Amazon Basin-wide fluxes of CO_2 and CH_4 from aircraft vertical profiles (*with support from CO and SF_6*)

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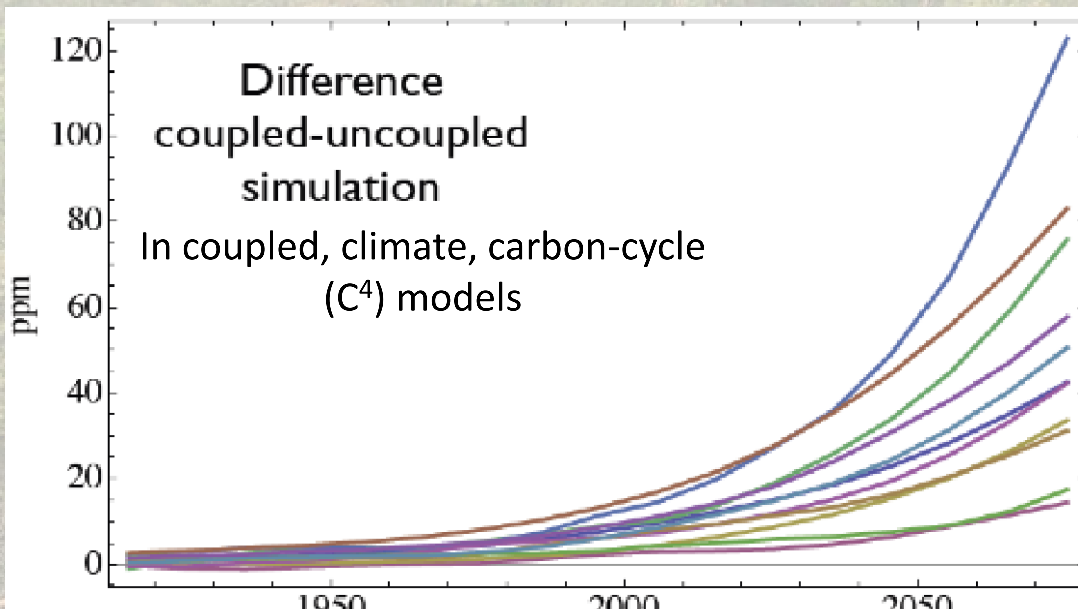
Amazonian (and tropical) C-cycle is critical to understanding the global C-cycle

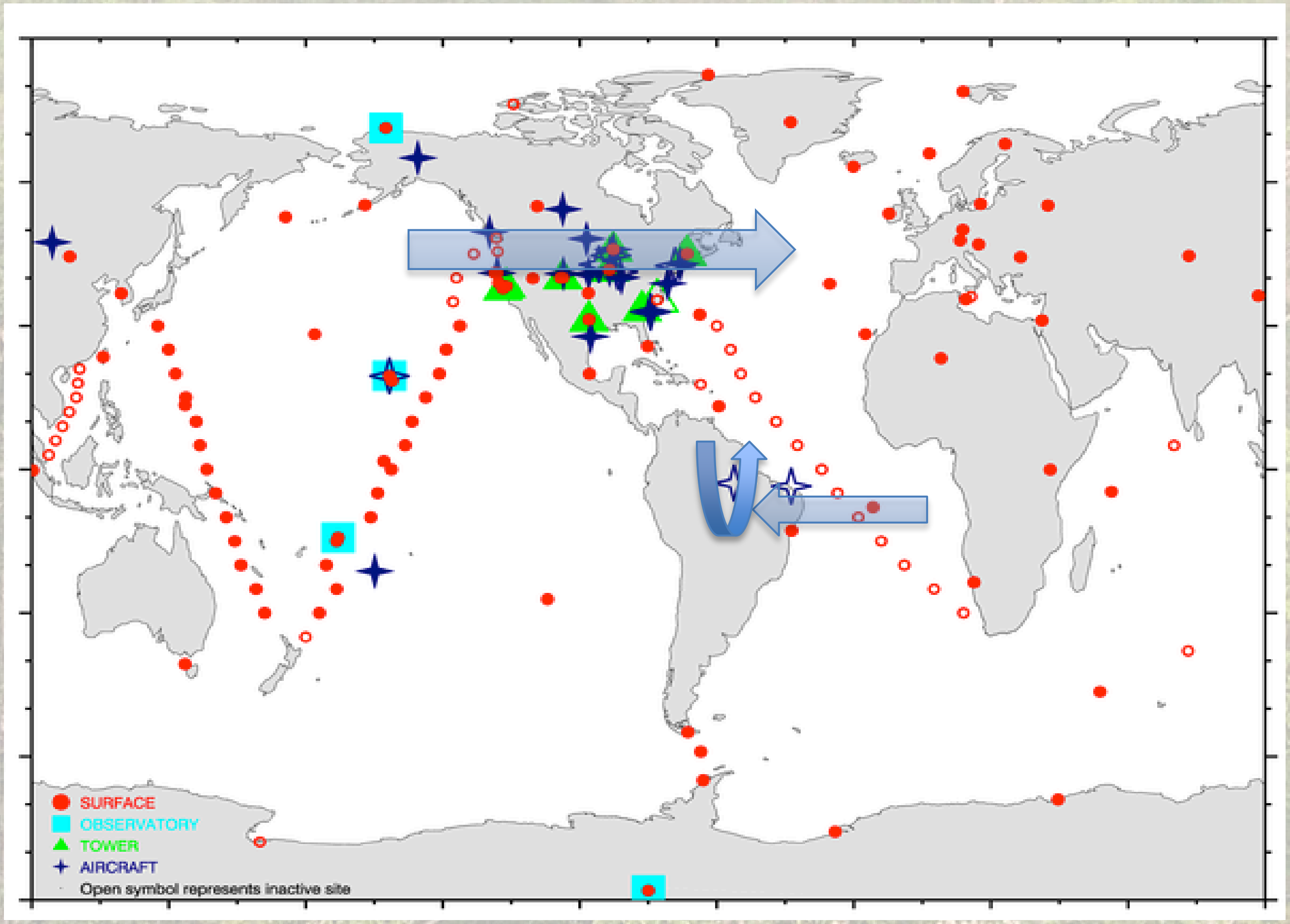


Friedlingstein et al, 2006, J. Clim.

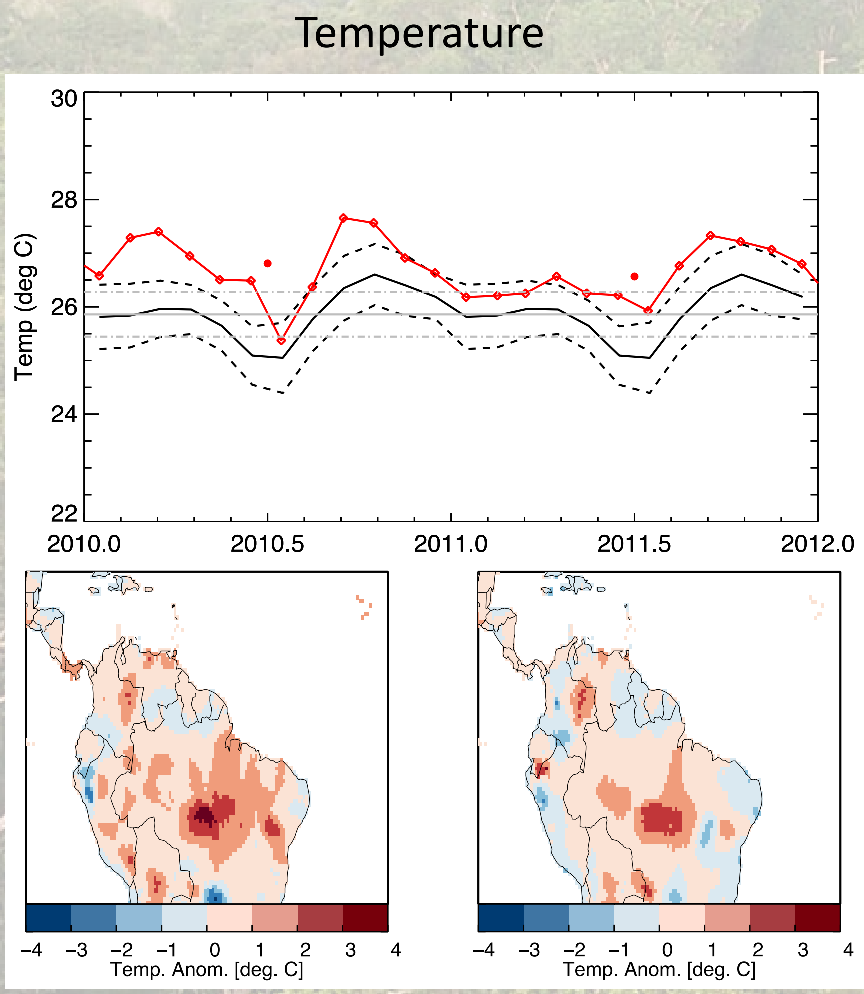
This spread, a ***first-order uncertainty in climate prediction***, is **largely a function of Amazonian response to climate.** (Fire, deforestation, hydrological feedbacks all play a role).

