#37497- Was California's winter 2013-14 really the warmest on record?

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1. Background

The National Climatic Data Center's (NCDC) gridded monthly climate data reported the 2013-14 winter, defined as November 1 to March 31, as the warmest winter on record at 9.94°C, marked by a circle in Figure 1. However, UCLA's California Surface Water Monitor (SWM) ranks the 2014 winter as the third warmest winter at 8.79°C, after 1934 and 1996; these three years are marked by a triangle in Figure 1. Figure 1 suggests that the difference in inferred long-term trends between the SWM and NCDC data sets may also be reflected in the relative magnitude of winter 2013-14 temperatures, which motivated us to examine several other data sets. In particular, we examine here the trends in six long-term data sets for California, and evaluate their estimates of winter 2013-14 and 2014-15 in an historical context.

Table 1 – Data sets, years of data accessed, and source

NCDC	1921 – 2015	http://www.ncdc.noaa.gov/cag/time-series/us
HCN[1]	1921 – 2013	http://cdiac.ornl.gov/epubs/ndp/ushcn/ushcn.html
SWM	1921 – 2015	Wood, AW, and DP Lettenmaier, 2006. *Bull. Amer. Met. Soc.*, **87**, 1699 – 1712.
PRISM[2]	1921 – 2014	Di Luzio, et al., 2008. *Amer. Meteor. Soc.*, **47**, 475 – 497.
BEST	1921 – 2014	Chen et al., 2002. *Amer. Meteor. Soc.*, **3**, 249 – 266.
VOSE	1921 – 2014	Vose, RS, et al., 2014. *J. App. Meteor. Clim.*, **53**, 1232 – 1251.

1. HCN – Historical Climatology Network
2. PRISM – Parameter-Elevation Relationships on Independent Slopes Model

2. Gridded Dataset Comparisons

The SWM gridded data were created by using the SYMAP algorithm of Shepard (1984): station data are used to find a long-term mean and resulting station anomalies. The station anomalies are then subtracted from the climatology of a published gridded data set, and the results are applied to a grid. The SWM winter average was constructed by taking an area-weighted average of daily data over the winter season. The data set grid encompasses the entire state of California. The NCDC, PRISM, BEST, and VOSE winter averages were compiled from the monthly statewide average values for minimum and maximum temperature. The NCDC monthly averages can be obtained from the source in Table 1. PRISM, BEST, and VOSE data were obtained from the Lahment-Doherty Earth Observatory.

Figure 1 – Average winter (Nov – Mar) temperatures for NCDC and SWM gridded datasets from 1921 – 2015. Circle marks the warmest temperatures (2014 and 2015) for NCDC while triangles mark the four warmest winters, 1934, 1996, 2014, and 2015 for SWM.

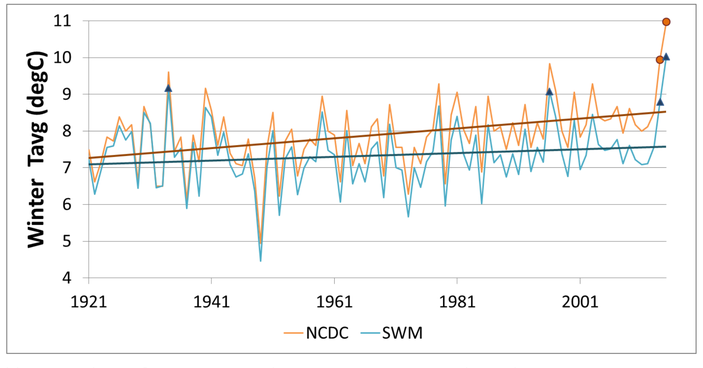


Table 2 – ranking of 2013-2014 and 2014-2015 winters and trends in winter temperature

	2013 - 14	2014 - 15	Trend in degC/100 years
NCDC	2ND	1ST	1.34
SWM	4TH	1ST	0.51
PRISM	1ST	NA	1.02
BEST	1ST	NA	1.00
VOSE	1ST	NA	1.16

SWM and NCDC agree that the 2014-15 winter is the warmest winter on record. All gridded data sets except SWM agree that 2013-14 winter is the warmest winter experienced up to that year, whereas SWM has the 2013-14 winter as the third warmest winter up to that year. However, regression estimates of trends from 1921 to 2015 show disparate trends between datasets. NCDC has the largest upward trend of 1.3°C/century, whereas SWM has the smallest trend at 0.51°C/century. All data sets except SWM show a change of over 1° Celsius over 100 years.

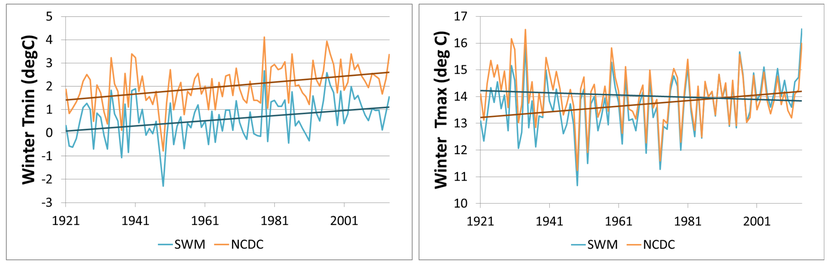
Maximum and Minimum Temperature Data

By examining the minimum and maximum temperatures separately, we see that the minimum temperature trends are similar, but the NCDC maximum temperature has a large upward trend that is lacking in the SWM data, which affects the magnitude of average winter temperatures. Overall, NCDC has the strongest upward trend for maximum temperature out of the five data sets while SWM has the lowest and is the only data set to not have an upward trend.

