ENVIRONMENTAL RESEARCH
LETTERS

OPEN ACCESS

RECEIVED
28 August 2020

REVISED
16 November 2020

ACCEPTED FOR PUBLICATION
11 December 2020

PUBLISHED
9 February 2021

LETTER

Increasing importance of temperature as a contributor to the spatial extent of streamflow drought

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Keywords: drought, spatial extent, drivers, climate change, United States, precipitation, extremes

Supplementary material for this article is available online

Abstract

Widespread streamflow droughts can pose substantially greater societal challenges than spatially less extensive events because of the complex realities of trans-regional water management. In a warming climate, drought spatial extent may change along with changes in underlying hydro-meteorological contributors. Here, we assess changes in streamflow drought spatial extent over the period 1981–2018 across the conterminous United States, and how the importance of potential hydro-meteorological contributors has changed over time. We first derive a monthly time series of drought spatial extent and look at trends in streamflow drought spatial extent. We then determine the spatial percentage 'overlap' of precipitation droughts, temperature anomalies, snow-water-equivalent deficits, and soil moisture deficits with the area under streamflow drought to look at the changing influence of these contributors on spatial extent. Our results show that (1) the spatial extent of droughts has increased, mainly because of increases in the extent of small droughts; (2) streamflow drought extents overall substantially overlap with soil moisture deficits and the relationship of drought to precipitation and temperature anomalies varies seasonally; and (3) the importance of temperature as a contributor to drought extent has increased over time. We therefore conclude that continued global warming may further increase drought extents, requiring adaptation of regional drought management strategies.

1. Introduction

Droughts often affect larger geographic regions than do most other types of hydro-meteorological extremes, and subsequently can have potentially severe impacts on water supply, agriculture, hydro-power production, and ecosystems (e.g. Seager *et al* 2009). Over the last two decades, several notable widespread drought events have occurred in the United States (US)—including the California (2012–2016; Diffenbaugh *et al* 2015, Luo *et al* 2017), Colorado River basin (2000–2014; Udall and Overpeck 2017) and Missouri River basin droughts (2000–2010; Martin *et al* 2020, Woodhouse and Wise 2020). While not all of these events were historically unprecedented from a precipitation perspective (Andreadis *et al* 2005, Woodhouse *et al* 2009, Hanel *et al* 2018, Williams *et al* 2020a), their co-occurrence with anomalously warm and, in some cases, record-breaking temperatures (Weiss *et al* 2009, Luo *et al* 2017, Udall and Overpeck 2017, Hanel *et al* 2018, Martin *et al* 2020, Woodhouse and Wise 2020) produced impacts that were indeed extraordinary in a historical context (Diffenbaugh *et al* 2015, Martin *et al* 2020).

Drought events with large spatial extents particularly challenge existing water management strategies because they can make drought-alleviating, regional water transfers from upstream or adjacent basins impossible (Patterson *et al* 2013). Subsequently, the societal impacts of large-scale droughts can be amplified, since many drought mitigation strategies are predicated on some degree of water availability in less severely affected adjacent regions.