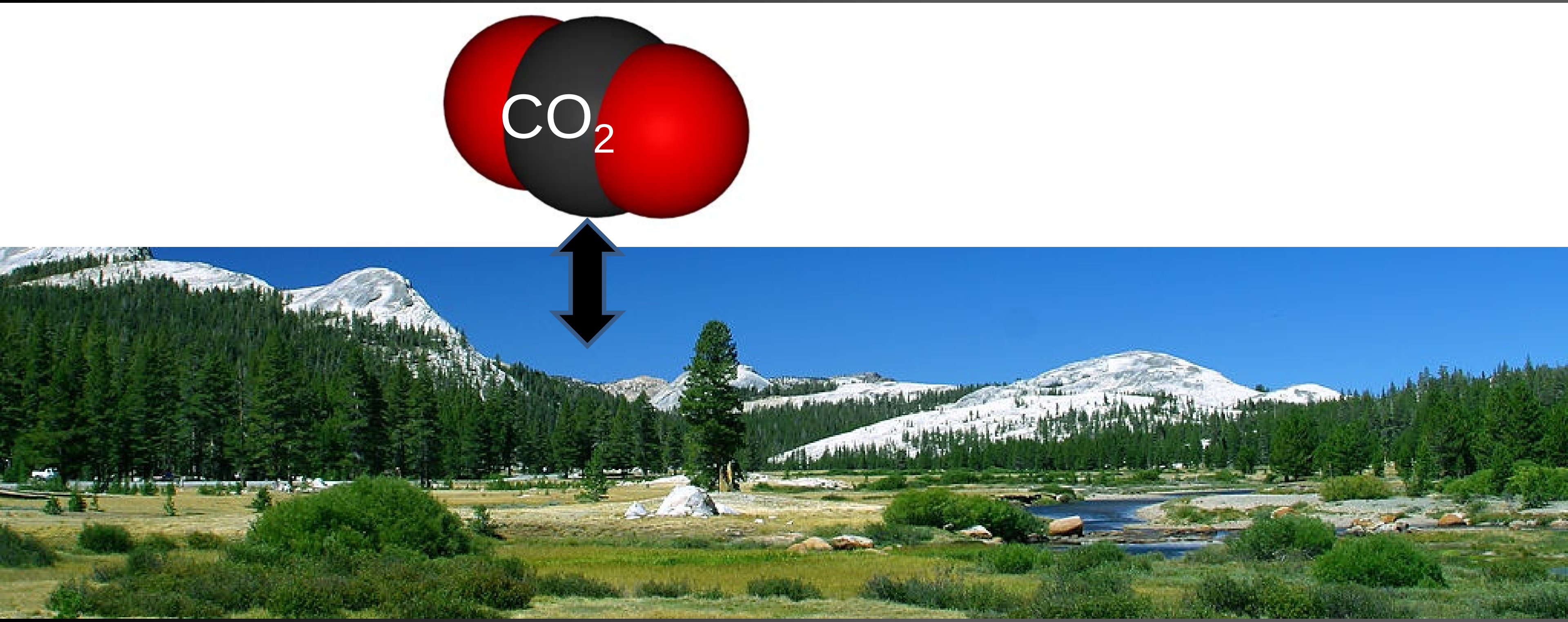
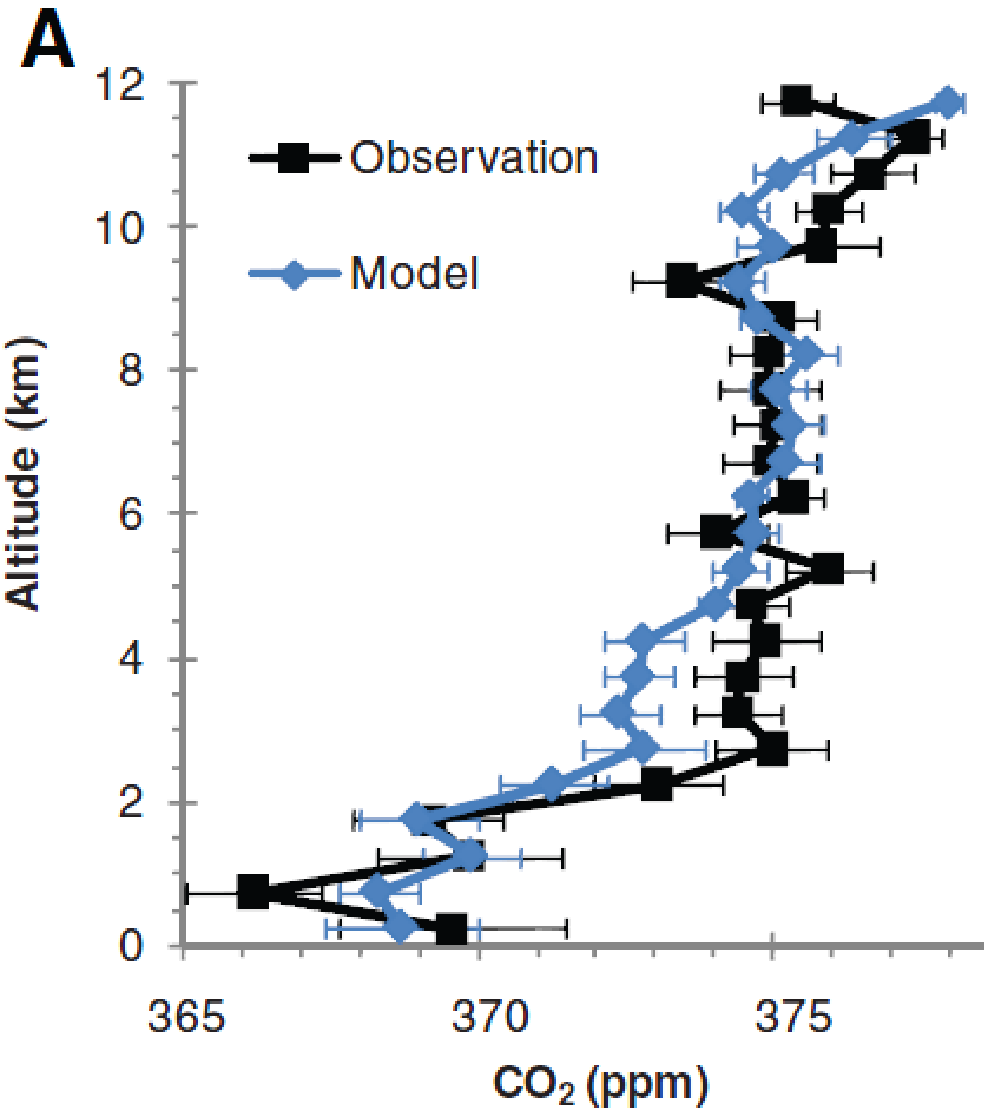
What carbonyl sulfide teaches us about Earth's biosphere

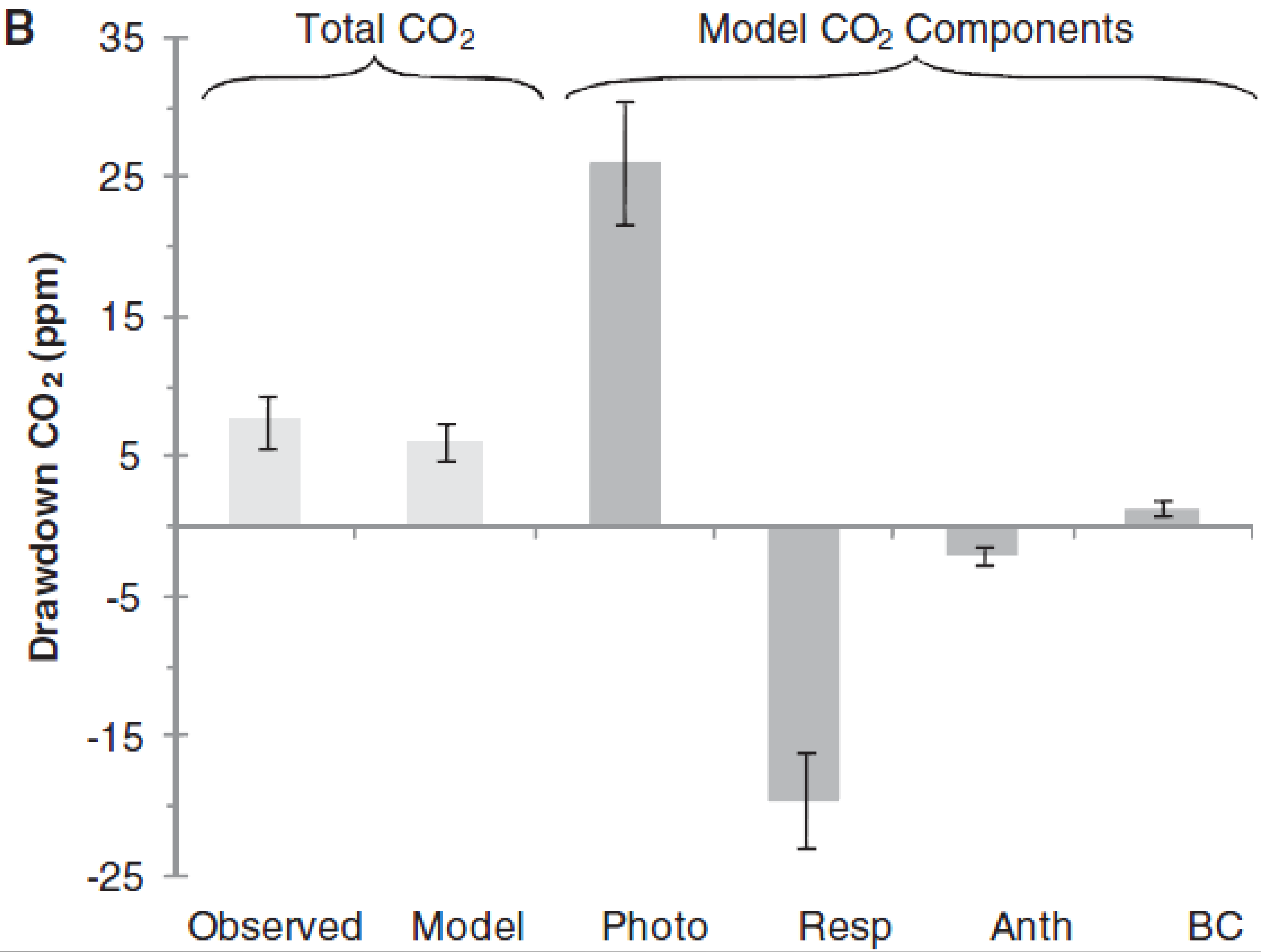
Elliott Campbell
UC Santa Cruz

1) A new tracer for the terrestrial biosphere

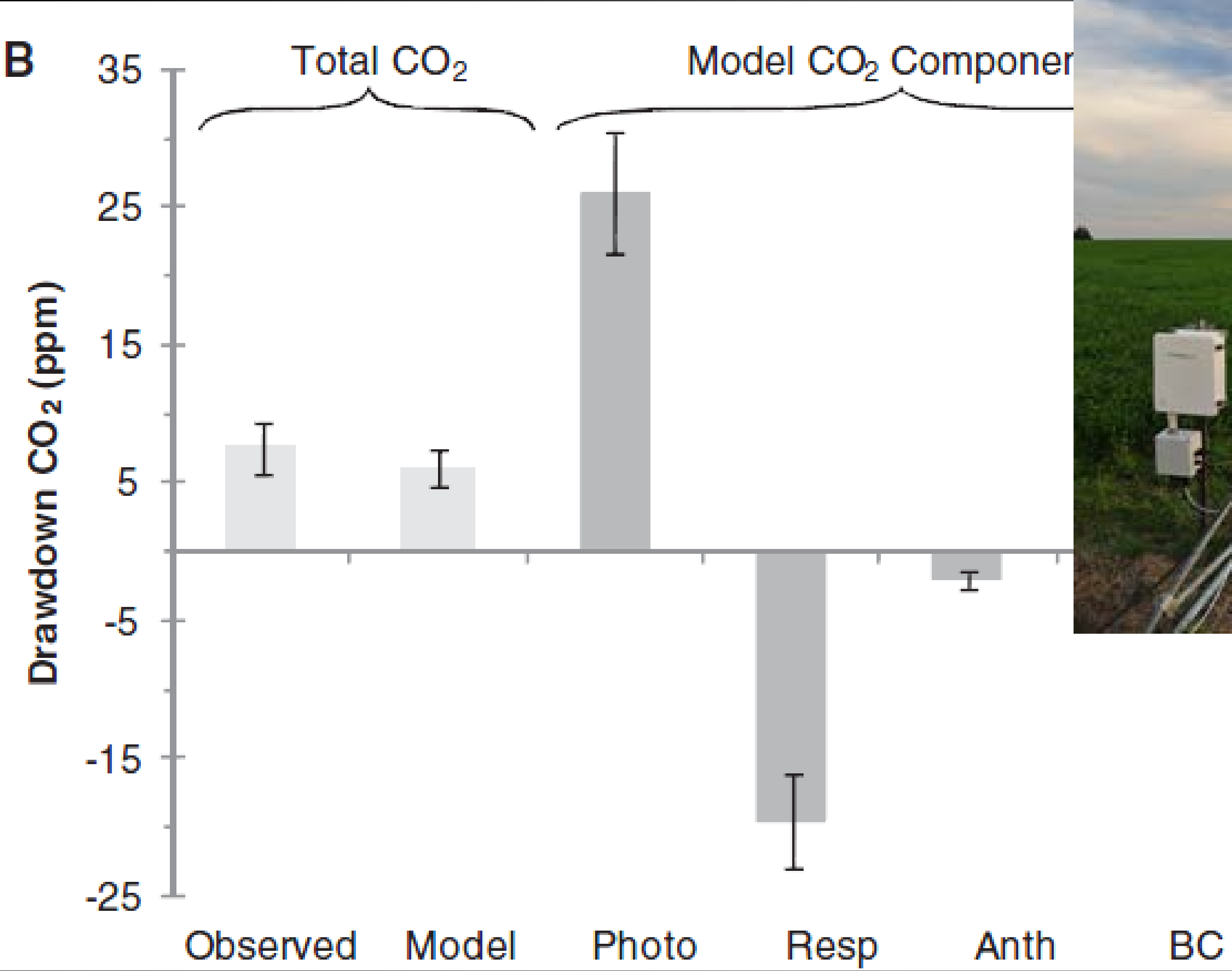

CO_2



(Campbell et al., *Science*, 2008)

