Controls on soil respiration rates at sites throughout North America

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Abstract

Soil respiration represents one of the dominant fluxes of CO2 from terrestrial ecosystems to the atmosphere, therefore, it is important to understand how it is controlled across a wide variety of sites. As part of developing a soil respiration data product based on freely available National Ecological Observatory Network (NEON) data, soil respiration rates were calculated at 30 sites throughout the USA (from Puerto Rico to North Dakota and Virginia to California) to investigate controls on soil respiration at a continental scale. The sites spanned a wide range of ecosystems, including deserts, grasslands, and forests, as well as managed and wildland sites. Soil respiration was calculated in 30-minute intervals using the gradient method based on soil CO2 concentrations measured at three different depths in conjunction with estimates of soil CO2 diffusivity based on soil physical properties, soil moisture and temperature profiles, and barometric pressure. Inevitably with such a large number of data inputs, the temporal coverage of good quality (i.e., unflagged) soil respiration values was relatively low (8%) because one or more of the input data were flagged, but this was significantly higher for some sites and soil plots (maximum: 58%). Ongoing efforts to increase the quality of input data are expected to substantially improve temporal coverage. Despite these gaps, over 54,000 unflagged half-hourly soil respiration data points were generated for the period of Apr-Jun 2019 (the temporal range and the number of sites will be increased further over coming months). Across all sites and times, soil temperature and soil moisture explained only a moderate amount of variation in soil respiration (20%). However, including site in the model increased the proportions of variation explained to 85%, indicating the importance of site-specific properties, such as vegetation and microbial community composition and the accessibility of soil carbon, in controlling soil respiration rates. Within each site, soil temperature was typically positively correlated with respiration and in the cases where it was not, this was often due to large fluxes of CO2 leaving the soil during snowmelt. The relationship between soil moisture and respiration within each site was more variable, with both positive and negative relationships observed.

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INTRODUCTION

Soil respiration is the largest flux of carbon from terrestrial ecosystems to the atmosphere. In addition, soil respiration is ecologically important since it represents total biological activity of soil biota. This project had two aims:

1. Develop an open-access soil respiration data product based on freely available National Ecological Observatory Network (NEON) data.
2. Investigate controls on soil respiration across the NEON sites.

NEON is an ecological monitoring network consisting of 81 sites throughout the US (Fig. 1a). A wide range of data are collected using standardized protocols and all data are freely available. Each of the 47 terrestrial sites include five sensor-based soil plots, which contain soil CO_2 concentration measurements at 3 depths (from 2 cm to ~12 cm), as well as soil temperature and moisture profiles and other measurements (Fig 1b).

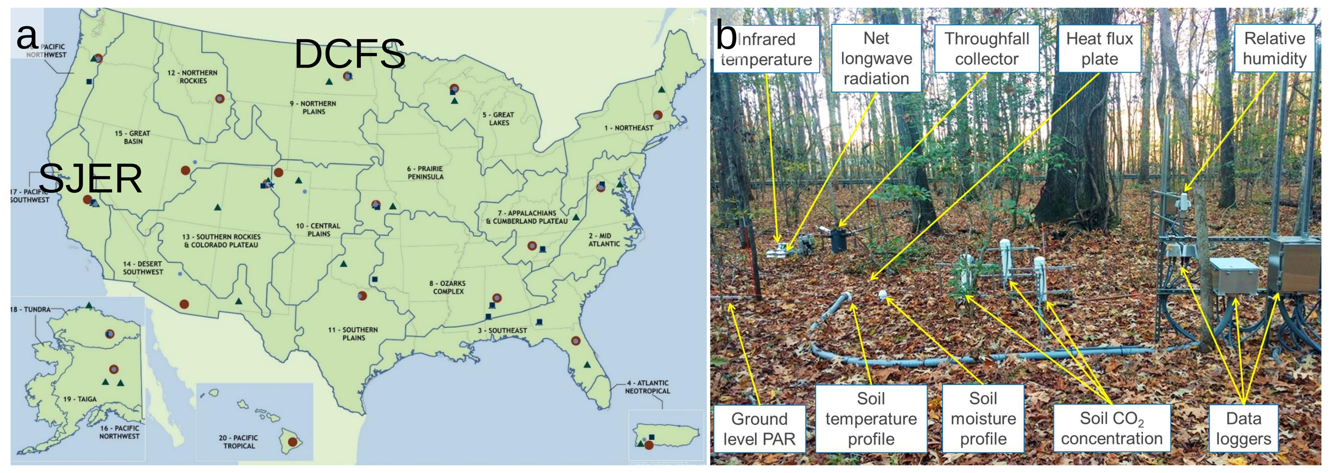

Figure 1. Location of NEON sites (a). A sensor-based soil plot (b).

