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Climate Change Response Program
Natural Resource Stewardship and Science

Coming to Terms with Climate Change: Working Definitions

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Established in 2010, the National Park Service Climate Change Response Program advances efforts to address the effects of climate change across the breadth of the National Park System. The Program works across directorates and program areas to support parks through technical expertise and research, guidance and training, project and planning support, and provision of communication products. The Program works with other agencies, organizations, and stakeholder groups—nationally and internationally—to maximize information sharing, support, learning, and project effectiveness.

This report received formal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data, and whose background and expertise put them on par technically and scientifically with the authors of the information.

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ON THE COVER

Left: Structure wrap placed around the base of the General Sherman Tree in Sequoia National Park to protect against the approaching KNP Complex Fire, 2021. Top right: The Cape Hatteras Lighthouse was moved to a new inland location away from encroaching sea, 1999. “Eco-Tent” lodging units in Everglades National Park can be disassembled in advance of a hurricane, 2019. Consistent terminology is needed across all these domains (natural resource management, facilities management, visitor experience) to ensure effective adaptation. (All photos are public domain.)

Preface

Climate change is a multi-disciplinary challenge that affects resources, assets, operations, visitor experience and human well-being across the National Park System. When multiple disciplines address a common challenge, their specialized vocabularies can result in inconsistent use of important words or terms, causing confusion, misunderstanding, and inefficiencies in collaboration. The purpose of this glossary is to clarify definitions of key climate change-related terms and support effective communication and action among staff of the Climate Change Response Program and other NPS staff, collaborators, and partners.

To support periodic updates of this document, the Climate Change Response Program welcomes comments on the content, as well as contributions of additional terms or useful cited definitions.

Glossary

Absolute sea-level rise: Rise in the height of the ocean surface above the center of the Earth, without regard to whether nearby land is rising or falling (EPA 2018).

Accept change: A class of adaptation response (alongside *direct change* and *resist change*) in which managers do not intervene to alter the trajectory of change and the target responds to change autonomously (Schuurman et al. 2020). Also sometimes referred to as an "accommodate change" strategy (Fisichelli et al. 2016).

Adaptation: See *climate change adaptation*.

Adaptation action: The tactical and implementation components of the management response to observed climate changes or plausible climate futures. Often intended to refer to implemented actions, but can also refer to intended actions not yet executed. See *adaptation strategy*, *climate change adaptation*.

Adaptation strategy: The planning component of the management response to observed climate changes or plausible climate futures. An adaptation strategy is implemented to manage potential risks stemming from vulnerability of a resource or asset to climate change impacts or natural hazards exacerbated by climate change.

Adaptive capacity: The ability of systems, institutions, humans and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences of climate change (IPCC 2014). For an institution, the term applies to the ability to persist in its own right and to foster adaptation among other systems, humans, or organisms. Adaptive capacity is considered a component of vulnerability in some frameworks, including natural resources (Stein et al. 2014) where it is intrinsic; it is not recommended as part of vulnerability for non-living cultural resources and infrastructure (Rockman et al. 2016; WCU and NPS 2016) where it is extrinsic (e.g. economic, social).

Adaptive management: A decision process that promotes learning in the face of uncertainties as outcomes from management actions and other events become better understood (Williams et al. 2007). Careful monitoring of outcomes both advances scientific understanding and helps adjust policies or operations as part of an iterative learning process. It is not managing by "trial and error"; it involves predicting expected outcomes, usually from competing models representing the system, and formally comparing predictions to observed outcomes to guide learning (Williams and Brown 2012). The formal comparison against observed outcomes presumes a well-defined monitoring component (Williams and Brown 2012).

Anthropogenic: Resulting from or produced by human activities (IPCC 2014). Also often referred to as "human-caused" (e.g., "anthropogenic climate change").

Asset: Real or personal property which the NPS desires to track and manage as a distinct identifiable entity. It may be a physical structure or grouping of structures, land features, or other tangible

property that has a specific service or function, such as a farm, cemetery, campground, marina, road, building, or sewage treatment plant. The term "asset" can also be applied to movable items, such as vehicles and equipment (NPS Facility Condition Assessment Survey, ND).

