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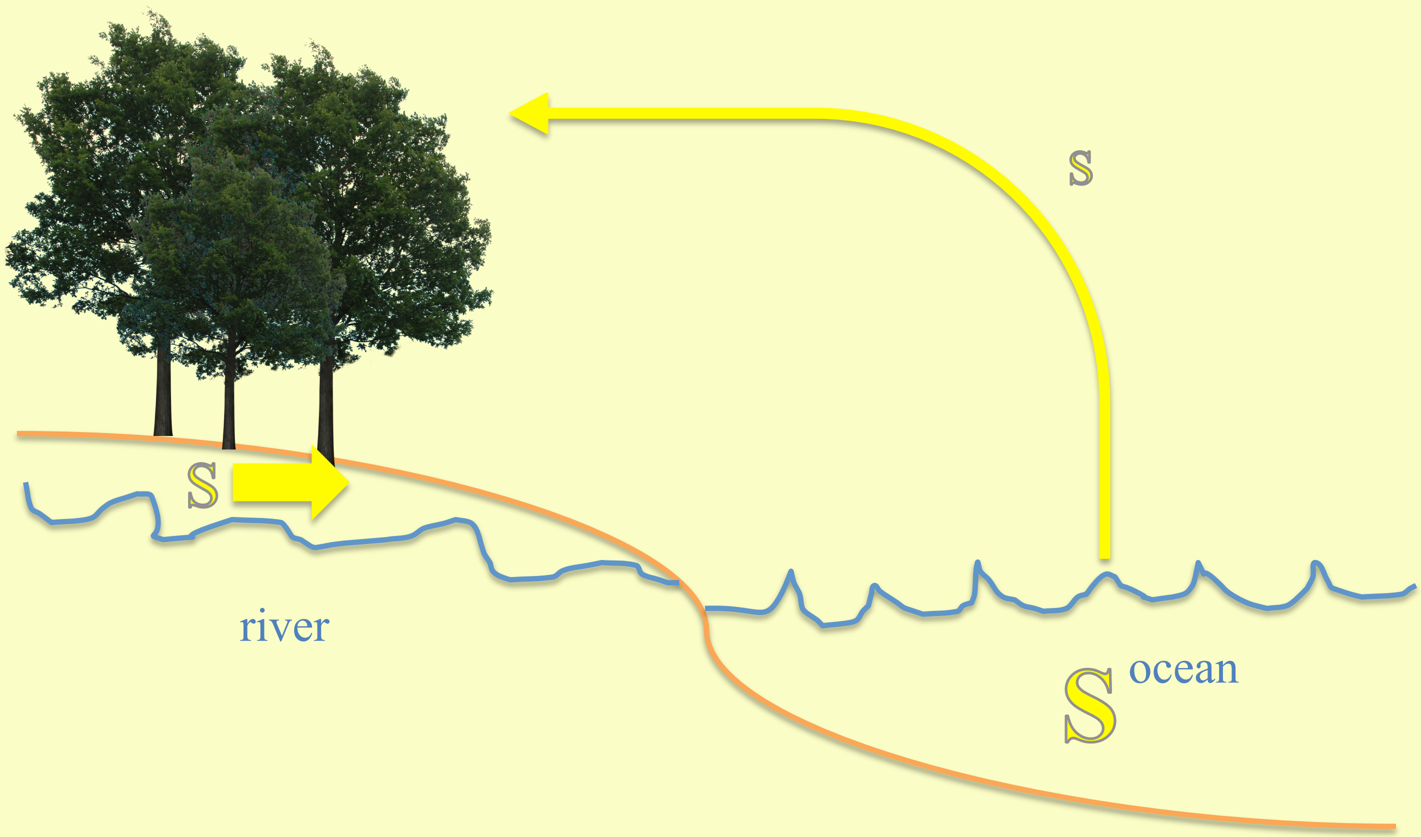
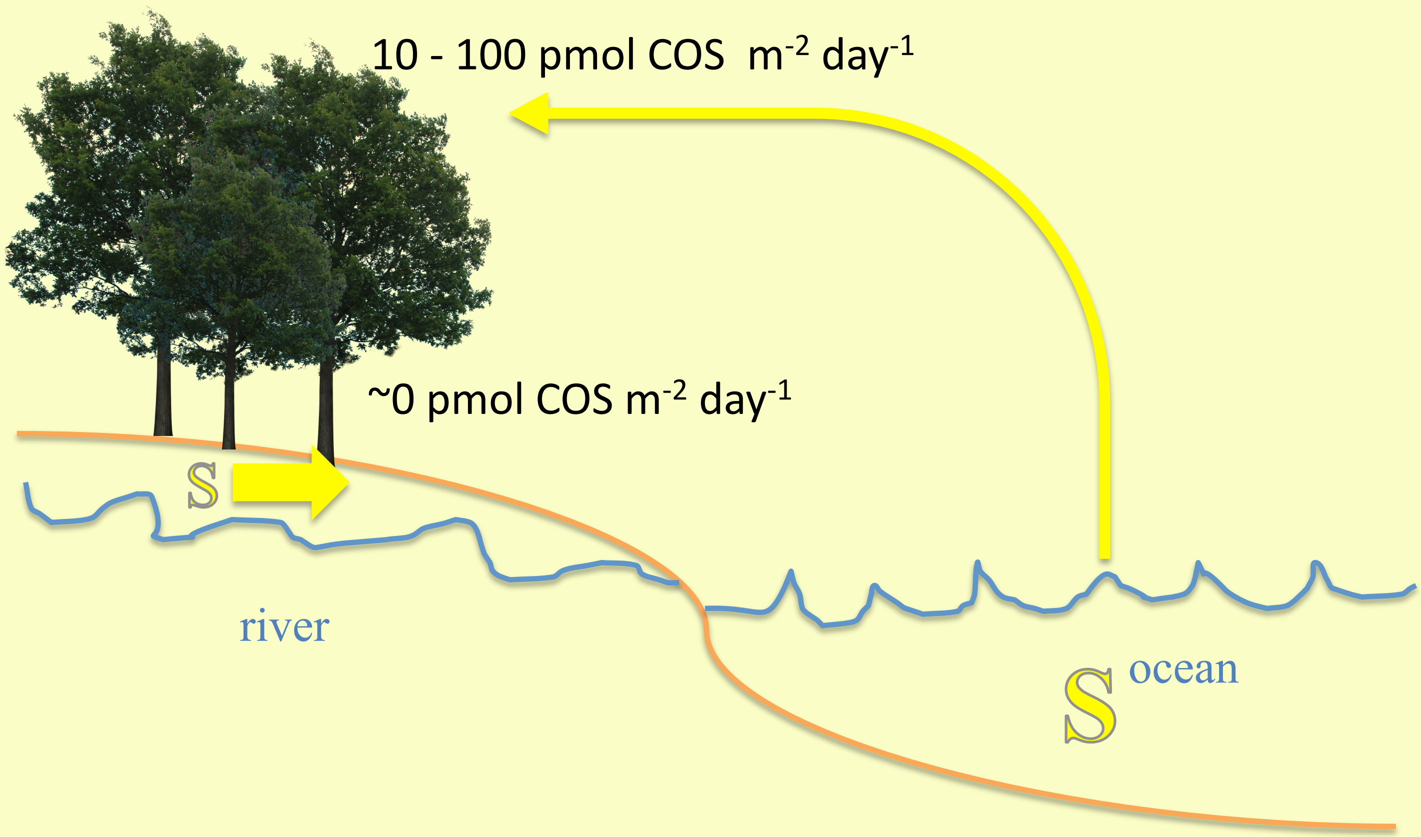
carbonyl sulfide and soil: a primer

