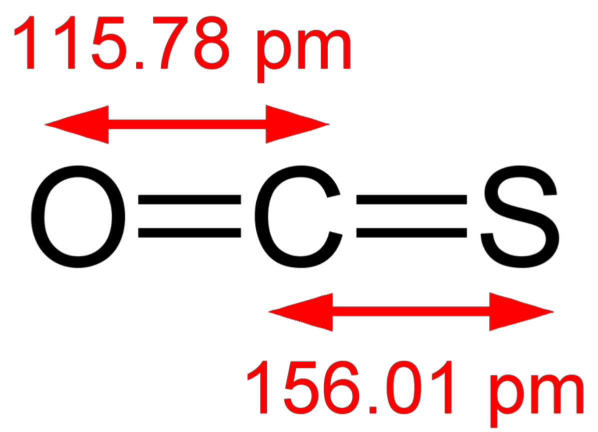
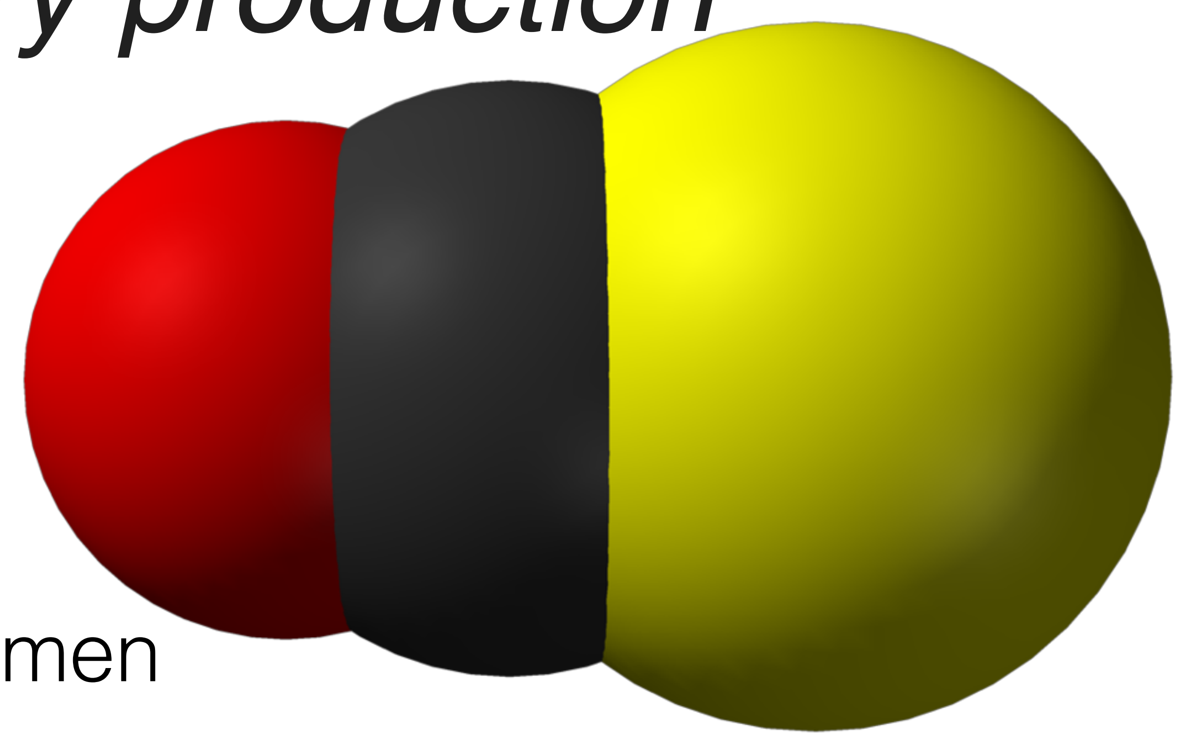


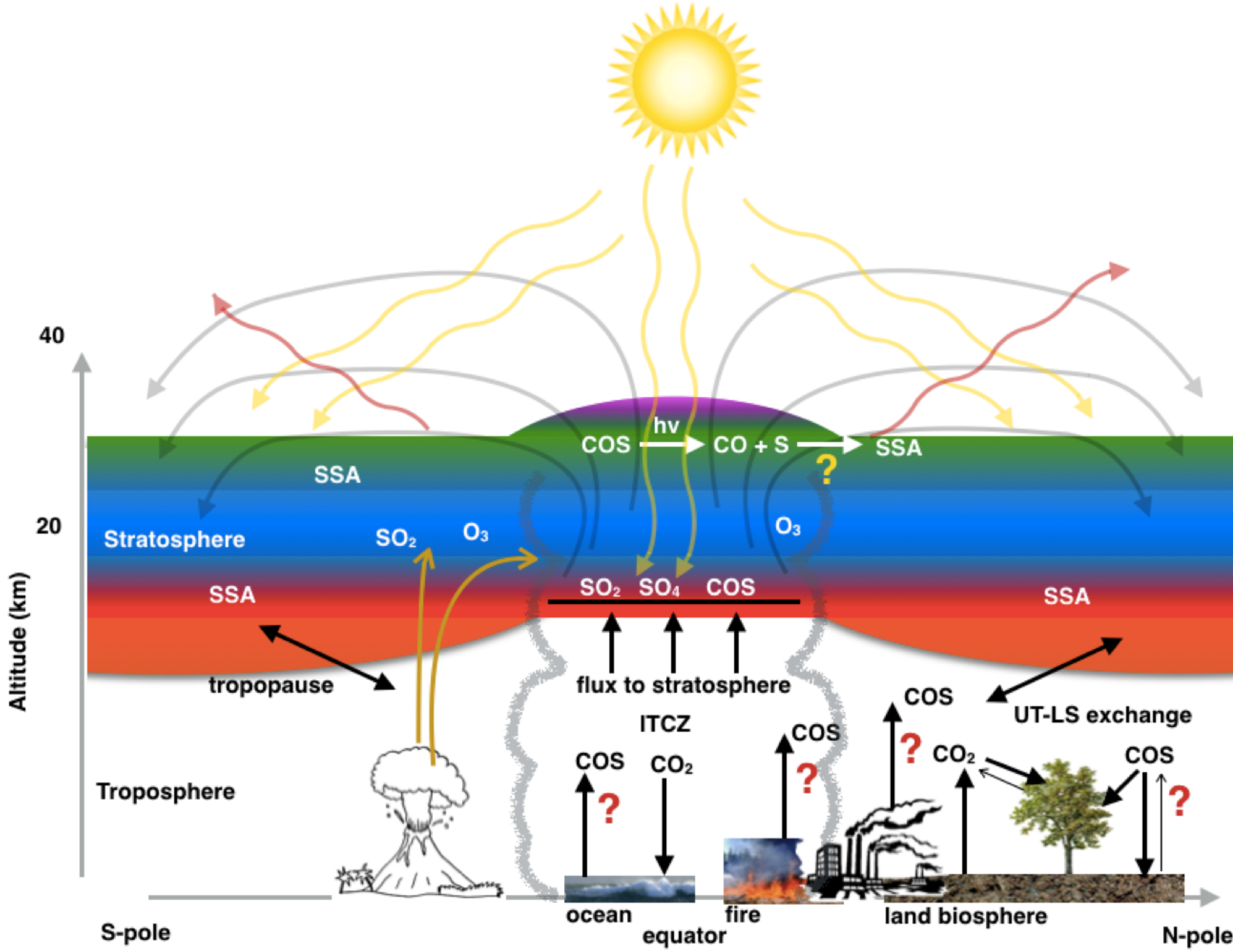
***COS**: Towards an inverse modelling framework to constrain the global budget and global primary production*



Maarten Krol, Wageningen University &
Utrecht University, 28th TM5 meeting, Bremen

This project has received funding from the European Research Council (ERC) under the European Union's H2020 research and innovation programme under grant agreement No 742798

COS-OCS


40
20
Altitude (km)
hv
COS
CO + S
SSA
?
SSA
Stratosphere
SO2
O3
O3
SO2 SO4 COS
SSA
SSA
tropopause
flux to stratosphere
ITCZ
COS
UT-LS exchange
COS
?
CO2
COS
Troposphere
COS
CO2
?
?
?
ocean
fire
land biosphere
equator
S-pole
N-pole

Objectives COS-OCS

Sophie Baartman/Elena Popa

- **Perform the first world-wid[illegible]ation of COS isotopologues by m[illegible]sonal, latitudinal, and altitude variations in tr[illegible]nd stratosphere**
- Measure COS [illegible] over the troposphere–stratosphere transition up to 30 km altitude using innovative AirCore sampling techniques
- Investigate fractionation effects during soil and plant uptake in laboratory experiments
- Develop the first model with capabilities to simulate COS-isotopologues and the coupled COS and CO_2 cycles
- Pioneer the use of satellite observations of COS and its isotopologues
- Constrain the budgets of COS and CO_2 using inverse modelling techniques employing surface measurements, satellite data, and new AirCore and isotopic COS measurements

