Revising Carbon Uptake Estimates in the European Arctic with a regional satellite algorithm and BGC-Argo data

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Alexandra Loginova, Astrid Bracher

25 November 2nd Ocean Carbon from Space workshop

Marine Organic Carbon Atlas (MOCA)
Pilot Demonstration for the Arctic

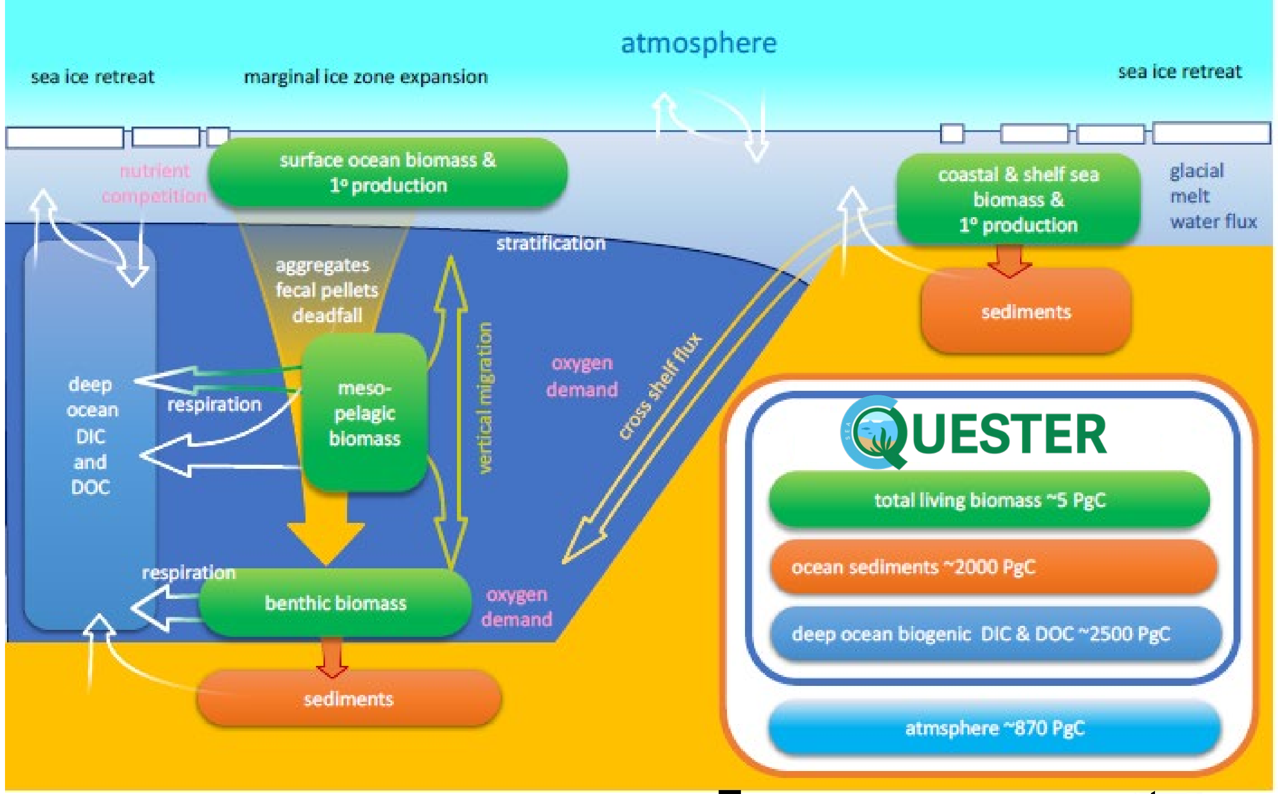
MOCA
marine organic carbon atlas

C uptake

C export

C recycling

C burial



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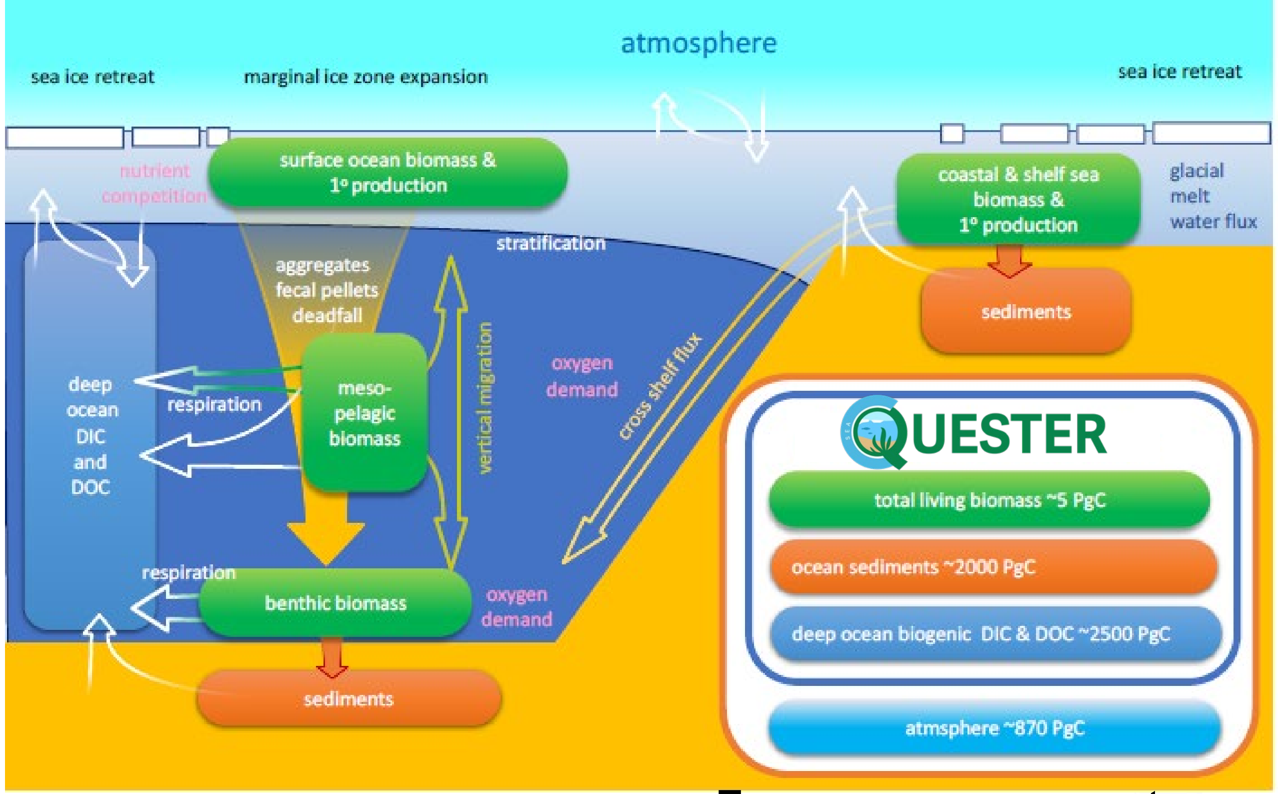

