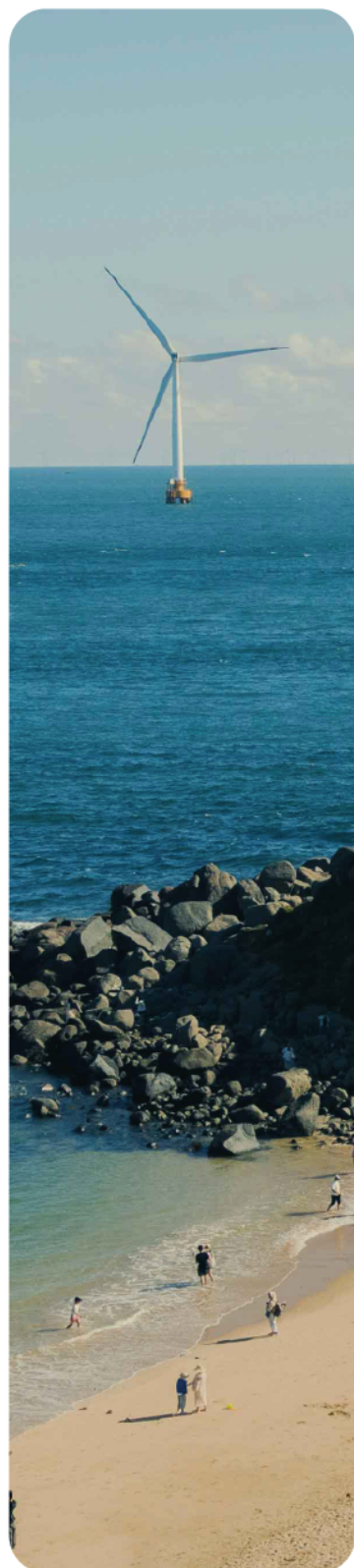
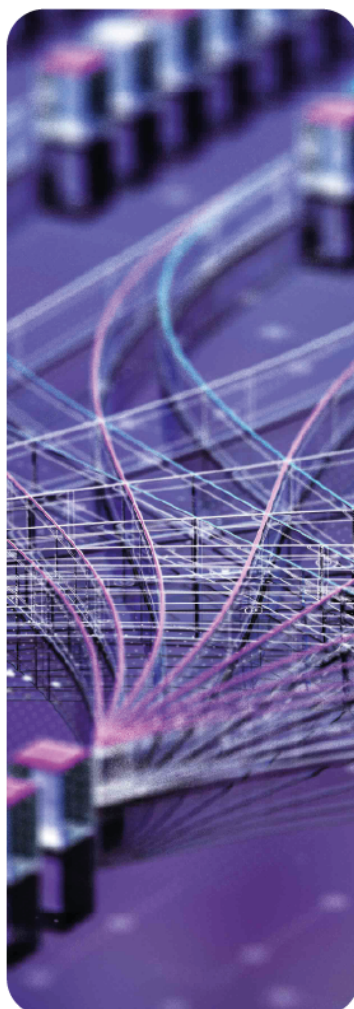
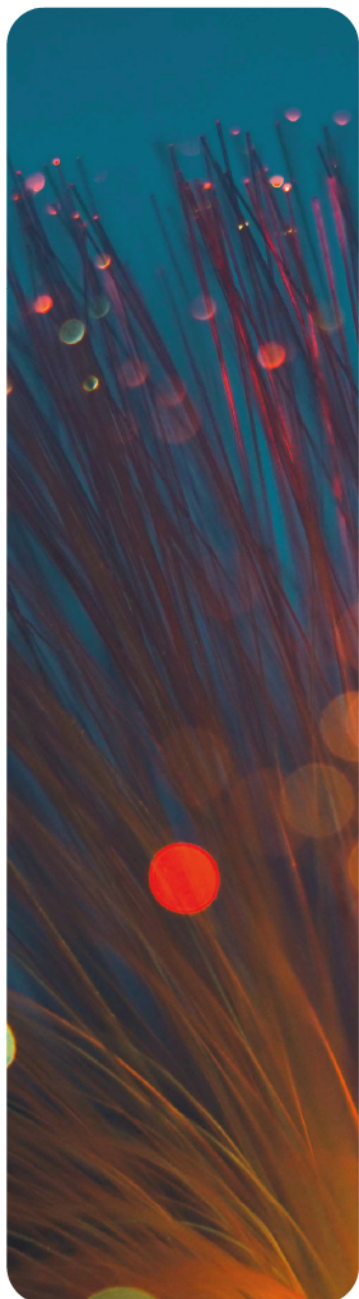




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2025

Annual Report





The CMCC Foundation – Euro-Mediterranean Center on Climate Change is an international, independent, and multidisciplinary research center dedicated to studying the interactions between the climate system and socio-economic transformations.

CMCC Annual Report 2025

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CMCC

Climate Insight for Global Impact

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 PROVIDES 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 impact analyses, and policy recommendations.



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2025 Research Highlights

Across 2025, CMCC research followed the climate challenge wherever it unfolds: in the ocean and along vulnerable coasts, in soil, land and water, in cities and local communities, in the energy systems that must decarbonize, and in the economies, societies and legal frameworks that shape the response. Artificial intelligence and Earth system modeling sharpened predictions of heatwaves, floods, fires and marine extremes, while the overshoot of 1.5°C moved from projection to policy question. These highlights gather the year's studies, climate services, events, training and outreach.

Artificial Intelligence for climate sciences

Faster forecasts, sharper projections. CMCC research in 2025 puts artificial intelligence to work across the climate system: AI emulators that predict the Mediterranean Sea in seconds rather than hours, deep learning that anticipates tropical Atlantic extremes months ahead, methods that cut uncertainty in Earth system models, and a European foundation model for Earth system science.

New AI ocean emulator enhances safety and preparedness for Mediterranean coastal communities

CMCC has developed MedFormer, a novel AI assisted model that predicts Mediterranean Sea conditions up to nine days in advance with more accuracy and faster than traditional models. The new AI ocean emulator can make ocean forecasting more precise and

efficient, providing information and data that might support marine safety, environmental protection, and coastal management by aiding in route planning, risk prevention, and response to storms, pollution, or heatwaves.

www.cmcc.it/article/ai-ocean-emulator-makes-mediterranean-coastal-communities-safer-and-more-prepared

Machine learning reduces uncertainty in Earth System Models

Earth System Models are the main tools scientists use to study and improve our understanding of the climate system and project climate change. However, even the best models still exhibit uncertainties in their projections. A research led by CMCC introduces a novel method that reduces uncertainties in near-surface air temperature

projections by up to 54% compared to state-of-the-art approaches, making predictions more precise and reliable. This can help provide better guidance for governments and communities in planning effective adaptation and mitigation strategies to meet the challenges posed by climate change.

www.cmcc.it/article/machine-learning-reduces-uncertainty-in-earth-system-models

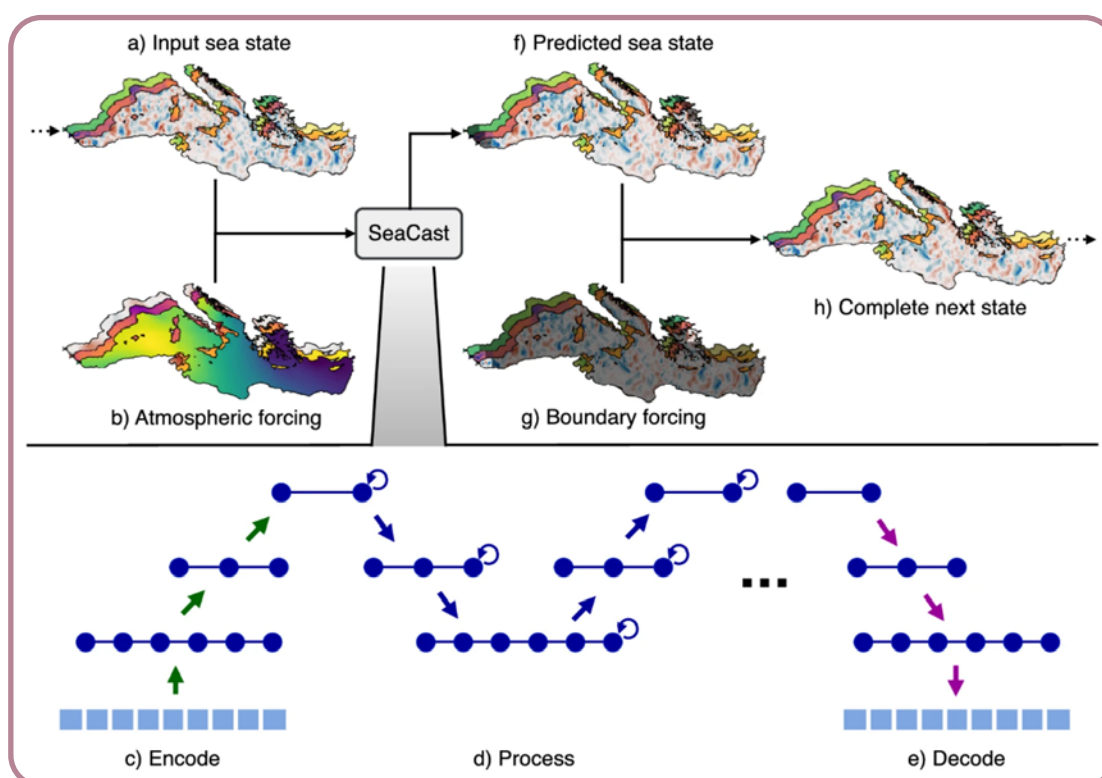
SeaCast revolutionises Mediterranean Sea forecasting with AI-powered speed and accuracy

SeaCast is an innovative high-resolution forecasting system for the Mediterranean that harnesses AI to deliver faster and more energy-efficient predictions than traditional models. Unlike existing global AI models, which operate at lower resolutions and primarily rely on ocean data, SeaCast integrates both ocean and atmospheric variables, capturing complex regional dynamics. Its graph-based neural network accounts for intricate coastlines and lateral boundary conditions, overcoming one of the major challenges in regional ocean forecasting.

The model operates at a high resolution of about 4 km ($1/24^\circ$), the same resolution as the CMCC Mediterranean operational forecasting system MedFS (which is coupled with a wave model and covers the full ocean depth), delivered through the Copernicus

Marine Service, and produces forecasts down to a depth of 200 meters. This is made possible by training the model on CMCC Mediterranean reanalysis data, which are provided at the same resolution and are freely available through the Copernicus Marine website. SeaCast consistently outperforms the Copernicus operational model over the standard 10-day forecast horizon and extends predictions to 15 days. The efficiency gains are striking: while the operational numerical system requires around 70 minutes on 89 CPUs (central processing units, conventional processors used in most computers) to produce a 10-day forecast, SeaCast can generate a 15-day forecast in about 20 seconds using a single GPU, a highly efficient processor designed for parallel calculations and widely used in machine learning.

www.cmcc.it/article/seacast-revolutionizes-mediterranean-sea-forecasting-with-ai-powered-speed-and-accuracy



SeaCast performs autoregressive ocean forecasting using a graph neural network (GNN). Source: Accurate Mediterranean Sea forecasting via graph-based deep learning. Sci Rep 15, 45051 (2025). <https://doi.org/10.1038/s41598-025-31177-w>

WeatherGenerator: European leadership in AI-Driven climate science

The WeatherGenerator project officially launched on February 5, 2025. The ambitious project, coordinated by ECMWF and involving CMCC as one of the key partners, aims to transform weather and climate prediction capabilities, utilising state-of-the-art AI and machine learning to create a cutting-edge

European foundation model for Earth system science. Combining advanced machine learning techniques with high-performance computing, the project offers innovative solutions for both scientific research and real-world applications.



www.cmcc.it/article/ai-driven-climate-and-weather-predictions-cmcc-helps-launch-the-weathergenerator-project

Algorithms going wild: Machine learning techniques for terrestrial ecology

Machine learning is increasingly being used to study and protect nature. However, some of the drawbacks related to its use include environmental sustainability concerns which lead to the question: Do the benefits of applying machine learning for nature conservation outweigh the ecological and climate footprint? A new study led by CMCC

looks at ML's role in terrestrial ecology, analyzing 326 studies and concluding that algorithms hold great promise for delivering more accurate, scalable, and timely data, advancing real-time monitoring and near-instantaneous predictions for applications such as in seasonal forecasting.

www.cmcc.it/article/algorithms-going-wild-machine-learning-techniques-for-terrestrial-ecology

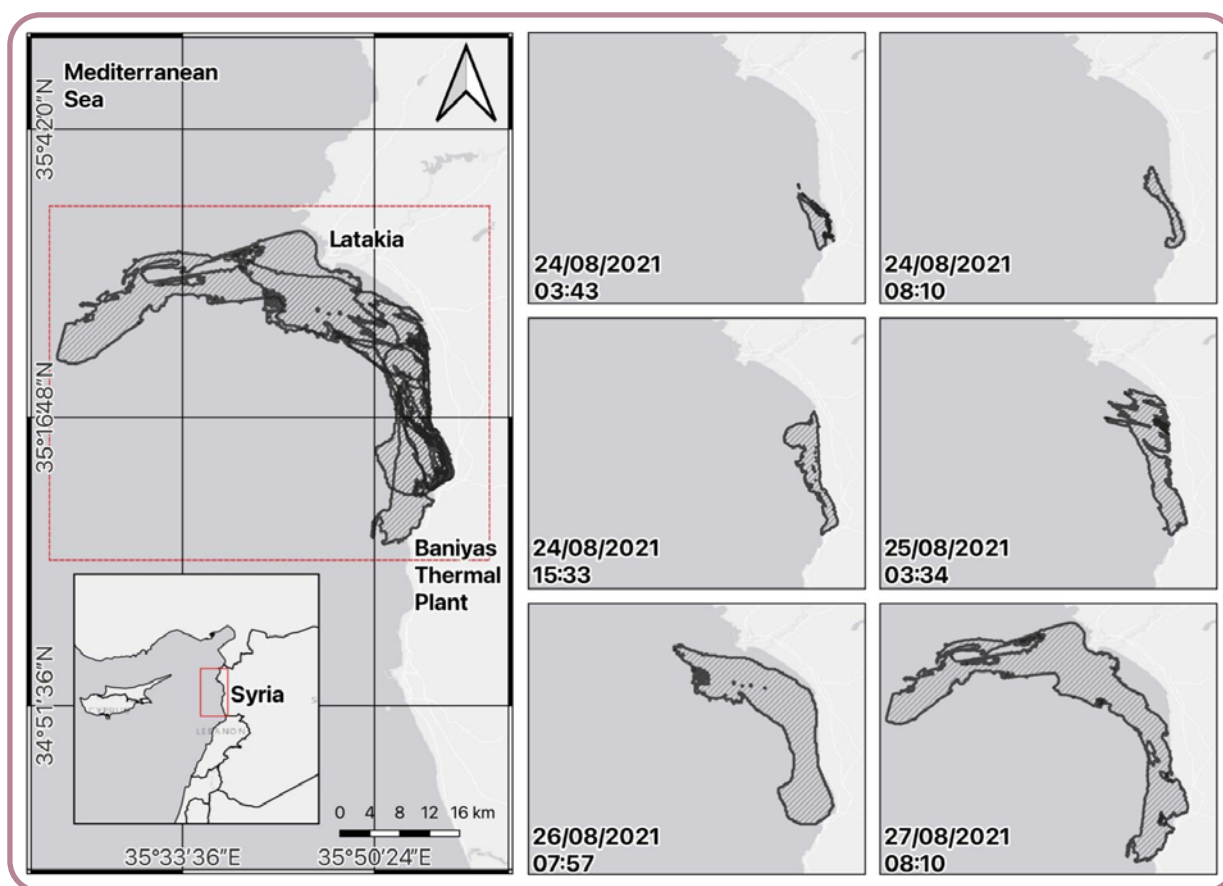
AI-powered oil spill prediction system improves accuracy by up to 25%, with significant potential to enhance emergency responses

CMCC work significantly improves oil spill trajectory predictions by integrating artificial intelligence with traditional numerical ocean models. The research shows how to obtain more accurate and timely forecasts, enabling faster analyses and scenario testing, which could be a crucial development for emergency response efforts. This innovative framework also offers significant potential for

adaptation in other environmental forecasting systems that face similar challenges of uncertainty and limited observations.

For example, the approach could also be applied in atmospheric and general ocean circulation models, potentially reducing long-standing modeling biases and improving the representation of small-scale physical processes.

www.cmcc.it/article/ai-powered-oil-spill-prediction-system-improves-accuracy-by-up-to-25-with-significant-potential-to-enhance-emergency-responses



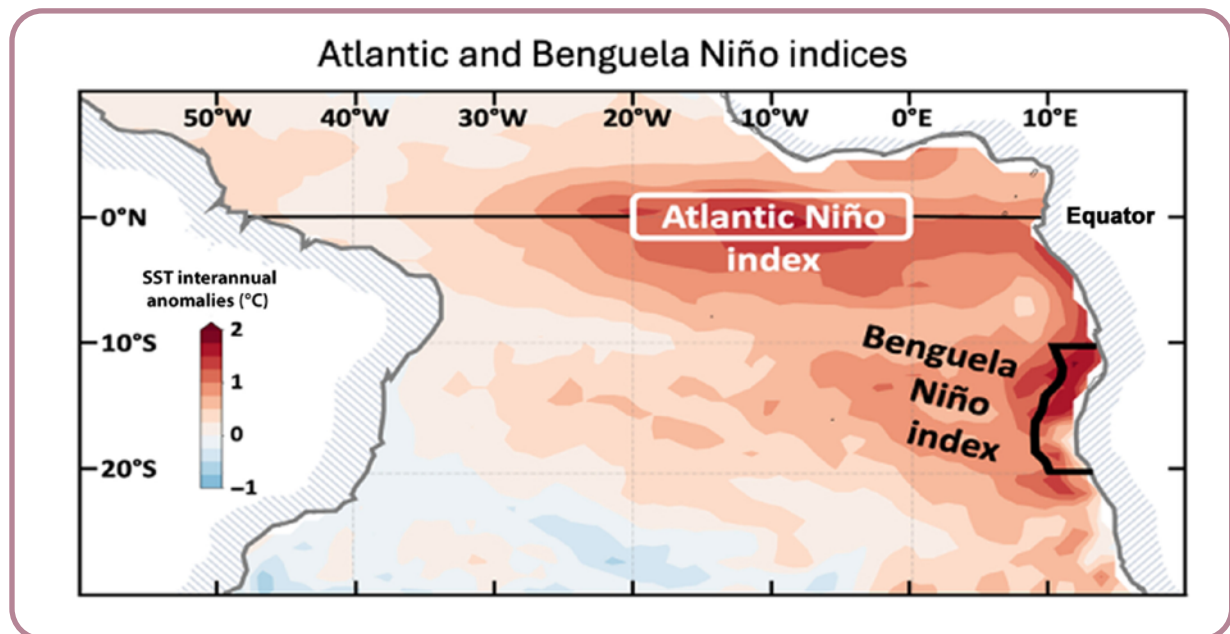
Oil slicks selected from August 24th to 27th, 2021 targeting the Baniyas oil spill accident in Syria. Each panel reports consecutive stages of the oil slick according to satellite retrievals and revisit times. Source: Improving oil slick trajectory simulations with Bayesian optimization, Ecological Informatics, Volume 91, 2025, 103368, ISSN 1574-9541, <https://doi.org/10.1016/j.ecoinf.2025.103368>

AI improves seasonal predictions of extreme tropical Atlantic events

Led by CMCC, the paper “Predicting Atlantic and Benguela Niño events with deep learning” harnesses artificial intelligence (AI) to predict extreme Atlantic Niño and Benguela Niño events up to 3 months in advance. This offers an unprecedented opportunity to safeguard marine ecosystems and local economies, whilst also laying the groundwork for future applications to other hard-to-predict phenomena worldwide.

The study involved developing a convolutional neural network (CNN), a type of deep learning algorithm trained on 90 years of historical ocean temperature data. The AI model demonstrated remarkable accuracy, predicting these extreme events up to 3–4 months ahead – with even 5 months for peak-season occurrences. This level of advance warning surpasses traditional climate models, which often struggle to capture the complex interactions between ocean and atmosphere in the tropical Atlantic.

www.cmcc.it/article/ai-improves-seasonal-predictions-of-extreme-tropical-atlantic-events



Map of ORAS5 interannual SST anomalies (°C) during the 2021 Atlantic and Benguela Niño events (May-August 2021). The ANi (20°W-0°E/3°S-3°N) and BNi (10°S-20°S/2°-wide coastal band) domains are outlined in white and black, respectively. Source: Predicting Atlantic and Benguela Niño events with deep learning. Sci. Adv.11, eads5185(2025). DOI: [10.1126/sciadv.ads5185](https://doi.org/10.1126/sciadv.ads5185)

Integrating AI and climate change scenarios for multi-risk assessment in the coastal municipalities of the Veneto region

Global warming is increasing the frequency and intensity of extreme events, putting coastal regions—where populations, economies, and ecosystems concentrate—at growing risk from hazards such as heavy precipitation, sea-level rise, and storm surges. This study proposes an integrated, two-tier machine-learning framework to assess multi-risk impacts in the coastal

municipalities of Veneto under present and future climate scenarios. Results show a rising risk trend already by mid-century, strongly influenced by sea-level rise and non-linear interactions among marine and atmospheric drivers, while end-century outcomes depend mainly on precipitation and sea-level rise.

Integrating AI and climate change scenarios for multi-risk assessment in the coastal municipalities of the Veneto region. *Sci Total Environ.* 2025 Feb 15;965:178586. doi: [10.1016/j.scitotenv.2025.178586](https://doi.org/10.1016/j.scitotenv.2025.178586)

Artificial intelligence for modeling and understanding extreme weather and climate events

In recent years, AI has had a significant impact on various fields, including Earth system sciences, by improving weather forecasting, model emulation, parameter estimation, and the prediction of extreme events. The latter presents specific challenges, such as developing accurate predictors from noisy, heterogeneous

data with small sample sizes and limited annotations. This paper reviews how AI is used to analyse extreme climate events (such as floods, droughts, wildfires, and heatwaves), highlighting the importance of developing accurate, transparent, and reliable AI models.

Artificial intelligence for modeling and understanding extreme weather and climate events. *Nat Commun* 16, 1919 (2025). <https://doi.org/10.1038/s41467-025-56573-8>

Earth system modeling: Predictive innovation

Predicting the climate further into the future and in finer detail. CMCC contributions to Earth system modeling in 2025 extend forecasts from seasons to years, sharpen the resolution at which extreme events are simulated, deliver climate datasets tailored to Italy, and help design the next generation of emission scenarios and the machine learning methods that refine them.

Long-term temperature extremes can now be predicted up to two years ahead with increased accuracy

Temperature extremes pose escalating threats to human health, energy systems, agriculture, and infrastructure, with their impacts extending across multiple sectors and requiring long-term planning and risk management strategies. While seasonal and decadal climate predictions have been operationally available for years, the intermediate multi-annual timescale – covering forecasts from one to several years ahead – has remained largely unexplored despite its high relevance for decision-makers and end users across various socioeconomic sectors.

This research led by a team of CMCC scientists and published in the journal *Environmental Research Letters*, addresses this gap by conducting a comprehensive global assessment of temperature extremes predictability on multi-annual timescales using the Community Earth System Model's Seasonal-to-Multiyear Large Ensemble prediction system. This study evaluates forecast skill for both warm and cold temperature extremes across all calendar seasons and regions worldwide, extending predictions up to two years ahead.

www.cmcc.it/article/long-term-temperature-extremes-predicted-two-years-ahead

Extreme events: New stride forward in high-resolution climate modeling

Understanding the connections between large-scale climate change and local impacts remains a significant challenge that the scientific community is trying to solve through the development of climate models that have higher horizontal resolution (i.e. reduced grid spacing) that better represent key components of the Earth system.

