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PROGRESS REPORT / STATUS REPORT

Atlantic from Space Workshop summary report, 23-25 Jan 2019, Southampton, U.K.

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Acronyms

EO Earth Observation
ESA European Space Agency
EU European Union
NGO Non-Governmental Organization
OECD Organization for Economic Cooperation and Development
SDG Sustainable Development Goals
UAV Unmanned Air Vehicle
UN United Nations
WOC World Ocean Council

1 INTRODUCTION

1.1 Background

The countries bordering the wider Atlantic, including the southern Atlantic and North Sea coastal states, generate almost half of the total global economic output. The Atlantic hosts a significant and expanding portion of the global maritime traffic, and ports bordering the Atlantic represent some of the busiest in the World and Atlantic countries flag a large fraction of the global commercial shipping fleet. However many coastal areas have been developing more slowly than national averages in the region due to consolidation or decline of traditional industries such as fishing and ship building and consequent migration to more prosperous areas. Atlantic wind, waves and current systems are considered to be a major potential source of renewable energy while Atlantic fisheries are supported by one of the most sophisticated fisheries management regimes in the World (although significant IUU fishing still takes place). The Atlantic receives large fresh water inflows both from major river systems and glacier melt while at the same time functions as an important component of the global ocean conveyor belt transporting heat to the poles. Atmospheric dynamics and air-sea exchanges in the Atlantic region are important elements of many global biogeochemical cycles while tele-connections via Rossby waves and other mechanisms cause a range of impacts outside the immediate Atlantic area (eg the North Atlantic Oscillation or links between tropical Atlantic SST anomalies and the Southern Ocean circulation dynamics).

The Atlantic region is experiencing a range of different pressures driven by climate change and other factors. These affect the environment and related socioeconomic activities in the region: e.g. ocean oxygen deficiency, increased temperature, changed ocean salinity and increased acidification are expected to have impacts on the marine ecosystem in several ways and may erode its resilience. There is an increasing need for adaptive management strategies in the Atlantic area (e.g. for forestry, agriculture, urban complexes and the coastal environment), which deal with both climate change but also with emissions of nutrients, aerosols, carbon dioxide and other anthropogenic drivers. At the same time, the Atlantic region is a focal area for measures to stimulate enhanced economic expansion through infrastructure development, support to new industries (eg deep sea mining, ocean pharmaceuticals, aquaculture, ocean energy), application of new governance structures (e.g. Areas Beyond National Jurisdiction) and expansion of traditional sectors such as tourism and maritime transport. Adaptive management strategies require a comprehensive mix of different information layers and compiling representative measurements on reasonable timescales is not viable without satellites. In this context, Earth Observation (EO) combined with conventional data collection and analysis assets can support innovative science, applications and information services to address the issues highlighted above, while at the same time acting as a potential catalyser for innovation and growth in the region.

Although many Atlantic research scientists have been using EO for some time, in recent years there has been a step change in the range, quality and frequency of satellite observations as well as a corresponding revolution in access to high performance data processing and collaborative infrastructure. To maximize the full exploitation of these unprecedented capabilities, new dedicated research and development efforts are required, complemented by ensuring that the required data access, processing and analysis capabilities are put in place. To be effective, these developments must be executed as a total collaboration between the EO communities and the various scientific, private sector and public institutional professionals working on Atlantic related issues.

1.2 Workshop organization, objectives and outcomes

In the frame of the EO Atlantic Regional Initiative, the European Space Agency is also analysing the various policy frameworks related to the Atlantic and is engaging with key stakeholders. Therefore, in preparation of the Atlantic from Space workshop, and noting that the *European Union* is working towards the definition of an *Atlantic Action Plan*, consulting and supporting stakeholders to this end, ESA decided to take part in the 5th Atlantic Stakeholder Platform Conference, which took place on the 23-24 October 2018 in Vigo, Spain. A dedicated report summarizing the findings and recommendations stemming out of these discussions, presentations and interactions related to the conference theme "Blue Economy in the EU Atlantic area", was published by ESA on the 24 Oct 2018 (ref. EOP-SD-RP-2018-086). The key priorities of the EU Action Plan which were discussed are Priority 1- promote entrepreneurship and innovation (e.g. Sharing knowledge between the public and private sectors; Enhancing competitiveness and innovation capacities in the maritime economy of the Atlantic Area (e.g. education/training, sea related careers); Supporting the reform of the Common Fisheries Policy) and Priority 2 - protect, secure and develop the potential of the Atlantic marine and coastal environments (e.g. Improving maritime safety and security; Exploring and protecting marine waters and coastal zones; Sustainable management of marine resources; Exploitation of renewable energy potential).

ESA intends to conduct focussed EO research and development, downstream activities and ICT evolution, which may be the basis for future investments to address some of the key information needs of the Atlantic region. In order to assess and respond to these challenges and opportunities, ESA organized the *Atlantic from Space workshop*, held at the National Oceanographic Centre, Southampton, U.K. on 23-25 January 2019. The main opportunities were framed with respect to emerging Earth science, development of novel applications, testing innovative information services and implementing required upgrades to capabilities to manage and manipulate large data volumes.

The main ESA *Atlantic from Space* ***workshop*** **objectives** were:

1. to review the main requirements from geo-information in the Atlantic region from science to information services
2. to review the main activities, projects and initiatives taking place in the region where Earth Observation may contribute
3. to assess the potential of the increasing observation capacity offered by satellites to address the needs for science, applications and future information services;
4. to characterise gaps and identify high-level requirements and associated solutions for support ICT infrastructure in the Atlantic region, including the basis for eventually developing an Atlantic Regional Earth Observation Exploitation Platform

The workshop was organised around invited oral presentations and discussions, and the various sessions were designed around dedicated topics related to these workshop's objectives. In fact, the workshop addressed key themes in the many areas of interest, and it was very well attended by renewed scientists and researchers, industry representatives, institutional members and public authorities, and some key Atlantic **stakeholders** such as OECD, WOC, EC DG-MARE, United Nations, Eurocean, Mercator-Ocean, NEREUS, Eurisy.

In particular, the **science sessions** included presentations on Open Ocean and Coastal Processes: Ocean Circulation, Temperature and Salinity, Ocean topography, Local Sea Level trends; Biogeochemical Oceanography: Land-Sea biogeochemical feedback in the Atlantic region, Aerosols, River discharge; Atmospheric dynamics, transport and energy exchange: Atmospheric dynamics, Transport, Energy exchange; Regional Climate Modelling and

extreme events: Regional Climate Evolution Modelling, Projections, Natural Hazards, Extreme events.

The **applications sessions** focused on Supporting and Strengthening Innovation Clusters, Natural resources and infrastructure's management (fishing, sea tourism, coastal transportation, off-shore infrastructures, environment and archaeological site protection, prevention of natural disasters, marine animal monitoring, Renewable Energy Wind, Renewable Energy Waves, Aquaculture, Seabed mining, Emerging industries), Port Development, Maritime Transport and its safety and security related aspects (sea borders surveillance, sea and coastal traffic, illegal activities detection, ship identification, monitoring of maritime transport, safety of maritime transport and ports; Search & Rescue, navigation, operations, autonomous shipping, communication, information transfer, logistics, autonomous shipping, automation and control, e-Navigation, management of maritime transport operations, sustainable and smart ports development), Protecting the ocean (detection, monitoring, and characterisation of plastic litter as well as support to mitigation; Eutrification; Pollution at sea; Aggregates extraction; Ballast water exchange; Protecting biodiversity; Protecting sensitive ecosystems; Protecting Natural Capital), Blue economy and Space (develop technology for the safe exploration and exploitation of see's floors (deep sea); Maritime Spatial Planning; Emerging Ocean based industries; Ocean Services).

The **data management and platforms sessions** addressed themes such as technologies employed in the data generation and exploitation, platforms and applications running in cloud based environments, and services provided by such platforms for Scientific and Commercial Applications which are relevant for the Atlantic Region (Data sets derived from Earth Observation and other sources; Technologies for data generation; Technologies for data exploitation, GPU processing, High Performance Computing; Machine Learning; Artificial Intelligence; Application in Cloud based environment; Thematic Exploitation Platforms; Platform services supporting the development of applications; Platform services supporting the execution of 3rd party services; Commercial applications on data processing platforms).

The main outputs of the ESA *Atlantic from Space workshop* are:

- The Workshop **abstract** book: https://eo4society.esa.int/wp-content/uploads/2019/10/Atlantic-From-Space-Workshop-Abstract-Book.pdf
- The Workshop **presentations**: https://eo4society.esa.int/resources/atlantic-from-space-2019/
- This Workshop **report** summarizing the main findings and recommendations for dedicated scientific activities, applications development, service innovation and underlying ICT capabilities for a wide spectrum of users (scientific, institutional, private sector, international bodies).

This report will support ESA in defining future investments in EO research and development activities to foster EO innovation in the Atlantic region and launch a dedicated Atlantic initiative in 2019. This enables new forms of collaboration between EO communities and the various scientific, private sector and public institutional professionals working on Atlantic related issues.

2 SETTING THE SCENE

In his welcoming remarks, **Maurice Borgeaud**, Head of the Science, Applications and Climate Department of the Earth Observation Programme Directorate at ESA, presented the ESA EO Regional Initiatives and the Future EO Programme outline which will be presented by ESA at the Space19+ Ministerial Conference in November 2019.

The UK Space Agency, represented by **Beth Greenaway**, welcomed the participants outlining the strategic importance for the UK of investing in Earth Observation, to support science and innovation, creating a fruitful link between research and applications.

Angela Hatton highlighted the value of this joint initiative between ESA and the National Oceanography Centre (NOC), which is a centre of excellence in marine research and applications, with extensive experience in the use of Earth Observation in tackling science and societal challenges for the Atlantic.

Christine Gommenginger (NOC) delivered a Keynote on the topic "*From the deep ocean to the coast: open issues for UK marine science in the Atlantic sector & the contribution of spaceborne Earth Observation*". She outlined the importance of addressing science questions, the south Atlantic and heat transport towards the equator, hurricanes and sea level rise, as well as filling the data gaps, making reference to the World climate Research Program report 2017, and highlighting the value of combined data and models (e.g. sea level, winds, waves).

Ned Dwyer, outgoing Director of Eurocean, delivered a Keynote on the topic: "*Fostering Inclusivity and promoting Innovation for a healthy Atlantic*". He presented the MARINE project (EU), outlining the importance of responsible research and innovation, users engagement, citizen science and co-design and co-creation of solutions, and he highlighted the role of EurOcean, the European Centre for information on Marine Science and Technology, established in 2002. It is an independent scientific non-governmental organisation whose membership comprises leading European marine research, funding and outreach organisations, aiming at facilitating information exchange and generating value-added products in the field of marine sciences and technologies between a wide range of governmental and non-governmental bodies.

Claire Jolly, OECD, delivered a Keynote on the topic "*Space and Ocean: New Economic Frontiers*", presenting the activities of OECD in Space and Blue economy, and summarized in the report *The ocean economy in 2030*, OECD (2016). She highlighted how the value of Ocean-based industries is expected to double by 2030 (from 1.5 to 3 trillion USD), involving various economic sectors, such as maritime and coastal tourism, offshore oil and gas, port activities, maritime equipment, fish processing, offshore wind. She mentioned the upcoming conference in 2020 in Lisbon, tackling climate change, pollution, acidification and overfishing, and the upcoming OECD report (2019) *Rethinking innovation for a sustainable ocean economy*.

Anny Cazenave, LEGOS, ISSI France, delivered a Keynote on the topic "*Need for space-based and in-situ observing systems for monitoring coastal zone changes in the Atlantic region*". In this context, she referred to hydro-dynamics aspects, the importance of tide gauges collocated with GPS/GNSS to measure the relative coastal sea level, and potential activities in the areas of multi sensor monitoring of hydro-meteo-marine phenomena in River Deltas, to improve knowledge of coastal flooding processes; monitor coastal sea-level rise, with a focus on river runoff change in Western Africa.

