Black Carbon in California Mountain Snow and Coastal Precipitation

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Outline:

- Why these measurements are important
- Field experiment
  - Collection sites
  - Analysis
- Results
  - Black carbon concentration
  - Factors controlling BC concentration
  - Possible sources
- Implications for California climate
- Conclusions
- Future field work

Modeled Global Climate response from soot in snow and ice

- Hanson and Nazarenko (2004)
  - Forcing of 0.3 W m^{-2} N. Hemisphere. Mean efficacy of 2.
- Flanner et al (2007)
  - Forcing of 0.049 – 0.054 W m^{-2} globally. Mean efficacy of 3.

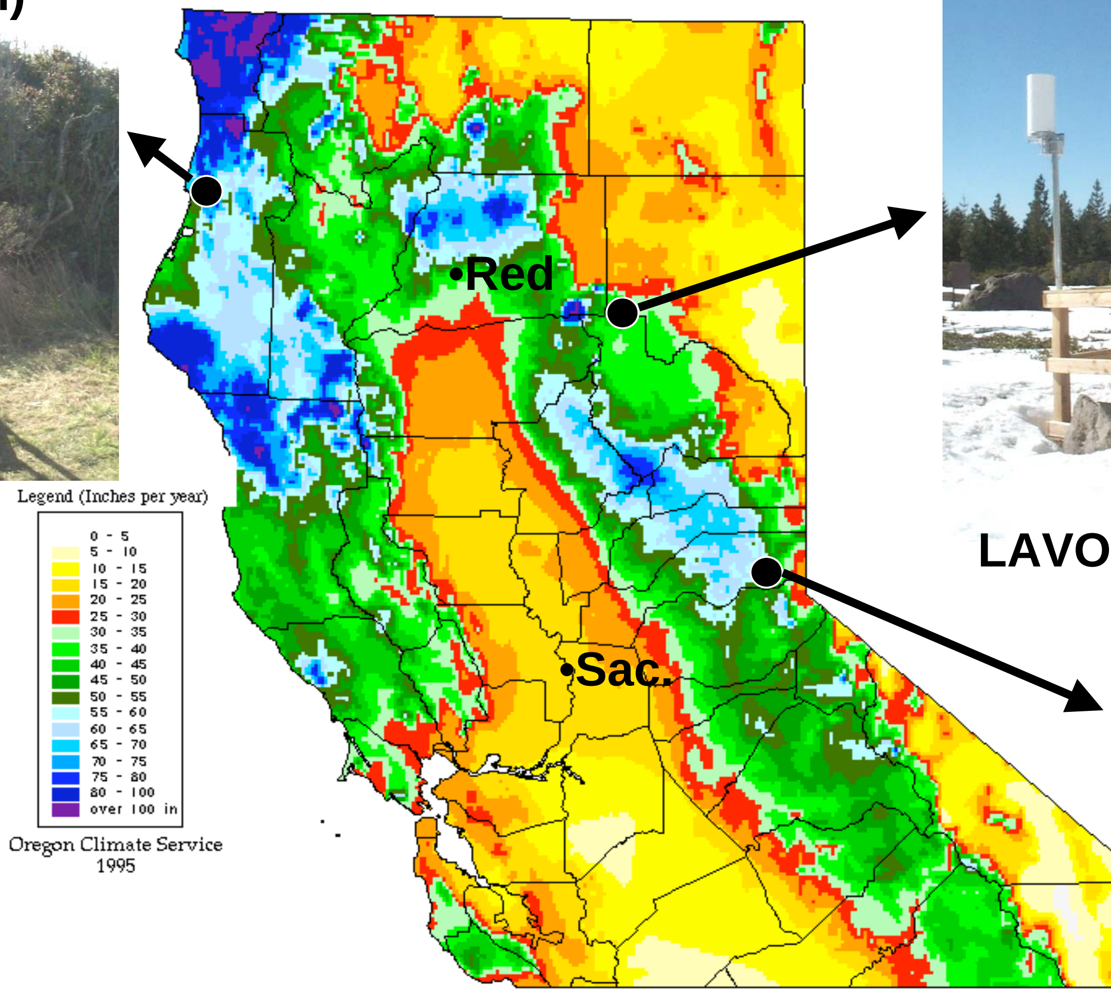
$$\text{Efficacy} = (\triangle T_{BC}/F_{BC})/(\triangle T_{CO2}/F_{CO2})$$

measure of the temperature response to BC in global snow and ice compared to equal forcing by CO_2