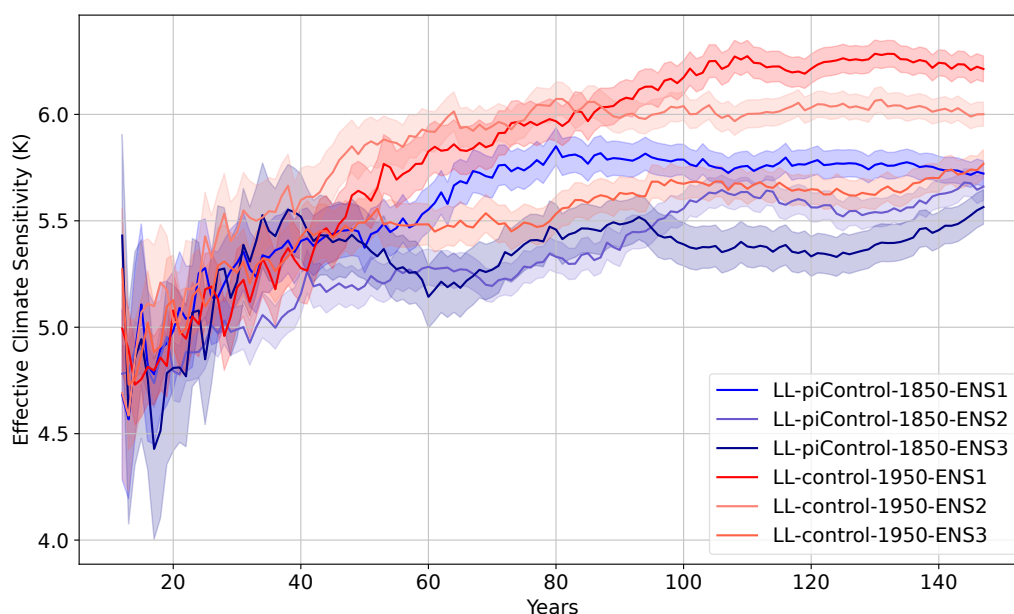
These models also provide useful information for impact studies, especially when talking about extreme events as certain processes – such as tropical cyclones and extreme precipitation for example – can be represented only with horizontal resolution that is high enough to capture the dynamic behind the process formation.

A new international effort to further develop

the Coupled Model Intercomparison Project (CMIP), involving CMCC, improves how we simulate and understand extreme weather events and their relationship to the climate system, making climate models more detailed and useful for decision-makers and placing CMCC at the forefront of global climate modeling efforts.

In addition to over 250 peer-reviewed manuscripts using the published High-ResMIP1 datasets, the results were also widely cited in Intergovernmental Panel on Climate Change (IPCC) reports and formed the basis of a variety of derived datasets, including tracked cyclones (both tropical and extratropical), river discharge, storm surge, and impact studies.

www.cmcc.it/article/extreme-events-new-stride-forward-in-high-resolution-climate-modeling



An illustrative example of model metrics enabled by new HighResMIP2 simulations. Source: High-Resolution Model Intercomparison Project phase 2 (HighResMIP2) towards CMIP7, Geosci. Model Dev., 18, 1307–1332, <https://doi.org/10.5194/gmd-18-1307-2025>, 2025.

Understanding and predicting annual to multi-decadal climate variations

In a world stricken by unprecedented climate anomalies and impactful weather extremes, there is an increasing need for reliable climate predictions on multiple forecast horizons. Even though large-ensemble predictions exhibiting statistically significant skill in various aspects have been developed, and are produced operationally by several centers globally, there are still important gaps in understanding the origins and the limits of the associated predictability. In particular, the fundamental drivers of historical and future climate variations are still, in part, poorly understood and often mis-represented in the climate models, limiting our confidence in predictions and projections. Hence, an integrated attribution and prediction is needed, in which the drivers of forecast signals are understood and model fidelity

is assessed regarding the representation of relevant processes, to improve confidence in predictions of regional climate extremes. This workshop focuses on climate variations on annual to multi-decadal timescales (1–30 years) and invites contributions on a wide range of topics, including: skill assessments of predictions; studies on the role of external forcings and climate variability; investigations on the mechanisms underlying specific aspects of predictability; prediction and predictability of climate extremes; evaluations of novel post-processing methods and new modelling techniques; studies on integrated attribution and prediction of climate and extremes. Around these themes, we also welcome studies employing explainable artificial intelligence and machine learning approaches.

www.cmcc.it/lectures_conferences/open-workshop-on-understanding-and-predicting-annual-to-multi-decadal-climate-variations

Italy's first high-resolution CMIP6 dataset now available

The first high-resolution CMIP6 dataset for Italy is now available, offering daily values for key climate variables, including temperature, wind speed, relative humidity and accumulated precipitation. Information that is crucial when implementing adaptation policies that rely on the latest scientific knowledge. Italy's complex topography makes it particularly challenging to capture climate variability on a local scale. However, the demand for detailed climate projections continues to increase with rising climate hazards and extreme events, highlighting the need for improved methodologies that can capture climate variables.

In an effort to support the scientific community in advancing climate studies at the local scale, CMCC has applied a statistical downscaling approach, which allows for a computationally efficient and robust refinement of climate projections. This method has proven effective in providing high-resolution climate data which CMCC has made widely accessible through the Data Delivery System (DDS), in terms of raw climate data, and Dataclime platform providing maps for key climate indicators (some of which were also used in the Italy's National Plan for Adaptation to Climate Change).

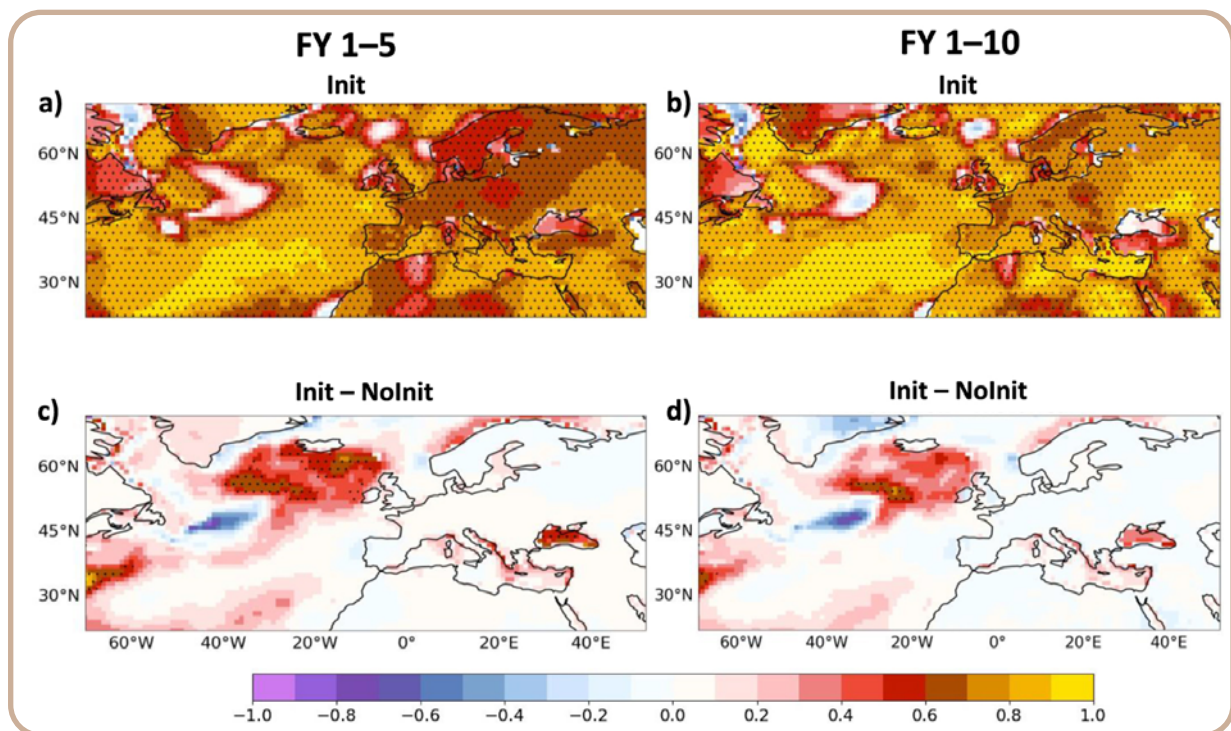
www.cmcc.it/article/cmccs-latest-tailored-climate-dataset-for-italy-now-available

Mediterranean wintertime precipitation: The advantages of decadal predictions

The Mediterranean region is highly vulnerable to climate change, with rising temperatures and decreasing rainfall posing risks to agriculture, water management, and disaster preparedness. In this context, accurately predicting climate trends 5 to 10 years in advance is essential so that decision-makers and stakeholders can adequately prepare. CMCC research reveals how decadal climate predictions (i.e., those focusing on the next decade) provide a more reliable and accurate tool for forecasting winter rainfall in Southern Europe and North Africa than traditional long-term climate predictions.

Decadal predictions also enable enhanced regional climate assessments through dynamical and statistical downscaling, as well as machine learning and artificial-intelligence methods, which could further improve climate risk evaluation, inform policy decisions, and support the development of targeted adaptation and mitigation strategies. The promising results of this study, therefore, emphasise the need to integrate decadal predictions into these efforts.

www.cmcc.it/article/mediterranean-wintertime-precipitation-the-advantages-of-decadal-predictions



Anomaly correlation coefficient (ACC) from Decadal predictions outperform climate projections in forecasting Mediterranean wintertime precipitation, 2025, Environ. Res. Lett. 20 034034 [DOI 10.1088/1748-9326/adb59e](https://doi.org/10.1088/1748-9326/adb59e)

LIQUIDICE: addressing the role of snow, ice and permafrost in the global climate system

CMCC contributes to Liquidice (Linking and QUantifying the Impacts of climate change on inland ICE, snow cover, and permafrost on water resources and society in vulnerable regions), the research project that joins an international team of expert cryospheric observers and modelers to assess the central role played by snow, ice and permafrost in the global climate system. The project has three main goals: to comprehensively assess climate-induced changes in inland ice components, including snow cover, glaciers, ice sheets, and permafrost; Improve the tools

necessary for accurately resolving these changes at appropriate scales; assess the impacts of these changes on water resources, examining their effects on hydropower, as well as other socio-economic consequences for local communities and stakeholders.

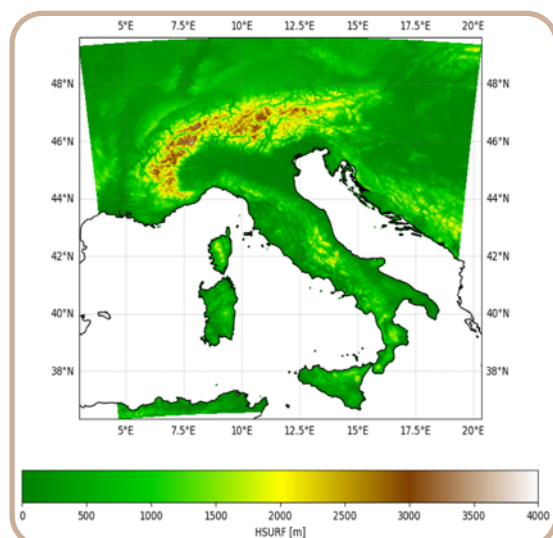


www.cmcc.it/projects/liquidice-linking-and-quantifying-the-impacts-of-climate-change-on-inland-ice-snow-cover-and-permafrost-on-water-resources-and-society-in-vulnerable-regionS

Uncovering spatial shift driven by climate change over the Italian Peninsula

This study is aimed at investigating the spatial-time pattern of extreme daily precipitation events on the entire Italian peninsula using a k-means cluster analysis that is applied to high-resolution climate projections. The clustering methodology identifies 13 different precipitation patterns and illustrates the decisive influence of complex orography, geographical location and maritime influence in shaping extreme precipitation regimes. The results show considerable seasonal fluctuations in precipitation patterns, with the highest intensities being observed in winter, especially in mountain regions. One of the remarkable changes includes intensification of precipitation in the Eastern Alps and northern Apennin, while a decreasing trend is observed in Sicily, Sardinia, and generally along the Tyrrhenian coast during the Summer.

Identifying recurring patterns of extreme daily precipitation using K-means algorithm: *Uncovering spatial shift driven by climate change over the Italian Peninsula, Weather and Climate Extremes, Volume 51, 2026, 100849, ISSN 2212-0947, <https://doi.org/10.1016/j.wace.2025.100849>*

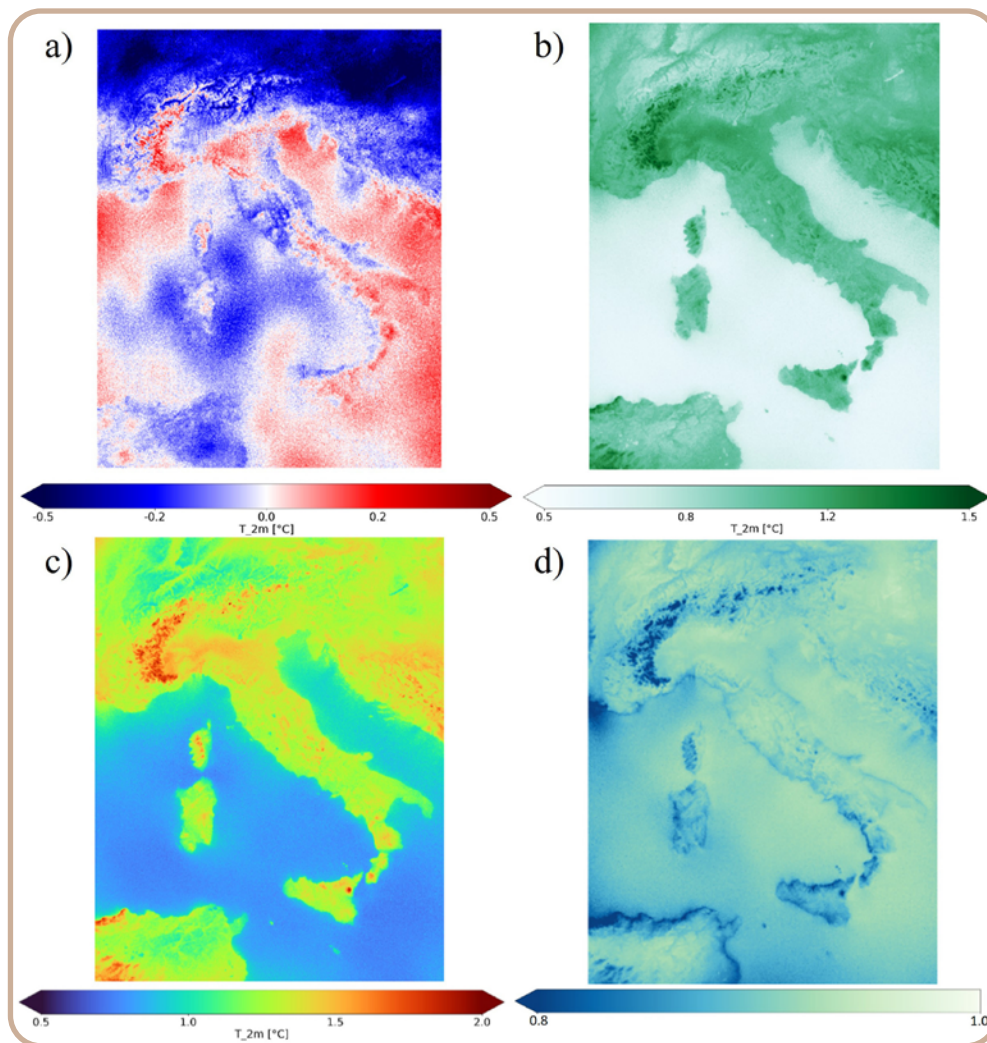


Maps of topography VHR-PRO_IT dataset. Source: *Uncovering spatial shift driven by climate change over the Italian Peninsula, <https://doi.org/10.1016/j.wace.2025.100849>*

A new conditional generative adversarial neural network approach for statistical downscaling of the ERA5 reanalysis over the Italian Peninsula

State-of-the-art General Circulation Models (GCMs) typically operate at a coarse spatial resolution, requiring a refinement to assess regional climate changes and their impacts. This weakness is mainly known for representing regional-scale topography and meteorological processes, particularly those responsible for extreme events. Dynamical downscaling methods are computationally demanding. In contrast, though computationally efficient, statistical approaches often sacrifice spatial

consistency. To address these limitations, this CMCC study introduces an innovative and robust Conditional Generative Adversarial Neural Network (cGAN) architecture for statistical downscaling, discussing the methodology, advantages, and contributions to refining predictions at a finer scale. The results obtained show the cGAN's architecture presented accurately reproduces the patterns, value range, and extreme values generated by dynamical models for the 2-m temperature over the Italian Peninsula.



Maps of error metrics. Source: A new conditional generative adversarial neural network approach for statistical downscaling of the ERA5 reanalysis over the Italian Peninsula, *Environmental Modelling & Software*, Volume 188, 2025, <https://doi.org/10.1016/j.envsoft.2025.106427>

Oceans, marine ecosystems & coastal resilience

It is about predicting ocean conditions. It is about using the best available technologies for timely and effective analyses. And it is about people: those who live on the coasts, those developing activities and economies at sea, and those who need scientific information to make decisions. CMCC work on oceans and coastal resilience maps flood hazard down to the single dune breach, traces where oil spills travel, projects climate for small islands, and uses AI to chart the seagrass meadows that protect shorelines, alongside the legal and participatory tools that put this knowledge to work in coastal communities.

Protecting those most vulnerable: High-resolution projections of future climate for small islands and other areas at high risk

Complex orography and dependence on localized climate patterns can hinder projections of future climate and the identification of adaptation and mitigation measures for vulnerable territories such as the Macaronesian archipelagos and other small islands. A study, led by CMCC

researchers, uses innovative approaches to provide detailed and coordinated climate information over small islands, which in turn helps support the development of adaptation strategies and mitigation measures, which are crucial for safeguarding these regions from the impacts of climate change.

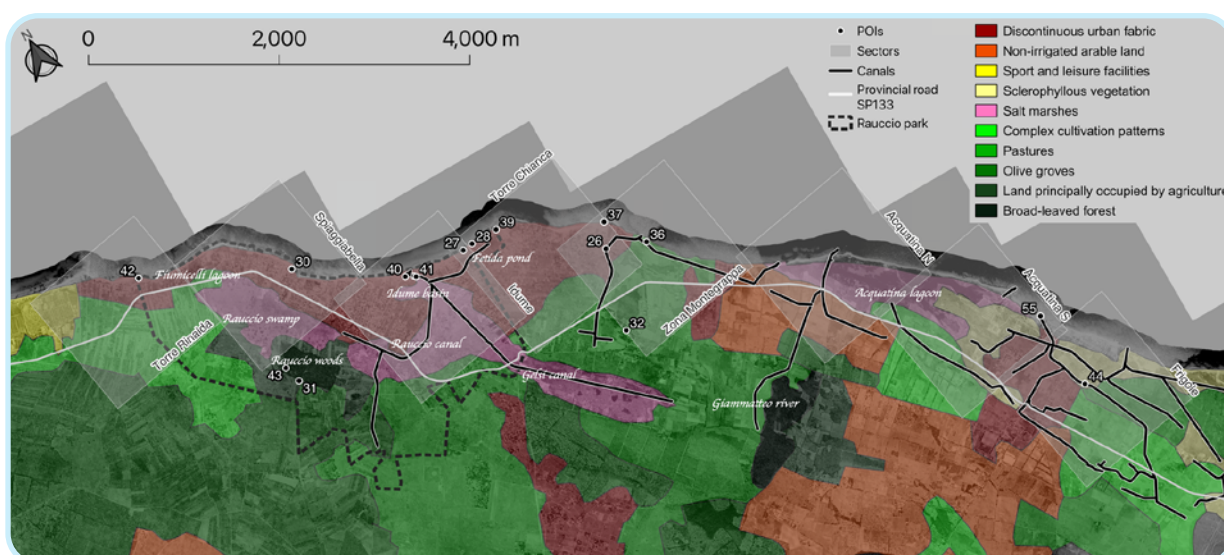
www.cmcc.it/article/protecting-those-most-vulnerable-cmcc-presents-high-resolution-projections-of-future-climate-for-small-islands-and-other-areas-at-high-risk

Where coasts are most vulnerable to flooding and how to protect them: A high-resolution map

A CMCC-led study predicts how flooding may expand in a specific area as sea levels rise, offering actionable guidance for urban planning and coastal resilience. The research identifies where seawater is most likely to pass through gaps in dunes and inundate urban and agricultural areas during extreme sea level events.

The findings pinpoint the areas most at risk, highlighting specific streets, former lagoons, and compromised dune belts where flooding could occur. The study also offers concrete recommendations for preserving dune systems, maintaining drainage canals, and integrating flood risk into long-term urban planning, providing crucial guidance for local authorities, stakeholders, and residents.

www.cmcc.it/article/protecting-those-most-vulnerable-cmcc-presents-high-resolution-projections-of-future-climate-for-small-islands-and-other-areas-at-high-risk



Overview map with indication of the POI of PUG's draft. Source: Coastal flood hazard for Lecce, Italy, from breaches in the dunes. *Journal of Water and Climate Change* 2025; jwc2025764. doi: <https://doi.org/10.2166/wcc.2025.764>

ADRIACLIMPlus: Stakeholder engagement of Coastal Municipalities in Puglia

The first technical meeting with coastal municipalities that have joined the Covenant of Mayors for Climate and Energy was held on May 19, 2025, at the headquarters of the Puglia Region, as part of the AdriaClimPlus project, co-funded by the Interreg Italy-Croatia 2021–2027 Programme. The event, organized by the Puglia Region, marked

a significant opportunity to engage in dialogue with local authorities, aiming to support municipalities in the drafting and implementation of their Sustainable Energy and Climate Action Plans (SECAPs) and to promote shared strategies for climate change adaptation.

www.italy-croatia.eu/web/adriacimplus/ettaglio?articleId=26580080&groupId=7574637

The fate of oil spills in the Mediterranean Sea

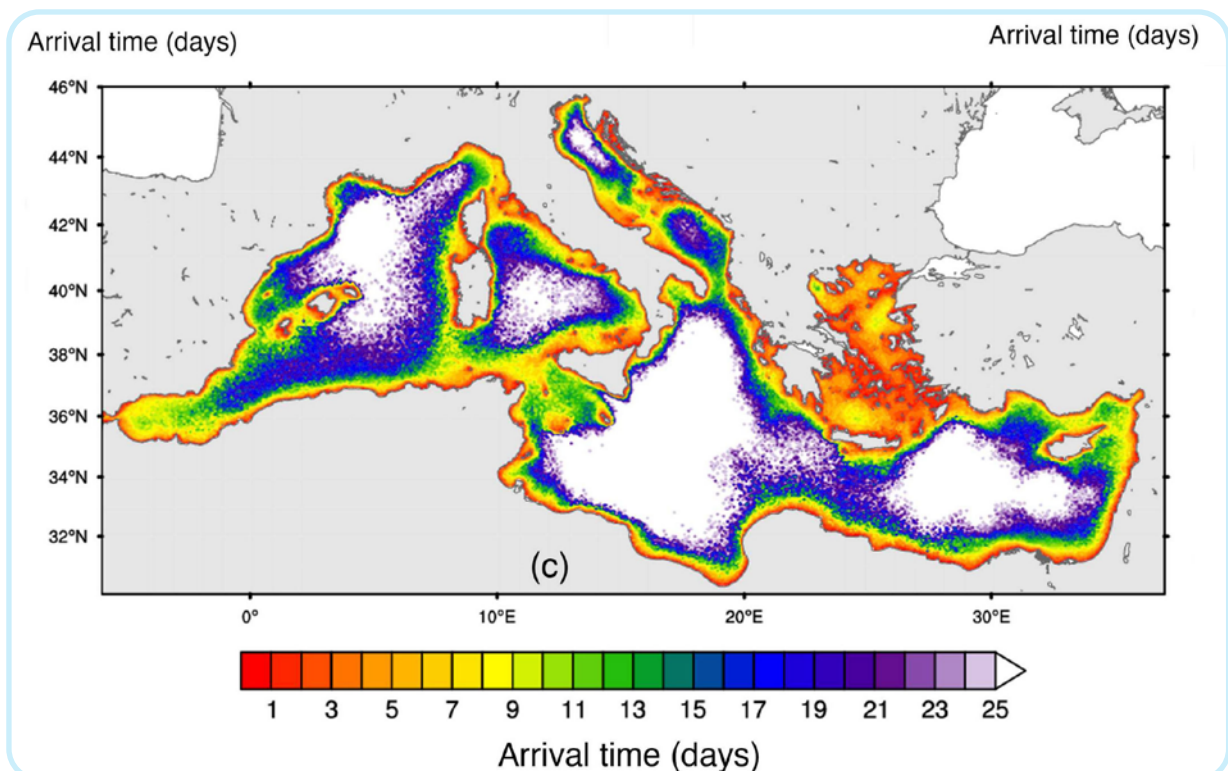
The routes that oil slicks take in the Mediterranean, as a result of accidents at sea, are no longer a mystery. CMCC uses high-resolution numerical models to plot the trajectories and fate of oil slicks resulting from accidental spills.

