COS: A new tracer to constrain photosynthetic CO2 fluxes

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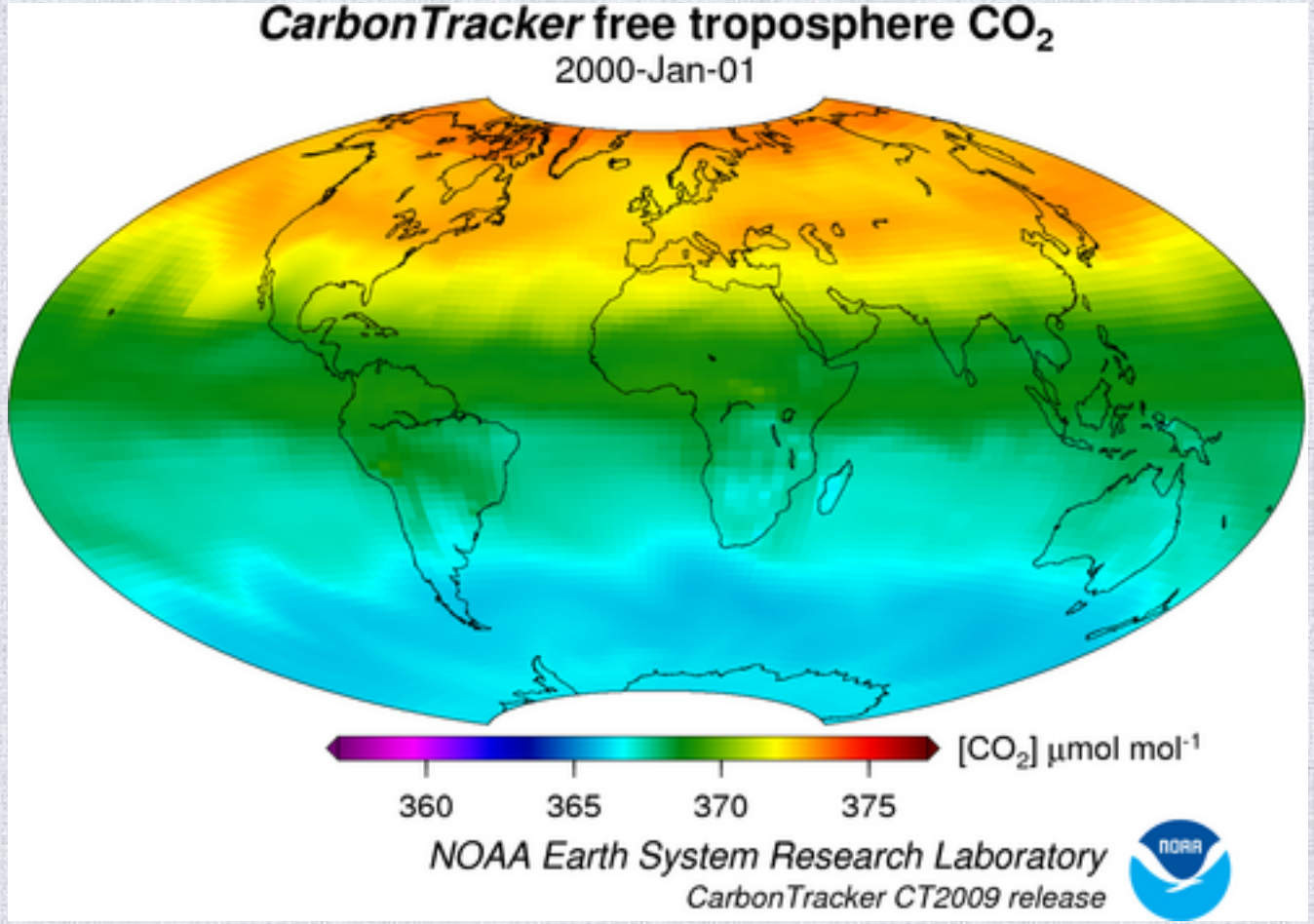
NOAA-GMD, Boulder, [3]CIREES, UC Boulder


CarbonTracker free troposphere CO2
2000-Jan-01
[CO2] µmol mol-1
360
365
370
375
NOAA Earth System Research Laboratory
CarbonTracker CT2009 release
NOAA

A greatest sources of uncertainty for future climate predictions Is the response of the global carbon cycle to climate change

...our mass balance analysis shows that net global carbon uptake has increased significantly by about 0.05 Gt C per year and that global carbon uptake doubled, from 2.4±0.8 to 5.0±0.9 Gt per year between 1960 and 2010...

