

CORDEX—Advancing High-Resolution Climate Information and Its Use in Society

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Climate prediction;
Downscaling;
Regional models;
Climate services;
Regional effects;
Societal impacts

The International Conference on Regional Climate, ICRC-CORDEX, 2023

What: About 500 scientists, stakeholders, and users came together in person and online to discuss the latest scientific advancements in regional climate downscaling and in climate information for impacts and adaptation applications at regional and local scales. The conference also served as a platform for extending existing and creating new networks and collaborations.

When: 25–29 September 2023

Where: Trieste, Italy; Pune, India; Zoom and YouTube

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1. Introduction

There is an ever-increasing need for reliable climate information on regional and local scales, i.e., the scales where most decisions directly affecting people's lives happen. This information needs to be both scientifically rigorous and communicated in a manner so that all potential end users, from water managers in Africa to city planners in Manila or forest owners in Sweden, for example, can utilize it for effective impact and adaptation planning.

The World Climate Research Programme (WCRP) global collaborative initiative “Coordinated Regional Climate Downscaling Experiment” (CORDEX) is working toward meeting the challenge that this increasing need poses as part of the WCRP and in collaboration with other global change initiatives and partners across the world (CORDEX 2023a).

CORDEX aims to provide the detailed, regional climate information necessary for investigating present and future changes of climate processes at regional and local scales relevant for vulnerability, impacts, adaptation, and climate services (VIACS) at local and regional levels (e.g., Gutowski et al. 2016; Giorgi et al. 2021). CORDEX results based on the downscaling of phase 5 of the Coupled Model Intercomparison Project (CMIP5) were prominent in the Sixth Assessment Report (AR6) by the Intergovernmental Panel on Climate Change (IPCC) and its Interactive Atlas (Gutiérrez et al. 2021). Downscaling of the latest global models from CMIP6 is ongoing, aiming for contribution to the IPCC AR7.

The International Conference on Regional Climate–CORDEX (ICRC-CORDEX) 2023 conference had a special focus on societal needs emphasizing sessions on CORDEX interactions with society and CORDEX for impacts (CORDEX 2023b). This conference was thus, more than before (e.g., Lake et al. 2017), on dialogue and discussion on how the regional climate research community can best access CORDEX results and its applications for vulnerability, impacts, and adaptation including the full spectrum of potential end users of regional climate information. It promoted the CORDEX vision to advance and coordinate the science and application of regional climate downscaling through global partnerships. The conference also featured discussions on the improvement of regional climate models (RCMs), including coupled models, statistical downscaling techniques, and VIACS relevant metrics.

CORDEX is divided into 14 regional domains that cover almost all land areas plus the Arctic and Antarctic. CORDEX conferences are thus a matter of global importance. Some of these regions face alarming consequences from climate change, which calls for urgent mitigation and adaptation measures.

2. Conference summary and highlights

CORDEX conferences serve as platforms for networking and discussions around advancements and use of climate information on actionable scales. This time around 500 participants from all over the world gathered for the truly hybrid, fifth International Conference on Regional Climate, ICRC-CORDEX 2023 in Trieste (Italy), Pune (India), and online on 25–29 September 2023. The hybrid and hub format reduced the carbon footprint and

enabled greater participation. It was co-organized by the International Project Office for CORDEX (IPOC) hosted at the Swedish Meteorological and Hydrological Institute (SMHI), the Abdus Salam International Centre for Theoretical Physics (ICTP), and the Indian Institute of Tropical Meteorology (IITM).

The conference brought together the international regional climate research community, focusing on high-resolution climate information and its applications to vulnerability, impacts, and adaptation, while including the full spectrum of potential end users of regional climate information.

While offering traditional presentation sessions, the conference focused on discussions on how the regional climate science community, including the WCRP CORDEX, in a coordinated manner can better respond to societal and political needs and challenges and connect climate science with solutions. The discussion also addressed ways in which the regional climate information community can enhance its provision of timely, relevant, and actionable information including decision support systems, while maintaining coordination amid the challenges posed by the continual push for higher modeling resolutions, which can complicate coordination efforts. Among the application topics discussed were climate change in view of the energy sector, water security, agriculture, and high-impact regional weather and climate phenomena.

