

# Causality guided machine learning model on wetland CH<sub>4</sub> emissions across global wetlands

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## Science Question

- How to model the spatially heterogenous and temporally high varied wetland CH<sub>4</sub> emission?
- How to combine machine learning and physical understanding to capture wetland CH<sub>4</sub> emissions?
- How to generalize the site-level CH<sub>4</sub> emission model to global wetland ecosystems?

## Analysis

- Utilize FLUXNET-CH<sub>4</sub> synthesis dataset, which compiles, standardizes, and gap-fills available daily eddy covariance CH<sub>4</sub> emission data, via the regional networks of AmeriFlux, EuroFlux, OzFlux, and AsiaFlux
- Develop models for major wetland type: Bog, Fen, Marsh, Wet Tundra.
- Identify causality structure between CH<sub>4</sub> emissions and environmental (e.g., temperature) and biological variables (e.g., GPP).
- Develop causality guided machine learning framework to improve model performance on simulating wetland CH<sub>4</sub> emissions.
- Conduct warming experiment to reveal the importance of causality constraint on the modelled responses of wetland CH<sub>4</sub> emissions.

## Results/Significance

- Soil temperature is the dominant factor for CH<sub>4</sub> emissions across all studied wetland types.
- Ecosystem respiration (CO<sub>2</sub>) and gross primary productivity exert controls at bog, fen, and marsh sites with lagged responses of days to weeks.
- Integrating these asynchronous environmental and biological causal relationships in predictive models significantly improved model performance.
- Modelled CH<sub>4</sub> emissions differed by up to a factor of 4 under a +1C warming scenario when causality constraints were considered.

## Acknowledgements

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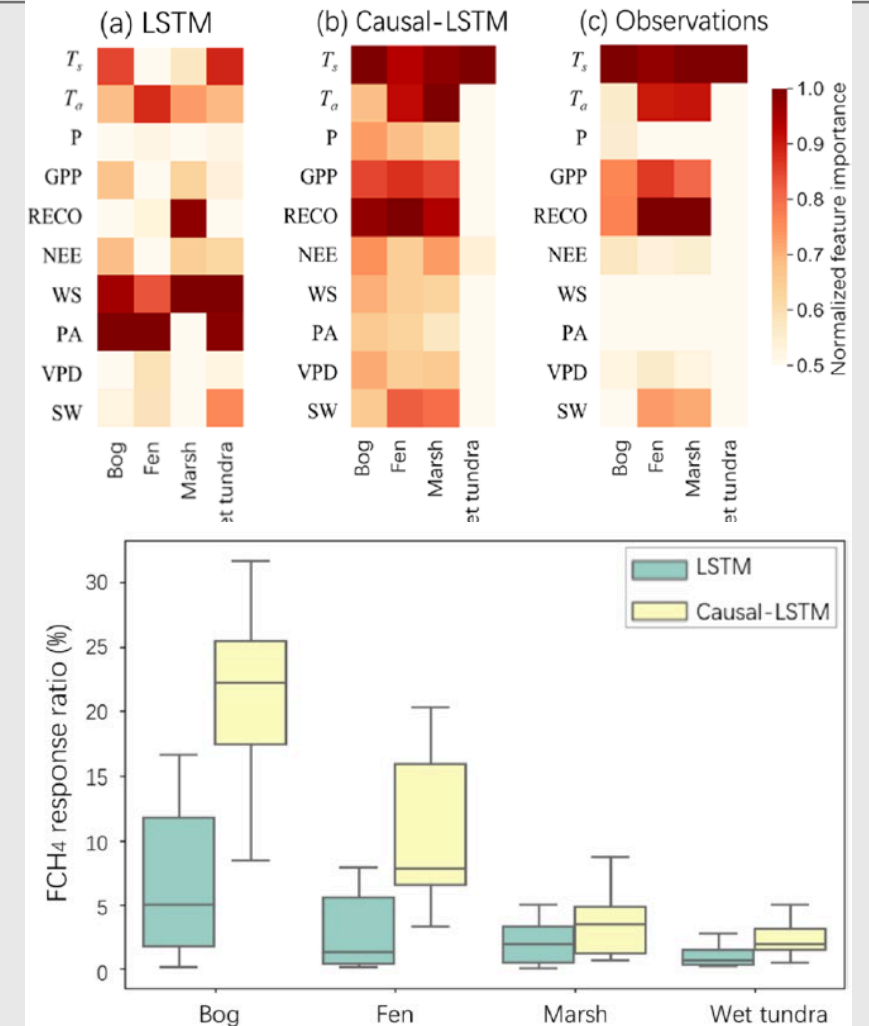


Figure 1: Modelled and observed causality structures on wetland CH<sub>4</sub> emissions (upper panel); and the impacts of causality on CH<sub>4</sub> emission predictions (lower panel)