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Centro Euro-Mediterraneo
sui Cambiamenti Climatici

CMCC's Views on the Ocean Research and Innovation Strategy

July 2026

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Executive Summary

The Euro-Mediterranean Center on Climate Change (CMCC) welcomes the European Ocean Research and Innovation Strategy as a cross-cutting pillar of the European Ocean Pact and a decisive opportunity to close Europe's ocean-knowledge gap, counter fragmentation of the R&I landscape and sustain competitiveness across the full ocean-science value chain. Drawing on its integrated expertise in high-resolution ocean and climate modelling, sustained observations, impact assessment and environmental economics, CMCC views ocean R&I as foundational to climate resilience, a sustainable blue economy and effective, source-to-sea ocean governance.

CMCC's contribution sets out six priority objectives for the Strategy: (1) embedding multidisciplinary research institutions as structural partners in long-term ocean governance; (2) advancing coupled, AI-enabled ocean modelling and the assessment of extremes; (3) ensuring the stability and continuity of ocean observations, prioritizing under-observed coastal hot spots; (4) strengthening interoperable marine data through an "interoperability-by-design" principle; (5) accelerating innovation and operational uptake via a structured "coastal innovation-to-operations" pathway; and (6) supporting robust Monitoring, Reporting and Verification standards for marine carbon and emerging blue-economy sectors.

Realizing these objectives will require sustained, cross-cutting investment under Horizon Europe 2028–2034 and related instruments, turning Europe's observations and models into decision-grade knowledge for a resilient, competitive and sustainable ocean economy.

1. Introduction

The **Euro-Mediterranean Center on Climate Change (CMCC)** welcomes the opportunity to provide input for the forthcoming European Ocean Research and Innovation Strategy.

Drawing on its extensive experience integrating high-resolution modelling, sustained observations, impact assessments and environmental economics, CMCC views ocean research and innovation as foundational to **climate resilience, sustainable blue economy development, and effective ocean governance**.

As a leading multidisciplinary research institution active across the full ocean-science value chain, with recognised expertise in ocean modelling, forecasting and operational applications, CMCC shares the analysis that insufficient knowledge of the ocean system, intensifying global competition, fragmentation of the R&I landscape and uneven support along the investment journey are the core challenges facing EU ocean R&I, and therefore supports the development of a European Ocean R&I Strategy as a cross-cutting pillar of the European Ocean Pact.

2. Priority Objectives

From CMCC's perspective, the development of a European Ocean R&I Strategy is an opportunity to advance the following six priority objectives:

2.1 Embedding ocean science into long-term governance

High-resolution ocean and climate modelling systems, seasonal-to-decadal forecasts and climate-risk assessments are essential to support coastal resilience, adaptation strategies and sustainable maritime activities. Sustaining this capacity requires continuity that extends beyond individual project cycles. This is increasingly evident at the land-sea interface. **Coastal regions are the fault line where socio-economic development collides with intensifying climate risks**, such as sea-level rise, extreme events, coastal erosion, ecosystem degradation and pollution. Yet, existing tools remain fragmented, lack resolution at the coastal scale, and fail to integrate terrestrial, oceanic and socio-economic dimensions.

To increase coordination and ensure coherent, structured programming of EU ocean R&I, research institutions should be treated as partners in the science-policy cycle: **embedding multidisciplinary research entities as structural partners of European, national and regional authorities would enable science-based policy-making, and support effective responses to these converging pressures**. A climate-smart approach to marine spatial planning, one that builds climate-risk and cumulative-impact assessments directly into sea-basin planning

and licensing, depends on exactly this kind of durable science-policy relationship. CMCC therefore recommends recognising multidisciplinary research institutions as structural partners in ocean governance, ensuring stable science-policy interfaces and long-term continuity beyond project-based cycles.

