Possible Errors in Marine vs. Terrestrial Carbon Sequestration Budget for the Arctic Region

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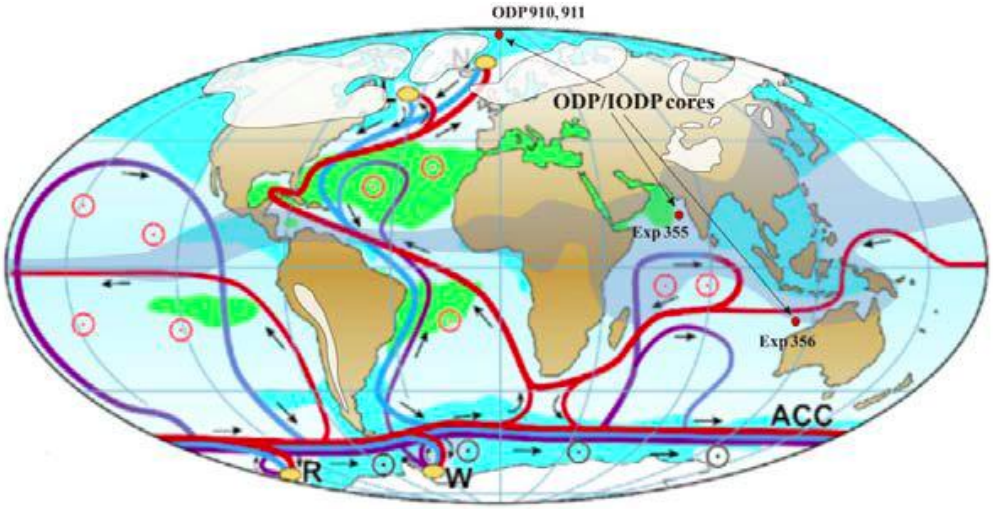
Pliocene Arctic Climate Teleconnections (PACT)



Quantitative estimates of Mid-Pliocene Warmth in the Arctic region and explore its teleconnections with South Asian and Australian Monsoon systems

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First evidence of denitrification vis-à-vis monsoon in the Arabian Sea since Late Miocene

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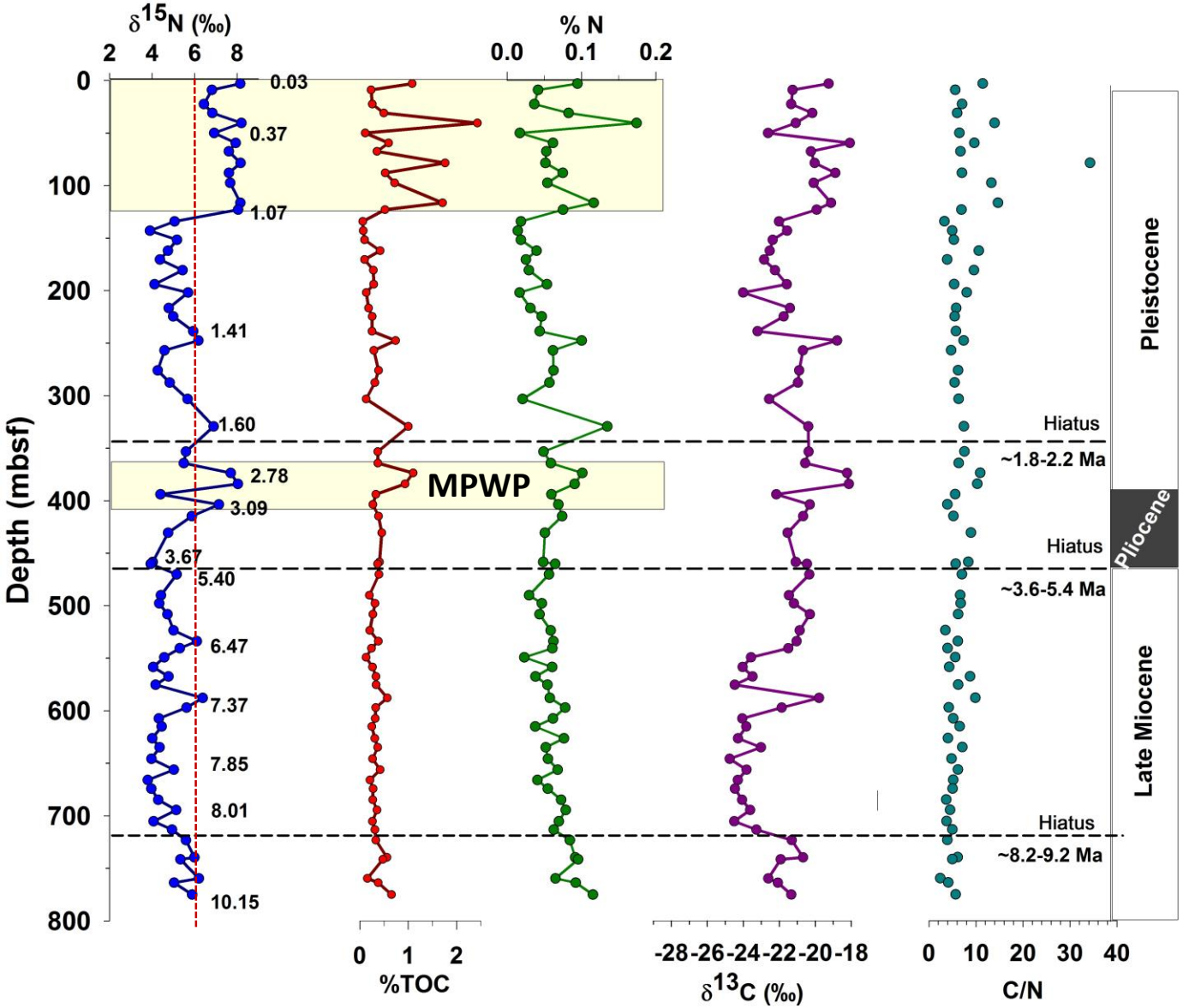
In the Arabian Sea, South Asian monsoon (SAM)-induced high surface water productivity coupled with poor ventilation of intermediate water results in strong denitrification within the oxygen minimum zone (OMZ). Despite the significance of denitrification in the Arabian Sea, we have no long-term record of its evolution spanning the past several million years. Here, we present the *first* record of denitrification evolution since Late Miocene (~10.2 Ma) in the Eastern Arabian Sea, where the SAM generates

