Center for Science in the Earth System (CSES)

Annual Report

April 1, 2007-March 31, 2008

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Center for Science in the Earth System (CSES) Annual Report

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The Center for Science in the Earth System (CSES) conducts integrated research on the impacts of climate variability and change on the U.S. Pacific Northwest (PNW). It does this by combining and integrating expertise in climate dynamics, hydrology and water resources, forests and aquatic ecosystems, coastal systems, and institutional and policy analysis for the study of PNW climate, impacts, and decision support. The CSES also researches the methodologies for accomplishing climate research, and researches the application of climate information in regional decision-making processes in support of the regional aspects of an eventual national Climate Service. Outreach and education are important elements in making contact with, understanding, and working with our stakeholders.

The CSES comprises two inextricably integrated groups: the Climate Dynamics Group (CDG) and the Climate Impacts Group (CIG). CSES also provides support to the Office of the Washington State Climatologist. *This report highlights recent (April 1, 2007-March 31, 2008) accomplishments made by CSES with respect to climate science and the application of climate information in decision making at different time and spatial scales.*

A more complete summary of CSES activities, organized by research sector and sub-sector research area(s) (or theme) as described in Table 1, and a list of presentations is provided in Appendices A and B. The report also identifies key linkages to other NOAA Regional Integrated Sciences and Assessment (RISA) teams and NOAA programs (Table 2), CSES stakeholders (Table 3), outreach highlights, recent examples of CSES's influence in the region, publications (Appendix C), personnel (Appendix D). The budget justification to support CSES's 2008-09 research year is attached in Appendix E.

Major Highlights of the '07-'08 Reporting Period

The 2007-08 reporting period was a very busy and exciting year for the CSES. The following highlights key research accomplishments, stakeholder collaboration, and tool development during the April 1, 2007 to March 31, 2008 reporting period. Many of projects highlighted here, and others described in Appendix A, have important linkages to other NOAA programs and RISAs as noted in Table 2.

1. Washington State Climate Change Impacts Assessment (IA-1A[1]; ongoing)

On the basis of the core RISA funding and the work done over the last decade on assessing the impacts of climate change on the PNW across four sectors, the CIG was able to leverage $1.5 million in funding over two years from the Washington State Legislature to conduct the most detailed assessment of climate change impacts to Washington State to date. The additional funding, provided through House Bill 1303 (HB 1303), temporarily expands the team's research capabilities while also extending its reach.

The overarching motivating question of the HB 1303 study is: "How will the State of Washington be affected by the range of climate change possibilities over the next century as identified by IPCC AR4, and what mitigation and adaptation strategies are most feasible in the near term (next 10-25 years) and in the medium term (25-50) years?" Research is focused on the following issues and sectors: adaptation and legal barriers,

[1] Research projects are referenced by project code to their appropriate sector and theme (i.e., "IA-1A" for Integrated Assessment, theme 1, project A). Project status is also noted.

Table 1 - CSES Research Sectors and Themes. The following is a summary of the CSES's major research projects (ongoing and completed) for the 2007-08 reporting year organized by sector and research theme. Summary descriptions of each of the listed projects are provided in Appendix A.

Sector	*Related Research Themes*	*Major CSES Research Projects*
Aquatic Ecosystems and Fisheries (AEF)	1. Salmon and Climate	• Effects of Climate on Juvenile Salmon Survival in the Freshwater Environment (AEF-1A) • Modeling Climate Change and Land Use Impacts on Salmon Recovery in the Snohomish River Basin (AEF-1B) • Quantitative Tools for Evaluating the Effects of Climate Change on the Population Dynamics of Pacific Salmon (AEF-1C) • Salmon MALBEC: Modeling Studies to Support Conservation Planning for Pacific Salmon (AEF-1D)
	2. Climate Impacts on Coastal Marine Fisheries	• Improving Rebuilding Plans for Overfished West Coast Fish Stocks Through Inclusion of Climate Information (AEF-2A)
	3. Climate Impacts on Estuaries	• Reconstructing Historical Baselines of the Puget Sound Groundfish and Invertebrate Communities (AEF-3A) • Climate Impacts on Harmful Algal Blooms in the PNW (AEF-3B)
Climate (CLIM)	1. Climate Modeling and Prediction	• Meteorological Processes and Regional Climate Impacts (CLIM-1A) • Climate, Air Quality, and Wildfire (CLIM-1B) • High-resolution Regional Climate Scenarios for Impacts Studies (CLIM-1C) • Analysis of Global Climate Model Projections for the Pacific Northwest (CLIM-1D)
	2. Climate Diagnostics	• Coastal Upwelling: Past, Present, and Future (CLIM-2A) • Early Winter Pacific Northwest Precipitation Forecast Skill (CLIM-2B) • Documenting and Interpreting the Southeast U.S. Drought (CLIM-2C)
	3. Climate Data and Information	• Climate Services Delivery through the Office of the Washington State Climatologist (CLIM-3A)
Coasts (COAST)	1. Watersheds and Ecology	• Anthropogenic Stresses on Marine Ecosystems (COAST-1A)
	2. Coastal Hazards	• Anticipating Sea Level Rise Response in Puget Sound (COAST-2A) • Sea Level Rise in the Coastal Waters of Washington State (COAST-2B)
Forests (FOREST)	1. Climate and Forest Ecosystems	• Direct Impacts of Climate on Forest Growth, Distribution, and Function (FOREST-1A)
	2. Fire and Forest Hydrology	• Landscape Scale Change in Forest Composition and Structure due to Climate Change, Hydrology, Wildfire, and their Interactions (FOREST-2A)
	3. Climate, Disturbance Regimes, and Carbon Dynamics	• Simulating the Effects of Climate-Driven Changes in Disturbance Regimes and Productivity on Net Ecosystem Carbon Balance of Forested Landscapes (FOREST-3A)
Human Dimensions (HD)	1. Climate Impacts on Society and the Economy	• Snake River Economic Model (HD-1A) • Climate Change and the Economics of Ski Resorts (HD-1B)
	2. Effects of Institutional	• Institutions, Adaptation, the Prior Appropriation

	Frameworks on Adaptation to Climate Change	Doctrine, and the Development of Water Markets: Snake and Klamath Institutions (HD-2A)
Hydrology and Water Resources (HWR)	1. Hydrologic Aspects of Climate	• Basin Classification and Hydrologic Sensitivity to Warming for Fine Scale Watersheds in the PNW (HWR-1A) • Hydrologic Effects of 20th Century Warming and Climate Variability in the Western U.S. (HWR-1B) • Reconciling Projections of Future Colorado River Streamflow (HWR-1C)
	2. Regional Hydrologic Forecasting	• UW Surface Water Monitor (HWR-2A) • Streamflow Forecast Calibration (HWR-2B) • Importance of Hydrologic Model Calibration to Seasonal Hydrologic Forecasting (HWR-2C)
	3. Applications to Water Resource Management	• Droughts and Water Shortages: Economic Impacts and Reducing Vulnerability (HWR-3A) • West-Wide Drought Forecasting System: A Scientific Foundation for NIDIS (HWR-3B) • Central Puget Sound Regional Water Supply Planning (HWR-3C)
Integrated Assessment (IA)	1. Horizontally-Integrated Assessment of Climate Impacts	• Washington State Climate Change Impacts Assessment (IA-1A)
Outreach, Education, and Service (OES)	1. Decision Support Products	• Preparing for Climate Change: A Guidebook for Local, Regional, and State Governments (OES-1A) • Adaptation Case Study Database (OES-1B)
	2. Outreach to Stakeholders	• Key CSES Stakeholder Meetings and Web Services (OES-2A) • K-5 Hydrology and Climate Studies (OES-2B)
	3. Climate Advice/Contributions to the Region, Nation, and World	• Advice to Washington State Planning/Adaptation Working Groups (OES-3A) • Service to NOAA (OES-3B) • Other Climate Advice/Service (OES-3C)

Table 2. CSES Research Links to Other NOAA and RISA Programs

Project Code	Project Title	NOAA Program Links	RISA Program Links
AEF-1A	Effects of Climate on Juvenile Salmon Survival in the Freshwater Environment	NOAA Fisheries	
AEF-1B	Modeling Climate Change and Land Use Impacts on Salmon Recovery in the Snohomish River Basin	NOAA Fisheries	
AEF-1C	Quantitative Tools for Evaluating the Effects of Climate Change on the Population Dynamics of Pacific Salmon	NOAA Fisheries Northwest Fisheries Science Center's Fisheries and Their Environment (FATE)	
AEF-2A	Improving Rebuilding Plans for Overfished West Coast Fish Stocks Through Inclusion of Climate Information	NOAA Fisheries Northwest Fisheries Science Center	
AEF-3B	Climate Impacts on Harmful Algal Blooms in the PNW	NOAA Fisheries Northwest Fisheries Science Center's West Coast Center for	

		Oceans and Human Health	
CLIM-3A	Climate Services Delivery through the Office of the Washington State Climatologist	NWS Regional Climate Centers (RCCs), National Climatic Data Center	
FOREST-1A	Direct Impacts of Climate on Forest Growth, Distribution, and Function (FOREST-1A)	Sectoral Applications Research Program (SARP)	Western Water Assessment (WWA), Climate Assessment for the Southwest (CLIMAS)
HWR-1B	Hydrologic Effects of 20th Century Warming and Climate Variability in the Western U.S.		California Applications Program (CAP)
HWR-1C	Reconciling Projections of Future Colorado River Streamflow		CLIMAS, WWA, CAP
HWR-2A	UW Surface Water Monitor	National Center for Environmental Prediction (EMC/CPC), NWS RCCs, CPO (TRACS, CPPA, CDEP)	
HWR-2B	Streamflow Forecast Calibration	NWS Office of Hydrological Development (OHD) and River Forecast Centers	
HWR-2C	Importance of Hydrologic Model Calibration to Seasonal Hydrologic Forecasting	NWS OHD	
HWR-3A	Droughts and Water Shortages: Economic Impacts and Reducing Vulnerability	National Integrated Drought Information System (NIDIS)	
HWR-3B	West-Wide Drought Forecasting System: A Scientific Foundation for NIDIS	NIDIS, CPC	CAP
OES-1A	Preparing for Climate Change: A Guidebook for Local, Regional, and State Governments	NOAA Climate Program Office	
OES-1B	Adaptation Case Study Database		All NOAA RISAs

agriculture, coasts, estuaries, and harbors, energy (hydropower), forests, hydrology and water resources, human health, and salmon and ecosystems. New climate change scenarios were produced to be used by all the issue/sector sub-groups.

The results of the assessment will inform the official planning activities of the State. The CIG has been working closely with the Office of Community, Trade, and Economic Development (in the Governor's Office) and the Washington Dept. of Ecology on this project.

2. Climate Impacts on Harmful Algal Blooms in the PNW (AEF-3B; ongoing/decision support tools developed)

Harmful Algal Blooms (HABs) present a significant health threat for Puget Sound residents and an economic threat to the region's shellfish industry. Paralytic shellfish toxins are produced by the harmful dinoflagellate species *Alexandrium catenella* and accumulate in filter feeding shellfish. Exceptionally toxic events have previously been attributed to large-scale patterns of climate variability, such as El Niño events.

This objectives of this research are to: (1) evaluate the role that climate and oceanographic variability plays in the frequency and distribution of HABs in Puget Sound; (2) quantify the degree to which environmental monitoring and/or prediction can be used to skillfully predict the risks for shellfish-contaminating HAB events in Puget Sound; and

(3) quantify the temporal and spatial patterns of variability in Puget Sound oceanographic properties.

Our quantitative analysis found that a combination of high frequency "weather" events precede toxic events. A sensitivity analysis of environmental precursors was conducted to contribute towards an assessment of the capacity for prediction of paralytic shellfish poisoning risk in Puget Sound.

A set of empirical models have been developed based on relationships between regional climate factors and past HAB events in the PNW region, allowing for an integrated risk assessment for HAB events in Puget Sound. This tool can be linked with weather and tide forecast information, and has the potential to provide risk assessments to lead times of one to several days into the future. This tool may have management applications for decision-support in Washington's Department of Health and the shellfish industry.

3. Development of High-resolution Regional Climate Scenarios for Impacts Studies (CLIM-1C; ongoing)

Climate impacts studies require scenarios of climate change at very high spatial resolution and at temporal resolution of daily or hourly time steps. These scenarios are derived from global climate model projections using downscaling methods. To understand uncertainties in future climate projections, a large ensemble of scenarios based on multiple global climate models and multiple future emissions scenarios is required.

In this project, we are using statistical downscaling are a regional climate model to produce regional climate scenarios to support climate impacts studies. Recent improvements in the techniques include statistical downscaling to 1/16-degree (approximately 6-km) spatial resolution over the PNW. These data are suitable for simulating river flows in very small basins that are important to municipal water supply. Scenarios produced with the regional climate model (dynamical downscaling) are suitable for understanding the impacts of extreme events. All data will be made publicly available over the Internet.

4. UW Surface Water Monitor (HWR-2A; ongoing/decision support tool enhanced)

Over the last decade, great strides have been made in land surface modeling at regional to continental scales. The North American Land Data Assimilation System has developed new approaches for estimating current land surface moisture conditions (e.g., soil moisture, snow and runoff) as well as retrospective reconstructions of the same variables. These science-based products were motivated by a need to improve initialization of numerical weather prediction models, but have many other potential applications both in research and operations.

An experimental effort called the Surface Water Monitor (SWM) has melded these advances into a system serving both objectives in the area of water and potentially drought management. The SWM is a continental U.S. implementation of the Variable Infiltration Capacity hydrologic model that combines a retrospective daily analysis of over 90 years with real-time, daily-updating simulations of land surface climate and moisture conditions. The retrospective dataset provides a foundation for research toward understanding hydrologic trends and variability on a national scale since 1915. It also provides an unusually consistent statistical background for interpreting the real-time moisture estimates, enabling their depiction as anomalies or percentiles with respect to historical conditions.

The real-time percentile maps and predictions have already become an input to national-scale operational drought management efforts such as the US Drought Monitor and the Climate Prediction Center Drought Outlook. The system is also used for prediction at seasonal lead times, enabling the production of operational hydrologic, drought-oriented forecasts that complement those

currently available from operational centers.

Under the NOAA TRACS program funding, the SW Monitor was advanced by the inclusion of 1) real-time cumulative runoff products; 2) real-time drought indices (SPI, Standardized Runoff Index); and 3) weekly updating drought relevant forecasts of soil moisture and runoff (which serve as input to the CPC Drought Briefing and CPC Drought Outlook). The SW Monitor is available at: http://www.hydro.washington.edu/forecast/monitor/index.shtml.

5. Central Puget Sound Water Supply Planning (HWR-3C; research/decision support tool completed)

In February 2005, representatives from more than 20 cities, counties, tribes, state agencies, utility districts, and other organizations in the central Puget Sound (WA) region embarked on a voluntarily effort to identify and compile information on key issues relevant to water supply planning in the region.

The Climate Change Committee was tasked with assessing the impacts of climate change on water demand, water supplies and instream flows. The project involved five phases:

- Phase 1 involved working with Committee members to understand and reach agreement on key aspects of climate change sciences and impacts as it related to the planning process.
- Phase 2 required developing daily temperature and precipitation data for 2025, 2050, and 2075 at select locations in the central Puget Sound region. The analysis used a combination of three different climate models and two different emissions scenarios (IPSL A2, GISS B1 and ECHAM5 A2).
- Phase 3 used the climate change scenarios developed in Phase 1 and a fine-scale hydrologic model to determine how climate change may affect daily streamflow at select locations, particularly inflows into reservoirs serving (or anticipated to serve) as major water supplies.
- Phase 4 required developing a framework that other technical committees could use to estimate the impacts of climate change on municipal water demand and water supply.
- Phase 5 provided a literature review of specific questions raised by the Committee about the possible impacts of climate change on cloud cover and groundwater.

Technical support to the Climate Change Committee was provided by the Climate Impacts Group and graduate students from the University of Washington's Department of Civil and Environmental Engineering.

The Climate Change Committee completed its work in December 2007. A number of keystone products were developed for the effort. These key products include:

- Eight technical memoranda outlining the methodologies used to develop the meteorological and hydrologic climate change scenarios for the Climate Change Technical Committee (Alemu and Palmer 2007; Alexander and Palmer 2007; Alexander et al. 2007; O'Neill and Palmer 2007; Palmer 2007a,b; Polebitski et al. 2007a,b,c);
- A white paper[2] describing 13 fully-referenced climate change "building blocks" about the impacts of climate change on temperature, precipitation, snowpack and glaciers, streamflows, sea level rise, and salmon habitat and populations. The building blocks, which were individually reviewed and agreed upon by committee members, helped bring the committee members to a common level of understanding about climate change and climate impacts.
- An online climate variables database for evaluating climate change impacts on water

[2] Palmer, R.N., M.W. Wiley, A. Polebitski, B. Enfield, K. King, C. O'Neill, and L. Traynham. 2006. *Climate Change Building Blocks*. A report prepared by the Climate Change Technical Subcommittee of the Regional Water Supply Planning Process, Seattle, WA.

resources in King, Snohomish, and Pierce Counties. Products on the website include downloadable meteorological and hydrological data, graphs of projected changes in streamflows at 15 locations in the three-county area, and spatial plots displaying changes in climate over the entire region. All of the products generated by the database can be customized by the user according to climate model, climate parameters (e.g., temperature and precipitation), time step (daily vs. monthly), seasons, and years (e.g., 2000, 2025, 2050, and 2075), among others.

The online database is available at http://www.climate.tag.washington.edu/index.html. Final Committee reports and other project documentation are available at http://www.govlink.org/regional-water-planning/tech-committees/climate-change/index.htm.

6. *Preparing for Climate Change Adaptation Guidebook (OES-1A; research/decision support tool completed)*

The Climate Impacts Group and King County, Washington, in partnership with ICLEI – Local Governments for Sustainability, released *Preparing for Climate Change: A Guidebook for Local, Regional, and State Governments* in September 2007. The guidebook is designed to facilitate planning for climate impacts at the local level by specifying practical steps and strategies that can be used to build community resilience into the future. These steps include creating a climate change preparedness team; identifying community vulnerabilities to climate change; and identifying, selecting, and implementing adaptation options. Questions addressed in the guidebook included:

- How do you scope out the problems of climate change across sectors of your community?
- How do you raise and maintain support to prepare for climate change?
- Whom should you include on a climate change preparedness team?
- What are climate change planning areas, and how do you identify them for your community?
- How do you identify your sensitivity, adaptive capacity, and risk to climate change impacts – i.e., conduct a vulnerability assessment and a risk assessment ?
- How do identify your climate change priority planning areas?
- How do you establish a vision and guiding principles for a climate resilient community in these priority planning areas?
- How do you begin to develop climate change preparedness goals and actions in these priority planning areas?
- How do you develop a climate change preparedness plan?
- How do you ensure that you have the right implementation tools to take your preparedness actions?
- How do you develop measures of resilience to track your progress and update your plans over time, to ensure that your efforts are really making your community more resilient to climate change?

