



## Questions & Answers Session 2

Please type your questions in the Question Box. We will try our best to get to all your questions. If we don't, feel free to email Sean McCartney ([sean.mccartney@nasa.gov](mailto:sean.mccartney@nasa.gov)) or Amita Mehta ([amita.v.mehta@nasa.gov](mailto:amita.v.mehta@nasa.gov)).

Question 1: The resolution of climate models is improved thanks to higher-resolution satellites or thanks to higher calculation power?

Answer 1: Both! Satellites and other observational sets have improved our ability to observe and understand fine-scale features of the climate system, resulting in improved physics and model representation of more advanced processes. This improved understanding could not necessarily be implemented in the models without high-performance computers, which give us the computational power to resolve higher-resolution processes.

Question 2: How can I assess the effect of climate change in a specific region on a local scale using Earth observations and for how long of a period should the analysis be carried out?

Answer 2: Part I of this ARSET training described vast resources within NASA and partners that have observational products related to many aspects of the climate system (temperature, precipitation, ocean salinity, snow, ice, fire, etc.). Climate phenomena can occur on fast or slow time scales, but we recommend at least 20 years of data to capture robust statistics of long-term trends or distributional changes (e.g., shifts toward more extreme events). For the most rare extreme events longer time series may be needed.

Question 3: What is the ideal climate modelling for maritime countries such as Indonesia compared to a landmass such as the USA or Australia?

Answer 3: Some aspects of maritime climate are better captured by regional climate models that are able to capture complex land/sea circulations and the influence of mountains. Regional models will add important local detail, even as much of the large-scale pattern is captured by global climate models. Finer resolution is not always a better signal.

Question 4: How does one downscale climate models? What is the highest resolution that can be attained?



Answer 4: For example, climate models at 100km resolution can be used as boundary conditions to drive a regional climate model at 30km, which in turn may be used to drive an additional downscaling model at 10km, etc. This “nesting” of climate models can be extended down to very fine scales (some atmospheric models get down to the meter scales), however there is a degradation of signal with each model and there is a tradeoff between model resolution and robust climate change signals. In other words, just because we can scale down to very fine resolutions doesn’t mean that it is always the most useful thing to do (especially when resources are limited). We recommend choosing your resolution depending on the application you have in mind and the likelihood that fine-resolution processes and geographies will have an influence. A major challenge is directly representing atmospheric convection, which introduces a new set of important physics to directly resolve when resolutions are finer than  $\sim 8$ km.

Question 5: Which climate models do you use? Are they open source? Also, which programming languages are they developed in?

Answer 5: The Sixth Coupled Model Intercomparison Project (CMIP6) included around 100 models from around 50 modeling groups. All models are documented in peer-reviewed publications and many are open source and freely available (including the NASA GISS Model-E). Models are developed in a variety of languages, but often use Fortran due to its computational efficiency.

Question 6: What does the 0 indicate in slide 24?

Answer 6: Zero represents the time when net-zero carbon emissions occur, meaning that the total amount of carbon (greenhouse gas) emissions from human activity is reduced to a level that can be matched by human activities that remove carbon from the climate system.

Question 7: Are corals a net contributor to atmospheric CO<sub>2</sub> or do they help in sequestration?

Answer 7: Corals use carbon in their skeletons and therefore can help sequester carbon from the climate system.

Question 8: Which is the scenario that seems to be the one we follow according to the decisions that are already implemented? RCP 1.5 or RCP 8.5 ?



Answer 8: Most of the scenarios are quite similar in recent years given that they all initialize from the same starting point in the early 21st century. Emissions have been among the higher pathways in recent years, but these pathways are much more distinguished in future decades (10+ years out into the future, and especially 30+ years in the future). RCP7.0 is increasingly being used as a high emissions pathway rather than RCP8.5 given recent trends in coal use.

Question 9: Currently there are a series of scenarios that have been generated around the world, in your case which is the best scenario for Mexico?

Answer 9: The best approach for any region is to look at a variety of climate models and SSP-RCP scenarios in order to understand climate and pathway uncertainties. Downscaled scenarios (e.g., from NARCCAP or CORDEX) may be appealing for more regional information, as would the NEX bias-adjusted scenarios.

Question 10: How can I assess the effects of climate change on a specific region on a local scale using Earth observations? and for how long should the analysis be carried out?

Answer 10: It is important to characterize current climate using weather stations and remote sensing products that capture key aspects of the climate that affect the things you care about. For example, we have precipitation products for heavy rainfall and drought and we have temperature products for extreme heat. Climate models then tell us how the climate will change, indicating shifts in trends and the distribution of extreme events, and we can potentially use bias-adjustment or downscaling to reach the scales of decision making. It is important to look at changes over at least 20 years to capture climate signals rather than internal variability; sometimes longer time periods are needed to capture more rare, extreme statistics.

