EOOS Technology Forum 2022

THINKING AHEAD: THE TECHNOLOGY OF THE SCIENCE WE WILL NEED FOR THE OCEAN WE WANT

2021 2030 United Nations Decade of Ocean Science for Sustainable Development

Organised by: EuroGOOS European Global Ocean Observing System

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REPORT
FROM THE EOOS TECHNOLOGY FORUM
22-24 March 2022

AUTHORS

EuroGOOS Office, EuroGOOS Technology Planning Working Group Chairs and EOOS Technology Forum Foresight Workshop Organising Committee

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INTRODUCTION

The **Ocean** **is under pressure** from human activities leading to an increase in temperature, acidification, deoxygenation, pollution and diversity loss. The recognition that action is urgently needed to reverse the decline in ocean health and to create the conditions for the sustainable development of the ocean led to the declaration of the **UN Decade of Ocean Science for Sustainable Development 2021-2030** (the Ocean Decade).

The Ocean Decade, together with other important European initiatives such as the Green Deal and Horizon Europe, provide a framework to improve knowledge, build infrastructures, and foster trans-disciplinary relationships, towards sustainable management of our ocean and coasts for future generations.

Scientific research and innovative technologies are crucial to achieving global sustainability and adequate stewardship of the ocean. They enable us to deepen our understanding and to respond to societal needs including a clean, healthy, and resilient ocean.

Science, **technology**, **data infrastructures** and **innovation activities** are currently undergoing rapid changes that are transforming ocean research and innovation processes. Disruptive technologies such as artificial intelligence, big data or blockchain are starting to shape research and innovation cycles. Sustained ocean observations, essential to increase our understanding of the ocean and its functions, require a suite of increasingly efficient technologies and instruments to gather, store, transfer and process large volumes of ocean data. We need the capacity to incorporate new and better technologies into the observing systems as the readiness level increases to improve efficiency. However, it is also important that we help guide technological development to enable fit for purpose observations and outputs that address societal needs and that anticipate future requirements.

The **EOOS Technology Forum** provides the structure to enable the comparison of old and new technologies for their usefulness in ocean observing systems, understand data management and processing needs and provide guidance to technology developers about technology user requirements.

INTRODUCTION

The second edition of the **EOOS Technology Forum** was held from 22 to 24 March 2022 as a virtual foresight workshop endorsed as an **UN Ocean Decade activity**. focusing on foresight aspects of Ocean Observing technologies, data processing and handling techniques including Artificial Intelligence and Machine Learning. The event was organised by EuroGOOS with the support and collaboration of the EU Horizon H2020 projects **EuroSea** and **Minke**.

The workshop brought together over 120 participants from several continents for discussions on the technologies that will be needed to achieve two specific goals of the UN Decade for Ocean Science and Sustainable Development:

"A clean ocean where sources of pollution are identified and removed"

"A healthy and resilient ocean where marine ecosystems are mapped and protected".

The attendees, representing a broad mix of users and stakeholders from both the public and private domains, included instrument manufacturers, technicians, technologists, scientists and policymakers.

The three-day workshop comprised several keynote addresses, panel discussions, high-level talks and Show-and-Tell presentations, with time allocated for audience interaction with speakers, panellists and presenters to facilitate a greater flow of information and ideas. A number of different subjects were explored. A session on the role of state-of-the-art and foreseeable technology in achieving Ocean Decade goals touched on the Marine Life 2030 programme, the Ocean Biomolecular Observing Network (OBON), marine litter monitoring and the "Digital Twin of the Ocean" paradigm. Another session focussed on technology providers, with discussions on the current technological landscape, effective ways to achieve a distributed embedded, multi-parameter ocean observing network, and the establishment of a systematic and robust data value chain. The integration of multiple platforms and the potential of new platforms were pondered in detail, as well as the expected impacts of advances in the areas of cyberinfrastructure, Big Data, Machine Learning (ML) and Artificial Intelligence (AI) were also debated. The last session debated on what is the role of the EOOS technology forum in the framework of the UN Ocean Decade.

The presentations (keynote addresses, showcase talks and Show-and-Tell Sessions) can be accessed here.