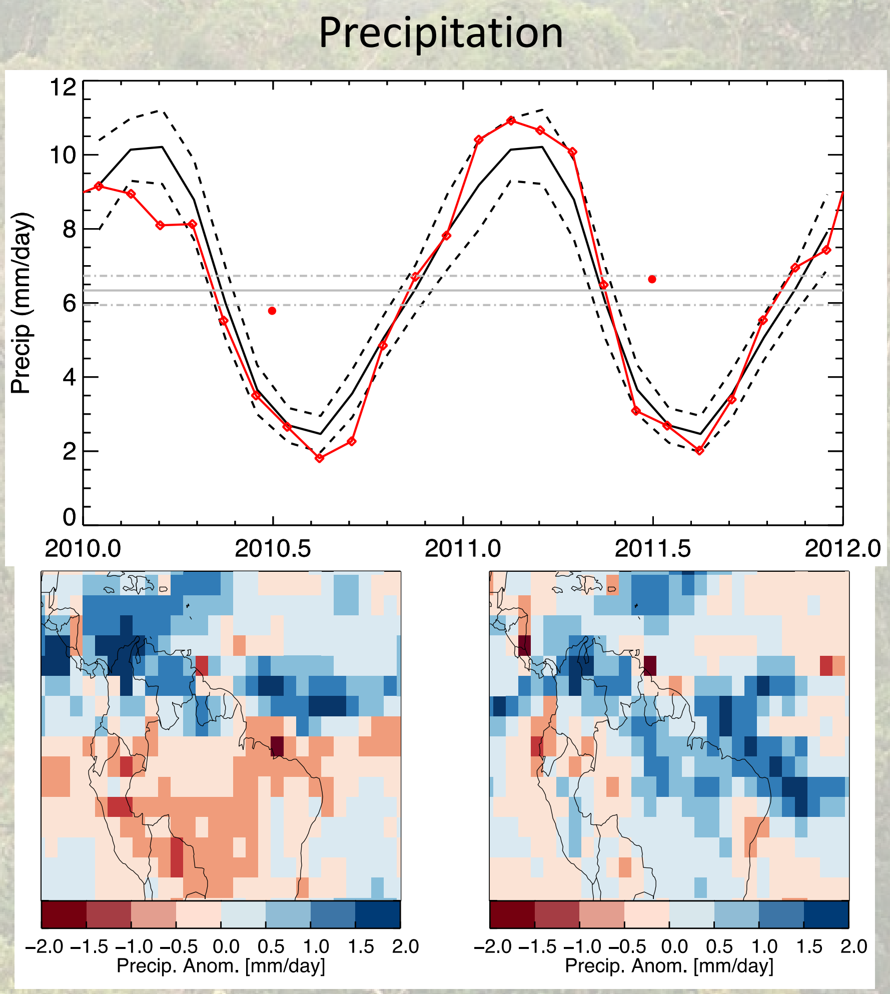
→ We can quantify relationships between Carbon flux and climate over annual to decadal periods with accurate observations of both.

Amazonian C fluxes are underconstrained, because we don't have enough obs in the right places



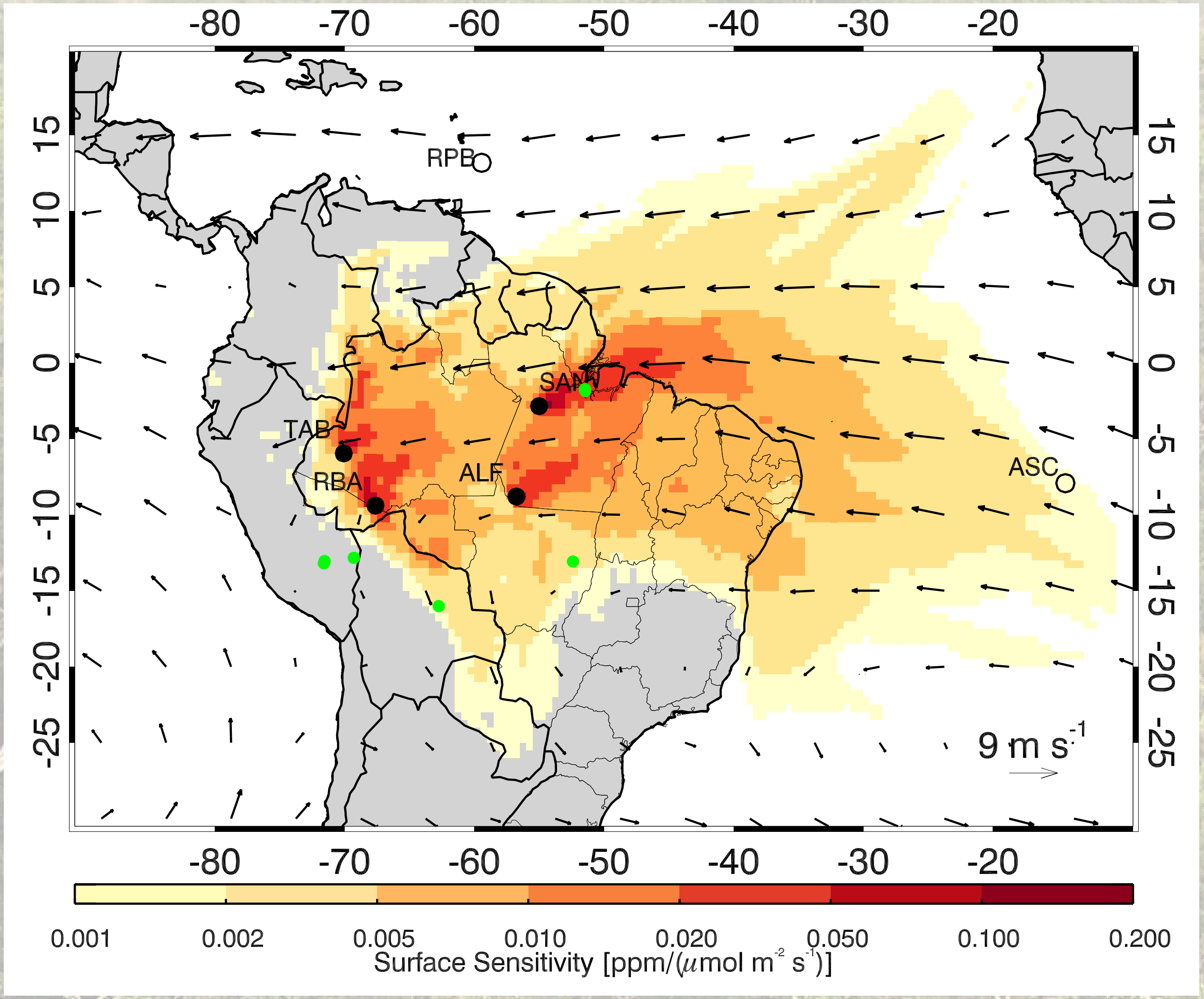
Large Temp and Moisture Anomalies in 2010; 2011 returned to 'normal'





Gatti et al., Nature, 2014

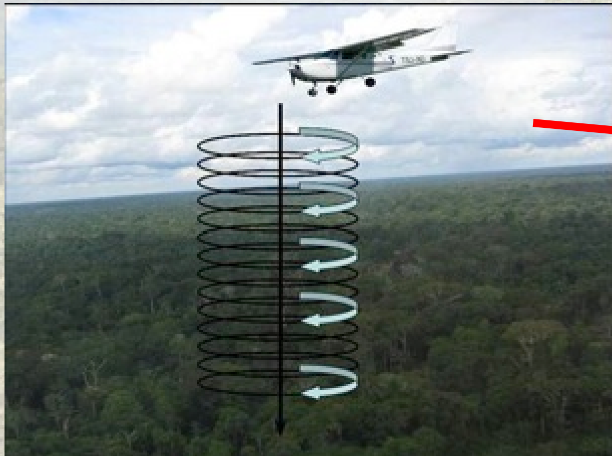
Aircraft vertical profiles sensitive to a large fraction of Amazonia.

