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Future Projections of U.S. Drought and Pluvial Event Characteristics

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1. Introduction

Drought and pluvial events have large socio-economic impact in the U.S. and around the world. In order to increase resilience to these events, it is necessary to understand how these dry and wet periods will change in the future. Much prior work has focused on drought, and results show increasing drought frequency and intensity, especially in subtropical regions (*e.g.* Cook *et al.*, 2014, Touma *et al.* 2015, Dai and Zhao 2016, Hunt 2011). However, there has been much less focus on how extended wet periods, or pluvial events will change in the future and how these changes relate to the overall precipitation trends. While we expect the most intense rain events to increase (*e.g.* O'Gorman and Schneider 2009), it is not known if this will be true for pluvial events, like the May 2015 heavy rainfall event in Oklahoma and Texas. Although there are numerous definitions of droughts, this study uses a meteorological definition that only considers precipitation. This study will determine how future precipitation trends manifest in terms of frequency, severity, and duration of both droughts and pluvials.

2. Data and methodology

Observations of precipitation from two monthly datasets are used; Climate Research Unit (CRU) TS v3.23 precipitation at 0.5° resolution from 1901-2014 and Global Precipitation Climatology Center (GPCC) v7 precipitation at 1° resolution from 1901-2015. Historical and future projection (scenario Representative Concentration Pathway (RCP) 8.5) experiments are used from 24 Coupled Model Intercomparison Project Phase 5 (CMIP5) models (Taylor *et al.* 2012). Changes in future characteristics are established using differences between 2080-2100 RCP8.5 output and 1980-2000 historical output. All model data are regridded bilinearly to a common 2° horizontal resolution to facilitate comparison between the models and create a multi-model mean.

To identify meteorological drought and pluvial events, the 6-month standardized precipitation index (SPI) is calculated for the observations and model output (McKee *et al.*, 1993). SPI is calculated at each grid point, for the duration of the observations and the model output (1900-2100), and drought and pluvial events are defined based on two categories: moderate (±1) and severe (±2). An event is identified when the SPI exceeds the threshold, and the duration of the event is the number of months that the threshold is exceeded. As the 6-month SPI is used, the thresholds only need to be exceeded for 1-month to be identified as an event. The average SPI during an event is used as a measure of the event intensity.

3. Results

3.1 Climatology and trends

Since 1901, both observational datasets show a wetting trend (in precipitation and SPI) across most of North America, with the exception of the Southwest. The multi-model mean of the CMIP5 historical model simulations also show a similar pattern, with a drying to wetting gradient from the southwest to northeast, as shown in numerous prior studies. In the future, the models are in good agreement that this trend will continue in the future. However, a northwest to southeast swath across the US has less agreement on the sign of the trend in the transition zone from wetting to drying. However, the variability of SPI (and precipitation) shows a very different signal. Using the 9-year running standard deviation of SPI, the two observational datasets do not agree as well, especially across Canada. A trend of increasing variability in precipitation is evident in

