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THE CLIMATE IMPACTS GROUP:
PILOTING CLIMATE SERVICES FOR THE PACIFIC NORTHWEST

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1. INTRODUCTION

The Climate Impacts Group (CIG) at the University of Washington (funded under NOAA's Regional Integrated Science and Assessments Program) works to increase the resilience of the Pacific Northwest (PNW) to fluctuations in climate. CIG develops, tests, and introduces natural resources planning and decision-making tools that are based on seasonal/inter-annual climate forecasts and/or projections of anthropogenic climate change derived from global climate models. Over recent years, CIG has been evolving towards a regional "climate service," that is, an information broker providing users with the information about climate impacts and response strategies they need to make climate forecasts relevant to planning and decision making. Here we describe CIG's scope, research approach, and strategies and objectives for developing and maintaining long-term relationships with stakeholders; highlight CIG's annual water resources planning workshops; and introduce new products and ongoing research on applications of climate forecasts for PNW natural resource management.

2. REGIONAL INTEGRATED ASSESSMENT IN THE CLIMATE IMPACTS GROUP

CIG is an interdisciplinary research group studying the impacts of natural climate variability and anthropogenic climate change on the US PNW (Figure 1), in particular for the sectors of water resources (including irrigated agriculture), aquatic and marine ecosystems (with an emphasis on salmonids), forests, and coasts. We evaluate the implications of climate variations for both the natural systems and the human systems that depend on them and use this information and advances in climate forecasting capabilities to develop new forecast products for the regional natural resources management community.

CIG's research approach is retrospective, interdisciplinary and integrated, and contextual. We begin with an analysis of the patterns and predictability of regional climate variability and the impacts that past climate variations had on the PNW. By investigating observed institutional responses to past climatic stresses, we can assess the PNW's sensitivity, adaptability, and vulnerability to climate variability. We use the evidence and understanding gained from these retrospective studies as a basis for projecting the regional implications of global climate change. By specifying the processes through which natural variations in regional climate were manifested as impacts on natural and human systems, and by understanding the role that human choices played in determining these impacts, we establish a basis for suggesting how the same systems may respond to future climate change. By evaluating how human systems can adapt to better cope with or respond to climate variability, we can suggest how these same systems might adapt to future climate change.

Our approach to this work is three-dimensional, comprising natural sciences research (to understand and quantify the consequences of climate variability and change for PNW climate and natural resources), social sciences research (to understand the human systems associated with natural resources management in the PNW and the role that human choices play in determining climate impacts), and outreach and interaction with the regional stakeholder community (to link large-scale climate forecast information to local/regional management needs).

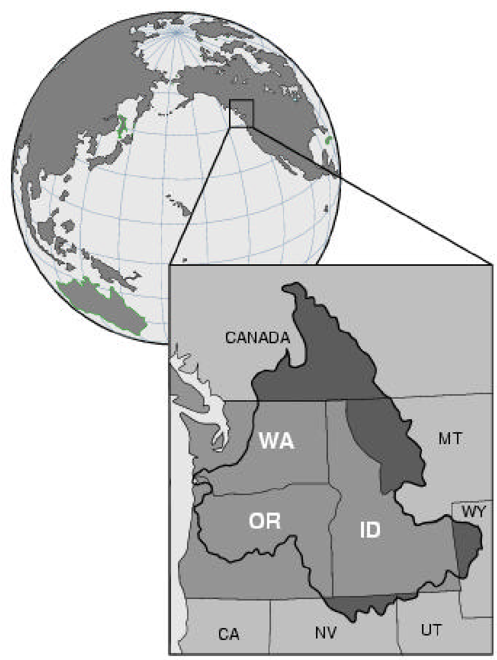

Figure 1: The Climate Impacts Group focuses on the US Pacific Northwest: the Columbia River basin (outlined and shaded) and the states of Washington, Oregon, and Idaho.

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CIG has developed close connections with the public, private, and North American tribal groups and agencies responsible for managing the region's water, forest, fishery, and coastal resources. CIG engages in continual networking to identify appropriate stakeholders to target, i.e., those whose management of natural resources could potentially benefit from the use of climate information. Regional workshops on climate and resource forecasting and surveys and interviews with the user community provided means for initial contact. Capitalizing on high-profile climate events (such as the El Niño of 1996-1997) and demonstrating a long-term commitment to serving regional stakeholders has helped solidify these relationships. As a result of this interaction, CIG has gained a clear picture of the current use and perceived value of climate forecasts by natural resource managers, insight into their decision calendars, and an understanding of institutional barriers to adaptability. Stakeholders benefit from the development of improved tools and information for planning, such as resource forecasts and regional- and resource-specific interpretations of global climate change. Members of CIG's user community are listed in Table 1.

