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Can we detect changes in high-latitude soil respiration over decadal time scales?

Ben Bond-Lamberty (bondlamberty@pnl.gov) and Allison Thomson; JGCRI / Pacific Northwest National Laboratory

Introduction

Soil respiration (R_S), the flux of CO_2 from the soil surface to the atmosphere, comprises the second-largest terrestrial carbon flux, but its dynamics are incompletely understood, and large-scale fluxes remain poorly constrained.

Ecosystem warming experiments, modeling analyses, and fundamental biokinetics all suggest that R_S should change with climate. This has been difficult to confirm observationally because of the high spatial variability of R_S, inaccessibility of the soil medium, and inability of remote sensing instruments to measure large-scale R_S fluxes.

Given these constraints, is it possible to discern climate-driven changes in high-latitude R_S fluxes in the extant record of R_S chamber measurements?

Figure 1. Spatial distribution of field-measured R_S fluxes in the published scientific literature, N=192, by ecosystem.

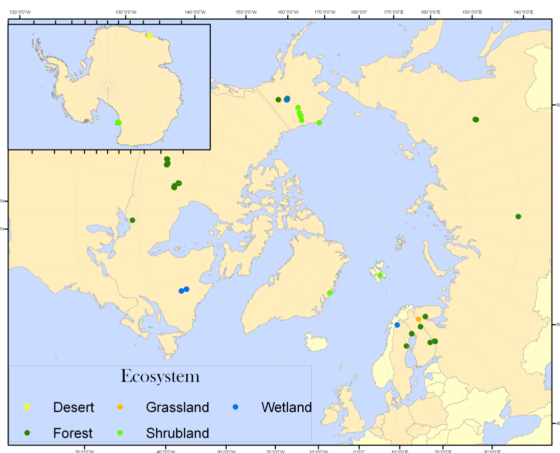
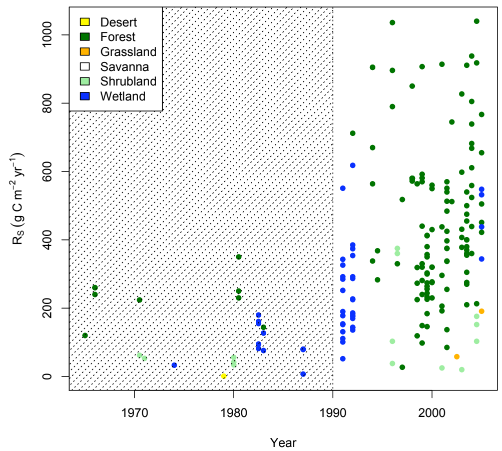


Figure 2. Observed high-latitude R_S rates in the published scientific literature, N=192, by ecosystem. The shaded box indicates older data points that were excluded from this analysis.



Methods

We collected all available studies in the scientific literature reporting annual R_S measured in the field. A total of 192 data points drawn from 53 studies, 1965-2005, met these conditions; a subset of these data (145 data points from 45 studies) formed the primary basis for study. Global climate, leaf area, cell area, and nitrogen deposition data were downloaded from online sources and matched to R_S data.

Linear models were used to examine the effects of climate (both mean annual climate and climate anomaly), biophysical variables, and year of measurement. Observations were weighted by the years of observed data reported, and checked for influential outliers. A Monte Carlo approach was used to propagate model errors to regional estimates.

Results

R_S was correlated with mean annual temperature, precipitation, and leaf area (Table 1). Unexpectedly, there was a strong *negative* correlation (T_{145}=-2.825; P=0.002) between temperature anomaly and R_S in high-latitude ecosystems. Several possibilities could explain this result:

- Positive temperature anomalies are in fact associated with lower R_S, because of another correlated variable.
- A type I (false positive) error. The boreal data set is relatively small and deletion of as few as 10% of the data points made the R_S-temperature anomaly relationship nonsignificant.
- A systematic error in the underlying climate data.

We estimate that high-latitude ecosystems contribute ~13% of an estimated 98 Pg yr^{-1} global flux (based on a global data set, not shown). This implies that the boreal/Arctic flux has increased ~7% in the last 20 years, consistent with the greater degree of climate change being experienced by boreal and Arctic areas.

Table 1. Significance of tested effects in the linear model. Model RSE= 4.834, df=149; adjusted R^2=0.47.

Effect	Estimate	T	P
Mean annual temperature	0.876	3.744	<0.001
Mean annual precipitation	-0.047	-3.823	<0.001
Temp anomaly	-5.896	-2.750	0.007
Precip anomaly	-0.009	2.455	0.015
LAI	1.215	2.261	0.010

Conclusion

The current high-latitude R_S data set is too small to conclude whether R_S is changing in these systems over decadal timescales.

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