Amazon Column CO_2 Observations from Ground and Space to Evaluate Tropical Ecosystem Models

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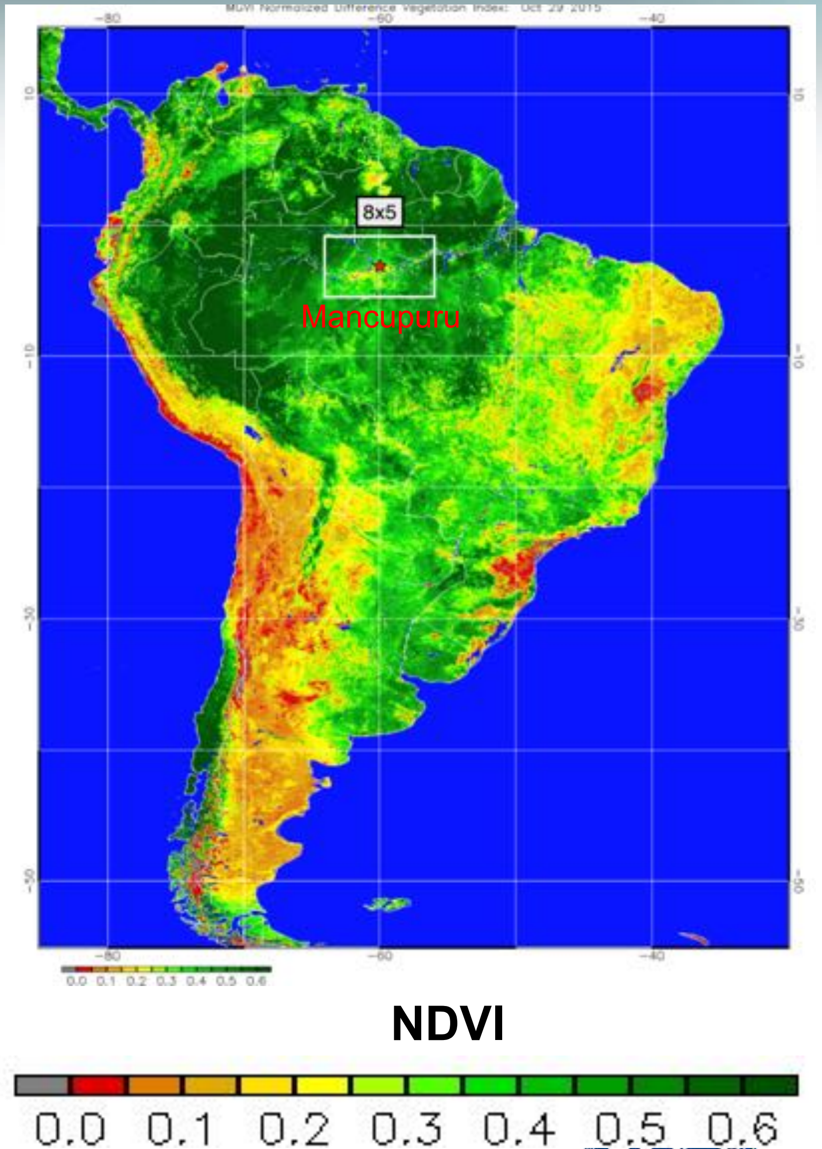
Evaluate Amazon Carbon Cycle Mechanisms

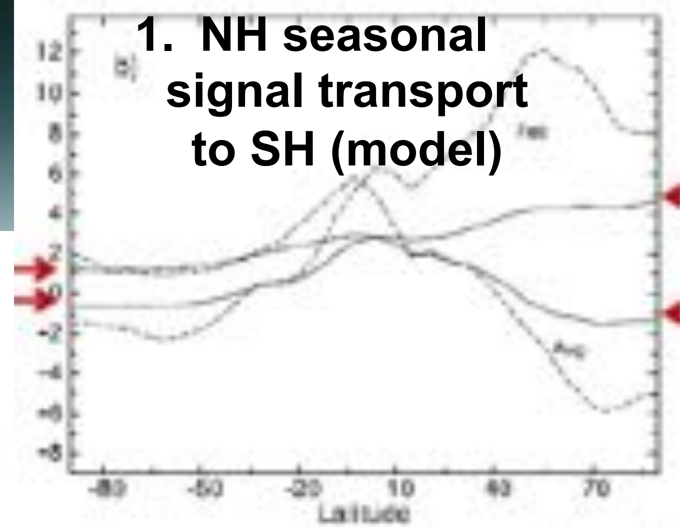
- Amazon Carbon Budget
  - Biomass burning emissions and rainforest uptake
- Leaf phenology explain *in situ* Amazon tower seasonal data but are missing in models: Does this scale up?
- TCCON-Manaus X_{CO2} Seasonal Cycle
  - Isolate rainforest from fire (CO), trend & transport terms
- TCCON-Manaus X_{CO2} Daytime Drawdown
  - Isolate photosynthesis from respiration
- TCCON – OCO-2 Comparisons

Tropical Carbon-Climate Feedback Uncertain: Large Reservoir, Dynamic Fluxes, Multiple Sources, Sparse Data

- Stores 150-200 PgC
- Cycles 18 Pg C/y
- Large CO_2 sources & sinks
- Uptake '90-'07 ~0.5 PgC/y
- Processes at daily, seasonal & decadal time scales from fires, rainforest & land use change
- Need to scale 'sparse fine-scale" data to coarse GCM grid and evaluate predictions of Amazon carbon cycle response to climate & land-use change.
- Leverage NGEE-Tr & OCO-2

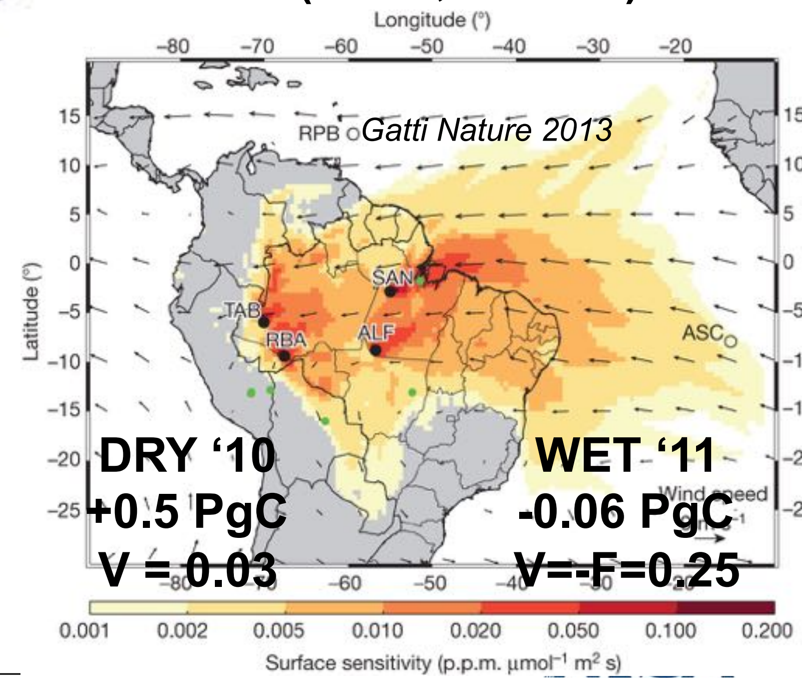


Processes Controlling Column CO_2 Variations in Amazon



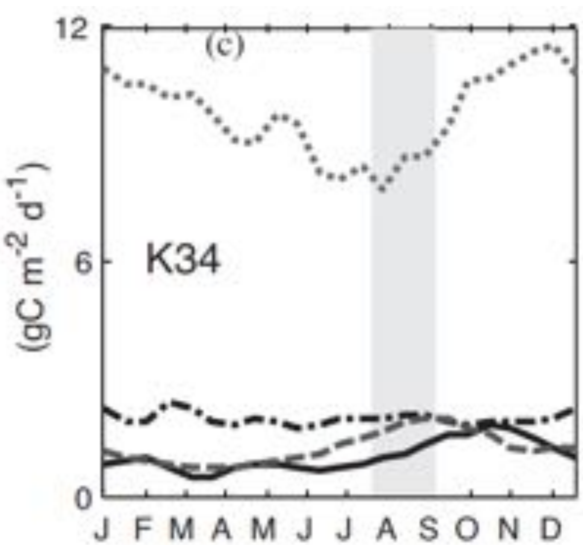
Olsen & Randerson, JGR, (2004)

