Biosphere-atmosphere exchange of CO_2 over the Amazon

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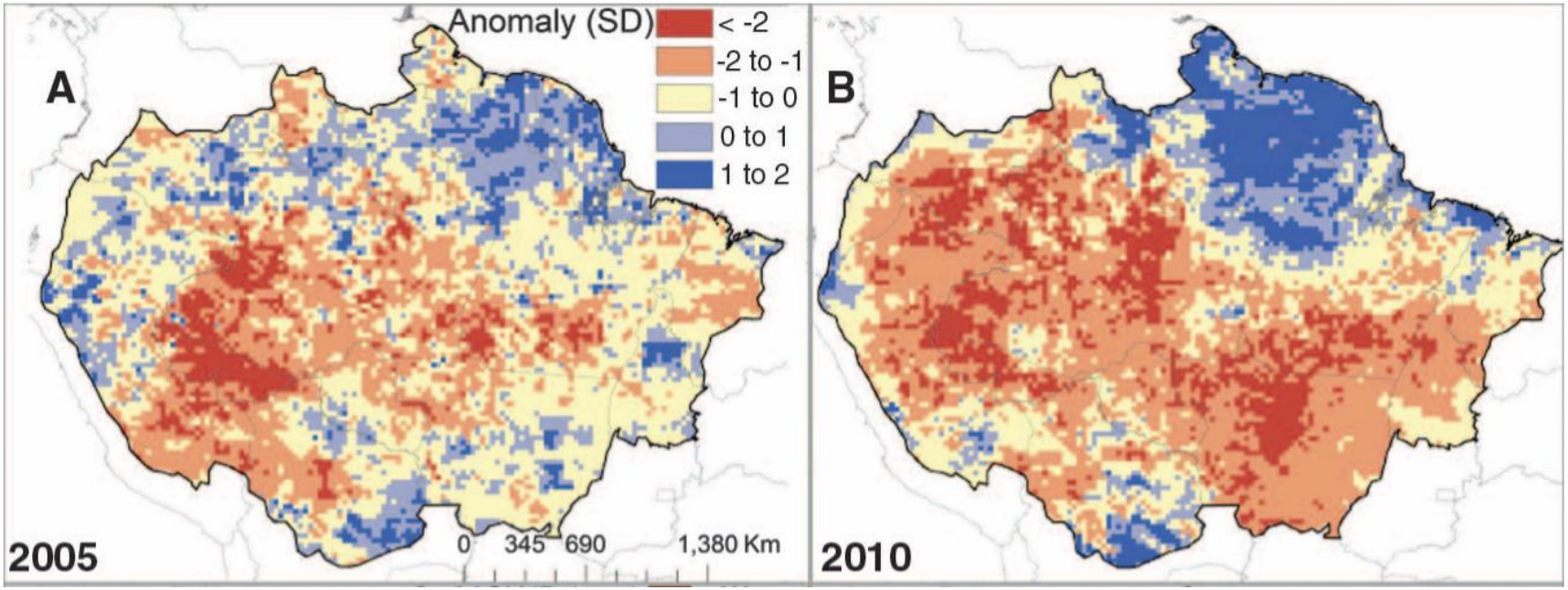
CO_2 exchange over the Amazon

- 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

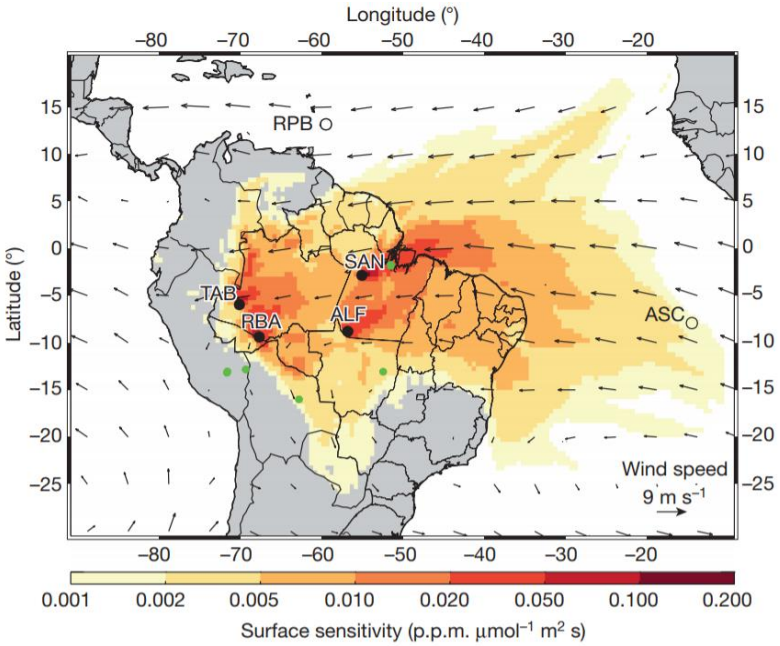


Precipitation anomalies in Amazon region (Lewis et al., Science, 2011)

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
- SF_6: source of air over Amazon
- CO: biomass burning
- CO_2: net biome exchange