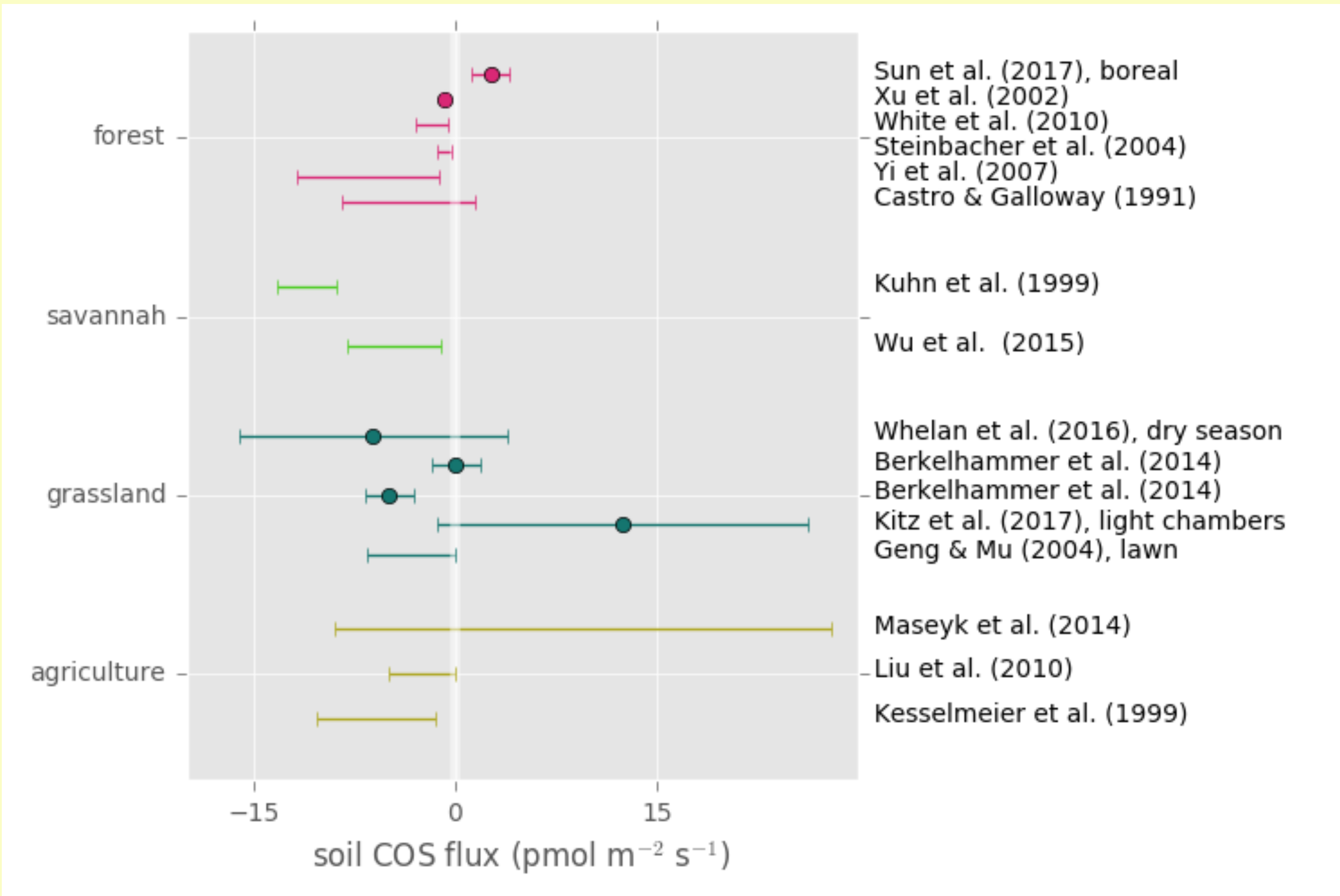
Mary Whelan

The Sulfur Cycle (abridged)



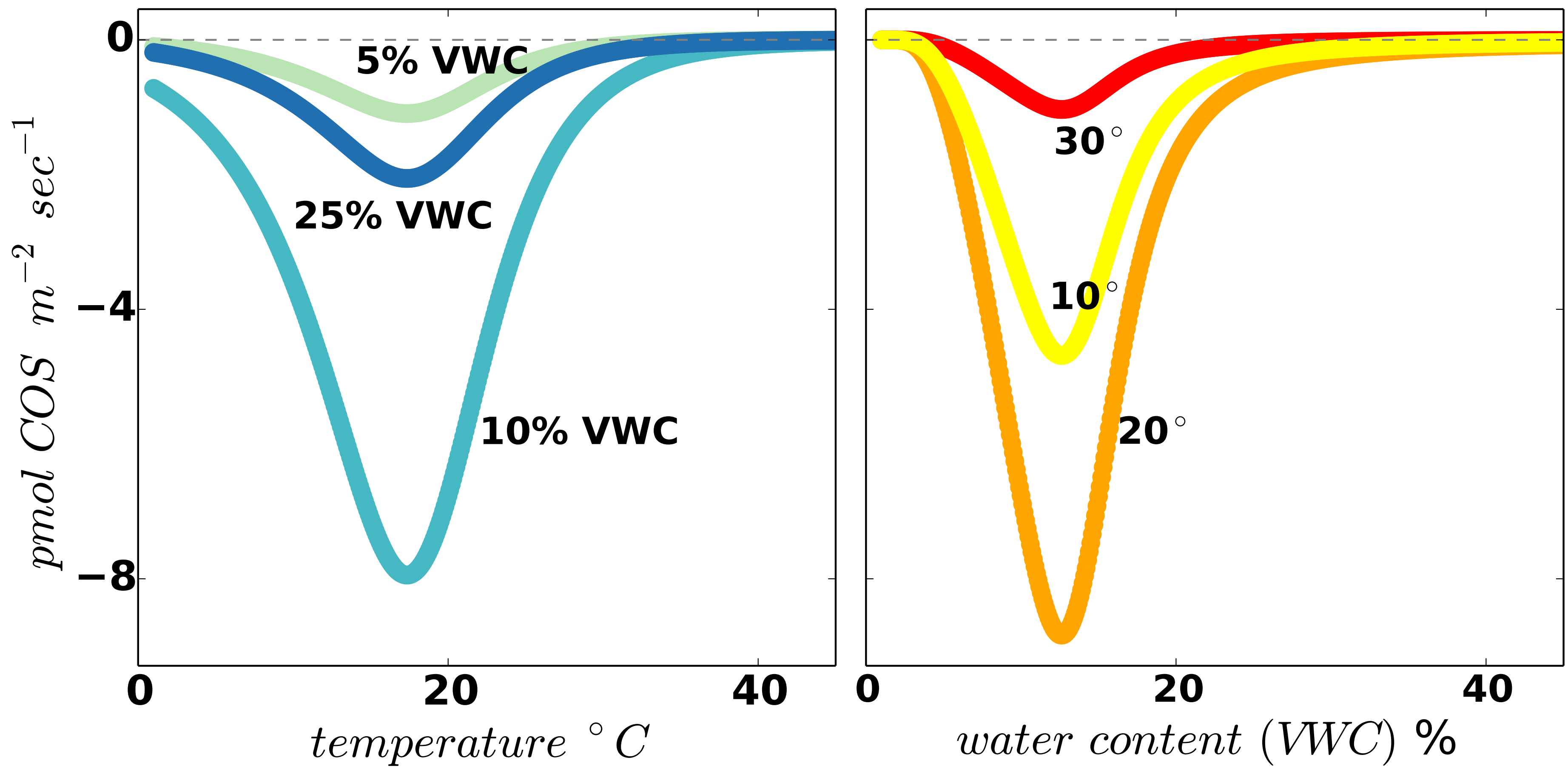
The Sulfur Cycle (abridged)





