Interannual variations of CO_2 exchange over the Amazon during 2010-2017

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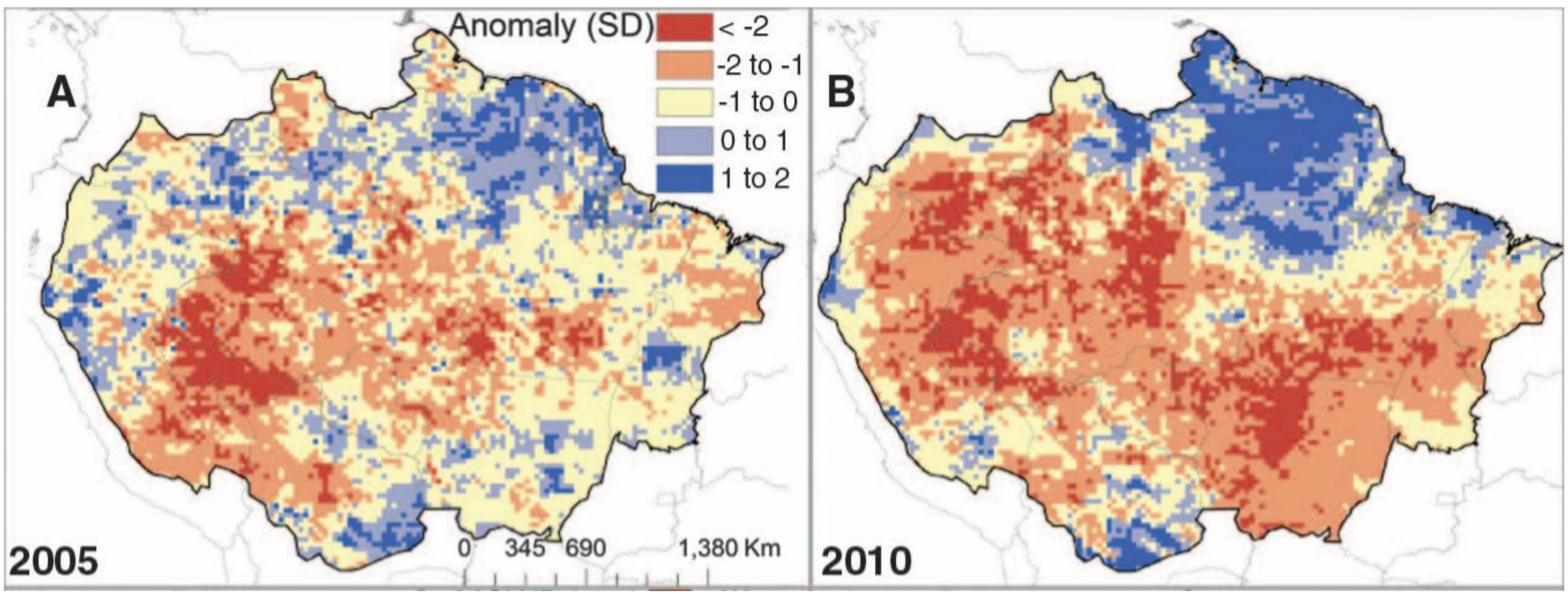
CO_2 exchange over the Amazon

- Tropical land drives inter-annual variability in atm. CO_2 growth rate (Cox et al., Nature, 2013)
- Amazon forest is largest tropical forest: 49% of trop. biomass (Saatchi et al., PNAS, 2011)
- Major droughts occurred in 2005, 2010 and 2015 in the Amazon

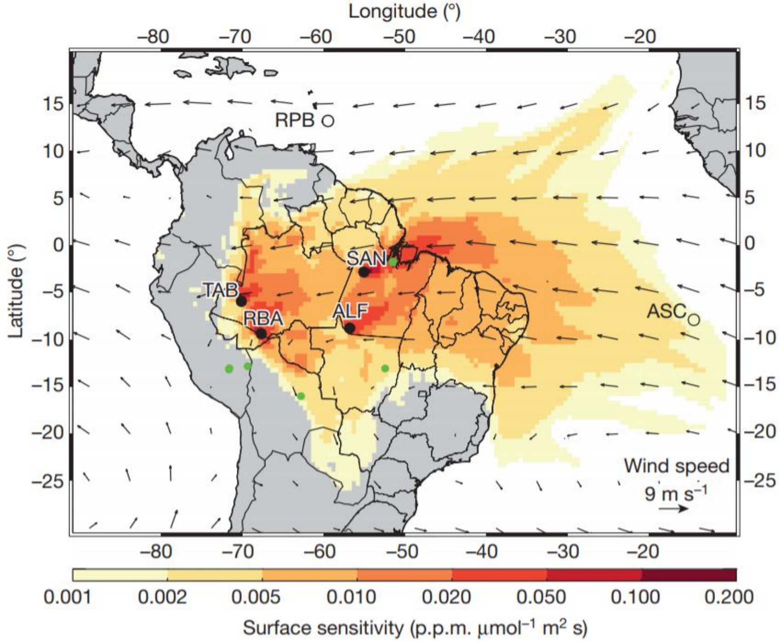


Precipitation anomalies in Amazon region (Lewis et al., Science, 2011)

2010 Amazon drought

CO_2 exchange estimated by Gatti et al., (Nature, 2014):

- Aircraft profiles of CO, CO_2 and SF_6 from four different sites in the Amazon
- Background obs. from NOAA stations



	Fires (PgC)	NBE (PgC)
2010	+0.51 ± 0.12	-0.03 ± 0.22
2011	+0.30 ± 0.10	-0.25 ± 0.14

2010 Amazon drought

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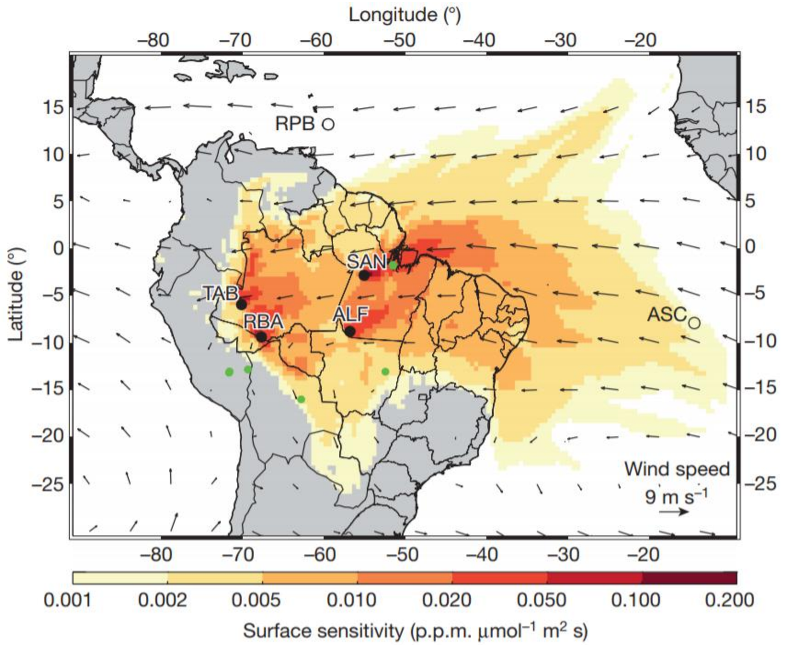
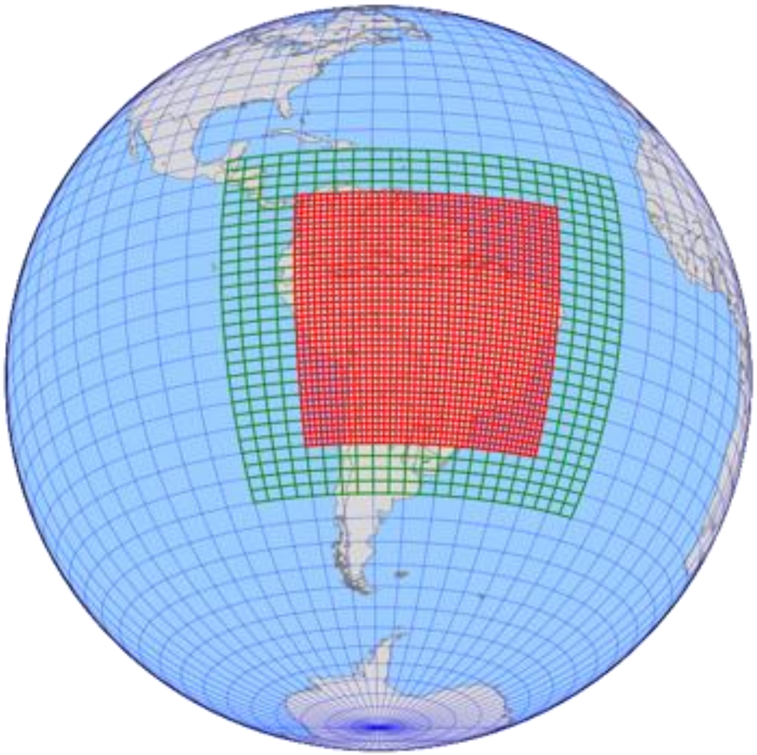


