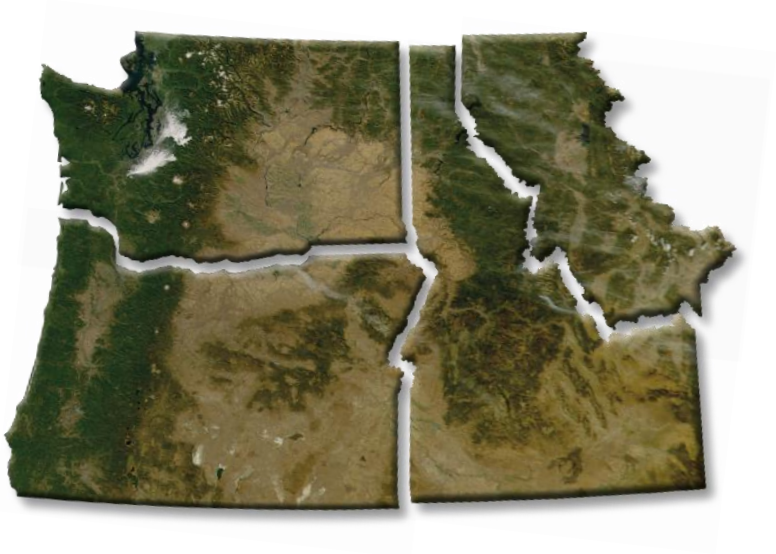
Department of the Interior
U.S. Geological Survey

Northwest Climate Science Center

Strategic Plan 2012-2016



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Strategic Plan 2012-2016

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INTRODUCTION

The Northwest Climate Science Center (NW CSC or Center) was established in 2010, as one of the first of eight regional Climate Science Centers to be initiated by the National Climate Change and Wildlife Science Center (NCCWSC) at the Department of the Interior's (DOI) U.S. Geological Survey (USGS). The Center's mission is to coordinate the expertise of federal and university scientists to provide scientific information and tools necessary to address federal, state, and tribal resource managers' priorities in response to a changing climate. The NW CSC is supported by a consortium of Northwest academic institutions[1] primarily led by Oregon State University (OSU), University of Idaho (UI), and the University of Washington (UW). Together, these universities offer capabilities in climate science, ecology, impacts assessment, modeling, and advanced information technology, all of which are necessary to address and respond to climate change in the Northwest. This partnership provides a remarkable opportunity to strategically address science issues of regional significance by purposely blending recognized academic expertise and federal resources.

The geographic area generally encompassed by the NW CSC includes terrestrial, freshwater and near-shore marine ecosystems in Washington, Oregon, Idaho, and western Montana. This conventional definition is not meant to establish a rigid segregation from surrounding localities, but rather outline a practical administrative area. The NW CSC partially overlaps three Landscape Conservation Cooperatives (LCCs): Great Northern, Great Basin, and North Pacific. LCCs are voluntary partnerships that coordinate shared objectives to manage climate risks to natural and cultural resources, and on-the-ground adaptation efforts launched by federal, state, tribal, international, local, and other stakeholders. Collaboration between the NW CSC and these three LCCs will address the highest priority regional climate science needs, and deliver the necessary scientific information required by natural and cultural resource managers in the Pacific Northwest.

The purpose of this Strategic Plan (Plan) for the period 2012-2016 is to provide a practical blueprint for how the NW CSC intends to support DOI's coordinated strategy to address current and future impacts of climate change. In accordance with the overall goals of the LCC/CSC concept as described in Secretarial Order 3289, science conducted by the NW CSC will be focused on addressing the climate science needs of LCCs, natural- and cultural-resource managers, Tribes, and other stakeholders in the Pacific Northwest. Addressing these needs effectively and efficiently will require a collaborative approach to summon existing expertise in multiple scientific disciplines at different institutions. There are scientific efforts underway - by federal and state science agencies, universities, Tribes, and non-governmental organizations - to understand and address climate change. Developing scientific partnerships between science agencies and organizations to coordinate these ongoing efforts and leverage resources will be a key aspect of the NW CSC science strategy.