2. Basin budgets (zonal, aircraft)



3. Local uptake, Leaf phenology (tower) & Fire

N. Restrepo-Coupe Ag. For. Met. 2013
Wu Science 2015



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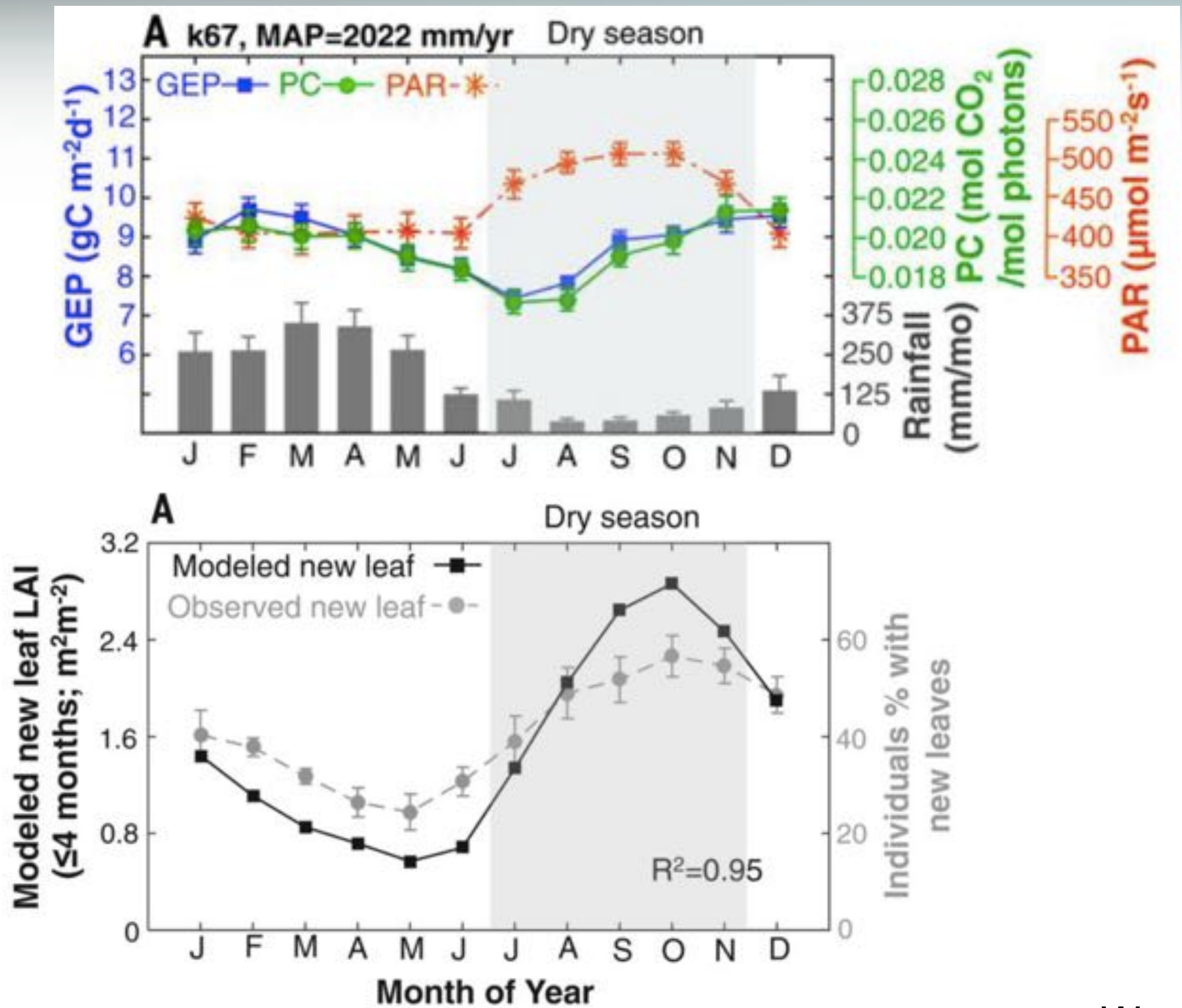
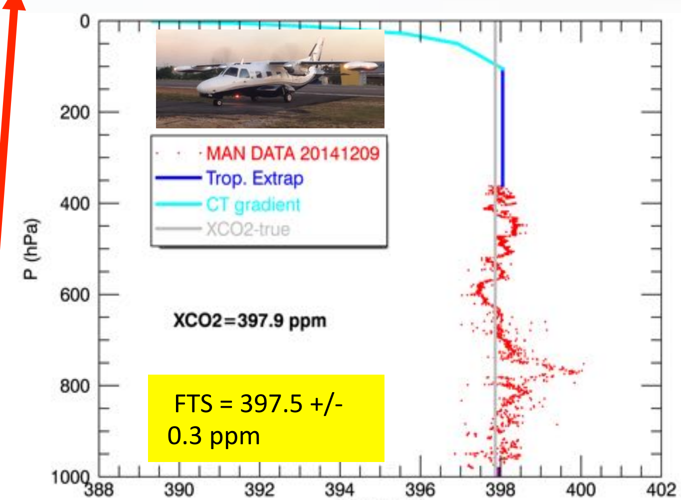
Leaf development & demography explain photosynthetic seasonality in Amazon evergreen forests

