PROCEEDINGS OF THE TRAINING ON

Regional climate change projections

Climate change analysis using CORDEX regional climate models over South Asia

12–14 and 19–21 October 2020 | Platform: Microsoft Teams

Executive summary

Regional climate projections can inform detailed impact and adaptation assessments and planning, especially in vulnerable regions like South Asia. Compared to global climate models (GCMs), they are better able to capture local meteorological phenomena as they simulate climates at higher spatial scales and also aim to improve the reliability and usability of climate projections at the regional scale. It was in this context that the staff working in the national and regional institutions delivering climate services expressed the need to be trained in the analysis of such projections for informed climate change responses in South Asia.

Thus, ICIMOD, the Met Office (the UK's national meteorological agency), the World Climate Research Programme (WCRP), and the Coordinated Regional Climate Downscaling Experiment (CORDEX) office organized – under the auspices of the UK-funded Asia Regional Resilience to a Changing Climate (ARRCC) programme – a six-day training event on regional climate change projections over two weeks in October 2020. Twenty-five participants, including eight women, attended the training; there were four trainees from Afghanistan, five from Bangladesh, nine from Nepal, and seven from Pakistan.

The six-day training programme, organized virtually over the Microsoft Teams platform, focused on imparting knowledge and skills for analysing regional climate change projections using CORDEX regional climate models across South Asia. It covered aspects of climate change science and projections, and instructed the participants on how to access and analyse CORDEX data sets. Through dedicated hands-on exercises, resource persons from ICIMOD, the Met Office, and the Indian Institute of Tropical Meteorology (IITM)–Pune, guided the participants on how to use different open-source tools to analyse and visualize climate change projections at different timescales for user-specified locations.

The programme was part of ARRCC's institutional capacity-building approach, which aims to develop and deliver training services to enhance the institutional capacities of national climate service institutions in the ARRCC focal countries of Afghanistan, Bangladesh, Nepal, and Pakistan; the overall goal is to strengthen these countries' capacity to analyse, assess, use, and communicate future climate projections. This approach targets national meteorological and hydrological services (NMHSs) and other organizations that are working towards providing climate services to government/non-government organizations, communities, and industrial sectors; the underlying motive of the approach is to serve those who are vulnerable to climate change impacts.

During the pre-training surveys, around 25 per cent of the participants had stated that they had poor to average knowledge on climate projections and the topics covered at the workshop. Following the training, this percentage reduced to 2, with 38 per cent of the participants stating that they now had very good knowledge about these topics, and 15 per cent stating that they had gained excellent insights from the overall training programme.

Moreover, the resource persons and participants discussed and charted a road map to support further institutional capacity building on climate projections and services. An engagement plan was also developed, which clearly identifies the roles and responsibilities of the relevant institutions. Moving forward, ICIMOD, the Met Office, and their partners are set to organize a series of similar training activities in 2021 and 2022; these are intended to further build the capacities of individuals at the targeted institutions, develop their skills and knowledge to analyse climate projections, and to produce information products for use in different sectoral applications.

SECTION 1

Background

South Asia and the Hindu Kush Himalaya (HKH) are highly sensitive to climate variability and change. In the recent decades, increasing temperatures, erratic rainfall patterns, and changes in climatic extremes have had profound impacts on agriculture, biodiversity, water, and ecosystems, thereby affecting lives and livelihoods. Thus, to mitigate and adapt to climate-related issues, a thorough understanding of climate change in the past and likely changes in the future is needed.

Institutional capacity-building approach

Ahead of the training programme, it was concluded that the knowledge and capabilities of the staff working at key national and regional institutions delivering climate services needed to be strengthened so that they could be better informed and provide better information on climate change responses in South Asia. The Climate Analysis for Risk Information & Services in South Asia (CARISSA) project, a part of the ARRCC programme funded by the UK's Foreign, Commonwealth & Development Office (FCDO), has been adopting an institutional capacity-building approach on regional climate projections to help meet this need. This approach aims to develop and deliver training to enhance the institutional capacity of the national climate service institutions in the focal ARRCC countries, thereby strengthening their capacity to analyse, assess, use, and communicate future climate projections. The approach targets national meteorological and hydrological services, and other organizations that are working towards providing climate services to government/non-government organizations, communities, and industrial sectors; the focus of the approach is to serve those who are vulnerable to climate change impacts.

A series of training activities between 2020 and 2022 will build the capacities of individuals at targeted institutions so that they can analyse climate projections and produce information products for use in different sectoral applications. These activities will be jointly developed and delivered by ICIMOD and the Met Office, with support from other organizations, including WCRP, the Swedish Meteorological and Hydrological Institute (SMHI), and IITM–Pune.

Objectives and outcomes

The training aimed at building the knowledge and skills of the relevant staff in analysing regional climate change projections using CORDEX regional climate model simulations. It introduced participants to climate change science, modelling, and downscaling, and to accessing and using CORDEX data sets. It also included introductions to tools for analysing and visualizing climate change projections at different timescales.

The specific objectives were to:

- Provide the participants an understanding of the basic principles and concepts of climate science and modelling
- Enable the participants to access and download CORDEX data from the IITM data portal
- Familiarize the participants with the coding language R, using examples to complete the analysis of model data sets over a city or region; and
- Promote discussion on gaps in knowledge and capabilities that can be met with further training.

On the last day of the training programme, the facilitators and trainees co-developed a road map to further support institutional capacity building in climate change projections and services over the coming years; this also included shared objectives and an engagement plan for the participants, clearly delineating their roles and responsibilities. The agenda of the training can be accessed here.

The training enabled the participants to better understand climate model projections and science, as well as access and use CORDEX data to broadly evaluate future climate change over areas of interest. The participants also developed an improved understanding of climate modelling and downscaling. Specifically, they were able to: access and download CORDEX data sets; visualize climate change information; and convert the data sets into different temporal resolutions (monthly, seasonal, annual, decadal) using a pre-prepared code. The programme also outlined a road map for future training and engagement.

Participation

Representatives from institutions involved in the production of national or regional climate projections from South Asian NMHSs, including ARRCC focal countries (Afghanistan, Bangladesh, Nepal, and Pakistan), regional centres, and research organizations attended the training. A total of 25 participants, including eight women, were part of the training; this included four trainees from Afghanistan, five from Bangladesh, nine from Nepal, and seven from Pakistan. The details of the participants can be accessed here.

Follow-up trainings

The original training format, designed to be in person, was changed due to the COVID crisis. Now, follow-up trainings are scheduled for the second and last quarters of 2021. Specifically, before the monsoon of 2021, an in-person training event, based on the R coding language, is set to be held, subject to the COVID situation. This event will build on the 2020 training programme and will include options for spatial and temporal analysis of climate change, comparison with observation data sets, and bias correction. After the monsoon, the CORDEX data extraction and visualization techniques will be based on an advanced analytical tool. The data extraction will be further segregated into different physiographic zones (in terms of elevation and ecological zones) and seasons within the area of interest. Moreover, the training module will include a more thorough concept of climate change science, projections, and uncertainty analysis.

SECTION 2

Day 1

12 October 2020

Opening session

Mandira Singh Shrestha, ICIMOD, facilitated the opening session and provided a brief background of the joint training programme. She explained that in the light of the COVID-19 pandemic, the training was scaled down to a virtual mode and that following ARRCC's institutional capacity-building approach, the training was the first of a series of planned capacity-building events.

Ghulam Rasul, ICIMOD, welcomed all the participants and resource persons to the training event and thanked them for making the virtual training possible amidst the pandemic. He provided information about the three initiatives under ICIMOD's regional programme on Mountain Environment Regional Information System (MENRIS) – SERVIR Hindu Kush Himalaya (SERVIR-HKH), Regional Database System (RDS), and the Climate Services Initiative (CSI). He said these initiatives, with the help of scientific data, Earth observation (EO) information, and geospatial technologies, have contributed to effective evidence-based decision-making processes by governments, communities, and individuals in the areas of agriculture, environment, natural resources, and climate change in ICIMOD's regional member countries. He also stated that ICIMOD has been extending multiple training opportunities, especially for women, and has been organizing regular quorums, workshops, and forums to bridge the gap between science, policy, and practice.

Joseph Daron, Met Office, thanked all the participants for attending the training, and the facilitators for organizing it during such a difficult time. He stated that ARRCC aims to strengthen climate services across South Asia by focusing on four focal countries – Afghanistan, Bangladesh, Nepal, and Pakistan. He also introduced the CARISSA project that aims to improve the uptake and use of future climate projections. He explained that CARISSA is also developing a regional climate change forum in the region so that evidence-based science is fed into the decision-making processes.