Sun et al. (2017), boreal
Xu et al. (2002)
White et al. (2010)
Steinbacher et al. (2004)
Yi et al. (2007)
Castro & Galloway (1991)
Kuhn et al. (1999)
Wu et al. (2015)
Whelan et al. (2016), dry season
Berkelhammer et al. (2014)
Berkelhammer et al. (2014)
Kitz et al. (2017), light chambers
Geng & Mu (2004), lawn
Maseyk et al. (2014)
Liu et al. (2010)
Kesselmeier et al. (1999)
forest
savannah
grassland
agriculture
−15
0
15
soil COS flux (pmol m−2 s−1)

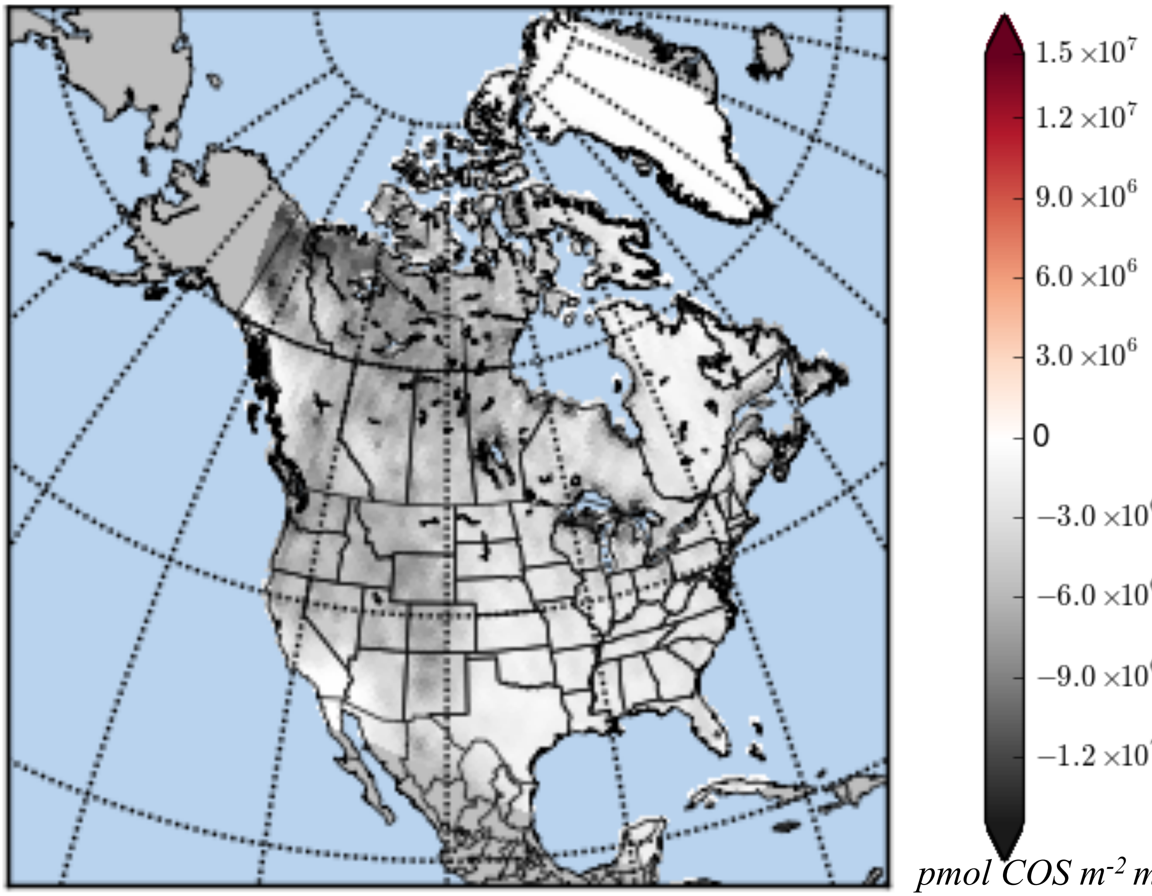
Previous framework



Kesselemeier et al. 1999

Previous framework

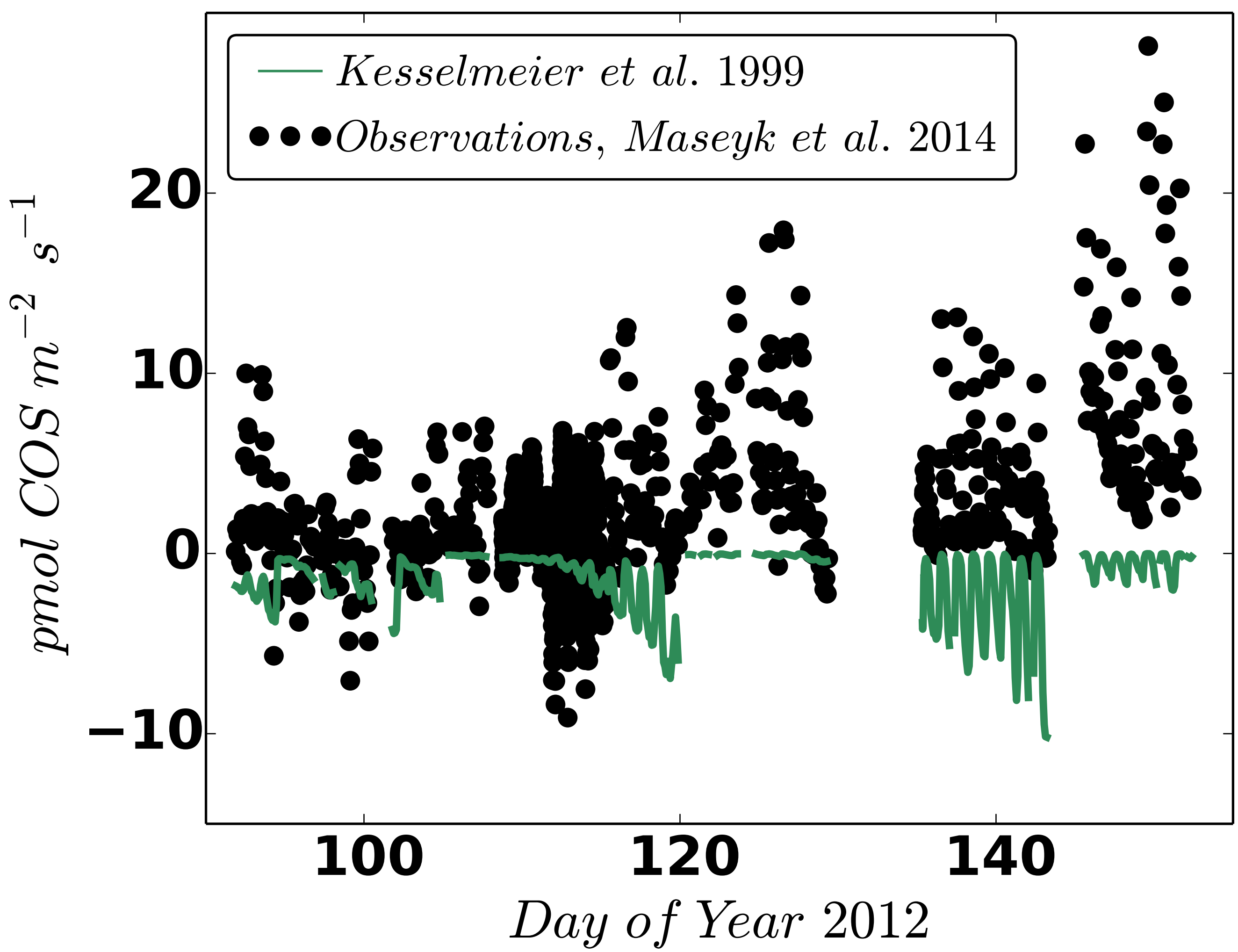
Kesselmeier et al. 1999 soil fluxes on N America