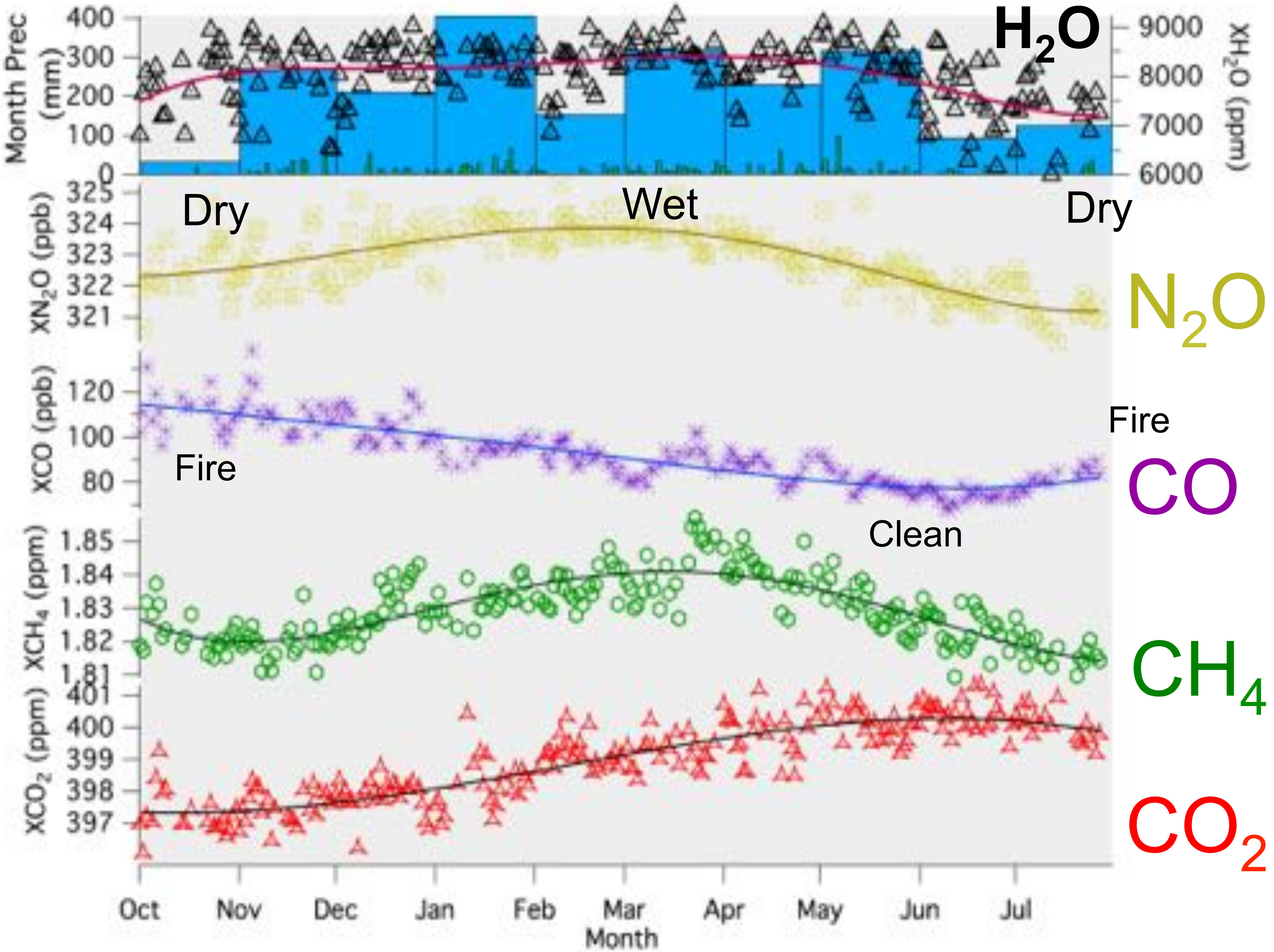


Wu *et al.* *Science* **2016**

TCCON in Amazon Rainforest Oct 14 – July 15

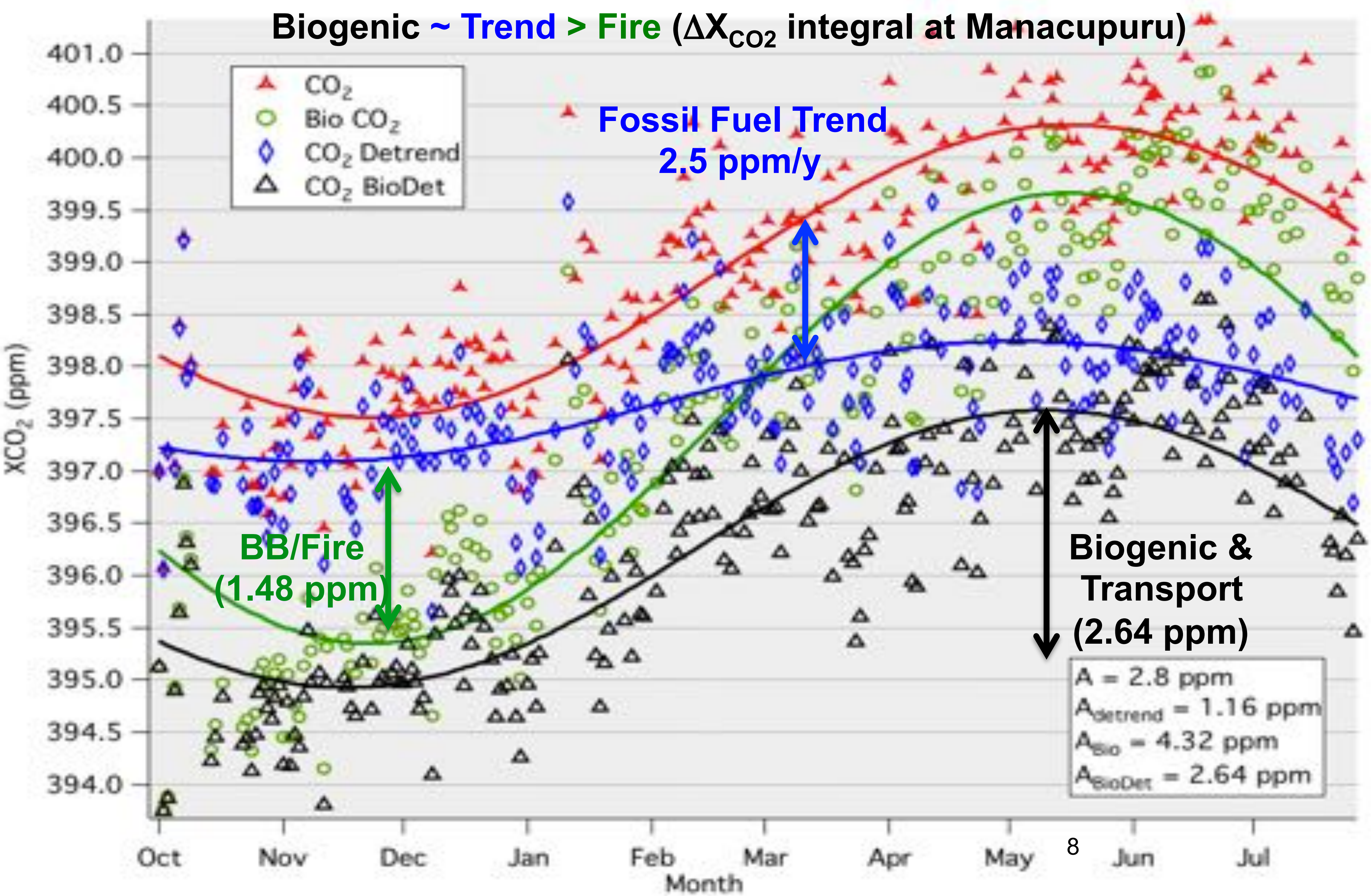
- Measure column dry column mixing ratios of trace gases to evaluate models
- Seasonality of CO_2, CO, CH_4, N_2O, H_2O and HOD.
- Delineate CO_2 changes from global secular rise, biomass burning & rainforest uptake.
- Evaluate CO_2 seasonal change in OCO-2 data.
- Compare seasonality and daily photosynthetic uptake with optimized carbon transport models



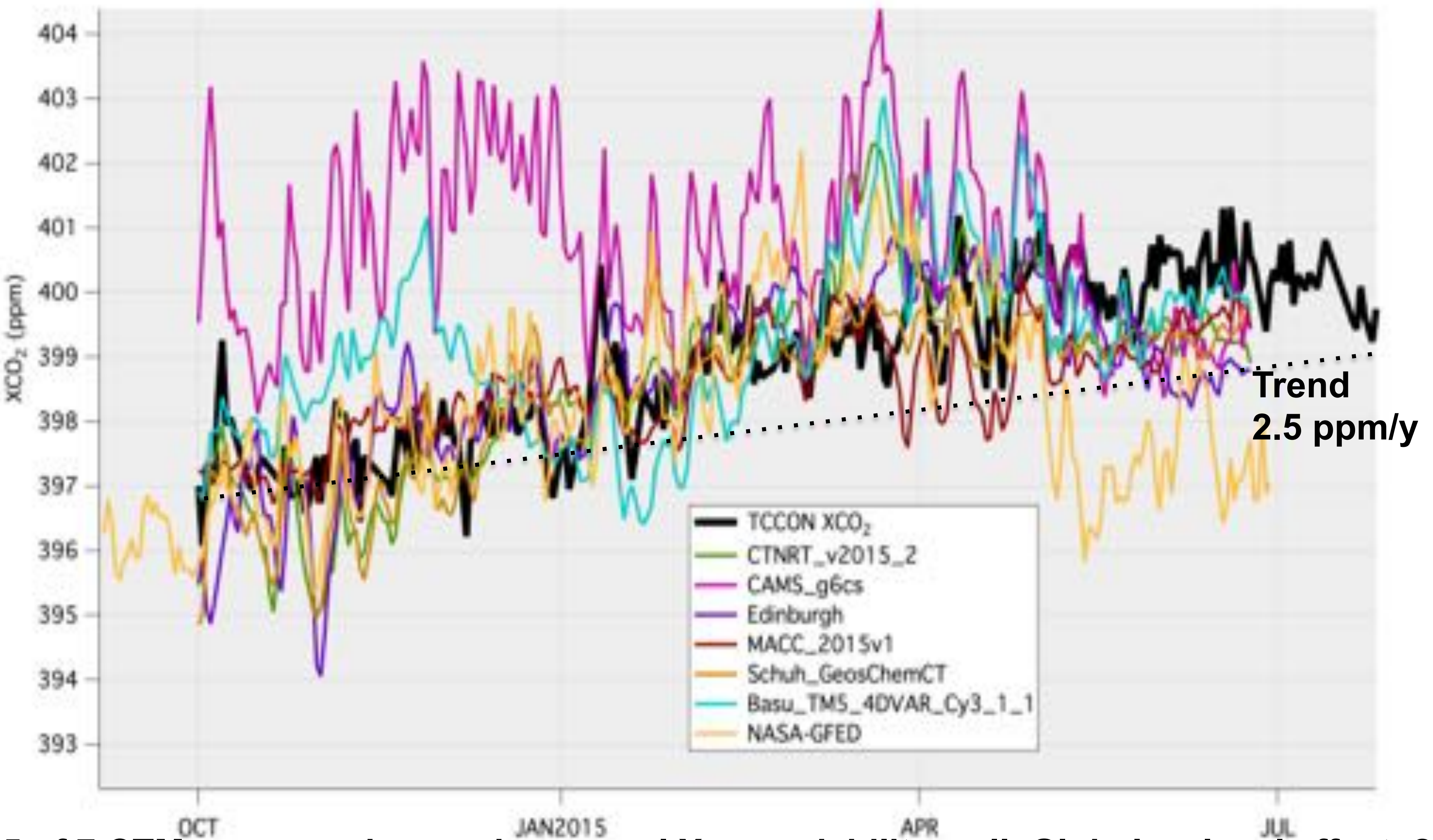


H2O
Month Prec (mm)
XH2O (ppm)
Dry
Wet
Dry
N2O
XN2O (ppb)
Fire
Fire
CO
XCO (ppb)
Clean
CH4
XCH4 (ppm)
CO2
XCO2 (ppm)
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Month

Decompose X_{CO2} (t): Detrend (-2.5ppm/y) and subtracting fire contributions (CO) to get biogenic