BACKGROUND

Future Climate in the Northwest

The climate of the Northwest is expected to warm over the next century, with potentially serious consequences for landscapes, ecosystems, and natural and cultural resources. Climate records show

[1] Institutions that participate in the NW CSC consortium include: Boise State University, Idaho National Laboratory, Idaho State University, Montana State University, Oregon Health and Science University, Oregon State University, Pacific Northwest National Laboratory, Portland State University, University of Idaho, University of Montana, University of Oregon, University of Washington, Washington State University, and Western Regional Climate Center.

that the Pacific Northwest has warmed about 1.0°C since 1900, or about 50% more than the global average warming over the same period. The warming rate for the Northwest over the next century is projected to be in the range of 0.1-0.6°C/decade. Models predict warming during all seasons, but temperature increases will be largest in summer months.

Projections are less consistent with regard to changes in future annual precipitation, although most models show relative changes in the seasonal distribution with decreases in precipitation during the summer and increases during fall and winter. The warming predicted in the coming decades is expected to result in a shift in the form of precipitation from snow to rain, particularly at intermediate elevations where much of the Northwest's snowpack accumulates. As a consequence, a larger proportion of autumn and winter precipitation will run off at the time it falls, and less water will be stored as snow over the winter. The reduction in snowpack will result in diminished snowmelt-fed streamflow during the spring and summer. The net effect will be a shift in the timing of runoff, with more streamflow during the winter and less during the summer. The change in precipitation timing, snow hydrology, and surface-water regimes will also affect groundwater systems.

Effects of Climate Change in the Northwest

Climate change will have a large influence on vegetation in the Northwest. Vegetation will change not only in response to shifting moisture and energy balances, but to altered disturbance regimes (such as fire and insects). Several studies suggest that forests, woodlands, and shrublands may diminish in favor of grasslands and desert. Areas of alpine and subalpine vegetation are expected to diminish. The ranges of invasive species will likely expand under future climate regimes. Increases in fire activity are expected for all major forest types in the Northwest under projected future climate. Higher fall, winter, and spring precipitation along with warmer temperatures forecast larger and more frequent fires and longer fire seasons in rangeland areas of the Northwest.

Fish and wildlife are also susceptible to the effects of climate change. Increases in water temperature and changes in flood regimes are expected to reduce suitable habitat for spawning, rearing, and migration of salmon in the Northwest. Invertebrates, an important food source for fish, are also vulnerable to warming. Climate-driven changes in hydrology, vegetation, and other landscape elements will affect certain terrestrial species either by shrinking their ranges, as is the case with small mammals in mountainous areas, or allowing ranges to expand, as is the case with certain insect species. Of particular concern are changes in the timing of life stages or migration of various interdependent plant and animal species. Any single change can cascade through the food chain and affect many plant and animal species. Many of these changes may result in alterations of normal ecosystem processes, which will have associated impacts on fish and wildlife.

Coastal and marine systems in the Northwest will also be affected by changes in atmospheric chemistry and warming. Effects are anticipated to include sea level rise, increased water temperatures, ocean acidification, and increased frequency of severe storms. Sea level rise is expected to result in inundation of low-lying areas along the coast, increased erosion, saltwater intrusion in coastal aquifers, and increased salinity in estuaries.

The physical and biological responses to climate change in the Northwest described in the preceding paragraphs all have social dimensions. The Secretarial Order touches on this by pointing out that Native Americans heavily rely on the landscape for their economies and cultural identity, and that DOI lands are a nationally important source of water for public supply and irrigation. Parks and refuges are also mentioned as important for recreation and other human needs. Climate-induced changes in landscape

processes also have potentially broad effects on infrastructure, natural hazards, and public health and safety. Conversely, human population shifts, changes in agriculture and other land-use practices, and changes in both municipal and agricultural water demand could have major implications for water, land, and species management. Landscapes in the Northwest are inextricably linked to the identity and economic well-being of individuals, communities, and the region as a whole. Understanding the connections between social and ecological dynamics will be important to our ability to fully address the implications of climate change.

