Climate Change Session
Heejun Chang, Chair
Tuesday, May 24
9:30 AM – 3:00 PM

The Oregon Water Conference 2011: Evaluating and Managing Water Resources in a Climate of Uncertainty
Oregon State University – CH2M Hill Alumni Center – Corvallis, Oregon
OR Section, American Water Resources Association and OR Section, American Institute of Hydrology

Climate Change: Natural Variability is a Big Deal Too!

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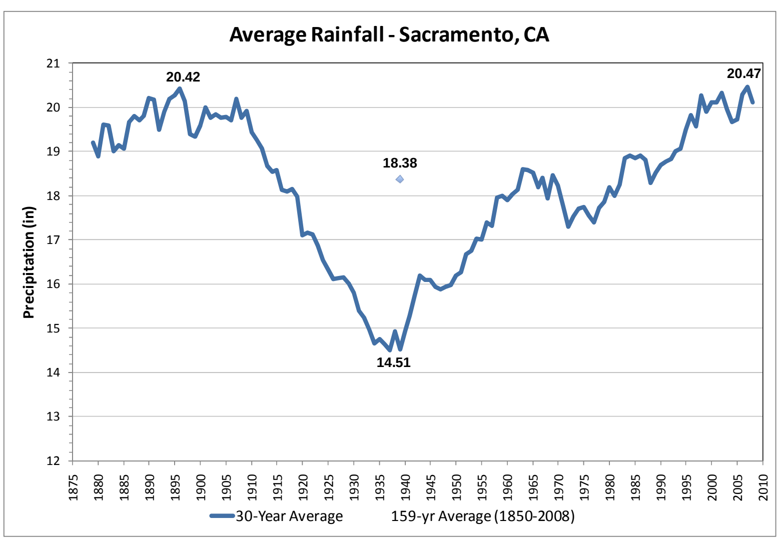
ABSTRACT

Climate changes. That's what climate does. It is a natural and dynamic process. The National Weather Service (NWS) recognizes on-going climate change by publishing new figures for average climate every ten years. Climate averages for precipitation, temperature, and other weather parameters are computed on a 30 year basis but only updated once per decade. From 2001-2010, the NWS average high temperature for July in Salem, OR, for example, was based on the 30 year period, 1971-2000. Now, in 2011, climate averages are reported for a new 30 year period, 1981-2010, which will remain the norm until 2021.

With all of the discussion about anthropogenic (i.e. man-made) climate change, it is easy to overlook just how variable our natural climate can be in the relatively short-term. Our climate can and does vary by significant amounts within one human lifetime and well within the design lifetime of our water infrastructure. Sometimes this fact gets lost in the noise of the climate change debate. Part of the reason is the relatively short records of our key meteorologic and hydrologic parameters.

Here's an example. Sacramento, CA, has one of the longest rainfall records in the western US. Annual rainfall totals are available from 1850 to present. Over the 159 year record from 1850-2008, the average annual rainfall was 18.38 inches. However, the 30-year moving average rainfall varies from 20.42 inches in 1896 down to 14.51 inches in 1937 and up again to 20.47 inches by 2007. That's 30-40% swing of 30-year average rainfall in a single lifetime. (Lifetime, not geologic time!) Most of our short records completely miss that signal. That such significant changes can occur relatively fast has major implications for water resources infrastructure design.



This paper explores and presents findings regarding rapid variation of "climate averages" in northern California and Oregon using long term rainfall records. The results suggest that not only is stationarity dead, it likely wasn't really alive in the first place. We simply assumed it was.

Keywords: Climate change; Rainfall; Hydrologic design

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Assessment of Climate Change Impacts on Drought Return Periods Using Copula Functions

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ABSTRACT

Drought events are usually characterized by their duration, severity, and intensity which are calculated based on different indices for drought recognition. Streamflow Drought Index (SDI) used in hydrological droughts is applied in this study to calculate drought variables of historical events in Upper Klamath River basin in Oregon. Historical extreme events in this area necessitate studies on possible potentials of future droughts in the region. While the return period of drought variables are mostly studied by separate probability distributions modeling individual variables, this study employs Copula functions as multivariate probability distributions to model correlated drought variables altogether within a single function. The analysis follows by development of trivariate return periods and conditional probabilities to assess drought occurrence based on joint behavior of its variables. The trivariate return period is developed for two different cases: either 1) all the variables exceed particular values or 2) each variable does. Furthermore, the impacts of climate change are investigated by application of six GCMs and one emission scenario for the future time period of 2020-2090. The results indicate less severe droughts with smaller duration in future for Upper Klamath River basin comparing to historical events which generally implies wetter climate for the region. Maximum duration of 8 months for historical droughts shrinks to 6 months for future droughts, and the maximum severity is reduced from 12 to 8 for employed index. Moreover, the GCM IPSL-CM4 predicts the most water availability in the region among other applied GCMs.