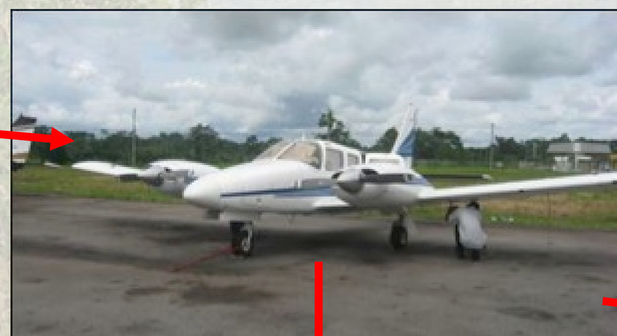


Gatti et al., Nature, 2014

- Aircraft vertical profiles from the surface to 4.4 km
- Sampling every two weeks.
- Measurements of CO2, CO and SF6 (also other gases) at Gatti lab in Sao Paulo.
- → Measurements are differenced from Atlantic sites.

Vertical profiles are collected using light aircraft

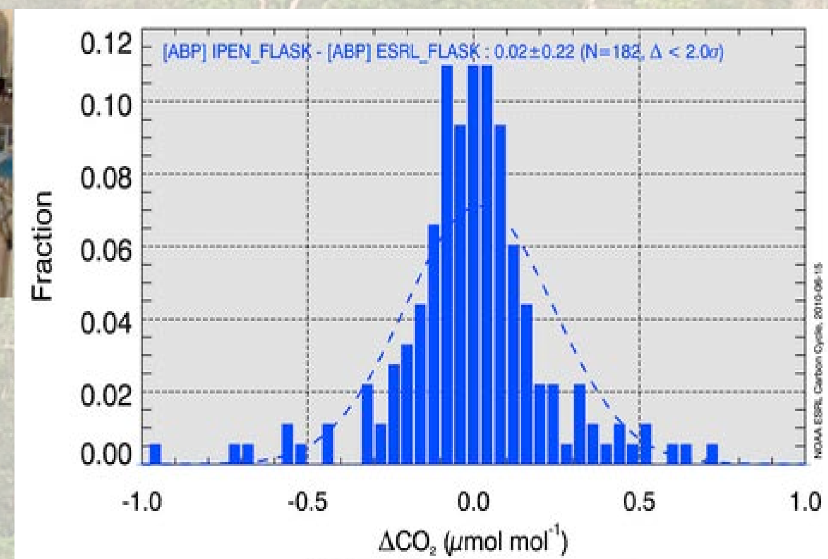


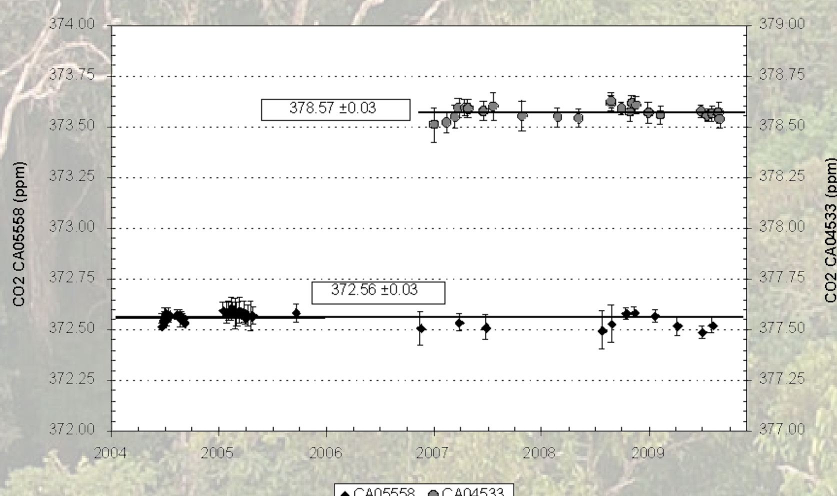


Analysis system at Gatti Lab in Sao Paulo

PFP and PCP

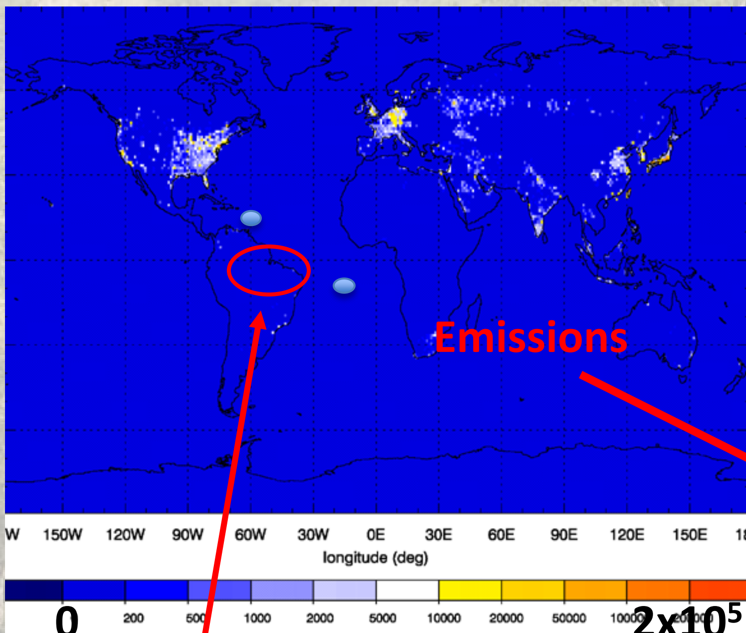
IPEN measurements are highly precise and compatible with NOAA's





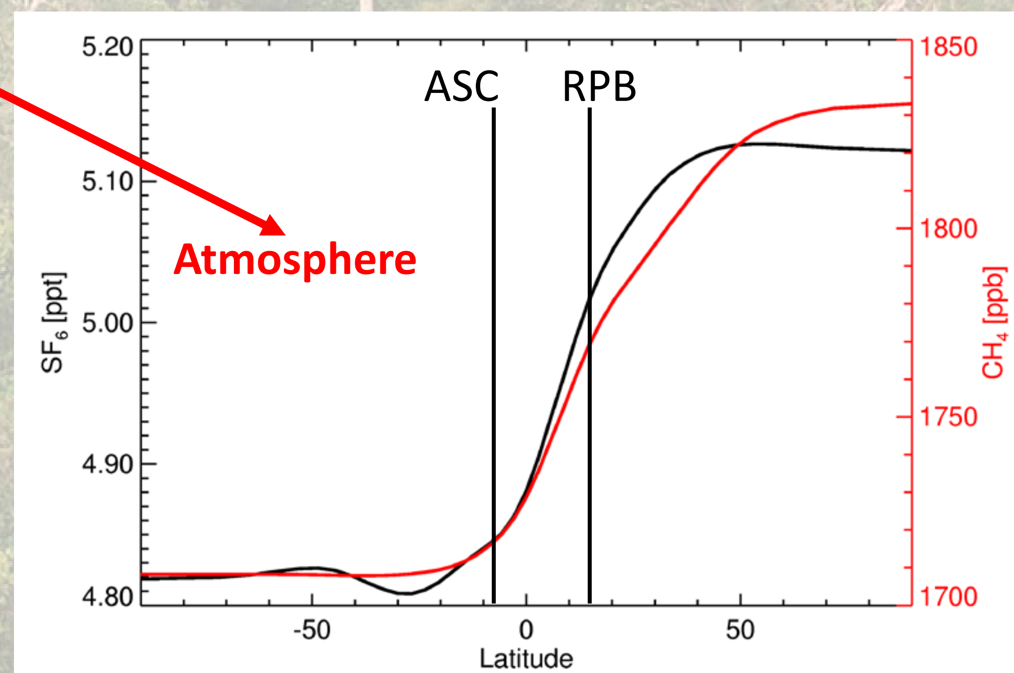
Long term stability and accuracy better than 0.1 ppm (2 sigma).