NW CSC STRATEGIC PLAN

The fundamental elements of this Strategic Plan include a **vision** and two overarching **goals**. The two goals are supported by a set of five related **objectives** that describe the core services provided by the NW CSC to partners and other stakeholders to fulfill the stated vision: Executive Services, Science Services, Data Services, Communication Services, and Training and Education Services. These objectives contain specific **tasks** that constitute the reference benchmark to report on the performance of the NW CSC. Review and approval of this Strategic Plan and its subsequent iterations are the responsibility of the NW CSC Director and the NCCWSC Director. This Strategic Plan will be reviewed at least once every four years, or as dictated by the NW CSC mission.

Vision

The **vision** statement that will guide the NW CSC into the future is:

To become nationally recognized as a best-practice model for the provision of climate science and decision support tools to address conservation and management issues in the Pacific Northwest Region.

The genesis of this vision rests on the following guiding statements:

- Identify major climate-related research questions and key climate science needs of natural- and cultural-resource managers in the Northwest.
- Provide state-of-the-art science and decision support tools such that land, water, and wildlife resource managers, and Tribes can better understand vulnerabilities to climate change and develop adaptation strategies in response to those anticipated changes.
- Pursue and facilitate collaborative and interdisciplinary research to leverage the most efficient use of time, resources, and expertise within the scientific community of the Pacific Northwest.
- Stimulate active communications between audiences that include users and providers of climate information, to discuss how to best deliver safety, economic and environmental benefits to industries, government and citizens of the Pacific Northwest.
- Apply an integrated data management and networking infrastructure that inspire innovation in the conduct of science. Ensure that data-management efforts are coordinated with other appropriate state, federal, Tribal, and non-governmental climate-science efforts.
- Provide guidance to natural- and cultural-resource managers, Tribes, and other stakeholders with regard to accessing and using well-vetted climate science and models for education, strategic planning, and on-the-ground decision making.

Goal 1.
Establish a significant and effective leadership presence to strengthen the region's ability to plan and implement a coordinated climate science portfolio.

Objective 1.1 - Executive Services

To provide leadership, guidance, and support for climate-related activities through coordination and engagement with relevant stakeholders.

The function of Executive Services is to provide leadership and general oversight of the Center's operations. The NW CSC Director is responsible for strategic decision making and is accountable for the administration of the Center's financial resources. Pivotal among these functions are the preparation of a long-term Science Agenda – to outline the general direction of the Center's science enterprise – and an Annual Science Work Plan – to provide specific guidance on coordination and implementation. These two elements are detailed further under Science Services, below. On a broader scale, the Director serves as an ambassador for the NW CSC's work and promotes mutually beneficial networks and relationships by maintaining a wide-ranging involvement and participation in regional and national climate-related endeavors. The Director will chronicle the Center's performance and accomplishments in an Annual Report for the Center's operations and expenses throughout the preceding year. In addition to operational funds and non-discretionary distributions such as the Cooperative Agreement with the academic consortium, the NW CSC makes science funding available to conduct climate research. The decisions by the NW CSC Director to fund specific science projects require management oversight of the entire contract cycle, from the initial award to the project administrative closure. Administrative support for the Director and contract management for the NW CSC will be shared jointly by the USGS NCCWSC headquartered in Reston, Virginia, and the USGS Forest and Rangeland Ecosystem Science Center (FRESC) in Corvallis, Oregon.

A central function of the NW CSC is to bring the regional resource management and science communities together to calibrate priorities and ensure efficient use of science resources on a continuing basis. This convening function offers an important way to gain mutual understanding between scientists and managers. One the one hand, it brings researchers together to plan and carry out scientific research; on the other, it brings decision makers looking for scientific advice and products to inform their management concerns. In the end, the integration of science and policy stimulates the generation of ideas and improves the "fit" between scientific products and management needs.