Iréne Lake, SMHI, gave an introduction about WCRP and also provided updates on CORDEX developments. She said that WRCP is undergoing a restructuring process and that CORDEX is looking to engage more people in open discussions and in developing points of contacts across communities. She stated that the discussion on the next phase of CORDEX, CMIP6 (Coupled Model Intercomparison Project), are at its final stage and open for the relevant communities to be part of it. She added that flagship pilot studies are in place to address regional and local phenomena and to advance the science within CORDEX. She said that in the new structure of WCRP, CORDEX's importance would lie in bridging the gaps in society through capacity-building initiatives and products. She concluded by expressing the hope that the workshop would be the beginning of tighter cooperation in all areas, especially research.

Mandira Singh Shrestha, ICIMOD, made a presentation on ICIMOD's CSI and institutional capacity-building approach on regional climate change projections. She stated that the CSI seeks to enhance the resilience of mountain communities to climatic risks by reducing socio-economic and physical vulnerabilities; this, she said, would protect the lives, livelihoods, and properties of the vulnerable communities (especially women and children) in the HKH countries. She also informed that ICIMOD is working to establish an HKH Climate Centre to provide a platform for knowledge-sharing activities; this centre, she said, would address transboundary issues, introduce and exchange new technologies, build institutional and individual capacities, and co-develop appropriate solutions.

Santosh Nepal, ICIMOD, the training coordinator provided a brief overview of the training on regional climate change projections. He explained that the changes in climate need to be quantified to help in the decision-making process and in designing strategies to adapt to climate change. Climate data, he said, need to be studied to understand extreme events and their sectorial impacts. Such studies, he emphasized, would help create science-based knowledge to guide the policymakers in making informed decisions.

Setting up the virtual training platform

Utsav Maden, ICIMOD, provided an overview of the Microsoft Teams environment and its different features; he also guided the participants in setting up the Teams platform and in dealing with troubleshooting issues. Saurav Pradhananga and Kabi Raj Khatiwada, both from ICIMOD, were part of setting up the virtual training environments involving the installation of the required software – R, RStudio and the Earth System Grid Federation (ESGF) registration.

Day 2

13 October 2020

The second day of the training covered key concepts on the fundamentals of climate change and CORDEX data.

Joseph Daron, Met Office, made a presentation on the fundamental concepts of climate change science and prediction. He highlighted the key components of the climate and earth systems (such as the atmosphere and biosphere) and explained how various climate drivers – internal and external– influence climate variability and change. He also talked about the role of internal atmosphere–ocean interactions – like the El Niño Southern Oscillation (ENSO), North Atlantic Oscillation (NAO) and the Indian Ocean Dipole (IOD) – and their impacts on multi-year climate variability. Besides, he spoke about how climate modelling could help us understand the dynamics of past and future climate, while emphasizing the importance of dealing with uncertainties to inform decision-making. He explained that there are three main types of uncertainties in climate projection: inter-climate variability; greenhouse gas scenarios; and "model spread".

Cathryn Fox, Met Office, provided an overview of climate modelling and the approaches used in regional and local downscaling of GCMs. She touched upon exploring the suitability of the downscaling methods and discussed different Regional Climate Model (RCM) evaluation techniques and aspects, including statistical downscaling and dynamical downscaling. She then highlighted the shortcomings in GCMs (such as that they cannot resolve small-scale systems like thunderstorms) and that the downscaling of GCMs would help us better understand the processes at a finer resolution and help in assessing vulnerability and in making adaptation strategies. She also explained key concepts such as lateral boundary conditions (LBCs), which are meteorological boundary conditions at the lateral boundaries that provide information from GCMs and reanalysis data to drive RCM simulations.

In her presentation, several examples that compared RCM and GCM data were provided, and the steps of model evaluation were outlined in terms of how well models could simulate the present-day climate. "We do not need a perfect model, just one that serves the purpose"[1] she quoted, going on to say that RCM evaluation was important as it enabled familiarization with the model and its projected output.

Arun B. Shrestha, ICIMOD, made a presentation on climate change and its impact on the HKH region and downstream areas. Citing the Hindu Kush Himalaya Assessment report, he said that the HKH is warming whereby the warm extremes are increasing and the cold ones are decreasing. In terms of precipitation in the region, while the Precipitation Standardized Anomaly (PSA) and the Precipitation Percent Anomaly (PPA) have shown a decrease, they are not significant. Shrestha noted that for the HKH domain, a 1.5 °C global temperature increase means a temperature increase of 1.8 ± 0.4 °C, which is 0.3 °C–0.7 °C higher than the global value. He also stated that the consensus among climate models for the HKH region is weak because of the region's complex topography and the coarse resolution of global climate models.

[1] R. Knutti (2008). "Should We Believe Model Predictions of Future Climate Change?", https://doi.org/10.1098/rsta.2008.0169

Santosh Nepal, ICIMOD, spoke on the impacts of climate change on various sectors. He stated that climate change affects the patterns of rainfall, snow- cover levels, glacier, and permafrost, thereby creating adverse impacts on water availability and hence, human systems and ecosystems. Citing the HKH Assessment report of 2019, he said that one-third of the Himalayan ice would disappear by 2100 as per the Representative Concentration Pathway (RCP 2.6), which he found to be an optimistic scenario at best. He noted that RCP 8.5 is showing that two-third of the glaciers would not exist by the end of this century and pointed out that natural disaster risk events have been increasing in the recent years in the HKH – such as the Uttarakhand flash flood, the Sunkoshi landslide, and GLOF events elsewhere. In case of the Koshi river basin, hydropower plants are at risk due to the potentially dangerous glacial lakes in Nepal and the Tibet Autonomous Region, China. Droughts, which impacted 330 million people in India in 2016, are also an important issue. Nepal stated that while the people are aware of the gradual impacts of climate change, they need to be prepared for sudden and extreme climatic events which are getting common. He noted that a better understanding about climate change and the issues that it brings about would help in designing better adaptation strategies and thus make society more resilient in the future.

Saurav Pradhananga and Santosh Nepal, ICIMOD, spoke on the climate change scenarios for Nepal and shared their experiences from the National Adaptation Plan (NAP) process in the country. In 2015, ICIMOD collaborated with Nepal's Department of Hydrology and Meteorology (DHM) to develop climate change scenarios for the country. Four models for each scenario were selected from a large pool of GCMs. Pradhananga and Nepal spoke about how the team concerned analysed the 11extreme climatic indices that were determined by the NAP for seven different sectors using the selected data sets. During this process, ICIMOD had carried out statistical downscaling of the GCM data using quantile mapping. Thereafter, results from the simulations were presented and it was argued that the scenarios could help design better and more flexible adaptation plans which could deal with the inherent uncertainties.

Burhan Ahmad, Pakistan Meteorological Department (PMD), made a presentation on climate change projections in Pakistan and spoke about the work the relevant agencies have been carrying out in consultation and collaboration with different organizations. The projects have been focusing on climate downscaling using the CMIP5 data set and with the help of collaborations with various partners – such as the Commonwealth Scientific and Industrial Research Organization (CSIRO) and the FutureWater organization. For downscaling, statistical downscaling via delta mean and variability have been used for generating high-resolution data. Ahmad noted that the PMD had collaborated with the University of Agriculture Faisalabad (UAF) to carry out an agriculture model inter-comparison and improvement project which was based on the different regions of the world. In 2018, the PMD had carried out statistical downscaling using the quantile method for CORDEX data for a project on projections and attributions of streamflow composition in the river basins of China and Pakistan. The PMD had also carried out statistical bias correction in the projections derived from CORDEX South Asia across Pakistan. Ahmad pointed out that the impact assessment showed that the intensity of extreme events was increasing and that the model and various scenarios were indicating towards greater temperature increases in the basin. He also cited that the projected streamflow would be rather high for RCP 8.5 by the end of the century during the summer season.

Day 3

14 October 2020

On the third day of the training programme, IITM-Pune made a demonstration on how to access and download CORDEX South Asia data. The resource persons walked the participants through the steps to register with the ESGF and download sample data sets for their specific cities to perform climate analysis. A brief overview of the R codes, along with the installation and setting up of the R software and the required R packages, was also demonstrated.

Introduction to CORDEX data sets

J. Sanjay, Sandip Ingle, and Mahesh Ramadoss, IITM-Pune, provided an overview of data access, data formats, availability, and download options using the CORDEX data extraction tool. Sanjay focused on CORDEX's vision to advance and coordinate the science and application of regional climate downscaling through global partnerships. The CORDEX South Asia RCMs have a resolution of 50 km, downscaled from the CMIP5 climate projections based on RCP scenarios – the historical period was from 1951 to 2005 and the future period from 2006 to 2099.

