Export (new) production in N-depleted extratropical oceans:

Implications of N_2 fixation

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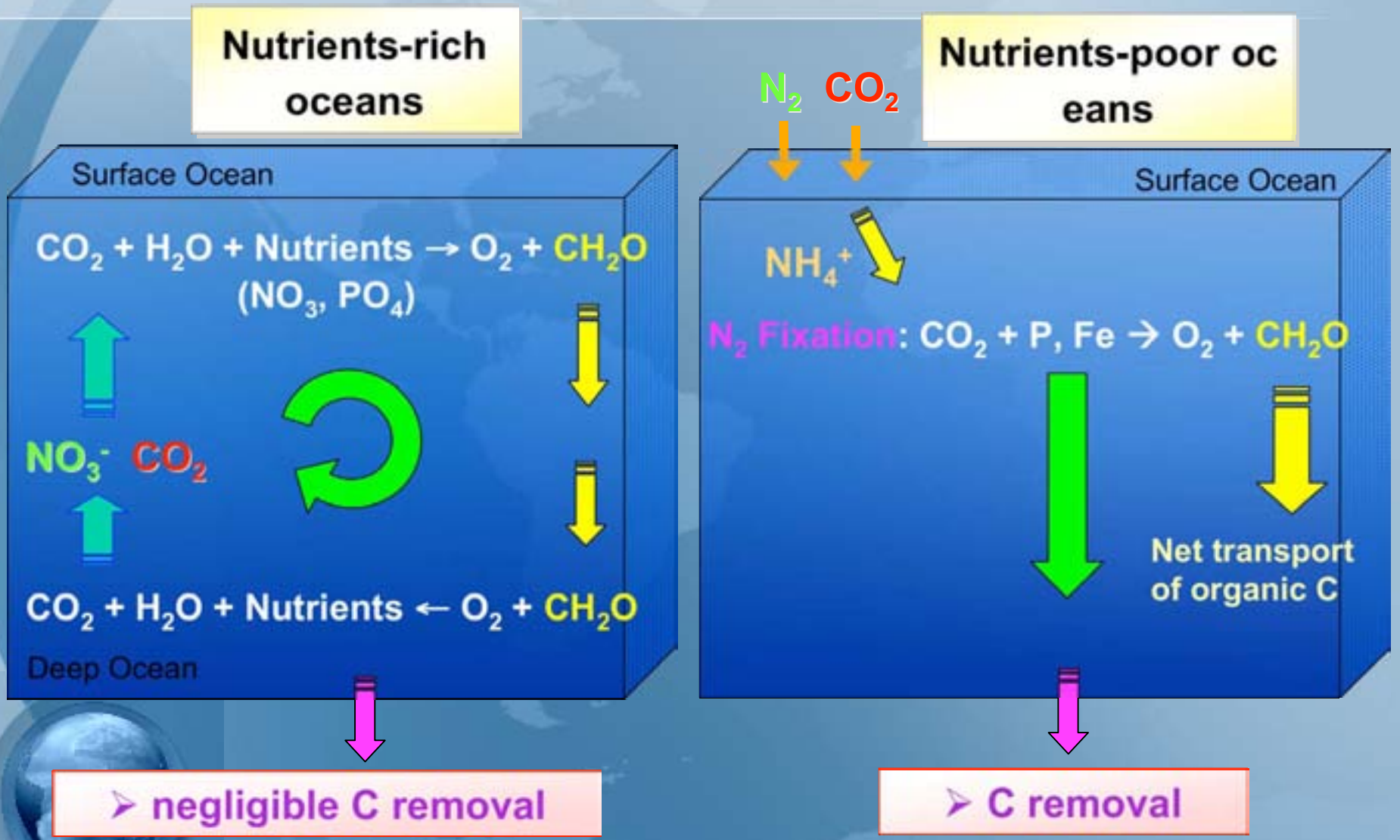
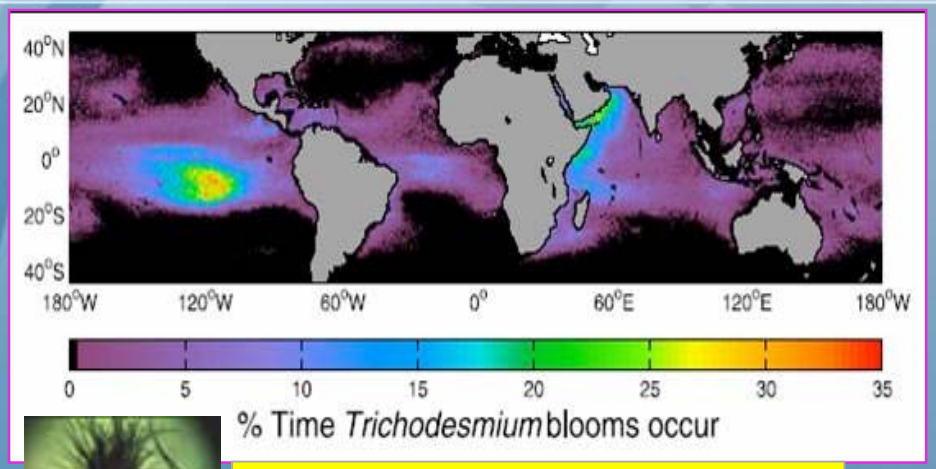
Biological pumps



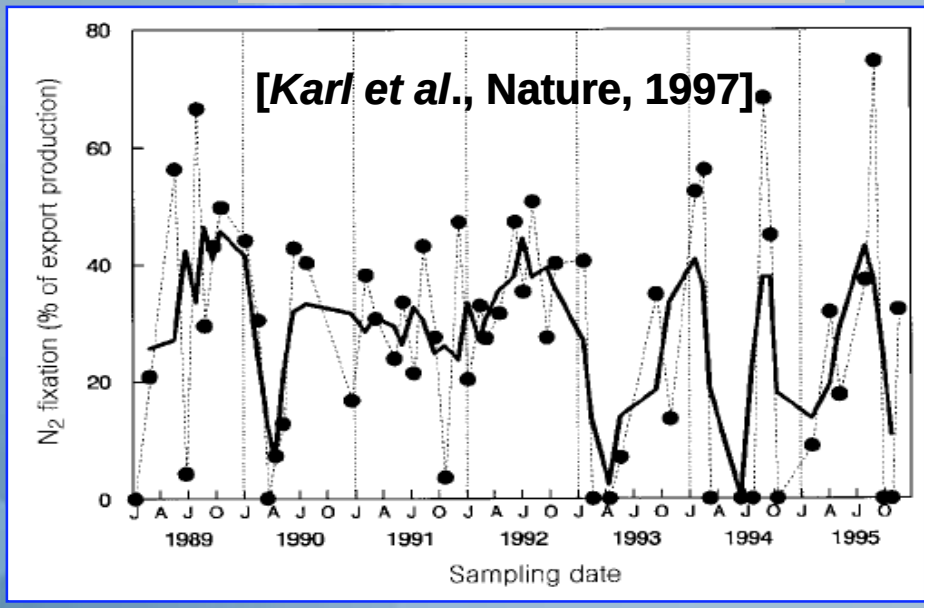
Marine N_2 fixation



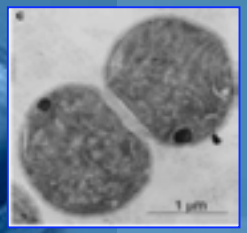
- ❖ no detectable nitrate
- ❖ >25°C

[*Westberry & Siegel*., GBC, 2006]

N_2 fixation at HOT



- ♦ 20–40% of the total export production

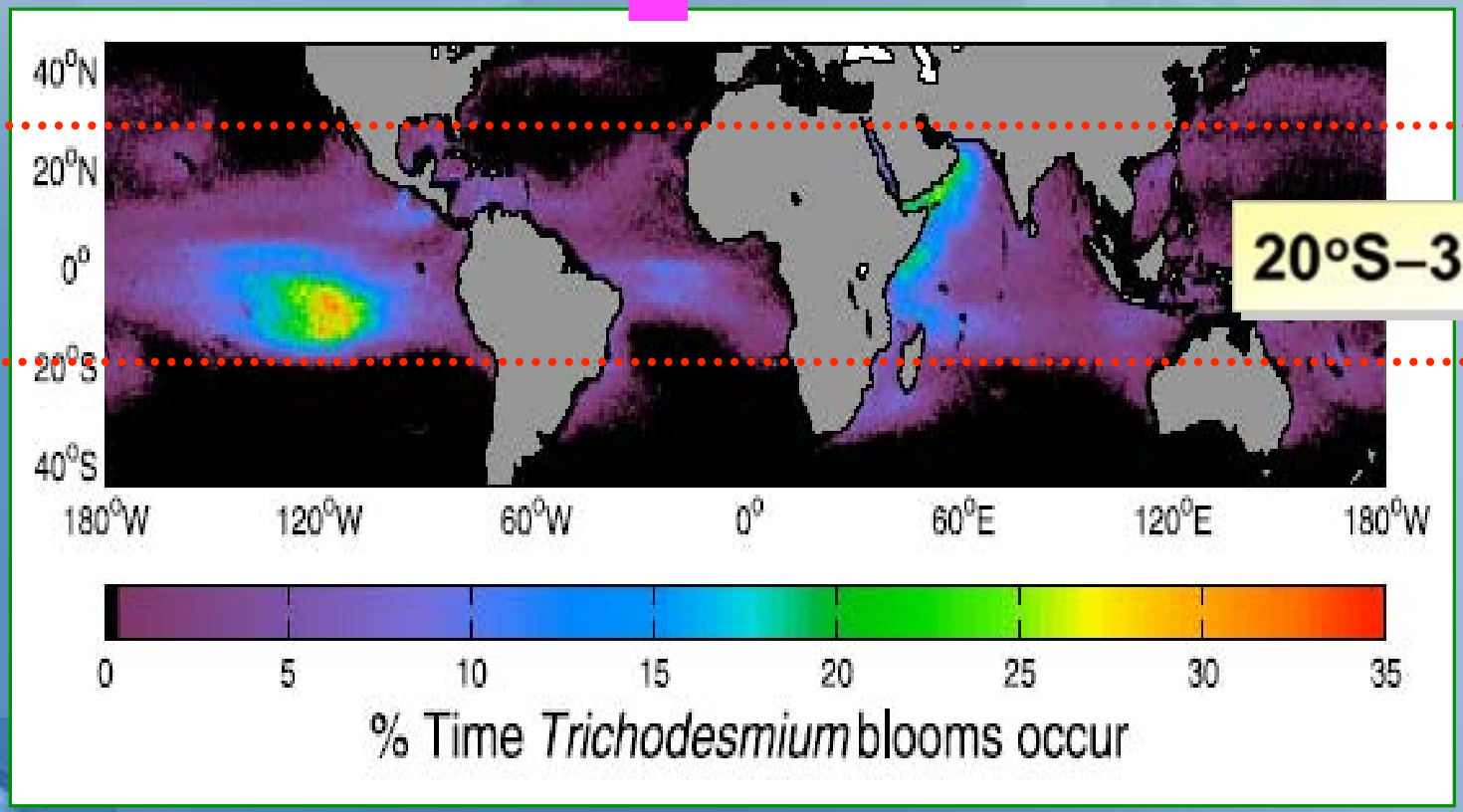


Other unicellular cyanobacteria (*Synechocystis* sp.)