Leadership of the NW CSC is a shared responsibility. The magnitude of the science and ecological dimensions of climate change offers a galvanizing opportunity to promote synergies and align limited regional resources and funding behind shared objectives. Two primary regional groups support the Center Director's efforts. One of them is the Executive Stakeholder Advisory Committee (ESAC) that ensures broad participation by 22 federal, state, and tribal agencies and organizations (Appendix A). Because of its broad representation, the ESAC has a key role in setting the Climate Science Agenda for the Pacific Northwest as well as ensuring that the NW CSC's Annual Science Work Plan reflects the highest of those strategic science priorities. The second group is the Leadership Team (LT), established to allow for open and frequent communication amongst key entities and individuals with involvement in the functions of the NW CSC. LT participants include the NW CSC Director, the USGS Regional Executive for the Northwest Area, and the Principal Investigators (PIs) representing the primary academic institutions involved in the NW CSC partnership.

Tasks:

- Implement administrative and operational best-practice standards and procedures to maintain transparency and accountability.
- Review and periodically revise a Strategic Plan for the NW CSC, for endorsement by the NCCWSC.
- Administer NW CSC finances consistent with Federal regulations and USGS Headquarters guidance, to advance a regional climate portfolio within approved budgets.
- Engage and convene regional science and policy stakeholders to exchange information that improves the planning, production, and use of climate science products.
- Prepare an Annual Report for the Center's operations, accomplishments, and expenses.

Objective 1.2. - Science Services

To develop and implement a comprehensive Science Agenda to address current and emerging climate priorities in the Pacific Northwest.

Science Services include the design of a long term (4-year horizon) Science Agenda and ensuing Annual Science Work Plans that provide guidance for the progressive implementation of the broad Science Agenda. Both products rely heavily on the regional input regarding climate information needed for management, and detected climate science gaps. The relevance of these guidance documents to the research and management communities in the Northwest hinges on successful consultations with (1) the ESAC, (2) designated coordinators from associated LCCs, (3) tribal leaders, and (4) non-governmental organizations (NGOs) and other resource-user groups in the Northwest. Ultimately, this regional statement of climate science needs is rolled up together with the collective contributions of all Climate Science Centers throughout the United States to articulate a national program for climate science. Ideally, future versions of the NW CSC Science Agenda will rest on a foundation provided by LCC Science Assessments and other descriptors and inventories that help identify gaps and needs in the regional climate science portfolio. Those sources of guidance are not yet fully mature in the Northwest region.

The current Science Agenda (Attachment B) provides the science direction for the NW CSC in 2012-2016. The Science Agenda is the centerpiece of the NW CSC contribution to the Northwest region and offers a common platform for the delivery of all other NW CSC services. Importantly, this agenda will be used to make determinations about climate science projects that will be funded by the NW CSC. Every year, the ESAC identifies specific research priorities and provides the NW CSC Director with recommendations to establish a working Annual Science Work Plan based on the Science Agenda. The NW CSC Director also works closely with LCC coordinators to identify key areas of mutual interest for consideration in the annual science planning process. Other sources of research guidance emerge from consultations with the NOAA-funded Pacific Northwest Climate Impacts Research Consortium (CIRC), Tribal leaders, NGOs and other regional stakeholders. The NW CSC Director summarizes comments and finalizes a coordinated Annual Science Work Plan that contains priority subthemes of the Science Agenda, a solicitation for project proposals to address those priorities, and guidance for proposal preparation. The Work Plan further describes the proposal review cycle leading to the final project selection. The NW CSC Director will coordinate an annual project review and assessment session with the ESAC, university partners, and other parties to discuss how these project accomplishments contribute to meet the strategic goals of the Science Agenda. This project evaluation activity conveys full accountability and helps improve the rigor of science planning for the NW CSC.

