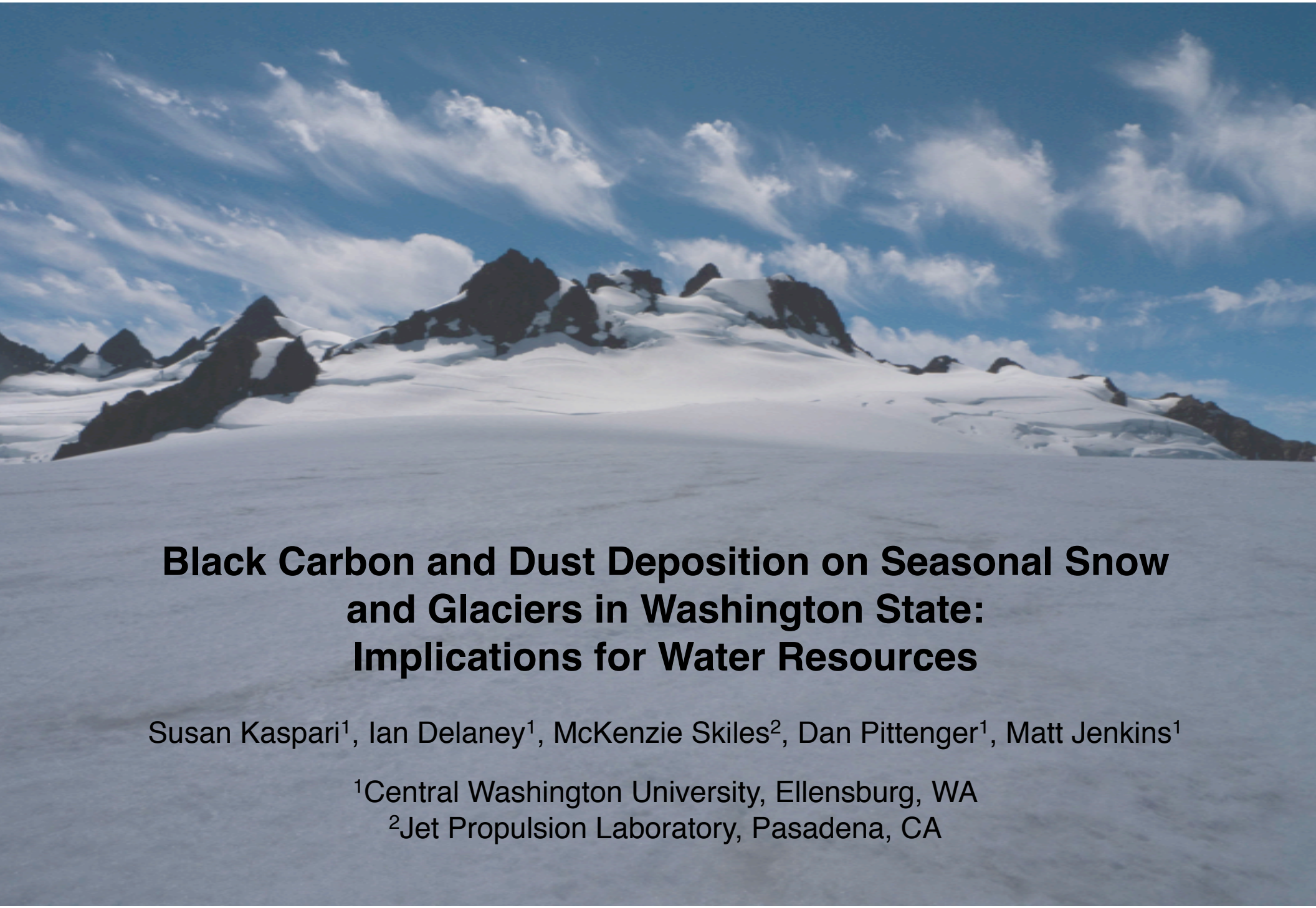


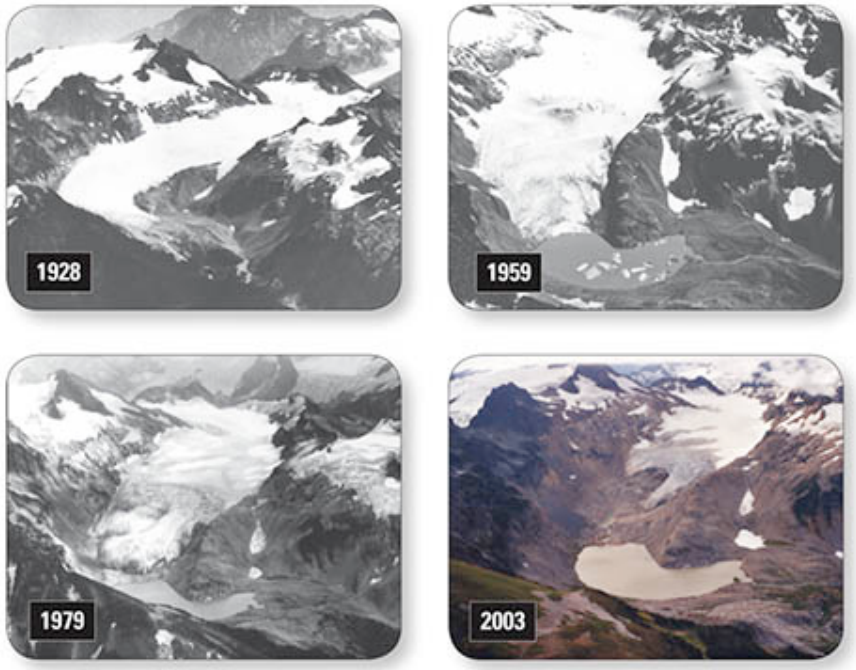
Black Carbon and Dust Deposition on Seasonal Snow and Glaciers in Washington State: Implications for Water Resources

Susan Kaspari[1], Ian Delaney[1], McKenzie Skiles[2], Dan Pittenger[1], Matt Jenkins[1]

[1]Central Washington University, Ellensburg, WA
[2]Jet Propulsion Laboratory, Pasadena, CA

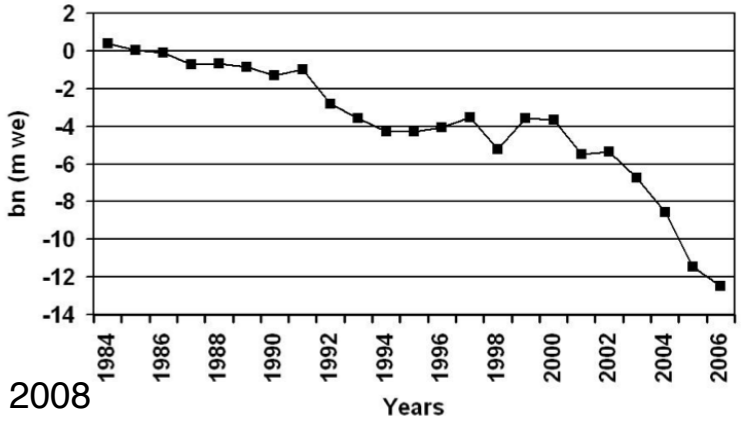
Retreat of Glaciers and Melting Snowpack in the Pacific Northwest

South Cascade Glacier



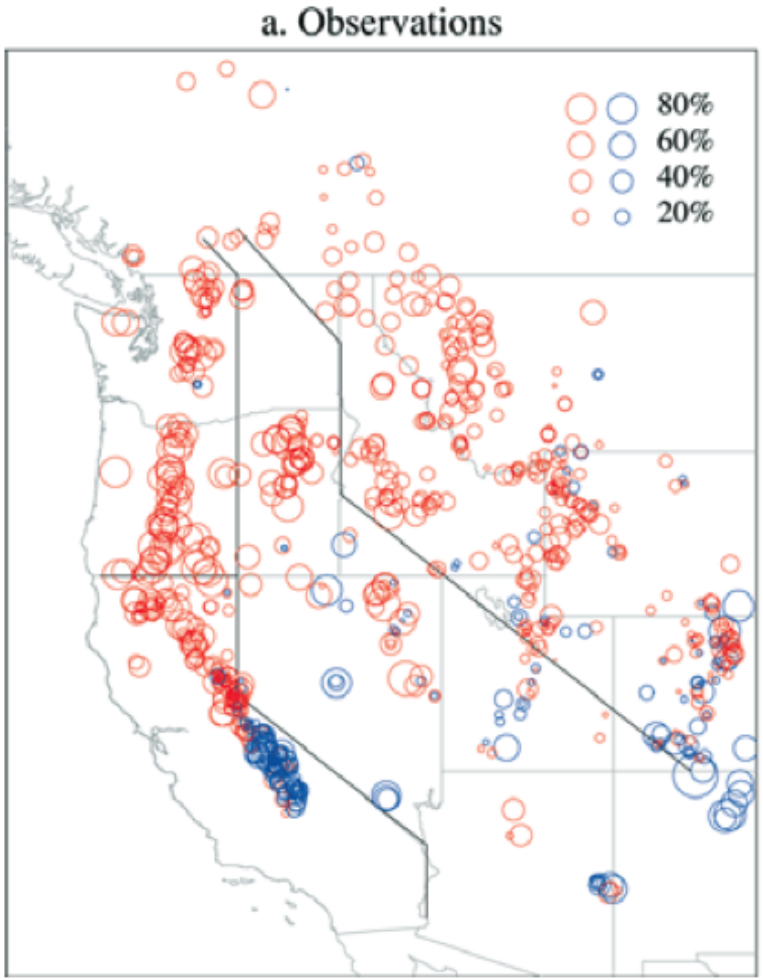
USGS

Glacier Mass Balance



Pelto, 2008

Linear Trend in April 1 Snow Water Equivalent 1950-1997



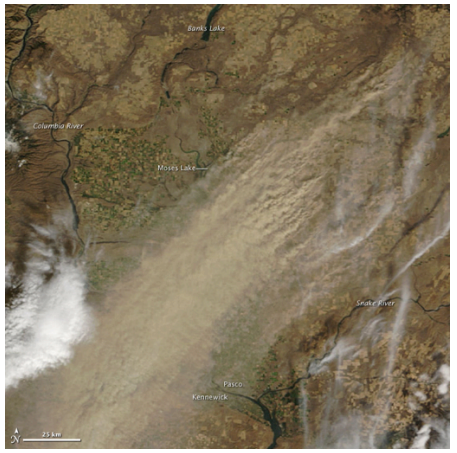
Mote et al., 2005

Light Absorbing Impurities include:

- Black carbon (soot) produced by the incomplete combustion of biomass, coal and diesel fuels.
- Dust
- Organics
- Ash

Black Carbon Sources

Dust storms in Central Washington

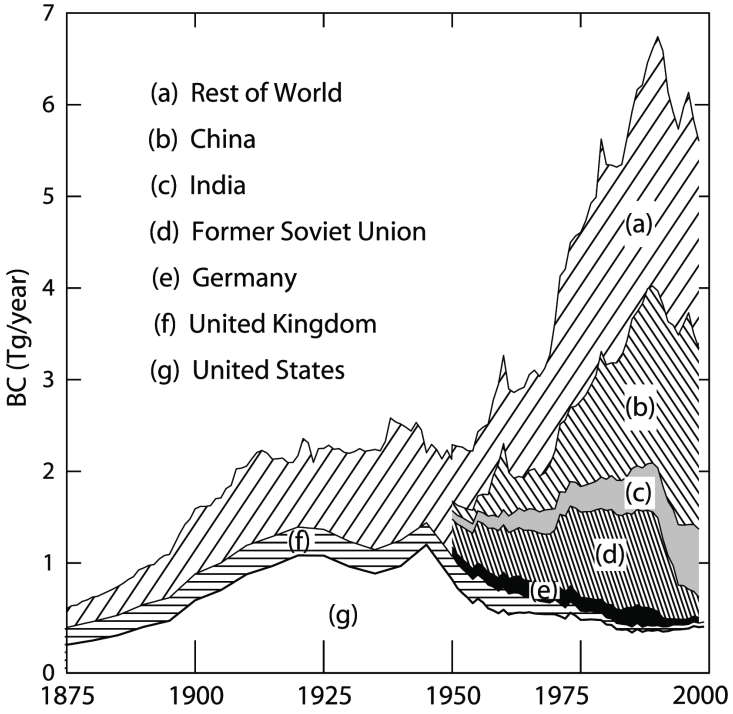


Light Absorbing Impurities in snow/ on glaciers:

- Reduce albedo (i.e. reflectivity)
- Accelerate melt

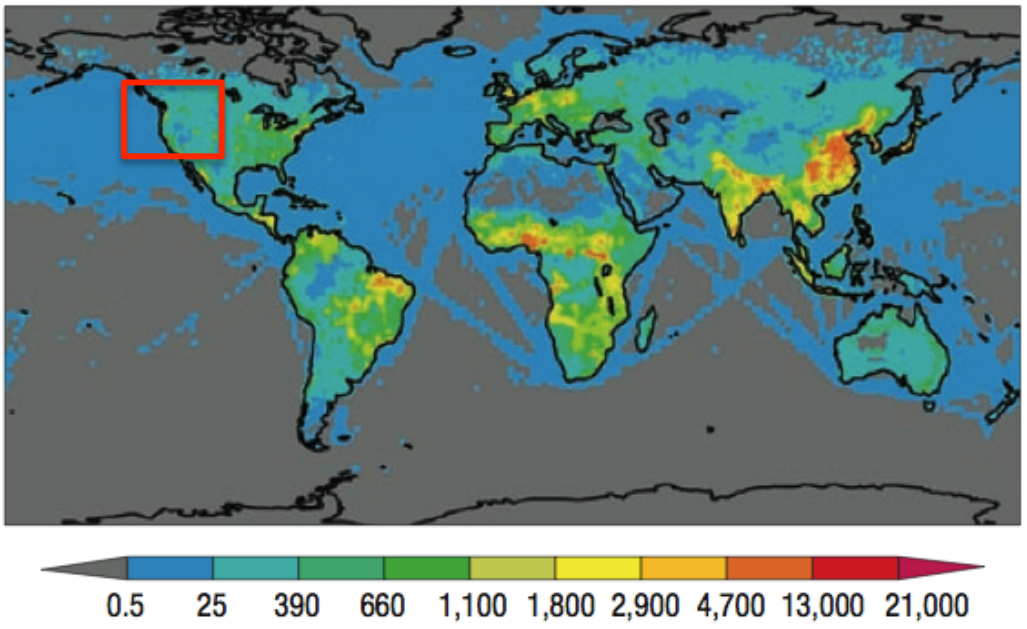
"We suggest that soot contributes to near worldwide melting of ice that is usually attributed solely to global warming."
-Hansen and Nazarenko, 2004

Estimated Fossil Fuel Black Carbon Emissions



Novakov et al., 2003

Black Carbon Emission Strength (tons/yr: 1996)



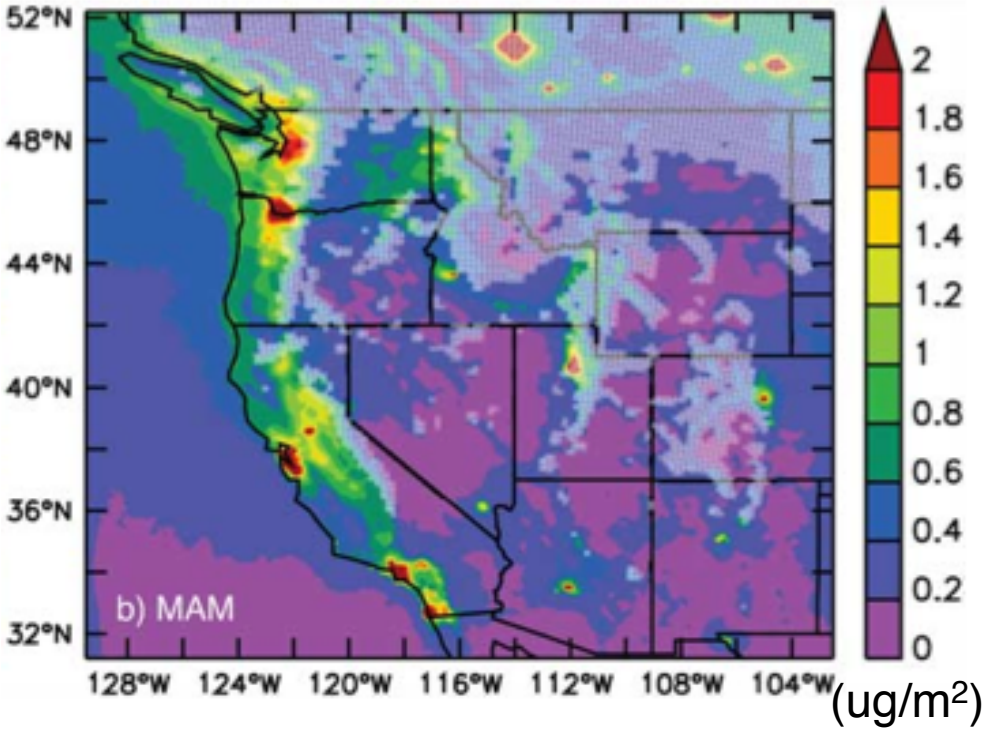
Ramanathan and Carmichael, 2008

Why Focus on Black Carbon in the Pacific Northwest?

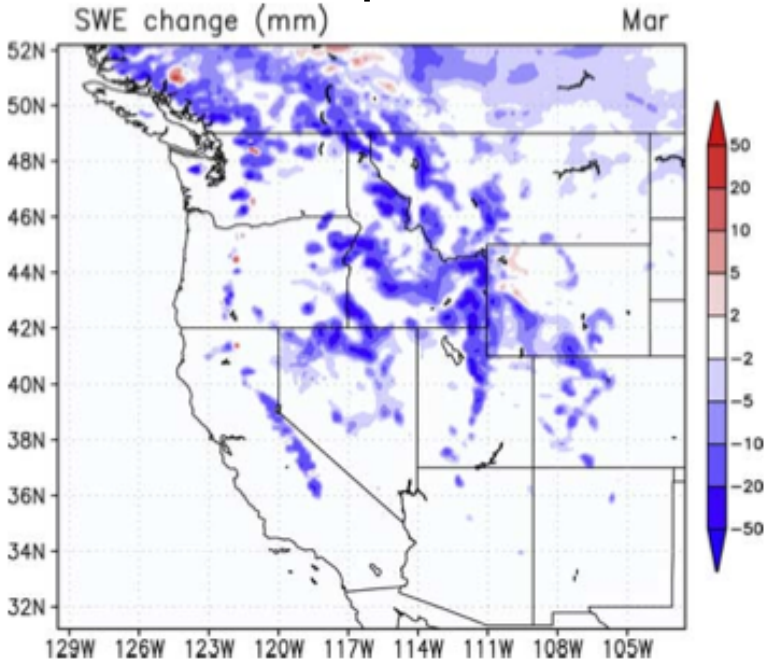
- Glaciated region of continental US
- Snowpack and glaciers are warm
- Low elevation= close to regional emissions
- Downwind of large BC sources