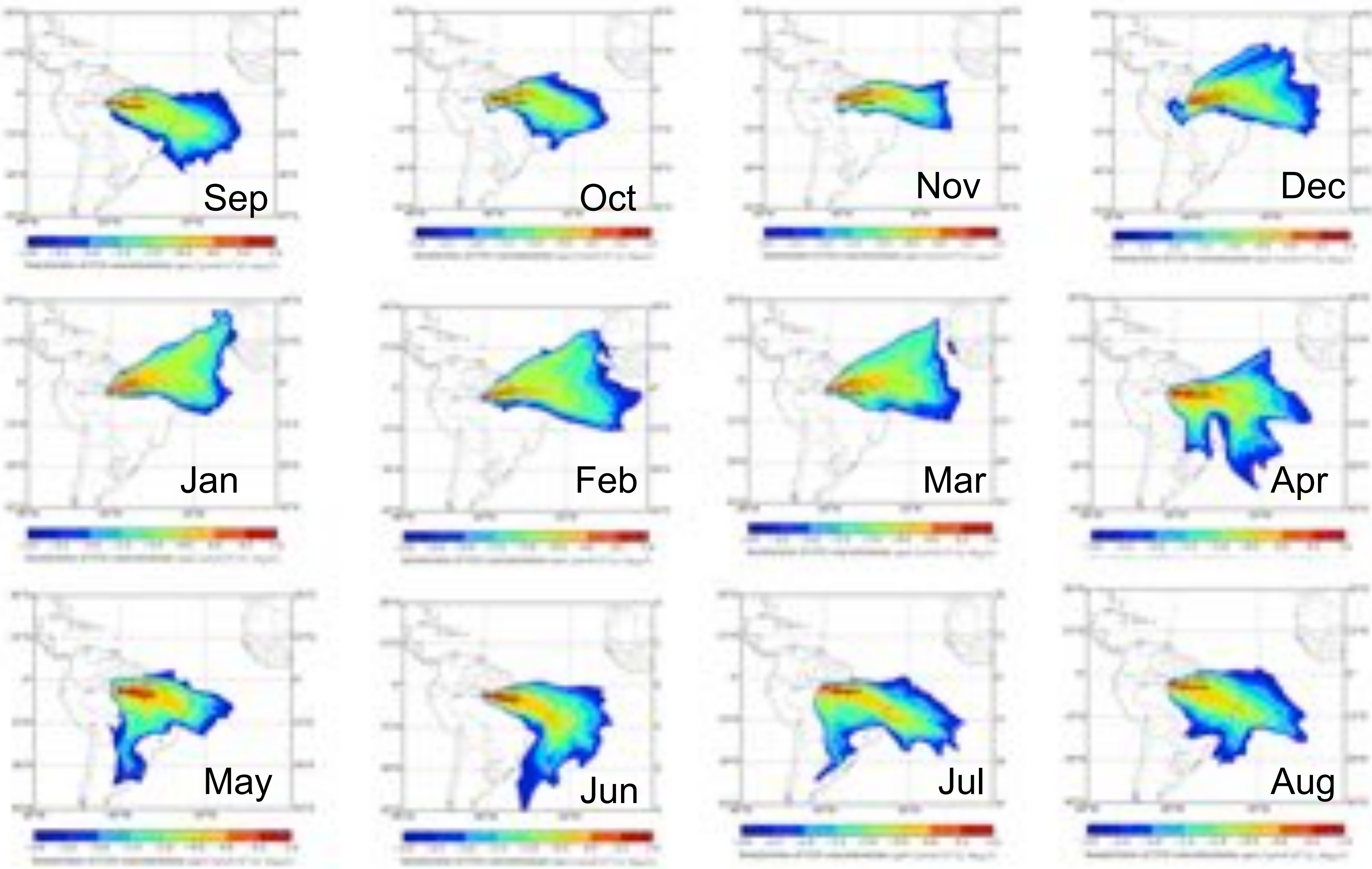
TCCON Seasonal Observations Compared with "Optimized" Global Transport Models (14-15)



5 of 7 CTMs capure observed seasonal X_{CO2} variability well. Global vs local effects?

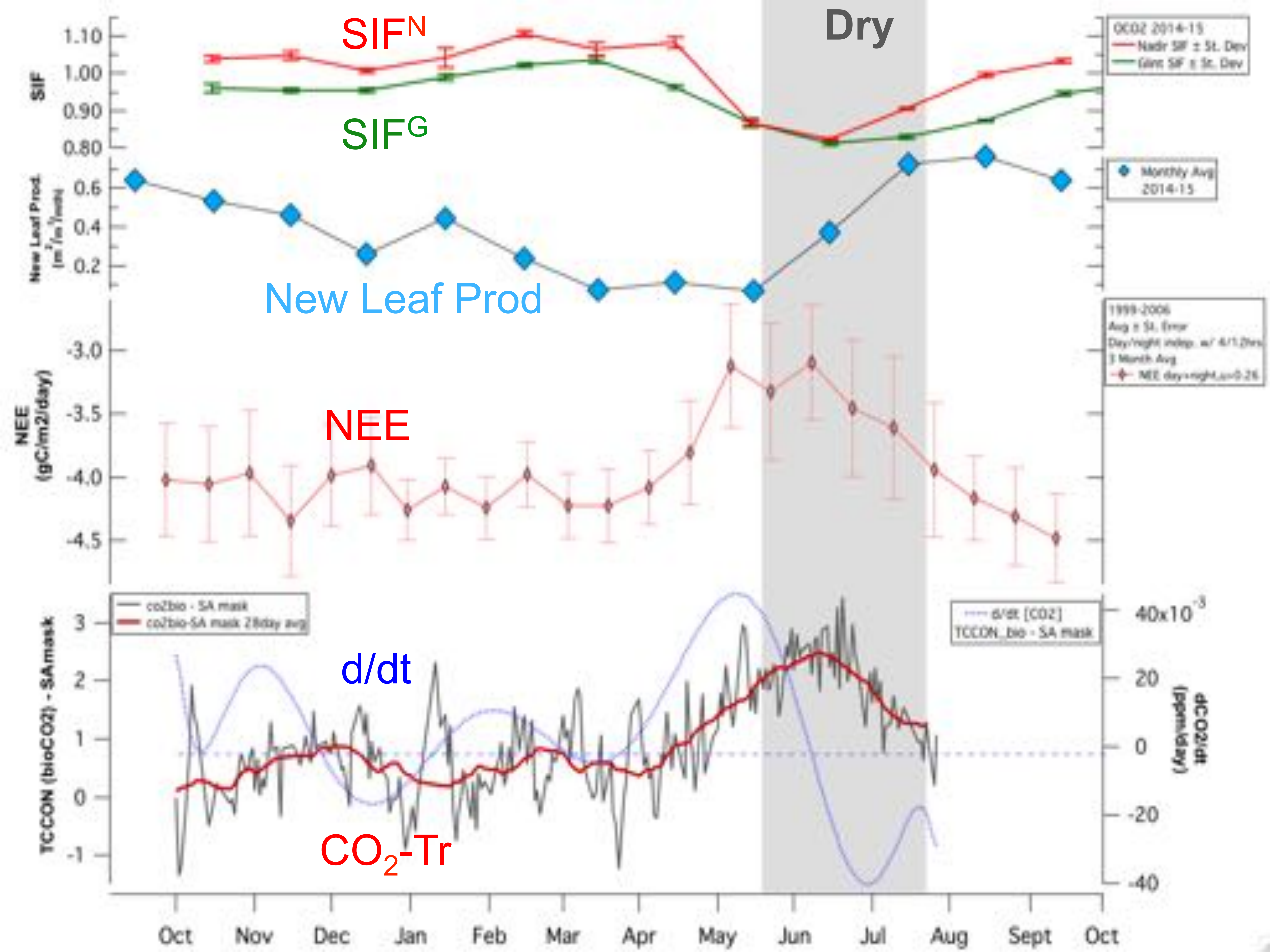
Manaus Footprint (3 day): Transport Affects X_{CO2}