Denitrification & Productivity Variability related to the South Asian Monsoon



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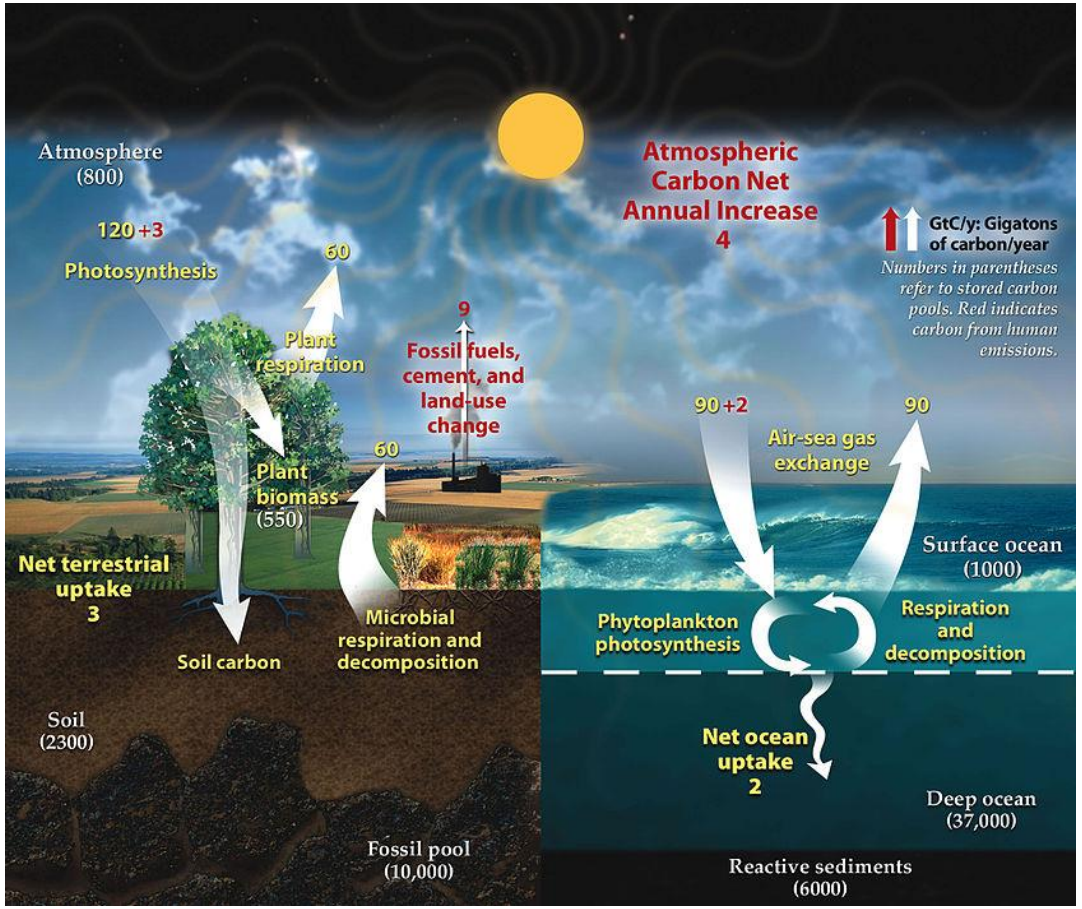
Evidence of Anomalously Low $\delta^{13}C$ of Marine Organic Matter in an Arctic Fjord

