Gross uptake of carbon in the U.S. is largest in the Midwest Region

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Prediction is very difficult, especially about the future.

- Danish proverb
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- some of us here in this room, among others
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GPP was Northerly/Midwestern!

July/Aug 2008 GPP (μmol C m$^{-2}$ s$^{-1}$)

CASA-GFED3

SiB3

0 6.5 13
Prediction is very difficult, especially about the future. past

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GPP was Northerly/Midwestern!

Nope, GPP was southeasterly!

CASA-GFED3

SiB3

Can-IBIS

July/Aug 2008 GPP (\(\mu\text{mol C m}^{-2} \text{ s}^{-1}\))

0 6.5 13
carbonyl sulfide primer

carbon dioxide

$\text{CO}_2$

carbonyl sulfide

$\text{COS}$ or $\text{OCS}$
carbonyl sulfide primer
carbonyl sulfide primer

anthropogenic

soils plants ocean
Our approach

COS plant flux models  2nd-order COS surface fluxes

Regional transport model

Simulated regional [COS]

compare to

NOAA airborne [COS] observations
(big thanks to Steve Montzka, Colm Sweeney, Ben Miller, et al.)
Modeling setup

STEM domain boundary

NOAA airborne [COS] observation sites
COS plant flux models

mechanistic

Berry et al. (2013)

Leaf-scale Relative Uptake (LRU)

e.g. Montzka et al. (2007), Stimler et al. (2010, 2011, 2012)

\[ F_{plant} = GPP \times LRU \times \frac{[COS]}{[CO_2]} \]
COS plant flux models

<table>
<thead>
<tr>
<th>GPP model</th>
<th>COS uptake model</th>
</tr>
</thead>
<tbody>
<tr>
<td>CASA-GFED3</td>
<td>LRU = 1.61</td>
</tr>
<tr>
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<td>LRU = C3/C4 weighted</td>
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<tr>
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<tr>
<td>SiB</td>
<td>mechanistic canopy</td>
</tr>
</tbody>
</table>

see also:
Hilton et al., Tellus B, 2015
Results I: 2nd-order COS fluxes

Soils

- Kettle et al. (2002)
- Whelan et al. (2016)

Anthropogenic

- Kettle et al. (2002)
- Campbell et al. (2015)

Boundaries

- Climatological
- Constant
Results I: 2nd-order COS fluxes

Soils

Anthropogenic

Boundaries

Kettle et al. (2002) × 2

Whelan et al. (2016) × 2

Kettle et al. (2002)

Campbell et al. (2015)

COS [pmol m⁻² s⁻¹]

COS [pmol m⁻² s⁻¹]

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COS [pmol m⁻² s⁻¹]

climatological

constant

2 x 2 = 8
Results II: [COS] variability

drawdown variability drivers: GPP >> [soils, anthropogenic, bounds, leaf model]
Results III: spatial diagnosis

COS Drawdown (pptv)

NHA CMA SCA

COS Drawdown (pptv)

CAR WBI AAO HIL CMA

COS Drawdown (pptv)

ETL DND LEF WBI BNE SGP

Observed
SIB, mechanistic
SIB, LRU=1.61
CASA–GFED3, LRU=C3/C4
CASA–GFED3, LRU=1.61
Can–IBIS, LRU=C3/C4
Can–IBIS, LRU=1.61
Reserve Slides
Prediction is very difficult, especially about the future.  
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GPP was
Northerly/
Midwestern!

No, GPP was southeasterly!

CASA-GFED3  SiB3  Can-IBIS

July/Aug 2008 GPP (μmol C m⁻² s⁻¹)

annual mean GPP  
[gC m⁻² yr⁻¹]

Jung et al. (2011)
At a flux tower, atmospheric mixing has not yet "washed out". Though we use Can-IBIS to illustrate the point, this result well at many northerly Mid-continent sites, its estimates in This satisfies a critical requirement for using COS as a tracer variability does not a Hilton can GPP in the Southeastern USA. ecosystem models [comparisons summarized here disagree with a number of is likely not unique to Can-IBIS. The simulation–observation the Southeastern USA are larger than observations indicate. matches COS vertical drawdown observations reasonably for regional GPP. uncertainty (as estimated by inter-model GPP di [fact constant [LRU as a constant introduces considerably less error than GPP the LRU variability signal. drive LRU variations, and also have high temporal resolution. observations are made at the surface near to the processes that tower COS flux observations more heavily because these ob- [change model includes diurnal variability in the relative leaf surface measurements. The mechanistic leaf-level COS ex- fore averaged across larger spaces and longer timescales than atmospheric mixing processes. Airborne observations are there- airborne observations observe air that has experienced regional airborne COS drawdown observations significantly, because or by a COS–CO [eq. 12]–1 eq. 14]. The results in fig. 40˚N 60˚N 120˚W 90˚W The top row shows GPP CO [LRU = 1.61 or C3/C4]. However, the tran- er starkly when driven by diLRU (1.61 or C3/C4). However, the tran- er starkly when driven by di [LRU = 1.61]; this is also seen in observations LRU (1.61 or C3/C4). LRU = 1.61 [LRU=1.61] DRAFT GPP assignments (northern-USA-focused vs. southern-USA- sect drawdowns diLRU (1.61 or C3/C4). However, the tran- er starkly when driven by diLRU (1.61 or C3/C4). However, the tran- er starkly when driven by di SiB and CASA-GFED3 place the strongest North Ameri- canistic uncertainty supports the use of COS as a tracer for GPP dominantly drives the consistency of modeled COS plant [c3, c4] that place the strongest North Ameri- canistic uncertainty supports the use of COS as a tracer for GPP dominantly drives the consistency of modeled COS plant STEM input, results
Soil COS fluxes