Belikov et al ACPD 2016



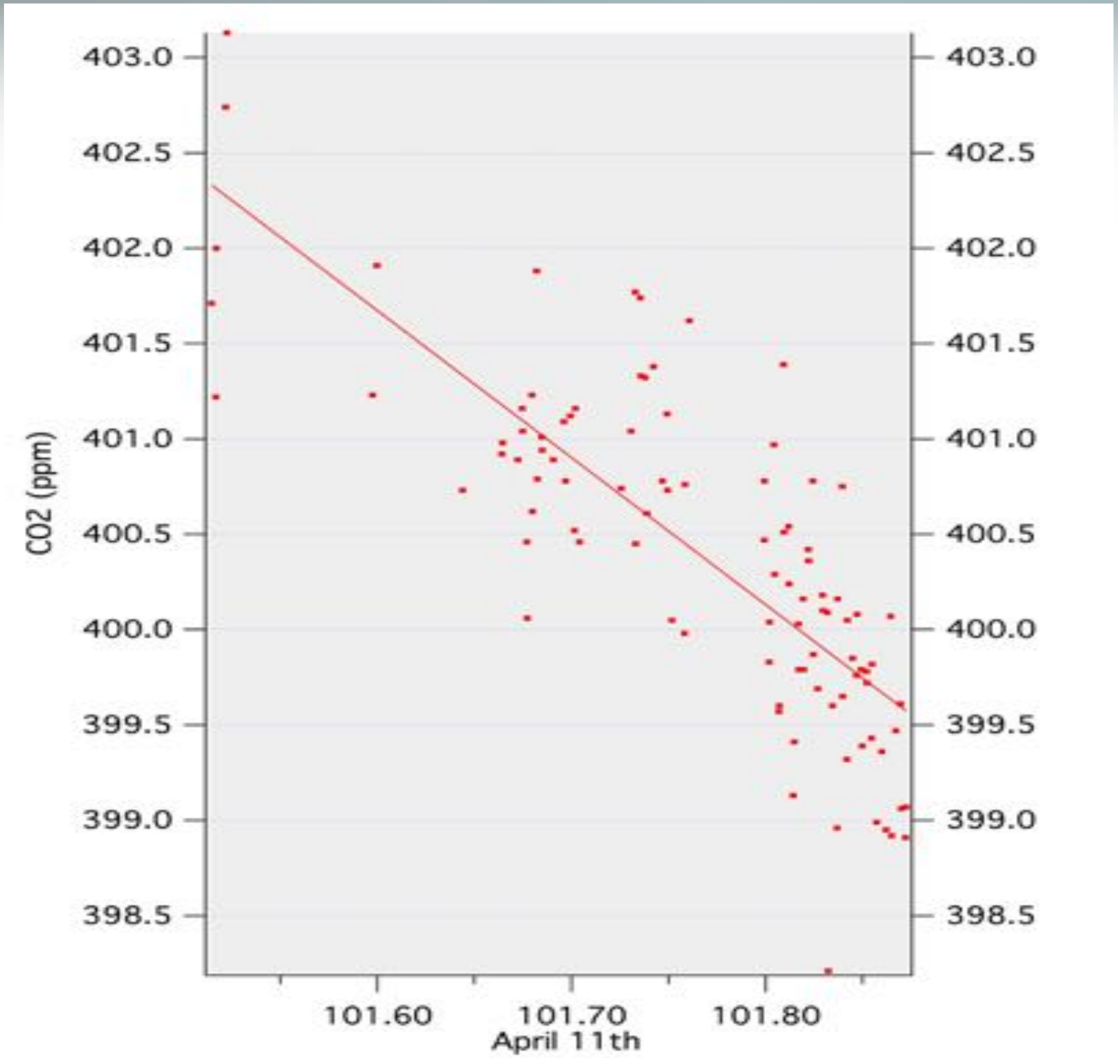
Remove Transport: C-Tracker S. Am. Mask

Andy Jacobson



Dry
SIF^N
SIF^G
New Leaf Prod
NEE
d/dt
CO2-Tr
SIF
New Leaf Prod. [m²/m²/mth]
NEE (gC/m2/day)
TCCON (bioCO2) - SAmask
dCO2/dt (ppm/day)
OCO2 2014-15
Nadir SIF ± St. Dev
Glint SIF ± St. Dev
Monthly Avg 2014-15
1999-2006
Avg ± St. Error
3 Month Avg
co2bio - SA mask
co2bio-SA mask 28day avg
d/dt [CO2]
TCCON_bio - SA mask
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sept
Oct

Daily CO_2 photosynthetic drawdown

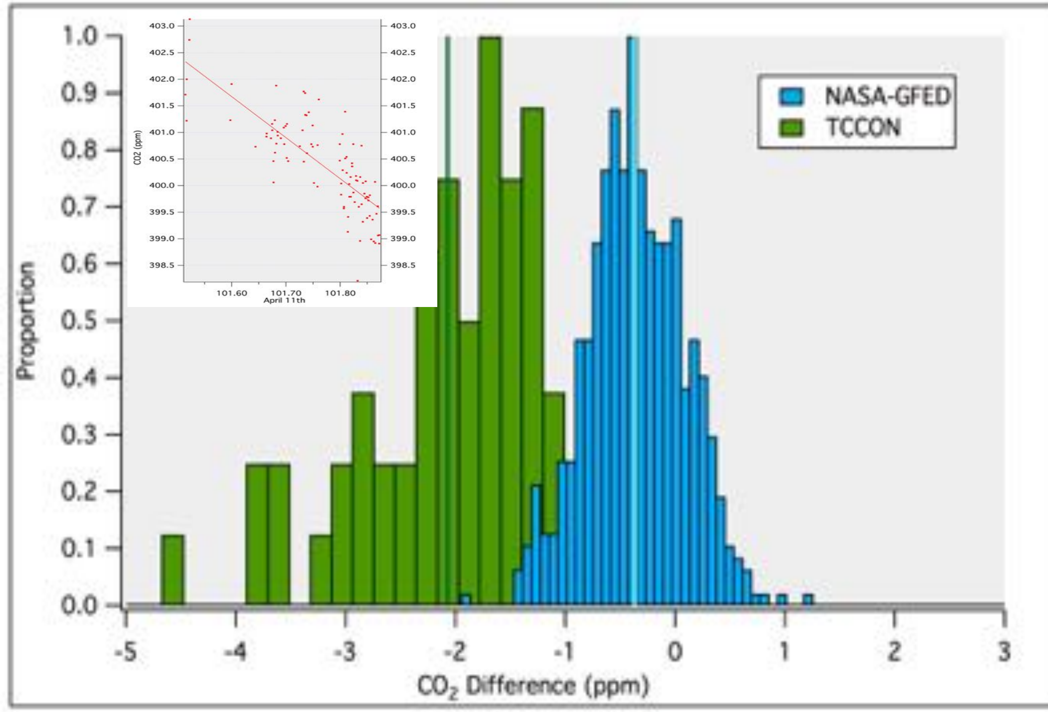


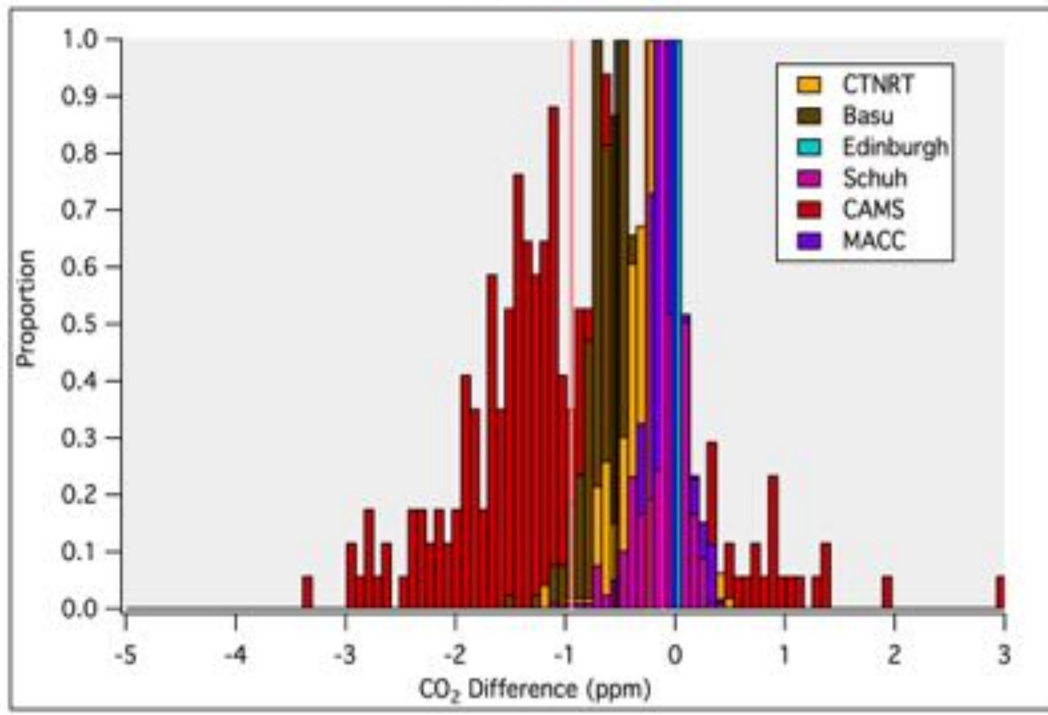
Daily Photosynthetic X_{CO2} Drawdown 12 hr (Local Amazon Signal)

TCCON	-2.1 ppm
GFED	-0.4 ppm
CTNRT	-0.3 ppm
Basu*	-0.5 ppm
Edinb	-0.0 ppm
Schuh	-0.1 ppm
CAMS*	-0.9 ppm
MACC	-0.1 ppm