More than 700 copies of the guidebook have been downloaded electronically and more than 300 hard copies distributed around the world. A follow-up survey will be conducted in 2008-2009 to evaluate how effectively the guidebook is being applied at the local level. *Preparing for Climate Change* is available for download at http://www.cses.washington.edu/cig/fpt/guidebook.shtml.

New and Enhanced Decision Support Tools

Decision support is central to the CSES's goal of helping the PNW become more resilient to the impacts of climate variability and change. The following highlights models and decision support tools developed or otherwise improved during the

current reporting period. More details on each project can be found in the projects summaries provided in Appendix B.

- *Salmon MALBEC: Modeling Studies to Support Conservation Planning for Pacific Salmon (AEF-1D):* A working model of the North Pacific salmon ecosystem was developed to serve as a policy gaming tool for potentially exploring the impacts of climate change, hatchery and harvest policies, and changes in freshwater habitat productive capacity at the scale of the North Pacific Ocean.

- *Climate Impacts on Harmful Algal Blooms (HABs) in the PNW (AEF-3B):* A set of empirical models were developed based on relationships between regional climate factors and past HAB events in the PNW region, allowing for an integrated risk assessment for HAB events in Puget Sound. This tool can be linked with weather and tide forecast information, and has the potential to provide risk assessments to lead times of one to several days into the future. This tool may have management applications for decision-support in Washington's Department of Health and the shellfish industry.

- *Office of the Washington State Climatologist trends mapping tool and newsletter (CLIM-3A):* Several tools have been developed or improved in the past year the Office of the Washington State Climatologist, including a climate trends mapping tool for individual locations around the PNW.

- *Sea Level Rise in the Coastal Waters of Washington State (COAST-2B):* A White Paper updating a range of projected sea level rise estimates for three regions of Washington State was produced to support coastal planning needs.

- *Effects of Climate on Juvenile Salmon Survival in the Freshwater Environment (AEF-1A):* Fine scale hydrologic models for the Wenatchee and Salmon basins were applied to assess the impacts of climate change on salmon recovery and planning.

- *UW Surface Water Monitor (HWR-2A):* NOAA TRACS funding was used to enhance the Surface Water Monitor, an online tool providing current and projected changes in soil moisture, snowpack, and streamflow runoff.

- *Central Puget Sound Water Supply Planning documents and database (HWR-3C)*: Eight technical memoranda, white paper, and an online climate variables database for evaluating climate change impacts on water resources in King, Snohomish, and Pierce Counties.

- *Preparing for Climate Change: A Guidebook for Local, Regional, and State Governments (OES-1A):* An adaptation planning guidebook was completed and released free of charge to support adaptation planning at the local scale.

Outreach Highlights: New Levels of Stakeholder Interaction

A major shift in the public's interest in dealing with both climate change mitigation and adaptation has been observed both regionally and nationally over the last few years, resulting in an unprecedented number of information and presentation requests to the CSES from federal, state, and local governments and the general public. Between April 1, 2007 and March 31, 2008, CSES researchers and staff gave over 200 presentations on a variety of topics related to CSES research and PNW climate change impacts. Many of these talks are listed in Appendix B. A sample list of CSES stakeholders is provided in Table 3.

Another notable change for the CSES in the 2007-08 reporting period is the number of staff climate change training sessions in which the CSES has been asked to participate. Beginning in fall 2007, CSES researchers gave ten presentations to U.S. Environmental Protection Agency (EPA) Region X staff and executive team members as part of a "Climate Change 101" lecture series. In February 2008, CSES researchers gave over a dozen presentations at four regional US Fish and Wildlife Service-sponsored "Climate Change 101" staff training sessions held at the Boise (ID), Spokane (WA), Lacey (WA), and Portland (OR) district offices. CSES is currently working with U.S. Forest Service (USFS) staff to plan a similar "Climate Change 101" staff training for USFS staff in May 2008, and was invited to participate in a "Climate Change 101" training workshop for western U.S. staff of The Nature Conservancy (April 2008). These training sessions, along with other meetings and presentations to planning staff around the region, represent an important shift in the region's planning agencies from general interest in climate change impacts to active learning and a focus on building internal capacity at the staff level.

In addition to giving presentations around the region, CSES continued to provide and enhance other core outreach activities, including:

- *CSES annual Climate and Water Fall Forecast Meetings* - Every fall, CSES hosts workshops highlighting the seasonal climate forecast and water resource outlook for the PNW for the upcoming water year. The fall 2007 meetings were held in Olympia, Washington (October 2, 2007) and Boise, Idaho (October 17, 2007) (see Appendix B, OES-2A for more detail); and

- *CSES Website, List-serve, and Online Newsletter* - CSES continues to make improvements to the CSES (i.e., CIG) website (www.cses.washington.edu/cig) to increase its utility as an information source for PNW decision makers and resource managers. This

Table 3 - CSES Stakeholders

Local Level:
Central Puget Sound Water Suppliers' Forum
King County, Washington
City of Olympia, Washington
Puget Sound Energy
Seattle City Council
Seattle City Light
Seattle Public Utilities
Tacoma Power and Light

State Level:
California Dept. of Water Resources
California Energy Commission
Idaho Dept. of Water Resources
Oregon Dept. of Energy
State Governor's Offices *(WA, OR, ID)*
Washington, Oregon, Idaho State Legislatures
Washington Dept. of Community, Trade & Economic Development
Washington Dept. of Ecology
Washington Dept. of Fish and Wildlife
Washington Dept. of Health
Washington Dept. of Natural Resources

Federal Level:
Bonneville Power Administration
National Marine Fisheries Service
National Oceanic and Atmospheric Admin.
U.S. Army Corps of Engineers
U.S. Bureau of Reclamation
U.S. Congress, PNW delegation
USDA, Natural Resource Conservation Service
U.S. Dept. of Energy, Pacific Northwest National Laboratory
U.S. Environmental Protection Agency
U.S. Fish and Wildlife Service
U.S. Forest Service
U.S. Geologic Survey

Other:
BC Hydro
Columbia Basin Trust
Columbia River Inter-Tribal Fish Commission
Idaho Power Company
International Joint Commission *(U.S., Canada)*
National Wildlife Federation
North Pacific Fisheries Management Council
Northwest Power and Conservation Council
Oregon State University
Pacific Climate Impacts Consortium
PNW news media *(print and broadcast)*
University of Idaho
Washington State University Agricultural Extension Service
Wild Salmon Center

includes monthly updates of the PNW climate outlook (http://www.cses.washington.edu/cig/fpt/cloutlook.shtml), continued use of the CSES list-serve for distributing information on CSES research and meetings to more than 800 subscribers, and production of a quarterly electronic newsletter (http://www.cses.washington.edu/cig/outreach/newsletter.shtml).

Research That Makes a Difference

CSES's research over the last decade demonstrating the potential for significant climate change impacts to the PNW continues to influence policy making around the PNW and the nation, as demonstrated in the following recent examples:

1. The State of Washington initiated a multi-stakeholder advisory process in 2007 to develop recommendations on how the state can prepare for the impacts of climate change (see OES-3A). The state is now developing a strategy for implementing the recommendations with technical guidance, where relevant, from CSES. Additionally, Washington House Bill ESHB-2815, passed in March 2008, requires that the Dept. of Ecology consult CSES (via the CIG) within eighteen months of each successive global or national assessment of climate change science for updates on PNW climate change projections. The Dept. of Ecology will use that assessment to determine whether the state's greenhouse gas emissions reduction requirements need to be adjusted.

2. Idaho's State Water Plan, last adopted in 1996, is being updated to address issues related to climate variability and change (among other issues). The State Water Plan is the guiding document for water in the state of Idaho.

3. Very close working relationships have been built with King County (WA) Executive Ron Sims, who is actively integrating the results of the climate change assessments completed with the benefit of core RISA funding into the County's policy development activities. This close collaboration also extends to the ongoing work between CSES and King County on the adaptation planning guidebook written by CSES and King County.

4. Seattle Mayor Greg Nickels and his chief environmental aide have on more than one occasion acknowledged to Edward Miles that the basis for Mayor Nickels's strategy to mobilize the National Conference of Mayors on the issue of climate change (via the US Mayor's Climate Protection Agreement), was heavily influenced by the work of the CSES. To date more than 800 mayors have signed onto the agreement, in which communities pledge to reduce greenhouse gas emissions.

5. Washington State's Puget Sound Partnership, which was established by the Governor to build an Action Agenda to guide Puget Sound protection and restoration, has suggested to the landscape architecture firm of Jones and Jones of Seattle, WA, that they would be willing to fund a collaboration between Jones and Jones and the CSES to integrate CSES climate change scenarios into the watershed scale land use planning work that Jones and Jones will be doing in 2008/09. CSES is pleased not only to collaborate with a firm of such high caliber, but also to open up a new avenue of potential applications for climate information (pending funding).

6. The paper by Miles et al.[3] on the design of a National Climate Service has received a considerable amount of attention nationally.

[3] Miles, E.L., A.K. Snover, L.C. Whitely Binder, E. Sarachik, P.W. Mote, and N.J. Mantua. 2006. An approach to designing a National Climate Service. *Proceedings of the National Academies of Sciences* 103(52):19616–19623.

The basic design recommended in the paper is at present in Senate Bill 2307, which is jointly sponsored by Senators John Kerry of Massachusetts and Olympia Snowe of Maine.

This influence in expected to continue as regional efforts to begin planning for climate change expand.

Looking Ahead

Research in 2008-09 will continue to further the CSES's objective of providing innovative and regionally relevant scientific research on climate, climate impacts, and adaptation in the PNW. Many of the projects highlighted here and in Appendix B of this report are continuing into the 2008-09 reporting year. Many other research projects not reported here are getting underway.

A key deliverable in the upcoming reporting year is completion of the climate change impacts assessment for Washington State (the HB 1303 assessment; IA-1A). In addition to the final report that will be prepared for the State Legislature (December 2008), CSES is planning to host a state-wide meeting on the assessment results for an estimated 1,000 participants in spring 2009. Meteorological and hydrological data produced through the HB 1303 assessment will be made publicly available to support impacts assessment and adaptation planning in the region. Finally, CSES is investigating the possibility of publishing a series of papers based on the HB 1303 assessment in a special issue of the journal *Climatic Change.*

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Another notable area of work in 2008-09 is collaboration with the Climate Prediction Center (CPC) /Climate Test Bed (CTB). In an August 2007 MOU between CSES and CPC, CSES and CPC will look to 1) make continued enhancements to University of Washington's Surface Water Monitor and transition the product to CPC; 2) improve tools and products for the Drought Monitor and Drought Outlook; and 3) test alternative nowcast and forecast methods.

The budget justification to support CSES's 2008-09 research year is attached in Appendix E.

APPENDIX A
CSES PROJECT SUMMARIES

The following project summaries provide a brief overview of many of the research projects CSES researchers and staff have been involved with between April 1, 2007 and March 31, 2008. Projects are broken out by sectors and research themes as follows:

- **Aquatic Ecosystems and Fisheries** (AEF): 1) Salmon and Climate, 2) Climate Impacts on Coastal Marine Fisheries, 3) Climate Impacts on Estuaries
- **Climate** (CLIM): 1) Climate Modeling and Prediction, 2) Climate Diagnostics, 3) Climate Data and Information
- **Coasts** (COAST): 1) Watersheds and Ecology, 2) Coastal Hazards
- **Forests** (FOREST): 1) Climate and Forest Ecosystems, 2) Fire and Forest Hydrology, 3) Climate, Disturbance Regimes, and Carbon Dynamics
- **Human Dimensions** (HD): 1) Climate Impacts on Society and the Economy, 2) Effects of Institutional Frameworks on Adaptation to Climate Change
- **Hydrology and Water Resources** (HWR): 1) Hydrologic Aspects of Climate, 2) Regional Hydrologic Forecasting, 3) Applications to Water Resource Management
- **Integrated Assessment** (IA): 1) Horizontally-Integrated Assessment of Climate Impacts
- **Outreach, Education, and Service** (OES): 1) Decision Support Products, 2) Outreach to Stakeholders, 3) Climate Advice/Contributions to the Region, Nation, and World

Each project summary includes the project title, project code (for cross-referencing), project status (ongoing/completed), primary core funding source (CDEP/RISA), a short summary of the research project, collaborators, and references to in-press or published publications related to the project. CSES publications are listed in Appendix C.

Aquatic Ecosystems and Fisheries

Research in the Aquatic Ecosystems and Fisheries sector is organized around the following general research themes: 1) salmon and climate, 2) climate impacts on coastal marine fisheries, and 3) climate impacts on estuaries. Key research projects completed or ongoing in the reporting period are described under each relevant theme. Presentations for the Aquatic Ecosystems and Fisheries sector are provided in Appendix B.

Theme 1. Salmon and Climate

Project Title:	***Effects of Climate on Juvenile Salmon Survival in the Freshwater Environment***
Project Code:	AEF-1A
CSES Personnel:	Alan F. Hamlet, Nate Mantua
Status:	Ongoing
Core Funding:	CDEP

Summary:	Changing hydrologic conditions associated with climate change have the potential to affect freshwater survival of Pacific Northwest salmonids via a number of impact pathways. Habitat conditions mediate the effects of climate, however, so neighboring populations with differing habitat conditions may differ in their responses to climate change. Here, we explore potential differential responses of the viability of four salmon populations in the Salmon River (ID) and Wenatchee River (WA) basins. For the Salmon River basin populations, we linked predicted changes in air temperature and precipitation from several General Circulation Models to a local hydrological model to project streamflow and air temperature under two climate-change scenarios. We then developed a stochastic, density-dependent life-cycle model with independent environmental effects in juvenile and ocean stages, and parameterized the model for each population. We found that mean abundance decreased 20–50% and the probability of quasi-extinction increased dramatically (from 0.1–0.4 to 0.3–0.9) for all populations in both scenarios. Differences between populations were greater in the more moderate climate scenario than in the more extreme, hot/dry scenario. Model results were relatively robust to realistic uncertainty in freshwater survival parameters in all scenarios. Our results for the Salmon River basin demonstrate that detailed population models can usefully incorporate climate-change predictions, and that global warming poses a direct threat to freshwater stages in these fish, increasing their risk of extinction. Because differences in habitat may contribute to the individualistic population responses we observed, we infer that maintaining habitat diversity will help buffer some species from the impacts of climate change. Currently this work is being extended to the Wenatchee basin in eastern WA using fine scale hydrologic models incorporating stream temperature. Fine scale models are also being developed for several specific sub-basins in the Salmon River basin to help extend and refine the previous studies which used the macro-scale VIC model for hydrologic simulations and regression models for stream temperature.
Collaborators:	NOAA Fisheries Northwest Fisheries Science Center, UW Dept. of Civil and Environmental Engineering
Publications:	Crozier et al. 2008b
Project Title:	***Modeling Climate Change and Land Use Impacts on Salmon Recovery in the Snohomish River Basin***
Project Code:	AEF-1B
CSES Personnel:	Rick Palmer, Matt Wiley
Status:	Completed
Core Funding:	RISA

Summary:	Climate change, as well as changes in land use and stream habitat, may impact the effectiveness of salmon recovery efforts in the Pacific Northwest as warmer temperatures bring more rain and less snow to the region's mountains, earlier (and lower) peak spring runoff, and lower (and warmer) summer streamflows. An innovative collaboration between NOAA and the University of Washington evaluated the effects of future climate change and large scale land use changes on Chinook salmon in the Snohomish River (WA) basin. The study is significant given the potential for climate change to affect the basin's $133.7 million salmon recovery plan. The study used changes in temperature and precipitation derived from climate models to project shifts in streamflow and water temperature in the years 2025 and 2050. The model also accounted for the recovery plan's planned changes in land cover and land use. The outputs from the hydrology and water quality model then served as inputs into a salmon life cycle model that calculated how Chinook salmon might respond to the altered conditions. The analysis found that climate change is likely to decrease the ability to reach salmon population targets established in the recovery plan, although habitat restoration slows the decline and may allow some populations to increase in some sub-basins. Even with implementation of the recovery activities, the average Chinook salmon population was projected to decrease 5-25% by 2050 from current levels. The decline was more dramatic (15- 35%) with no restoration activities, showing the value of the plan's restoration strategies in slowing salmon declines and providing time to adjust future actions. The analysis also demonstrated how salmon recovery planning may need to adjust spatially to compensate for climate change impacts. The impacts of climate change will be most significant in the protected and more pristine higher reaches of the Snohomish River watershed where little additional restoration is possible. Restoration efforts focused on mid-elevation, unprotected areas of the watershed are likely to be more successful in helping to restore salmon populations.
Collaborators:	NOAA Fisheries Northwest Fisheries Science Center; University of Washington Dept. of Civil and Environmental Engineering
Publications:	Battin et al. 2007
Project Title:	***Quantitative Tools for Evaluating the Effects of Climate Change on the Population Dynamics of Pacific Salmon***
Project Code:	AEF-1C
CSES Personnel:	Nathan Mantua, Jessica Beetz
Status:	Ongoing
Core Funding:	CDEP
Summary:	Climate variations during the 20th century are now a widely recognized driver of

Pacific salmon production. In all likelihood, future changes in climate will continue to structure the population dynamics of Pacific salmon. At this time, however, there is a distinct lack of stock specific information on climate impacts over the entire life-cycle of Pacific salmon as most studies concentrate on either the marine or freshwater environments. To date, nobody has explored the interplay of climate change in the oceans, atmosphere, and continental land mass on the population dynamics of Pacific salmon. Therefore, quantitative models linking existing climate change scenarios to changes in Pacific salmon demographics over their entire life cycle are now needed to assess future climate impacts on the viability of salmon populations throughout their range.

Our analysis adopts a life-cycle modeling framework that will allow us to project future population trajectories and estimate viability measures such as annual growth, mean abundance, and probability of extinction. Then, we will incorporate various regional climate change scenarios to develop scenarios for future ocean conditions and for stream temperature and flows. Finally, we will estimate how salmon population viability will respond to climate change scenarios.

Collaborators: NOAA Fisheries Northwest Fisheries Science Center's Fisheries and Their Environment Program

Project Title: ***Salmon MALBEC: Modeling Studies to Support Conservation Planning for Pacific Salmon***

Project Code: AEF-1D

CSES Personnel: Nathan Mantua

Status: Ongoing

Core Funding: CDEP

Summary: We have developed a working model of the North Pacific salmon ecosystem that serves as a policy gaming tool with potential to explore the impacts of climate change, hatchery and harvest policies, and changes in freshwater habitat productive capacity at the scale of the North Pacific Ocean. The model is supported by a data base that includes annual run-sizes, catches, escapements, and hatchery releases for a total of 146 regional stock groups of hatchery and wild pink, sockeye, and chum salmon around the Pacific Rim for the period 1950-2002. These data show that hatchery salmon contribute significantly to overall abundance of salmon in some regions and that hatchery chum salmon abundance has exceeded that of wild chum salmon since the early 1980s. For this historical period, various hypotheses about density-dependent interactions in the marine environment are evaluated based on the goodness-of-fit between simulated and observed annual run-sizes.

