Northwestern Pacific Ocean Circulation & Climate Experiment

5th NPOCE webinar, 2022.10.19

Sea-air CO_2 fluxes and carbon export & remineralization in the subtropical Northwestern Pacific

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OUTLINE

1. Intro: Ocean C sink and biological pump

2. Findings in the subtropical NW Pacific
   - I. CO_2 fluxes at the sea-air interface
   - II. POC export from the euphotic zone
   - III. OM remineralization in the twilight zone

3. Conclusions and implication

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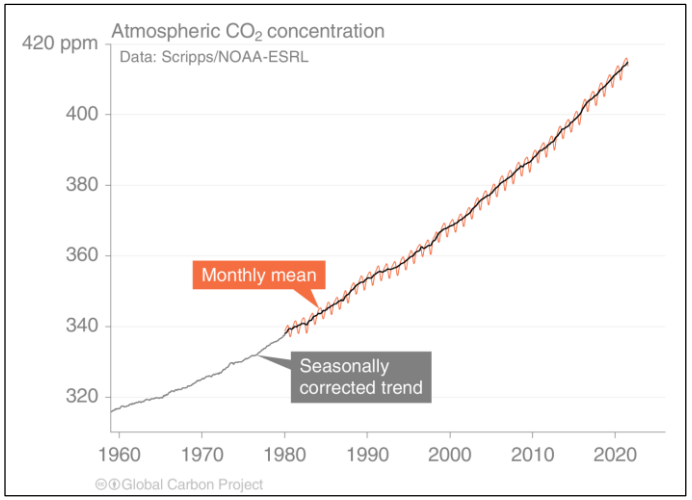
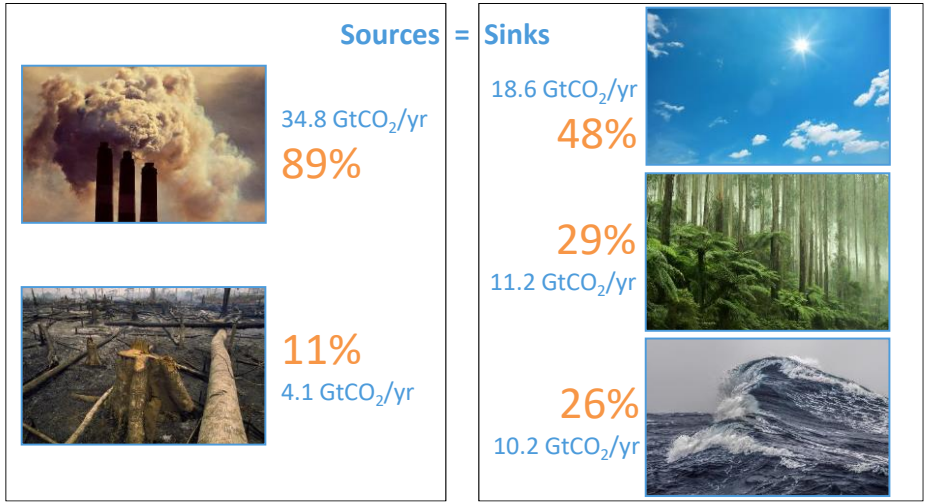
Ocean: an important sink of atmospheric CO_2

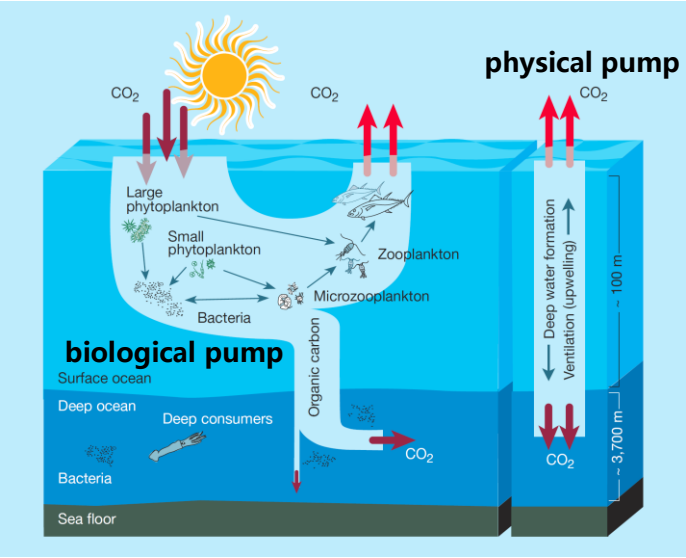




(Global Carbon Budget, 2021)

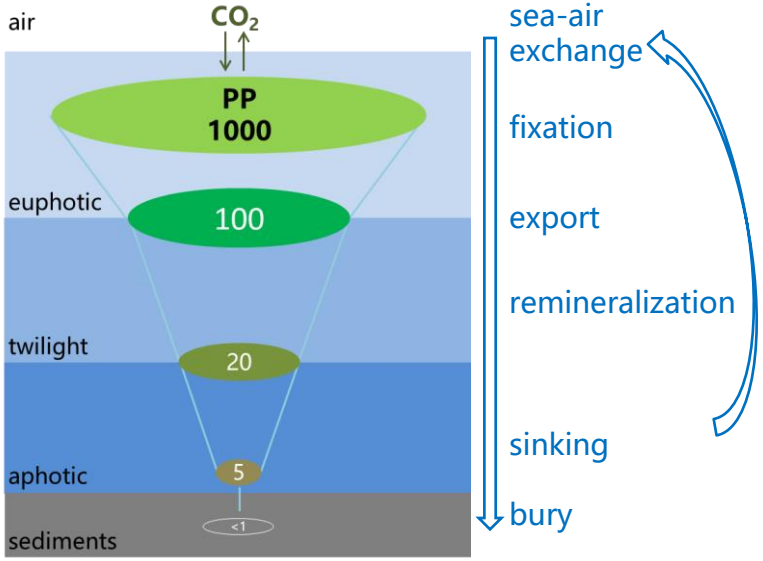
- atmospheric CO_2 concentrations are approaching 420 ppm
- globally, ocean uptakes about 25% of the anthropogenic CO_2
- sea-air CO_2 exchange is the first-order issue of the ocean C sink

How ocean modulates atmospheric CO_2?



