Primary production dynamics during the decline phase of the North Atlantic annual spring bloom

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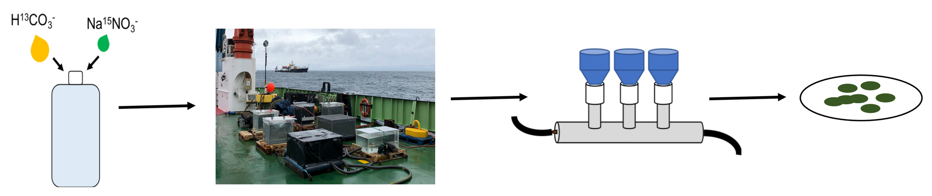
Introduction

The second field campaign of the NASA EXport Processes in the Ocean from RemoTe Sensing (EXPORTS) program was conducted in the late spring of 2021 within the vicinity of the Porcupine Abyssal Plain (49.0ºN, 16.5ºW) in the North Atlantic Ocean. Observations from EXPORTS support previous characterizations of this system as highly productive and rich in organic matter, with the majority of primary production occurring in large cells (≥ 5 µm) such as diatoms that are primarily utilizing nitrate. Daily rates of total euphotic zone depth-integrated net primary production ranged from 36.4 to 146.6 mmol C m^{-2} d^{-1}, with a cruise-wide average f-ratio of 0.74, indicating predominantly new production. Substantial variability in the contribution of small (<5 µm) and large cells occurred over the observation period, coinciding with the end of the annual North Atlantic spring phytoplankton bloom. Physical changes associated with storms appear to have impacted the integrated production rates substantially, enhancing rates by ~10%. These disturbances altered the balance between contributions of the different phytoplankton size fractions, thus reiterating the important role of mixed layer variability in nutrient entrainment into the upper water column and production dynamics. This second field campaign serves as the high productivity endmember within the EXPORTS research program and as such, elucidates how nutrient concentrations and size class play key roles in both low and high productivity endmember systems but in differing ways. Our results highlight the critical role that resource limitation and a turbulent physical environment play in controlling primary production and phytoplankton community composition during bloom decline.

Methods

- Sampling occurred in a quasi-langrangian framework from May 6th – 29th, 2021 (JDs 126-149) in the vicinity of the Porcupine Abyssal Plain (PAP) region
- Incubation experiments were conducted to estimate size-fractionated gross primary production (GPP, 6 hr) net primary production (NPP, 24 hr), new production, regenerated production, and siliceous phytoplankton production via $NaH^{13}CO_3^-$, $Na^{15}NO_3^-$, and $^{32}Si(OH)_4$ additions



$$Percent\ Siliceous\ NPP = \frac{(^{32}Si\text{−}\rho Si \div 0.13)}{^{13}C\text{−}\rho DIC} * 100$$

- Additional samples for phytoplankton biomass (chl *a*, PC), physiology (VDIC, VNO_3^-) and environmental parameters were collected
- Four storms occurred during the observational period and are identified on results plots

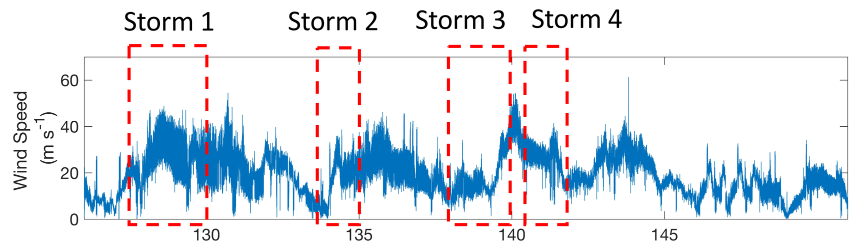


Fig. 1. Wind speed (m s^{-1}) through time. Storms 1-4 are indicated.