Objectives COS-OCS

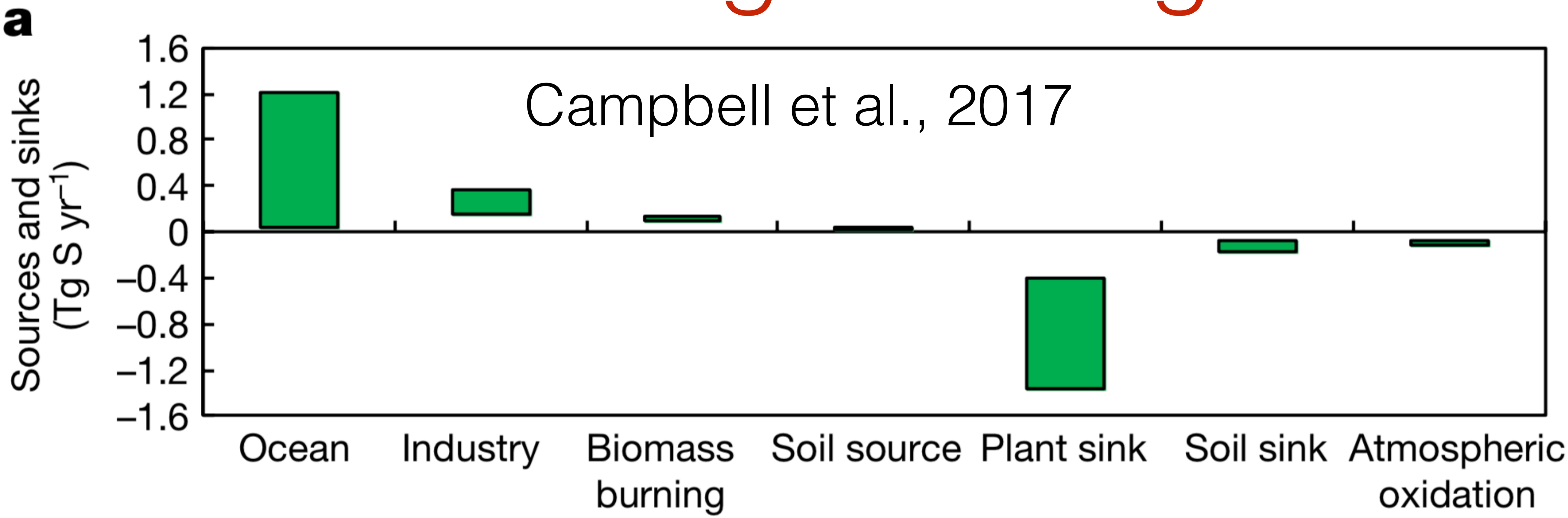
- Perform the first world-wide characterisation [illegible] COS isotopologues by measuring seasonal, latitudinal, and [illegible]ations in troposphere and stratosphere
- **Measure COS gradient[illegible]oposphere–stratosphere transition up to [illegible]de using innovative AirCore sampling [illegible]**
- Investigate [illegible]ation effects during soil and plant uptake in laboratory experiments
- Develop the first model with capabilities to simulate COS-isotopologues and the coupled COS and CO_2 cycles
- Pioneer the use of satellite observations of COS and its isotopologues
- Constrain the budgets of COS and CO_2 using inverse modelling techniques employing surface measurements, satellite data, and new AirCore and isotopic COS measurements
-

Steven van Heuven/Huilin Chen

Objectives COS-OCS

- Perform the first world-wide characterisation of COS isotopologues by measuring seasonal, latitudinal, and altitude variations in troposphere and stratosphere
- Measure COS gradients over the troposphere–stratosphere transition up to 30 km altitude using innovative AirCore sampling techniques
- Investigate fractionation effects during soil and plant uptake in laboratory experiments
- **Develop the first model with capabilities to simulate COS-isotopologues and the coupled COS and CO_2 cycles**
- Pioneer the use of satellite observations of COS and its isotopologues
- Constrain the budgets of COS and CO_2 using inverse modelling techniques employing surface measurements, satellite data, and new AirCore and isotopic COS measurements

COS Modelling: Building Blocks



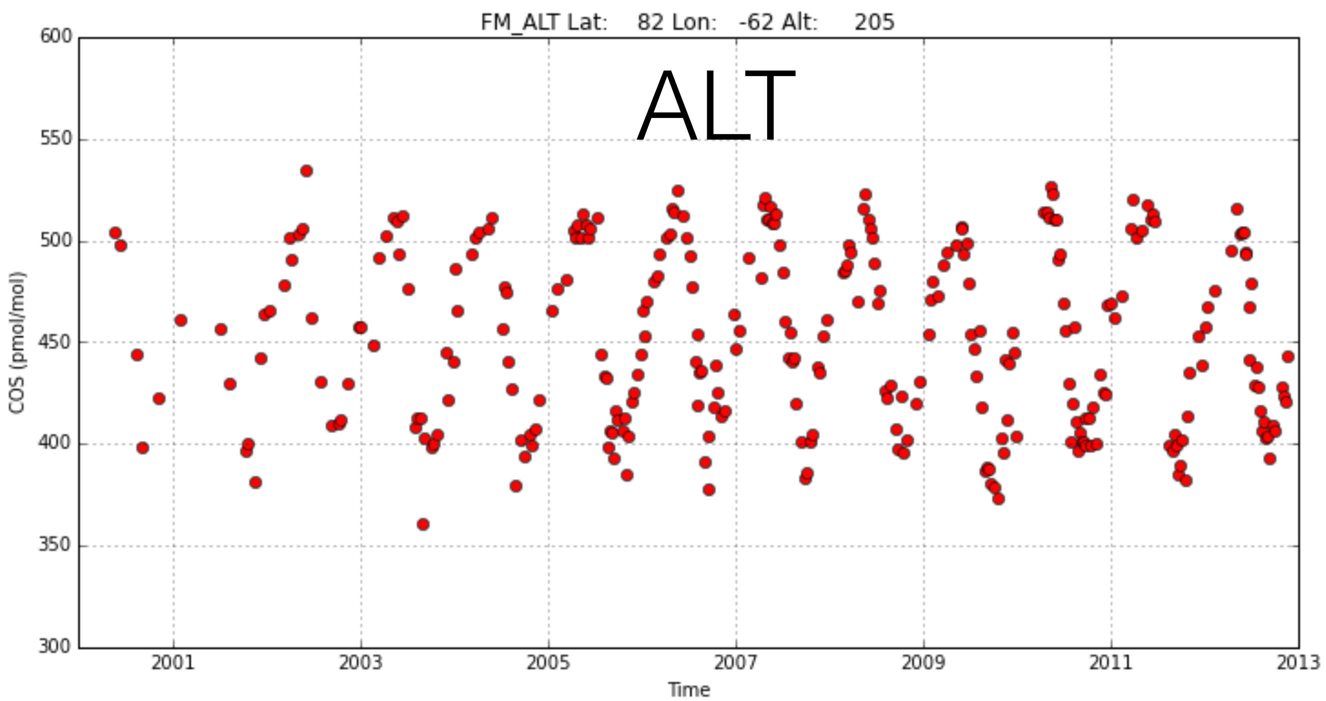
Anthropogenic Emissions	Atmospheric Oxidation (OH)	Observations
Biosphere Exchange	Stratospheric Photolysis	Biomass Burning
Ocean Emissions	Isotopologues	Coupled COS-CO_2