Assisted colonization: See *managed relocation*. For most situations, managed relocation is the preferred term.

Assisted dispersal: See *managed relocation*.

Assisted migration: See *managed relocation*.

Attribution: The process of evaluating the relative contributions of multiple causal factors to a change or event with an assignment of statistical confidence (Hegerl et al. 2010). See *detection and attribution*.

Climate: The average weather patterns or trends for a region over a period of many years; components usually include seasonal patterns of temperature, precipitation, wind, relative humidity, etc. Climate "normals" are the averages of climate variables for (typically) a 30-year period.

Climate change: A change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forces, or to persistent *anthropogenic* changes in the composition of the atmosphere or in land use (IPCC 2007).

Climate change adaptation: An intentional management response to observed climate changes or plausible future changes that involves identifying, preparing for (e.g., developing strategy and specific actions), and responding to (e.g., implementing actions) those changes. The desired outcome from the management response is to retain current conditions, recover from climate variations (perhaps to an altered state), or adjust to changing conditions that may include major transformation in practices or state. Adaptation may seek to "moderate harm or exploit beneficial opportunities" (IPCC 2014). See *accept change*, *adaptation action*, *adaptation strategy*, *direct change*, *resist change*.

Climate change refugia: See *refugia (from climate change)*.

Climate driver: (1) When referring to an effect of climate on a conservation or preservation target, any climate variable or climate-related effect that causes change or impacts the target. For this use, common climate drivers include temperature, precipitation, sea-level, and snow cover. (2) When referring to changes in climate, any natural or human-induced factor that directly or indirectly causes a change in climate. Greenhouse gases and land use are important drivers of climate (Gross et al. 2016).

Climate envelope model: A subset of species distribution models that use climate variables to make spatial predictions of environmental suitability for a species (Watling et al. 2012). Relationships derived from contemporary data can be used to project distributional changes using estimates of anticipated climate change.

Climate future: A description of the physical attributes of climate that could plausibly occur at a specific place and time in the future (Runyon et al. 2019). A set of climate futures is the foundation for constructing climate-resource scenarios (see *scenario*). A plausible climate future is based on the best available science. In a given planning context, a climate future's usefulness increases as the climate metrics used to define it are more directly relevant to the management decision. Typically, multiple climate futures are used to consider the range of ways climate could change.

Climate model: A numerical representation of the climate system based on the physical, chemical, and biological properties of its components, their interactions, and feedback processes, and accounting for some of its known properties. The climate system can be represented by models of varying complexity (IPCC 2014). See *global climate model*.

Climate projections: The simulated response of the climate system to a scenario of future emission or concentration of greenhouse gases and aerosols, generally derived using climate models. Climate *projections* are distinguished from climate *predictions* by their dependence on the emission/concentration/radiative forcing scenario used, which is in turn based on assumptions concerning, for example, future socioeconomic and technological developments that may or may not occur (IPCC 2014).

Climate-resource scenario: See *scenario*.

Climate-smart: The intentional and deliberate consideration of climate change in planning and management, realized through the adoption of forward-looking goals and explicit linkage of strategies to key climate impacts and vulnerabilities (adapted from Stein et al. 2014).

Climate variability: Variations in climate from the average over a region (spatial scale) and time period (temporal scale) beyond that of individual weather events (IPCC 2014). Usage requires defining the spatial and temporal scales of interest as well as the climate statistic of interest (such as annual mean temperature, annual mean precipitation, frequency of extreme precipitation events, etc.). Drivers of climate variability include "natural" processes internal to the climate system (such as the El Niño Southern Oscillation and other phenomena (USGCRP 2019)) or changes in external forcing (IPCC 2014).

CMIP (Coupled Model Intercomparison Projects): Coherent set of experimental conditions used to evaluate climate models and future conditions. These are the basis for the IPCC assessment reports.

