American Geophysical Union (AGU) Fall Meeting, Chicago, IL, December 12-16, 2022

AGU #1125877

Controls of Methane Emission Fluxes from Freshwater Wetlands at the Global Scale

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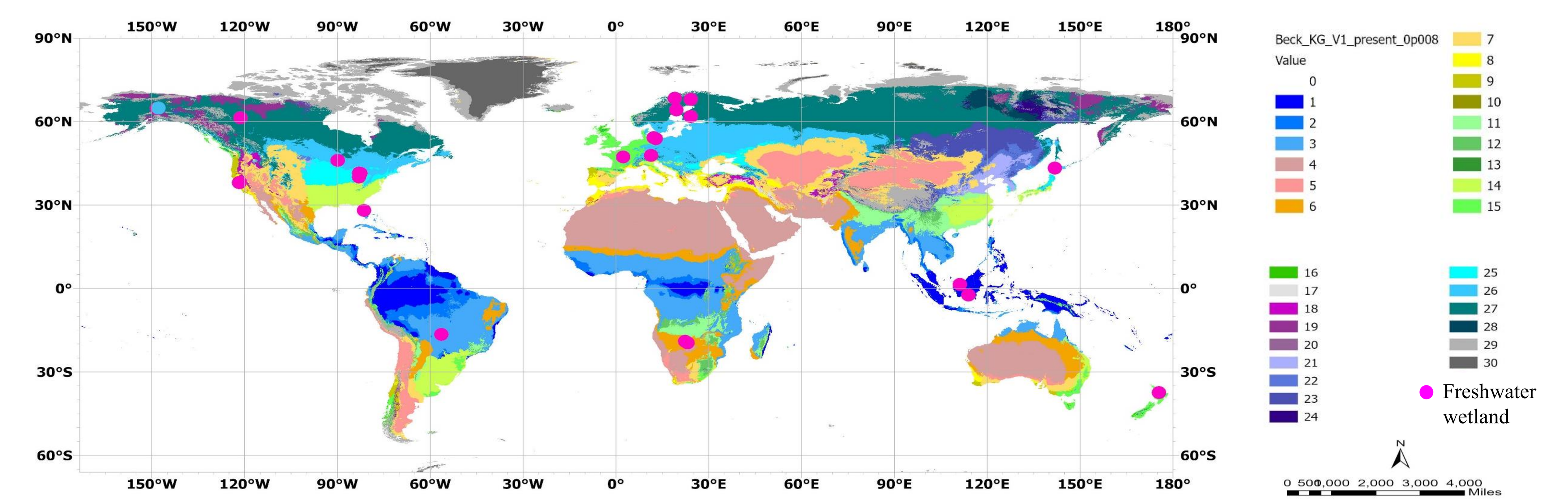
Introduction

Since pre-industrial times, increases in atmospheric methane have contributed to a quarter of the climate-warming effect from greenhouse gases. Methane is emitted from anthropogenic sources such as landfills, agriculture, and fossil fuels, as well as from natural systems such as forests and wetlands. We investigated the climatic and eco-hydrological controls of the monthly **methane emission fluxes from 31 freshwater wetlands sites across the globe.** Multivariate techniques (correlation matrix, principal component analysis, and factor analysis) were employed to identify the dominant drivers (Ishtiaq and Abdul-Aziz 2015). Explanatory partial least squares regression models were developed to estimate the relative linkages of net emission fluxes of methane with the climatic and environmental variables.

Study site and data



List of variables

Net emission fluxes of methane (FCH4)	**Sensible heat flux (H)**	**Soil temperature (TS)**	**WTD > 0 (i.e., +ve) indicates flooding.**
Photosynthetically active radiation (PAR)	**Wind speed (WS)**	**Vapor pressure deficit (VPD)**	**WTD < 0 (i.e., –ve) when no flooding. Water level (WL)**
Latent heat flux (LE)	**Friction velocity (USTAR)**	**Water table depth (WTD)**	**WL = WTD + 2m**

Data analytics framework

Obtain the correlation structure of variables through Pearson correlation matrix in the Z-score domain

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Identify groupings and inter-relation patterns of variables using principal component analysis

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Extract hidden factors and identify dominant drivers by factor analysis

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Determine the relative linkages of different drivers with the net emission fluxes of methane by estimating PLSR model coefficients (β).

