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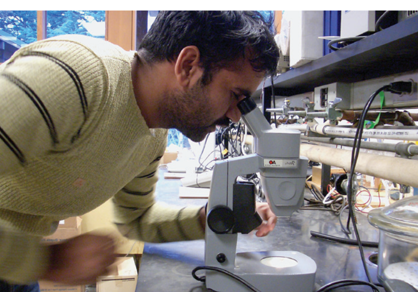
Water, Washington, and the World:

Ensuring Economically and Environmentally Sustainable Water Resources




Summary of the Proceedings of the Fifth Annual Symposium

Held as Part of the 2012 Annual Meeting of the

Washington State Academy of Sciences

September 20, 2012, Museum of Flight, Seattle, WA

Spring 2013

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About the Washington State Academy of Sciences

WSAS is an organization of Washington state's leading scientists and engineers dedicated to serving the state with scientific counsel. Formed as a working academy, not an honorary society, the academy is modeled on the National Research Council. Its mission is two-fold:

- To provide expert scientific and engineering analysis to inform public policymaking in Washington state, and
- To increase the role and visibility of science in the state.

Governor Christine Gregoire authorized legislation establishing WSAS in 2005. Its 12-member Founding Board of Directors was recommended by the presidents of Washington State University and the University of Washington and was duly appointed by the governor. In April 2007 WSAS was constituted by the Secretary of State as a private, independent 501(c)(3) organization.

Symposium materials

Source material for the Fifth Annual Symposium may be found on the WSAS website, including

- Speakers' slides;
- Video of the invited speakers' presentations;
- After-dinner address by Dr. Howard Frumkin, Dean, University of Washington School of Public Health;
- Symposium handouts; and
- Symposium photographs.

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Welcome to the proceedings of our Fifth Annual Symposium, "Water, Washington and the World." Water is vitally important to the people, wildlife, vegetation and landscape of Washington state. Climate change impacts water and all the services we derive from it—municipal water supplies, hydropower, irrigation for agriculture, and flood control. This year's symposium presents an expansive view of water—from global perspectives to case studies of individual local crops. As we go to press, the nation is facing the loss and devastation caused by Superstorm Sandy. The information and data that the speakers bring forth aid in our understanding of climate change and what we can do about it.

Executive director

President

Executive Summary

Water—its availability, its quality, its scarcity, its ownership—affects every person in the state of Washington. One of the major impacts of climate change is the effect a warming earth will have on water. Will increasingly arid summers dry up municipal water supplies? Will hotter temperatures benefit or harm established crops? Will changes occur for people who own water rights but are not using them?

Scientists throughout the state have been conducting fundamental research on hydrology and the drivers of climate change. What they are finding has elements, in turn, of both optimism and alarm.

Global climate change is affecting the Pacific Northwest

Dr. Robert W. Corell pointed out that the Northwest's climate is influenced more by global climate change than by regional oscillations like El Niño. Temperatures here are projected to increase by 2.0°F (1.1°C) by the 2020s and up to 5.3°F (2.9°C) by the 2080s. Some of the effects of rising temperatures are already evident—snow melt times are coming earlier in the spring, up to more than 20 days sooner than in the past, which as Dr. Corell notes, "is a non-trivial amount." In addition, carbon is causing the ocean to acidify more rapidly, which will affect the marine food chain.

Climate models and what they can forecast

In the past, when the climate was more stationary, it was expected that the future climate would be like the past. But today the climate is being altered, and the only way to really find out what it will look like is to simulate it in models.

Dr. Edward Sarachik demonstrated how climate models can forecast local temperature and rainfall variabilities. Dr. Dennis P. Lettenmaier presented examples of models that help predict seasonal variations in soil moisture, snow level, and stream flow, and how those will change over the next century. Dr. Jennifer Adam shared research showing climate impacts on agriculture, including the effects, crop by crop, of a changing climate. While an understanding of global climate change is important, many lives and businesses such as farming are affected by what next year's local climate will be. Some effects of these changes will be damaging, and some will be beneficial. Washington's scientists are modeling the local and regional climate to help forecast short-term as well as long-term change, giving people an opportunity to plan ahead.

Adaptation vs. mitigation

As climate change panels around the world grapple with global mitigation of climate change, scientists here prescribe that on local scales, adaptation is more important than mitigation. Washington's agriculture is an important part of the state's economy, and warming temperatures will lengthen the growing season but reduce crop yields. Dr. Jennifer Adam used modeling projections for individual crops that offer the potential for various adaptation strategies. For example, planting dates can be changed, perennial fruit loads can be managed differently, and crop varieties can be planted or developed that will be more productive in future climate conditions. Water management can be adapted through measures such as water diversions or modification of reservoir operations.

Water rights are like a dam

Dr. Jonathan Yoder defined both as entities that help distribute water over time and space to where it's more useful and valuable. Today, traditional water rights seniority in the West allotted under the doctrine of Prior Appropriations increasingly does not coincide with highest value uses. Water markets and water banking can help in a variety of ways to better manage scarce water resources. Water transfers and other market programs have been slow to develop and far from perfect, but are picking up steam as people recognize the role that they can play in adapting to the economic and environmental conditions coming about due to climate change.

Climate change at the Washington state policy level

In 2007, the state Legislature passed HOB 1303, which mandated the preparation of a comprehensive assessment of the impacts of climate change on the state. Part of the assessment focused on the Puget Sound Basin and the Yakima River Basin and showed the balances and shortcomings of those water systems. Scientists acknowledged that there has been improved inter-agency cooperation, but said that information about climate and climate impacts should be more accessible statewide. Technical capabilities could be increased to incorporate information on climate impacts. More work could be done on horizontal integration among Washington state sectors impacted by climate change—for example, integrated management of water resources for hydropower, agriculture, ecosystems, and flood control.

Engaging the public

Dr. Corell noted that worldwide climate change is tied to CO^2 emissions into the atmosphere, which are currently the highest in 2.1 million years and rising. Yet, he pointed out, people could cut energy use in their homes by 90 percent by simply incorporating existing technologies. Dr. Howard Frumkin talked about the importance of accurate data to direct attention and allocate resources for global waterborne health problems. Washington's scientists are conducting hydrological research that offers information to try to ensure economically and environmentally sustainable water resources in the face of climate change. Scientists agreed that the problems are complex but by no means hopeless. However, both mitigation and adaptation require both the public and politicians to be convinced to take action.

Session I

Climate change and hydrologic implications

Session Chair: Edward L. Miles
Professor Emeritus of Marine Studies and Public Affairs
University of Washington

Keynote

Global Climate Change and Water Resources

Robert W. Corell
Principal, Global Environment and Technology Foundation; and Lead, Center for Energy and Climate Solutions

Synopsis

Water and the hydrological cycle can be described as the circulatory system of the planet. Whether it's rain, or rivers, or oceans, water is moving energy and nutrients.

Global climate change is affecting the Pacific Northwest climate

People are familiar with regional climate changes like El Niño, and while those changes are important for the Pacific Northwest, they are not the main driving force of the region's climate. About 70 percent of the region's climate variability is estimated to be due to global changes in the climate system.

Globally, climate change is tied to carbon dioxide levels. After 10,000 years of very stable conditions, humans are currently pushing millions of metric tons of CO^2 into the atmosphere. The Intergovernmental Panel on Climate Change has presented a number of scenarios, and today the planet is in the worst case scenario.

CO^2 in the atmosphere is at highest level in 2.1 million years

Around 1750, the world began using fossil fuels as a primary energy source to drive the industrial revolution. In 1751, CO^2 emissions were 2.55 million metric tons. In 2012, that amount has increased more than 3,000 times. Present day atmospheric CO^2 is at its highest level in the past 2.1 million years.

Table 1. Global CO^2 Emissions 1751 to 2012

	Global CO^2 emissions	Global population
1751	2.55 million metric tons (MMT)	
1770	3.35 MMT	850 million
1800	7.67 MMT	1.0 billion
1900	533.11 MMT	1.6 billion
1950	1580.67 MMT	2.5 billion
2000	6556.32 MMT	6.0 billion
2005	7613.69 MMT	6.5 billion
2012	9139.00 MMT	7.0 billion

There is massive population change in the developing world. The amount of emissions in the air has been linearly tied to population for the past 60 years. Since the mid-20th century, global population growth is almost entirely concentrated in the world's less economically developed nations.

Bellweather sea changes and worldwide sea level rise

From 1880 to 2003, the global mean surface temperature has increased ~0.8 °C (0.1.44°F). Arctic mean surface temperature has increased two to three times that or about 2°C (3.6°F). The Arctic is the bellweather for the rest of the planet. The Arctic sea ice was stable from 1770 to 1950 but then began to change around 1950. There's been a 50 percent reduction of both size and volume or thickness of Arctic sea ice since 1979 (Figure 1).