Current study objective:

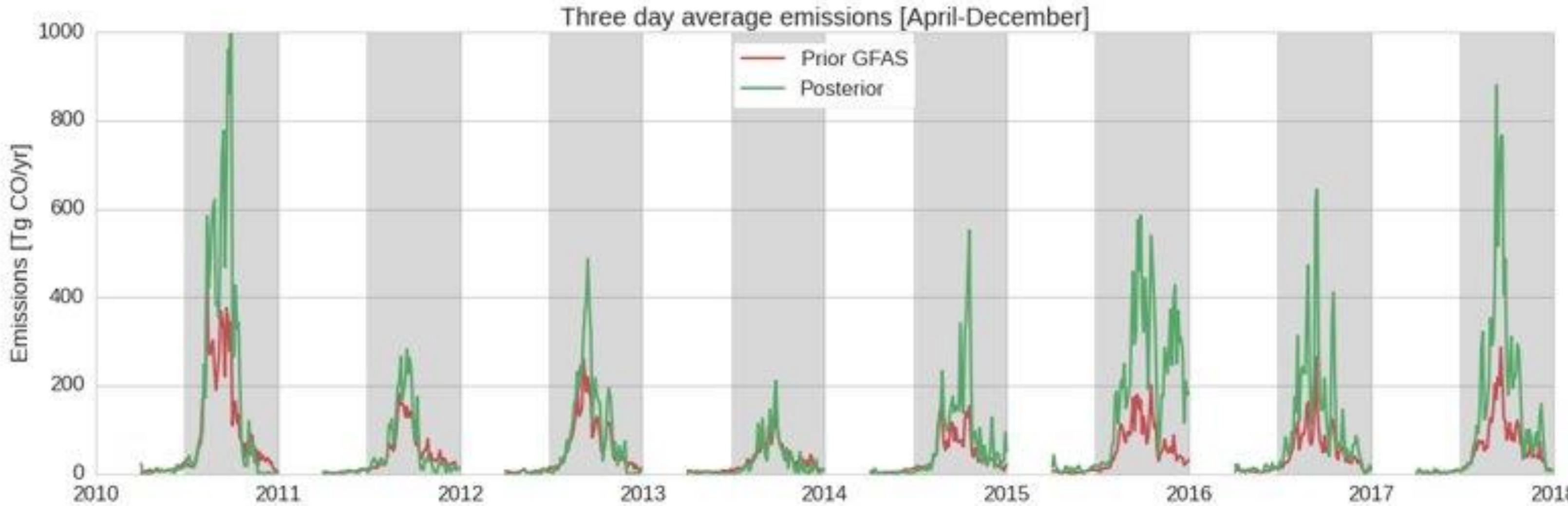
- Extend analysis period to more recent years (including 2015 drought and 2016)
- Assess the changes of fires, photosynthesis (and respiration) separately

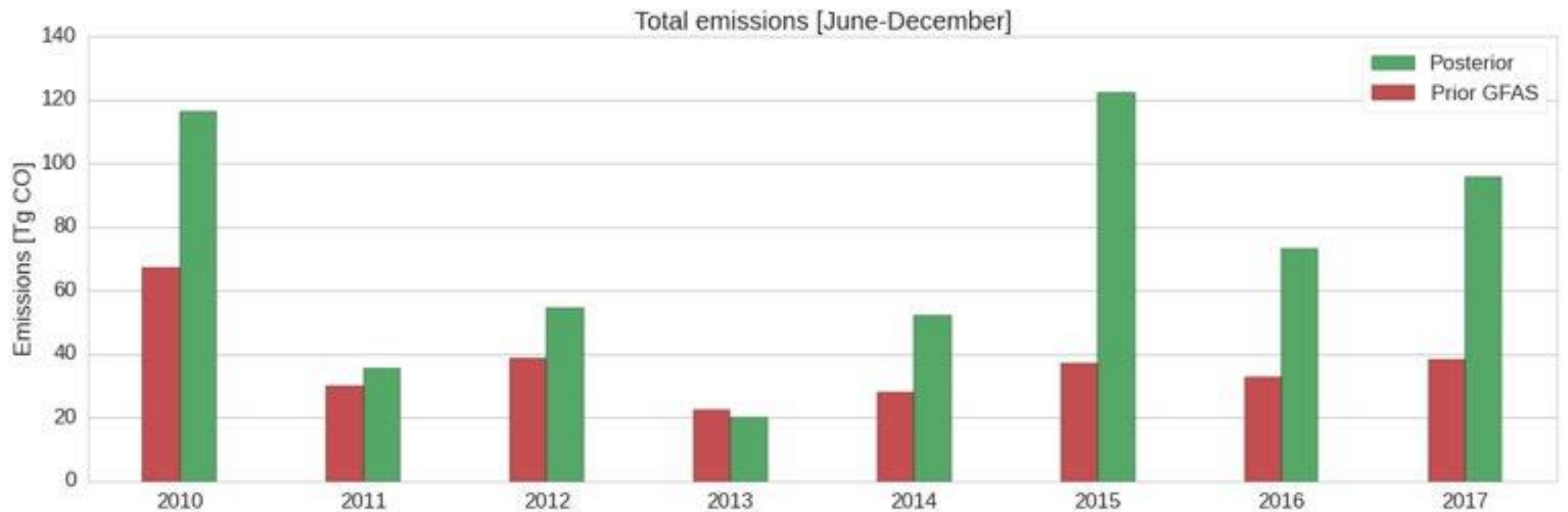
TM5-4DVAR CO inversions

- Zoom version of TM5-4DVAR
- GFAS emissions as prior
- Observations:
  - IASI
  - NOAA surface network
- We optimize:
  - biomass burning over Amazon
  - total emissions globally
- Simulations by Stijn Naus (WUR)