The Centre for Climate Change Research (CCCR) at IITM-Pune has generated six CORDEX South Asia model data sets using the ICTP RegCM4 model and the SMHI has generated 10 model data sets for the region using the RCA4 model. So far, IITM-Pune has contributed to the development of the ESGF data node for CORDEX in South Asia, and the CCCR is developing a global high-resolution (27 km) atmospheric version of the IITM Earth System Model.

Sanjay presented a few examples on the application of CORDEX data for climate change assessments such as in the HKH Assessment report of 2019 and the National Climate Change report for India of 2020. These assessments suggest that the CORDEX data show a good correlation with IMD's historical data for India, but the use of this data for local assessments is an area for further exploration.

Sanjay also introduced the CORDEX data website and provided brief overviews of RCMs, GCMs, driving models, and the various nodes for CORDEX data downloading. He showed a data extraction tool for directly clipping and downloading the CORDEX data through the CCCR website and demonstrated the steps for data extraction using IITM-Pune's tool.

Practical session

The practical session began by registering for the ESGF portal to download the CORDEX data sets. An "OpenID" registered with the ESGF email was used to extract data from the IITM data portal. The resource persons demonstrated how the downloaded data sets are organized to run the analysis codes smoothly and how the data for specific regions of capital cities can be subset to generate 3x3 grids for analysis. The data were shown to be downloaded in the .nc (network common) data format. During this practical session, the participants downloaded data for two variables – surface air temperature (tas) and precipitation (pr) under RCP 8.5 and RCP 4.5 – from two models.

Day 4

19 October 2020

The fourth day of the training event focused on the analysis and visualization of CORDEX data sets using R studio and supplied R codes. The training began with the participants updating their status on the installation of R studio and acquiring the required packages as well as access to the provided R codes. A shared Google sheet kept track of the status on the data downloads and the installation of the software. Then, a short troubleshooting session investigated the problems that the participants faced while installing the software and the packages.

Saurav Pradhananga, ICIMOD, showcased the historical data analysis and visualization of CORDEX data sets in R studio with the supplied R codes. His presentation covered setting up of the variables, RCPs, time period, the analysis period, reading and extracting .nc files, and temporal aggregations. He also provided general information on the statistics used for the analysis. Five R packages – DevTools, Kendell, Trend, Zyp, and ESD tools – he said, were used for the analysis. The NetCDF (Network Common Data Form) file format is being used for storing multidimensional scientific data such as on temperature, humidity, pressure, and wind speed and its direction. Pradhananga displayed example plots of daily mean temperature, monthly mean temperature, and monthly climatology for mean temperatures and explained how the R codes could be used to generate such plots. The parent GCM determines the inclusion of leap years in the data. He also explained the common statistical methods that are used to test the hypothesis of the existence of a long-term trend.

Practical session: CORDEX historical data analysis using R codes

This interactive practical session focused on the visualization of the monthly and annual plots as well as the trend analysis of the historical IITM-Pune and SMHI data extracted from the CORDEX website. The resource persons guided the participants through every line of the code and syntax included in the supplied R code.

For this training, the participants used RegCM4 and RCA4 data for five major capital cities – Dhaka, Islamabad, Kabul, Kathmandu, and New Delhi – based on two variables in the form of tas and pr. In this context, the practical exercises included the following major steps and analyses:

Installation and loading of the required packages in R for the CORDEX data analysis

Setting the working directory for input and output files

Accessing data sets and recording the required information (in terms of city, time period, models, and variables)

Earmarking the reference period (1976–2005) and removing leap days

Daily data analysis

Monthly data analysis

Monthly climatology

Conducting the Mann-Kendall Trend Test and Sen's slope estimation

Visualizing the output for the historical period
Institutional capacity?

At the end of the day, the participants were able to plot the monthly climatology and trends using the historical data sets pertaining to their area of interest. They also provided plots in the MS Teams chat to show that they had completed their tasks.

Day 5

20 October 2020

Analysis and visualization of future climate change using CORDEX data sets

The day started with the participants reflecting on the accomplishments of the fourth day. What followed was a brief overview of the practical session planned for the day, along with analysis of future climate change scenarios and examples from Nepal's NAP.

Practical session: Climate model analysis

Saurav Pradhananga, ICIMOD, described each line of the code, explaining the significance of each step adapted for the analysis. Santosh Nepal and Kabi Raj Khatiwada, also from ICIMOD, helped the participants with troubleshooting errors during code execution and ensured that none of the participants missed the steps.

When it comes to climate change analysis, it is important to have representative data sets; 30 years is often used as the minimum time length that is required for data to observe changes. On the fifth day, different model runs were conducted by way of understanding future climate change scenarios. All the models had a set reference period from 1976 to 2005. From 2006 onwards, the models differed in terms of projections as they were forced with different RCPs which represented the possible future concentration trajectories of greenhouse gases (GHGs) – according to IPCC AR5. Two RCP scenarios were used – RCP 4.5 and RCP 8.5; while RCP 8.5 is a high-GHG–forcing scenario leading to large temperature increases and impacts, RCP 4.5 is a lower-GHG–forcing scenario with relatively lower temperature increases and impacts.

The major points that were touched upon during the analysis of climate change scenarios were:

Setting up variables (variables, RCPs, time period, analysis period)

Extraction of future climate data from different variables and GCMs

Reading and extracting of .nc files in rows and columns

Temporal aggregation: daily monthly, and yearly mean of all grids

Future changes in climatic variables (in terms of precipitation and temperature)