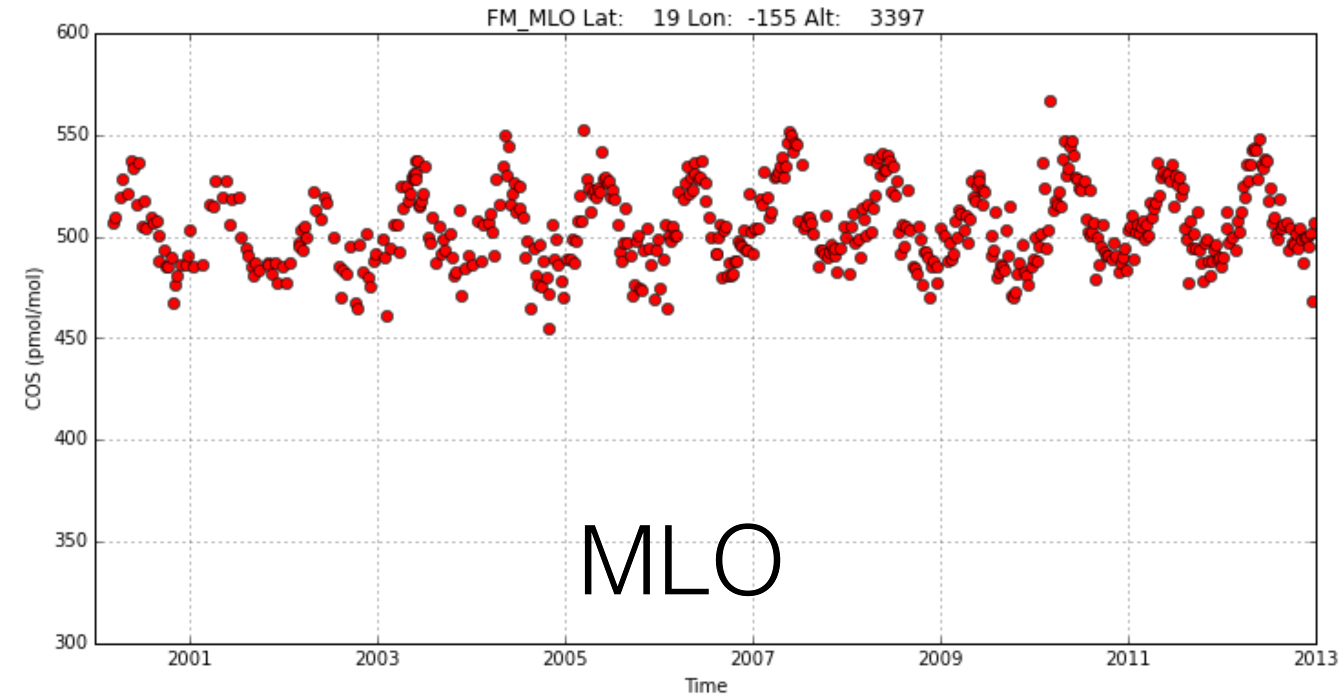
To be done

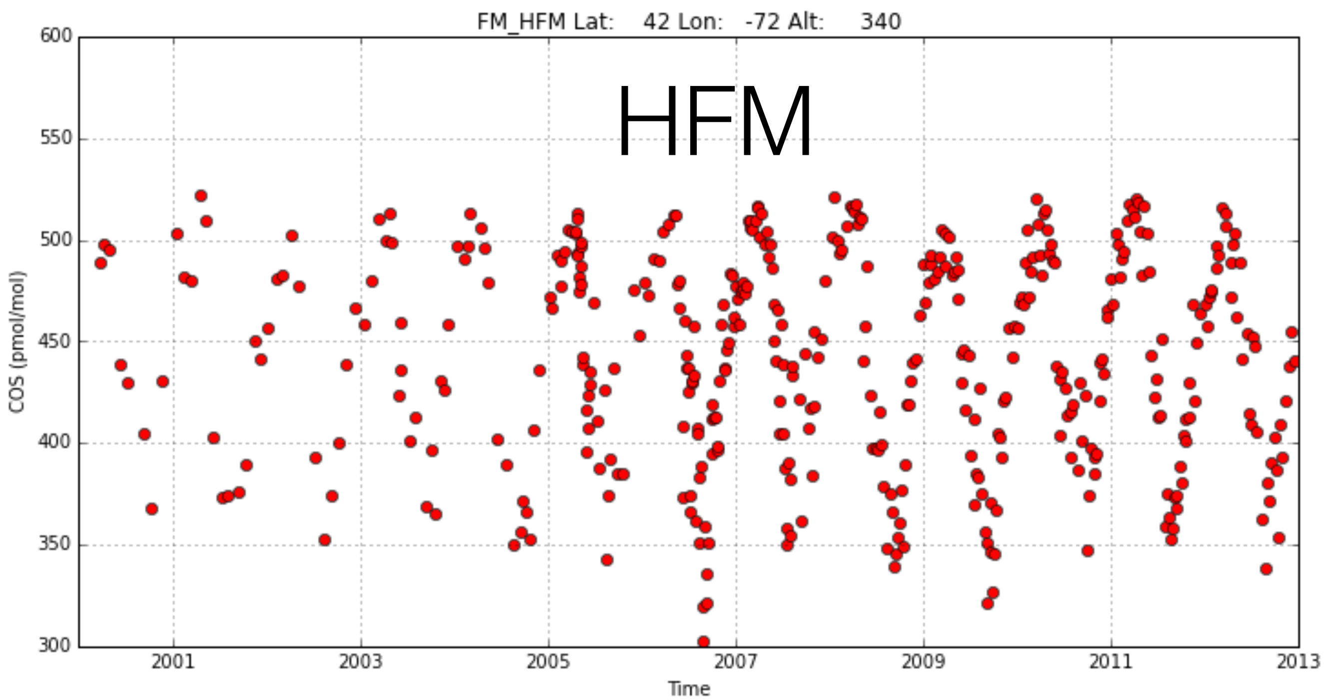
Finished

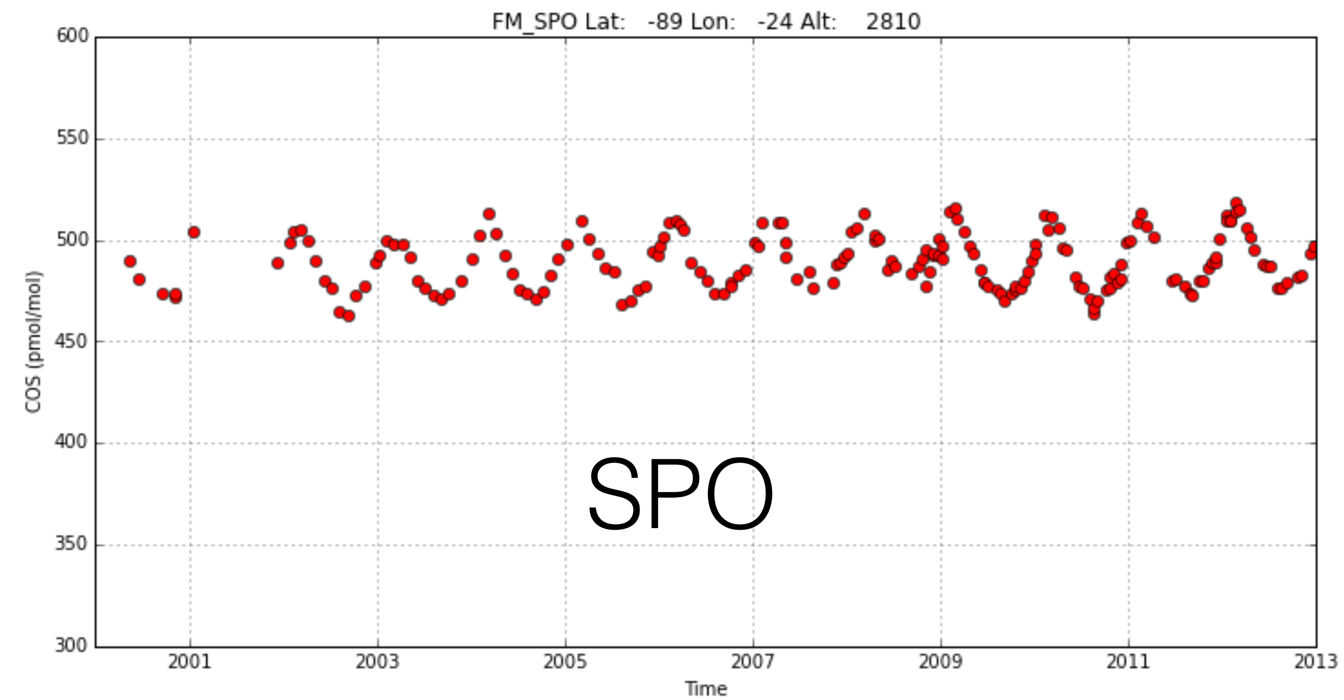
In progress

COS-OCS





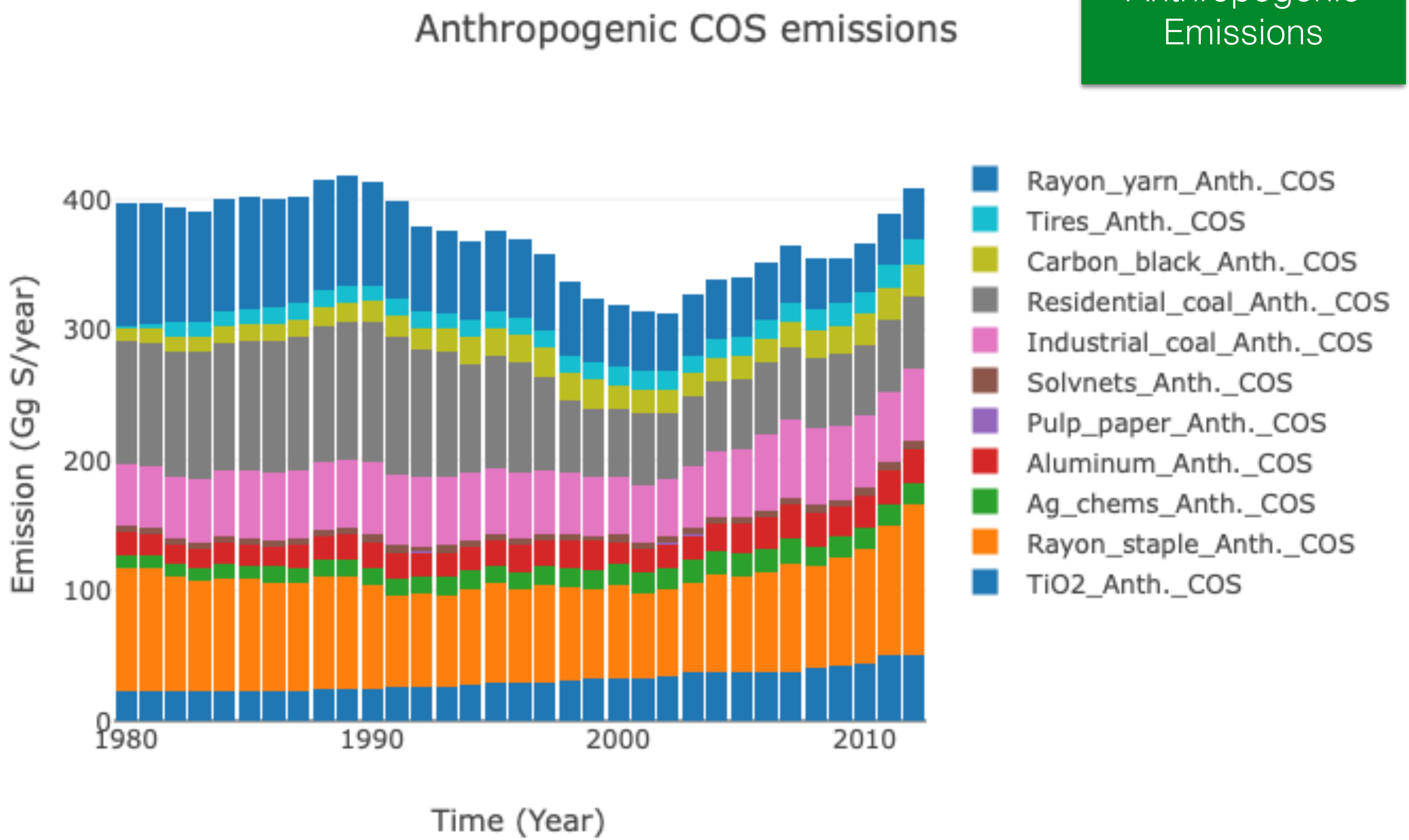




Observations

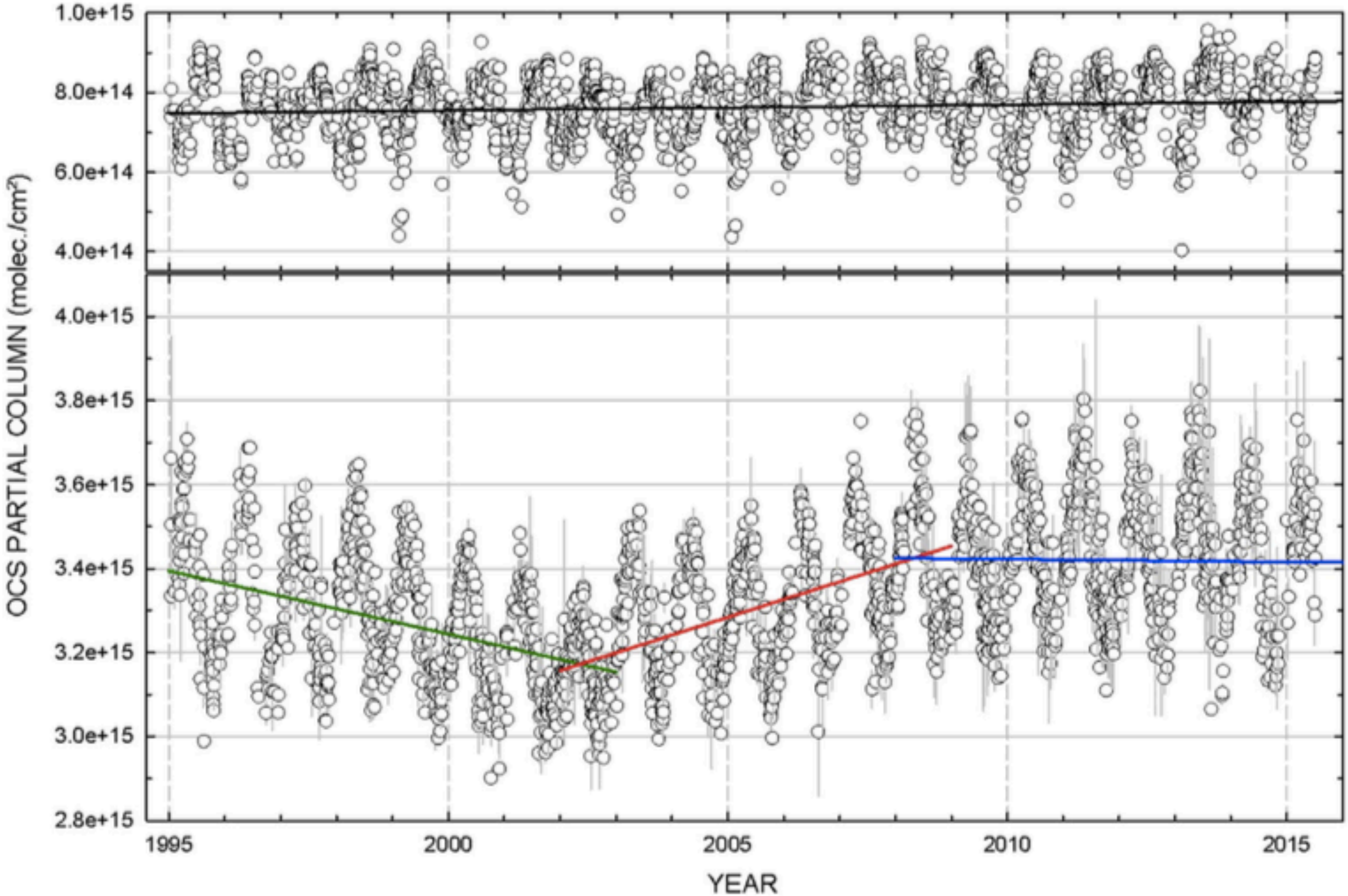
COS-OCS

Anthropogenic Emissions



Zumkehr, A. et al. Global gridded anthropogenic emissions inventory of carbonyl sulfide. Atmos Environ 183, 11–19 (2018).

This project has received funding from the European Research Council (ERC) under