"Increase of an importance of unicellular cyanobacteria that are expressing nitrogenase" [*Zehr et al.*, Nature, 2001]

What about N_2 fixation in extratropical oceans?

in the eastern N. Atlantic (46°N)

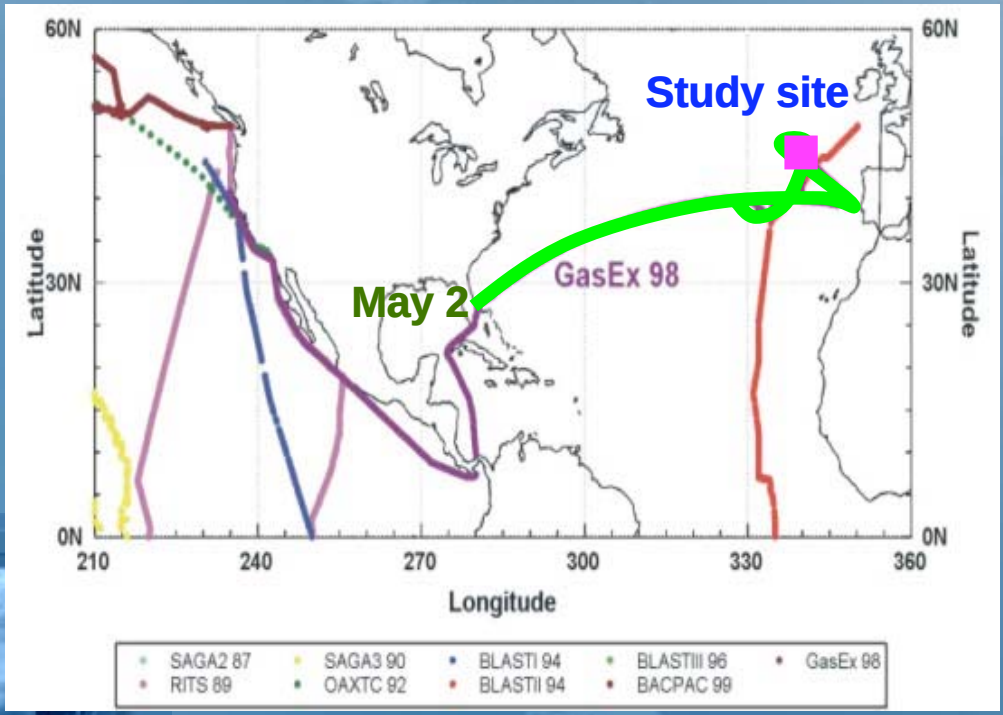


[*Westberry & Siegel*., GBC, 2006]

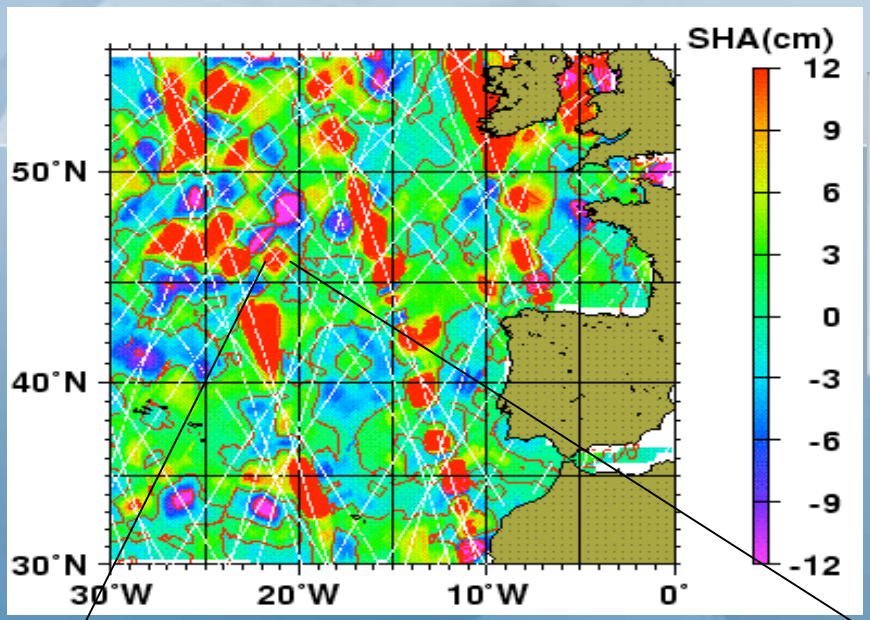
Gas Exchange Experiment in 1998 (Gas Ex-98 Cruise)

- **Goal:**

¢°To measure the exchange rate of CO_2 at the air-sea interface using multidisciplinary approaches



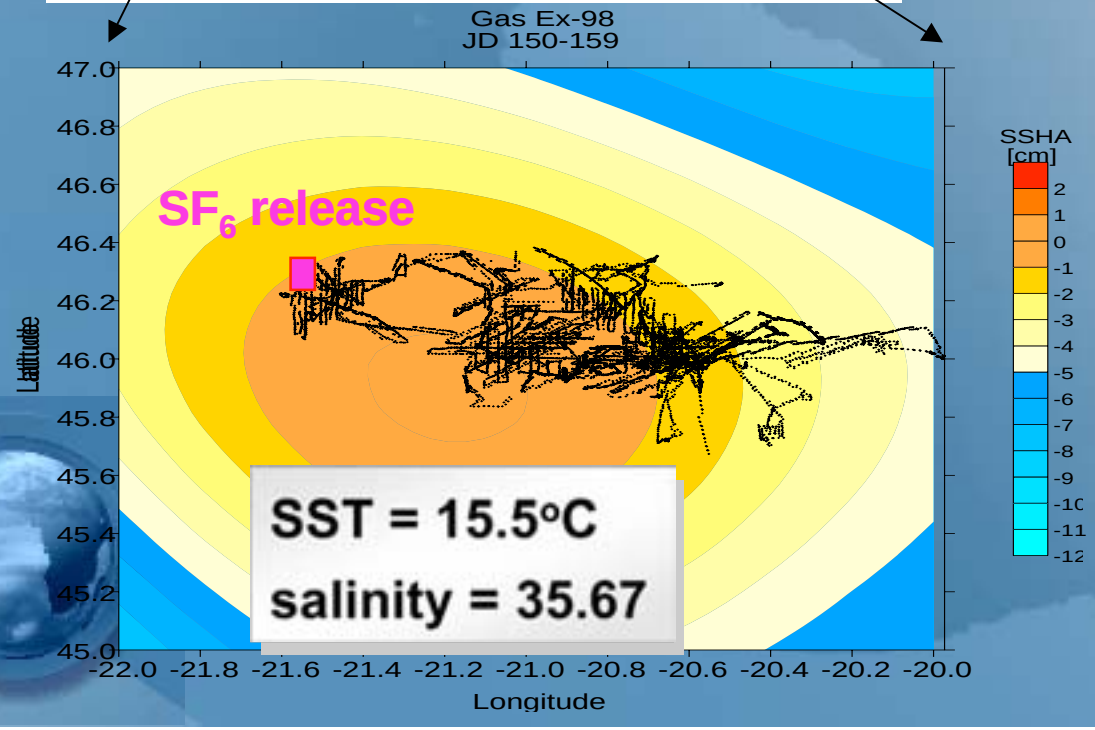
Cruise track Gas Ex-98



- Cruise period:

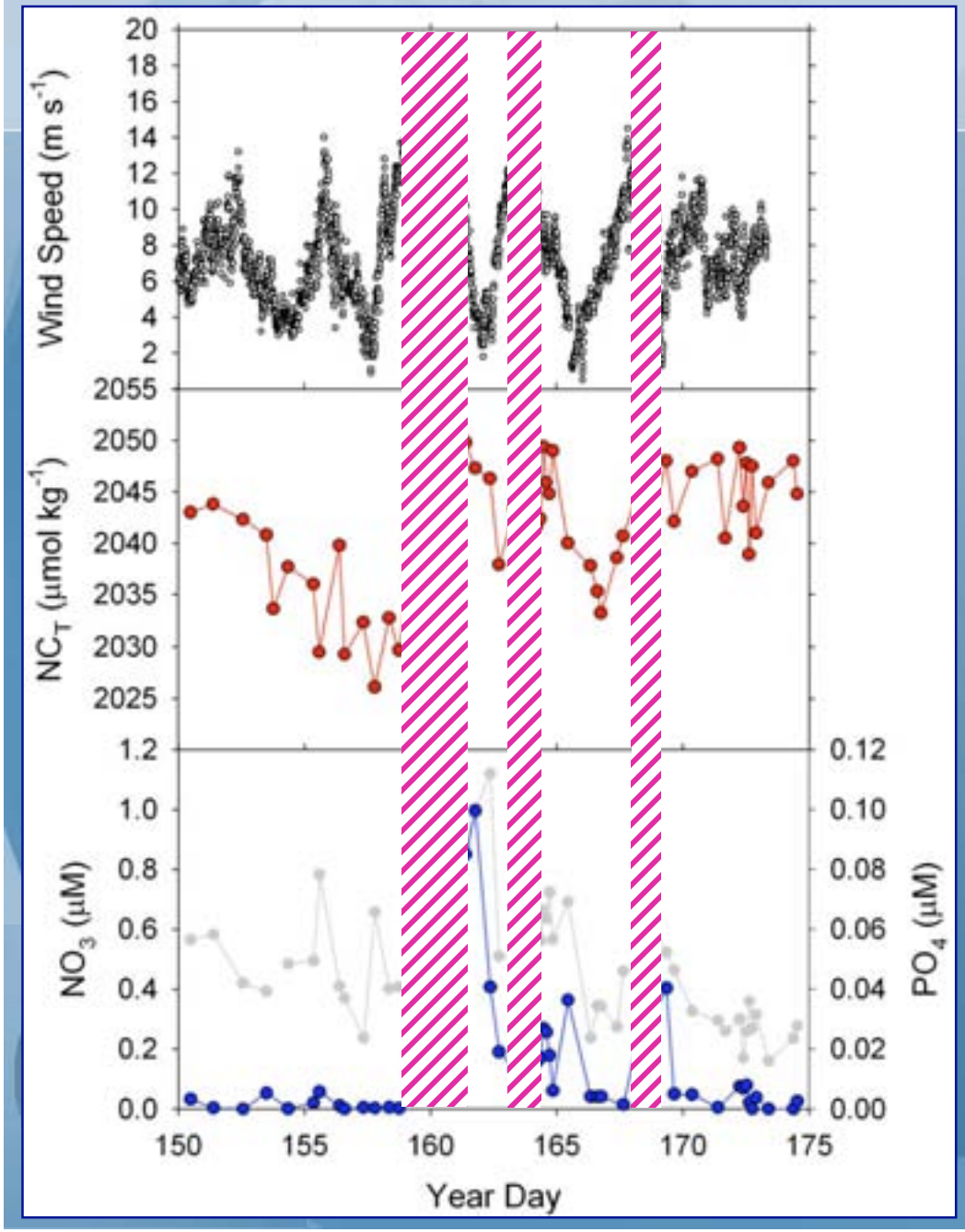
May 25 – July 26, 1998

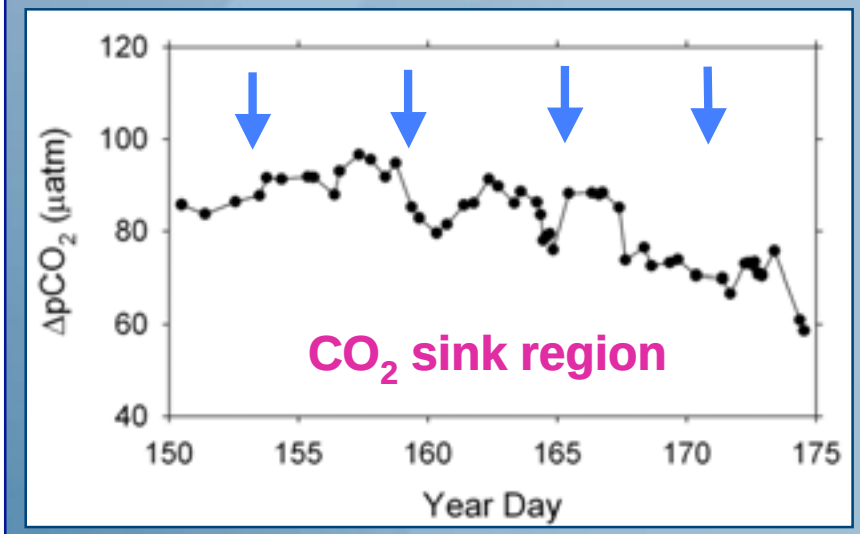
(after the spring bloom)



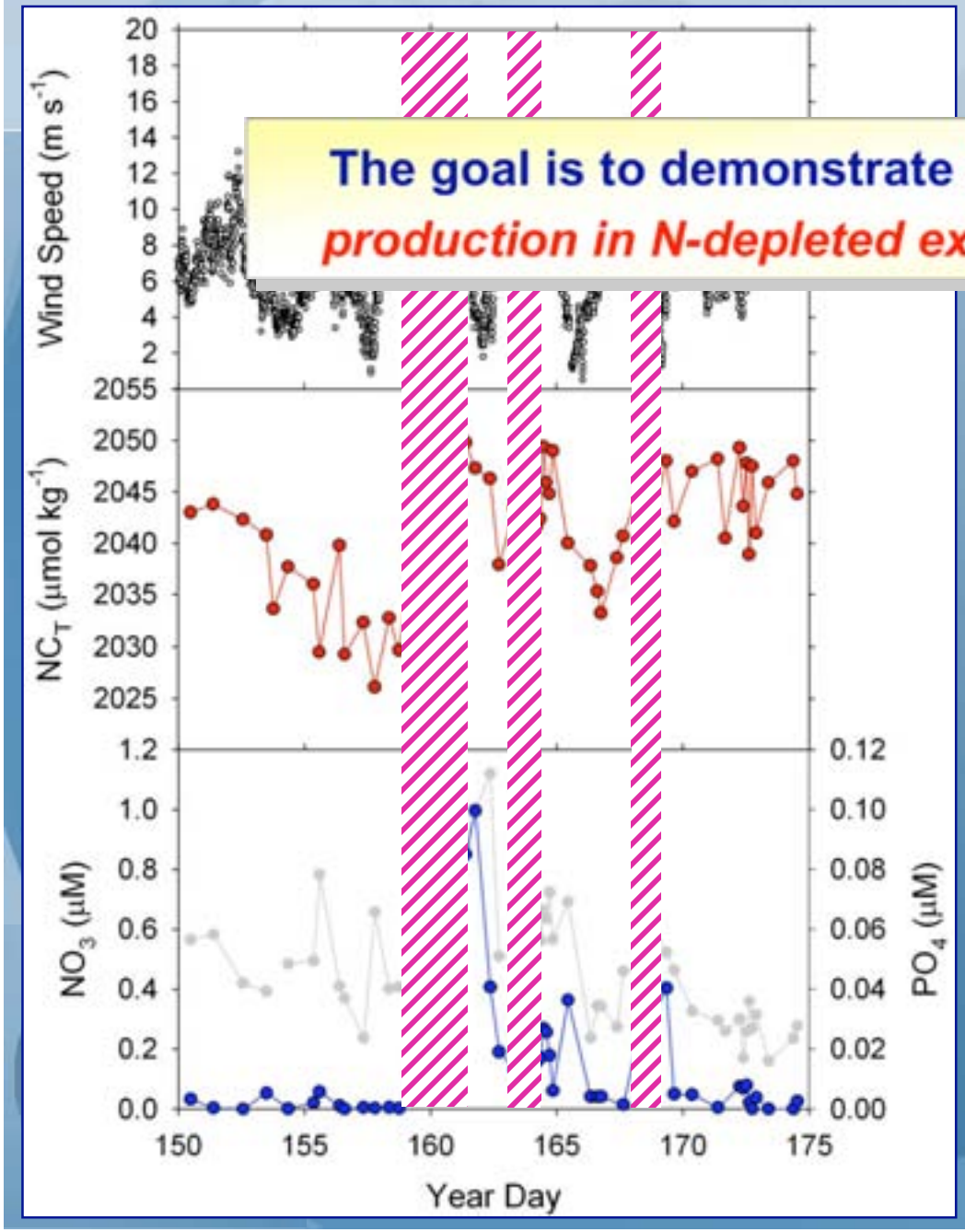
The SF_6 remained in the warm core eddy

Some key measurements during Gas Ex-98

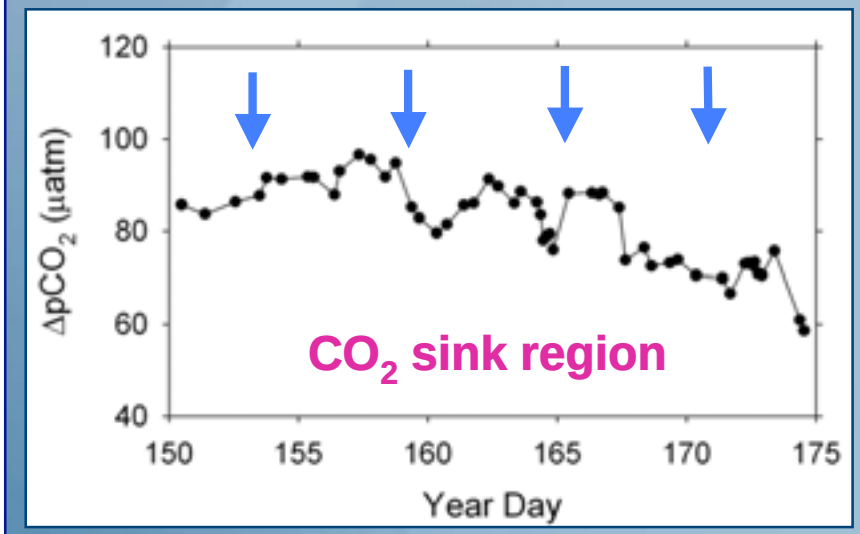




Some key measurements during Gas Ex-98

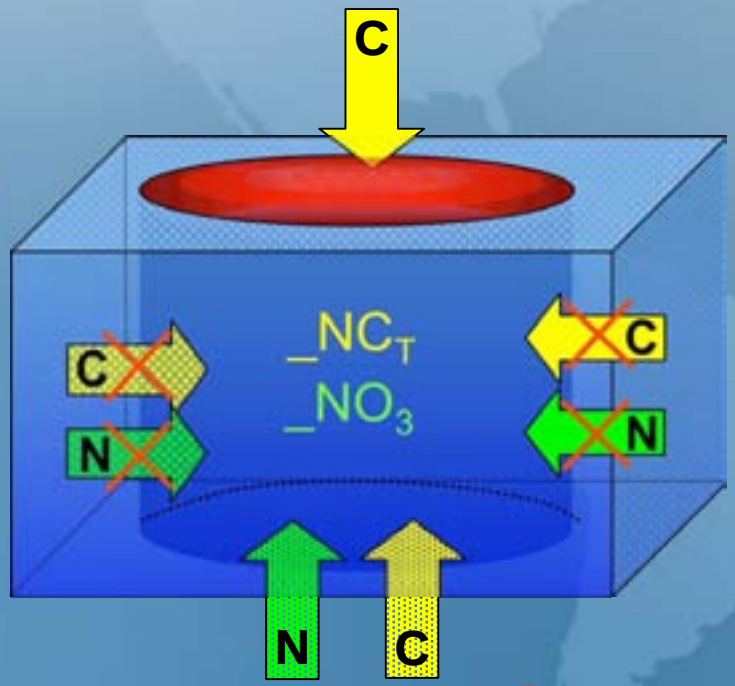


The goal is to demonstrate *"the importance of export production in N-depleted extratropical oceans (46°N)"*