(Chisholm, 2000)

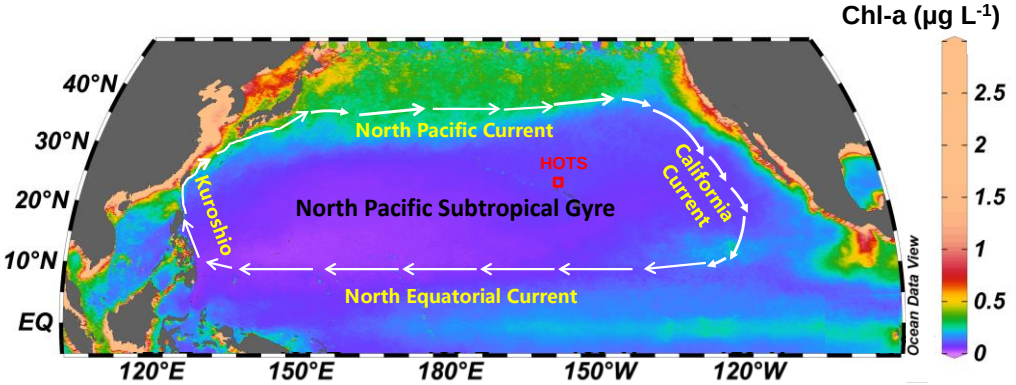
- if close biological pump, air CO_2 will increase by another 150-200 ppm (Falkowski et al., 2000)

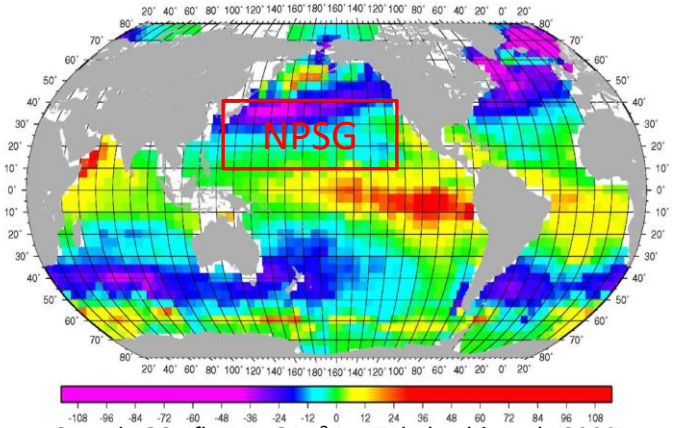


(Neuer et al., 2014; numbers denote carbon flux proportion)

- export from the euphotic zone: indicating the efficiency of BP
- remineralization in the twilight zone: largest decline of exported POC

NPSG: ocean desert but CO_2 sink

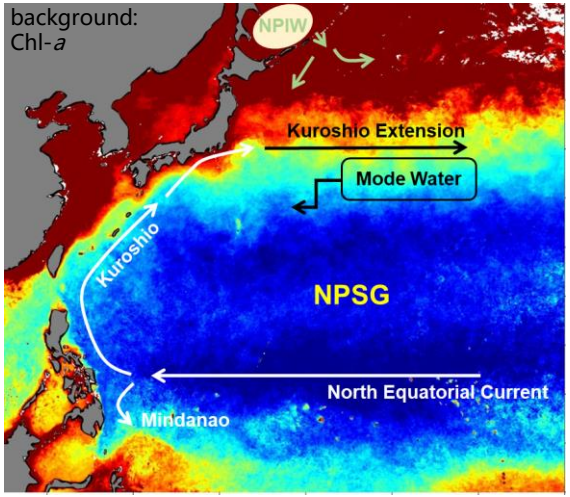




Sea-air CO_2 flux (g C/m^2/yr; Takahashi et al., 2009)

- the largest continuous ecosystem on Earth
- oligotrophic: low nutrient, low Chl-a, low productivity
- carbon sink: annual CO_2 uptake is ~12.5% of the global ocean carbon sink

Subtropical NW Pacific: “hotspot”

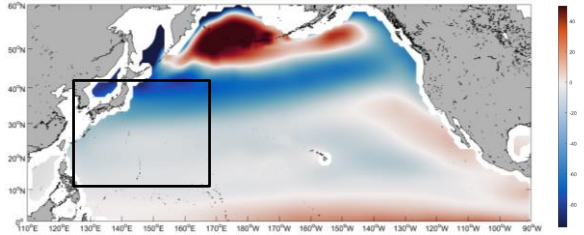


hydrography:

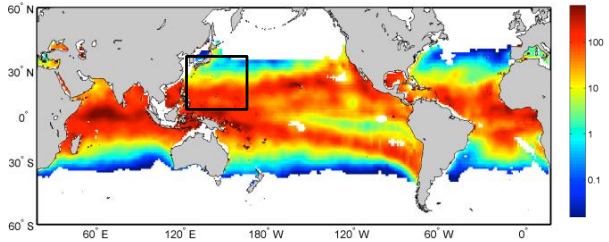
- west boundary system: Kuroshio and Kuroshio Extension
- high-latitude influence: NPIW and Mode Water

sea-air exchange:

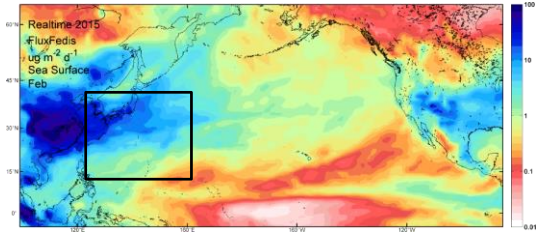
- the largest CO_2 sink in the NP
- high N_2 fixation and dust Fe input



sea-air CO_2 flux (g C/m^2/yr; Zhong et al., 2022)

