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Urban water consumption and weather variation in the Portland, Oregon metropolitan area

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ABSTRACT

This paper analyzed the evolving response of daily water use to weather fluctuations over 29 years (1981–2009) for two Portland-area municipal water providers – Portland Water Bureau (PWB), serving a dense urban area, and Tualatin Valley Water District (TVWD), serving a rapidly growing suburban area. Temperature sensitivity, the response of water use to a temperature increase, generally declined for both water providers. A downward shift in temperature sensitivity was identified for PWB in 1992, owing to outdoor water use curtailment during a water scarcity event, followed by aggressive demand management measures. No corresponding shift was detected for TVWD due to high suburban growth rates throughout the 1990s. Recent downward step changes in temperature sensitivity for both providers indicated some modicum of convergence in water use patterns, reflecting converging trends in socio-economic and land development characteristics in both areas. We argue that a confluence of historical factors, including the 1992 drought, aggressive (though uneven) demand management, changes to the building code, and ongoing densification of both urban and suburban areas, have reduced per-capita water use and attenuated the connection between water use and temperature. Softening the seasonality of water use represents an important but often-overlooked component of urban climate change adaptation.

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1. Introduction

1.1. Climate change and urban water provisioning systems

Urban areas across the Western U.S. experience water stress arising from the interactions between population growth and urban development, particularly when water demand peaks in summer (Miller and Yates, 2006). Temperature increases and shifts in precipitation patterns associated with anthropogenic climate change are likely to change the timing and magnitude of streamflow, compounding water stress and increasing the risk of drought-induced water scarcity (IPCC, 2007). Recent evidence has shown no sign of reduction in greenhouse gas emissions (Peters et al., 2012). Higher surface temperature over landmasses, increased incidence of drought, and extreme heat events are now considered virtually certain (IPCC, 2012).

Much of the research on climate change impacts on urban water provisioning has centered on modeling relationships between streamflow and water availability. Although it has received less scrutiny, the relationship between climate and human uses of water is potentially more relevant for building urban resilience to climate change (Gober et al., 2013). Urban water use is positively correlated with air temperature, particularly in summer, and the seasonal component of water use has been found to increase nonlinearly during extreme heat events in some contexts (Miaou, 1990; Zhou et al., 2001; Ruth et al., 2007; Praskievicz and Chang, 2009). However, seasonal use also exhibits the largest price and income elasticity (Arbues et al., 2003) and thus has a greater potential for change (Quay, 2011). Urban water supply infrastructure, by contrast, is largely fixed since new construction projects have become increasingly cost-prohibitive from economic, social, and ecological standpoints (Coomes et al., 2010). Because of supply-side rigidity, municipal water resource managers have increasingly focused on managing the demand for water though prices, incentives, outreach, and technological change (Gleick, 2003a). Per capita U.S. water use has steadily declined as a result, although population growth has partially offset some of the effects of conservation in the aggregate.

The prospect of climate-induced reductions in supply and increases in demand creates a need to identify new pathways to water conservation in order to lessen water stress associated with warming climate patterns. Understanding and attenuating the linkages between climate and water use could represent a key strategy for climate change planning and adaptation. Recognizing these connections, we examined changes in the relationship between daily weather variation and municipal water consumption in the case of the Portland, Oregon metropolitan area.

1.2. Research questions

This paper analyzed the evolving response of daily water use to weather fluctuations over 29 years (1981–2009) for two large water providers located along an urban gradient in Portland, Oregon. We compared Portland Water Bureau (PWB), serving an increasingly dense urban area, with Tualatin Valley Water District (TVWD), situated in a rapidly growing suburban area. Specific research questions are as follows.

1. What is the trend of daily base and seasonal water use components in the two water providers in the past 29 years?
2. Have there been any step changes in water use to weather variability (weather coefficient) in two providers? If so, when did they occur?
3. What might explain such step changes in weather coefficients in the two water providers?

The paper is structured as follows. Section 2 reviews relevant literature on urban water use research and management. Section 3 presents the study area, data sources, and methodology. Section 4 contains the results of analysis. Section 5 discusses these results. Section 6 draws conclusions.