Confidence: The validity of a finding based on the type, amount, quality, and consistency of evidence (e.g., mechanistic understanding, theory, data, models, expert judgment) and on the degree of agreement. Confidence is expressed qualitatively (Mastrandrea et al. 2010; as in IPCC 2014); the terms used should be explicitly defined. See *uncertainty (climate)* and *likelihood*.

Criticality: The importance or significance of a resource or asset (e.g. functional, historical, financial). This term is most often focused on infrastructure.

Cultural resources: Archeological resources, cultural landscapes, ethnographic resources, historic and prehistoric structures, and museum collections (NPS 2006).

Detection and attribution: Detection of change is the process of demonstrating that a system has changed in some defined statistical sense, without providing a reason for that change. An identified change is detected in observations if its likelihood of occurrence by chance due to internal variability alone is determined to be small, for example, <10% (i.e., variations results from natural causes). Attribution is defined as the process of evaluating the relative contributions of multiple causal factors to a change or event with an assignment of statistical confidence (Hegerl et al. 2010).

Direct change: A class of adaptation response (alongside *accept change* and *resist change*) in which managers intervene to actively influence the trajectory of change and shape change in the target towards specific desired new conditions. (Schuurman et al. 2020).

Dispersal: The movement of individual organisms away from their birth site or breeding site to another location (USGCRP 2019).

Downscaling: A method that derives local- to regional-scale (< 1 to ~50 km) information from larger-scale models or data analyses. Dynamical downscaling, or regional climate modelling, simulates the physical processes of a smaller area at a fine resolution and is computationally intensive. Statistical downscaling relies on a fixed statistical relationship between observed (historical) climate variables and forecasts from a global climate model.

Drought: A period of abnormally dry weather marked by little or no precipitation that causes water shortage for people and natural systems (USGCRP 2019). See *ecological drought*.

Dynamic downscaling: See *downscaling*.

Ecological drought: An episodic deficit in water availability that drives ecosystems beyond thresholds of vulnerability, impacts ecosystem services, and triggers feedbacks in natural and/or human systems (Crausbay et al. 2017). See *drought*.

Ecological replacement: The intentional movement and release of an organism outside its indigenous range to perform a specific ecological function (IUCN 2013). In the context of climate change, the motivation is to direct climate change-driven change towards specific desired conditions. See *managed relocation*.

Ecological resilience: See *resilience (ecological)*.

Ecological threshold: A point at which there is an abrupt change in an ecosystem quality, property, or phenomenon, or where small changes in an environmental driver produce large responses in the ecosystem (Groffman et al. 2006).

Ecological transformation: A dramatic and irreversible shift in multiple ecological characteristics of an ecological system, the basis of which is a high degree of turnover in ecological communities,

and not just change in a single species (Shimadzu et al. 2015; Schuurman et al. 2020). See *ecological threshold* and *tipping point*.

Ecosystem services: The benefits produced by ecosystems on which people depend, including, for example, fisheries, drinking water, fertile soils for growing crops, climate regulation, recreation, and aesthetic and cultural value (USGCRP 2019).

Emissions scenarios: Quantitative descriptions of how the release of different amounts of climate-altering ("greenhouse") gases and particles into the atmosphere, from human and natural sources, will produce different future climate conditions. Emissions scenarios are developed using a wide range of assumptions about population growth, economic and technological development, and other factors (USGCRP 2019).

Equivalent carbon dioxide (CO_2) emission: The amount of carbon dioxide emission that would cause the same radiative forcing, over a given time horizon, as an emitted amount of a greenhouse gas or a mixture of greenhouse gases (IPCC 2013).

Exposure: A measure of the character, magnitude, and rate of changes a target may experience. In the climate change context, this includes changes in climate drivers (e.g. temperature, precipitation, solar radiation) as well as changes in related factors (e.g. sea-level, water temperatures, drought intensity, ocean acidification) (Gross et al. 2014).