2.2 Advancing ocean modelling and the assessment of extremes

Through global, regional and coastal ocean modelling, CMCC provides high-resolution climate-risk information, such as projections of sea-level rise, extreme events, marine heatwaves and cumulative pressures. These outputs improve the understanding of the ocean system and the pressures it faces, providing essential intelligence for strengthening the resilience of coastal and island communities, and protecting maritime infrastructure and for informing adaptation and civil-protection decisions.

By coupling ocean dynamics with waves, sediments and morphology, biogeochemistry and freshwater inputs across the land-sea continuum, and by integrating high-resolution data such as that from the Copernicus Mediterranean Monitoring and Forecasting Centre (MED MFC), CMCC is moving beyond traditional forecast skill to enable anticipatory insights that predict system-wide impacts, such as disruptions to food supply chains, infrastructure stress and ecosystem decline.

In this context, CMCC supports the systematic integration of climate-risk assessments and high-resolution projections to strengthen the long-term resilience of coastal and maritime infrastructure.

AI and machine learning can strengthen this chain further through automated quality control, gap-filling, downscaling and better uncertainty characterisation, provided models are trained and validated on well-designed benchmark datasets. To fully realise this potential, R&I investment in coupled, AI-enabled modelling - the foundation of a digital twin of the coastal ocean - must be prioritised.

2.3 Ensuring stability and continuity of ocean observations

Operational climate services depend on long-term, consistent datasets and on sustained ocean observations to initialise, validate and improve forecasting and reanalysis systems. Fragmented or discontinuous observation funding undermines the entire downstream chain of forecasts, services and policy assessments.

In this context, CMCC supports the objective of **strengthening the ocean observation and monitoring system** through OceanEye, the EU ocean observation initiative, in particular where **observing gaps are largest and decision demand is highest: in coastal hot spots such as estuaries, deltas and urban coasts.**

The Ocean R&I strategy should prioritise these coastal zones, scaling nearshore-robust satellite products alongside cost-effective in-situ networks (tide gauges and low-cost sea-level sensors, high-frequency coastal radars and drifters, video-based shoreline monitoring, scalable temperature and salinity sampling), reducing dependencies in sensor supply chains, and structured integration of citizen science, drawing on proven patterns from the UN Ocean Decade's CoastPredict/GlobalCoast programme. Citizen science, supported by common protocols, metadata traceability and quality labelling, should be considered as a genuine complementary observation layer. A stable governance framework should give the observation system a clear mandate for transparent decision-making, rigorous monitoring and adaptive reporting, guaranteeing continuity and policy coherence across sea basins.

2.4 Strengthening interoperable marine data

CMCC contributes to interoperable data and modelling infrastructures connected with EMODnet, the Copernicus Marine Service and the European Digital Twin of the Ocean. In this context, promoting the sharing and pooling of knowledge and data, and its aim of building common methodologies and interoperable data systems, are best achieved by designing interoperability into publicly funded data from the outset. This also underpins the responsible development and use of AI in ocean R&I.

A **“measure once, use many” principle should govern the whole data value chain**, supported by harmonised metadata, consistent Quality Assurance and Quality Control, machine-actionable interfaces (APIs), cloud-based processing and storage, provenance and versioning, and uncertainty descriptors so that products flow seamlessly into modelling, AI assimilation and EU DTO services. In this respect, CMCC recommends **adopting an “interoperability-by-design” principle for publicly funded marine data, ensuring seamless integration between observation systems, operational services and digital platforms.**

To this end, the **functional roles of Europe's assets should be clearly defined and enforced**: EMODnet as the harmonised in-situ backbone and steward, Copernicus Marine for operational Earth-observation and forecasting, WISE-Marine for policy reporting, and the EU DTO for scenario and decision services. R&I priorities should also target the persistent knowledge gaps that limit these systems - high-resolution bathymetry, coastal biogeochemistry, biodiversity, seabed habitats, carbon fluxes, and integration of river discharge and nutrient loads needed to assess compound risks such as concurrent river flooding and storm surge.