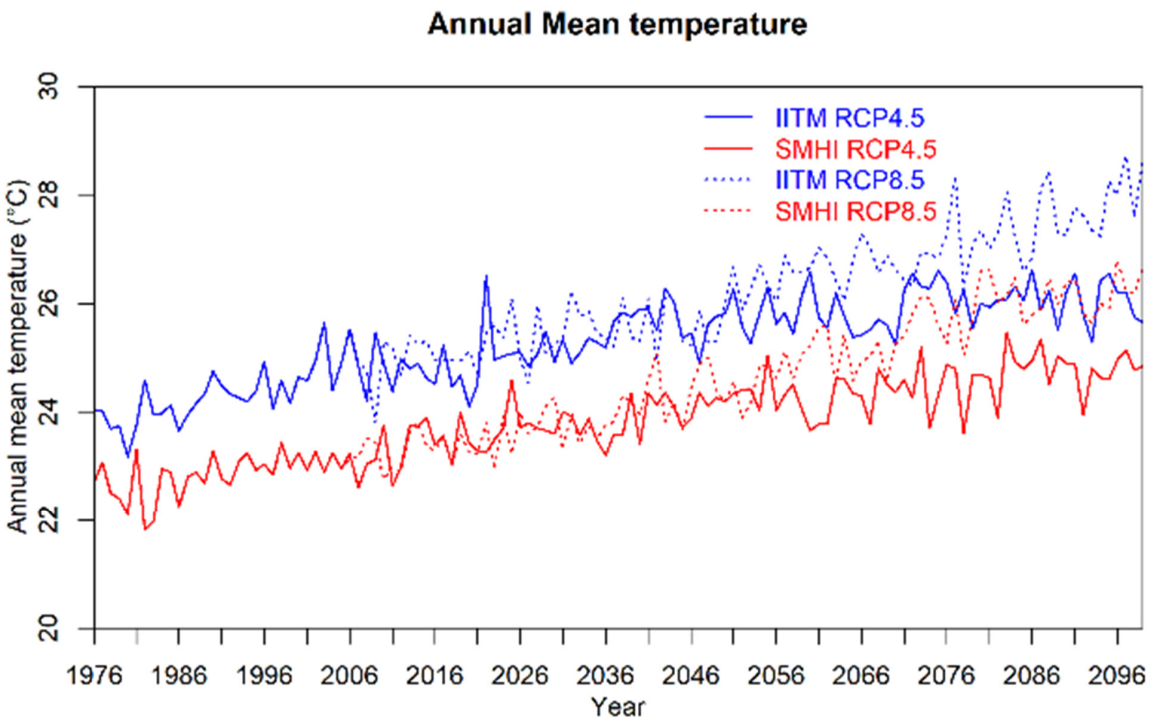
Plotting of relevant maps

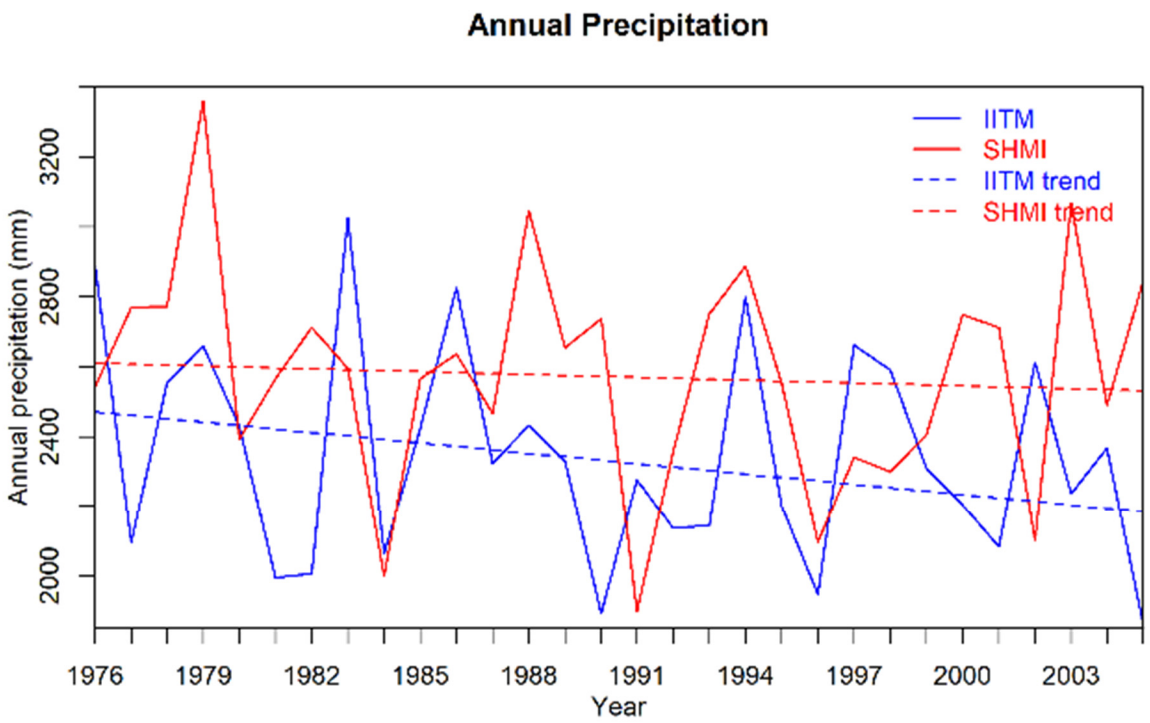
The daily, monthly, yearly, climatological, and future climate change analysis, along with the relevant plots, were prepared by the participants from their respective country capitals. The analysis was helpful in providing knowledge on future climate change scenarios that could inform adaptation strategies.

Data from two regional climatic models – RegCM4-4, driven by GCM CanESM2, and RCA4, driven by GCM and CNRM-CM5 – as well as two variables (mean temperature and precipitation) were used for the analysis. The future period selected was from the year 2070 to 2099. Then the daily, monthly, and yearly analyses, as well as climatological and future change evaluations, accompanied by the relevant plots, were carried out for both RCPs.

The participants produced the climate change analysis results for their respective country capitals. These practical exercises in handling climate data are expected to help the participants in expanding their knowledge about climate change and give them a better idea about sectoral implications which is a priority of the CARISSA project. The follow-up trainings that are scheduled for this year are to focus on more detailed instructions on the spatio-temporal variability of climate change and the impact of the change on some key sectors.

FIGURE 1 EXAMPLE OF THE PLOTS PREPARED BY THE PARTICIPANTS FOR THEIR CITY (DHAKA)





Day 6

21 October 2020

The sixth day saw discussions on a road map for future training programmes which would also define roles and responsibilities. This had been preceded by a consultation workshop with the same participants on establishing the needs and priorities of an enhanced regional climate data portal as part of a separate activity under the CARISSA project (see a separate report).

Road map discussion on future training

Participants were requested to fill in pre- and post-training assessment forms to receive their feedback. During the pre-training surveys, around 25 per cent of the participants had stated that they had poor to average knowledge on climate projections and the topics covered at the workshop. Following the training, this percentage reduced to 2, with 38 per cent of the participants stating that they now had very good knowledge about these topics, and 15 per cent stating that they had gained excellent insights from the overall training programme.

And, 50 per cent of the trainees stated that they were very likely to use the knowledge that they had gained during the entire training programme, while 35 per cent stated that they would use the learnings in their line of work. A summary of the pre- and post-training assessments is included in Annex I.

Breakout session

The participants were divided into four groups in terms of country and allotted thirty minutes to discuss the following questions.

Questions

- What was the most useful part of the training for you personally?
- What was the most challenging part?
- In what ways will you use the information or knowledge gained in this training in your normal job?
- What additional items would you like to see in future trainings?

The answers to these questions are tabulated below (Table 1).

FIGURE 2 PARTICIPANTS' RESPONSE TO KNOWLEDGE ON WORKSHOP TOPICS (PRE- AND POST-TRAINING)

