Supporting Information for

On the causes of the summer 2015 Eastern Washington wildfires

Ruth A. Engel[a], Miriam E. Marlier[a], and Dennis P. Lettenmaier[a]

[a] Department of Geography, University of California, Los Angeles

Corresponding Author: Dennis P. Lettenmaier (dlettenm@ucla.edu)

1.0 Burned area anomaly

We evaluated the MTBS burned area dataset (1984-2015) with NASA Fire Information for Resource Management System (FIRMS) active fire points (2003-2015) [*Davies et al*., 2009]. We also compared the 2015 burned area anomaly with fire perimeters from the USGS Geospatial Multi-Agency Coordination Group (GeoMAC) [*Walters et al.* 2008]. The MTBS and FIRMS data were generally consistent during the 2003-2015 overlap period, especially for the last 10 years of the overlap period (Figure S1). In particular, the rankings of the largest fire years were consistent across all data sets, as was (aside from small variability) the magnitude of the 2015 anomaly. Data from the multiple data sets were also consistent spatially across our study domain.

2.0 Land cover change

We examined forest change over our 1984-2015 period of record using the Global Forest Change database v1.2 [*Hansen et al.,* 2013]. We found no spatial correlation between burned area and prior forest loss (2000-2014) or forest gain (2000-2012). Clusters of forest loss reflect fires from previous years; because there was very little reburning in 2015, we did not consider previous forest loss in burned areas to be a driver of the extreme fire season (Figure S2).

3.0 Propagation

We examined propagation by coding each FIRMS active fire point to a particular large fire based on MTBS perimeters, and then assigning it as a forested point or grassland point based on 2011 NLCD land cover [*Davies et al.,* 2009; *Eidenshenk*, 2007; *Homer et al.*, 2012]. Figure

S3 illustrates that process for the Chelan Complex fire, the third-largest 2015 fire and one that showed a trend in propagation from grassland into forests (Section 3.2.4).

4.0 Ignition

We examined ignition statistics compiled by the Northwest Interagency Coordination Center (NWCC) in its annual reports. The NWCC reports classify numbers of fires and burned area by ignition source (lightning or human) within the domain of each land management agency in the region [*NWCC*, 2005-2015]. There was no apparent relationship between burned area and either percentage of lightning-caused fires or percentage of area burned from lightning-caused fires (Figure S3). The increase in recent years in percentage of area burned from lightning-caused fires might be statistical noise (given the small sample size, probably not statistically significant) although prioritization of firefighting efforts in populous areas during major fire seasons might have played some role [*NWCC*, 2015]. In any event, the 2015 fire season was not anomalous in terms of ignition type relative to the recent historical record. Within the fire season, we did find that the timing of ignition played a role: a single cold front caused dry lightning across the state in mid-August ignited 10 of the 15 largest fires (see Section 3.2.3).

5.0 Dead Fuel Moisture

We compared Dead Fuel Moisture (DFM) climatologies across our 32-year period of record to 2015 values. We calculated 100-hour DFM for coarse fuels in forested regions and 1-hour DFM for fine fuels in grasslands following *Cohen and Deeming* [1985], and averaged values over the fire season (May-September). The 2015 DFM values are lower than climatology, signifying drier conditions and a higher fire risk (Figure S4). 1-hour DFM values are slightly more extreme because they are dependent on summer temperature, which was anomalously high in 2015. DFM values across our domain were the second-lowest in our historical record (see Section 3.1).

6.0 Fuel Load

6.1 Greenness

We examined Landsat NDVI 8-day composite images at a 30m resolution between 2000 and 2015 to evaluate whether multi-year cycles played a role in either long-term drought or fuel load accumulation. While summer of 2014 had relatively low NDVI values, the winter and spring of 2015 had high values (winter 2015 had the highest value in our 16-year record). In combination with above-average winter 2015 precipitation (Figure 3), the high NDVI values suggest that there was enough moisture for substantial growth to occur between the 2014 and 2015 fire seasons. While there were multiple dry summers in a row, the winter precipitation rules out a multi-year drought effect (summers in the region are always much drier than winters).

