
Modeling Evaluation of the Contribution of Wildland Fire Emissions to Black Carbon Deposition Rates in the Western U.S.

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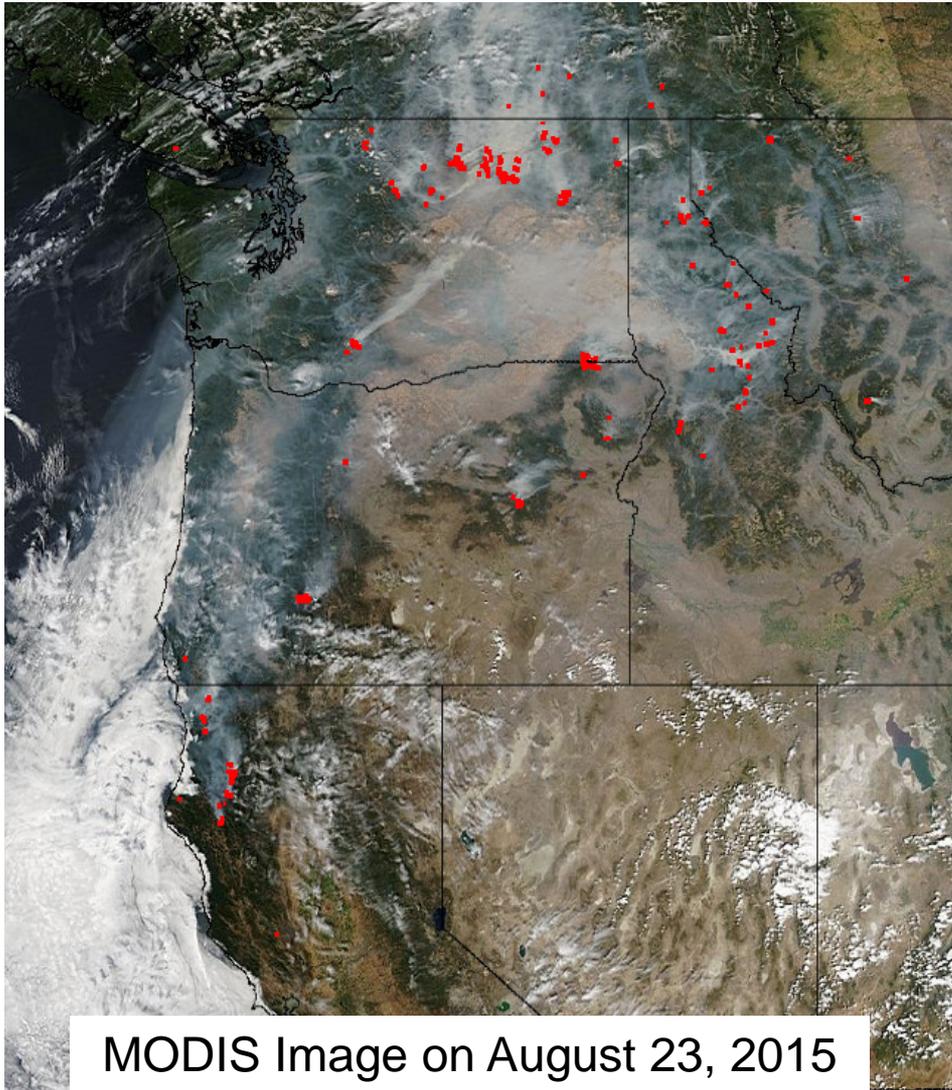
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Pullman, WA
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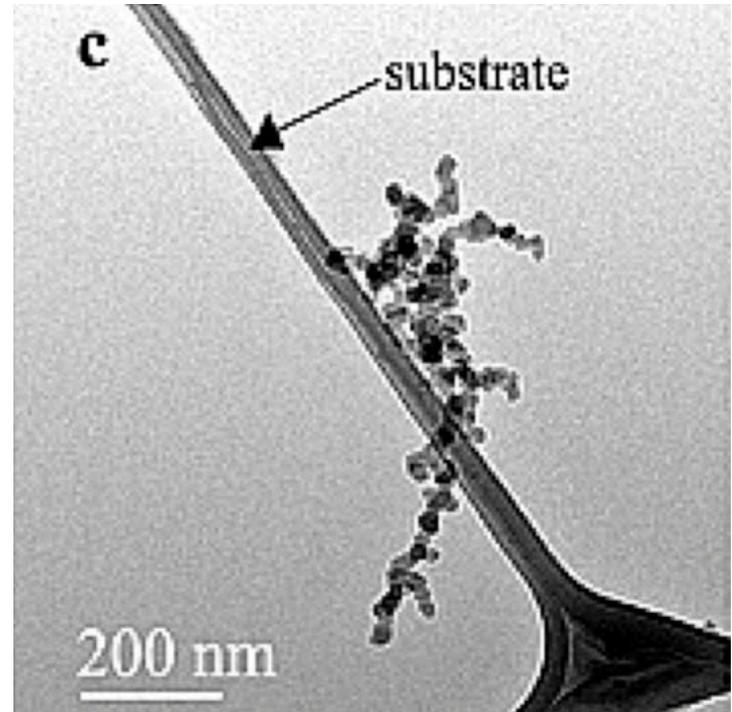
Wildland Fires in the Western U.S.



- Wildland fires include wildfires and prescribed fires burning on natural landscapes.
- They emit a large amount of pollutants, including black carbon.
- Wildfires in the western U.S. has increased since the mid 1980s (Westerling et al., *Science*, 2006).
- Wildfire risk is projected to increase due to climate change (Flannigan et al., *Intl. J. Wildland Fire*, 2009).

Atmospheric Black Carbon

- Black carbon (BC) is the dominant absorptive component of sub-micron particles in the atmosphere.
- BC is roughly equivalent to elemental carbon (EC).
- BC is the second most important human emission in terms of its climate forcing (Bond et al., *J. Geophys. Res.*, 2013).