- Jacobson (2004)
  - Global temperature increase of .06K/decade
  - Larger temperature increase in the high latitudes of N. Hemisphere

Field Sites

THD (107 m)



Annual Average Precipitation (Inches)
Northern California

Period: 1961-1990

LAVO (1732 m)

2100 m)

http://www.wrcc.dri.edu/pcpn/ca_north.gif

Wet rain and snow sampler

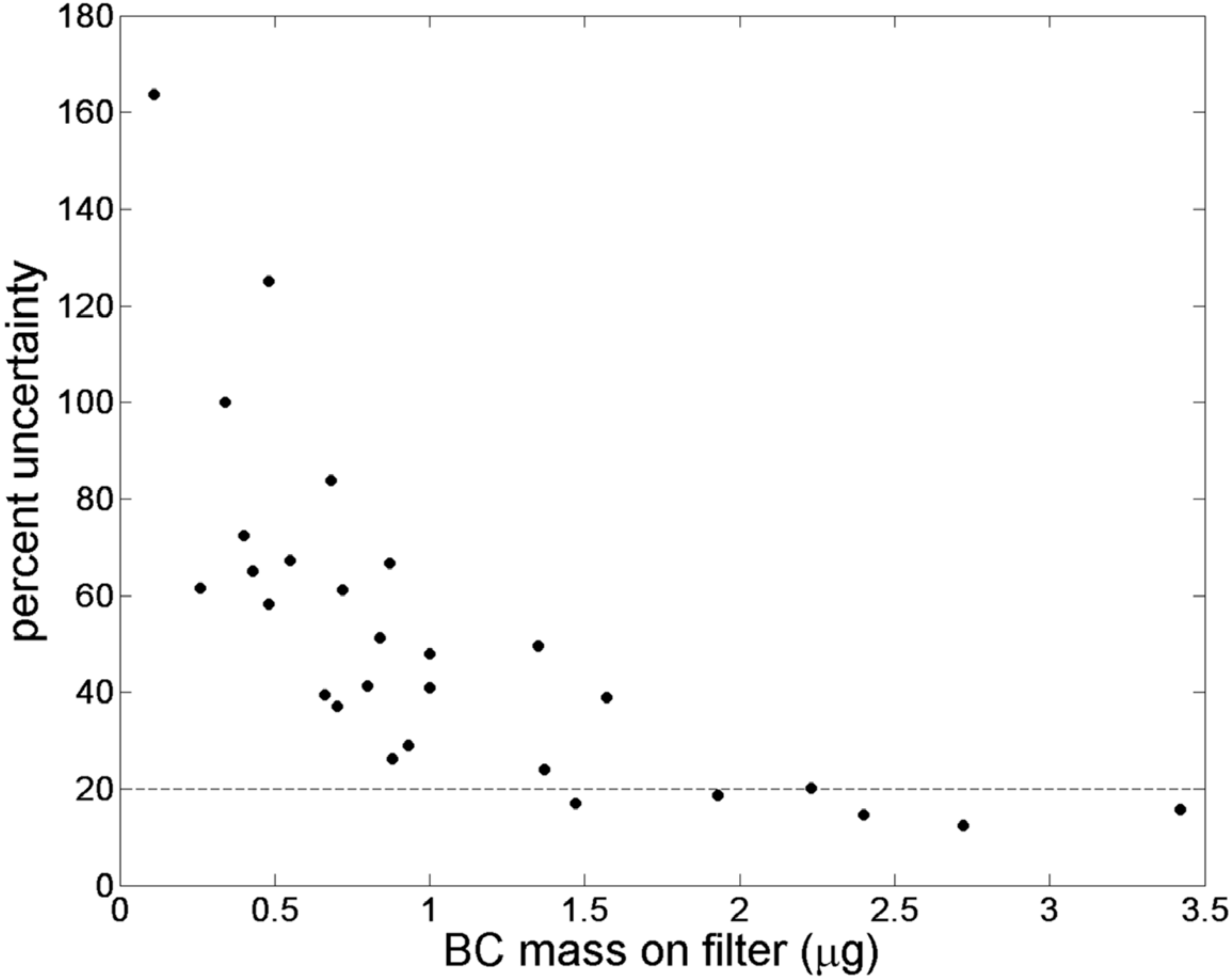
- Collector is automated to open and close during a precipitation event.
- Heated funnel melts the snow.
- Precipitation is collected in discrete daily samples.
- Data logger records time, intensity, and duration of each event.
- Collects up to 8 days of precipitation.

