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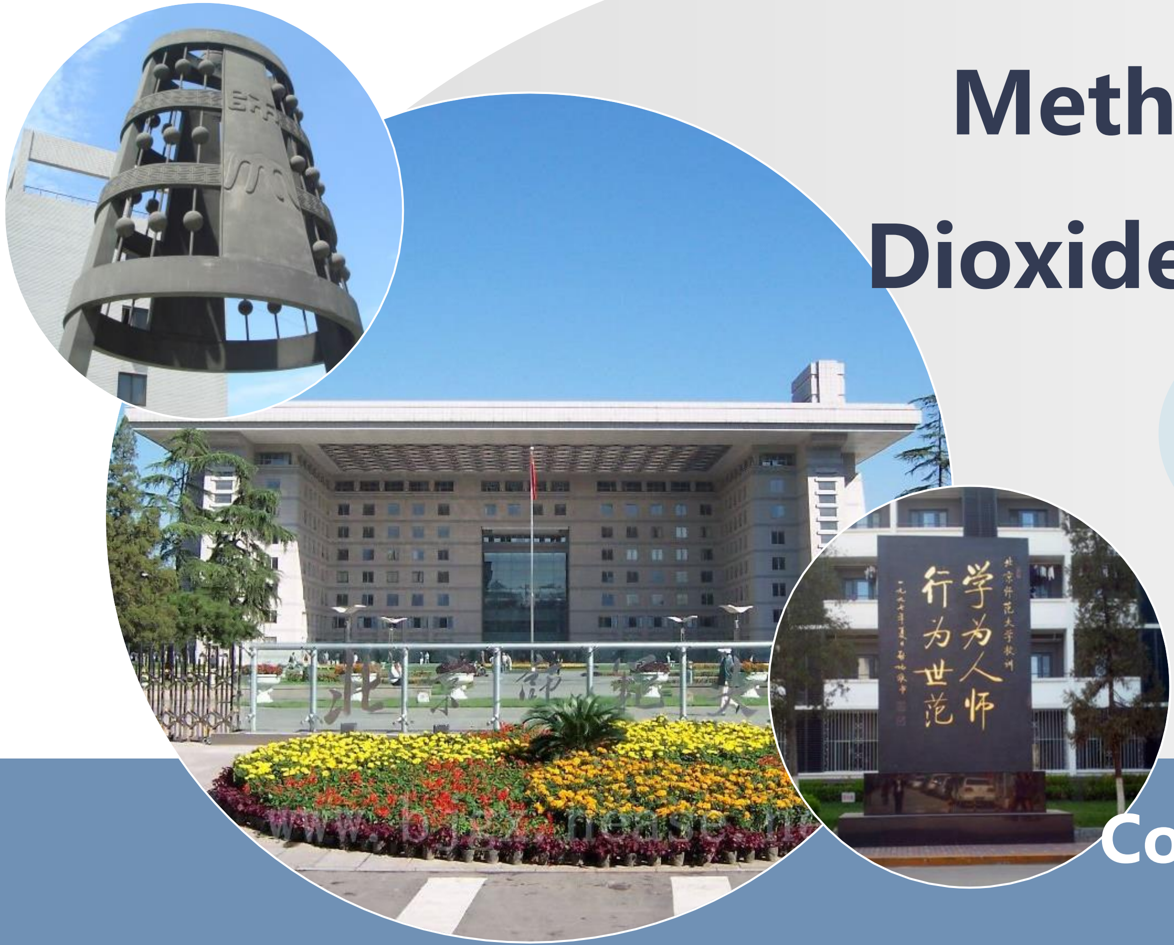


Methane Emissions offset Carbon Dioxide Uptake in Costal Blue Carbon Ecosystems

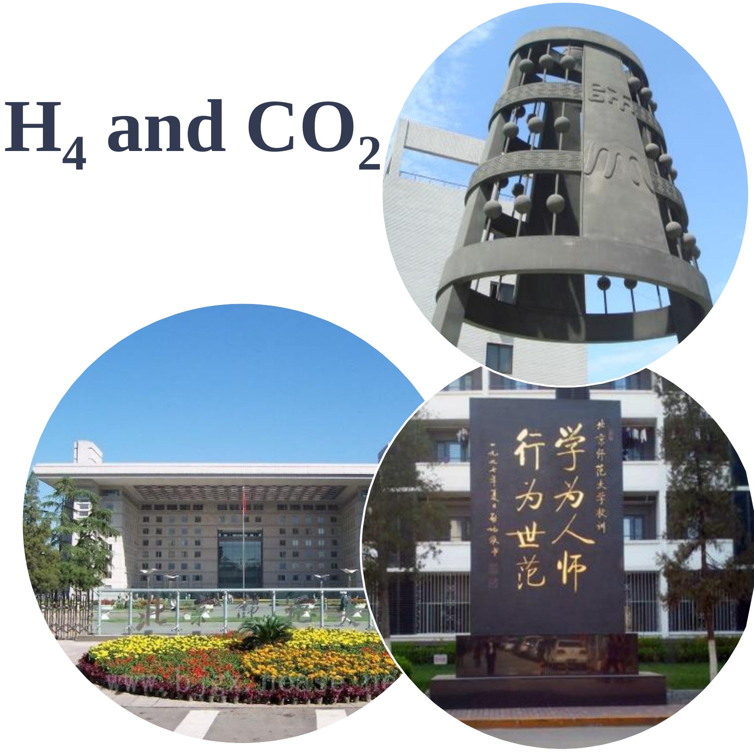
Reporter：Dr. Xianglan Li

College of Global Change and Earth System Science, Beijing Normal University

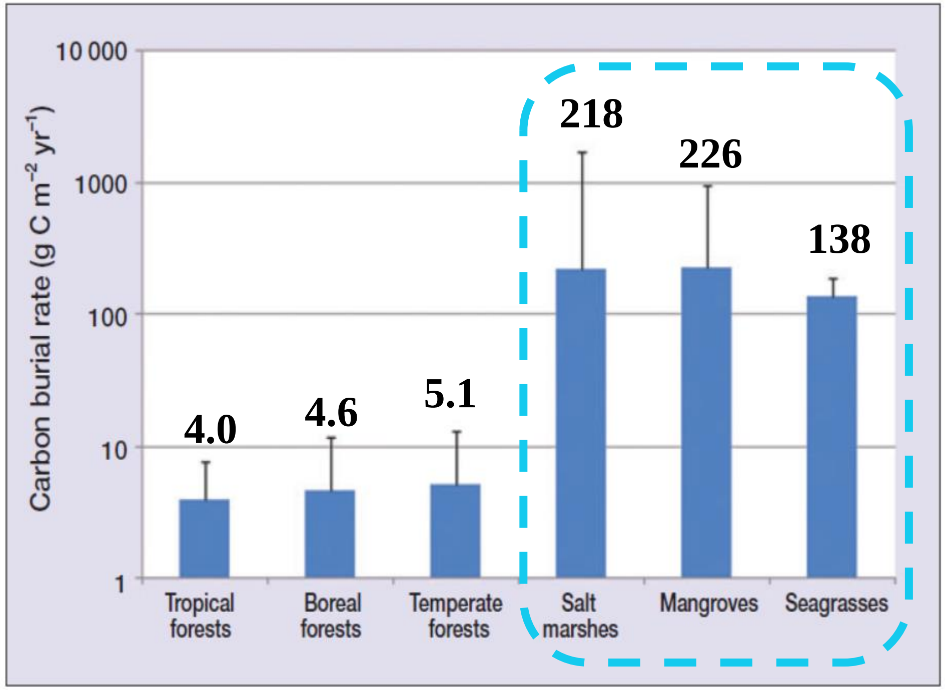
July 28th, 2023

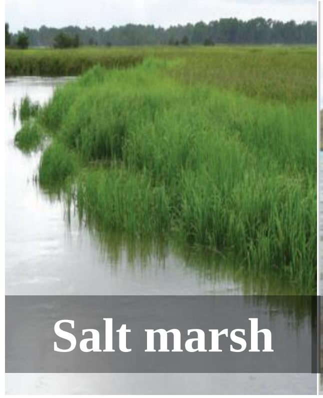
Outline

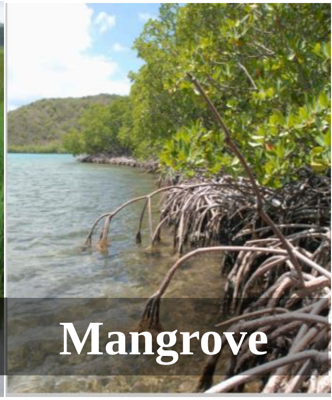
1. **Background**
2. **Point-scale analysis of CH_4 and CO_2 fluxes in mangrove restoration ecosystems**
3. **Regional scale assessments of integrated GWPs of CH_4 and CO_2 fluxes in mangrove forests and island forests**
4. **Conclusions and prospects**

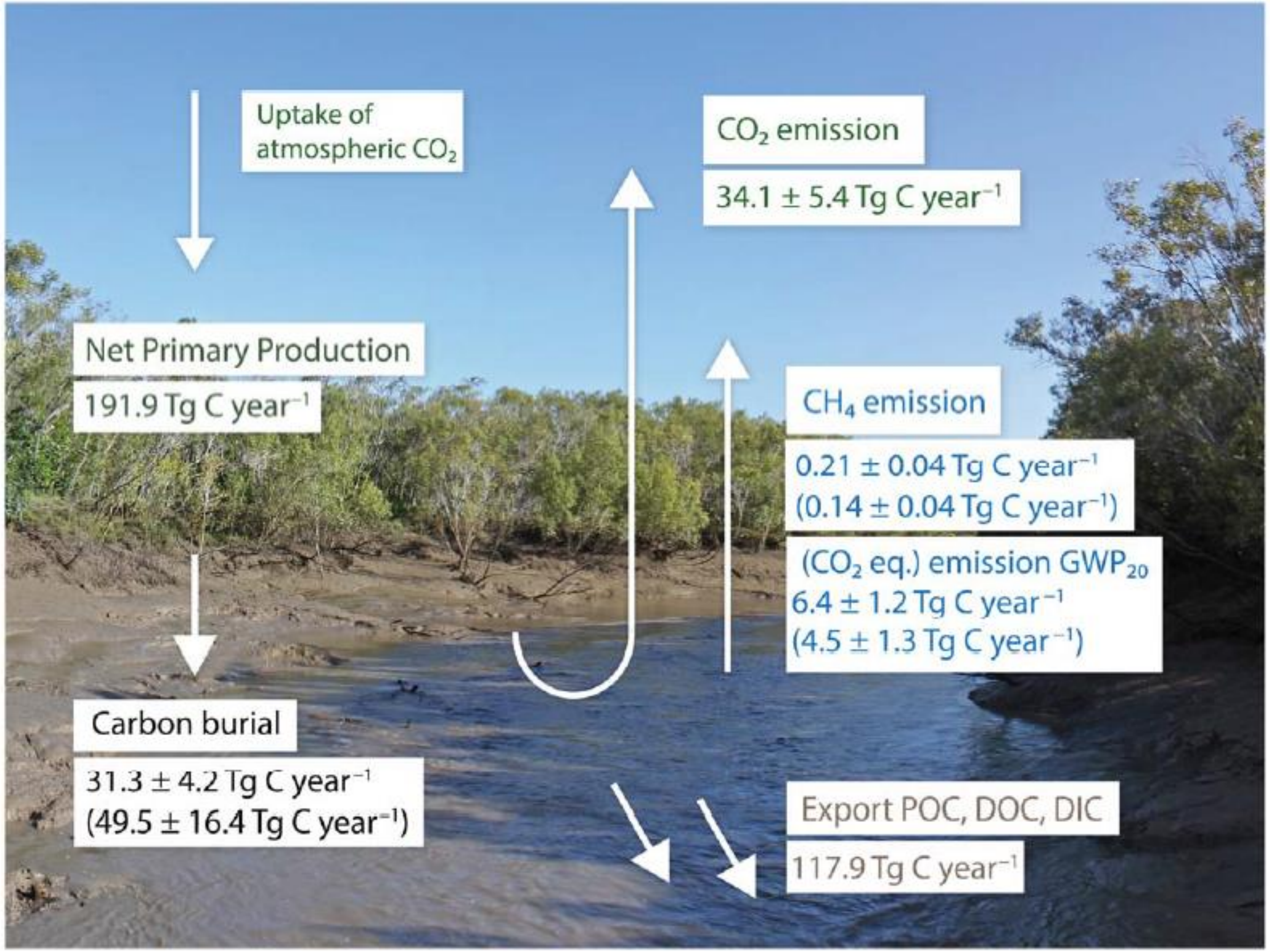


Carbon sequestration potentials of coastal blue carbon ecosystems









Uptake of atmospheric CO_2

CO_2 emission

34.1 ± 5.4 Tg C $year^{-1}$

Net Primary Production

191.9 Tg C $year^{-1}$

CH_4 emission

0.21 ± 0.04 Tg C $year^{-1}$
(0.14 ± 0.04 Tg C $year^{-1}$)

