



# Climate Change Scenario Planning for Northwest Alaska Parks

## *Cape Krusenstern and Bering Land Bridge*

Natural Resource Report NPS/AKSO/NRR—2014/830



Scenarios Network  
FOR ALASKA & ARCTIC PLANNING



## **ON THE COVER**

The autumn tundra rolls across the landscape into the distance as silent white clouds glide through a blue sky overhead.  
Photograph by: Chris Russoniello, National Park Service.

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## Executive Summary

Changing climatic conditions are rapidly impacting environmental, social, and economic conditions in and around National Park Service (NPS) areas in Alaska. With over 50 million acres of parklands to administer, Alaska park managers must better understand possible climate change trends in order to better manage arctic, subarctic, and coastal ecosystems, as well as human uses of these areas. As such, NPS managers undertook an exploration of scenario planning as an innovative approach to science-based decision-making in the face of an uncertain future. Climate change scenarios are defined herein as plausible yet divergent futures based on the best available current knowledge of driving climate variables. These scenarios will help prepare NPS Alaska park managers for impending changes to make informed decisions for future outcomes.

This effort took off in 2010, when NPS national and Alaska Regional offices released climate change response strategies for the National Park System and the Alaska Region, respectively (NPS 2010a, NPS 2010b). Scenario planning was identified in both strategies as a high priority for understanding potential climate change impacts to park resources, assets and operations. As a result, NPS and the University of Alaska's Scenarios Network for Alaska and Arctic Planning (SNAP), a research group focused on climate change modeling and adaptation, embarked on a three-year collaborative project to help Alaska NPS managers, cooperating personnel, and key stakeholders consider potential consequences of climate change by developing plausible climate change scenarios for all NPS areas in Alaska. Final products include climate change scenario planning exercises, reports and other informational products for all NPS units in Alaska, with efforts organized around each of the four Inventory and Monitoring (I&M) networks.

The Climate Change Scenario Planning project began in August 2010, when the NPS Climate Change Response Program partnered with Jonathan Star of the Global Business Network (GBN) to initiate a series of scenario planning training workshops across the National Park System. A team of NPS Alaska Region and SNAP employees participated in the Alaska training workshop, learning how to develop scenarios based on nested frameworks of critical uncertainties, and fleshing out the beginnings of climate change scenarios for two pilot parks.

Building from the learning experiences from the training workshop and the Southwest Alaska workshop, Northwest Alaska was the second area in Alaska to be examined by NPS through a scenarios workshop on April 19-21, 2011. This workshop was based on the framework introduced by GBN, and led by a core team who had participated in at least one training session and one workshop. This April 2011 workshop focused on two coastal parks in the Arctic Network (ARCN): Cape Krusenstern National Monument (CAKR) and Bering Land Bridge National Preserve (BELA). The other ARCN parks (Noatak National Preserve, Kobuk Valley National Park, and Gates of the Arctic National Park and Preserve) were addressed in a separate workshop in 2012.

Participants included representatives from the parks in question, NPS staff from the Alaska Regional Office, SNAP personnel, and key individuals from other agencies, nongovernment organizations, and communities with a stake in this region. These individuals contributed a wide range of perspectives and expertise to the process and outcomes of the workshop.

Participants identified key issues facing the parks in this particular region of Alaska. Key issues included the many possible effects of permafrost thaw, loss of shore-fast ice and sea ice, and increased storms and precipitation. More specifically, future scenarios focused on potential impacts to ecosystems and humans who rely on them, as loss of frozen soils, loss of ice, increased storms, and general warming trends cause community-threatening and landscape-altering erosion, as well as changes in vegetation, hydrology, wildlife, and subsistence species.

General findings and recommendations include a range of potential changes to species presence and abundance and their assemblages both onshore and offshore; disappearance of or changes to subsistence resources; loss of some cultural resources; risks to infrastructure; and changes in development pressure. Participants agreed that most or all potential scenarios pointed toward a need to revisit park mandates; improve interagency collaboration and planning; improve integration of Traditional Ecological Knowledge (TEK) into science, planning and management; increase flexibility in management, direction and principles; undertake long-range adaptive planning to conserve limited funds; develop good outreach tools for diverse audiences; and find and cultivate partners for funding.

Workshop participants further suggested the need for developing research proposals for projects that address research needs identified through CCSP; creating and maintaining coordinated seamless data collection and sharing; maintaining a robust Inventory & Monitoring (I &M) program focused on determining critical resources and habitat; identifying creative strategies to work across interdisciplinary boundaries; encouraging interdisciplinary coordination with feedback loops and partnering; and expediting data recovery of archaeological/paleontological sites.

The climate change scenario planning process does not end with these workshops, reports, and presentations. Rather, this living process is intended to stimulate creative thinking to address changing but still undetermined future environmental and socio-political future conditions. The process should be refreshed periodically as important new information becomes available. In summary, park managers, park neighbors, and stakeholders can be best prepared for the future by using the best available scientific information and climate projections to create plausible, divergent, relevant, and challenging future climate change scenarios. These scenarios can help us all better prepare for uncertain future conditions in the face of changing climate.

## **Acknowledgments**

All the National Park Service Scenario Planning Workshops were highly participatory, relying on input from every attendee. We would like to thank each of the individuals listed in Appendix B, as well as the organizations and communities that made it possible for them to attend by allowing them the time to do so.

## List of Terms & Acronyms

|                   |                                                                                                                                                                                                                                                                                                |
|-------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| ARCN              | Arctic Network, the National Park Service’s Inventory & Monitoring network of parks in northern Alaska                                                                                                                                                                                         |
| BELA              | Bering Land Bridge National Preserve, coastal park in ARCN                                                                                                                                                                                                                                     |
| CAKR              | Cape Krusenstern National Monument, coastal park in ARCN                                                                                                                                                                                                                                       |
| CCSP              | Climate Change Scenario Planning                                                                                                                                                                                                                                                               |
| Climate driver    | A climate variable that drives changes in weather, vegetation, habitat, wildlife, etc. Also referred to as a <i>critical force and a scenario driver</i> .                                                                                                                                     |
| Climate effects   | Existing or potential consequences, outcomes, or results of changes in climate. Can appear beneficial or deleterious, depending on perspectives.                                                                                                                                               |
| Critical force    | A climate variable that drives changes in weather, vegetation, habitat, wildlife, etc. Also referred to as a <i>scenario driver</i> .                                                                                                                                                          |
| ENSO              | El Nino-Southern Oscillation. A climate pattern that occurs across the tropical Pacific Ocean on an approximately 5-year time scale, which can cause extreme weather events in many regions of the world.                                                                                      |
| Impact            | A forceful or particularly significant consequence. An effect that is likely to warrant a response.                                                                                                                                                                                            |
| Narrative         | In scenario planning, a story, in any variety of formats, used to visualize potential future circumstances.                                                                                                                                                                                    |
| Nested scenario   | A set of projected future environmental conditions “nested” within a sociopolitical framework.                                                                                                                                                                                                 |
| PDO               | Pacific Decadal Oscillation. A pattern of Pacific Ocean climate variability that shifts between a cool (negative) phase and warm (positive) phase on a 20-30 year time scale.                                                                                                                  |
| Potential effects | Inherently possible, likely, or expected, but not necessarily certain.                                                                                                                                                                                                                         |
| Scenario          | A projected course of events or situations, used to understand different ways that future events might unfold.                                                                                                                                                                                 |
| TEK               | Traditional Ecological (or Environmental) Knowledge. A cumulative body of knowledge built up by a group of people over many generations of close contact with nature. Sometimes distinguished from other forms of local knowledge, developed through fewer years or generations of experience. |



# Introduction

In this paper, we describe the Climate Change Scenarios Planning (CCSP) effort at several different levels. First, we introduce the rationale and need for such an effort, at the national, statewide, and local level. Next, we provide background on the particular Global Business Network (GBN) methods used in this project – as well as in parallel projects for the other park networks in Alaska. This background places GBN methods in the context of other possible planning tools. In this context, we discuss modifications that were necessary to best address the particular challenges of climate change planning.

In the Workshop Group Products section, we provide significant detail with regard to the products and outcomes of the scenarios process. This includes intermediate data from the brainstorming processes that took place during the three-day Scenarios Planning Workshop, although some of these products are linked only via appendices. These details are included in order to allow this paper to serve as not only a project summary, but also a roadmap or case study for any similar efforts that may take place in the future, either in Alaska or elsewhere.

The Common Implications, Actions, and Needs section of the paper pulls together these products into a more cohesive summary of outcomes. Finally, we discuss the ramifications of these outcomes from the perspective of management, future collaboration, and future research.

## Project Rationale

Climate change is occurring at a global scale, and its effects are felt very strongly in Alaska (Chapin et al. 2005). We can no longer manage for old goals and priorities that assume a static climate. Given the complexities and multiple disciplines involved with climate-change challenges, collaboration and knowledge sharing are essential. Scenario planning is an educational process that helps park employees and others understand climate trends; anticipate future changes that may affect resources, assets, and operations in parks and surrounding areas; and consider a range of possible climate change response strategies. This effort represents a collaboration between the National Park Service (NPS) and the Scenarios Network for Alaska and Arctic Planning (SNAP), whose mission is to “develop plausible scenarios of future conditions through a diverse and varied network of people and organizations, which allow better planning for the uncertain future of Alaska and the Arctic” ([www.snap.uaf.edu](http://www.snap.uaf.edu)).

The focus of the workshop described in this report was largely on examples from coastal Arctic Alaska National Parks (Figure 1). However, concerns and effects of climate change are clearly not limited by property lines. The results from this scenario planning workshop can be equally relevant to residents and managers of surrounding areas.

## Focal Question

The focal question of this workshop was “How can NPS managers best preserve the natural and cultural resources and other values within their jurisdiction in the face of climate change?” Although parks were a primary focus, participants were also invited from affiliated communities and other areas for broader, regional-scale perspectives. Answers to the focal question were intended

to be advisory rather than in any way binding. As will be discussed, the focal question was intended to be addressed in the context of scenario planning. Thus, some recommendations for managers are robust to all possible futures, while some are more heavily weighted toward preventing negative outcomes (or enhancing positive outcomes) associated with only one of several possible futures.

## Scenario Planning Process

Natural resource managers and others have explored multiple methods for making management decisions in the face of uncertainty and/or ongoing change. In cases where the future can be predicted via predictive modeling with a relatively small error margin, managers generally choose to seek optimal control. However, in the real world, natural systems uncertainty is often more uncontrollable and irreducible (Peterson et al. 2003, Schwartz 1996).

Under highly uncertain conditions, action based on single predictive forecasts can be extremely risky. Other available planning methods include adaptive planning (Walters 1986) and scenario planning. The two methods have some similarities, in that both recognize the role of uncertainty and the need for resilience in the face of unknown futures. However, in the case of scenario planning, management experiments are built into the models, rather than playing out over time.

Scenario planning explores multiple possible futures based on the best available information of future conditions. Peterson et al. (2003) note that: “Ideally, scenarios should be constructed by a diverse group of people for a single, stated purpose. Scenario planning can incorporate a variety of quantitative and qualitative information in the decision-making process. Often, consideration of this diverse information in a systemic way leads to better decisions. Furthermore, the

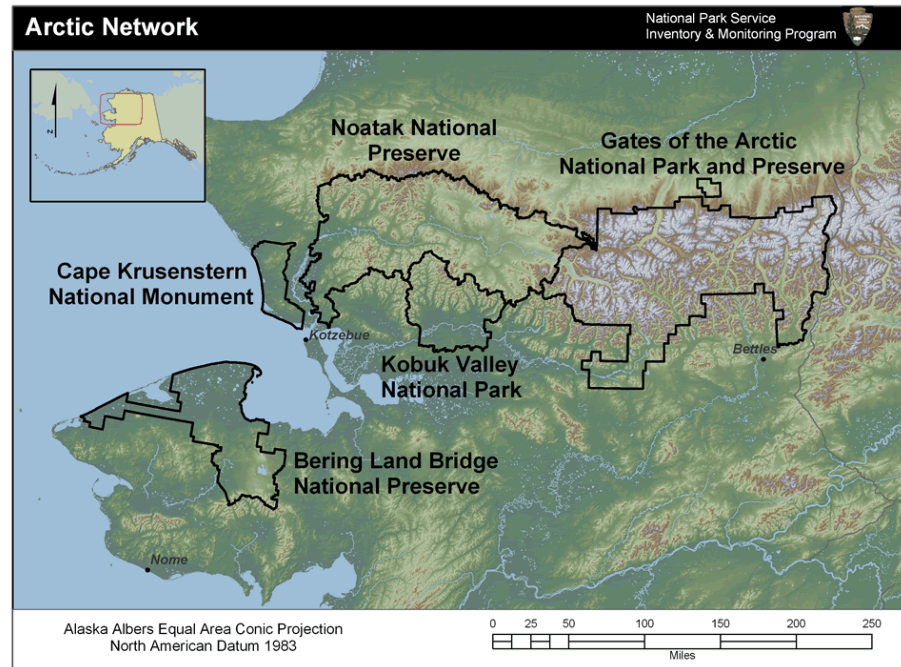


**Figure 1.** Arctic Network National Parks. For the purposes of this project, the network was divided into coastal and interior regions. Thus, the focus was on Cape Krusenstern National Monument (CAKR) and Bering Land Bridge National Preserve (BFI A).

participation of a diverse group of people in a systemic process of collecting, discussing, and analyzing scenarios builds shared understanding.” This combined goal of building understanding and sharing high-quality information in a diverse group was key to this project.

Scenario planning, as outlined by the Global Business Network (GBN) has been used successfully by corporations, government and nongovernmental organizations, and was selected as the most effective way to create management tools and frameworks that would be both useful and flexible in the face of uncertainty (Schwartz 1996).

Unlike forecasting, scenario planning emphasizes multiple possible futures (Figure 2). Forecasts assume that the future is fairly predictable, at least within some range of variability. Scenarios conversely, are possibilities rather than predictions about the future. Scenarios can use modeling output, but they recognize the inherent unpredictability of complex systems. Scenarios envision a range of plausible, relevant, divergent and challenging futures and then ask the question “What if this was to happen?” Consequently, the scenarios provide a richer background for planning and decision making than traditional forecasting methods. These scenarios should be created and selected to be relevant, plausible, divergent, and challenging.

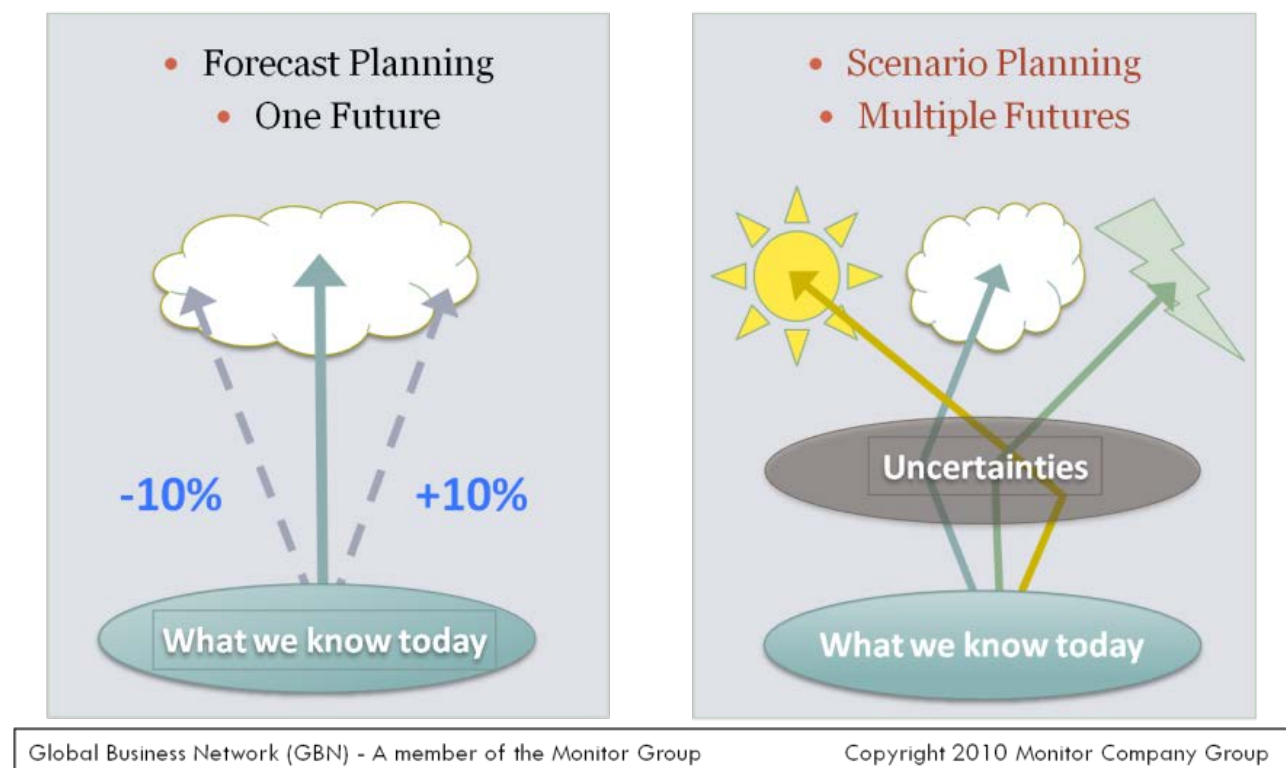


**Figure 2.** Difference between forecasting and scenario planning. Diagram courtesy of GBN.

The scenario planning process asks participants to orient on a focal question; explore and synthesize potential scenarios; act, by identifying and implementing actions appropriate to address potential outcomes; and monitor the results of these actions (Figure 3). The latter two steps (Act and Monitor) occur after the CCSP workshop.

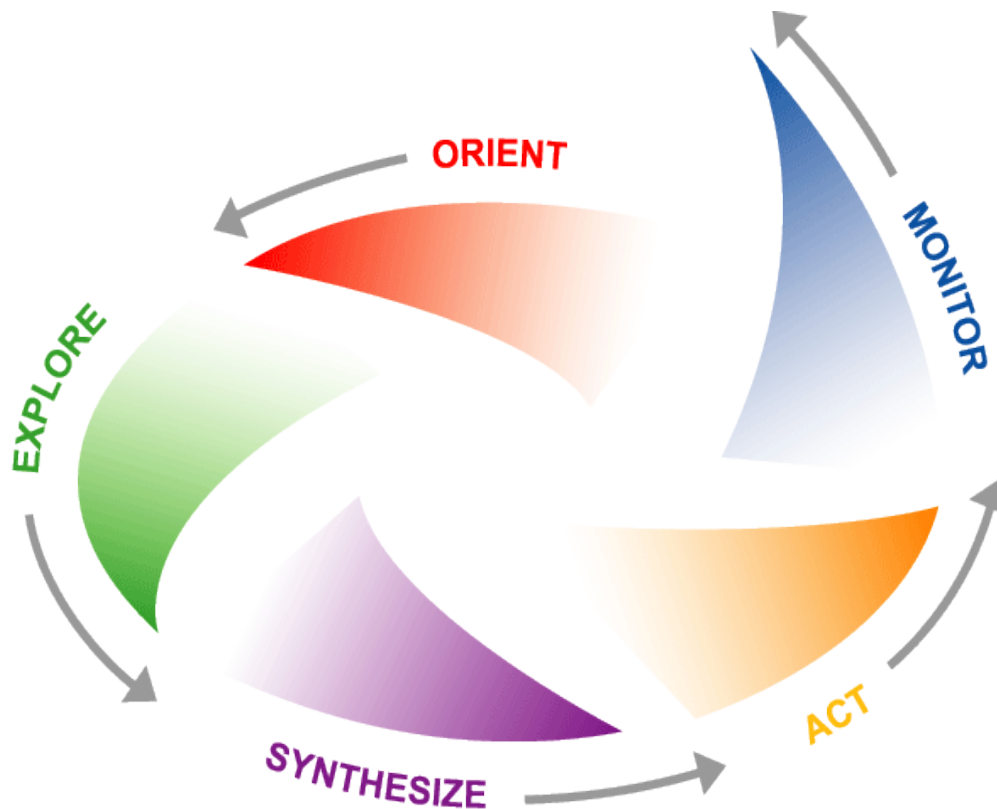


**Figure 3.** Stages in the scenarios building process. Diagram provided by the Global Business Network (GBN).

Scenario synthesis is dependent on a multi-step process in which participants select two key drivers of change that are both important (likely to cause multiple significant effects) and uncertain (in terms of the magnitude or direction of the change). These drivers, when intersected, yield four possible futures (Figure 4). By selecting the drivers with the greatest importance and uncertainty, workshop participants insure that these four futures represent highly divergent scenarios that approximate the full range of possibilities worth exploring in depth.

In this workshop, the primary drivers were biophysical drivers of climate change. Participants first fleshed out some of the details of the four outcomes suggested by these primary drivers, by creating bulleted lists of potential effects to humans, ecosystems, and infrastructure in and around parks. They then took the scenarios process to a higher level by examining each possible future in a sociopolitical framework that incorporated a wide range of societal concern and an equally wide range of institutional support (Figure 5). Selected divergent scenarios from this framework were fully described in both summary and narrative forms, and management actions were suggested based upon selected scenario.

Scenario planning offers participants the opportunity to search for actions that perform well under all scenarios (often called “no-regrets” or “robust” actions); current actions the park should continue doing, and actions that are unlikely to make sense in any future scenario. These actions are often among the immediate and powerful scenario outcomes. There are also a variety of other strategic approaches that offer different levels of risk when developing a range of actions as illustrated in Figure 6.

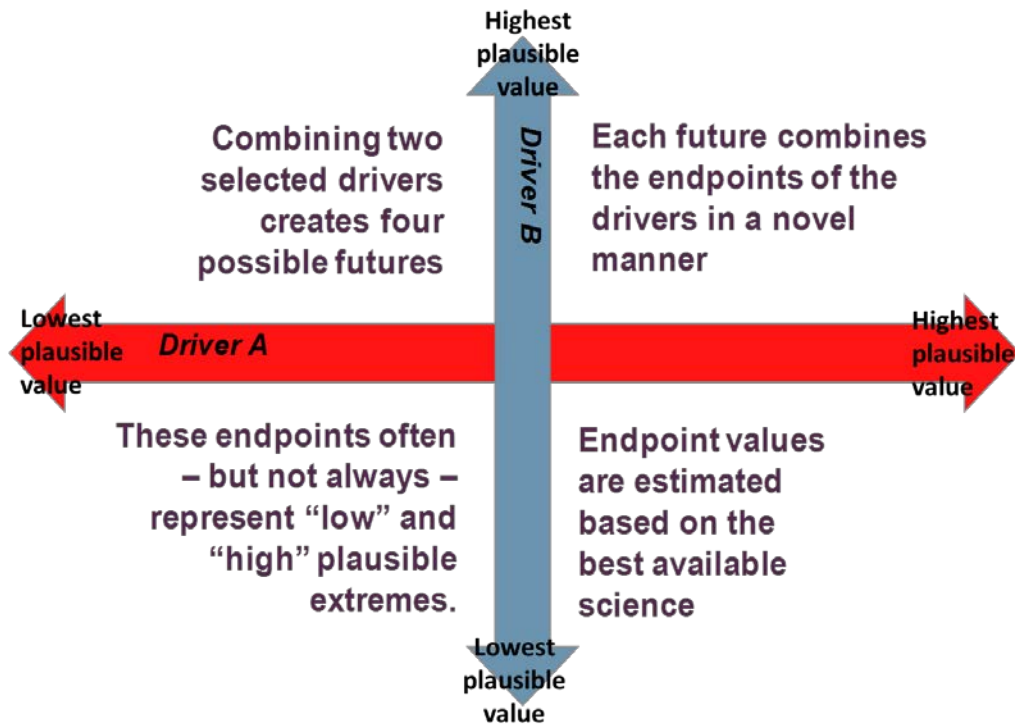


**Figure 4:** Creating a primary scenarios matrix. Two key climate-related drivers of change are crossed to create four possible futures.

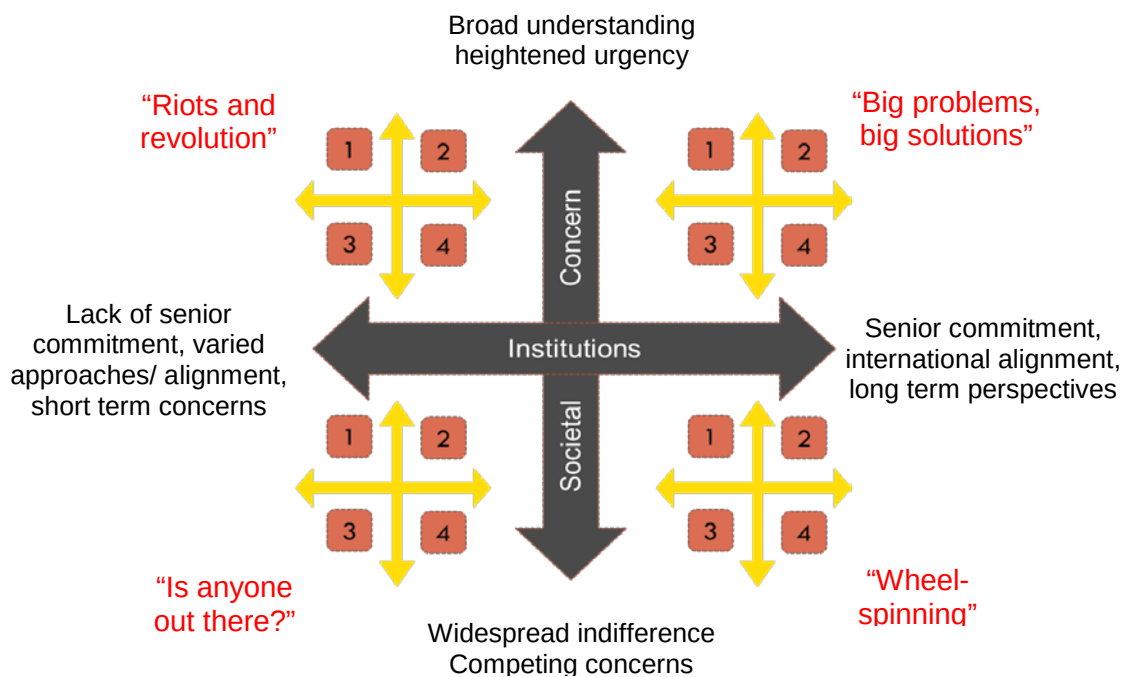
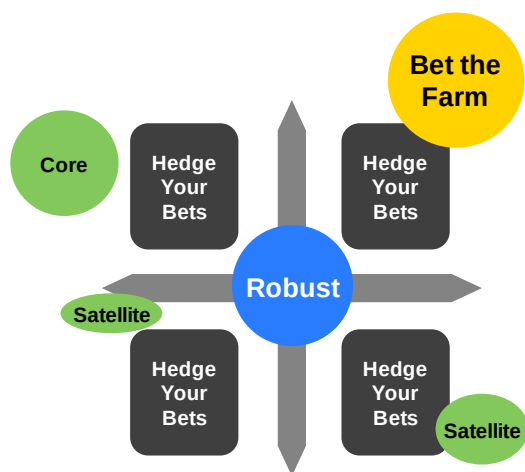


**Figure 5:** General design for a socio-political framework that incorporates the degree of societal concern in the future and the nature of future leadership. Adapted from the Global Business Network (GBN).



