Nutrients vs. turbulence, and the future of Arctic Ocean primary production

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Background

Weak upward mixing of new nutrients and little insolation due to sea ice conspire to severely restrict primary productivity in the Arctic Ocean. These two phenomena might become disentangled in a seasonally ice free Arctic Ocean, and so their relative contributions have to be known in order to understand the ecology and carbon cycle of the present and future Arctic Ocean.

Stratification varies strongly across the Arctic Ocean (Fig. 1). This restricts nutrient fluxes either predominantly on a seasonal (shelf) or perennial scale (basin). Accordingly, the role of upward mixing of nutrients depends on when and where they are evaluated (Fig. 5). **This poster presents estimates of nitrate fluxes in the Arctic Ocean and speculates on the associated primary production in a future climate.**

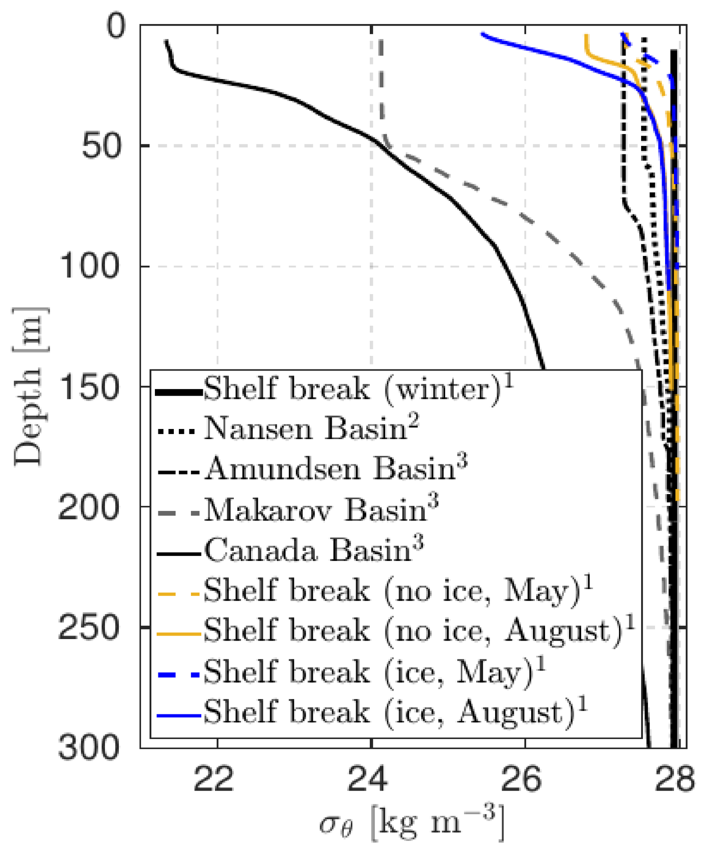
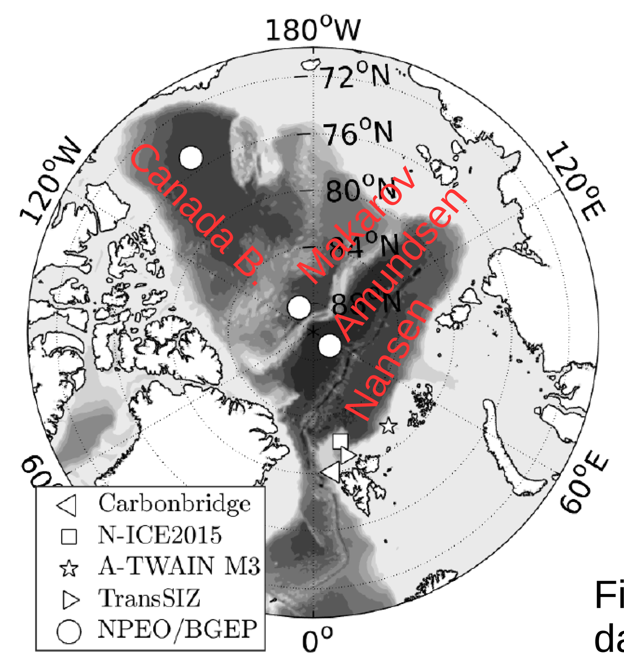


Fig. 1: Representative vertical density profiles across the Arctic Ocean, from the seasonally stratified shelf (here the shelf break in the Atlantic inflow region) to the year-round stratified deep basins.