Extreme event: A weather event that is rare at a place and time of year, including, for example, a heat wave, cold wave, heavy rain, period of drought or flooding, or a severe storm. The definition of "extreme" is a statistical concept that varies depending on location, season, and length of the historical record (USGCRP 2019).

Extreme (or heavy) precipitation (event): An episode of abnormally high rain or snow. The definition of "extreme" is a statistical concept that varies depending on location, season, and length of the historical record (USGCRP 2019).

Global climate model: Global climate models are complex, three-dimensional coupled models that incorporate the latest understanding of the physical processes at work in the atmosphere, oceans, and Earth's surface to generate climate projections. They range from lower-level General Circulation Models (GCMs) to coupled Atmosphere–Ocean General Circulation Models (AOGCMs) (IPCC 2007). Also sometimes referred to as "Earth System Models" (ESMs). See *climate model*.

Greenhouse gases: Gases that absorb heat in the atmosphere near the Earth's surface, preventing it from escaping into space. If the atmospheric concentrations of these gases rise, the average temperature of the lower atmosphere will gradually increase, a phenomenon known as the "greenhouse effect." Greenhouse gases include, for example, carbon dioxide, methane, nitrous oxide, and water vapor (USGCRP 2019).

Hazard: The potential occurrence of a natural or human-induced event, trend, or impact that may cause loss of life, injury, or other health impacts, as well as damage and loss to property,

infrastructure, livelihoods, provision of services, ecosystems, and environmental resources (IPCC 2014).

Hindcast: Assessing the performance of a model that is designed to make future projections by using it to simulate a historical period to compare to empirical, observed data.

Indicator-based vulnerability assessments (IBVA): An assessment based on attributes or characteristics of a system, rather than on direct impacts. Often used for social systems or infrastructure, where economics or maintenance history may relate to vulnerability (Tonmoy et al. 2014). In ecological applications, these are often termed "trait-based vulnerability assessments" (e.g., Willis et al. 2015).

Infrastructure: Buildings, roads, utilities, equipment, and other structures or facilities. In a vulnerability assessment, infrastructure can be considered both as a feature to preserve as well as a stressor on resources (Crist et al. 2012).

Isostatic rebound: Rise of land masses that were depressed by the huge weight of ice sheets during the last ice age (NSIDC 2020). More broadly, isostatic adjustment can include rapid sinking in areas that were formerly bulged upwards (relative to the Earth's mantle) due to the depression of adjacent areas under ice, contributing to relatively rapid local relative sea-level rise.

Key vulnerability: Those vulnerabilities that merit more attention because they pose the greatest risk to achieving conservation goals and objectives (Gross et al. 2014).

Likelihood: The chance of a specific outcome occurring, which might be estimated probabilistically. Likelihood is expressed in IPCC reports using a standard terminology (Mastrandrea et al. 2010). In statistical use, likelihood refers to the relative plausibility of a value for a parameter, given specific data.

Maladaptive actions (Maladaptation): Actions that may lead to increased risk of adverse climate-related outcomes, increased vulnerability to climate change, or diminished welfare, now or in the future (IPCC 2014).

Managed relocation: The intentional movement and release of an organism outside its indigenous range (paraphrased from IUCN 2013; Karasov-Olson et al. 2021).

Mechanistic models: Numerical models whose structure reflects an understanding of important components and processes that account for observed dynamics. By contrast, an *empirical model* may account for observed dynamics with no representation of the underlying processes. Also called "process-based models."

Metric Tons of Carbon Dioxide Equivalent ($MTCO_2E$): See *equivalent carbon dioxide (CO2) emission*.

Microclimate: Variations in climate within a small area or atmospheric zone relative to the larger general area. Microclimates usually result from differences in local topography, vegetation,

structures, or proximity to water and can vary substantially from the general climate of an area (Bagne et al. 2011).

Mitigation (climate change context): A human intervention to reduce the sources or enhance the sinks of greenhouse gases (IPCC 2014).

Mitigation (emergency response context): The effort to reduce loss of life and property by lessening the impact of disasters (FEMA 2019).

