Atmospheric COS measurements

to evaluate model Gross Primary Productivity (GPP): (CMIP5 / CMIP6 / TRENDY simulations)

Philippe Peylin*, Mylene Haslehner, Sauveur Belviso,*
Patricia Cadule, Marine Remaud, Fabienne Maignan,
Camille Abadie, Elliott Campbell
And contribution from "data people"

Modelling activities at the LSCE

Global

1. Global forward atmospheric modelling to derive and constraint global atmospheric COS budget: All

2. Global evaluation of model GPP using [COS]: P. Peylin

3. Forward modelling of Plant / Soil COS fluxes: F. Maignan

4. Atmospheric COS/CO2 flux inversion: M. Remaud

Regional

➔ Local scale “inversions” to valorise LSCE [COS] measurements (S. Belviso) using back-trajectories

Global evaluation of model GPP using [COS]

1. CMIP5 historical simulations
   (23 simulations, different land surface model and climate)

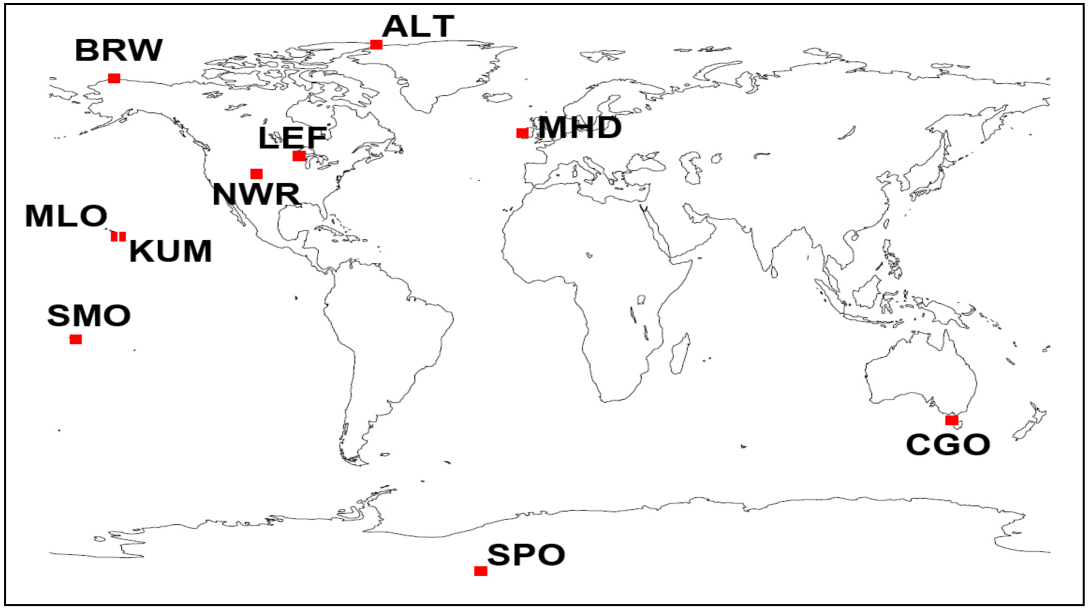
2. CMIP6 historical simulations
   (13 simulations, different land surface model and climate)

3. TRENDY model intercomparison (S3 ; same climate)
   (Cable-POP, CLM5, CLASS, DLEM, JSBACH, JULES, LPJ, LPX, OCN, ORCHIDEE, ORCHIDEE-CNP, SDGVM, SURFEX)

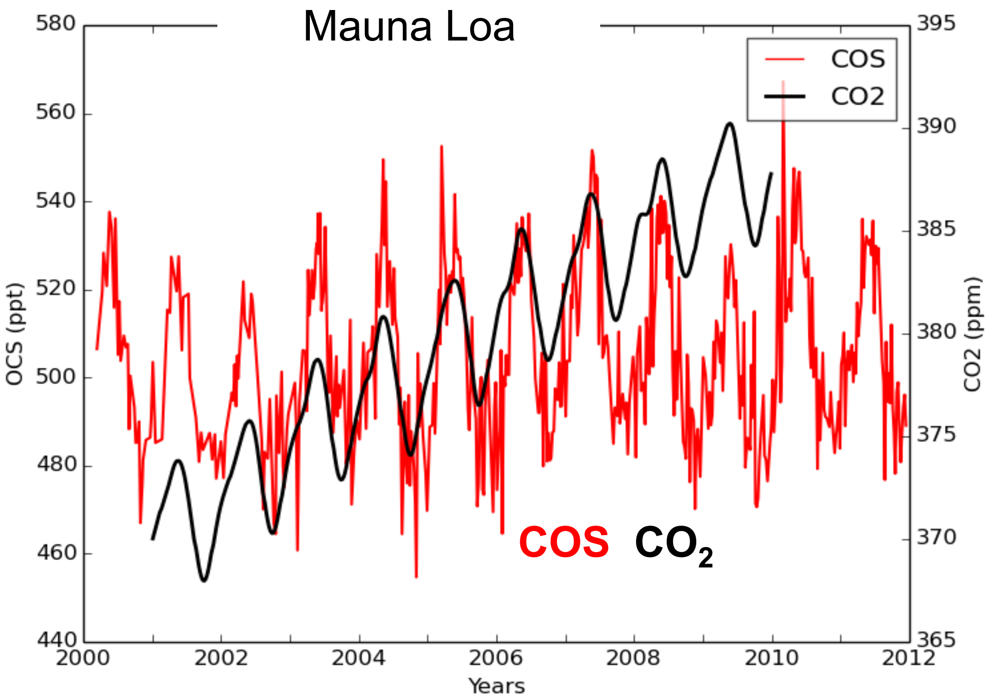
➔ Different scenarios with different LRU estimates !

LRU : values tested…

	Seibt et al. (2010) Seibt Ref	Seibt Low	Seibt high	Whealan et al. C3 / C4	ORC
['1 Bare soil',	0.00	0.00	0.00	0.00	0.00]
['2 Tropical broadleaf evergreen',	3.09	2.27	3.40	1.68	1.57]
['3 Tropical broadleaf raingreen',	3.38	2.48	3.71	1.68	1.56]
['4 Temperate needleleaf evergreen',	1.89	1.39	2.08	1.68	1.21]
['5 Temperate broadleaf evergreen',	3.60	2.64	3.96	1.68	1.08]
['6 Temperate broadleaf summergreen',	3.60	2.64	3.96	1.68	1.17]
['7 boreal needleleaf evergreen',	1.89	1.39	2.08	1.68	1.05]
['8 boreal broadleaf summergreen',	1.94	1.43	2.14	1.68	0.85]
['9 boreal needleleaf summergreen',	1.89	1.39	2.08	1.68	0.80]
['10 Temperate C3 grass',	2.53	1.85	2.77	1.68	1.08]
['11 C4 grass',	2.00	1.46	2.19	1.21	1.90]
['12 C3 Agriculture',	2.26	1.66	2.48	1.68	1.32]
['13 C4 Agriculture',	2.00	1.46	2.19	1.21	2.24]
['10 Tropical C3 grass',	2.39	1.75	2.62	1.68	1.46]
['10 Boreal C3 grass',	2.02	1.48	2.22	1.68	0.95]

