Annual Report
2020

cmcc
Centro Euro-Mediterraneo
sui Cambiamenti Climatici

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Contents

Message from the President

This was a difficult year. The pandemic came over like a rising tide and slowly submerged all our activities, bringing international networks and exchanges to a standstill, preventing visits and collaborations. The methods and norms of international cooperation were overturned, and working conditions were made difficult by safety concerns for individuals and their families.

Nevertheless, we endured. Electronics communications, virtualization of meetings and training was relatively easy to set up in our environment that, to some extent, is already highly virtualized. Numerical modeling is the core of our activity, and our cultural base was already prepared for concepts and methods that were not connected with physical localization. We were able to continue our scientific work and we were even able to expand in terms of funding and publishing results.

As reported in the following pages, we increased the number of funded research projects (173), the production of refereed papers (186), inaugurated new activities, and, driven by necessity, transformed many events into digital and remote formats. In this way, the work planned in a very different reality from that experienced in 2020 has been done.

The pandemic also made us think about the proper role of science in society. As the availability of sound scientific knowledge became once again of paramount importance, it was a harsh reminder of the value of the search for truth. It showed the foundational value of pushing and supporting a public discourse based on facts and evidence. The events of this year have made our commitment to scientific integrity, freedom of expression and equal opportunity for all even stronger, and our search for truth even more pressing.

In this uncertain environment, we were able to continue the transition to our new main building in Lecce, launching complex procurement for the finalization of the building so that we could maintain the deadline for consolidation of our offices in Lecce for 2021. We also launched the procedure for the updating of our computing system and the new data center.

I would like to thank all our staff that made all this possible. Scientists, students, managers, administrators: they all showed a degree of commitment above their duties, showing once again the resilience and the enthusiasm of the CMCC community. It is, therefore, with special gratitude and pride that we present the Annual Report of 2020.

Highlights of 2020

9 Research divisions

173 Projects

197 People

186 Refereed papers

148 Events

A snapshot of the year seen through the CMCC's multidisciplinary activities

2020:
selected
topics

Health

Virus spillovers, CO_2 emissions, tipping points in the Earth's climate system, the One Health approach, air pollution and green recovery. Do we need profound shocks to change emissions pathways? Crisis, opportunity, the way science informs policy decisions, and how COVID-19 is hindering the process. The CMCC's research contribution to these challenging issues.

Can we not mention it? 2020 was the year in which, more than any other, the link between health, environmental sustainability and air pollution came into the spotlight. We are talking about the COVID-19 pandemic, how it has changed everyone's lives, from work to private life. Above all, we are talking about how points of contact between the pandemic and climate change have emerged, such as global issues, the search for local solutions, the need for large computing infrastructures to run complex mathematical models to build scenarios, resilience and adaptation, the reduction of pollutants emissions, sustainable development as a way out of the crisis (both pandemic and climate), factors such as deforestation that is at the root of both global crises. In this multiplicity of aspects, the multidisciplinary and international research of CMCC has developed studies and initiatives to deepen the knowledge of these links, making available its computing infrastructure and in close collaboration with the network of international partners. Through peer-reviewed papers, webinars, interviews with experts and research,

interconnections have emerged between numerous fields, from sustainable finance to mobility, from deforestation to the media, from climate change mitigation to adaptation measures, all of which are highly relevant in defining and understanding scenarios for the near future.

Forests: Where the Covid Crisis and Climate Action Meet. The starting point is the One-Health approach, which considers people's health closely linked to the health of animals, and our shared environment. CMCC Scientist Monia Santini explores the forest-climate-health nexus and how limiting forest fragmentation in the tropics can act as a multiplier of benefits. The One-Health approach, in fact, is also used to study how anthropized environments have an attractive effect on bats, as they meet their roosting and hunting needs, which comes with a major risk factor in the emergence of novel bat-borne diseases in both humans and animals. Santini explains how forest restoration, as well as rigorous actions to counteract the uncontrolled devastation of forest landscapes, can create a virtuous cycle

of benefits for the environment in general, by ensuring the provision of key ecosystem services – as local to global climate regulation – to nature and people, and hence human systems, by reducing their exposure and vulnerability to epidemics and to cascading social and economic crises.

This article is part of the series "**Moving Forward. Foresight's collection on COVID-19, climate, and shaping the future**, a collection of op-ed, interview and articles published in the CMCC's Digital magazine Foresight (www.climateforesight.eu). Economists, journalists, media experts, scientists, propose their vision of the pandemic through the lens of its discipline, highlighting the links with sustainable development as an opportunity to get out of the crisis and build a concrete future.

Fostering green finance for a climate - resilient post-COVID-19 recovery is the title of the webinar that hosted an open dialogue with Barbara Buchner (Global Managing Director of Climate Policy Initiative), Ivan Faiella (Senior Economist at the Bank of Italy), Sara Lovisolo (Group Sustainability Manager, London Stock Exchange Group), and Massimo Tavoni (Director, RFF-CMCC European Institute on Economics and the Environment (EIEE) and Professor, Politecn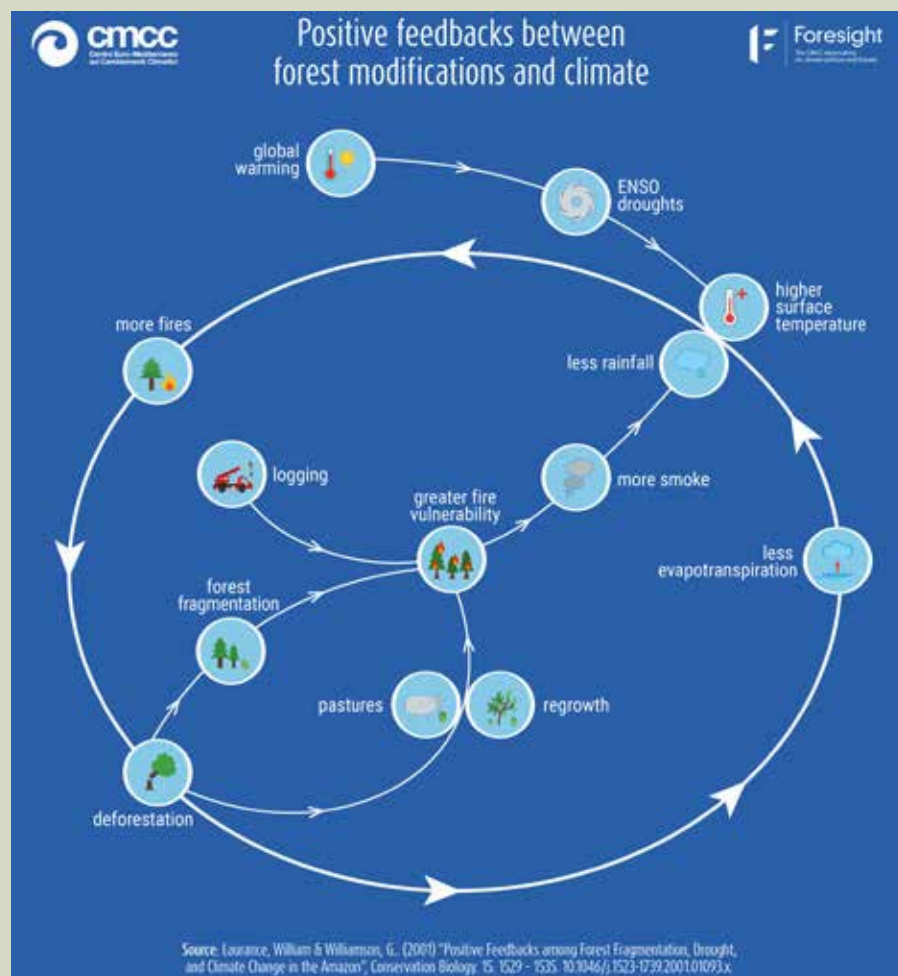ico di Milano). The main topic was a focus on the COVID-19 crisis, and how it can be seen as a wake-up call for our social and financial system to be better prepared for the long-term climate crisis. Today's financial interventions, while addressing the short-term health and economic urgencies linked to the

pandemic, must think about the chronic climate crisis to design a resilient and green recovery. Forgetting the global climate emergency in such a crucial moment for financial investments would mean losing the opportunity to reverse the previous pattern, locking us into long-term unsustainable investments and moving the world away from the possibility to meet the Paris Agreement's goals.

COVID-19: Fast access to HPC supercomputing facilities. In an initiative promoted by Associazione Big Data (ABD), the Italian most powerful supercomputing facilities, among which the CMCC supercomputer infrastructure, were made available to public and private scientific research working against the coronavirus. 8 million hours of calculation were allocated for free to meet the request for computing resources to contribute to the mitigation of the impact of the COVID-19 pandemic.

Health, air pollution, COVID-19: an integrated approach. In a publication in Environmental Research Letters, researchers from the European Institute on Economics and the Environment (EIEE), Bocconi University and Politecnico di Milano have quantified the health repercussions of the lock-down measures implemented in Lombardy in spring 2020. The researchers have applied

Positive feedbacks between forest modifications and climate

Source: Laurance, William & Williamson, G. (2001) "Positive Feedbacks among Forest Fragmentation, Drought, and Climate Change in the Amazon", Conservation Biology. 15. 1529 - 1535. 10.1046/j.1523-1739.2001.01093.x.

novel machine learning techniques to project what the pollution would have been without lock-down, using data from 83 monitoring stations in the region from the past years to train the model. This has allowed isolating the effect of lock-down restrictions from confounding factors such as weather. Previous work has mostly compared similar periods in the last years, without accounting for the variation in weather patterns.

A clear reduction in urban CO_2 emissions as a result of COVID-19 lockdown. Cities with dense commercial activities and intense road traffic experienced up to 75% emissions reduction linked to lockdown-measures. The effect of the COVID-19 lockdown on CO_2 emissions in seven European cities has been observed by the European infrastructure ICOS – Integrated Carbon Observation System. The study, conducted by an international team and coordinated by CMCC and the University of Tuscia, shows a clear temporal connection between the restrictions and the emissions reduction, whose entity depends on the characteristics of the sampled areas and the stringency of the lockdown restrictions in place.

Health and climate change: responding to converging crises. The COVID-19 pandemic and climate change represent converging crises that have and will have impacts on health. The importance of aligning response strategies is central in the 2020 edition of "The Lancet Countdown on health and climate change", edited by the outstanding journal on medical science. The CMCC Foundation is among the institutions that contributed to the report and presented it in the Bangladeshi Launch on December 10, 2020. "This year's report reveals the most concerning outlook for human health since the inception of the Lancet Countdown" affirms Shouro Dasgupta, CMCC researcher and author of the Lancet Countdown 2020. "Climate change impacts are claiming lives, damaging human health and disrupting livelihoods in all parts of the world, right now. This is not projected: these are the impacts that are currently happening. And the most vulnerable in our society are facing the greatest burden".

Future
Earth

Learning about the future climate change and its impacts thanks to very high-resolution climate simulations. Understanding how their distribution will change in limited areas at hourly scale, but also developing enhanced decadal and seasonal prediction systems: in 2020, the frontier research of the CMCC provided science-based information to tell us what the world will be like in the coming decades.

Climate change adaptation plans and measures existing worldwide are based on future scenarios made available to decision-makers by the world of research. Regional Climate Models are high-resolution models of the Earth's climate that are able to improve simulations of extreme weather events that may be affected by climate change and thus contribute to limiting impacts through timely action. The CMCC is realizing several studies in the framework of international projects and collaboration to improve this next generation of high-resolution climate models and develop high-quality regional climate information and projections. In 2020, the CMCC's cutting-edge research on the Earth System focused also on producing unprecedented weather and climate predictions, and enhanced decadal and seasonal prediction systems for an advanced analysis of physical processes and their interactions with societies and economy.

