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Centro Euro-Mediterraneo
sui Cambiamenti Climatici

CMCC views on the European Ocean Observation Initiative

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Executive Summary

The European Ocean Observation Initiative is a timely step to deliver the European Ocean Pact's ambition for accessible marine knowledge enabling the European Digital Twin of the Ocean (EU DTO) with trusted, interoperable, and sustainable observation streams. Currently, Europe's ocean observation system is fragmented, with insufficient coastal coverage and a lack of interoperable standards. In this context. CMCC highlights the following elements:

1. **Build an integrated observation framework,** clarifying roles of key assets, such as EMODnet, Copernicus Marine, WISE-Marine and EU DTO, to ensure interoperability-by-design, "measure once, use many" approach, joint planning of observation initiatives and an EU–national collaboration framework, to reduce duplications.
2. **Prioritize coastal zones**, where hazards, pollution and ecosystem stresses, translate into impacts, and observing gaps are largest and operational needs are most urgent, by **strengthening high-resolution nearshore satellite products** to complement in-situ networks and enable scalable coastal services, and deploying **AI-derived products** to transform satellite data into "analysis-ready" coastal layers for direct integration into Digital Twin of the Ocean (DTO) models.
3. **Promote cost-effective coastal in-situ networks**, designed for long-term maintainability required to develop climate services.
4. **Consider citizen science as a key monitoring resource** and a complementary observation layer, with common protocols, metadata traceability and quality labelling, to extend coverage, especially along the coast.
5. **Support pilot sites "coastal innovation-to-operations" pathways**, to prove that targeted coastal observation investments measurably improve decisions and competitiveness.
6. **Foster interdisciplinary partnerships between academia and industry** to prevent "brain drain" and build a world-class talent pool dedicated to coastal resilience.

Introduction

The European Ocean Observation Initiative is essential to accelerate scientific discovery and enhance the Union's global competitiveness in strategic maritime sectors. At CMCC, we view ocean observation not merely as a monitoring exercise, but as the foundational layer for a methodological revolution: the transition from reactive analysis to anticipatory insight.

Ocean observation underpins three interdependent capabilities: climate services (with focus on extremes, sea-level rise, compound flooding and coastal erosion), ecosystem status and restoration monitoring (including habitats, biodiversity proxies, pressures and recovery signals), and pollution detection and response (turbidity/sediments, contaminants/pathogens, oil spills, debris). CMCC strongly underscores that the coastal zone must be a primary implementation focus, as it is the land–sea interface where hazards, pollution, biodiversity loss and economic exposure converge, yet where observation gaps and "decision urgency" are greatest. In this zone, impacts on people and assets are immediate; observation must therefore be designed to deliver decision-grade indicators and rapid event monitoring, not only long-term archives.

A coast-focused initiative should therefore scale high-resolution coastal satellite products, with a focus on nearshore-robust L3/L4 fields and derived indicators and complement them with cost-effective in-situ networks and structured citizen science, following proven solution patterns from CoastPredict/GlobalCoast. These include, inter alia, low-cost sea-level and waves sensors and tide gauges, high frequency coastal radars and drifters for currents, CoastSnap/video imaging for shoreline change, FVON-type approaches for scalable temperature/salinity sampling, and multi-parametric surveys in estuaries and nearshore waters.

Models turn diverse observations into coherent estimates and scenarios. By integrating high-resolution data from the Copernicus Mediterranean Monitoring and Forecasting Centre (MED MFC) into our modeling chains, CMCC is moving beyond traditional forecast skills to predict system-wide impacts, such as disruptions in food supply chains and infrastructure stress and ecosystem collapse. In this context, CMCC considers the Initiative an opportunity to build a sovereign, AI-enabled "what-if" engine to societal resilience, thus placing evidence at the heart of effective maritime decision-making.

