Warming Trends in the Colorado Mountains: A Comparison of SNOTEL and COOP Data

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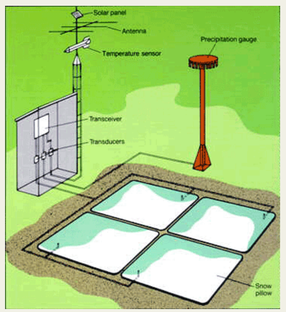
Colorado's Water Supply

The Colorado mountains are the main supply of water for over 40 million people and 5.5 million acres of irrigated land (Deems et al., 2013). If temperatures are warming at high altitude, delayed snow accumulation coupled with earlier spring snowmelt could lead to a net decrease in snowpack. This would have grave consequences for Colorado and the surrounding western states.

Snow Telemetry System (SNOTEL)



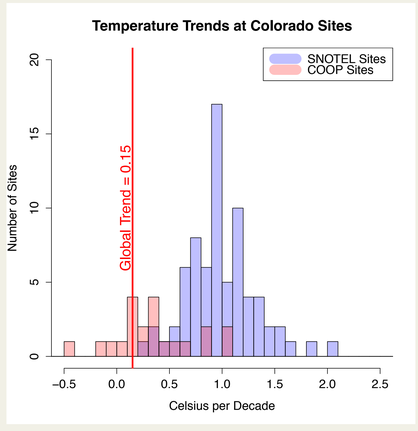
Nationalatlas.gov/articles/climate/a_snow.html

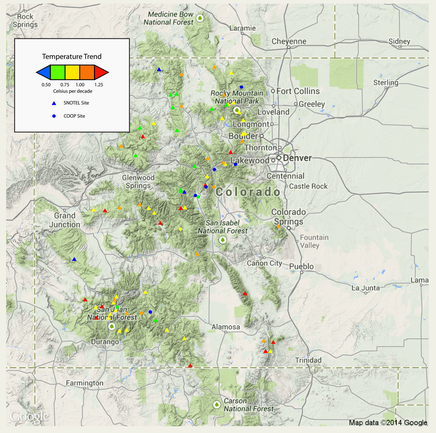
- Measures snow mass, depth, precipitation, and temperature
- 858 automated stations in 13 Western states
- Mainly in high wilderness areas

National Weather Service COOP Cooperative Observer Network

- 11,000 volunteer stations nationwide (automated and manual)
- Mainly in areas affected by human activity

Warming Trends ?

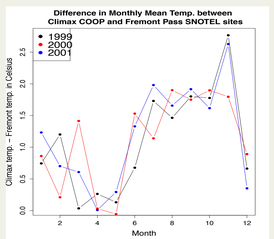


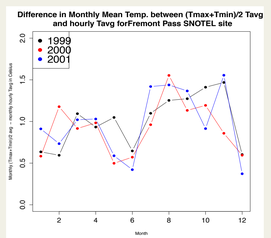


- Colorado SNOTEL sites show an average warming trend of 1.00 ^{o}C per decade, much higher than the average global trend of 0.15 ^{o}C per decade
- Colorado COOP sites at an equivalent elevation (> 8500 ft) show an average trend of 0.29 ^{o}C per decade
- SNOTEL sites show the highest seasonal trends in fall (1.18 ^{o}C per decade) and winter (1.12 ^{o}C per decade)
- COOP sites show the highest seasonal trends in spring (0.54 ^{o}C per decade) and summer (0.33 ^{o}C per decade)

Climax COOP and Fremont Pass SNOTEL

- Sites are within 1.7km of each other – would expect similar temperature readings
- Difference plot of monthly mean temperatures shows COOP temp. > SNOTEL temp., and a periodic pattern
- COOP daily average temperature is found by daily (Tmax + Tmin)/2 ; SNOTEL daily average temperature is an average of 24 measurements, one per hour
- Similar pattern can be produced by taking difference plot of SNOTEL (Tmax + Tmin)/2 and 24-hourly avg.





Why the difference?

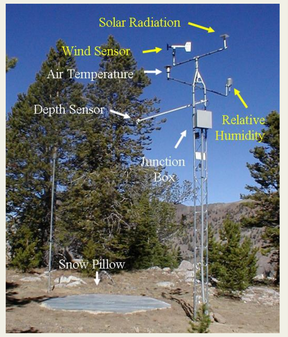
Grant, a representative COOP site

Vallecito, a representative SNOTEL site

A COOP Cotton Region Shelter

Differences between COOP and Snotel sites

- site location: COOP sites near human activity, very few at high altitudes; SNOTEL sites in high, remote locations
- COOP stations less standardized, can result in microclimates that obscure long-term temperature trends (Davey and Pielke, 2005)



A SNOTEL station

- type of enclosure: COOP instruments are often in a wooden shelter for shielding from direct sun, elements; SNOTEL temperature sensor is more exposed
- method of calculating average daily temperature: (Tmax + Tmin)/2 appears to produce a net positive bias compared to the average calculated from 24 hourly measurements. The appropriate weighting of Tmax varies with the number of daylight hours, and even near equinoxes, temperatures close to Tmax are short in duration at high elevations (Tmax is more often a spike than a plateau)

Implications

- Large alpine warming trend seen in SNOTEL data cannot be dismissed due to absence of same trend in COOP data
- Warming trends seen in SNOTEL data for other western mountain ranges
- Larger trend in fall/winter could be due to delayed snow accumulation, or to wind-borne dust deposits