We did find that high NDVI values between 2013 and 2015 may have increased fuel loads in grasslands. The primary grassland growing season in our domain is early spring [*Zouhair*, 2003], and the high winter and spring NDVI values in 2015 demonstrate substantial growth. In combination with high winter and spring NDVI values in the preceding years, this growth might mean that fuel loads (especially of fine fuels) were especially high, and that the long drying season of 2015 (Section 3.1.1) therefore led to an abundance of dead fuel (again, especially fine fuels).

6.2 Soil moisture

We also examined UCLA Drought Monitor's modeled spring (March-May) soil moisture at a 1/16º resolution across our domain to determine whether an anomalous moisture increased the growing season [*Xiao et al.*, 2016]. We found that soil moisture was average in spring 2015 (13th in the 31-year record), and that 2013-2014 values were below average. It is therefore possible that the length of the growing season, rather than the seasonal moisture, contributed to the increased fuel load.

7.0 Large Fires

We have labeled the largest fires around the state in 2015. The fires were distributed mostly in forests, but are clustered near the forest-grassland interface. They burned primarily in mid-August of 2015.

Supplement Figures

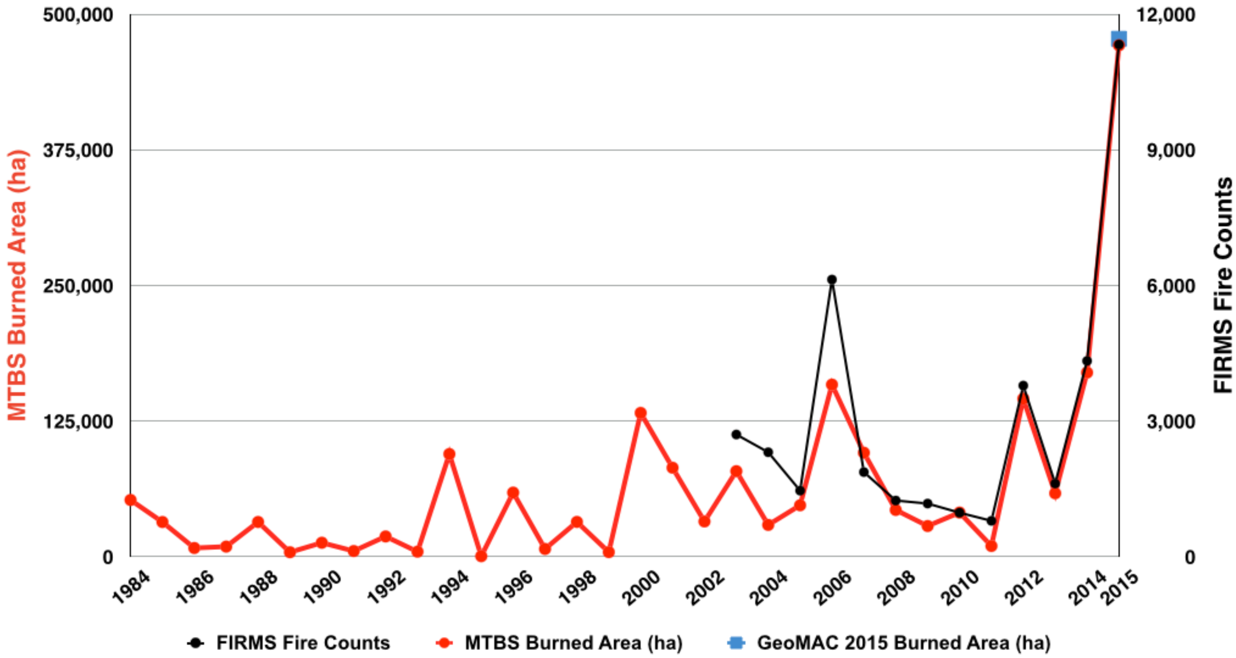

Figure S1. MTBS 1984-2015 burned area from perimeters (red), and data validation from GeoMAC 2015 burned area from perimeters (blue point, 2015 only) and 2003-2015 FIRMS fire counts (black) in Washington.