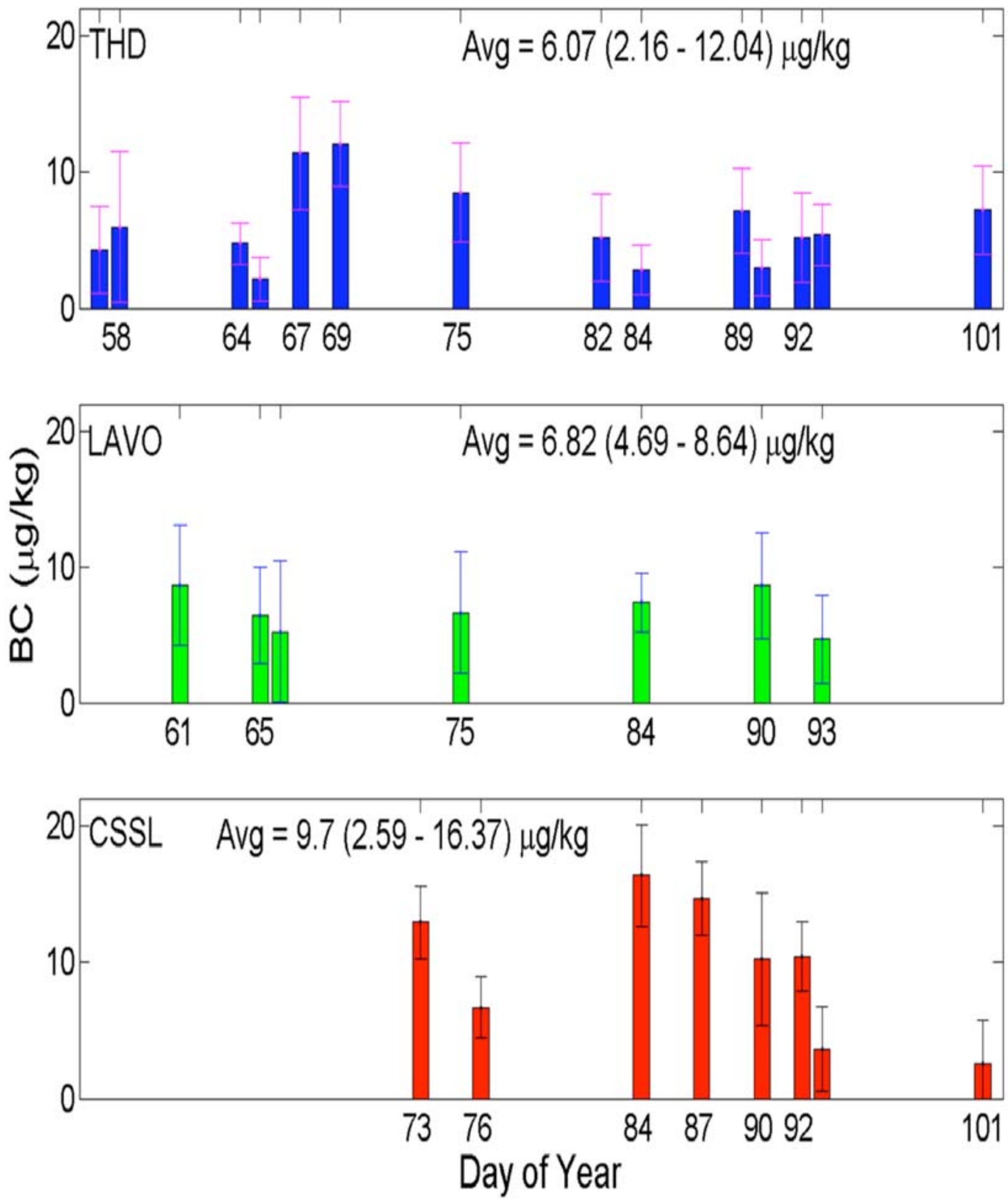
Analysis Procedures

- Samples are triple filtered through quartz fiber filters. (92 ± 7% recovery)

- Combine optical and thermally evolved CO_2 measurements to determine BC mass.
  - Use wavelength spectral dependence of light absorption to separate black carbon signal from the charring organic interference.