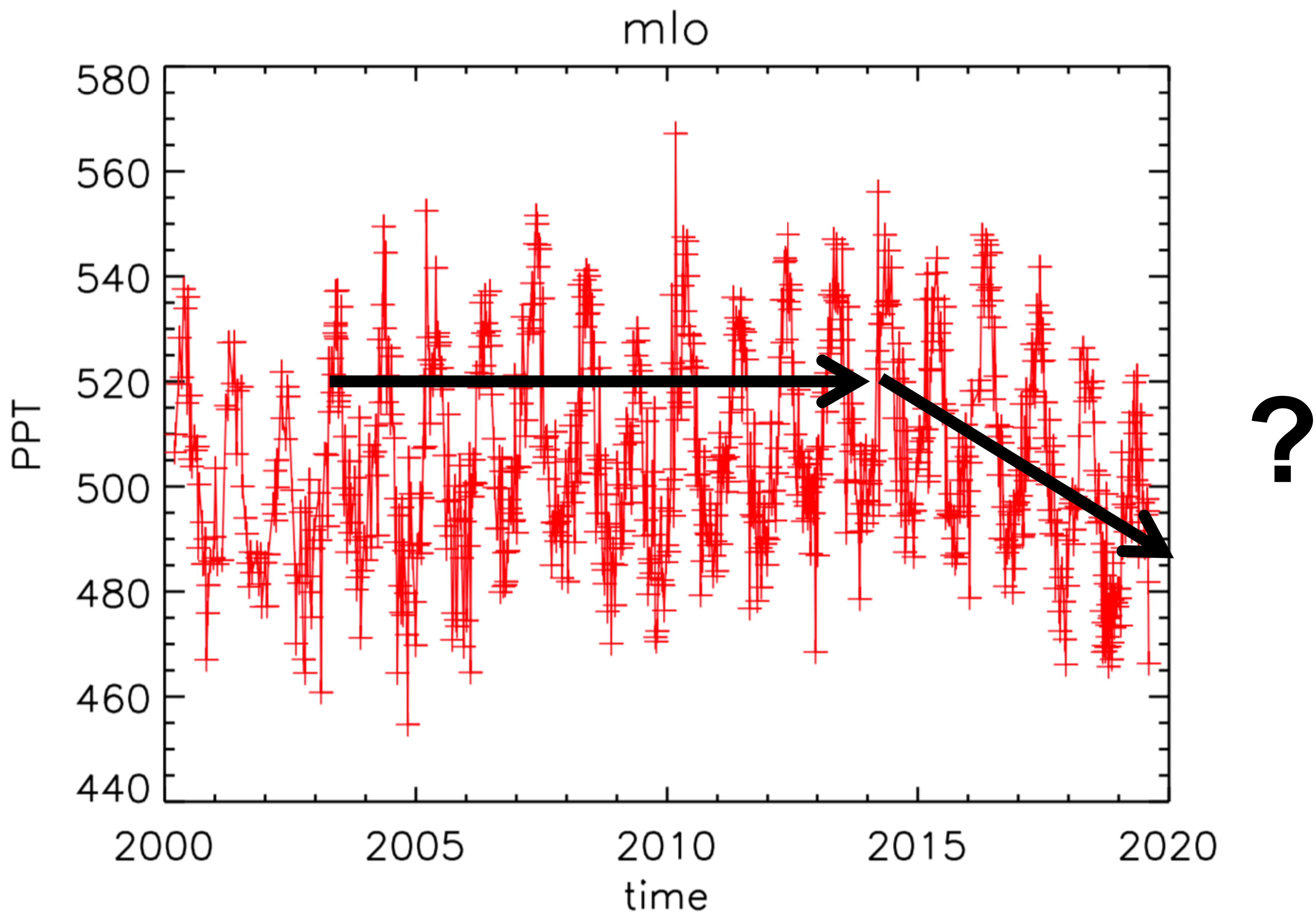


Atmospheric COS as a potential tracer of GPP

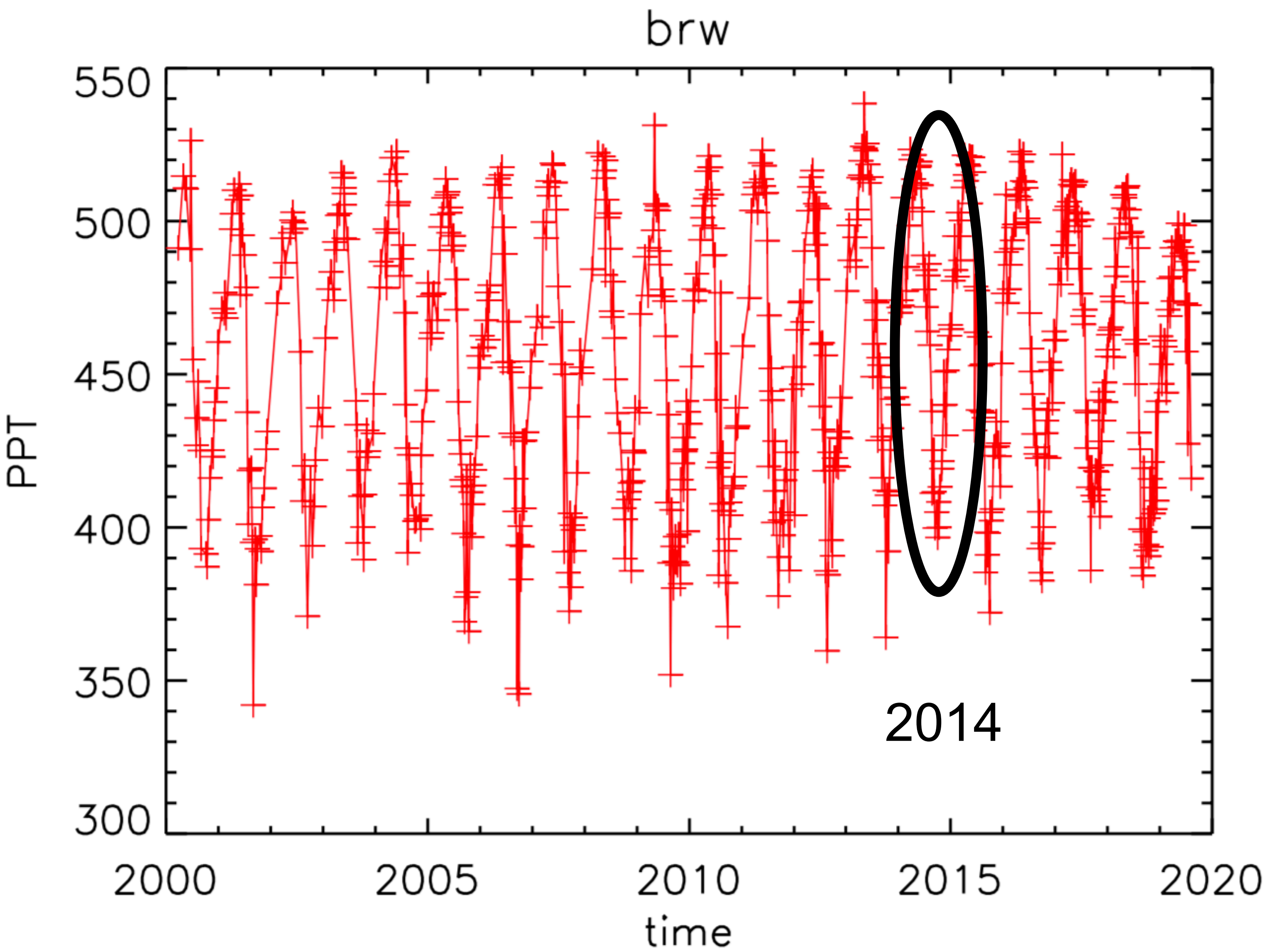


- ➔ In situ stations (NOAA)
- ➔ Regular measurements since 2000

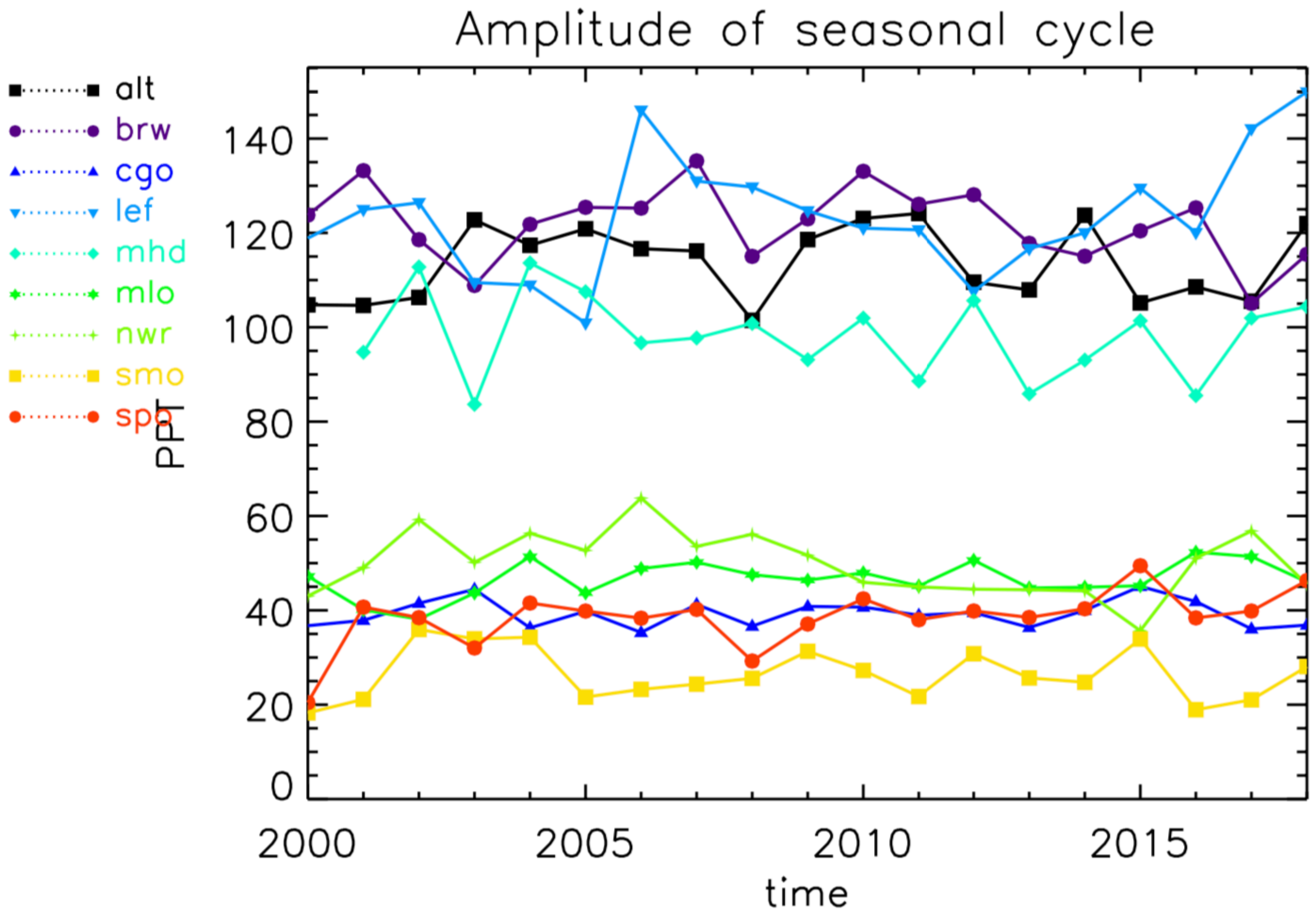
Atmospheric COS as a potential tracer of GPP