the European Union's H2020 research and innovation programme under grant agreement No 742798



1.0e+15
8.0e+14
6.0e+14
4.0e+14
4.0e+15
3.8e+15
3.6e+15
3.4e+15
3.2e+15
3.0e+15
2.8e+15
OCS PARTIAL COLUMN (molec./cm²)
1995
2000
2005
2010
2015
YEAR

Direct/Indirect Emissions

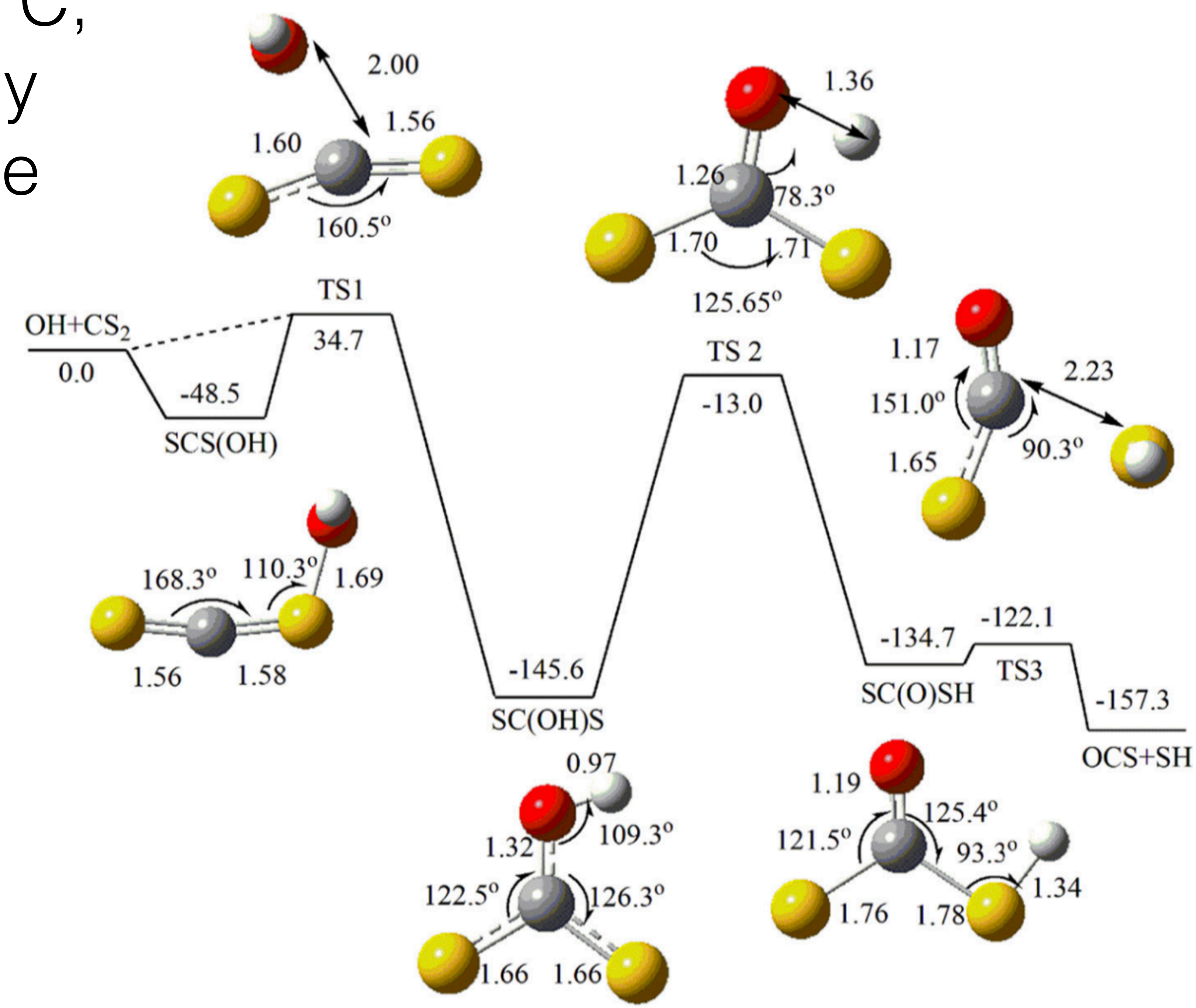
Anthropogenic sources of COS are dominated by indirect sources (CS_2) and include rayon production, aluminum production, coal combustion, biomass burning, oil refineries and fuel combustion.