Data Set

New measurements: Colocated vertical profiles of turbulent microstructure (MSS dropsonde, IWS Wassermesstechnik; ~850 profiles) and nitrate concentrations (ISUS, Satlantic; ~125 profiles and 1 year of mooring data).



In addition, reanalysis of pre-existing (North Pole Environmental Observatory) ISUS and micro-/finestructure turbulence data provided new insights about nutrient supply across the deep Arctic Ocean basin.

Fig. 2: The Arctic Ocean and location of data sets discussed on this poster.

Central Arctic Ocean[c]

- Weak mixing and strong stratification constrain nitrate fluxes (F_N)
- Atlantic sector has largest present-day and also the largest potential for increases in F_N (hence light is limiting), while the Amundsen and Canadian Basins are nutrient-limited
- Increasing stratification alone in a future Arctic Ocean can drive strong reductions in nutrient supply, but net change possibly insignificant
- Future of near-inertial turbulent mixing under a seasonal ice cover important for nitrate fluxes, but so far uncertain

Table 1. Nitrate fluxes by region of the Central Arctic Ocean

Region	F_N [a]	$F_{N,max}$ [a,b]	$F_{N,max\ (2100)}$ [a,c]
Nansen/Yermak	7.0	24	12
Amundsen Basin	1.8	3.2	1.6
Makarov Basin	0.5	0.5	0.3
Canada Basin	0.4	0.4	0.4
Area-weighted mean[d]	1.4	3.2	1.7

[a]Units [g C m^{-2} yr^{-1}] converted using the Redfield C:N ratio
[b]maximum possible given current mixing and stratification
[c]assuming change only in stratification following NorESM RCP8.5 scenario
[d]uncertainty around ±0.5

Seasonal upper-ocean fluxes[a,b,d]

- Strong and shallow stratification due to ice melt water lenses in Arctic summer
- Wind-driven mixing is attenuated rapidly below the upper tens of meters, which isolates the seasonal nitracline
- In Atlantic sector: Upward nitrate flux 0.3 and 0.7 mmol m^{-2} d^{-1} under ice cover and in open water, respectively, due to stronger stratification under melting sea ice

