



**Barcelona
Supercomputing
Center**

Centro Nacional de Supercomputación

SUMMARY 2023



Who we are



The Barcelona Supercomputing Center – Centro Nacional de Supercomputación (BSC) is the leader in supercomputing in Spain and an international center of reference in this field.

BSC's missions



Supercomputing services for Spanish and European researchers



R&D in Computer, Life, Earth and Engineering Sciences



Knowledge transfer (education, tech transfer and public engagement)

We are a multidisciplinary research center of reference. We host high-performance computing and data management infrastructures, and one of the world's most powerful AI development platforms at the service of the international scientific community.

We are a EuroHPC pre-exascale hosting Entity, we manage the Spanish Supercomputing Network (RES), a Singular Scientific and Technical Infrastructure (ICTS) that distributes HPC and data management resources, and we support the international biomedical community by coordinating the Elixir and INB-ISCIII infrastructures.

Created in 2005, based on the experience of fruitful collaborations between the public administration and private companies, such as CEPBA and CIRI, we have quickly grown from a staff of 60 people to around 1,000, thanks to the continuous commitment of our trustees and our ability to raise competitive funds from companies and public institutions.

We have installed five consecutive versions of the MareNostrum supercomputer and we are currently preparing the sixth version.

BSC is a public consortium made up of:



Where we are, where we are going

BSC ended 2023 looking to the future, welcoming a strategic asset for Europe: the MareNostrum 5 supercomputer. This new infrastructure will provide Europe with one of the most versatile and complete machines in the world at the service of science and progress. MareNostrum 5 is a tool that will be key to making progress with the great challenges of science—such as the new era of digital twins to tackle climate change and curing currently incurable diseases— as well as boosting public-private innovation and strengthening the business sector.



Mateo Valero and Josep M. Martorell
Director and Associate Director of BSC

The commissioning of this supercomputer is the result of the hard work of our Operations team, and of the combined efforts of the different administrations. This was clear during its inauguration, attended by Pedro Sánchez, the Spanish Prime Minister, Pere Aragonès, the Catalan Prime Minister, and Roberto Viola, Director General of DG CONNECT at the European Commission. We thank them all for their firm commitment to this great European project.

With this infrastructure, the European Union has completed its goal of having three high-performance supercomputers, launching Europe's ability to compete globally in the digital age into orbit. In November, MareNostrum 5 became the only supercomputer with two entries in the list of the world's 20 most powerful supercomputers. Its accelerated partition reached number 8 on the world list, making it one of the most powerful and versatile machines for artificial intelligence.

Looking to the future also means a new site for MareNostrum 5, which is leaving behind the chapel that has staged the MareNostrum saga for almost 20 years. Now this iconic site is being readied to host two quantum computers that will be integrated with the new supercomputer, as well as new European HPC technologies. The initial delivery of one of the quantum computers was carried out in 2023. This is part of the Quantum Spain initiative, coordinated by BSC, which aims to boost and promote the development of quantum computing in Spain. This quantum computer will be completed at BSC during the coming year and will be based exclusively on European technology. This marks a major milestone for European technological and industrial development.

In fact, one of the ideas that was very much present at the inauguration of MareNostrum 5 was the dream of having European technology in the future MareNostrum 6. This is the framework for one of the most ambitious goals of the BSC: become one of Europe's major hubs for chip design based on open RISC-V technology. In 2023, with the aim of advancing European technological and economic sovereignty, the European Commission gave the green light to the Digital Autonomy with RISC-V in Europe (DARE) initiative. Under BSC's coordination, this will seek to design and implement initiatives that contribute to the development of innovative technologies based on this type of processor. This European commitment will also support the BSC Zettascale Laboratory project, which will develop the technologies necessary to create prototypes based on RISC-V technology so that the supercomputers of the future can break the zettascale barrier.

Another major milestone in 2023 is the consolidation as a leading center for artificial intelligence, with a particular focus on generative artificial intelligence, such as that of large language models. The BSC's unique capabilities in big data analytics and artificial intelligence make our center a benchmark for the advancement of these new



technologies. For example, the AINA project, funded by the Catalan Government to promote the inclusion of Catalan in artificial intelligence applications for both large tech companies and local industry. Also, its sister project, ILENIA, which is part of the New Language Economy Strategic Project for Economic Recovery and Transformation. Its aim is to promote the potential of Spanish and the co-official languages as a factor for economic growth. In addition, the most complete anonymized corpus of medical records in Spanish was presented in 2023, the result of collaboration between BSC and Hospital Clínic de Barcelona, which will enable the application of artificial intelligence in health care.

















In 2023 BSC has continued to consolidate its position as an international reference center in supercomputing, entering into major agreements and collaborations with international institutions. One example is BSC's participation in the Trillion Parameter Consortium, a group of research institutes, universities, and companies from around the world that addresses the key challenges of generating fundamental AI models. Another example of this international collaboration is a meeting held with Columbia University in which international experts explored the impact of artificial intelligence and new technologies on treatment and prevention of cancer and other diseases.

Climate science and engineering are other fields in which our research groups have shone. Projects such as Destination Earth and the numerous European Centers of Excellence led by BSC, not to mention emerging dual technologies, demonstrate our capabilities in all of these knowledge areas. Our research staff produced more than 400 scientific publications this year, with a weighted impact index of more than two. Such figures were unimaginable just a few years ago.

Also in 2023, the new Computational Social Sciences program started at the BSC. This new program will take a pioneering approach in Europe to explore new applications of data and supercomputing in social science research, in where disciplines such as economics, political science, sociology and anthropology converge.

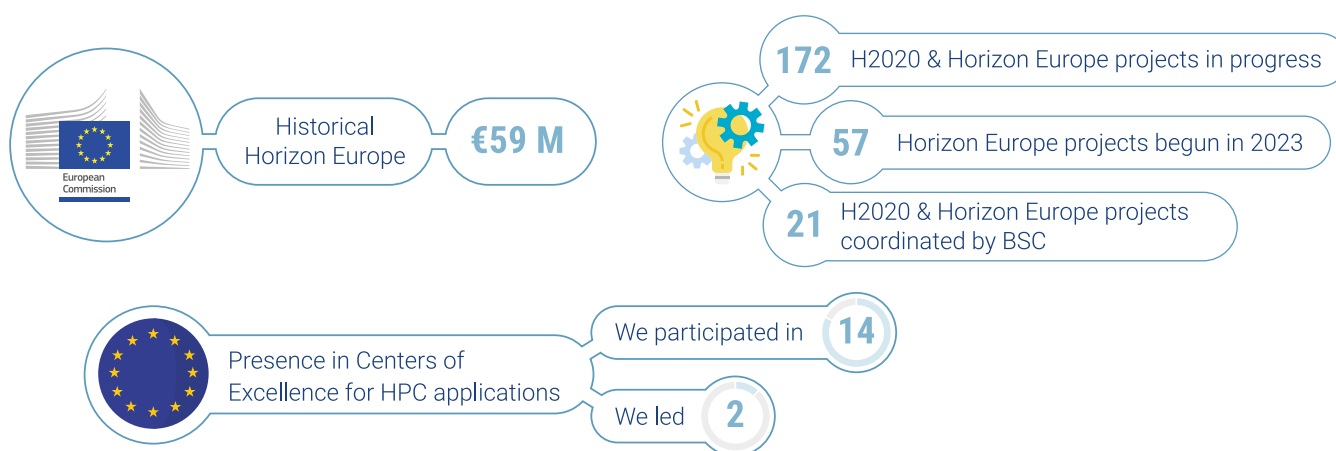
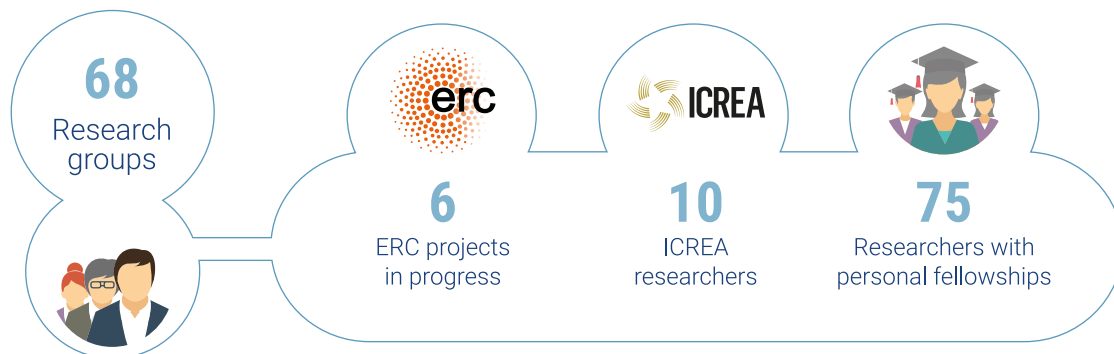
These and many other achievements made 2023 a very successful year. We are grateful to our patrons, all the staff at BSC, and everyone who has made it possible to write this great new chapter of our center's history. We already have our eyes set on the next one.