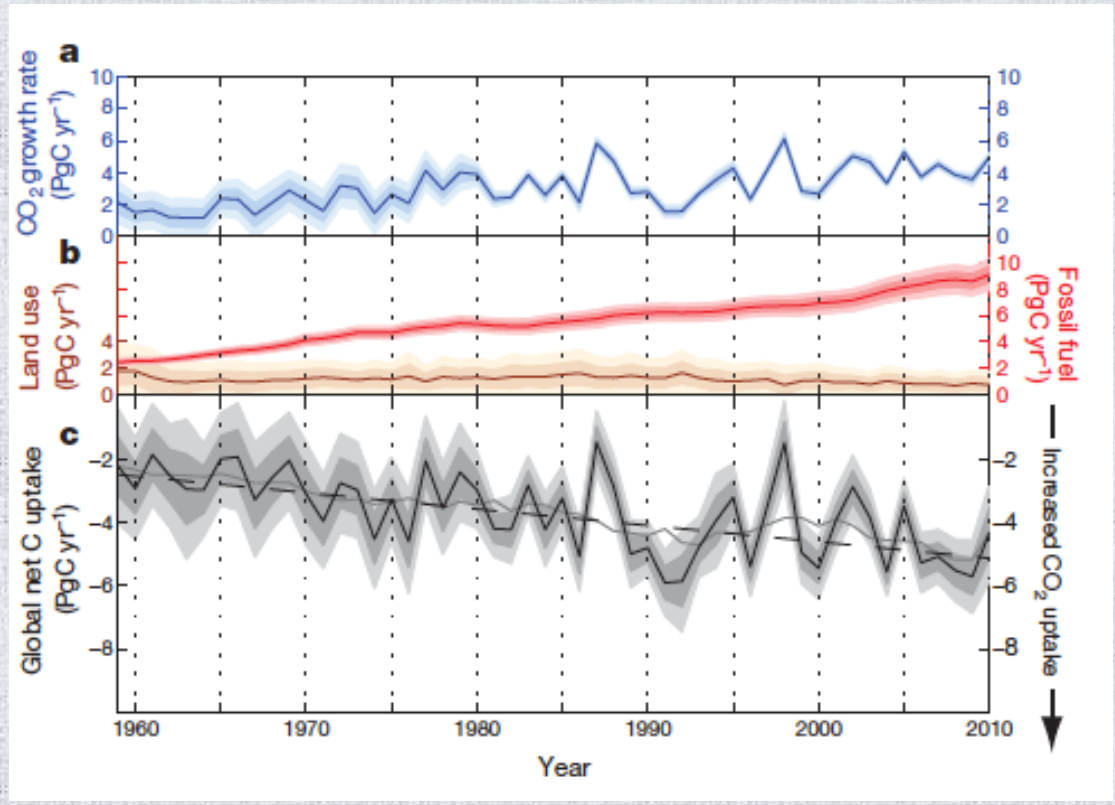
Ballantyne et al 2012

LETTER

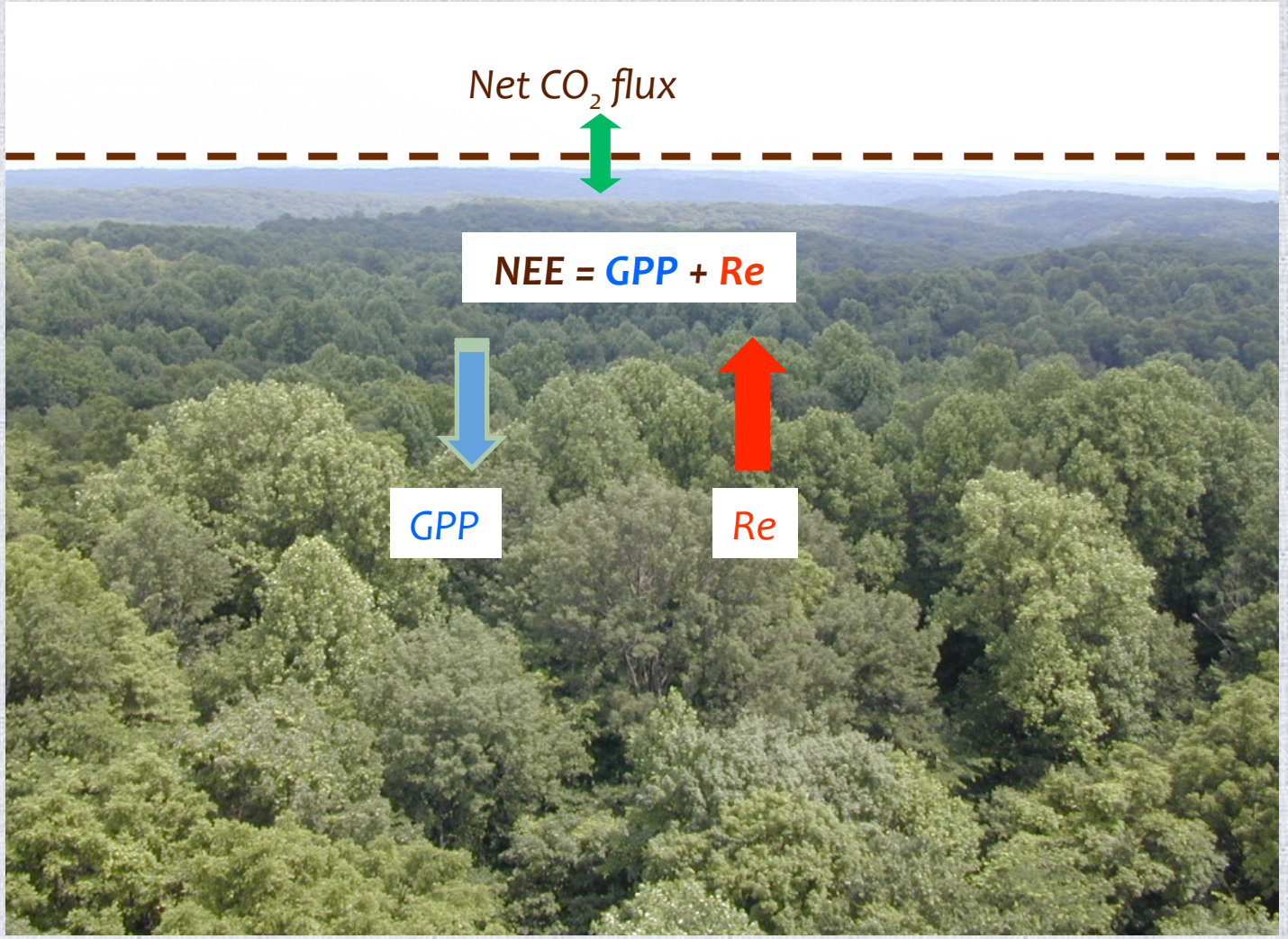
doi:10.1038/nature11299

Increase in observed net carbon dioxide uptake by land and oceans during the past 50 years

A. P. Ballantyne[1]†, C. B. Alden[2], J. B. Miller[3,4], P. P. Tans[4] & J. W. C. White[1,2]

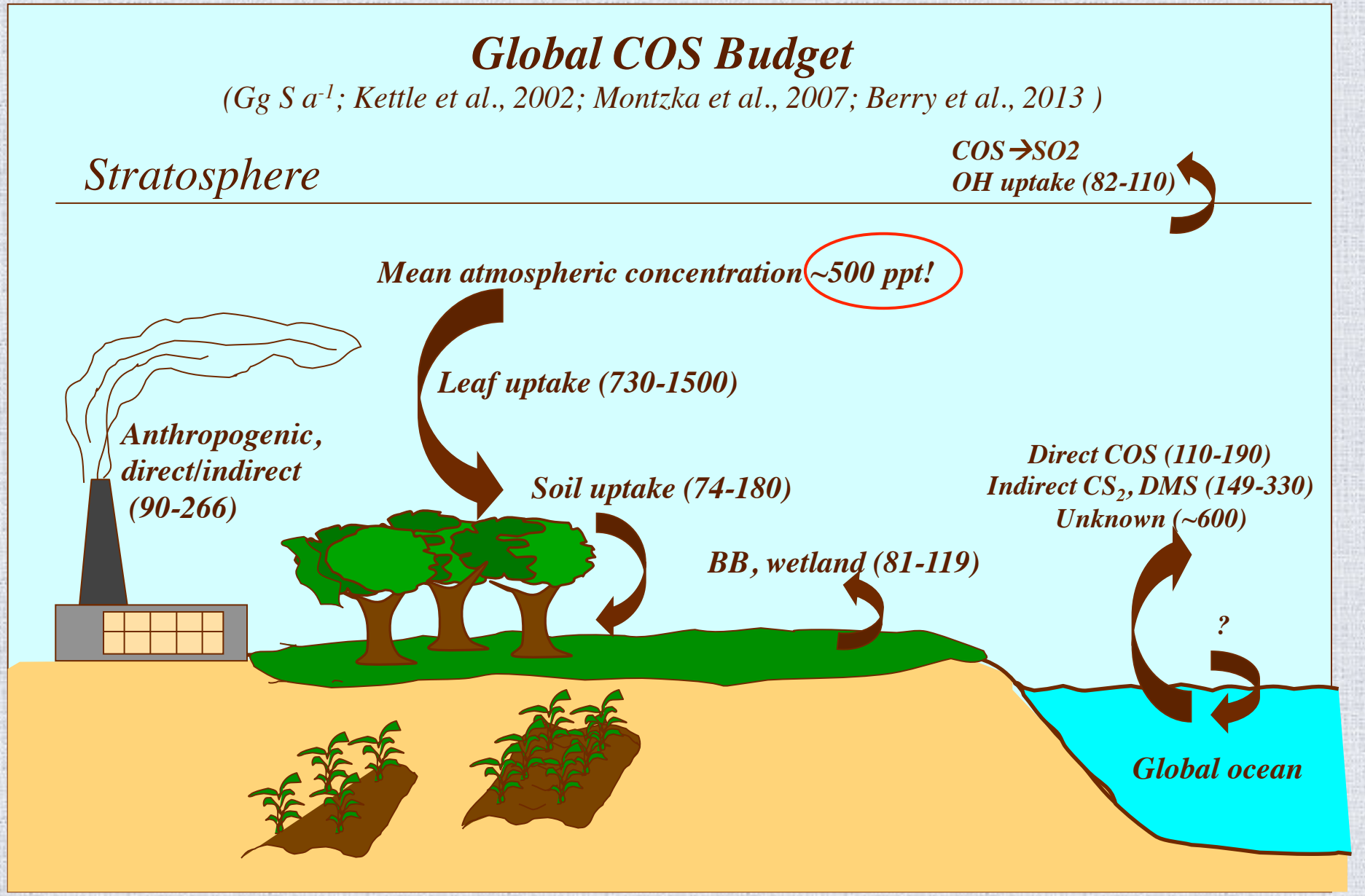


A major limitation: we cannot measure photosynthesis above the leaf scale



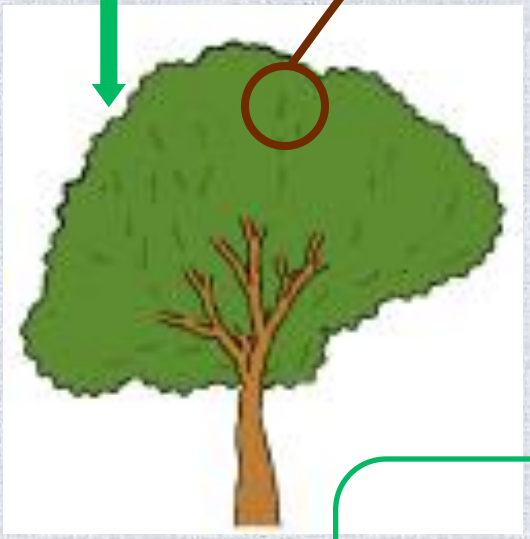
Global COS Budget

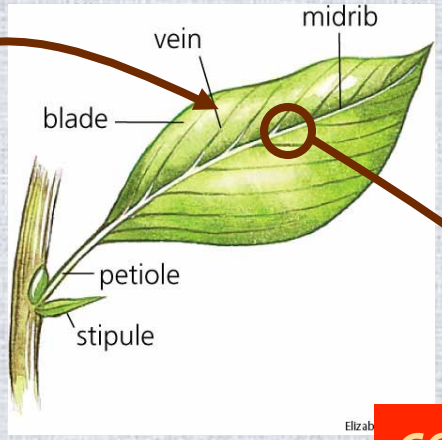
(Gg S a^{-1}; Kettle et al., 2002; Montzka et al., 2007; Berry et al., 2013)



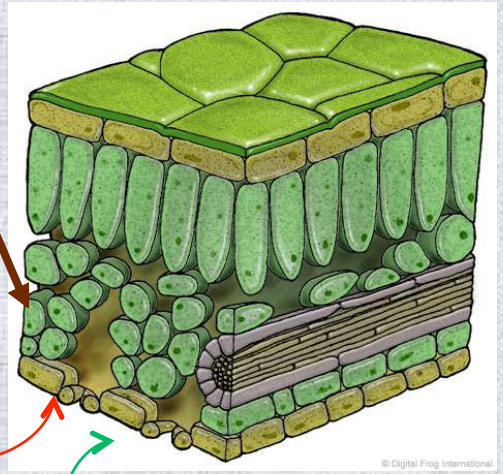
COS Uptake by Leaf During Photosynthesis