- COS / CS_2
- CS_2 + OH (+O_2) —> COS + HOSO
- COS + OH —> CO_2 + HS

Atmospheric Oxidation (OH)

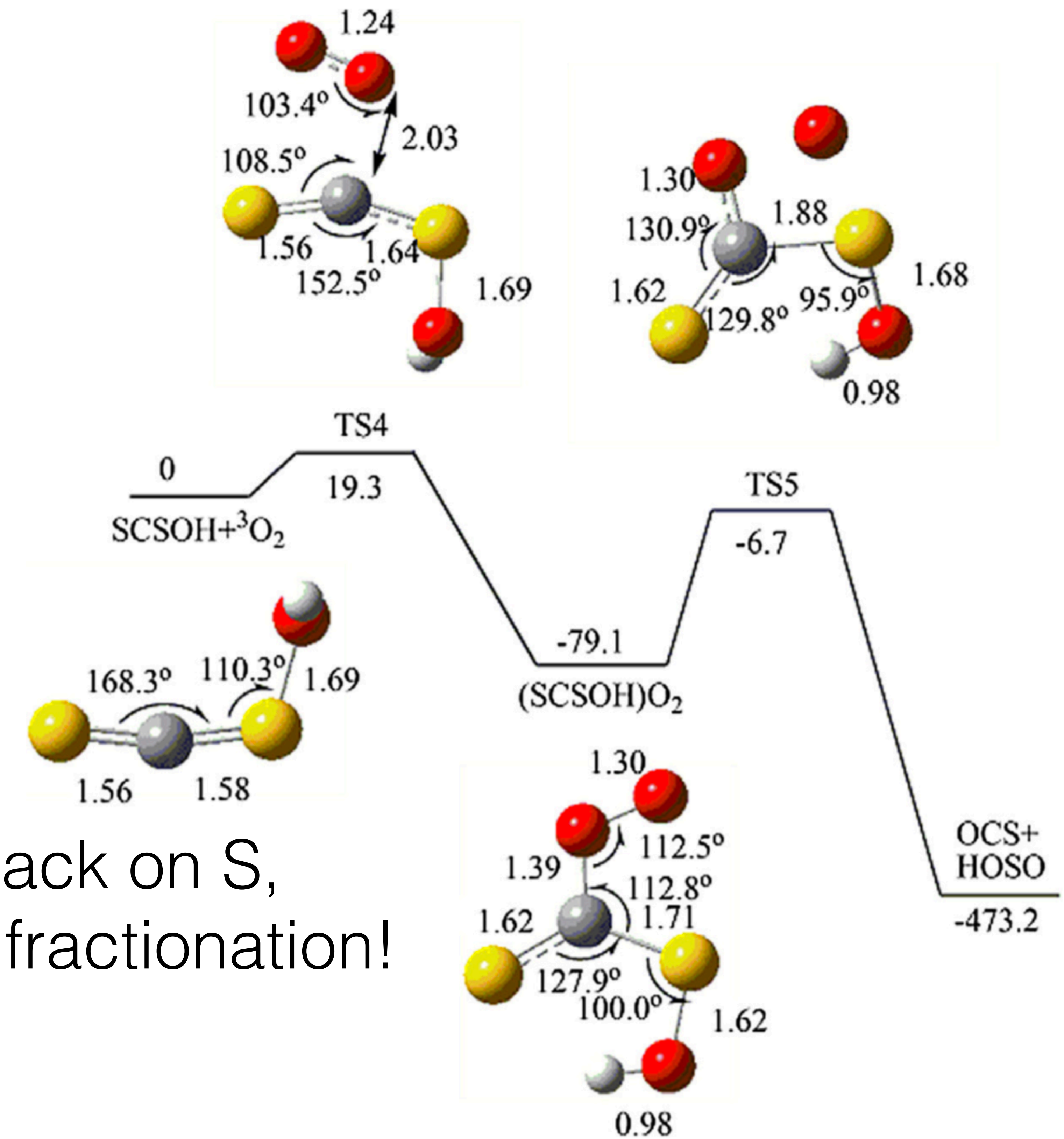
1. Angert, A., Said-Ahmad, W., Davidson, C. & Amrani, A. Sulfur isotopes ratio of atmospheric carbonyl sulfide constrains its sources. Sci Rep 1–8 (2019). doi:10.1038/s41598-018-37131-3

OH-attack on C,
Energetically
unfavourable



Zeng, 2017

This project has received funding from the European Research Council (ERC) under the European Union’s H2020 research and innovation programme under grant agreement No 742798



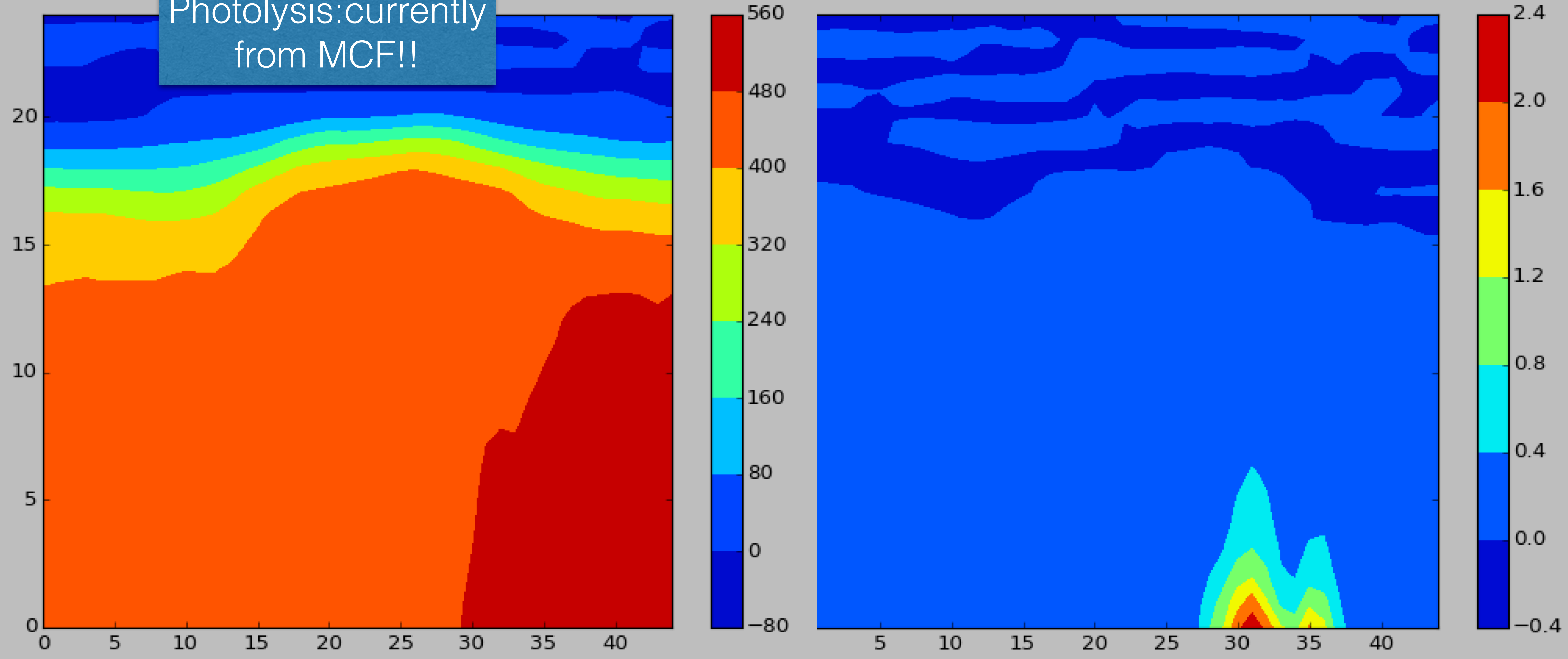
OH-attack on S,
Implies S- fractionation!

Zeng, 2017

This project has received funding from the European Research Council (ERC) under the European Union's H2020 research and innovation programme under grant agreement No 742798

COS-OCS

Stratospheric Photolysis:currently from MCF!!



Zonal Averages

COS (ppt, 8/2008)

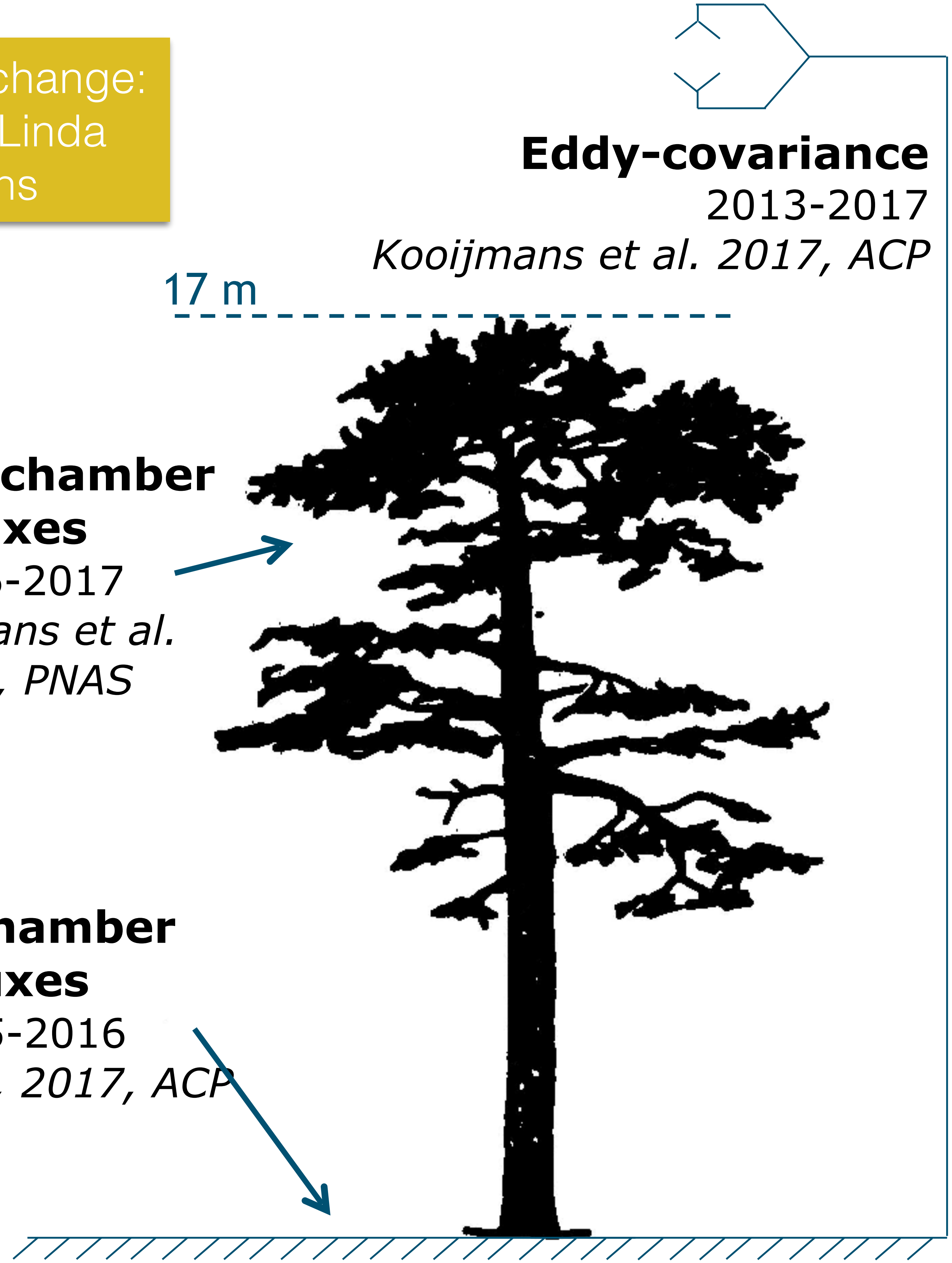
CS2 (ppt, 8/2008)

