



cmcc

Centro Euro-Mediterraneo
sui Cambiamenti Climatici

Climate Sciences in the **21st** century

www.cmcc.it





We are a multidisciplinary, advanced research center focused on understanding the interaction between climate change and society.

We ensure
reliable, rigorous, and timely scientific results

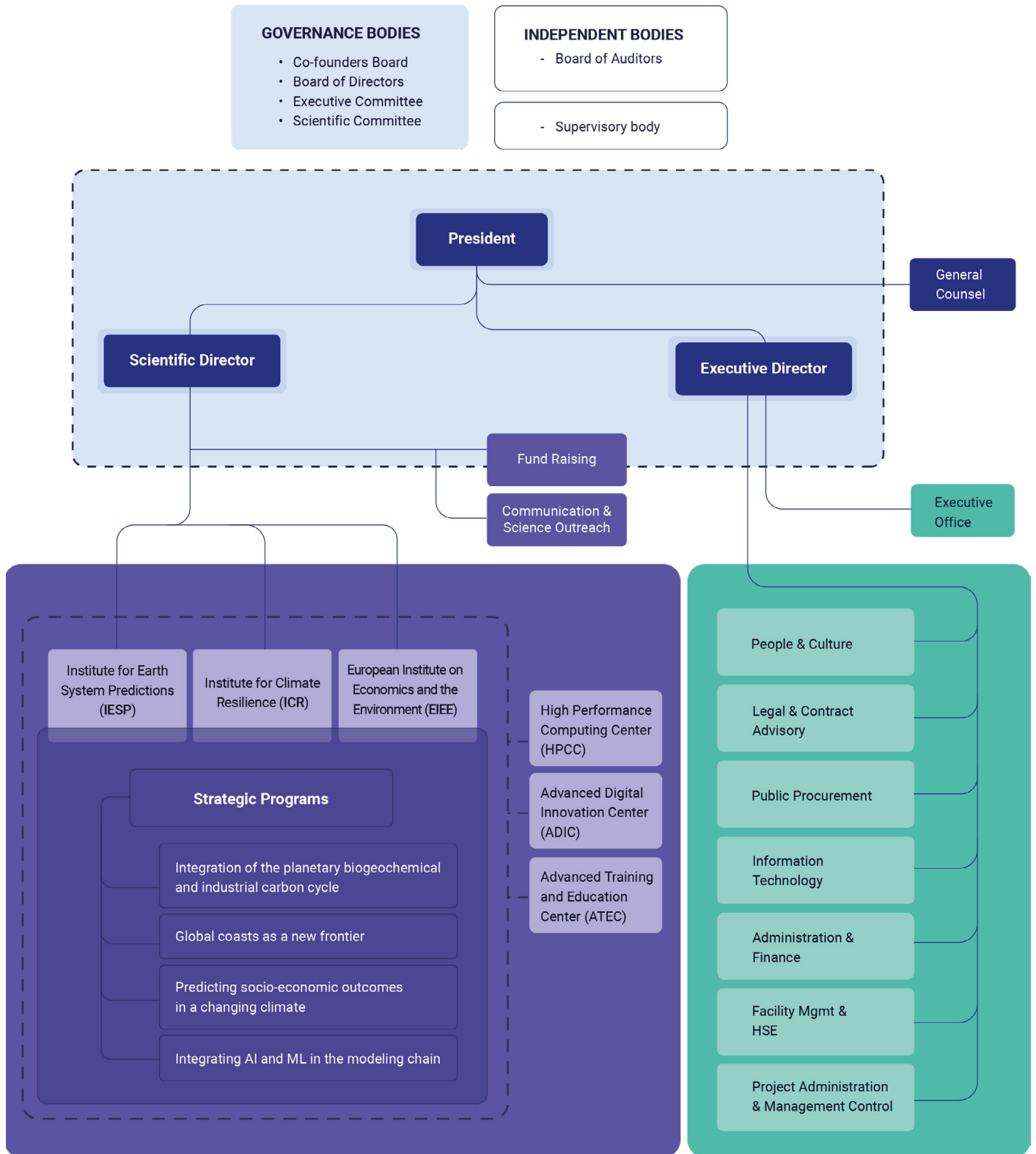
that stimulate sustainable growth, protect the environment, and develop
science-driven adaptation and mitigation policies in a changing world.

We provide
foresight and quantitative analysis on our future planet and society.

We deliver the crucial scientific insight needed for
a successful transition to a sustainable future.

We are among the
world leaders and reference points
in advanced scientific research,
integrating all aspects of
social, economic, and environmental systems affected by climate change.