The event also addressed issues such as the benefits of climate downscaling and explored questions regarding model biases and uncertainties. Additionally, discussions included advancement of resolutions of a few kilometers [i.e., convection-permitting modeling (CPM)], regional Earth system models (RESM), and possible coordinated efforts over new domains. The meeting provided a platform for scientists and users from all parts of the globe to convene, fostering capacity development, training, and knowledge exchange, while also facilitating the creation and strengthening of collaborations.

The sessions included the following:

- plenary sessions with comprehensive overviews, summaries, and insights from preceding sessions, discussions on future directions, and the delivery of key messages;
- “traditional” seminar sessions with talks on the latest scientific advances in regional climate downscaling including artificial intelligence (AI) and machine learning (ML);
- introductory inspirational talks followed by panel discussions on how we communicate with society and integrate climate information into real-world decisions;
- high-impact regional weather and climate phenomena and their implications for various societal sectors and ecosystems;
- workshop-oriented sessions focused on the practical application of CORDEX and coordination of downscaling over oceans, islands, and urban areas, as well as enhancing climate services;
- a hands-on exercise on what a future society adapted to climate change might look like;
- contributions for the Kigali Declaration of the WCRP Open Science Conference 2023;
- an Early Career Scientist event; and
- various side events on, for instance, ongoing CORDEX Flagship Pilot Studies (FPS).

The main venue was at the ICTP in Trieste, Italy, but the meeting also included a regional hub with its own program in Pune, India. There were joint presentations/sessions, whereas some sessions were held only in Italy and online, or in India and online, considering time zone differences and specific regional climate challenges.

The official first conference day, Tuesday 26 September, had two welcoming and keynote speaker sessions, one in Trieste and one in Pune, both streamed and with interactive Zoom participants. The opening keynotes included former CORDEX co-chair Filippo Giorgi,

host directors Atish Dabholkar and Krishnan Raghavan, vice chair of IPCC Working Group I (WGI) Nana Ama Browne Klutse, and CORDEX co-chairs Silvina Solman and Daniela Jacob, Fig. 1.

The opening in Trieste was followed by the three A sessions on “Advancing the regional climate science on decision making scales.”

The first subsession on “Earth system modelling in the regional context” included discussion on the importance of adding additional Earth system components to atmosphere-focused RCMs and topics to consider when doing so, such as the following:

- urban processes, aerosols, oceans, dynamic vegetation, hydrology, groundwater, and glaciers;
- standardization of RCMs of increased complexity/RESMs, including standardized coupling interfaces, documentation, simulation protocols, evaluation approaches, data access, modern software development, best practices, and comparability of RCM results;
- new CORDEX ensembles with RESMs;
- the implications for decision-makers; and
- vulnerability, impacts, adaptation, and climate services applications.

Next was the subsession on “Convection-permitting modeling,” which revolved mostly around the following issues:

- how CPM can improve the representation of different phenomena in different regions and time scales;
- future strategies and cooperation to address issues on resources;
- scarcity of observations for evaluation; and
- implications for impact studies.

The third subsession on the first day was on “Statistical methods/machine learning techniques for regional climate modelling/downscaling” and spanned the following:

- the lack of observational data for model development and evaluation;
- RCM emulators for large ensembles of high-resolution simulations and use of machine learning techniques to downscale full CORDEX domains;
- bias adjustment of RCM boundary conditions;
- whether or not there may be a single model that performs best for all regions and metrics;
- which statistical downscaling techniques are fit for purpose; and
- identifying the climate impact drivers pertinent to a wide range of stakeholders.



FIG. 1. The opening speakers in Trieste and Raghavan Krishnan, director IITM, on the screen.

