Does snowpack sensitivity to warming temperature differ across the east/west divide of the Oregon Cascades?

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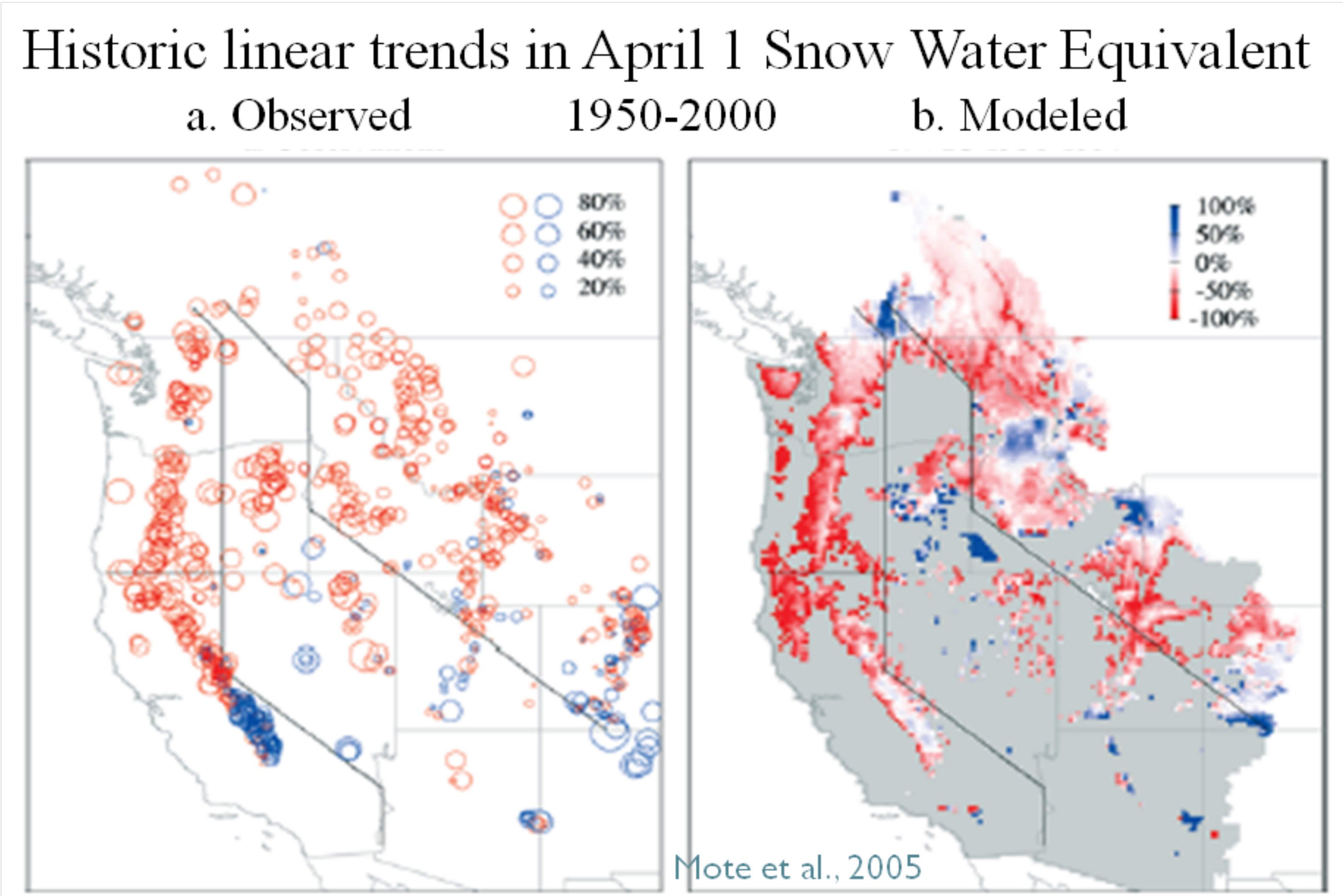
Outline

- Snowpacks are gradually diminishing in the PNW
- Watershed-scale impacts are uncertain
- We are modeling sensitivity in watersheds on east and west side of Cascades
- We quantify sensitivity vs. elevation, volumetric loss of peak SWE, and average snowpack with 2^{o}C warming
- We compare temperature lapse rates from two commonly used model forcing datasets
- Revisit of warming impacts
- Conclusions

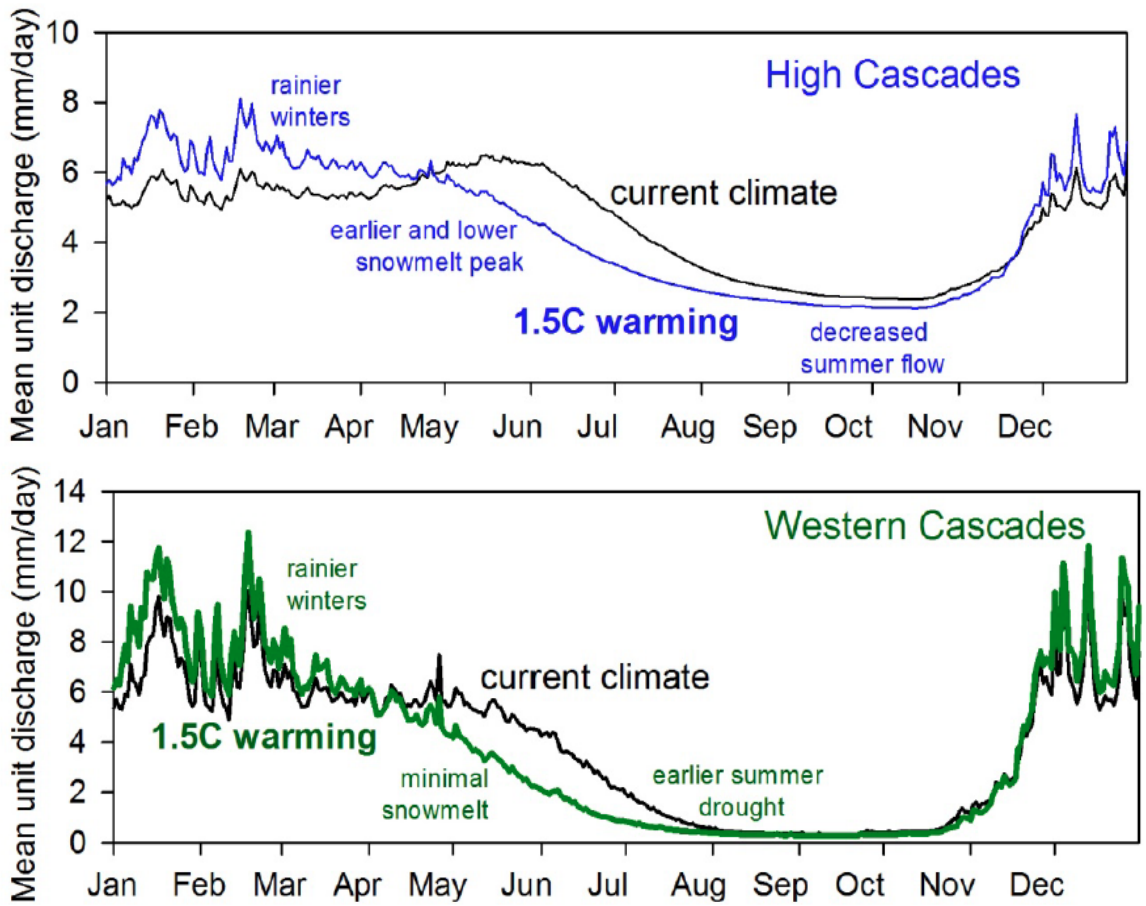
Snowmelt provides water for irrigation, fish, recreation, and municipalities

Snowpacks are gradually diminishing



How will these regional trends emerge at the watershed scale?

