Biophysical Processes and Feedback Mechanisms Controlling the Methane Budget of an Amazonian Peatland

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1. Project introduction

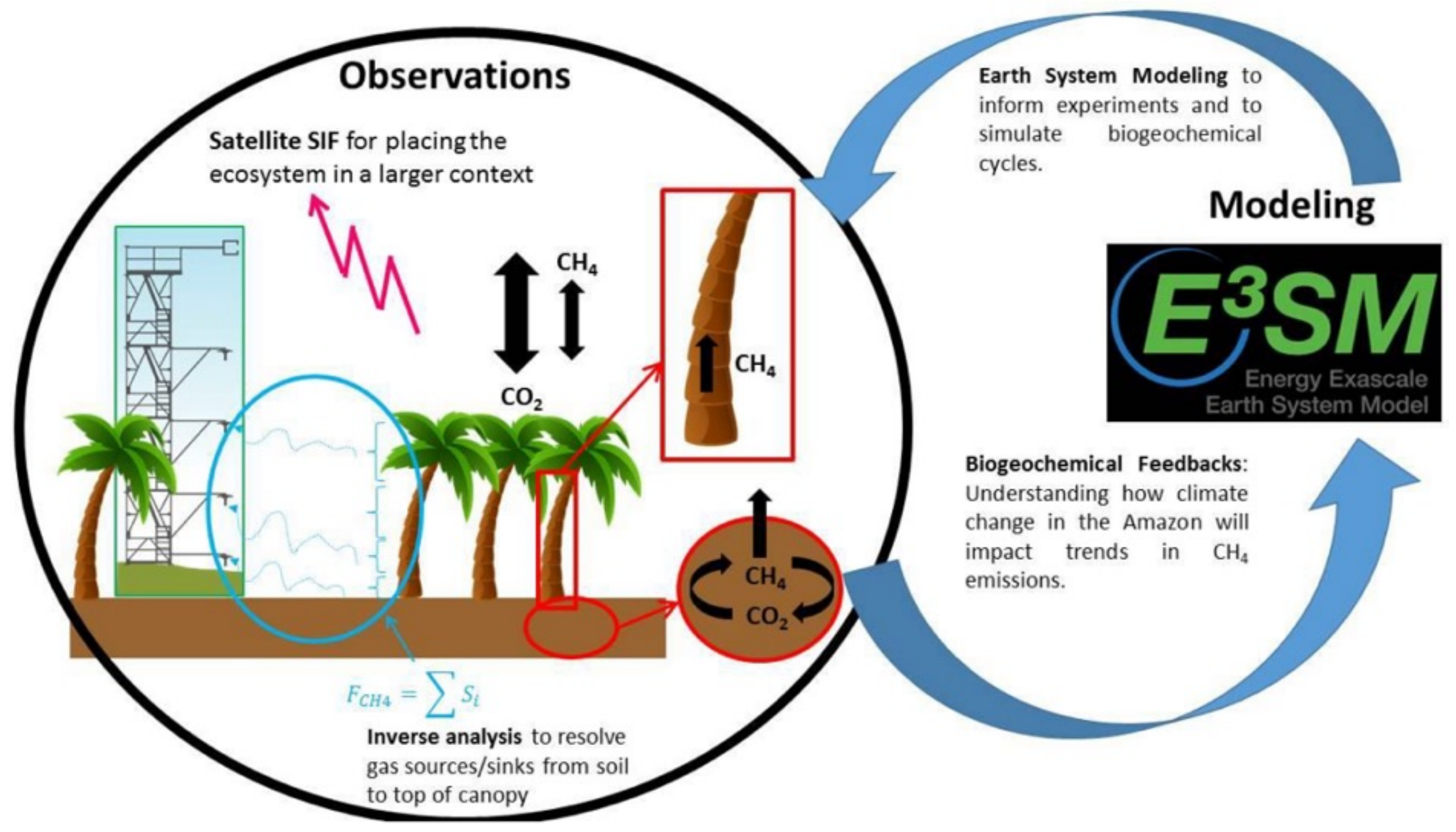


FIGURE 1. Experimental and modeling approach illustrating the links among experimental process studies and model development, validation and forecasting.

