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Title: GoAmazon – Scaling Amazon Carbon Water Couplings

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GoAmazon – Scaling Amazon Carbon Water Couplings

Final Campaign Report

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1.0 Summary (1 to 2 pages)

Forests soak up 25% of the carbon dioxide (CO_2) emitted by anthropogenic fossil energy use (10 Gt C y^{-1}) moderating its atmospheric accumulation. How this terrestrial CO_2 uptake will evolve with climate change in the 21st century is largely unknown. Rainforests are the most active ecosystems with the Amazon basin storing 120 Gt C as biomass and exchanging 18 Gt C y^{-1} of CO_2 via photosynthesis and respiration and fixing carbon at 2-3 kg C m^{-2} y^{-1}. Furthermore, the intense hydrologic and carbon cycles are tightly coupled in the Amazon where about half of the water is recycled by evapotranspiration and the other half imported from the ocean by Northeasterly trade winds. Climate models predict a drying in the Amazon with reduced carbon uptake while observationally guided assessments indicate sustained uptake. We will resolve this huge discrepancy in the size and sign of the future Amazon carbon cycle by performing the first simultaneous regional scale high frequency measurements of atmospheric CO_2, H_2O, HOD, CH_4, N_2O and CO at the T3 site in Manacupuru, Brazil as part of DOE's GoAmazon project. Our data will be used to inform and develop DOE's CLM on the tropical carbon-water couplings at the appropriate grid scale (10-50km). Our measurements will also validate the CO_2 data from Japan's GOSAT and NASA's imminent OCO-2 satellite (launch date July 2014). Our data will be used to address the following science questions

1. How does ecosystem heterogeneity & climate variability influence the rainforest carbon cycle?

2. How well do current tropical ecosystem models simulate the observed regional carbon cycle?

3. Does nitrogen deposition (from the Manaus plume) enhance rainforest carbon uptake?

Figure 1. Global TCCON network sites (left). Our LANL solar FTS Manus IOP site (red star with box for OCO-2 sampling) filled a gap in N. American rainforest carbon where image shows NDVI colors.

The core activity entailed the deployment of a solar tracking Fourier Transform Spectrometer (FTS, Bruker 125HR) that records high-resolution solar spectra in the near infrared in Manaus, Brazil, during the collaborative multi-program OBER-funded GOAMAZON campaign. The automated system locks in and continuously tracks the sun-collecting spectra in the near infrared every 1-2 minutes from sunrise to sunset and measures regional column concentrations averaged over 10-50 km scales. The atmospheric solar absorption spectra are fitted using laboratory spectra of species to retrieve atmospheric column abundances of constituents that include CO_2, CH_4, N_2O, H_2O, HOD, and CO. The LANL solar FTS is part of the global Total Column Carbon Observing Network (TCCON) and uses stringent operational and retrieval protocols that achieve very accurate and precise observations (better than 0.25% or 1 ppm for CO_2) necessary to evaluate regional carbon cycle mechanisms and models. We were the first and only ground based regional column trace gas monitoring site in the tropics that filled key gap in the international TCCON (https://tccon-wiki.caltech.edu).

Figure 2. The LANL solar FTS deployed on the left from T3 site in Manacupuru, Brazil for GoAmazon in 2014-2015 (left), Manvendra Dubey & Dean Green during installation (middle), operational FTS (right).

Our IOP expanded ARM's GoAmazon aerosol campaign to include carbon cycle and ecosystem science in partnership with Brazilian scientists. The IOP logistics were supported by ARM (Sally McFarland PM) and the deployment and research were funded by TES (Dan Stover PM) and integrated. The project entailed collaboration with NASA, where our site was targeted routinely for OCO-2 satellite and our data used for validation of column CO_2 over the tropics. We collaborated with NOAA-ESRL Boulder to perform airborne vertical profiles using WMO standard in situ instruments. We have collected and compiled the first regional scale column CO_2 and other trace gas column composition over a season above the Amazon rainforest. Our data is being used to evaluate tropical ecosystem carbon cycle models and is synergistic with OBER's NGEE-Tropics and ILAMB programs.

The site preparation occurred from February to May 2014 while then solar FTS was calibrated, serviced and hardened for deployment at LANL. There was a site visit in February 2014. The FTS container was packed and shipped in June 2014 and arrived in Brazil in mid August 2014. A site visit and installation occurred in September 2014 and the system collected data from October 2014 early August 2015 and returned to LANL in December 2015. NOAA airborne in situ flights calibrated our FTS column CO_2 and CH_4 observations in February and June 2015. NASA OCO-2 targeted our site from September 2014 to August 2015.

2.0 Results

Our project has produced a unique high quality on the regional greenhouse and trace gas composition of the atmosphere above the Amazon rainforest. The high time resolution (1-2) minute data enables the examination of daily to monthly to seasonal (wet/dry) changes and evaluate model parameterizations of the tropical ecosystem response to natural variations and potential climate change.

Our results were calibrated by WMO calibrated in situ airborne profiles by NOAA and Brazilian collaborators and then used to validate the OCO-2 satellite that targeted us periodically (Fig 1). Our quality-controlled data set has been uploaded to the ORNL DOE TCCON and ARM IOP archives for use by the international climate research community. We are actively leading research and collaborating with DOE (NGEE-Tropics, ILAMB), NASA (OCO-2 validation) and academics (tropical land model evaluation) on projects that leverage our data. Results have been presented at program, national and international meetings and publications are beginning to appear, some of which are heighted here.