Estimations of N, C-based export production

Net air-sea CO_2 flux ($F_{air\text{-}sea} = k\,\Delta pCO_2$)



Diffusion (K_V)

Advection (W)

Lateral exchange is negligible

- **N-based export production**

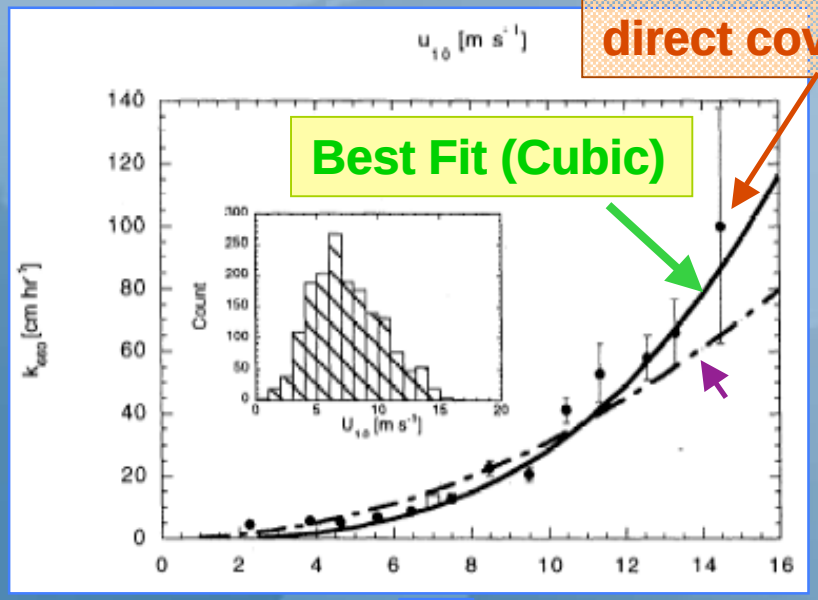
$$= \bullet\!\!\int NO_3 + K_V(dNO_3/dz) + W$$

- **C-based export production**

$$= \bullet\!\!\int NC_T + F_{air\text{-}sea} + K_V(dC_T/dz) + W$$

1. Gas exchange rate (*k*)

➢Using the dual-deliberate tracers, ^3He and SF_6



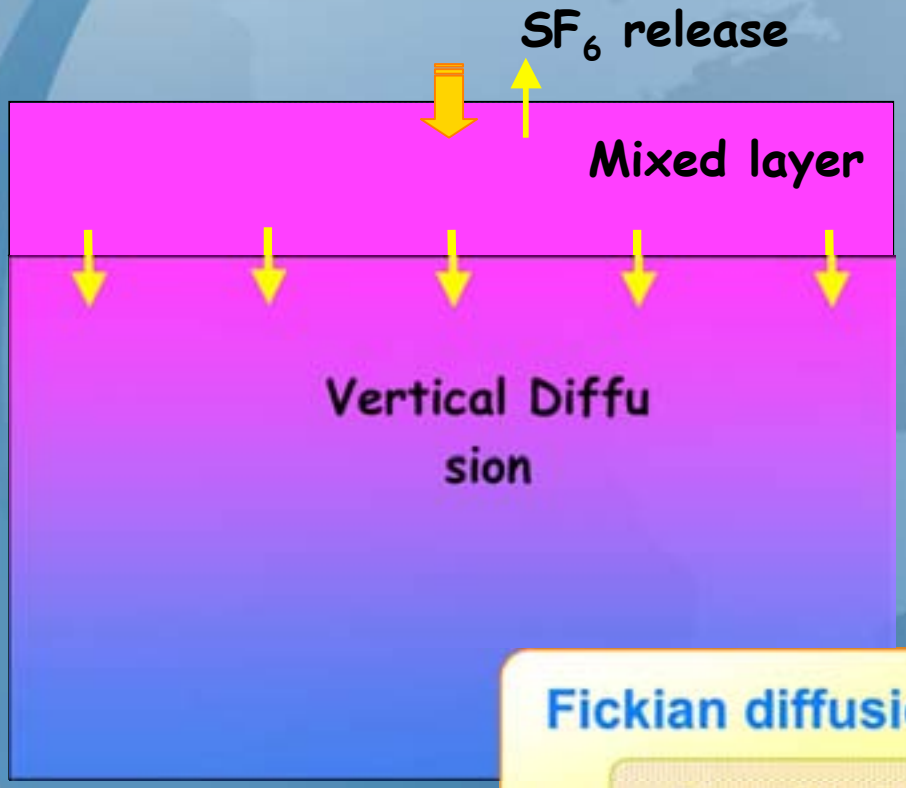
Steady/short term wind

- $k = 0.0283\ WS^3\ (Sc/660)^{-1/2}$

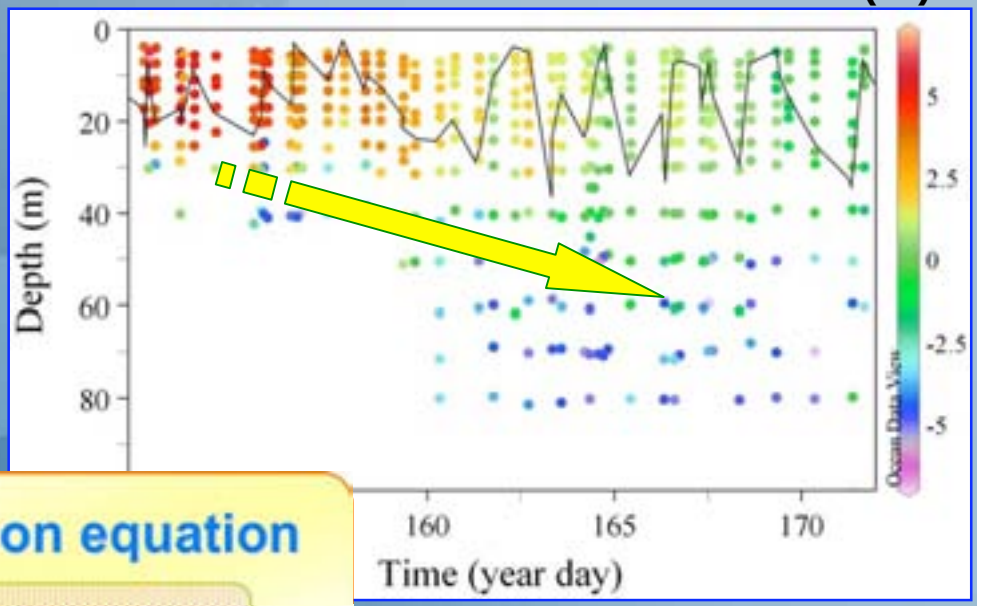
(*Sc*: Schmidt number)

[*Wanninkhof & McGillis*., 1999; *McGillis et al*., 2001]

2. Vertical Diffusivity (K_v)



Vertical distribution of [SF_6]



Fickian diffusion equation

$$F_s = K_v (dSF_6/dZ)$$

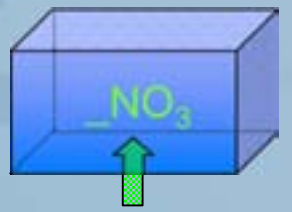
Obtained K_v = 0.3 cm^2 s^{-1}

[*Kim et al.*, JGR, 2005]

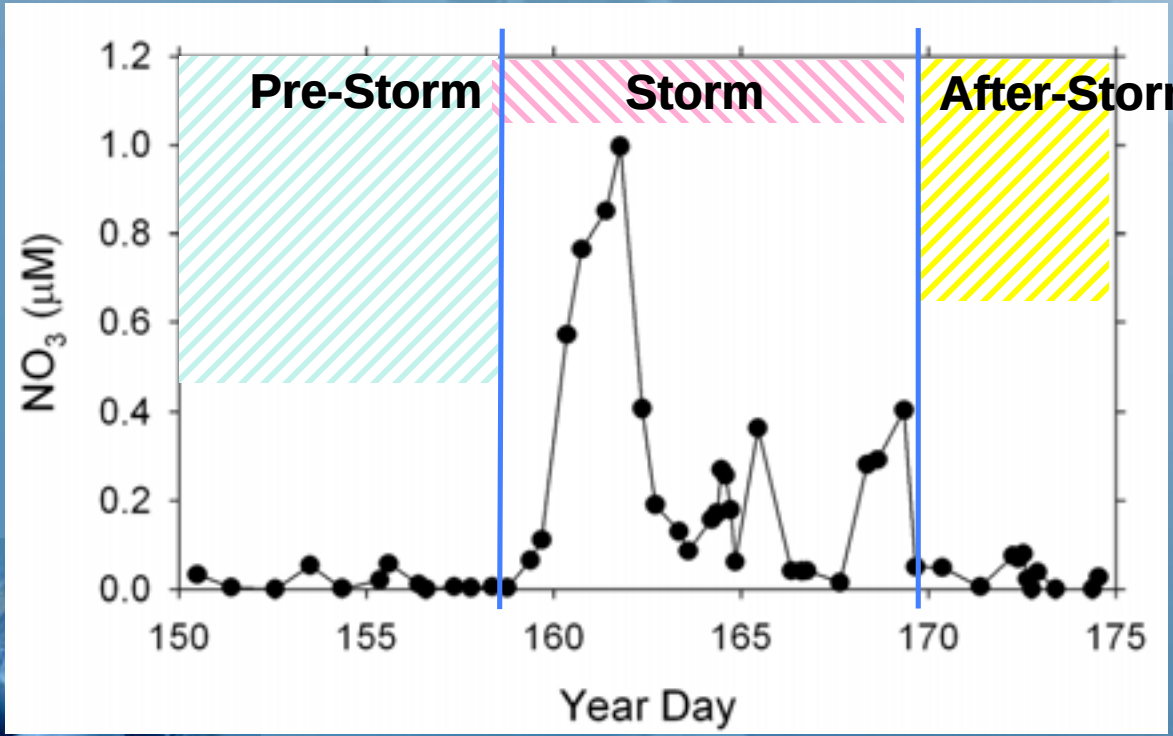
N-based export production

- **N-based export production**

  $= [\bullet K_V NO_3 + K_V(dNO_3/dz)] \times (C/N = 7)$



Diffusive flux of N



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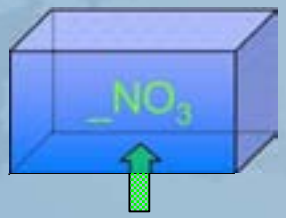