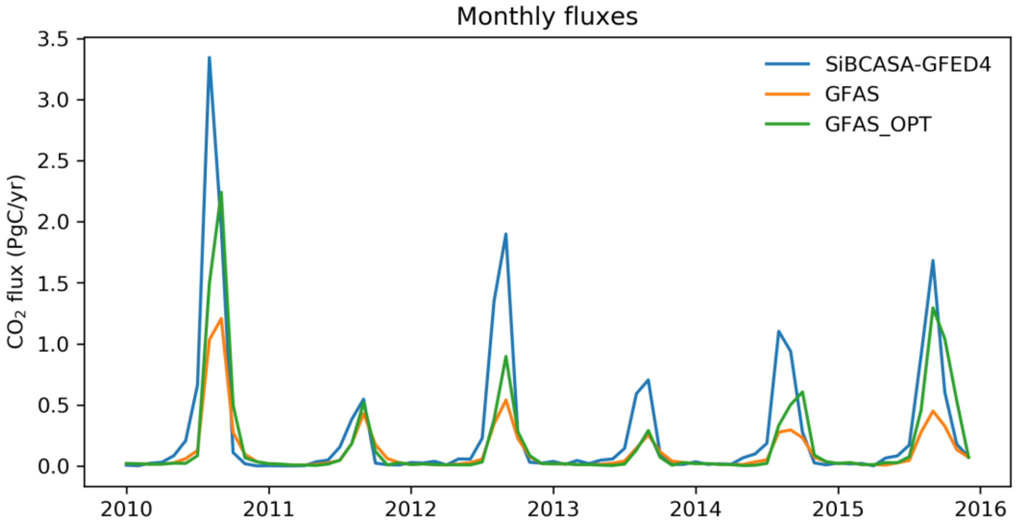


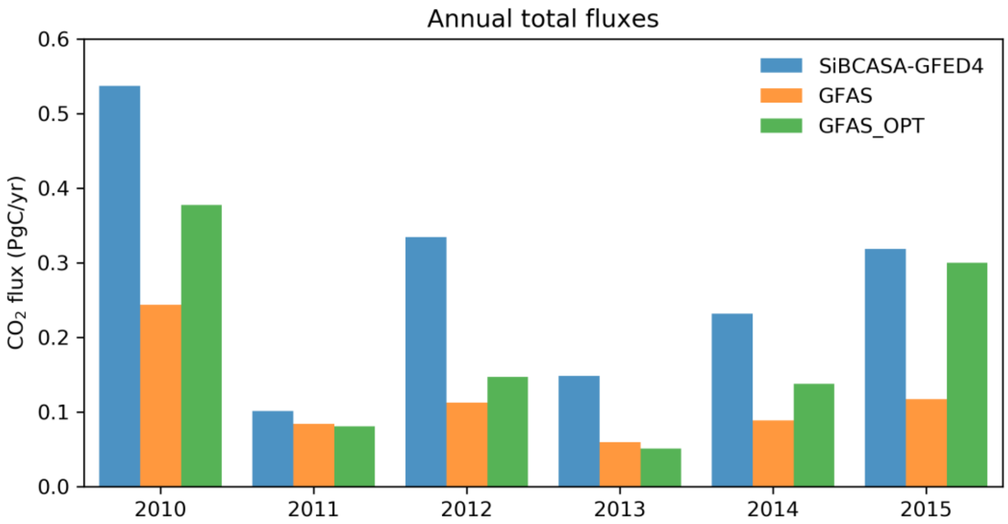
CO fire emissions





CO_2 fire emissions

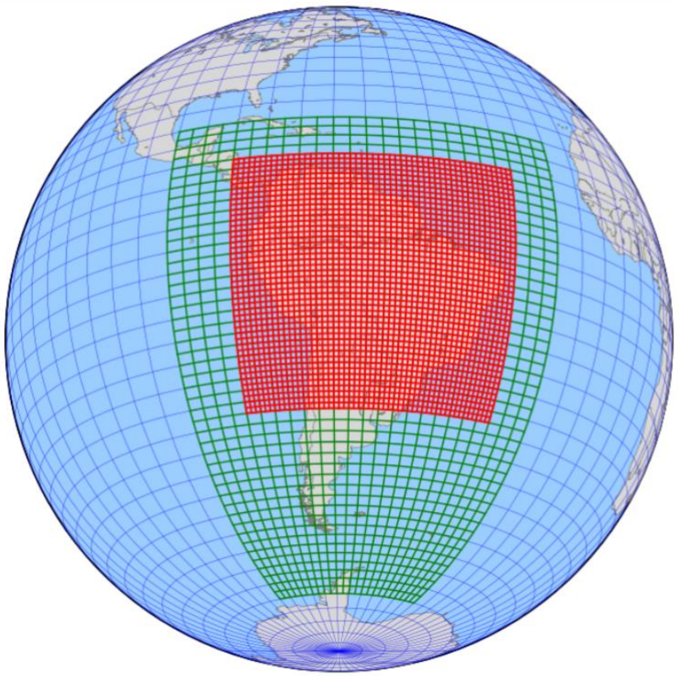




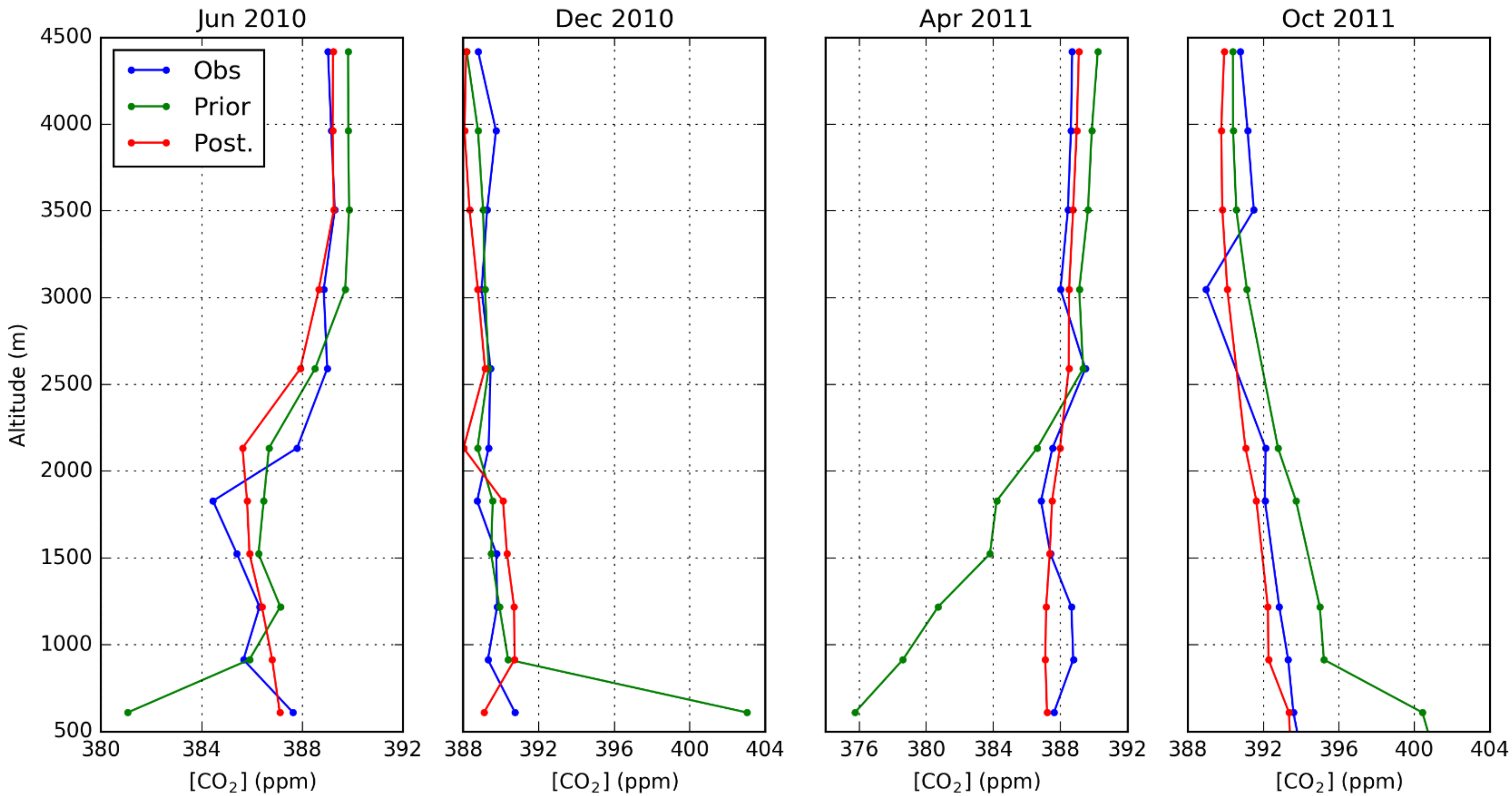
- GFAS prior CO_2 emissions multiplied with ratio of posterior-to-prior CO emissions to obtain 'optimized' GFAS CO_2 emissions
- On average better agreement between optimized GFAS and SiBCASA-GFED4 emissions
- High emissions in drought years 2010 and 2015

CarbonTracker South America

- TM5 with 6°×4° global grid and nested 3°×2° and 1°×1° zoom regions over South America (van der Laan-Luijkx et al., 2015)
- Ensemble Kalman Filter (Peters et al., 2005)
- Gridded statevector
- CO_2 profiles from Amazon (Gatti network)