Question 11: Given that climate change is mostly attributed to human activities, how is natural climate change differentiated from anthropogenic sources?

Answer 11: We can use our climate models to simulate conditions with only natural forcings (e.g., shifts in the sun's output, volcanoes) vs. under conditions that also include human influences (land use change, greenhouse gas emissions). These simulations allow us to disentangle the natural and human influences in the recent decades, giving us a strong basis to project humans' continuing influences in the decades ahead.



Question 12: How are policies included in the models?

Answer 12: We represent policies within the driving socioeconomic pathways, which in turn affect greenhouse gas emissions and the broader climate system. We currently use a set of representative policy scenarios, but new scenarios are often developed to explore specific policy options and their ramifications for the climate systems. We used an example of policy implementations of ev's.

Question 13: Do you know a website that displays paleoclimate changes throughout the Cenozoic or the Pleistocene?

Answer 13: The link below is to a web portal providing paleoclimate during the Miocene (23 mya - 5 mya): <https://bolin.su.se/data/miocene-temperature-portal>

Question 14: Is the 1.5 degrees ceiling (Paris Agreement) sufficient to check the spate of increasing frequency of climate related disasters currently experienced across the world?

Answer 14: The recent IPCC report showed that human influence is already changing the climate in all regions of the world, including shifts toward more extreme events. These changes will be more pronounced and more widespread with each increment of climate change (and therefore each amount of greenhouse gas emissions). Global warming is currently ~1.1C above pre-industrial conditions, which means the 1.5C target would include further climate disruption beyond that already seen today.

Question 15: As noted in the presentation, sub-100km information from climate models is not reliable at the moment, what could be the best approach to integrate local data with available climate models?

Answer 15: You would have to use downscaling to get information sub-100km. Bias adjustment also uses local information to account for patterns that can be missed by global data.

Question 16: What do you mean by the heat hot spots in New York city presented in slide 40 and how did you identify it? Is it the same as urban heat islands? Can we consider the urban heat islands a form of climate change?

Answer 16: The urban heat island (UHI) is a phenomenon that refers to elevated temperatures in urban areas compared to their surrounding, more rural areas. Slide 40 shows areas within New York City with elevated temperatures - within the city, there are warm



spots and cooler locations (e.g. parks). These hot spots can be identified by remote sensing and satellite instruments. However, the city as a whole is still warmer than its surrounding areas, which is the UHI.

Question 17: I am interested to know the sea temperature at a certain depth and bottom in the past and future. Any advice on where to find the climate data I should use and the equation I should use to do the analysis would be much appreciated!

Answer 17: There is a program called ARGO, which includes a set of autonomous buoys that can dive into the water column and then transfer its data. All of these climate models include 3D information of oceans as well. Please refer to Part 1 of this webinar series to learn more about ARGO floats.

Question 18: LULC classification for relatively large areas incurs errors (if compared with relatively small areas, e.g. city). How can we get the same result for both small and large areas? Please mention models, algorithms etc. Thanks!

Answer 18: When looking at a region with complex and homogeneous land use, a regional model does make sense. Within our climate models we use tiles that include different types of land uses which can be aggregated into a larger classification.

Question 19: How is a global climate model differentiated from a regional climate model?

Answer 19: Regional climate models operate at finer resolutions than global models. Regional models contain more complex dynamics that global models do not. Global models are more earth system models that include information from different natural forces. Regional models do rely on global models to operate.

Question 20: As climate changes become increasingly more severe and more prevalent, I imagine many sectors (public health, international development, etc.) will have to adapt to take climate factors into consideration more so than they currently are. What fields of work/study do you think will begin to emerge to address the climate crisis?

Answer 20: As noted, climate change impacts will span many sectors. The IPCC, Working Group II includes terrestrial and freshwater ecosystems, ocean and coastal ecosystems, water, food systems, cities and infrastructure, health, poverty and sustainable development as systems that may be impacted by climate change. It's also important to consider that extreme weather and climate events can have unforeseen impacts, which can lead to additional



emergent areas of study. There are increasing studies assessing vulnerability to climate change effects, such as heatwaves. Contextual implementation of adaptation is also a growing area of research.

Question 21: Why is it necessary for CMIP6 to add an even lower radiative force scenario (RCP 1.9)? I was working with CMIP5, RCP 2.6 was the lowest and the research I checked out mostly focused on RCP 4.5 and 8.5, ignoring the 2.6 one because it is less probable to happen, so why should an even lower RCP 1.9 be considered?

