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The value and skill of seasonal forecasts for water resources management in the Upper Santa Cruz River basin, southern Arizona

Eylon Shamir

Hydrologic Research Center, San Diego, CA, United States

A R T I C L E I N F O

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A B S T R A C T

The potential for adaptive water resources management based on seasonal forecasts in the arid Upper Santa Cruz River, southern Arizona was examined. We demonstrated that seasonal forecasts can be used to optimize water resources management and increase supply. Using El Nino Southern Oscillation (ENSO) to forecast the wet seasons (winter and summer) can provide information during extreme ENSO. We found that ENSO is a better indicator for dryer than normal winters during La Nina and dryer than normal summers during El Nino. As in indicator of wetter than normal seasons (i.e. El Nino and La Nina in the winter and summer, respectively) ENSO is often not a consistent predictor and moreover, on several occasions the wetter than normal rainfall did not yield above normal seasonal flows. We also examined the seasonal precipitation forecasts for the region from the Climate Forecast System (CFS). The CFS showed reasonable predictive skill for the winter that extends up to four months lead-time. The only CFS skill for forecasting summer rainfall was observed for predicting above normal rainfall in July with one-month lead-time. Seasonal forecasts can substantially improve water resources management but currently requires considerations of large uncertainties in the operationally available forecasts.

1. Introduction

Improvement of water supply reliability by optimizing the existing water resources management practices can provide a considerable benefit in water-stressed arid regions. One potential optimization strategy is to implement adaptive management scheme that is based on seasonal weather forecasts. For example, by predicting an approaching above normal wet season the existing water reservoirs can be further exploited and anticipated to be replenished, on the other hand, a prediction of a below normal wet season may activate conservative management measures to conserve reservoirs' carry over for the next season. Many studies have assessed the use of seasonal forecasts in conjunction with hydrological models for adaptive water resources management in various climatic and hydrologic regions worldwide (e.g. Georgakakos et al., 2012a; Georgakakos et al., 2012b; Gong et al., 2010; Graham et al., 2006; Chiew et al., 2003). The recurring challenge in this adaptive management strategy is to manage the risk and benefits that emanate from uncertain forecasts. Therefore, a useful adaptive management strategy has to balance risk and benefits by considering the skill and utility of the available forecasts.

The value of seasonal forecasts for the Upper Santa Cruz River (USCR), southern Arizona was previously recognized for mitigation of floods (Sprouse and Vaughan, 2003). In this study, we evaluate the potential benefit and the skill of seasonal forecasts to water resources management in the USCR. The water resources system in this arid environment is reliant on the highly variable local climate and has to be carefully managed in order to sustain the riparian vegetation ecosystem along the river.

The objectives of this study are two fold, first, to evaluate whether seasonal weather forecasts can benefit the water resources management practices in the region, and second, to evaluate whether the operationally readily available forecasts are sufficiently skillful to support adaptive management strategy in the region. The two forecast sources that were assessed herein are the observed sea surface temperature index El Nino Southern Oscillation (ENSO) during the transition to the wet seasons and the precipitation forecasts for the region from the Climate Forecast Model (CFS) The National Centers for Environmental Prediction (NCEP) National Oceanic and Atmospheric Administration (NOAA).

Following section 2 that describes the study area, in Section 3 we assess the value of seasonal forecast to the management of

E-mail address: EShamir@hrcwater.org.

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water resources in the USCR. This assessment is carried out by using a hydrologic modeling framework that was developed for the region and enables assessment of various management scenarios (Shamir et al., 2007a; 2015). In Section 4, we examine the observed ENSO in the spring and fall seasons as a predictor for rainfall and streamflow during the summer and winter, respectively. In Section 6, the skill of the CFS precipitation forecasts for the region is examined and the discussion and conclusions Section is last.

2. Study area

The Santa Cruz River, a tributary of the Gila River that flows into the Colorado River, is mostly an ephemeral stream with some relatively short perennial and intermittent sections. The Santa Cruz flows southward into Mexico from its headwater in the San Rafael Valley, southern Arizona. About 50 km through Mexico, the river reenters Arizona, about 10 km east of the city of Nogales, Arizona. A U.S. Geological Survey streamflow gauge (USGS # 09480500) with drainage area of ~1400 km^2, of which approximately 1150 km^2 are in Mexico, has been operating on the Santa Cruz River at the border crossing (Fig. 1).

Downstream of the USGS gauge the ephemeral channel overlays a series of four relatively shallow, highly permeable and with limited storage capacity alluvial aquifers that are bounded by the low permeability Nogales Formation (Erwin, 2007; Page et al., 2016). These shallow aquifers, often referred to as the micro-basins (MB), extend along the channel of the river for about 25 km to the confluence with Nogales Wash near the International Wastewater Treatment Plant (IWTP) (Fig. 1).

Recent studies suggest the existence of a highly permeable deeper layer below the stream alluvium (Nelson, 2010; Page et al., 2016). It is evident that during long dry periods with no streamflow to recharge the aquifer, the water level in the MB dropped considerably. In addition, the rate of groundwater flow to the downstream northern aquifer is likely to be higher than the receiving underflow that crosses from Mexico.