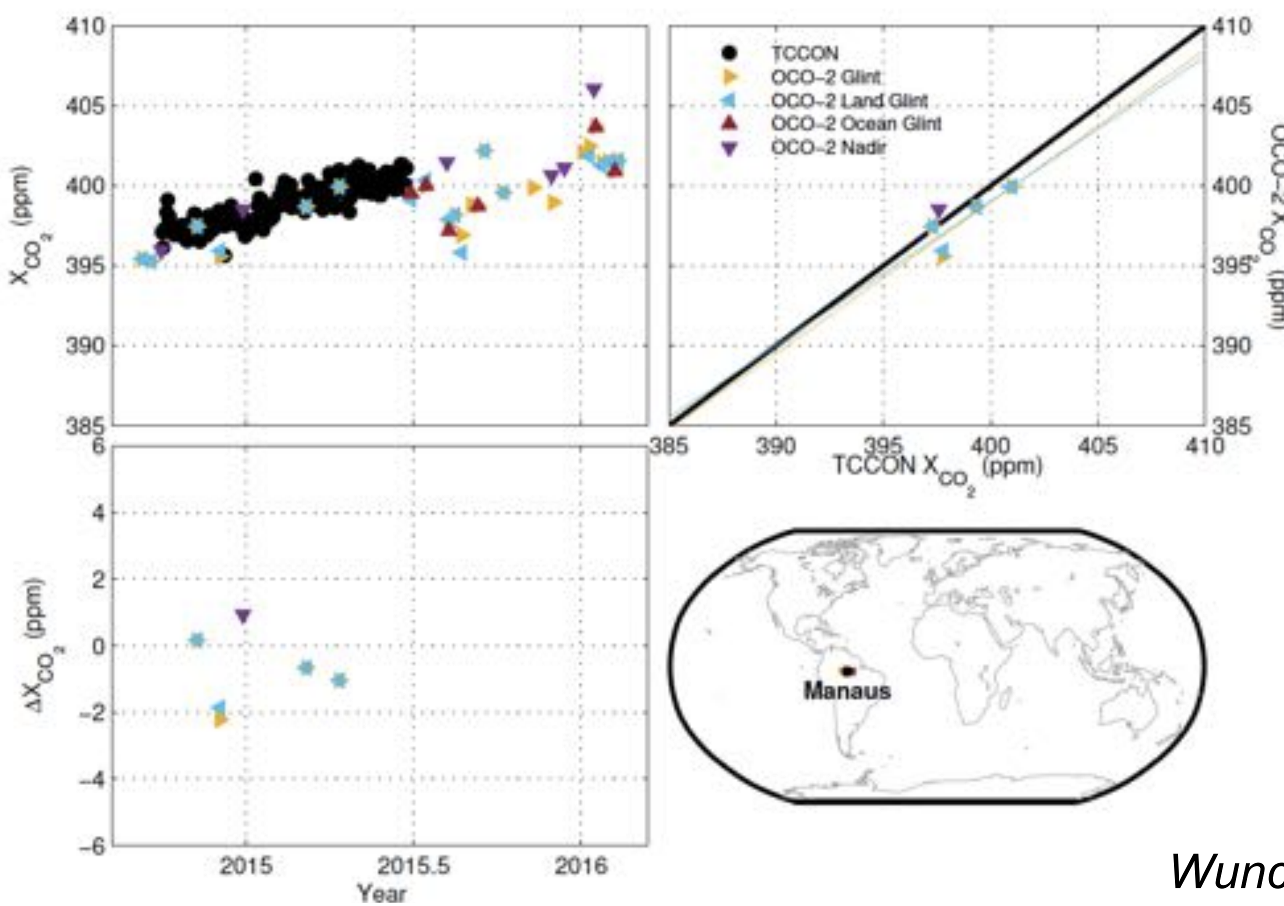
TCCON > 4•Model

*Do not simulate seasonality





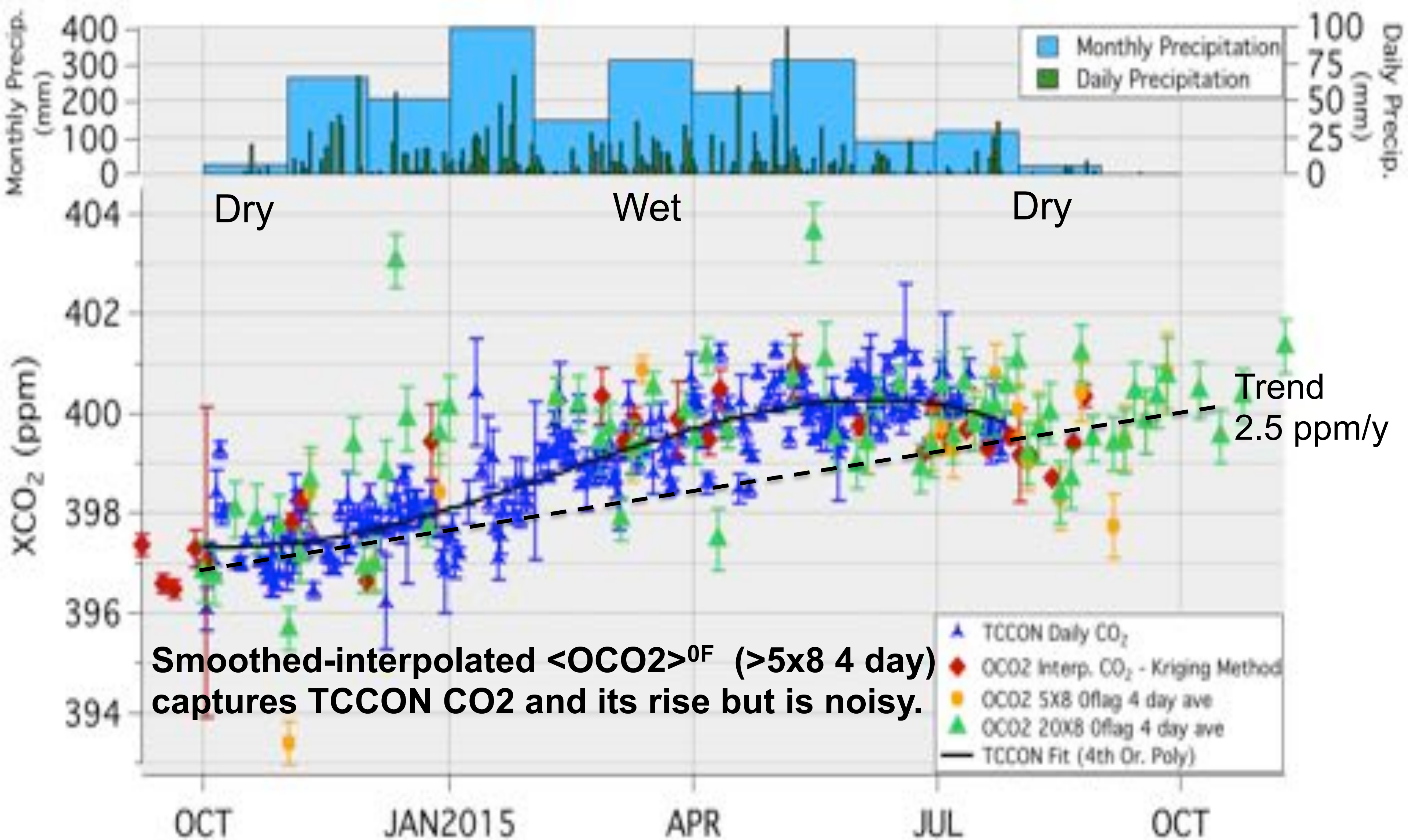
OCO-2 - TCCON Comparison (5 x 10 deg, 1 day)



	Glint Land		
TCCON Site	**slope**	R^2	**N**
Manaus	0.90±0.35	0.770	4

Wunch et al AMTD Draft 2016

TCCON-OCO2 X_{CO2} Comparison @ Manacupuru

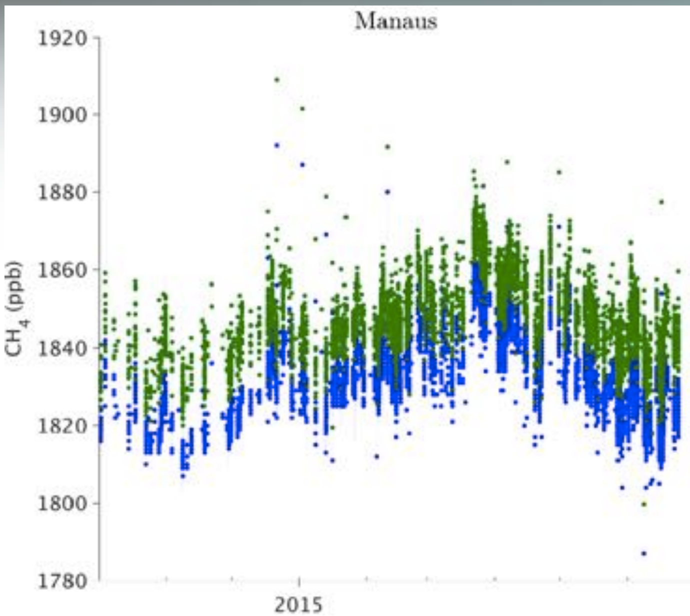


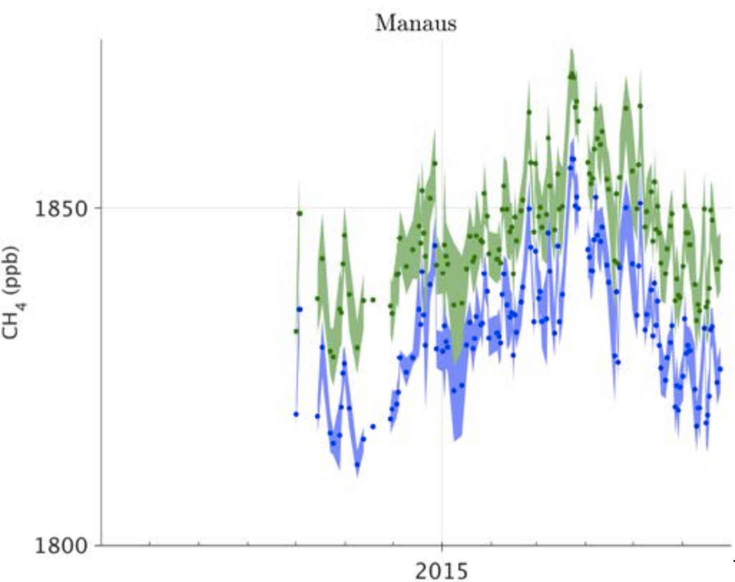
Smoothed-interpolated <OCO2>^{0F} (>5x8 4 day) captures TCCON CO2 and its rise but is noisy.

