THE NORTHERN CALIFORNIA 2018 EXTREME FIRE SEASON

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INTRODUCTION. The fire season of 2018 was the most extreme on record in Northern California in terms of the number of fatalities (95), over 22,000 structures destroyed, and over 600,000 hectares burned (https://www.fire.ca.gov/media/5511/top20_destruction.pdf; accessed November 24, 2019). The most deadly and destructive fire in California history, the Camp Fire, occurred in Butte County in the Sierra Nevada foothills in early November, and caused 85 fatalities and destroyed nearly 19,000 structures. The largest fire complex in state history, the Mendocino Complex, which included the Ranch fire, the largest single fire in state history, burned nearly 186,000 hectares. It occurred in July and August killing one fire fighter. In western Shasta County nearly 138,000 hectares burned from July through September in the Carr, Hirz, and Delta Fires. These fires caused multiple closures of Interstate 5 and exhibited some of the most extreme fire behavior ever observed in California. The Carr Fire caused eight fatalities, including two fire fighters and two workers supporting firefighting efforts, burned over 1,100 homes in west Redding, caused the evacuation of one-third of the city, and produced an extreme fire vortex with an Enhanced Fujita scale rating between 136 to 165 mph, making it arguably the strongest tornado type event in state history, and one of the strongest documented cases in the world (Lareau et al. 2018).

Actual weather during the onset of these large fires was not outside of what would normally be expected during periods of higher fire danger that occur during most fire seasons, as opposed to the extreme offshore wind event that led to the October 2017 wine country fires (Nauslar et al. 2018). The Tubbs fire during that period caused 22 fatalities and the loss of 5,636 structures, and at the time was California's most destructive fire on record dating back to the early 1900's. Instead, a series of climate and fuels conditions aligned to create an exceptional and explosive fire environment between June to November 2018 in naturally fire prone areas with a substantial wildland-urban interface – a zone where human development meets and intermingles with wildland fuels.

CLIMATE AND FUELS. Climate enables fire and weather drives fire. The 2018 northern California fire season origins began during the winter of 2016-17. Precipitation, which was much above normal, exceeding the 90th percentile ranking across much of the state at low to mid-elevations. Some of the higher elevations in the Sierra Nevada range were the wettest on record. November through April is climatologically the wet season in northern California. This particular wet winter ended the statewide hydrologic drought from 2011-2017. The significance of this wet season was that it led to the 2nd consecutive spring with above average fine fuel (grasses) crop across much of northern California.

The 2017-2018 northern California wet season was drier than normal, and temperatures were generally above normal, with the warmest conditions from the Cascade-Sierra foothills through the Sacramento Valley and into the northern Coast Range. A lack of stormy weather during this period allowed above normal standing carry-over fine fuels from the previous wet year. April 2018 was warmer and wetter than normal. This was perfectly timed to produce above normal spring brush growth and grow a record fine fuel crop at elevations below 1200 meters, despite the overall wet season rainfall deficit (Figure 1). This was the third straight spring with an above average fine fuel crop based on data taken at the University of California Sierra Foothill Research and Extension Center. Brown's Valley, California research station forage production data has been reported continuously since the 1979/80 growing season. Three straight above normal growing seasons had not occurred in the dataset prior to the 2017/18 growing season. Peak forage production towards the end of spring was 150% of normal (https://ucanr.shinyapps.io/SFREC_Web_Application/; accessed November 24, 2019) and the maximum value during the 40-year history. As a testament to the abundant and continuous fine fuel growth, firefighters during 2018 often described arriving to a larger fire compared to what was normally observed during initial attack situations, thus making the fires harder to contain (Northern California Predictive Services, personal communication, July 24, 2019).

The summer of 2018 in northern California had two notable climate anomalies – lack of rain and warmer than average temperatures. This led to a rapid curing of the annual fine fuels and drying of live fuels. For the most part, rain shut off in late April and did not return until late November. In the Sacramento Valley and foothills only two light rain events produced approximately 15mm each, one in late May and the other in late September-early October. The lack of precipitation from late spring through the middle of November caused fuels to dry out to record levels.

