The Climate Impacts Group’s research on the impacts of climate variability and change in the Pacific Northwest (PNW), and the application of this information to regional resource management issues, has led to significant contributions to the fields of science and natural resource management in the PNW. The following summarizes many successes of the Climate Impacts Group (CIG), grouped into seven general categories:

1. Contributions to Climate Science
2. Contributions to Decision Support: Tool and Resource Forecasts
3. Engaging Stakeholders
4. Influencing Operations and Policy
5. Contributions to Education
6. NOAA Partnerships
7. Benefits to Observations

**Contributions to Climate Science**

- **Defining the Pacific Decadal Oscillation.** The CIG demonstrated a solid connection between interdecadal variations in North Pacific climate and the abundance of salmon and other marine species in the PNW and Alaska and in so doing named and defined the "Pacific Decadal Oscillation (PDO)". The PDO is now recognized internationally as a major climate driver with wide-scale impacts on natural resources in the western U.S., Canada, and eastern Russia.

- **Identifying the influence of climate variability on PNW winter climate.** The CIG characterized PNW climate variability and trends, noting, for example, (1) the association of warm-dry and cool-wet winters with warm and cool phases of ENSO and PDO, and (2) the links between several other large-scale climate modes (e.g., Pacific North America pattern and the Arctic Oscillation) and extreme weather events such as windstorms, cold air outbreaks, and snow.

- **Identifying impacts of climate variability on key PNW resources.** The CIG has demonstrated how the El Niño/Southern Oscillation (ENSO), PDO, and other aspects of climate influence key natural resources in the PNW, including: snowpack, streamflow, flooding, and droughts; forest productivity and risk of forest fire; salmon returns; and quality of coastal and near-shore habitat. Warm phases of ENSO and/or PDO, for example:
  - increase the probability for reduced snowpack, streamflow, flooding, salmon returns (PDO only), and coastal and near-shore habitat quality,
  - increase the probability for drought and forest fires, and
  - contribute to increased tree growth and ecosystem productivity at higher elevations (with the opposite effect at lower elevations).
• Identifying relationships between climate, habitat and ecosystem structure in the California Current. CIG research indicates that Pacific hake and sardine appear to have evolved to use space to compensate for variability in their environment. Hake spawning habitat is influenced most strongly by ENSO scale variability; their migratory extent in the northern feeding grounds is influenced by variability at the PDO scale. Sardine spawning habitat is influenced most strongly by PDO scale variability.

• Developing the first climate driven ecosystem scale model of the PNW coastal ocean to support fisheries management in the Northern California Current (NCC), resulting in a picture of how climate structures NCC production. Cool phase PDO years tend to be associated with significantly greater success for juvenile salmon, crab, rockfish, sablefish, shrimp, and other residents. The opposite tends to be true in other years, particularly warm phase PDO and/or El Niño years.

• Identifying 20th century trends in PNW hydroclimatic variables. The CIG analyzed 20th century trends in temperature, precipitation, and snow water equivalent (an important indicator for predicting summer water supplies) for the PNW. The research finds that annually averaged PNW temperature and precipitation increased more than the global average during the 20th century. The research also identified significant decreases - up to 60% at some locations - in PNW snow water equivalent over the second half of the 20th century. These results, which can only in part be explained by natural climate variability, are consistent with projected climate change impacts for the PNW and, as such, have generated significant interest among water resources managers throughout the PNW.

• Extending the paleoclimatic record. In an effort to extend our understanding of PNW climate and climate variability beyond the current instrumental record, the CIG has utilized tree rings and geoduck shells to place 20th century climate in a broader historical context. As a result of this research, the CIG has been able to conclude, for example, that:

  o The 1930s drought in the Columbia Basin was probably the second worst in the last 250 years (after the 1840s). This finding is important for water resource managers using the 1930s drought for “worst case scenario” planning and generated significant interest among water, salmon, and hydropower interests.

  o Innovative use of geoduck shells to reveal climate signals since the mid-1840s places the 1990s as the warmest decade of the last 154 years for March through October sea surface temperatures in the Strait of Juan de Fuca. Other warm periods occurred during 1870s, the 1900s, and the years from 1926 to 1934.

  o The variability of the PDO over the past several hundred years has fluctuated, with the period of 1800 to 1920 (roughly) having lower interdecadal variance than other times.

  o Climate is a major driver of vegetation change for montane forests of the Cascade Range over millennial time scales, and fire and other disturbances are
important agents of change at decadal to century time scales. Lake sediment charcoal, macrofossil, and pollen records indicated that fire frequency has not significantly changed over millennial time scales, but fire return intervals were highly variable.

The extension of the PNW’s climatological record provides valuable insight into the potential range of climate variability in the PNW, potentially allowing for more complete evaluation of infrastructure planning needs and future climate impacts. Tree-ring chronologies derived by CIG researchers, for example, were featured in a NOAA National Climatic Data Center discussion of the paleoclimatic significance of the 2005 drought in Oregon.