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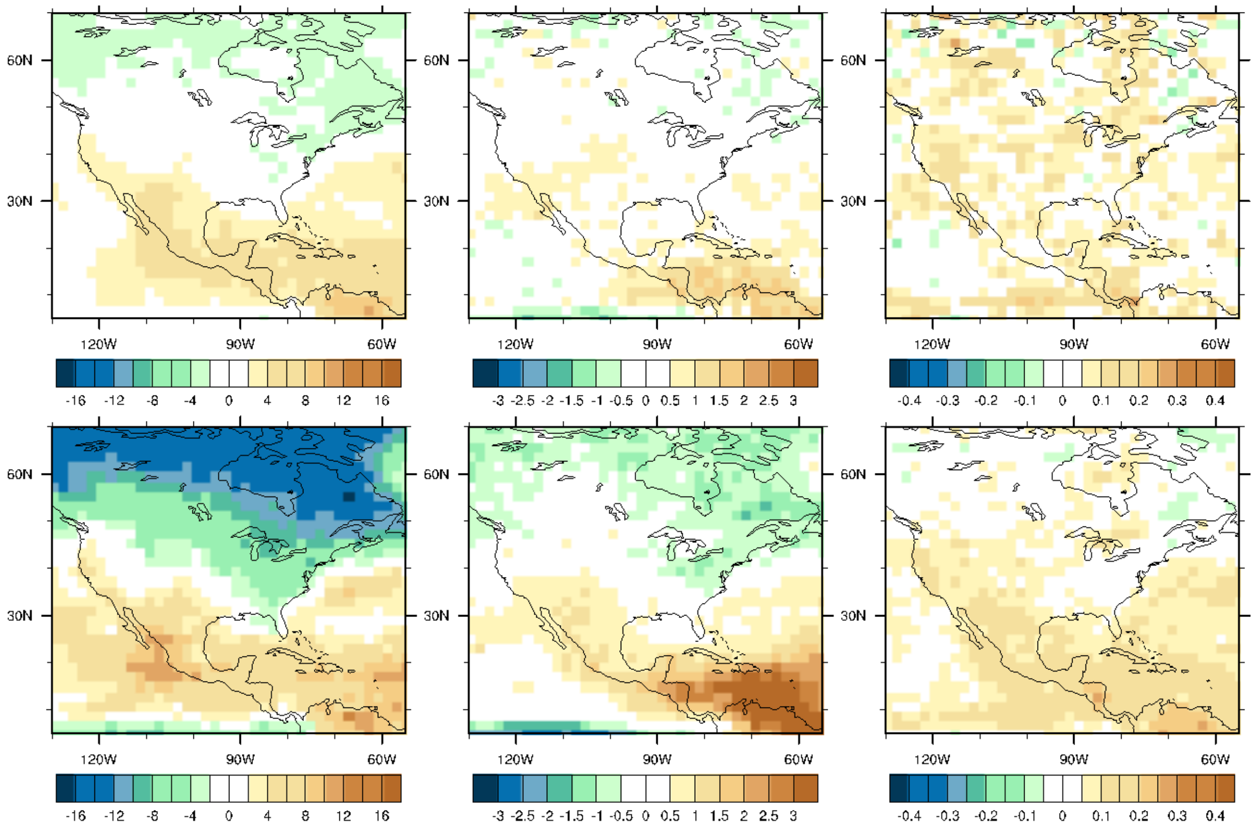

Fig. 1 Multi-model mean change in drought event characteristics (number (left column), duration (middle column), and intensity (right column)) between 2080-2100 and 1980-2000. Top row for severe (SPI<-2) and bottom for moderate (SPI<-1) drought events.

much of the western and northeastern U.S. Historical CMIP5 model simulations show almost no trend in this variability, but in the future, almost all models show a strong trend of increasing variability across the entirety of North (and Central) America. This increase in variability suggests more frequent drought and pluvial events will occur in the future.

3.2 Future changes

The multi-model mean changes in drought and pluvial event characteristics are shown in Fig. 1 and Fig. 2, respectively. In all cases, the changes are larger in moderate events in comparison to severe events. The spatial pattern of the change in number of drought events matches well with the precipitation trends in moderate and severe drought cases. In moderate events, droughts are projected to increase in length by approximately 1 month in the southwest U.S. and over 3 months in parts of the Caribbean. Interestingly, the intensity of droughts is projected to increase across the whole North and Central America, irrespective of whether the precipitation is increasing or decreasing. Drought intensities increase up to approximately 0.2 SPI in moderate and severe drought events.

Similar results are seen in the cases of projected changes to pluvial events. Moderate and severe pluvial events are projected to increase across much of North America, especially in the north and east. As for drought events, the average intensity of pluvials is projected to increase for moderate and severe events across North America. Hence, both wet and dry events will become more intense in the future across North America.

When comparing the drought and pluvial event characteristics with precipitation trends, it is evident that there are some locations where “opposite” projections are occurring. For example, precipitation is projected to increase but drought frequency, duration, and/or intensity are also increasing. To investigate the locations where this is occurring, Fig. 3 highlights regions where drought and pluvial characteristics are in the opposite direction to the precipitation trend in the multi-model mean CMIP5 simulations. For the number of events, the