EVENT AGENDA

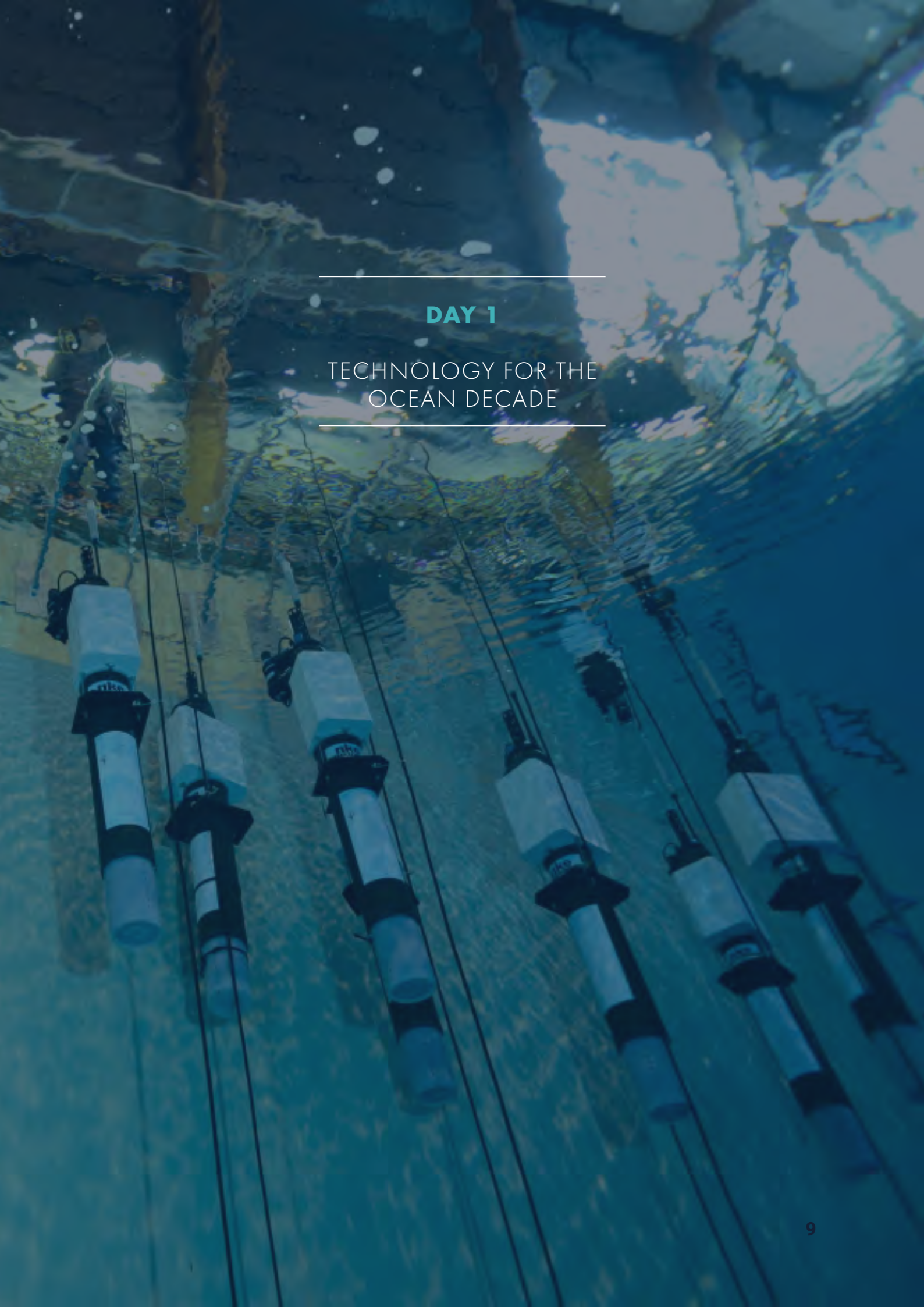
DAY 1 (22 MARCH 2022)		
Time UTC	Time CET	
14:00-14:10	15:00-15:10	**Welcome and housekeeping: Rajesh Nair and Laurent Delauney** (Co-chairs of EOOS Technology Forum)
		Setting the scene: Technology for the Ocean Decade (Moderator: **Steve Hall**, Rapporteur: **Laurent Delauney**)
14:10-14:30	15:10-15:30	**KEYNOTE: Jyotika Virmani** (Executive Director, Schmidt Ocean Institute) The role of state-of-the-art and foreseeable technology to achieve Ocean Decade goals
14:30-14:45	15:30-15:45	**Shubha Sathyendranath** (Scientist, Plymouth Marine Laboratory) Marine Life 2030
14:45-15:00	15:45-16:00	**Francisco Chavez** (Senior Scientist, Monterey Bay Aquarium Research Institute) Ocean Biomolecular Observing Network (OBON)
15:00-15:15	16:00-16:15	**Marta Ottogalli** (Product and Knowledge Manager, UNEP) Marine Litter Monitoring data lifecycle needs
15:15-15:30	16:15 - 16:30	**Martin Visbeck** (Head of research unit, GEOMAR Helmholtz-Centre for Ocean Research Kiel) Digital Twin of the Ocean (DITTO)
15:30-15:45	16:30-16:45	**Break**
15:45-16:25	16:45-17:25	**PANEL DISCUSSION:** The technology we need and role of technology to achieve Ocean Decade goals. Moderator: **Steve Hall** Panellists: **Jyotika Virmani** (Executive Director, Schmidt Ocean Institute) **Simona Aracri** (Researcher, Italian National Research Council) **Matthew Mowlem** (Head of Ocean Technology and Engineering, National Oceanography Centre) **Emma Heslop** (Programme Specialist, UNESCO IOC-Global Ocean Observing System) **Rudolph Bannasch** (CEO, EvoLogics) Rapporteur: **Francisco Chavez**
16:25-16:40	17:25-17:40	**Break**
		Show and Tell Session: Sensor and technology (Chair: **Urmas Lips**, Rapporteur: **Vicente Fernández**)
16:40-16:55	17:40-17:55	**KEYNOTE: René Garello** (Professor Emeritus, MIT Atlantique) The role of technology providers, how they can respond to community requirements, and what are the challenges
16:55-17:40	17:55-18:40	Contributed 5-minute presentations **Didier Clec'h** Key ocean measurements using high-accuracy, low-power, and non-toxic sensors. Changing the value paradigm for reliable and sustainable ocean observation **Roberto Gomez** WERA HF Radar, a valuable resource against marine pollution **Ivar Wangen** Scientific echo sounders for ecosystem monitoring and more **Adrian Goodsell** Precision submersible chemical sensors for scientific, industrial, and environmental monitoring applications **Matt Mowlem** Technologies for Ocean Sensing (TechOceanS project) **Monica Miranda** Zero drift pH Sensing across the entire Salinity Range **Ben Goymer** Revolutionising Primary Productivity Measurements in Our Oceans **Luca Sanfilippo** Online and in-situ nutrient water quality monitoring: technology overview and applications **Heinz Schewalt** Marine technologies
17:40-18:00	18:40-19:00	Additional time provided for breakout rooms with show and tell presenters

EVENT AGENDA

DAY 2 (23 MARCH 2022)		
Time UTC	Time CET	
14:00-14:05	15:00-15:05	**Housekeeping: Rajesh Nair** and **Laurent Delauney** (Co-Chairs of EOOS Tech Forum)
14:05-14:25	15:05-15:25	**KEYNOTE: Justin Manley** (President, Marine Technology Society) Current technological landscape
14:25-15:10	15:25-16:10	**PANEL DISCUSSION:** How do we achieve a distributed, embedded, multi-parameter ocean network? Moderator: **Steve Hall** Panellists: **Heinz Schelwat** (CEO and President, Sea and Sun Technology GmbH) **Justin Manley** (President, Marine Technology Society) **Dariia Atamanchuk** (Researcher, Dalhousie University) **Sara Iverson** (Scientific Director, Ocean Tracking Network, Dalhousie University) **Johannes Post** (CEO, Deepsea Mining Alliance) **Blair Thornton** (Professor, University of Southampton) Rapporteur: **Frank Muller-Karger**
15:10-15:25	16:10-16:25	**Break**
15:25-16:10	16:25-17:10	**PANEL DISCUSSION:** How do we establish a systematic and robust data value chain? Moderator: **Steve Hall** Panellists: **Ward Appeltans** (Project Manager, IOC-Ocean Biodiversity Information System) **Pierre-Yves Le Traon** (Scientific Director, Mercator International) **Conor Delaney** (Technical Coordinator, EMODnet) **Florence Salvetat** (Head of Metrology, Ifremer) **Gegerly Sipo** (Head of the Services, Solutions and Support department, EGI – Advanced Computing Services for Research) **Nick Wise** (CEO, OceanMind) Rapporteur: **Artur Palacz**
16:10-16:25	17:10-17:25	**Break**
Show and Tell Session: Instrument platforms and Integration (Chair: **Stefania Sparnocchia**, Rapporteur: **Rajesh Nair**)		
16:25-16:40	17:25-17:40	**KEYNOTE: Chiara Petrioli** (Professor at University of Rome La Sapienza, Founder and Director WSense Srl) Understanding the potential of new platforms and integration for a multi-prong approach to marine pollution
16:40-17:25	17:40-18:25	Contributed 5-minute presentations **Einar Hauge-Hansen** Lofoten-Vesterålen Ocean Observatory **César González-Pola** LanderPick, a Remote Operated Trawled Vehicle to cost-effectively deploy and recover lightweight oceanographic landers **Carsten-S. Wibel** SWATH@A&R - reliable platform for technologies and sensors **Carlos Barrera** Autonomous Surface Vehicles (ASV) technology in support to EOOS **Daniel Hayes** Underwater Gliders: Novel Payloads for Monitoring Anthropogenic Inputs and Impacts **Luc SIMON** YUCO micro-AUV platform opening new ways to monitor coastal environments **Nuno Nunes** Calling all stations: using compact ocean monitoring systems to turn (almost) any boat into a research vessel **Kanna Rajan** METEOR: A Mobile (portable) ocEan roboTic ObsErvatORy
17:25-17:45	18:25-18:45	Additional time provided for breakout rooms with show and tell presenters