Shubha Sathyendranath, PML UK, delivered a Keynote on the topic "*Atlantic Biogeochemistry from Satellites*". Referring to IPCC, she mentioned the importance of building an Earth carbon budget, and an ocean carbon budget also using satellite data. She underlined the link between ecosystems health and human health, particularly in relation to climate change, which is a global phenomenon with distinct regional impacts. Another important challenge to tackle would be to identify interconnections among Essential climate Variables and satellite data.

Roya Ayazi, NEREUS, delivered a Keynote on the topic "*NEREUS: European Regions Partner with the Atlantic*".

Cecilia Donati, Mercator Ocean France, delivered a Keynote on the topic "*A digital dive into sustainable oceans: the Copernicus Marine Service*"

Paul Holthus, World Ocean Council (WOC), delivered a Keynote on the topic "*SMART Ocean-SMART Industries: Supporting Atlantic Observations from Space by Scaling up Ocean Observations from Industry Ships and Platforms*".

Richard Thompson, Head of the International Marine Litter Research Unit at the University of Plymouth U.K., delivered a Keynote on the topic "*Plastic debris in the oceans, current understanding and the need for rapid and reliable monitoring*", highlighting that plastic marine litter is among the most urgent and critical issues affecting the ocean. It is of global nature, impacting both all the seas and freshwater systems, with an estimated $13 billion of yearly financial damage to marine ecosystems, according to the United Nations. In this context, he stressed the importance to fill the scientific gaps about the global plastic litter mass budget and the identification of sources and sinks, focussing the monitoring on areas closer to coasts (where most of the litter comes from, in particular from main rivers), and he addressed the monitoring as an important tool supporting policy makers in the introduction of dedicated regulations and assessing their effectiveness over time.

3 SESSION S1: OPEN OCEAN AND COASTAL PROCESSES

Chairs: Anny Cazenave and Jérôme Benveniste
Rapporteur: Marie-Hélène Rio

The S1 session was dedicated to open ocean and coastal processes. Open ocean contributions included topics such as salinity retrieval and analysis, ocean colour validation, tropical cyclones. Coastal ocean contributions covered topics such as tide modelling, internal waves and wave/current interactions, coastal altimetry processing, coastal dynamics (eddies, sea state, etc.), regional and local sea level monitoring, coastal storm surges, oil spill monitoring. General recommendations include fostering the development of new methodologies (spatial correlation, pattern identification, machine learning, etc.), new products (Frontal boundaries, etc.) and new visualisation tools. A general need for in situ observations was expressed in order to correctly and consistently validate the different space-borne datasets. Also, it was recommended that this regional initiative should provide a framework with access to all data needed for the Atlantic region.

Wind was identified as one of the main knowledge gaps for oceanographic studies, calling for further focus and support regarding the use of all available data for Wind improvement. In particular the need for further work on wind retrieval from SMOS data processing and the future integration of Aeolus measurements were mentioned.

A few talks were dedicated to salinity retrieval and analysis. Improved salinity products are needed in polar regions. In order to complement the existing Arctic+ initiative, a dedicated Antarctic study on salinity was recommended. Also, the need to embrace long term monitoring issues was identified, capitalizing on the new CCI salinity project. Finally, a future mission recommendation was expressed for a high-resolution SMOS mission.

Recommendations for further studies on Hurricanes and Water masses were also expressed.

A clear outstanding recommendation emerged regarding the need for a strong focus on **coastal areas** where many challenges occur, both scientific and societal. Ocean-Atmosphere-Biosphere-Land integrated, multidisciplinary coastal studies are needed to improve all the **different physical and biogeochemical parameters**, and further understand their **interactions**.

Physical variables include tides, sea state, sea level, currents, eddies, vertical motion, bathymetry, coastal erosion. Regarding bathymetry, the need for **high-resolution bathymetry (<100m) was identified,** not only static fields but **also time varying.** When possible, ESA was asked to help facilitating access to high-resolution bathymetry products, most often not publicly available for scientific purposes.

In order to precisely and consistently address **Regional coastal sea level,** the generation of **precise and homogeneous satellite altimetry products tuned for coastal studies** (using dedicated retracking and improved geophysical corrections) is highly recommended.

A need for **higher resolution** and **higher frequency products** on shelves and coastal areas was identified, possibly exploiting the increased capability provided by the **synergetic use of space data, in situ measurements and models**. In that context a need for **increased in situ data coverage in coastal areas** was identified.

Eastern Boundary Upwelling Systems (EBUS) were identified as privileged hotspots to perform such an integrated multidisciplinary study.

4 SESSION S2: BIOGEOCHEMICAL OCEANOGRAPHY

Chairs: Christine Gommenginger and Shubha Sathyendranath
Rapporteur: Marie-Hélène Rio

The session was opened by **Stefano Ciavatta (PML)** who gave an overview of ocean colour (OC) data assimilation (DA) applications in the Atlantic. He showed that assimilation of other OC products (such as the light attenuation coefficient k_d, and the Phytoplankton Functional Types or PFT) outperforms the traditional assimilation of total chlorophyll. **Jozef Skakala (PML)** followed by showing results from a joint PML/MetOffice Project on The Assimilation of PFT for Operational Forecasting in the Northwest European Shelf. The four PFT classes are Diatoms, Nanoplankton, Picoplankton, Dinoflagellates. PFT DA outperforms total Chl DA in PFT forecasting skills, and has comparable results in the representation and forecasts of total chlorophyll. **Heather Bouman (Univ. of Oxford)** discussed methods to develop remotely-sensed Ecosystem indicators such as Primary Production (PP). PP computation needs photosynthetic parameters that are difficult to obtain (normally done with radioisotopes), investigated by the ESA MAPPS (Marine Primary Production Parameters from Space) Project. Combining in situ flow cytometry (cell abundance) with remote sensing data is the way forward. **Silvia Pardo (PML)** continued on the issue of deriving Ocean Monitoring Indicators over the Atlantic Ocean – she used Copernicus CMEMS OC data in turn based on the OC times series from the ESA Climate Change Initiative (CCI), and showed global and regional trends. **Bror Jonsson (PML)** addressed the problem that most biology processes have shorter time scales than most model/satellite studies on the biological pump, and showed how to find the dominating time scales with the "Running STD" method. Ideally, we should have geostationary satellites to get hourly OC data. **Peter Croot (Nat. University of Ireland, Galway)** showed work (including a detailed description of the observing system) to understand the impact of multiple stressors on the marine ecosystem services, in particular what controls Phytoplankton production, along the Irish continental shelf.
The discussion highlighted a number of recommendations:

- A province-based approach (using eco-regions) is appropriate to achieve a better understanding of pools and fluxes of carbon in the ocean and additional products beyond Chl should be used (phytoplankton types, primary production, spatial structure of phytoplankton, Dissolved Organic Carbon).
- It is crucial to involve the modellers (including colleagues who specialise in data assimilation techniques) for process understanding (e.g. primary production) and in the specification and development of products.
- Focus should be put on **dynamical processes and the carbon cycle in coastal and estuarine waters**, trying to exploit the multiple types of in situ measurements in combination with EO data to elucidate the role of the many processes at play.
- Regional and coastal high-resolution wind products (both satellite-derived and reanalysis) are needed in support of the coastal focus.
- At a larger scale, focus should be put on **linking surface observations and the sub-surface ocean**, both for the physical and biogeochemical processes, using

satellites in combination with Argo / Biogeochemical-Argo floats to monitor the large-scale 3D transport and its impact on the biogeochemistry.

- A topic that deserves attention is also marine dust (aerosol), for its multiple impacts on human health, ocean biogeochemistry and economic activities.

5 SESSION S3: ATMOSPHERIC DYNAMICS, TRANSPORT AND ENERGY EXCHANGE

Chairs: Tom Bell and Christine Gommenginger
Rapporteur: Paolo Cipollini

The session was opened by an invited talk by **Tom Bell (PML)** on how the Surface Ocean-Lower Atmosphere Study (SOLAS) is contributing to our understanding of air/sea exchange in the Atlantic. SOLAS is a comprehensive project with several core themes plus integrated topics (such as upwelling areas, and coastal waters) and 'Science and Society' topics (example being the impact of ship plumes), and results were presented, for example on quantifying air/sea CO2 exchange in the Atlantic from the AMT cruises. SOLAS recommends a distributed network of continuous flux measurements and studies to improve the satellite retrievals of concentration and fluxes of other gases (for instance DMS). **Simon Josey (NOC)** then discussed how the North Atlantic cold anomaly ("Big Blue Blob") of 2015 is linked to a surface salinity anomaly ("Big Fresh Blob"). He demonstrated that the cold anomaly was due to the extreme winter heat losses in 2013-2014 and 2014-2015, rather than a sign of Atlantic Meridional Overturning Circulation (AMOC) decline. Sea Surface Salinity indicates that the cold anomaly is accompanied by ocean freshening and this will be investigated in the ESA Salinity Climate Change Initiative (CCI) Project. Finally, **Saleh Abdalla (ECMWF)** reviewed the use of satellite data to support ocean wind and wave forecasting, describing the ECMWF modeling infrastructure for sea state, and how ocean wind and waves measurements from altimetry are used, as well as their validation against in situ data. Winds from scatterometers are of course also used, and recently ECMWF started looking at SMOS data. Saleh concluded that there is still potential for improvements and listed some desirable extra measurements – amongst which a reference observation dataset for high winds would be particularly needed.
The discussion highlighted a number of recommendations:

- There is a need to investigate further the links between **ocean ecosystems** (including the plankton functional type assessments), **aerosols precursors** (e.g. DMS concentrations), **aerosols and clouds**. This is related to some of the recommendations of the Biogeochemistry session S2.
- The **crucial role of wind and waves in air/sea fluxes** underline the importance of the coupled Earth System modelling approach and this should be reflected in the studies that use EO (i.e. there should be a 'coupled' approach when possible).
- Still related to the recommendation above is the proposal of the **creation and validation of a mean square slope product** using satellite measurements of roughness. Such a product would be very useful to assess gas transfer.
- **Gas transfer** measurements should also be evaluated by applying existing and/or novel satellite data products such as SAR-derived products, **whitecaps** and **wave** products.

6 SESSION S4: REGIONAL CLIMATE MODELLING, EXTREME EVENTS AND CLIMATE RESILIENCE

Chairs: Anny Cazenave and Jérôme Benveniste
Rapporteur: Paolo Cipollini

Paolo Cipollini (Telespazio Vega UK for ESA) gave an overview of the ESA Climate Change Initiative (CCI) Programme and several examples of the use of CCI-derived Essential Climate Variables (ECVs) to look at climate related processes over the Atlantic. He stressed that the ECVs inventories are available for anyone to use. **Meric Srokosz (NOC)** talked about the importance of monitoring the Atlantic Meridional Overturning Circulation (AMOC), predicted to slowdown or stop under global warming and to have other major effects including on hurricanes, and presented the sustained measurements carried out in the RAPID programme and several other studies. He highlighted the continuing challenge of linking in situ and satellite observations to improve understanding and prediction of this major component of the global oceanic circulation. The overarching challenge is to build a sustained observing system. **Sonia Ponce De Leon Alvarez (CENTEC PT)** presented a study of extratropical cyclones (ETCs) extreme waves from satellite altimetry observations, motivated by maritime safety, ship routing and wave monitoring needs in the coastal Western Europe, and recommended the development of specific data products for ETCs by integrating sea surface and atmospheric data. Finally, **Carlos Domenech (GMV)** introduced a new paradigm for Climate Resilience programmes over the Atlantic region, which is being developed within the ESA EO4SD-CLIMATE Project, that includes a user-driven approach with stakeholder involvement and capacity building (with a forthcoming workshop in Nairobi in March 2019). This project leads to the development of a Climate and Disaster Risk Observatory and the promotion of state-of-the art solutions.