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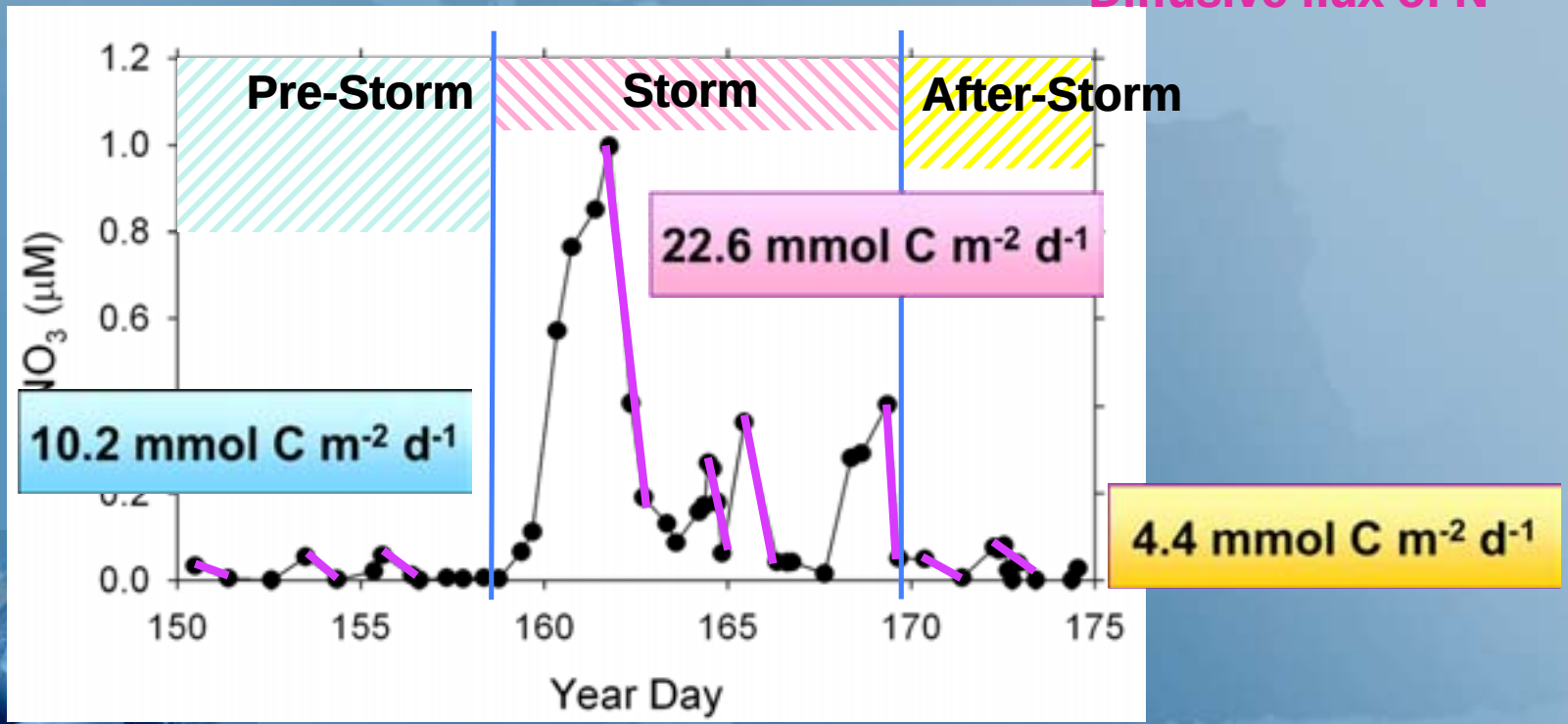

C-based export production

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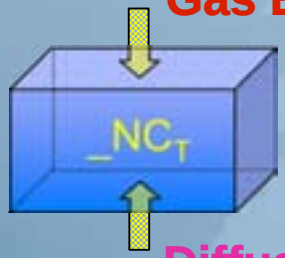
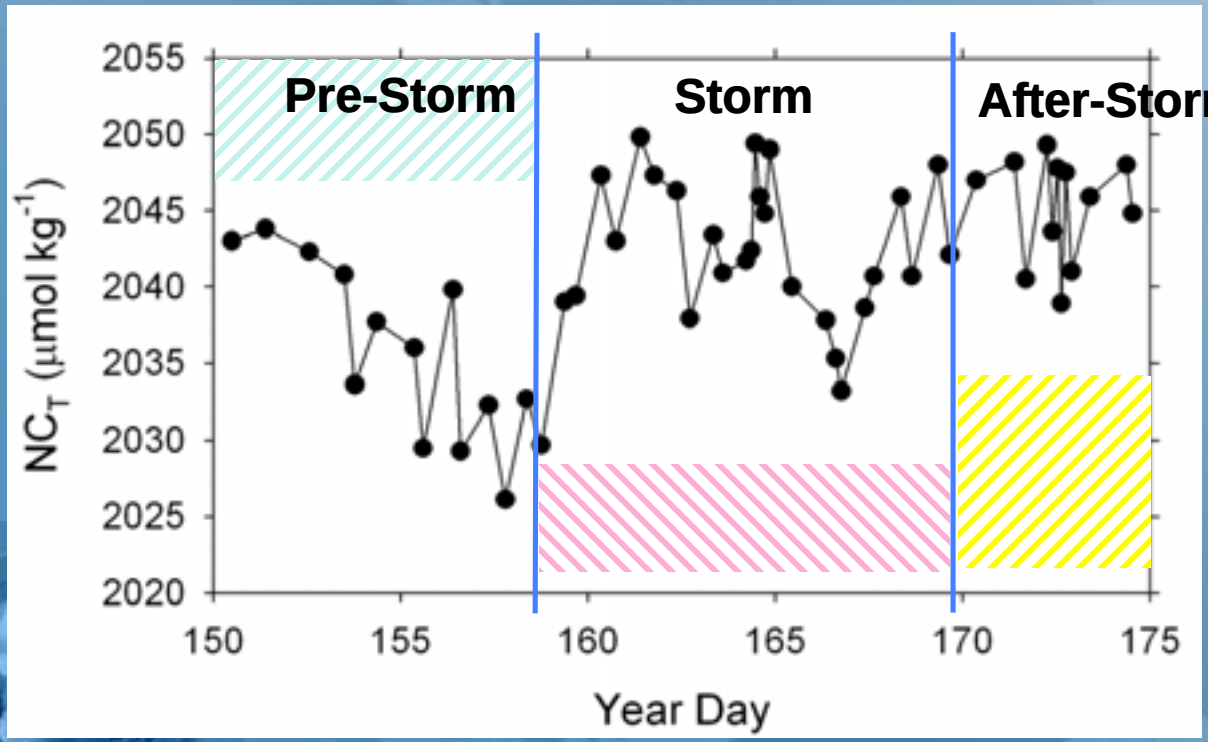
$$= \bullet \int NC_T + F_{air\text{-}sea} + K_V(dC_T/dz)$$





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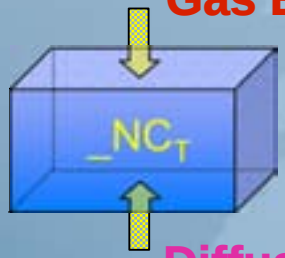