EVENT AGENDA

DAY 3 (24 MARCH 2022)		
Time UTC	Time CET	
14:00-14:05	15:00-15:05	**Housekeeping: Laurent Delauney** and **Rajesh Nair** (Co-Chairs EOOS Tech Forum)
14:05-14:25	15:05-15:25	**KEYNOTE: Nick Wise** (CEO, OceanMind) New developments in big data approaches
Show and Tell Session: Cyberinfrastructure, AI and applications Chair: **Henning Wehde**, Rapporteur: **Simone Marini/Laurent Delauney**		
14:25-15:10	15:25-16:10	Contributed 5-minute presentations **Artash Nath** Silence of Global Oceans: Acoustic Impact of COVID-19 Lockdown **Ferdinando** Villa ARIES: semantic knowledge integration for sustainability **Kakani Katija** FathomNet: An open-source image database to train artificial intelligence algorithms that help us understand our ocean and its inhabitants **Jeroen Steenbeek** Marine Ecosystem Modelling for the Ocean Decade: facing the challenges **Peer Fietzek** Blue Insight – a digital ecosystem to maximize observing efficiency **Linwood Pendleton** Is Web3 a New Way of Funding Ocean Science and Data Collection?
15:10-15:40	16:10-16:40	**Break** (this break will include time for breakout rooms from show and tell session)
15:40-16:25	16:40-17:25	**PANEL DISCUSSION:** Recommendations, what can we do within this decade and the role of EOOS Technology Forum Moderator: **Steve Hall** Panellists: **Emma Heslop** (Programme specialist, IOC-Global Ocean Observing System) **Inga Lips** (Secretary General, EuroGOOS / EOOS) **Kate Larkin** (Deputy Head, EMODnet) **Matthew Mowlem** (Head of Ocean Technology and Engineering, National Oceanography Centre) **Martin Visbeck** (Head of research unit, GEOMAR Helmholtz-Centre for Ocean Research Kiel) **Iain Shepherd** (European Commission's Directorate general for Maritime Affairs and Fisheries) Rapporteur: **Simone Marini/Vicente Fernández**
16:25-17:00	17:25-18:00	**Summary and conclusions: Laurent Delauney** and **Rajesh Nair** (Co-Chairs of EOOS Tech Forum)



DAY 1

TECHNOLOGY FOR THE OCEAN DECADE

DAY 1

The Forum was opened by **Rajesh Nair** and **Laurent Delauney**, Co-chairs of the EuroGOOS Technology Plan Working Group. Rajesh Nair welcomed the participants and introduced the topics and scope of the event.

The first day, devoted to '**Setting the scene**', began with a session on '**Technology for the Ocean Decade**', followed by a panel discussion and a Show-and-Tell session on '**Sensor and technology**'.

Rajesh Nair

EUROGOOS TECHNOLOGY PLAN WORKING GROUP CO-CHAIR

PRESENTER

Rajesh Nair has more 30 years of experience in Oceanography and the Marine Sciences, with a strong experimental background, extensive field skills and "hands-on" knowledge of a wirde variety of marine instrumentation. As part of the permanent staff of the Centro di Tararuta e Metrologia Oceanografica (CTMO), the oceanographic calibration and metrology laboratory of the Istituto Nazionale di Oceanografia e di Geofisica Sperimentale.

PRESENTER

Laurent Delauney

EUROGOOS TECHNOLOGY PLAN WORKING GROUP CO-CHAIR

Laurent Delauney is working at Ifremer Centre de Bretagne for 27 years on in-situ monitoring systems. He created the calibration laboratory for marine physical and chemical parameters and then was the Quality Control manager. In 1995 he obtained the COFRAC accreditation for Pressure and Temperature parameters. Then Laurent Delauney dedicated his research work on biofouling protection for marine in situ sensors.

Laurent Delauney is now coordinator of the EU project JERICO-S3 and scientific and technical coordinator of the EU project JERICO-DS.

DAY 1

SETTING THE **SCENE:** SESSION ON 'TECHNOLOGY FOR THE OCEAN DECADE'.

Steve Hall introduced the session on '**Technology for the Ocean Decade**'.

MODERATOR

Steve Hall

INDEPENDENT CONSULTANT AND FORMER VICE-CHAIR OF UNESCO'S INTERGOVERNMENTAL OCEANOGRAPHIC COMMISSION

Steve Hall CMarSci FIMarEST is an ocean science, technology, planning and policy consultant, based in UK. He is a former vice-chair of UNESCO's Intergovernmental Oceanographic Commission, and worked at the National Oceanography Centre for 27 years on marine autonomous systems, sustained ocean observing and ocean-related policy.

Jyotika I. Virmani

EXECUTIVE DIRECTOR OF THE SCHMIDT OCEAN INSTITUTE

Former Executive Director of Planet & Environment at XPRIZE overseeing global competitions to spur innovation in this domain.

Co-Chair of the UN Ocean Decade Technology & Innovation Informal Working Group, serving on National Geographic's Executive Committee for Research & Exploration, the U.S. IOOS Federal Advisory Committee, and Monterey Bay Aquarium Research Institute's Board.

KEYNOTE

In her keynote talk, **Jyotika Virmani** (**Executive Director, Schmidt Ocean Institute**) highlighted that this is the age where new technologies are shaping ocean science. New advances in technology are making measurements possible in remote areas of the oceans, many that were not easily accessible until now. Technologies such as ROVs, USVs, drones, and OMICS analyzers (eDNA, etc.) which are being operationalised and automatised, are already changing our understanding of ocean processes.

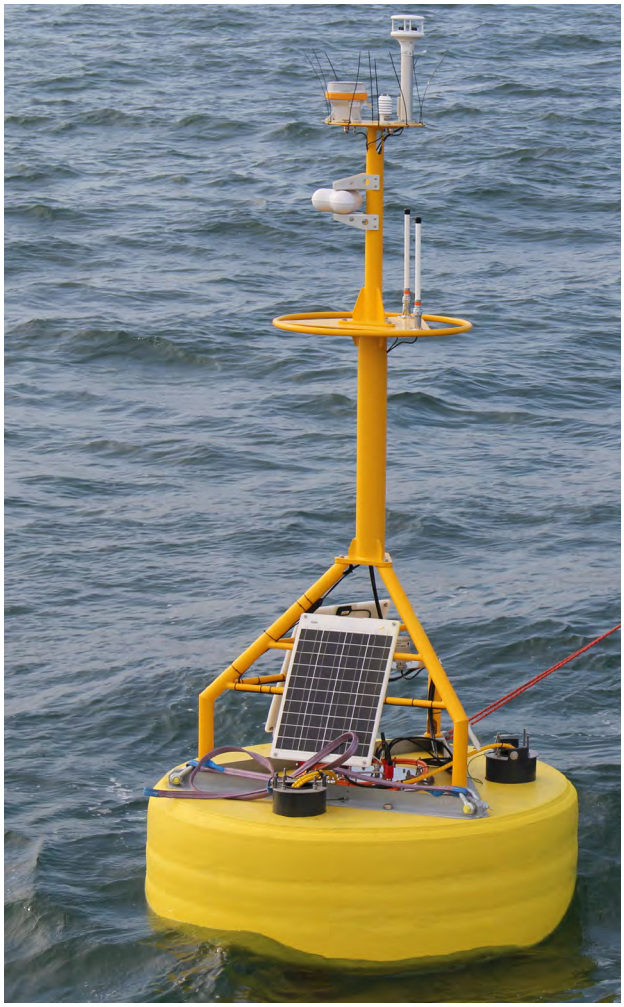
Technology is evolving rapidly with promising developments outside the marine science field (e.g., high **bandwidth communications, improved power sources, Artificial Intelligence, new biocompatible materials** and **miniaturisation**), which could be taken advantage of by the marine observing community.