The new generation of climate models: the future of rainfall in the Alps. Less intense mean daily precipitation, more intense and localized extreme events. This is what the future climate scenarios indicate for the Eastern Alps, according to the study "Evaluation and Expected Changes of Summer Precipitation at Convection Permitting Scale with COSMO-CLM over Alpine Space", published by the CMCC Foundation in the journal Atmosphere. The research is conducted in the context of the European project H2020 EUCP (European Climate Prediction system) and contributes to the work of the international scientific community for the development of climate models that can support decision makers in a proper assessment of extreme events and their evolution considering climate change, with the ultimate goal of limiting its negative impacts on societies and economies.

Next generation climate models are developed and applied by the CMCC Foundation in several international projects and contexts. Some examples include the study of urban heatwaves and the evolution of rainfall extremes in support of adaptation policies on an urban scale: all contexts that will benefit from having simulations on hourly scales.

Data Delivery System: the CMCC platform for obtaining and sharing climate data. Temperature, precipitation, ocean salinity, evapotranspiration, indicators: climate data relates not only to observations that represent our climate system in a specific location and time, but also to numerical models that simulate the climate of the past and the future. Data produced through research can feed further research, thus highlighting the importance of distributing and sharing information with the scientific community, so that our global knowledge on climate change is more efficient and progresses faster.

In this framework, the CMCC Foundation has developed and made available the CMCC Data Delivery System (dds.cmcc.it): a free, unique, seamless and open access point that facilitates the dissemination of data produced and used by the CMCC's research activities.

The web portal already contains several datasets and others will be added in the coming months. *BioClim* is a dataset of 35 bioclimatic indicators – such as annual mean temperature, evapotranspiration, annual and seasonal precipitation – useful for different studies, including those in the field of ecology and environment. *Black Sea physics analysis and Forecasting System* offers daily means of Black Sea oceanographic variables – such as temperature, salinity, and currents – from July 2018. *Historical Global Cooling and Heating degree-days* (1970-2019) contains high-resolution historical global gridded datasets of monthly and annual cooling and heating degree-days (1970-2019).

ESCAPE2: world-class, extreme-scale computing capabilities for weather and climate predictions. New challenges and optimization strategies were addressed by CMCC within the ESCAPE2 project by means of new languages (e.g. PSyClone and GTClang) and solutions leading to very high resolution (1/36°) configurations of the NEMO ocean model.

CMIP6: modelling the future climate. Under the World Climate Research Programme (WCRP) the Working Group on Coupled Modelling (WGCM) established the Coupled Model Intercomparison Project (CMIP) as a standard experimental protocol for studying the output of coupled atmosphere-ocean General Circulation Models (AOGCMs). Models results are used to perform research of relevance to climate scientists preparing the Intergovernmental Panel on Climate Change Assessment Reports (IPCC-ARs).

We are now in the 6th phase of CMIP (CMIP6) and CMCC participates in this effort based on the CMCC-CM2 model in four different configurations, ranging from standard horizontal resolution (one degree) for both atmosphere and ocean components, to the highest ¼ degree

resolution. Different CMIP6 experiments have been provided participating in the different efforts focusing on Carbon Cycle, Land use, Ocean, Regional Phenomena, Scenarios and finally Decadal Predictions.

CMCC-CM2 model data are now available for the community on the ESGF data portal.

A prototype service developed together with ENEL Hydropower. CMCC provides Decadal Predictions to the scientific community, and within the Copernicus Climate Change Service a recent prototype service, based on multi-model decadal predictions, has been developed together with ENEL Hydropower. The forecast is based on the multi-model ensemble (in total 37 members) of four decadal prediction systems (UKMO, BSC, DWD, CMCC).

Seasonal prediction systems: enhanced operational forecasts with the new SP3.5 version. Seasonal forecasts, performed using global numerical climate models, can have a time horizon ranging from one to several months. The feasibility of such forecasts relies on the existence, in the climate system, of low frequency, slower processes, taking place in the stratosphere and at the land surface, as well as in the ocean and in the sea ice. Such processes generate phenomena which last longer than the typical atmospheric synoptic timescale and produce effects on the atmosphere which can last for several months, providing essential sources of seasonal predictability. The most well-known of such phenomena is ENSO (El Niño Southern Oscillation).

The CMCC improved its Operational Seasonal Prediction System SPS3 to the new SPS3.5 version starting from the operational forecast of October 1st, 2020. The new version differs from the previous one essentially only for the horizontal resolution of the atmospheric model component (CAM 5.3), now reaching 50 km, plus a number of comparatively minor details. Several combinations of three parametrization settings (Orographic Gravity-Wave Drag, surface friction and vertical diffusion) were tried until a satisfactory set of new parameters was achieved, showing noticeable overall improvements in comparison with both the old SPS3 maps and the un-tuned SPS3.5 maps.
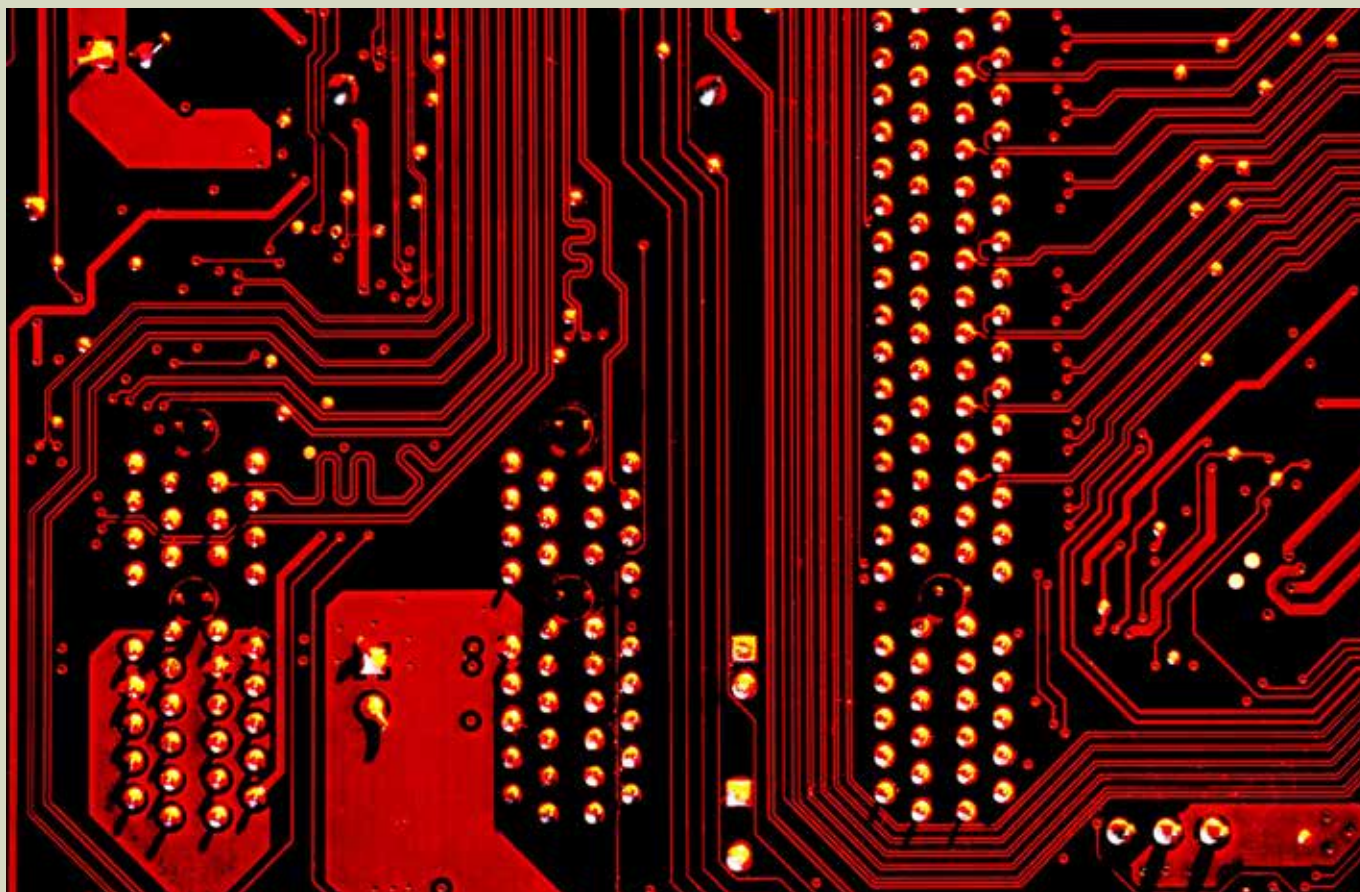
Ocean

The global ocean supports unique habitats, provides food and water supply, renewable energy, benefits for health, cultural values, tourism, trade, and transport. It is interconnected and has a key role within the climate system. From interactive portals to participating in global research initiatives, in 2020 the CMCC releases advanced scientific products constantly updated to support all the activities and research at sea, foster the Blue Growth and protect the marine environment.

Marine forecasters face the challenge of predicting a very complex and constantly changing marine environment by applying ocean science, knowledge and technological skills to produce predictions of the state of the ocean.

Operational ocean forecasts are delivered daily in near real time and rely on numerical model runs to predict how the ocean will change over time and space by means of equations that describe a variety of ocean processes including interactions with waves, atmosphere and land. Ocean forecasts provide predictions of many aspects of the blue ocean, including the ocean temperature, salinity, currents, sea level, tides. Marine observations, both from in-situ and satellite observing systems, are used to produce comprehensive analyses of the ocean used as initial state for the ocean forecast models.

Such information is used to build services and applications for supporting societal activities and Blue Growth in a sustainable way, such as: support safe maritime operations including storm surge and cyclone predictions, search and rescue, navigation, oil spill emergency management; provide regular information to industrial and private sector applications, protection agencies, coastal engineering, fishing and tourism; support the Marine Strategy Framework Directive (MSFD) implementation.

Improved forecast and new insights for the Mediterranean and Black Seas. CMCC contributes to the Copernicus Marine Environment and Monitoring Service (CMEMS), for the provisioning of regular and systematic information of the blue ocean in the Mediterranean and the Black Seas.