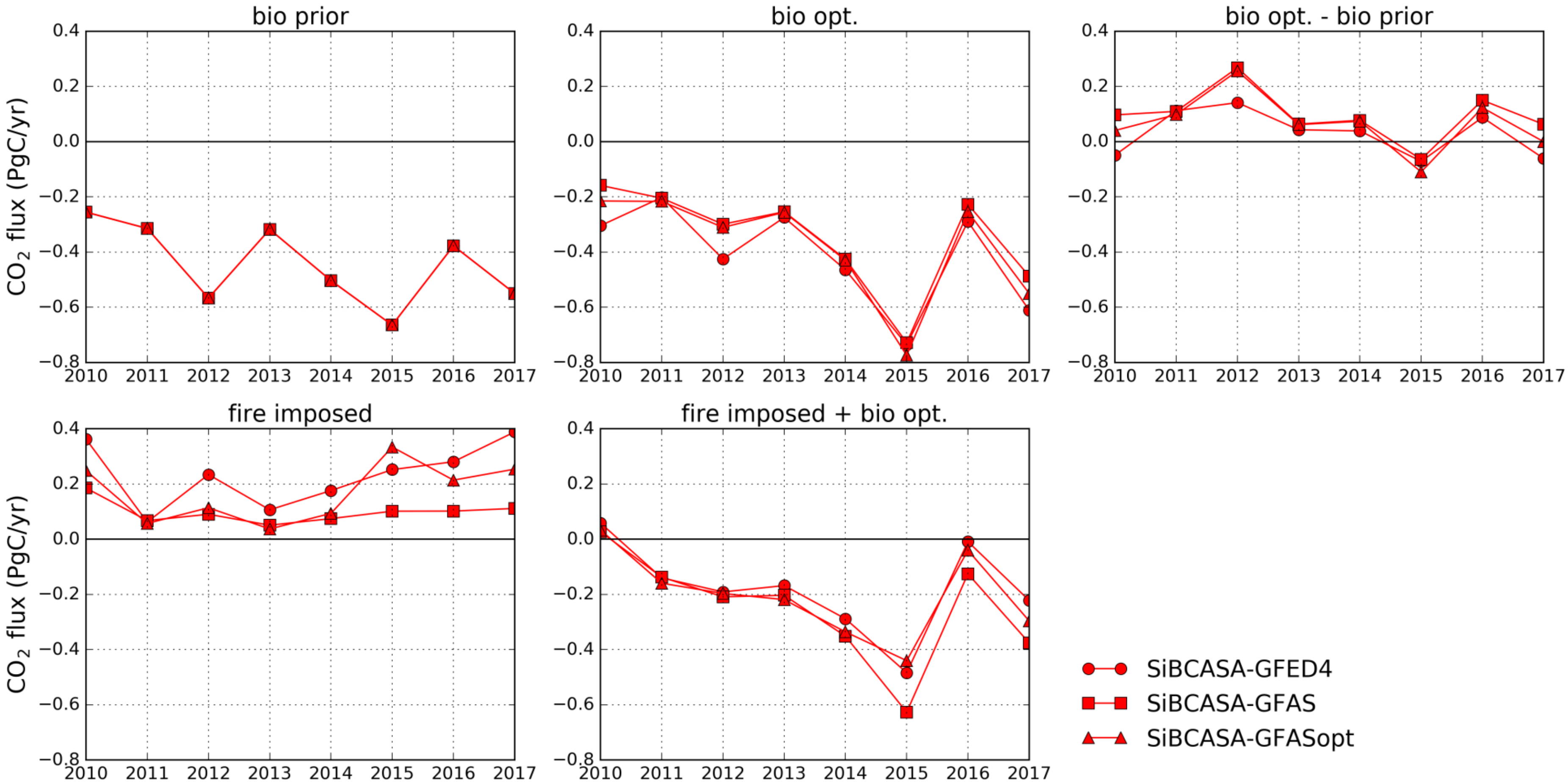


CarbonTracker-South America CO_2 profiles



- Examples of CO_2 profiles for Alta Floresta (ALF), obs. data from Luciana Gatti
- Posterior profile matches better with obs. than the prior profile

CO_2 fluxes for Amazon



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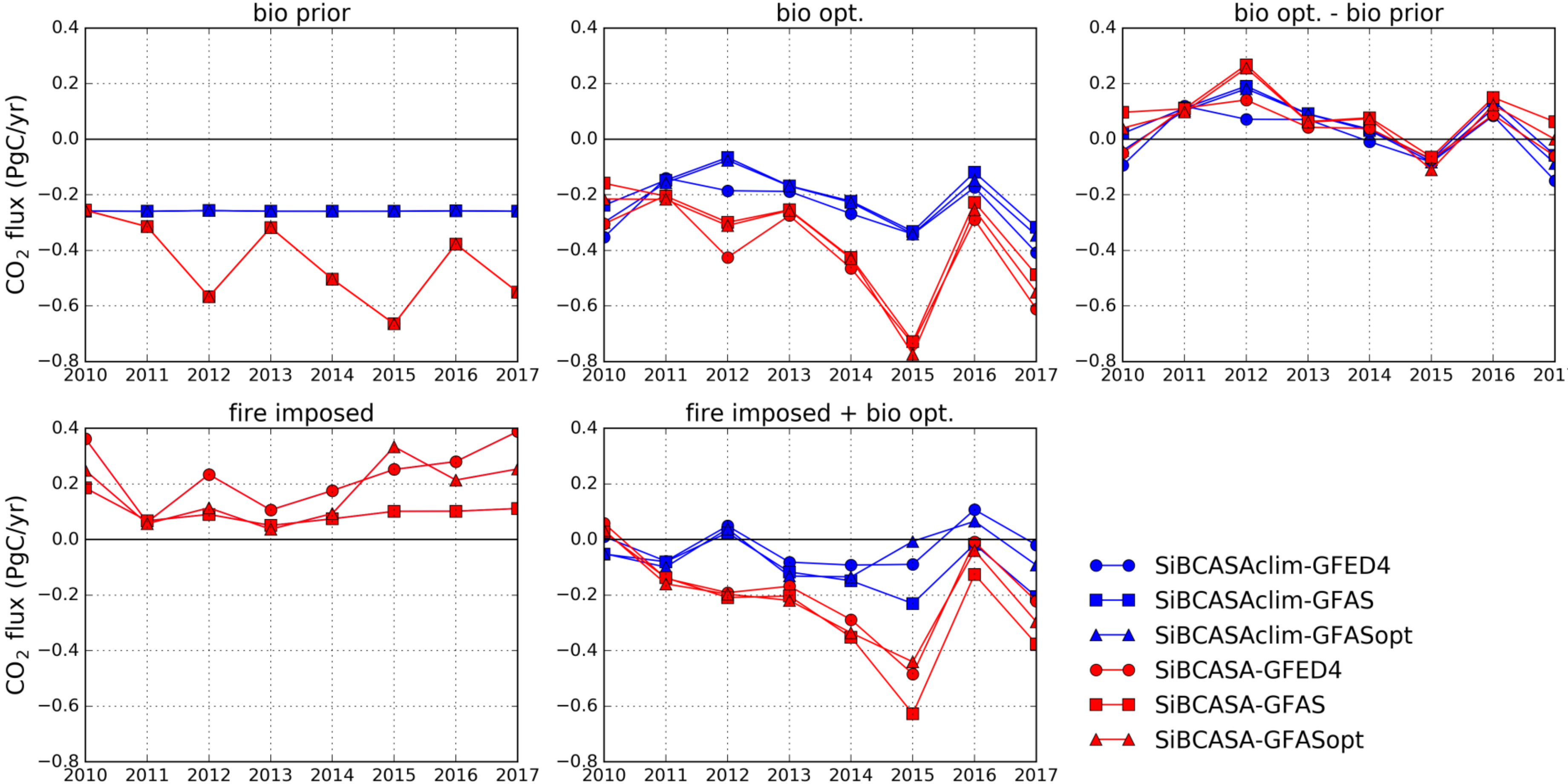

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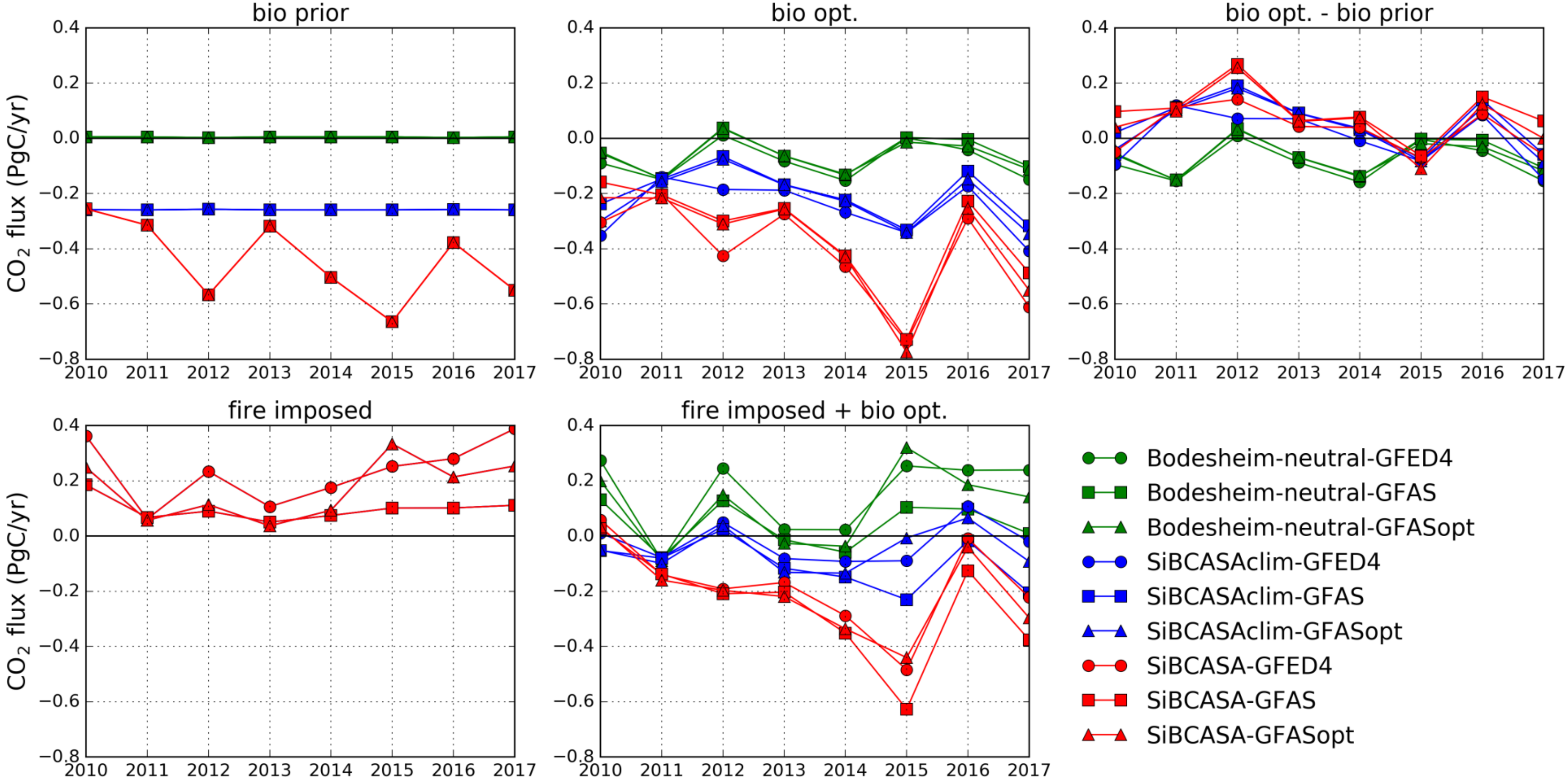