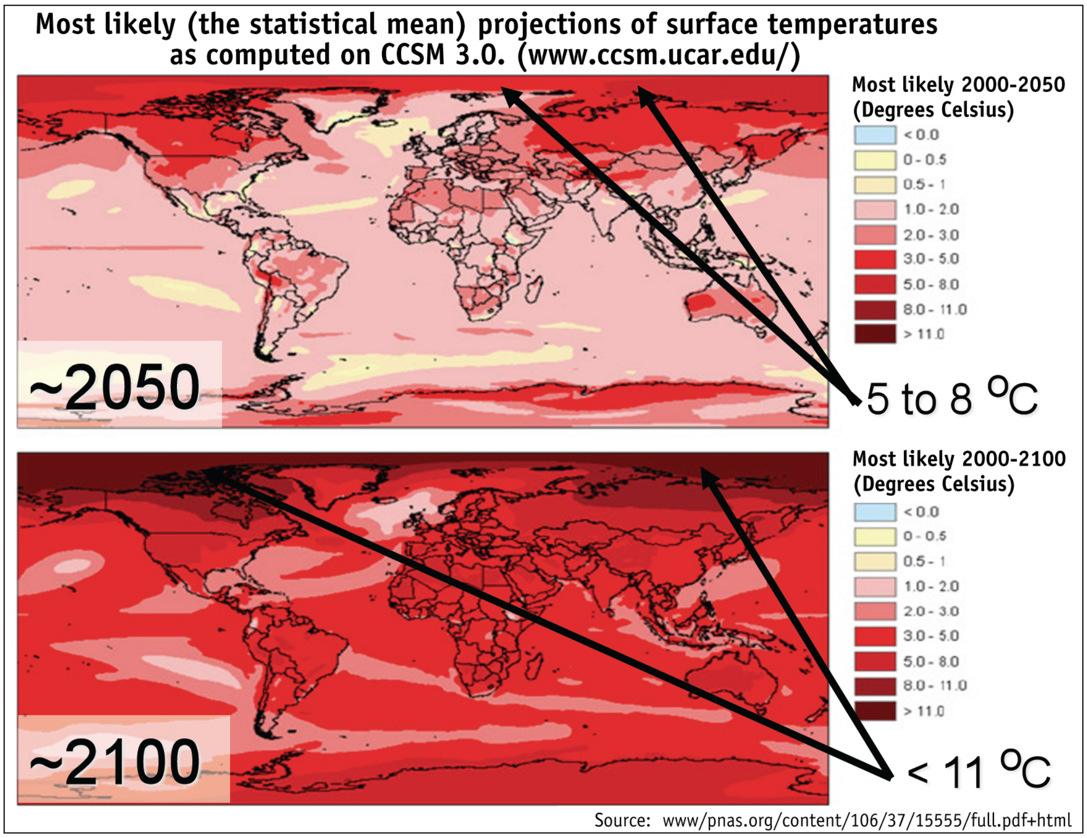
"This is an intergenerational issue. My grandchildren are not going to be happy with what we did, in my view."

Robert W. Corell

Water dynamics in the Pacific Northwest are profound and serious

Worldwide, projections show that the total sea level rise will likely exceed 1.0 meter (3.2 ft.) per century and closer to 2.0 meters (6.5 ft.) by 2100. Sea levels are rising in the western Pacific at a greater rate than in the North Atlantic at a rate that is three to five times the global average.

Figure 1. Projected surface temperature increases by 2050 and 2100



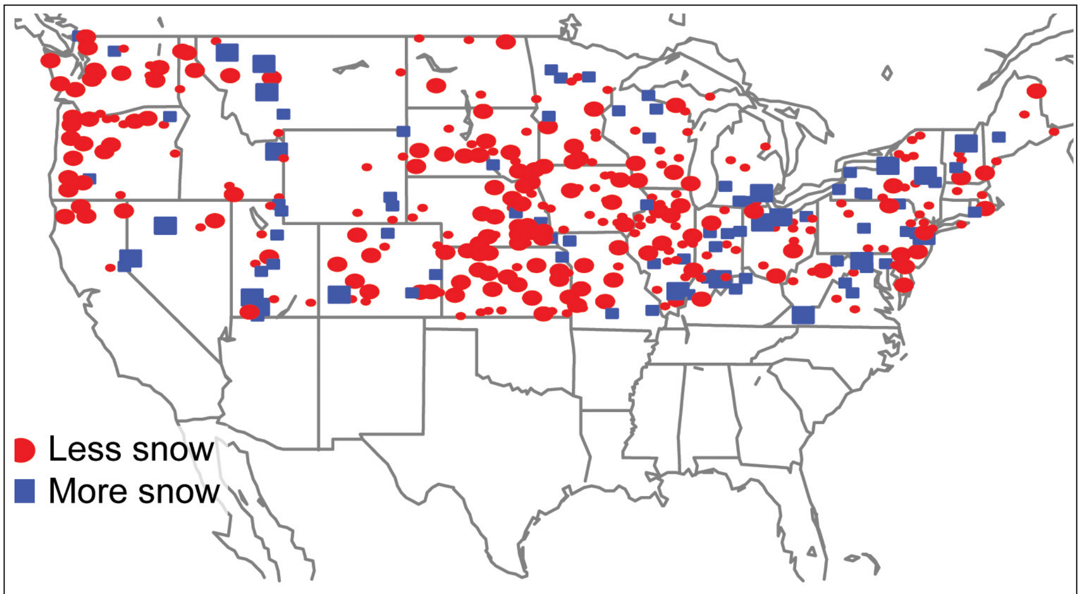
With global climate change, annual precipitation is projected to increase only in single digits, but the amount of rain per unit of time is going way up: There has been a 30 percent increase in severe precipitation in the last 30 years across the lower 48 states.

Except for extreme precipitation events in the western Cascades, projected precipitation increases for the Pacific Northwest are small (+1 to +2 percent). Projections, however, show reductions in snowpack (see Figure 2). Snowfall is the "water bank" and long-term reservoir for hydropower, so these changes are notable. Melt times are coming earlier in the spring, by non-trivial amounts—in many areas from 10 to more than 20 days sooner than in the past.

Two substantial challenges to the future of planet Earth and humankind

One major concern is that ocean acidification is accelerating. Recent projections indicate that changes in the acidification of the deep ocean may exceed anything seen in the past 65 million years. The increasing CO^2 in the oceans has enormous consequences on all marine life because it affects the bottom of the food chain.

Figure 2. Trends in winter snow-to-total precipitation ratio from 1949 to 2005



Smaller circles indicate less snow, while smaller squares indicate more snow. Large circles and squares indicate the most significant trends.[143] Areas south of 37°N latitude were excluded from the analysis because most of the area receives little snowfall. White areas above that line have inadequate data for this analysis.

A second major issue is the thawing of permafrost and released methane. Northern Canada, Alaska, Russia, and Greenland have experienced temperature increases up to 4°C (7.2°F), resulting in thawing of permafrost and release of methane. Along the eastern Siberian Arctic shelf, researchers found plumes of methane bubbles rising from the seabed to the ocean surface and into the atmosphere at scales not seen before.

"We have already seen pretty substantial changes in the last century. We have to focus on solutions and tell the world what it's all about."

Robert W. Corell

Understand the threats, reduce consequences, focus on solutions

Humankind faces a set of emerging realities. Scientists need to learn more—to substantially expand the understanding of how the planet's natural and socioeconomic systems work. Following from that, there's a need to more deeply understand the consequences of changes that are most threatening. Society needs to develop ways to reduce those consequences by minimizing downsides and strengthening resilience. And finally, everyone needs to focus on solutions, exploring the options and ways to support the peoples and nations of the world.

Slides and a video for this talk are available at www.washacad.org.

Climate Dynamics

Edward S. Sarachik
Professor Emeritus of Atmospheric Sciences,
University of Washington

Synopsis

Long-range climate change projections forecast what's going to happen in 50 and 100 years. But farmers are thinking about what's going to happen next year and what's going to happen in 50 years. They want to know if they're going to have a crop next year, and they want to know if they're going to have a farm to leave to their kids.

What is next year's climate going to be?

In the past, when climate was more stationary, it seemed certain that the future was going to be pretty much like the past. But humans are altering the climate, and the only way to really find out what it will look like is to simulate it in models.

The earth's climate has an existing natural variability that's determined by a number of factors. The factors are weather, including extremes of weather; the annual cycle; and intra-seasonal variability. Longer-term natural variabilities are the El Niño/Southern Oscillation phenomenon (interannual), the Pacific Decadal Oscillation (decadal), and the Atlantic Multidecadal Variability (~ 50 years).