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

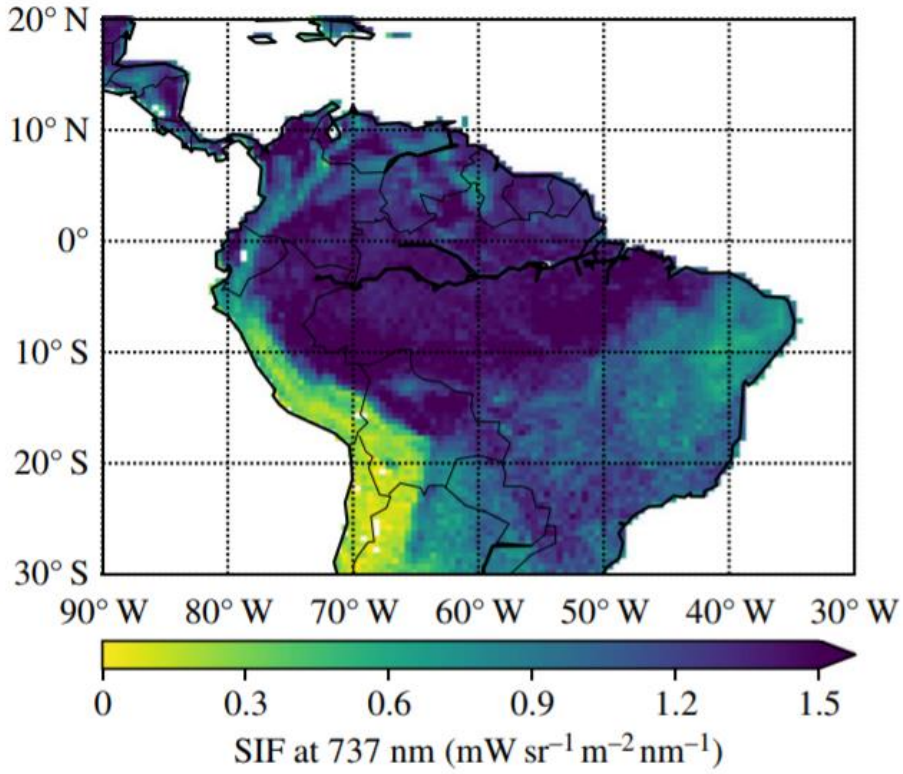
2010 Amazon drought

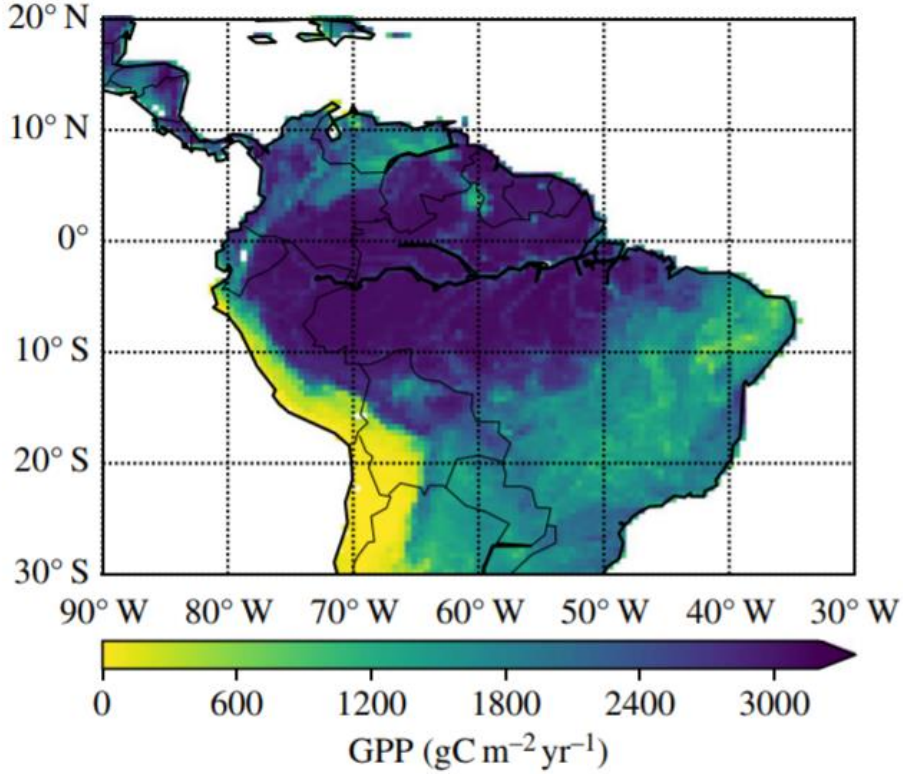
CO_2 exchange estimated by van der Laan-Luijkx et al. (2015)

- CO_2 inversion with CarbonTracker South America
- Fires optimized using CO obs. from IASI and TM5-4DVAR system
- Good overall agreement with the Gatti et al. results (except for fires in 2011)

	Fires (PgC)	NBE (PgC)	Source
2010	+0.51 ± 0.12 +0.24 to +0.53	-0.03 ± 0.22 -0.40 to -0.10	Gatti et al. van der Laan-Luijkx et al.
2011	+0.30 ± 0.10 +0.05 to +0.17	-0.25 ± 0.14 -0.43 to -0.23	Gatti et al. van der Laan-Luijkx et al.