COS and CO_2 are taken up through leaf stomata during photosynthesis





COS



CO_2

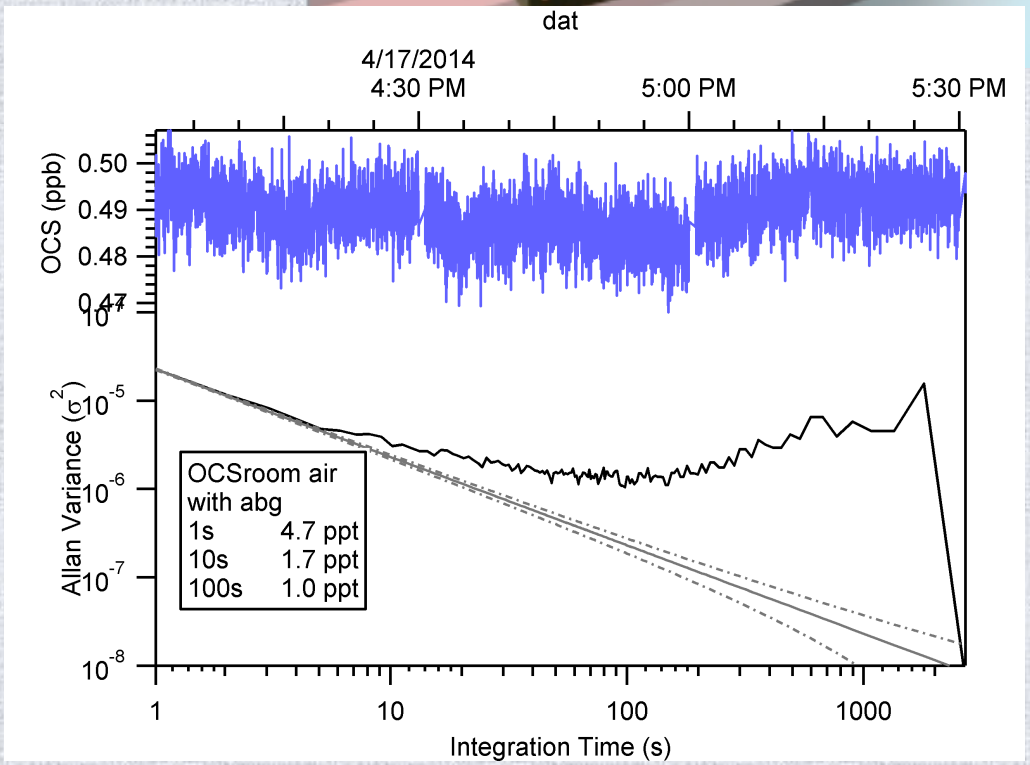
Carbonic Anhydrase (CA)

$$COS + H_2O \longrightarrow CO_2 + H_2S$$

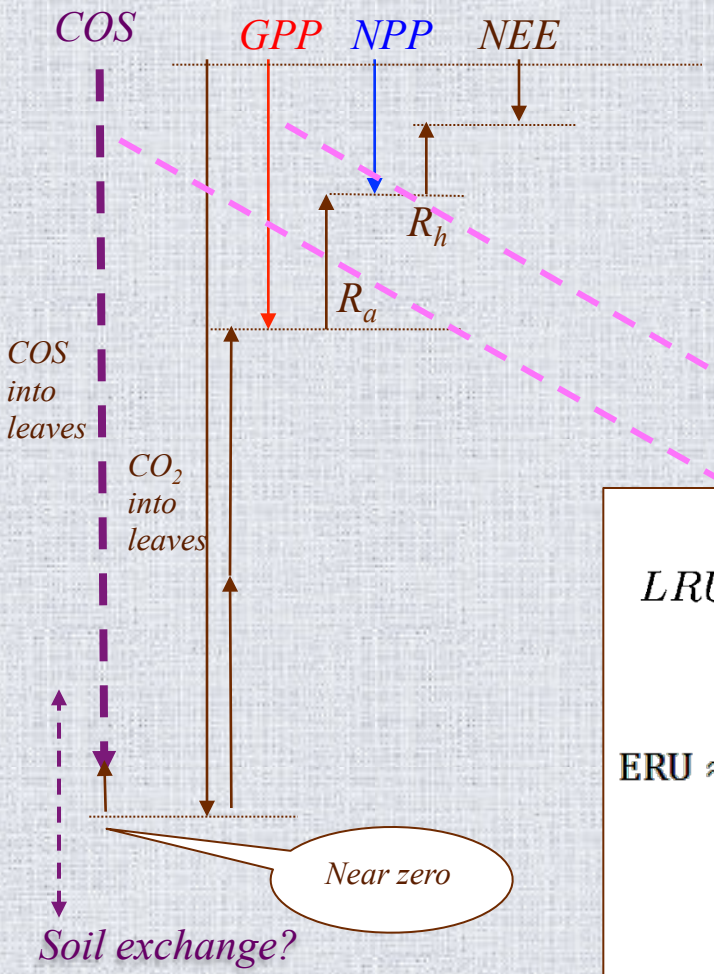
$$CO_2 + H_2O \longleftrightarrow HCO_3^- + H^+$$

$$H_2^{18}O + CO_2 \overset{CA}{\leftrightarrow} H^+ + [HCO_3^{18}]^- \overset{CA}{\leftrightarrow} H_2O + CO^{18}O$$

Exiting new technological advances (Quantum cascade, mid IR lasers, Mobile lab….



Changes in ratio of COS to CO_2 uptake across scales



~Constant across species and conditions

$$LRU = \frac{A_{COS}}{[\mathrm{COS}]} \Big/ \frac{A_{CO_2}}{[\mathrm{CO_2}]} \qquad \sim 1.6 \pm 0.2$$

$$\mathrm{ERU} \approx \frac{\frac{A^{s}_{ecosystem}}{[\mathrm{COS}]}\, LRU}{\frac{\text{Net } \mathrm{CO_2} \text{ exchange}}{[\mathrm{CO_2}]}} \approx \frac{\mathrm{GPP}}{\mathrm{NEE}}$$

$$LRU = \frac{A^{\cos}}{Aco2}\frac{[CO2]_a}{[COS]_a}$$

$$GPP = F^{\cos}\frac{[CO2_a]}{[COS_a]}.\frac{1}{LRU}$$

GPP/NEE= 1.9 to 2.2

LETTERS
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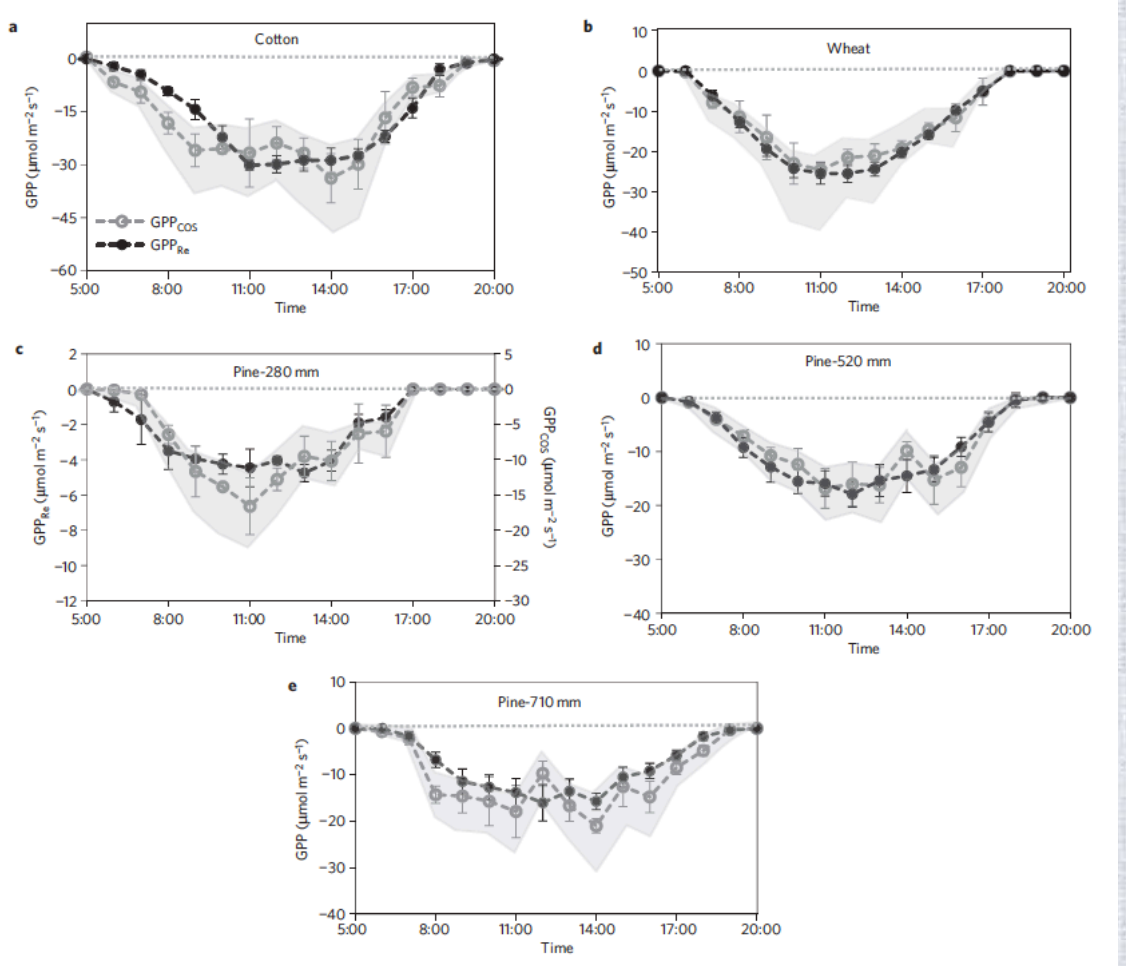
nature geoscience

