Selecting Climate Information to Use in Climate risk and impact assessments

GUIDE FOR FEDERAL AGENCY CLIMATE ADAPTATION PLANNERS

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About This Document

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About the Office of Science and Technology Policy

The Office of Science and Technology Policy (OSTP) was established by the National Science and Technology Policy, Organization, and Priorities Act of 1976 to provide the President and others within the Executive Office of the President with advice on the scientific, engineering, and technological aspects of the economy, national security, homeland security, health, foreign relations, the environment, and the technological recovery and use of resources, among other topics. OSTP leads interagency science and technology policy coordination efforts, assists the Office of Management and Budget with an annual review and analysis of federal research and development in budgets, and serves as a source of scientific and technological analysis and judgment for the President with respect to major policies, plans, and programs of the federal government. More information is available at http://www.whitehouse.gov/ostp.

Statement of Purpose

As Federal agencies continue their efforts to advance climate adaptation and resilience, as required by Executive Order 14008, they should use available, authoritative (e.g., Federal or Federally reviewed) climate information resources where feasible and appropriate. Many different resources exist, and some resources may be more appropriate for particular climate adaptation planning purposes than others.

In 2022, Congress directed the White House Office of Science and Technology Policy (OSTP) to

> *develop, and make public, guidance for Federal agencies as they create and update their Climate Action Plans and annual progress reports to (1) assist agencies in identifying and accessing quality and appropriate climate information; (2) ensure consistent application of climate information parameters, including but not limited to timeframes, emissions scenarios, and risk tolerance levels; (3) ensure appropriate interpretation of climate information; and (4) ensure consistency across agencies with regard to the scope of the evaluations of the impacts of climate change to their operations, capabilities, facilities, and public services.*[1]

[1] H.Rept. 117-97 (Committee Report to accompany H.R. 4505, Commerce, Justice, Science, and Related Agencies Appropriations Bill, 2022) adopted by reference in the Joint Explanatory Statement for Division B—Commerce,

This document provides a high-level guide for Federal agencies on selecting resources (e.g., data, tools, reports, case studies, etc.) for understanding agency climate vulnerabilities, with a particular focus on understanding exposure to current and future climate-related hazards and their potential impacts. The resources discussed in this document include climate model outputs based on different scenarios. The document also provides background information on climate models and projections, scenarios that drive climate model projections, and downscaling techniques. In addition, it provides direction on selecting scenarios. This document is particularly relevant for developing and updating agency climate adaptation plans and may be relevant for other agency climate risk assessment and adaptation and resilience efforts.

This document does not include recommendations on the full scope of climate adaptation planning. The document focuses on climate information, which can help agencies identify possible climate adaptation and resilience options and inform their adaptation plans, but the identification and implementation of climate adaptation and resilience actions are not specifically covered in this guide. The White House Council on Environmental Quality (CEQ) provides instructions for agencies through the Climate Adaptation Planning process on standard approaches to developing adaptive strategies for Federal assets and programs. Climate change poses costly risks to Federal Government assets and operations. Climate adaptation and resilience actions can reduce those risks and may result in certain benefits that advance other goals, such as sustainability and environmental justice. Climate adaptation and resilience actions can reduce burdens today on frontline communities and vulnerable ecosystems, while nations work in concert to reduce their greenhouse gas emissions. Other Federal resources and guidance documents can help agencies identify adaptation actions that have multiple benefits. For example, in 2022, CEQ, OSTP, and the White House Domestic Climate Policy Office released a roadmap for accelerating nature-based solutions. According to this roadmap, nature-based solutions are "actions to protect, sustainably manage, or restore natural or modified ecosystems to address societal challenges, simultaneously providing benefits for people and the environment."[2] Additionally, good practices for adaptation are being discussed within Federal interagency working groups and communities of practice, such as the Federal Climate Adaptation Plan Network and the U.S. Global Change Research Program's Federal Adaptation and Resilience Group.

Justice, Science, and Related Agencies Appropriations Act, 2022 accompanying Consolidated Appropriations Act, 2022 (Pub. L. 117-103), p. 120-121.

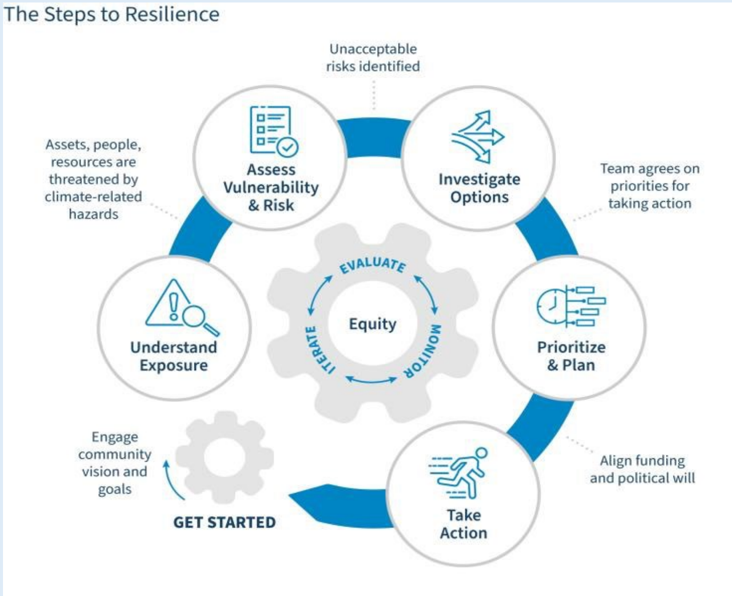
[2] White House Council on Environmental Quality, White House Office of Science and Technology Policy, White House Domestic Climate Policy Office, 2022: *Opportunities for Accelerating Nature-Based Solutions: A Roadmap for Climate Progress, Thriving Nature, Equity, and Prosperity*. Report to the National Climate Task Force. Washington, D.C. https://www.whitehouse.gov/wp-content/uploads/2022/11/Nature-Based-Solutions-Roadmap.pdf.