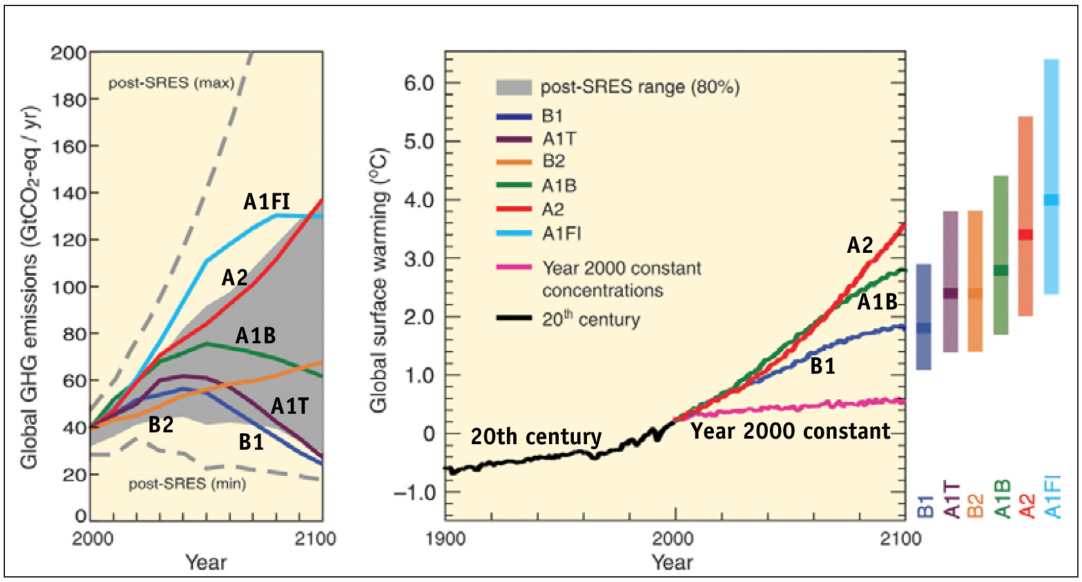
Human alterations of climate are produced by emissions of carbon dioxide, methane, chlorofluorocarbons, and nitric oxide that heat the surface; and aerosols, most of which cool the surface. These human alterations result in global long-term trends and the alteration of natural variability. The future global climate partly depends on how humanity chooses to deal with both the amount and the mix of future emissions.

Climate models predict rising temperatures

Climate modeling can be used to predict what the climate will be in the next few years. It's the only way to definitely describe how assumptions about future emissions will affect future climate. For example, these graphs (see Figure 3) depict the projected rise in greenhouse gas emissions and projected global surface warming from 2000 to 2100 for a number of assumptions about future emissions.

Currently, humans are putting levels of CO^2 and other gases into the atmosphere that are at the very top of the scientists' scenarios, and the future indicates that temperatures will increase by ~4°C (7.2°F) over the next 100 years.

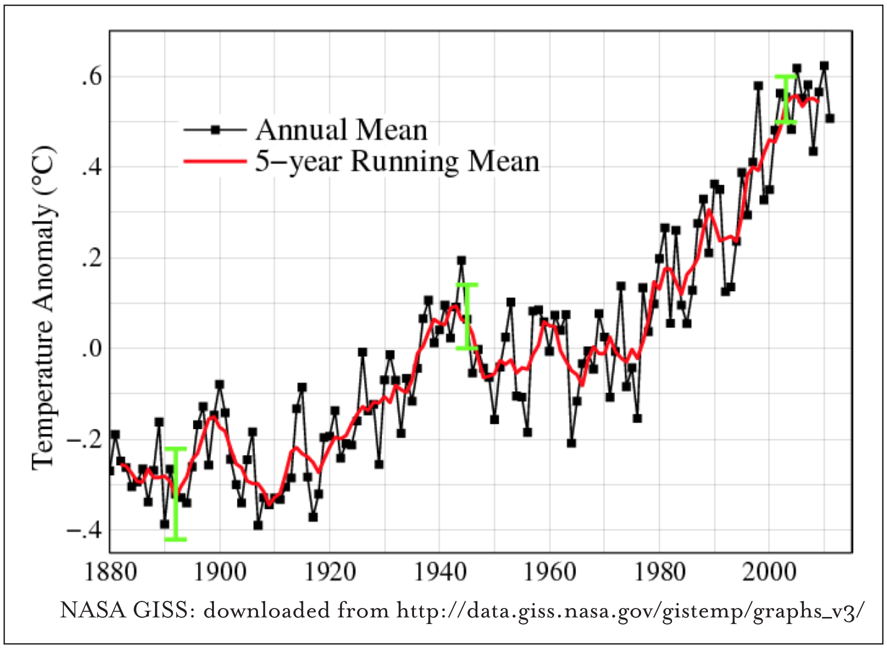
Figure 3. Climate models used to predict near-term climate and calculate the response to predictions of future emissions.



Climate variability is greater at local levels

When we look at the globally averaged temperature, the year to year variability is rather small. Indeed, we look at globally averaged temperatures so that we can more distinctly see the trends (see Figure 4).

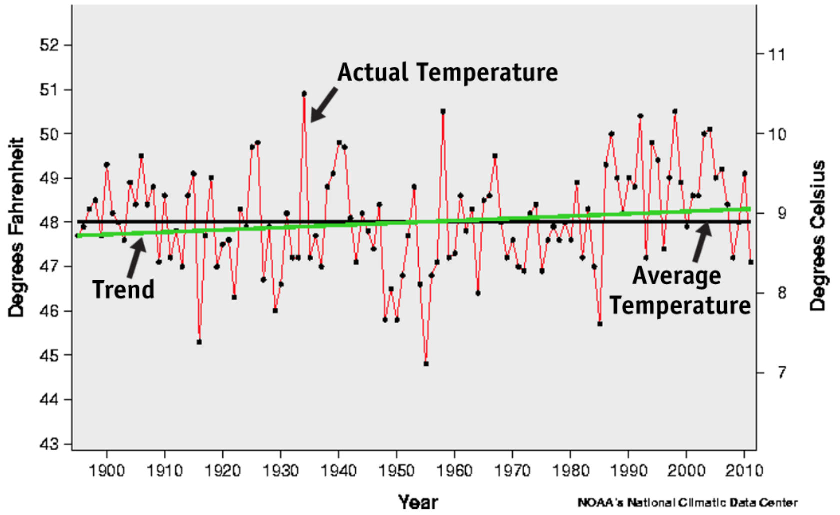
Figure 4. Global land-ocean temperature index



Globally averaged temperature

Even when climate does not seem to be changing that dramatically on a global level, variability at the local level can be rather large—in fact, variability increases as we go to smaller spatial scales. Temperature-wise, it might take 100 years for the globally averaged temperature to vary 2 or 3°C (3.6-5.4°F), yet that much variability could occur year-to-year in the state of Washington (see Figure 5).

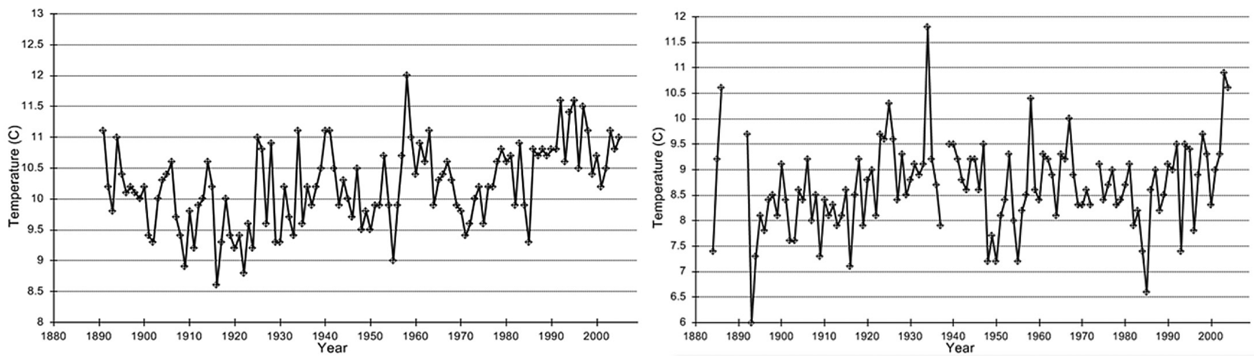
Figure 5. State of Washington surface temperature year-to-year



Plotted and downloaded from the NOAA NCDC site: www.ncdc.noaa.gov/oa/climate/research/cag3/cag3.html

By the time we get to individual stations, the temperature variability is quite large and the effects of global warming can hardly be seen, as in the graphs depicting surface temperature in Aberdeen and Ellensburg, Washington (see Figure 6).

Figure 6. Local temperature variability of individual local stations



Aberdeen, Washington **Ellensburg, Washington**

Rainfall is also more variable at the local level than it is globally and regionally. It should be noted that rainfall exhibits the same type of pattern, increasing variability as the spatial scale gets smaller.

While global warming may seem more like a long-term problem, concerns about next year's temperature and rainfall are more immediate. What will the climate look like next year? People and businesses plan and budget one year at a time. Even when planning extends to the 50-year time scale, plans are still made one year at a time, and it becomes important to factor next year's climate into the slow growth of overall temperatures.

Adapting to next year's climate

One way to think about climate service is to compare it to the weather service, which tries to inform people about what tomorrow's weather and next week's weather is going to be. It has the same advantage: If people knew what the climate was going to be next year, they could adapt to it.