Ecosystem photosynthesis inferred from measurements of carbonyl sulphide flux

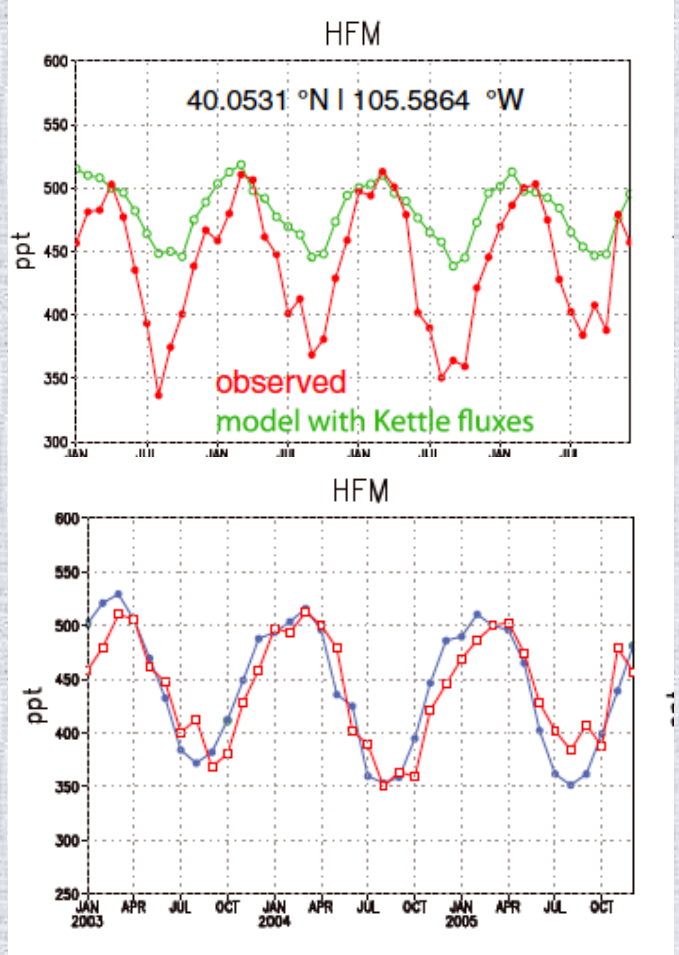
David Asaf[1], Eyal Rotenberg[1], Fyodor Tatarinov[1], Uri Dicken[1], Stephen A. Montzka[2] and Dan Yakir[1]*



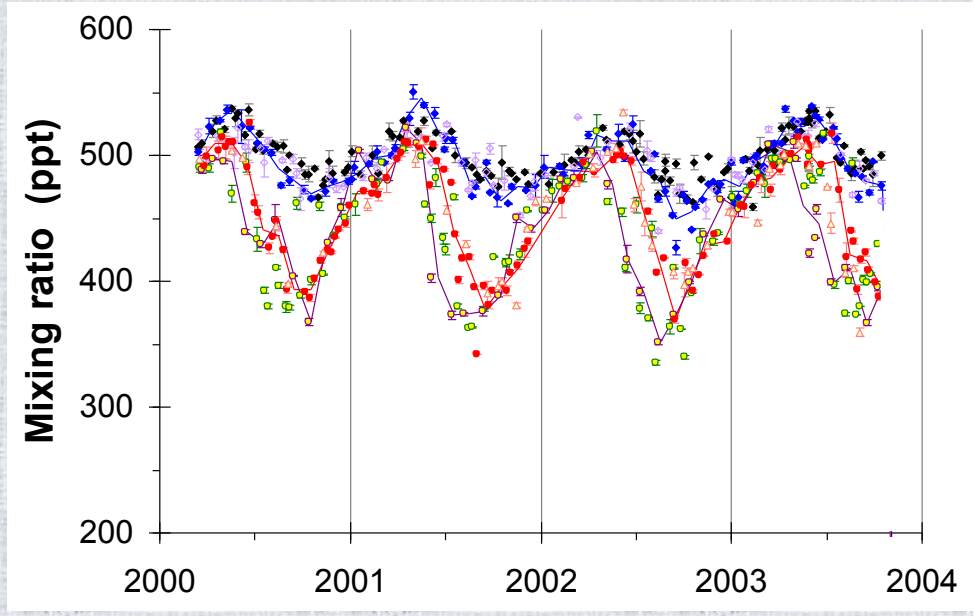
JOURNAL OF GEOPHYSICAL RESEARCH: BIOGEOSCIENCES, VOL. 118, 1–11, doi:10.1002/jgrg.20068, 2013

A coupled model of the global cycles of carbonyl sulfide and CO_2: A possible new window on the carbon cycle

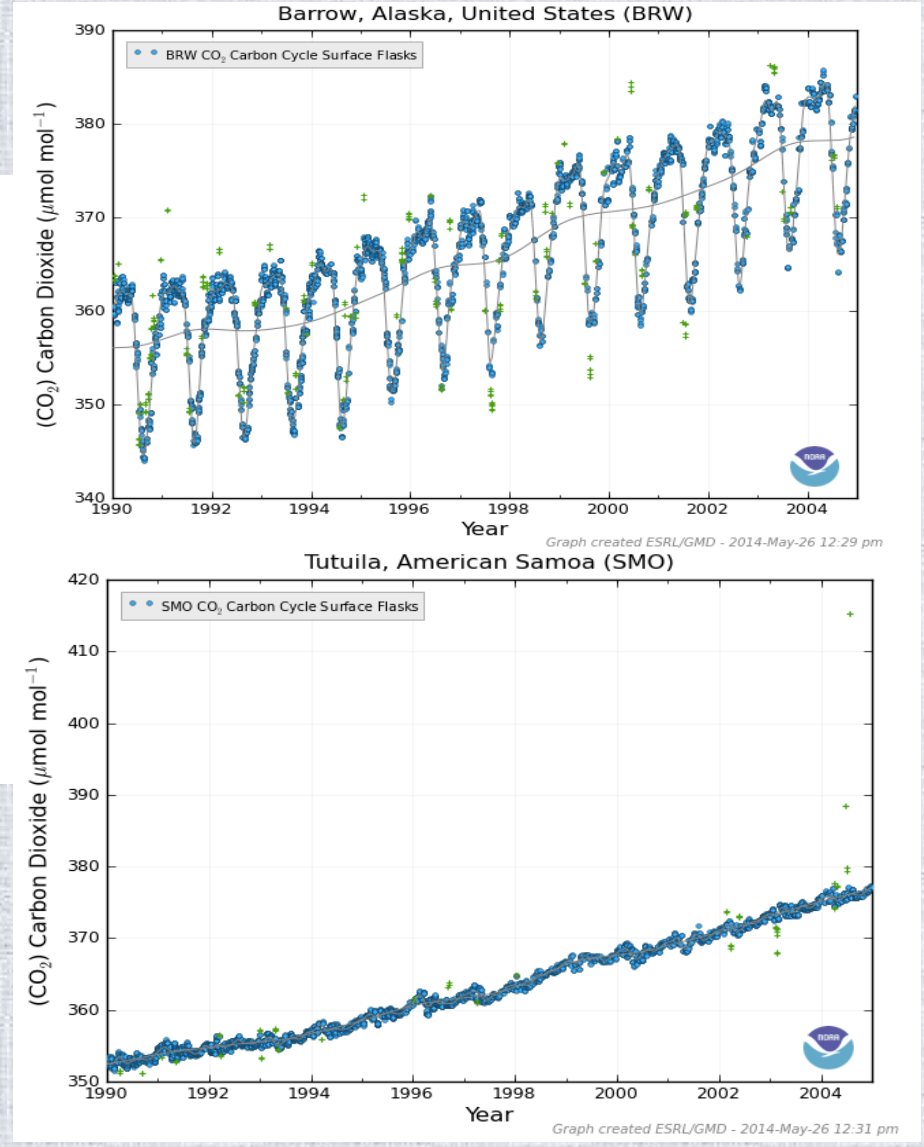
Joe Berry,[1] Adam Wolf,[2] J. Elliott Campbell,[3] Ian Baker,[4] Nicola Blake,[5] Don Blake,[5] A. Scott Denning,[4] S. Randy Kawa,[6] Stephen A. Montzka,[7] Ulrike Seibt,[8] Keren Stimler,[9] Dan Yakir,[9] and Zhengxin Zhu[6]



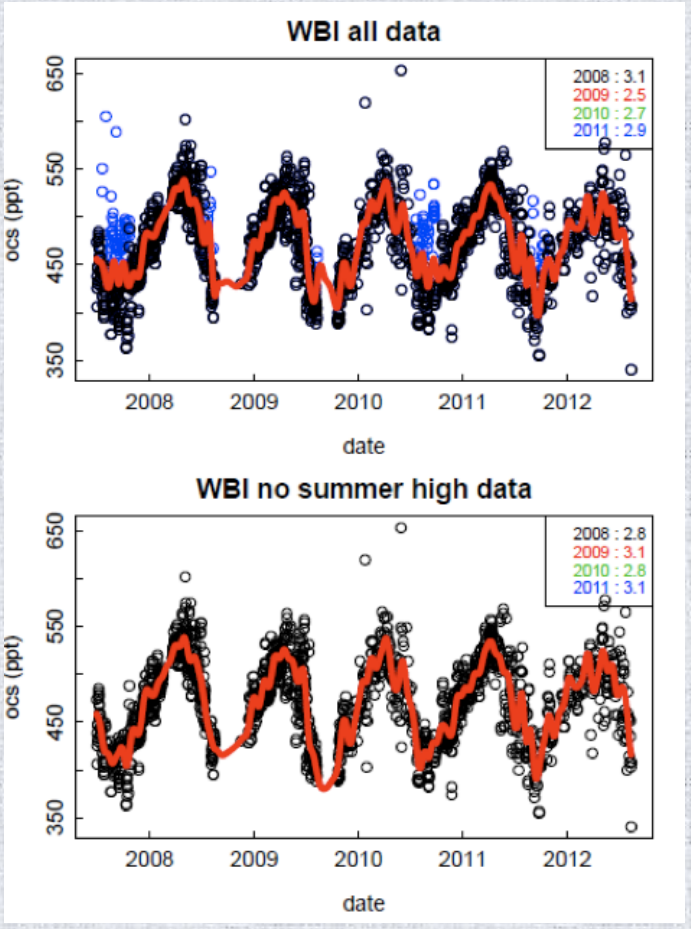
The signature of the Terrestrial Biosphere