A Starting Point for Climate Adaptation Planning

Climate adaptation planning can be a complex process, requiring the use of multiple types of information and tools. As we gain more experience adapting to a changing climate, the climate adaptation community is continually sharing and improving its practices and leveraging new and updated tools. Thousands of scientists around the world, including hundreds of U.S. scientists, contribute to each cycle of Intergovernmental Panel on Climate Change (IPCC) reports, which provide a global view of the latest climate science. The National Climate Assessment (NCA) currently serves as our Nation's authoritative and most comprehensive resource on climate change (NCA4 (2018) is the most recent; NCA5 is expected in late 2023), and climate adaptation planners may find it particularly helpful to review the chapter on climate adaptation, one of two chapters on responses to climate change.[3] Planners may also find it useful to review climate adaptation and resilience case studies or examples that are included across the entire NCA. To assist decision-makers and analysts, each of whom has a particular job role and/or set of objectives in mind, the U.S. Climate Resilience Toolkit brings together case studies, NCA overviews, data, reports, methods, and a framework for adaptation and resilience known as the Steps to Resilience (see Box 1).

[3] Lempert, R., J. Arnold, R. Pulwarty, K. Gordon, K. Greig, C. Hawkins Hoffman, D. Sands, and C. Werrell, 2018: Reducing Risks Through Adaptation Actions. In *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II* [Reidmiller, D.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock, and B.C. Stewart (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, pp. 1309–1345. https://doi.org/10.7930/NCA4.2018.CH28.

Box 1. The U.S. Climate Resilience Toolkit's Steps to Resilience Framework



The U.S. Climate Resilience Toolkit's Steps to Resilience framework describes an iterative process to identify and address pressing climate-related vulnerabilities and risks. NOAA recently developed a practitioner's guide for implementing these Steps to Resilience.[4] Following the Steps, groups start by compiling a list of assets or systems they care about (e.g., critical infrastructure, people, ecosystems, economies, agency mission and programs, etc., or a combination) and evaluate potential climate-related effects to those assets or systems. Groups then assess which of their assets are vulnerable and at risk, investigate possible solutions, and make plans to address their greatest concerns. The framework also helps people recognize potential opportunities presented by changing climate conditions.

The information in this OSTP guide primarily falls under Step 1 (Understand Exposure) and Step 2 (Assess Vulnerability and Risk) of the Steps to Resilience framework and is intended to support Federal agencies.

A Four-Step Process for Selecting Climate Information to Use in Assessments of Climate Risks and Resulting Effects

This guide is organized around a four-step process.

1. Understand current exposure to climate hazards and additional stressors and frame your vulnerability assessment.

[4] Gardiner, N., ed., M. Hutchins, J. Fox, A. Patel, and K. Rhodes, 2022. *Implementing the Steps to Resilience: a Practitioner's Guide*. Climate-Smart Communities Series, Vol. 6. NOAA Climate Program Office. https://doi.org/10.25923/9hhx-2m82.

2. Select climate scenarios for your assessment and decide whether downscaled data are relevant.
3. Identify effects from other future climate-related hazards and stressors to assess.
4. Select climate information resource(s) to use.

Step 1: Understand current exposure to climate hazards and additional stressors and frame your vulnerability assessment

When developing an adaptation plan, it is important for a Federal agency to consider its mission and programs and identify related assets of interest (e.g., infrastructure, lands, waters, workforce, etc.), where those assets are located, and whether they are permanent or temporary. Assets will mean different things to different agencies and programs.

Next, an agency needs to understand the current exposure of these assets to climate-related hazards (e.g., wildfire, flood, sea level rise, drought, extreme weather, etc.). In a changing climate, past experience is often insufficient for an accurate, quantitative estimate of current exposure, and it does not fully consider non-linear changes or potentially unprecedented future risks. Federal agencies have developed many publicly available tools that help the public and other decision-makers understand their climate vulnerabilities, including their exposure to climate-related hazards. For example, NOAA's Disaster and Risk Mapping tool examines state, county, and census block-level economic risks from seven different impacts; FEMA's National Risk Index examines 18 natural hazards that appear in state hazard mitigation plans; and Wildfire Risk to Communities, LANDFIRE.gov, and the AirNow Fire and Smoke Map give users a way to explore their current risk to wildfire and smoke. Other tools examine other specific hazards. Engaging with local communities and Tribes and other Indigenous peoples may provide additional insights and perspectives on emerging risks that may be relevant to agency interests.

While exposure to climate-related hazards is an important determinant of climate vulnerability, some assets or systems may be more sensitive than others—meaning they are more susceptible to the impacts of those hazards. For example, deteriorating infrastructure may be more sensitive to climate-related hazards than newer infrastructure. Once you have identified your agency's current exposure to climate-related hazards, identify any additional stressors that can exacerbate vulnerabilities. Non-climate stressors contribute to the impacts of a hazard (see Table 1). They can come from and affect all natural systems—from terrestrial to aquatic to the ocean—and include changes in biodiversity, nutrient levels, land use, use of resources (energy and water), and ocean acidification. Non-climate stressors also include economic and social conditions and infrastructure. Resources like the NCA and other Federal tools can help agencies identify these non-climate stressors. For example, CEQ has released the Climate and Economic Justice Screening Tool to help identify communities that are on the frontlines of climate change and are overburdened. The tool uses datasets that are indicators of burdens in eight categories: climate change, energy, health, housing, legacy pollution, transportation, water and wastewater, and workforce development.