The study uses marine circulation models to identify the most vulnerable areas of the Mediterranean basin. These areas include the Strait of Sicily, the northern Adriatic, and the eastern part of the basin, as they are at the greatest risk of environmental impacts. The analysis considered various spill scenarios and took seasonal weather and sea conditions into account. The analysis considered various spill scenarios and took seasonal weather and sea conditions into account. The study provides useful

tools for authorities to plan rapid, targeted interventions in case of an emergency. With this piece of research, CMCC provides useful tools for authorities to plan rapid, targeted interventions in case of an emergency, because the question is not if there will be an oil spill in the Mediterranean, but rather, how severe the consequences will be.

The research was conducted as part of the NECCTON project, which is funded by the European Commission's Horizon Europe RIA program, with the aim of developing new Copernicus products that include information on pollutants, environmental pressures, and the distribution of species that contribute to biodiversity or the economies of the sea.

www.cmcc.it/article/an-international-study-analyzes-the-fate-of-oil-spills-in-the-mediterranean-sea



The arrival times of the oil spill on the Mediterranean coasts. Source: Model-based insights into pathways and fate of oil spills in the Mediterranean Sea, Marine Pollution Bulletin, <https://doi.org/10.1016/j.marpolbul.2025.118061>

CoastPredict and decade collaborative centre for coastal resilience annual events

CMCC Foundation hosted the annual events of the CoastPredict UN Ocean Decade Programme and the Decade Collaborative Centre for Coastal Resilience (DCC-CR) in Lecce from February 3rd to 7th, 2025.

At the event, more than 100 scientists from around the world gathered to discuss the latest solutions and knowledge for protecting coasts and coastal economies from climate change events. CoastPredict, a United Nations Ocean Decade program, and UNESCO's Decade Collaborative Centre for

Coastal Resilience (DCC-CR) aim to transform science and technology to improve coastal hazard prediction and promote climate adaptation. To address challenges such as continued sea level rise and the impacts of coastal changes, the research community is leveraging technological innovations such as big data, cloud, and artificial intelligence, along with the creation of international scientific networks and communities to monitor and develop global solutions.



www.cmcc.it/lectures_conferences/coastpredict-and-decade-collaborative-centre-for-coastal-resilience-annual-events

Fostering coastal resilience in Europe using climate litigation as an empowering legal tool: A toolkit for civil society in coastal areas

Fostering Coastal Resilience in Europe Using Climate Litigation as an Empowering Legal Tool: A Toolkit for Civil Society in Coastal Areas was produced by the Sea Legal Rise project, a collaboration between the CMCC Foundation and the Sciences Po Paris Law Clinic during the 2024–25 academic year.

The document draws on insights from climate litigation to support civil society stakeholders in navigating the evolving legal dimensions of climate change. It highlights key aspects that delineate the profile of this litigation, uncovering the main actors, typical legal grounds—from international to domestic and local norms—and their related claims.

www.cmcc.it/publications/fostering-coastal-resilience-in-europe-using-climate-litigation-as-an-empowering-legal-tool-a-toolkit-for-civil-society-in-coastal-areas

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The big picture: appraising the risk of cumulative impacts on seagrass meadows in the Mediterranean Sea

Human well-being and societal resilience are deeply tied to marine coastal ecosystems, yet they are threatened by multiple endogenic and exogenic pressures. This study implements a MACHINE leaRNING-based Cumulative Impact Assessment (MARITIME) model to better understand the risk of cumulative impacts on seagrass meadows in the Mediterranean Sea and their cascading effects on the capacity to

provide ecosystem services for this vital blue carbon ecosystem under a reference state (2017) and future climate change scenarios, which encompass various levels of global warming, from moderate to more extreme. The results indicate a shrinkage of seagrass meadows, particularly at lower depths, and a corresponding reduction in ecosystem services capacity by the years 2050 and 2100.

www.sciencedirect.com/science/article/pii/S1574954125004704

Multi-criteria evaluation of blue nature-based solutions: Suitability of *Posidonia oceanica* in the Mediterranean Sea under climate scenarios

Posidonia oceanica meadows are among the Mediterranean's most valuable natural assets, filtering water, stabilising coastlines and storing carbon. But where will they still be able to do so as the sea warms? This study answers that question at eco-region scale, combining GIS analysis with an Analytic Hierarchy Process to weigh geomorphological, water quality and climatic criteria into a single suitability

map, for present conditions and for RCP4.5 and RCP8.5 in 2050 and 2100. Barely a quarter of the study area is suitable or very suitable today, and that share falls sharply under future scenarios, with thermal stress overtaking water quality as the dominant constraint. By showing where meadows can still thrive, the work turns a conservation question into a planning tool for marine managers.

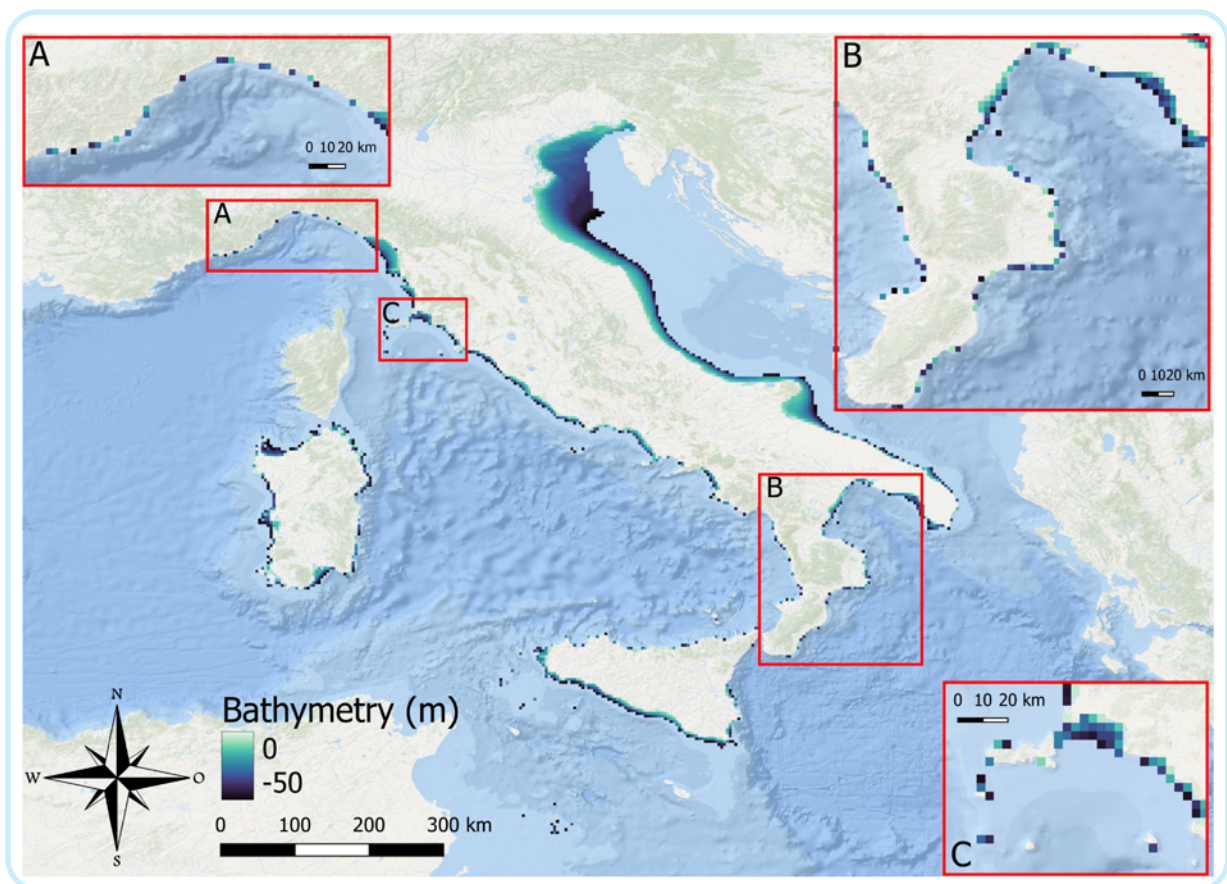
www.sciencedirect.com/science/article/pii/S0964569125004958

Leveraging artificial intelligence methods to map seagrass ecosystems in Italian Seas: Tackling human impact and climate change

Marine coastal ecosystems (MCEs) are crucial for human health, playing a key role in climate change adaptation. However, MCEs are globally threatened by environmental and human pressures. This study applies Graph Neural Networks (GNNs) to model seagrass distribution in the Italian Seas using a dataset of spatial units with environmental, climatic, and anthropogenic factors harmonised at 4 km resolution. GNN models, including Graph

Convolutional and Attention Networks, were benchmarked against traditional machine learning methods: Random Forest, Support Vector Machine, and Multi-Layer Perceptron. These insights support the implementation of blue Nature-based Solutions (NbS) to protect and restore seagrass habitats, aiding biodiversity conservation and climate change mitigation while guiding effective policymaking.

<https://www.sciencedirect.com/science/article/pii/S1364815225003627>



Case study area corresponding to a bathymetry layer up to 50 m depth; Focus A: Ligurian coast; Focus B: Calabria, Basilicata and part of Puglia coasts; Focus C: Elba Island and part of the Tuscan coast. Source: Leveraging artificial intelligence methods to map seagrass ecosystems in Italian Seas: Tackling human impact and climate change. *Environmental Modelling & Software* <https://doi.org/10.1016/j.envsoft.2025.106678>

Climate hazards: Understanding land, atmosphere, and sea to manage risk

Heat, fire, water, ground: climate change is reshaping the hazards that threaten European lives and assets. CMCC research pushes heatwave warnings weeks ahead of summer, identifies what triggers Mediterranean marine heatwaves, explains why certain valleys trap storms into catastrophic floods, projects global fire weather to the end of the century, traces the growing overlap between heatwaves and megafires, and reviews how a warming climate will destabilize slopes. With the E3CI climate service, this work turns hazard science into the monitoring and early warning that civil protection needs.

Integrated fire management as an adaptation and mitigation strategy to altered fire regimes

Altered fire regimes are a global challenge, increasingly exacerbated by climate change, which modifies fire weather and prolongs fire seasons. These changing conditions heighten the vulnerability of ecosystems and human populations to wildfire impacts on the environment, society, and the economy. The rapid pace of these changes exposes significant gaps in knowledge,

tools, technology, and governance structures needed to adopt informed, holistic approaches to fire management that address both current and future challenges. Integrated Fire Management is an approach that combines fire prevention, response, and recovery while integrating ecological, socio-economic, and cultural factors into management strategies.

Integrated fire management as an adaptation and mitigation strategy to altered fire regimes. Commun Earth Environ, <https://doi.org/10.1038/s43247-025-02165-9>

Heatwave predictions months in advance with machine learning: A new study delivers improved accuracy and efficiency

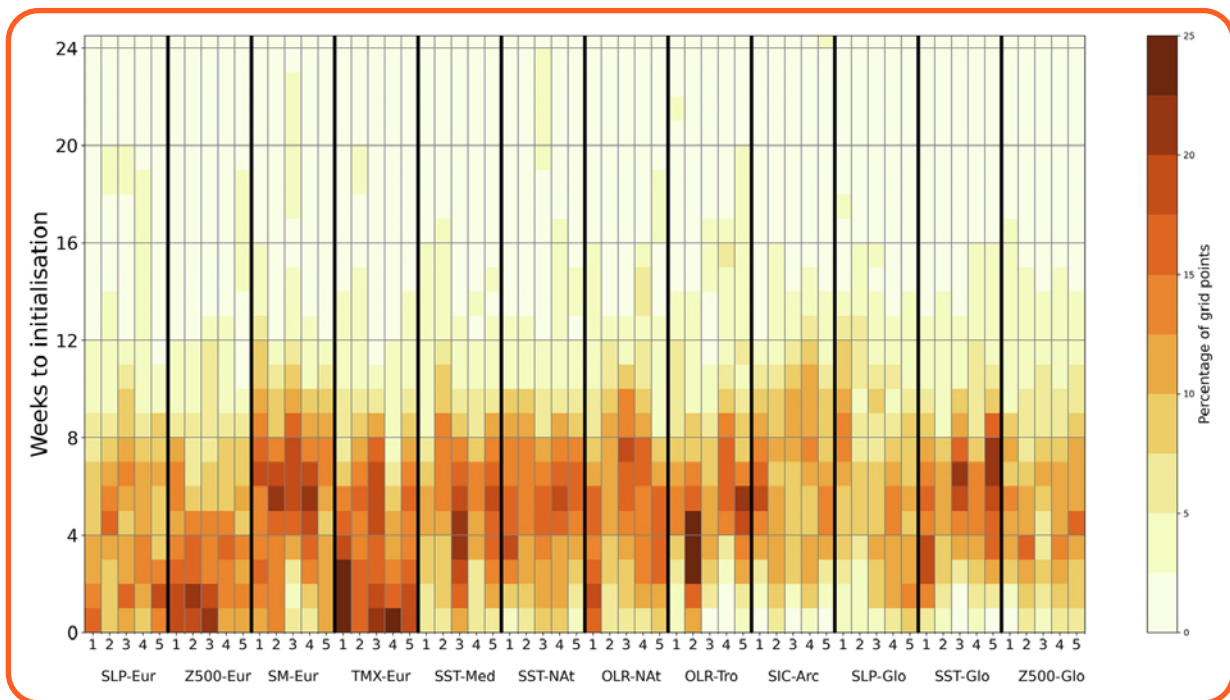
The study “Feature selection for data-driven seasonal forecasts of European heatwaves”, published in Nature Communications Earth & Environment, showcases CMCC’s leadership in integrating cutting-edge artificial intelligence with climate science to address one of Europe’s most pressing climate challenges: heatwaves.

It demonstrates how machine learning (ML) and artificial intelligence (AI) techniques are revolutionizing climate science by enabling more accurate, cost-effective predictions than traditional approaches. Furthermore, where conventional dynamical forecasting systems require massive computational

resources and struggle with reliability in northern European regions, this data-driven approach offers an alternative.

Heatwaves cause devastating impacts across Europe, including agricultural losses, energy usage spikes, health crises, and increased mortality. Recent deadly events in 2003, 2010, and 2022 underscore the urgent need for early warning systems that can help dampen the impacts of heatwaves. This is particularly important as climate projections suggest further intensification of heatwaves in the coming decades, making accurate seasonal forecasting crucial for saving lives.

www.cmcc.it/article/heatwave-predictions-months-in-advance-with-machine-learning-a-new-study-delivers-improved-accuracy-and-efficiency



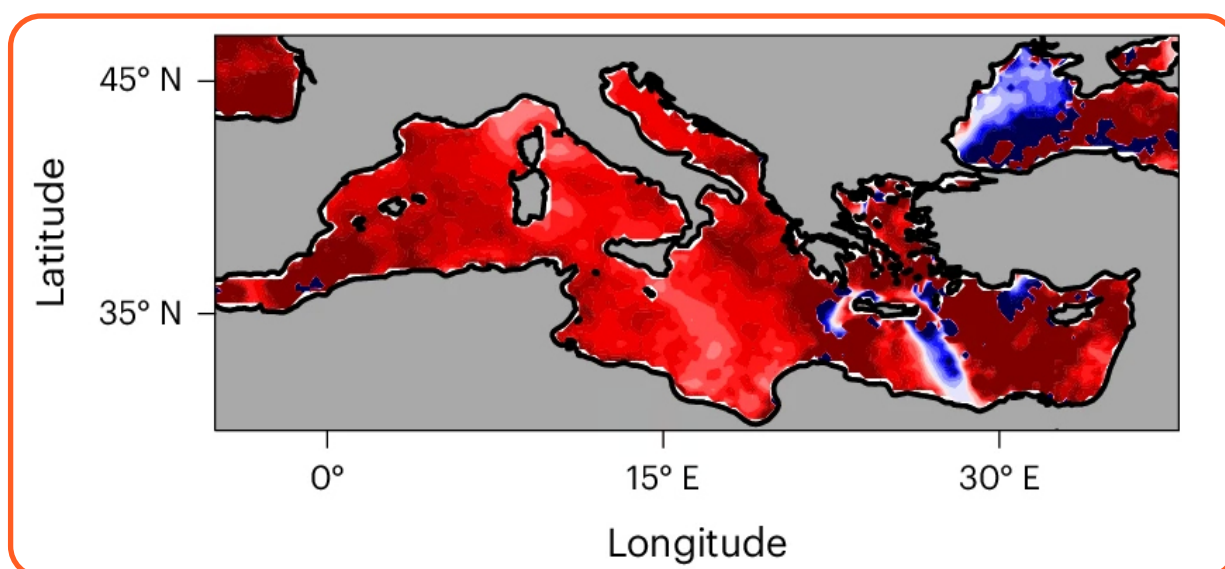
The matrix displays the percentage of grid points with respect to the entire European domain in which the cluster and time-lag appear in the optimal solutions. Initialisation is on May 1st. Variable labels: mean sea level pressure (SLP), geopotential height at 500 hPa (z500), soil moisture (SM), daily maximum 2 m temperature (TMX), sea surface temperature (SST), outgoing longwave radiation (OLR), and sea ice concentration (SIC). Source: Feature selection for data-driven seasonal forecasts of European heatwaves. Commun Earth Environ, <https://doi.org/10.1038/s43247-025-02863-4>

New research reveals the spark that ignites Mediterranean marine heatwaves

The Mediterranean Sea is particularly susceptible to marine heatwaves – such as the record breaking 2022 heatwave which was characterized by anomalously high sea surface temperatures – due to the interplay of air-sea heat fluxes and local oceanographic processes, leading to significant impacts on marine ecosystems and coastal communities. This study, led by CMCC, brings the scientific community one step closer to identifying the

driving forces behind these events. Analyzing over hundreds of marine heatwave events identified through advanced satellite data and clustering analysis, the study shows that persistent subtropical ridges – intrusions of warm air from over the African continent into Europe, often informally referred to as African anticyclones – do far more than simply raise air temperatures.

www.cmcc.it/article/new-research-reveals-the-spark-that-ignites-mediterranean-marine-heatwaves



Source: Mediterranean summer marine heatwaves triggered by weaker winds under subtropical ridges. *Nat. Geosci.* <https://doi.org/10.1038/s41561-025-01762-9>

Climate change and landslide hazard in stiff clays and clay shales

Recently, the effects of climate change on the atmospheric patterns are becoming more and more evident. Quantifying the potential impact on communities and assets is thus becoming a priority. Certainly, a major issue to consider is the risk of landslide, a challenging and still unsolved topic. The slope response to the effects of climate change is in fact affected by the concurrent role of a

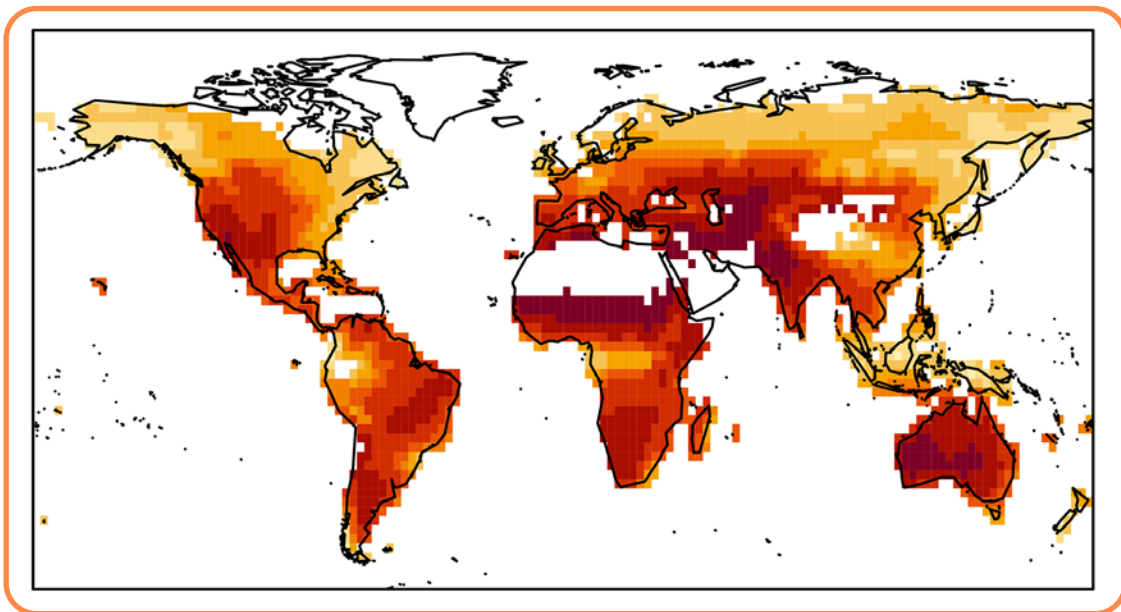
variety of weather- and soil-related factors that strongly affect any problem solution. The paper focuses on the potential consequences of changing rainfall and evapotranspiration regimes on landslide hazard in stiff clays and clay shales, a major problem all along the Italian Apennines chain where slope movements are a typical feature of the landscape.

Climate change and landslide hazard in stiff clays and clay shales, Landslides, <https://doi.org/10.1007/s10346-025-02487-x>

Future impacts of climate change on global fire weather: Insight from weighted CMIP6 multi-model ensembles

Climate is a key driver of spatiotemporal variability in wildfire regimes. Increasingly warmer temperatures and changes in precipitation patterns are linked to an increase in fire danger across the world. There is therefore a need to develop the most reliable projections of future climate-driven fire danger to enable decision-makers and forest managers to prepare for and respond to future fire events. Earth system

model (ESM) simulations are the foundation for understanding future changes in fire-conductive weather associated with a warming world. Fire weather projections have typically been expressed by a single model or through a multimodel mean, with the models' relative strengths and weaknesses rarely taken into consideration. This research highlights the potential benefit to targeted prevention strategies and long-term fire management.



