Prototyping a monitoring system of global wetland CH_4 emissions with machine learning and satellite remote sensing

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ABSTRACT

Wetlands are highly dynamic terrestrial-aquatic interfaces widely distributed across tropical, temperate, and high latitude ecosystems. As the largest natural source to the atmosphere, wetlands are responsible for 30% of global methane emissions, which accounts for about 25% of cumulative anthropogenic radiative forcing since the industrial revolution. Flux chambers and Eddy Covariance (EC) flux towers provide high-frequency data of CH_4 exchanges between land and atmosphere. However, the complexity of wetland CH_4 production and consumption processes makes it challenging to upscale and estimate the net emission flux at large scales and has resulted in large uncertainties in regional and global CH_4 emission products. Advanced Machine Learning (ML) techniques, such as Artificial Intelligence frameworks, are skilled in modeling complex relationships between predictors and target variable (CH_4 emission). Utilizing remote sensing data, ML models, globally distributed EC tower and flux chamber measurements, and ancillary datasets this proposal aims to develop a prototype monitoring system of global wetland CH_4 emissions and to improve understanding of how the physical environment and vegetation activity affect the spatial and temporal dynamics of CH_4 emissions.

OBJECTIVES

We propose to develop an open-source integrated software infrastructure and products that:

(1)collects in situ and remote sensing data;

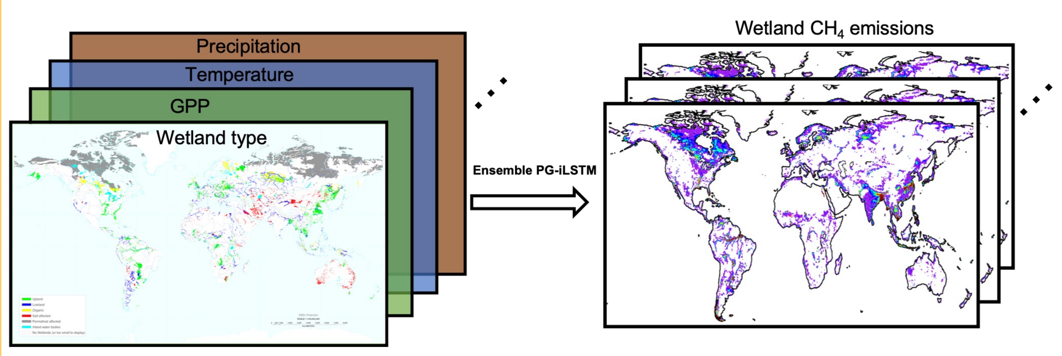
(2)pre-processes data (e.g., gap-filling, feature engineering);

(3)performs initial training of candidate machine learning models;

(4)performs model selection and fine-tuning;

(5)model and evaluates global wetland CH_4 emissions.

This development will generate high-resolution monthly products of global wetland CH_4 emissions and with uncertainty quantification. The resulting product will be used to diagnose the spatial and temporal evolution of the underlying drivers and evaluate existing wetland CH_4 emission estimates in scientific publications and national and international reports.



