ADVANCES IN FOREST FIRE RESEARCH

2022

Edited by

DOMINGOS XAVIER VIEGAS
LUÍS MÁRIO RIBEIRO

Exploring atmospheric evaporative demand in relation to wildland fire

Timothy Brown[1]*; Daniel McEvoy[1], Andrew Andrade[1], Britt Parker[2]

[1]*Desert Research Institute, Reno, Nevada, {tim.brown, dan.mcevoy, andrew.andrade}@dri.edu*
[2]*NOAA/CIRES University of Colorado, Boulder, Colorado, USA, {britt.parker@noaa.gov}*

**Corresponding author*

Keywords

Evaporative demand, fire danger, wildfire, prescribed fire

Abstract

Evaporative demand, the upper limit of actual evapotranspiration (ET) that could occur given unlimited surface water supply, has a strong connection to drought and wildfire potential in the western United States and globally. A physically based evaporative demand formulation incorporates temperature, wind speed, humidity, and incoming shortwave radiation – components that drive land surface-atmosphere interactions and drying. These are also the primary physically based components in the U.S. National Fire Danger Rating System – some combination of temperature, humidity, and wind speed are also common inputs to other fire danger systems. Thus, association between evaporative demand and fire danger can be expected and this has previously been demonstrated such as via the Evaporative Demand Drought Index (EDDI) indicator. For example, EDDI can be decomposed to examine the weighted physical factors over time leading up to a fire event. Utilizing evaporative demand for monitoring and prediction can serve as an early warning of fire potential depending on climatological persistence patterns for weeks to possibly months in advance though rapid onset anomalies may yield a similar result. Evaporative demand can also inform prescribed burn planning. Based on the exploration of EDDI indicators prior to fire events, this presentation will discuss analyses of evaporative demand in the context of both wildfire and prescribed fire to better understand if and how evaporative demand can be used to inform wildland fire management decisions.

1. Discussion

Evaporative demand (E_0), the upper limit of actual evapotranspiration that could occur given unlimited surface water supply, has a strong connection to drought and wildfire potential globally. Plant water cycle processes including soil water uptake, plant water storage, and water loss through transpiration all influence plant water availability. Extensive transpiration can dominate the plant water cycle leading to increased fuel flammability. A physically based E_0 formulation incorporates temperature, wind speed, humidity, and incoming shortwave radiation (Allen et al. 2005) – components that drive land surface-atmosphere interactions and drying. These are also the primary physically based components in the U.S. National Fire Danger Rating System as well as inputs to other fire danger systems (e.g., temperature, humidity, and wind are primary inputs for the Australia Forest Fire Danger Index).

The Evaporative Demand Drought Index (EDDI; Hobbins et al. 2016; McEvoy et al. 2016) is based only on E_0, which has been shown to signal the onset of rapid drying and flash drought before other indicators such as precipitation, soil moisture, and actual ET. EDDI may better capture short- and long-time scale dry dynamics and provide early warning for fire activity. McEvoy et al. (2019) showed that EDDI generally had higher correlations to fire danger outputs than other commonly used drought indicators.

Figure 1 shows EDDI for three 2018 fire events in California – the Mendocino and Carr fires in July and the Camp fire in November. Colors denote the EDDI percentiles with red colors signifying higher percentiles. In this example these three major fires occurred when EDDI averaged above the 95th percentile for the two months leading up to the fires.