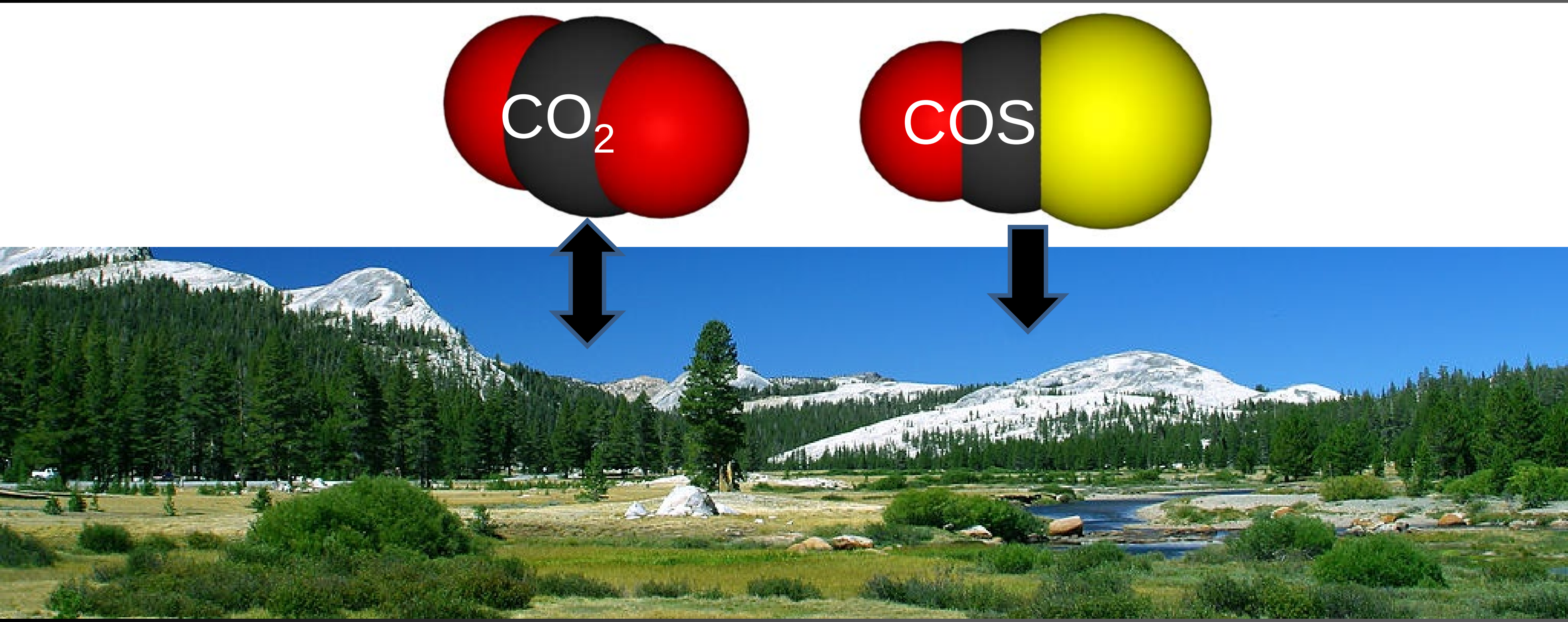


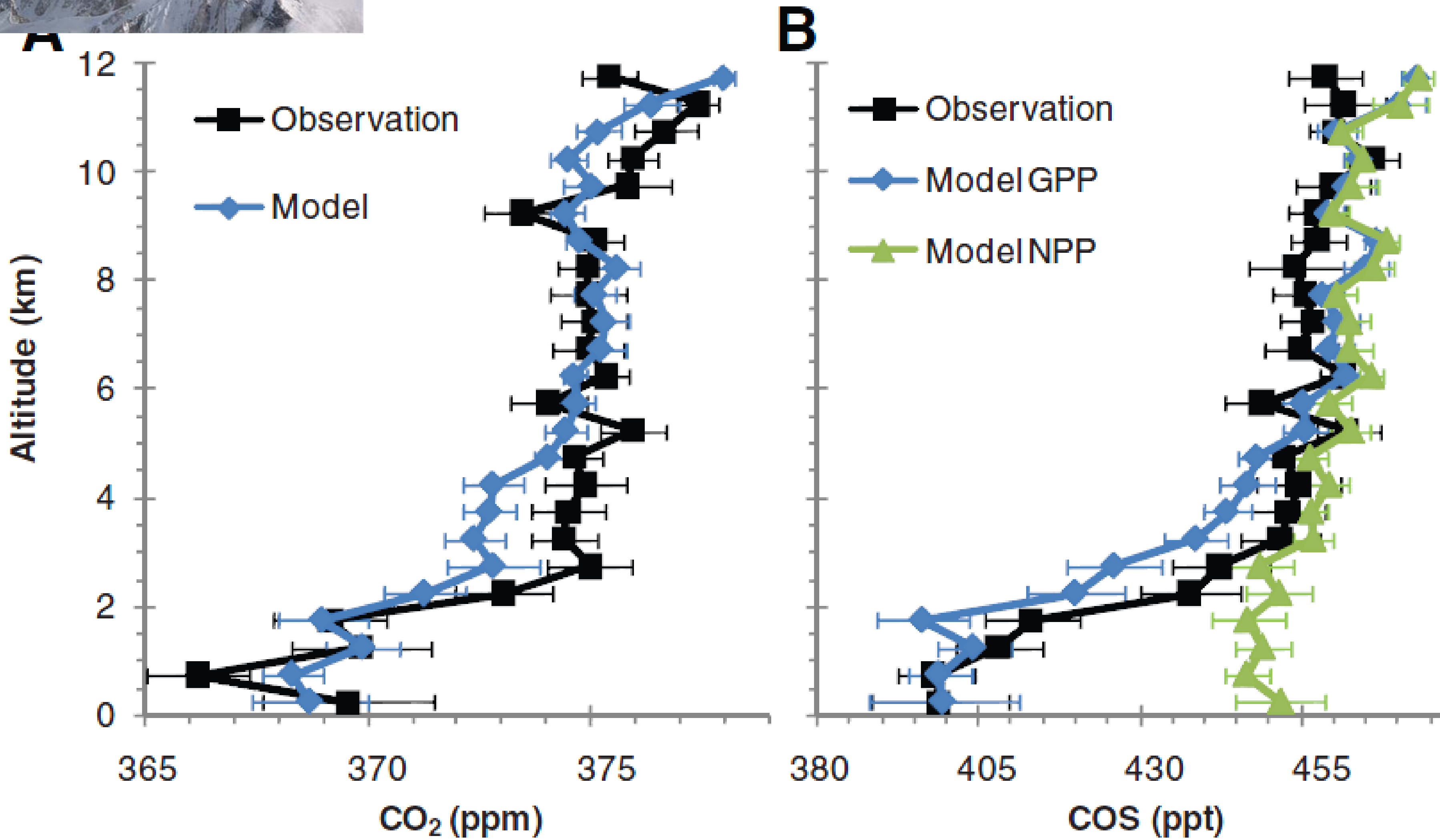
(Campbell et al., *Science*, 2008)



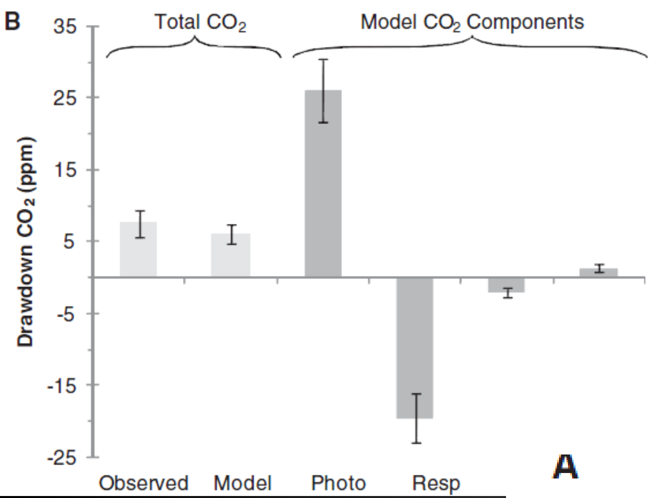
(Campbell et al., *Science*, 2008)

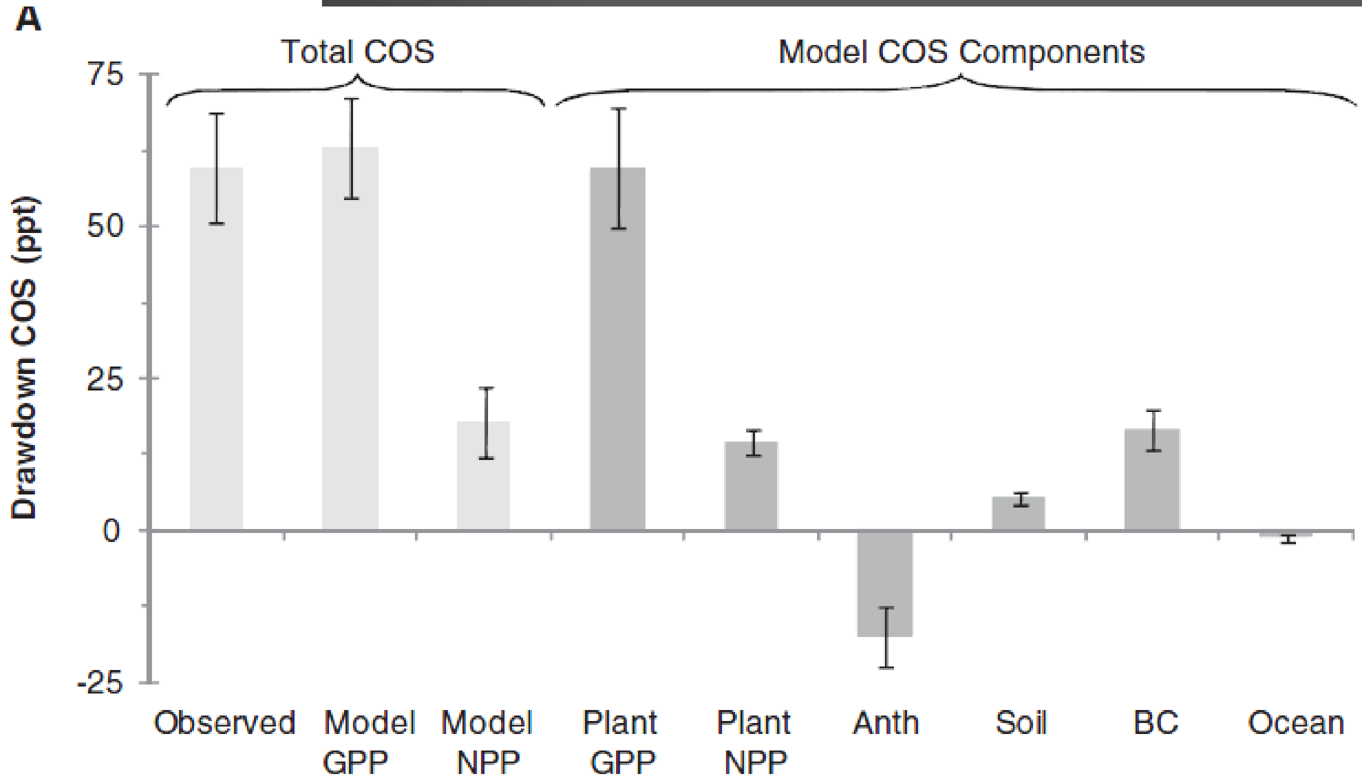
Carbonyl Sulfide (COS or OCS)



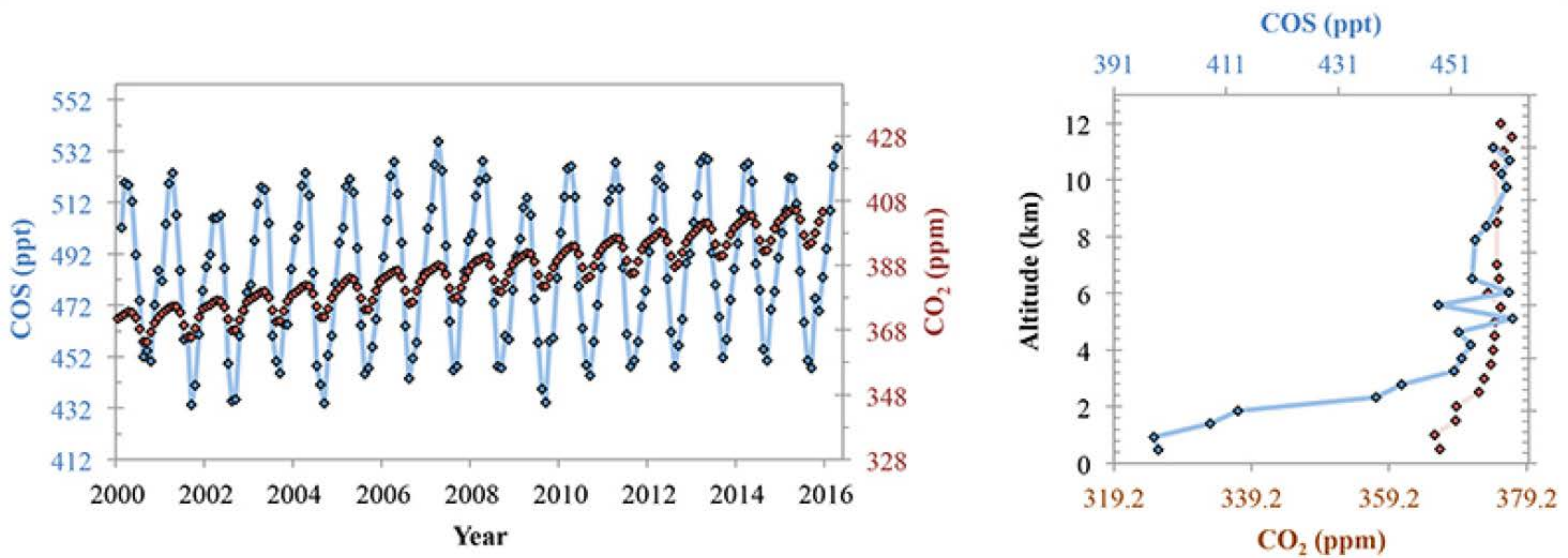


(Campbell et al., *Science*, 2008)