Model Results of Black Carbon in the Pacific Northwest

March- May
Black Carbon Deposition



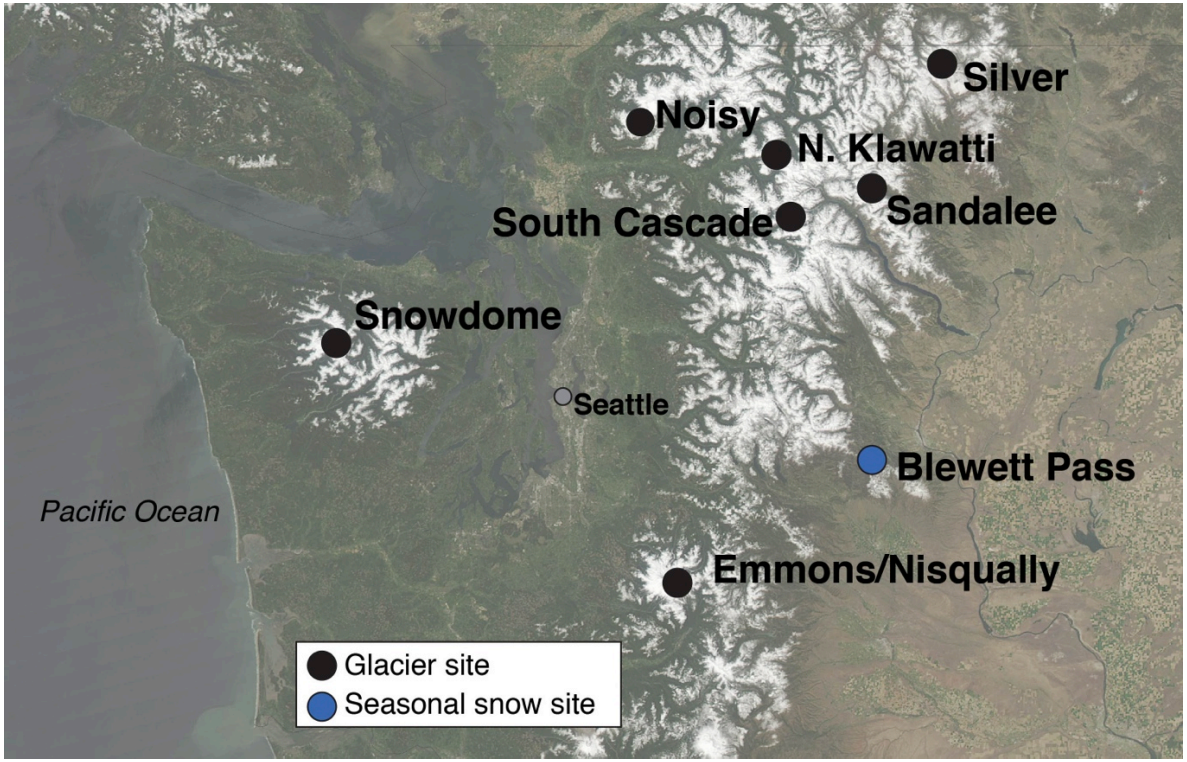
Change in Spring Snow Water Equivalent due to BC Deposition



But nearly no observations

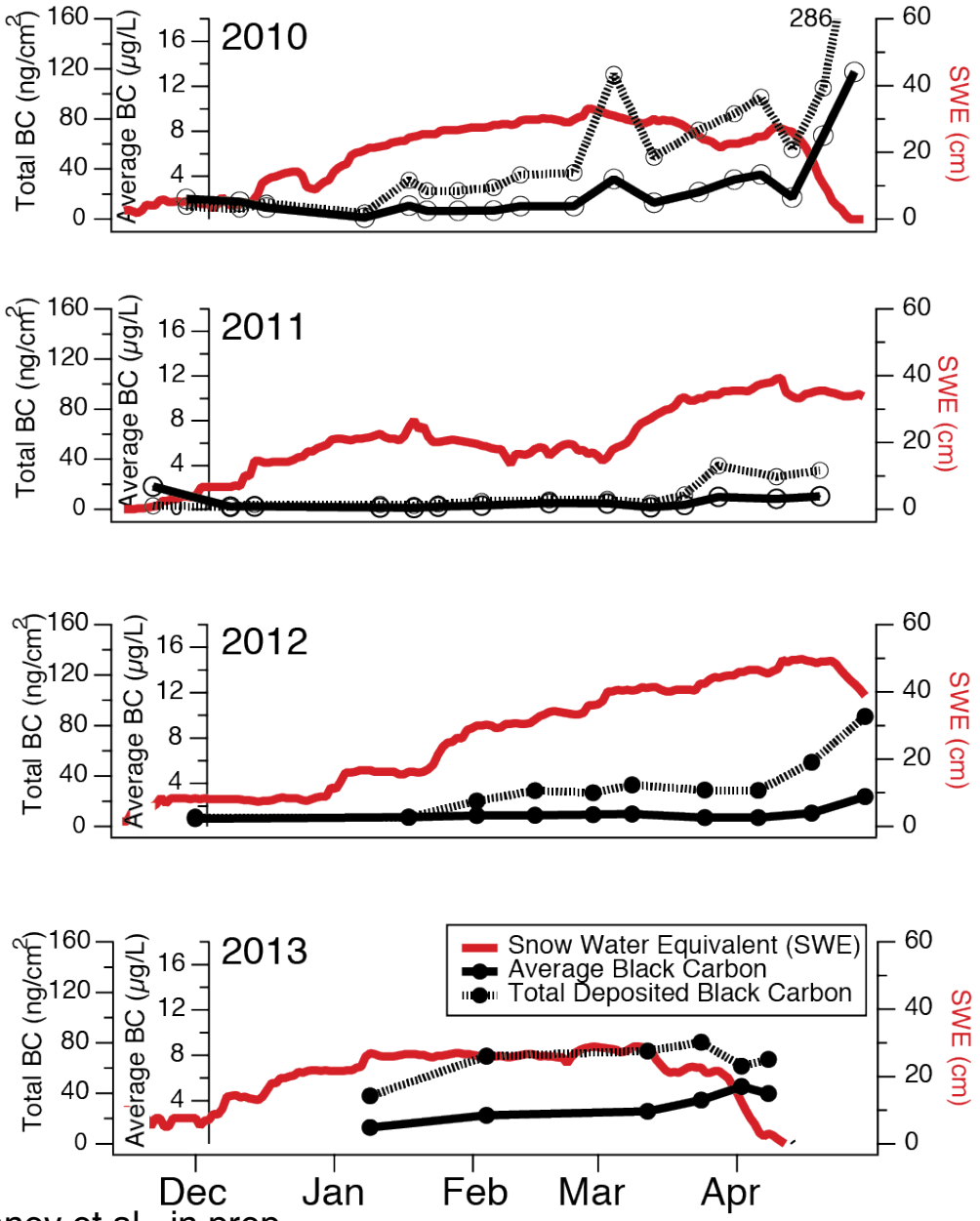
From *Qian et al.* [2009]

Study Area
Washington State



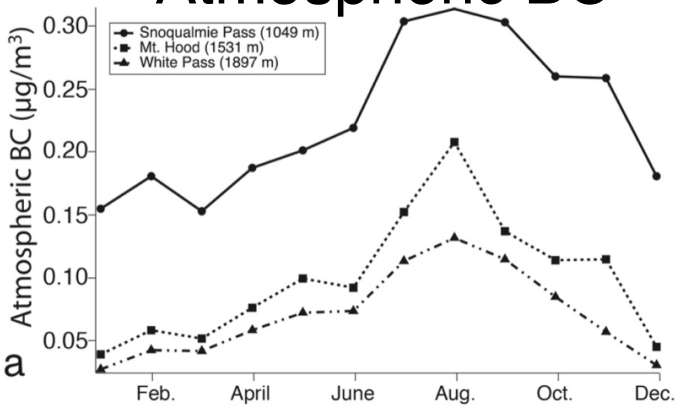
- Seasonal variations in BC concentrations in the seasonal snowpack and on glaciers
- Role of Forest Fire
- 20th Century Black Carbon deposition from the South Cascade Ice Core

