SIDEBAR 5.3: WILDLAND FIRE IN BOREAL AND ARCTIC NORTH AMERICA—A. YORK, U. BHATT, R. THOMAN, AND R. ZIEL

Despite the low temperatures and short growing seasons of northern ecosystems, wildland fire is the dominant ecological disturbance in the boreal forest, the world's largest terrestrial biome. Wildland fire also affects adjacent tundra regions. This sidebar, with a focus on the 2017 Alaska fire season, addresses the history and variability of fire disturbance in Alaska (US) and Northwest Territories (Canada), outlines how short-term weather conditions (temperature, precipitation, convection, and wind) influence area burned, and discusses projections for future tendencies in fire susceptibility.

Beyond immediate threats to lives and property, fire impacts include compromised human health and limited visibility due to smoke. Fire disturbance affects terrestrial ecosystems at multiple scales, including carbon release through combustion (Kasischke et al. 2000). About 35% of global soil carbon is stored in tundra and boreal ecosystems (Scharlemann et al. 2014) that are potentially vulnerable to fire disturbance (Turetsky et al. 2015). Other impacts include interactions with vegetation succession (Mann et al. 2012; Johnstone et al. 2010), biogeochemical cycles (Bond-Lamberty et al. 2007), energy balance (Rogers et al. 2015), and hydrology (He. Liu et al. 2005). Combustion of the insulating surface organic layer can destabilize underlying permafrost. Because permafrost impedes drainage and ice-rich permafrost settles upon thawing (thermokarst), accelerating degradation of the permafrost may have large consequences for northern ecosystems (Jorgenson et al. 2010; Jones et al. 2015).

Weather is a dominant control of fire activity on a year-to-year basis. Over the longer term, high-latitude fire regimes appear to be responding rapidly to environmental changes associated with the warming climate. Although highly variable, area burned has increased since the 1960s in much of boreal North America (Kasischke and Turetsky 2006; Gillett et al. 2004). Over that time, both the number and size of individual fire events has increased, contributing to more frequent large fire years in northwestern North America (Kasischke and Turetsky 2006). Figure SB5.3 shows area burned each year since 1980 in Alaska and Northwest Territories, including both boreal and tundra regions.

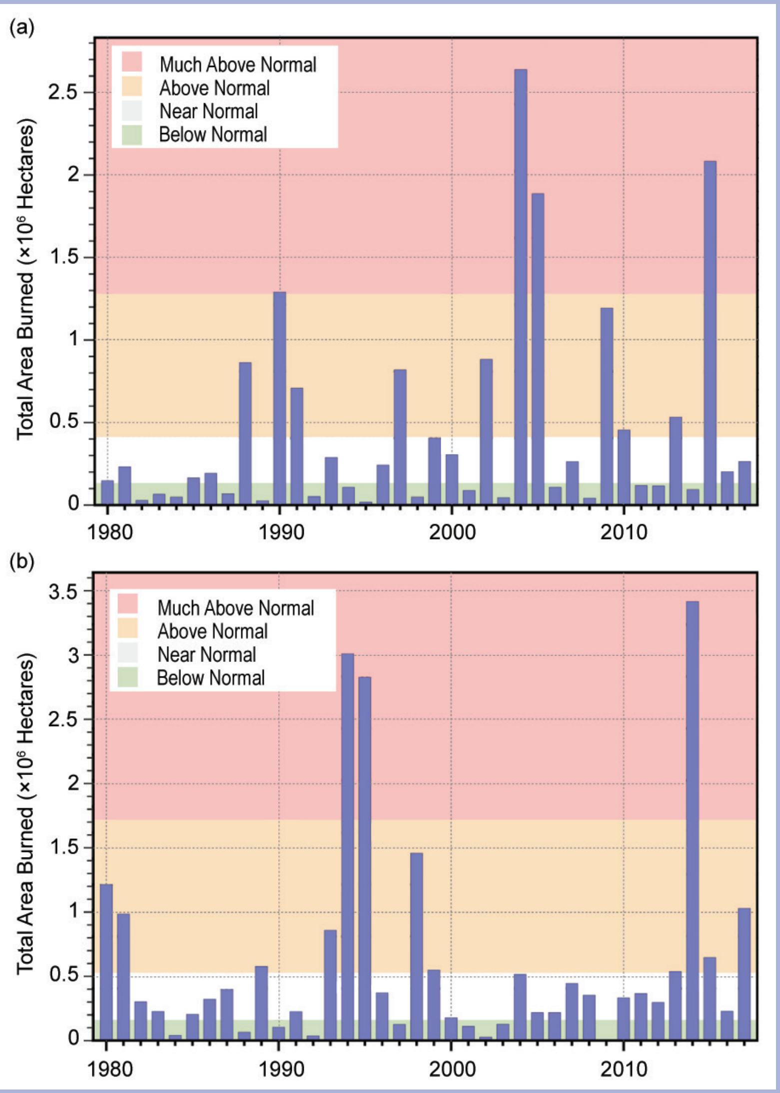

FIG. SB5.3. Annual area burned (ha) each year since 1980 in (a) Alaska and (b) Northwest Territories (Canada), including both boreal and tundra regions. Note that high fire years are not coincident in these subregions, indicating the importance of local weather and other conditions (e.g., fuels, ignition). Category definitions used here are from the fitted log-normal distribution to the observed 1980–2017 area burned; below normal is the 0–33rd percentiles, near normal is the 33rd–66th percentiles, above normal is the 66th–90th percentiles, much above is greater than the 90th percentile.

