Flash Droughts in the Mountain West: Emerging Risks under a Warmer Climate

Imtiaz Rangwala[1,2,3] and Mike Hobbins[1,4]
[1]*Cooperative Institute for Research in Environmental Sciences (CIRES),*
University of Colorado-Boulder, Boulder, Colorado
[2]*North Central Climate Adaptation Science Center, University of Colorado-Boulder, Boulder, Colorado*
[3]*Western Water Assessment, University of Colorado-Boulder, Boulder, Colorado*
[4]*National Oceanic and Atmospheric Administration-Physical Sciences Division, Boulder, Colorado*

Imtiaz Rangwala is a Climate Researcher at the University of Colorado-Boulder with interests in advancing the understanding of changing water balance and climate extremes driven by anthropogenic climate change, and its relevance to ecosystem response.

Mike Hobbins is a Research Scientist at the University of Colorado-Boulder and NOAA's Physical Sciences Division with interests in advancing drought and famine early warning by improved estimation and innovative exploitation of atmospheric evaporative demand.

McNeeley, S.M., Dewes, C.F., Stiles, C.J., Beeton, T.A., Rangwala, I., Hobbins, M.T., and Knutson, C.L. 2018. Anatomy of an interrupted irrigation season: Micro-drought at the Wind River Indian Reservation. Climate Risk Management 19:61-82.

Flash droughts have been much in the news recently. The flash drought event in the Northern Great Plains in 2017 received especially widespread news coverage due to its severe impacts on agriculture and livestock—the economic losses of which led NOAA to categorize it as a billion-dollar weather and climate disaster (NOAA Climate.gov 2018). Another billion-dollar disaster that year resulted from wildfires in the Mountain West, which we show here, were also driven by rapidly evolving dry conditions from anomalously wet antecedent conditions.

For climatologists, emergency managers, and natural resource decision-makers alike, such incidents raise many questions, including the following:

a. Are we observing an increased risk of rapidly evolving extreme drought conditions under a warmer climate when we encounter dry spells that last for weeks to months?

b. From a preparedness perspective, do these incidents catch us off guard, particularly when regions are experiencing anomalously wet conditions?

c. Are there indicators of early warning of flash droughts that could help with preparedness?

Here we present some recent case studies from the US Mountain West to demonstrate occurrence of flash droughts that developed from normal to anomalously wet antecedent conditions and caused severe impacts (e.g., with respect to wildfire, agriculture, and ecosystem productivity), and likely caught managers unprepared. We also demonstrate here the application of a new indicator of drought and wildfire-risk, the Evaporative Demand Drought Index (EDDI; NOAA-EDDI 2019), to capture the signals of flash droughts during these specific incidents. EDDI solely represents atmospheric dryness, and its variability is driven by air temperature, relative humidity, radiation, and wind speed.

2015 "Micro Drought" in the Wind River Range, WY

A very short-lived (a few weeks in length) drought occurred in September, 2015 in the eastern foothills of the Wind River Range of central Wyoming, a region largely surrounded by the Wind River Indian Reservation (McNeeley et al. 2018). While this drought resulted in severe impacts to human and natural resources (Scientific American 2018), it is particularly significant for highlighting a transition from a record-wet to a record-dry condition in a period of few weeks (Fig. 1). At the end of May the region was experiencing record-wet conditions, as indicated by the 1-month EDDI ending in May, which was the lowest since 1980 (Fig. 2a). However, dry, windy, and clear-sky conditions ensued in early August, which resulted in rapid land-surface drying that subsequently led to large increases in temperature by September. All these factors contributed to a record atmospheric dryness for the region for the month of September (Fig. 2b).

