Biogeosciences Discuss.,
https://doi.org/10.5194/bg-2017-208-AC1, 2017

Interactive comment on "A zero power warming chamber for investigating plant responses to rising temperature" *by* Keith F. Lewin et al.

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Received and published: 24 July 2017

Referee #1

Most of the data reported from passive warming experiments is daily mean temperature and therefore we provide this data to facilitate comparison with other approaches. The reviewer raises an important point about presenting daytime and nighttime mean temperature differentials. In many locations this would be a important result to report. However, in Barrow Alaska, there was no "night" during most of the time period we ran this experiment. We could have selected an arbitrary solar radiation threshold to define day and "night" but low levels of solar radiation were also observed under heavy cloud cover. Therefore, as noted by the referee, we framed our discussion around the diur-

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nal temperature range. The referee also raises some good points about how readers would interpret our data given that it was collected in an Arctic system. We agree that it would help the reader if we emphasized some of the unique features of the Arctic e.g. 24h daylight, permafrost.

We agree with the suggested focus on modulation rather than control and would be happy to make that change in addition to other suggested edits.

Figures

We have attempted to use color consistently throughout the manuscript. In all cases we aimed to use red when discussing the ZPW chambers, black for the control chamber and blue for ambient. Where we discuss a differential between ZPW and ambient that differential is also shown in red and differentials between the control chamber and ambient are shown in black. We did spot a couple of discrepancies that could be changed for consistency throughout the manuscript; in figure 3 the plots in panels c and d could be in red and in figure 11 the plots in panel a could be blue and c and d could be red. The referee's specific point is possibly due to the use of red and black to distinguish differential temperatures in addition to absolute temperatures. We feel that introducing two additional colors would not enhance understanding.

We would be happy to amend the legend for Fig 8c.

When viewed independently from the text the goal of figure 10 is not clear and therefore we'd be happy to add some text to the legend to make our focus on VPD clear. The goal of figure 10 is to demonstrate that the VPD very rarely increased to the point where it might be expected to negatively impact stomatal conductance (>1.5 kPa). We feel our point is clearly demonstrated by Figure 10 but agree that three panels (one each for ambient, control and ZPW) may allow the reader to better assess the data. However, we disagree with the referee's suggested temperature frequency plots because a frequency distribution of temperatures would not communicate the same information and is a topic we covered earlier in the manuscript in figure 5 through 7.

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Referee #2

General comments

The referee is correct that the design can be tuned to a specific environment and a desired amount of warming. While the paper does not describe this in detail, it is quite simple to tune the chambers to raise or lower the temperature differential and both procedures outlined below can be accomplished by one person within a few minutes. However, it is important to note that tuning requires access to data on the air temperature inside and outside the chamber and the result of any adjustment has to be monitored over time to determine the effect of the tuning on the magnitude and rate of warming.

(1) The first, and most straight forward method to change the magnitude of warming, i.e. the temperature differential between the inside and outside of the chamber, is to adjust the relative extensions of the pistons connected to the internal and external heat exchangers. This changes the "preload" on the vents, which affects how quickly the vents will begin to open as the temperature differential increases. If the preload is reduced, the vents will not immediately begin to open when the temperature differential becomes positive. If the preload is increased, the vents will begin moving as soon as the temperature differential becomes positive. This will increase the degree of vent opening for a given temperature differential, lowering the maximum differential. Adjusting the preload is easy to do and requires no tools. Simply open a valve to one of two oil reservoirs in the interior heat exchanger assembly (we have one on the piston and one on the heat exchanger), lift the vents open, which draws more oil into the cylinder as the piston rod is extended, and then close the valve to the reservoir. Similarly, oil can be pushed out of the system into a reservoir by opening the valve and lowering the vents, thereby reducing the preload and increasing the temperature differential required to initiate vent opening. (2) The sensitivity of the system to a temperature differential can also be adjusted by changing the attachment point where the piston rod is connected to the vent. We drilled a set of holes to allow us to easily adjust the distance

of the piston attachment point to the fulcrum of the vents. Moving the attachment point closer to the fulcrum results in greater vent opening and more rapid cooling for a given change in temperature differential and piston movement. Moving the attachment point further away from the fulcrum makes the vents less responsive.

Our initial prototype chamber was operated for three years at Brookhaven National Laboratory on Long Island, NY. It weathered tropical storms Irene and Sandy and withstood significant winter snow storms. Our Arctic prototype withstood deployment during the thaw season, including winds in excess of 20 m/s. In Barrow we anchored the chambers to the ground by sinking metal rods into holes drilled into the permafrost, allowed them to freeze in place and then attached the chamber to the anchors. We have no plans to leave the chambers out through the Arctic winter, but expect the structures could survive the low temperatures, high winds and snow loads. The heat exchanger settings and fluid would need to be changed to accommodate the lower temperatures.

There are many potential options for the fluid used in the heat exchangers. We decided to use hydraulic oil because it has a relatively large coefficient of heat expansion and low vapor pressure. We chose a vegetable based hydraulic fluid due to its low toxicity and biodegradability. The hydraulic fluid used in this study has a pour point below -20°C. There are similar hydraulic fluids available with pour points down to -54°C. Deployment at alternative locations may require the use of heat exchanger fluids with different properties.

We acknowledge the recent advances in solar and wind power options highlighted by the reviewer. Our group does in fact develop and operate equipment and facilities that use control systems powered by solar, wind and grid based electricity. These systems usually work well, but there can be issues with their long-term reliability, especially in remote locations and harsh environments. Our goal for this study was to design a system that did not require any electric power so that the chambers could be deployed with no supporting infrastructure and contain a minimal number of potential points of failure. While we used a relatively extensive and complex collection of sensors,

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data loggers and communications equipment to document the performance of these chambers for this report, the bare minimum equipment required for an experiment is a chamber equipped with a battery powered temperature recorder. Of course, in a location with reliable electric power you could install a complex electronic control system which includes precipitation activated opening of the entire roof, infrared gas analyzers to modulate CO2 concentration, supplemental heating for nighttime and other periods with low solar inputs and other desirable features. Such a system has recognized advantages, but each of these additional features brings with it additional complexity and additional points of failure. In harsh environments remote from technical support, there are advantages to reduced complexity.

Since the concept we describe here could be applied to a wide range of chamber dimensions and tailored to individual research needs, the shipping weight, size and costs are specific to the size of the (dismantled) chambers, the number of chambers, and the ship to and ship from addresses.

Specific comments & technical corrections

We agree with the referee’s comments and would be happy to make these changes.

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