2015/2016 Amazon drought





Analysis of photosynthesis response during the 2015/2016 drought (Koren et al., 2018):

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

Research objectives and methods

Research objectives:

- Long-term perspective on the Amazon carbon cycle (2010-present)
- Asses the carbon cycle in drought and non-drought years (possible trend and IAV)
- Analyze contributions from fires, photosynthesis and respiration separately

Methods:

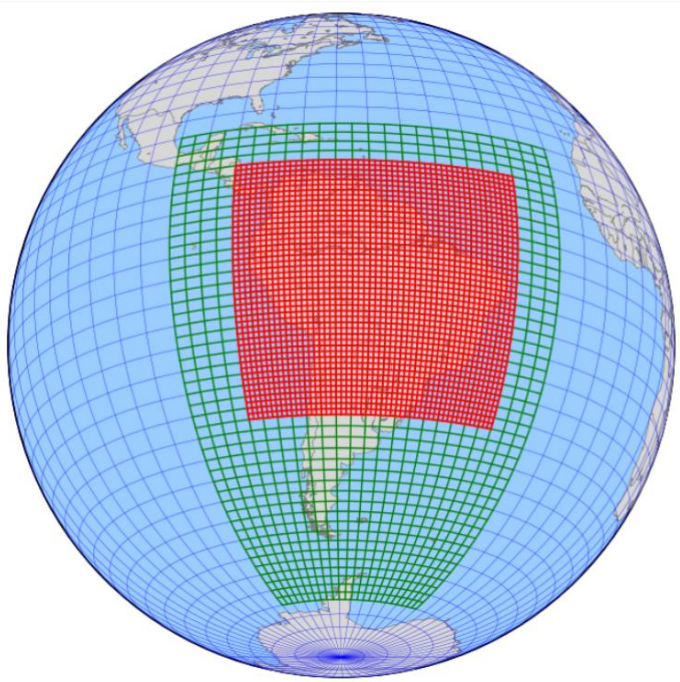
- Optimized fires from IASI CO obs. and TM5-4DVAR system (Stijn Naus)
- NBE estimated from CarbonTracker South America
- Remotely sensed photosynthesis proxies (SIF and NIRv)

GFAS CO_2 fire emissions

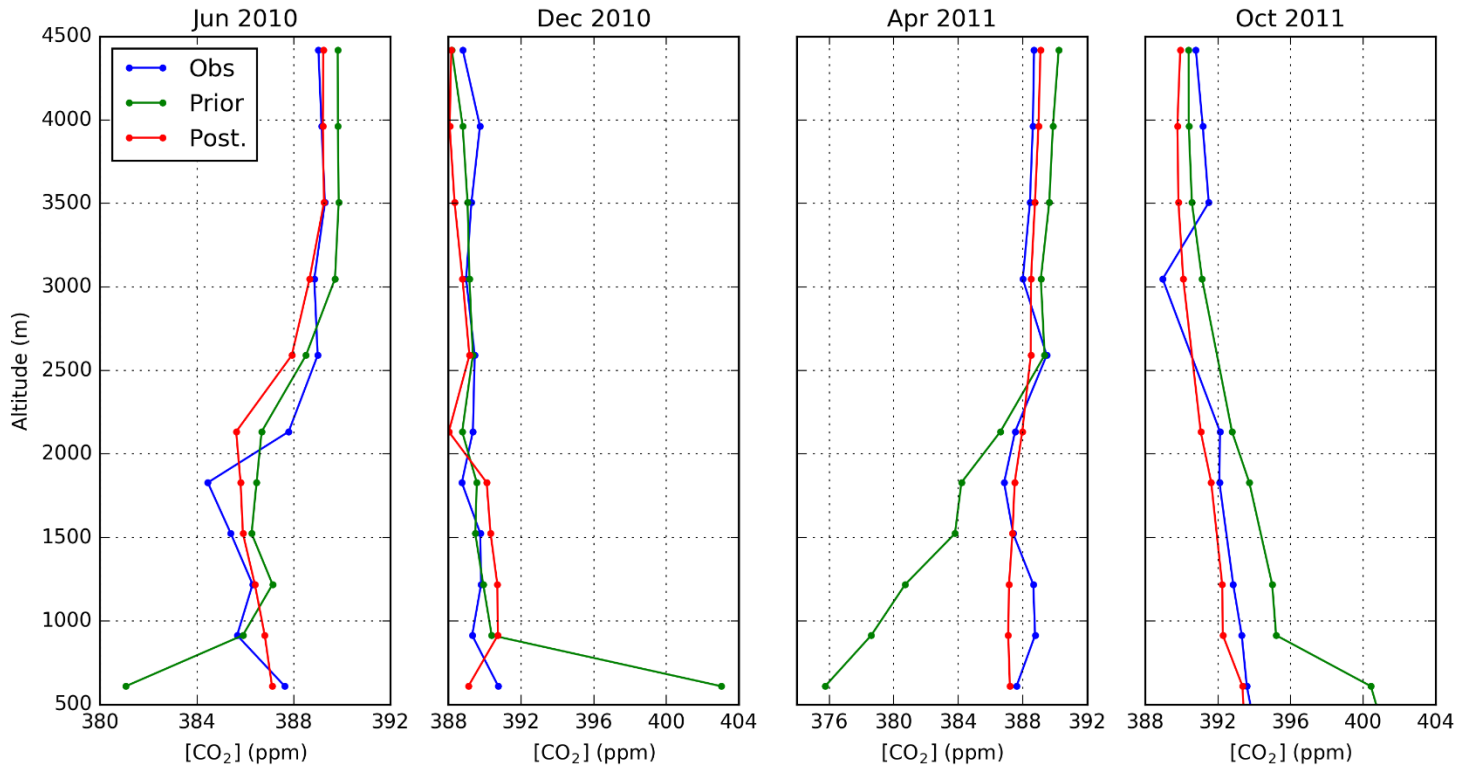
- CO inversions with TM5-4DVAR system based on IASI obs. (Stijn Naus)
- GFAS prior CO_2 emissions multiplied with ratio of posterior-to-prior CO emissions to obtain 'posterior' GFAS CO_2 emissions