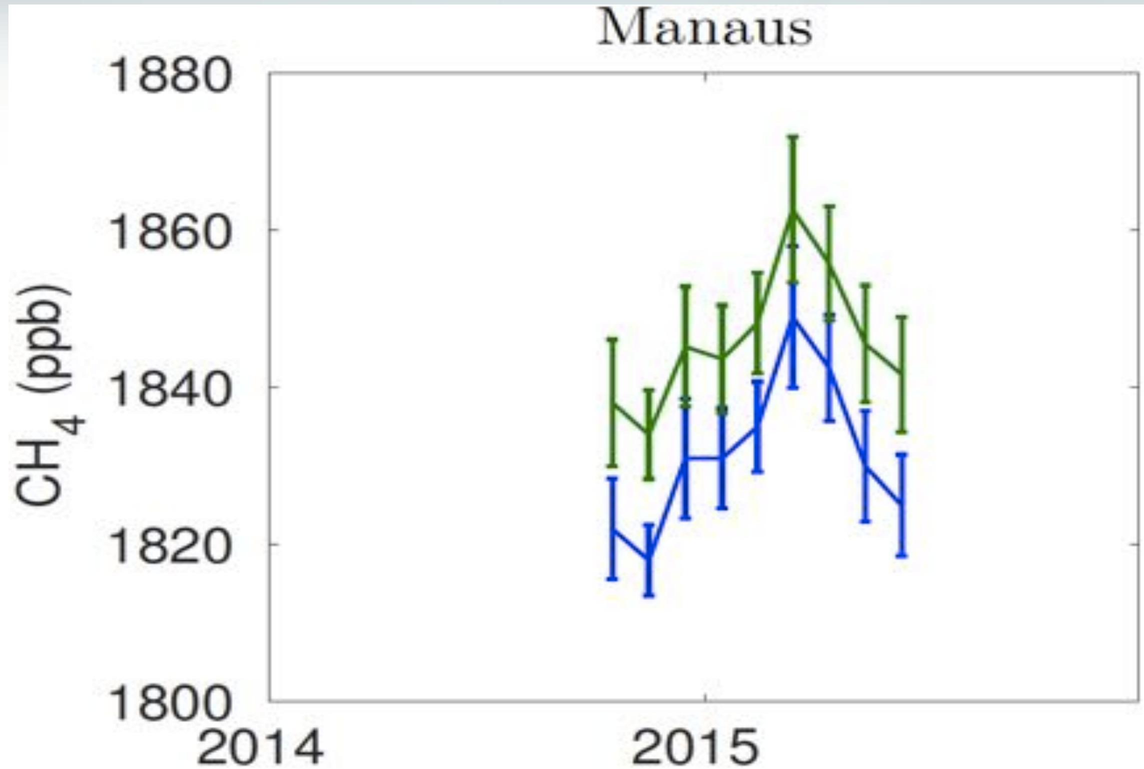
Conclusion

- Column X_{CO2} Observations in the Amazon rainforest show:
  - Seasonal cycle that is a sum of 2.3 ppm (biogenic), 0.4 ppm (transport), -1.5 ppm (biomass burning) and 2.5 ppm (trend)
  - Implies a net CO2 sink '14-'15 sink in the wet Manaus region
  - Mean daily photosynthetic drawdown of -2.1 ppm.
- 5 of 7 transport models capture the observed seasonal changes of column X_{CO2}. However, the daily photosynthetic drawdown is too low by a factor of > 4, suggesting models do not partition the respiration and uptake correctly.
- Seasonality of biogenic X_{CO2} and SIF is consistent with *in situ* tower results indicating leaf phenology (flushing) plays a key role at larger scales in the Amazon.

Tropospheric Methane



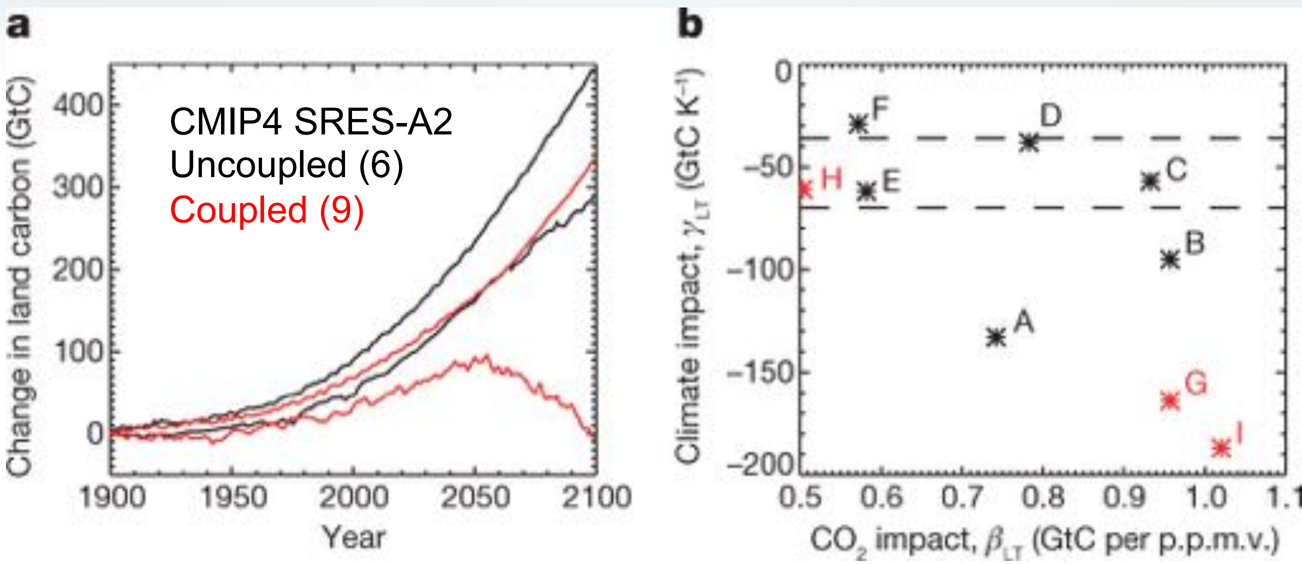




Saad et al 2016

Tropical C storage uncertainty in climate-carbon model

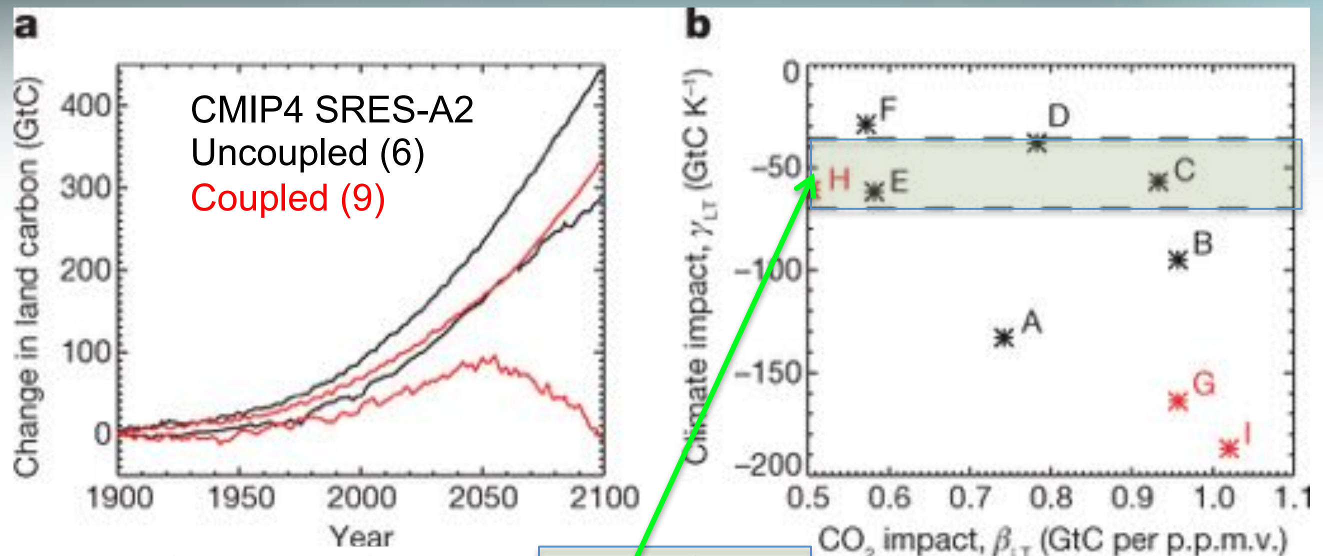
- Land C-storage increases from enhanced photo-synthesis and water use efficiency at higher CO_2 (**β_{LT}**) but decreases from higher soil and plant respiration rates with warming (**γ_{LT}**).
- Coupled simulations have a much larger uncertainty in C-storage (330 GtC) than uncoupled ones.