- Evaluating the impacts of global climate change. The CIG has taken a lead role in researching the regional impacts of climate change on the PNW, conducting the nation’s first comprehensive examination of climate change impacts on the PNW, and using the results of that work as a foundation for outreach and continued research. The CIG’s research projects significant challenges in the decades ahead for the region’s water resources, salmon, forests, and coasts as a result of human caused global warming. These challenges include:

  o an increased risk of winter flooding and summer drought;
  o an increased risk of salmon mortality in freshwater habitats as a result of warmer water temperatures, winter flooding, reduced summer flows, and summer drought;
  o an increased risk of forest fires – even at the very low end of climate change projections, climate change is likely to lengthen the fire season and roughly double the total area burned in some regions by the end of the century;
  o changes in forest growth and regeneration at the high elevation forest/alpine meadow interface (increased growth) and low elevation forest reaches (decreased growth, particularly in drier forests east of the Cascade mountains); and
  o an increased risk of coastal erosion and flooding as a result of sea level rise.

  o Identifying barriers to effective use of climate information. Elite surveys with PNW natural resource managers has revealed that barriers to the use of climate forecasts include lack of knowledge on the part of forecast users, problems with the forecasts themselves, and institutional barriers to use of forecasts.

  o Characterizing adaptive institutions. The CIG has shown that the inherent capacity of institutions to adapt to, or prepare for, climate variations is a function of several factors, including: the time scale(s) of climate variations relevant for management of a particular resource, the structure and historical development of existing institutions, and the complexity of the management domain.

  o Identifying institutional requirements for delivery of climate services. The CIG’s work at the interface of climate science and society has revealed criteria required of an institution aiming to provide climate services. The successful delivery of climate services requires the establishment (and maintenance over time) of a middle-
man between the providers and users of climate information. Developing the institutional capacity to provide climate services is neither quick nor easy and requires careful determination and production of useful information and products; building trust with stakeholders over time; and developing an integrated research and outreach team.

**Contributions to Decision Support: Tools and Resource Forecasts**

- **Seasonal climate outlook for the PNW.** The CIG translates global-scale climate forecasts and conditions into regional-scale climate forecasts for Pacific Northwest (PNW) resource managers and the general public. The climate outlook also provides the basis for natural resource forecasts, including the CIG’s annual streamflow forecasts.

- **Translating ENSO forecasts for use in resource management.** The CIG translates long-range ENSO forecasts into regional climate and water resource forecasts and works closely with agencies in applying these forecasts to resource management. As a result, many agencies now consider ENSO forecasts in resource management decisions. For example:
  
  - Seattle Public Utilities (SPU) averted costly water use restrictions during the 1998 summer drought by modifying planning and system operations to take into account the CIG’s projected impacts on snowpack and water resources for the preceding 1997-1998 El Niño winter. **ENSO forecasts are now regularly incorporated into SPU reservoir management decisions.**

- **Climate-based long-lead seasonal streamflow forecasts.** The CIG has developed new long-lead seasonal streamflow forecasting methodologies for the Columbia River basin incorporating (1) long-range climate forecasts for ENSO and PDO, and more recently, (2) seasonal climate model simulations, and (3) Synthetic ensembles based on official forecasts for the region from NOAA’s Climate Prediction Center. These forecasts, presented annually to more than 100 public, private, and tribal resource managers, provide probabilistic estimates of critical spring runoff 6-8 months sooner than the traditional forecasting method. According to CIG research, **using these forecasts could provide additional hydropower revenues on the order of $100 million/yr** with almost no loss of reliability in other water resource management objectives. The CIG has expanded this forecasting capability to include the Snake River basin and other large western U.S. river systems. The forecasts are produced monthly and are available to the public for free on the web. ([http://www.hydro.washington.edu/Lettenmaier/Projects/fcst/](http://www.hydro.washington.edu/Lettenmaier/Projects/fcst/))

- **Seasonal forecasts for coho salmon survival.** The CIG has developed a new method for predicting marine survival for Oregon coastal coho salmon. These long-lead (1 year) forecasts, made in collaboration with NOAA Fisheries, provide coho program managers at Washington and Oregon Departments of Fish and Wildlife with additional, independent, and likely improved run-size estimates early enough to be considered in annual harvest decisions. ([http://www.cses.washington.edu/cig/fpt/orcohofc.shtml](http://www.cses.washington.edu/cig/fpt/orcohofc.shtml))
• **Forecasting fire season severity in the PNW.** Using 47 years of wildfire data on U.S. National Forest land in the PNW, the CIG has identified several key atmospheric patterns that could potentially be used to forecast fire-season severity.