The CMCC Foundation



From models to solutions

CMCC is an international institution producing advanced research on climate modeling **whilst at the same time developing transversal and multidisciplinary competencies that combine first-class climate modeling with climate change impact modeling and environmental economics.**



Three multidisciplinary research institutes



Four strategic programs on frontier topics



A computing infrastructure dedicated exclusively to the study of climate change



Two specialized centers on digital innovation, and high-level education and training



Over 200 international research projects
A management structure that supports research

Guaranteeing **globally relevant** results for:

- the scientific community
- decision-makers
- stakeholders
- civil society

Supporting decisions and actions that promote sustainable development.



Antonio Navarra
President



Giulio Boccaletti
Scientific Director



Laura Panzera
Executive Director

Prosperous economies amid unprecedented changes

The climate system is at the center of a series of momentous changes that are transforming our relationship with Earth.

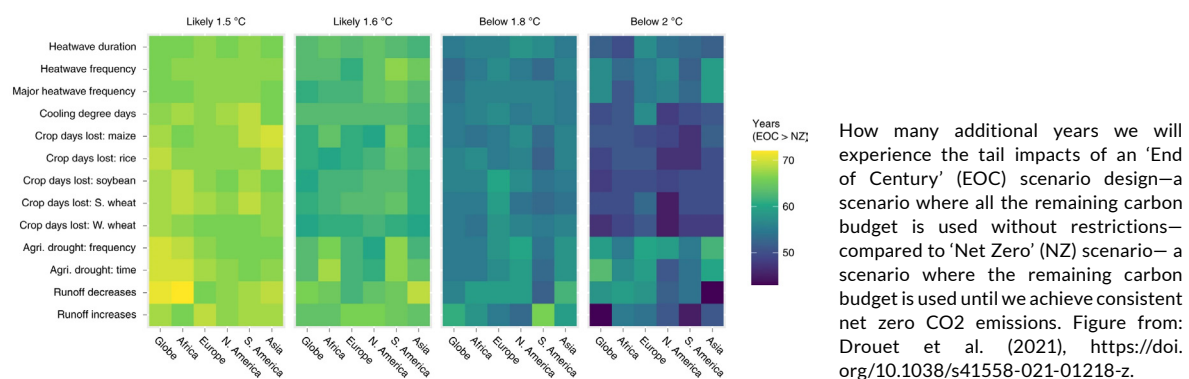
To address these changes we must intertwine transformations in industrial systems on the road to a net-zero carbon society, technological innovations that support this transition, the need for and availability of natural resources, as well as the technologies and scientific research required to produce and disseminate knowledge. No region of the planet or segment of society is left untouched by climate change.

Despite significant advances in climate science since the 1950s and 60s, we now find ourselves at a standstill. Although climate science is central to political discussions, there is a risk that its findings will be overlooked or ineffective.

The necessary shift in focus involves moving beyond mere predictions and high-resolution models. We must focus on practical, comprehensive, impactful solutions that address real-world problems and threats, providing actionable strategies to tackle the challenges posed by climate change.

What will economies in the net-zero carbon world of the coming decades look like? How will society adapt to changing material conditions, ensuring security and prosperity? What will it take to pursue that prosperity and wellbeing in the midst of radical change?

CMCC provides insight and data to address these questions, enhance our understanding of the climate system and prepare for change across socio-economic sectors.



