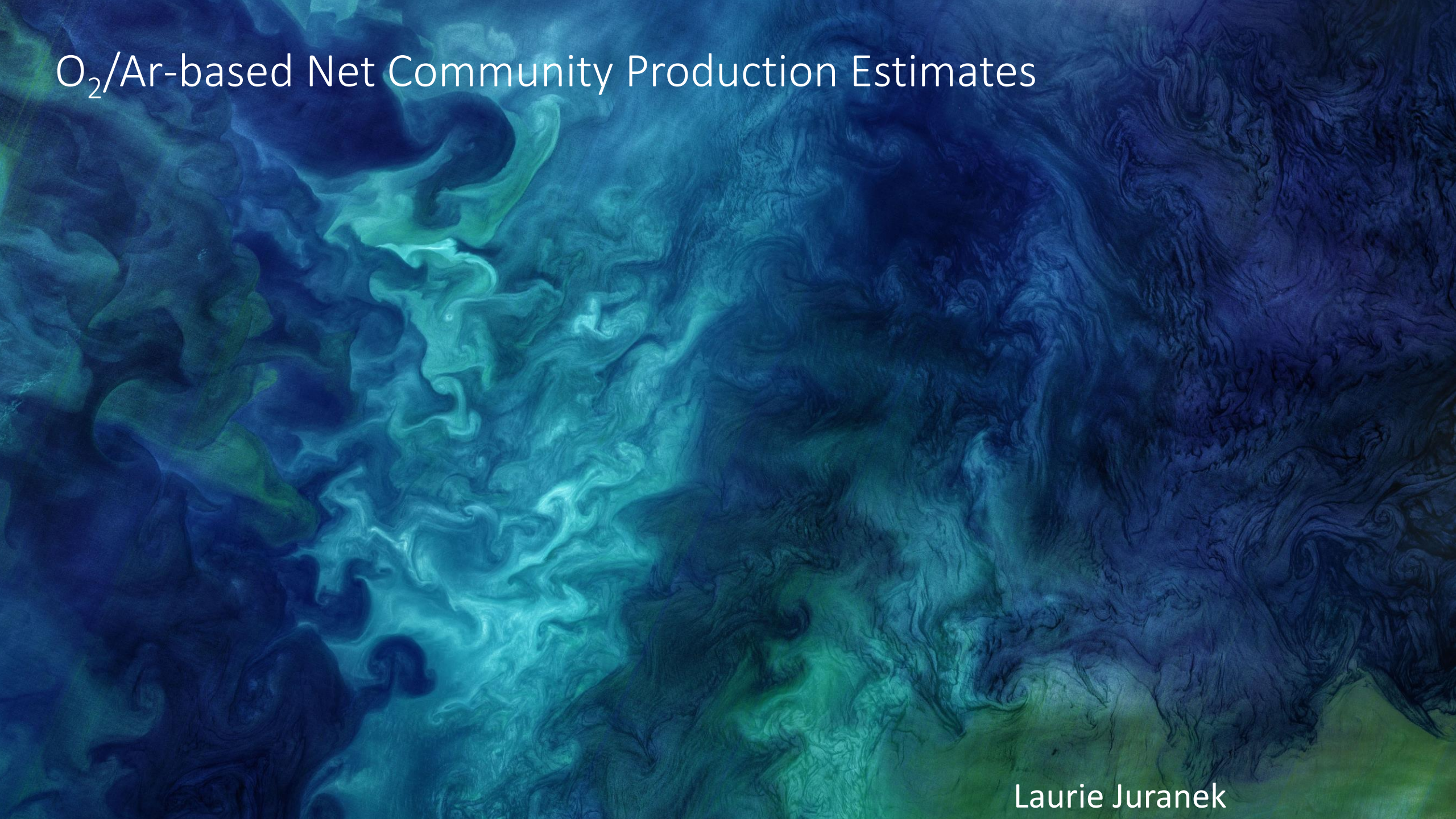
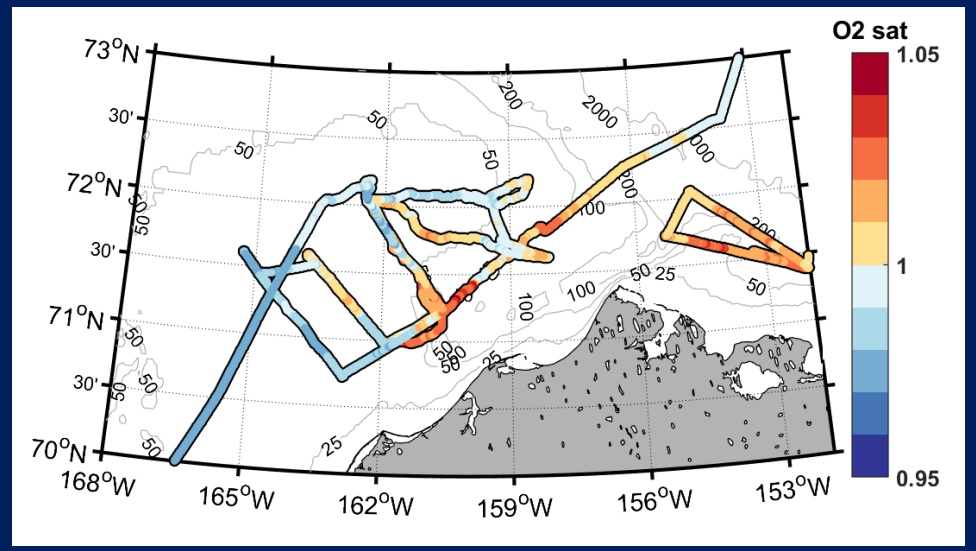
O_2/Ar-based Net Community Production Estimates