While the model does not reproduce the observed data for some specific stock groups, it does predict the same overall temporal production pattern of salmon abundance that was observed by reconstructing run sizes with catch and escapement data alone. Our results to date indicate that simulations that include

	density-dependent interactions in the ocean yield better fits to the observed run-size data than those simulations without density-dependent interactions in the ocean. This suggests that for any level of ocean productivity, the ocean will only support a certain biomass of fish but that this biomass could consist of different combinations of stocks, stock numbers and individual fish size.
Collaborators:	University of Washington School of Aquatic and Fishery Sciences; Natural Resources Consultants; University of British Columbia Fisheries Centre; Pangaea Consulting; Simon Fraser University, School of Resource and Environmental Management; The Wild Salmon Center; University of Montana, Flathead Lake Biological Station.
Publications:	Mantua et al. 2007.

Theme 2. Climate Impacts on Coastal Marine Fisheries

Project Title:	***Improving Rebuilding Plans for Overfished West Coast Fish Stocks Through Inclusion of Climate Information***
Project Code:	AEF-2A
CSES Personnel:	Nathan Mantua
Status:	Ongoing
Core Funding:	CDEP
Summary:	The Magnuson-Stevens Fisheries Conservation and Management Act mandates that overfished fish stocks be rebuilt in as short a time as possible. A key component of a rebuilding plan is a technical rebuilding analysis. Rebuilding analyses determine the trade-off between the time for the stock to recover to the population size at which Maximum Sustainable Yield is achieved, B_{MSY}, and the fishing mortality during the period of rebuilding. However, the results of rebuilding analyses may be impacted by climatic regime shifts that impact both stock productivity and B_{MSY} The aims of this project are to: a) assess whether climate indices can be linked to measures of productivity for fish stocks off the U.S. west coast, and b) modify existing tools for conducting rebuilding analyses to include climate impacts (and their associated uncertainties).
Collaborators:	NOAA's Northwest Fisheries Science Center; NASA's Jet Propulsion Lab

Theme 3. Climate Impacts on Estuaries

Project Title:	***Reconstructing Historical Baselines of the Puget Sound Groundfish and Invertebrate Communities***
Project Code:	AEF-3A
CSES Personnel:	Tim Essington
Status:	Ongoing

Core Funding:	RISA
Summary:	Although human activity has impinged on the Puget Sound ecosystem for years, we have limited understanding about the long-term dynamics of this ecosystem and the roles of human activity therein. This fundamental lack of understanding is now widely acknowledged to be a major impediment to restoring Puget Sound. We seek to collect, organize, and analyze all of the environmental data collected in Puget Sound over the past century, evaluate the cumulative impacts of human activities on this ecosystem, and identify indicator species that can be used to monitor the effectiveness of restoration efforts. This goal is an ambitious one requiring several years of research. Here we aim to initiate the first phase of this endeavor, which will not only provide the essential foundation for our overall goal, but will also produce tangible products that can immediately be used to develop recovery plans. The objectives of this project are to (1) Compile and digitize all possible data on the Puget Sound fish community; (2) Evaluate the data quality for putative "sentinel species" that might serve as ecosystem indicators; (3) Quantitatively analyze the long-term trends in putative indicator species. We focus on the fish and macroinvertebrate community for the simple reason that there is an exceptional amount of data collected on fish and fisheries in Puget Sound.
Collaborators:	University of Washington School of Aquatic and Fishery Sciences, Washington Dept. of Fish and Wildlife
Project Title:	***Climate Impacts on Harmful Algal Blooms in the PNW***
Project Code:	AEF-3B
CSES Personnel:	Nathan Mantua, Stephanie Moore
Status:	Ongoing
Core Funding:	CDEP
Summary:	Paralytic shellfish toxins are produced by the harmful dinoflagellate species *Alexandrium catenella* and accumulate in filter feeding shellfish. Exceptionally toxic events have previously been attributed to large-scale patterns of climate variability, such as El Niño events. This objectives of this project are to: (1) evaluate the role that climate and oceanographic variability plays in the frequency and distribution of Harmful Algae Blooms in Puget Sound; (2) quantify the degree to which environmental monitoring and/or prediction can be used to skillfully predict the risks for shellfish-contaminating HAB events in Puget Sound; and (3) quantify the temporal and spatial patterns of variability in Puget Sound oceanographic properties The results of this research will provide quantitative assessments for the role that local to large scale climate variations play in the frequency and distribution of HAB events in Puget Sound.

	Our quantitative analysis found that a combination of high frequency "weather" events precede toxic events. A sensitivity analysis of environmental precursors was conducted to contribute towards an assessment of the capacity for prediction of paralytic shellfish poisoning risk in Puget Sound. The development of risk assessment tools has potential decision-making applications for Washington's Department of Health and the Puget Sound shellfish industry.
Collaborators:	NOAA Fisheries Northwest Fisheries Science Center's West Coast Center for Oceans and Human Health
Publications:	Moore et al., in press (a) and (b)

Related CSES Projects

The interdisciplinary nature of CSES's research often means that research in one sector supports research objectives in another sector. To that end, the following research projects, described in other sectors of this report, also support the CSES's Aquatic and Ecosystem Fisheries sector research objectives:

- CLIM-2A: Coastal Upwelling: Past, Present, and Future *(related to AEF Theme 2)*
- COAST-1A: Anthropogenic Stresses on Marine Ecosystems *(related to AEF Theme 2)*

Please refer to the project's description for more details on this work.

Climate

Research in the Climate sector is organized around the following general research themes: 1) climate modeling and prediction, 2) climate diagnostics, and 3) climate data and information. Key research projects completed or ongoing in the reporting period are described under each relevant theme. Presentations for the Climate sector are provided in Appendix B.

Theme 1. Climate Modeling and Prediction

Project Title:	***Meteorological Processes and Regional Climate Impacts***
Project Code:	CLIM-1A
CSES Personnel:	Eric Salathé
Status:	Ongoing
Core Funding:	CDEP
Summary:	The U.S. Pacific Northwest is characterized by complex terrain and land-water contrasts, which produce strong spatial gradients in the regional climate and in the atmospheric processes controlling that climate. Global climate models indicate large-scale patterns of change associated with global warming, but they cannot

capture the effects of narrow mountain ranges, complex land/water interaction, or regional variations in land-use. The CSES Climate Impacts Group, in collaboration with researchers in the Department of Atmospheric Science, has developed a state-of-the-art high resolution regional climate model for the Pacific Northwest. This project is aimed at addressing the shortcomings of statistical downscaling and coarse-resolution regional models and account for physical interactions in the climate system at all spatial scales.

Several important climate parameters can only be captured in high-resolution model since they involve fine-scale interactions within the regional climate system. These include the frequency of extreme events such as intense precipitation, heat waves, wind storms, and droughts. Furthermore, modeling land-surface processes, such as snowpack and soil moisture, require simulating the interactions between the atmosphere and land surface over decadal times. These issues are critical to understanding the impacts of climate change on the region.

Collaborators: University of Washington Dept. of Atmospheric Sciences, Pacific Northwest National Laboratory, Washington State University.

Publications: Salathé et al. 2007

Project Title: ***Climate, Air Quality, and Wildfire***

Project Code: CLIM-1B

CSES Personnel: Eric Salathé, Don McKenzie

Status: Ongoing

Core Funding: CDEP

Summary: In this project, we are using an ensemble modeling approach that will address the impacts and uncertainties related to the effects of global change on regional air quality in the U.S. These next steps include:

1) the simulation of an ensemble of climate model forcings and regional modeling simulations with an emphasis on the IPCC range of emissions scenarios;
2) expansion of the current model framework to use WRF/SMOKE/CMAQ for hemispheric simulations to avoid MOZART matchup issues and to provide better consistency between global and US emissions;
3) continuation of the explicit treatment of fire, urban growth, landcover change and landcover management and exploration of their impacts on regional air quality.

Collaborators: Washington State University, National Center for Atmospheric Research, USDA Forest Service, USDA Natural Resources Conservation Service, Colorado State University.

Project Title:	***High-resolution Regional Climate Scenarios for Impacts Studies***
Project Code:	CLIM-1C
CSES Personnel:	Eric Salathé, Todd Mitchell
Status:	Ongoing
Core Funding:	CDEP
Summary:	Climate impacts studies require scenarios of climate change at very high spatial resolution and at temporal resolution of daily or hourly time steps. These scenarios are derived from global climate model projections using downscaling methods. To understand uncertainties in future climate projections, a large ensemble of scenarios based on multiple global climate models and multiple future emissions scenarios is required. In this project, we use statistical downscaling are a regional climate model to produce regional climate scenarios to support climate impacts studies. Recent improvements in the techniques include statistical downscaling to 1/16-degree (approximately 6-km) spatial resolution over the Pacific Northwest. These data are suitable for simulating river flows in very small basins that are important to municipal water supply. Scenarios produced with the regional climate model (dynamical downscaling) are suitable for understanding the impacts of extreme events. Mitchell assisted Seattle City Light in learning how to use downscaled IPCC precipitation estimates.
Collaborators:	Pacific Northwest National Laboratory
Publications:	Salathé et al. 2007

Project Title:	***Analysis of Global Climate Model Projections for the Pacific Northwest***
Project Code:	CLIM-1D
CSES Personnel:	Philip Mote, Eric Salathé
Status:	Ongoing
Core Funding:	CDEP
Summary:	Climate change projections for the Pacific Northwest used for impacts studies are derived from global climate model simulations. As part of the IPCC Fourth Assessment, research centers around the world have completed a suite of climate change simulations and the output from these simulations is publicly available for applied research. The Climate Impacts Group has analyzed simulations from 20 global climate models for the 20th C and projections for the 21st C based on three emissions pathways (SRES A2 A1B and B1). This analysis has enabled us to ascertain the ability of the global models to capture the observed climate of the Pacific Northwest and to compare the projected trends in temperature and precipitation simulated by the various models.

Collaborators:	Washington Dept. of Ecology, Washington Dept. of Community, Trace, and Economic Development
Publications:	Salathé et al. 2007, Mote et al. 2008c

Theme 2. Climate Diagnostics

Project Title:	***Coastal Upwelling: Past, Present, and Future***
Project Code:	CLIM-2A
CSES Personnel:	Todd Mitchell, Nate Mantua
Status:	Ongoing
Core Funding:	CDEP
Summary:	The failure of the 2005 upwelling season along the Oregon and Washington coast focused interest in understanding how large-scale atmospheric climate variability influences upwelling along the west coast of the U.S. and in coastal upwelling regions around the globe. In support of a NOAA-led effort to understand the 2005 upwelling episode, an historical upwelling index was developed from sea-level pressure records, and the index used to document the regional scale of the phenomenon. Studies of the response of low spatial-resolution atmospheric models to increased CO2 concentrations suggest that changes in sea-level pressure would affect coastal upwelling, and analyses of ocean-atmosphere models, as part of the IPCC assessment, have suggested that a slowdown of the tropical circulation has already occurred and is a part of the global warming signature. The slowing down of the circulation is manifested by a weakening of the subtropical highs in the Pacific (associated with the Southern Oscillation), and this weakening might be expected to weaken the coastal upwelling. We are analyzing observations and IPCC model outputs to document changes in the large –scale atmospheric circulation during the upwelling seasons (May-June-July for the Northern Hemisphere, and December-January-February for the Southern Hemisphere). Twentieth century observations and the GFDL CM2.1 simulation show a weakening of the tropical portion of the subtropical highs in the Pacific, and decreased pressure over land in the global upwelling regions, the latter which might enhance upwelling. The GFDL model simulates diminished land pressures and a generally more zonal pattern of pressure changes in the 21st century under increased greenhouse forcing. Calculations with other IPCC models are in progress.
Project Title:	***Early Winter Pacific Northwest Precipitation Forecast Skill***
Project Code:	CLIM-2B
CSES Personnel:	Todd Mitchell, Nate Mantua, Dennis Lettenmaier
Status:	Ongoing

Core Funding:	CDEP
Summary:	As part of a larger project to characterize the skill of hydrological forecasts for regions around the globe, the skill of two-week tropospheric geopotential height (500 hPa) forecasts is evaluated for the Northern Hemisphere extratropics during October-November-December (OND), the calendar months of floods in western Washington. The goal of this work is to document the skill of forecasts of the atmospheric component of the atmosphere-hydrology system, to understand the source of the skill (persistence or the Madden and Julian Oscillation (MJO)), and to evaluate the degree to which ENSO's influence on the large-scale circulation modulates the skill. The present work has been to replicate and update published skill calculations with geopotential height as both the predict and (lead) and predictor (lag) fields for December-January-February, and to repeat the calculation for October-November-December (OND). The skill of both the mechanistic NOAA Reforecast model and an empirical model constructed by canonical correlation analysis are evaluated. The OND skill has been calculated for cold, neutral, and warm ENSO episodes, with the results suggesting that the forecasts are most skillful during warm ENSO episodes (years of diminished PNW precipitation due to ENSO). Future work will finish quantitative assessments of the skill, repeat the calculations using precipitation observations as the predictor field, and repeat the calculations using the outputs of tropical intraseasonal variability (MJO) model forecasts under development by NOAA as the predictand field. Published studies have related MJO variability to western Washington floods, and documenting the limits and opportunities of forecasts at the two-week timescale is extremely useful to planners and the public.
Project Title:	***Documenting and Interpreting the Southeast U.S. Drought***
Project Code:	CLIM-2C
CSES Personnel:	Todd Mitchell, Nate Mantua, Dennis Lettenmaier
Status:	Ongoing
Core Funding:	CDEP
Summary:	Drought conditions befell the southeast U.S. in late 2005 and, depending on the metric, may be continuing. Analyses of monthly precipitation for the southeast were instigated in support of the NOAA Climate Attribution effort headed by Martin Hoerling of NOAA ESRL. Time series of annual precipitation for the region were related to global sea surface temperature (SST) anomalies to identify regions where slowly evolving ocean conditions may be contributing to the drought. Future work is to analyze total column soil moisture output for the region from an hydrological model driven by temperature, precipitation, pressure and other meteorological observations (Justin Sheffield and Eric Wood, Princeton University). Analysis of the 60-year record of the hydrological model will suggest

	the degree to which the drought conditions are contributed to by local processes. Droughts have historically been a feature of the U.S. climate and have dominated the climate of the southwest for the last decade. Future simulations that are part of the Intergovernmental Panel on Climate Change (IPCC) suggest that droughts in the southern U.S. and other parts of the world may be a manifestation of the secular increase in atmospheric CO2 concentrations. Documenting and understanding the processes responsible for present drought conditions will be very useful for water resource planners, and may suggest processes that should be included in future IPCC analyses.

Theme 3. Climate Data and Information

Project Title:	***Climate Services Delivery through the Office of the Washington State Climatologist***
Project Code:	CLIM-3A
CSES Personnel:	Philip Mote, Josiah Mault
Status:	Ongoing
Core Funding:	Other (Washington Dept. of Ecology)
Summary:	In the past year the Office of the Washington State Climatologist (OWSC) has developed or improved several tools that enable users with a range of technical skills to examine and understand patterns of climate variability and change in the Pacific Northwest. One tool, http://www.climate.washington.edu/trendanalysis, developed by the Office of Washington State Climatologist, allows users to plot maps of trends in station data for the whole Pacific Northwest over user-specified intervals, and plot individual time series. This tool aids stakeholders who want to know details of the patterns of climate variability and change, often with specific applications. The OWSC also launched a newsletter for providing updates on Washington State climate events.
Collaborators:	Washington Dept. of Ecology

Coasts

Research in the Coasts sector is organized around the following general research themes: 1) watersheds and ecology, and 2) coastal hazards. Key research projects completed or ongoing in the reporting period are described under each relevant theme. Presentations for the Coastal sector are provided in Appendix B.

Theme 1. Watersheds and Ecology

Project Title:	***Anthropogenic Stresses on Marine Ecosystems***
Project Code:	COAST-1A
CSES Personnel:	Edward Miles
Status:	Ongoing
Core Funding:	RISA
Summary:	This project is looking to develop a place-based research program in the Northeast Pacific focusing on impact of two major stressors in the NE Pacific: 1) ocean acidification, and 2) changing ocean thermal structure. A workshop funded by University of Washington's College of Ocean Fishery Sciences (COFS) was held April 23-24, 2007 at the University of Washington (report available at http://www.uwpcc.washington.edu/documents/PCC/anthropogenicstressesreport.pdf). This workshop led to the creation of a Steering Committee seeking to build a multi-institutional research program focusing on the effects of changing ocean thermal structure and ocean acidification. The Steering Committee consists of Miles (Chair); Jim Murray, UW/Oceanography, Richard Feely, NOAA/PMEL, John Stein, Deputy Director, NOAA Northwest Fisheries Science Center, Mike Sigler, NOAA Alaska Fisheries Science Center, John Guignotte, MBCI, and Brad Warren, former editor of the Pacific Fisherman. In addition to Miles's leadership in the effort, CSES will contribute research on potential changes in coastal upwelling and how this may affect shoaling of acidic waters of the Pacific NE coast, and will investigate what changes in management are necessary to address the coastal impacts of these stresses.
Collaborators:	University of Washington; NOAA Pacific Marine Environmental Laboratory; Northwest and Alaska Fisheries Centers; Marine Biology Conservation Institute; The H. john Heinz Center for Science, Economics and the Environment; and the Joint Institute for Global Change Research, University of Maryland.

Theme 2. Coastal Hazards

Project Title:	***Anticipating Sea Level Rise Response in Puget Sound***
Project Code:	COAST-2A
CSES Personnel:	Alexander (Sascha) Petersen, Edward Miles
Status:	Completed
Core Funding:	RISA
Summary:	When faced with the issues of climate change and sea level rise, decision-makers are unable to wait for scientific uncertainties to be resolved before taking action. Sea level rise predictions are complicated by the complex non-linear nature of the climate system and long-term dependence on human choices. This study analyzes the regulatory and institutional structure surrounding coastal zone management in Puget Sound, Washington, in order to identify barriers to and opportunities for sea level rise response.

	Focusing on local government, four potential sea level rise response options are identified along with associated barriers: 1) increase the update frequency for floodplain maps to more accurately reflect environmental changes; 2) include consideration of a dynamic shoreline when making shoreline armoring, cumulative impacts, and no net loss of ecological function determinations; 3) use shoreline designations in the Shoreline Management Act to tailor responses to the coastal environment; and 4) leverage the Federal Consistency and funding provisions of the Coastal Zone Management Act to enhance response options.
Publications:	Petersen, A. (Sascha) 2007
Project Title:	***Sea Level Rise in the Coastal Waters of Washington State***
Project Code:	COAST-2B
CSES Personnel:	Philip Mote, Alexander (Sascha) Petersen, Lara Whitely Binder
Status:	Completed
Core Funding:	RISA
Summary:	Local sea level rise (SLR) is produced by the combined effects of global sea level rise and local factors such as vertical land deformation (e.g., tectonic movement, isostatic rebound) and seasonal ocean elevation changes due to atmospheric circulation effects. In this document, we reviewed available projections of these factors for the coastal waters of Washington and provide low, medium, and high estimates of local SLR for 2050 and 2100 for the Puget Sound Basin, the central and southern Washington Coast, and the Northwest Olympic Peninsula. Based on the current science, our "medium" estimate of 21st century SLR in Washington is that in Puget Sound, local SLR will closely match global SLR (medium estimate for 2100 for Puget Sound: +13 inches). On the northwest Olympic Peninsula, very little relative SLR will be apparent due to rates of local tectonic uplift that currently exceed projected rates of global SLR (medium estimate for 2100 for the NW Olympic Peninsula : +2 inches). Available data on vertical land movements along the central and southern WA coast suggest that uplift is occurring in this region, leading to a medium estimate for sea level rise in 2100 for this region of +11 inches. Higher estimates (e.g., +50 inches of sea level rise in the Puget Sound region in 2100) cannot be ruled out given the uncertainties over glacial melt rates in Antarctica and Greenland.
Collaborators:	Washington Dept. of Ecology
Publications:	Mote et al. 2008b

Related CSES Projects

The interdisciplinary nature of CSES's research often means that research in one sector supports research

objectives in another sector. To that end, the following research projects, described in other sectors of this report, also support the CSES's Coasts sector research objectives:

- AEF-3B: Climate Impacts on Harmful Algal Blooms in the PNW *(related to COAST Theme 1)*

Please refer to the project's description for more details on this work.

