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Towards a generalized model to represent the complexities of methane flux processes in forested wetlands

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BACKGROUND

- Understanding the complex relationship between CO_2 uptake and CH_4 release in wetlands is vital for comprehending their role in attenuating or exacerbating climate change (Mitsch et al., 2013).
- Forested wetlands are known for their forest biomass and soil carbon pools (Kolka et al., 2018). These forested wetlands constitute the largest category (49.5 %) of wetlands in the freshwater system (U.S. Fish and Wildlife Service, National Wetlands Inventory; Dahl, 2011).
- Modeling forested wetlands is key to understanding processes, source-sink dynamics, and quantifying carbon and methane flux.

METHODOLOGICAL PROCESS

1. Utilize data from FLUXNET, FCH4 community product (Delwiche et al 2021).
2. Analyze the data to understand the mechanisms governing carbon and methane fluxes.
3. Update the model structure by incorporating the major ecological processes.
4. Evaluate the model performance with eddy-covariance flux datasets.

MODELING APPROACH

PEPRMT model (Oikawa et al., 2017, JGR: Biogeos) + DALEC model (Bloom et al., 2016, PNAS; William et al 2005, GCB). = PEPRMT+

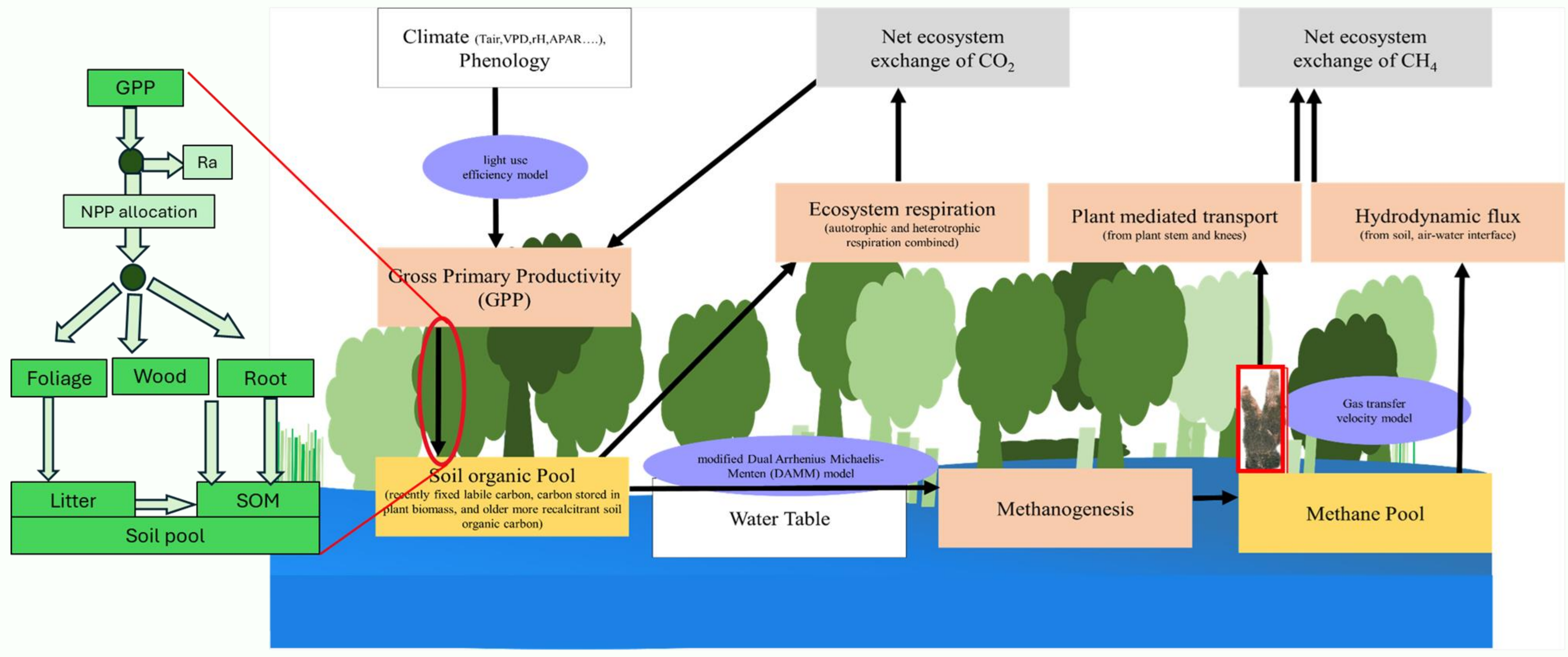


Figure 5. Peatland Ecosystem Photosynthesis Respiration and Methane Transport (PEPRMT) model (Oikawa et al 2017, JGR: Biogeos) with the integration of Data Assimilation Linked Ecosystem Carbon (DELAC) model (William et al 2005, GCB). Inputs are shown in white, outputs in grey, processes in orange, model equations in purple, and pools are yellow boxes.

