Examining the thermal impact of the eosGP on its environment

Introduction

The Eosense CO_2 Gas Probe (eosGPCO_2) measures CO_2 concentration in the atmosphere, soil, and shallow water. In some applications, such as soil respiration studies, the rate at which CO_2 is produced is strongly temperature dependent (Lloyd and Taylor, 1994). Temperature sensitivity of soil respiration, as quantified by Q_{10} values, indicates the factor by which soil respiration increases in response to a temperature increase of 10 degrees Celsius (Yi et al., 2013). Figure 1 shows the spatial pattern of optimal Q_{10} values as presented by Zhou et al. (2009).

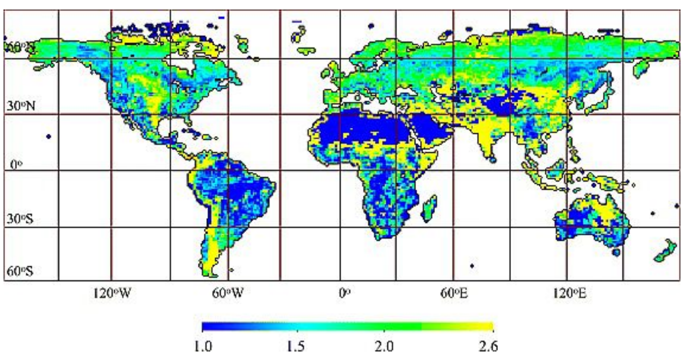

Figure 1. Spatial pattern of optimal Q_{10} values (Zhou et al., 2009)

For the mean (1.72) of the Q_{10} values presented in Zhou et al. (2009), a 10 °C increase in soil temperature results in a 72% increase in soil respiration. Therefore, in order to measure CO_2 without influencing respiration rates it is desirable that the thermal impact of measurement devices be minimal.

Methods

In order to evaluate the thermal impact of the eosGP, we performed a laboratory experiment to measure the temperature distribution around the eosGP during continuous operation. The experiment was conducted in two different soil mediums: moist sand and potting soil. The properties of each soil medium are summarized in Table 1.

Table 1. Physical properties of test mediums

	Moisture (% wt)	Density (kg m^{-3})
Potting soil	59	567.3
Sand	11	1453.7

For each medium, the eosGP was oriented in the soil at a controlled depth with the membrane surface downward. A total of six thermistors were distributed around the eosGP; three radially from the eosGP housing, two below the membrane face, and one at the surface of the soil to measure changes in air temperature. Figure 2 shows the thermistor distribution.

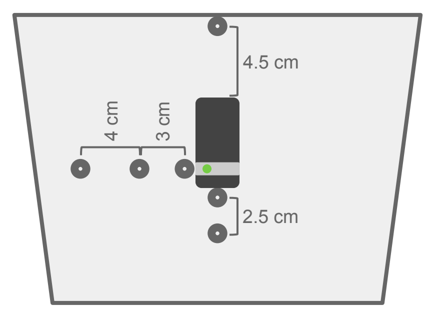

Figure 2. Diagram of the spatial distribution of thermistors around the buried eosGP (not to scale)

Figure 3. Left) Placement of radial thermistors. Right) Surface thermistor to measure ambient temperature.

The system was allowed to thermally equilibrate for a time after the soil medium was packed, then the eosGP was powered-on. The ΔT at each spatial measurement point was determined from the thermistor data (example in Figure 4).

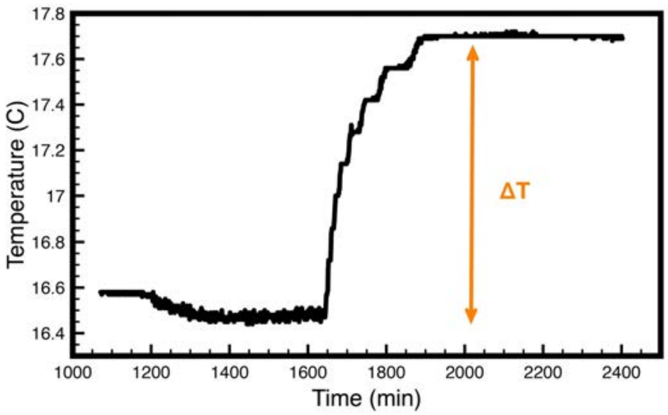

Figure 4. Example data showing soil temperature before and after powering the eosGP, and how ΔT was calculated.

