

Understanding the role of environmental drivers in determining methane flux in forested wetlands

Kabi Raj Khatiwada¹, Rongyun Tang², Bassil El Masri^{3,4}, J.B. Moon^{4,5}, Gary Stinchcomb⁶, Benjamin Runkle^{1,2}

¹ Environmental Dynamics, University of Arkansas, Fayetteville, AR,

² Department of Biological and Agricultural Engineering, University of Arkansas, Fayetteville, AR,

³ Biological Sciences Department, Murray State University, Murray, KY,

⁴ Watershed Studies Institute, Murray State University, Murray, KY,

⁵ Department of Earth and Environmental Sciences, Murray State University, Murray, KY

⁶ Department of Earth Sciences, University of Memphis, Memphis, TN,



BACKGROUND

The largest biogenic source of atmospheric methane is wetlands; however, there is high variability in methane flux across spatial and temporal scales, impacting the predictability of this greenhouse gas's atmospheric dynamics (Cui et al., 2024, CEE).

An extreme environment is characterized by deviations from typical weather and climate patterns, with conditions outside the range of normally observed values. These conditions often manifest as unusual or severe weather events, including heavy precipitation, continuous drought or other environmental conditions (Seneviratne et al. 2012, IPCC).

Methane (CH_4) flux varies significantly, especially during years with extreme conditions (Turner et al., 2021, JGR Biogeo).

Factors influencing CH_4 flux and carbon balance are:

- seasonal air temperature (Lagergren et al., 2008, Tellus B),
- soil temperature (Kuh et al, 2009, Hydrobio),
- precipitation including droughts and water table fluctuations (Pugh et al., 2018, Biogeochem),
- soil moisture (Gondwe et al., 2021, PTRS)

