SIDEBAR 7.1: RECORD-SETTING 2018 CALIFORNIA WILDFIRES—

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California experienced its deadliest and most destructive wildfire season on record in 2018, only one year after the previous most destructive wildfire season. Two of the deadliest 2018 wildfires (Camp and Carr Fires), three of the eight most destructive wildfires (Camp, Carr, and Woolsey Fires), and three of the twenty largest wildfires (Mendocino Complex, Camp, and Carr Fires) in California's history all occurred during 2018 (CAL FIRE 2019f–h). The Camp, Woolsey, and Carr Fires were estimated to cost more than $27 billion (U.S. dollars) in insured losses, suppression, and cleanup, with the Camp Fire being the costliest international disaster during the year (McBride 2018; CAL FIRE 2019b–d,i; Reyes-Velarde 2019; NIFC 2019; Finch II 2019). More than 730 000 ha burned across California, which is the most area burned on record in the last 30+ years (based on reliable fire data). Most of the year's wildfire ignitions were human-related (CAL FIRE 2019a; NIFC 2019), which is not uncommon for California. The largest wildfire in California's history, the Ranch Fire, ignited on 27 July and burned 166 003 ha within the Mendocino Complex (comprised of the River Fire and Ranch Fire) in northwest California (CAL FIRE 2019e–f). Following is a summary of the Camp and Carr Fires, illustrating the importance of the climate–weather nexus for wildfires.

Climate has a strong influence on vegetation availability and ignition for fire—climate enables fire while weather drives fire. The multi-year (2012–16) drought increased vegetation stress and mortality in and around California, especially with larger fuels (e.g., trees and shrubs). Because summer and early autumn in northern California is climatologically warm and dry, fine fuels (e.g., grasses) normally cure out and become available for burning. However, longer-term drought exacerbates drying of live fuel moisture in shrubs and trees. The 5-year drought abruptly ended when much-above-normal precipitation occurred in the winter–spring seasons of 2016–17, allowing for a greatly increased grass fuel load, which carried over through 2018. At the time of the Camp Fire, grass fuel loadings were 180% of normal.

The shorter climate time scales of 1–6 months using the Evaporative Demand Drought Index (EDDI; Hobbins et al. 2016; www.esrl.noaa.gov/psd/eddi/) highlights the role of evaporative demand in the lead up to the Carr and Camp Fires (Fig. SB7.1). Spikes in evaporative demand (high EDDI values), driven by extended periods of high temperatures,