CMIP6 unweighted multimodel mean for SSP5-8.5 and (b) period 2041-60. Source: Future Impacts of Climate Change on Global Fire Weather: Insight from Weighted CMIP6 Multimodel Ensembles, *Journal of Climate*, <https://doi.org/10.1175/JCLI-D-24-0540.1>

The growing link between heatwaves and megafires: evidence from southern Mediterranean countries of Europe

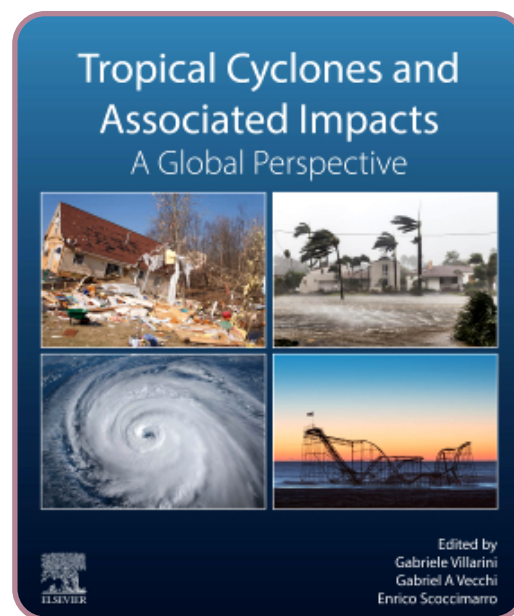
The increasing trend of extreme wildfire events is concerning national agencies at multiple levels because of their potential impacts on ecosystem services and the capacities of emergency management systems. This concern is exacerbated by the increasing occurrence of heatwaves (HWs) which intensify the impacts of concomitant events. The paper assesses recent trends

on HWs and megafires and the spatial and temporal co-occurrence of these events. The team of scientists focused on the most fire-prone countries in Europe, i.e., Portugal, Spain, France, Italy and Greece, and considered varying fire size thresholds for defining megafires. The analysis shows that HWs and megafires have increased over the last 16 years, particularly larger ones.

The growing link between heatwaves and megafires: evidence from southern Mediterranean countries of Europe, *Natural Hazards*, <https://doi.org/10.1007/s11069-025-07545-0>

Tropical cyclones and associated Impacts: A global perspective

Tropical Cyclones and Associated Impacts: A Global Perspective provides a one-stop-shop for readers interested in the impacts of tropical cyclones, capturing the convergence of knowledge across disciplines and fields. Chapters in this book provide a coherent structure that reflects the hazards associated with these storms (e.g., storm surge, inland flooding and heavy rainfall, damaging winds) and their impacts on many spheres of our lives (e.g., energy, public health). This book is geared towards readers who have an interest in tropical cyclones, with a broad appeal to different audiences ranging from academia to federal and state agencies dealing with these storms.



www.cmcc.it/publications/tropical-cyclones-and-associated-impacts-a-global-perspective

European extreme events climate index (E3CI): a climate service for weather-induced hazard

In recent years, Europe has experienced a notable increase in the frequency and severity of extreme weather events, including heatwaves, floods, droughts, storms, and wildfires. These events have had profound impacts on human life, infrastructure, ecosystems, and economies, highlighting the urgent need to develop effective climate services to prevent, manage and respond in a timely manner to associated impacts. CMCC

contributed to the European Extreme Climate Index (E3CI), the first index developed in Europe to monitor and manage the impact of extreme weather events. In more detail, the index is intended to provide a useful measure of how weather extremes are changing to support the assessment of changes in risk and to provide crucial support for estimating and modeling climate-related insurance and financial risks.

European extreme events climate index (E3CI): a climate service for weather-induced hazard, *Frontiers in Climate - Climate Services*, <https://doi.org/10.3389/fclim.2025.1628534>

Energy and decarbonization

Net zero is no longer a question of whether the technology exists, but of how the transition is designed. CMCC research shows that electrification, efficiency, and changes in how we travel and heat our homes could cut emissions in buildings and transport by up to 91% by 2050, and maps how electricity and hydrogen will couple Europe's energy sectors. On the economic side, modelling finds that green industrial policy paired with a mild carbon tax can decarbonize fast while creating jobs and preserving stability. Open modelling platforms keep that evidence verifiable.

Workshop on artificial intelligence for carbon

Climate change is one of the defining challenges of our time, driven by the accumulation of greenhouse gases — particularly carbon dioxide— in the atmosphere. At the heart of this challenge lies the global carbon cycle, a dynamic system that regulates the flow of carbon between the Earth's atmosphere, oceans, ecosystems, and geological reservoirs. While natural processes have maintained this balance for millennia, human activities—from fossil fuel combustion to land-use changes—now release nearly 40 gigatons of CO₂ annually, overwhelming the planet's natural sinks and accelerating global warming. To mitigate and adapt to these changes, we need unprecedented innovation in how we monitor, model, and manage carbon fluxes and their interactions with the climate and socio-economic systems. The Workshop on Artificial Intelligence for

Carbon explored the potential of Artificial Intelligence (AI) in advancing carbon science and its benefits to society. The main objective of the meeting was to discuss the latest AI carbon science, identify research gaps and priorities and lay out a vision for the future of AI science to serve society. A final brainstorming session identified research priorities and defined the building blocks of a position paper summarizing the needs across the six thematic sessions.



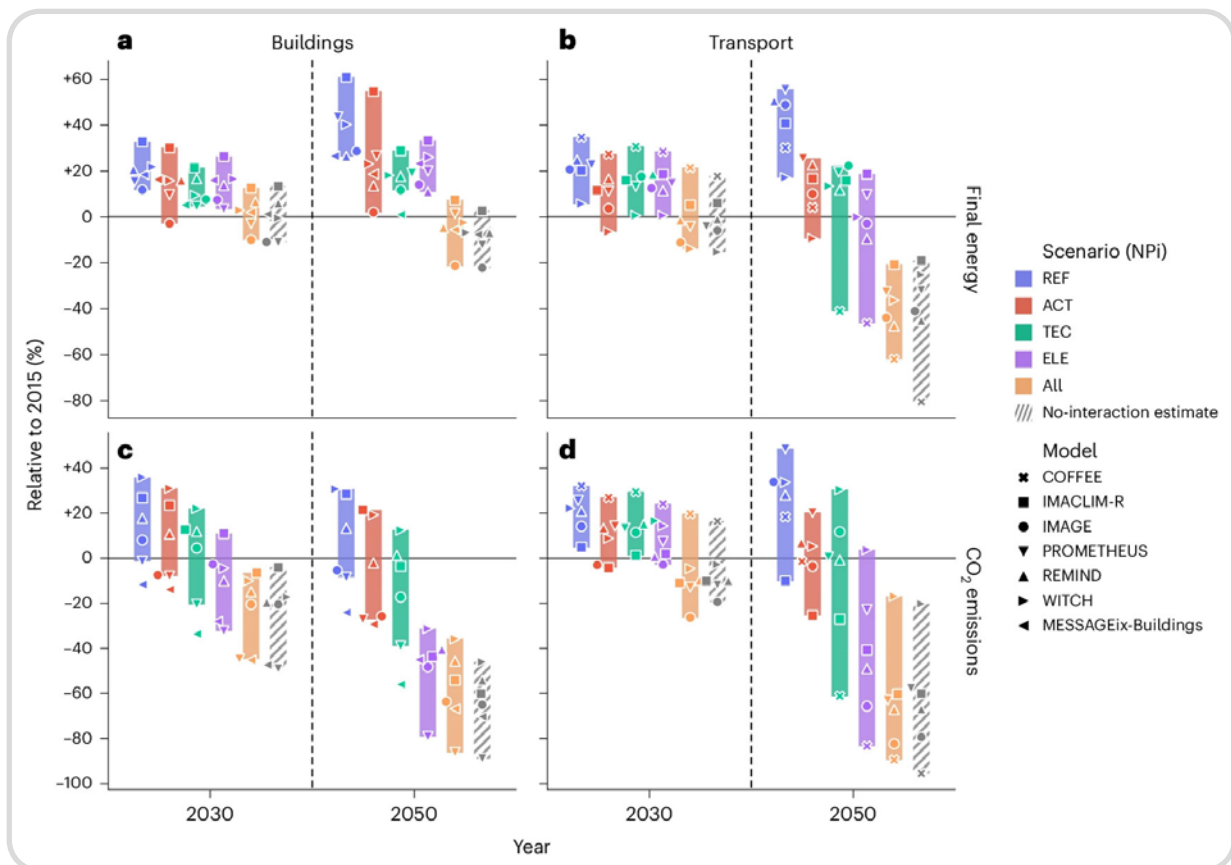
www.cmcc.it/lectures_conferences/icc-program-workshop-on-artificial-intelligence-for-carbon

Cutting emissions in buildings and transport: Key strategies for 2050

The study, published in *Nature Energy*, highlights that electrification alone—such as switching to electric vehicles and heat pumps—could reduce direct emissions by 45-77% in buildings and 22-86% in transport by 2050. Combining electrification with efficiency improvements and behavioral changes could further reduce emissions, achieving reductions of 51-85% for buildings and 37-91% for transport.

The paper titled “Demand-side strategies

enable rapid and deep cuts in buildings and transport emissions to 2050”—and co-authored by researchers from CMCC—also shows that this multi-strategy approach could lower overall electricity demand by 8-33% per year, making the transition more cost-effective and reducing strain on power grids. The results are in line with global climate goals and demonstrate that integrating these strategies could significantly contribute to limiting global warming to 1.5°C by 2050.

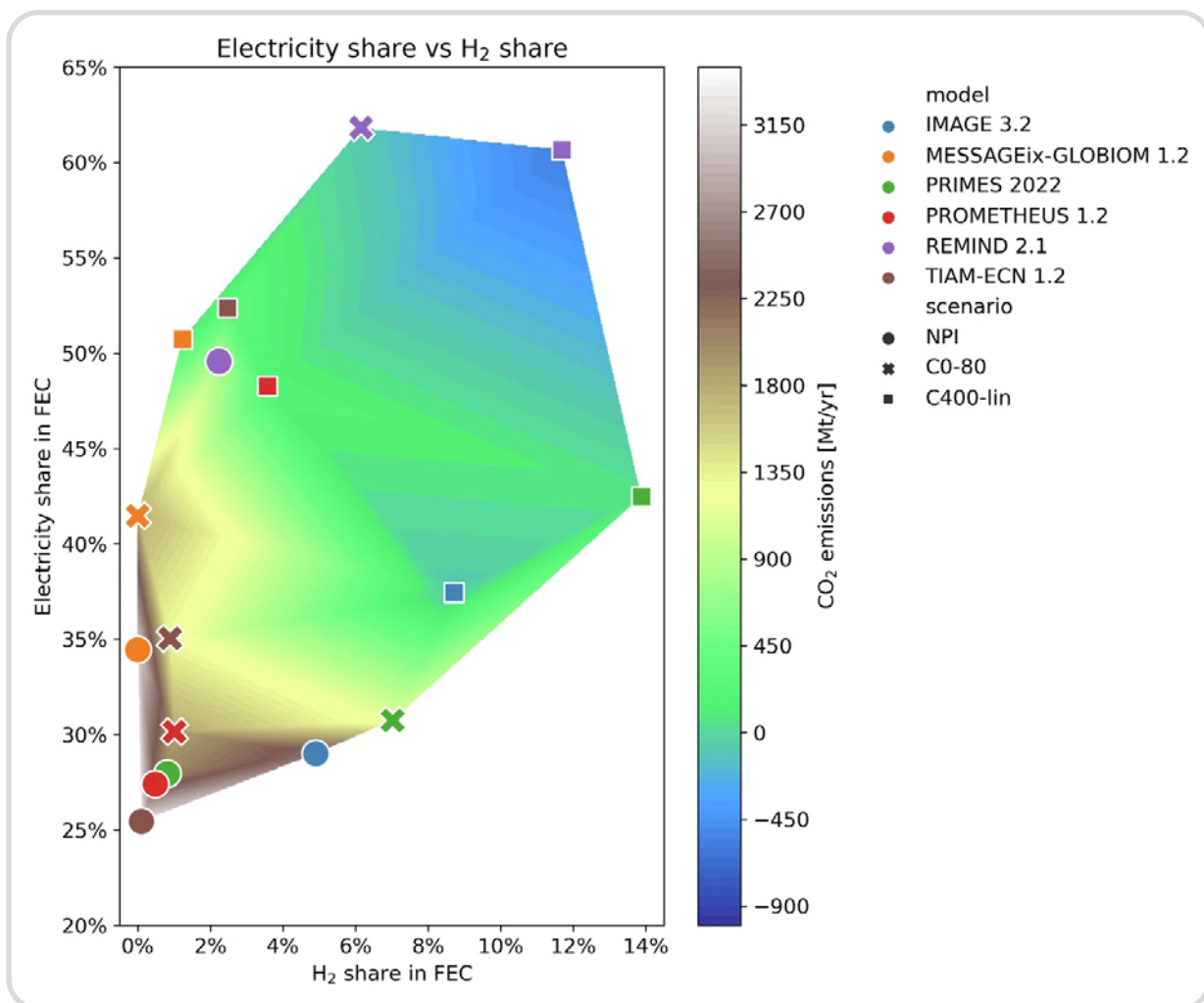


Change in global final energy use and direct CO₂ emissions from fuel combustion in the buildings and transport sectors. Source: Demand-side strategies enable rapid and deep cuts in buildings and transport emissions to 2050. *Nat Energy*. <https://doi.org/10.1038/s41560-025-01703-1>

Electricity- and hydrogen-driven energy system sector-coupling in net-zero CO₂ emission pathways

Electricity- and hydrogen-based sector coupling contributes to realizing the transition towards greenhouse gas neutrality in the European energy system. Energy system and integrated assessment models show that, to follow pathways compatible with the European policy target of net-zero greenhouse gas emissions by 2050, large amounts of renewable electricity and H₂ need to be generated, mostly by scaling up wind and solar energy production capacity. With a set of such models, under jointly adopted deep decarbonisation scenario assumptions, the authors of the paper show that the

ensuing direct penetration of electricity and H₂ in final energy consumption may rise to average shares of around 60% and 6%, respectively, by 2050. The study also demonstrates that electrification proves the most cost-efficient decarbonisation route in all economic sectors, while the direct use of H₂ in final energy consumption provides a relatively small, though essential, contribution to deep decarbonisation. The variance observed across results from different models reflects the uncertainties that abound in the shape of deep decarbonisation pathways, in particular with regard to the role of H₂.



Electricity versus H₂ shares (%) in final energy consumption (FEC) (scatterplot), and CO₂ emissions (contour plot) in 2050 across models and scenarios. Source: Electricity- and hydrogen-driven energy system sector-coupling in net-zero CO₂ emission pathways. Nat Commun. <https://doi.org/10.1038/s41467-025-56365-0>

Towards an open model intercomparison platform for integrated assessment models scenarios

The majority of scenarios in the IPCC database are generated by integrated assessment models (IAMs) and come from model intercomparison projects. However, the way in which the current model intercomparison projects are organized is not open to all IAM teams worldwide. This paper proposes a transparent and inclusive platform that is open to anyone with an IAM regarding protocols development, scenario

submissions and results evaluation. The authors discuss the challenges of this approach, particularly human resources and financial support, and identify diversity in the level of model capability and quality of model output as possibly critical issues. Despite such challenges, the IAM community and its scientific activities can improve and benefit from the proposed platform, ultimately contributing to better climate policymaking.

Towards an open model intercomparison platform for integrated assessment models scenarios. Nat. Clim. Chang. <https://doi.org/10.1038/s41558-025-02462-3>

Decarbonization with economic growth and job creation

An ensemble of green industrial policies and targeted subsidies, coupled with a mild carbon tax, is the most promising strategy to support an orderly transition towards achieving the Paris Agreement targets. Such a policy package can be designed to have a neutral effect on public finances and boost job creation, while preserving economic stability and income growth.

The authors of the paper provide some recommendations for policy makers:

- Green industrial policies should be implemented to achieve rapid decarbonization while maintaining high employment and macro-financial stability.

- Combining energy and industry regulations with subsidies for green research and development and renewable deployment ensures rapid and orderly mitigation.

- Carbon taxes should be mild, mostly enabling green public spending, discouraging fossil investments and accelerating renewable deployment, especially when tax rates are higher in hard-to-abate sectors.

- Sectors with long investment cycles (such as heavy industry) should be targeted early to prevent decarbonization bottlenecks and the lock-in of carbon-intensive assets, even if initial costs are higher.

Decarbonization with economic growth and job creation. Nat Sustain. www.nature.com/articles/s41893-025-01679-6

Policies for rapid decarbonization with steady economic transition and employment creation

A large number of countries have by now pledged to undertake policies aimed at reducing greenhouse gas emissions and achieving carbon neutrality. However, evidence for a suitable policy package to induce an effective and orderly transition is scarce. Recent studies suggest that abrupt and aggressive climate policies may trigger significant transition risks, potentially leading to macroeconomic imbalances. In this study, the authors extend a macro-financial agent-based integrated assessment model grounded in evolutionary economics and complex systems science to test a variety of policy packages aimed at rapidly decarbonizing the global economy and study

how they affect job creation and economic stability. The research shows that carbon taxation alone is self-defeating: its role in internalizing environmental costs while triggering rapid decarbonization finds little support. However, an ensemble of industrial regulations and public subsidies coupled with a mild carbon tax is the most promising policy toolkit to support a rapid and orderly transition. Such a policy mix can be designed to have a neutral impact on public finances and to boost job creation during the transition process. Carbon taxation serves primarily as a tool for raising public revenues to support government spending, rather than as a direct driver of rapid decarbonization.

Policies for rapid decarbonization with steady economic transition and employment creation. Nat Sustain. www.nature.com/articles/s41893-025-01683-w

Demand-side policies can significantly reduce emissions from energy use in buildings and transport

Large emission reductions in buildings and transport are possible by integrating demand-side strategies to electrify energy use, improve technological efficiency, and reduce or shift patterns of activity. With enabling policies and infrastructures, final energy users can make significant contributions to climate goals, particularly through widespread deployment of heat pumps and electric vehicles. The international team of authors of this paper identifies a set of messages for policy:

- Developing targets and corresponding policies to increase the share of electricity and sustainable fuels in energy-using sectors globally will yield significant emission reductions, especially in the medium term.

- Adopting a mix of policy measures, including both technological solutions and in support of behavioural changes, can alleviate the burden of mitigation on energy supply and infrastructure.
- End-use policies, such as efficiency improvements and promoting electrification, mostly interact synergistically with minimal trade-offs. A coordinated mix of these policies accelerates decarbonization.
- Transformative changes in buildings and transport can significantly reduce emissions. Key actions include electrification, smarter use of space, better insulation, enhanced vehicle efficiency, less driving, more biking, and better public transport.

Demand-side policies can significantly reduce emissions from energy use in buildings and transport. Nat Energy, www.nature.com/articles/s41560-025-01721-z

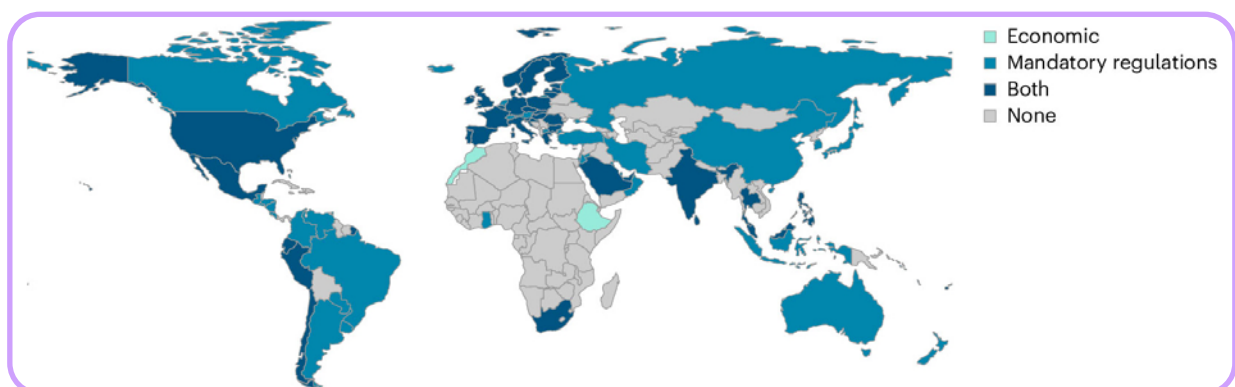
The local dimension of climate change

Adaptation happens in places, not in averages. CMCC research resolves the climate of cities and regions at the scale where choices are made: urban models that capture the urban heat islands in the cities, an interactive service monitoring warming at local scale, the first high-resolution CMIP6 dataset tailored to Italy, and prioritised resilience measures for the Venice lagoon. Studies of who suffers most in a heatwave, and of impacts cascading into Europe from elsewhere, show that the local scale is never isolated from the global one.

Governance and resilience as entry points for transforming food systems in the countdown to 2030

Due to complex interactions, changes in any one area of food systems are likely to impact—and possibly depend on—changes in other areas. This study presents the first annual monitoring update of the indicator framework proposed by the Food Systems Countdown Initiative, with new qualitative analysis elucidating interactions across indicators. Since 2000, the authors find

that 20 of 42 indicators with time series have been trending in a desirable direction, indicating modest positive change. Qualitative expert elicitation assessed governance and resilience indicators to be most connected to other indicators across themes, highlighting entry points for action—particularly governance action.



Health-related food environment policies. Source: Governance and resilience as entry points for transforming food systems in the countdown to 2030, Nat Food. <https://doi.org/10.1038/s43016-024-01109-4>

Social vulnerabilities and extreme heat: Towards transformative urban adaptation

Climate change is exacerbating pre-existing inequalities, particularly in the most vulnerable urban contexts. Heatwaves are striking our cities with increasing frequency, yet not all people and neighborhoods are affected equally. Existing social and spatial vulnerabilities intersect with climate impacts, amplifying inequalities and posing a challenge for the development of effective risk management policies and measures. Through an interdisciplinary approach that combines climate science, socio-economic analysis, and local participation, this event, included in the CMCC talks webinar series, explores how heat-related risks manifest unevenly across space and society. Speakers reflected on ways to integrate diverse methods and competences from urban research and practice, leading to

the development of participatory and co-design methodologies. Social inclusion practices, ranging from citizen engagement to incorporate perceptions of risk, to interviews with policymakers to investigate current challenges, are combined with the design of tools and methods that can support public decisions aimed at fostering a just and resilient urban transformation — one that connects data, communities, and policy. In this context, the webinar will also offer an opportunity to reflect on the concept of transformative adaptation — which implies systemic, structural, and deep-rooted change to address the underlying causes of vulnerability and climate injustice — assessing its operational meaning, implications, and potential for integration into long-term urban strategies.

www.cmcc.it/lectures_conferences/social-vulnerabilities-and-extreme-heat-towards-transformative-urban-adaptation

Uniting adaptation and mitigation in cities: Guglielmo Ricciardi wins the Emilio D'Alessio Award 2025

As cities continue to play a central role in discussions around climate change adaptation and mitigation, research can help policymakers and stakeholders leverage accelerating technological progress as a source of solutions. CMCC researcher Guglielmo Ricciardi has been awarded the prestigious Premio Emilio D'Alessio 2025 award for his work bridging climate adaptation and mitigation approaches to sustainable urban design using digital tools

such as urban digital twins. The award winning thesis, "The Green and Blue Nexus. Developing an integrated approach for managing climate change and using digital twinning in urban design", uses innovative approaches and technologies to address what Ricciardi identifies as a critical gap in climate policy and urban design: the historical separation between climate change mitigation (CCM) and climate change adaptation (CCA).