Observation site

- Established in 2017 AmeriFlux ID：PE-QFR
- Location: Iquitos, Peru (73°19′ 8.1" W; 3°50′ 3.9" S)

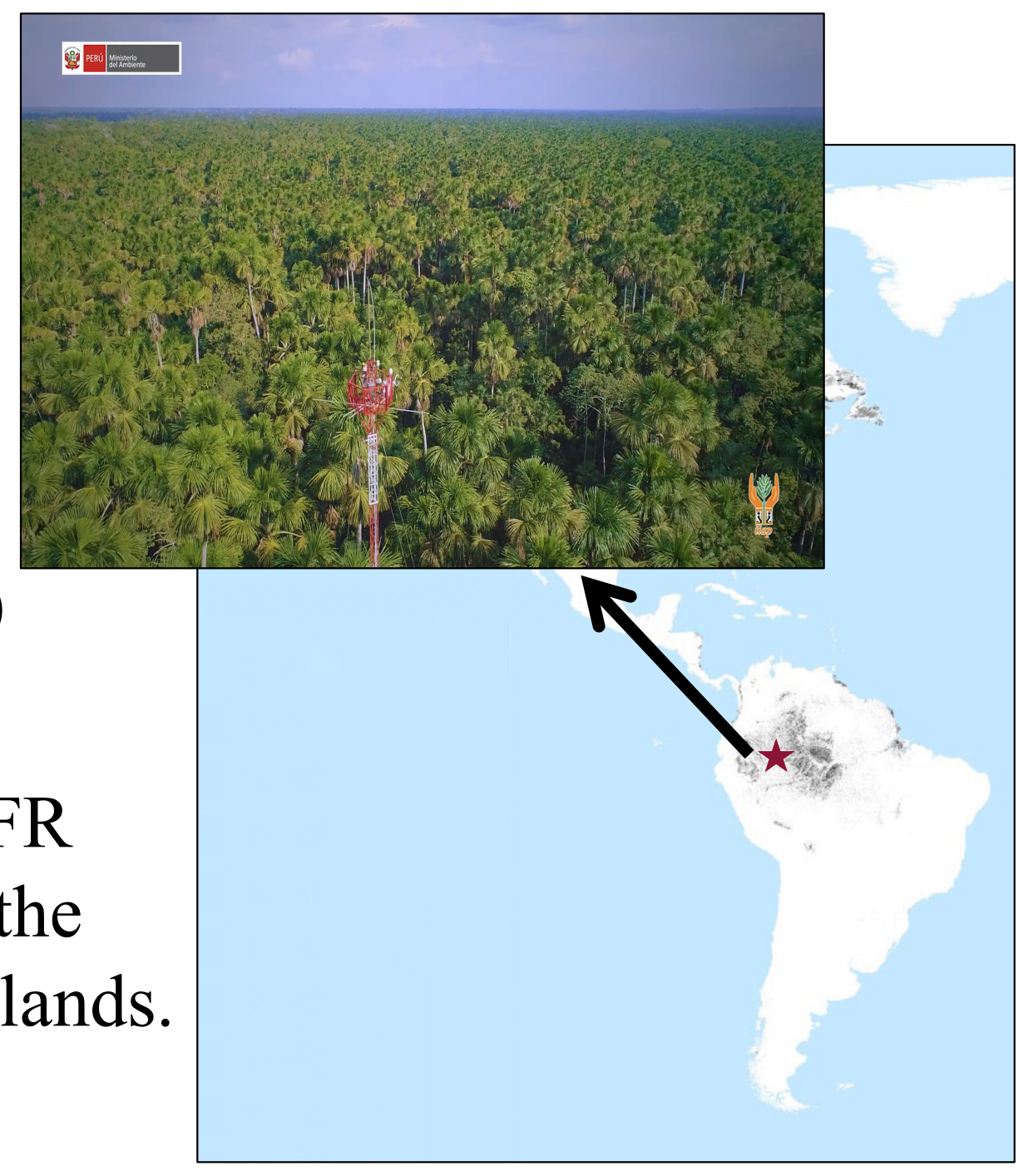
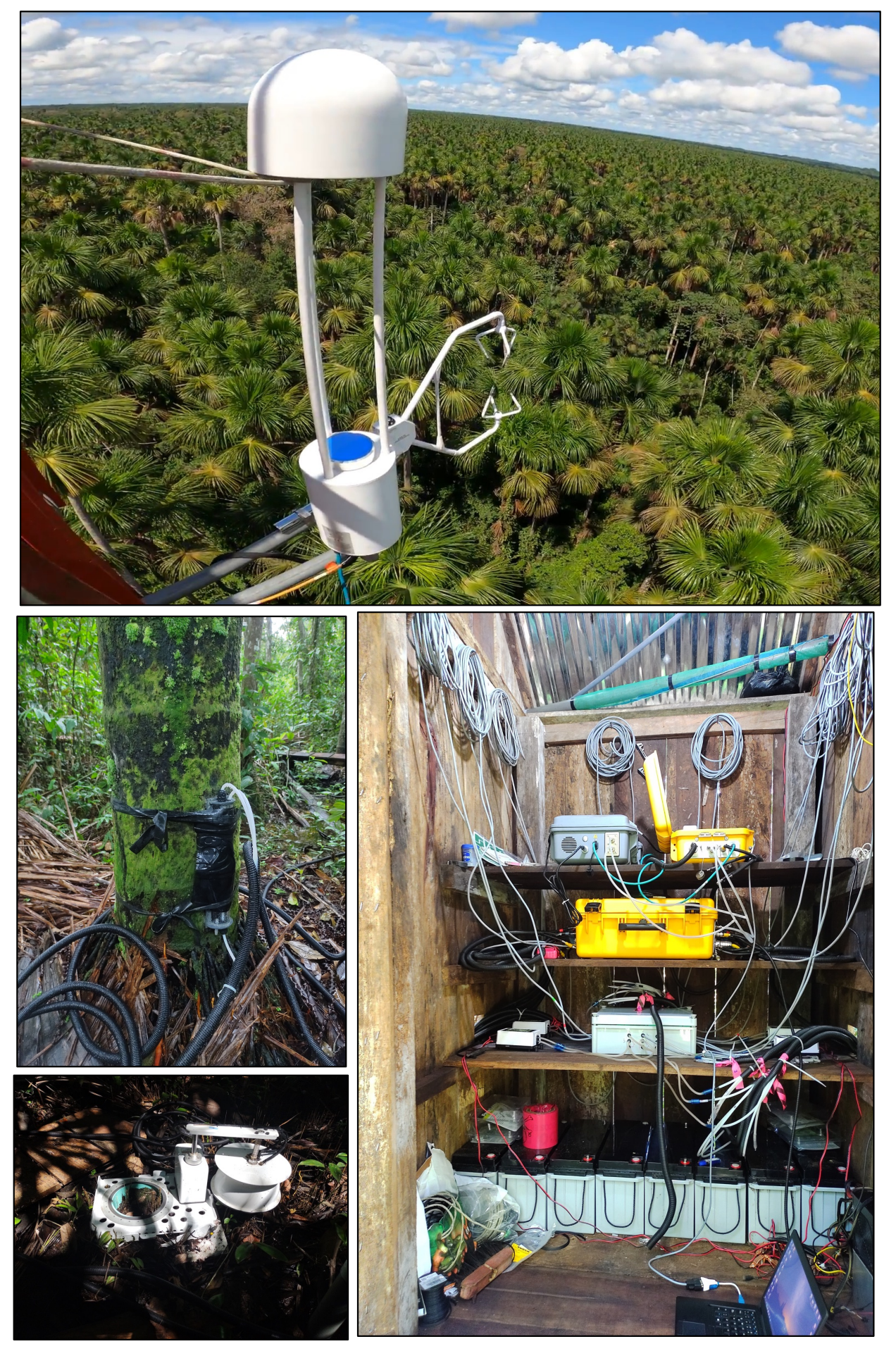


