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Precipitation regime change in Western North America: The role of Atmospheric Rivers

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Daily precipitation in California has been projected to become less frequent even as precipitation extremes intensify, leading to uncertainty in the overall response to climate warming. Precipitation extremes are historically associated with Atmospheric Rivers (ARs). Sixteen global climate models are evaluated for realism in modeled historical AR behavior and contribution of the resulting daily precipitation to annual total precipitation over Western North America. The five most realistic models display consistent changes in future AR behavior, constraining the spread of the full ensemble. They, moreover, project increasing year-to-year variability of total annual precipitation, particularly over California, where change in total annual precipitation is not projected with confidence. Focusing on three representative river basins along the West Coast, we show that, while the decrease in precipitation frequency is mostly due to non-AR events, the increase in heavy and extreme precipitation is almost entirely due to ARs. This research demonstrates that examining meteorological causes of precipitation regime change can lead to better and more nuanced understanding of climate projections. It highlights the critical role of future changes in ARs to Western water resources, especially over California.

Atmospheric rivers and west coast precipitation volatility. Coastal western North America (West Coast) receives much of its annual precipitation in the form of orographic heavy rain and snow produced by atmospheric rivers (ARs)[1–3]. These "rivers in the sky" deliver intense pulses of water vapor onshore and largely drive the hydroclimate of this region[3–5]. This is particularly true in California, where against the backdrop of recent dryness and persistently mounting anomalous warmth, the notorious volatility of the state's water resources[3] has been on display. Only four wet years have occurred so far in the 21st century (water years 2005, 2011, 2017 and 2019). The most recent period included five years of historic drought (2012–2016) with the first three years constituting an exceptionally dry period (water years 2012–2014) in the instrumental record spanning over 120 years[6]. Water year 2014, which tied for the driest year on record, was followed by 2015 – the year of unprecedented warmth and snow drought[7] (5% of normal snow accumulation in the Sierra Nevada[8]). These dry years were followed by the wettest water year on record for much of California[9–11] – 2017 – a wet season marked by widespread flooding[12] and AR activity unprecedented in seven decades of record[5]. This deluge was then followed by a dry water year 2018, especially in Southern California, parts of which received less than 1/3 of normal precipitation. Yet, even 2018 was punctuated with anomalously warm flood-producing storms[13]. Currently, a long series of alternating cold frontal and warm AR storms is resulting in a very wet water year 2019 in California featuring AR-driven flooding[14].

This volatility is associated with California's Mediterranean climate, which generates annual precipitation in a narrow window of opportunity during the cool season[3]. Recent extreme hydroclimatic variation over the region was notably marked with unprecedented warmth. The heightened water resource volatility and associated impacts exemplify expectations from a warming climate in Mediterranean California, where precipitation will be delivered with progressively declining frequency but increasing intensity[15,16]. In climate-change projections, shrinking

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