Black Carbon in the Seasonal Snowpack at Blewett Pass, WA

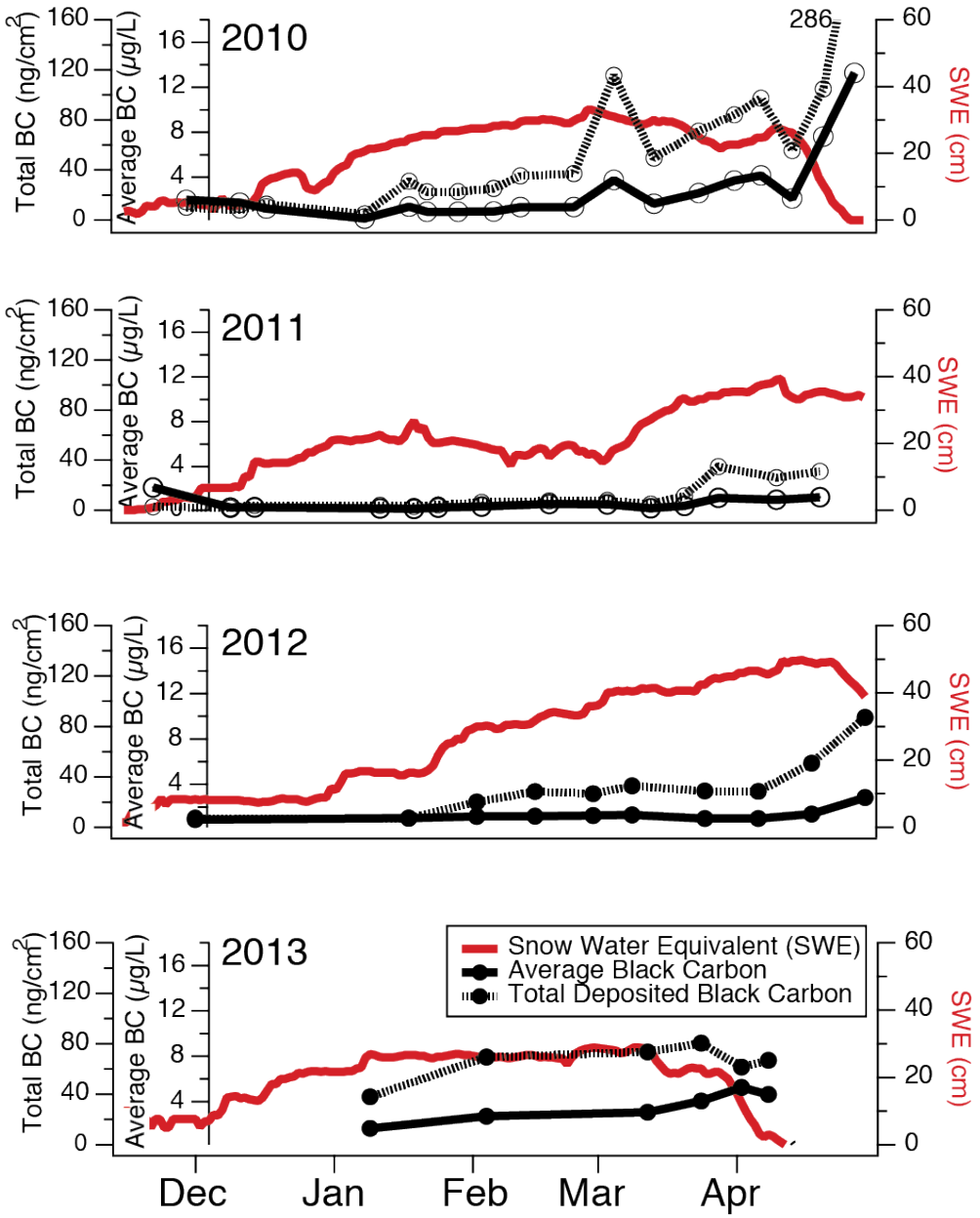


Delaney et al., in prep.

Atmospheric BC



Black Carbon in the Seasonal Snowpack at Blewett Pass, WA



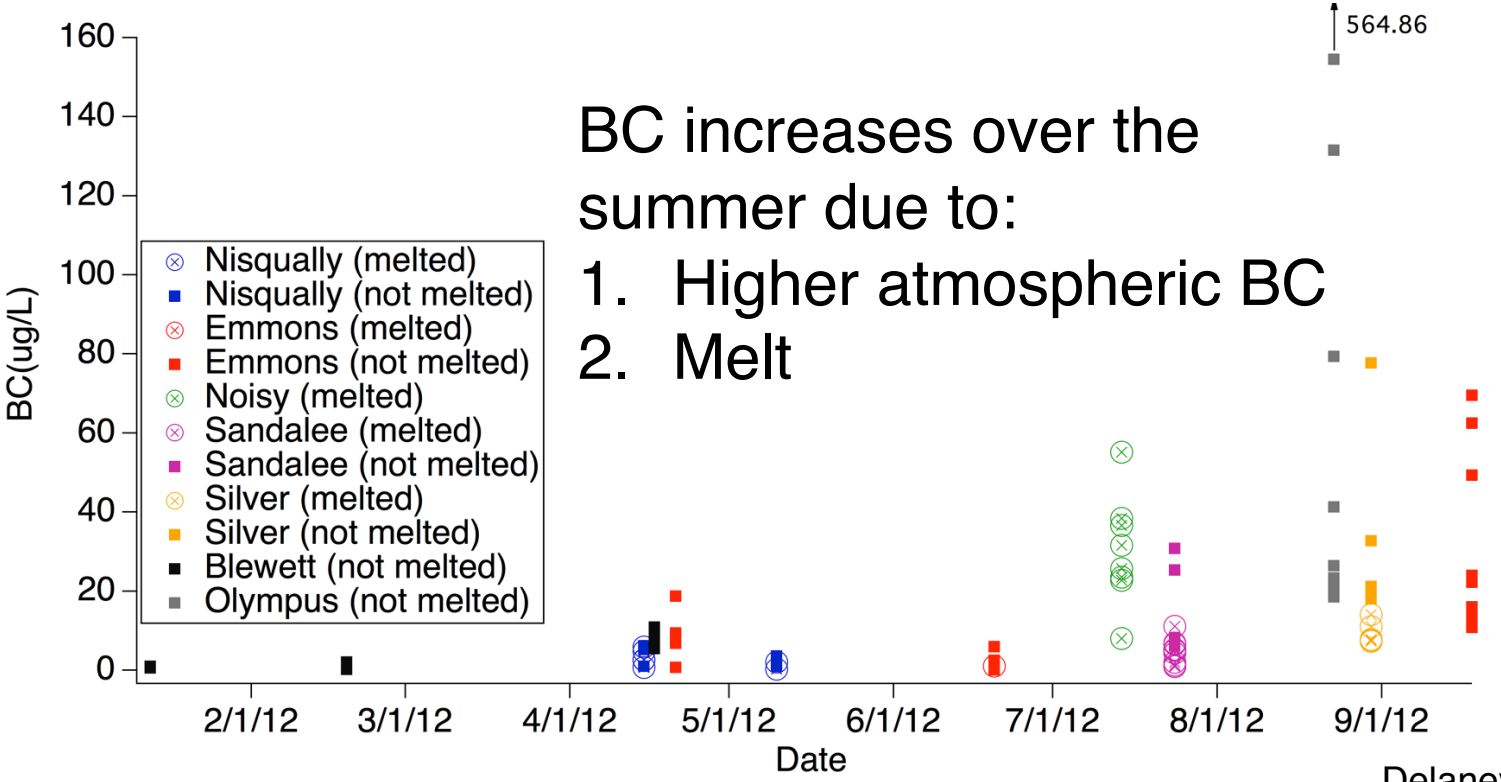
Black carbon concentrations in the snowpack increase in the spring due to

1. Melt
2. Higher BC in the atmosphere

The higher spring BC accelerates melt.

Delaney et al., in prep.

Black Carbon Concentrations in Surface Snow on Washington's Glaciers

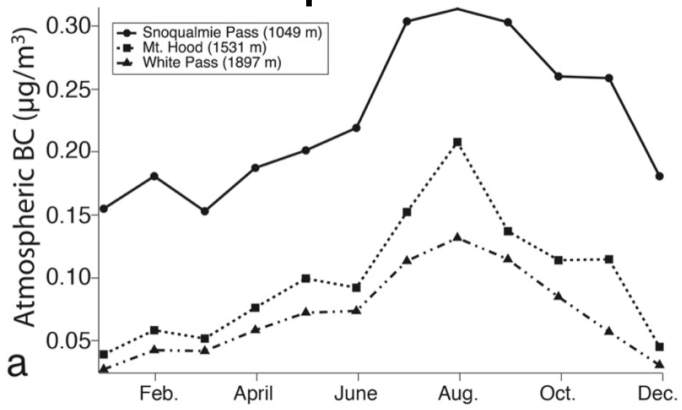


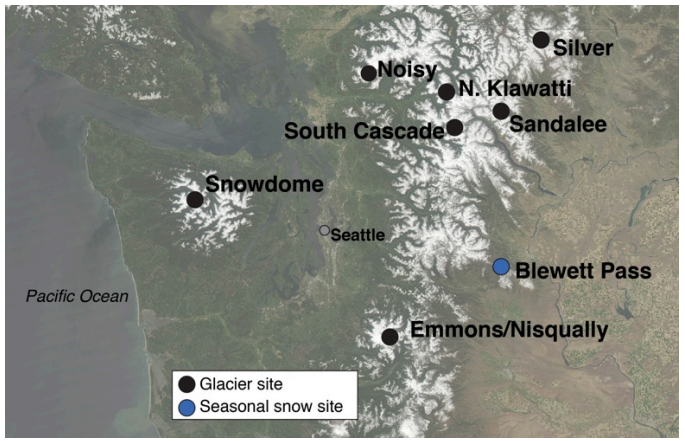
BC increases over the summer due to:

1. Higher atmospheric BC
2. Melt

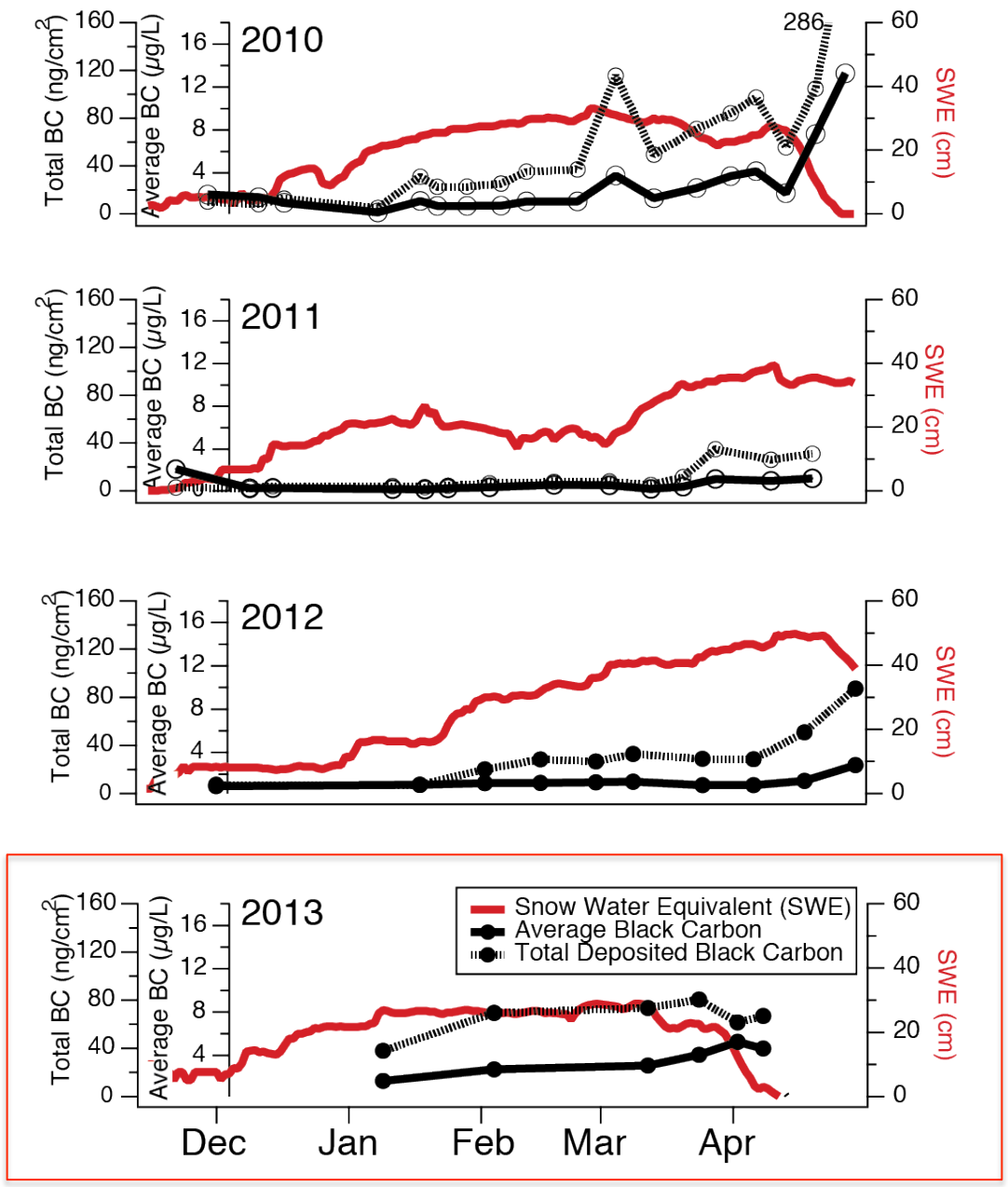
Delaney et al., in prep.

Atmospheric BC





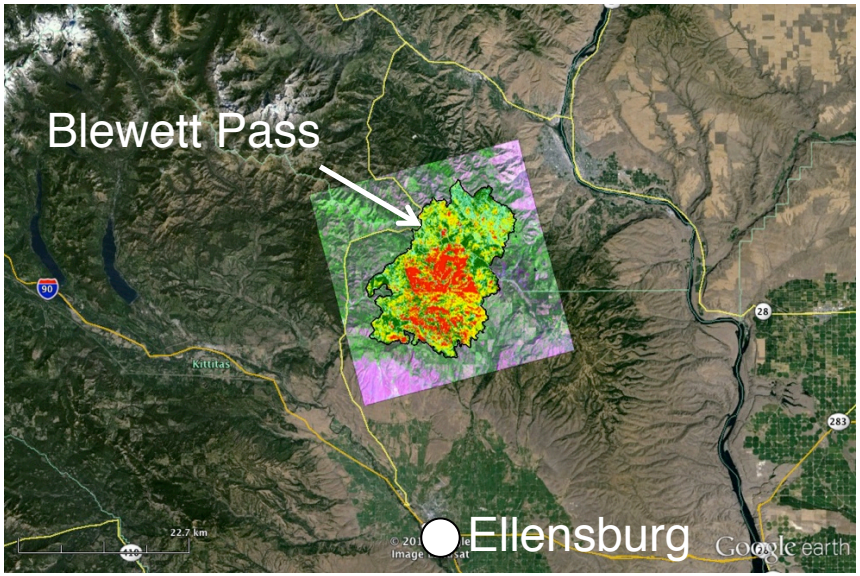
Black Carbon in the Seasonal Snowpack at Blewett Pass, WA

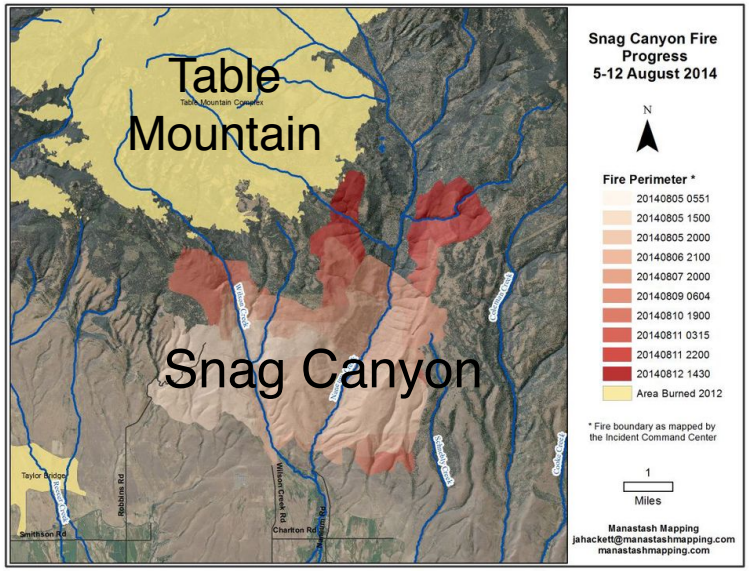


Elevated concentrations in 2013 post-wildfire

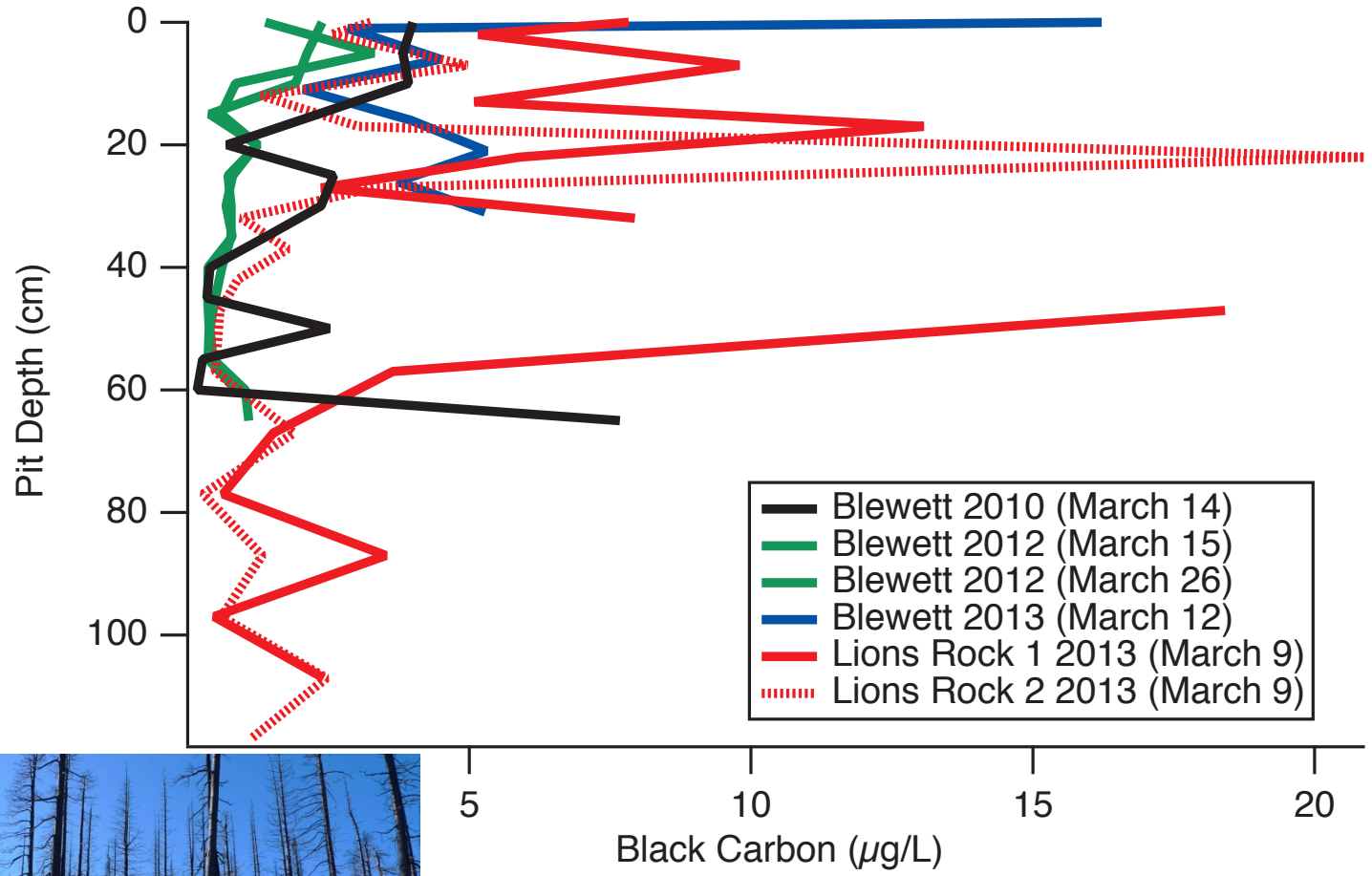
Delaney et al., in prep.

