cmcc
Centro Euro-Mediterraneo
sui Cambiamenti Climatici

Annual Report 2024

Mission

To investigate and model our climate system and its interactions with society; supply reliable, rigorous, and timely scientific results; stimulate sustainable growth; protect the environment; and develop science driven adaptation and mitigation policies in a changing climate.

CMCC Annual Report 2024

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We are a leading research center focused on understanding the interaction between climate change and society

The CMCC Foundation - Euro-Mediterranean Center on Climate Change is a leading research institution dedicated to climate science, providing cutting-edge insights and innovative solutions for climate adaptation and mitigation strategies.

CMCC plays a pivotal role in global climate research, working closely with international partners to advance climate modeling, forecasting, climate impacts analyses, and policy recommendations.

The Center carries out advanced, cross-disciplinary studies on climate change and its interacrion with socio-economic systems by integrating climate modelling with impact assessment models and analyses of climate change effects, as well as environmental and economic dynamics, employing state-of-the-art methods and technologies in climate science.

Antonio Navarra
President

Giulio Boccaletti
Scientific Director

Laura Panzera
Executive Director

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2024 RESEARCH HIGHLIGHTS

Frontier topics in climate research, including scientific findings, papers, datasets, models, scenarios and analyses: a selection of the activities carried out in 2024 by the cross-disciplinary, international research team organised within the CMCC Institutes, which contributes to producing world-class science on a global scale.

Institute for Earth System Predictions – **IESP**

Institute for Climate Resilience - **ICR**

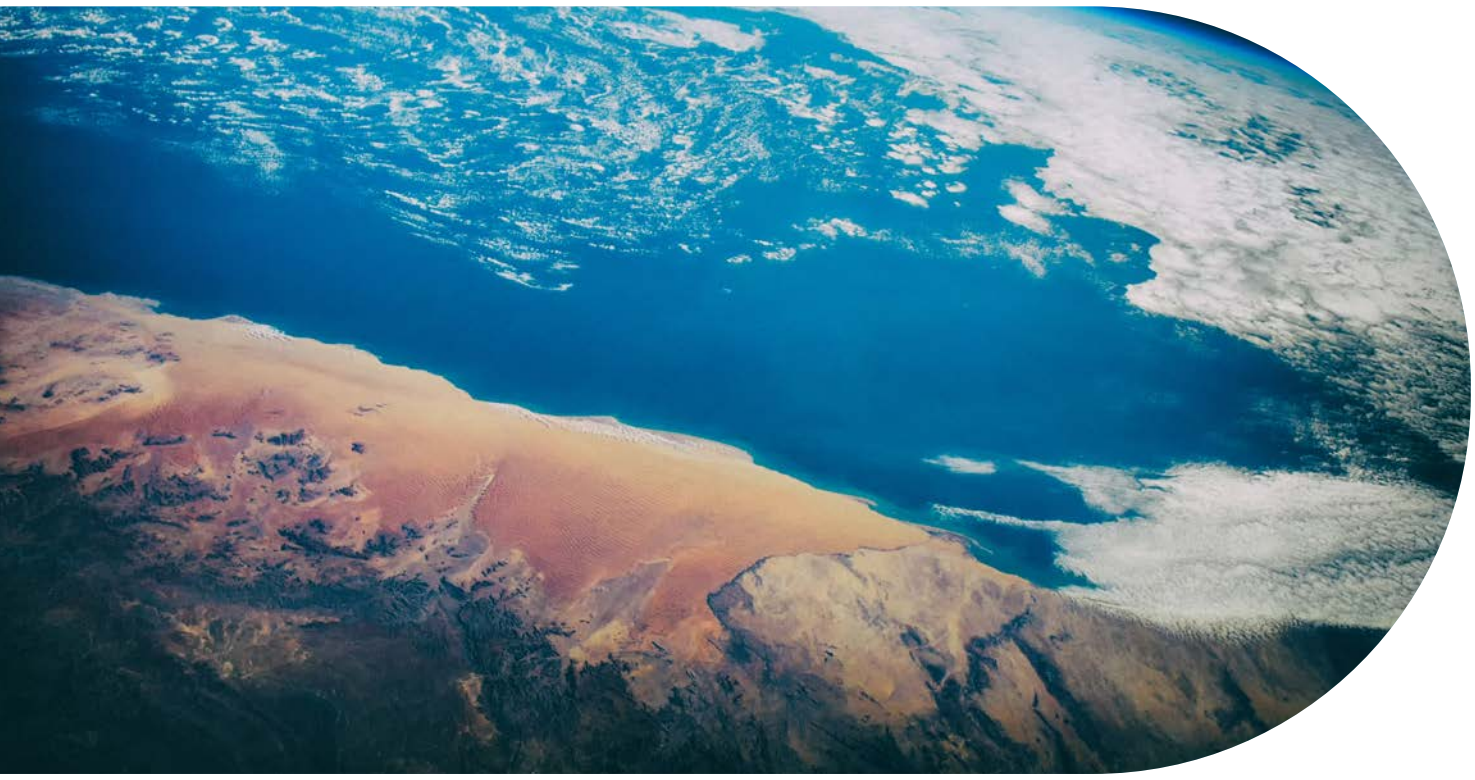
European Institute on Economics and the Environment – **EIEE**

Institute for Earth System Predictions - IESP

Climate modeling for science-based decision-making

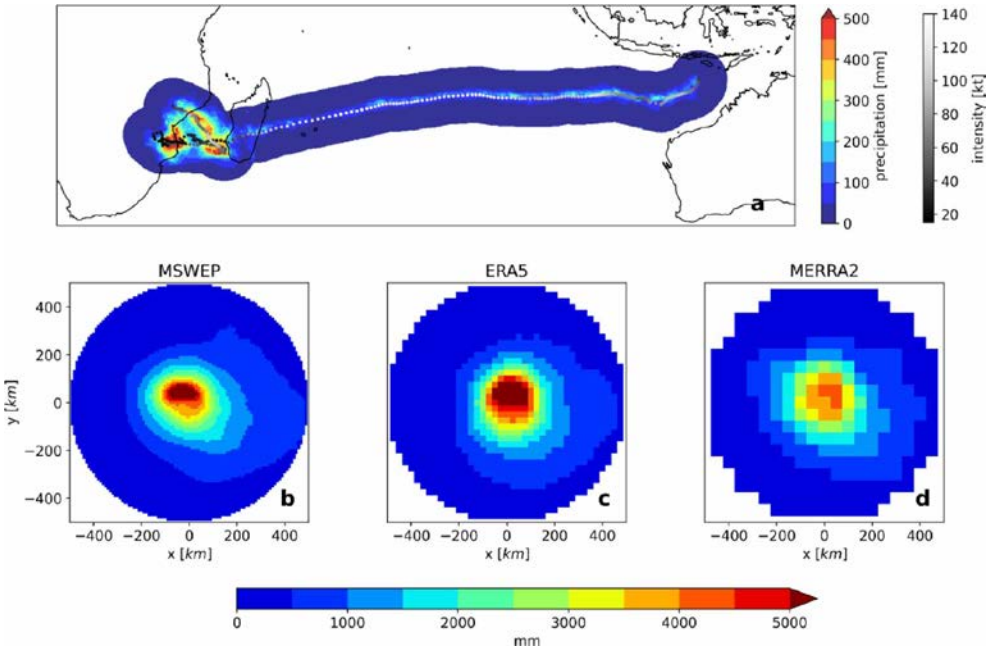
Committed to improving climate modeling capabilities and turning scientific knowledge into advanced predictive tools, IESP contributes to advancing understanding of the climate system and how it changes across both spatial and temporal scales, whilst supporting local and national responses to emerging climate risks.

The institute addresses critical climate science questions relevant to society, delivering seamless Earth system predictions that support science-based decision-making.



Be prepared for tropical cyclones with climate models and AI-driven approaches. The case of Freddy.

Heavy precipitation and flooding associated with tropical cyclones are responsible for a large number of fatalities and economic damage worldwide. Reliable quantification of the amount of water associated with tropical cyclones is pivotal for helping stakeholders and policymakers anticipate and prepare for events that cause significant impacts on society and ecosystems. A study conducted by CMCC brings to light the added value of models in determining historical trends in extreme events such as tropical cyclones and their precipitation.



Freddy accumulated precipitation. More info: Freddy: breaking record for tropical cyclone precipitation? 2024 Environ. Res. Lett. Doi: 10.1088/1748-9326/ad44b5

From cyber infrastructure to climate policy: the CMCC-Princeton HMEI partnership.

In 2024, CMCC and the Princeton University High Meadows Environmental Institute (HMEI) established a collaboration to advance scientific excellence in climate change, earth science, environmental research, and the use of high-performance computing infrastructure. Kicked off at HMEI's Princeton premises, the partnership unites two of the most cutting-edge research institutes in climate science and is a joint effort toward improved understanding and prediction of climate change, as well as the development of effective, socially just climate protection policies.

Understanding and predicting marine heatwaves.

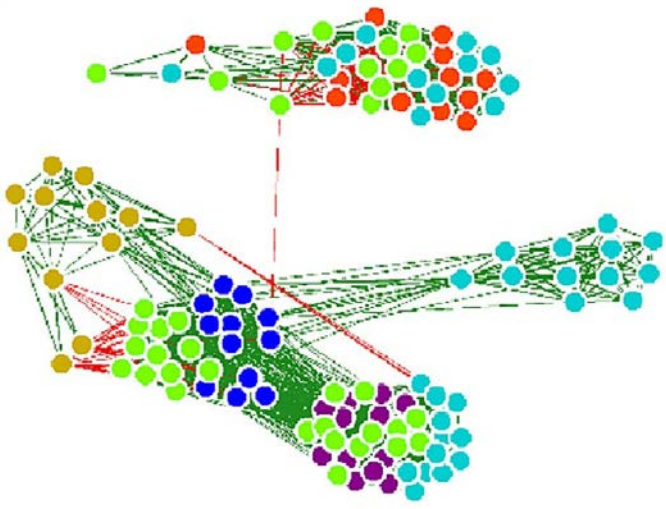
Marine heatwaves affect marine ecosystems, economies, and societies. CMCC contributed to a global review of the latest advances in this field, from the 3D structure and evolution of these events to their drivers, future projections, and predictability, all crucial for effective adaptation and mitigation.

“The ocean warming projected by climate models to intensify and spread by the end of the century exacerbates natural temperature excursions, increasing the frequency, intensity, and duration of extreme temperatures,” says CMCC’s Simona Masina. “Gaining deeper insight into MHWs and their effects is crucial for shaping and supporting effective adaptation strategies.”

More info: A global overview of marine heatwaves in a changing climate. Commun Earth Environ 5, 701 (2024). https://doi.org/10.1038/s43247-024-01806-9

Climate scenarios for adaptation measures: water management and the benefits of modernising irrigation.

Dams and water regulation help manage water, but can harm river life and favour invasive species. Climate change is increasing pressure on water resources, requiring updated river basin management plans. CMCC scientists contributed to a study evaluating adaptation strategies, focusing on improving farm water use by replacing traditional irrigation with more efficient methods, such as drip irrigation.