Uncertainty in the measurement





Measured BC in CA precipitation

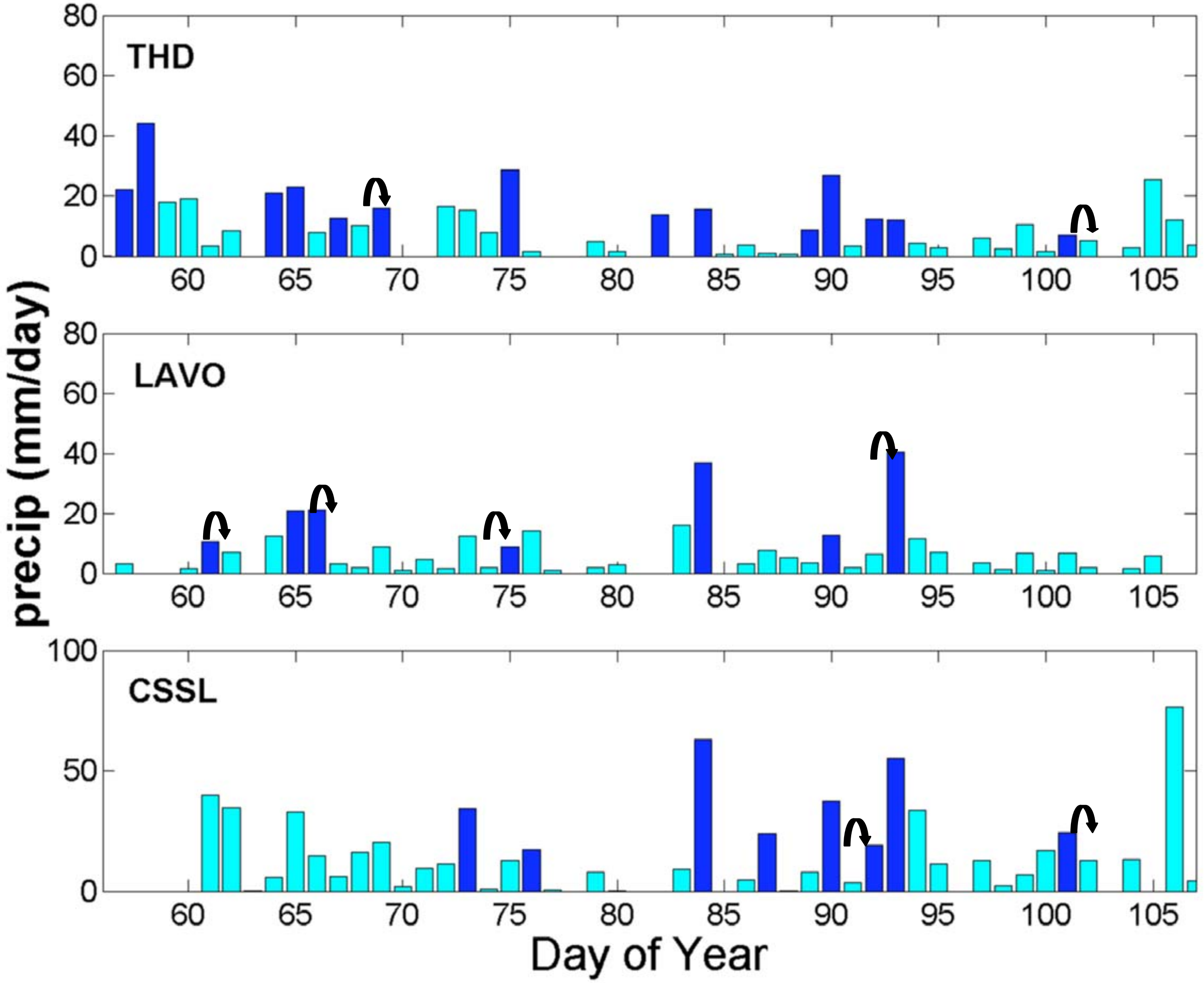
- Average BC conc. is not significantly different between the sites.
- May be biases due to preferential analysis of samples from high volume precipitation days.

