Assessing Integrated Satellite-Float Productivity Estimates in the NASA EXPORTS Campaigns

Shawnee Traylor[1,2], Yibin Huang[3,4], Andrea J. Fassbender[3,4], David P. Nicholson[1]

[1] Department of Marine Chemistry and Geochemistry, Woods Hole Oceanographic Institution, Woods Hole, Massachusetts, USA
[2] Department of Earth, Atmospheric, and Planetary Sciences, Massachusetts Institute of Technology, Cambridge, Massachusetts, USA
[3] Department of Ocean Sciences, University of California, Santa Cruz, California, USA
[4] NOAA/OAR Pacific Marine Environmental Laboratory, Seattle, WA, USA

Background

- **EX**port **P**rocesses in the **O**cean from **R**emo**T**e **S**ensing (EXPORTS) is a NASA-led field campaign to quantify the export and fate of upper-ocean net primary productivity through two cruises in the North Pacific (August 2018) and North Atlantic (May 2021).
- A dominant mechanism is the **biological carbon pump,** or the biologically-mediated transfer of organic carbon from the upper, sunlit euphotic zone to the deep ocean, where it is sequestered from the atmosphere for centuries to millennia.
- This maintains an **atmospheric pCO_2 ~200 ppm_v lower** than with an abiotic ocean. Current global estimates range from **5-12 Pg C yr^{-1}**, approximately the magnitude of human perturbations.
- In a steady-state ocean, the carbon available for export is equal to the annual **Net Community Production (NCP)**, or the balance between gross primary production and all respiratory losses of carbon.
- NCP can be estimated *in situ* using a **mass balance approach** with tracers of productivity (e.g. O_2, NO_3^-) or from remote sensing as a function of sea surface temperature and **modeled NPP**.

Data Sources

- **Float data** from Global Ocean Biogeochemistry Array (GO-BGC) Project
  - All data (e.g. NO_3, CHL, and $B_{bp,700}$) underwent BGC-ARGO program QA/QC. O_2 values further calibrated against discrete Winkler samples.
- **Net Primary Productivity** from the CAFE, CbPM, and VGPM models using MODIS-A data (Oregon State University Ocean Productivity Group)
- **Sea Surface Temperature** (GHRSST Level 4 MUR, 8-day, 4 km resolution)
- **Meteorological data** from Station Papa (NOAA PMEL) and NCEP Reanalysis
- **Euphotic zone depth**, photosynthetically active radiation **(PAR)**, and **chlorophyll-a** (MODIS-A)
- **Wind stress** fields (6-hr, NOAA FNMOC)
- Monthly climatology of diapycnal **diffusivity** in North Pacific (*Cronin et al., 2015*)
- Summertime diapycnal **diffusivity** in North Atlantic (*Van Haren et al., 2021*)

NCP Calculations

Float

- Gas flux broken into diffusive, partially collapsing, and fully collapsing bubble fluxes
- Physical fluxes broken into Ekman pumping, diapycnal diffusion, and entrainment

Observed / Modeled

$$NCP = \frac{\partial O_2}{\partial t}\bigg|_{BIO} = \boxed{\frac{dO_2}{dt}} - \boxed{\frac{\partial O_2}{\partial t}\bigg|_{GAS} - \frac{\partial O_2}{\partial t}\bigg|_{PHYS}}$$

$$NCP = \frac{\partial NO_3^-}{\partial t}\bigg|_{BIO} = \boxed{\frac{dNO_3^-}{dt}} - \boxed{\frac{\partial NO_3^-}{\partial t}\bigg|_{PHYS}}$$

