CLIMATE CHANGE EFFECTS ON WATER SUPPLY: LINKAGES BETWEEN WILDFIRE AND ACCELERATED SNOWMELT

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Problem and Research Objectives

In Washington State the majority of runoff comes from the melting snowpack (Mote et al., 2005). In recent decades reductions in the seasonal snowpack have affected runoff timing and magnitude, and the availability of water resources. A consequence of the earlier snowmelt is an increase in wildfire activity (Westerling et al., 2006), which in turn affects snowmelt because decreased forest canopy in the post-fire environment causes an increase in snowpack net radiation, increasing the rate and advancing the timing of snowmelt (Burles and Boon, 2011; Harpold et al., 2014; Winkler, 2011). Recent research has demonstrated that snowmelt is further accelerated by the deposition of burned woody debris from charred snags (dead trees) on the snowpack that reduces snow albedo (i.e., reflectivity) and further accelerates melt (Gleason et al., 2013). However, it is not known how this effect attenuates over time, how it varies with burn severity, nor how black carbon from the charred snags contributes to the snow albedo reductions. We are working to quantify the duration and magnitude of earlier snowmelt in the post-wildfire environment by measuring: black carbon, charcoal and burned woody debris deposition; snow albedo; and snowmelt timing in forest plots of varying burn age and burn severity.

Methodology and Principal Findings

Note: Funding for this project became available in March 2015. 2015 was an anomalously low snowpack year in Washington State, and we were limited in our ability to conduct the required fieldwork to test our hypotheses. We conducted extensive fieldwork in 2016, and are currently conducting laboratory analyses.

To measure how BC deposition in the post-wildfire environment changes with time, three sites in the Cascades with varying burn age but similar burn severity and forest composition were sampled during the period of peak snowpack recorded by Snow Telemetry (SNOTEL) sensors (wcc.nrcs.usda.gov/snow). The sample sites include the 2006 Tripod Complex fire in northern Washington, the 2012 Table Mountain fire and the 2015 Chelan Complex fire, both in central Washington (Figure 1). Variations in BC deposition with burn severity was addressed by sampling in areas of low, moderate and high burn severity as classified using Monitoring Trends in Burn Severity maps (mtbs.gov). Hemispheric digital photographs of the forest canopy were taken at each sample location using a leveled fish-eye lens. These images will be evaluated using Gap Light Analyzer 2.0 (Frazer et al., 1999) to quantify canopy closure and determine forest density.

Transects were sampled at each study site. At each transect location, the entire snow column was sampled using a two-meter coring device, so each core sample represents BC deposition over the entire snow accumulation period. Surface snow samples were collected from the upper 2 cm of the snowpack where impurities most strongly affect snow albedo, and snow albedo was measured using a Spectral Evolution portable ultraviolet-visible near-infrared (UV-VIS-NIR) spectroradiometer. Additional measurements taken in the field included snow density and depth for calculating snow water equivalent, as well as classification of the surrounding forest structure and composition.

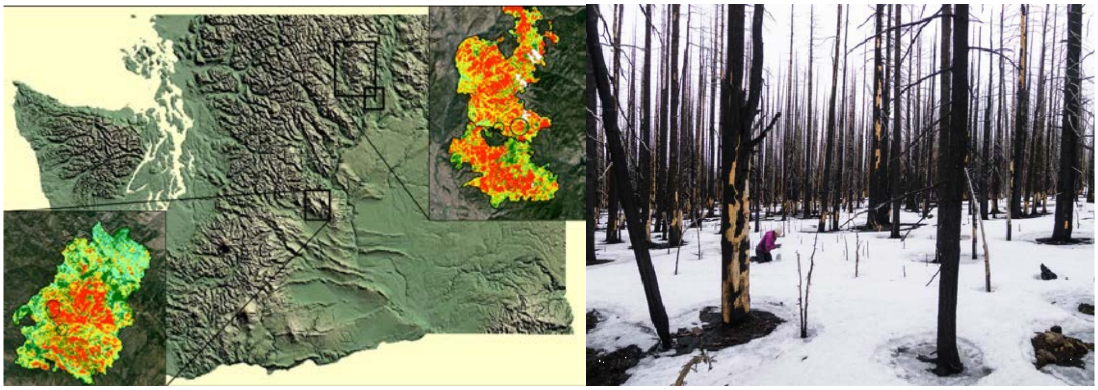

Figure 1. Left: Study areas in the Cascade Range including the 2006 Tripod Complex fire (upper right), and the 2012 Table Mountain fire (lower left). Burn severity is represented in by dark green (unburned), light green (light burn), yellow (moderate burn), and red (severely burned). Black circles represent sample sites (modified from MTBS.gov). Right: Collecting snow samples in a severely burned portion of the 2012 Table Mountain fire.