2012 Table Mountain and 2014 Snag Canyon Wildfires in Central Washington



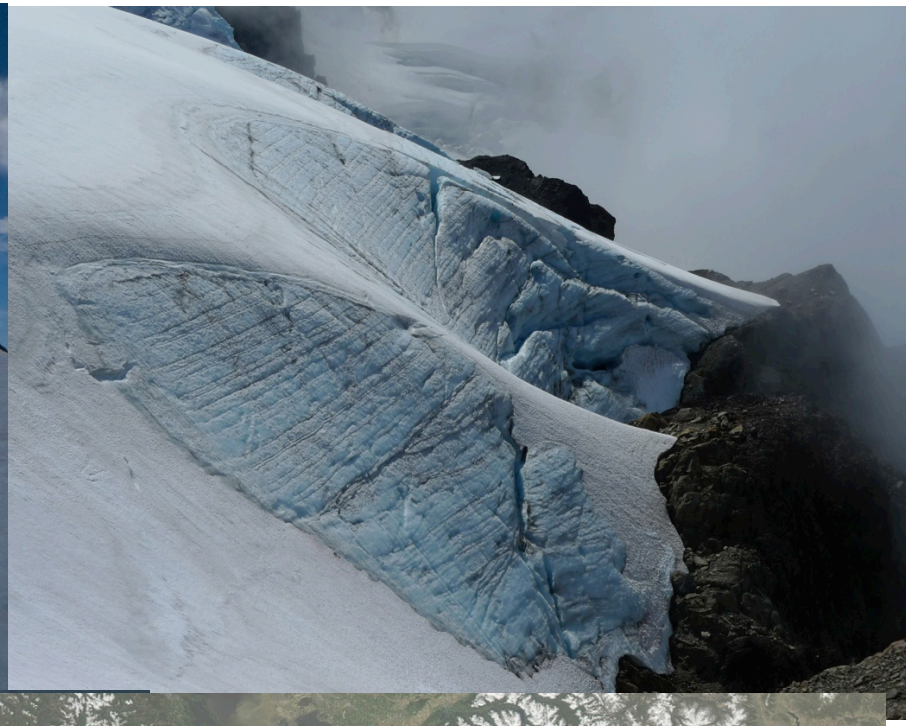


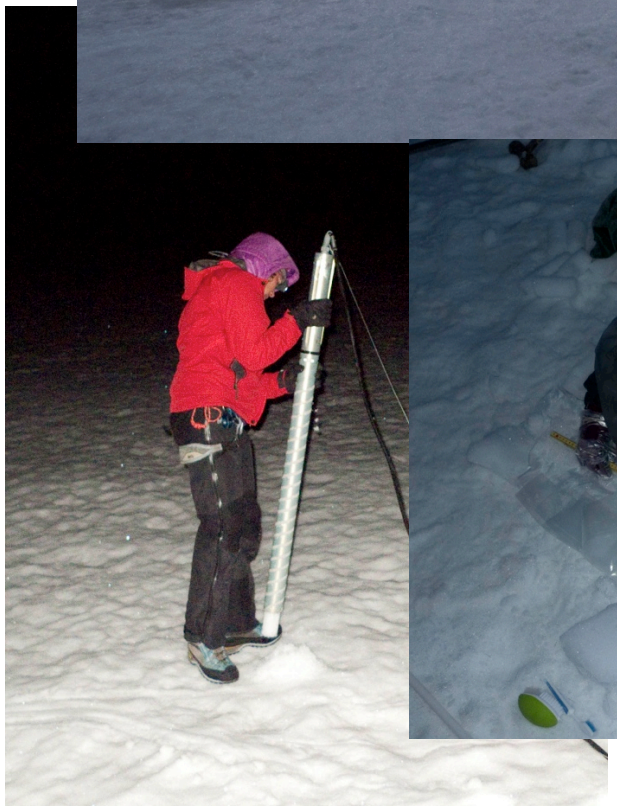
Post Wildfire Black Carbon Concentrations in the Snowpack are Elevated

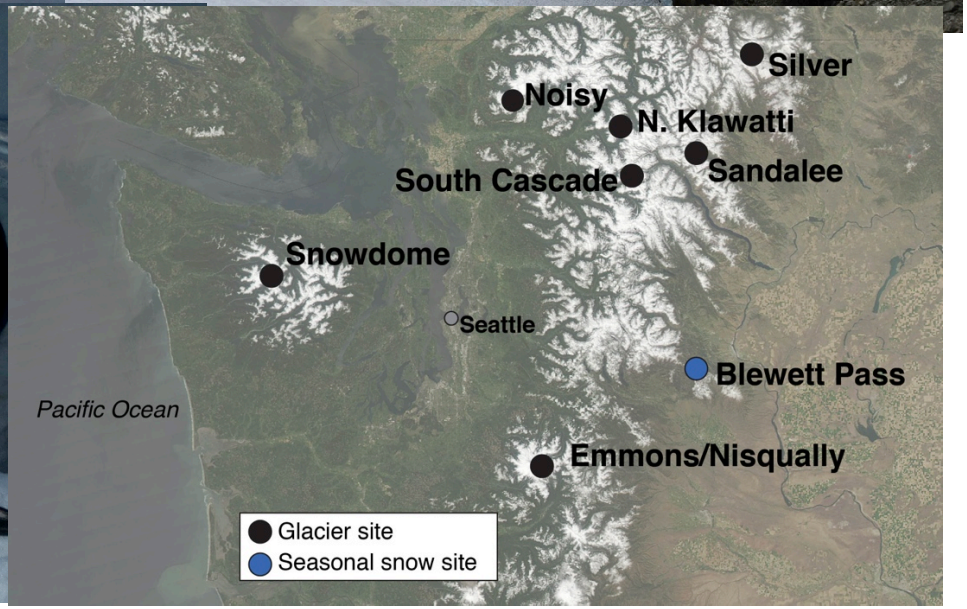


Delaney et al., in prep.

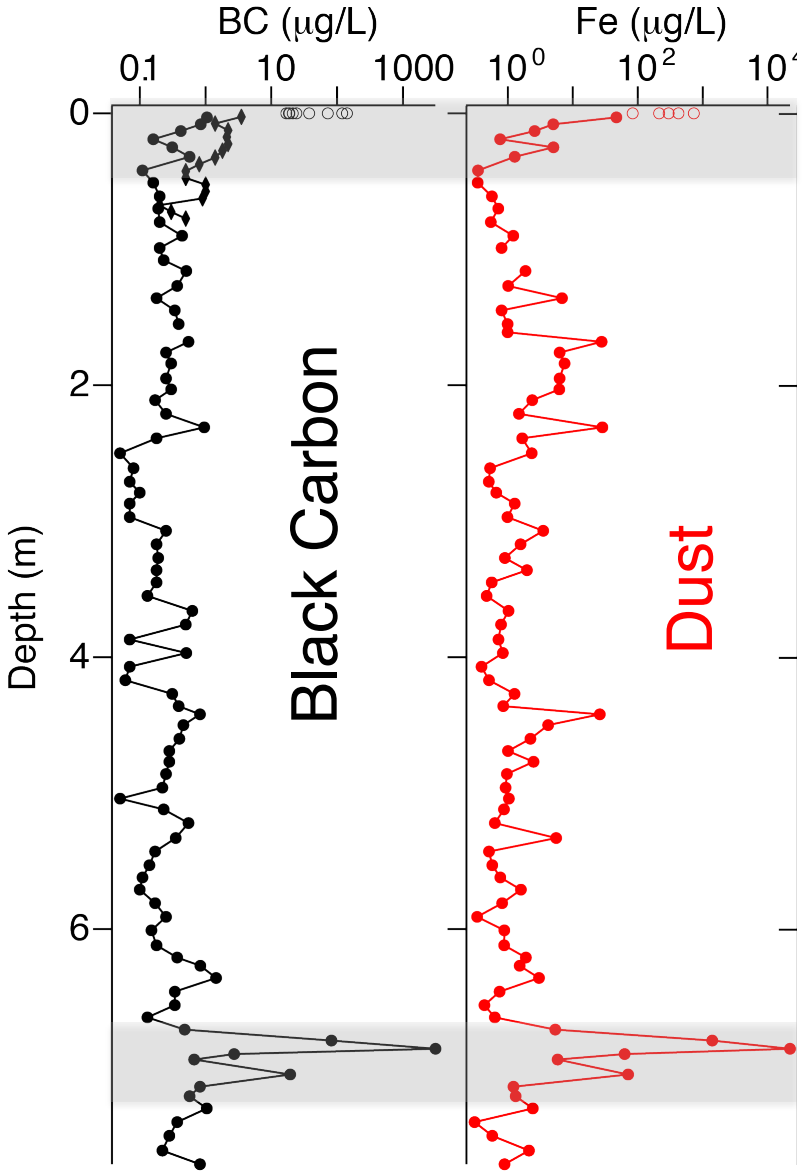
Investigating Black Carbon at Snowdome, Mt. Olympus