Satellite

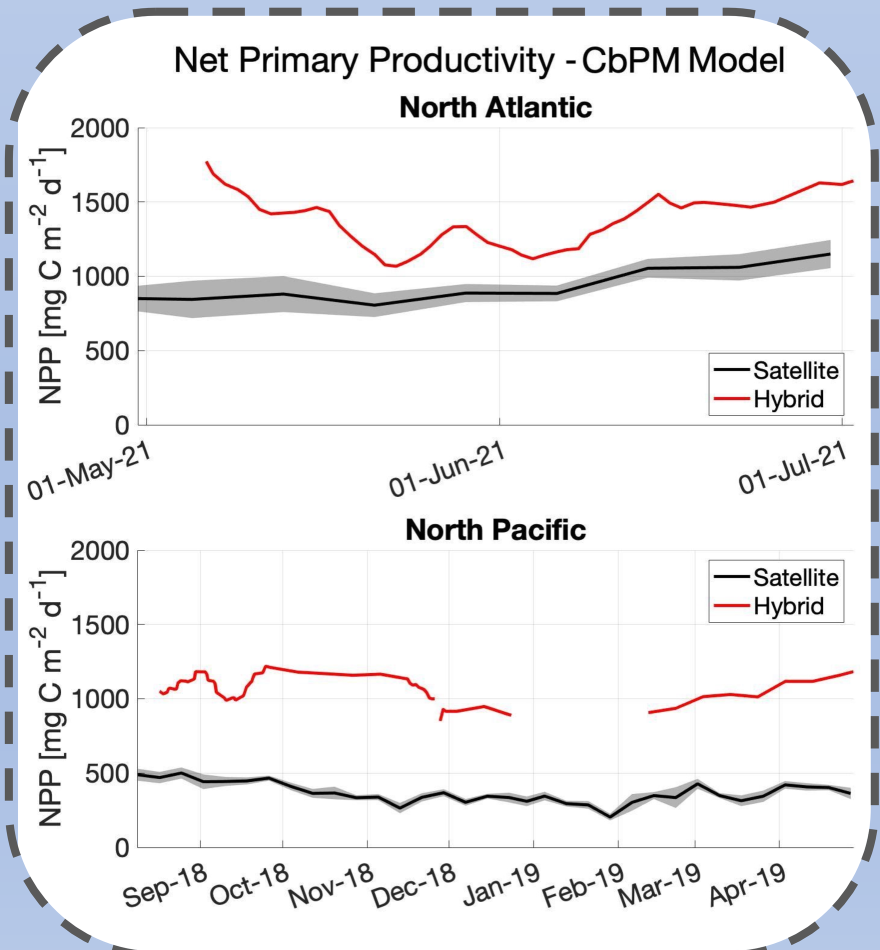
- NPP from CAFE, CbPM, VGPM models run with MODIS-A data

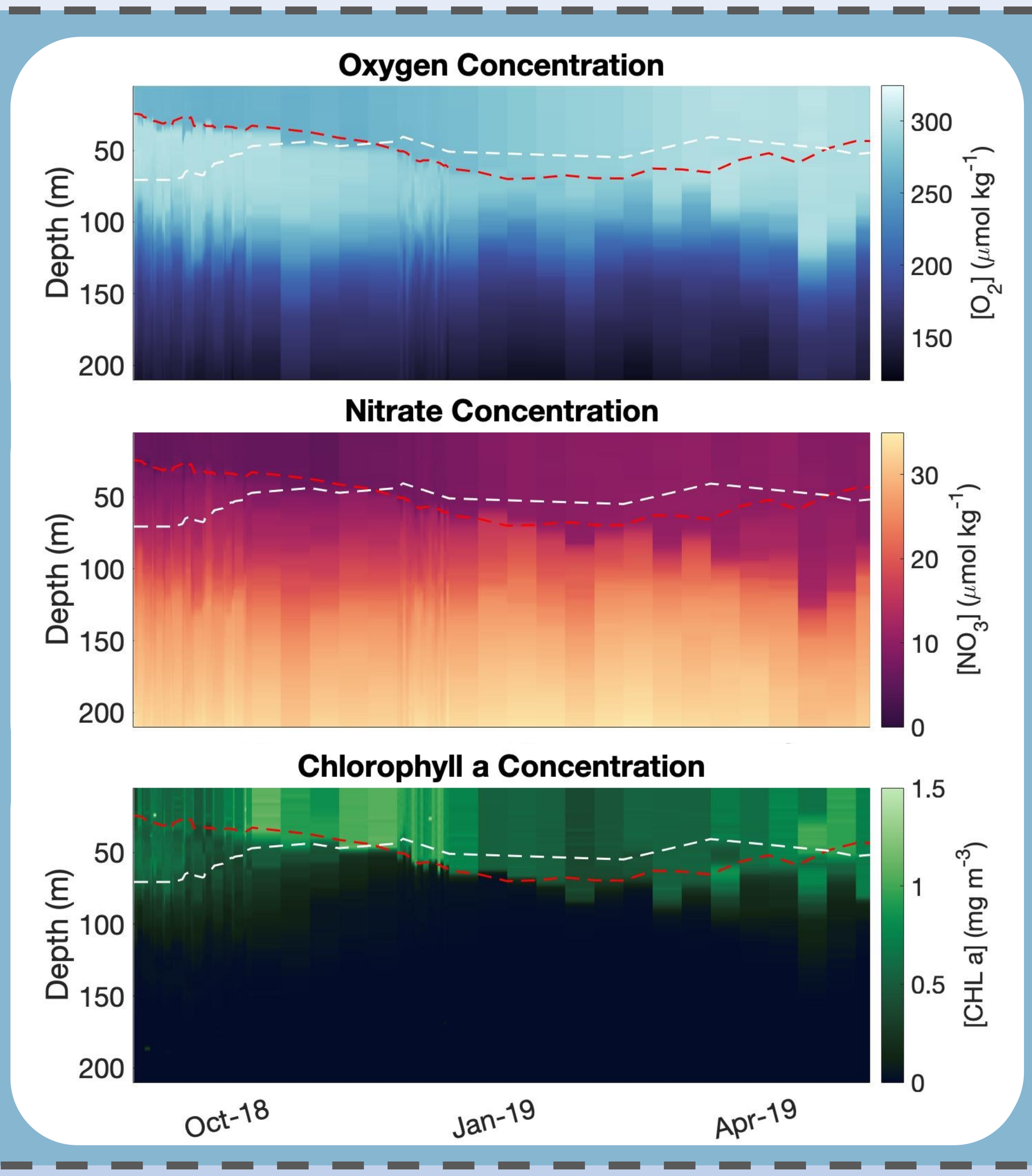
$$NCP_1 = \frac{8.57 \times NPP}{SST + 17.9}$$