METHODOLOGY

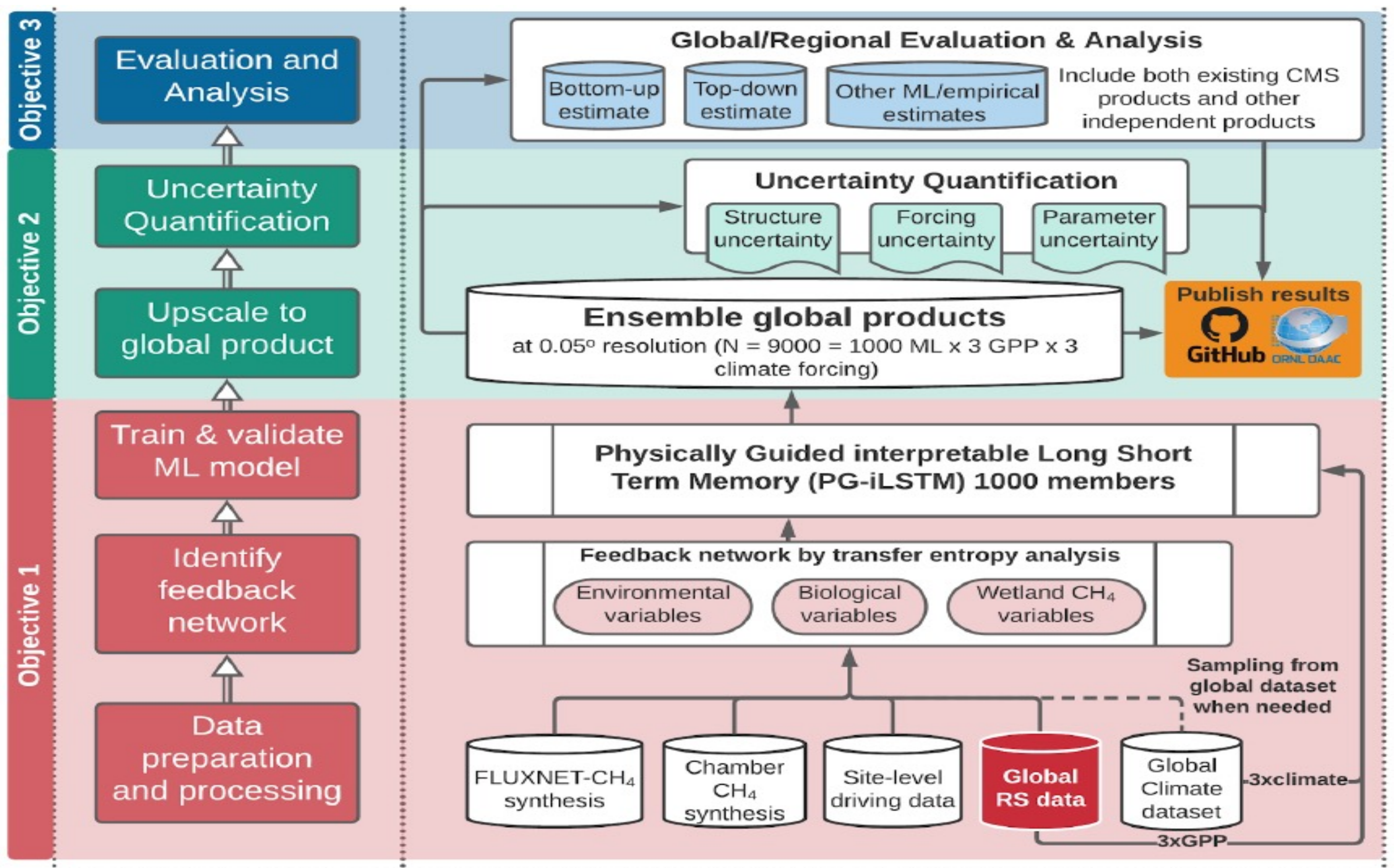


Figure 1. Overview of the methodology and data products from this proposal. RS, ML are remote sensing and machine learning. Multiple NASA-supported remote sensing datasets are used.