Laurie Juranek

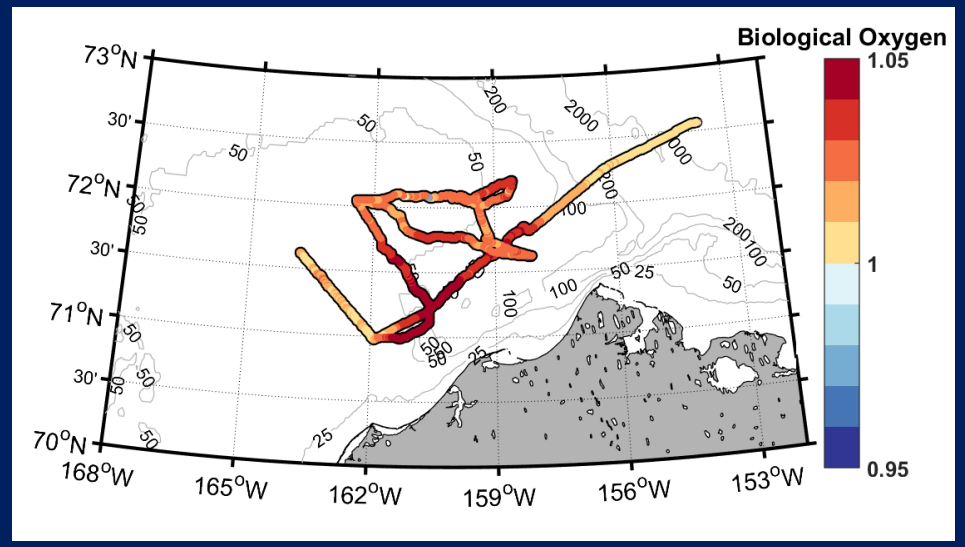
O_2/Ar theory: Surface Oxygen balance is a way to diagnose net biological activity



O_2 sat can allow us to evaluate net community metabolism (balance of photsynthesis and respiration)

BUT

O_2 sat also affected by physical processes like warming and cooling



Because Argon tracks physical changes, using a tracer pair like O_2/Ar allows us to look solely at net biological production of O_2 (net community production)