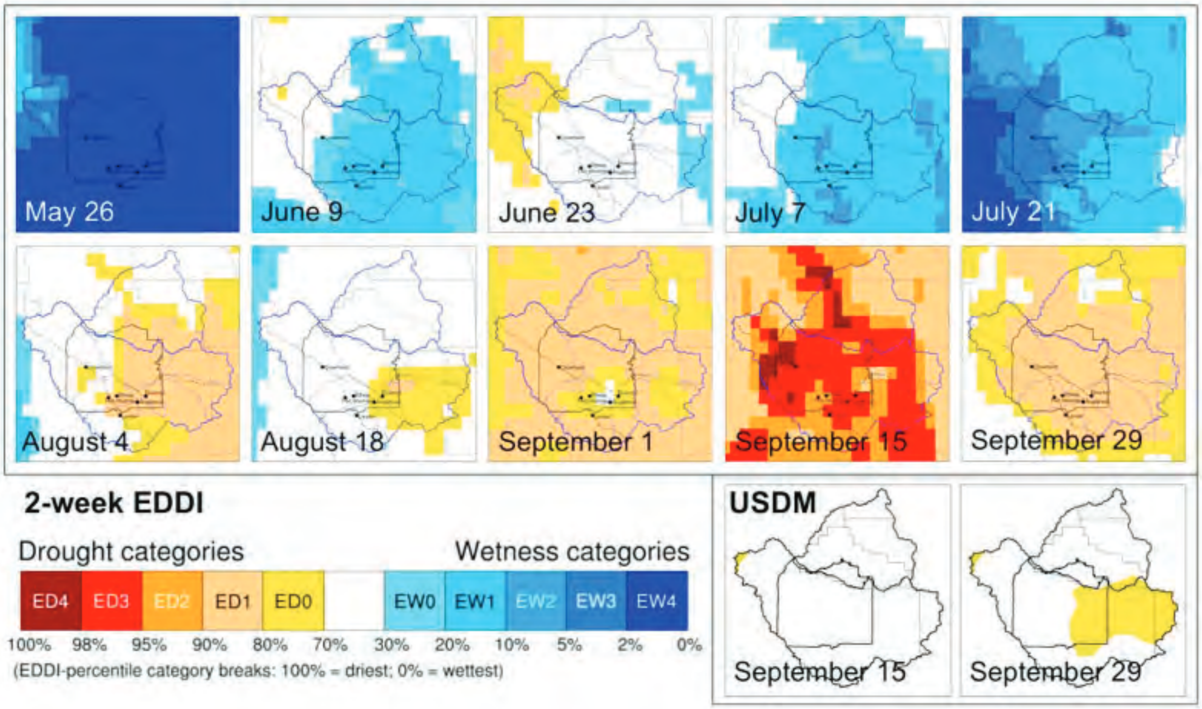


Figure 1. Flash drought development, as measured by the 2-week EDDI at 2-week intervals, in the Wind River Indian Reservation during the 2015 growing season after record wet conditions at the end of spring. The US Drought Monitor (bottom two plots) does not show significant drought conditions in September, when the region experienced record atmospheric dryness. Source: McNeeley et al. 2018.

