significance for the process of the video animation production, to deliver an explicit and accurate set of use case animated scenarios (https://vimeo.com/252918771, https://vimeo.com/252908758).

Overall, this event was a critical step to keep the project on track and to assure the commitment and interest of the industries, SME's and Start-Up companies, in this project that aims to be a reference to the application of a PCP procedure in EO.

5. ANALYSIS OF THE REQUEST FOR INFORMATION QUESTIONNAIRE

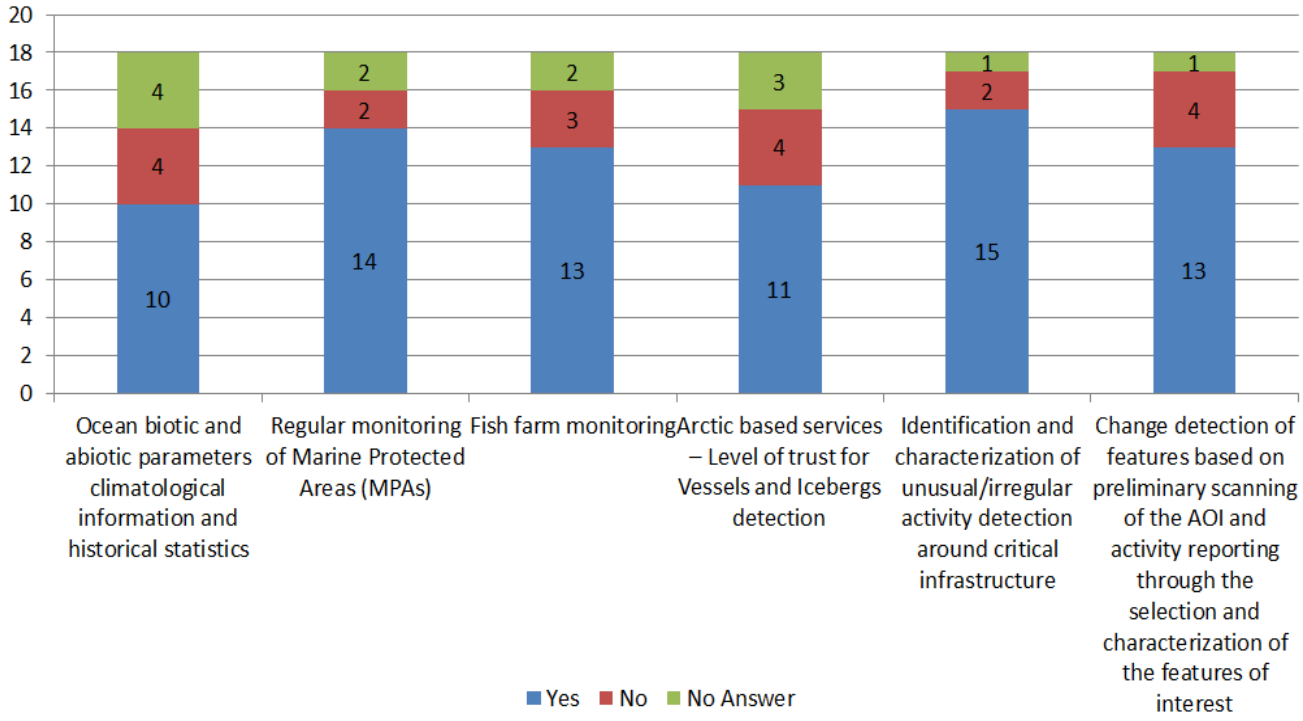
The RFI has been launched by the MARINE-EO project in order to get insights from the industry about: i) What is currently available on the market (state of the art) ii) What are the current developments and their maturity levels iii) Whether the obstacles faced by the Users can be addressed with these developments iv) To what extent can MARINE-EO contribute to pre-operational validation of technologies of Satellite Downstream Services given the time frame, budget and business model proposed v) Whether the market companies are available to exploit some kind of partnership, when incapable of responding themselves to the full range of solutions requested by MARINE-EO and v) Which companies would be ready to participate in the tendering process. The RFI was published on the project website[7] and collected input from the industry. Thirteen small and five large EO companies, from European and EEA countries, responded to the RFI questionnaire. A part of the statistical analysis applied on the collected information is presented below as well as a list of comments and recommendations derived from the replies collected from the industry, which were also taken into account for the drafting of the tender documents.