Vikash Kumar, Manish Tiwari, Siddhesh Nagoji & Shubham Tripathi

Accurate estimation of relative carbon deposition (marine vs. terrestrial) is required for understanding the global carbon budget, particularly in the Arctic region, which holds disproportionate importance with respect to global carbon cycling. Although the sedimentary organic matter (SOM) concentration and its isotopic composition are important tools for such calculations, uncertainties loom over estimates provided by organic-geochemical bulk parameters. We report carbon and nitrogen concentrations and isotopes ($\delta^{13}C$ and $\delta^{15}N$) of SOM at an Arctic fjord namely Kongsfjorden. We find that the bound inorganic nitrogen (ammonium attached to the clay minerals) forms a significant proportion

Carbon Sinks: CO_2 Sequestration from the Atmosphere

- The atmosphere is essentially a large flux reservoir for carbon whose concentration depends on the exchanges with other reservoirs
- Among various other sinks (vegetation, solubility pump, biological pump etc.) is the removal of atmospheric CO_2 via transportation of land-derived organic matter into the oceans where they are buried within the sediments
- Marine vs. terrigenous organic matter burial

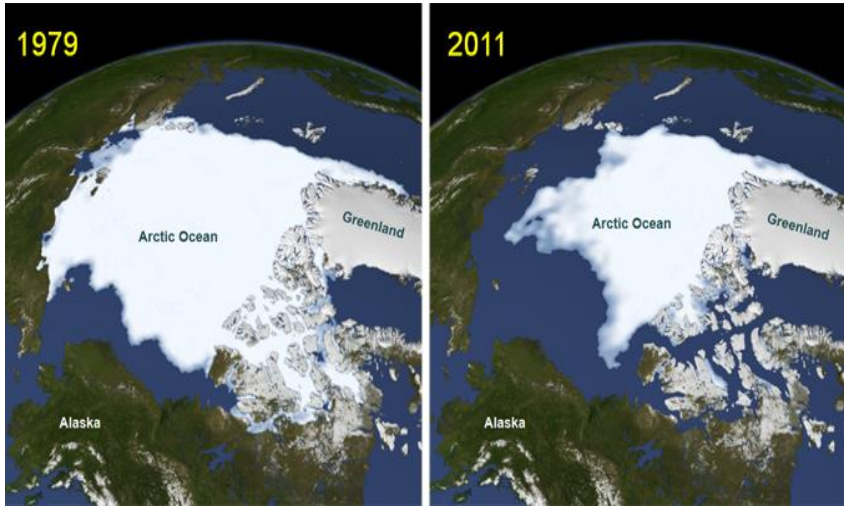


Carbon Cycle

The Importance of the Arctic Region for Terrestrial Carbon Sequestration

- Though, the Arctic Ocean represents only 2.5% of the world ocean area, it plays an important role in the global carbon cycle by accounting for 7–11% of the global burial flux
- Marine productivity is low in the Arctic region due to sea-ice cover
- Terrestrial carbon is refractory, marine carbon is labile; Less than 1% of primary production is available for burial
- High terrestrial deposition in central and marginal environments of Arctic Ocean where transportation is facilitated via sea ice.

Sea Ice Cover over Arctic



- Terrestrial carbon constitute major proportion of organic carbon in buried sediments: Up to 0.1 Gt/y of the total 0.16 Gt/y of estimated burial flux

How to estimate marine vs. terrestrial carbon in sediments?

