**A test of predicting of annual soil respiration from its flux at mean annual temperature**

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**Abstract**

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**Introduction**

*(Outline)*

* SR is an important flux with a high spatial and temporal variability (Refs).
* It has been shown on a global dataset that SRannual can be predicted from SRmat (Bahn et al. 2010), which could provide an important constraint when assessing the spatial variability of SR across ecosystems, landscapes and regions.
* While the suggested relationship between SRmat and SRannual has been confirmed in comparative studies of neighboring sites (e.g. Litton et al. 2011, Oishi et al. 2013), some important questions still remain to be explored:

1. SRmat may vary between seasons due to phenological effects: SR may be higher in springtime, when rhizosphere activity is high and the autotrophic component of SR (Ra) causes higher SR rates at a given T than in fall (Curiel Yuste et al. 2004; Davidson et al. 2006). This could cause a global bias in that SRannual of sites more strongly dominated by Ra (i.e. sites with higher SR, cf. Bond-Lamberty et al. 2004, Subke et al. 2006, Bond-Lamberty & Thomson 2010) should be less predictable from SRmat, SRannual being overestimated when SRmat is measured during spring and underestimated when it is obtained during fall. (*Note, however, that the non-linearity of the SRmat-SRannual relationship could partly account for such an effect- this could be taken up in the discussion*).
2. Seasonally dry ecosystems: how well does an aridity index capture effects across sites? Furthermore, a fixed correction factor relating to average site aridity, may fail to account for effects caused by a distinct interannual variation in precipitation / soil moisture.
3. Interannual variability: to what degree is the cross-site relationship between SRMAT and SRannual suited for estimating the interannual variation of SRannual?

* Here, we use the largest available global dataset (Bond-Lamberty & Thomson 2010; more than an order of magnitude larger than the one used by Bahn et al. 2010) 1) to test the general validity of the relationship suggested by Bahn et al. (2010) both across sites and, within sites, across years; 2) to explore how the relationship is affected by aridity, and how such aridity effects can be accounted for; 3) to test the hypothesis that the relationship predicts Rh-dominated sites better than Ra-dominated ones.

Introduction.

“Spatial assessments of total annual SR (SRannual) are difficult to achieve given a finite availability of resources and the resulting trade-off between the temporal resolution required for obtaining an annual estimate and the spatial coverage required for achieving a defensible regional up-scaling (Savage and Davidson, 2003). For this reason it has been attempted to identify proxies for estimating SRannual, including monthly air temperature and precipitation (Raich and Potter, 1995; Raich et al., 2002), lit- terfall (Davidson et al., 2002; Raich and Nadelhoffer, 1989) and productivity indices, such as leaf area index or gross primary productivity (Bahn et al., 2008; Hibbard et al., 2005; Janssens et al., 2001; Reichstein et al., 2003).” –Bahn ms

We tested this idea by using a much (order of magnitude) larger, but in some respects less detailed, database than that used by Bahn et al. {, 2010 #2659}. Specifically, we asked the following questions: how well would the Bahn et al. relationship predict SRannual across a much broader range of sites? How much error can be expected from such a prediction, and what factors affect or bias it?

**Methods**

Here we follow the notation of Bahn et al., and refer to SR, the instantaneous soil-to-atmosphere CO2 flux (µmol m-2 s-1), SR at mean annual soil temperature (SRMAT), and the annual flux SRannual (g C m-2 yr-1).

*Primary soil respiration data*

This study used a recent version (XXX, downloaded XXX from <http://code.google.com/p/srdb/>; also available at the Oak Ridge National Laboratory DAAC) of a global soil respiration database {Bond-Lamberty, 2010 #2320}. We limited our analysis to studies that performed in non-manipulated ecosystems (no agricultural or experimentally manipulated sites); reported positive SRannual values; reported either SRMAT or the relationship between SR and soil temperature; and used standard infrared gas analyzers or gas chromatography techniques.

Most studies did not report SRMAT specifically. In these cases, we used the study’s reported relationship between soil temperature and SR (SR~T, expressed in many mathematical forms, but most typically as an exponential relationship SR=*a*e*b*T). Mean annual air temperature, computed from the climate data (below) for the year of the study, was used as a proxy for mean annual soil temperature, and SRMAT then computed from the SR~T model. The database includes measured soil temperature ranges associated with each study’s results, and in some cases, calculated MAT fell outside this range (e.g., a boreal forest with a MAT of -1 °C, but the study reports a SR~T model measured across a soil temperature range of 2-20 °C). There are obvious risks in extrapolating any statistical model outside of its fitted range, so we broke these cases out separately.

In general, studies estimate SRannual in one of two ways: by integrating year-round measurements of SR, or by extrapolation from measurements performed in a limited time period (typically the growing season). In the former case, the annual flux is largely independent of the T~SR model, but in the latter, there is some degree of dependence, potentially compromising the comparison between SRannual and SRMAT. To address this, we separately examined studies with year-round measurements (and thus SRannual values relatively independent of model-derived SRMAT values), which should provide the most rigorous test of SRannual prediction.

*Climate and other ancillary data*

Global climate data (“Monthly Mean Air Temperature (Global 1900-2008)” and “Monthly Total Precipitation (Global 1900-2008)”) sets were downloaded from http://climate.geog.udel.edu/~climate/; these data were used because of their high spatial resolution and currency (through 2008). These data were matched using a nearest-neighbour algorithm to the geographic coordinates of the collected database studies, and MAT computed for the 1961-1990 period. OR YEAR-SPECIFIC?!?

We used NCEP/NCAR reanalysis climate data {Kalnay, 1996 #848}{Kanamitsu, 2002 #3422}, accessed and aggregated using the RNCEP package {Kemp, 2011 #3072} in R, to examine the influence of local climate on stand dynamics. These data included 2 m air temperature (monthly mean, minimum, maximum), precipitation (P), and relative humidity.

*Statistical analysis*

Observations were weighted by the years of reported data, to account for studies that reported multi-year SRannual means. Models were checked for influential outliers using a Cook’s distance threshold of 0.5 and re-fit, if necessary, after outlier removal.

Transformation? Check residuals

We report prediction error using two methods. One is by simply reporting residual standard error (RSE) associated with each fitted model. We also use k-fold validation…

Analyses was performed using the R statistical computing package {R Development Core Team, 2013 #3489}, version 3.0.1; all code and data are included in the Supplementary Information.

**Results**

**1. How well did Bahn et al. equation predict annual soil respiration?**

-- was there an effect/bias of extrapolating models outside of measured range?

-- effect of WC\_effect? I.e., studies in which authors report significant water content effects on SR might/should exhibit bias

-- effect of PDI or something like it?

-- effect of year-round measuring? (need to go back and do this in database)

-- effect of Ra or Rh dominant?

**2. Equation based on these data, with prediction errors**

**3. What about predicting RH?**

-- the toughest flux and in some ways most important…could predict it and compare to (i) measurements and (ii) CMIP5 outputs.

**Discussion**

Discussion.

We expected, a priori, biases at sites with (i) seasonally dry conditions that restrict RS and/or (ii) strong phenological effects on *R*S. Do we see any such influences?

-- residual as indication of how much Ra influenced by phenology/contributes to Rs?

Mean annual \*air\* temperature is more useful? Certainly easier to acquire.

Raises the possibility of greatly improving our understanding of spatial variability!

Interannual variability and multi-year lags (B-L 2012): prediction should be only for that year presumably…

**Conclusions**

Conclusions.

**References**

**Table 1.** Summary of data analyzed.

**Table 2.**

**Figure 1.** Figure 1.