SCIENCE MAGAZINE

ELEMENTS

SPECIAL EDITION
September 2025

CLIMATE SERVICES IN FOCUS

Art and Climate Change: Time to Act Together

Climate and Social Justice

Climate Literacy

ISSN 2406-3002

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SCIENCE MAGAZINE

ELEMENTS

CLIMATE CHANGE is no longer a distant projection, it is a lived reality. It is in the air we breathe, the food we grow, and the rhythms of the seasons that no longer follow familiar patterns. Yet amid this uncertainty, one principle still holds: the future is not something we await, it is something we create.

In the face of planetary challenges, knowledge becomes our most powerful form of resilience. It empowers us to anticipate, adapt, and above all, to act with intention. Climate services, tools that translate scientific data into meaningful insights, are not just technical instruments. They are bridges between research and everyday life, between global understanding and local action.

They support farmers, urban planners, educators, and citizens in making informed decisions, rooted in evidence and guided by concern for our shared future.

But knowledge alone is not enough. We need imagination. We need innovation. And we need the courage to reimagine how we live, build, move, and relate, to one another and to the planet.

From emerging climate technologies to community-driven solutions, it is clear: the path forward will not be linear, but it can be transformative. As every researcher and innovator knows, great discoveries happen only when we dare to step outside our habitual contexts.

This edition of *Elements* stands as a reflection of that belief. It is a space to explore the role of science, technology, and creativity in shaping a climate-resilient world, a space to ask not only what the future holds, but what kind of future we want to shape, together.

Danijela Vučićević,
Acting Director
Center for the Promotion of Science

*Photograph by **Marko Risović***

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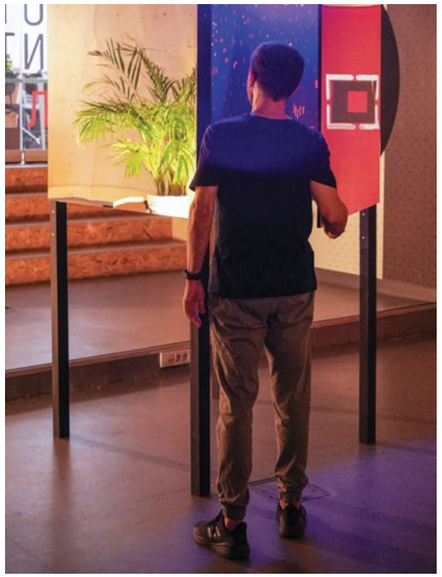
Cover Illustration by **Monika Lang**



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Elements

ELEMENTS
Science Magazine
Special Edition—September 2025

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CIP – Каталогизација у публикацији
Народна библиотека Србије, Београд

002

ЕЛЕМЕНТИ : часопис за промоцију науке / главни и одговорни уредник Иван Умељић . - 2015, бр. 2- . - Београд : Центар за промоцију науке, 2015- (Београд : Биограф). - 28 cm

Тромесечно. - Са спец. изд. од јан. (2024) на енгл. језику: Elements

ISSN 2406-3002 = Елементи (Београд)

COBISS.SR-ID 215847180

Digital Climate Atlas of Serbia

Climate services integrate data from various sources, offering personalized information that can be useful to researchers, decision-makers, companies, and individuals

By
Milica Tošić
Vladimir Đurđević
Irida Lazić

Illustrations by ***Željko Lončar***

THE LAST TWO YEARS HAVE BEEN the hottest on record to date, both in Serbia and globally. Meanwhile, extreme weather events, heat waves, raging storms, prolonged droughts, and downpours have become increasingly frequent and severe. Understanding this change is essential for adapting to it and mitigating its consequences. Central to these efforts are observations from the land, the air, the sea, and space, along with climate models.

"What cannot be measured cannot be controlled" has been a guiding principle for researchers and experts worldwide, and in the fight against climate change, data are fundamental. Every day, 2.5 billion gigabytes of data are generated globally, and their proper analysis helps us better understand the unfolding changes and formulate effective adaptation strategies. For example, scientists apply climate models to examine how the number and intensity of extreme weather events have changed and to what extent these trends can be attributed to greenhouse gas emissions. Research findings serve as a clear warning that climate change has led to extreme climate events becoming more frequent and more destructive than previously. Although rare by definition, extreme weather events—such as droughts, heat waves, floods, storms, forest fires, and hurricanes—have been closely studied due to their impact on society and ecosystems.

According to the National Council on Climate Change, agriculture is one of the sectors in Serbia most vulnerable to climate change. This is evidenced by the 2012 drought, which resulted in an estimated USD 2 billion loss in the agricultural sector. Long-term analyses show that the frequency of summer droughts has doubled in Serbia, with nearly every other year in the last two decades marked by dry conditions, a trend directly linked to climate change. A similar pattern occurred in 2024, when an extreme drought affected 92 percent of Serbia's territory. In addition to droughts, rising temperatures are also driving other extreme events, like flash floods, which result from severe storms and dry soil with reduced water absorption capacity. Climatological analyses unequivocally place Serbia among the high-risk regions, as it is situated within the Mediterranean zone, where climate change is more pronounced and advancing at a faster pace than in many other parts of the world.

Climate change poses a global challenge that calls for a multidisciplinary approach and international cooperation. For example, if the research focus is on climate extremes, meteorologists play a key role in collecting, monitoring, and analyzing weather data, while engineers and urban planners assess their impact on infrastructure and urban environments. Biologists and environmentalists study how climate change affects ecosystems and biodiversity, while sociologists may analyze its social and economic repercussions. All these perspectives are important for understanding the implications of climate extremes and developing effective strategies for adapting to and mitigating their effects. In such a world, climate services become a key tool for informed decision-making across all sectors of society. These systems help access, analyze, and interpret climate data, thus facilitating planning and adaptation efforts. Their objective is to make scientific findings on the climate available and applicable in the real world—from urban planning and agriculture to the energy and healthcare sectors. They connect science and practice, providing users with reliable information on past, present, and future climate conditions.

Therefore, the objective of climate services is to establish a centralized and comprehensive database to support sectoral studies on the impacts of climate change (agriculture, public health, infrastructure, water management, forestry), as well as improve the education of early-career scientists and professionals from various disciplines in the analysis, interpretation, and application of meteorological data. Providing users in sectors such as agriculture and forestry with easy, open access to the information helps make more accurate assessments of the risks and consequences of extreme weather and climate events for life and the economy in Serbia. In addition to ensuring long-term resilience to climate change, quality information enables timely responses to extreme weather events. With reliable data, we can more effectively alert populations in at-risk areas, plan protective measures, and organize timely relief efforts in the event of natural disasters. With this approach in place, we strengthen society's capacity to adapt and build resilience to growing climate challenges. As science and technology continue to advance, we gain access to modern instruments for data collection at meteorological stations, precise satellite measurements, and tools for their systematization. While data can offer detailed insights into past and current climate conditions, we can now also rely on climate projections based on numerical models to give us valuable information and insights into future conditions. Climate services integrate data from various sources, offering personalized information that can be useful to researchers, decision-makers, companies, and individuals.

There is an interesting ongoing project dubbed *Destination Earth*, an initiative that aims to create a digital twin of the Earth. The simulation is actually its computer version, which will enable an integrated study of climate change, its socio-economic consequences, and possible adaptation and mitigation strategies.

While global research centers have been collecting and analyzing climate data for years,

The Digital Climate Atlas of Serbia provides systematized and visualized projections—maps and graphs for various seasonal and annual analyses and data—thus saving time and facilitating informed decision-making

Serbia has only recently acquired a digital tool that allows a wide range of users to access relevant information. This is the Digital Climate Atlas tailored for Serbia—a free online platform that draws on meteorological and geospatial data to give us insight into ongoing and anticipated climate change impacts. The Digital Climate Atlas of Serbia has been developed in cooperation with the Faculty of Physics at the University of Belgrade, and the Neopix design studio, as part of the NAP project (Advancing Medium and Long-Term Adaptation Planning in the Republic of Serbia), with support from the United Nations Development Programme (UNDP) and the Serbian Ministry of Environmental Protection.

This platform integrates historical climate data and projections from regional climate models for the entire country, as well as for regional and local contexts. What is particularly useful is that one can easily access information relevant to our country—both on the patterns of climate change documented over several decades, and potential future trends depending on the selected greenhouse gas emissions scenario.

Although climate research across Europe relies on the same global databases, such as the Copernicus Climate Data Store, having a service tailored specifically to Serbia gives access to more precise information that can be readily applied in local analyses. Instead of users processing vast amounts of data on their own, the Atlas provides systematized and visualized projections—maps and graphs for various seasonal and annual analyses and data—thus saving time and facilitating informed decision-making. The Atlas covers a wide range of climate variables, including temperature, precipitation, and specific climate indices.

All climate data presented in the Digital Climate Atlas of Serbia are publicly available and free of charge, extracted in a digital format suitable for further analysis in tools such as Excel or GIS. The platform includes the option to download raw data, which is particularly valuable for climate researchers and experts. Additionally, the Atlas provides detailed user instructions, project information, and contact details for further inquiries.

The Digital Climate Atlas of Serbia was developed to bridge the gap between climate information and its application across various sectors. Unlike similar initiatives worldwide, this platform has been designed to be accessible to a broad spectrum of users, from those with minimal prior knowledge, including pupils and teachers who can use it for educational purposes, to experts who require precise and reliable data for advanced research. So far, several workshops on the applications of the Digital Atlas have been organized, bringing together researchers and experts from the academic community, representatives of ministries and decision-makers in the public administration and local self-governments, as well as experts from various institutes in Serbia. —Ⓔ

Milica Tošić is a PhD student in meteorology at the Faculty of Physics, University of Belgrade, where she works as a research associate and teaching assistant. Her work focuses on climatology, the analysis of climatological data, and numerical atmospheric modelling. As part of her doctoral research, she is examining extreme weather and climate events and exploring new methods for their prediction.

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Irida Lazić is a researcher and teaching assistant at the Faculty of Physics, University of Belgrade. As a PhD student, she is working on numerical climate modeling, exploring ways to improve climate projections and provide a clearer picture of the climate we can expect in the future.

INTERVIEW

Dr. Francisco J. Doblas-Reyes
Barcelona Supercomputing Center (BSC)

Dr. Asunción Lera St. Clair
DNV and Barcelona Supercomputing Center (BSC)

On the Path to an Equitable and Diverse Climate Services Community in Europe

"Climateurope2 is a project that's helping expand the community, bringing in voices from the social sciences, humanities, private sector, and the policy world. And it's making those connections meaningful, especially through its focus on standardization"

By
Inés Martín del Real
Barcelona Supercomputing Center (BSC)

AS EUROPE FACES INCREASING CLIMATE challenges, one EU-funded project is working behind the scenes to make climate services more effective, equitable, and trustworthy. Climateurope2 is working to build an equitable and diverse climate services community in Europe that help to shape the future of climate services through dialogue, collaboration, and standardisation.

Ahead of its upcoming Festival "Empowering society through climate services" in Belgrade (September 29–October 1, 2025), we spoke with two of the project's leading voices:

Francisco Doblas-Reyes is an ICREA research professor and Director of the Earth Sciences Department at the Barcelona Supercomputer Center. He coordinates the Climateurope2 project and has contributed as a lead author to both the AR5 and AR6 reports of the IPCC in climate modelling and climate information chapters.

Asun Lera St.Clair is a philosopher and sociologist, also lead author in AR5 working group on adaptation, currently working as Climate Change Lead in the Renewables team at DNV Group Research and Development. She is also a visiting leading researcher at the Earth Sciences Department of the Barcelona Supercomputing Center. Within the project, she leads the formulation of synthesis recommendations that set the ground for standardising climate services.

Together, they reflect on the project's effort to build a connected climate services community and discuss why standards are key to future resilience and adaptation in Europe.

*Photographs courtesy of **Dr. Francisco J. Doblas-Reyes and Dr. Asunción Lera St. Clair***

To start off, how would you explain what a climate service is to someone who's never heard the term before?

ALS: A climate service is the provision of climate data and information together with other relevant data, such as socioeconomic, vulnerability, or environmental factors, in a way that makes it usable and useful for decision-making.

This is a very complete definition, yet there still seems to be disagreement around what a climate service really is. Why do you think that is?

ALS: Many people confuse climate services with simply having a website or portal that provides climate data and information. But climate information alone usually tells very little about what it actually means for people.

However, the keyword here is 'service', which implies doing something for either a customer, a client or, in our case, the user of the climate service. A climate service entails reaching out to users, understanding their needs, and creating processes that allow meaningful interaction with them.

So, in short, the disagreement stems from a lack of understanding of what the full process entails and the different components involved in delivering a climate service that is truly useful.

To move toward shared understanding of what climate services involve, Climateurope2 has proposed four key components that define what a fit-for-purpose climate service should include. How do these help clarify what a climate service really is?

FDR: The components are essential for structuring conversations around climate services. As someone from the technical side, I tend to think mainly about climate data, observations, and models when talking about climate services. But these components help to see the full picture and recognize that other elements are just as critical and that climate data per se cannot go very far in delivering the service.

The components allow all the relevant actors involved in the process of developing a climate service to have a shared understanding and a

more balanced discussion about what climate services really are, how they are built, and how we can work toward standardizing them.

Can you briefly describe these four components and explain why each of them matters?

ALS: The four components form a logical sequence. The first component is understanding the decision context in which the climate service is going to be used. This means knowing who will use the service and to understand what kind of decisions they need to make and under what conditions.

The second is the co-production process. Once the relevant actors involved in the development and take up of the climate service are identified, they must be involved from the beginning to the end, following robust methodologies. There are a lot of methodologies that describe how to execute co-production successfully in many different ways.

The third component involves the integration of climate information with other relevant data and information, such as socioeconomic or environmental data, domain or local knowledge, as some examples. This integration is key to making climate information meaningful in real-world settings.

The fourth component brings two important aspects: delivery mode and evaluation. It's about how the climate service is presented and shared. Is it a platform thath is easy to use? Are the maps or visuals intuitive or confusing? And finally, there should be a feedback mechanism to learn from users' experiences so that the services can be improved.

From all these four components, Climateurope2 is searching for key requirements that climate services should meet in order to be truly fit-for-purpose and as a starting point for setting standards.

These components clearly support climate service providers in developing effective services. But how do they benefit users?

ALS: By identifying the requirements for climate services that are fit for purpose, we could tell the users "These are the kinds of things you should expect a climate service to offer."

In a way, it's like knowing your consumer rights. As we define these requirements, we are also helping users understand what a good climate service should look like. Because standards work both ways: they don't just guide the providers, they also help educate users about what they can and should demand from providers.

ALS mentioned co-production as a key component of climate services, which suggests that a wide range of people must be involved in their development. One of Climateurope2's goals is to build a European climate services community that includes providers, purveyors, and users. Why is it important to have such a diverse and representative community? And how can this help in developing standards for climate services?

FDR: As Asun mentioned, climate services should put climate information into context. This means considering the values and needs of those that are going to make the decisions. When developing requirements or standards for climate services, we have to make sure that they respond to all these different needs without being biased. It would be easy to imagine that a climate service is successful just because it works well for sectors that are already familiar with climate data and information, like insurance or energy. There are, however, other sectors that are less familiar with climate services, yet are still highly sensitive to climate change and variability, like food production, tourism, or sectors involved in protecting vulnerable populations, such as disaster risk management. They also need success measures and feedback mechanisms that identify their requirements.

That's why building an inclusive, representative community is so important. It helps ensure that climate services are accessible, usable, and relevant across different sectors and levels of decision-making.

How is Climateurope2 facilitating this dialogue to build this climate services community?

FDR: Climateurope2 is organizing a variety of activities that increase the engagement with the community, such as festivals, webstivals, workshops, questionnaires, surveys... These events serve both to identify the community and to gather knowledge and experience from the community itself.

One of the activities of Climateurope2 was an in-person workshop with private providers in Barcelona. Similar events are planned, for example, one with the health sector later this year. What are the main objectives of these workshops?

FDR: These sector-specific workshops aim to better understand how different sectors are affected by the standardization of climate services. We want to learn whether they are currently using climate services, and for those who are using them or planning to, which aspects they consider most important when it comes to defining standards.

The recommendations for standardization that Climateurope2 will make will eventually feed into the official standardization process led by CEN-CENELEC. These standards could significantly shape the future market of climate services, not just in Europe, but globally. So these events offer sectors an opportunity to have a say in how those standards are designed.

Why did you want to start these workshops with private providers?

ALS: We already work closely with public providers of climate services and the WMO. But for these workshops, we chose to begin with private providers because they're really the ones in the trenches. They create services that are replicable while adapting the climate information and data to different types of customers doing very different things.

We want private providers to be involved in the maturing of recommendations for standardization and feel part of it. The best way to make that happen is by bringing them into the conversation from day one, which is now, before the formal process of standardization begins.

What were the main messages that emerged from the workshop with private-sector providers, especially those that might be relevant for the broader conversation around climate services?

FDR: One thing that is interesting to mention is that this event was probably one of the very few where different types of climate services providers were put together. For many of them, this was the first time they had a chance to talk to each other, not in a research or academic setting, but in a space focused entirely on their real-world experiences. This approach was key to reaching a point where new knowledge was identified. The discussions were not driven by academic papers or research presentations, but about the issues that mattered to them. And

that is what the market is about. It is crucial for Climateurope2 to understand it for the standardization to be relevant and effective.

ASL: One of the key insights is that the community of private climate services providers is completely heterogeneous. It includes everything from very large to very small organizations, all working in very different ways. But despite this diversity, one thing was very clear: they are serious players who want to have available benchmarking of a minimum quality and key performance indicators.

Another takeaway is the need to avoid what is called 'unfair marketing', where some providers claim their services can do more than they actually can. So there is a strong desire for regulation that can help level the playing field. A more balanced market is both more effective and more trustworthy. This is not just about private actors working with other companies. Many of them have public-sector clients too, such as governments, cities, even communities. So, the standards we are talking about would benefit public services as well.

Another point that came up was how much providers value the possibility of delivering services that are partly repeatable and partly bespoke. It makes business sense: you create a robust service that can be replicated, but still adapt it to different local needs.

Looking ahead to the event with the health sector planned for September, what do you hope to learn from it? And how do you expect it to differ from the workshop with the private sector?

FDR: To begin with, in the climate and health sector, the number of actors already familiar with how climate affects health is quite small, and among them, even fewer are familiar with climate services. That's a big difference compared to the private-sector event.

Also, the climate and health sector deals with very different challenges depending on the region. The problems faced in developed regions are not the same as those in regions with economies in transition. For this reason, one of the main goals is to collect input from a wide range of voices and places. This goes back to the importance of having a diverse network that we can rely on.

We've been talking about the importance of including a wide range of sectors and voices. The upcoming Climateurope2 Festival in Belgrade is especially relevant in this regard, as Eastern Europe has historically been underrepresented in the climate services community. Why do you think this underrepresentation exists?

FDR: In Eastern Europe, the public and private climate services markets have not had the same opportunities to grow as in Western Europe. Part of this is related to political priorities. Probably, climate adaptation and mitigation have not often been at the top of the national agendas. As a result, solutions like climate services, which play an important role in increasing climate resilience, have had very little visibility.