FIGURE 2. Location of PE-QFR AmeriFlux site. Also shown is the Amazonian distribution of peatlands. (*Xu et al. 2018*).

2. Field measurements



- Eddy covariance system for measuring CO_2/CH_4 and energy fluxes (Jan 2018 - present).
- Automatic 16-chamber-based system for measuring soil and stem CO_2 and CH_4 emissions (June 2021 - present).
- Vertical canopy profile system for measuring CO_2 and CH_4 concentrations has been successfully installed last year (July 2022 - present).

To learn more about this project:

FIGURE 3. Eddy covariance and chamber flux measurements.

3. Soil and stem CO_2 and CH_4 fluxes

- Soil CO_2 fluxes significantly increased during the dry months, but soil CH_4 fluxes are higher during the wet season.
- Stem CO_2 and CH_4 fluxes didn't show variation between dry and wet seasons, which could indicate stem fluxes gain importance as CH_4 source during the dry season.
- Stem CO_2 fluxes were higher on *Mauritiella armata* and *Tabebuia insignis,* whereas stem CH_4 fluxes were higher on *Mauritia flexuosa*.
- Stem fluxes significantly varied among species. *M. armata* and *T. insignis* had the highest CO_2 fluxes. In contrast *M. flexuosa* had the highest CH_4 fluxes.