RESULTS & DISCUSSION

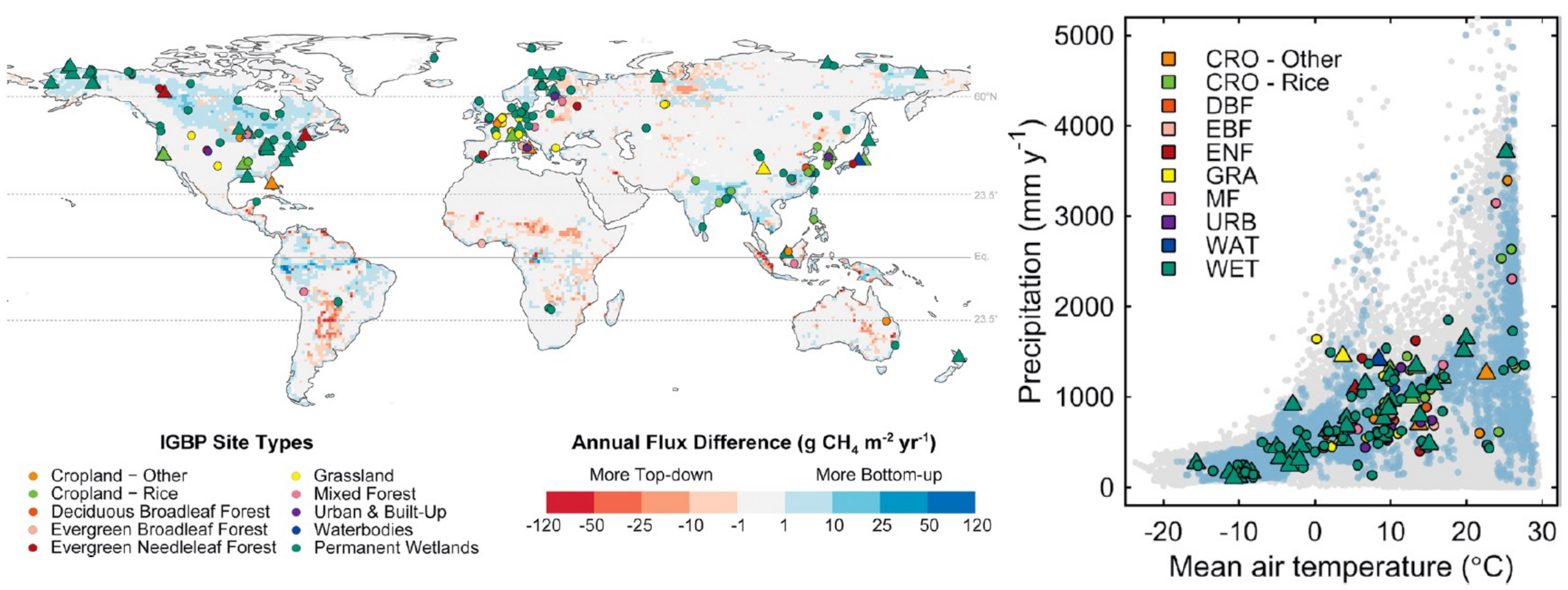


Figure 2. FLUXNET-CH_4 sites available for training and validation of ML models.

