Elevational and Seasonal Dependence in Climate Change Within a Mid-latitude High Mountain System, Colorado Front Range USA

Jennifer F. Morse[1], Timothy G.F. Kittel[1], Mark W. Williams[1], Kurt Chowanski[1], Michael Hartman[2], Todd Ackerman[1], Mark Losleben[3], and Peter Blanken[4]

[1]The Institute of Arctic and Alpine Research, University of Colorado Boulder, [2]National Oceanic and Atmospheric Administration, [3]Laboratory of Tree-Ring Research, University of Arizona, [4]Department of Geography, University of Colorado Boulder

We contrasted 59-year (1952-2010) climate records of two high-elevation sites in the Colorado Rocky Mountains Front Range, USA; one a subalpine forest (3021 m asl) and the other high alpine tundra (3739 m asl), to evaluate the degree of synchrony versus decoupling in their long-term climate trends.

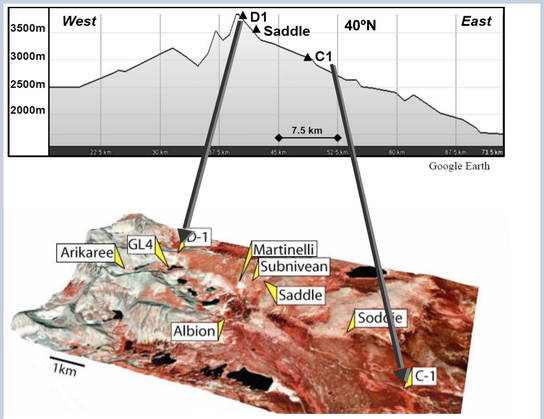


Figure 1

Figure 1. Location of Niwot Ridge subalpine (C1) and high alpine (D1) climate stations in context of Colorado Front Range west-east topographic profile along ~40ºN latitude (from Google Earth) and local geomorphology and vegetation cover (Bowman and Seastedt 2001).

59 Year Record Results:

Subalpine (C1):

- T max (annual average maximum air temperature) increased (+0.42ºC per decade).
- No significant change in T min (annual average minimum air temperature) or total annual precipitation
- Mirrors or amplifies regional signal in T max and precipitation, departure from regional signal in T min.

Alpine (D1):

- No significant change in T max or T min
- Increase in total annual precipitation (Figure 2) with most of this increase during the cold season of October through April (Figure 5).
- Decoupling from regional trends in cold season.

Figure 2. Record precipitation annual time series for subalpine (C1) and high alpine (D1) stations.

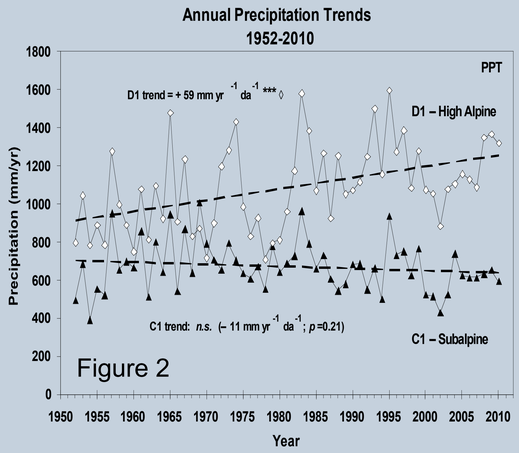
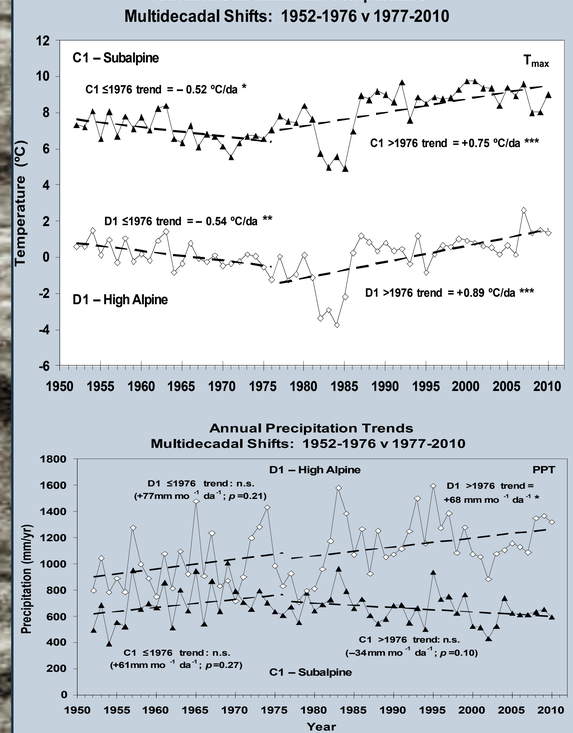


Figure 2

Record annual trends mask a more complex pattern: that there were significant and strongly different trends by season, and by early and late portions of the record.