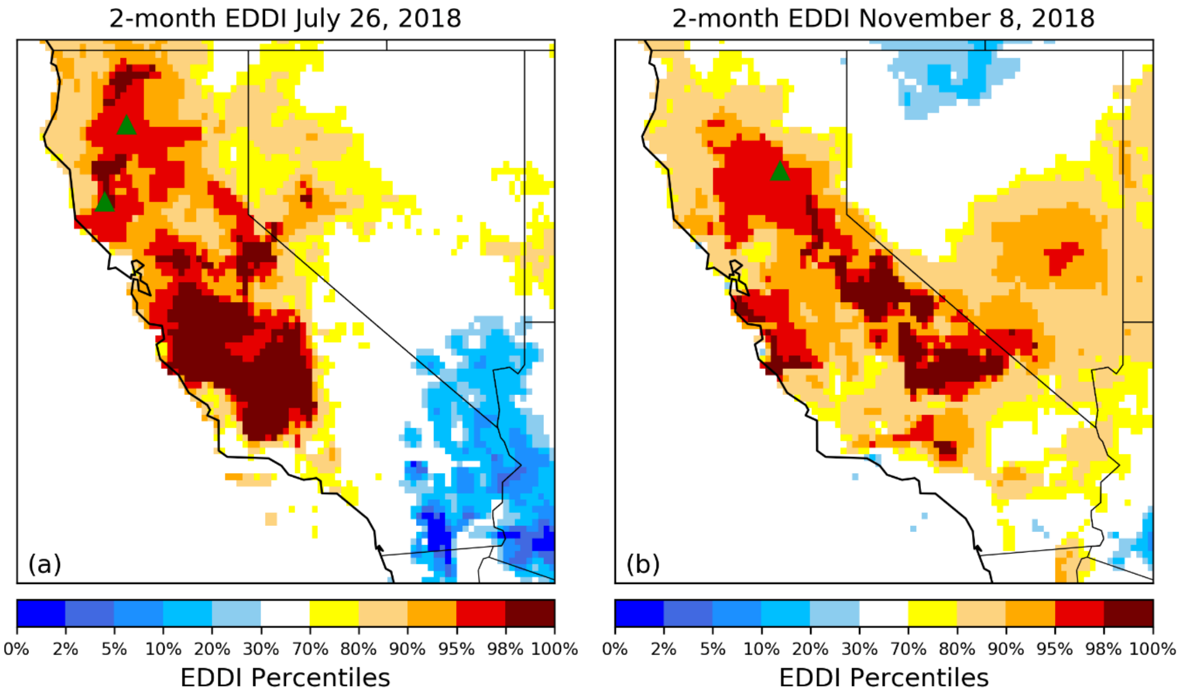

Figure 1 EDDI 2-month percentile categories for (a) 26 Jul 2018, and (b) 8 Nov 2018. Triangles represent the Mendocino (lower) and Carr (upper) fires in(a) and the Camp fire in (b). From Brown et al. (2020).

EDDI can be decomposed to examine the weighted physical factors over time leading up to a fire event. Figure 2 shows the E_0 anomaly and the contributions from each of its drivers aggregated over a two-week window moving forward daily across Sonoma County, California from mid-August through the end of October 2018, a period of eight weeks prior to and three weeks following the ignition of the Tubbs Fire. E_0 is elevated above its climatological median (50th percentile) throughout the period. A notable spike of much above-normal temperatures occurred prior to the fire outbreak from 31 August until 5 September. During the first two weeks of September a positive E_0 anomaly remains but becomes near normal for the second half of September due to the mitigating effects of above-normal humidity and below-normal wind speeds and solar radiation. In early October temperature remains near normal but the combined effects of now-below-normal humidity and above-normal wind speed and solar radiation dominate the E_0 anomaly, which climbs again through the day of the fire ignition (8 October) and afterwards. On the day of ignition, E_0 reaches its second spike when it exceeds its 95th percentile. This indicates that near-surface moisture was decreasing and a drying of the air mass was taking place even during a period of near-normal temperatures. It is also worth noting that wind speed had the largest contributions during the onset of the second spike from 29 September through 2 October. These patterns are suggestive of an important role of rapid (flash) meteorological impacts on fuels. Autumn in California is climatologically dry; an E_0 indicator such as EDDI highlights factors besides soil moisture drought that contributes significantly to drying of fuel moisture. E_0 should work suitably well in other fire prone regions.