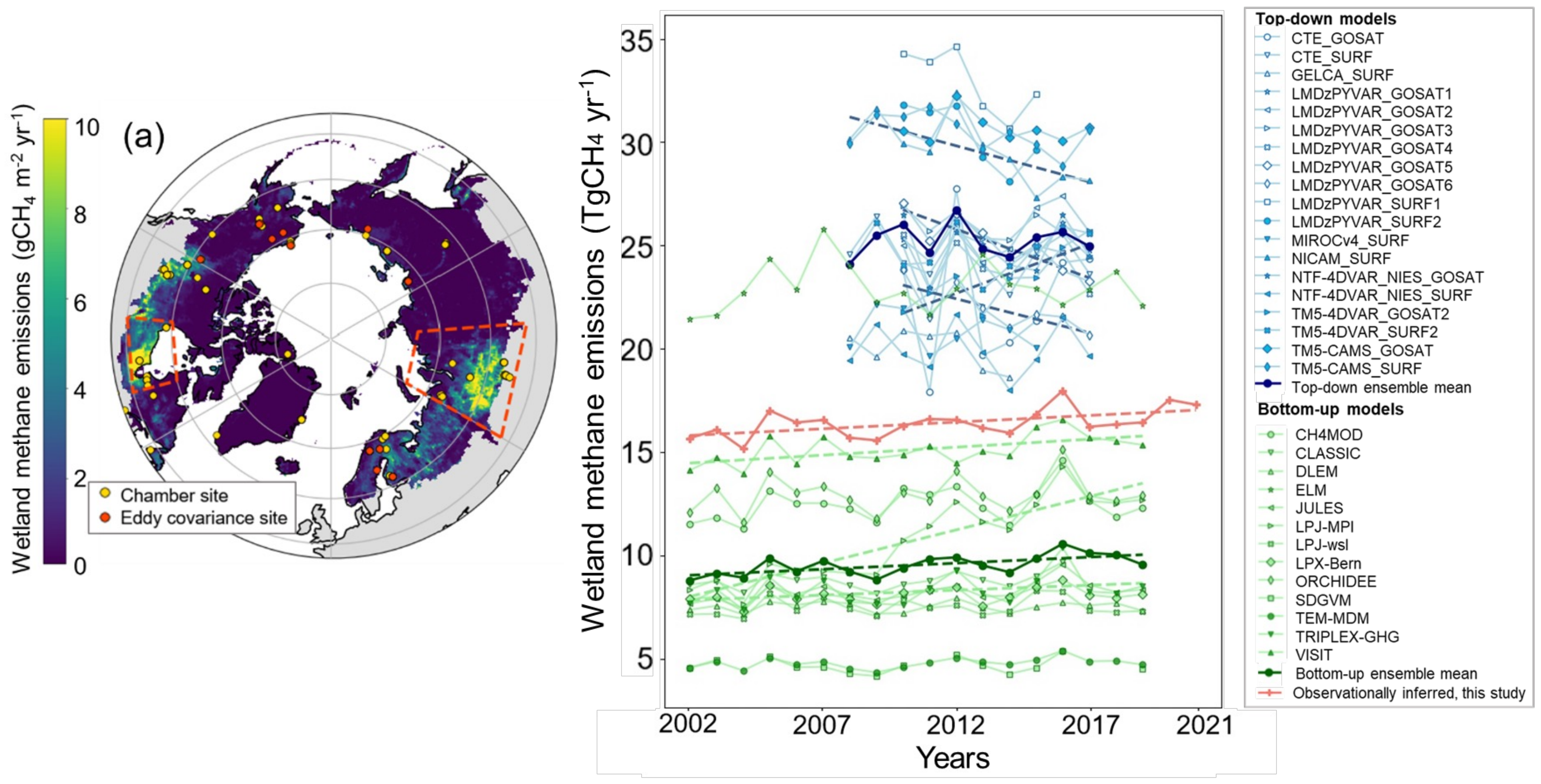


Figure 3. Focused analysis over Boreal-Arctic region, comparison among bottom-up biogeochemistry models, top-down transport inversion models, and upscaled product (this project)