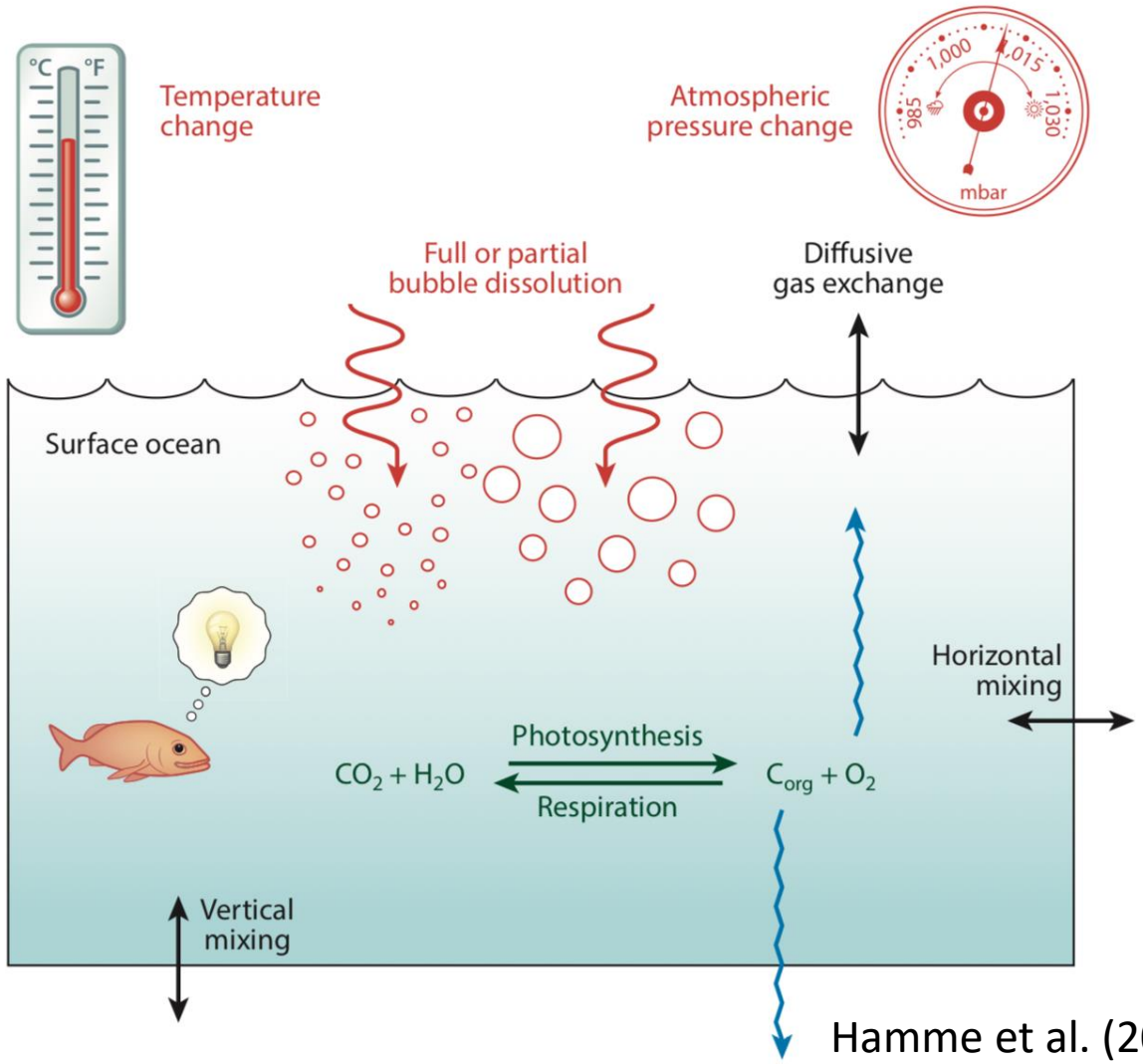
Principles of method – mass balance of O_2

$$\Delta O_2/Ar\ (\%) = 100\left[\left(\frac{O_2}{Ar}\right)meas\Big/\left(\frac{O_2}{Ar}\right)sat - 1\right]$$

dO_2/dt= gas exchange + NCP + Mixing + Entrainment

$dO_2/dt = 0$
NCP= gas exchange
NCP $= k \cdot C_{sat} \cdot \Delta O_2/Ar$

Assumptions: Δ Ar = 0; steady-state



Hamme et al. (2018)

Evolution of method – early results

Open ocean sites –

- Subsurface O_2 max in oligotrophic ocean (Schulenberger & Reid, 1981; Jenkins & Goldman, 1985)
- Surface annual export budgets (too many refs to list here, summarized by Emerson 2014)

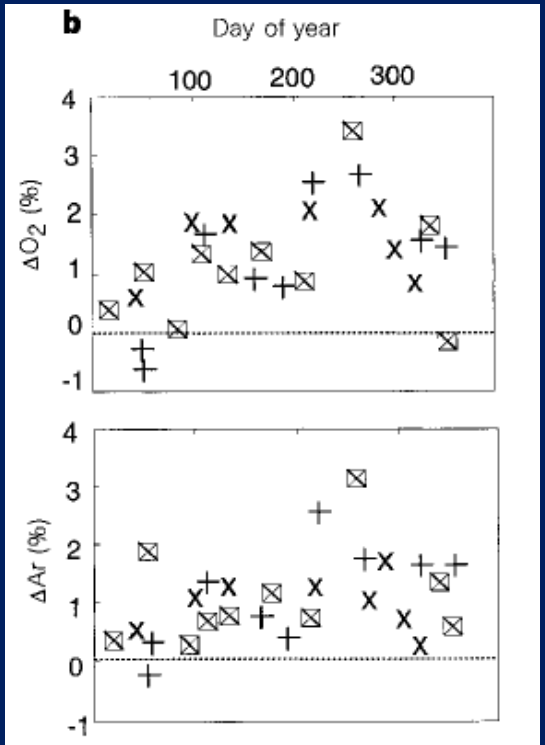


Table 4. Summary of ANCP Values Determined by Oxygen and Carbon Mass Balance and by Satellite-Based Methods at Three Locations Where Annual Experimental Data Exist[a]