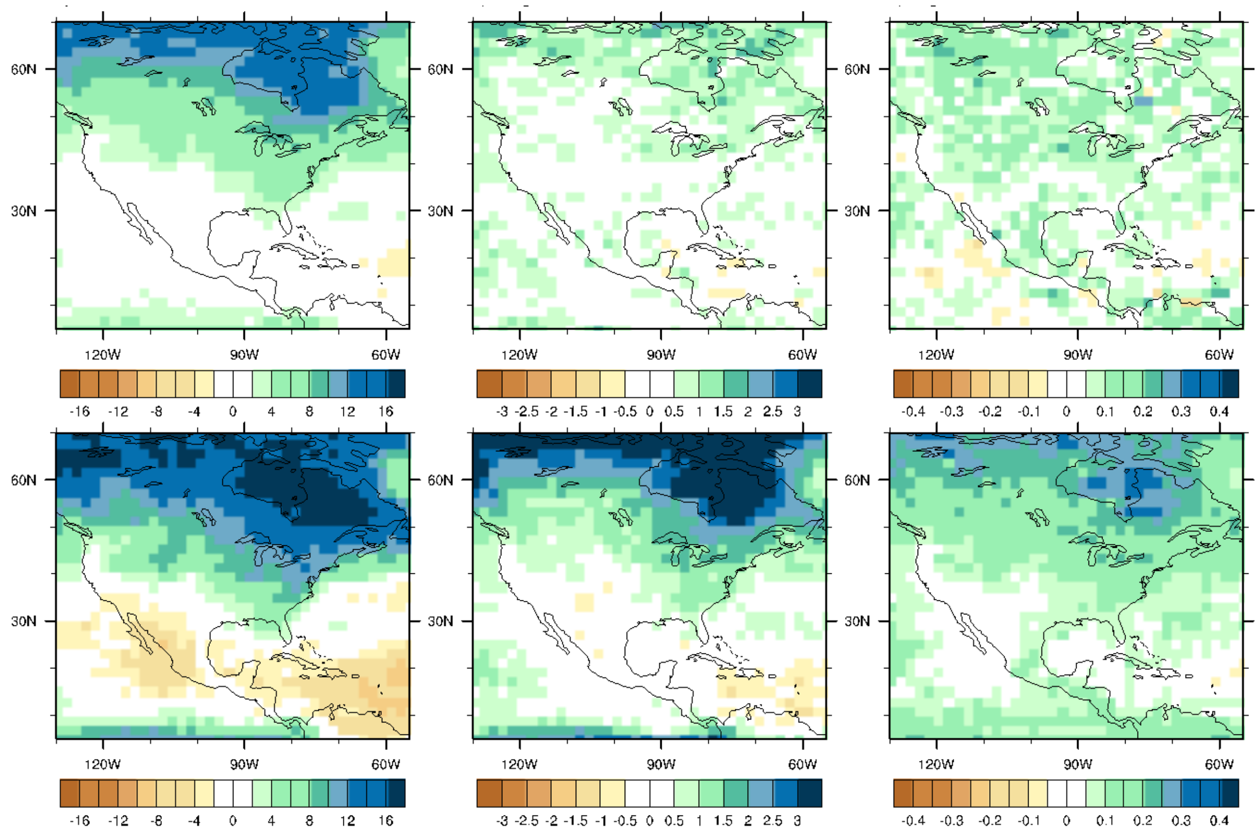

Fig. 2 As in Figure 1 but for pluvial events characteristics.

signal is across the central U.S. in the region between increasing and decreasing precipitation trends where the model agreement on the sign of the trend is smaller. This is also the case for the duration of events, although there is some area expansion, especially in the severe category. The most spatially extensive signal is for the intensity of events. These results suggest that even in regions where precipitation is projected to increase (the north and east U.S.), severe (and moderate to some extent) drought events are projected to increase in duration and intensity (and vice versa with pluvial events in the southwest U.S. and Central America. This has important implications for planning and resilience to events.

4. Summary

Precipitation trends alone do not give information about future drought and pluvial characteristics that are important for planning and impacts. Comparing two observational datasets of precipitation with simulations from the CMIP5 suite of experiments, good agreement is seen in precipitation trends in the historical period but there is less agreement (between the two observational datasets themselves and the models) in the variability. In the future, the variability in the 6-month SPI is projected to increase across the whole North America, suggesting that the characteristics of drought and pluvial events will be changing. As expected from prior studies, generally, wet regions are getting wetter with more frequent, longer lasting, stronger pluvials (and vice versa for drought events). Uniquely, this study also investigates when wet and dry events occur in regions where the precipitation trend is of the opposite sign. Especially for severe droughts/pluvials we see wetting areas with more, longer, and stronger droughts (and vice versa). There is still a need to understand the drivers, spatial variability and predictability of these events across North and Central America.