Factors controlling BC concentration in Precipitation

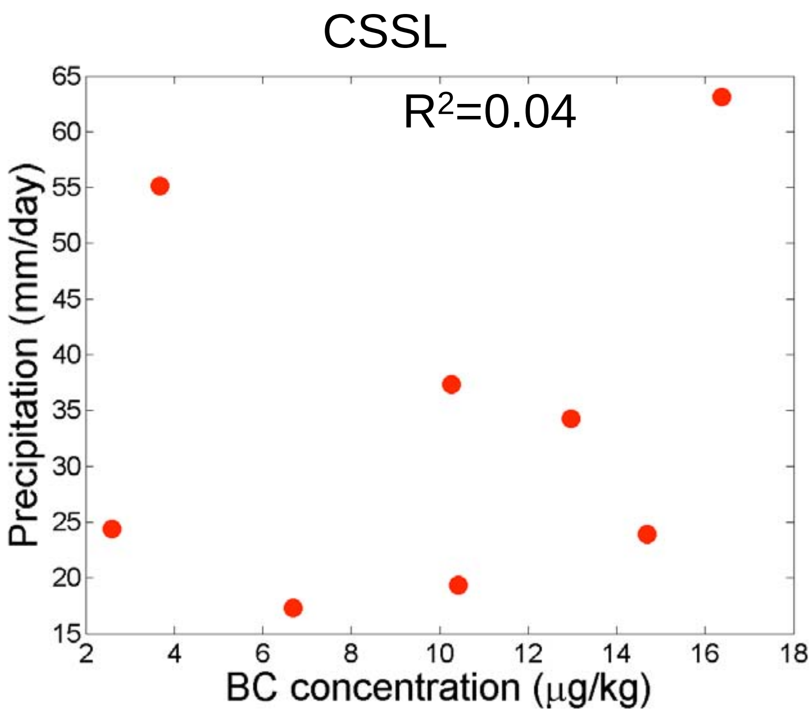
- Concentrations of BC particles:
  - Incorporated into drops during cloud formation (Rain-out)
  - Captured by falling rain or snow (Wash-out)

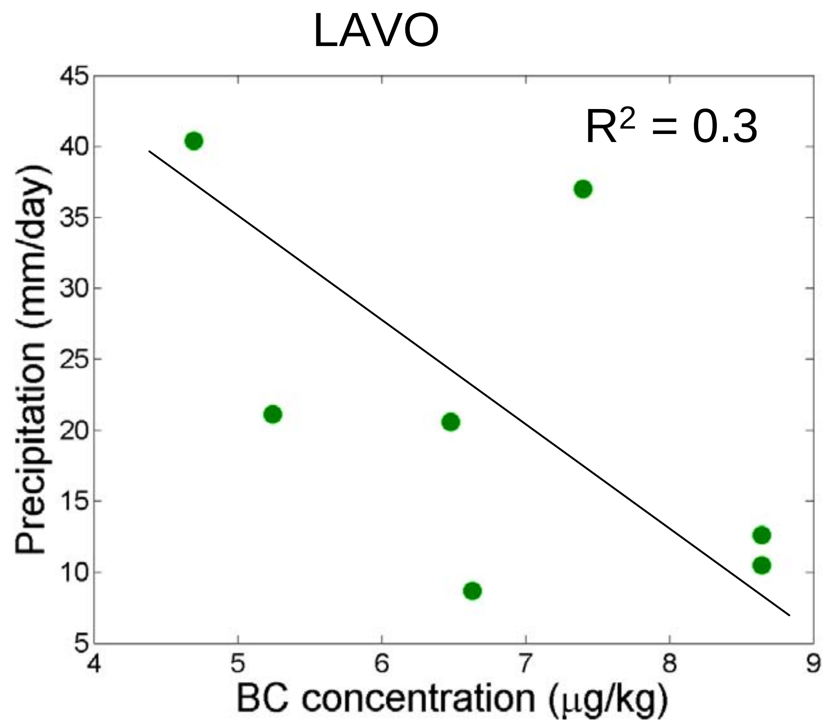
- Available atmospheric water to dilute BC concentration.

Total vs. sampled precipitation



Does event intensity affect BC concentration?