$$NCP_2 = \frac{105 + 8.57 \times NPP}{SST + 23.5}$$

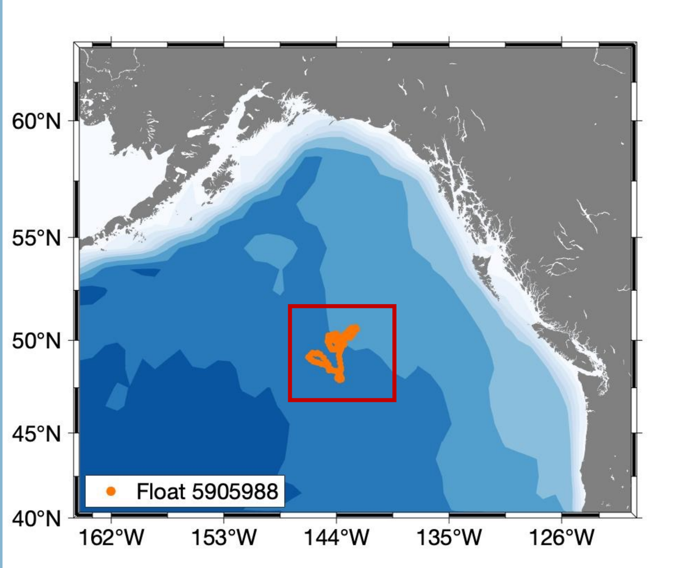
From *Li & Cassar (2016)*

Hybrid satellite-float NCP:
- NPP from CbPM using float data
- NCP calculated as above
- NCP algorithm derived from O_2/Ar method