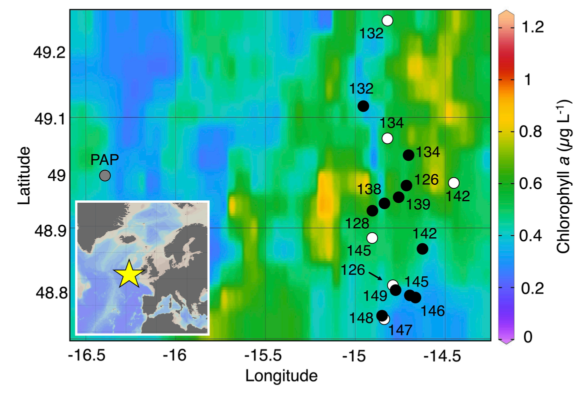


Fig. 2. EXPORTS sampling (by JD) overlain onto MODIS chlorophyll *a* concentrations averaged for May 2021. Black dots refer to the RRS Cook sample sites, and white dots refer to the RRS Discovery sample sites.

Temporal patterns in biomass and production

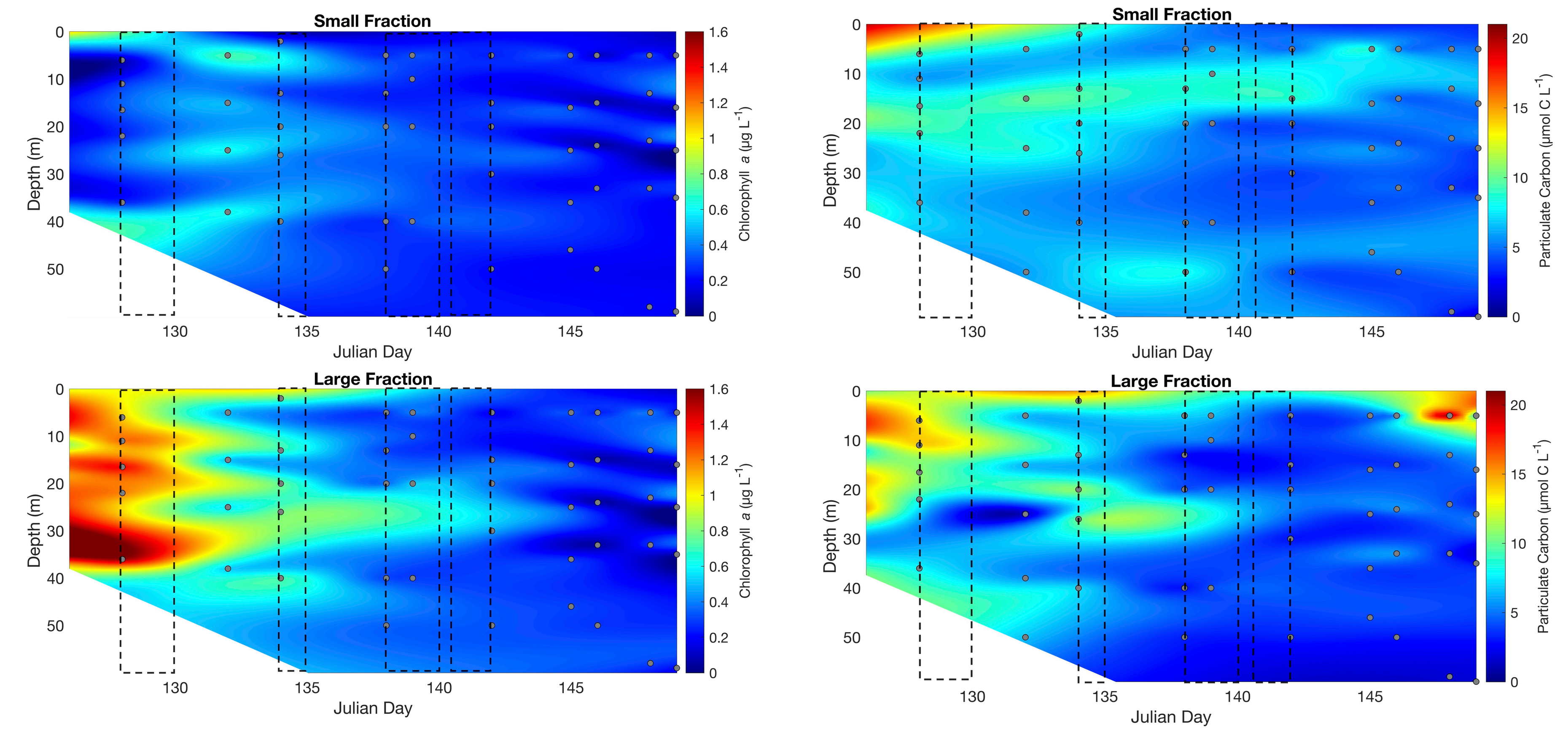


Fig. 3. Small (<5 µm) and large (≥5 µm) size-fractionated chlorophyll *a* and particulate carbon (PC) concentrations through time.

- Large size-fraction biomass dominates through space and time, but both size fraction concentrations decrease markedly through time
- Large size-fraction chlorophyll *a* and PC exhibit the largest decline (41.5% and 34.5%, respectively) following Storm 1

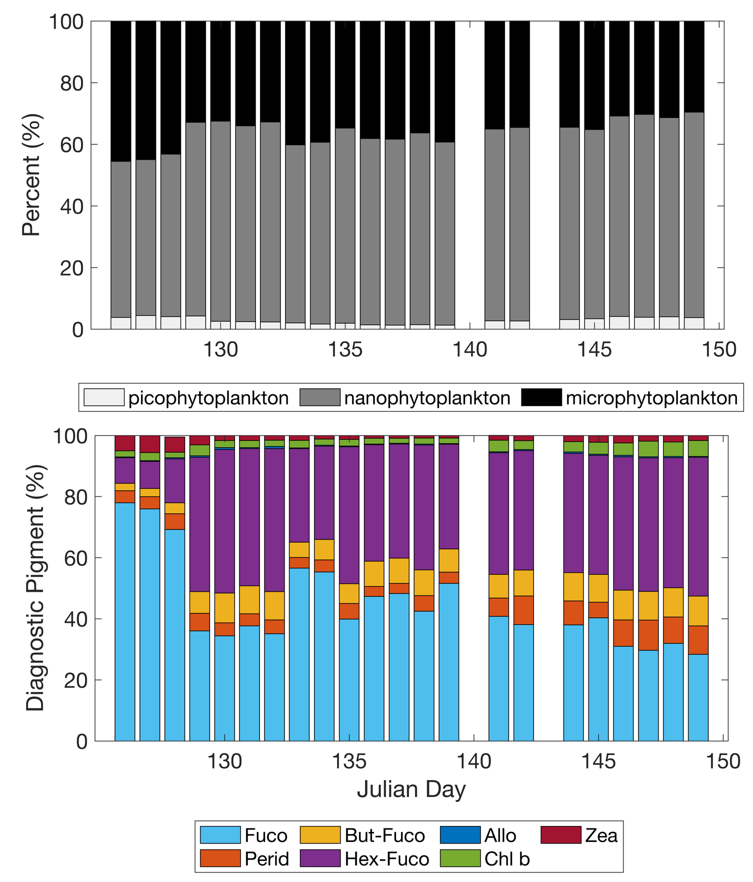
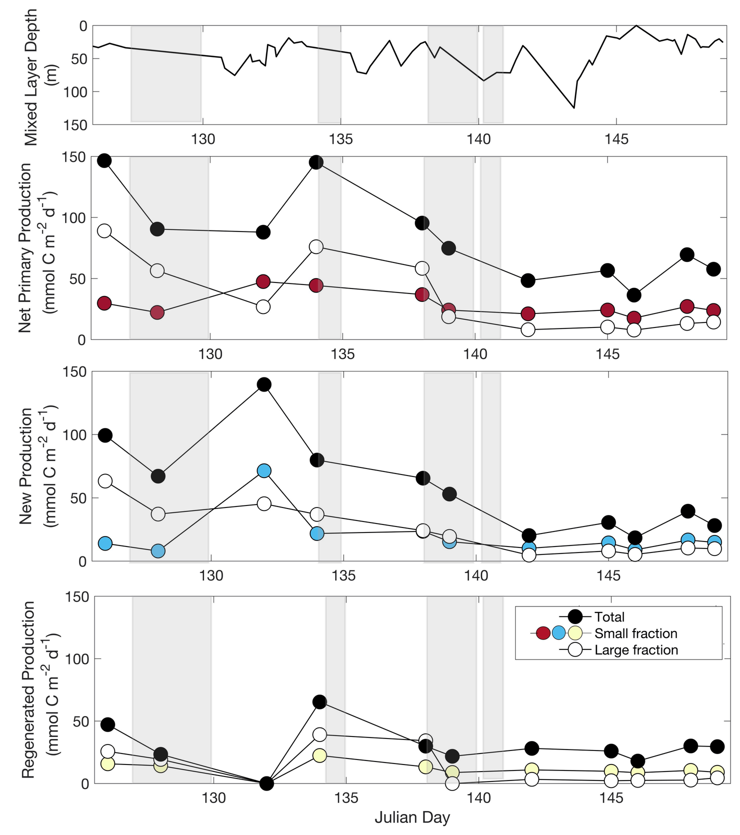