That's why it is so important for Climateurope2 to hold the Festival in Belgrade. It is a way of showing that the climate services community values being present there and a chance to illustrate how the climate services market in the region can develop for the benefit of society.

Beyond organizing events such the Festival in Belgrade, what other actions are needed to better involve Eastern European countries in the climate services community and support the uptake of climate services in these regions?

FDR: One of Climateurope2's goals has been to identify the key actors working in climate services in Eastern Europe. But this has not been easy or fully successful yet, but we need to keep trying. It is only by identifying who is there, reaching out to them, and making them aware of the opportunities that exist that we can start having some local impact. Of course, the change ultimately has to come from the local and regional actors, we cannot expect to just go in and tell people what they should be doing. What we try to do is to build with them an honest and clear picture of what is possible, and build capacity.

ALS: Apart from what is in the hands of Climateurope2, in EU-funded research projects there are often specific requirements to include partners from Eastern Europe. But that alone is not enough. I think something else needs to happen at the European Commission level to go the extra mile to build real capacity in the region. People and institutions in these regions need the capacity not only to understand and use climate information, but also to implement the standards we are now starting to develop. This, in fact, is also the case for all European countries.

The potential impact of Climateurope2, from building a stronger climate services community to shaping standards and supporting more inclusive development, is very much long-term. What personally motivates you to commit to this kind of work over time?

FDR: A few years ago, I was involved in a project on quality assurance for the Copernicus Climate Change Service (C3S). Someone asked me why I would focus on something so unglamorous and unlikely to lead to many publications or academic prestige. My response was simple: if we, as experts, do not engage in this work, someone else will, likely without the knowledge or perspective needed to do it well.

It is for this same reason that I am involved in Climateurope2. It may not be the flashiest scientific project, but it addresses something essential: building a foundation for trustworthy, effective, and inclusive climate services. If we do not engage, we risk ending up with standards and frameworks that do not reflect the values or realities of those who actually work in or depend on climate services. So, for me, this is about taking responsibility and making sure things are done right.

ALS: In my case, I've been working in climate services for over 14 years and early on I saw how dominated the field was by the physical sciences. But climate is not just a physical phenomenon. It's deeply human, social, political, and economic. In fact a big part of climate change is about values. So, I became very motivated to look at the broader picture and the human and social dimensions.

Climateurope2 is a project that allows exactly that. It's helping expand the community, bringing in voices from the social sciences, humanities, private sector, and the policy world. And it's making those connections meaningful, especially through its focus on standardization.

Standards are a form of governance. And right now, there's a real opportunity to shape how climate science supports European climate policy, resilience planning, and implementation of major frameworks like the EU Green Deal and the European Climate Law. Climateurope2 is right at that intersection. —Ⓔ

Inés Martín del Real is a Science Communicator in the Earth Sciences Department at the Barcelona Supercomputing Center in Spain. She holds a degree in Biology and a Masters' in Sustainable Development and is interested in communicating complex topics combining concise writing with graphic elements through her hobby of creating comics.

INTERVIEW

Dr. Nikola Obrenović
BioSense Institute

When Data Tell a Story: Decoding Climate Change

“Today’s technologies can communicate with users, ask for additional information, provide advice, and offer the best possible guidance on how to act on climate change”

By
Bogdan Đorđević

Photographs by
Vladimir Janić

DR. NIKOLA OBRENOVIĆ, a senior researcher at the Center for Information Technologies, BioSense Institute in Novi Sad, is a scientist who successfully integrates academic expertise, research, and industrial practice. After completing his PhD at the Faculty of Technical Sciences in Novi Sad and working as a postdoctoral researcher at the prestigious Federal Polytechnic School of Lausanne, Nikola participated in several European projects in the fields of mathematical optimization, software engineering, and machine learning. Today he is engaged in projects such as UDENE and SONATA, and the AgroSense platform, which use data analysis to provide farmers, urban planners, and decision-makers with tools to understand and manage climate risks. From a conversation with Dr. Obrenović, we learn why the availability and proper application of data should be seen as one of our greatest allies in the age of climate change.

How do you see the role of information technologies in facilitating adaptation to climate change, particularly in agriculture? What are the key opportunities that these tech tools open up for us? And what can we do today that was once out of reach?

The rapid development of AI-driven information technologies is something we need to keep pace with, as this advancement enables us to solve problems that were previously beyond our grasp. Although the basic mathematical concepts behind these models are not particularly complex, the models themselves are huge, allowing us to detect dependencies and model regressions that we previously could not. This lays the groundwork for making more accurate assumptions and precise projections about the changes ahead.

Moreover, large language models help bring technology closer to people. One no longer needs to be highly digitally literate, or even willing to educate themselves in that field, as today’s technologies can communicate with users, ask for additional information, provide advice, and offer the best possible guidance on how to act on climate change.

Can you please explain how the AgroSense platform works, and how it supports farmers in making informed and sustainable decisions?

The first and most important function of the AgroSense platform is data collection. Farmers need to register, input their land parcels, and record activities taking place on them, including the crop yields achieved. In parallel, the platform gathers meteorological and other relevant data. The synthesis of all this information enables us to provide farmers with recommendations on what to do on their land in the upcoming season and when exactly, based on expected climate conditions and the analysis of prior data.

The platform also gives them guidance on how to adapt to climate change. For example, relying on historical data and forecasts, farmers can plan which crops to grow and when, which can result in higher yields and more effective crop rotation.

It is important to mention that the platform currently has around 25,000 registered users, which is essential, as the quality of ML and AI models depends on the volume of data. Without a sufficient amount of data, it is impossible to develop a reliable and precise model capable of providing sound recommendations.

What have been the biggest obstacles so far to the implementation of such technologies in agriculture—technical, organizational, or those linked to users’ trust?

In agriculture, the transfer of knowledge from one generation to the next has a strong influence—farmers often continue doing things the way their family members did. So, one of the main challenges is that technology often seems very remote from users' daily lives, both visually and in terms of user experience, especially in the agricultural sector.

To mitigate this challenge, we organized workshops, activities as part of the Digital Village project, and other forms of assistance. Through these efforts, we have brought technology closer to users, making this hurdle easier to overcome.

At the international climate festival held in Venice as part of the Climateurope2 project, you presented another project—UDENE (Horizon Europe programme). Could you tell us a bit more about this project?

The UDENE project focuses on applying natural experiments to help mitigate the effects of climate change and improve environmental conditions in various urban and rural zones. My team and I are developing the use case for Novi Sad as we want to estimate air pollution levels in light of the planned changes to the transportation infrastructure.

Put simply, two bridges are currently under construction in Novi Sad due to ongoing works on a ring road. The earlier plan was to convert the road running through the so-called Lower Town of the Petrovaradin Fortress to a pedestrian zone. However, we already have heavy traffic in these streets, and this will cause major traffic changes so our objective is to see how this will affect air pollution. Whenever we have big traffic jams, we also see rising air pollution levels.

What insights can be derived from comparing the city's transportation potential with real-time mobility data? What are the challenges associated with the application of agent-based models in this context?

We approach this project from two perspectives—macroscopic and microscopic. At the macroscopic level, we analyze citywide dynamics. Based on the transportation data for Novi Sad, which we obtained from various city administrations or found on open data websites, we are identifying correlations. These data on the city's transportation potential have proven very useful for the macroscopic approach to transportation and air pollution modelling. Primarily used by urban planners, the data describe the potential of each street segment—whether there are shops, cinemas, or other venues that attract people—and indicate a street's capacity to serve as a connection between two points in the city. Here I would like to mention Professor Marina Carević-Tomić from the Faculty of Technical Sciences, who collected all the data and granted us access.

It is very important that the data are accessible and that their collection is much easier and more affordable than that of real-time transportation data, which require costly infrastructure and complex systems. Although the data are descriptive, we have demonstrated that it is possible to use them effectively to model and estimate harmful emissions without the need for continuous transportation monitoring.

On the other hand, agent-based models, which simulate the behaviour of each transportation participant as a distinct software agent, provide a more detailed and dynamic picture of the transportation system. However, their application is significantly constrained by the lack of adequate and comprehensive data.

In Novi Sad, we have a data sample from previous years covering around 11,000 to 12,000 citizens, which is less than 5 percent of the total population. Our team has developed a cutting-edge algorithm to synthesize the data required for building an agent-based model and has successfully applied it to the available data. This novel agent-based model helps us do a more precise simulation of minor traffic events, such as the frequent stopping and starting of vehicles, which contribute most to harmful emissions and negatively impact air quality in urban environments.

It seems that such projects call for intersectoral and interdisciplinary cooperation among various professionals—from urban planners and climatologists to transportation engineers?

Absolutely. And this has been our approach throughout the project. Currently, three new project proposals are being prepared, each directly stemming from this work. Of course, we still need to see whether we will get financial backing, but for now, the initiative is there. This time, we have expanded the cooperation, and involved the Faculty of Transport and Traffic Engineering in Belgrade, the Faculty of Transport and Traffic Sciences in Zagreb, and many other colleagues from across Europe.

What else is happening at the BioSense Institute as part of its climate research efforts?

You have already mentioned three prospective projects resulting from the work done so far. Is anything else noteworthy underway?

Well, ideas are overlapping. I am preparing an expression of interest for a consortium that would deal with the timely mitigation of climate change. In that context, we would like to show how we can contribute to the application of nature-based solutions, which we are already working on, so as to upgrade agricultural practices and reduce the use of chemical solutions. Additionally, we are exploring ways to restore certain wetlands and thus preserve biodiversity, which is now at risk due to more frequent droughts.

Our second workstream focuses on technological development—primarily the application of large language models. We have already prepared several project proposals, and we are still waiting for some responses. The aim is to integrate an AI component into the AgroSense system to make it more accessible and intuitive for end users.

And the third workstream, which I have already mentioned, addresses the sustainability of urban environments. In that field, we are strengthening our cooperation with colleagues from the Faculty of Technical Sciences and urban planning experts, so that we can act in concert to develop models for sustainable development in urban areas.

Given your experience of working in Switzerland and participating in numerous European projects, how would you rate our country in terms of developing and implementing digital tools for tackling climate change?

As an institution, BioSense is increasingly broadening its scope to include sustainable development—we are no longer focused solely on agriculture and biosystems, but are also striving to encompass other aspects vital to a sustainable future. As for the quality of cooperation, approach to work, and the number of projects, I can say that BioSense is quite well positioned so I do not see any real difference compared to my experience in Switzerland. With one important note: now I work in my own country. —Ⓔ

More about the author on page 50

Weather Fortune-Telling

Although weather fortune-telling remains deeply rooted in our cultural heritage, an adequate response to the challenges of climate change must be based on up-to-date, reliable scientific data provided by climate services

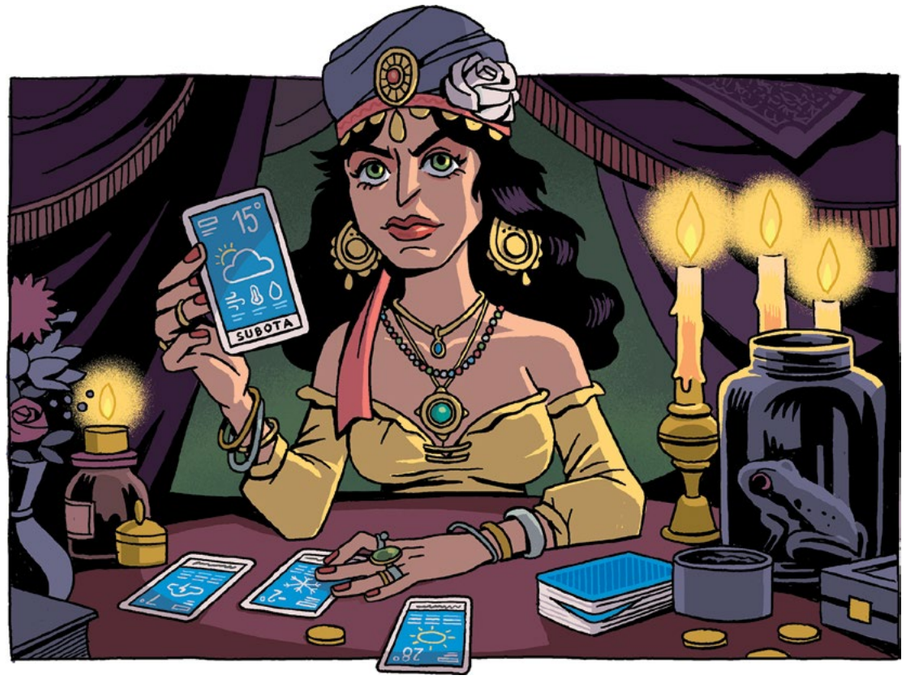

Illustration by ***Nikola Korać***

By
Đorđe Petrović

IN THE LATE 19TH CENTURY, Serbia was home to an annual, illustrated calendar entitled *Orao* (*The Eagle*), which, in addition to the church calendar and helpful information on traditional festivities and holidays, also featured a section on weather fortune-telling. This was a form of weather forecasting rooted in folklore. Such methods of predicting weather were not confined to calendars alone—weather divination also appeared in certain magazines and daily newspapers of the time, and even in a Croatian encyclopedia published half a century later.

Of course, this *folk meteorology* originated long before the 19th century. Without access to modern science, our ancestors relied on weather lore passed down from one generation to the next. They looked for signs in religious holidays, celestial phenomena, animal and plant behavior, and other natural events that might offer clues about the weather ahead, whether for the following day or the approaching winter. It was on the accuracy of these predictions that the fate of their crops and livestock depended—and sometimes their very lives.

COME ST. MRATA'S DAY, SNOW DRIFTS TO YOUR DOOR

The weather was often forecast based on signs revealed during major religious holidays. As folk tradition holds, the weather conditions on a particular holiday could predict the weather for the entire year. For example, if it rained on Theophany—celebrated in the Serbian Orthodox tradition on January 19—it was believed that the year would be rainy, while frost on that night was thought to signal a fertile and prosperous year. Clear skies, however, were interpreted as a sign of drought.

Similar beliefs applied to other religious holidays. It was believed that the weather on the Nativity of the Virgin Mary—celebrated in the Serbian Orthodox tradition on September 21, anticipated what kind of fall and winter might be expected—a bright day heralded a sunny fall and a mild winter, while rain and clouds brought a bleak fall, followed by cold and snow.

Twenty days later, on October 12, Serbs celebrate St. Michael's Day (*Miholjdan*). A stretch of fair weather around this feast is commonly referred to as *miholjsko leto*, often translated as *an Indian summer*. Folk belief holds that after this brief spell of warmth, true fall sets in. Moreover, if the weather is warm and sunny on St. Michael's Day, it is thought to signal a long and cold winter ahead. If October is marked by rain and fog, a popular proverb warns: "*As much fog in October, as much snow in February*."

In Serbia, St. Demetrius' Day is marked on November 8 and is one of the most widely celebrated patron saint days. The weather on this day was traditionally believed to hint at what winter would bring. Sunny weather was seen as a sign of a cold and severe winter, while clouds or the first snow suggested a somewhat milder season. On St. Demetrius' Day, people used to observe animal behavior closely—if sheep were lying with their legs drawn in, it was believed that winter would be mild, but if they were lying with their legs stretched out, the expectation was that winter would be harsh with strong frosts.

St. Mrata's Day, celebrated in the Serbian Orthodox tradition on November 24, marked the beginning of the winter period, so a popular folk saying goes: "Come St. Mrata's Day, snow drifts to your door." Fair weather on this day signaled a bitterly cold winter, while fog indicated changeable weather conditions.

Although weather forecasting based on traditional holidays is part of Serbia's cultural heritage, modern science has shown that such predictions are completely unreliable and no more than a coincidence—akin to flipping a coin or rolling a die.

NATURAL PREDICTORS

Once again this year, on *Sretenje*—the day when, in folk tradition, winter and spring meet—the media reported that Uroš the bear from the Belgrade Zoo came out of his den, stretched, went for a walk, and did not go back inside. In folk tradition, this could mean only one thing: winter was over, and bright and sunny days were coming. Had Uroš been frightened by his own shadow and retreated to his den, winter would have allegedly lasted another six weeks.

Observing the bear's behavior is today more of an entertaining tradition than a dependable method of weather forecasting. A comparable tradition exists in the United States, but it focuses on the groundhog. Surveys conducted in the U.S. have shown that the accuracy of predictions by Punxsutawney Phil, the most famous furry meteorologist in the country, is below 40 percent.

Another animal historically associated with weather forecasting is the European tree frog. Interestingly, its name in Serbian—*gatalinka*—

derives from the verb *gatati* meaning to tell fortunes. As the tree frog feeds on insects, it is left without food when insects sense a change in weather and retreat to their shelters. Consequently, people noticed that in such cases, frogs would also withdraw into puddles, which signaled approaching rain. In the early 19th century, people even kept frogs in glass jars with tiny ladders, believing that if the frog climbed the ladder, fair weather could be expected. However, if it remained lazily at the bottom, rain was imminent. Later studies revealed that the frog's behavior depended more on the conditions inside the jar than on actual weather changes outside.

Folk wisdom says that when birds fly low, one should expect rain and a storm. This belief has some scientific basis—a drop in the atmospheric pressure, which typically precedes inclement weather, makes it harder for birds to reach higher altitudes. That is why birds tend to fly closer to the ground, where the air is denser and movement is easier. Some species, such as swallows, adjust their flight height because they follow insects that also stay low when the humidity levels rise. Still, scientists emphasize that this pattern is not always a reliable predictor of weather, as many other factors influence birds' movements.

Not only animals, but plants as well, were used to foretell the weather. For example, pine cones have been traditionally used to predict the weather, as their shape changes depending on external conditions. When the weather is warm and dry, pine cones open to release their seeds, and their scales become pronounced and firm. In humid conditions, the scales close to protect the seeds, ensuring the best chance for the species to reproduce.

A similar phenomenon has been observed in daisies. Their flowers remain open during sunny weather, but when they sense increased humidity in the air, the petals shut down and seal the flower to protect its reproductive organs from the rain. This reaction is part of a natural adaptation strategy that helps preserve pollen and allows pollination to occur under more favorable conditions.

Although the sensitivity of certain living organisms to weather conditions—such as temperature, air pressure, or humidity—is a well-established scientific fact, changes in these parameters are primarily indicators of the current state of the atmosphere. For this reason, animals and plants cannot serve as reliable predictors of the weather, especially when it comes to long-term forecasts. Meteorologists insist that the accuracy of these predictions, though somewhat higher than pure coincidence, remains quite low.

SOMEWHERE OVER THE RAINBOW

"When it is evening, you say, '*It will be* fair weather, for the sky is red;' and in the morning, '*It will be* foul weather today, for the sky is red and threatening.'" (Matthew 16:2) This method of weather prediction, found in the New Testament, is thousands of years old and still persists in many cultures today. The weather was foretold by observing the reddish glow of the morning and evening sky, which occurred when trapped particles of dust or soot scattered the sun's blue light in a stable air mass.