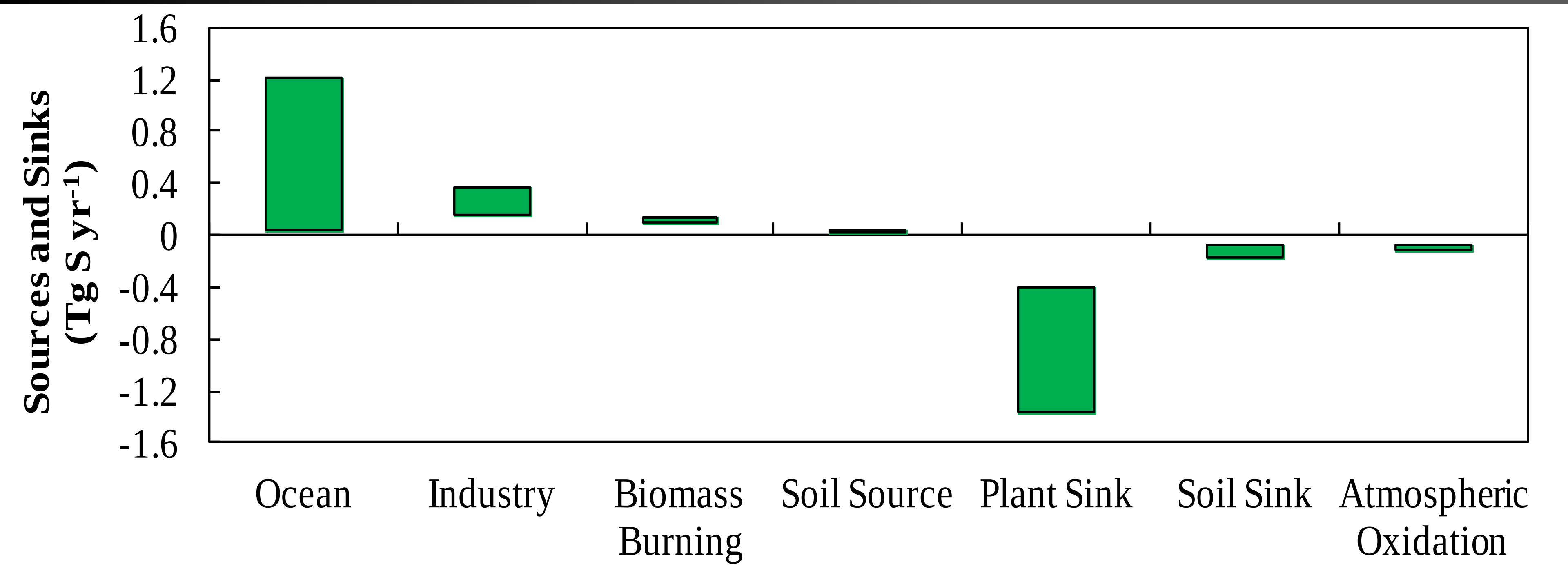


(Campbell et al., *Science*, 2008)



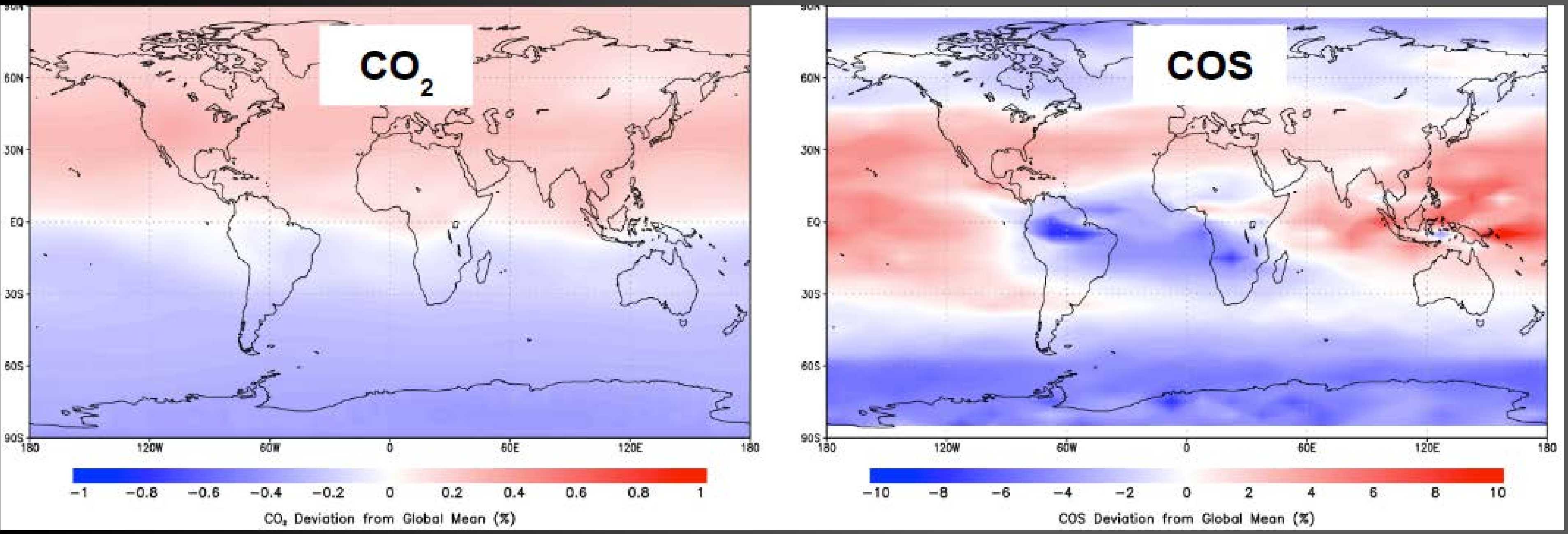
(Campbell et al., *EOS*, 2017; Montzka et al., JGR, 2007; Campbell et al., Science, 2008)

Global Sources and Sinks



(Campbell et al., *Nature*, 2017)

Remote Sensing



(Glatthor et al., *GRL*, 2015)

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CLIMATE CHANGE Feature

Assessing a New Clue to How Much Carbon Plants Take Up

Current climate models disagree on how much carbon dioxide land ecosystems take up for photosynthesis. Tracking the stronger carbonyl sulfide signal could help.

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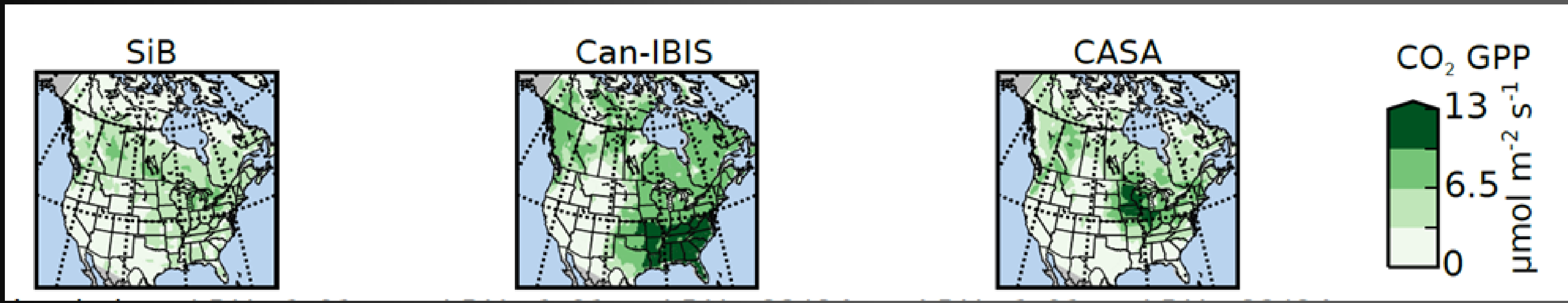
CLIMATE CHANGE · Feature

Assessing a New Clue to How Much Carbon Plants Take Up

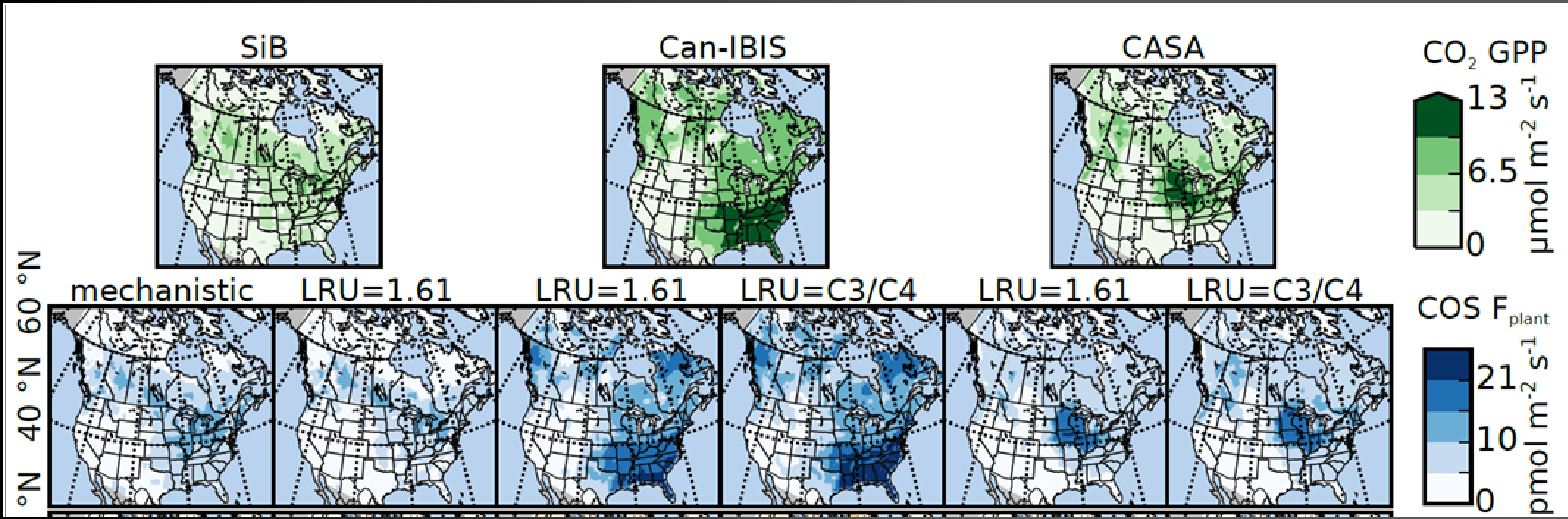
Current climate models disagree on how much carbon dioxide land ecosystems take up for photosynthesis. Tracking the stronger carbonyl sulfide signal could help.

1. **Continental:** Spatial separation of dominant sink and source
2. **Hemispheric:** Seasonality driven by plant uptake
3. **Northern Extratropics**: Long-lifetime and relatively little buffering

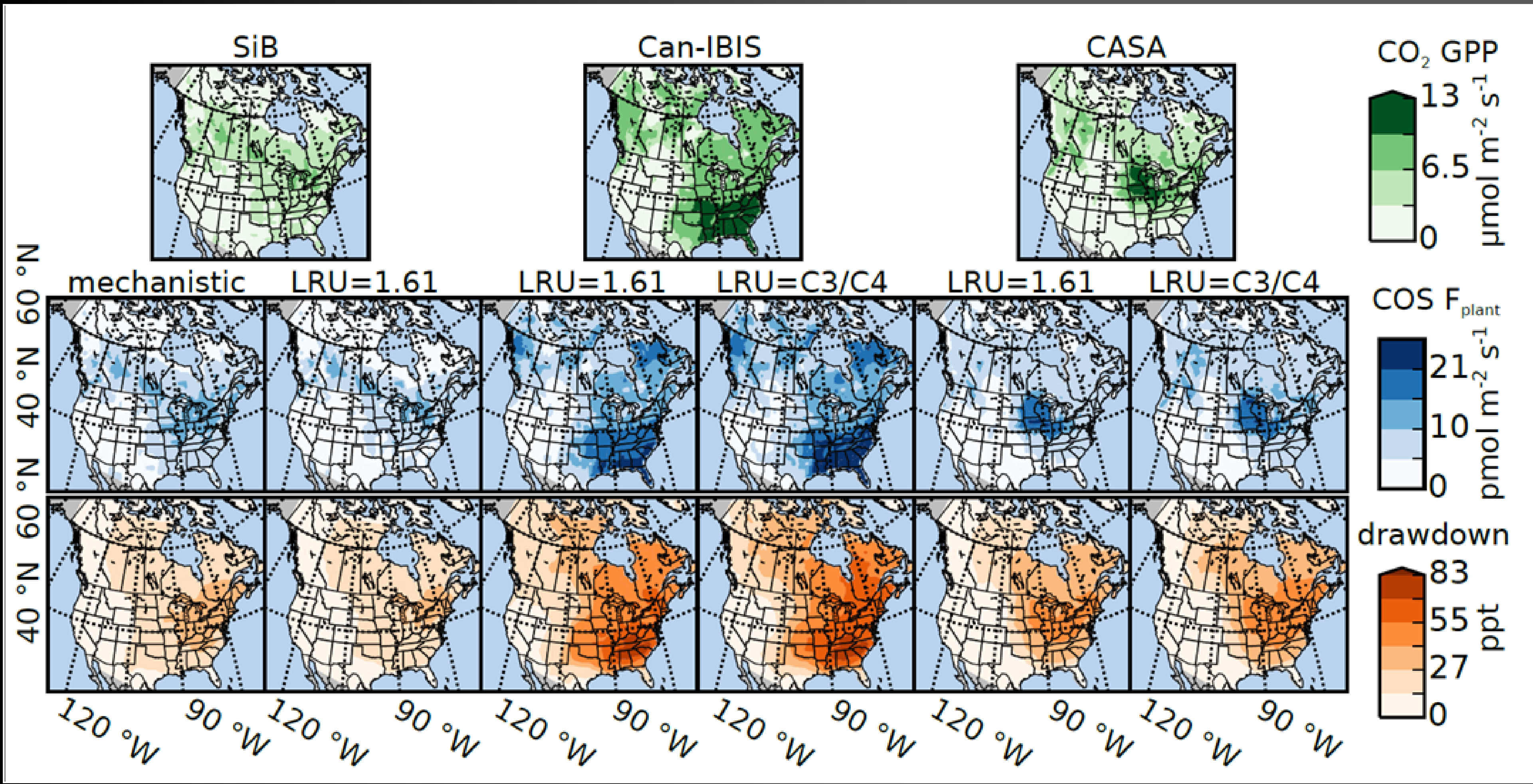
2) COS application: Continental Scale



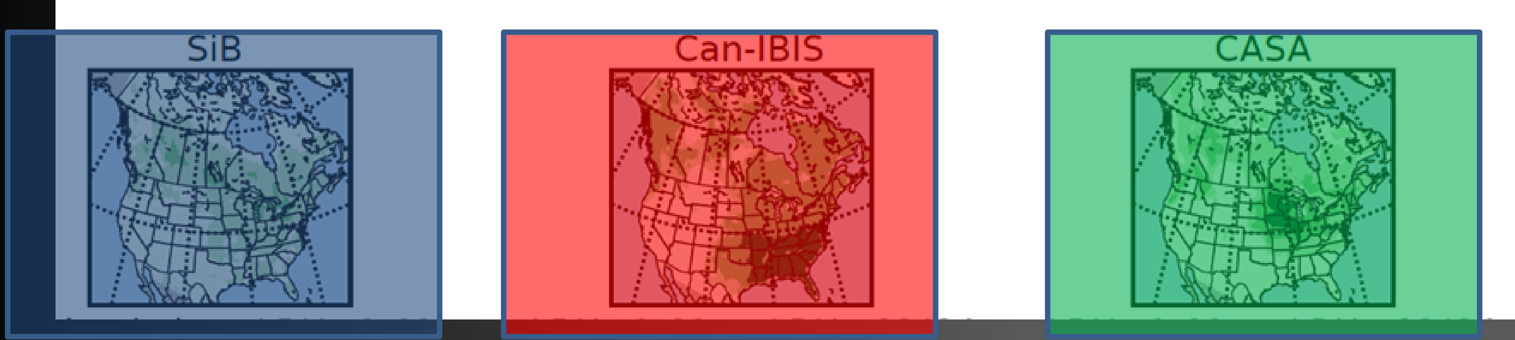
(Hilton et al., *Nature Climate Change*, 2017)