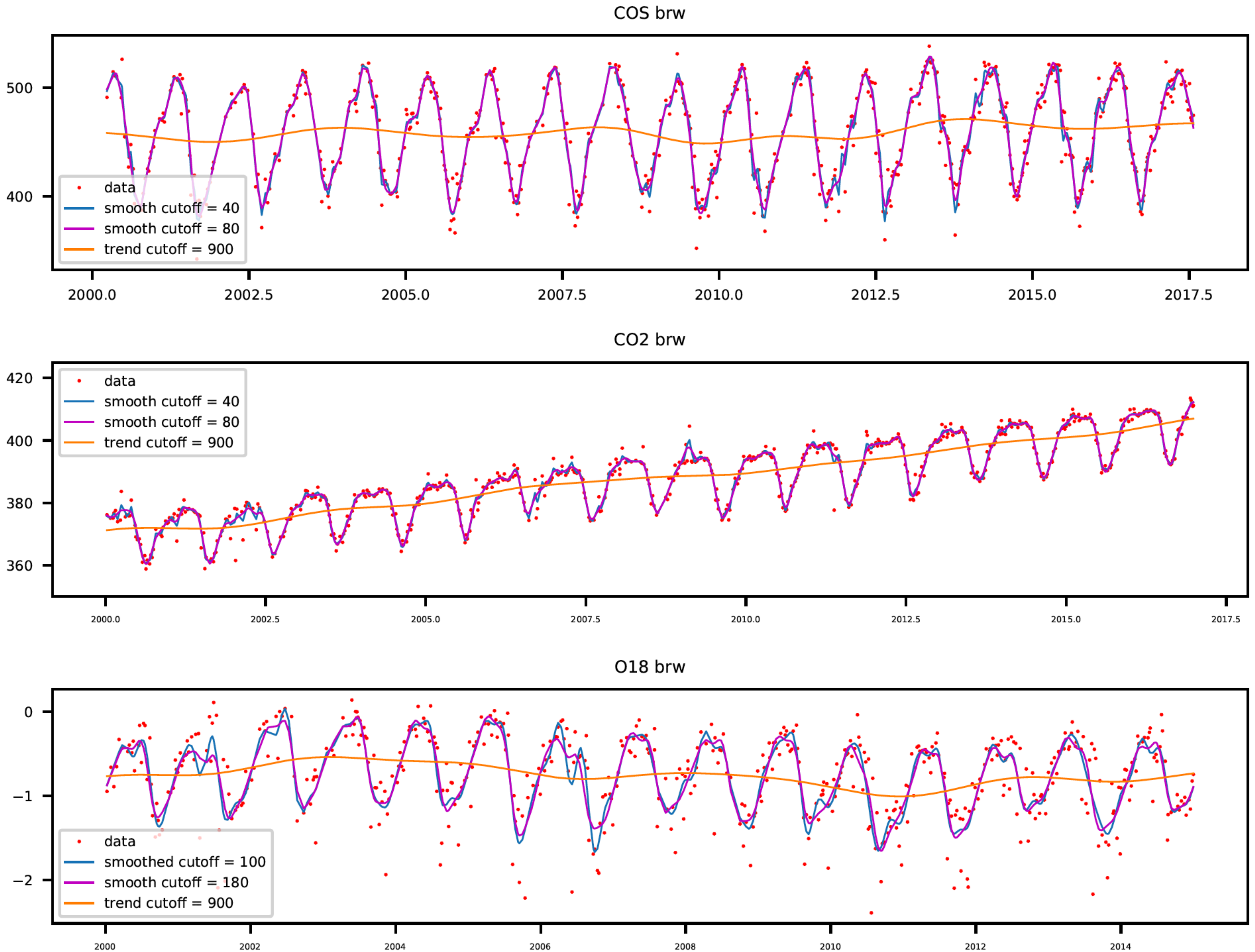


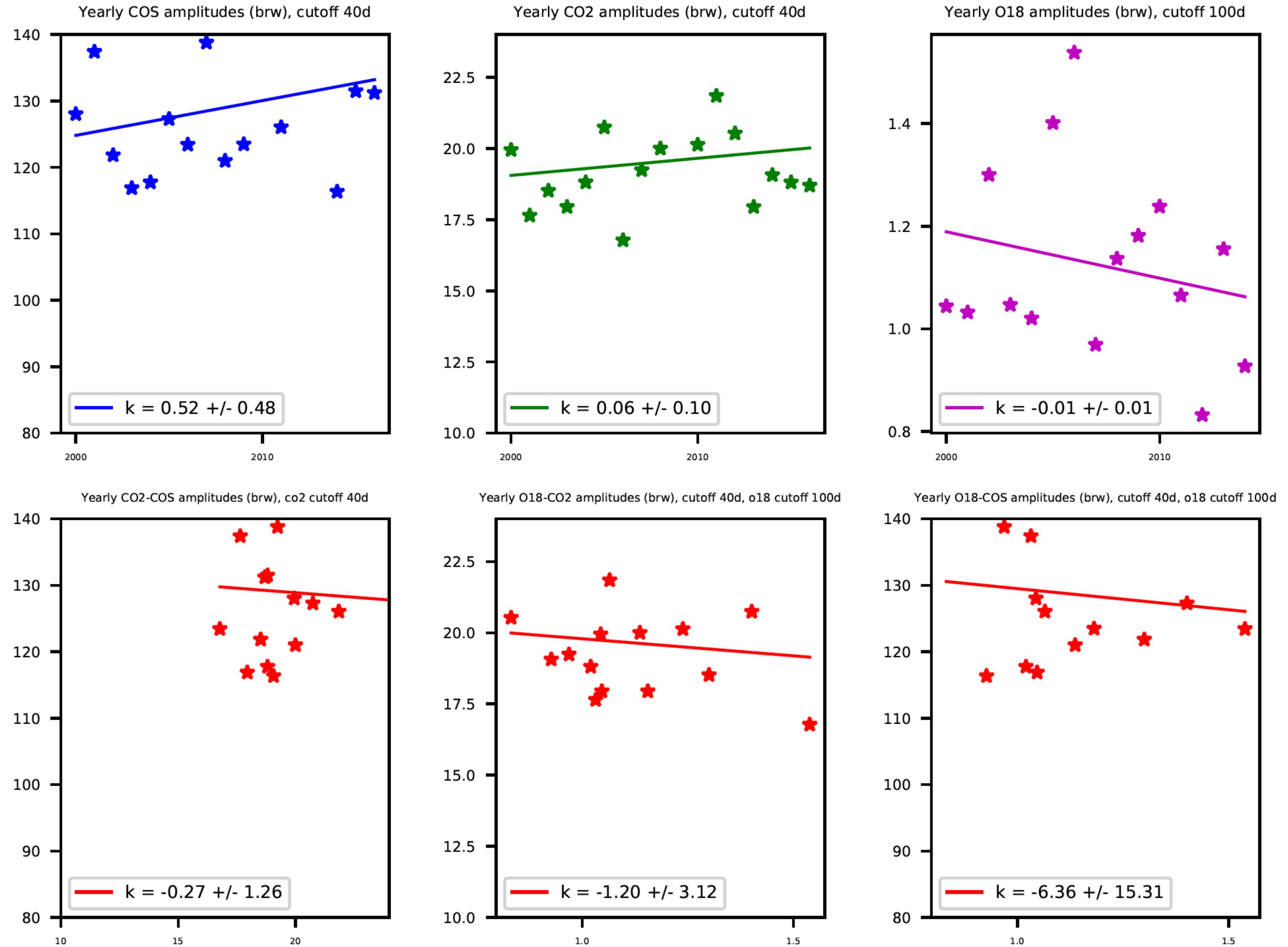
Atmospheric COS as a potential tracer of GPP

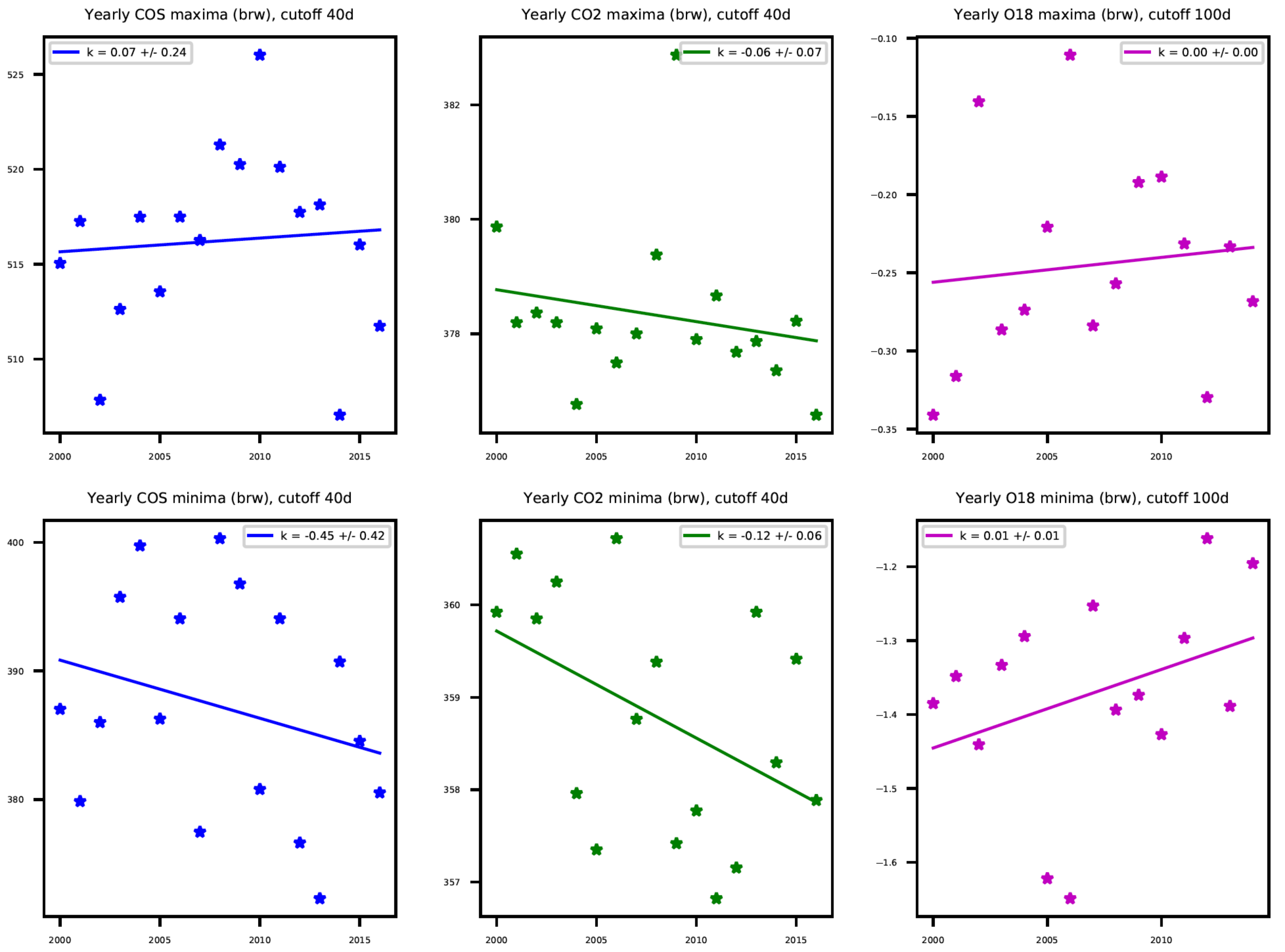


Atmospheric COS as a potential tracer of GPP




COS brw
data
smooth cutoff = 40
smooth cutoff = 80
trend cutoff = 900
500
400
2000.0
2002.5
2005.0
2007.5
2010.0
2012.5
2015.0
2017.5
CO2 brw
data
smooth cutoff = 40
smooth cutoff = 80
trend cutoff = 900
420
400
380
360
2000.0
2002.5
2005.0
2007.5
2010.0
2012.5
2015.0
2017.5
O18 brw
data
smoothed cutoff = 100
smooth cutoff = 180
trend cutoff = 900
0
−1
−2
2000
2002
2004
2006
2008
2010
2012
2014


Yearly COS amplitudes (brw), cutoff 40d
k = 0.52 +/- 0.48
Yearly CO2 amplitudes (brw), cutoff 40d
k = 0.06 +/- 0.10
Yearly O18 amplitudes (brw), cutoff 100d
k = -0.01 +/- 0.01
Yearly CO2-COS amplitudes (brw), co2 cutoff 40d
k = -0.27 +/- 1.26
Yearly O18-CO2 amplitudes (brw), cutoff 40d, o18 cutoff 100d
k = -1.20 +/- 3.12
Yearly O18-COS amplitudes (brw), cutoff 40d, o18 cutoff 100d
k = -6.36 +/- 15.31

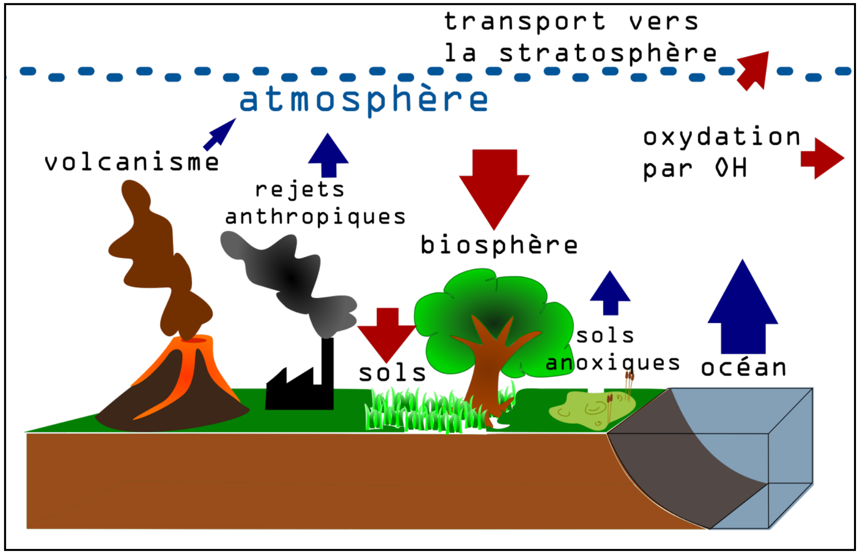

Yearly COS maxima (brw), cutoff 40d
k = 0.07 +/- 0.24
Yearly CO2 maxima (brw), cutoff 40d
k = -0.06 +/- 0.07
Yearly O18 maxima (brw), cutoff 100d
k = 0.00 +/- 0.00
Yearly COS minima (brw), cutoff 40d
k = -0.45 +/- 0.42
Yearly CO2 minima (brw), cutoff 40d
k = -0.12 +/- 0.06
Yearly O18 minima (brw), cutoff 100d
k = 0.01 +/- 0.01

Revised COS fluxes

- ✓ Anthropogenic fluxes from Zumkehr et al. (2018): x 2 larger
- ✓ Several test with respect to the LRU values (Seibt et al., 2010)
- ✓ Correction of the direct ocean emissions: ≈ 800 ➔ ≈ 270 GgS/y