Answer 21: RCP 1.9 is an extreme scenario in this case. There are decisions that could be made to push us into a situation similar to that of RCP 1.9. We are not trying to predict this pathway, but it is useful to help with the understanding of this potential situation to policy makers based on high mitigation and low emissions.

Question 22: Within the modeling of scenarios that have been crossed with vegetation layers, this gives us which types of vegetation which would benefit and others would be at risk and could these be the cause of fires and pests among other things?

Answer 22: We presented the framework during this training series, but this would be a useful topic for a more advanced training series in the future. We take your feedback seriously!

Look for future ARSET trainings on impacts of climate change.

Question 23: Does modelling using grids (GPS) the impacts of climate change in any way counter the biases from climate models?

Answer 23: Bias adjustment is an important aspect in utilizing climate models since there are different variations in models and it helps to account for potential gaps that the model may have missed. When factoring in different ecosystems, bias adjustments also help to account for their various differences.

Question 24: Do you have examples or/and case studies about the situation in different Latin American and Caribbean Countries? (i.e. The case of the biomass [sugar-cane] policy in Brazil and its impact on agriculture and the Amazonas).



Answer 24: From a climate standpoint, the Caribbean has a lot of small scale features not captured properly by global models. Using the example of sugar cane, there are examples of models that look at sugar cane and compare them to other agricultural crops such as soy. Broader patterns (like drought) though can be captured by global models.

Refer to the link below for information on how the Agricultural Model Intercomparison and Improvement Project (AgMIP) is advancing methods for improving predictions on the future performance of agricultural and food systems:

<https://agmip.org/>

Question 25: What are some current efforts to get more precise localized data?

Answer 25: For example, NYC is using more instruments on building rooftops to gather more accurate data. Having local validation will always be important.

Question 26: Is there an interface or portal to incorporate environmental datasets into these broader modelling constructs?

Answer 26: Different communities are looking for better methods to help provide more accurate data as well as to better synchronize their datasets into a broader model.

Question 27: Since climate models are dependent on different initial conditions, boundary conditions, and ECS; what does this mean for the climate model users?

Answer 27: It is important for the users to recognize the modeling groups will give different projections dependent upon emissions scenarios as drivers. Initial conditions will affect the first years or decades in a model. They have less of an effect as you go forward in the long term though.

Question 28: As climate science is dynamic, how best is existing technology to serve people's adaptation and mitigation measures? Considering the worst case scenario do we have a robust system to communicate such rapid changes with informed decision making? How about reaching the last mile (i.e., poor nations, SIDS being facilitated in this regard)?

Answer 28: While we did not cover this particular topic in this training series, it is important to understand.

Implementation of actions would be a good topic for a training. Regarding planning, different populations have different needs. Connecting climate information to the specific actions under consideration.



Question 29: The climate simulation models often rely on additional models like crop yield. This clearly indicates that the uncertainty thereby increases exponentially with minor errors in any of these models. How do the climate models mitigate these errors?

Answer 29: There are different types of error propagation, so I do not necessarily agree with it being exponential. If the broad variety of models gives us an uncertainty large enough we cannot work with, then we will look back and see what we measured improperly.

Question 30: What is the timeline for the CMIP6 NASA Nex dataset to be available to users?

Answer 30: The expectation is that the data should be available sometime this month: October, 2021.

Question 31: What kind of downscaling is preferred; Dynamical or Statistical and why?

Answer 31: The type of downscaling is sometimes dependent on the application of the climate science information. For broader climate assessment, stakeholders may be comfortable with results from statistical downscaling of climate models. An example is how many cities use climate projections developed using statistical downscaling for adaptation planning. For more specific applications, such as sector-focused analysis, regional climate models and dynamical downscaling may be more appropriate. Dynamical downscaling may also be more applicable for regions with terrain or land-sea breezes.

Question 32: I'm still hung up on the plot graph that showed the data projections for Alabama -- with discrepancies between drought v. increased water as temp increases. How does one plan for adaptation and/or mitigation absent agreement on the models?

Answer 32: Projections for Alabama showed a very clear signal of temperature increase growing over time even as the precipitation signal was more uncertain in the future. If we run these through a crop model we get a range of results that represent potential future impacts -- we can then ask farm managers and related agricultural stakeholders whether that distribution includes problematic outcomes, and then calculate the percentage of undesirable outcomes. Then we might ask what adaptation measures they would consider and potentially re-run our crop models to see if we end up with a new set of outcomes that has reduced that likelihood of undesirable outcomes. This gives us a cost and a benefit for that adaptation option and helps in planning.