Location	$ANCP_{meas}$ (mol C m^{-2} yr^{-1})	NPP_{sat} (mg C m^{-2} d^{-1})		NCP:NPP		$ANCP_{sat}$ (mol C m^{-2} yr^{-1})	
		VGPM	CbPM	Laws	Dunne	VGPM	CbPM
OSP	**2.3 ± 0.6**	446 (130–900)	340 (70–650)	0.31 (0.18–0.49)	0.31 (0.28–0.35)	**4.6 ± 0.5**	**3.2 ± 0.6**
HOT	**2.5 ± 0.7**	265 (170–330)	503 (420–550)	0.16 (0.16–0.17)	0.13 (0.12–0.15)	**1.4 ± 0.0**	**2.5 ± 0.1**
BATS	**3.8 ± 1.2**	321 (150–600)	281 (100–350)	0.17 (0.16–0.18)	0.14 (0.09–0.19)	**1.5 ± 0.1**	**1.4 ± 0.1**

[a]ANCP values are the product of NPP from the CbPM algorithm and NCP:NPP ratios from *Laws et al.* [2000]. Values in parentheses indicate seasonal ranges for VGPM and CbPM. Measured and predicted ANCP values are in bold.

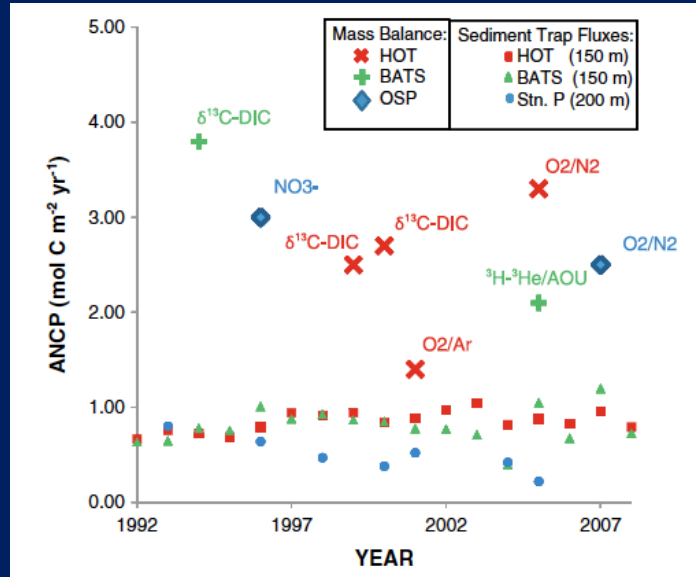
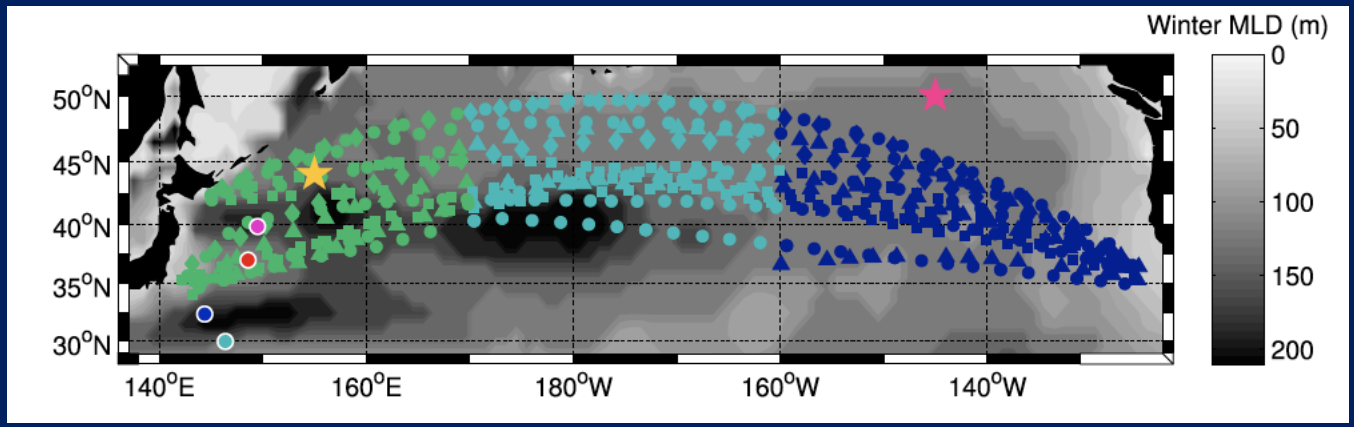