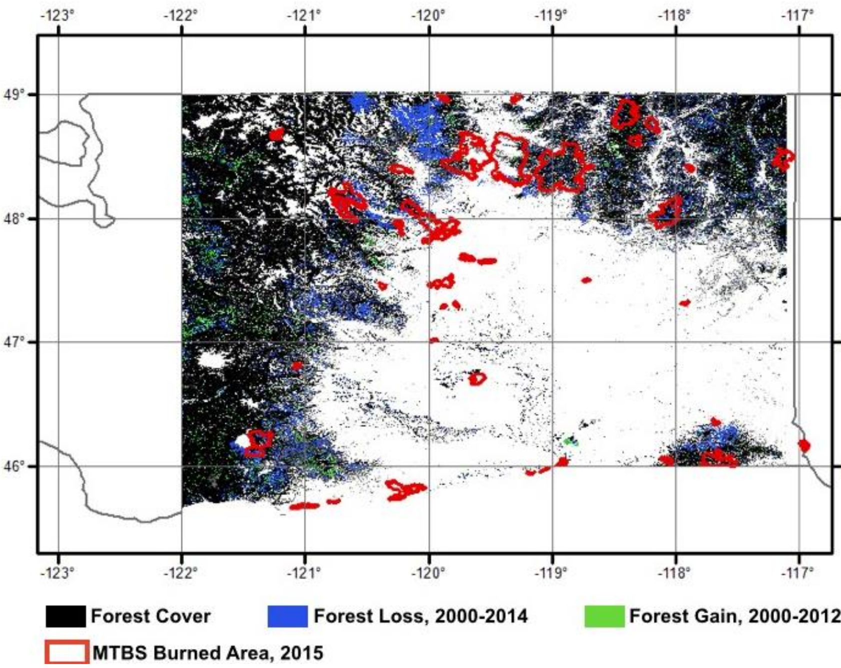

Figure S2. Forest loss and gain per Global Forest Change database v1.2 [*Hansen et al.* 2013]. Forest cover is shown in black, forest loss (2000-2014) in blue, and forest gain (2000-2012) in green. MTBS burned area perimeters are included in red for reference.