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Compute the aggregated linkages of the 'radiation-energy' (β_{RE}), 'hydro-climatic'(β_{HC}), and 'aerodynamic' (β_{AD}) components as follows:

$$\beta_{RE} = \sqrt{(\beta^2_{PAR} + \beta^2_{LE} + \beta^2_{H})}$$
$$\beta_{HC} = \sqrt{(\beta^2_{TS} + \beta^2_{VPD} + \beta^2_{WL})}$$
$$\beta_{AD} = \sqrt{(\beta^2_{WS} + \beta^2_{USTAR})}$$

Results

Bivariate correlation coefficients of FCH4 with the drivers

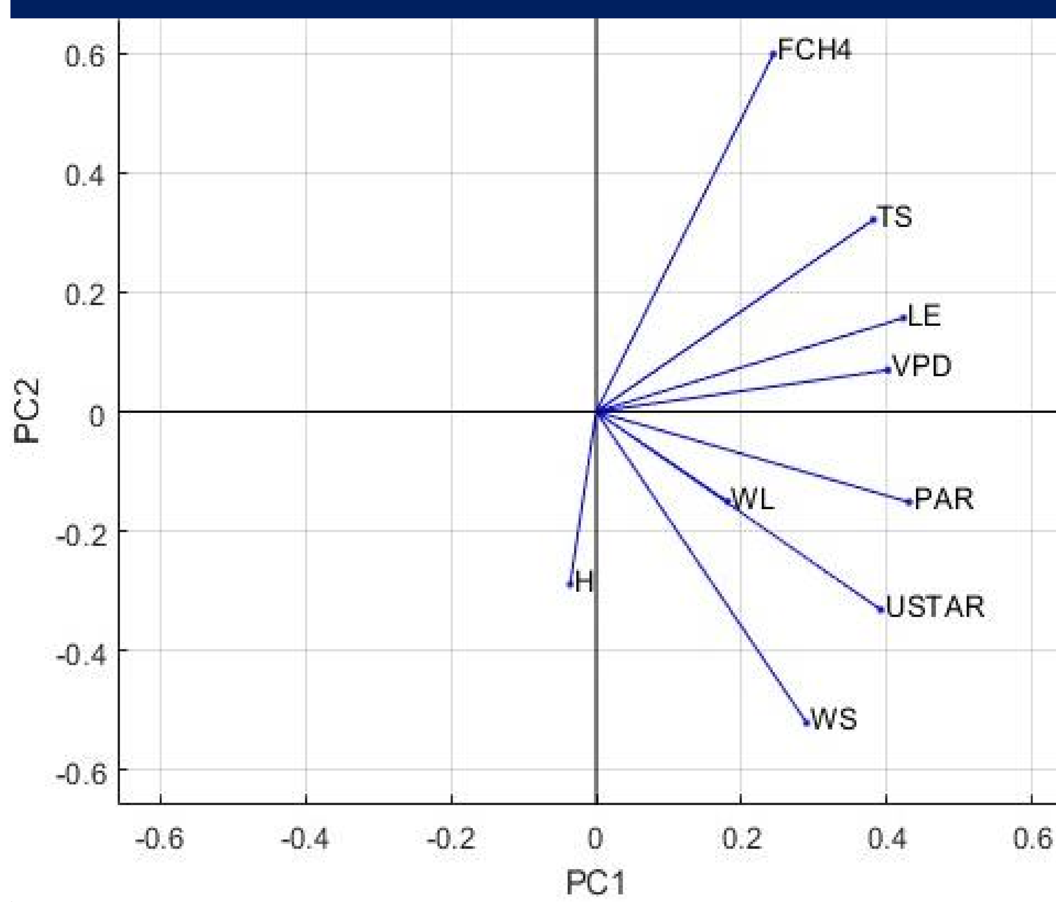
	Case	PAR	LE	H	WS	USTAR	TS	VPD	WL
WTD >0	Correlation coefficient	0.32	0.54	-0.15	-0.12	0.19	0.67	0.44	0.14
	p-value	0.00	0.00	0.01	0.05	0.00	0.00	0.00	0.02
WTD<0	Correlation coefficient	0.44	0.30	-0.18	-0.14	0.22	0.39	0.29	-0.21
	p-value	0.00	0.00	0.02	0.06	0.00	0.00	0.00	0.01

WL = WTD + 2m. WTD > 0 (i.e., +ve) when the water table depth is above the ground surface and WTD < 0 when below the surface.