Figure 3. Partial trends in alpine and subalpine annual mean Tmax and precipitation.



A 1976 PDO regime shift is roughly concurrent with a break in Niwot Ridge and western US temperature and precipitation trends (Pepin and Losleben 2002).

Figures 4-6. Monthly Trends in precipitation, maximum temperature, and minimum temperature for subalpine (C1) and high alpine (D1) stations.

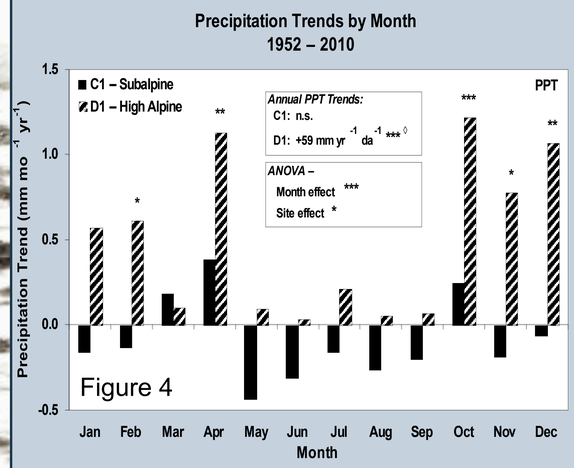
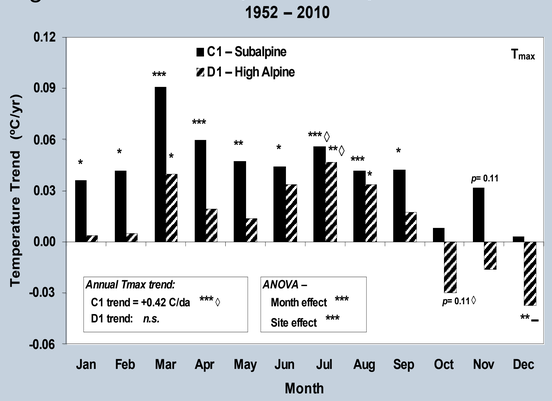


Figure 4

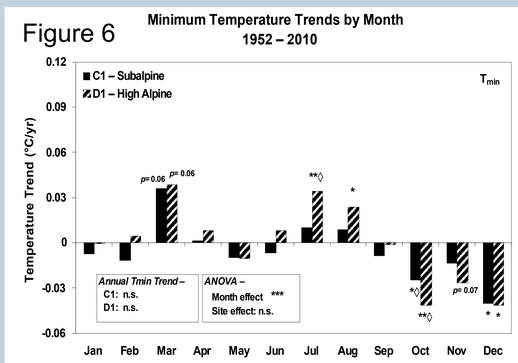
Increased snow fall at alpine site in early winter (October through November) may account for decrease in temperature due to snow cover caused changes in surface energy flux.

Figure 5



Nocturnal drainage flows advect alpine air downslope into the subalpine and may explain departure of subalpine site from regional T min trends.

Figure 6



Arikaree glacier is dying

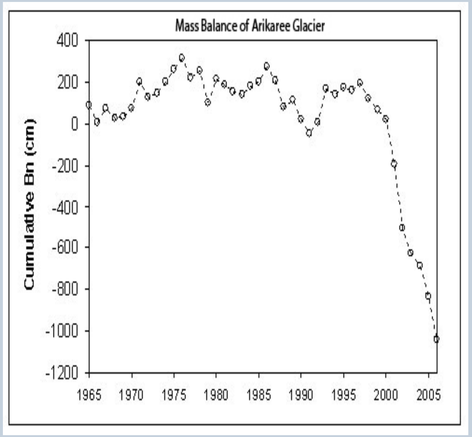


Figure 7. Arikaree Glacier: Mass balance (Bn), cm water equivalent.

The decline of the Arikaree glacier (see Figure 1 for location) during a drought in the early 2000's indicates a possible tipping point and highlights the importance of surface energy budgets in mountain climates.

Implications:

The dichotomy of alpine versus subalpine response to climate dynamics has implications for thresholds and tipping points in snow cover-altered surface energetics in high mountain regions above or at mean melt-line.

References

Bowman, W.D. and T.R. Seastedt. 2001. *Structure and Function of an Alpine Ecosystem. Niwot Ridge, Colorado*. Oxford University Press, New York.

Pepin, N.C., and M.L. Losleben. 2002. Climate change in the Colorado Rocky Mountains: Free-Air versus surface temperature trends. International Journal of Climatology 22: 311-329.