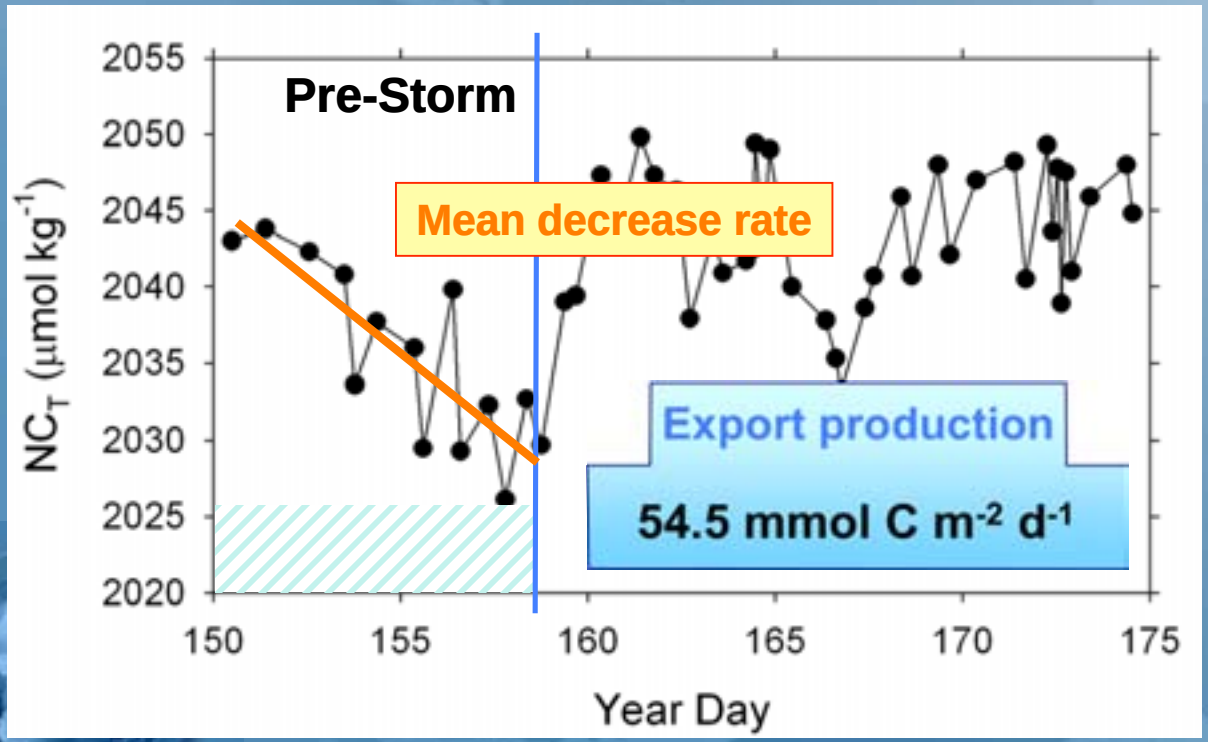

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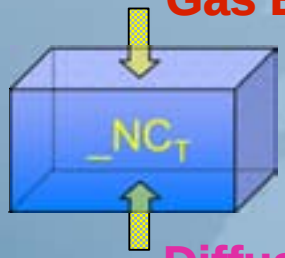

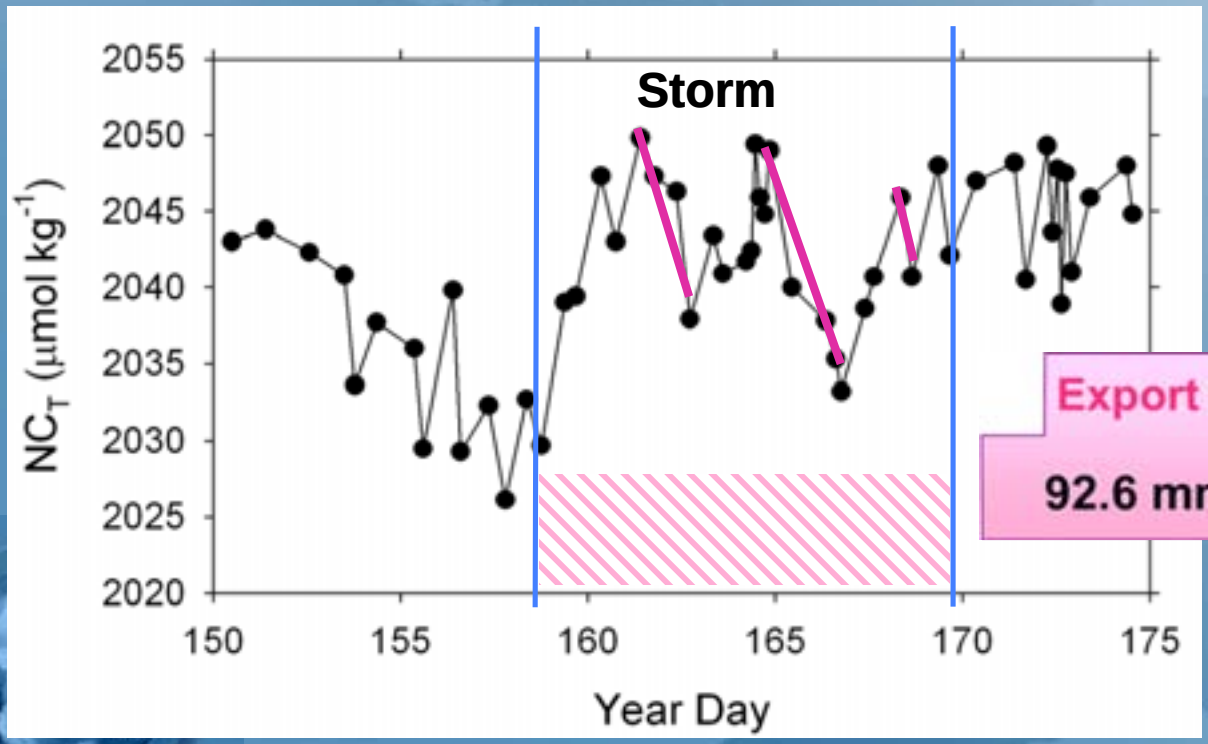

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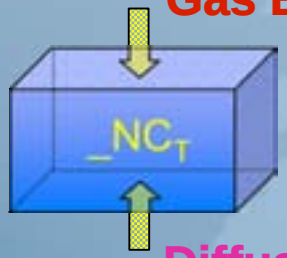
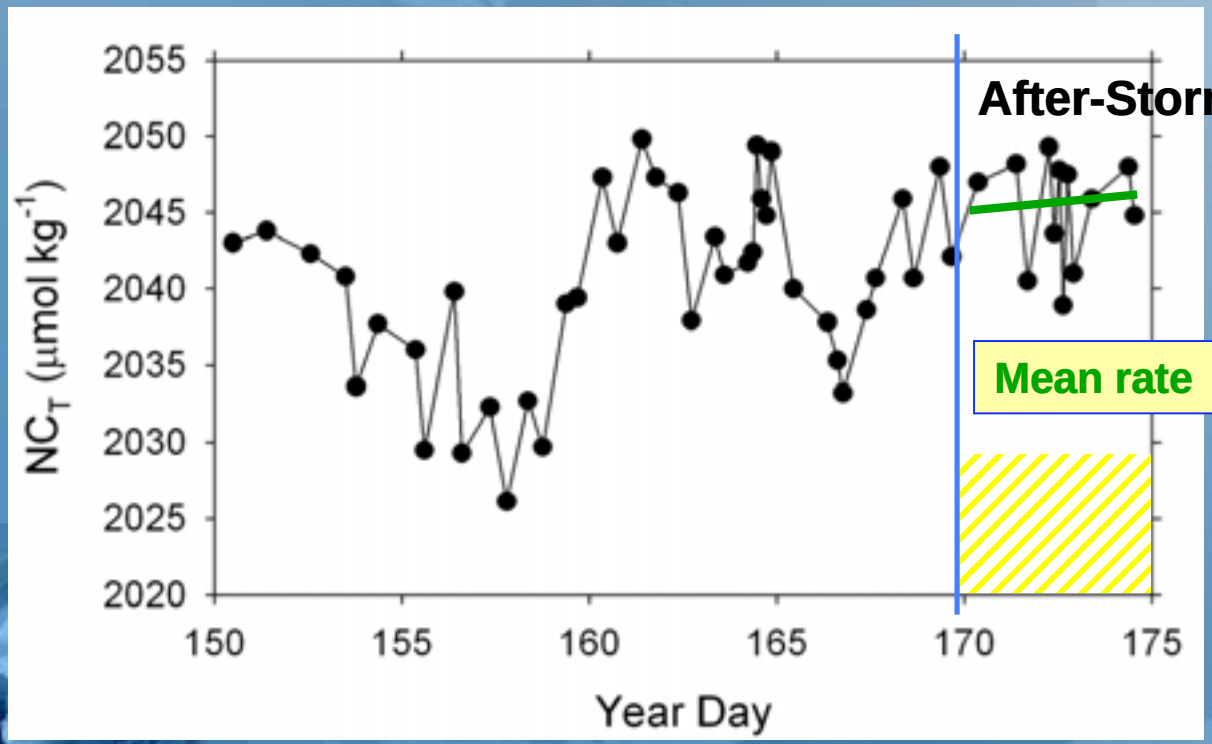
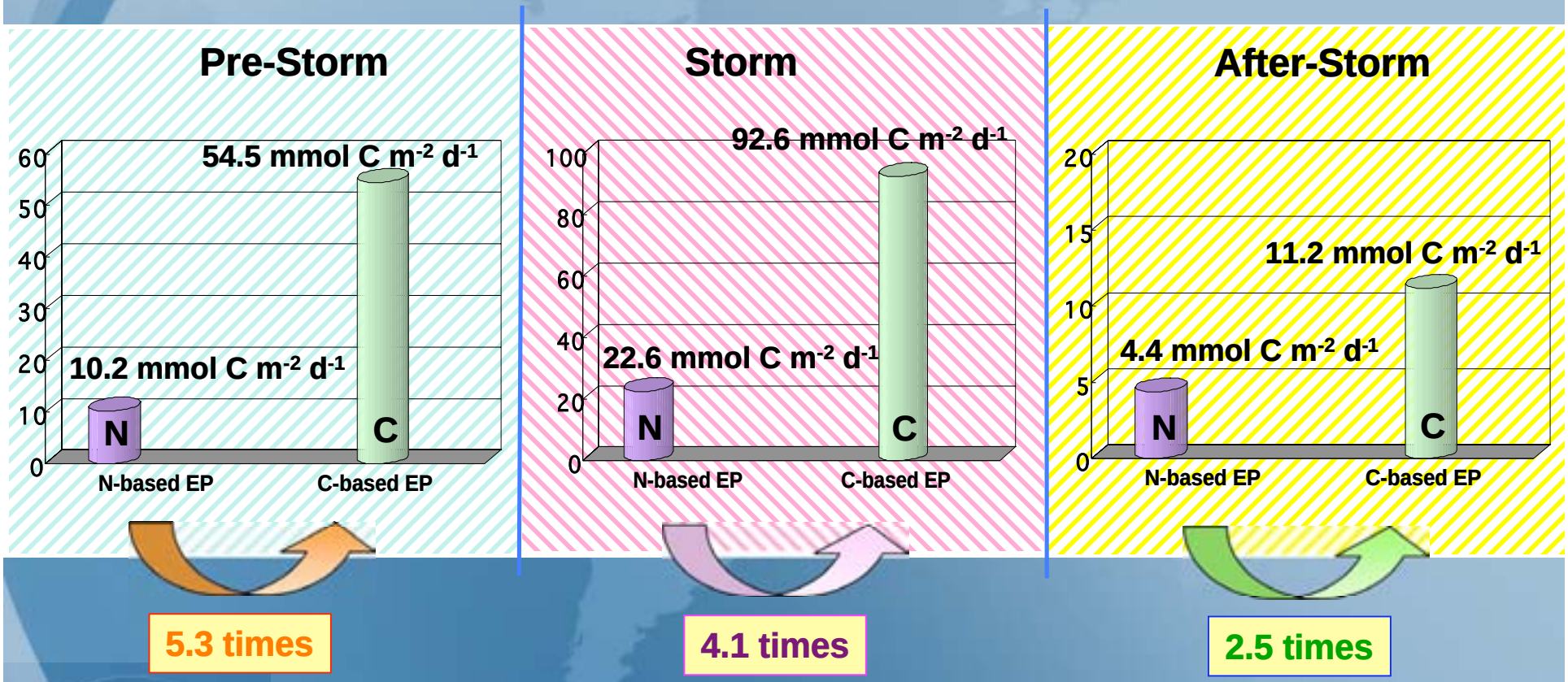