3. FORECAST PRODUCTS AND ONGOING RESEARCH ACTIVITIES

3.1 Water Resources Planning Workshops

At the beginning of each water year (i.e., in the fall) since 1997, CIG has convened water resources planning workshops for local and regional water resource managers on both the east and west sides of the hydrologic, ecologic, economic, and cultural divide of the Cascade Mountains. The workshops feature an exposition of the expected climate for the coming winter, the influence of climate variability on water resources, the predictability of those climate variations and their impacts, reports from regional managers on their use of climate information, and presentations about the possible impacts of anthropogenic climate change. CIG also uses these workshops to highlight newly developed forecasting techniques and applications. The workshops

Table 1: Members of the Climate Impacts Group's User Community. Partnerships indicate two-way flows – of information, funding or in-kind assistance – between the Climate Impacts Group and the user. Assistance indicates a one-way flow of information from the Climate Impacts Group to the user.

Partnerships	Assistance
• Seattle Public Utility, Water Department • Portland Water Bureau • Oregon Department of Land Conservation and Development • Oregon State University: Coastal Impacts • Washington Department of Ecology • Washington Department of Health • Washington Department of Fish and Wildlife • Sustainable Development Research Institute, University of British Columbia • Columbia Basin Ecosystem Management • Northwest Power Planning Council • US Bureau of Reclamation • International Pacific Halibut Commission • National Marine Fisheries Service: Alaska Fisheries Science Center • National Marine Fisheries Service, Office of the Regional Director • National Park Service • North Pacific Fisheries Management Council	• Seattle City Light • Seattle City Council • Tacoma Power and Light • Alaska Department of Fish and Game • Washington Department of Natural Resources • Washington Department of Transportation • Washington National Guard • Washington State: • Division of Emergency Management • Governor's Office (Washington and Oregon) • Legislative Budget Committees • Washington State Legislature • Washington State Office of Financial Management • Bonneville Power Administration • Columbia River Intertribal Fisheries Commission • Northwest Indian Fisheries Commission • Bureau of Land Management • Environmental Protection Agency • National Marine Fisheries Service: Northwest Fisheries Science Center • Pacific Fisheries Management Council • NOAA River Forecast Center • US Army Corps of Engineers • USDA Natural Resource Conservation Service • US Fish and Wildlife Service • PNW news media

often lead to stronger partnerships with regional stakeholders. As a result of their participation at one of the water resources workshops, for example, the Portland (Oregon) Water Bureau worked with CIG to develop estimates of climate change impacts on urban water demand (see below and Palmer and Hahn (2002)). The workshops also provide crucial feedback to CIG about specific needs of the management community, thereby informing our research agenda.

3.2 Long-Lead Streamflow Forecasts

Since 1997, CIG has been producing experimental long-lead streamflow forecasts for the Columbia River basin using forecasted ENSO conditions for the upcoming winter to condition resampling of historical meteorological data used to drive the Variable Infiltration Capacity (VIC) macro-scale hydrologic model initialized with current hydrologic conditions. In these forecasts, about 1/3 of the climatological streamflow probability distribution is eliminated and the forecast lead-time is increased by about six months (compared to existing statistical forecasts based on observations of snowpack) (Hamlet and Lettenmaier (1999a)). These forecasts have important applications for water management in the Columbia basin (Hamlet and Lettenmaier (2000), Hamlet et al. (2002)). Based on expected El Niño conditions, for example, the forecast for water year 2003 is for somewhat above average to below average streamflow (Figure 2). As a result of drier than average conditions experienced in 2002, reservoirs in Idaho's Snake River basin began the 2003 water year lower than usual – Boise system reservoirs were at 20% capacity in October. Major water uses in this area are hydropower production (60% of Idaho's power is typically hydropower) and irrigated agriculture. If 2003 results in near normal streamflow conditions, the system will probably be able to make it to the end of the year without running out of water, but a second year of low flow conditions would likely result in significant impacts.