	COS budget	Approach	Annual budget (in GgS/y)		
Sinks	**CMIP5 plant uptake**	**LRU approach**	mean	min	max
		LRU_{ref}	**-1339**	**-2306**	**-992**
		LRU_{high}	**-1470**	**-2533**	**-1089**
		LRU_{low}	**-981**	**-1690**	**-727**
		LRU_{const}	**-742**	**-1279**	**-551**
	Soil uptake (oxic soils)	H2 monthly soil uptake flux map (Morfopoulos *et al.* 2012)	-510		
	Oxidation by OH radicals	OH^{-} radical maps (Hauglustaine *et al.* 1998)	-100		
	Total sinks	LRU_{ref}	**-1949**		
		LRU_{high}	**-2080**		
		LRU_{low}	**-1590**		
		LRU_{const}	**-1352**		
Sources	Anoxic soils	methane emission maps (Wania *et al.* 2010)	101		
	Direct oceanic emissions	from NEMO-PISCES (Launois *et al.* 2015a)	≈ 270		
	Indirect oceanic emissions	CS2 flux maps from Kettle *et al.* (2002)	133+81		
	Biomass burning	gridded CO2 emission maps (Van der Werf *et al.* 2010)	70		
	Anthropogenic emissions (direct and indirect)	**Zumkehr *et al.* (2018)**	**357**		
	Total sources		**1555**		
	Net total	LRU_{ref}	**-394**		
		LRU_{high}	**-525**		
		LRU_{low}	**-35**		
		LRU_{const}	**203**		

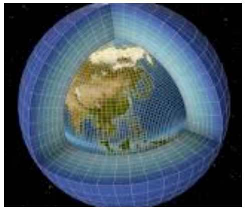
Combining COS and CO_2 Atmospheric data

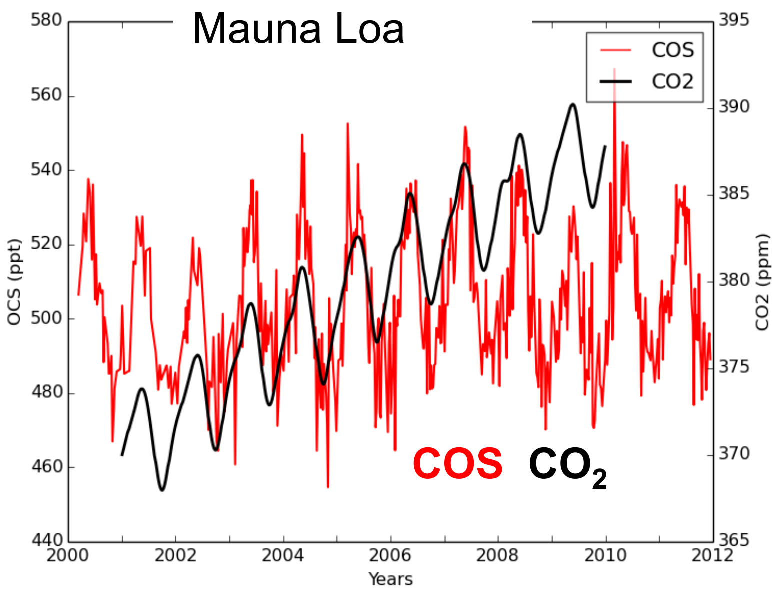


COS flux scenarios

- Fbio = f(model GPP)

LMDz transport model

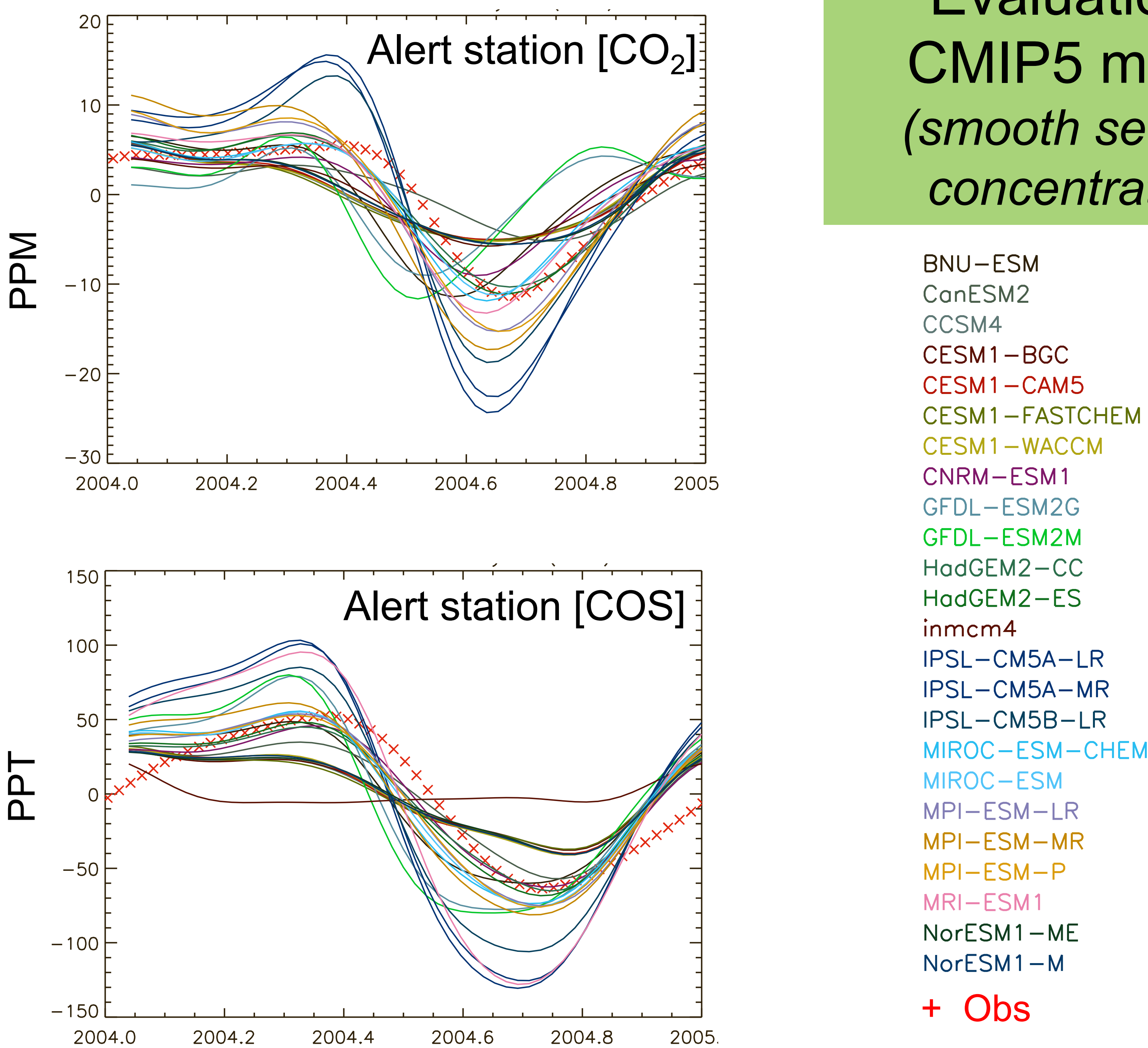




CO2 flux scenarios

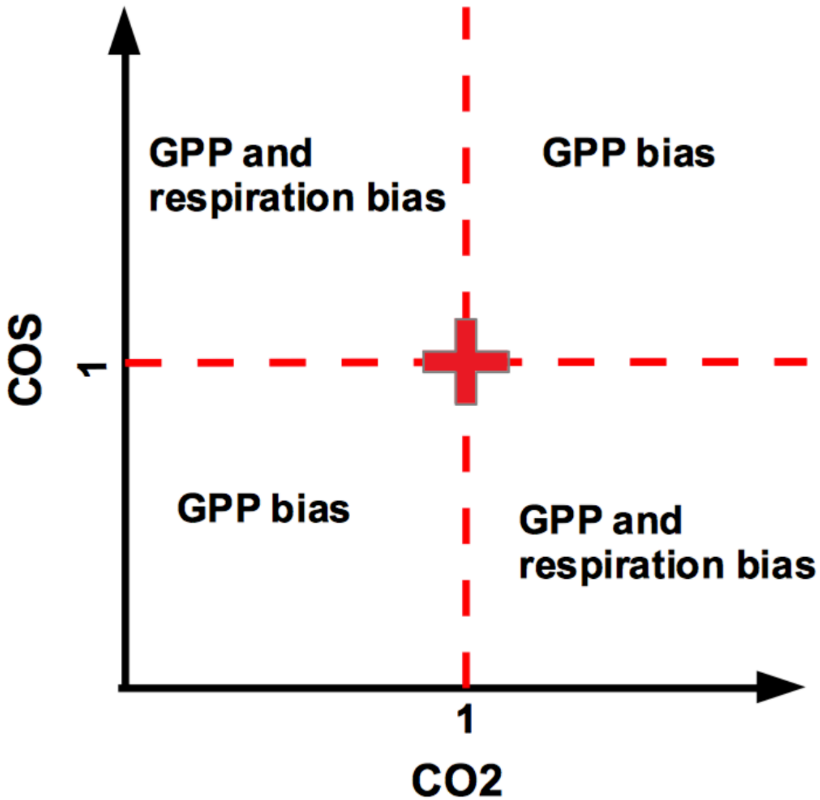
- Model NEE
- Ocean flux from Takahashi
- Fossil fuel + biomass burning

Evaluation of CMIP5 models
(smooth seasonal concentrations)

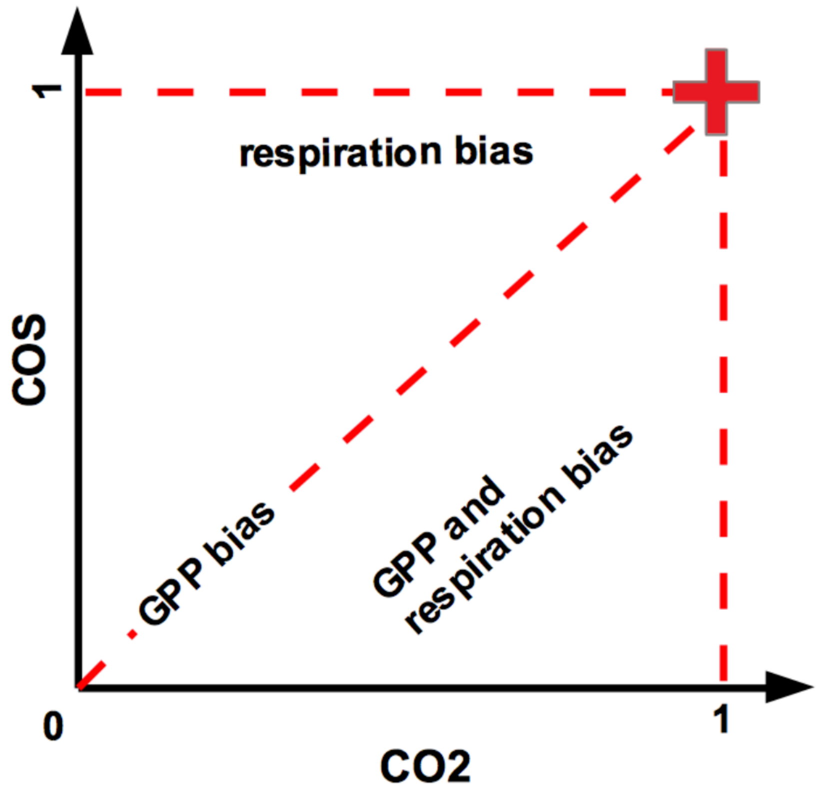


Further evaluation of the concentration misfit..

