Lateral transfer of detritus carbon across an estuary wetland invaded by *Spartina alterniflora*

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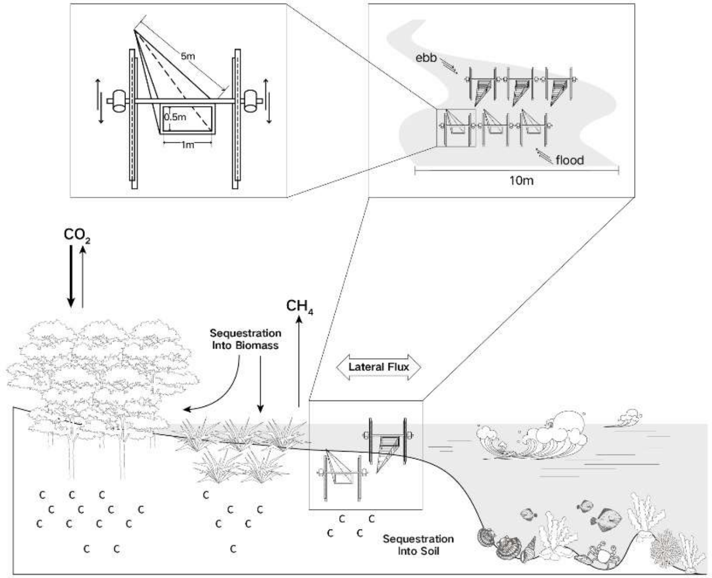
Outline

- Introduction
- Methods and study area
- Results
- Discussion
- Summary



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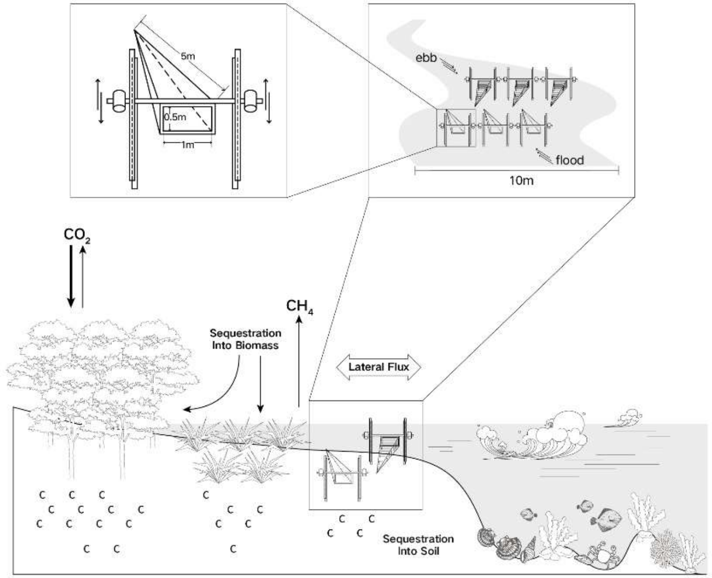
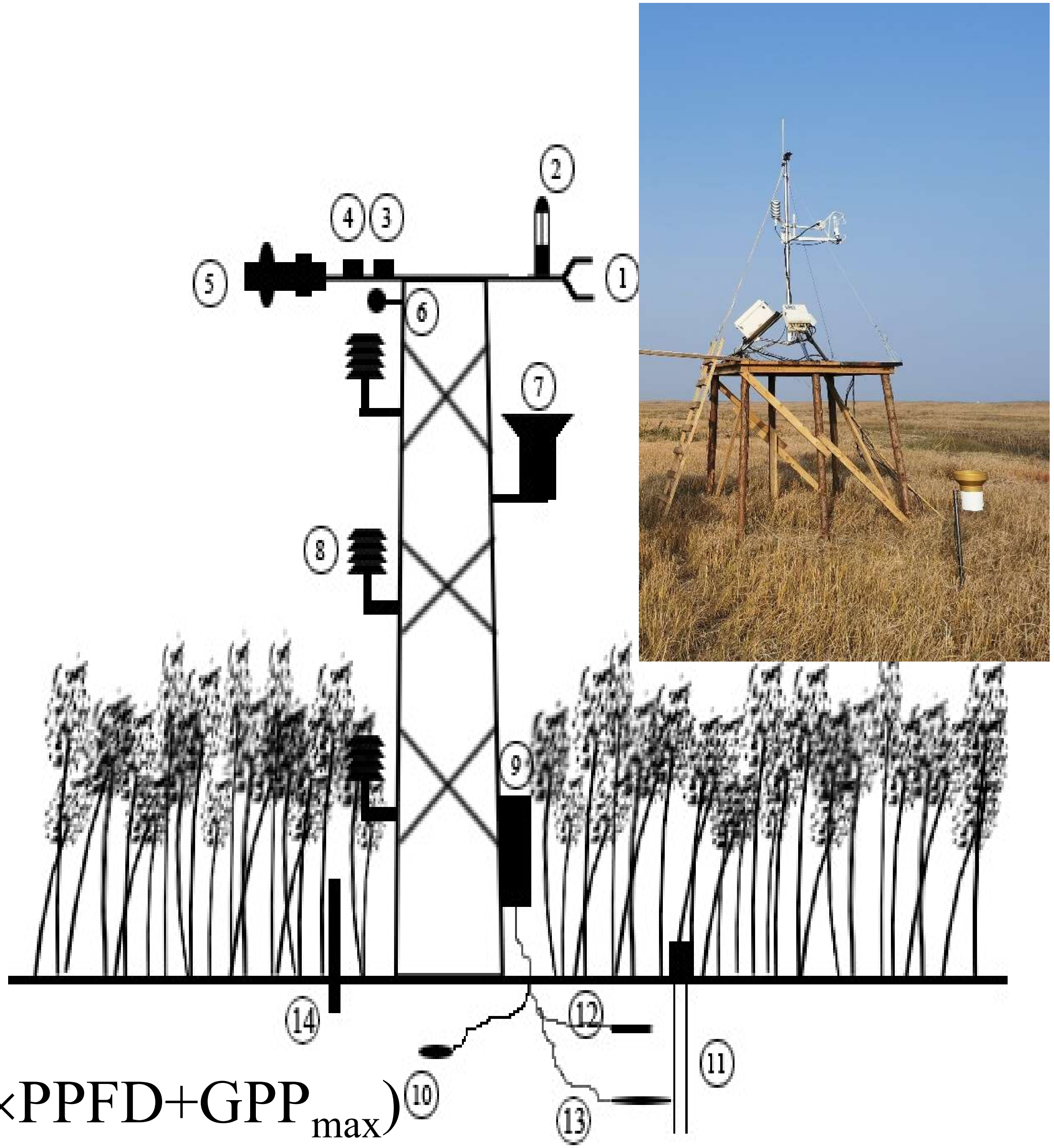


Terrestrial Carbon Cycle

- Growth, mortality, decay
- GPP: Gross Primary Production (climate, CO_2, soil H_2O, resource limitation)
- Ra: Autotrophic respiration (T, live mass,…)
- Rh: Heterotrophic respiration: Decay (T, soil H_2O,..)
- NPP=GPP – Ra
- NEP=Rh – NPP



$$NEE=R_e-\varepsilon_0\times PPFD\times GPP_{max}/(\varepsilon_0\times PPFD+GPP_{max})$$

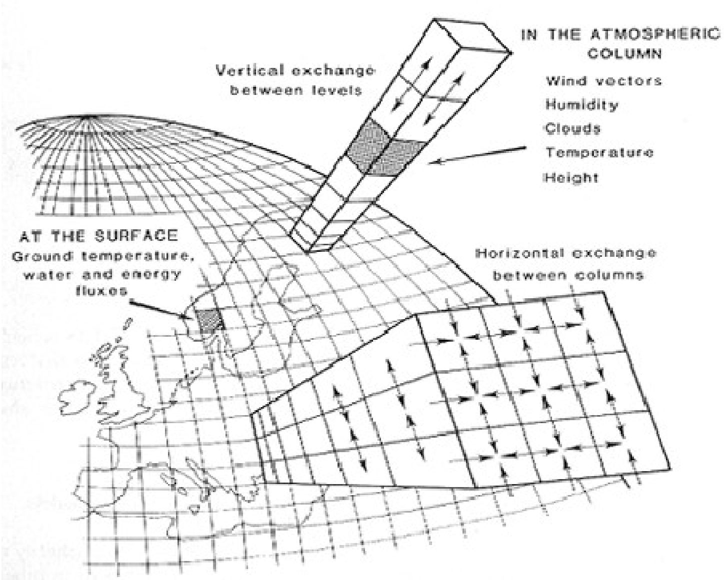
Why MODIS?

$$NDVI = \frac{\rho_{nir} - \rho_{red}}{\rho_{nir} + \rho_{red}}$$

(normalized difference vegetation index)

$$EVI = G \times \frac{\rho_{nir} - \rho_{red}}{\rho_{nir} + C_1 \times \rho_{red} - C_2 \times \rho_{blue} + L}$$

(enhanced vegetation index)



Vegetation covering the Earth is now routinely monitored at high resolution using remotely sense data.