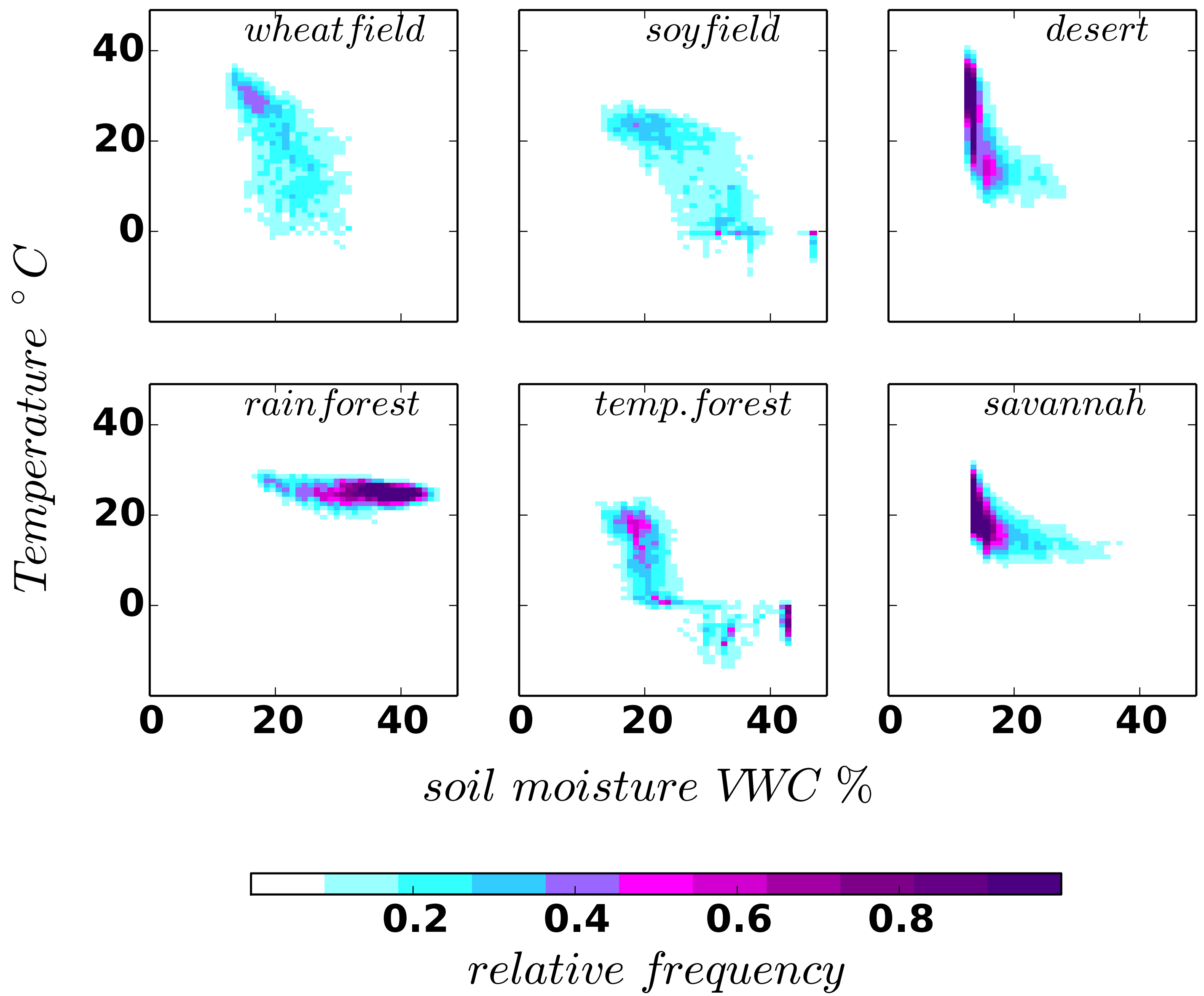


pmol COS m^{-2} $month^{-1}$

Hilton et al.