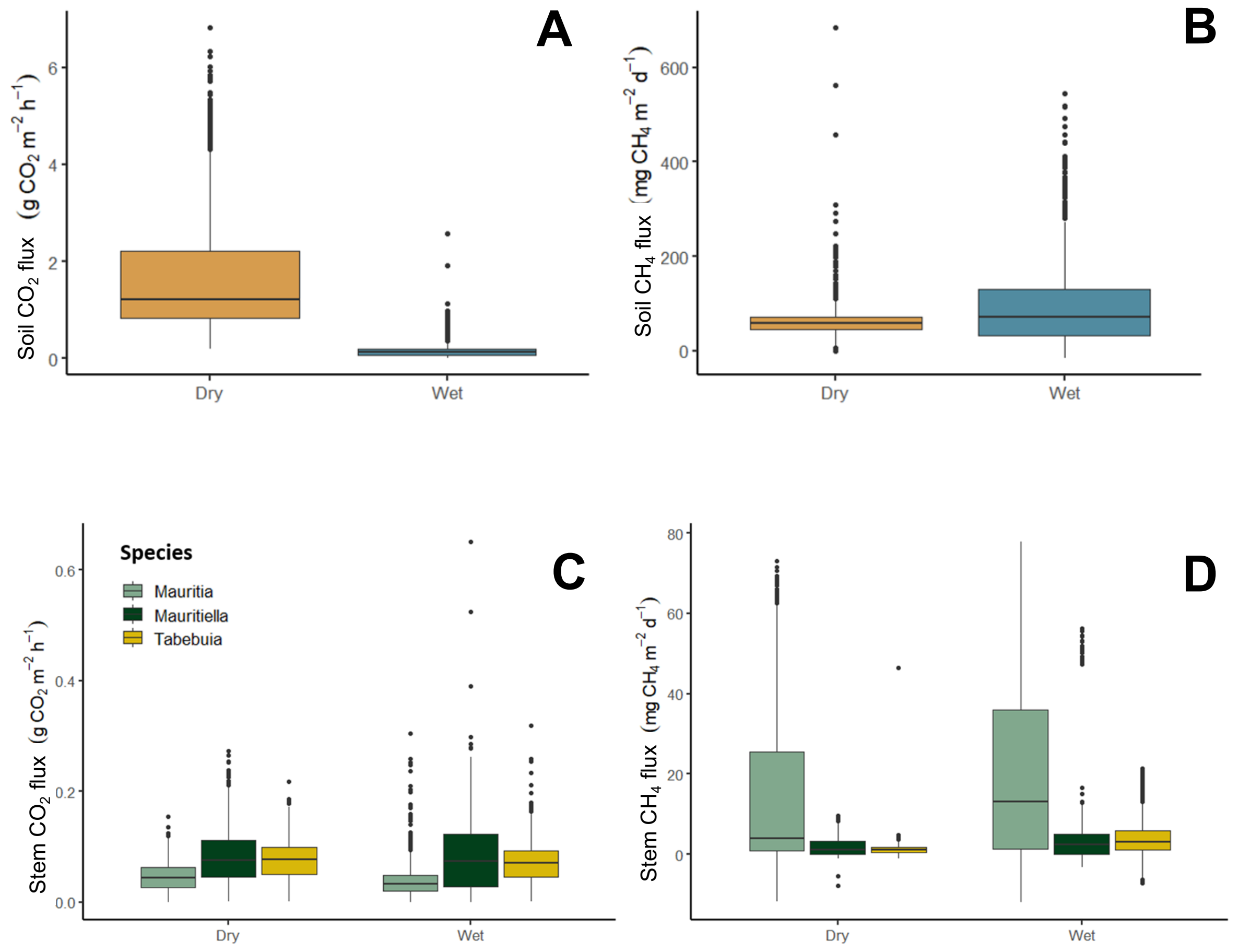
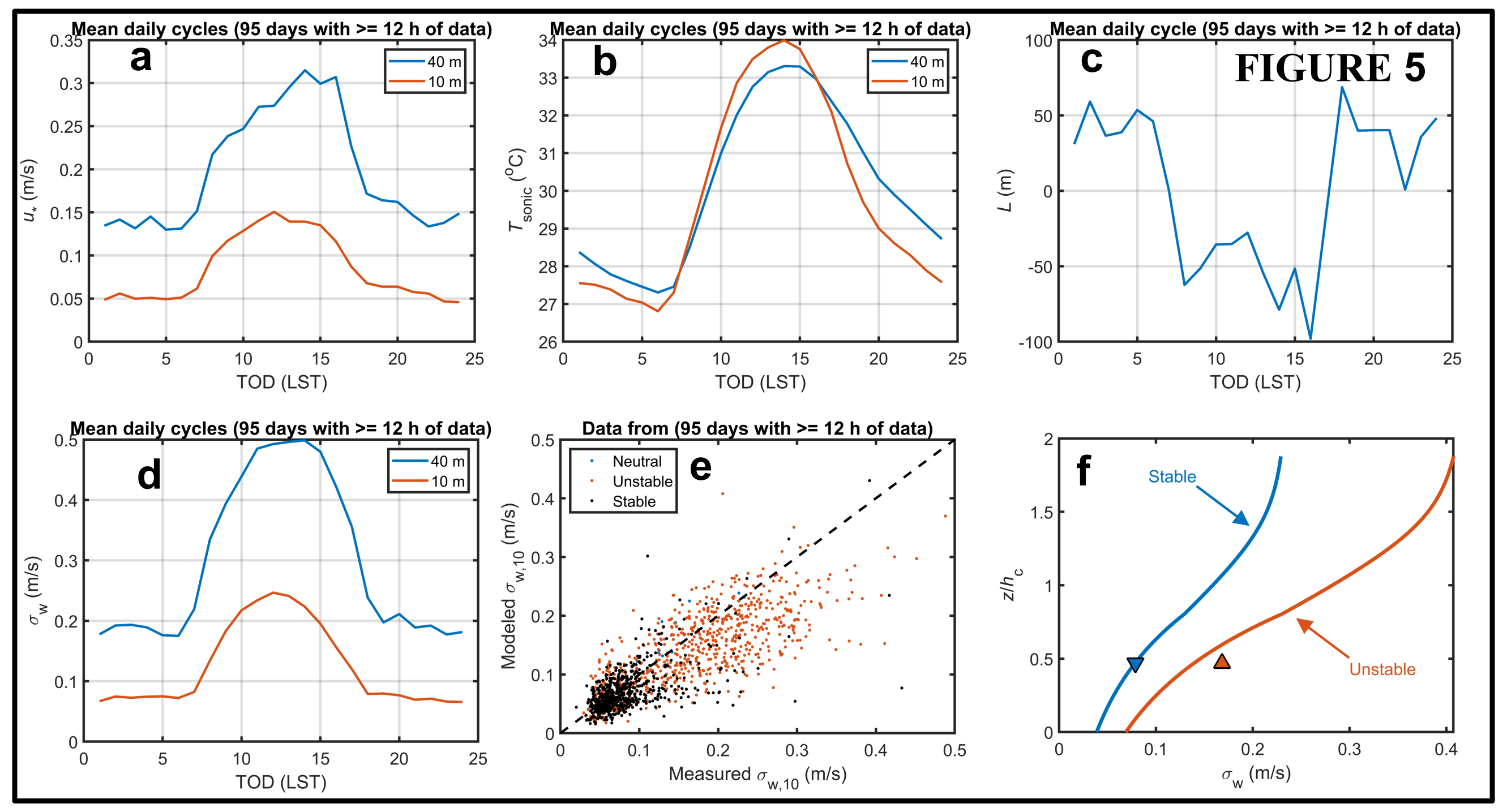