(CO_2 eq.) emission GWP_{20}
6.4 ± 1.2 Tg C $year^{-1}$
(4.5 ± 1.3 Tg C $year^{-1}$)

Carbon burial

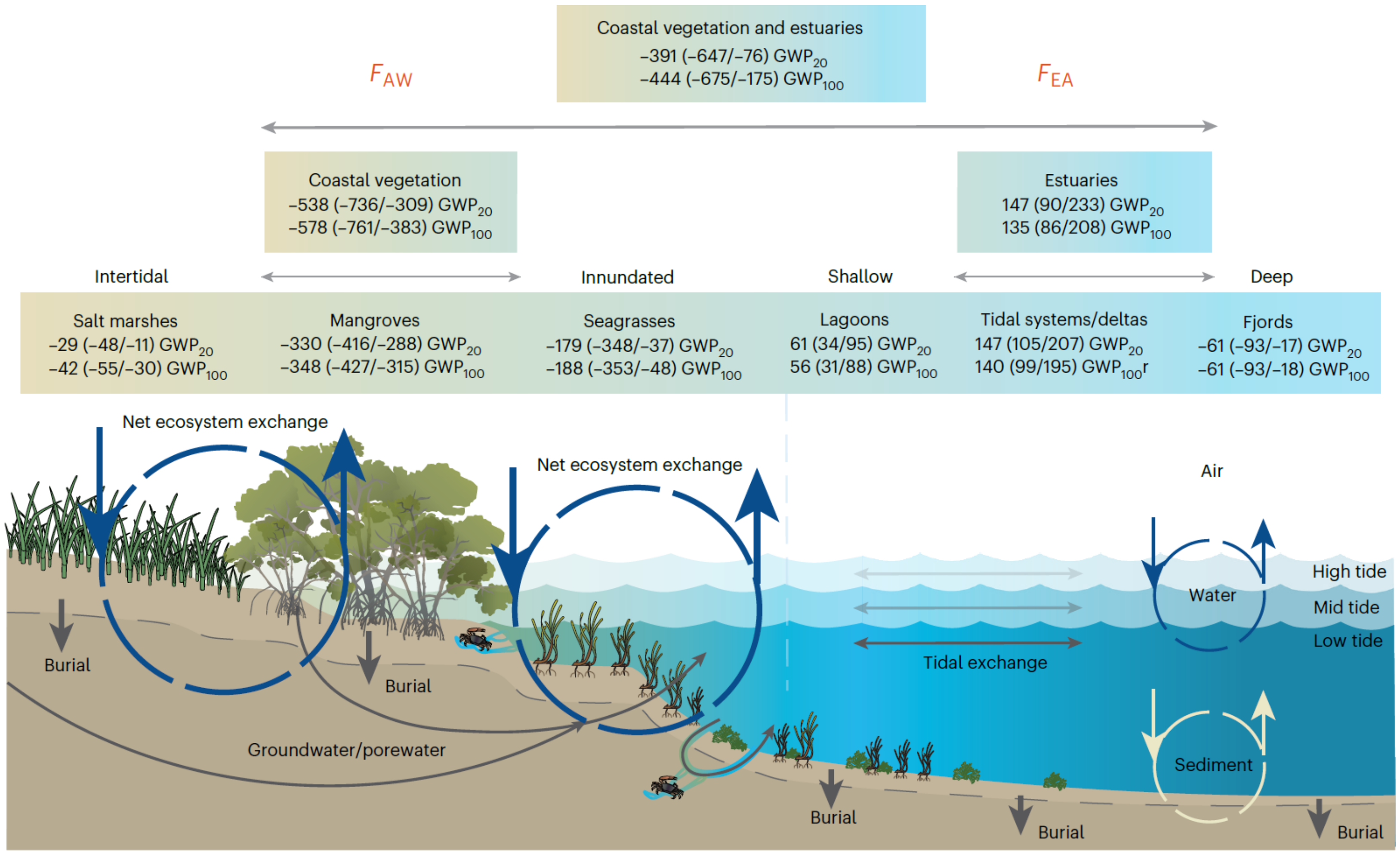
31.3 ± 4.2 Tg C $year^{-1}$
(49.5 ± 16.4 Tg C $year^{-1}$)

Export POC, DOC, DIC

117.9 Tg C $year^{-1}$

(Rosentreter et al., 2018; Mcleod et al., 2011)

Coastal and estuarine vegetation act as significant "sinks" for GHGs



Coastal vegetation and estuaries
−391 (−647/−76) GWP$_{20}$
−444 (−675/−175) GWP$_{100}$

F_{AW}

F_{EA}

Coastal vegetation
−538 (−736/−309) GWP$_{20}$
−578 (−761/−383) GWP$_{100}$

Estuaries
147 (90/233) GWP$_{20}$
135 (86/208) GWP$_{100}$

Intertidal
Innundated
Shallow
Deep

Salt marshes
−29 (−48/−11) GWP$_{20}$
−42 (−55/−30) GWP$_{100}$

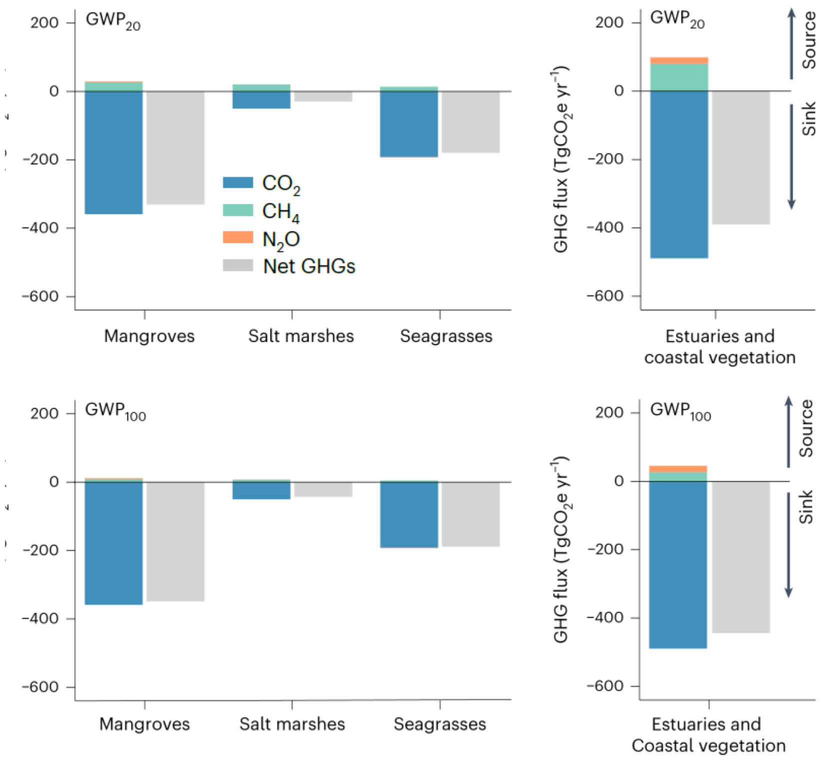
Mangroves
−330 (−416/−288) GWP$_{20}$
−348 (−427/−315) GWP$_{100}$

Seagrasses
−179 (−348/−37) GWP$_{20}$
−188 (−353/−48) GWP$_{100}$

Lagoons
61 (34/95) GWP$_{20}$
56 (31/88) GWP$_{100}$

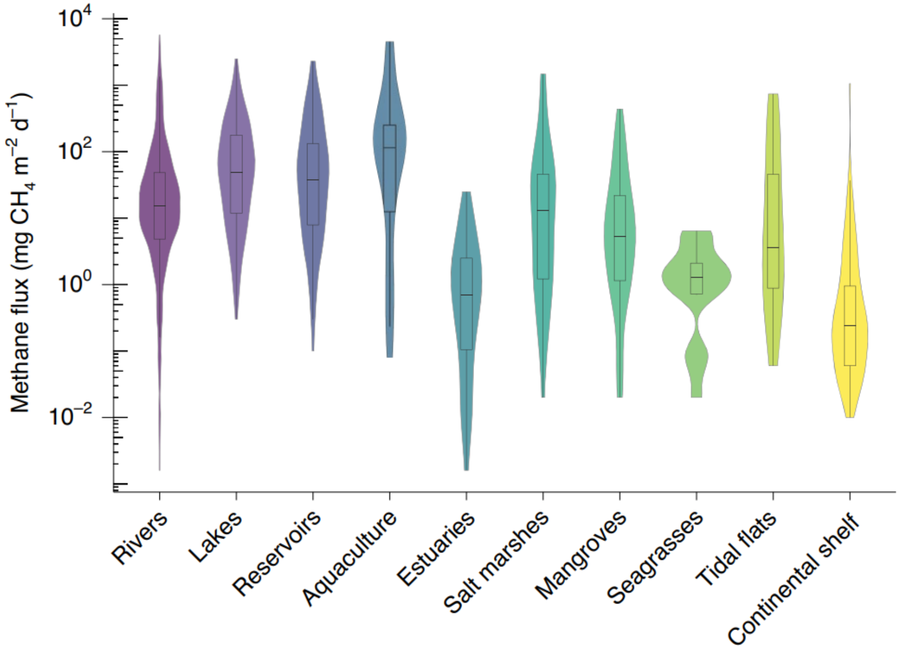
Tidal systems/deltas
147 (105/207) GWP$_{20}$
140 (99/195) GWP$_{100}$r

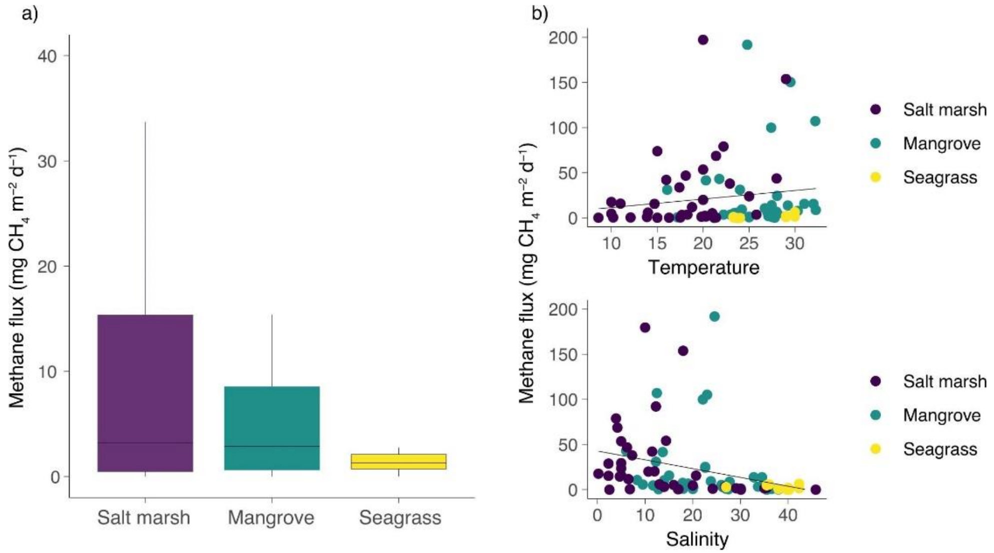
Fjords
−61 (−93/−17) GWP$_{20}$
−61 (−93/−18) GWP$_{100}$