Montzka et al., 2007

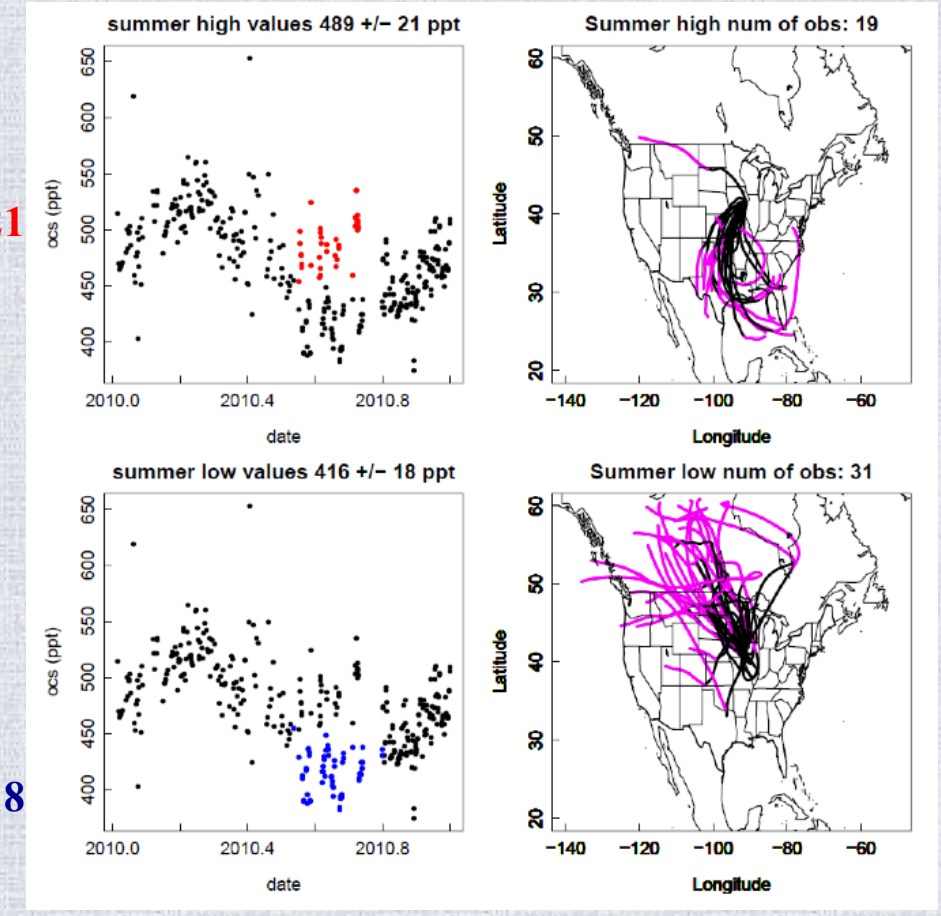


Atmospheric caveats…



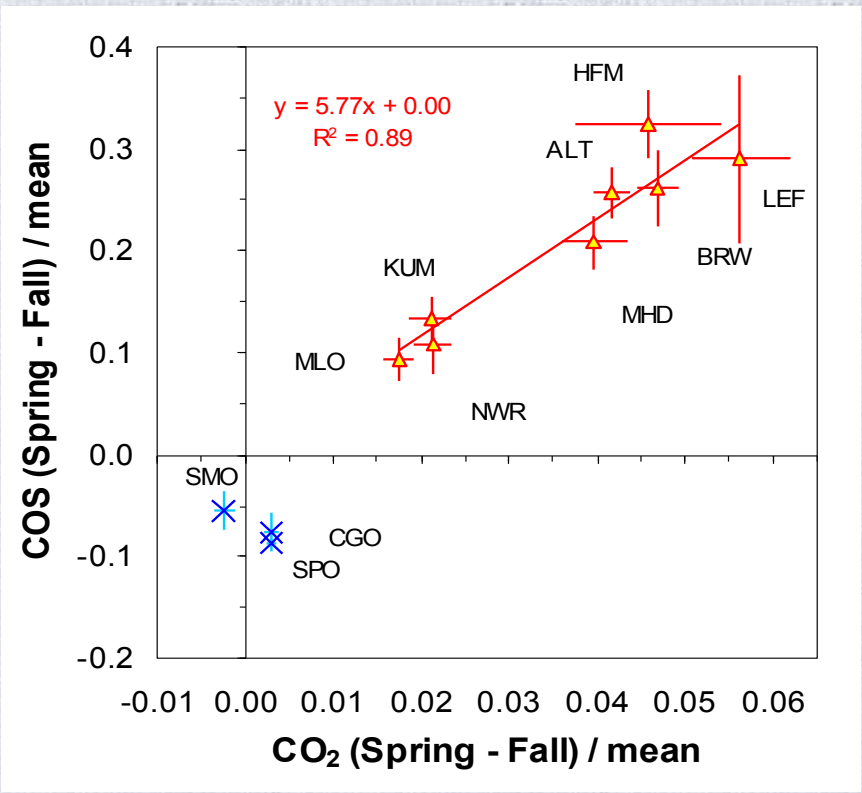
489±21

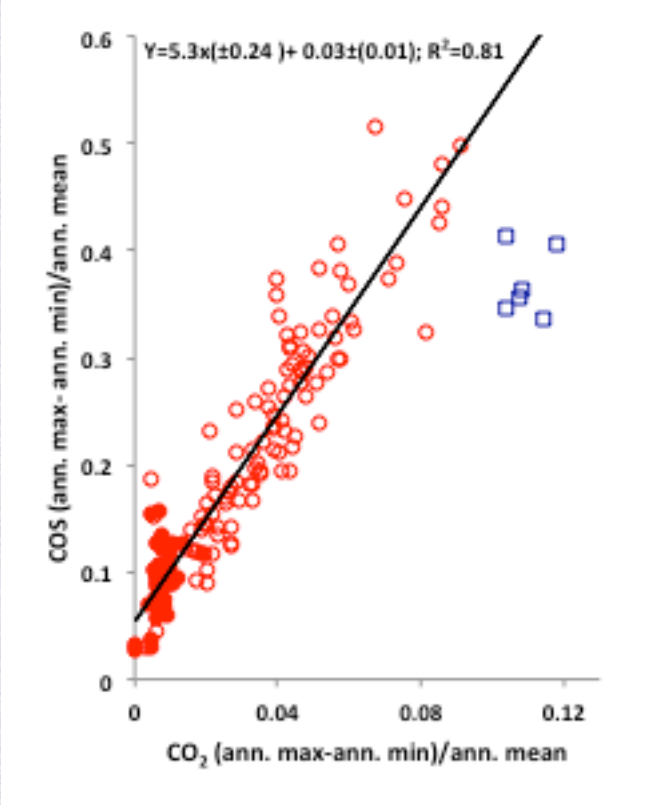
416±18



Huilin Chen

Signature of GPP: COS/CO2 seasonal draw-down

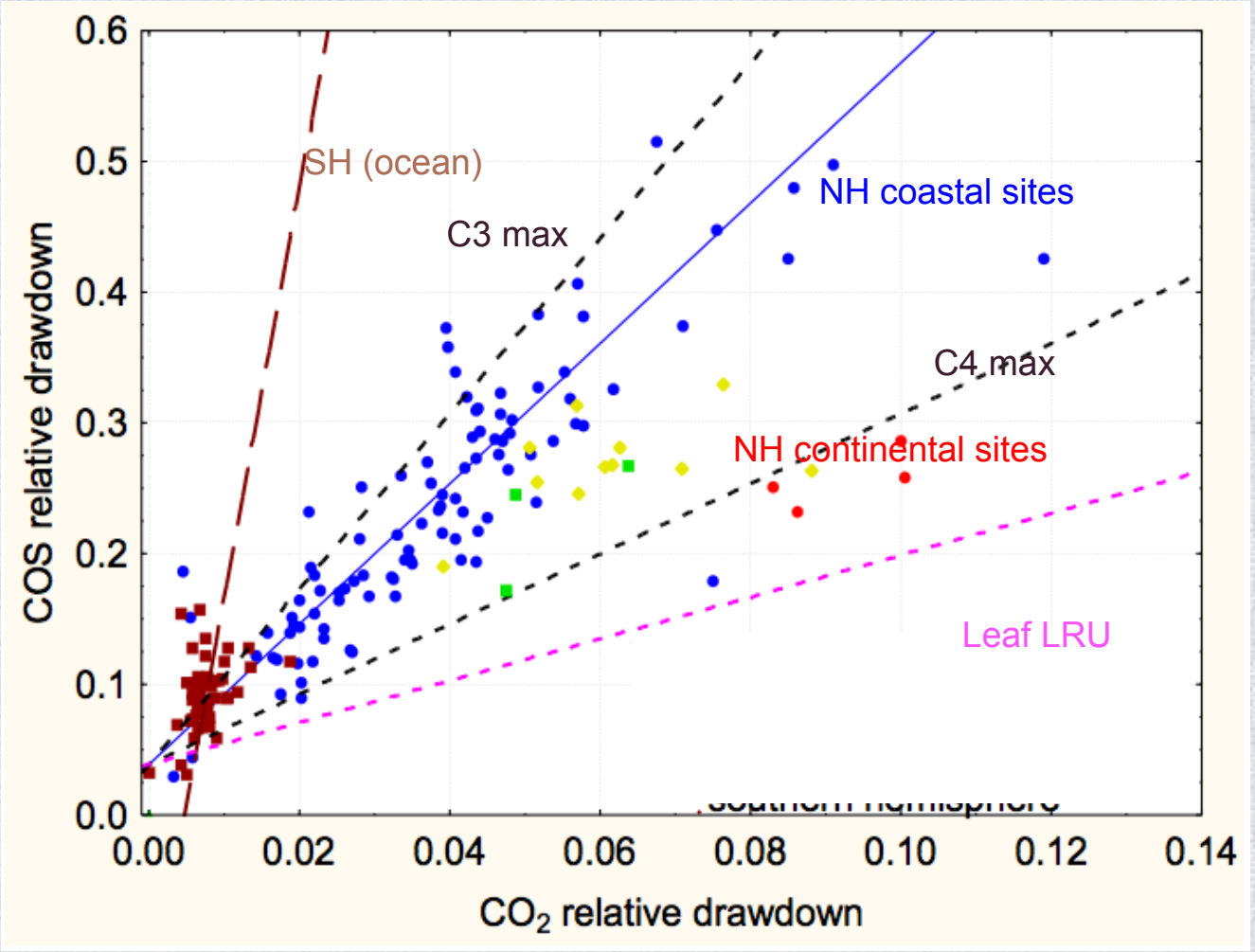


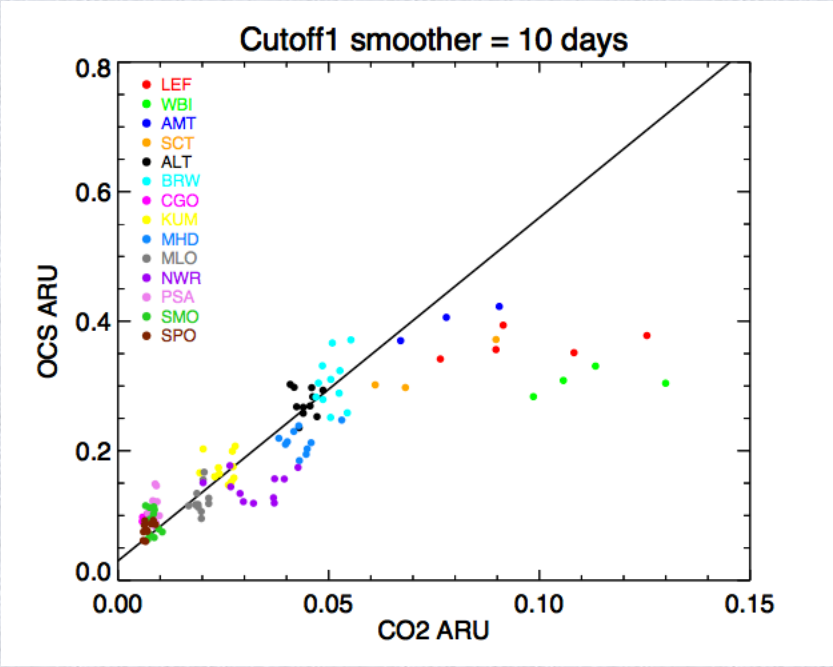


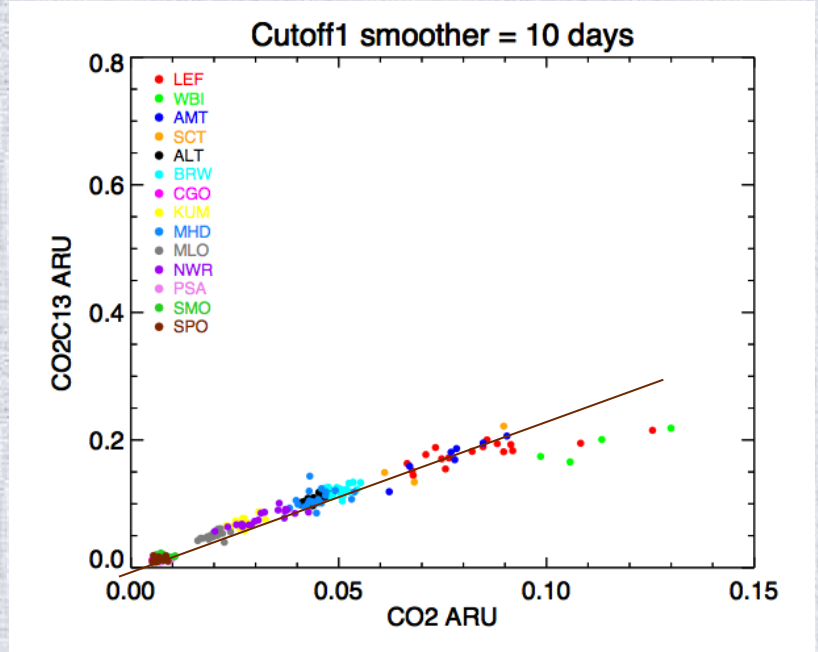
Montzka et al., 2007

Asaf et al., 2013