CMCC coordinates, develops and maintains the Mediterranean and Black Sea operational physical modelling systems. CMCC is responsible for the Mediterranean and Black Sea Physical components, for the operational provisioning of analysis, forecast and reanalysis of essential variables in the regions. It coordinates the CMEMS Med-MFC (Mediterranean Monitoring and Forecasting Centre) and co-coordinates the BS-MFC (Black Sea Monitoring and
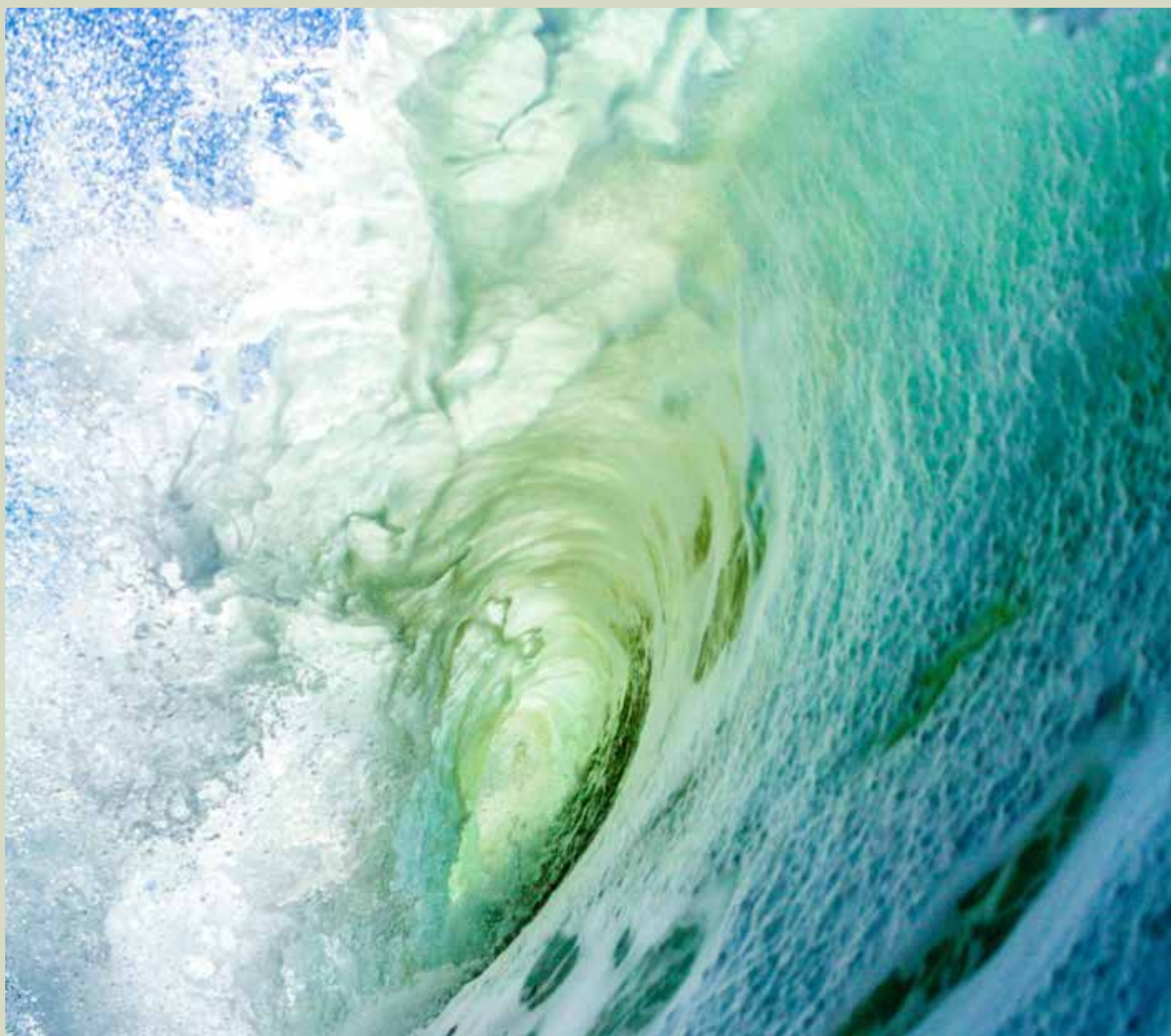
Forecasting Centre) which is led by IO-BAS (Bulgaria).

Reconstructing the past of the Ocean. In 2020, a team of CMCC scientists produced Mediterranean and Black Seas new reanalyses with an increased model resolution and novel parameterization schemes. In addition to the upgrades in the modeling and data assimilation systems, the CMCC implemented a parallel version at the global scale with the aim to solve and accurately represent mesoscale processes.

The CMCC contributions to the Copernicus Climate Change Service (C3S), Copernicus Marine Environment and Monitoring Service (CMEMS) and related applications were the focus of a session of the the CMCC Annual Meeting 2020.

Predicting the Ocean for a sustainable future. On World Oceans Day 2021, the UN Decade of Ocean Science for Sustainable Development announces its endorsement to CoastPredict, the programme launched in 2020 that is focused on a predicted global coastal ocean where society understands and can respond to changing ocean conditions. CoastPredict has therefore been included in the first set of Ocean Decade Actions.

The Chair of the Programme CoastPredict is Prof. Nadia Pinardi, renowned oceanographer of the University of Bologna and member of the CMCC Strategic Board; Giovanni Coppini, Director of the CMCC scientific Division Ocean Predictions and Applications is among the members of the Steering Group of the Programme.

MYSEA: CMCC research for marine turtle protection. Cutting-edge sensors, operational forecasts for the Mediterranean Sea, and a dedicated web app able to track the routes of sea turtles and collect key information to monitor climate change impacts on sea turtle habitats and behaviours, in order to design and plan strategies to protect them. The CMCC is partner of MYSEA, a project coordinated and funded by Consorzio di Gestione Torre Guaceto that aims at creating a "Puglia Marine Observatory" for the protection of *Caretta caretta* turtles.

The potential of marine coastal ecosystems to address climate change. The EU 2020 Biodiversity strategy and 7th Environment Action Programme highlight the importance of halting the loss of biodiversity and ecosystem services by preserving ecosystems and fully integrating environmental requirements into policymaking to face climate change. To fill the lack of knowledge on the impacts of climate change on the most important marine coastal ecosystems (seagrass beds, coral reefs, mangroves, coralligenous and calcareous bio-concretion assemblages, salt marshes and kelp forests) is the focus of the project MaCoBioS, a EU funded project whose main objective is to ensure efficient and integrated management and conservation strategies for European marine coastal ecosystems to face climate change.

Building the Generation Ocean in Italy. 126 participants and 26 new ideas: this is the result of Oceanthon, the first hackathon to raise awareness about the ocean's key role in creating a healthier, more resilient and sustainable future. The UNESCO's Intergovernmental Oceanographic Commission (IOC-UNESCO) and CMCC, with the support of Hack for Italy, launched in 2020 the Oceanthon to find innovative solutions to ocean related issues.
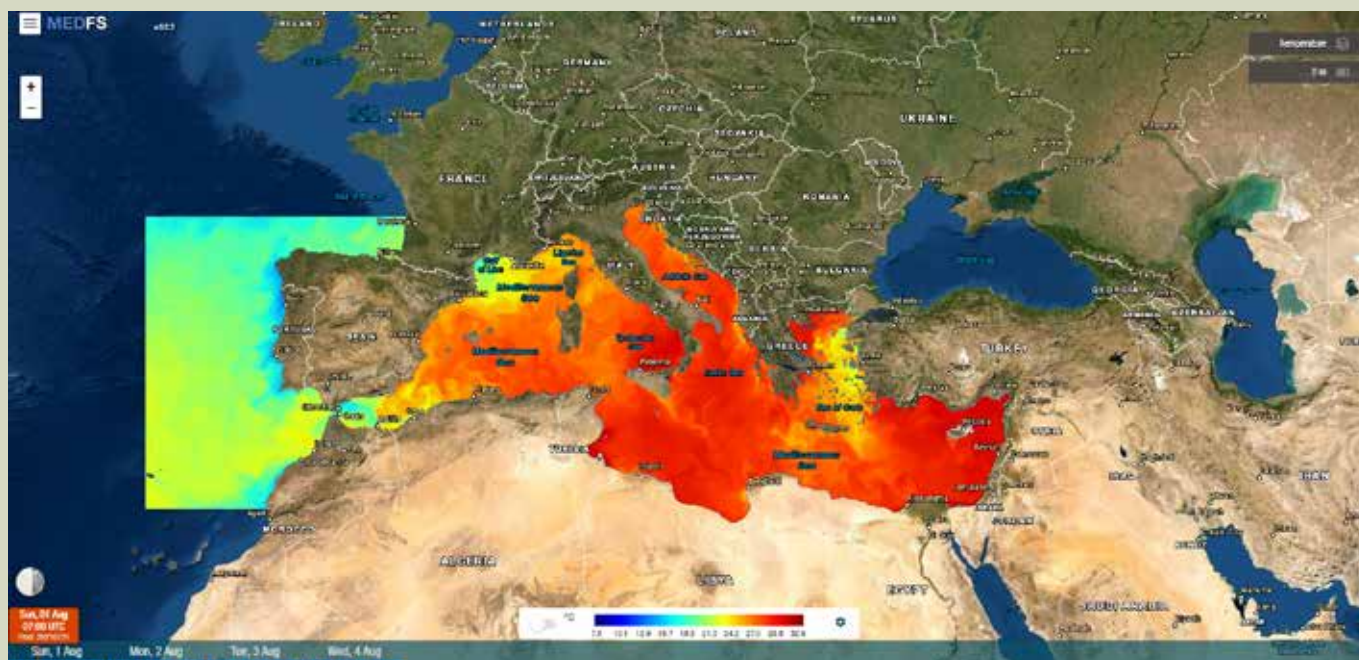
From science to services

Climate information to assist decision-making. User-friendly interactive platforms that allow users to evaluate multiple features of simulated and observed data over different geographical domains. The CMCC contributes to the world of climate services through its studies and projects to smooth and accelerate the deployment of climate forecast-enabled services by fostering their market uptake.

Climate change entails critical economic, social, and environmental risks. Societies need a deep transformation to face these risks by designing a more climate-resilient future, driven by innovation. Thanks to an unprecedentedly fast scientific progress, bespoke indicators and metrics can now signal where the climate can be hostile to productive activities for every sector around the globe. Climate services identify the risks associated with adverse climate events and offer data products and tailored information to allow the users to make climate-smart decisions. This approach puts the future risks into present considerations, preventing losses and increasing the profit margin. In 2020, the CMCC supported the realization of leading-edge climate services through its projects and Copernicus contracts to support impact studies and the risk assessment of extreme events, with a special focus on urban areas, ensuring that the best available climate science was effectively communicated with agriculture, water, health, and other sectors, to develop and evaluate adaptation strategies.
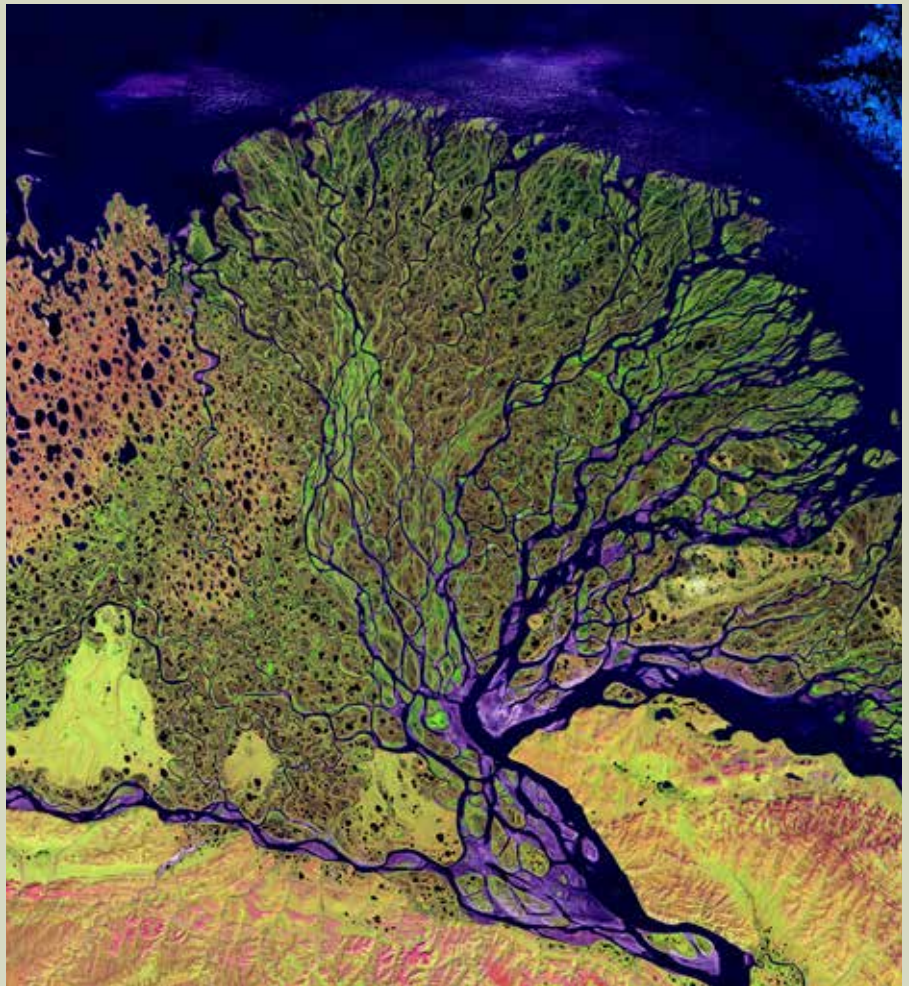
Climate services: the legacy of the CLARA project. 15 climate services developed and supported in their market uptake, an original card game and a new website showcasing the scientific knowledge developed by an outstanding international team. On the International Day of Disaster Risk Reduction 2020, the CMCC Foundation presented the legacy of the project "Climate forecast enabled knowledge services" - CLARA. Funded by the European Commission under the EU Horizon 2020 – Research and Innovation program and carried on by an international partnership led by the CMCC Foundation, the project concluded on September 30, 2020, announcing the CLARA website redesign and the launch of a card game, "Climate Devil's Advocate".

