Ocean Science Cluster Introduction

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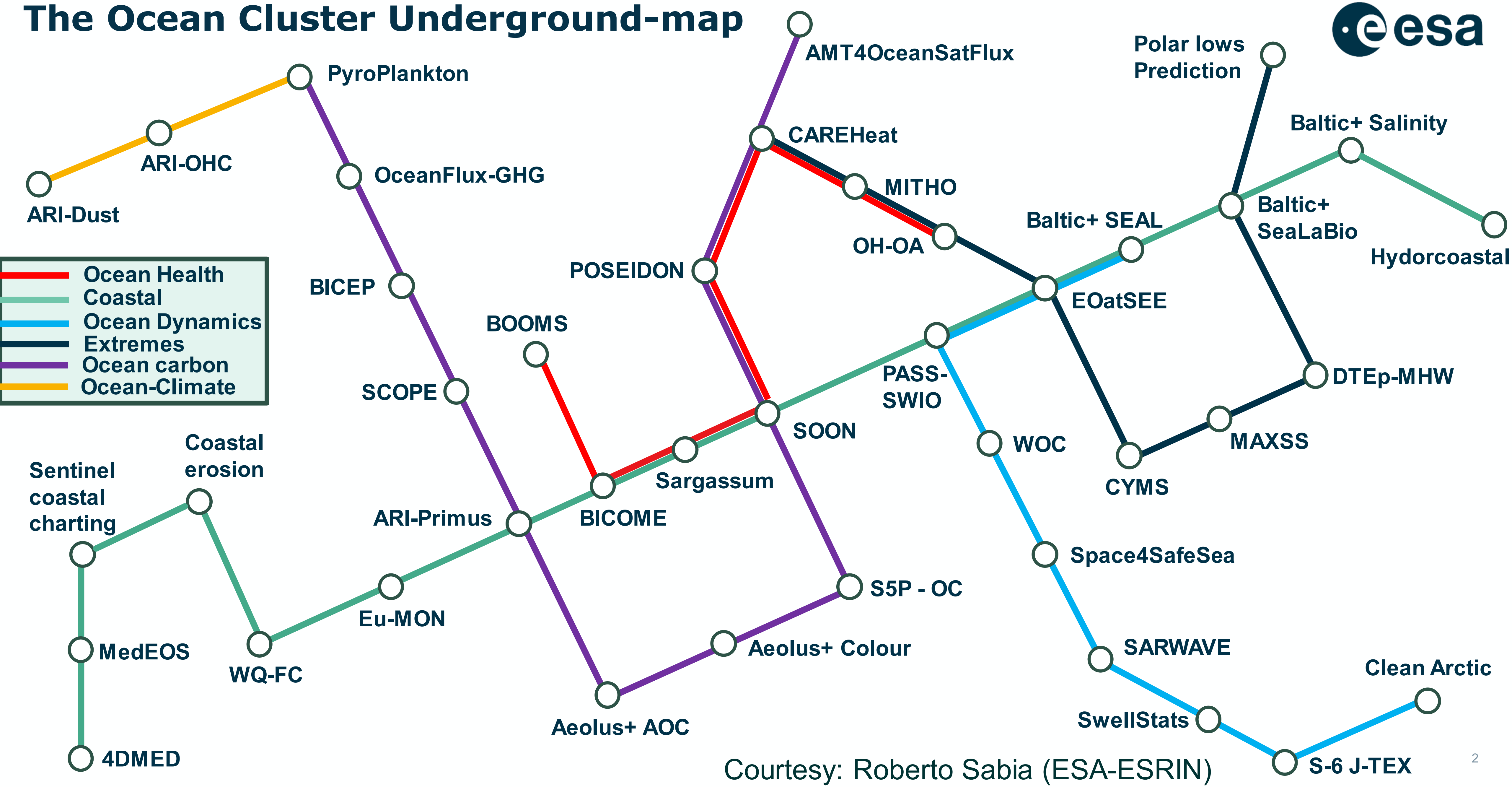
Daniele Ciani (CNR), Florian Le Guillou (ESA-ESRIN), Vincent Rossi (CNRS), Shubha Sathyendranath (PML), Nathalie Verbrugge (CLS), John Gittings (University of Athens), Joan Llort (BSC), Jerome Benveniste (ESA-ESRIN), Gemma Kulk (PML), Vittorio Brando (CNR) and all the Ocean Science Cluster session participants!