"We spend most of our time talking about mitigation, which we have by no means done—things have gotten worse—and very little time talking about adaptation, which we could do."

Edward S. Sarachik

While mitigation is significant on a global scale—enacting laws that reduce emissions, for example—on a local scale, adaptation is clearly more important. Even if there were no global warming, we would have to deal with next year's climate.

Adaptation consists of lessening the effects of damaging climate and taking advantage of the effects of beneficial climate. The basic tool of adaptation is short-range climate prediction.

To summarize:

- Mitigation is global and mostly about trends.
- Adaptation is local and mostly about variability.

Slides and a video for this talk are available at www.washacad.org.

Implications of Climate Change for Hydrology and Water Resources

Dennis P. Lettenmaier

Professor of Civil and Environmental Engineering,
University of Washington

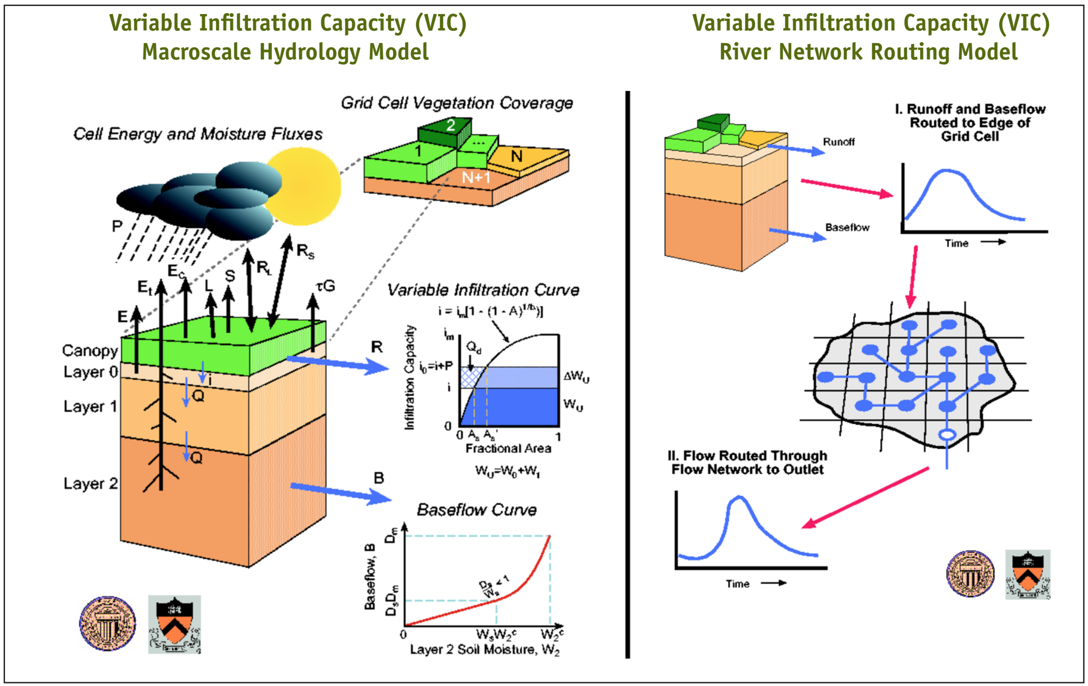
Synopsis

A water manager who is making decisions over an economic life that may span 20 to 40 years needs to ask, "What does climate change mean to me?" This is especially critical because hydrological extremes—floods and droughts—are projected to become more frequent.

Assessment approaches

To help answer that simple question, scientists use models that are increasingly complex. Models analyze the motion of the atmosphere, the ocean and the land surface. Over land, they can predict things like soil moisture, snow (extent and water content), and streamflow (see Figure 7).

Figure 7. Macroscale hydrology and river network routing models



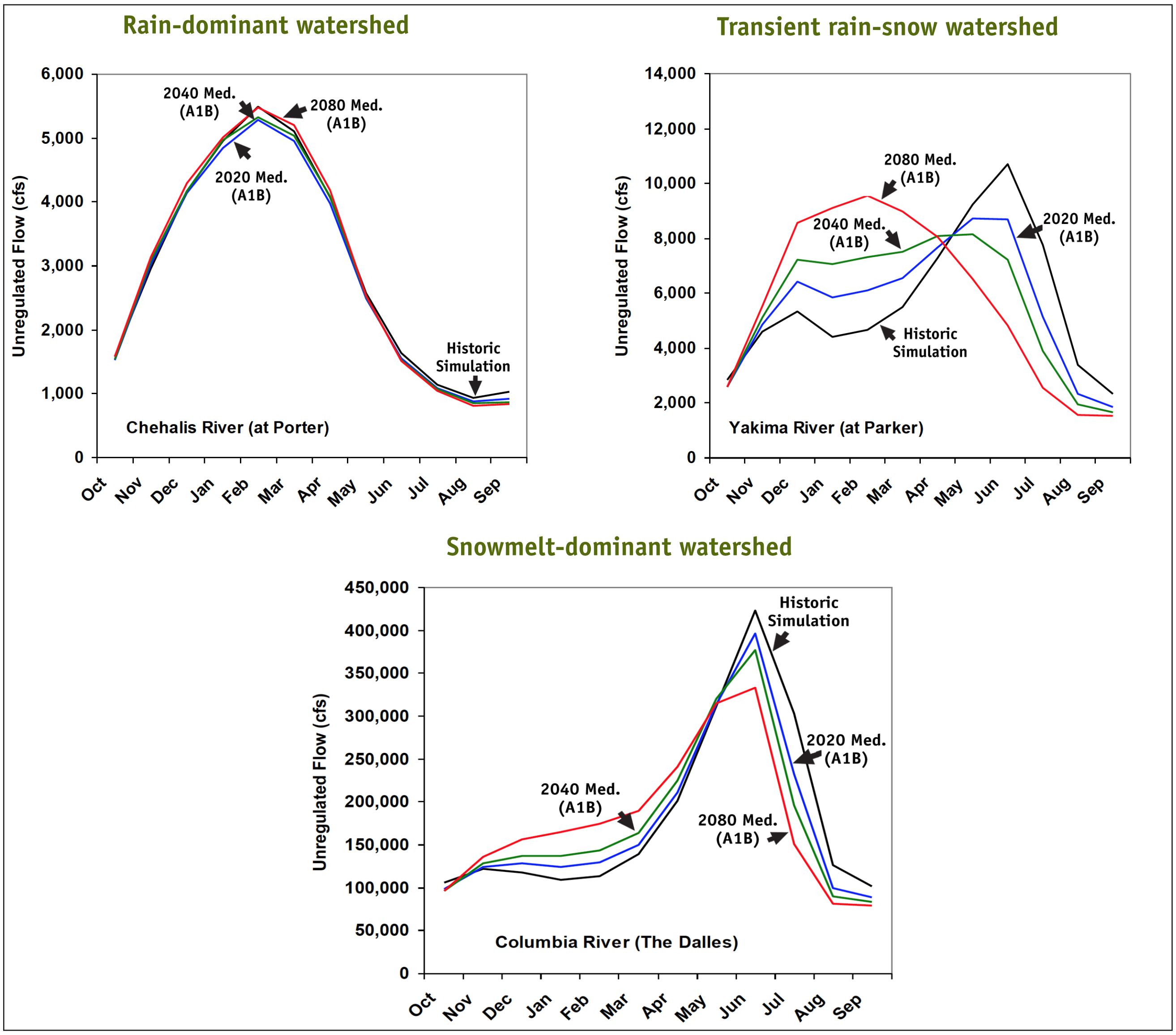
In Washington state, scientists have employed models that are used in reports of the Intergovernmental Panel on Climate Change. These models incorporate a huge volume of data, and project 100 years and more into the future. These climate projections, run through hydrological models of Washington's major river basins, can help predict the impacts of climate change on the state's water resources.

> *"Seasonal, not annual, changes are the big deal in Washington."*
>
> Dennis P. Lettenmaier

Rivers respond to summer and winter changes

Lettenmaier's team at the University of Washington has modeled local variations in seasonal streamflow patterns and sensitivities in the Pacific Northwest. They produced comparisons of the Chehalis River, which is a rain-dominant watershed, vs. the Yakima River, which is a transient rain-snow watershed, vs. the Columbia River, a snowmelt-dominant watershed. This modeling enables them to project ranges of streamflow conditions as far ahead as 2020, 2040, and 2080.

Figure 8. Variations in seasonal streamflow patterns and sensitivities in the Pacific Northwest



Hydrologic extremes

Are changes in extreme precipitation a function of temperature? Models show that extreme precipitation should be increasing as the climate warms. Lettenmaier's team modeled trends in annual precipitation in the 100 largest urban areas of the U.S. and found that most of the U.S. has been getting wetter over the last 100 years. It does appear that rising temperatures are connected with increased rain, higher soil moisture, and evaporation.

How does streamflow change in terms of other factors like flood stage? One study looked at more than 14,000 U.S. Geological Survey stream gauge sites to examine magnification factors for flooding. An average of 10% of sites had significant positive trends.