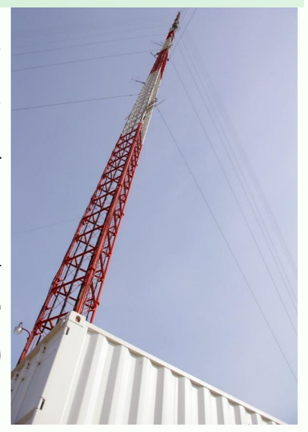
STUDY AREA: FOUR FLUXNET SITES

US-HO1, Howland Forest (main tower), Maine
Upland woody vegetation, Closed conifer forest, minimal disturbance
(45.2041°N 68.7402°W)

US-MYB, Mayberry Wetland, California
Restored wetland, Herbaceous or woody vegetation
(38.050 °N, 121.765 °W)

US-NC4, Alligator River, North Carolina
>100-year-old mixed hardwood swamp forest, Natural drainage
(35.47°N, 75.54°W)

US-PFA, Park Falls / WLEF, Wisconsin
Highly heterogeneous, Mixed forest and wetland landscape
(45.95°N, 90.27°W)



INITIAL RESULTS: FROM PEPRMT+ MODEL

GPP

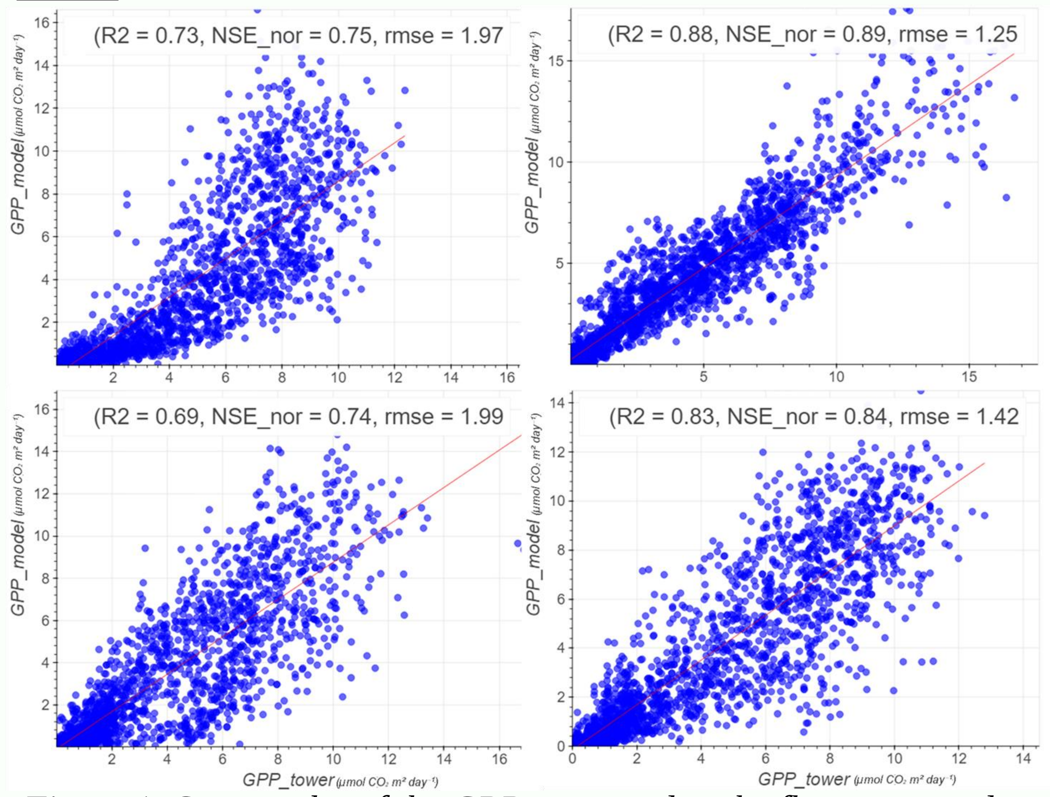


Figure 1: Scatter plot of the GPP measured at the flux tower and estimated from the model .

- The model effectively captures daily GPP (Figure 1), methane flux (Figure 2) and ecosystem respiration (Figure 3) from different forested wetlands.
- The PEPRMT+ model is successful in representing high or low flux intensity years (Figure 2) as well as monthly patterns (Figure 3).
- The model successfully accounts temperature dependent dynamics of ecosystem respiration (Figure 4).