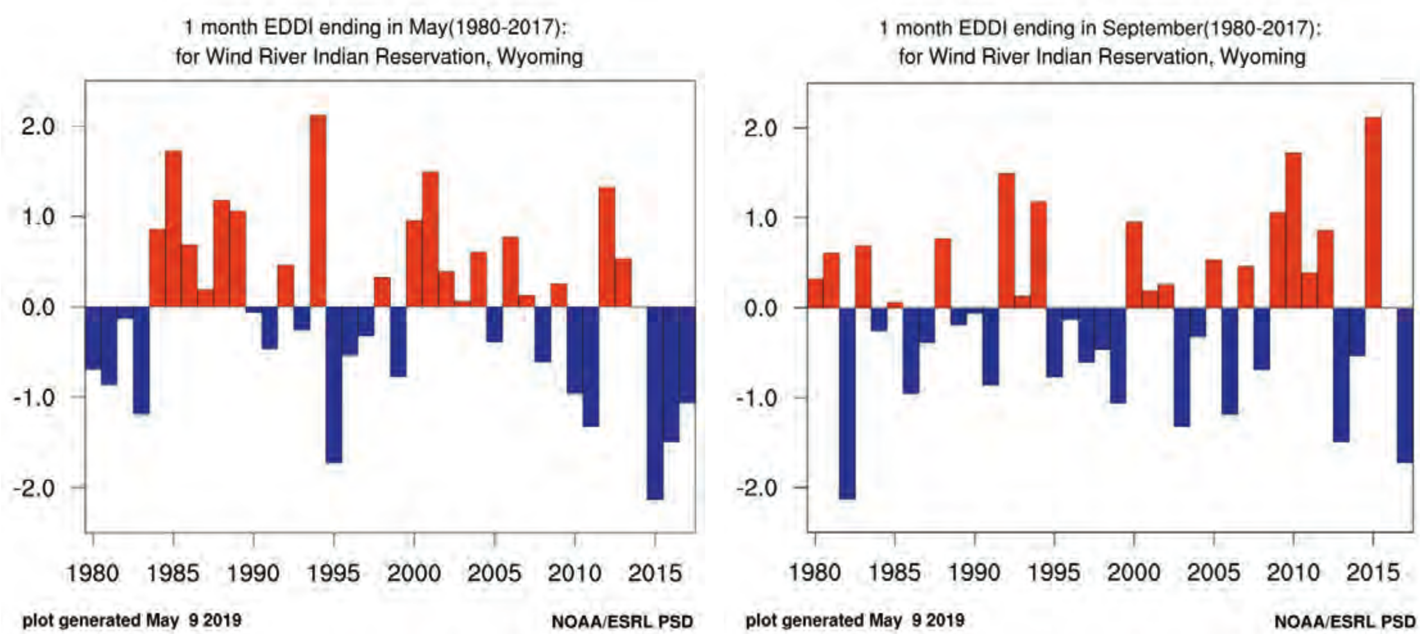


Figure 2. Time series of 1-month EDDI in May and September between 1980 and 2017 for the Wind River Indian Reservation. Source: https://www.esrl.noaa.gov/psd/eddi/.

2017 Wildfires in the Northern Rockies and Pacific Northwest

2017 was a historic wildfire season across many western and north-western states in the US, with about 10 million acres of forested land burned, and over 1 million acres in Montana alone. The end of spring saw anomalously wet conditions in the Northern Rockies and Pacific Northwest. However, episodic dry conditions emerged during summer, which were then followed by extreme atmospheric dryness in the last week of August and first week of September, coinciding with the occurrence of many of these wildfires (Fig. 3).