Is it possible to provide the requested services using solely Copernicus Satellite data and data from freely available Contributing missions (e.g. from NOAA, NASA)?

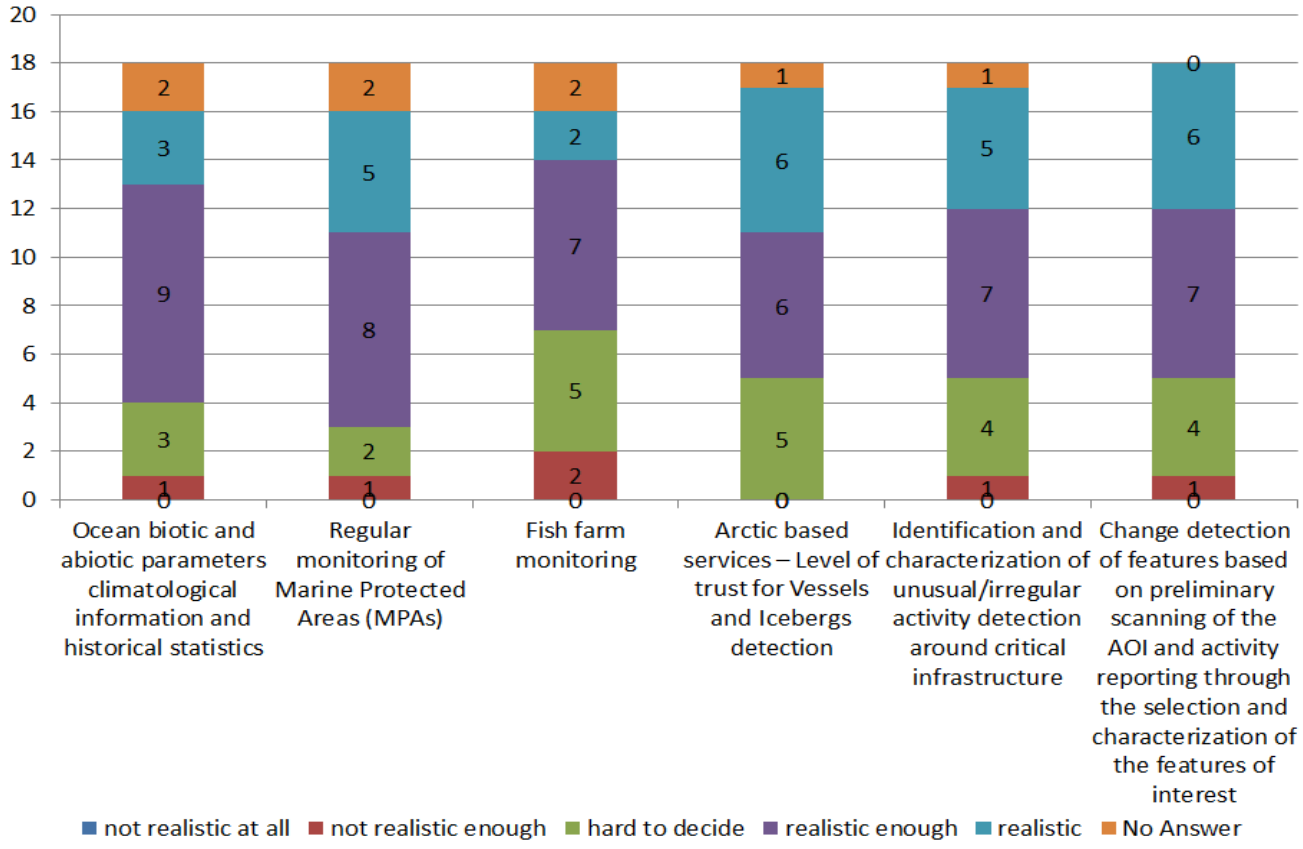


[7] https://marine-eo.eu/request-information-rfi

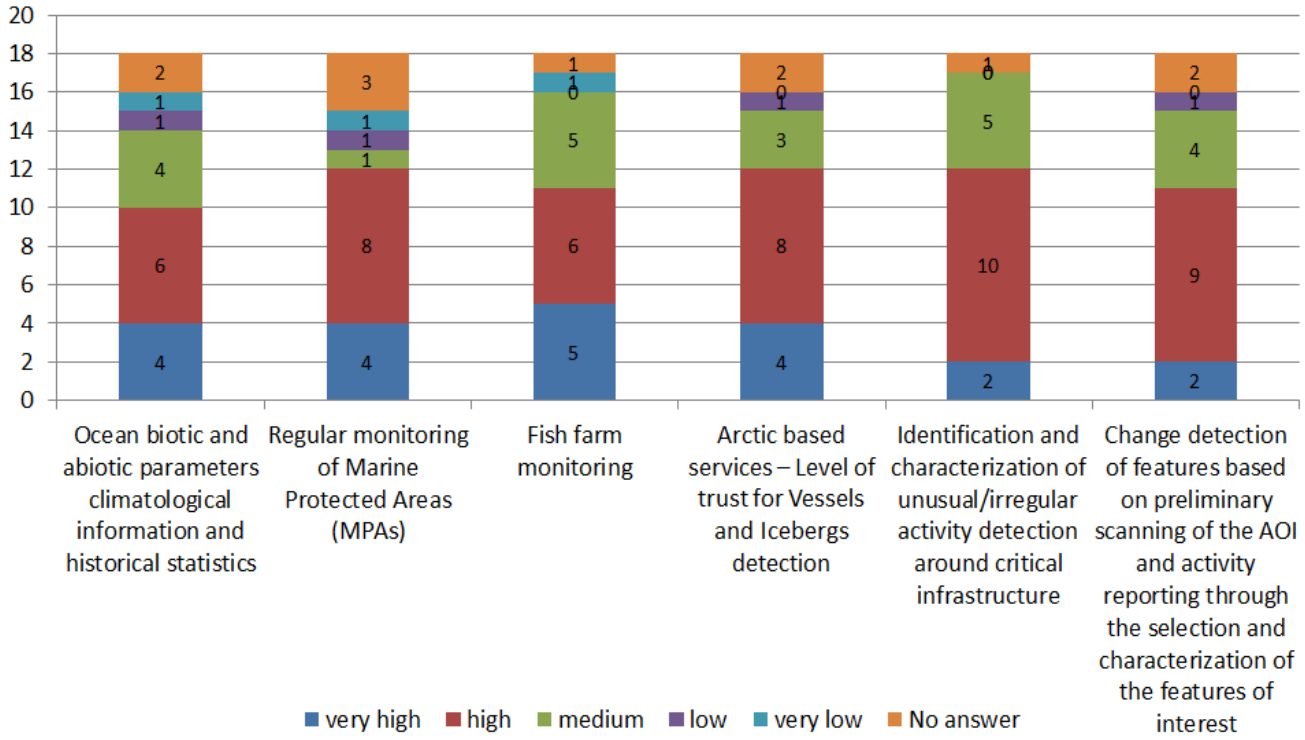
Please check the features that your organization has competences to develop



How realistic is the development of each feature from a technological point of view?



Which is the level of the innovation potential that each Marine-EO service feature could bring to the market?



5.1 Comments and further Explanations from the participants

The information received from the industries was also processed in qualitative analysis by retrieving relevant information from the companies' comments. This process, based on the companies' experience and comprehensive market knowledge, allowed the consortium to fine-tune the tender specifications, to meet the market needs and available technology.

The industry feedback can be grouped in four main sections: regarding the solutions available in the market, the funds available for the public procurement, operational aspects of the procurement process and technical aspects of the data acquisition.

An extensive report with 32 bullets containing all the qualitative analysis was produced, to feed the specifications of the tender documents. Among them, we have selected the seven most relevant, not only as an example of the analysis, but also their relevance:

1. Some industries stated that the challenge of the PCP must be further clarified, namely regarding objectives and indicators;
2. Despite the availability of solutions in both thematic areas currently available in the market, in some cases, they are not very functional, and they lack in situ validation;
3. For thematic area 2, several services have been already deployed and are in use by maritime authorities. Several industries and European authorities are actively working in this area;
4. Most companies consider that the budget of the PCP is too short to deliver disruptive solutions, which can significantly enhance what is already available in the market;
5. The companies stated that the following validation procedures could be used: Baseline Design Review; Critical Design Review; Customer Acceptance Tests; Customer feedback; Test campaign with customers.; Define KPIs that are concrete and easy to measure, where any estimation of values are kept to a minimum; Authority-based validation;
6. SME's stated some constraints, for both services, regarding:
    - The data sources (coverage/statistics) and technical architecture can be expanded and elastically scaled to meet operational needs.