• **Forecasting extreme weather event risks.** The CIG has demonstrated strong associations between the statistics of extreme daily weather events and phases of the daily wintertime Pacific/North America (PNA) index in coastal Alaska, the PNW, the Great Lakes region, and the Southeastern US. This work, combined with the persistence of the PNA pattern, shows that **existing operational PNA forecasts can be used to generate skilled extreme event risk forecasts for select locations up to two weeks in advance.** Improved forecasting of the probability for extreme weather events, including extreme cold temperatures, extreme daily precipitation, freezing temperature days, snow days, maximum temperatures, and surface wind gusts, may provide significant benefits for utilities, water suppliers, and other resource managers. ([http://www.cses.washington.edu/cig/fpt/extreme.shtml](http://www.cses.washington.edu/cig/fpt/extreme.shtml))

• **Mid-range streamflow forecasts for Puget Sound water suppliers.** The CIG is working with members of the Puget Sound Water Suppliers' Forum to develop six month lead-time monthly streamflow forecasts for Puget Sound water suppliers. The tool will allow reservoir managers to consider how forecasted streamflow and reservoir conditions may affect seasonal water resource management decisions such as reservoir storage and instream flows. The project incorporates 6-month climate signals developed by the National Centers for Environmental Prediction to drive a hydrologic model. Forecasted metrics include streamflow, reservoir storage, and demand. ([http://www.cses.washington.edu/cig/fpt/waterfc/waterfc.shtml](http://www.cses.washington.edu/cig/fpt/waterfc/waterfc.shtml))

• **Climate change streamflow scenarios for planning.** The CIG has developed an online decision support tool that allows users to easily obtain climate change streamflow scenarios for targeted locations in many rivers throughout the PNW for incorporation into existing agency planning frameworks. The data server, designed to **facilitate consideration of climate change impacts in water resource planning,** was developed in consultation with the Idaho Dept. of Water Resources and the Northwest Power and Conservation Council. The streamflow scenarios are freely available to the public on the web. ([http://www.cses.washington.edu/cig/fpt/ccstreamflowtool/sft.shtml](http://www.cses.washington.edu/cig/fpt/ccstreamflowtool/sft.shtml)).

• **Client-based research consultancies**

  • **Climate change impacts on municipal water supplies.** The City of Portland, Oregon commissioned the CIG to provide a detailed numerical analysis of the impacts of climate change and population growth on their future water supply and demand. The study found that by 2050, climate change impacts on Portland’s water supply system would be, on average, 50% of the total impact expected from population growth in that same period. Similar studies have been completed for Seattle Public Utilities and for the Tualatin River Basin in Oregon. **The results of the studies for Portland and Seattle will be used by their respective utilities to guide long-range planning decisions in PNW's two largest metropolitan areas.**
• **Climate change impacts on the Pacific Northwest ski industry.** At the request of several PNW ski resort owners, the CIG developed scenarios of possible climate change impacts on snow conditions and recreational ski resorts.

**Engaging Stakeholders**

• **Annual climate and streamflow forecast meetings.** Since 1998, the CIG has conducted annual workshops on seasonal forecasts for climate and water resources. Well attended (80-100 persons per year) and highly regarded, the workshops are cited by public, private, and tribal PNW water resource managers as one of the most helpful educational opportunities they encounter. Agencies represented at these meetings have included: Bonneville Power Administration; the Columbia River Intertribal Fish Commission; Washington Departments of Ecology and Fish and Wildlife; Idaho Departments of Water Resources and Agriculture; Idaho Power Company; National Park Service; National Weather Service; Natural Resources Conservation Service (USDA); Northwest Power Planning Council; US Army Corps of Engineers, Bureau of Reclamation, and Environmental Protection Agency; and numerous Pacific Northwest city and county water and electric utilities.

• **Workshops on climate impacts on salmon recovery planning and harvest management.** The CIG held two well-attended workshops on the impacts of climate variability and change on PNW salmon recovery planning and harvest management. The workshops brought together PNW resource managers and technical level staff from federal, state, tribal, and local level resource management agencies, public/private utilities, and other interested parties to discuss integrated climate/salmonid ecology and the connection to management and policy in (1) short-term harvest, allocation, and hatchery production and operations decisions, and (2) long-term recovery planning activities.

• **Regional education about climate variability and change.** The CIG has developed and maintains an extensive education and outreach program intended to facilitate ongoing dialogue between the CIG and its stakeholders. Outreach activities include meetings and workshops; presentations, guest lectures, and briefings at local, regional, national, and international meetings; consultancies and technical assistance; work with the media; instructing academic courses at the University of Washington; and weekly CIG seminars. Recent examples of all these activities are available at [http://www.cses.washington.edu/cig/outreach/outreach.shtml](http://www.cses.washington.edu/cig/outreach/outreach.shtml).

  o As a result of the CIG’s work, for example, the PNW water management community has become well versed in the water management issues associated with interannual climate variability and change, and understands and interprets climate forecasts and climate information for their systems and customers. When climate change is discussed, water managers talk knowledgeably about regional warming, loss of snowpack, and the potential for water resources impacts due to reduced water availability in summer.

  o Water resource managers at public and private sector hydropower marketing agencies (e.g., Seattle City Light and Bonneville Power Administration) and small municipal water management agencies (e.g., Seattle Public Utilities and
Portland Water Bureau) use information on climate variability to inform power marketing decisions, for example.