INITIAL RESULTS

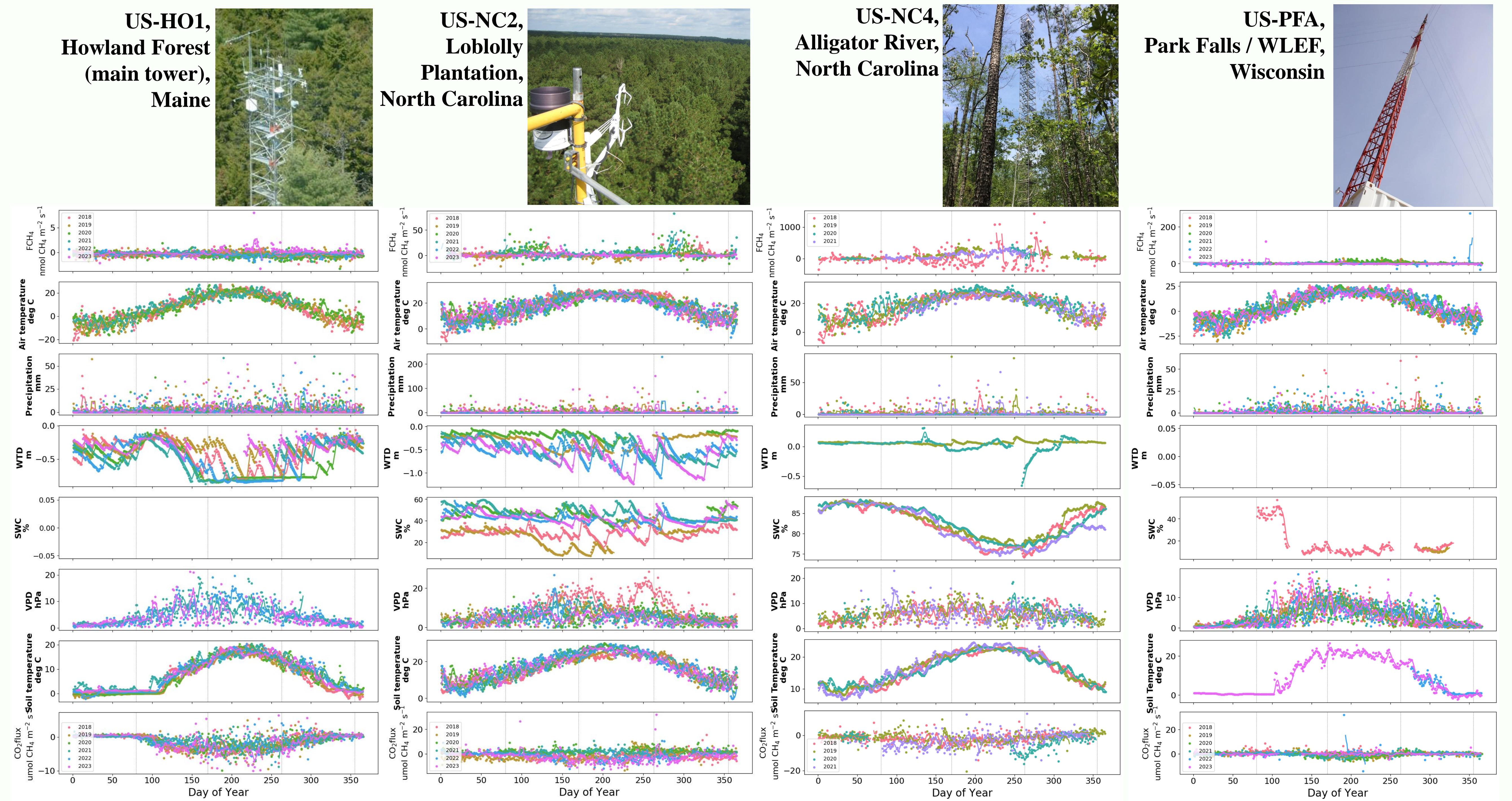


Figure 2: The methane flux (top row) and carbon dioxide flux (bottom row) with the environmental variables -- air temperature, precipitation, water table depth (WTD), soil water content (SWC), vapor pressure deficit (VPD), soil temperature -- in between. The daily data from Ameriflux are shown as dots while lines represent five-day moving averages. The four vertical lines separate four seasons -- spring, summer, fall, winter resp.

➤ The flux is higher than average for the year 2023 in HO1; 2020, 2022 in NC2; 2018, 2020 in NC4; 2022 in PFA.

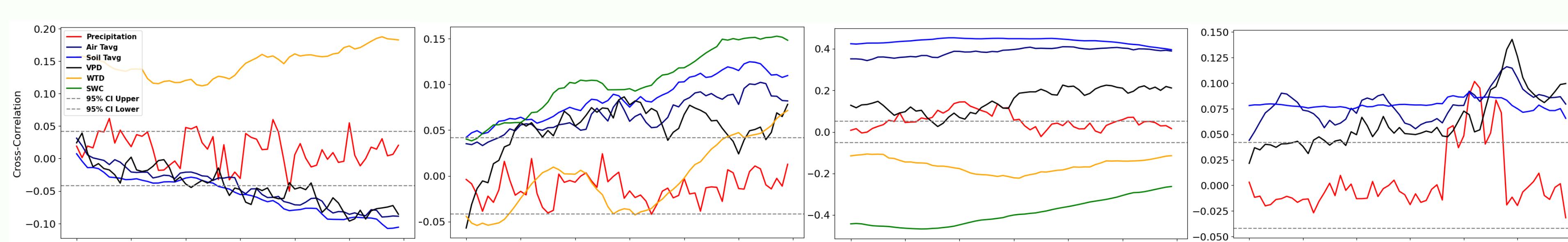


Figure 3: Cross-correlation analysis is performed to understand the lag effect of environmental variables (precipitation, air temperature (Air Tavg), soil temperature (soil Tavg), vapor pressure deficit (VPD), water table depth (WTD), soil water content (SWC) with methane flux, for the sites US-HO1, US-NC2, US-NC4, and US-PFA respectively.

➤ Changes in precipitation seem to be correlated with changes in methane flux with a lag of approx. day 10 or day 40.

HYPOTHESES

The magnitude of methane or carbon flux is influenced by the severity of environmental variables.

There is a spike in methane flux following extreme environmental conditions, typically delayed by several days.

STEPS

Download data from Ameriflux

Analyze how environmental variables change in relation to carbon fluxes

Perform cross correlation analysis to assess lag effect of environmental variables on methane flux

Test if precipitation can forecast methane flux, using Granger causality test

Formulate a theorem that could be applied to process-based models

MOTIVATION

Understanding the linkage between environmental variables can significantly improve the accuracy of methane flux estimates.