Are droughts changing? Another study reconstructed U.S. soil moisture trends for the last century, then used that information to evaluate trends in U.S. drought duration and severity. Patterns emerged where over much of the country droughts have become less severe over the last century, however the reverse is true over the western U.S., where there is evidence of trends toward increased drought severity, primarily as a result of warmer temperature (increased evaporative demand) more than counteracting increased precipitation.

Implications for Washington's water resources

In 2007, the state Legislature passed HB 1303, which mandated the preparation of a comprehensive assessment of the impacts of climate change on the state. The assessment was to focus specifically on public health, agriculture, coastal zones, forestry, infrastructure, water supply and management, salmon and ecosystems, and energy.

Part of the assessment examined the Puget Sound Basin and the Yakima River. In the Puget Sound Basin, consumption of water (mostly for municipal water supply) has been going down over the past 20 to 30 years, not only on a per capita basis, but even on a total basis despite population growth. Reasons include more efficient appliances and less urban irrigation because of high-density housing. Even if the demand for water increases, the assessment showed there will not be much of a problem unless it climbs to 125 or 150 percent of current.

However, in the Yakima Basin, the scenario is much different. The basin's irrigated crops represent the largest agriculture value in the state but are highly water dependent. In years when the basin's water is in short supply, water entitlements are impacted. With a changing climate, the basin would shift from snow-dominant to more rain-dominant. As a result, water allocations will have to be pro-rated more often. Even at present, junior water users receive only 75 percent or less of their allocation about one year in seven, so even without climate change, the basin is over-allocated.

Conclusions

- Compared with the rest of the U.S., Washington is in an area of modest annual runoff sensitivity to global warming.
- The differences between summer and winter streamflow, and runoff, are substantial. Seasonal, not annual, changes are the major issue here.
- Washington's westside water supply systems—mostly urban—are fairly robust in the face of shifts in the seasonality of streamflow. This will continue as long as demand remains stable or lowers.
- The Yakima Basin is probably the state's most climatically sensitive water resources system. Even modest changes in streamflow patterns (increased winter flow, reduced spring and summer flow) will substantially erode the system's reliability.

"The Yakima basin water system has a real problem with just a little bit of climate change."

Dennis P. Lettenmaier

Slides and a video for this talk are available at www.washacad.org.

Q&A Highlights

Left to right: Robert W. Corell, Edward S. Sarachik, Dennis P. Lettenmaier, and Edward L. Miles

Session I speakers:

Robert W. Corell, Principal, Global Environment and Technology Foundation; and Lead, Center for Energy and Climate Solutions

Edward S. Sarachik, Professor Emeritus of Atmospheric Sciences, University of Washington

Dennis P. Lettenmaier, Professor of Civil and Environmental Engineering, University of Washington

Session Chair/Panelist:

Edward L. Miles, Professor Emeritus of Marine Studies and Public Affairs, University of Washington

Question: Climate change is a formidable and frightening topic. Based on the data that you're reporting, how do you retain your hopefulness?

"No one has ever accused me of being optimistic. The problem is that we are not really dealing with the issue. This is being played out on the field of science when it should be played out on the field of politics. I do not see that the world is coming to any sort of realization that carbon emissions have to be decreased."

Edward S. Sarachik

"Before 1972 there were water pollution laws, but basically they said that if you could show that your discharge didn't cause a specific impact, you didn't have to do anything. One of the major changes was the '72 Water Pollution Control Act, which said that all discharges would be eliminated in the interest of making the rivers fishable and swimmable. Nobody really argues any more that it's okay to just dump untreated waste in a river. We're way past that. What I don't understand is why we have a whole segment of the population that can't understand or thinks that dumping carbon into the atmosphere is okay. We haven't gotten the message across."

Dennis P. Lettenmaier

Question: What kind of societal transformation would have to happen in order to see enough CO^2 reductions to stop the climate change that is going on?

"No new technologies are required. We can cut our energy use in our homes by as much as 90 percent. The European Climate Foundation found that there could be zero emissions by 2050. All it takes are changes in the utility of the kind of energy systems you use. Our job is to continue to provide at least some reasonable understanding of how this system works, and that there are optimistic ways to go and that we can get there."

Robert W. Corell

Question: We're not going to make the right choices if we're not understanding of what kinds of adaptations are going to be necessary. What can we do to get the public better informed?

"It's not clear to me that we have to convince the public. We have to convince the politicians and there we've done a horrible job. How good a job have we done when there are politicians who deny that global warming is occurring?"

Robert W. Corell

Question: As a student, I was wondering how can we start at our generation to improve the situation?

"In my view, you guys hold the key to the future. I was on a field trip where a company owner said, 'We just can't deal with this because economically it would destroy our company.' His 17-year-old daughter went up to him and said, 'You're going to leave us a world where we can't raise our children in. Please fix it.' Your voice can be heard; your voice is needed."

Robert W. Corell

"Pursue your education, both in the science and in the policy sciences. We need people to understand both the science and how to communicate the science."

Dennis P. Lettenmaier

Session II

Hydrologic impacts

Session Chair: Robert W. Corell
Principal, Global Environment and Technology Foundation;
and Lead, Center for Energy and Climate Solutions

Modeling Hydrological Impacts in Agriculture

Jennifer Adam
Assistant Professor of Civil and Environmental Engineering, Washington State University

Synopsis

Agriculture makes up 11 percent of the state's economy. Adapting to climate change is a crucial element to continued success of this economy. What can scientists predict about the effect of changes in temperatures, rainfall, and the availability of water? A team of scientists from Washington State University, funded by the Washington State Department of Ecology, are working to provide data that will help with agricultural decision-making.

Washington's agriculture is a major portion of the state's economy

Farmers in the state raise 300 commodities, both irrigated and non-irrigated (dryland). For 11 of those crops, Washington is first in the U.S. Livestock and crops together create $6-7 billion of annual revenue.

Climate change has the potential to directly and indirectly impact the state's agriculture in a number of ways. Warming temperatures lengthen the growing season, but because plants reach growing stages faster there is a reduction in crop yields. For non-irrigated crops, precipitation changes will also affect crop growth. Increasing CO^2 increases radiation and water-use efficiencies. Indirect impacts due to climate change include pests, weeds, and diseases. Potential water rights curtailment would impact irrigated crops.

"Increases in temperature will lengthen the potential growing season but reduce yields."

Jennifer Adam

Columbia River Basin water supply and demand forecast

Agriculture is one of the multiple competing water uses in the Columbia River Basin, vying with municipal and industrial uses as well as hydropower, flood control, fish flows, navigation, and recreation.

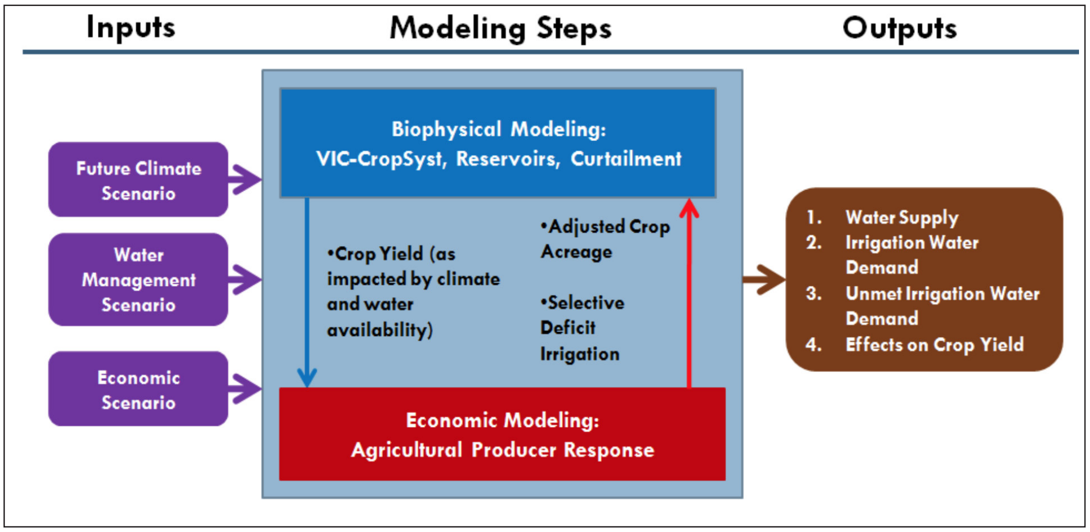
Every five years, the Washington State Department of Ecology's Office of the Columbia River is required to submit a long-term water supply and demand forecast to the state legislature. It helps to improve understanding of where additional water supply is more critically needed, now and in the future. Washington State University was assigned to develop the agricultural component of the 2030s forecast.

Modeling scenarios look at hydrology, crops, and water management

A team of collaborators from Washington State University—including professors, researchers, and students from Biological Systems Engineering, Center for Sustaining Agriculture and Natural Resources, Civil and Environmental Engineering, the State of Washington Water Research Center, and the School of Economics—tackled the forecasting project.