The red color of the sky indicates the presence of dust particles in the air, which suggests the air is dry. If the air is dry, then the weather must be fair. As the sun sets in the west, and most weather systems in temperate latitudes move from west to east, a red sky at sunset typically implies that fair weather is approaching and will likely arrive the next day. On the other hand, a red glow in the morning sky can only be seen in the east, where the sun rises. This means the fair weather has already passed, and rain-bearing conditions may soon come from the west.

People not only relied on the color of the sky to anticipate the weather, but they also considered a rainbow a powerful predictor. According to folk tradition, a morning rainbow on the western horizon is a sign of approaching rain. Yet, if it appears in the evening in the east, it is a sign of beautiful weather.

This explanation has some grounding in science because a rainbow occurs when sunlight is scattered and refracted by raindrops in the atmosphere. Since the sun rises in the east, a morning rainbow indicates rain is already in the west, and likely to arrive during the day. In contrast, an evening rainbow in the east suggests the rain is moving away, leaving clear skies behind. This simple observation helped our ancestors anticipate changes in the weather.

As the above examples illustrate, the direct or indirect observations of weather conditions at a great distance can help us see what kind of weather is approaching. In that sense, this forecasting method is far more reliable than the one based on the behavior of animals and plants.

"Not only animals, but plants as well, were used to foretell the weather. For example, pine cones have been traditionally used to predict the weather, as their shape changes depending on external conditions. When the weather is warm and dry, pine cones open to release their seeds, and their scales become pronounced and firm. In humid conditions, the scales close to protect the seeds, ensuring the best chance for the species to reproduce."

FROM FORTUNE-TELLING TO CLIMATE SERVICES

Although folk weather lore is truly fascinating as a testament to our ancestors' ingenuity in interpreting nature and its changing patterns, modern science employs a different methodological approach. Instead of guessing the weather from a bear's fear of its shadow, the flight of birds, or red skies, contemporary meteorology measures parameters such as temperature, precipitation, atmospheric pressure, air humidity, wind speed, and other relevant factors. These data are then processed using advanced software tools and models that simulate atmospheric processes, empowering today's meteorologists to produce increasingly detailed and accurate forecasts.

Still, the atmosphere is such a complex system that even minor changes in one part can cause significant repercussions in another. This is why accurate weather forecasting, especially on a daily basis, is such a challenging task. For example, storms or local showers with thunderstorms are often hard to predict as they typically result from a complex interplay of several factors. Yet, though imperfect, the modern weather forecast remains the most reliable method available for predicting weather conditions.

As meteorologists focus on short-term weather forecasts to assist people in planning their daily activities, climatologists study long-term changes in climate patterns. They collect a vast amount of weather data from meteorological stations, balloons, satellites, and radars, which they later analyze using specialized software and supercomputers. Based on these data, climatologists model different scenarios in order to understand the current state of the climate and anticipate future changes.

Considering the comprehensive impact of climate change on the environment and various aspects of our lives, we must rely on expert climate information. In this context, climate services play a crucial role. They provide diverse and timely information about the current state of the climate, long-term trends, and climate change. These services offer historical data on climate patterns, as well as up-to-date information on temperature, precipitation, winds, and other variable factors.

One such service is the Digital Climate Atlas of Serbia, an interactive online platform that provides quick and easy access to information about climate change within Serbia's territory. If you want to know what the average temperature might be in your hometown in ten years, or whether we may expect milder or harsher winters, you do not need to read signs or omens—you can find out in just a couple of clicks on this platform.

At a time when swift and effective responses to climate change are needed, the reliable and timely information provided by climate services represents a key prerequisite for an adequate response to the challenges that come with it. Thanks to these services, decision-makers, the energy sector, public health authorities, the transportation sector, farmers, and the broader public can better adapt to new climate conditions and reduce potential risks. —Ⓔ

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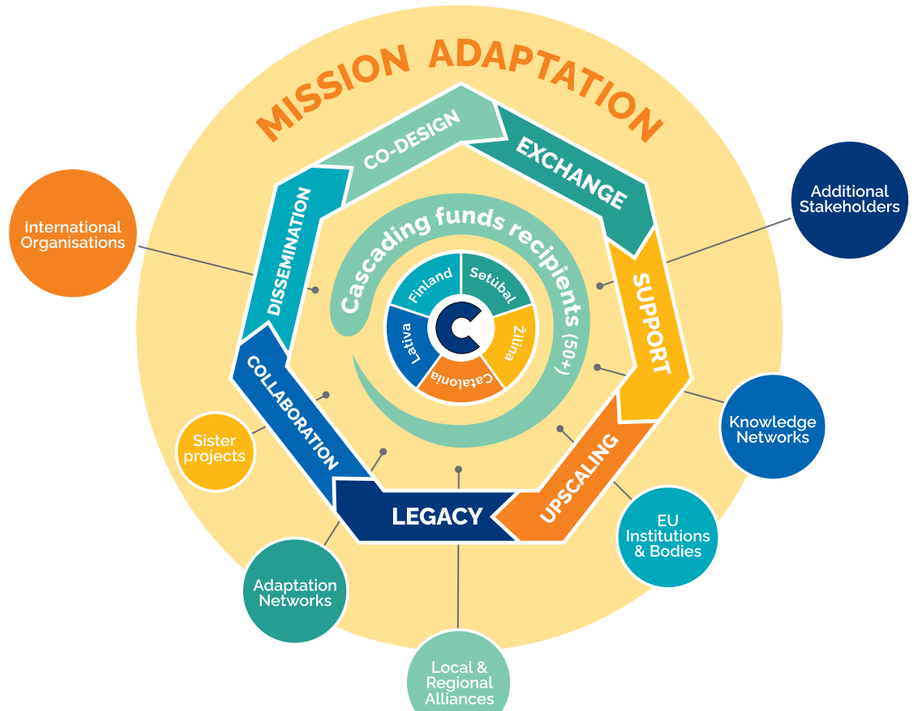
From Insight to Impact: How Climate Services Support Transformative Climate Adaptation

Climate services are no longer just data—they have become essential tools for policy, planning, and investment ecosystems

By
Jaroslav Mysiak and Arianna Acierno
Euro-Mediterranean Center on Climate Change

UNDERSTANDING HOW CLIMATE variability and change are shaping our lives and environment is now essential for developing informed policies and making smarter decisions at every level of society. From guiding production and business strategies to framing risk adaptation and resilience planning, climate services are now integral to evidence-based action. Defined in the report entitled *A European Research and Innovation Roadmap for Climate Services* as "the transformation of climate-related data—combined with other relevant information—into tailored products such as projections, forecasts, risk assessments, economic analyses, and best-practice guidance,"[1] climate services provide actionable insights for society at large.

Recognizing that effective climate adaptation requires more than data and analysis alone, the EU Mission on Adaptation to Climate Change has placed strong emphasis on creating the conditions for transformative adaptation, with climate data and services as a key component. The Mission—launched in 2021[2] as a flagship initiative under the Horizon Europe Framework Programme—drives interdisciplinary and cross-sectoral research and innovation to strengthen Europe's resilience to climate risks and shocks. National and subnational public authorities work hand in hand with research and innovation institutions as equal partners, ensuring that adaptation solutions are co-created, practical, and widely owned. Serving as the innovation arm of the EU Strategy on Adaptation to Climate Change[2], the Mission sets out bold objectives—among them, empowering local and regional authorities (LRAs) with the tools and knowledge to access, interpret, and apply climate risk data, methods, and services, thus enabling the design and implementation of robust, science-informed adaptation strategies and investments.



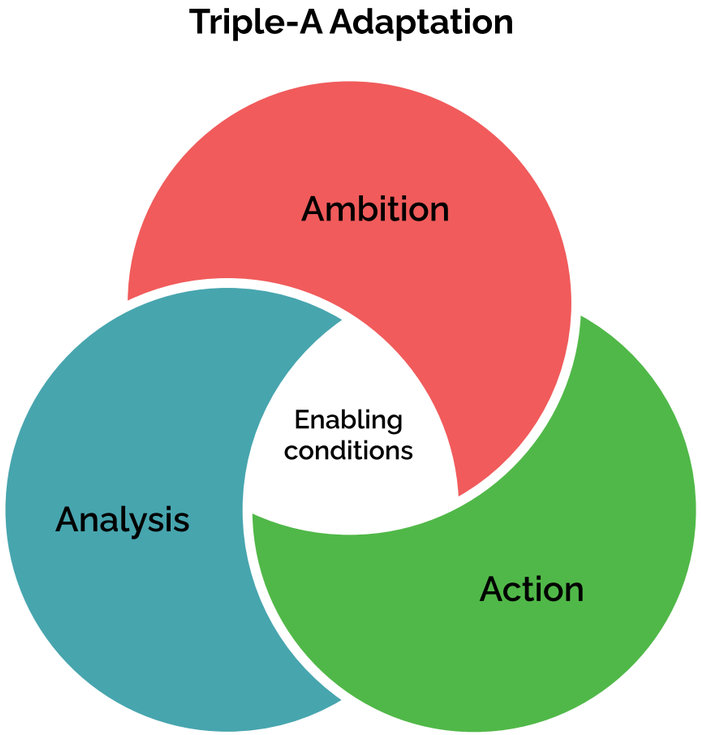
Bringing together diverse climate services can help accelerate and strengthen transformative adaptation

To support this ambition, the **CLIMAAX**[1] (Climate Risk and Vulnerability Assessment Framework and Toolbox) initiative has served as both a technical enabler and a capacity-building platform for regional climate risk assessment. The initiative has developed a regional climate risk assessment framework and an open-source, customizable Python-based toolbox that combines state-of-the-art methods with practical workflows to assess multiple hazards—such as floods, droughts, heat waves, wildfires, and windstorms—while allowing users to add their own data for locally tailored results. The choice of methods and tools is flexible enough to work in diverse governance settings, climates, and data environments across Europe. A defining feature of the initiative has been its cascading funding mechanism, which enables a wide range of local and regional authorities to take ownership of their assessments. Through competitive calls, authorities from multiple climate zones and institutional contexts have received financial and technical support, ensuring that the toolbox is tested, refined, and validated in real-world conditions. CLIMAAX has also built a Community of Practice linking authorities, technical partners, and stakeholders. This network supports peer learning, sharing experiences, and replicating good practices, laying the foundations for a long-lasting ecosystem of regional climate risk assessment that will continue beyond the project and the EU Mission on Adaptation.

Another European initiative, **REACHOUT**[2] (Resilience in Europe through Activating City Hubs), has been working hand in hand with seven pilot cities across Europe to co-create the Triple-A Framework and Toolbox of climate services—one of the project's flagship results—as a flexible, modular, and expandable set of tools designed to help cities, communities, and regional authorities advance their climate

1) Horizon Europe initiative: https://www.climaax.eu/news/

2) Horizon 2020 funded initiative: https://reachout-cities.eu/



adaptation efforts. This Toolbox is an example of how individual tools and services, originally developed for specific applications, can be integrated and applied together to generate deeper insights and support adaptation processes more effectively.

The Toolbox enables users to explore climate risks, design adaptation goals and ambition, and evaluate and prioritize adaptation actions aligned with local policy and planning cycles. Climate services are used differently depending on the stage of the adaptation process. In the *ambition* mode, climate services support visioning and priority setting, stakeholder mobilization, and framing adaptation as a transformative process, fostering institutional learning and capacity development. In contrast, the implementation of adaptation planning employs climate services in a more instrumental role—guiding risk assessments, evaluating adaptation options, supporting decision-making, and monitoring performance. While the Triple-A framework is helpful for both modes, it is particularly valuable for informing the *ambition mode*, ensuring that climate services are effectively integrated into strategic planning and that they lay the groundwork for more inclusive and adaptive governance.

Ambition setting in climate adaptation is a policy process that involves defining long-term visions and identifying concrete goals and actions to achieve them[3]. In contrast to an instrumental, risk-based planning approach, it explores a desirable climate-resilient future and integrates multiple policy objectives, including mitigation and sustainable development. It requires a structured, stakeholder-driven process that accounts for systemic vulnerabilities and long-term aspirations. Climate services play an important role in facilitating ambition setting by providing evidence-based insights, guiding stakeholder engagement, supporting systemic thinking, and linking broad visions with actionable strategies.

Through a structured approach, based on the Triple-A Framework, the Toolbox facilitates a stepwise process that ensures that cities are not only equipped with high-quality climate services but also have the institutional, financial, and technical capacities to implement and sustain adaptation actions over time. In line with the goals of the EU Mission on Adaptation, the Toolbox promotes systemic transformation by embedding climate resilience planning into broader urban development policies and investment strategies. This helps cities align climate adaptation efforts with economic growth, social equity, and sustainable urban development goals. The value proposition, therefore, goes beyond simply providing tools and data—it lies in fostering a shift in governance, decision-making, and market structures to support effective and sustained climate action at the urban level.

Analysis
involves assessing hazards, vulnerabilities, and risks related to climate change. It includes identifying at-risk areas (hotspot prioritization), understanding root causes, and communicating this information to create a sense of urgency.

Ambition
involves setting visions and goals and designing actions to achieve them. It builds on understanding the desired transformation (e.g., socio-ecological) and the root causes of current challenges while envisioning positive futures. This entails exploring options and describing pathways to reach the visions.

Action
is about the implementation of the ambitions: an action plan including opportunities to mainstream with other policy domains, using opportunities for piggybacking, for example.

Enabling conditions
encompasses a range of factors such as access to relevant knowledge and data, effective governance structures, meaningful stakeholder engagement, adequate financial resources, and capabilities and skills.

Climate information is a public good that benefits many users and sectors. Governments at all levels play a key role in collecting, managing, and sharing climate data. National governments build and operate meteorological networks, set rules for data sharing, and provide essential services such as early-warning systems and climate information to support development and economic planning. Local governments are on the frontlines of climate adaptation. Cities are where climate risks are most acutely felt, but also where action and innovation thrive. Here, public–private partnerships drive solutions, and public investments help develop value-added climate services that make data more useful and accessible. These services support sectors such as insurance, water management, finance, and infrastructure planning.

In this context, the Adaptation AGORA project exemplifies how local and regional actors can take a leading role in driving climate resilience. The project actively contributes to the objectives of the EU Mission on Adaptation to Climate Change by scaling up innovative approaches, governance models, and policy tools that empower communities. Working across four European regions (Italy, Germany, Sweden, and Spain), Adaptation AGORA engages local stakeholders to address place-based adaptation challenges and co-develop digital solutions, such as online academies and a mobile app, to foster collaboration, share best practices, and raise awareness. This bottom-up approach reinforces the role of cities and regions as key enablers of the transformation toward a climate-resilient Europe.

Local authorities have a special responsibility to promote tailored climate analytics, risk assessments, and decision-support tools. Some services are open and free, while others are commercial products. Balancing open access with innovation is key: open data ensure broad use, while specialized applications create business opportunities and strengthen urban resilience. Local frameworks for climate services should be closely coordinated with national strategies to ensure that they are effective, scalable, and aligned with broader adaptation goals.

This dual role of governments is also reflected in climate governance frameworks. The National Framework for Climate Services (NFCS) is a central mechanism for ensuring that climate information is effectively used in policy and decision-making. NFCSs serve as platforms that coordinate and strengthen collaboration

Photograph by ***Euro-Mediterranean Center on Climate Change***

among national institutions. Regional and Local Frameworks for Climate Services (LFCSs) build on this foundation by translating national strategies into locally relevant actions. When integrated into regional and municipal plans, LFCSs can reinforce NFCSs—just as local adaptation strategies support national adaptation plans. Within this hierarchy, LFCSs help drive climate-resilient economic growth. By connecting with local initiatives to make public data reusable and improve local data infrastructure, they help create the conditions for a faster, systemic transformation toward resilience—aligned with the EU Adaptation Strategy and the EU Mission on Adaptation to Climate Change.

So far, there has been limited guidance on how to define Local Frameworks for Climate Services. Recent research has addressed this gap by proposing a three-pillar structure: **Data Spaces, Marketplaces, and Communities of Practice**.

- **Data Spaces** are organized environments in which climate data are collected, stored, managed, and accessed. They enhance interoperability, accessibility, and usability, simplifying data discovery, sharing, and analysis.
- **Marketplaces** act as convergence points for the supply and demand of climate services. They connect producers and users, facilitating the efficient transfer of services, promoting innovation, and supporting co-development.
- **Communities of Practice** are networks of individuals and organizations that share common interests, knowledge, and experience, working together to improve the development and use of climate services.

Drawing on a comprehensive review of the literature and practice, a **self-assessment tool** has been developed and tested to support the LFCS design and implementation. It includes **18 criteria and 56 proxy indicators** to help evaluate readiness, functionality, and integration with broader frameworks[4].

Climate risks are becoming a part of everyday decisions for governments, businesses, and communities. To respond, we need more than just data—we need knowledge that is clear, useful, and tailored to real needs. This is where climate services come in. By turning climate data into practical information, they act as a catalyst and an essential enabler for climate adaptation. Projects like CLIMAAX, REACHOUT, and Adaptation AGORA demonstrate how open tools, local knowledge, and strong partnerships can help cities and regions take control of their climate risk assessments and turn them into concrete plans. With the right services in place, adaptation can transform from a challenge into an opportunity, helping to build stronger, safer, and more resilient communities for the future.

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INTERVIEW

Dr. Vladimir Janković
Historian of Science
University of Manchester

What Are We Really Talking About When We Talk About the Climate Crisis?

“Climate change has racial, class, and even gender dimensions. It does not affect everyone equally”

By
Đorđe Petrović

Photographs by
Marko Risović

WHO IS RESPONSIBLE *for climate change? How should we talk about it? What role does science communication play in society, and what challenges arise when trying to make science more open?*

These were some of the questions we discussed with Dr. Vladimir Janković, Professor of the History of Science at the University of Manchester and a keynote speaker at the international OpenSciComm conference dedicated to science communication and organized by the Center for the Promotion of Science (CPN) in late November 2022. Professor Janković holds a PhD in the history of meteorology and atmospheric sciences from the University of Notre Dame in the United States—a compromise, as he puts it, between his interest in history and his expertise in meteorology, gained during his undergraduate studies in Belgrade. He is the author of one of the most significant studies on weather observation and interpretation in 18th-century Britain, as well as numerous publications in related fields, and formerly served as President of the International Commission on the History of Meteorology.

The adverse consequences of climate change constitute one of the most significant global threats of our time. In one of your papers, co-authored with David Schultz, you explore the concept of *atmosfear* and how the effects of climate change are communicated in the context of extreme weather. Could you tell us more about what the term *atmosfear* means, and why it is so frequently resorted to?

Climate change manifests in altered rainfall patterns and temperature regimes, disrupting vegetative cycles and, more broadly, plant life, with consequences for flora, fauna, and humanity—and, ultimately, society as a whole. In recent decades, there has been a clear tendency to interpret the effects of climate change primarily through the lens of anomalous or extreme weather events, such as hurricanes. In other words, climate change is increasingly being read through an "alphabet of extremes."

There is even a scientific field called *attribution science*, which investigates the connection between long-term climate change trends and specific weather events, in an attempt to determine which of them can be directly linked to anthropogenic climate change. For a long time, such connections were considered scientifically unreliable. Today, however, thanks to various specialized methods, it is increasingly possible to establish such links in some instances.