GPP_{MODIS} estimation depends on vegetation characteristics (e.g., the LAI) (leaf area index)

What is a light-use efficiency model?

Model	FAPAR	ε_g	ε_0	Reference
TURC	f(NDVI)	ε_0	0.24	Ruimy et al. (1994)
GLO-PEM	f(NDVI)	$\varepsilon_0 \times T \times SM \times VPD$	0.14	Prince and Goward (1995)
MODIS-PSN	f(LAI)	$\varepsilon_0 \times T \times VPD$	0.22	Running et al. (2004); Running and Zhao (2019)
3-PG	f(LAI)	$\varepsilon_0 \times T \times SM \times VPD$	0.48	Law et al. (2000)
VPM	f(EVI)	$\varepsilon_0 \times T \times SM \times W \times P$	0.48	Xiao et al. (2004)

Comparison of light-use efficiency models for GPP

Coupled modelling and sampling to assess lateral C transfer

$$GEE = GPP + F_{lateral} + F_{CH_4} + F_{other}$$

$$GEE = GPP_{EC}$$

$$GPP = GPP_{MODIS}$$

$$GPP_{EC} = GPP_{MODIS} + F_{lateral} + F_{CH_4} + F_{other}$$

$$\Delta GPP = GPP_{EC} - GPP_{MODIS}$$

$$= F_{lateral} + F_{CH_4} + F_{other}$$

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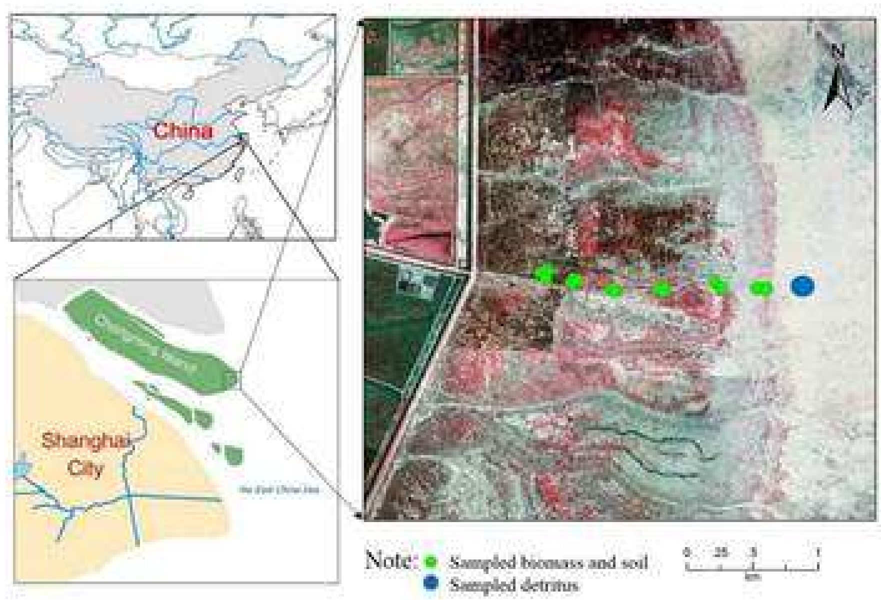
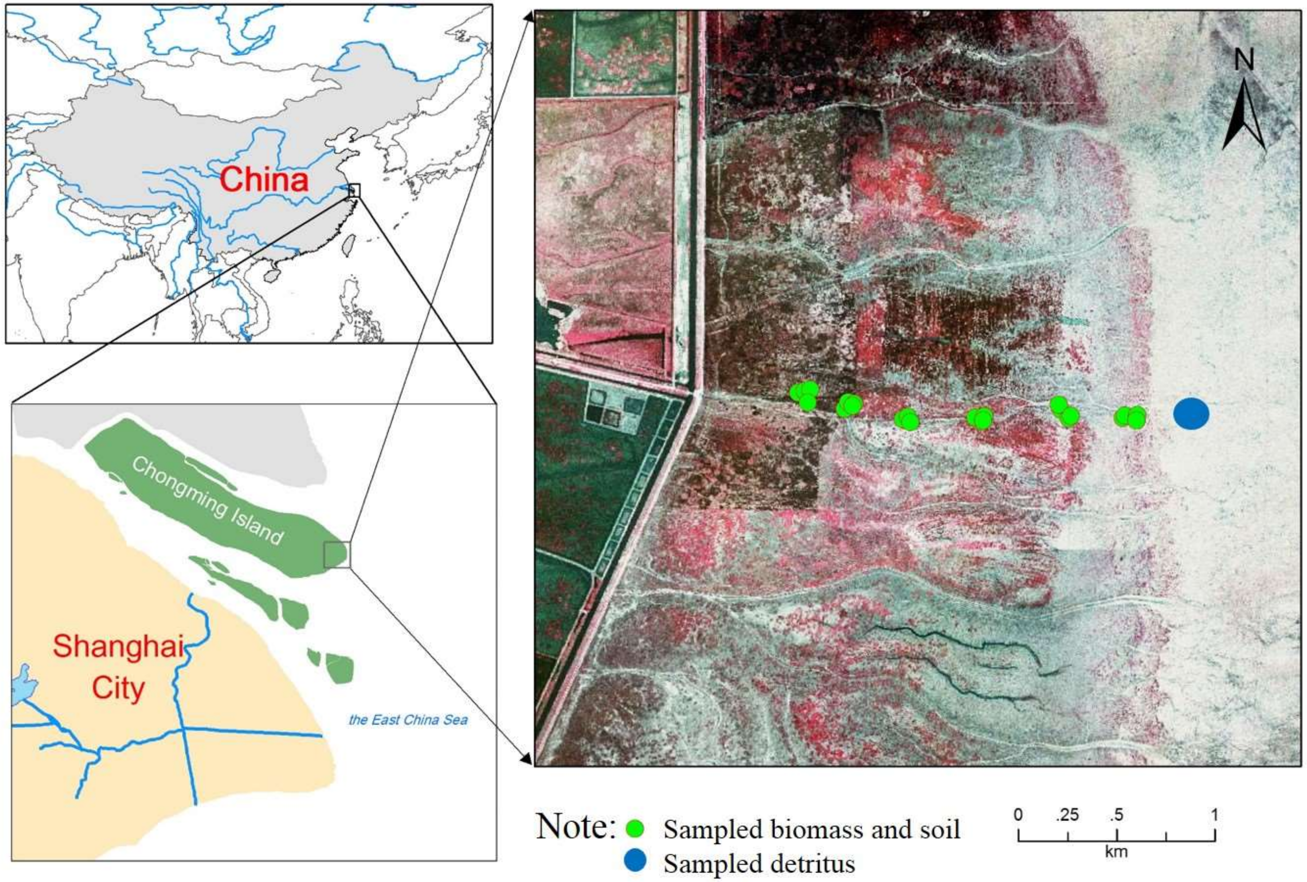


Locations of the sampled ecosystems in Dongtan, Chongming Island, the Yangtze Estuary, China



The location of the detritus field measurement platform was 31.51° N, 121.98° E at the mouth of a large creek in this wetland.