DATACLIME: the tailored tool for climate analysis. DATACLIME is a climate service developed by the CMCC Foundation under the Horizon 2020 project CLARA – Climate forecast enabled knowledge services aimed at providing climate data and solutions to different types of users with different backgrounds and needs. Conceived as a web-based and multi-product tool, DATACLIME aims at supporting decision-making by offering highly scientific results in user-friendly formats.

DATACLIME is aimed at users, experts and non-experts, for the assessment and study of impacts related to climate change: consulting companies, engineers, researchers, public administration and scientists. In particular, DATACLIME includes products aimed at supporting both public and private users in an easier integration of the effects of climate change into policies, strategies and adaptation plans.

DATACLIME is able to take care of the whole information production chain: from the climate data collection/storage to processing of climate data according to user needs. The processing of climate data includes bias correction and climate analyses using high-resolution climate projections. It is also able to provide climate data in support of different impact studies (e.g. floods, drought, landslides, heat waves, wind storms).

Pluvial flood risk assessment in urban areas. In 2020, the CMCC developed a climate service that generates information required for assessing risks associated to extreme rainfall events and support Disaster Risk Reduction (DRR) in Europe, starting from data made available by the Copernicus Climate Change Service (C3S), with a special focus on urban areas.

The Copernicus Sectoral Information System to support Disaster Risk Reduction contract (C3S_430) coordinated by the CMCC exploits and combines several sources of data. First, datasets already available on Copernicus Data Store (CDS), such as ERA-5 reanalysis and E-OBS, permitted characterizing extreme rainfall regimes over Europe and gave the historical perspective of extreme precipitation events. Furthermore, dynamical downscaling of ERA5 reanalysis at very high resolution (about 2 km) allowed a higher level of detail (in spatial and temporal terms) of twenty urban centres over Europe. Such data were used as input for pluvial flooding risk analysis.

The service for pluvial flood risk assessment in urban areas is being developed in a process of co-creation with users having interest in DRR issues.

A catalogue of high impact weather events is being developed, combined with empirical damage and loss records from public repositories. Within these case studies focused on pluvial floods, the value of the service is being demonstrated by combining high-resolution, probabilistic description of extreme precipitation as provided by observations and reanalysis, exposure datasets and damage/vulnerability models into a comprehensive pluvial flood risk assessment. The climate service develops datasets and applications enabling us to address requests from users and practitioners such as general features of precipitation, data on frequency, pluvial flooding hazard and risk, a ranking of past extreme precipitation events in terms of affected area, magnitude and severity (impact/losses) at pan-European scale and city scale for 20 case studies in Europe, etc.

A Europe-wide framework for Earth-system modelling and climate service activities. "Climate information at your service" was the broad topic of the Climateurope webfestivals, a series of online events to further the dialogue between science and society organized in the framework of the Horizon 2020 Climateurope project. The project aimed to coordinate and support Europe's knowledge base to enable better management of climate-related risks and opportunities, thereby creating greater social and economic value.

With more than 150 institutions involved, the webfestivals events were a mix of plenary talks and virtual rooms/spaces where it was possible to discuss the talks and events, or just take the opportunity to make new connections. The events focused on climate services tools, demo cases, analyses and platforms, with a special focus on adaptation and climate transition in the urban environment, soil erosion, and a multi-sector array of examples and stories.

Land

Environment and natural resources meet information and communication technology: High Performance Computing, advanced data processing, and high-resolution climate projections are the key to address and reduce risks associated with climate change. The cutting-edge research of the CMCC Foundation to address the challenges of climate change impacts on land and ecosystems, for a more sustainable land use and agriculture.

To limit global warming and achieve the goal of the Paris Agreement, we must change the way we use land while reducing emissions from deforestation, as well as enhancing the current capacity of CO_2 sinks. Changes in land use and land management contribute around 14% of the total global anthropogenic CO_2 emissions, mainly through deforestation. Simultaneously, terrestrial ecosystems, mainly forests, absorb nearly one third of the total CO_2 emissions caused by human activities.

Therefore land use choices can have a significant impact on climate change mitigation and help meet the increased ambition foreseen by the "European Green Deal". The CMCC developed international projects and collaboration that focus on forests, ecosystem services, land use and management, and the implementation of adaptation and mitigation plans.

Focus Story "Land is part of the solution". The unprecedented wildfires in Australia and in the Amazon region; the key benefits provided by nature, with perspectives and solutions for creating cities that are resilient, sustainable, liveable and just for everyone; Anthropocene, an art project that documents the ways in which mankind has changed the Earth, bearing witness to the effects of the human footprint on natural processes. Climate, land and ecosystems in the IPCC Special Report: Italy has much to say about climate change and how it affects land. In 2020, the CMCC explored these challenging issues with the articles of its magazine Foresight.

Climate-smarter and sustainable: the future of landscape management in Italy. High performance computing, climate projections, data analysis techniques, agriculture, cutting-edge applications and services for better land management: if we were to describe the Highlander project, these are probably the words we would use. Highlander – High performance computing to support smart and land services wants to prevent or mitigate climate change impacts on land. Thanks to High Performance Computing, the project integrates high-resolution climate simulations, satellite observations, ground monitoring into
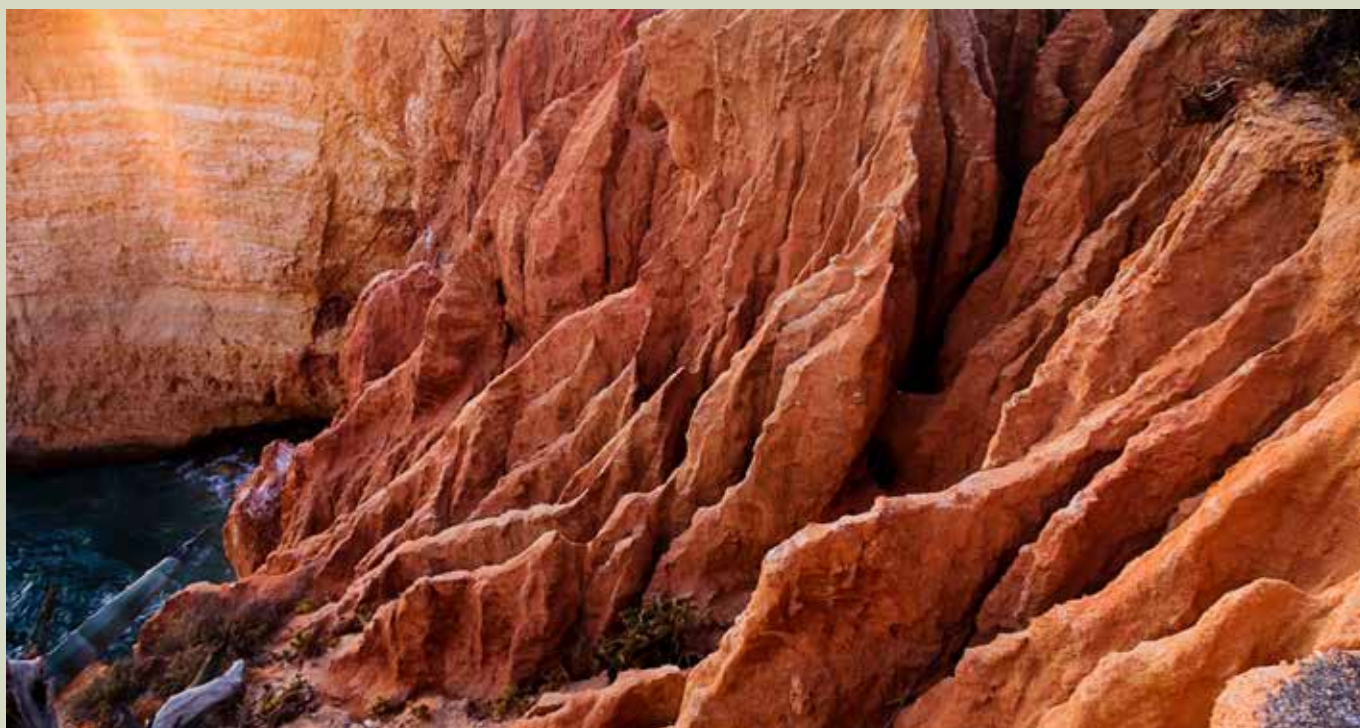
decision support tools for a better and sustainable management of interacting natural resources, human systems and activity sectors.

In the frame of the project, the CMCC realized the downscaling of climate reanalysis over Italy at very high resolution (~2 km) using the model COSMO-CLM.

It's a level of detail never reached before and it will act as a reference for the next projections to be run at the same resolution, further improving the projections currently available for Italy and produced by the CMCC using the same model (~8 km) or those provided by the European downscaling experiment EURO-CORDEX (~12 km). The new simulations will serve as input to several Downstream Applications and pre-Operational Services (DApOS) in the project, four of which are coordinated by CMCC: land suitability for forests, soil erosion hazard, water resources availability and human wellbeing.

Soil erosion: addressing the hazard through Copernicus data and tools. Water-induced soil erosion happens when soil becomes detached and is then transported and deposited due to rainfall, runoff, snow melting or irrigation. When the soil erosion rate is higher than the soil formation rate, the soil becomes depleted and the potential for the land to be used productively is reduced.

Soil erosion comes with a range of negative consequences, from reducing agricultural yield to damaging buildings, and the country that suffers the highest economic impact in the EU is Italy (*Data source: Panagos et al. 2018*). Using data and tools from the C3S Climate Data Store (CDS), the CMCC has developed a dataset and two applications for investigating rainfall-induced soil erosion in Italy.

CMCC produced the "Soil erosion indicators for Italy from 1981 to 2080" dataset by integrating CDS rainfall data with non-climate data to assess soil susceptibility to water erosion according to the Revised Universal Soil Loss Equation (RUSLE) approach. RUSLE is an empirical model of soil loss that accounts for soil susceptibility to erosion and rainfall erosivity. The soil erosion dataset and two applications are freely available in the CDS. One application allows users to explore soil erosion for Italy from 1981–2080, and the other is a "what if" tool for exploring how land use – related to vegetation cover, management and soil erosion protection practices - can impact soil loss under different climatic scenarios. The applications will increase awareness amongst land management actors and territorial planners on how farming practices, forest management or post-disturbance recovery of soil (for example, after floods and fires) can contribute to mitigating the hazards associated with soil erosion and consequently decrease physical and economic risks.

Understanding future species distribution: new data for biogeographers. In 2020, the CMCC presented on Nature Scientific Data a new CMCC global and free access dataset of 35 bioclimatic indicators. This dataset, called CMCC-BioClimInd, complements and enlarges the availability of spatialized bioclimatic information, a crucial aspect in many ecological and environmental studies and for several disciplines, including forestry, biodiversity conservation, plant and landscape ecology.

The FLUXNET2015 dataset: measuring biosphere-atmosphere exchanges of greenhouse gases, water, and energy. The CMCC contributed to the FLUXNET2015 dataset that provides ecosystem-scale data on CO_2, water, and energy exchange between the biosphere and the atmosphere, and other meteorological and biological measurements, from 212 sites around the globe. The dataset is already being used in a number of applications, including ecophysiology studies, remote sensing studies, and development of ecosystem and Earth system models.