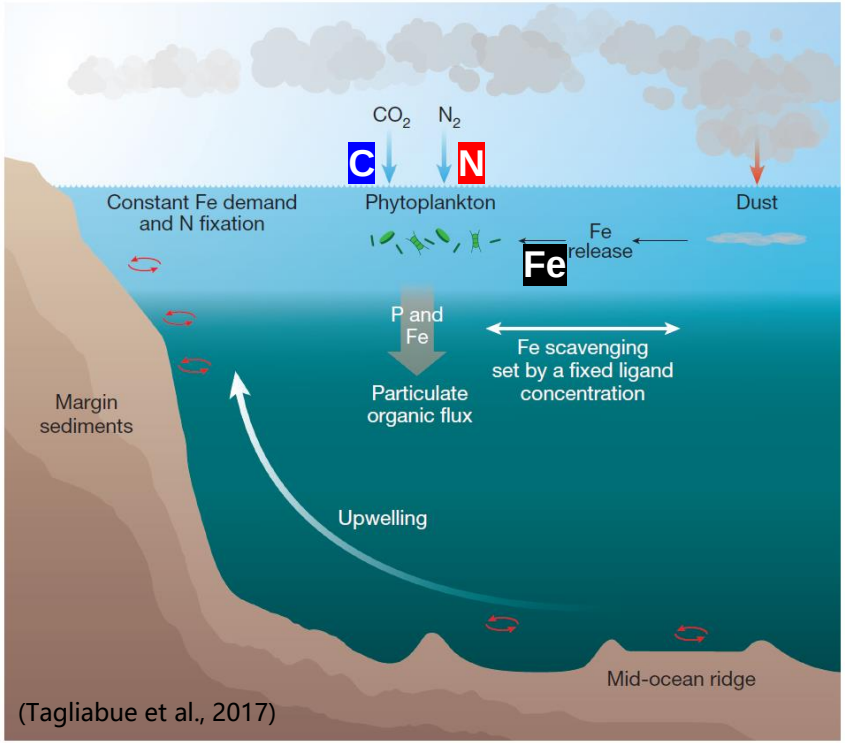


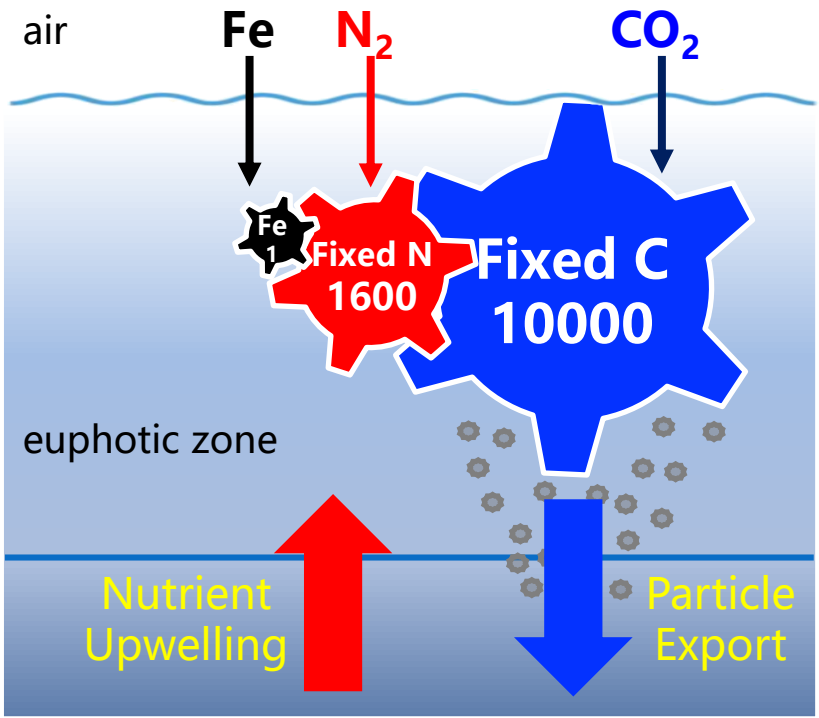
N_2 fixation (umol N/m^2/d; Luo et al., 2014)



dust Fe input (ug Fe/m^2/d; from P Xiu)

Biological pump: C-N-Fe interactions



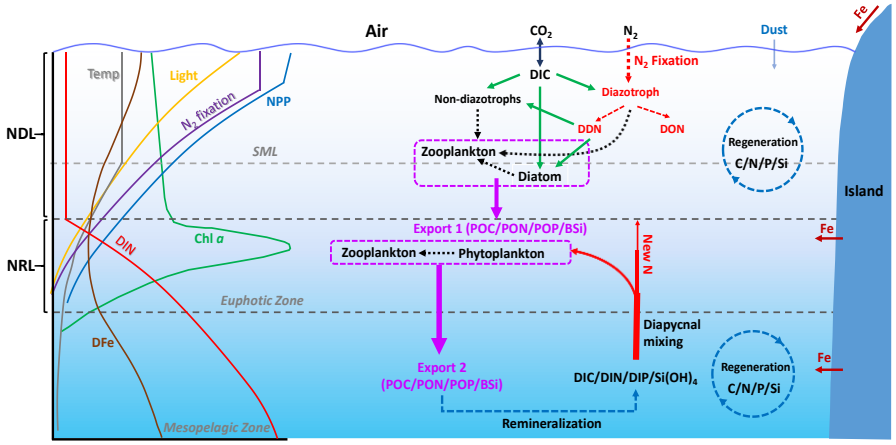


NSFC Major Program: CARBON-FE

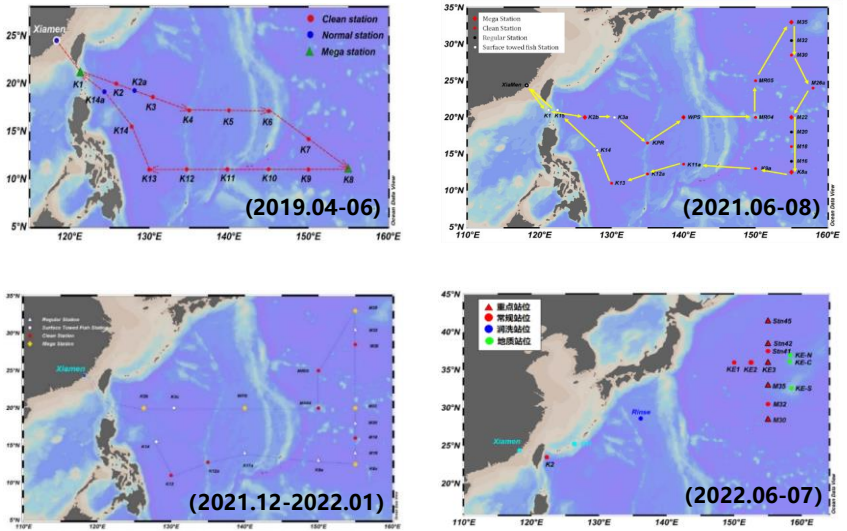
2019-2023, led by Minhan Dai

CARBON Fixation and Export in the oligotrophic ocean

海洋荒漠固碳、固氮机理及增汇潜力



two-layered structure of bioelement biogeochemistry in the euphotic zone of oligotrophic subtropical gyres



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I. CO_2 Fluxes at the Sea-air Interface

led by Xianghui Guo

Sink (Flux < 0)