In the very near future, disrupting technologies such as 'Avatars' and 'Virtual Reality (VR)' also have the potential to change the way we observe the ocean.

DAY 1

Shubba Sathyendranath (Plymouth Marine Laboratory, UK) presented an overview of the technological requirements for oceanic observations relating to biology, biodiversity and biogeochemistry.

Observing requirements for biology, biodiversity and biogeochemistry need to take into account feasibility, cost and impact of the available technologies. 'Big Questions' are replacing narrow interests, and the traditional system of prioritisation of variables to measure may no longer be adequate, meaning that new mechanisms may be needed to address this aspect. Many times, though the technology exists, resources to meet operational requirements are lacking (especially in the case of biological observations). More measurements relating to ocean-atmosphere interactions (e.g., surface fluxes and rates) are also required. As the problems are global, strong coordination at the same level is needed if actions are to be planned or taken and solutions are to be found.



Shubba Sathyendranath

MERIT REMOTE SENSING SCIENTIST

Dr Sathyendranath's research interests include ocean colour modelling, spectral characteristics of light penetration underwater, bio-optical properties of phytoplankton, modelling primary production, bio-geochemical cycles in the sea, climate change, biological-physical interactions in the marine system, ecological provinces in the sea, ecological indicators and phytoplankton functional types.

KEYNOTE

DAY 1

Francisco Chavez (**Monterey Bay Aquarium Research Institute, US**) gave a talk entitled 'Developing new and scalable technologies for observations of life in the sea'

Multi-omics and eDNA sampling technologies are swiftly gaining ground as an essential and powerful tool for observing biology in the ocean, especially at the community-level, and for studying dynamics and biodiversity. eDNA monitoring is becoming an established mature investigative technique. Some challenges remain but there are tremendous opportunities ahead including routine global observations of marine biodiversity.

The current frontiers of technological innovation in observing life in the sea are in sampling methodology, automation, and operationalisation of in-situ analysis. There is a need to change the way we observe the ocean, moving towards a more multi-disciplinary approach. The envisaged future is in-situ eDNA sequencing (e.g.: using miniature field analyzers) and bioinformatics providing near-real time data.

PANELLIST

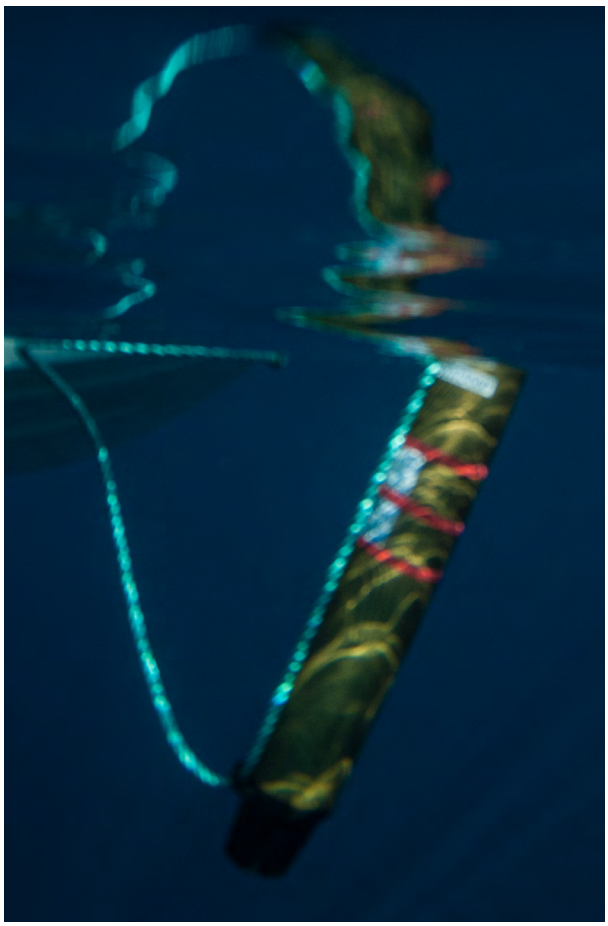
Francisco Chavez

FOUNDING MEMBER OF THE MONTEREY BAY AQUARIUM RESEARCH INSTITUTE

Francisco Chavez is a biological oceanographer who studies how climate variability and change impact ocean ecosystems on local to basin scales. He is a founding member of the Monterey Bay Aquarium Research Institute (MBARI) where he has pioneered time series research and the development of new instruments and systems to make this type of research sustainable. He has over 250 peer-reviewed publications with 15 in Nature and Science. He is a Fellow of the American Association for the Advancement of the Sciences, honored for distinguished research on the impact of climate variability on oceanic ecosystems and global carbon cycling; and of the American Geophysical Union, honored for advancing fundamental knowledge of the physical-biological coupling between Pacific Decadal Oscillations, productivity, and fisheries. He was awarded a Doctor Honoris Causa by the Universidad Pedro Ruiz Gallo in Peru in recognition of his distinguished scientific career and for contributing to elevate academic and cultural levels of university and society. Chavez is the 2014 recipient of the Ed Ricketts Memorial award.

DAY 1

Marta Ottogali (**United Nations Environmental Protection Agency, UNEP**) gave a talk entitled 'Marine Litter Monitoring data lifecycle needs', where she presented an overview of the Global Partnership on Marine Litter (GPML), touching also on the overarching challenges and needed solutions in the ongoing 'war' on marine litter.



Marine litter monitoring is a global imperative. A common framework is needed to develop and implement action plans. The integrated Marine Debris Observing System (IMDOS) is a backbone of the GPML. The main difficulties lie in wasteful duplication of efforts and still weak communication, harmonisation and coordination amongst the various actors involved. It is necessary to create a community of practice and centres of excellence. Numerical modelling incorporating AI is a promising new approach in tracking and forecasting trajectories of marine litter and forecasting its environmental impacts.

Marta Ottogali

KNOWLEDGE MANAGER CONSULTANT AT UNEP

Marta Ottogalli coordinates concept-to-launch of the UNEP Global Partnership on Marine Litter (GPML) Digital Platform. The Digital Platform is a partly open-source, multi-stakeholder platform that compiles different resources, connects stakeholders, and integrates data to guide action towards the long term elimination of marine litter and plastic pollution. She is specialized in open-source and AI digital platforms supporting evidence-based decision-making, enabling forecasting, presonalisation and match-making functionalities. Lastly she has extensive experience implementing agile, user experience (UX), and design thinking frameworks to foster innovation.

KEYNOTE

DAY 1

Martin Visbeck (**GEOMAR, Germany**) gave a talk entitled 'Digital Twins of the Ocean (DITTO) - Opportunities to connect Science to Society' where he presented the 'Digital Twins of the Ocean' programme of the UN Ocean Decade.