Urban environment

Climate change has critical impacts on cities, with significant consequences for societies. Local-level adaptation action is being recognized as crucial by key international frameworks and European policies. Climate change impacts in cities and the effectiveness of adaptation options, the implications of climate change on buildings and infrastructures are among the topics explored in 2020 by the CMCC research to find effective and sustainable solutions.

Urban settlements play a pivotal role in social and economic development as well as in changes at a global, national and local scale, representing one of the most important challenges and opportunities of the 21st century. With more than half of the world's people living in urban areas, cities are among the main causes of climate change and, at the same time, they are suffering its negative consequences in several fields: economics, socio-cultural, political and environmental. Climate projections over Europe based on the IPCC (Intergovernmental Panel on Climate Change) scenarios and the expected increase of population in urban areas highlight the importance of ensuring a proper functioning of cities, enabling them to cope with climate impacts, both in the short- and long-term, and avoiding negative consequences for society, economy and environment. Moreover, buildings and infrastructure also need to adapt to the changing climate. Updating structural design standards is crucial to improving European climate resilience and ensuring the safety of constructions that are expected to suffer from changes in

atmospheric variables and more frequent and intense extreme weather events.

In 2020, the CMCC Foundation gave a key contribution on these topics by realizing frontier research, studies and reports exploring green urban planning and the role of green infrastructures, ecosystem-based approaches as a strategy to support the development of innovative and sustainable solutions for climate change adaptation in cities, and the implications of climate change on the thermal design of structures supporting the sustainability and climate resilience of infrastructure and buildings.

The evolution of adaptation to climate change in Europe. Talking about the European Topic Centre on Climate Change Impacts, Vulnerability and Adaptation (ETC/CCA) means unfolding the evolution of knowledge, policy processes, actions and awareness on adaptation in Europe, from their first steps to the implementation of the new EU Climate Adaptation Strategy. We explore the story of this long collaboration between the ETC/CCA and the European Environment Agency in a

journey at the interface between science and policy.

Countries and cities in Europe need to step up adaptation to climate change impacts. Despite the increasing awareness of climate change impacts and the need to adapt, many of Europe's cities and towns are struggling to handle the impacts of heatwaves, severe droughts and destructive floods. Two European Environment Agency (EEA) reports stressed the urgent need for action to improve adaptation and resilience at local and national government levels. The CMCC Foundation contributed to the reports in the framework of the activities of ETC/CCA, the international consortium of 15 European institutions working with the European Environment Agency under a framework partnership agreement and led by the CMCC Foundation.

Green cities: urban infrastructures to effectively respond to climate change. The fight against climate change resides in how we plan the cities of tomorrow. Cities are growing, they are causes of the changing climate and they suffer the consequences of climate change; but there are strategies to transform urban contexts in concrete solutions for Sustainable Development and a better quality of life, with economic, social and environmental benefits. Looking at nature-based solutions, the contribution of the CMCC Foundation to the Report to the French Prime Minister and the French Parliament "Des Solutions Fondées sur la Nature pour s'adapter au changement climatique".

Climate change undermines the safety of buildings and infrastructure in Europe. The higher temperatures expected over the next 50 years in Europe will accelerate corrosion of buildings, and will expose infrastructure to higher stresses, thus undermining the safety of constructions. CMCC researchers and members of the scientific network

on adaptation of structural design to climate change established by the Joint Research Centre (JRC) of the European Commission, co-authored two studies, suggesting a review of the EU standards for structural design.

Behaviour of energy piles under climate-change scenarios. Energy geostructures are renewable-energy solutions that are strongly recommended as mitigation policy tools for facing the issue of global warming. Meanwhile, ongoing climate changes influence society through impacts on cities and structures, potentially affecting their effectiveness and functionalities and requiring assessments regarding adaptation. A study realized by the CMCC Foundation and published on *Environmental Geotechnics* considers the future behaviour (until 2100) of an energy pile installed in Naples, Italy, supposing the influence of climate change on underground soil temperature and energy demand. The outcomes, obtained with a thermo-hydro-mechanical model, give key insights into the geotechnical performance and thermal exchange, from a climate-change perspective, to support the future development of energy geostructures and design strategies.

Impact of urban morphology and vegetation on microclimate: parameterization of housing blocks in the Euro-Mediterranean context. The urban forms influence on outdoor thermal comfort in Euro-Mediterranean cities is the topic addressed in a study led by the CMCC Foundation by investigating performances and characteristics of typical Euro-Mediterranean housing blocks to highlight their effects on local microclimate.

ADAPT: moving towards greater resilience of cities in the face of climate change. The objective of ADAPT is to provide the Upper Tyrrhenian region with a joint action plan so that the region's cities become more resilient to the risks posed by climate change, and floods in particular. Like other urban areas, the cities in this region straddling both Italy and France are increasingly prone to flooding caused by sudden and intense rainfall. In real terms, the municipalities participating in the initiative were supported in the preparation, implementation and monitoring of local adaptation plans that will have a direct positive impact on the safety of both people and infrastructure. The initiative made very specific improvements to people's daily lives, thanks in particular to the construction of drainage infrastructure that improved the area's resistance to flooding.

A scientific research program for a "regulated" lagoon - The CMCC is involved in the project Venezia 2021 – CORILA (Consortium for coordination of research activities concerning the Venice lagoon system) focusing on the assessment of environmental risks and economic impacts induced by climate change. In the framework of the project, the CMCC aims at outlining the most likely evolution of weather and climate-related parameters relevant for the implementation of environmental risk assessment methodologies in the Metropolitan city of Venice while realizing an analysis of economic impacts of multiple climate-induced phenomena.

Risks

As extreme weather events increase in frequency, they inevitably put the lives and assets of people at ever greater risk. Between 1998 and 2017 alone, countries hit by extreme weather events reported direct economic losses valued at 2,908 billion USD, of which 2,245 billion USD were caused by climate-related disasters. In 2020, the CMCC signed international partnerships and collaborations to develop advanced and reliable instruments to improve the resilience of our societies.

Natural hazards are a major threat to sustainable development, economic stability and growth, territorial cohesion, and community resilience. According to the estimates of the European Environment Agency, the economic damage due to only natural hazard risks in the EU amounted to more than EUR 557 billion in 1980–2017, mostly triggered by extreme weather and climate-related events whose frequencies and/or intensities are expected to increase as a result of human-induced climate change. The CMCC has enhanced its capacity to develop high quality information and innovative tools to better address climate-related risks.

Landslides: new early warning systems reduce false alarms. Italy is particularly vulnerable to landslides. As the impacts of climate change worsen, including the occurrence of very intense and short rainfall in localized areas, there is a growing need to understand the dynamics that induce such events more precisely and develop models that can predict them. When employed through adequate early warning systems, these tools can support decision-makers in adopting effective and efficient measures to protect people and the areas themselves from landslides. The CMCC explored the potential of the fifth generation of atmospheric models (known as reanalysis dataset ERA5) for improving the performance of early warning systems used, for example, by the Civil Protection. Published on *Landslides*, the results of the study suggested the potential of this tool especially for minimizing false alarms, while avoiding missed alarms.

Modelling adaptation to climate change. In 2020 a CMCC team of scientists supported the European Commission's Directorate-General for Climate Action (DG CLIMA) to get improved knowledge and access to the models, methodologies, and data at the frontier of the study of climate change risk and adaptation, in the framework of the SAM PS tender. The results of the project have been presented during a high level expert workshop on Climate Adaptation Modelling on 8-10 September 2020.

European Extreme Events Climate Index. **Advanced Science and Innovation for Resilient Societies**. The "European Extreme Events Climate Index" (E³CI) is the first index developed in Europe to monitor and manage the impact of extreme weather events. It is the result of applied research for weather-induced hazard assessment and management, developed by IFAB – International Foundation Big Data and Artificial Intelligence for Human Development, together with CMCC and Leithà (Unipol Group). The Index provides support for identifying the areas affected by extreme events and a measure of the severity of such events, constituting valuable support primarily for the worlds of finance, insurance, and reinsurance. It can also be used by policymakers for choices related to the reduction of weather-induced risks and to spread awareness on climate change adaptation.

Assessing the future humanitarian risk and vulnerability using climate change and population projections within INFORM framework. The INFORM Risk Index is a global, open-source risk assessment for humanitarian crises and disasters. It can support decisions about prevention, preparedness and response. The CMCC collaborated with JRC to try to understand how the INFORM Risk
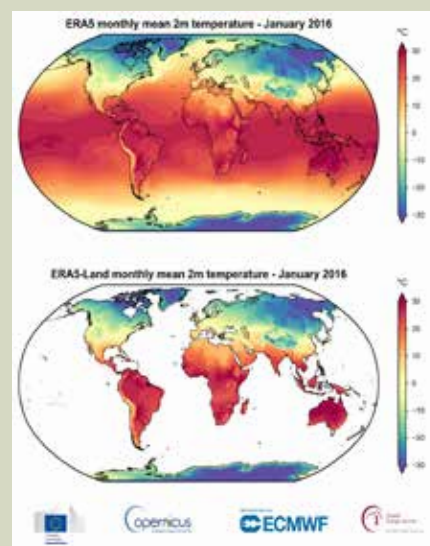
Index would be affected by the impacts of climate change in a study realized in the frame of RECEIPT, a project that develops a novel storytelling concept that maps representative connections between European socio-economic activities and remote climatic hazards, in order to outline Europe's vulnerability to remote climate events. In this work, the CMCC expanded the index to include projected climate change related hazards to generate changes in the index, alongside changes in population, and estimated what level of vulnerability reduction would be required to offset increasing risk.

Towards a better understanding of natural hazard risk and economic losses in Europe. The consequences of disasters on population, economic sectors, critical infrastructures, ecosystem services and cultural heritage were the focus of the report "Science for Disaster Risk Management 2020: acting today, protecting tomorrow" realized with the CMCC contribution. The report provided the reader with accurate and updated information on the effects that disasters have on key assets of society and how these can be managed.

The age of global emergencies: climate change and action. "Risk" and "Action" were the watchwords of the 2020 edition of the Annual Conference of the Italian Society for Climate Sciences (SISC). Organized in partnership with the CMCC Foundation, the programme included reflections on how to explore, predict and project climate variations and extremes, and on the study of climate related impacts and risks.

Cities at risk: a snapshot of urban adaptation actions worldwide. By 2050, two-thirds of the global population will live in cities. We are already seeing the impacts of climate change which, unchecked, will subject populations to untold risk and suffering, push already struggling services to the brink and undermine city government's efforts to protect their citizens. The first step to addressing climate risk is to measure and understand it. On October 13, 2020, in the framework of a CMCC Webinar Series on Urban Adaptation event, the CMCC provided a snapshot of urban adaptations actions worldwide while discussing several case studies of innovative solutions to address specific risks, focusing on nature based solutions.

Energy transitions

Clean and affordable energy is crucial to achieve a sustainable future and limit global warming below 2°C. From global to local, from technology to models and scenarios, the CMCC's advanced research provides knowledge that can be used by policymakers to identify and exploit specific adaptation strategies.