A couple of possible studies were recommended from the discussion:

- **AMOC variability is a key issue** where considerable progress is in sight by a combined EO + in situ (RAPID/OSNAP) + modelling approach – with links into effects on fluxes and biogeochemistry (as seen in Sessions S2 and S3). Also, AMOC variability has impact on coastal sea levels so it links with the coastal work explored in session S1.

- **Storms / Extra Tropical Cyclones / Extreme Sea States** are also very important (for their impacts on exchanges/NWP/operations at sea). The theme of climate resilience and related capacity building can also be linked into this.

Finally, it was recommended that ESA Climate Change Initiative (CCI) inventories of Essential Climate Variables, freely available with analysis and visualization toolboxes at http://cci.esa.int, should provide the climate perspective to any exploitation study.

Science Sessions Posters

More than 20 posters from the Science sessions were exposed all throughout the workshop, covering and extending the topics reported above. In the limelight was, among others, the monitoring of North Atlantic storms, which have a significant impact on coastal communities and on seafarers. Satellites such as Envisat and Sentinel-3 provide simultaneous observations by active microwave, passive microwave and infrared instruments providing a synoptic view of conditions high in the cloud and the interaction with the sea surface. This potential needs to be developed into routine retrieval and interpretation. As the storms develop significant rain cells occur, distorting the altimeters' Ku-band waveforms and making geophysical retrievals problematic. More effort should be expended on using the available C-band or S-band data from dual-frequency altimeters and properly processing in near real time the waveforms distorted by rain, extreme wind and wave as the information on these conditions is critical for issuing advice by the Coastguards. Used in synergy with sea state retrievals from Sentinel-1 SAR instruments, these data are a precious asset in extreme events when in situ measurements are rendered problematic.

7 SESSION A1 INNOVATION CLUSTERS

Roberta Mugellesi, from **ESA Business Applications**, introduced the topic of space for ocean, from the perspective of the ESA convention and its reference to space applications. The approach of the TIA directorate is user driven, with a focus on commercial sustainable services, selected on the basis of a credible business plan and possibly applying the co-design methodology. In this way the users better understand the capabilities offered by space and what type of services to expect. This can happen through direct collaboration with end users (e.g. regional innovation agencies) to build sustainable business together. A good example is represented by ports that need operational solutions timely, and this can be a challenge for co-design processes and allocation of users resources.

The end goal for ESA is to integrate space assets (EO, galileo, tech,) and various established sectors (maritime transport and ports, aquaculture, renewable energy, etc…). But the Agency is also looking beyond towards new areas of technological development, such as big data, 5G, IoT, and AI. These technologies can be applied to emerging economic sectors such as **autonomous shipping** (ESA-Rolls Royce agreement in 2018), opening avenues for collaborations with Singapore Port and the International Maritime Association, based on more than 20 studies in this field. The next steps will be to consolidate a roadmap for demonstration in collaboration with EDA.

Another topic of interest is off-shore energy, with a set of relevant information provided by space: from forecast to nowcast of wind and waves, possibly opening new economic opportunities as outcome of these research activities. The collaboration with the European Maritime Safety Agency (RAPSODY project – operational service since Dec 2017) and the "**Ports of the future**" initiative, that include air quality monitoring in the surrounding area, will assess the impact to local population and tourism of maritime traffic and port operations, through the provision of integrated services. An example along these lines is intermodal logistics at Europort, with similar applications developed for Poland and Portugal, estimating arrival time of the ships and planning logistic operations.

Certainly the upcoming 5G network and its associated new services, will significantly benefit also the maritime sector, including high definition real time maps. Future opportunities, which are part of the Atlantic Kick start, include topics such as biodiversity, environmental crime (illegal dumping and fishing), marine plastic challenge and sustainable development, navigation safety, underwater network to satellite communications, Virtual Reality maritime education (Poland), dredging environment COASTMADE (Ireland), water data UNDERSEE (Portugal).

Nuno Catarino (**DEIMOS**) and AIR CENTER (Portugal) expressed the need to further collaboration through GEOSS, illustrating needs data, computing resources, platform set-up, operations stages (Feb 2019 release of a catalogue). In this context it has been envisaged the possibility to create an **Atlantic GEOSS** for the sustainable development of the Atlantic region through users federation, knowledge sharing, environmental sustainability research (marine, maritime, coastal). These will be the initial focus areas, with a budget allocated for 2020-2022 from various funding institutions (see roadmap 2019 www.atlanticgeoss.org). This proposal will be presented in Nov 2019 to the plenary of GEO.

Fabio Viera, from the **Regional government of the Azores**, discussed the Marine-EO project, and pre-commercial procurement (PCP) as a good approach to innovation, which includes tailored solutions to customer needs, innovative avenues for the provision of

funding, risk sharing between companies and public authorities. In this context IPRs are retained by the companies and governments have specific access rights to these IPRs.
In this context two services are being procured from a consortium which include public authorities from various Member States (PT, S, NO, GR):
- SATOCEAN for fishing
- SATSURVELLIANCE (SAR to detect ships, follow route, forecast of route; combined with AIS and help define coast line; detect illegal activities via behaviour pattern detection vs expected route) for security to support the "guardia civil".
Some recommendations from Marine-EO project were highlighted:
1) it is an useful tool to develop tailored solutions (use cases, regional needs, bridge companies-public needs)
2) PCP implementation process can be quite heavy in the tendering process, requiring ad hoc management capabilities and legal advice
3) the process can favour disruptive innovation, but requires some time to be effective. It support access to market were industries are already established.
4) MSFD challenge can be addressed using PCP.

Jose Mouthino (**AIR CENTER**) presented a strategy to **leverage innovation through science diplomacy**, which is being implemented since 2016, involving more than 15 governments at high political level, around Brazil, Capo Verde, Canary Islands and Azores. He outlined a collaboration framework with three key partners: Azores region, PLOCAN, Nigeria and soon South Africa, in line with the Belem Statement. There are also other associated countries, plus academia and affiliated institutions. With whom the AIR CENTER is willing to create synergies around marine resources, clean ocean, deep sea, climate change mitigation, renewable off shore energy, data science deep learning, including supercomputing centers across the Atlantic (e.g. AIR_DataNET (Texas, Barcelona, South Africa Cape Town, Brazil)). Portuguese national priorities are also addressing global challenges and respond to the United Nations Sustainable Development Goals, around which the AIR CENTER built a partnership with UNOOSA. With GEO there is an ongoing discussion to provide new services for the Atlantic. And it is foreseen to organize around ten EO PhD positions in the Azores to set-up the AIR center secretariat, in partnerships with global and regional actors and networks, to leverage Capacity Building efforts.

Ayoze Castro presented the activities of **PLOCAN in the Canary Islands**, were the research centre was founded eight years ago to promote ocean science and innovation in the region, having also a focus on tourism and a strategic link with Europe, Africa and South America. Science research is also conducted in astrophysics in Tenerife. PLOCAN is a marine test site which can host up to forty researchers for science experiments, it has a coastal observatory and test facilities, with sensing technologies and platforms, connecting research infrastructures and blue growth, in terms of technologies (e.g. energy converters) and multi use platforms. They are currently managing around 15 new projects funded by Horizon 2020, being close to industry, to the regional cluster in Spain, the Maritime Alliance in San Diego and they are linked with EU strategies (Sea basin, Atlantic strategy, integrated maritime policy) and AORA Galway statement (EU-North America), Atlantos, the Macaronesia region with a link to the Caribbeans.

Jonathan Williams from **Marine South East** presented the cluster organization that exploits strong historical strengths in naval equipment manufacture, building and operation, ports and maritime logistics, marine science and leisure craft. The cluster is focussed upon developing capability to exploit the emerging 'Blue Growth' markets through

diversification which has been stimulated by major investment in ocean science, marine instrumentation, advanced marine manufacturing and marine/offshore renewable energy. MSE participated in H2020, FP7, Interreg and nationally funded programmes, collaborating with industry, academia and public sector, to facilitate companies' investment in innovation by improved access to technology, skills and market intelligence; forging new relationships to help companies gain market access particularly in emerging maritime market areas; and promoting the capabilities and growth potential of the marine industries and their supply chains to Governments and policy makers. Mr. Williams presented the EU funded Space Wave project on how to optimise Europe's full potential of the use of Earth Observation technologies in Blue Growth. The Internationalisation Strategy covers a timescale of 5 years (2018-2022) and aims to establish SpaceWave as the reference point and gateway for Europe for Earth Observation applications in Blue Growth industries. The activity focus on what is needed and how the community can address it, looking at the challenges EO can be valuable for also in terms of commercialization at international level for the blue economy sectors.
The focus is on few countries and areas where there is high potential for success, including Canada and South Africa, Blue tech cluster alliance, key actors and research centres, collecting their needs and areas of interest (e.g. fisheries and aquaculture, coastal erosion, value chain mapping integrating in-situ data with EO, ICT, public authorities, consortiums and networks in various business domains). Some case studies were presented on aquaculture and how to operate it sustainably, fisheries and unreported illegal fishing, coastal erosion and novel applications for decision making (e.g. insured losses for coastal flooding where 2 hours warnings can reduce significantly damages, improve forecasting capacity). He outlined the limitations of SAR and AIS, and the Blue Belt approach integrating EO, drones and at-sea solutions. In conclusion, there are concrete opportunities to look for new solutions following an interdisciplinary approach and working with non-obvious partners, introducing existing EO capabilities and setting a roadmap for developing new technologies with ESA, supporting PPPs for innovative solutions and opening channels to new customers.

In the **Q&A and Panel Discussion** some interesting points were raised concerning:
- Social aspects and local culture influence the clusters, therefore the challenge is to have an "Atlantic culture"
- Composition of the cluster: mix of small spin off, university, industry, EU policy
- Cluster size. Portugal has one marine cluster for the entire country, while France has two clusters. All work differently, some are membership based. It is important to leave several possibilities open to be inclusive. Each small cluster in a region can develop their focus and then it would be possible to create clusters of clusters (Atlantic GEOSS is a very interesting proposal to the GEO ministerial). The key drivers should be easy ways of interaction, meeting and financing.
- Innovation role of the clusters/networks, as highlighted by OECD. Maritime alliance is industry led, while NOC and PLOCAN have a key role as orchestrator in some sectors. They are a good way to identify challenges by members of the clusters and their extended network. ESA supports long term / high risk challenges and is ready to support innovation in a cluster environment
- New ways of working together to have an impact on industry-scientists collaboration (e.g. Korea work differently)

- Technology transfer activities are on going in some of the clusters: AIR center is working on capacity building with Ghana (north-south cooperation) and PLOCAN on Atlantic collaborations.
- Commercial applications are a new area, being the end-users not only institutions but more and more also private users (industry as next customers: what are new challenges for emerging industries where we can use EO ? what are showstoppers in expanding autonomous shipping ? what is the next species for aquaculture ?)
- Road-mapping emerging sectors: what are common needs in multiple sectors ? invest in one area that will benefit many sectors (*anchoring system* for example)

Round Table: Supporting and Strengthening Innovation Clusters in the Atlantic Region

Johnny Johannessen from **Nansen environmental and remote sensing center (Norway)** explained that NERSC vision is based on better understanding of the Earth system, on a science based innovation for the benefit of society, and on transferring of research to mature operational services. NERSC also disseminate and communicate EO knowledge to stakeholders and society in support of sustainable development and blue growth, contributing to education and capacity building. This last one is aligned with the role of a Copernicus Relay and how it could support the development of Innovation Clusters. He explained that in order to get to end-users and to industry, creating added value services, NERSC provides sustainable funding for research for a long time. Important users are policy makers that could contribute to foster the use of EO, since they would be the main beneficiaries. EO applications are "Multidisciplinary activities" and the potential of areas of application is enormous. With respect to the cluster of cluster he considers that it is important that all participants contributes.