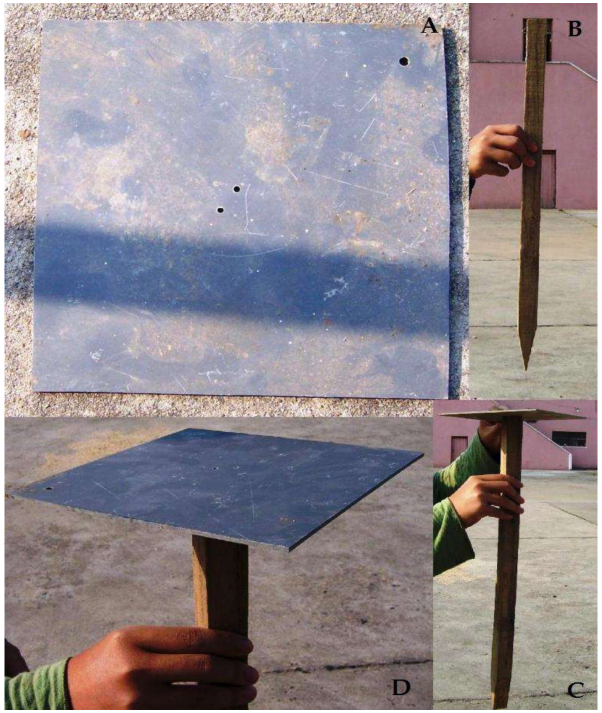
invasive *Spartina alterniflora* has altered the ecosystem structure and functions

- **the vegetation area consists of**
  - ***Phragmites australis* (Left) and *Spartina alterniflora* (Right)**

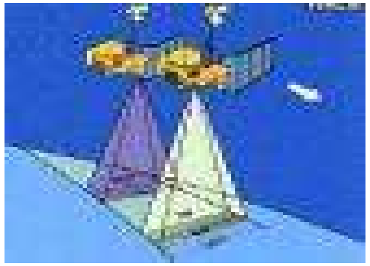
- **We hypothesized that**
  - ***Spartina* invasion is coupled with changes in lateral exchanges and that in turn alters the ecosystem C cycle at various spatial and temporal scales.**
  - **characteristics of land surface (e.g., soil texture, surface roughness, albedo, emissivity, vegetation type, cover extent, leaf area index, and seasonality)**
  - **exchanges of momentum, energy, water vapor, CO_2, …**

Plant biomass and primary production

- **Exchange processes with the atmosphere**
  - **Momentum**
  - **Energy (reflected shortwave, emitted longwave, latent/sensible heat)**
  - **Water (evapotranspiration)**
  - **Trace gases (CO_2, CH_4, N_2O, BVOCs)/dusts/aerosols/pollutants**
- **Exchange processes with the ocean**
  - **Fresh water**
  - **Sediments/nutrients**
  - **Salinity**

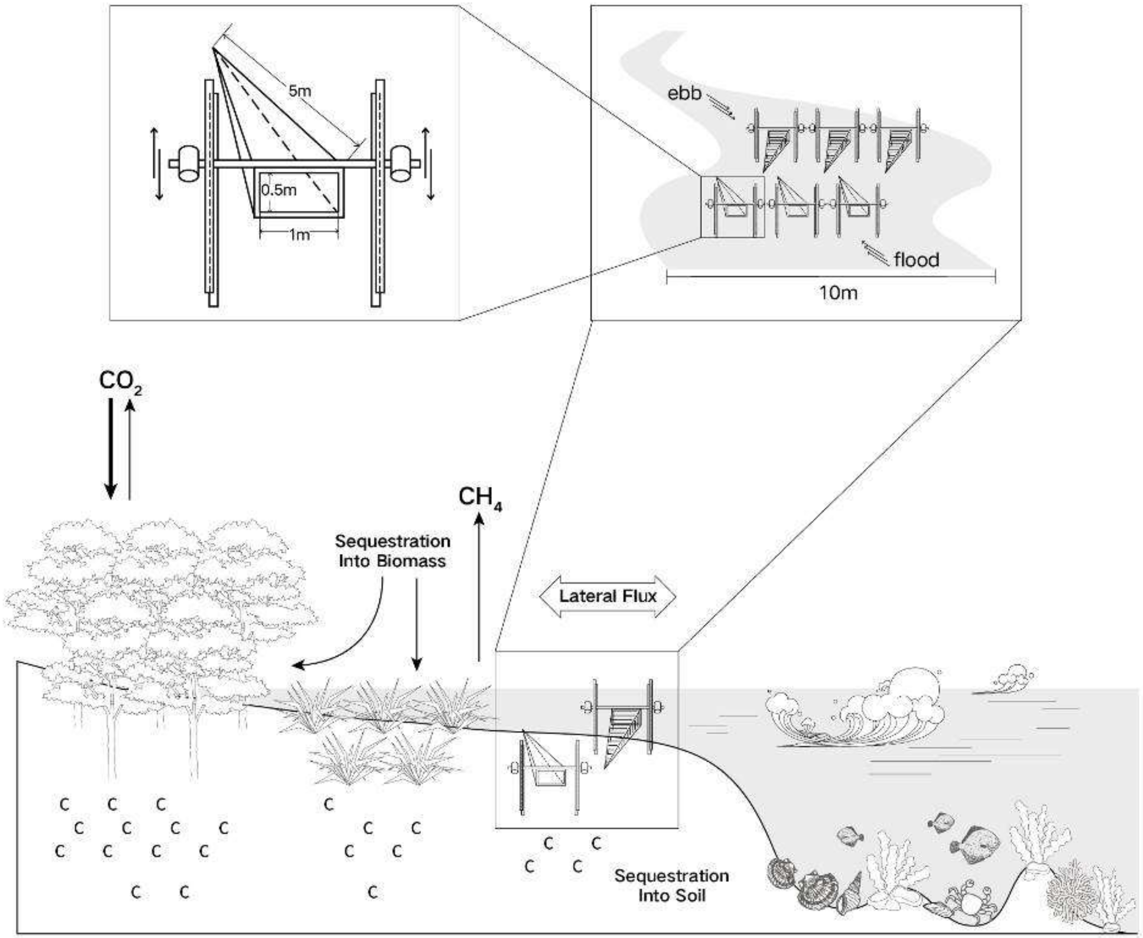


Modeling estuarine C balance



- GPP$_{EC}$: The eddy-covariance method was applied to quantify the half-hourly net ecosystem exchanges of CO_2 (F_{CO2}) and CH_4 (F_{CH4})
- GPP$_{MODIS}$: based on the gap-filled product MOD17A2HGF version 6.

Sampling lateral detrital C fluxes



- A schematic diagram showing the design of nets for catching imported and exported detritus in coastal wetlands, the location of the nets, and the layout of the nets.