The atmospheric COS/CO_2 "continuum"





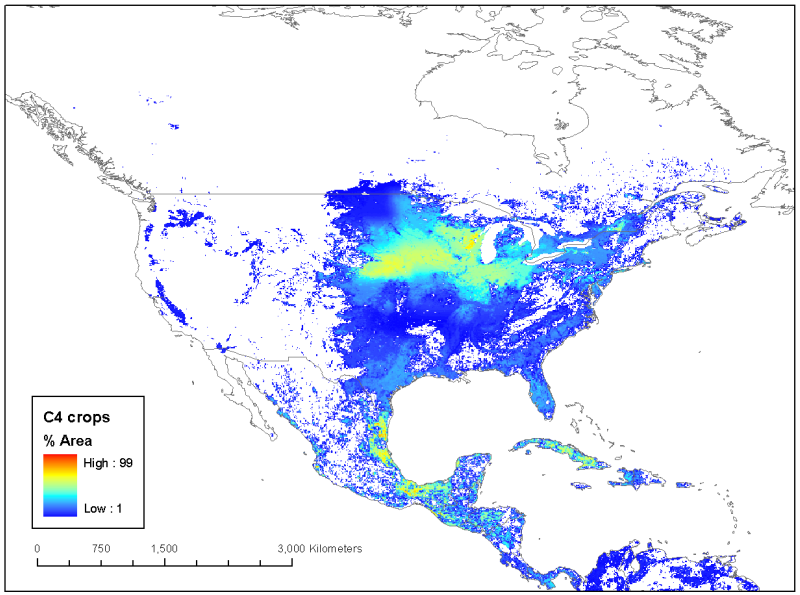


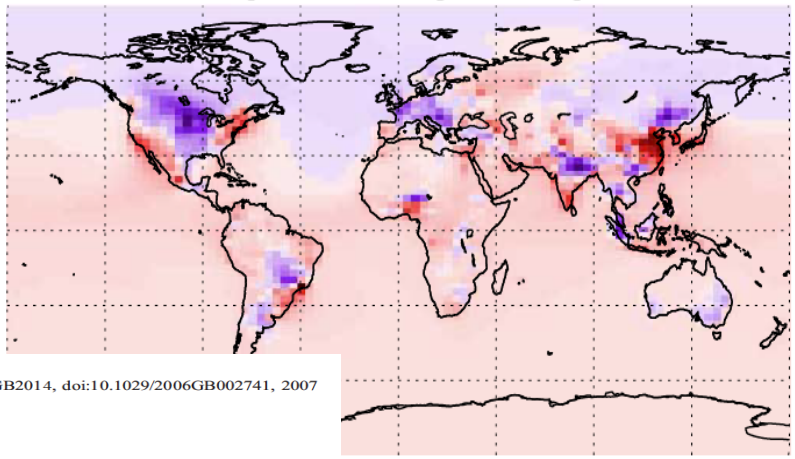
Terrestrial &agricultural sites: Wisconsin; Iowa; S. Carolina

ARU approaches LRU
C4 effects

site	delta-bio	unc.
lef	-21.9	0.3
wbi	-21.2	0.3
amt	-26.1	0.4
sct	-26	0.5
alt	-28.7	0.6
brw	-28.2	0.6
cgo		
kum	-26.9	0.7
mhd	-29.9	0.6
mlo	-30.6	0.7

C4 distribution and impact on surface [CO2]