Keywords: Drought event; Copula function; Trivariate return period; Climate change impacts

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Climate Change Impact on Drought Risk and Uncertainty in the Willamette River Basin

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ABSTRACT

Climate change due to global warming could induce more frequent droughts in the Willamette River Basin because less snowfall in winter and earlier snowmelt due to temperature increase may lead to decreases in spring and summer streamflow. This study examines possible changes in drought risk using two drought indices, Standardized Precipitation Index (SPI) and Standardized Runoff Index (SRI). SPI represents a climatological drought index that considers only precipitation change, while SRI is a hydrological drought index that considers water balance change. In rainfall-dominated regions in the Willamette Valley, SPI is a useful drought index. In snow-dominated regions in the High Cascades, SRI can show more realistic drought risk change because SRI can represent snowmelt and geology effects.

Our results show that the Willamette Valley is more vulnerable to drought risk than the High Cascades in the 21st century. SPI shows increasing frequency and intensity of short-term drought over the whole Willamette River basin due to summer precipitation decrease, while SRI in the High Cascades shows no change because the High Cascades have young permeable volcanic rocks and gentle slopes, which create a deep groundwater system. Additionally, the frequency of short-term extreme drought, such as droughts lasting 1 to 3 months, is projected to increase in the Willamette Valley, but long-term extreme droughts are not expected to change significantly. The increase in short-term extreme droughts is attributed to decreases in summer precipitation, and the lack of change in long-term extreme droughts is caused by increased winter runoff prompted by earlier snowmelt and winter precipitation increases.

Keywords: Drought; Climate change; SPI; SRI; Uncertainty; Willamette River; Oregon

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Assessment of the Hydrologic Response to Climate Change in the Upper Deschutes River Basin, Central Oregon

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ABSTRACT

Effects of climate change in the Cascade Range will likely include more rain, less snow, and earlier snowmelt in the Cascade Range as compared to present conditions. These changes, in turn, will affect the timing of runoff, groundwater recharge, and groundwater discharge to spring-fed streams. This hydrologic response needs to be examined and understood due to implications for water management.

In this study, a water- and energy-balance model was used to explore 21st century changes in the water budget in the upper Deschutes Basin, and a groundwater model was used to evaluate the response of the groundwater system to those changes. A Deep Percolation Model (DPM) developed for the basin in the 1990s uses spatially distributed climate data to calculate a daily mass balance for the major components of the hydrologic budget. For this work, we drove the DPM using ensemble means of eight downscaled global climate models with the Intergovernmental Panel on Climate Change's A1B and B1 emission scenarios.

Although similar for both scenarios, greater changes in the timing of runoff and recharge as well as higher reductions in snowpack occur using the A1B scenario. Considering both scenarios, diminished snowpack results in reductions in spring runoff ranging from 40% to 63% and recharge from 21% to 37%. These reductions are offset by late fall and winter increases. Also, spatial changes in the mean annual ratio of recharge to runoff occur due to changes in soil infiltration rates.

The modeled response of the groundwater system to changes in the time and amount of recharge varies spatially. Short flow-path systems in the upper part of the basin are most sensitive to change in seasonality of recharge. At regional scales, diffusion along groundwater flow paths partially attenuates the effects of changes in recharge timing. Furthermore, slight increases in total annual groundwater discharge to smaller streams in the upper portion of the basin, and slight decreases in discharge to larger stream systems in the north-central portion of the basin are projected.

Keywords: Groundwater; Hydrology; Climate change; Global Climate Model (GCM)

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Hydrologic Response to Climate Change in the Sprague River Basin, Oregon

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ABSTRACT

In 2008 the U.S. Geological Survey began a Global Change study that evaluated the watershed scale response to climate change in selected basins across the United States. Fourteen basins for which the Precipitation Runoff Modeling System (PRMS) had been calibrated and evaluated were selected as study sites. PRMS is a deterministic, distributed-parameter, watershed model developed to evaluate the effects of various combinations of precipitation, temperature, and land use on streamflow and general basin hydrology. PRMS results for the Sprague River basin located in the Upper Klamath Basin in south-central Oregon are summarized below.

Five General Circulation Models (GCMs) incorporating three climate change scenarios were used to develop an ensemble of climate change inputs to PRMS. Although the climate change projections for 2001–2099 showed a wide range of variability between the GCMs, which would indicate a large amount of uncertainty, the central tendency lines showed an increase in temperature and precipitation over the 21st century. Using these data as model input, simulated streamflow output from PRMS for the Sprague River indicate earlier spring high flows as a consequence of increased and decreased proportions of rainfall and snowfall, respectively. Supplying approximately 25 percent of inflow to the Upper Klamath Lake, the Sprague River basin is vital to environmental and human water needs within the Klamath River basin. As water demands increase, the reliability and timing of flow from the Sprague River becomes increasingly critical in water-management decisions. Potential alterations in flows to the Upper Klamath Lake as a result of climate change could necessitate (1) modifications to the operation of the lake as a storage reservoir and (2) creation of additional storage capacity to meet water demand during the summer.