Calculation of Amazonian site background using SF_6

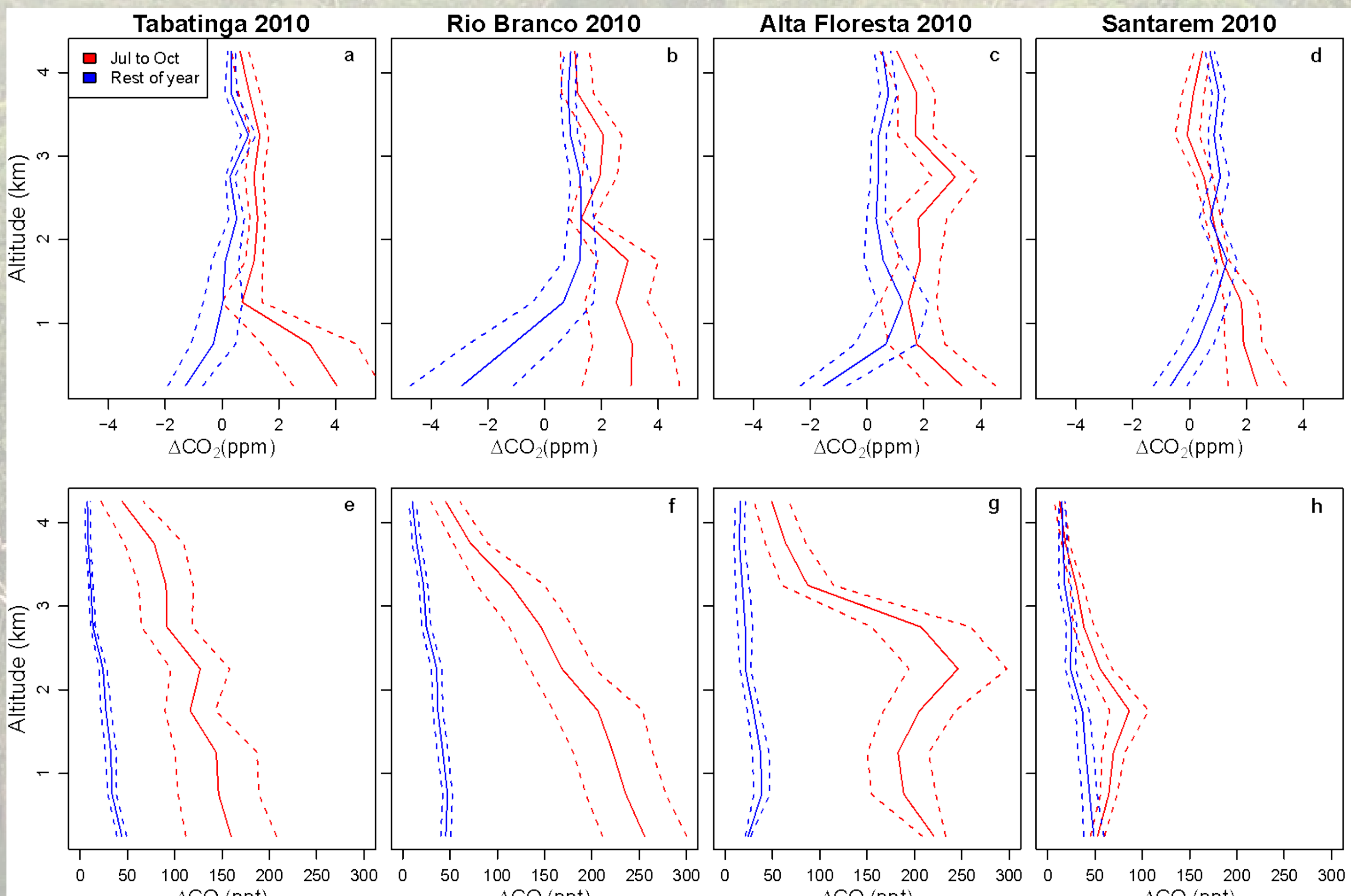


'No' SF6 Emissions in Amazonia

- → By comparing vertical profiles of SF_6 with background SF_6, we can determine the relative influence of Northern and Southern Hemisphere air.
- → These fractions can then be applied to other gases to determine their background.



Average CO_2 and CO profiles by season show wet season uptake and dry season emission – but dry season emission is largely due to fire.



$\Delta CO2 = CO2_{site} - CO2_{background}$

How we calculate fluxes of CO2 and CO…
…a 5 millon km² flux chamber (with a leaky top)

$$F_X = \int_{z=0(agl)}^{4.4\,km(asl)} \frac{\Delta X}{t(z)} dz$$

$$F_{CO_2}^{NBE} = F_{CO_2}^{tot} - F_{CO_2}^{bb}$$

$$F_{CO_2}^{bb} = r_{CO_2:CO}^{bb} (F_{CO} - F_{CO}^{bio})$$

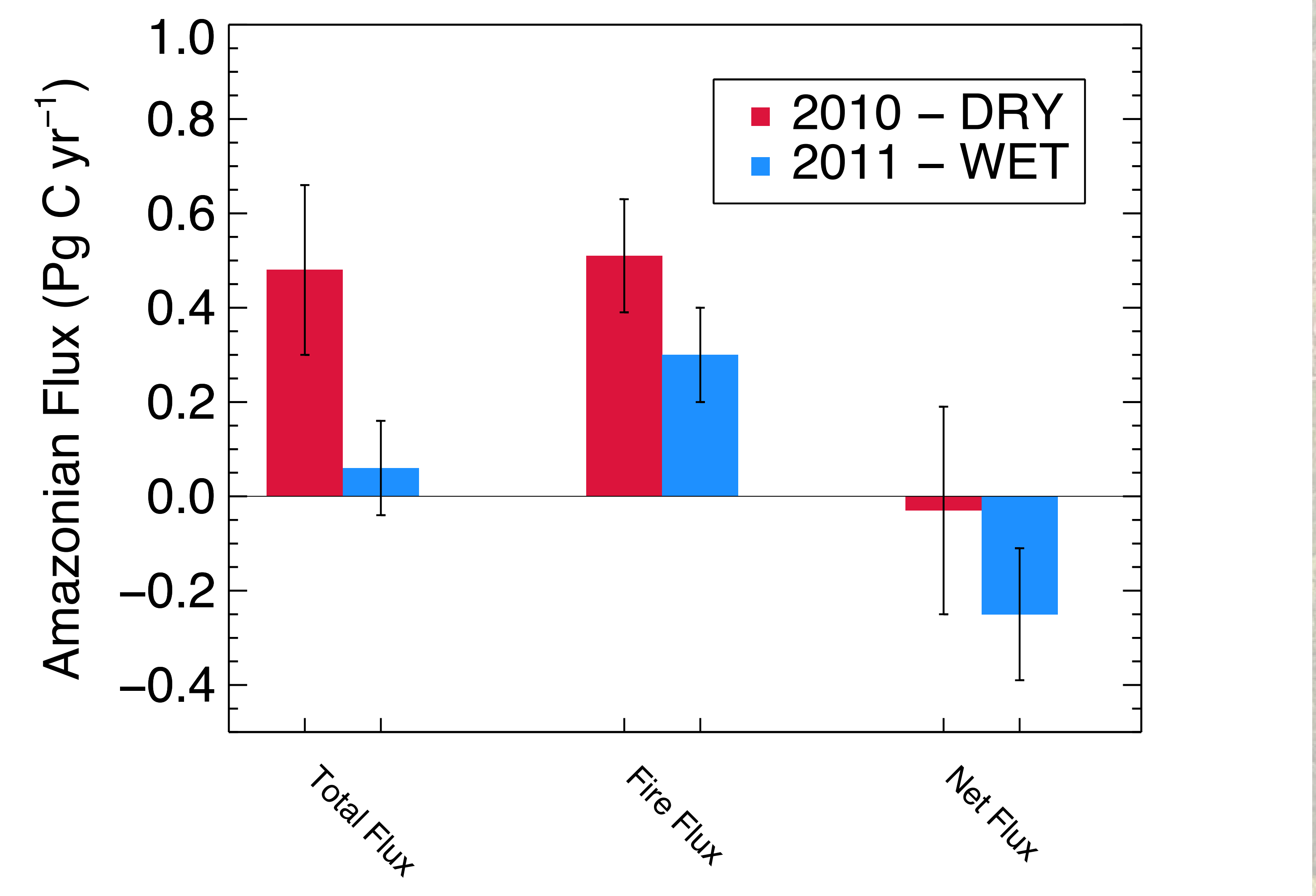
$\Delta X = X_{site} - X_{bg}$

t = residence time of air on continent

$r_{CO2:CO}$ = emission ratio of fires
(detected from obvious fire plumes)