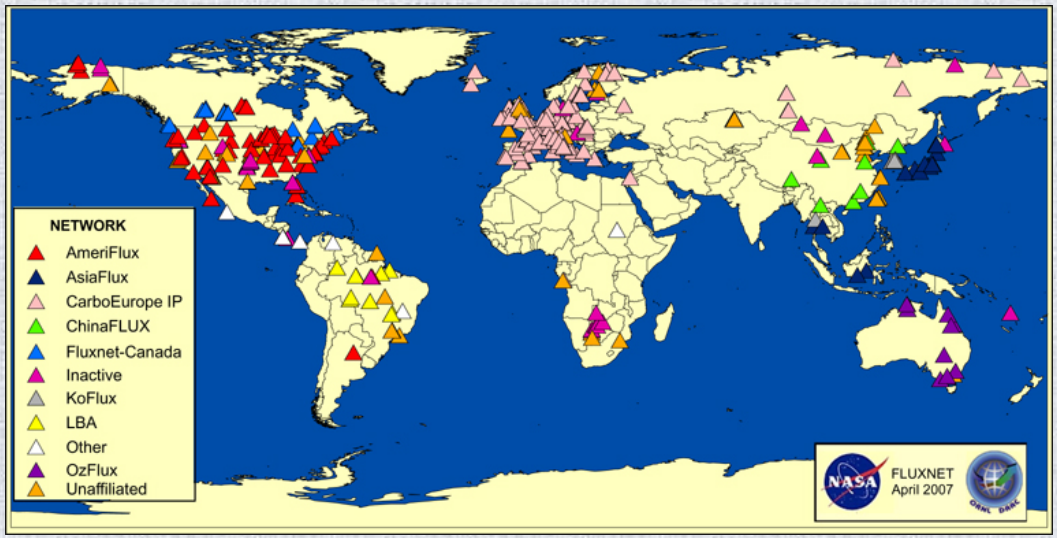


GLOBAL BIOGEOCHEMICAL CYCLES, VOL. 21, GB2014, doi:10.1029/2006GB002741, 2007

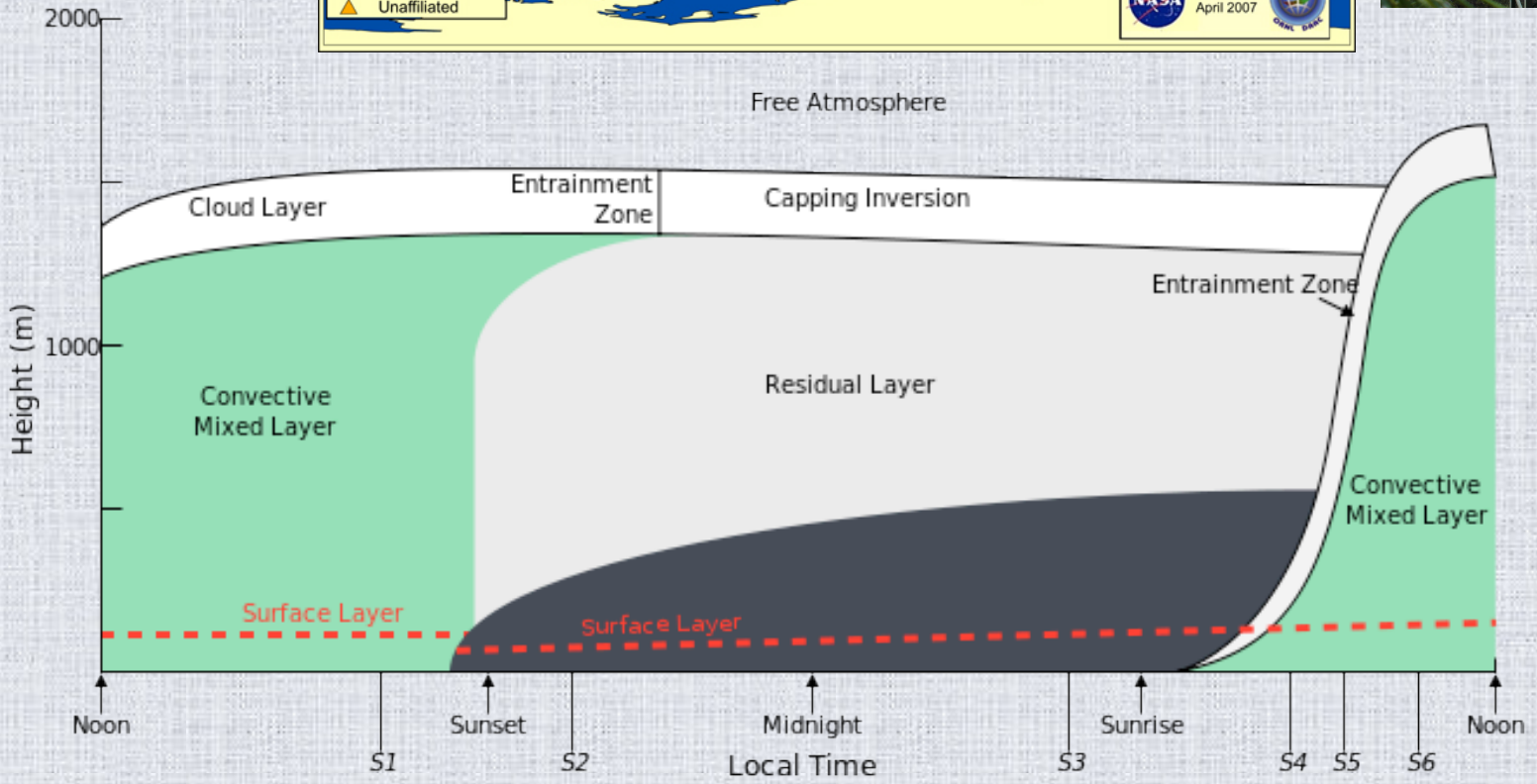
Click Here for Full Article

Horizontal displacement of carbon associated with agriculture and its impacts on atmospheric CO_2

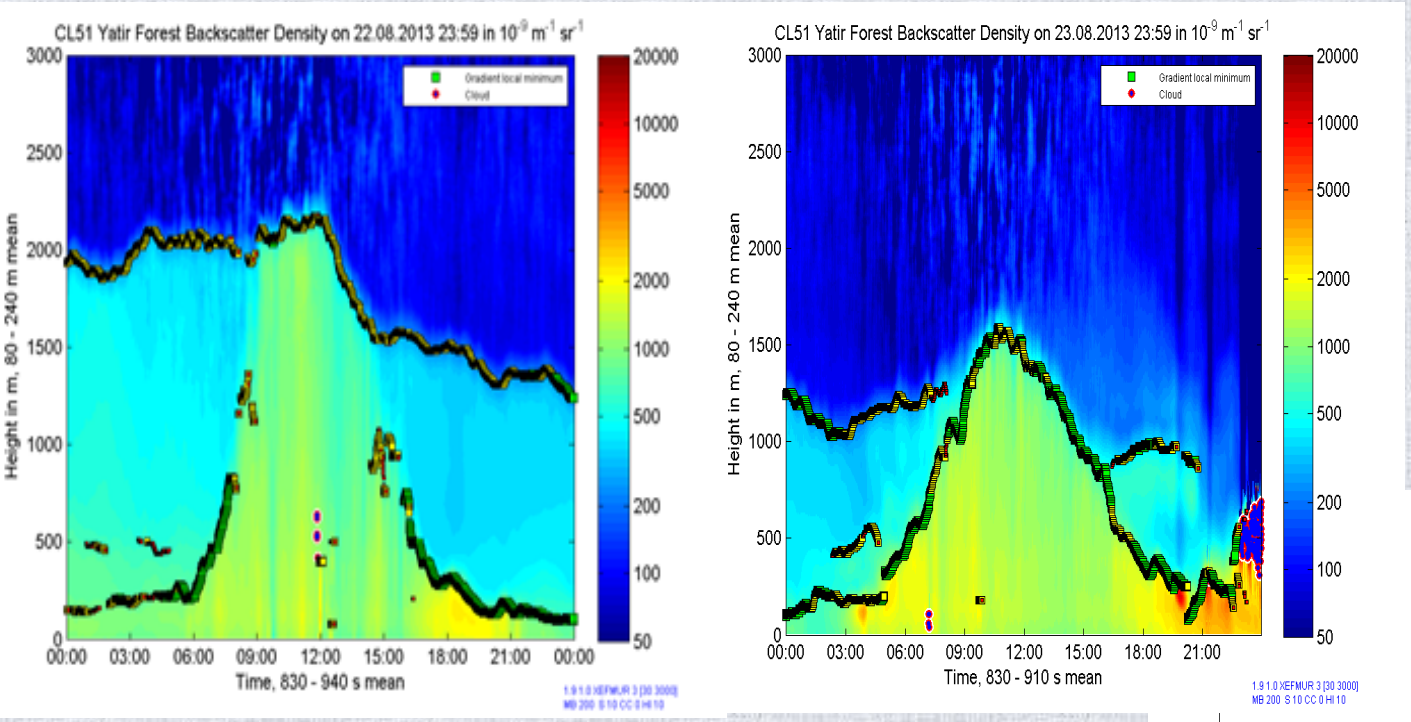
P. Ciais,[1] P. Bousquet,[1,2] A. Freibauer,[3] and T. Naegler[1,4]


NETWORK
AmeriFlux
AsiaFlux
CarboEurope IP
ChinaFLUX
Fluxnet-Canada
Inactive
KoFlux
LBA
Other
OzFlux
Unaffiliated
NASA
FLUXNET
April 2007