- The pivotal challenge is ensuring unified; curated data is published in an interoperable state that allows both breakthrough and incremental progress across all SatOcean and SatSurveillance Services. Data/information rate and volume do not support real-time information;
- Products from CMEMS are not real-time, not even near real-time;
- Spatial resolution;
- Communications, especially in the Artic area;

7. In the fish farming services, it was identified the ICES data source that can be used for the project;
8. For all proposed services was referred that many open data sources already exist and can be integrated but without reference to the specific data sources. For Arctic based services of the Copernicus Thematic Area 1 the Imaging radar (SAR) (Sentinel-1, TerraSar, Tandem-X) was referred. For the Change detection feature of the Copernicus Thematic Area 2, was mentioned that these technologies are related to data analytics and big data making also reference to the EC/ESA C-DIAS initiative.

6. ETHICS REQUIREMENTS

6.1 Ethical considerations in the context of MARINE-EO data collection and processing operations

From an ethical standpoint, the regulatory landscape in the area of marine monitoring and maritime surveillance is identified. Firstly, the data mapping in the framework of marine environment monitoring is conducted. This scenario is associated with relatively few serious privacy and data protection risks as these missions are focused on events (e.g. Oil spill events), climatological information, ocean biotic and abiotic parameters, or objects (e.g. jellyfish blooms, algal blooms, phytoplankton etc.), rather than people. The only service that might raise a concern is the detection and monitoring of vessels in the seas, that is some details on vessels, vessel movement/direction and speed and distinction/sorting out of those which can potentially be irregular vessels, e.g. those that do not report to the AIS or LRIT systems or other traffic controlling systems, or simply vessels with no flag. In this case, the operator is not concerned about the individuals or capturing footage of individuals inside the vessels. Instead, the operator is focused on the vessel and its movement. However, the operator has a clear obligation to meet the data protection requirements associated with the collection and processing of these images. Operators should also consider privacy enhancement technologies and data minimization practices, like blurring irrelevant images or limiting their recording to images essential for the mission.

Secondly, the data mapping regarding the maritime surveillance operations is conducted. Apart from the vessels detection in the seas, category that is thoroughly examined before, there is also the images capture with low level of details, (e.g. live and still images, collected through satellites and UAVs with different degrees of details), and the images capture with high level of details (use of high resolution cameras) that should be ethically checked during the project's implementation. In both categories, the data collected should be considered as personal data because it can lead to re-identification of individuals later on and should thus be considered as ethically sensitive.

Within Marine EO context, it is clear that the data processing is necessary primarily for the purpose of ensuring a high level of internal security within the European Union. A specific personal data policy within the EUROSUR Regulation[8] prevails, as *lex specialis*, despite the fact that MARINE EO project only foresees to process personal data in exceptional cases (e.g. trials testing). After the Digital Rights Ireland judgment[9], it should be noticed that in any case, any processing of personal data should respect the principles of necessity and proportionality. Any operation should be organized in a humane manner and with full respect for fundamental rights, in particular the principles of human dignity, the

[8] The European Border Surveillance System (EUROSUR) is a cooperation mechanism and aims at increasing coordination within and between Member States to reinforce border surveillance, prevent and tackle serious crime, such as drug trafficking and the trafficking of human beings. EUROSUR also aims to make a serious contribution to the protection and saving of lives of refugees and migrants trying to reach European shores by sea. It became operational in December 2013 when the EC Regulation No 1512/2013 of 22 October 2013 on establishing the European Border Surveillance System was adopted. Regulation (EU) No 1052/2013, and Regulation (EC) No 562/2006 of 15 March 2006 establishing a Community Code on the rules governing the movement of persons across borders (Schengen Borders Code) with the Charter of Fundamental Rights of the European Union are the basic legal framework that produce legally binding effects and can be invoked before a national court or tribunal as far as this issue is concerned.

[9] Court of Justice (Grand Chamber), Judgment of 8 April 2014, Joint Cases C-293/12 and C-594/12 Digital Rights Ireland Ltd v. Ireland, nyr.

prohibition of stigmatization, discrimination, and people intimidation. Regarding the privacy issues, the risk of function creep should be particularly examined during the project's implementation[10].

