Questions & Answers Part 1

Please type your questions in the Question Box. We will try our best to answer all your questions. If we don't, feel free to email Alexander Ruane (alexander.c.ruane@nasa.gov) or Brock Blevins (brock.blevins@nasa.gov).

Question 1: Are you aware of any case studies using the CMIP 6 model projection for local studies at the basin scale in the current changing climate? If so, could you share?
Answer 1: Hard to answer this question. There are hundreds of studies using climate projections for basin scale applications, but most use CMIP3 and CMIP5 or earlier datasets. Those using CMIP6 are being published now and you will increasingly see them. They use downscaling or bias adjustments. I would look to the CORDEX community and LOCA in the United States, to get to the basin level. ISIMIP information was used to run hydrology models around the world, and also fed into regional studies.

Question 2: It seems most papers use RCPs, which makes it easier, but I saw a paper that talked about 3-degree warming, and I have trouble understanding how that compares to all the RCP-based research.
Answer 2: Projections built around RCPs are effectively tracking a given set of societal actions and greenhouse gas emissions over time (for example, from today through the end of the 21st century). Along this **pathway** global temperatures increase from today's ~1.1C warming above pre-industrial conditions out to higher levels. Along the way these may pass benchmark global warming levels like 3 degrees Celsius, but this warming level may come at a different year in each ESM and RCP examined. By looking at benchmark global warming levels we can link multiple ESMs and RCPs – here uncertainty comes from the amount of time we have to reach each GWL, but we can capture consistent climate information associated with that amount of global warming.

Many climate conditions are similar at a given level of global warming level regardless of whether that global warming level happens sooner or later, but lagged responses such as the melting of glaciers and sea level rise can have a strong dependence on the amount of time it takes to reach a global warming level. Because the equilibrium global warming level depends largely on total emissions and land use change, this approach

is particularly appealing for mitigation studies relevant to international UNFCCC negotiations.

Question 3: Is the "forcing level" the same as degrees of temperature change?
Answer 3: Forcing levels are strongly related to the total amount of temperature change with higher forcing levels leading to higher temperatures, but it is not the same thing. When we see RCP8.5 that indicates a radiative forcing of 8.5 W/m2 caused by human influences at the end of the century, but this should not be confused for an 8.5C rise in temperature. RCPs also have a time progression, so the overall level of warming and the difference between RCPs generally grows over time.

Question 4: On the slide titled “2. Scenarios and Storylines”, what does Tier 2 refer to?
Answer 4: Climate models had to prioritize the specific SSP-RCP scenarios that they ran, so the ScenarioMIP community within CMIP6 developed tiers to denote the set of scenarios that would be most useful for applications and understanding. Higher tier scenarios are the most commonly available.

Question 5: How do we project future scenarios by using change factors for temperature and percentage change for precipitation together with historical observed temperature and precipitation data?
Answer 5: Relating to bias adjustments, we can take the outputs we trust (larger scale, broader) and impose extreme temps, etc. and good observations into the model world. Or secondary approaches, take model data and impose climate changes into the observed data.

Question 6: Do we apply the same bias adjustment calculated between observation and baseline projected climate to the future period? If so, are we not forcing the same historical statistics to future periods?
Answer 6: If we apply bias to the future based on recent years, we have to ask if those relationships will continue to hold in the future. Things like large snowpack or irrigated conditions that might be altered by climate change, imposing those into the future may not make sense anymore.

Question 7: Are RCPs scenarios now considered to be outdated, and only SSPs should be used from now on?

Answer 7: I want to draw a distinction, RCP are used to get climate information, and SSPs are for societal information. SSP combined with RCPs is the method being used in CMIP6.

Question 8: I'm interested to know where we can download the CMIP6 downscaled dataset. Earlier datasets like CMIP5 were available on the CIAT site. Is there any website for CMIP6?
Answer 8: Various modeling groups may provide downloadable data from their individual institutions or centers, but there are several central hubs where users can access CMIP6 data for multiple modeling groups, GCMs, variables, and experiments/scenarios. One such hub is the Earth System Grid Federation (ESGF), which is available under multiple nodes. Downscaled or post-processed CMIP6 data may be available from project websites, such as NEX-GDDP-CMIP6 or ISMIP3.

Question 9: To clarify- is downscaling a type of post-processing always, or is it somehow a different thing? My understanding from this is that all downscaling is post-processing, but not all post-processing is downscaling.
Answer 9: There are semantics involved here- when I am talking about post-processing in this context, I mean after the output has been simulated. It is possible to have nested grids global models and all run together. **Not all post-processing is downscaling, that is true.** Some post-processing may have a different motivation than purely downscaling.