METHODS

Soil CO_2 fluxes were calculated using the gradient method from April to September 2019 at all sites. The soil CO_2 concentration gradient was combined with estimates of soil CO_2 diffusivity in Fick's first law to calculate the flux between the measurement levels. These fluxes were extrapolated to the soil surface to determine the CO_2 flux from the soil to the atmosphere.

METHODS cont.

Fluxes were flagged and excluded if one or more input data streams were flagged, if the flux deeper in soil was greater than surface flux, or if the surface flux was <-1 µmol m^{-2} s^{-1} since this indicated that one or more of the assumptions of the gradient method were violated.

RESULTS

Only 5% of the flux data between Apr-Sept 2019 was unflagged, which was primarily due to one or more input data streams being flagged. Despite this, over 100,000 unflagged half-hourly soil CO_2 flux data points were generated during this 6 month period, which is equivalent to ~6 site-years of continuous flux data.

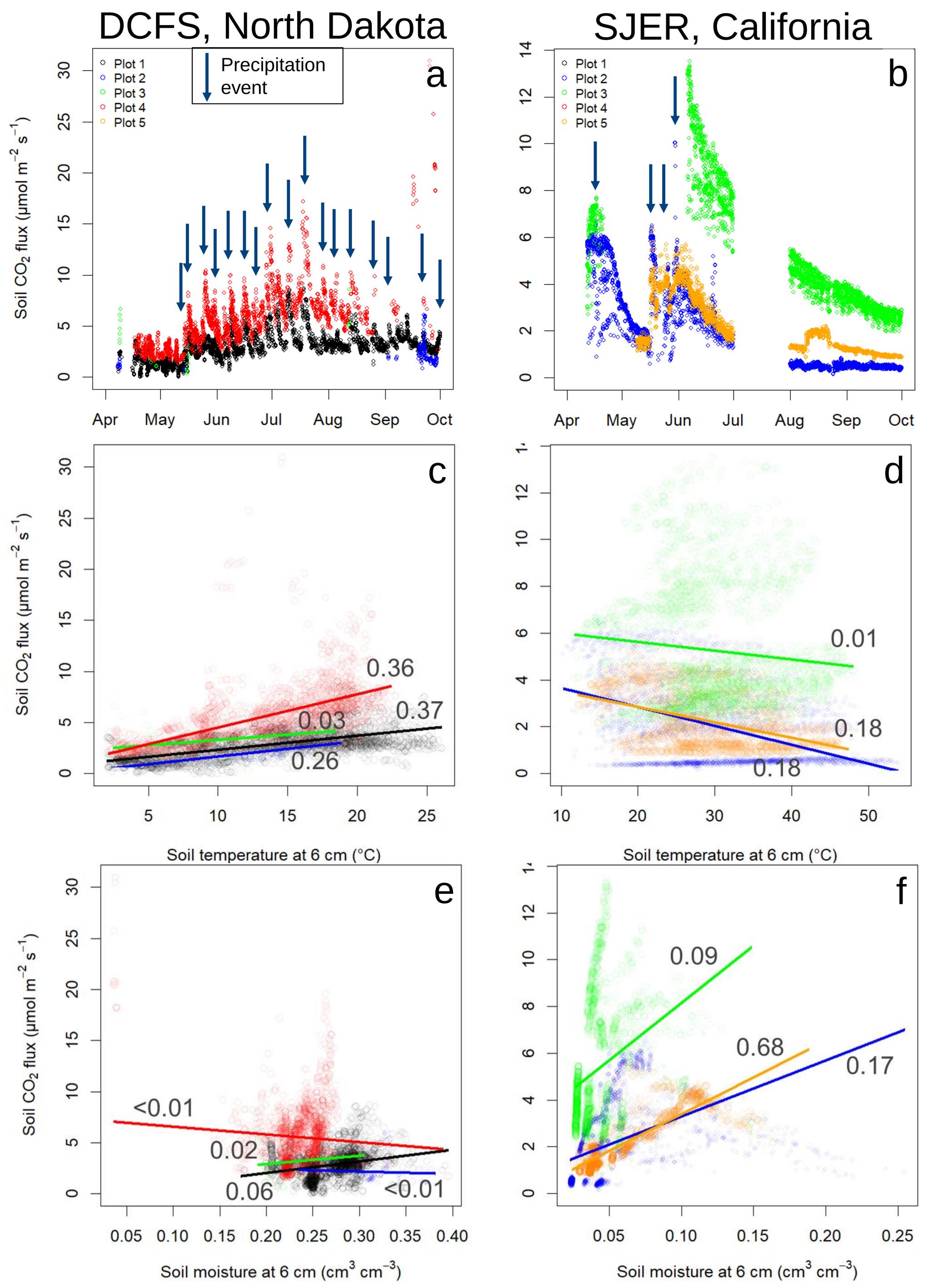

Figure 2. Soil respiration at DCFS (a) and SJER (b). Colors represent the different soil plots at each site. Soil respiration versus soil temperature (c & d) and soil moisture (e & f) are shown with a regression annotated with the proportion of variation explained.

