

Economic and Human Dimensions of Climate Variability and Climate Change: Insights from the First Three Years of Research

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An Integrated Assessment of Climate Variability and Climate
Change on the Pacific Northwest
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Our research team studies the natural climate variability of the Pacific Northwest (PNW) using, primarily, instrumental records of temperature, precipitation, streamflow and snowpack. In addition, we have collected paleoclimate data spanning the last several hundred years (using tree ring data) and plan to add lake sediment data spanning the last 10,000 years. Climate variations occur on a range of timescales. The dominant one for temperature and precipitation is the familiar seasonal pattern. Another important timescale is 2-7 years, the period of the El Niño Southern Oscillation (ENSO), and in fact we have found many connections between ENSO and the regional climate of the PNW. The Pacific Decadal Oscillation (PDO) is a pattern of variability with a longer timescale, with reversals in phase occurring every 2-3 decades.

In addition to natural climate variability, we also study the potential impacts of human activities on the global and regional climate. Our research team is charged with providing the PNW regional contribution to the U.S. Global Change Research Program (USGCRP). There is no doubt that carbon dioxide in the atmosphere is increasing, and that it will continue to increase for the foreseeable future. Increasing carbon dioxide will, almost certainly, lead eventually to an increase in global mean temperature. This does not imply that the mean temperature everywhere will rise; regional impacts of global climate change may be subtle and surprising. Part of our purpose is to learn how global climate change might impact the PNW, given our understanding of past climate variability and its impacts. We think that the regional impacts of climate change will not be experienced as changes in conditions per se, but rather as changes in patterns of climate variability.

Many components of the ecosystems in the PNW are sensitive to climate variations such as those related to ENSO and PDO. We study the connections between natural climate variations and variations in natural systems, for example by examining the correlations between Niño 3.4 (an index for ENSO) and snowpack, and between the PDO and salmon production. Our efforts to date have focused on four primary sectors: water resources (especially the Columbia River), aquatic ecosystems (especially salmon), forests, and coastal processes (erosion, coastal flooding, exotic species invasion). Apart from coastal processes, the impacts of climate variability are largely mediated by the region's hydrology, i.e. variations in the quantity, quality and timing of available water translate to impacts on a variety of human activities and areas of concern. In the future we will expand our analysis to include energy, human health and agriculture.

All of the above-mentioned natural systems have economic importance in the PNW and are partly under human control. Our human dimensions research component focuses on how managers make decisions about these systems and how their decisions are informed by past and future climate variability. In addition, we consider how an improving understanding of the past, present and future climate may contribute to better informed decision making in a number of economically important sectors. Research to date has been centered on three primary components:

- Patterns of social organization and management capacities to incorporate climate information
- Socio-economic implications, e.g. economic value of climate forecasts
- Response strategies, i.e. changes in institutional arrangements or operating procedures that can reduce vulnerabilities to climate impacts

The bulk of our effort has dealt with the first component through the use of structured interviews and institutional analysis. We have mapped out the organizational context of each of the four sectors, identified prevailing patterns of interaction (including conflict), gauged the

potential utility of climate forecasts, and have evaluated the capacities of managers to incorporate climate information into decision making.

Our work on the second component has focused on the economic value of climate forecasts. We have completed an assessment of forecast value in the context of managing salmon fisheries, and are close to completing our work in the hydropower sector. In both cases we have constructed formal models that apply principles of decision analysis to measure forecast value in a specific decision-making scenario.

Only after understanding the current state of the system can we explore future directions. It follows that investigating response strategies is a major focus of our future work. A project is already underway to explore new institutional frameworks for managing water resources in the PNW. We intend to carry out detailed analyses of potential policy alternatives, such as the creation of water markets and energy policy alternatives under the assumption of deregulation for the PNW.