Forests

Research in the Forests sector is organized around the following general research themes: 1) climate and forest ecosystems, 2) fire and forest hydrology, and 3) climate, disturbance regimes, and carbon dynamics. Key research projects completed or ongoing in the reporting period are described under each relevant theme. Presentations for the Forests sector are provided in Appendix B.

Theme 1. Climate and Forest Ecosystems

Project Title:	***Direct Impacts of Climate on Forest Growth, Distribution, and Function***
Project Code:	FOREST-1A
CSES Personnel:	Don McKenzie, Jeremy Littell
Status:	Ongoing
Core Funding:	RISA
Summary:	Stakeholders in Pacific Northwest forests are a diverse group, ranging from the timber industry to forest managers on public lands to outdoor enthusiasts. Principal concerns of these groups include potential declines in forest productivity, changing forest species composition, and loss of wilderness values and biodiversity. We are using basic research in climate-vegetation relationships to provide estimates of future changes to forests of the PNW in direct response to changing climate. Eco-physiological research, using dendrochronology, suggests that Douglas-fir forests in the PNW will become increasingly water-limited as temperatures increase, reducing productivity in montane ecosystems and eventually in low-elevation westside forests. We are developing statistical models of tree species distributions to project changes in forest composition due to warming temperatures, particularly on the east side of the Cascades. We may see substantial shifts to species associated with warmer drier climates. Productivity of high-elevation forests will likely increase, as limiting factors associated with winter temperatures and snowpack decrease in strength. Research at upper treeline suggests a large recent increase in tree seedling establishment at some sites. We are identifying climatic variables associated with the increases and whether decadal climate variability and/or climate change is implicated. Finally, we are using tree-rings and the VIC hydrological model to update, improve and extend hydroclimate reconstructions in the Columbia Basin and the Cascades for water managers. Results to date suggest that land managers, both private and public, will need to

	develop adaptation strategies to manage changing ecosystems. For example, production forests may need to change stand densities to compensate for greater demand for water by growing trees. Public land managers concerned with managing fire or insect risk, habitat for wildlife, or water resources may need to consider active management of non-commercial forests.
Collaborators:	U.S. Forest Service, College of Forest Resources, University of Washington
Publications:	McKenzie et al., in press(a); Littell et al., in press; Cushman et al. 2007

Theme 2. Fire and Forest Hydrology

Project Title:	***Landscape Scale Change in Forest Composition and Structure due to Climate Change, Hydrology, Wildfire, and their Interactions***
Project Code:	FOREST-2A
CSES Personnel:	Richard Gwozdz, Don McKenzie
Status:	Ongoing
Core Funding:	RISA
Summary:	Wildfire disturbance is important in shaping the composition and structure of inland Northwest forests. Climate, in turn, plays a strong role in the shaping the fire regime. In addition, climate is also important in determining the successional trajectory of post-fire forests. As the climate changes, fire regimes and the composition and structure of post-fire forest are likely to change as well. However, predicting how forests will look and function in the future is difficult because of the complex interactions between climate, hydrology, fire, and forest growth. We are linking state of the art models of hydrology (DHSVM) and forest growth (ZELIG) with a new model of wildfire disturbance. This linked suite of models will be driven by data derived from a regional climate model and implemented over a meso-scale watershed in the eastern Cascade Mountains (WA). The coupled models will represent the major feedbacks between climate, hydrology, and fire within the forest system. Thus, these models will provide a method to more fully understand and project the response of forests to climate change. Such projections will aid in the development of adaptation plans for fire, forest, wildlife, and freshwater resource management.

Theme 3. Climate, Disturbance Regimes, and Carbon Dynamics

Project Title:	***Simulating the Effects of Climate-Driven Changes in Disturbance Regimes and Productivity on Net Ecosystem Carbon Balance of Forested Landscapes***
Project Code:	FOREST-3A
CSES Personnel:	Crystal Raymond, Don McKenzie
Status:	Ongoing
Core Funding:	RISA

Summary:	The goal of this research is to develop a landscape model that can incorporate the multiple pathways through which climate change can affect net biome production of Pacific Northwest forested landscapes. The model will allow for testing of alternative disturbance regime scenarios (combinations of harvest and fire severity, frequency, and extent) and changes to net ecosystem productivity (NEP) that may be expected with projected changes in temperature and precipitation in the Pacific Northwest. The model is not intended to make predictions of how disturbance regimes and NEP will change with future climate change, but rather the objective is to compare the relative effects of potential changes in disturbance regimes and productivity on the carbon balance of forested landscapes. The model will incorporate spatial variability of climate change impacts on forest growth and disturbance regimes in the PNW to determine potential future scenarios. The effects of these scenarios can then be evaluated to determine the cumulative impact on carbon stores and fluxes. The scale of the landscapes to be evaluated will be management units (10^4 – 10^6 hectares). Therefore, this research will aid land managers in determining how net biome production within the boundaries of management units may be impacted by future changes in disturbance regimes and productivity. The scale of this analysis will provide information that is conducive to making land management decisions for mitigating and adapting to climate change in forest systems.

Related CSES Projects

The interdisciplinary nature of CSES's research often means that research in one sector supports research objectives in another sector. To that end, the following research projects, described in other sectors of this report, also support the CSES's Forest sector research objectives:

- CLIM-1B: Climate, Air Quality, and Wildfire *(related to FOREST Theme3)*

Please refer to the project's description for more details on this work.

Human Dimensions

Research in the Human Dimensions sector is organized around the following general research themes: 1) climate impacts on society and the economy, and 2) effects of institutional frameworks on adaptation to climate change. Key research projects completed or ongoing in the reporting period are described under each relevant theme. Presentations for the Human Dimensions sector are provided in Appendix B.

Theme 1. Climate Impacts on Society and the Economy

Project Title:	***Snake River Economic Model***
Project Code:	HD-1A

CSES Personnel:	Richard Slaughter, Don Reading
Status:	Ongoing
Core Funding:	RISA
Summary:	The Columbia Basin, consisting of the Snake and Columbia rivers and their tributaries, has come to support intensive utilization for irrigated agriculture and hydropower, and through these activities supports a major portion of the Pacific Northwest economy. One major feature of the Columbia, and more specifically the Snake, is that snowpack is historically significant in relation to total flow. Snowpack provides at least three major benefits: 1) it feeds underground water courses resulting in springs and continuous summer flow in the river; 2) it extends the availability of water over the summer for plants throughout the region; and 3) it provides storage for the irrigation and hydro systems built during the 19th and 20th centuries. Climate change is expected to result in a progressively smaller snowpack, and earlier runoff. In addition to biological and hydrologic effects, because the Snake does not have sufficient storage for total annual flow, earlier runoff will reduce water availability during the summer as well as increasing hydropower production at the time of year when it is least valuable. This project consists of modeling the flow of hydrologic and climate change on the Eastern Snake Plain and its aquifer through to impacts on agriculture and secondary impacts on the economies of the counties that lie above the aquifer. This portion of the Snake contributes approximately 40% of the flow of the Columbia system.
Publications:	Slaughter and Wiener 2007
Project Title:	***Climate Change and the Economics of Ski Resorts***
Project Code:	HD-1B
CSES Personnel:	Don Reading
Status:	Complete
Core Funding:	RISA
Summary:	For ski areas at moderate elevation, the CIG has found that even modest increases in PNW temperature and precipitation as a result of climate change could significantly decrease revenues by shortening the length of the ski season. Warmer winter temperatures projected under climate change imply later opening and earlier closing dates for ski areas. Shorter ski seasons can have a significant impact on the economic viability of ski resorts. Increasingly ski areas are turning to artificial snowmaking in an effort to increase skier days and hence profitability. Depending on the location of the ski area, artificial snowmaking may not be economically viable. Snowmaking requires large amounts of water; it takes 139,322 gallons of water to make an acre-foot of snow. A ‘typical’ ski run of 200 feet wide with a drop of 1,500 feet would take three acre feet of water (55 tanker truck loads) to

	make one foot of snow. If the resort has affordable water available then snowmaking can be economically be used to extend the season. For those ski areas that don't have sufficient water availability, the future will mean coping with shorter ski seasons.
Publications:	Mote et al., in press

Theme 2. Effects of Institutional Frameworks on Adaptation to Climate Change

Project Title:	***Institutions, Adaptation, the Prior Appropriation Doctrine, and the Development of Water Markets: Snake and Klamath Institutions***
Project Code:	HD-2A
CSES Personnel:	Richard Slaughter
Status:	Complete
Core Funding:	RISA
Summary:	The water resource implications of climate change raise the question of how well water institutions in the Western United States might be expected to adapt to changed volume or timing of water flows. Within that context, it would helpful to know what institutional structures are conducive to adaptation, and to what extent new or changed institutions might be required or expected to emerge. This study examines whether the prior appropriation doctrine is a hindrance to change or alternatively provides the legal underpinnings for emerging markets. These questions are examined in the context of a comparison of institutions developed on the Snake River in Idaho and those of the Klamath River in Oregon and California.
Publications:	Slaughter and Wiener 2007

Related CSES Projects

The interdisciplinary nature of CSES's research often means that research in one sector supports research objectives in another sector. To that end, the following research projects, described in other sectors of this report, also support the CSES's Human Dimensions sector research objectives:

- HWR-3A: Droughts and Water Shortages: Economic Impacts and Reducing Vulnerability *(related to HD Theme 1)*

Please refer to the project's description for more details on this work.

Hydrology and Water Resources

Research in the Hydrology and Water Resources sector is organized around the following general research themes: 1) hydrologic aspects of climate, 2) regional hydrologic forecasting, and 3) applications to water resource management. Key research projects completed or ongoing in the reporting period are described under each relevant theme. Presentations for the Human Dimensions sector are provided in Appendix B.

Theme 1. Hydrologic Aspects of Climate

Project Title:	***Basin Classification and Hydrologic Sensitivity to Warming for Fine Scale Watersheds in the PNW***
Project Code:	HWR-1A
CSES Personnel:	Alan F. Hamlet, Rob Norheim
Status:	Complete
Core Funding:	CDEP
Summary:	There is currently great interest in understanding the effects of climate change on smaller scale watersheds in the Pacific Northwest, but comprehensive data bases developed using a consistent set of methods are generally not available for this purpose. In this study we used 1/8th degree gridded data sets of precipitation and temperature and corresponding 1/8th degree VIC simulations of snowpack and runoff to classify the hydrologic type (rain, mixed rain/snow, snowmelt) of each watershed at the Hydrologic Unit Code 4 (HUC4) scale in the PNW, and to quantify the sensitivity of each watershed's snowpack and long-term average hydrograph to several levels of warming both in the historic period and for a simple climate change scenario representing a 2˚C warming over the PNW (i.e. ~mid 21st century). The study products provide a set of regional scale maps showing sensitive mixed rain/snow areas, and Excel data bases for quickly assessing and displaying the streamflow sensitivity to warming of each watershed in the study area.
Collaborators:	University of Oregon Institute for a Sustainable Environment
Publications:	Project report and data bases (*non peer-reviewed*): ftp://ftp.hydro.washington.edu/pub/hamleaf/huc4_climate_change/
Project Title:	***Hydrologic Effects of 20th Century Warming and Climate Variability in the Western U.S.***
Project Code:	HWR-1B
CSES Personnel:	Alan F. Hamlet, Dennis P. Lettenmaier, Philip W. Mote, Eric Salathé
Status:	Ongoing
Core Funding:	CDEP

Summary:	Although in the past climate has frequently been assumed to be stationary in time, it is now widely recognized as an important variable affecting hydrologic processes at a number of different time scales. This improved understanding of the role of climate has resulted in major research initiatives to improve the understanding of climate dynamics and the impacts of climate variability and climate change on various scientific, engineering, and management problems. Understanding past hydroclimatic variability is a central component of this research. Historic observations are the basis for relating climatic variability to hydrologic processes, and provide the foundation for constructing and evaluating hydrologic models based on these physical relationships. Using models, it is possible to more fully analyze the impacts of climate in the observed record, and also to project the impacts of climate forwards in time with lead times ranging from a few months up to a century or more. Given suitable hydrologic simulation models and meteorological driving data sets, another important use of the observed climate record is to produce simulated hydrologic data as surrogates for long-term observations. Such an approach can improve the temporal and spatial resolution of observed hydroclimatic data, provide surrogates for unmeasured variables, and provide a means for more fully evaluating observed changes in climate and hydrologic variability at the regional and river basin scale. The use of models, for example, can facilitate clearly-defined diagnoses and sensitivity analyses that are not possible using observations alone. Models also facilitate the examination of relatively large areas in a consistent manner, avoiding problems with inconsistencies between observing systems, missing data, or other issues frequently encountered in the analysis of observed data. Furthermore, given that neither model simulations nor observations are perfect realizations of the past, corroborating data from both sources greatly strengthens conclusions derived from analysis of the historic record. The project has produced a series of publications exploring the effects of 20th century warming and climate variability on a number of important hydrologic and water resources variables using both observed and simulated data.
Collaborators:	Scripps Institute of Oceanography (California Applications Program)
Publications:	Hamlet and Lettenmaier 2007, Mote et al. 2008a
Project Title:	***Reconciling Projections of Future Colorado River Streamflow***
Project Code:	HWR-1C
CSES Personnel:	Dennis P. Lettenmaier
Status:	Ongoing
Core Funding:	CDEP
Summary:	Within the Upper Colorado River Basin, reductions in naturalized streamflow (water management effects removed) by the mid 21st century have been projected

	to range from 6 to 45% in published studies, and a recent analysis of future P-E (a proxy for runoff) suggests an "imminent transition to a more arid climate in southwestern North America". While the range of projections may be of intellectual interest and stimulate scientific debate, to users and decision makers at the federal level, in the seven basin states, and internationally, providing what appears to be conflicting information on future conditions is a serious impediment to drought and climate change planning. To better understand the reasons for the wide range of projections, we have undertaken a systematic intercomparison of methodologies and models to understand why different modeling approaches produce such different levels of flow reduction. To date, we have evaluated annual elasticities of annual streamflow (fractional change in runoff divided by fractional change in precipitation) as inferred from observations and from three spatially distributed land surface schemes: the Variable Infiltration Capacity (VIC) model, the NOAH land scheme, and a grid-based version of the NWS Sacramento soil moisture accounting model. From the models, we have also evaluated the sensitivity of runoff to temperature changes as fractional changes in annual runoff per °C of (uniform) temperature increase. From observations, the inferred elasticity of the Colorado River discharge at Lees Ferry is about 1.5, whereas the range from the three models is about 1.75 to 1.90. Temperature sensitivities cannot easily be inferred from observations, however the model sensitivities at Lees Ferry range from about 2.2 to 2.85% per °C for equal changes in daily maxima and minima (which implies no change in downward solar radiation in the method used to prescribe model forcings), whereas the range is about 3.3 to 4.1% for a one degree uniform increase in daily temperature when the daily minima were unchanged (constant dew point). Ongoing work is diagnosing the spatial distribution of elasticities and sensitivities across the basin for the three models, and is extending the analysis to other models applied to smaller subcatchments of the Colorado.
Collaborators:	Western Water Assessment, California Applications Project, Climate Assessment for the Southwest (CLIMAS)

Theme 2. Regional Hydrologic Forecasting

Project Title:	***UW Surface Water Monitor***
Project Code:	HWR-2A
CSES Personnel:	Andrew W. Wood
Status:	Ongoing
Core Funding:	CDEP
Summary:	Over the last decade, great strides have been made in land surface modeling at

regional to continental scales. The North American Land Data Assimilation System has developed new approaches for estimating current land surface moisture conditions (e.g., soil moisture, snow and runoff) as well as retrospective reconstructions of the same variables. These science-based products were motivated by a need to improve initialization of numerical weather prediction models, but have many other potential applications both in research and operations.

An experimental effort called the Surface Water Monitor (SWM) has melded these advances into a system serving both objectives in the area of water and potentially drought management. The SWM is a continental U.S. implementation of the Variable Infiltration Capacity hydrologic model that combines a retrospective daily analysis of over 90 years with real-time, daily-updating simulations of land surface climate and moisture conditions. The retrospective dataset provides a foundation for research toward understanding hydrologic trends and variability on a national scale since 1915. It also provides an unusually consistent statistical background for interpreting the real-time moisture estimates, enabling their depiction as anomalies or percentiles with respect to historical conditions. The real-time percentile maps and predictions have already become an input to national-scale operational drought management efforts such as the US Drought Monitor and the Climate Prediction Center Drought Outlook. The system is also used for prediction at seasonal lead times, enabling the production of operational hydrologic, drought-oriented forecasts that complement those currently available from operational centers.

Under the NOAA TRACS program funding, the SW Monitor was advanced by the inclusion of 1) real-time cumulative runoff products; 2) real-time drought indices (SPI, Standardized Runoff Index); and 3) weekly updating drought relevant forecasts of soil moisture and runoff (which serve as input to the CPC Drought Briefing and CPC Drought Outlook). The SW Monitor is available at: http://www.hydro.washington.edu/forecast/monitor/index.shtml.