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Table 1. Examples of Climate-Related Hazards and Associated Climate and Non-Climate Stressors.

Hazard	Climate Stressors	Non-Climate Stressors
Tidal flooding	• Sea level rise • Heavy precipitation	• Deteriorating infrastructure or cybersecurity risks • Increased development/impervious surfaces • Elevated coastal ground water levels; decreased drainage and more standing water
Storm surge	• Sea level rise • Tropical systems	• Deteriorating infrastructure or cybersecurity risks • Increased development/impervious surfaces • Lack of coastal vegetation (e.g., dunes, coral reefs)
Floodplain inundation	• Sea level rise • Increase in rainfall frequency/intensity	• Increased development/impervious surfaces • Socioeconomic vulnerability
Extreme heat	• Temperature variability	• Increased development/impervious surfaces/decrease in trees, vegetation, etc. • Socioeconomic vulnerability
Wildfire	• Drought (water shortage and vegetation desiccation) • Temperature variability	• Wildland–urban interface/fuels and vegetation, historic fire suppression • Invasive grasses • Human-caused ignitions, historic fire suppression
Landslides	• Increase in rainfall frequency/intensity, high temperatures, and snowstorms	• Development/vegetation removal • Wildfire-affected landscapes

Source: adapted from the U.S. Climate Resilience Toolkit.

Finally, an agency should answer the following questions:

- What time horizon is relevant to managing the agency's selected assets of interest?
- What is the agency's risk tolerance in managing the assets?
- What would be the consequences of over- and underestimating climate risks?
- Are there potential unintended consequences of over- and underestimating climate risks that could lead to maladaptation?[5]

Answering these questions will require broad engagement within an agency and possibly with partner communities and organizations. Understanding an agency's assets of interest, the exposure of those assets to current climate hazards, additional stressors, and the asset

[5] According to the IPCC, maladaptations are actions that may lead to increased risk of adverse climate-related outcomes, including via increased GHG emissions, increased vulnerability to climate change, or diminished welfare, now or in the future. Maladaptation is usually an unintended consequence.

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management criteria described above will provide a foundation for understanding future climate exposure and impacts.

Step 2: Select climate scenarios for your assessment and decide whether downscaled climate data are relevant

After identifying current exposure to hazards, determine how that exposure may change as a result of climate change and select climate scenarios against which to assess future exposure. Understanding climate scenarios is critical to being able to understand and use climate projections. *A Practitioner's Guide to Climate Model Scenarios* provides a description of the history and use of climate scenarios.[6]

Background on Climate Models and Projections

Future climate cannot be predicted in the same way that weather is predicted, both because future climate is largely based on societal choices and because some aspects of climate system dynamics are not yet well understood, such as tipping points.[7] While improved climate modeling is reducing the range of uncertainty in warming associated with greenhouse gas (GHG) emissions, future climate scenarios ultimately depend on future human GHG emissions, which depend on societal choices across the globe. This becomes especially true beyond mid-century, at which point the results of societal decisions today become more apparent. As a result, scientists and decision-makers explore a range of possible future climate outcomes (i.e., projections) using a range of model scenarios. These scenarios are based on different assumptions about policy decisions, economic and population growth, and technological development over the coming decades.

Scenarios that Drive Model Projections

A scenario is a coherent, internally consistent, and plausible description of a possible future, based on representations of Earth system properties and how those properties respond to natural and human drivers of change (IPCC, 2021). Scenarios are used as key inputs into climate models to understand how the Earth system may respond. While there are no explicit probabilities or likelihoods associated with the different scenarios, they can provide useful information on the potential range of climate futures we might expect given specific choices or actions as well as the robustness of adaptation responses.

In the last decade, climate scenarios have been developed to explore different possible climate futures based on divergent societal pathways. Modeling groups around the world use these

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[6] Great Lakes Integrated Sciences and Assessments (GLISA), 2021: *A Practitioner's Guide to Climate Model Scenarios*. Briley, L., et al., eds. Ann Arbor, MI. https://toolkit.climate.gov/reports/practitioners-guide-climate-model-scenarios.

[7] According to the U.S. Global Change Research Program's 2022-2031 Strategic Plan, tipping points occur when Earth system changes become irreversible, leading to large-scale shifts in the Earth system that can have significant impacts on society or the natural world.

USGCRP, 2022: *The U.S. Global Change Research Program 2022–2031 Strategic Plan*. U.S. Global Change Research Program, Washington, DC, USA. https://www.doi.org/10.7930/usgcrp-2022- 2031-strategic-plan.

scenarios to periodically release a coordinated set of climate model projections, typically aligned with each cycle of the IPCC assessment reports. The coordination of these projections is known as the Coupled Model Intercomparison Project (CMIP). Results of these coordinated model projections are available in the CMIP archive and can be accessed via the IPCC Atlas.

Scenarios have evolved and improved significantly over time, based on greater sophistication of climate models and new questions being posed to them by society. The most recent scenarios combine GHG concentrations with socioeconomic conditions to provide more nuanced specifications of possible futures. Initially, there was a focus on scenarios that follow GHG concentration pathways (Representative Concentration Pathways, or RCPs). More recent scenarios show how these concentration pathways relate to socioeconomic narratives, such as population growth, GDP, and energy demand (Shared Socioeconomic Pathways, or SSPs).

Climate Model Output Availability

A new phase of CMIP is typically released with every IPCC assessment cycle. CMIP5 projections (used in IPCC Assessment Report 5) and associated tools provide important, reliable information for understanding climate risks, while CMIP6 projections (used in IPCC Assessment Report 6) draw on some improvements in how Earth system processes are represented and are driven by more sophisticated SSP scenarios.[8] While CMIP6 projections rely on more sophisticated scenarios, CMIP5 and CMIP6 projections are similar enough that both are considered acceptable for use by the international climate community. When deciding whether to use CMIP5 or CMIP6, the differences between them are less important than other factors, such as the availability and accessibility of information.