The fourth and fifth subsessions were held in Pune on the morning of the second day on “Regional climate modelling/downscaling for the South Asia Monsoon region,” which involved, among others, these issues:

- the importance of different South Asia RCMs, including RESMs;
- contributions to the IPCC and the importance of communicating uncertainties to policymakers;
- how countries that have least contributed to greenhouse gas emissions are the most vulnerable to climate extremes; and
- the need for accessible, adequate, and carefully selected climate information for societal sectors such as agriculture, hydrology, energy, health, tourism, or insurance.

The first conference day ended with a poster session followed by an icebreaker with catering and a DJ in Trieste and a conference dinner in Pune.

On the second day, a joint hub celebration of Filippo Giorgi, one of the founders of CORDEX, set the stage for open and lively discussions. This informal element was followed by a joint discussion on insights from the first meeting day and then B sessions aligned with the theme of “CORDEX Interaction with Society.” The Trieste component of this session included the following:

- the importance of context/understanding partners/users, capacity building, and co-creation;
- WCRP Regional Information for Society (RIFS) and its aim to facilitate two-way interaction between scientists and society; and
- different downscaling techniques and how to combine results.

In Pune, there were two B sessions on their third morning. The first was on “Integration of available climate information in support of decision making” with discussions on the following:

- the availability and utilization of data, difficulties finding data and how to use it, and thus the need for structured databases and information systems;
- the acquisition of high-quality data for both observation and network development;
- the pressing need to disseminate existing climate information at a local scale, ensuring the information reaches local-level stakeholders including women farmers and the broader community;
- training and capacity-building programs on the access and use of climate data; and
- a transdisciplinary approach to climate services.

The second B session in Pune focused on “Providing timely and relevant climate information for societal needs,” and offered discussions on the following:

- climatological monitoring and understanding of sector-specific regional impacts;
- the gap between climate science and local climate adaptations and the involvement of rural agencies to make agro-technology affordable for farmers;
- enabling young scientists and students to lead the development of new research through capacity building; and
- management of climate hazards and risks, multimodel and multimethod ensembles complemented by a hybrid strategy, and impacts of human interventions.

A poster session took place in the evening in Trieste, as well as several side events, including one involving the CORDEX FPS: URban environments and Regional Climate Change and two involving the Mediterranean and North America CORDEX domains, as well as an early career scientist event with a focus on “The challenges of data management and data sharing” in a type of circular networking format.

Joint, parallel C sessions on the third day followed the theme “CORDEX for impacts.” For the parallel session on “Societal impacts,” including urban areas, health, renewable energy, disaster management, and land use, some of the topics discussed included the following:

- afforestation causing warming in models;
- fire events in models;
- how models reproduce historical climate;
- the skill of different scale models for predicting winds and the impacts on renewable energy research;
- regional model input to global flood models;
- uncertainties and bias adjustments and how they impact model output;
- how to quantify the impacts of climate change on crop yield with the help of downscaled simulations; and
- impacts of climate change on reindeer husbandry in indigenous populations.

The other C session was on “Natural ecosystem impacts,” including climate change implications/risks for marine and terrestrial ecosystems, coastal environments, biodiversity and wildlife, and featured discussions on the following:

- complex coupled RCMs/RESMs for coastal and sea regions and mountainous regions;
- the need for ensembles;
- future sea level rise and marine heatwaves;
- biogeochemical processes, including levels and dynamics of chemicals and chlorophyll, nutrients, and oxygen;
- cumulative human pressure on the environment; and
- development of particulate matter under various scenarios.

The C sessions were followed by a complementary panel discussion. This panel was kicked off by IPCC WGI co-chair Bart van der Hurk. The discussion then continued with insights from the B sessions. The third day’s last sessions in Trieste were the D sessions, coordinated in a more workshop-oriented style, and with a wide range of topics, including islands, oceans, polar regions, climate services, downscaling methods, urban modeling, and global warming levels. Finally, there were side events on different CORDEX FPSs, one on the impacts of land-use changes on climate and one on extreme precipitation events in southeastern South America.