Mitigation (Cultural Resources Section 106): A measure to resolve specific adverse effects to identified cultural resource(s) by offsetting such effects (36 CFR Part 800). A nexus is required between the mitigation measure(s) and the adverse effects on the cultural resource(s).

Mitigation (NEPA): Avoiding the impact of a human intervention in a natural system altogether by not taking a certain action or parts of an action; minimizing impacts by limiting the degree or magnitude of the action and its implementation; rectifying the impact by repairing, rehabilitating, or restoring the affected environment; reducing or eliminating the impact over time by preservation and maintenance operations during the life of the action; and compensating for the impact by replacing or providing substitute resources or environments (40 C.F.R. § 1508.20).

Mitigation (NRDA/Conservation): The effort to offset or repair damage to natural resources, typically as part of a legal settlement for violations of the Clean Water Act.

Persistence: Current/past target conditions continue to exist, either because the target is inherently resistant to change or because of adaptation efforts to resist change (Beavers et al. 2016).

Phenology: The pattern of seasonal life cycle events in plants and animals, such as timing of blooming, hibernation, and migration (USGCRP 2019).

Phenotypic plasticity: The ability of an organism to change its behavior, physiology, or physical characteristics in response to its environment. This change occurs within an organism's lifetime and therefore does not require genetic change (USGCRP 2019). Often considered an important component of adaptive capacity for species.

Radiative forcing: The balance of incoming (solar) and outgoing (re-radiated to space) energy in the Earth-atmosphere system averaged across the globe (IPCC 2014). This term is usually used in reference to the balance at the tropopause or top of atmosphere (IPCC 2014).

Refugia (from climate change): Areas relatively buffered from contemporary climate change over time that enable persistence of valued physical, ecological, and socio-cultural resources (Morelli et al. 2016).

Relative sea-level rise: The increase in ocean water levels at a specific location, taking into account both absolute sea-level rise and local factors, such as local subsidence and uplift. Relative sea-level rise is measured with respect to a specified vertical datum relative to the land, which may also be changing elevation over time (Beavers et al. 2016).

Representative concentration pathway (RCP): Scenario that include time series of emissions and concentrations of the full suite of greenhouse gases and aerosols and chemically active gases, as well as land use/land cover (Moss et al. 2008).

Resilience (ecological): The ability of a natural system to return to a prior condition after disturbance (Millar et al. 2007). The term "resilience" is used in different ways in the historically disparate fields now united in climate change adaptation, and this ambiguity can impede communication and adaptation if not recognized and addressed (Fisichelli et al. 2016, Siders 2016). See *resilience (human context)*.

Resilience (human context): A capability to anticipate, prepare for, respond to, and recover from significant multi-hazard threats with minimum damage to social well-being, the economy, and the environment (USGCRP 2019). See *resilience (ecological)*.

Resistance: The ability to withstand perturbations without significant loss of structure or function (Beavers et al. 2016, Connell and Ghedini 2015). Resistance is similar to resilience in implying persistence, but differs from it in that it is about preventing—rather than recovering from—impacts.

Resist change: A class of adaptation response (alongside *accept change* and *direct change*) in which managers intervene to prevent or reverse the trajectory of change and maintain or restore the target within current or past conditions (Beavers et al. 2016, Schuurman et al. 2020).

Risk: Threats to life, health and safety, the environment, economic well-being, and other things of value. Risks are often evaluated in terms of how likely they are to occur (probability) and the damages that would result if they did happen (consequences) (USGCRP 2019). The consequences or damages are derived from the vulnerability of the thing of value (see *vulnerability*).

Risk assessment: The process of identifying the magnitude or consequences of an adverse event or impact as well as the probability that the event or impact will occur (Jones 2001).

Scenario: A coherent, internally consistent description of plausible future states of a system used to support planning and decision making. In the context of climate change adaptation, scenarios consist of a set of "climate futures" with their associated resource implications (Runyon et al. 2019), and are often termed "climate-resource scenarios." Managers sometimes include potential management responses as part of scenarios. See *climate future*.