Groupings of drivers with the net emission fluxes of CH_4

PCA and FA above the ground surface(i.e. WTD > 0)

Orientations and groupings of PCA

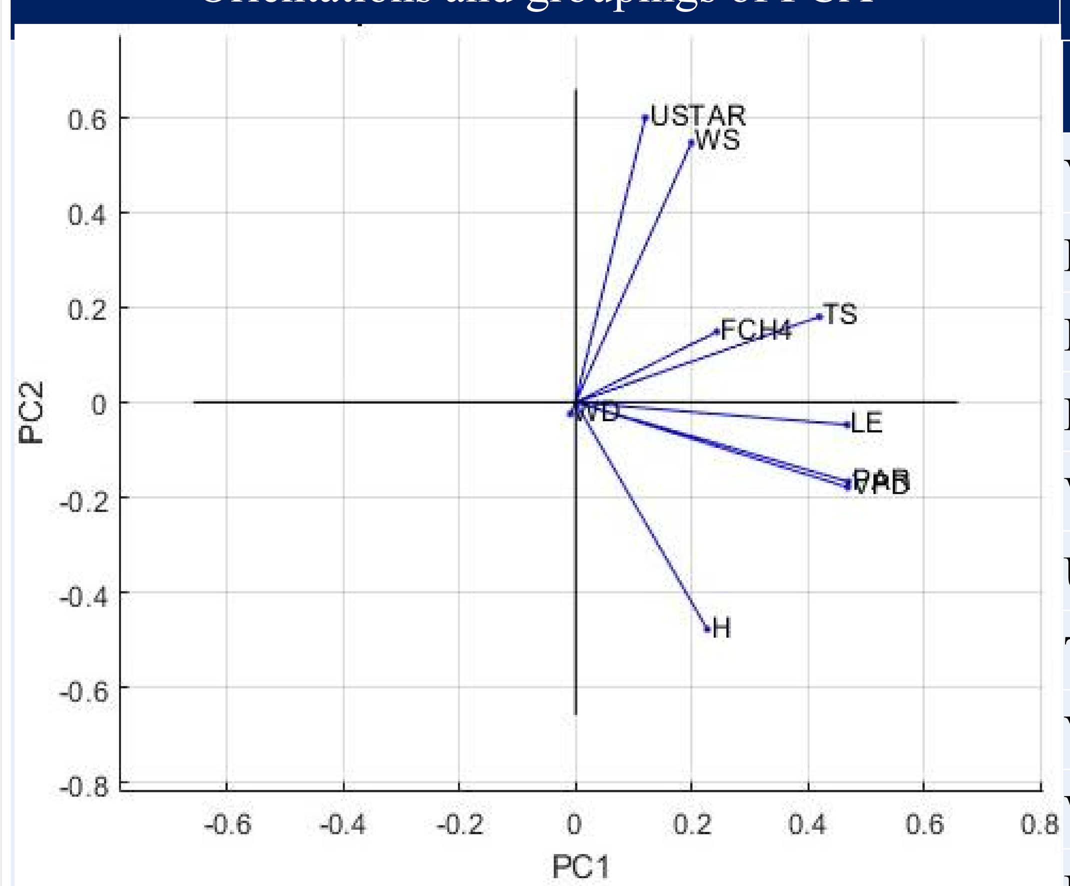


Dominant factors from FA

Case	WTD > 0		
Variables	F1	F2	F3
PAR	**0.65**	**0.69**	-0.14
LE	**0.80**	0.42	0.09
H	-0.04	0.00	**-0.53**
WS	-0.01	**0.98**	0.17
USTAR	0.41	**0.78**	-0.05
TS	**0.80**	0.24	0.31
WL	0.13	0.30	0.31
FCH4	**0.75**	-0.17	0.31

PCA and FA below the ground surface (i.e. WTD < 0)

Orientations and groupings of PCA



Dominant factors from FA

Case	WTD < 0		
Variables	F1	F2	F3
PAR	**0.86**	0.09	0.17
LE	**0.82**	0.21	0.02
H	0.49	-0.19	-0.34
WS	0.11	**0.96**	-0.26
USTAR	0.02	**0.50**	0.19
TS	**0.57**	**0.53**	0.17
VPD	**0.92**	0.06	-0.02
WL	0.04	0.00	-0.24
FCH4	0.32	0.08	**0.94**

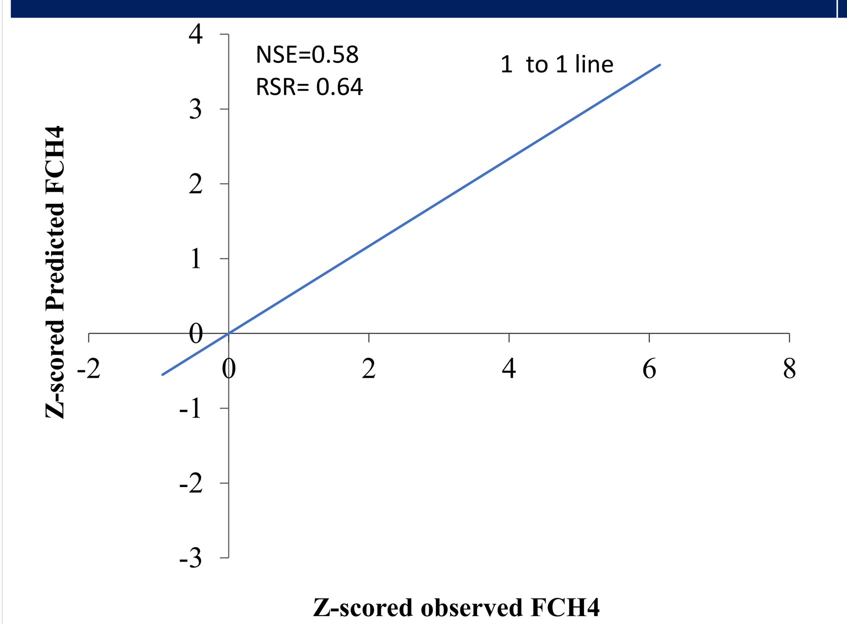
Partial Least Squares Regression (PLSR)