The energy sector is the biggest source of greenhouse gas emissions and therefore the main responsible of the observed human-caused changes in the climate system, but it is also vulnerable to the changing climate. If thermal electricity generation bears most of the risk from heatwaves and droughts, transmission and renewable technologies are highly risk-sensitive to many other extreme climate-related events, such as cold waves, wildfires, flooding, heavy snow, ice storms and windstorms. The expected change in the frequency and strength of such events may result in more power grid and transmission lines interruptions, thus affecting energy costs and supply. Understanding the impacts of climate change on the energy systems at a global level is an important input for the Sixth Assessment Report of the IPCC and for the implementation of the Paris Agreement. Moreover, results from this work can be used for studies related to the implementation of the Sustainable Development Goals (SDGs), and in particular to clarify synergies and trade-offs between SDG7 (Affordable and Clean Energy) and SDG13 (Climate Action). But deep studies at a regional and national level are also critical, because they also allow us to face behavioural issues: people's behaviour is extremely important when it comes to our energy demand in the future. Moreover, increased global warming can have a significant detrimental impact on both labor supply and food security. There is in fact evidence that climate change affects both the quantity and quality of food production, reducing food security, and nutrition intake. In developing countries, where the agricultural sector dominates the economy, the impacts of the changing climate on the agricultural supply chain will substantially hinder economic growth and well-being of the local communities. The CMCC's research is deeply involved and engaged in addressing these issues.

Energy at risk: the impact of climate change on supply and costs. The energy sector is not only a cause, but also a victim of climate change. As global temperatures rise, cooling demand is increasing. But in the face of an increased energy demand in the hot season, energy reliability may be jeopardized, due to climate change

impacts on the energy system, especially in South Asia and Latin America. A review paper on Nature Energy, realized with the contribution of the CMCC Foundation, shows how extreme climate-related events are affecting the efficiency of energy infrastructures and threatening renewable technologies.

The influence of social norms and behaviour on energy use. People tend to conform to what others do and what others regard as right. Do these two social norms influence electric energy consumption? In the prestigious journal Nature Energy, a team of Italian scientists from the RFF-CMCC European Institute on Economics and the Environment (EIEE) have identified, for the first time, how these norms interact and influence the energy use of hundreds of thousands of Italian households.

One of the more recent research developments at the CMCC Foundation

is the coupling of high spatial resolution climatic data with sub-national socio-economic data. This enables the application of spatial econometric techniques to the assessment of the relation between climate change and different indicators of social economic performance and their projection to the future. This is an innovation compared with the predominant investigation approaches based on country-level data. This methodology has been recently applied in a research collaboration with the Food and Agriculture Organization of the United Nations (FAO) aimed at assessing the impact of climate change on labour supply and income in Near East and North Africa (NENA) countries. The study estimated impacts at the country and sub national levels, highlighting high vulnerability in the region that can experience drops in the order of 6.8% and 8.4% of agricultural income and hours worked respectively in 2070 in the RCP8.5 "unmitigated" climate scenario.

The study also emphasized that these effects fall disproportionately on the female labour force.

Uganda: 20% decline in economic output without climate action. Less nutrition, less productivity, less development: the changing climate hinders poor rural areas of developing countries. A study with contribution from the CMCC Foundation shows the impacts of climate change on the labor supply in the 21st century, and how decision makers should act today to prevent the potential negative outcomes. The study analyses the case of Uganda, a Sub-Saharan African country already struggling with malnutrition and susceptible to the effects of climate change, with about 80 percent of the population depending on rain-fed agriculture for their livelihood. The analysis sheds light on an important but understudied linkage between climate change and labor supply through food consumption.

South Africa: the rising temperatures will cost up to 20% of per capita GDP. Reduced wage gap between high-skilled and low-skilled workers, and severe impacts on economic productivity. Climate change effects on economics and labour were explored further in the study "Climate change and development in South Africa: the impact of rising temperatures on economic productivity and labour availability" led by the CMCC Foundation and EIEE – RFF-CMCC European Institute on Economics and the Environment.

NAVIGATE aims at developing the Next generation of AdVanced InteGrated Assessment modelling to support climaTE policy making. The project critically improves the capability of Integrated Assessment Models (IAMs) to inform the design and evaluation of climate policies by targeting major advancements in two areas: describing transformative change in the economy, in technology and in consumer goods and services, and describing distributional impacts of climate change and climate policy. In 2020, the project organized a NAVIGATE Webinar Series (hosted by RFF-CMCC EIEE) with scientists and outstanding experts who shared their knowledge about some important topics for the project.

A study presented during the **EIEE-GREEN series event** "Grand Challenges and Local Beliefs: How Belief in Climate Change Relates to Greenhouse Gas Emissions in U.S. Manufacturing Facilities" provides the first empirical evidence on whether the degree of climate change (dis)belief is associated with changes in firms' behaviours. It emerges that facilities located in counties with stronger climate change beliefs demonstrate greater reductions in greenhouse gas emissions over time, and that this effect is amplified when their headquarters are also in counties with high belief in climate change.

RFF-CMCC-EDF Policy Session: Policies to support workers and communities in the transition to clean energy economies in the US and the EU, a virtual event organized in the framework of the EAERE 2020 conference, promoted debate and exchange about the crucial challenges of pursuing an equitable clean energy transition for workers and fossil-fuel dependent communities.

New start for the Research Network on Energy Workforce Transitions. The Research Network on Energy Workforce Transitions (ReNEWT) is a consortium of policy analysts and researchers from all over the world aimed at evaluating and designing solutions to ensure a just and equitable transition to carbon neutrality for all. Established in 2018 by the London School of Economics and Political Science and currently managed by the RFF-CMCC European Institute on Economics and the Environment (EIEE), in 2020 the network announces the launch of the new website of ReNEWT (renewt.org), which provides information about the network's objectives and members, and allows being up to date on the network activities.

RENEWT

Research Network on

Energy Workforce Transitions

A Focus on Italy

The expected climate for Italy in the coming decades told by climate models, and the current scientific knowledge on the main risks arising from climate change in Italy as a result of different potential levels of global warming and development models. In 2020, the CMCC Foundation publishes the climate scenarios for Italy and the report "Risk Analysis. Climate change in Italy". A work in progress, the result of ongoing research that keeps improving the definition and detail of data to be made available to the public.

It is not only because it is an Italian research centre with international activities. It is not only because the Foundation's offices and branches are distributed throughout the country, covering seven cities. The analyses and studies carried out by CMCC on Italy are the results of one of the most advanced aspects of the work carried out by our researchers: the production of high-resolution data, with a level of detail that increases over the years, and provides information for decision-makers, both public and private, and development of strategies and actions to address the climate crisis successfully and in a timely manner.

Actually, this aspect of CMCC research concerns numerous activities looking at different areas of the planet. During 2020, there was a specific focus on Italy which, in addition to a series of scientific articles published in peer-reviewed journals describing in detail the methodology and the evolution of the climate models used and developed by CMCC, culminated in initiatives aimed at making scientific knowledge on current and future climate change available to a wider public that can benefit from it for their professional activity or even simply improve their awareness on the subject.

High-resolution climate data, analyses of climate scenarios for the coming decades, their interactions with socio-economic and environmental systems are presented with interactive and navigable web applications, texts, infographics and fact sheets designed to facilitate the understanding and use of the material, which is the result of rigorous scientific research.

Climate Scenarios for Italy

A snapshot of the expected climate for Italy in the coming decades is presented in a series of maps available on the website of the CMCC Foundation – Euro-Mediterranean Center on Climate Change (www.cmcc.it/it/scenari-climatici-per-litalia). Much will depend on the choices that will be made to reduce greenhouse gas emissions. Much will depend on whether the international community will succeed in containing the temperature rise and the consequences of this increase at different geographic scales.
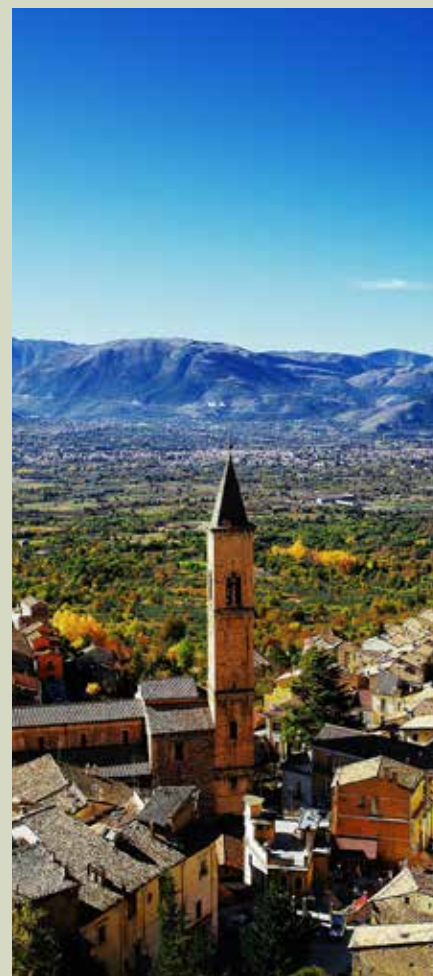
These maps represent a tool available to anyone wishing to learn more about the results of scientific research. The climate data are presented in a usable form that allows users to navigate between 10 climate indicators, two different scenarios, and three periods (2021-2050, 2041-2070, 2071-2100).

The list of indicators and scenarios is based on the requests that CMCC scientists received in recent years from researchers and public and private bodies that study the impacts of climate change on Italy. This is a first selection that we plan to enrich in the coming months, always based on our research activities and on the interaction with the community that uses such data.

The climate scenarios for Italy are the result of scientific research that used the COSMO-CLM Regional Climate Model in a particular configuration specific to Italy, specially developed by the CMCC Foundation. The published maps will be updated in the future, as they are to be understood as the result of continuous research aimed at improving the definition of the data produced. This process will provide even more advanced support in the evaluation of the extreme events expected for the next decades.

Climate: risks and future strategies in Italy

Risks associated with climate change affect all Italian regions and their economic sectors. Despite contrasts, with different areas being affected in different ways, there are no regions that can be considered immune from climate risks, which have already increased in recent years, in particular when considering extreme events.

These are some of the messages that emerge from the report **Analisi del Rischio. I cambiamenti climatici in Italia** (Risk Analysis. Climate Change in Italy), the first integrated analysis of climate risk in Italy. A document that bases itself on climate predictions for the coming years whilst focusing on specific sectors so as to provide information on what to expect from the future. It is a valuable support tool for concrete resilience and sustainable development strategies.

The analysis carried out by the CMCC Foundation starts from climate scenarios that, through advanced use of high-resolution climate models applied to the study of the Italian context, provide information on Italy's future climate.

This information is then applied to risk analysis for a number of sectors of the Italian socio-economic system. What emerges is a framework where, in the coming decades, risk grows in many areas with significant economic and financial costs for the country. Furthermore, the impacts will affect disadvantaged members of society more severely and also involve all sectors, not least of which infrastructure, agriculture and tourism.

The report contains the most up to date and advanced knowledge of the impacts and integrated risk analysis of climate change in Italy. Analysis of risks and their effects on environmental, natural, social and economic capital allows us to take response options identified by scientific research into account and develop integrated and sustainable management plans for Italy, enhancing specific features, peculiarities and competences of the different territorial contexts. This knowledge is the result of innovative research, networking between the universities that contribute to the CMCC Foundation's work, and international collaborations. It is also the product of top-level computing infrastructure at a global level. Putting all these aspects together in a multidisciplinary research perspective is a scientific community

endeavour, the results of which are at the service of society and produce knowledge that benefits the entire country.

The challenge of risk connected to climate change starts from scientific knowledge and integrates adaptation and the solutions needed to face risks, in all phases of the decision-making processes including public policies, investment programs and the planning of public expenditure, so as to guarantee sustainable development at all territorial and governance levels.

The report begins with an analysis of climate scenarios for Italy and with the definition of aggregate risk. Then, climate risk is described in its interaction with 5 sectors (urban environment, geohydrological aspects, water management, agriculture, forests and wildfires), a chapter on economic costs, tools and financial resources, and concludes with a review of some policy tools and projects. The report is accompanied by a series of key messages, infographics and an executive summary that facilitates the reading and use of the content.