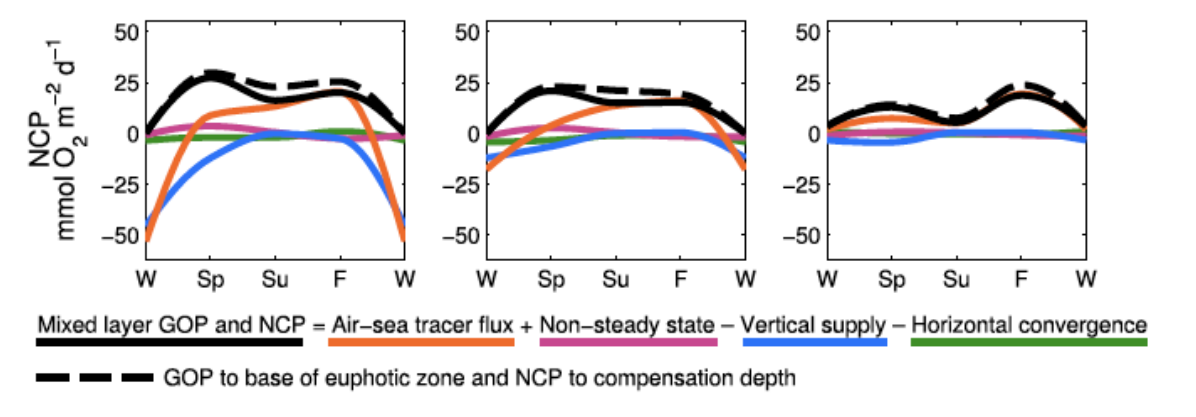
Figure 1. Experimental estimates of ANCP (mol C m^{-2} yr^{-1}) as a function of year from 1992 to 2008. Large symbols indicate ANCP determined from mass balances of O_2, NO_3^-, and the stable carbon isotopes of dissolved inorganic carbon (δ^{13}-DIC). The method is indicated next to the symbols, and references are given in Table 2. Smaller symbols are annually averaged particulate organic carbon fluxes from sediment trap deployments at HOT, BATS (150 m), and OSP (200 m). Data were downloaded from the compilations on the HOT and BATS websites and are from [*Timothy et al.*, 2013] for OSP.

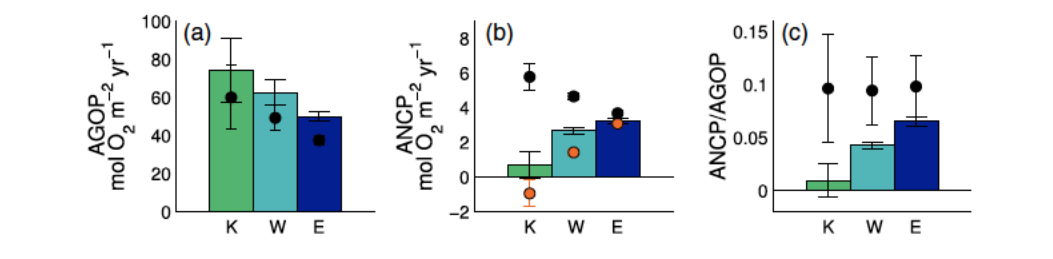
Evolution of method – ships of opportunity

Bottle-based $\Delta O_2/Ar$ on ships of opportunity lessons learned

- Evidence of O_2 uptake (respiration) on some ship flow-through systems (Juranek et al. 2011)
- Use of O_2 climatology to get at physical supply terms
- Shallow export/ remineralization can substantially reduce ANCP in some regions (Palevsky et al., 2016)
- Winter mixed layer is appropriate depth horizon for ANCP budgets