- Biosphere priors have larger effect on optimized total fluxes than the fire products
- Similar IAV in optimized biosphere fluxes except for years with little observations (2015)

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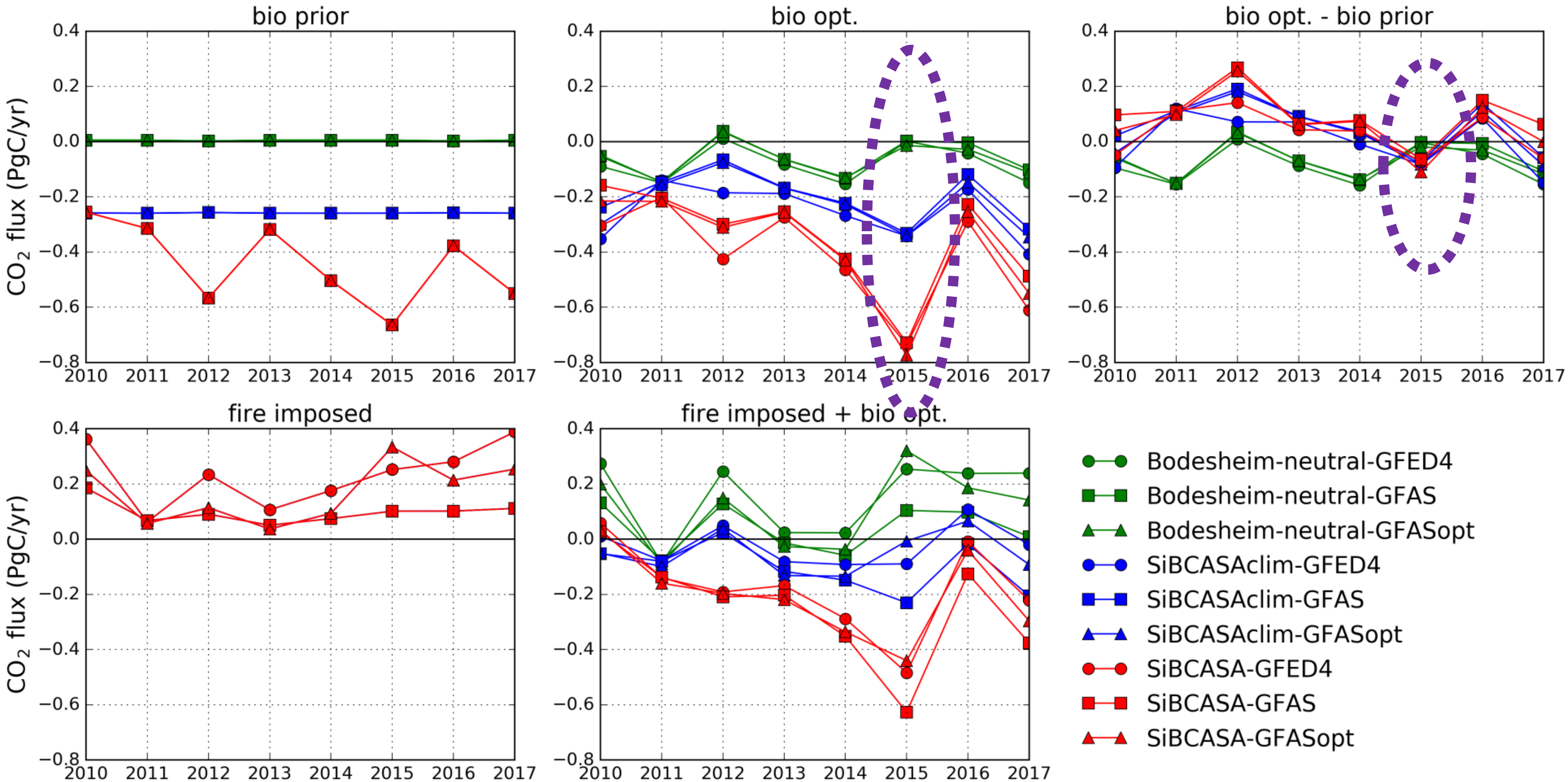