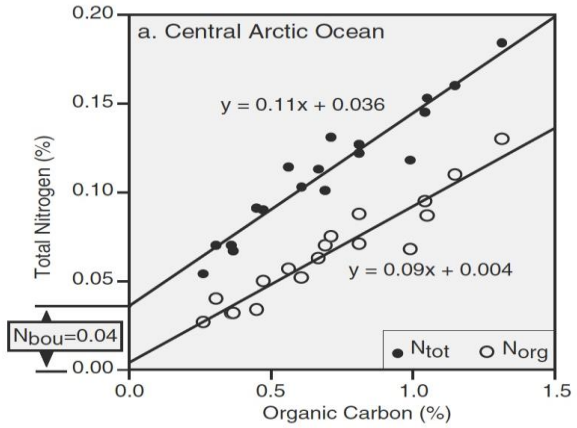
- End-member $\delta^{13}C$ based reconstruction (most widely used)
- C-3 plants are the most common terrestrial source of organic matter in sediments

	$\delta^{13}C$
Atmospheric CO_2:	-6 ‰ to -7 ‰
C-3 land plants:	average -27 ‰
Marine organic matter:	average -21 ‰

- **Problem in the Arctic region**: high pCO_2 may give rise to highly depleted Marine Organic Carbon (MOC).
- Using fixed end-member values without proper constraining may lead to gross error in our estimates.

C/N Ratio as Source Indicator

- The C/N ratio in marine organisms, given by Redfield (1934) and later modified by Takahashi et al. (1985) ranges between 6.5 and 8.7
- Terrestrial organic matter predominantly consists of compounds like cellulose, lignin etc. with much lower nitrogen content
- The C/N value in land derived organic matter therefore is much higher and found to vary between 20 and 100 (Meyers 2003)
- Inorganic nitrogen bound to ammonium in potassium rich clay minerals should be removed



The presence of bound inorganic nitrogen in Arctic sediments due to high clay content (Schubert & Calvert, 2001)

This may significantly underestimate terrestrial fraction if bound nitrogen is not removed

Impact of land derived "Bound Nitrogen" on the C/N ratio of SOM

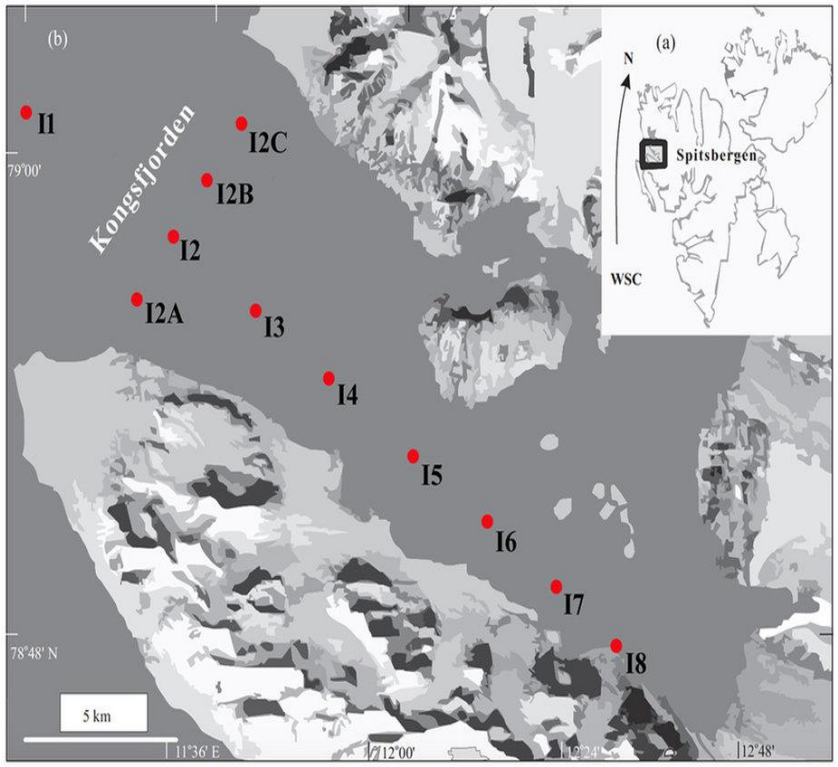
Study Area

Kongsfjorden: A Fjord in the Arctic Region, Western Part of Spitsbergen Island

- We investigated the spatial variability of SOM and its carbon and nitrogen isotopic composition using surface sediments at a site with steep marine productivity gradient and ample terrestrial input.