Risk Analysis. Climate Change in Italy, DOI: 10.25424/cmcc/analisi_del_rischio
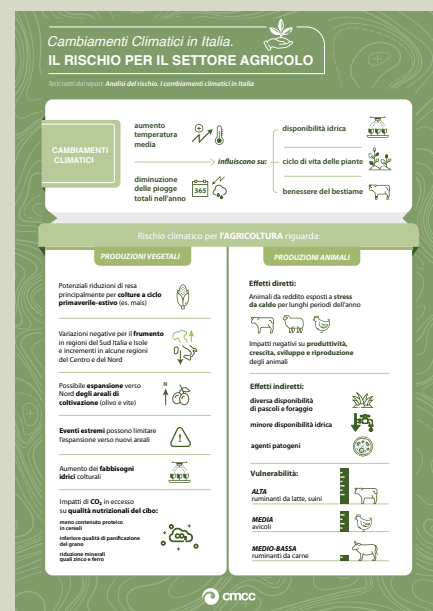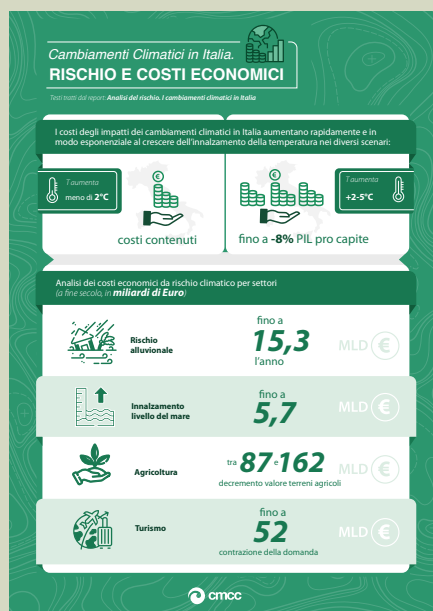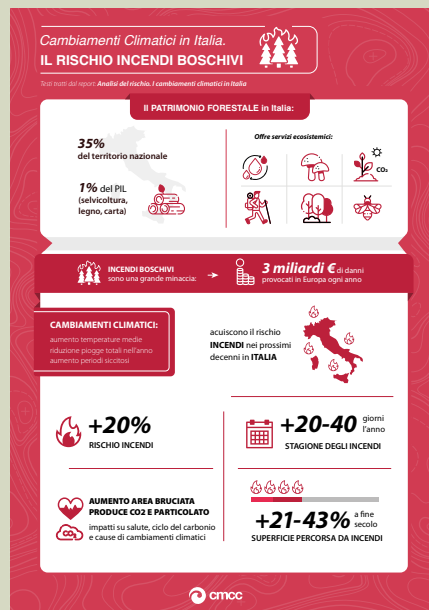
Education

It is not only about the future. It is about the decision that we take today and that shape the coming years. The young generations are the protagonists in everything related to climate change: they, the adults of tomorrow, will have to deal with the world we are changing today. How to deal with the change? Science has a lot to say to young people. That is why CMCC has developed a series of activities that experiment with innovation and climate science, searching for tools and initiatives to engage with students and teachers.

Looking into the future: this is vital for climate sciences. CMCC scientists work starts from specific conditions to build hypotheses about the years to come. What will the climate of the future look like based on the decisions we make today? And how do the decisions that influence the climate system and its changes interact with social, economic and environmental systems? The answer to these questions benefits from the dialogue with the younger generations, with those who will be the adults of tomorrow and who today have a naturally direct relationship with innovation and technology. A series of CMCC activities are aimed at involving young people and schools, illustrating the advances in science and, above all, helping improve public awareness of the results of climate sciences. Meetings with experts, videos and infographics, activities to be done live with children of different ages and a video game that simulates the interactions between climate and human activities are some of the initiatives that CMCC has developed in education.

Change Game. Play with the Planet

Change Game is a video game that confronts the complexity of climate change and how it interacts with society and natural ecosystems. Players will find out how the choices they make, affect both their environment and other people. By creating a city from scratch, they will discover how the decisions they make impact climate change. Collaborating with other players, making the right investments and pursuing sustainable development goals will help to create communities that are resilient to natural disasters. Learning to recognize the importance of science is essential to understanding the world in which we live and the possible trajectories of future developments.

This is Change Game, the video game realized by CMCC in collaboration with Melazeta S.r.l., a specialist developer of educational games, and with the financial support of Climate KIC EIT.

The groundbreaking innovation of Change Game is that all game scenarios are based on real climate data and

scientific research. The higher the level of emissions players generate, the greater the challenges they will all face – heatwaves, droughts, floods, rising sea levels, the spread of new diseases. By investing in research, players can find new solutions and take advantage of the technologies of the future. Through education, they can promote more sustainable social behaviour, and there are ways in which they can interact with neighbouring cities through trade, climate strikes, corruption attacks and fake news. Every action taken has consequences, positive or negative, on the planet: everything is governed by the climate emergency.

Change Game leverages the potential of video games to process climate-related information in a fun, educational and interactive way, and to represent the complexity of the climate system and its interactions with humankind and natural ecosystems.

The most advanced science for an interactive game: the groundbreaking innovation of Change Game is that all game scenarios are based on scientific data developed by climate scientists. Science represents the anchor of all the choices made in different phases of the game. In addition, the game aims to encourage a debate among players about what innovations are necessary to create resilient and zero-emission societies.

Change Game was developed using the Game Thinking methodology, conceived through a co-design process, and tested in training sessions based on its first release on the Apple and Google Play stores. The training and presentation events actively involved about 600 people, including students and teachers.

Science for kids

Many initiatives dedicated to schools were conceived to be developed and implemented within the framework of the Rome Science Festival. Originally designed to bring children and young people together with professional experts and scientists to discuss and explore the issue of climate change, due to the pandemic the plans had to be changed to activities that could also be carried out and followed remotely.

Among these, "Like an ice cream at the equator" is an educational activity, a video that, through experiments, numbers, images and animations, presents a story of the consequences of climate change for the ice and the sea of our planet.

"The Children's Planet" was a meeting with scientists, popularisers and experts on the language of communication on climate change. A book, a video game or a video may not be enough, but the integration of different platforms can lead to a productive dialogue with a solid scientific basis.

Bringing resilience at school

What is resilience? This is the question around which the educational offer of "A Well of Science" revolved, an initiative in which CMCC participated and which was promoted by the Hera Group under the patronage of the Regional School Office of Emilia-Romagna and implemented by ComunicaMente, Tecnoscienza and IS – Science Center Immaginario Scientifico of Trieste with the support of a Scientific Committee.

The initiatives involved a composite series of activities, such as the Science Stories, meetings characterised by a solid interactive and participatory component and held by university lecturers, scientists, journalists, experts and young researchers. Other aspects included game conferences with an even more practical and experiential approach, the production and distribution of teaching kits, and interactive workshops based on innovative and participatory methodologies.

The CMCC Supercomputing Center

Supercomputing Center

12,528 cores

1,202 TFlops — *Theoretical peak performance (1TFlop = 1,000 billion operations per second)*

4 PetaBytes over — *Storage system capacity*

5 PetaBytes — *Tape Library (archiving system)*

Since 2008, CMCC operates its own Supercomputing Center (SCC) located within the University of Salento Campus in Lecce. It was inaugurated on January 30, 2009 with the presentation conference and the participation of the President of the CMCC Antonio Navarra and the SCC Director Giovanni Aloisio.

The CMCC Supercomputing Center is the only computational facility in Italy specializing in Climate Change research. Zeus, the supercomputer currently in operation, is based on 348 Lenovo SD530 biprocessor nodes (for a total of 12.528 cores) all interconnected by means of an Infiniband EDR network. The HPC system has a computing power (theoretical peak performance) of 1.202 TFlops.

Zeus and the entire CMCC computing infrastructure contribute significantly to the IPCC coordinated climate scenario experiments.

The CMCC long term archiving system

In order to manage and preserve for medium/long term the huge quantity of climate data produced by the research and operational activities at CMCC, in 2019 a new archiving system has been deployed.

The hardware components of this new system are:

- IBM TS4500 tape library with nr 6 LTO8 drives and 2 accessors, 5PBytes of capacity
- Nr 2 servers Lenovo ThinkSystem SR630
- Nr 1 IBM DS2200 FC storage system
- 16Gbps FC SAN implemented with nr 2 Lenovo FC switches B6505

IBM Spectrum Archive Enterprise Edition is the software that manages the tape library operations and stores the data on the tape tier in the Linear Tape File System (LTFS) format.
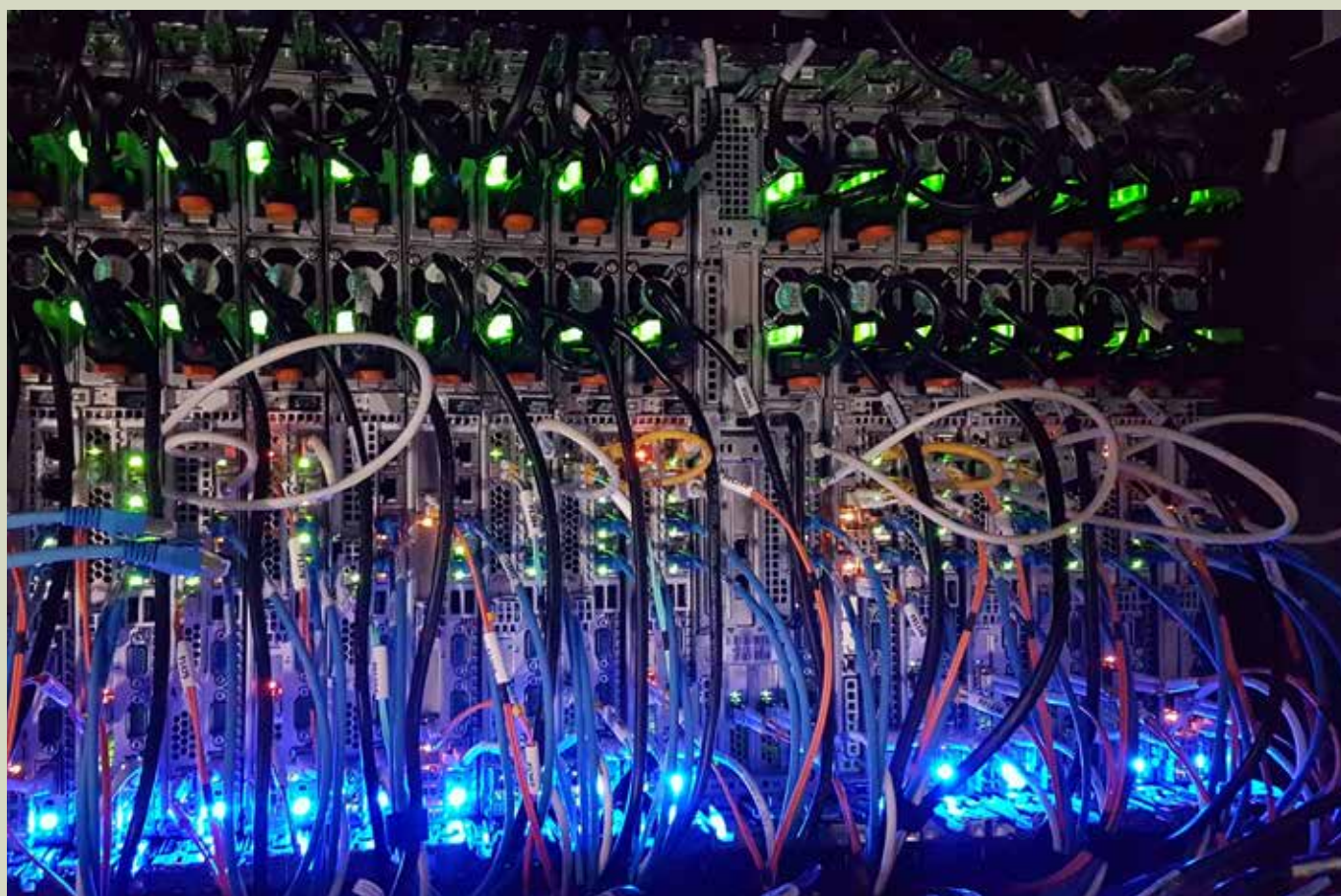
2020 in numbers

People

FTE (full-time equivalent)

197
People
at CMCC

65%
Research Area

35%
Services for Research

46%
Senior positions

Women at CMCC
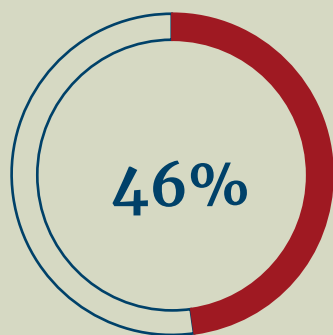
46% of the people
at CMCC
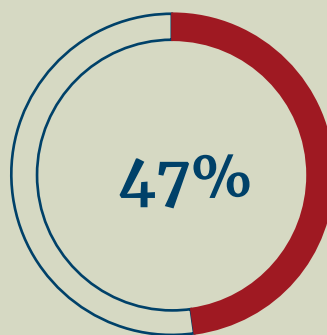
47% with a
senior role

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

Publications

View the full list of publications: www.cmcc.it/publications

186
Refereed papers
published

Events

148 | 43
Webinars

Education and Training Programs

View the complete list of Education and Training Programs:
www.cmcc.it/education-programs

6
PhD Programs in collaboration
with partner Universities

198
Students

1
Master of research

Research Projects

173

Running Projects
in 2020

Fund Raising Capacity

The CMCC's capacity to attract new funds over the last three years.
These funds are over and above the annual operating grants (Million €).