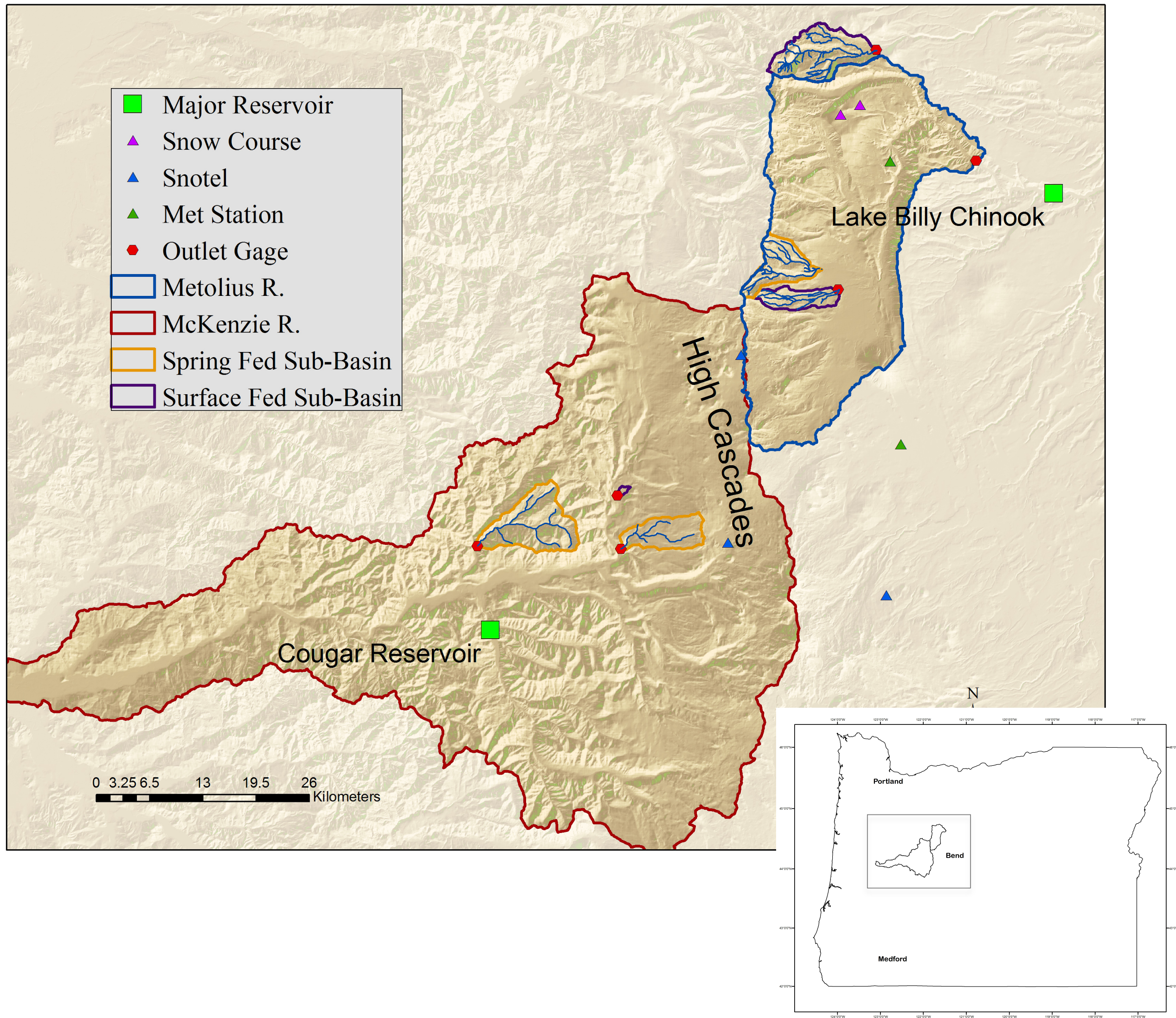
Modeled Change in streamflow – McKenzie R. Basin + 1.5 °C (Courtesy Naomi Tague)



West and east-side study watersheds

West – McKenzie
- Frontal (2000 mm)
- Humid (82% RH)
- 3.8°C wet day T
- Deep snowpack

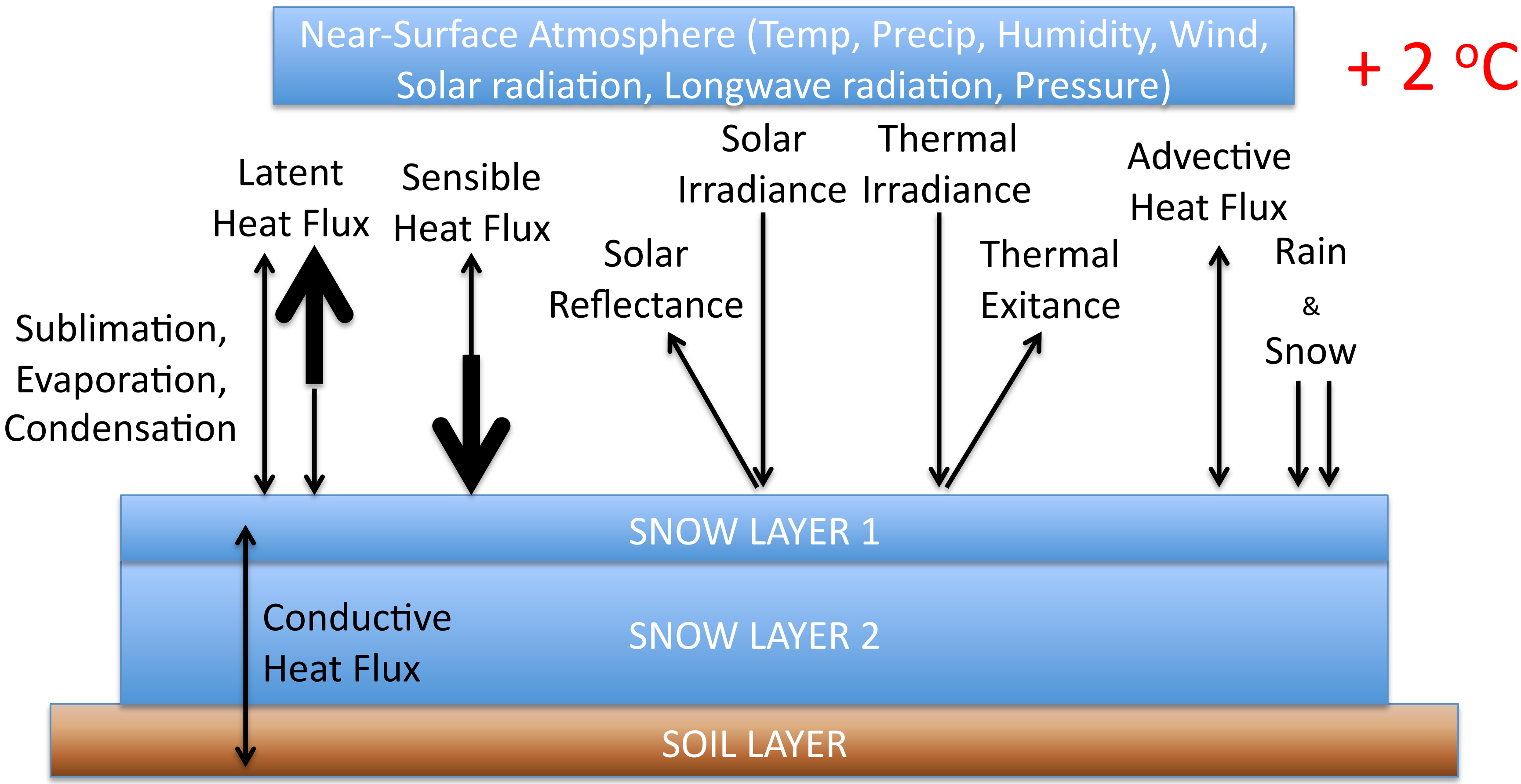
East – Deschutes
- Leeward (600 mm)
- Dry (72% RH)
- 4.4°C wet day T
- Shallow snowpack