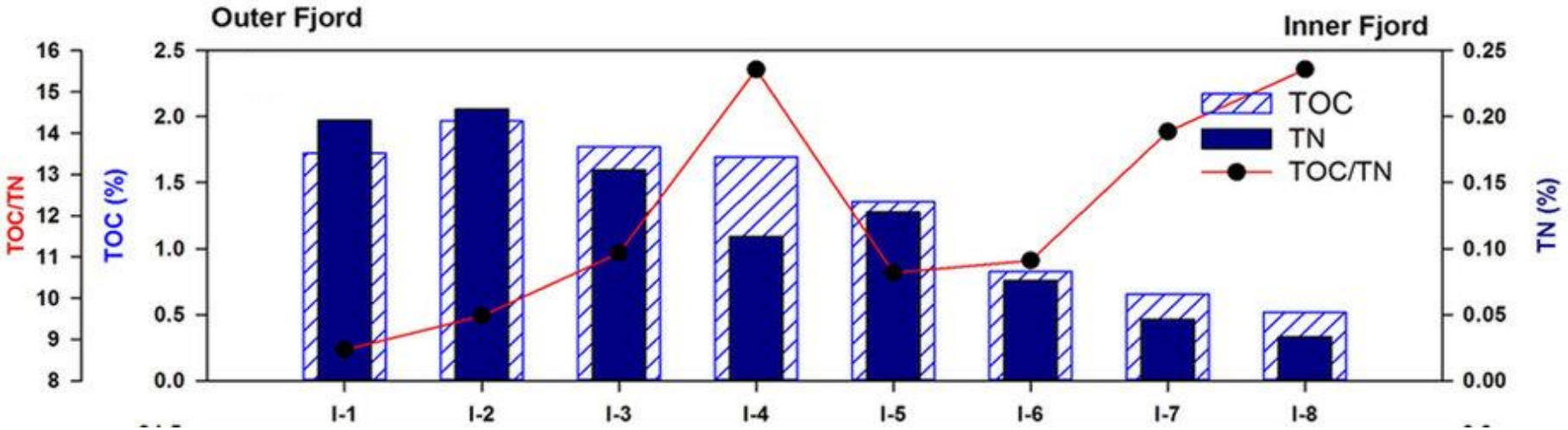
- Productivity gradient leads to variation in the mixing ratio between the marine and the terrestrial carbon along the gradient.

- Isotopic measurements along the gradient would thus help in constraining the end-member isotopic compositions.



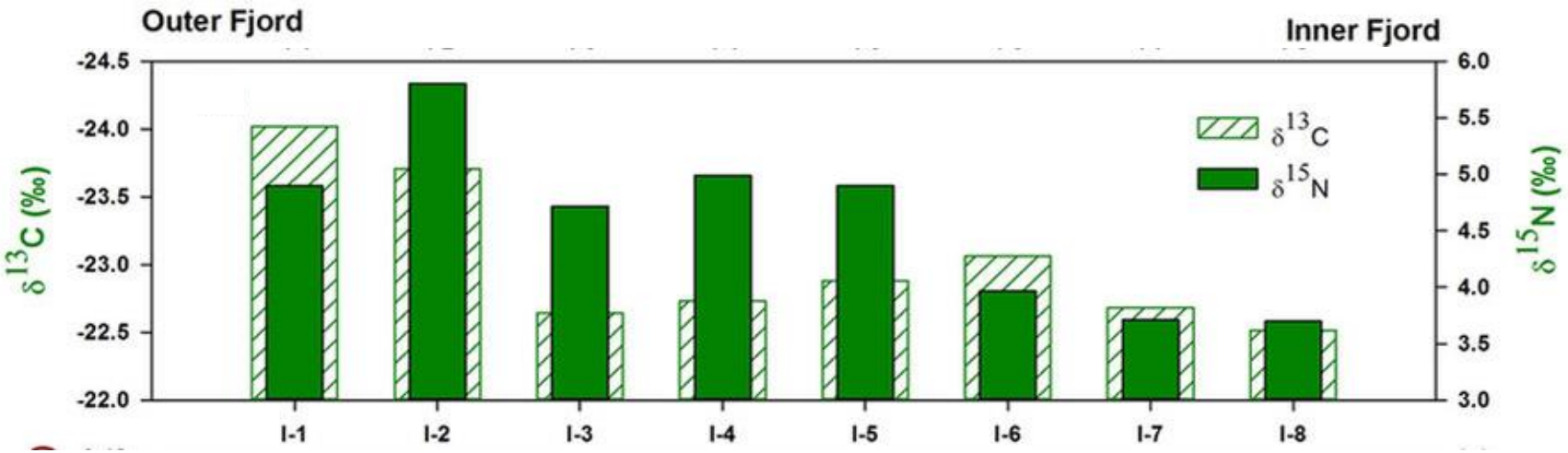
TOC and TN Variability

- TOC and TN variation shows steep gradient along the fjord.
- Low productivity in the inner turbid water may explain such a trend
- C/N ratio suggests carbon type changes from mixed-marine terrestrial in the inner part to marine dominated in the outer part.