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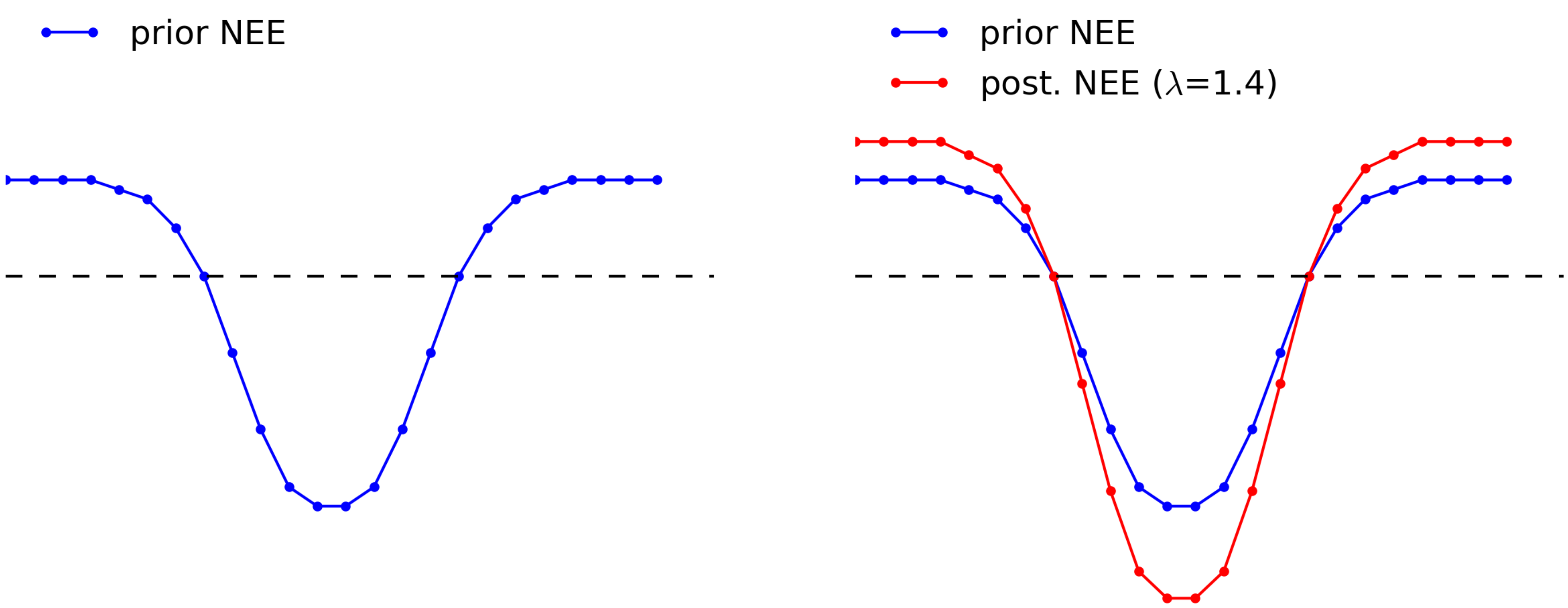
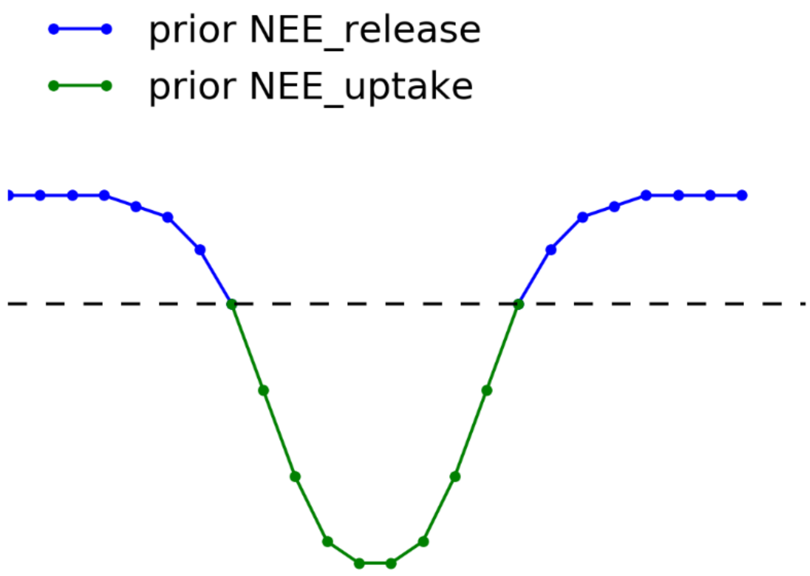
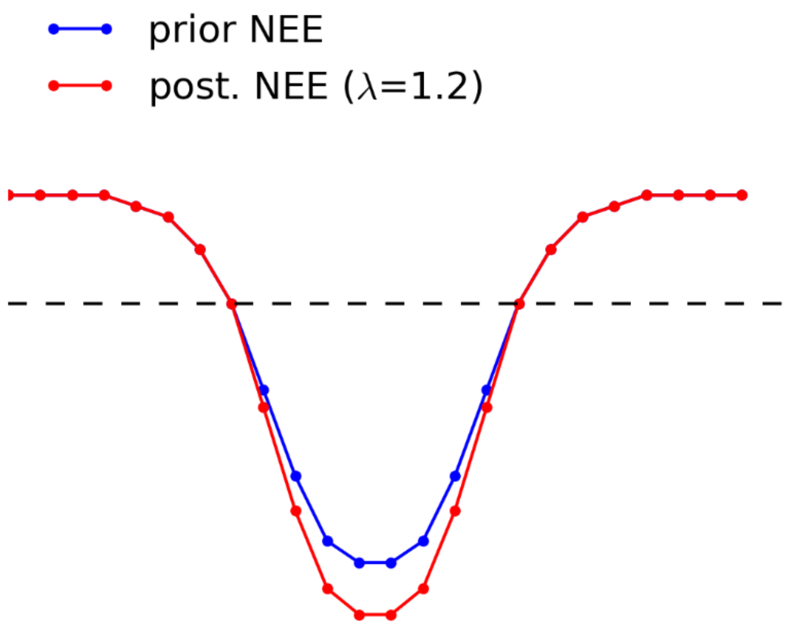
Default CarbonTracker scaling



- In default setup, CarbonTracker scales both positive and negative NEE with same factor
- Averaged over the diurnal cycle NEE is relatively small
- Large scaling factors (λ>>1 or λ<<1) needed to substantially modify net emissions

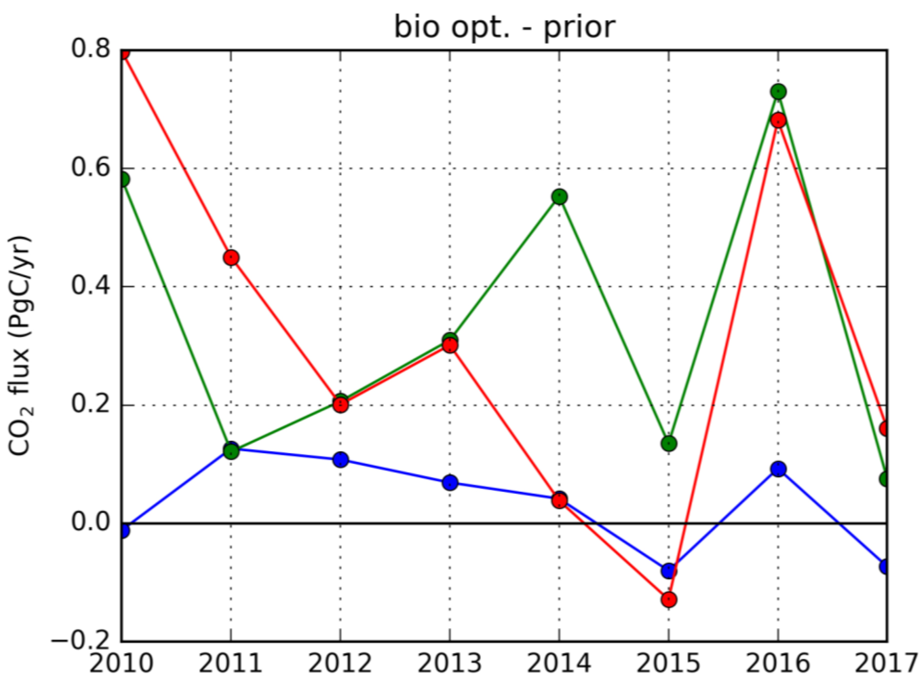
Alternative scaling methods

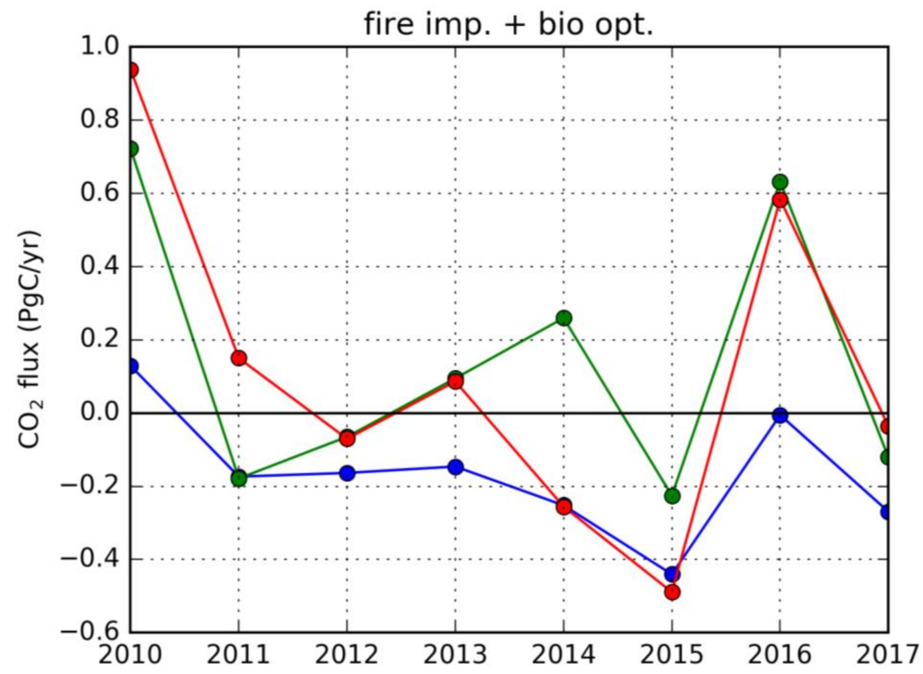




- In alternative setup, scaling factor is applied only to negative NEE (“uptake scaling”)
- Smaller scaling factors are sufficient to substantially modify net emissions
- Zero-crossings of NEE remain in place
- Same principle can be applied to positive NEE (“release scaling”)