Results

The maximum measured ΔT was 0.44 °C in the sand and 1.29 °C in the soil. In both cases, the maximum ΔT was observed at the radial surface of the eosGP. The ΔT at the membrane face was lower than at the radial surface with values of 0.33 °C and 1.23 °C for sand and soil, respectively. Figure 5 shows the radial distribution of ΔT for the two different mediums.

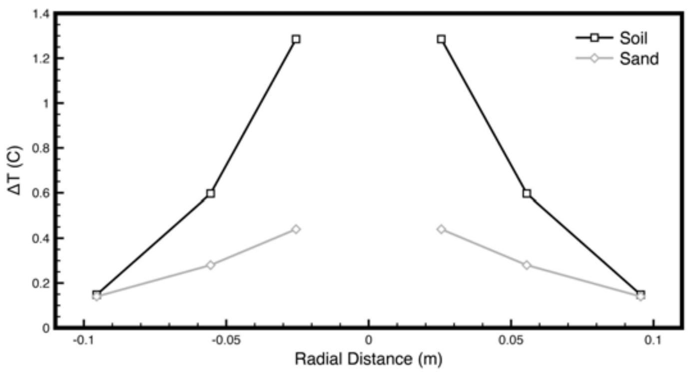

Figure 5. Distribution of ΔT around the radial axis of the eosGP sensor. Data mirrored about x=0.

Discussion

The eosGP draws approximately 0.5 W at 12 V. Using a conservative estimate that all power was converted to heat, the experimental thermal conductivities were calculated to be 0.626 W m^{-1} K^{-1} for the soil and 1.285 W m^{-1} K^{-1} for the sand. These are within the expected ranges (Abu-Hamdeh and Reeder, 2000).

Similar CO_2 probes have power consumptions ranging from 1 W to 4 W. Using the experimental thermal conductivities, we can extrapolate the expected thermal impact of sensors with varying power consumptions. Figures 6a and 6b show theoretical ΔTs for sensors with 2x and 3x the average power consumption of the eosGP in soil and sand, respectively.

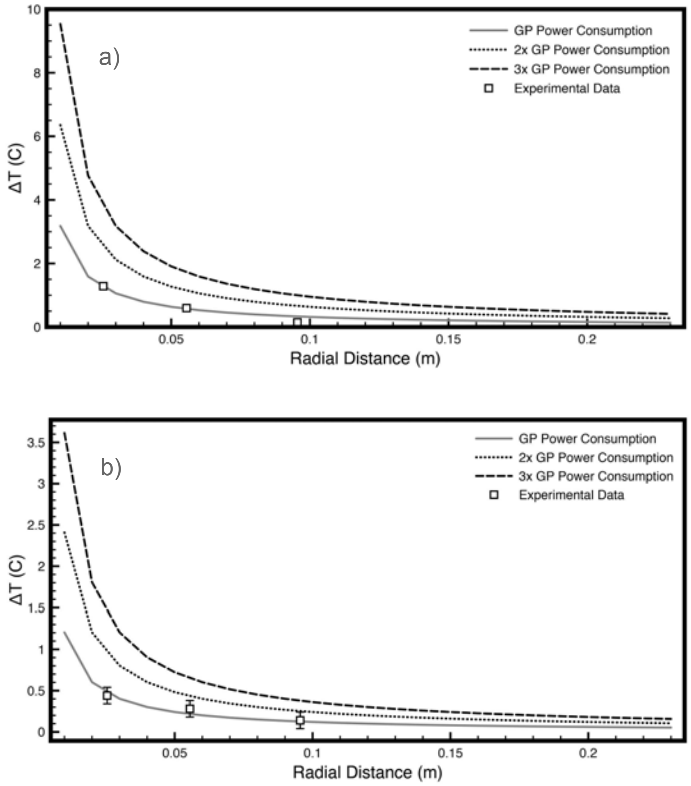

Figure 6. a) Predicted increases in temperature around sensors of varying power consumption in potting soil. b) Predicted increases in temperature around sensors of varying power consumption in sand.

Conclusion

Experimental maximum ΔT values were 0.44 °C in the sand and 1.29 °C in the soil. Theoretical fitting of these temperature perturbations is consistent with published thermal conductivities in the two media. Based on the published power consumption of other in-situ CO_2 sensors, the eosGP should provide the smallest perturbation to the measurement environment during continuous operation. If required, this perturbation could be further reduced by cycling power to the unit on a fixed measurement schedule using an external control device.