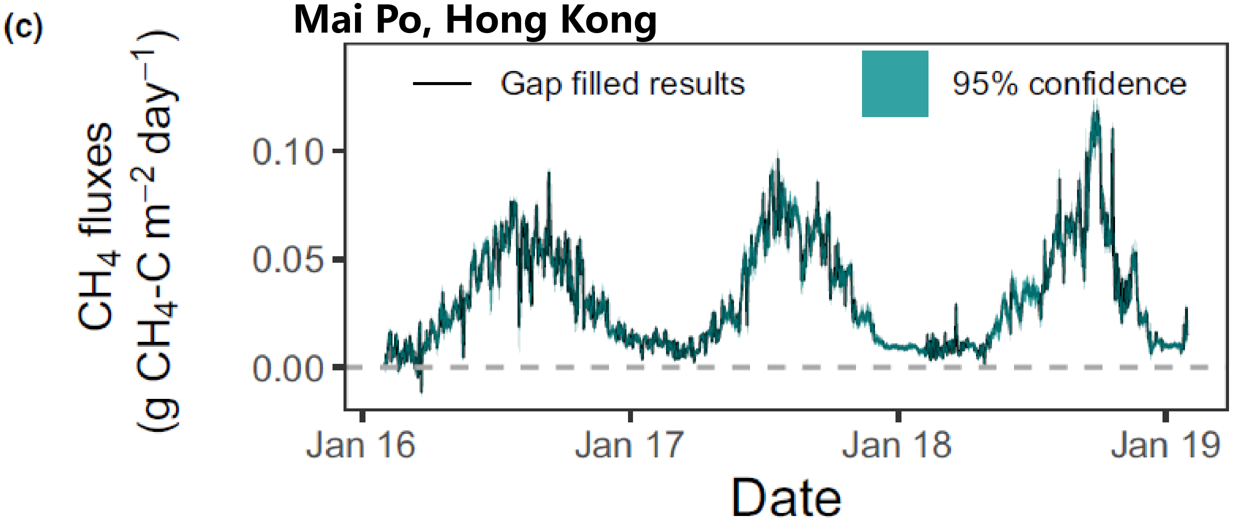
(Rosentreter et al., 2022)

Temperature and salinity are important factors on methane emissions

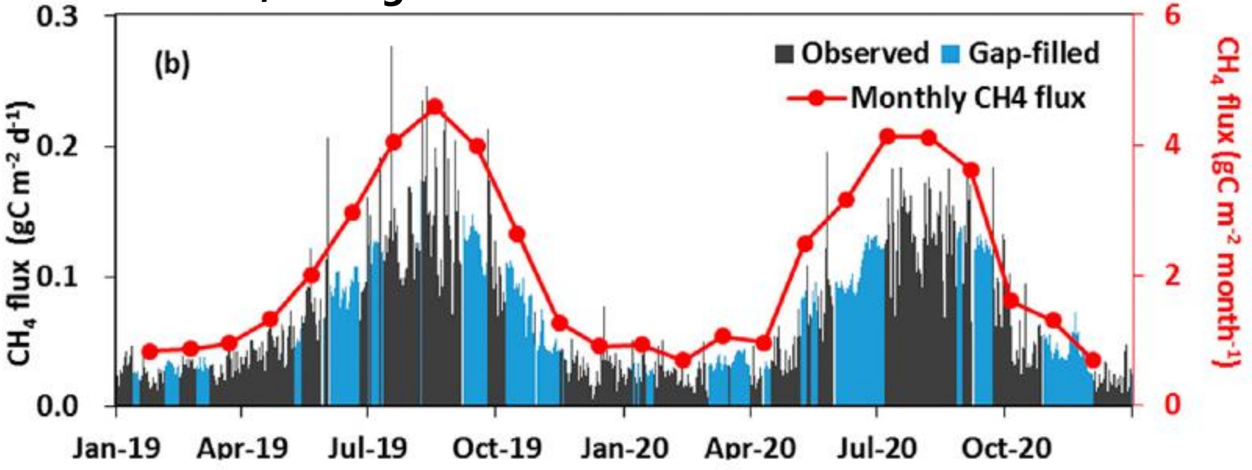




Mai Po, Hong Kong



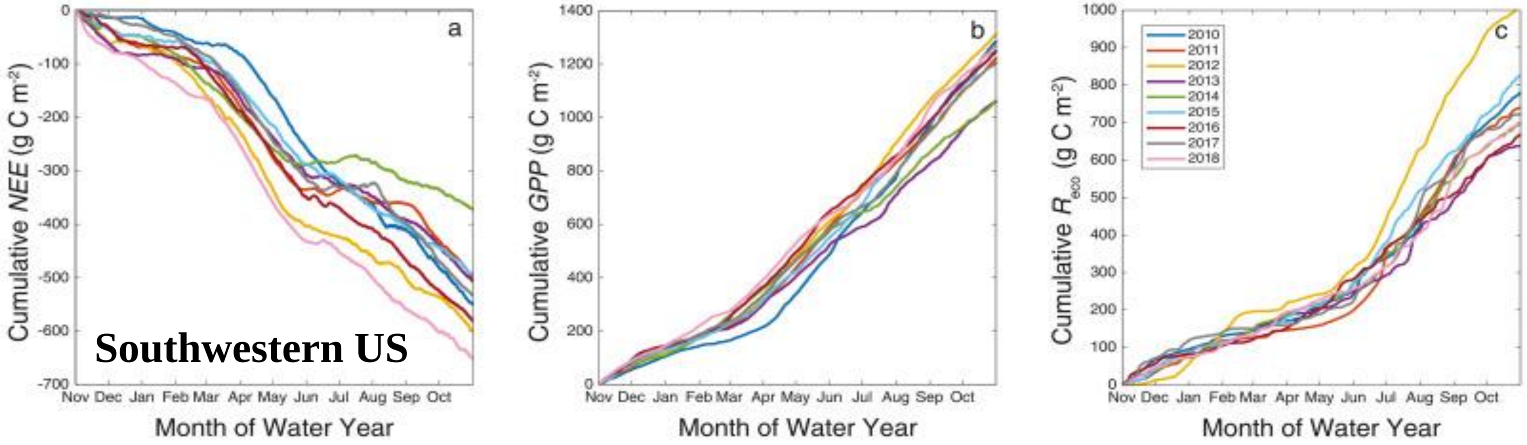
Nansha, Guangzhou



(Rosentreter et al., 2021; Liu et al., 2020; Zhao et al., 2022)

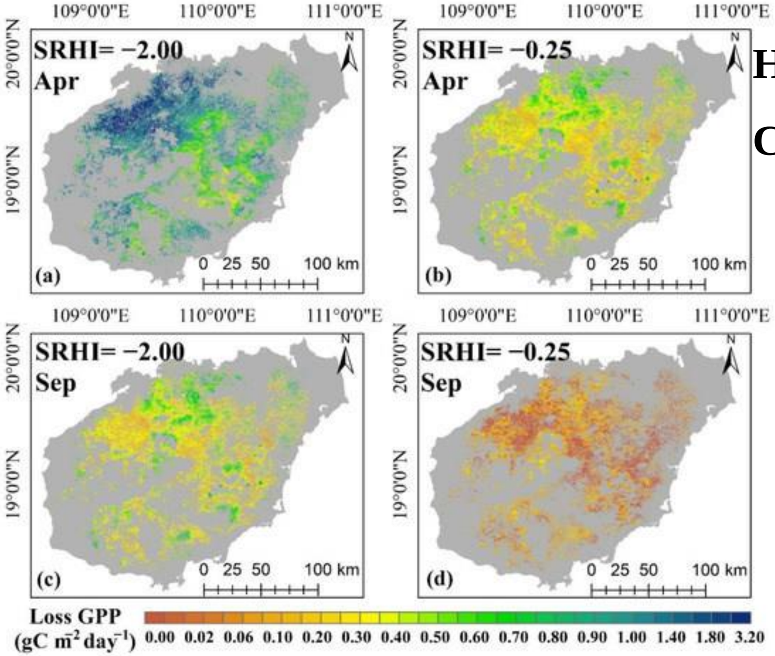
Monitoring carbon fluxes in island forests and mitigation potentials for climate change

The mitigation potential of island forests in mitigating climate change is often overlooked due to their exclusion from ecosystem carbon sink estimation systems, primarily due to geographical limitations.



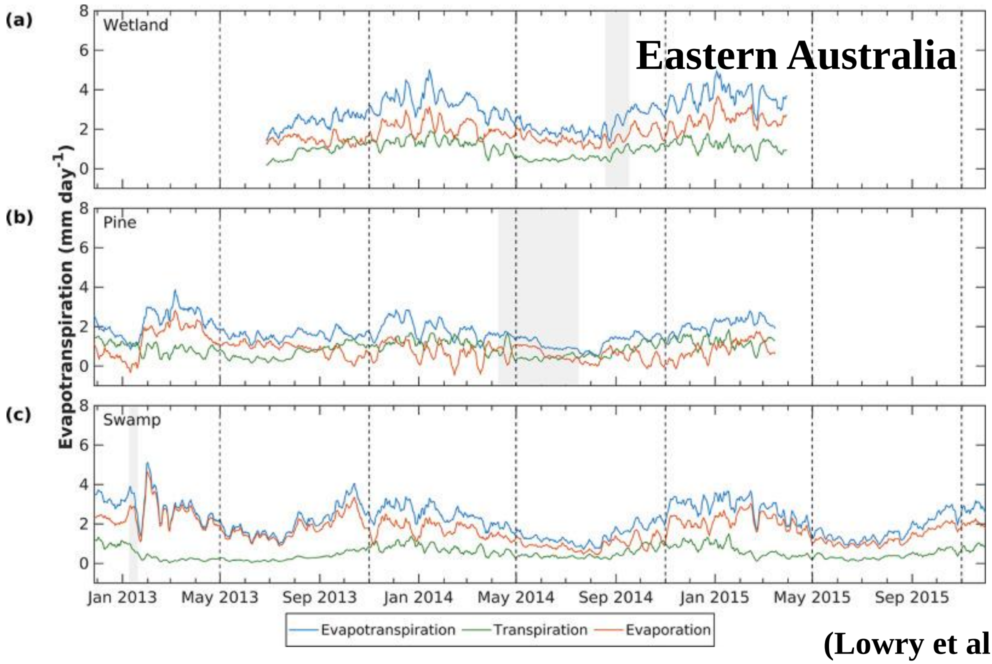
Southwestern US

(Knowles et al., 2020)



Hainan island, China

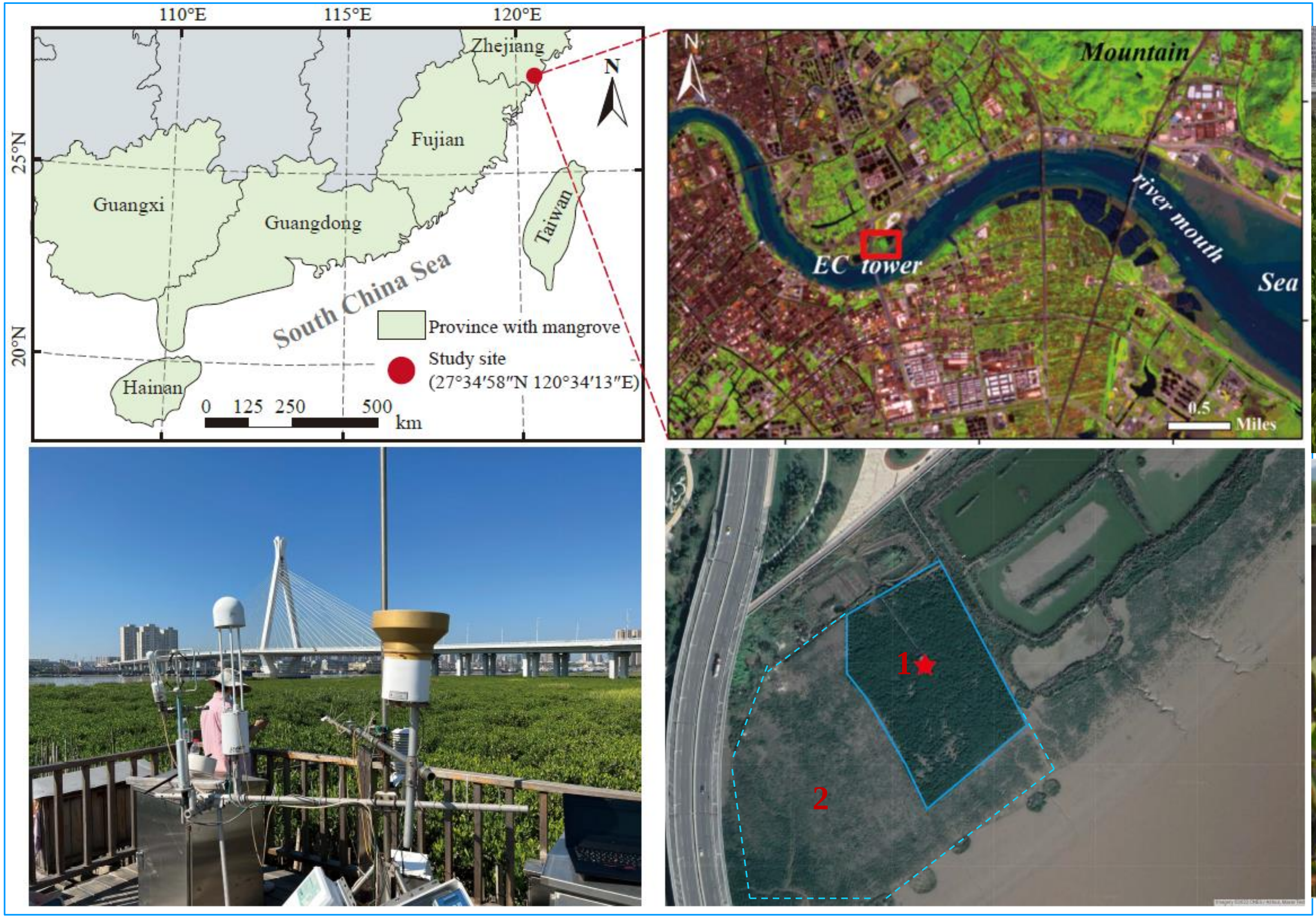
(Cui et al., 2022)