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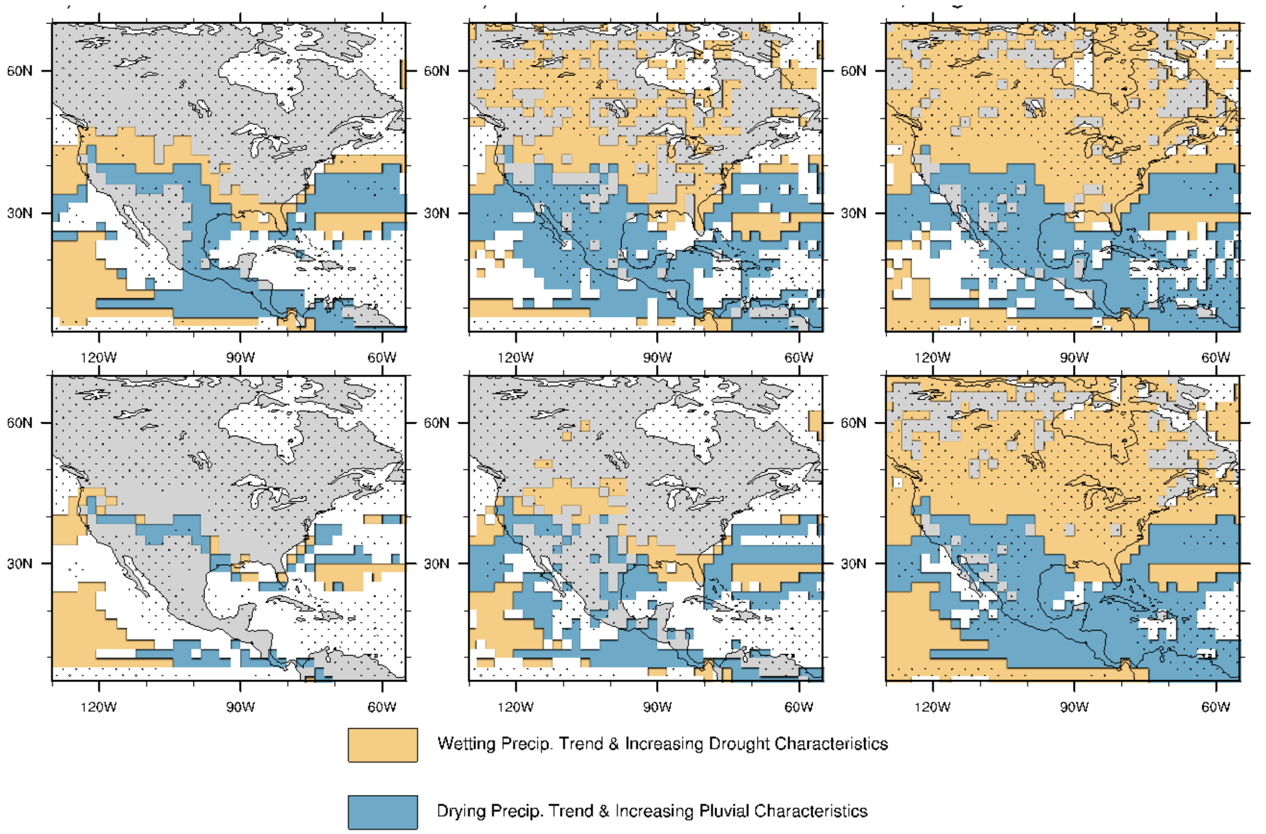

Fig. 3 Multi-model mean locations showing increases in drought (orange) and pluvial (blue) characteristics (number (left column), duration (middle column), and intensity (right column)) when the precipitation trend is wetting and drying, respectively (*i.e.* opposite sign). Top row for severe (SPI<-2) and bottom for moderate (SPI<-1) drought events.

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