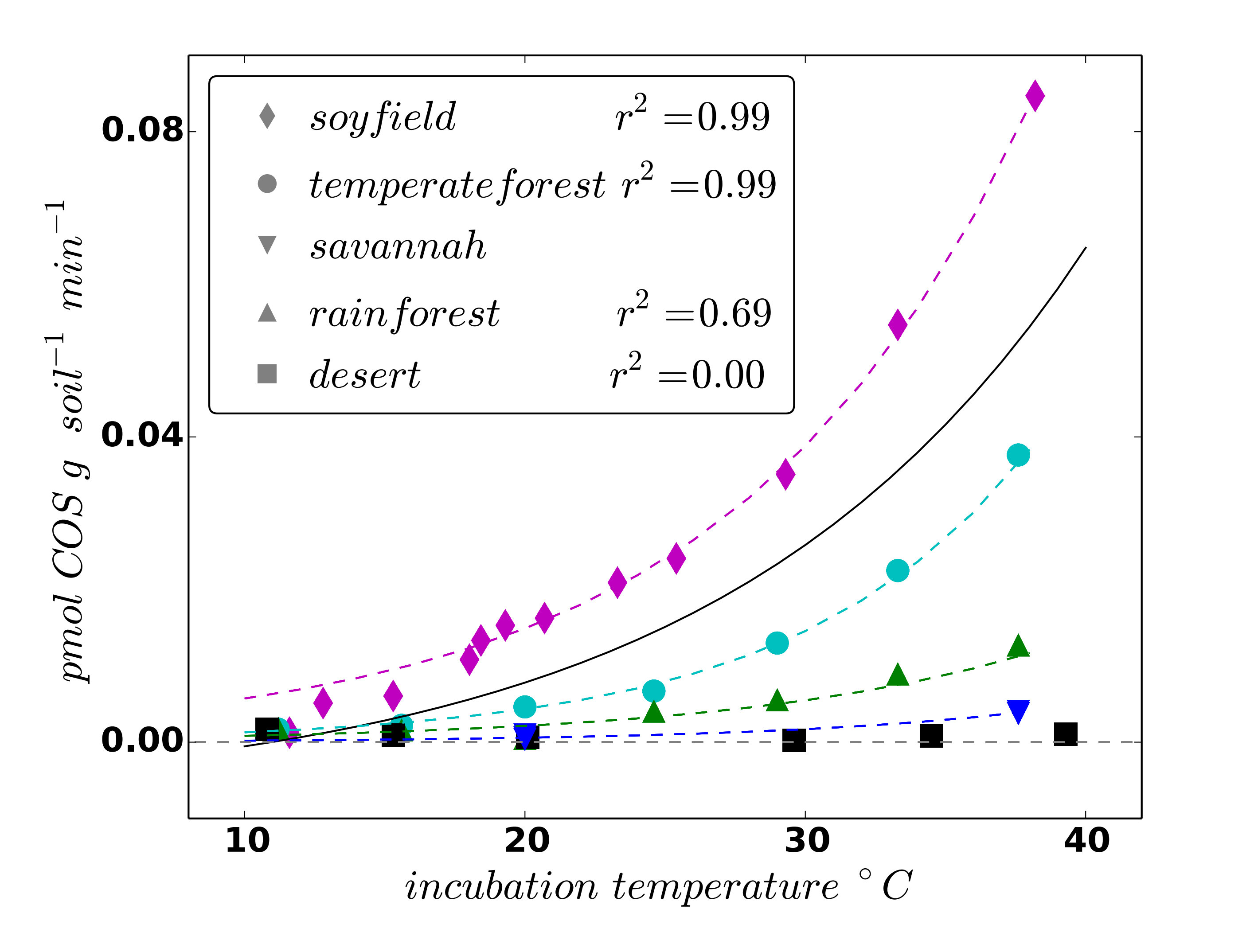
Soils both emit and consume COS





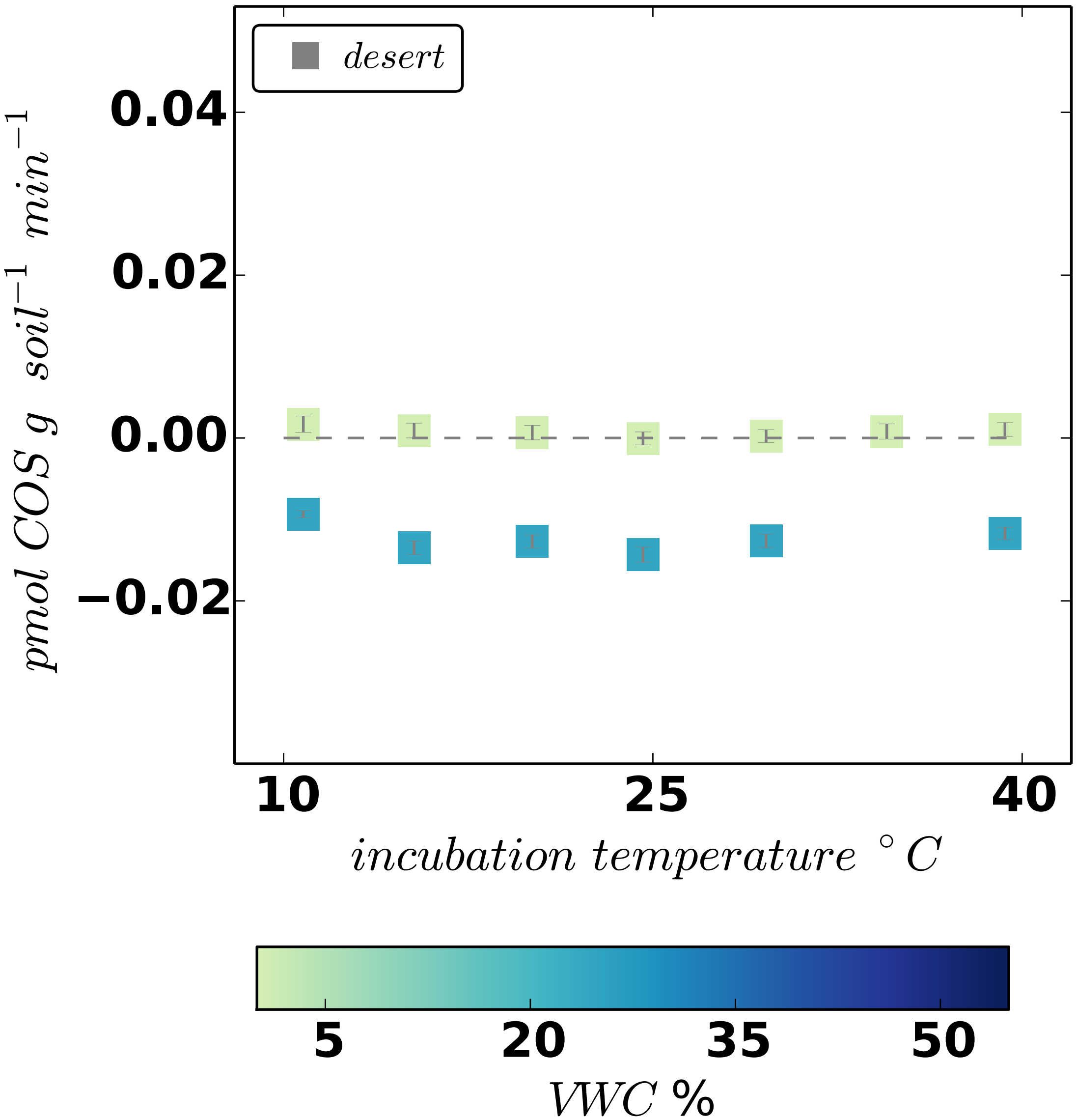
Whelan et al., ACPD, 2015

COS production from dry soils



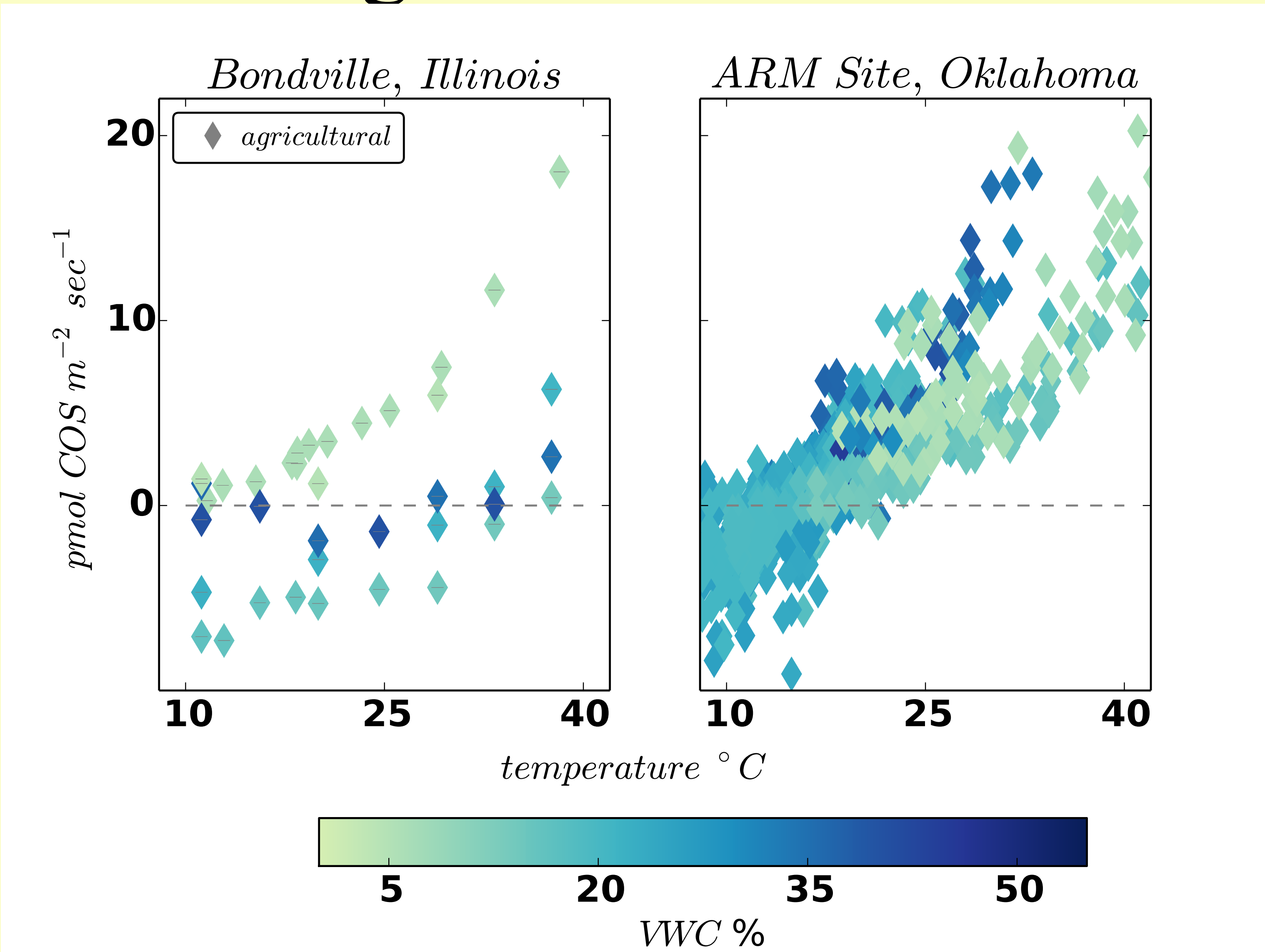