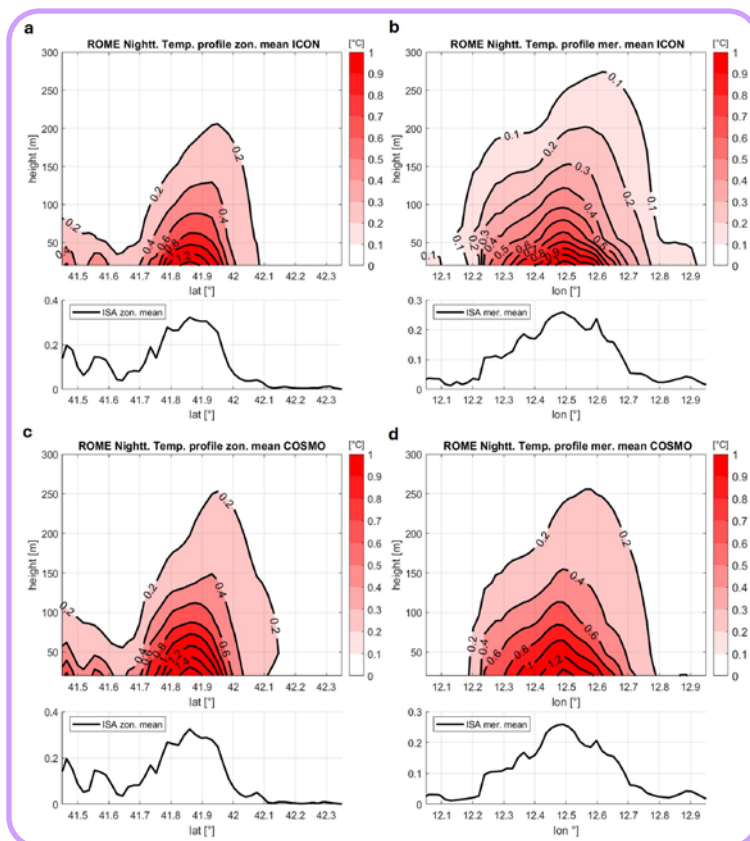
www.cmcc.it/article/uniting-adaptation-and-mitigation-in-cities-guglielmo-ricciardi-wins-the-emilio-dalessio-award-2025

Setting new standards in urban climate modeling

As cities face increasing risks from climate change, the need for high-resolution climate models that accurately simulate urban dynamics has never been greater. Urban parameterizations that capture interactions between cities and climate are essential for assessing climate change impacts and developing effective mitigation strategies. The study, Investigating Urban Heat Islands Over Rome and Milan During a Summer Period Through the TERRA_URB Parameterization in the ICON Model, evaluates the performance of TERRA_URB within ICON, a state-of-the-art atmospheric model. Focusing on Rome and Milan, researchers assessed its ability to simulate Urban Heat Island (UHI) effects and other key urban climate phenomena. The results show that ICON, when coupled with TERRA_URB, significantly improves the simulation of UHI and Urban Dry Island

effects, both in terms of spatial distribution and hourly dynamics. This enhanced capability offers a more detailed and realistic representation of temperature variations, particularly in densely populated areas. With this integration, ICON has become an essential tool for assessing the impact of climate change on cities and can now be applied to a range of urban studies, from evaluating future climate scenarios to extreme weather conditions such as heatwaves, storms, and intense precipitation. The ability to capture fine-scale temperature variations throughout the day and night, as well as identify hotspots and vulnerable populations, makes ICON a key tool for local decision-makers developing adaptation strategies, while CMCC is setting a new standard for climate simulations in urban environments.

www.cmcc.it/article/cmcc-at-the-forefront-of-climate-research-advancing-urban-climate-modeling



Differences of temperature zonal and meridional vertical cross sections (TU_ON-TU_OFF) at nighttime, against the respective impervious surface area zonal and meridional cross sections over Rome (subplot a-b for ICON and subplot c-d for COSMO). Zonal mean refers to the computation, for every latitude, of the mean value of the field over all longitudes. Meridional mean refers to the computation, for every longitude, of the mean values of the field over all latitudes.

Protecting Venice: CMCC and Ca' Foscari University win the Aspen Prize for climate research

The coastal system of the Venice lagoon is increasingly under pressure due to climate change, compounded by urbanization, tourism, land use, and socio-economic dynamics. In this context, the study “Prioritization of Resilience Initiatives for Climate-Related Disasters in the Metropolitan City of Venice” presents a review of the most innovative solutions to prepare Venice for the future, improve its resilience, and reduce risks from heatwaves, flooding, and other climate-related events. The scientists suggest adopting a portfolio of risk management measures to strengthen the resilience of the entire system as the best strategy. This portfolio should include both physical and engineering measures – such as adapting hydraulic defense structures that withstand

large-scale, intense events – and cognitive and social measures – such as updating and implementing plans and regulations – which are flexible enough to address a wide range of climate hazards. Social measures promote new risk awareness through education and citizen participation; informational measures, such as rapid and widespread alert systems, ensure the timely and broad dissemination of relevant information; and cognitive measures include updated urban plans and nature-based solutions for more sustainable land management. For this study, researchers from CMCC and Ca' Foscari University of Venice won the 10th Aspen Institute Italia Award 2025 for scientific collaboration between Italy and the United States.

www.cmcc.it/article/protecting-venice-cmcc-and-ca-foscari-university-win-the-aspen-prize-for-climate-research

Critical intervention points for European adaptation to cascading climate change impacts

In an interconnected world, climate change impacts can cascade across sectors and regions, creating systemic risks. This study analyses cascading climate change impacts on the EU, originating from outside the region, and identifies critical intervention points for adaptation. Using network analysis, the authors integrate stakeholder-co-

produced impact chains with quantitative data for 102 countries across foreign policy, human security, trade and finance. The archetypal impact cascade model reveals critical intervention points related to water, livelihoods, agriculture, infrastructure and economy, and violent conflict.

Critical intervention points for European adaptation to cascading climate change impacts. Nat. Clim. Chang. <https://doi.org/10.1038/s41558-025-02455-2>

Rome's warming climate in numbers: CMCC presents the first interactive climate monitoring service for the city

2024 was the hottest year on record for the Italian capital, with rising trends across all temperature-related indicators and their impacts on people. This was compounded by a decrease in annual rainfall and an increase in episodes of intense and violent precipitation. And the future is not looking

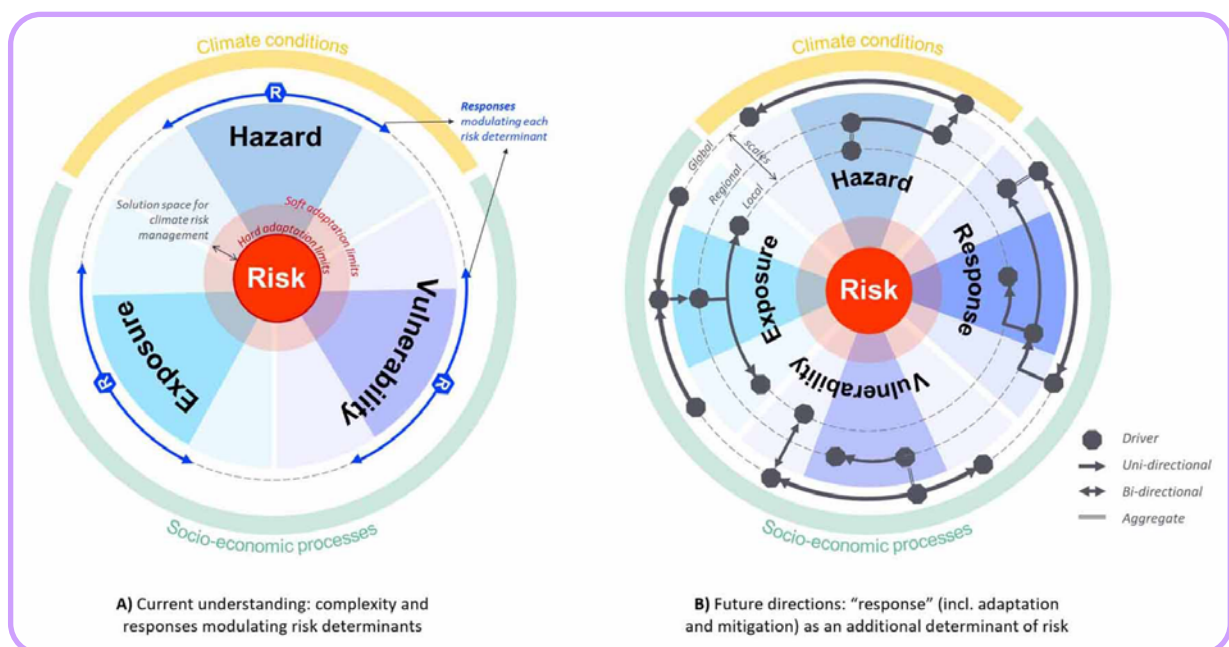
much brighter, as summer heatwaves are projected to rise by up to 186%. CMCC presents a comprehensive climate analysis for Rome: an interactive monitoring system with ultra-high-resolution climate indicators to support the identification of locally tailored climate adaptation actions.

www.cmcc.it/article/romes-warming-climate-in-numbers-cmcc-presents-the-first-interactive-climate-monitoring-service-for-the-city

Challenges and opportunities in climate risk assessment: future directions for assessing complex climate risks

As climate change impacts intensify worldwide, comprehensive assessment of climate risks is essential to guide effective disaster risk management and adaptation strategies. This systematic literature review examines the latest developments in Climate Risk Assessment (CRA), focusing on how climate risks are framed and assessed. It

explores advancements, ongoing challenges, and emerging opportunities to guide future generations of CRAs. Key findings highlight a more nuanced risk framework that incorporates climate responses, modulating the three risk determinants (exposure, vulnerability, and hazards), as outlined in the latest IPCC assessment.



Modified representation of the IPCC AR6 'Risk Propeller', emphasizing complexity and the role of responses. Source: Challenges and opportunities in climate risk assessment: future directions for assessing complex climate risks, Environmental Research Letters, <https://iopscience.iop.org/article/10.1088/1748-9326/adc756>

New tailored dataset for Italy helps fill gaps in effective adaptation planning

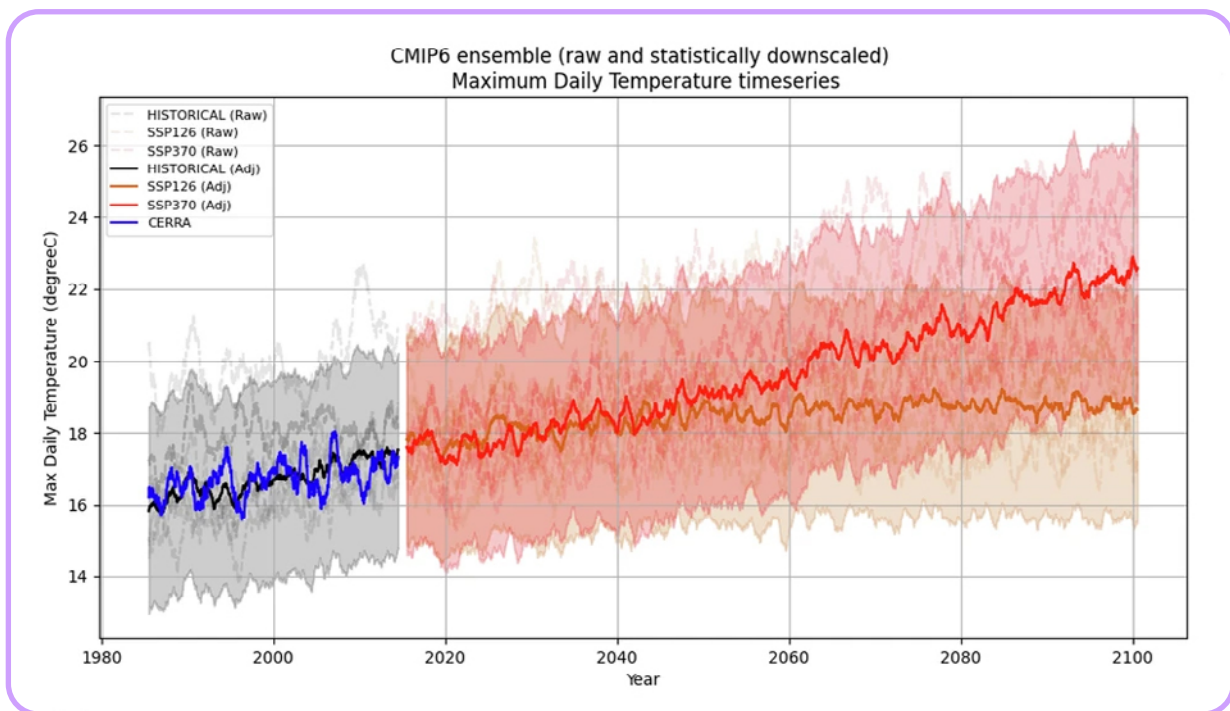
From coastal wind patterns to regional temperatures and precipitation, CMCC delivers the first high-resolution CMIP6-based climate dataset tailored for Italy, so that researchers and planners can gain access to high-resolution and reliable information on potential future climate conditions and reproduce Italy's local climate, up to the year 2100, with higher detail.

This study, conducted entirely by CMCC researchers, presents a high-resolution dataset (SD-EQM_GCMs_IT) offering climate projections for Italy from 1985 to 2100

and filling a critical gap between a coarse ensemble of global projections and the local-dependent information needed by policymakers, resource managers, and the public seeking to counter the ever-increasing impacts of climate change.

By adjusting nine global models against a detailed reanalysis provided by Copernicus (CERRA), the team was able to remove consistent biases and bring out local features – including local climate details – that coarser models miss.

www.cmcc.it/article/new-tailored-dataset-for-italy-helps-fill-gaps-in-effective-adaptation-planning



CMIP6 ensemble raw (dashed lines) timeseries. Source: Statistical Downscaling over Italy using EQM: CMIP6 Climate Projections for the 1985-2100 Period. Sci Data. <https://doi.org/10.1038/s41597-025-05270-8>

Soil, land and water

Land and water are where climate change is absorbed, and where it bites. CMCC research in 2025 measures what the land takes up, through a global database of ecosystem productivity, the Global Methane Budget, and a first catalog of land-based solutions, and tracks what people ask of scarce water: irrigation in Mediterranean orchards, groundwater in Qatar, drought across the water-energy-food nexus. Studies on coffee yields and on the land cost of a healthier global diet close the loop between what we grow, what we eat, and the forests left standing.

A global diet to slim down deforestation and emissions

New research published in *Global Change Biology* highlights the impact of increasing vegetable oil consumption under the EAT-Lancet diet on global land use, deforestation, and greenhouse gas emissions. The research, titled "Pressure on Global Forests: Implications of Rising Vegetable Oils Consumption under the EAT-Lancet Diet", examines the potential consequences of shifting dietary patterns recommended by the EAT-Lancet Commission – a global team of experts in nutrition, public health, sustainable agriculture, and climate change. Their proposed "planetary diet" aims to

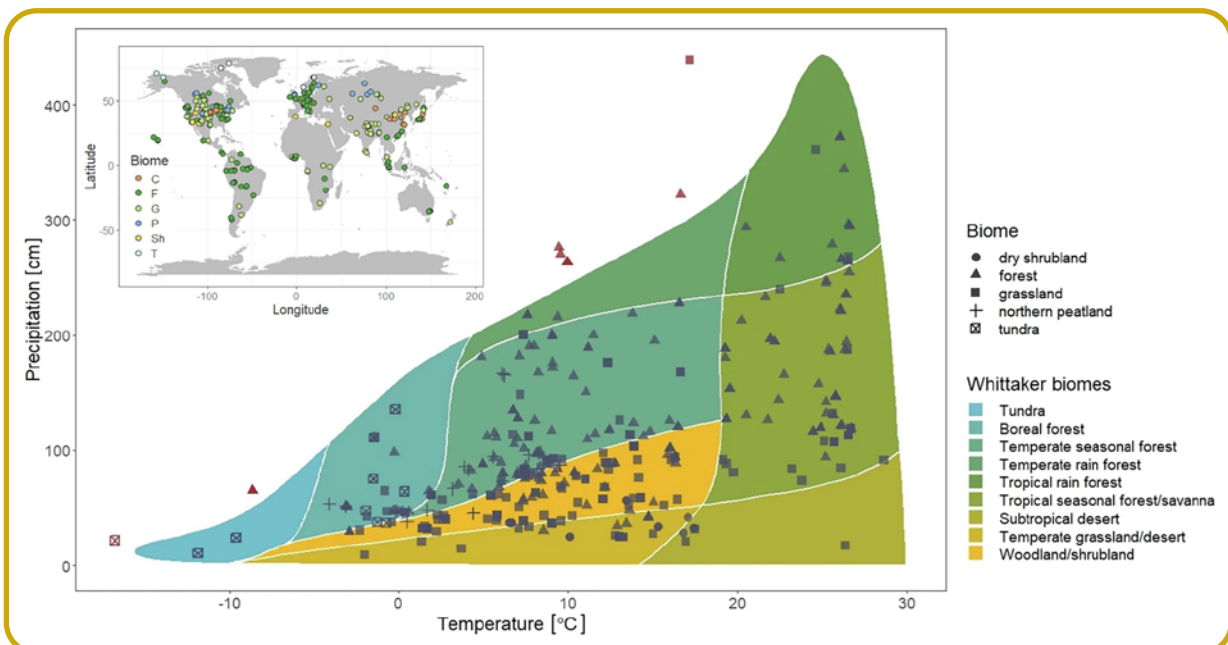
reduce consumption of resource-intensive foods such as meat and eggs while increasing global per capita intake of unsaturated oils (such as soybean, sunflower, and rapeseed) by 67% and maintaining current palm oil consumption levels. Using a spatially explicit land allocation algorithm, the study assesses how the expected global population of 9.2 billion people by 2050 might drive demand for vegetable oils and its associated environmental impacts on carbon-rich ecosystems and land-use change emissions.

Pressure on global forests: Implications of rising vegetable oils consumption under the EAT-Lancet diet, Global Change Biology. <https://onlinelibrary.wiley.com/doi/10.1111/gcb.70077>

New global database opens the door for better understanding of terrestrial ecosystem productivity

New research, published in the journal "Scientific Data", showcases a novel and groundbreaking global database containing net primary production measurements from 456 sites across major terrestrial ecosystems worldwide. The research provides scientists with an unprecedented resource for understanding how Earth's land systems store carbon and produce biomass, establishing a benchmark for calibrating vegetation models and assessing ecosystem responses to environmental change.

Net primary production (NPP) represents the carbon accumulated by plants through photosynthesis after accounting for their own respiration – essentially the amount of biomass ecosystems produce annually. This fundamental measurement underpins our understanding of global carbon cycling, food production, and climate change impacts on terrestrial systems.



Whittaker plot of the sites in the database, with outliers marked in red. Source: A global database of net primary production of terrestrial ecosystems. *Sci Data*. <https://doi.org/10.1038/s41597-025-05773-4>

Longform: Water management and the climate crisis

Climate change has turned water into a central issue, challenging how societies manage this essential resource. From the scarcity in drought-stricken regions to catastrophic floods, we are witnessing the consequences of a changing climate. Successful adaptation examples offer

integrated solutions for water management, but challenges remain. Education and innovative policies are critical to addressing this water crisis. A longform realized by the Future Earth Research School (FERS), a permanent initiative of CMCC Foundation.

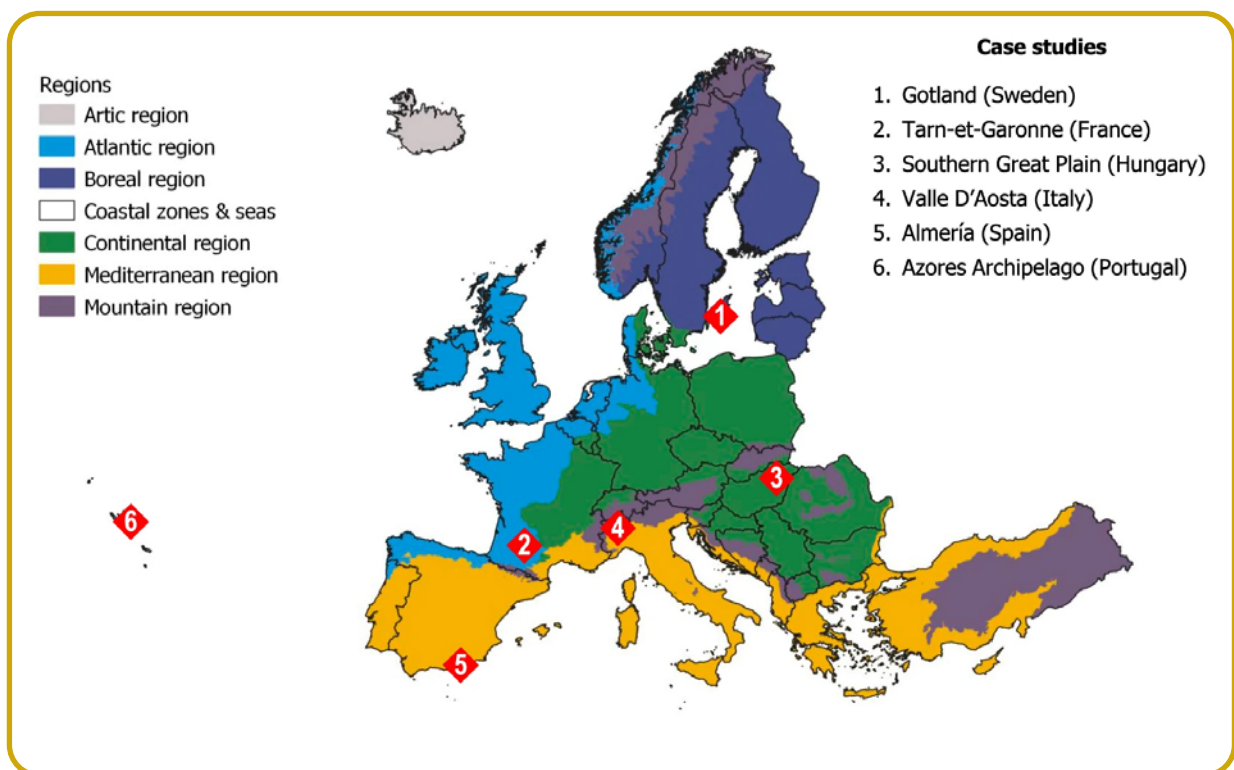
<https://fers.shorthandstories.com/water-management-and-the-climate-crisis/>

Land-based adaptation and mitigation solutions that tackle climate change

Land is at the forefront of climate action, playing a key role in both adaptation and mitigation at global, EU, and local levels. With its various uses, including cropland, grassland, wetlands, forests, and settlements, it can act as a carbon sink when absorbing more carbon from the atmosphere than it emits, or a carbon source when releasing carbon into the atmosphere, for instance, through deforestation or soil disturbance. To enhance the role of the land sector, it is essential to engage and inform all stakeholders – including landowners, managers, researchers, policymakers, and

citizens – about the most effective sustainable land-based solutions and behavioral changes needed.

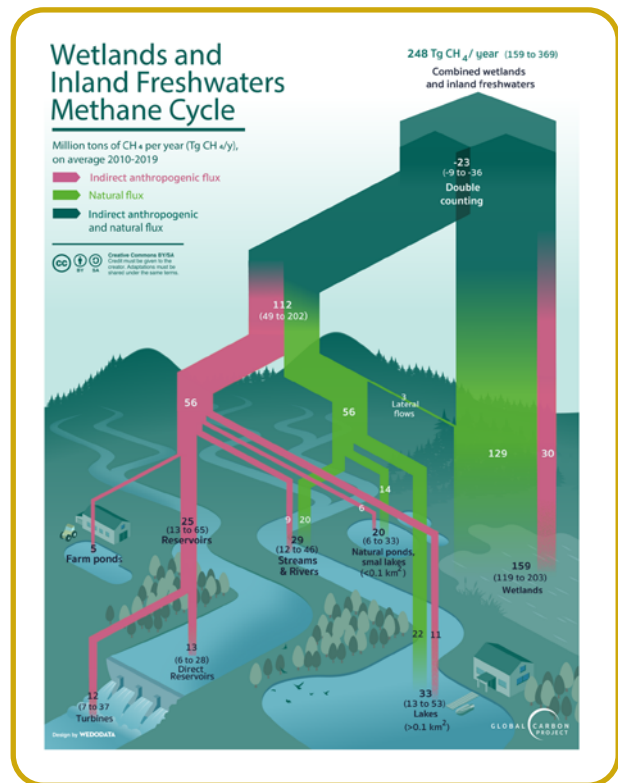
A first-of-its-kind catalog that compiles key information on land-based solutions for tackling climate change, both in terms of mitigation and adaptation, has been developed by an international team of researchers led by CMCC. From implementing wind energy products to applying precision farming and artificial intelligence in agricultural practices, the catalog offers an innovative tool for analyzing context-specific cost-benefits of a range of LAMS.