Fig. 4. Phytoplankton diagnostic pigment analysis and the percentage of weighted diagnostic pigment to High Performance Liquid Chromatography total.

- HPLC results indicate a predominance of nano- and microphytoplankton, primarily diatoms (Fuco) and haptophytes (Hex-Fuco) over the observational period
- Following Storm 1 (JD 128), the % pigment analysis suggests a shift in the dominant phytoplankton groups
- Diatoms remain a substantial proportion of the assemblage despite substantial changes to their contribution to NPP (%siliceous phytoplankton NPP)



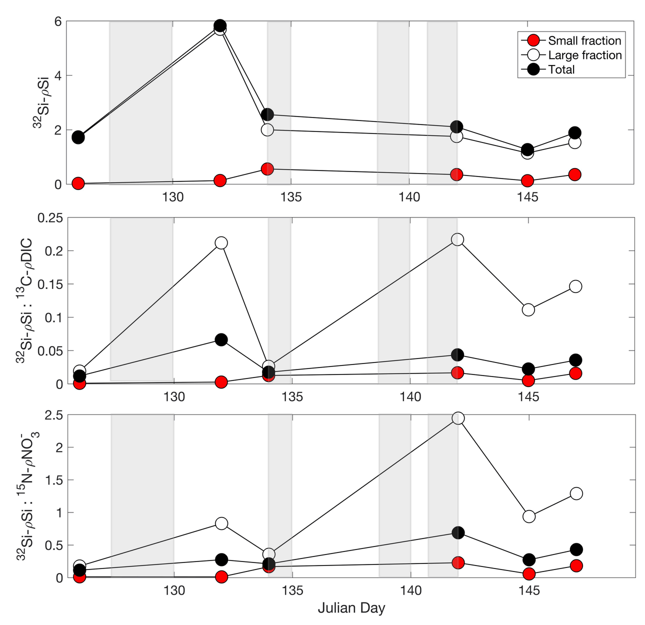


Fig. 5. Mixed layer depth and size-fractionated NPP, new production, regenerated production, ^{32}Si-ρSi, ^{32}Si-ρSi: ^{13}C-ρDIC, and ^{32}Si-ρSi: ^{15}N-ρNO_3^- through time.

- Total NPP was high and primarily driven by new production (f-ratio = 0.74) occurring in the large size-fraction cells
- NPP and new production exhibit net declines over time but with increased rates following Storm 1 (JD 134 and JD 132, respectively)
- ^{32}Si-ρSi experiments indicates a high but variable %siliceous phytoplankton NPP, ranging from 9.0 (JD 126) to 49.8% (JD 132)