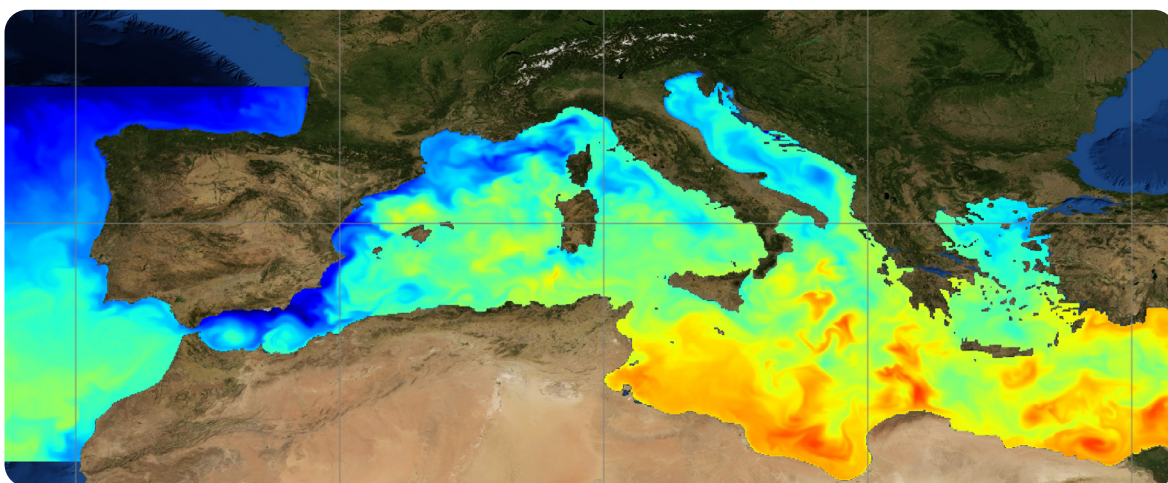
Science that simply cannot be ignored

Scientific evidence clearly shows that the transition to a net-zero world is less costly than inaction. It is well understood that this shift will have a plurality of social, economic, and financial impacts across the globe. Furthermore, some regions will face higher costs than others when dealing with the effects of climate change on wealth, welfare, and geopolitics.

A deeper understanding of these processes enables decision-makers to manage potential impacts and achieve welfare and security goals.

Parallel to this new industrial revolution, in which all value chains are stimulated in the direction of a sustainable transition, a second revolution is marking the 21st century. A methodological and technological revolution: Earth Observation Systems are being enriched with unprecedented data and information; and at the same time the spread of artificial intelligence and machine learning tools is enabling researchers in the detection of changes and simulation of dynamic processes.

CMCC engages in frontier activities that explore the opportunities offered by artificial intelligence and the application of advanced machine learning algorithms, capitalizing on them through a data-driven approach to climate modeling and analysis.



Mediterranean Sea Surface Temperature daily mean from MedFS - Mediterranean Forecasting System (available at <https://medfs.cmcc.it/>), a numerical ocean prediction system that produces analysis and short-term (10 days) forecasts for the entire Mediterranean Sea and its adjacent Atlantic Ocean area of the essential ocean variables at ~4km horizontal resolution and 141 vertical levels. It is developed and operationally implemented at CMCC in the framework of the Copernicus Marine Service.

Research institutes

CMCC research is organized into three institutes that are home to Earth's sciences and social sciences researchers from all over the world who collaborate in a highly multidisciplinary environment whilst leveraging the advanced technology of CMCC's High Performance Computing Center.

The interplay of these three institutes ensures a cross-disciplinary dimension that makes CMCC a unique player in climate studies and allows the center to work on the entire chain of climate research (from drivers to impacts), as well as the social, economic and technological dimensions.

The three institutes are

Institute for Earth System Predictions

IESP

Institute for Climate Resilience

ICR

**European Institute on Economics
and the Environment**

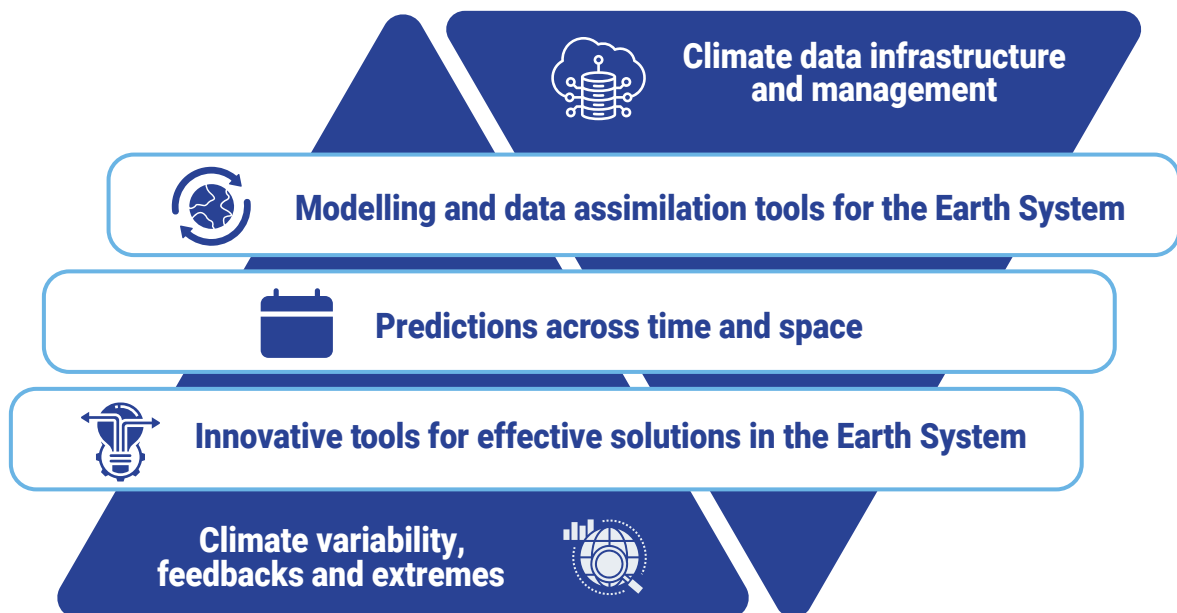
EIEE

Institute for Earth System Predictions - IESP

Leveraging CMCC's climate modeling capabilities and turning scientific knowledge into improved predictive tools.