Table 3 – trends in degrees Celsius/100 years for gridded data sets' minimum and maximum temperatures

	Tmin Trend	Tmax Trend
NCDC	1.43	1.24
SWM	1.25	-0.22
PRISM	1.77	0.48
BEST	1.30	1.15
VOSE	1.37	0.93

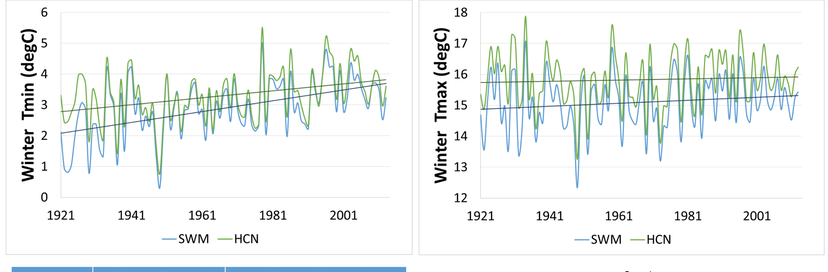
Figure 2 – (a) minimum and (b) maximum winter temperatures for gridded SWM and NCDC



3. Station Data Comparisons

We also retrieved the station data used to construct the SWM gridded fields as well as station data for the Historical Climatology Network (HCN). HCN is intended to be used for long-term trend analysis; it includes 54 stations in California. SWM uses 102 stations in California, which were selected on the basis of their record lengths, and their availability in near-real time. There are 21 stations in common between the two networks. We computed winter averages of daily temperature from all stations in both data sets. The HCN trends are smaller for both minimum and maximum temperature; the maximum temperature trend is less than half that of SWM's.

Figure 3 – (a) min and (b) max winter temperatures averaged over stations for SWM and HCN



	Tmin Trend	Tmax Trend
SWM	1.89	0.78
HCN	1.13	0.34

Table 4 – Mean trends in °C/100 years averaged over stations for minimum and maximum temperature

Effects of Gridding and Missing Data

The SWM gridded data are based on an interpolation of the stations within the SWM network. However, the station averages and the gridded data averages **have different trend magnitudes over 1921 – 2015. This could be related to missing values in the station data, which are especially problematic before the 1960s, or the interpolation procedure itself. From 1961 to 2015, the SWM station average and the SWM gridded average trends are much more similar** than the trends from 1921 – 2014. The HCN trends for this truncated period are still the smallest trends (Table 5). Figure 4 shows the trend from 1961 – 2015 for each individual grid cell (0.625 degrees latitude by 0.625 degrees longitude). Figure 5 shows the difference between the individual station's trend and the statewide average trend. The station trends have a much wider and improbable range than the interpolated data. The interpolation of data from raw station data to gridded data has large effects on the temperature trend and the seasonal average temperature. Lack of knowledge about how the station data is used to create the NCDC gridded data impedes further comparisons of temperature trends between networks.

	Tmin Trend	Tmax Trend
Gridded SWM	2.08	1.60
Station SWM	2.12	1.90
Station HCN	1.80	1.57

Table 5 – trends in degrees Celsius/100 years over 1961-2015 for gridded data and station minimum and maximum temperatures

Figure 4 – (a) minimum and (b) maximum winter temperatures trends for each gridded cell in the SWM gridded dataset

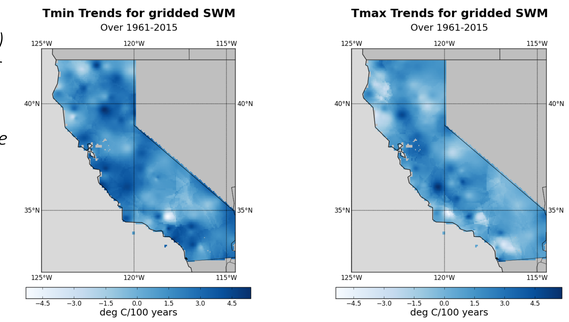
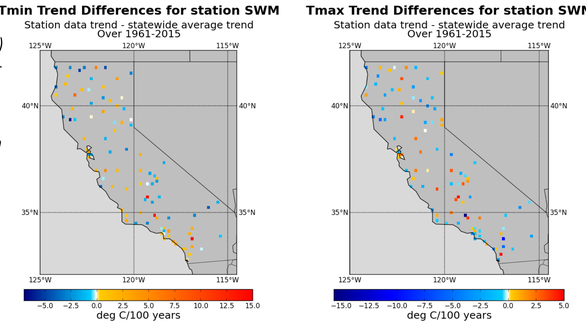


Figure 5 – (a) minimum and (b) maximum winter temperatures trends for the individual station trend minus the statewide trend



4. Key Points

- All gridded datasets except SWM agree that 2013-14 was the warmest winter up to that year
- SWM and NCDC agree that 2014-15 is the warmest winter of record
- SWM reports the smallest trend in temperature time among the five gridded data sets
- HCN indicates smaller trends for station averages than SWM
- More information is needed about what stations are used in NCDC gridded data as well as interpolation methods to unravel the differences in trends

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References:
Shepard, D. S., 1984: Computer mapping: The SYMAP interpolation algorithm. Spatial Statistics and Models, G. L. Gaile and C. J. Willmott, Eds., D. Reidel, 133–145.