18 9 2007

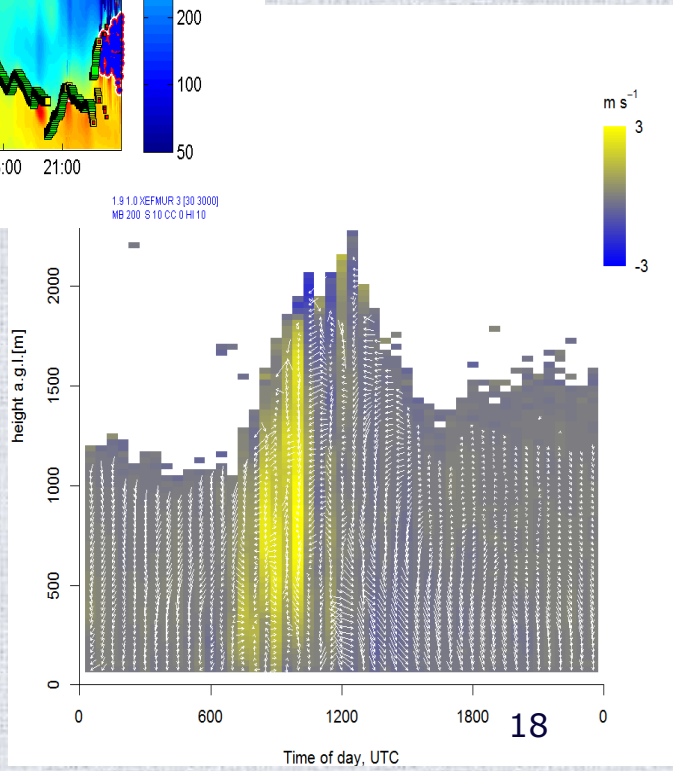

2000
1000
Height (m)
Free Atmosphere
Cloud Layer
Entrainment Zone
Capping Inversion
Entrainment Zone
Convective Mixed Layer
Residual Layer
Convective Mixed Layer
Surface Layer
Surface Layer
Noon
Sunset
Midnight
Sunrise
Noon
S1
S2
S3
S4
S5
S6
Local Time

Perspective from the Planetary Boundary Layer (PBL)



Ceilometer,
two consecutive days

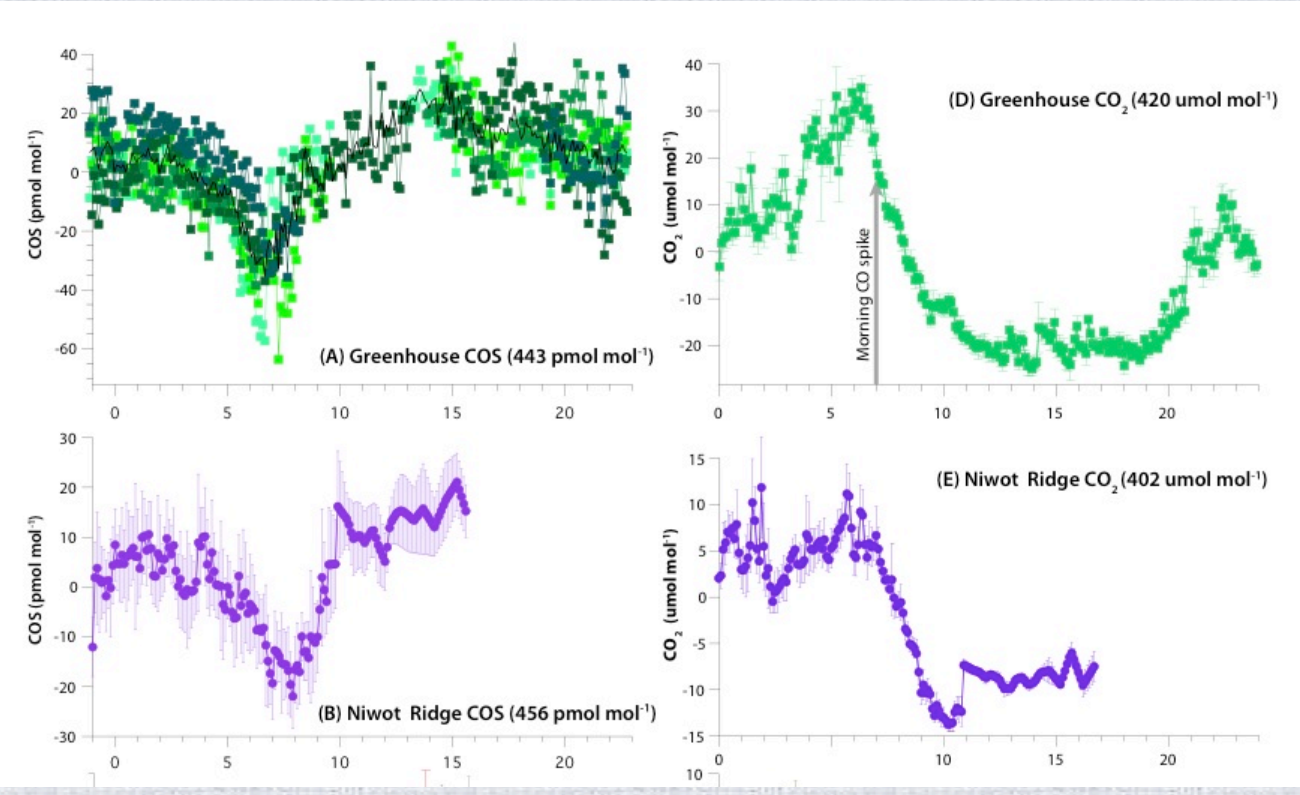
Wind Lidar:



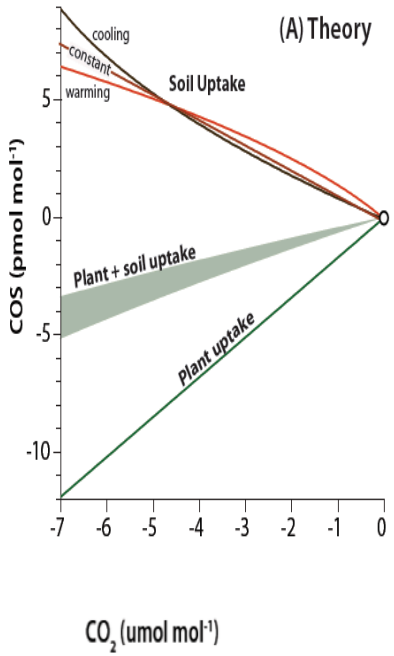
Karlsruhe Institute of Technology

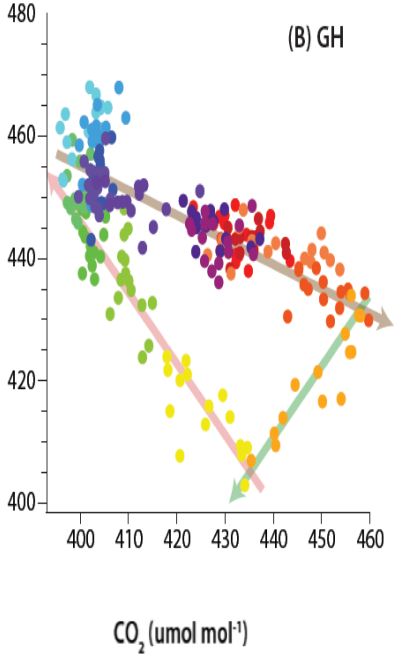
Mauder & Eder, unpublished

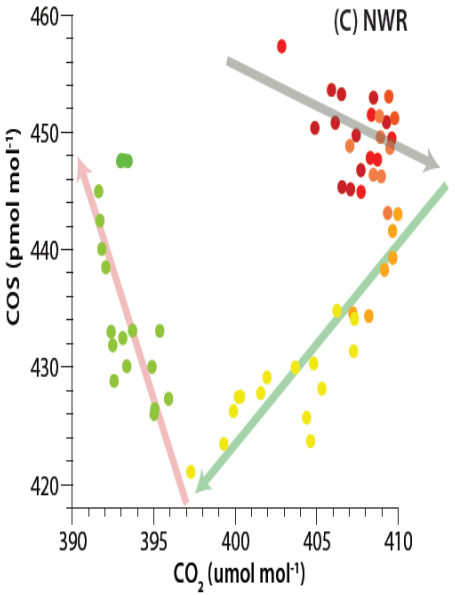
Perspective from canopy air measurements:
Diurnal surface concentration measurements

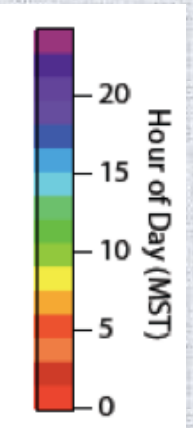


Linking events in the surface layer to the PBL









$$\frac{dC_{cos}}{dt} = k(C_{cos-trop} - C_{cos-surface}) + (F_{cos-soil} + F_{cos-leaf})$$

$$\frac{dC_{co2}}{dt} = k(C_{co2-trop} - C_{co2-surface}) + (F_{co2-soil} + F_{co2-leaf})$$

Equations for both CO_2 and COS with measured NEE and surface C_s solved for k and C_{trop}

Conclusions

- **COS is a useful tracer of CO_2 exchange with the terrestrial ecosystems and will add a powerful tool to a very limited arsenal..**
- **There is no alternative "observational" means to directly estimate GPP on global scale (new sun fluorescence is also developing)**
- **Incorporating the use of several tracers controlled by different processes (such as COS and CO_2 and its stable isotopes) provide additional insights to the biosphere response to global change**

Thank you