Run 2000 —-> 2013 (6x4): 10% emitted as CS2

This project has received funding from the European Research Council (ERC) under the European Union's H2020 research and innovation programme under grant agreement No 742798

Measurements, Hyytiälä (Finland)

Biosphere Exchange: Slides from Linda Kooijmans

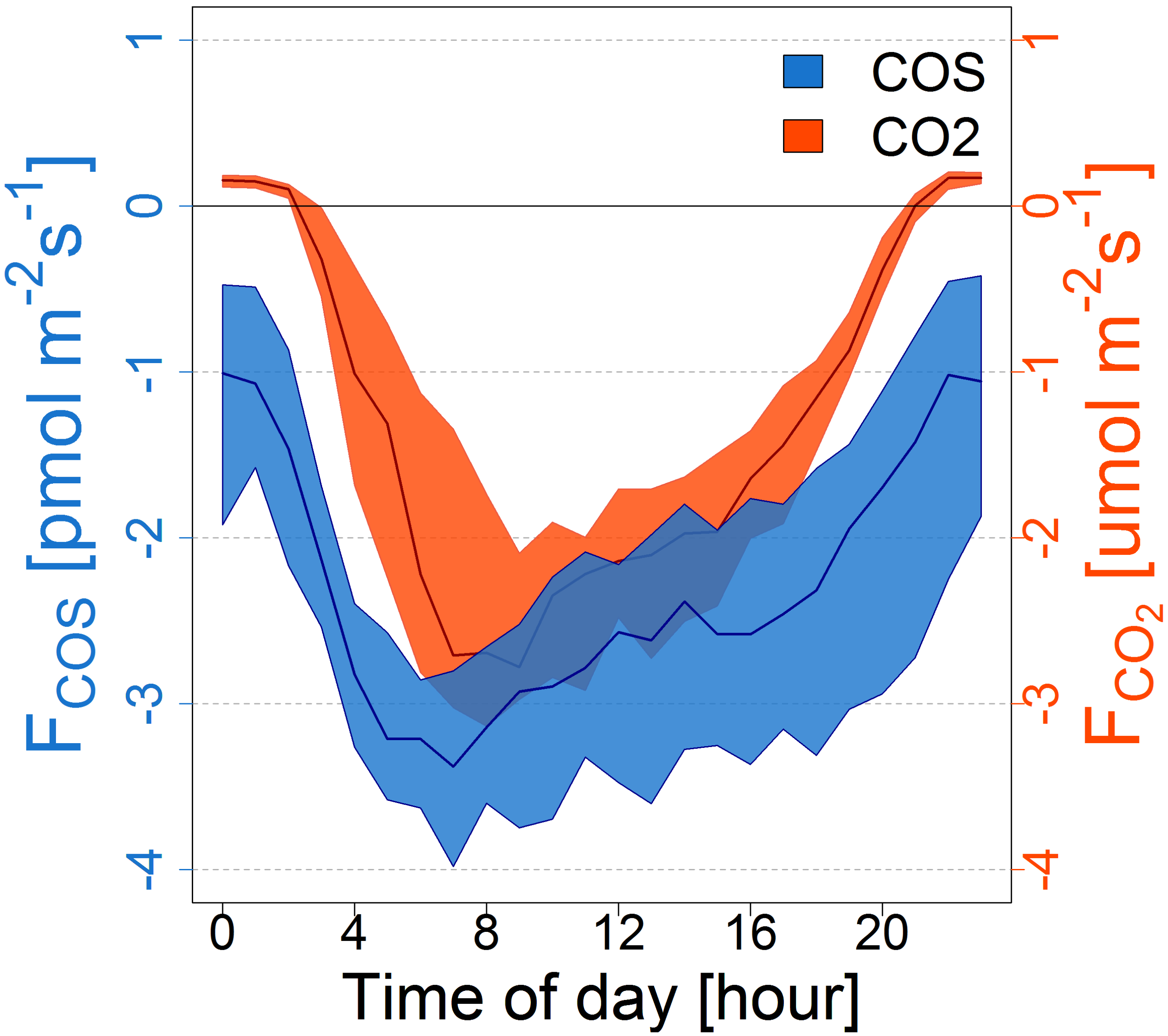


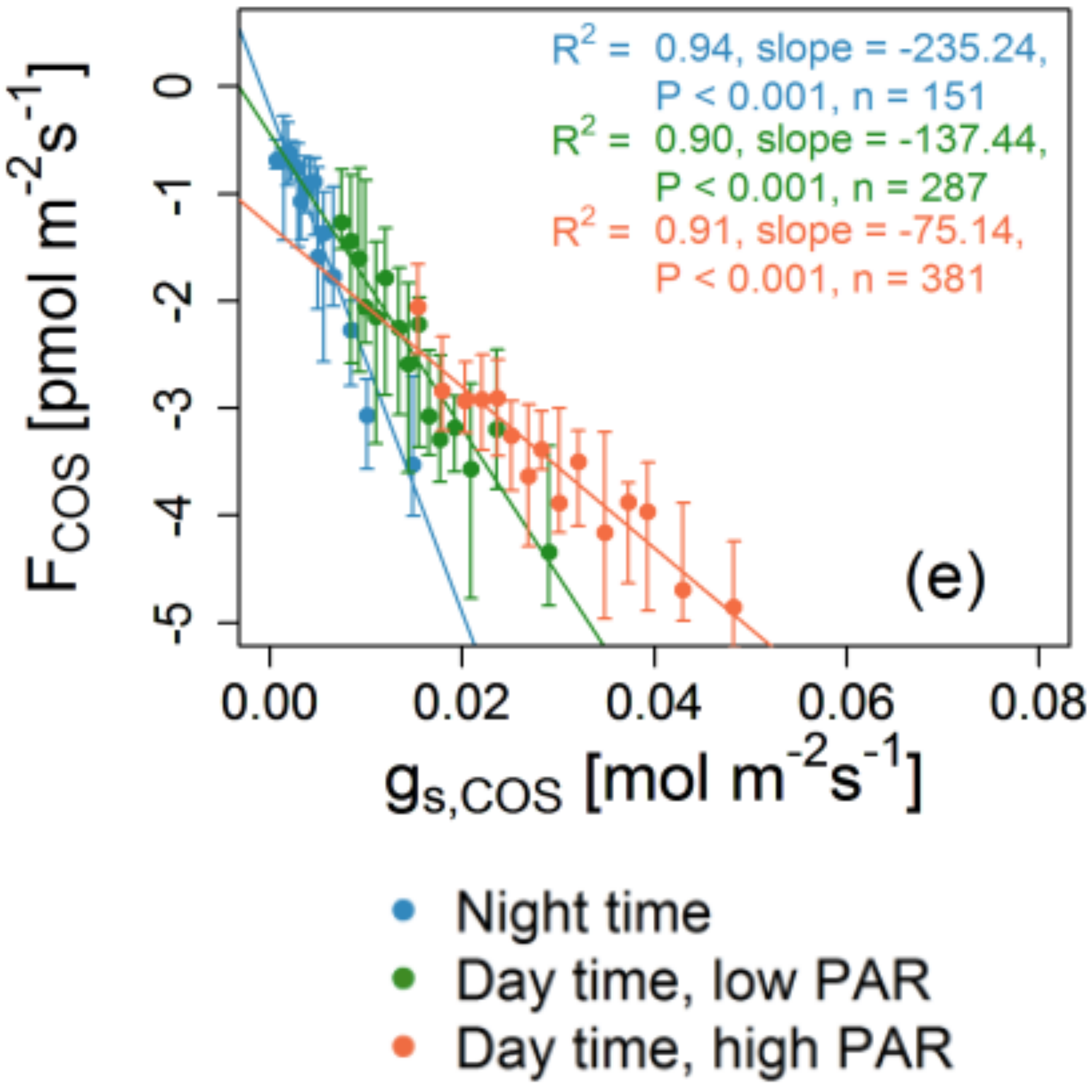
Eddy-covariance
2013-2017
Kooijmans et al. 2017, ACP