Adachi et al., *J. Geophys. Res.* (2007)

Black Carbon and Climate

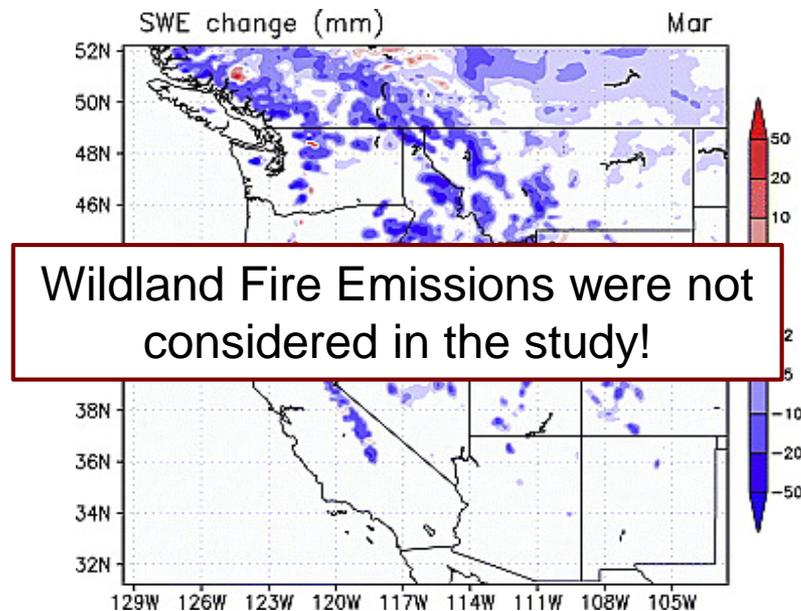
- Direct Radiative Effect
 - warming due to absorbed solar radiation
- Semi-Direct Effect
 - warming due to reduced cloud cover
- **Snow-Albedo Effect**
 - warming due to decreased reflectivity of snow and ice surfaces



Photograph: Henrik Egede Lassen/Alpha Film

Impacts of Snow-Albedo Effect

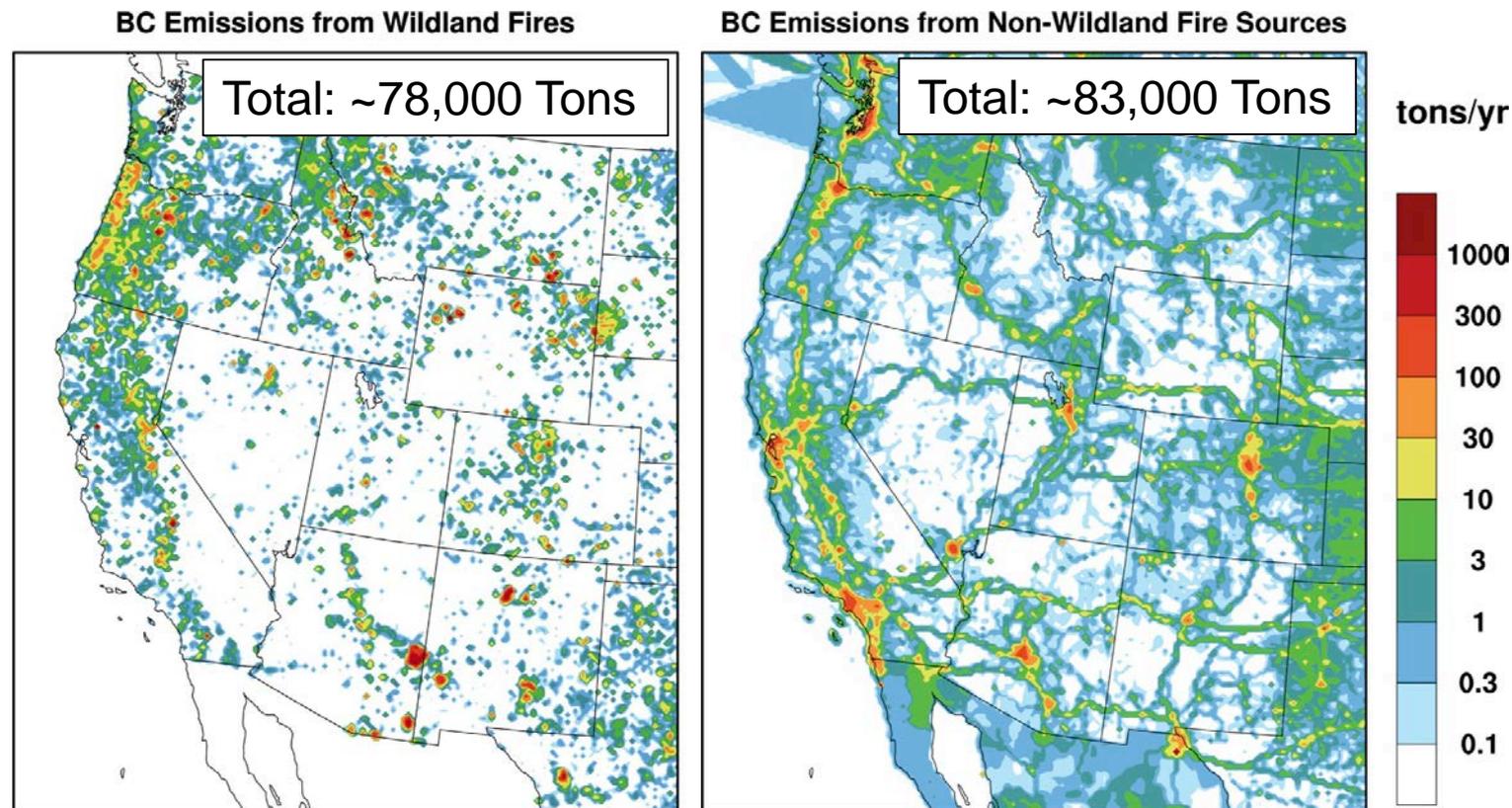
- Many studies have focused on the Arctic or Himalayas, the effect is also important in the Western U.S.
- Qian et al., *J. Geophys. Res.* (2009)
 - Increases surface air temperature
 - Reduces snow accumulation during winter



- Leads to reduced runoff during spring and summer when water demands are the greatest
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Black Carbon Emission from Wildland Fires

- Wildland fires release a large amount of black carbon.