While general climate model outputs provide information on many key variables like temperature, precipitation, and humidity, they do not represent many hazards of interest (e.g., sea level rise, storm surge, wildfire, inland flooding) very well or at all. Future projections of these hazards use climate model output as an input to specialized models (see Step 3 for more information).

Selecting Scenarios to Use for Assessing Vulnerability to Climate Change

Commonly Used Climate Scenarios

Given the uncertainty in future climate projections, a best practice in climate change risk assessment is the use of multiple scenarios and consideration of the range of projections within a scenario. A range of potential impacts should be explored using both high-end and low-end scenarios. Different scenarios do not diverge widely before 2050. The choice of which scenario to use is more relevant for longer late-century time horizons (e.g., 2050–2100), where the conditions and impacts diverge.

Although explicit likelihoods or probabilities are not attached to individual scenarios, the IPCC's Sixth Assessment Report (AR6) states the following:

[8] Arias, P.A., et al., 2021: Technical Summary. In *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* [Masson-Delmotte, V., et al., (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 33−144. doi:10.1017/9781009157896.002.

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In the scenario literature, the plausibility of some scenarios with high CO2 emissions, such as RCP8.5 or SSP5-8.5, has been debated in light of recent developments in the energy sector. However, climate projections from these scenarios can still be valuable because the concentration levels reached in RCP8.5 or SSP5-8.5 and corresponding simulated climate futures cannot be ruled out.[9]

Table 2: Commonly Used Scenarios

Model Generation	Commonly Used Scenarios	Notes
CMIP5	RCP2.6 RCP4.5 RCP6.0 RCP8.5	• By using both RCP4.5 and RCP8.5, those assessing risk can incorporate a range of possible futures and take advantage of the large literature base available on climate impacts.[10] • RCP4.5 and RCP6.0 are the most similar to current emissions trajectories based on global climate policy, but RCP6.0 data are generally less available and accessible. • RCP8.5 may most accurately reflect near-term risk because it closely follows historical emissions but represents an upper-bound/ high-consequence future for the end of the century.
CMIP6	SSP1-1.9 SSP1-2.6 SSP2-4.5 SSP4-6.0 or SSP3-7.0 SSP5-8.5	• SSP1-1.9 and SSP1-2.6 assume aggressive mitigation, well beyond current policies. Low emissions scenarios (e.g., SSP1-1.9) can be used as lower bounding scenarios, with the understanding that little literature is available on climate impacts under this scenario. • SSP2-4.5 and SSP4-6.0 are roughly consistent with continuation of current policies. • SSP3-7.0 may be a more plausible high-end, no climate policy scenario than SSP5-8.5. • SSP5-8.5 can also be used as an upper-bounding scenario, particularly for the end of the century.

[9] Arias, P.A., et al., 2021: Technical Summary. In *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* [Masson-Delmotte, V., et al., (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 33−144. doi:10.1017/9781009157896.002.

[10] For examples of tools using RCP4.5 and/or RCP8.5 for climate change projections and impacts, see the Climate Explorer and the Climate Mapping for Resilience and Adaptation portal.

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Considerations for Scenario Selection

Various factors influence the selection of climate and socioeconomic scenarios in climate risk assessments, including the following:

- **Availability of Variables and Information Tools** – Some model output variables—such as global temperature or precipitation data—are more widely available than others. Furthermore, most Federal climate resources do not include climate projections for all scenarios.
- **Planning Time Horizon** – For near-term planning time horizons (2050 or earlier), there are limited differences expected among existing climate scenarios. Scenario selection is more important for long-term planning horizons. After 2050, the climate system impacts increasingly diverge under different scenarios, primarily due to uncertainty in mitigation actions.
- **Risk Tolerance** – The societal value of the asset at risk should be considered by decision-makers when including scenarios on the higher end of potential impacts (e.g., SSP3-7.0 or RCP8.5), especially when planning for critical or long-lived assets or natural resources (e.g., critical infrastructure, endangered species, etc.).
- **Benefits of Mitigation and Adaptation** – When information is sought regarding the benefits of GHG reductions and adaptation actions, inclusion of a low-emissions scenario may be warranted as a contrast against higher-emissions scenarios.

Availability of Federal Resources that Use Climate Scenarios

Federal climate resources (e.g., reports, information websites, interactive tools, etc.) may include climate projection data that come from a variety of climate scenarios. NCA4 primarily featured comparisons of two CMIP5 scenarios, RCP4.5 and RCP8.5, for which outputs were available from more models than for the other scenarios. This reflected the common use of these two climate scenarios in climate impact analyses reported in the literature at the time of development and enabled comparison between lower- and higher-emissions futures. Given the wide availability of literature using these scenarios, other Federal resilience and decision-support tools have adopted these two scenarios. For example, location-specific climate projections and maps for RCP4.5 and RCP8.5 are available via the Climate Explorer and the Climate Mapping for Resilience and Adaptation (CMRA) portal. In addition, the U.S. Climate Resilience Toolkit contains a diverse array of tools that project future climate change, hazards, and impacts, largely drawing on RCP4.5 and RCP8.5. Note that different Federal tools take different approaches in presenting these results, and users will find slight differences among tools.

Alternative Approaches for Scenarios

Before deciding to use more spatially explicit downscaled datasets, another approach is to use a class of techniques called *decision-making under deep uncertainty* that acknowledges the inherent limitations of explicit models. One variation on this theme is called *scenario planning*, which uses exercises to engage diverse stakeholders and explore the broad scope of potential future conditions. Scenario planning is a valuable decision-support method for integrating irreducible and uncontrollable uncertainties into climate change adaptation and may be used to explore possible future trajectories for a system, consider the consequences of management alternatives, and develop indicators of important future decision points. Once alternatives have been explored, downscaled datasets can then provide some bounds for design studies.