Tasks:

- Secure appropriate regional engagement for the development of a Climate Science Agenda that focuses on current and future impacts of climate change in the Northwest.
- Prepare an Annual Science Work Plan that identifies priority research needs contained in the Science Agenda, and articulates the necessary steps and specific actions to address them.
- Leverage NW CSC investments in science capacity, projects, and data with partners in the research and resource management communities to the maximum extent possible.
- Perform an annual evaluation of research projects to assess their accomplishments and consider revisions to future science guidance.

Goal 2.
Develop resources and programs to enhance climate science literacy, and give regional audiences the necessary tools and information to promote climate change awareness.

Objective 2.1 - Data Services

To collect and secure climate data, while providing timely access, analytical functions, and interpretive services.

There is strong demand for climate data as they provide an essential platform for robust decision–making. These data must be managed and made available in ways that facilitate synthesis, catalyze new ideas, and advance the conduct of science as a social phenomenon. Data Services provide a core business function to Northwest stakeholders by linking data owners, providers and users, to users of comprehensive, high–quality climate data. This high level function is responsible for data administration standards and procedures, processing and validation, technical tools and analytical services, risk management, security and presentation.

The Northwest Knowledge Network (NKN), based at the University of Idaho and in cooperation with Oregon State University, the University of Washington, and the Idaho National Laboratory, will provide cyber-infrastructure capabilities within its contribution to the NW CSC partnership to support databases, networking, and work processes for system applications. Furthermore, Data Services provided by NKN have been selected by USGS leadership as a regional pilot for data management and cyber-infrastructure for the national Climate Science Center network. This flagship effort by the University of Idaho and NKN, supported through several key partnerships, is fundamental to DOI's national climate science efforts.

Tasks:

- Engage relevant stakeholders in discussions of data–related matters, including data administration and standards, technical tools, networking, and products.
- Provide data extracts, technical tools and analytical services to data users, and prepare data summaries and reports.
- Fully integrated data management planning with domain science planning during the conceptualization stage of NW CSC research and outreach projects.
- Provide expert analysis and synthesis of NW CSC data and related information to support identified priority needs in the Science Agenda.

Objective 2.2 - Communication Services

To provide professional communication and outreach services that support the exchange of information among regional stakeholders, and effectively raise awareness of climate issues in the Pacific Northwest.

The key role of Communication Services is to provide logistical and technical support for effective outreach and community involvement in the activities of the NW CSC. Appropriate messages, mechanisms for outreach, and other aspects of the strategy depend on the nature and level of understanding of the target groups. Often, these audiences are rather diverse, and priorities must be established to discern which groups to reach first or most frequently. Clear identification of different target audiences will determine what types of input can be sought from various constituencies. Messages should be tailored to specific target audiences. Key points must be identified and specifically crafted to effectively convey the nature and importance of the information while simultaneously addressing the unique concerns of different stakeholder groups. The fundamental relevance of these functions is so paramount that those involved in the drafting of the NW CSC Science Agenda (Attachment B) recognized the Communication of Science Findings as one of the key elements to be included in it. The University of Washington currently leads the communication portfolio within its contribution to the NW CSC partnership.

There are many different mechanisms for communication, and it is important to select those methods that will most effectively reach the intended audiences. Various print and electronic means can be used as part of a coordinated multimedia approach that includes exhibits, training sessions, web-accessible media, study materials, and brochures. For example, the NW CSC will be served by two complementary websites: one maintained and served by DOI; the other maintained by the NW CSC academic consortium. The consortium site is scheduled to come on-line in the near future. In addition to material resources, individuals can also play important roles in disseminating information, and, in many cases, the people who communicate messages will be pivotal to the credibility and compelling nature of outreach efforts.

Each research project funded through the NW CSC will be required to have an outreach component that describes proposed efforts to disseminate research findings and other information to various target end users. These efforts may be general in nature, such as the use of web sites or other broadly distributed media, or they may be specific and targeted, such as presentations in stakeholder meetings or professional publications. Regardless of the approach, the emphasis will be on the dissemination of information generated by the NW CSC science program.