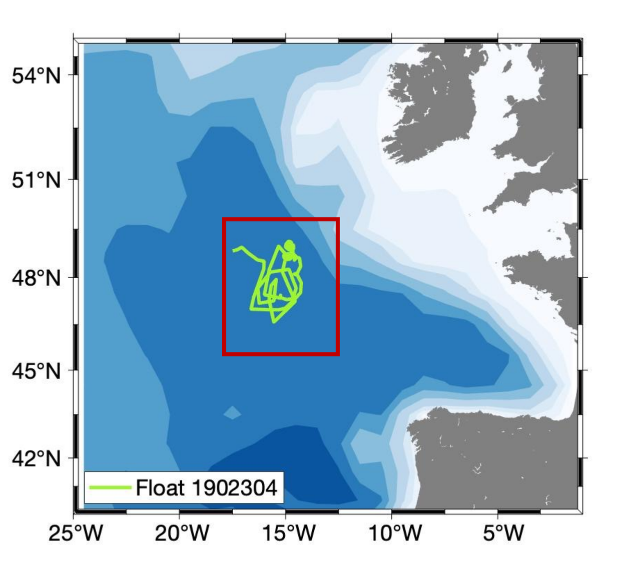


North Pacific

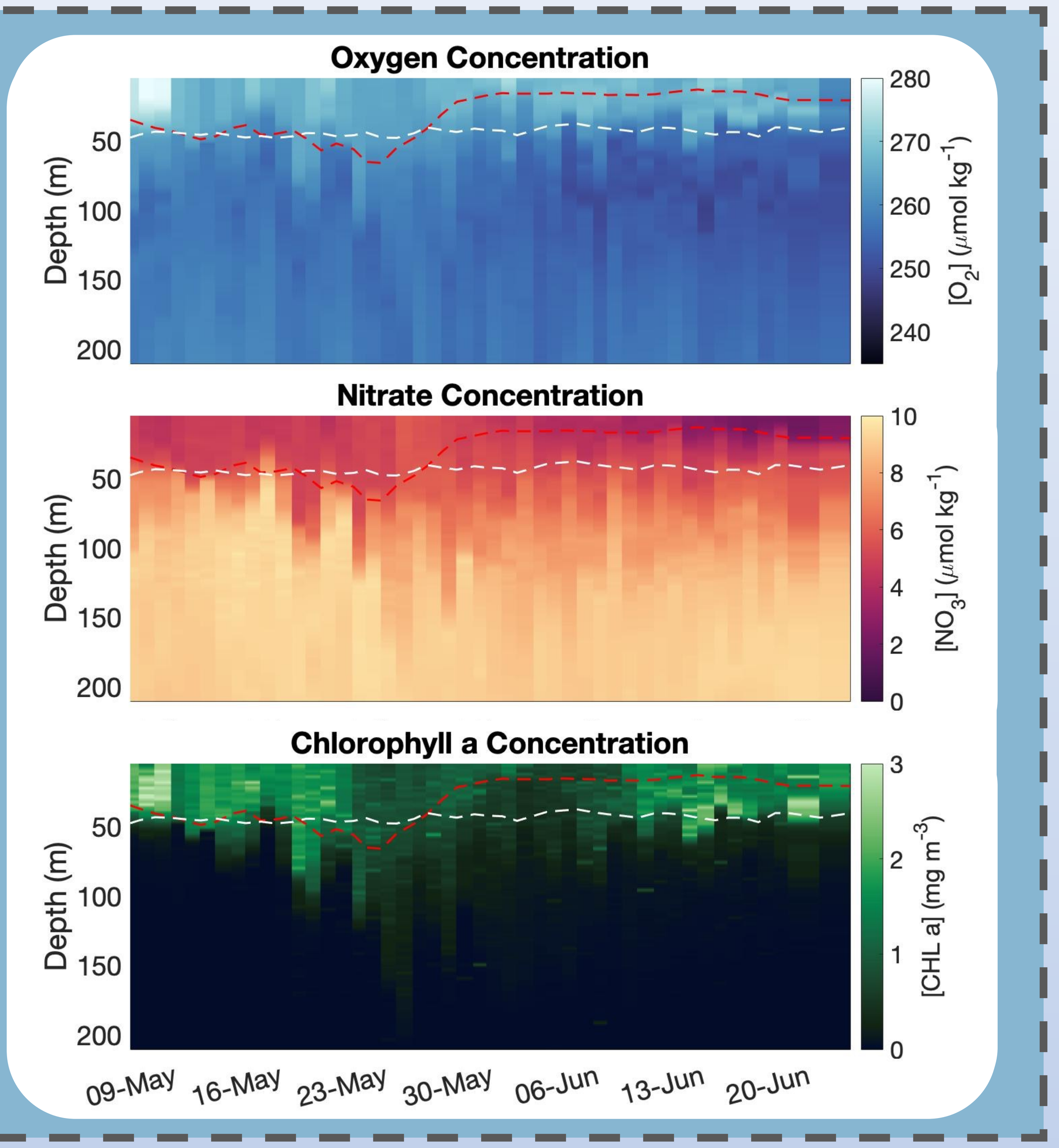


Weak horizontal advection at study site (e.g., *Pelland et al., 2018*)