**Robust:** Pursue only those options that would work out well (or at least not hurt you too much) in any of the four scenarios

OR

**Bet the Farm / Shaping:** Bet the Farm / Shaping: Make one clear bet that a certain future will happen — and then do everything you can to prepare for that scenario becoming a reality

OR

**Hedge Your Bets / Wait and See:** Make several distinct bets of relatively equal size

OR

**Core / Satellite:** Place one major bet, with one or more small bets as a hedge against uncertainty, experiments, and real options

**Figure 6:** Categorizing options to help set strategy. Optimal planning depends on weighing choices based on their short-term and long-term outcomes. Diagram adapted from the Global Business Network (GBN).

## Adapting the Scenarios Process to CCSP in Alaska

This report provides a detailed description and case study illustrating how managers can use scenario planning for land management in the face of climate change. In order to implement the strategies described above in the context of climate change planning in Alaska's National Parks, the project leadership team – consisting of individuals from the NPS Alaska Regional Office, NPS staff from outside Alaska already trained in scenarios planning, and SNAP climate modelers – set up a scenarios planning effort intended to meet the goals of diverse and intensive participation and reliance on the best available information.

As such, the leadership team pulled together project participants to participate in a three-day workshop preceded by informational webinars. These participants were intentionally selected to include NPS employees, local residents, and representatives from other agencies and businesses that had a stake in the region. The team also gathered, prior to the initiation of the webinars, extensive scientific information from published literature, climate models, and expert knowledge. These were summarized into tables and brief documents in order to facilitate access by all participants.

## Pre-Workshop Webinars

Prior to the workshop, participants were invited to take part in three one-hour webinars. The goals of these webinars were to orient participants on the scenario planning process, introduce climate change maps and data, and share existing knowledge among the group. These webinars contained information summarized from scenarios planning training with Alaska Region NPS

staff, other NPS staff, and SNAP researchers, conducted in August 2010 by Jonathan Star of the Global Business Network (GBN) and Leigh Welling (NPS).

Webinar 1, led by Nancy Fresco of SNAP, covered an introduction to scenarios planning. Webinar 2, also led by Nancy Fresco, focused on climate drivers (key forces driving climate change) in the Northwest Alaska National Parks. (See Appendix F for a table of Northwest Alaska climate drivers). Webinar 3, led by Robert Winfree of NPS, was focused on climate change effects in the Northwest Alaska parks. (See Appendix G for a table of climate change effects.) Participants were asked to help rank the relative importance of these effects. (See Appendix H for the Northwest Alaska ranked climate change effects table.) PowerPoint presentations and recordings of each webinar are available in the “Webinar 1,” “Webinar 2” and “Webinar 3” folders at: [http://www.snap.uaf.edu/webshared/NPS-CCSP/2011\\_Western\\_Arctic/](http://www.snap.uaf.edu/webshared/NPS-CCSP/2011_Western_Arctic/)

### **Models, Data, Maps, and Other Information**

To help inform consideration of a range of possible futures, workshop participants were provided with data, maps, and summaries of climate projections specific to the western Arctic region (Appendix D, Appendix E). Other climate change information, including drivers of change (Appendix F) and effects of those drivers (Appendix G), were shared prior to and during the webinars and workshop. This information was drawn from multiple sources. Prior to embarking on the project, NPS prepared regional summary documents on climate change impacts, including talking points on impacts to Alaska’s boreal and Arctic regions (Appendix D). More quantitative assessments of ongoing change and projected future change to multiple climate variables were obtained from SNAP data and from peer-reviewed scientific literature.

Additional knowledge was drawn directly from project participants, including NPS employees and local residents, and Alaska Natives who were familiar with the landscapes and the management issues facing those landscapes. This traditional, historical and experiential ecological knowledge provided much of the core information and many of the key insights in the workshop process.

Partnering with SNAP allowed NPS access to cutting-edge climate data, maps, and models. SNAP employs a variety of modeling and research methods that have been approved by the scientific community through large-scale research programs and peer-reviewed publications. Core SNAP climate data are derived from historical Climate Research Unit (CRU) data and from the five Global Climate Models (GCM) that have been shown to perform best in Alaska and the Arctic. Outputs from these models are downscaled using PRISM data—which accounts for land features such as slope, elevation, and proximity to coastline. A more complete description of SNAP methodology is available at <http://www.snap.uaf.edu/methods.php>. SNAP also contributed links to sources available via their many partners and collaborators, such as those at the University of Alaska Fairbanks (UAF) Geophysical Institute Permafrost Lab (<http://permafrost.gi.alaska.edu/content/modeling>)

In particular, SNAP provided data summaries from climate models (contained within the Climate Summary reports for individual parks and incorporated into the Climate Drivers table in Appendix G). SNAP also provided maps depicting baseline (recent historical) climate and projections of future change to key variables, including monthly mean temperature, monthly

mean precipitation, date of freeze, date of thaw, summer season length (Figure 7), and mean annual ground temperature at one meter depth (Figure 8). Updated versions of a subset of these maps are available in Appendix F, and the complete set is available in the SNAP maps folder at [http://www.snap.uaf.edu/webshared/NPS-CCSP/2011\\_Western\\_Arctic/](http://www.snap.uaf.edu/webshared/NPS-CCSP/2011_Western_Arctic/)

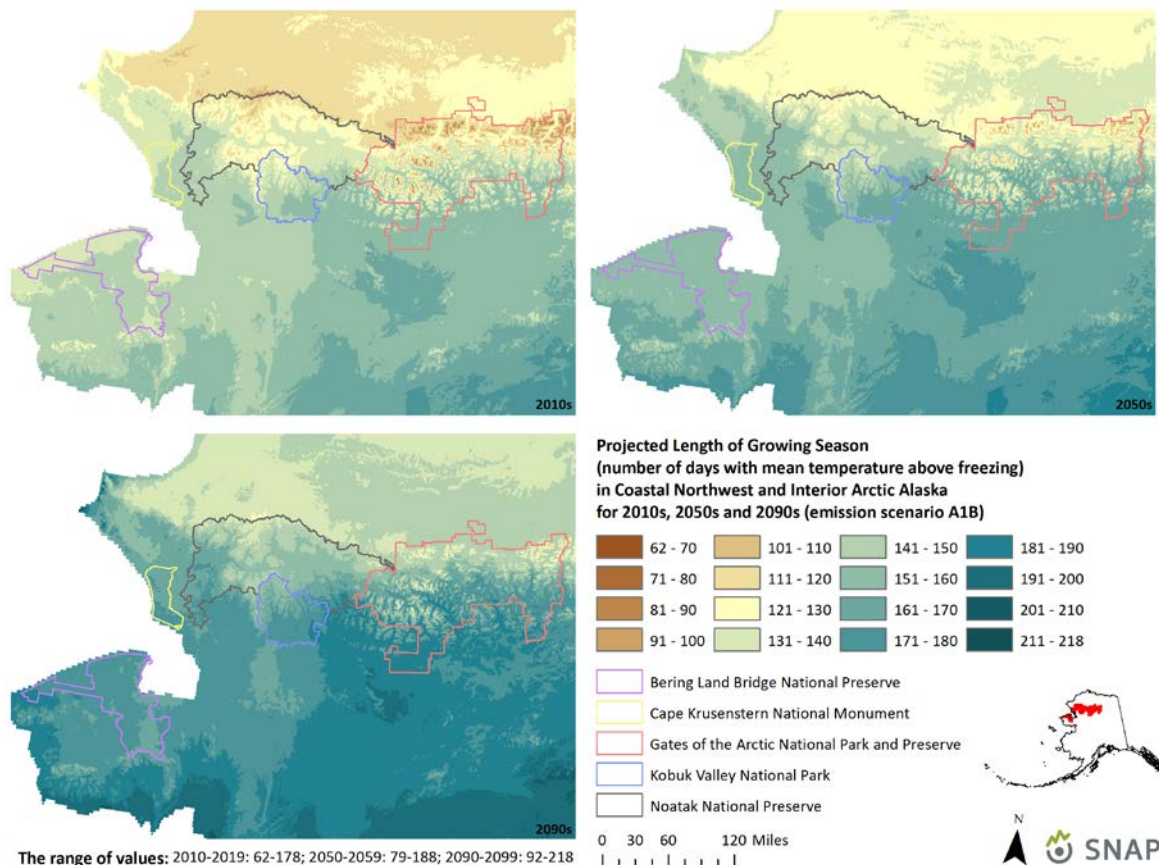


**Figure 7:** Mean summer season length. These maps show the projected number of days between the date the running mean temperature crosses the freezing point in the spring, and the date when that point is crossed again in the fall. The above-freezing season is likely to be up to 40 days longer in BELA and CAKR by the end of the 21st century. See Appendix E for additional maps of projected thaw and freeze dates, ground temperature, growing season, and precipitation by season.

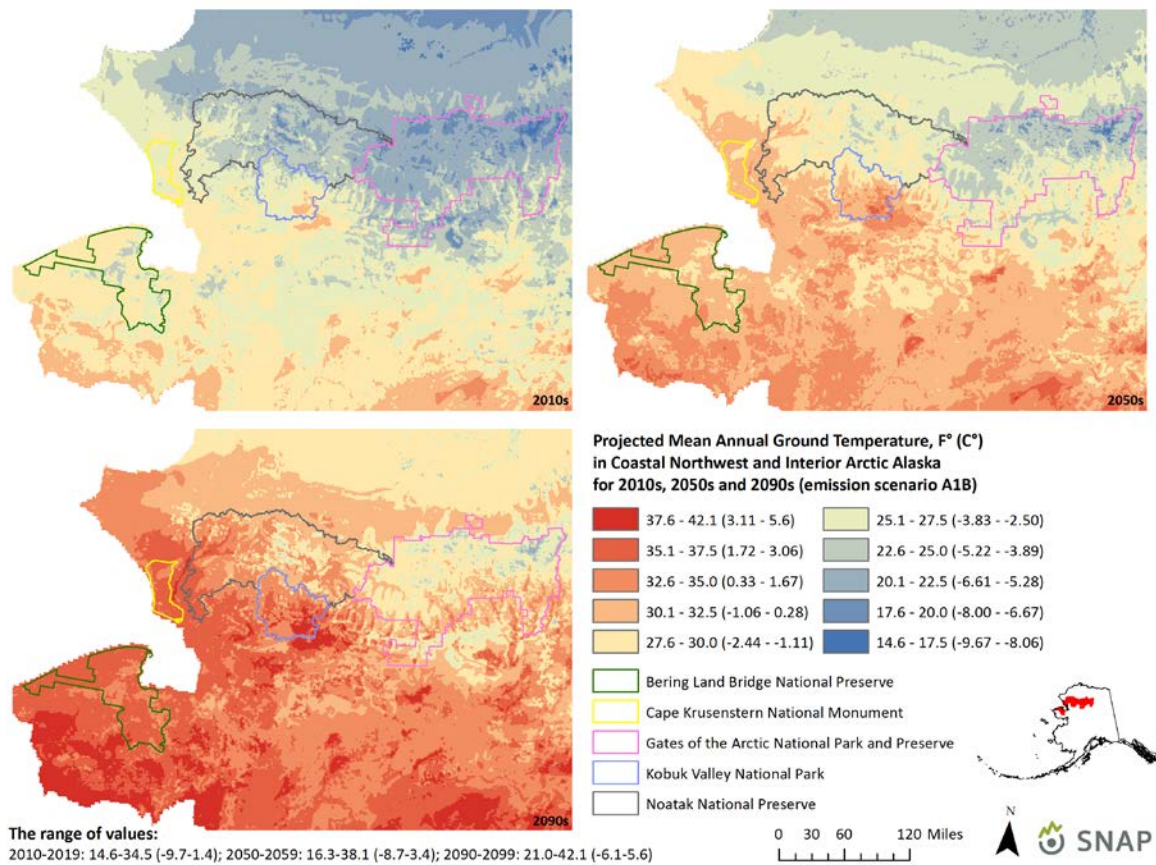


**Figure 8:** Mean annual ground temperature at one meter depth. Based on SNAP climate data and Geophysical Institute Permafrost Lab (GIPL) permafrost modeling, these maps depict projected ground temperature conditions. Discontinuous permafrost thaw is projected in both BELA and CAKR by the end of the 21st century.

## Additional Workshop Documents, Maps, & Reference Materials

A reading list was provided before the workshop to orient participants on regional climate change observations and concepts on planning and management into uncertain futures (Schwartz 1996, Cole and Yung 2010, Jezierski et al. 2010, Marris 2011). Further details about the workshop described in this document are contained in the summary PowerPoint “Northwest Arctic Climate Scenarios,” available in the Reports and Products folder at [http://www.snap.uaf.edu/webshared/NPS-CCSP/2011\\_Western\\_Arctic/](http://www.snap.uaf.edu/webshared/NPS-CCSP/2011_Western_Arctic/). Workshop documents are also posted online at: <http://www.nps.gov/akso/nature/climate/scenario.cfm>

Additional documents will be added to the website as they are produced.

## Plenary Sessions

Three plenary talks were given by workshop organizers in order to flesh out topics introduced in the pre-workshop webinars, explain and clarify the available background information, and introduce new topics. Plenary sessions were interspersed with collaborative (working group) sessions, which comprised the bulk of the workshop.

Nancy Fresco of the Scenarios Network for Alaska Planning (SNAP) presented scientific information relevant to climate change, climate drivers and uncertainties, including climate modeling, downscaling, and available SNAP data for the parks. Nancy also introduced the project background and scenario planning process. This information familiarized participants who did not attend the pre-workshop webinars, and served as a review and elaboration for those who did.

Don Callaway of the National Park Service described the sociopolitical framework relevant to Alaska, and provided examples of nested scenarios and narratives derived from these scenarios.

Jeff Mow of the National Park Service discussed implications for park management and potential decisions and actions to which park managers can apply insights from scenario planning. Jeff also provided tips on communicating scenarios and formulating no-regrets actions.

These presentations are available at the above NPS site or as Powerpoint or PDF files in the “Workshop documents western Arctic” folder at: [http://www.snap.uaf.edu/webshared/NPS-CCSP/2011\\_Western\\_Arctic/](http://www.snap.uaf.edu/webshared/NPS-CCSP/2011_Western_Arctic/)

## Workshop Work Group Products

Participants divided into two work groups for breakout sessions. Participants divided based on park affiliation, so that one group focused on scenario planning in the Bering Land Bridge National Preserve, and another group focused on the Cape Krusenstern National Preserve. Working group efforts included several stages of analysis, discussion, brainstorming, and creative effort, covering both the “explore” and “synthesize” components of the scenarios planning process.

Participants first assessed the relative importance and uncertainty of climate-related scenario drivers, and then selected two drivers with relatively high importance (in order to maximize the relevance of resulting scenarios) and relatively high uncertainty (in order to maximize divergence).

Crossing these two drivers produced four quadrants, each representing a different future or scenario. The biophysical effects or implications of all four different scenarios were fleshed out by workshop participants. Next, the four scenarios were nested in a social/institutional matrix (Figure 5), which yielded sixteen different scenarios that take into account the future socio-political environment as well as the biophysical effects of future climate. The participants in each group then selected two of the most divergent, plausible, relevant and challenging futures out of the sixteen nested scenarios and developed a narrative – as a story, play, song, skit, etc. – to describe the selected nested scenarios. These full-fledged scenarios were then assessed in terms of their management implications. Participants were asked to list appropriate management actions and research opportunities for each selected future. Finally, these actions and research opportunities were examined across all selected scenarios to determine what no-regrets choices might be common to all the selected futures.

Climate drivers, scenarios, implications, research needs and actions that emerged from each group’s discussions are presented below, followed by management implications and actions that were common to both groups.

### **Bering Land Bridge National Preserve (BELA) Group**

#### ***BELA Climate Driver Selection***

The BELA group first assessed the relative importance and uncertainty of climate-related scenario drivers (Table 1, Appendix G). These drivers had been presented and discussed during pre-workshop webinars, and were reintroduced in workshop plenary sessions. For the purposes of scenario planning, the goal was to select two drivers with high importance (in order to maximize the relevance of resulting scenarios) and high uncertainty (in order to maximize divergence).

**Table 1:** Rankings of climate drivers for the BELA work group. L, M, H = low, medium, high. Votes reflect how many group members selected each driver, given three votes per person. The highlighted drivers were selected for the BELA scenarios.

| Climate variable/driver                         | Uncertainty | Importance | Votes |
|-------------------------------------------------|-------------|------------|-------|
| Temperature                                     | M           | H          | 4     |
| Precipitation                                   | M           | H          |       |
| Relative Humidity                               | M           | L          |       |
| Length of growing season                        | M           | M-H        | 3     |
| Ocean acidification                             | H           | H          | 1     |
| Sea ice extent (decline)                        | M           | H          | 7     |
| Extreme weather events (severity and frequency) | H           | H          | 4     |
| Coastal permafrost degradation                  | H           | H          | 3     |
| Pacific Decadal Oscillation (PDO)               | H           | H          | 1     |
| Sea level rise                                  | L           | H          | 3     |
| Change in hydrologic regime                     | H           | M-H        | 2     |
| Length of ice-free season                       | M           | H          |       |
| Freeze-up date                                  | M-H         | H          |       |
| Wind pattern shifts                             | L           | M          |       |
| Snowpack                                        | M           | H          | 2     |
| Fire                                            | M-H         | M          |       |
| Interior permafrost degradation                 | M           | H          |       |

Importance has multiple dimensions. A driver can be important because it causes effects across a broad area (oceans, rivers, uplands); because it affects multiple sectors (tourism, subsistence, cultural sites) or because the effects in any one sector could be potentially catastrophic. In selecting drivers, the BELA group considered not only the effects that had been discussed in the third webinar and in the workshop plenary session, but also the purposes for which BELA was established: subsistence, geological resources, cultural resources/archaeological sites (up to 12,000 years old), migrations across Beringia; fish, wildlife and plant conservation; and reindeer herding.

A discussion of uncertainty included the clarification that there are two distinct forms of uncertainty at work: threshold uncertainty, and uncertainty of degree. The former refers to the confidence that a type of change would occur, e.g. 95% (high certainty) vs. only 50% (uncertain). The latter refers to the range within which that change might be expressed, e.g. an average temperature increase of 1-5°C. A broad range reflects higher uncertainty than a narrow one. Since both types of uncertainty yield the divergence in potential futures that works best for scenario planning, both were taken into account in selecting climate drivers.

Participants also discussed the relative merits of selecting a “high level” driver such as temperature or precipitation, versus a lower level, “derived” driver such as loss of sea ice, which is essentially a consequence of temperature increase. The group agreed that lower-level drivers might yield scenarios that were easier to explain and define, and perhaps more relevant to stakeholder interests. However, lower level drivers could also result in scenarios that were less

detailed, challenging and divergent. Ultimately, the group opted for relatively high-level drivers: temperature crossed with extreme precipitation/storm events (Figure 9).

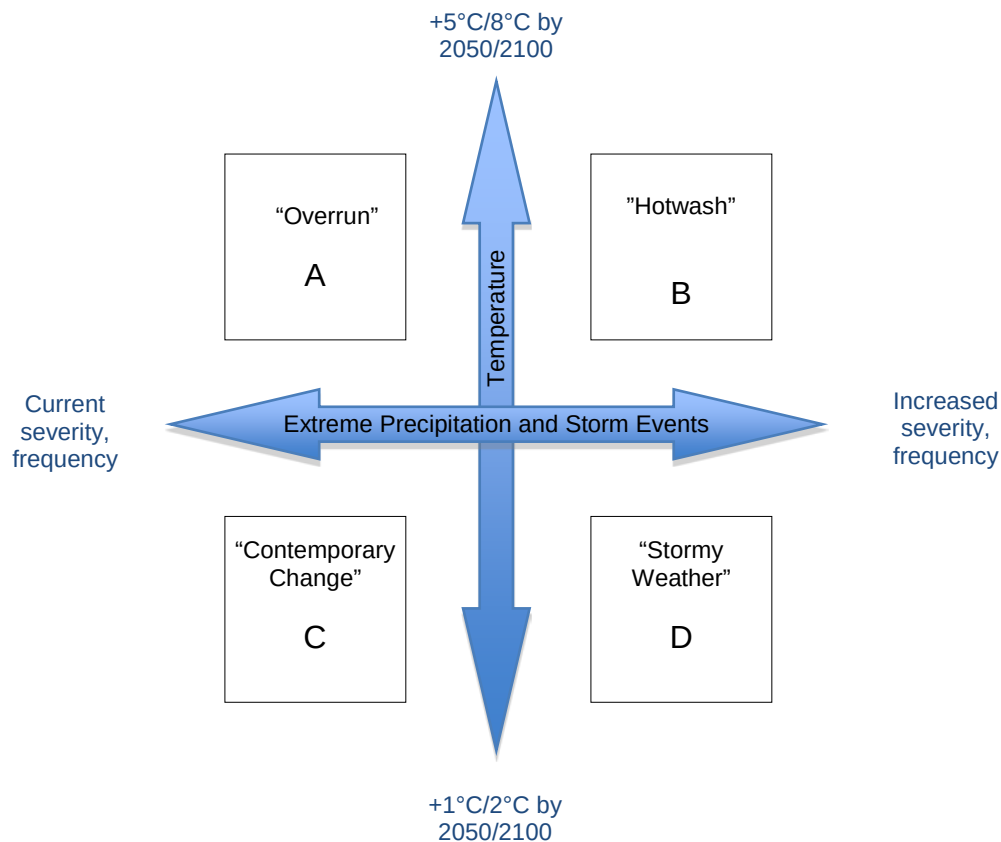


**Figure 9:** Primary matrix of climate drivers produced by the BELA group. Each quadrant represents a different combination of potential future temperature and extreme precipitation and storm events. Details of each quadrant are described in the text.

### ***BELA Bio-physical Scenarios Developed from Selected Drivers***

Each quadrant resulting from selected drivers represents a different scenario of potential future temperature and storm/precipitation conditions (Figure 9). In order to flesh out each of these scenarios, participants referred back to the effects tables derived during the pre-workshop webinars, as well as scientific literature, maps, and other information shared during both the webinars and workshop plenary sessions. The diversity of each working group also allowed for expert knowledge input from those with first-hand knowledge of the parks, the surrounding area, and climate impacts already occurring.

The resulting scenarios for the BELA group were:

- A. “Overrun”, with a +5-8°C temperature increase and little change in precipitation and storms.
- B. “Hotwash”, with a +5-8°C temperature increase as well as an increase in precipitation and storm severity and frequency.

- C. Contemporary Change”, with a +1-2°C temperature increase and little change in precipitation and storms.
- D. “Stormy Weather” with a +1-2°C temperature increase and an increase in precipitation and storms.

The potential effects of each of the four future biophysical scenarios, as defined by the group, are fleshed out below.

#### BELA Scenario A: “Overrun”

The “Overrun” scenario envisions a much warmer future, with storm frequency and intensity similar to the early 21<sup>st</sup> century. Potential effects of such conditions include:

- Decreased ability to travel in winter
- Decreased marine mammal populations and distributions
- New marine species move into the area
- Infrastructure and habitat loss from permafrost thaw and deepening of active-layer
- Shrub expansion into tundra, lichen loss
- Boreal forest expands, moves in to tundra areas
- Ocean development increases, ocean travel and tourism, oil and gas, mining, fisheries leading to increased risk for subsistence users/boats, etc. (but also more employment options)
- Increased risk of oil spills and associated losses of fish, wildlife, and habitat, and ecosystem services
- Marine noise and disturbance affect subsistence
- Loss of arctic endemic species, e.g. musk ox, tundra hares (Beringeal relic species)
- Increased grasses and drought
- Aquatic invasive species
- Terrestrial invasive species
- Possible reduction in freight costs
- Potential for more research to support development
- Moose population increase
- Beaver population increase and dispersal
- Potential change of fish habitat leading to changes in species

#### BELA Scenario B: “Hotwash”

The “Hotwash” scenario envisions a much warmer and much stormier future, as compared to the early 21<sup>st</sup> century. Potential effects of such conditions include:

- More coastal erosion
- Increased rain on snow events
- Increased travel danger
- Increased sedimentation and river erosion
- Decrease in marine mammals

- Migratory birds change
- Large scale losses of archaeological resources
- Increase in fire occurrence
- More shrub expansion and lichen loss
- Decreased winter caribou range
- Infrastructure and habitat loss even more severe than other quadrants due to permafrost loss
- Increased risk of village relocation/destruction
- Boreal forest expansion, moves into tundra areas
- Ocean development, ocean travel and tourism, oil and gas, mining, fisheries leading to increased risk for subsistence users, boats, etc. (but also more employment options). Less tourism development due to storms.
- Increased risk of oil spills and associated losses of fish, wildlife, habitat, and ecosystem services
- Marine noise and disturbance affect subsistence
- Loss of arctic endemic species, e.g. musk ox, tundra hares (beringeal relic species)
- Aquatic invasive species
- Increased disease and insects
- Possible reduction in freight costs

#### BELA Scenario C: “Contemporary Change”

The “Contemporary Change” scenario envisions a future with temperatures and storm frequency and intensity similar to, or slightly higher than, the early 21<sup>st</sup> century. Potential effects of such conditions include:

- Continuation of current trends
- This does not mean there is no change, just not as accelerated as in other quadrants
- Continued erosion at current rates
- More Endangered Species Act (ESA) listings than at present, but fewer than in other quadrants.