Correlation network analyses. More info: Adaptation measures to global change in the Serpis River Basin (Spain): An evaluation considering agricultural benefits, environmental flows, and invasive fishes; 2024, Ecological Indicators, https://doi.org/10.1016/j.ecolind.2024.111979

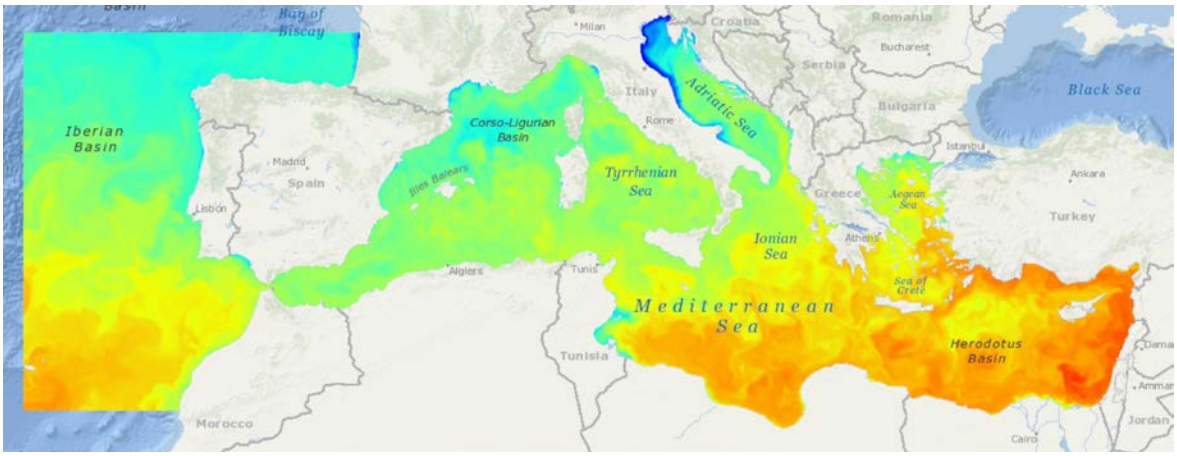
World-class research for Copernicus Climate Change Service.

CMCC plays a leading role in Copernicus, contributing cutting-edge science to services that provide authoritative information on the past, present, and future climate in Europe and around the world.

Among the operational and research activities through which CMCC contributes to C3S (Copernicus Climate Change Service), the coordination of the Mediterranean Monitoring and Forecasting Centre (MED MFC) of the Copernicus Marine Service provides ocean analysis and forecasting products, including real-time and delayed-time physical, wave, and biogeochemical products.

The CMCC is also part of the Black Sea Monitoring and Forecasting Centre (BS-MFC), participates in the development of modelling platforms, provides technical solutions for the production of monthly seasonal forecasts in real time, and contributes to the annual provision of operational-quality decadal forecasts, delivering a large ensemble and covering fundamental climate variables. Furthermore, the centre contributes to the provision of global physical reanalyses and the production of the global reanalysis ensemble product. This field is particularly significant for climate research because, in addition to its scientific importance, reanalysed reconstructions are increasingly popular in the AI sector and are widely used as reference states for training forecasters or simulators based on machine learning.

The detailed list of CMCC's contributions to Copernicus is available on the CMCC website



The Mediterranean Analysis and Forecasting System (MedFS) is part of the Copernicus Marine Service and provides regular and systematic information about the physical state of the Mediterranean Sea. The service is available 24 hours a day, 365 days a year.

Institute for Climate Resilience - ICR

Interdisciplinary research for climate resilient futures

ICR is at the forefront of interdisciplinary research that connects climate, ecosystems and society. Its mission is to empower decision-makers with the knowledge they need for both immediate actions and long-term planning, helping guide planning and investments towards a climate-resilient future.

Resilience is the capacity of systems to withstand, recover from, and adapt to shocks and changing conditions in ways that both safeguard existing progress and forge innovative future paths. This concept lies at the heart of the ICR's mission. In a world facing climate change, resilience requires integrated approaches to mitigation, disaster risk reduction and adaptation.

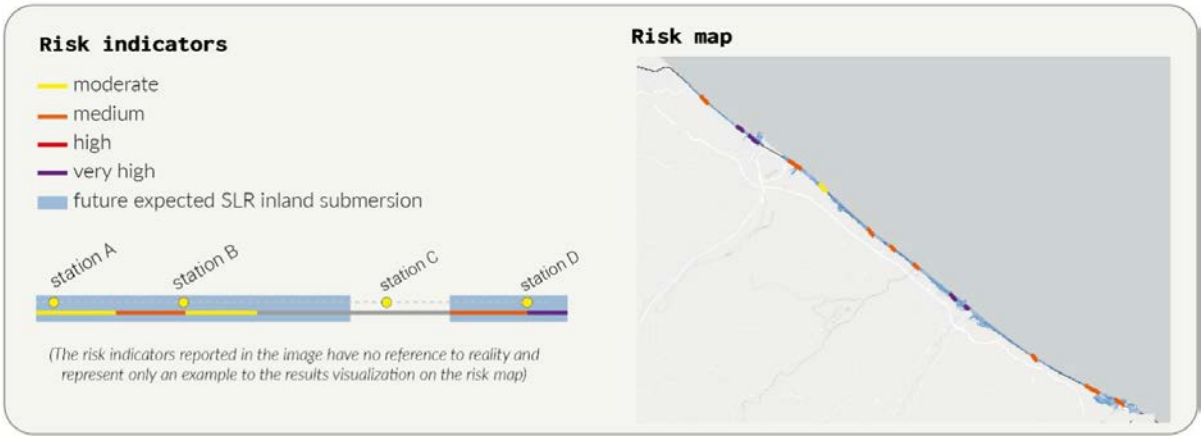
Usefulness and performance of climate services.

Tools that communicate climate-related information to users – whether these be dam managers, irrigation consortia, or energy producers, to name a few – are rapidly evolving. However, it is crucial that the quality of the information provided, along with economic, environmental and/or societal gains, is measured and verified to maximise societal benefits. CMCC scientists contributed to the study "A framework for joint verification and evaluation of seasonal climate services across socio-economic sectors", which introduces a new framework for evaluating and verifying climate services. Drawing on experiences from both service developers and users, the study offers recommendations for future evaluations, proposing a structured approach to joint verification and evaluation that involves experts from various fields, including climate science, hydrology, economics, and decision analysis.

More info: A framework for joint verification and evaluation of seasonal climate services across socio-economic sectors. Bulletin of the American Meteorological Society (published online ahead of print 2024). https://doi.org/10.1175/BAMS-D-23-0026.1

From data to infrastructure.

Railways are particularly vulnerable to climate change and carry approximately 4 billion people and 10 billion metric tonnes of goods per kilometre every year. CMCC risk analyses inform policymakers and stakeholders in the implementation of adaptation strategies for infrastructure, such as rail networks.



Source: Risk assessment of national railway infrastructure due to sea-level rise: an application of a methodological framework in Italian coastal railways. Environ Monit Assess, https://doi.org/10.1007/s10661-024-13111-1

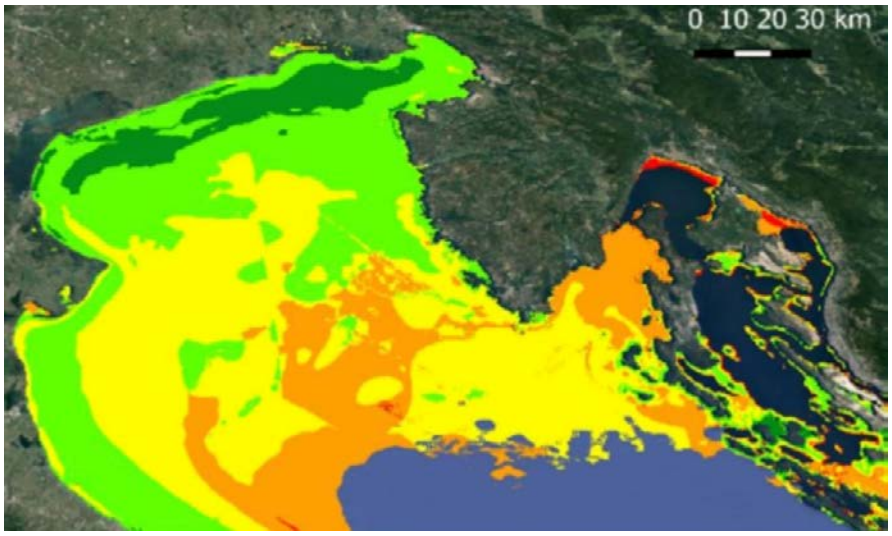
Assessing climate risk for cereals and livestock to inform adaptation strategies.

Climate change is strongly affecting Mediterranean agriculture, prompting urgent adaptation measures to cope with its negative impacts and enhance the resilience of agricultural systems. A team of CMCC scientists published a study assessing climate-related risks to the cereals and livestock sectors in the Sardinia Region. The study integrated statistical socio-economic indicators with results from dynamic crop simulation models and climate change scenarios to investigate risk components. The assessed levels of risk, in terms of hazard, exposure, and vulnerability, were used to develop the Regional Adaptation Strategy to Climate Change (SRACC) for the Sardinia Region.

More info: Assessing climate risk for cereals and livestock to inform adaptation planning at regional and local scale, Journal of Rural Studies, https://doi.org/10.1016/j.jrurstud.2024.103360

Nature-based solutions in the Mediterranean: a set of suitability maps

Nature-based solutions (NBS) have emerged as vital tools for climate adaptation and mitigation, facing biodiversity loss and societal challenges. CMCC developed a suitability model for Blue-NBS, with a specific focus on Posidonia oceanica meadows in the Mediterranean Sea. The research produced environmental suitability maps that provide a basis for integrating socio-economic and governance-related indicators into a more complex, multi-tier approach to support NBS mainstreaming.



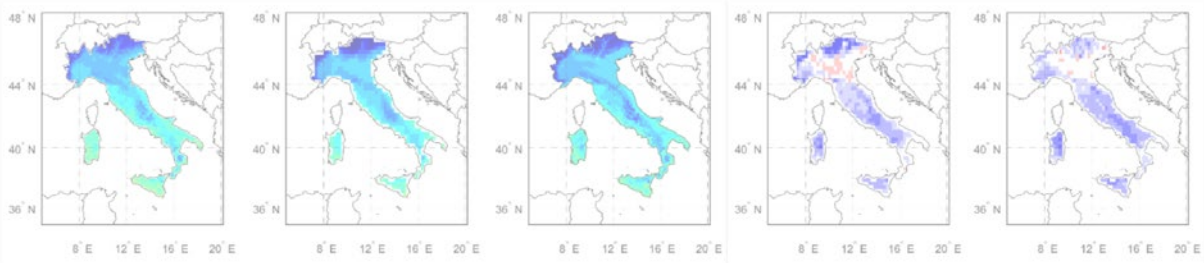
Source: A GIS-MCDA approach to map environmental suitability of Posidonia oceanica meadows as blue nature-based solutions in the Mediterranean eco-region, Science of The Total Environment, https://doi.org/10.1016/j.scitotenv.2024.176803

Up-to-date and high-quality climate data available to all

CMCC has made its latest and most up-to-date climatological dataset available to all interested parties and stakeholders via the Data Delivery System (DDS) and the Highlander platform, providing vital tools for stakeholders seeking to implement adaptation strategies.

Information on these platforms forms the basis for predicting climate impacts, including extreme weather events, rising temperatures and changing precipitation patterns. The platforms also highlight the importance of cooperation between institutions to address climate change challenges through solutions based on shared data and advanced technologies.

More info: The CMCC climate dataset on the Data Delivery System (DDS)



Source: VHR-REA_IT Dataset: Very High Resolution Dynamical Downscaling of ERA5 Reanalysis over Italy by COSMO-CLM.
DOI: 10.3390/data6080088

Deforestation-free oil: sustainable agriculture to cut emissions.

Oil crops significantly impact global land use. A CMCC study suggests an alternative to the simplistic substitution of palm oil with other vegetable oils, focusing instead on oils certified as "deforestation-free." This approach, in the case of palm oil, could cut emissions by up to 92%, highlighting the need for strategies that support sustainable agriculture and the global food system.

More info: Deforestation and greenhouse gas emissions could arise when replacing palm oil with other vegetable oils, Science of The Total Environment, https://doi.org/10.1016/j.scitotenv.2023.169486.