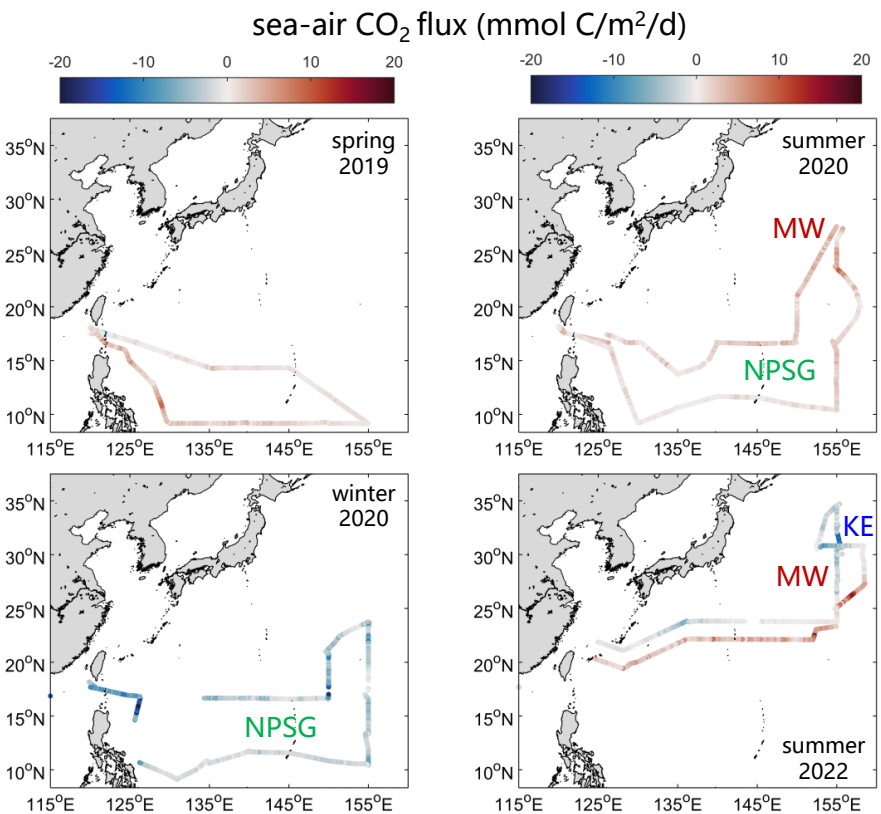
Source (Flux > 0)

underway pCO_2 measurement

Sea-air CO_2 Flux = $k \cdot s \cdot \Delta pCO_2$

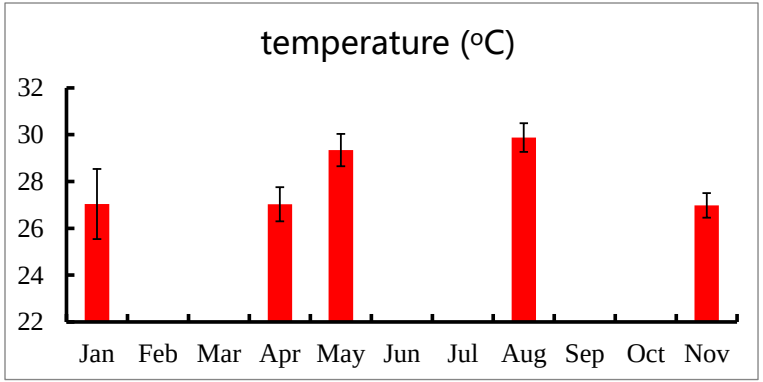
- k – gas exchange coefficient
- s – CO_2 solubility
- $\Delta pCO_2 = pCO_{2\_seawater} - pCO_{2\_air}$

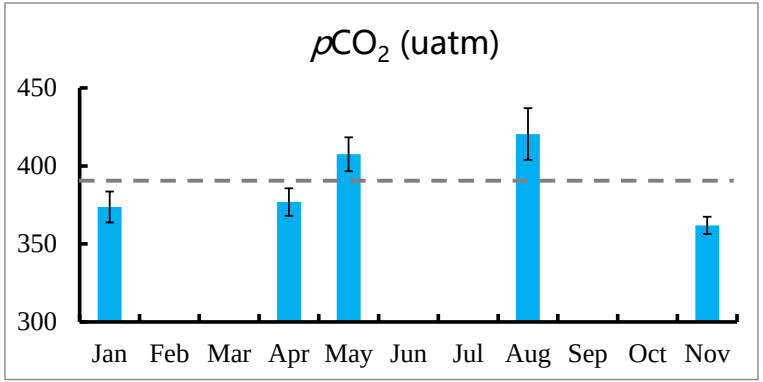
CO_2 flux: seasonal variations

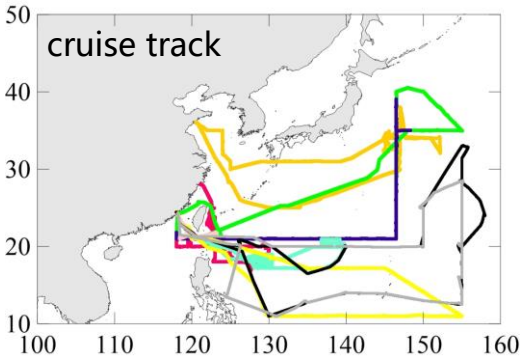


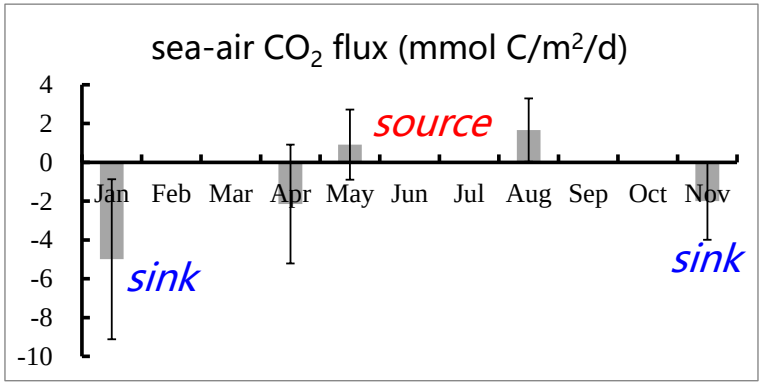
- **subtropical gyre:**
  summer – weak CO_2 source
  winter – weak CO_2 sink
  temperature control
- **kuroshio extension (KE):**
  strong CO_2 sink
  biological productivity control
- **mode water (MW):**
  CO_2 source in summer 2020
  CO_2 sink in summer 2022