#### BELA Scenario D: “Stormy Weather”

The “Stormy Weather” scenario envisions more and higher intensity storms, with temperatures slightly higher than the early 21<sup>st</sup> century. Potential effects of such conditions include:

- Less severe coastal erosion than in the “Hotwash” scenario
- Some loss of archeological resources
- More snowpack which would affect ungulates
- Changing wetland composition and possible return to sedgy Beringea?
- Flooding of airstrips and coastal communities

### ***BELA Scenarios Nested in a Socio-Political Matrix***

The BELA group nested the four scenarios above in the social/institutional matrix (Figure 5). This framework explores how each story might play out in a world with greater or lesser degrees of societal concern and institutional commitment. Note that this framework was altered slightly from that presented by GBN, in which the horizontal axis was defined as “governmental” rather than “institutional” and was thus interpreted to take place at a national and international scale rather than at a national, state, and local scale.

While this theoretically yields 16 scenarios, they are not likely to all be divergent or plausible, and the group did not elaborate upon all of them. Instead, they first discussed the nature of the new matrix and the ramifications and plausibility of various combinations, then selected two nested scenarios to explore further. This narrowing of the field is in keeping with the scenarios planning methods outlined by GBN; the goal is to avoid redundancy and unnecessary use of time and effort, while maximizing the range of possibilities under consideration.

Points of discussion included the question of whether a high level of social and institutional engagement (Figure 10, upper right quadrant) was truly plausible, and whether the idea of public disinterest (Figure 10, lower half) would be plausible in the context of extreme change, especially given the fact that local communities have already been talking about and experiencing climate change for 30 years. The group decided that public disengagement might result from people feeling overwhelmed, dispersing, and “giving up,” so that all quadrants were plausible. Through voting and additional discussion, the BELA group selected two scenarios for further development discussion (Table 2). Each member of the group voted for two nested scenarios to explore further. The two nested scenarios that received the most total votes are marked by blue stars in Figure 10, and described in further detail below.

**Table 2:** BELA group votes on nested scenarios. Scenarios selected for narratives are highlighted.

| <b>Scenario</b>     | <b>Bio-physical quadrant</b> | <b>Socio-political quadrant</b> | <b>Total votes</b> |
|---------------------|------------------------------|---------------------------------|--------------------|
| Overrun             | A                            | Riots & Revolution              | 8                  |
| Hotwash             | B                            | Is Anyone Out There?            | 6                  |
| Overrun             | A                            | Is Anyone Out There             | 5                  |
| Overrun             | A                            | Big Problems, Big Solutions     | 4                  |
| Contemporary Change | C                            | Big Problems, Big Solutions     | 2                  |
| Stormy Weather      | D                            | Big Problems, Big Solutions     | 2                  |

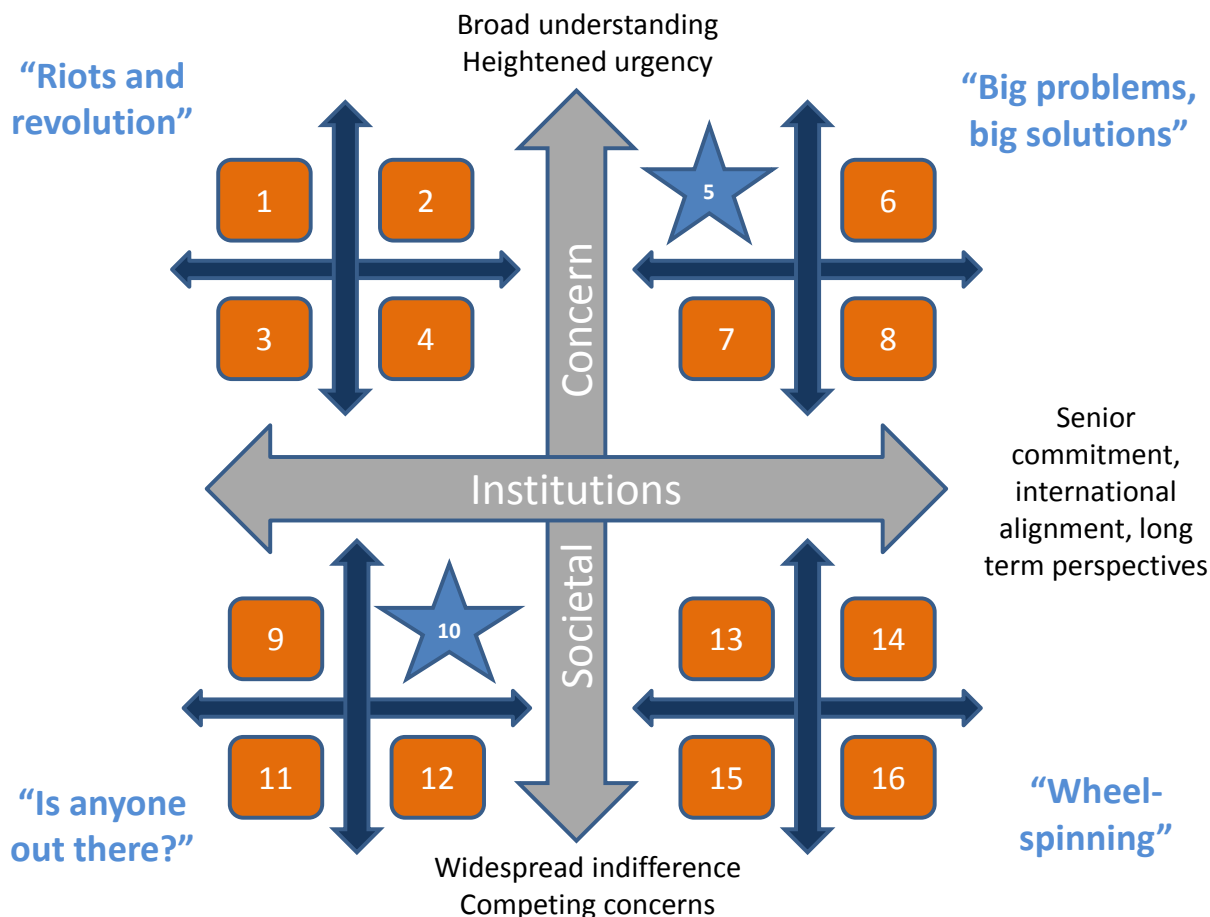


**Figure 10:** BELA nested scenarios. The two nested scenarios selected by the BELA group are marked by blue stars. The “Hotwash” scenario (increased storms and precipitation coupled with a sharp rise in temperature) is nested in “Is Anyone Out There?” (little social or institutional support for climate change adaptation efforts). “Overrun” (unchanged precipitation coupled with increased temperature) is nested in “Big Problems, Big Solutions” (strong and coordinated support for climate change at the local and institutional levels). The implications, management actions, research needs, and narratives associated with these two scenarios are elaborated upon below.

After fleshing out the potential effects and future implications of selected nested scenarios, the BELA group assessed possible management actions and research needs to address those implications.

#### First BELA Nested Scenario: “Hotwash” in “Is Anyone Out There?”

The following were identified by the BELA group as potential impacts, implications, and management actions in the event that the “Hotwash” scenario (a warmer and much stormier future) was to occur under the conditions described for the “Is Anyone Out There?” quadrant (competing local concerns and less coordinated institutions) (Figure 5). It should be noted that while local people would be unlikely to be indifferent to the biophysical changes in this scenario, they might adapt to the changes in any way necessary to survive. The BELA group named this nested scenario “The Sign.”

### *Natural Resources*

- Loss of biodiversity through decreased ice and heating of riverine systems; loss of marine mammal species; loss of subsistence fish.
- Sea level rise may exacerbate damage from storm surges
- Sea ice season recedes and is limited to about one month/year, limiting ability to hunt on ice and exacerbating erosion
- Changing migration patterns could result in inappropriate harvest seasons, methods and take/limits
- Erosion of landing sites; impact to delivery of bulk cargo (e.g. fuel); rising cost of living
- Storms will have been hammering the coast for several decades, causing massive erosion and communities washing away
- Shrubs and forest encroaching leading to more moose and beaver
- Inland permafrost degradation leading to damaged roads, new developable thawed lands

### *Cultural Resources*

- Massive loss of archaeological sites due to erosion, irretrievable loss of cultural history and possible compromise of park mandate

### *Facilities/ Infrastructure*

- Potentially greater need to accommodate cruise ships and road travel, but no funding and large erosion problems

### *Communication*

- Less funding for interpretation and no strong forums for discussion due to community losses and funding cuts
- Great needs for communities near the park to communicate needs and get help

### *Social/Economic/Subsistence*

- Decreased subsistence harvests
- Health impacts with loss of important sources of nutrition
- Loss of important social roles
- Increased costs of living due to substitution of expensive imported food
- Huge increase in social problems associated with relocation of village residents
  - Alcoholism
  - Drug use
  - Domestic violence
- Community evacuation leads to dispersion to cities and other communities
- Dispersion (diaspora) causes breakdown of sharing networks, cultural socialization, traditional roles
- Institutional help and protections against damage to communities is missing, leading to more rapid erosion, destruction

- Dissolution of community from storm surges may lead to a loss of traditional ways of life
- Damage to community infrastructure may lead to a rise in the cost of living

#### *Important Management Actions*

- Flexibility in access and economic use of park resources by affiliated communities, e.g. berry jam, carved driftwood, horns, etc.
- Integrated response = one contact point for communities for delivering services from agencies
- Restructure NEPA to accommodate “collaborative learning” and “adaptive management” processes
- Increase coordination and consultation with stakeholders outside park boundaries
- Flexibility from federal subsistence board in changing seasons and bag limits to traditional methods and means, e.g. community quotas, new seasons as ice changes, new species
- Increase resources for development of cooperative management regimes
- Use forward-thinking and planning of development and infrastructure to avoid habitat impacts as habitats change
- Prioritize use of limited money for most effective community aid
- Increase integration of TEK in management regulations, policies, and enforcement

#### *Research and Information Needs*

- Eliminate “stovepipe” research funding with its categorically restricted uses
- Reward interdisciplinary research projects through funding, tenure, and recognition
- Organize research around management issues and require interdisciplinary proposals
- Collect good baseline information about species, water resources, permafrost and coastal stability, interdependence of resources, and trajectories of change
- Develop interdisciplinary regional studies plan
- Conduct more research on potential invasive species and species shifts

#### Second BELA Nested Scenario: “Overrun” in “Big Problems, Big Solutions”

The following were identified by the BELA group as potential impacts, implications, and management actions in the case that the “Overrun” scenario (a warmer future, with little change in storm frequency and intensity) was nested in the “Big Problems, Big Solutions” quadrant (high societal concern and more integrated institutions) in the socio-political matrix (Figure 5). The BELA group named this nested scenario “Climate Kumbaya.”

#### *Natural Resources*

- Shrub expansion leads to an increase in moose population, changes in subsistence uses, and cascading effects on vegetation and natural environment
- Lichen loss leads to reduced caribou population and reduced subsistence uses
- Change in fish species, commercial fisheries, historic resources/environmental integrity and wilderness

- Increased fire could lead to smoke, change in vegetation, permafrost, loss of historic building sites, increased employment for fire management
- Rain on snow events leads to reduced availability of winter forage for caribou and muskox, with associated wildlife population losses
- Change in sea ice results in change in sea mammal species and distribution
  - Change in subsistence practices
  - Ice-dependent species moving to land (polar bears, walrus)
- Invasive species
  - Decreased biodiversity
  - Decreased endemic/iconic species
  - Change in ecosystem function
  - Altered subsistence patterns
  - Impacts to environmental integrity (wilderness values)
  - Increased “trammeling” (due to management action to control invasive species)
- Drying of wetlands
  - Change in waterfowl and fish populations
  - Impact to yellow-billed loon could lead to listing under the Endangered Species Act
  - Freshwater shortages
  - Change in nutrient transportation
  - Reduced filtration of contaminants
  - Decrease in insect populations and wood frogs
- Degradation of permafrost
  - Sedimentation and associated changes in aquatic habitat
  - Thermokarst, earlier seasonal thaw, and later seasonal freeze make travel on snow, ice, and land less reliable
  - Loss of traditional landscape (changes the view)

#### *Cultural Resources*

- Dramatic loss of cultural and paleontological resources
- Loss of archaeological, paleontological, and ethnographic resources requires increased inventory and monitoring for cultural resources (catalogue and preserve)
- Loss or degradation of other historic structures, e.g. Cold War buildings, whaling sites, due to permafrost and erosion

#### *Facilities/Infrastructure*

- Decreased ability to travel into park creates decreased opportunities for subsistence, recreation, village travel, and visitation
- Infrastructure loss (roads, buildings) cause reduced ability to access area and affect safety of residents and visitors
- Loss of permafrost causes damage to roads, gravel pads, facilities (means rethinking construction types/areas)

### *Communication*

- Educational curriculum is needed to increase awareness of the rapid changes
- More and different types of visitation will put demands on park interpretation

### *Social/Economic/Subsistence*

- Increase in marine travel noise can disturb migration routes and subsistence
- Increase in economic opportunities leads to environmental and subsistence impacts
- People will have to adapt to different subsistence species to eat (wildlife and plant, fish, sea weeds, etc.)
- Increased opportunity/requests for mineral and oil exploration and development

### *Important Management Actions*

- Ensure that construction of facilities, roads, etc. considers future climate effects
- Increase outreach and education efforts (plan and implement)
- Increased need for interagency collaboration on fishing and hunting regulations
- Increase inventory and monitoring of archaeological and paleontological sites (strategy, plan, funding)
- Work with other state/federal agencies to monitor resource development to ensure any development has benefits to the park (money, research)
- Model, collaborate and promote energy efficient techniques and practices
- Integrate traditional knowledge in meaningful way
- Establish and maintain long term relationships with partnered funding streams (sustain funding at local, regional, and national levels)
- Coordinate and collaborate with local, tribal, state agencies on creating a regional level plan that addresses climate change
- Incorporate climate change into all park planning efforts
- Develop fire management plans that address increased fire and potential concerns over caribou winter habitat
- Consider park needs to facilitate increased visitation
- Streamline agreements process to facilitate effective collaborations
- Be a BIG player in Landscape Conservation Cooperatives (LCC), ocean stewardship, NOAA ShoreZone, and other initiatives

### *Research and Information Needs*

- Find and share specialized expertise in different disciplines
- Host periodic state of knowledge symposia and develop collaborate approach to identify and address info/research/management needs
- Work with Russian counterparts to collaborate on arctic issues (e.g. subsistence, conservation)
- Incorporate local knowledge into research, information needs and management actions
- Develop visitor/backcountry plans that address access and visitor facilities

- Use an interdisciplinary approach to climate change research
- Increase monitoring of impacts of fire on vegetation and wildlife habitat under changing climate.
- Increase wildlife monitoring
- Create detailed vegetation maps
- Monitor phenology of plants
- Increase coastal, lagoon, and fish research
- Add volume loss dimension to estimates of coastal erosion

## Cape Krusenstern National Monument (CAKR) Group

### **CAKR Climate Driver Selection**

The methods and procedures for the CAKR group were nearly identical to those described for the BELA group. However, the two groups' preferences and discussions produced different results. The CAKR group began by ranking climate drivers as either "important" or "highly certain" (Table 3). These drivers were presented and discussed during the pre-workshop webinars, and were reintroduced in workshop plenary sessions. For the purposes of scenario planning, the goal was to select the two drivers of high importance (in order to maximize the relevance of resulting scenarios) and high uncertainty (in order to maximize divergence). Similar to the BELA group, CAKR participants decided on extreme storm events crossed with temperature, shown in Figure 11. In this case, it was decided that both were important variables, in terms of potential effects, and while storm frequency was relatively uncertain overall, temperature also qualified as uncertain based on its large potential range of increase. It was further determined that while important, PDO should not be treated as a primary driver, but instead considered within each scenario as a potentially exacerbating factor.

**Table 3:** Drivers rated by certainty and importance by the CAKR group. Selected drivers are highlighted.

| Driver                        | Degree of Certainty | Important |
|-------------------------------|---------------------|-----------|
| Temperature                   | High                | X         |
| Wind speed                    |                     |           |
| PDO                           | High                | X         |
| Extreme events: temperature   |                     |           |
| Extreme events: precipitation |                     |           |
| Extreme events: storms        | 66%                 | X         |
| Sea ice                       |                     | X         |
| Snow                          | High                | X         |
| Freeze-up date                |                     |           |
| Ice-free season               |                     |           |
| Rive/stream temperatures      |                     |           |
| Length of growing season      |                     |           |
| Permafrost                    |                     |           |
| Sea level                     | High                | X         |
| Ocean acidification           | High                |           |

### **CAKR Bio-physical Scenarios Developed from Selected Drivers**

Each quadrant resulting from the selected drivers represents a different scenario of potential future temperature and extreme storm events (Figure 11). The resulting scenarios for the CAKR group were:

- A. “Caribou Melt,” with a 6°C temperature increase and low occurrence of extreme storm events
- B. “911,” with a 6°C temperature increase and high occurrence of extreme storm events
- C. “Tarpits,” with no temperature increase and low occurrence of extreme storm events
- D. “Chill Out,” with no temperature increase and high occurrence of extreme storm events.

The potential effects of each of the four future biophysical scenarios, as defined by the group, are fleshed out below.

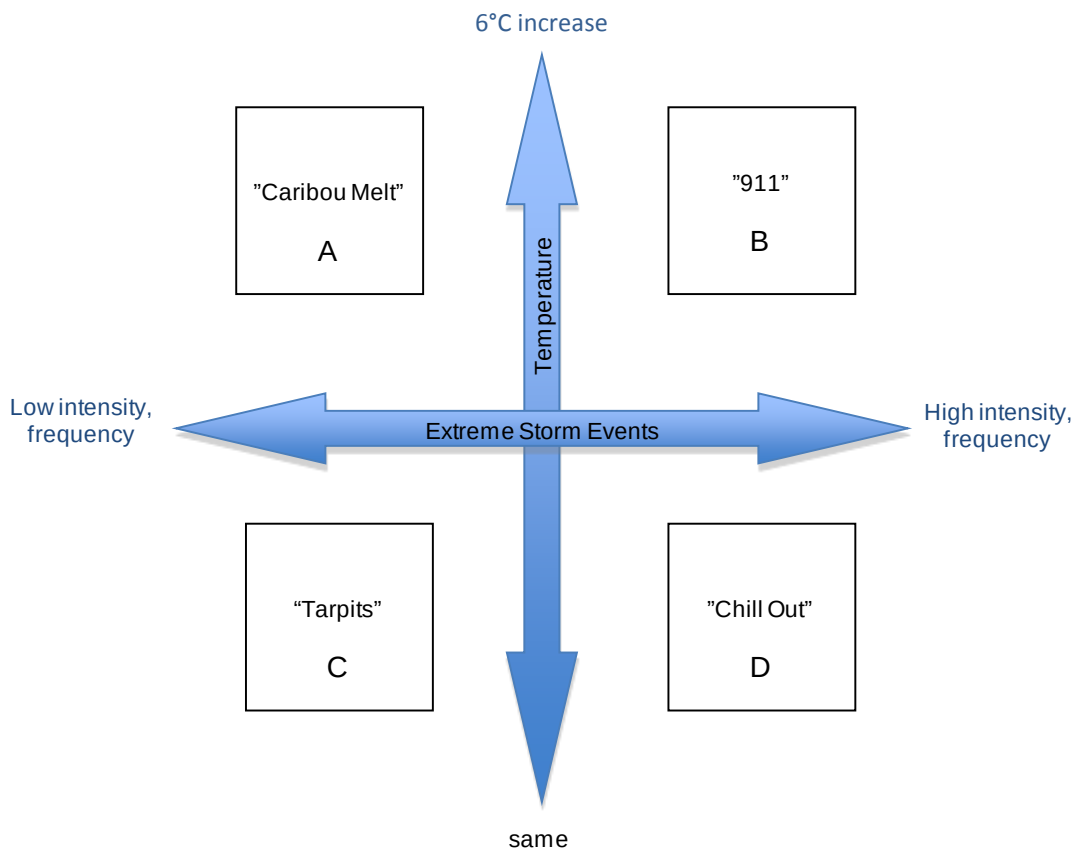


**Figure 11:** Primary matrix of climate drivers selected by the CAKR group. Each quadrant represents a different combination of potential future temperature (including PDO as a factor in order to maximize variability) and extreme storm events.

#### CAKR Scenario A: “Caribou Melt”

The “Caribou Melt” scenario envisions a much warmer future (+6°C) with low storm intensity and frequency. Potential effects of such conditions include:

- Increased marine shipping
- Polar bear population decreases or moves onto land
- Drier landscape with vegetation shift to shrubs
- Increased moose hunting activities
- Increased summer erosion
- Increased risk to cultural resources
- Threat of invasive species
- Better caribou habitat
- Increased permafrost thaw
- Communities at risk due to environmental change
- Salty lagoons (instead of freshwater)
- Increased fisheries
- Increased mineral/energy development

#### CAKR Scenario B: “911”

The “911” scenario envisions a much warmer future (+6°C) with high storm intensity and frequency. Potential effects of such conditions include:

- Declining wildlife populations
- Winter icing increases wildlife stress
- Severe coastal erosion
- Increased frequency and size of hazardous material spills
- Increased need for medical/emergency response
- Increased need for evacuation of coastal communities
- Increased marine transportation
- Increased noise impacts
- Increased ocean acidification (lower seawater pH equals higher acidity)
- Need for “hardened” infrastructure
- Increased fires
- More incorporation of Traditional Ecological Knowledge (TEK)
- Changing vegetation
- Increased dispersal of contaminants
- Decreased habitat for mountain nesting shore birds

#### CAKR Scenario C: “Tarpits”

The “Tarpits” scenario envisions a future with little change in temperature and low storm intensity and frequency. Potential effects of such conditions include:

- Fewer extreme storms
- Moderate coastal erosion
- Favor status quo of existing management infrastructure
- Normal maintenance of infrastructure
- Similar patterns of transportation, tourism and development
- Moderate increase in shipping and offshore drilling
- Little to no change in subsistence resources and patterns

- Less marine hunting
- More terrestrial mammal hunting
- Slower effects on cultural resources, gradual losses

#### CAKR Scenario D: “Chill Out”

The “Chill Out” scenario envisions a future with little change in temperature and high storm intensity and frequency. Potential effects of such conditions include:

- Wildlife winter-kill events
- Increased coastal erosion
- Winter travel hazards
- Increased impacts to cultural resources
- Increased spill risk
- Need for “hardened” (more resilient to storms) infrastructure
- Increased energy costs and maintenance costs
- Increased dispersal of contaminants
- Decreased habitat for mountain-nesting shore birds

#### ***CAKR Scenarios Nested in a Socio-Political Matrix***

As with the BELA group, the CAKR group nested each biophysical scenario within a larger social/institutional framework, as shown in Figure 12. This framework explores how each story might play out in a world with greater or lesser degrees of societal concern and institutional commitment. Note that this framework was altered slightly from that presented by GBN, in which the horizontal axis was defined as “governmental” rather than “institutional” and was thus interpreted to take place at a national and international scale rather than at a national, state, and local scale.

While this theoretically yields 16 scenarios, they are not likely to all be divergent or plausible, and the group did not elaborate upon all of them. Instead, group members first discussed the nature of the new matrix and the ramifications and plausibility of various combinations, then selected two nested scenarios to explore further. This narrowing of the field is in keeping with the scenarios planning methods outlined by GBN; the goal is to avoid redundancy and unnecessary use of time and effort, while maximizing the range of possibilities under consideration.

After fleshing out the potential effects and future implications of selected nested scenarios, the CAKR group assessed possible management actions and research needs to address those implications.

The CAKR group selected two nested scenarios to explore through discussion and consensus rather than by voting, as the BELA group had done. The two scenarios selected by the CAKR group are marked by blue stars in Figure 12, and are described below, including their implications, important management actions, and research and information needs.