European Institute on Economics and the Environment - EIEE

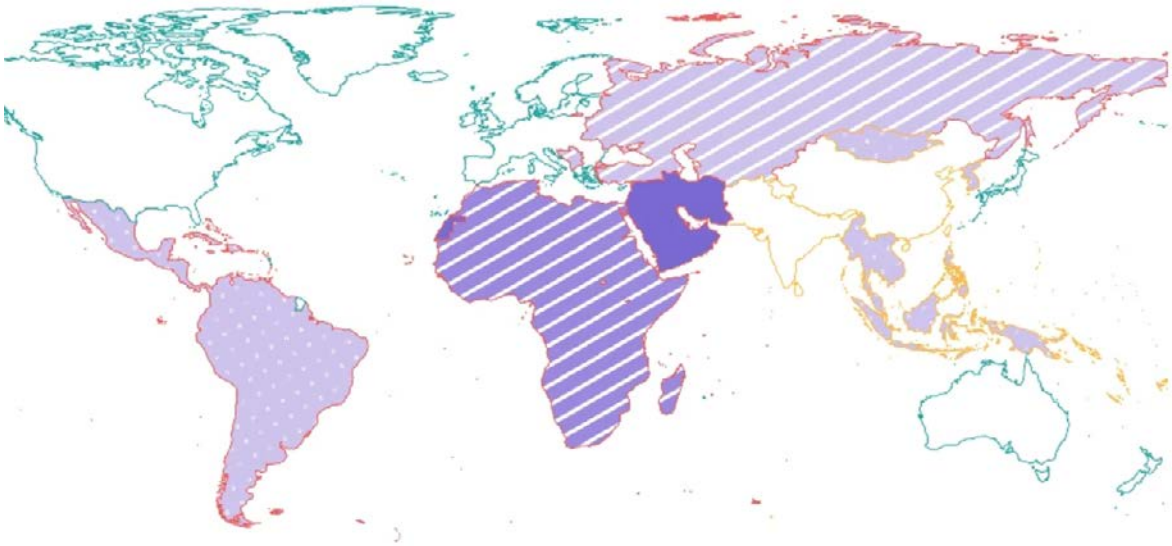
Reuniting economics and climate for a sustainable world

EIEE stands at the intersection of environment, technology and the economy, evaluating sustainable and socially enhancing strategies that confront climate change and other major environmental challenges.

EIEE is committed to improving environmental, energy, and natural resource decisions through impartial research and policy engagement, using a variety of methodological approaches, including data science, integrated modeling, and experimental economics.

Clean energy transition: Increasing global equity with finance.

Financing is a crucial element in the low-carbon transition as it facilitates energy availability, affordability, and equity at a global level. CMCC scientists uses novel empirically estimated cost of capital values to show how impactful financing costs are in the development of renewable energy sources. The study "Reducing the cost of capital to finance the energy transition in developing countries" draws conclusions with important implications for policy choices, as they reveal that equalizing the cost of capital of the energy sector internationally can play a significant role in greening electricity generation, lowering the cost of mitigation and improving equity.



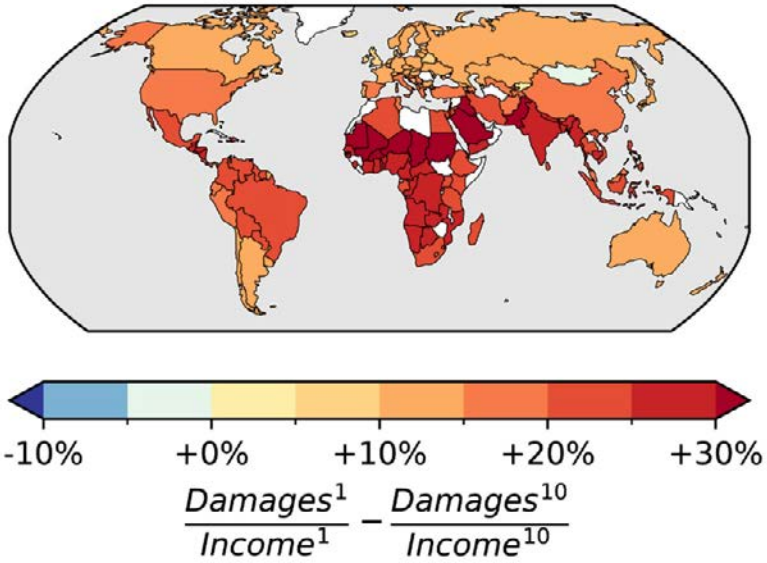
The costs of a changing landscape.

How does renewable energy affect local communities? Renewable energy, especially from wind power, is vital for a sustainable future. However, its adoption encounters challenges, primarily local resistance. This is a factor that can influence energy policies and help understand how to address potential NIMBY concerns. For example, the study published in Proceedings of the National Academy of Sciences (PNAS) offers a comprehensive perspective on this issue, crucial for evaluating the trade-offs between the benefits and costs of renewable energy sources, and for gaining a thorough understanding of their impacts. More in detals, the research explores the frequently neglected aspect of wind turbine visibility affecting property values across the U.S.

More info: The visual effect of wind turbines on property values is small and diminishing in space and time. Proc. Natl. Acad. Sci. U.S.A., https://doi.org/10.1073/pnas.2309372121.

Climate damages are more costly for the poorest. Outcomes from a CMCC study.

The poorest people within countries will suffer the most severe economic impacts of climate change: globally, a 1% increase in income decreases the costs of climate damages by 0.4%. CMCC research provides an in-depth view of the economic damages caused by climate change and inequalities in the distribution of impacts between and within countries. The results highlight the need to consider adaptation differences and distributive consequences in climate policies.



Source: Climate change impacts on the within-country income distributions, Journal of Environmental Economics and Management, https://doi.org/10.1016/j.jeem.2024.103012.

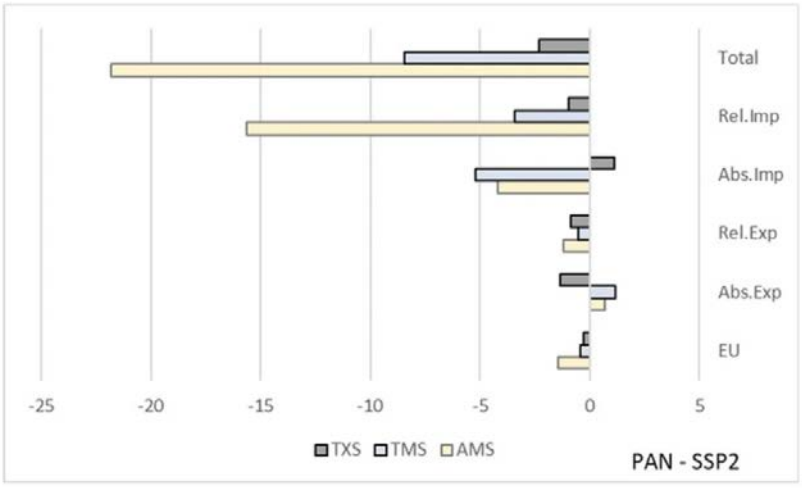
The biodiversity impact on GDP and the agricultural sector

In recent years, farms have become more specialised, with less semi-natural land, causing a decline in biodiversity and the ecosystem services it provides. CMCC analyses show that increasing the variety of species within local areas and ensuring a balanced mix across regions can boost both the agricultural sector and GDP. However, when local landscapes become more uniform and regional diversity rises, the impact can be negative for both farming and the economy.

More info: An integrated assessment of the impact of agrobiodiversity on the economy of the Euro-Mediterranean region, Ecological Economics, https://doi.org/10.1016/j.ecolecon.2024.108125.

The cost of climate change for International trade

Global trade relies on maritime routes that pass through key chokepoints to ensure smooth, timely shipments. Analyzing how climate change will impact these key areas for global trade, and hence both national and global economies, is an area of concern when assessing the adaptation measures, particularly in the context of the unequal distribution of climate change impacts on agriculture. According to a study conducted by an international team of scientists, CMCC climate change may affect chokepoints' operations with effects on production and prices of agricultural commodities that, in turn, brought a downturn in global GDP. In fact, the study found that although trade re-composition generates winners and losers, total losses tend to prevail and could reach 34 billion USD (2014 prices) in 2030.



Source: Potential climate-induced impacts on trade: the case of agricultural commodities and maritime chokepoints. J. shipp. trd., https://doi.org/10.1186/s41072-024-00170-3

International shipping in a world below 2 °C

A substantial part of international trade goes through shipping routes, which has made it a challenging sector to decarbonize. An international team, including CMCC scientists, investigates how the global shipping industry could reduce its carbon emissions in line with climate goals. Under ambitious climate scenarios, the study shows how shipping emissions could be reduced by up to 86% by 2050 compared to 2020 levels. This would be achieved primarily through a shift to low-carbon fuels like biofuels, renewable alcohols, and green ammonia, whereby models that included an emphasis on these low-carbon fuel options tended to show a deeper decarbonization potential.

More info: International shipping in a world below 2 °C. Nat. Clim. Chang., https://doi.org/10.1038/s41558-024-01997-1

2024 STRATEGIC PROGRAMS HIGHLIGHTS

Integration of the planetary biogeochemical and industrial carbon cycle

Predicting socio-economic outcomes in a changing climate

Global coasts as a new frontier

Integrating AI and ML in the modeling chain

CMCC strategic programs are designed to address the most pressing frontier issues in climate science and socio-economic research.

By integrating expertise across CMCC institutes, these programs focus on understanding the complex challenges facing societies in a changing climate, fostering innovation, and advancing scientific knowledge to inform policymaking.

- **Understanding what form the net-zero carbon economy will take in the years ahead.**

- **Characterizing the socio-economic impacts of climate change to inform sustainable development, adapt and build resilience.**

- **Investigate the evolution of coastal systems to ensure socio-economic development and environmental protection between the ocean and the land.**

These are the main themes of three strategic programs.

A fourth program, covering CMCC's modeling production, is devoted to integrating

artificial intelligence and machine learning in the modeling chain.

The following pages present a selection of the CMCC's 2024 research results on strategic programs.

Integration of the planetary biogeochemical and industrial carbon cycle

- **Integrate biogeochemical processes with industrial processes.**

- **Describe climate system responses to climate neutrality policies.**

- **Integrate physical and analytical models that support carbon management and the net-zero carbon transition.**

Leading Europe towards improved carbon cycle representation

In 2024, the CMCC won the tender to carry out some of the most important European initiatives to improve the monitoring and modelling of the terrestrial carbon cycle. Improved Carbon Cycle (CC) representation through multi-scale models and Earth observation for Terrestrial ecosystems (CONCERTO) is a Horizon project aimed at developing a novel framework for understanding, monitoring and modeling the terrestrial carbon cycle to improve the quantification of ecosystem dynamics and enhance Earth system model climate projections.

Novel representations of underrepresented ecosystem processes will be developed and included in the Community Land Model (CLM), embedded within the CMCC-Earth System Models. Dedicated seasonal and climate experiments will demonstrate how improved representation of land surface processes benefits the accuracy and trustworthiness of global Earth System simulations.

This will improve the predictability of land management's influence on CC and underpin avenues towards carbon neutrality.