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Greenland Sea Primary Production (PP) algorithm development

$$P = (12/4.6) CHL_{tot} \overline{PAR}(0^{+}) \overline{a^{*}} \overline{\varphi_{\mu}}$$

Morel(1991)

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Data used for Greenland Sea adaptation:

- Chlorophyll a
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- PI parameters (from Bouman et al. 2018)
- Primary production (for validation)

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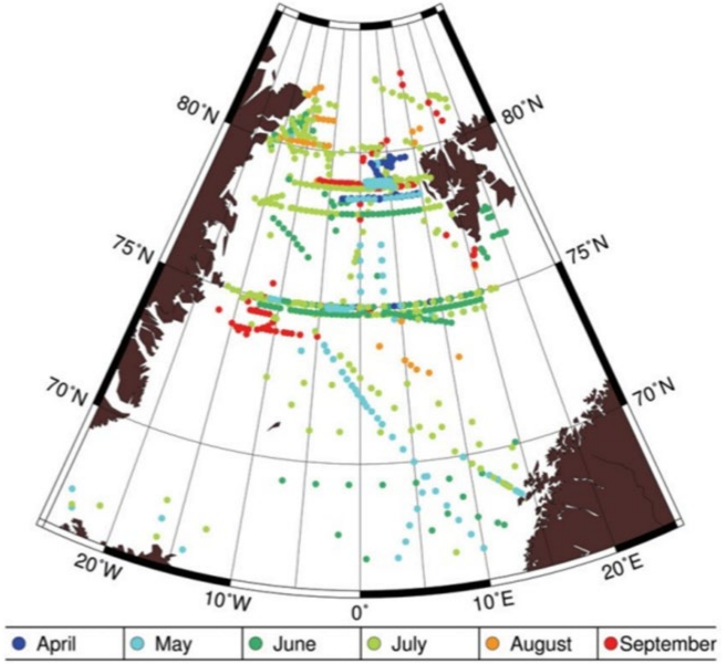
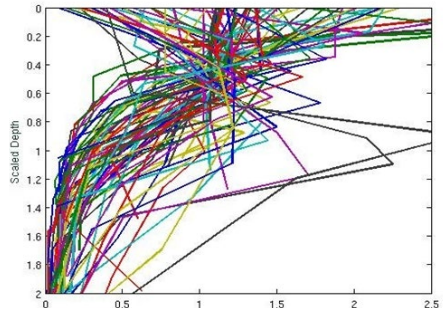
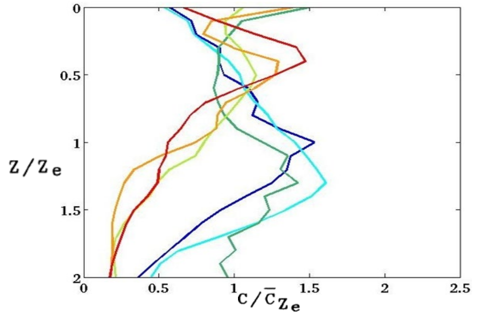
Example: CHL profile parameterization



- 1680 data profiles
- years from 1957

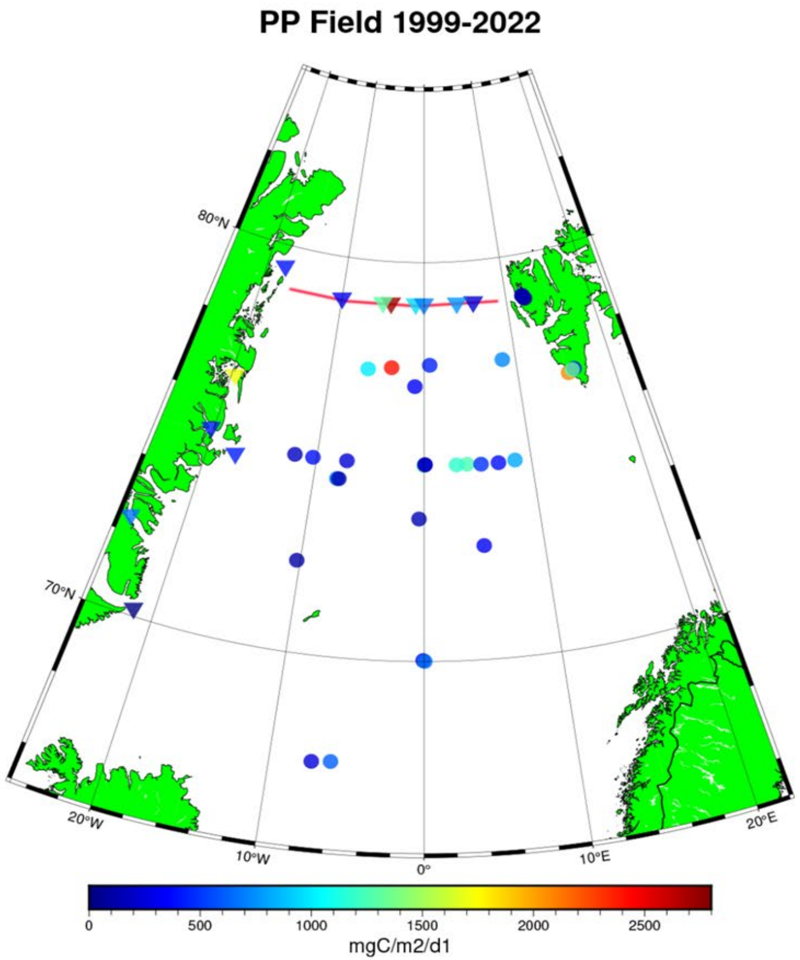


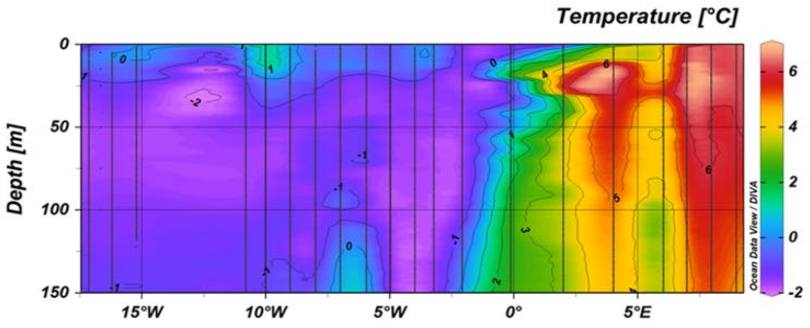
more than 3 depth
choice of categories

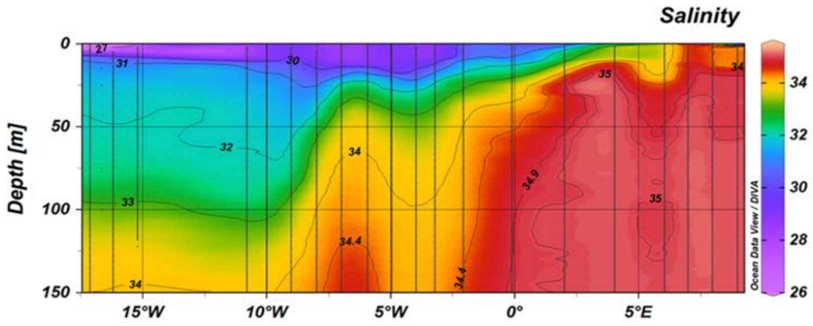


Cherkasheva et al. (2013)