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)
- SIBCASA-GFED4 fire prior
- CO_2 profiles from 2010, 2011 (1848 obs.)



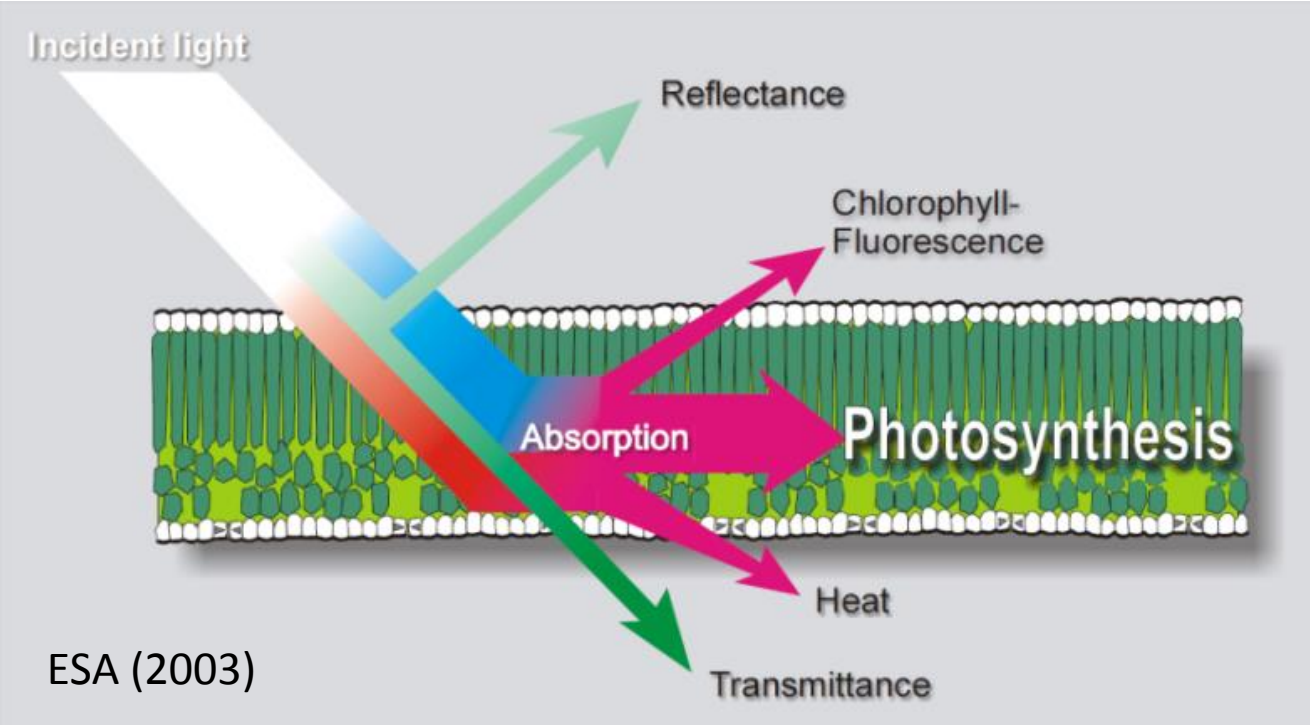
CarbonTracker-South America CO_2 profiles



RMSE [ppm]	ALF	RBA	SAN	TAB
prior	4.9	5.5	3.1	4.7
posterior	1.8	1.8	1.3	2.3

- CO_2 profiles for ALF
- RMSE for all sites (1848 obs.)