IESP contributes to an advancement in the 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 tackles critical climate science questions that are relevant to society, delivering seamless Earth system predictions that support science-based decision-making.



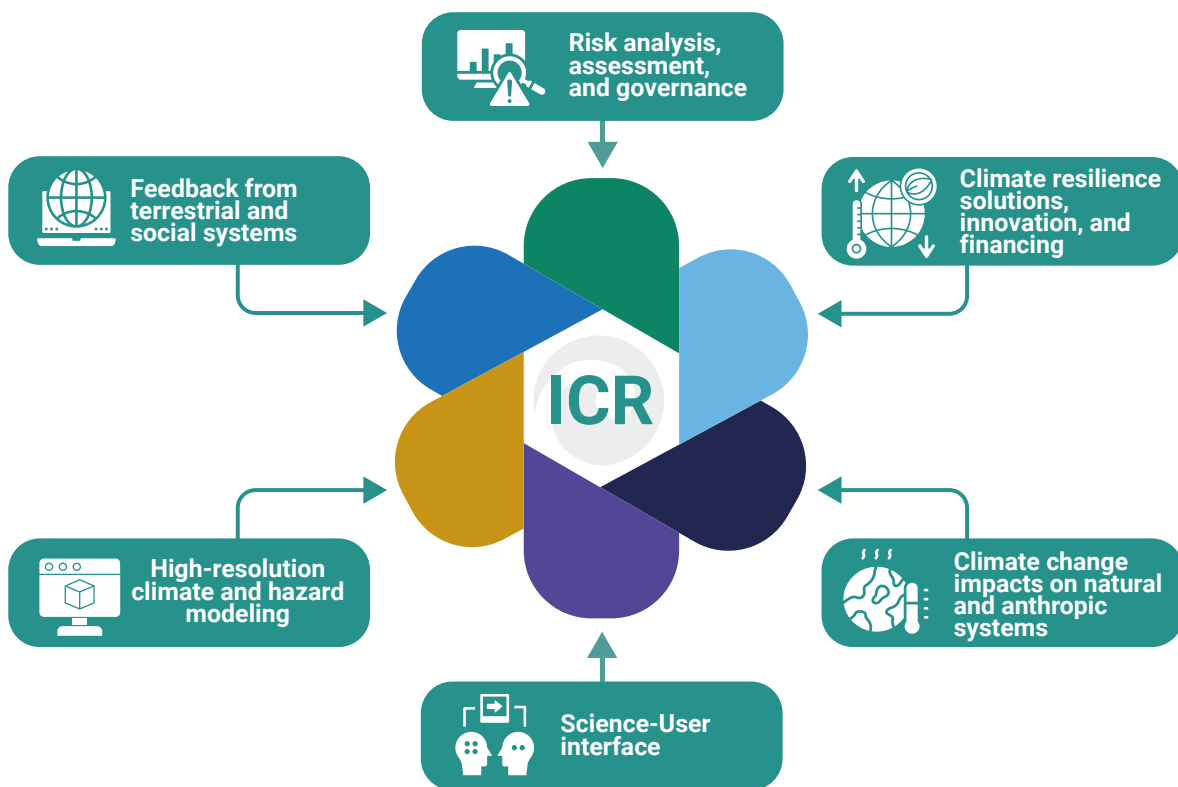
Scan the QR code for more information on **IESP** research

Institute for Climate Resilience - ICR

Empowering decision-makers with the knowledge they need for both immediate action and long-term strategies when planning for a climate-resilient future.

ICR is at the forefront of interdisciplinary research that connects climate, ecosystems and society.

Resilience refers to the ability of systems to withstand, recover 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 ICR's mission. In a world facing climate change, resilience requires integrated approaches to mitigation, disaster risk reduction and adaptation.