Drivers between systems

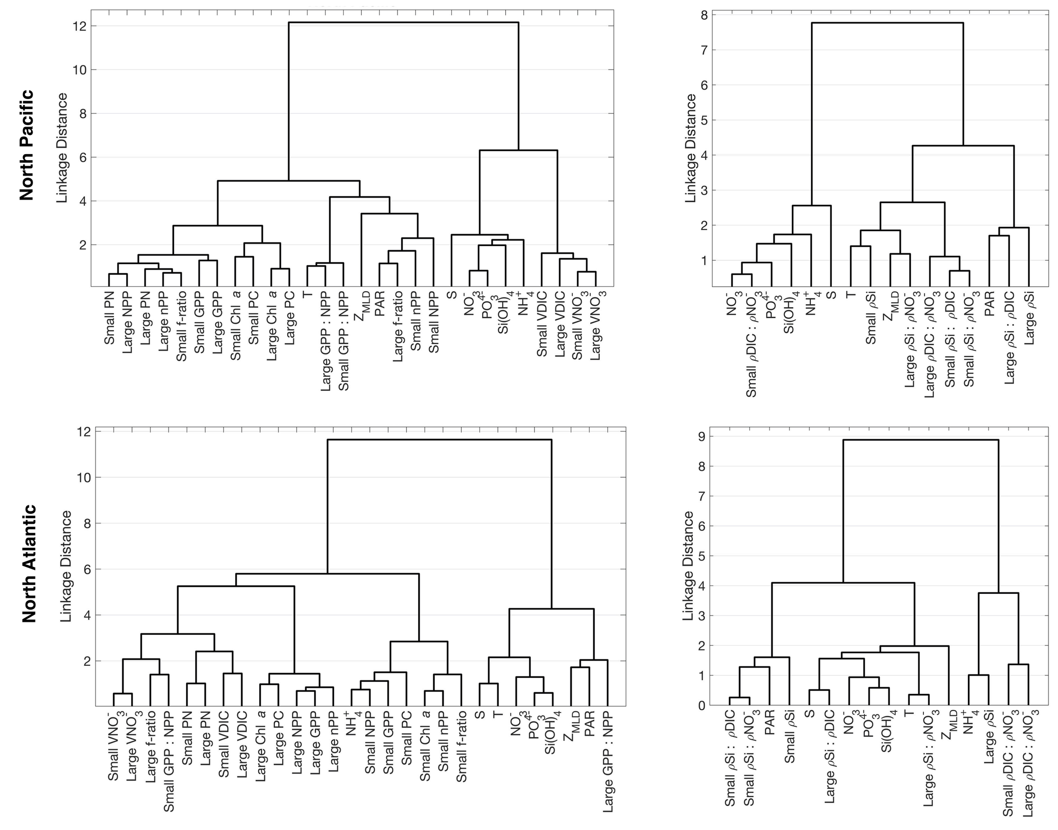


Fig. 6. Euclidean distance-based dendrograms of environmental parameters and phytoplankton biomass, production, and physiological informative ratios for the EXPORTS North Pacific and North Atlantic campaigns.

- Production and biomass appear more separated by size-fractions in the North Atlantic relative to the North Pacific
- Large size-fraction ρSi branches distinctly from ^{32}Si-ρSi: ^{13}C-ρDIC, supporting the notion of the uncoupling of silicic acid dynamics from production dynamics

Key Findings

- A turbulent physical environment enhanced nutrient concentrations and prevented monotonic bloom decline
- Diatoms appear to increase silicic acid uptake without increasing NPP
  - Decoupled ^{32}Si and ^{13}C uptake suggests enhanced silicification, likely making the cells heavier and increasing their physical export potential
- In both the EXPORTS North Pacific and North Atlantic campaigns, one size fraction appears to play a role in baseline ecosystem conditions while the other size fraction plays a dominant role in periods of disturbance from the baseline

Images from M.L. Parker and D. Steinberg

Acknowledgements

We thank the EXPORTS lead scientists Dr. Dave Siegel and Dr. Ivona Cetinic, chief scientists Dr. Deborah Steinberg and Dr. Jason Graff as well as the rest of the EXPORTS team, particularly the Hydro team for providing macronutrient concentrations. We also thank the captains and crews of the *RRS* James Cook and the *RRS* Discovery. This work was supported by NASA grant 80NSSC17K0552 to A.M, S.G., and N.C.