Branch chamber fluxes
2016-2017
Kooijmans et al. 2019, PNAS

Soil chamber fluxes
2015-2016
Sun et al., 2017, ACP

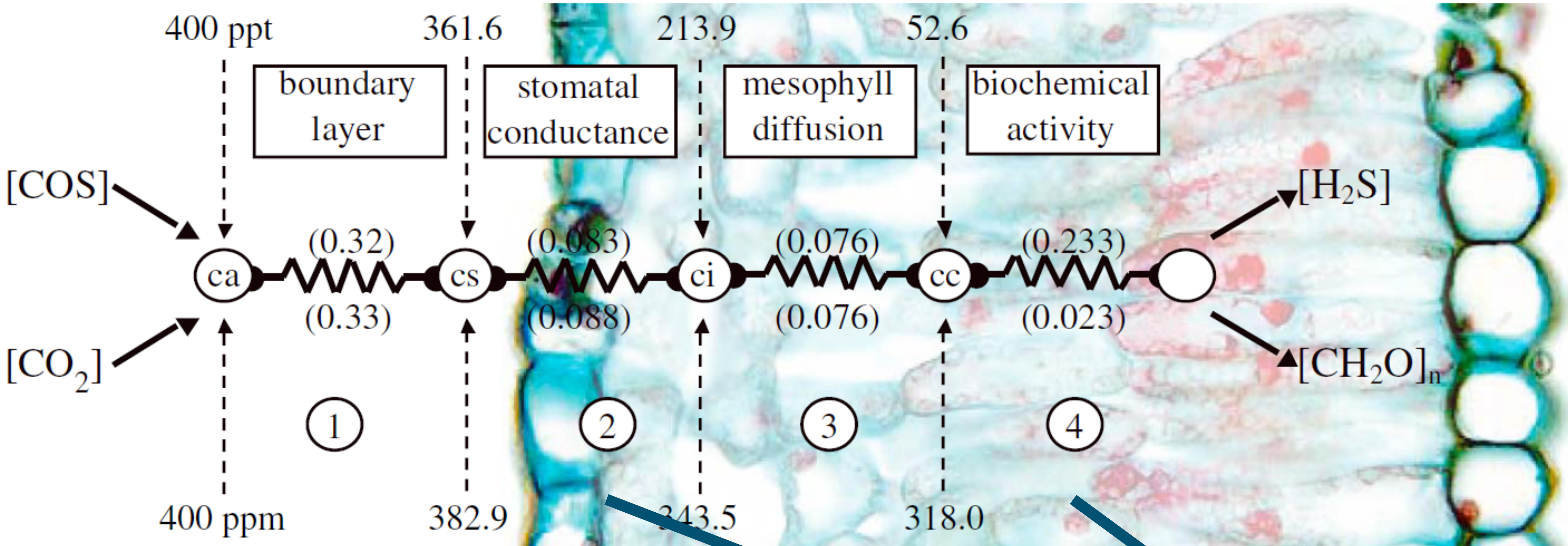
Branch COS and CO_2 flux





Kooijmans et al. 2019, PNAS

COS in SiB4



$$F_{COS} = [COS]_a * [1.56/gb + 1.94/g_s + 1.0/g_{cos}]^{-1}$$

$$g_s = m*An*h/[CO_2]_a + b$$

Stomatal conductance

$$g_{cos} = \alpha*f(V_{max0})$$

Maximum capacity to convert CO_2 into sugars

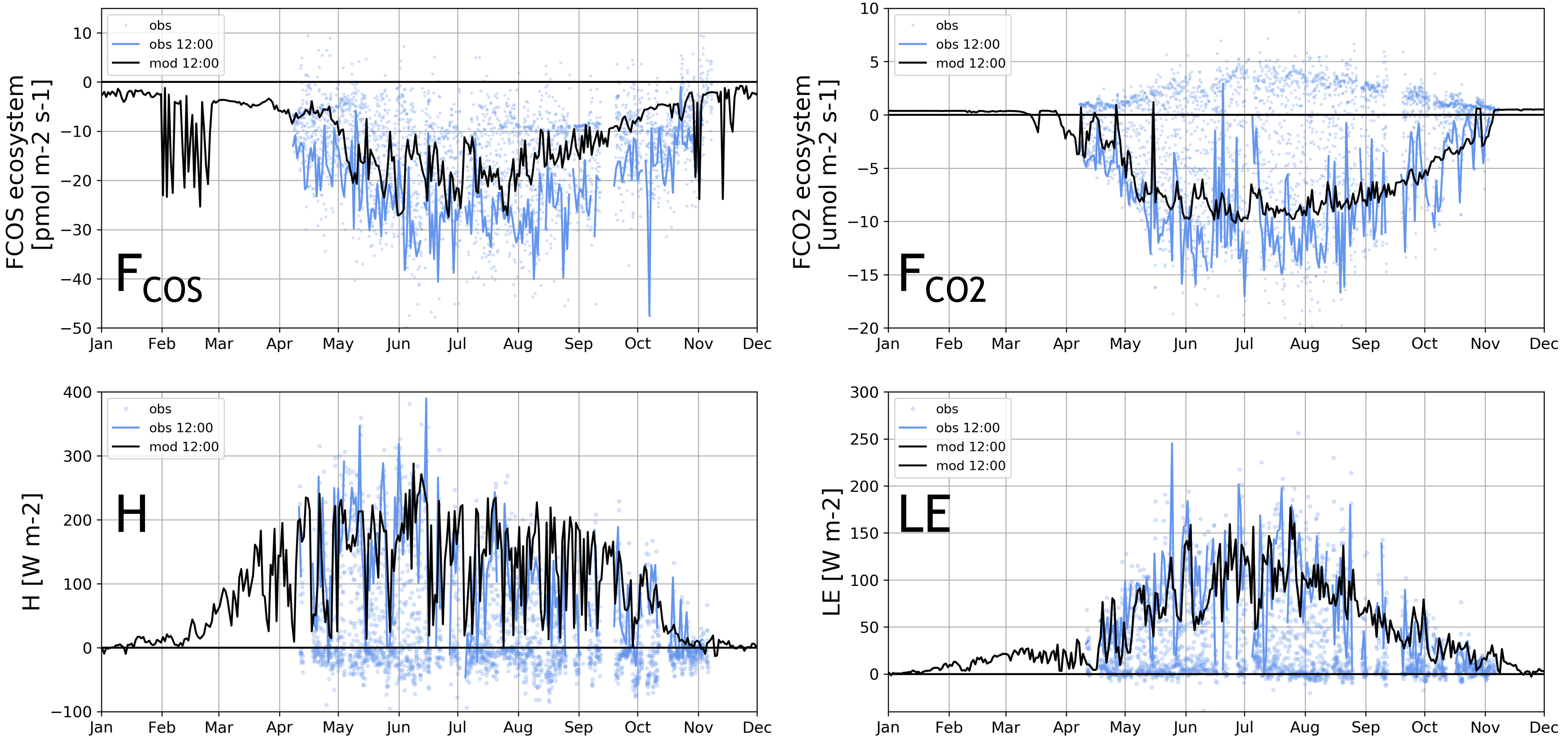
WAGENINGEN UNIVERSITY & RESEARCH

Berry et al., 2013

Ecosystem COS and CO2 flux in SiB4

Observations Hyytiälä, Finland

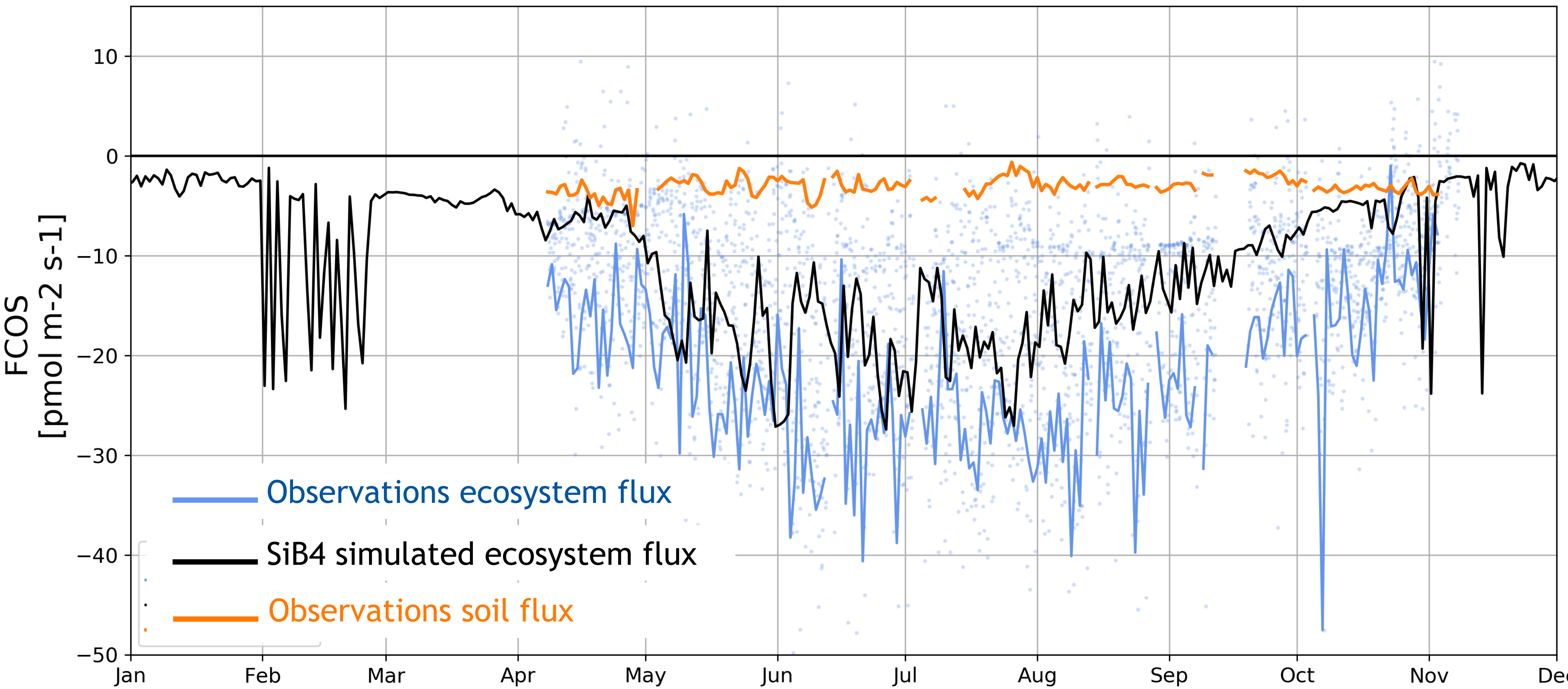
SiB4 simulation



WAGENINGEN
UNIVERSITY & RESEARCH

COS soil exchange in SiB4

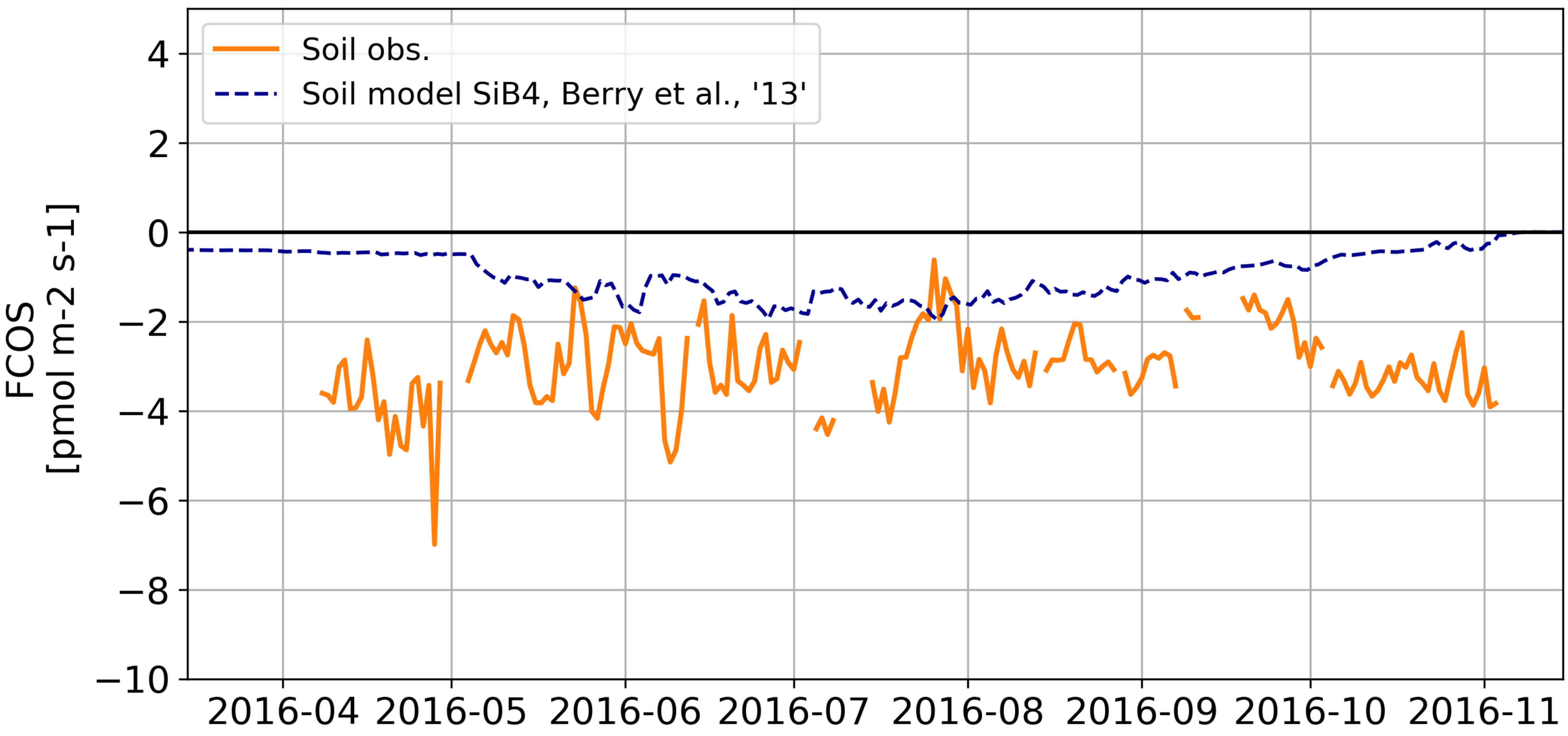