Alternative scaling methods

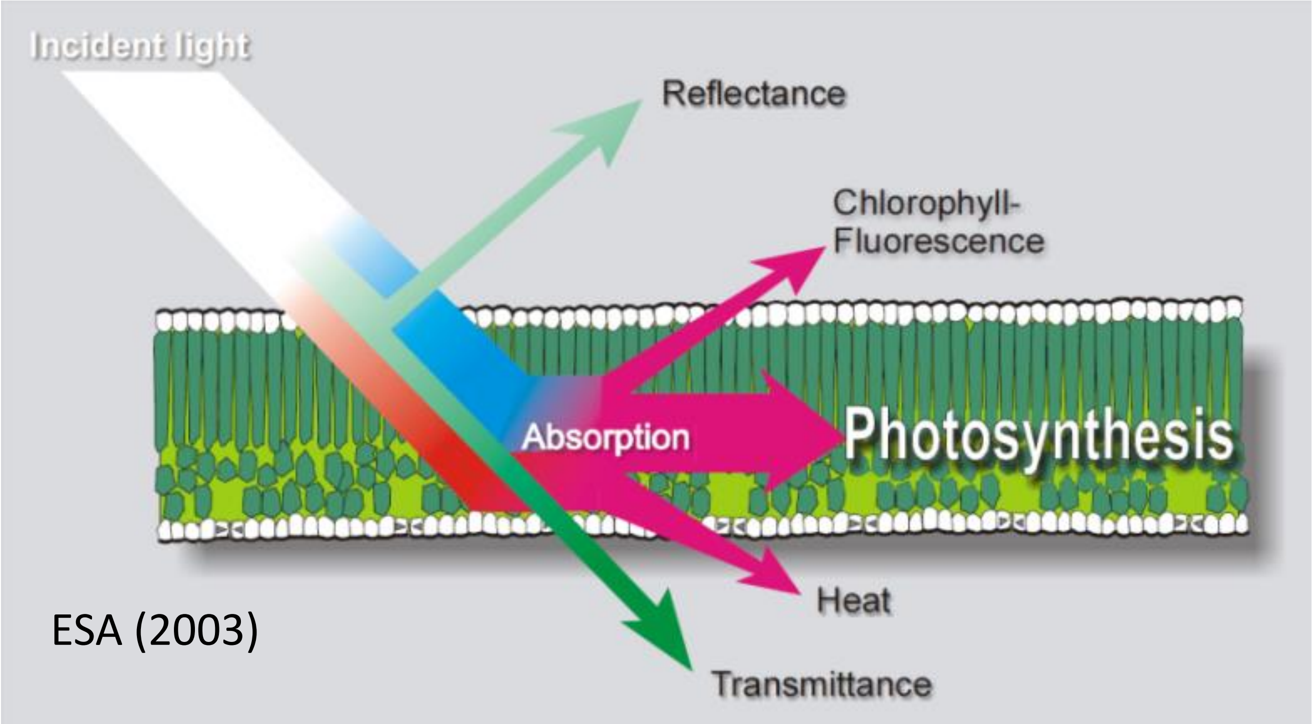




default scaling
uptake scaling
release scaling

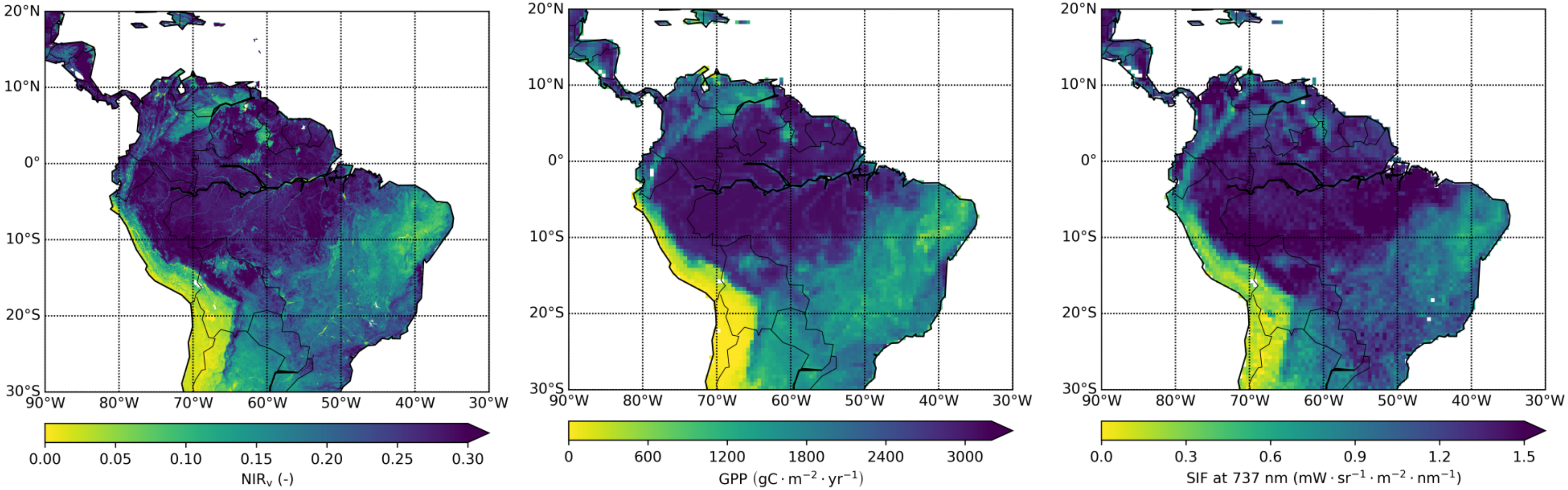
- Large emissions during drought year 2010 and post-drought year 2016

Proxies for photosynthesis: SIF and NIRv



- SIF is a small fraction of light (~1%) that is re-emitted from chloroplast at higher wavelengths
- NIRv reflects amount of vegetation in cell and structure of the canopy (Badgley et al, 2017)

Annual mean NIRv, MPI-GPP and SIF

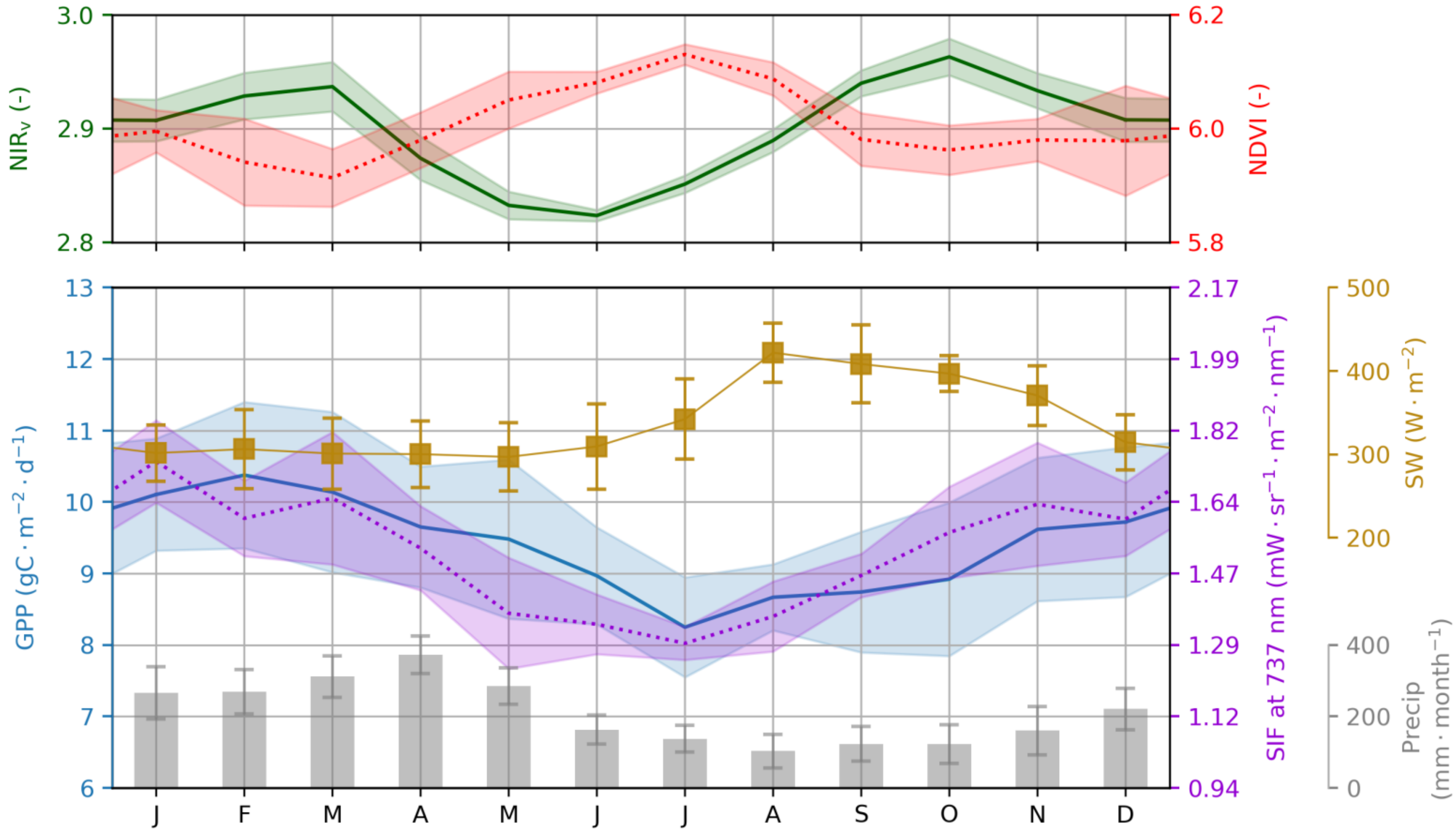


Similar spatial patterns in (from left to right):