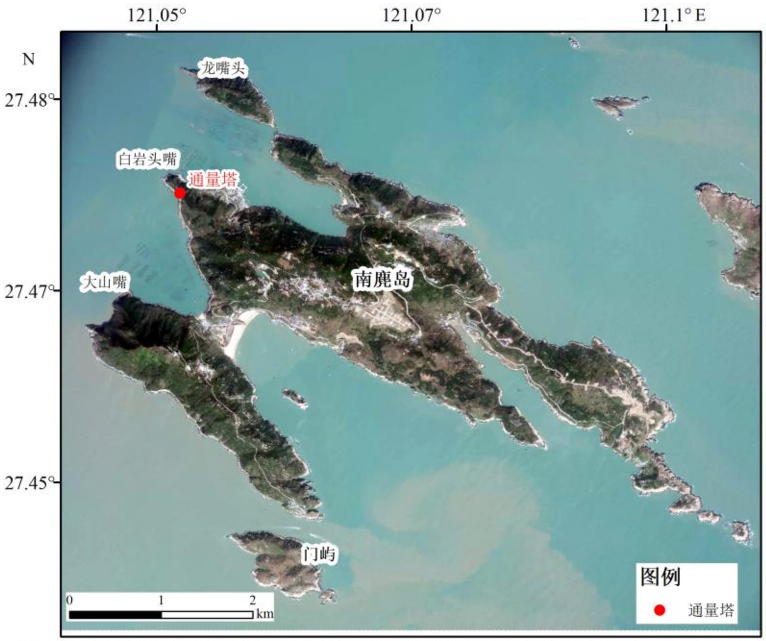
Eastern Australia

(Lowry et al., 2021)

The northernmost distribution of the restored mangroves in China

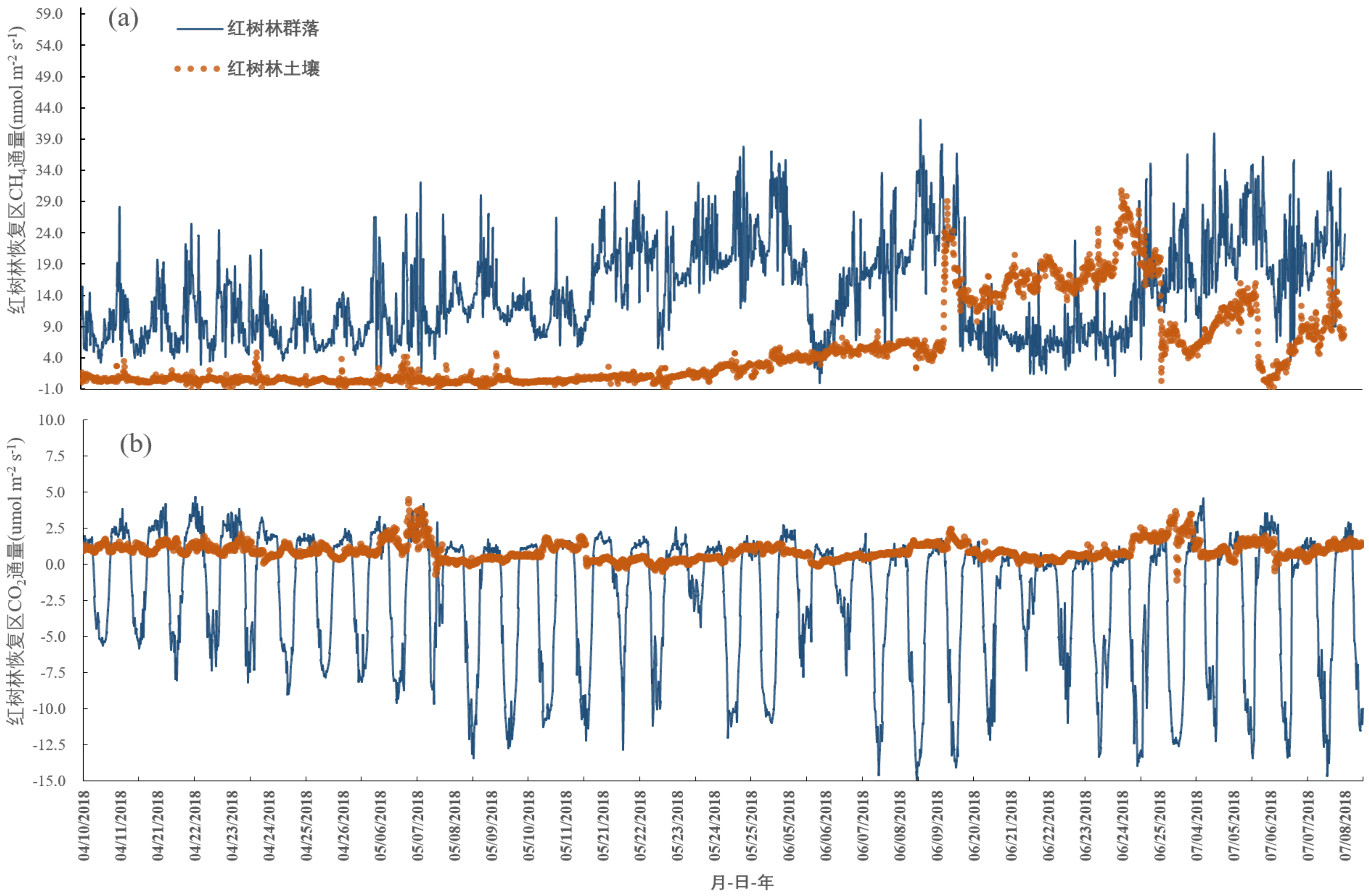


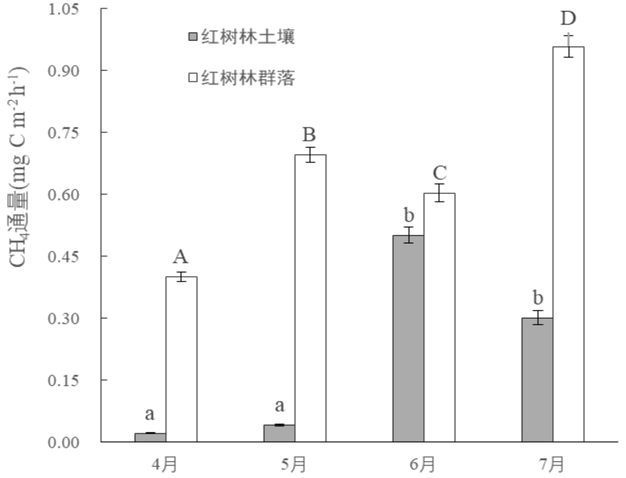
Island forest: Nanji islands national marine nature reserve