As the coordinator of the European consortium of experts and European institutes active in this research area, the CMCC plays a leading role in one of the most advanced and significant challenges of the coming decades.

https://www.projectconcerto.eu/

Understanding the terrestrial carbon cycle with remote sensing-based monitoring

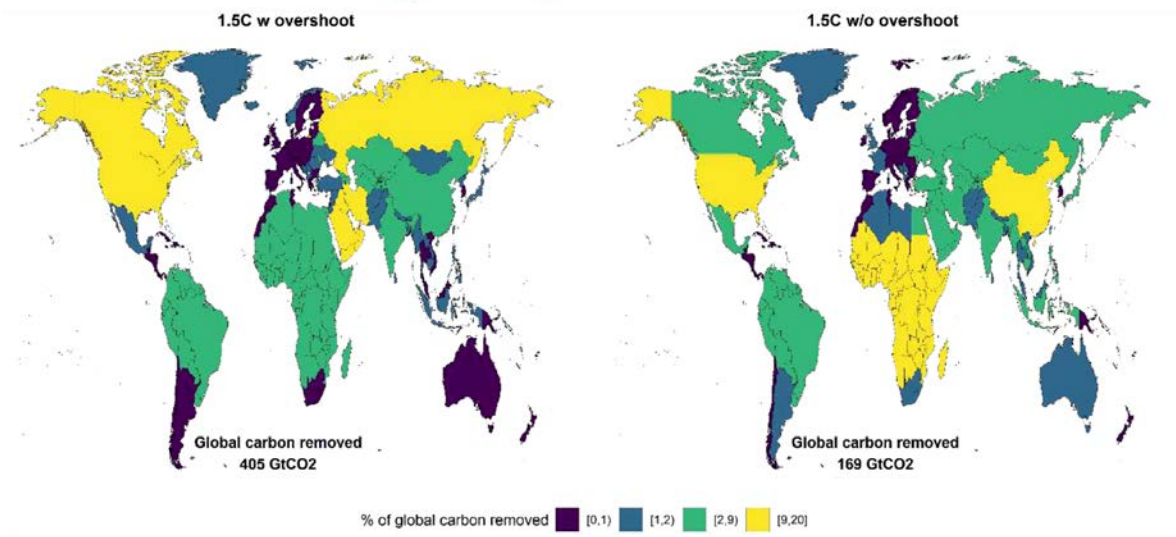
Improving our understanding of the terrestrial carbon cycle's responses to environmental change is a key ingredient in progressing climate science. A CMCC study looks at how remote sensing-based models for gross primary production in plants can be improved both theoretically and empirically in an effort to provide more accurate results.

More info: Principles for satellite monitoring of vegetation carbon uptake. Nat Rev Earth Environ, https://doi.org/10.1038/s43017-024-00601-6

Negative Emissions at Scale: public finance and social inequalities.

Negative emission technologies allow the capture of CO2 from the atmosphere and are a fundamental option for achieving carbon neutrality.

In scenarios consistent with the Paris agreement, the carbon removal industry might capture more than a billion tons of CO2 per year and be worth a trillion dollars in the second half of the century. Public incentives are going to be necessary to finance negative emissions at this scale, for example, introducing negative emissions into a carbon market alongside other emission reduction strategies such as renewable energy. The CMCC research develops analyses and studies on CO2 removal and related policies, such as the paper "Inequality repercussions of financing negative emissions," published in Nature Climate Change, which shows that incentives might increase economic inequality in the long term.



Source: Inequality repercussions of financing negative emissions. Nat. Clim. Chang. https://doi.org/10.1038/s41558-023-01870-7

GHG emissions from rural and forest fires.

Rural and forest fires represent one of the most significant sources of emissions in the atmosphere of trace gases and aerosol particles, which significantly impact the carbon budget, air quality, and human health. The CMCC is one of the most advanced centres in developing an integrated modelling approach that combines spatial and non-spatial inputs to study the implications of fires for climate change, land use, environmental and societal consequences, and related policies.

More info: Estimating annual GHG and particulate matter emissions from rural and forest fires based on an integrated modelling approach, Science of The Total Environment, https://doi.org/10.1016/j.scitotenv.2023

High-Resolution Data to track biomass loss.

The use of satellite data, the ability to combine them with on-the-ground measurements, and the ability to combine them with data provided by computational models are crucial aspects of research on the natural and industrial carbon cycle. Consequently, the CMCC strategic program dedicated to this theme pays particular attention to the creation and use of datasets, utilising the most innovative technologies available to the global scientific community. For example, a 2024 study uses unique datasets gathered from direct measurements of selective logging, terrestrial laser scanning to create detailed 3D images of trees, and standard forest inventory methods. Scientists combine satellite data and on-the-ground measurements to identify the best method for tracking biomass loss in tropical forests and to improve how we map small-scale damage.

Source: Detecting selective logging in tropical forests with optical satellite data: an experiment in Peru shows texture at 3 m gives the best results. Remote Sens Ecol Conserv. https://doi.org/10.1002/rse2.414

World-leaders in CO2 capture

A global team of scientists has worked for years to produce the first analysis of West African tropical forests, particularly those in Ghana, for their carbon absorption capacity. CMCC played a pioneering role in this research, being among the first to conduct such measurements in African tropical forests. This legacy of extensive data collection and analysis has now culminated in the publication of a significant paper. The initiative, part of a project funded by an ERC Advanced Grant and coordinated by CMCC, included the construction of a measurement tower in the African tropical forest and collected data over several years from 14 forest areas along a gradient of African forests.

More info: African forests: World-leaders in CO2 capture and Contrasting carbon cycle along tropical forest aridity gradients in West Africa and Amazonia. Nat Commun. https://doi.org/10.1038/s41467-024-47202-x

Predicting socio-economic outcomes in a changing climate

- **Integrate climate drivers and socio-economics in advanced modeling chains, storylines, and multi-sector analyses.**

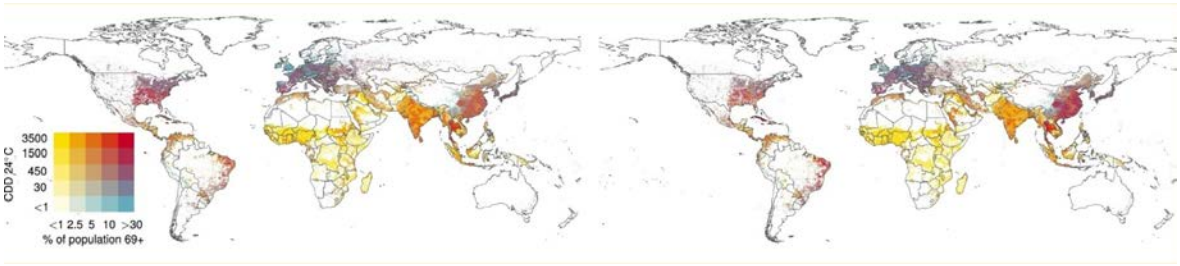
- **Provide high-resolution data to inform urban, agricultural, and natural environment responses, developing information on climate, vulnerability, and exposure and assessing complex risks.**

- **Push climate research beyond scenarios and climate forecasts toward the understanding of future compounding and cascading risks of impacts and related losses and damages.**

Climate and health: Projections, visualization tools, and policy implications.

The rising temperatures are increasingly evident in their negative impacts on human health, affecting the most vulnerable groups more severely due to age, socio-economic conditions, or occupation. The analysis of the impacts of climate change on health and potential solutions is central to CMCC's research. In collaboration with experts from Boston University, a study has been developed that provides in-depth information on demographic trends and the risks associated with rising temperatures across several countries worldwide. The findings of the research can help inform regional heat risk assessments and public health decision-making, while an interactive visualization dashboard displays the current and projected demographic changes and heat-related hazards across countries.

More info: Heat's toll on aging populations: Projections and policy implications



Source: Heat Exposures of Global Elderly Populations in CMIP6 Scenarios. Nature Communications.
DOI: https://doi.org/10.1038/s41467-024-47197-5

Heat stress threatens workers' health and economic output.

Labour, which can make up 50% of total value added, is greatly affected by heat stress. A growing body of literature shows that heat impacts workers' health and economic growth negatively, varying by region and sector. A detailed and nuanced understanding of how warming affects labour and how responses from workers, firms, and governments evolve is crucial as global temperatures rise.

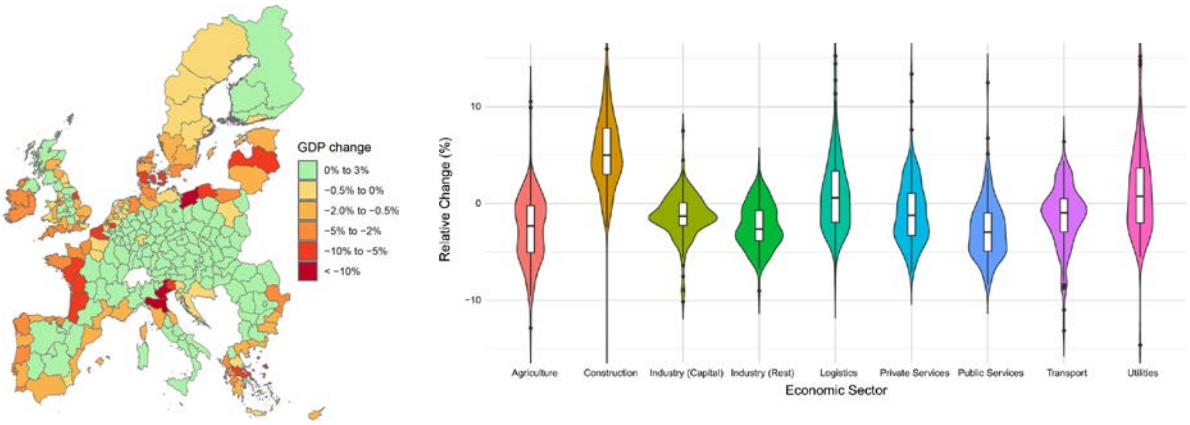
CMCC contributed to the realisation of the first comprehensive review to explore explicitly the extent to which heat stress affects the different components of the labour force – labour supply, labour productivity, and labour capacity, and the corresponding occupational health and economic impacts.

More info: Extreme heat: Protecting the global workforce.

How much do the impacts of climate change cost Europe?

One of the main issues fueling the public debate on climate change, and consequently policies and decisions, concerns the possibility of quantifying the economic costs of climate change. This is a research path on which the CMCC is committed, dedicating attention to analysis, publications, and projects, and contributing to the development of models capable of producing useful information in this field. For example, the COACC project (CO-designing the Assessment of Climate Change costs) was dedicated to this theme, which produced data subsequently used in a study published in Scientific Reports. Authors modelled the potential economic impacts of sea level rise for 271 European regions by 2100 under a high-emissions scenario, with no new coastal protection measures implemented after 2015. They estimated potential economic losses and gains compared to a scenario with no sea-level rise and 2% annual economic growth across all regions. Scientists also modelled the impact of targeted investment across different economic sectors on regional economies following sea-level rise.

More info: Sea level rises could cost EU and UK economies up to 872 billion Euros by 2100



Source: Distribution of economic damages due to climate-driven sea-level rise across European regions and sectors. Sci Rep. https://doi.org/10.1038/s41598-023-48136-y

Assesing cities flood defence

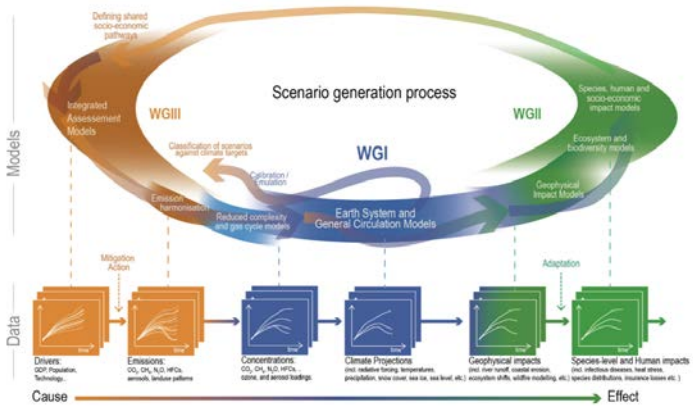
Sea-level rise and flooding are among the main climate change stressors challenging human society in the 21st century. Many coastal areas and cities are implementing innovative solutions to mitigate flood risks and enhance resilience. CMCC team contributed to a study that addresses exclusively economic aspects of the MOSE, the system of storm surge mobile barriers developed in Venice.