- Fisheries managers, including those at the Washington and Oregon Departments of Fish and Wildlife and the Federally-established North Pacific Fishery Management Council, now routinely refer to the PDO in discussions of allowable catch. NOAA Fisheries, in both the Alaska Fisheries Science Center and the Northwest Fishery Science Center, is paying close attention to the PDO and ecosystem regime shifts; "regime-shifts" are one of the key issues behind a new NOAA Fisheries research initiative called "Fisheries and Their Environments (FATE)."

- Various operational forecasting agencies, such as the USDA Natural Resources Conservation Service and the National Weather Service’s Northwest River Forecast Center, pay more attention to climate forecasts now than five years ago. For example, they all have sections in their web sites on ENSO, due in part to the CIG outreach program.

- **Climate and Water Policy meetings.** The CIG convened high-level meetings with key policymakers and water agency directors in July 2001 and May 2002 to discuss the implications of climate change for PNW water management. A significant outcome of the meetings has been increased participant understanding of climate change impacts and recognition of the need to consider strategies for adapting to climate change. Participants included: state water directors (Idaho Department of Water Resources, Oregon Water Resources Department, and Washington Department of Ecology); state legislative chairs (Idaho State House and Senate Resources Committees, and Washington Senate Environment, Energy, and Water Committee); senior analysts for the Northwest Power Planning Council; tribal members and resource management staff (Confederated Tribes of the Colville Reservation, Confederated Tribes of the Warm Springs Reservation); federal agency representatives (National Marine Fisheries Service, U.S. Geological Survey, Bureau of Reclamation); and a senior staffer for U.S. Senator Mike Crapo (ID), among others.

- **Drought workshops.** In response to emerging events, the CIG has held two drought workshops:
  
  - **Washington Water Outlook 2005.** The CIG held a special workshop for regional water resource managers, hydropower interests, fisheries biologists, environmental and science reporters, and others interested in the state’s water outlook to discuss the precedents and implications of the 2005 PNW snowpack, one of the worst in the past 50 years. In addition to evaluating the likely severity and implications of the resultant streamflows, the workshop included a description of the climatic conditions that led to this situation and the likelihood of a reprise. Agency experts also discussed the implications of the evolving drought for the region’s water resources and salmon.
  
  - **Drought preparedness workshop.** CIG held a drought preparedness exercise in September 2001 bringing together Puget Sound municipal water managers to discuss strategies for increasing regional resilience to droughts. The discussion about risks and tradeoffs at the 2001 meeting proved valuable to managers during the fall drought of 2002, when several
utilities instituted voluntary restrictions on water use as a result of several months of record low flows. Participants in the drought workshop included the cities of Seattle, Everett, and Tacoma; King and Snohomish Counties; Washington State Departments of Ecology, Fish and Wildlife, and Natural Resources; the Muckleshoot Tribe; the U.S. Army Corps of Engineers; and the National Marine Fisheries Service.

- **Work With the Media.** The CIG has established an important and valuable working relationship with local and national media. Hundreds of local and national news stories featuring CIG research and researchers have appeared, including:
  - Stories in *San Francisco Chronicle*, *Seattle P-I*, *Idaho Statesman*, *Albuquerque Journal*, *The Oregonian*
  - Featured in radio, television programs (KPLU (88.5 FM), KZOK (102.5 FM), PBS's The NewsHour with Jim Lehrer)
  - An up-to-date listing of major news coverage can be found at: [http://www.cses.washington.edu/cig/about/cignews.shtml](http://www.cses.washington.edu/cig/about/cignews.shtml).

- **Individual presentations and consultations.** CIG team members frequently make presentations to stakeholder groups around the region. Recent audiences include: the University of Idaho Water Resources Research Institute, the planning department of Idaho Department of Water Resources, the King County Council, and Washington Department of Natural Resources.

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**Influencing Operations and Policy**

- **Increased agency interest in planning for climate variability.** In 1995, few regional natural resource managers considered information on or forecasts of climate variability in their management decision making. **Now, due in large part to the CIG's research and outreach efforts, many agencies and management activities incorporate information about regional climate variability.**
  - **Portland General Electric (PGE):** Portland General Electric is a major Pacific Northwest utility serving more than 767,000 retail customers in northwest Oregon and wholesale customers throughout the western United States. PGE made their first ENSO-based streamflow forecast in fall 2004 and has met with CIG to share experiences with PDO/ENSO-based forecasting. PGE has also been a regular participant at the CIG’s annual fall forecast meetings.
  - **Western States Water Council (WSWC):** The significance of climate for water management and the CIG’s work with state and federal water resource managers on issues related to climate and water supply planning (particularly drought) were explicitly mentioned by Washington and Idaho water managers at the September 2004 Western States Water Council meeting in Salt Lake City, Utah. The WSWC is a subcommittee of the Western Governors Association.
- **Seattle Public Utilities**: Seattle Public Utilities now incorporates ENSO/PDO information and forecasts into their seasonal water supply planning, a method learned from CIG.