Tasks:

- Implement and monitor communication strategies with external stakeholders to build partnerships and raise awareness.
- Maintain a vibrant NW CSC website environment and content as a reference source of climate information for regional users.
- Engage audiences by preparing periodic media releases profiling NW CSC achievements and other climate issues in the Pacific Northwest.
- Promote science-based climate literacy among NW CSC partners by increasing understanding and use of climate science data, information, and programs.

Objective 2.3 - Training and Education Services

To promote broad participation and support education of diverse young scientists in the work of the NW CSC.

As the social and economic development of the Pacific Northwest increasingly depends upon the knowledge and skills of its citizens, the NW CSC will provide Training and Education Services to deliver science-based knowledge and informal educational programs to the larger community, enabling people to make practical decisions. In the context of building awareness about climate change issues, the NW CSC believes that improvements in training and education will greatly help persuade society to participate in the ongoing climate change dialogue between the federal government, academia, and various stakeholder groups.

Investments in graduate students and post-doctoral researchers can expand the influence of the NW CSC since they not only conduct much research themselves, but also will become the next generation of scientists and educators. Ultimately, this approach will also strengthen the NW CSC mission to include the research community into the federal policy-making process. Training and education Services will therefore aim to develop and sustain a revolving corps of young researchers by elevating the priority of student and post-doctoral opportunities in budget planning and requests for additional support. Grants, contracts, and other awards that originate from the NW CSC will be evaluated and prioritized according to their ability to support young researchers.

Tasks:

- Assist in disseminating information about opportunities for early career professionals transitioning to the climate workforce or interested in gaining work experience in climate-related fields.
- Plan and implement a graduate fellowship program to help prepare students for interdisciplinary careers in climate science, education, and outreach.
- Actively explore opportunities to partner with others within government and academia to develop graduate fellowships that enhance students' preparations for interdisciplinary careers in science, education and outreach.
- Consult with experts in K-12 and informal education as to how we might structure and present scientific findings from the NW CSC such that it is accessible and useful to those working to increase climate change literacy of youth and adults.

APPENDIX A – Executive Stakeholder Advisory Committee (ESAC)

(22 agencies and organizations: 3 State agencies, 3 Tribal organizations, 3 LCCs, 13 Federal agencies)

Federal Agencies

Army Corps of Engineers, Northwest Division
Bonneville Power Administration
Bureau of Indian Affairs
Bureau of Land Management, Oregon/Washington Office
Bureau of Reclamation, Pacific Northwest Region
Environmental Protection Agency, Region 10
Federal Highway Administration, Western Federal Lands Highway Division
National Oceanic and Atmospheric Administration, Northwest Fisheries Science Center
National Park Service, Pacific West Region
Natural Resources Conservation Service, National Water and Climate Center
U.S. Fish and Wildlife Service, Pacific Region
U.S Forest Service
U.S. Geological Survey, Northwest Area

State Agencies

Montana Fish, Wildlife, and Parks
Oregon Department of Fish and Wildlife
Washington State Department of Ecology

Tribal Organizations

Affiliated Tribes of Northwest Indians (44 Tribes)
Columbia River Inter-Tribal Fish Commission (4 Tribes)
Northwest Indian Fisheries Commission (25 Tribes)

Landscape Conservation Cooperatives (LCCs)

Great Basin Landscape Conservation Cooperative
Great Northern Landscape Conservation Cooperative
North Pacific Landscape Conservation Cooperative

Appendix B – NW CLIMATE SCIENCE CENTER: SCIENCE AGENDA FOR 2012-2016

Key Science Needs

Identifying key science needs is a fundamental step in developing climate science for natural- and cultural-resource managers, Tribes, and other stakeholders in the Northwest. The key science needs that have been identified to date are organized below into seven interrelated Research Themes that broadly reflect the scale of the relevant processes and the flow of information. The science themes are not intended to represent any hierarchy of importance, need, or order of effort. The NW CSC will work in cooperation with the ESAC to prioritize the key science needs. Prioritization will reflect the needs of LCCs and other stakeholders, and consider ongoing efforts and identified science and information gaps. Once priorities have been identified, it is anticipated that priority science needs under multiple themes will be addressed in parallel.

