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Covariability of climate and streamflow in the Upper Rio Grande from interannual to interdecadal timescales

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A R T I C L E I N F O

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A B S T R A C T

Study region: The Upper Rio Grande (URG) flows from its headwaters in Colorado, U.S., and provides an important source of water to millions of people in the U.S. states of Colorado, New Mexico, Texas, and also Mexico.

Study focus: We reassess the explanatory power of the relationship of sea surface temperatures (SST) on URG streamflow variability on interannual to interdecadal timescales. We find a significant amount of the variance of spring-summer URG streamflow cannot be fully explained by SST.

New hydrological insights: We find that the interdecadal teleconnection between SST and streamflow is more clear than on interannual timescales. The highest ranked years tend to be clustered during positive phases of the Pacific Decadal Oscillation (PDO). During the periods of decadal high flow (1900–1920, and 1979–1995), Pacific SST resembles a positive PDO pattern and the Atlantic a negative Atlantic Multidecadal Oscillation (AMO) pattern; an interbasin pattern shown in prior studies to be conducive to high precipitation and streamflow. To account for the part of streamflow variance not explained by SST, we analyze atmospheric Reanalysis data for the months preceding the highest spring-summer streamflow events. A variety of atmospheric configurations are found to precede the highest flow years through anomalous moisture convergence. This lack of consistency suggests that, on interannual timescales, weather and not climate can dominate the generation of high streamflow events.

1. Introduction

At 3051 km in length, and with a drainage area of approximately 472,000 km^2, the Rio Grande is the fourth longest river in North America. It provides water to 5 million people for agricultural, municipal and industrial purposes in the U.S. states of Colorado, New Mexico, and Texas, and in Mexico (Woodhouse et al., 2012) (Fig. 1). The majority of the flow in the river above its confluence with the Rio Conchos near Presidio, Texas, originates as snowmelt runoff from the mountains in southeastern Colorado and northern New Mexico (Lee et al., 2004; Khedun et al., 2010; Woodhouse et al., 2012) (collectively, the Upper Rio Grande (URG), with a drainage area of approximately 43,000 km^2 (Lee et al., 2004)). Sixty to sixty-five percent of inflows originate in the headwaters region, consisting of the southern Rocky Mountains and San Luis Valley of southwestern Colorado; flows along the Rio Chama and the Jemez River collectively account for another 25 percent of native inflows to the URG, with the remaining inflows coming from minor

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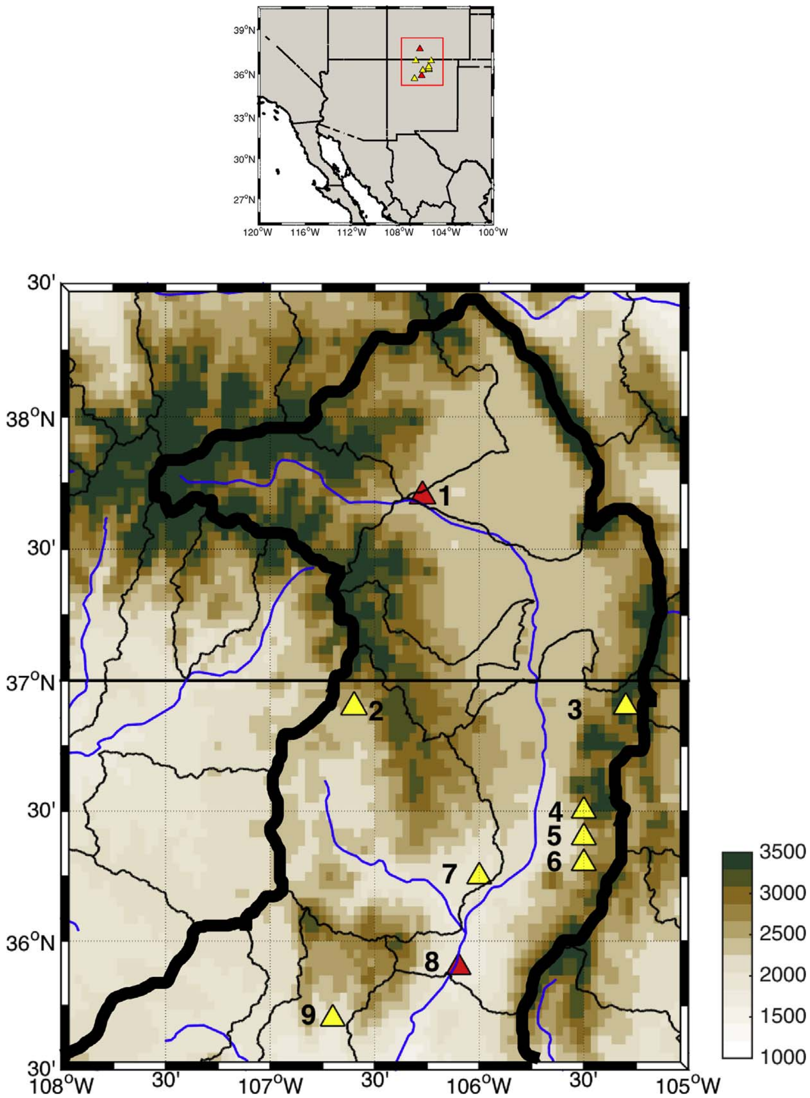

Fig. 1. Map showing elevation (meters), delineation of upper Rio Grande basin (thick black line), and location of USGS stream gages used in this study: (1) Del Norte, (2) Rio Chama, (3) Santistaven creek, (4) Rio Hondo, (5) Rio Lucero, (6) Rio Pueblo de Taos near Taos, (7) Rio Ojo, (8) Otowi, (9) Jemez river. Red marker indicates stream gage is located on main stem, yellow marker indicates stream gage is located on a tributary. Inset above shows location of upper Rio Grande region.

tributaries (Llewellyn and Vaddey, 2013). The majority of the 5 million water users are located south of the Jemez River confluence in the Middle Rio Grande (from the Jemez River to the El Paso Valley). High interannual variability in streamflow poses significant challenges for water supply and flood risk management. Improved understanding of the climate controls on Rio Grande flow variability is essential to improve management of water resources.

Studies have shown that precipitation and streamflow in the Southwestern United States (SWUS) in general are affected by a range of diverse drivers, including the El Niño-Southern Oscillation (ENSO), the Pacific Decadal Oscillation (PDO) and the Atlantic Multidecadal Oscillation (AMO), as well as the North American Monsoon (NAM). However, the failure of recent El Niño events to generate correspondingly large spring runoff volumes suggests that these relationships are not straightforward. This paper reassesses the impacts of ENSO, PDO, and AMO on streamflow in the Rio Grande basin above Albuquerque, New Mexico, and shows that these teleconnections are an incomplete explanation of the variance in flows.

On interannual timescales, ENSO produces above normal precipitation and streamflow for the SWUS when it is in its warm phase (El Niño) (Kahya and Dracup, 1993, 1994). On interannual timescales El Niño has also been found to be associated with above-normal precipitation and streamflow anomalies in the URG basin (Lee et al., 2004; Khedun et al., 2010). The PDO has also been found to produce above normal northern hemisphere winter (December–January–February (DJF)) precipitation and streamflow during its positive phase (Barlow et al., 2001; Cayan et al., 1999; Khedun et al., 2010; Pascolini-Campbell et al., 2015; Guan et al., 2005). The cold (warm) AMO produces positive (negative) streamflow and precipitation anomalies in the SWUS (Enfield et al., 2001; Thomas, 2007; Nowak et al., 2012). This relationship is strengthened with a concurrent positive PDO phase (McCabe et al., 2004). The NAM