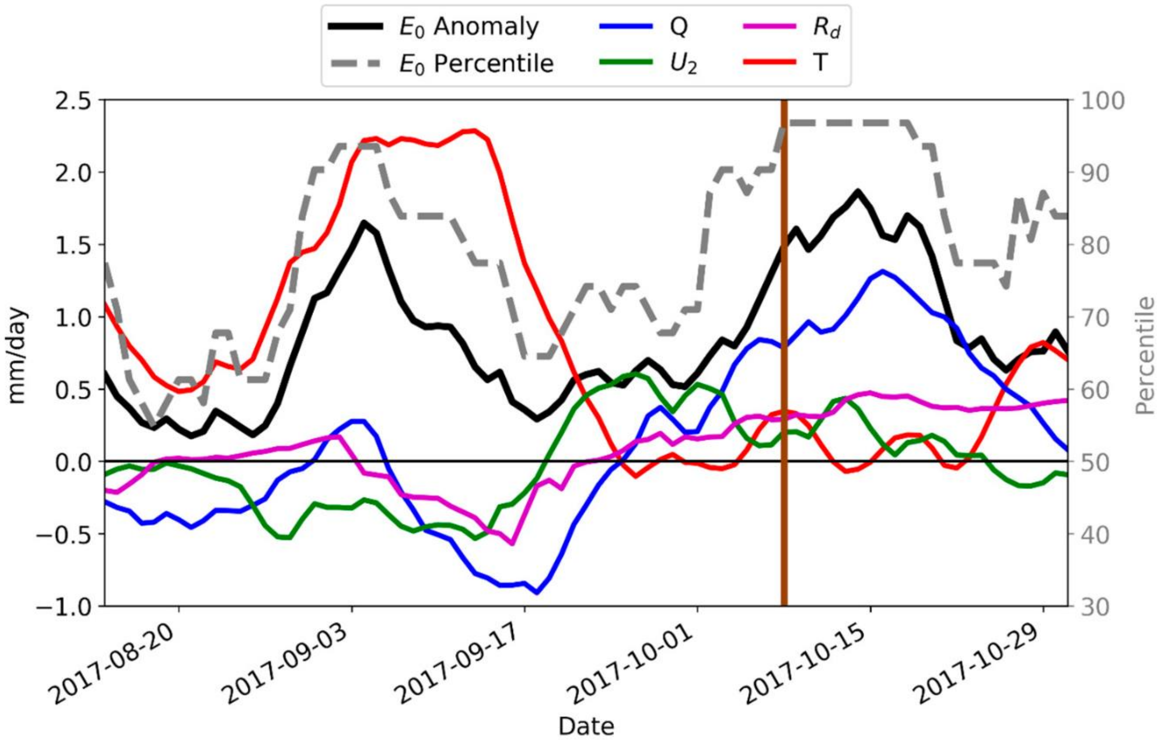

Figure 2 Evaporative demand (E_0) anomaly prior to and during the October 2017 Tubbs fire in Sonoma County, California. The 2-week E_0 anomaly (black line) is spatially averaged across Sonoma County. The contributions from each of its drivers are shown as colored lines (temperature (T) in red, specific humidity (Q) in blue, downwelling shortwave radiation (Rd) in purple, wind speed (U2) in green); percentiles of 2-week E0 are shown in dashed grey (right-hand axis); and the ignition date of the Tubbs fire is shown as a vertical brown line. From McEvoy et al. (2019).

Utilizing E_0 for monitoring and prediction can serve as an early warning of significant fire potential weeks to possibly months in advance especially given persistent climatological patterns though rapid onset anomalies may yield a similar result. The scope of this project is to determine the extent that E_0 can be used as an early warning for significant wildfire potential. Soil moisture drought alone is not always a sufficient indicator of fire potential. Cases of large fires with normal soil moisture conditions but high E_0 have been observed. Short time (e.g., weekly scale) periods of anomalous high E_0 may be sufficient to allow for periods of increased fuel flammability, though this likely will vary depending on vegetation type. Persistence of high E_0 can serve as one indicator of fire potential. That is, while weekly-scale anomalous E_0 can serve as an indicator of increased fire potential, monthly to seasonal scales that are persistent with anomalous E_0 can also serve as an indicator. E_0 could also be used for prescribed burning. For example, if E_0 was calibrated to fuel flammability, then observed E_0 could help inform the potential success of a burn given a specific management goal or serve as indicator of a potential burn escape.

E_0 is already being utilized for some fire activities, especially in California. Examples include successful integration of EDDI into fire management operations with California Predictive Services such as submitting Severity Funding Requests, daily fire weather briefings, seasonal fire potential outlooks, and incorporated into the Fire Behavior Field Reference guide and wildland fire fighter training curriculum (Brent Wachter, *pers. comm.*).

2. References

Allen, R.G.; Walter, I.A.; Elliott, R.; Howell, T.; Itenfisu, D.; Jensen, M., 20-05: The ASCE Standardized Reference Evapotranspiration Equation; American Society of Civil Engineers: Reston, VA, USA, pp. 59.

Brown, T.J., S. Leach, B. Wachter, and B. Gardunio, 2020: The Northern California 2018 Wildfire Season. *Special Supplement to the Bulletin American Meteorological Society*, Vol. 101, No. 1, January 2020, S1-S4. DOI:10.1175/BAMS-D-19-0275.1

Hobbins, M.T.; Wood, A.W.; McEvoy, D.J.; Huntington, J.L.; Morton, C.; Anderson, M.C.; Hain, C.R., 2016: The Evaporative Demand Drought Index: Part I—Linking drought evolution to variations in evaporativedemand. J. Hydrometeorol., 17, 1745–1761.

McEvoy, D.J.; Huntington, J.L.; Hobbins, M.T.; Wood, A.W.; Morton, C.; Anderson, M.C.; Hain, C.R., 2016: The Evaporative Demand Drought Index: Part II—CONUS-wide assessment against common drought indicators. J. Hydrometeorol., 17, 1763–1779.

McEvoy, D. J., Hobbins, M., Brown, T. J., VanderMolen, K.A., Wall, T. U., Huntington, J. L., 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 (4), https://doi.org/10.3390/cli7040052