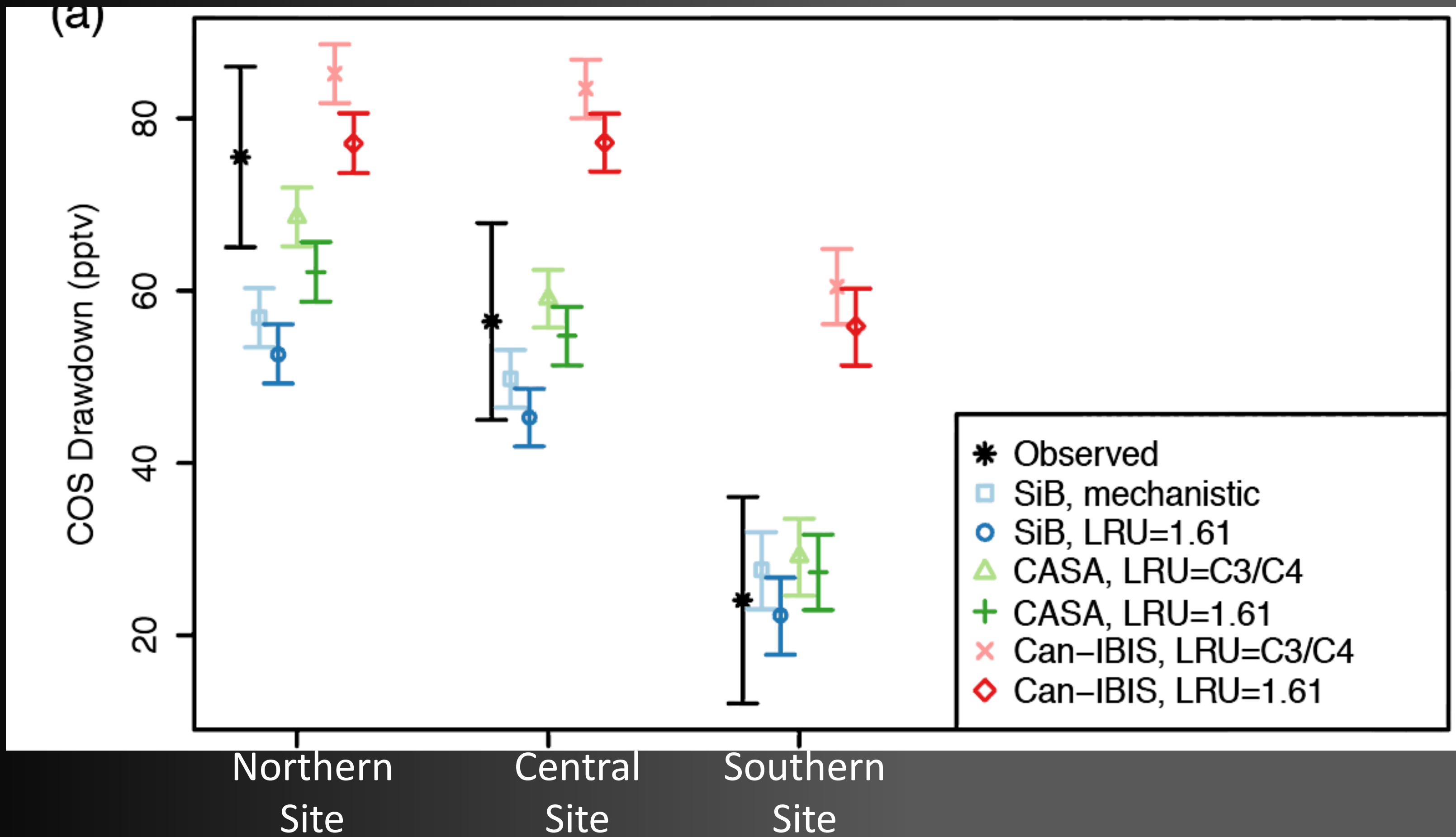


(Hilton et al., *Nature Climate Change*, 2017)



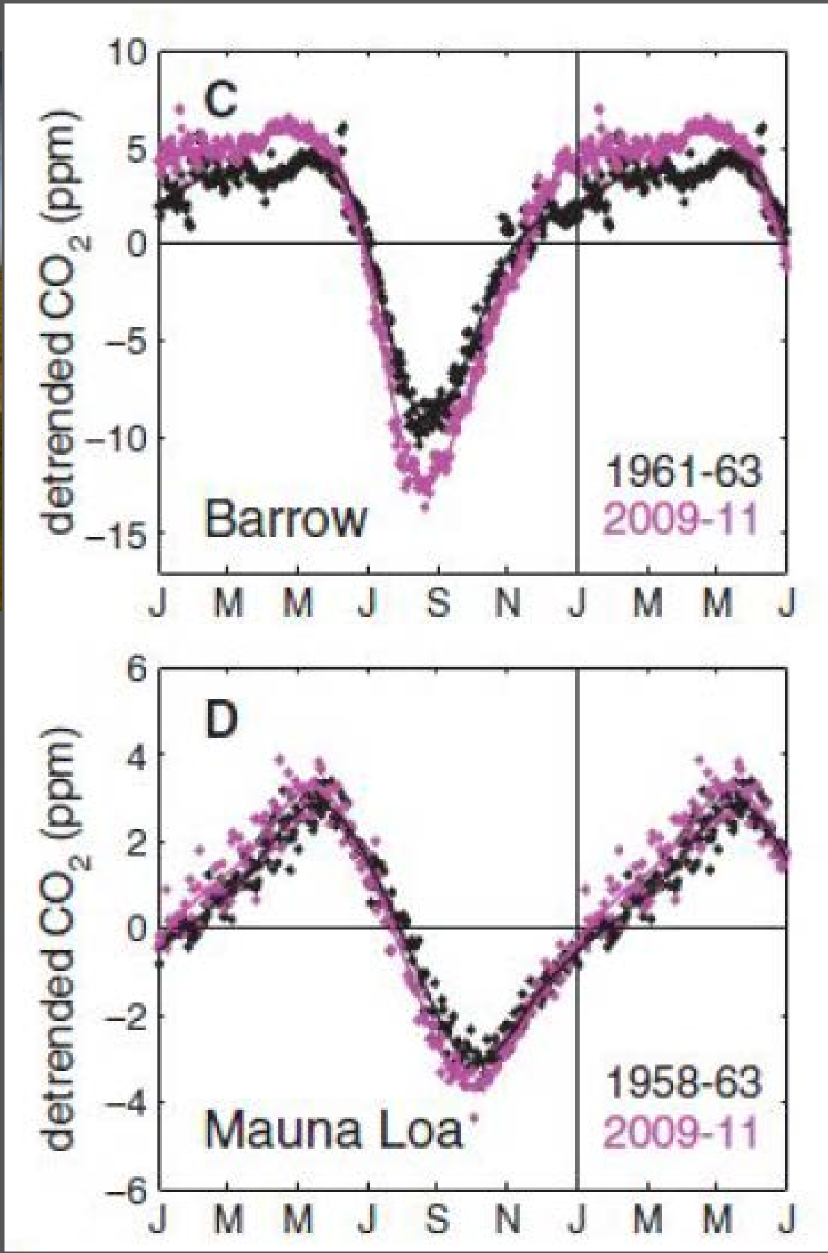
(Hilton et al., *Nature Climate Change*, 2017)



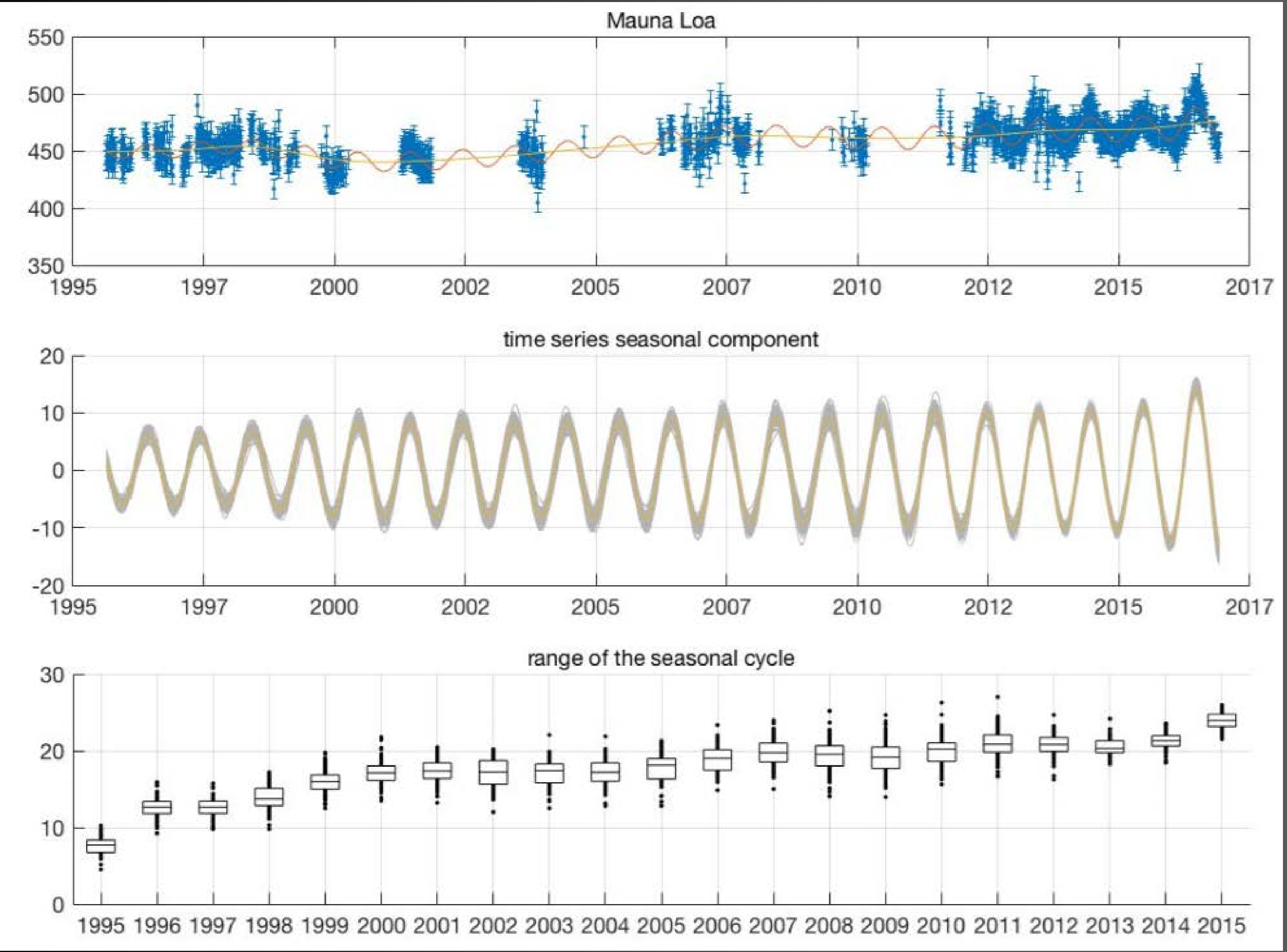


(Hilton et al., *Nature Climate Change*, 2017)

3) COS Applications: Northern Extratropics



(Graven et al., *Science*, 2013)



Mauna Loa
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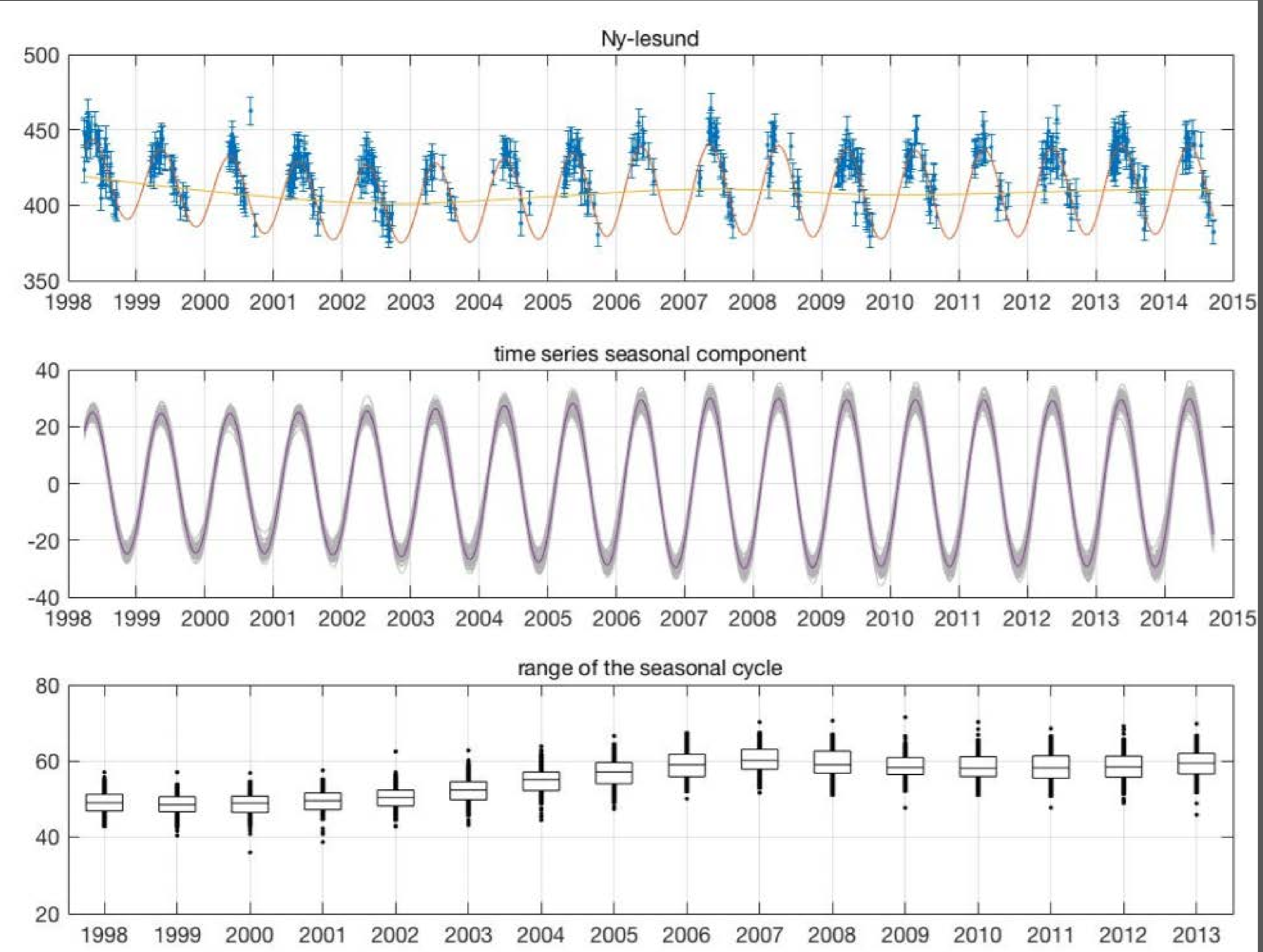