However, while framing climate change primarily through extreme weather events may get people thinking, it still relies on an old communication strategy known as the *fear appeal*. Think, for instance, of those large billboards showing diseased lungs alongside the warning, "This is what your lungs will look like if you keep smoking." It is the same communication strategy: the public is shown the consequences of a particular behavior, with the expectation that this shocking information will prompt people to change.

The trouble is, this approach often fails. People keep smoking even when shown such images—even when cigarette packs display the health warning "Smoking kills." Why? Because they do not perceive this caution as a personal or real risk, but rather as something imposed by regulatory authorities. Cigarettes are just as harmful as ever, but nowadays someone is obliged to state that harm publicly.

Aside from the questionable effectiveness of the *fear appeal* approach, as you put it, what other concerns might it raise?

If we narrow the risks of climate change to just extreme weather events, we may overlook other, more serious consequences, some of which may have little to do with ecology. Take Hurricane Katrina, for example, which devastated New Orleans in 2005. It was linked to climate change, but also to longstanding structural racism, reflected in the segregation of African American communities living in far more vulnerable areas than wealthier residents. If we look at it that way, the impact of Katrina was highly selective: those least able to protect themselves suffered the most severe losses, while those privileged, with more resources, fared much better. Katrina did not hit everyone equally. That is crucial to understand—just as future climate extremes will not affect everyone equally, even those within the same geographical area. Climate change, then, has racial, class, and even gender dimensions. It does not happen to everyone equally.

What can the social sciences reveal about climate change?

The natural sciences, bolstered by substantial investment, have produced remarkable insights into the physical world. There is hardly any doubt now that their findings are reliable. But we also need to understand human behavior. When I talk to my students or others about climate change, I often hear, "Why should I worry? It is not going to happen to me—and even if it does, we will figure something out." So, how to counter that argument? A scientist may respond, "Madam or Sir, you do not seem to be aware of the facts, and that way of thinking is irresponsible." But that is not an effective way to engage with the public. People do not like being lectured. They want their perspectives to be acknowledged and treated with respect.

"We must think carefully about what the right approach to science communication should be—neither purely declarative, nor merely ceremonial. It is like walking into a place where background music is playing, and saying, 'Could you please put on some real music?'"

When someone asks me, "Why don't you live in a more climate-conscious way?"—well, let's see what I can actually do. For example, I don't drive much, I rarely fly, I use energy-efficient bulbs, and I try not to waste energy. However, the problem is that the public cannot contribute to solving this issue beyond what is considered voluntary action. This is all voluntarism. You and I may choose to make climate-friendly choices, but two of our friends may not—and that effectively cancels out our efforts. Does that mean I should stop acting responsibly? No. I do it because it aligns with my values. After all, I enjoy it. It makes me feel good.

Yet we must be clear: these are voluntary actions, and as long as something is voluntary, we will not see a substantial effect—no matter how many individuals act responsibly, because the majority will not. Most people will simply say, "I don't have time for that."

This is where the social sciences come into play. How can we better understand the psychology behind voluntary behavior in the context of environmental sustainability? How much are we really talking about this? At this moment, insights from psychology, anthropology, ethnology, sociology, and social psychology may be more valuable than ever—perhaps even more so than atmospheric modeling. We need to draw on these disciplines to understand how our societies will transform in response to physical changes in the atmosphere. We need to understand how best to communicate the reality of climate change, which does not occur solely "up there" in the sky, but also affects our finances, social mobility, consumption patterns, and everyday lives.

We often see a climate change narrative in the media that we are all to blame for the fallout. But are we really equally responsible for the climate crisis?

We might just as well ask who is responsible for air pollution. This has been a major topic in the Western world since the 1950s. Who is to blame? Back then, people drove cars without catalytic converters, heated their homes with coal—that was simply how life worked. Big companies, especially in the U.S., produced coal-based energy, releasing vast amounts of smoke near major cities like New York.

So, who is responsible for pollution? Let's consider the actors involved. First, the consumers, but they simply use what is available to them. Second, the companies that burn coal to generate energy. Third, the legal systems that permit these companies to operate in such a way, regardless of whether the consequences are taken into account. In short, we are talking about a synergy of actors where no single party can be isolated as *the* culprit. Historically speaking, we reached a point in the 1950s where the way we consumed fuel in our everyday lives created a major environmental problem. And now we must solve it.

People still need to heat their homes and drive cars. Companies must remain profitable for society to function. So, technological innovation and policy measures have been introduced to mitigate the issue, and led to a shift toward other energy sources, and so on.

The situation with climate change is similar. Today, we all rely on devices that emit greenhouse gases. Should we simply stop using them? That would mean abandoning the lifestyle we have grown accustomed to. So, the real questions are: what can realistically change? Who has the capacity to change? And which parts of the system are capable—but currently unwilling—to do so?

We can say that the blame lies with the big corporations that profit from fossil fuels. This is a frequently cited argument. But then someone might ask, "What about the people who work for them?" For instance, British Petroleum (BP) employs around 120,000 people worldwide. We cannot blame them for simply making a living and supporting their families. Instead, we need to consider where and how the situation can realistically be brought under some kind of control.

De facto, we all carry some of the blame, but not in the same way as someone who deliberately harms another when they can choose not to. Blame is tied to conscious action. The fact that we are polluting the planet because we need to live is not the result of malicious intent—it is simply one of the consequences of how life is currently structured.

"There is no such thing as a free lunch," goes a well-known slogan coined by American environmentalist Barry Commoner. Yet, people attend conferences where they are served lunch free of charge. Free for some, but not for others. Ultimately, the environmental cost of that lunch is borne elsewhere—by someone or something else. Even according to the laws of thermodynamics, no activity in this world is without its consequences. The world is built on the paradigm of traces. When you get up in the morning and walk through pristine snow, you leave a mark.

Here we also have a profound philosophical question: Is it environmentally harmful to leave footprints in the snow? Almost no one asks this. And yet, the truth is I have done something to nature—I have left a trace. I have altered the ecosystem. The reptiles and amphibians beneath the snow are certainly not thrilled. Now consider skiing, for example: the ski tracks, the resorts sprawling across entire mountains for the enjoyment of tourists—this too could be described as ecological destruction for the sake of profit and leisure.

"It's time to move on to something more substantial. The question is, are we ready to level up?"

At the conference, you spoke about the importance of public trust in science, which has been significantly shaken in recent years. How can that trust be restored? What is the role of science communication in that process?

I emphasized that trust in science cannot be taken for granted—it must be earned. For years, due to its funding structures and societal status, science has operated on the assumption that it deserves public trust by default—and that those who withhold that trust simply fail to understand it. Their skepticism was dismissed.

However, with the rise of social media and the "tyranny of choice" in today's hyper-democratic landscape, people now believe they can choose their own version of the truth—regardless of whether it is grounded in scientific or expert consensus. That means I can choose to believe that the Earth is flat, or that vaccines contain microchips planted by global conspirators—and still feel entitled to that belief.

If we allow this kind of hyper-democracy, this radical freedom to choose one's own version of knowledge—what role remains for science communication? Today, someone could establish an "alternative" Center for the Promotion of Science and spread ideas they either genuinely believe or are paid to present as the truth. Could we prevent such activity? Would it be illegal? On what grounds could we ban an institution that systematically promotes such ideas? These are serious questions.

So what, then, is the role of science communication? Above all, it is an ethical one. We have a responsibility to protect people—not just from misinformation (because what is information to me may be misinformation to someone else), but from the consequences of collective belief in ideas that are not based on reliable, verifiable knowledge.

If a herbalist sends my mother three kilos of herbal honey claiming it will cure her, and I ask, "Do you guarantee it will help? What happens if it fails—will you return the money?"—and the answer is "no," then the basic ethical contract

has been broken. They are offering services for which they cannot guarantee the promised outcome.

Now, if that herbalist cannot heal me, I—as a pragmatist—will say, "This didn't work. It's not true." But if I go to a doctor and he gives me penicillin while I have a high fever and a severe throat infection, and two days later I am entirely well, I conclude that those pills—even though I have no idea what is in them—are extraordinary. And then I begin to ask, "Why did this happen?"

In fact, one of the most powerful moments of science communication is the sudden recovery of a loved one. We ask, "How is it possible that they were so ill and then recovered almost overnight?" In our daily lives, we see that science, medicine, and technology work. They produce real results. The information that fails to deliver on its promises must either be revised or discarded.

One of the main topics of the OpenSciComm conference—and of your speech—was *open science*. What does "opening science" mean to you, and why did you compare it to opening a Pandora's box?

"If we allow this kind of hyper-democracy, this radical freedom to choose one's own version of knowledge—what role remains for science communication?"

There is broad consensus in the scientific community that science, technology, and medicine provide a rational framework for understanding the world—and that the outcomes of scientific and technological endeavors are generally worthy of respect and consideration in everyday life. Without science, we would never have sent a man to the Moon. These are powerful indicators that science works.

However, at the conference, one presentation also pointed out that results of a significant number of studies published in leading international journals cannot be reproduced—and replicability is one of the key criteria for determining the reliability of scientific research. Do we really want to open science fully and reveal to the public that around 70 percent of published research findings have never been replicated?

Those unversed in the scientific process might respond, "Wait a minute—people developing medicines have based their work on experiments that cannot be reproduced? That's not science, that's black magic!" And from there, the conclusions often follow swiftly: "It's all a scam. Scientists are just chasing funding. Let them stay in their labs if they like, but their work is irrelevant to the rest of us."

That is how you end up with sweeping conspiracy theories: "This is just a closed circle of people publishing incomprehensible studies. Have you ever flipped through a mathematics journal? You can't make sense of a single sentence, let alone an entire page. Hundreds of thousands of people earn a living writing things no one understands, and we have no idea how or where that knowledge will ever be applied."

So, if we open science in that way, we risk not only inviting questions but also conspiracy theories that challenge the very legitimacy of science itself.

It is not inconceivable that, in some future dystopia, science as a way of making sense of the world might fade away entirely. In 50, 100, or 300 years, we might instead turn to a form of radical spiritualism—more socially palatable and more effective at fostering solidarity, coexistence, shared resources, love, understanding, and the end of conflict. After all, if you look at the historical period during which science flourished, you will also see it brought a rise in alienation, more frequent wars, and the increasing commercialization of life.

So now the question arises: as a science communicator, am I perhaps siding with something that has partially contributed to the shaping of this world, and brought it to the brink of catastrophe, including the climate crisis, which is in part the result of our understanding of combustion engines and other technological innovations?

How, then, is it possible that I still want to promote a type of knowledge that may, ultimately, lead to negative outcomes? That is a Pandora's question. That is what I meant by a Pandora's box. But it is more than that—it is also a profoundly political and ideological issue.

Are we, by asking this, opening the door to a radical critique of science? And what would such a critique bring us—especially when many of the things science has produced are genuinely beneficial? That is precisely why I have emphasized the need to communicate the complexity of this question, and of science as a phenomenon.

Science has both created and destroyed—and it will continue to do so, on an even larger scale. As drones evolve and warfare becomes increasingly digitized, the number of casualties is expected to rise sharply. At the same time, advancements in medicine and improvements in daily life are likely to reduce overall mortality.

These are questions that experts need to sit down and discuss. We must think carefully about what the right approach to science communication should be—neither purely declarative, nor merely ceremonial. It is like walking into a place where background music is playing, and saying, "Could you please put on some real music?"

Well, I think the time has come to say the same about science communication: we no longer want to keep demonstrating how Foucault's pendulum works and entertaining ourselves with Earth's rotation—something we more or less all accept as true, although the experiment is indeed fascinating to watch. No, it's time to move on to something more substantial. The question is, are we ready to level up? —Ⓔ

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Climate and Social Justice

Climate action is not only about cutting emissions or investing in green technologies—it also entails recognizing and supporting those most affected by climate change and addressing the specific needs of different social groups

By
Ivana Stjelja

CLIMATE CHANGE AFFECTS every living being on Earth, albeit unevenly. The biggest polluters are usually not those who face the most severe consequences. The most vulnerable communities—such as children, the elderly, people with disabilities, women, rural residents, and other disadvantaged social groups—are often the first to feel the impact of drought, flooding, and biodiversity loss. Hence, those who have contributed the least are now taking the hardest hit from the climate crisis.

For this reason, the fight against climate change is no longer just an environmental issue, but also one of human rights and social justice. Climate justice is a concept that calls for a fair distribution of climate-related risks between those who have a lot and those who do not have enough. The most vulnerable, who have the fewest resources for adaptation, are most at risk and bear the heaviest burden. This is the core of climate injustice. It is therefore important to view climate change through the lens of human rights and place equality at the centre of all climate action and decision-making.

The term *climate justice* is not explicitly used in national legislation in Serbia. Meanwhile, it is recognised as a guiding principle in international law. The Paris Agreement, for example, refers to it in the preamble and recognises "the importance for some of the concept of *climate justice*, when taking action to address climate change." This recognition emphasises the growing awareness that climate action must also reflect the principles of fairness, inclusion, and human rights.

In theory, climate justice rests on several interlinked elements, all of which must be upheld to achieve a fair response to the climate crisis. One of the key pillars of climate justice is distributive justice. Distributive climate justice addresses how climate-related risks and benefits are shared among the various groups within society. Are the consequences of flooding, drought, and pollution borne equally by all? Does everyone have equal access to clean water, air, renewable energy, or resources to adapt to climate change? If the answer is no, as it almost always is, then we are witnessing the reality of an unjust society. Distributive justice requires that inequalities be acknowledged and addressed, that the burdens of the climate crisis be distributed fairly, and that everyone benefits from the green transition.

The second element is procedural. Procedural climate justice highlights that climate-related decisions should be made through fair and inclusive processes. This means that everyone, especially those most affected by climate change, should have a meaningful voice in shaping the laws, policies, and actions that impact their lives. A fundamental mechanism for achieving procedural climate justice is public participation—that is, ensuring that citizens and civil society are involved in drafting laws, policies, strategies, and administrative legal acts, and given access to climate-related information and the opportunity to protect their rights before a court. In these processes, all social groups must be treated fairly, and their voices must be substantially incorporated at every stage of decision-making and as broadly as possible.

At the heart of procedural justice lies the public's meaningful participation in decisions

Illustration by ***Nikola Korać***

that influence their lives and livelihoods. Yet, it goes even further as it is also about access to information of public importance, transparent and accountable institutions, and effective legal protection when people's rights are in jeopardy. Therefore, there can be no climate justice without the rule of law, a functioning democracy, and an independent judiciary.

Consequently, fair and inclusive decision-making is a prerequisite for achieving climate justice. Although essential, a fair process alone is simply not enough. Hence, the decision-making process must recognize and respect the diverse needs, experiences, and circumstances of all social groups. So, the third key element is social recognition. This is not only about including diverse social groups in decision-making, but also about honoring their unique needs, interests, and cultural identities. In this sense, climate justice, in the form of social recognition, shapes public participation by ensuring that climate-related decision-making is not only open but also sensitive to the realities of different communities. Recognizing who is at the table and what they bring to it is just as important as giving them a seat.

Intergenerational justice, another element of climate justice, refers to the responsibility of present generations to act in ways that do not place an unfair burden on future generations. For climate action to be just, it must rely on decisions that are wise today and fair tomorrow.

A just transition, yet another vital pillar of climate justice, means making the shift to a carbon-free future fair for everyone. The goal is not just to slash emissions, but to do so in such a way that ensures no one is left behind. Therefore, we must make sure that climate policy is inclusive, socially responsible, and grounded in a meaningful dialogue with all affected groups. To avert the further deepening of existing inequalities, governments must adopt just transition strategies that promote economic diversification while protecting the most vulnerable communities. In Serbia, for example, and across much of Europe, the Roma community continues to face deplorable living conditions, a high risk of poverty, and significant barriers to accessing fundamental rights, services, and energy. The recent data from the EU Fundamental Rights Agency (2021) show that 23 percent of Roma in the EU live disproportionately more often in areas with environmental issues such as pollution, grime, smoke, dust, odors, or polluted water compared to the general population (14 percent). There is growing evidence that the most vulnerable populations are at a higher risk of being affected by environmental disasters and degradation, as well as experiencing unequal access to ecological resources. Put simply, environmental risks are likely to make the existing inequalities even worse. This means that failure to address these specific circumstances may result in the Roma population not benefiting from the green transition and being left behind.

Climate education is one of the aspects of climate justice that emphasises how important it is to raise awareness about climate change and engage communities in climate action. It underlines the need for education, information exchange, and participatory initiatives.

In Serbia, youth climate education is slowly developing, but it mostly takes place in schools and focuses on technical topics such as greenhouse gases, renewable energy, and environmental protection. Though essential, the social and justice dimensions of climate change are rarely addressed.

But what if climate education went beyond the classroom and created a space where young people could envision and develop real-world solutions? One such example comes from Serbia, where the LEVERS community is using science education to raise awareness of the importance of urban pollinators for food production, through both theory and hands-on learning. The LEVERS project, funded by the European Union's Horizon Europe programme and running through 2026, focuses on developing educational models that foster climate action. Climate justice lies at the heart of LEVERS, with an emphasis on inclusion across communities and social groups, engagement with complex socioscientific issues, and civic participation in science education. Through an education model anchored in *learning ventures*, the project provides a unique framework for collaborative learning, one shaped by partnerships and shared exploration. In Serbia, this approach involves developing community-based learning programs that lead to policy recommendations and actionable changes—such as reevaluating mosquito-spraying and grass-cutting practices—in an effort to protect pollinator-friendly urban environments. Social justice issues related to pollination, such as biodiversity loss or food insecurity, are addressed through activities and resources that help learners understand the deep interconnections between pollinators, the environment, and climate justice.

Another initiative within the LEVERS project took place in Brussels, where a group of teenagers from the Molenbeek neighbourhood —often described as diverse, disadvantaged, and low-income—showed what this approach could look like. In a creative, participatory process, they co-designed *Karavan'ke*, a colourful, mobile structure that provides shade and relief during heat waves. It also came to represent youth empowerment and creativity. Their journey was part of the EU Horizon LEVERS project (*Learning Ventures for Climate Justice*), which explores how local learning ecosystems can serve as a tool for community climate engagement, learning, and action. This particular learning initiative was organized by Stickydot, a Brussels-based collective. The workshops taught young people about climate change while also encouraging them to respond to local issues with imagination, practical tools, and collective reflection. Rather than framing climate change as a distant threat, the teenagers examined how rising urban heat is already affecting their lives and neighbourhoods, especially in poorer areas where green spaces are scarce and concrete prevails. Under the guidance of designers, scientists, and facilitators, the young participants identified extreme heat as a pressing issue, and developed prototypes for real-world solutions: shaded benches, solar lighting, and mobile cooling stations. The creation of *Karavan'ke* required not only technical skills, such as welding and 3D printing, but also vibrant dialogue and close collaboration. In a neighbourhood often excluded from policy conversations, these young makers have built not just a shelter from the heat, but a space where community, creativity, and climate action come together.

Climate action is not only about cutting emissions or investing in green technologies—it also entails recognizing and supporting those most affected by climate change and addressing the specific needs of different social groups. Social justice, therefore, is a vital pillar of climate justice.