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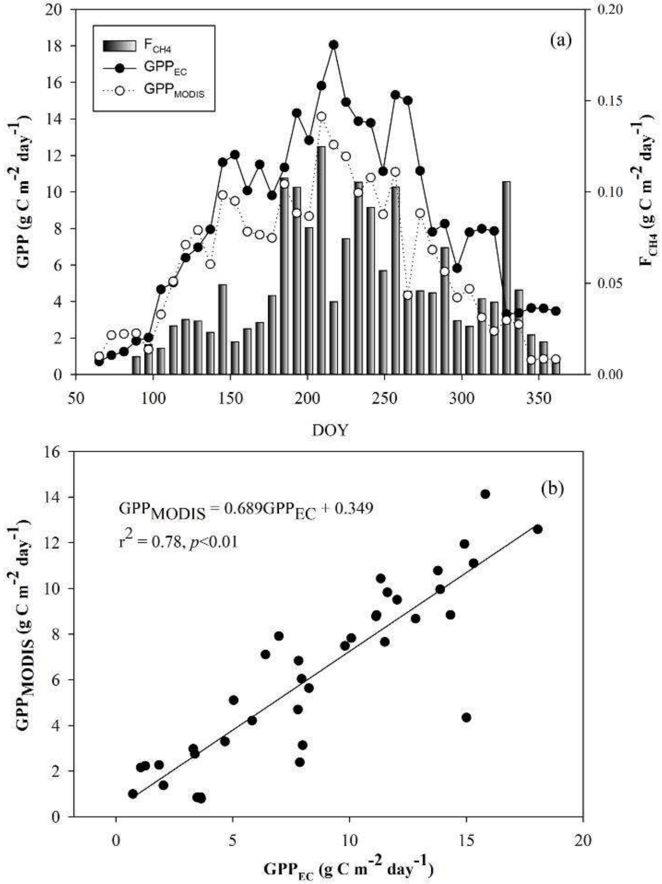
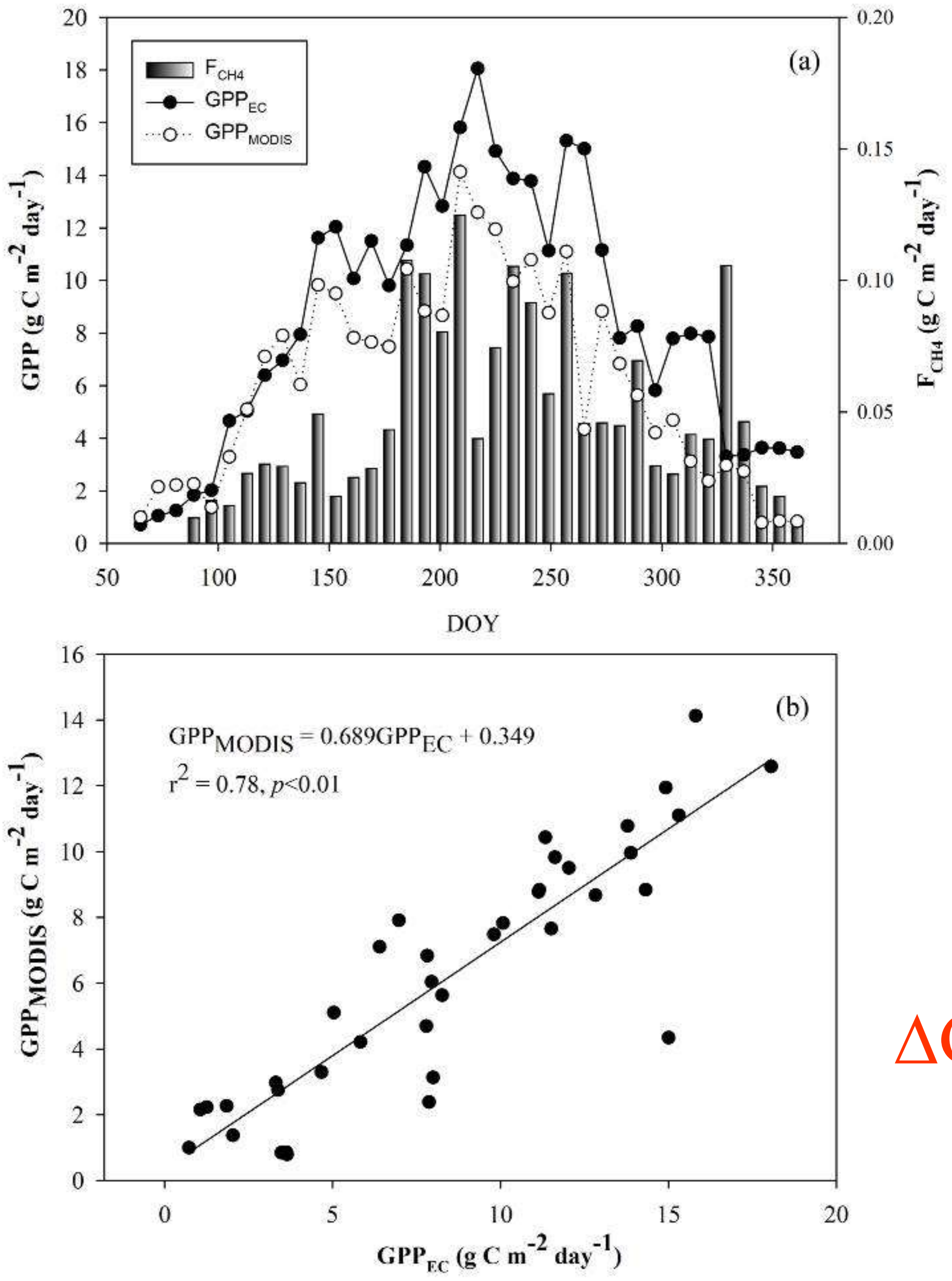


Estimating lateral C flux

- Variation in total C pools in the plants and C input by NPP calculated using data collected in September 2010 (n=24, belowground biomass to a depth of 20 cm).

Plant	*Phragmites*	*Spartina*
Phragmites		
Total plant C stock (kg m^{-2})	0.85±0.04	1.12±0.06
Belowground plant C stock (kg m^{-2})	0.52±0.03	0.61±0.04
Aboveground plant C stock (kg m^{-2})	0.33±0.02	0.51±0.02
NPP (kg C m^{-2} y^{-1})	0.64±0.04	0.82±0.06
Sediments into soil (kg C m^{-2} y^{-1})	0.42±0.05	0.66±0.08
Sediment thickness (cm yr^{-1})	1.4±0.2	2.6±0.3

- The total C release through lateral flows ranged from 0.21 to 0.30 kg C m^{-2} y^{-1}, which on average was 25.8% of NPP.



Simple "Bucket"

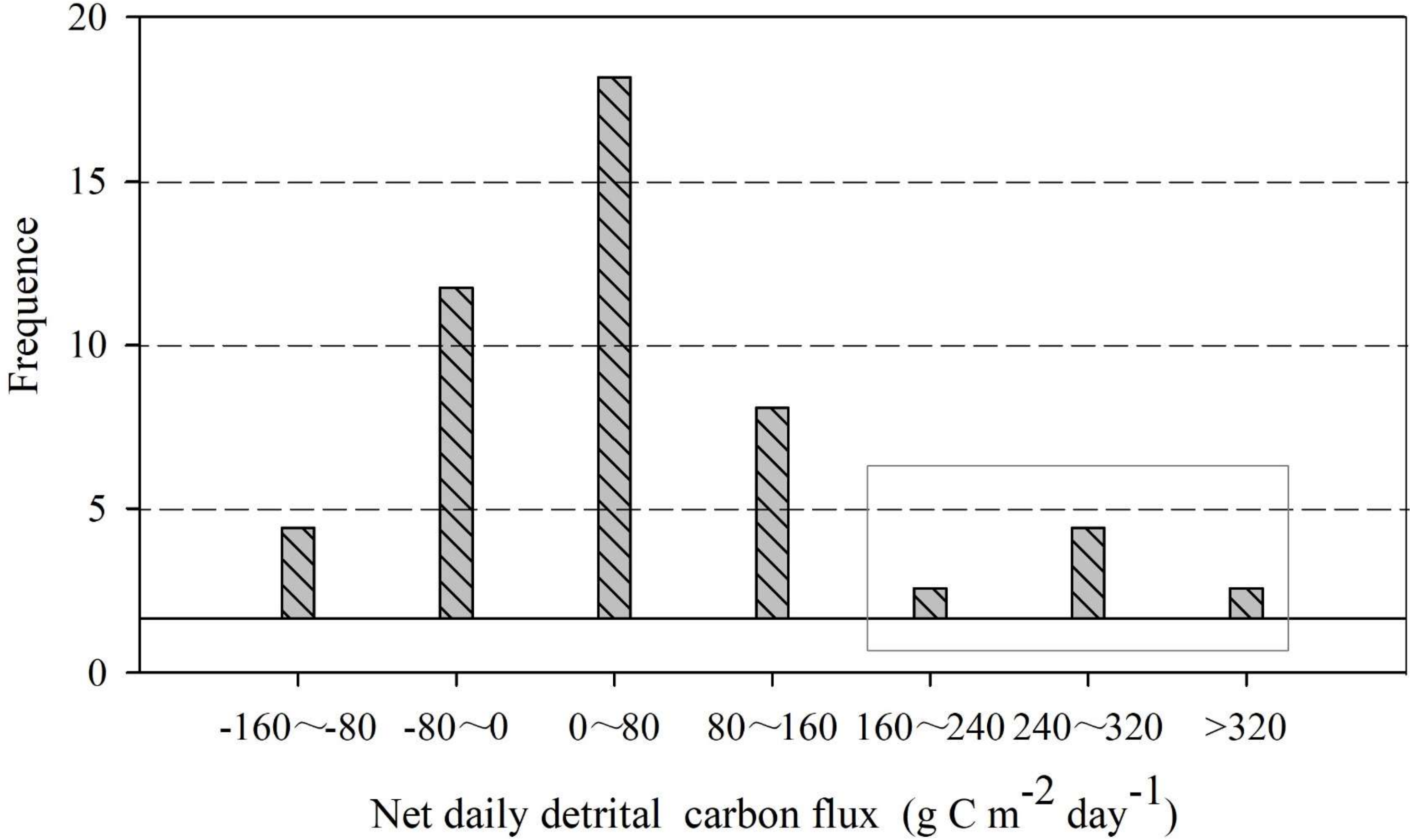
- **Seasonal changes in gross primary production from eddy covariance towers (GPP_{EC}), MODIS (GPP_{MODIS}) GPP, and net ecosystem exchange of CH_4 (F_{CH4}) (a) and the linear relationship between GPP_{EC} and GPP_{MODIS} (b).**
  - **the GPP_{MODIS} (472.6 g C m^{-2} y^{-1}) was 73.0% of GPP_{EC} (646.9 ± 70.7 g C m^{-2} y^{-1}) during the 2010 growing season**
  - **the emission of C in non-CO_2 form (i.e., CH_4) accounts for 2.8% of the GPP_{EC}**