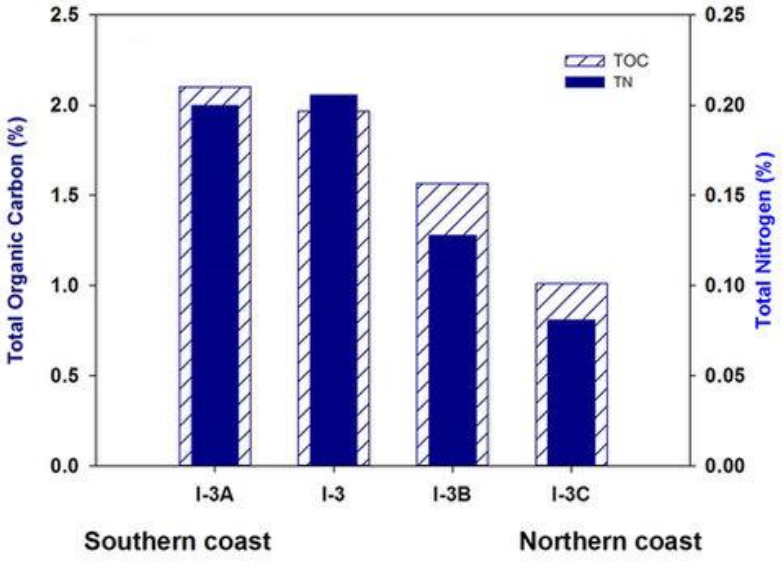


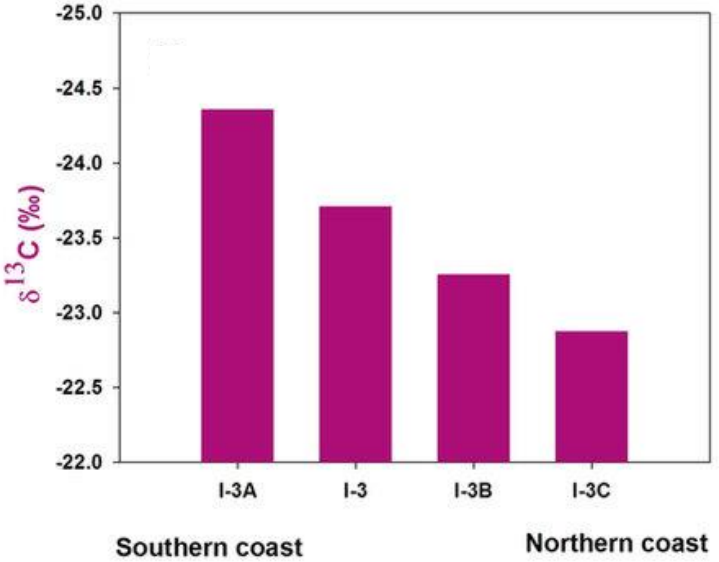
$\delta^{13}C$ and $\delta^{15}N$ Variability

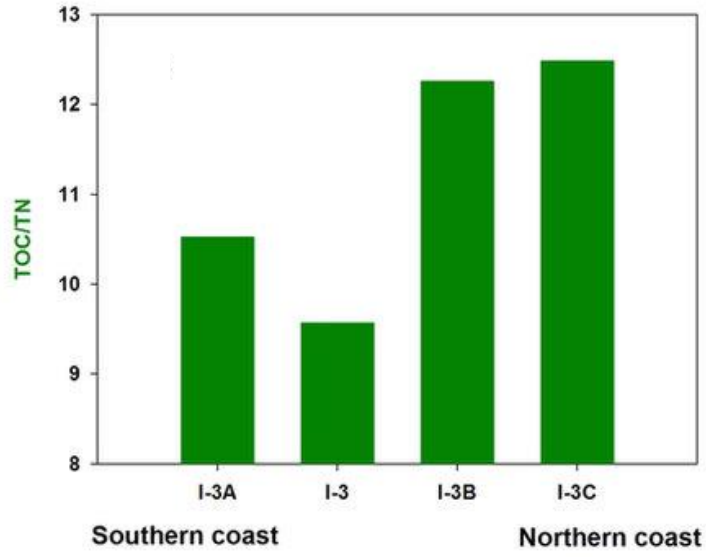
- $\delta^{13}C$ & $\delta^{15}N$ also shows similar gradient along the fjord
- $\delta^{15}N$ suggests better nutrient utilization in the relatively more productive outer part of the fjord
- $\delta^{13}C$ in the inner part is higher compared to the outer part: suggests terrestrial organic matter in Kongsfjorden is more enriched compared to that of the marine