A digital twin of the ocean (DTO), i.e., a virtual comprehensive digital representation of the real ocean, can enable ocean information users to address 'what if' type questions based on shared data, models and knowledge. DTOs are powerful tools to empower ocean professionals, citizen scientists, policymakers and the general public in the management of the oceans and their resources. An adequate and complete observing system is the foundation of any DTO, whose core component is the so-called 'data lakes'. It is crucial to feed the 'data lake' properly to get DTOs to perform at their best. Indirectly, this means that the more sensors there are in the sea providing valid observations, the better a DTO will perform. Furthermore, DTOs can help to optimise observing networks whilst benefiting from them at the same time. Incorporating, as they usually do, the most recent advances in data visualisation technologies, they also form excellent 'Decision- making Theatres', which can support more knowledgeable planning and implementation of strategies and actions.

PANELLIST

Martin Visbeck

HEAD OF RESEARCH UNIT PHYSICAL OCEANOGRAPHY AT GEOMAR

Martin Visbeck is head of research unit Physical Oceanography at GEOMAR Helmholtz Centre for Ocean Research Kiel and professor at Kiel University, Germany. His research interests revolve around ocean's role in the climate system, ocean circulation, upwelling systems, integrated global ocean observation, digital-twins of the ocean and the ocean dimension of sustainable development. He led the 'Future Ocean' Network in Kiel to advance integrated marine sciences by bringing together different disciplines to work on marine issues. He serves on a number of national and international advisory committees including member of the Governing Board of the International Science Council (ISC), Joint Scientific Committee of the World Climate Research Programme (WCRP), leadership council of the Sustainable Development Solutions Network (SDSN), and past member of the Interim Decade Advisory Board for the UN Decade of Ocean Science Decade for Sustainable Development 2021-2030 and the EU ocean mission board assembly. He was elected fellow of the AGU, AMS, TOS and the European Academy of Sciences. Martin Visbeck is involved in strategic planning and decision-making processes about the ocean and sustainable development at a national, European and global level.

PANEL DISCUSSION

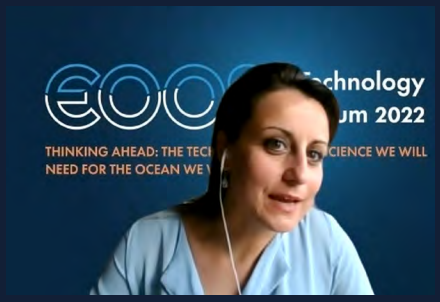
PANEL DISCUSSION DAY 1
THE TECHNOLOGY WE NEED AND ROLE OF TECHNOLOGY TO ACHIEVE OCEAN DECADE GOALS

Moderator: Steve Hall

EMMA HESLOP
UNESCO IOC

MATTHEW MOWLEM
National Oceanography Centre

JYOTIKA VIRMANI
Schmidt Ocean Institute



SIMONA ARACRI
Italian National Research Council

RUDOLPH BANNASCH
EvoLogics

STEVE HALL
Moderator

PANEL DISCUSSION

1. What are the main bottlenecks in technology development and uptake?

- A main gap in ocean observing is **under-sampling** in some remote areas because of the associated high logistical costs.
- There is a need to make data acquisition more efficient and less costly. New technologies will help to meet these needs and recent advances in **AI** and **computing** for **intelligent platforms** offer solutions to reduce human participation in the process.
- **Industry involvement** and engagement needs strengthening, also in the **sharing of assets and data.**
- **Communication** between technologies and networks globally across the entire ocean space over long periods: the technology is there (e.g. Internet of Things (IoT), but the **implementation is slow.**
- Program exchanges to improve knowledge transfer - e.g. educational programs.
- Environmental impact of the observing platform in the ocean: **use of sustainable materials** for new technology to avoid exacerbating the issues of **marine litter and pollution.**
- **Low-cost sensors and high automation** will support expanding coverage, particularly in chronically under-sampled areas, but compromises involving accuracy, size and power are necessary.
- **Industry must be integrated in the whole ocean value chain** (e.g., the GOOS/MTS dialogues with industry were mentioned as a relevant example).
- Need of **technology that is easy to use.**
- There is a demand for **self-sustaining technology** (e.g., auto-calibrating sensors).
- Some problems from the point of view of manufacturers: **sourcing Research and Development (R&D) capital; maximising marketability** of products while assuring **technological readiness** to meet evolving user/stakeholder needs.
- Important to find ways to **prioritise what is needed for technology developers** to focus on and narrow down the priorities: the **EOV framework** is a very good example.
- More **funding** needed **for achieving long-term goals**; general problem of market scale to favour the lowering of costs.
- Ships and supporting infrastructure are very expensive to run, often costs are higher than for the observing systems themselves, and money needs to be invested by the nations. **Cost-effectiveness** is a constant issue, and can mould decisions and actions (e.g., can ships be replaced by autonomous platforms in the future?).
- The UN Decade of Ocean Science has already helped the Ocean Observing community by **increasing collaboration within and across sectors**, and giving Ocean issues major visibility to society as a whole (communicating and engaging with the world outside the Ocean community is very important).

PANEL DISCUSSION

2. How do we evolve EOVs and integrate with regional requirements (MSFD/OSPAR/Barcelona convention, other)?

- It is important to ensure the existing **EOV scheme** can evolve to be able **to align and address current requirements and identify gaps.**
- **New EOVs** could be proposed with a subset of them tailored **to regional needs,** however consensus and consistency must be maintained, which is especially difficult for biology (more variables are needed).
- **EOVs** have been very **helpful to focus efforts** within the ocean observing community and also among technology developers.
- Providing **a priority list based on needs** rather than feasibility will be most helpful to technology developers.
- Need to **leverage recent advances in AI and edge computing** to make autonomous vehicles intelligent platforms with system solutions that reduce the need for human involvement, render possible immediately usable data, and enhance operational capabilities in remote areas.

SHOW AND TELL SESSION: SENSOR AND TECHNOLOGY.

René Garello **(Professor Emeritus, MIT Atlantique)** gave a keynote talk entitled 'Role of technology providers, community requirements, challenges', where he presented an overview of the state of the art in the observation, monitoring, forecasting and mitigation of marine pollution.

Technology plays a key role in the identification of marine pollution in all regions of the ocean. But, different devices and sensors exist, which leads to a variety of multi-source observations, data processing schemes and communication protocols.

90% of the plastic in the ocean comes from river outflows. So, it is important to integrate observations with lagrangian drifting models to help track the plastic debris coming from river mouths and forecast their eventual dispersion trajectories.

Current challenges that need to be faced: integration of diversity of sources, communities and data processing techniques. Artificial Intelligence and deep learning are helping to merge, and process, all the diverse marine pollution data coming from the 'real world', bringing models and observations closer to 'guide' cleanup applications.

The GPML (**Global Partnership on Marine Litter**), supported by GEO Blue Planet, is preparing a white paper on a global platform for monitoring and predicting marine litter and informing action concerning this global problem.

A series of 5-minute presentations showing different sensors and technologies followed. The links to the presentations are here.

