

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.

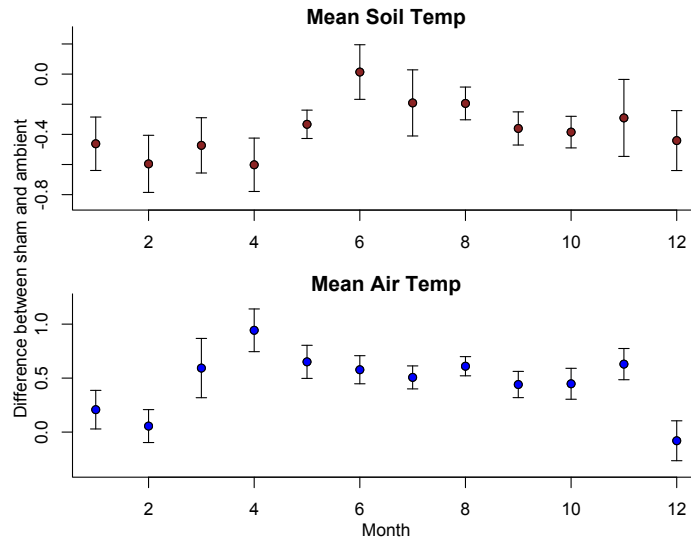
3 Experimental climate change vs. real climate: how do they compare?

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.

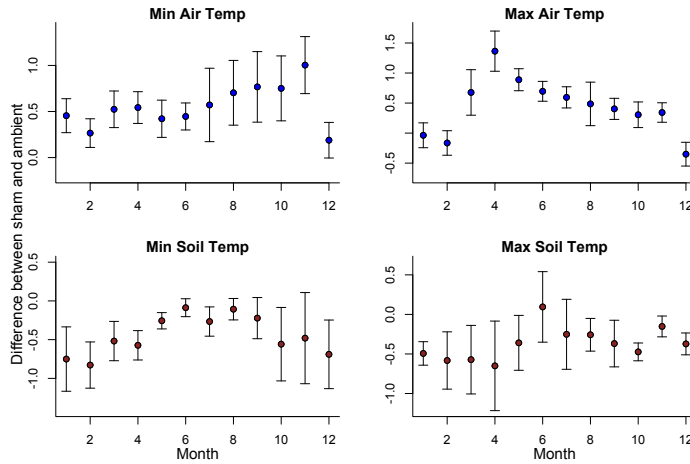
3.1 Structures

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 (e.g. Clark et al.)

3.4 Secondary effects of warming

Temperature interacts with many other climatatic and nonclimatic factors to alter the abiotic environment. For example, there are clear effects of experimental warming on soil moisture (add Miriams analysis here) and air humidity.

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

The criticisms we describe are not meant to imply that experimental warming studies are not worthwhile. On the contrary, we believe that climate change experiments provide invaluable information about biological responses to warming. We also believe that investigators need to fully explore the ways in which these warming experiments are altering climate, as it is clearly not simply shifting the mean. Here we describe a few recommendations to improve implementation, interpretation, and communication of future climate change experiments.

- Include sham and ambient controls, and collect, use, and report data collected within them.
- Carefully consider and report the timing of warming treatment applied, including exact start and end dates within and across years.
- Collect climate data at least twice daily, and ideally hourly; report these data, in particular, variations in daytime and nighttime and season variations in climate variables,
- Report the number and cause of missing data points for climate, especially those collected in warming treatments. For example, are data missing because the heaters went out, or because rodents ate the sensors?
- Consider implementing and following community standards for reporting climate data (and phenology -Chuine et al. 2017)
- Construct regression designs to examine possible nonlinear responses to warming