Centro Euro-Mediterraneo sui Cambiamenti Climatici

CMCC's views on AI in Science

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Executive Summary

1. Promoting AI in European science is essential to accelerate discovery, drive innovation, enhance global competitiveness, and position the EU as a global AI leader.
2. High-quality, interoperable, and well-governed data, supported by robust digital systems, are fundamental for AI uptake in science.
3. Secure and scalable data infrastructure, including cloud-based solutions, is crucial for advancing scientific excellence and delivering real-time insights, especially for complex systems like Earth System Science.
4. Transparent data exchanges, supported by encryption, provenance tracking, and standardized formats, are vital for maintaining trust, reproducibility, and a reliable AI ecosystem.
5. There is a need for advanced AI infrastructure, high-performance computing, and data lakes, to counter the dominance of a few large corporations.
6. The establishment of a decentralized network of public research organizations can foster collaboration, leverage existing resources, and promote open research.
7. To boost EU's attractiveness for top AI talent, it is essential to strengthen interdisciplinary teamwork, enhance reskilling programs, and offer competitive salaries.
8. Europe must enhance its AI capabilities across the entire value chain, from research to manufacturing, through robust academia-industry collaboration to ensure competitiveness.

Impact of AI in science

Promoting the uptake of Artificial Intelligence (AI) in science is essential to accelerate scientific discovery, drive frontier innovation, enhance Europe's global competitiveness in strategic sectors and position the EU as a global leader in AI.

AI is revolutionizing science across disciplines by enabling new forms of discovery, accelerating complex analyses, and expanding our capacity to predict system-level impacts. **AI is facilitating the transition from reactive analysis to anticipatory insight - identifying not only what is likely to happen, but also what the broader implications might be for systems, stakeholders, and society at large.** As science increasingly grapples with problems that are complex, interconnected, and urgent - whether in healthcare, sustainability, or technological innovation - **AI is emerging not just as a tool for analysis, but as a core driver of discovery, collaboration, and societal impact.**

Critically, **AI is also reshaping the scientific method itself**. Automated experimentation, model optimization, and data-driven hypothesis generation are accelerating the pace of research while reducing manual overhead. Self-supervised learning and continual learning techniques allow models to adapt to new domains or data with minimal intervention, making them more resilient in rapidly evolving research areas. Explainable AI frameworks are enhancing trust and interpretability, allowing researchers to scrutinize and validate results rather than treat them as “black-box” outputs.

The development of AI tools and technologies specialized for scientific work is key to fostering AI integration in all research fields and collaboration across disciplines. The scientific community and research stakeholders should collaboratively work to develop **target guidance to address open ethical questions posed by the use of AI applications**, and to develop best practices for integrating AI in scientific workflows.

In climate science, AI enables the assimilation of massive and heterogeneous data streams - ranging from satellite observations to social media signals - into coherent models that can detect subtle patterns, anticipate nonlinear feedbacks, and deliver early warnings for extreme events. AI moves beyond improving forecast skill to predicting system-wide impacts, such as disruptions in food supply chains, heat-related mortality, infrastructure stress, or ecosystem collapse. This predictive power supports evidence-based decision-making in disaster risk reduction, urban planning, and climate adaptation. By enabling predictive modeling of complex, interconnected systems, AI empowers scientists and policymakers to better understand vulnerabilities, evaluate adaptive strategies, and implement proactive responses. This shift, from pure prediction to impact anticipation, marks a crucial evolution in scientific practice, thus placing AI-enabled science at the heart of effective decision-making.

For these reasons, CMCC remains steadfast in the pursuit of its forward-looking research priorities through the responsible and swift adoption of AI systems and its integration in our modelling chain and research processes.

Data & Infrastructure

The successful uptake of AI in science depends on the quality, interoperability, and governance of its underlying data infrastructure. High-quality data and robust digital systems form the foundation of modern scientific progress. As research becomes more data-intensive, the ability to collect, process, share, and analyze large, diverse datasets securely and efficiently is essential across nearly every discipline - from biomedical research and materials science to environmental monitoring and social science. This growing demand places pressure not just on storage and computing

capacity, but also on data architectures that can handle streaming inputs, multi-scale analysis, and the interactive exploration of complex visual and numerical information.