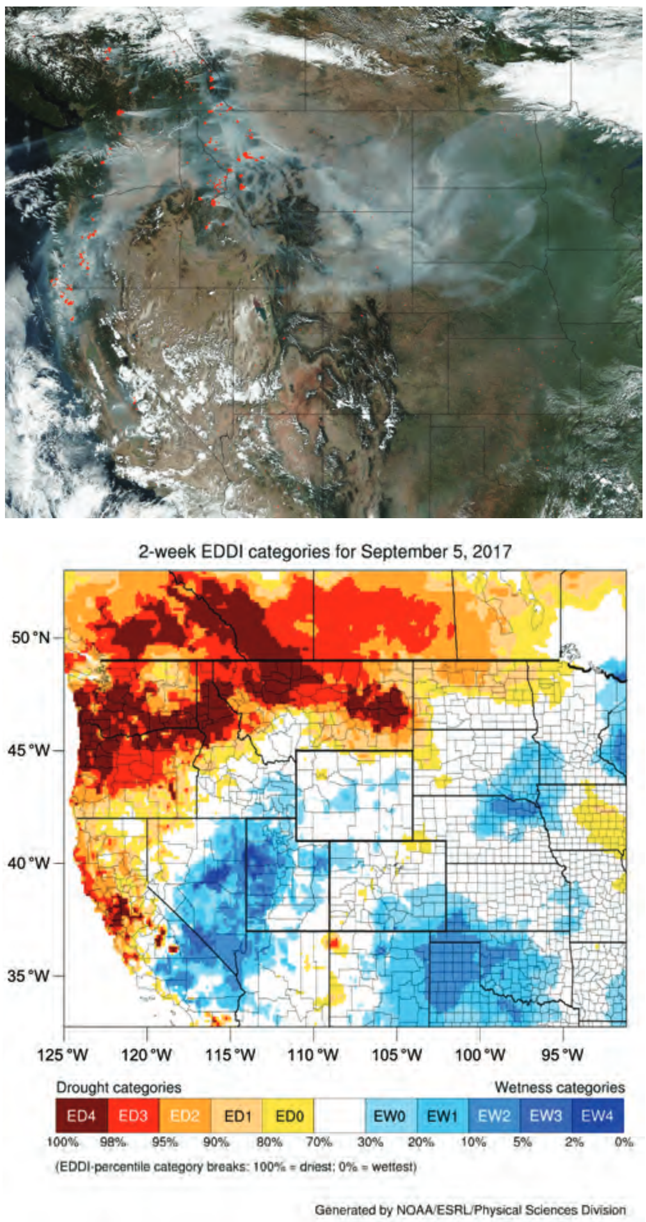


Figure 3. Top: Wildfires in the Northern Rockies and Pacific Northwest as observed by NASA's Suomi NPP using the VIIRS (Visible Infrared Imaging Radiometer Suite) instrument on September 4, 2017 Source:https://www.nasa.gov/image-feature/goddard/2017/smoke-and-fires-light-up-pacific-northwest. Bottom: 2-week EDDI on September 5, 2017.

2018 Camp Fire, California

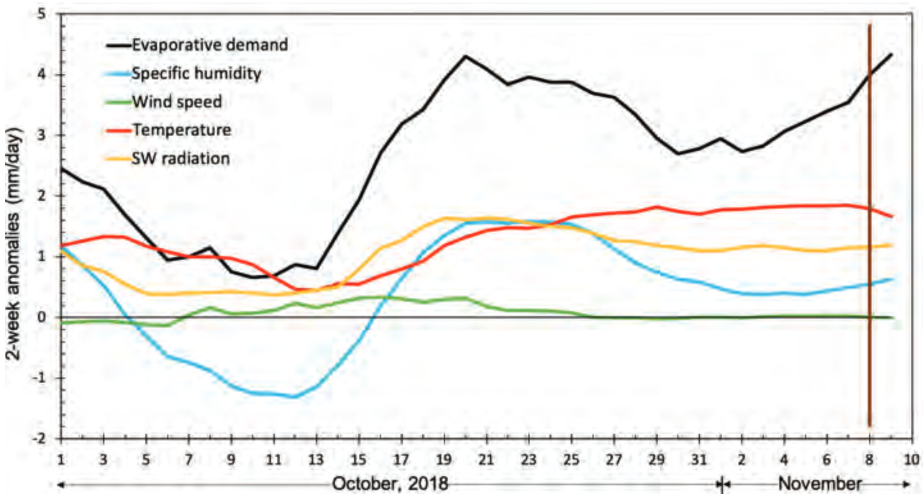
The Camp Fire was the deadliest and most destructive fire in California's history, burning over 153,000 acres from November 8 and leading to upwards of 85 deaths, $16.5 billion in damages, and the loss of 14,000 residences. Examination of the atmospheric dryness signal of this event provides a good example of the sort of interaction between EDDI and weather that can signal incipient fire conditions.

The long dry season in northern California normally ends with the onset of rains in October, which then last from late fall to early spring. In 2018, however, this rainy season did not get underway until November 21 (AccuWeather 2018), nearly two weeks after the outbreak of the Camp Fire. In this case, the failure of the onset of the rains may be indicative of a precipitation-forced flash drought. The effects of this anomalous weather are clear from Fig. 4a, which shows the 2-week running anomaly in atmospheric dryness and its decomposition into its drivers for the period from October 1 through November 9, 2018 (the day after the Camp Fire broke out). The atmospheric dryness had a positive anomaly throughout the period, with peaks in mid-October and then again at the fire onset (Fig. 4b). There appears to have been a turn-around in the weather on or about October 14, after which point, lower-than-normal humidity contributed significantly to this earlier peak, and above-normal and rising temperatures to the second. Throughout the period, solar radiation (associated with the clearer skies that bore no precipitation) also made significant contributions to the anomaly.