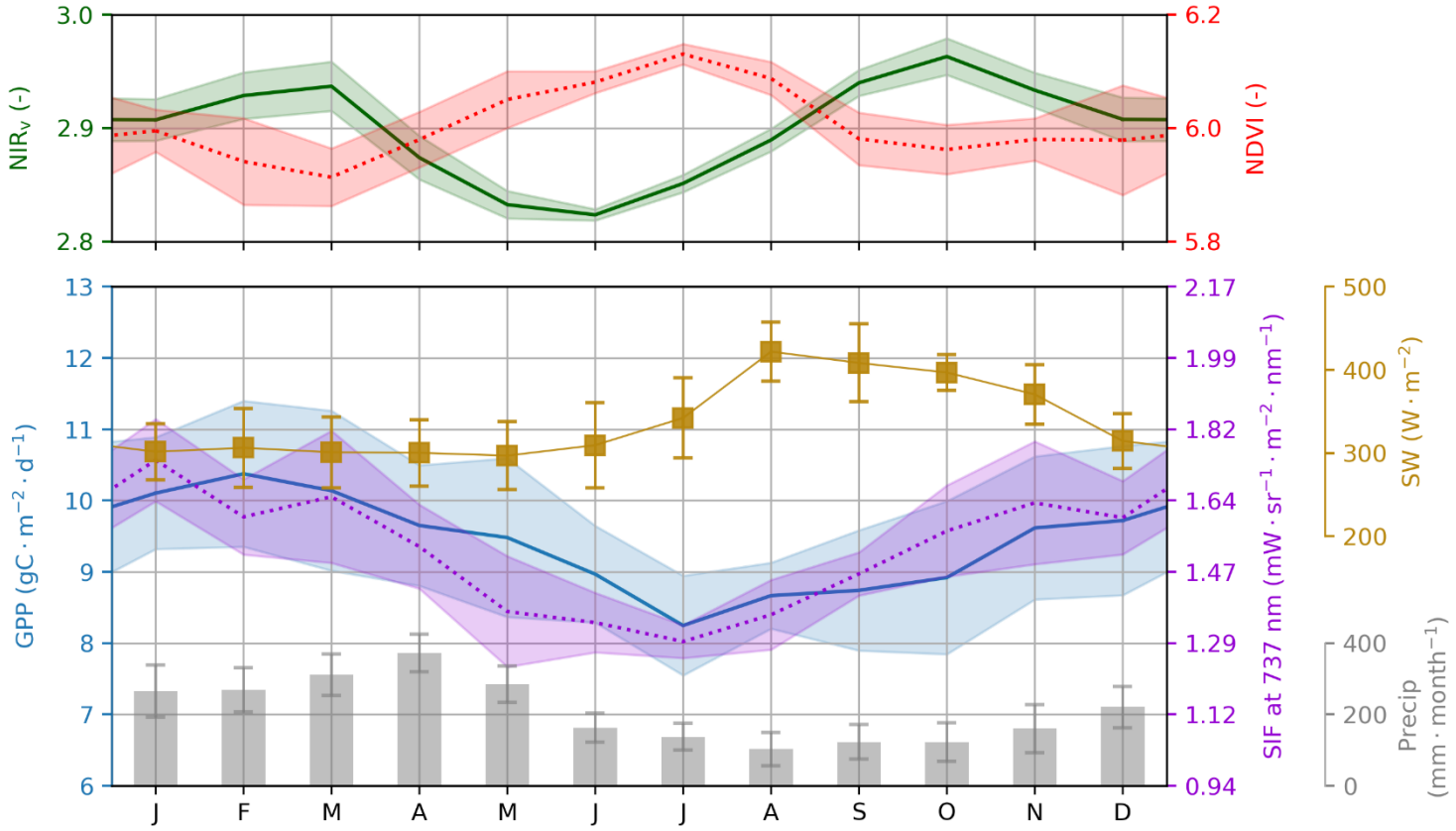
Proxies for photosynthesis: SIF and NIRv