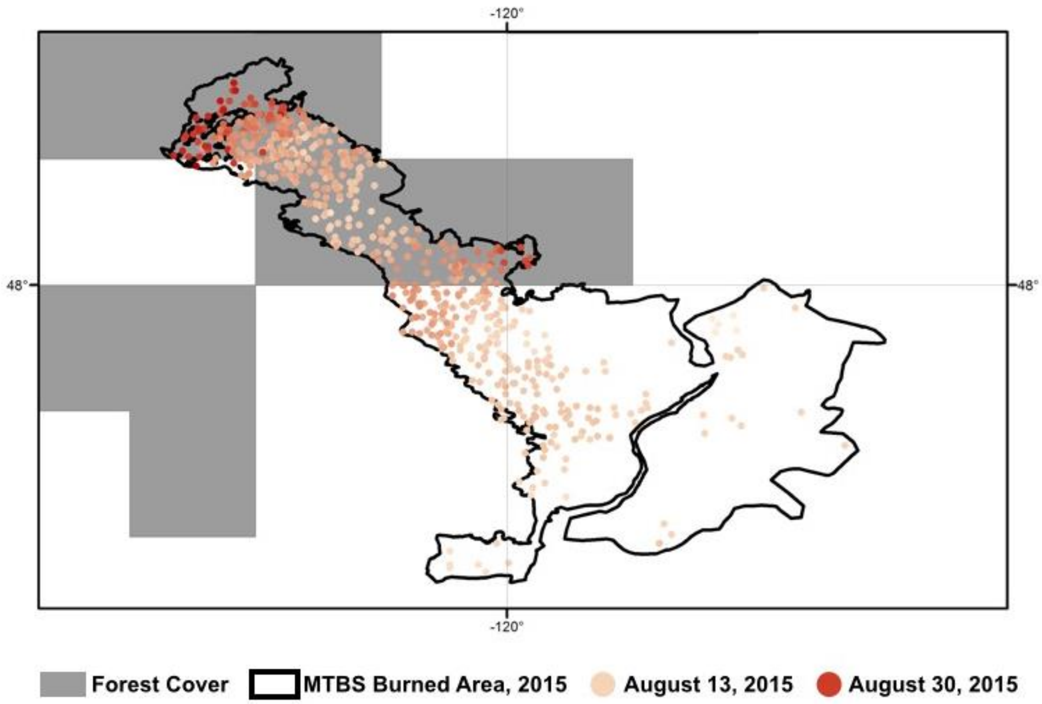

Figure S3. FIRMS active fire points displayed chronologically from August 14-August 30, 2015 [*Davies et al.*, 2009] within the MTBS outline for the Chelan Complex Fire [*Eidenshenk et al.*, 2007]. Grey pixels are forested, and white are grassland according to the 2011 NLCD [*Homer*, 2012]. Fire points burned primarily in grasslands at early stages, and then propagated into more forested areas (Figure 5).

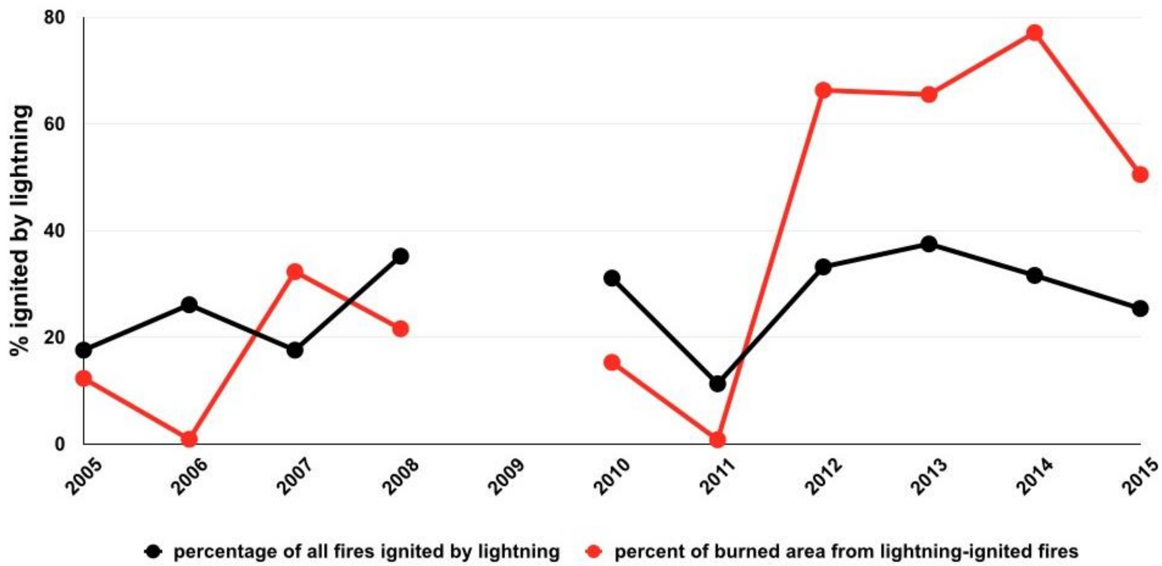

Figure S4. Percentage of all fires ignited by lightning and percent of burned area from lightning-ignited fires in Washington, 2005-2015 (no data compiled for 2009) [*NWCC*, 2005-2015].