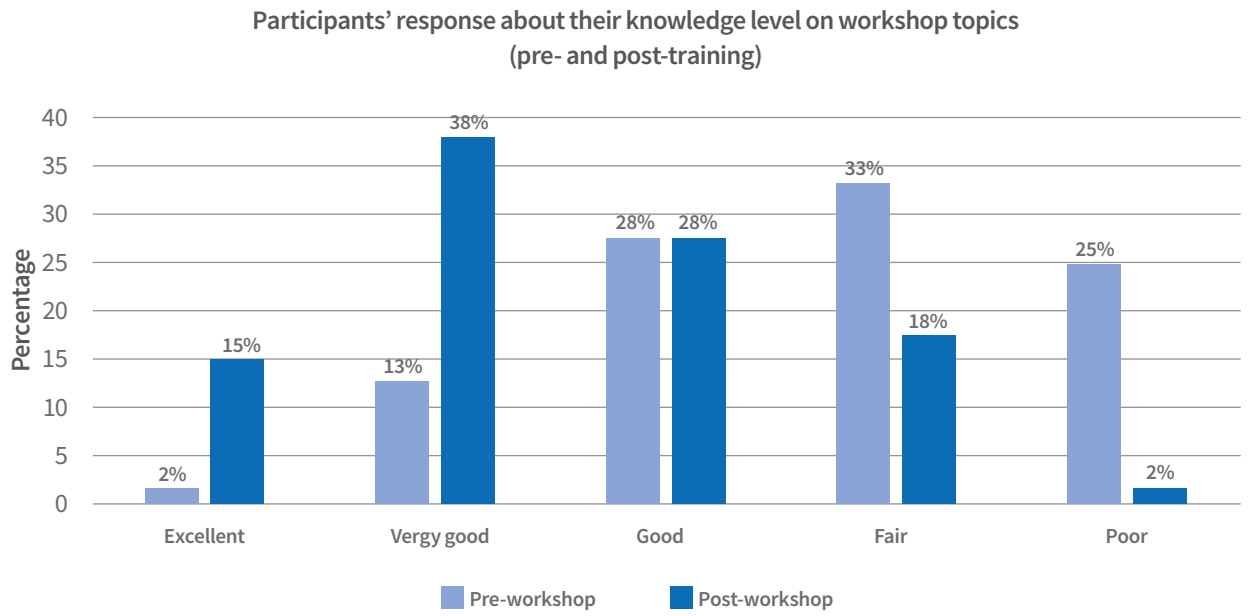


FIGURE 3 **PARTICIPANTS' RESPONSE ON KNOWLEDGE ON WORKSHOP TOPICS POST-TRAINING**

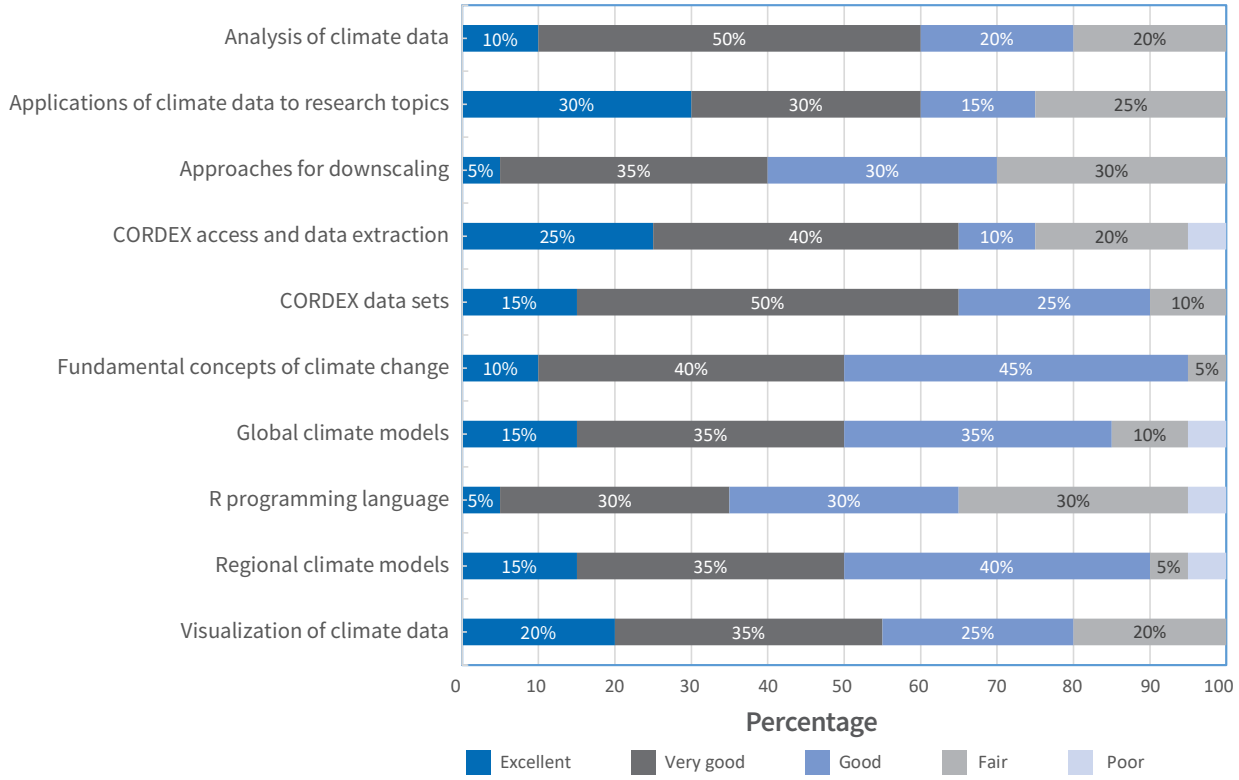


TABLE 1 **OUTPUT TABLE FROM THE BREAKOUT SESSION**

Country	What was the most useful part of the training for you personally?	What was the most challenging part?	In what ways will you use the information or knowledge gained in this training in your normal job?	What additional items would you like to see in future trainings?
Bangladesh	Learning to use CORDEX data using the R coding language	Setting and installing different packages in R, accessing CORDEX data sets, and networking with other participants	Will download and use CORDEX data in the future and use R for analysis and data visualization	More inputs on climate projections and analyses
Nepal	Insights into R, CORDEX data download and extraction, concepts of climate change, climate models and data sets, as well as practical exercises on data extraction and visualization. The final day of the group exercise was helpful in terms of consultation and trend analysis.	Understanding of the R script without prior knowledge was challenging; then there were issues with the selection of an appropriate driving model and the CCCR portal; also, individual data downloading was tedious and time consuming	In research on climate change impact analysis in various sectors; and in climatic research. Decision-making will improve and be more reliable with the climatic information obtained from CORDEX.	Ensemble prediction of climate-bias correction procedures of data. Different downscaling methods, multi-source data extraction, correction, seasonal prediction, uncertainty analysis; and validation of the climate model data with in situ data and weather forecasting data
Pakistan	Climate projections, R language learning, networking, and data downloading	The practical work as a beginner to R language; chat communication; understanding the scripting language; and the time of training which was too early	Will use R language in future research; and utilize CORDEX simulations and R language in research work for future projections and simulations analyses.	Spatial analysis, multiple model outputs, in terms of ensemble averages, more theoretical knowledge in atmospheric science, advance analysis with R, and a data portal facility for downloading

Panel discussion on institutional capacities and future direction

A panel discussion on the road map for such future training programmes discussed the roles and responsibilities that could help develop institutional capacity within the establishments that deliver national meteorological and hydrological services (NMHSs) and other such relevant organizations in the ARRCC focal countries. This session also discussed present and future plans in terms of climate projection analysis in the focal NMHSs and about possible collaboration under the ARRCC programme.

Santosh Nepal, ICIMOD and Cathryn Fox, Met Office, moderated a discussion comprising of the following panellists:

- Farzana Hashimi, Afghanistan Meteorological Department (AMD)
- Bazlur Rashid, Bangladesh Meteorological department (BMD)
- Rajudhar Pradhananga, Department of Hydrology and Meteorology (DHM), Nepal
- Ahsan Ali, Pakistan Meteorological Department (PMD)

The panellists reflected on their respective institutional perspectives regarding the following statements/questions.

Institutional commitments

Q: What institutional commitments (institutional capacities and priorities in terms of resources and infrastructure) are in place to further develop capabilities in climate modelling and analysis?

Afghanistan does not have the capabilities in climate modelling and so capacities need to be built. This is being planned under the Climate Risk and Early Warning Systems (CREWS) initiative.

In Bangladesh, BMD is the only government organization mandated to provide accurate meteorological and climate forecasts on a timely basis; thereby combating and reducing meteorological disasters, protecting public life and property, and properly using climate resources to make meteorological services strong, consolidated, target-oriented, and updated as per the Meteorological Act (2018). In this regard, BMD established a 9-km weather research and forecasting (WRF) model in 2019 and is now running such a fully automated model. Besides, BMD is operating next-generation tools for monthly forecasts, but there's large scope for development in climate analysis and projections. While Bangladesh did present its first official climate report in 2016, the country does not yet have an official climate projection report. BMD is strongly committed to developing its capacity in climate modelling and analysis, and the ARRCC programme will go a long way to be of aid in this sphere.

Nepal's DHM has been developing capabilities in climate modelling and its institutional capacity is improving slowly. At present, DHM lacks staff who are knowledgeable about climate modelling and downscaling and who can use model products like CORDEX. DHM has plans to institutionalize climate-related research and procure a state-of-the-art computational system. DHM requires additional hands-on training on climate modelling and needs to carry out statistical and dynamical downscaling.

PMD in Pakistan has been having discussions with the Met Office on developing climate information. PMD's research and development (R & D) division specializes in climate modelling and has been working to generate country-specific climate projections using GCMs, RCMs, and statistical methods. The R &D division publishes articles and provides data to NGOs in easily readable files. The research community in Pakistan is also using this data. Looking forward, PMD is interested in enhancing its climate modelling capabilities through modern computing technology. At the same time, it is also looking to be part of international research, innovative initiatives, community engagement, and regional groups working on the modelling of climate change dynamics.

Knowledge requirements to build institutional capacities

Q: What kind of trainings or additional knowledge on climate projections is required to further build capacity at your institution? How would this knowledge be used? For example, what kind of further studies, research or climate services are planned?

Afghanistan: The World Meteorological Organization's (WMO's) Commission for Climatology has created a competency framework to help institutions better plan their education and training activities to deliver high-quality climate services in compliance with WMO standards and regulations, specifically those defined by the commission and the Global Framework for Climate Services. To

achieve this, the relevant institutions, through the collective efforts of their staff, must demonstrate the following competencies, or an appropriate set of them, depending on their mission and institutional capacity:

- Create and manage climate data sets
- Extract products from climate data
- Create and/or interpret climate forecasts and model output
- Ensure the quality of climate information and services
- Communicate climatological information with users
- Develop climate projection modelling capabilities

The most important requirement is to fill the data gaps. AMD plans to build its climate services with support from the CREWS project and other similar endeavours. Entities such as Afghanistan's Water Resource Department is already working on filling gaps and arranging the data sets in line with the standard WMO format and also creating an accepted database for meteorology. Besides, AMD is closely coordinating with other related entities working in the areas of water and weather to have stations cover a wider area. Afghanistan has five main climatic regions and multiple microclimate zones which have been divided into sub-climatic zones. Thus, its Ministry of Agriculture, Irrigation and Livestock (MAIL) and its National Water Affairs Regulation Authority (NWARA) have already set up their stations and rain gauges in different parts of the country to connect to the Global Telecommunication System.

Bangladesh: Bangladesh is a small country, yet the resolution of GCMs is insufficient in terms of providing information across different parts of the country. Therefore, there's a requirement for training on statistical and dynamical downscaling so that national-level climate projections can be obtained. Besides, the skills of the forecasters at BMD need to be developed so that they can better analyse climate data.