Source: National Emissions Inventory (NEI) for 2011

Research Objectives

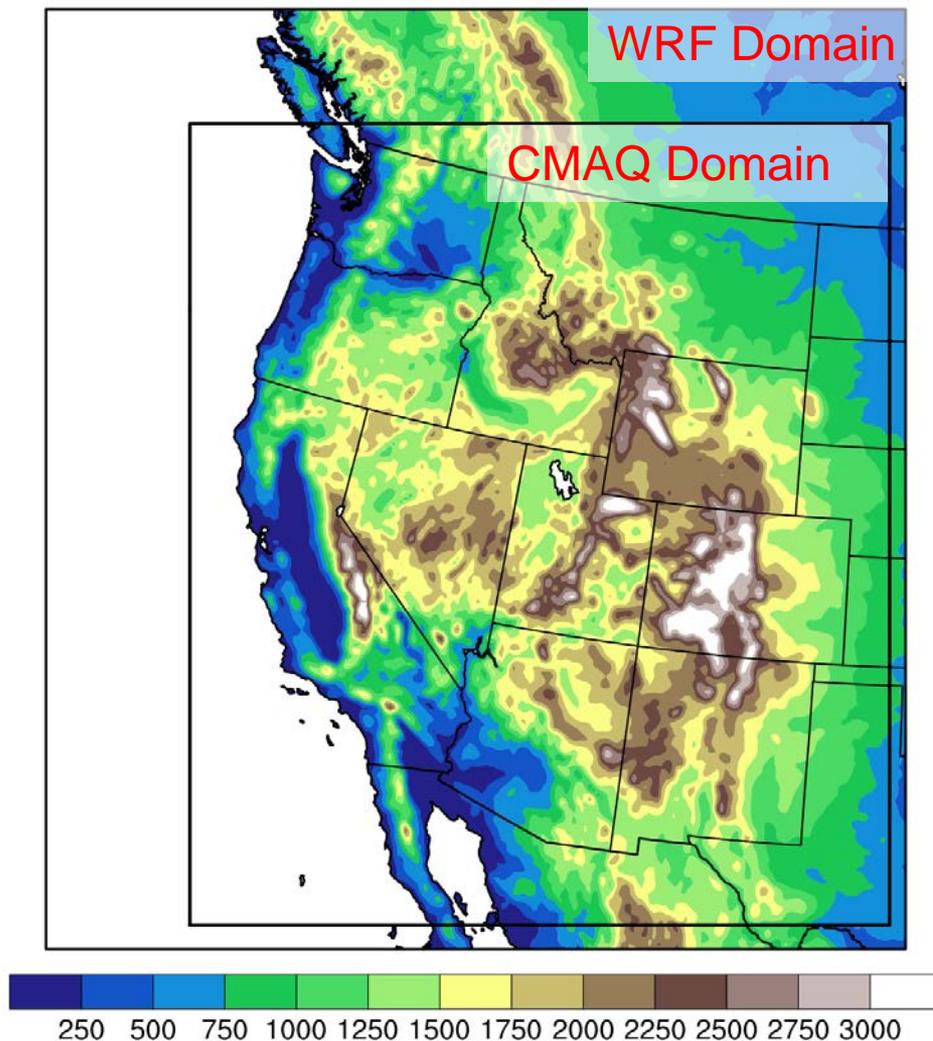
- Estimate the contributions of wildland fire emissions to BC deposition in the western U.S. to
 - Glacial Areas
 - Snow Surfaces
- Distinguish contributions of prescribed fires vs. wildfires
- Understand the seasonality

The Soda Fire in Sequoia National Forest in January 2014
(U.S. Forest Service)



Regional Air Quality Modeling System

Terrain Height (m) on 12-km x 12-km grid



- Meteorology:
 - Weather Research and Forecasting (WRF)
- Chemistry and transport:
 - Community Multiscale Air Quality (CMAQ)
- Emissions:
 - NEI 2011
- Three annual simulations for 2011:
 - All Emissions
 - No Prescribed Fire Emissions
 - No Wildland Fire Emissions

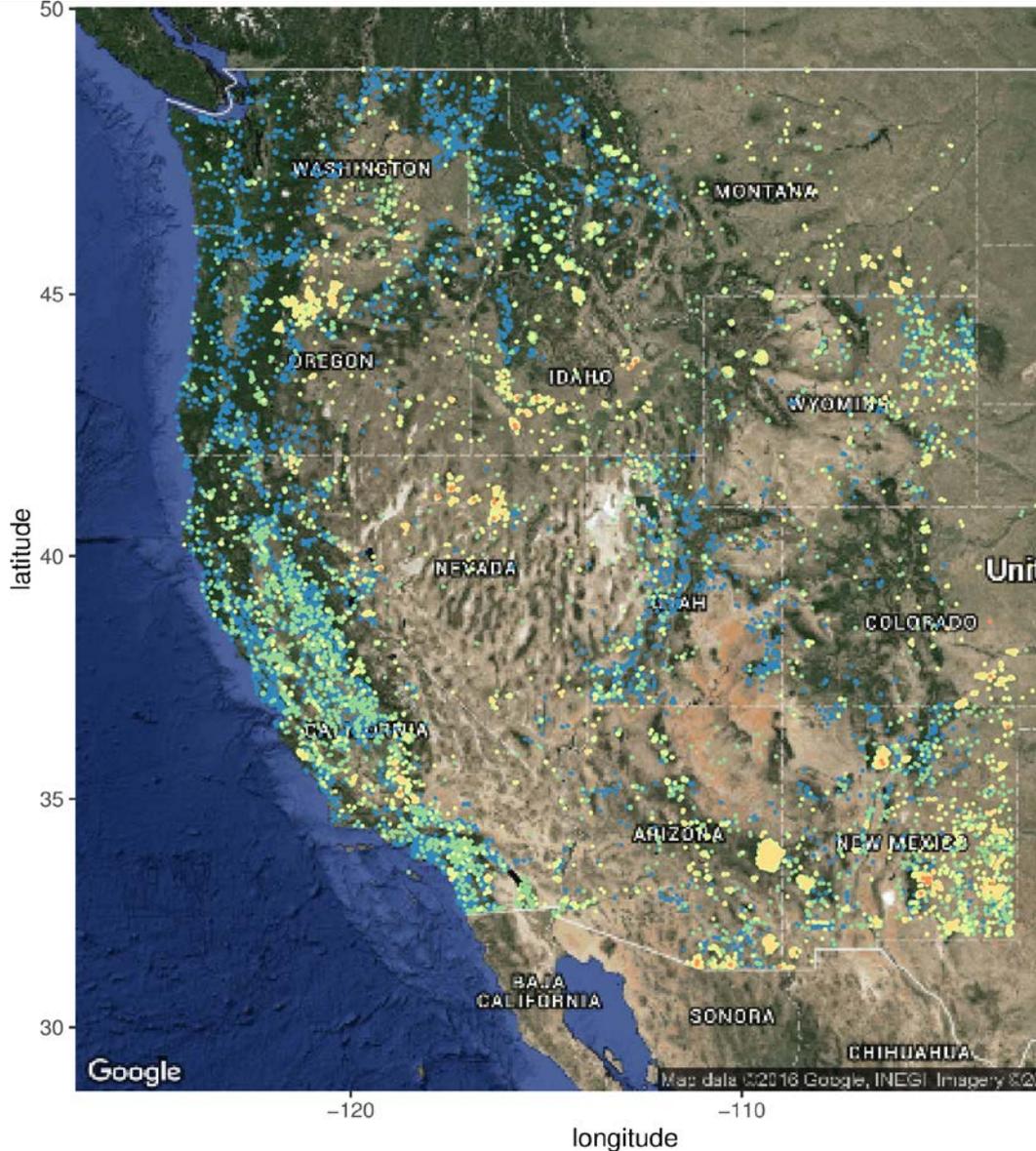
NEI 2011 Wildland Fire Emissions

- Locations, times, and sizes are based on 6 national databases, local data, and satellite information, including:
 - U.S. Forest Service's Fire Activity Tracking System
 - Incident Command Reports
 - NOAA Hazard Mapping System (HMS)
 - GeoMAC fire perimeters
- BlueSky Modeling Framework was used to model daily $PM_{2.5}$ emissions and heat fluxes.
- SMOKE emission processing tool was used to:
 - Split $PM_{2.5}$ into 9.5% (wildfire) and 10.9% (prescribed) BC
 - Diurnal profile
 - Calculate plume rise