2.5 Accelerating innovation and operational uptake

CMCC has extensive experience translating research outputs, such as climate services, risk indicators and scenario-based analyses, into operational tools for policymakers, coastal authorities and blue-economy stakeholders, often through pilot deployments that test and refine solutions under real-world conditions.

The value of this pilot-based approach at international scale is illustrated by CoastPredict, the UN Ocean Decade-endorsed programme for coastal ocean observing and forecasting, coordinated by the CMCC through its Secretariat. The programme's GlobalCoast Experiment, a network of over 210 pilot sites across the world's coastal regions, pairs local, fit-for-purpose observing and modelling systems with structured stakeholder engagement, allowing findings on multi-hazard early warning, ecosystem monitoring and community resilience solutions to be tested locally and then compared and replicated across very different coastal settings. Similarly, a European network of real-world demonstrators could shorten the path from research to deployment, enabling proven solutions to be replicated across Europe's sea basins, while fostering interdisciplinary ecosystems that bridge academia and industry, countering “brain drain”.

A structured “coastal innovation-to-operations” pathway, institutionalised through regulatory sandboxes and validated service pilots, would let ports, coastal cities, Marine Protected Areas (MPAs) and aquaculture operators test Digital Twin applications and climate services in real conditions. This would address the financing and deployment gap for blue-economy start-ups and scale-ups.

2.6 Supporting robust governance for marine carbon and blue economy transitions

As the blue economy expands into marine carbon and other emerging sectors, environmental integrity and policy credibility depend on rigorous, science-based verification. Through coupled physical–biogeochemical modelling and climate-impact analysis, CMCC evaluates marine carbon dynamics, blue carbon potential and mitigation scenarios, treating the carbon system as a unified planetary process.

Marine Carbon Dioxide Removal (CDR) in particular requires a robust evidence base for implementation. Nature-based solutions are perhaps the clearest example of this governance challenge. Blue-carbon habitats such as seagrass meadows, saltmarshes and mangroves are increasingly proposed as mitigation assets, yet their sequestration potential and permanence vary widely by setting, and remain imperfectly quantified, creating a real risk that removals are credited without a

sound evidential basis. Ecosystem and biogeochemical modelling helps distinguish durable climate benefits from optimistic accounting.

In this context, R&I should support Monitoring, Reporting and Verification protocols that combine continuous observation with Digital-Twin-based scenario modelling, so that the potential, permanence and side-effects of marine CDR, blue-carbon and other interventions can be assessed before deployment and accurately tracked afterwards.

About CMCC Foundation

CMCC is a leading European multidisciplinary research center dedicated to the study of climate change and its interactions with society, economy, and the environment. Its mission is to produce advanced climate knowledge, multidisciplinary analyses and datasets by 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, serves as Italy's National Focal Point for the Intergovernmental Panel on Climate Change (IPCC), contributes to the Integrated Carbon Observation System (ICOS ERIC), and coordinates CoastPredict (through its Secretariat), a programme endorsed by the UN Ocean Decade and affiliated with UNESCO-IOC's Global Ocean Observing System (GOOS). It collaborates with a network of over 700 partner organisations across 71 countries. As a strategic research infrastructure, CMCC hosts the most powerful computational facility in Italy fully dedicated to climate change research, and one of the most advanced of its kind in Europe.

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. Over the next two decades, the key challenge is sustaining broad-based economic growth in the face of rapidly changing material conditions while transitioning to a low-carbon economy. CMCC addresses this through four priorities: integrating climate and socio-economic modeling for decision-making; focusing on vulnerable coastal zones using AI-driven digital twins for natural and engineered infrastructures; advancing a comprehensive understanding of the integrated carbon cycle to guide mitigation; and embedding AI across all research to enhance modeling, data assimilation, and risk assessment.

This 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 CMCC and our work, please visit www.cmcc.it.

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