CO_2 flux: seasonal variations



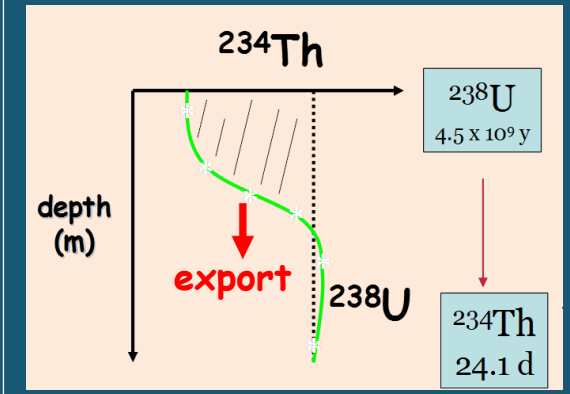






II. POC Export from the Euphotic Zone

led by Kuanbo Zhou

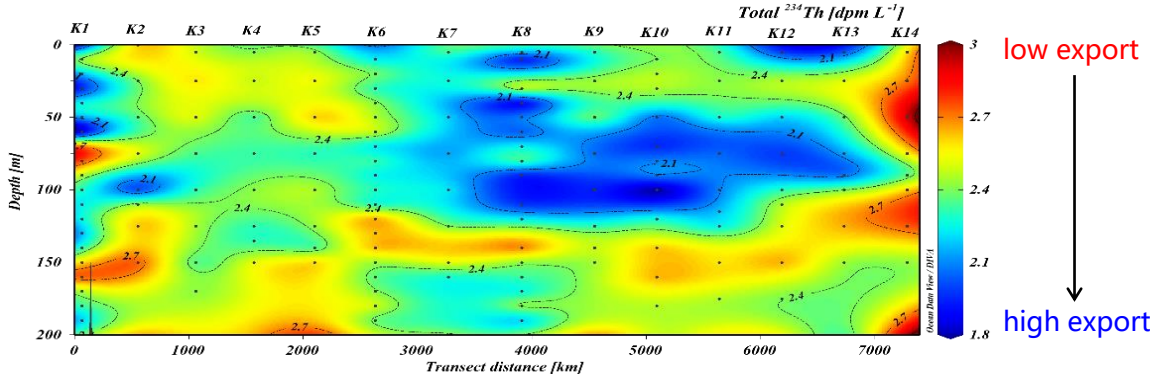


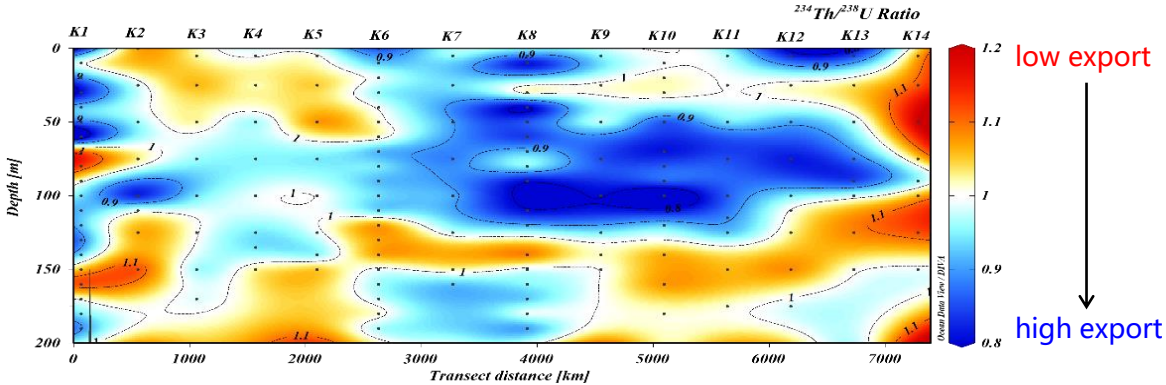
$$dTh/dt = \lambda_{Th} \cdot A_U - \lambda_{Th} \cdot A_{Th} - P_{234Th}$$

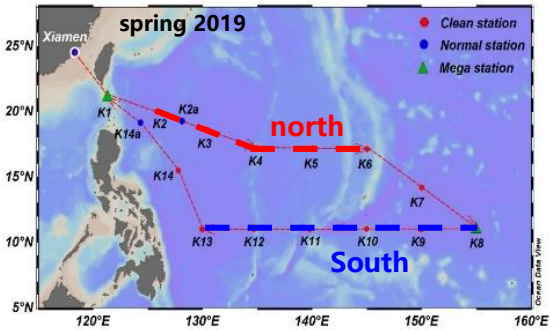
$$POC\ flux = P_{234Th} \cdot (POC/Th)$$

- dTh/dt: temporal variation of ^{234}Th
- A_U and A_{Th}: the activity of ^{238}U and ^{234}Th
- λ_{Th}: ^{234}Th decay constant (0.02876 d^{-1})
- P_{234Th}: the downward ^{234}Th flux (dpm m^{-2} d^{-1})