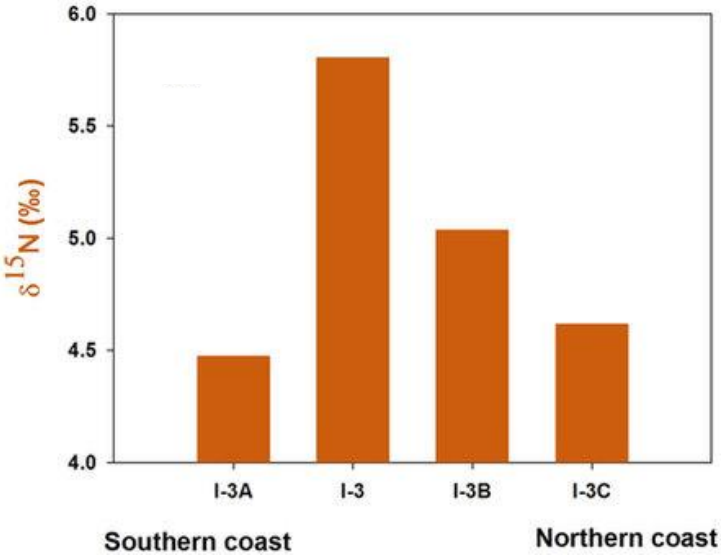


SOM Variability Across the Fjord Axis





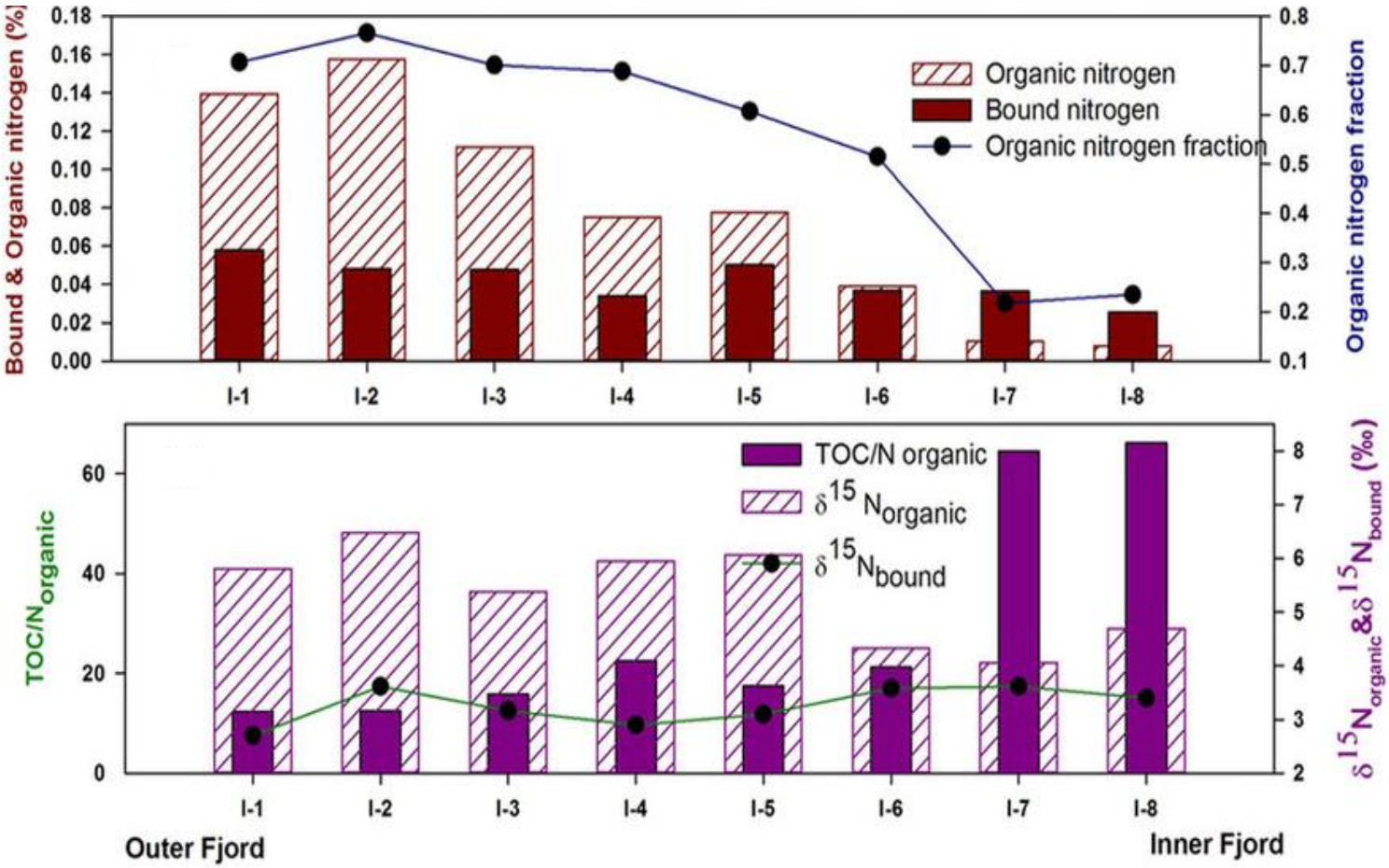




A glacial-marine contrast similar to that shown along the fjord axis also exist across the axis between the glaciated northern coast and glacier-free southern coast.

Role of bound Nitrogen

- Significant proportion of bound nitrogen in surface sediments due to high clay content (~77% in the inner fjord to ~24% in the outer part)
- $C/N_{organic}$ shows terrestrial fraction in surface sediments was significantly underestimated. New values shows the inner most station to be predominantly of terrestrial origin (>60)



This help us constrain terrestrial $\delta^{13}C$ end-member value as that of station I-8 (−22.5‰) which is surprisingly higher than the marine $\delta^{13}C$ value (−24.2‰), determined using mass balance calculations

Higher $\delta^{13}C$ values in Arctic sediments despite high terrestrial organic matter contribution