Validation: PP field data







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Best performing model setup

Type of CHL	Type of PAR	CHL vertical profile	PAR/PUR	Integration depth
[3] - GlobColour Level 3 CHL	[1] - NOAA/NCEP Reanalysis PAR	[0] - Global CHL profile following Morel and Berthon (1988)	[0] - no coefficient applied to PAR	[0] - profiles integrated till euphotic layer depth
[4] - Copernicus-GlobColour Level 4 CHL;	[2] - EUMETSAT Level 2 OLCI PAR	[1] - Local CHL profile following Cherkasheva et al. (2013)	[1] - PAR converted to local PUR	[1] - profiles integrated till productive layer depth
	[3] - GlobColour Level 3 MODIS/ VIIRSN merged PAR		[2] - PAR converted to global PUR	

Cherkasheva et al., 2025 https://doi.org/10.3389/fmars.2024.1491180

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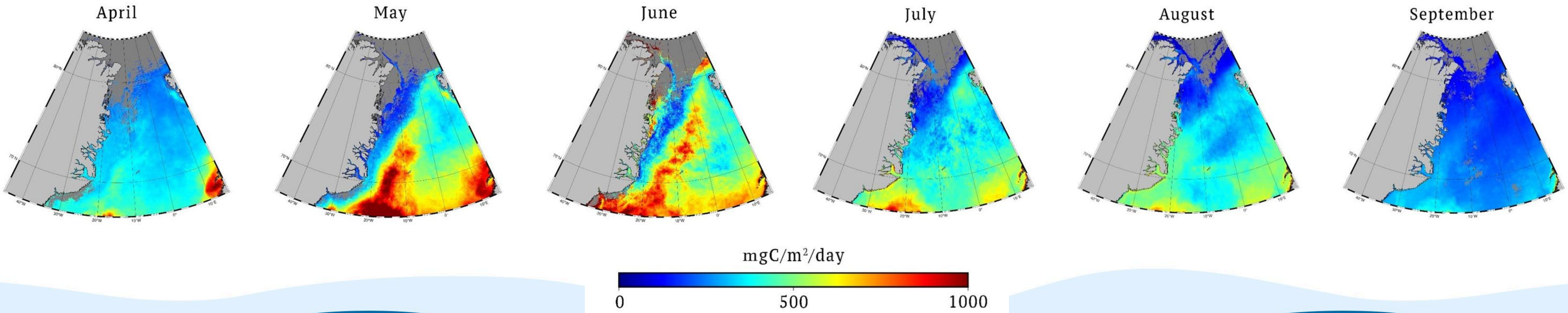
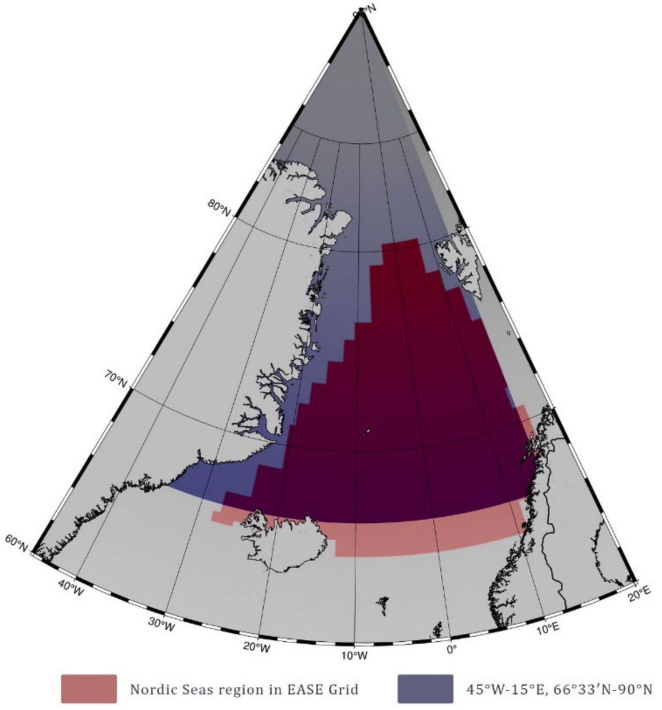
Monthly averaged PP, 1998-2022



Cherkasheva et al., 2025 https://doi.org/10.3389/fmars.2024.1491180

Results: Greenland Sea Basin estimates

	This study	Hill et al. (2013)	Arrigo and van Dijken (2015)	Ardyna et al (2013)
period	1998-2022	1998-2007	1998-2012	1998, 2007
annual (TgC/year)	330-346	308	136	228-230
monthly range(TgC/month)	33-77	13-122	ND	ND



Why is it larger? possible reasons

- account for local and not Arctic dataset (5 points vs 45 points),
- more spatial coverage in the northern part,
- account for CHL maximum

Results: Greenland Sea Basin estimates

	Source	Region	Period	Annual (TgC/year)	Month (TgC/month)					
					Apr	May	Jun	Jul	Aug	Sep
1	Hill et al. (2013) with SCM	Nordic Seas region in EASE Grid	1998-2007	308	*33.4*	*122.5*	*42.3*	*27.5*	*13.4*	*44.5*
2	Arrigo and van Dijken (2015)	45°W-15°E, 66°33′N-90°N	1998-2012	136.3	ND	ND	ND	ND	ND	ND
3	Ardyna et al. (2013)	Greenland-Norwegian Seas	1998	227.9	ND	ND	ND	ND	ND	ND
			2007	230.8	ND	ND	ND	ND	ND	ND
4	This study (related to #1)	Nordic Seas region in EASE Grid	1998-2007	344.1 (5.4)	45.3	77.9	73.7	60.3	54.1	32.7
5	This study (related to #2)	45°W-15°E, 66°33′N-90°N	1998-2012	340.0 (10.6)						
6	This study (related to #3)	45°W-15°E, 66°33′N-90°N	1998	333.1 (29.8)						
			2007	333.7 (1.5)						
7	This study (own estimates)	Nordic Seas region in EASE Grid	1998-2022	346.6 (2.4)	44.4	77.1	76.0	60.6	55.2	33.2
8	This study (own estimates)	45°W-15°E, 66°33′N-90°N	1998-2022	342.1 (9.6)	42.8	69.7	74.1	62.3	58.3	35.0

The average between the two setups of models [4,2,1,1,1] and [3,2,1,1,0] is given, the standard deviation is the number in the brackets. Monthly values from Hill et al. (2013) are in italics as we have calculated them ourselves from Hill et al. (2013) averages without SCM using a method given in the source. ND, no data found in the source.