Seasonal Amplitude
Amplitude ratio (model / obs)

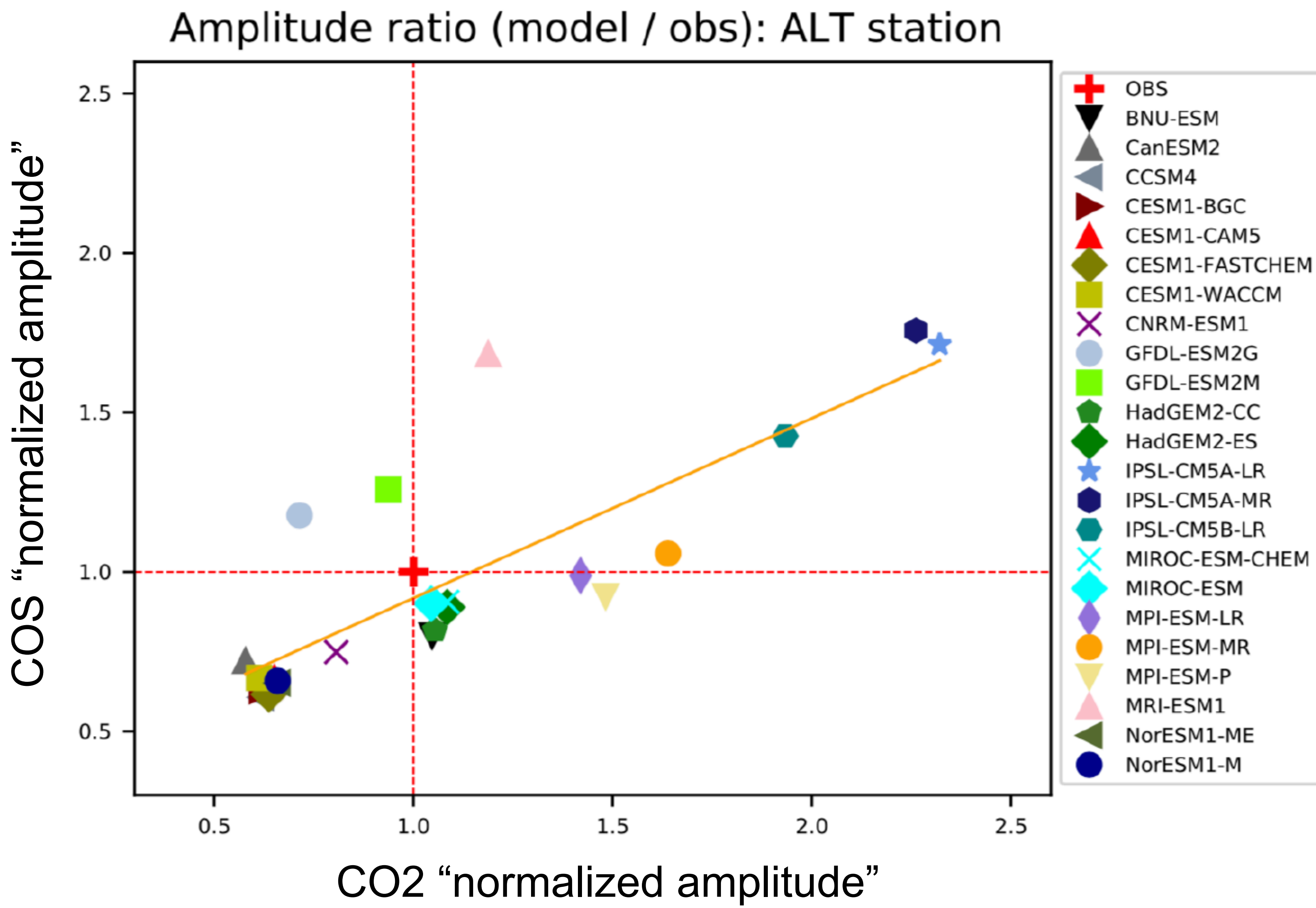


Phase issues
|1 – « model vs obs correl »|

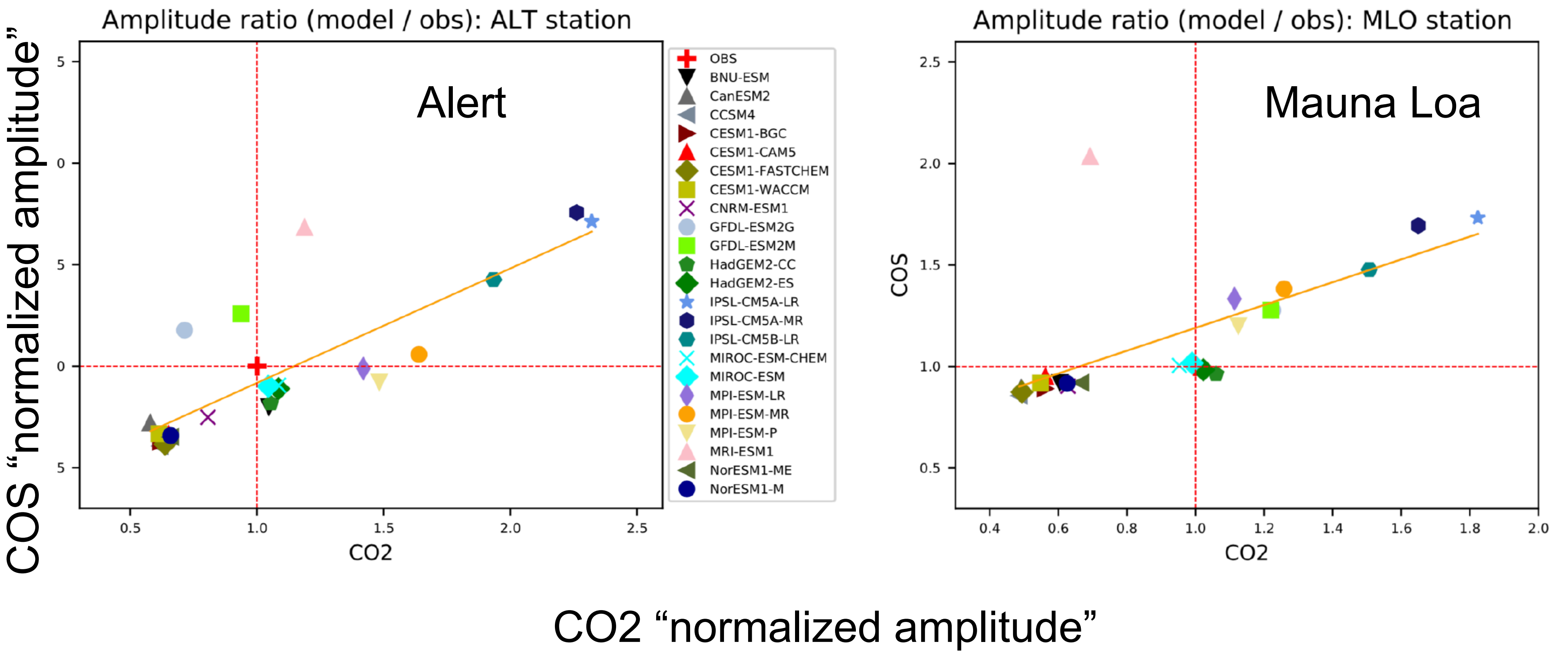


Amplitude of CMIP5 model seasonal cycles

Using medium LRU values in Seibt et al. 2010 (ref case)