Schubert & Calvert, 2001

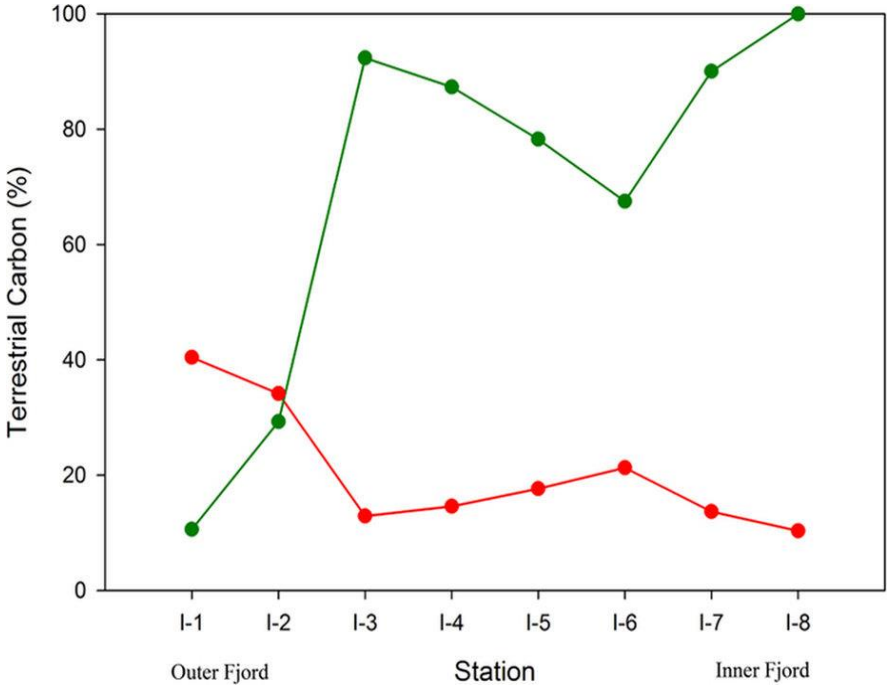
"The significantly heavier $\delta^{13}C$ values in central Arctic Ocean sediments are somewhat surprising in view of the suggestion that there is a high terrestrial organic matter contribution to the sediments (Schubert and Stein, 1997; Stein et al., 1994)…

- Present finding explain high $\delta^{13}C$ values of SOM as noted by earlier studies in central Arctic sediments despite a high terrestrial contribution

Conclusion

- Marine organic matter is unusually more depleted in ^{13}C (−24.2‰) than the terrestrial organic matter (−22.5‰).

- Our calculation shows large difference between fixed-endmember approach (red) and the one adopted in our study for terrestrial vs. marine carbon fraction in Kongsfjorden



- We recommend active removal of bound nitrogen in clay-rich sediments and proper carbon isotope end-member constraining for carbon burial budget calculation for different regions of Arctic


THANK YOU