Differential Temperature Trends across Elevation within the “Warming Hole” of the Southeast United States

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1. Background

The area of insignificant or negative temperature trends across the southeastern United States, or “warming hole,” has received much attention in recent years. With many meteorological stations sited at low elevations and within urban settings, a closer examination of temperature changes across elevation within the southern Appalachian Mountains is a useful contribution to better understanding the warming hole.

2. Objectives

- Identify surface stations with continuous data (≤ 2 days missing per month) for a record of 1967-2016.
- Separate stations by elevation into categories 200-600 m and 600-1200 m above sea level.
- Analyze time series of mean monthly maximum and minimum air temperature for each station by month and elevation.
- Compare time series results from two overlapping 30-year periods: 1967-1996 and 1987-2016.

3. Methods

Mean monthly maximum and minimum temperature data were analyzed for 20 stations from the Global Historical Climatology Network spanning 1967-2016. Stations varied in elevation from 200-1200 m (Figure 1).

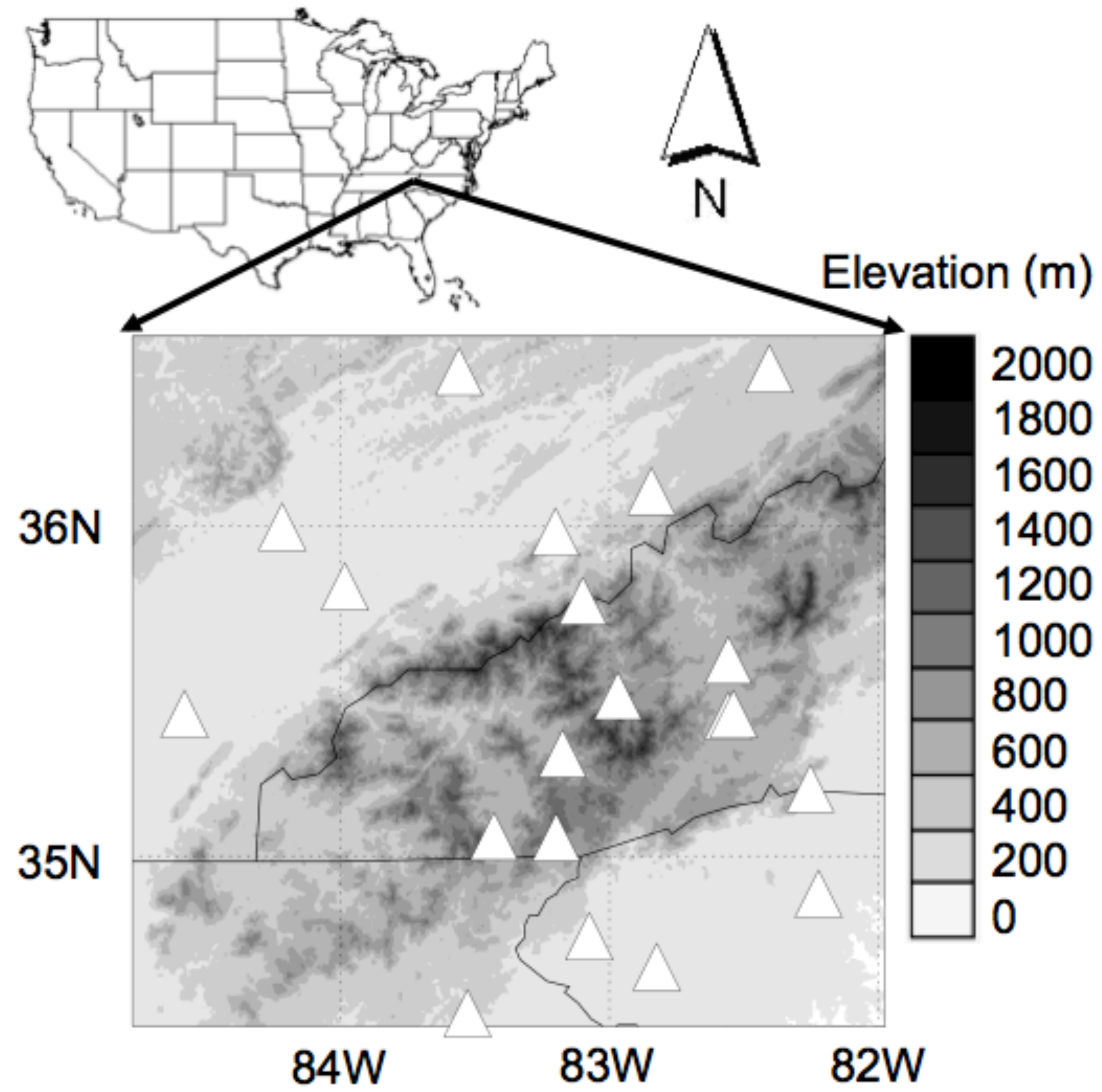

Figure 1. Study site bounded by 34.50 to 36.55 °N and 82.00 to 84.75 °W. Triangles indicate 20 station locations.