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Different types of production

$$CO_2 + H_2O \;\; \overbrace{\underbrace{\overrightarrow{NCP}\;\overleftarrow{HR}}_{NPP}\;\;\overleftarrow{AR}}^{\overrightarrow{\quad GPP \quad}} \;\; Organic\ Matter + O_2$$

GPP - Gross Primary Production

NPP - Net Primary Production

NCP - Net Community Production

AR - Autotrophic Respiration

HR - Heterotrophic Respiration

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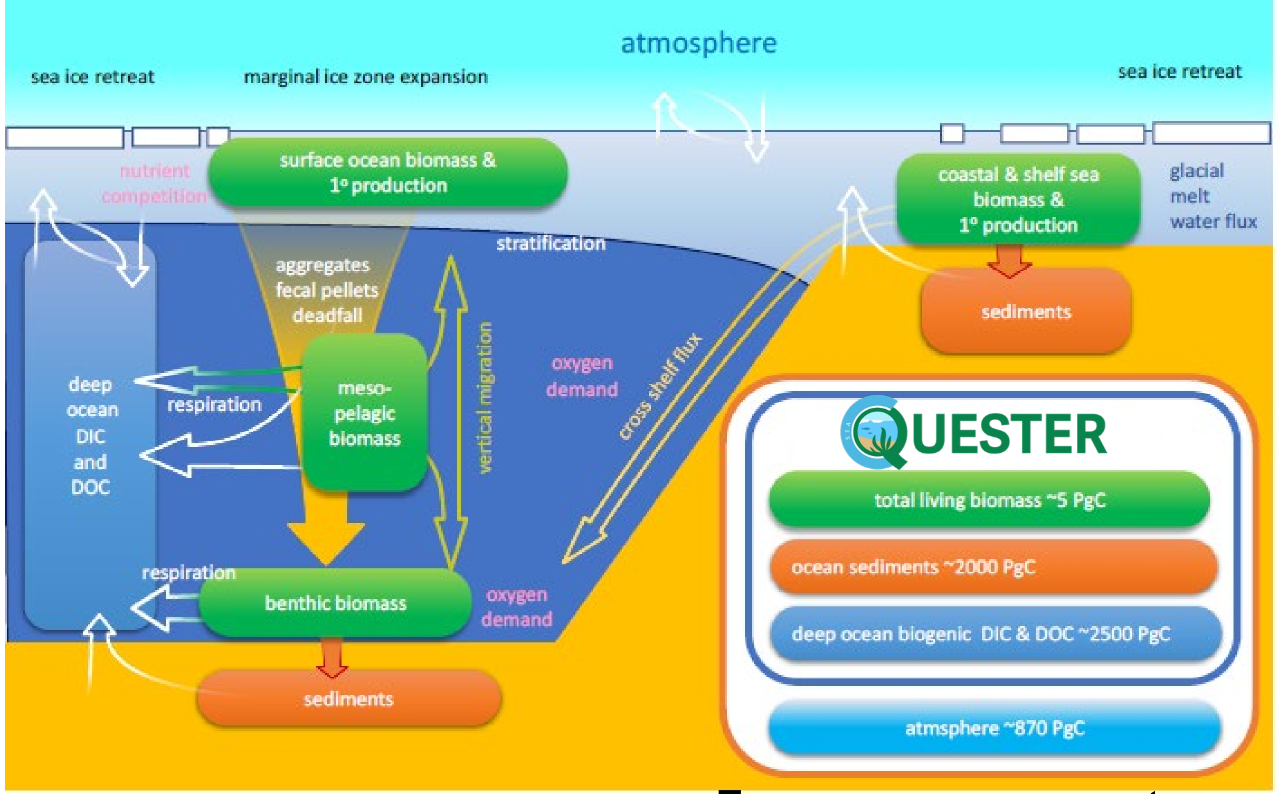