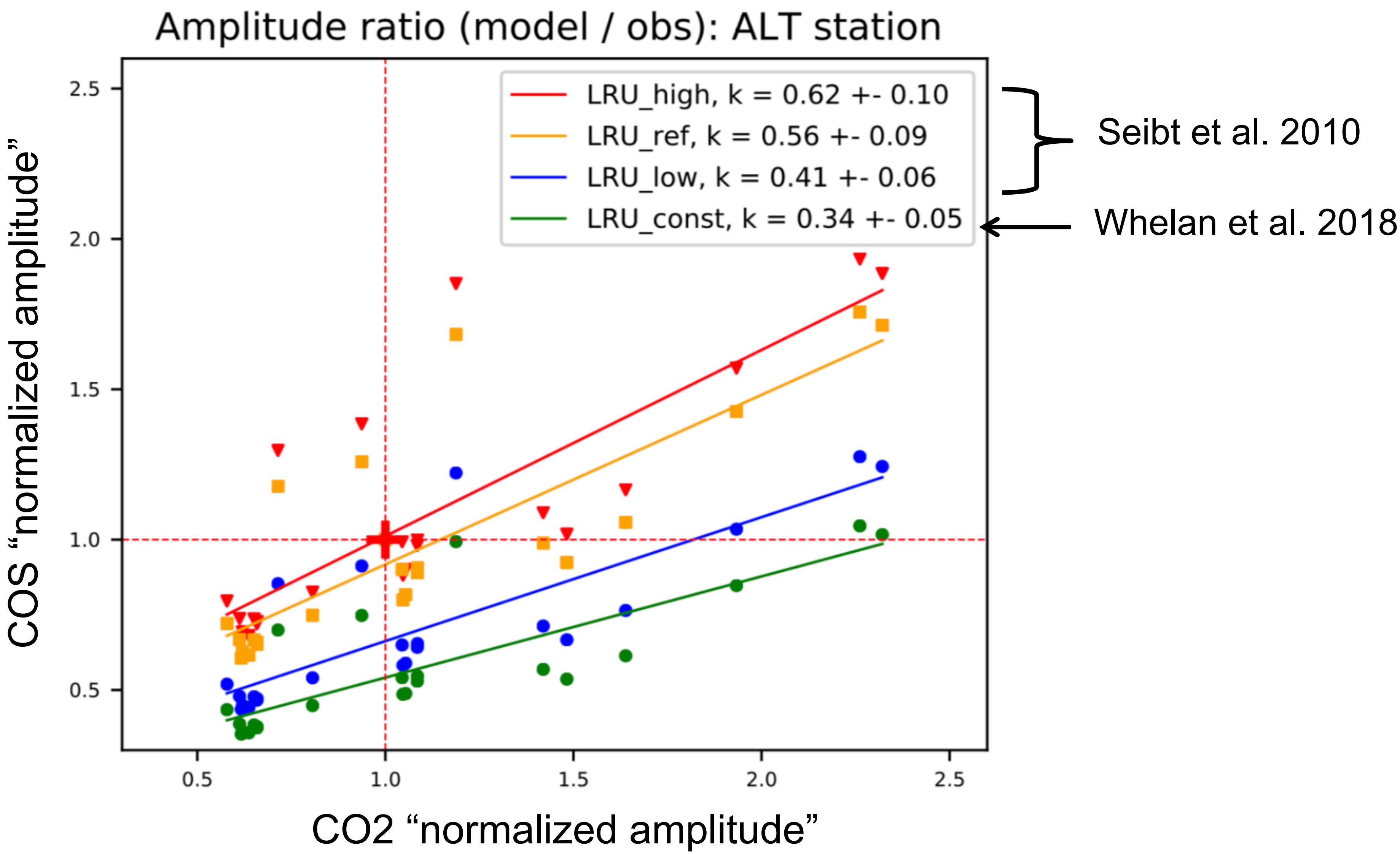


Amplitude of CMIP5 model seasonal cycles



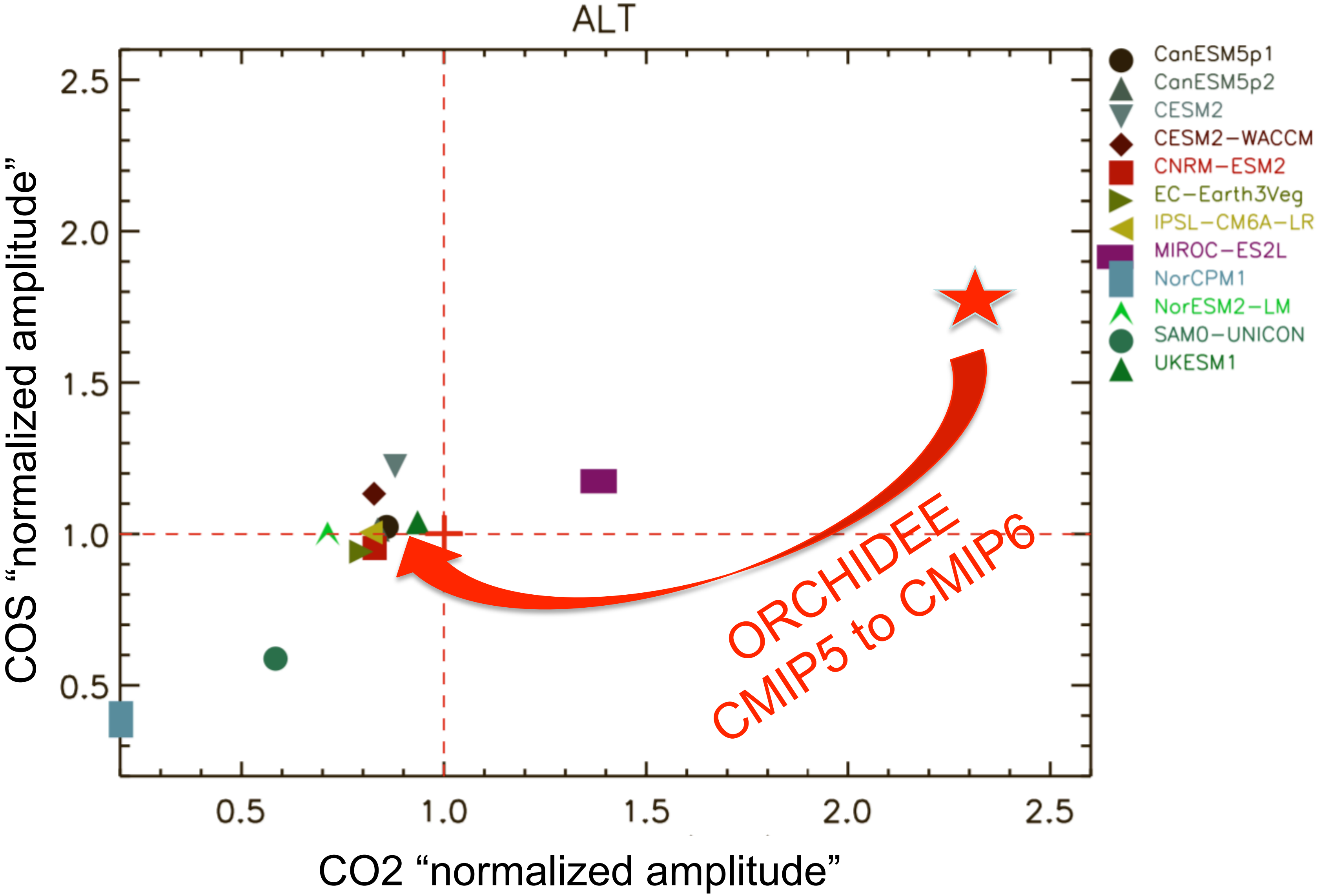
Amplitude of CMIP5 model seasonal cycles

Impact of using different “Leaf Relative Uptake”

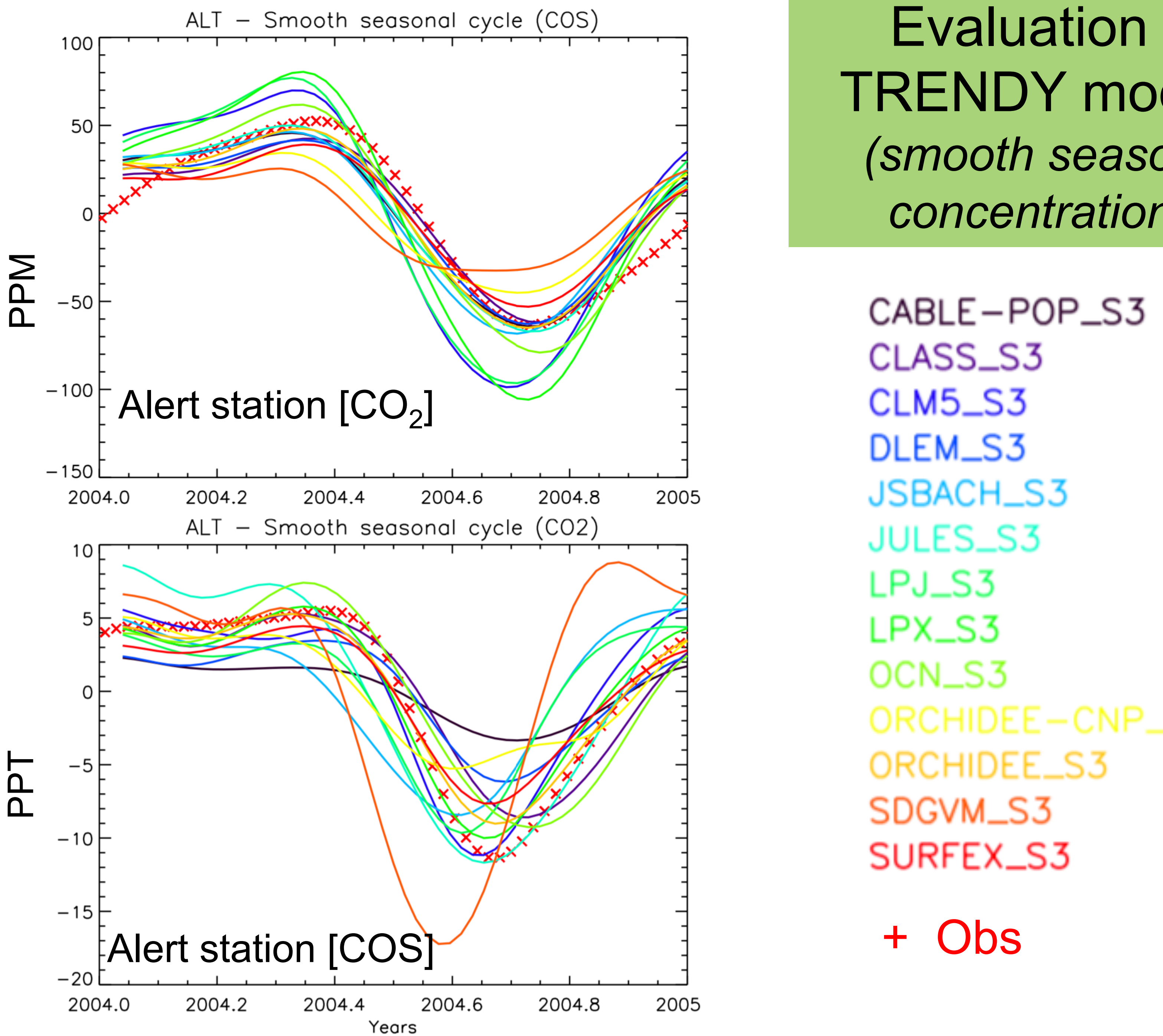


Amplitude of CMIP5 model seasonal cycles

Using medium LRU values in Seibt et al. 2010 (ref case)