More info: Balancing act: Assessing Venice's flood defence. The study: Boon and burden: economic performance and future perspectives of the Venice flood protection system. Reg Environ Change. https://doi.org/10.1007/s10113-024-02193-9

Driving global climate insights

Climate scenarios are crucial elements for investigating the current and future socioeconomic outcomes of climate change. For years, CMCC has played a leading role in international communities that focus on the most advanced tools and methods for producing climate scenarios, such as those developed through CMIP experiments, which are then utilised for IPCC Assessment Reports, or scenarios used for risk analysis, impact assessment, and mitigation pathways. An example of this high-level participation in the global climate scenarios community is the work that led to the publication in Nature npj Climate Action of "Scenarios in IPCC assessments: lessons from AR6 and opportunities for AR7', which presents lessons learned from the Sixth Assessment Report (AR6) of the Intergovernmental Panel on Climate Change (IPCC), characterised by an unprecedented level of coordination and integration across Working Groups.

More info: IPCC scenarios: Lessons from AR6 and pathways to improvement



Source: Scenarios in IPCC assessments: lessons from AR6 and opportunities for AR7. npj Clim. Action. https://doi.org/10.1038/s44168-023-00082-1

SHARE-ENV: the database that links health, life stories, and the changing environment

SHARE-ENV is the open access database that augments the public database SHARE, a longitudinal Survey of Health, Ageing and Retirement in Europe, with a rich set of geospatial variables characterizing the quality of the environment and climate-related hazards. SHARE covers the health conditions of 120.000 Europeans. Individuals report not only their current health condition, but also their retrospective socio-economic and health history. In SHARE-ENV, individuals' well-being is traced over time along with the changes in the climate and environmental conditions they encountered during their lifetime.

More info: SHARE-ENV: an open access dataset to better understand the relationship between the environment & wellbeing

Global coasts as a new frontier

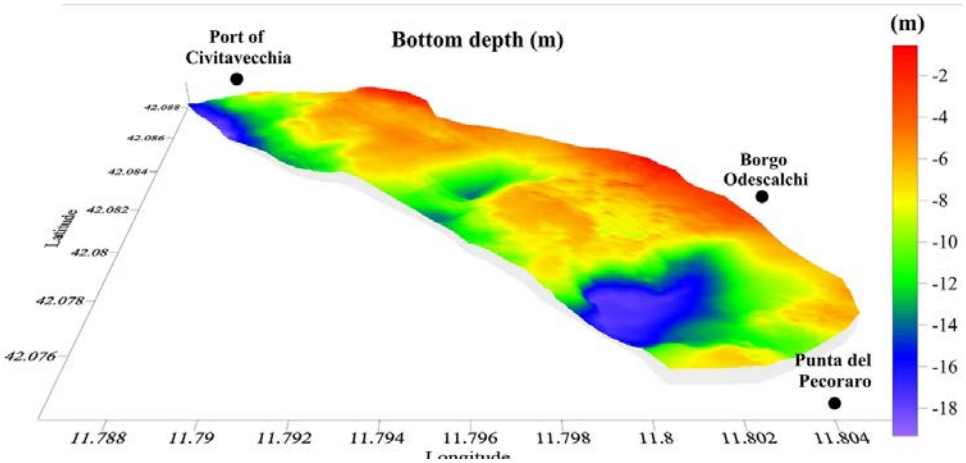
- **Integrate advanced modeling and artificial intelligence methods into portable digital twins of the global coastal ocean.**

- **Focus on risk assessment, observation, forecasting, adaptation planning, and tailored solutions (e.g. what-if scenarios) to manage and solve complex and non-linear environmental and socio-economic challenges in coastal areas.**

- **Enhance research for economically beneficial and viable coastal ecosystem restoration that improves coastal protection, biodiversity, and carbon absorption.**

Leveraging integrated technologies to support the sustainable development of the coasts.

Marine ecosystems, particularly those in the Mediterranean region, face numerous threats that affect environmental biodiversity, ecosystem services, and, consequently, society and economies in coastal areas. Among the strategic activities focused on the coastal environment, the CMCC studies the application of innovative technologies that can contribute to the development of advanced knowledge to support decision-making processes. CMCC coordinates the Renovate project, one of the most ambitious European initiatives for marine habitat restoration. Multi-platform approaches are being studied to integrate the use of tools and first-rate ocean modelling to enable mapping, monitoring, and analysing marine habitats, and to design future interventions with a view to sustainable development.



Source: An integrated approach for the benthic habitat mapping based on innovative surveying technologies and ecosystem functioning measurements. Sci Rep. https://doi.org/10.1038/s41598-024-56662-6

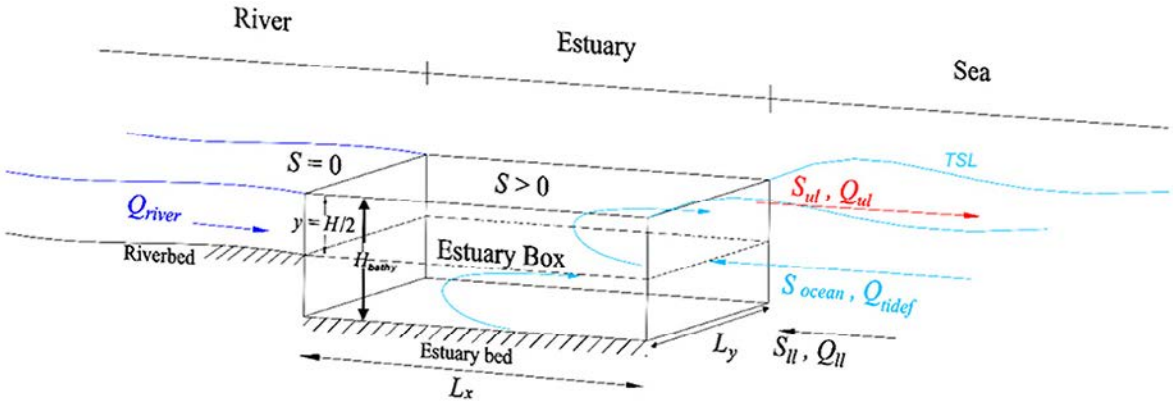
Big data, cloud and AI for coastal resilience.

CMCC is an active member in the promotion, animation, and coordination of GlobalCoast. Following the survey launched in 2023 to identify pilot sites, in 2024 the initiative born within the framework of CoastPredict, the United Nations Ocean Decade program aimed at transforming science and technology to improve coastal risk prediction and promote climate adaptation, has made significant progress. Co-led by CMCC, GlobalCoast is advancing a global discussion on local challenges and opportunities arising from global cooperation and is leveraging technological innovations such as big data, cloud and artificial intelligence to monitor and develop global solutions.

More info: Global cooperation for coastal resilience

A digital twin for coastal Nature-Based Solutions

Finding effective solutions for coastal resilience depends on advanced tools that can analyse the complexity of coastal ecosystems, their interactions, and generate reliable future scenarios. These tools must anticipate critical issues and help identify appropriate responses. Among the most advanced technologies studied by CMCC, the Digital Twin plays a key role. It produces a virtual replica of coastal and marine environments, integrates hazard and extreme event observations and simulations, and supports rapid, integrated decision-making to reduce risks and enhance resilience. Thanks to the computing capacity of its High Performance Computing Centre, CMCC can use the Digital Twin to run experiments based on real-time data, forecasts, and climate models. This allows researchers to track hydrology and ocean conditions and to analyse changes in ecosystems. One application, for example, focuses on resilience challenges linked to climate-induced salinisation in river estuaries and explores how Nature-Based Solutions can help reduce the threat of salt-wedge intrusion.



Source: Salt-wedge estuary's response to rising sea level, reduced discharge, and Nature-Based Solution. Front. Clim. https://doi.org/10.3389/fclim.2024.1408038

Operational applications for the safety of the marine environment and people.

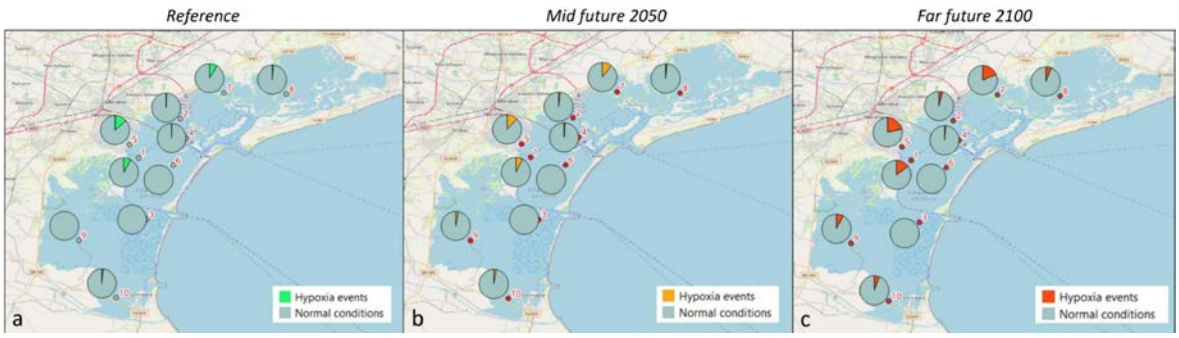
CMCC's oceanographic research produces a series of operational applications that support stakeholders involved in the management, monitoring, prevention, and risk management of activities carried out at sea. An example of these applications is the daily production of oil spill forecasts in the event of an incident at sea. In such cases, the CMCC provides national and international authorities with timely information, the accuracy of which is crucial for understanding the dynamics of marine spills and for supporting competent authorities in planning their actions at sea.

More info: Oil Spill. Accurate forecasts from CMCC on the Kerch Strait

Machine learning to improve the predictability of climate change pressure in the Venice Lagoon

The application of Machine Learning represents a methodological and technological frontier for climate modelling. CMCC explores these possibilities to ensure the availability of high-quality data and information, with accuracy, reliability, and timeliness. Among the numerous applications in this field, there are studies investigating the potential of machine learning and deterministic models to produce future scenarios in specific ecosystems.

For example, in the Venice area, they are used to analyse how the pressures of climate change are connected to dissolved oxygen decline, which in lagoon ecosystems can lead to hypoxia.



Source: Hypoxia extreme events in a changing climate: Machine learning methods and deterministic simulations for future scenarios development in the Venice Lagoon, Marine Pollution Bulletin, https://doi.org/10.1016/j.marpolbul.2024.117028

The first European Assessment Report on Sea Level Rise

Sea-level rise is one of the most significant challenges of climate change, threatening coastal communities, ecosystems, and infrastructure across Europe.

JPI Climate and JPI Oceans, with co-direction and key input from CMCC experts, have published the 1st European Assessment Report on Sea Level Rise, providing essential insights to guide policymakers, coastal planners, and practitioners in addressing the multifaceted challenges of rising seas.

The report was designed with significant stakeholder input, ensuring that coastal planners, policymakers, and other end users received targeted, practical knowledge to better address the challenges posed by rising sea levels in their regions.

Building on the IPCC's findings, the report incorporates recent research, providing updated sea-level rise projections, impact assessments, and adaptation strategies to support policy and planning across Europe.