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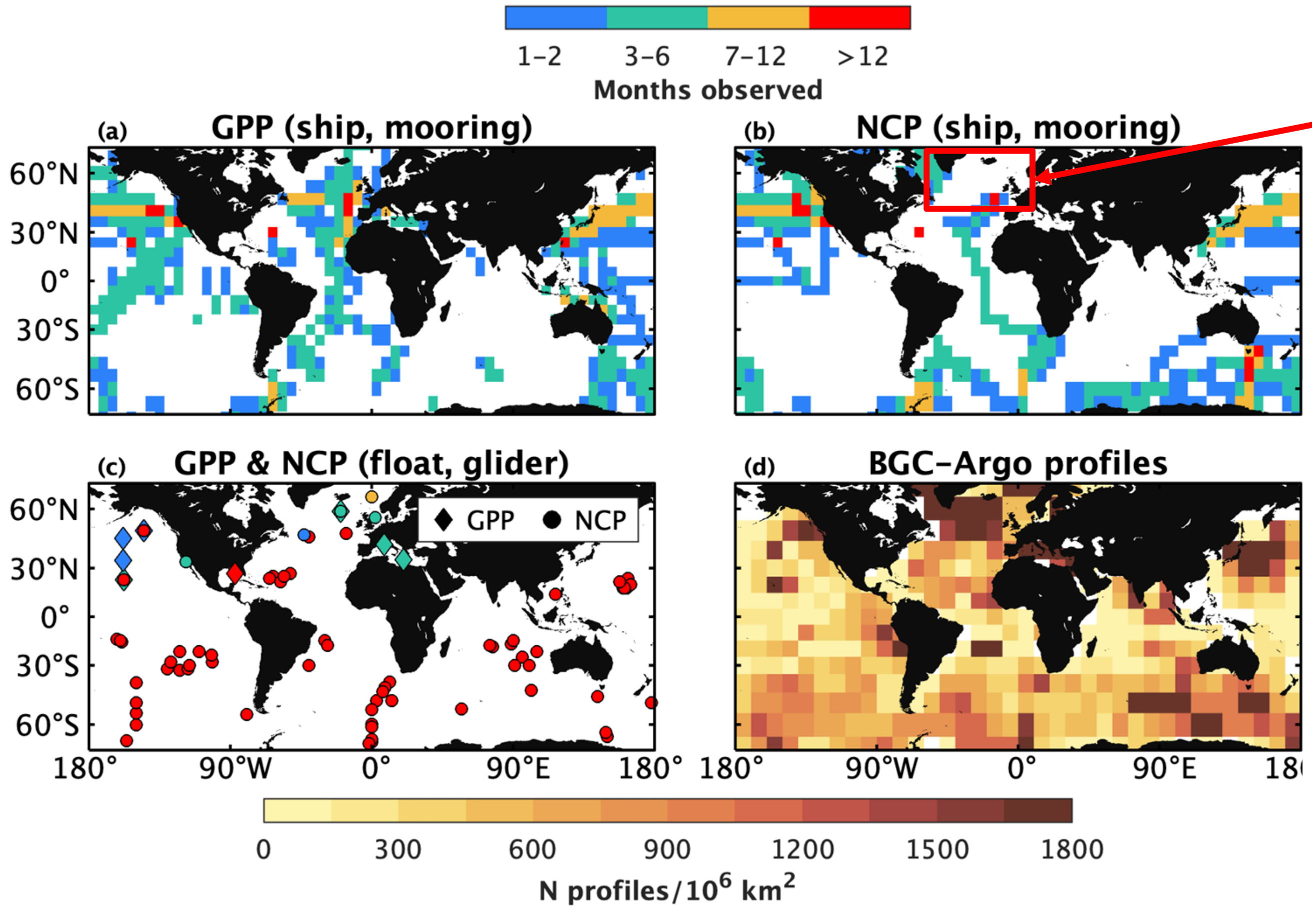
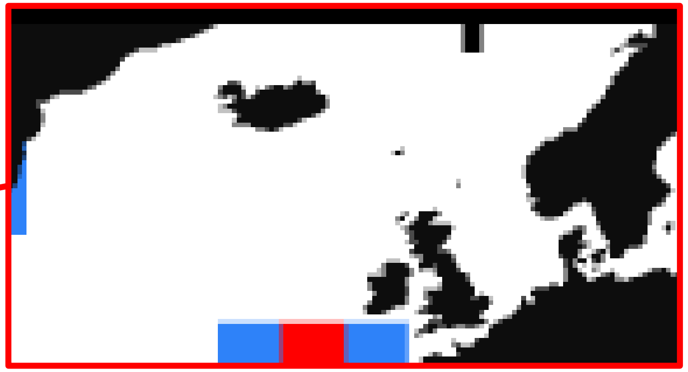
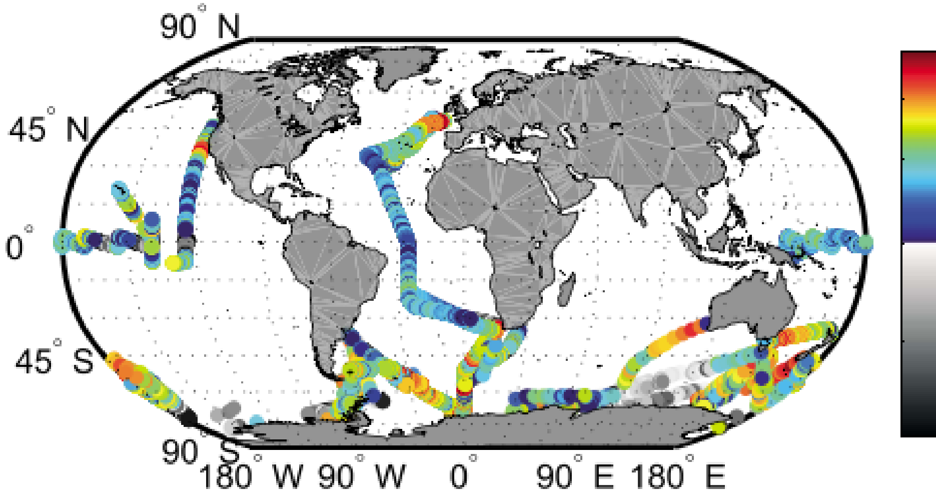
NCP estimates: main challenges







Izett et al., 2024
https://doi.org/10.5194/bg-21-13-2024

Li and Cassar, 2016
doi:10.1002/2015GB005314

NCP estimates: main challenges

Method	Field Data Needed	Temporal scale	Cons
In Situ Incubations	O_2 or DIC changes in light/dark bottles	Daily	high sampling effort, short-term estimates
Oxygen-to-Argon (O_2/Ar) Method	O_2/Ar ratio, temperature, wind speed	Daily to weekly	Requires specialized equipment, surface-limited
Oxygen Mass Balance (BGC-Argo)	O_2 profiles, wind speed, MLD	Weekly to annual	Sensitive to gas exchange errors
Nitrate sensors (BGC-Argo)	nitrate profiles, MLD	Weekly to annual	Ignores regenerated production, weekly to annual estimates (not daily)
DIC Mass Balance	pCO_2 (converted to DIC), salinity, temperature	Seasonal to annual	mostly surface-limited, sensitive to gas exchange errors
Nitrate Drawdown (from water samples)	Nitrate profiles	Seasonal to annual	Ignores regenerated production (leads to underestimation), could be challenging to estimate winter nitrate levels
Triple Oxygen Isotopes	Isotopic O_2 samples	Daily to weekly	Lab processing effort unknown to me, specialized equipment needed
Optical Sensors (BGC-Argo) (?)	Backscatter, fluorescence	Daily	Indirect, calibration needed
Thorium-234 Method (attached to sinking particles)	^{234}Th and POC profiles	Weekly to monthly	Requires radionuclide handling, gives a componet of NCP usually used as an additional method in NCP intercomparison
Sediment Traps	POC flux data	Seasonal to annual	Expensive, gives a componet of NCP usually used as an additional method in NCP intercomparison
Various sensors on gliders (oxygen, pCO2)	same as p.4	Weekly to seasonal	same as p.4