STUDY AREA

The sites were selected based on the following criteria at the Ameri flux website. (<https://ameriflux.lbl.gov/sites/site-search/?availability>)

- Identify the site having FCH4 – found 77
- Filter with record length of greater than 3 years – found 59
- Add NEE in the filter – found 23
- Add filter, sites in USA – found 18
- Add forest in the site description -- found the following 5 sites (accessed 3 Sept. 2024). Note: The site 'Skr' was not used for the analysis because it was not available in CC-BY 4.0

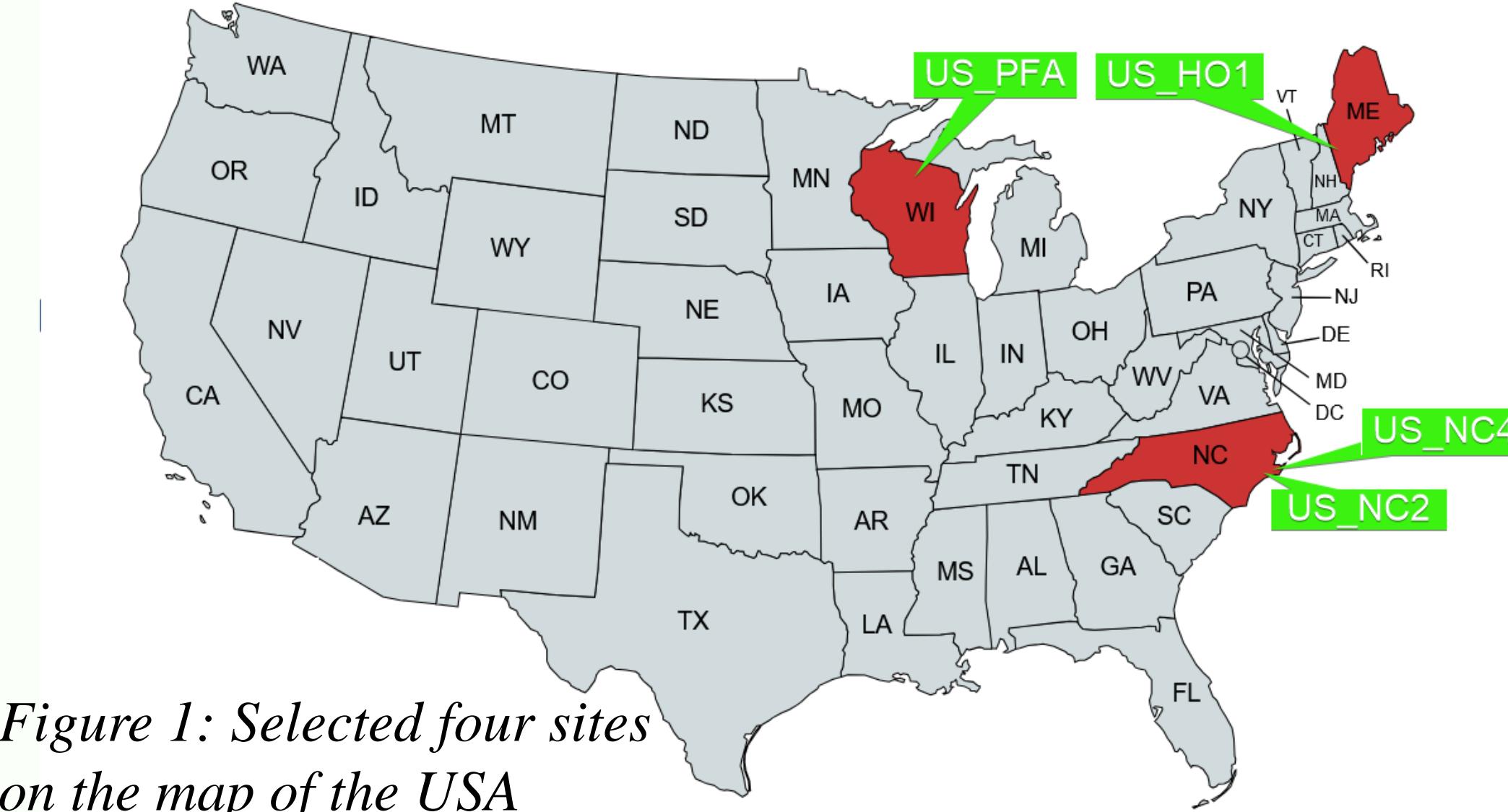


Figure 1: Selected four sites on the map of the USA

- ❖ The Howland research site (US-HO1) has undisturbed stands of trees with mean age of 120 years (Richardson et al., 2019, Nature SD).
- ❖ The North Carolina Loblolly Pine site (US-NC2) is a pine plantation amongst mixed forests.
- ❖ The site at Alligator River National Wildlife Refuge (US-NC4) includes a 100-year-old natural coastal bottomland hardwood forest (Aguilos et al., 2022, AgrForMet).
- ❖ The television tower (US-PFA) is a highly heterogeneous mixed forest representing temperate ecosystems (Davis et al., 2003, GCB).