FIGURE 4. Chamber-based carbon fluxes in dry and wet seasons. (A) Soil CO_2 flux; (B) Soil CH_4 flux; (C) Stem CO_2 flux by tree species; (D) Stem CH_4 flux by tree species.

4. Source/sink distributions of CO_2 and CH_4 in canopy

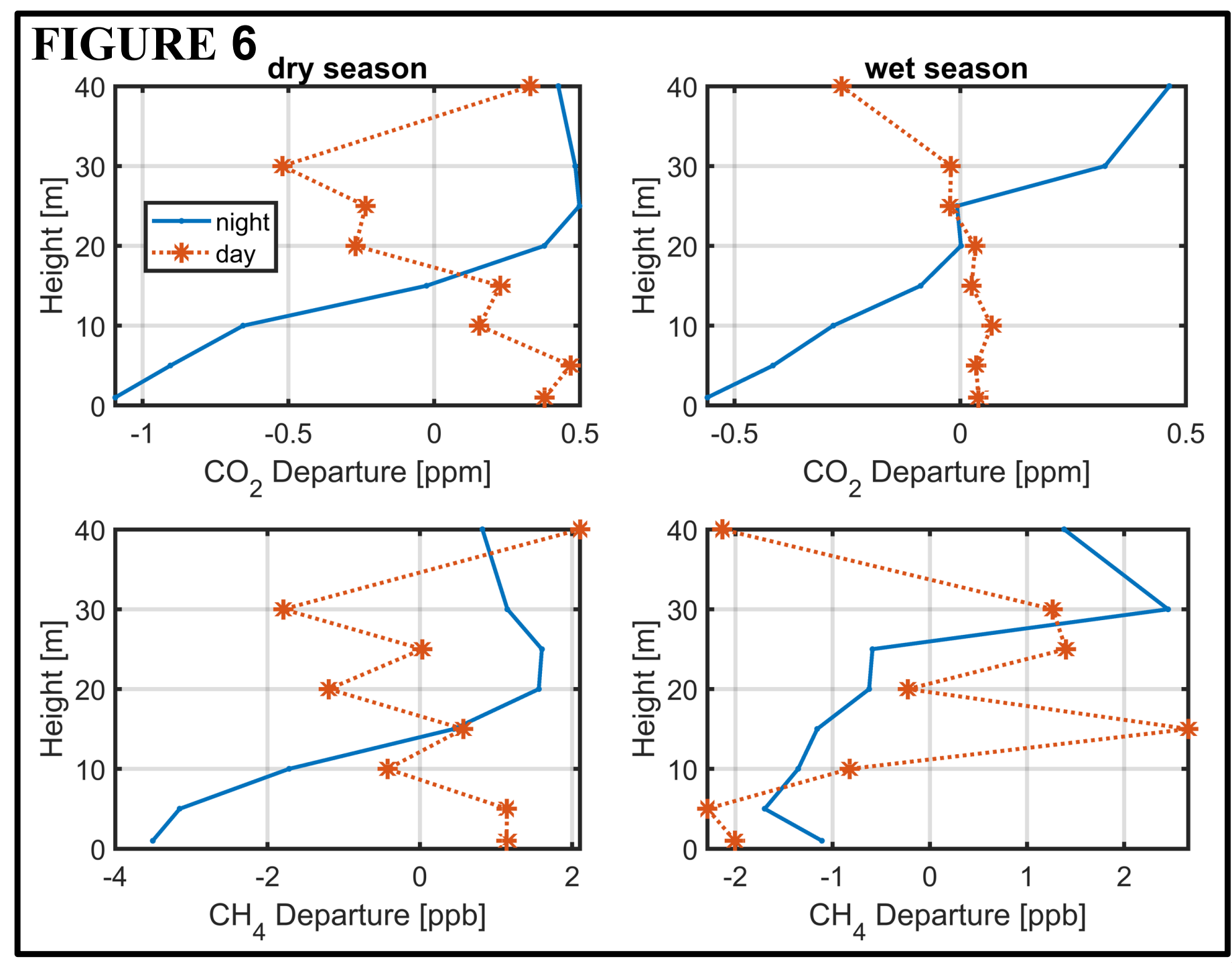
- Mean daily cycles of friction velocity (u_*), sonic temperature (T_{sonic}), Obukhov length (L) and standard deviation of the vertical velocity component, σ_w (**FIGURE 5** a–d, respectively).
- Using within canopy turbulence measurements at 10 m height, we validated the σ_w profile model for this site (**FIGURE 5** e&f).



The model is biased low when the atmosphere is unstable and highly turbulent (**FIGURE 5** e&f).