To truly achieve climate justice, climate action must ensure the fair distribution of climate risks, meaningful public participation, and recognition of diverse social needs in decision-making. It also calls for a just transition from a fossil fuel–based economy to a low-carbon future, actions that do not place undue burdens on future generations, and climate education that is accessible to all. However, all these elements of climate justice cannot be fully realized without a genuine commitment to building a society that upholds the principles of the rule of law, democracy, and human rights. Social justice and democratic governance are, therefore, essential prerequisites for a successful fight against climate change. —Ⓔ

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Unprecedented Transformation: Climate Change and Health

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Smoke billows from the chimneys.
That is the womb of the Earth burning.
We have set fire to the planet that gave us life—
just to keep ourselves warm.

Dušan Radović, *Good Morning, Belgrade*

By
Srđa Janković

IN RECENT YEARS, we have witnessed global climate change—after decades of unequivocal indicators derived from scientific analyses, billions upon billions of data points collected and processed, and climatologists' persistent warnings and calls for action—finally become visible even to the naked eye. We are living at a turning point, as the world is rapidly changing at a pace unmatched in human memory. If, up to now, we have been lulled into the comfortable notion that a technology-driven civilization has helped us rise above our natural surroundings, reality is now forcing us to accept a harsh truth: any deeper disturbance to the biosphere's delicate balance affects all its parts, including us. Of course, anthropogenic climate change is only one facet of humankind's transforming impact on Earth and its natural environment, which led to the current epoch being named the Anthropocene—a term that, nowadays, is more or less on everyone's lips.

Although on a very long geological timescale, climate change is linked to natural processes that feature significantly in the multi-billion-year story of life on our planet, this is, for all that we know, the first time such changes have been so drastically driven by the actions of sentient beings. When one considers the pace at which anthropogenic climate change is occurring—unprecedented over the past tens of millions of years—it becomes clear that, within the framework of so-called deep history, the present moment can only be compared to the Big Five mass extinction events. Put simply, what we humans are doing to the planet today evokes cataclysms such as the asteroid impact that created the Chicxulub crater, triggered a global environmental collapse, and brought an end to the age of dinosaurs.

Illustration by ***Uroš Pavlović***

According to some estimates from the relevant UN agencies, approximately 3.6 billion people are exposed to the diverse impacts of climate change, with indirect and direct health risks among the critical concerns. The latest projections from the Intergovernmental Panel on Climate Change (IPCC) indicate the most likely pace and intensity would, unfortunately, be closer to the high end of preliminary warming scenarios. The most recent reports give us less and less hope that, even with comprehensive measures in place, we would manage to curb global warming to below 2°C above pre-industrial levels, as certain calculations suggest this increase could be much higher. These data have qualitative—and quite ominous—implications, as some models demonstrate that in the event of a global temperature rise of more than 1.5°C, we may expect a further deterioration in adverse processes discussed in this article.

The possible effects of climate change on human health are as diverse as the change itself, so analyzing them thoroughly would be a complex undertaking. Yet, their common denominator is undoubtedly a severe disruption (or even collapse) of the dynamic balance within a complex system such as the Earth's biosphere. In addition to the direct effect of high temperatures on human organisms (as heat waves have become more frequent and severe in recent years, and unfortunately led to more fatalities), first we need to mention an elevated risk of both communicable and non-communicable diseases, interruptions to global food supply chains and overall instability in that regard, difficulties in access to safe drinking water at multiple locations across the globe, and inevitable social and economic impacts of drastic changes in the living conditions, including mass migrations and conflicts, alongside a critical overload, even a potential collapse of the infrastructure safeguarding human health and well-being. And on top of all this, we have the psychological impacts—multiple and large-scale harmful effects that climate change and the processes it sets in motion have on mental health, which can eventually plunge us into despair and confusion. With this in mind, it is hard to discuss the impacts of climate change without acknowledging its close interplay with various forms of social injustice and inequality. Hence, for the sake of brevity, this article will focus solely on the purely medical aspects of the issue.

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A loss in biodiversity occurring alongside climate change implies the irreversible extinction of unique species, and even entire ecosystems, which contributes to the rise of new threats to human health. It is important to note that the influence of contributing factors is never isolated, but rather intertwined. For example, the spread of infectious diseases to environments where they have never occurred, or at least not for a very long time, is influenced by the biological characteristics of an infectious agent and its life cycle, interactions with domestic or wild animals that make up a reservoir of infection, and the latter's migrations, which again can be triggered or enhanced by climate change. A classic example is the role of migratory birds and the dominant routes of their seasonal movements in the spread of West Nile virus to the wetland areas of Europe. With that, the destruction of forests and rainforests leads to more intensive contact between wildlife and people, stimulating the transfer of pathogens, the subsequent spread of existing zoonoses (diseases transmitted from animals to humans), and the emergence of new ones. The direct link between deforestation and infectious diseases has already been documented in the case of Ebola, malaria, and West Nile virus, but this seems to be only the tip of an iceberg. Moreover, a declining population of animals that serve as a natural reservoir for certain infections or are natural hosts to infectious agents results in heightened environmental pressure to find a new host—and, as things stand, humans are often one of the readily available options, given their number and omnipresence.

Among the infectious diseases transmitted by insects or other arthropods (so-called vector-borne diseases), malaria and dengue are often mentioned as the primary threats, but also Chikungunya virus and Zika virus, as well as Japanese encephalitis virus, which are transmitted by mosquitoes. Due to climate change, the vectors of these and many other diseases are spreading to new territories, and the most well-known example is the invasion of Europe by the tiger mosquito (*Aedes albopictus* and, to a lesser extent, *Aedes aegypti*) in the past one or two decades. The first of these two species has so far gained a foothold in thirteen European countries, significantly changing the Old Continent's epidemiological landscape. An elevated aerial distribution of disease vectors has been primarily driven by more frequent heat waves, heavy rainfall, and prolonged droughts (which are only different manifestations of the same process—dysfunction in the natural regulation of hydrological cycles). Hence, it is not surprising that diseases that used to occur only in tropical and subtropical regions are now knocking at the doors of temperate zones. Besides vector insects, high temperatures can also boost the reproduction of pathogens in them, which is particularly relevant considering that mean temperatures recorded in Europe during the summer of 2024 were 1.54°C above the 1991-2020 seasonal average.

It is essential to highlight that virtually all experts, regardless of their professional background or discipline, agree on one thing: well-formulated, coordinated efforts to address or overcome the causes of climate change can undoubtedly limit their harmful effects on human health and help steer us away from particularly catastrophic future scenarios

At least in Europe, vector-borne diseases are under close surveillance, with research teams employing a multi-disciplinary approach to their detection, analysis, control, and prevention. It cannot be overstated how important it is to have a well-established institutional framework for the effective detection of potential causal agents, which again requires broad international cooperation and sufficient investment in the prevention and public awareness efforts. It is also important to note that the effect of a temperature rise is not linear—for any given difference in the average temperature, we may expect a much higher increase in parameters that signal the looming epidemiological threats. For example, at higher temperatures, as we have mentioned, there is an accelerated growth and reproduction of pathogenic organisms within the carrier, as well as its capacity to spread the disease, which has been exceptionally well-documented in the case of dengue virus. Changing seasonal temperature patterns can also contribute to the spread of vector-borne diseases to new areas, and that is another critical characteristic of climate change that leads to infections occurring at higher altitudes (as well as in new latitudes). Yet, Chikungunya virus, which causes a disease that is not life-threatening but often becomes chronic and aggravated by severe arthritis, thrives under changing precipitation patterns: an average annual rainfall of 500mm provides optimal conditions for the spread of this highly debilitating disease.

While dengue, Chikungunya and Zika viruses have already established in certain parts of Europe (France, Italy, Cyprus and Madeira), and West Nile virus is no longer considered a tropical disease, as it has become autochthonous, other viruses not yet present on our continent (aside from imported cases) may soon emerge, as their carriers are around. This group includes O'nyong-nyong virus and Rift Valley fever, as well as Yellow fever—a deadly disease that epidemiology and social medicine textbooks classify among the four major quarantine diseases, alongside plague, cholera, and smallpox (which have, fortunately, been eradicated from our planet, mainly due to successful vaccination campaigns and practical public health awareness efforts in the late 20th century). It is worth noting that we also have an effective vaccine against Yellow fever. For the time being, it is only given to travelers to endemic regions, but with the current pace of climate change, it may not sound far-fetched to imagine that one day it could also come in handy to those staying at home.

Understandably, the pandemic of the coronavirus (severe acute respiratory syndrome coronavirus 2- SARS-CoV-2) is still—although we do not know for how much longer—a compelling testimony to the destructive potential unleashed during the evolution of newly-emerged pathogenic viruses, when they transition to humans from animal hosts that have carried them for millions of years. Hundreds of thousands of viruses harbored by other species

have a considerable capacity to adapt to human hosts, which is one of the main reasons why we must remain forever vigilant concerning the prospects for novel disease outbreaks, symbolically dubbed Disease X by the World Health Organization (WHO). It should be made clear straight away that such pandemic threats do not stem solely from the consumption of meat from wild animals caught in the natural hotbeds of potential zoonoses (which most likely played a key role in the emergence of the last pandemic). There is quite a wide array of possibilities for the outbreak of new infections, and the dynamics of similar events are incredibly diverse and subject to all the above factors that can undermine the balance in the environment.

Along with viruses, insects also carry diseases caused by protozoa and other eukaryotic parasites. A quintessential example of this is malaria, which even nowadays claims around 600,00 lives per year, a fifth of them being children under the age of five. That malaria has been eliminated from many developed regions in the temperate zone has been considered one of mankind's remarkable achievements, and rightly so. Meanwhile, it is somewhat ironic that the same civilization, through modifications in living conditions and patterns, is setting the stage for malaria to return to many regions where it was once eradicated. Here, we need to mention that the optimal temperature for the prosperity of the malaria-causing *Plasmodium* is around 25°C, which means that, with the advancement of climate change, the high incidence of malaria in the hottest regions may ease a bit and that would be a touch of poetic justice in the sea of global injustice. Still, this does not change the fact that the overall risk of malaria is growing, and that in recent years, after a prolonged lull, the disease is again on the rise around the world.

Climate change is also undermining global food security. In many regions, food production may dwindle, leading to widespread malnutrition that can make people even more vulnerable to various risk factors. With that, it is becoming increasingly challenging to meet the food demands of a growing global population, which calls for a more extensive and intensive use of arable land. This, in turn, leads to further encroachment on natural ecosystems, exacerbating the vicious cycle and creating favorable conditions for the outbreak of infectious diseases. What makes the situation even more complex is a notable increase in the global movement of people, for various reasons (business networking, economic migration, tourism, wars). For a moment, we must also mention non-communicable diseases: a growing body of research indicates that climate change contributes to an increase in the incidence rates of, for example, allergic and autoimmune diseases. Many contributing factors in the complex, long-term process that leads to a loss of control over immune responses, even a loss of tolerance to one's own tissues and organs, have been intensified by heat waves, storms, wildfires, droughts, increased ultraviolet radiation, food supply chain disruptions, and previously mentioned infections with shifting geographic ranges.

In a recent literature review, it has been noted that only 9 percent of scientific studies published so far concentrated on Sub-Saharan Africa—the region that is, by all measures, among the most vulnerable

Additionally, there is a clear multifaceted link between climate change and the challenge of ensuring sufficient drinking water for the global population. Apart from being a serious issue in its own right, water scarcity impacts sanitary and hygiene conditions, increasing the risk of the epidemic spread of infectious diseases—particularly those transmitted through contaminated water, such as cholera—especially when these outbreaks coincide with mass migration. The latter is likely, given estimates that within several decades, 19 percent of the world's land may be situated within regions no longer considered habitable, while tens of millions of people living in coastal and island areas could be forced to leave their homes due to rising sea levels from melting polar ice caps and glaciers. Frequent extreme weather events—such as snowstorms, supercell storms, hurricanes, or typhoons—could further aggravate an already complex epidemiological situation, and the future of climate change holds a grim promise in this regard. Alongside all this, shifting epidemiological patterns are driving increased resistance to antimicrobial drugs in many causal agents, and here we see the effects of climate change intersecting with one of the most pressing medical concerns of our time.

Of course, the essential purpose of all these insights is not to instill fear or despair in people, but to enable the formulation and implementation of effective strategies to mitigate harmful processes and their consequences. Such a strategy should include core elements like social and economic development, sustainable urbanization, innovative land use strategies, adaptation measures to a changed reality in various aspects of life, and, of course, it should look for ways to redirect the unsustainable management of planetary resources—and the global system that reinforces it—toward a path that is environmentally, economically, and ethically sustainable.

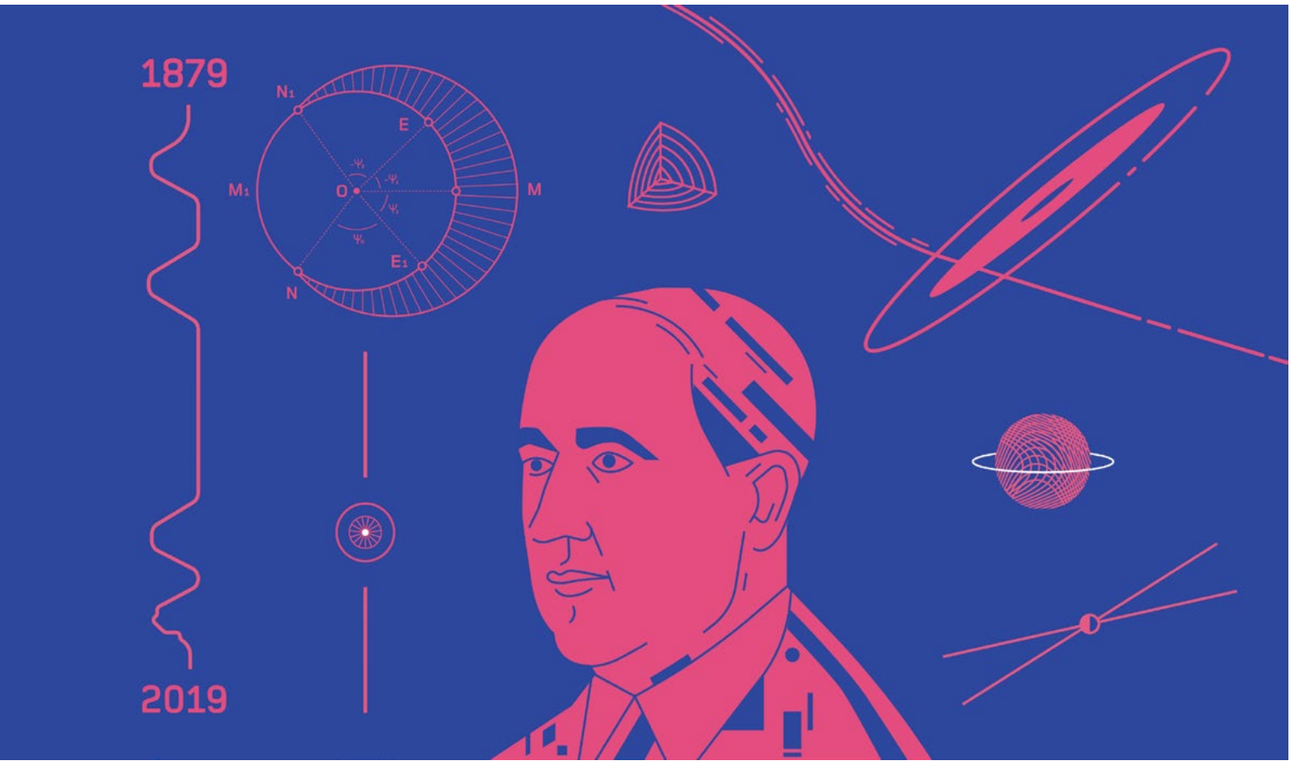
As with all other aspects of climate change, its impact on health, as we mentioned at the beginning, is inextricably linked to deepening social inequalities and injustice. This is evident from the very fact that, according to some realistic estimates, the most devastating impact is expected in countries with modest living standards, those that have contributed the least to climate change. On the other hand, hardly any community can reasonably hope to be entirely spared. Disparities between nations and regions are also intensifying because most research on the consequences of climate change, and possible prevention or mitigation measures, is focused on the affluent countries of the Global North. For example, in a recent literature review, it has been noted that only 9 percent of scientific studies published so far concentrated on Sub-Saharan Africa—the region that is, by all measures, among the most vulnerable. Last year, the United Nations recognized climate change as a *threat multiplier*. This essentially means that various adverse social processes can be significantly aggravated and accelerated amid climate change, including mass poverty, the disintegration of social structures, the loss of means of subsistence, and deteriorating living conditions, alongside all social and political repercussions that may follow.