Flux data from two sites (DCFS, ND, and SJER, CA) are shown in Figure 2. DCFS is a grassland with cold winters and warm humid summers. While SJER is an open canopy oak-grassland site with cool wet winters and hot dry summers. At DCFS soil respiration was positively correlated with soil temperature and unrelated to moisture in most soil plots (Fig. 2).

RESULTS cont.

In contrast, at SJER respiration was either negatively related or unrelated to temperature, but positively related to moisture (Fig. 2). This is consistent with expected relationships to climate at these sites.

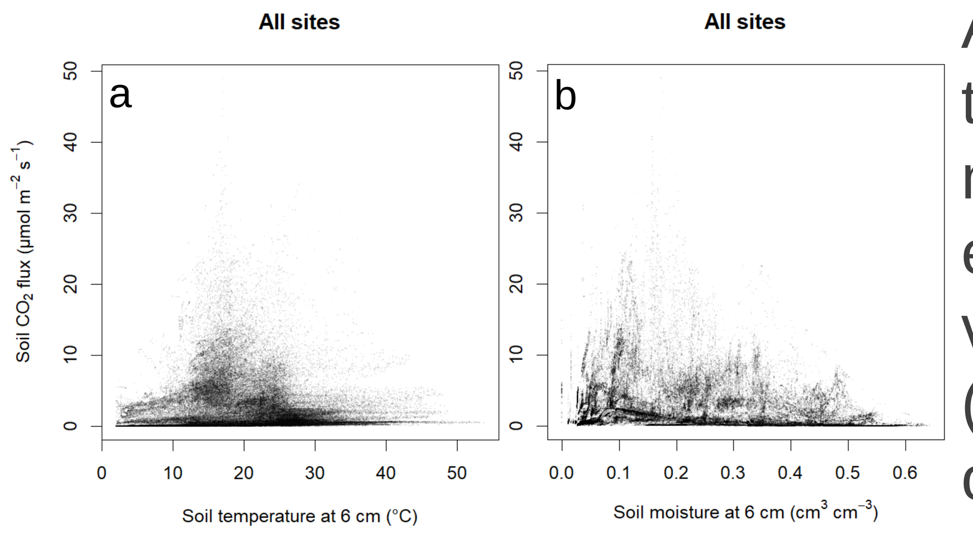

Figure 3. Soil respiration data from all sites and soil plot plotted against soil temperature (a) and moisture (b).

Across all sites soil temperature and moisture only explained 34% of the variation in respiration (Fig. 3), indicating that other properties must also be important in controlling respiration at this scale.

CONCLUSION

Soil respiration data product

The soil CO_2 flux data product seems plausible in terms of the magnitude of the fluxes, their seasonality, and relationship to temperature and moisture. This suggests that they are accurate, but further validation is required.

Controls on soil respiration

Temperature and moisture only explain about one third of the variation in soil respiration. The role of other potentially controlling factors requires further investigation, with many relevant types of data available from NEON, including photosynthetic rates, root biomass, microbial biomass and community composition, and soil organic matter content.

ACKNOWLEDGEMENTS

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