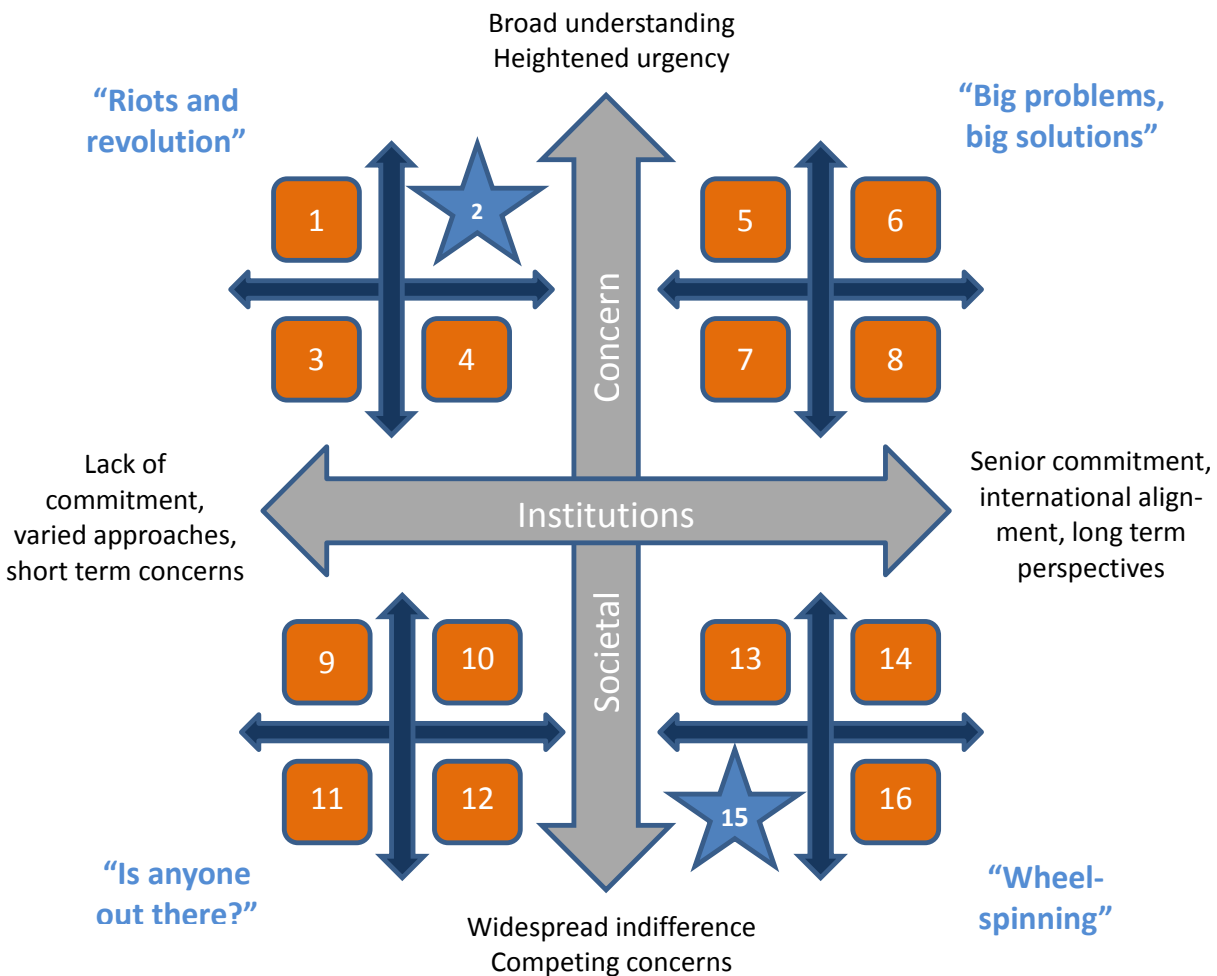


**Figure 12:** CAKR Nested Scenarios. The two nested scenarios selected by the CAKR group are marked by blue stars. The “Tarpits” scenario (little change in temperature, low storm intensity and frequency) is nested in “Wheel-spinning” (better-integrated government and less societal concern) and the “911” scenario (increased temperatures with high storm intensity and frequency) is nested in “Riots and Revolution” (heightened societal concern, but less integrated institutions).

#### First CAKR Nested Scenario: “Chronic Directional Change”

The CAKR group identified the following as potential impacts, implications, and management actions in the case of the “Tarpits” scenario (little change in temperature with low storm intensity and frequency) nested in the “Wheel-spinning” (less societal concern, with a more integrated government) quadrant of the socio-political matrix (Figure 7). The CAKR group named this nested scenario “Chronic Directional Change.”

### *Natural Resources*

- Habitat degradation
- Increased fire frequency and scale
- Gradual loss of marine mammals
- Change in species composition and distribution of fisheries
- Increase in non-native species in disturbed areas
- Pressure for intensive management
- Increased contamination from resource development
- Habitat fragmentation from roads
- Degraded wilderness conditions

### *Cultural Resources*

- Gradual loss of cultural resources with coastal physical changes
- Increased ravine erosion

### *Facilities/Infrastructure*

- Increased operational expense to maintain back country facilities
- Future retrofitting of park headquarters as permafrost thaws
- Employee housing improvements and relocation needed
- Thaw lakes developing along the Red Dog haul road

### *Communication*

- Pressure to relax regulations
- Competing messages about intensive vs. adaptive management
- Park viewed as impediment to change
- Ostracism from community meetings

### *Social/Economic/Community/Subsistence*

- Demoralized staff
- Reduced productivity
- Rapid employee turn over
- Increased competition for program funding
- Loss of marine subsistence
- Increased terrestrial subsistence pressure
- Civil disobedience (off-road vehicle use, poaching, camps)
- Greater public law enforcement conflicts

### *Important Management Actions*

- Engage communities in scenario planning
- Openness/encouragement for co-management opportunities where appropriate
- Engage staff in identifying solution and incentivize
- Develop specialized expertise at appropriate level (park vs. region)
- Expand community liaison program
- Focus interpretation on communication, compelling/engaging messages
- Cultivate park advocacy at all levels (including local)

- Develop fire management plans for resource benefits
- Advocate for conservation at interagency forums

#### *Research and Information Needs*

- Monitor and research subsistence trends
- Modeling and monitoring of future habitat
- Expanded village outreach and education
- Establish a trend
- Cooperative resolution to user conflicts
- Anticipate demand and conflict with increased community services
- Prioritize exotic species management based on potential for success

#### *Other*

- Ask if interpretation of park purposes is achievable
- Co-locate federal/state/local employees (Landscape Conservation Cooperative)
- Walk the talk of sustainability
- Consider feasible renewable investment
- Strengthen ties with the National Parks Conservation Association (NPCA) and other supportive nongovernment organizations

#### Second CAKR Nested Scenario: “Katrina Comes to the Chukchi”

The CAKR group identified the following as potential impacts, implications, and management actions in the case that the “911” scenario (increased temperatures with high storm intensity and frequency) was nested in the “Riots and Revolution” (heightened societal concern, but less integrated institutions) quadrant in the socio-political matrix (Figure 7). The CAKR group named this nested scenario “Katrina Comes to the Chukchi.”

#### *Natural Resources*

- Habitat for migratory birds severely damaged
- Loss of iconic native species
- Widespread contamination from lead/zinc dust
- Loss of sea ice as habitat for marine mammals
- Natural biological processes become increasingly more valuable in protected areas of CAKR

#### *Cultural Resources*

- Archaeological resources damaged/lost

#### *Facilities/Infrastructure*

- Need for temporary and permanent housing
- Loss of infrastructure (NPS, communities)
- Communications systems severely damaged
- Waste disposal issues
- Deterioration or destruction of the port site, resulting in fuel and lead/zinc contamination
- Oil rigs damaged by wave driven ice

### *Communication*

- Lost Traditional Ecological Knowledge (TEK) from coastal communities
- No coordination in communicating messages to the public

### *Social/Economic/Community/Subsistence*

- Land base shortage for community
- Undeveloped landscape qualities degraded
- Clean drinking water needed
- Increase in community collaboration
- Increased reliance on terrestrial species for subsistence
- Loss of symbolic resources
- Increased community pressure for policy changes
- Transportation more difficult
- Damages to economic drivers (mines, oil, tourism) shut them down for months at a time
- Temporary disruption of visitor opportunities
- Increased demand for access to information
- Decrease in NPS capacity to manage parks
- Increased noise
- Increased hubbub and air traffic, leading to decreased opportunities for solitude
- Increased need for coordination of responders
- Potential lack of public support to fund restoration

### *Important Management Actions*

- Reaffirm park purpose, relevance, and objective for natural and cultural resources in the park's General Management Plan (GMP)
- Robust consultation process
- Complete interagency strategic plans to address climate change and disasters
- Infrastructure that is appropriately designed for location and climate change
- Multiple media outreach to local, state, and national audience
- The park's General Management Plan should reflect whether to emphasize naturalness or to allow a certain level of manipulation

### *Research and Information Needs*

- Conduct research and I&M for critical fish and wildlife habitat
- Seamless data collection and sharing
- Coordinate monitoring of coastal erosion
- Prioritize recovery of archaeological sites near coasts
- Archaeological triage

### *Other*

- Complete oral histories and TEK recovery
- Interagency strategic planning

## Narratives

Climate change scenarios can be used to create multiple outreach tools to assist land managers and to educate the public. One such product is a set of narratives or stories that help to visualize and synthesize a range of plausible yet divergent futures.

The fictional narratives created by participants in this workshop (included in Appendix H) were a collaborative and creative effort to turn relatively dry lists of bulleted climate change impacts into vibrant and memorable stories. The format for these stories was open to interpretation and imagination. Thus, one group performed a skit between a young woman and her grandmother; another group wrote an ominous keynote speech for a park superintendent; a third group wrote a briefing from a wildlife biologist; and the fourth imagined a testimony to Congress in the wake of a massive storm.

While such products could be considered unscientific, or even frivolous, from a management perspective, they serve several useful purposes. First, they offer an opportunity for workshop participants to make their own immersive experience more memorable through creative collaboration. Second, they create products – or ideas for products that might be further developed later – that speak directly to the public, with a minimum of jargon and the strongest possible emotional connection. Although care must be taken to present such stories within a scenarios context, they can bring home the message that while climate change may seem abstract, its effects will be very real to those who are impacted in and around Alaska's national parks.

## Common Implications, Actions and Needs

A good set of common needs can be an excellent starting point for responding to change through “no regrets actions” that would make good sense under any conditions, such as when determining safe locations for new facilities.

Scenario planning enables participants to assess potential vulnerabilities (effects and implications) and identify appropriate responses to address the implications and manage risks. Divergent scenarios typically yield different effects and implications. Serious differences in implications typically warrant different responses, especially when the effects could be catastrophic. When the same actions are listed for multiple scenarios, either a suite of no regrets actions has been identified, or the scenarios were not sufficiently divergent.

If the recommended actions appear too closely to reflect current practices, complacency can create a false sense of security. It is important to revisit the implications for the individual scenarios, to flag any that could potentially be catastrophic if they were to occur (such as rapid erosion near critical facilities). Such effects warrant careful consideration of appropriate monitoring and responses. As shown in Figure 6, robust strategies are not the only ones that make sense in terms of policy selection. In many cases, the potentially negative results of climate change effects that appear in only one, two, or three of the outlined scenarios may nonetheless be serious enough to warrant hedging of bets.

Management actions and research needs identified by both work groups and common to all four nested scenarios selected for this planning workshop are outlined in Table 4.

**Table 4:** Implications, management actions and research needs identified for several different scenarios by both the BELA and CAKR work groups.

| Category                                               | Common Implication, Action, or Need                                                                                                                  |
|--------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------|
| Natural Resource Implications                          | Loss of biodiversity of unique arctic species                                                                                                        |
|                                                        | Shifting species                                                                                                                                     |
|                                                        | Expansion of invasive species                                                                                                                        |
|                                                        | Habitat transformation (land, sea and freshwater)                                                                                                    |
|                                                        | Changes to disturbance regimes                                                                                                                       |
|                                                        | Increased contamination/pollution of water and land                                                                                                  |
| Cultural Resource Implications                         | Loss of archaeological and paleontological sites and associated history                                                                              |
| Facilities/ Infrastructure Implications                | Pollution from new development and tourism is already occurring                                                                                      |
|                                                        | Risks to roads, communities, airstrips, telecommunication infrastructure                                                                             |
|                                                        | Threats to park facilities, vulnerable infrastructure                                                                                                |
|                                                        | Demand for new infrastructure for industry and tourism                                                                                               |
| Communication/ Education & Interpretation Implications | Need for effective collaborative communication across agencies and communities                                                                       |
|                                                        | Increased need to capture traditional ecological knowledge (TEK)                                                                                     |
|                                                        | Need for more consistent messages coming to/from parks                                                                                               |
| Social/ Economic/ Subsistence Implications             | Subsistence patterns are changing                                                                                                                    |
|                                                        | Depletion of marine mammals and increasing pressure on terrestrial wildlife. This could in turn lead to conflict between terrestrial wildlife users. |
|                                                        | Loss of cultural traditions and norms                                                                                                                |
|                                                        | Pressure for more flexible regulations                                                                                                               |
|                                                        | Pressure for more industry and tourism                                                                                                               |
| Management Actions                                     | Revisit park mandates                                                                                                                                |
|                                                        | Improve interagency collaboration and planning                                                                                                       |
|                                                        | Improve integration of TEK into science, planning and management                                                                                     |
|                                                        | Increased flexibility in management, direction and principles                                                                                        |
|                                                        | Long-range adaptive planning to conserve limited funds                                                                                               |
|                                                        | Develop good outreach tools for diverse audiences                                                                                                    |
|                                                        | Find and cultivate partners for funding                                                                                                              |
| Research and Information Needs                         | Develop research proposals for projects that address research needs identified through CCSP                                                          |
|                                                        | Create and maintain coordinated seamless data collection and sharing                                                                                 |
|                                                        | Robust I & M program focused on critical resources and habitat                                                                                       |
|                                                        | Identify creative strategies to work across interdisciplinary boundaries                                                                             |
|                                                        | Encourage interdisciplinary coordination with feedback loops and partnering                                                                          |
|                                                        | Data recovery of archaeological/paleontological sites                                                                                                |

## Discussion

The scenario planning process is not prescriptive; it does not set or determine policy -- however, it does offer useful information for policymakers, land managers, and other stakeholders as they face the task of planning for an uncertain future.

The Northwest Alaska project began with the focal question, “How can NPS managers best preserve the natural and cultural resources and other values within their jurisdiction in the face of climate change?” Through the workshop process described in this report, not only was this question addressed, but so too was the broader question of protecting the natural and cultural landscape in which the Bering Land Bridge National Preserve and Cape Krusenstern National Monument exist.

Two important factors enriched and strengthened the process. First, the group that came together – first via teleconference and later in the workshop itself – represented a broad range of interests, experiences, and knowledge. Not only was NPS represented at the Park and regional level, but these experts were joined by modelers and climate researchers from SNAP; representatives of Alaska Native subsistence, and other local interests; representatives from nonprofit conservation organizations; and experts from other government agencies. Participants were engaged in the process, and contributed to the inputs, analysis, and outcomes. Second, although representation of uncertainty is built into the scenarios process – and is indeed integral to interpretation of the outputs – the analysis performed by workshop participants was based on the best available science. SNAP’s maps, data, and tools offer cutting-edge climate science in formats that help stakeholders connect raw data to real landscape changes and pertinent environmental and human effects. Moreover, the maps created specifically for this project have uses and implications that extend beyond the limits of this project, since they are publicly available and have direct pertinence for stakeholders region-wide who are concerned about issues ranging from construction and development to ecological diversity, and human health and safety. (For all maps, including region-wide and park-specific maps, see Appendix E and [http://www.snap.uaf.edu/webshared/NPS-CCSP/2011\\_Western\\_Arctic/](http://www.snap.uaf.edu/webshared/NPS-CCSP/2011_Western_Arctic/)).

SNAP’s website ([www.snap.uaf.edu](http://www.snap.uaf.edu)) offers further insights into the inherent uncertainties associated with climate modeling, including unknown future emissions rates of greenhouse gases; the complexity of creating and interpreting global circulation models (GCMs) that fully account for the distribution of heat and moisture via atmosphere and oceans; and the challenges of scaling down GCMs to the local level. Forecasts for precipitation are particularly challenging, because of the innate variability of rainfall and snowfall across fairly small-scale landscapes and short time periods. Given these uncertainties – but also given the existence of some clear trends, and ongoing evidence of climate change – the scenarios process creates a unique way of exploring possible futures.

Because Alaska is such a geographically large and diverse state, spanning many cultures and many ecosystems, project outputs from climate change scenario planning workshops vary by region, although some recommended management actions may be applicable in all park networks. Holding these workshops on a regional basis proved an effective means of providing regional focus within a statewide framework.

Climate change impacts of particular concern in the Western Arctic, as identified via this process, include coastal erosion and its effects on cultural and historical resources, natural resources, communities, subsistence, and even Park mandates. This potential change is primarily driven by loss of frozen ground, loss of sea ice and by increasing storms. These changes threaten NPS infrastructure and drastically alter human experience for both visitors and locals. New economic opportunities with loss of sea ice, changes to terrestrial and marine ecosystems, and shifting local livelihoods are likely to complicate management choices, both inside and outside of National Parks.

As shown in Figure 3, the scenarios process is multi-step and iterative. The 2012 Central Alaska workshop took the process through the orienting, exploring, and synthesizing steps, and offered suggestions to promote or direct action. Near the end of the workshop process, participants referred back to the strategy-setting diagram provided by GBN (Figure 6). As outlined, the group assessed which management strategies and information needs were robust and common to all scenarios. Discussions of strategies that offer ways to hedge bets or plan for uncertain but potentially catastrophic effects are also valuable, and these strategies should not be overlooked. An immediate “bet the farm” approach may be needed in places where severe effects from coastal erosion are a near certainty. “Wait and see” may be the preferable approach (and consistent with NPS policy) for dealing with range shifts in native species. Hedging might be the appropriate solution for exotic species: education, prevention, and control where the risks are high while for low-risk species acceptance may be the best approach.

The climate change scenario planning process does not end with these workshops, reports, and presentations. Rather, these products are intended to stimulate creative thinking to address changing but still undetermined future environmental and socio-political future conditions. Post-workshop long-term monitoring and feedback to workshop outcomes are still necessary. Scenario planning is a learning process, and new or unexpected information can make it important to revisit or repeat the process. The planning steps should be refreshed periodically as important new information becomes available to validate existing scenarios or to create new ones.

One of the most useful outcomes from this process can be the development of a suite of tools that can be used to communicate climate change impacts, choices, and potential outcomes to a wide range of stakeholders, including park staff, park visitors, administrators, Alaska Natives, schoolchildren, and the general public. Potential products include video productions, podcasts, interactive displays, posters, fact sheets, interactive web sites, and more.

In summary, park managers, park neighbors, and stakeholders can learn from the future by using the best available scientific information and climate projections and a thoughtful and creative group of stakeholders to create plausible, divergent, relevant, and challenging future climate change scenarios. These scenarios can help us all better prepare for uncertain future conditions in face of climate change.

## Literature Cited

- Chapin III, F. S., M. Sturm, M.C. Serreze, J.P. McFadden, J.R. Key, A.H. Lloyd, A.D. McGuire, T.S. Rupp, A.H. Lynch, J.P. Schimel, J. Beringer, W.L. Chapman, H.E. Epstein, E.S. Euskirchen, L.D. Hinzman, G. Jia, C.-L. Ping, K.D. Tape, C.D.C. Thompson, D.A. Walker, and J.M. Welker. 2005. Role of land-surface changes in arctic summer warming. *Science* 310 (5748): 657-660.
- Cole, D.N., and L. Yung. 2010. Beyond Naturalness: Rethinking park and wilderness stewardship in an era of rapid change. Island Press, Washington, DC.
- Fresco, N.F. 2011. University of Alaska, Scenarios Network for Alaska Planning with Climate Briefs, Climate Drivers Table, Climate Projections, and other documents. Available from <http://bit.ly/jYBKxs> (accessed 10 May 2014).
- Jezierski, C., R. Loehman, and A. Schramm. 2010. Understanding the science of climate change: Talking points - impacts to Alaska Maritime and Transitional. Natural Resource Report NPS/NRPC/NRR—2010/223. National Park Service, Fort Collins, Colorado.
- Marris, E. 2011. Rambunctious Garden: Saving nature in a post-wild world. Bloomsbury, New York, New York.
- National Park Service. 2010a. National Park Service Climate Change Response Strategy. National Park Service Climate Change Response Program. National Park Service, Fort Collins, Colorado. Available from [http://www.nps.gov/climatechange/docs/NPS\\_CCRS.pdf](http://www.nps.gov/climatechange/docs/NPS_CCRS.pdf) (accessed 10 June 2012).
- National Park Service. 2010b. Alaska Region Climate Change Response Strategy 2010-2014. National Park Service, Alaska Region, Anchorage, Alaska. Available from <http://www.nps.gov/akso/docs/AKCCRS.pdf> (accessed 14 April 2014).
- Peterson, G.D., G.S. Cumming, and S.R. Carpenter. 2003. Scenario planning: a tool for conservation in an uncertain world. *Conservation Biology* 17: 358–366.
- Schwartz, P. 1996. The Art of the Long View: Planning for the future in an uncertain world. Doubleday, New York, New York.
- Walters, C.J. 1986. Adaptive Management of Renewable Resources. Blackburn Press, New York, New York.

## Appendix A: Participant Agenda

For videos and presentations from the workshop,  
see <http://www.nps.gov/akso/nature/climate/scenario.cfm>



### Northwestern Alaska National Parks Climate Change Scenario Planning Workshop

AK Regional Office, Anchorage

April 19-21, 2011 — Room 309



#### AGENDA

#### Tuesday April 19<sup>th</sup>

|            |                                                                             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
|------------|-----------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 9:30 a.m.  |                                                                             | ARRIVAL and COFFEE                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| 10:00 a.m. | Plenary<br>(Bob W.)<br><br>(John M.)                                        | <ul style="list-style-type: none"> <li>➤ Welcome:</li> <li>➤ Introductions &amp; Participant Expectations</li> <li>➤ Workshop Objectives, Agenda, Ground Rules</li> <li>➤ Explain Scenario Planning, Review Scenario Process, and Introduce the Focal Question(s)</li> <li>➤ Present science information / overview / present a case study to illustrate scenario process                             <ul style="list-style-type: none"> <li>○ General insights</li> <li>○ Climate drivers / uncertainties -&gt; handouts</li> <li>○ Potential impacts -&gt; handouts</li> <li>○ How to create scenarios using uncertainties Drawing from drivers and impacts tables to build scenarios</li> </ul> </li> </ul> |
| 10:30 a.m. | Plenary<br>(Nancy F.)                                                       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| 11:15 a.m. | Plenary<br>(Nancy F.)                                                       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| 12:00      |                                                                             | LUNCH                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| 1:00 pm    | Plenary<br>(John M)<br><br>Groups<br>(Don /John;<br>Nancy F. &<br>Nancy S.) | <ul style="list-style-type: none"> <li>➤ Video of CC Scenario, break into 2 groups by park (rooms 309 &amp; 322)</li> <li>➤ Build Scenario Frameworks: <i>Identify key climate drivers with “high uncertainty” but “high impact and importance” leading to challenging, plausible, relevant, and divergent futures. Also identify relatively certain climate drivers.</i></li> </ul>                                                                                                                                                                                                                                                                                                                           |
| 2:45 pm    |                                                                             | BREAK                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| 3:00 pm    | Groups                                                                      | <ul style="list-style-type: none"> <li>➤ Continue to build climate driver framework identify key characteristics of scenarios: <i>Select climate drivers and test matrix combinations. Draw from impacts table to detail implications for each scenario (e.g. natural &amp; cultural resources, facilities, interpretation)</i></li> </ul>                                                                                                                                                                                                                                                                                                                                                                     |
| 4:45 p.m.  | Plenary<br>John/Nancy                                                       | ADJOURN – final thoughts for the day                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |

## Wednesday April 20th

|          |                                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
|----------|------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 8:00 am  |                                    | ARRIVAL and COFFEE                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| 8:15 am  | Plenary<br>(John M. /<br>Nancy S.) | <ul style="list-style-type: none"> <li>➤ CC Video</li> <li>➤ Second thoughts and overnight insights</li> <li>➤ Re-cap process (what we did and where we are going, including the next step to nest climate scenarios into a socio-political framework)</li> </ul>                                                                                                                                                                                                                                  |
| 8:45 am  | Plenary                            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| 9:15 am  | Plenary<br>(Don C<br>w/John<br>M.) |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
|          |                                    | <ul style="list-style-type: none"> <li>➤ Report-out: Groups share draft climate driver frameworks with key characteristics of scenarios</li> <li>➤ Describe Socio-Political Framework relevant to Alaska</li> <li>➤ Explain nested scenarios</li> <li>➤ Provide a few example narratives from nested scenarios</li> </ul>                                                                                                                                                                          |
| 9:45 am  |                                    | BREAK                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| 10:00 am | Groups                             | <ul style="list-style-type: none"> <li>➤ Explore Socio-Political drivers and implications<br/>Combine selected “bioregional climate drivers” and “socio-political” frameworks to develop nested scenarios leading to challenging, plausible, relevant, and divergent futures. <i>Briefly discuss all 4 climate driver scenarios within each quadrant of the socio-political framework, and select 2 or 3 nested futures to develop and build robust narratives for these scenarios.</i></li> </ul> |
| 12:00 pm |                                    | LUNCH                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| 1:00 pm  | Groups                             | Continue building robust narratives and characters for the selected nested scenarios and draft two scenario narratives. <i>(Groups may subdivide into 2 scenario teams for each park unit)</i>                                                                                                                                                                                                                                                                                                     |
| 2:45 pm  |                                    | BREAK                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| 3:00 pm  | Groups                             | Groups report out internally the process for climate driver selection and nested scenario selection and describe the selected nested climate futures (stories) and refine, as needed for report out to larger group                                                                                                                                                                                                                                                                                |
| 4:15 pm  | Plenary<br>(John M.)               | <ul style="list-style-type: none"> <li>➤ Groups share process for selecting 2-3 nested scenarios for challenging, plausible, relevant, and divergent futures and re-cap selected scenarios and draft storylines (15 min each + discussion)</li> <li>➤ Groups prepare to bring back printed narratives by 8 AM next morning.</li> </ul>                                                                                                                                                             |
| 4:45 pm  | Plenary<br>(Nancy S.)              | FINAL THOUGHTS / QUESTIONS/ADJOURN for Day & Group Dinner @ Muse                                                                                                                                                                                                                                                                                                                                                                                                                                   |