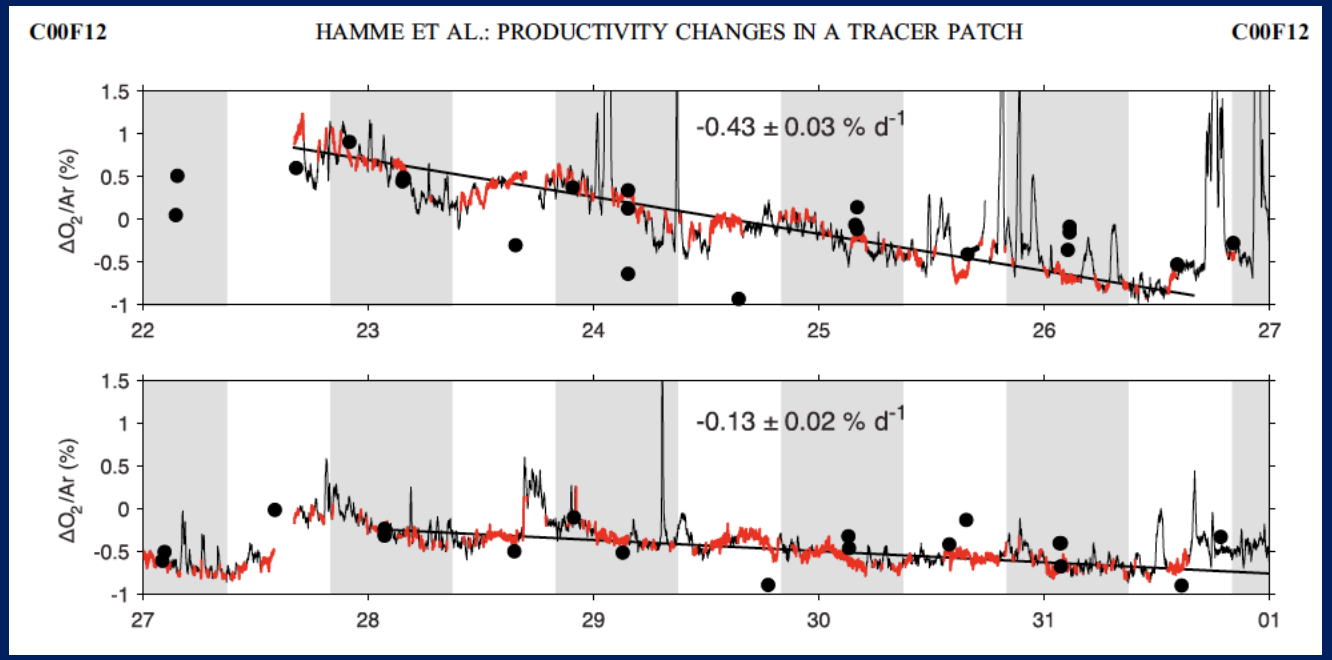




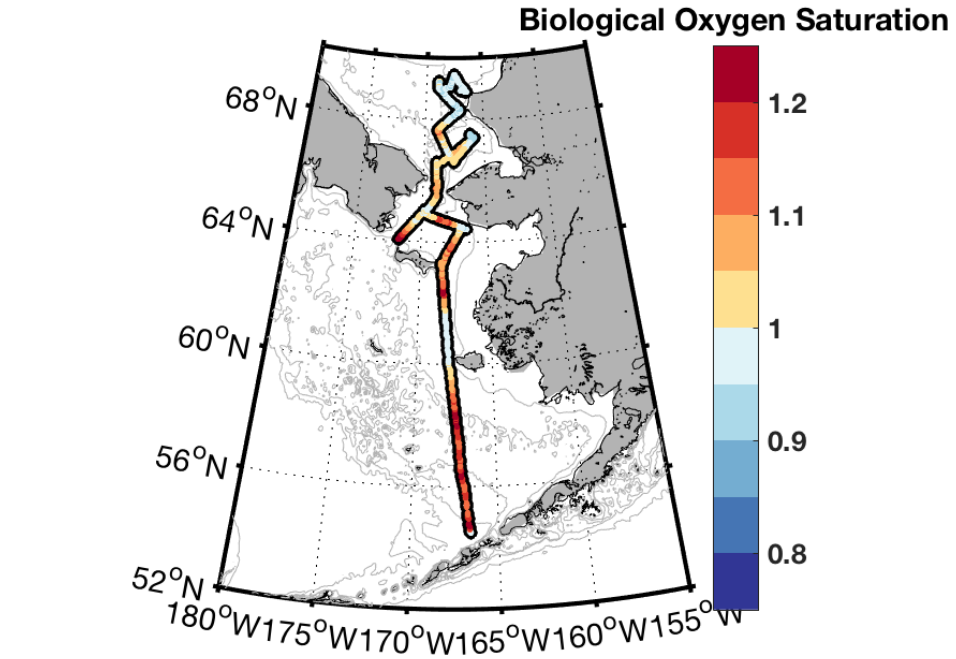
Palevsky et al (2016)