$F_{CO}^{bio} = F_{CO}$ in wet season

Basinwide CO_2 Fluxes

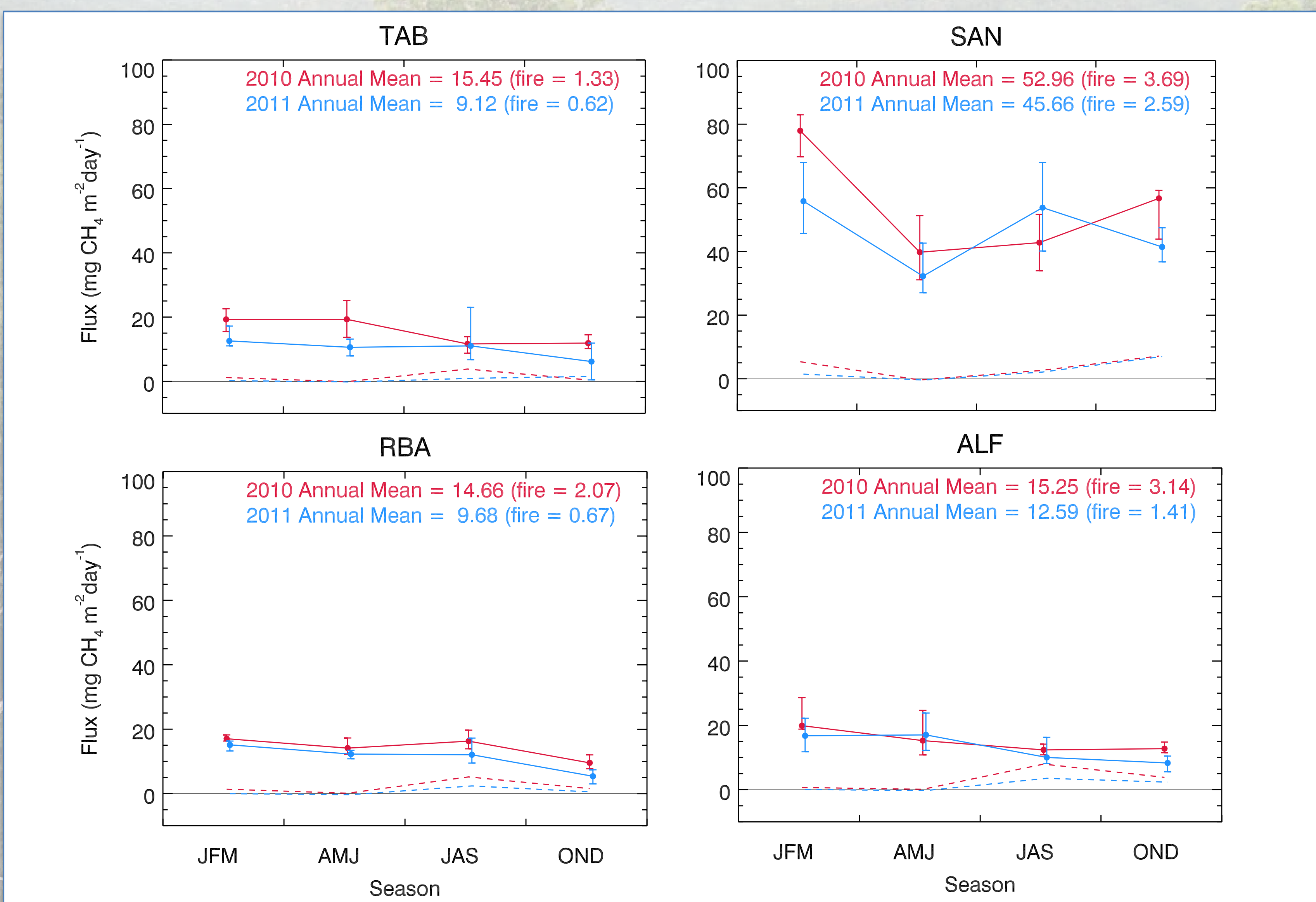


Gatti et al., Nature, 2014

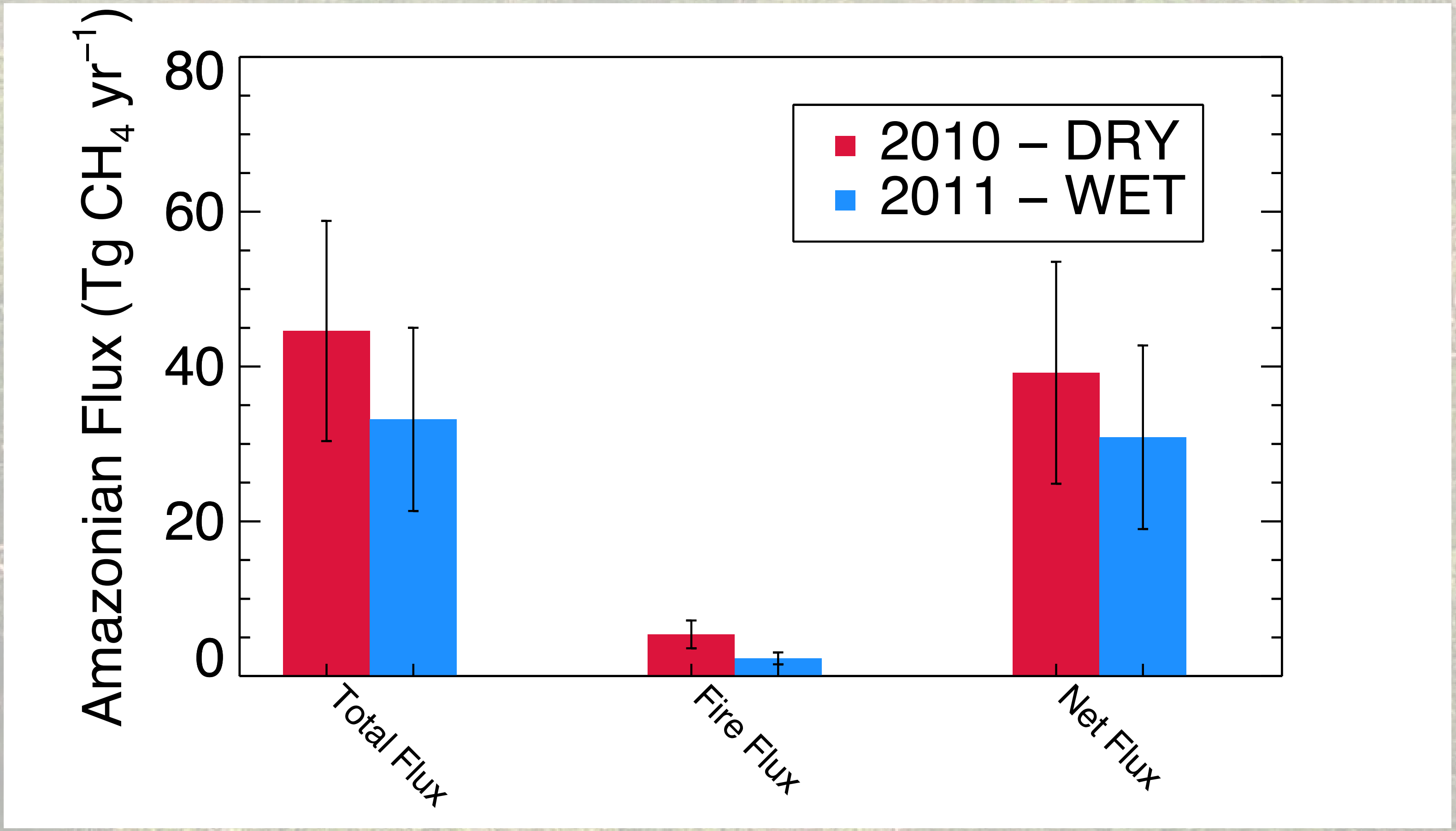
Comparison to independent CO_2 fluxes

1. RAINFOR forest inventory plots give long term uptake of -0.4 PgC/yr
    1. We find -0.25 in 2011, but this includes deforestation respiration. (i.e. deforestation is more than just fire.)
    2. If we assume a 2:1 ratio of fire:respiration in deforestation, then F_{NEE} = -0.25 – 0.3/2 = -0.4
2. GFED fire emissions are +0.5 and +0.1 PgC/yr in 2010 and 2011.
    1. We observe +0.5 and +0.3 PgCyr.

Basinwide CH_4 Fluxes



Basinwide CH_4 Fluxes



Comparison to independent CH_4 fluxes

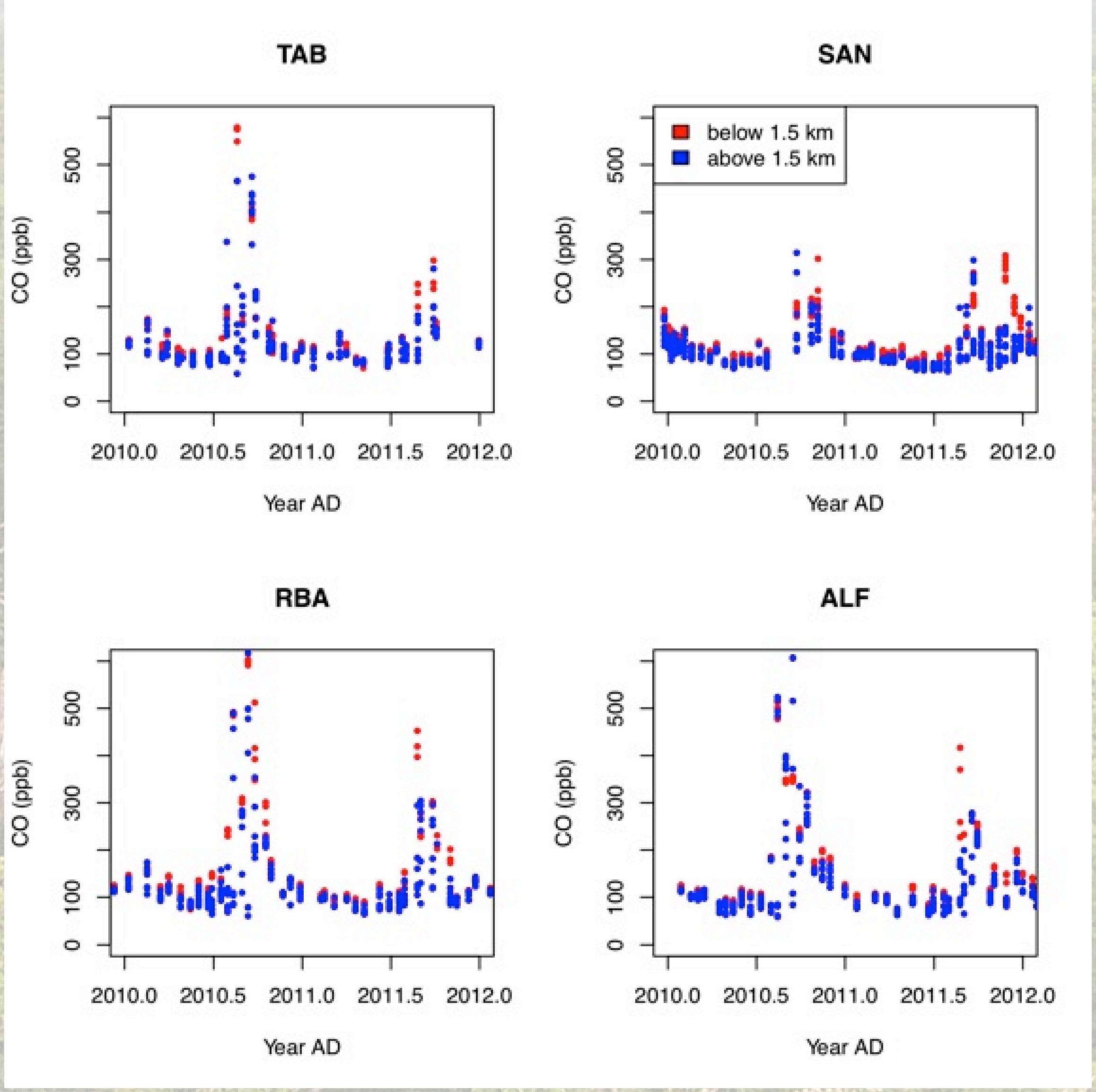
1. Kirschke et al (2013) Tropical S. America
   1. Top-down: 20-45 Tg CH4/yr
   2. Bottom-up: 40-90 Tg CH4/yr
   3. *This study: 30 and 40 Tg CH4/yr*
2. Bottom-up models can not reproduce the spatial pattern we see: high fluxes in the east.
3. Will modeled fluxes show higher emissions in 2010 than 2011?

Conclusions

1. CO_2
   a. Moisture may be more significant than temperature in controlling Amazonian CO_2 flux (in contrast to Cox et al, Nature, 2013)
   b. Leaky box top – how does convection impact fluxes? More work needed to quantify these losses. Seasonality is likely bigger than currently estimated.
   c. Basinwide seasonality shows wet season net uptake.
2. CH_4
   a. Basinwide fluxes are similar to other top-down estimates, but spatial patterns are different.
   b. Higher 2010 (dry year) fluxes remains a mystery.

→ *Sustained monitoring is needed to understand climate – carbon relationships (and thus have some confidence in future predictions).*