Question 33: Is there a checklist of minimum data requirements (per sector), required to assess and design effective responses to the effect of climate change (both adaptation and mitigation)?

Answer 33: IPCC AR6 WGI Chapter 12 included a table (12.2) showing connections between each sector and the climate phenomena that cause substantial responses. This tells us which climate information is relevant for each sector. WGII has sectoral chapters with more information about what would be needed for each sector beyond the climate information. A future ARSET training may go into further detail about specific climate applications for each sector and the data requirements for each.

Question 34: Can we get information about GHG ceilings for each country from the climate change model?

Answer 34: The climate model can tell us how climate will change for each country depending on the GHG concentrations, but constraints on greenhouse gas emissions (and associated mitigations) would come from integrated assessment models that were used to generate the specific SSP-RCP pathways.

Question 35: What are the best ways to assess uncertainties related to climate downscaling and modelling?

Answer 35: Compare against observed conditions in the recent past, compare against paleoclimate conditions in the distant past, run a series of protocol-based simulations of future socioeconomic and greenhouse gas concentration pathways. CMIP6 organizes climate modeling groups to do all of these.

Question 36: What observations not currently made would help initialize or validate climate modeling? Which observations need lower uncertainty to improve results?

Answer 36: Better observations of the full profile of soil moisture and water movement on the surface would be helpful to understand aridity, drought and flood events. Fine resolution information on land use and land cover would help for a number of climate applications. High resolution information is also needed to capture the most acute extreme events that affect people and nature. In general we need to extend our observational products to have longer records so that our climate analysis is even more robust.

Question 37: Why isn't the NASA GISS model part of the CMIP6 ensemble?



Answer 37: NASA GISS Model-E is a part of the CMIP6 ensemble (several versions of the model are included, each with slightly different physical package options).

Question 38: In Egypt the sea level rise is a hazard that threatens the country and its effect will appear in the long term. What do you recommend to study this effect in the short term, in case there is not much altimetry data available?

Answer 38: IPCC included sea level rise projections for many parts of the world.

Question 39: How does climate change impact US western wildfires in terms of frequency and intensity?

Answer 39: Climate change increases fire weather conditions, including warmer temperatures and periods with low humidity. This means conditions are more conducive to fires starting and spreading.

Question 40: Is there any source available from where the model data for different RCP scenario maps can be downloaded and processed in GIS to prepare country-specific maps? Like the maps shown in slides 49, 50.

Answer 40: Check out the IPCC WGI Interactive Atlas, which provides an online interface to explore a number of climate products across different SSP-RCPs.

<https://interactive-atlas.ipcc.ch/>

Question 41: Global models are often based on relatively large cell sizes. However, cells of a given dimension get less square and smaller, as they move away from the equator [the earth's surface is not a rectangle, like a grid or a map]. How do these models account for that?

Answer 41: The models are based first on physical equations that span multiple grid cells, then results are placed on the grid for further analysis and physical interactions. Simulations have also been conducted that altered the grid cells' orientation around alternative "poles", and the results are robust given the geographical approaches taken.



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Question 1: How do aerosols affect precipitation patterns and cloud formation?

Answer 1: Aerosols interact with clouds and precipitation patterns in several ways. Depending on their characteristics, aerosols can reflect sunlight or absorb heat at different levels of the atmosphere, changing atmospheric stability and potential heights at which



clouds could form. Aerosols also act as cloud condensation nuclei, acting as a particle on which water can condense to form cloud droplets. More cloud condensation nuclei can also lead to more (but smaller) cloud droplets, which can reduce the size of cloud droplets and the likelihood that droplets can grow large enough to form rainfall.

Question 2: Slide 14: please give a layman's definition of initial conditions and boundary forcings (if not covered later in presentation).

Answer 2: Initial conditions are the starting point state of the climate system. For example, what is the temperature over Bermuda when the simulation begins? Initial conditions include a large number of 3D variables to represent the full climate system. Boundary forcings represent conditions that affect the climate system from outside the simulated components, for example changes in the sun's radiation, volcanoes, or greenhouse gas emissions. These are external boundary conditions.

Question 3: Is AMOC destabilization really still considered low-likelihood?

Answer 3: Yes, destabilization of the Atlantic Meridional Overturning Circulation (AMOC) that governs many ocean circulation patterns is simulated by several climate models, but a collapse of this system is not clear and robust across the broader CMIP ensemble. Within the latest IPCC report we noted AMOC collapse as one of several low-probability but high-impact events that merits attention even as major scientific questions are still being explored. Elements of the AMOC collapse process have been observed, for example changes in the freshwater flux from the Labrador Sea into the North Atlantic, and improved ocean observations (for example from ARGO floats) are helping us understand the dynamics and resilience of the AMOC.