Collaborators: Climate Prediction Center

Publications: Wood 2008

Project Title: ***Streamflow Forecast Calibration***

Project Code: HWR-2B

CSES Personnel: Andrew W. Wood

Status: Completed

Core Funding: CDEP

Summary: When hydrological models are used for probabilistic streamflow forecasting in the Ensemble Streamflow Prediction (ESP) framework, the deterministic components of the approach can lead to errors in the estimation of forecast uncertainty, as represented by the spread of the forecast ensemble. One avenue for correcting the resulting forecast reliability errors is to calibrate the streamflow forecast ensemble

	to match observed error characteristics. This paper outlines and evaluates a method for forecast calibration as applied to seasonal streamflow prediction. The approach uses the correlation of forecast ensemble means with observations to generate a conditional forecast mean and spread that lie between the climatological mean and spread (when the forecast has no skill) and the raw forecast mean with zero spread (when the forecast is perfect). Retrospective forecasts of summer period runoff in the Feather River basin, California, are used to demonstrate that the approach improves upon the performance of traditional ESP forecasts by reducing errors in forecast mean and improving spread estimates, thereby increasing forecast reliability and skill.
Collaborators:	National Weather Service Office of Hydrological Development
Publications:	Wood and Schaake 2008
Project Title:	***Importance of Hydrologic Model Calibration to Seasonal Hydrologic Forecasting***
Project Code:	HWR-2C
CSES Personnel:	Dennis P. Lettenmaier
Status:	Completed
Core Funding:	CDEP
Summary:	Hydrologic model calibration is usually viewed as a central element of streamflow forecasting based on the Ensemble Streamflow Prediction (ESP) method. Evaluation measures of forecast errors such as root mean squared error (RMSE) are heavily influenced by bias, which in turn is readily reduced by calibration. On the other hand, bias can also be reduced by post-processing -- e.g., "training" bias correction schemes based on retrospective simulation error statistics. This observation invites the question: how much is forecast error reduced by calibration, beyond what can be accomplished by post-processing to remove bias? We address this question through retrospective evaluation of forecast errors at eight streamflow forecast locations distributed across the western U.S. Forecast periods of length ranging from one to six months are investigated, for forecasts initiated from December 1 through June 1, which span the period when most runoff occurs from snowmelt-dominated western U.S. rivers. ESP forecast errors are evaluated both for uncalibrated forecasts to which a percentile mapping bias correction approach is applied, and for forecasts from an objectively-calibrated model without explicit bias correction. Using the coefficient of prediction (*Cp*), which essentially is a measure of the fraction of variance explained by the forecast, we find that the reduction in forecast error as measured by *Cp* that is achieved by bias correction alone is nearly as great as that resulting from hydrologic model calibration.

Theme 3. Applications to Water Resource Management

Project Title:	***Droughts and Water Shortages: Economic Impacts and Reducing Vulnerability***

Project Code:	HWR-3A
CSES Personnel:	Anne Steinemann
Status:	Ongoing
Core Funding:	RISA
Summary:	Drought presents a significant economic risk to Washington State. Indicators are important to monitor and forecast drought conditions, characterize and compare drought severity, and provide a basis for triggering drought responses. Responses are important to reduce drought impacts, and include mitigations and adaptations taken before, during, and after a drought. We are conducting a comprehensive study of drought and water shortages in Washington State to (a) analyze impacts from recent droughts, (b) identify the most vulnerable areas and sectors, (c) develop indicators to monitor and forecast drought conditions, and (d) determine ways to reduce drought vulnerability and impacts in the future. A focus is the economic assessment of drought in the state. A result of this study will be an economic assessment of drought, and the benefits and costs of taking early action to reduce the widespread and long-lasting effects of droughts.
Collaborators:	Washington State Dept. of Community, Trade, and Economic Development; National Integrated Drought Information System
Project Title:	***West-Wide Drought Forecasting System: A Scientific Foundation for NIDIS***
Project Code:	HWR-3B
CSES Personnel:	Anne Steinemann, Andrew Wood
Status:	Ongoing
Core Funding:	RISA
Summary:	Drought is the costliest natural hazard in the U.S., averaging $6-8 billion in damages annually. Forecasts and real-time assessments of drought offer the potential to mitigate drought impacts. However, current drought monitoring systems for the western U.S. lack a predictive component for specific hydrologic indicators. Further, given that hydrologic impacts account for most drought losses, USGS data are essential to making drought forecasts useful. We are developing a drought forecast and nowcast system for the western U.S., which will serve as a scientific framework for prediction and assessment of agricultural (soil moisture) and hydrologic (streamflow) drought in the region. This work, in collaboration with USGS personnel, will provide early warning capabilities and science-based indicators that are critical for the National Integrated Drought Information System (NIDIS), an effort of the Western Governors' Association (WGA), the National Drought Mitigation Center (NDMC), NOAA,

	the USGS, and other agencies. Our work will also contribute to the U.S. Drought Monitor, which currently uses our National Surface Water Monitor, by incorporating USGS data into methods to characterize and forecast drought conditions, persistence, and recovery. Further, we are working directly with water managers in selected states in the region (Washington, California, and others) to apply this forecast system to water resources decisions. Our specific objectives are to (1) implement a version of the Variable Infiltration Capacity (VIC) model that represents near-surface groundwater directly and thus can incorporate USGS well level data; (2) assimilate observations not presently used in the West-Wide system that are highly relevant to drought, such as USGS streamflow data from HCDN and similar stations, soil moisture information, and USGS well data; (3) produce probabilistic forecasts of drought persistence and recovery using ensemble prediction methods that incorporate climate forecasts out to one year; and (4) work with the WGA, the NDMC, and other users, such as state water agencies, to incorporate the resulting drought forecasts and nowcasts into drought information systems and water management decisions.
Collaborators:	U.S. Geological Survey; California Applications Program; National Integrated Drought Information System; NOAA Climate Prediction Center
Project Title:	***Central Puget Sound Regional Water Supply Planning***
Project Code:	HWR-3C
CSES Personnel:	Richard Palmer
Status:	Completed
Core Funding:	RISA
Summary:	In February 2005, representatives from more than 20 cities, counties, tribes, state agencies, utility districts, and other organizations in the central Puget Sound (WA) region embarked on a voluntarily effort to identify and compile information on key issues relevant to water supply planning in the region. The effort focused on seven topics areas, each of which was assigned a committee: water demand forecast, water supply assessment, climate change impacts, reclaimed water, tributary stream flows, source exchange strategies, and small water systems. The Climate Change Committee was tasked with assessing the impacts of climate change on water demand, water supplies and instream flows. Technical support to the Climate Change Committee was provided by the Climate Impacts Group and graduate students from the University of Washington's Department of Civil and Environmental Engineering. A number of keystone products were developed for the effort, including: • Eight technical memoranda outlining the methodologies used to develop the

	meteorological and hydrologic climate change scenarios for the Climate Change Technical Committee; • A white paper describing (published 2006) 13 fully-referenced climate change "building blocks" about the impacts of climate change on temperature, precipitation, snowpack and glaciers, streamflows, sea level rise, and salmon habitat and populations. • An online climate variables database for evaluating climate change impacts on water resources in King, Snohomish, and Pierce Counties. Products on the website include downloadable meteorological and hydrological data, graphs of projected changes in streamflows at 15 locations in the three-county area, and spatial plots displaying changes in climate over the entire region. All of the products generated by the database can be customized by the user according to climate model, climate parameters (e.g., temperature and precipitation), time step (daily vs. monthly), seasons, and years (e.g., 2000, 2025, 2050, and 2075), among others. The online database is available at http://www.climate.tag.washington.edu/index.html. Final Committee reports and other project documentation are available at http://www.govlink.org/regional-water-planning/tech-committees/climate-change/index.htm.
Collaborators:	King County Department of Natural Resources; multiple central Puget Sound water suppliers ; UW Dept. of Civil and Environmental Engineering
Publications:	Alemu and Palmer 2007; Alexander and Palmer 2007; Alexander et al. 2007; O'Neill and Palmer 2007; Palmer 2007a,b; Polebitski et al. 2007a,b,c

Related CSES Projects

The interdisciplinary nature of CSES's research often means that research in one sector supports research objectives in another sector. To that end, the following research projects, described in other sectors of this report, also support the CSES's Hydrology and Water Resources's sector research objectives:

- AEF-1A: Effects of Climate on Juvenile Salmon Survival in the Freshwater Environment *(related to HWR Theme 3)*
- AEF-1B: Modeling Climate Change and Land Use Impacts on Salmon Recovery in the Snohomish River Basin *(related to HWR Theme 3)*
- OES-2B: K-5 Hydrology and Climate Studies *(related to HWR Theme 1)*

Please refer to the project's description for more details on this work.

Integrated Assessment

Research in the Integrated Assessment sector is organized around the general research theme of horizontally-integrated assessment of climate impacts. Key research projects completed or ongoing in the reporting period are described. Presentations for the Integrated Assessment sector are provided in Appendix B.

Theme 1. Horizontally-Integrated Assessment of Climate Impacts

Project Title:	***Washington State Climate Change Impacts Assessment***
Project Code:	IA-1A
CSES Personnel:	All CIG researchers and staff, co-PIs: Ed Miles and Dennis Lettenmaier
Status:	Ongoing
Core Funding:	RISA
Summary:	The CIG, in partnership with Pacific Northwest National Laboratory and Washington State University, is involved in a major research effort to develop an updated climate change impacts assessment for Washington State. The $1.5 million effort focuses on seven key areas: water resources, public health, irrigated agriculture, infrastructure, forests, coasts, salmon. Updated climate change scenarios at a range of scales from state-wide to 15-km grid size were developed for the assessment (see CLIM-1D for additional details). Information on adapting to climate change impacts will also be provided. Funding for the assessment was provided by the Washington State legislature under House Bill 1303 (HB 1303). HB 1303 asks the CIG to examine how climate change will affect the people and resources of Washington State over the next 50 years. Major deliverables include • A report describing how climate change is projected to affect the people and resources of Washington state over the next 50 years, focusing on impacts on water resources, public health, irrigated agriculture, forests, coast lines, and salmon. Where possible, the report will indicate how impacts vary by region across the state and indicate locations of high and low sensitivity to climate change. The report will also characterize barriers to adaptation to these impacts (e.g., legal, institutional) and prioritize areas for future action; and • A web portal providing free access to data, maps, and information indicating projected changes in temperature, precipitation, sea level rise, snowpack, streamflow, agricultural and public health impacts, salmon risk, forest risk, coastal vulnerability. A final report on the HB 1303 assessment is due on December 15, 2008.
Collaborators:	Washington State University; Pacific Northwest National Laboratory; Washington Dept. of Ecology; Washington Dept. of Community, Trade, and Economic Devel.
Publications:	Climate Impacts Group 2007

Outreach, Education, and Service

Outreach, education, and service (OES) are a core function of the CIG and one which involves all members of the team. OES activities at the CIG generally fall within one of the following areas: 1) decision support products, 2) outreach to stakeholders, and 3) climate advice/contributions to the region, nation, and world, as described in the following. Presentations related to OES are provided in Appendix B.

Theme 1. Decision Support Products

Project Title:	***Preparing for Climate Change: A Guidebook for Local, Regional, and State Governments***
Project Code:	OES-1A
CSES Personnel:	Amy Snover, Lara Whitely Binder
Status:	Completed
Core Funding:	RISA
Summary:	Public decision makers have a critical opportunity – and a need – to start preparing for the impacts of climate change. Preparing for climate change is not a "one size fits all" process, however. Just as the impacts of climate change will vary from place to place, the combination of institutions and legal and political tools available to public decision-makers are unique from region to region. Preparedness actions will need to be tailored to the circumstances of different communities. The Climate Impacts Group and King County, Washington, in partnership with ICLEI – Local Governments for Sustainability, released *Preparing for Climate Change: A Guidebook for Local, Regional, and State Governments* in September 2007. The guidebook is designed to facilitate planning for climate impacts at the local level by specifying practical steps and strategies that can be used to build community resilience into the future. These steps include creating a climate change preparedness team; identifying community vulnerabilities to climate change; and identifying, selecting, and implementing adaptation options. More than 700 copies of the guidebook have been downloaded electronically and more than 300 hard copies distributed around the world. A follow-up survey will be conducted in 2008-2009 to evaluate how effectively the guidebook is being applied at the local level. The guidebook is available for download from: http://www.cses.washington.edu/cig/fpt/guidebook.shtml. Funding for publication of the guidebook was provided to ICLEI through NOAA Climate Program Office Grant #NA05OAR4601120.
Collaborators:	King County, Washington; ICLEI- Local Governments for Sustainability
Publications:	Snover et al. 2007

Project Title:	***Adaptation Case Study Database***
Project Code:	OES-1B
CSES Personnel:	Lara Whitely Binder
Status:	Ongoing
Core Funding:	RISA
Summary:	Communities interested in preparing for climate change frequently express the need for examples of how adaptation strategies are being implemented in other communities. To support this need, the CIG is developing an adaptation case study database that will allow interested individuals to search for examples from communities of similar size, climate impacts concerns, and geographic region. The database will be populated through three primary means: 1) Initially, CIG/RISA development of case studies from communities known to be planning for climate change; then through 2) A planned survey of communities that received/downloaded copies of *Preparing for Climate Change: A Guidebook for Local, Regional, and State Government*, through which case studies will be developed by CIG in partnership with willing communities; and 3) Voluntary submittal of case studies by communities to the site. These voluntary submittals will be sought through list-serves and other mechanisms for promoting the site to national and international audiences.
Collaborators:	The NOAA RISA programs

Theme 2. Outreach to Stakeholders

Project Title:	***Key CSES Stakeholder Meetings and Web Services***
Project Code:	OES-2A
CSES Personnel:	CIG Team
Status:	Ongoing
Core Funding:	RISA
Summary:	In addition to the dozens of more individualized meetings CSES researchers have with stakeholders, CSES sponsored or was otherwise involved with the following key stakeholder meetings: • **Fall Forecast Meetings.** Every fall, the CIG hosts workshops highlighting the seasonal climate forecast and water resource outlook for the PNW for the upcoming water year. The information presented at these meetings provides public and private resource managers the opportunity to consider how projected seasonal streamflow levels may affect operational decisions in the PNW. The meetings also provide the opportunity to learn about new water

	resource forecasting techniques and tools. The CIG's fall forecast meetings are open to the public and include a diverse range of participants, including federal, state, and local level water resource managers; public and private electric utility managers; consultants; fish specialists; agricultural specialists; non-profit organizations; and researchers. The fall 2007 meetings were held in Olympia, Washington (October 2, 2007) and Boise, Idaho (October 17, 2007). • **Climate Change 101 Training Sessions.** Beginning in fall 2007, CSES researchers gave ten presentations to U.S. Environmental Protection Agency (EPA) Region X staff and executive team members as part of an EPA-sponsored "Climate Change 101" lecture series. In February 2008, CSES researchers gave over a dozen presentations at four regional US Fish and Wildlife Service-sponsored "Climate Change 101" staff training sessions held at the Boise (ID), Spokane (WA), Lacey (WA), and Portland (OR) district offices. CSES is currently working with U.S. Forest Service (USFS) staff to plan a similar "Climate Change 101" staff training for USFS staff in May 2008, and was invited to participate in a "Climate Change 101" training workshop for western U.S. staff of The Nature Conservancy (April 2008). The CSES also continues to enhance the CSES/CIG web site (www.cses.washington.edu/CIG), the CIG quarterly electronic newsletter (http://www.cses.washington.edu/cig/outreach/newsletter.shtml), and the CIG monthly climate outlook (http://www.cses.washington.edu/cig/fpt/cloutlook.shtml)
Collaborators:	Idaho Department of Water Resources; U.S. Environmental Protection Agency; U.S. Fish and Wildlife Service; U.S. Forest Service
Project Title:	***K-5 Hydrology and Climate Studies***
Project Code:	OES-2B
CSES Personnel:	Alan F. Hamlet
Status:	Ongoing
Core Funding:	CDEP
Summary:	In February, 2008, CIG hydrologist Alan Hamlet prepared a series of demonstrations and lectures on hydrology and climate targeting K-5 students at Salmon Bay Elementary School in Seattle. Using a physical river basin model made of epoxy-covered plywood with a fleece "soil", four elementary school classes explored watershed function and the role of soil and snow as storage mechanisms in PNW watersheds. In a follow on lecture, the classes explored the causes of interannual climate variability and climate change and its implications for snowmelt watersheds. Students measured cool season and warm season runoff for a rain dominant basin, a snowmelt basin with substantial snowpack (represented by Tupperware containers on the slopes of the basin model), and finally for the snowmelt basin in a warmer climate. The model demonstrates the

	loss of water availability in summer associated with snowpack loss in a way that almost anyone can understand. 5th grade students measure runoff from a physical river basin model at Salmon Bay Elementary for a "rain dominant" basin and "snowmelt basin". Although K-5 students have fairly rudimentary math skills, the physical model presents the material in a visual and hands-on manner which make the subject easily accessible to students even at the first grade level.
Collaborators:	Salmon Bay Elementary School, Seattle, WA

Theme 3. Climate Advice/Contributions to the Region, Nation, and World

Project Title:	***Advice to Washington State Planning/Adaptation Working Groups***
Project Code:	OES-3A
CSES Personnel:	Alan Hamlet, Jeremy Littell, Lara Whitely Binder
Status:	Completed
Core Funding:	RISA
Summary:	Under Executive Order 07-02, the Washington Climate Change Challenge, Washington State Governor Christine Gregoire tasked the Washington Department of Community, Trade, and Economic Development (CTED) and Department of Ecology (ECY) to determine what steps Washington needs to take to prepare for the impacts of climate change. To accomplish this task, multi-stakeholder Preparation/Adaptation Working Groups (PAWGs) were created in five key economic sectors: fresh water, agriculture, public health, coasts and infrastructure, and forests. Members included representatives from the public and private sector, non-profit groups, tribes, and the research community. CIG representatives serve on each of the five PAWGs (Agriculture, Coasts and Infrastructure, Forest Resources, Human Health, and Water Resources) to provide future climate projections, scientific information on each sector, and critical reviews of PAWG recommendations. In addition, the CIG contributed climate and adaptation information to the PAWG process. CIG summarized extensive internal and external research on 20th and 21st Century climate and impacts in a document titled "Climate Facts" (Climate Impacts Group 2007). CIG also provided key adaptation principles from the CIG/King County guidebook *Preparing for Climate Change: A Guidebook for Local, Regional, and State Governments* (Snover et al. 2007). Finally, CIG provided updated climate scenarios and sector-specific impact baselines for the final PAWG report, which will be completed in February 2008. The PAWGs concluded their work in December 2007 and a report summarizing their recommendations was presented to the Governor on February 7, 2008. Washington State is now implementing the PAWG recommendations in

consultation with the CIG where appropriate.