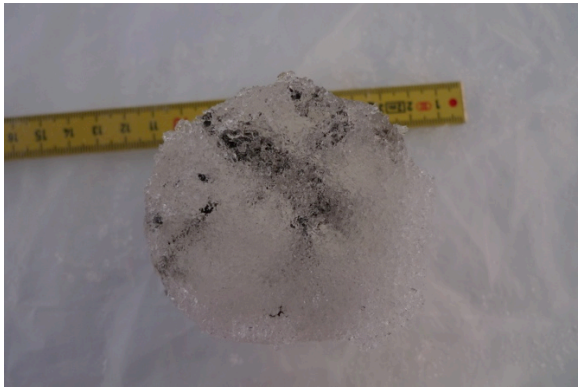




Black Carbon and Dust Deposition on Snowdome, Mt. Olympus

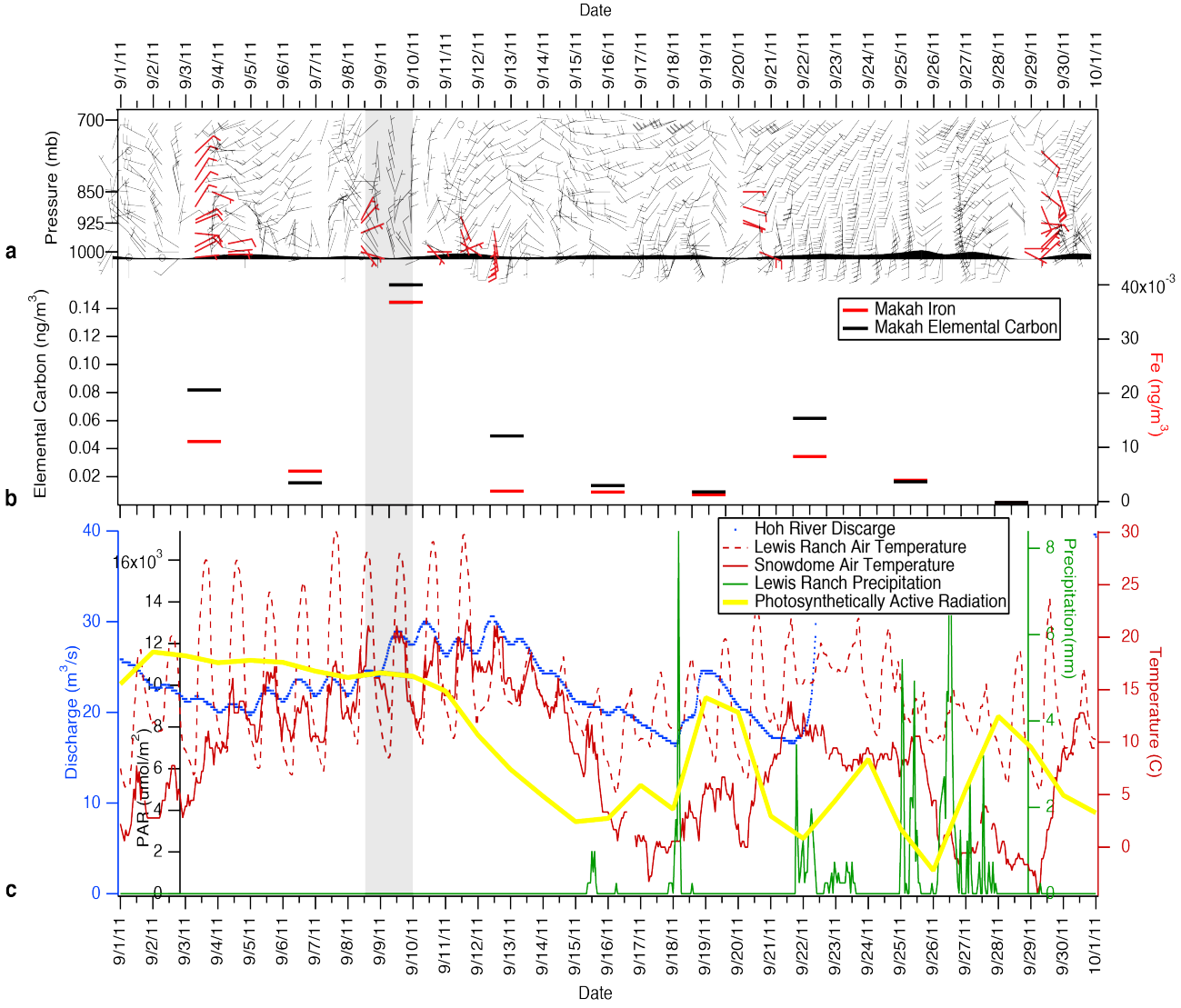


- 2011 summer black carbon and dust concentrations are a magnitude higher than summer 2012.
- 2011 summer also higher than observed on glaciers elsewhere in the state.



Kaspari et al., in prep.

Black Carbon and Dust Deposition on Mt. Olympus from the 2011 Big Hump Fire



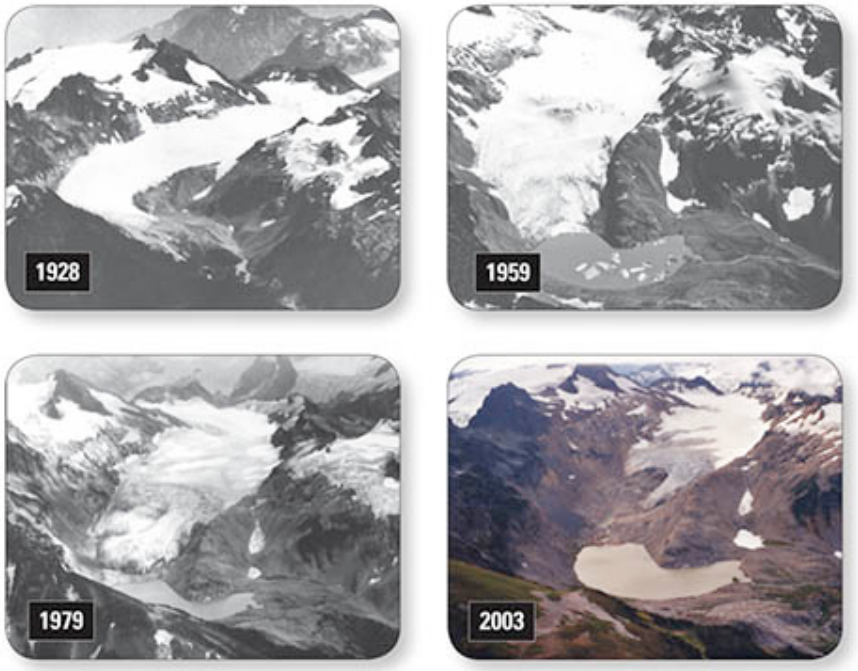
Sep. 1

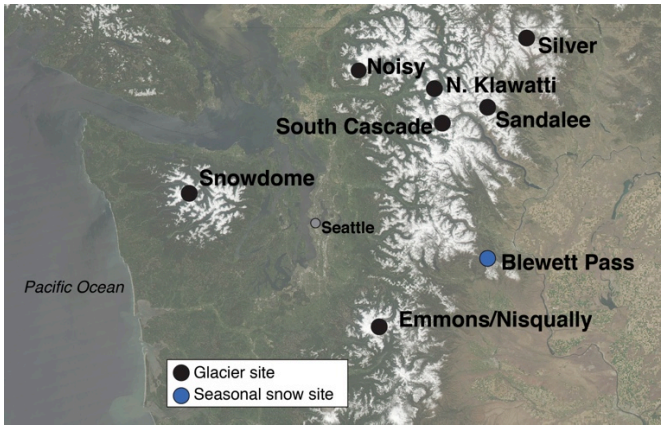
Oct. 1

Kaspari et al., in prep.

Fire impurity deposition resulted in a threefold rate of increase in river discharge

20th Century Black Carbon and Dust Deposition in the North Cascades from the South Cascade Ice Core