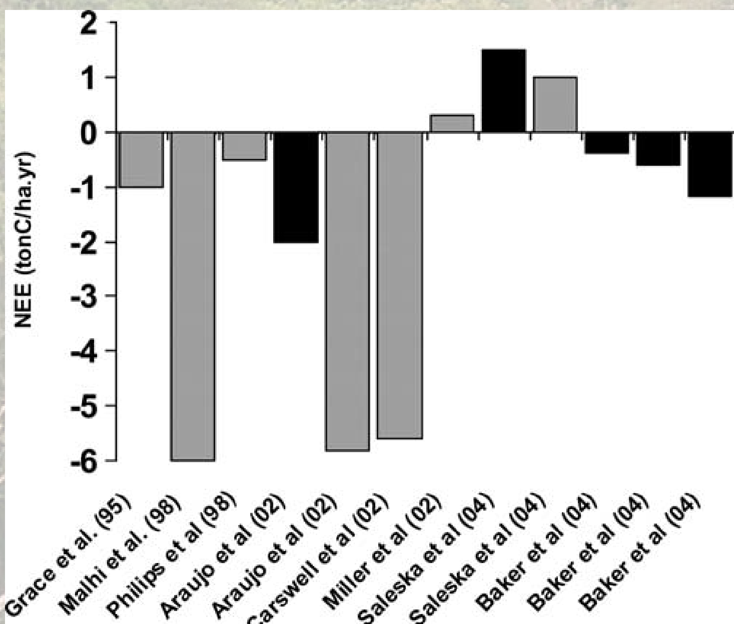
CO time series



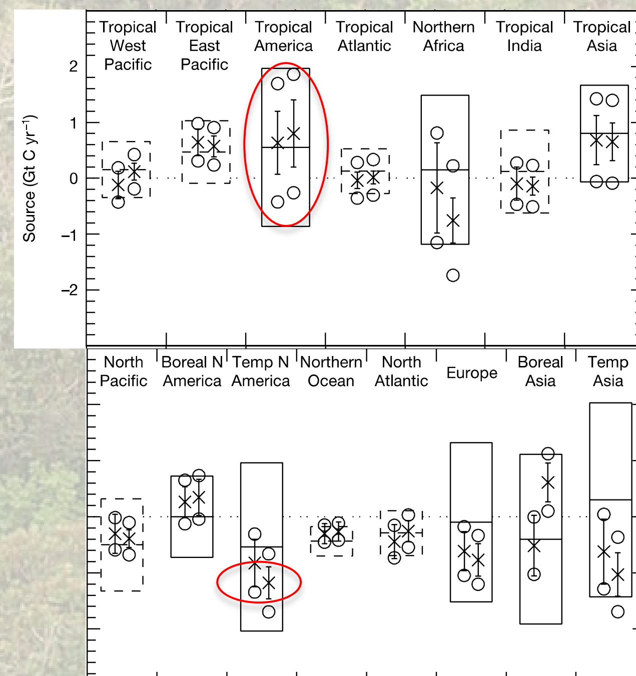
Amazonian C flux is currently woefully under-constrained

The "Residual dumping ground" of global inversions

-- Prof. Denning



Ometto et al., 2005, Oecologia



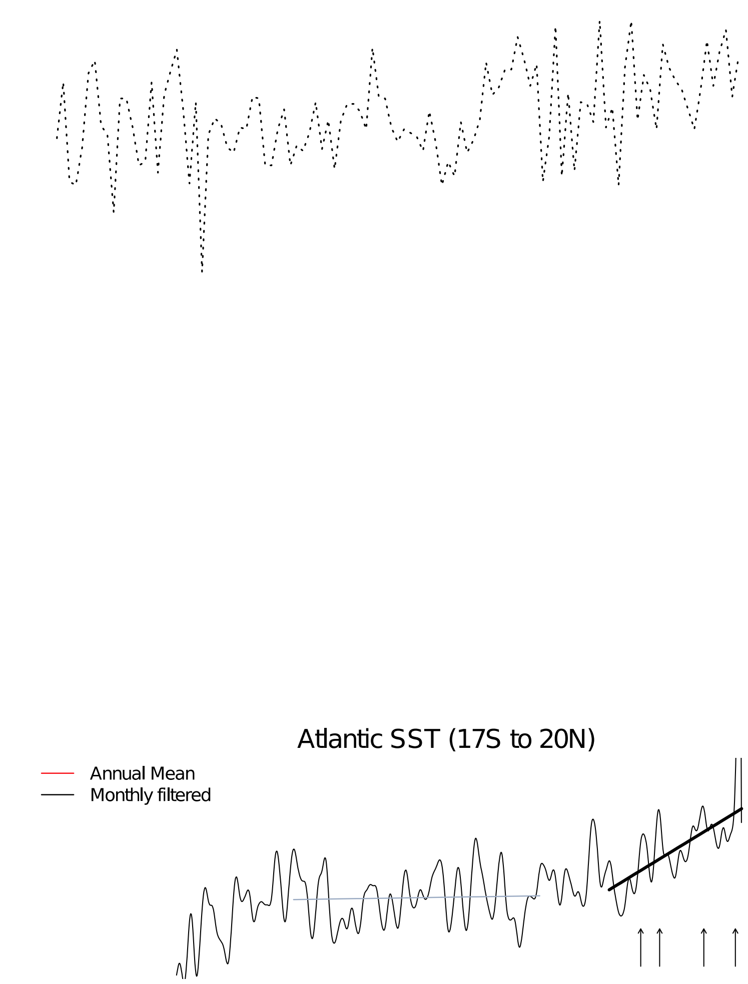
Gurney et al., 2002, Nature

S. American estimates vary widely

…not so for the temperate north, especially in the last ~ 5 years (more obs).

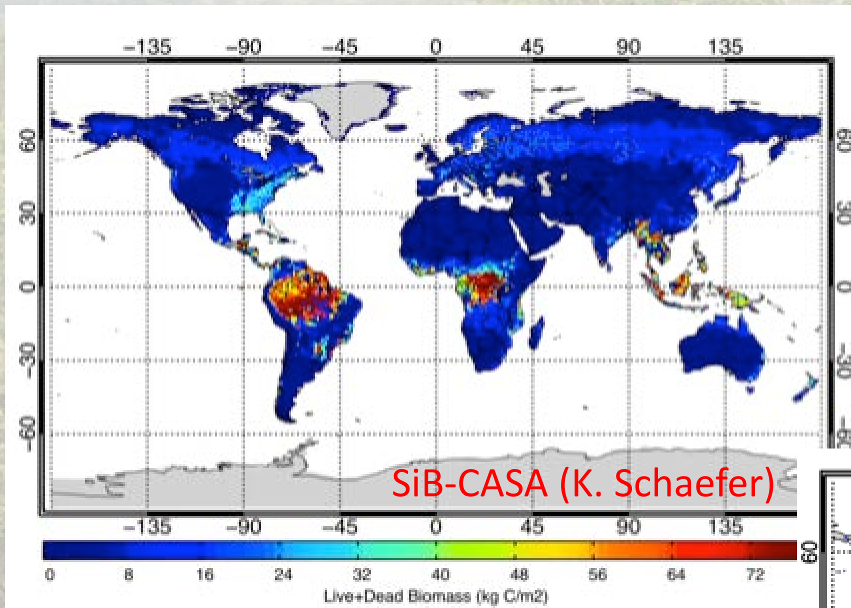
Large Trends in Amazonian Climate

- Amazon temperatures rising over the last 20 years
- as everywhere else rising CO_2
- and there are also changes in the hydrological cycle: general upward trend, with dryer dry seasons and wetter wet seasons



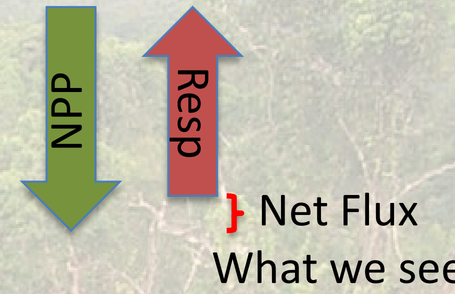
Gloor et al. 2013, GRL

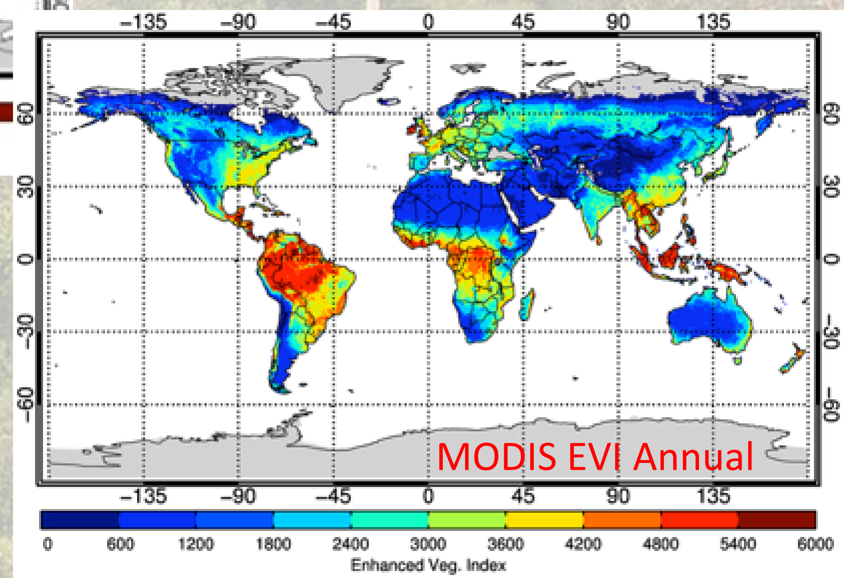
Amazonian (and tropical) C-cycle is critical to understanding the global C-cycle



Stocks… (~25%)