Project Title:	***Service to NOAA***
Project Code:	OES-3B
CSES Personnel:	Varies with project
Status:	Varies with project
Core Funding:	CDEP and RISA

Summary:

- *Lettenmaier* - Chair, CPO CPPA core program review, March 2008; Section lead author, U.S. Climate Change Science Program (CCSP) Synthesis and Assessment Product (SAP) 4.3, "Water and Land Resources", lead by USDA (completed March 08); Section lead author, UNESCO World Water Development Report 3 (Section 4.2, "Changes in the Global Water Cycle")
- *Littell and McKenzie* – Authors, U.S. CCSP SAP 4.4 (in review), "Preliminary Review of Adaptation Options for Climate-Sensitive Ecosystems and Resources". Littell was author on Ch.3, McKenzie was author on Ch. 4.
- *Mantua and Wood* – Authors, U.S. CCSP SAP 5.3 (in review), "Decision-Support Experiments and Evaluations Using Seasonal to Interannual Forecasts and Observational Data". Mantua has also been serving as lead author for Ch.2, "A Description and Evaluation of Hydrologic and Climate Forecast and Data Products that Support Decision-making for Water Resource Managers".
- *Miles* –
  - Chaired and co-organized, with Dick Feely (NOAA/PMEL), and Jim Murray (UW/Oceanography) a national meeting on "Anthropogenic Stresses on Marine Ecosystems" on April 23-24, 2007 (program involves the UW, NOAA/PMEL, the NMFS Northwest Fisheries Science Center, and the Alaska Fisheries Science Center, the Marine Conservation Biology Institute, The Heinz Center of Washington, D.C., and the Joint Institute of Global Change Research at the University of Maryland.)
  - On invitation of Chet Koblinsky, attended a CPO meeting in Chicago on May 22, 2007 which was to elaborate the role of NIDIS in a National Climate Service. Chet asked me to present the Miles et al (2006) design of an NCS. In addition, during the meeting, Miles was asked to make a short presentation on how climate change impacts marine ecosystems.
  - In connection with a visit to NOAA HQ in his capacity as supervisor of one of the young recruits in the International Office of the National Ocean Services who is receiving her MMA degree this Spring (the result of a collaborative program between SMA & NOS), Miles was asked to give a seminar in the regular seminar series which is held on Fridays. Miles made a presentation on "Climate Impacts on the World Ocean: The Challenge of Multiple Stresses" on July 19, 2007.
  - On the occasion of the 50th Anniversary of "The Keeling Curve", Jointly sponsored by NOAA and Scripps Institution of Oceanography, Miles was invited to organize and chair a panel of carbon cycle science specialists to address issues of how carbon cycle science could link more effectively to

	decision-makers and the public. o On January 16-18, 2008, Miles and Chet Koblinsky each presented at two panels on the design and implementation of a National Climate Service at the National Council of Science and the Environment annual meeting. • *Mote* - National Integrated Drought Information System (NIDIS) implementation team. • *Wood* - Author, U.S. CCSP SAP 5.3, " Decision-Support Experiments and Evaluations Using Seasonal to Interannual Forecasts and Observational Data", National Research Council *(in review);* Review Panel Member, CDEP ESRL; - CPC Drought Outlook panel member (Drought Briefing contributor); National Weather Service L3MTO reviewer; NWS Hydrologic Ensemble Prediction Experiment (HEPEX) Science Steering Group member, Workshop participant; NOAA TRACS proposal review
Project Title:	***Other Climate Advice/Service***
Project Code:	OES-3C
CSES Personnel:	Varies with project
Status:	Varies with project
Core Funding:	CDEP and RISA
Summary:	• *CIG Team* - University of Washington's "Focus the Nation" event, a day-long teach-in on climate change. Several CSES/CIG members were asked to participate in different panels. (January 2008) • *Hamlet and Whitely Binder* – Columbia Basin Trust "Communities Adapting to Climate Change" advisory committee • *Mantua* - Scientific advisor for the Puget Sound Georgia Basin 2007 annual meeting planning committee; Member of the U.S. CLIVAR Panel on Predictability, Predictions and Applications Interface; Member of the PICES Physical Oceanography and Climate Committee; Lead author for sections 3.2 and 4.1 of *Sound Science: Synthesizing Ecological and Socioeconomic Information about the Puget Sound Ecosystem* (2007). M H Ruckelshaus and M McClure, coordinators; prepared in cooperation with the Sound Science collaborate team. U.S. Dept. of Commerce, National Oceanoic and Anmostpheric Administration (NMFS), Northwest Fisheries Science Center. Seattle, Washington. 93p. • *Miles and Mantua* - received Steve Dettman, newly appointed Manager of the World Wildlife Fund-UK, to discuss and learn how we did our work and what design and procedures might be transferable to the UK situation. His program , The Thames River Climate Change Program, has a key goal of developing a comprehensive adaptation plan for climate change for the entire Thames River Basin. (April 2008) • *Mote* – American Meteorological Society Committee on Climate Variations and Change; Organized a student workshop on climate change at the 2008 AMS annual meeting in New Orleans; UW advisory committee on the National

	Ecological Observation Network; Co-hosted the 2007 annual meeting of the American Association of State Climatologists; Provided testimony on reorienting the U.S. Global Change Research Program toward a user-driven endeavor, May 2007, Rayburn House Office Building, Washington DC. • *Wood* - Goddard, L., A.W. Wood, N. Mantua and K. Jacobs, 2007, Decadal Climate Prediction: Learning from the Oceans. Project Report to California Department of Water Resources.; Reviewer, US Bureau of Reclamation Climate Technical Working Group final report on climate change and water

Related CSES Projects

The interdisciplinary nature of CSES's research often means that research in one sector supports research objectives in another sector. To that end, the following research projects, described in other sectors of this report, also support the CSES's Outreach, Education, and Service's sector research objectives:

- AEF-1C: Quantitative Tools for Evaluating the Effects of Climate Change on the Population Dynamics of Pacific Salmon *(related to OES Theme 1)*
- AEF-1D: Salmon MALBEC: Modeling Studies to Support Conservation Planning for Pacific Salmon *(related to OES Theme 1)*
- CLIM-3A: Climate Services Delivery through the Office of the Washington State Climatologist
- COAST-2B : Sea Level Rise in the Coastal Waters of Washington State
- HWR-2A: UW Surface Water Monitor
- HWR-3A: Droughts and Water Shortages: Economic Impacts and Reducing Vulnerability
- HWR-3B: West-Wide Drought Forecasting System: A Scientific Foundation for NIDIS
- HWR-3: Central Puget Sound Regional Water Supply Planning

Please refer to the project's description for more details on this work.

Appendix B

CSES Presentations

Aquatic Ecosystems and Fisheries

"Predicting differential impacts of climate change at the population level using life-cycle models of spring Chinook salmon", Annual Meeting of the Oregon Chapter of the American Fisheries Society, March 2007, Eugene, OR.

"Climate variability and paralytic shellfish toxins in Puget Sound shellfish". Puget Sound Georgia Basin Research Conference, March 2007, Vancouver, British Columbia, Canada.

"Climate impacts on Puget Sound oceanography". Puget Sound Georgia Basin Research Conference, March 2007, Vancouver, British Columbia, Canada.

"Climate variability and paralytic shellfish toxins in Puget Sound shellfish". University of Washington Climate Impacts Group Seminar Series, April 2007, Seattle, WA.

"Climate variability and paralytic shellfish toxins in Puget Sound shellfish". University of California Santa Cruz Department of Ocean Sciences Seminar Series, April 2007, Santa Cruz, CA.

"Salmon MALBEC: Model for assessing links between ecosystems", Oregon Sea Grant Workshop on Resilience in Salmon Ecosystems, April 2007, Portland OR.

"Investigations of climate impacts on aquatic ecosystems", Faculty Research Highlights Seminar, University of Washington School of Aquatic and Fishery Sciences, April 2007, Seattle, WA.

"Salmon MALBEC: Research in support of conservation planning" (poster), Oregon Sea Grant meeting on Resilience in Salmon Ecosystems, April 2007, Portland OR.

"Climate impacts on salmon at sea - implications for resilience management", Oregon Sea Grant meeting on Resilience in Salmon Ecosystems, April 2007, Portland OR.

"Climate Change impacts on Puget Sound ecosystems", Lyceum Lecture Series, Whidbey Institute, April 2007, Whidbey Island, WA.

"Decadal variations in ENSO and the PDO", DecVar Workshop, April/May 2007, Waikoloa Village, HI.

"Methods for detecting regime shifts in marine ecosystems", University of Washington School of Marine Affairs graduate seminar, May 2007, Seattle, WA.

"Climate change impacts on Columbia Basin fish and wildlife", NW Power and Conservation council, May 2007, Walla Walla WA.

"Investigations of large-scale to local-scale climate impacts on marine ecosystems", QERM seminar, University of Washington, May 2007, Seattle, WA.

"Salmon MALBEC: Model for assessing links between ecosystems", NPIC/American Fisheries Society annual meeting, June 2007, Tacoma WA.

"Climate change, hydrologic systems, and aquatic resources in the PNW: Impacts, adaptation, and mitigation", USFS Aquatics Program Managers, June 2007, Hood River, OR.

"Climate Impacts on Puget Sound oceanography and Harmful Algal Blooms". PICES Early Career Scientists Conference: New Frontiers in Marine Science, June 2007, Baltimore, MD.

"MALBEC: A model for assessing links between ecosystems", Annual Meeting of the North Pacific International Chapter of the AFS, June 2007, Tacoma WA.

"Effects of climate change on Snake River Chinook salmon". The International Environmetrics Society, North American Regional Meeting, July 2007, Seattle, WA.

"Modeling climate change impacts on PNW salmon". NOAA FATE annual meeting, August 2007, San Jose, CA.

"Climate change impacts on the California Current System" NOAA's Marine Mammal Commission annual meeting, August 2007, Vancouver, WA.

"On the increasing vulnerability of the world ocean to multiple stresses", Rachel Carson Centennial Symposium, September 2007, Pittsburgh, PA.

"A North Pacific scale study to support salmon conservation planning", PICES 16th Annual Meeting, October 2007, Victoria, BC, Canada.

"Incorporating climate information into rebuilding analyses for overfished groundfish stocks". North Pacific Marine Science Organization (PICES) Annual Meeting. October 2007, Victoria, BC, Canada.

"Ecological and evolutionary effects of climate change on Snake River Chinook and Columbia River sockeye salmon". Pacific Salmonid Recovery Conference, November 2007, Seattle, WA.

"Linking models: a framework for evaluating salmon recovery strategies in a Puget Sound watershed". Northwest Fisheries Science Center 75th Anniversary Center-Wide Symposium. December 2007, Seattle, WA.

"Quantifying climate change impacts on population abundance and viability -- lessons from Snake River spring/summer Chinook salmon". American Fisheries Society, Western Division Annual Meeting, May 2008, Portland, OR.

"Climate impacts on paralytic shellfish toxic events for the Washington Coast and Puget Sound Estuary." Ocean Sciences Meeting, Orange County Convention Center, March 2008, Orlando, FL.

Climate

"A regional climate model for the Pacific Northwest." Northwest Weather Workshop, March 2007, Seattle, WA.

"Climate Science", Fourth Annual Transportation Technology and Alternative Energy Conference, May 2007, Redmond, WA.

"Multi-scale Modeling of the Effects of Global Change Upon Regional Air Quality". US EPA Region X "Climate Change 101" lecture series for EPA staff and managers, September 2007, Seattle, WA.

"OWSC/CIG Update". Washington State Department of Ecology headquarters, October 2007, Lacey, WA

"Weather service forecast errors for November-December warm, wet storms," CIG Climate and Water Resource Forecasts for the 2008 Water Year, October 2007, Olympia, WA.

"NCEP 2-Week Forecast Skill for Early-Winter Warm, Wet Storms in the Pacific Northwest", NOAA Climate Diagnostics and Prediction Workshop, October 2007.

"A Regional Climate Model for the Pacific Northwest." Thai Research Fund Climate Change Symposium, January 2008, Bangkok, Thailand.

"Understanding the Climate Drivers of the Pacific Northwest", Climate Change Effects to Fish and Wildlife Resources – US FWS Training, February 2008, Portland OR.

"Understanding the Climate Drivers of the Pacific Northwest", Climate Change Effects to Fish and Wildlife Resources – US FWS Training, February 2008, Boise, ID.

"Two-week forecast skill for October-November-December", 2008 Pacific Northwest Weather Workshop,

February/ March 2008.

Coasts

"PNW climate change and coastal impacts", Climate Change 101 for EPA Staff and Managers, September 2007, Seattle, WA.

"PNW Climate Change and Coastal Impacts", W.S.U. Beach Watchers volunteer training course, September 2007, Port Angeles, WA.

"Climate change impacts to Pacific Northwest coasts", 61st Annual Shellfish Growers Conference, October 2007, Welches, OR.

"Sea Level Rise in the Coastal Waters of Washington State", briefing for City of Olympia on sea level rise, February 2008, Olympia, WA.

"Changes in Climate and Sea Level in Puget Sound", PSNERP Nearshore Science Team (NST) "Science Morning", University of Washington, March 2008, Seattle, WA.

"Sea Level Rise in Puget Sound", Presentation to King County staff, March 2008, Seattle, WA.

"PNW Climate Change and Coastal Impacts", Volunteer training for the 2008 class of Whidbey Island Beach Watchers, March 2008, Coupeville, WA.

Forests

"Climate impacts to Columbia Basin vegetation species distributions " (panel). TNC Climate Change Monitoring Workshop, April 2007. Swauk Valley Ranch, WA.

"Climate impacts on Douglas fir growth and other forest processes." Northwest Pulp and Paper Association Annual Meeting, May 2007, Skamania, WA.

"Climate impacts on the hydrology, glaciers, and forests of Mt. Rainier NP". Mt. Rainer NPS Summer Speaker's Series, July 2007. Mt. Rainer National Park, WA.

"Modeling spatial variation of forest fuel moisture: Integrating effects of terrain and forest structure", Ecological Society of America, August 2007.

"Climate change and forest response in the West ". IJNR Learning Expeditions for Reporters and Editors. September 2007, Mt. Rainer National Park, WA.

"Climate impacts on Douglas-fir growth and other forest processes". NCASI 2007 West Coast Regional Meeting, September 2007, Portland, OR.

"Climate impacts on forest ecosystems of the Interior Columbia Basin" Department of Natural Resources All Hands Meeting, September 2007, Ellensburg, WA.

"Climate change, disturbance, and forest communities in the mountains of the Pacific Northwest", Washington Native Plant Society, January 2008, Seattle, WA.

"Climate change in the Pacific Northwest, with implications for forest management". Family Foresters' Workshop, January 2008, Spokane, WA.

"Climate change and forest management: Some thoughts for the Sierra Nevada". Forest Management Conf., February 2008, Reno, NV.

"Climate change, climate variability, and PNW forest ecosystems". Climate Change Training for FWS Staff, February 2008, Spokane, WA

"Climate change, climate variability, and PNW forest ecosystems". Climate Change Training for FWS Staff, February 2008. Boise, ID.

" The Pacific Northwest's Changing Forests", Climate Change Effects to Fish and Wildlife Resources – US FWS Training, February 2008, Portland OR.

"Climate change, climate variability, and PNW forest ecosystems". Montana Wildlife Society & NW Vertebrate Biology Annual Meeting, February 2008, Missoula, MT.

Human Dimensions

"Agricultural impacts of climate change on the Snake River". Idaho Environmental Forum, Annual Boise River Conference, August 2007, Boise, ID.

"Climate Change Economic Impacts on the Middle & Upper Snake River". CIG/Idaho Dept. of Water Resources Annual Climate and Water Forecasts meeting, October 2007, Boise, ID.

"Climate Change Economic Impacts on the Middle & Upper Snake River". Idaho Water Research Symposia 2007, December 2007.

"Climate Change Socioeconomic Impacts East of the Cascades with a Focus on Snake and Boise Basins." U.S. Fish and Wildlife Service "Climate Change101" meeting for staff, February 2008, Boise, ID.

"Climate Change Socioeconomic Impacts East of the Cascades. Focus on Yakima Basin." U.S. Fish and Wildlife Service "Climate Change101" meeting for staff. February 2008, Spokane, WA.

Hydrology and Water Resources

"Understanding the Effects of Climate Change and Climate Variability on River Recreation in the Pacific Northwest". Keynote Speaker, American Whitewater Association Dinner, April 2007, Portland, OR.

"Effects of Climate Change and Climate Variability on USBR Missions in the Western U.S". U.S. Bureau of Reclamation Meeting, April 2007, Boise, ID.

"Understanding the Effects of Climate Change on Water Resources in the Pacific Northwest". Seattle City Light Briefing, June 2007, Seattle, WA.

"Correcting errors in streamflow forecast ensemble mean and spread", NWS Hydrologic Ensemble Prediction Experiment, 3rd Workshop, June 2007, Stresa, Italy.

"Effects of Climate Change on Water Resources in the Pacific Northwest and Western U.S.". United Nations Assembly Meeting, June, 2007, Seattle, WA.

"Optimized Flood Control in the Columbia River Basin for a Global Warming Scenario", Seattle City Light, City Light Seattle, June 2007, Seattle WA.

"PNW climate change and impacts for water", 2007 Water Law conference, June 2007, Seattle, WA.

"Transboundary Implications of Climate Change for the Columbia River Basin". PNW Economic Region Summit Conference, July 2007, Anchorage, AK.

"Implications of Climate Change for Streamflow and Water Quality in the Western U.S." Western States Water Council Meeting, August 2007, Bozeman, MT.

"Climate and water", IEF Annual Boise River Conference, August 2007, Barber Park Education Center, Boise, ID.

"Optimized flood control in the Columbia River Basin for a global warming scenario", 2007 Flood Optimization Workshop, U.S. Army Corps of Engineers Seattle District Office, September 2007, Seattle, WA.

"Development of flood rule curves for the Columbia River Basin conditioned on ENSO climate classification", 2007 Hydrology and Water Resources Symposium, University of British Columbia, September 2007, Vancouver BC.

"Hydrologic Impacts of PNW Climate Change", Washington Hydrological Society (WHS), September 2007, Merecer Island, WA.

"Implications of Climate Change for Freshwater Availability in the Western U.S.", The Nature Conservancy Climate Change Meeting, September 2007, Portland, OR.

"Understanding the Effects of Climate Change on Water Resources in the Pacific Northwest", Snohomish PUD Planning Meeting, September 2007, Everett, WA.

"Understanding the Effects of Climate Change on Water Resources in the Pacific Northwest", Snohomish PUD Planning Meeting (2), October, 2007, Everett, WA.

"Recap of Water Year 2007 Hydrologic Forecast and Forecasts for Water Year 2008", CIG Climate and Water Fall Forecast Meeting, October, 2007, Olympia, WA.

"Climate Change in the Puget Sound: Will it Impact the Region's Water Resources?", Climate Change 101 for EPA Staff and Managers, October 2007, Seattle, WA.

"Climate Change and Water Quality", Ecology Water Quality All-staff Retreat, October 2007, Vancouver, WA.

"Climate change and drought", AWRA state conference, October 2007, MOHAI Seattle.

"Northwest Climate Change and Water Resources", Lake Roosevelt Forum Conference, November 2007, Spokane, WA.

"PNW Climate Change and Impacts for Water", Oregon Water Resources Congress 2007 Annual Conference, November 2007, Hood River, OR.

"Global and Regional Climate Change and Implications for Water", Oregon Water Resources Commission Climate Change Conference, November 2007, Portland, OR.

"Understanding the Effects of Climate Change and Climate Variability on the Water Cycle in the Pacific Northwest". Columbia Basin Trust Community Planning Initiative, November 2007, Cranbrook, British Columbia, Canada.

"Preparing for Climate Change", Columbia Basin Trust Community Planning Initiative, November 2007, Cranbrook, British Columbia, Canada.

"Understanding the Effects of Climate Change and Climate Variability on the Water Cycle in the Pacific Northwest", Columbia Basin Trust Community Planning Initiative Workshop, November 2007, Invermere, British Columbia, Canada.

"Understanding the Effects of Climate Change on Water Resources in the Western U.S.", Carpe Diem Conference, November 2007, Seattle, WA.

"Understanding the Water Resources Impacts of Climate Change in the Pacific Northwest", Seattle Metro Democratic Club Meeting, November 2007, Seattle, WA.

"Implications of Climate Change for the Columbia River Basin", Environmental Law Seminar - The Mighty Columbia, November 2007, Seattle, WA.