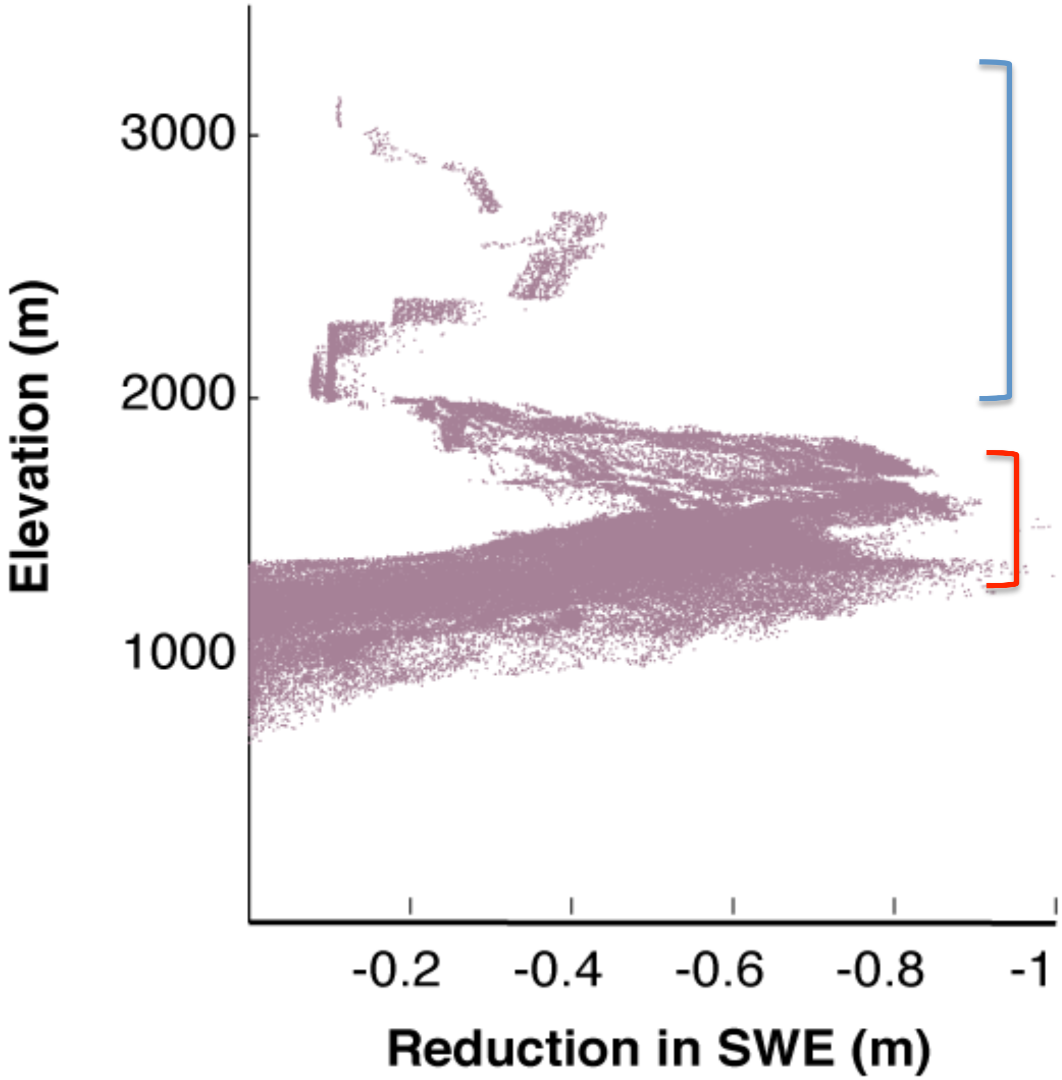
The snowmelt energy balance model

(*SnowModel*, Liston and Elder, 2006)

- We quantify seasonal snow accumulation and melt for 1989 – 2011
- Apply 2 ^{o}C warming scenario to test the response of the snowpack



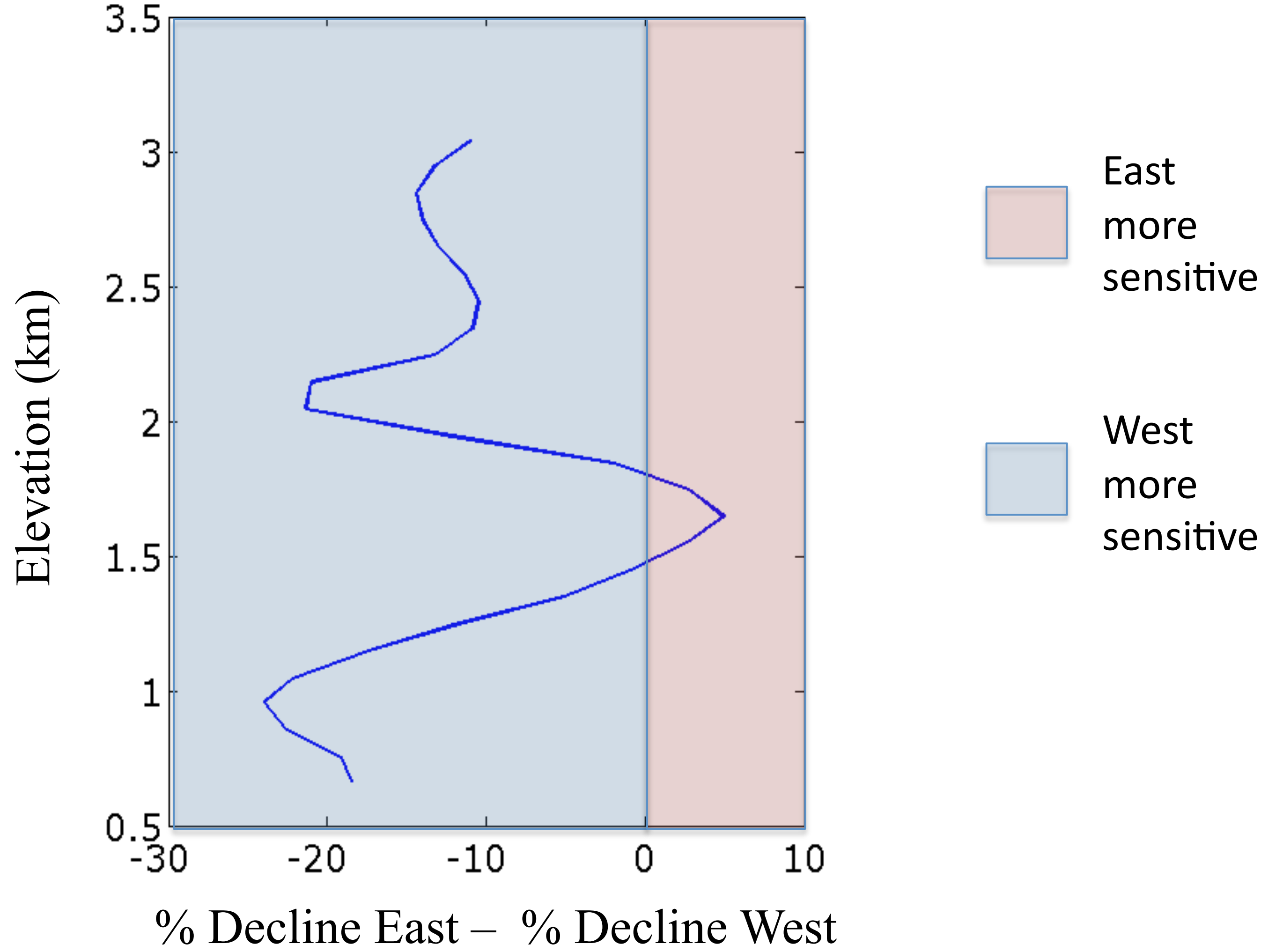
Research question – how does sensitivity vary with elevation?



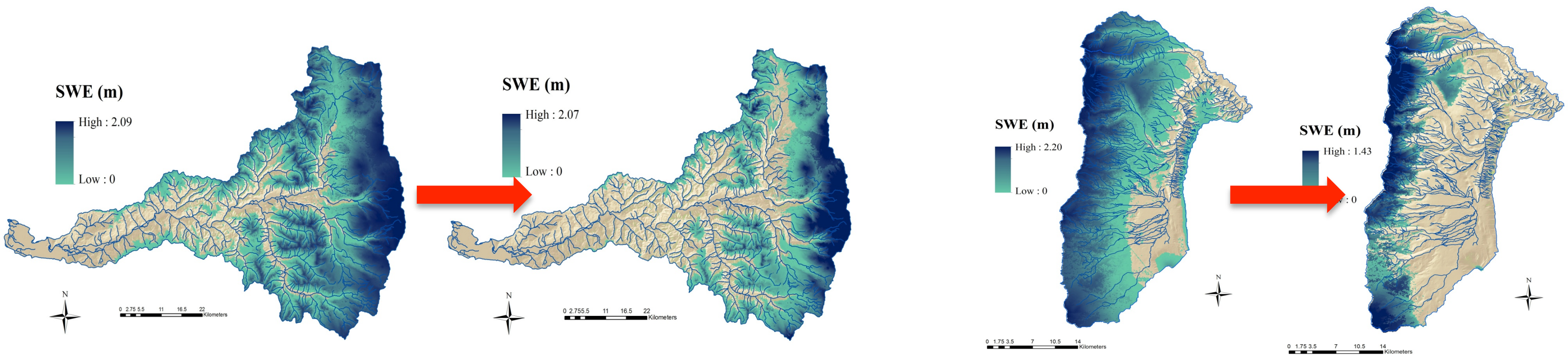
Snowpack less sensitive to warming

Snowpack more sensitive to warming
(Sproles et al. 2013)

Model results suggest the west side is more sensitive across most elevations



How does the total volume of SWE change on the west vs. the east?