Re-graphed from Whelan et al., ACP, 2016

Deserts



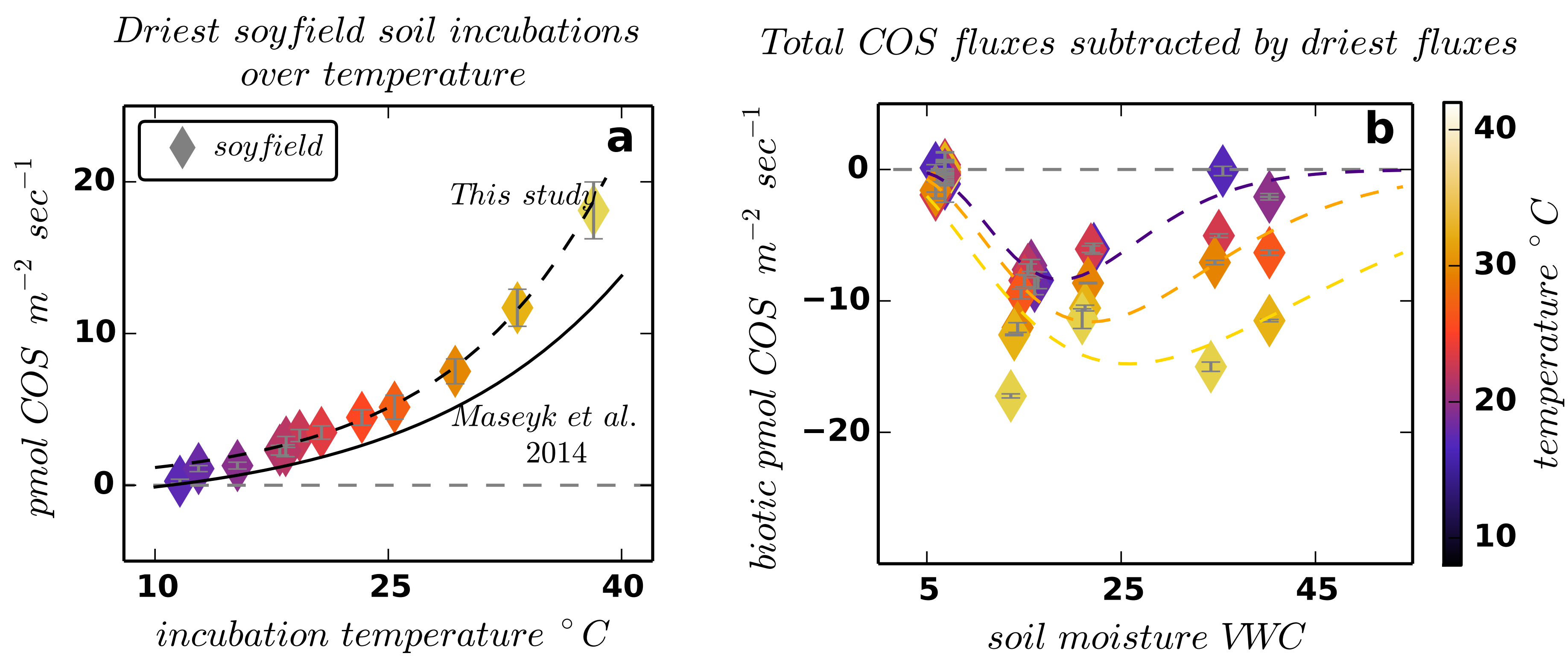
Whelan et al., ACP, 2016

Agricultural Soils



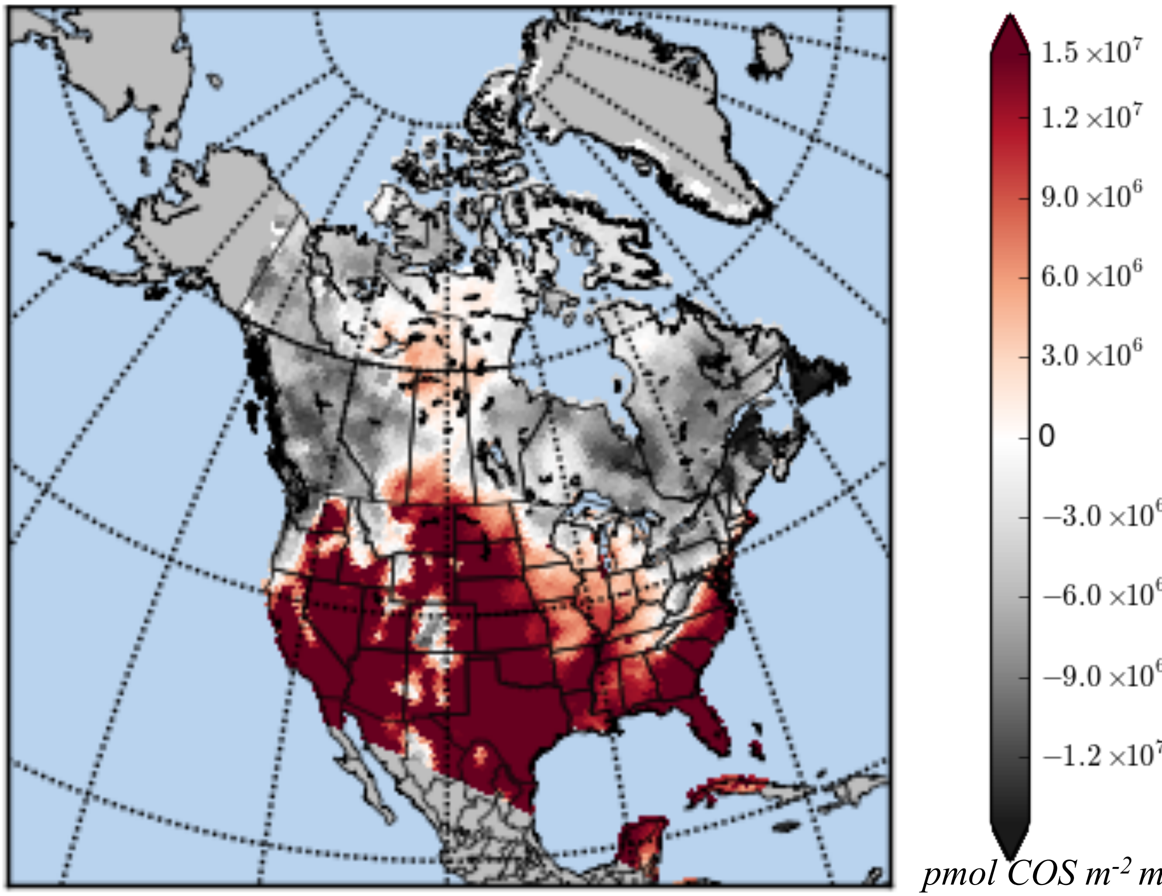
Whelan et al., ACP, 2016; Maseyk et al., PNAS, 2014

