

Expanding eddy covariance measurements from tropical wetland methane emissions to improve AI-aided emissions upscaling

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3. Focal Area(s): Expanding the network of methane eddy covariance measurements in tropical wetland ecosystems by facilitating new data collection and adding existing data into an updated version of the FLUXNET-CH₄ dataset. Combining this new network and AI/ML-based models with recent advances in mapping tropical inundation and wetland types to improve process-based emission models and enhance their agreement with top-down estimates of tropical methane emissions, such as satellite-based instruments.

4. Science or Technological Challenge: Global atmospheric methane (CH₄) concentrations are rising at an accelerating rate, yet uncertainties around major terrestrial and aquatic CH₄ sources currently prevent global CH₄ budget closure. Tropical latitudes account for roughly 68% of global emissions, and most tropical emissions come from wetlands (Saunio et al., 2020). Despite their importance to global methane emissions, current tropical wetland methane emissions and projected changes due to climate change are poorly understood. This uncertainty is due to multiple factors, including the paucity of field-based measurements of methane emissions from the tropics (Delwiche et al., 2021), a lack of process-based understanding of tropical methane emissions (Parker et al., 2018), and uncertainties surrounding inundation mapping both currently and under future hydrological change (Padney et al. 2021, Gerlein-Safdi et al. 2021). Accurately upscaling tropical wetland methane emissions will therefore require more field-based measurements (**particularly from eddy covariance towers and flux chambers**), AI-fueled advances in upscaling techniques, and improved modeling of hydrological and ecophysiological factors governing methane release.

5. Rationale: Eddy covariance systems are able to measure methane emissions at high temporal resolution over landscape scales, yet these systems require significant maintenance and are therefore less utilized in challenging tropical ecosystems. Furthermore, eddy covariance methane data that are currently being collected in tropical ecosystems are not all included in FLUXNET-CH₄, the global compilation of methane flux data (Delwiche et al., 2021), for a variety of practical, technical, and cultural reasons. Increasing the availability of these valuable datasets requires a systematic effort to work with local site teams to QA/QC, partition, and gap-fill eddy covariance methane and CO₂ data for inclusion in an updated version of FLUXNET-CH₄. Methodological advances enabling the combination of EC data with other high potential datasets such as chamber flux databases (Bond-Lamberty et al., 2020), would improve spatial representation and prediction.

Our recent work using AI-aided models to upscale global wetland CH₄ fluxes has found strong model divergence in humid tropical rainforest regions, highlighting the need for more tropical data. These new gridded products from upscaling global wetland CH₄ fluxes (UpCH₄, McNicol et al., in prep) and monsoon Asia paddy-rice CH₄ fluxes (RiceCH₄, Ouyang et al., 2023) both have insufficient training sites in the tropics. For UpCH₄, this leads to large differences between upscaled products and state-of-the-art process and inversion based models. However, better model convergence in ecosystems with more training data (temperate and boreal ecosystems) demonstrates the potential of AI-driven upscaled products as long as sufficient training data exist.

Two other critical needs for improving estimates of tropical wetland methane emissions are better maps classifying tropical wetlands and refined inundation maps. While inundation alone is insufficient to explain tropical CH₄ fluxes, which also vary with nutrient dynamics, vegetation and carbon inputs, inaccurate tropical hydrology can exacerbate mis-matches between process-based model estimates of methane emissions, and satellite based measurements from GOSAT or TROPOMI (Parker et al., 2018; Pandey et al., 2021). For example, by including inundation dynamics in wetland maps and linking these to methane emissions models, recent work by Gerlein-Safdi et al. (2021) resulted in improvements to the predicted seasonality and interannual variability of methane emissions. Thus, more work is needed to develop AI tools to detect inundation conditions over time with L-band radar capable of making measurements through cloud or vegetation cover (ie: CYGNSS; (Zeiger et al., 2022) and NISAR).

6. Narrative: To expand the amount of eddy covariance data available from tropical wetland ecosystems, we will develop partnerships with research groups currently making tropical eddy covariance measurements. In some cases, existing flux towers currently not measuring methane flux will be retrofitted to include methane sensors. We will identify existing methane eddy flux data sets and work with site PIs to QA/QC data in preparation for inclusion in FLUXNET-CH₄ Version 2.0. We will enhance tropical flux science by holding pantropical workshops on eddy covariance data processing to foster regional partnerships for technical guidance and knowledge transfer. We will build on the relationships developed during workshops and technical assistance to support the establishment of new flux towers in under-studied ecosystems, particularly in Africa and South America.

New flux tower sites will be located along hydrological gradients to address the seasonality of local flooding conditions, and gradient data will be paired with improvements in inundation mapping to enhance AI-driven upscaling of tropical methane emissions. In addition to establishing new flux towers sites, new chamber measurements will be taken across sites with eddy covariance towers to aid in chamber/tower data comparisons. This will allow us to develop the workflow to reconcile chamber- and EC-based flux measurements to gain better spatial representation, building upon ongoing chamber tower comparisons (Määttä et al., in prep).

This work to expand tropical wetland methane flux measurements will directly support existing efforts to upscale FLUXNET-CH₄ data using AI/ML models. Currently efforts are hampered by lack of data in the tropics, so this proposed expansion in tropical datasets will greatly improve our ability to estimate tropical wetland contributions to the global methane budget, as well as projected future changes in emissions under climate change. The upscaling work will be supported by improved seasonal inundation maps in tropical ecosystems, as well as the incorporation of new metadata and controlled vocabularies required for tropical wetland ecosystems (e.g., updating plant functional types to include tropical systems).

7. References

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