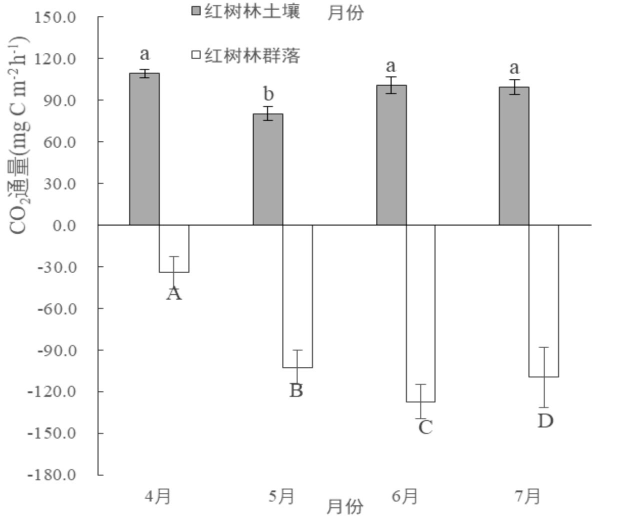


注：基于自然资源部标准地图服务网站下载的审图号为GS(2019)3333号的标准地图制作，底图无修改。

Point-scale analysis of CH_4 and CO_2 fluxes in restored mangrove



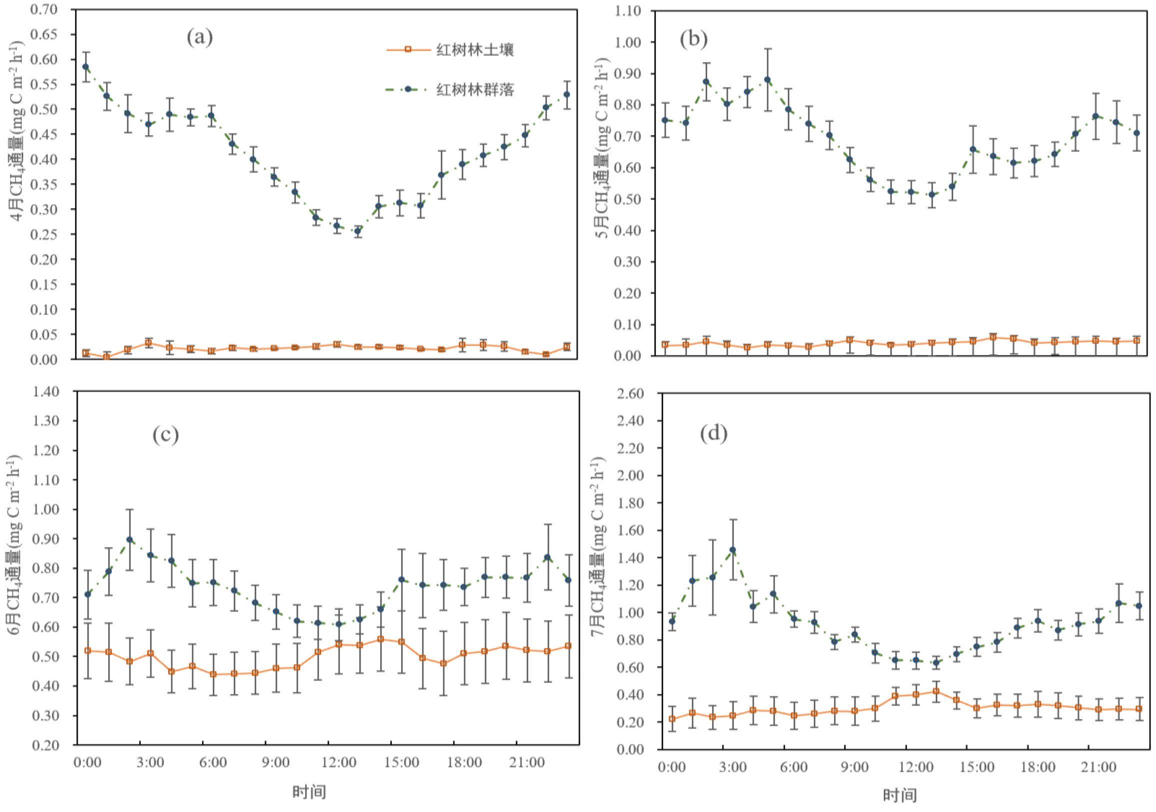


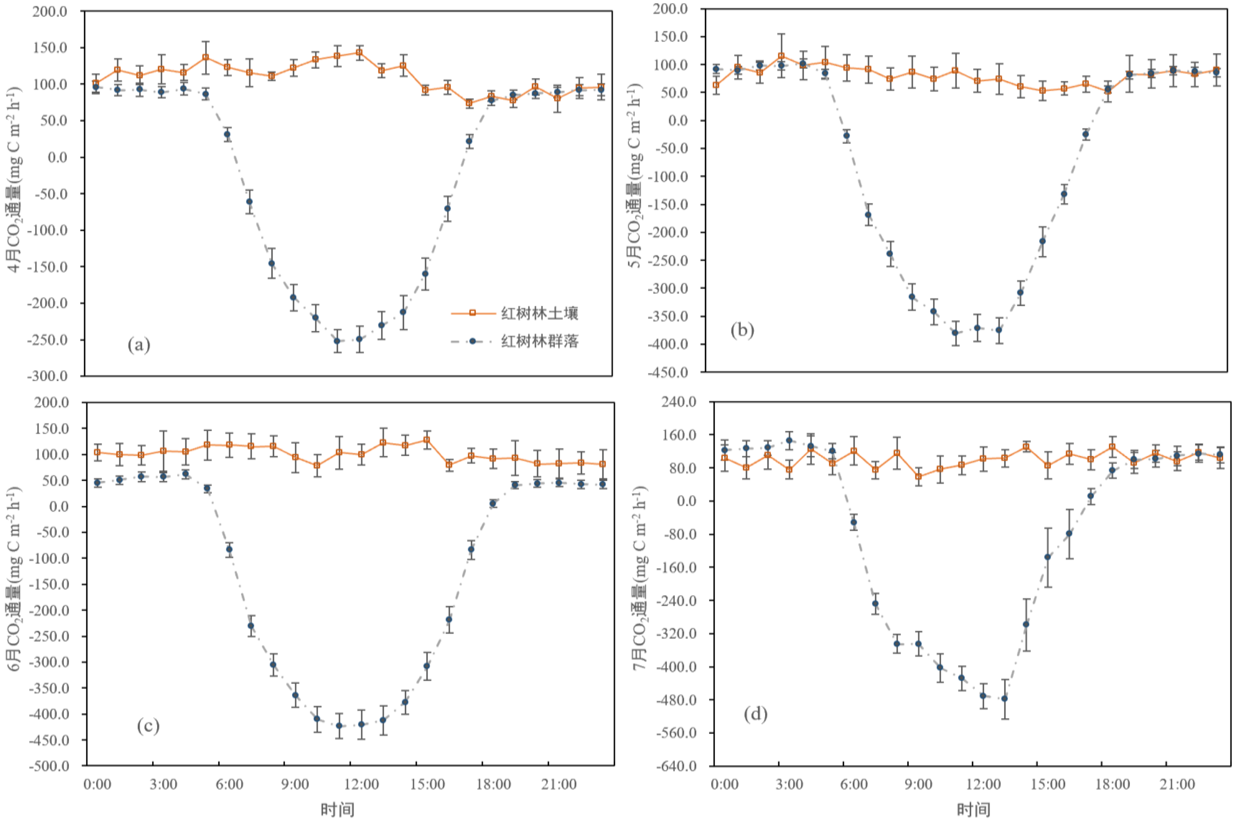


- □ **The mangrove restoration acted as both a source of CH_4 emissions and a sink for CO_2 uptake.**
- □ **From April to July, both methane emissions and carbon sequestrations in mangrove communities showed a significant increasing trend.（$P＜0.01$）。**

（Sen Li，2020）

Diurnal patterns of CH_4 and CO_2 fluxes in restored mangrove





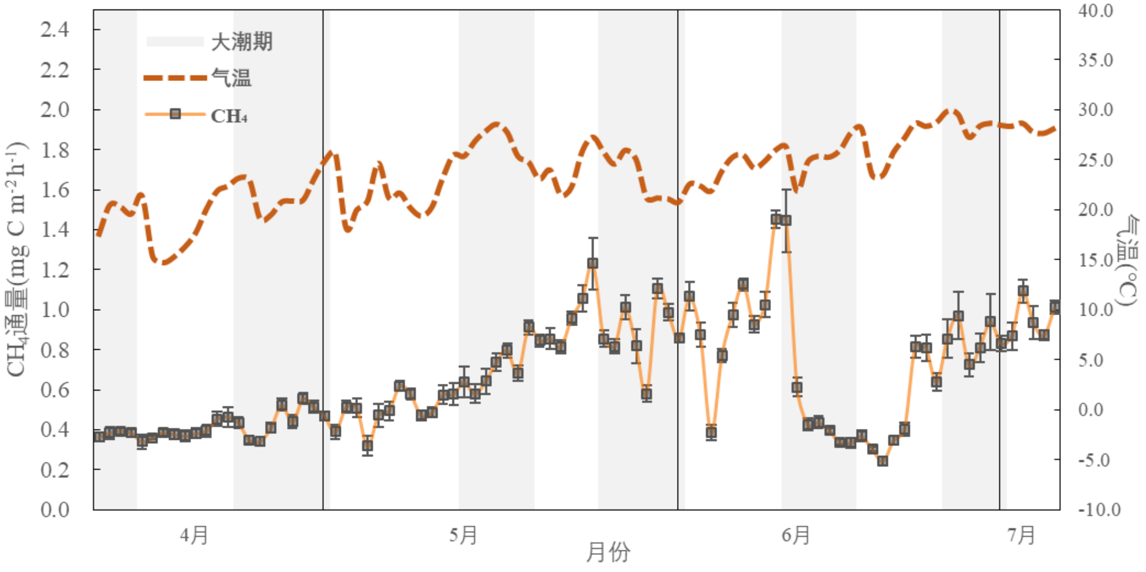
☐ **Double-edged sword**：**Mangrove vegetation played a crucial role as a carbon sink, but it also promoted methane emissions.**

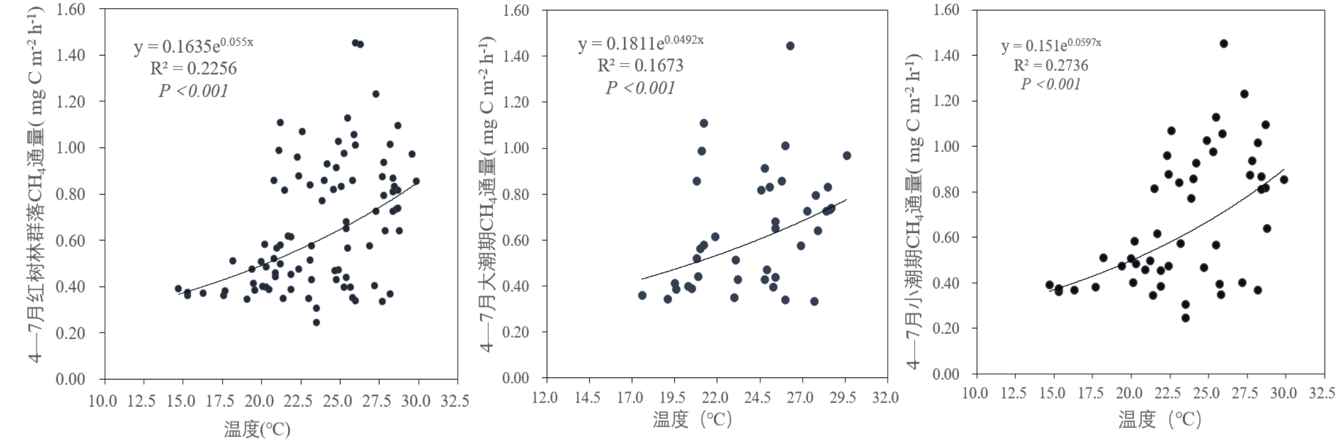
☐ **The diurnal variation of CO_2 flux in mangrove communities exhibited a "U" shaped curve, with nighttime emissions and daytime uptake.**

☐ **The CH_4 emissions were the lowest during midday.**

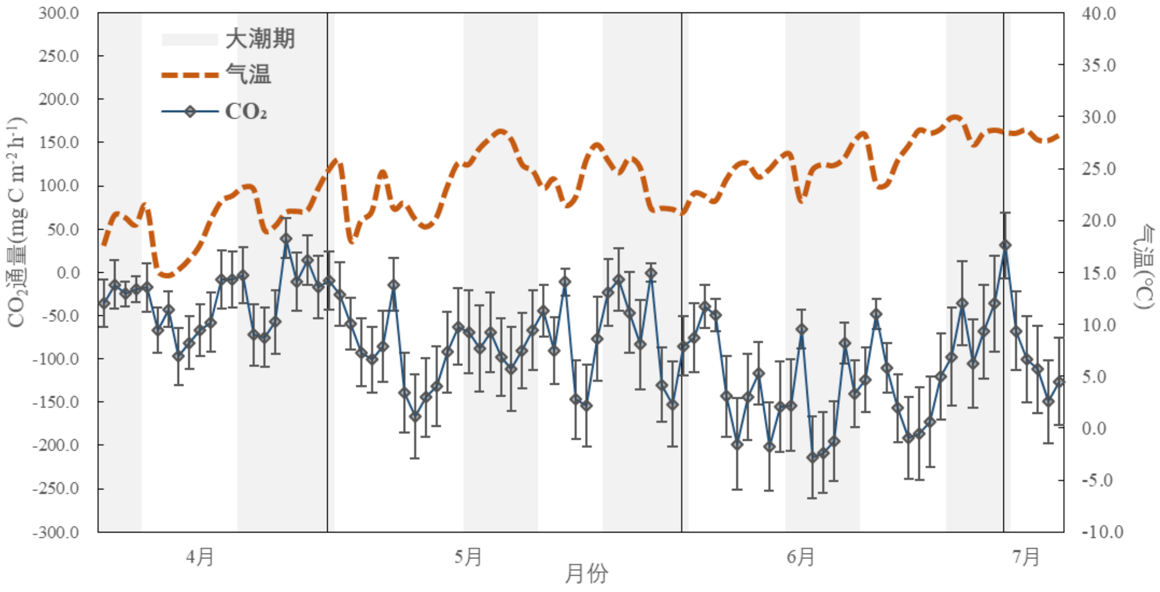
（Sen Li，2020）

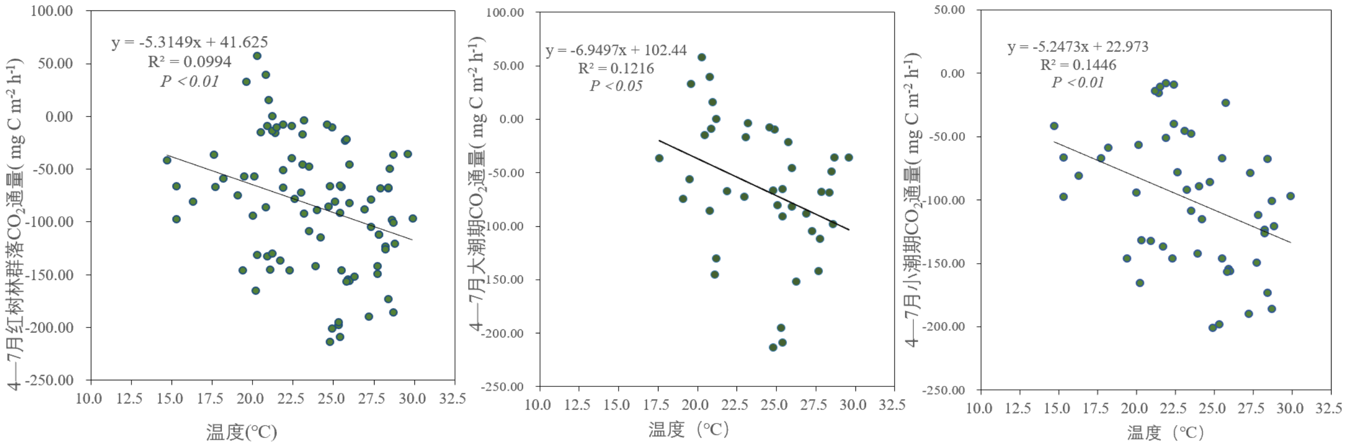
The influence of air temperature on CH_4 and CO_2 fluxes