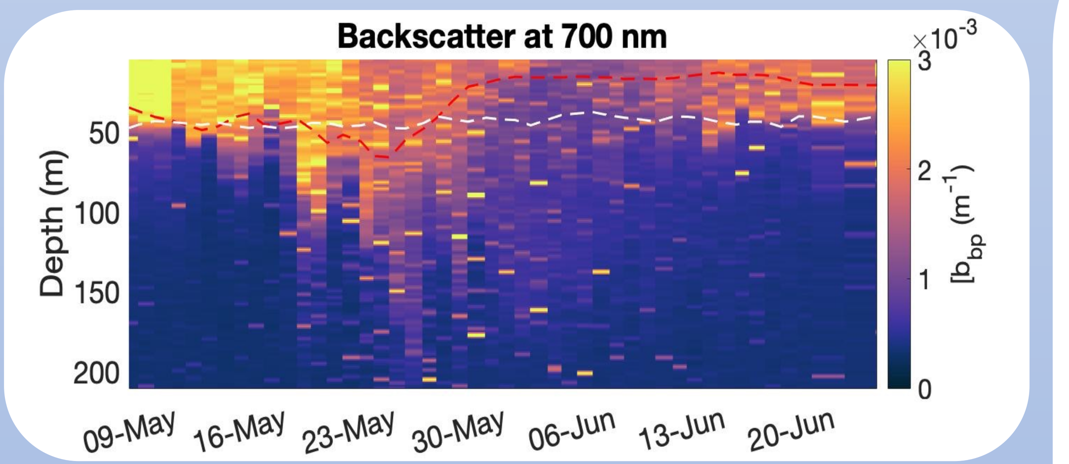
North Atlantic

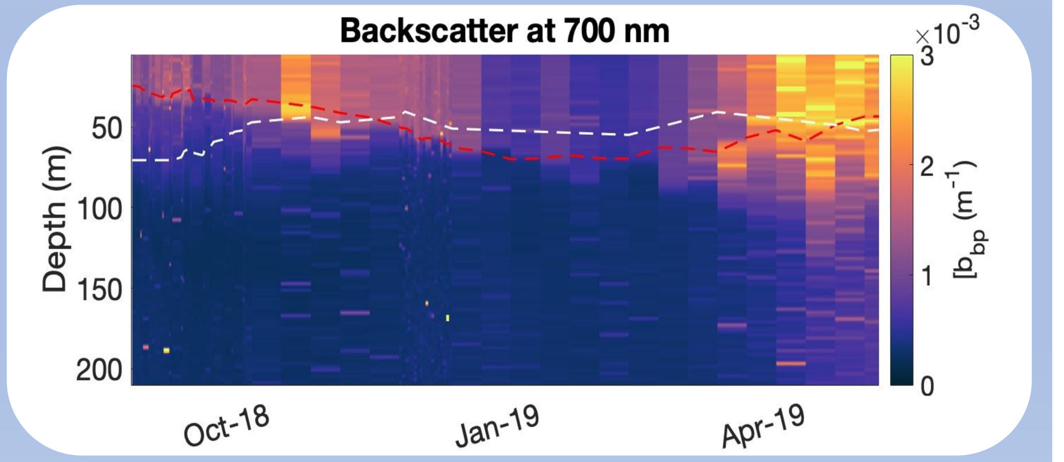


Quasi-Lagrangian framework: float followed a single eddy

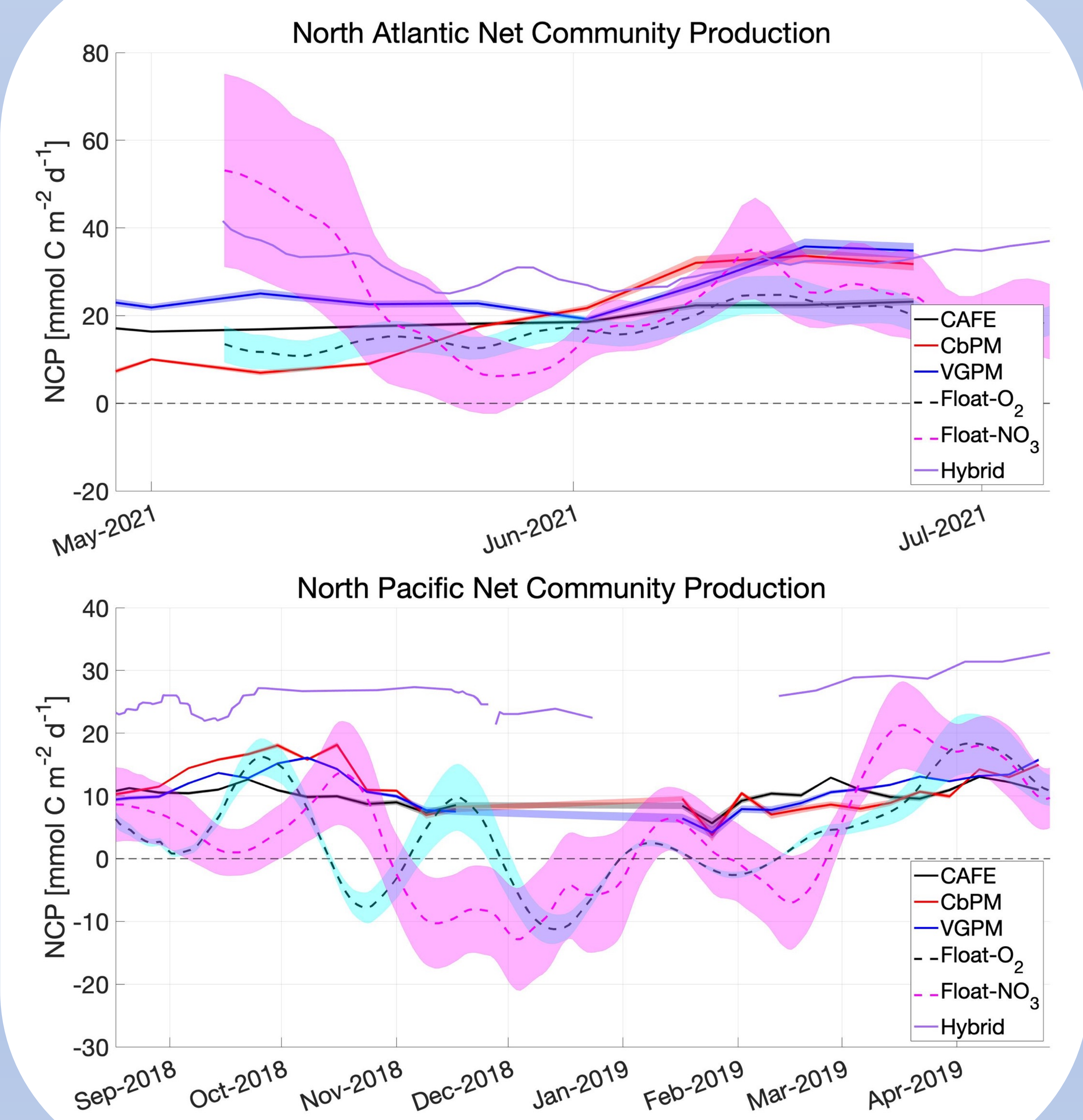


Evidence of Particle Export





Results



Conclusions

- In the context of the NASA EXPORTS field campaigns, both NPP and NCP during the North Atlantic spring bloom were roughly 2x higher than during the late summer North Pacific
- The magnitude of the productivity cycle in the North Pacific was less than the North Atlantic
- Higher backscatter, potentially indicative of particle export below the mixed layer, accompanied the North Atlantic boost in NCP
- Both satellites and floats offer autonomous measures of productivity in the ocean with varying strengths and weaknesses
- Floats offer opportunity for depth-resolved analyses and can observe when satellites cannot (e.g. bad weather)
- Comparisons between float-based NCP from O_2 and NO_3 show good agreement with satellite-based NCP
- Calibration of biogeochemical sensors is especially critical for chlorophyll - without discrete sample calibration, float-based estimates tend to be biased high

Acknowledgements

We gratefully thank our EXPORTS lead scientists Dr. Dave Siegel and Dr. Ivona Cetinic, chief scientist Dr. Craig Lee, the captain and crews of the *RV Sally Ride* and *RSS Discovery*, and the rest of the EXPORTS team. We are also grateful to the BGC-Argo team for their maintenance of quality-controlled float data, Yibin Huang for advice on float-based NCP estimates, and to James Fox and Jason Graff at OSU for advice on employing CbPM. This material is based upon work supported by the National Science Foundation (NSF) Graduate Research Fellowship under Grant No. 1745302, by NSF Grant OCE2023080, by the NOAA-GOMO program, and based upon work supported by NASA under Grant No. 80NSSC17K0663 issued through the EXPORTS program. All data used in this analysis are freely and publicly available. Data were collected and made freely available by the Global Ocean Biogeochemistry Array (GO-BGC) Project funded by the National Science Foundation, Division of Ocean Sciences (NSF OCE-1946578), and by the International Argo Program and the national programs that contribute to it. (http://www.argo.ucsd.edu, http://ocean-ops.org). The Argo Program is part of the Global Ocean Observing System.

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