Map of the six case studies selected as representative of the EU territory for the identification of land-based adaptation and mitigation solutions (LAMS). Source: A catalogue of land-based adaptation and mitigation solutions to tackle climate change. Sci Data. <https://doi.org/10.1038/s41597-025-04484-0>

Methane: Where it comes from and why we are running out of time

Emissions and atmospheric concentrations of methane continue to increase, making it the second most important human-influenced greenhouse gas in terms of climate forcing after carbon dioxide. In fact, methane concentrations have risen faster over the past five-year period than in any period since record-keeping began and yet research suggests that reducing methane emissions may be cheaper than carbon dioxide mitigation for a comparable climate benefit. The relative importance of methane compared to carbon dioxide for temperature change stems from its shorter atmospheric lifetime, stronger radiative forcing, and accelerated growth in atmospheric concentration over the past decade. Understanding where and why this acceleration is happening is therefore a central goal of the Global Carbon Project's Global Methane Budget 2000–2020. This paper, involving an international team of researchers including CMCC's authors, provides insight on global methane sources and sinks.



Estimation of wetland and inland freshwater emissions over the 2010–2019 decade. Source: Global Methane Budget 2000–2020, <https://doi.org/10.5194/essd-17-1873-2025>

Advancing the representation of human actions in large-scale hydrological models: Challenges and future research directions

Characterizing the impact of human actions on terrestrial water fluxes and storages at multi-basin, continental, and global scales has long been on the agenda of scientists engaged in climate science, hydrology, and water resources systems analysis. This need has resulted in a variety of modeling efforts focused on the representation of water infrastructure operations. Yet, the representation of human-water interactions in large-scale hydrological models is still relatively crude, fragmented across models,

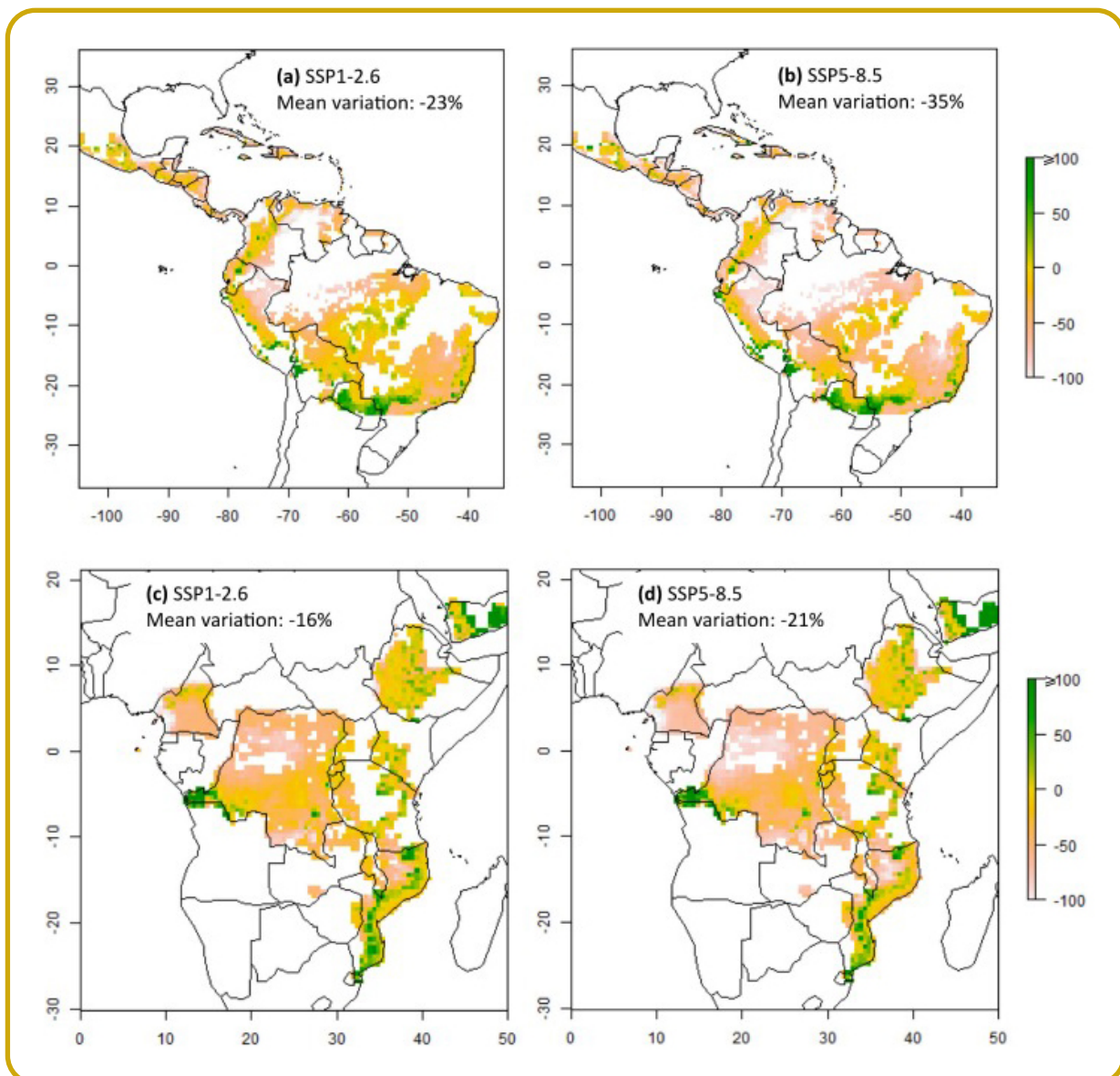
and often achieved at coarse resolutions (10–100 km) that cannot capture local water management decisions. In this paper, authors argue that the concomitance of four drivers and innovations is poised to change the status quo: “hyper-resolution” hydrological models, multi-sector modeling, satellite missions able to monitor the outcome of human actions, and machine learning are creating a fertile environment for human-water research to flourish.

Advancing the Representation of Human Actions in Large-Scale Hydrological Models: Challenges and Future Research Directions, *Water Resources Research*, <https://doi.org/10.1029/2024WR039486>

Projecting trends of arabica coffee yield under climate change: A process-based modelling study at continental scale

Climate change may lead to negative impacts on coffee production, such as reduced yields. Addressing this issue requires identifying climate risks and assessing the adaptation potential of agronomic practices across spatial and environmental gradients. This study aims to evaluate climate change impacts on arabica coffee yields at continental scale and evaluate a specific adaptation measure, i.e. increasing

shade tree density in agroforestry settings, by simulating the physiological links between coffee growth, climatic factors and agronomic management. After evaluating the performance of the process-based model DynACof in simulating arabica yields, authors developed a new tool called G-DynACof, a modelling framework for spatializing DynACof on a regional scale using extensive climate projections and soil geodata.

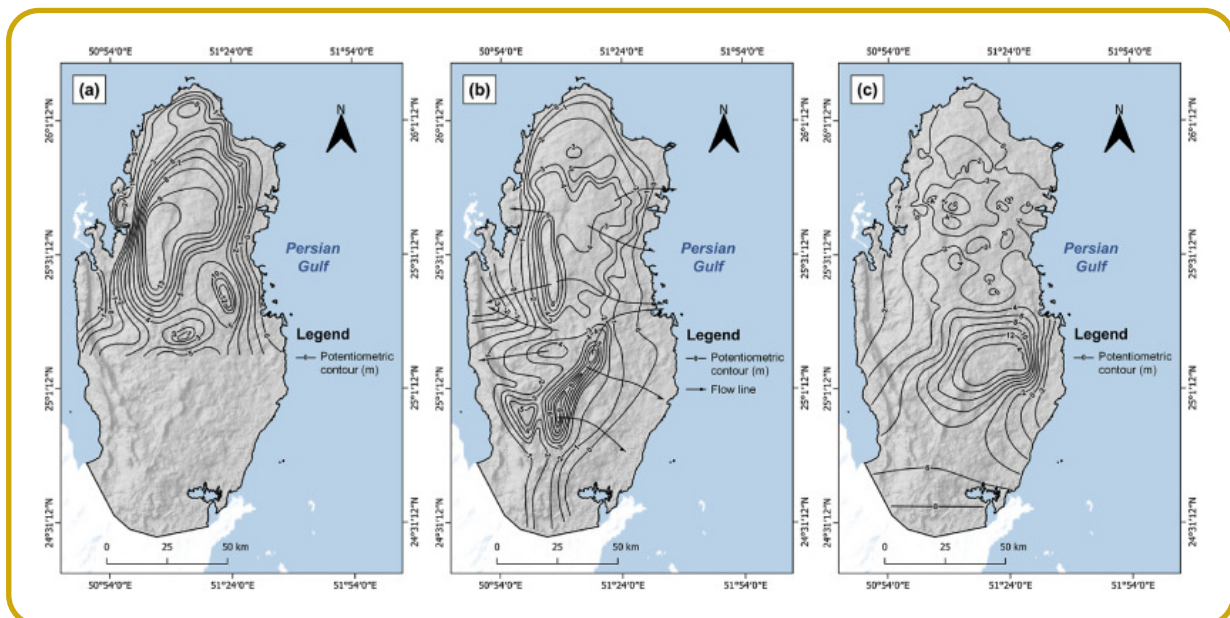


Predicted variation of potential yield in Latin America and Africa, climate projection (2036–2065) vs. historical climate (1985–2014). Multi-model average for SSP1–2.6 (a, c) and SSP5–8.5 (b, d). Source: Projecting trends of arabica coffee yield under climate change: A process-based modelling study at continental scale, Agricultural Systems, <https://www.sciencedirect.com/science/article/pii/S0308521X25000939>

Assessing groundwater quality and suitability in Qatar: Strategic insights for sustainable water management and environmental protection

Groundwater resources in arid regions are crucial for water and food security and for the maintenance of ecosystem services, but they face significant challenges from overexploitation and contamination, exacerbated by climate change. In Qatar, understanding the spatial variability of groundwater quality and its suitability for use remains limited. This study examines

groundwater quality across the peninsula and evaluates its suitability for drinking and irrigation employing comprehensive Geographic Information System (GIS) techniques and water quality assessments. Twelve physicochemical parameters were analyzed to evaluate groundwater quality and determine the hydrogeochemical facies.



Changes in the potentiometric map of Qatar's shallow aquifer over time. Source: Assessing groundwater quality and suitability in Qatar: Strategic insights for sustainable water management and environmental protection, *Environmental and Sustainability Indicators*, <https://doi.org/10.1016/j.indic.2025.100582>

High-resolution satellite imagery to assess orchard characteristics impacting water use

Most orchards throughout the Mediterranean basin rely heavily on irrigation, a dependency increasing due to climate change. Assessing the water requirement (WR) is crucial and depends on different factors, including orchard age, tree density per field, inter-row management. This study proposes new methods to evaluate these characteristics

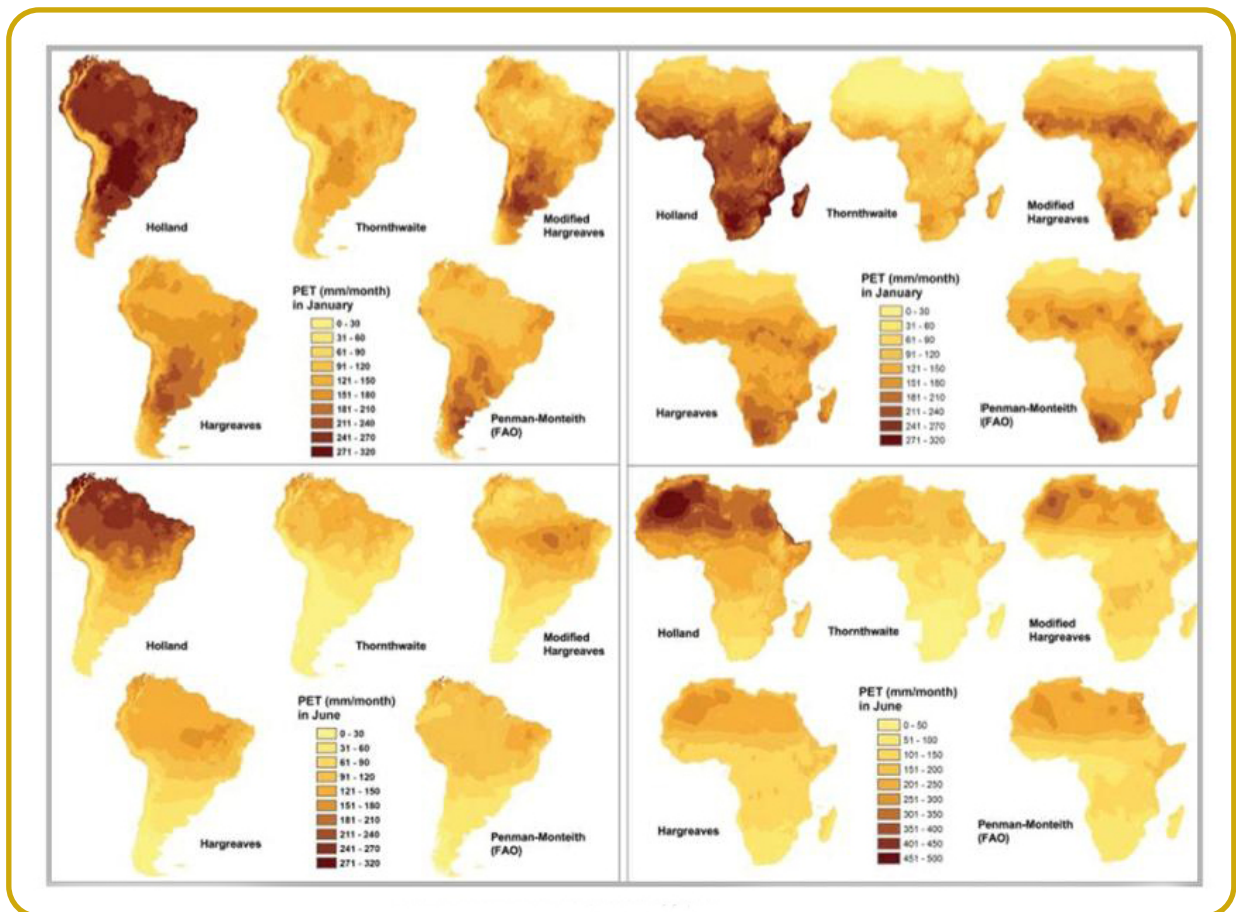
with remote sensing (RS). Various remote sensors providing high and very high spatial resolution images are investigated and their accuracy is assessed. The final objective is to assess WR using variables derived from remote sensing compared to data provided by water managers and from the FAO method.

High-resolution satellite imagery to assess orchard characteristics impacting water use, *Agricultural Water Management*, <https://doi.org/10.1016/j.agwat.2024.108763>

CMIP6-based global estimates of future aridity index and potential evapotranspiration for 2021-2060

The “Future Global Aridity Index and PET Database” provides high-resolution (30 arc-seconds) average annual and monthly global estimates of potential evapotranspiration (PET) and aridity index (AI) for 22 CMIP6 Earth System Models and two future (2021-2041; 2041-2060) and historical (1960-1990; 1970-2000) time periods, for each of four

shared socio-economic pathways (SSP). Three multimodel ensemble averages are also provided (All; Majority Consensus, High Risk) with different level of risks linked to climate model uncertainty. An overview of the methodological approach, geospatial implementation and a technical evaluation of the results is provided.

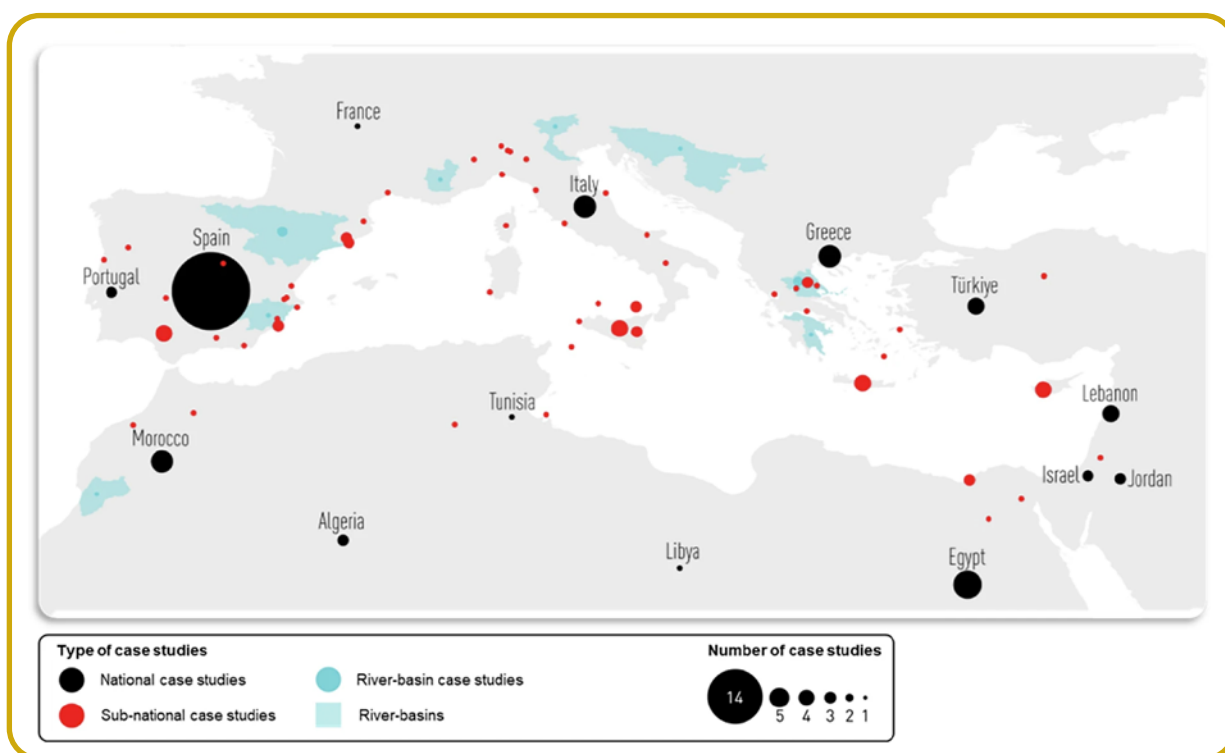


Comparison of four different temperature-based methods of calculating PET (Thornthwaite, Thornthwaite modified by Holland, Hargreaves, Hargreaves Modified by Droogers and Allen), against the reference FAO Global Penman-Monteith. Source: REVISED CMIP6-based global estimates of future aridity index and potential evapotranspiration for 2021-2060, <https://open-research-europe.ec.europa.eu/articles/4-157>

Nexus approach to enhance water-energy-food security and ecosystems resilience under climate change in the Mediterranean

The Mediterranean Basin, already a water-scarcity hotspot, faces intensifying droughts and warming that strain the water–energy–food–ecosystems (WEFE) nexus. Climate impacts cascade across sectors, while siloed responses risk maladaptation. Nexus-based solutions—centred on water—can foster synergies and reduce trade-offs, with nature-based, socially inclusive, and clean energy strategies offering transformative potential. Yet governance, cooperation, and data gaps

persist; closing these is vital to operationalize the nexus and advance regional sustainability. This study highlights that Silo approaches contribute to amplifying the negative impacts, while nexus-based technological, ecosystem-based, and behavioral solutions enhance synergies within the interactions among WEFE components and climate change, while at the same time reducing greenhouse gas emissions and fostering carbon storage.



Spatial distribution of implemented WEFE nexus solutions based on a review of 205 articles. Source: Nexus approach to enhance water-energy-food security and ecosystems resilience under climate change in the Mediterranean. npj Clim. Action. <https://doi.org/10.1038/s44168-025-00308-4>

The overshoot challenge

If we exceed 1.5°C, the harder question is what follows: can warming be brought back down, and what will have happened in the meantime? CMCC makes that question a research agenda of its own. A first comprehensive review sets out what overshoot means for risks, adaptation and emission requirements; a digital platform gathers the evidence as it grows; a lecture by Andy Reisinger and an IAMC webinar open the debate to a wider community; and work with information designers asks how a concept this complex can be made legible to policy and society.

Overshoot: What does it mean to exceed and return to global warming of 1.5°C?

Many national and corporate climate targets seek to limit global warming to 1.5°C. Yet, global warming continues to increase. It makes it almost inevitable that 1.5°C of global warming will be exceeded. Scientists, policymakers, and society will increasingly engage in a new discussion about what it now means to “keep 1.5°C alive”: is it possible to exceed 1.5°C but to return to or below this level within a given timeframe? What would be needed to at least keep that option on the table, and what would be its consequences? A first comprehensive conceptual review explores the implications of such “overshoot” pathways. Authored by an international team of scientists and design experts involved in assessments by the Intergovernmental Panel on Climate Change, the review considers climate-related damages and risks, adaptation and vulnerability, global

emission requirements, and issues arising for global and national climate policy. The review sets out evidence and knowledge gaps that illustrate the choices and challenges that decision-makers are now facing.

A key conclusion is that accelerated emission reductions in the near term are critical to limit peak warming and to keep the option of a return to 1.5°C on the table, but that effective and equitable adaptation will remain critical to limit damages along the way. Many more decisions and choices will determine what risks such a return would avoid, what damages would nonetheless be irreversible, and the implications for equity and climate justice.

CMCC introduces a digital information platform that will grow to inform these discussions.

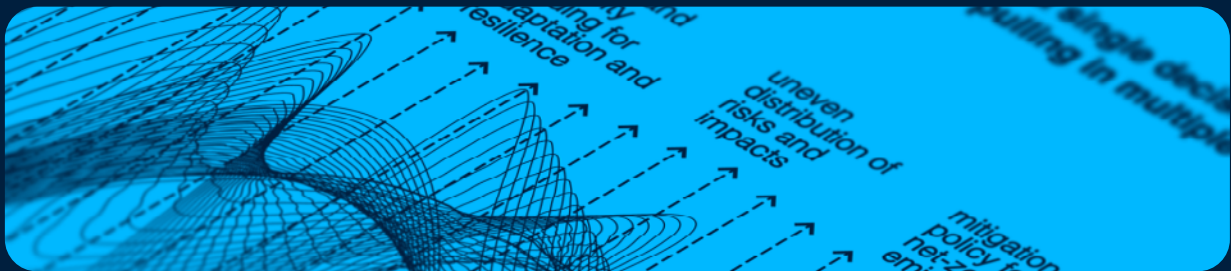
www.cmcc.it/article/overshoot-what-does-it-mean-to-exceed-and-return-to-global-warming-of-1-5c

Lecture: Challenges and choices after we exceed 1.5°C

The world is about to exceed 1.5°C of global warming — a milestone that raises a critical question: is it still possible to “keep 1.5°C alive” by bringing temperatures back down in the future? In this lecture, Andy Reisinger, a globally recognized expert in bridging the

gap between climate sciences and policy, explores the challenges and choices of the so-called ‘overshoot’ pathways, where global warming exceeds a given threshold for a period of time before being brought back to or below that level.