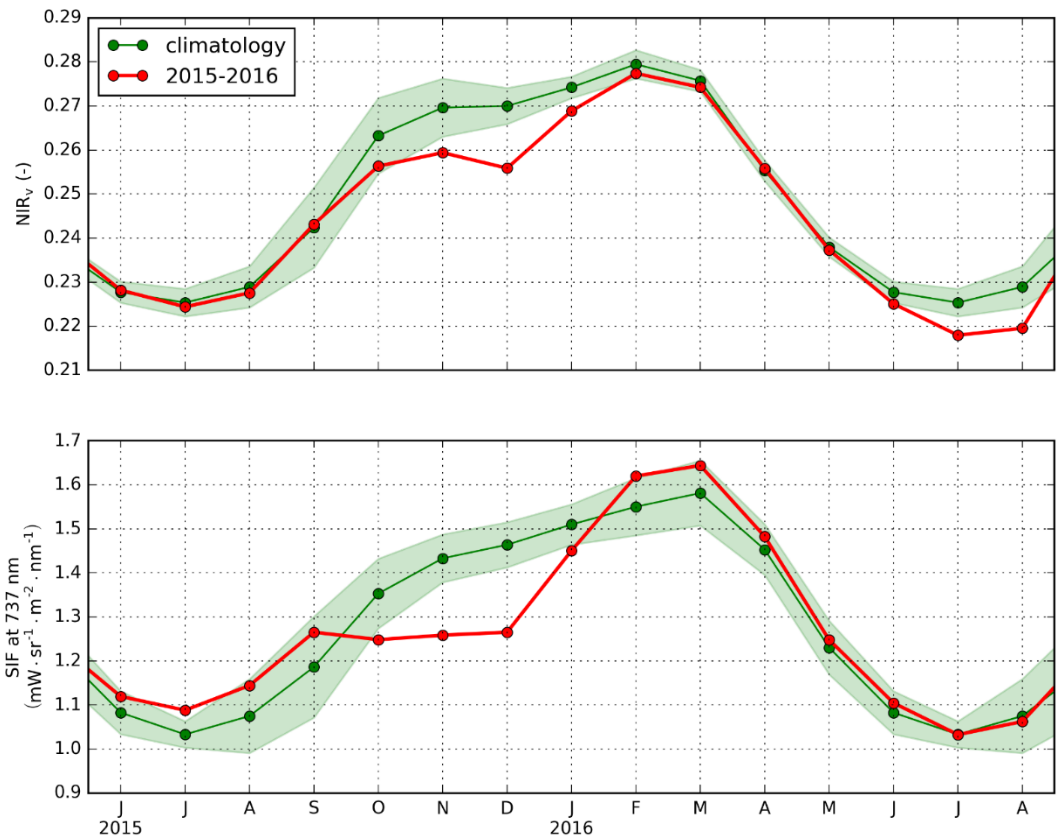
- NIRv derived from MODIS surface reflectance
- GPP product based on machine learning of EC data (Beer et al., Science, 2010)
- Remotely sensed SIFTER product developed by KNMI/WUR for tropical conditions

Manaus K34 flux tower

- Data from K34 tower (2000-2009) and SIF/NIRv (2007-2014)
- GPP LUE models show increase of GPP during dry period, SIF and NIRv follow GPP
- Opposite seasonal cycle of NDVI and NIRv



2015/2016 Amazon drought

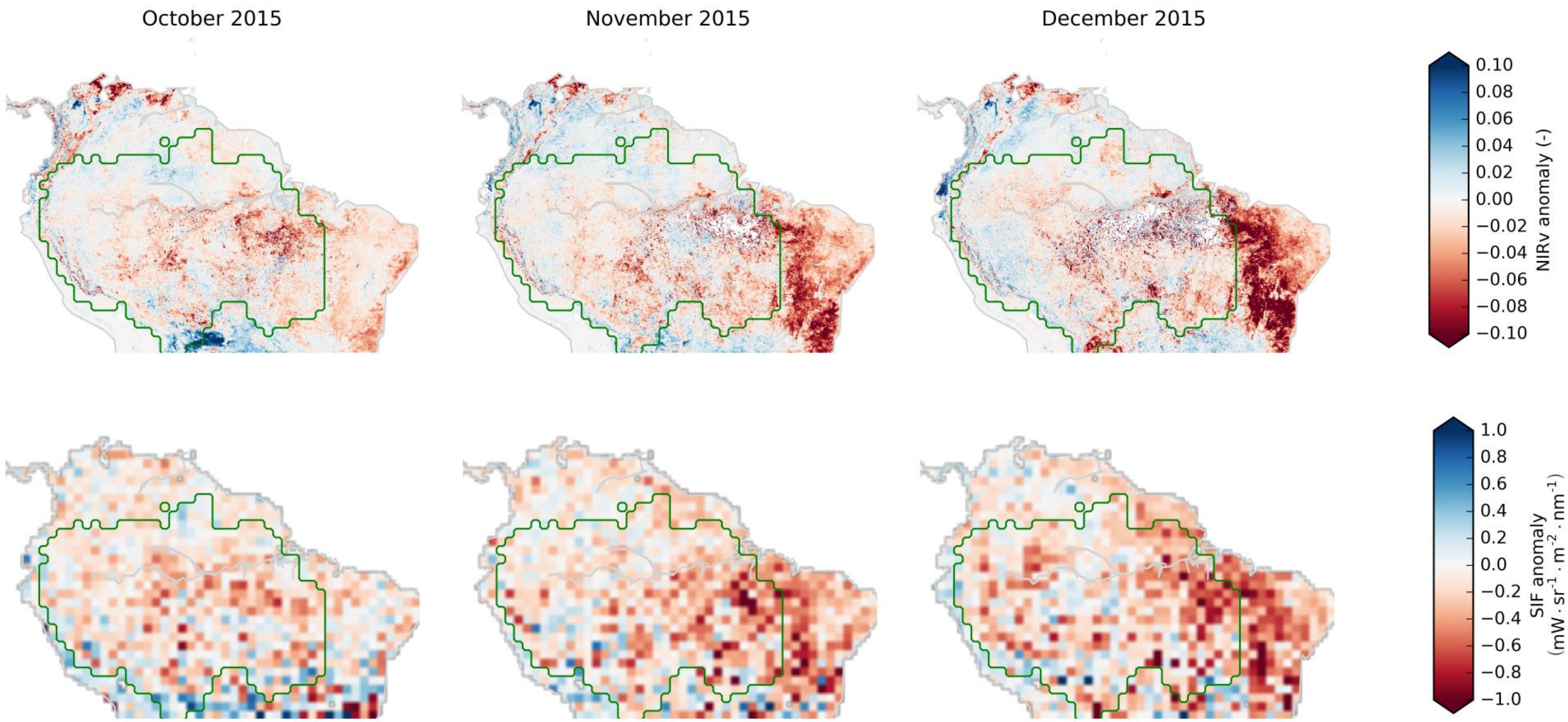


Widespread reduction in sun-induced fluorescence from the Amazon during the 2015/2016 El Niño

Gerbrand Koren[1], Erik van Schaik[1], Alessandro C. Araújo[2], K. Folkert Boersma[1,3], Antje Gärtner[1], Lars Killaars[4], Maurits L. Kooreman[3], Bart Kruijt[1], Ingrid T. van der Laan-Luijkx[1], Celso von Randow[5], Naomi E. Smith[1] and Wouter Peters[1,4]

- 'Extended' dry season
- Onset of drought and recovery occurs earlier in SIF

2015/2016 Amazon drought



- Green contour indicates Amazon forest region
- Large reduction of NIRv and SIF in Cerrado region (east of Amazon forest)

Conclusions

Fires:

- CO inversion with TM5-4DVAR based on IASI and NOAA data
- High fire emissions during drought years (2010, 2015)

NEE:

- CarbonTracker South America inversions with Amazon aircraft data
- IAV in biosphere fluxes can be retrieved from atmospheric data

GPP:

- Custom developed SIFTER retrieval for tropical conditions and NIRv calculated from MODIS surf. reflectance
- Reduction of SIF and NIRv during the 2015 drought suggest a reduction of GPP

Global fluxes