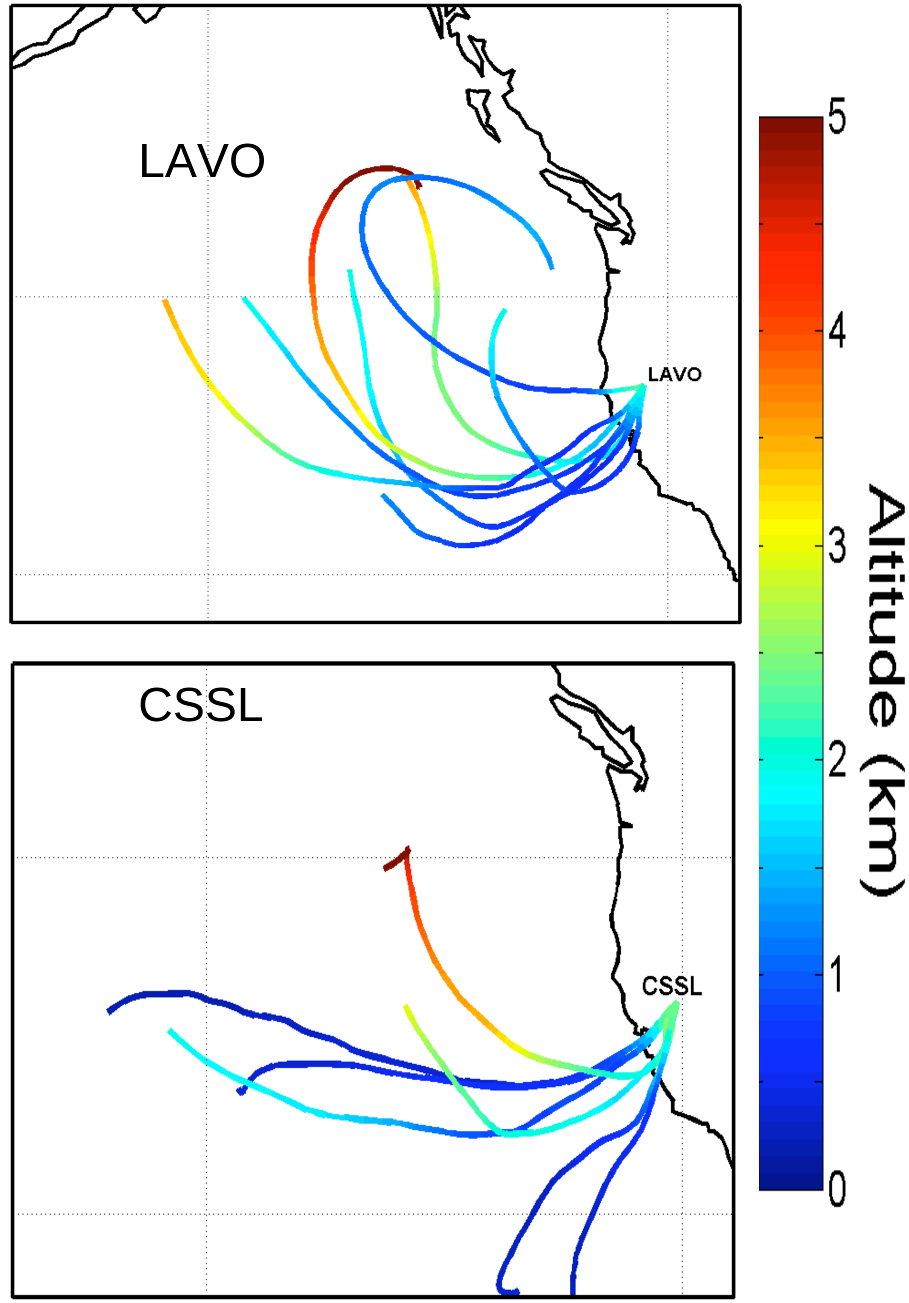




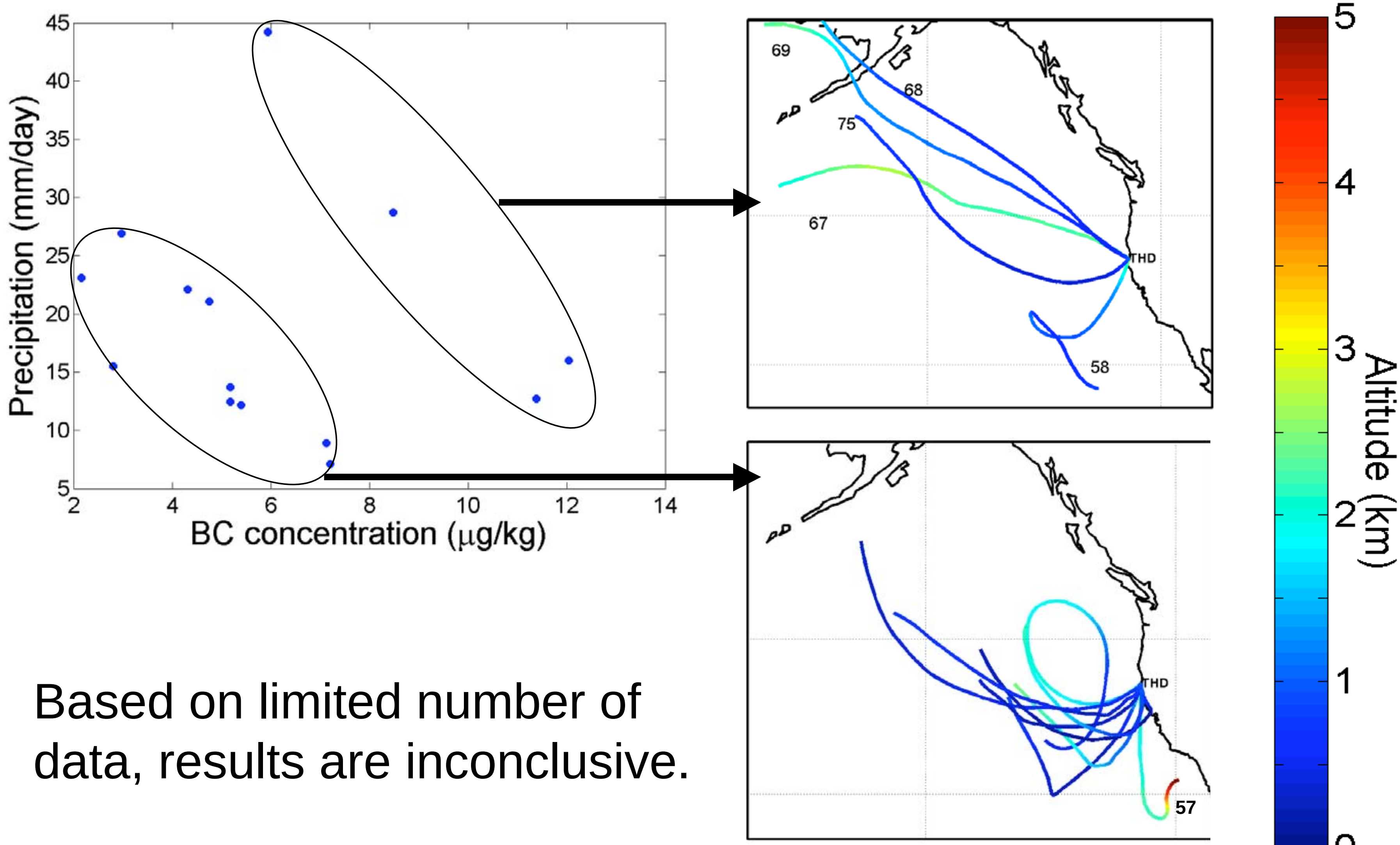
- Weak, negative correlation at LAVO
- No correlation at CSSL
- Results are inconclusive based on data available;
- Possible that a negative bias on reported concentrations may exist.

- Trajectories are similar for all sampled precipitation days

- BC in snow is probably predominantly local.



Long range transport may contribute to soot in coastal rain…



- Based on limited number of data, results are inconclusive.

Implications for CA climate

Modeled

Flanner et al (2007)

- 10 – 22 ng/g BC in snow for N. CA. (from global model output)

Jacobson (2006) CEC climate conference) model:

- 2.3 ng/g BC in snow
- 11 ng/g BC in rain

Measured

CSSL (snow)