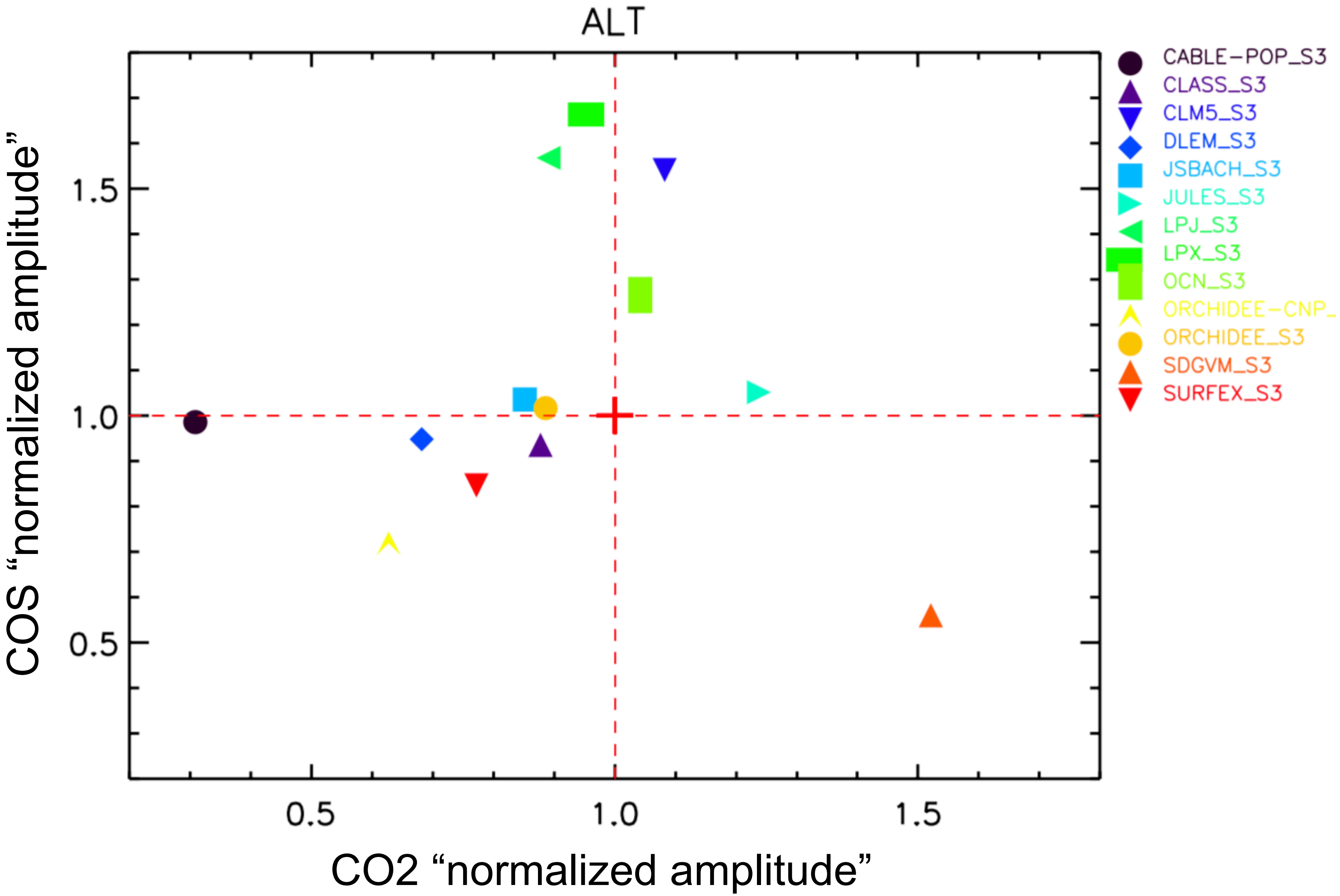


Evaluation of TRENDY models *(smooth seasonal concentrations)*



Amplitude of TRENDY model seasonal cycles

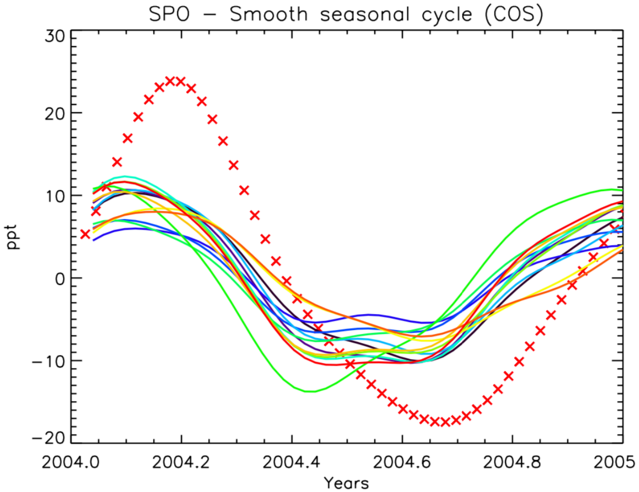
Using medium LRU values in Seibt et al. 2010 (ref case)



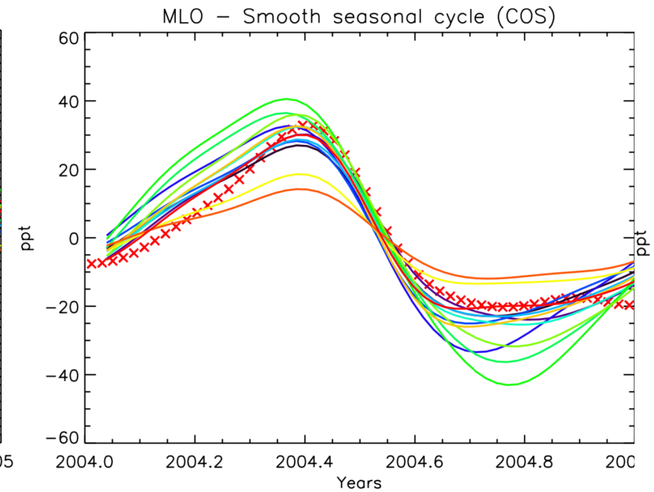
TRENDY model simulations at several sites