## Thursday April 21<sup>st</sup>

|          |                                                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
|----------|----------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 8:00 am  |                                                          | ARRIVAL and COFFEE                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| 8:15 am  | Plenary<br>(John M.)<br><br>(Jeff M.)                    | <ul style="list-style-type: none"> <li>➤ Video of Climate Change Scenario</li> <li>➤ Overnight Insights and share written narratives.</li> <li>➤ Explain management implications &amp; actions</li> <li>➤ Presentation: From implications &amp; actions to management decisions: various ways to use insights from scenarios; tips on communicating scenarios and formulating no regrets actions</li> <li>➤ Start to identify potential actions for each of 3-4 chosen nested scenarios.</li> </ul> |
| 10:00 am |                                                          | BREAK                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| 10:15 am | Groups                                                   | <ul style="list-style-type: none"> <li>➤ Develop recommendations for selected scenarios based on mgmt. implications. <i>Focus on no-regrets actions that apply to all selected climate futures, when possible. Prepare for testing and scientific validation of scenarios, and consider the best way to communicate the issues.</i></li> </ul>                                                                                                                                                      |
| 12:00 pm |                                                          | LUNCH                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| 1:00 pm  | Groups                                                   | <ul style="list-style-type: none"> <li>➤ Groups consider management implications to revise scenario narratives in follow-up webinar</li> </ul>                                                                                                                                                                                                                                                                                                                                                      |
| 2:00 pm  | Plenary<br>(Bob W.,<br>Nancy F.,<br>John M.,<br>Jeff M.) | <p>NEXT STEPS</p> <ul style="list-style-type: none"> <li>➤ How do we use this work and where do we go with it?</li> <li>➤ What actions apply to all scenarios =&gt; least regrets actions?</li> <li>➤ Incorporate scenario planning into landscape-scale collaboration and adaptation (working with neighbors and across jurisdictions)</li> </ul>                                                                                                                                                  |
| 3:00 pm  |                                                          | BREAK                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| 3:15 pm  | Plenary<br>(Bob W.,<br>Nancy F.,<br>John M.,<br>Jeff M.) | <ul style="list-style-type: none"> <li>➤ Need for follow-up discussions/teleconferences to flesh out scenarios and actions for up to 3 examples for each administrative unit</li> <li>➤ Draft report from SNAP, web links and access to data</li> <li>➤ Public Outreach and sharing CC scenarios within and outside NPS units.</li> <li>➤ Final thoughts from park superintendents.</li> </ul>                                                                                                      |
| 4:15 pm  | Plenary<br>(Bob W.)                                      | FINAL THOUGHTS / THANKS/ADJOURN                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |

## Appendix B: Workshop Participant List

### Lead Team

|               |                                                                                     |
|---------------|-------------------------------------------------------------------------------------|
| Bob Winfree   | National Park Service, Alaska Regional Office, Regional Science Advisor             |
| Don Callaway  | National Park Service, Alaska Regional Office, Senior Cultural Anthropologist       |
| John Morris   | National Park Service, Alaska Regional Office, Interpretation                       |
| Bud Rice      | National Park Service, Alaska Regional Office, Environmental Protection Specialist, |
| Jeff Mow      | National Park Service, Glacier National Park, Superintendent                        |
| Nancy Fresco  | Scenarios Network for Alaska and Arctic Planning, Coordinator                       |
| Anna Schemper | Scenarios Network for Alaska and Arctic Planning, GIS Specialist                    |
| Nancy Swanton | National Park Service, Alaska Regional Office, Beringia Program Manager             |

### Participants

|                   |                                                                              |
|-------------------|------------------------------------------------------------------------------|
| Ken Adkisson      | National Park Service, Bering Land Bridge, Anthropologist                    |
| Jennifer Barnes   | National Park Service, Fire Ecologist                                        |
| Matthew Brody     | United States Army Corps of Engineers                                        |
| Tara Callear      | University of Alaska Fairbanks, MS Student                                   |
| John Chase        | Northwest Alaska Borough, Community Development and Flood Program Specialist |
| Sally Cox         | Alaska Division of Community and Regional Affairs, Program Manager           |
| Tony DeGange      | United States Geological Survey, Supervisor Biologist                        |
| Ian Erlich        | Maniilaq Association, President/CEO                                          |
| Jean Gamache      | National Park Service, Alaska Regional Office, Tribal Coordination           |
| Bob Gorman        | University of Alaska Fairbanks, Cooperative Extension                        |
| Frank Hays        | National Park Service, Western Arctic, Superintendent                        |
| Linda Jeske       | National Park Service, Western Arctic, Interpretation                        |
| Corrie Knapp      | University of Alaska Fairbanks, PhD Students                                 |
| Paul Krabacher    | Bureau of Land Management, National Seed Coordinator                         |
| Jim Lawler        | National Park Service, Arctic Network Coordinator                            |
| Adrienne Lindholm | National Park Service, Alaska Regional Office, Wilderness                    |
| Wendy Loya        | The Wilderness Society, Lead Ecologist                                       |
| Brooke Merrell    | National Park Service, Alaska Regional Office, Community Planner             |
| Peter Neitlich    | National Park Service, Western Arctic, Ecologist                             |
| Jeanette Pomrenke | National Park Service, Bering Land Bridge, Superintendent                    |
| Lisa Rabbe        | United States Army Corps of Engineers, Project Manager                       |
| Sandy Tahbone     | Kawerak, Inc.                                                                |

## Appendix C: SNAP Tools for Planners

# SNAP Climate Projections: *tools for planners*

### What are SNAP climate projections?

The Scenarios Network for Alaska Planning provides predictions of how average temperatures and precipitation may change in Alaska as a result of global climate change. Communities, businesses, and agencies work with SNAP to link these projections to ecological, social, and economic changes, and to plan for the future.

### How are projections derived?

#### IPPC Global Climate Models

- ▶ The Intergovernmental Panel on Climate Change (IPCC) used fifteen different General Circulation Models (GCMs) when preparing its Fourth Assessment Report. Each model was created by a different nation or group using slightly different data and assumptions. Thus, models can be expected to perform with varying degrees of accuracy in any particular region. Accuracy can be checked by comparing model output for past years to actual climate data for the same time period.

#### Model Selection

- ▶ SNAP investigator Dr. John Walsh and colleagues analyzed how well each model predicted monthly mean values for three different climate variables (surface air temperature, precipitation, and sea level air pressure) over four overlapping northern regions (Alaska, Greenland, latitude 60-90°N and latitude 20-90°N) for the period from 1958–2000. They noted that models that performed well in one northern region tended to also perform well in others. SNAP climate models rely on output from the five models that provided the most accurate overall results.

#### Scaling down model results

- ▶ Results are scaled down to match local conditions using data from Alaskan weather stations and PRISM (Parameter-elevation Regressions on Independent Slopes Model), an analytical tool that uses point data, a digital elevation model, and other spatial data sets to generate gridded estimates of monthly, yearly, and



event-based climatic parameters, such as precipitation, temperature, and dew point.

### Presentation of data

Data can be accessed via our website ([www.snap.uaf.edu](http://www.snap.uaf.edu)) as ASCII files for GIS, or as GoogleEarth maps. Data include mean monthly temperatures and precipitation, as well as derived values such as decadal means, thaw dates and growing season length. Data for 353 communities statewide are also available, in tabular form.

### Time periods

SNAP offers climate projections from the present to the year 2099. We also have historical data derived from Climate Research Units and downscaled using PRISM. Data from 1980 onwards is available on our website.

### Scale and resolution

Climate projections have been scaled down to 2km resolution. Thus, each pixel in a climate map represents a 4km<sup>2</sup> area.

### Linking climate to resources

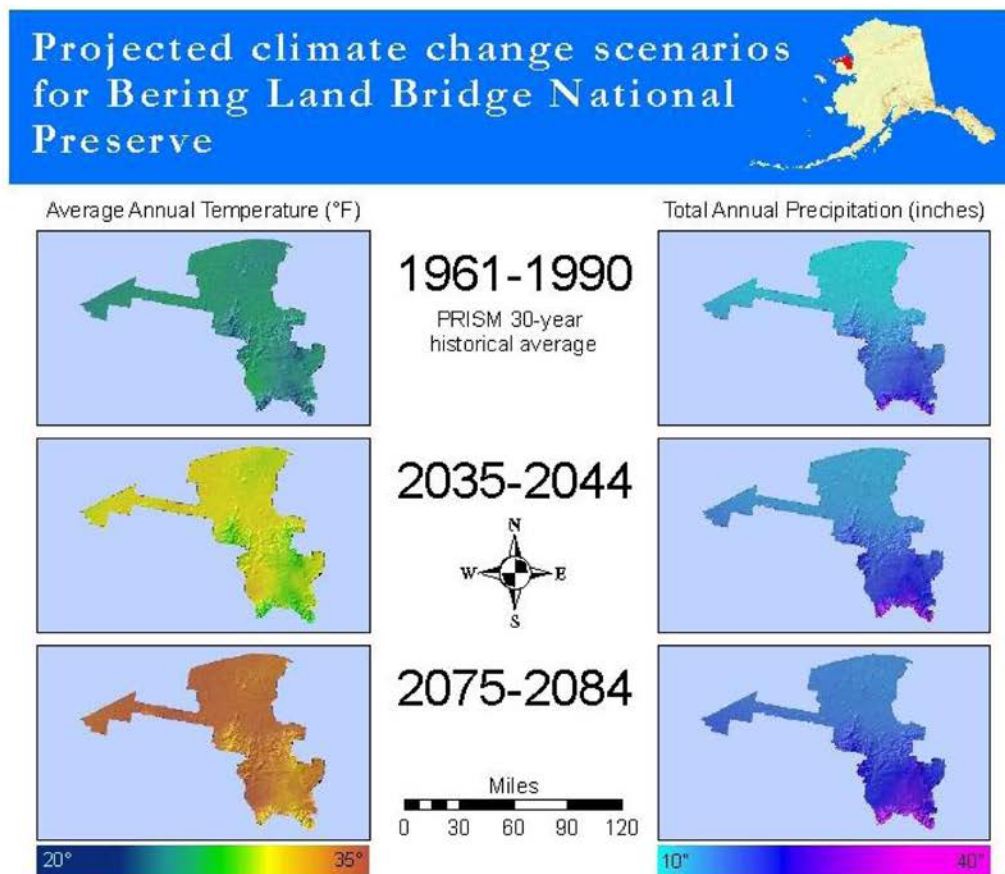
Estimating future air temperature, rainfall, and snowfall are just the first steps towards planning for change. Stakeholders who want more detailed information can create collaborative agreements with SNAP in order to work on projects that link climate data to variables such as permafrost thaw; timing of autumn freeze-up and spring breakup; frequency of flooding events; sea level change; and changes in evapotranspiration. These changes can, in turn, be linked to factors of direct concern to communities and land planners, such as ecosystem shifts; forest fires; agricultural opportunities; risks to infrastructure; and movement of game animals.



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*The University of Alaska is an AA/EEO employer and educational institution.*



## Appendix D: Climate Summary Reports



| Magnitude of climatic change                                                           |      |            |         |                                             |      |            |         |          |
|----------------------------------------------------------------------------------------|------|------------|---------|---------------------------------------------|------|------------|---------|----------|
| Projected Temperature (TEMP) Change (°F)                                               |      |            |         | Projected Precipitation (PRCP) Change (in.) |      |            |         |          |
| Season                                                                                 | Time | Avg. TEMP  | Δ TEMP* | Season                                      | Time | Total PRCP | Δ PRCP* | % Δ PRCP |
| Annual                                                                                 | Hist | 21.6 ± 0.2 | NA      | Annual                                      | Hist | 12.4 ± 1.5 | NA      | NA       |
|                                                                                        | 2040 | 27.2 ± 0.2 | 5.6     |                                             | 2040 | 15.4 ± 1.5 | 3.0     | 24%      |
|                                                                                        | 2080 | 31.9 ± 0.3 | 10.3    |                                             | 2080 | 18.1 ± 1.5 | 5.7     | 46%      |
| Summer                                                                                 | Hist | 43.6 ± 0.4 | NA      | Summer                                      | Hist | 7.4 ± 0.9  | NA      | NA       |
|                                                                                        | 2040 | 46.0 ± 0.4 | 2.4     |                                             | 2040 | 8.8 ± 0.9  | 1.5     | 20%      |
|                                                                                        | 2080 | 48.5 ± 0.4 | 4.8     |                                             | 2080 | 9.8 ± 0.9  | 2.4     | 33%      |
| Winter                                                                                 | Hist | 5.9 ± 0.4  | NA      | Winter                                      | Hist | 5.1 ± 0.6  | NA      | NA       |
|                                                                                        | 2040 | 13.8 ± 0.5 | 7.9     |                                             | 2040 | 6.6 ± 0.6  | 1.5     | 31%      |
|                                                                                        | 2080 | 20.1 ± 0.6 | 14.3    |                                             | 2080 | 8.3 ± 0.6  | 3.3     | 65%      |
| * Δ PRCP/TEMP: change in decadal precipitation/temperature average from historic value |      |            |         |                                             |      |            |         |          |

For more information:

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01/09

# Climate Change Implications for Bering Land Bridge National Preserve



## Climate Change in Alaska

**Many areas in Alaska are already showing signs of climate change.** Scientists have reported observations of wetland drying, glacial and polar sea ice recession, spruce-bark beetle infestations, and an increase in fire frequency and intensity throughout the state. A better understanding of where and when such changes could continue to occur is needed to help decision makers identify how Alaska's ecosystems may respond in the future.

In order to understand what these changes may be like, data from a composite of five down-scaled global circulation models was used to estimate decadal averages of future temperature and precipitation values within the preserve. These models assume a steady increase in carbon dioxide (CO<sub>2</sub>) emissions from fossil fuel combustion over the first several decades of the 21<sup>st</sup> century, followed by a gradual decline in emissions as several kinds of low-emission energy alternatives become more prevalent. This emissions regime is considered a "moderate" estimate<sup>1</sup>. Several other scenarios have predicted higher emission rates, and scientists have since determined current levels<sup>2</sup> are significantly greater than even the most extreme concentrations analyzed by the Intergovernmental Panel on Climate Change. Higher emissions rates will likely accelerate changes in climate and lead to more severe ecosystem impacts.

## Temperature changes in Bering Land Bridge National Preserve

**Temperatures are projected to increase over the coming decades at an average rate of about 1°F per decade.** Average annual temperature is expected to rise by about 6°F by 2040 and as much as 10°F by 2080.

Considering the natural variation in temperatures across the study area, this is likely to result in a transition from average annual temperatures below the freezing point (~22°F), to temperatures near or above the freezing point (~32°F).

A likely outcome of these changes is a lengthening of the growing season, a change that could have profound affects on wildlife mating cycles, plant growth and flowering, water availability in soil and rivers, and hunting and fishing.

**Winter temperatures are projected to change the most dramatically.** Mean winter temperatures could reach a high of 20°F by 2080, a figure that represents an impressive 14°F rise from the historical 6°F average. Average summer temperatures are projected to rise by almost 5°F by 2080 (from ~44°F to ~49°F). Some species may benefit from these changes, while others may not be able to adapt or find suitable habitat conditions to sustain their populations.

## Precipitation changes in Bering Land Bridge National Preserve

**Precipitation is predicted to increase across the study area.** Despite this area-wide increase, conditions are expected to become substantially drier in the summer and fall and potentially icier in winter. Although summer rainfall is expected to rise by 33%, this increase is unlikely to be enough to offset an increase in evapotranspiration caused by warmer temperatures and a longer growing season. Winter precipitation may increase by as much as 65% and could fall in the form of snow, ice, or rain, depending on the temperature. Ultimately, the timing and intensity of precipitation will determine how these changes affect the landscape and hydrology of the Preserve.

## Summary of findings

**Bering Land Bridge National Preserve is projected to become warmer and drier over the next century.** Warmer temperatures and a longer growing season are expected to increase evapotranspiration enough to outweigh a regional increase in precipitation. Seasonal changes in climate will have profound impacts on the condition and health of wildlife habitat, lead to increased fire risk, and contribute to the likelihood of wetlands, streams, and lakes drying.

It is important to note that predicting changes in environmental variables is difficult, especially in Alaska where historical climate monitoring data is sparse. Increasing the scope of precipitation, temperature, and ecological monitoring throughout Alaska is one of the best strategies for improving our understanding of changes in climate and the response of ecosystems.

<sup>1</sup> This emissions outlook is the "A1B" scenario from the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment, published in 2007. The models used in this analysis included ECHAM5, GFDL2.1, MIROC3.2MR, HadCM3, and CGCM3.1.

<sup>2</sup> Recent rates of global CO<sub>2</sub> emissions can be found on the Carbon Dioxide Information Analysis Center website ([www.cdiac.esd.ornl.gov](http://www.cdiac.esd.ornl.gov)).

## Projected climate change scenarios for Cape Krusenstern National Monument



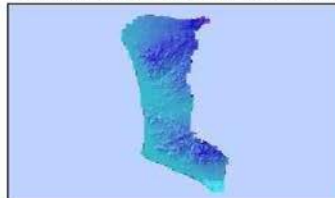
Average Annual Temperature (°F)



1961-1990

PRISM 30-year  
historical average

Total Annual Precipitation (inches)



2035-2044



2075-2084

Miles  
0 20 40 60 80



15° 30°

10° 30°

## Magnitude of climatic change

| Projected Temperature (TEMP) Change (°F) |      |            |         | Projected Precipitation (PRCP) Change (in.) |      |            |                   |
|------------------------------------------|------|------------|---------|---------------------------------------------|------|------------|-------------------|
| Season                                   | Time | Avg. TEMP  | Δ TEMP* | Season                                      | Time | Total PRCP | Δ PRCP* % Δ PRCP* |
| Annual                                   | Hist | 19.8 ± 0.3 | NA      | Annual                                      | Hist | 13.1 ± 0.7 | NA NA             |
|                                          | 2040 | 25.6 ± 0.2 | 5.8     |                                             | 2040 | 15.8 ± 0.7 | 2.7 20%           |
|                                          | 2080 | 30.3 ± 0.2 | 10.5    |                                             | 2080 | 18.2 ± 0.6 | 5.0 38%           |
| Summer                                   | Hist | 45.0 ± 0.2 | NA      | Summer                                      | Hist | 7.6 ± 0.4  | NA NA             |
|                                          | 2040 | 47.4 ± 0.2 | 2.4     |                                             | 2040 | 8.9 ± 0.4  | 1.3 16%           |
|                                          | 2080 | 49.9 ± 0.2 | 4.8     |                                             | 2080 | 9.7 ± 0.4  | 2.1 28%           |
| Winter                                   | Hist | 1.8 ± 0.4  | NA      | Winter                                      | Hist | 5.5 ± 0.3  | NA NA             |
|                                          | 2040 | 10.0 ± 0.4 | 8.2     |                                             | 2040 | 6.9 ± 0.3  | 1.4 26%           |
|                                          | 2080 | 16.4 ± 0.4 | 14.6    |                                             | 2080 | 8.4 ± 0.3  | 2.9 53%           |

\* Δ PRCP/TEMP: change in decadal precipitation/temperature average from historic value

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01/09

# Climate Change Implications for Cape Krusenstern National Monument



## Climate Change in Alaska

**Many areas in Alaska are already showing signs of climate change.** Scientists have reported observations of wetland drying, glacial and polar sea ice recession, spruce-bark beetle infestations, and an increase in fire frequency and intensity throughout the state. A better understanding of where and when such changes could continue to occur is needed to help decision makers identify how Alaska's ecosystems may respond in the future.

In order to understand what these changes may be like, data from a composite of five down-scaled global circulation models was used to estimate decadal averages of future temperature and precipitation values within the preserve. These models assume a steady increase in carbon dioxide (CO<sub>2</sub>) emissions from fossil fuel combustion over the first several decades of the 21<sup>st</sup> century, followed by a gradual decline in emissions as several kinds of low-emission energy alternatives become more prevalent. This emissions regime is considered a "moderate" estimate<sup>1</sup>. Several other scenarios have predicted higher emission rates, and scientists have since determined current levels<sup>2</sup> are significantly greater than even the most extreme concentrations analyzed by the Intergovernmental Panel on Climate Change. Higher emissions rates will likely accelerate changes in climate and lead to more severe ecosystem impacts.

## Temperature changes in Cape Krusenstern National Monument

**Temperatures are projected to increase over the coming decades at an average rate of about 1°F per decade.**

Average annual temperature is expected to rise by about 6°F by 2040 and as much as 11°F by 2080.

Considering the natural variation in temperatures across the study area, this is likely to result in a transition from average annual temperatures below the freezing point (~20°F), to temperatures near the freezing point (~30°F).

A likely outcome of these changes is a lengthening of the growing season, a change that could have profound effects on wildlife mating cycles, plant growth and flowering, water availability in soil and rivers, and hunting and fishing.

**Winter temperatures are projected to change the most dramatically.** Mean winter temperatures could reach a high of 16°F by 2080, a figure that represents an impressive 14°F rise from the historical 2°F average. Average summer temperatures are projected to rise by almost 5°F by 2080 (from ~45°F to ~50°F). Some species may benefit from these changes, while others may not be able to adapt or find suitable habitat conditions to sustain their populations.

## Precipitation changes in Cape Krusenstern National Monument

**Precipitation is predicted to increase across the study area.** Despite this area-wide increase, conditions are expected to become substantially drier in the summer and fall and potentially icier in winter. Although summer rainfall is expected to rise by 28%, this increase is unlikely to be enough to offset an increase in evapotranspiration caused by warmer temperatures and a longer growing season. Winter precipitation may increase by as much as 53% and could fall in the form of snow, ice, or rain, depending on the temperature. Ultimately, the timing and intensity of precipitation will determine how these changes affect the landscape and hydrology of the Preserve.

## Summary of findings

**Cape Krusenstern National Monument is projected to become warmer and drier over the next century.** Warmer temperatures and a longer growing season are expected to increase evapotranspiration enough to outweigh a regional increase in precipitation. Seasonal changes in climate will have profound impacts on the condition and health of wildlife habitat, lead to increased fire risk, and contribute to the likelihood of wetlands, streams, and lakes drying.

It is important to note that predicting changes in environmental variables is difficult, especially in Alaska where historical climate monitoring data is sparse. Increasing the scope of precipitation, temperature, and ecological monitoring throughout Alaska is one of the best strategies for improving our understanding of changes in climate and the response of ecosystems.

<sup>1</sup> This emissions outlook is the "A1B" scenario from the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment, published in 2007. The models used in this analysis included Ecam5, Gfdl2.1, Miroc3.2MR, HadCM3, and CGCM3.1.

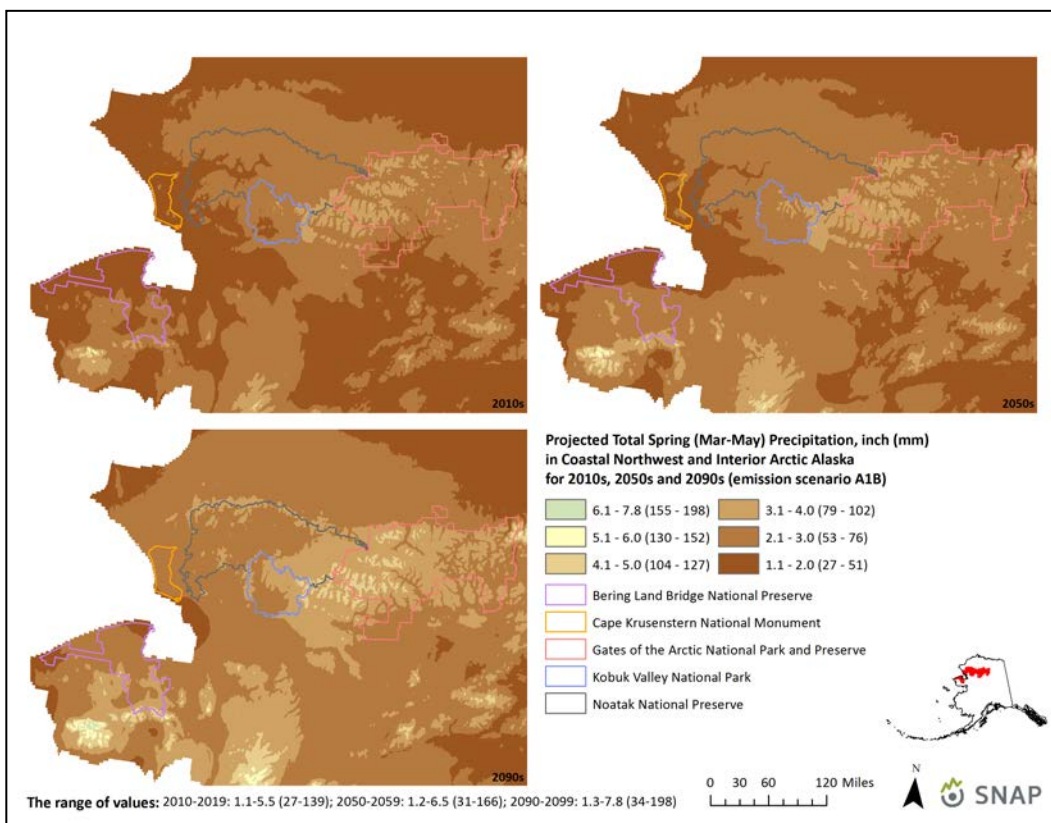
<sup>2</sup> Recent rates of global CO<sub>2</sub> emissions can be found on the Carbon Dioxide Information Analysis Center website ([www.cdiac.esd.ornl.gov](http://www.cdiac.esd.ornl.gov)).