Although highly variable, high-latitude fire seasons generally begin and end earlier than in more temperate areas

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(Fig. SB5.4). Depending on weather, fire danger can increase as soon as areas are snow-free in April and May; season-ending rains typically fall in July or August, but their absence can extend the season into September, as in the record years of 2004 (2.67 million ha) and 2005 (1.88 million ha) in Alaska. Recent large fire seasons in high latitudes include 2014 in Northwest Territories (Fig. SB5.3), where 385 fires burned 3.4 million ha, and 2015 in Alaska (Fig. SB5.3), where 766 fires burned 2 million ha—the latter was more than half the total area burned in the entire United States (NWT 2015; AICC 2015). Northern communities threatened or damaged by recent wildfires include Fort McMurray, located in the boreal forest in Alberta, Canada, where 88000 people were evacuated and 2400 structures were destroyed in May 2016 (Kochtubajda et al. 2017). The 2007 Anaktuvuk River Fire is the largest (104000 ha) and longest-burning (almost 3 months) fire known to have occurred on the North Slope of Alaska and initiated widespread thermokarst development (Jones et al. 2015).

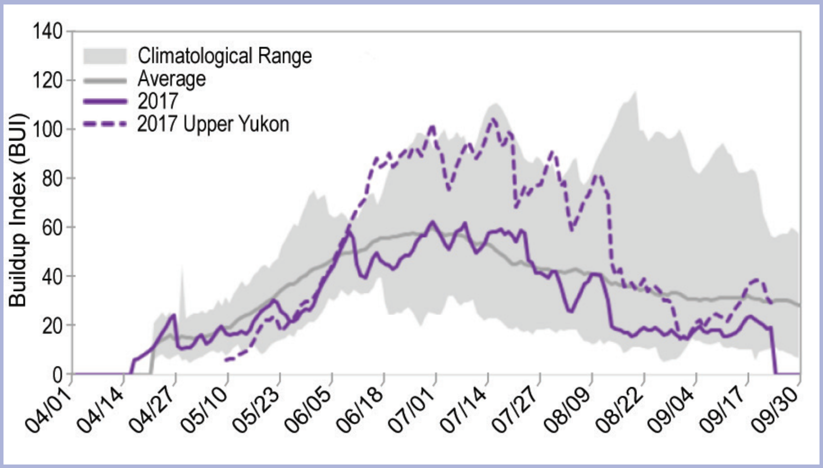

Fig. SB5.4. Average (gray line) and climatological range (gray shading) of BUI between 1 Apr and 30 Sep in Alaska's boreal interior for 1994–2017, compared to the 2017 average (solid purple line) and the 2017 predictive service area AK02 (Upper Yukon and surrounding uplands, centered around the Arctic Circle; dashed purple line). While the boreal interior average BUI for 2017 (purple line) was similar to the historic average BUI (gray line), the Upper Yukon Zone (dashed purple line), where the majority of the hectares burned in the territory in 2017, showed a significant elevation in BUI from mid-Jun to mid-Aug.

Most area burned in northern ecosystems occurs during sporadic periods of high fire activity. Half of the area burned in Alaska from 2002 to 2010 was consumed over just 36 days (Barrett et al. 2016). Recent analyses have identified a temperature threshold in Alaska with a much greater likelihood of fire occurrence within a 30-year period at locations where mean July temperatures exceed 13.4°C (Young et al. 2017). Large fire events require the confluence of warm and dry weather conditions with a source of ignition (often lightning from convective thunderstorms) and fuels that can carry fire. High latitude ecosystems are characterized by unique fuels, in particular, fast-drying beds of mosses, lichens, and accumulated organic material (duff) that underlie resinous shrubs and dense, highly flammable conifers. These understory fuels dry rapidly during periods of warm, dry weather and the long day lengths of June and July. Consequently, extended drought is not required to increase fire danger to extreme levels.

Historically, lightning is responsible for the majority of the acreage burned in high latitudes, as lightning-ignited fires occur in more remote locations and thus are subject to lower levels of suppression than human-started incidents. Veraverbeke et al. (2017) showed that lightning ignitions have increased in boreal North America since 1975 and were a major contributor in the extreme 2014 Northwest Territories and 2015 Alaska fire seasons. In addition, Partain et al. (2016) found that human-induced climate change—manifested as a combination of high surface air temperatures, low relative humidity, and low precipitation—increased the likelihood of the extremely dry fuel conditions seen in Alaska in 2015 by 34%–60%.