René Garello

PROFESSEUR EMERITUS AT IMT ATLANTIQUE, LIFE FELLOW IEEE

His main research interests lie in Remote Sensing, 2D signal processing, statistical and spectral analysis applied to ocean surface features detection and characterization. For the last two decades, he has worked in the development of signal and image processing tools for the interpretation of satellite signals and the extraction of sea surface features, either natural (wind, waves, currents) or manmade (ships, oil pollution, marine debris). These application fields were supported by several European projects and industrial contracts. He is presently engaged in several initiatives on the topic of Marine Debris and Plastic in the oceans.

KEYNOTE

DAY 2

CURRENT TECHNOLOGICAL LANDSCAPE

DAY 2

Rajesh Nair welcomed the participants to the second day of the workshop, and introduced the topics and scope of the event.

The second day, devoted to the '**Current technological landscape**', was opened by a keynote talk, followed by two panel discussions and a Show-and-Tell session on 'Instrument platforms and Integration', moderated by **Steve Hall.**

SETTING THE **SCENE:** SESSION ON 'CURRENT TECHNOLOGICAL LANDSCAPE'.

Justin Manley (**Marine Technology Society**) gave a keynote talk entitled 'Oceantech for Observation, a snapshot from 2022', where he reviewed some cutting-edge innovations in marine observing technologies like operating platforms, unmanned surface vehicles (USVs), acoustic monitoring systems, sensors and cabling accessories, showing a number of examples.

Operating platforms for observing instrumentation are diversifying and becoming more affordable. New classes of sensors are emerging. Business models are also evolving (the 'data as a service' paradigm was stressed). Global-scale ocean observing will demand ever-increasing collaboration between industry, academia, government, and the general public.

Justin Manley

PRESIDENT OF THE MARINE TECHNOLOGY SOCIETY

Justin Manley is a technologist and executive with experience in startup, public corporation, academic, and public sectors. After professional roles at MIT, supporting NOAA and in the private sector he founded Just Innovation Inc. in 2015 to support a variety of clients with a focus on uncrewed and undersea systems. Mr. Manley is President-Elect of the Marine Technology Society, a member of the NOAA Ocean Exploration Advisory Board and Co-Chairs the Technology & Innovation Informal Working Group for the UN Ocean Decade. He is also dedicated to innovation, advising startup companies and as a judge for the ANA AVATAR XPRIZE.

KEYNOTE

PANEL DISCUSSION

PANEL DISCUSSION DAY 2

HOW DO WE ACHIEVE A DISTRIBUTED, EMBEDDED, MULTI-PARAMETER OCEAN NETWORK?

Moderator: Steve Hall

HEINZ SCHELWAT
Sea and Sun Technology GmbH

JUSTIN MANLEY
Marine Technology Society

DARIIA ATAMANCHUK
Dalhousie University

SARA IVERSON
Ocean Tracking Network

JOHANNES POST
Deepsea Mining Alliance

BLAIR THORNTON
University of Southampton

PANEL DISCUSSION

'How do we achieve a distributed, embedded, multi-parameter ocean network?'

Steve Hall moderated the panel discussion, where the invited panellists replied to key questions on the announced topic giving a number of thoughtful insights for deliberation which have been condensed below.

- **Ocean observing activity should include industry** in a way that will benefit all; the deep sea is a very difficult environment where many companies are already heavily invested.
- **Implement programs where industry/research can interact, and identify gaps** in the essential parameters needed and in areas where there are market opportunities.
- More **collaboration between technologists, researchers and end-users** to collect feedback to design/improve platforms and sensors: **structured programs are needed** because relying on informal cooperation is very rarely efficient or productive.
- **Solve interoperability issues** (e.g., data and metadata formats, instrument communication protocols, cabling standards, etc.), without disregarding the **risks of excessive standardisation which may act as an obstacle to innovation.**
- Resolve questions concerning coverage, e.g., **differentiate** where **high-quality measurements** are needed and where **large volumes of data but of lesser quality** could suffice (Big Data).
- **Develop frameworks for collaboration; EOOS** and other aggregating networks can work on communication, coordination and information-sharing to create demand that can spin-off development, drive up investment and lower costs.
- The deep sea is a very difficult environment where many companies are putting attention, **monitoring using autonomous systems** is needed (e.g., to observe sediment mobility, existing organisms, etc.).
- Marine **animal-borne sensors** have been embraced in the Southern Ocean but not yet as effectively in the rest of the Ocean. Promising to deploy for widespread sampling **to document physical and some biological and ecological EOVs**. ANIBOS is an emerging GOOS global network that advances on these strategies.

PANEL DISCUSSION

PANEL DISCUSSION DAY 2

HOW DO WE ESTABLISH A SYSTEMATIC AND ROBUST DATA VALUE CHAIN?

Moderator: Steve Hall

WARD APPELTANS
IOC- Ocean Biodiversity Information System

PIERRE-YVES LE TRAON
Mercator Ocean International

CONOR DELANEY
EMODnet

FLORENCE SALVETAT
Ifremer

GEGERLY SIPOS
EGI – Advanced Computing Services for Research

NICK WISE
OceanMind

PANEL DISCUSSION

1. What should we invest in now and how can we accelerate development?

- **It is critical to secure long-term investment to support sustained ocean observing activity**, with targeted funding **for financing innovation over the entire value chain of ocean observations**, including explicit financing of the data management component.
- **Metadata traceability must be assured,** and data quality control practices based on standardised uncertainty estimation procedures should be reinforced; supplying clear information on these aspects is essential because many non-scientific users presume an adequate quality of any scientific data which is made available to them.
- It is necessary to develop mechanisms (an example could be the 'Blockchain') to assure **a transparent and secure tracking of the movement and distribution of data** so as to valorize as many elements of the whole data value chain as possible.

2. How do we engage the expertise outside ocean research to take advantage of these new developments?

- **Different ways to access freely and openly available data** are needed **for different types of users** to maximise the consumer space for turning data into products and applications while continuing to make resources more integrable.
- New products and services need to be developed by leveraging existing and emerging observing technologies to help respond to urgent and emerging concerns **in the fields of climate, biogeochemistry, biology and ecosystems.**
- **Publishing oceanographic data** should involve semantically enhanced outlets (e.g., internet browsers) to promote greater public access to the data from authoritative sources dedicated to oceanographic data management (as opposed to random sources which pop up in response to an average user's query).

3. What is the best way to take advantage of new developments like AI, Blockchain and Machine Learning, and how can we incentivise their use?

- **Cloud computing and search mechanisms are real enablers** when it comes **to accessing data on large scales**. If data being sourced in this way is really contributing to improving our knowledge and management of the planet we live on, then this could be viewed as a measure of our success in producing and gathering the data in the first place.
- **AI and ML** can **complement cloud computing and search applications**; AI will be fundamental in developing the capability of digital ocean ecosystems to handle complex questions of the multidisciplinary kind, but only if accompanied by scientific oversight by experts.
- Publications and datasets should have **mandatory requirements for identifying provenance** (e.g. by assigning DOIs), ensuring traceability and guaranteeing freedom from unauthorised modifications. This needs to be a top-down requirement for funding bodies.