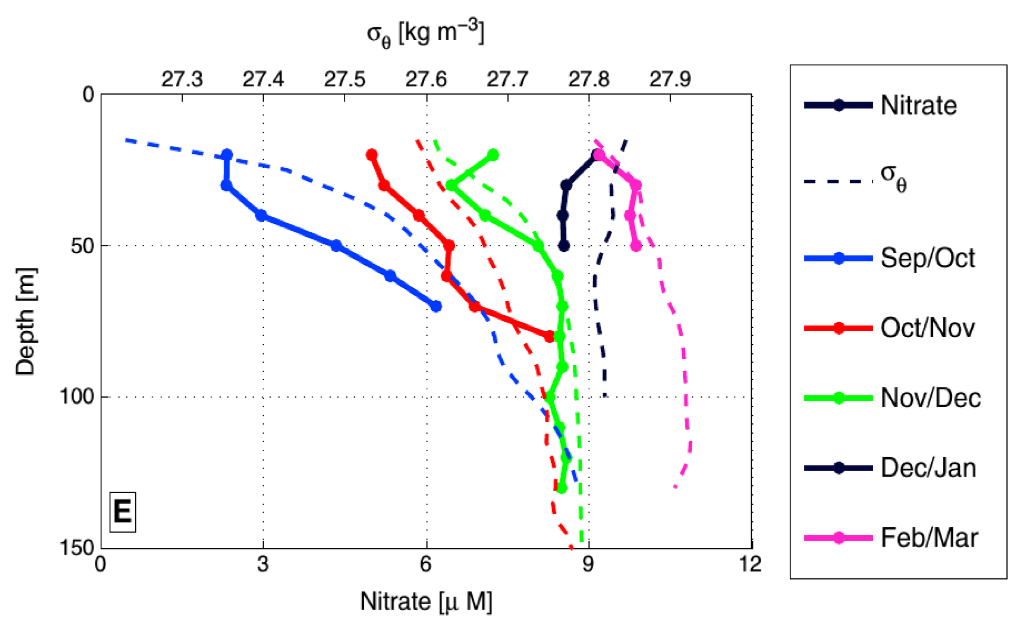


Fig. 3[a]: Vertical homogenization of NO_3 and density at the shelf slope north of Svalbard by December. Intense fall and winter mixing aided by convection replenishes upper ocean nitrate inventories (F_N≈2.5 mmol m^{-2} d^{-1}). This balances the bulk of the annual nitrate drawdown, such that summertime fluxes (see above) are insignificant for the annual net community production.

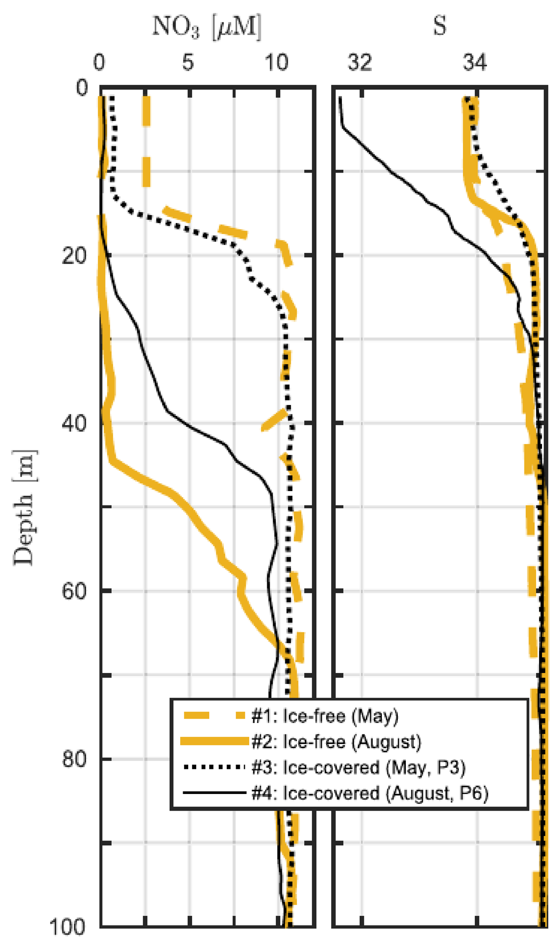


Fig. 4[b]: Example profiles of NO_3 concentration and salinity in the Marginal Ice Zone. In late summer, the nitracline has migrated below the pycnocline due to continued drawdown.

Conceptual framework

- After the spring bloom has depleted the mixed layer nitrate inventory, further new production depends on upward mixing of nitrate from deeper in the nitracline
- As the season progresses, the seasonal nitracline migrates downwards. Deep fall/winter mixing brings up nutrients from below the base of the nitracline, and erodes seasonal stratification
- All these seasonal processes are embedded into the upper parts of the winter mixed layer. They do not affect the year-round low fluxes through the perennial nitracline wherever one is present (central Arctic Ocean)
- All the fluxes we have measured are very small compared to the annual nitrate drawdown on the shelves. This also favours oligotrophic conditions and thus development of small-celled, low-export communities during summer