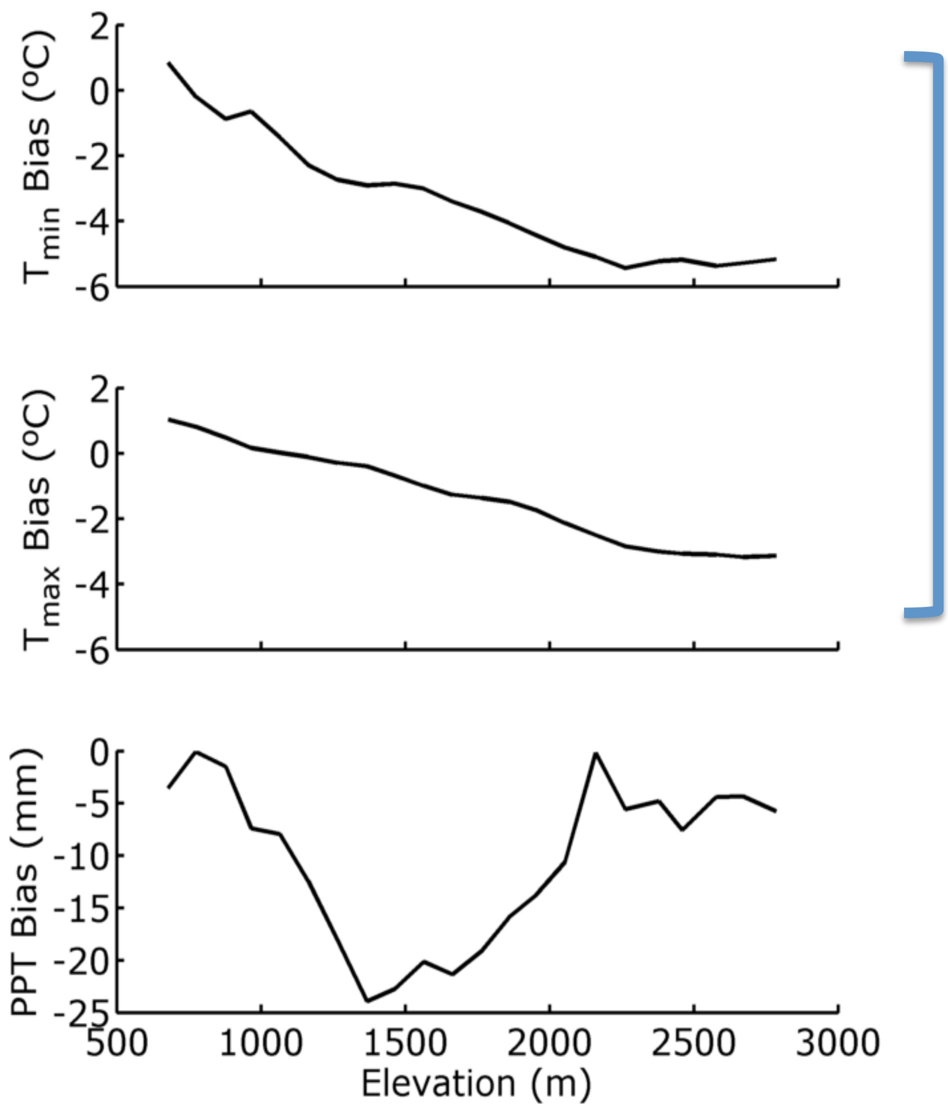
56% reduction in peak Snow Water Equivalent

0.82 km^3
~ 300% capacity of Cougar Reservoir

30% reduction in peak Snow Water Equivalent

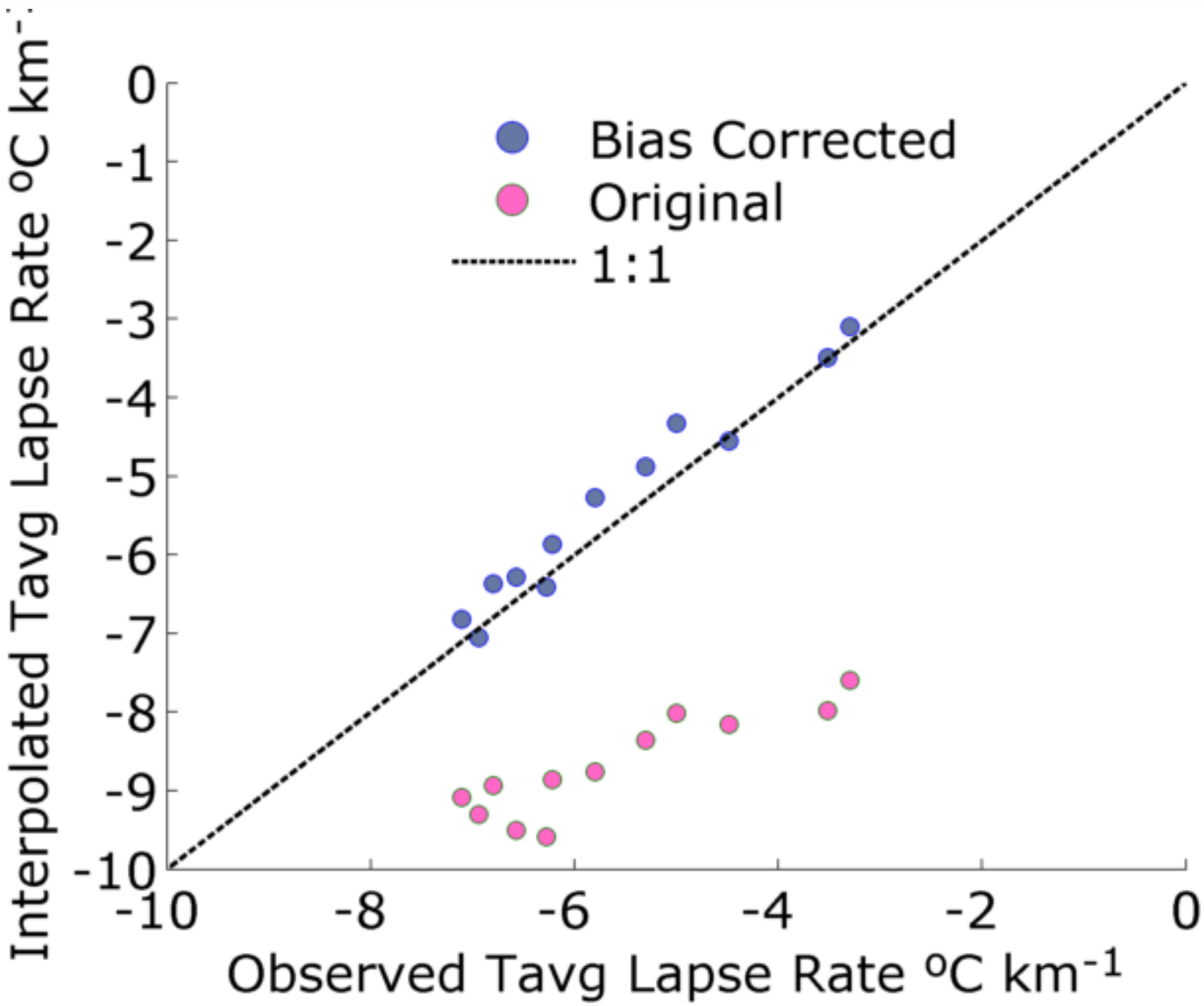
0.16 km^3
~ 40% capacity of Lake Billy Chinook