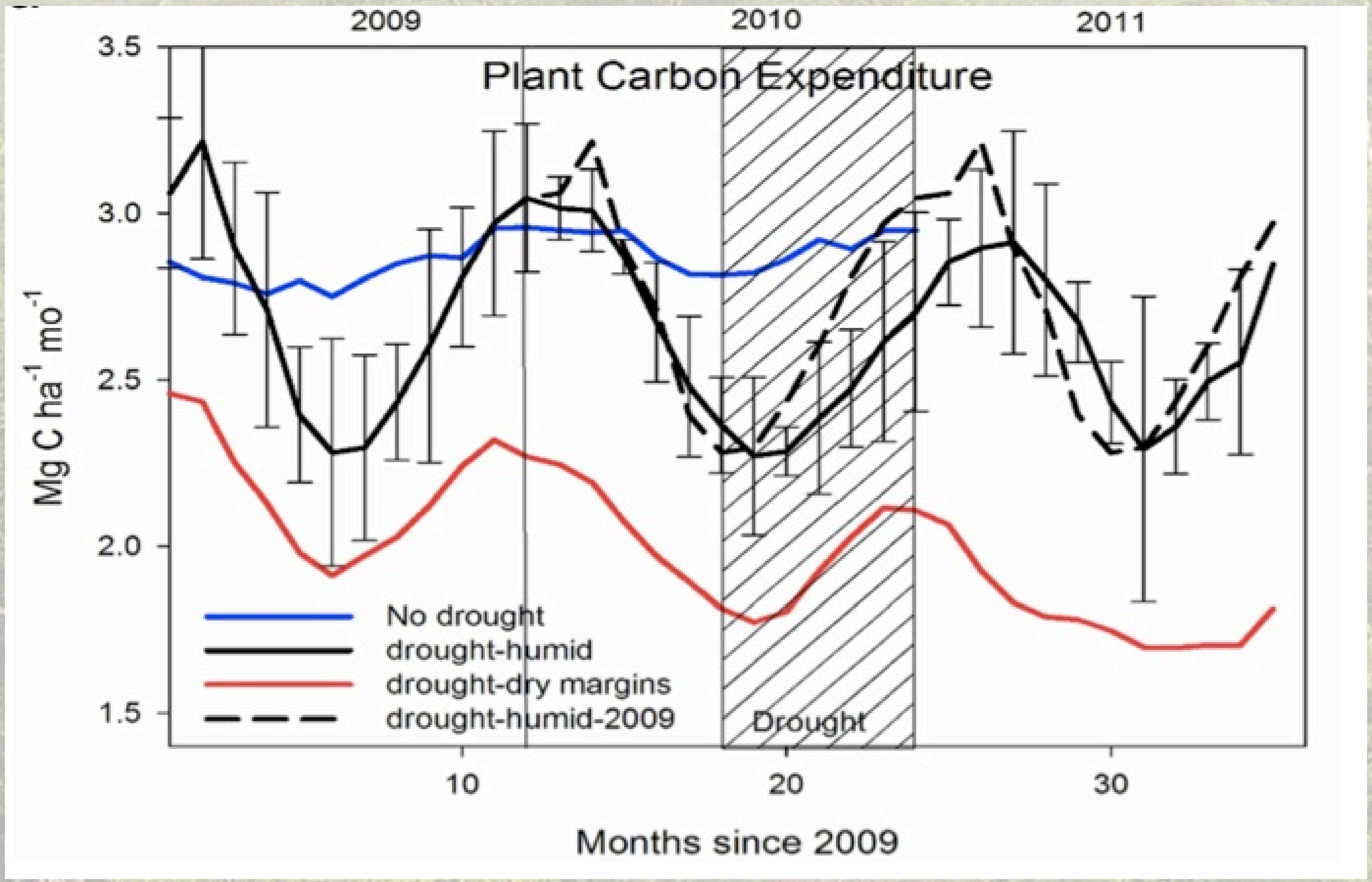
While stocks and gross fluxes aren't predictors of net fluxes, they are keys to capacity for future changes.





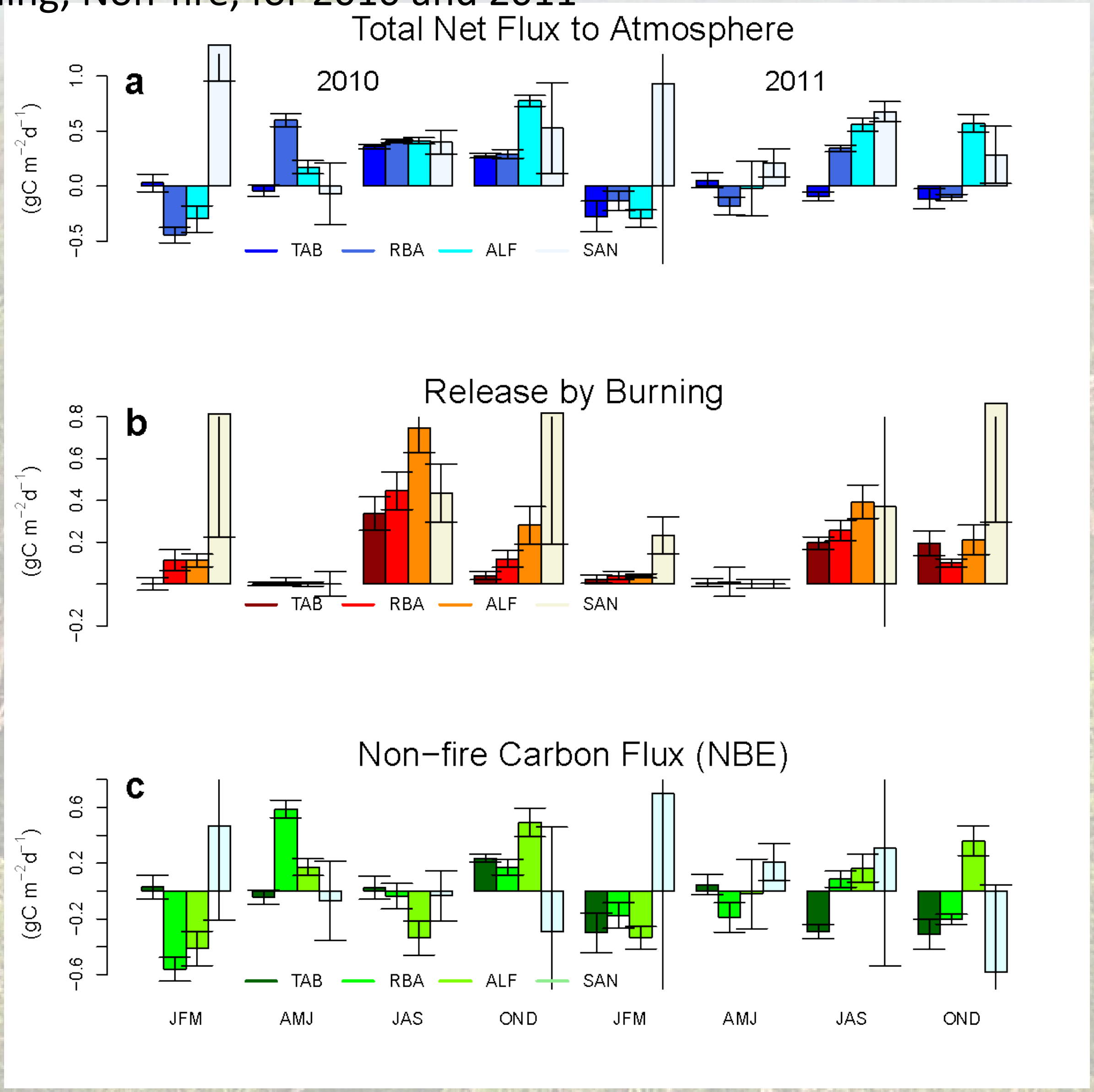
…and Gross "Fluxes" (~15%)

Intensive Forest Plot Results show drought suppressed GPP in 2010.



Plant Carbon Expenditure = NPP + R_{auto} ≈ GPP

Flux signals observed by site. -- Make new bar graph showing Basin Averages Total, Burning, Non-fire, for 2010 and 2011



Basinwide Fluxes

Sites