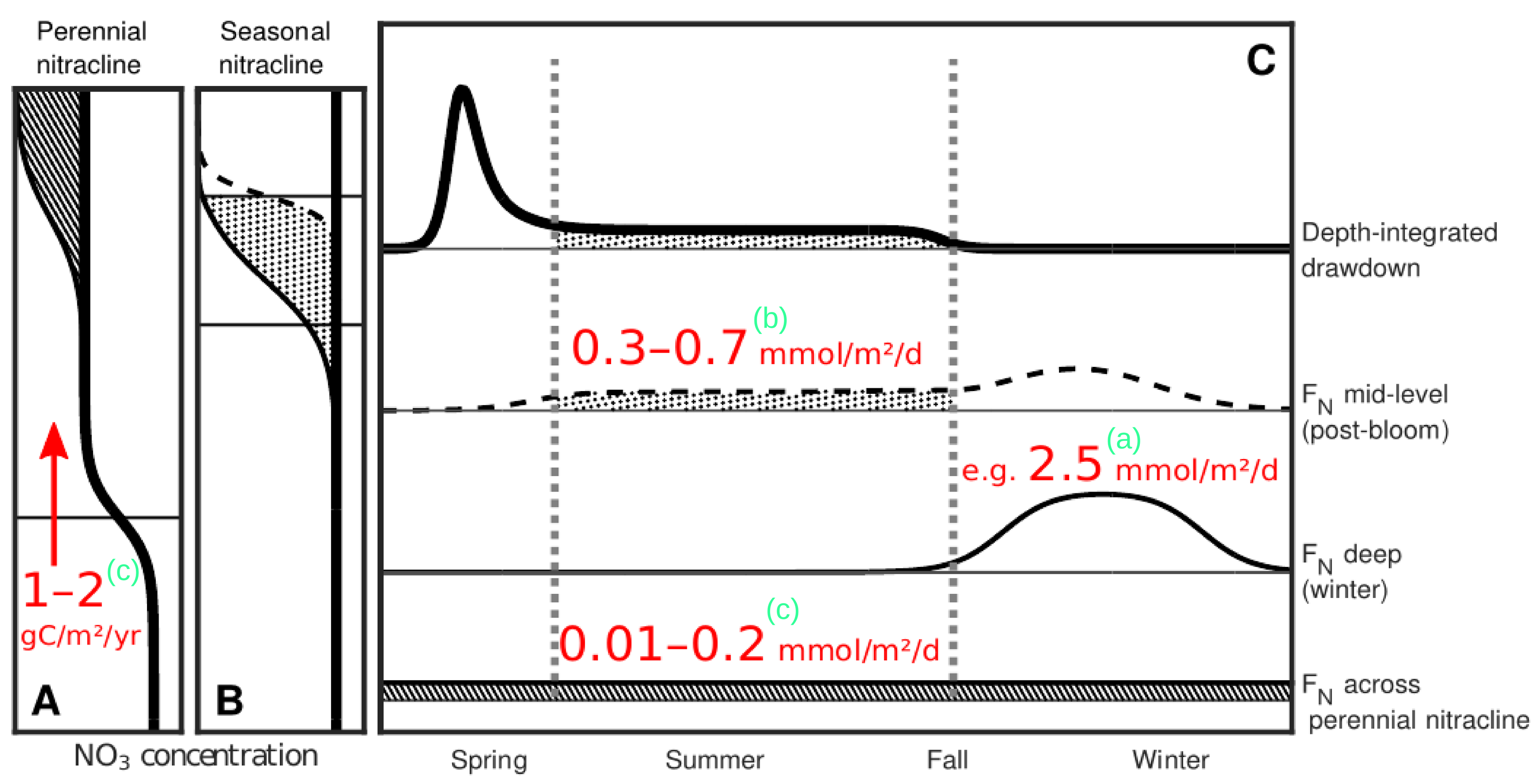


Fig. 5: Schematic nitrate profiles (Panels A,B) and associated turbulent fluxes through different seasons (Panel C). For each shading, the regions are equal in area content.

Conclusions

- Hydrographic contrasts govern processes determining seasonality and intensity of nitrate fluxes
- Little potential for new production under seasonal ice cover except in the Nansen Basin close to the inflow of Atlantic Water where light is currently strongly limiting primary production
- Fall blooms could provide substantial new production due to entrainment of deeper nutrients when mixed layers deepen after the ice is melted, but not when the nitracline is much deeper than the pycnocline
- Future changes in wind energy input and stratification can drive marked changes. However, the present-day baseline in diffusive fluxes is so low that even relatively large changes would be small in absolute numbers

References

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