Horseshoe Fire near Mt. Adams
in July 2015
(U.S. Forest Service)

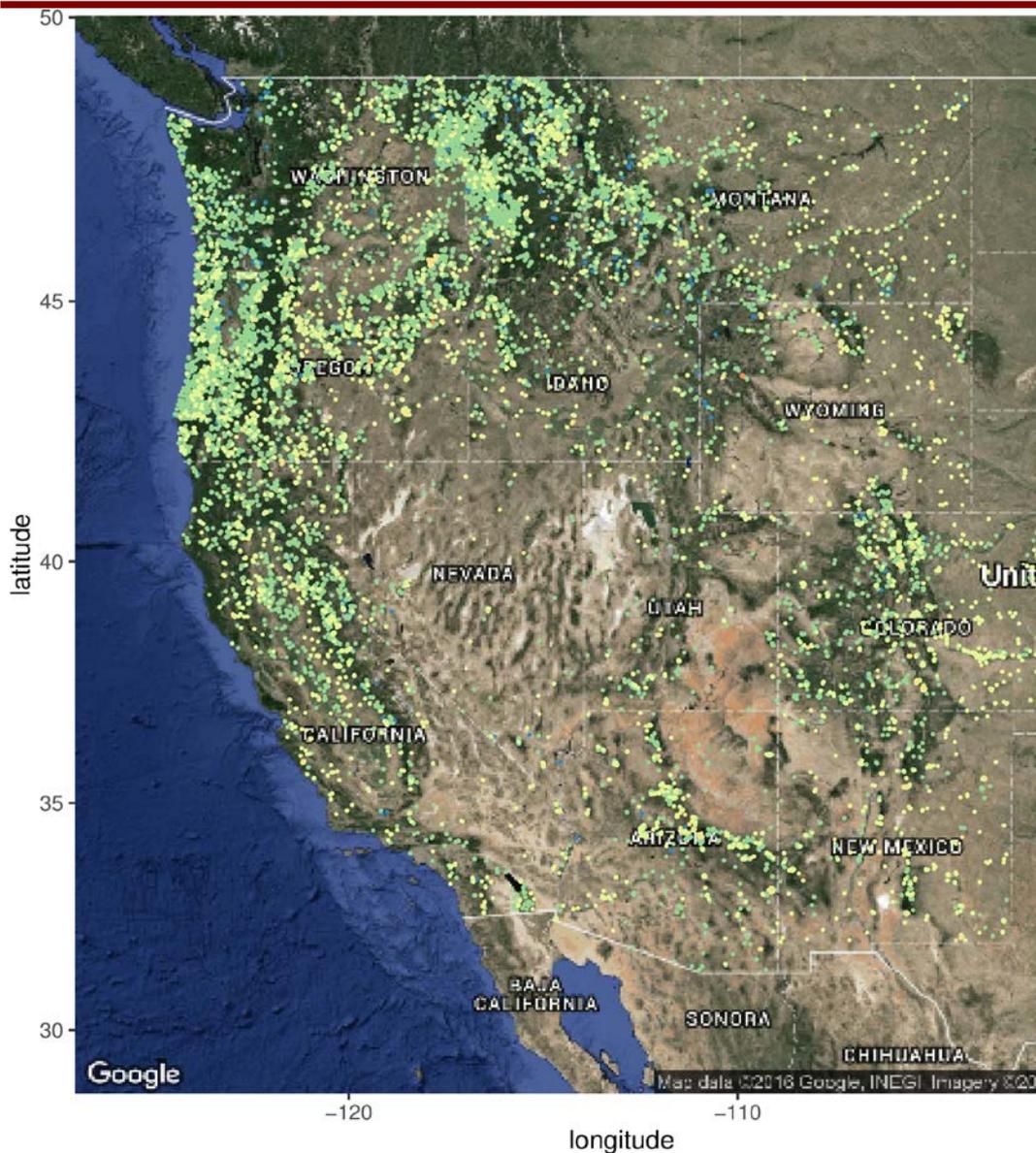
Wildfires in NEI 2011



~31,000 wildfire locations
in the 11 western states.