The final day in Pune started with one D session on extremes and a side event on the WCRP Lighthouse Activity “My Climate Risk.” The day then continued with joint sessions on insights from the day before, a discussion on the future of CORDEX and the way forward, and a summary of the whole conference, Fig. 2. The very last item on the conference agenda was a hands-on workshop called “Create your future” where participants envisioned a climate-adapted society 50 years from now.

3. Conference outcomes and future plans

This conference marked our first attempt at organizing a truly hybrid meeting. While there are areas for improvement, we deem it a success. The availability of streamed sessions,

with the exception of the D sessions, enables attendees to revisit seminars, panels, and discussions. Therefore, the final number of conference “participants” is virtually limitless. However, we note that physical meetings are very important for networking, particularly for early career scientists. Therefore, we need to find a better balance between climate considerations and fostering collaboration between in person and online attendees.

4. The most important take-home messages from this conference are

- It is essential to uphold and strengthen the CORDEX community network and collaborations to meet the opportunities and challenges we face with model complexity, increased temporal and spatial resolution with, e.g., convection-permitting simulations, additional variables, higher demand for data and capacity development, and growing issues with data storage.
- High-resolution simulations pose numerous challenges. To overcome these hurdles and facilitate the transfer of knowledge among scientists and stakeholders, multinational collaboration and innovative coordination strategies are essential.
- The global partnership established by CORDEX is an opportunity that can be expanded to include more global impact studies and engagement with climate services; that is, CORDEX is essential in bridging the gap between climate science and society and should embrace a transdisciplinary approach.
- CORDEX output is already widely used for climate impact assessments, risk management, and adaptation plans. Context is king and co-creation is key, and we need to disseminate existing climate information at the local scale, ensuring it reaches a diverse set of local-level stakeholders and practitioners.
- CORDEX FPS have and will play a pivotal role in advancing CORDEX and their focus on regional climate challenge issues combined with end user engagement could serve as benchmarks for other WCRP activities. One FPS focuses on the Himalayas, but more research in areas with complex topography is needed.
- There is a need for standards for simulation data quality to be more clearly defined and for additional protocol for CORDEX simulations on various scales/resolutions, using various methods.
- Weather and climate impacts do not respect boundaries; hence, international collaboration is crucial.
- Adding components like aerosols, ocean, cryosphere, hydrology, and dynamic vegetation/land use into simulations implies that if new feedback processes are studied, it could lead to a more complete and realistic understanding of the Earth system. It is also vital to maintain freedom of choice of components in RESMs as each region has specific physical processes, feedback mechanisms, and challenges.
- Machine learning/AI and other statistical methods need to be better integrated into CORDEX to provide a more complete picture of climate developments.



FIG. 2. Last day summary and outlook lead by CORDEX co-chairs Silvana Solman and Daniela Jacob.

- Uncertainties in both global and regional models require further attention, and the use of large ensembles may mitigate some of these uncertainties.
- Accessing and effectively utilizing data pose significant challenges, particularly in the developing world, where there is a substantial demand for data, so knowledge transfer is essential. This is particularly crucial as countries that have contributed least to greenhouse gas emissions are projected to be the most vulnerable to climate extremes.
- We need to establish resilient databases and information systems, ensuring accessibility for all relevant users and facilitating straightforward quantitative estimates. Packaging of climate information data and products is important—we need to deliver actionable underlay and help users choose from the plethora of data sources available.
- The lack of observations for validation of dynamical and statistical downscaling methods is a recurrent topic and calls for collaboration across disciplines and borders as well as involvement at local scales.
- We may be past the point of needing to discuss added value in the RCM community, as the value added is now well documented.
- RCMs of increased complexity/RESMs may be used for processes that need coupled approaches but should be compared with their uncoupled counterparts.
- Training and capacity-building programs on the access and use of climate data, along with an assessment of stakeholder perspectives and integration of their needs, may improve our overall efforts.
- Further work needs to be completed on how we/society should prepare for unexpected events and how extremes today will worsen/change in a changing climate.

The CORDEX co-chairs, on behalf of the Science Advisory Team (SAT), have also announced that during 2024, Task Teams will be established to focus on specific scientific challenges. Keep an eye out for a call for nominations.

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