Marek Moszyński from **POLSA** underlined the importance to involve end users in the innovation clusters strategy. He also pointed out that stakeholders will arise when EO is used and its benefits are made visible.

Roya Ayazi **NEREUS** presented the European regions network explaining that is important to create an ocean-economy innovation networks, developing a common strategy for using space. It is also important to promote interregional collaboration among the main stakeholders: users, researches, industry, academy, SMEs. She also pointed out the main challenge to involve traditional markets from marine/maritime communities. In order to produce new ideas and involve the appropriate partners, NEREUS develops users' EO uptake activities, stimulating exchange and partnership conferences. They collaborate strongly with ESA and projects funded by the European Commission (EC).
Regarding their strategy for fostering innovation and putting together all stakeholders, they focus on: involving Public administration, developing added-value application in areas related with economy and environment, involving relevant stakeholder by using existing structures.

Xavier Rebour presented **POLEMER,** a French initiative fostering Marine business for Blue economy, by developing new services and products. Regarding their strategy for fostering innovation and putting together all actors, they focus on involving relevant stakeholders in order to provide value-added applications in many areas, implementing PPI procurements and creating Cluster of clusters with a coordinator, as friendly ecosystems to link industry and academia.

Luisa Boquete Pumar from the **Galician Agency for Innovation (GAIN)** highlighted the importance of promoting and structuring innovation with policies. The smart specialization strategy includes innovative management, health lifestyle, industry model, and the Plan Galicia Innova 2020 aims at strengthening knowledge centres, improving tech transfer to industry from academia, organizing return on investment. The agency dedicate 25% funds for R&D, and the civil UAV initiative is the most important and it is built around a mini cluster. Pre-commercial procurement is used to boost innovation from early stage. Answering a question regarding the pre-commercial procurement, she explained that PPI are normally implemented by GAIN in order to develop key areas. Activities supported by GAIN are addressed to optimize users services. She also referred to Columbus project (EU) as a strategy for technology transfer from research to market. GAIN also implements a strategy for fostering innovation by putting together all stakeholders (end-users, SMEs, industry, …). Another important objective is to put together Digital Economy and Blue Economy, including all traditional marine/maritime users.

8 SESSION A2 NATURAL RESOURCES

Natural Resources Management requires the combination of space-based and in-situ observing systems, particularly for monitoring coastal zones and local environmental conditions related to sea level changes (e.g. multi sensor technology is particularly appropriate to the monitoring of hydro-meteo-marine phenomena). G. Rowlands, from the **University Of Oxford**, discussed the monitoring and surveillance of **fishing activity** in the central Atlantic, outlining how Earth Observation data are increasingly used to understand the dynamic ocean environment. These data are used by fishing vessels to target appropriate fishing grounds, and by science and management to understand and predict the distribution of target species, the activity of fleets which target them, and increasingly provide a means to monitor and survey the activities of fishing vessels in or near 'real time'. The information that satellite data provide can be used to design appropriate fisheries management measures (including spatial, temporal, species and gear restrictions), assess their ongoing effectiveness and ensure compliance. For example, designation of large expanses of the ocean as Marine Protected Area (MPA) is increasingly advocated and realised. However, the effectiveness of such MPAs, requires improvements to vessel monitoring and enforcement capability (e.g. some tests were performed using SAR RADARSAT-2, designed to survey Canada's coastlines and the Arctic for the detection of fishing vessels, fishing buoys, refuelling vessels, etc.…). The UK Blue Belt Program targets the protection of these expanding MPAs (e.g. up to 4 million sq. km by 2020). Drawing on data from a three-year study of Ascension Island the role Earth Observation data in applied monitoring and assessment of fisheries was illustrated, as well as how these data can be used to inform models used in fisheries management. In other areas the availability of Sentinel-1 free and open data is currently being tested to monitor Costarica maritime traffic, the Panama canal and validate AIS data. It was noted that there is a Copernicus data gap in Ascension island. The Visible Infrared Imaging Radiometer Suite (VIIRS), an instrument onboard the Suomi National Polar-Orbiting Partnership (Suomi NPP) spacecraft, was mentioned as well as the OCTOPUS, a tool developed at Oxford **Sustainable Ocean program**, for satellite data used in fisheries modelling, monitoring and enforcement, as well as to develop and manage policies. Such services complement the ones already provided by EMSA and EFCA.

Ioanna Karagali, **DTU** presented, in the context of offshore renewable energy, the **new European Wind Atlas**: NEWA, which is a joint effort of research agencies from eight European countries, leading to the creation and publication of an electronic wind atlas, extending 100 km from the European coasts. Mesoscale models along with various observational datasets are utilised, and satellite wind retrievals from scatterometers and Synthetic Aperture Radar (SAR) instruments were used to calculate offshore wind resources at 10 m and later extrapolated to 100 m. The aim of this study is to demonstrate the use and applicability of **EO data for ocean surface winds for wind energy** applications.

Sentinel and Copernicus data for operative and continuous monitoring of coastal waters and resources was presented by Daniela Drimaco in the context of **Rheticus® Marine**, an automatic cloud-based geoinformation service designed by **Planetek** Italia to deliver fresh and accurate satellite-based data and information for the monitoring of coastal seawater quality and marine resources. At European level the Marine Strategy Framework Directive (MSFD) requires Member States to reach Good Environmental Status (GES) through the evaluation and improvement of 11 qualitative descriptors among which **Eutrophication**. This service is designed around these requirements, as specified by the Italian Public authorities, and uses AQUA/TERRA, Sentinel-2 and Sentinel-3 and E.U. CMEMS data and time series of water quality parameters to identify sea areas that are

homogeneous in terms of eutrophic behaviour (i.e. MSFD zones for GES). It also provides **operational services for aquaculture**, by real time monitoring and forecasting of relevant water quality parameters (e.g. from MODIS and Sentinel-3/OLCI), and by modelling with a machine learning algorithm trained with historical data from CMEMS and the farms operators, the level of growth of the mussels/fishes in the Adriatic sea, predicting the best time to harvest in order to maximize profits. Another area being explored is the combination of Sentinel-2 and Sentinel-3 data, to provide real time alerts to **Desalination Plants** on the occurrence of algae blooms together with other water quality parameters in coastal areas, in the proximity of the *plant's water intake,* avoiding damages and interruptions of plant operations, as well as reducing the environmental impact on coastal areas (e.g. pilot project in United Arab Emirates). EUGENIUS, a H2020 project that provides viable market based Earth Observation services in different European regions, monitoring **water** quality during **summer bathing** season (chlorophyll level). All these examples outlined the importance of supporting the transition from product to info as a service, defining verticals, connecting with other initiatives, addressing the issues of the Atlantic users, and providing requirements to ESA for future missions.

L. Aouf, **Meteo France,** discussed the improvements on **wave forecasting in the North Atlantic Ocean**, which can induce severe damages on European coasts (e.g. winter 2013/2014, the Brittany buoy managed by Meteo-France has recorded more than five times significant wave heights exceeding 10 meters). Recent improvement have been implemented for the regional wave model MFWAM, the assimilation of altimeters and SAR directional wave spectra from open ocean to coastal zones and in the **coupling between waves and ocean models** developed in the frame of Copernicus Marine Service for Iberian-Biscay-Ireland (CMEMS-IBI) domain (e.g. better sea surface height forecast during storms events Petra and Hercules in 2014), and in its impact on key parameters such as sea surface temperature and surface currents. The impact of wind forcing from different atmospheric systems (IFS and ARPEGE) on **swell forecast in the channel during storms** has also been discussed. Further comments and conclusions were provided on the Copernicus involvement with Mercator, and the Iberia-Biscay collaboration with Ireland. The need to have a 10Km resolution globally, a daily coverage (altimetry and SAR wave spectra) was discussed, as well as archives of storms data and waves produced. **Coastal models** are being studied to better fit buoys models and satellite data, particularly in the CMEMS-IBI context and to predict storm consequences by coupling ocean and atmosphere data.

Ioanna Karagali, **DTU** presented **wave climate analysis** for the North Sea, looking at applications to support renewable energies. Offshore wind farms are installed at various regions of the Dutch, British, German, Danish and Belgian exclusive economic zones (EEZ), and wave energy converters are under development. In order to plan operation & maintenance activities offshore, wave climate analysis is an essential tool (e.g. ESA's GlobWave Altimeter Multimission SWH product was used to derive long-term monthly statistics of significant wave height for the North Sea). Currently, 16 GW Offshore Wind Energy is installed, with a projected budget of 20 Gw by 2020, and 80% of installed power is at 60 m depth or more (with a new tendency towards floating platforms). These developments could be supported by in situ buoys CMEMS (e.g. Anholt Denmark) and satellite, eventually merged in a **Wave Atlas,** with monthly climatology mean wave height, and along the lines of www.science.globalwindatlas.info It was also recommended to fill data gaps and to plan long term joint wind-wave distributions, to be used also for weather window analysis to support offshore operations and maintenance activities.

Armando Marino**, University Of Stirling,** presented the use of Sentinel-1 to detect aquaculture structures in Spain, which are a very valuable asset for many coastal countries and play an important role in food security (e.g. estimated value of 150 Billions from Financial Times). Temporal and geo-spatial analysis of these marine platforms, ensure asset integrity monitoring, especially after storms, and detection of illegal placement in protected areas. **Intensity Dual-Pol Ratio Anomaly Detector (iDPolRAD)** has been applied to identify smaller and non-metallic targets under rough sea conditions. The algorithm is based on the observation that most of the maritime targets exhibit a different polarimetric behaviour compared to the sea, with cross polarization channel and the ratio between cross- and co-polarizations (here referred to as depolarization ratio) increases. In fact **complex acquaculture platforms** provide scattering which will resemble Volume scattering or reflections from planes (mostly wet surfaces) with random orientations. They are therefore expected to have a polarimetric backscattering that is different from the one of the sea which is surface scattering. This was successfully demonstrated at a test site is in the coastal area near Vigo, Spain, where there is extensive production of mussels with hundreds of platforms.

Nuno Grosso, **Deimos Portugal,** presented a Fishery Support Service in view of the implementation of UN's SDG14 and SDG12. The development of integrated fishery support services based on EO and non-EO data sources can help public authorities and fishing companies, characterizing and spatially quantifying fishing pressures, linking fishing activities to catch/landing registers and environmental parameters, and providing information on fishing yields and potential fishing areas. To develop such a service it is important to engage with **end users willing to co-design and adopt the service**, including expert partners in different regions and with knowledge of various fish species, being able to provide EO data (e.g environmental/sea state parameters) and non-EO data (e.g. e-log-books or landing declarations), and in collaboration with key experts in fisheries, oceanography and ocean biology. A demo application developed with the Portuguese Hydrographic Institute (Hidrográfico) characterized potential **fishing areas of sardine and mackerel** in Portuguese coastal areas www.simocean.pt, and another demo will be developed together with the Portuguese Institute of Sea and Atmosphere for **deep waters pelagic species** (tuna and swordfish) in the Northeast Atlantic. This follows the work being developed collaboratively by Deimos (SIMOcean, Co-ReSyF, NextGEOSS, Marine-EO and SAGA), providing access points to marine datasets, and to a range of pre-operational and R&D services, from support to harbor navigation to coastal bathymetry and algae monitoring. Such services for sustainable fishing would require federation of user needs, collaborative R&D, access to non-EO datasets, and creating **public-private network of users for aquaculture**, and contributing to the **application co-development process** (e.g. potential fishing areas information to private sector, and to public authorities for stock management). To extend it to deep water, it is possible to use EURO GEOSS or the upcoming Atlantic GEOSS.