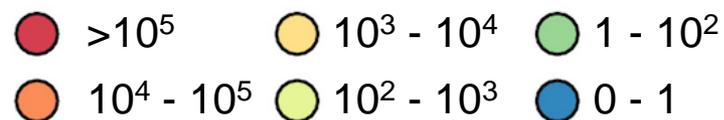


Prescribed Fires in NEI 2011

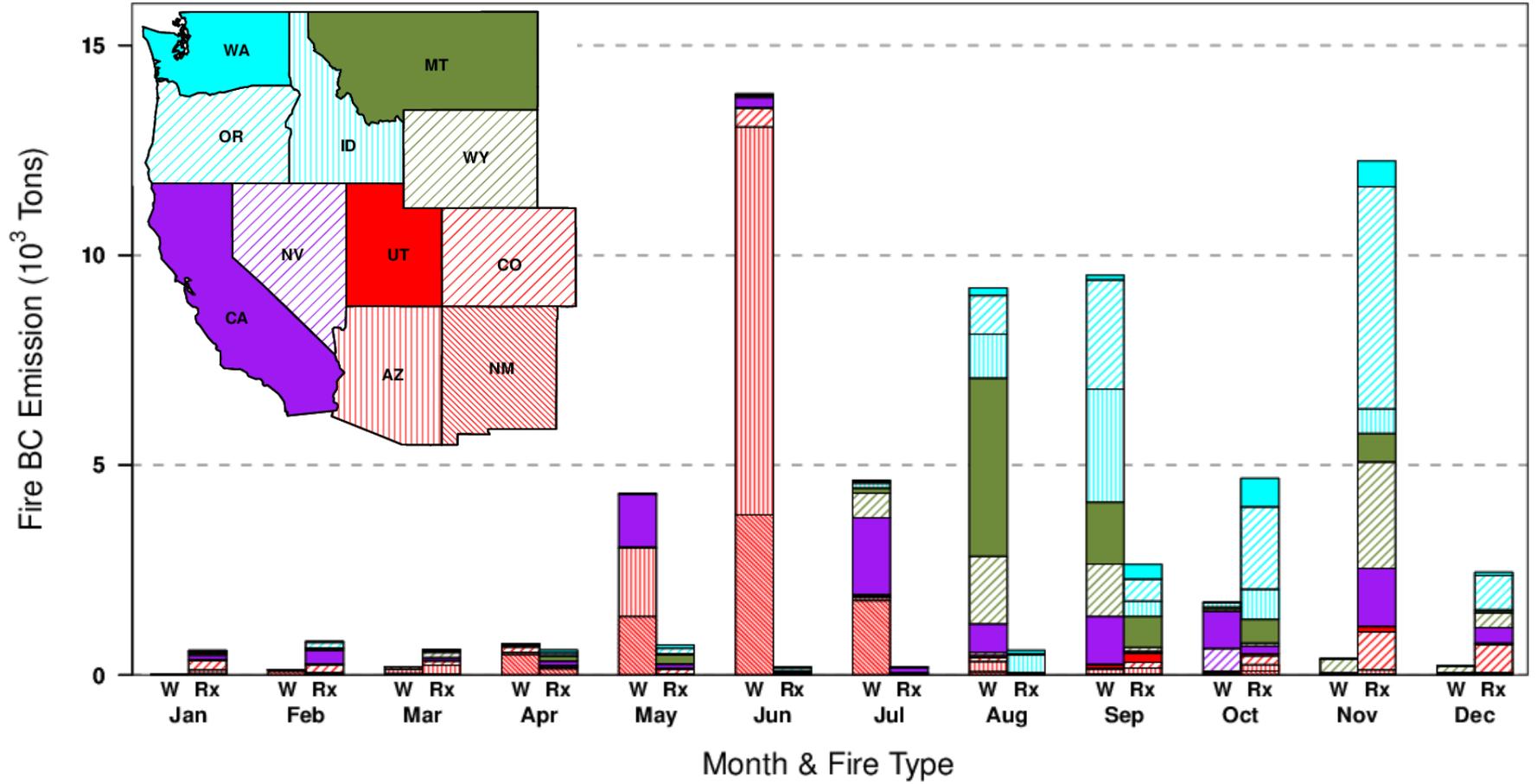


~18,000 prescribed fire locations in the 11 western states.