The Ocean Cluster Underground-map



Courtesy: Roberto Sabia (ESA-ESRIN)

Programme

Wednesday		Thursday		Friday	
8:30-10:00	Registration and Welcome coffee	08:30-9:00	Plenary: Breakfast Keynote	9:00-10:00	Session 6: Ocean Health - Pollution
10:00-11:00	Plenary: Welcome session	9:00-11:00	Session 2: Ocean Health - Biodiversity	10:00-11:00	Ocean Wrap-up
11:00-11:30	Coffee Break	11:00-11:30	Coffee Break	11:00-11:30	Coffee Break
11:30-13:20	Plenary: Frontiers of Science and Opportunities	11:30-13:20	Session 3: Ocean Health - Multi stressors	11:30-13:00	Plenary: Summary, Wrap-ups and Next steps
13:20-14:20	Lunch Break	13:20-14:20	Lunch Break		
14:20-15:35	Ocean Introduction	14:20-16:00	Session 4: Coastal Ocean and land-sea interactions		
15:35-16:00	Session 1: Upper Ocean Dynamics				
16:00-16:20	Coffee Break	16:00-16:20	Coffee Break		
16:20-18:05	Session 1: Upper Ocean Dynamics Cont.	16:20-17:50	Session 5: Ocean Carbon		
18:00-19:00	Posters and networking cocktail	18:00-19:00	Posters and networking cocktail		

COMMON RECOMMENDATIONS

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Common recommendations (1/3)

❑ Collaboration/networking activities

- Reinforce coordination within ESA projects and between ESA and EC projects identified in the EC-ESA Ocean Health Flagship Initiative
  - Organize a dedicated workshop on joining forces and streamlining the research questions between the ESA and the EC projects -> Annual meeting to discuss results and look for better joint outcomes.
  - Mapping of ESA/EC projects
  - Common webpage, data platform
  - Knowledge brocker – capacity building
- Resources for community building beyond ESA/EC projects
- Beyond Europe, collaboration with other international space agencies is key in order to address science collaboratively (e.g. ODYSEA mission on Ocean currents,…)

❑ Key ocean cross-topics parameters to further develop

- Accurate and long-term consistent winds are fundamental for many ocean topics. Start an ESA Wind ECV as part of CCI
- Mixed Layer Depth is a key parameter for many topics (upper ocean dynamics, carbon) Effort should be put to estimate reliable, interannual products.

❑ Climate studies

- Need for common/standard method for trend calculation -> IPCC standard could be more systematically used.
- For trend detection, long time series are crucial – this call for continuity of present satellite constellation

Common recommendations (2/3)

- ❑ Key importance of in-situ measurements for algorithms development, satellite measurements calibration and validation
  - ➢ Need of more, sustained in-situ measurements, also possibly including long-term fixed location time series
  - ➢ Data mining to be systematically included in projects
  - ➢ Harmonizing new and old techniques for in-situ measurements

- ❑ Make the best use of what already exists (in-situ, satellites)
  - ➢ Publish open access S3-OLCI full resolution L3 and L4 products, NRT and historical for the global ocean (for now, only coastal is distributed)
  - ➢ Publish best available coastal products from S-2 (turbidity, SPM, NRT and historical) for the entire S-2 coverage
  - ➢ Provide homogenous access to data from different data hubs

- ❑ New data
  - ➢ Support the optimal exploitation of upcoming missions (hyperspectral, wide-swath altimetry, Earth Explorers,…)
  - ➢ Start the development of a Geostationary Ocean Colour mission

- ❑ Systematic estimation/delivery of Data/Products accuracy
  - ➢ Work on uncertainties – also including Representativity error characterization (in-situ + satellite)
  - ➢ Need for more systematic, consistent intercomparison exercise (Data challenge…)

- ❑ Ensure science results are uptaken at stakeholder/policy/community levels

Common recommendations (3/3)

- Key areas to be further addressed
  - Coastal areas
    - Coastal is both a key priority area (of socio-economic importance, and subject to increasing hazards) and a challenge for many satellite data processing and process understanding.
    - Address the coastal challenge: how can we move from local coastal to global coastal?
  - High Latitudes

- Algorithm development
  - Maximize the use of Machine Learning / AI for Ocean Science

- ESA projects
  - Ensure continuity of the regional initiatives, continuity of the ocean science cluster
  - Extend projects duration (>2 years) in order to facilitate scientific development, impact studies and personnel recruitment, stakeholder engagements
  - Need for more fundamental research projects

- Prepare the next generation of oceanographers
  - Training of the new generation of scientist is key (more and more multi-disciplinary research needed)

- Recommendation for next meeting: More time for poster sessions and drinks!