$$\Delta GPP = GPP_{EC} - GPP_{MODIS}$$

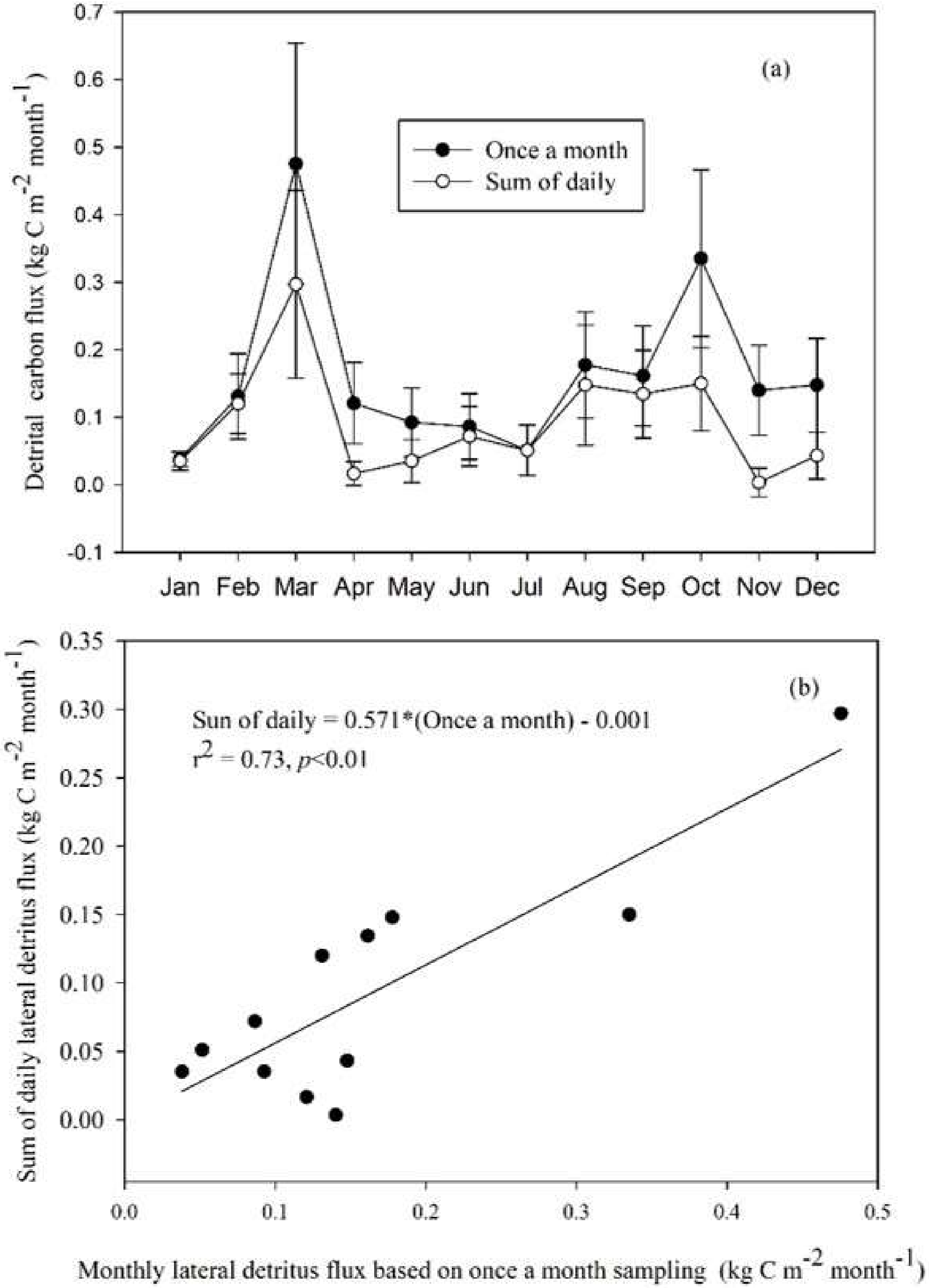
$$= F_{lateral} + F_{CH_4} + F_{other}$$