CH_4 emissions exhibited a significant positive correlation with air temperature（$P<0.001$，$R^2=0.23$）

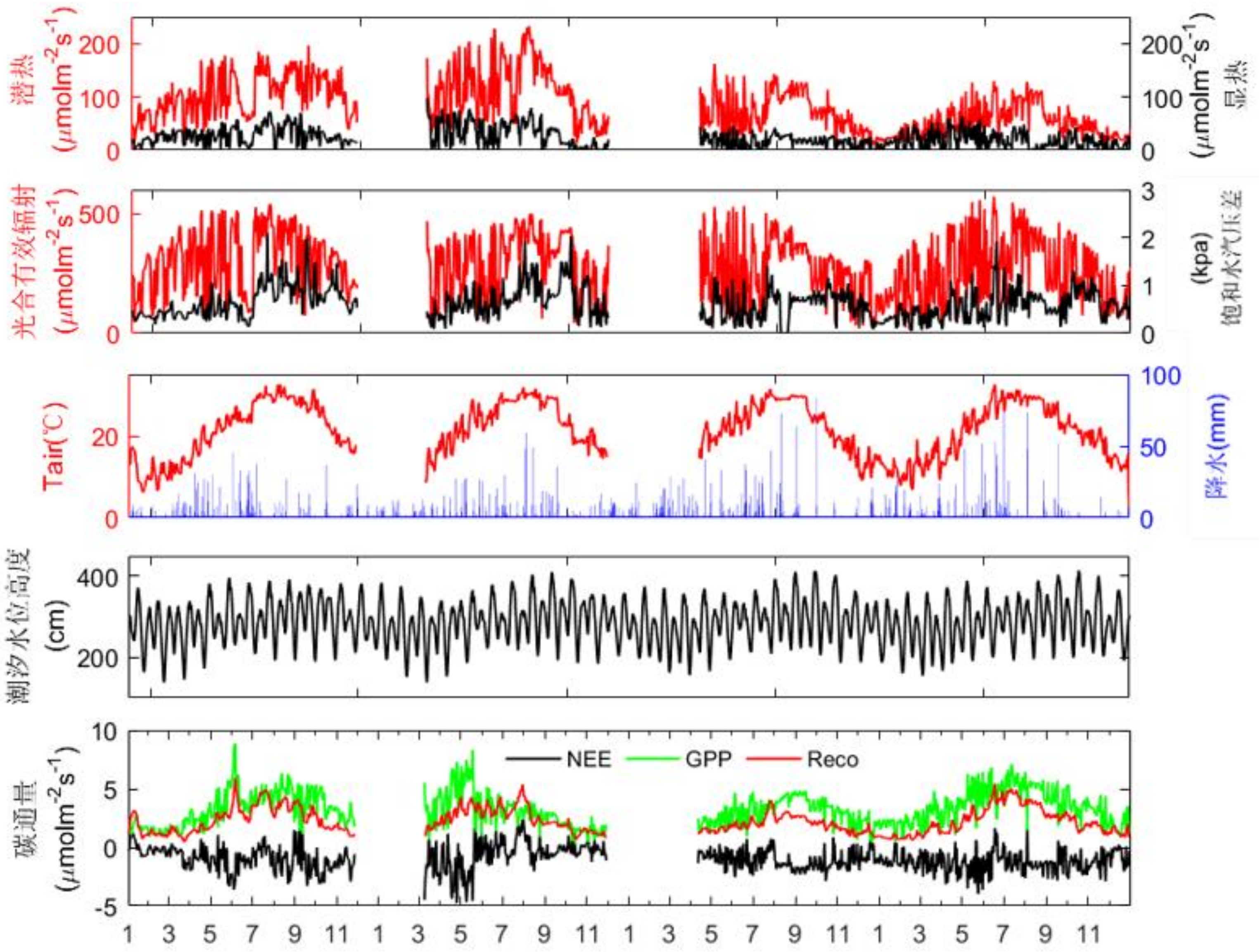




CO_2 flux exhibited a significant negative correlation with air temperature （$P<0.01$，$R^2=0.10$）

（Sen Li，2020）

Regional scale analysis of CH_4 and CO_2 fluxes in restored mangrove



Variations of environmental factors

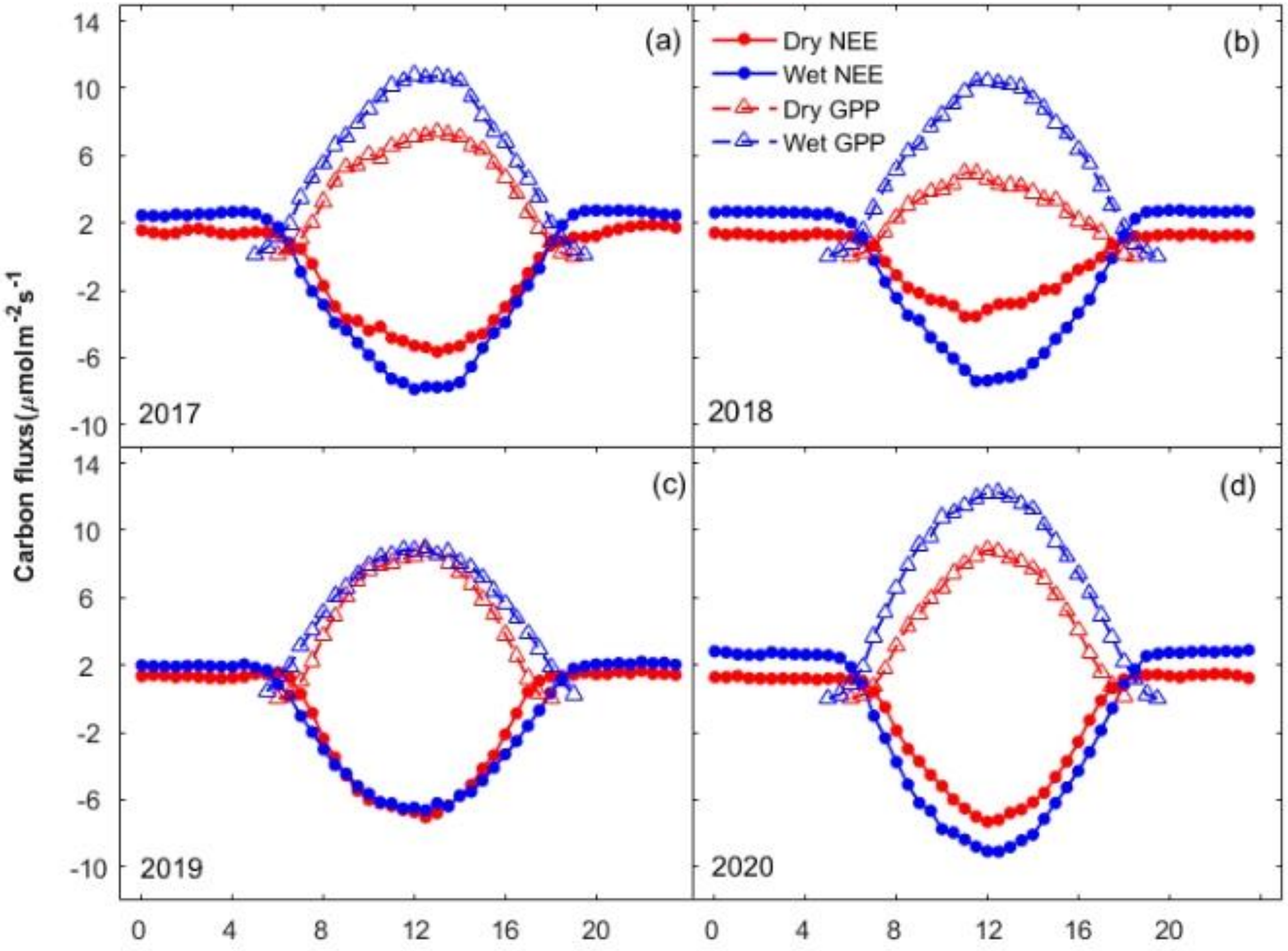
- ✓ Obvious seasonal and interannual changes
- ✓ PAR：June to July continuous rainy weather, PAR value was lower than the wet season average

Variations of carbon fluxes

- ✓ GPP-PAR；Reco-Tair
- ✓ Annual variations in NEE were in correlation with the simultaneous enhancement of carbon sinks.

(Meihui Dduan，2022)

Diurnal trends of NEE in mangrove restoration ecosystems

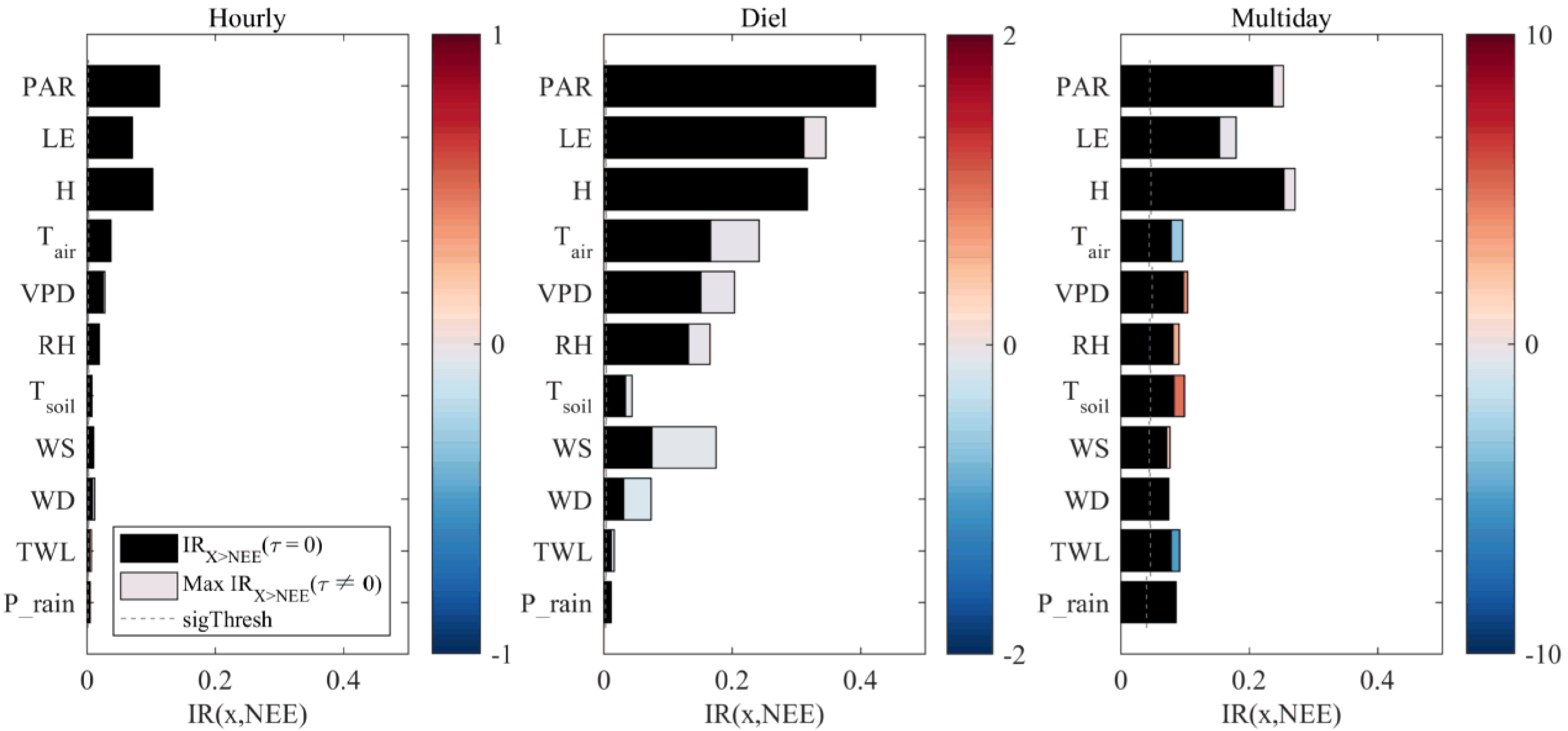


Wet season：Mar to Sep；Dry season：Oct to Feb

- During the daytime in the wet season, the NEE in mangrove was lower compared to the dry season, indicating a stronger carbon sink function.
- During the nighttime, in the wet season, the NEE in mangrove forests was higher compared to the dry season, indicating a greater carbon source function.
- **Higher GPP occurred in the wet season, playing great role in controlling the higher carbon sink potentials.**