DETAILED RECOMMENDATIONS PER TOPIC

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Ocean II
Upper Ocean Dynamics

Florian Le Guillou (ESA), Daniele Ciani (CNR)

Ocean II - Upper Ocean Dynamics

Recent Achievements

- Overall: advancement on points/recommendations raised at previous Ocean Science Cluster collocation meeting
- Improvement of upper ocean dynamics products via synergies between space based and in-situ observations, including improved L2 processing
- Advanced reconstruction methods based on innovative AI and physically-informed techniques.
- Ingestion of improved satellite-derived products in numerical models (data assimilation).
- Impact studies (e.g. ecosystems/pollutants/navigation) / users engagement
- Products publicly available

Ocean II - Upper Ocean Dynamics

Identified gaps

- Equatorial & Coastal (ageostrophic) dynamics poorly estimated
- Time / spatial coverage of the newly generated products
  (mostly regional products generated over non-homogeneous time periods)
- Availability of in-situ data for validation/algorithm development

Gap-filling Opportunities

- Contributions from recently-launched/future missions (SWOT,CIMR,LSTM,TRISHNA,S3NG,CRISTAL
  Harmony,...)
- Cross-fertilization and comparison between projects :
  -common areas/periods
  -common validation metrics
  -Open data challenges (emphasize strengths/weaknesses of different approaches)
- Design of innovative algorithms, (AI/dynamical/synergy), to focus on poorly resolved processes
- Explore applicability of regional algorithms to global-scale

Additional remarks/notes/hints

- Set up specific initiatives in order to facilitate cross-fertilization
- Suggestion to extend projects duration (>2 years) in order to facilitate scientific development, impact studies and personnel recruitment

Ocean III
Ocean Health - Biodiversity

Vincent Rossi (CNRS) and Shubha Sathyendranath (PML)

Summary

Summary

- Broad range of topics dealing with various components of biodiversity.
- Mostly focused on micro-organisms (i.e. plankton), habitat-forming species (i.e. seagrasses, corals) as well as all-inclusive (molecular) techniques.
- Multiple tools, ranging from remote sensing to field surveys and molecular techniques.

Main concepts

- Biodiversity is key for the resilience and stability of ecosystems, it supports ecosystem services, and is a recognized source of innovations.
- Issues of complexity, scales and connectivity associated with biodiversity assessment
- Need of integration, cooperation and harmonization across measurement tools and scientific disciplines, to tackle biodiversity mapping. In this context, remote sensing is an essential, but imperfect, tool, and auxiliary observation tools are needed, to obtain the full picture.
- Step change in complexity when shifting from biogeochemistry (most abundant organisms) to biodiversity, which concerns ALL living organisms at all organizational levels.
- Simple to complex: biodiversity is defined using a number of characteristics that range from simple to extremely complex. Challenge is to identify the underlying structure.
- Standardized, reproducible, and comparable observation tools are essential to obtain the large-scale picture.

Main discussion points

- How do we detect change? Importance of sustained, long-term observations was highlighted, but no consensus on this point.
- Need to break down the problem into bite-sized components to address the mammoth problem of investigating biodiversity.
- Tailor observations to meet specific objectives.

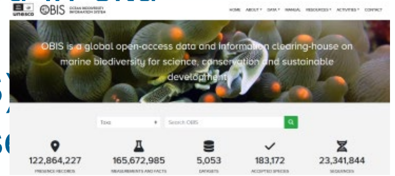
Conclusive remarks & next steps

Gaps

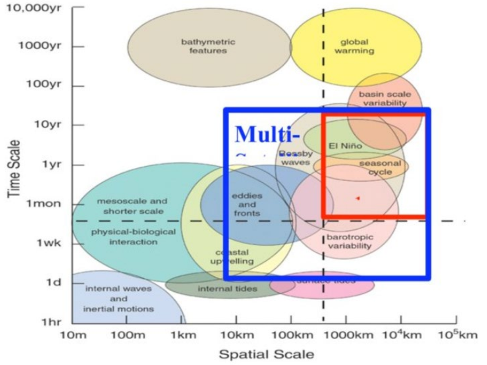
- Concurrent measurements of biodiversity and optical data amenable to remote sensing.
- Needs of merged, harmonized and extensive database of in-situ observations across scales/levels.
- Missing components of existing satellite-derived biodiversity estimates: intertidal & benthic ecosystems, fishes, megafauna (excluding GPS-tracked animals).