9.7(2.6 – 16.4) ng/g of BC in snow

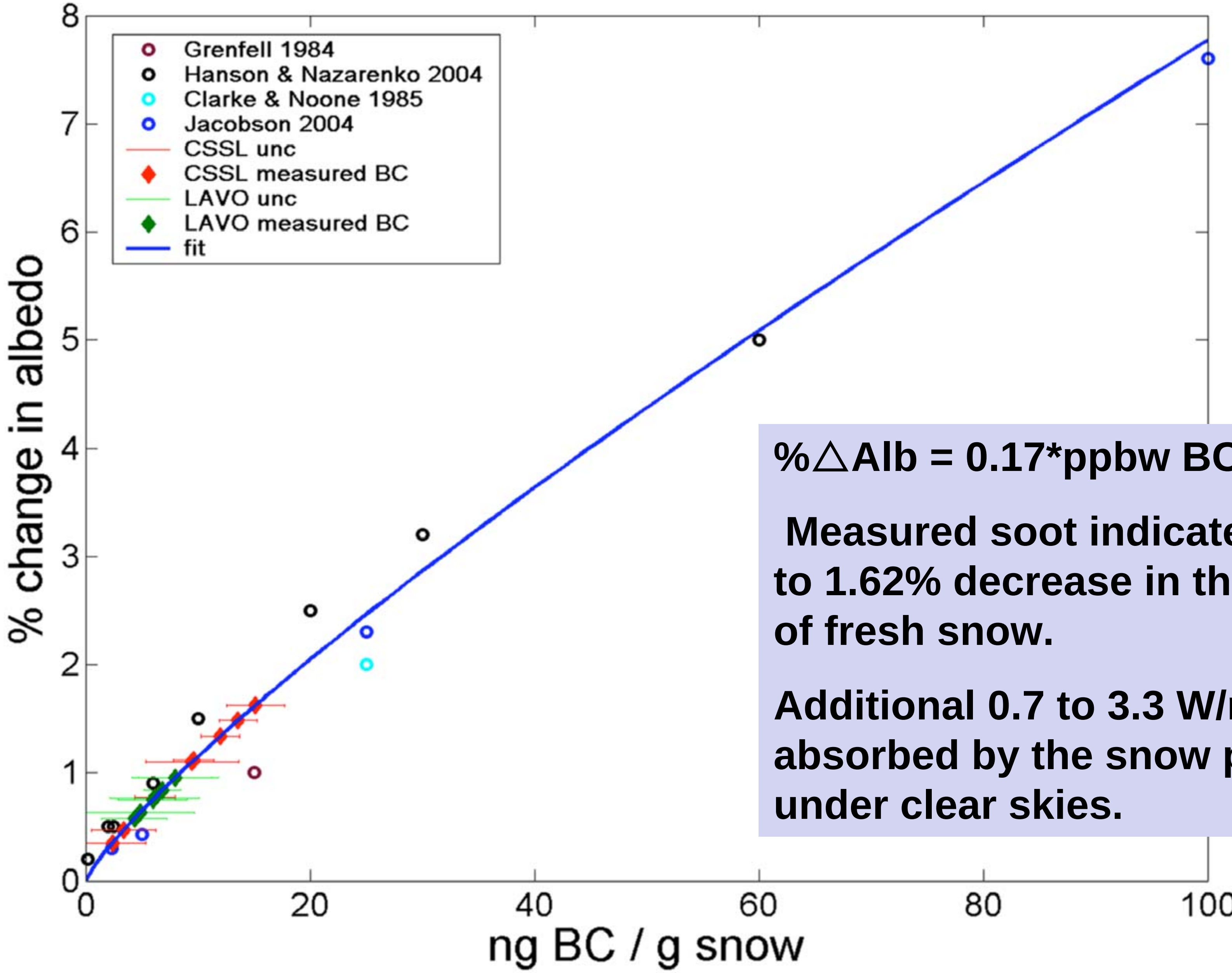
LAVO (snow)

6.8 (4.7 – 8.6) ng/g of BC in snow

THD (rain)

6.1 (2.2 – 12.0) ng/g of BC in snow

Modeled effect of BC on albedo (vis) of fresh snow



%△Alb = 0.17*ppbw BC$^{0.83}$

Measured soot indicates a 0.35 to 1.62% decrease in the albedo of fresh snow.

Additional 0.7 to 3.3 W/m^2 absorbed by the snow pack under clear skies.

Further considerations:

- All models show that as snow ages
  - the r_e of snow crystals increases
  - the effect of BC on albedo for large crystals (1000 μm) is 3 times greater than in fresh snow (100 μm).
- It is unknown how the BC is deposited through the snow pack during melt conditions
  - If soot is concentrated in snow rather than washed out, the positive feedback accelerating late season melting would be substantial.

Conclusions

- Average BC concentration measured in CA mountain snow is:
  - 6.8 ng/g at LAVO (4.7 to 8.6 ng/g)
  - 9.7 ng/g at CSSL (2.5 to 16.4 ng/g)
- May reduce fresh snow albedo by 0.3 to 1.6%, with increasing impact as snow ages.

Future studies:

- Include disdrometers to measure snow crystal and rain drop size distribution.
- Include radiation measurements of snow surface albedo.
- Collect and analyze snow pack cores, as well as falling snow.
- Larger collection funnels
  - Reduce event intensity bias by allowing more sample to be collected on lighter precipitation days.

Acknowledgments

- Guido Franco and the California Energy Commission
- Steven S. Cliff, University of California, Davis
- Randall Osterhuber, Central Sierra Snow Lab
- Michael Ives, Humboldt State Marine Lab
- Nancy Nordensten and Michael Magnuson, National Park Service
- Don Lucas and Amara Holder, LBL
- T. Novakov
- Jefferey Aguiar, LBL