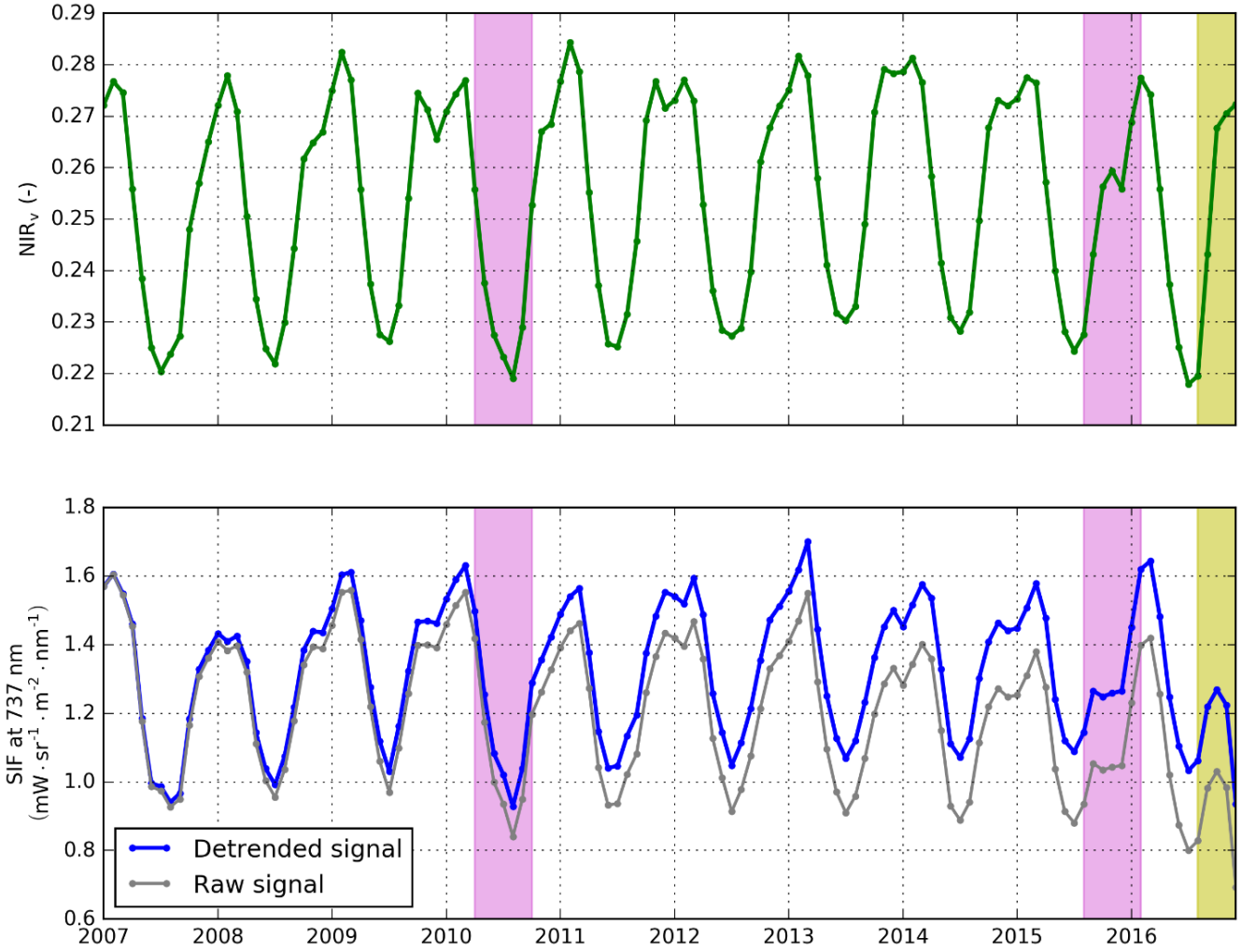
- Small fraction of light (~1%) is re-emitted from chloroplast at higher wavelengths
- SIFTER retrieval (KNMI/WUR) developed for humid tropical conditions for GOME-2
- NIRv reflects amount of vegetation in cell and structure of the canopy (Badgley et al, 2017) calculated from MODIS surf. reflectance

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 follows GPP
- Opposite seasonal cycle of NDVI and NIRv