Results and Insights

While more specific details may be found in the appropriate reports, the most significant findings gained from our human dimensions research may be summarized as follows:

Institutional dynamics

- Patterns of conflict between organizations (regulatory, management, others) cluster around the availability of water. The Columbia River water resource management system is very large and fragmented with over one hundred players at Federal, tribal, regional, state, county, and municipal levels. The institutional design is piecemeal and haphazard, legal agreements are not harmonized, and authority issues remain unresolved. As a consequence, there is great inertia in the system and even incremental improvements are hard to come by, limiting the capacity to respond to climate variability and climate change.
- The two hydrologic extremes, flood and drought, pose the greatest vulnerabilities. Drought is by far the more conflicted scenario as tensions over allocation between competing uses (hydropower, agriculture, fisheries, transportation and others) are heightened by scarcity, and there is no centralized decision-making authority. However, with respect to flood control, there are only three major players: the U.S. Army Corps of Engineers, the Bureau of Reclamation, and the Bonneville Power Administration. Among the three players, the Corps has clear decision-making authority over flood control.
- There are dramatic disconnects between the institutional system and the natural climate system. The region per se has little policy response capacity, particularly with respect to climate change, as most institutions operate at the watershed and sub-watershed scales. Major differences in spatial scales limit adaptability and increase vulnerability to climate impacts.
- Existing legal frameworks pose formidable constraints on the ability to take advantage of climate information. In some cases, narrowly defined legal mandates for public agencies preclude them from incorporating climate variability or projected climate change into the management framework. For example, with respect to the prospect of increased coastal flooding due to sea level rise, the Federal Emergency Management Agency (FEMA) is

precluded by law from altering the boundaries of a designated 100-year floodplain in response to new information. In other instances, the existing legal framework defines or constrains changes in the distribution of resources. In the case of water resources, Western Water Law, which is based on the concept of "first in use, first in right", is very resistant to change. Similarly, in the case of Washington State fisheries, tribal treaty rights (which guarantee treaty tribes 50% of the total harvest), as well as the requirement of co-management between the tribes and the state, place limits on the adaptability of the management system. Our contention is not that the various legal constructs should be criticized or dismantled, but that they must be recognized as real constraints that may impede to some extent the incorporation of climate information into decision making.

Potential utility and current use of climate forecasts

- In general, we have found that the potential utility of climate forecasts is quite high relative to the defined tasks of decision-makers in various sectors. We base this conclusion on both objective measures of the region's sensitivity to climate, and on the subjective perceptions of decision-makers. As to sensitivity, we note for example that El Niño events reduce streamflow in the Columbia River basin by approximately 10% compared to the long-term average, while La Niña events increase streamflow by a comparable amount. On a decadal scale, the warm and cool phases of the PDO are characterized by a similar signature on regional streamflow. When ENSO and PDO are "in-phase" (e.g. El Niño with warm PDO) the effects are roughly additive, leading to more substantial reductions or elevations in streamflow. Our interviews reveal that many decision-makers consider their areas of interest to be vulnerable to climate variability, in particular to the extremes of the hydrologic regime.
- However, despite the evident utility of climate forecasts, we find that at the present time only a small percentage of decision makers consult climate forecasts such as those issued by the Climate Prediction Center and the River Forecast Center, and few have the technical capacity to consume, understand and incorporate probabilistic forecasts into the decision making process as anything beyond background information. Why is this so? We conclude that barriers to forecast utilization arise at both ends of the line, i.e. the forecast producer and the forecast user, and that there is a need for increased feedback and intermediary interpretation between producers and users. Barriers include:
 - ◆ the inability of most users to understand and apply probabilistic information,
 - ◆ lack of interpretation and demonstrated applications,
 - ◆ low forecast skill (real and perceived),
 - ◆ low geographic resolution relative to scales of concern,
 - ◆ inadequate accompanying information,
 - ◆ organizational barriers to the incorporation of new tools into decision making, and
 - ◆ complex, highly fragmented management systems.

Apart from a need for greater forecast specificity, the lack of adequate interpretive services about impacts on specific resources or areas of concern stands out as a formidable barrier at this time. Simply improving forecast skill does not guarantee increased forecast utilization.