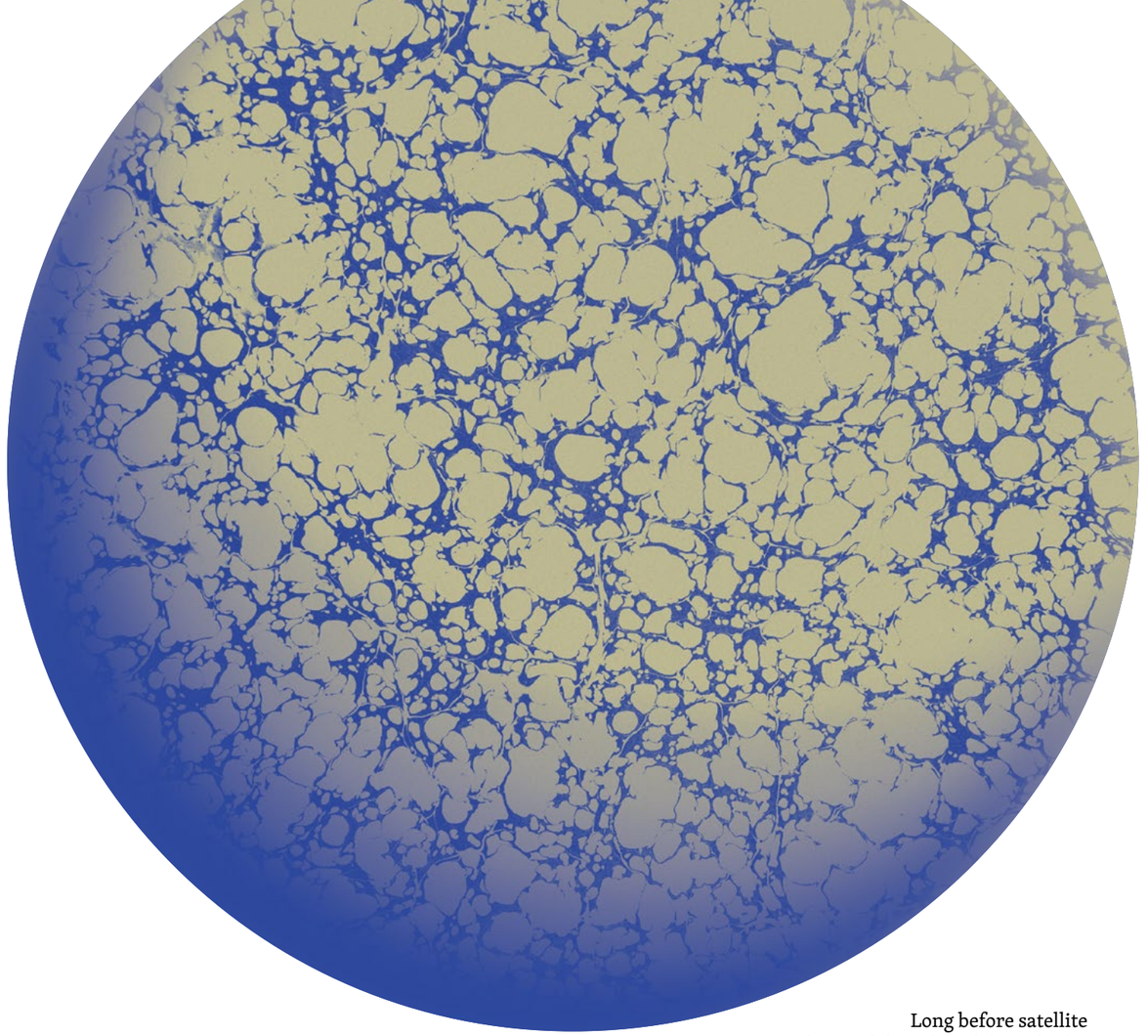
It is essential to highlight that virtually all experts, regardless of their professional background or discipline, agree on one thing: well-formulated, coordinated efforts to address or overcome the causes of climate change can undoubtedly limit their harmful effects on human health and help steer us away from particularly catastrophic future scenarios. As for medical aspects, much can be achieved by reinforcing good practices in the early detection and control of epidemic or pandemic risks, implementing long-term strategies to combat infectious diseases, and expanding healthcare capacities, alongside systemic changes that can make us more resilient to adverse effects—or *antifragile*, as Nassim Nicholas Taleb described it. Ideally, local and global actions in that direction should proceed in parallel with comprehensive international efforts to drastically reduce or eliminate greenhouse gas emissions. Of course, the situation is far from simple. Still, for now, we are left with nothing but hope that growing public awareness of the disastrous effects of inaction—or of insufficient or delayed action on climate change—will eventually be crowned by a much-needed global consensus on the steps we must take for the common good, a consensus that, like climate change itself, would constitute an unprecedented transformation. —Ⓔ

Srđa Janković graduated from the Faculty of Medicine at the University of Belgrade in 2002. Since 2007, he has been working at the laboratory for immunology of the University Children's Hospital in Belgrade, where he has also headed the Division of Immunology since 2015, the same year he completed his specialization in immunology. He acquired his PhD in 2016 with a thesis regarding the significance of Wilms tumor(WT)-1 gene and protein expression in children with acute leukemia. In addition to the biology of childhood leukemias, publications co-authored by Dr. Janković are focused on a number of areas: xenobiotic immunotoxicity by means of inflammatory reaction, dendritic cell maturation and acquisition of immunogenic vs. tolegogenic properties, diagnosis and treatment of primary immunodeficiency disorders, as well as pathogen-host interactions and prevention of infectious diseases by active immunization. He also pursues an active interest in the history and philosophy of science and interdisciplinary studies of life and its evolution.

Milutin Milanković: Architect of Earth's Climate Rhythms

A story of numbers, orbits, and the enduring power of ideas





Illustrations by ***Coba&associates***

By
Bogdan Đorđević

MILUTIN MILANKOVIĆ was one of those rare scientists whose legacy continues to shape our understanding of the world long after his time. Born in the late 19th century in a village along the Danube and trained as a civil engineer in Vienna, he went on to become a pioneer in planetary climatology and a visionary in mathematical modeling. Today, his theory of long-term climate cycles—known as *the Milankovitch cycles*—stands as a cornerstone of climate science.

But beyond the equations and astronomical calculations lies a deeper story—one of intellectual audacity, scientific persistence, and a lifelong effort to understand the forces that have shaped Earth's climate over geological epochs.

Long before satellite data and digital models, Milanković relied on mathematics, logic, and imagination. The result was a body of work so far ahead of his time that it remains central to how we study the climate today—especially in the context of a warming world.

WHERE CURIOSITY MEETS NUMBERS

Milanković's intellectual journey began in 1879 in Dalj, a small village in the Austro-Hungarian Empire. As he spent much of his time indoors due to poor health, Milanković developed a fascination with numbers and the structure they brought to the world. By the age of five, he had mastered the decimal system, and this early affinity for mathematics set the tone for his life's work.

Encouraged by his mathematics teacher, Vladimir Varičak, he enrolled to the Vienna University of Technology (TU Wien) at the age of seventeen. There, he pursued a degree in civil engineering and became the first Serb to earn a doctorate in technical sciences. In the early stages of his career, Milanković distinguished himself by applying advanced mathematical modeling to reinforced concrete construction—an emerging field at the time. He obtained several patents across Europe and the United States, and his engineering work extended to bridges, aqueducts, and hydroelectric projects throughout Central Europe.

Yet even as he found success in engineering, Milanković's thoughts increasingly turned skyward. He was drawn not only to the logic of structures, but to the logic of the cosmos itself—the silent laws governing celestial motion and the invisible rhythms of nature.

A TURN TOWARD THE HEAVENS

In 1909, Milanković made a momentous decision: he left a well-paid engineering job in Vienna to become a university professor in Belgrade—accepting a tenfold decrease in salary. "I was exchanging comfort for the calling of science," he would later reflect. In the academic halls of Captain Miša's Mansion, he began his transformative work at the crossroads of mathematics, astronomy, and geophysics.

Fascinated by the mystery of the ice ages, Milanković challenged prevailing theories that pointed to volcanism or ocean currents. He proposed instead that slow, predictable changes in Earth's orbit and axial tilt—governed by celestial mechanics—alter the distribution of solar radiation on Earth's surface over tens of thousands of years.

Using only a pen, paper, and an unwavering belief in logic, he identified three dominant astronomical parameters:

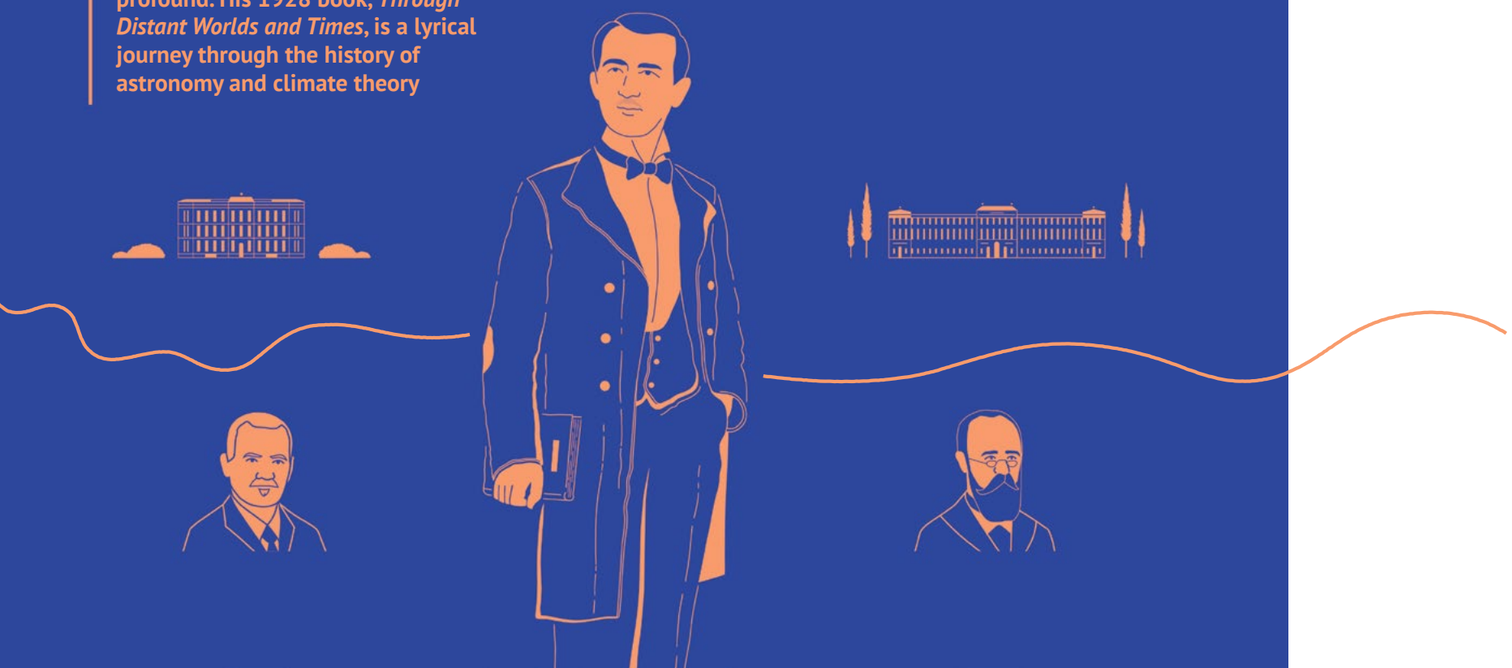
Precession (the wobble of Earth's axis), with a cycle of roughly 22,000 years;

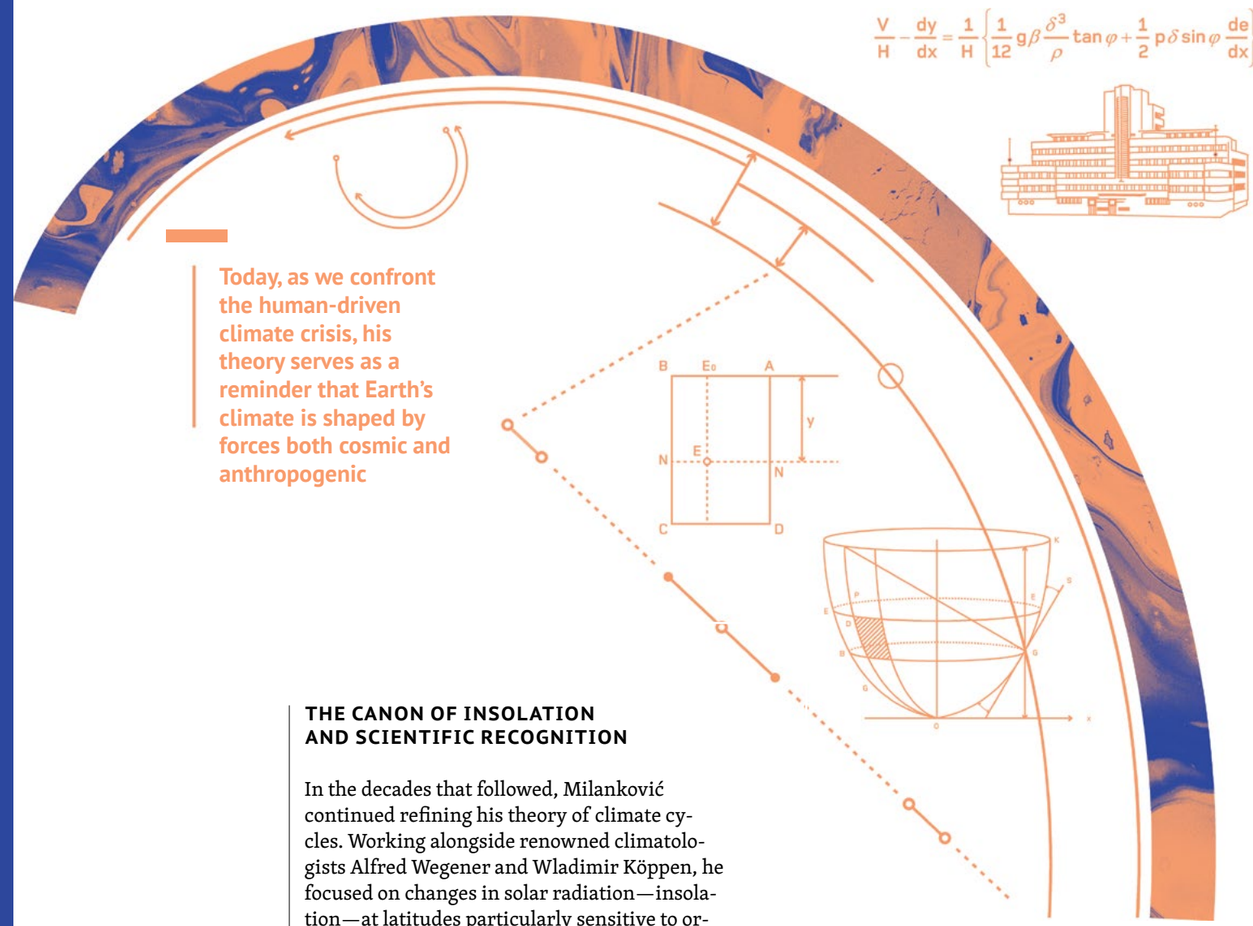
Obliquity (the tilt of Earth's axis), fluctuating between 21.5° and 24.5° over 41,000 years;

Eccentricity (the shape of Earth's orbit), which varies in a 100,000-year cycle.

Together, these orbital variations influence the intensity and spatial distribution of solar radiation—especially at higher latitudes—driving the growth or retreat of massive ice sheets. Milanković reasoned that by modeling these changes, it was possible not only to explain past climate shifts but to anticipate future ones. It was a bold hypothesis: using astronomy to decipher Earth's climatic memory.

In his later years, Milanković devoted himself to communicating science in ways that were both poetic and profound. His 1928 book, *Through Distant Worlds and Times*, is a lyrical journey through the history of astronomy and climate theory





Today, as we confront the human-driven climate crisis, his theory serves as a reminder that Earth's climate is shaped by forces both cosmic and anthropogenic

THE CANON OF INSOLATION AND SCIENTIFIC RECOGNITION

In the decades that followed, Milanković continued refining his theory of climate cycles. Working alongside renowned climatologists Alfred Wegener and Wladimir Köppen, he focused on changes in solar radiation—insolation—at latitudes particularly sensitive to orbital variations, such as 55°, 60°, and 65° north.

In 1941, he published his seminal work, *The Canon of Insolation of the Earth and Its Application to the Problem of Ice Ages*. The book offered a rigorous mathematical model of long-term climate dynamics, integrating astronomy, geophysics, and climatology.

Shortly after its publication, German bombs struck Belgrade. The printing house was damaged, and much of the edition was lost. Milanković managed to preserve a copy, which eventually reached scientific circles abroad—contributing to his growing international recognition.

Although initially met with skepticism, his theory gained increasing support over the following decades. As paleoclimatology and ice core analysis advanced, researchers observed a striking correlation between Earth's orbital variations and the timing of past ice ages. A pivotal 1976 paper in the *Science* journal confirmed that these astronomical cycles played a significant role in glacial-interglacial changes—validating what Milanković had calculated decades earlier.

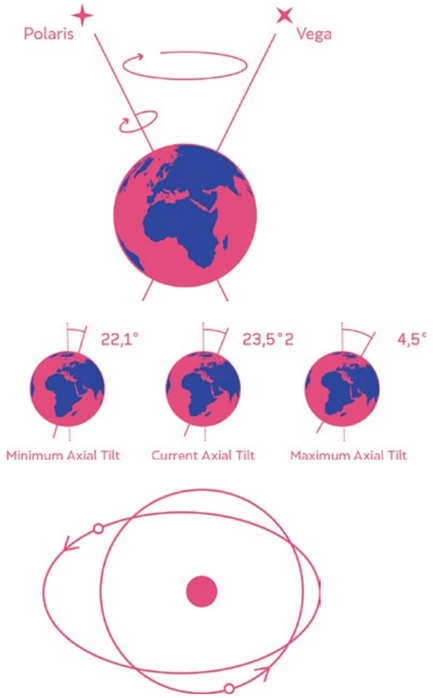
CLIMATES BEYOND EARTH

Even as he delved deep into Earth's climate, Milanković never lost sight of the wider cosmos. During World War I, while interned in Austria-Hungary, he began calculating theoretical climates for other planets using only his memory, a pencil, and paper. In 1920, he published *Mathematical Theory of Heat Phenomena Caused by Solar Radiation*, a pioneering study that modeled solar heating on Earth, Mars, and Venus.

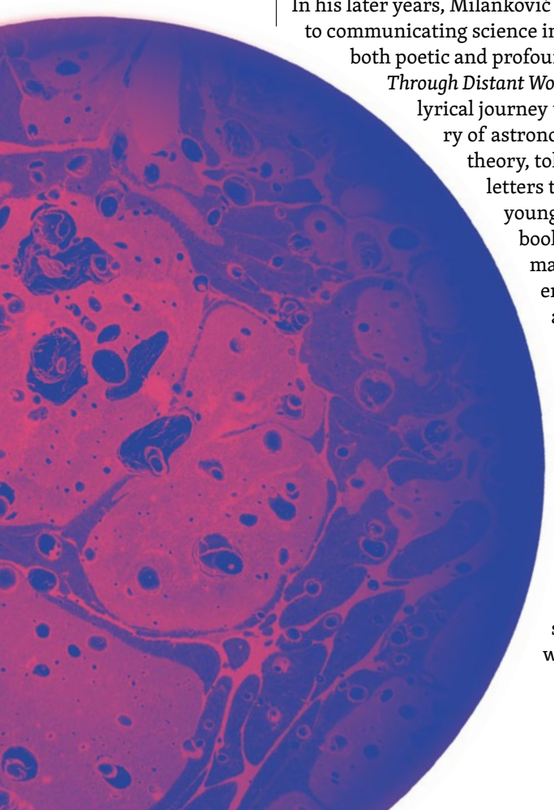
This work stands as one of the earliest contributions to planetary climatology. Though he lacked observational data, his methodology—

grounded in first principles and orbital mechanics—was astonishingly forward-looking. Decades before space probes would reach either Mars or Venus, Milanković envisioned their climates in mathematical form.

In 1923, he also proposed a reform of the Julian calendar at the Pan-Orthodox Congress in Constantinople. His new system, mathematically precise to within a few seconds per millennium, would not diverge from the solar year by even a day until the year 2800—thus surpassing the Gregorian calendar in accuracy.