Question 10: What is the role of trends from observational/historical data in building climate change scenarios?
Answer 10: There can be a gap between historical trend and projection set. It may be difficult to separate decadal trends. In some cases, they may point to potential bias in the model that should be looked at for further analysis.

Question 11: Given the difference in the level of development of different countries across the world, how do the existing projections consider the differences to offer in-depth information of current and future scenarios and adaptation interventions required based on country scenarios?
Answer 11: Stay tuned for Part 2, but the amount of data in the given region does need to be taken into account. Data rich areas are easier to apply bias.

Question 12: Do you know why the interactive CMIP6 mapping tool from IPCC took down their large hydrologic basin level data (for instance, the Colorado River basin in the US) that enabled comparison with CMIP5 datasets? And if that functionality will be made available in the future?
Answer 12: I assume you mean the IPCC, Interactive Atlas. I am not aware of this and do not have an informed answer.

Question 13: To calculate the mean of a long time series (MERRA-2 Mean September SSTs 1980-2009 (degrees C)), if changes have already happened or are happening now, should the values of all years have the same weight for calculating the mean? In this context, would it be appropriate/correct to have a long time series? How long?
Answer 13: Important point, it is always nice to have a long history of data. It's important to understand your reference period. We want a period most representative of the system we understand today, but long enough to include fundamental climatology statistics. You will want a time that WMS encourages 30 years for climate studies. This is sometimes shortened to 20 years but you should use caution.

Question 14: Regarding the data extracted from the netcdf files from CORDEX, how can we check the data validity? I normally use the coding to get the rainfall and temperature data, to clip the Regional data for the study area. How can I know the data validity after coding?
Answer 14: I don't want to claim to have the only solution, but I usually plot out a simple map of temperature and compare it to well known observations to check.

Question 15: What are the main criteria to consider applying Statistical downscaling and bias correction? / Are there any free softwares available for bias adjustments? If yes, then kindly suggest a few which are free of cost for academic research?
Answer 15: Statistical approaches to maintain inter-variable coherence and extreme event characteristics, the possible use of dynamical downscaling, a balance between the level of desired detail / resources available / quality of observational data, the extent to which bias-adjustment patterns are likely to be persistent over time (or respond to climate change itself), and the set of climate models and scenarios that contain the main human-driven responses. There are some available tools for downscaling (e.g., from ISIMIP) and many published methods – perhaps check out Bias-Corrected Spatially Disaggregated (BCSD) methods and others as well.

Question 16: What latest models are available to make projections of SLR at regional levels? And how reliable are they with respect to making accurate projections? Moreover, do these models consider any sensitivity analysis while making projections?

Answer 16: Relative sea level projections are most useful when they factor in different changes in the ocean system (mass additions from melting ice, thermal expansion from warmer temperatures, and changes to currents that can shift relative heights) and changes in local land subsidence or uplift (from glacial rebound, groundwater extraction, oil/gas extraction or river sediment flux changes). The IPCC has a sea level rise tool developed in conjunction with NASA that has more localized projections.

Question 17: How do you think that emission scenarios for CMIP7 will differ from SSP-RCP ? When do you expect them to get public?

Answer 17: These are not yet determined so I do not want to speculate. There are processes underway to develop coherent and applicable scenarios within CMIP, IPCC, ICONICS and other groups that use these scenarios. In the second training we will discuss how scenarios have changed over recent years, which also is indicative of the types of further changes we might expect for the next round of development.

Question 18: Which of the tools are important for NDC sectoral analysis MRV process, planning and implementation and monitoring and evaluation of nationally determined contributions (NDC)?

Answer 18: NDCs are themselves storylines of future societal actions related to greenhouse gas emissions and land use which will affect the overall level of warming. These lend themselves most strongly to mitigation applications that weight the challenges and benefits associated with such actions. NDCs and similar mitigation storylines also have large synergies and tradeoffs with sustainable development and underscore the importance of selecting projections sets that might be consistent with wider systems assumptions.

Question 19: Besides precipitation and temperature, how important are wind speed, solar radiation, and relative humidity for hydrological modeling under climate change? Can we use historical data of them with projected data of precipitation and temperature?

Answer 19: We know that wind speed, solar radiation and relative humidity are important factors related to potential evapotranspiration and the overall water balance

of lakes, rivers, aquifers and soils. This has important implications for water resource management, agriculture and ecosystems. In some cases sectoral impact models assume that these secondary influences on evapotranspiration remain consistent over time, but several applications have shown that these can change in ways that make them important drivers of future sectoral risks.