Keywords: Watershed modeling; Climate change; Water management; General Circulation Models (GCM); Upper Klamath River Basin

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Effects of Climate Change on Water Quality in the Yaquina Estuary, Oregon

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ABSTRACT

As part of a larger study to examine the effect of climate change (CC) on estuarine resources, we simulated the effect of rising sea level, alterations in river discharge, and increasing atmospheric temperatures on water quality in the Yaquina Estuary. Due to uncertainty in the effects of climate change, initial model simulations were performed for different steady river discharge rates that span the historical range in inflow, and for a range of increases in sea level and atmospheric temperature. Model simulations suggest that in the central portion of the estuary (19 km from mouth), a 60-cm increase in sea level will result in a 2-3 psu change in salinity across a broad range of river discharges. For the oligohaline portion of the estuary, salinity increases associated with a rise in sea level of 60 cm are only apparent at low river discharge rates ($< 50\ m^3\ s^{-1}$). Simulations suggest that the water temperatures near the mouth of the estuary will decrease due to rising sea level, while water temperatures in upriver portions of the estuary will increase due to rising atmospheric temperatures. We present results which demonstrate how the interaction of changes in river discharge, rising sea level, and atmospheric temperature associated with climate change produce non-linear patterns in the response of estuarine salinity and temperature, which vary with location inside the estuary and season. We also will discuss the importance of presenting results in a manner that incorporates uncertainty in climate projections.

Keywords: Climate change; Estuary; Modeling; Temperature; Salinity

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Climate Change and Oregon's Water Future

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ABSTRACT

The specter of climate change looms large over Oregon. Although hydroclimatologic models predict a warmer Oregon, the total volume of precipitation may not change significantly. However, the character (rain vs. snow) and spatial and temporal distributions of precipitation will likely change. The state is already witnessing earlier snowmelt in the Oregon Cascade Range. Much of the Cascade snowpack occurs at relatively low elevations and is thus very sensitive to even slight temperature changes. Earlier than normal snowmelt can produce unseasonal flooding and landslides and lead to storage problems since the snowpack provides natural 'free' storage. Without additional storage the resulting reduced summer runoff will likely produce: water shortages; insufficient flows to dilute waste and for environmental needs; higher stream temperatures and reduced dissolved oxygen levels; increased aquatic invasive species; and reductions in hydroelectric power generation. Reduced streamflows may lead to increase usage of nonrenewable groundwater. The effects on groundwater recharge are unclear.

Oregon must now adapt to prepare for a potentially water-stressed future by: 1) further investigating the potential for aquifer storage recovery and artificial recharge (ASR & AR); 2) assessing its surface water and groundwater supplies; 3) ensuring that climate change is incorporated into its Integrated Water Resources Strategy, currently under development; 4) educating its citizenry; 5) preparing for the possible influx of climate refugees; 6) exploring, with its US Columbia Basin partners, the development of a Columbia River Compact; 7) investigating market-based strategies; and 8) implementing, updating and revising various laws, regulations, practices, and policies so as to better enable the state to cope with an uncertain water future.

Keywords: Global warming; Water resources; Snowpack; Groundwater recharge; Market strategies; Climate refugees

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Climate Change and Shifts in Water Related Ecosystem Services in the Tualatin and Yamhill River Basins

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ABSTRACT

Water related ecosystem services (WES), such as flow regulation, drinking water supply, temperature regulation, and water recreational activities, are affected by anthropogenic climate change. Forecasting potential shifts in such WES is critical to identifying the form and magnitude of likely impacts. We quantified the levels and values of WES under multiple climate change scenarios in the two watersheds located in the Portland metropolitan area, Oregon, USA using the combination of a hydrologic model Better Assessment Science Integrating point and Non-point Sources - Soil and Water Assessment Tool (BASINS-SWAT) and an ecosystem evaluation model – Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST). Using the Intergovernmental Panel on Climate Change's AR4 climate change simulation results, we found that there is a slight relative increase in annual water yield, sediment yield, and dissolved phosphorus, but storm peak management does not change substantially by the 2050s. Spatial analysis shows that the locations of hot and cold spots remain relatively stable. It is also shown that there are high spatial and temporal uncertainties associated with climate change projections due to variations in precipitation projections toward the middle of the 21st century. The findings of our study provide useful information for water and land managers in identifying target areas for conservation to best sustain WES provision, use, and value under a range of climate change scenarios.

Keywords: Climate change; Ecosystem services; Spatial analysis; Tualatin and Yamhill Rivers,;Oregon