Coefficients (β) of drivers with FCH4 from PLSR models with Z-score

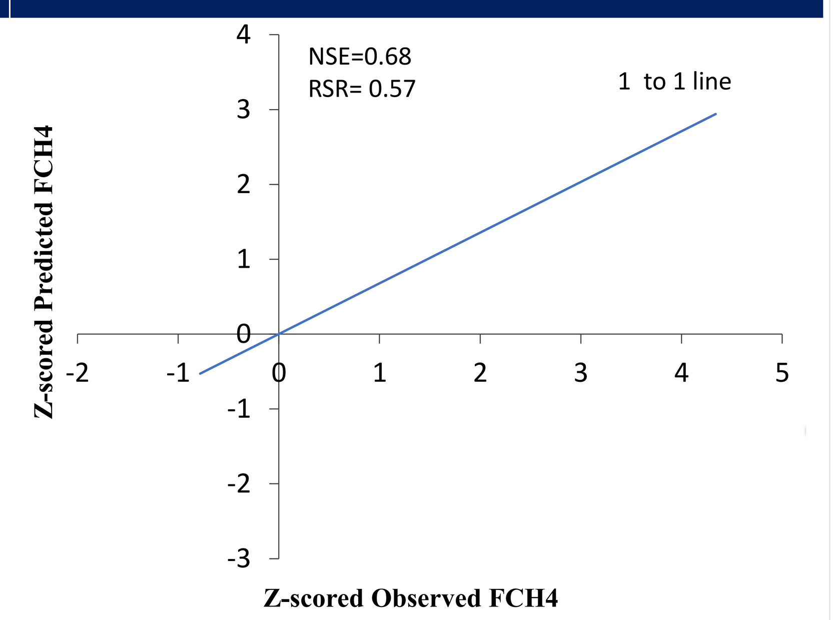
Case	Intercept	PAR	LE	TS	H	WS	USTAR	VPD	WL	NSE	RSR
WTD>0	0.00	-0.02	**0.26**	**0.53**	-0.02	**-0.43**	0.00	0.06	**0.10**	**0.58**	**0.64**
WTD<0	0.00	**0.46**	0.03	**0.57**	**-0.52**	**-0.72**	**0.32**	-0.05	0.03	**0.68**	**0.57**

Standardized PLSR models were developed using Z-scores of log-transformed data of all participatory variables.
WL represents WTD+ 2m datum.
NSE = 1.0 and RSR = 0 indicate a perfectly predictive model.

WTD > 0



WTD < 0



Conclusions

- When the wetlands were flooded; (i.e., WTD > 0): TS, WS, LE and WE had the strongest controls on the methane emission fluxes.
- In the absence of flooding ; (i.e., water table depth below the surface), the methane emission fluxes were mainly controlled by WS, TS, H, PAR, and USTAR.
- When WTD > 0, the aggregated linkage of the hydro-climatic (β_{HC}) component was 2.1 and 1.3 times stronger than that of the radiation-energy component (β_{RE}) and aerodynamic (β_{AD}) component, respectively.
- When WTD < 0, the aggregated linkage of the hydro-climatic (β_{HC}) was 1.6 and 1.4 times stronger than that of the radiation-energy component (β_{RE}) and aerodynamic (β_{AD}) component, respectively.
- Presence and absence of WTD indicate differences in wetland biogeochemical processes and methane emissions.

Acknowledgements

The research was funded by **National Science Foundation (NSF)** to **Dr. Omar I. Abdul-Aziz** (NSF CBET Number 1705941).

References

- Ishtiaq, K. S., and Abdul-Aziz, O. I., 2015. Relative linkages of canopy-level CO2 fluxes with the climatic and environmental variables for US deciduous forests. Environmental Management. 55(4), 943-960.

December, 2021