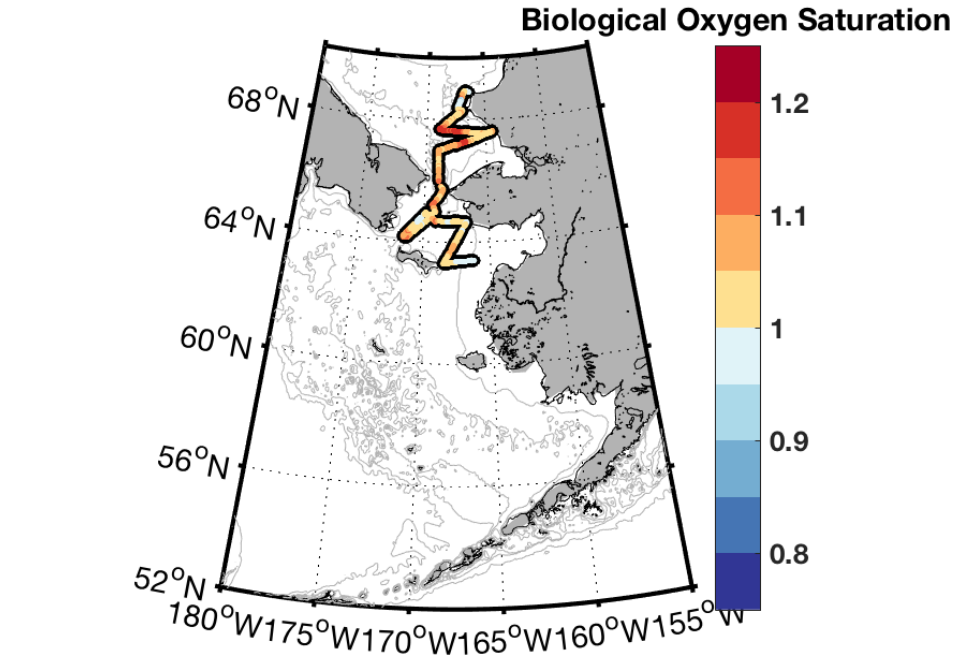
Evolution of method – MIMS and EIMS

- EIMS: slower response, but not as sensitive to temp (Cassar et al., 2009)
- MIMS: faster response, requires standards, temp control



Recent application of EIMS /MIMS – dynamic features



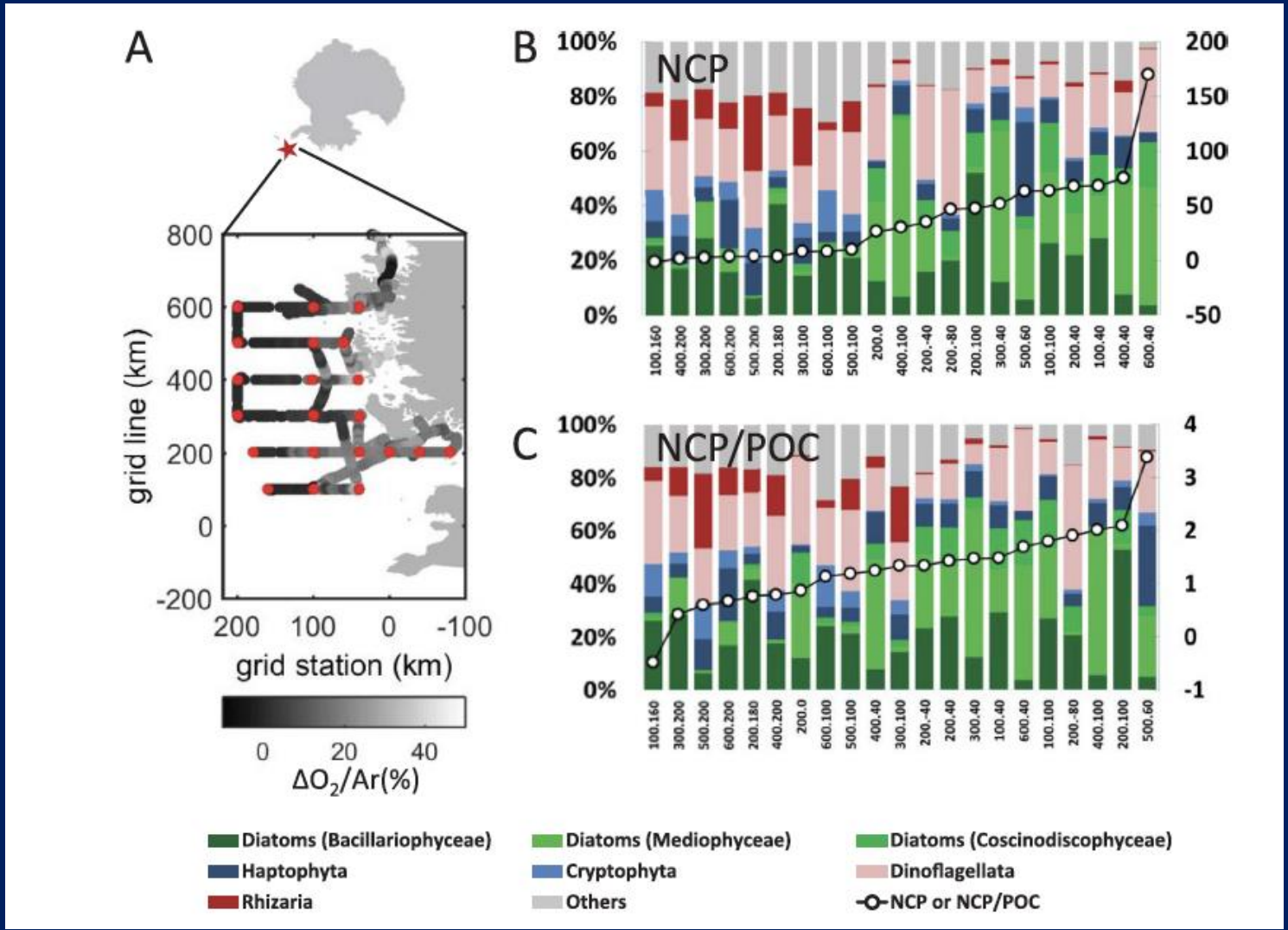


https://oceancolor.gsfc.nasa.gov/
Image from June 18, 2018

Juranek (unpublished)