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time series seasonal component
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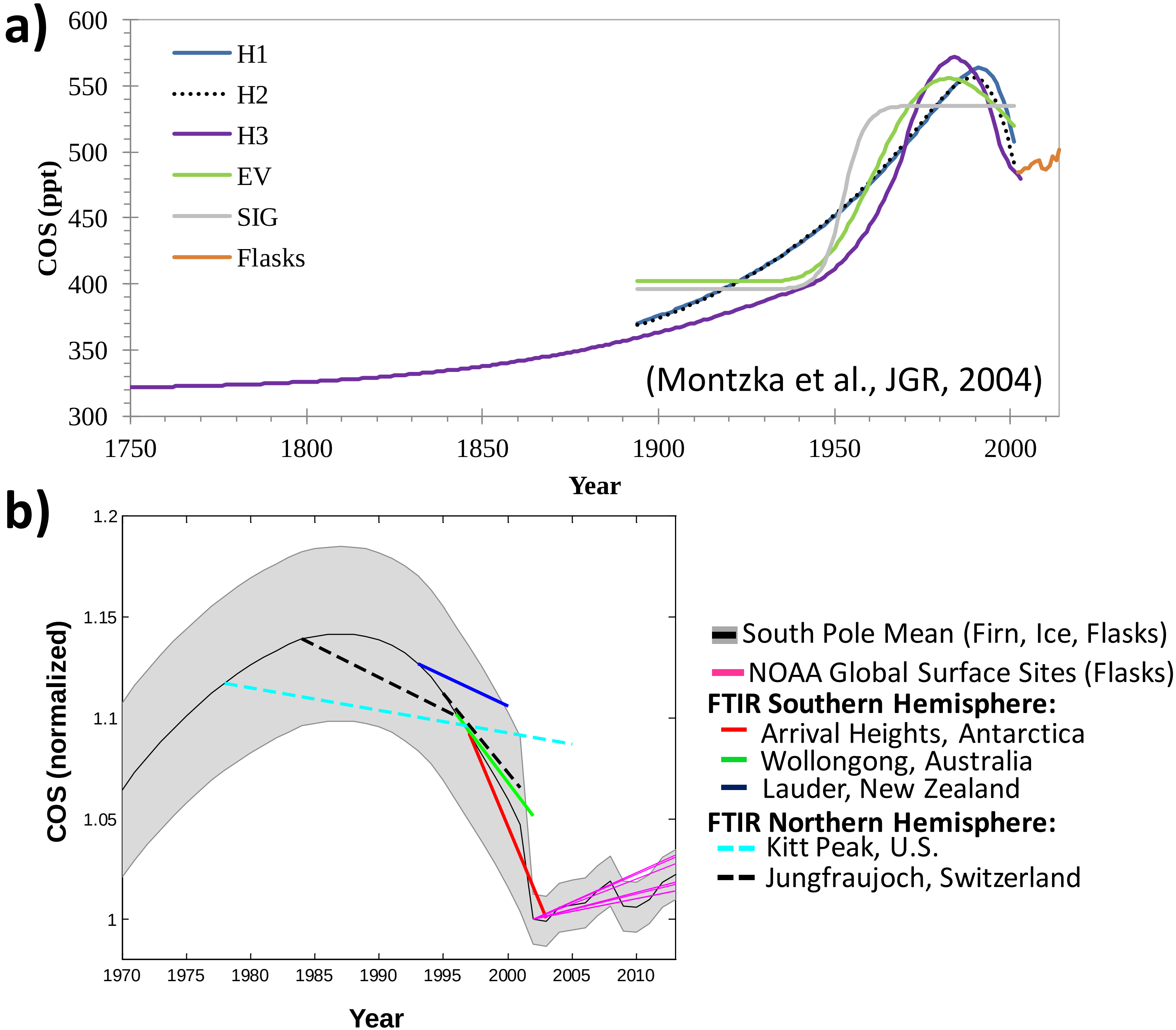
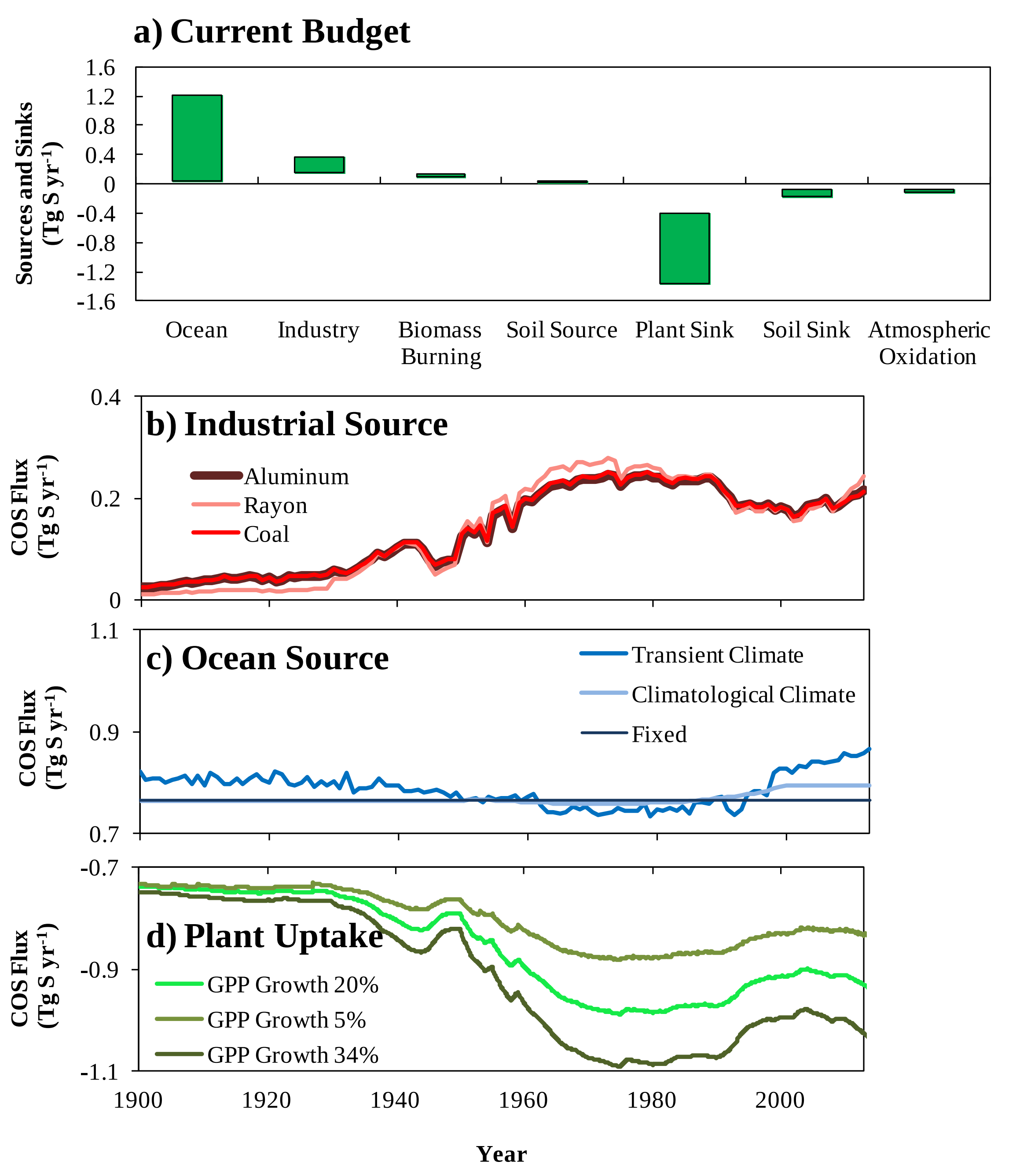
-40
range of the seasonal cycle
80
60
40
20

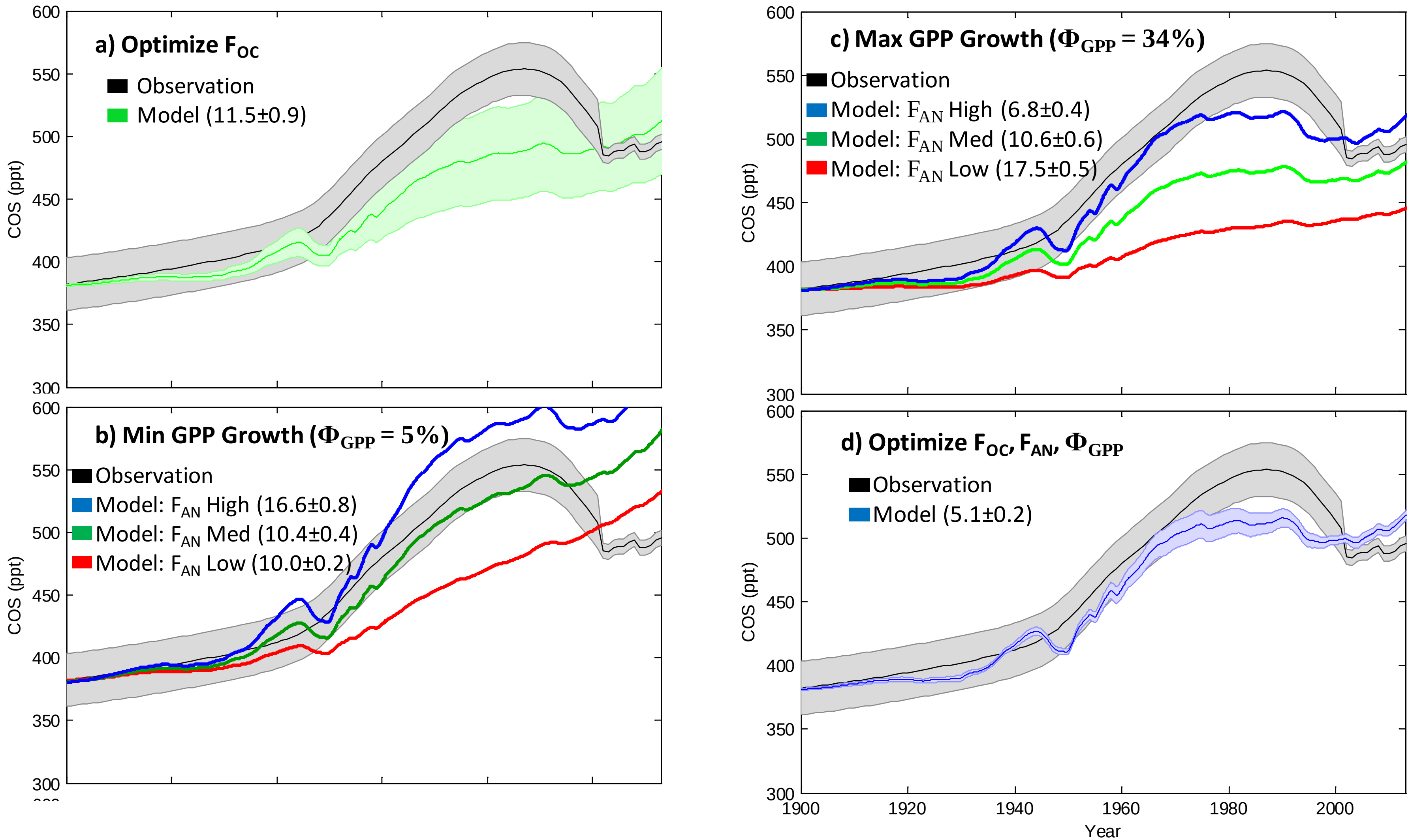
3) COS Applications: Global Scale


a)
H1
H2
H3
EV
SIG
Flasks
COS (ppt)
Year
(Montzka et al., JGR, 2004)
b)
COS (normalized)
Year
South Pole Mean (Firn, Ice, Flasks)
NOAA Global Surface Sites (Flasks)
FTIR Southern Hemisphere:
Arrival Heights, Antarctica
Wollongong, Australia
Lauder, New Zealand
FTIR Northern Hemisphere:
Kitt Peak, U.S.
Jungfraujoch, Switzerland