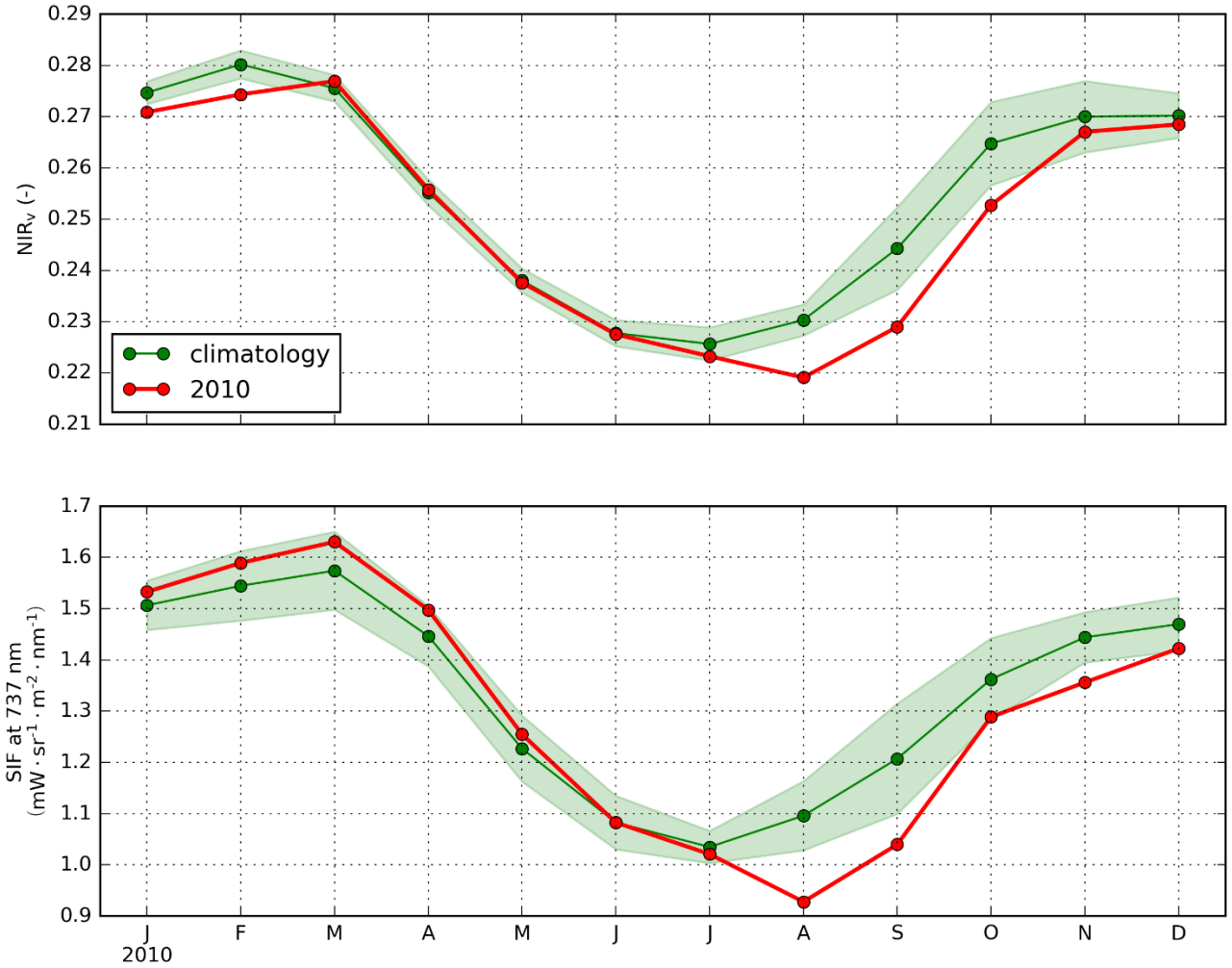


Amazon NIRv and SIF time series



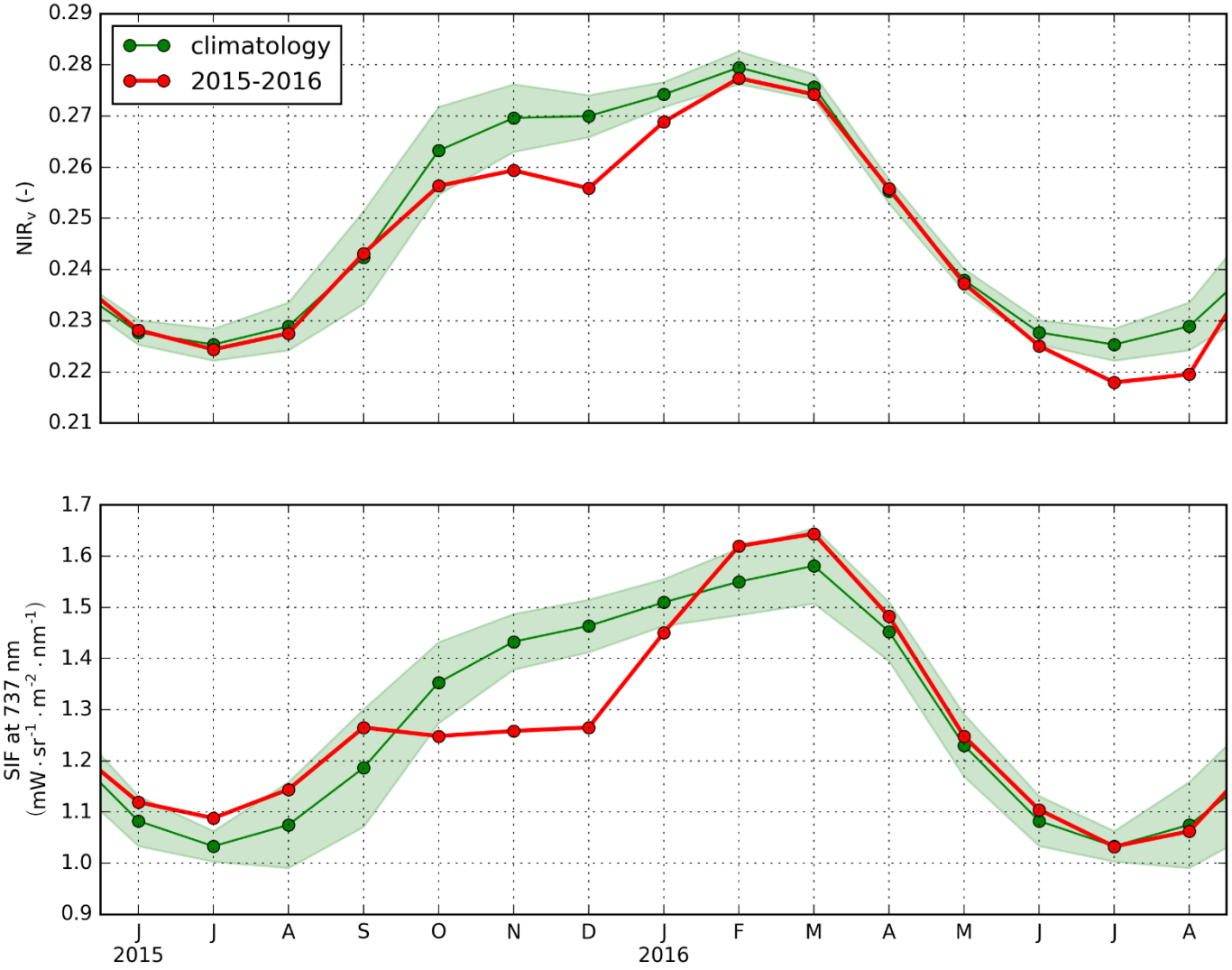
- Dry/wet season
- 2010 and 2015/2016 droughts
- GOME-2A sensor degradation