But, east-side model forcing data has a cold bias

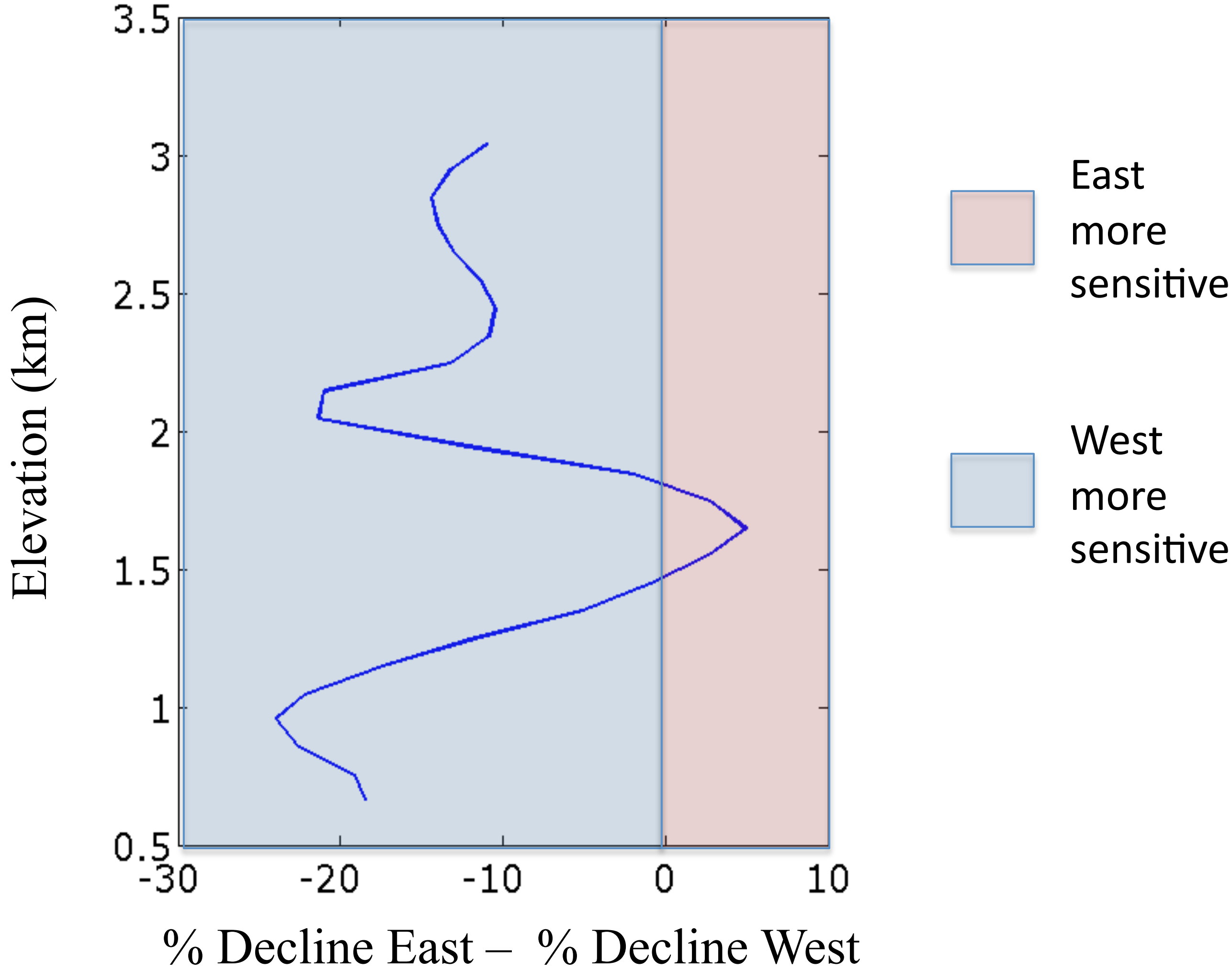


Temperature bias increases with increasing elevation

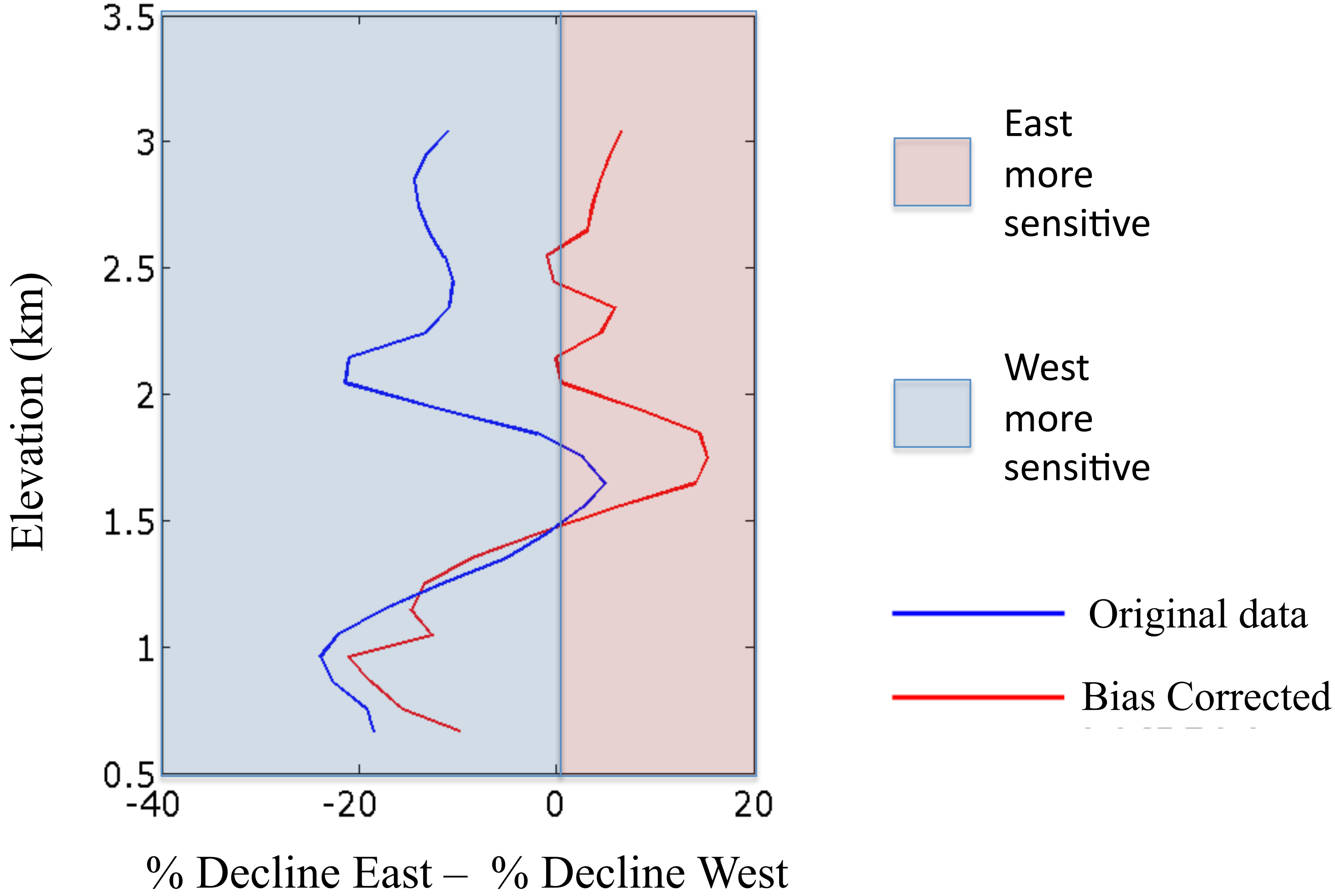
Bias corrected monthly temperature lapse rates