INITIAL CONCLUSION

The study shows that extreme precipitation is followed by higher methane flux, with a lag of around 10 or 40 days at some stations, though this is not statistically significant.

WAY FORWARD

To understand methane flux generation while emphasizing the role of extreme conditions and key other environmental factors.

ACKNOWLEDGMENTS

Financial support for this research is provided by the Department of Energy (Grant # DE-SC0022228), LI-COR LEEF program, and the Murray State Watershed Studies Institute. We also thank Ms. Kimberley Skyes (USFWS), for project assistance and advice.

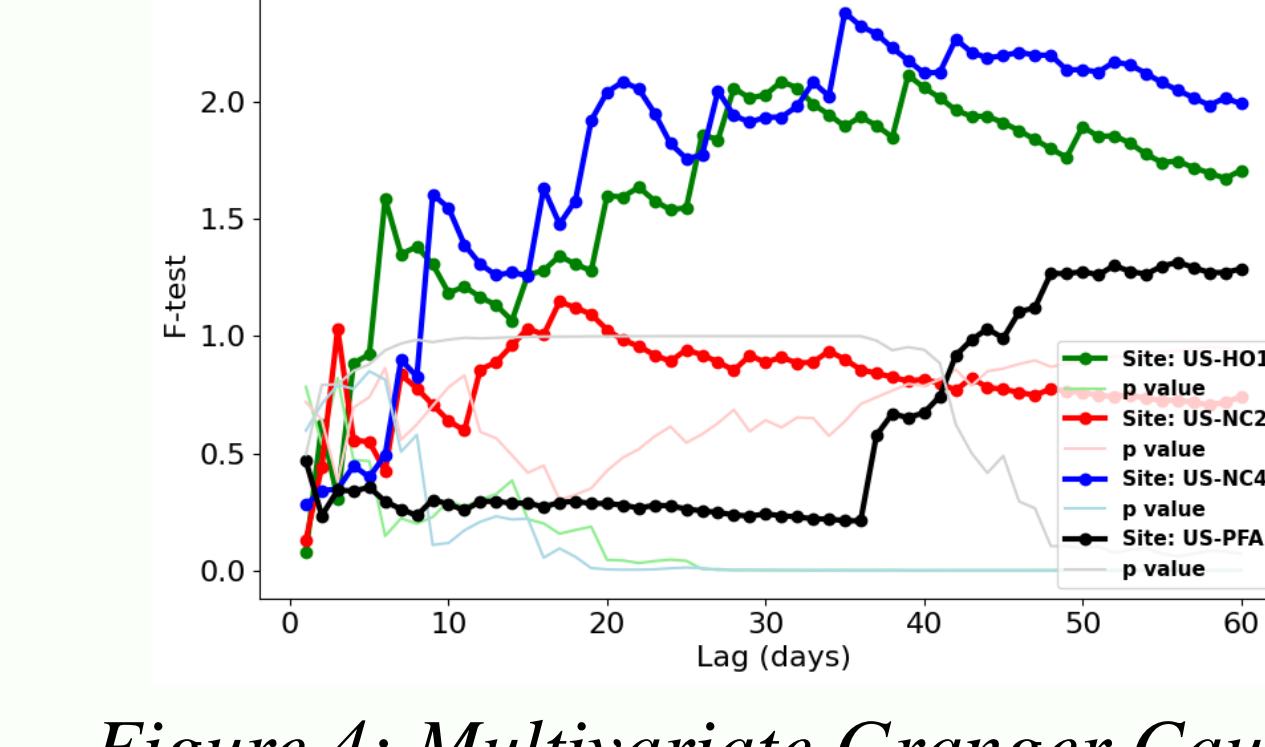


Figure 4: Multivariate Granger Causality using Vector Autoregression Model is used to understand if heavy precipitation causes higher methane flux.

➤ This method did not find that heavy precipitation is a statistically significant driver of higher methane flux.