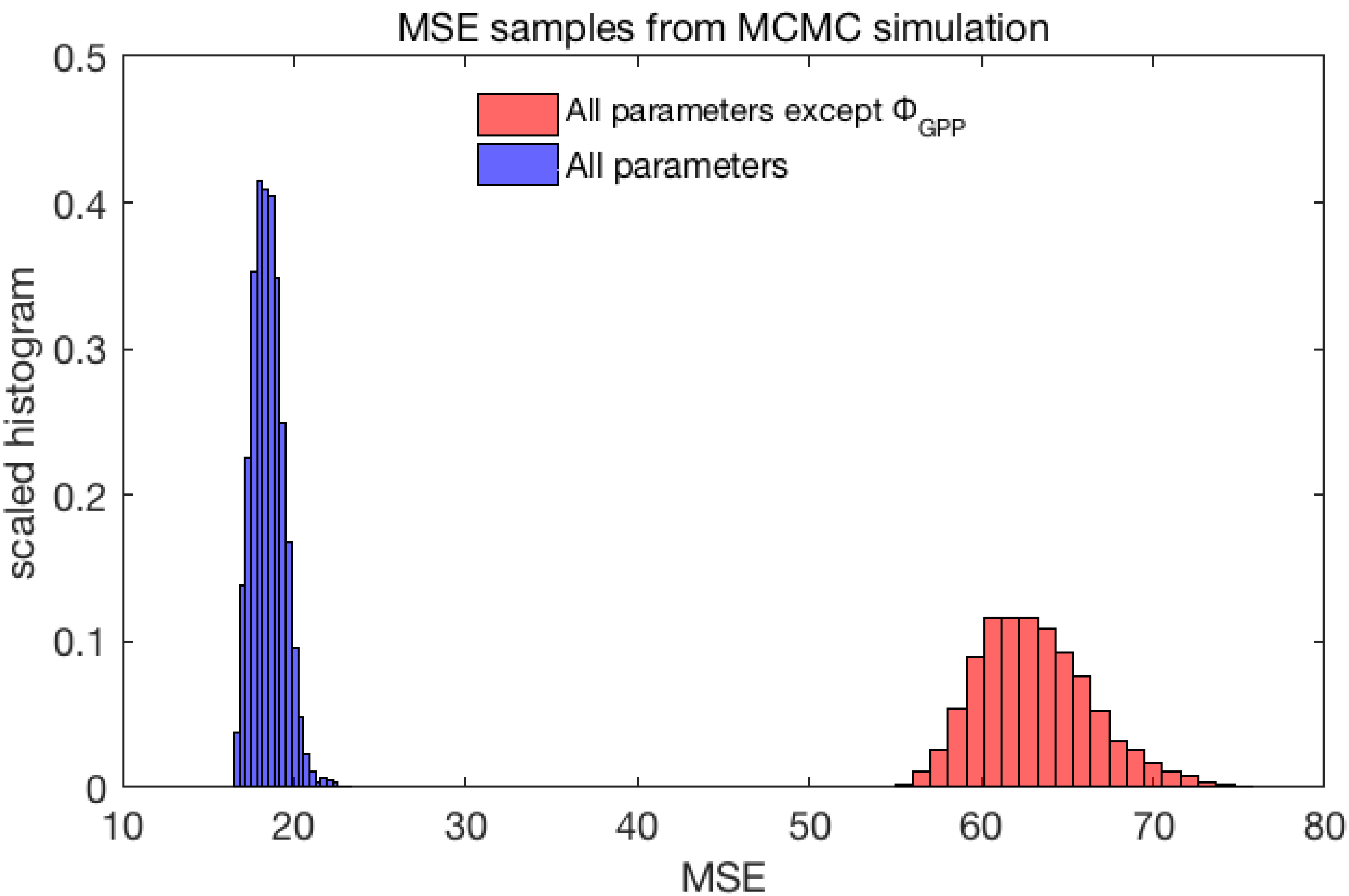
2017)



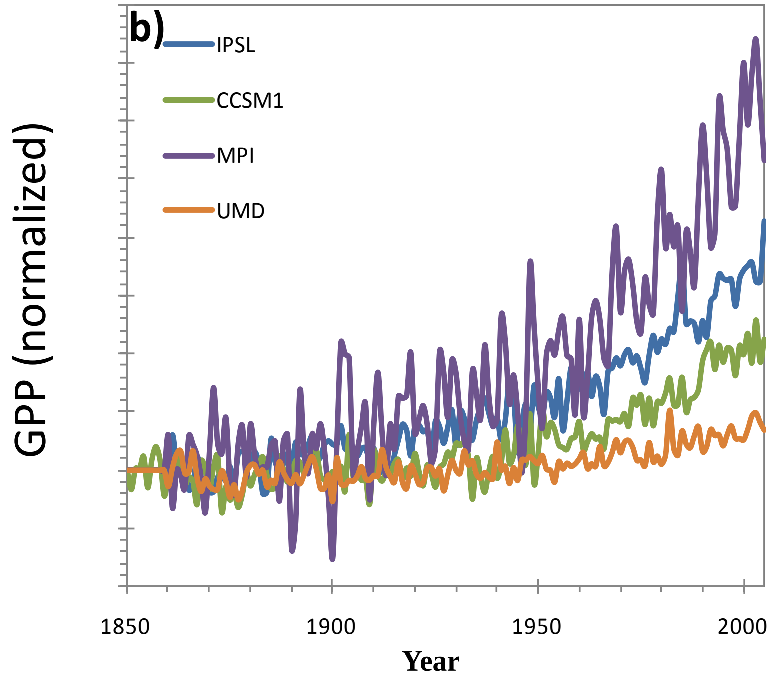
(Campbell et al., *Nature*, 2017)

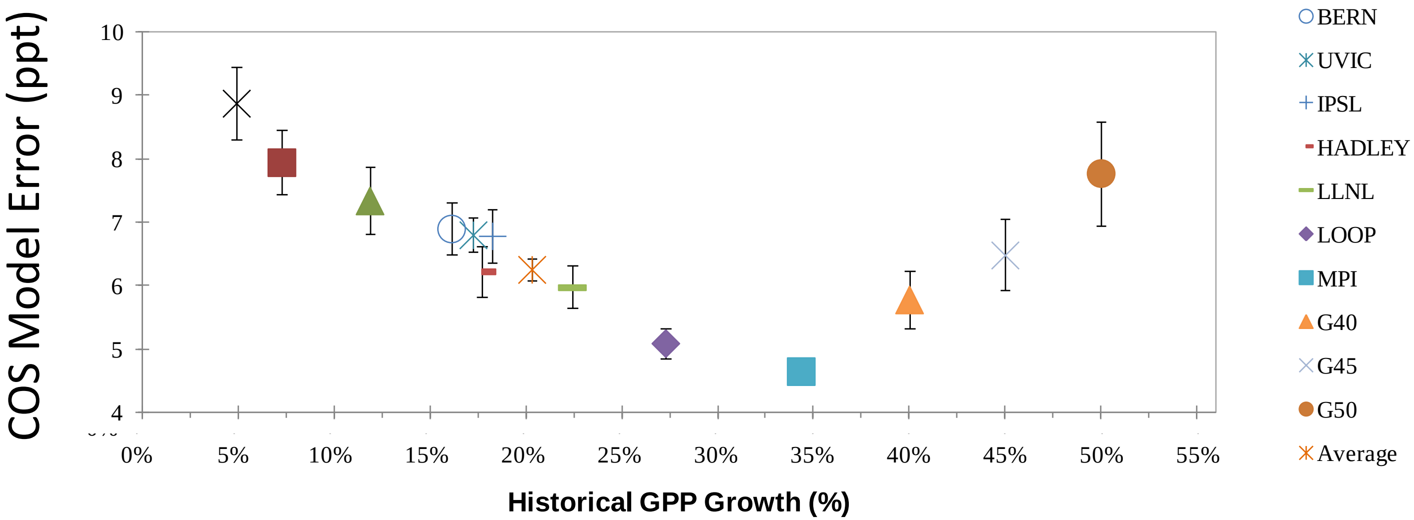


(Campbell et al., *Nature*, 2017)

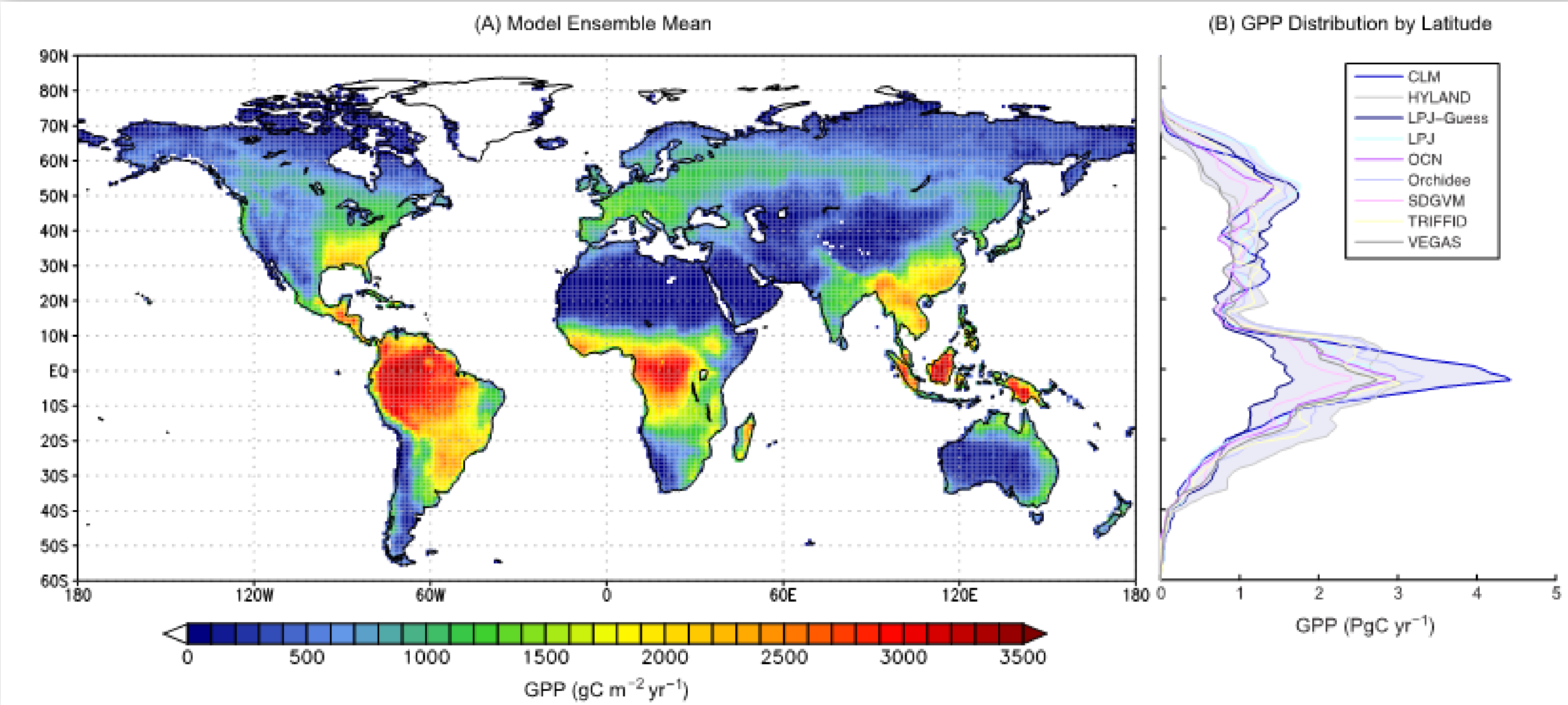


(Campbell et al., *Nature*, 2017)





(Campbell et al., *Nature*, 2017)

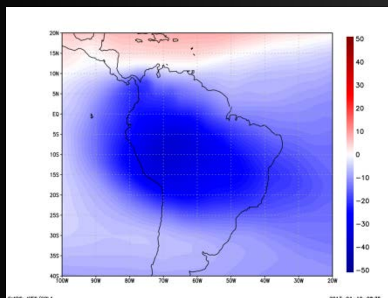


Annual mean and latitudinal distribution of TRENDY model ensemble members.

EXTRA SLIDES

3) Next Steps: Amazon

DOE - Terrestrial Ecosystem Sciences Grant (DE-SC0011999)

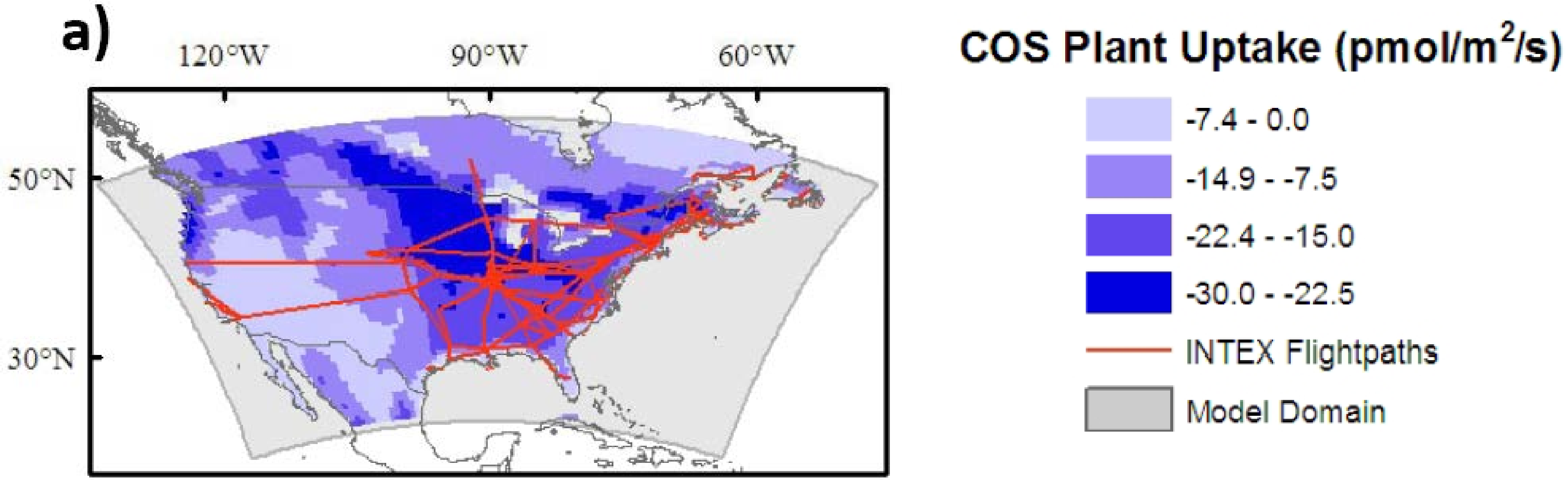


Modeling and data assimilation (UC Santa Cruz / UC Merced)

ATTO ambient concentration measurements, eddy flux, leaf chamber, and soil chamber (UCLA/INPA)