^{234}Th & $^{234}Th/^{238}U$ in the upper 200 m

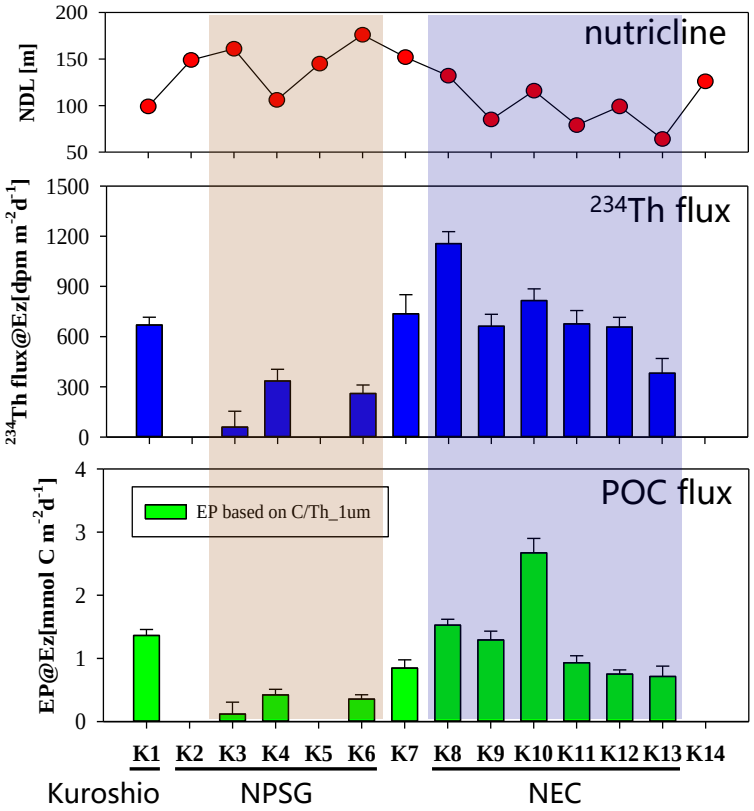


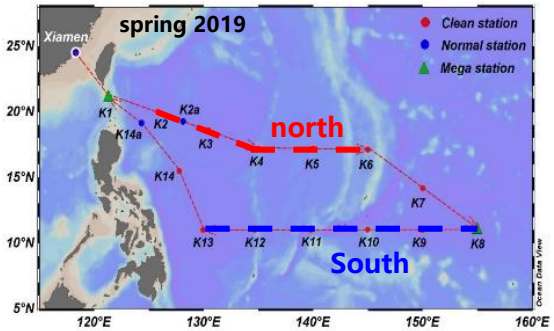




- **spatial variability:**
  north – low export
  south – high export

POC export from the euphotic zone



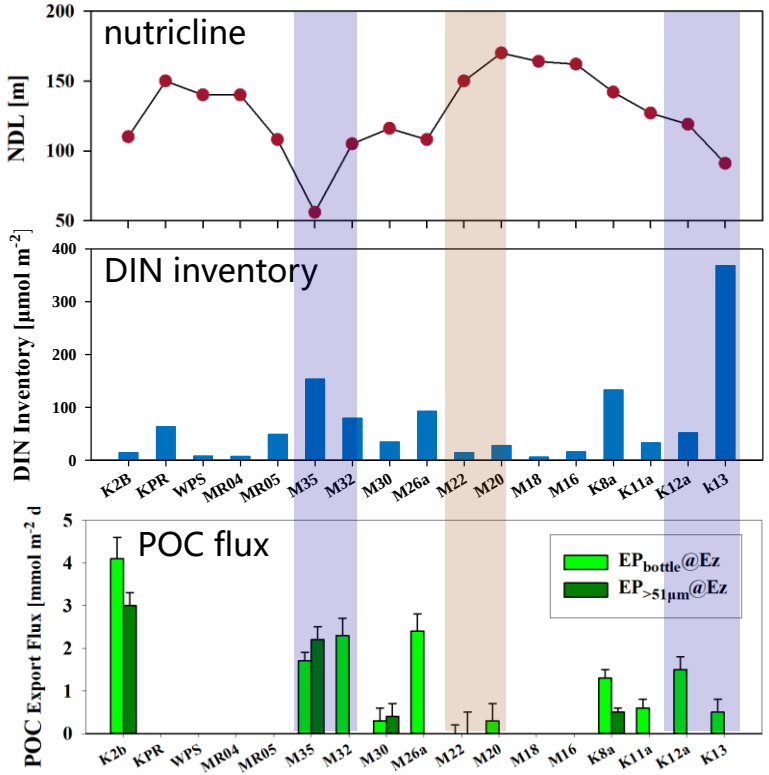


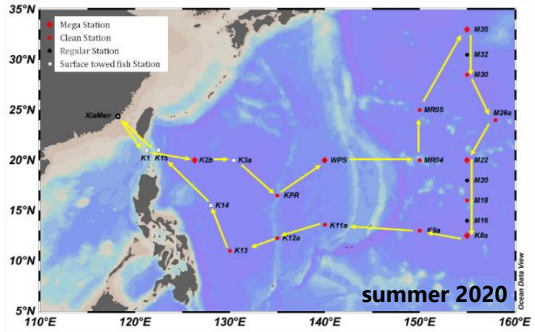
- **spatial variability:**

  north – deep nutricline, low export

  south – shallow nutricline, high export

POC export from the euphotic zone

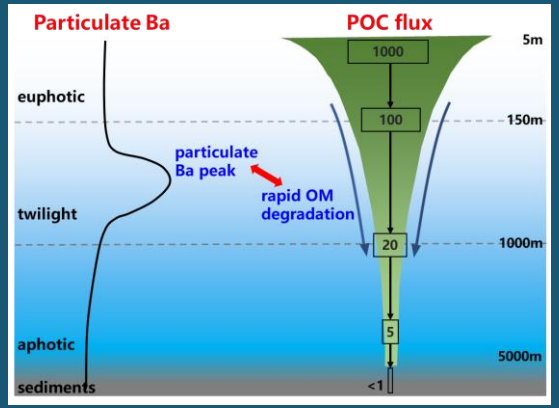


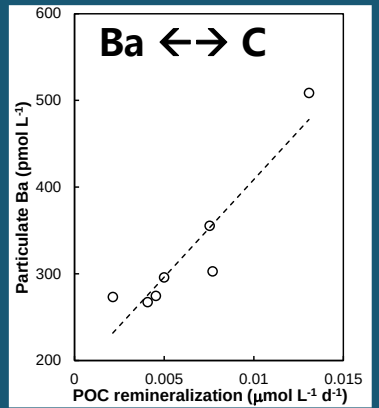


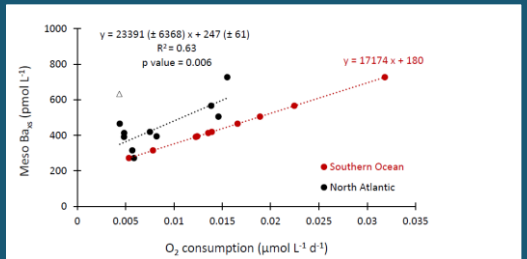
- upward nutrient flux modulates downward POC flux

III. OM Remineralization in the Twilight Zone

led by Zhimian Cao



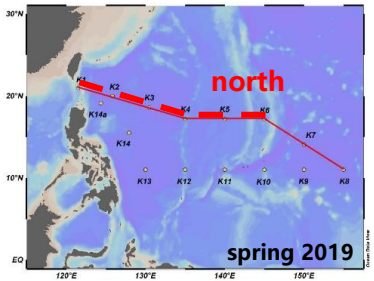


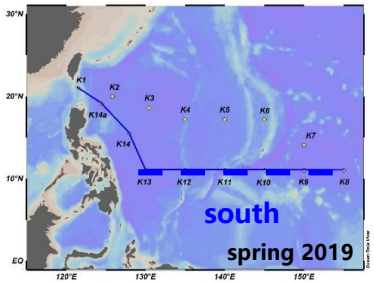


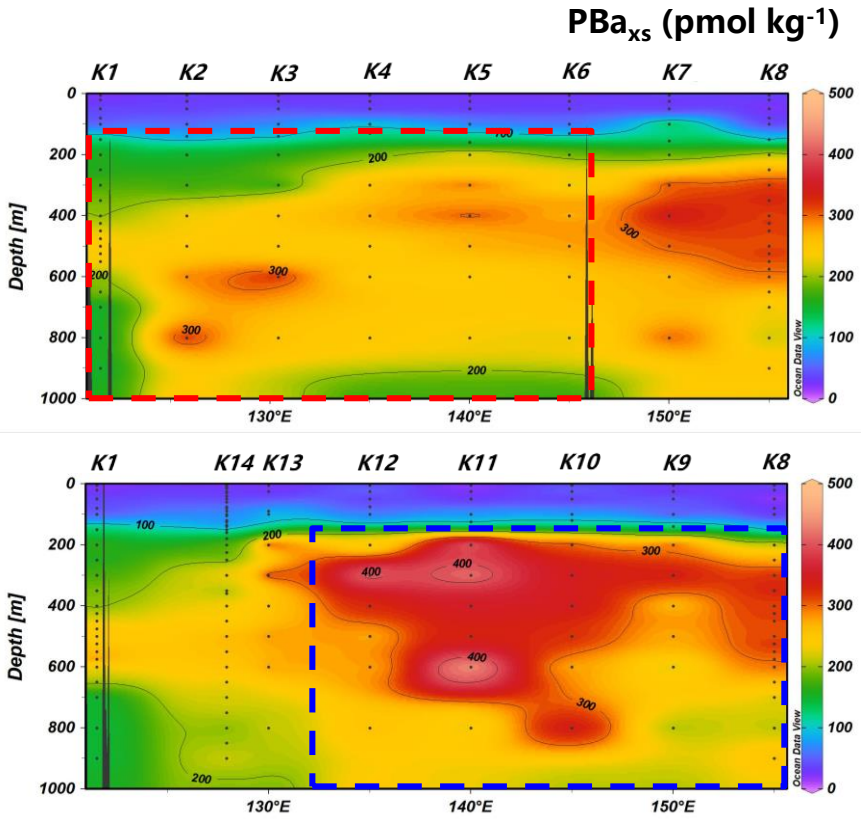
$$OUR = \frac{[PBa_{xs}] - Intercept}{Slope}$$