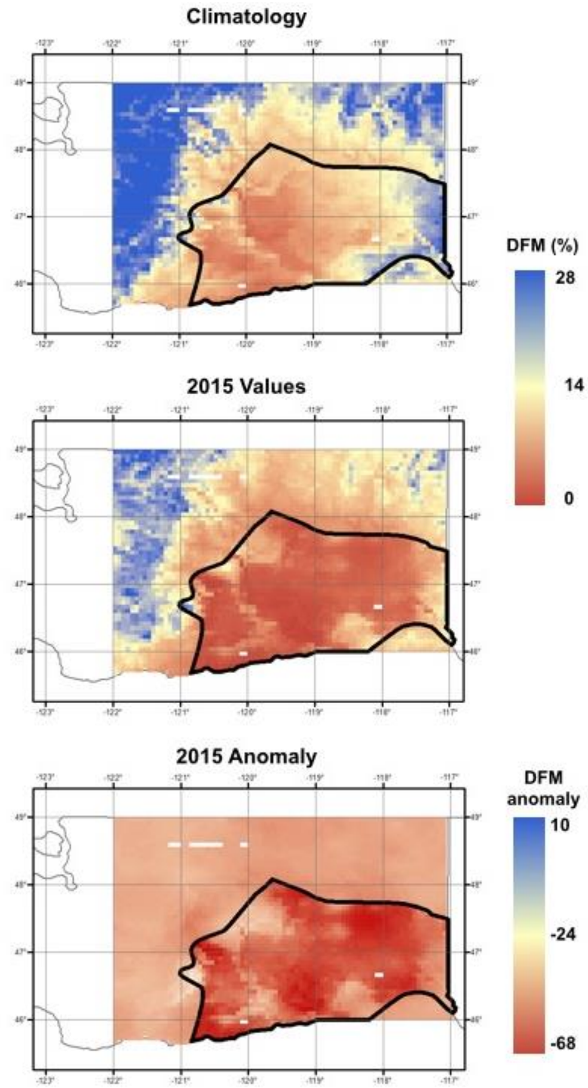

Figure S5. Dead Fuel Moisture (DFM) climatology 1984-2015, 2015 values, and normalized 2015 anomaly expressed as a percentage difference from the mean of the 32-year climatology. 100-hour DFM is shown across forests, and 1-hour DFM across grasslands. Black outline surrounds grassland in our domain.