Starting with tools developed at the University of Washington Climate Impacts Group, the scientists added integrated surface hydrology and crop systems modeling, and water management operations, including reservoirs and water rights curtailment (when junior irrigation water rights holders are not granted their full rights in a year of low water supplies). In addition, they used economics to model crop producer decision-making of future crop mixes due to projected changes in domestic growth and international trade. Forty different crop groups were modeled—vegetables, and minor crops including tree fruit.

Figure 9. Interactions with economic modeling



Projected impacts on Columbia and Yakima basins' water supply and demand

In the Columbia River Basin at Bonneville, for the climate projected for 2030, projections show a small increase in average annual water supplies; irrigation demand will increase; and unregulated water supplies will decrease in summer and fall, and increase in winter and spring. Without adequate reservoir storage, this seasonal shift in water availability combined with increases in demand will harm irrigated agriculture.

"What will be the future crop mix within the same amount of lands?"

Jennifer Adam

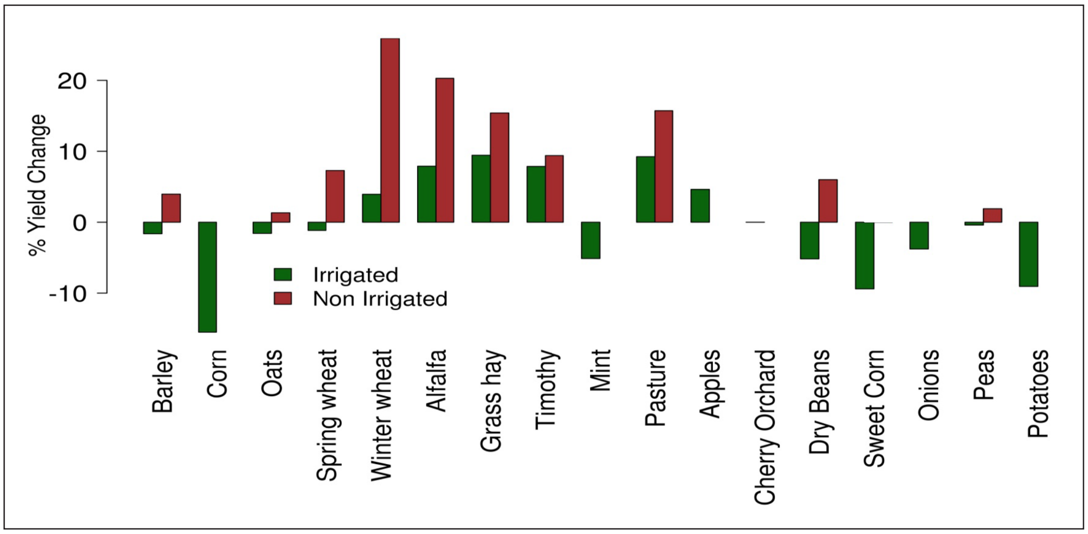
Washington's largest agricultural economy—the fifth in the nation—grows in the Yakima River Basin. Yields include tree fruit, vineyards, field crops, forage, pasture, vegetables, and specialty crops.

Modeling data show negative yields for many major crops

Modeling specific crops resulted in data that project which crops are likely to have increased yields as a result of climate change, and which yields will decrease, taking into account an expectation that the water rights of junior irrigators will be curtailed.

Solutions for adapting to climate change will involve both crop-management and water-management strategies, and increasing the state's adaptive capacity. Washington state needs to build adaptive capacity that minimizes vulnerability to climate change, no matter what that climate change will look like.

Figure 10. Projected climate change impacts on crop yield: curtailment (spacial mean)



Proposed Adaptation Strategies

Crop Management

Planting dates can be changed, perennial fruit loads can be managed differently, and crop varieties can be planted or developed that are better adapted to future climate conditions.

Water Management

Structural alternatives could include new seasonal storage, groundwater extraction, and water diversions. Non-structural alternatives may offer water conservation measures, modification of reservoir operations, and increased capabilities for water transfers between users.

Accessible Information

Information about climate and climate impacts should be more accessible statewide. Technical capabilities could be increased to incorporate information on climate impacts, and legal and administrative capacity to adapt to climate change could be increased as well.

Horizontal Integration

There is a need for horizontal integration among Washington state sectors impacted by climate change—for example, integrated management of our water resources for hydropower, agriculture, ecosystems, flood control, etc.

Video for this talk is available at www.washacad.org.

Washington State Department of Ecology's Office Columbia River link:

http://www.ecy.wa.gov/programs/wr/cwp/forecast/forecast.html

Water Rights, Markets and Prices: Helping Water Flow Toward High-Valued Use

Jonathan Yoder
Professor of Economics, School of Economic Sciences, Washington State University

Synopsis

How is a water market like a dam? They both help distribute water over time and space to where it's more useful and valuable. In the Northwest in the spring, a big flush of water flows through our river systems. The water levels decline, and in summer the landscape is dry. From an economic perspective, the value of adding an additional acre-foot of water in the spring is low. But in mid- to late summer, the value of water is much higher. The dam is a mechanism that can alter the location of water over time and space so it can be used when it's more valuable. That's what a market does as well, by allowing mutually beneficial trades that move water from low- to high-valued uses.

Western U.S. water history: Prior Appropriations Doctrine

The riparian water doctrine of the eastern U.S. did not work well as a legal doctrine transplanted to the arid West. Water rights here are governed by the Prior Appropriations Doctrine, which among other things has three characteristics for discussion. First is the "First in time, first in right" seniority system. Water rights that were claimed and granted first (earlier in time) have senior water rights, and later claims have junior status. In low-water years, when there is not enough water to satisfy all water rights, junior water rights holders may not be allowed to use the water under their right. Second is the "Use it or lose it" clause, which says that if you have a water right and don't use it for a period of time, you lose the rights for the water you didn't use. Third, in order for a water right to be granted, a water claim (a request for a right) must be made for a specific "Beneficial use" that is recognized by the state. The set of possible uses that are formally recognized by the state are historically limited.

Figure 11. A lateral canal on the Garland Division of the Shoshone Irrigation District near Powell, 1913 (Homesteader Museum photo)

Source: http://www.wyohistory.org/essays/order-out-chaos-elwood-mead-and-wyoming's-water-law?page=2

Water rights seniority increasingly does not coincide with highest-value uses

Most water allocated under early claims was for agricultural irrigation. Municipal demand has increased dramatically since the early days of irrigation development, and so original municipal rights are often junior to irrigation rights. Instream flows—keeping the water instream for various reasons such as to support salmon rearing, habitat, and migration—were not a historically recognized beneficial use, but the value of instream flows for the support of fisheries and other natural ecosystem functions has come into sharper focus.

"There is a lot of scope for market improvements, many interesting developments, and hope."

Jonathan Yoder

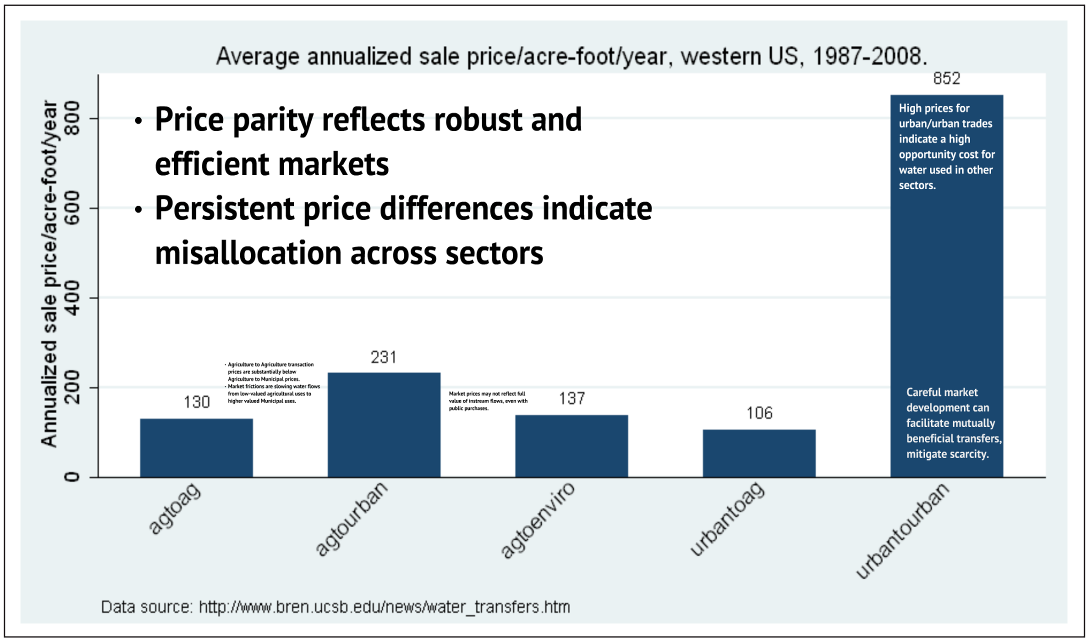
The seniority system clarifies priority of rights, which is especially useful in dry years. But seniority may not coincide with the highest-value use. The "Use it or lose it" requirement discourages hoarding, but it also encourages diverting water for low-valued use just to retain rights. The "Beneficial use" requirements discourage frivolous diversions, but some potential uses such as instream flows have not been and in some states still are not recognized as a beneficial use under the law. Furthermore, water rights are contentious, and often poorly documented and poorly enforced.