FCH_4

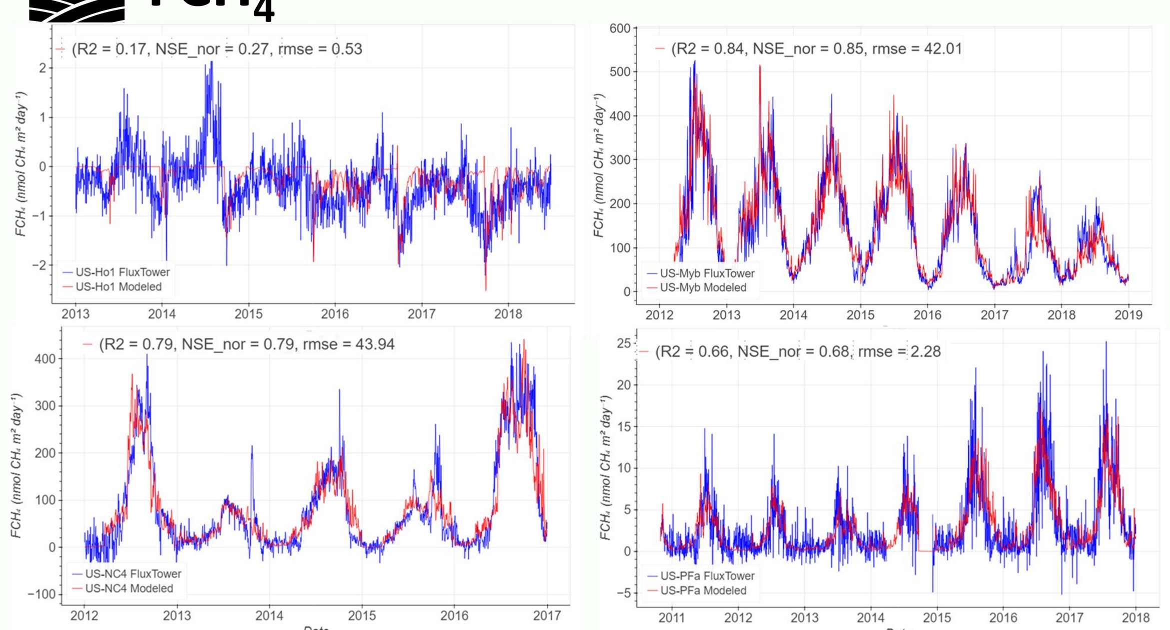


Figure 2: Time series of methane flux measured at flux tower (blue line) and estimated from the model (red line).

- The PEPRMT+ model efficiently represents the carbon fluxes across wetlands at various growth stages and types.

Sites:
US-H01 and US-MYB
(top row, left and right respectively),
US-NC4 and US-PFA
(bottom row, left and right respectively)

Efficiency criteria:
R2 -- Coefficient of determination ,
NSE_nor -- Normalized Nash-Sutcliffe Efficiency,
rmse -- root mean square error