The snow-free season has increased by approximately 5 days decade^{-1} in Alaska since 1979 (Liston and Hiemstra 2011). In response, in 2006 Alaska's fire management agencies shifted the statutory start of fire season ahead by a month, from 1 May to 1 April, to better prepare for early season events. In addition to adapting to long-term trends, managers in Alaska and Canada must track day-to-day variability in threats to dispersed populations with limited resources. Managers in both regions use the Canadian fire weather index (FWI) system on a daily basis to estimate the spatial and temporal distribution of wildfire potential from observed and forecast weather conditions (Lawson and Armitage 2008). Among the FWI indices, the buildup index (BUI), based on cumulative scoring of daily temperature, relative humidity, and precipitation, represents seasonal variability in fuel availability and flammability (Fig. SB5.4). A BUI threshold of 80 has been identified as a critical indicator of fire growth potential in Alaska (Ziel et al. 2015).

In 2017, the typical area burned in Alaska (264 221 ha; Fig. SB5.3) was reflected in a fairly normal BUI across the boreal region that essentially paralleled the climatological average (Fig. SB5.4). However, the impact of a "normal" season can fall disproportionately on specific areas in a landscape this large. In 2017, while there were no significant peaks in the BUI, local conditions in the Upper Yukon zone in northeast Alaska were significantly warmer and drier. Consistent with the Upper Yukon BUI trend (Fig. SB5.4), the fire season was extended and fairly severe in that large region of the state, with periods of high fire danger (BUI ≥80) from mid-June to mid-August near and north of the Arctic Circle. More than 160 000 ha (63% of the 2017 Alaska total) burned in the Upper Yukon area during this period.

Under a range of climate change scenarios, analyses using multiple approaches project significant increases (up to four-fold) in area burned in high latitude ecosystems by the end of the 21st century (French et al. 2015; Young et al. 2017; Yue et al. 2015, and references therein). In addition, annual lightning frequency is projected to increase by 12% ± 5% per °C of warming in the contiguous United States (Romps et al. 2014) and may increase correspondingly in high latitudes. Because specific fire events depend on multiple interacting factors, the resulting changes in high latitude fire regimes will vary greatly over space and time, but all evidence indicates that northern ecosystems will become increasingly susceptible to burning.

changes in winter weather, specifically reductions in snow cover areal extent due to winter warming events, which left the ground exposed to subsequent freezing and desiccation (Vikhamar-Schuler et al. 2016). Insect outbreaks were identified as a secondary contributor to vegetation mortality (Bjerke et al. 2017).

i. Terrestrial snow cover in the Arctic—C. Derksen, R. Brown, L. Mudryk, K. Luojus, and S. Helfrich

Satellite-derived estimates of snow cover extent (SCE) over Arctic land areas date back to 1967 and have revealed dramatic reductions since 2005. These changes are important to the Arctic system because spring snow cover over land areas significantly influences the surface energy budget (snow is highly reflective of incoming solar energy), ground thermal regime (snow is an effective insulator of the underlying soil), and hydrological processes (the snowpack stores water in solid form for many months before spring melt). Changes in snow cover also have the potential to impact fauna living above, in, and under the snowpack, vegetation, biogeochemical activity, and exchanges of carbon dioxide and other trace gases (Brown et al. 2017).

Spring (April–June) SCE anomalies for the Arctic (land areas north of 60°N) were regionally computed for North America and Eurasia using the NOAA snow chart climate data record, which extends from 1967 to present (maintained at Rutgers University; Estilow et al. 2015; http://climate.rutgers.edu/snowcover/; Fig. 5.23). For the first time in over a decade, 2017 Eurasian Arctic spring SCE was above average relative to the 1981–2010 reference period. April and May SCE anomalies were positive, including the second highest May SCE over the period of satellite observations. These are the first positive SCE anomalies observed in May over the Eurasian Arctic since 2005; June SCE anomalies were positive across the Eurasian Arctic for the first time since 2004. SCE anomalies over the North American Arctic were negative all spring but did not approach the series of record-breaking low SCE values observed in recent years.

Snow cover duration (SCD) departures were calculated from the NOAA Interactive Multisensor Snow and Ice Mapping System (IMS; Helfrich et al. 2007) product to identify differences in the onset of snow cover in fall and melt of snow cover in spring relative to a 1998–2010 reference period. While there was evidence of earlier snow cover onset over much of midlatitude Eurasia in autumn 2016 (consistent with cold surface air temperature anomalies), Arctic land areas (with the exception of Alaska) had near-normal snow onset timing (Fig. 5.24a). Later-than-normal snow melt onset across Eurasia (Fig. 5.24b), also reflected in the positive SCE anomalies (Fig. 5.23), was consistent with colder-than-normal surface air temperatures across this region (especially in May and June). Spring snow melt across the Canadian