Telespazio VEGA UK Ltd presented Managing Atlantic Ocean resource availability and exploitation: **Maritime vessel detection** and behavioural analysis to identify uncooperative vessels associated with oil pollution and illegal, unreported and unregulated fishing (IUU). The discussion focused on the Atlantic's resource and marine traffic access, as a complex and inter-connected set of needs, which are often competing. Illegal, unreported and unregulated fishing (IUU) monitoring requires a variety of data sources to detect vessels in protected and licensed areas, account for cooperative vessels and focus in on uncooperative vessels. Traditional VHF Automatic Identification System (AIS), marine

radar, vessel or shoreline reporting, aerial imaging alone are insufficient and ineffective in managing vast areas of ocean, but correlating it with satellite imaging and satellite AIS and combining the detections with behavioural analysis, fills the gap left by patrols and ground-based systems, thereby disrupting uncooperative behaviours of the vessels' owners and providing evidential records for prosecutions where the behaviours of uncooperative vessels persist. The proprietary **Maritime Surveillance Platform - SEonSE** (Smart Eyes on the Seas) http://www.e-geos.it/SEonSE/ supports the detection of vessels with failed or malfunctioning GPS and/or transmitting equipment, vessels that deliberately deactivate their AIS to avoid detection and vessels that, because of their smaller size, are not under the obligation of having an on-board positioning system, as well as sport fishing vessels. SEonSE identifies abnormal behaviours, such as trawlers in areas where trawling is forbidden, the presence of vessels in environmental protected areas; ships stationary in unusual locations, and ships sharing an unusually proximal location to one another. The platform may also identify oil spills and their characteristics, relevant met-ocean information and correlate these to obtain with high confidence the vessel and/or platform polluters. The operational use of satellite-derived analytics for maritime applications allows worldwide ocean and sea monitoring, irrespective of whether the area is within the range of coastal surveillance systems, the behaviour of ships is cooperative or uncooperative and the time of day. Where detections and behavioural analysis is required in **near real-time (NRT)**, it is possible to utilise ground station antenna to receive, downlink, and process satellite imagery at local processing environments in the form of a Cosmo Commercial User Terminal (CUT), which provides direct reception of imagery from the COSMO-SkyMed constellation and the COSMO central archives located in Matera, providing rapidly distributed notifications, with specific situational awareness calls-to-action, to multiple stakeholders across the Atlantic (e.g. including both Europe, Brazil and Argentina for illegal fishing, smuggling, illegal immigration by boat, drug trafficking, embargo breaching, etc…) and looking for vessels rendezvous, port activity, fishing intensity, piracy and oil & gas platforms.

9 SESSION A3-A4: MARITIME TRANSPORT AND PORT DEVELOPMENT

9.1 Atlantic Cities Port Development

Carlos Botana Lagaron, Director Port Of Vigo, contributed with the **Implementation of Blue Growth Strategy in the Port of Vigo,** which is located on the Norwest of Spain, specifically in the inner of the Bay of Vigo which provide excellent natural conditions for navigation. It is highly specialized in the movement of general merchandise, and it has a total port traffic of 4,233,680 t representing a "good's industrial value" of M 11,783.05 €, with a turnover of M 25,078 €. The basic port features include infrastructures, traffic lines, cargo and load/unload operative equipment. The Sustainability and Development Department of the port is responsible for the **Environmental management** (e.g. efficient use of energy and resources). The port manages high amounts of residuals daily, 80 % of them are valorised. There is also a strong compromise to reduce energy consumption and increase the percentage of renewable sources. All these activities are conducted within the context of the European Commission Strategy "Blue Growth" encouraging the investment and technological innovation in areas related to Marine Economy. The Port has pioneered in Europe the integral implementation of the strategy as a **collective effort by all the port's users**, under the principle that Blue Economy must be fostered equally by all stakeholders, and dedicated efforts are conducted to promote competitiveness, efficiency and sustainability in all the activities, facilities and services.

Tamara Espiñeira Guirao from **Atlantic Cities**, presented Atlantic Port Cities: looking back to the sea. The Port Cities of the Atlantic Area are dependent on large markets and remote centers of decision, reason why they see weakened their power of leadership. Also, due to the radial design of railway and road systems, the relationships with the hinterland they have not reached a critical mass. In these circumstances, the economic activity located in the ports of the Atlantic Arc cities is conditioned by the liberalization and internationalization of the economy, by the economic strategies of the large maritime operators, but also by the strategies of the Port Authorities themselves and the cities in which they are located. Other factors that must be taken into account are the industrial decline in areas where heavy industries once flourished, the necessary reorganization of port soils, changes in maritime transport and the development of logistics. However, from an urban point of view, the fight against climate change and the defense of sustainable development are the fundamental factors that determine the reorientation of port-city relations.

Athiye Jawad, **Planet Labs Gmbh,** presented **Unprecedented coverage of the Earth including ports and other important Maritime Areas.** Planet has launched more than 200 satellites to space and currently operates RapidEye, Dove and 13 SkySat satellites—the largest constellation ever deployed. This is enabled by a highly automated and scalable mission control and operations, as well as by the largest network of ground stations operated by any imaging company. This imagery is automatically processed via Planet's data pipeline and Platform, and made available to users visual or analytic purposes. Planet's proposed solution involves integrating imagery with machine learning based analytics and high resolution imagery to better understand movement and vessel activity at ports, to survey key areas of geopolitical interest for activity or change or provide additional detail on identified maritime objects of interest. Planet applies **deep learning techniques** to perform **advanced imagery analytics** to data collected by the Dove constellation.

Leveraging this unique constellation provides a deep temporal and spatially broad data set covering the entire earth's landmass including ports and maritime areas globally.

9.2 Safety and Security of Maritime Transport

Johnny Johannessen, from the **Nansen Center**, presented TOPVOYS - **Tools for Optimizing Performance of Voyages at Sea**. The main goal of the TOPVOYS project is to develop, test, implement and provide reliable voyage optimization capitalizing on new advances in observation-based tools and decision support system. This is based on a comprehensive view and understanding of the major challenges and deficiencies with respect to ship routing. TOPVOYS aims to advance searching, accessing, downloading, processing and analyzing of near real time satellite data for surface current retrievals; operational use of sensor synergy and visualization platform; automated tools and machine-learning system for routing planning and optimization; voyage undertakings and ship performance monitoring; and post-voyage analyses and assessment. The involvement of shipping companies in the consortium ensures clear hands on user requirements as well as ability to efficiently test, assess and refine the quality of the tools. The voyage optimization will have valuable impact on fuel savings and reduction in CO2, NOx and SOx emissions. These are highly compliant with the IMO regulations and the new CO2 reporting requirement for ships entering/leaving EU ports. Fuel savings and emission reductions will, moreover, clearly have a positive impact on the green environment and blue economy and altogether contribute to the United Nations Sustainable Development Goals, in particular to SDG 7: Affordable and Clean Energy; SDG12: Responsible Consumption and Production; SDG 13: Climate Action; and SDG 14 Life Below Water. The project is funded under the MarTERA program (ERA-NET Cofund) with their partners including Research Council of Norway (RCN), French Ministry of Environment, Energy and the Sea (MEEM), South African Department of Science and Technology (DST).

Robert Lynch, **Cork Institute Of Technology**, presented challenges for Maritime Traffic Monitoring within the North Atlantic and Arctic – How can Space Technology provide solutions ? From a maritime traffic management perspective, in the event of a vessel operating within the Arctic requiring search and rescue assistance, the limited communication network, poor infrastructure, and design limitations of satellite communications equipment pose a number of challenges for vessels seeking assistance from rescue agencies operating within the Arctic and North Atlantic regions. For Atlantic **stakeholders operating vessels** the lack of accuracy in relation to hydrographic data and survey results impairs the ability of industry partners to operate safely. The absence of accurate navigational knowledge and the increasing environmental changes within the Arctic have been identified despite incomplete and uncoordinated observing capabilities, limiting society's capability to identify, respond to and predict the extent and severity geographic modifications. A robust **Arctic observation network** is needed, from monitoring emissions from vessels to determining increases in marine traffic density across all spectrums within these environmentally sensitive areas, from the management of pollution control to policy related issues within governing bodies and international agreements (e.g. Polar Code). All five Arctic nations have advanced detailed national Arctic strategies within the past six years, a sign of the increased attention the region is receiving on a national stage. To addressi these challenges, space technology could provide solutions thanks to increased satellite coverage, earth observation developments, and technology innovations for a safe and secure marine traffic within the North Atlantic and Arctic (e.g. EU

ARCSAR project establishes the first Arctic and North Atlantic Security and Emergency Preparedness Network).

Ramona Pelich, from the **Luxembourg Institute of Science and Technology (LIST)**, presented **Vessel Monitoring** Based on **Dual-Polarization Sar Images** and **AIS** Data. Vessel monitoring is made possible by combining information from different data sources that are generally divided in cooperative Automatic Identification System (AIS) data flows, and non-cooperative Synthetic Aperture Radar (SAR) images. Over areas of maritime surveillance interest, Sentinel-1 is acquiring data in the VV-VH polarization configuration providing products (e.g. descriptors of complex VV-VH coherence and derived from the Eigenvalue decomposition of the VV-VH covariance matrix) which are validated with AIS data as ground truth. Sentinel-1 Interferometric Wide Swath images with a resolution of 20m, acquired over different areas including both coastal and open sea areas, have been used and further development will include a **coastline delineation algorithm** based on the bimodal distribution given by the different backscattering values of the sea and land areas.

Natasha Oppelt, **Kiel University**, presented Potential of Sentinel-2 to monitor Arctic sea ice. The development of the Artcic sea ice, especially during summer, is a critical element coupling the ocean and the atmosphere and influencing marine ecology, particularly in the context of climate change. Besides the use of radar, coarse resolution satellite missions are commonly used; higher spatial resolution missions, however, play a minor role. In this context, and although optical remote sensing is temporally limited by the seasonal availability of sunlight, the Sentinel-2 (S-2) mission offers potential to retrieve geophysical parameters such as spectral albedo of snow and ice as well as information about melt processes with a spatial resolution < 30m. With a spatial coverage reaching up to almost 84° north and a high revisit rate (up to one per day), S-2 can even cope with frequent cloud cover in the Arctic. The spatial, spectral and radiometric setting of the MSI instrument enables observations of sea ice parameters on a new level of detail. The high spatial resolution allows detailed mapping of sea ice features such as melt ponds, ridges and leads, which span a range of meters to tens of meters. Moreover, coupling S-2 data and biooptical models allow the assessment of pond extent, depth and optically active water constituents such as chlorophyll. **Expeditions with the RV Polarstern in 2017 and 2018** confirmed that the combination of enhanced spectral, spatial and resolution allows a monitoring of Arctic sea ice with its high-contrast spatial pattern of open water, snow and ice. These two expeditions served as a pilot for the international drift experiment **MOSAiC (2019-2020)**, where spectral sea ice and pond measurements will be conducted during the summer months in the far north of the Atlantic ocean. Currently, geographical coverage is limited to areas close to the shoreline, leaving large areas of the Arctic Ocean unrecorded. The geographical coverage may be extended on request, and demonstrating the potential of S-2 for Arctic research, it may open up opportunities for monitoring the Arctic sea ice operationally.

10 SESSION A5: PROTECTING THE OCEAN

10.1 EO Monitoring of Ocean/Marine Environment

Ocean colour (OC) remote sensing (RS) is a powerful tool to study phytoplankton communities in synoptic temporal and spatial scales. From estuaries to the open ocean, knowledge on phytoplankton is crucial to understand the biogeochemical cycles and ecosystems functioning. The Faculty of Sciences **University of Lisbon** (FCUL), focused on satellite OC data in the Northeast Atlantic, in collaboration with IPMA, Instituto Hidrográfico (IH), and CIMA-U Algarve, validating products for the Iberia coast since 2005 and setting up in situ databases for OC applications at a global scale, for the ESA projects Coastcolour and Ocean Colour Climate Change Initiative (OC-CCI). Applications include **Aquaculture** sites selection, monitoring and alert of harmful algal blooms, as well as detection of phytoplankton functional groups (PFT) and development of tools for the EU MSFD implementation (e.g. InterReg Atlantic Area, iFADO (Innovation in the framework of the Atlantic Deep Ocean, coordinated by IST, www.ifado.eu) and capacity building (e.g. Sophia training project (https://www.sophia-mar.pt/en). Other interesting EO research includes the H2020 project **Portwims** (www.portwims.org), with the participation of young researchers in **oceanographic cruises (e.g. Atlantic Meridional Transect)**, contributing for obtaining high-quality fiducial reference measurements, as well as addressing a key-question regarding the potential role of **Saharan dust** in promoting ocean productivity and influencing the marine carbon cycle (www.dustcoonline.com).