The representatives of BSC's three trustees who are members of our Governing Board

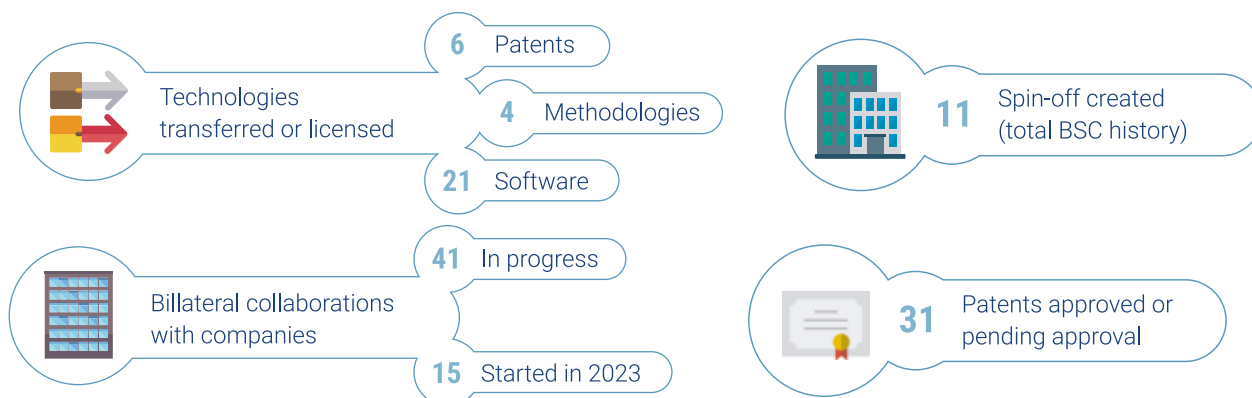
  <p>Raquel Yotti President Secretary General of Research</p>	  <p>Joaquim Nin Vice-president Secretary General of Research and Universities</p>	  <p>Gonzalo Arévalo Nieto Director General of Research Planning</p>	  <p>José Ignacio Doncel Deputy Director General of Large Scientific and Technical Facilities</p>
  <p>Joan Gómez Pallarès Director General of Research</p>	  <p>Lluís Juncà Director General for Innovation, Digital Economy and Entrepreneurship</p>	  <p>Daniel Crespo Rector</p>	  <p>Jordi Llorca Vice-Rector for Research</p>

BSC in numbers

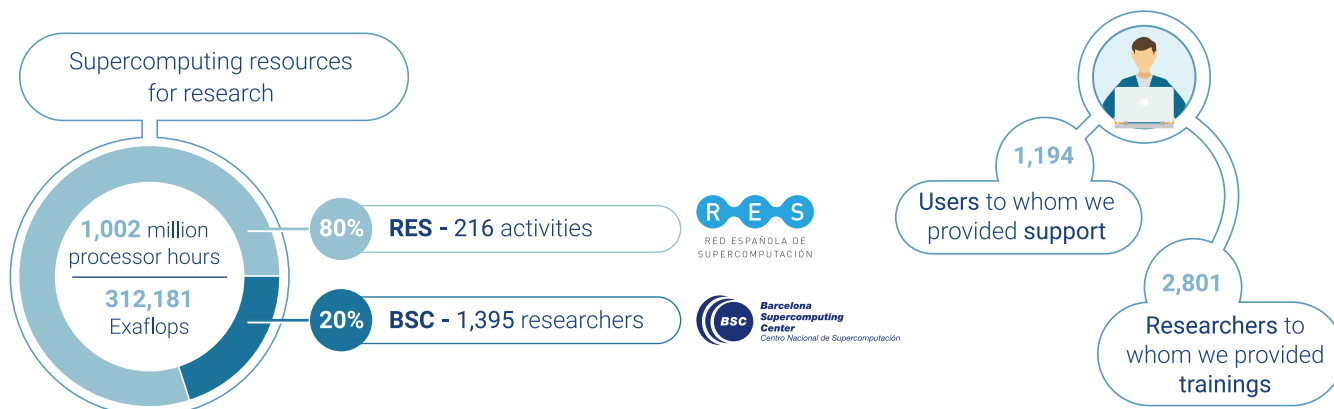
Research Data as of December 31, 2023



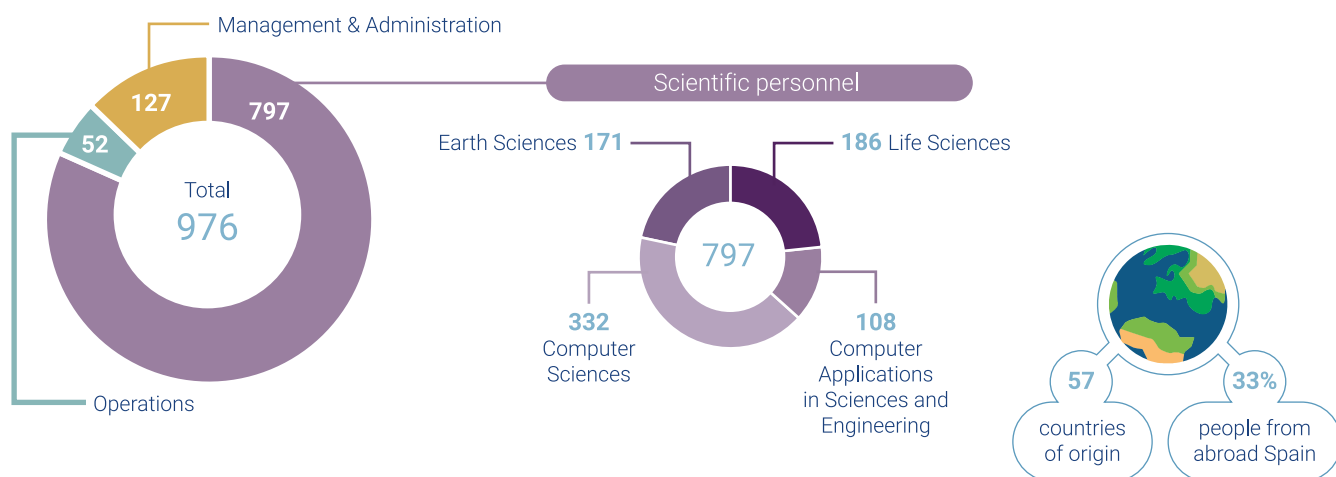
Technology transfer Data as of December 31, 2023