For coasts, this means coupling ocean dynamics with waves, sediments/morphology and biogeochemistry, and explicitly integrating freshwater inputs and the land–sea continuum. Reliable coastal prediction requires observations for calibration and validation purposes, realistic initial and boundary conditions, and geometry and forcing that include rivers and nearshore complexity. AI/ML further strengthens this infrastructure by enabling automated quality control and gap-filling, and coastal in-situ, satellite, and hydrology observations integration. AI downscaling and forecasting improves nearshore realism and uncertainty characterization, provided that models are trained and validated on well-designed benchmark datasets.

Because the ocean is inherently transboundary, EU-level coordination is a strategic necessity to ensure an integrated data value chain. Without adequate coordination, Europe risks fragmented investments, inconsistent standards, and silos hindering utilization of data across policies and sea basins. The Initiative should therefore implement a "measure once,

use many" approach through harmonized metadata, Quality Assurance (QA) and Quality Control (QC) interoperability, and a governance model that explicitly links observation to EMODnet/Copernicus/WISE-Marine pipelines as well as to the EU DTO services.

To expand coverage without compromising credibility, observation streams must be integrated as a first-class component through catalogued sensors and best practices (e.g. SCOOP), harmonized metadata and traceability, calibration/validation schemes, and quality labelling.

1. Marine Knowledge, Research & Innovation

The successful uptake of advanced digital applications in the maritime domain depends on the quality, interoperability, and governance of the underlying data infrastructure.

Europe possesses world-leading assets, yet major gaps persist across several critical domains. In terms of geography, observations remain scarcest in polar regions and coastal hot spots, such as estuaries, deltas, and urban coasts - where decision demand is highest. Further, there is a significant need for better data on high-resolution bathymetry, coastal biogeochemistry, biodiversity, and seabed habitats, alongside better tracking of carbon fluxes and environmental pressures like contaminants and turbidity. While nearshore-ready satellite products exist at L3/L4 levels, users still face limitations due to resolution, complex nearshore optics, and a lack of systematic calibration and validation. Furthermore, the land–sea continuum remains fragmented; river discharge and nutrient loads are rarely integrated into coastal observations, which limits our ability to assess compound risks like simultaneous river flooding and storm surges. Finally, data harmonization and trust are hindered by inconsistent metadata and variable QA/QC, which prevents the seamless reuse of data in modeling, AI assimilation, and policy workflows.

CMCC leverages physically consistent estimation and AI-driven assimilation to ensure that diverse observations - from deep-sea sensors to coastal satellites and citizen science streams- remain traceable, quality-controlled and usable for modelling and services, with a view to bridge critical knowledge blind spots in coastal hotspots, biodiversity and carbon fluxes,

It would be of paramount importance to further strengthen the role of EMODnet, including from a governance perspective, in order to enhance its strategic capacity to bring together and leverage Europe's diverse observing system communities. Such reinforcement would ensure greater coherence, efficiency, and long-term sustainability in the integration and management of marine data and knowledge across the European Union. The Initiative should reinforce EMODnet as the harmonized in-situ backbone and ensure interoperability-by-design with Copernicus Marine, WISE-Marine, and the EU Digital Twin of the Ocean (EU DTO). A coastal-first approach should explicitly include nearshore-robust satellite products, cost-effective in-situ networks and citizen science, and land–sea hydrological inputs, all made DTO-ready through common metadata, uncertainty descriptors, and standard APIs. By institutionalizing sandboxes and metadata-rich pipelines, the Initiative can shift from fragmented data collection to a trustworthy, reproducible observation-to-service ecosystem for both science and policy.

Further, the Initiative can close coastal gaps rapidly by scaling proven solution patterns from UN Ocean Science Decade Programme CoastPredict/GlobalCoast: leveraging existing coastal satellite products as the baseline layer and complementing them with cost-effective in-situ and citizen science observing (e.g. tide gauges and low-cost sea-level sensors; HF coastal radars and drifters for currents; FVON for scalable temperature/salinity; CoastSnap for shoreline change; multi-parameter surveys for estuaries and nearshore biogeochemistry; and river flow stations for discharge). The optimal combination should be tailored by coastal type, with modelling-informed design (OSSE/OSE) where possible.