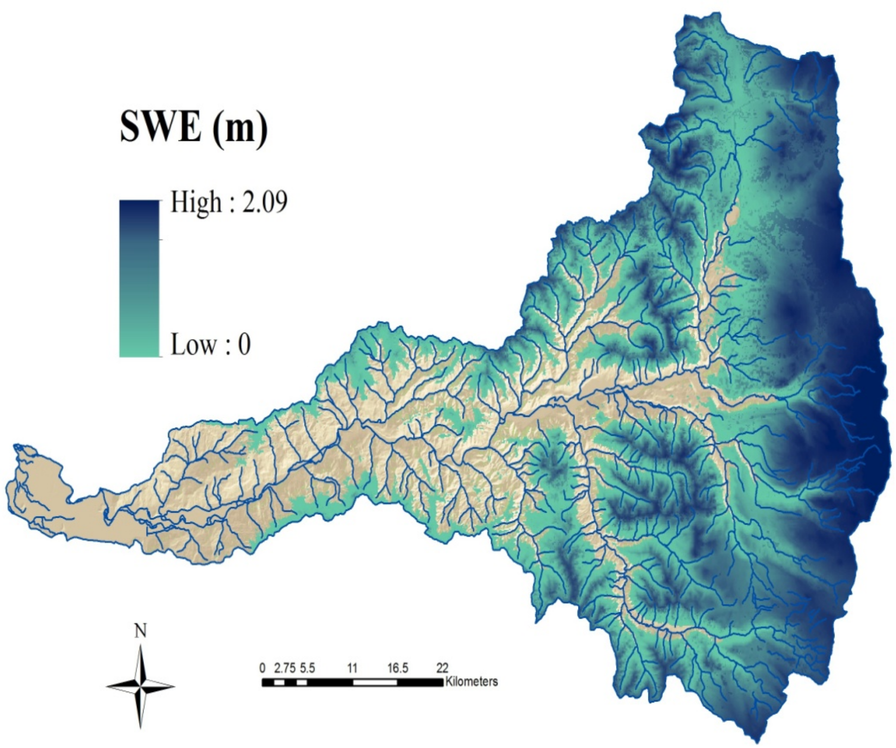
Original data suggests the west side is more sensitive across most elevations

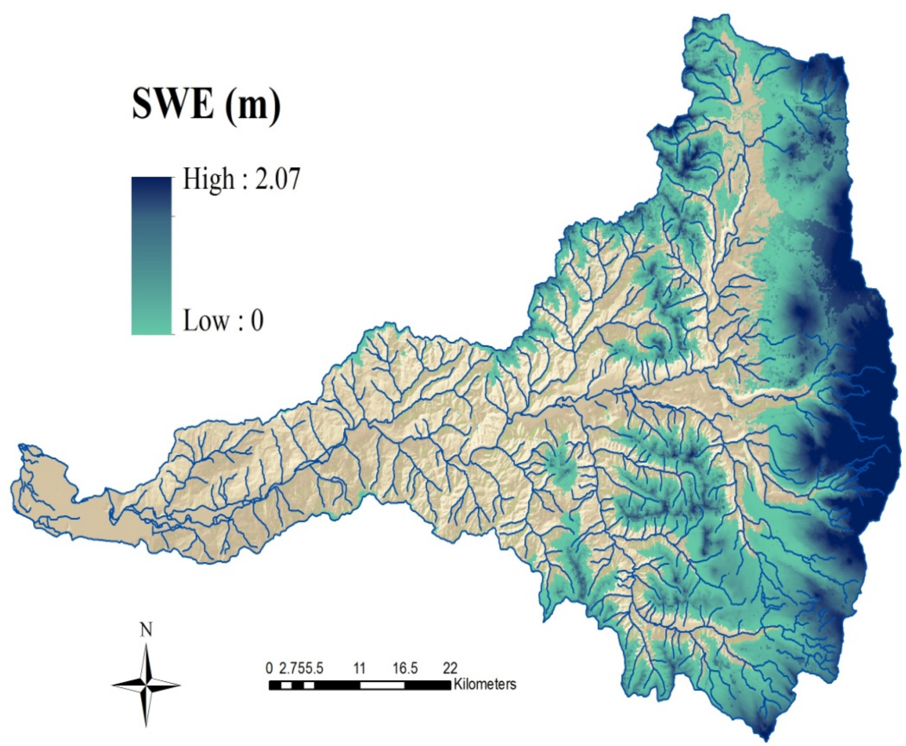


Bias corrected data suggests that sensitivity is similar on each side at high elevations

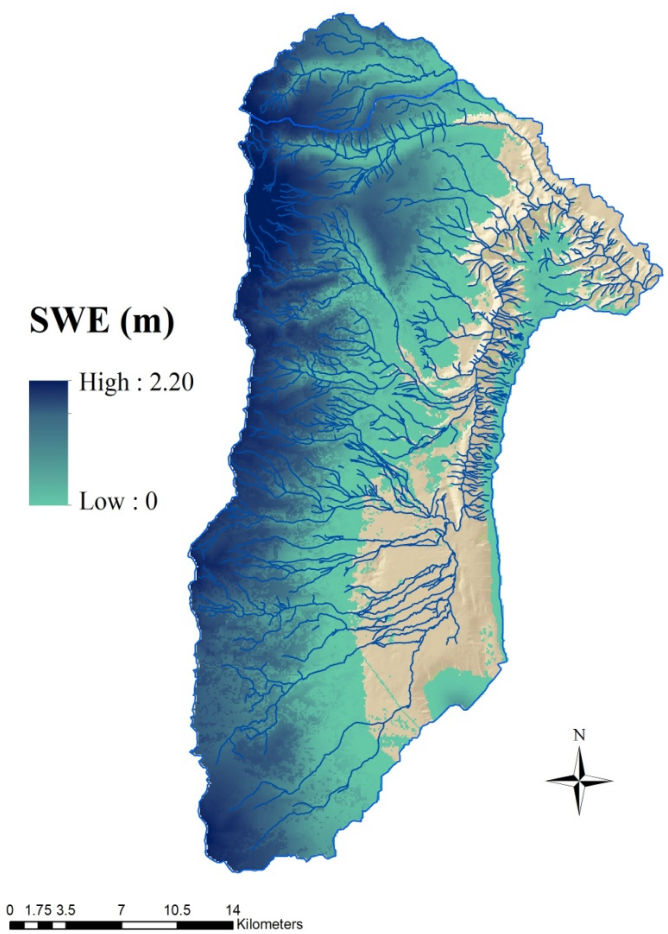


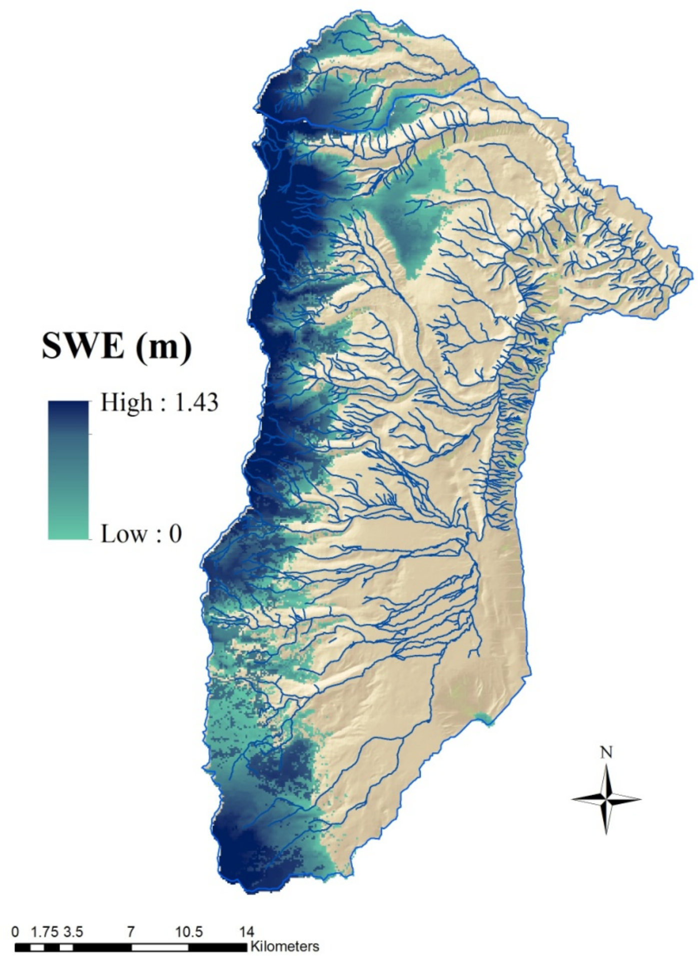
56% reduction in peak volumetric snowpack – west side +2°C warming