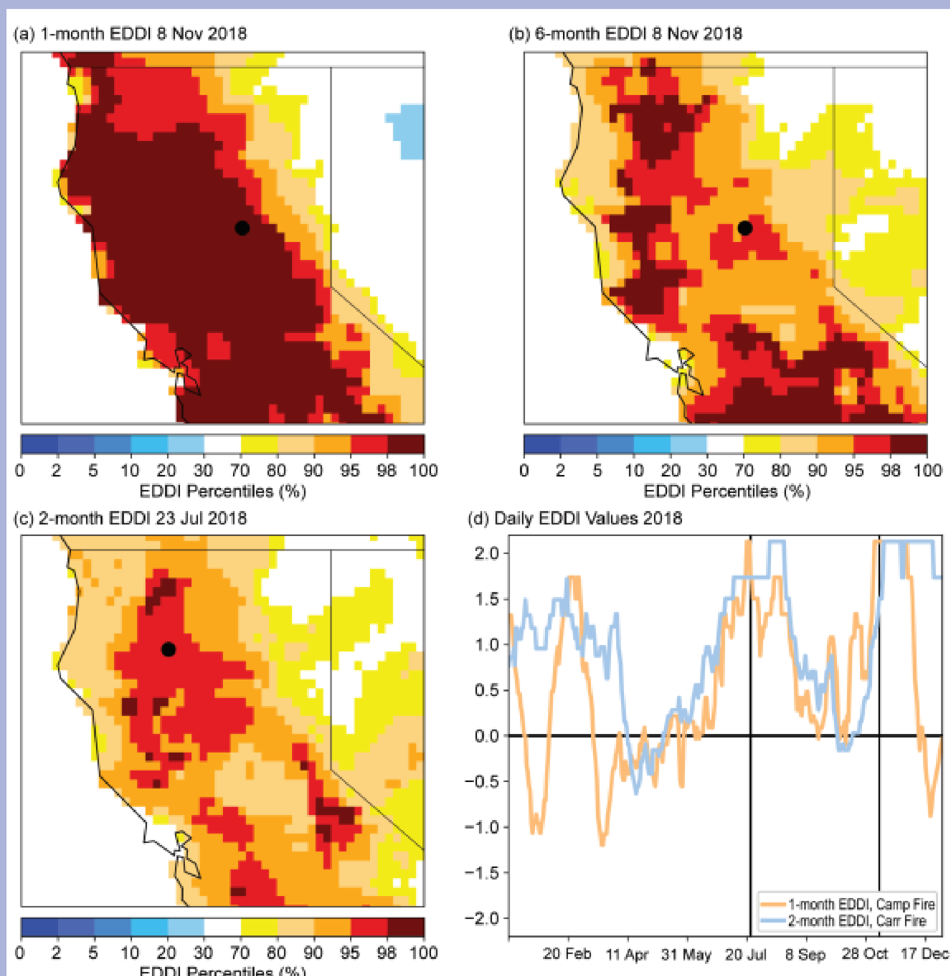

FIG. SB7.1. Evaporative Demand Drought Index (EDDI) spatial percentiles and time series during the 2018 northern California wildfires. (a) 1-month EDDI percentiles ending 8 Nov 2018, (b) 6-month EDDI percentiles ending 8 Nov 2018, and (c) 2-month EDDI percentiles ending 23 Jul 2018. Black circle in (a) and (b) denotes ignition point of the Camp Fire and black circle in (c) denotes ignition point of the Carr Fire. (d) Daily time series of 1-month EDDI at the grid cell nearest to the Camp Fire ignition point (orange line) and 2-month EDDI at the grid cell nearest to the Carr Fire ignition point (blue line). Vertical lines in (d) denote ignition date of the Carr Fire (23 Jul) and Camp Fire (8 Nov).

strong winds, and low humidity, were noted prior to both fires. Peak EDDI values (above 95th percentile) coincided with fire start dates (Fig. SB7.1). The EDDI is strongly correlated to dead fuel moisture in California and was used to identify extreme fire danger leading up to the 2017 Tubbs Fire (McEvoy et al. 2019).

The Carr Fire burned nearly 93077 ha, making it the seventh largest wildfire in California's history. It caused eight deaths and destroyed more than 1600 structures (CAL FIRE 2019c,f). The Carr Fire began on 23 July northwest of Redding, California. On 26 July, driven by hot, dry, and unstable conditions, it burned downslope to the east-southeast into portions of Redding and grew more than 13354 ha, its single largest growth day (CAL FIRE 2019c). A rare tornado-strength, fire-generated vortex (FGV) formed in northwest Redding as a 12-km tall pyrocumulonimbus developed over the fire (Fig. SB7.2a; Lareau et al. 2018). A National Weather Service storm survey found EF-3 rated damage associated with this FGV, and radar data showed rotational velocity values for the FGV similar to that of EF1-2 tornadoes (Lareau et al. 2018). Anomalously wet conditions followed by low fuel moisture, record heat, and anomalously dry conditions primed this area for large, rapidly growing wildfires (Lareau et al. 2018).