6.2 Good practice recommendations

The internal policy recommendations are built on the finding that compliance with all the ethical issues depends on the good execution of services providers. Given this interaction and taking into account that the ethics requirements should be respected by the entities that will provide the services in a dynamic way, specific requirements were added inside the Tender Documents that the service providers should comply with, that include the following general guidelines:

- Raising awareness of privacy and data protection requirements in the related field
- Enacting information and transparency protocols
- Conducting privacy impact assessments in specific circumstances conformingly to the GDPR legal framework[11]
- Identifying operators to monitor good practice in ethical issues
- Appointing of data protection officers and other individuals with responsibility for data protection and privacy
- Notifying the Data Protection Authorities, if needed.

7. CONCLUSIONS

In this paper, the objectives, the services, the expected impacts, the reference architecture, the Verification and Validation strategy, the Open Market consultation, the analysis of the request for information questionnaire and the Ethics requirements of the MARINE-EO project, the first European EO PCP project were presented. Currently MARINE-EO call for tender has been published and interested companies and consortia are expected to bid in one or more of the thematic areas and services available.

ACKNOWLEDGEMENTS

The research described in this paper is supported by the European research project "MARINE-EO - Bridging Innovative Downstream Earth Observation and Copernicus enabled Services for Integrated maritime environment, surveillance and security," Grant Agreement No. 730098, funded under Horizon 2020 research and innovation programme topic EO-2-2016 "Downstream services for public authorities". MARINE-EO is an ongoing PCP project coordinated by National Center for Scientific Research "DEMOKRITOS" (Greece) and running from 2017-01-01 to 2020-11-30.

REFERENCES

[1] Berizzi, F., Capria, A., Dalle Mese, E., Gabellone, A., Martorella, M., Matta, W., "MSA system concept for Mediterranean sea surveillance," RTO-SCI-211 (2011).
[2] CISE information, https://webgate.ec.europa.eu/maritimeforum/en/frontpage/1046
[3] Copernicus contributing missions https://spacedata.copernicus.eu/web/cscda/missions
[4] Copernicus services website, http://www.copernicus.eu/main/services
[5] Hoersch, B., Amans, V., "Copernicus Space Component Data Access Portfolio: Data Warehouse 2014-2020," COPE-PMAN-EOPG-TN-15-0004 ver. 2.2, ESA, (2017).
[6] Kanjira, U., Greidanusb, H., Oštir, K., "Vessel detection and classification from spaceborne optical images: A literature survey," Remote Sensing of Environment 207, 1-26 (2018).
[7] Marine-EO project website tender documents, https://marine-eo.eu/call-tender
[8] Moreira, A., Prats-Iraola, P., Younis, M., "A tutorial on synthetic aperture radar," IEEE Geoscience and Remote Sensing Magazine 1(1), (2013).

[10] The function creep occurs when the purposes of surveillance technologies usage expand, either to additional operations or to additional activities within the originally envisaged operation. For more information, see: Hayes, B. and Vermuelen, M., [Borderline: The EU's New Border Surveillance Initiatives. Assessing the Costs and Fundamental Rights Implications of EUROSUR and the "Smart Borders" Proposals"], Heinrich BöllStiftung and The Greens/European Free Alliance in the European Parliament, 20-21 (2012).

[11] Regulation (EU) of the European Parliament and of the Council 2016/679 of 27 April 2016 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data, http://eur-lex.europa.eu/eli/reg/2016/679/oj (8 February 2018).

[9] Opitz, F., Filusch, J., Dastner, K., "Information fusion in antiasymmetric warfare and low intensity conflicts," 10th International Conference on Information Fusion (2007).
[10] Roedler, G. J., Jones, C., "Technical Measurement, A Collaborative Project of PSM, INCOSE, and Industry Technical Report," INCOSE-TP-2003-020-01 Version 1.0 (2005).
[11] Schmitt, M., Zhu, X., X., "Data Fusion and Remote Sensing, An ever-growing relationship," IEEE Geoscience and Remote Sensing Magazine 4(4) (2016).
[12] Zhang, J., "Multi-source remote sensing data fusion: status and trends," International Journal of Image and Data Fusion 1(1), 5-24, (2010).
[13] Zhu, X. X., Tuia, D., Mou, L., Xia, G. S., Zhang, L., Xu, F., Fraundorfer, F., "Deep Leaning in Remote Sensing, A comprehensive review and list of resources," IEEE Geoscience and Remote Sensing Magazine 5(4) (2017).