link to table

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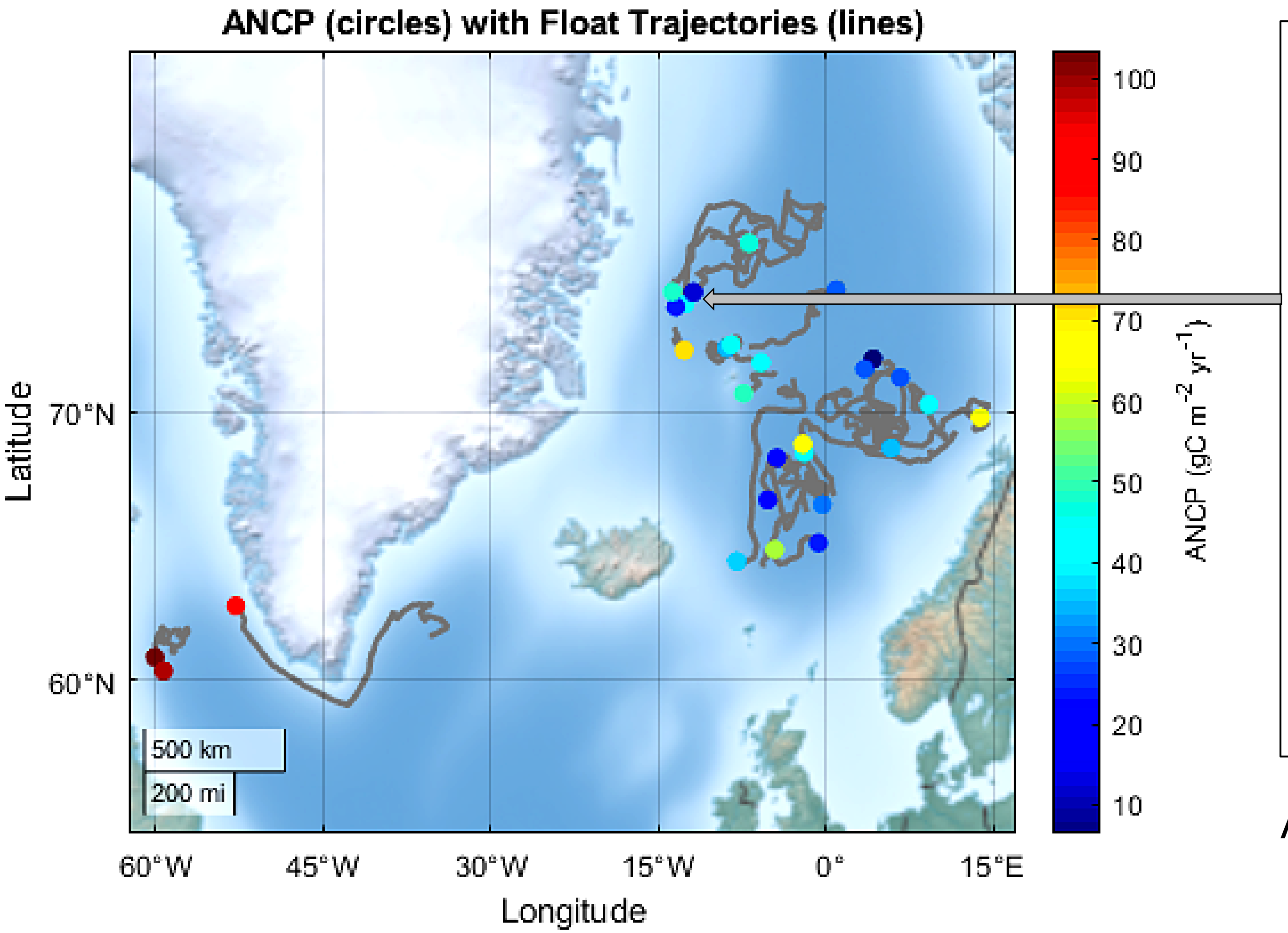
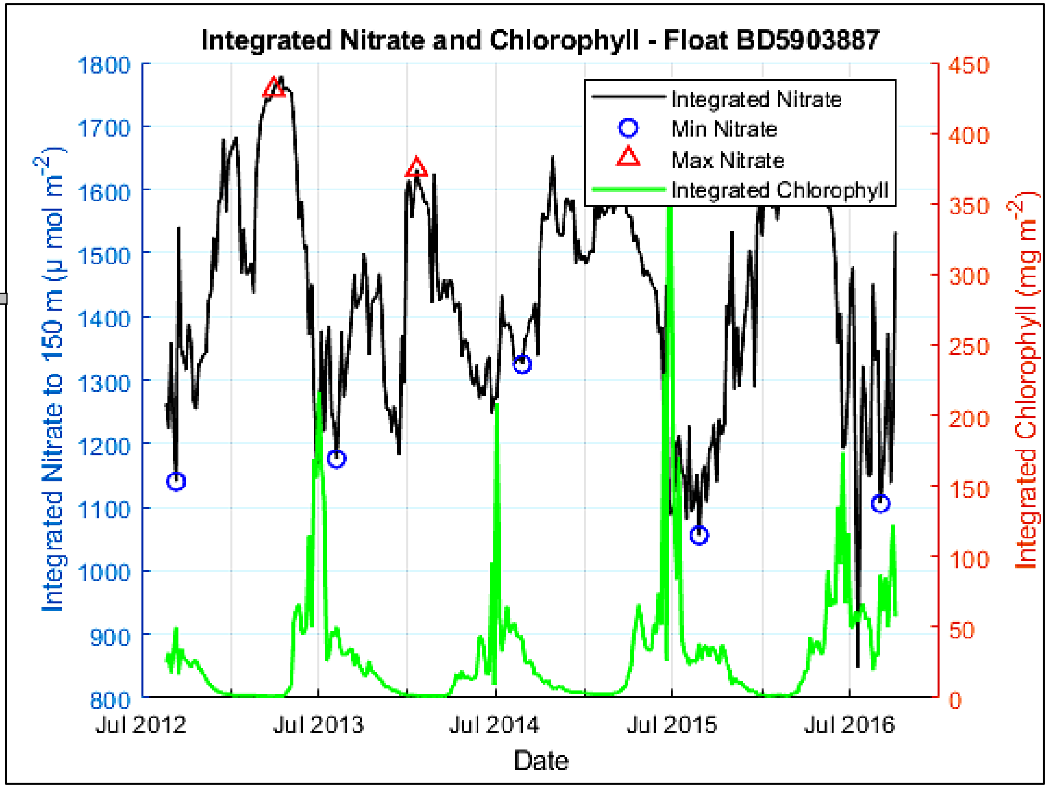
Annual Net Community Production (ANCP) from Argo Floats





ANCP calculation method following Johnson et al. (2017)