More info: Informing action on Sea Level Rise: Launch of the 1st European Assessment Report

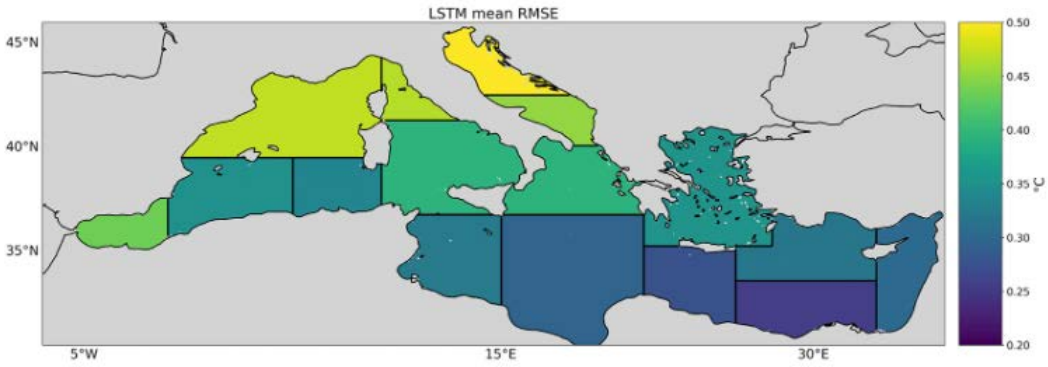
Integrating AI and ML in the modeling chain

The CMCC Artificial Intelligence and Machine Learning program comprises a range of cross-institute activities that leverage data-driven approaches and machine learning models to predict climate patterns, extreme weather events, and the effects of climate change on land use, agriculture, the ocean, and society.

Machine Learning helps predict the future state of the Mediterranean Sea

Marine heatwaves (MHWs) have significant social and ecological impacts. Therefore, predicting these extreme events is essential to prevent and mitigate their negative consequences and to provide decision-makers with valuable information on the nature and magnitude of specific MHW-related risks.

CMCC's strategic research lines include exploring how advanced data-driven techniques can enhance oceanographic predictions, potentially delivering faster, more efficient forecasting tools than dynamical models. The study "Machine learning methods to predict sea surface temperature and marine heatwave occurrence: a case study of the Mediterranean Sea" is a proof-of-concept demonstrating the use of ML to predict marine heatwaves. In detail, CMCC played a key role in developing the methodological framework by conducting experiments, interpreting results, and providing computational resources.



Source: Enhancing estuary salinity prediction: A Machine Learning and Deep Learning based approach, Applied Computing and Geosciences, https://doi.org/10.1016/j.acags.2024.100173

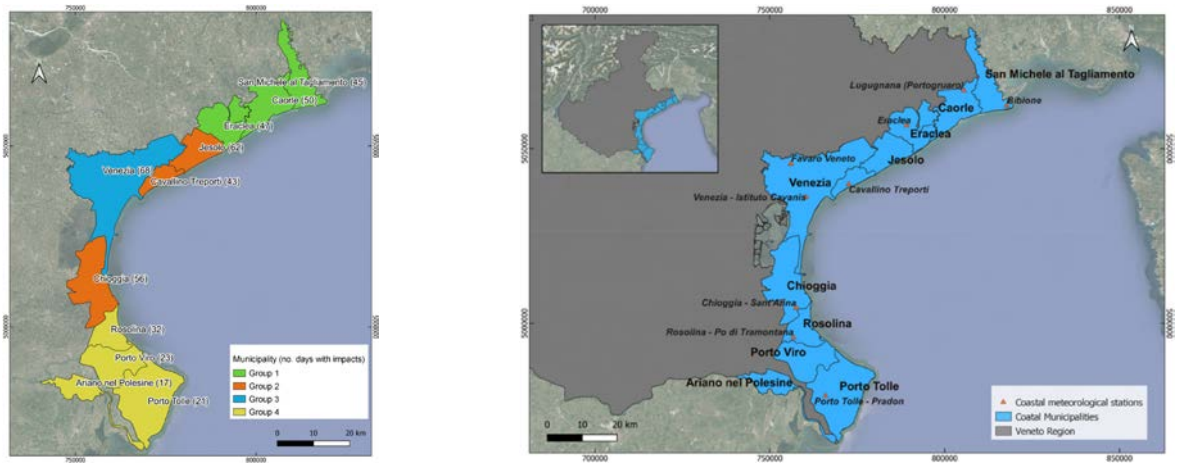
Testing innovative methods to simulate responses to greenhouse gas levels

General Circulation Models (GCMs) are contemporary, advanced tools designed to simulate the response of climate systems to changes in greenhouse gas levels. Increasing the spatial resolution of GCM outputs at the regional scale requires downscaling. Among the CMCC activities, a particular focus is on how Machine Learning models can improve downscaling quality by providing more detailed results and greater computational efficiency. This research highlights the strengths and limitations of ML techniques in this field, fundamental knowledge for understanding how to best utilise the potential that emerges in this sector.

Source: Intercomparison of machine learning methods for statistical downscaling of daily temperature under CMIP6 scenarios: a case study from Iran, Journal of Hydroinformatics, https://doi.org/10.2166/hydro.2024.227

A machine learning approach to evaluate coastal risks

Coastal areas, with their high population density, interconnected economic activities, and fragile ecosystems, are particularly vulnerable to extreme events, which in turn are on the rise due to climate change. However, due to the complex nature of these interactions, there is a need for improved methodologies and capabilities for assessing risks. Among the first studies of its kind, the paper entitled "A machine learning approach to evaluate coastal risks related to extreme weather events in the Veneto region (Italy)" uses Artificial Intelligence (AI) methodologies to estimate risks posed by extreme weather events across the coastal municipalities of the Veneto region. This offers new insight into how ML models can be employed for environmental and multi-risk assessment under climate change. The ML model developed for this research can be used to estimate the importance of different hazard factors, offering insight into their physical drivers and, in the process, contributing to the implementation of adaptation planning.



Source: A machine learning approach to evaluate coastal risks related to extreme weather events in the Veneto region (Italy), International Journal of Disaster Risk Reduction, https://doi.org/10.1016/j.ijdrr.2024.104526

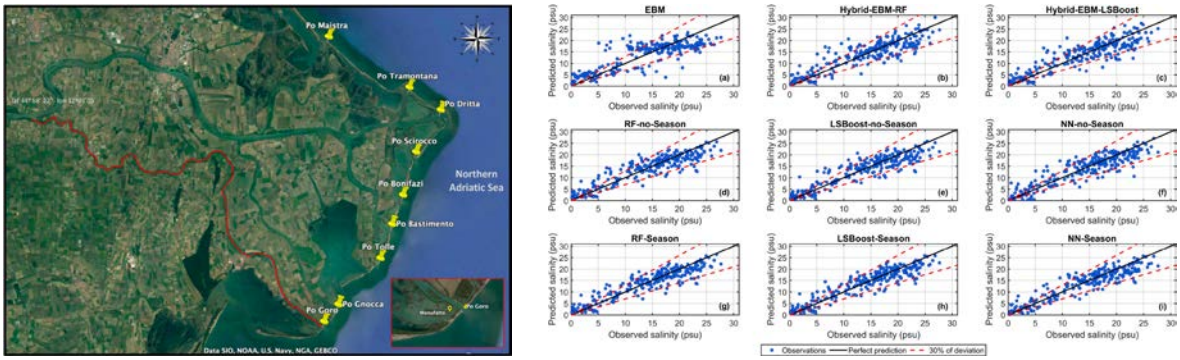
Snow density prediction with ML and satellite data

Seven machine learning methods for estimating and predicting snow density and the role of temperature. It is an example of the experiments in which the CMCC team collaborates with institutes around the world to advance the field of applying machine learning methods to satellite data. In this case, the experiment focused on snow density, which causes snow to melt quickly, so there is no runoff during the warmer months of the year. The study concludes that snow density can be estimated with good accuracy using a combination of machine learning methods and remote sensing.

More info: A comparison of machine learning methods for estimation of snow density using satellite images, Water and Environment Journal, https://doi.org/10.1111/wej.12939

How salty is the river? ML and DL models to predict salinity levels in estuarine environments.

Estuaries and their surrounding wetlands are home to unique plant and animal species, making them among the most productive ecosystems in the world. However, estuaries are also delicate ecosystems that are increasingly threatened by salt wedge intrusion, which impacts their ecological balance and human-dependent activities. In this context, accurately predicting estuary salinity is essential for water resource management, ecosystem preservation, and sustainable development along coastlines. A CMCC study investigates the application of various machine learning (ML) and deep learning (DL) models to predict salinity levels in estuarine environments. Leveraging a range of techniques, including Random Forest, Least-Squares Boosting, Artificial Neural Networks, and Long Short-Term Memory networks, the study aims to improve predictive accuracy to better understand the complex interplay of factors influencing estuarine salinity dynamics.



Source: Enhancing estuary salinity prediction: A Machine Learning and Deep Learning based approach, Applied Computing and Geosciences, https://doi.org/10.1016/j.acags.2024.100173

AI for SDGs: Monitoring environmental fluxes with

The Eddy Covariance (EC) method enables monitoring of carbon, water, and energy fluxes between Earth's surface and the atmosphere. Owing to its interdependent data streams and the sheer volume of data, EC is naturally suited to Artificial Intelligence (AI) approaches. Integrating AI and EC will likely play a crucial role in the climate change mitigation and adaptation goals defined in the Sustainable Development Goals (SDGs) of the Agenda 2030.

More info: Artificial intelligence and Eddy covariance: A review, Science of The Total Environment, https://doi.org/10.1016/j.scitotenv.2024.175406

Events

CMCC actively participates in a variety of events, including international conferences, round tables, and festivals, where our scientists are invited to share their expertise and the results of the latest research. These occasions offer valuable opportunities for discussion, idea exchange, and the development of new collaborations with sector experts. In addition to these initiatives, the centre regularly organises high-profile scientific conferences and events, inviting renowned scientists, experts, and policymakers from around the world. These events explore scientific topics and disseminate research on climate change, aiming to raise public awareness and foster an open dialogue between the scientific community, institutions, and citizens.

In 2024, CMCC participated in and organised more than 200 events. For the full list of CMCC events, go to the **CMCC website (events section).**

CMCC at COP29: Science supporting climate negotiations in Baku

Every year, CMCC scientists contribute to the UNFCCC climate conference and support climate negotiations with scientific insights and research findings, especially within the context of the European Union delegation. At COP29 in Baku, CMCC organized a series of side events on urgent climate challenges, encouraging dialogue and exploring innovative solutions that can help propel climate action in a variety of different fields.

More details on the CMCC contribution at COP29, go to the website.

Digital innovation for climate: The international EGI 2024 conference

Digital security, cloud computing, data management, and advanced computing were the central themes of the EGI 2024 conference, held in Lecce from September 30 to October 4. Scientists, digital infrastructure experts, and policymakers from around the world gathered to explore how managing large volumes of data and utilising supercomputers can accelerate research and innovation, with a particular focus on climate change.

Co-organized by the Euro-Mediterranean Center on Climate Change (CMCC), the annual EGI conference—an international infrastructure providing advanced computing and data analysis services for research and innovation—brought together leading global scientific communities, cloud computing service providers, and security experts.

Koopman Operator Theory: Fundamentals, Approximations and Applications

Digital security, cloud computing, data management, and advanced computing were the central themes of the EGI 2024 conference, held in Lecce from September 30 to October 4. Scientists, digital infrastructure experts, and policymakers from around the world gathered to explore how managing large volumes of data and utilising supercomputers can accelerate research and innovation, with a particular focus on climate change.

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More info: Manifestations of chaos: The rise, fall and revival of the Koopman operator.

At the heart of the most impactful international science

The CMCC participates in the most prestigious international scientific conferences dedicated to climate sciences. Among these, the general assemblies of the EGU - European Geosciences Union (Vienna, 14–19 April 2024) and the AGU - American Geophysical Union (Washington, D.C., 9–13 December 2024) are annual events in which CMCC scientists contribute by showcasing their expertise on topics including the impacts of climate change, innovative adaptation strategies, and the science-policy interface.

More info: CMCC at AGU24: What's next for science? and CMCC joins EGU General Assembly 2024.

Meet world-leading climate scientists, be inspired by the CMCC Lectures

CMCC Lectures are in-person and online, where prominent scientists and climate experts tackle the most pressing challenges shaping our future. These hybrid and digital events provide a unique opportunity to engage with leading voices in climate science as they address critical issues and share their latest research and perspectives.