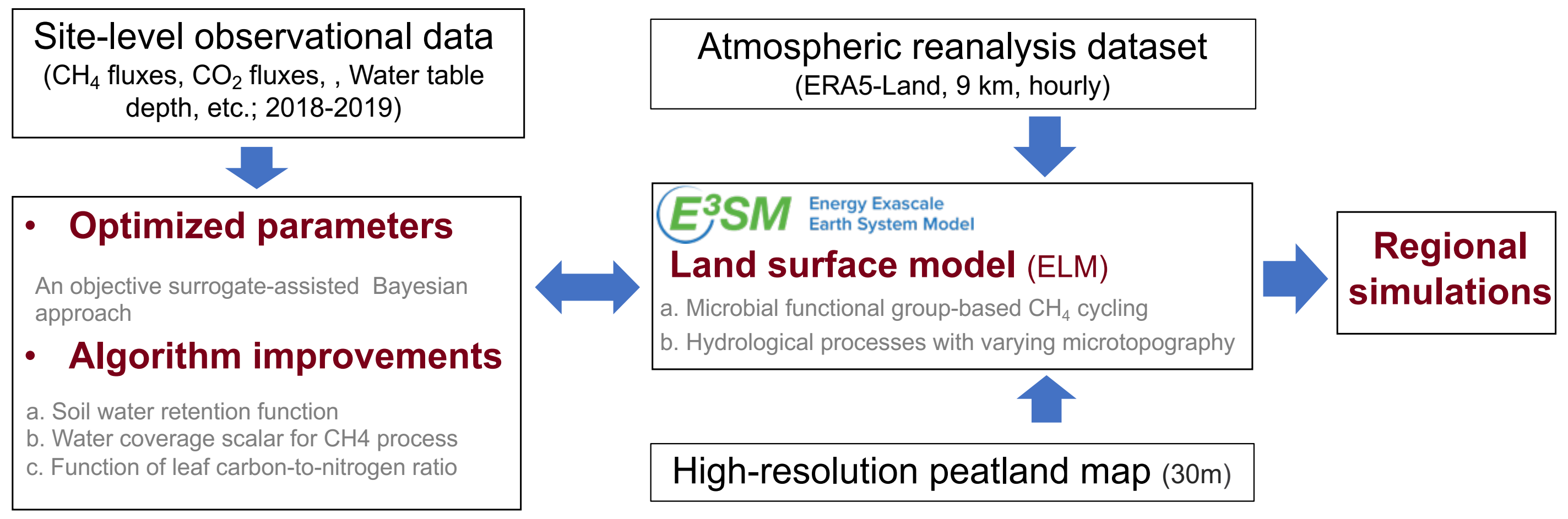
- Preliminary concentration profiles are shown in **FIGURE 6**. Data are presented as departures from the profile mean $[= 1/(z_r - z_1)\int_{z_1}^{z_r} C\,dz]$,

where z_r and z_1 are the top and bottom measurement heights, respectively, and *C* is the measured concentration.



5. Regional CH_4 budget simulation

Modeling processes:



Site-level observational data (CH_4 fluxes, CO_2 fluxes, , Water table depth, etc.; 2018-2019)

- **Optimized parameters**

An objective surrogate-assisted Bayesian approach

- **Algorithm improvements**

a. Soil water retention function
b. Water coverage scalar for CH4 process
c. Function of leaf carbon-to-nitrogen ratio

Atmospheric reanalysis dataset (ERA5-Land, 9 km, hourly)

E3SM Energy Exascale Earth System Model

Land surface model (ELM)

a. Microbial functional group-based CH_4 cycling
b. Hydrological processes with varying microtopography

High-resolution peatland map (30m)