Export production

11.2 mmol C m^{-2} d^{-1}

Comparison between N and C-based export production estimates



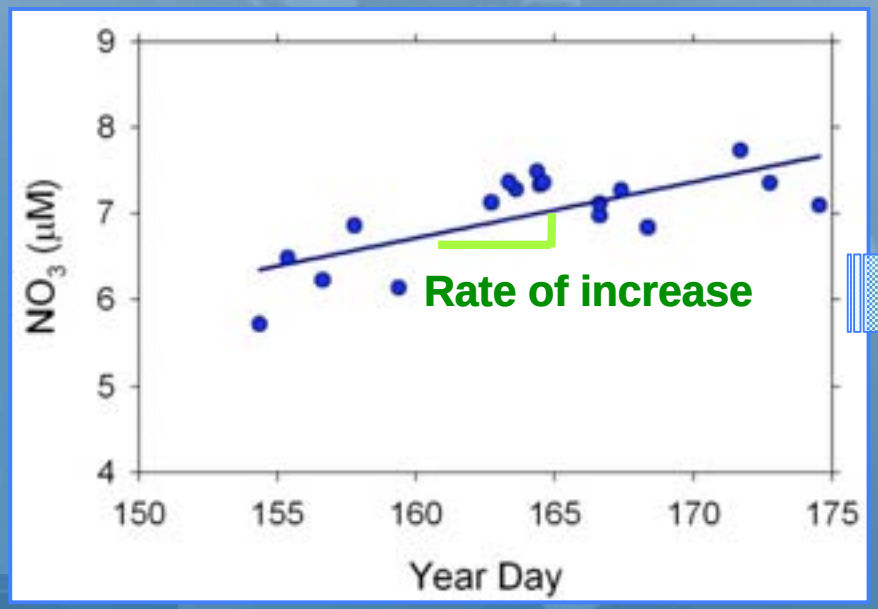
- Large differences (3–5 times) in two production estimates

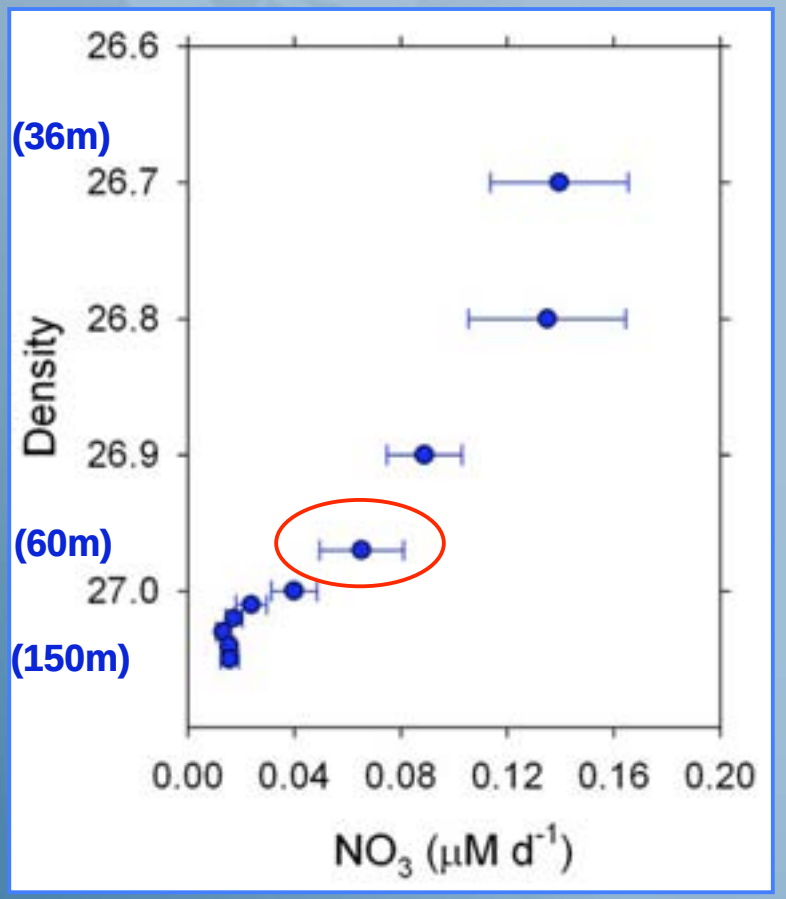
What causes these differences?