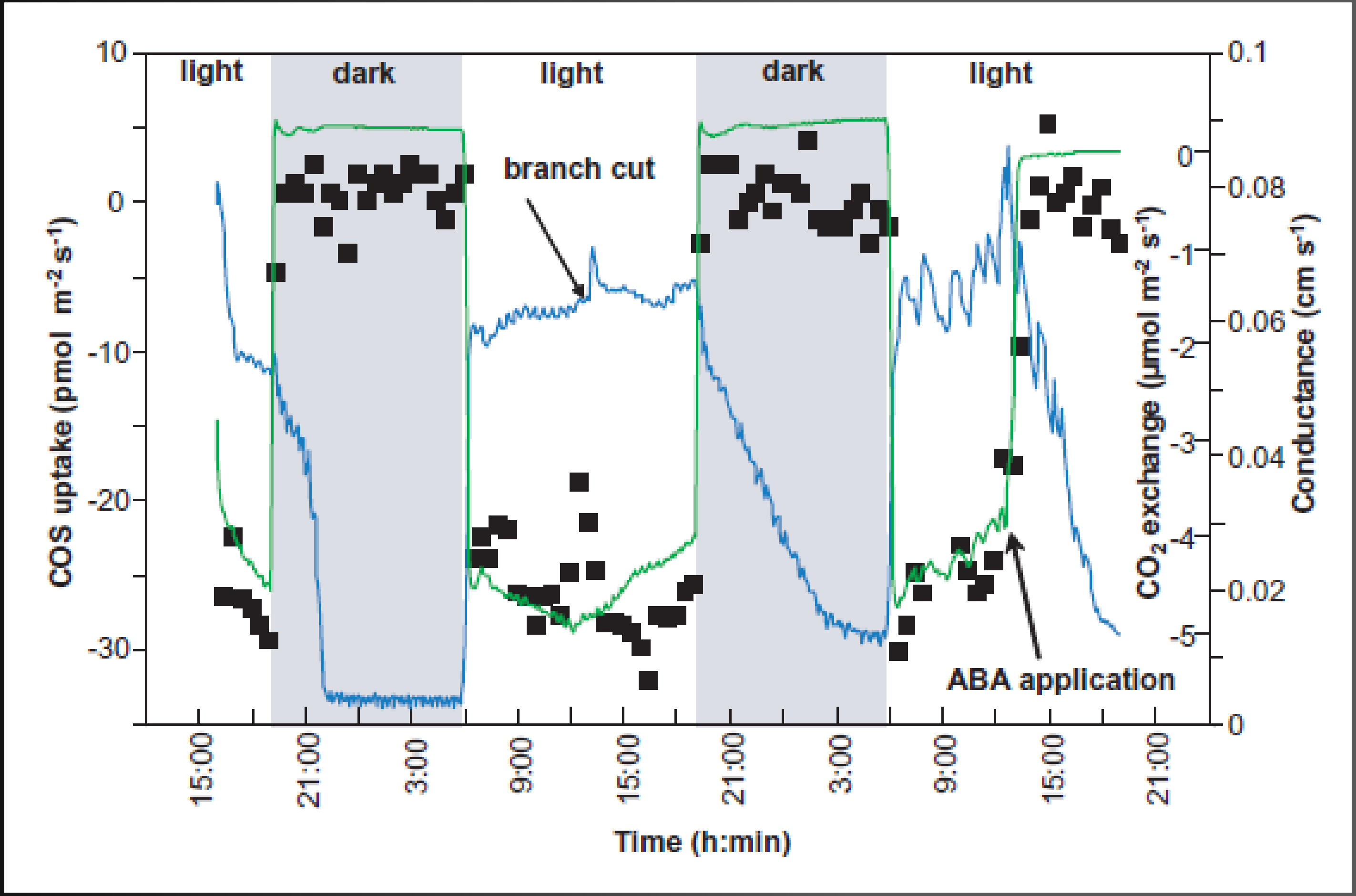
Airborne flask sampling (INPE / Carnegie / UC Merced)

Continental Drawdown



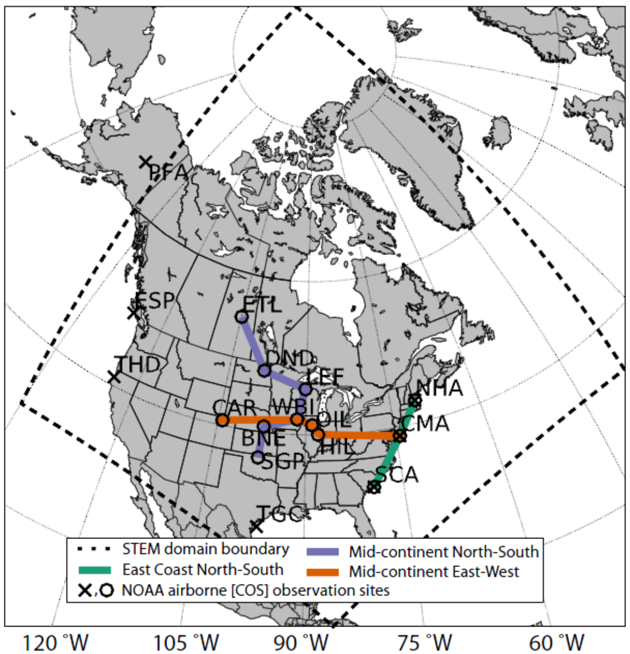
(Campbell et al., *Science*, 2008)

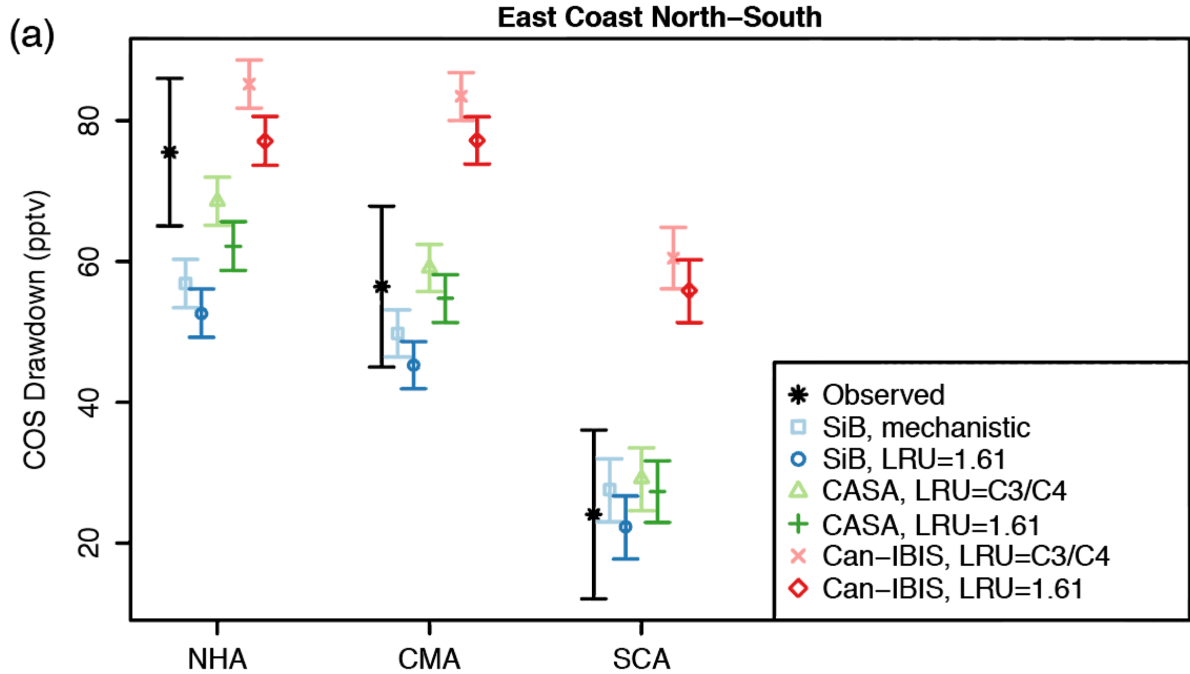
Leaf Chamber Observations



(Sandoval-Soto et al., *JGR Biogeosciences*, 2005)

Regional Analysis

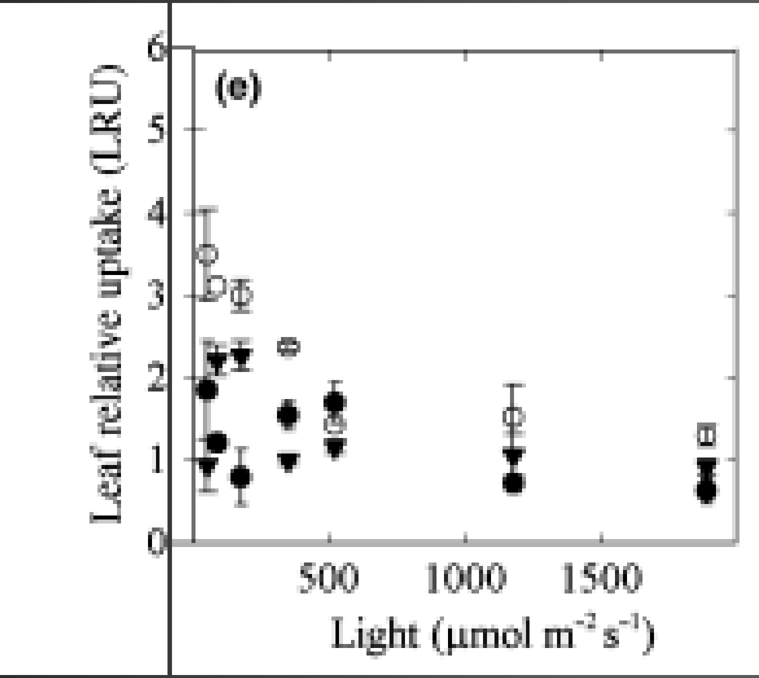




(Hilton et al., *Nature Climate Change*, In Press)

More Leaf Chamber Observations

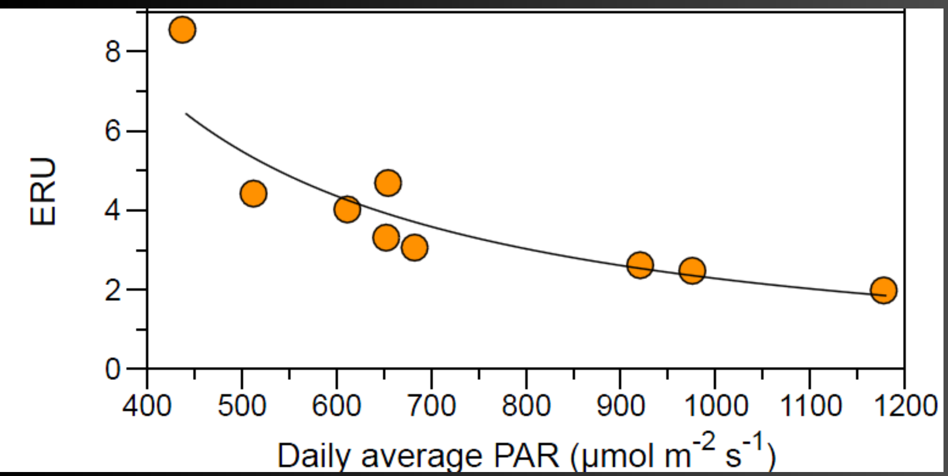
$$\mathrm{LRU} = \frac{F_{\mathrm{COS}_{\mathrm{leaf}}}}{[\mathrm{COS}]} \bigg/ \frac{F_{\mathrm{CO}_{2\,\mathrm{leaf}}}}{[\mathrm{CO}_2]}$$



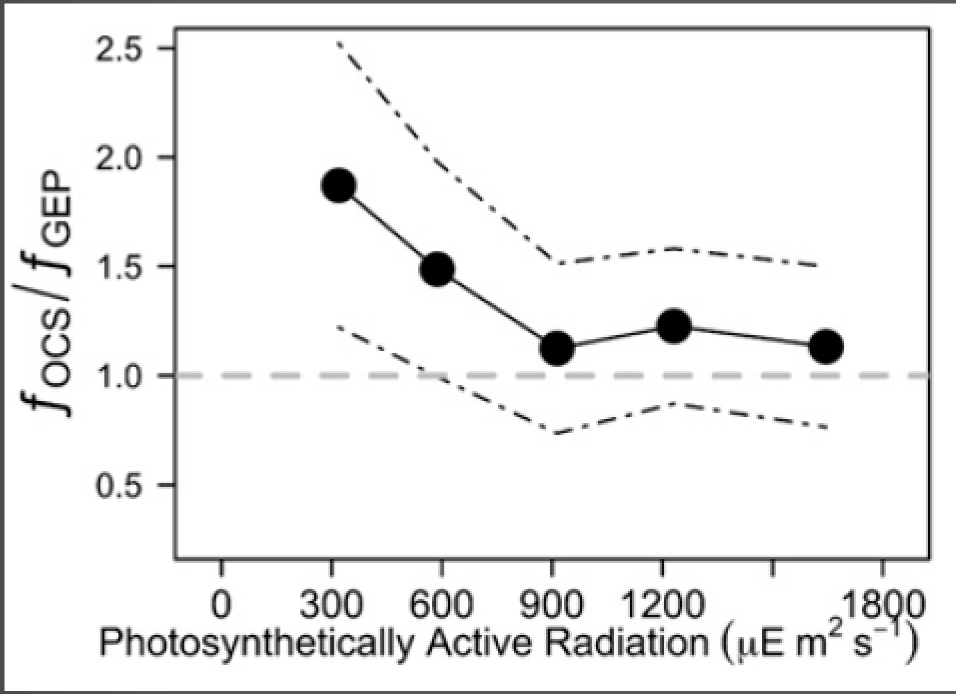
(Stimler et al., *New Phytologist*, 2010)