- We perceive the problem of forecast utilization as a question of the diffusion of social innovation. Research efforts on the introduction of innovations to society have identified attributes of innovations that enhance the rate at which they are adopted. In the perceptions of our interviewees, climate forecasts lack many of these attributes, which include low complexity, compatibility, relative advantage, trialability, and observability.

Economic value of climate forecasts

It is important to distinguish between the economic value of a forecast per se, and the economic value of understanding patterns of climate variability and how those patterns in turn affect particular economic sectors or areas of interest. In the first case, an analysis of economic value for a forecast is necessarily grounded in a specific decision making scenario. Simply stated, one can ask whether basing a decision on a forecast produces an expected benefit in desired outcomes. This benefit will be measured relative to a reference procedure, such as assuming historical average conditions or standard operating procedures in lieu of a forecast. This determination can only be made if we 1) characterize the distribution of the predictand (e.g. the marginal probability distribution of streamflow), 2) know the skill of the forecast mechanism (e.g. the conditional probability distribution), and 3) define the shape of the utility function (e.g. are costs and benefits linear, or are there threshold effects). Furthermore, one must consider *whose* benefits are being considered; apart from obvious examples such as the ability of accurate flood forecasts to save lives, changes in decisions often lead to changes in the distribution, rather than the total value, of benefits. This is particularly true in highly conflicted issues such as water resource management where a boon for one interest group may be a bust for another.

In the second case, knowledge of historical patterns of climate variability, and how those patterns translate to impacts, can be valuable for planning or decision making. While a particular user may not be able or willing to apply a specific forecast to a decision (e.g. basing water allocation decisions on a streamflow forecast for a particular month), the user can nevertheless construct more optimal operating procedures or rule curves on the basis of historically based probabilities.

- In our analysis of forecast value for the management of salmon fisheries, we constructed our model to reflect the most important features and limitations of the current management system. While we found the *potential* value of a forecast to be as high as 20-25% of the current economic value of the fishery, a forecast must be able to explain in excess of 60% of the total salmon recruitment variation *before it has any value whatsoever*. Similarly, other researchers have found that (in the agricultural sector) forecast value is non-linear with respect to forecast accuracy and that only very accurate forecasts are economically valuable.
- The economic value of a forecast is highly dependent on the coherence of spatial and temporal scale between the forecast and the requirements of the decision-making context. For example, if a particular system is highly adaptable to real-time information or short-lead forecasts, then the value of a six-month forecast may be very low even if it is accurate.
- We must also take care in distinguishing between climate forecasts and resource forecasts, the latter meaning the projected response of a variable of interest (e.g. Columbia river streamflow or salmon marine survival) to a particular climate scenario. Most decision-makers

are concerned with these resource responses rather than the state of the climate system per se. The errors inherent in predicting each of the two steps are compounded, reducing the predictive utility of a climate forecast.

Future Directions

The next phase of our economic and human dimensions research will build on our experiences and insights from the first three years, adding new areas of inquiry as well as tying up loose ends. With respect to forecast value, we plan to extend our formal modeling effort to include all four sectors and potentially different applications within sectors. We will also address any gaps in our institutional mapping effort. Our most significant future areas of research are the following:

- Consider what changes in the structure of institutional arrangements and substantive policies in each sector would increase adaptability and reduce vulnerability to climate variability and change.
- Use a physical template of the region to analyze impacts and vulnerabilities on finer spatial scales for all sectors under different scenarios of climate change.
- Develop a socio-economic database on time and space scales which are comparable to the physical and biological dimensions of our climate impacts model. Examine mitigation strategies in depth, beginning with an evaluation of the potential consequences of introducing water markets into the region.
- Evaluate the socio-economic impacts of climate change in the PNW on and through the energy (hydropower) sector.
- Design a strategy for increasing the capacity of local government to respond to climate variability and change.

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