Ice core drilled in 1994 by the USGS

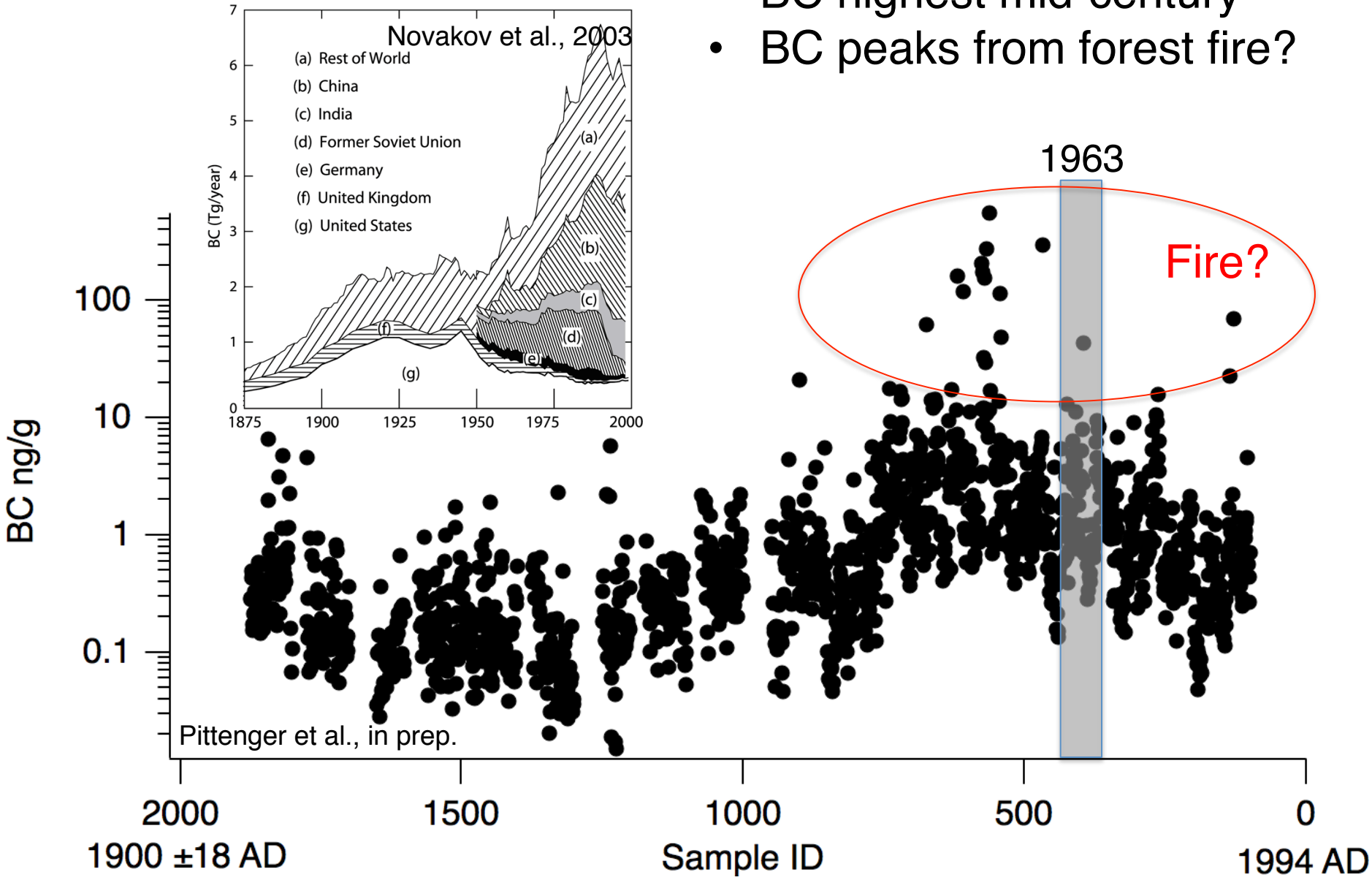

Dust
a


Black
Carbon
b


Depth (m)
10
20
30
40
50
c

20th Century Black Carbon Record from the South Cascade Ice Core

- BC highest mid-century
- BC peaks from forest fire?



Summary

- Black carbon and dust deposition on snow and glaciers in Washington State can reduce albedo and accelerate melt.
- This effect is greatest in the late spring-summer ➔ high elevation snowpacks and glaciers are most affected.
- Highest BC concentrations are associated with forest fires.
- Continued research will focus on the sources of black carbon (fossil vs. bio fuel) and dust (natural vs. anthropogenic), and the relative importance of black carbon versus dust in contributing to snow and glacier melt.

Relevance to Projected Changes in Climate in the PNW

- Precipitation changing from snow to rain=
  Smaller spring snowpack and continued glacier retreat=
  More concentrated impurities
- Projected increases in forest fires= increased impurity deposition.

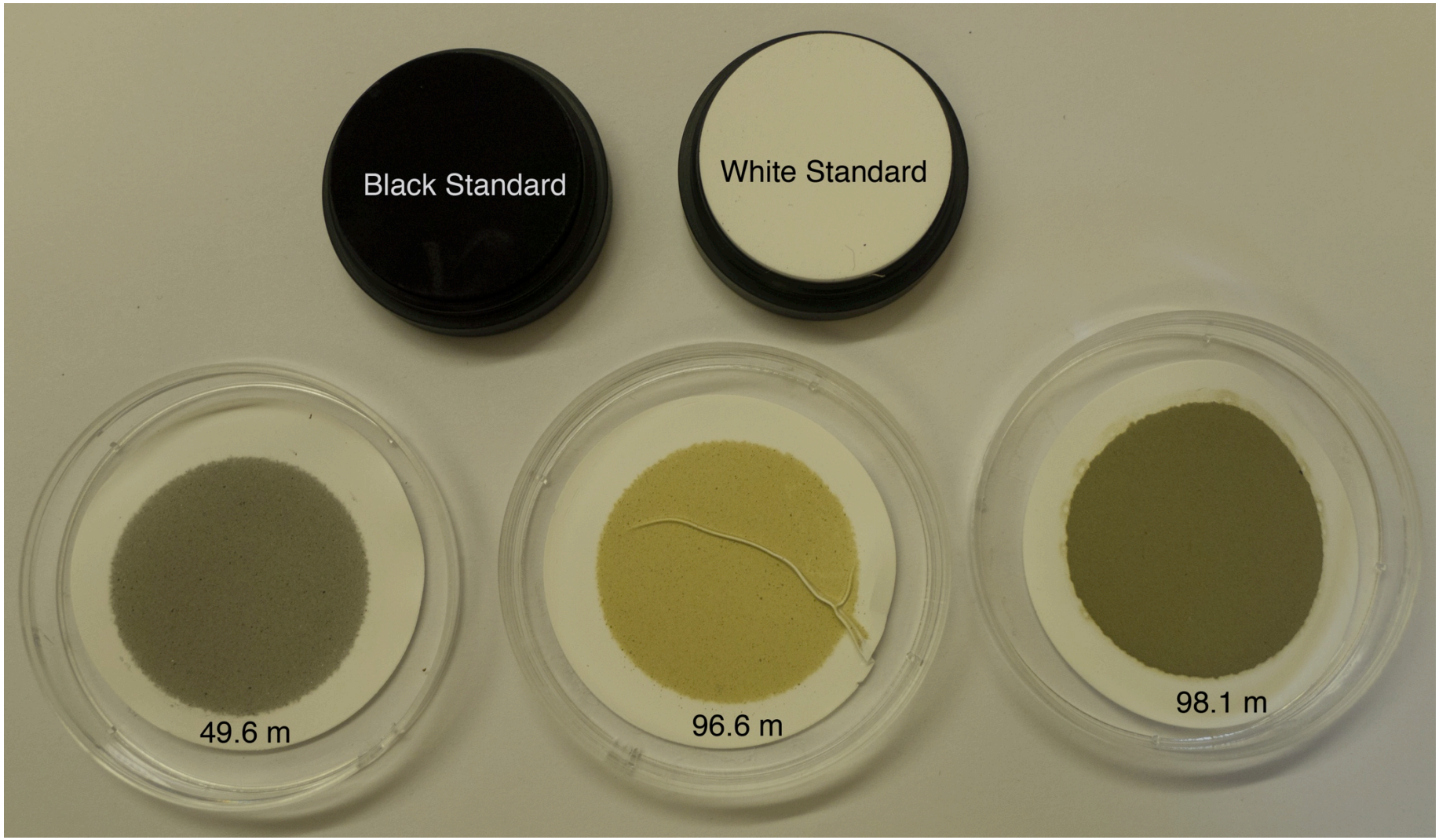
State of Washington
Water Research Center

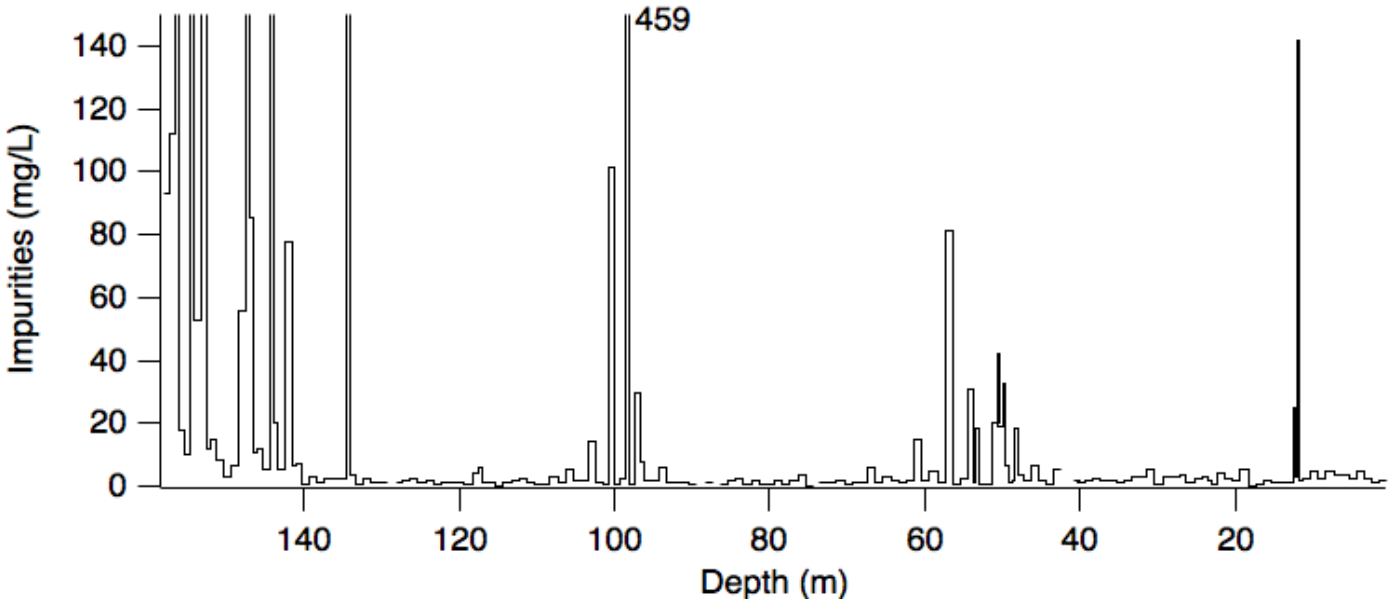
Light Absorbing Impurities on Snow

Dust

Black Carbon

Photos: Ian Delaney


Black Standard
White Standard
49.6 m
96.6 m
98.1 m


459
Impurities (mg/L)
0
20
40
60
80
100
120
140
140
120
100
80
60
40
20
Depth (m)