Production and Consumption



Whelan et al., ACP, 2016

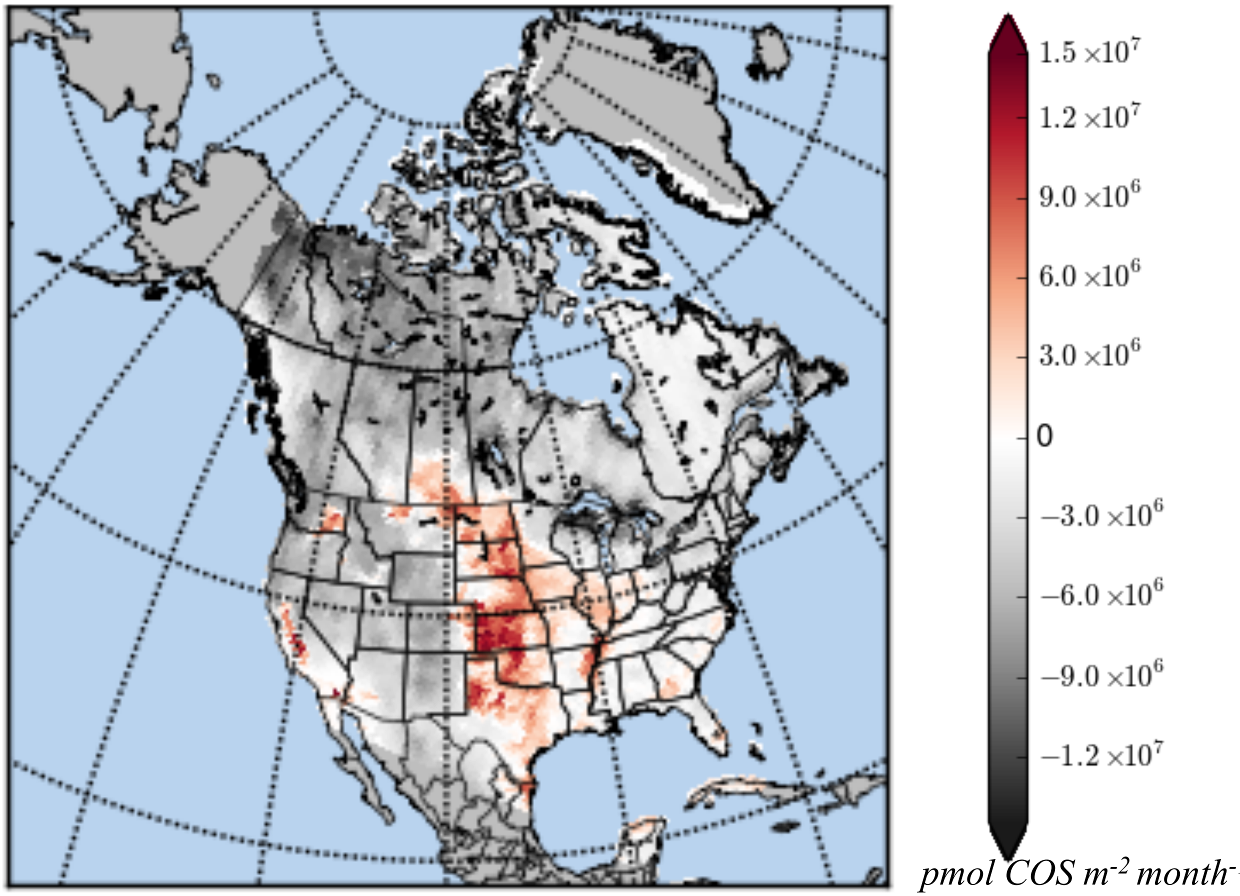
Continental Scale



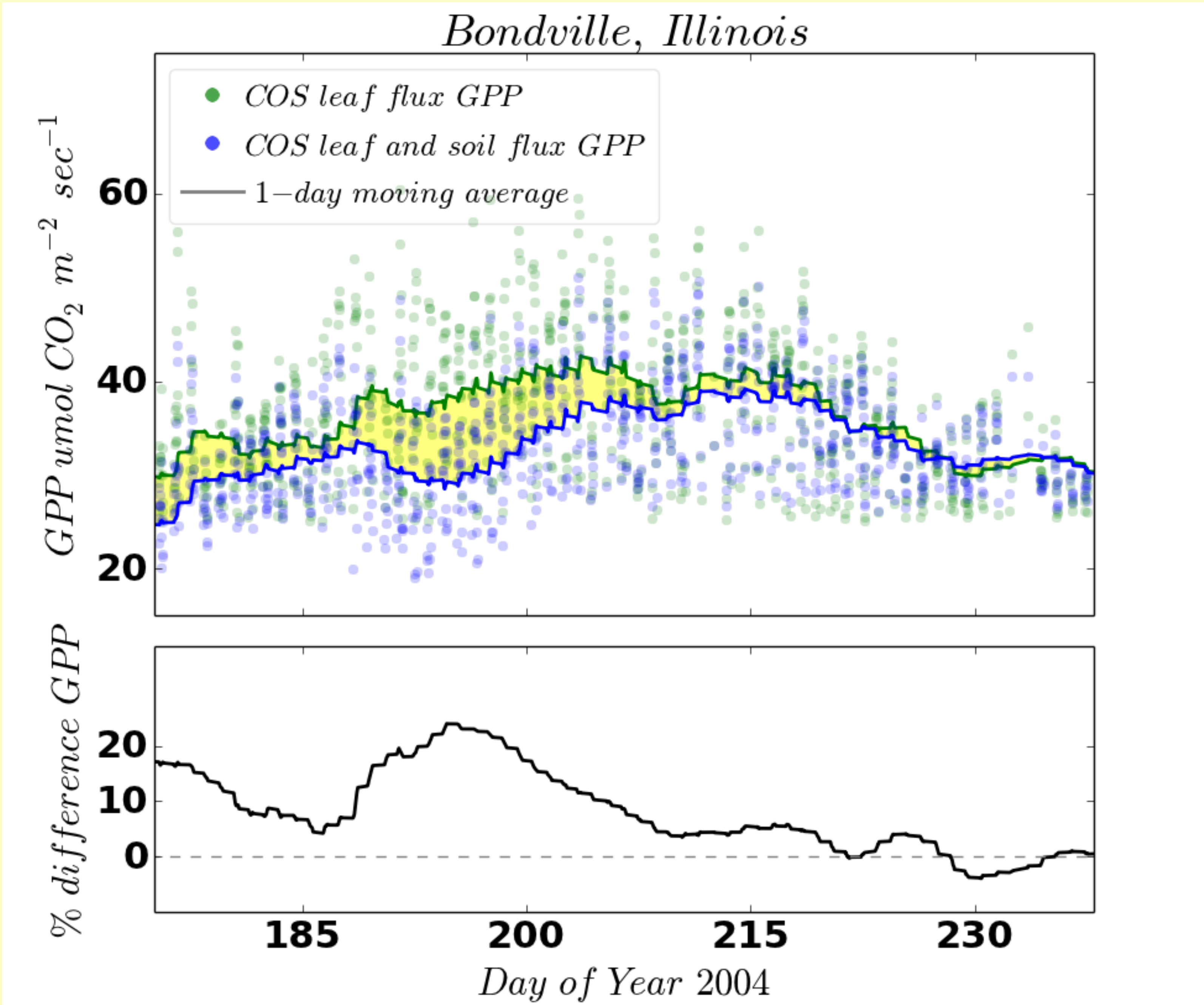
pmol COS m^{-2} $month^{-1}$

Hilton et al.

Continental Scale



Hilton et al.



Whelan et al., 2016

reactive transport model for soil COS flux

$$\frac{\partial (k_H \theta_w + \theta_a) C}{\partial t} = \frac{\partial}{\partial z}\left(D \frac{\partial C}{\partial z}\right) + \mathscr{U} + \mathscr{P}$$

COS uptake

$$\mathscr{U} = -V_{\max,U} \cdot \frac{k_H C}{k_H C + K_m} \cdot f(T) \cdot g(w)$$

COS production

$$\mathscr{P} = V_{\max,P} \cdot \exp\left[k\left(T - T_{\text{ref}}\right)\right]$$

k_H : solubility
D : diffusivity
K_m : Michaelis constant

Input variables (physical drivers):

- $T(z)$: soil temperature