Watch the full video: www.cmcc.it/lectures_conferences/overshoot-challenges-and-choices-after-we-exceed-1-5c

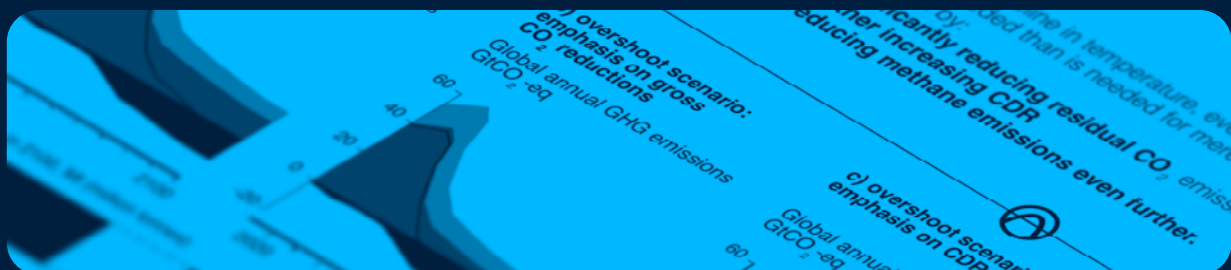


Designing climate: CMCC contributes to World Design Congress 2025 proceedings

How can design help us understand climate overshoot? CMCC contributed to this paper, alongside international climate researchers and information designers, with an accurate analysis on temperature overshoot. The study

was selected for the proceedings of the World Design Congress London 2025, showcasing how co-design can strengthen the way science informs policy and society.

www.cmcc.it/article/designing-climate-cmcc-contributes-to-world-design-congress-2025-proceedings



IAMC Webinar | Futures of overshoot: implications for climate pathways and mitigation strategies

As we inexorably overshoot critical climate thresholds, the discussion about future emissions pathways and climate risks intensifies and becomes more complex. This webinar reviews the history of overshoot

for emissions and mitigation pathways. We will discuss the multifaceted implications of overshoot for emissions, transforming energy and economic systems, and equity and technology.

Watch the full video: www.cmcc.it/lectures_conferences/iamc-webinar-futures-of-overshoot-implications-for-climate-pathways-and-mitigation-strategies

The social and economic dimension of climate change

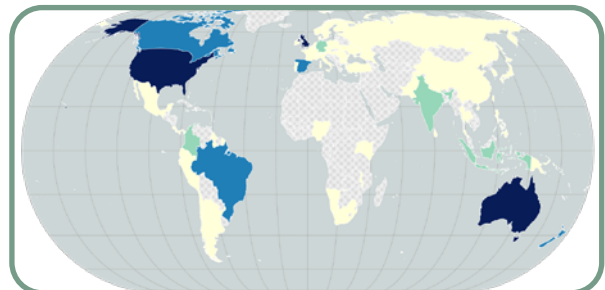
Who pays, who benefits, who resists. CMCC research puts figures on the social and economic stakes of climate action: 207,000 premature deaths and \$2,269 billion avoided by 2030 if overshoot is averted, health risks mounting across small island states, war-driven shocks cascading from commodity trade into financial markets, and adaptation spending by 300,000 businesses. Alongside these, work on climate litigation, nature credits and the green backlash examines the institutions and politics that decide whether action holds.

Climate change and the law: can legal systems help to address the climate crisis?

As the impacts of climate change intensify, legal systems are being called upon even more frequently to take action. However, despite the existence of legal and policy frameworks that set targets, deadlines and plans at all levels of governance, climate commitments are still largely failing to be met. Against this backdrop of climate obligation violations, alternative approaches to climate action are gaining traction. Litigation is emerging as a powerful tool for addressing the risks and impacts of climate change, with courts becoming key arenas for accountability in both the Global North and

South.

"Climate change and the law: can legal systems help to address the climate crisis?" is a longform realized by Future Earth Research School (FERS), a permanent initiative of CMCC Foundation.

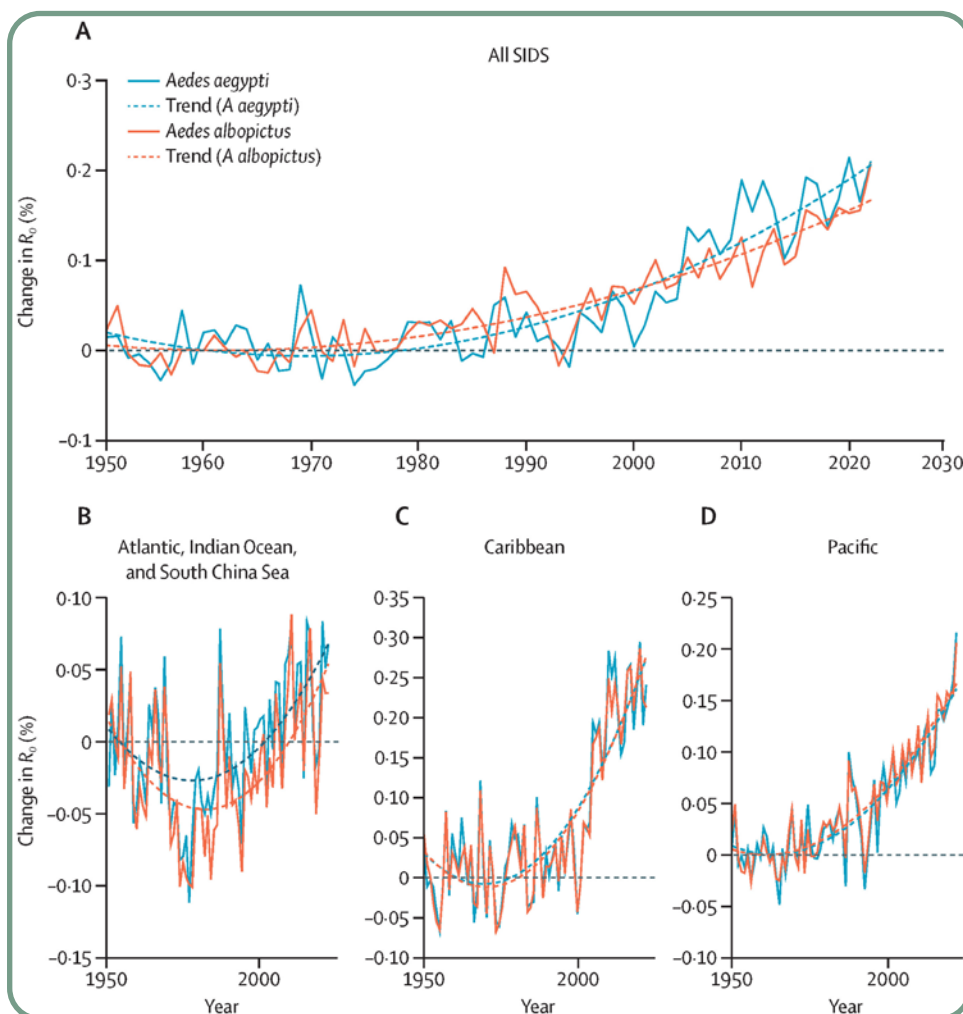


Cases per country (pre and post 2015/Paris Agreement). CMCC elaboration based on the data source from the Sabin Center for Climate Change Law. Source: <https://fersschool.cmcc.it/special-issue-climate-change-and-the-law-can-legal-systems-help-to-address-the-climate-crisis/>

The 2024 small island developing states report of the Lancet Countdown on health and climate change

CMCC contributed to the 2024 small island developing states (SIDS) report for the Lancet Countdown on Health and Climate Change expands on the global Lancet Countdown 2023 and 2024 reports to explore the unique contexts, geographies, vulnerabilities, and needs that shape the evolving links between health and climate change in SIDS in the Pacific, Caribbean, and Atlantic, Indian Ocean, and South China Sea regions. SIDS were first recognised as a distinct grouping of island nations at the 1992 UN Conference on Environment and Development; they share high vulnerability to extreme weather events,

climate change, and global economic shocks. The message of the global Lancet Countdown is echoed in this Lancet Countdown report for SIDS: a health-centred response is essential to allay the severity of the encroaching impacts of global climate change on the health and wellbeing of populations. Such a response requires international action from high-income countries to reduce greenhouse gas emissions. This action, in conjunction with other locally and internally driven efforts, should enable a prosperous future for the SIDS, which collectively have low emissions.



Risk of dengue in small island developing states overall (A) and in the Atlantic, Indian Ocean, and South China Sea (B), Caribbean (C), and Pacific (D) subregions. Source: The 2024 small island developing states report of the Lancet Countdown on health and climate change. The Lancet Global Health, [https://doi.org/10.1016/S2214-109X\(24\)00421-2](https://doi.org/10.1016/S2214-109X(24)00421-2)

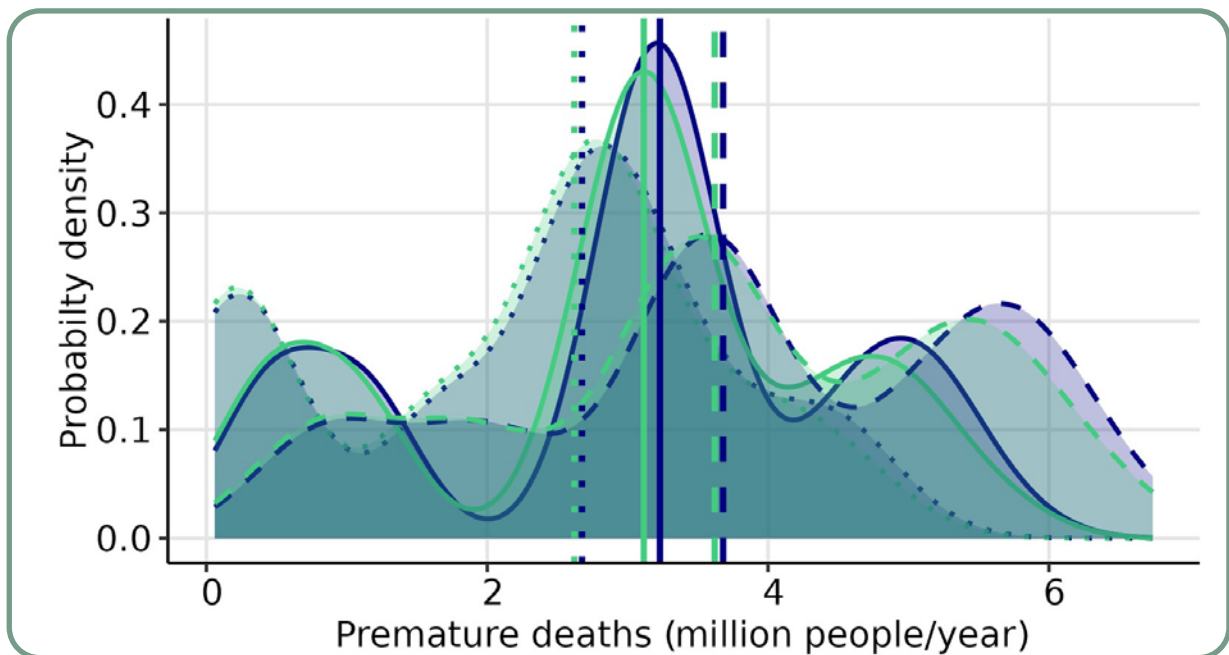
Health and economic co-benefits of stringent air quality related climate policies

Air pollution is one of the world's leading health risks, contributing to nearly 1 in 8 deaths globally. This study published in *Science Advances* by CMCC shows that stringent climate policies designed to avoid temporarily exceeding 1.5°C warming could prevent hundreds of thousands of premature deaths while avoiding trillions of dollars in economic damages.

The researchers used a global source-receptor air pollution model to estimate the impacts of net-zero pathways on air quality, health, and economic costs. They found that avoiding temperature overshoot could prevent 207,000 premature deaths and reduce \$2,269

billion USD in damages by 2030, equivalent to roughly 2% of 2020's global GDP. The benefits are particularly notable in regions with high population density and pollution, such as China and India.

The study is the first to quantify the air pollution co-benefits of limiting short-term temperature overshoot. By considering multiple scenarios, uncertainties, and regional variations, the research provides robust evidence that climate mitigation policies offer substantial dual benefits: reducing greenhouse gas emissions and saving lives through cleaner air.



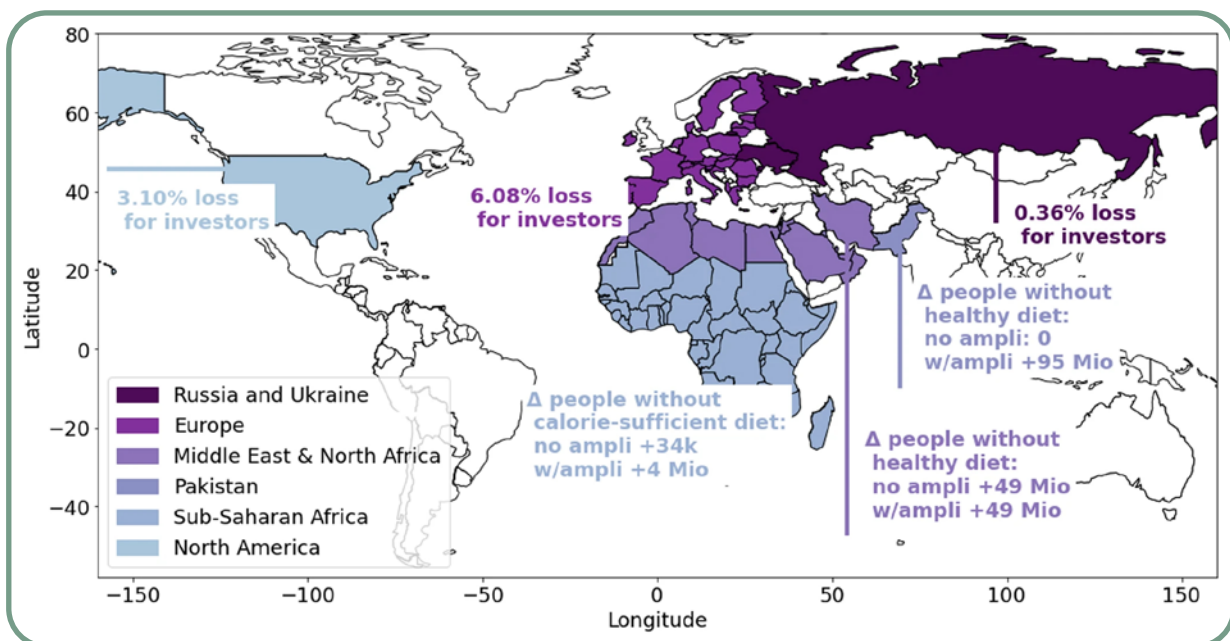
Global health cobenefits of reduced overshoot for the year 2030. Empirical probability density functions (ePDFs) of the estimated premature deaths expressed in millions of people. The vertical dashed line indicates the median. Source: Beyond the limit: The estimated air pollution damages of overshooting the temperature target. Sci. Adv. DOI: [10.1126/sciadv.adu7590](https://doi.org/10.1126/sciadv.adu7590)

Cascading socio-economic and financial impacts of the Russia-Ukraine war differ across sectors and regions

Disruptions in global food and energy trade can trigger cascading socio-economic losses. Financial markets can amplify such losses and generate systemic cross-sectoral effects, e.g. food insecurity. Our methodology links the real economy and financial markets to quantify cascading impacts across sectors and regions and to capture amplification effects by financial markets. Although applicable to any shock to global key commodity trade, the authors test its effectiveness with the Russia-Ukraine war, which reveals pronounced, regionally and sectorally diverse impacts. The analysis shows the importance of accounting for

cascading risks and amplification effects to strengthen economic, financial, and food system resilience. By integrating macroeconomic and financial aspects the authors capture both direct and amplified effects on various sectors and regions that traditional methods might miss. The research applies this methodology to study the consequences of the Russia-Ukraine war, focusing on the implications for food and energy markets. The results highlight the heterogeneity of cascading impacts across sectors and regions outside Russia and Ukraine, with the emergence of distinct winners and losers.

www.nature.com/articles/s43247-025-02119-1



Comparison of base and finance amplification case for highly impacted regions: Finance sector and food affordability results. Source: Cascading socio-economic and financial impacts of the Russia-Ukraine war differ across sectors and regions. Commun Earth Environ. <https://doi.org/10.1038/s43247-025-02119-1>

Green backlash and right-wing populism

This Review delves into the politics of climate policy, specifically focusing on the so-called green backlash—that is, rising resistance from voters, parties and governments to the climate transition. The authors present a narrative review of the literature on the political consequences of climate policies, highlighting the presence of backlash among citizens negatively affected by decarbonization efforts.

Populist right forces emerge as the primary

beneficiaries of the backlash as they tend to be more sceptical regarding anthropogenic climate change and less supportive of climate policies.

In turn, their electoral success has negative implications for countries' climate policymaking and performance. Finally, the paper draws insights from the literature to reflect on what can be done to improve the political sustainability of climate policies.

Green backlash and right-wing populism. Nat. Clim. Chang. <https://doi.org/10.1038/s41558-025-02384-0>

CMCC contributes to the European Commission Expert Group on Nature Credits

The European Commission has appointed Jaroslav Mysiak, CMCC Principal Scientist, as one of 10 individual experts to the Commission Expert Group on Nature Credits, positioning CMCC at the centre of one of Europe's most significant emerging policy initiatives, combining scientific rigour with practical market-based mechanisms to address the continent's critical biodiversity financing gap.

The appointment follows the publication of the European Commission's Roadmap towards Nature Credits in July 2025, a strategic initiative designed to unlock innovative financial mechanisms supporting the protection, restoration and sustainable management of Europe's ecosystems. The Expert Group on Nature Credits has been established to guide the development of the EU framework for certifying and rewarding nature restoration outcomes. Drawing on scientific evidence, practical experience and emerging methodologies, members

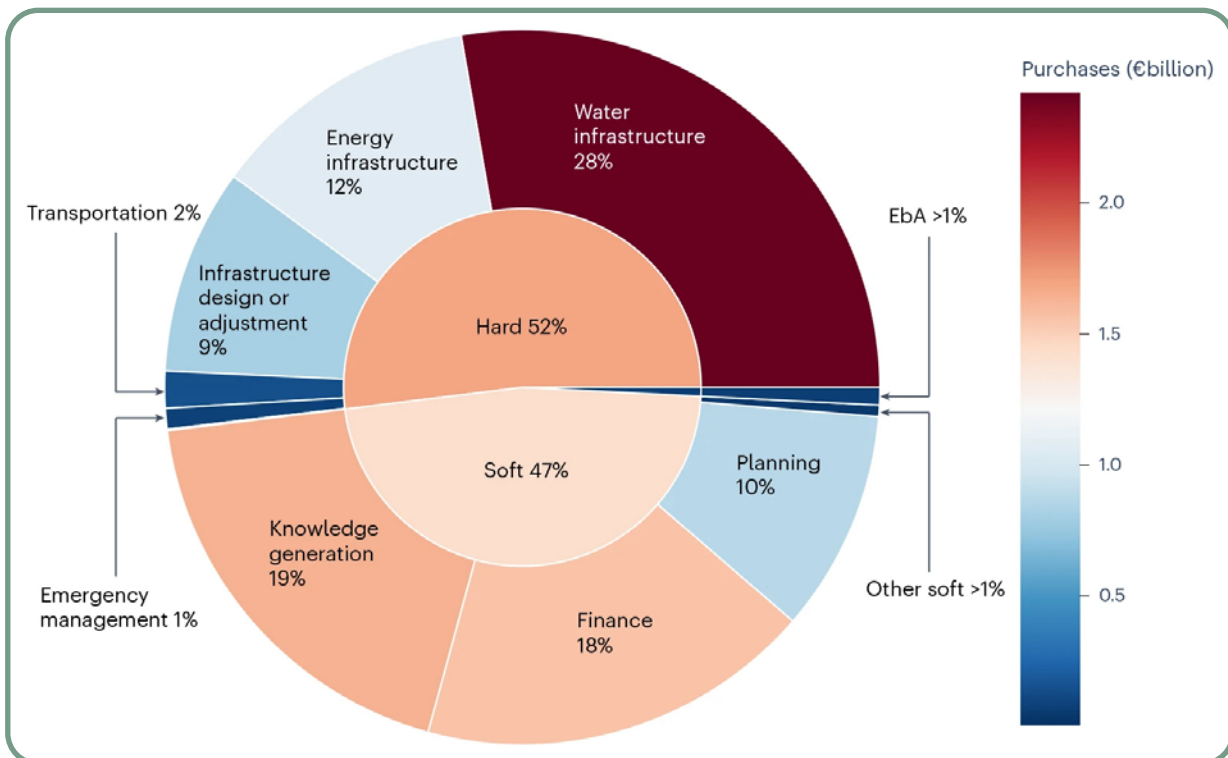
will advise the European Commission on designing the comprehensive roadmap for nature credits and defining what high-quality credits should look like. Their mandate encompasses multiple critical dimensions: developing technical standards for assessing ecosystem condition, establishing robust monitoring and verification protocols, defining appropriate indicators to ensure environmental integrity, and guaranteeing coherence with EU legislation spanning biodiversity, climate and carbon removal policies as well as international initiatives. The Roadmap therefore defines the concept of nature credits and proposes a phased approach whereby nature-positive actions are certified and subsequently converted into verified credits that reflect measurable ecological outcomes. It also announces the development of robust scientific methodologies, governance frameworks, and transparency safeguards to ensure market credibility and avoid greenwashing.

www.cmcc.it/article/cmccs-jaroslav-mysiak-appointed-to-european-commission-expert-group-on-nature-credits

Private sector investments in climate change adaptation

Amid escalating climate impacts, understanding private sector adaptation is critical. In this paper, using data of actual adaptation expenditures from nearly 300,000 businesses in five coastal regions, an international team including CMCC scientists reveals variations in private sector adaptation across sectors and regions. The agriculture sector leads in adaptation efforts, while transport, construction and utilities—which are potential sources of system-wide cascading effects—lag. Small, medium and large businesses prioritize hard and soft measures, barely investing in ecosystem-based adaptations. Adding to the multifaceted

discourse on adaptation effectiveness, the panel data reveal positive, although inelastic in the short run, relationships between private sector adaptations and aggregate regional economic performance. Business adaptations in the construction, transport and health sectors associate positively with regional economic performance, with the accommodation and food services sector yielding the highest return per euro invested in adaptation. Combining these findings with existing assessments of adaptation could support the development of societally effective adaptation strategies.



Types of private sector adaptations and their relative shares across five coastal regions. Source: Private sector investments in climate change adaptation, *Nature Climate Change*, <https://doi.org/10.1038/s41558-025-02423-w>

Events and networking

Wherever climate science is discussed and wherever it meets policy, CMCC was there in 2025. A delegation and seven side events at COP30 in Belém, and a webinar afterwards to read the outcomes. ECCA2025, Europe's leading adaptation conference and CMCC's flagship event, hosted in Italy for the first time. The EGU and AGU general assemblies, the UN Ocean Conference in Nice, the EAERE annual conference whose secretariat CMCC manages, and a bilateral workshop with India on machine learning for climate. The CMCC Lectures carry these conversations through the year.

Advanced science to support policy for climate action: CMCC at COP30

CMCC Foundation brought its international expertise to COP30, which will take place from 10 to 21 November in Belém, Brazil. CMCC is actively involved in key topics at the climate conference, such as forests and emission reductions, adaptation policies and solutions, the impacts of climate on health, and the resilience of coastal areas. CMCC scientists' knowledge and understanding of the latest findings from the most advanced climate studies support negotiations and decision-making on climate policies at the Conference of the Parties (COP30).