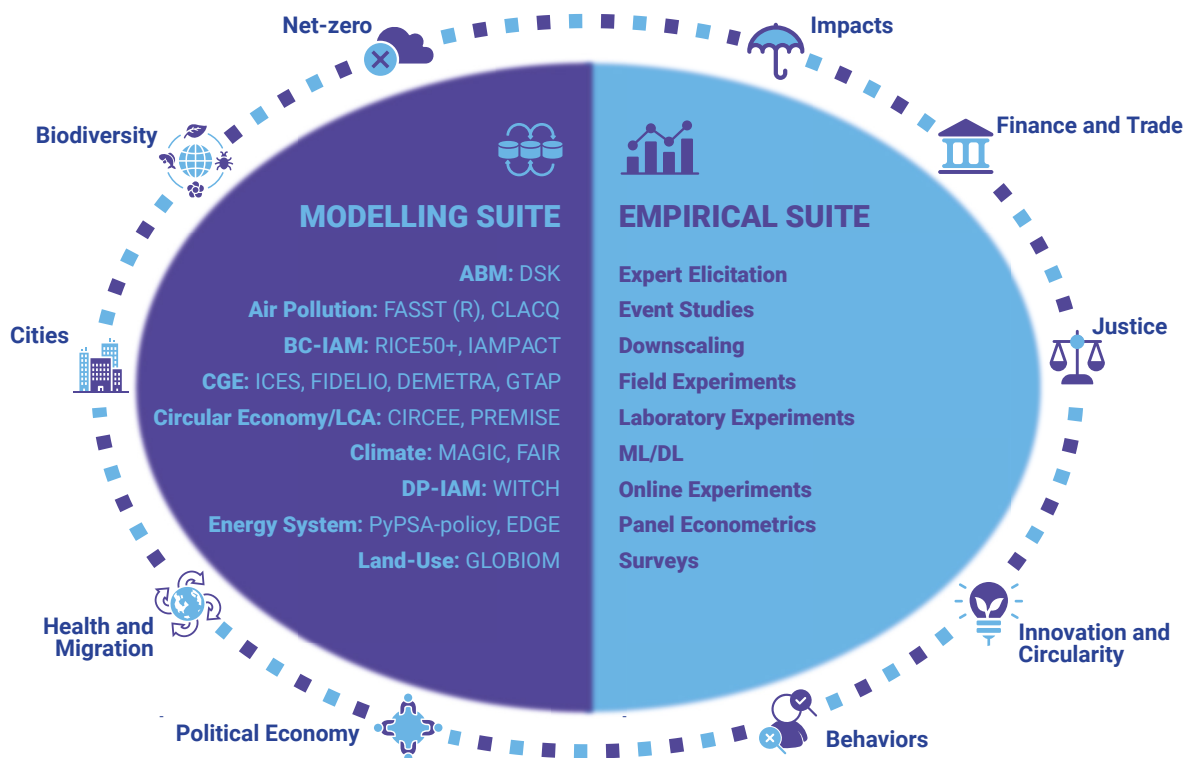
Scan the QR code for more information on **ICR** research

European Institute on Economics and the Environment - EIEE

Evaluating sustainable and socially enhancing strategies that confront climate change and other major challenges at the intersection between environment, technology and the economy.

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

EIEE provides crucial research and tools that have contributed to several global assessments, including IPCC reports.



Scan the QR code for more information on **EIEE** research

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)

The HPCC is composed of two interacting facilities:

CASSANDRA

Cassandra consists of 180 Lenovo SD650 V3 computing nodes, each featuring dual Intel Xeon Max 9480 processors with 56 cores each, resulting in a grand total of 20,160 cores. This configuration, supported by Intel's new Sapphire Rapids HBM family of processors, enables Cassandra to achieve an outstanding theoretical peak computing power of 1,225 TFlops.

Furthermore, to ensure the effective preservation and accessibility of vast amounts of climate data generated by CMCC's research activities, the HPCC incorporates the Deep Archive Storage System (DASS), offering a capacity of 62 Petabytes with 20 LTO8 tape-drives.

JUNO

Juno has a computing power (theoretical peak performance) of about 1,134 TFlops and is based on the 3rd generation Intel Xeon Scalable processors (code named "Ice Lake") and also on the NVIDIA A100 GPU (NVIDIA Ampere architecture).

The upgrading of the computing and storage facilities project was realized in 2021-22 through the European funds dedicated to the Regional Operational Programme 2014-2020 (Apulia region).

CMCC's long-term archiving system

CMCC is equipped with a system to manage and preserve the huge quantity of climate data produced by the research and operational activities at CMCC for the medium/long term.

The hardware components:

- IBM TS4500 tape library with 20 LTO8 drives and 2 accessors, 62PBytes of capacity
- 2 servers Lenovo ThinkSystem SR630
- 1 IBM Flash System 5000 storage system
- 16Gbps FC SAN implemented with 2 Lenovo FC switches DB6205

Strategic programs

CMCC builds its research agenda around a set of strategic programs that respond to frontier issues. These are crucial to understanding the challenges facing socio-economic systems in an environmental and social context characterized by a changing climate.