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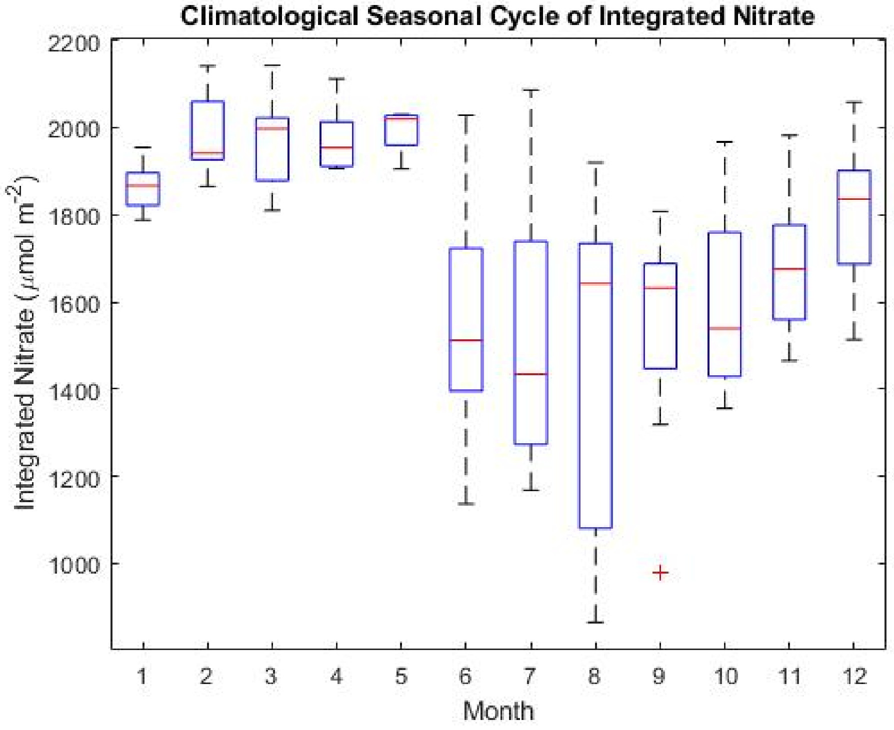
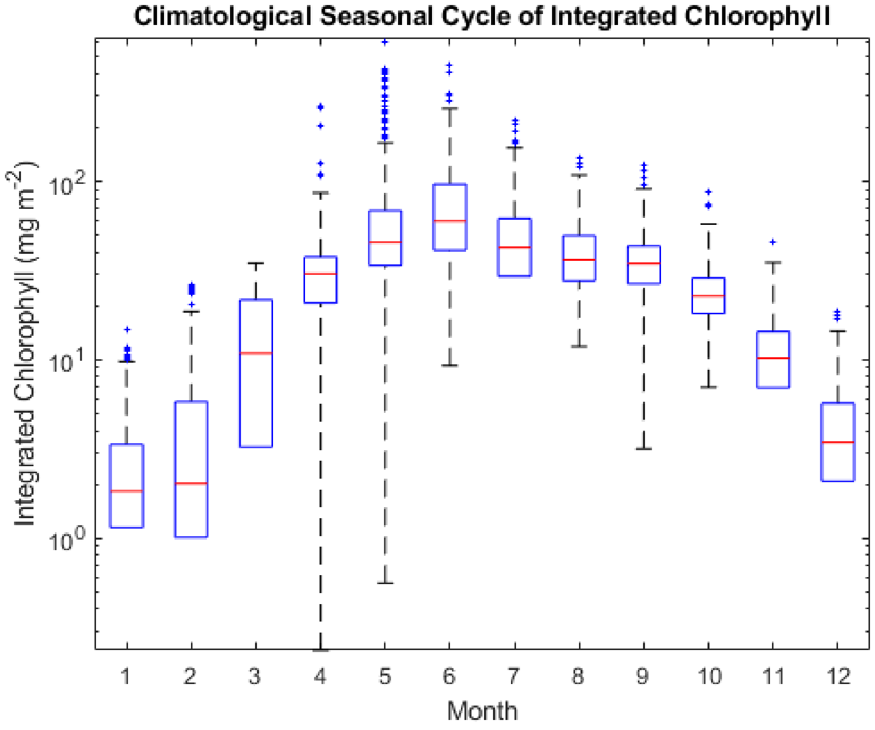
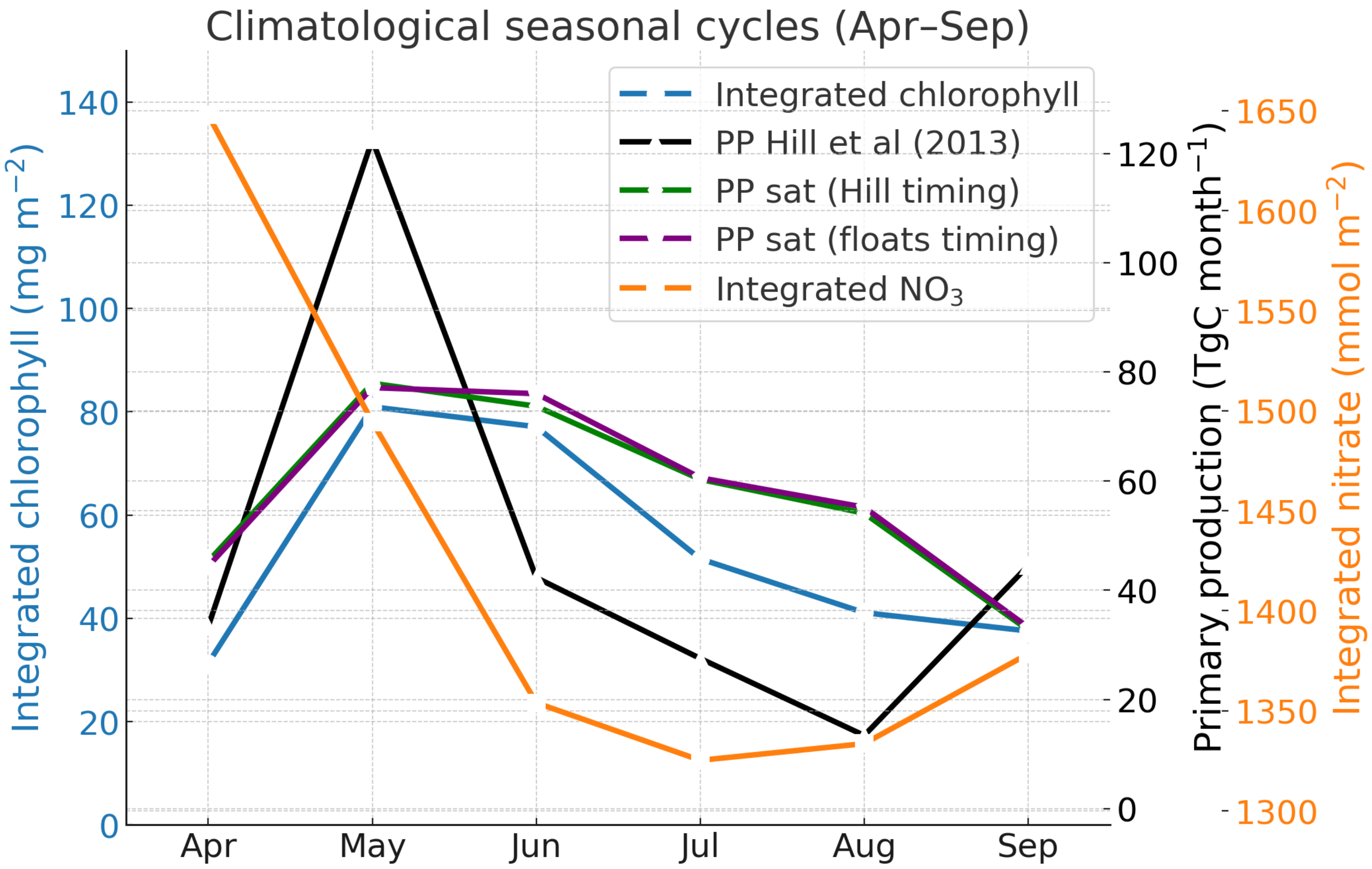
Climatological cycles





BGC Argo CHL and satellite PP agree well



Conclusions

PP algorithm is operational with Python codes uploaded online Accuracy of the selected model setups to reproduce the field data in terms of RMSD (RMSD=0.4) is better than in the related Arctic studies (RMSD=0.61-0.67)*.