See the full list of the CMCC delegation at COP30 here:

www.cmcc.it/article/advanced-science-to-support-policy-for-climate-action-cmcc-at-the-un-climate-change-conference

In addition, the CMCC took part in and organised a series of side events as part of

the COP programme in various pavilions. The list of events includes:

- Empowering Coastal Communities: science-based solutions for resilience and adaptation;
- What you can't measure, you can't manage: Improving GHG estimation for informed climate policy;
- Solutions for people and the planet: Reimagining land governance putting people at the centre of land and natural resources;
- Entangled destiny: Trees and humans of the Mediterranean;
- The costs of inaction for citizens, communities, and economies;
- Adaptation AGORA at COP 30: Empowering citizens with ICTs for climate resilience;
- Truth matters: From rumor to resilience by preventing misinformation in climate change response.

For further details on the CMCC's participation in COP30: www.cmcc.it/lectures_conferences/cmcc-at-cop30-advanced-science-to-support-policy-for-climate-action

Outcomes and prospects of the Belém Conference

Following the conference, the CMCC organised a webinar during which the Italian delegation, which had actively participated in the negotiations, analysed the outcomes of the Belém Conference, providing in-depth insights into the key themes of this year's event: the emerging role of science in decision-making processes, the new

dynamics between the Global South and high-income countries, the implications of climate finance and carbon markets, the strengthening of adaptation strategies, the new focus on ecosystems as key elements for mitigation, and global efforts towards a just transition.

28 Novembre 2025 | 15:00 - 16:30 CET

COP30:
Esiti e prospettive della
Conferenza di Belém

Relatori:
Federica Fricano - MASE, head of delegation
Alice Giallombardo - MASE
Giulia Maria Baldinelli - MASE
Marianna Ronchini - MASE
Caterina Guidi - CMCC

Modera:
Anna Pirani - CMCC
Mauro Buonocore - CMCC

www.cmcc.it
www.ipccitalia.cmcc.it



The full video of the webinar is available here: www.cmcc.it/lectures_conferences/cop30-esiti-e-prospettive-della-conferenza-di-belem

The 30th EAERE Annual Conference: CMCC at the forefront of environmental economics in Bergen, Norway

CMCC manages the EAERE Secretariat and was actively involved in the 30th Annual Conference of the European Association of Environmental and Resource Economists (EAERE 2025), which took place from June 16 to 19, 2025, at the Norwegian School of Economics (NHH) in Bergen, Norway. The EAERE Secretariat is managed by the CMCC Foundation.

The EAERE Annual Conference is an invaluable opportunity for meeting, exchanging and debating current topics in environmental and resource economics. In the 2025 edition of the Conference, CMCC

researchers play an active role in discussions on environmental and resource economics, presenting their research, organizing sessions, and leading workshops on a variety of key issues including climate and resource management. From circular economy, to resource efficiency, and policy frameworks for sustainability, the proceedings help encourage dialogue between science, policy, and business, with CMCC researchers aiming to further contribute to informed decision-making and highlighting the importance of research in guiding climate action and sustainable development.

www.cmcc.it/article/30th-eaere-annual-conference-cmcc

CMCC at AGU25: Connecting water, climate research, and global solutions

At AGU25, water became a symbol of connection, resilience, and shared responsibility – a theme deeply aligned with CMCC's work on water resources, vulnerable communities, and the natural and urban systems increasingly exposed to climate extremes. From Mediterranean agriculture and African river basins, to climate-proof cities and the role of artificial

intelligence in water management, CMCC scientists presented their latest research on water management, weather forecasting, and climate adaptation. Joining global researchers, practitioners, and policymakers in New Orleans from December 15 to 19, CMCC will explore solutions grounded in science, cooperation, and innovation.

www.cmcc.it/article/cmcc-at-agu25-connecting-water-climate-research-and-global-solutions



At the frontier of geosciences: CMCC at EGU General Assembly 2025

EGU25 (Vienna, April 27, May 2) hosted sessions focusing on a variety of topics – including climate policy, NASA's Juno mission, resilient climate technologies, plastics,

and climate hazards for example. CMCC researchers convened and co-convening multiple sessions on a variety of topics.

The full list of CMCC presentations and sessions is available here: www.cmcc.it/lectures_conferences/cmcc-at-egu-general-assembly-2025

ECCA 2025: Accelerating climate adaptation through collaboration, innovation, and community

Adaptation to climate change is not a distant challenge – it is an immediate necessity that must be addressed with both urgency and strategic planning. In the words of CMCC President Antonio Navarra, “Climate adaptation is not a 100-meter sprint – it’s a marathon.” The discussions at ECCA 2025 made clear that the path forward relies on building trust in science, ensuring that knowledge is both reliable and locally relevant, and connecting this knowledge directly with society and policy.

The 7th European Climate Change Adaptation Conference (ECCA2025), the CMCC’s flagship event and the leading conference on climate adaptation in Europe, will take place for the first time in Italy from 16 to 18 June 2025.

The Conference is a key milestone in the international climate calendar. This edition was set to bring together influential voices and stakeholders from across Europe and beyond to accelerate climate adaptation efforts. Entitled “Smarter, Faster and More Systemic Adaptation”, ECCA2025 provided a vibrant platform for showcasing cutting-edge research and innovative solutions, sharing knowledge and best practices, and fostering collaboration towards a climate-resilient society. It gathered together researchers, decision-makers, practitioners, and other relevant stakeholders to exchange research findings, innovative policy developments and solutions, and practical implementation experiences.

www.cmcc.it/article/ecca-2025-accelerating-climate-adaptation-through-collaboration-innovation-and-community



Italy-India cooperation on Machine Learning in climate, weather, and ocean

Leading scientists from Italy and India met in Pune to advance climate modeling and research using AI, improve predictive capabilities, and develop innovative solutions for climate resilience. The workshop, jointly organized by the Euro-Mediterranean Center on Climate Change (CMCC), the Indian

Institute of Tropical Meteorology, and the Indian Ministry of Earth Sciences, Govt. of India, aimed to strengthen collaborations among research institutions and global leaders in climate research and machine learning applications.

www.cmcc.it/article/italy-india-cooperation-on-machine-learning-in-climate-weather-and-ocean



One Ocean Science Congress & UN Ocean Conference 2025

CMCC representatives attended the One Ocean Science Congress (OOSC2025) and the 2025 UN Ocean Conference (UNOC2025), held in Nice from June 3 to 13, 2025. CMCC's presence underscores its commitment to

advancing marine science in the context of climate change, with a particular focus on the most vulnerable regions, particularly coastal areas.

www.cmcc.it/lectures_conferences/one-ocean-science-congress-un-ocean-conference-2025

The CMCC Lectures series

Be inspired by the world's leading experts in climate science and policy and join their insightful discussions on frontier topics. The CMCC Lectures webinar series offers

influential scientists a dynamic platform to share their groundbreaking research through meaningful conversations with CMCC peers and the broader scientific community.

See the full list of the CMCC Lectures: www.cmcc.it/what-we-do/events#lectures



cmcc 20 Lectures

Speaker: **Ian Sue Wing**
Dept. of Earth & Environment Boston University

Economic modeling of climate change impacts: current trends, new directions

Moderator: **Erica De Cian**, CMCC
15 October 2025, 12:00 CEST
Online event
[Register and participate](#)

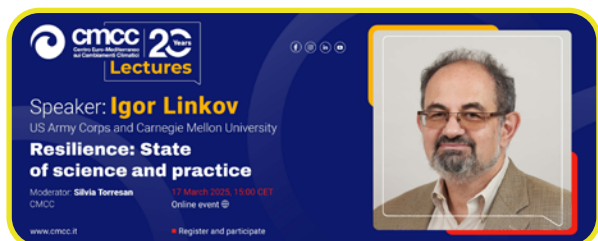


cmcc 20 Lectures

Speaker: **Alessandra Giannini**
Ecole normale supérieure – PSL & IPSL

Late 20th century Sahel drought: An obvious candidate for attribution?

Moderator: **Anna Pirani**, CMCC
1 May 2025, 13:00 CEST
Online event
[Register and participate](#)



cmcc 20 Lectures

Speaker: **Igor Linkov**
US Army Corps and Carnegie Mellon University

Resilience: State of science and practice

Moderator: **Silvia Torresan**, CMCC
17 March 2025, 15:00 CEST
Online event
[Register and participate](#)



cmcc 20 Lectures

Speaker: **Andy Reisinger**
Australian National University

Overshoot: challenges and choices after we exceed 1.5°C

Discussant: **Sohail Shayeegh**, CMCC
Moderator: **Anna Pirani**, CMCC
18 September 2025, 11:00 CEST
Online event
[Register and participate](#)

CMCC Talks

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: www.cmcc.it/what-we-do/events#talks

Advanced training

Training that tracks the frontier. The schools CMCC ran in 2025 took early-career researchers into cloud-native ocean data analysis, carbon dioxide removal, coastal resilience to sea level rise, and the climate of the Adriatic, while MAGICA turned sustainability goals into entrepreneurial projects. The VALORADA workshop carried the same expertise outside academia, to a regional administration learning to manage drought, agricultural vulnerability and coastal risk with new tools.

The CMCC Advanced Educational Program features six PhD programs, a Master of Research, seasonal schools, and a specialised school focused on emerging issues. Its aim is to address future challenges and develop sustainable solutions.

PhD Programs in collaboration with Partner Universities:

- Science and Management of Climate Change (Ca' Foscari University of Venice)
- Agrometeorology and Ecophysiology of Agricultural and Forestry Eco-Systems (University of Sassari)
- Sciences, Technologies and Biotechnologies for Sustainability (University of Tuscia)
- Biological and Environmental Sciences and Technologies (University of Salento)
- Complex Systems Engineering (University of Salento)
- Future Earth, Climate Change and Societal Challenges (Alma Mater University of Bologna)

Cloud native ocean data analysis and visualisation school takes place in Bologna

The Cloud Native Ocean Data Analysis and Visualisation School took place from 13 to 17 October 2025, a training initiative co-organized by CMCC, a member of the DCC-CR Partner Alliance Network, the University of Bologna and EGI, and in collaboration with EDITO.

www.cmcc.it/article/cloud-native-ocean-data-analysis-and-visualisation-school-takes-place-in-bologna

FERS – Future Earth Research School

The Future Earth Research School aims to provide high-level scientific courses that help researchers understand and anticipate future global environmental challenges in the more general context of sustainability and climate change.

Schools organized by FERS in 2025:

- Carbon Dioxide Removal for a Net-Zero Future
- Coastal Resilience to Sea Level Rise

All the details about the schools are available at: <https://fersschool.cmcc.it/>

Adriaclimplus: Introductory school on climate changes in the adriatic sea

The Introductory Summer School on Climate Change in the Adriatic Sea, taking place at the CMCC headquarters from July 20 to 25 and co-organized by the CMCC Foundation and the University of Bologna within the framework of the AdriaClimPlus project, will provide students with a science-based overview of the current and projected climate conditions in the Adriatic region.

www.cmcc.it/lectures_conferences/introductory-school-on-climate-changes-in-the-adriatic-sea

MAGICA Summer School 2025

The MAGICA Summer School at H-FARM Campus, jointly organised with CMCC, offers a unique opportunity to develop sustainable entrepreneurial projects, inspired by the UN SDGs and the EU Global Gateway Strategy, combining innovative ideas with emerging technologies.

www.cmcc.it/lectures_conferences/magica-summer-school-2025

VALORADA scalability workshop

VALORADA, a European project funded by Horizon Europe in which the CMCC is a partner, organised the online workshop 'Application and Development of Tools in the Molise Region'. The event presented the platform and indicators developed to support the Molise Region in managing climate risks, with a focus on drought, agricultural and social vulnerability, and coastal risks.

www.cmcc.it/lectures_conferences/scalability-workshop-applicazione-e-sviluppo-degli-strumenti-nella-regione-molise

CMCC 2025 in numbers



+450 people (fte)

300 researchers

specializing in climate
and social sciences

From

40 countries

5 continents



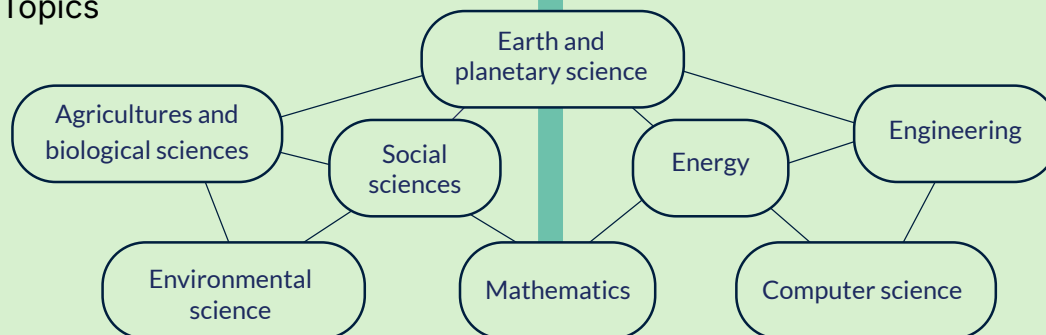
250+ publications

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

257+ MLN €

received from **competitive
& non competitive funding**
programs

25+ MLN € (as of 2025)

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 31.12.2025

456 people at CMCC

65%



Research area

31%



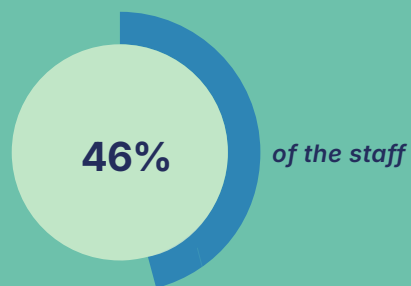
Senior positions

33%



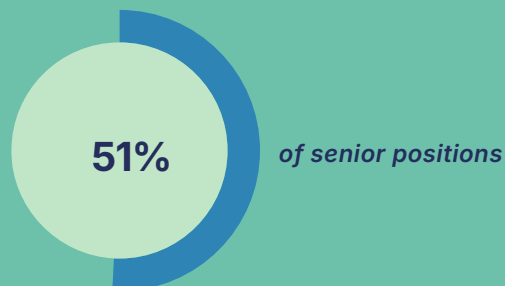
Services for research

Women at CMCC are



46%

of the staff



51%

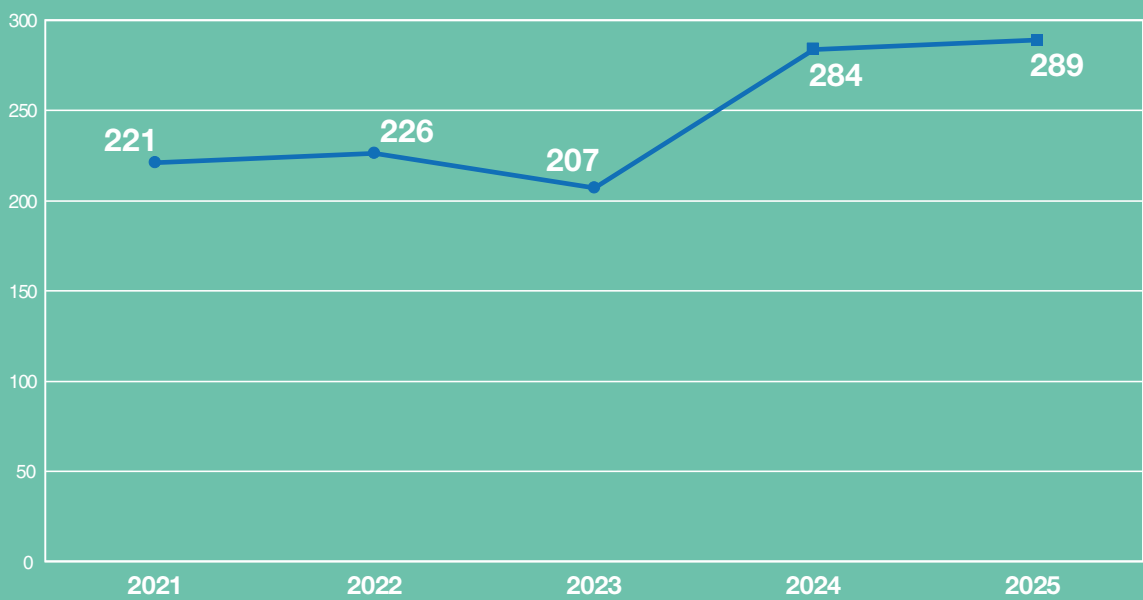
of senior positions

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

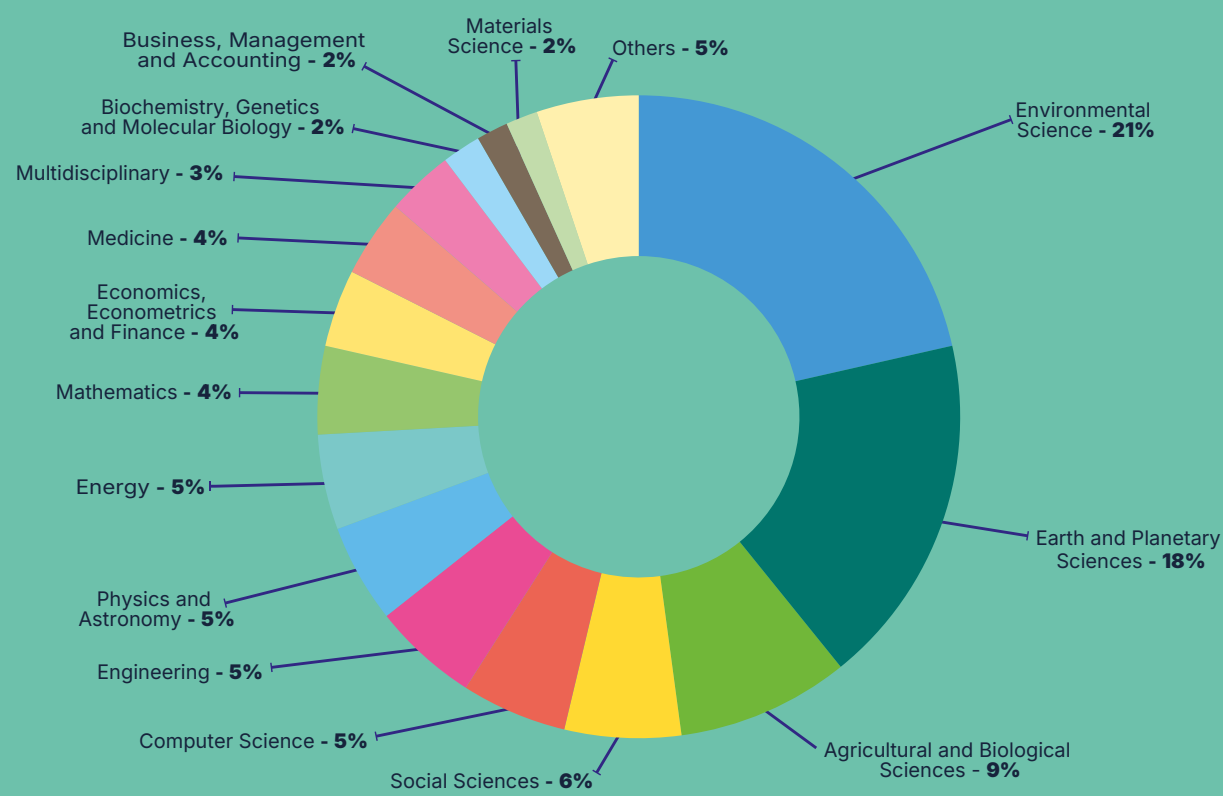
Find job opportunities at CMCC. Submit your CV, browse our open positions, and check if your requisites fit with any of them: www.cmcc.it/work-with-us

Publications

284 papers published in 2024

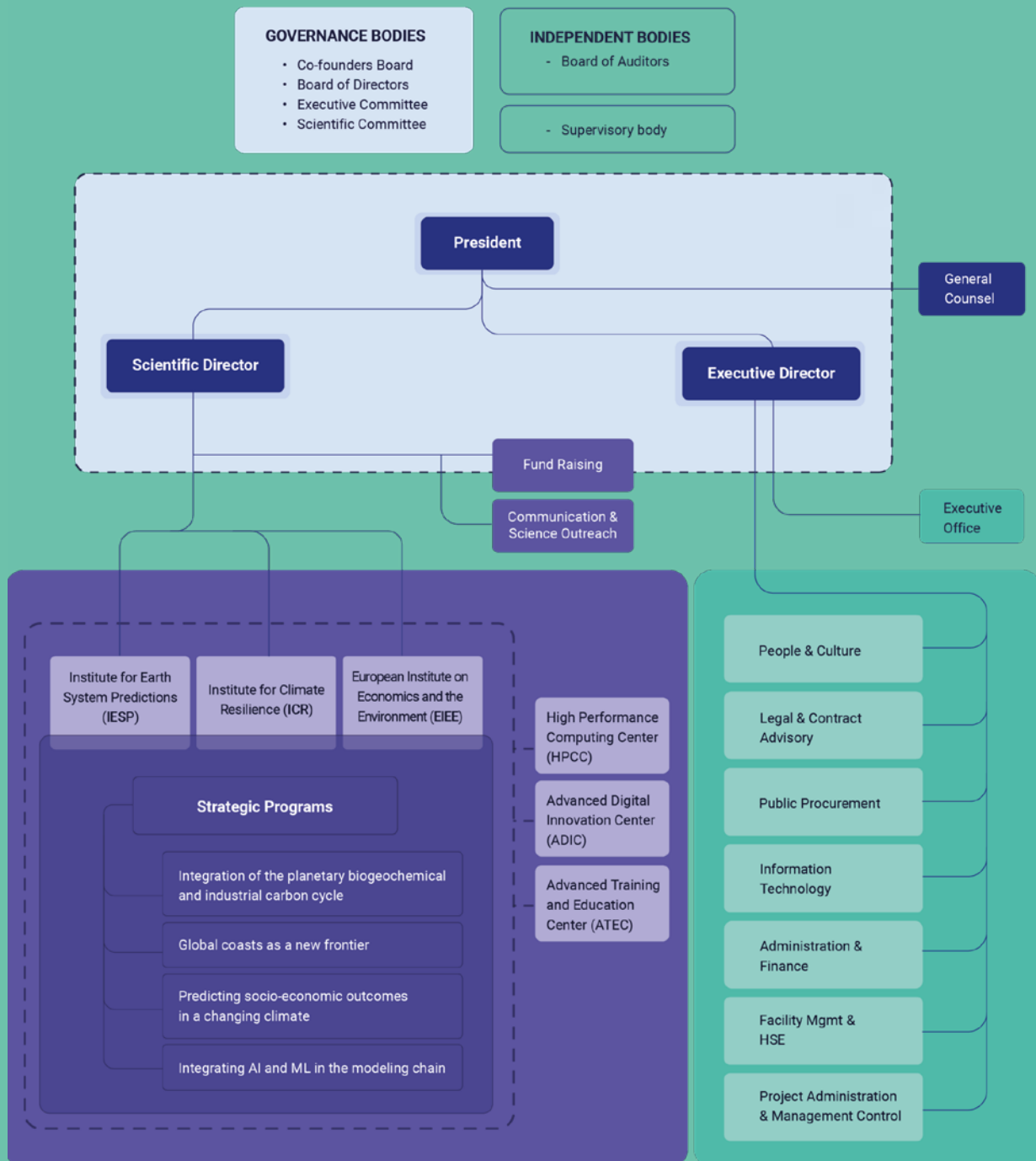


Share of CMCC publications per subject area



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 Toscana

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

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President



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Global Coasts as a New Frontier - GCNF Program
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Integration of the Planetary Biogeochemical and Industrial Carbon Cycle - ICC Program
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Predicting Socio-Economic Outcomes in a Changing Climate - PSEO Program
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Integrating AI and ML in the Modeling Chain - AI/ML Program
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High Performance Computing Center - HPCC
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Advanced Digital Innovation Center - ADIC
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Advanced Training and Education Center - ATEC
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