- **USDA Natural Resources Conservation Service (NRCS)**: The Natural Resources Conservation Service evaluates the climate-based long-lead seasonal streamflow forecasts developed by the CIG for inclusion in their forecast guidance.

- **Supporting watershed planning**: The CIG continues to offer technical assistance to watersheds participating in Washington State’s Watershed Planning Program. In addition to presentations and handling specific information requests, the CIG drafted language on the impacts of climate variability and change for use in watershed plans. The language, which is written for each hydrologic basin type (rain dominant, transient, and snow dominant), has been posted on the CIG’s web site for use by the watershed planning units and incorporated into several plans. [http://www.cses.washington.edu/cig/fpt/watershedplan.shtml](http://www.cses.washington.edu/cig/fpt/watershedplan.shtml)

- **Pacific fisheries management agencies**: Information about PDO and ecosystem regime shifts, and more generally climate variability and its influence on marine ecosystems, is now a regular part of assessment reports produced by Pacific fisheries management agencies, including the International Pacific Halibut Commission; International Pacific Salmon Commission; North Pacific Fisheries Management Council; Pacific Fisheries Management Council; and Alaska, Washington, and Oregon Departments of Fish and Wildlife.

- **Supporting energy utilities’ efforts to incorporate information about climate into operations**:
  - **Tacoma Power**: Tacoma Power, a publicly owned utility that owns and operates four hydroelectric projects in western Washington, has asked the CIG for seasonal forecasts or guidance about inflows (either long-term or short-term) into their reservoirs for water management planning. Tacoma Power has been a regular participant at the CIG’s annual fall streamflow forecast meetings.

  - **Climate-Energy Utilities Round Table**: Puget Sound Energy, a major gas and electricity utility in central Washington, invited the CIG to give a presentation on the implications of climate change for the PNW hydropower and energy demand at a working session with 35 members of the PSE executive team. PSE was specifically interested in considering the ramifications of climate change for the utility’s pricing and operations. This presentation led to the formation of a climate-energy utilities roundtable at the initiative of PSE. The roundtable includes personnel from the CIG and at least four area utilities and meets 2-3 times per year at critical decision periods to talk about climate, climate change, and the energy industry.

  - **Integrating climate impacts into US Army Corps of Engineers project planning and evaluation**: The US Army Corps of Engineers’ Seattle District Office has requested the CIG’s assistance in developing national guidance for
the Corps on incorporating analysis of climate change impacts into the Corps’ work.

- **Increased stakeholder interest in planning for climate change.** In 1997, policymakers and other stakeholders saw little need to plan for climate change. **Since 2002, partly in response to media coverage of the CIG’s work and outreach efforts, many agencies and planning efforts are considering climate change.**

  - **Puget Sound Action Team:** The Puget Sound Action Team (PSAT), a partnership of Washington state agencies and tribal and local governments charged with developing and coordinating conservation programs to protect and restore Puget Sound, commissioned the CIG to prepare a report on the projected impacts of climate change on Puget Sound. The PSAT is interested in how climate change will affect salmon recovery, nearshore habitat protection, and other species of concern such as forage fish, orca, and marine birds and wants to make information about these impacts available to decision-makers, opinion leaders and the informed public.

  - **West Coast Governors’ Global Warming Initiative:** The CIG was asked to participate on Washington and Oregon advisory committees for the West Coast Governors’ Global Warming Initiative, a regional greenhouse gas reduction initiative announced by the governors of California, Oregon, and Washington in September 2003. The CIG was asked to write a high-level briefing memorandum on PNW climate impacts for the three governors’ offices. The CIG and CIG’s research was mentioned specifically in the November 2004 “West Coast Governors’ Global Warming Initiative Staff Recommendations to the Governors”, a report prepared by the Executive Committee of the West Coast Governors’ Global Warming Initiative.

  - **USACOE ESA analysis for white sturgeon at Libby Dam:** The US Army Corps of Engineers requested information from the CIG on the projected impacts of climate change on Columbia River streamflow at Libby Dam as part of a Section 7 ESA consultation with the US Fish and Wildlife Service. The CIG was able to quickly provide a brief memo to the Corps discussing the projected changes using the climate-adjusted streamflows from the CIG’s on line streamflow scenarios tool.

  - **USDA Forest Service:** The USDA Forest Service Pacific Northwest and Rocky Mountain Research Stations, in conjunction with the Western Forestry and Conservation Association, are sponsoring a meeting entitled “Bringing Climate into Natural Resource Management.” The conference will “present developments in the area of climate change impacts and engage natural resource professionals in determining management responses for natural resources” and will draw on research and researchers from the CIG.

  - **Idaho Department of Water Resources:** At the urging of, and in partnership with the CIG, the Idaho Department of Water Resources (IDWR) is examining the implications of climate change streamflow scenarios for their planning. IDWR is providing data and consultation to the CIG, who is developing hydrologic planning models to analyze the implications of climate
change for Idaho water resources. The ultimate objective is to transfer these tools to IDWR for in-house analysis.