$$OC\ remineralization = Z \times OUR \times (C{:}O_2)_{RR}$$

Particulate Ba above the twilight zone

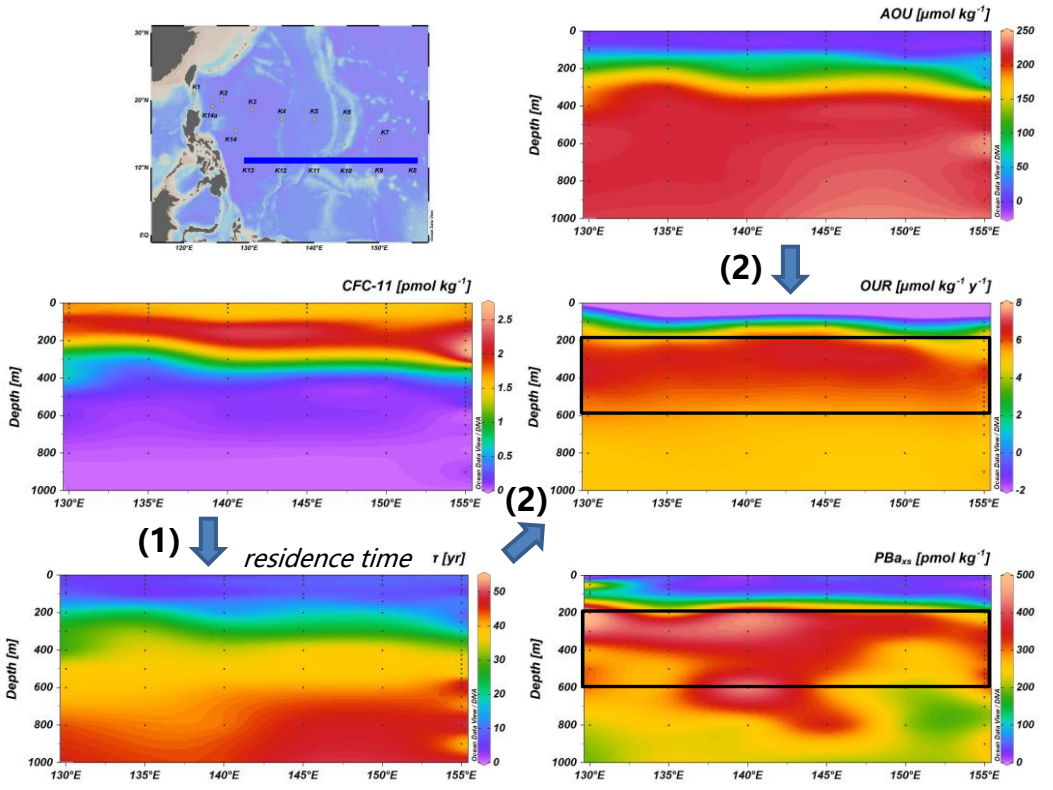


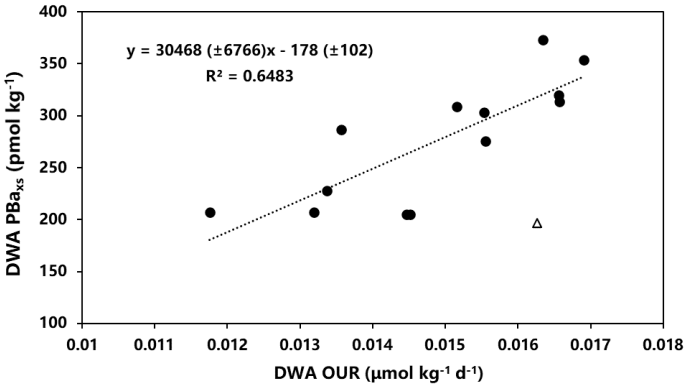




- PBa high conc. values center on 200-600 m in the twilight zone
- PBa conc. are overall higher in the south than in the north (i.e., NEC > NPSG)

Calibration between PBa and OUR



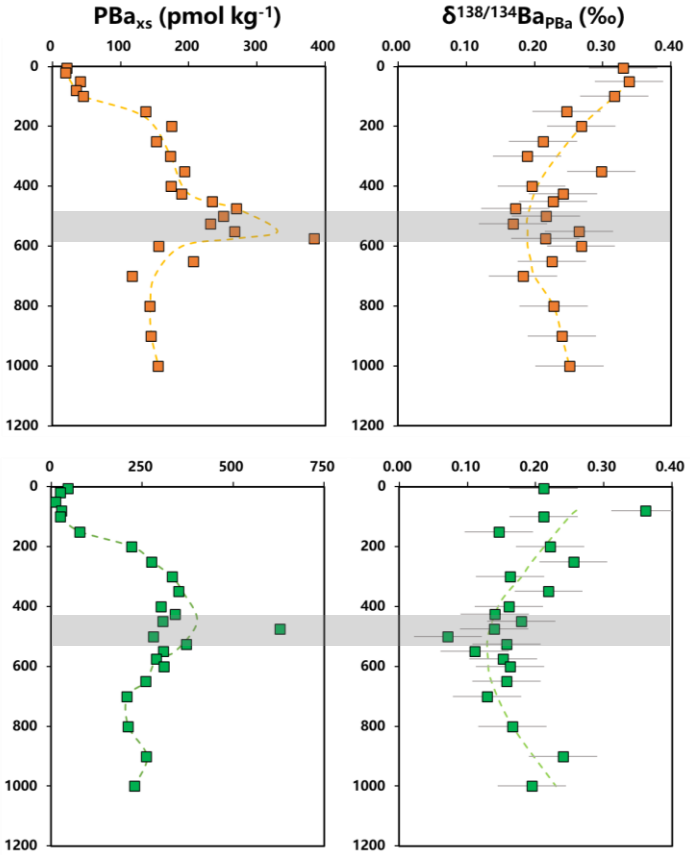


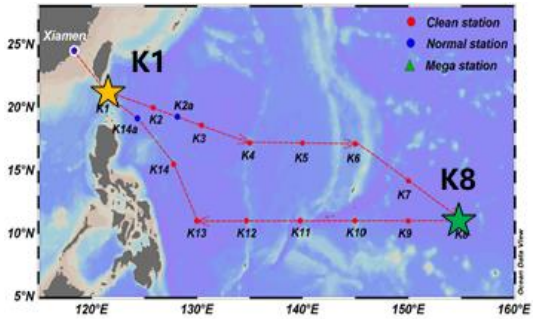
OM remineralization in the twilight zone