- $\theta_w(z)$: soil moisture
- $\theta_{tot}(z)$: soil total porosity
- C_{atm}: ambient COS concentration (boundary condition)

Tunable parameters (biological)

- microbial activity parameters, $V_{\max,\,U}$, $V_{\max,\,P}$
- Temperature and moisture optima in $f(T)$ and $g(w)$

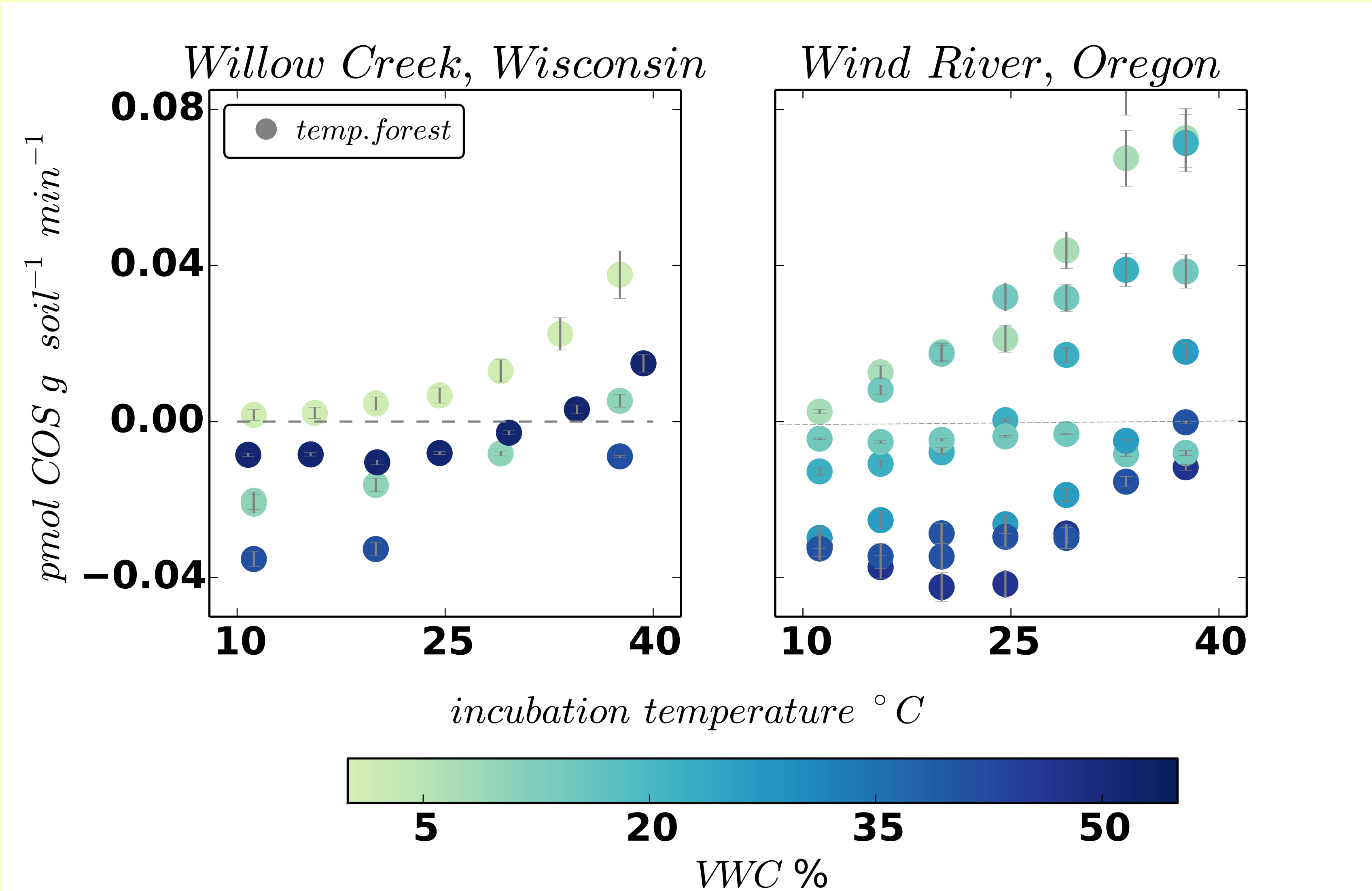
Sun *et al.* (2015) *Geosci. Model Dev.*

Summary

- COS exchange in soils needs to be taken into account to make GPP estimates over ecosystems better
  - Desert soils are small sinks when wet
  - US Agricultural fields are sources when hot/dry
  - Forest soils are variable, but may be predictable

The error from neglecting soil fluxes is still generally smaller than
the error in overall GPP estimates

Forest Soils



Whelan et al., ACP, 2016; Rastogi et al. In Prep