- **Northwest Power and Conservation Council:** At the urging of, and in partnership with the CIG, the Northwest Power and Conservation Council is working to incorporate streamflows from future climate scenarios in their hydrological planning tools. The Council is devoting a section of their 5th power plan to climate change, focusing on the implication of the streamflow scenarios for the power system.

- **North Pacific Research Board:** Climate change was added to the North Pacific Research Board’s Strategic Plan for physical/biological and human dimensions research to encourage systematic study [à la CIG] in the North Pacific.

- **The Future Water Needs Task Force for the Washington State Governor’s Central Puget Sound Water Initiative** recognized the potential impacts of climate change on Pacific Northwest snowpack and run-off, recommending “that the State initiate a targeted research effort to evaluate the potential impacts to water supplies in the region. Academic institutions in partnership with the State and local governments and utilities in the region should conduct this effort” (Future Water Needs Task Group Report, 2002, p.6).

- **Private sector and environmental organizations** demanded that the Oregon State Water Department include climate change in long-term planning as a result of media coverage of the CIG’s work on projected impacts on future water supply.

- **The Columbia River Intertribal Fisheries Commission** (CRITFC) has developed an alternative operating plan for the Columbia River water resources management system for use in a future world affected by climate change based on the CIG’s streamflow projections. The CIG and CRITFC are collaborating on a research project aimed at better understanding climate impacts on chinook salmon marine survival and growth rates.

- **City of Seattle:** As a result of a briefing by the CIG, the City of Seattle’s Office of Sustainability is working with Seattle City Light to consider use of the CIG’s climate change information in projecting electricity supply and demand.

- **Washington State’s Watershed Planning Program:** With the CIG’s assistance, several watersheds participating in Washington State’s Watershed Planning Program have begun to incorporate climate variability and change into long-range plans.

- **U.S. Congressional Testimony:** CIG researcher Philip Mote testified before the U.S. Senate’s Committee on Commerce, Science, and Transportation on declining trends in 20th century western U.S. snowpack. Dr. Mote was subsequently contacted by a staff assistant with the Committee with questions from Senator John Kerry concerning potential changes in federal policies to
improve federal agencies’ management of streamflow changes resulting from climate change.

- **US/UK AAAS Climate Change Panel:** At the invitation of Sir David King, Chief Scientific Advisor to the United Kingdom, the CIG participated in a UK/US climate change dialogue in Washington, D.C. and Seattle. The Washington, D.C. event was a Capitol Hill briefing on climate change and its impacts jointly sponsored by the House Science Committee and the American Association for the Advancement of Science (AAAS). This was followed by a U.S.-U.K. climate change dialogue conducted as a special session of the 2004 AAAS annual meeting in Seattle. The latter event generated a significant amount of press coverage for CIG results on potential impacts to snowpack and their implications for the region. These activities have lead to additional work with Sir David King and the UK Hadley and Tyndall Centres.

- **Special Presentation to the Idaho State Legislature Interim Committee on Natural Resources:** This was a one and a half hour presentation specifically on the topic of climate change and water resources. Because it was attended by approximately one quarter of the Idaho State Legislators and received front-page coverage in the *Idaho Statesman*, this presentation was considered a major indication of CIG’s credibility in the Idaho water resource management community. The invitation came from Karl Dreher, Director of the Idaho Department of Water Resources.

- **Washington State Department of Ecology:** At the request of the Department of Ecology, the CIG recently gave a presentation for staff at Ecology’s Bellevue, Washington regional office about climate change impacts on Ecology’s current and future programmatic work. A similar presentation was given at Ecology’s central district office.

- **King County (Washington; includes Seattle)**
  - **Office of the Executive:** Ron Sims, the Executive of King County, partnered with the CIG at a recent press conference to announce a new county initiative for dealing with future water needs in light of both the drought of 2005 and CIG’s climate change projections. This event was covered by National Public Radio, local television news, and had prominent coverage in Seattle and Tacoma newspapers. In addition, the CIG is a member of the committee planning a local community conference to develop a blueprint for climate change adaptation action by local, regional, and state entities, based on the CIG’s regional climate change scenarios.
  - **King County Council:** The CIG has been frequently called upon to brief the County Council about climate change and its local impacts. Recent events include (1) briefing the King County Council’s Committee on Natural Resources and Utilities about CIG research into recent drought conditions and scenarios for future climate and water resources in western Washington and (2) speaking about climate change impacts at a town hall-style County Council meeting.
  - **Department of Natural Resources:** the CIG has been contracted by the science bureau of the King County Department of Natural Resources
to report on the long-term impacts of climate change on water demand and supply for the county.

- **Puget Sound Water Suppliers’ Forum:** The CIG has been briefing the Water Forum, which comprises the regional heads of water agencies, in a series of presentations about climate variability and change. In addition to other work targeting the technical staff of resource agencies, these types of collaboration indicate the CIG’s contact with planners, policymakers, and long-term decision makers.

- **Washington’s Water Storage Task Force** referenced the CIG and climate change impacts in its 2002 discussion of future water storage needs.