Recent application of EIMS /MIMS – ecological features

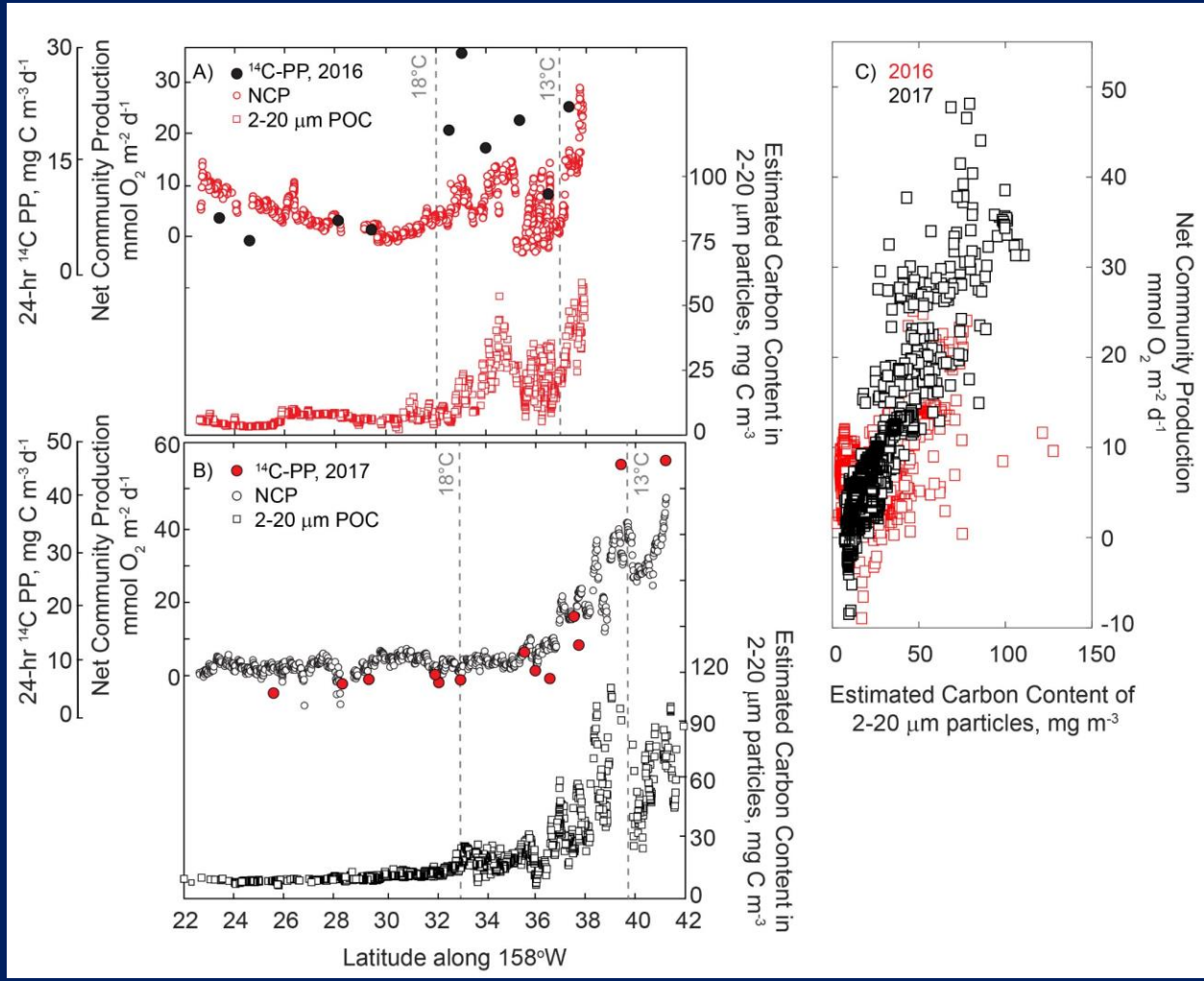
High-resolution NCP estimates paired with pigment/genomic analyses offer new insights into community drivers of productivity and carbon export



Lin et al. (2017)

Recent application of EIMS /MIMS – ecological features

Can also pair with optical proxies, IFCB to evaluate coupling of NCP and size/diversity/functional types



Juranek, White, et al. (submitted)

Summary

- The ΔO_2/Ar-NCP approach has reached ‘maturity’, enormous potential
- In some regions, and in some seasons physical terms are very important (similar for non steady-state dynamics)
- We need to be clear on how we are interpreting/scaling these observations (NCP vs ANCP), depth of integration