Nepal: It is vital for DHM to be equipped about climate modelling, dynamical downscaling, and climate projections. Hands-on training on regional climate models is also required. The skills and knowledge gained from this CORDEX training programme will be useful to analyse past climatic conditions and to be prepared for future climate change scenarios in Nepal.

Pakistan: PMD requires more advanced training. It also wishes to be part of regional collaborative activities under the ARRCC programme as it is a good platform to engage with regional research groups and experts at the Met Office. PMD further expects to specialize in the R coding language by way of spatial analysis, handling multiple NetCDF files, and the use of loops in coding. Similarly, PMD would like to have hands-on training in RCMs like PRECIS which is used for analysis to provide update on climate change profiles. PMD is also looking forward to enhancing its research capacity and updating the climate change assessment report for Pakistan which was done 10 years ago. Besides, PMD is working on improving its seasonal forecasting capacity; the knowledge gained in this training will be very helpful for this purpose.

Building institutional capacities

Q: How can the ARRCC programme and CORDEX help build institutional capacities?

Afghanistan: Training on the topics listed below are important requirements; these have also been suggested by WMO for climate service providers.

- Create and manage climate data sets
- Derive products from climate data
- High-resolution climate model for our region
- Create and/or interpret climate forecasts and model output
- Ensure the quality of climate information and services
- Communicate climatological information with the users

Bangladesh: This CORDEX training focused on using tools to analyse climate data sets. The results can be used in climate reports or tools which can be communicated to all community members so that they can use the data for their benefit. It is important that the results of projections are communicated to the communities.

Nepal: ARRCC can support DHM by providing advanced training on climate modelling, skill assessment of models, bias correction, downscaling (statistical and dynamical), and on the generation of information required by various sectors. In this way, ARRCC can enhance the knowledge and skill of the human resources at DHM in climate projection.

Pakistan: ARRCC can help PMD to enhance its capacity by providing access to such training events; this provides PMD with knowledge about the latest technologies in climate downscaling, analyses, and assessment, as well as about how to deal with

uncertainties. ARRCC can also help in improving the skills to deliver such knowledge effectively to the users.

Shahbaz Mehmood, Global Change Impact Study Centre (GCISC): The GCISC in Pakistan develops climate change projection estimates and has experience of developing climate change projections using regional climate models like PRECIS. It now plans to repeat simulation with the latest GCM data sets that have been acquired in a new server which will soon be operational. GCISC would appreciate on-site, long-term training for its researchers at the Met Office Hadley Centre. Training on models, software, and the environment where the models are run should also be useful for professionals who are involved in the computational aspect of the whole scheme. The inputs from the discussion provide very useful and detailed information for the CARISSA team to consider and take forward in its plans for upcoming trainings under ARRCC.

Closing session

Santosh Nepal, ICIMOD, summed up the entire CORDEX training exercise. He stated that the climate change analysis carried out using the R platform, along with some statistical analyses, would be useful in other areas as well. He added that the evaluation session was helpful in terms of knowing the challenges that the participants faced during the training and in getting an idea of the content that the participants would like to see in future trainings.

This training, he said, would be the first in a series of trainings aimed at institutional capacity building. Dwelling on the interactive panel discussions, he said that it allowed the participants from NMHSs to share their vision. This, he said, has paved the way for etching out future training programmes. He also referred to the information gathered from the breakout sessions and panel discussions, saying that it would be helpful in setting priorities for ARRCC, the Met Office, and ICIMOD. He went on to inform that, as a part of the institutional capacity-building approach, a series of training activities, from basic to advanced climate change analysis, would take place within the next two years.

Joseph Daron, Met Office, stated that the participants were able to learn new skills in climate data analysis with the R coding language. He expressed his happiness over the completion of the training event in a virtual environment and that too with negligible technical glitches. He also cited the fact that the Met Office and ICIMOD had organized a side event at the 6th International Conference on Climate Services (ICCS6) to explore the possibility of establishing a regular and sustainable regional forum on climate change projections in South Asia. He said that this forum would offer an opportunity to promote wider knowledge exchange and cooperation among climate scientists, climate service providers, boundary organizations, and climate change policymakers and specialists. The three components of the work are being performed: online community, South Asian Seasonal Climate Outlook Forum expansion and setup of dedicated forum. The forum could support further training and knowledge exchange amongst organisations attending the training. Finally, he thanked the resource persons, the organizing team, and the participants for their time and contribution.

Lindha Nilsson, CORDEX International Office, thanked the participants and organizers for a successful event. She said she really enjoyed listening to the feedback from the training. She emphasized that CORDEX is looking forward to continue to be part of such regional collaborations.

Ghulam Rasul, ICIMOD, congratulated all the participants for successfully completing the training programme and thanked the organizers for making it possible. He emphasized that mutual learning is more important and effective than learning from instructors. Saying that as the panel discussions involving the NMHS institutions from the four countries have been rendered fruitful, ICIMOD would try to include other private organizations as well in order to accommodate all shades of opinion. On the panel discussions, he said they have helped to create a clearer pathway in terms of understanding what would be needed in future training programmes.

Eklabya Sharma, ICIMOD, stated that along with technical advances, it was important to look at the value addition to the region through climate projection activities. The end users need to be considered, he emphasized. He also commended the fact that the training could be completed even during such a difficult pandemic. Such trainings and workshops, he said, could be stepping stones towards a bigger goal – the establishment of a regional climate centre, a long-term vision of ICIMOD that it hopes to materialize through enduring partnerships.

Additional event information and materials are available at:
https://www.icimod.org/event/regional-climate-change-projections-cordex/