Observed lateral detrital C flux

The frequencies of net daily detrital carbon flux

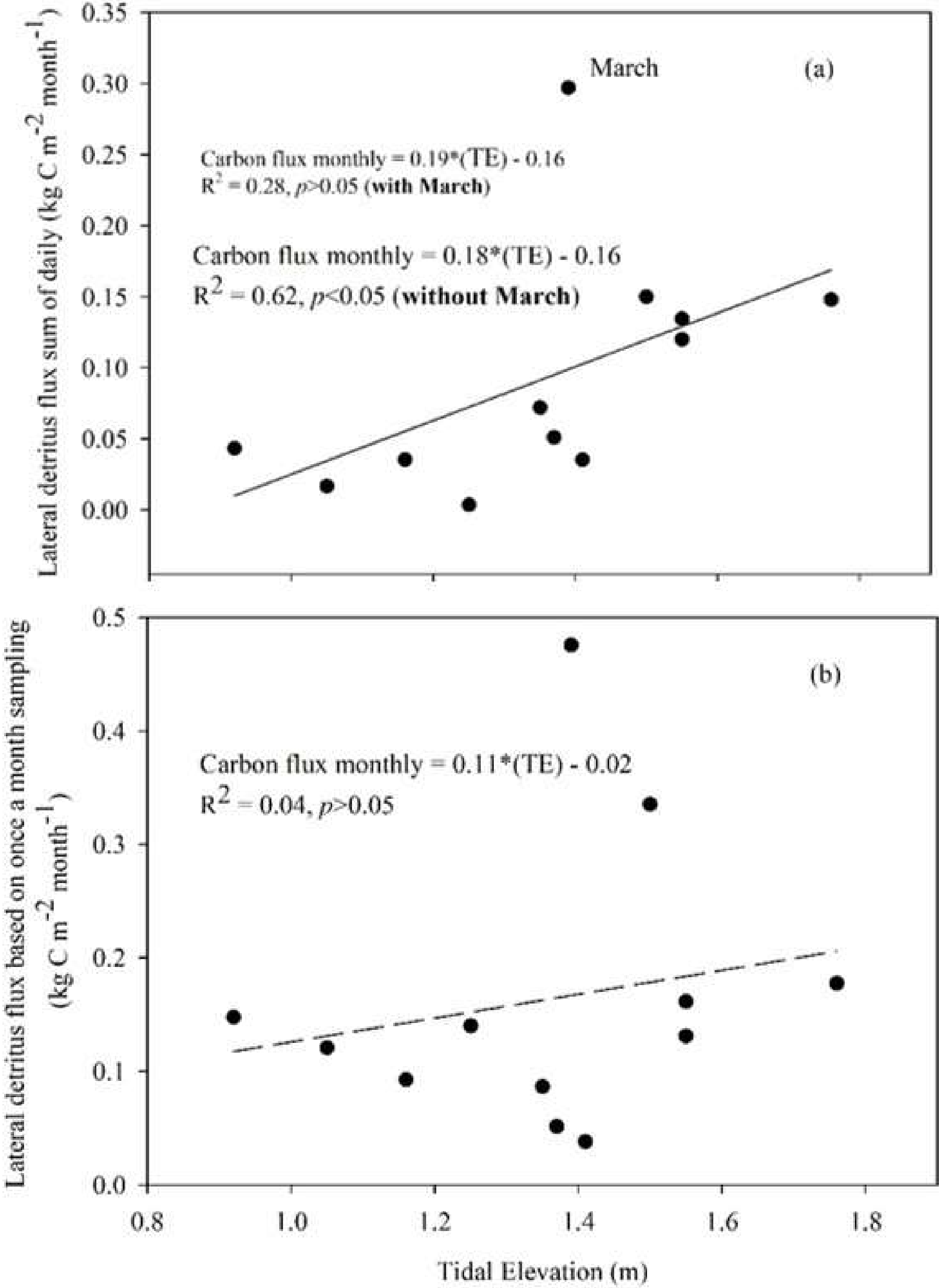


- **Positive flux suggests a net loss, and negative flux indicates a net gain.**



Simple monthly

- **Comparisons (a) and the linear relationship (b) of lateral detritus flux between daily sum and monthly total.**
  - **the lateral flux based on monthly sampling (i.e., once a month) was higher than that based on daily sampling (i.e., the sum of daily sampling), especially in March and October.**
  - **a high correlation (r^2=0.73*, *p*<0.01) between the estimates.**



Monthly or daily?

- **The relationship between lateral flux and tidal activity seemed to be statistically insignificant between the two sampling methods.**
  - **when the exceptional month of March was not considered, there was a significant correlation (r^2=0.62*, p<0.05) between the monthly lateral detritus fluxes based on daily samplings and the maximum tidal height.**
  - **A similar relationship was not detected in monthly sampled data .**

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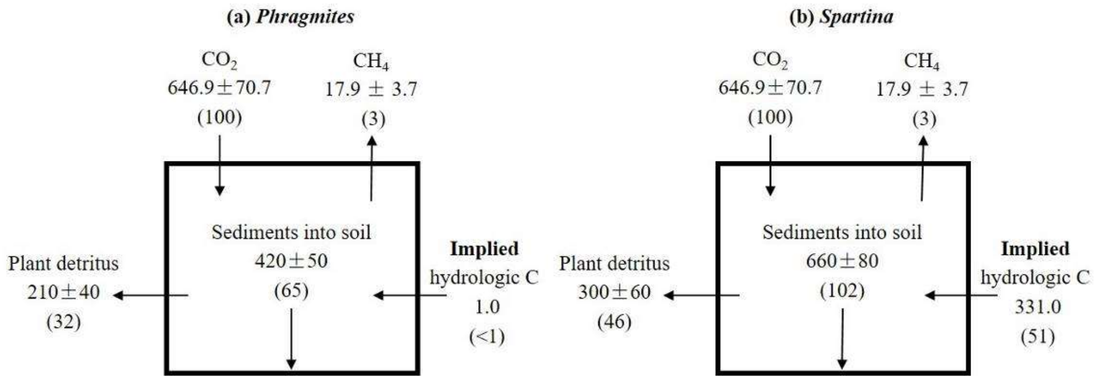
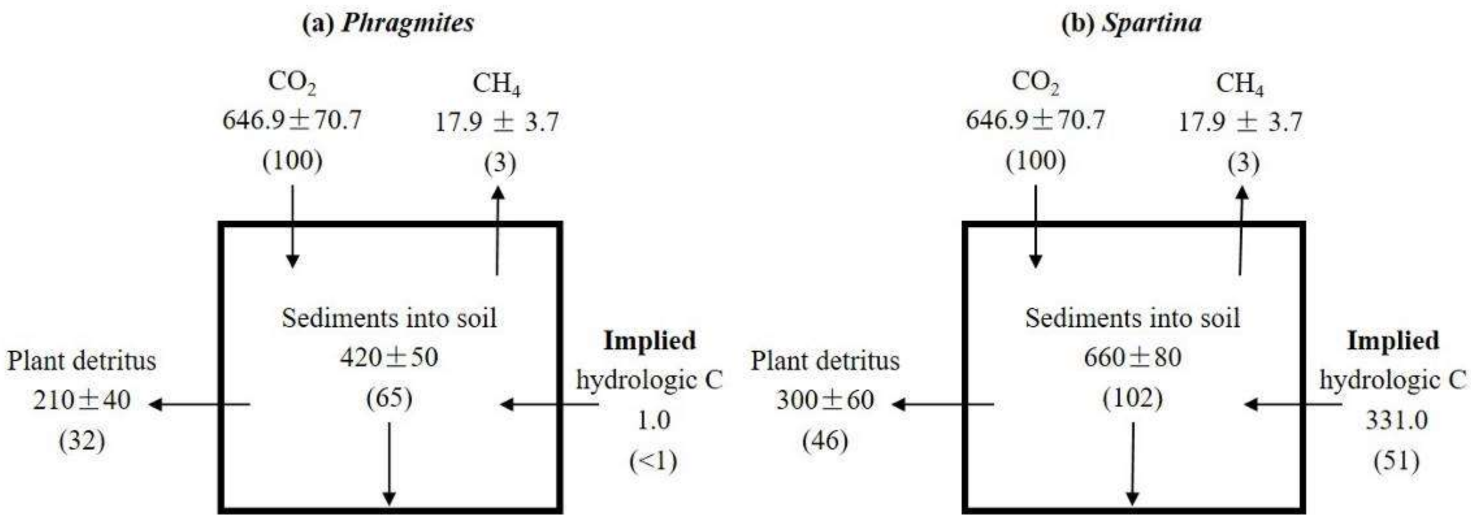


C budget of estuarine wetlands

- **Average annual C budget in coastal wetlands dominated by (a) *Phragmites* and (b) *Spartina*, including the net ecosystem CO_2 exchange (NEE), net ecosystem CH_4 exchanges (CH_4), lateral detrital C flux (plant detritus), and sediments into the soil.**
  - **The values of net uptake/loss imply the net hydrologic C fluxes (i.e., fluxes of DOC, POC, and DIC).**
  - **All observed fluxes are presented with absolute values (g C m^{-2} yr^{-1}, ±95% confidence intervals), while the arrows indicate the flux direction.**
  - **Values in parentheses indicate the relative magnitude (%) of each flux normalized with the NEE.**



Why use multiple temporal scales?

Many, many studies have provided evidence for mechanisms resulting in different sampling strategies of collecting lateral detritus at different study sites.