(Meihui Duan，2022)

Interactions between environmental factors and NEE in different time scales



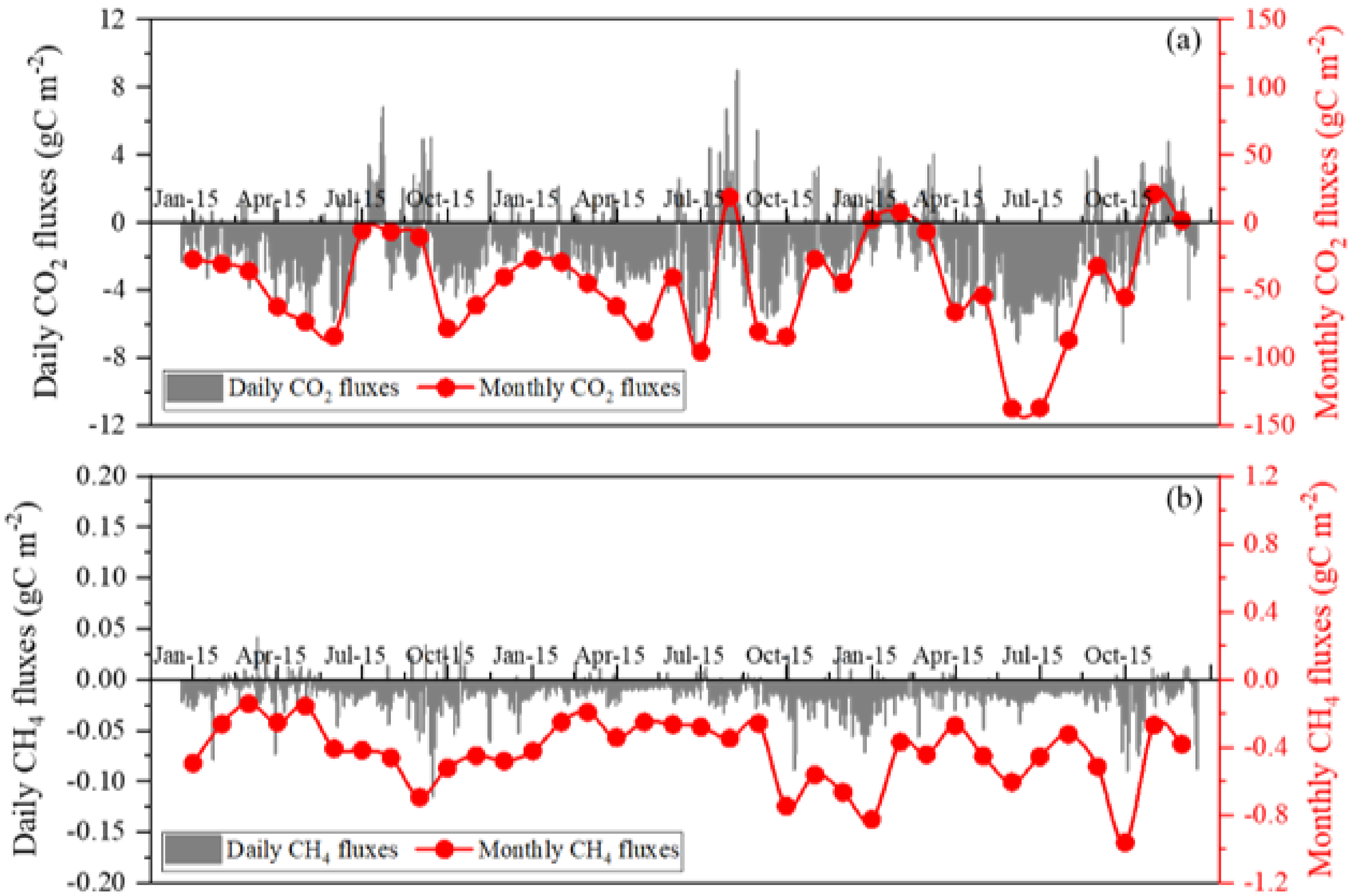
- PAR、LE、H

- PAR、LE、H
- Tair, VPD, and NEE have correlations
- WS>WD

- PAR、LE、H
- VPD>Tair

(Xianglan Li, in preparation)

Analysis of CH_4 and CO_2 fluxes in island forest and their GWP

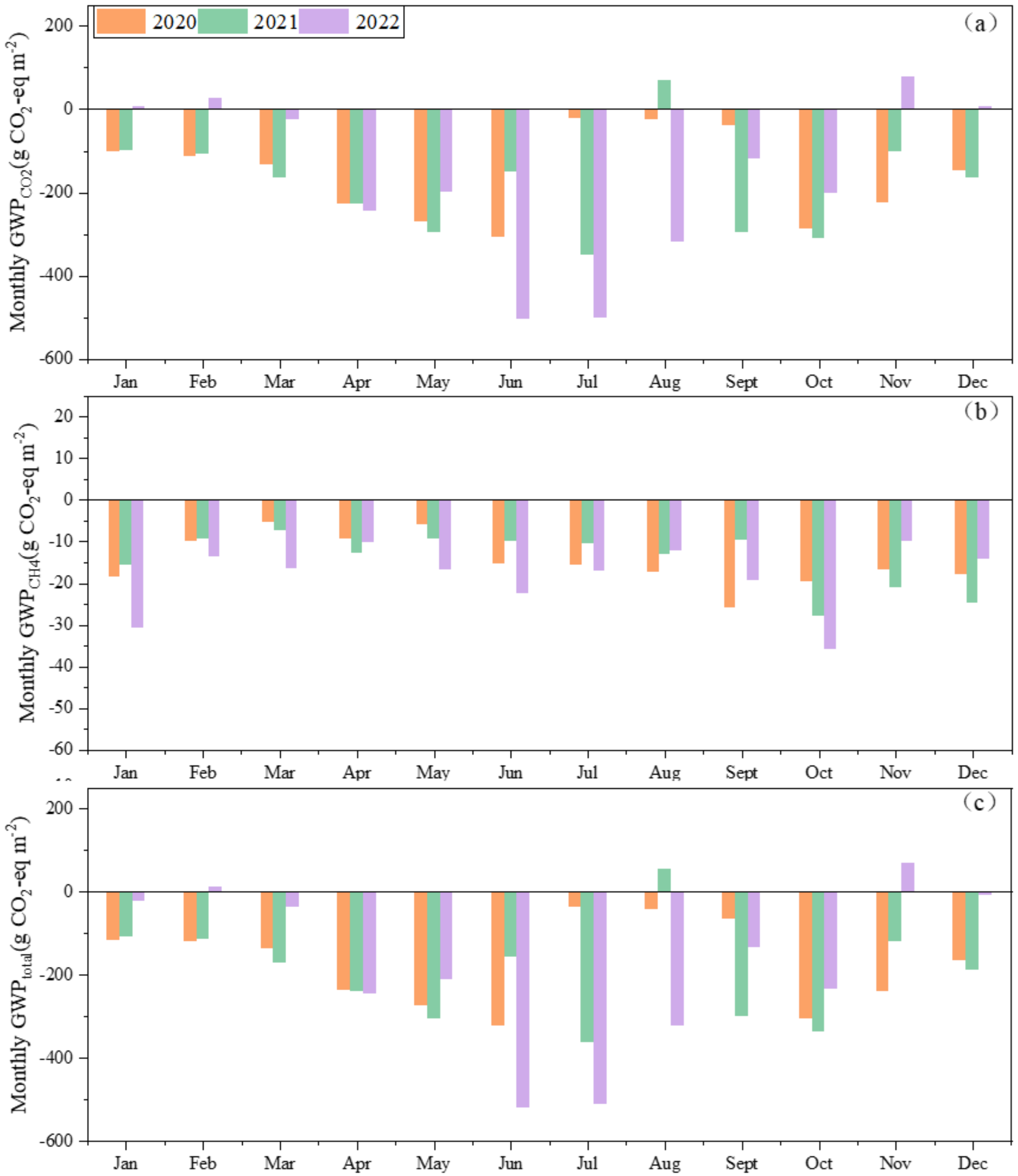


- CO_2 sink: 2020-2022 interannual flux in island forest was 552 g C m^{-2} yr^{-1} , higher in April to June, lower in November to February.

- CH_4 sink: 2020-2022 interannual flux was 5.06 g C m^{-2} yr^{-1}， lower in March and higher in October.

(Liangxu Wu et al., in preparation)

The contributions of CH_4 and CO_2 fluxes in GWP



g CO_2-eq m^{-2}

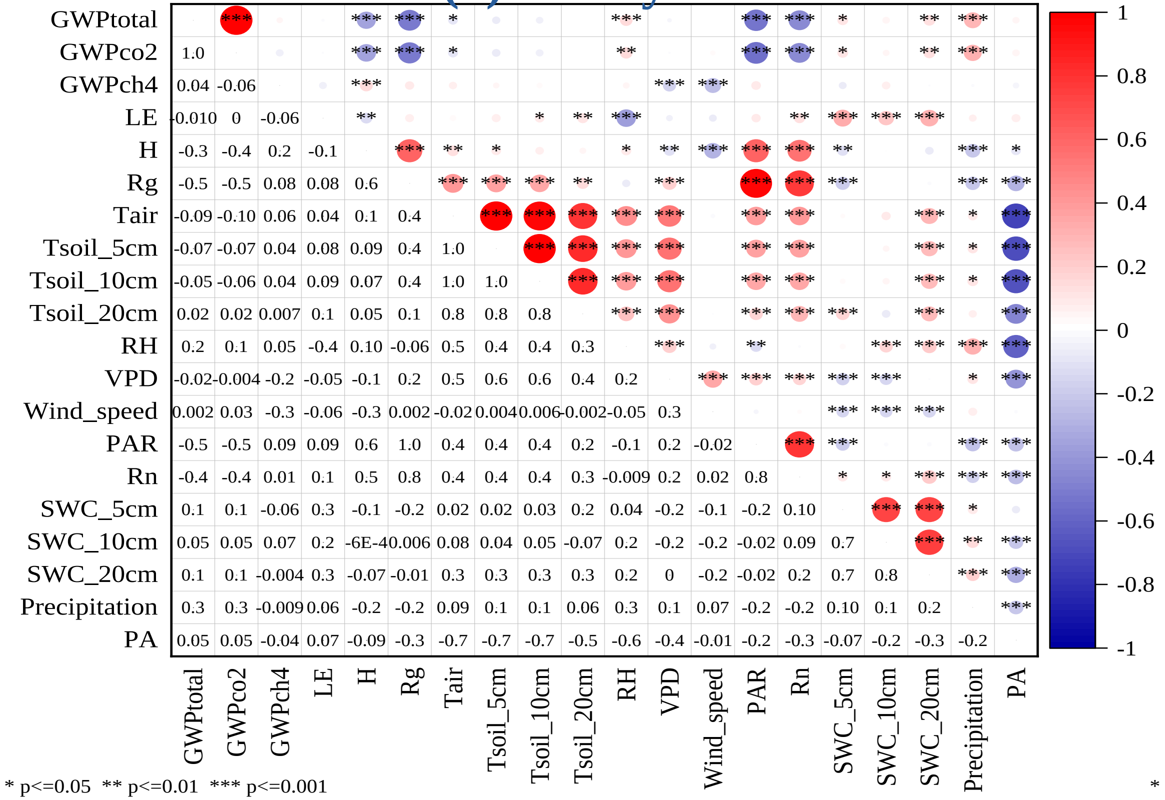
Type	GWP_{CO_2}	GWP_{CH_4}
Monthly average	-168.78	-15.75
Max	77.49	-5.33
Min	-503.41	-35.87

- GWP_{CO_2} *and* GWP_{CH_4} had obvious seasonal variations, the uptake rate of CH_4 was higher in January and October due to lower SWC.
- **GWP_{total} was dominated by CO_2 uptake.** GWP_{CO_2} and GWP_{CH_4} accounted for 91.5% and 8.5%, respectively.