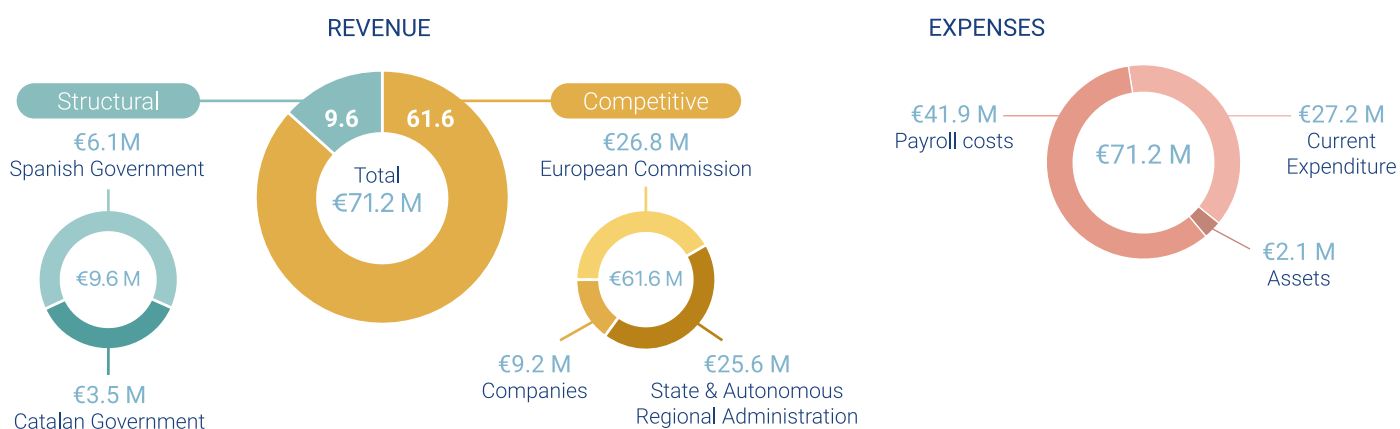
Supercomputing Data as of December 31, 2023



People Data as of December 31, 2023



Resources 2023 executed budget



UPC contributes, in terms of assigned staff and room space, the equivalent of 10% of structural funds. Revenue and expenses according to finance criteria. Investments according to budgetary criteria. Estimated data prior to the end of the 2023 financial year and the formulation of the annual accounts.

Inauguration of MareNostrum 5: a new EuroHPC world-class supercomputer

The new European supercomputer MareNostrum 5, one of the most complete and versatile machines in the world at the service of the scientific community, was inaugurated on December 21 at BSC. Thanks to its unique computational architecture, MareNostrum 5 will advance science in all areas, from the development of digital twins of the Earth and the human body, to the search for new treatments for diseases such as cancer, the design of healthier and more sustainable cities, or the search for new energy sources and new materials.

MareNostrum 5 is the largest investment ever made by Europe in scientific infrastructure in Spain with a cost of €202 million,

€151.4 million of which is for the acquisition of the system. This is funded jointly by the European High Performance Computing Joint Undertaking (EuroHPC JU), through the EU's Connecting Europe Facility and the Horizon 2020 research and innovation program, as well as the participating states: Spain –through the Ministry of Science, Innovation and Universities and Catalan Government–, Türkiye and Portugal.

With a maximum total performance of 314 petaflops, equivalent to the capacity to perform up to 314,000 European billion calculations per second, MareNostrum 5 joins two other EuroHPC systems: Lumi (Finland) and Leonardo (Italy) as the only three pre-exascale supercomputers in Europe. The capabilities and versatility of this new supercomputer will be instrumental in providing Europe with state-of-the-art supercomputing technology and accelerating the capacity for artificial intelligence research, enabling new scientific breakthroughs that will help solve global challenges.



The only European supercomputing center with two entries in the world's top 20

BSC is the only supercomputing center in Europe to have two entries in the world top 20, including both the general purpose partition, which is the 19th most powerful in the world and the largest based on x86 computing architecture, and the accelerated partition, which is the third most powerful in Europe and the eighth most powerful in the world, enabling research to advance in areas as important as artificial intelligence and numerical simulation.

This is according to LINPACK's Top500 list, a ranking of the world's 500 most powerful supercomputers that is updated twice a year. The latest ranking was released at the International Conference for High Performance Computing, Networking, Storage, and Analysis, the world's largest supercomputing event, held in Denver, USA, in November 2023.



Launch of the European Virtual Human Twins Initiative

The European Commission launched the European Virtual Human Twins (VHTs) Initiative to support the development and adoption of the next generation of digital human twin solutions in health and care. The event took place alongside the inauguration of the MareNostrum 5 supercomputer.

The initiative aims to accelerate the use of VHTs in health and care for more personalized care. It will bring tangible benefits to citizens and patients, while sustaining and advancing EU science and technology. Although VHTs already exist in many Member States, the initiative will also help to address the current fragmentation of the ecosystem in Europe.

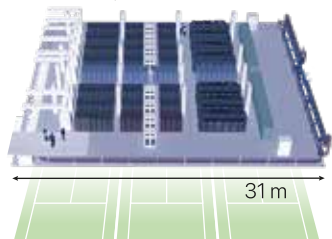


The MareNostrum 5 supercomputer

Millions of millions of millions of calculations per second to accelerate European science

Occupied area

The supercomputer occupies a room with an area of 800 m², equivalent to about 3 tennis courts.



Services (e.g. refrigeration and electrical transformers) occupy almost three times as much: 2,000 m²

Electricity

Reaches each of the rows using aluminium bars, which are more efficient than cables.

Computing power

The computing capacity of MareNostrum 5 is equivalent to about 380,000 high-end laptops. It does calculations in 1 hour that would take a laptop 46 years.

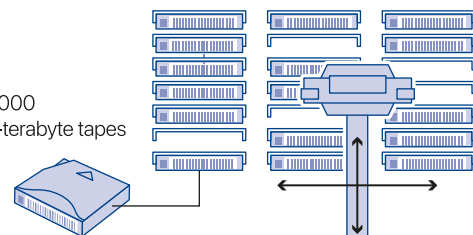
Peak performance: 314 Petaflops/s. (314,000 billion operations per second) with more than 2 petabytes of RAM.



General purpose partition

To help solve major scientific problems. 90 racks, 6,480 nodes and 12,960 chips.

20,000
20-terabyte tapes



Magnetic tapes

Slow to access, they are used because they consume less electricity. They store long-term data that is consulted less frequently.

Accelerated partition to make advances in Artificial Intelligence

35 racks, 1,120 nodes and 6,720 chips (4,480 of them, accelerated).

Electric panels

They distribute electricity in each row.

Row 1
Row 2
Row 3
Row 4
Row 5
Row 6
Row 7
Row 8

Robot with
10,000 tapes

Robot with
10,000 tapes

Elevated walkway

Air conditioning

Air conditioning

Experimental partitions

Research into technologies that will be part of the supercomputers of the future.

Management and communications

It connects all nodes to each other, sends the results to storage units and allows external queries.

Hard drives

The results of the calculations carried out are stored in 25 racks, each containing 816 18-terabyte hard drives. Total net space: 248,000 TB.



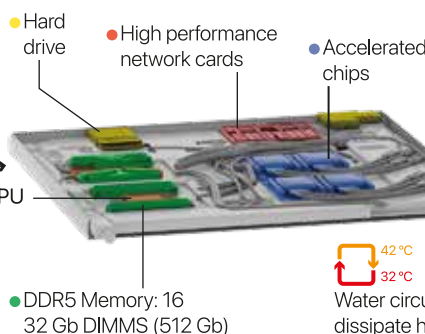
They could store 1,280 copies of every book catalogued throughout history.