PANEL DISCUSSION

4. How to best promote FAIR principles? Examples for doing that?

- FAIR principles are being strongly promoted but, perhaps, they are still not well enough understood, e.g., the interoperability concept; It is necessary **to convince the community to use standardised vocabularies and ontologies.** The **ENVRI-FAIR project is an example** of how **to implement and promote FAIR** in Environmental sciences (including EOOS domains).
- It was discussed that 'free data' financed through taxes may be not a sustainable model in the long-term, and the costs of **data have to be included in the business model of the Blue Economy. It is necessary to develop new business models,** especially **private-public partnerships** for very specific use cases, which would create incentives **to maintain and expand sustainable investment in data collection and management in the long-term.** This would be a valid alternative to the currently prevailing "tax-paid" model. Some data will always be of interest to a very broad group of users, e.g., weather data and forecasts.

SHOW AND TELL SESSION: INSTRUMENT PLATFORMS AND INTEGRATION.

Stefania Sparnocchia (CNR, Italy) chaired the session.

Chiara Petrioli (**University of Rome La Sapienza and WSense Srl**) gave a keynote talk on underwater/undersea connectivity entitled 'Understanding the potential of new platforms and integration for a multi-prong approach to marine pollution' that included examples of real-life applications.

KEYNOTE

Chiara Petrioli

PROFESSOR AT UNIVERSITY OF ROME LA SAPIENZA

Chiara Petrioli is Professor of Computer Science and Engineering at University of Rome La Sapienza, Founder and Director WSense Srl.

"As a kid I as always fascinated by the abysses described by Jules Verne. Today I am exploring them with the technology I invented. Hold on to your dreams!"

The problem with many of the existing marine observing networks is that they are built using legacy connectivity solutions that are complex and cable-intensive, with marginal versatility and limited options for intelligent expansion of functionality.

There is a strong need for an Internet of Underwater Things (IoUT) system that would permit multi-modal secure wireless communications and networking to link submarine observing assets with those at the sea surface and terrestrial networks.

Some notable examples of such systems are W-Cloud (a cloud software platform running on Amazon Web Services, W-Gateway (a bridge between undersea and land networks), and W-Node (connecting hubs). These systems have a lot of built-in flexibility because of the use of available state-of-the-art technical solutions.

The future potential for similar technology is enormous.

A series of 5-minute presentations on instrument platforms and integration followed. The links to the presentations are here.

DAY 3

NEW DEVELOPMENTS IN BIG DATA APPROACHES

DAY 3

Laurent Delauney welcomed the participants to the third day of the workshop, and introduced the topics and scope of the event.

The third day, devoted to '**New developments in big data approaches**', was opened by a keynote talk, followed by a Show-and-Tell session on '**Cyberinfrastructure, AI and applications**' and a panel discussion on '**Recommendations, what can we do within this decade and what should be the role of EOOS Technology Forum**'.

SETTING THE **SCENE:** SESSION ON 'CYBERINFRASTRUCTURE, AI AND APPLICATIONS'.

Nick Wise (**OceanMind**) gave a keynote talk on new developments in big data approaches entitled 'An Ocean of Data'.

The availability and volume of data are no longer limiting factors in progressing our understanding of ocean processes, though **it is important to continue to try to leverage existing observing systems** to meet new challenges by **focussing investment and resources where they are needed** (sensors, data gathering, analysis). 'Big Data' is now a tangible reality in Ocean Science.

The real challenge is to derive meaningful information from data for decision-making; ML techniques alone are not enough though, because **human participation is still necessary to interpret results and associate significance to them. Multi-disciplinary teams** including domain experts and data scientists are **essential to find answers and solutions** from 'Big Data', and **to develop adequate ML algorithms**; partnerships are important to help organisations **make better use of the existing systems employed for handling 'Big Data'.**

A series of 5-minutes presentations on 'Cyber infrastructure, AI and applications' followed. The presentations can be accessed here.

KEYNOTE

Nick Wise

CEO OCEANMIND

Nick Wise is founder and CEO of OceanMind, a non-profit organisation dedicated to protecting the world's oceans. Using satellites and artificial intelligence, OceanMind powers effective fisheries enforcement and enables more responsible seafood sourcing, increasing compliance and sustainability. Building on this success, OceanMind is now developing AI to detect modern slavery on the oceans, particularly in fisheries, and to detect the desecration of war graves through unauthorised undersea salvage.

PANEL DISCUSSION

PANEL DISCUSSION DAY 3

RECOMMENDATIONS, WHAT CAN WE DO WITHIN THIS DECADE AND THE ROLE OF EOOS TECHNOLOGY FORUM

Moderator: Steve Hall

EMMA HESLOP
IOC-Global Ocean Observing System

INGA LIPS
EuroGOOS / EOOS

KATE LARKIN
EMODnet

MATTHEW MOWLEM
National Oceanography Centre

IAIN SHEPHERD
European Commission's Directorate general for Maritime Affairs and Fisheries

STEVE HALL
Moderator

PANEL DISCUSSION

1. What actions can Europe and EOOS take to help integration of technologies for multi-disciplinary observations and increase the technology readiness for operationalisation?

- **User requirements have to be taken into account**; users and applications are very heterogeneous, so transdisciplinarity and collaboration between sectors are needed.
- **EOOS framework** is helping to unify ocean observing communities at national level, **thus improving the effectiveness of country contributions to regional-level decisions.**
- The EOOS Technology Forum is a good framework and platform to connect and create partnerships, particularly with the private sector.
- **Feedback loops in EOOS** will be important, including those involving funding.
- EOOS could help to set up the roadmaps that establish technology requirements in ocean observing by linking **user requirements to technology development.**
- **EOOS could help to promote the sharing of data and observing assets and infrastructures** between organisations and countries.
- EOOS could help to **fast-track promising technologies**, and coordinate their subsequent development in a way that meets requirements more closely.

2. How do we improve the connections and interactions between research, applications and technology development to understand and address needs, and how can the EOOS Technology Forum help facilitate this?

- **By mapping out challenging areas** where **industry** and **science** can work together on solutions.
- **By using the digital twin as a test bed** linking the private and public sectors **to pilot the design of ocean observing strategy/actions.**
- **By finding ways to involve expertise from outside the marine domain** to address problems and seek solutions.
- **By constantly monitoring needs** to anticipate technology demands and **linking with existing disruptive technologies.**
- By improving knowledge of ocean observing among investors to help drive up investment.
- By providing financial support, not only to develop new technology, but also **for production and marketing**, perhaps through something like an 'EOOS resource forum' (funding organisations) initiative.
- By facilitating dialogue between industry and research to understand where the barriers are and work together (e.g., by participating in the 'GOOS/MTS Dialogues' Ocean Decade Action).
- **By identifying opportunities in the policy landscape** for building the necessary rapport for possible exploitation. E.g, the European Investment Bank (EIB) is showing interest in the growing ocean observing market, particularly in the area of autonomous platforms; similarly, the European Commission is also looking at ways to facilitate capital investment in technology in the context of the Blue Economy..
- By exploring new emerging **"data-as-a-service" business models** (e.g. Saildrone), taking also into consideration the FAIRness of these data.