These research themes encompass CMCC's goals:

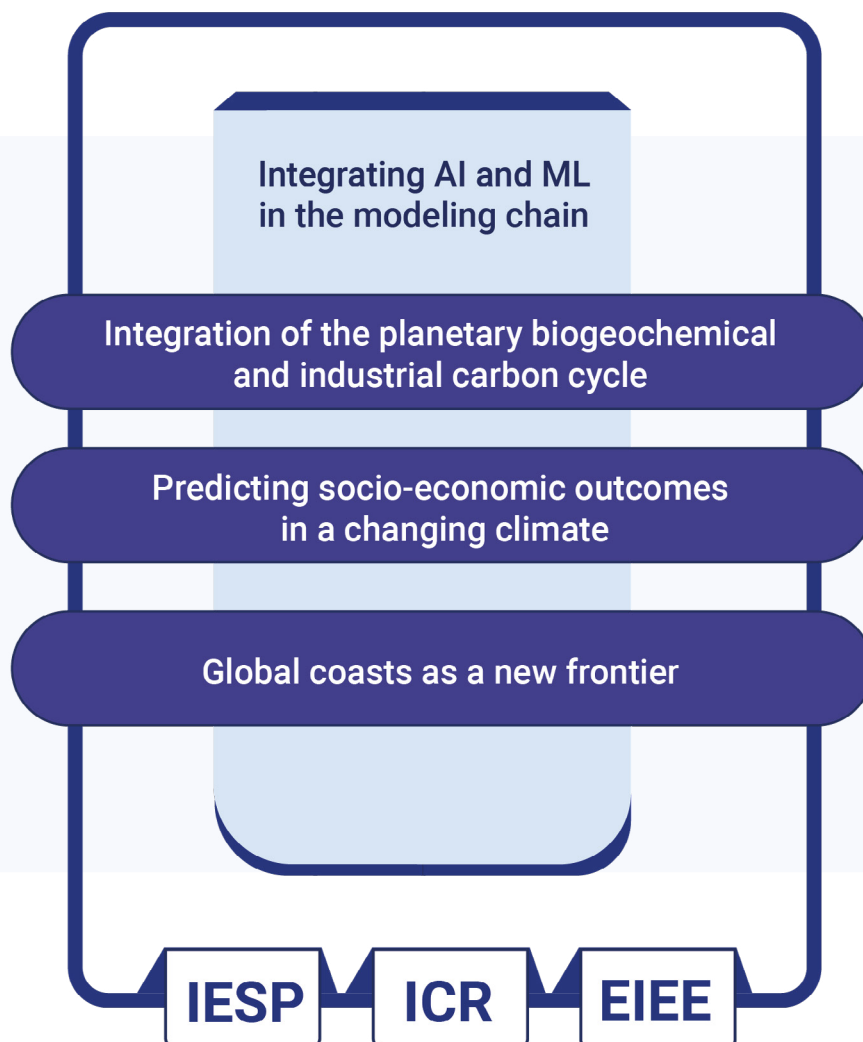
Integration of the planetary biogeochemical and industrial carbon cycle

Predicting socio-economic impacts of climate change

Global coasts as a new frontier

These strategic programs work both internally and across CMCC institutes in an integrated and cross-cutting manner.

A fourth program, covering CMCC's modeling production, is devoted to **integrating artificial intelligence and machine learning in the modeling chain**.



Integration of the planetary biogeochemical and industrial carbon cycle

Living in a net-zero carbon economy

For 300 years, industrial economies have prospered by emitting carbon. The coming decades will be defined by an opposite approach: building a net-zero carbon economy.

The entire value chain needs rethinking with new technologies and models that promote the goal of reducing atmospheric carbon concentrations without compromising on well-being and prosperity.

The future economy must not only reduce its carbon emissions but actively remove more carbon from the atmosphere than it emits. This relies on innovative technologies, sustainable practices, and robust policies that integrate industrial processes with natural biogeochemical cycles.

Understanding and shaping this new economic paradigm is essential to providing quantitative and narrative analyses of socio-economic systems in the context of a sustainable and resilient future.

CMCC analysis and research

- 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.

Predicting socio-economic outcomes in a changing climate

Sustainable development and well-being in a warmer world

Societies, economies, and policies are already facing the adverse effects of climate change in all regions of the world, including increasingly intense and more frequent extreme events, the occurrence of droughts, changes affecting ecosystems, and rising sea levels.

With increasing global warming there is a greater urgency for sustained emissions reductions, adaptation, and building resilience whilst enabling sustainable development, particularly in the Global South and most vulnerable communities.

This means informing society's ability to make choices that ensure growth and well-being.