Scenario analysis: A process of analyzing possible future events by considering alternative plausible outcomes or scenarios (Gross et al. 2016).

Scenario planning: A process for exploring science-based, plausible, and challenging trajectories of future change that encapsulate key uncertainties and system responses. Considering multiple scenarios based on climate projections enables managers to update near- and long-term goals and develop strategies that can succeed under a range of possible future conditions. In some cases individual scenarios include high-consequence events, which may require specific planning.

Sensitivity (to climate change): The degree to climate change affects a resource, facility, or other target either adversely or beneficially. The effect may be direct (e.g., increased stress or mortality of cold-water fish due to increased water temperatures on exceptionally hot days) or indirect (e.g., damages caused by an increase in the frequency of coastal flooding due to sea-level rise) (IPCC 2014).

Sequestration: The uptake and storage of carbon-containing substances, in particular carbon dioxide (CO_2), in terrestrial or marine ecosystems. Biological sequestration includes direct removal of CO_2 from the atmosphere through land-use change, afforestation, reforestation, revegetation, carbon storage in landfills, and practices that enhance soil carbon in agriculture (IPCC 2014).

SSP (Shared Socioeconomic Pathway): Emissions scenarios driven by different socioeconomic assumptions (Riahi et al. 2017). Used by IPCC and to drive CMIP6 model experiments.

Stationarity: The assumption that natural systems fluctuate within an unchanging envelope of variability through time (Milly et al. 2008).

Statistical downscaling: See *downscaling*.

Storm surge: The sea height during storms such as hurricanes that is above the normal level expected at that time and place based on the tides alone (USGCRP 2019).

Stressor: Events and trends, often not climate-related, that have an important effect on the exposed system and can increase vulnerability to climate related risk (IPCC 2014).

Target: The specific aspect of a system that decisions or actions aim to affect. The target could be a resource, an asset, a process, a subsystem, etc. Often used to define not only the feature of interest (e.g., a species or a historic structure) but also a specific characteristic of that feature (e.g., species distribution or condition of the historic structure).

Thresholds: A general concept from systems science referring to a situation where a small level of change in a system's states produces a relatively large, possibly abrupt, change in system configuration or behavior (Meadows 2008). The concept is applicable to natural systems and human-built systems (including cultural resources). See *ecological threshold*, *ecological transformation*, *tipping point*, and *transformation*.

Tipping point: A level of change in system properties beyond which a system reorganizes, often abruptly, and does not return to the initial state even if the drivers of the change are abated (IPCC 2014). See *ecological transformation* and *transformation*.

Transformation: A change in the fundamental attributes of natural and human systems (IPCC 2014). See *ecological transformation*.

Urban Flooding: Higher flood flows into urban areas stemming from a combination of extensive urban development, aging and frequently undersized infrastructure in older sections of communities,

an inability to maintain existing drainage systems, increases in intense rainfall events, and uncoordinated watershed management (UMD CDR and Texas A&M CTBS 2018).

Uncertainty (climate): A state of incomplete knowledge that can result from a lack of information or from disagreement about what is known or even knowable. It may have many types of sources, from imprecision in the data to ambiguously defined concepts or terminology, or uncertain projections of future human behavior. Uncertainty can be represented by quantitative measures (e.g., a probability density function) or by qualitative statements (e.g., reflecting the judgment of a team of experts) (see Moss and Schneider 2000; Manning et al. 2004; Mastrandrea et al. 2010; IPCC 2014). See *confidence* and *likelihood*.

Vulnerability: The degree to which a physical, biological, or socio-economic system is susceptible to and unable to cope with adverse impacts of climate change (USGCRP 2019). See *vulnerability assessment* for common components of vulnerability; also, see *risk*.

Vulnerability assessment: An evaluation of the extent to which a system is susceptible to harm from direct and indirect effects of climate change, including variability and extremes. Vulnerability is often based on measures of exposure and sensitivity with consideration for the adaptive capacity of living organisms (paraphrased from Rockman et al. 2016, USGCRP 2019).

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