All snow samples are kept frozen until just prior to analysis. The snow samples will be melted, and BC concentrations will be measured using a Single Particle Soot Photometer (SP2) (Wendl et al., 2014). Select samples will be measured using a Sunset Lab Organic Carbon-Elemental Carbon (OC-EC) Aerosol Analyzer (Zhang et al., 2012). SP2 measures individual BC particles (80-1000 nm diameter), whereas the Sunset OC-EC differentiates between organic and elemental carbon and is used to measure carbon particles larger than those detected by the SP2. Bulk samples will be filtered to measure total impurity load. These data will help establish how BC deposition varies with respect to time since burn, distance from burn, burn severity, and forest density. Comparing BC concentrations with measurements of surface albedo, snow depth, and snow water equivalent throughout the spring will help us characterize post-fire BC deposition and its contribution to accelerated snowmelt.

Preliminary results indicate that charred material from trees post wildfire can substantially reduce snow reflectivity (related to albedo) (Figure 2), and that the reduction in reflectivity is affected by forest density. If analysis of our 2016 data supports this result, this would suggest that the effect of BC and woody debris deposition is fairly localized (i.e., isn't transported long distances). This is counter to our earlier findings that suggested that BC from charred forests can be transported long distances (Delaney et al., 2015). We have considerable laboratory work and interpretation of the resultant data to address our hypotheses.

Significance

Spatial analysis conducted by Gleason et al. [2013] indicated that between 2000-2012, over 80% of forest fires in the western U.S. burned in the seasonal snow zone (Figure 3), and forest fires in the snow zone were 4.4 times larger than those outside the seasonal snow zone. Furthermore, in the Western United States 48% of all forest fires in the seasonal snow zone occurred within the Columbia River Basin, suggesting that runoff and water resources in the Pacific Northwest are particularly affected by the post-wildfire effect. Climate change models project that due to warming temperatures, the April 1 snowpack will decrease by approximately 38-46% by the 2040s relative to the 1917-2006 mean (Elsner et al., 2010). These projected changes will result in earlier snowmelt runoff, reduced summer flows, and a reduction in water supplies. Additionally, the area burned by fire regionally is projected to double by the 2040s and triple by the 2080's (Littell et al., 2009). In light of the observed and projected changes to the snowpack and wildfire activity, an improved understanding of the linkage between wildfire activity and snowmelt is necessary to understand climate change effects on water resources.

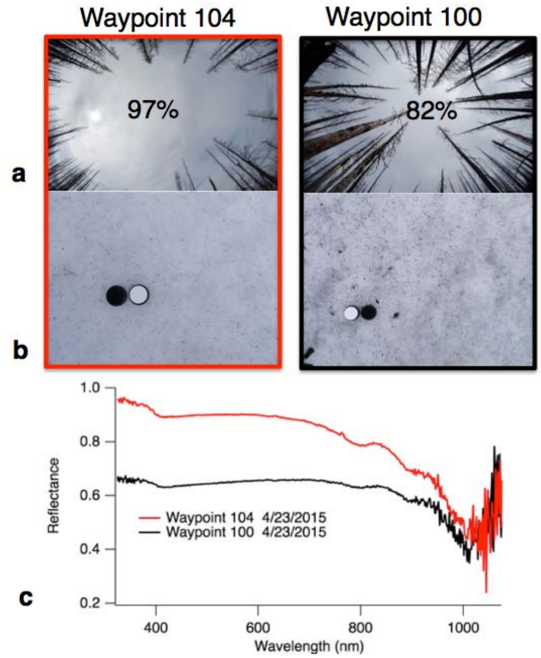

Figure 2. a) Hemispheric photos taken at Waypoints 104 (left) and 100 (right) at Table Mountain on 4/23/2015 showing percent canopy exposure, which is used to measure the amount of material available for deposition. b) Photos showing deposition of burned material on the snowpack; the black and white circles are reflectance standards. c) Snow reflectance data for Waypoints 104 and 100. Reflectance (related to albedo) is lower at Waypoint 100 than 104, which is consistent with higher tree density and greater impurity deposition as shown in b.

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