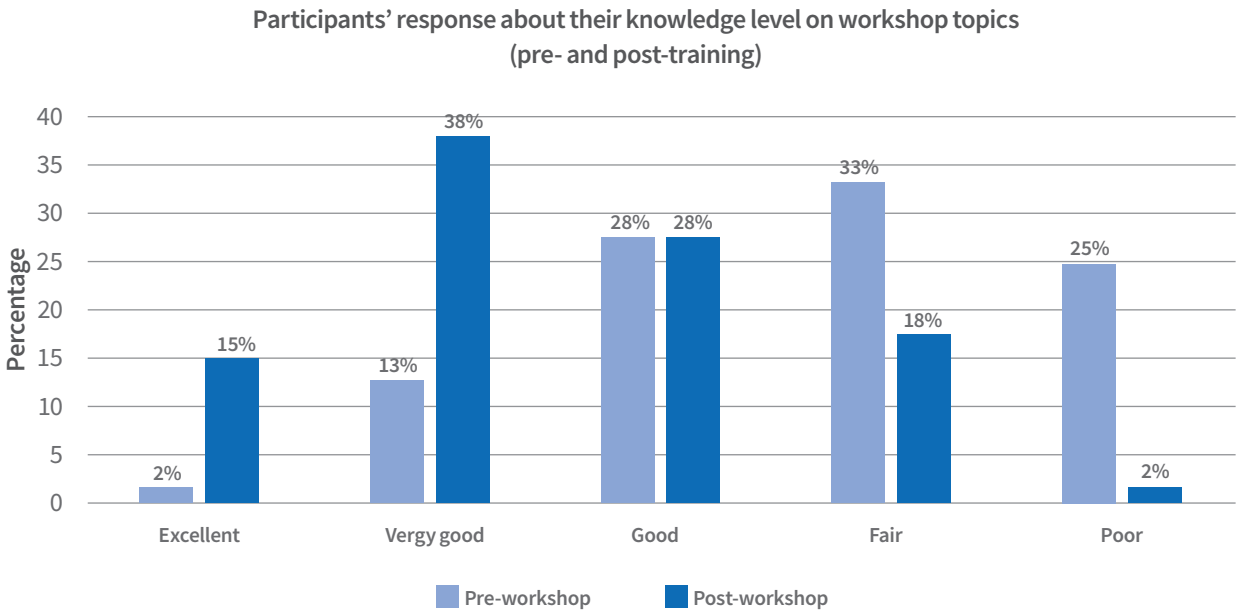
File links:
Agenda
List of participants

SECTION 3

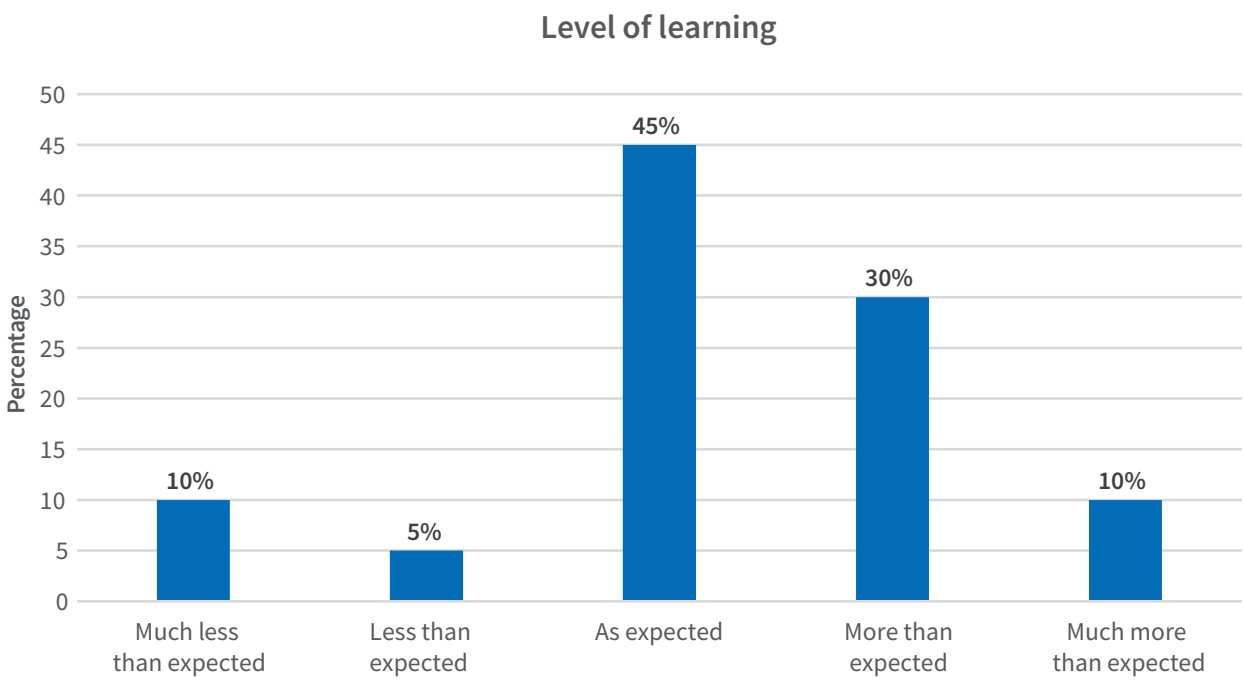
Annexes

Annex I: Participants' reflections on the training

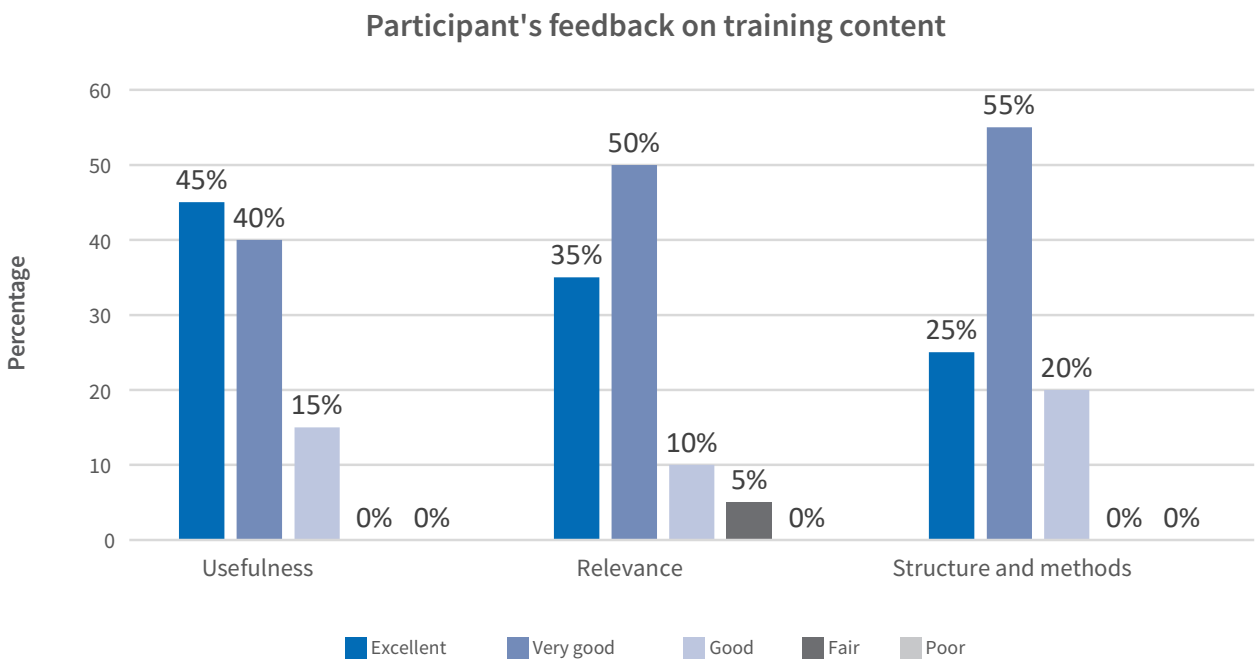
Participants' response about their knowledge level on workshop topics (pre- and post-training)



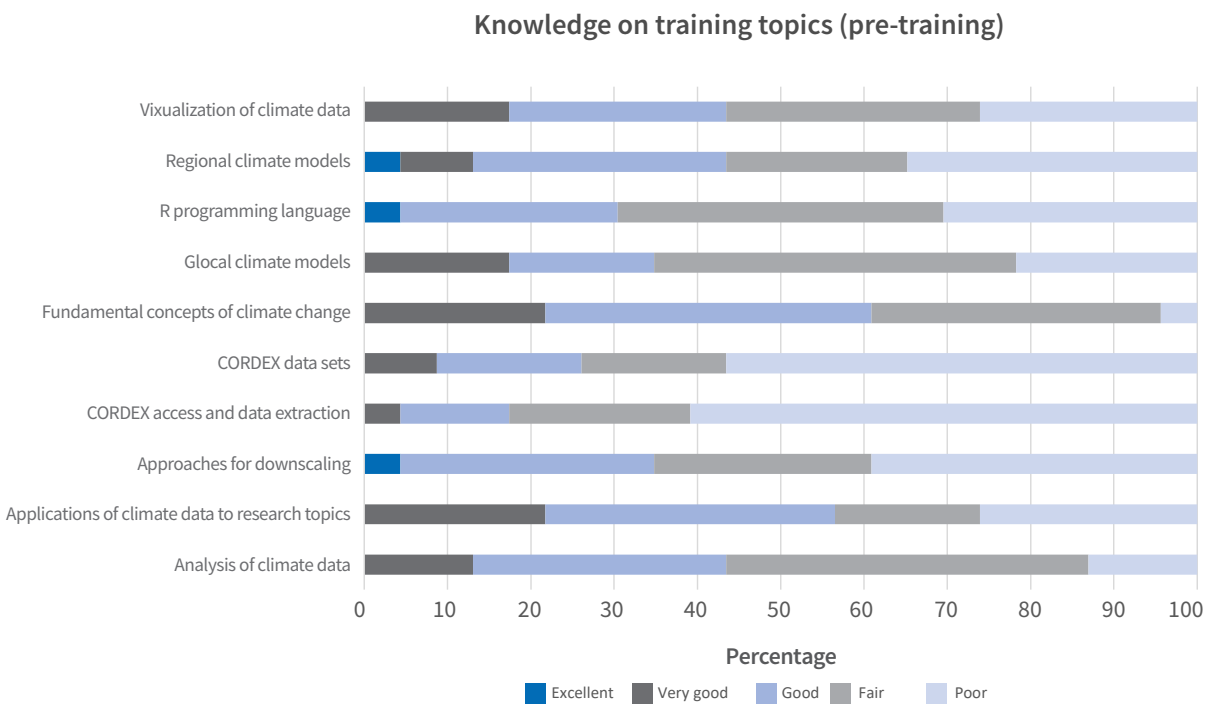
How much did you learn from the training?