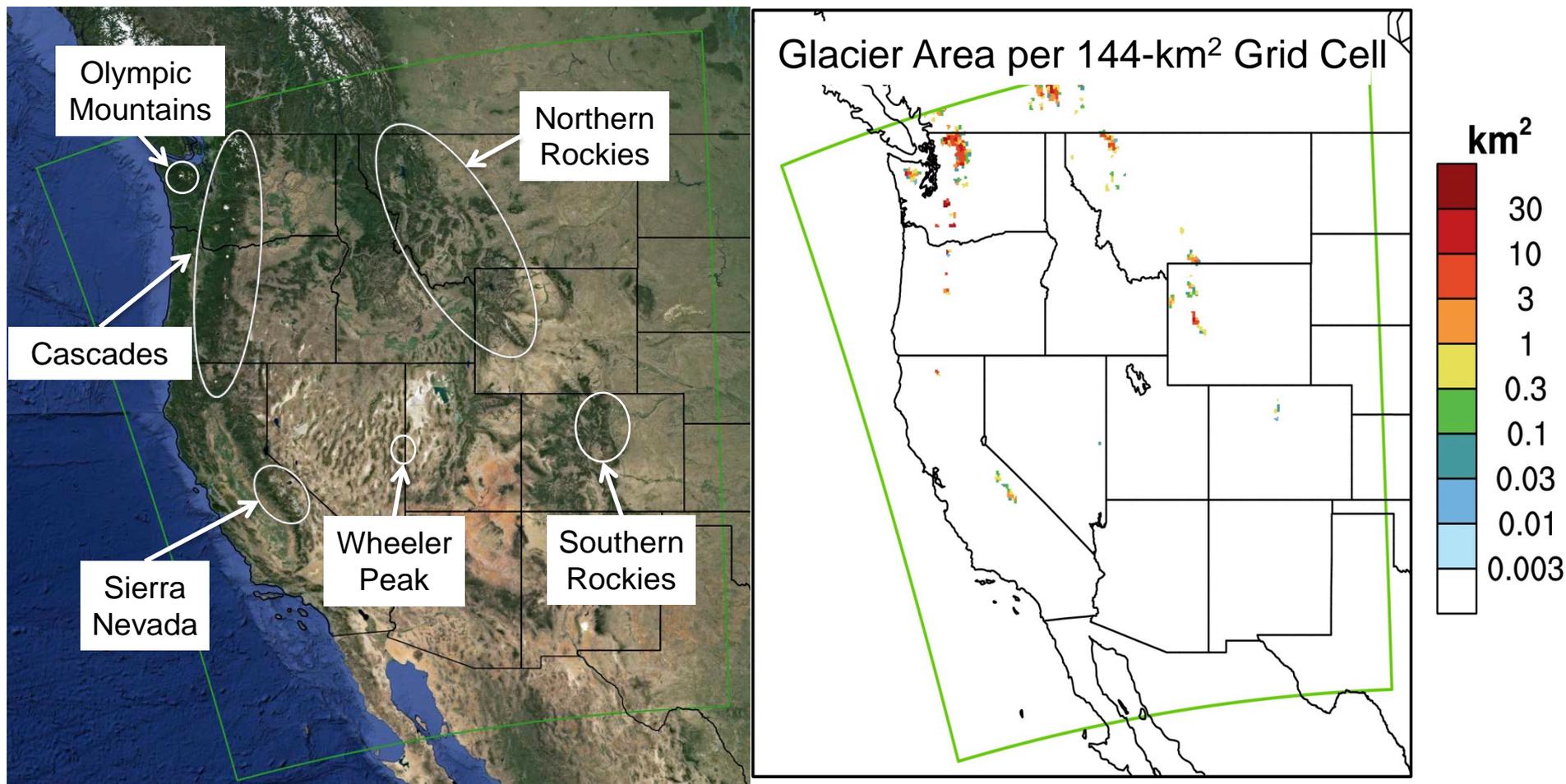
acres burned



2011 Monthly BC Emissions: Wild and Prescribed Fires

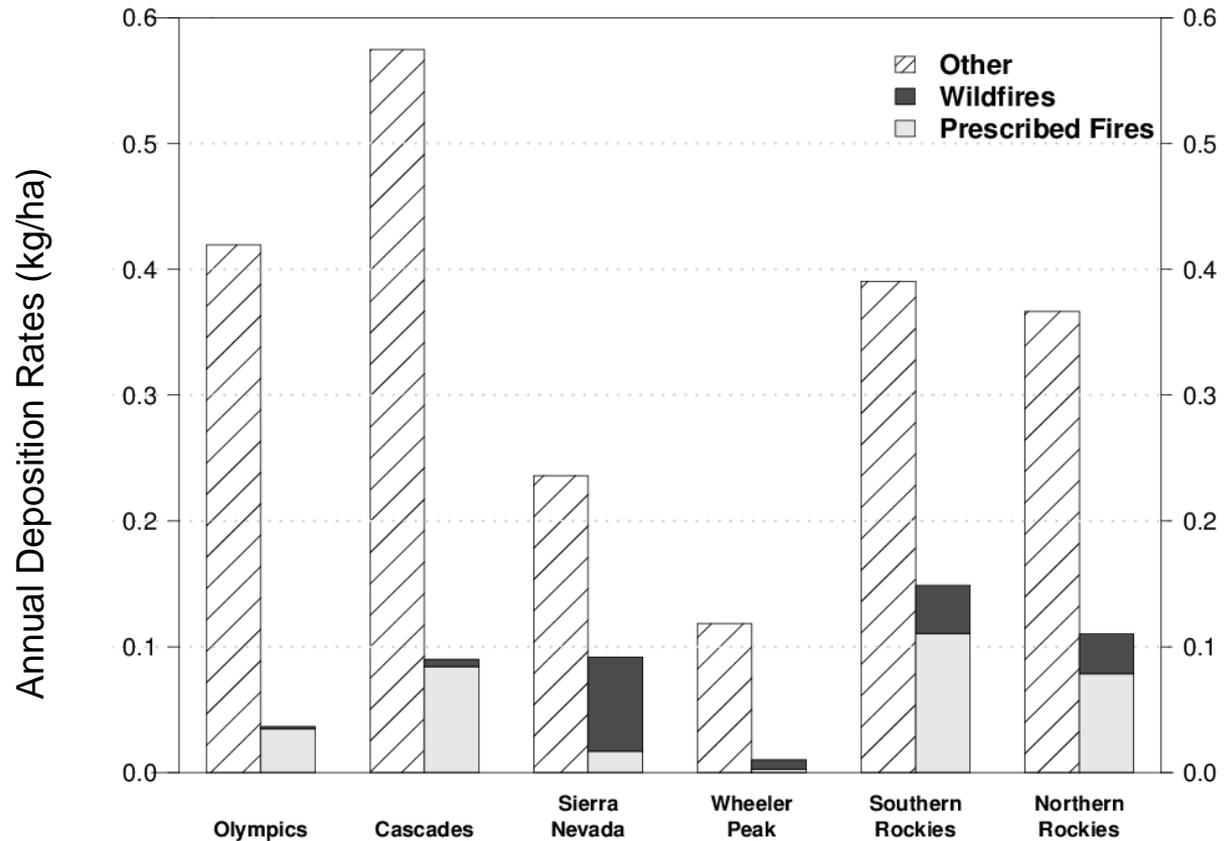


Glaciers in the Western U.S.



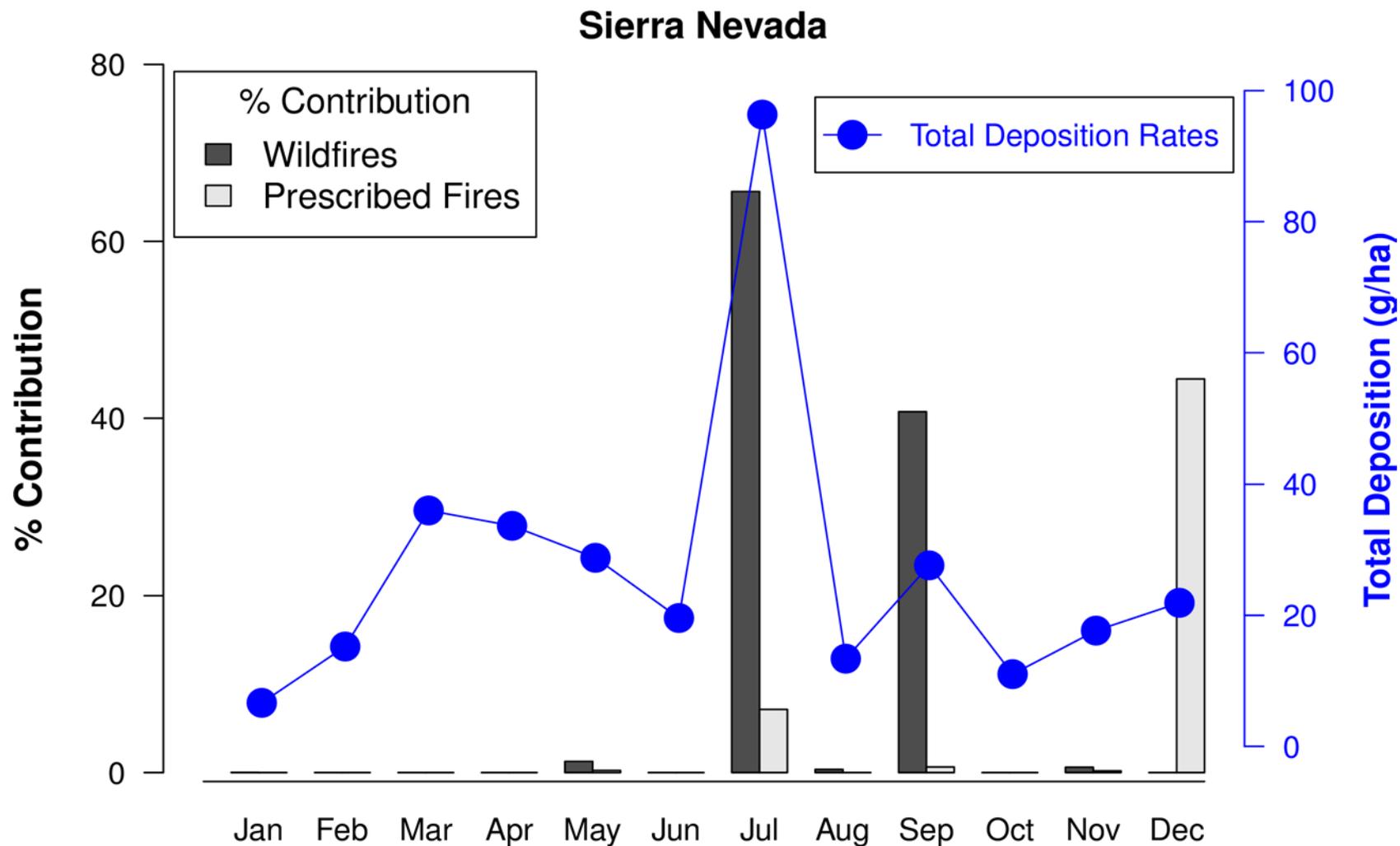
Source: National Snow & Ice Data Center's Global Land Ice Measurements from Space (GLIMS) glacier database