The main groundwater recharge mechanism of the MB is the infiltration in the alluvial channel during the occasional rain driven streamflow events on the Santa Cruz River. The dependence on streamflow events in conjunction with the net water loss of the MB compounds the impact of drought on water resources management in this region.

This relatively shallow aquifer (Depth to Water [DTW] ~3–15 m) is one of two sources of water to the City of Nogales, Arizona (population of over 20,000 people) (ADWR, 2012).

The second source of water to the City of Nogales is the Potrero wellfield along the Potrero Creek on the west side of the city. It is a deeper aquifer (~80–100 m DTW) and the sources of recharge for this aquifer are not yet well understood. Thus, a continuous and unmanaged withdrawal from this aquifer may cause an incurable decline in water levels. The City's annual consumption during 1990–2009 was about 4200 acre-feet per year (5.2 million m^3 yr^{-1}) split approximately evenly between the Potrero wellfield and the MB. The 2025 water demand for the city of Nogales is projected to

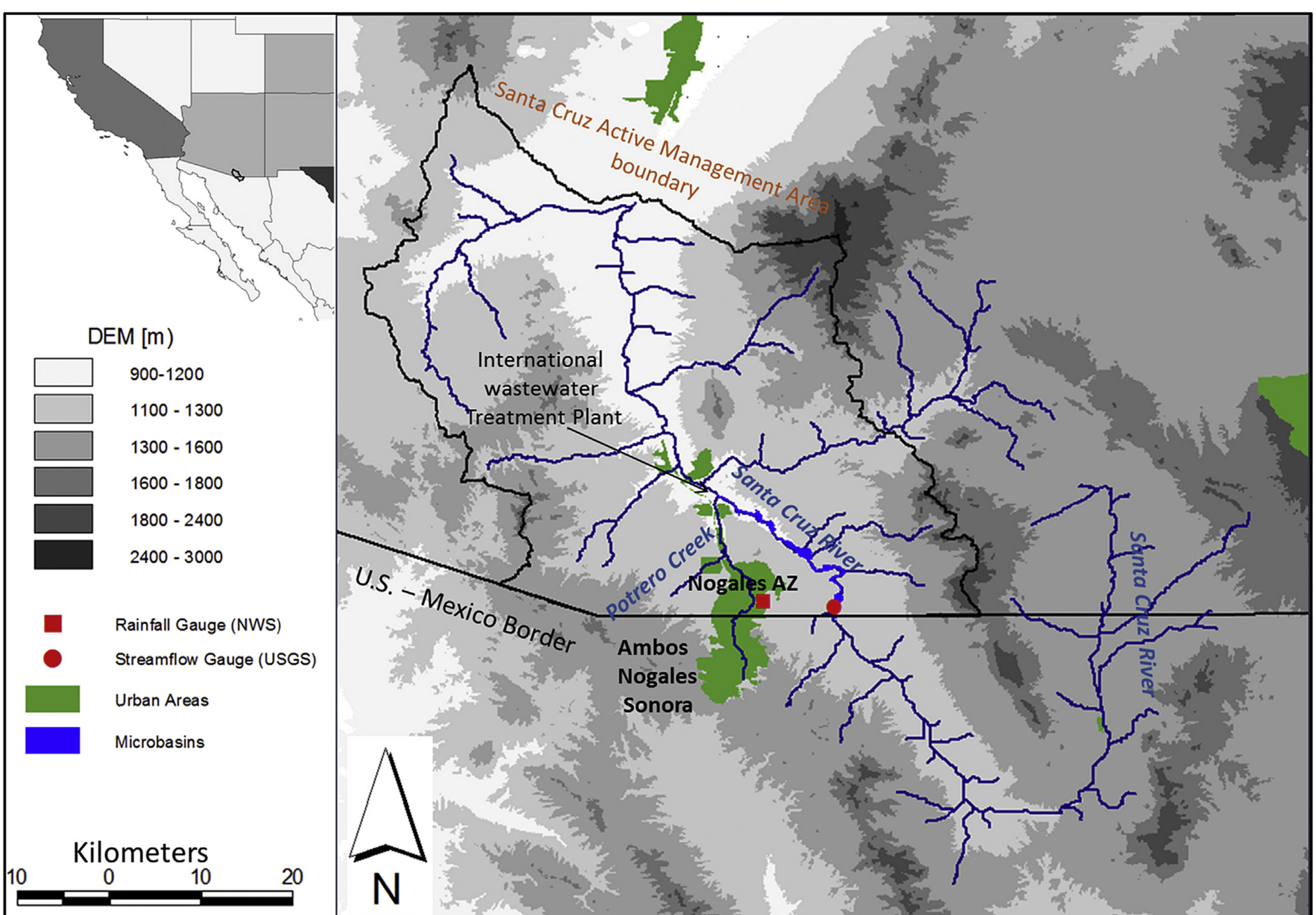

Fig. 1. A regional map.