Key Recommendations

1. Prioritize coastal hot spots and estuaries with sustained observing designed around hazards, water quality and ecosystem status.
2. Invest in nearshore-robust EO workstream (coastal altimetry/currents, SST, ocean colour/turbidity/Total Suspended Matter, shoreline change, bathymetry proxies) with routine calibration and validation.
3. Integrate cost-effective in-situ and citizen science tools by adopting protocols, QA/QC, calibration, metadata and quality labels, supported by sensor catalogues and best practices (e.g., SCOOP).
4. Promote AI-based Quality control, gap filling, fusion and derived indicators from in-situ and satellite, but require transparency, benchmarking, uncertainty descriptors, and fit-for-purpose validation.
5. integrate hydrological observations, including discharge, levels, sediments, nutrients, and contaminants, with coastal observing and downstream products to achieve land–sea integration.
6. require machine-actionable interfaces (APIs), provenance and versioning, and uncertainty metadata so products can feed modelling and AI assimilation and EU DTO services.
7. Define and enforce functional roles of EMODnet for in situ observations, harmonization, quality assurance and stewardship, Copernicus Marine, operational EO & forecasting interfaces, WISE-Marine, policy reporting interfaces, EU DTO, scenario and decision services.
8. Require once-only, machine-actionable reporting - standard formats, APIs, provenance/versioning - to reduce burden and improve comparability across policies and basins.
9. Fund “end-to-end” pilots where coastal observations, including citizen science and hydrology demonstrably reduce uncertainty and support decisions by authorities and operators.

2. Governance and international dimension

EU Competitiveness in Ocean Observation

To strengthen its global leadership in marine science, Europe can leverage recognized operational services and infrastructure, scientific excellence, and strong marine policy. However, competitiveness is constrained by fragmentation of observation investments, uneven coastal coverage and limited integration of cost-effective and citizen science streams, dependencies in sensor supply chains and digital infrastructure, and insufficient pathways that turn observation into deployable services. In this context, the Initiative must steer the transition from a fragmented research landscape to an integrated, service-oriented ecosystem. By prioritizing coastal-first deployments and addressing gaps in sensor supply chains, Europe can mitigate current dependencies and enhance its strategic autonomy. The Initiative's success hinges on accelerating the innovation-to-uptake pipeline, ensuring that citizen science and AI-validated data are seamlessly integrated into scalable platforms like EMODnet, Copernicus, and the Digital Twin of the Ocean.

Geopolitical and Strategic Autonomy

To ensure Europe remains competitive and sovereign in the next technological era, it must boost its capabilities across the entire value chain - from resilient supply chains for sensor manufacturing to AI-enabled analytics. Strategic autonomy in ocean observation activities depends primarily on these secure supply chains, and as such, the Initiative should focus on reducing dependencies by supporting European sensor ecosystems and the adoption of interoperable open standards.

CMCC supports the establishment of a decentralized network of public research organizations to counter the dominance of non-EU corporations over critical data and HPC infrastructures. This distributed capacity for modeling and AI workflows, designed to operate seamlessly across European infrastructures, combined with the "once-only" reporting principles of the European Ocean Act, will reduce administrative burdens while fostering a robust market for disruptive European ocean technologies. Such integration is particularly vital for coastal emergency response and for the decision services that underpin both European competitiveness and security.

Furthermore, to counter the "brain drain" and attract top global talent, the EU must offer interdisciplinary research ecosystems that bridge the gap between academia and industry. By fostering strategic partnerships and joint scientific endeavors, as CMCC does through its cross-disciplinary agenda, the EU can establish itself as a global leader, shaping an AI-enabled future of science that is grounded in data, scalable in design, and tailored for a resilient blue economy.