Figure S1: Surface COS soil fluxes (top row) and the associated STEM-simulated vertical COS drawdowns/enhancements (bottom row) for two different COS soil flux estimates. The left panels (a and c) show results for (1) soil COS fluxes, and the right panels (b and d) show results for the "hybrid" COS soil flux map derived from the weighed average of (2) COS soil fluxes for agricultural areas and (1) COS soil fluxes for non-agricultural areas. Cropland land area percentages are from (3).
Anthropogenic COS fluxes

Figure S3: COS surface fluxes from two different anthropogenic COS inventories (top row) and the resulting STEM-simulated COS vertical drawdown (bottom row). Panels a and c show Kettle et al. (2002) anthropogenic COS fluxes; panels b and d show Campbell et al. (2015) anthropogenic COS fluxes.
Boundary conditions

**Figure S5**: Climatological mean lateral boundary [COS]. The lateral boundary indices (horizontal axis) refer to the location of the column; they are indices to a ring surrounding the domain horizontally. Fig. S6 shows selected indices; column zero is the southernmost corner of the domain and the indices increase counter-clockwise.

**Figure S6**: Climatological mean top boundary [COS]. The green codes indicate the NOAA observation location (main text fig. 2) that supplied the [COS] for each horizontal grid cell. The lateral bounds indices (black numbers in white boxes) refer to the horizontal axis of fig. S5 – a handful of indices are plotted for orientation of fig. S5.
Figure S2: COS–CO$_2$ LRU (panel a) derived from weighted C3/C4 vegetation percentages (5) (panel b) as described in main text section Methods: Plant Fluxes.

Still et al. (2009)
References


Investigating uncertainties in quantifying GPP with carbonyl sulfide

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3 Department of Global Ecology, Carnegie Institution, Stanford, CA, USA.

The problem: CO$_2$ GPP is a critical unknown affecting future climate predictions, but quantifying it at scales less than global and greater than chamber-scale remains highly uncertain.

Figure 1: Time and spatial scales of NEE and/or GPP observations.

Figure 2: Carbonyl sulfide (OCS) is metabolized along with CO$_2$, but the plant flux is in one direction only (atmosphere to plant).

Motivation

Using eq (1) to constrain CO$_2$ GPP depends on at least four conditions:

1. no reemission from plant;
2. OCS and CO$_2$ do not interact.
3. $F_{\text{plant}}$ dominates other sources/sinks of OCS;
4. uncertainties in $LRU$, $[\text{OCS}] / [\text{CO}_2]$ transport, convection, etc. are smaller than uncertainty in GPP.

Stimler et al (2010)
Campbell et al (2008)

Stimler et al (2010)
Campbell et al (2008)

Modeling Experiments

Here we present experiments using the Sulfur Transport and Emission Model (STEM). We test the sensitivity of simulated COS vertical drawdown to COS plant flux, $LRU$, boundary conditions, and modeled convection intensity.

Modeling Experiments

Figure 3: Calculating $LRU$ as a weighted average by vegetation type.

...
COS exchange models

GPP models

CASA-GFED3  SiB3  Can-IBIS

COS Leaf flux models

mechanistic:
\[ F_{\text{plant}} = [\text{COS}_a] \times \left( \frac{1.94}{g_{sw}} + \frac{1.56}{g_{bw}} + \frac{1.0}{g_{\text{cos}}} \right)^{-1}, \]

Leaf relative uptake (LRU)-based:
\[ F_{\text{plant}} = \text{GPP} \times \text{LRU} \times \frac{[\text{OCS}]}{[\text{CO}_2]} \]
COS exchange models

GPP models

3 x

CASA-GFED3
SiB3
Can-IBIS

COS Leaf flux models

mechanistic:

\[ F_{plant} = [\text{COS}_a] \times \frac{1.94/g_{sw} + 1.56/g_{bw} + 1.0/g_{cos}}{1} \]

Leaf relative uptake (LRU)-based:

\[ F_{plant} = \text{GPP} \times \text{LRU} \times \frac{[\text{COS}]}{[\text{CO}_2]} \]

2 = 6