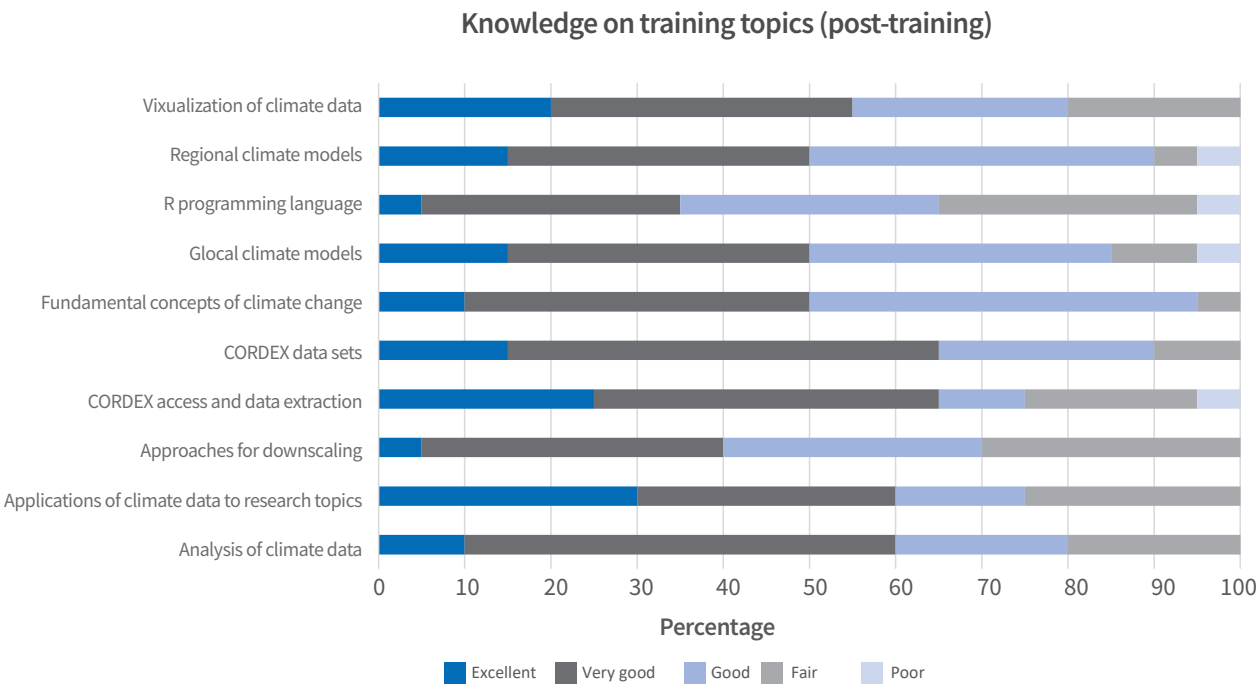
How would you rate the overall content of the training in the following areas?



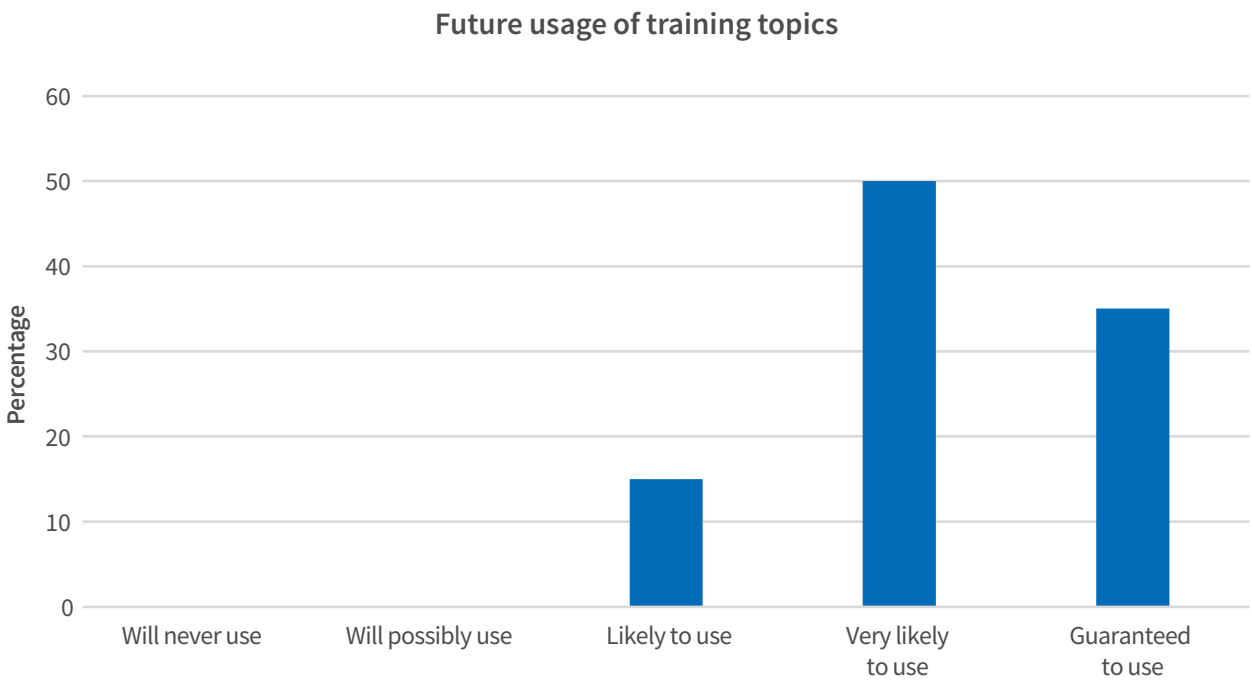
How would you rate the quality of the training in the following areas?



Post-training, how would you rate your knowledge on the following topics?



How likely are you to use the information or knowledge you gained in the training in your normal area of work?



Annex II: Pre-training assessment form

Thank you for your participation in this training. We would very much appreciate your support in responding to the questions below. Your contribution will help us in conducting an overall evaluation of our capacity-building efforts, update our training to meet our participants' needs better, and inform our follow-up activities. Please respond as appropriate.

1. Name (optional): _____

2. Gender

   - Woman
   - Man
   - Other
   - Prefer not to say

3. Organization/Department affiliation: _____

4. Role/Job title: ____

5. Why did you choose to participate in this event? (Choose the most appropriate one)

   - This training is relevant to my job
   - To build basic knowledge and skills on the subject
   - To enhance my knowledge and skills to an advanced level
   - Exposure and professional networking
   - Other ____

6. Was this event properly communicated to you on time?

   Yes / No

7. How would you rate your knowledge on the following topics?

	Poor	Fair	Good	Very good	Excellent
Fundamental concepts of climate change					
Global climate models					
Regional climate models					
Approaches for downscaling					
CORDEX data sets					
CORDEX access and data extraction					
R programming language					
Visualization of climate data					
Analysis of climate data					

8. Please list your expectations from the training.

_____

_____

9. Additional remarks

_____

_____

10. Video/photo release

I grant permission to ICIMOD and its agents and employees the irrevocable and unrestricted right to reproduce the images taken of me for the purpose of publication, promotion, illustration, advertising, or trade, in any manner or in any medium. I, hereby, release ICIMOD and its legal representatives from all claims and liability relating to said images or video. Furthermore, I grant permission to use my statements that were given during an interview or guest lecture, with or without my name, for the purpose of advertising and publicity without restriction. I waive my right to any compensation.

Yes / No

Annex III: Post-training assessment form

Thank you for your participation in this training. We would very much appreciate your support in responding to the questions below. Your contribution will help us in conducting an overall evaluation of our capacity-building efforts, update our training to meet our participants' needs better, and inform our follow-up activities. Please respond as appropriate.

1. Name (optional): _____

2. Gender

   - Woman
   - Man
   - Other
   - Prefer not to say

3. Organization/Department affiliation: _____

4. Role/Job title: _____

5. How would you rate the overall content of the training in the following areas?

	Poor	Fair	Good	Very good	Excellent
Usefulness					
Relevance					
Structure and methods					

6. How much did you learn from the training?

   - Much less than expected
   - Less than expected
   - As expected
   - More than expected
   - Much more than expected

7. How likely are you to use the information or knowledge you gained in the training in your normal area of work

   - Will never use
   - Will possibly use
   - Likely to use
   - Very likely to use
   - Guaranteed to use

8. How would you rate the quality of the training in the following areas?

	Poor	Fair	Good	Very good	Excellent
The presentations were clear and to the point					
The training was interactive					
The presenters were highly knowledgeable about the subject material					

The training achieved its goals and objectives					
The materials/handouts were useful					
The presentations were interesting and practical					
Adequate time was provided for attendee questions					
The content was well organized and easy to follow					
The training met my expectations					
Breaks were adequately provided					
The online delivery of the training was adequate					

9. How would you rate your knowledge of the following topics after the training?

	Poor	Fair	Good	Very good	Excellent
Fundamental concepts of climate change					
Global climate models					
Regional climate models					
Approaches for downscaling					
CORDEX data sets					
CORDEX access and data extraction					
R programming language					
Visualization of climate data					
Analysis of climate data					
Applications of climate data to research topics					
10. Additional remarks					

11. Video/photo release

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Yes / No

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