Long before satellite data and digital models, Milanković relied on mathematics, logic, and imagination. The result was a body of work so far ahead of his time that it remains central to how we study the climate today



A LEGACY FOR A CHANGING WORLD

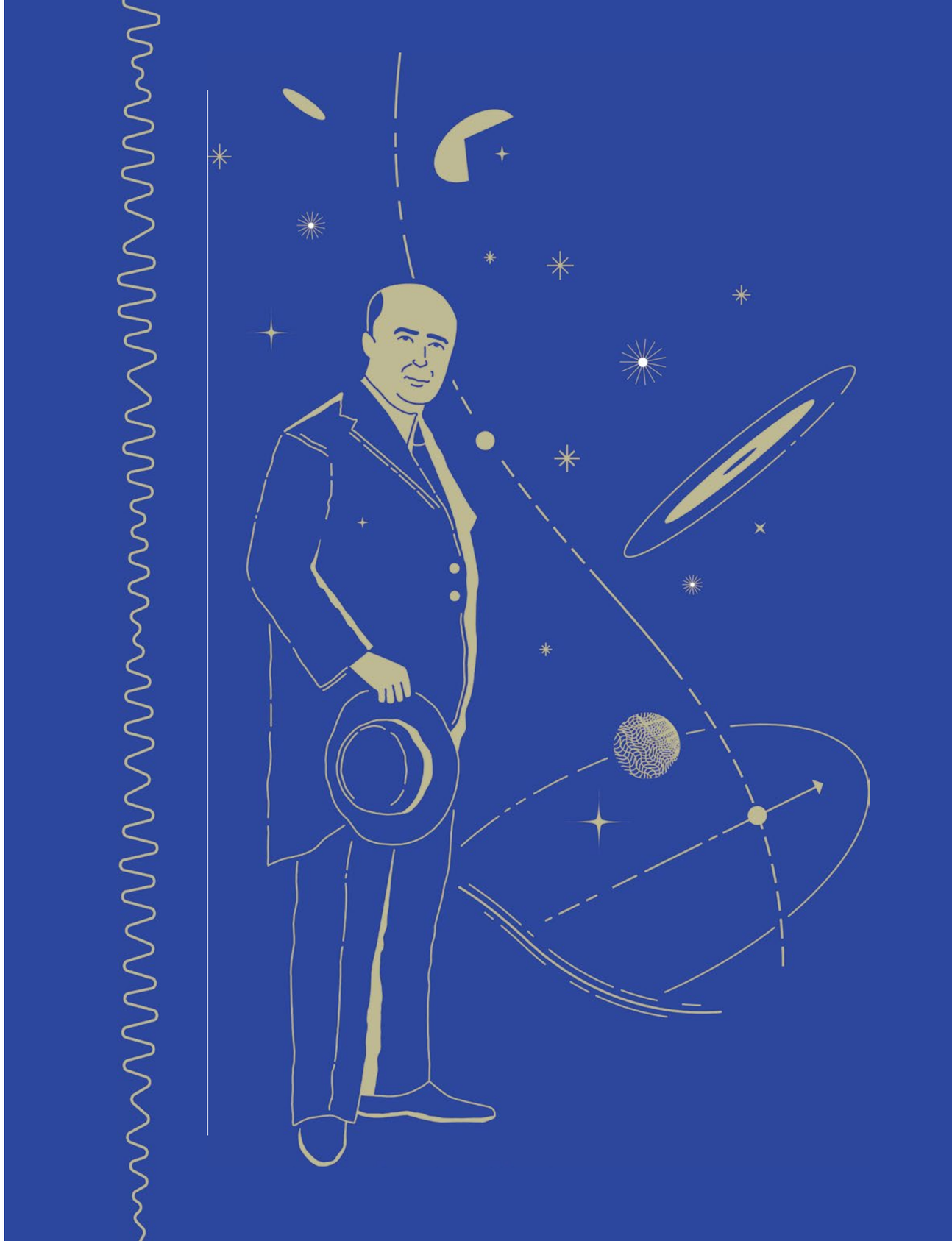
In his later years, Milanković devoted himself to communicating science in ways that were both poetic and profound. His 1928 book, *Through Distant Worlds and Times*, is a lyrical journey through the history of astronomy and climate theory, told in the form of letters to an imagined young woman. The book remains a landmark of Serbian science writing, balancing scientific rigor with literary charm.

He continued publishing until the end of his life, writing essays and books on the lives of Galileo, Newton, Archimedes, and other giants of science. These were not simply biographies—they were reflections on the pursuit of knowledge across generations.

Milutin Milanković died in 1958. Nearly two decades later, the scientific world fully embraced the scope of his contributions. Today, as we confront the human-driven climate crisis, his theory serves as a reminder that Earth's climate is shaped by forces both cosmic and anthropogenic. Natural rhythms typically unfold over tens of thousands of years; the warming we are now witnessing is taking place in mere decades.

Understanding this duality—of celestial cycles and human impact—is essential. Milanković showed that climate, far from being unknowable, is subject to the same laws and logic that govern the stars. His work continues to inspire a new generation of scientists seeking to understand not just what changes our world, but how—and why. —Ⓔ

Bogdan Đorđević holds a degree in Journalism and is currently pursuing studies in Sociology at the Faculty of Philosophy in Belgrade. He gained journalistic experience by reporting from sports events. He joined the Center for the Promotion of Science in 2019.



Building a Sustainable Future through Climate Literacy

Education plays a crucial role in tackling climate change, empowering people to rethink habits, make informed decisions, and engage in formulating sustainable policies

By
Bogdan Đorđević

*Illustrations by **Uroš Pavlović***

UNDERSTANDING CLIMATE CHANGE is not just a matter of science—it is a foundation for shaping the future. Climate literacy is becoming an essential part of 21st-century education, helping young people develop the knowledge, critical thinking, and motivation they need to respond to environmental challenges.

Climate literacy refers to the ability to understand the causes and consequences of climate change, critically evaluate information, and make informed choices that support environmental sustainability. It is not only about understanding the science behind rising temperatures and extreme weather, but also about recognizing the social, economic, and political dimensions of the climate crisis—and feeling empowered to take meaningful action.

The Center for the Promotion of Science (CPN) is involved in international projects such as IMPACT, Carbon Act, and VR4Clima, which aim to integrate climate literacy into classrooms and everyday life. These initiatives are designed to equip teachers, students, and communities with tools that encourage action and reinforce a shared sense of responsibility toward both nature and society. The following three international projects illustrate how climate literacy is being strengthened across different levels of education—from classroom activities and teacher training to digital innovation and public engagement.

Bringing Climate Education into Schools—the Carbon Act Project

Education plays a crucial role in tackling climate change, empowering people to rethink habits, make informed decisions, and engage in formulating sustainable policies. As part of the Carbon Act project, the CPN is collaborating with partners across Europe to support climate education within formal school systems.

The project unfolds in three phases: research and analysis of school curricula, development and testing of teaching materials, and wide dissemination through online courses, competitions, video content, and practical guides.

Between March and September 2023, the CPN and its partners in Belgium, Poland, Sweden, Ireland, and Portugal reviewed national curricula and gathered input from 350 primary and secondary school teachers. The research revealed that, although climate change remains underrepresented in official programs, many educators are already finding ways to include it—often relying on their own initiative and materials.

Interestingly, teachers with backgrounds in the social sciences tend to be less engaged in climate-related topics, even though the issues at stake are deeply social and political.

"Students are usually introduced to climate topics between the ages of nine and eleven. Many teachers prepare lessons using scientific papers, independent learning, or informal training. They are clearly motivated, but they often lack a clear framework and support," says CPN Acting Director Danijela Vučićević.

A key outcome of the project is an online course on climate change, which was piloted in fall 2024 for teachers in Serbia. The course offers knowledge, practical tools, and guidance for incorporating climate topics into everyday teaching. New learning materials are also being developed for the Scientix platform, making them accessible to educators across Europe.

Inside the Classroom: What Students Really Learn—the IMP>ACT Project

Launched in early 2024, the four-year IMP>ACT project seeks to understand how climate change and sustainability are taught in schools—and how this knowledge shapes students' attitudes, habits, and readiness to act. Rather than focusing solely on academic achievement, the project promotes a broader definition of climate competence—one that includes critical thinking, personal motivation, and the capacity to take action.

The project brings together universities and organizations from Belgium, the Czech Republic, the Netherlands, Italy, Germany, Sweden, and Serbia, combining diverse educational contexts and experiences to create a richer understanding of what works in climate education.

In Serbia, the CPN is contributing to the project by collecting data on current teaching practices, providing training for educators, and developing new classroom tools. Students are also engaged through hands-on activities and mini research projects, while several events are designed to involve the broader community in conversations on climate education.

One of the key interventions evaluated as part of IMP>ACT in Serbia was the CPN's Eco STEAM Challenge, a school-based initiative designed to raise awareness of climate change

through interdisciplinary, practical learning. This year, four elementary schools participated in the challenge, which involved measuring weather parameters throughout May and recording the data in a so-called *green diary*.

This data was then analyzed and compared with historical weather records, sparking discussions about local climate trends and their potential long-term impacts. The challenge culminated in a creative segment: under the guidance of their teachers, students developed actionable ideas to improve their school environments in sustainable, climate-resilient ways. By requiring a realistic budget proposal for each idea, the initiative encouraged both critical thinking and applied planning skills.

By drawing on international collaboration and local experience, IMP>ACT aims to develop flexible indicators and assessment tools that help schools and policymakers better evaluate the real impact of climate education. Ultimately, the project seeks to pave the way for more meaningful, evidence-based improvements to sustainability education, both in classrooms and across society.

Learning through Experience the VR4ClimaProject

The VR4Clima project relies on virtual reality and digital storytelling to make climate education more engaging and hands-on. By combining immersive technologies with innovative teaching strategies, the project aims to enhance climate awareness and spark meaningful learning experiences.

Two schools are directly involved in piloting the project: the 16th Experimental Primary School in Lamia, Greece, and the "Petro Kuzmjak" Primary and Secondary School with a dormitory in Ruski Krstur, Serbia.

At the heart of the project lies an interactive VR game that demonstrates how individual choices impact the environment. Currently in the testing phase, the game helps students link everyday actions to broader climate challenges in a fun and relatable way.

The project has already released several educational videos tailored for younger students, along with illustrated maps of Europe's microclimatic zones. These visuals offer clear, age-appropriate explanations of climate concepts.

A VR-based training course for teachers is currently being developed. The course is set to utilize game-based learning to support fresh, interactive approaches in the classroom. In the project's final stage, a Europe-wide competition will invite students to design sustainable schoolyards in virtual space, applying their knowledge while also exploring creativity and innovation.

Although schools are excited about the possibilities of digital learning, a major hurdle remains: access to VR technology is still limited, especially in under-resourced areas. Overcoming this challenge will be essential for scaling the project and ensuring that immersive climate education reaches more students across Europe.

As climate literacy becomes increasingly recognized as a pillar of quality education, the challenge now is to translate knowledge into lasting impact. This calls for investment not only in innovative tools and teaching strategies but also in collaboration among schools, researchers, policymakers, and communities. Projects such as Carbon Act, IMPACT, and VR4Clima demonstrate that real progress comes from empowering those at the heart of education: teachers and students. With the proper support, they can lead the way toward a more resilient and sustainable future. —Ⓔ

More about the author on page 50

Art and Climate Change: Time to Act Together

“Art can amplify science, bring it to life, and sometimes even make it more audible. In a world saturated with information, it offers another, more sensitive way to awaken consciences.”

By
Đorđe Petrović

“**CLIMATE CHANGE** is not just about data or facts, but also about our relationship to the world, to the future, and ourselves. Science is essential for understanding reality—it provides a precise, well-founded, and indispensable diagnosis. But it is not always enough to provoke an emotional reaction or a profound awakening. That’s where art comes in,” says French multidisciplinary artist Arnaud Laffond.

Laffond’s installation *Breathing* was selected as the winning work in the second open call of the Climateurope2 international project titled *Navigating Climate: The Art of Big Data*, organized by the Center for the Promotion of Science (CPN). The winner of the first art+science call—*Climatized art+science service*—was *M1L3NΛ*, a work by Serbian artist Ana Pinter. In addition to these two open calls for artists, the CPN also launched, within the Climateurope2 project, the *Traveling Climate Action Roadshow* and the open call *Climate Action through Poetry and Photography*. All of these initiatives were conceived as ways to allow art to come in—to invite artistic imagination into climate discourse and foster dialogue between art, science, and society on one of the most pressing issues of our time: climate change.

“The main goal of the Climateurope2 public calls has been to make climate data and services accessible and understandable not only to experts, but to all citizens,” explains Dr. Marjana Brkić, Climateurope2 Project Coordinator at the CPN. “Artists become important allies in this process, as their approach can open up space for new ways of thinking and perceiving the challenges that climate change brings.”

THE BREATHING OF THE EARTH

In March of this year, Laffond spent two weeks in Belgrade as part of a residency provided by the project, where he had the opportunity to further develop and refine his winning artwork through collaboration with local cultural and scientific figures.

“*Breathing* is based on a desire to translate climate data into artistic language so as to create an immersive experience that allows us to feel what numbers alone cannot convey. To achieve this, I collect and select scientific climate data that has the potential for aesthetic transformation—data such as temperature, CO_2 levels, precipitation, winds, or the evolution of climate extremes over time,” says this multidisciplinary artist.

This data comes from open-access European sources, primarily Copernicus, the European Earth Observation Program, which provides a large number of datasets on the past, present, and future state of the climate. He also notes that his residency work in Belgrade, carried out in collaboration with the CPN, gave him access to complementary resources: local data, scientific expertise, and a valuable framework for interdisciplinary exchange.

“These exchanges enriched the contextual dimension of the project and made it possible to forge links between global data and more territorially grounded realities,” explains Laffond. From there, he develops sensory translation systems: the data is transformed into visual, sound, or light signals, synchronized within the installation space. This creates a synergy between art and science, as the two disciplines interact to offer a new, emotional, almost organic perception of climatic phenomena.

“The inspiration behind *Breathing* came from a profound awareness of the climate upheavals we are experiencing—often imperceptible in daily life, yet clearly present in scientific data. This project was born from the desire to make that data—often cold, abstract, or technical—feel tangible, sensitive, almost alive,” says the artist, whose work centers on the creation of virtual environments and computer-generated materials, questioning the relationship between humans and new technologies. “The idea came to me while observing how our environment reacts, breathes, evolves in silence—and how we tend not to listen.”

Using concrete data from sources such as Copernicus, Laffond set out to create a work that gives rhythm, voice, and light to these changes. “The desire was to blend art and science in order to stir emotion—an intuitive and sensory awareness—whether through video, light, or sound, all orchestrated in an immersive installation,” he explains. “*Breathing* is the breath that Earth emits—sometimes serene, sometimes strained—and that we must learn to feel again.”

Photograph by ***Katarina Bugarin***

Ana Pinter

During his residency in Belgrade, the French artist placed particular emphasis on the importance of his collaboration with Serbian climatologist Dr. Vladimir Đurđević in developing the *Breathing* project. "His expertise in climatology helped me better understand the complex dynamics of climate change, not only on a global scale, but also in its regional and human dimensions," says Laffond. "Thanks to our discussions, I was able to refine the selection of climate data used in the work, moving beyond the obvious indicators."

This artist says Dr. Đurđević helped him consider how to represent this information responsibly, without falling into either sensationalism or cold abstraction. "This shaped the sensitive and immersive form of *Breathing*—the decision not to illustrate catastrophe, but rather to show and feel a world that breathes, that changes, that warns, sometimes silently," concludes Laffond. "This collaboration also fueled the desire to create a space where science and art do not merely illustrate but truly complement one another, each with its own way of telling the story of reality."

M1L3NΛ—A CLIMATE ORACLE

Two years ago, as part of the Climateurope2 project, the CPN launched its first open call, titled *Climatized art+science service*. The call invited artists to explore the potential of climate data, research, and services in supporting resilience to climate change. The winner was Serbian artist Ana Pinter, from the theatre group Threepenny Theatre (*Tri groša*).

Her impressive project *M1L3NΛ* is an interactive installation and poetic text generator centered on climate narratives. It guides visitors through contemporary forms of fortune-telling, reflecting a deep-rooted human need for certainty and hope in times of uncertainty. The installation merges poetic language with climate data, offering a symbolic and emotionally resonant exploration of the future.

"The work is called *M1L3NΛ*, a kind of homage to Milutin Milanković, the renowned Serbian mathematician and climatologist, whose twin sister bore that very name. In a way, I wanted to give her a voice too—one that comes from the notorious side of science: magic," says the Serbian artist, whose artwork combines participatory and socially engaged formats, integrating digital technology with performative elements to create interactive, immersive experiences.

Photograph by **Marko Risović**

Arnaud Laffond

The idea of a climate oracle emerged during a residency at the HafenCity University Hamburg, where, while experimenting with coding, climate data, and artistic disciplines, Pinter recognized both the predictive potential of new data-processing technologies and the deep trust people place in this possibility. As she explains, "Here, we are talking about the ability of technology to anticipate future climate conditions—not just for days or weeks, as weather forecasts do, but over much longer timescales, extending several hundred years. The Climateurope2 call for the promotion of climate services was a perfect opportunity for me to try to bring this idea to life."

The installation draws on climate data and interactive models from the Copernicus Interactive Climate Atlas and the NASA Vital Signs database. Based on a visitor's birth date and lifestyle choices, M1L3NΛ looks into the past to reveal the climate conditions of that specific year, then projects possible future scenarios—up to the year 2080—to anticipate how the climate is expected to change.

The artwork takes the form of a phone booth, deliberately referencing the automation of service industries and our growing tendency to form personal relationships with machines. Coming primarily from the field of performing arts, Pinter notes that the performative potential of the installation was particularly important to her.

"In a way, *M1L3NΛ* is a new media puppet. Puppetry is one of the oldest performing arts, and only recently has it become primarily associated with children. In many cultures, it remains part of ritual practice—a means of transmitting collective knowledge and heritage," says Pinter. "Its connection to natural cycles is striking, and it is laden with material on how communities have related to extreme weather conditions."

THE ROADSHOW GOES ON

"As an institution positioned at the intersection of science and society, the CPN recognizes that collaboration between science and art is not a luxury, but a necessity for communicating the climate crisis," says Dr. Marjana Brkić. "As the coordinator of the Climateurope2 project in Serbia, I believe it is essential to translate scientific knowledge and climate data into a language that can inspire, mobilize, and engage citizens. It was from this need that the CPN launched the *Traveling Climate Action Roadshow*, which has already brought artworks and interactive content to cities and communities across Southeast Europe—and will continue to do so in the months ahead, reaching people in public spaces such as squares, parks, and streets."

The Roadshow takes place at ten locations across Southeast Europe, with the first five stops completed in 2024: Rijeka (Croatia), Tirana (Albania), Kotor (Montenegro), Sarajevo (Bosnia and Herzegovina), and Skopje (North Macedonia). In collaboration with local partners in each city, the CPN organized panel discussions and talks on climate services, bringing together stakeholders and citizens interested in how climate information can support smarter decision-making and help build a stronger climate services community.

These events were complemented by a variety of engaging art+science activities. One of the highlights was the *Climate Capsule*, the CPN's renowned immersive installation, which was shortlisted two years ago for the prestigious International Award for Climate Communication Initiatives. The installation invited visitors to reflect on climate action through multimedia content depicting our planet and the projected impacts of climate change in the year 2057. Additional features included virtual and augmented reality technologies, offering an interactive experience of the natural world that surrounds us.

The tour was also a chance for people to experience the *M1L3NΛ* installation for the very first time. In addition to the artistic installations, the Roadshow event in Rijeka featured an informal poetic dialogue between poet Ljiljana Ilić and climatologist Dr. Vladimir Đurđević, who also announced the launch of the CPN's open call *Climate Action through Poetry and Photography*. The call, which closed last year, attracted over seventy photographers and poets—both professional and amateur—from across the region and all age groups. The winners were photographer Tanja Bažalac from Belgrade and poet Snježana Vračar Mihelač from Pula, who currently lives and works in Ljubljana.