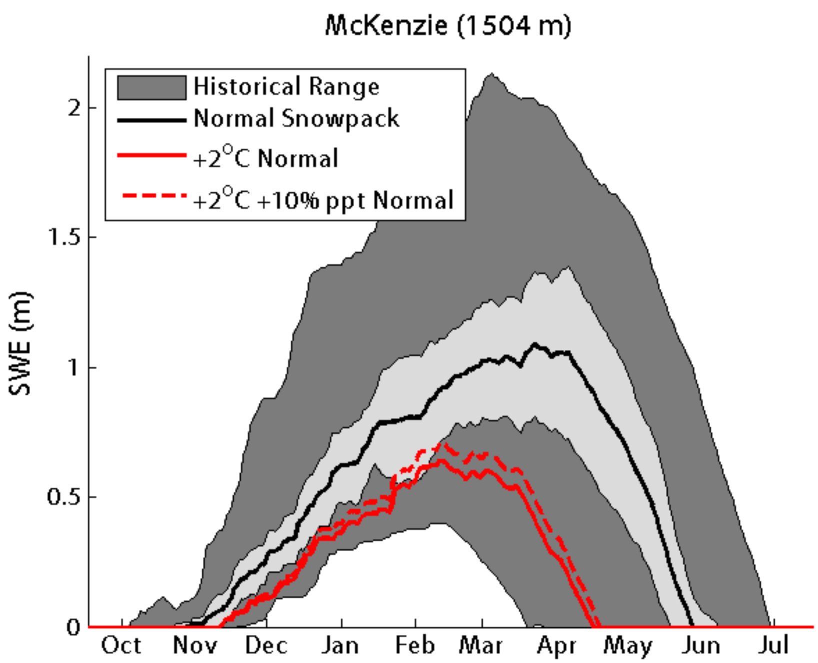
60% reduction in peak volumetric snowpack – east side +2°C warming



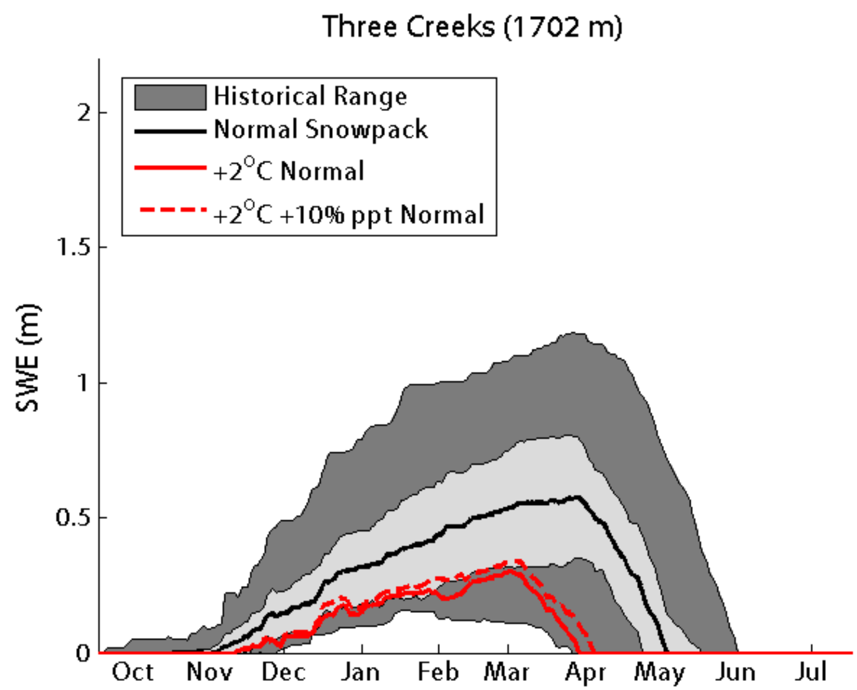


+2°C average conditions are in lowest percentiles of historical variability

West Side 2°C warming



East Side 2°C warming



What are the implications of a 2ºC warming for water resources in the region?

East

60% Basin-wide loss in peak SWE – Deschutes

0.32 km^3 difference in peak SWE, equivalent to

82% of Lake Billy Chinook's capacity, the largest reservoir in the basin

West

56% Basin-wide loss in peak SWE – McKenzie

0.8 km^3 difference in peak SWE, equivalent to

300% of Cougar Reservoir's capacity, the largest reservoir in the basin

Findings

- Warming impacts on snow on both sides of the range are significant – over 50% of volumetric peak SWE loss
- Sensitivity is similar on the east and west side at high elevations
- Biased lapse rates, either implicit in the forcing data or prescribed as parameters, can change these conclusions
- Large-scale gridded data has limitations when applied at the watershed scale

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Questions?

Thank you!