Question 20: Did we measure how much glaciers melt and how can we measure a century of data through CMIP 6? If we need good resolution data and we use new satellites, then why do we use downscaling to get better resolution?
Answer 20: Our best understanding of glacier melt comes from direct and satellite observations, with climate models providing important insights into the large-scale and fine-scale climate processes associated with these changes as well as the ways that melt might change in the future. While the global-scale losses of snow and ice can be fairly well captured in coarse models (particularly when compared with paleoclimate data), the fate of regional glaciers may be strongly affected by shifts in circulation patterns and land use that may affect wind speeds and directions, atmospheric moisture and energy and water balances at various elevations and slope directions. Models are also improving their representation of ice dynamics to incorporate information about local processes (e.g., grounding lines for ice shelves and the role of sub-surface liquid water flows for ice sheets).

Question 21: What is the main difference between CMIP6 and ISIMIP? Which is better for regional studies?
Answer 21: We will discuss ISIMIP further in the next training session. Some prominent differences: CMIP6 provides raw outputs from Earth System Models (ESMs), while ISIMIP further processes these data to reduce bias and re-scale onto a common, finer-resolution grid. ISIMIP only contains a subset of the models, scenarios and variables available within CMIP6, but has selected and processed its projections to facilitate consistent impacts modeling across many sectors.

Question 22: Mitigation is largely used around GHG emission reduction. Here you describe mitigation as a level of preparedness for climate change. Could you describe how you are discussing the difference between the two to not create confusion for stakeholders?
Answer 22: Adaptation, risk, mitigation: some depends on the context and the different decisions being made. If you are part of a farming comm or commodities, you may be

interested in adapting to the changing systems. Preparedness means variations of adaptation and risk management.

Question 23: Are there any presentations or tutorials for dynamic or statistical downscaling of climate data, whether it uses machine learning?
Answer 23: Not specific tutorials, But this is a hot and up and coming topics. There are tutorials on ML and ones on downscaling. Please note this in the post training survey and we can use that to justify a training on.

Question 24: What types of coupled climate-hydrological models are available for regional scale planning?
Answer 24: A deep topic. A coupled model is a 2 way interaction between the 2. We are looking to improve interactions in the climate model. ISIMIP

Question 25: What is the key difference between the delta method and advanced methods for bias corrections? Do the advanced methods affect timings of peaks? Do these correction methods affect the seasonality?
Answer 25: Delta was the most common approach (time series for an area) than take the projection and compare. Then take the hist obs and add that difference between the projection and obs. Adv techniques goes into frequency of rainfall events, it may impose a change in std dev, or # rainy days, rainfall intensities. In part 2 we will discuss the tradeoffs between. Both can address seasonality.

Question 26: About spatial resolution for projections, what would you recommend for a region such as the Andes, where the altitudinal gradient is really large?
Answer 26: This is a different region due to topography. A climate model struggles with this. Obs datasets may be available that captures these effects and suggests bias correction should be in order. Dynamically downscaled may be the more appropriate type.

Question 27: Is there a bibliography (or references) that recommends mitigation, adaptation, and risk management applications?
Answer 27: The major assessments reports (6th) from the IPCC. Working group 2 was published this year (2022). It breaks it down by region or sector. WG 3 (2022 report) focuses on mitigation. They look through 1000s of studies in the report. The 3 WG are being merged into a synthesis report.

Question 28: Are large-scale modes of variability (e.g., PDO, AMO, NAO, and ENSO) adequately represented by global climate models?
Answer 28: These are modes of atmospheric variability, and models to capture the behaviors in various degrees. Updated model should reflect these modes.

Question 29: How do you adjust for changing land cover since the Amazon and many other locations are losing their forests?
Answer 29: Bias adjustment, in the Amazon given the forests there today will not be reflected in the projections.

Question 30: Are there any R packages or QGIS plugins or servers (e.g., using FileZilla) through which these projections can be downloaded?
Answer 30: I imagine there are, there are excellent researchers looking at these and often share on github, etc. Climate4R
Information on Climate package in R
ClimateR GitHub
Climate4R GitHub and publication

Question 31: Is it reasonable to use the delta method on weather model or reanalysis data rather than observations?
Answer 31: In part of the world you cannot find observations. Weather models tend to be oriented to short term weather predictions. Realaysis models draw in obs from many sources, assimilated of the state variable fields of the weather models. Some variables are not assimilated (e.g. surface temp, or rain rate). Trade offs on observation quality.

Question 32: Where do you recommend we look for CMIP6 projections data to use in GIS software? I know of these two websites -
https://psl.noaa.gov/ipcc/cmip6/ and
https://www.worldclim.org/data/cmip6/cmip6climate.html
Are there other sources you could share?
Answer 32: There is a LONG list of information on these. Those 2 are good ones. Earth Systems Grid Federation (ESGF). Using raw climate projections may be downscaling and/or bias adjustments. Worldclim has fine resolution but does not always have high fidelity to all applications. There are many good uses of worldclim but it does not have sub-monthly data.