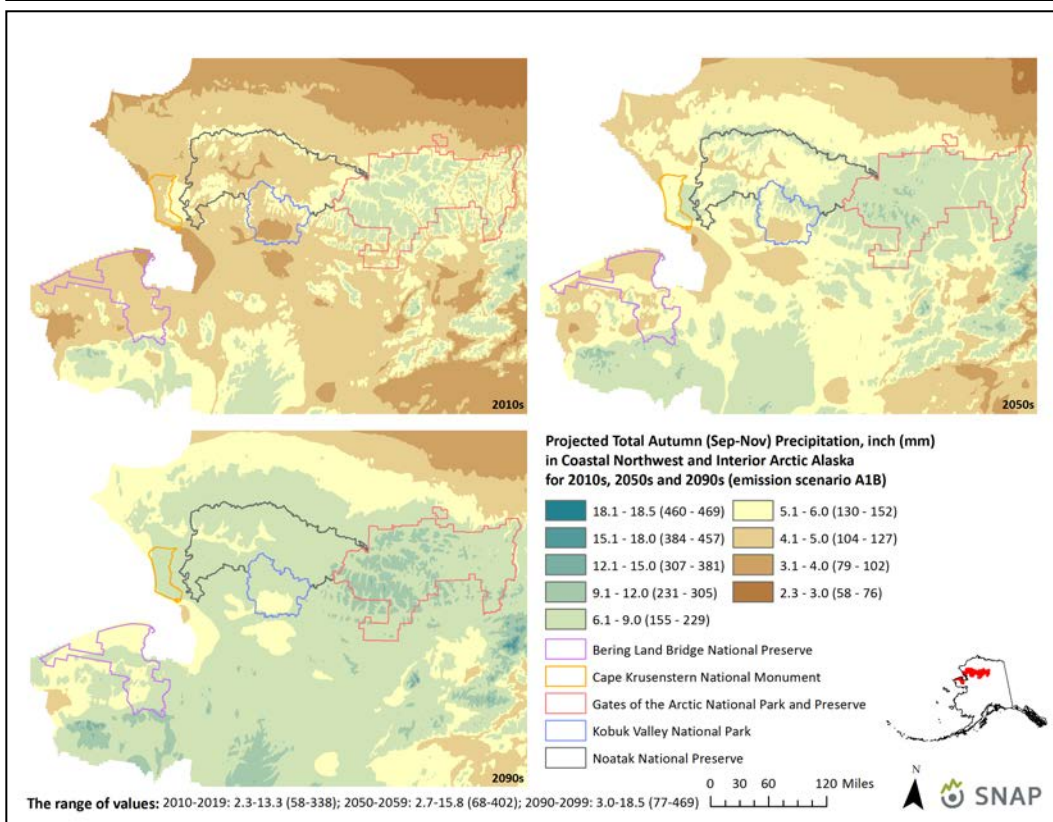
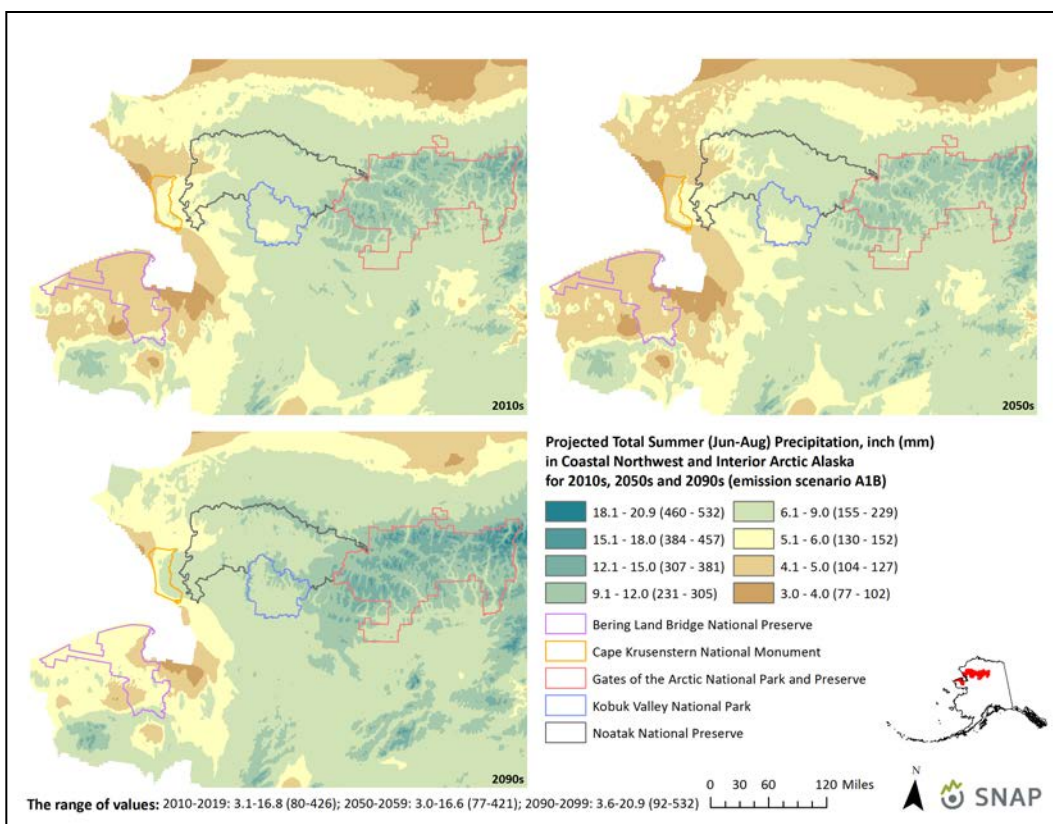
## Appendix E: Western Arctic Modeled Climate Variables

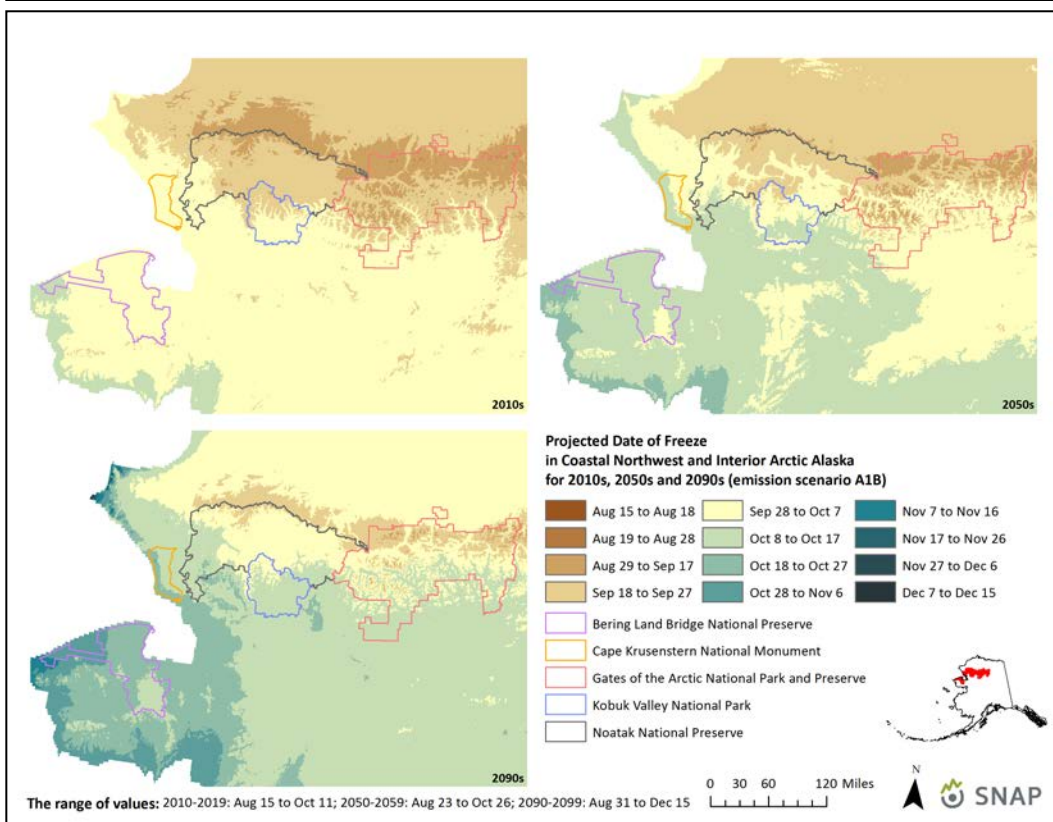
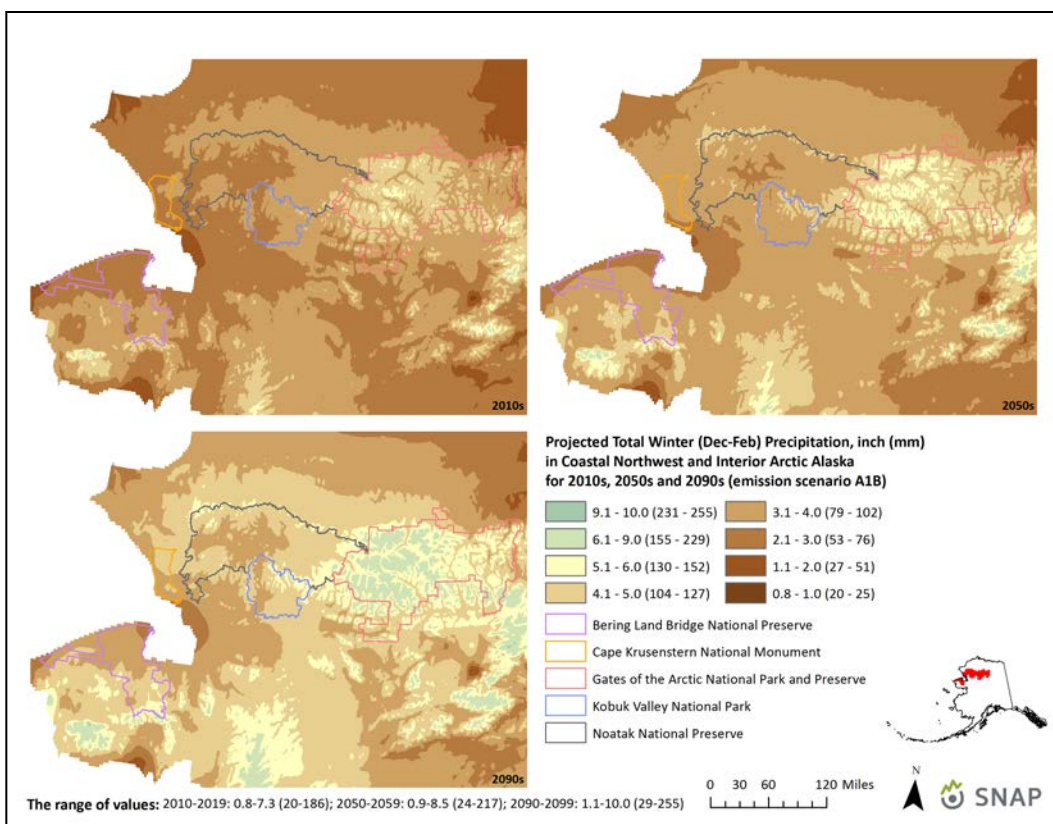
The set of maps included in this appendix were produced by SNAP. All maps represent projected data averaged across five downscaled GCMs and additionally averaged across decades (the 2010s, 2050s, and 2090s), in order to represent long-term trends. For a full description of SNAPs methods, see [www.snap.uaf.edu](http://www.snap.uaf.edu).

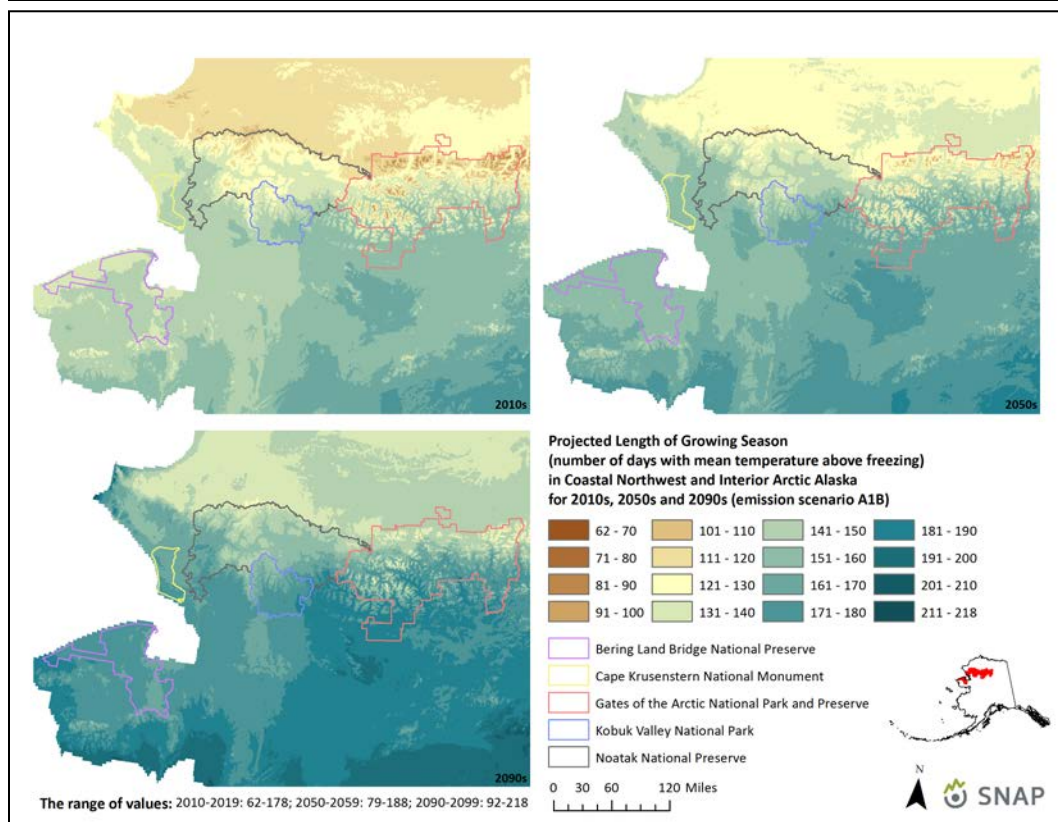
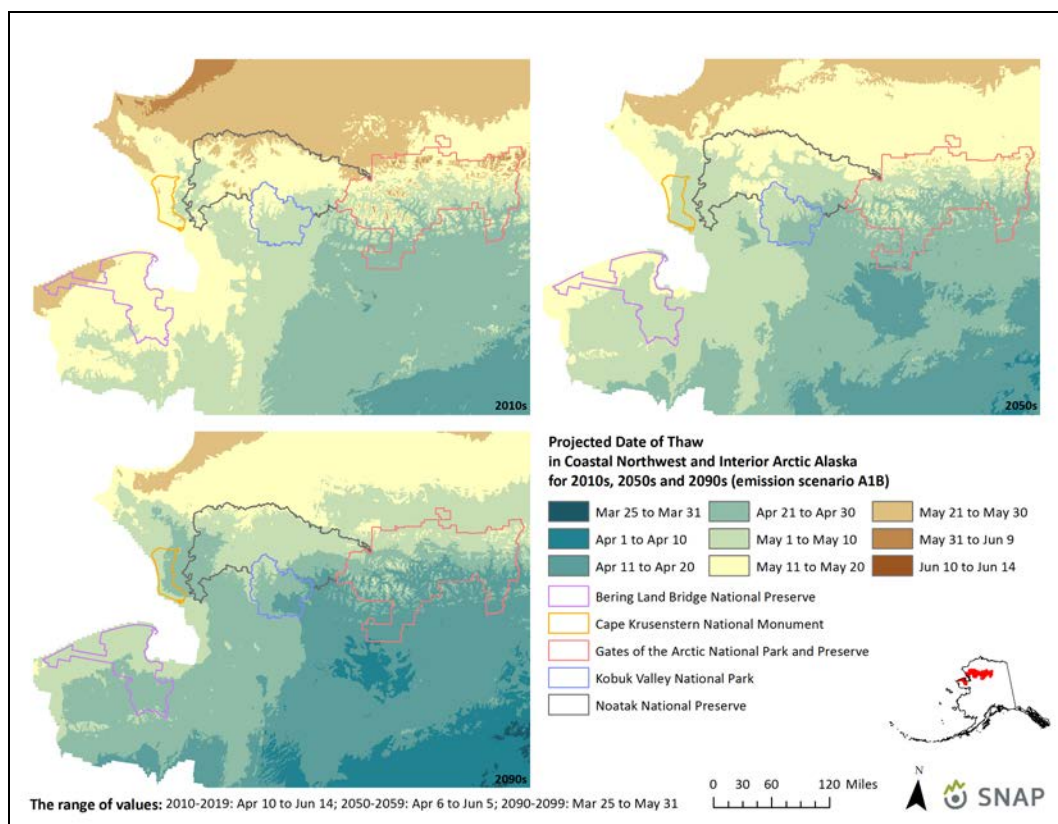
Maps included in this set include seasonal maps (three-month averages) for precipitation, as well as several temperature-linked maps, including projections for date of freeze, date of thaw, length of summer season, and ground temperature at once meter depth.

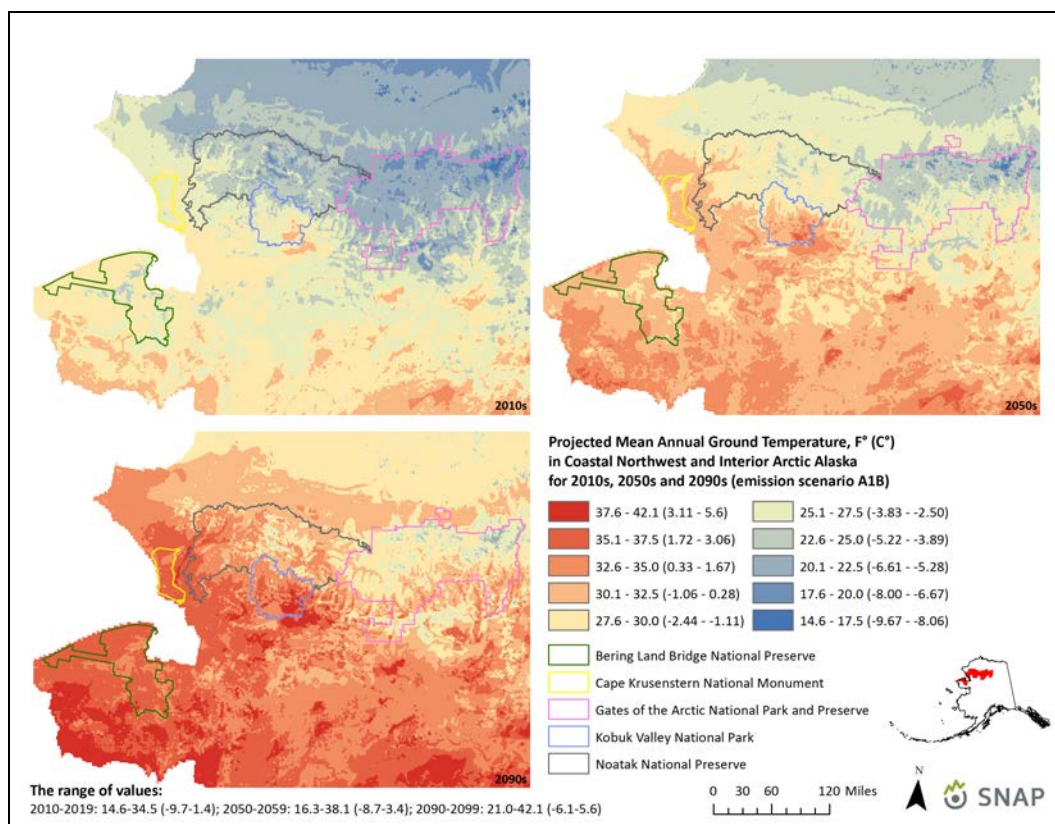
These maps show all Arctic Network Parks. They rely on a midrange (A1B) emissions scenario, as defined by the IPCC. For maps of individual parks, as well as maps depicting the more severe A2 climate change scenario, see [http://www.snap.uaf.edu/webshared/NPS-CCSP/2011\\_Western\\_Arctic/](http://www.snap.uaf.edu/webshared/NPS-CCSP/2011_Western_Arctic/).











## Appendix F: Climate Drivers Table

| SUMMARY OF PROJECTED CLIMATE CHANGES FOR ALASKA       |                                                                 |                                                                                                                                          |                                              |                                                                                                                                                                                                            |                                                 |                                               |
|-------------------------------------------------------|-----------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------|-----------------------------------------------|
| Climate Variable                                      | General Change Expected                                         | Specific Change Expected & Reference Period                                                                                              | Expected Change Relative to Recent Changes   | Patterns of Change                                                                                                                                                                                         | Confidence                                      | Source                                        |
| Temperature                                           | Increase                                                        | 2050: +3°C ±2°<br>2100: +5°C ±3°                                                                                                         | Large                                        | More pronounced in autumn-winter, with winter increases of +8°C likely by 2100                                                                                                                             | >95% very likely (sign)                         | IPCC (2007) and SNAP                          |
| Precipitation                                         | Increase                                                        | 2050: 15-25% ± 15%<br>2100: 25-50% ± 20%                                                                                                 | Large                                        | Fairly high % change, but high uncertainty and low baseline precip; drying effects of increased temperature and evapotranspiration may dominate                                                            | >90% very likely (sign)                         | IPCC(2007) and SNAP                           |
| Relative Humidity                                     | Little change                                                   | 2050: 0% ±10%<br>2100: 0% ±15%                                                                                                           | Small                                        | Absolute humidity increases                                                                                                                                                                                | 50%<br>About as likely as not                   | SNAP                                          |
| Wind Speed                                            | Increase                                                        | 2050: +2% ±4%<br>2100: +4% ±8%                                                                                                           | Small                                        | More pronounced in winter and spring                                                                                                                                                                       | >90% Likely (sign)                              | Abatzoglou and Brown (2011)                   |
| Pacific Decadal Oscillation (atmospheric circulation) | Decadal to multi-decadal circulation anomalies affecting Alaska | Unknown                                                                                                                                  | Large (comparable to climatic jump in 1970s) | Major effect on Alaskan temperatures in cold season; acts as a wildcard within ongoing climate trends                                                                                                      | Natural variation, essentially unpredictable    | Hartman and Wendler (2005)                    |
| Extreme Events: Temperature                           | Warm Events Increase/<br>Cold Events Decrease                   | 2050: 3-6x increase in warm events; 3-5x decrease in cold events;<br>2100: 5-8.5x increase in warm events; 8-12x decrease in cold events | Large                                        | Increase in frequency and length of extreme hot events and decrease in extreme cold events (winter) due to warming trend, but no clear changes in overall variability                                      | Modeled and observed<br>>95% Very likely (sign) | Abatzoglou and Brown; Timlin and Walsh (2007) |
| Extreme Events: Precipitation                         | Decrease/<br>Increase                                           | 2050: -20% to +50%; 2100: -20% to +50%                                                                                                   | Large                                        | Increase in frequency and contribution especially in winter. Largest increase in autumn (large inter-model differences). Decreases in spring. Percent of annual precipitation as extreme events increases. | Modeled and observed<br>Uncertain               | Abatzoglou and Brown (2011)                   |
| Extreme Events:                                       | Increase                                                        | Increase in frequency and                                                                                                                | Any increases exacerbated                    | Increases at southern periphery                                                                                                                                                                            | >66% Likely                                     | Field et al. (2007)                           |

| SUMMARY OF PROJECTED CLIMATE CHANGES FOR ALASKA |                                                                          |                                                                                           |                                             |                                                                                                                                                                   |                                                                             |                                                                   |
|-------------------------------------------------|--------------------------------------------------------------------------|-------------------------------------------------------------------------------------------|---------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------|-------------------------------------------------------------------|
| Climate Variable                                | General Change Expected                                                  | Specific Change Expected & Reference Period                                               | Expected Change Relative to Recent Changes  | Patterns of Change                                                                                                                                                | Confidence                                                                  | Source                                                            |
| Storms                                          |                                                                          | intensity                                                                                 | by sea ice reduction and sea level increase | of Arctic; little information for central Arctic                                                                                                                  |                                                                             | IPCC Working Group 2 AR41                                         |
| Sea ice                                         | Decrease                                                                 | 2050: 40-60% loss in Bering Sea (winter/spring); 20-70% loss in Chukchi/Beaufort (summer) | Comparable to recent changes                | Longer ice-free season; less loss of sea ice in winter than in summer                                                                                             | >90%<br>Very likely                                                         | Wang and Overland (2009)                                          |
| Snow                                            | Increased snowfall during winter, shorter snow season                    | 2050: 10-25%;<br>2100: 20-50%                                                             | Recent changes not well established         | Cold-season snow amounts will increase in Interior, Arctic; increased percentage of precipitation will fall as rain (especially in spring, autumn)                | Large uncertainty in timing of snowmelt (warmer springs, more snow to melt) | AMAP/ SWIPA (Snow, Water, Ice and Permafrost in the Arctic, 2011) |
| Freeze-up date                                  | Later in autumn                                                          | 2050: 5-20 days<br>2100: 10-40 days                                                       | Large                                       | highest near the north coast, but pronounced throughout the Arctic                                                                                                | >90%<br>Very likely (sign)                                                  | SNAP                                                              |
| Length of ice-free season for rivers, lakes     | Increase                                                                 | 2050: 10-20 days<br>2100: 20-40 days                                                      | Large                                       | Largest near coasts where sea ice retreats, open water season lengthens                                                                                           | >90%<br>Very likely                                                         | IPCC (2007); SNAP                                                 |
| River and stream temperatures                   | Increase                                                                 | 2050: 1-3°C<br>2100: 2-4°C                                                                | Large                                       | Consistent with earlier breakup and higher temperatures                                                                                                           | >90%<br>Very Likely                                                         | Kyle and Brabets (2001)                                           |
| Length of growing season                        | Increase                                                                 | 2050: 10 to 20 days<br>2100: 20 to 40 days                                                | Continuation of recent changes              | Largest near coasts                                                                                                                                               | >90%<br>Very likely                                                         | IPCC (2007); SNAP                                                 |
| Permafrost                                      | Increased area of permafrost degradation (annual mean temperature > 0°C) | 2050: ~100-200 km northward displacement<br>2100: ~150-300 km northward displacement      | Large                                       | Permafrost degradation primarily in area of warm permafrost; less pertinent in the Arctic, although some degradation likely in southern Arctic and coastal areas. | >90%<br>Very likely (sign)                                                  | SNAP and Geophysical Institute (UAF)                              |
| Sea level                                       | Increase                                                                 | 2050: 3 in. to 2 ft.<br>2100: 7 in. to 6 ft.                                              | Large                                       | Large uncertainties, esp. at upper end of range. Isostatic rebound is less likely in the north                                                                    | >90% for sign, except in areas of strong isostatic uplift                   | IPCC (2007)                                                       |
| Water availability (summer soil)                | Decrease                                                                 | 2050: decrease of 0-20+%;<br>2100: decrease of                                            | Recent changes not well                     | Most profound changes in areas where sub-freezing                                                                                                                 | >90%<br>Very likely, but likelihood                                         | SNAP; The Wilderne                                                |

| SUMMARY OF PROJECTED CLIMATE CHANGES FOR ALASKA |                         |                                             |                                            |                                                                                                                                                                |                  |            |
|-------------------------------------------------|-------------------------|---------------------------------------------|--------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------|------------|
| Climate Variable                                | General Change Expected | Specific Change Expected & Reference Period | Expected Change Relative to Recent Changes | Patterns of Change                                                                                                                                             | Confidence       | Source     |
| H2O = P-PET)                                    |                         | 10-40+%                                     | established                                | temperatures have historically limited PET, therefor highly pertinent in the Arctic. Much uncertainty regarding role of winter water storage and spring runoff | varies by region | ss Society |

### **Climate Drivers Table Citations**

- Abatzoglou, J.T., and T.J. Brown. 2011. A comparison of statistical downscaling methods suited for wildfire applications. *International Journal of Climatology* 32 (5): 772-780.
- Field, C.B., L.D. Mortsch, M. Brklacich, D.L. Forbes, P. Kovacs, J.A. Patz, S.W. Running, and M.J. Scott. 2007. North America. Climate Change 2007: Impacts, Adaptation and Vulnerability. Pages 617-652 in M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden, and C.E. Hanson, editors. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom.
- Hartmann, B., and G. Wendler. 2005. On the significance of the 1976 Pacific Climate Shift in the climatology of Alaska. *Journal of Climate* 18: 4824-4839.
- Intergovernmental Panel on Climate Change (IPCC). 2007. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Core Writing Team, R.K. Pachauri, and A. Reisinger, editors. IPCC, Geneva, Switzerland.
- Kyle, R.E., and T.P. Brabets. 2001. Water temperature of streams in the Cook Inlet Basin, Alaska, and implications of climate change. Water-Resources Investigations Report 01-4109. U.S. Geological Survey, Anchorage, Alaska.
- SNAP. 2013. The Scenarios Network for Alaska and Arctic Planning, University of Alaska Fairbanks. Data available from <http://www.snap.uaf.edu/> (accessed 24 February 2012).
- Timlin, M.S., and J.E. Walsh. 2007. Historical and projected distributions of daily temperature and pressure in the Arctic. *Arctic* 60 (4): 389-400.
- SWIPA. 2013. Snow, Water, Ice, Permafrost in the Arctic (SWIPA) assessment coordinated by Arctic Monitoring and Assessment Program (AMAP). <http://www.amap.no/swipa/> (accessed 10 May 2014).