Recommendation and Opportunities

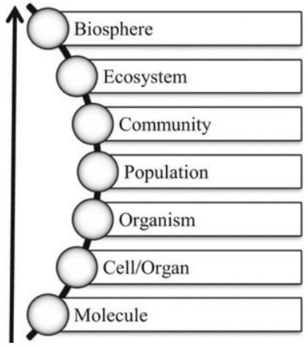
- New technologies (hyperspectral satellite sensors; molecular tools; automated in-situ methodologies…)
- Don't forget classical presence/absence observations (i.e. compiled by OBIS)
- Remote-sensed monitoring of biodiversity (planetary scale) needs in-situ obs… of both micro- and macro-organisms.
- Essential Biodiversity Variables & Essential Ocean Variables (i.e. GOOS)
- Methods developed in (local) pilot studies could be extended globally
- Hijack land sensors for marine applications (e.g., Sentinel-2)
- Link with modelling communities (Earth System Model, FishMIP, etc…).



Geophysics & Scales



Biodiversity & Organisational levels



Priorities

→ Investigation of trends and relation to drivers (climate or other) to advance from science into action.
→ Important to identify and involve stakeholders and co-design (at early stages)
→ Bring in more macroecology and biogeography into our communities

EC-ESA Joint Earth System Science Initiative

22-24 November 2023| ESA-ESRIN, Frascati, Italy

Ocean II
Ocean Health - Multistressors

Nathalie Verbrugg (CLS) and John Gittings (University of Athens)

Seed Questions for Discussion

1. Recent Achievements

- Improved MHW detection algorithms (CAREheat) and subsequent development of a MHW (surface and 4D) atlas that can ultimately feed into other ESA Ocean Health Cluster projects
- Similarly, MAXSS provides Atlases and various data products for the analysis of air/sea extreme interactions/events
- POSEIDON highlights usefulness of different phytoplankton ecological indicators for studying broader ecological phenomena and extreme events → shows future joint applicability of such approaches with outputs from projects like CAREheat and MAXSS
- MIiTHO will create extended partnership and use outputs from other ESA Health Cluster projects to produce and analyse datasets of ecosystem stressors
- EC-GES4SEAS provides a holistic assessment and toolbox towards better ecosystem management → direct importance for marine management

Seed Questions for Discussion

2. Identified gaps

- There is an overall consensus and agreement that a collective effort is needed to foster cross-collaboration and an awareness of datasets/deliverables/milestones within the Ocean Health Cluster

- Consideration of the complexities/sources of potential uncertainty from the deliverables/datasets of each project is needed (i.e., we need good quality inputs if they are to be shared between the ESSI scientific community)

- Ongoing efforts are needed for processing of quality controlled, high resolution satellite datasets (e.g., EC-GES4SEAS may require resolutions greater than 10m for benthic mapping as well as hyperspectral data for distinguishing different species)

- Similarly, gaps may be associated with *in situ* datasets that are essential for supporting the proposed objectives of the cluster (continuity and co-ordination)

- Long-term time series from stationary in situ platforms (e.g., moorings) are essential for long-term validation, monitoring changes, extreme event detection……

Seed Questions for Discussion

3. Gap-filling Opportunities

a. **Short-term**

- Continual and regular meetings (annual, such as this conference!) to increase inter-project awareness and encourage collaborative efforts (facilitate synergies).
- *Website/roadmap dedicated to Ocean Health cluster objectives (inclusion of HORIZON Europe projects)*

b. **Long-term**

- Targeted and co-ordinated *in situ* efforts at European level (e.g., EOOS) related to the Ocean Health cluster objectives and road map
- Expand and further develop synergies between satellite and other contemporary oceanographic platforms (e.g., CMEMS MULTIOBS)
- Machine learning/AI approaches for data integration

4. Additional remarks/notes/hints

- Online visualization tools, citizen science, direction for new generation of scientists?