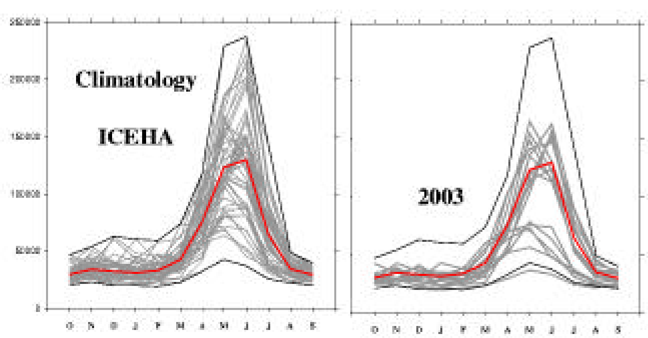


Figure 2: Climatological streamflow distribution for Ice Harbor, Idaho (left) compared to the long-range ensemble streamflow forecasts (right) for water year 2003 (warm ENSO) for the same location. The forecast ensemble is shown bracketed by the highest and lowest streamflow observed for each month in the 1948-2000 historical record. The red (bold) line indicates the long-term simulated mean for all years from 1948-2000.

3.3 Forecasting Salmon Returns

CIG has developed a relatively simple environmental model for translating observed coastal ocean temperatures, coastal sea level, and nearshore winds into estimates for Oregon coho salmon marine survival rates (Logerwell et al. (in press)). Model hindcasts capture a significant amount of the observed interannual variability in survival rates, the absolute values of survival, the long-term decline in salmon returns, and the persistently low survival rates in the 1991-1998 period. These environment-based "nowcasts" can provide salmon fishery management agencies run-size estimates in the winter before fisheries take place, early enough to be considered in the annual management negotiations over harvest size and allocation. The marine survival model can also make use of seasonal-to-interannual forecasts for coastal ocean parameters of interest, now based primarily on ENSO forecasts. This effort directly links large-scale climate forecasting information to local/regional fishery management needs at seasonal-to-interannual time scales.

3.4 Climate and Wildfire in the PNW

Using 47 years of wildfire data on US National Forest land in the PNW we have identified several key atmospheric structures that can potentially be used to forecast fire-season severity. Region wide increases in area burned are characterized by antecedent (winter and spring preceding the fire season) drought accompanied by persistent (high pressure) blocking events during the fire season (Figure 3). The underlying

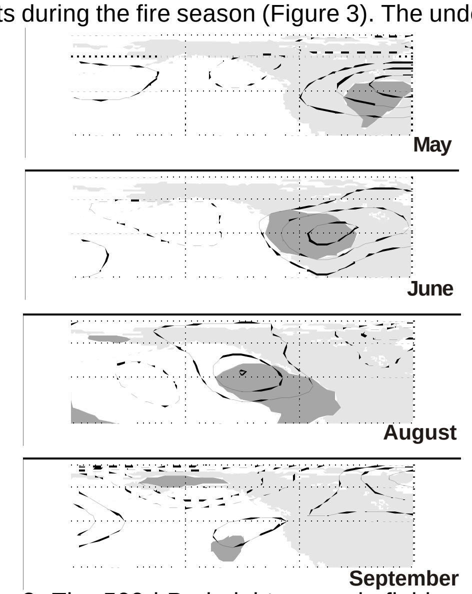


Figure 3: The 500 hPa height anomaly field projected onto the leading principal component of annual area burned by wildfire in the Pacific Northwest. This pattern describes the atmospheric variability associated with a 1σ perturbation in this pattern. The contour interval is 5 meters, with positive anomalies indicated by a solid contour, negative anomalies by a dashed contour, and the zero line not shown. Dark shaded regions indicate that the correlation is significant at 95 % confidence.

ecology appears to modulate the response to drought and circulation: more mesic forests require persistent drought, blocking events, and a source of ignition and spread, while drier forests are more responsive to shorter-scale (i.e., synoptic) processes. These relationships between climate and wildfire are non-linear; small changes in mean climate may lead to dramatic changes in wildfire activity.

3.5 Forecasting Extreme Weather Events

The wintertime Pacific/North America (PNA) pattern is the dominant mode of seasonal/interannual variability over the Pacific/North America sector and the most predictable northern hemisphere circulation pattern at lead-times of 6-10 days (Renwick and Wallace (1995)). Using daily station data for 1948-1998 (October-March only) we have demonstrated strong associations between the statistics of extreme daily weather events (those days in which the parameter of interest is more than 1.5σ from the daily mean value) and the phase of the daily PNA index in coastal Alaska, the US Pacific Northwest, around the Great Lakes region, and in the Southeastern US. Parts of the Southeast, for example, have experienced extreme cold temperatures 4-8 times more frequently during positive PNA days, while parts of the western US and coastal Alaska have experienced 8-20 times more extreme cold temperatures during negative PNA days (Figure 4). Similar analyses demonstrate the relationship between the PNA index and the relative frequencies of extreme daily precipitation, freezing temperature days, snow days, maximum temperatures, and surface wind gusts. This work shows that existing operational PNA forecasts (from NCEP) can be used to generate skilled extreme event risk forecasts for select locations at lead times up to two weeks.