PANEL DISCUSSION

3. What actions are needed to make high-quality, interoperable observations cheap and accessible for all?

- **Work with commercial networks providing marine observing services,** though this may also lead to greater competition for funding and lower financial returns for research.
- To manufacture cheap sensors. **The observing community needs to organise and help to drive-up demand:** lower prices come with **market scale**. The greater the demand, the lower the price is going to be.
- Moving towards autonomous platforms and self-sustaining sensors with low maintenance requirements.
- Perform regular cost-benefit analyses: Digital Twins may help.

MAIN **MESSAGES** AND **RECOMMENDATIONS**

Main messages and recommendations taken from the workshop are presented below, with a focus on how latest technological advances can help to accomplish the goals of the UN decade for Ocean Science and Sustainable Development to achieve a healthy Ocean.

> *"We live in the age where technology is shaping ocean science"*

Technology is evolving rapidly with **promising new developments** that we could take advantage of: e.g., **high bandwidth communication,** improved **power sources**, **AI, haptics** and **miniaturisation**.

This is a big opportunity if governed wisely, which means a consensus-driven, globally inclusive communal approach to strategic decision-making: need to consider **feasibility, cost, impact and available technology.**

- **Big Questions** are replacing **narrow interests:** the traditional system of prioritisation for **variables** may **no longer be adequate**, and new mechanisms may be needed to address this aspect.
- Technology exists but **resources to meet operational requirements are still lacking.**
- More in-situ measurements of air-sea interaction (e.g., fluxes or rates) are required.
- **More coordination** and collaboration are needed.
- There are **novel observing platforms** and a rapidly changing operational landscape.
- **Sensors** are **evolving rapidly** and **diversifying**.
- **Technologies** should work in combination.
- Business models are **evolving**. The increasingly relevant paradigm of 'data as a service' is growing in importance.
- **Scaling** is crucial for optimising affordability and versatility.
- Collaboration across **industry, academia, government and the broader public** is imperative.

WHAT IS STILL **NEEDED**

In a rapidly evolving technology world, some key points are still lacking with regards to the ocean observing landscape.

- A **common framework** to develop and implement action plans.
- An enhanced **EU contribution** for globally distributed, organised, democratised and accessible **open data.**
- **A fit for purpose and efficient ocean observing** system.
- **More operationalisation** of the observing devices, particularly for biological observations.

THE TECHNOLOGY WE NEED TO **ACHIEVE THE UN OCEAN DECADE GOALS**

There is a number of identified bottlenecks and challenges in the ocean observing landscape:

- Achieving technical sufficiency will be a challenge.
- **Data acquisition and transmission needs** to be made more efficient to close observational gaps.
- **Industry involvement** needs strengthening, including the **sharing of assets and data.**
- **Funding schemes** need to be driven up and maintained over the long term. There is a distinction between "underpinning" and "new development" funding.
- Increasing focus on sensors (e.g., low-cost) but not so much attention paid to **lowering costs on supportive infrastructure** (ships, calibration laboratories, etc.).
- Communication and engaging with the world outside the Ocean observing community should be improved.
- There is a need to **promote and demonstrate the value that the ocean observing** activity brings into other economically relevant areas, e.g. jobs creation.

Some points where the latest technology advances can help to better monitor the ocean and to achieve the UN Ocean Decade goals:

- Recent **advanced communication and data transmission technology,** able to work over the entire observing space and under water, can help to integrate observing technologies - the technology is already there (IoUT and others), but implementation is still slow.

- **Low cost and high automation** is needed to support expanding coverage, particularly in chronically under-sampled areas.
- **Recent advances in AI, ML and computing** for intelligent platforms can help to reduce human intervention in ocean observing.
- New **sustainable materials** for constructing observing platforms can help to avoid exacerbating the issues of marine litter and pollution.

A number of recommendations on how technology can help to achieve the UN Ocean Decade Goals have been derived.

- To improve **engagement**, **communication** and **involvement** of industry and private partners, including sharing of assets.
- To increase **knowledge transfer** through exchange programs.
- To establish **a priority list of parameters that need measuring** (EOVs).
- To communicate a **positive message** and focus on a **tangible objective** to drive up investment.
- **To establish a good governance and management of the observing system** with defined key performance indicators.
- To **demonstrate the value that ocean observing activities bring to societal areas as creation of jobs.**
- **To adapt how we undertake ocean observing to include industry** in a way that will benefit all, e.g. set up infrastructure to sell the data so multiple users across multiple locations can benefit.
- **To implement programs where industry and research interact and identify observing gaps** where there are potential market opportunities.
- **To solve the interoperability of sensors and platforms** where data can be provided in a standard format, protocols and enabling components that can be put into multiple uses; **consider risks of excessive standardisation.**
- **To optimise cost by differentiating** where **high quality measurements** are needed and where we need **large volumes of data but of lesser quality** (Big Data).
- To make **low quality data available**, end users can utilise this data as long as information on its **quality information is available in the metadata.**
- To work on a **data provenance model** and use available technologies (like **blockchain**) **to secure tracking of the movement and distribution of data**, with the aim to incentivize more people to share their data.

- Enable **innovative ways to access data**, a good data licence **to open the data for communities outside** ocean science to access and innovate.
- **Use and build on the infrastructure already in place**, including the use of **existing API's and data portals.**
- Improve cloud computing and search mechanisms, which are real enablers to access the data at scales that can help change the planet.
- To look at 'data as services' models and engage with service providers to identify issues in data FAIRness.

ROLE OF THE **UN OCEAN DECADE** AND THE **EOOS TECHNOLOGY FORUM**

The main recommendations from the workshop on how new technological advances and the EOOS Technology Forum can help to achieve the goals of the UN Decade for Ocean Science and Sustainable Development are summarised below.

- The UN Ocean Decade and its programmes) can provide a **strong framework for driving the development of new marine observing technologies.**
- **The EOOS Technology Forum can be a great venue for connecting the ocean observing community, including the private sector, and funders.**
- **A dialogue with all the actors in the full data value chain is needed** (e.g., establishing metrics by the data providers on how much data is being used); linking with national initiatives and engaging more with the private sector was strongly recommended.
- **Leverage Ocean Digital Twins** as test beds to link the private and public sectors in developing better technologies and observing systems.
- The EOOS Technology Forum should aim for wider participation and **collaboration with sectors outside the marine domain** (e.g., Medicine, Aerospace, etc.) where many technological advances take place and can be useful in the marine science domain. Better and **improved engagement, communication and involvement of industry is needed.**
- The **link with the Ocean Best Practices System initiative should be strengthened.**
- The **Essential Ocean Variables (EOV)** framework is a good way to prioritise observing requirements and link technology development with marine observing needs.
- The introduction of new technologies can be aided by creating more opportunities for **sharing expensive technological equipment** transnationally.

- The **EOOS Technology Forum can contribute to 'fast-tracking' new, advanced technologies** by providing opportunities for 'showcasing' them before an international audience.
- **EOOS should link with funding agencies** to press the case for a call focussing on a roadmap for solving technological challenges to help stimulate financing for development. This can be strengthened through the **EOOS Resource Forum.**
- The ocean **observing community** must be **less fragmented and more organised** to be attractive as a business partner.
- **EOOS and its Technology Forum should be involved and participate in the GOOS/MTS Dialogues between industry and research** to better understand how to overcome the barriers preventing the ocean observing community looking as a more attractive market.

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