False floor

Underneath the computers is a basement floor of cables, water pipes and network cabling. MareNostrum 5's copper and fibre optic cables have a total length of 160 km.



Accelerated node



Each of the 4,480 accelerated chips has more power than the entire MareNostrum 1 (from 2004).

Rack

There are over 180 racks. They contain nodes with chips, network cards, RAM and hard drives.

Water circuit in the rear door to cool the air expelled from the rack.

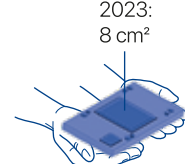


36 nodes
in each rack

42 °C
32 °C
Water circuit to
dissipate heat

2023:
8 cm²

2004:
180 m²



BSC and CCCB co-produce the 'AI: Artificial Intelligence' exhibition

BSC and Centre de Cultura Contemporània de Barcelona (CCCB) jointly produced the *AI: Artificial Intelligence* exhibition, which explores the history, functioning, creative possibilities, and ethical and legislative challenges of artificial intelligence today, as well as the enormous opportunities it presents for scientific and biomedical research (on display in Barcelona from October 18th 2023 to March 17th 2024).

Based on an original exhibition organized by the Barbican Centre in London in 2019, 'AI: Artificial Intelligence' is curated by Lluís Nacenta, a researcher at the confluence of music, art,



technology and science, with scientific advice from BSC researcher and UPC Professor Jordi Torres.

The showcased works include a large audiovisual installation created by BSC, 'Billions of operations per second', which shows how supercomputing is the great driving force behind artificial intelligence. It also displays its potential to accelerate scientific research by processing vast amounts of data. The installation shows, from the viewpoint of BSC researchers Fernando Cucchiatti, Amanda Duarte, Víctor Guallar, Oriol Jorba, Marta Melé, Alfonso Valencia and Marta Villegas, how supercomputing and AI enable progress in solving complex problems such as the construction of healthier, more sustainable cities adapted to climate change, the discovery of new drugs and the promotion of research into diseases such as cancer or identifying next-generation materials.

The exhibition also includes a comprehensive interactive timeline of key milestones in the development and evolution of artificial intelligence, which has been advised by BSC researcher and UPC professor Ulises Cortés and BSC researcher Darío García. Also noteworthy are some of the works created by scientists Maria Cristina Marinescu, Quim Moré and Maite Melero in collaboration with artists such as the composer Maria Arnal and the poet Eduardo Escoffet.

BSC explores the role of supercomputing as a key driver of AI in a new book

Artificial intelligence explained to humans, published by Plataforma Editorial, is a new book produced by BSC and written by the researcher Jordi Torres, which explains the economic, social and political implications of AI, as well as the possibilities and limitations that define the development of this technology, in an accessible way for readers without prior technical knowledge.

The presentation of the book at CCCB, in front of over 500 people, was carried out by Mateo Valero, BSC's Director; Alfonso Valencia, BSC's Life Sciences department Director; Karina

Gibert, Director of the Artificial Intelligence and Intelligent Data Science Research Center (IDEAI-UPC), and author Jordi Torres. In a round table moderated by journalist Pere Buhigas, they discussed the paths of this accelerated technological evolution and reflected on possible future scenarios.



BSC examines the musical history of 30 years of Sónar through ChatGPT

EXPLAIN, chat.in.a.box is a project developed by BSC's Data Analysis and Visualization group. It was presented at the 30th edition of the Sónar festival, as part of the Sónar+D programme held in Barcelona last June. The aim of the project is to overcome the underlying fears about AI that arise from the difficulty of understanding how these data-driven systems arrive at their results, by using techniques to visualize the inside of AI systems and identify patterns to help decipher how their black box works.

To try and show how AI works from the inside, BSC used the Sónar festival itself as a reference. The scientists collected lyrics from around 40,000 songs by more than a thousand artists who have performed at the festival over its three-decade history and fed them into GPT-4, the latest version of OpenAI's popular chatbot, to visualize patterns in the data and



compare them with other artists and other editions of the event to see how they have evolved over time. Visitors to Sónar+D were able to explore the visual representations of these patterns.

BSC partners with Fundació Telefónica to bring supercomputing and science to society

In 2023 BSC continued its fruitful collaboration with the Fundació Telefónica, which works to promote the inclusive digital development of society as a whole and to equip people with the digital skills they need to realise their full potential.

The Expanded World exhibition in the heart of Madrid is a result of this collaboration. This exhibition explores simulated worlds, their background, ethical, philosophical, legal, social, and economic implications.

BSC also participated in the exhibition *Algorithms and code*,

organised by the Fundació Telefónica, which travelled to the iMAL Art Center for Digital Cultures & Technology in Brussels on November 2023. Through interactive installations by twelve artists, the exhibition traces a journey through different areas in which algorithms impact our society: the importance of their neutrality and efficiency, the risks of algorithmic bias, tools to protect data privacy, the link between humans and artificial intelligence, and their contribution to finding solutions that would otherwise take years to solve or decipher.



One step closer to European quantum computing

The EuroHPC signed hosting agreements with six sites across Europe to host and operate EuroHPC quantum computers, including BSC. The six new EuroHPC quantum computers will be integrated into existing supercomputers in the Czech Republic, France, Germany, Italy, Poland and Spain, ensuring a diversity of quantum technologies and architectures, giving Europe the opportunity to be at the forefront of this still-novel field, and providing European users with access to diverse and complementary quantum technologies.

The deployment of this novel technology in Europe is the result of a collaborative effort by no less than 17 European countries to join forces to lead the way in quantum computing. Efforts will also be made to build on complementarities and thus create synergies between all these systems, which will be

made available primarily for R&D purposes to a wide range of European users, wherever they are in Europe, to the scientific community, as well as to industry and the public sector.



BSC and Esade join forces to strengthen links between science and business

BSC and international business school Esade signed an agreement to collaborate in scientific research, training and scientific and technological development at the intersection of









computer science and management. The aim of this alliance between the two organizations is to promote science and technology development through training, research and dissemination projects and activities in the field of high performance computing and its application to big data analytics and AI for business.

In order to transfer scientific knowledge to society, BSC and Esade will design, teach and coordinate educational programmes and internships, as well as participate in European and international research projects. These projects are mainly aimed at students of a joint major in Business Management and Artificial Intelligence, a new academic programme developed by Esade in response to the growing demand for business talent.



Research in MareNostrum 4

MareNostrum 4 provided 1,002 million processor hours in 2023 (312,181 Exaflops).
Some of the research projects developed by MareNostrum 4 are:

Project	Principal Investigator	Center
Earth Sciences		
Benchmarking ensemble data assimilation of atmospheric composition for reanalysis applications	Enza Di Tomaso	 Barcelona Supercomputing Center Centro Nacional de Supercomputación
Genetically modified cosmological hydrodynamical simulations of Milky Way-like galaxies	Matthew Orkney	 UNIVERSITAT DE BARCELONA
The three hundred galaxy clusters project: Next generation of high-resolution galaxy cluster simulations with GIZMO-SIMBA	Weiguang Cui	 Universidad Autónoma de Madrid
Life Sciences		
Metadynamics simulations for the study of the mechanical plasticity: towards the understanding of isoform selectivity	Carolina Estarellas	 UNIVERSITAT DE BARCELONA
Data Management Plan for paediatric cancer research	Soledad Gómez González	 Sant Joan de Déu Barcelona · Hospital
Unravelling the mechanism of cholesterol transport through the NPC1L1 protein	Salomé Llabrés	 UNIVERSITAT DE BARCELONA
Identifying mechanisms of activation and signalling of RAS oncogenic proteins and designing strategies for tumour blocking	Jordi Martí	 UNIVERSITAT POLITÈCNICA DE CATALUNYA BARCELONATECH
Physics		
Investigation of fullerene supported single-atom-catalysts (SAC) and single-cluster-catalysts (SCC) for the water splitting reaction to produce green hydrogen	María José López Santodomingo	 Universidad de Valladolid
Nucleation of methane, carbon dioxide, hydrogen, and nitrogen hydrates from computer simulation	Felipe J. Blas	 Universidad de Huelva
Dynamics of biophysical systems at the mesoscale	Chantal Valeriani	 UNIVERSIDAD COMPLUTENSE MADRID