Ocean IV
Coastal Ocean and Land-Sea interactions

Joan Llort (BSC) and Jerome Benveniste (ESA)

Coastal Ocean
Identified gaps

- A more accurate Digital Elevation Model for inland water regions with continuity to bathymetry
- Need better near-real-time altimetry and infrared for flood forecasting
- Develop an accurate Sea State Bias for SAR altimeter data in the coastal zone.
- Consistent MSS and geoid are necessary to connect the sea and land properly ➔ dedicated study.
- Improved bathymetry and tidal models for coastal zones/estuaries.
- Reduction of cross-track orbit variability for targets located in areas of complex topography.
- Sampling from current altimeter missions is not sufficient for day-to-day monitoring, and extreme events
- Improve spatial resolution for SDB, shoreline and SDT and temporal for sea level and waves
- River discharge measurements from altimetry are still quite challenging
- Increase time sampling with Geostationary missions
- Don’t rely on a global model only, but develop local ones
- Invest in bridging the gap between communities (e.g S1 and S2, HYDRO&COASTAL)
- Coastal hazards and resilience

Land-Ocean interactions - aerosols
Identified gaps

- Lack of information on dust concentration, deposition and vertical distribution
- Sparse ground-based observations of aerosols over the ocean
- Incomplete representation of wildfires emission – aerosol injections and dust-ash mix
- Automatic tracking of plumes (Sentinel 5 over EU)
- Need monitoring of aerosols at different stages (emission, transport, deposition)
- More work to merge satellite and autonomous platform data
- Sampling extreme events on the field, simultaneously from the ground and space
- Validate ocean colour algorithms in high aerosol conditions (black carbon in particular)
- Synoptic and near real time estimates of carbon export to inform/monitor CDR initiatives

Ocean V
Ocean Carbon

Gemma Kulk (PML) and Roberto Sabia (ESA)

Ocean Carbon – Seed Questions for Discussion

1. Recent Achievements

- EO-driven estimation of the whole Carbonate system [OH-Ocean Acidification]
- Initial work on Extreme/Compounds and downstream studies [OH-Ocean Acidification]
- Production of daily 1km Atlantic PP 1997-2022 and daily 300m regional PP 2017-2022 [PRIMUS]
- Data mining (recovered data that can be used for EO validation) [PRIMUS]
- Internally consistent dataset for biological carbon pools and fluxes with budget for mixed layer [BICEP]

2. Identified gaps

- *In situ* data availability for validation and/or algorithm training
- Data uncertainty (lack of/or full characterisation)
- Representation errors characterisation at various scales (H, V, time)
- Vertical distribution
- Underrepresentation of certain regions, such as coastal and polar
- Production of Dissolved Organic Carbon
- Consistency in methods and tools (e.g., trend analysis)

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Ocean Carbon – Seed Questions for Discussion

3. Gap-filling Opportunities

a. Short-term

- Longer-term funding from ESA (e.g., 3- instead of 2-year projects)
- Fully characterise multi-stressors impact (incl. OA)
- Ingest EO Acidification data in downstream applications
- Improve satellite algorithms and uncertainty estimates
- Fully exploit AI / ML techniques
- Bring carbon communities together and integrate EO with *in situ* data and models
- Engagement with Copernicus, GOOS and other international organisations

b. Long-term

- Improve fundamental understanding of ocean carbon cycle processes
- Earth System Science approach, link ocean to atmosphere and land
- Use of EO Acidification data for driving/assessing policies
- Use of ocean carbon data to respond to Global Stocktake and Paris Agreement efforts
- Commercialisation of EO-based ocean carbon products

4. Additional remarks/notes/hints

- Consider carbon and environmental footprints of research
- Use of hyperspectral and geostationary satellites

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Ocean VI
Ocean Health - Pollution

Vittorio Brando (CNR)

Ocean VI – Water Quality

Recent Achievements

- Regionally tuned algorithms to deal with optical variability and complexity
- Coastal water quality monitoring across spatial and spectral resolutions (i.e. S3/S2)
- Retrieval of "direct" and "indirect" water quality products from EO data
- First steps of data fusion across resolutions
- Assessment of human health related products
- Environmental reporting exploiting EO data
- Collaboration with local and regional stakeholders

Ocean VI – Water Quality

Identified gaps

- Limited in situ data for validation, particularly beyond chlorophyll
- Higher uncertainties for retrieval in optically complex waters
- Consistency for products across spatial and spectral resolutions
- Need to adjust algorithms for shallow waters
- Biogeochemical modelling for water quality forecasting from EO data cubes
- Some products need to be further develop as Harmful Algae Bloom
- Water quality and Human health

Ocean VI – Water Quality

3. Gap-filling Opportunities

a. Short-term

- Still need to uptake “modern” ML/AI/DL techniques for water quality and data fusion
- Collaboration with local authorities
- …

b. Long-term

- Water quality Forecasting has large economic potential
- Environmental reporting exploiting EO data supports societal benefits

4. Additional remarks/notes/hints

- Further support marine litter studies
- …

THANKS!

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