The series started in 2024 with Google DeepMind's scientist Remi Lam, , one of the 2024 Nature's Top 10, whose visionary work connects AI innovation with the challenges of our changing climate. The second Lecture was given by Gabriel Vecchi, Knox Taylor Professor of Geosciences at Princeton University and Director of the High Meadows Environmental Institute (HMEI), who shared insights on using past trends to improve predictions and enhance adaptation and preparedness.

Join the CMCC Lectures

Meet world-leading climate scientists, be inspired by the CMCC Lectures

From the geophysical cycles to the impacts on society, CMCC scientists and experts present the all-encompassing changes in our climate system through the latest academic advances. The CMCC Talks periodically collect the best results and the most innovative activities of our research.

The full list of CMCC talks

Digital Innovation and high-level education

In 2024, the CMCC improved with the establishment of two specialised centres that work across disciplines and in close collaboration with the research themes of the institutes, in line with strategic programs, to provide, on the one hand, technological innovation to support research and, on the other, education, training, exchange, and knowledge transfer on climate change.

Advanced Digital Innovation Center – ADIC

At the forefront of climate research and innovation, the Advanced Digital Innovation Center (ADIC) is a transformative hub dedicated to revolutionizing the way we understand and address climate change. As an integral part of the CMCC Foundation, ADIC bridges cutting-edge technology with the critical research needs of the future.

Working across the three key CMCC institutes, ADIC drives cross-disciplinary collaboration to create a holistic, data-driven approach to climate solutions. Our mission is to empower research through advanced tools and methodologies, ensuring that we not only keep pace with the evolving climate crisis but lead the charge in developing sustainable, scalable solutions.

The ADIC activities can be divided into two main areas:

- **Harnessing the Power of Innovation.** ADIC specializes in the development and application of groundbreaking technologies, including machine learning, big data analytics, and the optimization of climate models.

- **Accelerating Research for a Sustainable Future.** ADIC provides the expertise and technological framework that allows scientists, policymakers, and industry leaders to make data-driven decisions that protect our planet and its future.

Advanced Training and Education Center - ATEC

The Advanced Training and Education Center (ATEC) provides an interdisciplinary knowledge platform of education, training, and cross-cutting innovative research aimed at connecting the scientific community and policymakers towards a climate-resilient society. The Center bridges CMCC's two decades of scientific production and climate data with capacity-building, training, and knowledge-sharing activities that promote global progress on climate action.

ATEC plays a pivotal role in developing climate adaptation and transition strategies for future generations. The activities of ATEC open up a multidisciplinary range of initiatives that include:

Educating the next generation: The Center provides advanced education on climate change and sustainability for postdocs, students, and young professionals.

Building a Global Knowledge Hub: ATEC is establishing itself as a reference point for peer-to-peer knowledge sharing and advanced studies on climate science worldwide.

FERS - Future Earth Research School

CMCC coordinates FERS, an initiative in the field of environmental sustainability and climate change, which, right from the title, is oriented towards the future temporal dimension, offering a strategic overview on how to deal with future global challenges and building a fertile ground for innovation and new research pathways.

In 2024 FERS organized tw schools on two main topics connected to the climate sciences and policy: "Law, Finance, and LitigationLaw, Finance, and Litigation" (7th – 18th October), and Data Driven Modeling and Predictions of the Earth System (9 – 20 December).

More info: https://www.fersschool.it/

Training for Policy and Governance: ATEC offers specialized training for public authorities and the private sector at the EU and national levels on the science-policy interface and climate governance.

Accelerating Innovation in the Global South: ATEC promotes capacity enhancement in the design and scaling up of promising solutions for long-term, effective climate change adaptation and sustainable development. In addition to educational and training activities, ATEC conducts research on issues such as climate law & litigation, cultural heritage, sea level rise, coastal resilience and sustainable finance. These research themes provide policymakers and corporate actors with the strategic scientific information they need to make informed decisions about emerging climate science and governance issues.

High Performance Computing Center

The High Performance Computing Center (HPCC) is the infrastructure that enables CMCC research to produce, manage and store vast amounts of climate data.

Updated and upgraded since its first establishment in 2008, CMCC's High Performance Computing Center is among the most advanced computational facilities in Europe and the most powerful in Italy fully dedicated to climate research and the interaction between climate and socio-economic systems.

32,400 *cores*

2,359 *TFlops*
Theoretical peak performance (1TFlop = 1,000 billion operations per second)

37 *PetaBytes* Disk Storage capacity

62 *PetaBytes* Tape Library (archiving system)

CMCC by the numbers

~ 400 people

260+ researchers
specializing in climate and social sciences

130+ experts
for a management s tructure supporting our activities

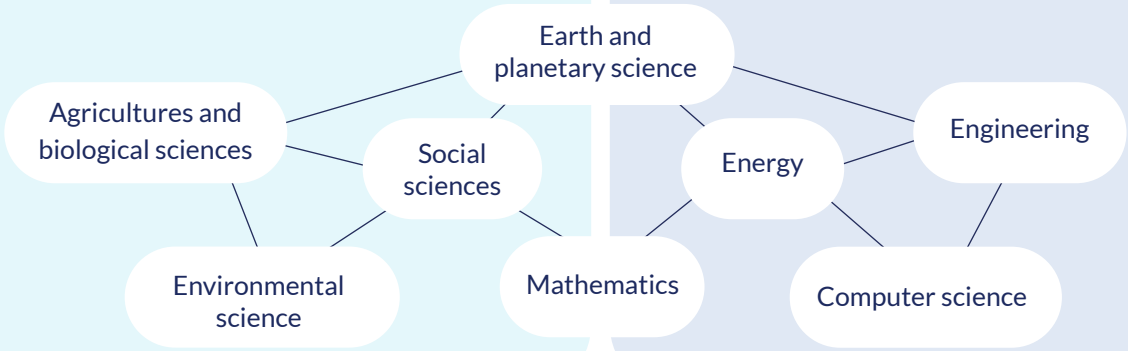
From
40 countries
5 continents

200+ publications

Every year · Over half in the **top 10%** journals by CiteScore · Covering a Broad Range of Topics

200+ projects

In progress worldwide · Tackling climate challenges through multidisciplinary research



Financial strength for research

223+ MLN €
received from **competitive and non competitive funding** programs

23+ MLN €
in **annual fundraising capacity** from national, European and international funding schemes

People

* The figures shown here represent a snapshot of the CMCC staff in FTE as at 31.12.2024

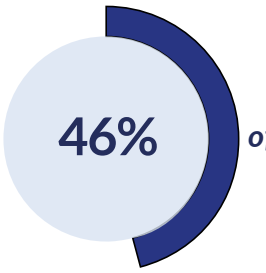
396 people at CMCC

65.5%
Research Area

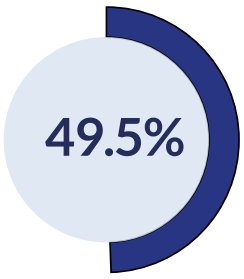
33%
Senior Positions

34.5%
Services for research

Women at CMCC are



of the staff



of senior positions

Be part of an international and multidisciplinary community of talented scientists committed to tackling the most advanced challenge of our time.

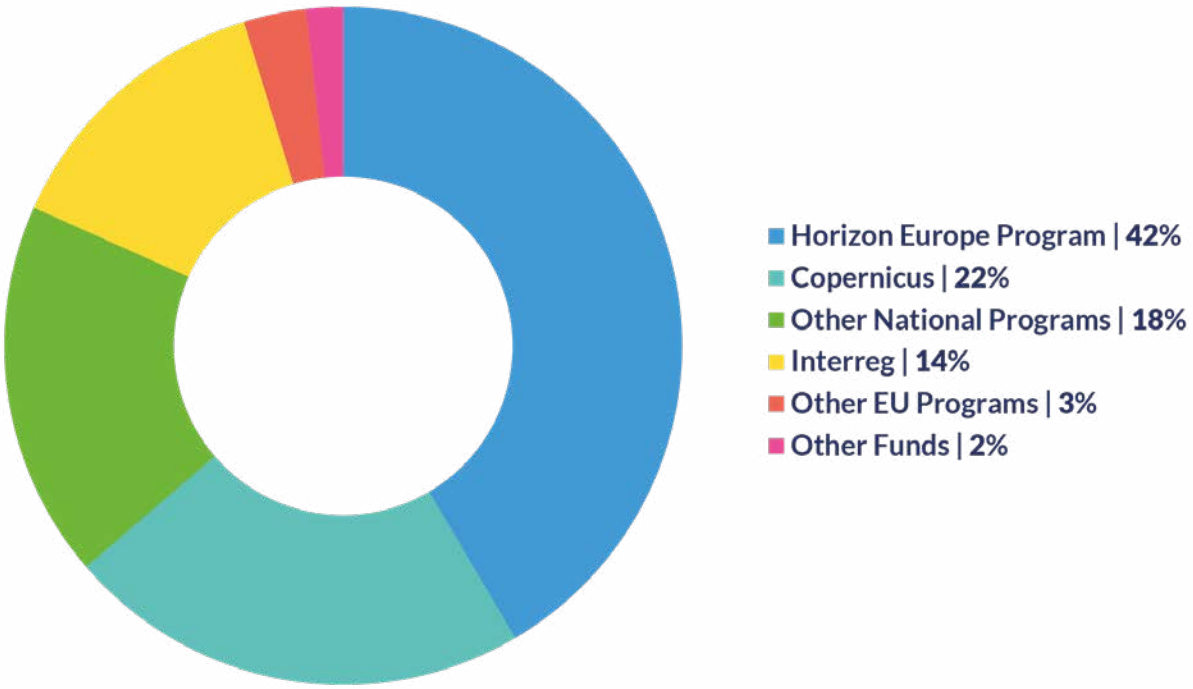
Find job opportunities at CMCC. Submit your CV, browse our open positions, and check if your requisites fit with any of them: www.cmcc.it/work-with-us

224 projects running and managed during 2024

25,5 MLN € in **annual fundraising capacity** from national, European, and international funding schemes

CMCC source of funding in 2024

(% budget, per start date)



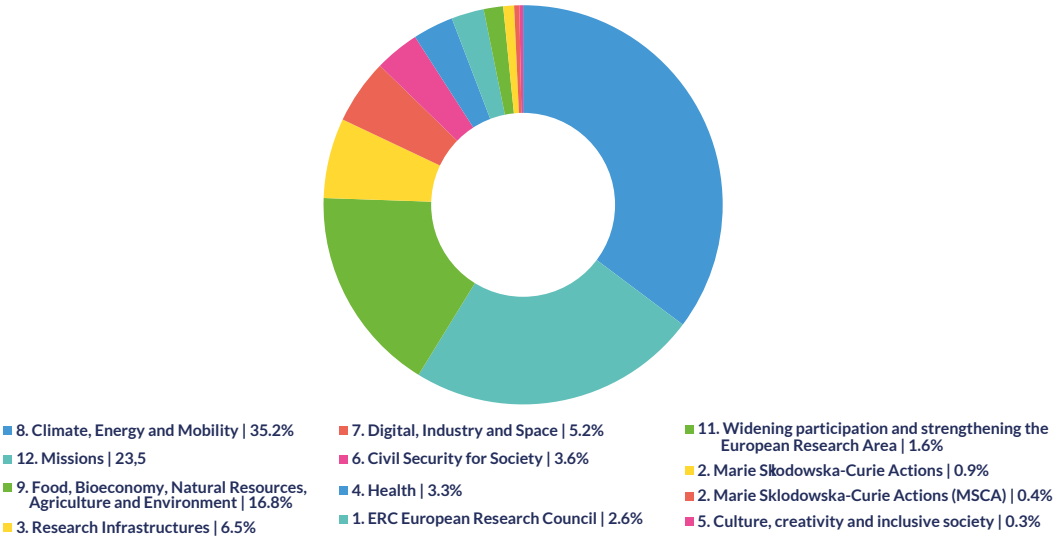
CMCC participation in Horizon Europe

(Work Program 2021 – 2024 calls)

260 proposals submitted
(of which **57 coordinated by CMCC**)
over the first three years of HEU.