1. Climate Science and Modeling – Continue development of climate science and modeling capabilities to provide resource managers and researchers across all disciplines reliable and defensible information on the range of probable future climate conditions and associated uncertainty in the Northwest.

a. Coordinate with and leverage efforts at the national level to advance techniques of analyzing and downscaling global and regional climate models as appropriate for the Northwest, including the understanding, quantification, and characterization of climate model uncertainty.
b. Connect with and leverage efforts at the national level to advance the understanding of nonlinear behavior of climate systems, and feedbacks between climate systems and other physical and biological systems, including development and application of coupled regional models suitable to this task.
c. Develop a data infrastructure for documentation, storage, and dissemination of a well-vetted set of future climate scenarios including multimodel ensembles, along with guidance regarding appropriate interpretation, use, and uncertainty.
d. Identify metadata standards for model data sets to ensure data are properly documented and appropriate for specific uses.

2. Response of Physical Systems to Climate Change – Characterize and model the response of physical systems (for example hydrologic, atmospheric, and earth-systems) to historic and future temperature and precipitation, taking into consideration the effects of uncertainty. Key among these processes is the hydrologic response, which directly influences streams and groundwater resources, ecosystems, historical and cultural resources, and ecosystem services.

a. Advance understanding of the response of hydrologic systems to future climate, including changes in snow hydrology, alpine glaciers, streams (both perennial and intermittent), lakes (both lotic and lentic systems), groundwater systems, wetlands, water temperature, water quality, and extreme events. This need relates to effects on aquatic habitat, as well as the timing and amount of water available for agricultural and municipal use, recreation, wildlife and stock use, and power generation. The hydrologic response also affects understanding of drought, flood risk, reservoir operations, and land management.
b. Advance understanding of changes in physical and chemical processes in marine systems, including sea level rise, salinity, acidity, circulation patterns, nutrients, dissolved oxygen, intensity of storm events, and shoreline erosion.
c. Advance understanding of atmospheric fluxes of carbon dioxide, other greenhouse gases, and water, as well as other of atmospheric processes, such as acid and nutrient deposition, airborne dust, and other contaminants.

d. Improve understanding of erosion, mass wasting, and sediment transport processes (including both wind and water) resulting from changes in precipitation and stream flow, sea level rise, and glacier retreat, particularly as they relate to hazards, water quality, aquatic habitat, cultural resources, and infrastructure.
e. Quantify probable changes in soil moisture and energy, particularly as they relate to vegetation, evapotranspiration, and hydrologic budgets. This need includes effects to irrigated agriculture (*e.g.,* soil suitability, water consumption rates, and cropping patterns).
f. Advance understanding of probable changes in air and water temperatures, and develop projections of the potential impacts to affected physical and biological systems.

3. Response of Biological Systems to Climate Change – Characterize and model the response of biota, terrestrial and aquatic ecosystems, and biogeochemical systems to changing climate, specifically including the effects of uncertainty. Characterization may include analysis of historic data, field research, and model analysis, as well as other approaches. The efforts in Research Theme 2 complement and provide the physical template for understanding the biological systems in this theme. The elements of this theme have importance to biodiversity, biotic components of culturally-important landscapes, as well as ecosystem services.

a. Characterize the response of species, populations, and ecosystems to climate change.
b. Improve understanding of threats to habitat connectivity and potential for fragmentation of terrestrial, aquatic, marine, and nearshore habitats.
c. Continue to advance understanding and modeling of changes in fire regimes.
d. Continue to develop understanding of the ecology and potential impacts of invasive species, plant and animal diseases, harmful algal blooms, pathogens, and epidemic insect infestations.
e. Enhance understanding of carbon cycling, biological carbon sequestration, and carbon emissions, particularly as they relate to land management, mitigation, and adaptation strategies.
f. Improve understanding of potential changes in phenology (relative timing of physical and biological cycles) and related monitoring needs.
g. Improve understanding of the feedback between biological systems and processes, and physical systems and processes (including climate).