Hyytiälä: soil COS uptake is 13 % of total ecosystem COS uptake



WAGENINGEN
UNIVERSITY & RESEARCH

COS soil exchange in SiB4

Initial SiB4 COS soil uptake is proportional to respiration (Berry et al. 2013)

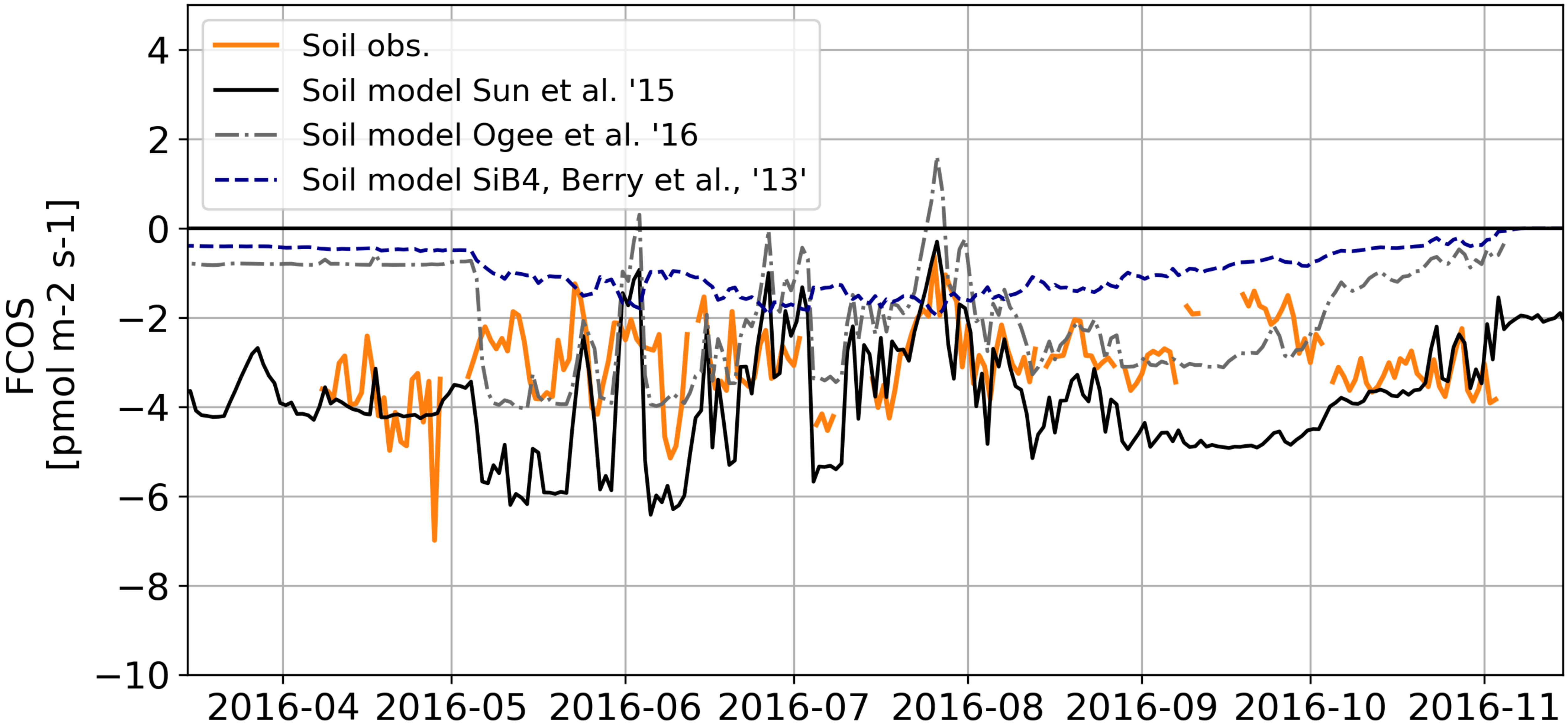


WAGENINGEN
UNIVERSITY & RESEARCH

COS soil exchange in SiB4

Initial SiB4 COS soil uptake is proportional to respiration (Berry et al. 2013)

New mechanistic COS soil models capture uptake and emission of COS:
Sun et al., 2015; Ogee et al., 2016



WAGENINGEN
UNIVERSITY & RESEARCH

Next Steps

- Further validation, e.g. Harvard forest, …
- Run SIB4 globally
- Store Biosphere COS exchange fluxes from SIB on a monthly basis
- Add photolysis and ocean exchange, and we can run first global inversions!