The Portuguese Exclusive Economic Zone (EEZ) is about to be extended to an area that covers more than ten times its continental size. It is a big ocean territory not yet well mapped nor understood that adds to the countries' responsibilities in terms of fulfilling EU directives towards the establishment of the Good Environmental Status (GES) of the marine waters, including monitoring of the different ocean components (physical, biogeochemical, and biological and ecosystems) for the purposes of discovery, understanding, management and protection. This improved understanding is critical to improve predictive capabilities and provide sustainable environmental stewardship of the ocean. Deep ocean science in the North Atlantic is being addressed as part of the **UT Austin-Portugal** program. The **European Multidisciplinary Seafloor Observatory** – Portugal (EMSO-PT) monitors the deep-ocean and develop innovative technological solutions for ocean exploration. EMSO-PT carries prototypical elements of a Deep Ocean Observing Strategy (DOOS), and contributing to the Global Ocean Observing System (GOOS), to better understand regional ocean circulation and heat content changes in the context of climate change, and to assess seafloor ecosystem disruptions in the context of pollution and seabed mining.

Ocean exploitation, namely mineral and biodiversity resources, is highly dependent on our knowledge of the deep-ocean environment, including sediment transport and ecosystems characterisation. Existing in-situ measurements are extremely sparse and therefore much denser observing networks must be implemented. Various connections have been established between extreme meteorological events and deep-ocean circulation changes, and the availability of high-resolution satellite data and mapping of meteo-oceanographic conditions can provide insights on the connections between surface and deep-ocean dynamics, helping modelling deep-ocean circulation patterns.

Due to their complexity, these models increasingly require extreme scale high-performance computing (HPC) infrastructure, novel algorithmic approaches that are being developed in computational science and engineering, as well as an advanced cyberinfrastructure for deploying cutting-edge data analytics tools.

TechWorks Marine provides in situ real time turbidity data which is useful for the protection of areas with high concentrations of fish farms (e.g. salmon) from algal blooms and jellyfish swarms, for monitoring dredging and dumping of dredge spoil at sea, and for planning and construction of wastewater treatment plants and for long-term planning of port activities. CoastMADE (Monitoring and Assessing Dredging Environments) combines turbidity information

from satellite and in-situ data, offering stakeholders with detailed real time and historical information on the status of relevant dredging locations (e.g. ports and harbours) and potential effects on nearby aquaculture sites.

The Marine Strategy Framework Directive (MSFD) provides an ambitious and comprehensive framework for the definition, monitoring and achievement of a **Good Environmental Status (GES) of the EU's marine waters**. Currently, quantitative baseline information from satellite, in-situ and model products is available for most MSFD descriptors but it's scattered over multiple data sources (e.g. CMEMS, Sentinel Data Hub, Copernicus Data Warehouse, EMODNET, SeaDataNet) and in different formats. SIMOcean and Co-ReSyF provide single access points to key marine and coastal datasets and to a wide range of pre-operational and R&D services and applications, from support to harbor navigation and fisheries to coastal bathymetry and altimetry. The Marine Environmental Status Monitoring service, part of H2020 Marine-EO project and developed by IPMA and Deimos, will provide Public Marine Authorities (PMAs) with easier and better access to oceanographic, climatological and environmental information to support MSFD related operational monitoring obligations.

10.2 R&D on Marine Litter

According to the **United Nations** (Measuring Marine Litter and Microplastics, Campbell J, UN Environment), in the last 50 years, plastic production has increased more than 22-fold while the global recycling rate of plastics in 2015 was only an estimated 9% . This rise in unmanaged plastic waste has resulted a growing threat to marine environments (millions tons from land to Oceans, UN SDG target 14.1). There are still very large knowledge gaps on marine litter and microplastics: a reliable figure for the volume of plastics entering the ocean, the accumulated volume in the marine environment, mapping of the source and sink location, and basic data on microplastic. Data from remote sensing, citizen science and in situ monitoring could help in better characterize the problem in the Ocean, while data related to beach litter is available in many regions. This is opening up opportunities for using satellite data and global models to better understand the state and flow of marine litter and microplastics.

ESA funded some initial R&D studies. For example the **Optical Methods for Marine Litter Detection (OPTIMAL)** better defines the observational needs and evaluates the potential for marine plastic detection using current EO assets, in two scenarios for plastics accumulation: on shore, and in the upper layer of the ocean. The study included laboratory measurements of microplastics optical properties, supported by in-situ observations during the Atlantic Meridional Transect (AMT) cruise. Another project focuses on increasing the available information, examining the potential use of Earth Observation (EO) to **detect, quantify and track marine litter at the surface** of the oceans, as summarized in a white paper presented at the decadal OceanObs 2019 (Maximenko et al, 2018). The combination of in situ data and EO data can be coupled with numerical models (e.g. UKSA/SSGP GeoInt Service for Marine Litter GML and ESA EO Track of Marine Litter) to bring a better understanding of the Marine Litter dynamics and budgets (Lebreton et al, 2018, Brach et al, 2018, van Sebille et al, 2015). There is definitely a need to better study ocean physical dynamics at eddy-resolving spatial scales, with better appreciation of the sea state, and to potentially use EO to obtain direct or indirect measurements of Marine Litter, to fill the gap in limited sampling / in situ data and better connecting its dynamics with oceans' one.

10.2.1 EU MSFD, OSPAR and in-situ data on Marine Litter

The IFADO (Innovation in the Framework of the Atlantic Deep Ocean) project aims to create **new marine services** to support the **European Marine Strategy Framework Directive** implementation in the North Atlantic Ocean. The objective is to identify convergence zones, pathways and main sources of marine litter for preventive and cleaning actions, with the support of the Opendrift tool of the **Norwegian Meteorological Institute** and using **GlobCurrent**

products. Dedicated indicators highlight preferential residence zones and pathways of plastic particles, which are released from land (e.g. beach litter and river discharge), and the trajectories of particles floating far offshore (shipping and fishing litter). Further improvements would include degradation and sinking of marine litter, analysis and statistics of the connection between sources and impacted areas (stranding, accumulation zones, etc.).

The **Blue-Labs** program of the **European commission** (https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/topic-details/emff-01-2018) funded the **LitterDrone project** to monitor stranded marine litter on beaches, both in terms of number and type of litter elements. This information is particularly useful to infer data on litter origin and on the influence of tides, currents and human activity. In particular it support the implementation of the **OSPAR convention** in monitoring periodically stranded marine litter on beaches. For example, Spain signed the convention in January 1994 and since then it monitors litter by human personnel counting and picking litter items in certain beaches at certain times (4 campaigns each year, one for each season). Now, with the LitterDrone project, the **University of Vigo**, Grafinta S.A. and the Spanish Association of Marine Litter (AEBAM), with the support of ECOEMBES and of the "Parque Nacional Marítimo-Terrestre de las Islas Atlánticas de Galicia" (PNIAG), aim at providing comparable results using ortho-mosaic of RGB and multispectral drone images, which in the future could be complemented with satellite images as well.

The **University of the Aegean** is studying the detection and quantification of marine plastics combining EO satellite images and Unmanned Aerial Systems (drones). The Plastic Litter Project 2018 looked for detecting artificial plastic targets on the sea surface, using **Sentinel-2 and Sentinel-1 data** in combination **with drones** to quantify the volume (three payloads were used: RGB, multi-spectral and thermal cameras) of three **plastic "targets"** 10 m x 10 m wide containing 3700 plastic bottles, 138 plastic bags and 200 sqm fishing nets, on the occasion of the Word Environment Day. Targets' spectral signatures were calculated for each pixel, comparing differences between UAV and satellite data, and highlighting the limitations due to atmospheric correction on satellite images.

An interesting opportunity for **data collection**, outreach and advocacy is represented by a **scientific research campaign** conducted during 2017-18 Round-the-World Sailing **Volvo Ocean Race**, together with the GEOMAR Helmholtz Centre for Ocean Research (https://archive.theoceanrace.com/en/news/12219_Science-Programme-scoops-award.html). The campaign aimed at addressing gaps in scientific knowledge, including lack of standardised methodology for accurate estimation of marine micro-plastic concentrations, and in the measurement of these emerging pollutants in the Ocean, using a pioneering combination of sampling and analysis techniques (e.g. direct measurements of oceanographic and environmental variables, drifter buoys deployed in areas difficult to access for sampling, salinity, temperature and chlorophyll-a) to contribute to calibration and validation of satellite-based measurements. Raman spectroscopy detected particles in 93% of samples collected along the route, including some of the most remote locations sampled, with the highest concentrations in the South China Sea and near the south European coast. This very successful collaboration demonstrated the efficacy of racing yachts as vessels of opportunity to capture high-quality oceanographic data, and the cross-sector outreach of the race, including its Sustainability Programme, elevated the scientific research to a headline position, helping to prompt advocacy for ocean health by governments, industry, business leaders and media.

10.3 A5 SESSION RECOMMENDATIONS (ESA D/TEC)

The session Protecting the ocean included fourteen abstracts (e.g. four posters and eleven oral presentations) of which seven presentations focused on the issue of (plastic) marine litter, covering topics such as plastic pollution indicators SDG 14.1.1, satellite monitoring, particle modelling, UAV-based monitoring, ground validation application. Two posters illustrated methodologies for plastic marine litter monitoring using EO and plastic particle modelling. 4 presentations dealt with more

general research and needs of EO monitoring of ocean/marine environment: e.g. Chl-a measurements, water quality, ocean dynamics for deep ocean exploration, aquaculture, turbidity. One poster showed the potential of deep learning for EO monitoring of intertidal habitat.

A summary of the key recommendations proposed by the presenters and participants regarding the specific topic of monitoring (plastic) marine litter is reported hereafter:

- Need for more representative/realistic experiments, in-situ validation campaigns and capacity building;
- Need for more access to available data (including field campaign);
- Citizen science should support in-situ measurements;
- Measurement data should be standardised and collected in accessible databases;
- Different EO data (direct measurements, indirect measurements and proxies) should be fused/combined to extract more information;
- Need to increase spatial resolution of variables and to add parameters (e.g. wind and current speed, tidal components) in numerical modelling;
- Exploitation of drones and boats as validation platform for satellites;
- Need for ad-hoc sensors satisfying identified system requirements from tests and modelling;
- Need to identify a representative international scientific group to define a wider scientific plan.

A summary of the key recommendations given by presenters and participants regarding the more general topic of EO monitoring of ocean/marine environment is reported hereafter:

- Need for in-situ data for satellite product validation;
- Need for higher spatial and temporal resolution, especially for coastal areas;
- Need of longer term series (both in-situ and EO data);
- Need for creation and curation of (platform-independent) databases, with possibly fast processing and distribution of standardized oceanographic products, also for quasi real-time assimilation in numerical models;
- Remote Sensing-derived information should be more easily available to citizens;
- Fusion of in-situ/EO/model data especially for marine processes;
- Multi-disciplinary approaches should be pursued;
- Efforts should be done to increase awareness in the oceanography domain of the potentialities of satellites as an observation/monitoring tool;
- Trans-Atlantic collaborations should be favoured;
- New actors (with no prior knowledge of EO) should be involved;
- Capacity building in public institutions for using EO data should be improved.

