Global Trend Analysis of Multi-decade Soil Temperature Records Show Soils Resistant to Warming

Katie Jennings[1*] and Serita Frey[1]

[1]Department of Natural Resources and the Environment, University of New Hampshire, Durham, NH, USA; *Main author: Katie.Jennings@unh.edu

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Background

Soil temperature is an important mediator for many biogeochemical processes, including plant growth, seed germination, nutrient cycling, soil respiration and carbon sequestration. Soils are expected to warm in response to increasing global surface temperatures. However, despite the importance of soil temperature to ecosystem processes, little attention has been given to examining if and to what extent soil temperatures are changing over time as air temperature rises.

Here, we have conducted trend analysis on long-term (>20 years) soil temperature series from 38 sites globally to examine how soils are responding to climate change.

Methods

- We searched for and analyzed soil temperature time series meeting the following criteria:
  - Series > 20 years
  - Preference for series with observation frequency of daily to sub-daily (but included series with monthly means to increase spatial distribution).
- Observations were aggregated into annual summer means defined as July-Sept (Northern hemisphere), Jan-Mar (Southern hemisphere)
- Mann-Kendall trend and Sen Slope analyses were preformed
- False discovery rate (FDR) correction was applied to trends significance

Results

Soil temperature series

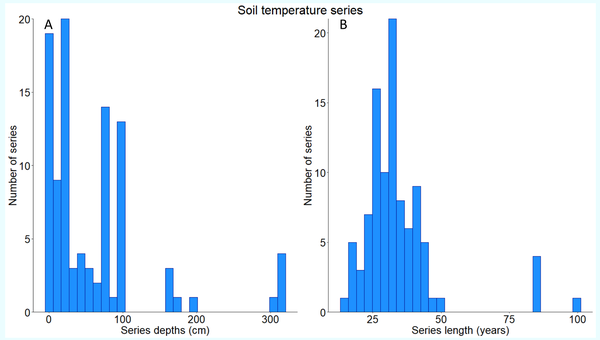

Fig. 1 Distribution of soil temperature series depths (cm; A), and length of series (years; B).

Description of soil temperature series		
Number of series		98
Series with significant trends		18
Number of sites		38
Number of countries		9
Depth of series (cm)	Range	5-320
	Mean ± SD	61 ± 74
Length of series (years)	Range	14-99
	Mean ± SD	32 ± 14

Table 1. Summary statistics of soil temperature series used in this analysis.

Annual summer mean trends

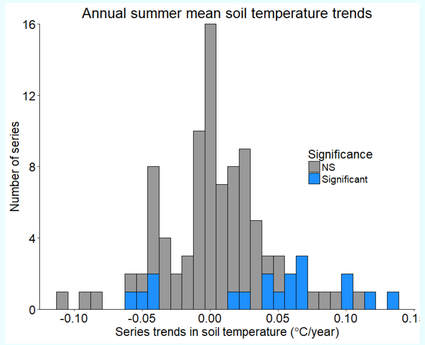

Fig. 2 Distribution of annual summer mean soil temperature trends for all series. Grey bars are series with no change in temperature over the observation period, while blue bars are series that are significant. Mean trend was 0.0085 ± 0.043 °C year^{-1} and was not significantly different than 0.

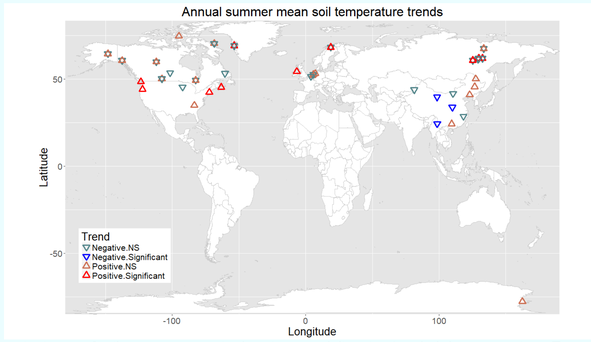

Fig. 3 Map of soil temperature series location, trend direction (symbol shape, negative = ∇, or positive = Δ), and trend significance (symbol color).

Discussion

- We analyzed 98 soil temperature series (site-depth combinations) from 38 global sites, across various soil depths and series lengths (Fig. 1 and Table 1).
- The mean annual summer soil temperature trend for all series was 0.0085 ± 0.043 °C year^{-1}, and was not statistically different from zero (Fig. 2), indicating that many soil series from different sites and depths are not warming as much as generally anticipated.
- After a false discovery rate correction, only 18 (out of 98) series had significant ($P < 0.05$) trends in annual summer mean soil temperature.
- Four series showed significant decreases in temperature over the observation period, while 14 series showed increases in temperature.
- Significance was not correlated with site location (Fig. 3), depth of measurement, time series length, or series start or end date.

Conclusions

- Soils may have a stronger thermal buffering capacity and not be as responsive to increases in global surface temperatures as expected.
- This could have important implications for soil carbon fluxes and storage, influencing the global carbon cycle.

Data Sources

Abisko Scientific Research Station. (2017). Soil *temperature data in peat and morraine soils from 1982-2015.* Available from Abisko Scientific Research Station Web site: http://polar.se/abisko
Armagh Observatory: http://climate.arm.ac.uk/calibrated/soil/
Center for Permafrost (CENPERM), University of Copenhagen
Institute of Atmospheric Physics, Chinese Academy of Sciences
Long Term Ecological Research Network packages: knb-lter-and-3980.15; knb-lter-bnz.158.19; knb-lter-cdr.382.5; knb-lter-bnz.3.20; knb-lter-hfr.5.23; knb-lter-cwt.1013.105; knb-lter-mcm.7003.16.
KNMI - Koninklijk Nederlands Meteorologisch Instituut, Royal Netherlands Meteorological Institute
Meteorological Services Canada, Environment Canada, Historical Climate Data
National Oceanic and Atmospheric Administration National Snow and Ice Data Center: http://dss.ucar.edu/datasets/ds570.0/
St. Paul Campus Climate Observatory, Department of Soil, Water and Climate, University of Minnesota

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