Area	Depth (m)	OM remineralization (mmol C m^{-2} d^{-1})	Method	Reference
north	150-600	4.3±0.4	OUR_{PBaxs}	this study
south	150-600	5.4±0.4	OUR_{PBaxs}	this study
20°N, 150°W	125-500	7.9±1.4	OUR_{path}	Sonnerup et al., 2013
20°-30°N, 152°W	250-500	3.0±0.3	OUR_{model}	Sonnerup et al., 1999

- **OM remineralization:** 4.0-5.9 mmol C m^{-2} d^{-1}, comparable to the eastern NPSG
- **south > north:** consistent with the spatial distribution pattern of POC export

Response from stable Ba isotopes





- PBa concentration maximum corresponds to PBa isotope minimum around 500 m
- Ba isotopes have potentials to be a new proxy of OC export and remineralization

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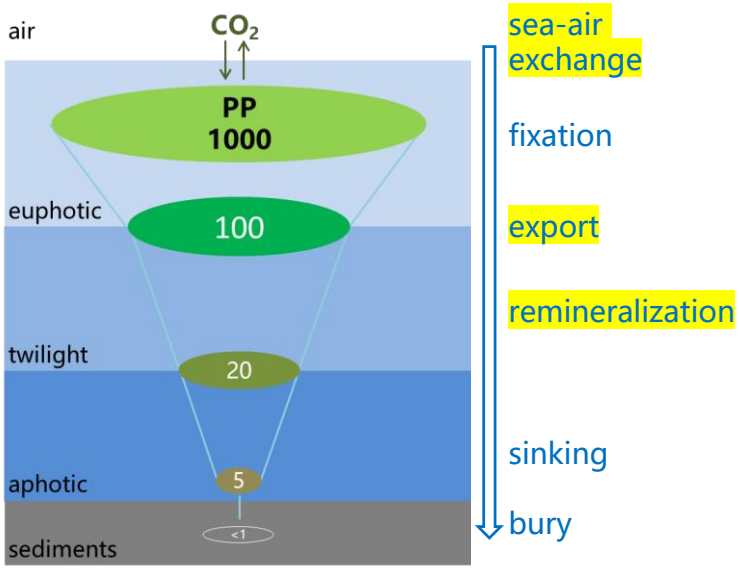
Conclusions: C dynamics in the upper ocean

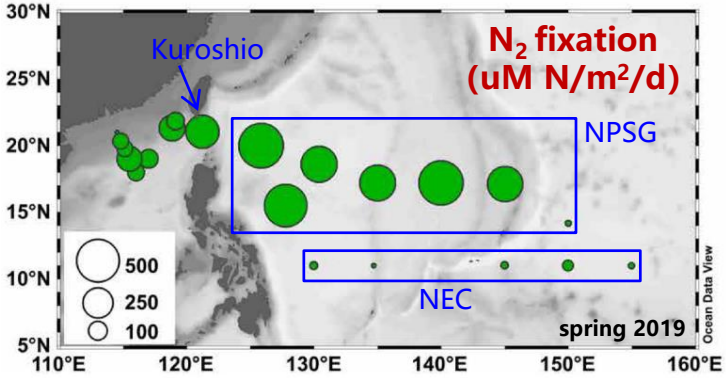


(Neuer et al., 2014; numbers denote carbon flux proportion)

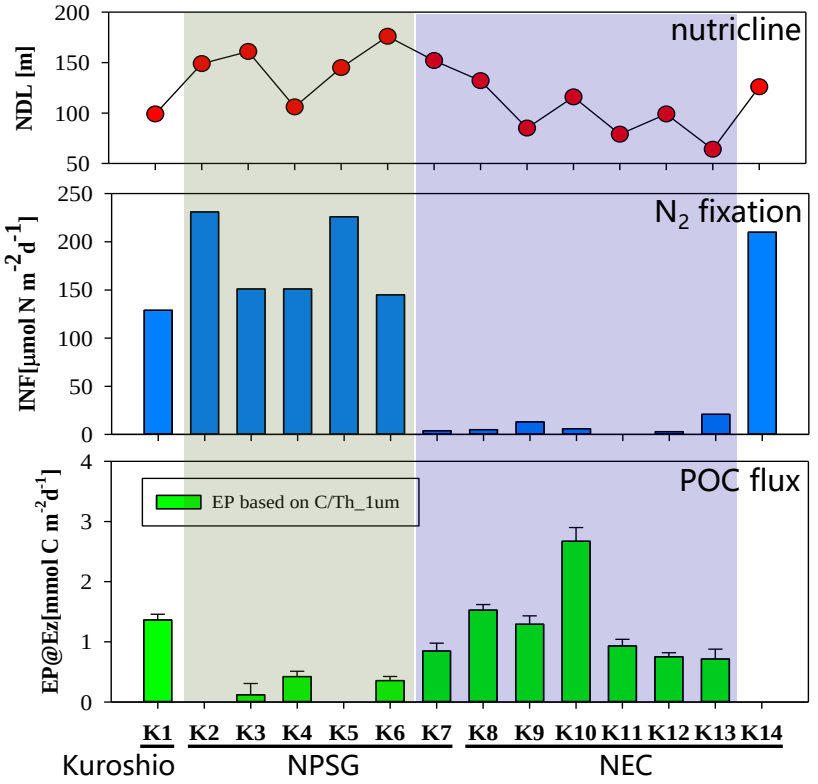
in the subtropical NW Pacific

- CO_2 flux: an import carbon sink annually but notable spatial and seasonal variability
- POC export: spatial variability with NEC > NPSG
- OM remineralization: Ba proxy; NEC > NPSG

Implication: C-N coupling/decoupling



(Wen et al., 2022)



- **N_2 fixation stimulates POC export ?**

  yes at ALOHA in the eastern NPSG

  not exactly in the western NPSG

R/V *Tan Kah Kee*
Xiamen University

Thanks for Listening !