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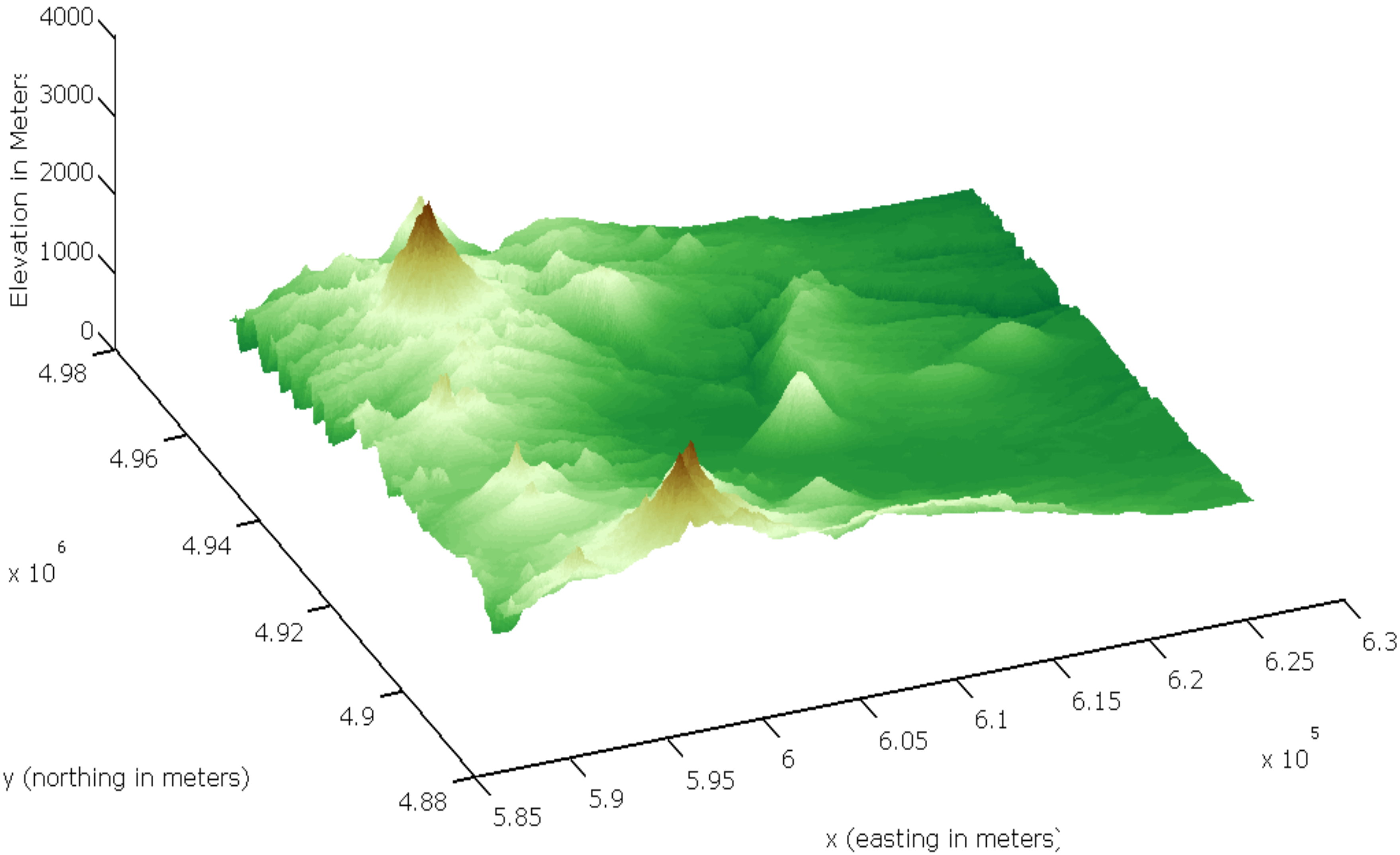
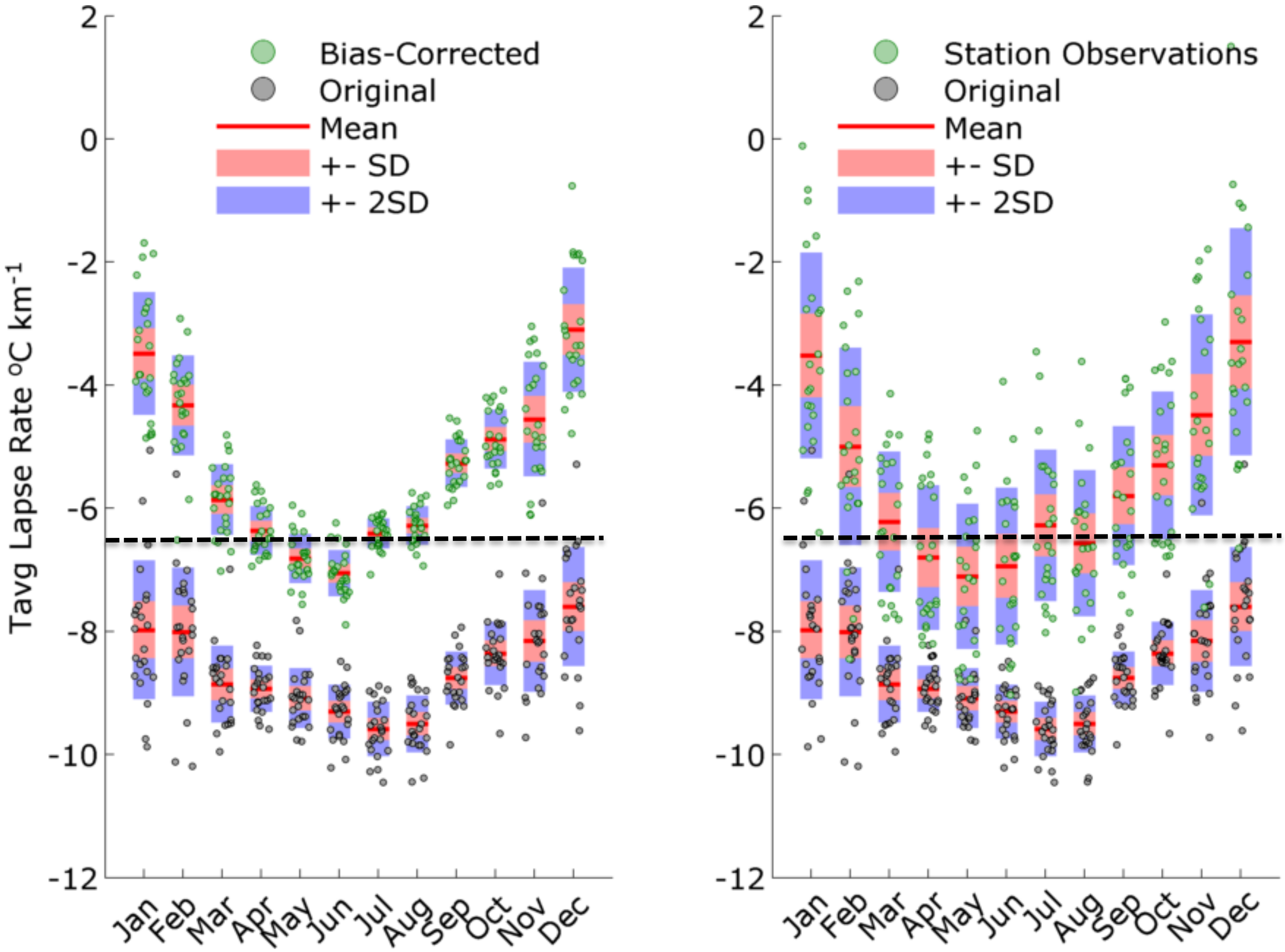
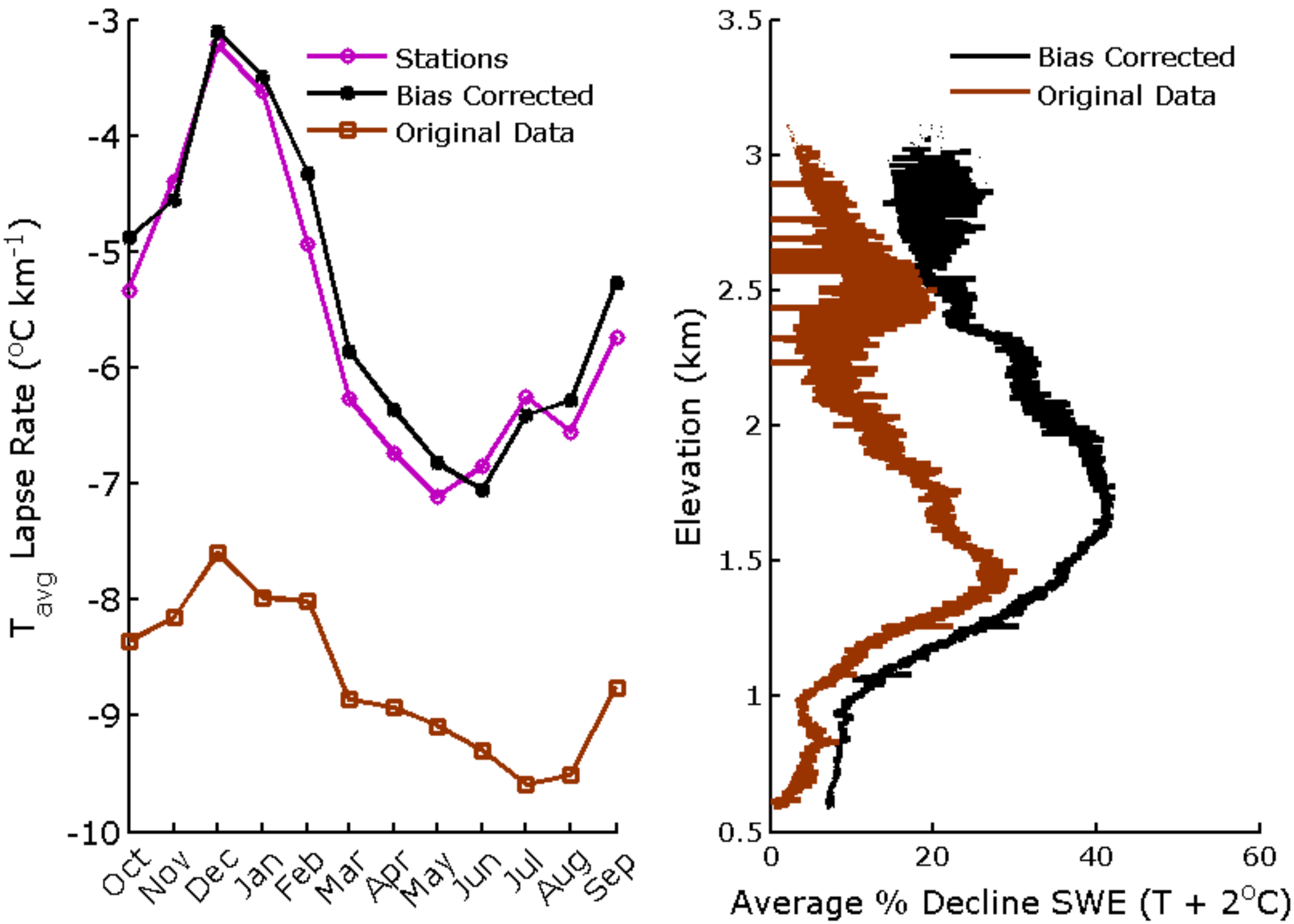
East-side modeling domain



Seasonal variability of lapse rates – gridded datasets compared to observations





-3
-4
-5
-6
-7
-8
-9
-10
T_{avg} Lapse Rate (^oC km^{-1})
Stations
Bias Corrected
Original Data
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
3.5
3
2.5
2
1.5
1
0.5
Elevation (km)
Bias Corrected
Original Data
0
20
40
60
Average % Decline SWE (T + 2^{o}C)

Bias Correction

(Watanabe et al. 2012)

- Use the **ratio method** for precipitation

$$ppt_{corrected,i} = ppt_{0,i} \times \frac{ppt_{PRISM,normal_i}}{ppt_{CIG,normal_i}}$$

- Use the **delta method** for temperature

$$temp_{corr,i} = temp_{0,i} + (temp_{PRISM,i} - temp_{CIG,i})$$