10.4 SEED QUESTIONS ON THE TOPIC OF MARINE LITTER

• Who are the users to be addressed?

Scientists, municipalities, regional and national authorities, NGOs, international organization (e.g. UN), citizens.

• What are the key areas to be addressed (relatively for marine litter), in terms of:

Scientific gaps: global concentrations (global mass) and transportation dynamics (including identification of sources and sinks);

Applications areas: to provide tools for policy makers for introducing measures and assess effectiveness of the measures taken; provide guidance for cleaning actions and assess their effectiveness

Data exploitation infrastructures: no data infrastructure are available, there is consequently a clear need for centralized data centres/nodes collecting standardised data, to be then put available for the users, possibly following guidelines to improve findability, accessibility, interoperability, and reuse of the provided digital data (FAIR guidelines).

- How to involve relevant stakeholders in the Atlantic Regional Initiative?

By organising large workshops involving both field experts and representatives of relevant organisations and institutions active not only in ocean conservation, but also in other related domains (e.g. OECD, WOC, etc.).
By linking different emerging networks of EO monitoring of marine litter in a larger framework under coordination of large organization (e.g. ESA, UN, EU).
By organizing calls for projects.

- What (external) actions can support the ESA Atlantic Regional Initiative?

For instance synergies with EU, UN, Emerging Atlantic networks.

- Would an ESA Atlantic Regional Office help in structuring, managing and supporting ideas, projects and stakeholders ?

In principle yes, it could act as a point of contact and promoter of EO monitoring activities in the Atlantic area, supporting the definition of roadmaps in coordination with other organizations, e.g. UN.

11 SESSION A6: MARITIME SPATIAL PLANNING AND BLUE ECONOMY

The second day of discussions around applications was concluded by the session A6 that focused on the Maritime Spatial Planning and Blue Economy in the Atlantic Region. The session was chaired by **Mr. Juan Ronco, European Commission DG MARE**, and Ned Dwyer, former director of Eurocean.

The session opened with an in-depth description of the **Maritime Spatial Planning (MSP)** provided by Mr. Ronco. As he explained, the MSP is a process that brings together multiple actors and users of the ocean to better tackle its exploitation, including challenges related to the protection of the maritime ecosystem, while promoting a sustainable use of the seas. In 2014, the European Union adopted the Maritime Spatial Planning Directive, that aims at creating a common framework in Europe. After the designation of the competent authorities at national level, the next step is to establish maritime spatial plans by 2021.

One of the key feature identified in the Directive is the ecosystem-based approach, for which, data and information delivered by Earth Observation (EO) technology can play an important role. In fact, EO can prove very useful in the assessment and monitoring of the marine environment and provides valuable tools for facilitating the planning and management of economic activities at sea.

In particular, one of the key sectors where EO significantly contributes is the off-shore wind energy production and management. As highlighted by Charlotte Hasager, Senior Scientist at the **Wind Energy Department at the Technical University of Denmark (DTU)**, the development of off-shore wind energy in Europe is rapid. Currently, Europe has more than 16 GW total installed offshore wind capacity and new projects in the pipeline are worth €7.5bn.

In perspective off-shore wind energy could become a major power source for the whole European continent, and the introduction of advanced technologies such as floating off-shore wind platforms could increase the economic development of this sector. The link with the MSP is important, since measuring wind speeds with the support of space tools could unleash the potential of some maritime areas for the production of renewable energy at sea. An example of innovative applications is the use of SAR in quantifying the offshore wind farm wake effects.

Valborg Byfield, from the **UK National Oceanography Centre**, presented the Earth Observation for Sustainable Development Marine and Coastal Resources (EO4SD-Marine) programme that aims at favouring the uptake of satellite based environmental information in development programmes, with the support of the International Financing Institutions (IFIs). The Blue Economy approach to sustainable development supports economic growth and the creation of better living conditions in developing countries.

In this sense, Earth Observation is a game changer because provides, in a relatively economical way, relevant information to be integrated and used in the planning and management of environmental resources. The UK National Oceanography Centre is currently working with ESA, IFIs and their Client Sates to better define needs in five regions and in the frame of this activity eight new clusters have been created.

The main focus of the activities supported is concentrated on four broad services: cartography and mapping, coastal environment around marine protected areas, near-real time monitoring services, support to Blue Economy growth. In all these areas Copernicus

data are mainly used, but they are complemented also by other satellite data, such as Cosmo Sky-MED. Other projects have been implemented in the Caribbean to strengthen capacity in ocean governance and marine geospatial planning, and in West Africa (Gulf of Guinea), to reinforce resiliency of coastal communities on the Atlantic, from Mauritania to Gabon.

On one side, it is important to understand how EO technology and data can already support the implementation of maritime strategies and policies, monitoring of the marine ecosystem, and boosting the coastal economies. On the other side it is necessary to collect, process and understand user needs around which designing future applications and services. The **Atlantic International Research (AIR) Centre** is one of the two organisation that brought to the audience concrete examples on how to work with end users. As explained by José Luiz Moutinho, the Portuguese centre based in the Azores, in coordination with the GEO Blue Planet, Future Earth Coasts and the Marine Biodiversity Network (MBON), are actively organising cross-sectoral and cross-disciplinary meetings and activities, to discuss directly with the end users their needs. The objective of such activities is to gather governments, businesses, researcher and civil society, to plan the sustainable use of marine resources, enhancing local and regional capacities for job creation and innovation promotion, especially in the Macaronesia and Sao Tome Principe region.

The outcomes of these users consultations is helpful in providing a set of needs for the development of EO information services for coastal areas, in the fields of fisheries, aquaculture, biodiversity and MSP. An innovative tool presented was the User Story Conversation Canvas, a useful questionnaire accessible by everyone, that helps in guiding the service providers and the users in finding the best solutions to a challenge.

A different approach was presented by **Eurisy**, whose activity focuses on connecting space and society. Eurisy has a more user centric approach, working mostly on identifying user needs and raising awareness on satellite benefits for societal needs. Alessandra Vernile, who represented Eurisy, illustrated how Earth Observation can be an enabler for the development of the Blue Economy. She brought to the attention of the audience some examples to illustrate how end users, institutions and SMEs, used EO data and technology to respond to challenges such as oil spills, algae bloom, water quality monitoring and finally sea level rise and coastal erosion.

What has been noticed by Eurisy's activities is that recently the demand of EO products is increasing, also in the maritime sector, whereas the demand is not matching the supply at its best because of the high volume of research projects that not always get to the "go-to-market" phase. Furthermore, it has been noticed that the main applications in the maritime sector are related to navigation and communication, in combination with EO.

What proved to be successful is the importance of targeting a wide group of different users, raising the awareness of EO benefits outside the space sector, and favouring the uptake of EO applications to boost the blue economy. It was definitely recommended to strengthen the relations between service providers and end users.

Prof. Niehaus, from the **University of Koblenz-Landau**, discussed the setting up of a framework for tailored risk and resource management for regional and local spatial planning with the support of mobile devices. The focus was on human and animal health and the integration of EO and big data in the field.

The presentation of the One Health activity raised the attention since it aims at bridging space technology and the health sector. The idea of creating an Emergency Mapping App for the maritime sector could represent an innovative tool. But some resistances may be identified in sharing information and data on the topic at a non-regional level but on a more

global one. This app combined with a dashboard switched the focus of the discussion on capacity building and crowdsourcing, a topic too often relegated to a more regional level.

The final discussion was centred on the possibility of including a range of relevant applications in the MSP at differing readiness levels. What has emerged, in conclusion, is that there might be a scope in integrating, for instance, health information data in MSP: the implementation of accessible solutions for everyone, combined with EO data would help in guaranteeing an improvement of MSP and the development of the Blue Economy in maritime regions in a sustainable and feasible way.

12 SESSIONS D1-D2: DATA AND TECHNOLOGIES AND PLATFORMS AND APPLICATIONS

During the joint sessions Data and Technologies (D1) and Platforms and Applications (D2), good examples of multidisciplinary in-situ data gathering for exploitation were presented, with some of the platforms that were described also offering tools to perform data quality assessment.

The speakers, and subsequent discussions during the questions and answers sessions, highlighted the emerging theme of data fusion, i.e. multi-sensors data combination. This is seen as an important factor not only for the monitoring of the Atlantic region but for the evolution of EO data exploitation in general.

Key to the use of existing and proposed technologies remains the capability of the platforms to enable users to create workflows from their algorithms, along with the important need for platform service providers to ensure consistent results from the identical datasets and algorithms for different users. From the presentations, it was noted that these features, although needed, are not yet existing as services with all providers, but are expected to be provided shortly.

It was noted during both sessions, that to the benefit of EO data exploitation, the data offering made available are using more and more standard formats, with the aim to avoid the duplication of data and the efforts needed to host them.

Components and tools appear to be overall developed by keeping an eye on the state of the art and the existing open technologies. The importance and adoption of the Common Architecture was stressed in one of the presentations, also representing a means in supporting this goal. Another key point was to build on top of existing frameworks to avoid duplication of efforts and limit costs.

Good examples showing the combination of EO and in-situ data, were also presented with some concrete use cases related to the Atlantic region (e.g. marine species preservation).

From the various presentations, many valuable comments and recommendations emerged:

- Common interfaces and standards are considered important for interoperability;
- The importance of service providers to provide flags for confidence / reliability in their portfolio, to allow potential users to understand the suitability of the offer;
- CCI data are readily open and available for incorporation into tools and services.

The various ICT aspects that have been discussed, included:

- Identification of some gaps in technology in the fusion of heterogenous datasets (including e.g. citizen science). According to some presenters, these gaps could be filled by the definition of further Use Cases;
- When requested by projects particularly in the research community, the sponsoring of the needed processing resources, in order to guarantee longevity and sustainability;

- The risk of losing value added data and algorithms when the cloud resources and related credits on the resources hosts (particularly commercial) end;
- Not all the presenters had the intention to follow the trend of moving their algorithms on the Cloud (in some cases for some of the points raised above).

It was also noted during the discussions inter alia:
-that the Atlantic regional domain needs to encompass not just ocean but also coastal, inland and urban issues.
-A gap in the production of standard pre-processed SAR products has been identified by different speakers.

Finally, with regards to commercialisation, it was concluded that a difficult challenge and uncertain roadmap for the exploitation platforms is moving to the market and crossing the pre-commercial barrier to an operational service.

13 CONCLUSIONS AND RECCOMENDATIONS

The ESA *Atlantic from Space Workshop* provided key insights for the development of the EO Atlantic Regional Initiative, as follows:

1. Atlantic regional stakeholders engagement and user requirements identification
2. Establishment of the state-of-the-art (on-going/planned Atlantic scientific research, applications projects, processing and platform capabilities; regional and national policy priorities for the Atlantic; operational environmental/geospatial information services)
3. Collection of user needs, identification of priority MS interests in the Atlantic, and characterization of the EO capacity to address them and/or identify gaps
4. Elaboration of an agreed roadmap of priorities to be addressed in the frame of the EO Atlantic Regional initiative (upcoming ITTs in 2019).

On **Friday 25 January** the closing plenary summarized the most pressing issues identified during the workshop and suggested a way forward, which was agreed among the stakeholders. Each session rapporteur reported the main findings to the participants in short summary presentations, which are available on the Atlantic from Space web-page.

At the beginning, the need to emphasize the link between the ESA Atlantic Regional Initiative and the Belem and Galway statements was underlined. In this context Eurocean suggested to include the Ocean Observing System (OOS) in the conceptualization of the Regional Initiative. It was also pointed out that discussions should be interdisciplinary at all levels and encompass, for example, both physics and geochemistry, science and applications avoiding the creation of an artificial boundary (e.g. there is a need for high resolution wind data, and the topic came up in both sessions stream). It would be ideal to address these topics all together, as part of Natural Resources Management, and ESA could think of re-organizing the structure of the Regional Initiative in this sense, noting also that EO retrieved wind parameters are excellent to conduct both science and applications.