Wang, M., and J.E. Overland. 2009. A sea ice free summer Arctic within 30 years? *Geophysical Research Letters* 36 (7) L07502, doi:10.1029/2009GL03782.

## Appendix G: Ranked Climate Effects Table

The table below outlines some of the possible effects of climate change in Northwest Alaska. These effects are drawn from model data, expert observations, and the existing literature, and were one of the primary references during upcoming workshop. Prior to the workshop, participants were invited to take some time to read through this table and fill it out, indicating the level of importance (high, medium, or low) they would assign to each of these impacts, based on their own knowledge and experience. Workshop participants were also invited to use the comments section to clarify responses and/or indicate which parks/regions would be impacted.

| Sector     | Sub-sector       | Potential Effects to Resources, Operations, and People                                                                                                                                                     | Level of impact (H/M/L) | Comments                                                                                                                                                             |
|------------|------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Atmosphere | Greenhouse gases | <b>Deliberate biological and geological sequestration</b> may be implemented on federally-owned and other lands                                                                                            | LLLLL                   | Peter Fix: As permafrost and peat start to decompose, there will be a large release of methane which is much more potent than CO2                                    |
|            | Air temperature  | <b>Air temperature increases</b> at an average rate of 1°F (0.56°C) per decade. For Bering Land Bridge, mean annual temps 10°F higher by 2080, with largest change in winter -- 8°F by 2040. 14°F by 2080. | HHHHH                   |                                                                                                                                                                      |
|            |                  | <b>Average annual temperatures shift from below freezing to above freezing</b> in coastal areas by the end of the century.                                                                                 | HHHHHH                  | Nancy Fresco: remember that all of these can be viewed as cascading effects.                                                                                         |
|            | Precipitation    | <b>Average annual precipitation increases</b> through the mid- to late-21 <sup>st</sup> Century. Relative proportions of moisture deposited as snow, ice or rain change as temperature increases.          | MMHHH                   | Don Callaway: this will have a particularly pernicious effect re: access and subsistence activities.                                                                 |
|            |                  | <b>Arctic likely to experience drying conditions</b> despite increased precipitation, due to higher temperature and increased rates of evapotranspiration.                                                 | MMHHH                   | Peter Neitlich: BELA has had huge fire episodes in past.                                                                                                             |
|            |                  | <b>More freezing rain events</b> affect foraging success and survival of wildlife, travel safety, and utility transmission.                                                                                | HHHH                    |                                                                                                                                                                      |
|            |                  | <b>Avalanche hazards increase in some areas</b> with rising precipitation and rising winter temperatures.                                                                                                  | LLLL                    |                                                                                                                                                                      |
| Atmosphere | Stormy weather   | <b>Lightning and lightning-ignited fires continue to increase.</b>                                                                                                                                         | MMH                     | Jennifer Barnes: if there is an increase, would influence fire probability, but how we determine this is very uncertain. If it were to happen, impact would be high. |

| Sector     | Sub-sector               | Potential Effects to Resources, Operations, and People                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Level of impact (H/M/L) | Comments                                                                                                                                             |
|------------|--------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------|
|            |                          | <b>Storm and wave impacts increase in Northern Alaska where land-fast sea ice forms later.</b>                                                                                                                                                                                                                                                                                                                                                                                                                           | HHH                     |                                                                                                                                                      |
|            | Air quality              | <b>More smoke from longer and more intense fire</b> seasons results in seasonal and locally-severe smoke events, with respiratory and other associated health risks to populations.                                                                                                                                                                                                                                                                                                                                      | LLM                     |                                                                                                                                                      |
|            | Atmospheric contaminants | <b>Shifting contaminant distribution.</b> Dieldrin, PP-DDE, and mercury concentrations in some NPS areas in Alaska exceed established human health thresholds for humans, fish and mammals. Consumption advisories may be warranted to reduce or curtail consumption of affected species and age/size classes, especially for children and women of child bearing age.                                                                                                                                                   | HH                      | Peter: if temps go up and peat mobilizes mercury and there is more dissolved organic carbon available, could see the mercury issue coming to a fore. |
|            |                          | <b>Increased contaminant bioavailability.</b> Fugitive dust releases from mining operations near the NOAT, and transportation of ore concentrates through CAKR have resulted in elevated lead, cadmium, and zinc levels in plants and small animals in CAKR and in plants in the NOAT. Increased bioavailability of zinc dust (a known moss killer) with changing climatic conditions could markedly alter vegetation communities over large areas, and affect other species, subsistence use patterns and human health. | MMH                     | Bud Rice: high for Cape Krusenstern, but medium for everywhere else.                                                                                 |
| Cryosphere | Snow/Ice                 | <b>Snow and ice season is shorter</b> with later onset of freeze-up and snowfalls and earlier spring snowmelt and ice breakup.                                                                                                                                                                                                                                                                                                                                                                                           | HHHHH                   |                                                                                                                                                      |
|            |                          | <b>Arctic snow cover declines</b> , with higher average air temperatures, earlier spring thaw, and cryoconite deposition (atmospheric soot and dust).                                                                                                                                                                                                                                                                                                                                                                    | MHH                     | Nancy: lots of uncertainty here.                                                                                                                     |
|            |                          | <b>Lack of snow cover leads to deeper freezing of water in the ground or river beds</b> resulting in more aufeis (overflow ice) on rivers and lakes and formations of pingos and yedomas on land.                                                                                                                                                                                                                                                                                                                        | M                       | Nancy: uncertainty here as well.                                                                                                                     |
| Cryosphere | Snow/Ice                 | <b>Undiscovered cultural resources are exposed</b> as perennial snow and ice patches melt and recede.                                                                                                                                                                                                                                                                                                                                                                                                                    | LL                      |                                                                                                                                                      |

| Sector      | Sub-sector | Potential Effects to Resources, Operations, and People                                                                                                                                                                                                                                                                                                                                                                                 | Level of impact (H/M/L) | Comments                                                                                                           |
|-------------|------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------|--------------------------------------------------------------------------------------------------------------------|
|             | Sea Ice    | <b>Shorter sea ice season, with less and thinner ice</b> complicates travel over ice, while easing boat travel through ice. Lack of sea ice in Spring-Fall impacts ecosystems (negatively for marine mammals/positively for some fish species), impacts subsistence access, increases risk and costs for marine mammal hunters. Adds energy to storm surges which increases erosion with high economic costs for community relocation. | HH                      |                                                                                                                    |
|             |            | <b>Seasonal reductions in Arctic sea ice enable more marine transportation and shipping accidents.</b> As passenger and cargo traffic increases, the potential for accidents and the risk of spills contaminating NPS coastal resources increases.                                                                                                                                                                                     | MM<br>HHHH              | Wendy Loya: A spill would be significant.<br>Peter Neitlich: O&G development/shipping major concern.               |
|             | Ice Roads  | <b>Reduced winter transportation opportunities on frozen tundra</b> affect opportunities for natural resource development, access to subsistence sites, and travel between villages, spurring discussion of alternative transportation routes and easements.                                                                                                                                                                           | MHHH                    |                                                                                                                    |
|             | Permafrost | <b>Mercury and other pollutants are released into the aquatic environment</b> as the permafrost thaws, increasing contaminant exposure for wildlife and humans that rely on the marine ecosystem for food.                                                                                                                                                                                                                             | MH                      |                                                                                                                    |
|             | Sea level  | <b>Some coastal villages rapidly lose ground relative to sea level</b> , such as Shishmaref and Kivalina in Northwest Alaska. Erosion and subsidence are complicating factors.                                                                                                                                                                                                                                                         | HHHH                    | Peter: relocations will have effect on parks.                                                                      |
|             |            | <b>Global average sea level is predicted to rise an additional 1-6 feet</b> by the end of the 21 <sup>st</sup> Century. However, regional trends in relative sea level vary widely with the effects of isostatic rebound, subsidence, warming, sediment deposition, etc.                                                                                                                                                               | MHHH                    | Bud: Thinks sea ice retreat and storm surges will have more impact than sea level rise.                            |
| Hydrosphere | Marine     | <b>Increasing sea surface temperature affects ice-dependent species and their foods</b> , distribution and population dynamics of fish, seabird, and wildlife species.                                                                                                                                                                                                                                                                 | MHH                     | Peter: although we don't have jurisdiction over these animals, this could increase hunting pressure terrestrially. |
| Hydrosphere | Marine     | <b>Falling global phytoplankton concentration could reduce ocean productivity and CO<sub>2</sub> sequestration.</b> Phytoplankton has declined at an average rate of ~1% of the global average per year over the last century. These fluctuations are strongly correlated with climate indices and sea surface temperature.                                                                                                            | HHHH                    |                                                                                                                    |
|             |            | <b>Toxic marine algae and shellfish poisoning</b> affects humans and marine mammals (e.g., PSP, ASP). Outbreaks are attributed to seasonal changes in coastal water temperature, nutrient enrichment, salinity, and ballast water discharge.                                                                                                                                                                                           | LLLM                    | Ken Adkisson: L/M in the near term; possibly greater over a longer time period.                                    |

| Sector      | Sub-sector       | Potential Effects to Resources, Operations, and People                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Level of impact (H/M/L) | Comments                                                                                                                                                                                                                                               |
|-------------|------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|             |                  | <b>Ocean acidification affects plankton and benthic calcifying fauna</b> (e.g., bivalves and echinoderms) in the Arctic more strongly than at lower latitudes, affecting food sources of fish, marine mammals such as walrus and gray whales, plankton feeding birds, and potentially the composition of the ecosystem.                                                                                                                                                                                                                                    | HHH                     | Bud: has learned that there is already measurable acidification in Arctic waters (not yet published)                                                                                                                                                   |
|             |                  | <b>Ocean acidification reduces sound absorption.</b> Based on current projections of future pH values for the oceans, a decrease in sound absorption of 40% is expected by mid-century.                                                                                                                                                                                                                                                                                                                                                                    | LMMM                    | Linda Jeschke: not yet an issue, but as shipping increases, it may be moderate.                                                                                                                                                                        |
|             | Estuarine        | <b>Coastal erosion and sea level rise increase the frequency of saltwater flooding in some coastal areas</b> , infiltrating freshwater coastal lagoons, marshes, and groundwater with salt.                                                                                                                                                                                                                                                                                                                                                                | HHH                     | Ken: Shifts in coastal biotic resources and perhaps human populations.                                                                                                                                                                                 |
|             | Freshwater       | <b>Ponds shrink as thermokarst drainage occurs in some permafrost areas.</b> Others form as ground ice thaws and ground surface subsides, but many drain through surface or subsurface discharge as thaw depth increases.                                                                                                                                                                                                                                                                                                                                  | MMH                     | Linda: Locals have already commented on change in bird populations and decreased diversity re: changing ponds.<br>Peter/Ken: this is a vital sign that ARCN monitors. Lots of forming and drying of lakes. The effect is real, but what is the impact? |
|             |                  | <b>Drainage from thawing waste and sewage dumps contaminates rural water supplies.</b> Two-thirds of Alaska's village residents still do not have access to sanitary means of sewage disposal or adequate supplies of safe water.                                                                                                                                                                                                                                                                                                                          | MMHH                    | Linda: already a problem in many villages; has seen many instances.                                                                                                                                                                                    |
|             |                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                         |                                                                                                                                                                                                                                                        |
| Lithosphere | Ground stability | <b>More constructed assets fail or require repairs.</b> Many locations in Alaska that are underlain by permafrost are susceptible to thaw damage. Modeling by University of Alaska researchers suggests that projected climate changes could raise future infrastructure costs about 10%.                                                                                                                                                                                                                                                                  | LLMHH                   | Wendy: because we can actually somewhat control this, she tends to rank it lower than she would a natural phenomenon.<br>Don C: still an issue for communities/ lower income areas.<br>Peter: such fixes could drain park budgets.                     |
|             |                  | <b>Coastal erosion claims both natural and cultural resources and constructed assets.</b> Coastal erosion is proceeding at an average of 20" (0.5 m)/year in some areas of CAKR and in BELA. Coasts in some communities are eroding much more rapidly than this (tens of meters per year). Some constructed assets, historic and prehistoric sites will no longer be sustainable and will require triage to determine which to repair, relocate, document, or abandon. Large areas of Alaska's coastal parks lack needed surveys for archaeological sites. | HH                      | Don C.: this has been an issue for a long time, but even now, we don't have the resources to mitigate it, let alone do the surveys.<br>Ken: Cultural resources potential loss could be mitigated through expanded archeological data recovery          |

| Sector    | Sub-sector      | Potential Effects to Resources, Operations, and People                                                                                                                                                                                                                                                                                                                           | Level of impact (H/M/L) | Comments                                                                                                                                                                                                              |
|-----------|-----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|           |                 | <b>Burials and other human remains are exposed in some areas</b> as cultural sites thaw and erode due to changing hydrology, ice, snow, and permafrost thaw.                                                                                                                                                                                                                     | H                       |                                                                                                                                                                                                                       |
|           | Soil            | <b>Soil moisture declines</b> due to rising soil temperature, increased evapotranspiration, thawing permafrost, and natural drainage.                                                                                                                                                                                                                                            | MH                      |                                                                                                                                                                                                                       |
|           | Rock and gravel | <b>Demand for rubble and rock increases</b> , as it is required for repairs and new construction, roads, and community relocation.                                                                                                                                                                                                                                               | MHH                     | Ken: Can be addressed by planning and human action. Linda Jeschke- people are already scrambling in Kotzebue for gravel.                                                                                              |
| Biosphere | General         | <b>Ecological “tipping points” are likely to result in rapid change</b> , when conditions exceed physical or physiological thresholds (e.g., thaw, drought, water temperature).                                                                                                                                                                                                  | LHH                     | Wendy: not sure that we will hit thresholds in the next several decades.                                                                                                                                              |
|           | Vegetation      | <b>Increased growing season length.</b> Modeling predicts that the mean number of frost free days for the Boreal and Arctic bioregion will increase between 20 and 40 days by the end of the century.                                                                                                                                                                            | LLH                     |                                                                                                                                                                                                                       |
| Biosphere | Vegetation      | <b>Increased agricultural production in Alaska.</b> A longer growing season and Alaska's abundant summer sunlight provide new agricultural opportunities in some areas.                                                                                                                                                                                                          | LLLM                    | Peter: right now USDA considers Nome to have 5 frost free days. It would take a lot to become an agriculturally significant area.<br>Linda: would be good if people did more local gardening. Only a few greenhouses. |
|           |                 | <b>Large-scale landcover changes occur over periods of years to decades.</b> Some terrestrial vegetation models suggest potential for large-scale conversion of low tundra to shrubs, then to conifers, and from conifers to deciduous forests, or perhaps to grass. Other models indicate increasing lichen, decreased sedges, and increases to deciduous and evergreen shrubs. | HHH                     | Peter: ranked as high mainly because of shrub increase. Doesn't see that reflected much in this document. This is what we mean by “landcover change.” Loss of tundra habitats would create challenges for ungulates.  |

| Sector    | Sub-sector | Potential Effects to Resources, Operations, and People                                                                                                                                                                                                                                                                                                          | Level of impact (H/M/L) | Comments                                                                                                                                                     |
|-----------|------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------|
|           |            | <b>Tree species and vegetation classes shift</b> as species typical of lower altitudes and latitudes expand into higher areas.                                                                                                                                                                                                                                  | LHHH                    | Linda: large impacts on all wildlife.                                                                                                                        |
|           |            | <b>Mountain and arctic ecosystems could change substantially</b> within 50 years, and conditions become unsuited for some native species. <b>Some rare species could become endangered and endangered plants species may go extinct as conditions change.</b>                                                                                                   | MHH                     |                                                                                                                                                              |
|           |            | <b>Atypical outbreaks of pests and plant diseases occur more widely</b> , increasing fire hazards and hastening decline of native and familiar species.                                                                                                                                                                                                         | LLMH                    | Peter: lots of uncertainty. Linda Jeschke: now prevalent south of us, may also happen here.                                                                  |
|           |            | <b>Invasive exotic species and native species from other areas expand into parks.</b> It becomes easier for invasive species that are already adapted to such conditions, to survive, reproduce and expand into available habitat as native species become increasingly stressed by changing conditions such as rising temperature and declining soil moisture. | LH                      | Peter: low, but again, lots of uncertainty. Ken-high. Could be a major concern over longer time periods, might be addressed on a regional or landscape scale |
|           |            | <b>Shrubs and trees expand further into tundra</b> primarily along hillsides and valleys. Some scenic tundra vistas become thick with deciduous trees and shrubs, obscuring wildlife observations from visitor centers and park roads.                                                                                                                          | LH                      |                                                                                                                                                              |
| Biosphere | Vegetation | <b>Black spruce may expand or contract</b> , expanding under warming conditions coupled with increasing fire interval – or contracting as underlying permafrost soils thaw and fire frequency increases.                                                                                                                                                        | LMM                     | Peter: too much uncertainty to say for sure.                                                                                                                 |
|           | Fire       | <b>Fire increases in boreal and tundra ecosystems.</b> Model simulations show a warming climate leads to slightly more fires and much larger fires, as well as expansion of forest into previously treeless tundra. Flammability increases rapidly in direct response to climate warming and more gradually in response to climate-induced vegetation changes.  | MHH                     |                                                                                                                                                              |
|           |            | <b>Wildland fire hazards increase</b> , affecting communities and isolated property owners.                                                                                                                                                                                                                                                                     | LLMM                    |                                                                                                                                                              |
|           |            | <b>Fire-related landcover and soil changes</b> include vegetation population shifts, major permafrost thawing, soil decomposition, and surface subsidence.                                                                                                                                                                                                      | HH                      | Peter: Fire resets the successional trajectories toward graminoid-dominated systems.                                                                         |

| Sector    | Sub-sector         | Potential Effects to Resources, Operations, and People                                                                                                                                                                                                                                                                                                                 | Level of impact (H/M/L) | Comments                                                               |
|-----------|--------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------|------------------------------------------------------------------------|
|           | Wildlife – General | <b>Changes to the terrestrial and aquatic species compositions in parks and refuges occur as ranges shift</b> , contract, or expand. Rare species and/or communities may become further at risk, and additional species could become rare. Some early-succession species will benefit from changes.                                                                    | MHH                     |                                                                        |
|           |                    | <b>Parks and refuges may not be able to meet their mandate of protecting current species within their boundaries</b> , or in the case of some refuges, the species for whose habitat protection they were designed. While some wildlife may be able to move northward or to higher elevations to escape some effects of climate change, federal boundaries are static. | MHH                     |                                                                        |
|           |                    | <b>Changes in terrestrial and marine wildlife distributions affect visitor experiences and subsistence</b> throughout the region.                                                                                                                                                                                                                                      | LHH                     |                                                                        |
|           |                    | <b>Some species suffer severe losses.</b> An analysis of potential climate change impacts on mammalian species in U.S. national parks indicates that on average about 8% of current mammalian species diversity may be lost. The greatest losses across all parks occurred in rodent species (44%), bats (22%), and carnivores (19%).                                  | HHH                     |                                                                        |
| Biosphere | Wildlife – General | <b>Predator-prey relationships may change</b> in unexpected ways.                                                                                                                                                                                                                                                                                                      | MH                      |                                                                        |
|           |                    | <b>Migratory routes and destinations will change</b> for some species (e.g., wetlands, open tundra, snow patches).                                                                                                                                                                                                                                                     | HHH                     | Peter: especially yellow-billed loons                                  |
|           | Wildlife – Birds   | <b>Arctic and alpine breeding birds' breeding habitats will be reduced</b> or eliminated as trees and shrubs encroach on areas currently occupied by tundra. 72% of Arctic and alpine birds are considered moderately or highly vulnerable to the impacts of climate change.                                                                                           | HHH                     | Peter: yellow-billed loons and montane nesting shorebirds main issues. |
|           |                    | <b>Boreal forest birds expand into the arctic</b> as climate changes, causing new avian communities to develop.                                                                                                                                                                                                                                                        | MMH                     |                                                                        |
|           |                    | <b>Millions of geese could lose almost half of their breeding habitat</b> due to a predicted change in vegetation in the Arctic from tundra to taiga and boreal forest.                                                                                                                                                                                                | H                       |                                                                        |
|           |                    | <b>Waterfowl shifts</b> occur as coastal ponds become more salty in some areas.                                                                                                                                                                                                                                                                                        | HHH                     |                                                                        |

| Sector    | Sub-sector                  | Potential Effects to Resources, Operations, and People                                                                                                                                                                                                          | Level of impact (H/M/L) | Comments                                                                               |
|-----------|-----------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------|----------------------------------------------------------------------------------------|
|           |                             | <b>Productivity of nesting shorebirds may increase</b> if they are able to change their migration and nesting schedules to coincide with the time when the most insects are available.                                                                          | M                       | Peter: Melanie Flame should contribute to this; Peter will send her the questionnaire. |
|           |                             | <b>Predation on ground nesting birds</b> could increase if alternate prey (lemming) abundance declines with changes to weather and tundra habitats.                                                                                                             | M                       |                                                                                        |
|           |                             | <b>Coastal seabirds show medium or high vulnerability</b> to climate change due to their low reproductive potential and their reliance on marine food webs that are also threatened by climate change.                                                          | H                       |                                                                                        |
|           | Wildlife – Marine Mammals   | <b>Ice dependent Arctic marine mammals are affected by sea ice decline</b> , including walrus, ice seals, and polar bear. Beluga and bowhead whales may move into territory previously unavailable to them.                                                     | HHH                     |                                                                                        |
|           |                             | <b>Increased ambient sound affects marine mammals.</b> Reduction in sound absorption and increased human vessel traffic due to receding sea ice and tidewater glaciers may affect marine mammals that rely on echolocation for communication and prey location. | MM                      |                                                                                        |
| Biosphere | Wildlife – Marine Mammals   | <b>Polar bear hazards increase in coastal communities.</b> As polar bears have increasingly difficult times accessing prey and finding appropriate shelter for reproduction and protection, they may be more likely to approach villages and encounter humans.  | LMMH                    |                                                                                        |
|           | Wildlife – Caribou/Reindeer | <b>Caribou and reindeer health may be affected</b> by changes in temperature and precipitation patterns, increases in insects and pests known to harass caribou and reductions of succulent forage.                                                             | MH                      |                                                                                        |
|           |                             | <b>Earlier green-up could improve caribou calf survival</b> due to more forage available to females during calving and lactation.                                                                                                                               | MH                      | Ken: Might be offset by stochastic events such as ice storms.                          |
|           |                             | <b>Loss in tundra plant species diversity could affect caribou and other wildlife.</b> For example, forbs that are selectively grazed upon by caribou during lactation or lichens used as over-wintering food.                                                  | HHH                     |                                                                                        |
|           |                             | <b>Caribou may suffer heavy losses</b> , if vegetation glazes over following rain-on-snow events, preventing successful feeding during cold weather.                                                                                                            | HHH                     | Peter: would include muskox in this area as well.                                      |