Question 4: While the climate models give us data at a resolution nearing to about 100km spatial grids, what should be the method to link these climate model outputs with the actual changes in temperature and other meteorological parameters at city level or for urban areas?

Answer 4: Downscaling allows us to bring climate information to the urban/city scale. Bias-adjustment methods combine climate model projections and finer-scale information from observed, historical weather data. When downscaling it is important to recognize which elements are based on processes versus statistical downscaling. Finer resolution does not always mean better quality.



Question 5: What missions are being planned to improve the quality of data available to climate modelers and scientists? Are there other aspects that are likely to substantially improve our predictions beyond future missions and simply more empirical data as the century progresses?

Answer 5: Planned NASA missions for climate can be found at the link below:

[https://climate.nasa.gov/nasa\\_science/missions/?page=0&per\\_page=40&order=title+asc&search=&category=32](https://climate.nasa.gov/nasa_science/missions/?page=0&per_page=40&order=title+asc&search=&category=32)

Question 6: Are there Bayesian forecasting methods for climate systems?

Answer 6: Bayesian forecasting uses statistical methods. For forecasting, there are several ways to tell what may come given current conditions. Projections are used when the future is based upon various scenarios.

Question 7: When can we expect NEX datasets of CMIP6 to be available, and what will be its spatial resolution?

Answer 7: Anticipated release is October, 2021. There will be different resolutions for different parts of the world.

Question 8: Are there remote sensing tools (sensors, algorithms) to evaluate N<sub>2</sub>O emissions from large Wastewater treatment plants?

Answer 8: Refer to the trainings below for more information:

<https://appliedsciences.nasa.gov/what-we-do/capacity-building/arset/arset-health-air-quality-trainings>

Question 9: Are there global or regional networks of groups working on dynamic downscaling, to locate potentially useful resources or groups?

Answer 9: One of the most prominent ones is CORDEX (Coordinate Regional Downscaling Experiment).

The program was created to link many regional modeling centers into a central protocol. This allows users to compare comparable datasets into an ensemble approach. Top modeling centers are banding together so datasets can be compared in one protocol/database/etc.

<https://cordex.org/>



Question 10: Please discuss briefly how satellite imagery can help in monitoring COVID 19 spread and its prediction with respect to climate parameters like temperature, etc.

Answer 10: From a climatological perspective we can look at many factors for spreading transmission - there are studies that look at how temp can lead to an indirect spread - both direct and indirect factors but indirect factors seem to be most prevalent.

<https://earthdata.nasa.gov/covid19/>

Question 11: How to approach cumulative impacts for risk assessment?

Answer 11: We will interpret this as there are multiple climate changes affecting each sector. If it's not one at a time these impacts seem to interrelate - we talk about compound risks as more than one hazard is impacting at one time - another challenge is a sequential set of risks that changes seasonally - another risk is simultaneous risk (e.g. if a hurricane were to hit multiple ports at the same time it can have an oversized impact on supply). This connects us to systemic risks where small impacts can set off a chain of events that lead to larger impacts (e.g. drought in the US west impacts food/gain prices and leads to global shocks). There are increasing efforts to characterize these risks so we aren't caught unaware.

Question 12: The felling of trees and the use of these trees for charcoal formation, which is used for cooking has increased drastically in my country. This has an adverse effect with increasing CO<sub>2</sub> in the air. What can be the best model to handle this in a third world country where poverty is on the increase?

Answer 12: There are two big parts we will answer - how has the burning of biomass increased climate change - more carbon given off. The other half is poverty and sustainable development - what are the specific policies affecting development in any given country. Climate models show the decisions related to policy and economic development do have an impact on climate predictions.

Question 13: New scenarios include more accurate information on socioeconomic pathways. How can these variables be included in the regional analysis and modeling of scenarios with an emphasis on extreme events?

Answer 13: The model scenarios presented today were global scenarios. These scenarios include emissions and land change and there is certainly room to improve regional scenarios. If one country were more proactive than their neighbors in addressing carbon emissions - there is room in regional models for climate impacts. Some hazards associated with global



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warming levels may be difficult for a country to mitigate which will lead inevitably to adaptation measures.

Question 14: Can we have a training from ARSET exclusively focused on different downscaling methods/approaches and/or datasets like CORDEX-CORE or NEX-GDDP in near future?

Answer 14: This could certainly be compelling in a future ARSET training on climate. We would emphasize this is a rich area for further analysis. Especially with the forthcoming release of the NEX-GDDP this could form a nice core of a future training and the analysis that are derived from this.