Reco

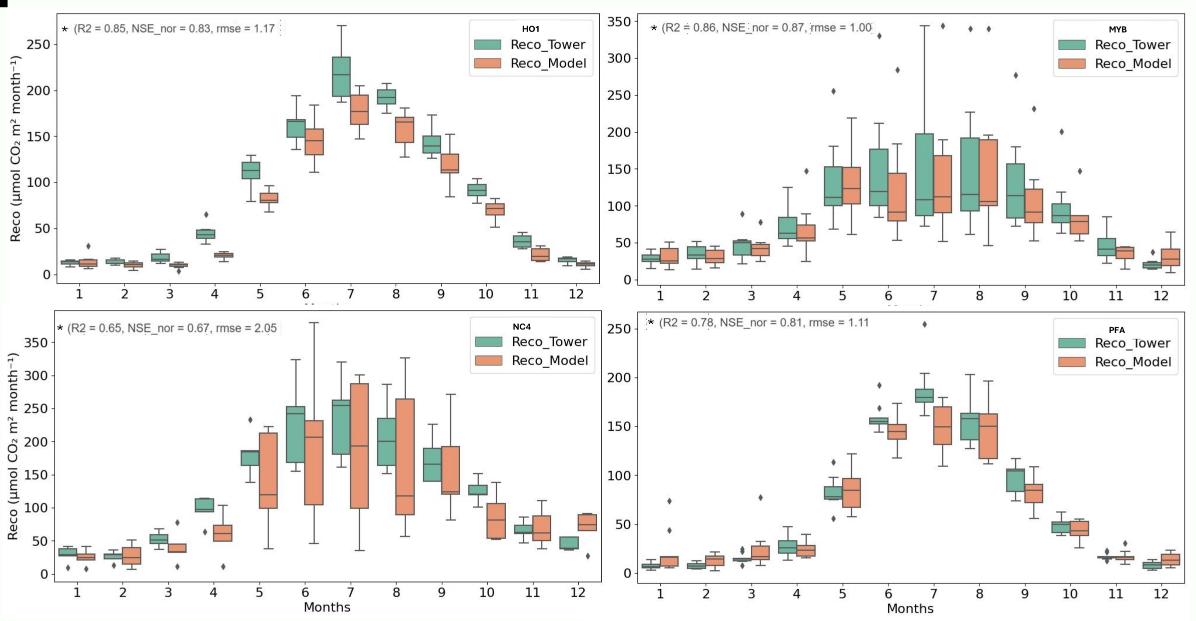
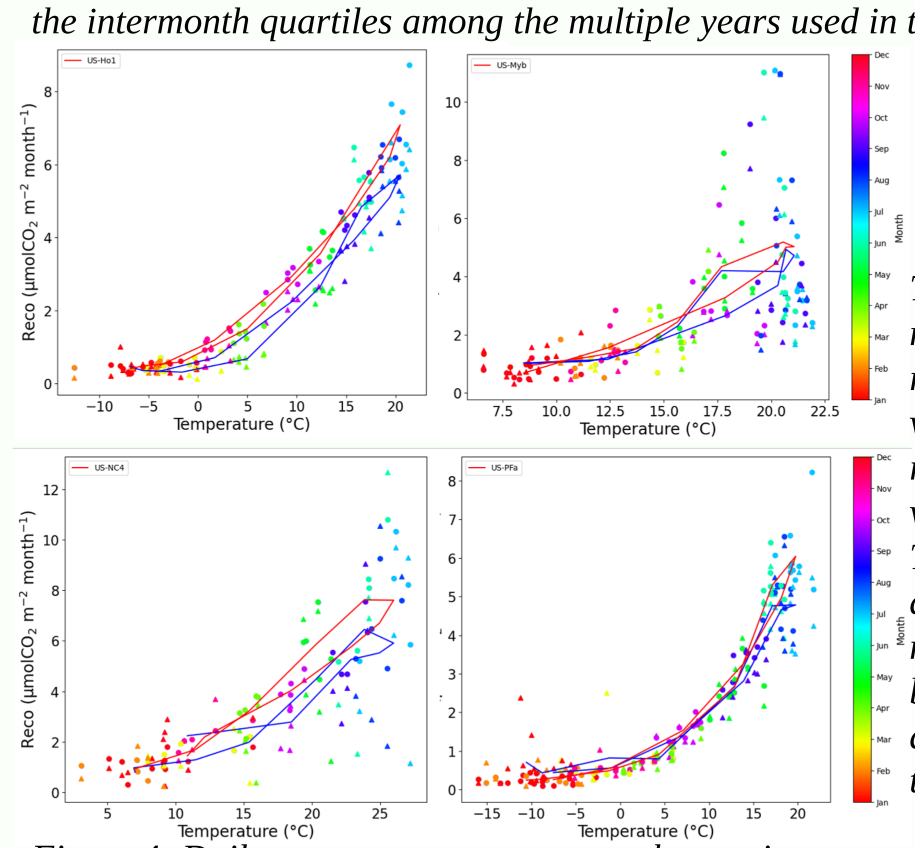


Figure 3: A box plot showing monthly sum of ecosystem respiration (Reco) on the y-axis, with months in the x-axis. The vertical lines in the box represent the intermonth quartiles among the multiple years used in the analysis.



The colors indicate months, circles represent modeled values, triangles represent flux tower values. The solid red line is an average from the model, while the blue line shows an average from flux tower data.

Figure 4: Daily average temperature on the x-axis vs ecosystem respiration (Reco) averaged for each month on the y-axis.

TAKE HOME MESSAGES

- The biogeochemical process of forested wetlands can be effectively represented by coupling existing models, incorporating missing representation of carbon cycle processes, and improving their parameterization using Markov chain Monte Carlo (MCMC) simulation.
- The updated PEPRMT+ model (Figure 5) captures carbon dynamics better than a simple process-based PEPRMT model by taking an advantage of DALEC model that helps to allocate carbon pools and fluxes effectively in the forest ecosystem.

NEXT STEPS

- Improve and validate CH4 transport from trees, including knees - the woody structures that form above the root of the bald cypress - in the model.
- Understand CH_4 flux generation, emphasizing the role of severe weather events, extreme conditions like drought, flood, and other key environmental factors.
- Clarify the interdependence and sensitivity of different parameters in generating carbon and methane flux.

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