4. Measures

A Pearson’s correlation and p-value were computed for mean monthly maximum and minimum temperature versus year for each station and month. A simple linear regression (temperature-year) was calculated and decadal linear temperature trends recorded. Trends with a “statistically suggestive” p-value level of ≤ 0.05 or “statistically significant” p-value level of ≤ 0.005 were noted, as recommended by Benjamin et al. (2017).

5. Results

Trends in mean monthly minimum air temperature for stations in the 200-600 m elevation range are shown in Table 1. Across all months and 80 station trends, the annual mean trend is +0.30 °C per decade. Exactly half of the trends have positive trends with p-values ≤ 0.05. Of those, 24 are significant at ≤ 0.005.

Table 1. Temporal trends in minimum temperature over 1967-2016 for stations located at 200-600 m elevation.

Month	Number of 200-600 m stations for T_{min}	Mean decadal trend (°C/decade)	Number of stations with positive trend significant at ≤ 0.05	Number of stations with positive trend significant at ≤ 0.005
January	7	+0.19	0	0
February	7	+0.40	3	1
March	5	+0.31	3	0
April	10	+0.32	4	2
May	8	+0.41	1	4
June	6	+0.47	0	5
July	9	+0.31	1	6
August	6	+0.32	0	4
September	6	+0.32	2	2
October	4	+0.22	1	0
November	6	-0.03	0	0
December	6	+0.28	1	0
ALL	**80**	**+0.30**	**16**	**24**

Table 2 shows mean monthly minimum air temperature results for the 600-1200 m range. All 12 months have positive mean decadal trends. The annual mean from the 42 trends is +0.23 °C per decade. Out of those trends, 17 have p-values of ≤ 0.05, and of those, 11 trends have p-values of ≤ 0.005.

Table 2. Same as Table 1, but for elevation 600-1200 m.

Month	Number of 600-1200 m stations for T_{min}	Mean decadal trend (°C/decade)	Number of stations with positive trend significant at ≤ 0.05	Number of stations with positive trend significant at ≤ 0.005
January	2	+0.22	0	0
February	4	+0.26	2	0
March	2	+0.30	0	0
April	3	+0.22	1	0
May	4	+0.29	2	0
June	5	+0.39	0	5
July	6	+0.19	1	3
August	5	+0.26	0	3
September	4	+0.08	0	0
October	3	+0.11	0	0
November	2	+0.08	0	0
December	2	+0.29	0	0
ALL	**42**	**+0.23**	**6**	**11**

For mean maximum temperature at stations within the 200-600 m elevation range, all 12 months are characterized by an overall positive trend, with the annual mean station trend being +0.19 °C per decade. Of 80 station time series considered, 20 have p-values of ≤ 0.05, five of which are significant at ≤ 0.005.

In the 600-1200 m range, 42 stations were analyzed for mean monthly maximum air temperature and the annual mean station trend is +0.15 °C per decade. Seven trends have p-values ≤ 0.05, with three significant at ≤ 0.005.

The mean of 30-year trends in maximum temperature for stations at 200-600 m decreased from +0.19 to +0.12 °C/decade from the early to the latter of the 30-year periods, while the mean for stations sited within 600-1200 m increased from +0.08 to +0.18 °C/decade. For minimum temperature at 200-600 m, the mean trend increased from +0.18 to +0.35 °C/decade, while the mean trend in minimum temperature for stations at 600-1200 m increased from +0.20 to +0.31 °C/decade.

6. Conclusion

Results indicate general warming in the southern Appalachians with largest increases favoring minimum temperature. Decadal trends of temperature were not clearly related to elevation, though the results do highlight overall warming within the southern Appalachian Mountains in elevations extending up to 1200 m despite cooling trends previously described as a warming hole for the southeastern United States.

References

Benjamin DJ, et al., 2017: Redefine statistical significance, *PsyArXiv*, https://pwyarxiv.com/mky9j

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