Another potential approach that uses a different viewpoint from the timelines inherent in RCPs and SSP-based approaches is to use *global warming levels* (GWLs). Rather than looking at when a certain temperature or amount of rainfall occurs in the future, one can consider which GWL would trigger a decision (e.g., 2°C). This approach may remove some of the complexity of navigating the RCP or SSP-RCP scenario framework by exploring the impact of a few key thresholds (i.e., 2°C, 3°C, or 4°C). This approach is becoming more common, such as in IPCC reports, and is comparable to how one explores the impact of sea level rise by focusing on a specific level of rise (e.g., 0.6 m or 2 ft) rather than focusing on a specific time period and RCP scenario (e.g., RCP6 in 2050). Ultimately, of course, the GWL approach relies on the same underpinning global climate model scenarios, so the time period when a certain GWL might be reached can still be considered.

Downscaled Projections

Regional- and local-scale climate phenomena and extreme events are not well-represented in global climate models. Downscaling methods have been developed to improve the spatial detail (resolution) of projected climate information for some variables and to account for land surface effects (e.g., mountains, lakes, cities, etc.) that are not considered in global climate models. However, like other modeling techniques, downscaling methods have limitations. Furthermore, the available range of downscaled climate variables, scenarios, and output metrics may be quite limited.

Overview of Downscaling Techniques

There are two major categories of downscaling techniques: statistical downscaling and dynamical downscaling. *Statistical downscaling* translates global climate model outputs to smaller spatial scale information (~25 km to ~1 km) with fewer computing resources than other approaches. *Dynamical downscaling* uses additional models to transform global input to smaller scales (~50 km to ~10 km) using physics-based equations. The dynamical downscaling approach is starting to mature and become useful for decision-making. Both techniques may be influenced by biases in the underlying datasets; both the global model output and any historical products such as gridded climatologies. Each downscaling technique has additional strengths and weaknesses that should be considered (see Table 3). Recent advances have improved both techniques.

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Table 3: Strengths and Weaknesses of Statistical Downscaling and Dynamical Downscaling

Technique	Strengths	Weaknesses
Statistical Downscaling	• More widely available outputs, as they are more frequently included in impact assessment studies and in freely accessible Federal climate tools. • Based on observed climate variable relationships (i.e., observed physical properties). • Usually requires fewer computing resources than dynamical downscaling. This faster computing time allows for the downscaling of a higher number of global models, enabling the exploration of how different models resolve different Earth system processes.	• Constrained by use of statistics from past climate periods. May not capture rapid, future climate changes if they are outside the underlying historical statistics. • Requires sufficient observed climate data to statistically train the technique.
Dynamical Downscaling	• Less constrained by observations, which allows application to locations for which robust historical records are unavailable. • Can add tremendous value due to the use of physical equations to represent changes over a region or local area—especially for quantities like precipitation, wind, and land cover—with high spatial and temporal resolution.	• Usually requires more computer resources to run additional models, which limits the number of downscaled global models, scenarios, and regions covered. • May not accurately capture all physical processes (e.g., thunderstorms, ice formation). However, regional models have the potential to include known local variable relationships.

Selecting Resources that Use Downscaled Datasets

Climate information resources and tools may leverage downscaled datasets. Many of the Federal Government's freely available and accessible tools, especially those intended for non-technical audiences, leverage the Localized Constructed Analogs (LOCA), a statistically downscaled product based on global CMIP5 projections. For example, NCA4 regional figures were based largely on LOCA, and the Climate Explorer and CMRA also show downscaled data from LOCA. Over 40 metrics were derived for NCA4 from downscaled precipitation and temperature values from the LOCA dataset, including extreme heat days, growing season length, freeze dates, annual consecutive wet days, annual consecutive dry days, and precipitation by inch thresholds. LOCA2, which uses CMIP6, is currently under development. Other new downscaled products that are also based on CMIP6 are also under development. Figures in NCA5 are expected to use two statistically downscaled products derived from CMIP6.

If Federal agencies decide to use downscaled datasets, they should consider the availability and accessibility of different products. If multiple downscaled datasets are available, agencies could use more than one downscaled dataset for comparative purposes. Agencies should also consider the pros and cons of the downscaling techniques (statistical and dynamical) that were used to derive the downscaled datasets and caveat their results appropriately.

Despite advances in downscaling techniques, many downscaled datasets are only available for the contiguous United States. There are regions (e.g., Alaska, Hawaiʻi, the U.S.-Affiliated Pacific Islands, the U.S. Caribbean) where direct use of global climate model projections may be necessary due to a lack of coverage by downscaled datasets. Additionally, specialized local data and knowledge can be found in the scientific literature and can be complemented with Indigenous Knowledge[11] and local knowledge. Specialized local data and knowledge are especially important when it comes to issues related to water (e.g., flooding or lake effects) and/or steep topographic regions (e.g., the Sierra Nevada mountain region). Experts with this specialized knowledge can be found across regions of the country via the U.S. Climate Resilience Toolkit's Find Experts page (e.g., State Climatologists, experts with the NOAA Climate Adaptation Partnerships Program, the USGS Climate Adaptation Science Centers, or the USDA Climate Hubs, etc.).