Water markets have been slow to develop and are far from perfect

Water transfers often require direct judicial intervention or executive mediation, because third-party impacts of transfers between a buyer and seller are common. In addition, markets are typically poor at accounting for instream values, such as fish habitat and other ecosystem services.

Price parity in water transactions between the major groups of water users—agriculture, municipalities, and public sector instream flows—would follow from and reflect robust and efficient markets. In contrast, persistent price differences indicate economic misallocation of water across sectors.

Figure 12. Water transactions between major groups of water users



Agriculture to Agriculture transaction prices are substantially below Agriculture to Municipal prices, which suggests that market frictions are slowing water flows from low-valued agricultural uses to higher-valued municipal uses. Transaction prices for transfers from agricultural to environmental uses (e.g., instream flows) are relatively low. Market prices may not reflect the full value of instream flows, even though they are generally driven by public purchases. Markets that do not account for ecosystem values can actually exacerbate environmental impacts.

Western water markets (and programs) are picking up steam

While water markets have been slow to develop, markets are developing, and imaginative market designs are being created to address the idiosyncrasies and complexities of water resources.

Among the most fundamental developments is the continued clarification of water rights through adjudication processes. Adjudications, while costly, can facilitate trade by reducing case-by-case transaction costs associated with water transfers. Other developments include state acquisitions (as opposed to other means of public water acquisition such as eminent domain), through which water-rights owners can offer to sell, lease, or donate water rights to the state for instream flow augmentation.

"Water markets and water banking programs can help with both the upside and downside of climate change."

Jonathan Yoder

Water banking also facilitates water-rights transfer to higher-valued uses by providing more flexibility in water transaction. Water trusts are designed to facilitate water transactions as well, and examples of these types of programs in the state of Washington include the State Trust Water Rights Program and the Washington Water Trust.

Other options allow water rights holders to stop the "Use it or lose it" clock by offering temporary donations and leases for other uses.

Water markets and institutions, and their role in adaptation to economic and environmental change, are still nascent, but recent developments in both are promising.

Water markets can help with scarce water resources

- Facilitate growth in the West with lower impact on existing rights and environmental values.
- Complement or substitute water project investment.
- Help maximize the value of water from storage facilities through trade.
- Help direct the location of new storage.
- Help analyze the cost/benefit assessment of new projects.
- Help move water to high-valued uses without new storage.
- Offer the advantages of clear and comprehensive property rights and low transaction costs.
- Indicate a high opportunity cost for water used in other sectors through high prices for urban/urban trades.
- Facilitate mutually beneficial transfers and mitigate for scarcity.
- Address the "public goods" values of instream flows.

Slides and a video for this talk are available at www.washacad.org.

Panel Discussion:

Effecting Policy Change at the State Level

Left to right: Ron Tressler, Hedia Adelsman, Kirk Cook, Peter Goldmark, Jennifer Adam, Jonathan Yoder

Session II speakers:

Jennifer Adam, Assistant Professor of Civil and Environmental Engineering, Washington State University

Jonathan Yoder, Professor of Economics, Washington State University

Panelists:

Hedia Adelsman, Senior Policy Advisor, Washington State Department of Ecology

Kirk Cook, Natural Resources Assessment Section Manager, Washington State Department of Agriculture

Peter Goldmark, Commissioner of Public Lands, Washington State Department of Natural Resources

Ron Tressler, Strategic Advisor/Environmental Affairs Division, Seattle City Light

Synopsis

Topic #1: Optimism or pessimism about markets and water resources scarcity?

"I share a pessimism about climate change mitigation. The complexity of the strategic problems faced by countries around the globe are immense, much more immense than adaptation."

Jonathan Yoder

“As I get further into these issues, it seems hopeful. Things happen very slowly, but they are happening. Institutional changes are like turning a huge tanker. It’s very, very slow and you may not see it until the direction’s completely changed. The state of Washington has very good scientists, and we are able to use their knowledge to develop programs and policies. We also have a public that’s much more receptive than many other places.”

Hedia Adelsman

“The agency I manage has responsibility for 3 million acres of upland, including about 50,000 acres in irrigated agriculture. I’m more optimistic. I have confidence in our biologists. People are developing whole new methodologies of storage—like storing waters in aquifers—and adaptation, where farmers will plant crops that are more water-efficient and more adapted to the changing climate. The bigger question is really about convincing the public that climate change is real and that individuals within society need to change their lifestyles to meet the changing needs being placed on society. Around climate change there is still a lot of skepticism.”

Peter Goldmark

“I have less optimism in the short run. The agricultural community is the largest holder of water rights in the state, but they are a relatively conservative group and don’t like a lot of change, especially related to “Use it or lose it.” There is a lot of mistrust about how water markets would operate. The Yakima project is optimistic, but in early stages. I think we are on the right path, but I see a lot of obstacles from the policy standpoint. We’re talking billions of dollars to adequately serve the water needs of urban, instream flow, salmon, agriculture, and industry.”

Kirk Cook

”Seattle City Light has been in the forefront of addressing climate change. Our utility has been carbon-neutral since 2005. We’ve also been working closely with state, local, federal agencies and tribes to ensure a sustainable fish population and minimize our impact on the environment and wildlife habitat. We are trying to have adaptable management of the dams, releasing water when it’s most beneficial and of the highest value, but also trying to protect healthy fish runs. I am optimistic. If we work together, we will have even healthier fish runs in the future.”

Ron Tressler

Topic #2: How much do agencies, tribes, and other utilities work together to develop strategies, and what are the obstacles?

"There's a lot of communication on near-term, but not a lot on long-term. For example, on the Skagit we are locked into a 30-year license that will run out in 2025. We have a flow committee that meets and talks about what's needed to protect the fish downstream, but the climate change discussions need to take place long before 2025."

Ron Tressler

"The National Resources Defense Council put us in a handful of states out of 50 that have done an excellent job with adaptation, but I think we have a long ways to go. At meetings, we often get blank eyes from people working at the agencies. We need the science and the community to help. Hopefully we'll see things start to change."

Hedia Adelsman

"The Department of Natural Resources has a unique mission. We own many types of vehicles, and operate from facilities across the state, so there are a lot of opportunities to achieve efficiencies. But it takes time to change the infrastructure to make it more carbon-friendly. We need to look for the appropriate management strategy."

Peter Goldmark

"The really good news is that over the last few years, with the issues of adaptation and preparedness, I've seen a real coming together of all the state's natural resources agencies. We're beginning to build a good solid foundation."

Kirk Cook

Topic #3: What will Washington state's agriculture look like in 2030?

"Based on our results, if we don't change the crop mix, we'll see some inclines and some declines. On a longer term, we're going to see much larger impacts."

Jennifer Adam

"At some point in time, climate change won't have as [many] benefits. Impacts from curtailments and from warming will become worse. Impacts on ground water will be worse. We're going to have to look at adaptation—developing different varieties that have slower growth and higher yield."

Jennifer Adam

"A 1920s adjudication in the Walla Walla area gave a majority of water to Oregon irrigators. As a result, on the Washington side crops are very diversified. The Oregon side is mostly water-intensive fruit trees. I predict that the Washington side will make it much better. When you have agriculture that is one crop or two, you have problems, especially water delivery problems. In Walla Walla, the farming is year-round."

Hedia Adelsman

"This brings to light two interesting variables for agriculture—regional climate change and global markets. Much of Washington's agriculture is driven by global demands. In some respect, it is going to adapt as much to the global market as it will to climate change."

Kirk Cook

A video for this talk is available at www.washacad.org.

After-dinner address

Water and Public Health: A Global View

Dr. Howard Frumkin spoke about the importance of accurate data to direct attention to and allocate resources for global waterborne health problems. He provided a comprehensive perspective on how climate change may affect the education, health, and opportunities for many of the world's most vulnerable populations. Dr. Frumkin is Dean and Professor of Environmental and Occupational Health Sciences, University of Washington School of Public Health.

Video for his talk is available at www.washacad.org.