Evidence: N_2 fixation-supported export production

Rates of increase in N on isopycnal surfaces

σ_θ = 26.97

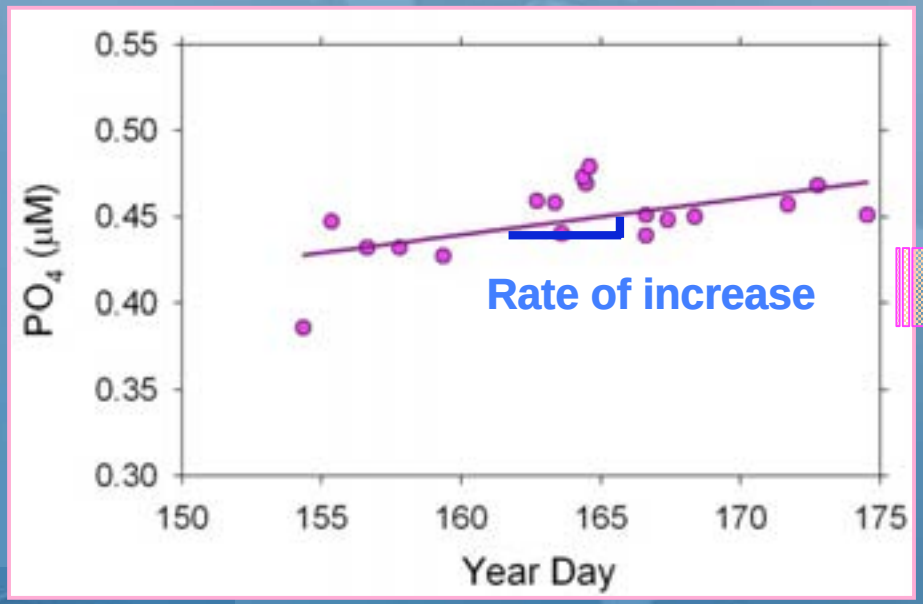


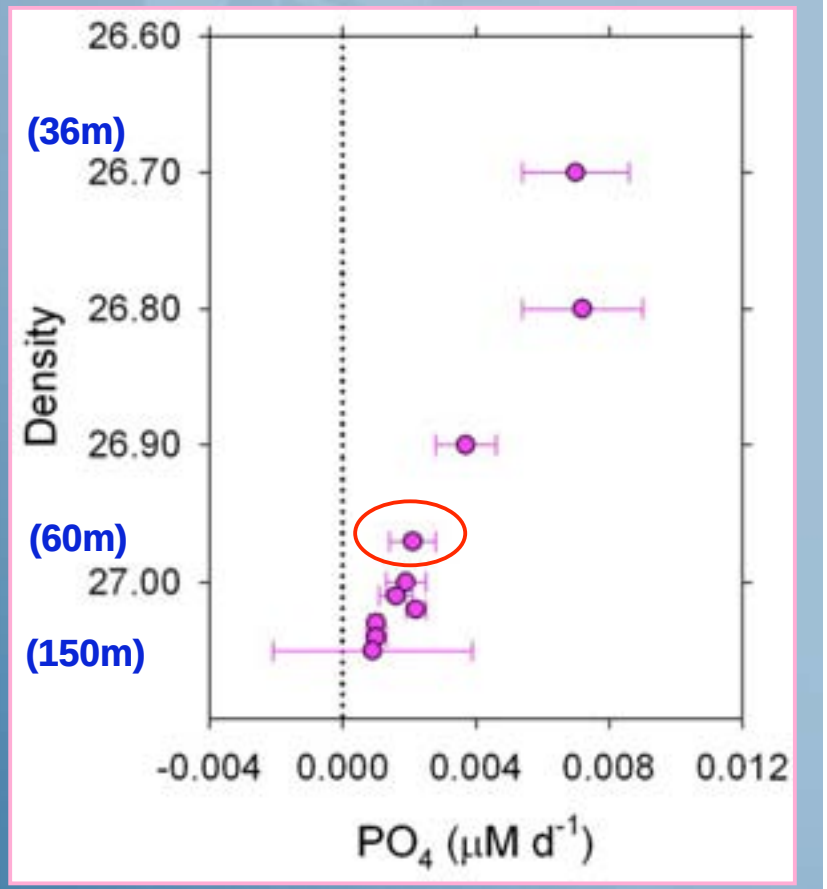


Evidence: N_2 fixation-supported export production

Rates of increase in P on isopycnal surfaces

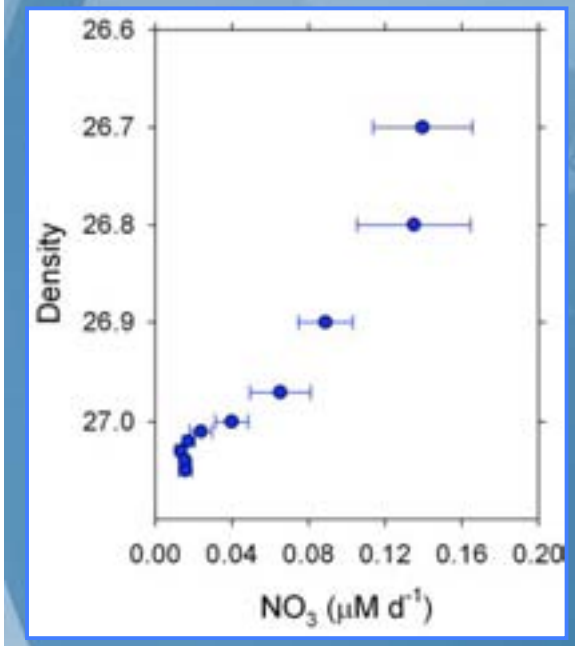
σ_θ = 26.97



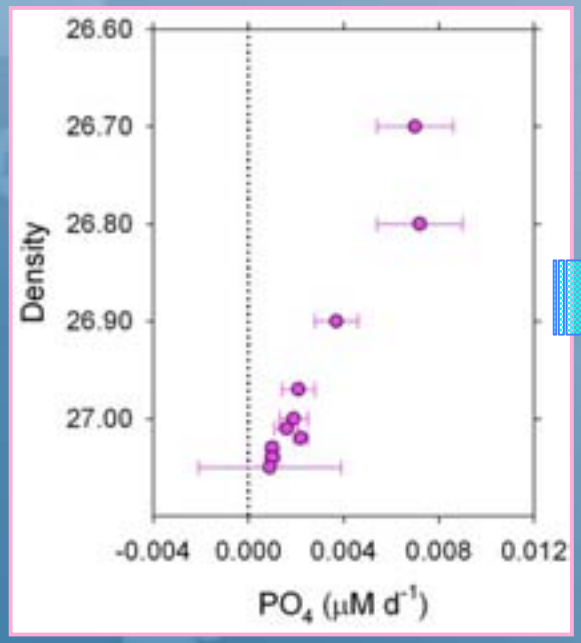


Evidence: N_2 fixation-supported export production

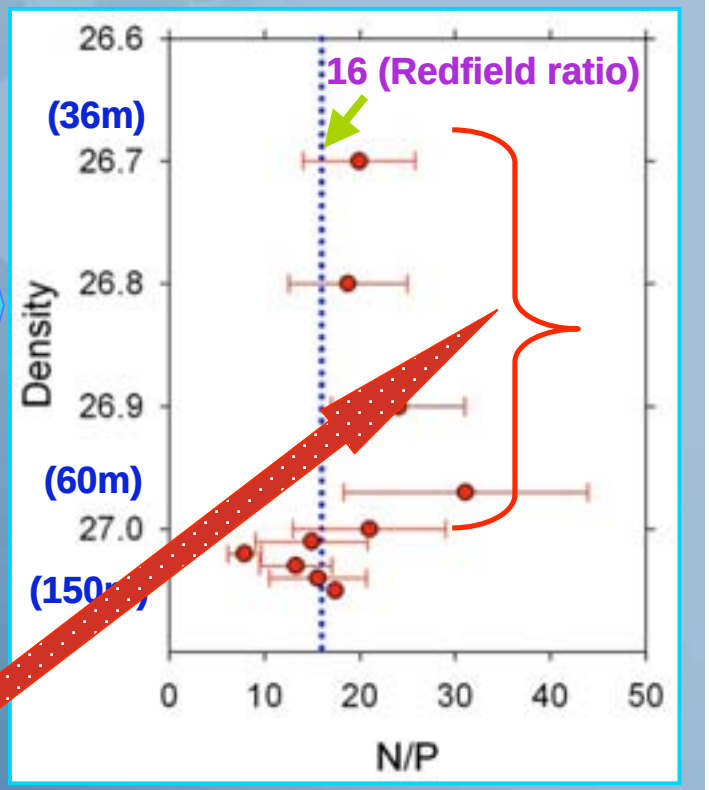
N increase rate



P increase rate



(_N/_P)



Regeneration of excess N

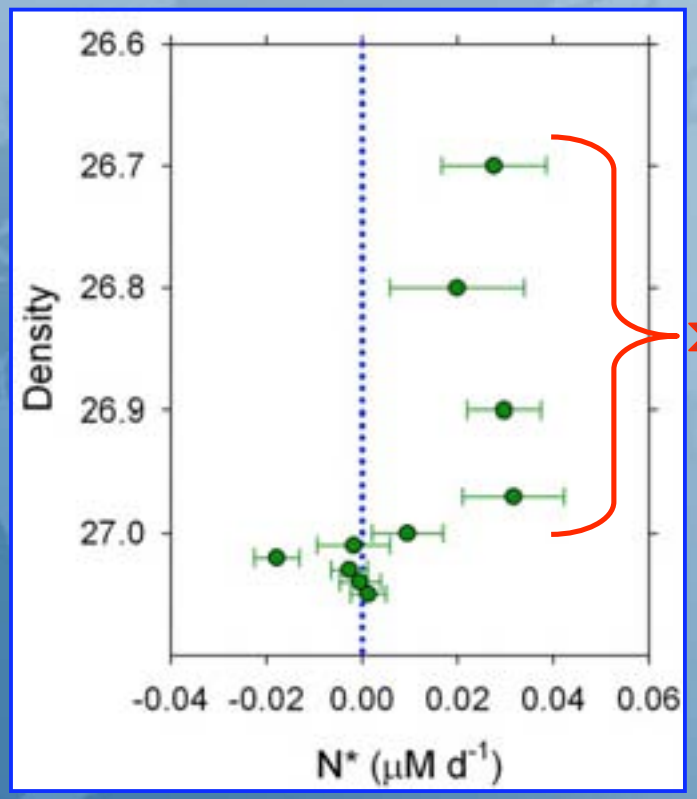
Evidence: N_2 fixation-supported export production

Increasing rate of N*

- $N^* = NO_3 - 16 \times PO_4$

  $N^* > 0$ N excess (N_2 fixation)

  $N^* < 0$ P excess

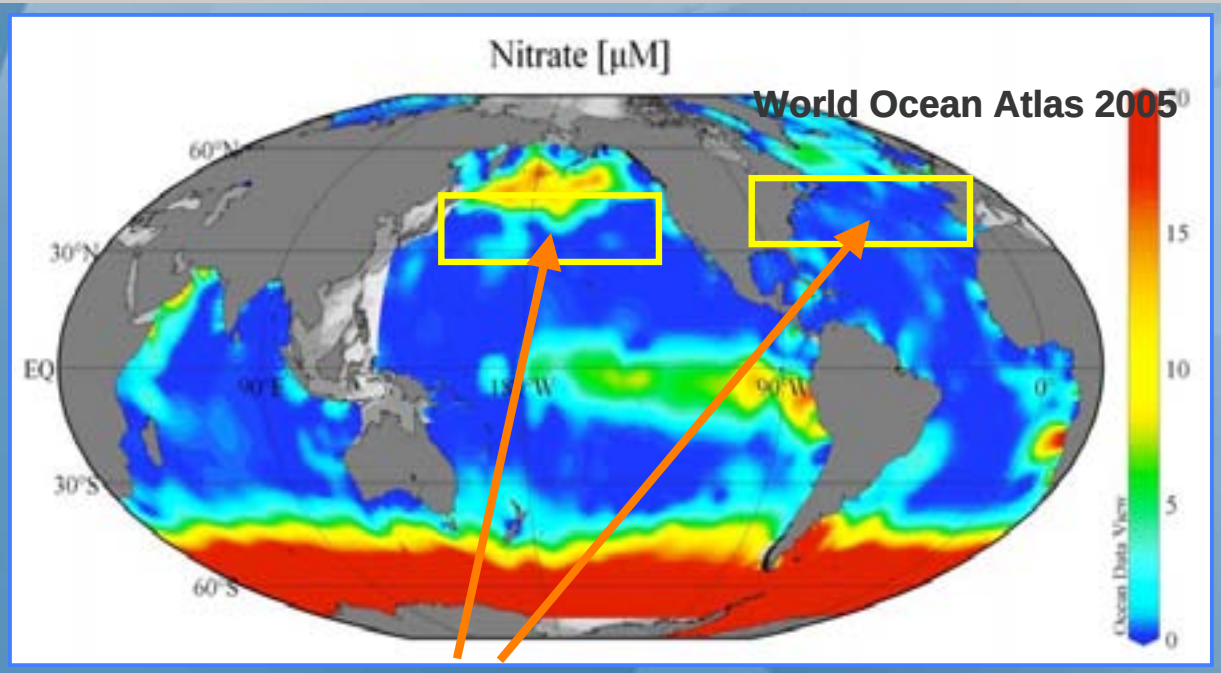


Indication of N_2 fixation!

- C export in N-depleted study site (46°N) was substantial.
- N_2 fixation (by Picoplankton *Synechococcus*) was probably a major contributor to this export production

Global implication

➢ Distribution of N concentration for August



Dark blue color

¢°N-depleted regio n (~0 µM)

Implication:

➢ N_2 fixation can be a non-negligible contributor to expor t production in colder waters in much part of N. Pacific a nd N. Atlantic

Acknowledgement

- **Principal Investigators:**

- **Carbon parameters: Rik Wanninkhof (AOML), Richard Feely (PMEL)**
- **Nutrients: Jia-Zong Zhang (AOML)**
- **SF_6: Rik Wanninkhof (AOML)**
- **DOC and DON: Dennis Hansel (RSMAS)**
- **Chief scientist: Jim Butler (CMDL)**

This is part of Guen-Ha Park's Ph.D thesis