RESULTS & DISCUSSION

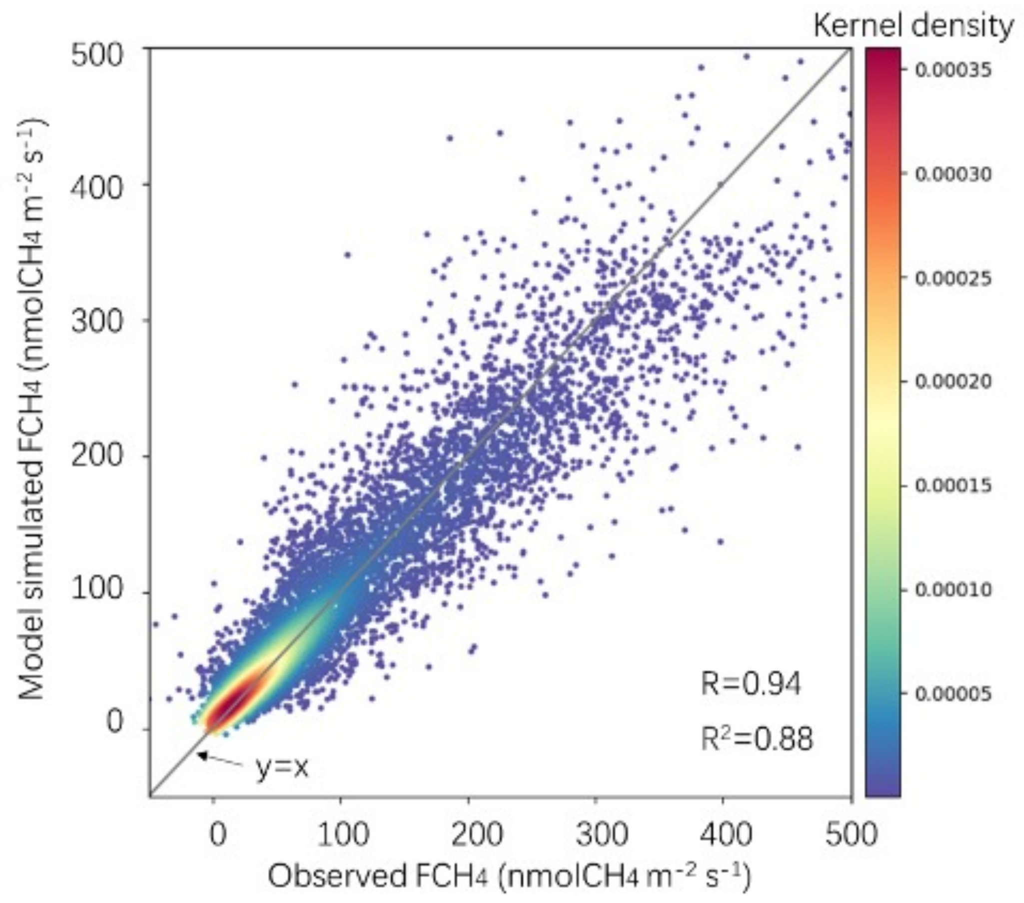


Figure 4. Model accuracy over testing dataset.

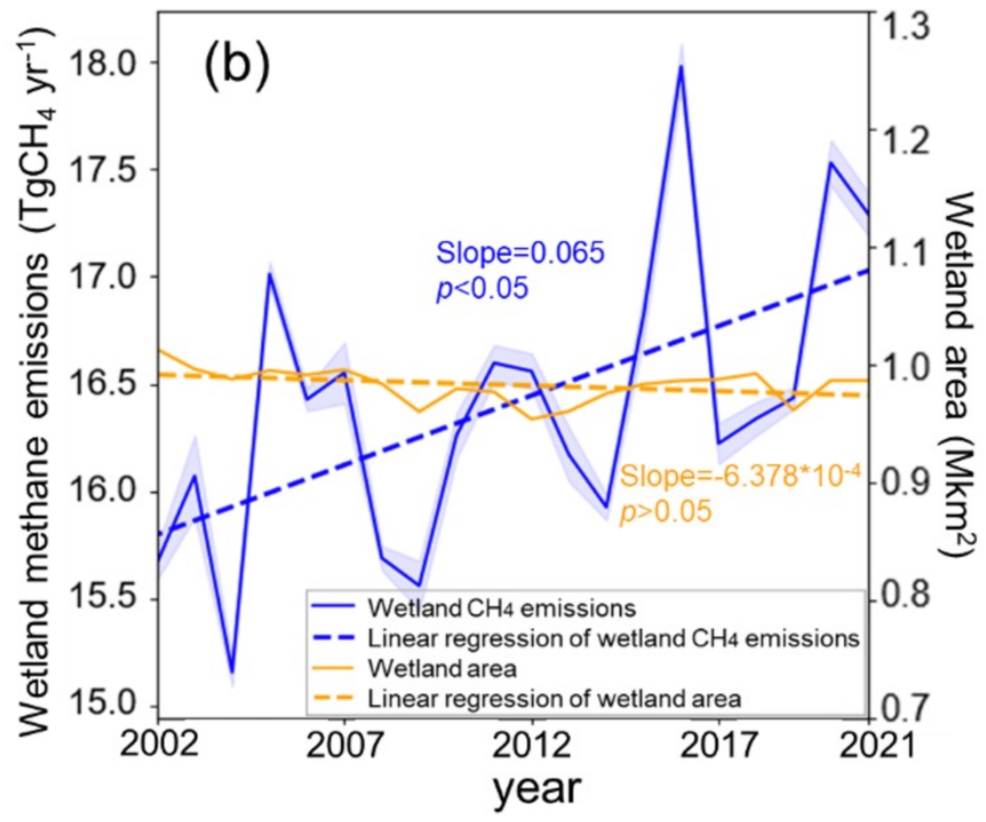


Figure 5. Two decades of Boreal-Arctic wetland CH4 emission. Emission increase was due to the enhancement of flux intensity rather than expansion of inundation area.

- We found a robust increasing trend of CH4 emissions (+8.3%) with strong inter-annual variability.
- The majority of emission increases occurred in early summer (June and July) and were mainly driven by warming (~64%) and ecosystem productivity (~15%).
- 2 C temperature anomaly in 2016 led to the largest recorded annual methane emissions (~18 TgCH4 yr-1) over this region, driven primarily by high emissions over Western Siberian lowlands.

ACKNOWLEDGMENTS

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