Emerging Risk of Flash Droughts

The enhanced warmth and dryness of the atmosphere because of climate change, particularly when a region is experiencing anti-cyclonic conditions (high pressure system), is expected to drive higher rates of moisture loss from the land surface, which may be experiencing normal to above-normal wetness (e.g., Wang et al. 2016). Such high rates of drying have the potential to set in amplifying feedbacks between the atmosphere and land surface causing increases in surface temperature and vapor pressure deficit, which in turn could severely affect ecosystem productivity and increase flammability of vegetation.

Atmospheric dryness at weather timescales (i.e., weeks) has the ability to indicate risk for wildfire and other ecosystem impacts. EDDI has shown promise as an early warning indicator of wildfire risk across California and Nevada (McEvoy et al. 2019).



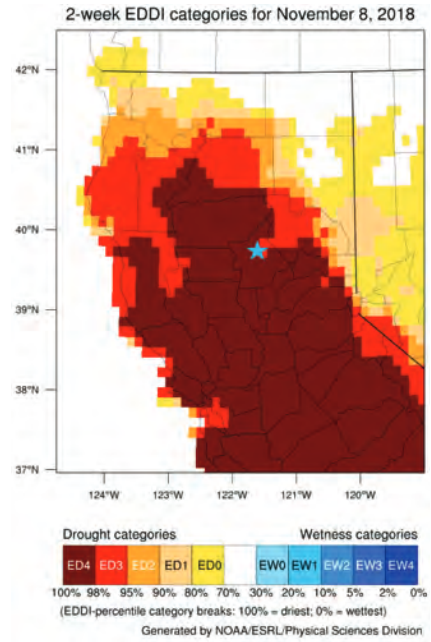


Figure 4. (4a. left) Attribution of 2-week atmospheric dryness anomaly prior to the Camp Fire in Butte County, California, into contributions from each of its climate drivers. Data are extracted from the NLDAS-2 reanalysis for the point of ignition at 121.4347º W, 39.8134º N. The 2-week atmospheric dryness anomaly is shown in black, and each driver's contribution is shown as a colored line. The ignition of the Camp Fire is shown as a vertical brown line on November 8. (4b. right) 2-week EDDI on November 8, 2018. The star indicates the location of the Camp Fire.

Relationships of atmospheric dryness to wildfire and drought impacts at the land surface operate at many timescales: the direct relationship between atmospheric dryness and plant physiology at the leaf scale leads to drought being reflected in plant-moisture stress and elevated live fuel loads at the forest scale.

References

AccuWeather 2018. https://www.accuweather.com/en/us/paradise-ca/95969/november-weather/337193?monyr=11/1/2018&view=table

McEvoy, D.J., Hobbins, M.T., Brown, T.J., VanderMolen, K., Wall, T., Huntington, J.L., and Svoboda, M. 2019. Establishing relationships between drought indices and wildfire danger outputs: A test case for the California-Nevada Drought Early Warning System. Climate 7: doi:10.3390/cli7040052.

McNeeley, S.M., Dewes, C.F., Stiles, C.J., Beeton, T.A., Rangwala, I., Hobbins, M.T., and Knutson, C.L. 2018. Anatomy of an interrupted irrigation season: Micro-drought at the Wind River Indian Reservation. Climate Risk Management 19:61-82.

NOAA Climate.gov 2018. https://www.climate.gov/news-features/blogs/beyond-data/2017-us-billion-dollar-weather-and-climate-disasters-historic-year

NOAA-EDDI 2019. https://www.esrl.noaa.gov/psd/eddi/

Scientific American 2018. https://www.scientificamerican.com/article/a-wyoming-reservation-shows-the-new-face-of-drought/

Wang, L., Yuan, X., Xie, Z., Wu, P., and Li, Y., 2016. Increasing flash droughts over China during the recent global warming hiatus. Scientific reports 6:30571.