Annual BC Deposition to Glacial Areas

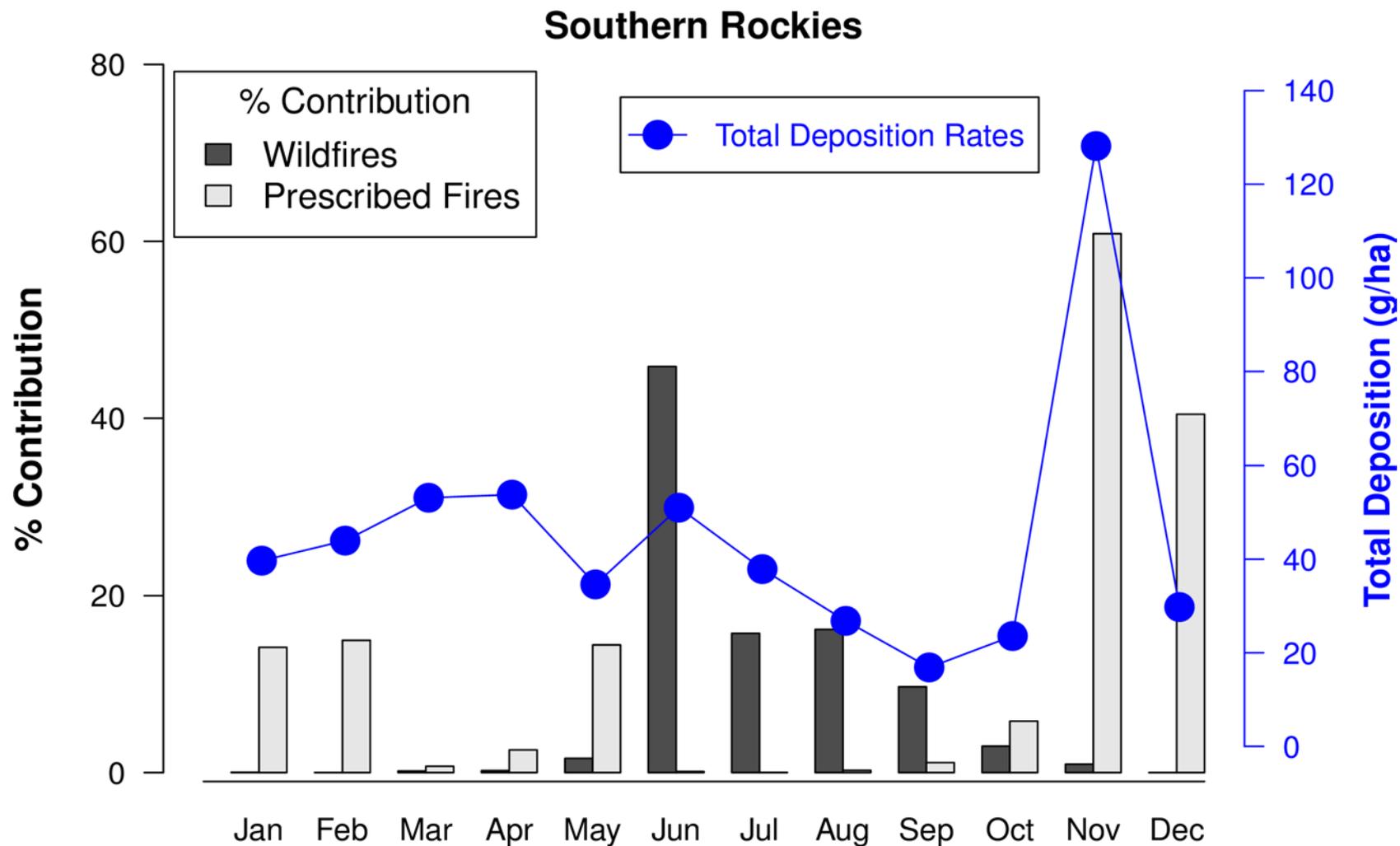


Contributions from wildland fires: 8% 14% 28% 8% 28% 23%

Monthly Deposition to Glaciers in the Sierra Nevada



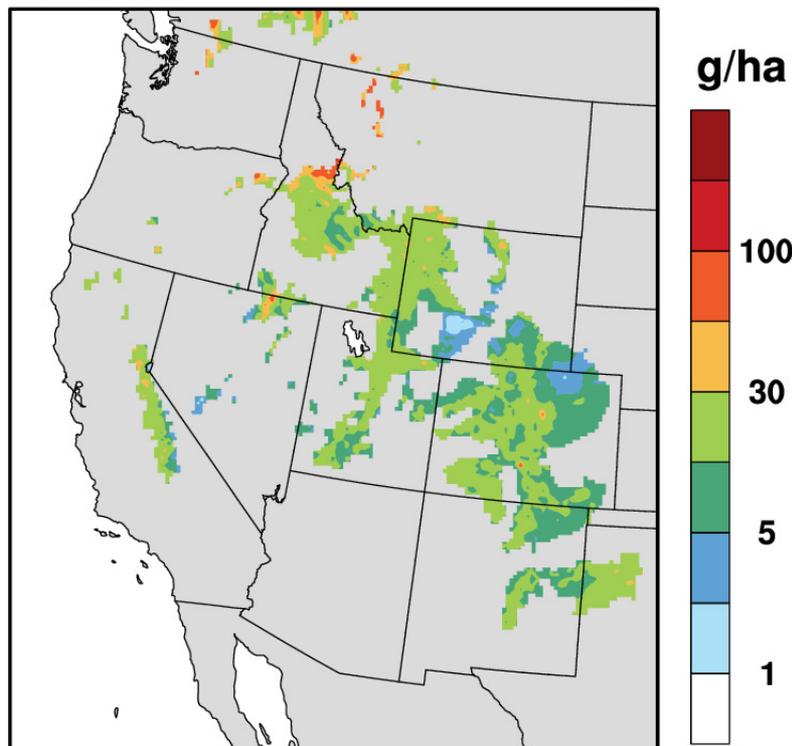
Monthly Deposition to Glaciers in the Southern Rockies