2010 Amazon drought



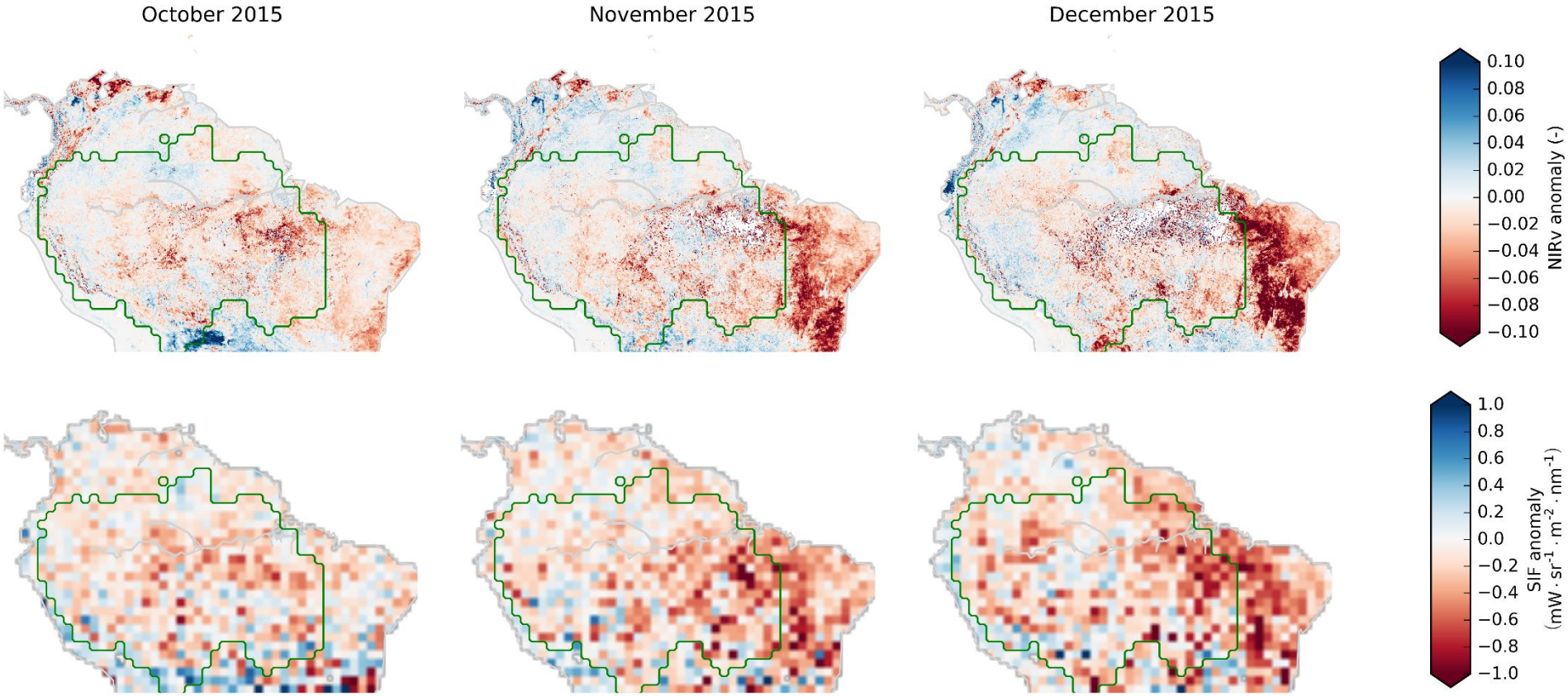
- Climatology based on years 2007-08-09, 2011-12-13-14 (N = 7)
- Shading indicates 1 sigma spread in the climatology
- Further analysis for different sub-regions will be made

2015/2016 Amazon drought



- '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)

Summary

Conclusions:

- GFAS emissions should be increased over Amazon region (based on CO obs. from IASI and TM5-4DVAR system, Stijn Naus)
- CTDAS posterior CO_2 mole fractions agree better with observed CO_2 profiles than the prior CO_2 profiles
- SIF and NIRv show reductions during droughts and show good agreement in their temporal and spatial patterns

Future work:

- Use different priors for CO_2 forward runs and inversion
- Extend CO_2 simulations over later years
- Continue ground based validation for SIF and NIRv