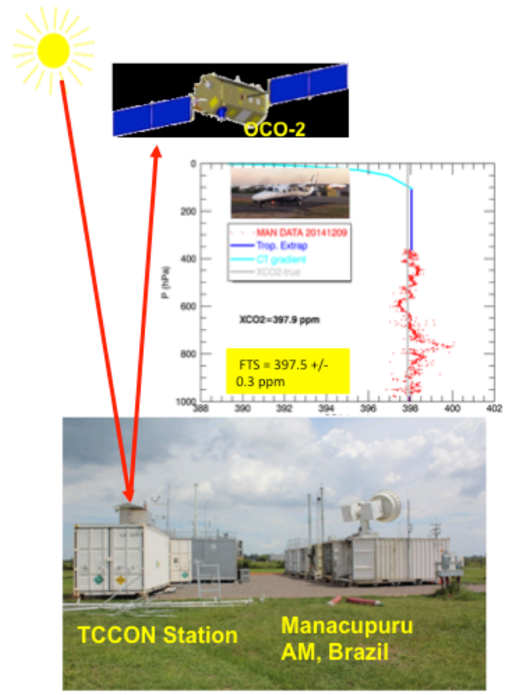

Figure 3. Our TCCON station observations were validated by in situ airborne profiles using WMO standards and then used to validate OCO-2 column CO_2 observations.

The cloud cover over the Amazon posed a key observational challenge for OCO-2 since it requires a cloud free scene that is rare in the afternoon during the overcast. In contrast, our Brazil FTS can observe during broken clouds and also during the less cloudy morning period. We were therefore able to combine our dense high resolution FTS data with coarser overpass target criteria (within 5 x 10 degree and 1 day of satellite) to validate the OCO-2 data. The OCO-2 column CO_2 data in various observational modes correlates well with our FTS data with a slope of 0.90 +/- 0.35 and a R^2 of 0.35. Our results provide confidence in the OCO-2 retrievals (that are empirically calibrated by TCCON globally) over the Amazon for the 2014-2015 period and will be invaluable to extend the data into future years.

Our data also captures the regional Amazon carbon seasonal cycle showing high CO during the dry biomass-burning season and low CO during the wet clean season. We have used this regional column CO signal to separate the biomass burning contributions and biological (photosynthesis and respiration) components of the seasonal column CO_2 cycle. Furthermore, have also used our robust detection of the

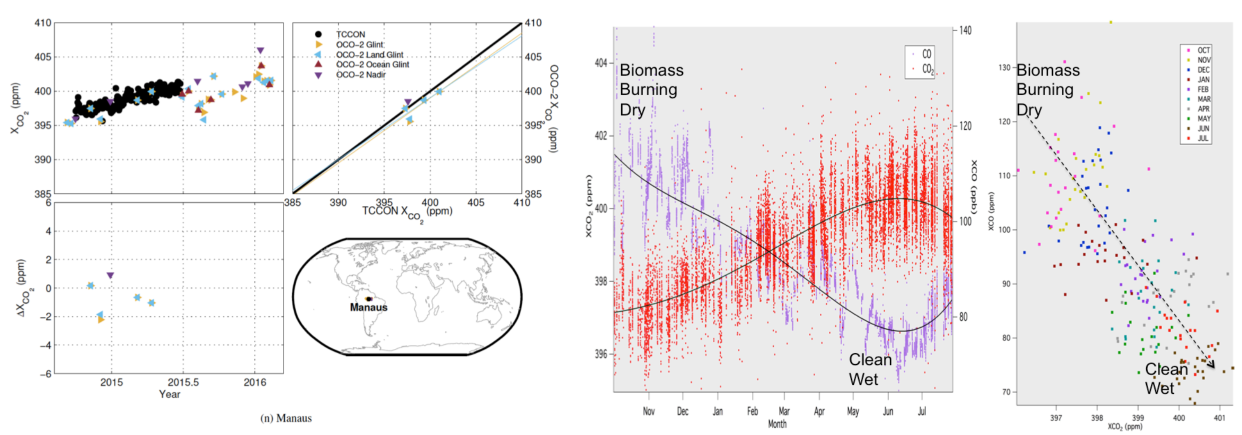

Figure 4: Validation of OCO-2 using our Brazil ground FTS column CO2 data (left). Right Observed daily, monthly and seasonal variations in column CO2 and CO trace the biomass burning/dry and the clean/wet seasons

daily photosynthetic drawdown to clearly separate it from the respiration fluxes. The IOP data are being mined extensively to evaluate tropical ecosystem models and help DOE guide TES and NGEE Tropics model development. We have also

Our data can be integrated with other ARM GoAmazon data to quantify contributions of trade wind import and local evapo-transpiration to the Amazon water cycle by using our water isotope data. Analysis of the Manus plume aerosol deposition on the Amazon carbon cycle could also be elucidated by this data. Finally, our 2014-2015 campaign serendipitously overlapped with a strong El Nino year for which we have succeeded in generating a good data set that will be valuable for follow-up studies as it wanes. Our breakthrough experiences from the IOP are being shared with groups in Belgium and Germany (MPI) to deploy other TCCON like stations in S. America. We have also built portable solar FTSs that are well calibrated that are suitable for deployment here and could be leveraged in collaboration with NGEE Tropics if resources are made available, and our IOP has created strong scientific synergy within DOE climate programs, between observations and models and the international community.

3.0 Publications and References

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OPTIONAL: Lessons Learned

The significant challenge for this IOP was that it was secondary to the main GoAmazon project and consequently shipment took longer and site support was more challenging. Despite this we were able to work the issues. While