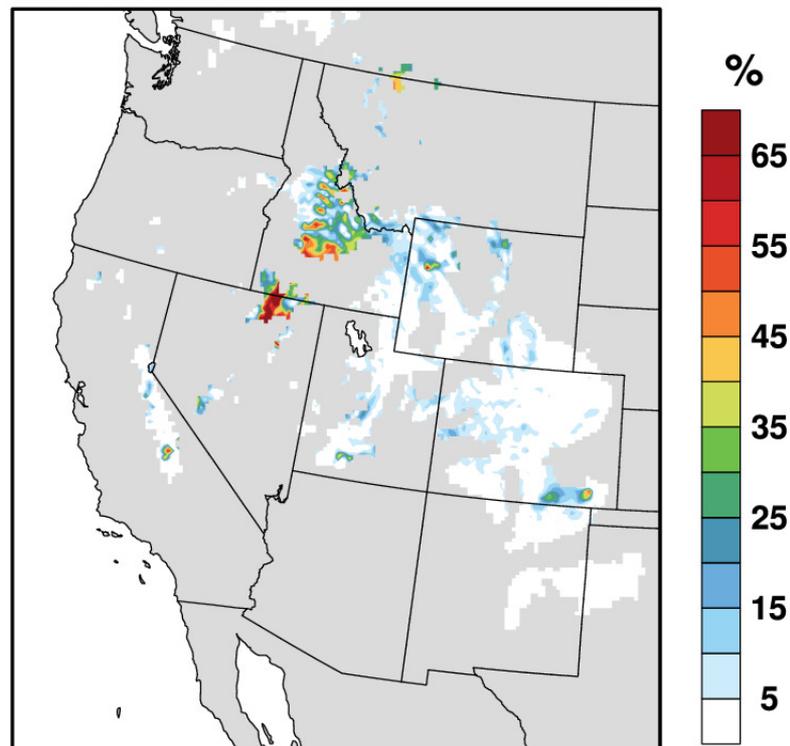
Deposition onto Snow Surfaces – Wildfire Contribution

- Wildfires occur in warm months and have little overlap with snow
- Largest overlap occurred in October

Total BC Deposition



Wildfire Contribution

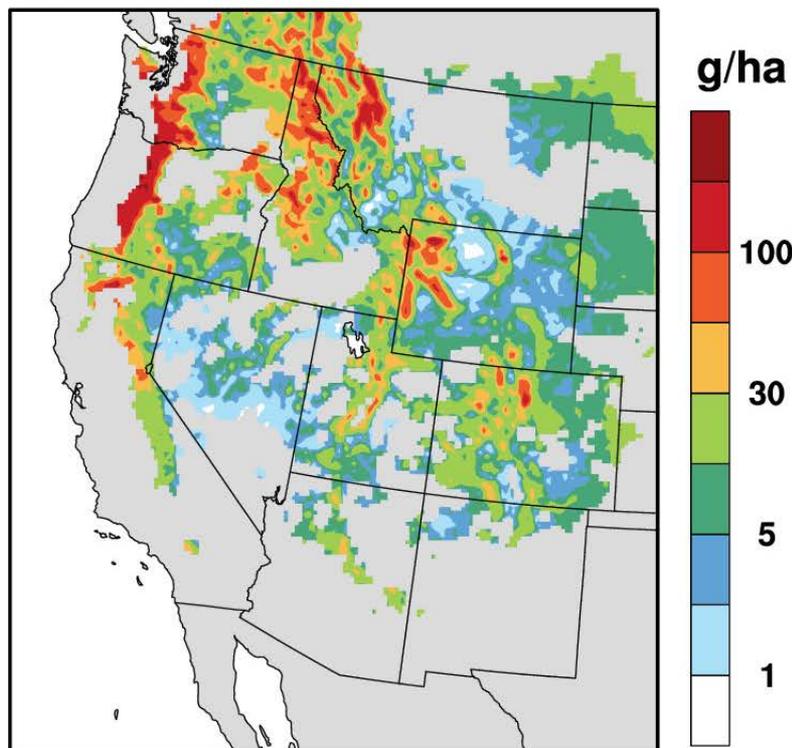


Gray color indicates monthly-mean snow depths were less than 3 cm or snow depth data were missing in the SNODAS (Snow Data Assimilation System) database.

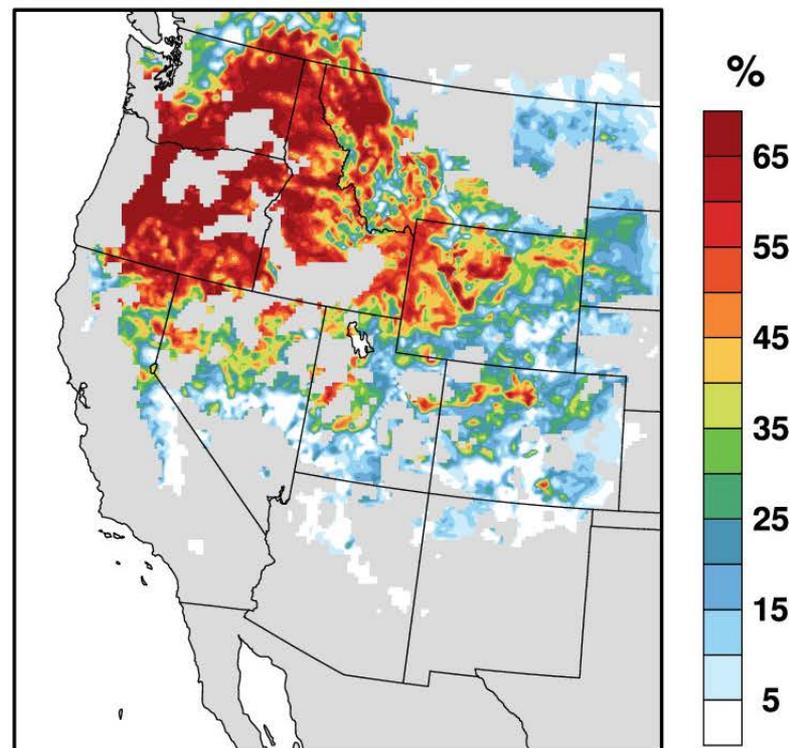
Deposition onto Snow Surfaces – Prescribed Fires

- During November, prescribed fire contribution dominated.

Total BC Deposition
in November



Prescribed Fire Contribution
in November



Gray color indicates monthly-mean snow depths were less than 3 cm or snow depth data were missing in the SNODAS database.

Summary

- Deposition to Glacier Areas:
 - On an annual basis, non-wildland fire sources dominated BC deposition rates to glacier areas
 - Largest contribution from wildland fires was 28% in the Sierra Nevada and the Southern Rockies.
 - During the summer months, wildfire contributions can be greater than 40% in the the Southern Rockies and the Sierra Nevada
 - Deposition to Snow Covered Surfaces:
 - Contributions from wildfires are generally negligible outside of October and May.
 - During November, prescribed fires contributed a large portion of BC deposition onto snow surfaces in Washington, Oregon, Idaho, Wyoming and Colorado.
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Future Directions

- Large uncertainty in model results due to uncertainties in:
 - Fire activity data – where, when, what fuel, and how big
 - Plume rise – how far smoke plume will travel?
 - Meteorological modeling, especially precipitation and transport in complex terrain.
 - Fire activities and snow vary from year to year.
 - Analysis based on one year is enough.
 - Nevertheless, this first estimate of fire contributions indicates further study on snow-albedo effect are needed.
 - Need observations of BC deposition.
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