| Sector    | Sub-sector               | Potential Effects to Resources, Operations, and People                                                                                                                                                                                    | Level of impact (H/M/L) | Comments                                                          |
|-----------|--------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------|-------------------------------------------------------------------|
|           | Wildlife – Moose         | <b>Predicted shifts in forest community could result in less suitable habitat for caribou, but potentially increased habitat for moose</b> in Yukon Flats National Wildlife Refuge and similar habitats.                                  | MM                      |                                                                   |
|           |                          | <b>Climate change could decouple</b> timing and synchrony of birth, hindering moose calf survival.                                                                                                                                        | M                       |                                                                   |
|           | Wildlife – Small mammals | <b>Fire may help yellow-cheeked vole populations</b> in the short-term, as it creates new burrowing habitat and aids in the growth of forage.                                                                                             | L                       |                                                                   |
|           |                          | <b>Reduced snow cover reduces survival of voles</b> and other subnivian species, due to increased predation and cold stresses, with changes in small and large mammal predator-prey relationships.                                        | M                       |                                                                   |
|           | Fisheries                | <b>Marine regimes could shift from benthic (bottom) to pelagic (open water) species.</b> Late ice retreat supports benthic organisms. When there is no ice, or early ice retreat, a mostly pelagic ecosystem is supported.                | H                       |                                                                   |
|           |                          | <b>Commercial fisheries shift.</b> Changes in ocean community organization in the Bering Sea caused by warming climate and associated loss of sea ice alter availability of snow crab and other fisheries resources.                      | MH                      | Linda: Coastal communities depend hugely on salmon and whitefish. |
| Biosphere | Fisheries                | <b>Ocean acidification affects fisheries.</b> Pteropods and crustaceans foods of salmon may decline with ocean acidification.                                                                                                             | HH                      | Peter: this could put more pressure on terrestrial food sources.  |
|           |                          | <b>Fish diseases such as <i>Ichthyophonus</i> increase with rising water temperatures.</b> Models indicate that temperature increase in streams in south-central Alaska will be around 3°C, a change that could increase disease in fish. | MH                      |                                                                   |
|           |                          | <b>Some existing salmon waters may become unsuitable</b> for migration, spawning and incubation.                                                                                                                                          | H                       |                                                                   |
|           |                          | <b>Fish habitats in some permafrost-dominated areas may be degraded</b> by thaw-related hill slumps and massive sediment input into rivers.                                                                                               | M                       |                                                                   |
|           | Invertebrates            | <b>Marine intertidal environments change</b> and may become more susceptible to exotic marine species.                                                                                                                                    | M                       |                                                                   |

| Sector                      | Sub-sector                    | Potential Effects to Resources, Operations, and People                                                                                                                                                                                                                                                                                                            | Level of impact (H/M/L) | Comments                                                                                                 |
|-----------------------------|-------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------|----------------------------------------------------------------------------------------------------------|
|                             |                               | <b>Exotic pests, diseases and their vectors expand into Alaska from warmer areas</b> , and endemic pests expand as host species are stressed by climate change (e.g., bark beetles, budworms, ticks, lice, West Nile virus, Lyme disease, HP avian influenza, hantavirus, plague, vespid [yellow jacket] outbreaks, black flies, mosquito swarms, botflies, etc.) | H                       |                                                                                                          |
|                             |                               | <b>Intensified management expands.</b> Some local residents and management agencies may advocate managing for new species that have the potential to replace diminished subsistence hunting, trapping, and fishing opportunities, and for intensified management of native species.                                                                               | MHHH                    |                                                                                                          |
|                             | Subsistence Fishing & Hunting | <b>Altered migration patterns make hunting more challenging.</b> Migration patterns of terrestrial animals are predicted to change as temperatures, precipitation patterns, and vegetation availability change.                                                                                                                                                   | HHH                     | Ken: depends on the resource.                                                                            |
|                             |                               | <b>Marine subsistence becomes more challenging.</b> As sea ice conditions change, hunting for marine mammals is becoming more dangerous and costly. Marine mammals may follow sea ice retreat, altering their distribution and taking them out of range for some hunters.                                                                                         | HHHH                    |                                                                                                          |
| Biosphere                   | Subsistence Fishing & Hunting | <b>Community resources available for subsistence activities decline</b> as increased storm surges, and permafrost erosion compound effects of change to relative sea level, impacting infrastructure in Native Alaskan communities, in some cases requiring relocation of entire communities.                                                                     | HHHH                    | Ken; This is a big concern for coastal parks and potentially those just inland such as KOVA and NOAT     |
| Other Human Uses and Values | Wilderness                    | <b>Large-scale physical and biological changes across broad landscapes</b> affect abundance and condition of wilderness-associated resources (glaciers, tundra, boreal forest, wildlife, scenic vistas, river flows, access routes, etc.)                                                                                                                         | LH                      | Ken: you could have a total transformation from tundra to desert and still have pristine wilderness      |
|                             |                               | <b>The scientific community becomes increasingly interested in wilderness sites</b> for a variety of inventories, monitoring and research projects, some of which involve highly technical instruments, mechanized access, and long-term installations.                                                                                                           | HHH                     | Peter: already a hugely contentious area and source of conflict.                                         |
|                             |                               | The changing biophysical landscape and increased human activity to research, monitor, and respond to threats associated with climate change affect key wilderness values such as naturalness, wild/untamed areas without permanent facilities, opportunities for solitude, etc.                                                                                   | M                       |                                                                                                          |
|                             |                               | <b>Tourism expands at higher latitudes.</b> The effects of these changes will depend greatly on the flexibility demonstrated by institutions and tourists as they react to climate change.                                                                                                                                                                        | LH                      | Ken: This could have positive as well as negative effects and may depend heavily on economic conditions. |

| Sector                      | Sub-sector            | Potential Effects to Resources, Operations, and People                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Level of impact (H/M/L) | Comments                                                                                         |
|-----------------------------|-----------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------|--------------------------------------------------------------------------------------------------|
| Other Human Uses and Values | Tourism               | <b>Tourism season lengthens</b> with increasing temperatures and more snow-free days. Some visitor activities increase, while others (e.g., snow sports) may decline.                                                                                                                                                                                                                                                                                                                                                | LL                      |                                                                                                  |
|                             |                       | <b>Landscape-level changes affect visitor experiences</b> as iconic scenery changes, and access for subsistence, hiking, boating, etc. changes with vegetation, soil, and water conditions. Some changes are conducive to visitation, and some are not, depending on local conditions and visitor expectations.                                                                                                                                                                                                      | LM                      |                                                                                                  |
|                             | Tourism               | <b>Visitor use patterns shift</b> as tour operators seek to provide visitors with more opportunities to experience increasingly uncommon glacier scenery. Cruise ships and day tour operators may shift some itineraries away from the parks they've traditionally visited, or seek more opportunities to shift itineraries deeper into the parks. Land based operators may press to bring groups further into the park through aircraft, airboats, snowmobile tours, off road vehicles (ORVs), and road extensions. | LLH                     | Linda: not much tourism here because there are few facilities.                                   |
|                             |                       | <b>Visitor demand for new interpretive/education media products, publications and services</b> that address changing climate will increase, putting pressure on existing programs and staffing.                                                                                                                                                                                                                                                                                                                      | LMHHH                   | John Morris: anticipates an increase in virtual interpretive services or requests. Others agree. |
|                             |                       | <b>More cruise ships pass through the Bering Strait</b> as ice-free conditions become more reliable.                                                                                                                                                                                                                                                                                                                                                                                                                 | LH                      |                                                                                                  |
|                             |                       | <b>Coastal tourism destinations are affected by increase coastal erosion</b> , and losses of natural and cultural resources, natural routes of access, and built infrastructure.                                                                                                                                                                                                                                                                                                                                     | LH                      |                                                                                                  |
|                             |                       | <b>Safety hazards develop, expand or are recognized in relation to climate change</b> , such as thin ice, erratic flooding, changing fire and smoke hazards, slope failures (mudslides, landslides, tsunami hazards), and expansion of more disease organisms (fish, wildlife, and human) and their vectors into Alaska.                                                                                                                                                                                             | MH                      | Peter: both snow machining and boating have become more dangerous.                               |
|                             | Other Hazards         | <b>The predictive uses of traditional ecological knowledge will change</b> , as unprecedented changes develop for weather, freeze/thaw conditions, plants, animals, fire, etc.                                                                                                                                                                                                                                                                                                                                       | HHHH                    |                                                                                                  |
|                             | Traditional Knowledge | <b>Natural resource development and economic activities expand in Alaska</b> with increasing global demand for energy and resources to supply rising global population.                                                                                                                                                                                                                                                                                                                                              | HHHHH                   |                                                                                                  |

| Sector                      | Sub-sector           | Potential Effects to Resources, Operations, and People                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Level of impact (H/M/L) | Comments                                                                             |
|-----------------------------|----------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------|--------------------------------------------------------------------------------------|
|                             | Economic Development | <b>Infrastructure development expands</b> along Alaska's coasts and Interior to provide needed services, facilities, and transportation systems for other expanded activities.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | MH                      |                                                                                      |
| Other Human Uses and Values | Economic Development | <b>Developmental pressures increase as direct or indirect effects of reduced snow and ice cover.</b> These include expanded global and regional transportation systems and their associated infrastructure (e.g. opening of the Northwest Passage due to reduced sea ice, permanent roads to replace ice roads), increased demand for natural resource development (construction materials – especially gravel and rock, energy and minerals for infrastructure repair, replacement, and expansion), shifting agricultural production zones, community resettlement and other population shifts.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | MH                      |                                                                                      |
|                             |                      | <b>Damage to roads, buildings, and other infrastructure increases</b> due largely to permafrost thaw (but also from storms, floods, and landslides) adding 10% to 20% by 2080.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | HH                      | Ken: could especially be a problem under flat or declining budgets.                  |
|                             |                      | <b>Relocating indigenous communities represents a large social burden</b> , not just financial cost for governments, but also impacts the communities themselves, potentially resulting in loss of integral cultural elements such as access to traditional use areas for subsistence activities, loss of history and sense of intact community, and potential loss of social networks and extended kin support. Significant increases in social pathologies such as alcoholism and domestic violence may be anticipated. In addition, tremendous stresses will be placed on traditional means of conflict resolution. In addition multiple strains will be placed on local governance and delivery of services. Finally, state and federal governments will have huge additional burdens placed on them as they try to provide relief from the impacts of climate change (flooding, destruction of infrastructure, high demands placed on social services and so forth). Response to climate change will require enormous pressures for integrated and efficient bureaucratic structures. | HHH                     | Ken: What is the NPS role in this?                                                   |
|                             |                      | <b>Fuel and energy prices increase substantially</b> as carbon mitigation measures are implemented (sequestration, carbon caps, offsets, etc.). Transporting fuels to remote locations by barge, ice roads, aircraft, etc. also becomes more challenging and costly.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | HHHH                    | Bud: anticipates that there will be increased demand for alternative energy sources. |

## Appendix H: Narratives

As noted in the body of this report, creatively framed narratives were an important outcome of the intensive group brainstorming efforts that went into this CCSP workshop. The following imaginative narratives were created to synthesize these climate change scenarios and to bring them to life in a manner intended to engage diverse audiences.

### ***Narrative 1: “The Sign”***

The following narrative was developed by the BELA group based on the “Hotwash” scenario (a warmer and much stormier future) nested in the “Is Anyone Out There?” quadrant (low societal concern and less integrated institutions) of the socio-political matrix (Figure 5).

*A short skit set several decades in the future*

A family is on a beach that used to be part of Bering Land Bridge National Preserve. The family is hunting for sea lions. The hunters have gone up to the haul-out. As they wait for the hunters to return, a young woman picks up an old faded sign with only a couple of letters left on it. “I wonder what this was?” she says to her grandmother. “Anyhow, it would make a good table. There’s plenty of other driftwood for the fire.”

The grandmother says, “Oh, that’s the old park service sign.”

The young woman sets up the old sign as a table.

The old woman says, “I’m so glad my nephew came to hunt with us. It’s been almost a year now since we lost his brother. That was so hard for him, and for all of us. His father was such a good provider, until he moved to Nome. The family kind of fell apart then, when the village was evacuated. That was really a shame. The storms got so bad, and we just couldn’t get any help, not even rocks. There was no clean water anymore either. Folks were getting sick. Things got really bad. Even before the big storm, the village was cut off when the flooding washed out all the roads.”

As they make the fire, the young woman says, “I sure hope the hunters get lucky. It’s too bad our cousin in Nome didn’t have the opportunity to harvest sea lions. He sure would have had fun, and he’d like the meat. I miss the taste of walrus, though, from when I was little.”

The grandmother says, “Your cousin sure had a hard time in high school. I regret that he didn’t have the chance to learn the traditional skills his father had.”

Her granddaughter nods. “And he could have done a lot of moose hunting, now that there’s enough for everyone – but not this time of year, though, when they’re getting so buggy from this heat.”

The hunters return, triumphant, and are greeted and congratulated.

Later, as they sit and eat sea lion around the old park sign, they discuss past hunts.

An older man says, “It’s kind of scary these days, trying to get across rivers when the ice is so thin, even in the middle of winter.”

“It’s hard to get around,” agrees another. “And I miss being able to go out on the ice to fish.”

“That doesn’t worry me as much as those cruise ships. Seems like they don’t pay attention to small boats, and they make so much noise, and pollute the water. Sure doesn’t help the hunters.”

“I think the oil rigs are the worst. They say they’re not spilling anything, but I’ve seen slicks on the water.”

“Well, the government sure isn’t going to do anything about it.”

“We’ll just have to do the best we can with what’s left.”

They all fall silent and enjoy their meat.

As the meal ends, they toss the old sign onto the fire. The last letters of “Bering Land Bridge National Preserve” turn black and disappear.

### ***Narrative 2: “Climate Kumbaya: Successfully Coping with Climate Change”***

The following narrative was developed by the BELA group based on the “Overrun” scenario (a warmer future, with little change in storm frequency and intensity) nested in the “Big Problems,

Big Solutions” quadrant (high societal concern and more integrated institutions) in the socio-political matrix (Figure 5).

*Abstract for the keynote speech at the Beringia Climate Change Conference (given by BELA superintendent several decades into the future)*

Changes in BELA and surrounding environs continue to be pronounced and dramatic. Because of our long term inventory and monitoring program, we have been able to document extensive changes to habitats, which have affected fish and wildlife in the area. Some examples of these changes include loss of wetlands and increased drying, increased frequency and severity of fire, increased salinization of coastal areas, increased shrub cover of tundra habitats, and dramatic changes to species composition of plants and animals. We are partnering with the U.S. Fish and Wildlife Service (USFWS), the National Marine Fisheries Service (NMFS), and other agencies to document changes in distributions and movements of key wildlife species—e.g., walrus and ice seals are no longer very abundant in our area, and whales are changing migration patterns. Because of loss of marine mammal resources, subsistence hunters are shifting to terrestrial wildlife resources, especially caribou, moose and musk ox. Fortunately, the Federal Subsistence Board has proven to be nimble in responding to the needs of subsistence users, in large part because of the multi-agency working groups that focus on the Northwest Alaska caribou herd and musk ox. These sorts of wildlife working groups have allowed us to find streamlined solutions to our problems, but these issues are complex and ever-changing.

We had success in moving the village of Shishmaref by working with local agencies to provide a good location to suit the village's needs. This relocation had the potential to cause huge amounts of contention because of using parklands, but due to cooperation between agencies, local peoples, and funding agencies, it was a success. Shishmaref is a poster child for climate impact on coastal communities, and a spotlight shines on this area as an example of successful global climate change mitigation. We continue to experience extreme storm events and extensive coastal erosion, and this will continue. Our continued cooperation with Shishmaref emergency services has allowed us to provide safe travel and shelter for locals.

Economically, local communities continue to benefit from the new offshore ground fisheries for cod and pollock, but the bycatch issue that plagued the Bering Sea decades ago is something we are still struggling with. Economic spin-offs from oil and gas development and mining in the general area have also increased economic opportunity, but at some costs to subsistence users and local values. The new Coast Guard station in Nome has provided an economic boon with increased safety in the Bering Straits region.

We've seen an increase in park visitation which has provided economic benefits but also created some additional challenges for park management. Pressure has arisen to finally put a road in to Nome, which has increased pressure on BELA to provide increased visitor services. We continue to try to find transport alternatives to Serpentine Hot Springs to allow for adequate visitation while keeping the springs' rustic feel. We are also working with the cruise industry to increase options for visitor experiences. Our cabins are being heated by geothermal or solar energy sources.

We have developed fire management options that rotate but still allow fires to occur on the landscape. These fire management options work to protect critical caribou winter habitat. However, stresses on caribou still continue due to climate-change-induced icing rain events and habitat changes.

Due to the cultural resource challenge of the last few decades and an influx of funding, we have been better able to document, preserve, and protect archaeological and paleontological resources. We now have extensive and accurate cultural and ethnographic inventories for the area, which have contributed to a better understanding of Bering Land Bridge.

Despite some successes in dealing with climate change issues, climate change solutions are moving targets which continue to create new challenges and opportunities for BELA. These challenges include: wildlife management as wildlife population and subsistence patterns continue to change; partnership development and maintenance of critical levels of funding; a continued international presence across the Bering Strait with our Russian partners; and changing priorities and initiatives that compete for funding with climate change.

### ***Narrative 3: "Chronic Directional Change"***

This narrative was developed by the CAKR group based on the "Tarpits" scenario (low temperatures (+0°C) and low storminess) nested in the "Wheel-spinning" quadrant (low societal concern and more integrated institutions) in the socio-political matrix (Figure 5).

#### ***Briefing Statement***

*Revised: December 3, 2030*

To: Superintendent, Western Arctic National Parklands

From: Staff Wildlife Biologist

Through: Chief of Natural and Subsistence Resources

Subject: Northern Seward Peninsula Caribou Herd Working Group (NSPCHWG) proposals

The NSPCHWG will meet next week to consider new proposals related to caribou herd protection and management. Several proposals have already been advanced to agency staff as informal suggestions, though not yet been formally submitted to the group for action. This briefing paper is to provide background on the issues, identify topics that we expect to be presented at the meeting, and to explain the basis for current agency positions on this issue.

#### **Background:**

The NSPCH is one of several herds that collectively make up the remnants of the Western Arctic Caribou Herd (WACH), which splintered into several smaller populations over the last 20 years. The NSPCH currently numbers 35,000 animals, or about half of the total remnant WACH population. The WACH once numbered about 500,000 animals. Most experts attribute the herd's breakup to habitat fragmentation, in part due to a long series of large-scale tundra fires that devastated much of the suitable winter caribou habitat, possibly confounded by traffic along a maze of new roads associated with mineral resource development. The herd has also experienced a combination of other pressures, such as a gradual long-term change in land cover vegetation, periodic severe losses as a result of rain-on-snow and icing events, and steadily increasing subsistence pressures as marine harvests declined with diminished sea ice. Most of the mineral resource development concerns working in the region have implemented voluntary bans on employee hunting in the vicinity of the mines and along haul roads. While widely supported, these actions have not been sufficient to reverse the long term declining trend in caribou numbers.

#### **Pending Proposals:**

Several NSPCHWG members have recently fielded calls to discuss the proposals for consideration during the upcoming meeting, including a number of increasingly-intensive resource management approaches. The proposed actions are intended to improve caribou survival and condition and increase rural harvest success. The following ideas have been mentioned as possible proposals:

1. Predator removal
2. Phase out of state hunting permits for caribou and other subsistence species
3. Expanded enforcement of local subsistence preferences for hunting permits
4. Snow plowing to expose winter forage for caribou
5. Mechanical reversal of shrub and forest encroachment by chaining (dragging a length of heavy chain or cable between bulldozers moving in parallel)
6. Distribution of lichen propagules into recently burned or cleared areas
7. Seeding of burned areas with high nutrient annual forage plants (e.g. grains)
8. Fertilization to enhance herbaceous growth rates
9. Expanded use of calving pens to protect vulnerable caribou cows and calves from predators
10. Winter feeding of caribou herds along access roads. (Note: Winter feeding of caribou herds is apparently more feasible now due recent expansion of the road network. Program costs might be recouped by collection and sale of shed antlers by local youth groups – perhaps junior rangers.)
11. Expanded reindeer ranching and range fencing

#### **Biologist's Perspective:**

Biologists from multiple agencies have been monitoring caribou herd status and trends for more than three decades. Numerous studies document long-term habitat stress due to directional environmental change. Caribou are one of many species stressed by more than 50 years of cumulative climate change and developmental pressures. Review of long-term monitoring data by agency botanists, indicates shrub encroachment into former lichen range since at least the mid-1950s. Annual grasses and several exotic weed species have also expanded into burned tundra. Research indicates that shrubs, weeds, and annual grasses do not afford sufficient winter forage. Many of the areas that are still dominated by the lichen species necessary for optimal caribou nutrition are severely degraded and already over-grazed. The causative factors of widespread lichen decline are actively investigated, and there appear to be a number of contributing factors. Use of high-sulfur fuels (coal for energy production and diesel for transportation) remains problematic despite regulatory controls. Regional expansion of open pit mining has also complicated efforts at controlling fugitive dusts, including heavy metals. However, regional support for the economic benefits of mineral development and locally-produced fuels is strong and increasing.

There is strong scientific consensus that Alaska's temporary reprieve from the globally-severe temperature rise of the last 30 years is coming to an end. Indications are that the Pacific Decadal Oscillation has begun to shift from the extended cold phase that we've "enjoyed" for the last 20-30 years into a warm phase of uncertain magnitude and duration. If the coming decades are characterized by rapid temperature increases equal to or exceeding other polar areas, then Northwest Alaska can expect extensive and potentially rapid habitat conversion to species more tolerant of warm dry conditions and short fire return intervals.

#### Recommendation:

Agency biologists strongly recommend allowing for continuity of ecological processes, biodiversity and evolution, while expanding interagency efforts to restore connectivity of migratory routes between fragmented habitats. Several range biologists have expressed concerns that short-term expansion of herd size by artificial means could eventually result in weaker stocks as the available winter range is further degraded. Natural predation to remove weaker individuals is an important selective pressure. Local resistance to this approach can be expected, as it will likely be perceived as another attempt by the agencies to stall needed actions by prioritizing intangible wilderness values over the immediate needs of community.

#### ***Narrative 4: "Katrina Comes to the Chukchi Sea"***

The following narrative was developed by the CAKR group based on the "911" scenario (increased temperatures (+6°C) and high storminess) nested in the "Riots and Revolution" (high societal concern and less integrated institutions) quadrant in the socio-political matrix (Figure 5).

#### *Testimony to Congress | April 2030*

Con Cerne, Superintendent of Western Arctic National Parklands  
Esteemed Senators:

Two months ago, a huge category four storm occurred in the Chukchi Sea with winds reaching 150 miles per hour and sea waves cresting to 30 feet. Open leads in sea ice enabled winds and waves to hurl large chunks of ice into oil platforms and fragile coasts with reduced permafrost depth. Oil platforms and fuel tanks in coastal areas were damaged and a large oil spill washed into lagoons surrounding Cape Krusenstern National Monument and Bering Land Bridge National Preserve. Coastal villages Shishmaref and Kivalina were devastated despite rock walls, and communications in the region, other than a few satellite phones, were down for weeks. Landing strips in these communities and hub communities were over-washed and were unusable for large aircraft. Extreme winds demolished large container storage buildings at the Red Dog Mine port facility, and lead and zinc concentrate were dispersed over the shrubby tundra.

Native organizations came to the rescue of surviving residents. They organized the relocation and distribution of food, and they were in charge of all on-site activities. The nearest federal emergency response unit was in the Aleutian Islands, and they were unable to get to the disaster area for weeks.

Residents of damaged communities relocated to other towns, Red Dog Mine, and to refugee camps both outside and inside the parks, such as Serpentine Hot Springs. Park infrastructure in Kotzebue was destroyed, and NPS operations moved to Nome where minor damage occurred.

Local resident survivors were hired to help with cleanup response, but outsiders were also brought in to help with efforts. Once the storm abated, the affected area was declared a disaster and in a state of emergency. The National Guard was deployed via large helicopters. Because of other multiple, long-term crises and a monstrous deficit, federal disaster funding was depleted. International press interest was high, but it was difficult to accommodate reporters to the disaster zone, so there is little press coverage from the ground. Images are provided via Google Earth satellites and over flights.

Missionaries, Red Cross, and native grassroots groups arrived to help, but conflict arose due to the National Guard's need to control and contain the situation.

The extreme warming trend has already weakened subsistence resources and cultural traditions. Community members were already frustrated with the lack of agency response to conserve subsistence resources, but are now in a crisis mode. Cultural resources were exposed in coastal areas during the storm event, and it was alleged that cleanup crews looted resources.

Migratory birds are expected within a month, but the salt water and oil breach of the lagoons is not yet cleaned up. The remaining musk ox herds near Cape Krusenstern and Cape Espenberg were caught in the storm and extirpated.

Local residents question response time and government efforts. Local native leaders have requested funding to flow directly to communities, because they were the ones best able to manage response efforts. Village and regional Native organizations are also requesting relaxation or removal of all federal regulations regarding subsistence activities, and assistance with firewood and other fuel sources. China, which has a strong economy, has sent messengers offering financial and logistical help in exchange for increased access to natural resources in the region.

I. M. Smooth, Senior Senator of Alaska:

Thank you Superintendent Cerne. Given our national financial situation and deteriorated conditions in Northwestern Alaska, what do you recommend Congress and the Administration do about this disaster at this time and to better prepare for the future?

Superintendent Con Cerne:

Thank you for the question Senator Smooth.

First, security of the local populations needs to be established. The Department of Homeland Security needs to step up its presence and work cooperatively with local governmental entities and Native organizations. Contaminated coasts and tundra need to be cleaned up as soon as possible.

Secondly, economic, natural, and cultural resources in the affected area need protection, especially with international presence and interest in the area. Rebuilt infrastructure in the area needs to take into account the extreme warming trends with reduced ice cover and increased storminess with storm surges. We need interagency strategic plans that address climate change and disasters such as this recent one that incorporate a robust consultation process with local communities, industry, and governmental entities in the region from national to local levels. Right now we need to clean oil from the most critical fish and wildlife habitat in the coastal lagoons before spring migrations bring threatened and endangered species and important subsistence resources back to these areas. We also need to conduct archeological triage for the affected coastal areas. The National Park Service stands ready to help in any way it can.

In the long run the National Park Service needs to update its General Management Plans for affected area parks to consider climate change impacts and reaffirm park purposes, relevance, and objectives, including emphasis on naturalness but allowing for a certain level of manipulation to protect threatened and endangered resources, including important subsistence resources for local rural populations. We also need to complete oral histories of surviving local residents with traditional ecological and local knowledge before it is lost forever. We need to prioritize recovery of data from archeological sites near threatened coasts before they too are lost forever. We need to continue monitoring coast lines and critical fish and wildlife habitat because these areas are changing rapidly with the warming and increasingly stormy conditions. Information collected by local, state, federal, and international entities in the area need to be shared and seamless because not any one party can complete all of the work for any one species or resource.



The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

NPS 183/125248, 182/125248, July 2014

**National Park Service**  
**U.S. Department of the Interior**



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