Step 3: Identify effects from other future climate-related hazards and stressors to assess

Modeling Climate-Related Effects

Global climate models can project certain variables like future temperature and precipitation patterns, but they do not model some major climate-related hazards that are of interest to decision-makers (e.g., inland flooding, wildfire, sea level rise, etc.). Furthermore, global climate models do not show how climate effects may be exacerbated by related stressors (e.g., methane emissions, land-use change, deforestation and carbon loss, habitat loss, coral reef degradation). A more comprehensive understanding of climate effects requires additional modeling efforts and spatial analyses, whose results may not be readily accessible to non-experts. Most assessments of future climate change effects are based on results from models that rely on both climate scenarios and non-climatic and human variables as inputs (e.g., changes in population, demography, biodiversity, and land and ocean use). Ongoing research activities are helping us gain a better understanding of compound risks (i.e., multiple stressors in parallel or sequence)—such as financial risk, food and water insecurity, conflict, and fragility. Furthermore, modeling these additional hazards, stressors, and resulting effects, using global climate information as just one of many inputs, introduces significant additional uncertainties.

Despite these challenges, many Federal resources are already available to understand how climate change will impact coastal flooding, drought, and other hazards (see Table 4). Some Departments and agencies have set up internal assessment tools to better understand some of these effects on their operations (e.g., DOI's SHIRA tool, DOD's Climate Assessment Tool). This guide primarily references Federal resources. However, many non-Federal tools are

[11] In 2022, the White House jointly released new Government-wide guidance for Federal Agencies on recognizing and including Indigenous Knowledge in Federal research, policy, and decision-making:

The White House Office of Science and Technology Policy and the Council on Environmental Quality (2022). *Guidance for Federal Departments and Agencies on Indigenous Knowledge*. https://www.whitehouse.gov/wp-content/uploads/2022/12/OSTP-CEQ-IK-Guidance.pdf.

emerging that model climate-related hazards and effects. Some of these tools are available in the public domain and others are proprietary. Agencies are encouraged to exercise due diligence when considering the adoption of such tools and assess their underlying methodologies and limitations.

In some cases, modeling climate effects requires highly regionalized or localized expertise. As mentioned earlier in this document, the U.S. Climate Resilience Toolkit's Find Experts page may be a useful resource for locating experts with regionally or locally specific expertise. Indigenous Knowledge may offer additional key insights. Assessing compound risks may also require additional expertise. The evolving impacts literature may point to some important relationships between climate variables and resulting hazards and impacts, especially at regional scales. Where even more expertise is required or where climate poses particularly large threats to an agency's mission, the agency might consider commissioning dedicated studies to support its adaptation planning process. This is often done after conducting a screening step using some of the tools in Table 4.

Assessing Sea Level Rise and Storm Surge Impacts

The Federal Government offers several tools that can help us understand risks from sea level rise and storm surge (see Box 2). Sea level rise is a major threat to the United States and an impact that is of particular interest to many planners. U.S. coastal counties are home to over 40% of the U.S. population.[12] Sea level rise is not uniform across the Nation's coastlines and can vary according to regional and local properties, such as land subsidence and land use. As such, many sea level rise products distinguish between *global sea level rise* and *relative sea level rise*.[13]

In 2022, an interagency team released a set of sea level rise projections, which were updated from a set of 2017 projections. These updated projections are serving as a technical input to NCA5. The set of projections includes near-term sea level rise projections through 2050 and five longer-term scenarios for global mean values in 2100: low (0.3m), intermediate-low (0.5m), intermediate (1m), intermediate-high (1.5m), and high (2m).[14] These scenarios are derived from CMIP6 projections and ice dynamics but do not align perfectly with the SSPs listed above. More information about the projections is available in a technical report, and an application guide supports practitioners in applying the information in the technical report. As described above with climate model projections, it is good practice to include at least two sea level rise scenarios

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[12] Fleming, E., et al., 2018: Coastal Effects. In *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II* [Reidmiller, D.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock, and B.C. Stewart (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, pp. 322–352. doi: 10.7930/NCA4.2018.CH8.

[13] Global sea level rise is the amount of sea level rise as a global average. According to the 2022 Sea Level Rise Technical Report, relative sea level rise is location specific and is affected by variations in ocean and earth surface processes (e.g., uneven heating, changes in ocean currents, and vertical land motion).

[14] Sweet et al., 2022: *Global and Regional Sea Level Rise Scenarios for the United States: Updated Mean Projections and Extreme Water Level Probabilities Along U.S. Coastlines.* NOAA Technical Report NOS 01. National Oceanic and Atmospheric Administration, National Ocean Service, Silver Spring, MD, 111 pp. https://aambpublicoceanservice.blob.core.windows.net/oceanserviceprod/hazards/sealevelrise/noaa-nos-techrpt01-global-regional-SLR-scenarios-US.pdf.

to provide a range of potential impacts and to keep in mind that uncertainties remain in our current understanding of tipping points that are likely to affect sea level rise.

Storm surge is an abnormal rise of seawater generated by a storm, which may be exacerbated by sea level rise. The USACE Sea Level Tracker allows users to easily visualize the indirect impacts of sea level change on extreme water levels, including storm surge, as calculated by USACE and NOAA. USGS's Coastal Storm Modeling System (CoSMoS) also allows users to understand coastal flooding as a result of future sea level rise, storms, and the long-term evolution of the coasts.

Box 2. Resources and Tools to Understand Sea Level Rise and Future Coastal Flooding

The following resources and tools could be used to understand sea level rise projections and coastal flooding:

- 2022 Sea Level Rise Technical Report
- Application Guide for the 2022 Sea Level Rise Technical Report
- Interagency Sea Level Rise Scenario Tool
- NOAA Sea Level Rise Viewer
- USACE Sea Level Tracker
- Coastal Storm Modeling System (CoSMoS)
- Hazard Exposure and Reporting Analytics (HERA)

For more information about these resources and other resources, see Table 4.

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Step 4: Select climate information resource(s) to use.