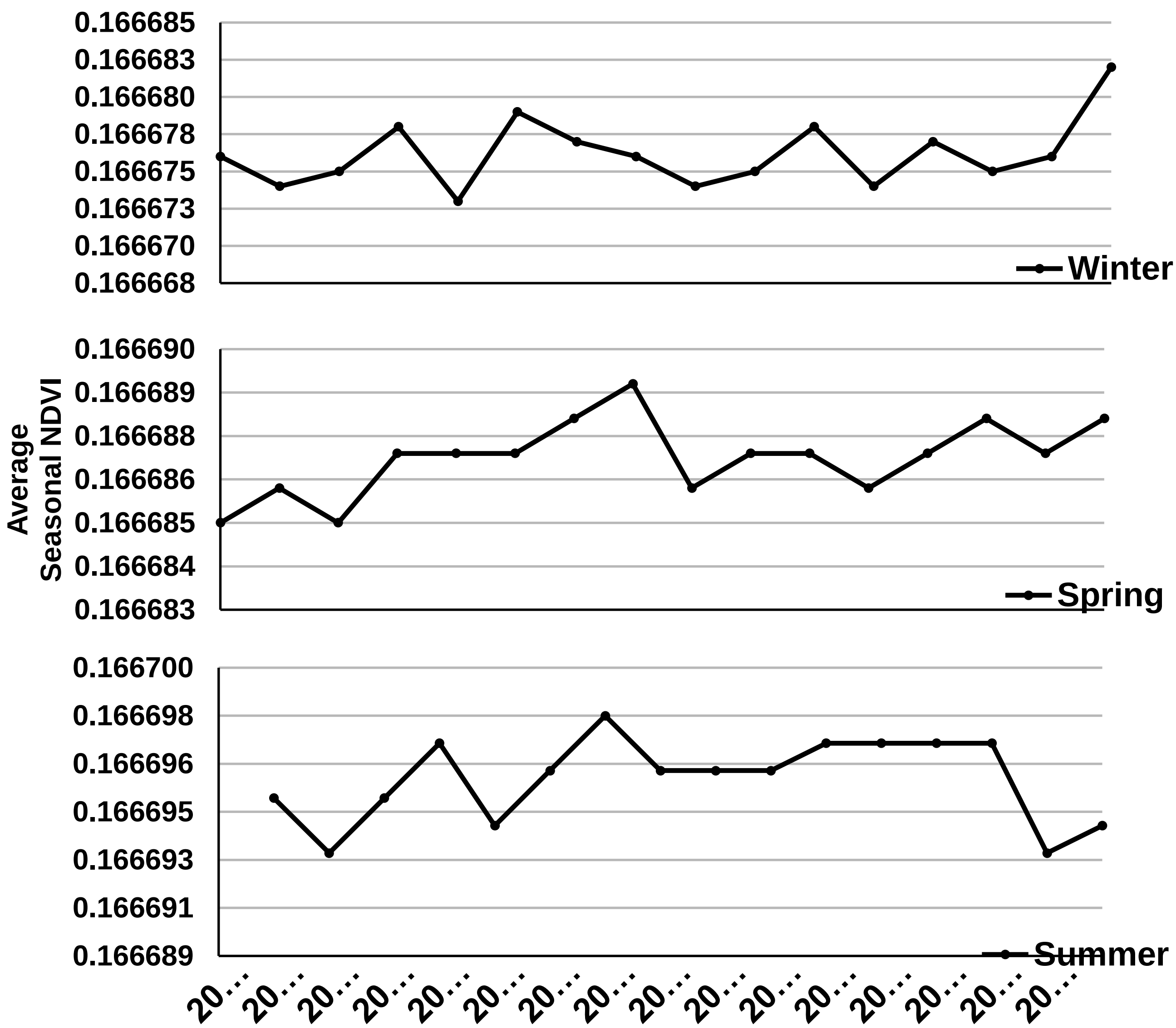

Figure S6a. Landsat NDVI for winter (December, January, February), spring (March, April, May), and summer (June, July, August) averaged for each season across our entire study area [*Chandler*, 2009]. We took the seasonal mean for the annual quarters with maximum precipitation, growth, and drying.