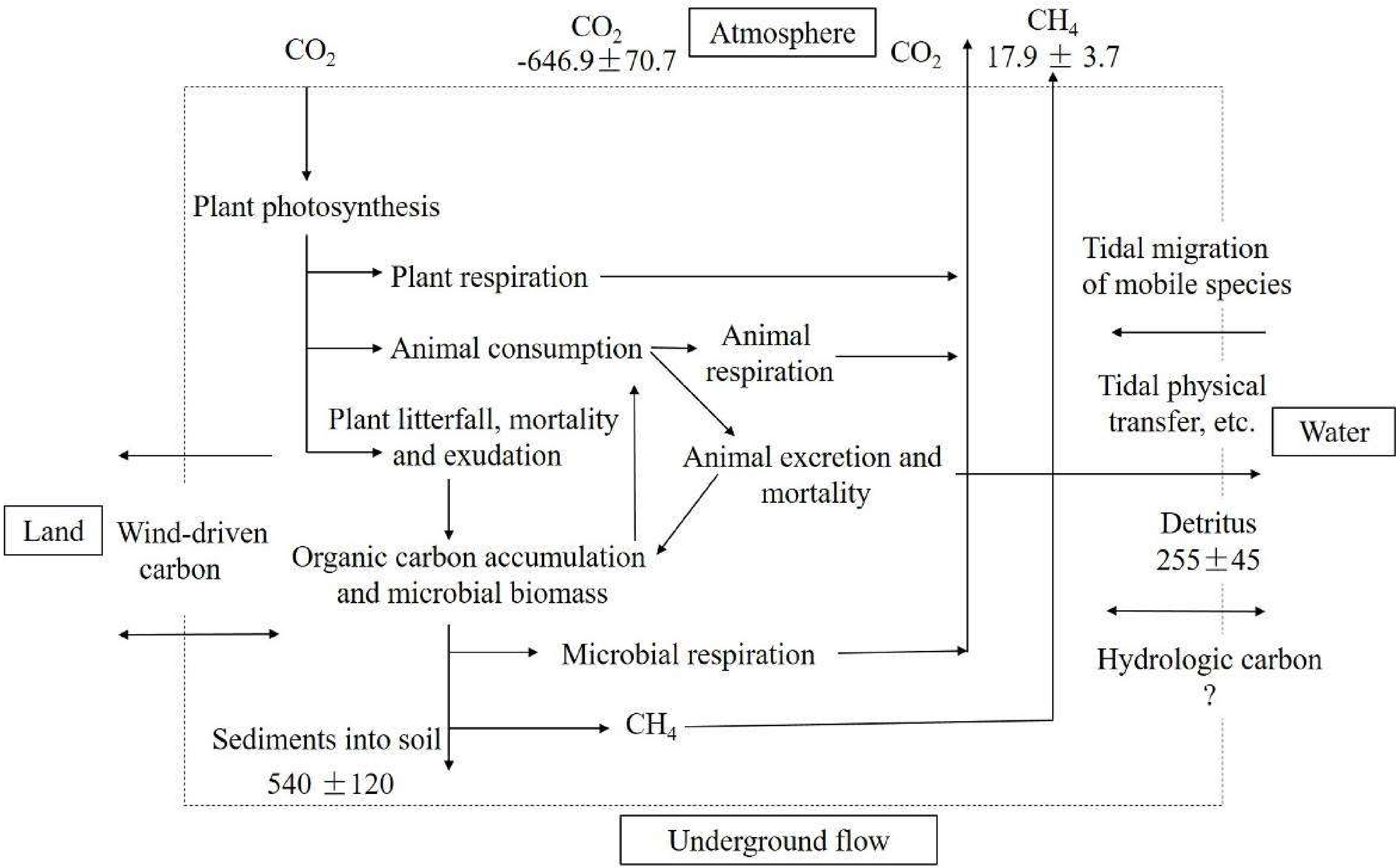
Reference	Site location	Marsh type	sampling strategies	Contribution of NAPP
our study	Chongming Island, Shanghai, China	*Phragmites australis; Spartina alterniflora*	yearly	21.6~27.3%
			daily and monthly	<1%
Teal (1962)	Sapelo Island, Georgia, USA	*Spartina alterniflora*	yearly	45%
Palomo et al., (2009)	Palmones River estuary, Spain	*Sarcocornia perennis* ssp. *alpini* (Lag.)	bimonthly	12%
Wolff et al., (1979)	Oosterschelde estuary, The Netherlands	*Halimione portulacoides; Spartina townsendii; Puccinellia maritima*	monthly	10%
Bouchard et al., (1998)	the South of the Normandy gulf, France	*Atriplex portulacoides (L.) Aellen*	weekly	14%
Dame et al., (1986)	North Carolina marsh, USA	*Spartina alterniflora*	daily	< 1%
Dankers et al., (1984)	Ems-Dollard estuary, The Netherlands	*Puccinellia maritima*	daily	1%
Hemminga et al., (1996)	Westerschelde estuary, The Netherlands	*Elymus pycnanthus; Scirpus maritimus; Phragmites australis; Puccinellia maritima*	daily	< 0.2%

Gao, et al., in prep

Test hypothesis

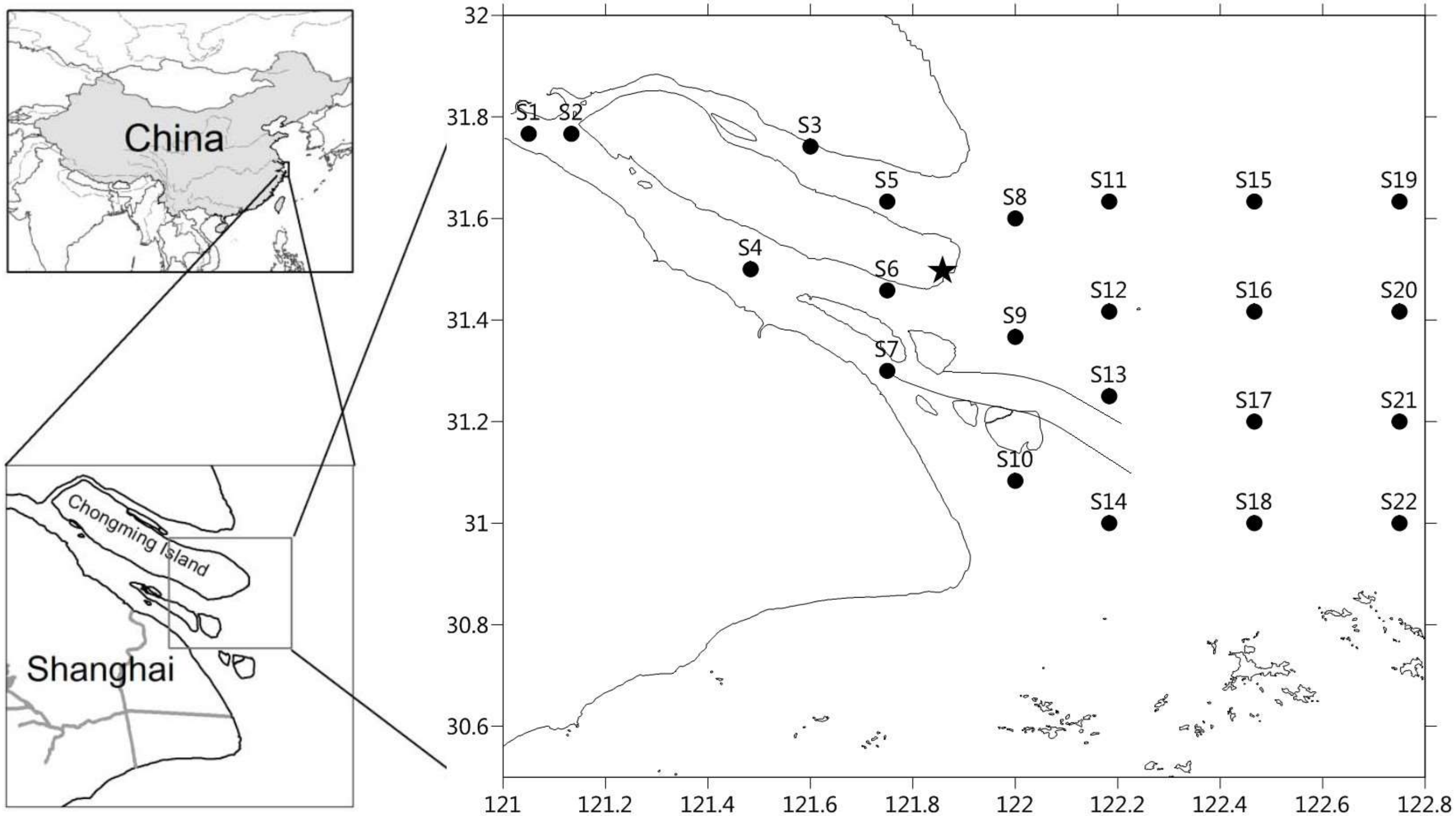
Be quantitative (put numbers on ideas)