- **Washington State Governor:** In his keynote address at a state watershed meeting, Washington State Governor Locke stated that climate change is a major long-term challenge and referenced likely impacts on the PNW derived from the CIG’s research.

- **International Institute for Sustainable Development (IISD):** The International Institute for Sustainable Development has contacted the CIG requesting information on the use of global climate model projections for assessing the impacts of climate change on water supply for hydropower. IISD is currently doing research for a local hydro-electric utility on climate change impact assessment strategies.

- **Skagit River System Cooperative:** The Skagit River System Cooperative (SRSC), a natural resource management agency working to improve fisheries in the Skagit River (Washington) basin on behalf of the Sauk-Suiattle and Swinomish Indian Communities, contacted the CIG to discuss collaborative opportunities. The SRSC is interested in improving understanding of climate impacts on resources of the Skagit River watershed, including juvenile salmon nearshore habitat capacity, productivity, and connectivity; sea level rise effects on nearshore habitats; and maintenance of instream flows for fish.

- **The Nature Conservancy:** The Nature Conservancy of Washington has expressed interest in having the CIG provide input and guidance into their efforts to incorporate climate change scenarios into conservation planning.

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**Contributions to Education**

- **Graduate course on climate impacts in the PNW.** The CIG developed a permanent interdisciplinary University of Washington graduate course (now in its fifth year) that examines the causes and consequences of regional climate variability and change as well as the natural, economic, and institutional contexts in which regional resource management decisions are made. The course is cross-listed among four major university departments: Atmospheric Sciences, Earth System Sciences, School of Marine Affairs, and the Program on the Environment.
• **Graduate seminar on decision-making in the face of uncertainty.** The CIG conducted a university-wide seminar on risk-based decision-making in public sector natural resources management entitled “Decision Making in the Face of Uncertainty: Practitioner Views on Environmental Resource Management Challenges”. The seminar brings public sector natural resource managers to the classroom to discuss how they address uncertainties in the management of PNW resources.

• **Graduate course on the role of science in environmental decision-making.** The CIG developed a new graduate course on “The Role of Science in Environmental Decisions” in collaboration with the University of Washington’s Evans School of Public Affairs. The course is required for the Environmental Management Graduate Certificate Program and is considered a core quantitative course in the Evans School. This course, now in its third year, examines how science contributes to decisions that involve the natural environment: how science and scientists help frame debates and decisions; how scientific findings are incorporated into decision-making processes; how scientists and nonscientists deal with uncertainty about scientific questions. Illustrates the need for accurate representation and critical evaluation of scientific information.

• **Graduate course on integrated assessment.** The CIG developed and taught an advanced graduate course on integrated assessment, applying the techniques and approaches developed by the CIG to marine policy problems. The course was developed in collaboration with the University of Washington’s School of Marine Affairs. This course, now in its second year, is an introduction to the approaches and techniques of integrated assessment, applying the techniques and approaches developed by the CIG to marine policy problems. The objective is to develop the students’ capabilities to link integrated assessment techniques to marine policy problems as part of the developing problematique of sustainability science. The course is offered through the University of Washington’s School of Marine Affairs.

• **New graduate course on climate and PNW forests.** CIG researchers developed a new graduate seminar in the University of Washington’s College of Forest Resources titled “Current topics: Consequences of climate change and climate variability for PNW forests”. The seminar built on previous reviews of climate change and climate variability impacts on forest ecosystems by incorporating a rapidly growing body of recent regional, national, and international research. Discussion emphasized the roles of variability, uncertainty, complexity, and vulnerability of forest ecosystems in adapting to environmental change within the construct of human natural resources management efforts and policy.

• **Graduate course on the science and policy of climate change.** CIG researcher Amy Snover developed and taught a one-week graduate course for masters-level education students as part of Oregon State University’s Hatfield Marine Science Summer Program (held in Newport, Oregon, August 2003).

• **Education for high school teachers.** CIG researchers provided informal support and taught a section on “Impacts of Climate Change on the Pacific Northwest” in Washington State University’s Summer Workshop for regional high school teachers on The Science of Global Climate Change (held in Vancouver, Washington, July 2002).
• **Other graduate courses integrating CIG research.** Several graduate courses at the University of Washington integrating specific aspects of CIG research were repeated during the academic year. Some of these courses were led by CIG researchers; others were led by other University faculty and staff. Courses included the following:

  o **Water Resource System Management and Operations.** This course, offered annually by the University of Washington’s Department of Civil and Environmental Engineering, introduces students to current operations and management issues affecting water resources projects in today’s environment.

  o **Water Resources Planning.** This course, offered annually by the University of Washington’s Department of Civil and Environmental Engineering, introduces students to issues essential to the planning and management of water resources projects in today’s environment.

  o **Marine Protected Area Management and Science.** This course is offered annually by the University of Washington’s School of Marine Affairs to encourage better understanding of the use of Marine Protected Areas (MPA) as management tools in ecosystem management. A key factor pervading the MPA designation and management portion of the course is the effects of climate variability and change. Sensitivity and vulnerability to climate variability and change is, so far, a little recognized element of MPA management concerns.

  o **Environmental Change and Human Health.** This course, offered through the University of Washington’s School of Public Health and Community Medicine, examines the role of environmental change in human disease, including West Nile Fever, SARS, asthma, and cancer.