COS

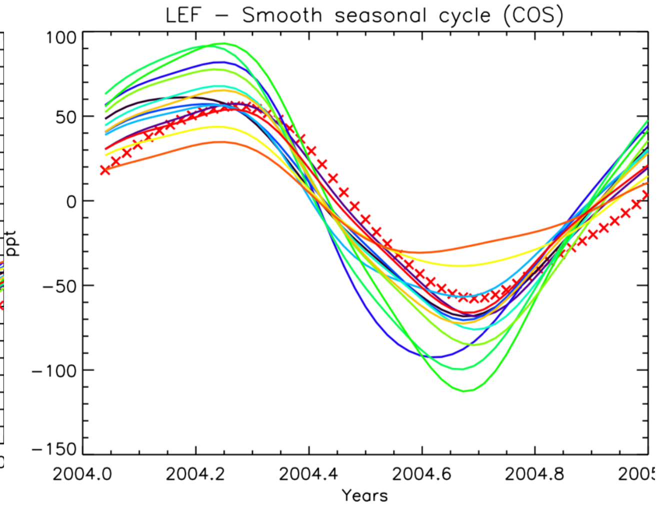
South Pole



Mauna Loa

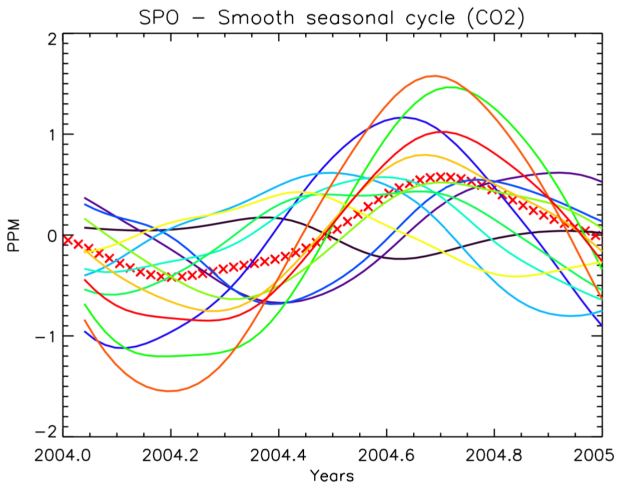


LEF tower

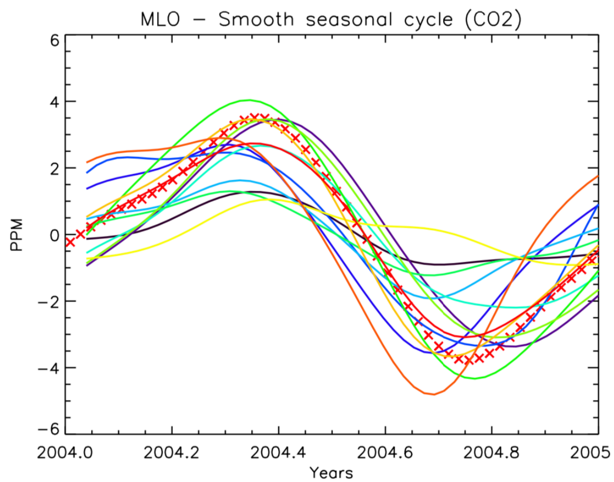


CO2

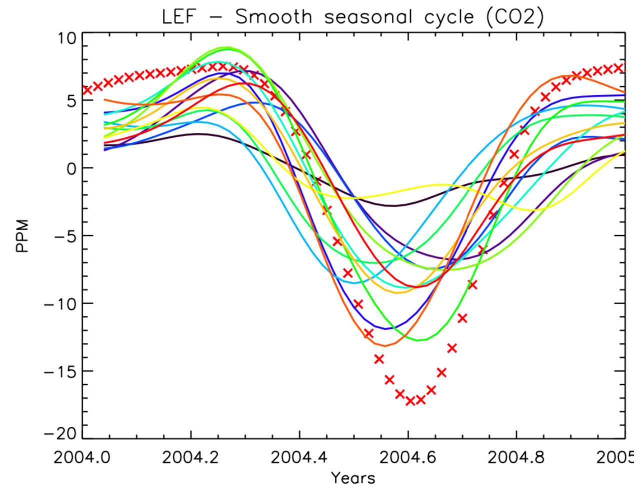
South Pole



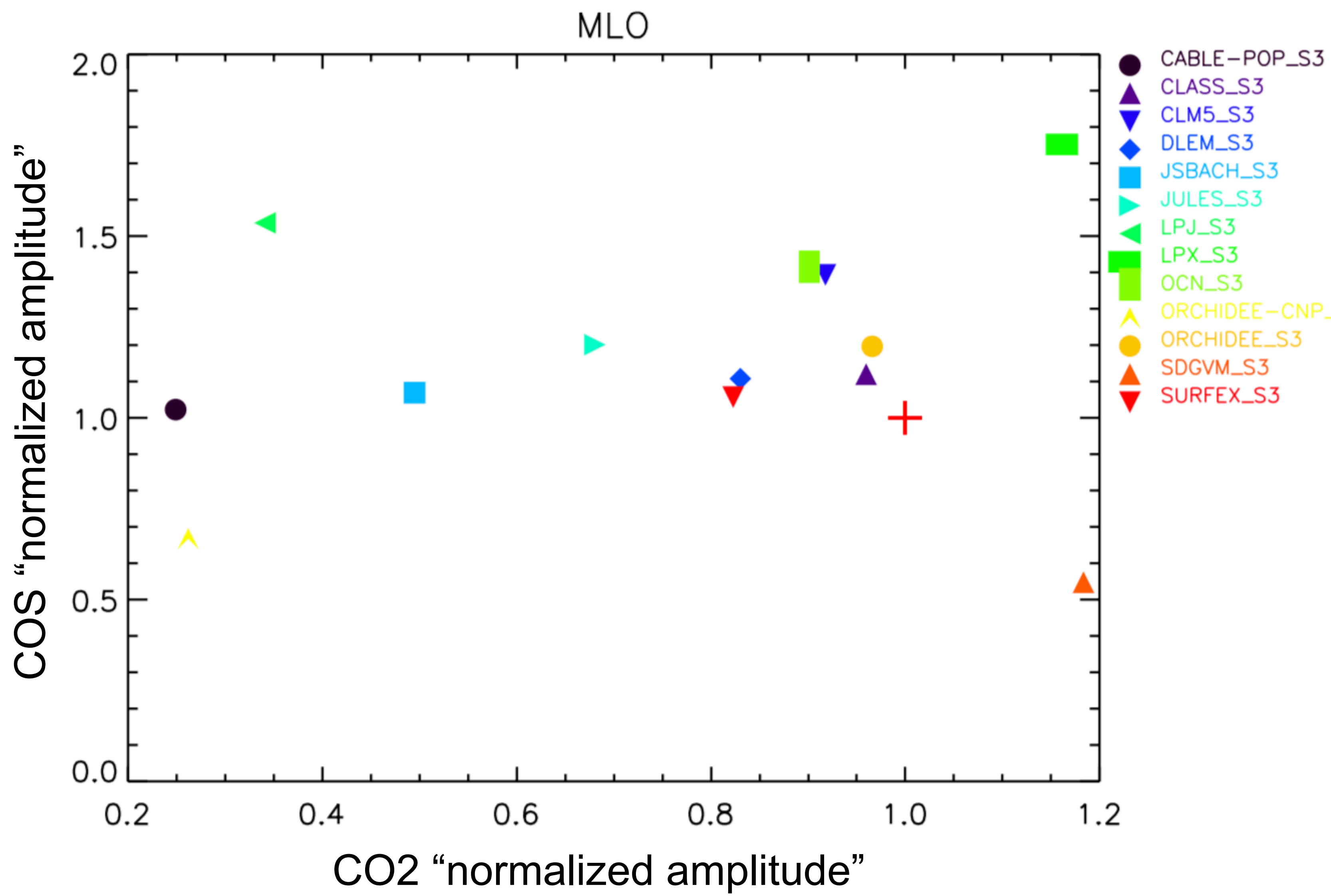
Mauna Loa



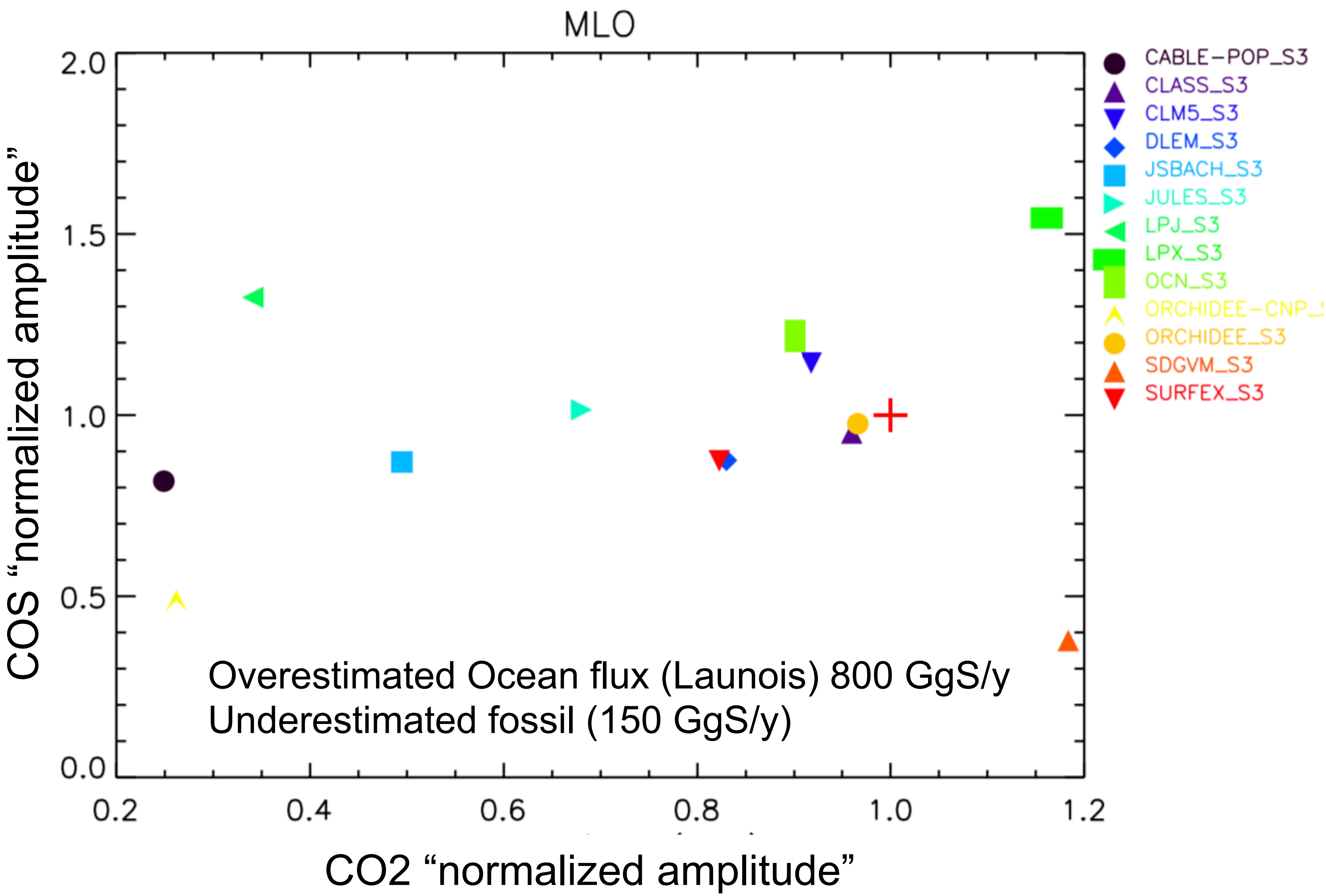
LEF tower



Impact of fossil fuel / ocean updates

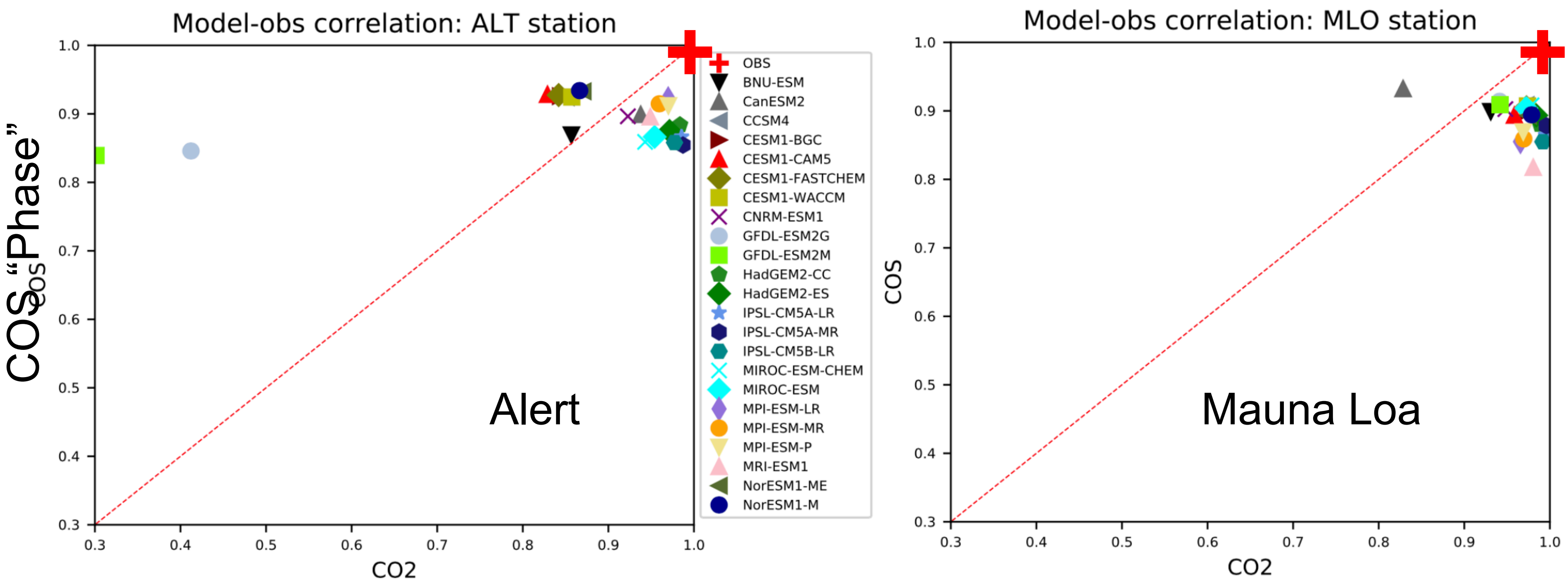


Impact of fossil fuel / ocean updates



Phase of CMIP5 model seasonal cycles

Phase issues: (|1 – « model vs Obs correl » |)



CO2 “Phase”

Summary….

- Potential to constrain model seasonal GPP variations:
  - ✓ Mainly the Amplitude of the seasonal cycle
  - ✓ Some constraint on the Phase
  - ✓ Additional constraint on Amplitude changes ?
  - ✓ Additional constraint on trends ?

- BUT large remaining issues (soil, ocean, anthropogenic,..)

- Steps forward (at LSCE)
  - ✓ Modeling LRU space/time dynamic (F. Maignan)
  - ✓ New soil model (test different approaches)
  - ✓ Assimilate COS with SIF to optimise model parameters

Inter-comparison experiment

Google document with all information:

https://docs.google.com/document/d/13853kInO9R1VNNw-CAu8rs2xUotQWLx_18PYWs7aJpU/edit#

Sharebox to exchange files:
https://sharebox.lsce.ipsl.fr/index.php/s/Yxbj6dZsrc6nsOZ

Objectives

- Assess **concentration differences** in terms of seasonal cycle (amplitude, phase) as well as spatial gradients (North - South for instance) induced by transport differences.
- Evaluate the **impact of the different flux components** (biospheric, soil, ocean, anthropogenic,...) on these concentration differences.
- Assess the **"synoptic effects"** that would be induced by day-to-day variations in biospheric COS uptake fluxes, compared to the use of monthly mean fluxes
- Assess similarly the **"diurnal effects"** that would be induced by using diurnal biospheric uptake fluxes compared to the use of daily / monthly mean fluxes

Process - model	**File name**	**Provider**	**Resolution**	**Period**	**Flux Unit**	**Total global flux**
Vegetation: ORCHIDEE monthly	**BIO-ORC-Month_yyy**	Fabienne	2° x 2°	2010-2015	umol/m2/s	~750 GgS/yr
Vegetation: ORCHIDEE Diurnal	**BIO-ORC-Diurn_yyy**	Fabienne	2° x 2°	2010-2015	umol/m2/s	~750 GgS/yr
Vegetation + SOIL: SIB4 monthly (both uptake by leaves & soil)	**cos_bio_sib4_yyy**	Linda/Ara/Jin	2° x 2°	2010-2015	umol/m2/s	-1000GgS/yr
Vegetation: SIB4 Diurnal	**?**					
Biomass burning from Stinecipher et al.,2020	**OCS_BMB_FLUX_CO_yyy_TOTAL2.nc**	Marine	2.5 x 2 (½ box at pole)	2010 - 2015		~55 GgS/y
Biomass burning from Guido V. Werf				2010 - 2015		
Anthropogenic indirect: COS effective (Zumker, 2018)	**cos_anthropogenic_indirect_yyy**	Jin	2x2	2010 - 2015	umol/m2/s	~400GgS/yr

Soil uptake for oxic soil (used in Launois et al.)	**Flux_soiloxic_LSCE**	Marine	3.75*1.9		kgS/m2/s	-501GgS/ye
Soil uptake for oxic soil (used in Launois et al.)	**Flux_soilanoxic_LSCE**	Marine	3.75x1.9		kgS/m2/s	101 GgS/y
Soil ????						
Ocean: direct flux from NEMO-PISCES; corrected to have around 300 GgS/y (Launois et al.)	**Flux_oce_direct_LSCE**	Marine	3.75 x 1.9		kS/m2/s	205 GgS/y
Ocean: indirect flux due to cs2 oxydation (Kettle et al.)	**Flux_oce_indirect_cs2_LSCE**	Marine	3.75 x 1.9			83 GgS/y
Ocean: indirect flux due to dms oxydation from Launois et al.	**Flux_oce_indirect_dms_LSCE**	Marine	3.75 x1.9			155 GgS/y
Ocean: flux COS, CS2 and DMS as total (Kettle 2002)	**cos_ocean_indirect_yyy**	Jin	91x144	2010 - 2015	umol/m2/s	~278 GgS/yr

Laboratory (key person)	Transport model including spatial resolution	Plan experiment ex: 1a, 1b, ….	Achieved experiment	Remark
LSCE (Marine)	LMDZ6 (96 lon x 96 lat x 39 lev)	1a,2a,3a..e, 2a		The stratospheric sink has not been implemented in LMDz yet.
IMAU (Jin)	TM5 (180 lon x 90 lat x 25 lev)	1a, 1c, 2a, 2b, 3a, 4a, 5a, 5d	1a, 3a	OH and UV chemistry has been implemented in TM5. Diurnal flux is not implemented yet.
LSCE (Philippe P.)	LMDZ3 (96 x 73 x 19 lev)	1a, 1c, 3a	done	Monthly obs with pre-computed adjoint

Thank you…

Questions :

- Should we have a synthesis of “global / regional” modelling studies to raise the need for more [COS] data
- At plot scale : How to convince that “COS data” bring new information compared to Fluxnet partitionning or to SIF
- How to combine COS / SIF observations ?
- Regular (annual) evaluation of GPP with COS data for the Global Carbon Project budget ?