The final step is to select resources to use for analyzing future exposure to climate-related hazards, other stressors, and resulting effects. As stated under Step 1, it is important to remember that assets or systems that are exposed to the same climate-related hazards may have varying sensitivity to those hazards and additional effects. Table 4 presents several suggested Federal (or Federally funded) resources for analyzing future exposure to climate-related hazards, other stressors, and resulting effects. The resources below rely on both observations and climate projections. Some resources may be used to understand exposure to all hazards and climate-related stressors; some resources are hazard specific. Steps 1–3 above may inform which resource(s) to use. Agencies may have internal resources not listed in Table 4 that are more appropriate to use, especially if these resources are designed with an agency's specific mission and climate adaptation and resilience goals in mind.

As this guide implies, the Federal climate information landscape is expansive and complex. Agencies are encouraged to understand the kinds of data, techniques, and limitations inherent in the tools and applications below and to exercise similar caution in using any non-Federal resources.

While Table 4 includes many climate information resources, this list will evolve over time as new information and resources become available.

Table 4: Suggested Federal Resources for Understanding Future Climate Scenarios and Effects

Resource	Type of Information				Description and Uses	Observations and/or Projections	Included Projections/Scenarios and Downscaled Datasets
	Report	Data	Maps	Examples			
Multiple Climate-Related Hazards and Stressors							
USGCRP Indicator Platform		✓	✓	✓	This platform shows key climate change indicators across Federal agencies. These indicators show trends over time that provide insight into how our climate is changing over time. These include, for example, atmospheric GHG levels, Arctic sea ice extent, growing season length, and the Palmer Drought Severity Index.	Observations	n/a
NCA4	✓	✓	✓	✓	Typically considered the Nation's most authoritative source on climate change and its impacts, Volume II of NCA4 summarizes key information about climate vulnerability, impacts, and adaptation by sector and region. NCA4 can be used for education and training or identifying evidence for a broader policy or organizational approach to addressing climate change.	Observations and Projections	CMIP5 (RCPs) and LOCA Downscaled Data
Scenarios for the NCA: LOCA Viewer		✓	✓		The LOCA Viewer allows users to access a suite of scenarios produced as input to NCA4.	Projections	CMIP5 (RCPs) and LOCA Downscaled Data
U.S. Climate Resilience Toolkit (CRT)		✓	✓	✓	The CRT was created alongside NCA4 to provide additional tools, data, and stories for a broad range of users.	Observations and Projections	Multiple, depending on resource of interest
2022 NOAA State Climate Summaries	✓			✓	State Climate Summaries were originally created to meet information demand after NCA3. The summaries provide information on observed climate changes for long-term trends and extreme climate events for each state. The Summaries can be used for research and planning. The 2022 version provides new information and extends the historical climate record to 2020 for each state.	Observations and Projections	CMIP5 (RCPs)

Resource	Type of Information				Description and Uses	Observations and/or Projections	Included Projections/Scenarios and Downscaled Datasets
	Report	Data	Maps	Examples			
Multiple Climate-Related Hazards and Stressors							
Climate Explorer		✓	✓	✓	The Climate Explorer was developed for NCA4 and included in the CRT. The explorer provides location-specific (i.e., city, state, associated territory) analyses of temperature and precipitation.	Observations and Projections	CMIP5 (RCPs), LOCA Downscaled Data
USGS Report, Using Information from Global Climate Models to Inform Policymaking	✓				The report provides guidance to help managers assess risks as they consider whether/how to take mitigation and adaptation actions.	Projections	CMIP5 (RCPs)
Locating and Selecting Scenarios Online (LASSO)		✓	✓		EPA's LASSO tool was developed to provide alternative approaches for systematically selecting and then downloading a set of climate change projections that are best suited for a given research question or objective.	Projections	CMIP5 (RCPs), LOCA Downscaled Data, Bias Correction Spatial Disaggregation
Climate Mapping for Resilience and Adaptation (CMRA)		✓	✓		CMRA allows users to explore communities' current exposure to five hazards (extreme heat, coastal flooding, inland flooding, drought, and wildfire) and overlay hazards with key future climate variables.	Observations and Projections	CMIP5 (RCPs) LOCA Downscaled Data
Climate Risk and Resilience Portal (ClimRR)			✓		ClimRR allows users to examine simulated future climate conditions at mid- and end-of-century for a range of climate risks.	Projections	RCPs, Dynamically Downscaled Data
Climate and Hazard Mitigation Planning (CHaMP) Tool		✓			CHaMP allows users to view county- and region-specific historical climate and hazard data and future projected climate information. CHaMP is designed to help local hazard mitigation, infrastructure, and land use planners integrate climate information into their hazard mitigation planning efforts.	Observations and Projections	CMIP5 (RCPs), LOCA Downscaled Data (Carolinas, Great Lakes, and Mid-Atlantic Regions)

Resource	Type of Information				Description and Uses	Observations and/or Projections	Included Projections/Scenarios and Downscaled Datasets
	Report	Data	Maps	Examples			
					Multiple Climate-Related Hazards and Stressors		
National Climate Change Viewer (NCCV)		✓	✓		The USGS NCCV shows historical (1950–2005) and future (2006–2009) climate projections for states and counties and Hydrologic Unit Code watersheds.	Projections	CMIP5 (RCPs 4.5 and 8.5), MACA v2 Downscaled Data
Climate Hydrology Assessment Tool (CHAT)		✓		✓	USACE's CHAT allows users to visualize simulations of streamflow over a historical period, temperature, and precipitation time series, as well as modeled future (i.e., projected) outputs of climate-changed hydrology and meteorology for the continental U.S.	Projections	CMIP5 (RCPs 4.5 and 8.5), LOCA Downscaled Data
Time Series Toolbox		✓		✓	The USACE Time Series Toolbox enables users to perform preliminary analysis on either user uploaded time series data or USGS annual peak streamflow data (from any annual instantaneous peak streamflow gage site). The tool detects trends, non-stationarities, and breakpoints in a dataset.	Observations	n/a (includes peak streamflow data time series)
NASA Earth Exchange Global Daily Downscaled Projections		✓			This portal provides global climate model outputs downscaled using the NASA Earth Exchange Global Daily Downscaled Projections (NEC-GDDP) method. Although coarser in resolution than LOCA, the dataset provides consistent information for all parts of the globe.	Projections	CMIP5, CMIP6, NEC-GDDP Downscaled Data
Climate Data Processing Tool		✓			This DOT tool is used to process readily available downscaled climate projections at the local level into relevant statistics for transportation planners.	Projections	CMIP5