Year	Value
2020	12,4
2019	12,9
2018	12,7

Source of Funding (Per Budget) Last 5 Years (2016–2020)
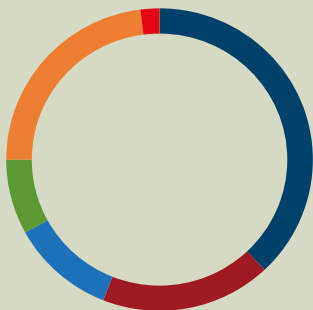
Source	%
■ EU H2020	38%
■ EU Copernicus	18%
■ EU Interreg	11%
■ Other EU Funds	8%
■ National Funds	23%
■ Other International Funds	2%

CMCC Participation in H2020 Pillars
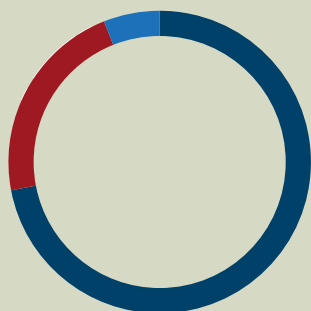
■ Societal Challenges	72%
■ Excellent Science	22%
■ Industrial Leadership	6%

CMCC Participation in H2020 Work Programs
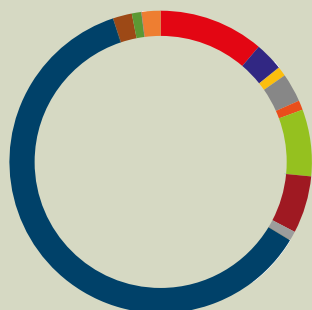
■ ERC	6%
■ Future and Emerging Technologies	1%
■ Climate action, environment, resource efficiency and raw materials	60%
■ Secure societies	2%
■ EuroHPC Joint Undertaking	1%
■ Secure, clean and efficient energy	2%
■ European Research Infrastructure	12%
■ Space	3%
■ ICT	1%
■ Marie Sklodowska-Curie Actions (MSCA)	3%
■ Health, demographic change and wellbeing	1%
■ Food security	7%

Type of funding % per budget

■ Grant
■ Service

Year	Grant	Service
2018	79%	21%
2019	84%	16%
2020	40%	60%
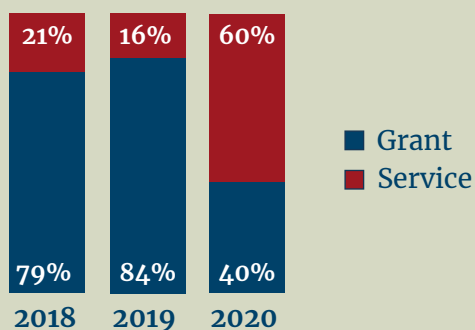
Financial Report

BALANCE SHEET: ASSETS	2020	2019
A) Receivables from shareholders for contributions due	0	0
B) Fixed assets	8,805,658	9,255,177
I. Intangible fixed assets	*246,900*	*284,795*
II. Tangible fixed assets	*7,747,408*	*8,324,441*
III. Financial assets	*811,350*	*645,940*
C) Current Assets	19,917,744	17,836,010
I. Inventories (Work in Progress - WIP)	*11,007,267*	*9,864,096*
II. Receivables	*1,197,408*	*777,290*
III. Current financial assets	*2,000,000*	*2,000,000*
IV. Cash at hand	*5,713,069*	*5,194,624*
D) Prepayments and accrued income	27,600	28,307
TOTAL ASSETS	**28,751,002**	**27,119,495**
BALANCE SHEET: LIABILITIES	2020	2019
A) Net Liabilities	6,369,857	5,717,156
Capital	*662,000*	*662,000*
Reserve Funds	*5,055,157*	*5,170,929*
Profit for the year	*652,700*	*-115,773*
B) Provisions for risks and charges	301,103	252,946
C) Employee Severance Indemnities	1,183,269	953,249
D) Payments from Clients	14,251,949	15,931,053
E) Accruals and deferred charges	6,644,824	4,265,089
TOTAL LIABILITIES	**28,751,002**	**27,119,493**

PROFIT AND LOSS	2020	2019
A) Revenues	16,482,168	15,225,763
Revenues from sales and services	4,410,694	3,012,148
Variations in stocks (WIP)	1,199,785	182,746
Other revenues	10,871,689	12,030,868
B) Expenses	15,770,480	15,142,797
Consumable	114,785	93,139
Services	6,570,475	6,501,520
Leases	345,706	327,275
Personnel	7,095,863	6,465,148
Depreciation	1,313,175	1,467,543
Other Operating Expenses	330,476	288,172
Difference between revenues and expenses (A-B)	711,688	**82,965**
C) Financial income and charges	8,688	−22,109
D) Impairment on financial assets	0	0
E) Extraordinary income and charges	−46,572	−158,241
Results before taxes (A−B±C±D±E)	**673,804**	**−97,385**
Income tax expenses – current and deferred	21,104	18,388
a) Current taxes	21,081	18,388
b) Deferred taxes	23	0
Profit (loss) for the year	**652,700**	**−115,773**

The CMCC Foundation

Mission

" *To investigate and model our climate system and its interactions with society to provide reliable, rigorous, and timely scientific results to stimulate sustainable growth, protect the environment and develop science driven adaptation and mitigation policies in a changing climate. To develop foresights and quantitative analysis of our future planet and society.* "

Administration and Management

President's Secretariat ◄◄◄

Scientific Organization ◄◄◄

President
Board of Directors
Executive Committee ►►►

Fund Raising

System Management

SCC Super Computing Center

Communication

Executive Directors & General Affairs ►►►

Management & Logistic Support - Secretary

Human resources

►►► **Job Contracts & Payslips**

►►► **Recruitment, Timesheets & Training**

►►► **Travel Reimbursements & Scientific Affiliations**

Administration & Business Management

►►► **Accountability & Balance Sheet**

►►► **Projects Administration**

►►► **Taxes & Audit**

Legal Office & Compilance

►►► **Safety & Health, Privacy, ISO**

►►► **Tenders & Governcance**

►►► **Procurement & Logistics**

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Università degli Studi del Salento
Centro Italiano di Ricerche Aerospaziali
Università Ca' Foscari Venezia
Università di Sassari
Università della Tuscia
Politecnico di Milano
Resources for the Future
Università di Bologna

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Massimo Tavoni – Sustainable Earth Modelling Economics

Indicators

List of indicators as defined
in "Climate Change in the
Future, fast Changing World.
The CMCC vision towards 2029.
Strategic Plan 2019–2029"

Science

S1	PAPERS PUBLISHED IN REFEREED JOURNALS (TOP 20%)		
		n.	**127**

S2	TOTAL NUMBER OF PAPERS PUBLISHED		
		n.	**186**

S3	REPORT AND RESEARCH PAPERS PUBLISHED		
		n.	**5**

S4	PRESENTATION AT CONFERENCES		
		n.	**29**

S5	DATA SETS PUBLISHED		
		n.	**20**

S6	CITATIONS BY DIVISION (WEB OF SCIENCE)		
		n.	**27,969**

Applications

A1	REANALYSES		
		n.	**5**

A2	FORECAST SYSTEMS		
		n.	**5**

A3	SKILL OF FORECASTS		
		n.	**1**

A4	RISK ANALYSIS SYSTEMS		
		n.	**15**

A5	MONITORING SYSTEMS		
		n.	**4**

A6	DECISION SUPPORT SYSTEMS		
		n.	**2**

A7	OTHER APPLICATIONS		
		n.	**12**

Resources

R1 — EUROPEAN FUNDING

	n.	23
	€	7,713,276
of which Coord. by CMCC – n.		5
of which Coord. by CMCC – €		571,000

R2 — NATIONAL FUNDING

	n.	13
	€	3,895,837
of which Coord. by CMCC – n.		9
of which Coord. by CMCC – €		2,385,562

R3 — OTHER FUNDING

	n.	1
	€	5,000
of which Coord. by CMCC – n.		1
of which Coord. by CMCC – €		5,000

R4 — STAFF NUMBER AND ROLES

Junior Research Associate	25
Junior Scientific Manager	4
Junior Scientist	21
Post Degree	12
Post Doc	20
Scientist	27
Senior Research Associate	22
Senior Scientific Manager	19
Senior Scientist	13
Junior Administrative Staff	27
Senior Administrative Staff	7
TOTAL	**197**

R5 — VISITORS

	n.	6

R6 — STUDENTS

Science and Management of Climate Change (Università Ca' Foscari Venezia)	n.	30
Agrometereology and Ecophysiology of Agricultural and Forestry Eco-Systems (Università di Sassari)	n.	8
Sciences, Technologies and Biotechnologies for Sustainability (Università della Tuscia)	n.	41
Biological and Environmental Sciences and Technologies (Università del Salento)	n.	49
Complex Systems Engineering (Università del Salento)	n.	33
Future Earth, Climate Change and Societal Challenges (Università di Bologna)	n.	37
TOTAL		**198**

R7 — GENDER BALANCE

ROLES	M (R7)	F (R7)	TOTAL (R4)
Junior Research Associate	19	6	25
Junior Scientific Manager	1	3	4
Junior Scientist	14	7	21
Post Degree	5	7	12
Post Doc	11	9	20
Scientist	15	12	27
Senior Research Associate	17	5	22
Senior Scientific Manager	1	18	19
Senior Scientist	10	3	13
Junior Administrative Staff	10	17	27
Senior Administrative Staff	4	3	7
Visitors	4	2	6
TOTAL			**203**

R8 — COMPUTATIONAL RESOURCES

2 supercomputers
20,240 CPU cores
1,362 TeraFlops of total Peak Performance

Dissemination

D1 — **ANALYTICS OF WEB PRESENCE**

More than 92k unique visitors
400k pages views

D2 — **ANALYTICS OF SOCIAL MEDIA PRESENCE**

LinkedIn	4K followers	**+48%**
Facebook	5,2K fans	**+17%**
Instagram	1,2K followers	**+62%**
Twitter	3,8K followers	**+25%**

D3 — **SEMINARS AND WEBINARS ORGANIZED**

33 Webinars + 9 Seminars

D4 — **EVENTS**

n. **138**