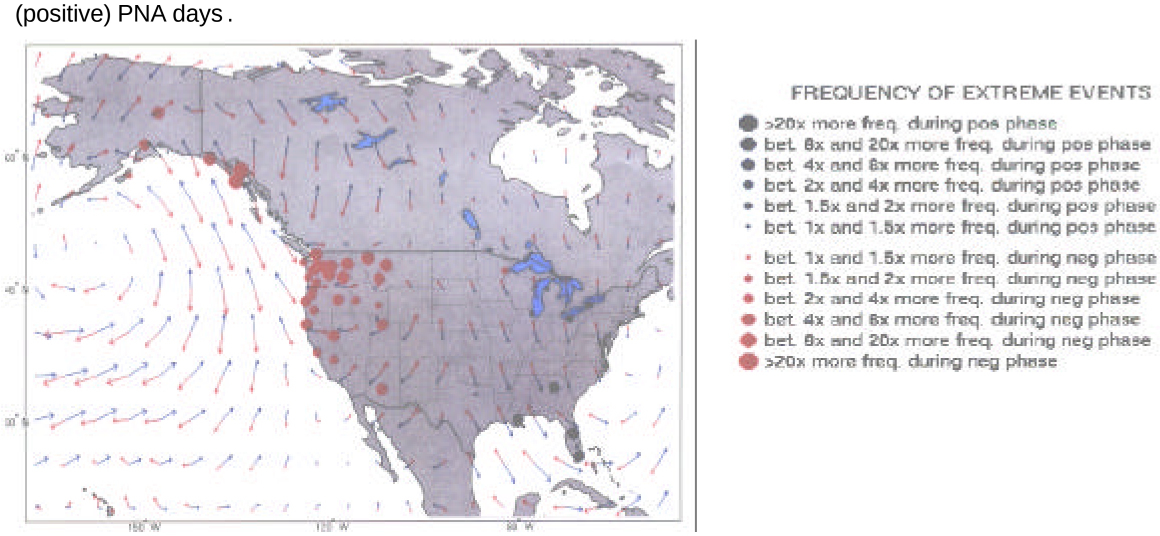
3.6 Watershed Planning for Climate Variability and Change

In 1998, the Washington State Legislature enacted a statewide Watershed Planning Program (WPP) to encourage comprehensive, long-range water resource planning through voluntary collaborative efforts at the watershed level. Because of its statewide enactment, high levels of support and participation, and its collaborative nature, the WPP presents a useful vehicle for adapting to/preparing for the impacts of climate variability/change. Through interviews and surveys with watershed planning leads, CIG determined that two-thirds of the planning groups have discussed the potential impacts of climate variability and change and just under half are including these impacts in the technical assessments required for each watershed (Whitely Binder (2002)). As a result of this interaction with WPP leads, CIG has identified the need for spatially detailed projections of climate scenarios (for both climate variability and change) and for low technology and low cost methods of assessing a watershed's vulnerability to climate-related hydrologic impacts.

3.7 Planning for Climate Change: Municipal Water Supply

Global climate models project substantial increases in temperature for the PNW by the 2040s, well outside the natural range of climate in the 20th century. The models suggest small changes in yearly average precipitation, but the seasonal trends are larger: nearly all the climate models show wetter winters and drier summers in the future (Mote et al. (1999), Mote et al. (in review)). The resultant reduction in winter snowpack would lead to reduced summer and fall streamflow in snow-dominated and transient river basins of the PNW (Hamlet and Lettenmaier 1999b). In addition, climate change can alter the demand for water, with demands increasing

Figure 4: The statistics of extremely cold temperatures in relation to the daily PNA index. The red and blue dots indicate the relative frequency of extremely cold daily temperature minimums (more than 1.5σ from the daily mean) recorded during positive versus negative PNA days. Red (blue) wind barbs are anomalous surface winds on negative (positive) PNA days.



during dry, warm periods and decreasing during cool, wet periods. This study uses a series of linked models (global climate models, a distributed hydrology model, and a dynamic system simulation model of water supply, transmission, and demand) to determine how projected climate change would alter streamflows, demand, and existing planning approaches for the City of Portland (Oregon) in the context of projected growth in regional population. The projected impacts of climate change – decreased system inflows during the reservoir drawdown cycle, resulting from changes in snowpack, and increased water demands, due to warmer temperatures – are approximately half those of regional population growth. On average, climate change is anticipated to reduce the system yield by 20 million gallons per day in 2050 (Palmer and Hahn (2002)).