"Understanding the Effects of Climate Change on Water Resources in the Western U.S." U.S. Bureau of Reclamation/U.S. Army Corps of Engineers Operational Planning Meeting, November 2007, Portland, OR.

"Hydrologic Implications of Climate Change for the Western U.S." City of Portland Planning Group Seminar, November 2007, Portland, OR.

"Application of LDAS-era land surface models to drought monitoring and prediction". Drought Monitor Forum 2007, Portland, OR.

"Understanding the Engineering Implications of Climate Change for the Western U.S." Class Lecture, University of Washington CEE 440, December 2007, Seattle, WA.

"How Essential is Hydrologic Model Calibration to Seasonal Streamflow Forecasting?", Poster presented at American Geophysical Union Fall Meeting, December 2007, San Francisco, CA.

"Using Climate Forecast Information in Water Resource Planning: Opportunities and Challenges in the Yakima River Basin, Washington." American Geophysical Union Fall Meeting, December 2007, San Francisco, CA.

"Connecting climate, hydrologic and drought predictions to water resources management in Washington State." American Geophysical Union Fall Meeting, December 2007, San Francisco, CA.

"Effects of Climate Change on Water Resources in the Pacific Northwest and Western U.S." WA Public Utilities Conference, December 2007, Seattle, WA.

"December 2007 Chehalis Flood: A climatic perspective", WA State Senate Natural Resources, Ocean & Recreation Committee work session, January 2008, Olympia, WA.

"Understanding the Civil Engineering Implications of Climate Change in the Western U.S.", University of Washington CEE Graduate Seminar, January 2008, Seattle, WA.

"Late 20th Century Precipitation Variability in the Western U.S. in the Context of Long-Term Climate Variability and Global Change", Climate Impacts Group Seminar, January 2008, Seattle, WA.

"Hydrologic Implications of Climate Change for the Western U.S.", Environmental Law Seminars – The Endangered Species Act and Climate Change, January 2008, Seattle, WA.

"Climate Change and NW Hydropower", NWPPA Environmental Task Force Meeting, January 2008, Seattle, WA.

"Hydrology in an Era of Global Change", American Meteorological Society Robert E. Horton Lecture, January 2008.

"Hydrologic Implications of Climate Change for the Western U.S.", Class Lecture, University of Washington CEE 100, February 2008, Seattle, WA.

"Connecting climate forecast information and drought predictions to water resource management: opportunities and challenges in the state of Washington." Water Center Annual Review, February 2008, Seattle, WA.

"Development of Optimized Flood Control Rule Curves for the Columbia River Basin in Response to Climate Change and Interannual Climate Variability", University of Washington, February 2008, Seattle, WA.

"Hydrologic Implications of Climate Change for the Western U.S.", Climate Change Effects to Fish and Wildlife Resources – FWS Training, February 2008, Lacey, WA.

"The Pacific Northwest's Changing Hydrology", Climate Change Effects to Fish and Wildlife Resources – US FWS Training, February 2008, Portland OR.

"The Pacific Northwest's Changing Hydrology", Climate Change Effects to Fish and Wildlife Resources – US FWS Training, February 2008, Boise, ID.

"Climate Change Impacts in Western Washington", Special meeting of the Watershed Committee and Board and interested residents of Lake Margaret Water District, February 2008, Duvall, WA.

"Utility of Seasonal Climate Outlooks for Water Supply Forecasts in Northern California." The Water Center's 18th Annual Review of Research, February 2008, Seattle, WA.

“Effects of Climate Variability and Change on the Columbia River Basin”, Class Lecture, Portland State University Columbia River as a Physical System, March 2008, Portland, OR.

“Drought-relevant information products based on LDAS-era hydrologic modeling”, NOAA Climate Prediction Applications Science Workshop, March 2008, Chapel Hill, NC.

Integrated Assessment/Outreach Education and Service

Presentations for the Integrated Assessment and Outreach, Education, and Service sectors are combined to reflect the fact that many of the general PNW climate impacts outreach presentations reflect the integrated research of CSES.

“Climate Change in the Pacific Northwest: Impacts, Choices, and Change”, University of Puget Sound Sustainability Speaker Series, April 2007, Tacoma, WA.

“Climate Change in the Pacific Northwest: Impacts, Choices, and Change”, American Public Works Association Spring Conference, April 2007, Everett, WA.

“Climate Change in the Pacific Northwest: Impacts, Choices, and Change”, Association of Women in Environmental Professions, April 2007, Seattle, WA.

“Climate Change in the Pacific Northwest: Impacts, Choices, and Change”, Climate Change: Impacting Our Mountains and thus our Environment and what policy makers are doing about it, April 2007, Mazama Climb Center, Portland, OR.

“PNW Climate Change Overview”, Chamber of Commerce meeting on climate change, April 2007, Seattle, WA.

“Climate Change in the Pacific Northwest: Impacts, Choices, and Change”, Department of Ecology Earth Day events, April 2007, Bellevue, WA.

“Global Warming in the Pacific Northwest: Impacts and Implications for Planning at Washington State Department of Ecology”, State Attorney General Ecology Division Retreat, April 2007, St. Andrew's conf center, Union WA (Hood Canal).

“Northwest Climate Change And Some Thoughts About Transportation”, Washington Dept. of Transportation, May 2007, Department of Transportation Headquarters, Olympia WA.

(Discussion only; no presentation), National Association of Science Writers local chapter meeting, Pacific Science Center, May 2007, Seattle, WA.

“Global Climate Change And Some Health Impacts”, PCMS monthly meeting, May 2007, Tacoma, WA.

“Preparing For A Changing Climate - Building The Capacity To Cope With Global Warming”, Lyceum Lecture Series, Whidbey Institute, May 2007, Whidbey Island.

“PNW Climate Change And Transportation Operations And Planning”, Washington Dept. of Transportation (#2), May 2007, Shoreline, WA.

“Climate Change in the Pacific Northwest”, class lecture in ATMS 211, Climate and Climate Change, University of Washington, May 2007, Seattle, WA.

“International Environmental Challenges and Policies”, class lecture in POL3125, International Law, Seattle Pacific University, May 2007, Seattle, WA.

“PNW Climate Change”, University Prep upper school (grades 9-12) science forum, May 2007, Seattle, WA.

Testimony on reorienting the U.S. Global Change Research Program toward a user-driven endeavor, May 2007, Rayburn House Office Building, Washington DC.

"The Climate Impacts Group: Climate science in the public interest", WSU state-wide planning meeting on engaging with the issue of climate change, May 2007, Ellensburg, WA.

"The Impacts Of Climate Change And Their Policy Implications", Mountain Pacific Regional UNA-USA, June 2007.

"Northwest Climate Change", Mt Rainier - training event for interpretive staff, June 2007, Mt Rainier National Park.

Testimony, Hearing for Subcommittee on Water and Power, Senate Committee on Energy and Natural Resources, June 2007, Washington, D.C.

"Northwest Climate Change", Environmental Health & Safety retreat, University of Washington, June 2007, Bothell, WA.

"Northwest Climate Change", Reporting the Climate Change Issue: reporting ahead of the curve, June 2007, Portland, OR

"PNW Climate Change and Why It Matters", Assoc. of Washington Cities annual meeting, June 2007, Tacoma Convention Center, Tacoma WA.

"Northwest Climate Change", Summer Water Law and Resource Issues Seminar, June 2007, Sun Valley, ID.

"Climate Change Impacts on the Pacific Northwest", USFS Regional Aquatics (Watershed and Fisheries) Program Managers, June 2007, Hood River, OR.

"Climate Change", UN Association of North America, Mountain-Pacific Regional Assembly, June 2007, Seattle Pacific University, Seattle, WA.

"PNW Climate Change", Heritage Institute (Antioch College) sustainability education event, June 2007, Seattle, WA.

"The Impacts of Global Climate Change in the Pacific Northwest", Snohomish County Long Range Planning Division, July 2007, Snohomish County, WA.

"Climate Change Impacts on the Puget Sound Nearshore Environment", Kitsap Nearshore Coordination Group quarterly meeting, July 2007, Bremerton, WA.

"Planning for Climate Change", Snohomish County Long Range Planning Division, July 2007, Snohomish County, WA.

"Planning for Climate Change", Washington City/County Management Association annual conference, August 2007, Walla Walla, WA.

"Northwest Climate Change and Transportation", 2007 Public Transportation Conference, August 2007, Vancouver, WA.

"Global Climate Change Comes to the Northwest?", Olympia Kiwanis, August 2007, Tugboat Annie's on Budd Inlet (WA).

"The Impacts of Global Climate Change in the Pacific Northwest", Tulalip Tribe Salmon Homecoming Forum, September 2007, Seattle, WA.

"Climate Change Science and Impacts", Mealey's Insurance Teleconference Series: Global Warming and What Companies Need to Know to Avoid Liability, September 2007, via conference call.

"Global and Regional Climate Change", September 2007, Lacey, WA.

"PNW Climate Change Impacts", RIMS Monthly Chapter Meeting, September 2007, Seattle, WA.

"Preparing for Climate Change: A Guidebook for Local, Regional, and State Governments", Fourth Annual Climate Change Research Conference, September 2007, Sacramento, CA.

"Global Climate Change And Regional Impacts", Climate Change 101 for EPA Staff and Managers, September 2007, Seattle, WA.

"The State of the Science: Northwest Regional Impacts", The Seminar Group Law Seminar, September 2007, Portland, OR.

"The Impacts of Climate Change on the Pacific Northwest". The Water Institute, University of Florida, October 2007.

"Climate Change Science and Impacts", King County Department of Transportation Climate Change Strategies, October 2007, 201 South Jackson, 8th Floor conference center.

"Global Climate Change", ACEEE's 4TH National Conference on Energy Efficiency as a Resource, October 2007, Berkeley, CA.

"Global Climate Change, with Thoughts about Human Health", Washington State Medical Association annual meeting, October 2007, Sheraton Hotel, Tacoma, WA.

"Impacts of Global Climate Change in the Pacific Northwest", 2007 Business and the Environment forum series (Pendleton event), October 2007, Portland, OR.

"Global Climate Change: Hoax or Catastrophe?", AVS International Symposium, October 2007, Seattle, WA.

"Planning for Climate Change", Climate Change 101 for EPA Staff and Managers, October 2007, Seattle, WA.

"Pacific Northwest Climate Change Impacts", Annual conference of the Hearing Examiners Association of Washington, October 2007, Chelan, WA.

"Global and Regional Climate Change", Changing Climate Issue: Reporting ahead of the curve, October 2007, Ashland, OR.

"Pacific Northwest Climate Change Impacts", Climate Action Day, November 2007, Olympia, WA.

"Climate Change Science And Projected Impacts On The Pacific Northwest", UW Libraries Science of Climate Change, November 2007, Seattle, WA.

"Pacific Northwest Climate Change Impacts and Adaptation", PNWER Economic Region Forum meeting, November 2007, Whistler, BC.

"Climate Change and Climate Impacts in the Pacific Northwest", Zoo Corps Fall Strand, November 2007, Woodland Park Zoo, Seattle, WA.

"PNW Climate Change", Washington Agriculture and Forestry Education Foundation Leadership Seminar, November 2007, Seattle, WA.

"PNW Climate Change Impacts and Related Studies", League of Women Voters panel on climate change, November 2007, Kent, WA.

"PNW Climate Change Impacts", Quarterly Meeting of the Pacific NW Chapter of the ACHMM, December 2007, Seattle, WA.

"Northwest Climate Change and Mitigation", Northwest climate funders, December 2007, Seattle, WA.

"Approaches to Re-designing the International Regime to Control Global Warming", Miller Institute, University of California, December 2007, Berkeley, CA.

"Global and Regional Climate Change", The Summit at First Hill lecture series, January 2008, Seattle, WA.

"Temperatures Rising: Climate Change Impacts to Public Health", World Affairs Council Educators Lecture Series, January 2008, Seattle, WA.

"Climate Change Impacts in the Pacific Northwest", Hood Canal Coordinating Council Board of Directors meeting, January 2008, Silverdale, WA.

"Climate Change Impacts in the Pacific Northwest", Climate: Impacts, Choices, and Change, Walla Walla Community College, January 2008,Walla Walla, WA.

"An Overview of Pacific Northwest Climate Change", Creating a Climate of Change: A Community Forum on Climate Change in the Pacific Northwest, January 2008, Olympia, WA.

"Climate Change Impacts in the Pacific Northwest", Focus the Nation, January 2008, Centralia College, Centralia, WA.

"Pacific Northwest Climate Change Impacts and Responses", Task Force class on climate change and US policy, University of Washington, February 2008, Seattle, WA.

"Climate Change and Northwest Energy Utilities", Puget Sound Energy's Energy Future: Facing the Challenge of Climate Change, February 2008, Bellevue, WA.

"An Integrated Assessment of the Impacts of Climate Change on Washington State", University of Washington Water Center's 18th Annual Review of Research, February 2008, Seattle, WA.

"Climate Change and Northwest Agriculture", 2008 Washington State University Westside Agriculture and Natural Resource Days, February 2008, Puyallup, WA.

"Northwest Climate Change and Dairy Farming", Annual Oregon Dairy Producer Conference, February 2008, Sun River, OR.

"Salmon Bay Elementary Hydrology and Climate Demonstrations", Salmon Bay Elementary, Feb/March 2008, Seattle, WA.

"Big Science and Collaborations", Biology 572 (Science and Policy), University of Washington, March 2008, Seattle, WA.

"Preparing for Climate Change: A Guidebook for Local, Regional, and State Governments", Researcher and Practitioner Partnerships for Action on Climate Change: Developing Guidance for Communities, March 2008, Richmond, British Columbia, Canada.

"An Integrated Assessment of the Impacts of Climate Change on WA State", Climate Prediction Applications Science Workshop (CPASW) 2008, March 2008, Chapel Hill, NC.

"Climate Change Impacts in the Pacific Northwest", Public lecture in series on environmental topics, March 2008, Everett, WA.

"Climate Change Impacts in Western Washington", Olympic Region Clean Air Agency, March 2008, Olympia, WA.

"Climate Change in the Puget Sound Region", Climate Change Impacts to Infrastructure - Technical Briefing by CIG, March 2008, Seattle, WA.

Appendix C

CSES Publications

The following publications were in press or published between April 1, 2007 and March 31, 2008. **Non-peer reviewed publications are noted with a # symbol.** This list does not include publications considered in review during the reporting period, or papers published after March 31, 2008, categories which both involved substantial work during the current reporting period. **All of the research represented by these publications is shared with stakeholders via presentations, meetings, paper requests, and one-on-one discussions.**

In Press

Fontaine, M., and A.C. Steinemann. (In press). Assessing vulnerability to natural hazards: An impact-based method and application to drought in Washington State. To appear in *Natural Hazards Review*.

Littell, J.S., D.L. Peterson, and M. Tjoelker. In press. Douglas-fir growth-climate relationships along biophysical gradients in mountain protected areas of the northwestern U.S. To appear in *Ecological Monographs.*

#McKenzie, D., D.L. Peterson, and J.S. Littell. (In press). Global warming and stress complexes in forests of western North America. To appear in A. Bytnerowicz, M. Arbaugh, C. Anderson, and A. Riebau (eds.), *Forest Fires and Air Pollution Issues*. Amsterdam, The Netherlands: Elsevier Science, Ltd.

#McKenzie, D., C.L. Raymond, and S.C. Cushman. (In press(a)). Modeling understory vegetation and its response to fire. To appear in J. Millspaugh and F.R. Thompson III, *Models for Planning Wildlife Conservation in Large Landscapes*.

Moore, S.K., N.J. Mantua, J.P. Kellogg, and J.A. Newton. (In press(b)). Local and large-scale climate forcing of Puget Sound oceanographic properties on seasonal to interdecadal timescales. To appear in *Limnology and Oceanography*.

Moore, S.K., V.L. Trainer, N.J. Mantua, D. Parker, E.A. Laws, L.C. Backer, and L.E. Fleming. (In press). Impacts of climate variability and future climate change on harmful algal blooms and human health. To appear in *Environmental Health*.

#Mote, P.W. (In press). Variability and trends in mountain snowpack in western North America. To appear in F. Wagner (ed.), *Proceedings of the AAAS Pacific Division Annual Meeting*.

#Mote, P.W., J. Casson, A.F. Hamlet, and D.C. Reading. (In press). Sensitivity of Northwest ski areas to warming. To appear in B. McGurk (ed.), *Proceedings of the 75th Western Snow Conference*, April 16-19, 2007, Kailua-Kona, Hawaii. Soda Springs, CA: Western Snow Conference.

#Petersen, A. (Sascha), D.J. Canning, T.M. Leschine, and E.L. Miles. (In press). Adapting decision making to uncertainty when addressing sea level rise response in Puget Sound. To appear in *Proceedings of the 15th Biennial Coastal Zone Conference, July 22-26, 2007, Portland, Oregon*. Charleston, SC: NOAA Coastal Services Center.

Salathé, E.P., R. Steed, C.F. Mass, and P. Zahn. (In press). A high-resolution climate model for the United States Pacific Northwest: Mesoscale feedbacks and local responses to climate change. To appear in *Journal of Climate*.

Sloyan, B.M., and I.V. Kamenkovich. (In press). Simulation of Subantartic mode and Antarctic intermediate waters in climate models. To appear in *Journal of Climate*.

Voisin, N., A.W. Wood, and D.P. Lettenmaier. (In press). Evaluation of precipitation products for global hydrological prediction. To appear in *Journal of Hydrometeorology*.

Wu, Z., E.K. Schneider, B.P. Kirtman, E. Sarachik, B. Huang, and C.J. Tucker. (In press). The modulated annual cycle - an alternative reference frame for climate anomalies. To appear in *Climate Dynamics*

2008

Barnett, T., D.W. Pierce, H. Hidalgo, C. Bonfils, B.D. Santer, T. Das, G. Bala, A.W. Wood, T. Nazawa, A, Mirin, D. Cayan, and M. Dettinger. 2008. Human-induced changes in the hydrology of the western United States. *Science Science Express Reports* 10.1126/science.1152538.

Crozier, L.G., A.P. Hendry, P.W. Lawson, T.P. Quinn, N.J. Mantua, J. Battin, R.G. Shaw, and R.B. Huey. 2008a. Potential responses to climate change for organisms with complex life histories: Evolution and plasticity in Pacific salmon. *Evolutionary Applications* 2: 252–270, doi:10.1111/j.1752-4571.2008.00033.x.

Crozier, L.G., R.W. Zabel, and A.F. Hamlet. 2008b. Predicting differential effects of climate change at the population level with life-cycle models of spring Chinook salmon. *Global Change Biology* 14(2): 236–249, doi:10.1111/j.1365-2486.2007.01497.x.

Heyerdahl, E.K., D. McKenzie, L. Daniels, A.E. Hessl, J.S. Littell, and N.J. Mantua. 2008. Climate drivers of regionally synchronous fires in the inland Northwest (1651-1900). *International Journal of Wildland Fire* 17:40-49.

Milly, P.C.D., J. Betancourt, M. Falkenmark, R.M. Hirsch, Z.W. Kundzewicz, D.P. Lettenmaier, and R.J. Stouffer. 2008. Stationarity is dead: Whither water management? *Science* 319 (5863): 573-574, DOI: 10.1126/science.1151915.