Engineering and Mathematics

Numerical study of the propagation patterns of ultra-lean hydrogen-air flames in Hele-Shaw chambers

Anne Dejoan



High-fidelity aeroelastic simulations of a wind turbine blade undergoing vortex induced vibrations (VIV)

Vasilis Riziotis



Computational Mechano-Electric Model of the Human Diseased Heart

Beatriz Trenor Gomis



Chemistry

Towards the Design of Efficient Inhibitors of SARS-CoV-2 Mpro Variants

Vicent Moliner



Metal oxides for catalytic applications in sustainable chemistry and nanozymology

M. Verónica Ganduglia-Pirovano



Disclosing the complete photodynamical profile of the native nucleobase uracil

Inés Corral Pérez



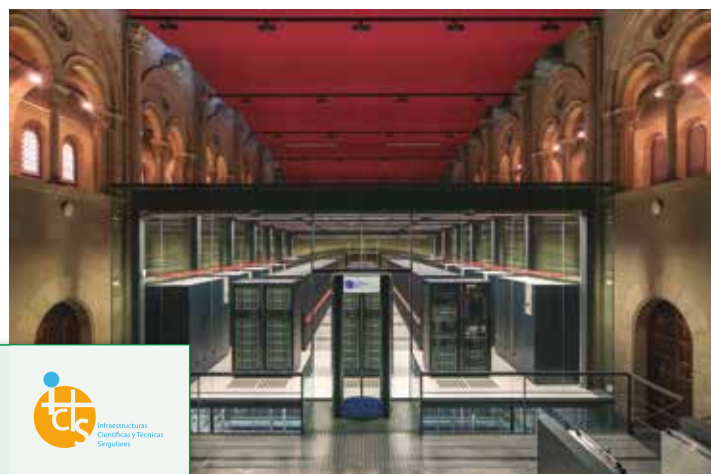
Titanium-Organic Frameworks for CO2 Capture

Carlos Martí Gastaldo



Providing a service for researchers all around Europe

The MareNostrum 4 supercomputer is available to European researchers through the calls of the Spanish Supercomputing Network (RES), which allocates 80% of its computing capacity. This is assigned through an open application process in which proposals are received and evaluated by the Access Committee, composed of experts from different scientific disciplines. The remaining 20% of the supercomputer's capacity is allocated to BSC research.



MareNostrum 4 supercomputer has a maximum capacity of **13.9 PetaFlop/s** or, in other words, **13,900 European billion operations per second**

MareNostrum 4 is co-financed by the Intelligent Growth Operation Programme 2014-2020 of the European Regional Development Fund (ERDF)



BSC Distinctions



BSC Director Mateo Valero receives triple recognition

BSC Director Mateo Valero won three important awards in 2023. Valero was elected a corresponding member of the Cuban Academy of Sciences.

BSC Director was also honored for his contributions to advanced computing cooperation with Latin America and the Caribbean. Valero received the first award named in his honor, which is presented annually by the Advanced Computing System for Latin America and the Caribbean (SCALAC) in conjunction with the CARLA conference.

The Sesé Foundation Awards, in their first edition, recognized the contribution of researcher Mateo Valero in the category of talent to the improvement of society.



City of Barcelona Award for Marta Villegas for the AINA and MarIA projects

Marta Villegas, Head of the Language Technologies Unit, won the City of Barcelona Award 2022 in the Experimental Sciences and Technology

category for constructing and developing natural language processing models for Catalan and Spanish, AINA and MarIA, respectively.



The MultiSeq project receives funding from the ERC

The MultiSeq project, led by researcher Toni Gabaldón, was awarded an ERC Proof of Concept grant of €150,000 for 18 months to optimize sequencing and explore market

potential. Through a combination of computational analysis and slight modifications to the laboratory protocol, this project allows the design of a strategy to sequence multiple samples in parallel.



Antonio Peña, winner of the Agustín de Betancourt award for young researchers

The BSC researcher Antonio Peña has received the Agustín de Betancourt y Molina Prize for young researchers awarded by the Real Academia de Ingeniería (RAI). This award recognizes

professionals who have made original and relevant contributions in any engineering field.

Earth Sciences Department, awarded at the 28th Nit de les Telecomunicacions

The Earth Sciences Department, led by Francisco Doblas, received special recognition as a leading initiative in ICT, climate change and sustainability at the 28th Nit de les Telecomunicacions i la Informàtica awards ceremony.



Rosa M. Badia, appointed new member of the IEC and chair of the ACM Europe Council

Rosa M. Badia, Leader of the Research Group on Workflows and Distributed Computing, was appointed as a new member of Institut d'Estudis Catalans (IEC). Badia was also elected as chair of the Association for Computing Machine (ACM) Europe Council. She was ACM Europe Councilor since 2021.



Ulises Cortés, Honorary Doctor of Universitat de Girona

Universitat de Girona (UdG) awarded the distinction of doctor honoris causa to Ulises Cortés, high-performance artificial intelligence group manager. Cortés was also appointed as advisor to the Mexican Senate on artificial intelligence.



Mercè Crosas, new President of the Committee on Data of the International Science Council

Mercè Crosas, Head of Computational Social Sciences programme at BSC, was elected the new President of CODATA. Crosas is the first female president of CODATA since it was founded in 1966.



Ezequiel Goldberg, awarded a EUROfusion Bernard Bigot Researcher Grant

Ezequiel Goldberg, a recognized researcher at the Fusion group, was one of the recipients of the EUROfusion Bernard Bigot Researcher Grants, which is awarded to talented post-doctoral researchers across Europe.



Scientific impact

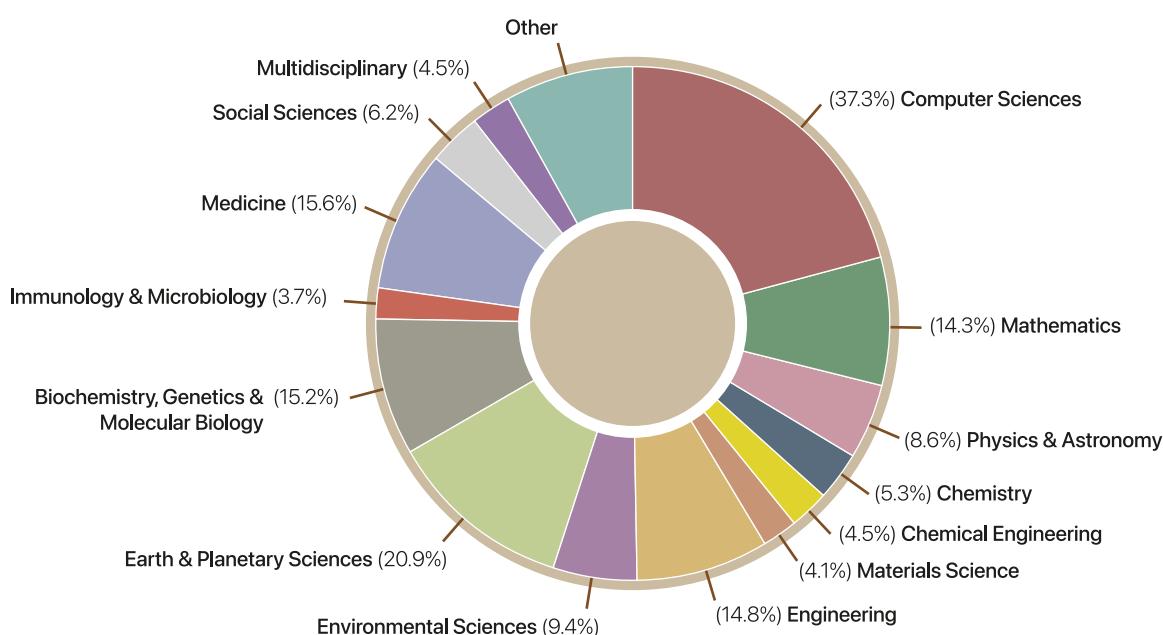
One of the BSC's mechanisms to ensure the exploitation of the center's scientific production is by publishing the main research results in the most appropriate media and channels for each of them, including works derived from doctoral theses. This section shows the multidisciplinary nature of the BSC research through the top journals where BSC researchers publish their results and their scientific domains, as well as the evolution of the scientific production of the center in the last five years.

Top 10 journals with BSC publications in 2023

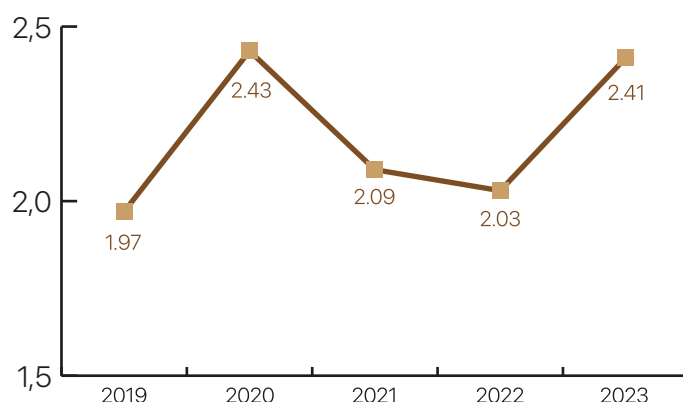
IEEE Conferences	36
ACM	19
Lecture Notes	17
Nature Communications	10
Astronomy & Astrophysics	10
Atmospheric Chemistry and Physics	8
Climate Services	8
Future Generation Computer Systems	7
Nature	6
Nuclear Fusion	6

Multidisciplinary

The subject area chart is based on the Scopus All Subject Journal Classification (ASJC); a publication may appear in more than one subject area. Therefore, if you add up the percentages in the pie or doughnut charts, they will add up to more than 100%.



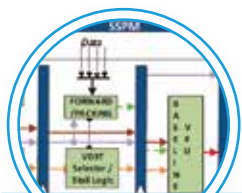
Field-Weighted Citation Impact 2019-2023



Featured publications

The multidisciplinary nature of BSC can be seen in the wide range of fields in which researchers publish scientific articles.

Below is a selection of the most notable publications in 2023.



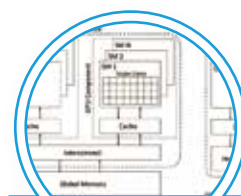
HPCA 2023

VAQUERO: A Scratchpad-based Vector Accelerator for Query Processing

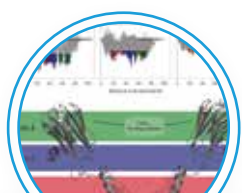
VIA is a vector architecture that aims at accelerating sparse matrix computation. VIA features a smart scratchpad memory designed to cope with sparse-dense (SpMV) and sparse-sparse (SpMM) matrix computations. For SpMV, VIA manages the high-locality dense vector in the scratchpad, thus reducing memory traffic. For SpMM, VIA features a specialized parallel lookup structure in the scratchpad that enables the functional units to compute index matching operations efficiently, one of the main bottlenecks in SpMM kernels. [Julián Pavón](#), [Iván Vargas Valdivieso](#), [Joan Marimon](#), [Roger Figueras](#), [Francesc Moll](#), [Osman S. Unsal](#), [Mateo Valero](#) and [Adrián Cristal](#). HPCA 2023. February 2023.

GPU Devices for Safety-Critical Systems. A Survey

Graphics Processing Unit (GPU) devices can deliver the computing performance required to facilitate the development of next-generation high-performance safety-critical systems, yet, the integration of complex parallel software with different safety-criticality levels on GPU devices contributes to several safety certification challenges. This survey categorizes and provides an overview of research contributions that address GPU devices' random hardware failures, systematic failures, and execution independence. [Jon Pérez](#), [Jaume Abella](#), [Leonidas Kosmidis](#), [Alejandro J. Calderón](#), [Francisco J. Cazorla](#) and [José Luis Flores](#). ACM Computing Surveys. July 2023.



ACM Computing Surveys



Nature Catalysis

Sub-micro-and nano-sized polyethylene terephthalate deconstruction with engineered protein nanopores

Identifying or designing biocatalysts to mitigate the accumulation of plastics, including sub-micro- and nano-sized polyethylene terephthalate (nPET), is becoming a global challenge. Here we computationally incorporated two hydrolytic active sites with geometries like that of *Idionella sakaiensis* PET hydrolase, to fragaceatoxin C (FraC), a membrane pore-forming protein. [Ana Robles-Martín](#), [Rafael Amigot-Sánchez](#), [Laura Fernández-López](#), [José L. González-Alfonso](#), [Sergi Rodà](#), [Víctor Alcolea-Rodríguez](#), [Diego Heras-Márquez](#), [David Almendral](#), [Cristina Coscolín](#), [Francisco J. Plou](#), [Raquel Portela](#), [Miguel A. Bañares](#), [Álvaro Martínez del Pozo](#), [Sara García-Linares](#), [Manuel Ferrer](#) and [Víctor Guallar](#). Nature Catalysis. October 2023.

The landscape of expression and alternative splicing variation across human traits

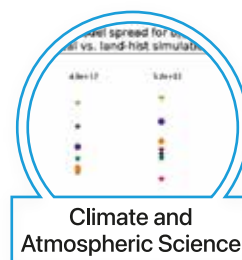
We implement a statistical framework to quantify the contributions of 21 individual traits as drivers of gene expression and alternative splicing variation across 46 human tissues and 781 individuals from the Genotype-Tissue Expression project. [Raquel García-Pérez](#), [Jose Miguel Ramírez](#), [Aida Ripoll-Cladellas](#), [Ruben Chazarra-Gil](#), [Winona Oliveros](#), [Oleksandra Soldatkina](#), [Mattia Bosio](#), [Paul Joris Rognon](#), [Salvador Capella-Gutiérrez](#), [Miquel Calvo](#), [Ferran Reverter](#), [Roderic Guigó](#), [François Aguet](#), [Pedro G. Ferreira](#), [Kristin G. Ardlie](#) and [Marta Melé](#). Cell Genomics. January 2023.



Cell Genomics

Large spread in interannual variance of atmospheric CO₂ concentration across CMIP6 Earth System Models

This study examines the reasons for the large uncertainty across various Earth System models in how these represent the year-to-year changes in atmospheric CO₂ concentrations. This uncertainty is shown to be primarily caused by the differences in the simulated CO₂ fluxes between land and atmosphere in response to internal variability, which is ultimately linked to structural differences in the underlying vegetation models. [Verónica Martín-Gómez](#), [Yohan Ruprich-Robert](#), [Etienne Tourigny](#), [Raffaele Bernardello](#), [Pablo Ortega](#), [Markus G. Donat](#) and [Margarida Samsó Cabré](#). *Climate and Atmospheric Science*. December 2023.



Climate and Atmospheric Science



The Lancet

The 2023 report of the Lancet Countdown on health and climate change: the imperative for a health-centred response in a world facing irreversible harms

The Global Health Resilience (GHR) group contributed to "The 2023 report of the Lancet Countdown on health and climate change: the imperative for a health-centred response in a world facing irreversible harms". The report highlighted the impacts of a changing climate on a wide range of global health impacts. GHR contributed to an indicator tracking the malaria transmission conditions since 1950 and produced projections towards the end of the century. [Marina Romanello](#), [Claudia di Napoli](#), [Carole Green](#), [Harry Kennard](#), [Pete Lampard](#), [Martín Lotto Batista](#), [Rachel Lowe et al.](#) *The Lancet*. November 2023.

Development, validation, and prognostic evaluation of a risk score for long-term liver-related outcomes in the general population: a multicohort study

We developed an AI-powered method for early detection of cirrhosis, which can be fatal when symptoms become noticeable. The paper presents the validation of the method in a European-wide transversal study with almost 15 thousand participants. [Miquel Serra-Burriel](#), [Adrià Juanola](#), [Feliu Serra-Burriel](#), [Maja Thiele](#), [Isabel Graupera](#), [Fernando Cucchiatti et al.](#) *The Lancet*. September 2023.



The Lancet

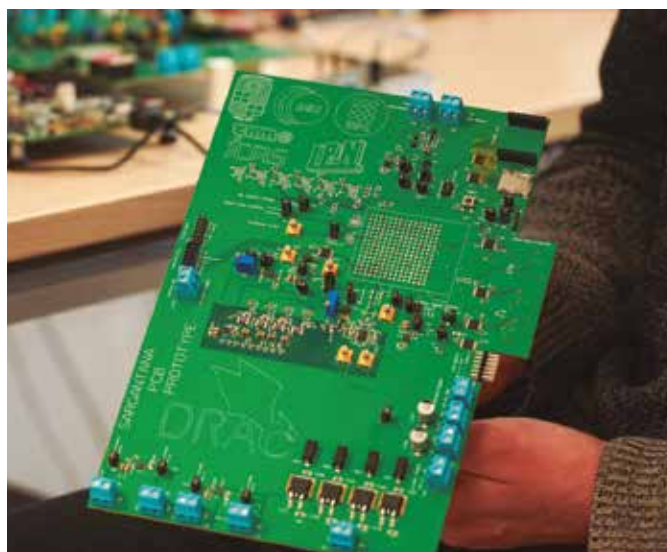


AIAA Journal

Flow Separation in Airfoils with Rough Leading Edges

We consider the flow over airfoils with leading-edge roughness, designed to mimic the ice depositions that may occur on an aircraft in flight. We observe the formation of hairpin vortices downstream of the roughness elements, which eventually merge; this causes the formation of wider channels that remain coherent and affect the trailing-edge separation. The mean-separation line is highly distorted, and the separation length can vary by up to 30% of the chord length along the span. Thanks to this discoveries more ice-proved wings for aircraft will be designed in the future. [Vishal Kumar](#), [Arnau Miró](#), [Oriol Lehmkühl](#) and [Ugo Piomelli](#). *AIAA Journal*. February 2023.

Research Highlights



BSC presents Sargantana, the new generation of the first open source chips designed in Spain

BSC presented the new Sargantana chip, the third generation of open-source processors designed entirely at the BSC. The development of Sargantana is a decisive step in strengthening BSC's leading position in the research of RISC-V open-source computing technology in Europe.

Sargantana is the third generation of the Lagarto processors, the first open-source chips developed in Spain under the DRAC project (Designing RISC-V-based Accelerators for next generation Computers), and is one of the most advanced open-source chips in Europe at the academic level. The new Sargantana offers better performance than its two predecessors –Lagarto Hun (2019) and DVINO (2021) – and is the first processor in the Lagarto family to break the gigahertz operating frequency barrier.

The Future of Computing, a BSC and IBM initiative to develop European technology

At the RISC-V Summit Europe, held in Barcelona, IBM and BSC announced that they are extending their long-term research and technology partnership by working together to develop The Future of Computing. This joint initiative between BSC and IBM reinforces their shared commitment to developing European technology and supports the EU's strategy for technological sovereignty.

Under this partnership agreement, IBM and BSC scientists and engineers will work together to conduct fundamental research in support of the Future of Computing vision that will be valuable to future technologies and IBM products, solutions and services. At the same time, the initiative aims to develop local talent and research projects to create and expand European technologies, such as new and more energy-efficient processors with European technology that will help alleviate the chip shortage.



Barcelona to test whether it is a 15-minute city with a digital twin developed by BSC

Barcelona City Council and BSC presented the initial results of a collaboration carried out within the framework of a digital twin programme for cities. This is a web platform for analyzing the accessibility of public facilities, which makes it possible to

assess whether Barcelona complies with the provision of services or facilities in the so-called 15-minute city model.

The platform is the result of the first phase of an ambitious project carried out by BSC researchers in collaboration with the Municipal Institute of Informatics (IMI) and Barcelona Regional (BR). The aim of developing this digital twin of the city was to approach the understanding of the urban phenomenon by analyzing data, evaluating resources, understanding the accessibility of services and working with models that represent a simplification of this complexity in an attempt to make it comprehensible.

Models make it possible to work with hypotheses, generate scenarios and visualize several variables or combinations of variables, which can be crucial in order to test the impact of the implementation of certain projects or the effects of the application of certain policies.



Genes that make each person unique and different analyzed in new BSC study

Researchers at BSC led a study, published in the journal *Cell Genomics*, which for the first time analyzed the variation in the expression of our genes in organs and tissues of the human body in hundreds of individuals with different traits. The work helps us to understand how the behavior of our genes makes us different from others, and provides fundamental information for deciphering human biology and the workings of diseases such as diabetes.

The main novelty of the study is that all the genes in the genome were analyzed simultaneously in multiple human tissues, taking into account several demographic and clinical characteristics, something that has not been done before. The results show specific differences in the expression of these genes in healthy people according to age, sex, genetic ancestry (the geographical origin of their genome) and body mass index (BMI), which allows us to assess a possible risk and progression of certain diseases.



BSC develops an AI tool to improve access to technology for the deaf and hard of hearing

Researchers at BSC and Universitat Politècnica de Catalunya (UPC) developed an automatic sign language translation research tool that uses artificial intelligence to overcome some of the communication barriers commonly faced by people who are deaf and hard of hearing.



The development of this new open-source software is an important step toward making communication accessible and barrier-free for all. To this end, BSC and UPC researchers combined computer vision, natural language processing and machine learning techniques to advance research in automatic sign language translation, a complex problem due in part to the variability and large number of sign languages in the world.

The system, which is still in an experimental phase, uses a machine learning model called Transformers, which underpins other AI tools such as ChatGPT, to convert entire sign language sentences in video format into spoken language in text format. It is currently focused on American Sign Language (ASL) but could be adapted to any other language once all the necessary data is available.

BSC unveils AI models, protocols and the most complete anonymized corpus of medical records in Spanish

The latest resources and advances of the Language Technologies Plan applied to the field of health and biomedicine, promoted by the State Secretariat for Digitalization and Artificial Intelligence (SEDIA), were presented at the Infoday 'AI and language technologies applied to clinical data: CARMEN-I (Corpus of Anonymized Records for Medical information Extraction) resources, systems and applications', organized by BSC and Hospital Clínic de Barcelona.

The Infoday was an opportunity to introduce the most complete anonymized corpus of real clinical reports in Spanish, known as CARMEN-I, which will be made publicly available to clinicians, AI researchers, academics and industry in Spain and globally, once specific conditions have been accomplished. The aim is to provide a freely-accessible health database that enables the application of AI in health, and

serves as a resource with an appropriate information structure for the creation of documented, evaluated and licensed clinical Natural Language Processing components.



BSC scientists create artificial protein capable of degrading microplastics in bottles

PET (polyethylene terephthalate), which is found in many packaging and beverage bottles, accounts for more than 10% of global plastic production and recycling is scarce and inefficient. Over time, this material wears down into smaller and smaller particles –so-called microplastics– which aggravates environmental problems.

Scientists from BSC, together with research groups from the Institute of Catalysis and Petrochemistry of the CSIC (ICP-CSIC) and the Complutense University of Madrid (UCM), developed artificial proteins capable of degrading PET microplastics and nanoplastics, and reducing them to their essential components, which would allow them to be broken down or recycled.

Researchers used a defense protein from the strawberry anemone (*Actinia fragacea*), to which they have added the new function after design using computational methods. Machine learning and supercomputers such as BSC's MareNostrum used in this protein engineering make it possible to predict where the particles will join and where we must



place the new amino acids so they can exert their action.

The results, which were published in the journal *Nature Catalysis*, indicate that the new protein is capable of degrading PET micro- and nanoplastics with an efficiency between 5 and 10 times higher than the PETases currently on the market.

BSC predicts global-mean temperature could reach 1.5°C warming limit within 5 years

The BSC 2023 decadal projection predicts that the global mean surface temperature will continue to rise in the coming years due to increasing greenhouse gas concentrations. Over the period 2023–2027, the global mean surface temperature is projected to be 1.44–1.55°C warmer than pre-industrial levels (defined as the average from 1850 to 1900), with a central estimate of 1.49°C. Therefore, there is a significant chance of exceeding 1.5°C above pre-industrial levels within the next five years, indicating that the world is rapidly approaching the Paris Agreement target.

The Climate Variability and Change group in BSC's Earth Sciences Department develops the BSC decadal prediction system, which forecasts changes in average climate condi-

tions (such as temperature and precipitation, among many other variables) and the frequency and intensity of extreme climate events (such as floods and droughts) over the next decade. BSC is one of five Global Producing Centers of Near-Term Climate Prediction, endorsed by the World Meteorological Organization (WMO), which produce operational decadal climate predictions every year.

The service combines observations and climate models, which are mathematical representations of the Earth's climate that typically includes the atmosphere, ocean, sea ice and land, to provide the best estimate of the climate system at a given time, providing many opportunities to adapt to a changing climate in the near future.

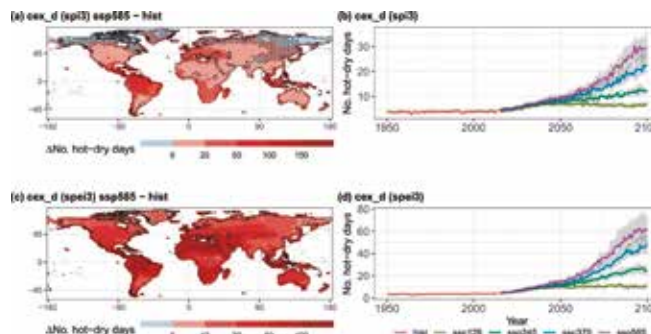


BSC contributes to WMO report on the health risks of climate change

The Global Health Resilience team of BSC's Earth Sciences Department contributed to the World Meteorological Organization's (WMO) report on the state of human health-related climate services in 2023. BSC researchers provided a case study based on indicators from The Lancet Countdown in Europe, a BSC-led initiative to monitor the relationship between health and climate change in Europe, as well as models to predict the risk of climate-related diseases in Barbados and a dengue early warning system in Vietnam.



The WMO report on the state of climate services highlights that while the scientific knowledge and resources to address the situation are now available, they are not yet sufficiently accessible or used in the health sector, with a particular impact on the world's most vulnerable communities. In fact, less than a quarter of the world's ministries of health have a monitoring system that uses climate information, which is critical to understanding how and when health systems and population health may be affected by the impacts of climate change.



BSC and CSIC set up a joint computational geophysics unit

BSC and Spanish National Research Council (CSIC) have launched a new associated unit, called the Computational Geophysics Unit, which combines the expertise and resources of both institutions to carry out research in the field of geophysics and natural hazards.

The new unit will allow the research team from both institutions to share resources and knowledge, using the supercomputing software and hardware tools available at the BSC, as well as the data provided by CSIC, to collaborate on interdis-

iplinary research projects related to geophysics. They will draw on the expertise in computer science, physics, mathematics and other disciplines of the people involved in the unit.

The BSC is a leading research center in Europe in the field of supercomputing, while the CSIC is a world-renowned research institution with expertise in a wide range of scientific disciplines, so this collaboration can bring significant value to geophysical research.



Meet us in person

Breaking boundaries: 'We are Young Women Researchers' programme launched at RES

Since 2018, BSC has been promoting STEM careers to female children through *We are Young Women Researchers* programme, which is aimed at primary schools for 9 and 10-year-old students. The motivation for this campaign comes from studies that report that girls lose interest in scientific careers at the age of 12, and its aim is to make these children aware of the role of female scientists in these fields.

The great success of the programme over the last few years has encouraged BSC to consider adapting the materials and exporting it to the rest of the country, as part of the activities of the EuroCC-Spain National Center of Excellence and the Spanish Supercomputing Network (RES). In a first phase, this

initiative was successfully adopted by SCAYLE (León) and a pilot was carried out by BIFI (Zaragoza).

The *We are Young Women Researchers* initiative continued to be a great success, as evidenced by the remarkable number of visitors last year: 7,618 were third- and fourth-year primary school children.

In terms of general visits to our supercomputer, the number of guided tours to the MareNostrum supercomputer in 2023 was very similar to that in 2022. In total, 18,563 people came to our facilities to visit the supercomputer. In addition, 2,738 people took part in the online tour and 17,101 people watched the tour remotely.



BSC organizes GAGO conference to discuss new forms of digital observation and governance in health, urban planning and environment

Under the title 'How can supercomputing and the use of digital twins contribute to shaping our common future in times of growing uncertainty and instability?', the 6th edition of the Gago Conference, a forum for debate on European science policy, was organized by BSC together with Ciencia Viva, as part of the events of the Spanish Presidency of the Council of the European Union in the second half of 2023.

Raquel Yotti, the Secretary of State for Research; Joaquim Nadal, the Catalan Minister for Universities and Research; Jordi Valls, the Deputy Mayor and Councilor for Economic Promotion of the City of Barcelona, and representatives from BSC and Universitat Politècnica de Catalunya (UPC) attended the closing session, which highlighted the importance of policy-makers relying on scientific evidence to develop policies that improve citizens' welfare.

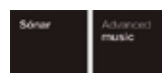
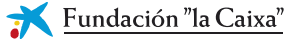
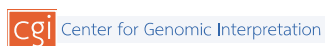
The 'Gago Awards on European Science Policy' named in honor of the Portuguese scientist and politician José Mariano Gago, were presented. The winners were Mateo Valero, BSC Director; Cristina Garmendia, former Minister of Science and



Innovation; Carmen Vela, former Secretary of State for Research; Andreu Mas-Colell, former Minister of Economy and Universities of the Catalan Government; Anna Omedes, former Director of the Museum of Natural Sciences of Barcelona; and Per-Edvin Persson, Director of the Finnish research center Heureka.

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