Resource	Type of Information				Description and Uses	Observations and/or Projections	Included Projections/Scenarios and Downscaled Datasets
	Report	Data	Maps	Examples			
					Coastal Hazards		
2022 Sea Level Rise Technical Report	✓	✓			This report updated a semi-independent set of sea level rise scenarios. Updates were based on modeling and Earth system science expertise.	Observations and Projections	CMIP6 (SSPs *adapted) and Localized Sea Level Rise Data
Application Guide for the 2022 Sea Level Rise Technical Report	✓				This report helps local practitioners apply the information from the 2022 Sea Level Rise Technical Report to their communities while taking local considerations into account.	Observations and Projections	CMIP6 (SSPs *adapted) and Localized Sea Level Rise Data
NOAA Sea Level Rise Viewer		✓	✓		The interactive viewer shows community-level impacts from coastal flooding or sea level rise. The viewer also includes simulations of how future flooding might impact local landmarks. The viewer shows areas along the contiguous United States coast, except for the Great Lakes. The viewer includes data from the 2022 Sea Level Rise Technical Report.	Observations and Projections	Regional Sea Level Rise Projections (based on 2022 Sea Level Rise Technical Report)
IPCC AR6 Sea Level Projection Tool		✓			The NASA Sea Level Projection Tool allows users to visualize and download the sea level projection data from the IPCC 6th Assessment Report. The tool allows users to view both global and regional sea level projections from 2020 to 2150, along with how these projections differ depending on future scenario or warming level.	Observations	Global Sea Level Rise Projections
Coastal Storm Modeling System (CoSMoS)		✓	✓		The USGS CoSMoS allows users to understand coastal flooding as a result of future sea level rise, storms, and long-term evolution of the coasts. Projections of multiple storm scenarios are provided under a suite of sea level rise scenarios. CoSMoS is currently available for some parts of coastal California.	Projections	n/a
Hazard Exposure Reporting and Analytics (HERA)		✓	✓		USGS's HERA leverages storm and sea level rise data from CoSMoS to show exposure of communities and populations to coastal flood hazard zones.	Projections	n/a

Resource	Type of Information				Description and Uses	Observations and/or Projections	Included Projections/Scenarios and Downscaled Datasets
	Report	Data	Maps	Examples			
					Coastal Hazards		
[USACE Sea Level Tracker]()		✓	✓		The USACE Sea Level Tracker can be used to visualize the dynamic nature of coastal water levels. It allows comparison to projected sea level change and supports exploration of how sea level change has or will intersect with local elevation thresholds related to buildings and infrastructure (e.g., roads, power generating facilities, dunes).	Observations and Projections	Tide Gauge Data and Sea Level Rise Scenario Projections (from Coastal Assessment Regional Scenario Working Group—USACE and NOAA)
					Drought Hazards		
Drought.gov		✓	✓		Drought.gov consolidates drought monitoring information, tools, and maps at national, state, and local levels. It presents drought forecasts and outlooks (which are different from long-term climate projections).	Observations	n/a, uses short-term outlooks
					Extreme Heat Hazards		
Heat.gov		✓	✓		Heat.gov is a centralized place for information, tools, and data about extreme heat risk and resilience. It also links to extreme heat forecasts and outlooks (which are different from long-term climate projections).	Observations	n/a, uses short-term outlooks

Acronym List

AR6: Sixth Assessment Report

CEQ: Council on Environmental Quality

CHaMP: Climate and Hazard Mitigation Planning

CHAT: Climate Hydrology Assessment Tool

ClimRR: Climate Risk and Resilience Portal

CMRA: Climate Mapping for Resilience and Adaptation

CMIP (CMIP5, CMIP6): Coupled Model Intercomparison Project

CoSMoS: Coastal Storm Modeling System

CRT: U.S. Climate Resilience Toolkit

DOD: Department of Defense

DOI: Department of the Interior

DOT: Department of Transportation

EPA: U.S. Environmental Protection Agency

FEMA: Federal Emergency Management Agency

GHG: greenhouse gas

GWL: Global Warming Level

HERA: Hazard Exposure Reporting and Analytics

IPCC: Intergovernmental Panel on Climate Change

LASSO: Locating and Selecting Scenarios Online

LOCA (LOCA2): Localized Constructed Analogs

MACA: Multivariate Adaptive Constructed Analogs

NASA: National Aeronautics and Space Administration

NCA (NCA4, NCA5): National Climate Assessment

NCCV: National Climate Change Viewer

NEC-GDDP: NASA Earth Exchange Global Daily Downscaled Projections

NOAA: National Oceanic and Atmospheric Administration

OSTP: Office of Science and Technology Policy

RCP: Representative Concentration Pathway

SHIRA: Strategic Hazard Identification and Risk Assessment

SSP: Shared Socioeconomic Pathway

USACE: U.S. Army Corps of Engineers

USDA: U.S. Department of Agriculture

USGCRP: U.S. Global Change Research Program

USGS: U.S. Geological Survey