97 proposals funded
(of which **18 coordinated by CMCC**),
for a CMCC contribution of **51.7 Mln €**
distributed over the Work Programs
shown in the picture.

CMCC budget per Work Program

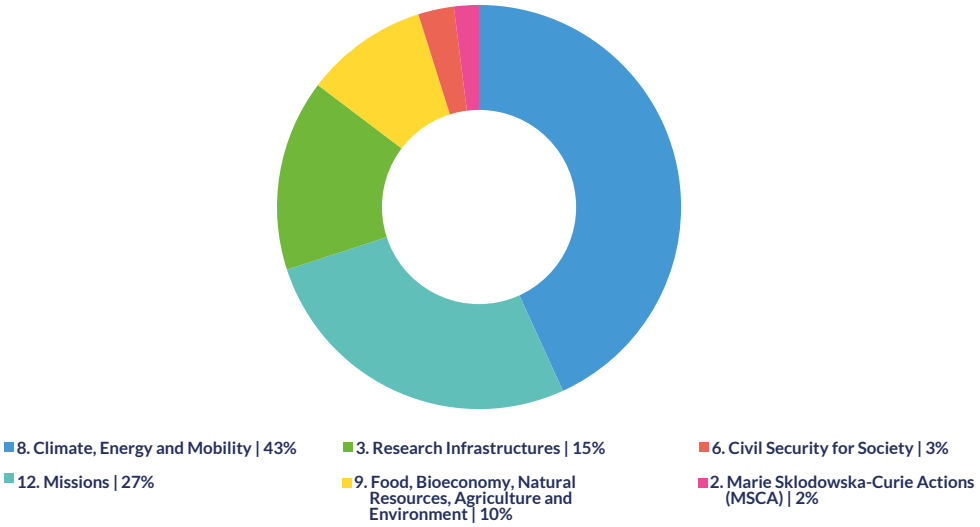


Focus 2023 only

63 proposals submitted
(of which **13 coordinated by CMCC**)
during 2024.

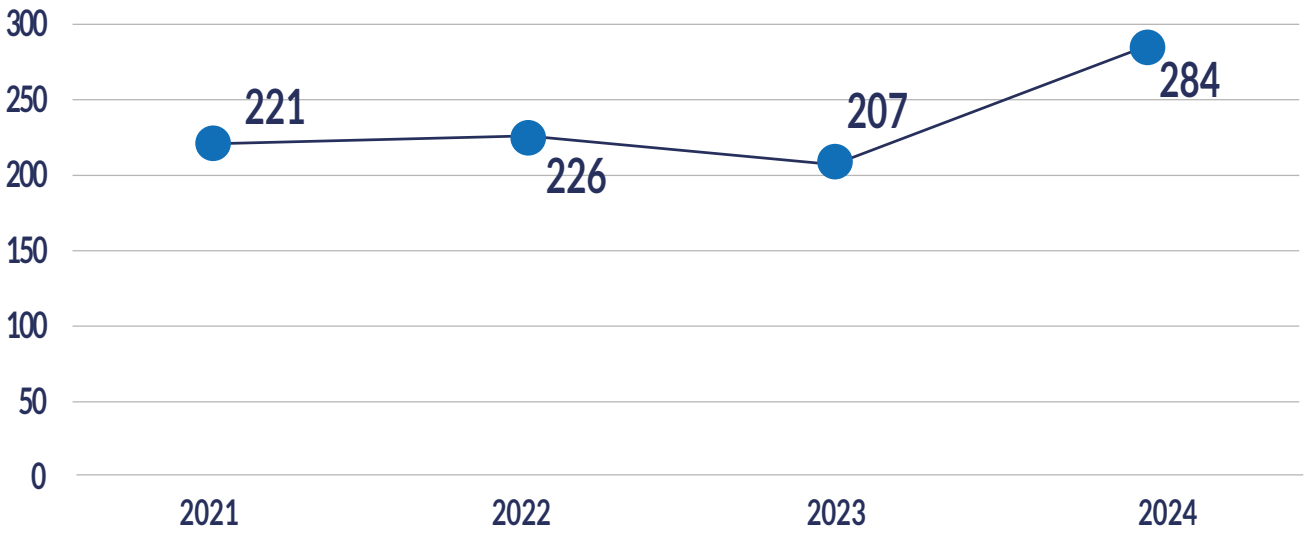
20 proposals funded, for a CMCC
contribution of **10,5 Mln€** distributed over
the Work Programs shown in the picture.

CMCC budget per Work Program (2024 only)



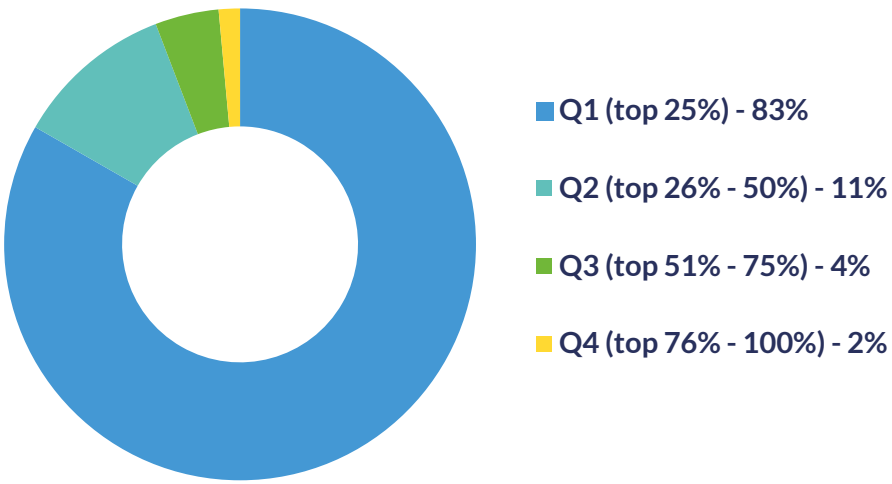
Publications

284 papers published in 2024



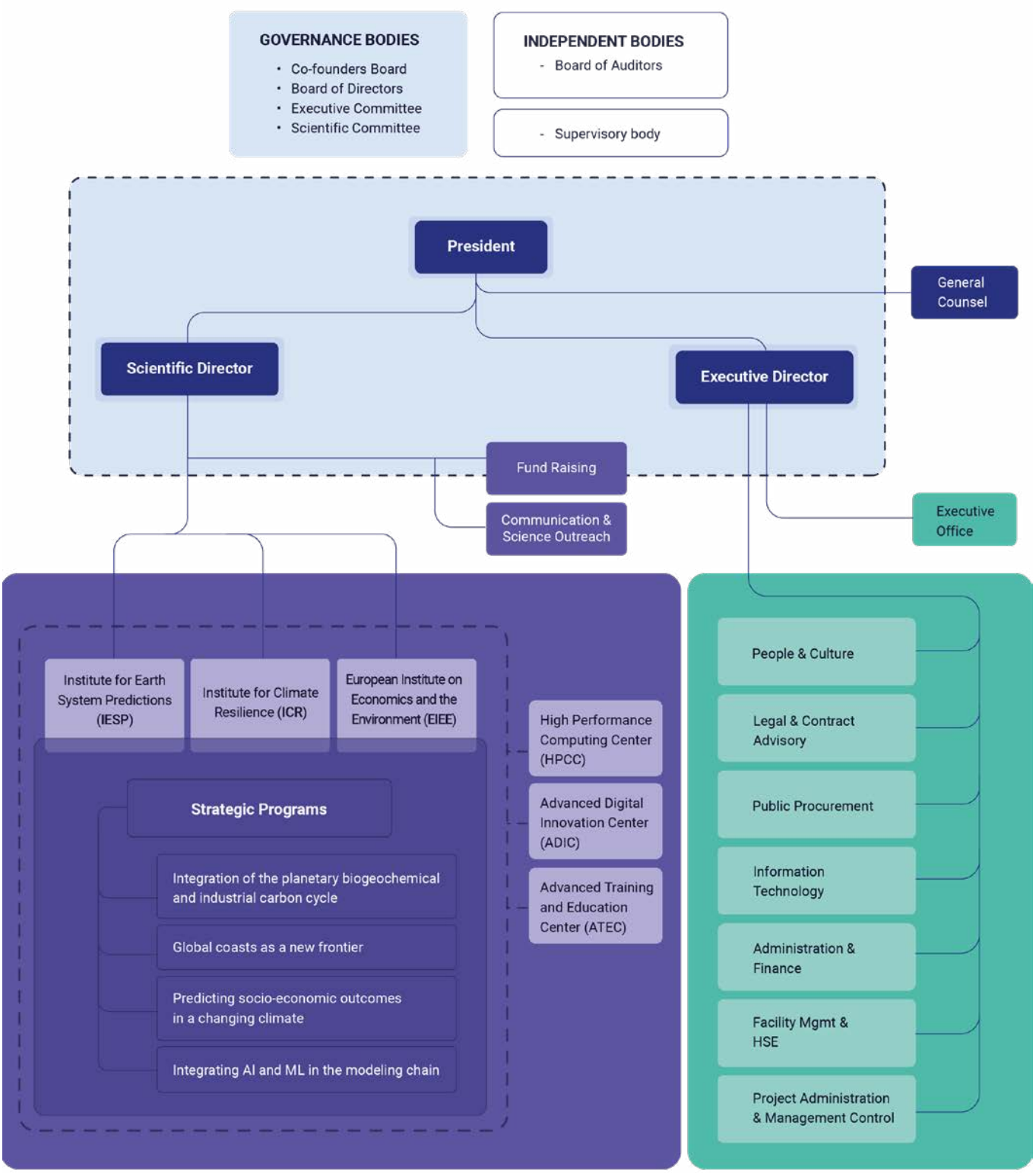
52,8% in the top **10%** journals by CiteScore.

Share of CMCC publications per Journal quartile in 2024 by CiteScore Percentile



The CMCC Foundation

Our organizational structure



Executive Leadership

Antonio Navarra - President
Laura Panzera - Executive Director
Giulio Boccaletti - Scientific Director

Board of Directors

Antonio Navarra – CMCC President, Full Professor, Università di Bologna
Antonio Marcomini – Università Ca' Foscari Venezia
Fabio Pollice – Università degli Studi del Salento
Donatella Spano – Università di Sassari
Giorgiana De Franceschi – INGV
Stefano Ubertini - Università della Tuscia
Richard Newell - RFF
Stefano Consonni - Politecnico di Milano

Scientific Committee

Antonio J. Busalacchi Jr.
Cameron J. Hepburn
Charles E. Miller
Helena Freitas
Iain Shepherd
Julie Pullen
Mattia Romani

Research Institutes Directors

Simona Masina - Institute for Earth System Predictions – IESP
Monia Santini - Institute for Climate Resilience – ICR
Massimo Tavoni - European Institute on Economics and the Environment – EIEE

Strategic Programs Directors

Anna Pirani – Predicting socio-economic outcomes in a changing climate
Giovanni Coppini – Global coasts as a new frontier
Soheil Shayegh – Integration of the planetary biogeochemical and industrial carbon cycle

Centers Directors

Giulia Galluccio - Advanced Training and Education Center
Paola Nassisi - Advanced Digital Innovation Center
Osvaldo Marra - High Performance Computing Center

Founding Fellows

Giovanni Aloisio
Carlo Carraro
Antonio Marcomini
Antonio Navarra
Nadia Pinardi
Pasquale Schiano
Donatella Spano
Riccardo Valentini

cmcc
Centro Euro-Mediterraneo
sui Cambiamenti Climatici

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