Investing in robust, forward-looking data infrastructure is critical not only for advancing scientific excellence but also for delivering real-time, actionable insights in an era of rapid technological and environmental change. **Secure infrastructure safeguards sensitive datasets and intellectual property, while transparent standards ensure scientific accountability.** Interoperable platforms and intelligent metadata pipelines make large-scale, cross-disciplinary analysis possible. Meanwhile, decentralized technologies like **federated learning** protect privacy without limiting collaboration.

Modern Earth System Science heavily depends on the seamless integration of high-quality data and scalable infrastructure. Physically consistent data estimation and advanced data assimilation techniques - particularly coupled and ensemble-based approaches - ensure that diverse observations conform to fundamental physical laws while capturing cross-domain feedback. As datasets grow in size and diversity, particularly with the localization of physical and human systems data, the need for robust data pipelines, metadata standards, and cloud-based infrastructure becomes critical.

The infrastructure must also support hyper-local climate modeling, where fine-scale terrain, urban morphology, and community-level observations inform region-specific forecasts. GeoAI and integrated spatial decision support systems further empower stakeholders by linking real-time environmental data with demographic and infrastructural contexts. Together, these systems enable a new era of climate science - grounded in data, scalable in design, and tailored to inform adaptive, resilient, and just responses at all levels of society. This is a mission that CMCC is already actively pursuing through its distinctive cross-disciplinary agenda. In this context, public and semi-public research organisations should be encouraged and supported to equip themselves with state-of the-art physical and digital infrastructure and data solutions.

CMCC joins the wider scientific community in underlining the importance of addressing the ethical implications related to the design and use of AI systems.

As science becomes increasingly data-intensive and collaborative, secure and transparent data exchanges are essential for maintaining trust, reproducibility, and operational integrity, with a view to **build a trustworthy and reliable AI ecosystem.**

Encryption protocols, blockchain-enabled provenance tracking, and role-based access control systems ensure that sensitive observations and proprietary models remain protected against tampering or unauthorized access. Equally important is transparency through documented metadata, traceable data lineage, and standardized data formats in support of scientific accountability and interoperability.

Research ecosystem

CMCC welcomes the EU's continued support of research and innovation through its framework programmes. **EU funding for advanced AI applications in science fosters excellence and global competitiveness, while strengthening both scientific progress and societal resilience.** At the same time, both the EU and its Member States have invested significantly to develop the capabilities of public research organizations across Europe. However, given the current pace of AI technology innovation, **CMCC emphasizes the urgent need for infrastructure to develop AI systems, including high performance computers, data lakes, and data connectivity.**

Public research organizations across diverse disciplines need to be empowered to produce cutting-edge, impact-driven research that drives innovation, and counters the dominance of few corporations and organizations over AI infrastructure. Therefore, CMCC supports the establishment of a **distributed institute, formed by a decentralized network of research entities that perform AI-enabled research in different domains**. This approach would foster cooperation and coordination among existing bodies and facilitate the development and addition of new hubs, thus enabling distributed, collaborative and open research. Such a distributed approach could leverage existing infrastructures, to reach extensive computational resources and cloud storage levels in a rapid and cost-effective manner, while also boost cross-pollination and specialised training for scientists.

As Europe continues to face a “brain drain”, it is crucial to boost the EU's attractiveness for top AI talent by offering more robust research ecosystems and opportunities. To nurture talent in AI, it is essential to ensure better integration of AI training within educational curricula, as well as in reskilling and upskilling programs. This foundational approach helps create a steady pipeline of skilled professionals capable of meeting the sector's evolving demands. In addition, the level of competitiveness of EU salaries is a factor that may influence the movement of talents and skills across Europe, especially in less developed regions, as well as the ability to attract top scientists globally. In this context, **CMCC welcomes the measures to attract and support scientists, researchers, academics and highly skilled workers from Europe and around the world**, such as the recently-launched “Choose Europe for science” initiative, and **calls for increased funding for interdisciplinary AI-enabled research and for AI-focused research positions and academic programs.**

Drawing on its extensive experience in conducting multidisciplinary research, CMCC believes that the successful integration and application of AI in research will increasingly depend on the ability of teams to collaborate across a wide range of disciplines. It is therefore crucial that researchers and managers are able to **harness interdisciplinary** and to find a common language across the different domains.