CMCC contributes to European and international research infrastructures and initiatives and works with extensive public and private partner networks to translate observations into actionable services - particularly in coastal zones, where risks and societal impacts are concentrated. At a time of rapid technological change, CMCC is strengthening AI-enabled data science and modelling workflows to improve the quality, usability and uptake of ocean and climate knowledge.

Key recommendations

1. Establish a "coastal innovation-to-operations" pathway with validated service pilots that transform observation results into decision-support tools in key sectors, including smart ports, resilient coastal cities, Marine Protected Areas (MPAs), and sustainable aquaculture.
2. Invest in European sensor supply chain to develop cost-effective, next-generation monitoring hardware and citizen science tools, including rigorous quality-labelling (e.g. the SCOOP model) to accelerate uptake, reduce cost.
3. Strengthen coastal Earth Observation capabilities and validation to bolster the EU's downstream service market.
4. Promote interoperable open standards to ensure seamless data exchange and collaboration across European observation networks.
5. Invest in a distributed capacity for AI-enabled modeling and workflows that can operate across a decentralized network of European infrastructures.
6. Foster interdisciplinary research ecosystems that bridge academia and industry to combat "brain drain" and attract top global talent.

About CMCC Foundation

The CMCC Foundation – Euro-Mediterranean Center on Climate Change (CMCC) is an international, independent, and multidisciplinary research center dedicated to studying the interactions between climate change and society. Its mission is to produce rigorous and policy-relevant scientific knowledge that supports sustainable development, environmental protection, and the formulation of science-based strategies for climate adaptation and mitigation. CMCC conducts advanced climate research and provides multidisciplinary analyses and datasets, integrating state-of-the-art climate modeling with impact assessments and environmental economics. CMCC is one of the institutions selected by the World Meteorological Organization (WMO) to produce seasonal climate forecasts and collaborates with a network of over 700 partner organizations across 71 countries. Since 2006, CMCC has served as Italy's National Focal Point for the Intergovernmental Panel on Climate Change (IPCC). It also contributes to the Integrated Carbon Observation System (ICOS) European Research Infrastructure Consortium (ERIC), as a member of the ICOS Italy network and coordinator of the Ecosystem Thematic Center (ETC). CMCC contributes to CoastPredict, a Program endorsed by the UN Ocean Decade Program and the Decade Collaborative Centre for Coastal Resilience (DCC-CR), affiliated with UNESCO-IOC's Global Ocean Observing System GOOS.

At a time of extraordinary change, CMCC is doubling down on its commitment to advanced applied research at the nexus of climate science and socio-economic transformation, powered by a wide adoption of advanced machine learning and data science tools. The central question of the next two decades will be how to sustain broad-based economic growth in the face of rapidly changing material conditions, while continuing to transition to a low carbon industrial base. CMCC intends to answer this question through four interconnected research priorities. First, CMCC aims to transition the suite of climate services and climate prediction tools towards modelling chains that help us predict the socio-economic outcomes, providing tools and insights that inform long-term investment, policy and planning. This includes assessing the economic returns on investments to improve human health, infrastructure, livelihoods, and economies under varying climate scenarios, offering actionable pathways to foster sustainable, resilient communities. Second, CMCC will deepen its focus on global coastal zones, regions that are both increasingly vulnerable to climate change and vital to the global economy. We intend to build portable AI-enabled digital twins to support dynamic management of all coastal infrastructure, both natural and engineered. Third, CMCC will advance a more holistic understanding of the carbon cycle by integrating its industrial, biogeochemical, and physical components by approaching the carbon system as a unified planetary process. These priorities will be supported by a deep integration of artificial intelligence (AI) and machine learning (ML) methods in all research work to enhance every stage of our modeling and analysis chain, from data assimilation and scenario development to impact forecasting and risk assessments. The above strategic framework reinforces CMCC's commitment to producing high-impact science that drives informed decision-making and tackles climate change challenges. By doing so, CMCC continues to shape the critical knowledge needed for a more sustainable, equitable, and resilient future.

For further information about the CMCC and our work, please visit www.cmcc.it.