Eddy Flux Observations

ARM/SGP

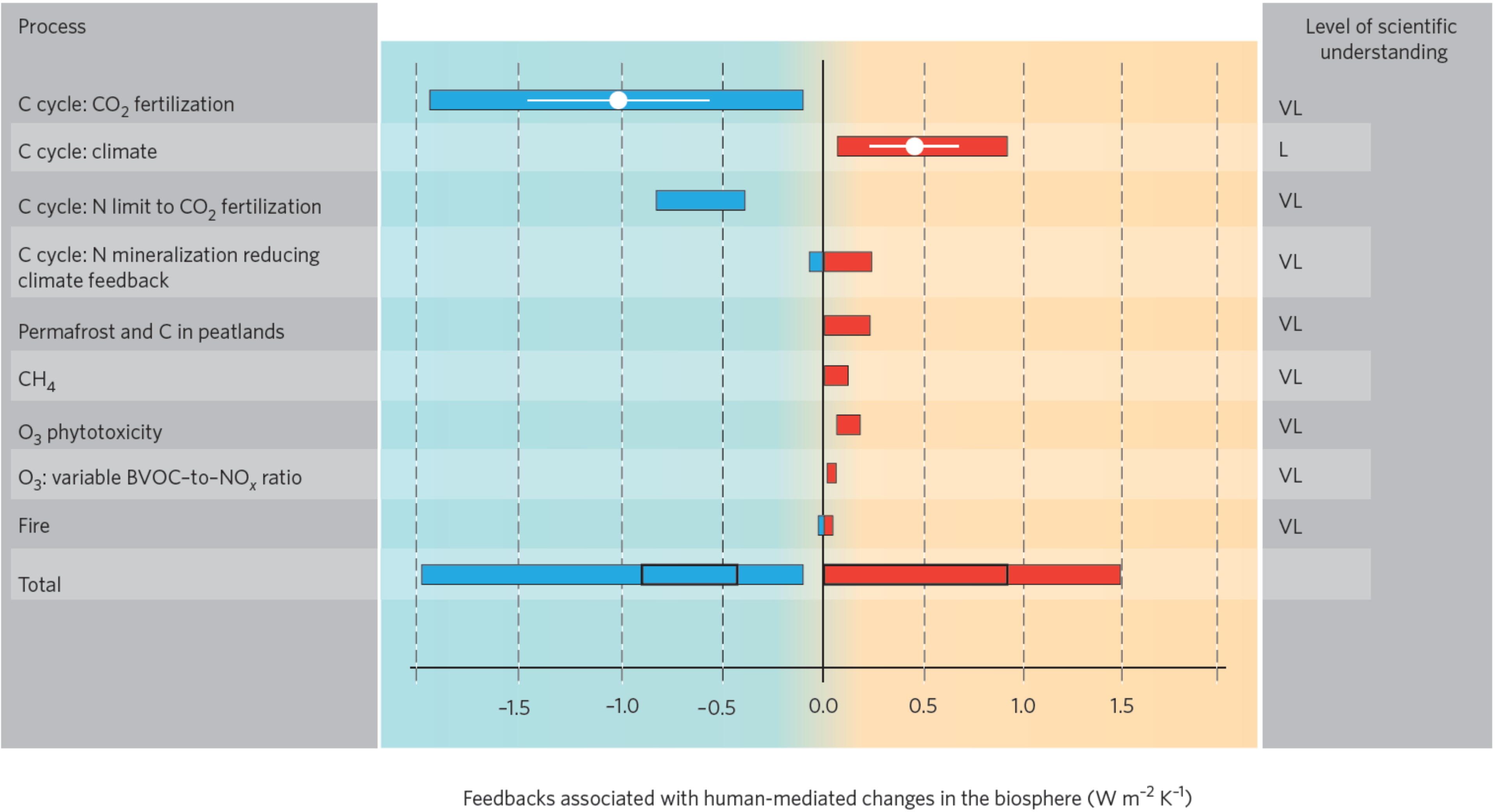


Harvard



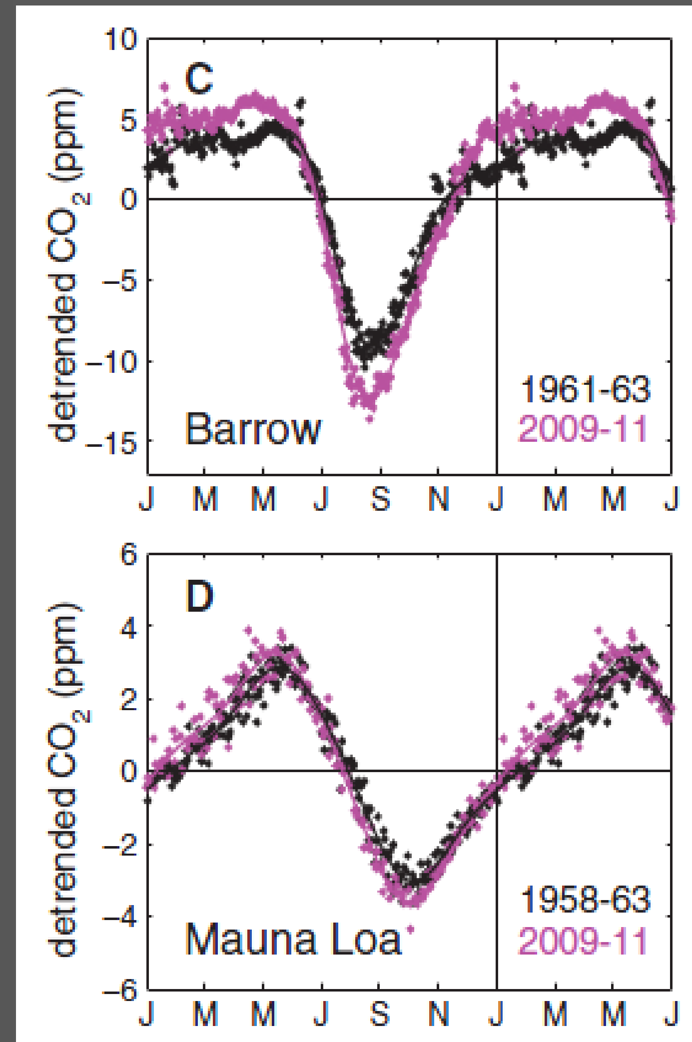
(Maseyk et al., *PNAS*, 2014; Commane et al., *PNAS*, 2015)

Terrestrial Climate Feedbacks



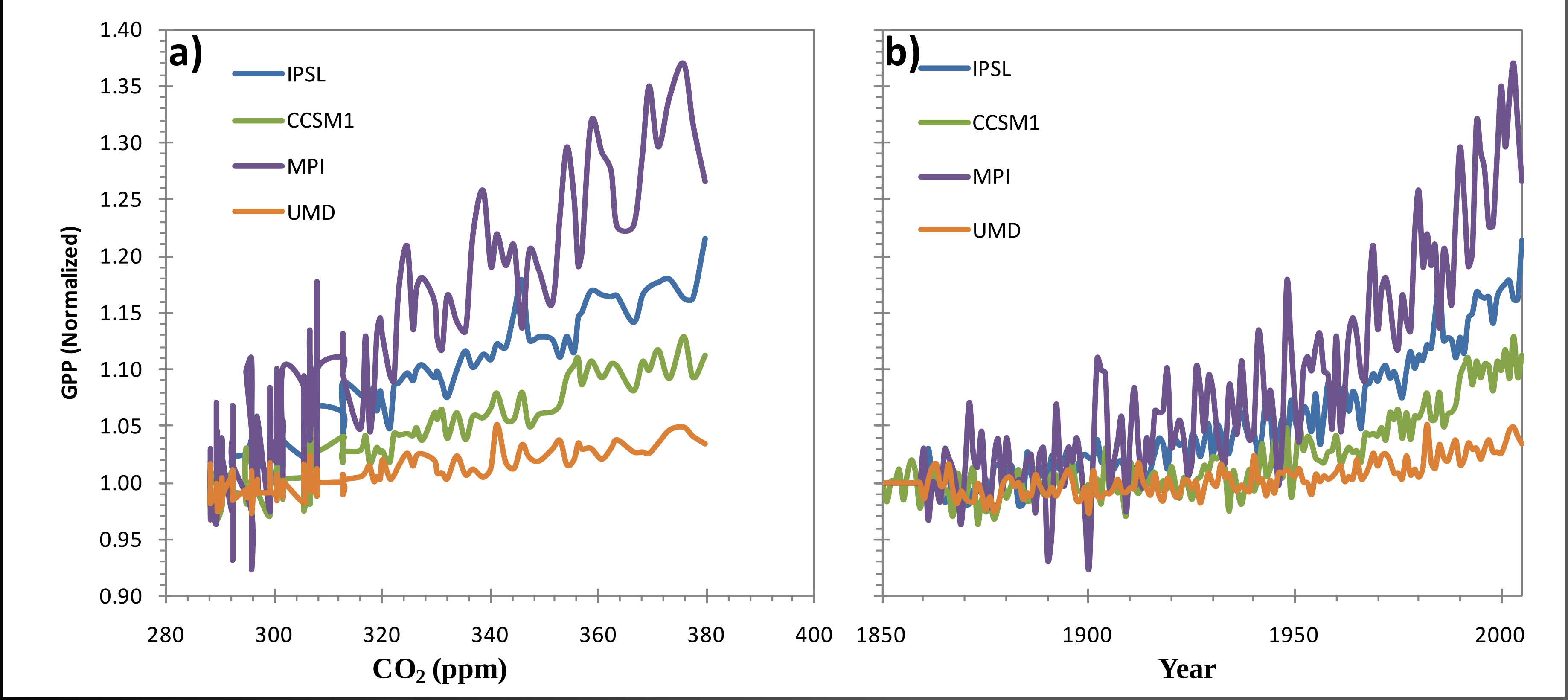
(Arneth, et al., *Nature Geoscience*, 2010)

Mixed Results

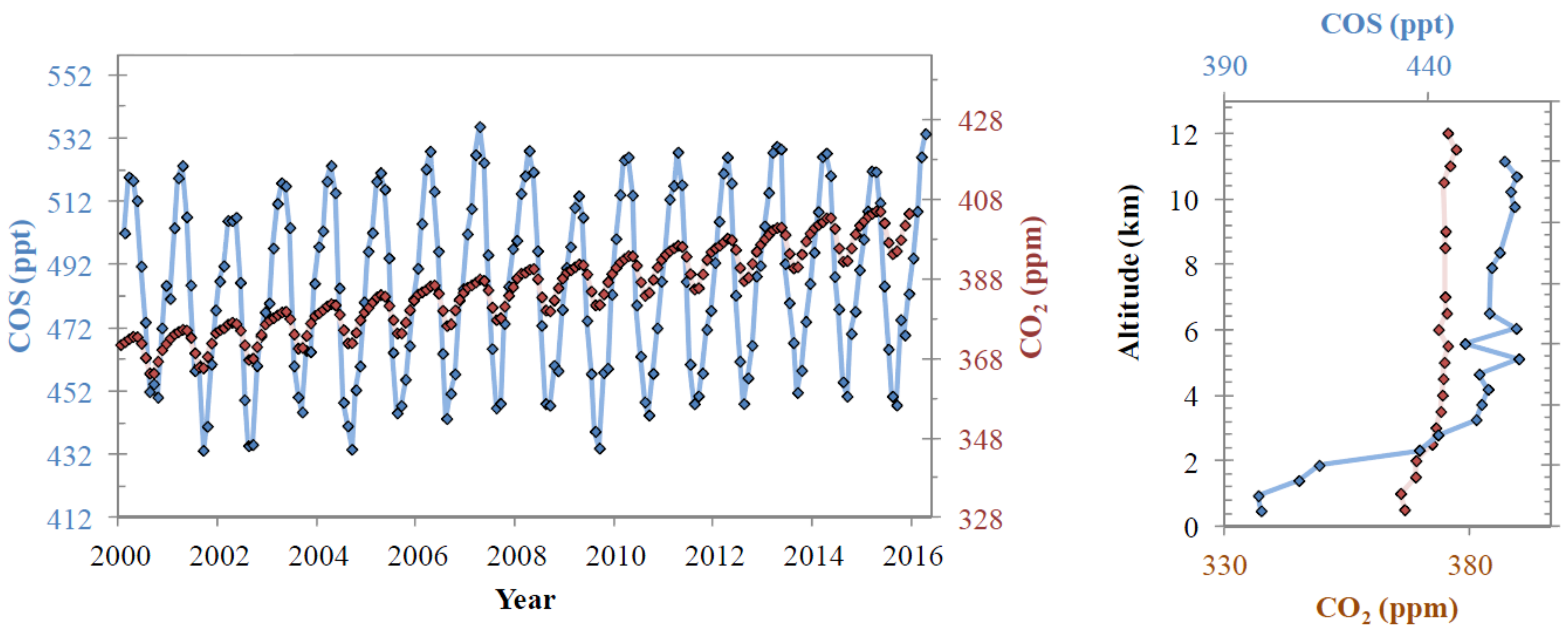


(Duke FACE; MODIS NDVI; Graven et al., *Nature*, 2014)

Photosynthesis in Carbon-Climate Models



Large-Scale Variability



(Campbell et al., *EOS*, In Press)

New era for COS

- **First** eddy flux (Maseyk et al., PNAS, 2014)
- **First** global satellite maps (Kuai et al., JGR, 2015; Glatthor et al., GRL, 2015)
- **First** obs of glacial transition (Aydin et al., JGR, 2016)
- Anthropogenic inventory (Campbell et al., GRL, 2015)
- Soil incubations (Whelan et al., ACP, 2016)
- Column spectrometer (Wang et al., ACP, 2016)
- NOAA network (Montzka et al., JGR, 2007)

Global Budget

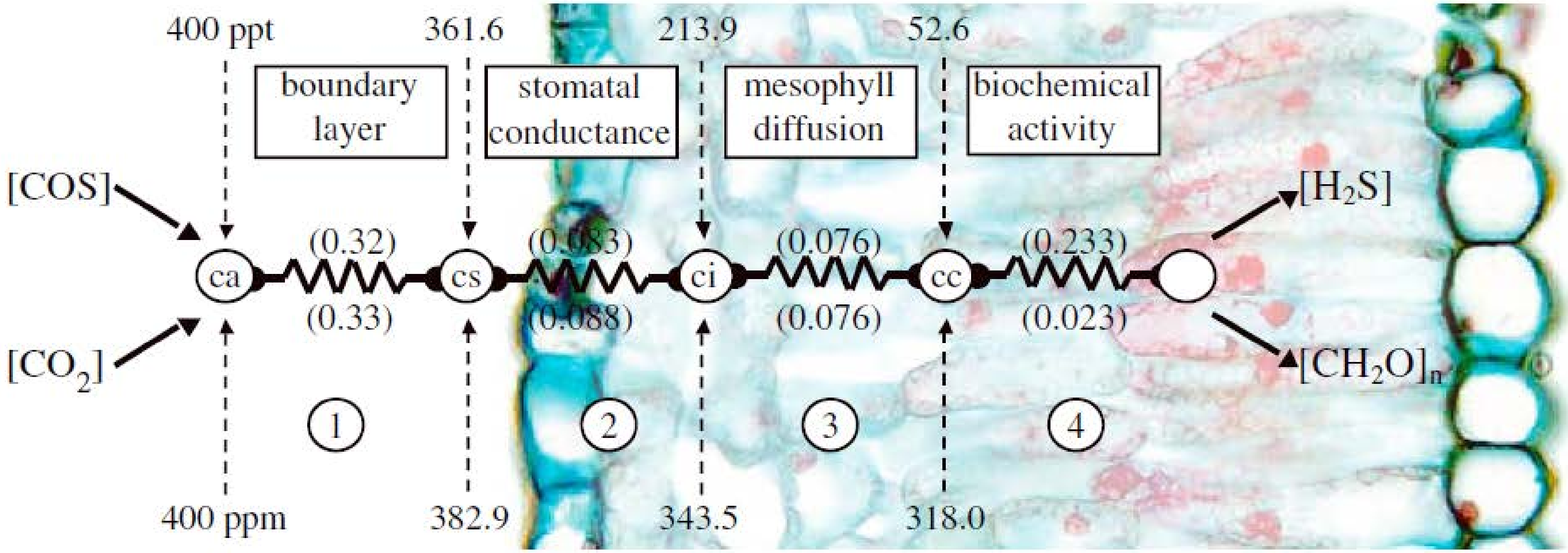
Table 1. A Compilation of the Global Sources and Sinks Used for PCTM Simulations of Atmospheric COS[a]

Sources	*Kettle et al.*, 2002	This Study
Direct COS Flux From Oceans	39	39
Indirect COS Flux as DMS From Oceans	81	81
Indirect COS Flux as CS_2 From Oceans	156	156
Direct Anthropogenic Flux	64	64
Indirect Anthropogenic Flux From CS_2	116	116
Indirect Anthropogenic Flux From DMS	0.5	0.5
Biomass Burning	11	**136**
Additional (Photochemical) Ocean Flux		**600**
Sinks		
Destruction by OH Radical	−94	−**101**
Uptake by Canopy	−238	−**738**
Uptake by Soil	−130	−**355**
Net Total	−5	−2.5

[a]Units are 1.0×10^9 g of sulfur. Fluxes changed in this study are highlighted with bold type.

(Berry et al., *JGR-Biogeosciences*, 2013)

Leaf Uptake of COS and CO_2



(Berry et al., *JGR Biogeosciences*, 2013)