Mote, P.W., A.F. Hamlet, and E.P. Salathé. 2008a. Has spring snowpack declined in the Washington Cascades? *Hydrology and Earth System Sciences* 12: 193-206. (http://www.hydrol-earth-syst-sci.net/12/193/2008/hess-12-193-2008.html)

#Mote, P.W., A. (Sascha) Petersen, S. Reeder, H. Shipman, and L.C. Whitely Binder. 2008b. *Sea Level Rise Scenarios for Washington State*. Report prepared by the Climate Impacts Group, Center for Science in the Earth System, Joint Institute for the Study of the Atmosphere and Oceans, University of Washington, Seattle, Washington and the Washington Department of Ecology, Lacey, Washington. (http://www.cses.washington.edu/db/pdf/moteetalslr579.pdf)

#Mote, P.W., E.P. Salathé, V. Dulière, and E. Jump. 2008c. *Scenarios of Future Climate Change for the Pacific Northwest.* Report prepared by the Climate Impacts Group, Center for Science in the Earth System, Joint Institute for the Study of the Atmosphere and Oceans, University of Washington, Seattle.

#National Research Council 2008. *Research and Networks for Decision Support in the NOAA Sectoral Applications Research Program*. Panel on Design Issues for the NOAA Sectoral Applications Research Program, H.M. Ingram and P.C. Stern (eds.), Committee on the Human Dimensions of Global Change, Division of Behavioral and Social Sciences and Education. The National Academies Press, Washington, DC. 84 pp.

Shukla, S., and A.W. Wood. 2008. Use of a standardized runoff index for characterizing hydrologic drought. *Geophysical Research Letters* 35, L02405, doi:10.1029/2007GL032487.

Wood, A.W. 2008. The University of Washington Surface Water Monitor: An experimental platform for national hydrologic assessment and prediction. In *Proceedings of the AMS 22nd Conference on Hydrology*, New Orleans, LA, January 20-24. (http://ams.confex.com/ams/pdfpapers/134844.pdf)

Wood, A.W., and J.C. Schaake. 2008. Correcting errors in streamflow forecast ensemble mean and spread. *Journal of Hydrometeorology* 9(1): 132-148.

2007

#Alemu, E., and R.N. Palmer. 2007. *Technical Memorandum #7: Impacts of Climate Change on Cloud Cover in the Puget Sound Region*. A report prepared by the Climate Change Technical Subcommittee of the Regional Water Supply Planning Process, Seattle, WA. (http://www.govlink.org/regional-water-planning/tech-committees/climate-change/index.htm).

#Alexander, D., and R.N. Palmer. 2007. *Technical Memorandum #8: Impacts of Climate Change on Groundwater Resources- A Literature Review*. A report prepared by the Climate Change Technical Subcommittee of the Regional Water Supply Planning Process, Seattle, WA. (http://www.govlink.org/regional-water-planning/tech-committees/climate-change/index.htm)

#Alexander, D., R.N. Palmer, and A. Polebitski. 2007. *Technical Memorandum #1: Literature Review of Research Incorporating Climate Change into Water Resources Planning*. A report prepared by the Climate Change Technical Subcommittee of the Regional Water Supply Planning Process, Seattle, WA. (http://www.govlink.org/regional-water-planning/tech-committees/climate-change/index.htm)

Battin, J., M.W. Wiley, M.H. Ruckelshaus, R.N. Palmer, E. Korb, K.K. Bartz, and H. Imaki. 2007. Projected impacts of climate change on salmon habitat restoration. *Proceedings of the National Academy of Sciences* 104(16): 6720–6725.

Case, M.J., and D.L. Peterson. 2007. Growth-climate relations of Lodgepole Pine in the North Cascades National Park, Washington. *Northwest Science* 81(1):62-75.

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Colman, R., W. Collins, J. Haywood, M. Manning, and P.W. Mote. 2007. The physical science behind climate change. *Scientific American* 297(2): 64-71.

#Cushman, S.C., D. McKenzie, D.L. Peterson, J.S. Littell, and K.S. McKelvey. 2007. *Research Agenda for Integrated Landscape Modeling*. General Technical Report RMRS-GTR-194. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. (http://treesearch.fs.fed.us/pubs/viewpub.jsp?index=27437)

Falk, D.A., C.M. Miller, D. McKenzie, and A.E. Black. 2007. Cross-scale analysis of fire regimes. *Ecosystems* 10(5): 809-823, doi 10.1007/s10021-007-9070-7.

Hamlet, A.F., and D.P. Lettenmaier. 2007. Effects of 20th century warming and climate variability on flood risk in the western U.S. *Water Resources Research* 43, W06427, doi:10.1029/2006WR005099.

#Independent Science Advisory Board 2007. *Climate Change Impacts on Columbia River Basin Fish and Wildlife*. Independent Scientific Advisory Board (ISAB) Climate Change Report ISAB 2007-2, Portland, OR. (http://www.nwcouncil.org/library/isab/isab2007-2.htm)

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Kaje, J.H., and D. Huppert. 2007. The value of short-run climate forecasts in managing the coastal coho salmon *(Oncorhynchus kisutch)* fishery in Washington State. *Natural Resource Modeling* 20(2):321-349.

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#Lemke, P., J. Ren, R.B. Alley, I. Allison, J. Carrasco, G. Flato, Y. Fujii, G. Kaser, P.W. Mote, R.H. Thomas, and T. Zhang. 2007. Observations: Changes in snow, ice and frozen ground. Chapter 4 in S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.), *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. (http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-chapter4.pdf)

#Mantua, N.J., N.G. Taylor, G.T. Ruggerone, K.W. Myers, D. Preikshot, X. Augerot, N.D. Davis, B. Dorner, R. Hilborn, R.M. Peterman, P. Rand, D. Schindler, J. Stanford, R.V. Walker, and C.J. Walters. 2007. The salmon MALBEC project: a North Pacific-scale study to support salmon conservation planning. (NPAFC Doc. 1060) School of Aquatic and Fishery Sciences, University of Washington, Seattle. (http://www.npafc.org/new/publications/Documents/PDF%202007/1060(USA).pdf)

McKenzie, D., C.L. Raymond, J.P. Kellogg, R.A. Norheim, A.G. Andreu, A.C. Bayard, K.E. Kopper, and E Elman. 2007. Mapping fuels at multiple scales: Landscape application of the Fuel Characteristic Classification System. *Canadian Journal of Forest Research* 37: 2421-2437, doi:10.1139/X07-056.

#Mitchell, T.P., and E. Sarachik. 2007. El Niño. pp 98-103 in Vol.6, *2007 McGraw-Hill Encyclopedia of Science and Technology, 10th Edition.* New York, New York: McGraw-Hill Publishing.

Mote, P.W., and G. Kaser. 2007. The shrinking glaciers of Kilimanjaro: Can global warming be blamed? *American Scientist* 95(4):318-325.

#O'Neill, C., and R.N. Palmer. 2007. *Technical Memorandum #3: Online Database Functionality and Design for Climate Impacted Data*. A report prepared by the Climate Change Technical Subcommittee of the Regional Water Supply Planning Process, Seattle, WA. (http://www.govlink.org/regional-water-planning/tech-committees/climate-change/index.htm)

#Palmer, R.N. 2007a. *Final Report of the Climate Change Technical Committee*. A report prepared by the Climate Change Technical Subcommittee of the Regional Water Supply Planning Process, Seattle, WA. (http://www.govlink.org/regional-water-planning/tech-committees/climate-change/index.htm)

#Palmer, R.N. 2007b. *Technical Memorandum #6: Framework for Incorporating Climate Change into Water Resources Planning*. A report prepared by the Climate Change Technical Subcommittee of the Regional Water Supply Planning Process, Seattle, WA. (http://www.govlink.org/regional-water-planning/tech-committees/climate-change/index.htm)

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#Petersen, A. (Sascha) 2007. Anticipating sea level rise response in Puget Sound. M.M.A. thesis, School of Marine Affairs, University of Washington, Seattle. (http://www.cses.washington.edu/db/pdf/petersenthesis559.pdf)

#Polebitski, A., L. Traynham, and R.N. Palmer. 2007a. *Technical Memorandum #4: Approach for Developing Climate Impacted Meteorological Data and its Quality Assurance/Quality Control.* A report prepared by the Climate Change Technical Subcommittee of the Regional Water Supply Planning Process, Seattle, WA. (http://www.govlink.org/regional-water-planning/tech-committees/climate-change/index.htm)

#Polebitski, A., L. Traynham, and R.N. Palmer. 2007b. *Technical Memorandum #5: Approach for Developing Climate Impacted Streamflow Data and its Quality Assurance/Quality Control.* A report prepared by the Climate Change Technical Subcommittee of the Regional Water Supply Planning Process, Seattle, WA (http://www.govlink.org/regional-water-planning/tech-committees/climate-change/index.htm)

#Polebitski, A., M.W. Wiley, and R.N. Palmer. 2007c. *Technical Memorandum #2: Methodology for Downscaling Meteorological Data for Evaluating Climate Change*. A report prepared by the Climate Change Technical Subcommittee of the Regional Water Supply Planning Process, Seattle, WA. (http://www.govlink.org/regional-water-planning/tech-committees/climate-change/index.htm)

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Trenberth, K.E., P.D. Jones, P. Ambenje, R. Bojariu, D. Easterling, A. Klein Tank, D. Parker, F. Rahimzadeh, J.A. Renwick, M. Rusticucci, B. Soden, and P. Zhai. 2007. Observations: Surface and atmospheric climate change. Chapter 3 in S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.), *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. (Contributing author: Mote)

Appendix D

CSES Personnel: April 1, 2007-March 31, 2008

Beetz, Jessica Graduate Student	*Areas of Expertise:* Aquatic Ecosystems	*Affiliations:* Climate Impacts Group UW School of Aquatic and Fishery Sciences
Booth, Derek Affiliate Professor	*Areas of Expertise:* Hydrology & Water Resources Infrastructure	*Affiliations:* Climate Impacts Group UW Dept. of Civil and Environmental Engineering UW Dept. of Earth & Space Sciences
Cuo, Lan Research Scientist	*Areas of Expertise:* Hydrology & Water Resources	*Affiliations:* Climate Impacts Group UW Dept. of Civil and Environmental Engineering PRISM
Duliére, Valèrie Research Scientist	*Areas of Expertise:* Climate Modeling and Dynamics Dynamical Downscaling	*Affiliations:* Climate Impacts Group
Essington, Tim CSES Principal and Assistant Professor	*Areas of Expertise:* Aquatic Ecosystems	*Affiliations:* Climate Impacts Group UW School of Aquatic and Fishery Sciences
Fenske, Richard Professor and Associate Chair	*Areas of Expertise:* Human Health	*Affiliations:* Climate Impacts Group UW Dept. of Environ. and Occupational Health Sciences
Fluharty, David Professor	*Areas of Expertise:* Societal Dimensions	*Affiliations:* Climate Impacts Group UW School of Marine Affairs
Gwozdz, Rich Graduate Student	*Areas of Expertise:* Forests	*Affiliations:* Climate Impacts Group UW College of Forest Resources
Hamlet, Alan Research Scientist	*Areas of Expertise:* Energy Hydrologic Prediction Hydrology & Water Resources	*Affiliations:* Climate Impacts Group UW Dept. of Civil Engineering
Harrison, D. Edmund Senior Scientist and Professor	*Areas of Expertise:* Climate Modeling and Dynamics Ocean Modeling	*Affiliations:* Climate Dynamics Group NOAA Pacific Marine Environmental Laboratory UW Dept. of Atmospheric Sciences
Hoskins, Richard CSES Principal and Clinical Assistant Professor	*Areas of Expertise:* Human Health	*Affiliations:* Climate Impacts Group UW School of Public Health and Community Medicine Washington State Dept. of Health
Huppert, Daniel Professor	*Areas of Expertise:* Coasts	*Affiliations:* Climate Impacts Group UW School of Marine Affairs

Jackson, J. Elizabeth Researcher	*Areas of Expertise:* Human Health	*Affiliations:* Climate Impacts Group UW Dept. of Sociology
Karpov, Adrienne Program Administrator	*Areas of Expertise:* Program administration	*Affiliations:* Climate Impacts Group
Karr, Catherine Acting Assistant Professor	*Areas of Expertise:* Human Health	*Affiliations:* Climate Impacts Group UW School of Public Health and Community Medicine
Keys, Patrick Graduate Student	*Areas of Expertise:* Infrastructure	*Affiliations:* Climate Impacts Group UW Dept. of Civil and Environmental Engineering
Kimball, Ann Marie CSES Principal and Professor	*Areas of Expertise:* Human Health	*Affiliations:* Climate Impacts Group UW School of Public Health and Community Medicine
Kruger, Chad BIOAg Educator	*Areas of Expertise:* Agriculture, Economics	*Affiliations:* Climate Impacts Group WSU Center for Sustaining Ag. And Nat. Resources
Lettenmaier, Dennis CSES Principal and Professor	*Areas of Expertise:* Hydrology & Water Resources	*Affiliations:* Climate Impacts Group UW Dept. of Civil Engineering
Leung, Ruby Research Scientist	*Areas of Expertise:* Climate Dynamics	*Affiliations:* Climate Impacts Group Pacific Northwest National Laboratory
Levy, Zenobia Administrative Assistant	*Areas of Expertise:* Program administration	*Affiliations:* Climate Impacts Group
Littell, Jeremy Research Scientist	*Areas of Expertise:* Forests	*Affiliations:* Climate Impacts Group Fire and Mountain Ecology Lab UW College of Forest Resources
Mantua, Nathan CSES Associate Director, CSES Principal, Research Associate Professor	*Areas of Expertise:* Aquatic Ecosystems Climate Dynamics	*Affiliations:* Climate Dynamics Group Climate Impacts Group UW Dept. of Atmospheric Sciences UW School of Aquatic and Fishery Sciences
McGuire Elsner, Marketa Research Scientist	*Areas of Expertise:* Hydrology & Water Resources Integrated Assessment	*Affiliations:* Climate Impacts Group
McKenzie, Don CSES Principal and Affiliate Assistant Professor	*Areas of Expertise:* Forests	*Affiliations:* Climate Impacts Group USFS, Fire and Environmental Research Applications UW College of Forest Resources
Miles, Edward CSES Co-Director,	*Areas of Expertise:* Integrated Assessment	*Affiliations:* Climate Impacts Group

CSES Principal Investigator, Professor	Societal Dimensions	UW School of Marine Affairs
Mitchell, Todd Meteorologist	*Areas of Expertise:* Climate Diagnostics	*Affiliations:* Climate Dynamics Group
Moore, Amber Graduate Student	*Areas of Expertise:* Coasts	*Affiliations:* Climate Impacts Group UW School of Marine Affairs
Moore, Stephanie Research Scientist	*Areas of Expertise:* Aquatic Ecosystems	*Other Affiliations:* UW School of Oceanography
Mote, Philip CSES Principal and Assistant Professor	*Areas of Expertise:* Climate Dynamics Cryospheric Dynamics Integrated Assessment Outreach	*Affiliations:* Climate Dynamics Group Climate Impacts Group UW Dept. of Atmospheric Sciences
Norheim, Robert GIS Analyst	*Areas of Expertise:* Integrated Assessment	*Affiliations:* Climate Impacts Group Fire and Mountain Ecology Lab UW College of Forest Resources
Palmer, Richard CSES Principal and Professor	*Areas of Expertise:* Hydrology & Water Resources	*Affiliations:* Climate Impacts Group UW Dept. of Civil Engineering
Peterson, Alexander ("Sascha") Graduate Student	*Areas of Expertise:* Coasts	*Affiliations:* Climate Impacts Group UW School of Marine Affairs
Raymond, Crystal Graduate Student	*Areas of Expertise:* Forests	*Affiliations:* Climate Impacts Group UW College of Forest Resources
Reading, Don Consulting Economist	*Areas of Expertise:* Agriculture, Economics Hydrology & Water Resources	*Affiliations:* Climate Impacts Group Ben Johnson & Associates
Reum, Jonathan Research Scientist	*Areas of Expertise:* Aquatic Ecosystems	*Affiliations:* Climate Impacts Group UW School of Aquatic and Fishery Sciences
Rogers, Erin Research Scientist	*Areas of Expertise:* Hydrology & Water Resources	*Affiliations:* Climate Impacts Group
Rosenblatt, Roger Professor	*Areas of Expertise:* Human Health	*Affiliations:* Climate Impacts Group UW School of Public Health and Community Medicine
Salathé, Eric Research Scientist and Affiliate Assist. Professor	*Areas of Expertise:* Dynamical Downscaling	*Affiliations:* Climate Dynamics Group Climate Impacts Group UW Dept. of Atmospheric Sciences
Sarachik, Ed CSES Co-Director, CSES Principal, Prof.	*Areas of Expertise:* Climate Dynamics	*Affiliations:* Climate Dynamics Group UW Dept. of Atmospheric Sciences

Scott, Michael Scientist	*Areas of Expertise:* Agriculture, Economics, Hydrology & Water Resources	*Affiliations:* Climate Impacts Group Pacific Northwest National Laboratory
Slaughter, Richard Consulting Economist	*Areas of Expertise:* Societal Dimensions	*Other Affiliations:* Richard Slaughter Associates
Snover, Amy CSES Principal and Research Scientist	*Areas of Expertise:* Integrated Assessment Outreach	*Other Affiliations:*
Steed, Rick Graduate Student	*Areas of Expertise:* Dynamical Downscaling	*Other Affiliations:* UW Dept. of Atmospheric Sciences
Steinemann, Anne CSES Principal and Professor	*Areas of Expertise:* Hydrology & Water Resources	*Other Affiliations:* Daniel J. Evans School of Public Affairs The Water Center UW Dept. of Civil Engineering
Stockle, Claudio Professor	*Areas of Expertise:* Agriculture	*Affiliations:* Climate Impacts Group WSU Dept. of Biological Systems Engineering
Tohver, Ingrid Research Scientist	*Areas of Expertise:* Aquatic Ecosystems	*Affiliations:* Climate Impacts Group
Wallace, J. Michael JISAO Senior Fellow, Professor	*Areas of Expertise:* Climate Dynamics	*Affiliations:* Climate Dynamics Group UW Dept. of Atmospheric Sciences
Warner, Michael Graduate Student	*Areas of Expertise:* Dynamical Downscaling	*Affiliations*: Climate Impacts Group UW Dept. of Atmospheric Sciences
Whitely Binder, Lara Outreach Specialist	*Areas of Expertise:* Outreach	*Affiliations:* Climate Impacts Group
Whittmann, Sasha Fiscal Specialist	*Areas of Expertise:*	*Affiliations:* Climate Impacts Group
Wood, Andrew Research Assistant Professor	*Areas of Expertise:* Hydrologic Predictions	*Affiliations:* Climate Impacts Group UW Dept. of Civil Engineering
Zhang, Yongxin Research Scientist	*Areas of Expertise:* Climate Modeling and Dynamics	*Affiliations*: Climate Impacts Group

Appendix E

CSES Budget Justification