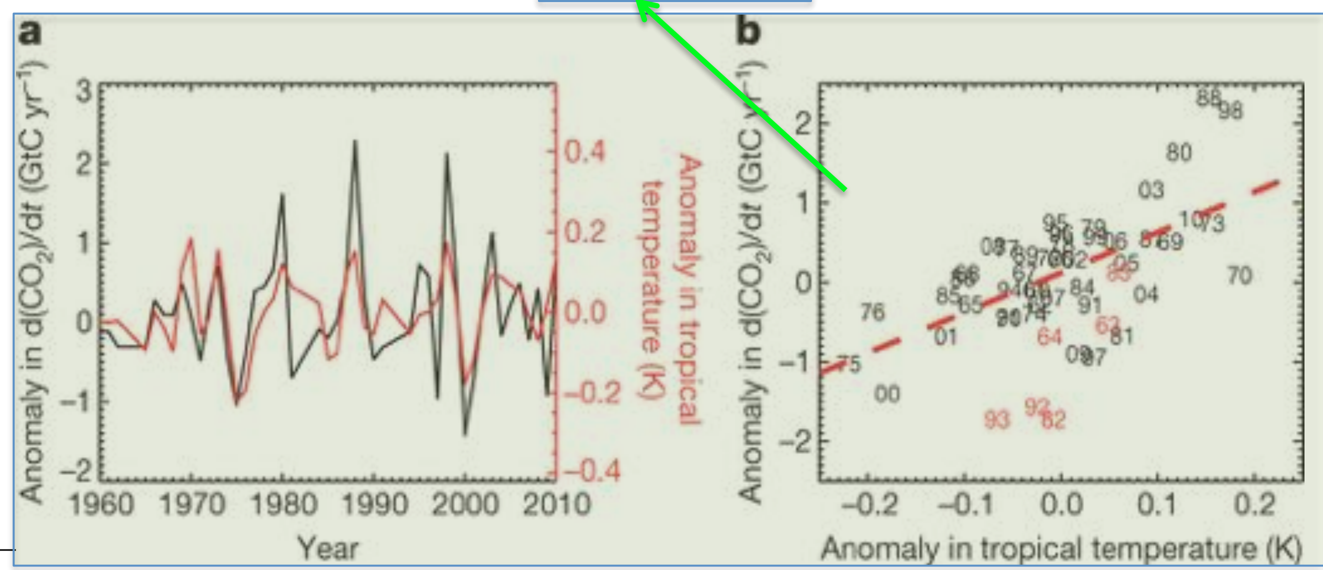
$$\Delta C_{LT} = \beta_{LT}\Delta C_a + \gamma_{LT}\Delta T_T$$

PM Cox et al. Nature (2013)

Contemporary CO_2 variability used to evaluate γ_{LT}



$$\Delta C_{LT} = \beta_{LT} \Delta C_a + \gamma_{LT} \Delta T_T$$



- Data consistent with **uncoupled models** that show much smaller tropical carbon release than in **coupled models**

PM Cox et al. Nature (2013)

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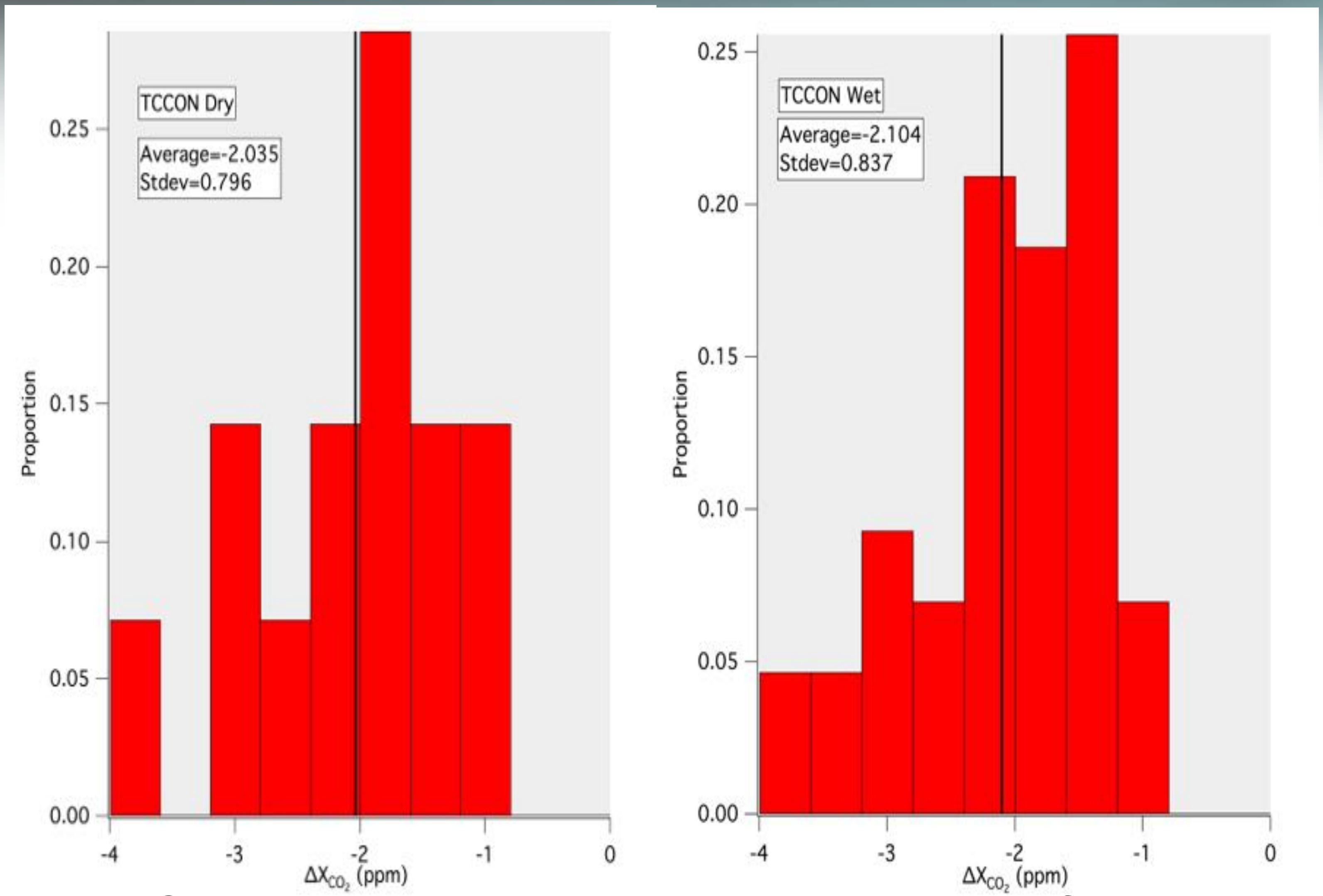
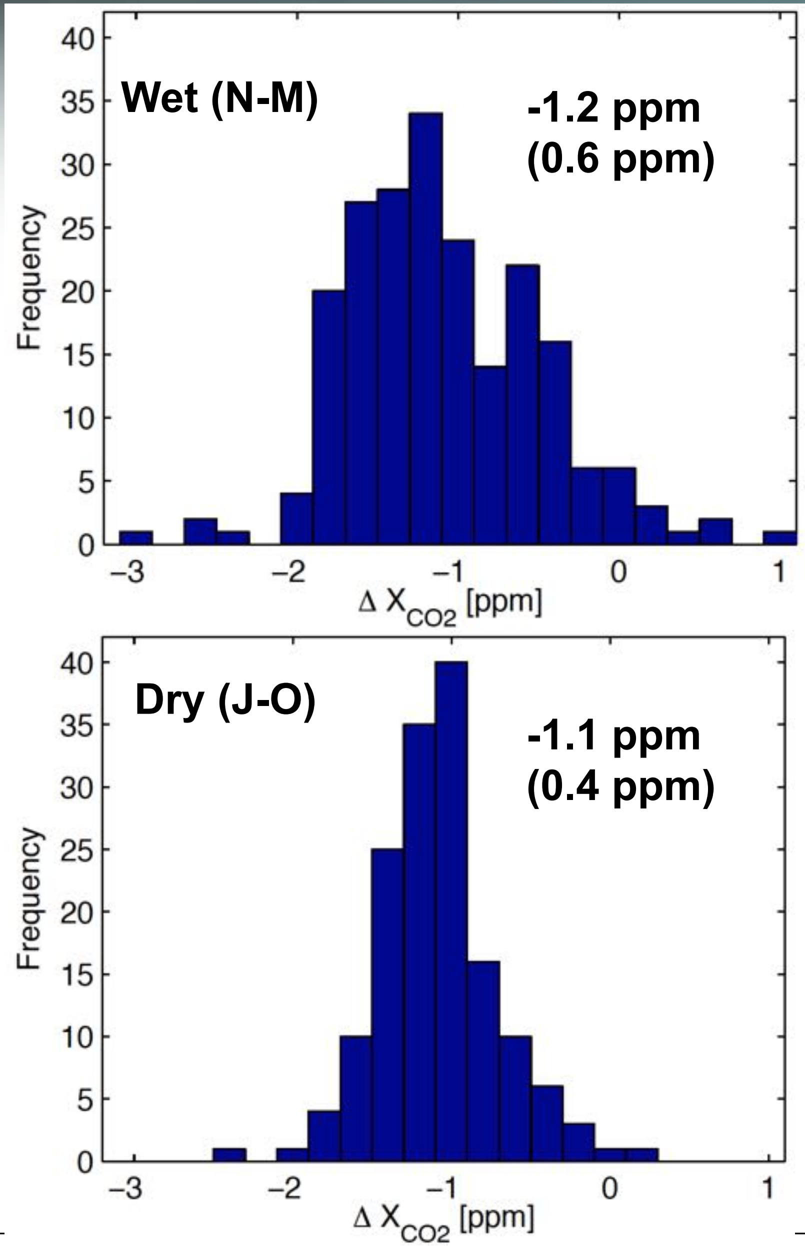
TCCON daily CO_2 drawdown – Wet versus Dry



Consistent Wet > Dry, but not statistically significant.
Observations biased to relatively cloud free conditions.

How does process based prognostic CLM perform?



Annual Mean
CO_2 daily drawdown

•CLM
-1.1 ppm (0.5 ppm)

•TCCON
-2.1 ppm

•Inverse Models
-0.1 to -0.5 ppm

•CLM better than Transport Models still half of data

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Dean Green, Gregor Surawicz, Vagner Castro, Norton Allen, J. F. Blavier & LANL ARM FIDO team.