Larger Greenland Sea basin PP annual estimates, seasonal cycle pattern align with BGC Argo CHL

NCP algorithm is in progress as function of PP satellite, NCP BGC Argo estimates are in the range of glider studies

Cherkasheva et al., 2025 https://doi.org/10.3389/fmars.2024.1491180

*Lee et al. (2015), Saba et al. (2011)

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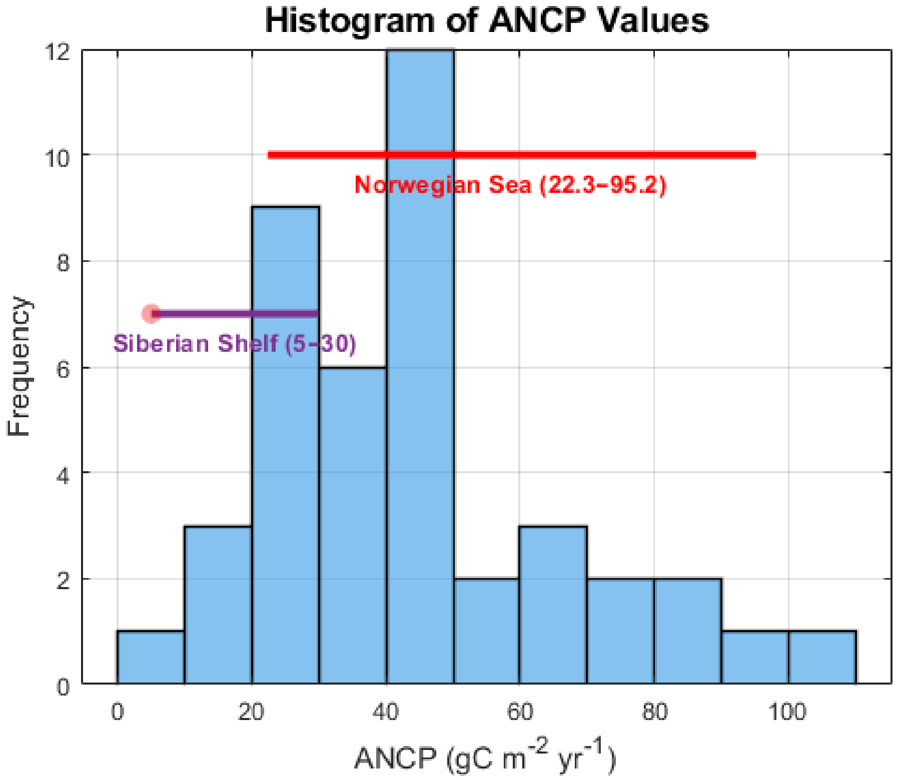

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Knowledge gaps and priorities for next steps

- Scarce to no data for validation of PP and NCP at polar latitudes
  - Use not only traditional methods (C14), but also alternative (oxygen sensors, BGC floats)
    Include at least PP and maybe NCP as GOOS Essential Ocean Variable
- Need for Arctic-specific CHL satellite algorithm
  - Zoffoli et al is planned to be soon available on Copernicus, better to use it if you're working in the Arctic
- Need for reliable PAR level 3 product
  - Using climatologies or level 2 PAR from EUMETSAT instead
- No salinity sensor for half of the BGC float dives (3445 out of 6881)
  - Include it in basic setup

Global Observing Ocean System EOV specification sheets

Physics	Biochemistry	Biology and Ecosystems
Sea state Ocean surface stress Sea ice Sea surface height Sea surface temperature Subsurface temperature Surface currents Subsurface currents Sea surface salinity Subsurface salinity Ocean surface heat flux Ocean bottom pressure Turbulent diapycnal fluxes (*pilot)	Oxygen Nutrients Inorganic carbon Transient tracers Particulate matter Nitrous oxide Stable carbon isotopes Dissolved organic carbon	Phytoplankton biomass and diversity Zooplankton biomass and diversity Fish abundance and distribution Sea turtles abundance and distribution Seabirds abundance and distribution Marine mammal abundance and distribution Coral cover and composition Seagrass cover and composition Macroalgal canopy cover and composition Mangrove cover and composition Microbe biomass and diversity (*pilot) Benthic invertebrate abundance and distribution (*pilot)
Cross-disciplinary (including human impact)		
	Ocean colour Marine debris (*pilot)	Ocean sound

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1. EOV information

ESSENTIAL OCEAN VARIABLE (EOV)	Phytoplankton biomass and diversity
DEFINITION	Phytoplankton biomass typically refers to either: weight (mass as the concentration per unit area/volume) and/or abundance or quantity of organisms (number of individuals per volume). Phytoplankton diversity or composition refers to the variability among phytoplankton from all sources including, inter alia, marine and other aquatic ecosystems; this includes diversity within species and between species (e.g., genetic diversity, taxonomic diversity, size, etc.) (https://www.cbd.int/convention/articles?a=cbd-02) Cyanobacteria are primarily addressed here as key members of the phytoplankton, but also addressed in the microbes EOV as members of the Bacteria.
EOV SUB-VARIABLES key measurements that are used to estimate the EOV *bare minimum	*Phytoplankton biomass (concentration) *Composition (species, functional types) Number of HAB Events
SUPPORTING VARIABLES - other measurements that are useful to provide scale or context to the sub-variables of the EOV	Nutrients, sea surface temperature, subsurface temperature, sea surface salinity, subsurface salinity, oxygen, inorganic carbon, particulate organic matter concentration, total suspended organic matter concentration, ocean colour and bio-optical variables (remote sensing reflectance, absorption, scattering coefficients, photic or euphotic zone depth), mixed layer depth, surface currents and subsurface currents (vertical, horizontal), primary productivity Complementary: cell size, "biovolume", nutritional content, density, DNA composition, ocean colour (bio-optics)
DERIVED PRODUCTS outputs calculated from the EOV and sub-variables, often in combination with the supporting variables	Phytoplankton Functional Types Diversity indices: species richness, species evenness, Simpson, etc.

Phytoplankton Biomass and Diversity

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Key stakeholders

BioEcoOcean

International Ocean Carbon Coordination Project IOCCP

GOOS BioEco

DBO arctic change — Distributed Biological Observatory

ODIS

Partners

Uppsala Universitet

DTU

EuroGOOS — European Global Ocean Observing System

Università di Pisa

unesco — Intergovernmental Oceanographic Commission

GOOS — The Global Ocean Observing System

OBIS — Ocean Biodiversity Information System

ciimar — Centro Interdisciplinar de Investigação Marinha e Ambiental

Institute of Oceanology Polish Academy of Sciences

Mercator Ocean International

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