Title: How do climate change experiments actually change climate?

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1 Summary

A Concept/Synthesis Paper with the main message being that climate change experiments need to report what climate variables are modified by their experiment and how, in order to maximize the benefits of these experiments, as well as our understanding of biological impacts of climate change.

2 Introduction

Experimental in situ climate manipulations offer several advantages to understanding biological impacts of climate change: (controlled, relative speed- i.e. multiple manipulations can be conducted simultaneously, can hit higher temps, can do them in places where other data collection is hard).

These advantages come at a cost, however. Experimental in situ climate manipulations are logistically challenging, and expensive.

Problem: People want to extrapolate warming experiments to real life to understand (and forecast) biological impacts of climate change. However, a detailed assessment of exactly how experimental warming treatments alter climate, and the extent to which these manipulations accurately model the real world, is lacking.

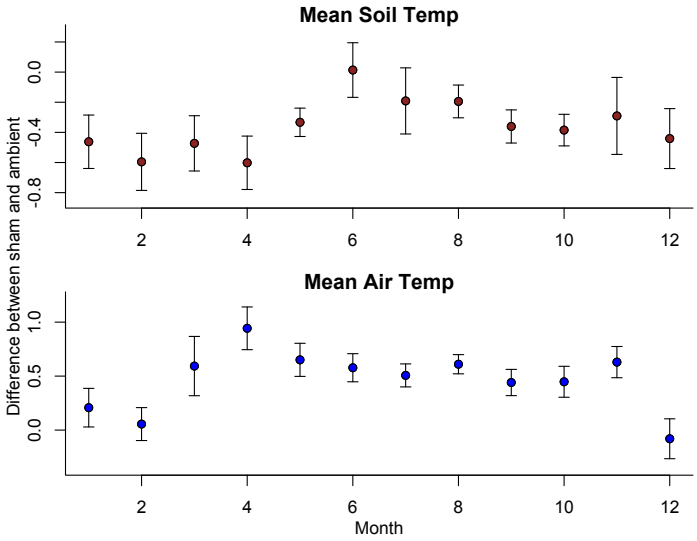
3 Experimental climate change vs. real climate: how do they compare?

Experimental warming alters climate in several ways that are rarely quantified, summarized, or interpreted in studies reporting on experimental warming, despite the fact that these alterations are likely to have important biological implications.

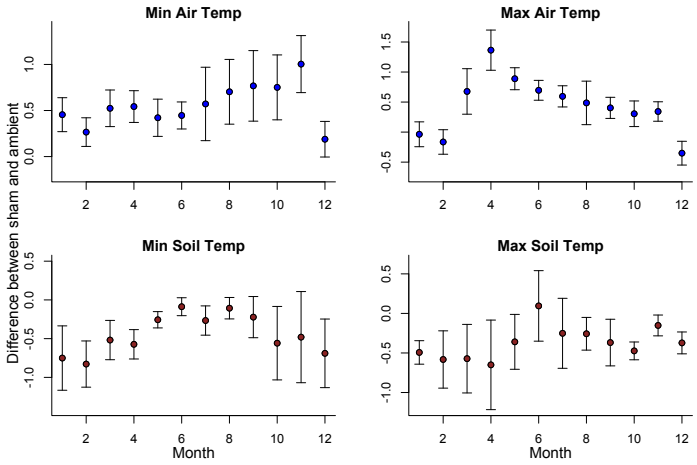
3.1 Structures

The experimental structures themselves alter temperature, in ways that are not generally examined or reported in experimental warming studies. Compare sham and ambient data on temperature (mixed effects models).

- Soil temperature is LOWER in the shams, compared with the ambient air.
- Air temperature is HIGHER in the shams, compared with the ambient air. Below, mean daily soil temperature (for the shallowest depth) and air temperature are shown, for all sites for which these data are available (5-6 sites).



- The pattern was consistent for min and max air and soil temperatures, as well. See below:



3.2 Space

There is spatial variation in warming effects. Analysis of plot vs. block level variation vs. treatment. also variation within a plot?

3.3 Time

- Seasonal variations in experimental warming effects (plots over time)
- Daily variations in experimental warming effects (min vs max)
- Comparison to observational data: compare warmest years to coolest years. Plot and compare to experimental data
- Treatments aren?t applied consistently over the year- IR heaters can?t apply consistent warming, and some studies stop warming in different times of year (clark)
- Secondary effects of warming: Effects of warming on soil moisture (add Miriams analysis here), air humidity, people need to measure these things.

4 Biological Implications

We have laid out several ways in which experimental warming alters more than just the mean temperature. We argue that these unintended alterations are important for scientists to fully understand and report in their research because they are likely to have biological implications.

- For example, plant phenology is likely to be altered in opposing ways by the increased air temperatures and decrease soil moisture/temperature.
- Other examples?

5 Recommendations for future climate change experiments

1) (Easy) things everyone should try to do in their experiments a. Include controls and collect/use/report their data. Measure before and after experiment, have shams and ambient controls, and collect all data in them 2) Things everyone should report about their experiments a. Control/Sham data b. Timing of warming treatment applied (e.g., summer application impacts fall events more): exact date it started and how it ran throughout seasons/years c. Day/night variation (across seasons) d. Try to collect climate data at least 2X day, ideally hourly e. Number of missing data points for warming and why (rodents ate sensors? Heaters went out?) 3) Regression designs for nonlinearity? 4) Community standards for reporting experimental climate data (and phenology -Chuine et al. 2017) 5) Monitoring of temperature that is more useful across designs and that is closest to what focal organisms experience