The summer of 2018 was warmer than average in northern California. Afternoon maximum temperatures were not extraordinarily high compared to 2017. Rather, it was the warm morning minimum temperatures that pushed the overall average temperature in July 2018 to record high levels. Record high lows for California were observed in July, continuing a positive trend of nighttime warming since 1895, (https://www.climate.gov/news-features/event-tracker/extreme-overnight-heat-california-and-great-basin-july-2018; accessed November 24, 2019). These warm temperatures led to more nights of poor overnight humidity recovery, which has direct implications on the flammability of fuel. The poor recoveries led to unusually long active burn periods during the overnights and set the stage for earlier active burning during the daytime hours. This created more hours of active to extreme fire behavior and provided less opportunity for direct attack by firefighters (Northern California Predictive Services, personal communication, July 24, 2019)

WEATHER. Long periods dominated by strong high pressure occurred in July, which hastened the summer drying of fuels. The hottest day of the year in the Sacramento Valley was July 26th, setting all-time records for the date, and was a key element in the conditions that rapidly brought the Carr Fire into Redding, CA. Other large-scale fires started that week as well, including the Mendocino Complex. Interestingly, temperatures were slightly cooler than normal during August and September in areas where thick smoke from nearby wildfires persisted for unusually long periods. Northern California had a very low occurrence of lightning during the 2018 fire season.

Roughly 12,000 lightning strikes were recorded during the fire season, compared to the long-term average of more than 30,000 strikes (in northern California lightning accounts for the majority of fire ignitions, while in southern California human causes dominate ignitions; Balch et al. 2017). Dry offshore wind events, which typically increase in occurrence after the middle of September, occurred with fuels at extreme and record dry levels. The Camp Fire on November 8th was the result of an ignition occurring in extremely dry fuels during an enhanced strong and dry downslope wind pattern.

FIRE ENVIRONMENT. The precipitation deficit at the close of the 2017-2018 rainy season combined with drier and warmer than normal summer conditions caused an expansion and intensification of short-term drought across northern California. The Evaporative Demand Drought Index (EDDI; Hobbins et al. 2016; McEvoy et al. 2016) clearly illustrates the intensity of short-term drought conditions during late July when significant fires started (Figure 2a), and even more so in November as dry NE/Offshore wind patterns became more frequent and the Camp Fire broke out (Figure 2b). Evaporative demand relates to the thirst of the atmosphere which directly corresponds to fuel stress – higher values equate to more stress. There is a close correlation between EDDI values and fire danger (McEvoy et al. 2019) including extreme fire behavior and spread rates. EDDI comprises inputs of temperature, humidity, wind speed, and solar radiation. These are also key factors in determining dead fuel moisture calculated in the newly updated National Fire Danger Rating System (https://gacc.nifc.gov/eacc/predictive_services/fuels_fire-danger/documents/Overview%20of%20NFDRS2016%20and%20Implementation%20and%20Evaluation.pdf; accessed November 24, 2019). Starting in late July, fire danger indicators in northern California such as the energy release component (the amount of energy at the head of fire's flaming front) approached all-time record high values accentuating the impact of the anomalously warm and dry summer on fuels. In effect, fuel regimes found at all elevations (sea level to over 3000 meters), large fire potential by July.

SUMMARY. Both 2017 and 2018 were extreme fire years in California. While this paper has focused on northern California in 2018, southern California that year also saw its share of extreme fire including the Ferguson (two firefighter fatalities, 19 structures destroyed, and approximately 39,000 hectares burned), Cranston, and Holy Fires. On the same day as the Camp Fire, November 8th, two large fires developed in Ventura and Los Angeles County, including the Woolsey Fire (approximately 39,000 hectares burned and over 1600 structures destroyed). Following the unusually late season December 2017 Thomas Fire in the Ventura and Santa Barbara county area, a post fire debris flow event occurred over the burn area on January 9th resulting in 23 fatalities and 246 structures destroyed (Oakley et al., 2018).

Climate, fuels, and people are the three confluent factors for California's recent destructive wildfires. The wildland-urban interface has been growing extensively within the state during the past few decades (e.g., Radeloff et al. 2018), placing people in fire prone areas. Climate is an enabler of wildfire by providing seasonal moisture to grow fuels, and seasonal warming and drying that increases fuel flammability. Increasing temperature trend enables longer and more extreme fire seasons. California's annual temperatures have been increasing substantially during the past four decades and is expected to continue warming this Century (California's Fourth Climate Assessment; Bedsworth et al. 2018). Abotzoglou and Williams (2016) have shown that

California (as well as all of the West) has had significantly enhanced fuel aridity due to anthropogenic increases in temperature and vapor pressure deficit over the past several decades. This can also be seen in the increasing number of days of fire weather season length based on fire danger indicators (e.g., Jolly et al. 2014). Nighttime temperature trends especially may be playing an important role in more extreme fire behavior. Research is currently underway to examine the specific relationship of this warming to nighttime fuel drying and subsequent extreme fire behavior that was observed during the California 2018 fire season.