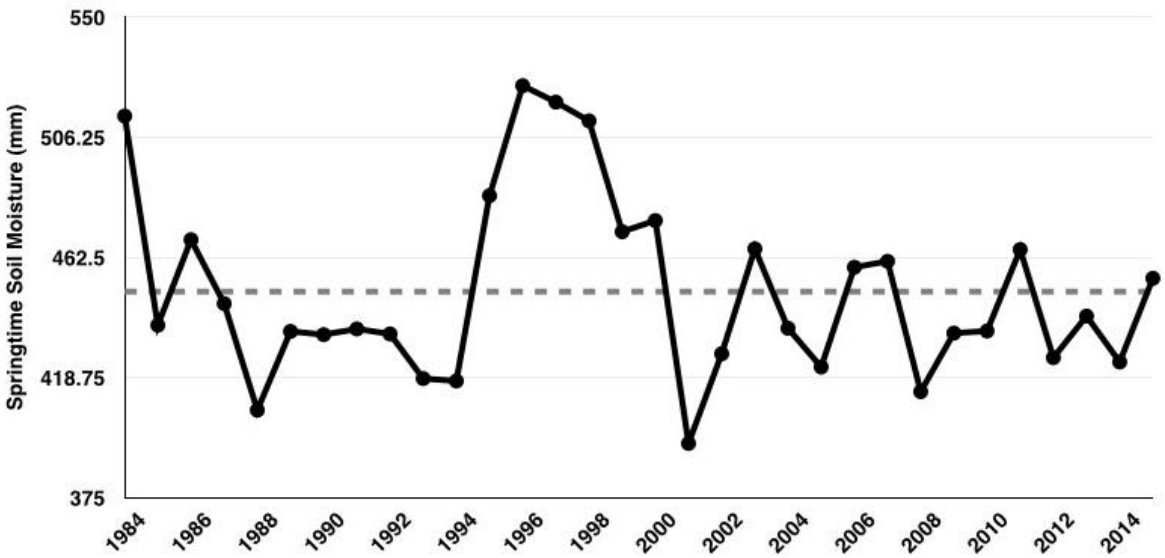

Figure S6b. Spring (March, April, May) soil moisture averaged across our study area [*Xiao et al.*, 2016].We found that 2015 was not outstanding in either grasslands or forests, and that additional soil moisture likely did not contribute to increased fuel loads.

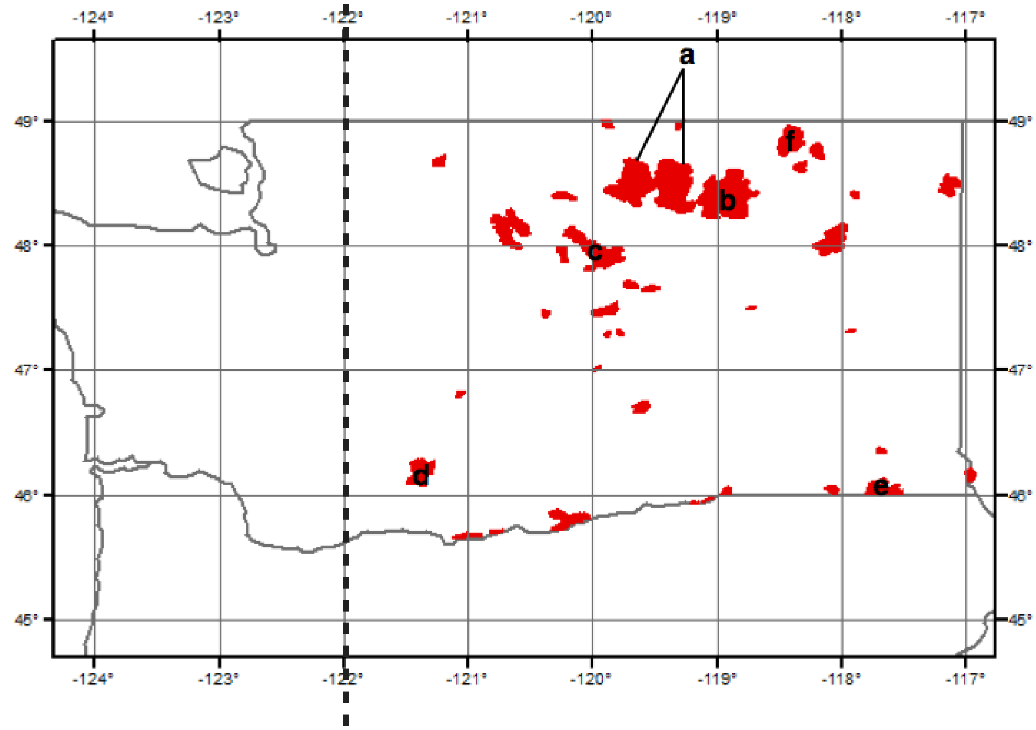

Figure S7. Large fires in Eastern Washington, 2015: (a) Okanagan Complex, (b) North Star, (c) Chelan Complex, (d) Mt. Adams Complex, (e) Grizzly Bear Complex, (f) Kettle Complex [*NWCC*, 2015].