Regional simulations

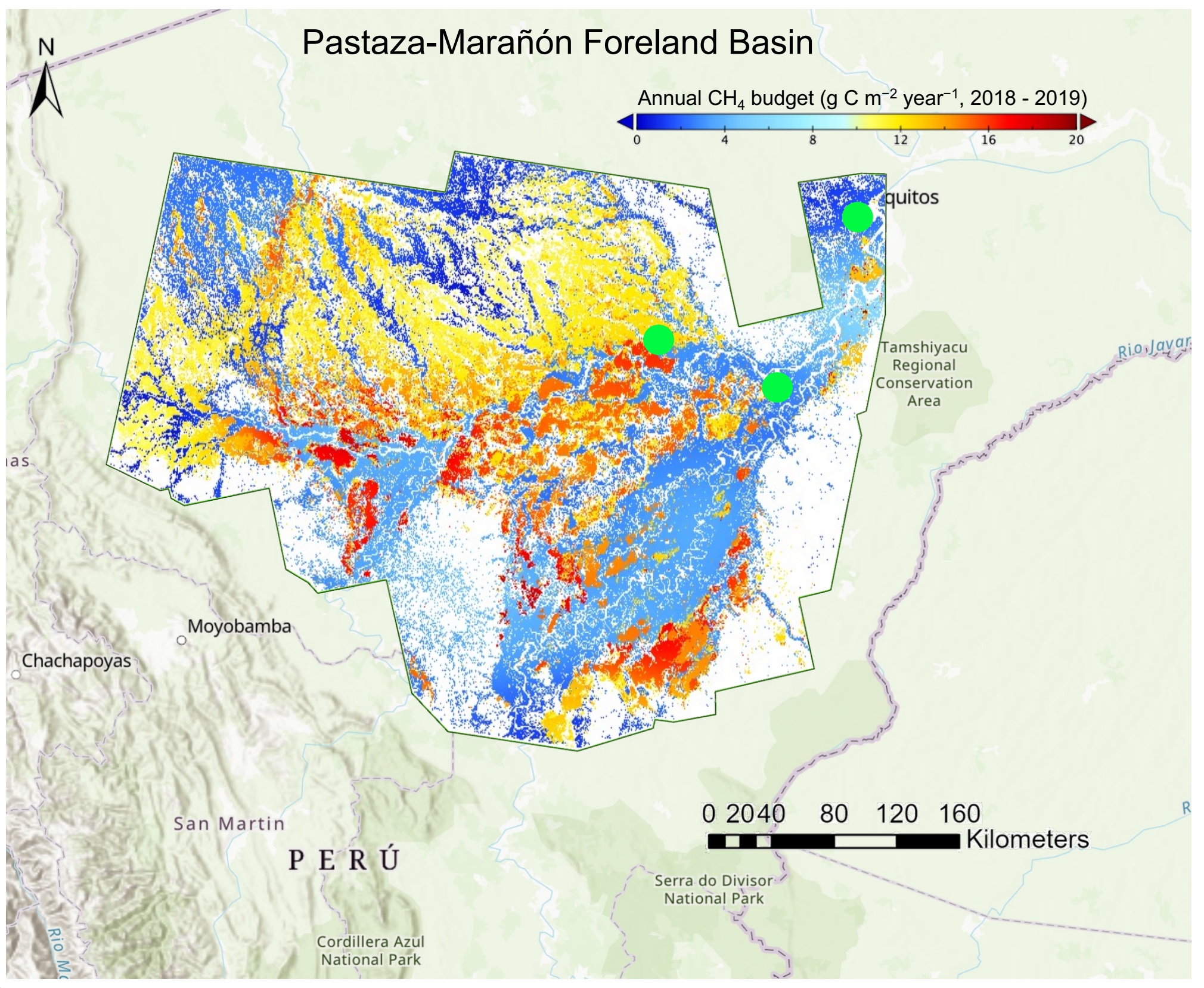


TABLE 1: Pastaza-Marañón Foreland Basin (PMFB) in Peru has complex peatland types. Specific sites are shown as green points in Fig 7.

Peatland Type	Area Coverage (%)	Peat Thickness (cm)	Peat Organic Carbon (Mg C ha^{-1})	Peat Carbon Stock (Pg C)
Swamp	11.9	198	846	3.83
Open peatland	3.1	248	1061	0.69
Pole forest	12.3	246	1054	0.72

FIGURE 7: Spatial variation of CH_4 budget in the PMFB.

6. Ongoing work

- Analyze carbon flux partitioning combining the results of chamber and profile observations.
- Improve screening and processing pipeline for profile concentration data, then apply Inverse Lagrangian model to infer vertical source/sink distribution.
- Evaluate the impacts of canopy scheme on simulating energy and carbon exchange in the swamp peatland with profile observations.
- Advance regional simulation of CH_4 emissions in the PMFB by collecting more site situ observations; analyze regional temporal variation in CH_4 budget.

Publications and paper plans:

[1] Griffis T.J. *et al.* 2020. Hydrometeorological sensitivities of net ecosystem carbon dioxide and methane exchange of an Amazonian palm swamp peatland. Agricultural and Forest Meteorology, 295:108167.

[2] Yuan F., *et al.* 2023. Evaluation and improvement of the E3SM land model for simulating energy and carbon fluxes in an Amazonian peatland. Agricultural and Forest Meteorology, 332: 109364.

[3] Wood J.D, *et al.* Amazonian peatland flips between strong sink and carbon neutral: Can models capture this behavior? (In preparation)

[4] Lafuente A., *et al.* Soil and stem carbon dioxide and methane fluxes of an Amazonian palm peatland. (In preparation)

[5] Yuan F., *et al.* Impact of different canopy schemes on simulating energy and carbon exchange in an Amazonian swamp peatland. (In preparation)

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