(Liangxu Wu et al., in preparation)

Biophysical drivers of GWPs (CH_4 and CO_2) in island forest

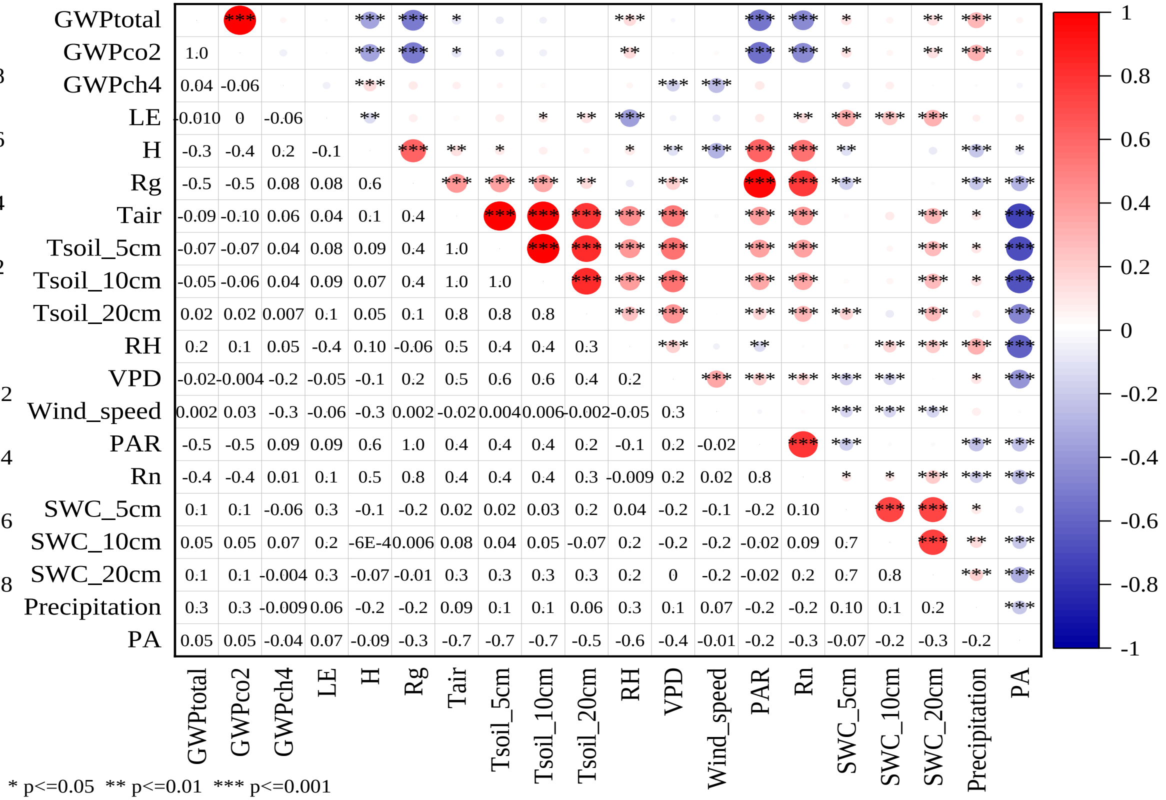
(a) hourly



	GWPtotal	GWPco2	GWPch4	LE	H	Rg	Tair	Tsoil_5cm	Tsoil_10cm	Tsoil_20cm	RH	VPD	Wind_speed	PAR	Rn	SWC_5cm	SWC_10cm	SWC_20cm	Precipitation	PA
GWPtotal		***			***	***	*				***			***	***	*		**	***	
GWPco2	1.0				***	***	*				**			***	***	*		**	***	
GWPch4	0.04	-0.06			***							***	***							
LE	-0.010	0	-0.06		**				*	**	***				**	***	***	***		
H	-0.3	-0.4	0.2	-0.1		***	**	*			*	**	***	***	***	**			***	*
Rg	-0.5	-0.5	0.08	0.08	0.6		***	***	***	**		***		***	***	***			***	***
Tair	-0.09	-0.10	0.06	0.04	0.1	0.4		***	***	***	***	***		***	***			***	*	***
Tsoil_5cm	-0.07	-0.07	0.04	0.08	0.09	0.4	1.0		***	***	***	***		***	***			***	*	***
Tsoil_10cm	-0.05	-0.06	0.04	0.09	0.07	0.4	1.0	1.0		***	***	***		***	***			***	*	***
Tsoil_20cm	0.02	0.02	0.007	0.1	0.05	0.1	0.8	0.8	0.8		***	***		***	***	***		***		***
RH	0.2	0.1	0.05	-0.4	0.10	-0.06	0.5	0.4	0.4	0.3		***		**			***	***	***	***
VPD	-0.02	-0.004	-0.2	-0.05	-0.1	0.2	0.5	0.6	0.6	0.4	0.2		***	***	***	***	***		*	***
Wind_speed	0.002	0.03	-0.3	-0.06	-0.3	0.002	-0.02	0.004	0.006	-0.002	-0.05	0.3				***	***	***		
PAR	-0.5	-0.5	0.09	0.09	0.6	1.0	0.4	0.4	0.4	0.2	-0.1	0.2	-0.02		***	***			***	***
Rn	-0.4	-0.4	0.01	0.1	0.5	0.8	0.4	0.4	0.4	0.3	-0.009	0.2	0.02	0.8		*	*	***	***	***
SWC_5cm	0.1	0.1	-0.06	0.3	-0.1	-0.2	0.02	0.02	0.03	0.2	0.04	-0.2	-0.1	-0.2	0.10		***	***	*	
SWC_10cm	0.05	0.05	0.07	0.2	-6E-4	0.006	0.08	0.04	0.05	-0.07	0.2	-0.2	-0.2	-0.02	0.09	0.7		***	**	***
SWC_20cm	0.1	0.1	-0.004	0.3	-0.07	-0.01	0.3	0.3	0.3	0.3	0.2	0	-0.2	-0.02	0.2	0.7	0.8		***	***
Precipitation	0.3	0.3	-0.009	0.06	-0.2	-0.2	0.09	0.1	0.1	0.06	0.3	0.1	0.07	-0.2	-0.2	0.10	0.1	0.2		***
PA	0.05	0.05	-0.04	0.07	-0.09	-0.3	-0.7	-0.7	-0.7	-0.5	-0.6	-0.4	-0.01	-0.2	-0.3	-0.07	-0.2	-0.3	-0.2	

* p<=0.05 ** p<=0.01 *** p<=0.001

(b) daily



	GWPtotal	GWPco2	GWPch4	LE	H	Rg	Tair	Tsoil_5cm	Tsoil_10cm	Tsoil_20cm	RH	VPD	Wind_speed	PAR	Rn	SWC_5cm	SWC_10cm	SWC_20cm	Precipitation	PA
GWPtotal		***			***	***	*				***			***	***	*		**	***	
GWPco2	1.0				***	***	*				**			***	***	*		**	***	
GWPch4	0.04	-0.06			***							***	***							
LE	-0.010	0	-0.06		**				*	**	***				**	***	***	***		
H	-0.3	-0.4	0.2	-0.1		***	**	*			*	**	***	***	***	**			***	*
Rg	-0.5	-0.5	0.08	0.08	0.6		***	***	***	**		***		***	***	***			***	***
Tair	-0.09	-0.10	0.06	0.04	0.1	0.4		***	***	***	***	***		***	***			***	*	***
Tsoil_5cm	-0.07	-0.07	0.04	0.08	0.09	0.4	1.0		***	***	***	***		***	***			***	*	***
Tsoil_10cm	-0.05	-0.06	0.04	0.09	0.07	0.4	1.0	1.0		***	***	***		***	***			***	*	***
Tsoil_20cm	0.02	0.02	0.007	0.1	0.05	0.1	0.8	0.8	0.8		***	***		***	***	***		***		***
RH	0.2	0.1	0.05	-0.4	0.10	-0.06	0.5	0.4	0.4	0.3		***		**			***	***	***	***
VPD	-0.02	-0.004	-0.2	-0.05	-0.1	0.2	0.5	0.6	0.6	0.4	0.2		***	***	***	***	***		*	***
Wind_speed	0.002	0.03	-0.3	-0.06	-0.3	0.002	-0.02	0.004	0.006	-0.002	-0.05	0.3				***	***	***		
PAR	-0.5	-0.5	0.09	0.09	0.6	1.0	0.4	0.4	0.4	0.2	-0.1	0.2	-0.02		***	***			***	***
Rn	-0.4	-0.4	0.01	0.1	0.5	0.8	0.4	0.4	0.4	0.3	-0.009	0.2	0.02	0.8		*	*	***	***	***
SWC_5cm	0.1	0.1	-0.06	0.3	-0.1	-0.2	0.02	0.02	0.03	0.2	0.04	-0.2	-0.1	-0.2	0.10		***	***	*	
SWC_10cm	0.05	0.05	0.07	0.2	-6E-4	0.006	0.08	0.04	0.05	-0.07	0.2	-0.2	-0.2	-0.02	0.09	0.7		***	**	***
SWC_20cm	0.1	0.1	-0.004	0.3	-0.07	-0.01	0.3	0.3	0.3	0.3	0.2	0	-0.2	-0.02	0.2	0.7	0.8		***	***
Precipitation	0.3	0.3	-0.009	0.06	-0.2	-0.2	0.09	0.1	0.1	0.06	0.3	0.1	0.07	-0.2	-0.2	0.10	0.1	0.2		***
PA	0.05	0.05	-0.04	0.07	-0.09	-0.3	-0.7	-0.7	-0.7	-0.5	-0.6	-0.4	-0.01	-0.2	-0.3	-0.07	-0.2	-0.3	-0.2	

* p<=0.05 ** p<=0.01 *** p<=0.001

- GWP$_{total}$ was highly correlated with GWP$_{CO_2}$ **(R$_2$=0.98, p≤0.001).**
- **PAR，Rg，Rn，H，Tsoil, SWC, and Precipitation were the dominated drives.**

Assessment of GWPs in mangrove restoration and island forest

Type	year	CO_2 GWP g CO_2-eq m^{-2} yr^{-1}	CH_4 GWP_{20} g CO_2-eq m^{-2} yr^{-1}	Offset in 20-year（%）	CH_4 GWP_{100} g CO_2-eq m^{-2} yr^{-1}	Offset in 100-year（%）
Mangrove restoration	2020	-2314	982	42.4	337	14.6
	2021	-1705	768	45.0	264	15.5
	2022	-2341	665	28.4	229	9.78
Island forest	2020	-1892	-513	-27.1	-176	-9.3
	2021	-2193	-496	-22.6	-170	-7.8
	2022	-1991	-634	-31.9	-218	-10.9

- Both of them were the atmospheric CO_2 sinks, with comparable integrated GWPs.
- Mangrove restoration acted as CH_4 source, offsetting 28-45% over a 20-year timescale and 10-16% over a 100-year timescale.
- Island forests contributed to the uptake of CH_4, with a GWP accounting for 27-32% of CO_2 over a 20-year timescale

Conclusions and prospects

- Mangroves and island forests play an important role as CO_2 sinks, with annual average fluxes of 578 and 552 g C m^{-2} yr^{-1}, respectively. Mangrove emitted CH_4 (7.44 g C m^{-2} yr^{-1}) into the atmosphere, while island forest acted CH_4 sinks (5.06 g C m^{-2} yr^{-1}). Over a 20-year timescale, CH_4 emissions offset 28-45% in restored mangrove, while island forest contributed 91.5% and 8.5% to the GWP of CO_2 and CH_4, respectively.

- Mangrove provided a significant pathway for CH_4 emissions to the atmosphere, and air temperature was the main controlling factors influencing CH_4 emissions.

- Conducting long-term monitoring of CH_4 and CO_2 dynamics in blue carbon ecosystems in southern China will provide crucial data and theoretical basis for establishing carbon budget estimation systems and achieving "nature-based solutions" carbon neutrality targets.

Thank you!

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