K-12 Special Guests

The Future of Science: The American Junior Academy of Science

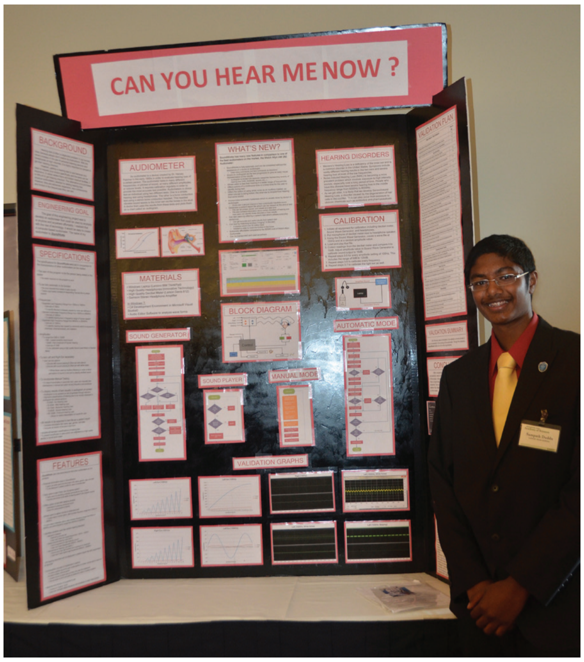
In 2011, the WSAS launched a program enabled by member-donated funds to support the attendance of selected high-school students each year at the annual meeting of the National Association of Academics of Science (NAAS) and American Junior Academy of Science (AJAS). In 2012, Kelly Giffey, from W.F. West High School in Chehalis and Sampath Duddu, from Capital High School in Olympia were announced as the awardees to attend the 2013 AJAS Conference in Boston, MA. Also honored, were Anjani Patel of Cedarcrest High School in Duvall and Sophie Shoemaker of Camas High School in Camas as recipients of The Stockholm Junior Water Prize for their water-related science projects. Parents and teachers were also present to witness their students receive WSAS student certificates and awards.

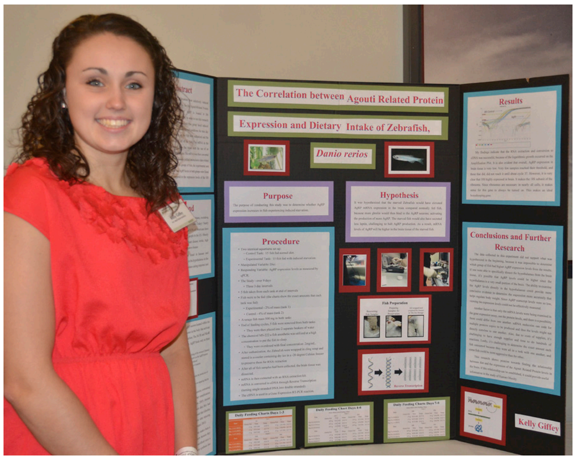
A special thank you goes out to the business sponsors on behalf of the teachers and students, The Boeing Company, Pacific Northwest National Laboratory, and Seattle City Light.

AJAS award winners Sampath Duddu and Kelly Giffey with Subhash Singhal, WSAS President-elect and K-12 Chair.

President Earll Murman and President-elect Subhash Singhal present the award acknowledging Sophie Shoemaker as recipient of The Stockholm Junior Water Prize.

(Top) Sampath Duddu and Kelly Giffey (bottom) proudly exhibit their presentations that gained them the AJAS awards.





WSAS members and guests viewing the prize-winning student science displays.

Anjani Patel explains her project to another guest student from the Advanced Placement Environmental Science Class at Mt. Vernon High School.

Speaker bios

Dr. Jennifer Adam is an Assistant Professor in the Civil and Environmental Engineering Department at Washington State University. Prior to graduate school, she served as a Peace Corps volunteer in the Solomon Islands. Dr. Adam's research involves the use of computer models to understand climate and land use change impacts on the hydrologic cycle. She is involved in a number of climate change impact studies, from small watersheds to global scales. She is also interested in land/atmosphere interactions as well as the coupled interactions among biogeochemistry, hydrology, and climate. Dr. Adam is also committed to education and is involved in research to improve learning in undergraduate engineering courses.

Hedia Adelsman serves as Executive Policy Advisor in the Director's Office at the Washington State Department of Ecology where she is involved with major statewide policies and programs that implement some of the governor's and the agency's priority initiatives. She works on ocean acidification, climate change mitigation and adaptation, energy facilities siting and development, and innovative water management programs. She managed the State Water Resources Program, and led major efforts on statewide salmon recovery, and regulatory integration and streamlining.

Kirk Cook is the Senior Science Policy Advisor to the Director of the Washington State Department of Agriculture. He also supervises the department's Natural Resources Assessment Section and serves as the agency's Climate Change expert. Kirk is a licensed geologist and hydrogeologist, and has worked in the environmental field for over 35 years. State publications that he has co-authored include the recently released, "Preparing for a Changing Climate—Washington State Integrated Climate Response Strategy" and the 2008 "Recommendations for the Development of Agricultural Sector Carbon Offsets in Washington State."

Dr. Robert W. Corell, Keynote speaker, is a Principal at the Global Environmental Technology Foundation and leads its Center for Energy and Climate Solutions. He was recognized with the other scientists for the 2007 Nobel Peace Prize for his work with the Intergovernmental Panel on Climate Change assessments. He is Founder and Chair of the 2008-established Global Climate Action Initiative, created to assist international negotiators (U.S., China, Indonesia and others) in the United Nations Framework Convention on Climate Change. In 2010, Dr. Corell, an oceanographer and engineer by background and training, was awarded an Honorary Doctor of Veterinarian Medicine by the Norges Veterinærhøgskole (Norwegian School of Veterinarian Science).

Dr. Corell is actively engaged in research concerned with the sciences of global change and the interface between science and public policy. In particular, he is involved in research activities that are focused on global and regional climate change, related environmental issues, and science to facilitate understanding of vulnerability and sustainable development.

Dr. Peter Goldmark is the elected Commissioner of Public Lands and manages the Washington State Department of Natural Resources, administering its $625 million, two-year budget. The Department manages approximately 2.6 million acres of aquatic lands across the state. Dr. Goldmark chairs the state Board of Natural Resources, which sets policy for the management of state trust lands. He has a lifelong involvement with agriculture, science, education, and public service, and maintains at his ranch a small scientific research facility engaged in a wheat-breeding program, which has recently released new varieties for Washington wheat farmers.

Dr. Dennis P. Lettenmaier is the Robert and Irene Sylvester Professor of Civil and Environmental Engineering at the University of Washington. Dr. Lettenmaier received the American Society of Civil Engineers Huber Research Award in 1990 and the American Geophysical Union's Hydrology Section Award in 2000. He is the past president of the Hydrology Section of the American Geophysical Union, and is an author or co-author of over 250 journal articles. His areas of research interest are large-scale hydrology, hydrologic aspects of remote sensing, and hydrology-climate interactions. He was elected to the National Academy of Engineering in 2010.

Dr. Edward S. Sarachik was Professor of Atmospheric Sciences and Adjunct Professor of Oceanography and Applied Mathematics at the University of Washington, and is now Professor Emeritus of Atmospheric Sciences. Along with three other scientists, he shared the 2008 Nobel Peace Prize for Peace awarded to the Intergovernmental Panel of Climate Change (IPCC). He serves as the Chair of the International Research Institute for Science and chaired the National Research Council committee that produced the report, "Improving the Effectiveness of U.S. Climate Modeling" in 2001. His areas of scientific expertise include tropical meteorology and oceanography, especially the ENSO phenomenon, and the role of the ocean in climate.

Ron Tressler is a Strategic Advisor in the Environmental Affairs Division of Seattle City Light. Previously he spent more than 20 years in environmental consulting. He works with hydroelectric project operators, climate scientists, hydrologists, planners, engineers, ecologists, and geomorphologists to study impacts of climate change on the utility's hydroelectric projects on the Skagit, Tolt, Cedar, and Pend Oreille rivers. He also served on the Washington State Climate Change Response Strategy Topic Advisory Group working on species, habitats, and ecosystems.

Dr. Jonathan Yoder is Professor of Economics in the School of Economic Sciences at Washington State University. He currently serves as a WSU delegate to the Universities Council on Water Resources. He is a Principal Investigator on multiple multidisciplinary projects funded by the National Science Foundation and the U.S. Department of Agriculture that focus on dynamic environmental/economic systems and nutrient cycling in hydrologic systems. He has published on water demand in Africa, energy, biofuel, and climate policy. Dr. Yoder's research specialization is natural resource and environmental economics, with a focus on policy design and impact analysis, law, and contracts.

Acknowledgements

The WSAS acknowledges with grateful thanks the financial support and sponsorship by Boeing, Pacific Northwest National Laboratory in Richland operated by Battelle, and Seattle City Light. Gary Foss, Associate Technical Fellow at the Boeing Company and Vice President of the Washington State Science and Engineering Fair, was a valuable liaison to the science and engineering fair directors and students, enabling their effective participation in the symposium. The WSAS greatly appreciates his continued leadership in engaging the next generation of scientists.

The success of the symposium reflects the work of the scientific organizing committee: R. James Cook, Kristina Katsaros, Thomas Marsh, Edward L. Miles, and Guy H. Palmer (Chair). Special thanks also go to WSAS staff members Mary McDonough and Laurel le Noble for their invaluable administrative support and organizational and technical skills so critical to the success of this annual meeting and symposium, and this report.

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