3.8 Planning for Climate Change: Water Resources in the Columbia River Basin

Water planning activities at many water management agencies tend to be strongly linked to internally developed planning tools driven by a particular period of observed streamflow. This can impede evaluation of the consequences of alternate flow conditions, when those flows are produced by other hydrological models or using a different period of historical flows. CIG is working to create climate change streamflow scenarios that cover the same period of record and are numerically consistent with the historic record of streamflow traditionally used in water planning studies in the PNW. We are making these streamflow scenarios freely available on the web for a large number of river locations (Figure 5) to facilitate the incorporation of climate change information into existing water planning efforts in the PNW and to support agency testing of preferred planning alternatives for robustness under various climate change scenarios. This work is a response to specific recommendations from policy makers attending an upper level climate change workshop that was held in Skamania, Washington in 2001. Collaborative partnerships with the Northwest Power Planning Council and Idaho's Department of Water Resources, designed to support specific long-term planning efforts in these agencies, are in progress.

4. CONCLUDING REMARKS

Through innovative scientific research on how the Pacific Northwest's natural resources are affected by predictable climate variations, the Climate Impacts Group at the University of Washington provides a service to the region and helps guide resource managers toward more informed decisions relative to the implications of climate variability and change. CIG's unique focus is on the intersection of climate science and public policy - performing basic research aimed at understanding the consequences of climate variations for the region, and ensuring that this information is applied to regional decisions.

CIG has made great progress in elucidating patterns of climate variability and their impacts on four valuable types of resources: water, forests, aquatic ecosystems (primarily salmonids), and the coasts. Understanding these patterns and their impacts forms a crucial foundation for understanding how global climate change is likely to influence the PNW. CIG is committed to regional outreach and education, and works closely with regional decision-makers to ensure that our research products are both useful and used to inform management and planning decisions.

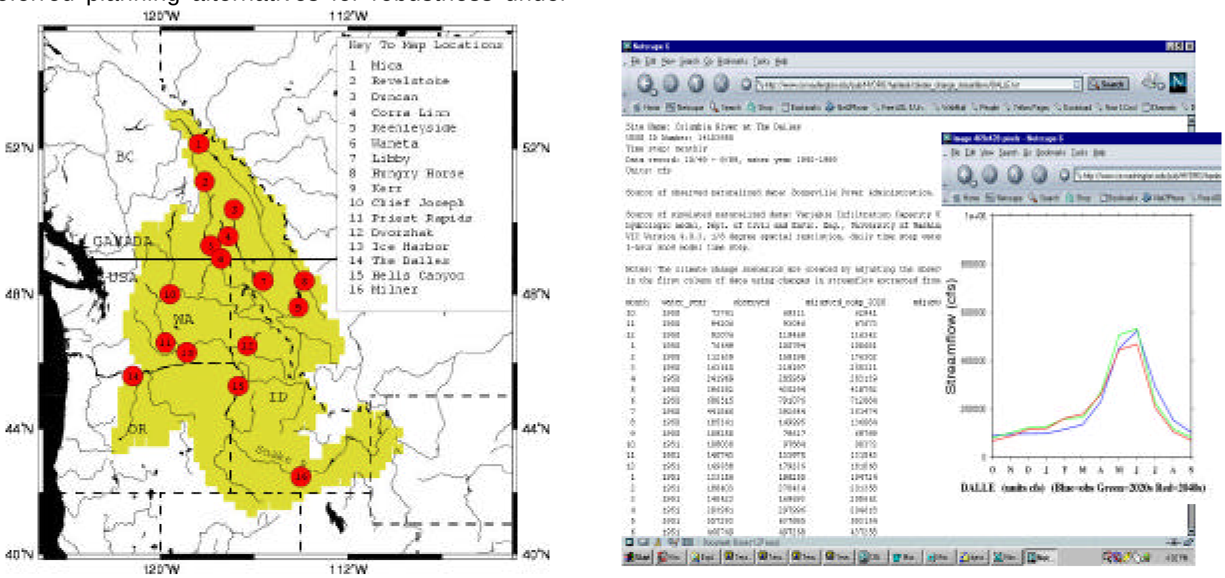


Figure 5: Pilot web-based decision support system for water resources management is currently available for 16 locations in the Columbia River basin (left). Adjusted realizations of the historic streamflow record are generated based on simulations from a physically based hydrologic model driven by scenarios of projected climate change; the water resources manager can retrieve the adjusted streamflow data both graphically and in tabular form (right).

5. ACKNOWLEDGEMENTS

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