The key to position the EU and its scientific community as a global leader in shaping an AI-enabled future of science, is to **strengthen international collaboration**. **Research organizations in Europe and beyond should be actively supported in forming strategic partnerships, promoting joint scientific endeavours and building multi-stakeholder partnerships and networks**. Coordinated efforts of this kind are vital to align funding strategies and shape cohesive policies for AI research. At the same time, they ensure that the EU's scientific voice plays a central role in establishing internationally recognized benchmarks, standards, and best practices through high-level global forums.

Europe's technological ecosystem, particularly in AI, remains underdeveloped compared to the EU's global counterparts. This slows down innovation, increases vulnerability to supply chain disruptions, and deepens dependence on non-EU countries for critical technologies. However, momentum is building. The EU has taken significant steps, including passing the AI Act, the world's first comprehensive AI regulation, and launched strategic initiatives to boost public-private collaboration and innovation.

CMCC believes in collaboration between academia and industry as an opportunity to leverage mutual, reinforcing synergies by co-creating projects based on shared methodologies, resources, infrastructures, and costs. If Europe is to remain competitive and sovereign in the next technological era, it must boost its capabilities across the entire AI value chain, from research to infrastructure and manufacturing.

About CMCC Foundation

The **CMCC Foundation – Euro-Mediterranean Center on Climate Change (CMCC) is an international, independent, and multidisciplinary research center dedicated to studying the interactions between climate change and society.** Its mission is to produce advanced climate knowledge and multidisciplinary analyses and datasets by integrating state-of-the-art climate modeling with impact assessments and environmental economics. This work supports the development of science-based strategies for climate adaptation and mitigation, informing decisions that promote sustainable development and environmental protection.

As a strategic research infrastructure, CMCC hosts the most powerful computational facility in Italy and one of the most advanced in Europe, fully dedicated to climate change research. CMCC is one of the institutions selected by the World Meteorological Organization (WMO) to produce seasonal climate forecasts, and collaborates with a network of over 700 partner organizations across 71 countries. It also contributes to the Integrated Carbon Observation System (ICOS) European Research Infrastructure Consortium (ERIC), as a member of the ICOS Italy network and coordinator of the Ecosystem Thematic Center (ETC). Since 2006, CMCC has served as Italy's National Focal Point for the Intergovernmental Panel on Climate Change (IPCC).

At a time of extraordinary change, CMCC is doubling down on its commitment to advanced applied research at the nexus of climate science and socio-economic transformation, powered by a wide adoption of advanced machine learning and data science tools. The central question of the next two decades will be how to sustain broad-based economic growth in the face of rapidly changing material conditions, while continuing to transition to a low carbon industrial base. CMCC intends to answer this question through four interconnected research priorities.

First, CMCC aims to enhance its climate prediction capabilities by developing integrated modelling chains that translate climate data into socio-economic insights. This includes providing tools that inform long-term investment, policy and planning, and assess the economic returns on investments to improve human health, infrastructure, livelihoods, and economies under varying climate scenarios, offering actionable pathways to foster sustainable, resilient communities.

Second, CMCC will deepen its focus on global coastal zones, regions that are both increasingly vulnerable to climate change and vital to the global economy, where environmental stress, high population density, and economic activities intersect. We intend to build portable AI-enabled digital twins to support dynamic management of all coastal infrastructure, both natural and engineered.

Third, CMCC will advance a more holistic understanding of the carbon cycle by integrating its industrial, biogeochemical, and physical components. By approaching the carbon system as a unified planetary process, we aim to generate the scientific insights needed to guide effective mitigation strategies and support international climate commitments.

These priorities will be supported by a **deep integration of AI and machine learning (ML) methods across all areas of research, enhancing every stage of the modeling and analysis chain, from data assimilation and scenario development to impact forecasting and risk assessments**.

This strategic framework reinforces CMCC's commitment to producing high-impact science that drives informed decision-making and tackles climate change challenges. By doing so, CMCC continues to shape the critical knowledge needed for a more sustainable, equitable, and resilient future.

For further information about the CMCC and our work, please visit www.cmcc.it.

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