Implications for hydrologic C fluxes



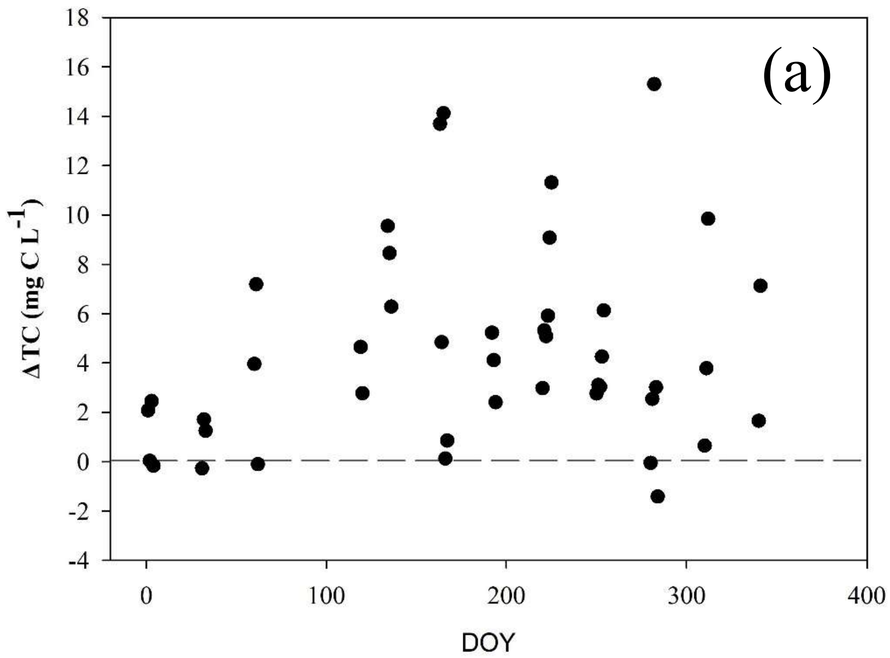
- Conceptual model illustrating the significant pathways of C flux across the estuarine wetland ecosystem.

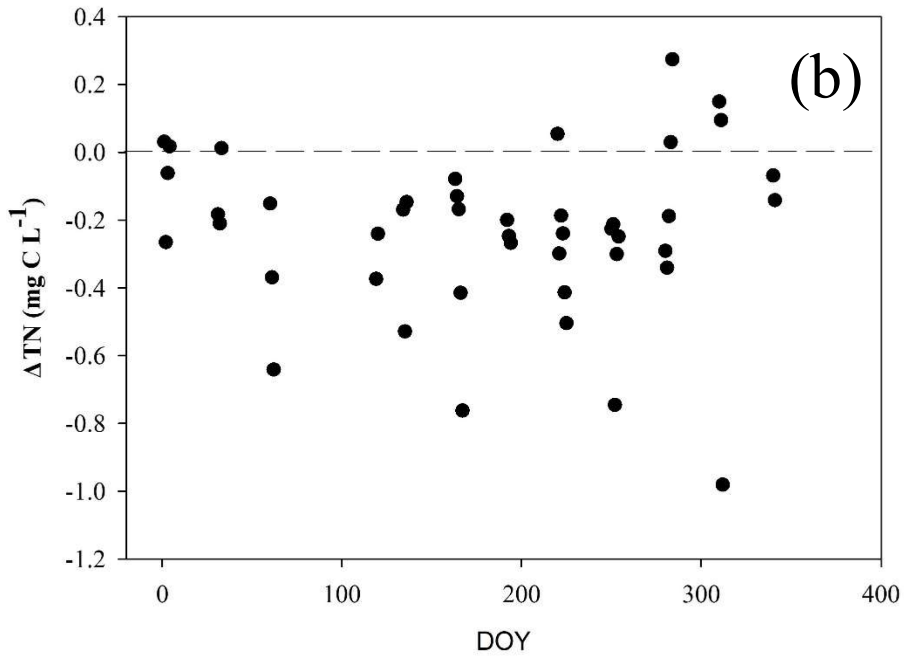
Modeling Carbon transport by rivers from land to coastal wetlands and to coastal ocean



- spatiotemporal granularities were responsible for the dominant uncertainty contributor to the variation in lateral detrital C exchange under typical hydrological conditions.

Tidal Control of Reciprocal Lateral C / N flows





- **The relationship between net hydrologic C flows (i.e., DOC, POC, and DIC) (a) and N flows (b) seemed Reciprocal (Gao et al. (2021) in prep)**

Negative-sign indicate net fluxes into the wetland

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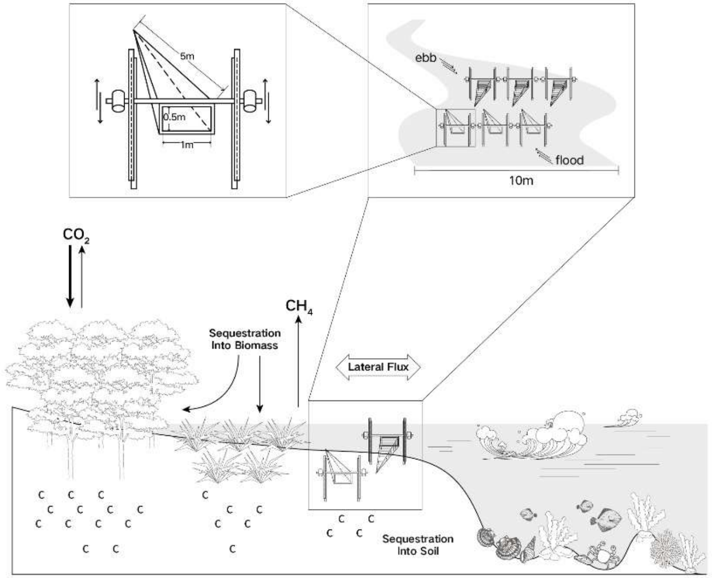
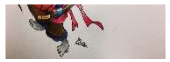


Summary

- This research demonstrates that an integrated framework incorporating modeling and field sampling can quantitatively assess lateral detritus C transport processes across the terrestrial-aquatic interface in estuarine wetlands;
- However, we note some limitations in our research approach associated with applying the light-use efficiency model method to tidal wetlands;
- Our results highlight that *Spartina* invasion can turn the lateral C balance from a C source of productive *Phragmites*-dominated marshes into a slight C sink.
- To best understand the lateral hydrologic C flux, increased sampling over a longer period of time (ca. an entire season) and continuous measurements are important in determining the contribution of different processes of lateral detritus C flux to close estuarine ecosystem C budgets.
- The sampling spatiotemporal granularities can be the key to assessing lateral detritus carbon transfer.



Summary

- What is Lateral C ?
- Why Lateral C ?
- How to model and estimate Lateral C ?
- Do we believe in everything from observed Lateral C ?
- The new normal focused on hydrologic C flux measurements (i.e., DOC, POC, and DIC).

Key Reference

Gao, Y., J. Chen, T.-T. Zhang, B. Zhao, S. McNulty, H.-Q. Guo, F. Zhao, P. Zhuang, 2021: Lateral carbon detritus transfer across a *Spartina alterniflora* invaded estuarine wetland [J]. Ecological Processes, *submitted (*under review*)*

The End
Thanks!☺

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