The five Roadshow events attracted more than 1,000 visitors from across the fields of science, art, the public and private sectors, NGOs,

and broader civil society. “Audience engagement with the Roadshow was incredibly strong—people stayed, talked, commented, and shared personal stories about the changes they are witnessing in their surroundings,” said Dr. Brkić, adding that the turnout exceeded expectations. She hopes for even greater engagement at the Climateurope2 Festival in Belgrade, taking place from September 29 to October 1, 2025, where visitors will have the opportunity to see all the selected works from the CPN open calls and the Roadshow tour—some of them for the very first time.

A NEW KIND OF RESONANCE

These initiatives—ranging from immersive installations and poetic dialogues to interactive street actions—demonstrate how art can translate climate data into meaningful, lived experiences. They also reveal a growing need for new forms of engagement—ones that move beyond sharing information to reach people on emotional and symbolic levels. In this context, both Ana Pinter and Arnaud Laffond reflect on the deeper role of art in a time of climate crisis.

“Art, among other things, engages with the most pressing issues of contemporary human experience. Climate change will significantly alter the quality of human life—in fact, it already does. I can hardly think of a topic more important than this one,” says Pinter. She believes that art should encourage and inspire its audience to reflect on their experience with the work in multiple ways—not only by retelling it or sharing memories of it, thereby reaching those who did not have the chance to see it firsthand, but also by offering critical perspectives that are, at their core, creative.

One of the major challenges in addressing climate change lies in the way it is communicated to the public. Pinter points out that once scientific discourse enters the domain of mass media, it is often misrepresented or handled irresponsibly. As she explains, “This, among other things, generates skepticism—if not permanent distrust—toward anything communicated from a scientific standpoint. This is evident in the mass media, among conspiracy theorists, and among those who profit from the misuse of science.”

What, then, is the role of art? What can art do for science? “I am not saying that art is the best way to overcome this challenge, but I do believe in its potential to present science as a field of inquiry rather than a source of dogmatic answers. Like art, science is driven by curiosity,” explains the Serbian artist. “Together, they can offer critical perspectives not only on the phenomena we face, but—more importantly—on the interpretations of those phenomena presented to us via television, newspapers, the internet, and other public spaces.”

Her colleague, Arnaud Laffond, highlights the power of artistic expression to move beyond reason—reaching the senses, emotions, and something deeply visceral, creating an embodied, affective experience of climate reality. “Art has this unique ability to speak directly to the senses, to emotions, to intuition. It can translate scientific complexity into lived experiences, images, sounds, and feelings,” explains the French artist. “With *Breathing*, I seek to convey the climate as a living being, breathing, suffering, and adapting. This feeling is often what is missing in public discourse: an intimate, human, almost physical connection with what seems distant or abstract.”

Laffond sees art as something open and unbounded—free in its form, and capable of giving science a new kind of resonance. “Art can also open spaces for dialogue—not by imposing a single truth, but by building bridges between disciplines, between audiences, and between generations. It can challenge without guilt, touch without explaining, and sow seeds where words are no longer sufficient,” concludes Laffond. “In this sense, art can amplify science, bring it to life, and sometimes even make it more audible. In a world saturated with information, it offers another, more sensitive way to awaken consciences.” —Ⓔ

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Artpiece *M1L3NΛ*, photograph by Marko Risović

INTERVIEW

Dr. Dragana Bojović
Barcelona Supercomputing Center

New Policy Needed to Tackle Climate Change

“Even if we could miraculously halt greenhouse gas emissions that drive climate change, their impact would still be felt for decades, even centuries”

By
Ivana Nikolić

Photographs by
Bojan Živojinović

DRAGANA BOJOVIĆ GRADUATED in ecology and environmental protection from the University of Belgrade. As she likes to say, ecology is the field that has shaped her scientific approach. After graduation, she began working on issues associated with environmental changes, applying the methods commonly used in the social sciences. She completed her master’s at the University of Oxford, and then doctoral studies at the Ca’ Foscari University of Venice, and has been working at the Barcelona Supercomputing Center (BSC) since 2016. Dr. Bojović and her home research institute also collaborate on various projects with Serbian institutions, including the Center for the Promotion of Science (CPN). In this interview, Dr. Bojović explains what her job is all about, why climate services are so important, how to adapt to climate change, and describes the concept of climate shelters.

You work at the Barcelona Supercomputing Center where, among other things, you explore strategies to mitigate climate change. Can you give our readers a better sense of what your day-to-day work looks like?

I work at the Earth Sciences Department, and our main research focus is on climate change

and air quality. For example, my colleagues—climatologists—develop climate models. Based on these models, we can predict the climate for the upcoming season, year, or even decades ahead, depending on the type of model being used. Previously, such issues were mainly approached from the standpoint of fundamental science, without much interdisciplinary collaboration. With time, we realized the need to approach this complex issue from different angles, bringing new disciplines and methods into the process. That is how my group came into being, as it deals with climate services for the environment, and my team is responsible for knowledge integration. The aim is to connect climatology as a science and climatologists with other segments of society, so that this climate knowledge can be truly useful for decision-making, for instance, on adapting to climate change. To achieve this, we rely on a transdisciplinary approach—or rather, we combine different types of knowledge: scientific, practical, and experiential.

Can you explain to us what climate services are?

In recent years, the part of climate science focused on climate services has seen rapid growth. However, climate change had long been an isolated discipline, as scientists failed to make their findings available or understandable to the broader public. This led to the emergence of climate services, designed to transform the way these findings on climate change are presented and disseminated. We need to understand how climate information is used, what information remains unavailable to decision-makers, and what key challenges decision-makers or those who rely on that knowledge face today. This helps us prepare the data in a way that can directly inform new decisions.

When people hear the word *scientists*, they usually picture men in white coats who spend most of their time in a lab. What does your job involve, and what is your team of 18 working on?

Our job is different as we help build connections, both among scientists and between science and the broader society. The team comprises 18 researchers, and the entire department has around 150 employees. We try to arrive at new findings through an integrative approach. We regularly hold internal team meetings, as well as discussions with colleagues from other parts of the department. We also conduct consultations with various institutions and individuals, as users of climate information. With them, we have interviews, also focus groups, we go to conferences, and conduct field research. As far as Africa is concerned, we try to understand the issues on the ground, how they solve them, and how they utilize climate information. We are in contact with national hydrometeorological institutes, farmers' associations, and individual farmers. We organize focus groups with farmers to understand the dynamics of the problems. During these discussions, we learn about the crops they grow, the challenges they encounter, and how their output has been affected by droughts or flooding; and socio-economic or environmental issues often arise, and usually stir a heated discussion. In Malawi and Tanzania, for example, we asked whether more men or women worked in the fields. Initially, the response was that the numbers were roughly equal, but then we heard murmurs of disagreement, and it turned out the situation was different. "No, actually, women do all the work, and men help with the hard digging at the beginning, and then go to sell the produce so they control the money." Sometimes, we even have a good laugh, and then engage in a deeper, more wide-ranging discussion. Through interviews and focus groups, we learn things that cannot be found in the literature, and this is my favorite part of the job.

"No region has been spared from the impact of climate change, from the melting Arctic, where local communities are completely changing their way of life, widespread wildfires in Canada, prolonged droughts in Africa or severe flooding in Bangladesh"

What do you do with the information that you gather from such diverse groups, whether in Africa or elsewhere? And how is this information communicated to actual decision-makers?

Climate services are both about creating new climate knowledge and finding the best ways to share it. Let me go back to the example of delivering climate information to farmers in Eastern Africa. A standard weather forecast typically tells us how much rainfall we can expect in the upcoming season or whether the rainy season may be delayed. When we shared the forecast with farmers, we learned that it was vital for them to know whether there would be stretches of dry days during the rainy season, since that could have a significant impact on their yields. With this in mind, we developed a new climate index, called Consecutive Dry Days, and then considered ways to effectively share this information. For this reason, in our conversations with farmers, it was essential to understand who was responsible for managing the household's material resources. If we wanted to share the information in a WhatsApp group, used in some farming communities, we needed to know which household member had access to a mobile phone and was likely to see the message, as well as who did most of the field work. This new information is put into practice through collaboration with the national meteorological institute. For instance, in some Eastern African countries, seasonal climate outlooks are printed as posters displayed at local markets in all agriculturally active villages. Still, printing posters is a slow and costly process. To upgrade it, we are developing a platform as part of the project Focus Africa, which will make it possible for users to access climate information and forecasts with a single click. To get a useful final product, we need to understand the entire cycle, from the provision of climate information to its real-life application.

Do you pass this information on to decision-makers in Spain, at the EU level or beyond?

Yes, the main objective is to ensure the information reaches end-users. So, we first identify what kind of information users need, and in what format—whether it should be a report, or just raw data, or an operating system. Finally, we consider which communication channel we should use to deliver this information.

You mentioned climate services as the focus of the *Climateurope2* project, in which the Center for the Promotion of Science also participates and the Barcelona Supercomputing Center acts as the coordinator. What can you tell us about the project and its objectives? *Climateurope2* is set to run through 2026 or 2027.

The project launched in late September 2022 , aiming to connect various actors engaged in the entire cycle of climate services, from producers or climatologists themselves, through intermediaries who help refine the information, and end-users. The aim is to create a network and thus help spread and enhance climate knowledge and boost cooperation between those participating in climate services. This had already started with a previous project dubbed *Climateurope1*. The second important part of the project is the standardization of climate services. The concept of climate services initially stemmed from climate sciences, and social sciences and other types of knowledge joined at a later stage. Yet, the concept has never really taken a rigid form, but rather developed and changed over time. Consequently, there are different definitions and approaches to climate services—on the one hand, this is good as it speeds up efforts dedicated to climate services, but on the other hand, it is somewhat limiting as there are no quality standards. So, I believe this work on the standardization of climate services will help both those producing the climate information and those ultimately relying on it.

There are many EU- or UN-funded projects, and scores of initiatives focused on either mitigating the effects of climate change or adapting to them. What is the key issue linked to climate change? What do we need the most—a rise in awareness at the local level or are these projects only capable of responding to scenarios already playing out?

A great deal of funding goes to new technologies. For example, new climate models operate at a high resolution and can no longer run on a supercomputer. This means that models required for a better understanding of the climate are too demanding for today's supercomputers. At my institute, we are working on a next-generation computer that should become operational later this year. Technological development must

continue, but also efforts to raise awareness about climate change and formulate a new policy. Of course, there is a global climate policy backed by most states, which is good, but has its downsides: it is difficult to formulate radical solutions that all countries would sign up to. We need a new policy on climate change: available findings give us a picture of how urgent it is to deliver new measures that would be ambitious enough to bring about change.

And how urgent is it?

Quite urgent. Even if we could miraculously halt greenhouse gas emissions that drive climate change, their impact would still be felt for decades, even centuries. Only 10 percent of the heat in the atmosphere is directly linked to human activity, and the oceans have already absorbed 90 percent of that excess heat. Oceans have sluggish cycles, so they slowly release the heat. Oceanic circulation is important for the functioning of the entire climate system. In fact, climate forecasts are based on studies of oceanic patterns, which themselves are changing due to climate change, both in terms of their physical properties and the marine life they sustain. We must slash greenhouse gas emissions to delay or curtail their inevitable fallout.

So, do we need to adapt to climate change, and what exactly would that mean?

The Mediterranean is a good example. Climate projections and predictions from various scientific centers show strong alignment, all pointing to a substantial temperature increase in the Mediterranean region. We will need to adapt to more intense heat waves, while other parts will be facing droughts, something people in Barcelona and across Spain are already experiencing.

Multiple studies have shown that Serbia is in a pretty precarious situation when it comes to the impact of climate change. Sometimes we tend to cling to the belief that we have got it the worst. You work on this issue, you travel a lot—how bad is the situation in Serbia and the Balkans when compared to other countries you have had a chance to visit and witness the consequences of climate change, and how people are coming to grips with them?

“Climate change had long been an isolated discipline, as scientists failed to make their findings available or understandable to the broader public. This led to the emergence of climate services, designed to transform the way these findings on climate change are presented and disseminated”

What is characteristic of Serbia, though not unique to us, is the exposure to a wide range of extreme weather events as a consequence of climate change. We have seen heat waves, drought and flooding, spring frost, as well as storms that are not really common in our region. We need to adapt to a diverse array of effects, which naturally stretches our overall adaptive capacity. Still, no region has been spared from the impact of climate change, from the melting Arctic, where local communities are completely changing their way of life, widespread wildfires in Canada, prolonged droughts in Africa or severe flooding in Bangladesh. All regions are vulnerable. Low-lying coastal areas and small island countries are susceptible to rising sea levels. Poor countries, like Malawi, have low adaptive capacity due to their fragile socio-economic position, exposure to adverse weather, and a population that relies almost entirely on agriculture, a sector susceptible to climate. The situation is so critical there that they need international assistance to ensure the population’s survival. Wealthier countries have more resources to earmark for adaptation, but this does not mean they would be less affected by climate change.

From what you have just described, the future does not look bright for any region. What are your predictions?

If we rely solely on climate models, predictions are rather depressing. I find hope in new movements that seek to drive lifestyle changes: building greener cities, reducing reliance on private vehicles, cutting energy consumption, and, generally speaking, introducing shifts within the consumerist society itself. New generations are heading in that direction, and I am glad to see that. I think a shift in awareness and lifestyles will bring results. Many different solutions are effective across multiple levels. For instance, there is a strong push in Barcelona to curb car use and expand networks of paths for cyclists and pedestrians. This solution aims to streamline movement across the city and brings many benefits: lower greenhouse gas emissions from fossil fuels and cars. Cities become more livable and more inclusive as public transportation is accessible to all residents. Cutting car traffic and relocating parking lots can open up space for green zones. In cities hard hit by heat waves, green areas are seen as climate shelters. In Barcelona, and other cities in Catalonia, there is an official map of climate shelters. Sometimes, these are public buildings, like libraries, but also parks, where temperatures can be noticeably lower.

Hopefully, by the time you visit us again, we will also have climate shelters in Belgrade.

Unfortunately, I think we will need climate shelters, so it is really important to preserve green areas in Belgrade.

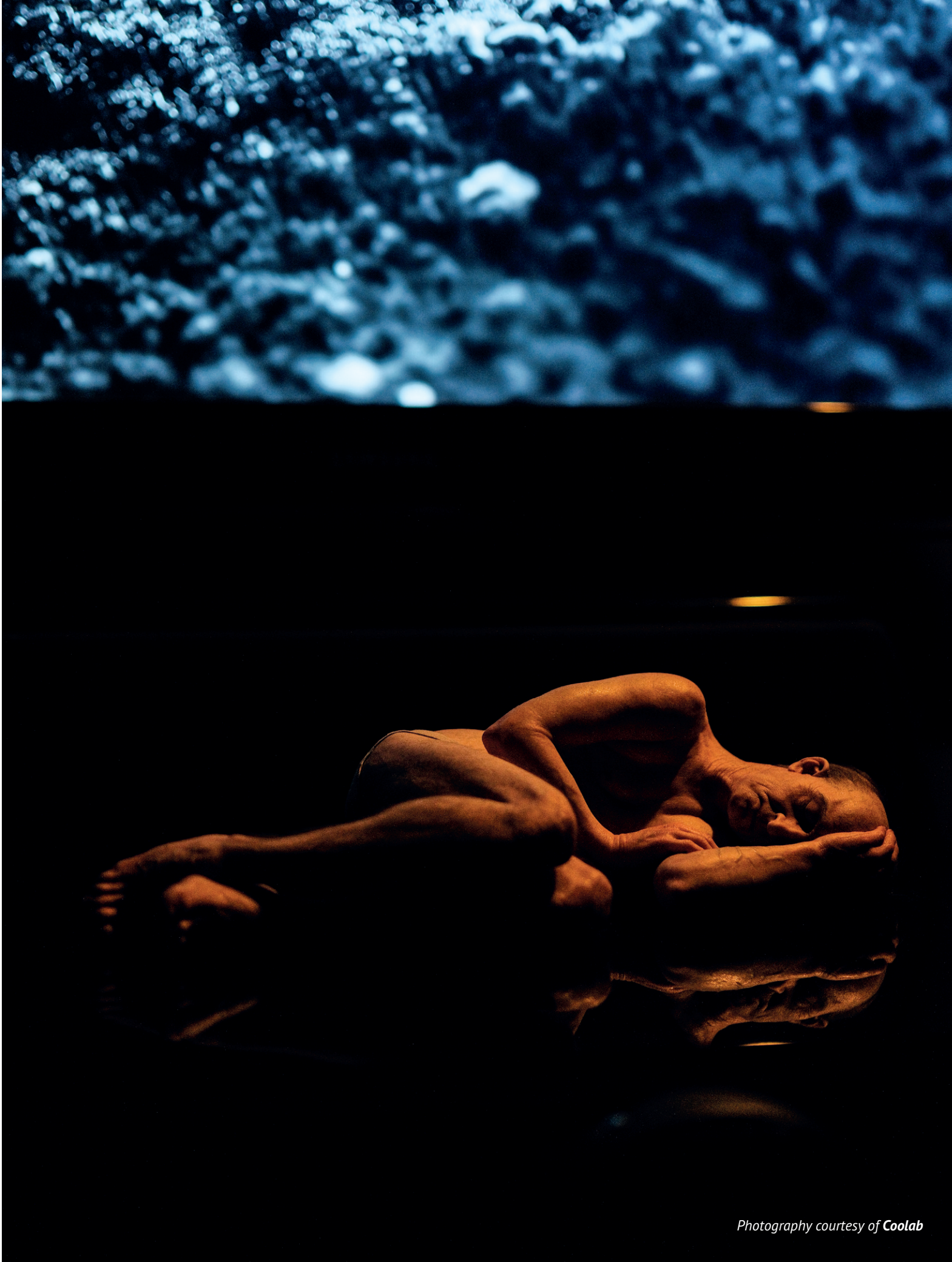
You have described climatology as an inclusive discipline. Does that apply to women, and how does the status of female scientists in Spain compare to their colleagues in Serbia?

Climatology may not be an inclusive discipline by default, but climate services, which are the focus of some climate sciences, are inclusive because of their interdisciplinary approach. For instance, climatology is a male-dominated field, but other disciplines integrated in climate services are not. So, in my team of 18, 16 are women and only two are men. Diversity is essential in any project, not only in terms of gender, but also nationality and age. We can learn a lot from our colleagues from around the world, and early-career researchers bring about fresh perspectives and new momentum. This diversity pushes our projects forward. —Ⓔ

Ivana Nikolić holds a B.A. in Journalism and Communication from the Faculty of Political Sciences in Belgrade. She has been working as a journalist since 2014.

THE CLIMATE CAPSULE—a mobile, interactive installation developed by the Center for the Promotion of Science—invites citizens to reflect on both tangible and emotional dimensions of climate change. By blending art, science, and storytelling, the capsule creates a space where personal memories, scientific facts, and imagined futures converge. As it travels across Southeast Europe as part of the *Traveling Climate Action Roadshow* within the Climateurope2 project, the *Climate Capsule* sparks dialogue, raises awareness, and brings communities closer together on a shared journey toward resilience and sustainability. Join us on this journey!

Photograph by ***Vladimir Janić***



*Photography courtesy of **Coolab***