In the frame of Open Ocean and Coastal Processes, it was indicated that there is a lack in situ data to validate and an obvious link with applications (e.g. high res surface currents to better monitor oil spills, strong surges and altimetry linked to extreme events). It would be useful to improve salinity data in artic and wind knowledge, also related to hurricanes. At high latitudes and in coastal areas there is a lack of data acquired, that could be addressed in future programs, as well as a possible high resolution SMOS mission should be considered. Concerning validation of the products, it would be important to clearly define the resolution, scales and the products types (e.g. especially when considering in-situ data). Coastal zones would require high frequency and high latitudes coverage would be needed around the artic, and there is also a need for new ways to monitor ocean currents in high resolution, extremes wind and waves. All these are new needs for both science and applications: we could therefore envisage joint activities and even consolidate requirements for future satellite missions addressing both areas (e.g. measuring winds, capturing temporal variability) ?

It was then discussed briefly how to manage data, when it is needed and what it is used for, referring, for example, to existing various data providers and to the fact that ESA is developing long term data sets with Climate Change Initiative. Also the NASA SWOT mission was mentioned, highlighting that oceanographers and hydrologists have joined forces to develop the first global survey of Earth's surface water, observe the fine details of the ocean's surface topography, and measure how water bodies change over time. It has a world coverage

at mid latitude, enrich time sampling of a satellite, mapping height in 2 D in 21 days and every point is covered in 2-3 days. It was underlined that a call for calibration of SWOT data with in situ measurement would be important and highly relevant to this discussion. Another area to be addressed in the future is polar regions salinity data, which is currently not available, but it would be particularly useful for scientific research.

In the context of Natural Resources management, there was a focus on Wind and Fisheries research related topics and some key recommendations were provided from the various presentations. It was suggested to improve in situ networks, also due to the fact that wind information needs could vary significantly based on the type of applications (energy, science, etc…), and there is a need to integrate ocean winds data from different technologies (SAR, Scatterometers, Lidar, etc..). Another key topic is the identification of weather windows for proper operations management of wind farms (e.g. some critical locations were accessible even two years after the need arose), based on detailed information on temperature, humidity, solar irradiance, wind, waves, etc…) that would allow companies to go out and maintain energy installations off-shore during identified good time slots, thanks to precious EO data. Such services would be extremely useful and near real time data availability is a key aspect to be address for the vertical sectors to be addressed (e.g. energy users near shore in the Atlantic). The assimilation of data will also improve forecasts and statistics for planning new energy installations.

Sentinel-1 and Sentinel-2 do not match all the boundaries: mission planning should occur taking into account where the base stations are located to support fisheries, which draw on broad ranges of data, and in this context having both a science and an applications perspective is key. New trends indicate the use of data which is related to the commercial exploitation side (e.g. thermal IR, etc.), and ESA would need to expand its activities towards the fisheries stakeholders communities, engaging them extensively and collecting needs and requirements. The idea of using a Near Real Time platform was discussed, with ESA trying to push boundaries on this aspect, to support some services even in pre-commercial scenarios, since this aspect is highly relevant (e.g. the delivery time of the data could vary between 3 hours and 30 minutes depending on the infrastructure and a fast changing commercial landscape).

In the context of Maritime Transport and Ports, there is a strong need to have key users to be part of stakeholders consultations and the role of the World Ocean Council in linking the private sector with space is essential. Reducing the anthropogenic impact of these activities is a relevant cost driver, including also plastic litter, and it is also important in the context of ocean governance, which can be enhanced with the support of satellites, sensors on board of ships, information and data from industrial sectors.

Discussing the protection of the Ocean, Prof. Thompson highlighted the need to seriously address the issue of microplastics, since there is a significant gap on its source, evolution/interaction up to hot spots. There is a clear link among maritime transport, ports, Atlantic cities and sustainable development, where citizens engagement is also an essential part of the equation, and it is important to create synergies from a bottom up approach to top down EU policies. There is ground data being collected for validation from a number of actors (including sailors, drones and boats), and a need to focus on the coasts, including river discharge into the sea of plastic, and a relevant science gap on global concentrations. Monitoring is not only for science but a key tool for policy makers to act, enforce regulations and legislation. There is a strong need to carry out capacity building activities since it is a new field of research. Dr. Gommenginer highlighted the aspect of in situ validation, using

also new technologies to find new ways to observe the ocean, and new platforms to measure parameters that are not available from satellite. Therefore there is a strong need to interact with other communities, which is a challenge, and to demonstrate that satellite can provide key information which can be integrated also as part of international collaborations. Marine litter is a new topic and a good example for that, requiring this cooperation framework to be built in order to avoid duplications.

Climate Change is a priority to be addressed in the Atlantic context and integration of science and applications is key: coastal land management, erosion and river discharge are considered particularly relevant and it was suggested to run a new study on coastal processes, to include biogeochemical aspects (e.g. freshwater, sediments, coastal ecosystem and habitats). Some ECVs are not observable from Space but ESA can help retrieve some parameters as inputs to ecosystem models. The West African complex convection system impact many people, for example tropical cyclones originate from this. Therefore it is recommended to focus on wind measurements (e.g. SMOS for wind, Aelous mission, Copernicus high priority candidate missions, etc..). A good example of what is being done in EO exploitation is SMOS wind data. The ESA POC can receive proposals that can be exploited and this data is well promoted and should be used, underlining limitations and synergies (e.g. scientists might find a new parameter by linking datasets). ESA is also exploring HAPS, looking at different platforms that can carry instruments, as complementary technologies to satellites.

EO common infrastructure and standards was addressed, indicating the need for "quality flags" for reliability. Gaps in the technology can be filled by the definition of use cases including fusion of data sets (e.g. from various origin and including and citizen science), and in this case standardization is the need (e.g. a working group was created in Bruxelles on (open) data standards for all sciences). ESA is providing support also in form of resources, but the real challenge is to move to the market and developing applications on the cloud is not always the best solution, while new activities can build also on top of existing services. Interoperability of platforms remains the key aspect to address, bot for manned and unmanned (ocean transport estimate example in a poster), as well as standard data and products.

Blue economy can benefit largely of wind retrieval data and EO can serve well global southern countries for sustainable development in the Atlantic region, focusing on the management of coastal economies and on supporting with simple solutions the decision making processes. There is also a large potential for capacity building, linking the benefits of EO to the broader stakeholder communities, using user stories conversation canvas. It would be useful to perform a wider consultation, building on the benefits of crowdsourcing information and closing the loop with citizen science and science from ground zero to space.

EO has also great potential for public health and it can be exploited by creating apps on mobiles, while integrating the EO data for health in Maritime Spatial Planning could represent the long term vision. More in general the potential of EO for Maritime Spatial Planning is very high and it should be exploited at the earliest, even considering that applications might have at present very different readiness levels.

Building an ESA EO Atlantic strategy ?

All the activities presented at the workshop are relevant for the Atlantic region, and even if they will not be explicitly part of this specific Regional Initiative, ESA has a number of frameworks, programs and instruments to accommodate specific user needs. The first one being the **Permanent Open Call** for proposals, that is the ideal instrument to start small and very innovative activities. If proven, dedicated larger activities can then be developed as part of the Atlantic Regional Initiative calls, which are Invitations To Tenders, or others.

The intended **Atlantic RI Applications ITT** will be the start for creating a Road Map at ESA, and it would be interesting if industry and academia will respond highlighting some links with the science gaps discussed earlier. The second one will be a dedicated **Atlantic+ science ITT** and thee third one the **Atlantic Project Office**.

Another key aspect being addressed by ESA, is related to EO data collocated in a cloud environment to be made available in **Near Real Time**, for which there is an on-going ESA plan under preparation (e.g. EO data for Atlantic users could be made available through this platform). For example Atlantic islands and other areas not covered by on-going activities could benefit of services (e.g. marine resources, transport) that requires fast delivery of data. The user needs could be collected by ESA and the Atlantic project office, aiming at creating a two way channel for EO information at disposal of existing and potential users and service providers. In this context, **data fusion** for coastal activities and coastal resilience characterization (more effective combining physics and biogeochemistry) is becoming also a key application element for operational activities, as well as wind-wave data sets which are crucial for renewable energy sites assessment and operations.

The World Ocean Council, represented by Paul Holtus, offered to enrich EO and is-situ data sets with their initiative around "***Vessels of opportunity***", which collects in situ data on the Atlantic from vessels. It is important to understand together how to balance operational commercial services to vessels using EO and the back flow of in situ data from the vessels to the EO community: it would be interesting to conduct a joint exploratory activity. Another area for identifying new ways of working together with external actors and stakeholders is related to **clusters activities and regional innovation**. EO is still not as connected as it might be to generate new opportunities for the blue economy and there is now a momentum on Atlantic activities, which is an excellent opportunity to make EO accessible and support innovation in expanding industrial sectors (autonomous shipping, alternative power systems). It would be important to create links between the EO community and the innovation clusters / regional networks in significant economic areas of interest with potential, focusing on three to five priorities.

The fundamental question around **marine plastics (litter)** is how to move forward. On the basis of the ESA funded studies presented at the Workshop there isn't a credible basis that the community is ready for applications development, while it is appropriate to conduct activities at research/science level (e.g. with a focus on ocean process, fluxes, etc…). This is a fundamental scientific problem that needs to be addressed, hopefully together with an effective EO service for monitoring the coastal zones, which would still require to improve and develop new EO techniques. In this sense the activity presented by the Greek team is going in the right direction since it verifies satellite data against ground targets, also using drones, and it would be worth to further investigate. The other aspect related to marine litter that needs to be addressed is related to stakeholders engagement (policy/decision makers) by the scientists. In this context the topic could also become of a larger activity focused on

Maritime Spatial Planning and **natural resources management**. The MSP and WFD MSD could significantly be supported by EO and looking at this aspect is extremely interesting, since it could address marine protected areas as well. There are also other applications which are quite mature and ready to evolve into such an operational service (e.g. security).

The Atlantic from Space workshop will take place again **in about 18 months** and it would be welcome to **discuss new applications**. Some interesting areas where there could be a good interaction between science and applications are related to: near shore bathymetry (10 m would be needed), perhaps using new datasets (e.g. commercial data to be used by the scientists) that can be constantly updated after storms, precisely monitoring the shoreline position; Waves and currents data, linked with land use and erosion could be highly effective when integrated in the Earth System models, using also in-situ data of coastal areas; Monitoring and identification of fronts; Coastline evolution could also be studied using Sentinel-2, which would be very important also for estuaries. Earth System science and the ECVs are focused on large scale dominance and validation/understanding of phenomena, while the short term focus is on applications: taking into account these differences in time and scales, the approach might be to address long term issues putting them into the climate perspective. 13 CCI variables could be enriched with river discharge information which is very important for coastal zones. In these areas optical data based applications differ from the open ocean ones (e.g. processing chains), therefore it was concluded that three streams of activities could be developed in the future (e.g. one focusing on Open, one on Coastal areas and one in between). Though a single platform to collect all the data is advisable, including citizen and in-situ data, but it is importance to use existing resources rather than creating a new platform. The challenge of combining satellite and in-situ data is that these are very different data sets, but it was stressed that unless we all together tackle that challenge, we will not be able to properly address the Atlantic community. ESA is constructing an EO network of resources, to exploit more existing clouds and services co-locating data sets (e.g. for example the needs of West Africa could be addressed since this is an areas of interest and it is coastal). It is possible for ESA to fund also non-European scientists as part of the ITT proposals (e.g. subcontracting max 10 % of contract out of ESA MS, but there is also GMES for Africa which is around 27 millions and include coastal (Cape town, Ghana, Tunisia) so we can leverage this instrument as well). All the participants will be welcome to discuss these and other new ideas at the next Atlantic from Space workshop in 2020.