Policymakers need the knowledge and tools required to assess the implications of climatic trends, as well as the potential for low probability, high impact outcomes, for a thriving and sustainable future. Such actions may require transformative changes and we need to understand how this can play out given our established societal infrastructure and operations that were historically based on stable climate conditions.

We need to characterize the socio-economic impacts of climate change to inform sustainable development, adapt and build resilience in the context of sustained efforts to reduce emissions and limit global warming. This requires advanced knowledge of the interactions between climate change and crucial sectors of economies as well as ecosystems, with attention to equity, justice, and the distributional aspects of impacts and actions.

CMCC analysis and research

- 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.

Global coasts as a new frontier

Environmental protection and socioeconomic development between ocean and land

Coasts are more than just a boundary between land and sea. They represent the intersection of physical, social, and economic processes that determine both a substantial part of the global economy and its vulnerability to climate change.

The strategic value of coastal areas is immense: key infrastructure is built along coastlines around the world; approximately 90% of freight trade passes through coastal ports; and 200 million people are employed in the fishery sector alone. These are just a few examples of the productive forces that are concentrated at the intersection between land and sea.

Although strategically vital to global socio-economic systems, coasts are also exposed to significant threats. Pollution, urbanization, climate change, natural hazards, storm surges, tropical and extratropical cyclones, sea level rise, salt intrusion, and coastal erosion all present critical challenges for coastal communities and both natural and engineered infrastructure.

CMCC, with its distinctive multidisciplinary and interdisciplinary approach, sees in coastal areas a strategic research direction. This involves the development of multidisciplinary digital twins of the global coastal ocean, integrating new satellites and in-situ observations (including citizen science), and developing advanced modeling and artificial intelligence methods to provide tools, information and solutions for decision-makers.

CMCC analysis and research

- 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.

Integrating artificial intelligence and machine learning in the modeling chain

Beyond forecasting: Data-driven climate science

More than technological innovation.

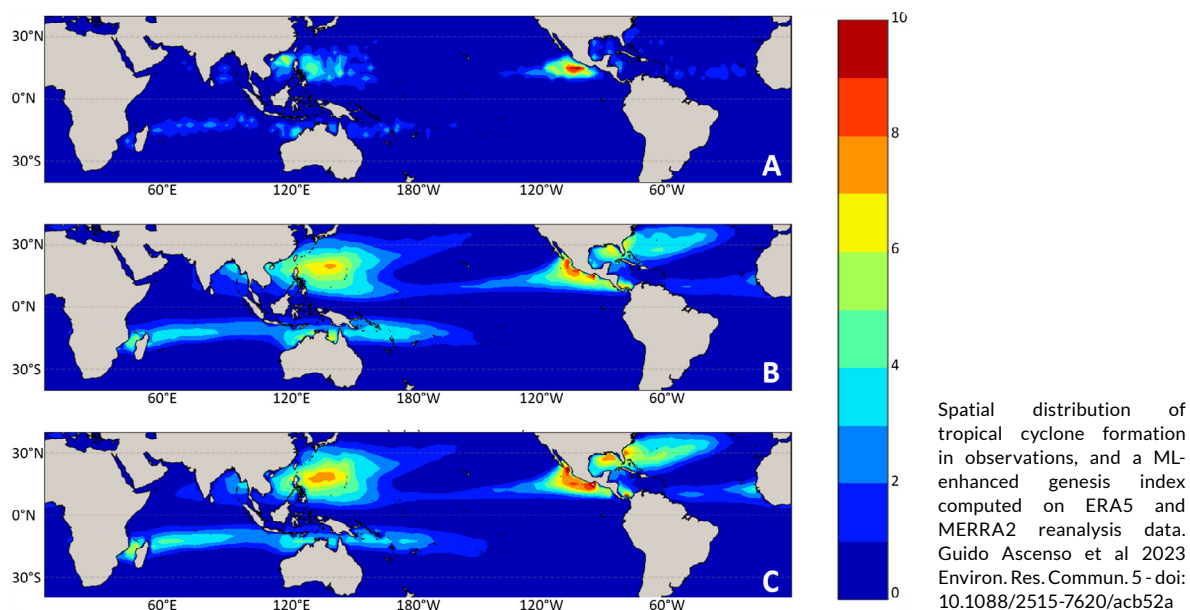
More than the growing volume of data enriching Earth Observation Systems.

It is about how technology and data availability have brought unprecedented possibilities to climate science.

A methodological revolution that opens new possibilities in climate science, offering methods for a deeper and more robust understanding of the climate system and how to shape resilient and sustainable societies.