An estimated 54% of California ecosystems are fire dependent and most of the rest are fire adaptive (Pyne 2016). California has always had fire given its climate, topography, and distinctive varieties of combustible vegetation. Today it is a state of nearly 40 million people, and one in four Californians live in a 'high risk' wildfire area (https://www.latimes.com/local/lanow/la-me-california-braces-for-new-wildfires-20190614-story.html; accessed November 24, 2019). California insured losses in 2018 from wildfire topped $13B (https://www.insurancejournal.com/news/west/2019/05/08/525930.htm; accessed November 24, 2019). The year 2018 now holds the record for the most destructive wildfire, the largest wildfire, and the costliest wildfire season in California state history.

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Figure 1. Photo of fine fuel grass loading taken on 12 September 2018 60 miles northwest of the Camp Fire location. Left of the fence line shows a continuous bed of fine fuel. The paddock to the right of the fence line has less fuel due to grazing. Photo: Brent Wachter, Predictive Services.

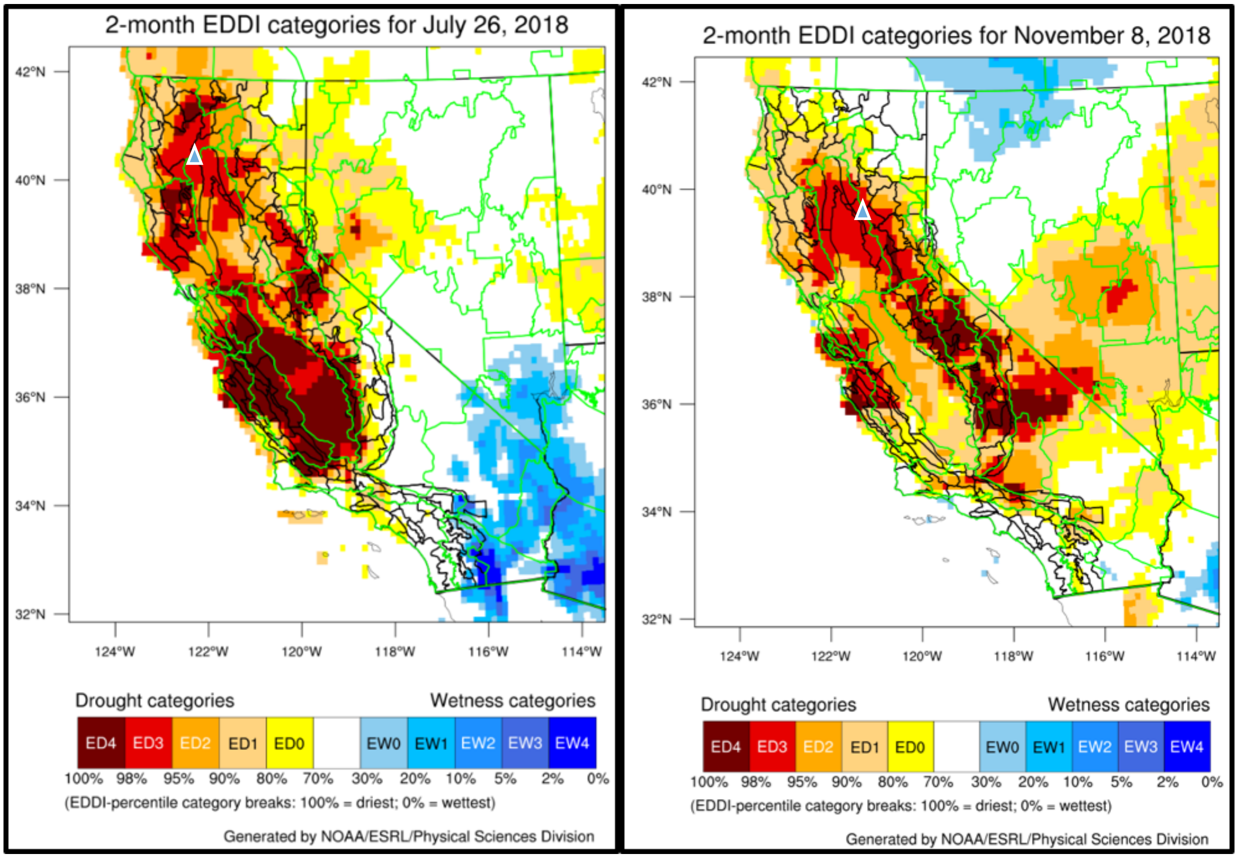

Figure 2. Evaporative Demand Drought Index 2-month categories for a) 26 July 2018, and b) 8 November 2018. Triangles represent Carr and Camp fire locations, respectively.