4. Vulnerability and Adaptation – Identify vulnerabilities of specific physical systems, ecosystems, human health, cultural resources, and infrastructure to climate change, and identify actions or practices that may improve prospects for adaptation. This theme complements understandings developed in Research Themes 2 and 3.

a. Assess the vulnerabilities (as well as resiliencies) of terrestrial, aquatic, and near-shore marine ecosystems, as well as individual species and populations, to climate change and non-climate-change stressors.
b. Identify vulnerabilities of physical and biological systems and landscape characteristics critical to Native American Tribes. These efforts must consider the unique relation between Tribes and the landscape, and the large degree to which Tribes rely on the landscape for their economic well-being and cultural identity.
c. Assess climate-related increases in vulnerability of threatened and endangered species or other species of concern.
d. Identify vulnerabilities of freshwater resources, particularly as they relate to ecosystem needs, cultural and historical resources, human needs, infrastructure, and shifting demands.
e. Develop adaptation strategies for vulnerabilities identified at the full range of spatial scales.

5. Monitoring and Observation Systems – Evaluate, enhance, develop (if necessary) new programs for monitoring and observation of key physical and biological systems, and develop systematic methods for analyzing, storing, and serving information. This theme centers on the need for data (including traditional knowledge) required to quantify physical and biological processes, track changes, and evaluate effectiveness of adaptation and mitigation measures.

a. Inventory and evaluate existing monitoring networks, expand and modify networks as necessary, and, where feasible, integrate efforts across agencies. Ensure monitoring and observation efforts inform understanding of physical and biological systems, and inform assessment and modification of adaptation efforts.
b. Develop new metrics for tracking the response of physical systems, ecosystems, and individual biota to climate change, and establish new monitoring and observation systems where needed.
c. Use models, where applicable, to evaluate data from and guide design of monitoring networks.

6. Data Infrastructure, Analysis, and Modeling – Improve methods for data analysis and storage, modeling, forecasting, and decision-support. This cross-cutting theme relates to science application across the full range of disciplines, processes, and scales. Efforts related to decision support systems should be coordinated with the CDSC.

a. Expand retrospective analyses of the response of physical and biological systems to historic climate and advance paleoclimate research. This effort needs to occur at a range of scales and, where possible, incorporate traditional knowledge.
b. Continue development and application of a set of coherent and well-vetted models of regional climate, physical and biological systems, using best practices and employing multimodel ensembles. Develop standard methods for evaluating model application, calibration, and uncertainty.
c. Incorporate models into decision support systems.
d. Characterize and, where possible, quantify uncertainty. Develop methods to include uncertainty in decision making and to characterize and assess risk associated with action or non-action.
e. Improve existing (or develop new) data management practices and, as appropriate, infrastructure to ensure common standards for data collection and processing, formatting, quality assurance, storage and archiving, and data sharing.

7. Communication of Science Findings – Develop strategies for communicating results and current thinking to the full range of agencies, stakeholders, and the general public. Efforts under this theme relate to all other science themes and should be coordinated with other major efforts such as the LCCs and the NOAA-funded Pacific Northwest Climate Impacts Research Consortium (CIRC), as appropriate. Because of the importance of communication of science findings to society at large, particular attention should be paid to communication of science findings to non-science agencies, agency staff, and the general public.

a. Develop an information infrastructure that allows on-the-ground resource managers and non-technical decision makers ready access to current, thoroughly peer reviewed syntheses of climate science, future climate projections, assessments of uncertainty, responses of physical and biological systems, and vulnerabilities. The overall goal of such an effort would be to enable users to have a single source of information they need for resource management and decision support.
b. Translate and transfer scientific information and data to scientists, resource managers, stakeholders, and the general public in a manner appropriate to target audience. Utilize as appropriate the full range of tools and techniques, such as factsheets, websites, webinars, seminars, workshops, and training courses.