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

Data-driven methods have immense potential in climate science, utilizing vast datasets from numerical models, satellites, and ground-based sensors. These approaches **improve model efficiency, enhance extreme event forecasting, and support early-warning systems**. Machine learning also helps extract valuable insights to better represent physical processes and assess climate risks, impacts, and adaptation strategies.



Establishing CMCC as a global leader in machine learning and artificial intelligence for climate science

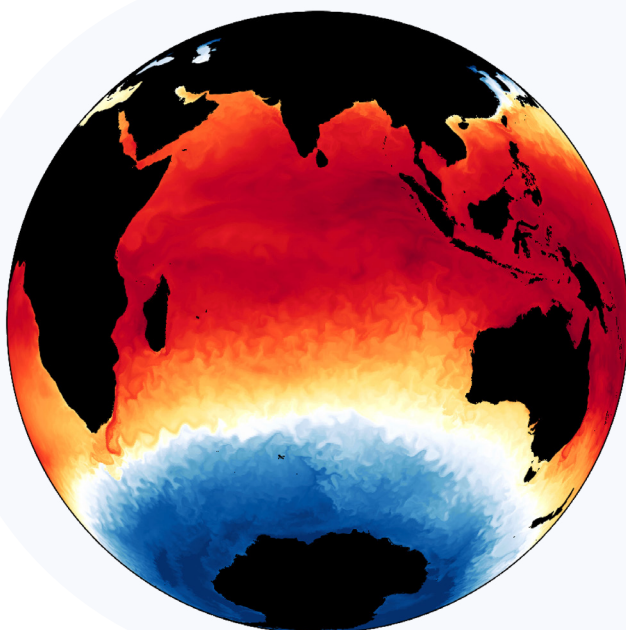
CMCC is **pioneering initiatives centered on advanced downscaling techniques with regional applications** and models addressing climate impacts across diverse contexts, spanning from soil and agriculture to coastal erosion. The program also uses machine learning to **analyze satellite data for land use classification, aiding decision-making in environmental management.**

Ongoing initiatives such as **fire monitoring** highlight CMCC's commitment to **integrating machine learning across diverse areas of climate research. Internationally, CMCC stands out by integrating human behavior and economic dynamics into its climate models**, positioning itself as a leader in climate research, adaptation and resilience efforts.

Looking ahead, the program has ambitious goals to:

- Create an Earth System Model entirely driven by data
- Develop Machine-Learning models that forecast the economic impacts of climate change
- Expand efforts to predict effects on vegetation, land use, urban systems, and society

These efforts aim to **establish CMCC as a global leader in the application of machine learning for climate change research.**



Daily mean Sea Surface Temperature (SST) simulated by the CMCC GLOB16 global ocean model, with a spatial resolution of 1/16°.

The model and the simulation are described in Iovino et al., Evaluation of the CMCC global eddying ocean model for the Ocean Model Intercomparison Project (OMIP2), 2023
<https://doi.org/10.5194/gmd-16-6127-2023>

Research Products

CMCC produces and uses a wide range of tools and products to address the most advanced challenges posed by climate change



Numerical **Models** for climate simulations.

Datasets for seasonal forecasts, decadal forecasts, climate change projections.



Climate forecasting systems that make operational climate forecasts available on diverse time and spatial scales.

Software and applications for the management, distribution and use of climate data.



Data visualization systems for interactive data visualization according to different needs.

Data delivery systems for a single, consistent and continuous access point to all data produced and used by CMCC.



Collaborations with more than 700 institutions worldwide

CMCC collaborates with top international centers specializing in advanced and applied climate research.

CMCC coordinates and participates in a number of international initiatives at the interface between climate science and decision-making.

In this field CMCC:

European Environment Agency
European Topic Centre on Climate Change
Impacts, Vulnerability and Adaptation



Coordinates the ETC-CCA (European Topic Centre - Climate Change impacts, vulnerability and Adaptation) of the EEA (European Environment Agency)

ICOS

European
Research
Infrastructure
Consortium

Coordinates the ETC (Ecosystem Thematic Center) of ICOS-ERIC, a European research infrastructure on the measurement of greenhouse gas emissions



Coordinates marine and seasonal forecasts within the European COPERNICUS Service

ipcc
INTERGOVERNMENTAL PANEL ON
climate change

Is the IPCC FOCAL POINT for Italy, the meeting point between the Italian research community and the United Nations Intergovernmental Panel on Climate Change



Is a member of the Global Compact, a United Nations initiative for corporate social responsibility and sustainability



Is an active member of the JPI - Joint Programming Initiatives on climate and marine issues

CMCC is a non-profit foundation and a charitable organization under Section 501(c)(3) of the U.S. Internal Revenue Code.



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