In November, the Camp Fire, the deadliest and most destructive wildfire in California's history, caused 85 deaths and destroyed nearly 19000 structures as it burned 62040 ha on the western slopes and foothills of the northern Sierra Nevada (CAL FIRE 2019b, g–h). It began on 8 November near Jarbo Gap, California, fueled by strong northeast downslope winds (Fig. SB7.2b). Winds increased during the evening of 7 November and peaked early in the morning on the 8th; sustained winds exceeded 10 m s^{-1} with wind gusts over 20 m s^{-1} for eight consecutive hours overnight at the Jarbo Gap Remote Automated Weather Station (RAWS). Highest values of sustained wind speeds, wind gusts, and Fosberg Fire Weather Index (FFWI) for the Jarbo Gap RAWS (2003–18 period of record) occurred overnight and early morning of 7–8 November. Using METDATA (Abatzoglou 2013), the National Fire Danger Rating System (NFDRS) burning index, which combines fire spread and fuel moisture, was the highest in nearly 40 years; the NFDRS energy release component and 100-hour dead fuel moisture were also the highest and lowest, respectively. The highest wind speeds and FFWI values at Jarbo Gap typically occur with a northeast wind direction during October and November, indicating the proclivity of strong downslope wind events in this area during autumn when fuels can be at their driest, similar to Diablo and Santa Ana Winds (Abatzoglou et al. 2013; Bowers 2018; Smith et al. 2018). Supported by anomalously strong downslope winds and dry fuels, the fire spread southwest across the complex terrain in the region, eventually burning through the town of Paradise, California, where many of the deaths and much of the destruction occurred (Fig. SB7.2b).

Separated by 75 miles and less than four months, the Carr and Camp Fires were fueled by climate conditions that proliferated abundant, dry fuels followed by critical fire weather conditions that drove rapid growth. Similar to the large fire events in 2017 across California (Nauslar et al. 2018), these fires occurred in a rare parameter space of weather, climate, and fuels proximate to populated areas near complex terrain. Given the expanding wildland–urban interface and wildfire–climate change relationship (Abatzoglou and Kolden 2013; Barbero et al. 2015; Abatzoglou and Williams 2016), especially in California, wildfire events like these may become more common.

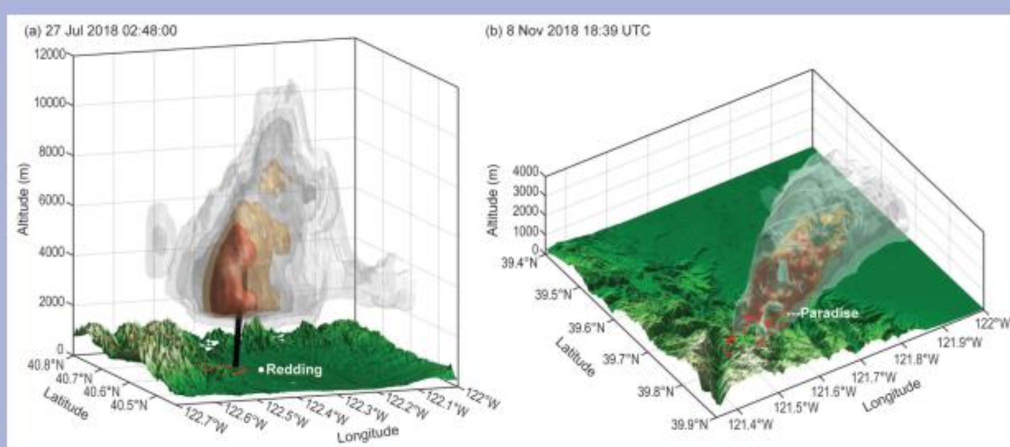

FIG. SB7.2. Radar reflectivity isosurface analyses of the (a) Carr and (b) Camp Fires. Also shown are regional topography and fire perimeters. Perimeter data for the Carr Fire is from infrared aircraft observations; Camp Fire data are from Landsat 8. Carr Fire analysis also includes a solid black line indicating the center locations of the radar-detected tornado-strength, fire-generated vortex. The time of the observations are shown at the top, in UTC.