In addition to research and teaching, CIG researchers are regularly invited to give guest lectures in classes, seminars, and special University-wide speaking engagements.

• **Continuing legal education.** CIG discussed the applicability of climate change information to Washington state land use and environmental law (e.g., regulatory/legal liability issues) for the Washington State Bar Association’s Land Use and Environmental Section.

• **International Conferences on Climate Impacts Assessment.** CIG researchers took a leading role in organizing the First and Second International Conferences on Climate Impacts Assessment. These international meetings on integrated assessment were organized and held by the CIG in Italy in 2002 and Germany in 2004. These conferences, augmented by a list serve, have generated a vibrant network of researchers from around the world and have proven especially helpful for participants from developing countries whose limited means make their international contacts hugely important.

**NOAA Partnerships**

• **Northwest Fishery Science Center (NWFSC)**
o Collaboration on climate and coho life cycle studies in conjunction with scientists at the Alaska and Northwest Fisheries Science Centers. This collaborative effort began with a focus on climate impacts on coho marine survival. Subsequent studies focused first on climate and freshwater productivity for coho, and then a study linking climate variations to the full lifecycle for coho productivity.

o Proposed NOAA/NWFSC initiative on climate change and freshwater ecosystems (CIG, NWFSC, University of Idaho). This is an initiative internal to NOAA Fisheries that aims to integrate NOAA fisheries research into freshwater ecosystems with CIG research into climate impacts on hydrology.

o NOAA/NWFSC Oceans and Human Health Initiative collaboration. The NWFSC was recently awarded a grant as a Center for Excellence in Oceans and Human Health. This will support the development of a new interdisciplinary research program to enhance NOAA's ability to understand the interrelationships among marine ecosystems, climate, and public health. The Center will consist of four core program areas: microbiology, ecotoxicology, marine mammal ecology, and climate impacts. Scientists from the CIG will participate in the climate impacts part of this program by providing expertise in quantifying relationships between large-scale climate variations, local environmental changes, and variations in harmful algal bloom dynamics. The NOAA award will support a CIG postdoctoral fellow to provide climate expertise for the new Center.

o Scientists at CIG are undertaking research funded by NOAA/NWFSC to study the implications of climate change for Snohomish River (Washington) salmon recovery planning. This work is being done in conjunction with the NOAA/NWFSC technical recovery team under the “Shared Strategy” approach to salmon recovery planning.

• **NOAA Climate Diagnostics Center**: Researchers at the CIG and NOAA CDC continue to have a mutually beneficial discussion about the nature and predictability of the Pacific Decadal Oscillation (PDO). CIG hydrologists have implemented the so-called “Schaake Shuffle” (developed by M. Clark et al.) to develop ensemble hydrologic forecasts, based on the CPC official forecasts, in our west-wide hydrologic forecast system described above.

• **NOAA National Climatic Data Center**: CIG research on tree ring chronologies in mountain hemlock in the Cascade Mountains was featured in the National Climatic Data Center's discussion of the paleoclimatic significance of the 2005 drought ([http://www.ncdc.noaa.gov/oa/climate/research/2005/feb/st035dv00pcp200502.html#pal eo](http://www.ncdc.noaa.gov/oa/climate/research/2005/feb/st035dv00pcp200502.html#pal eo)).

**Benefits to Observations**

• The CIG is working with the Natural Resources Conservation Service at their request to define needs for additional real-time climate monitoring stations (or real-time reporting capability for existing climate stations) to be used in CIG’s west-wide
hydrologic forecasts. The objective is to increase the number of stations (in areas that are currently deficient) reporting through the Applied Climate Information System.

- Because **climate monitoring is not of sufficiently high priority**, the number of climate observations being made is inadequate at the same time that existing measurement programs are being allowed to lapse. For example, the Automated Surface Observing System (ASOS) site at Stampede Pass, Washington – the only climate-quality monitoring station in Washington’s Cascade Mountains – is being shut down for budgetary reasons.

- CIG’s research on the regional impacts of large scale modes of climate variability (PDO etc.) indicates that **a climate observing system must both track climate at regional scales and connect it to resource responses** (e.g., snow, water, fish, tree growth, and fire) at regional – and finer – scales.

- **Regional climate observations are a necessary part of bringing regional benefits.** In order to predict and manage climate sensitive resources and we need to be able to monitor and understand regional climate. The regional observing system (ROS) needs to resolve the major scales of regional variability. The ROS is embedded in a large scale network which provides essential global context for the regional climate. The ROS, in turn, contributes to the large scale network. In addition to climate observations, the ROS must keep track of regional streamflow, ecology, land properties, and other quantities needed for risk and resource management. The relationship between regional climate services and global scale climate services can be summarized by the following diagram, with the user at the center: