Consiglio Nazionale delle Ricerche

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Greening of Svalbard in the twentieth century driven by sea ice loss and glaciers retreat

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CENTRO RICERCHE ENI-CNR Aldo Pontremoli

ISP Istituto di Scienze Polari Consiglio Nazionale delle Ricerche

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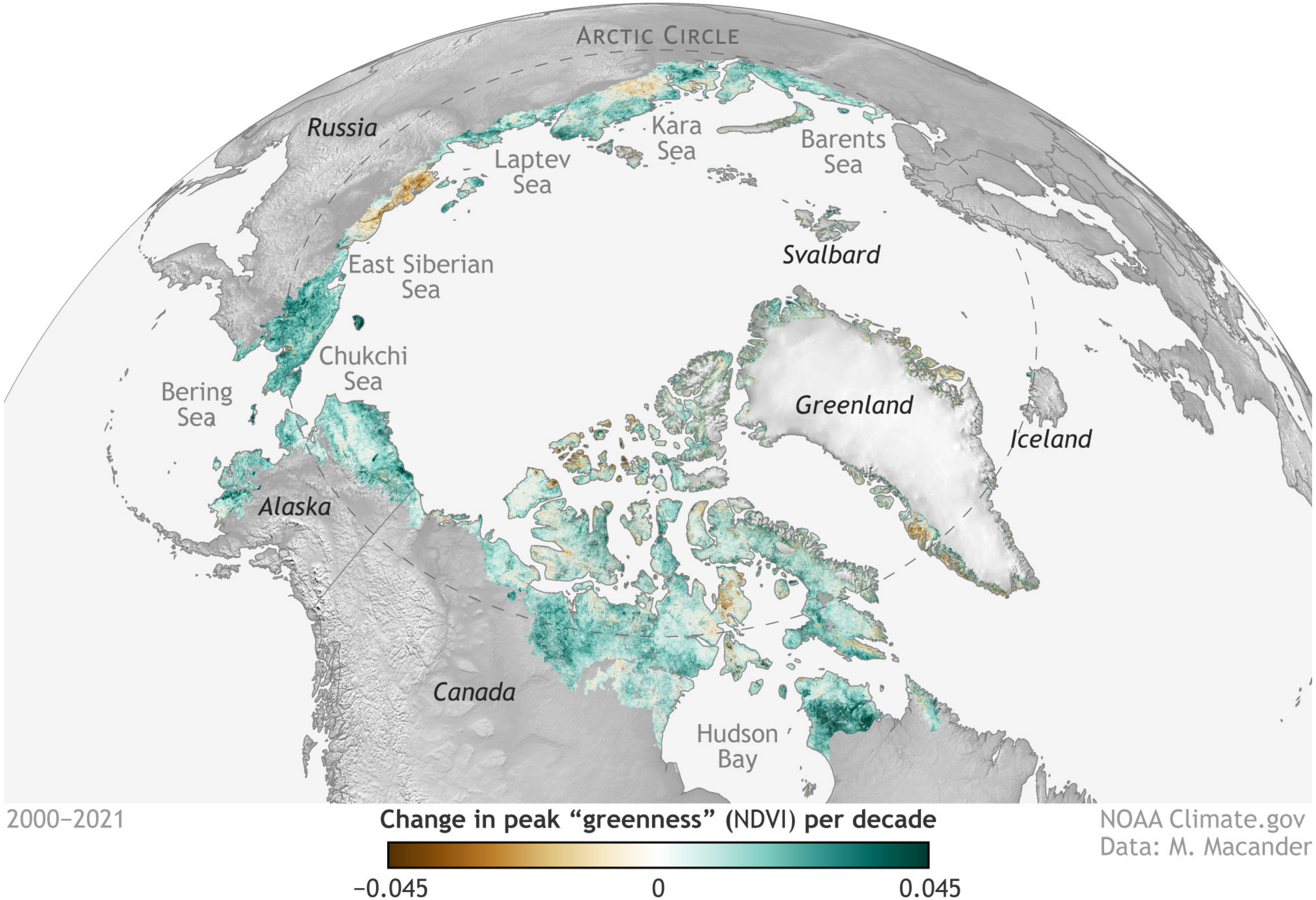
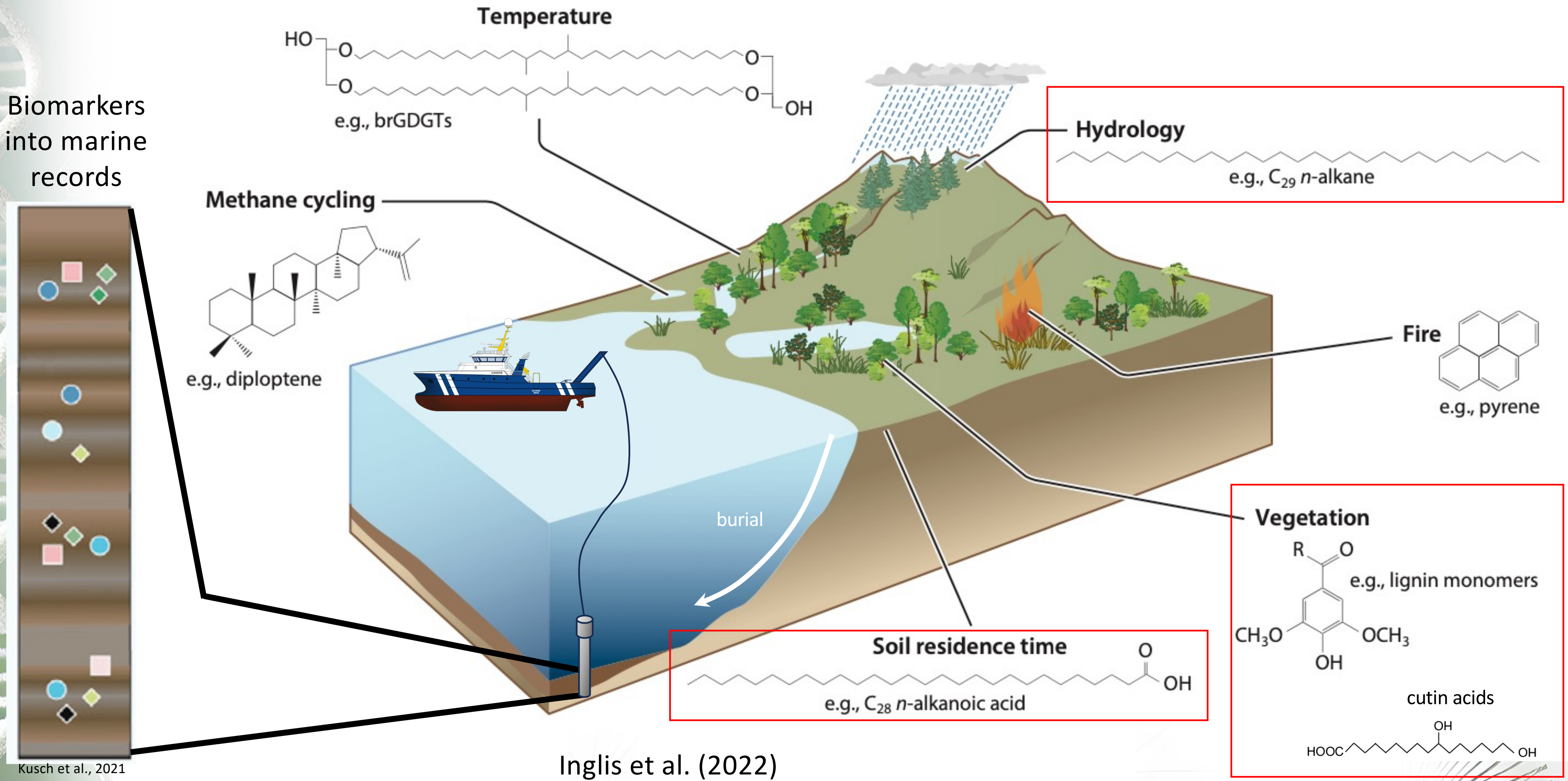
AWI

2021 CONTINUES SUMMER GREENING TREND ACROSS ARCTIC TUNDRA



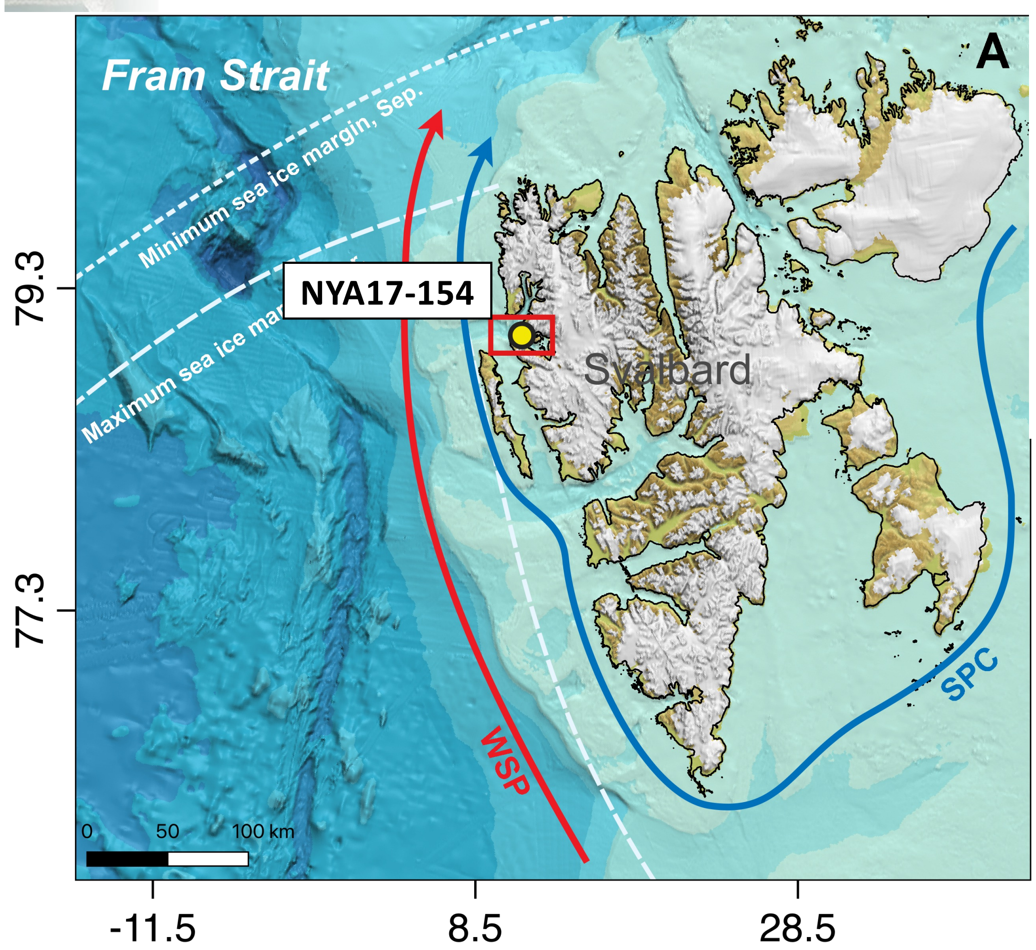
The Arctic Fjords of Svalbard are also showing important signals of greening due to the unprecedented collapse of the glacial environment.

Biomarkers into marine records



Inglis et al. (2022)

SCOPE: historical reconstruction of greening from marine archives



SCIENCE ADVANCES | RESEARCH ARTICLE

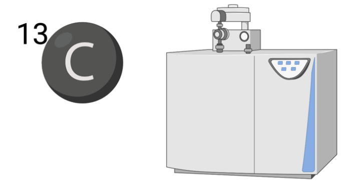
CLIMATOLOGY

Rapid Atlantification along the Fram Strait at the beginning of the 20th century

Tommaso Tesi[1]*†, Francesco Muschitiello[2,3]†, Gesine Mollenhauer[4,5], Stefano Miserocchi[1], Leonardo Langone[1], Chiara Ceccarelli[6], Giuliana Panieri[7], Jacopo Chiggiato[8], Alessio Nogarotto[1,9], Jens Hefter[4], Gianmarco Ingrosso[1], Federico Giglio[1], Patrizia Giordano[1], Lucilla Capotondi[8]

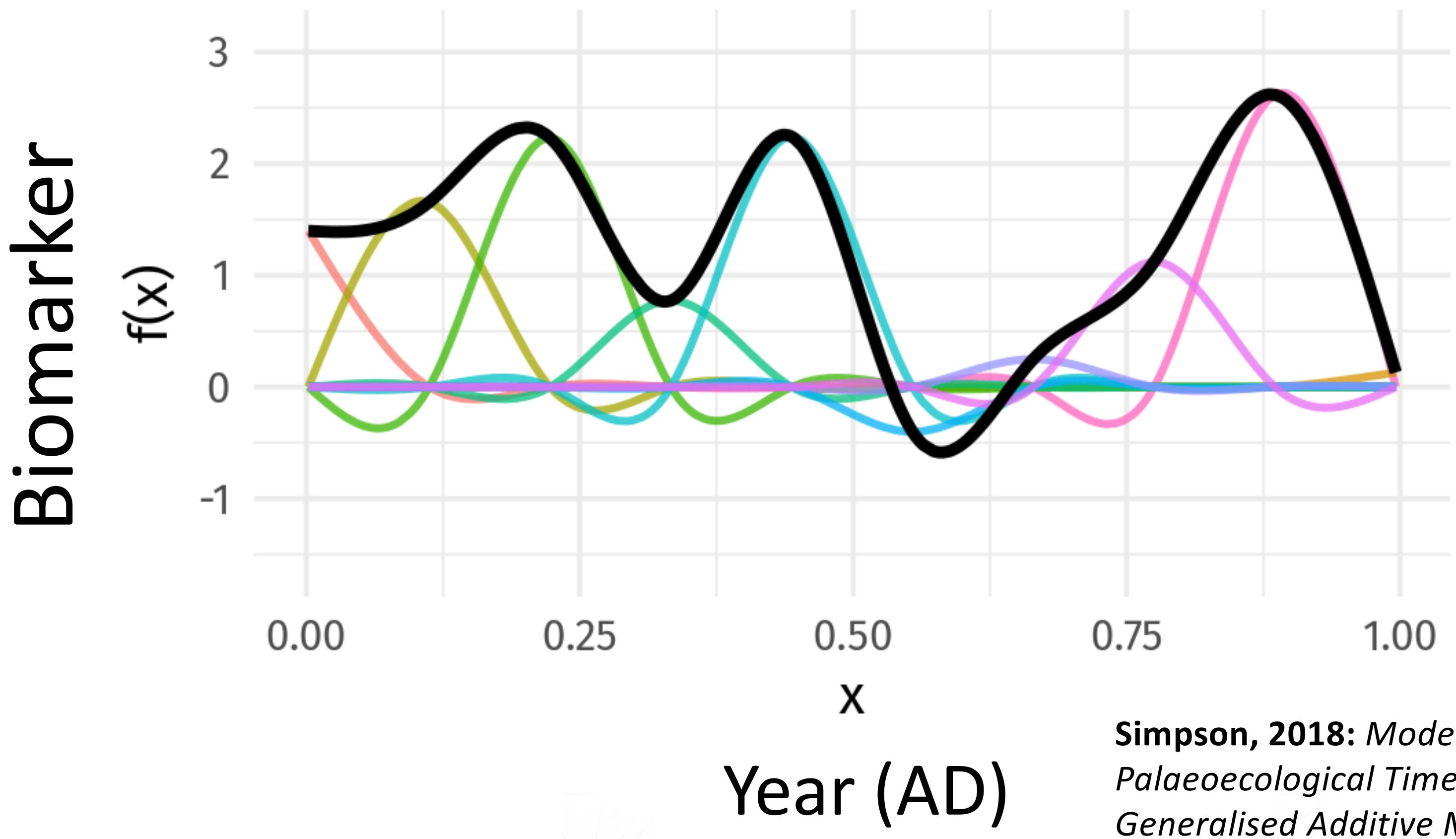
The recent expansion of Atlantic waters into the Arctic Ocean represents undisputable evidence of the rapid changes occurring in this region. Understanding the past variability of this "Atlantification" is thus crucial in providing a longer perspective on the modern Arctic changes. Here, we reconstruct the history of Atlantification along the eastern Fram Strait during the past 800 years using precisely dated paleoceanographic records based on organic biomarkers and benthic foraminiferal data. Our results show rapid changes in water mass properties that commenced in the early 20th century—several decades before the documented Atlantification by instrumental records. Comparison with regional records suggests a poleward expansion of subtropical waters since the end of the Little Ice Age in response to a rapid hydrographic reorganization in the North Atlantic. Understanding of this mechanism will require further investigations using climate model simulations.

BULK
- Total organic carbon (TOC)
- Radiocarbon ($\Delta^{14}C$)
- stable carbon isotope ($\delta^{13}C$)

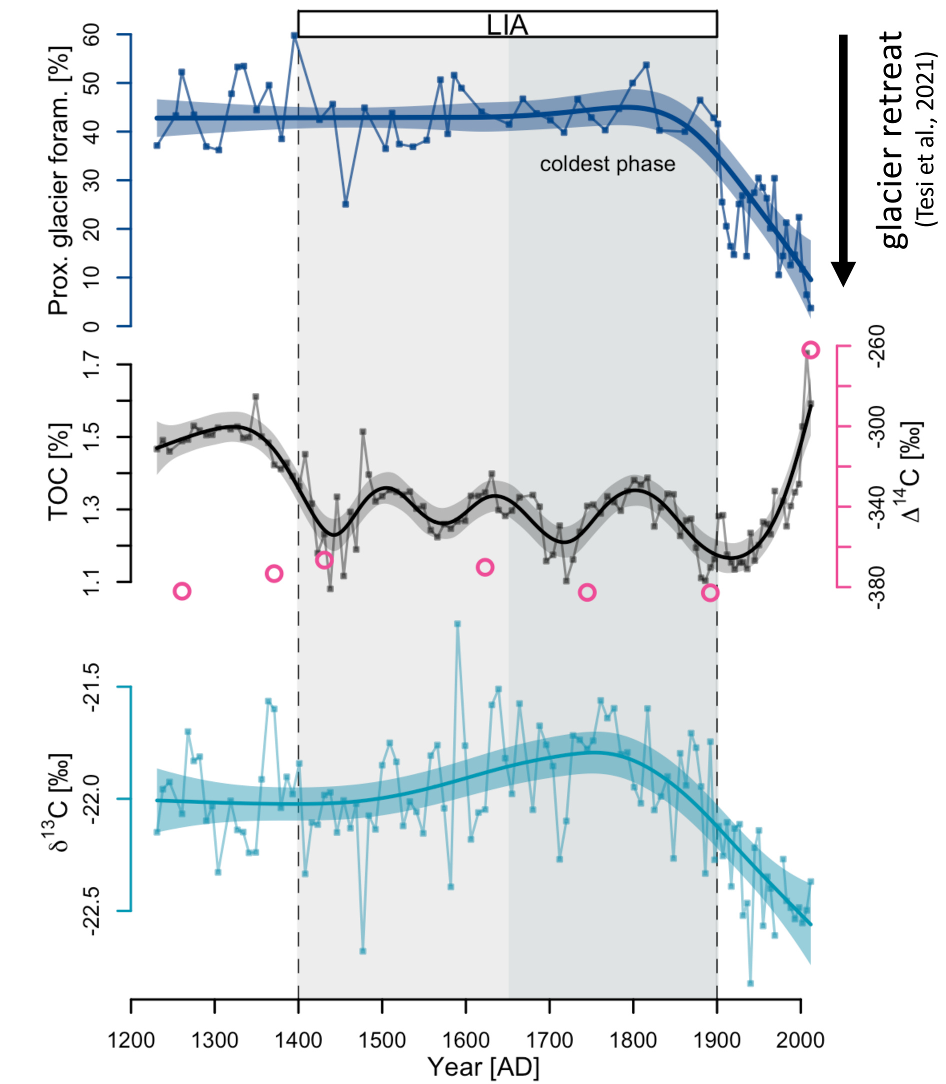


TERRESTRIAL BIOMARKER
- Long chain *n*-alkanes
- Long chain fatty acids
- Lignin phenols
- Cutin acids

Generalised additive models (GAMs) analysis of trend

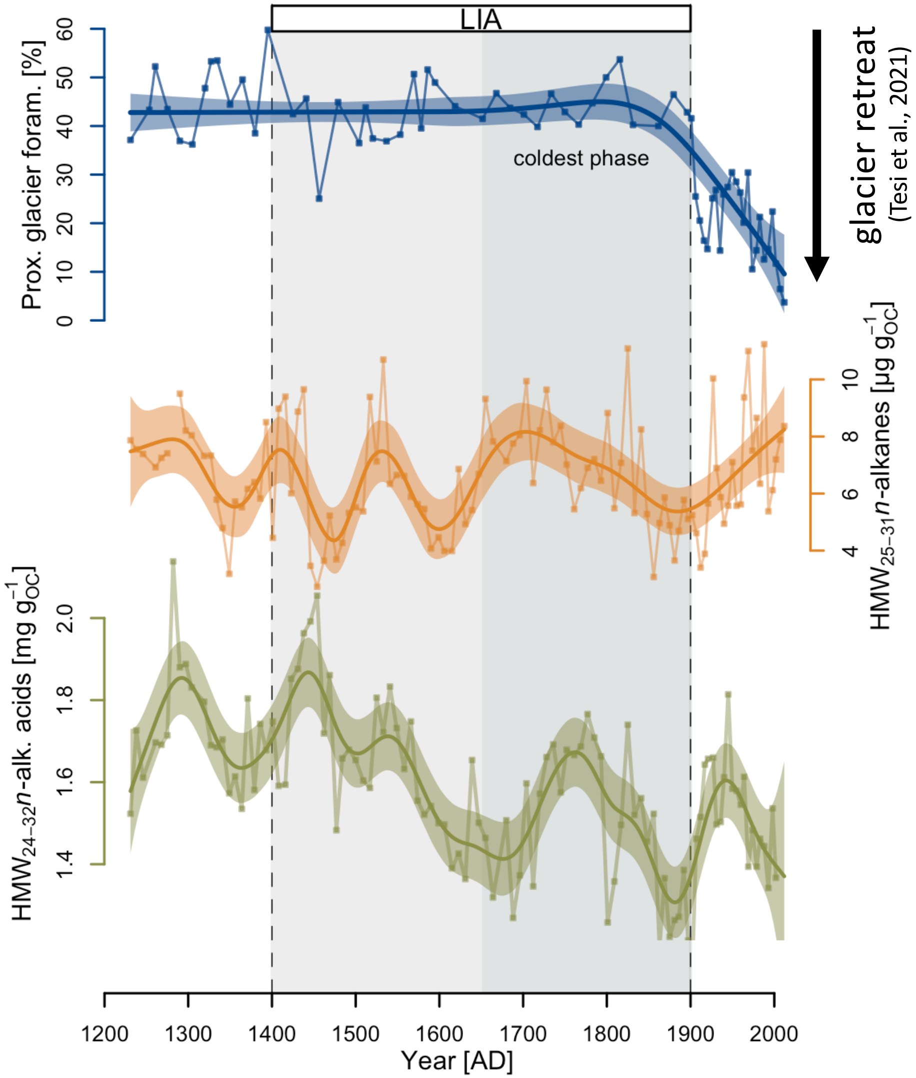


Simpson, 2018: *Modelling Palaeoecological Time Series Using Generalised Additive Models*



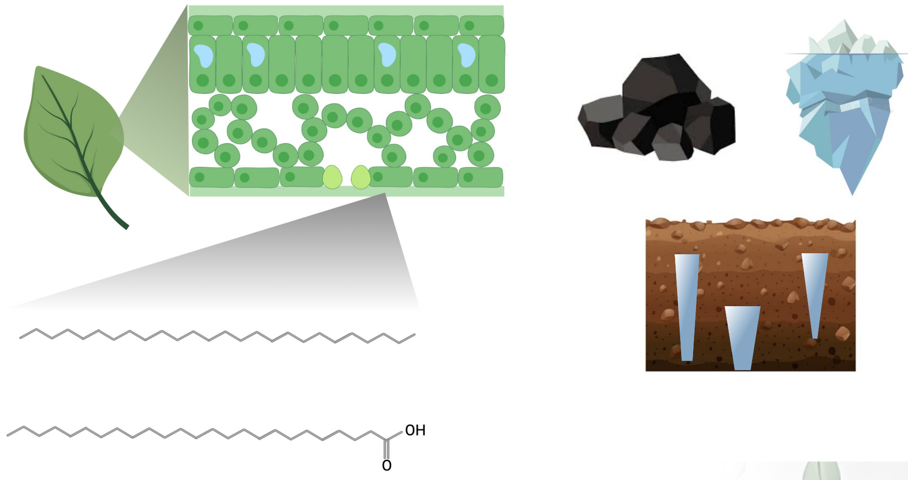
Bulk

- The dynamic driving TOC trend was not easily to interpret
- Depleted radiocarbon content indicated inputs of fossil material (ice-rafted detritus, permafrost, coal)
- the $\delta^{13}C$ signature suggested a mixture of terrestrial and marine OC

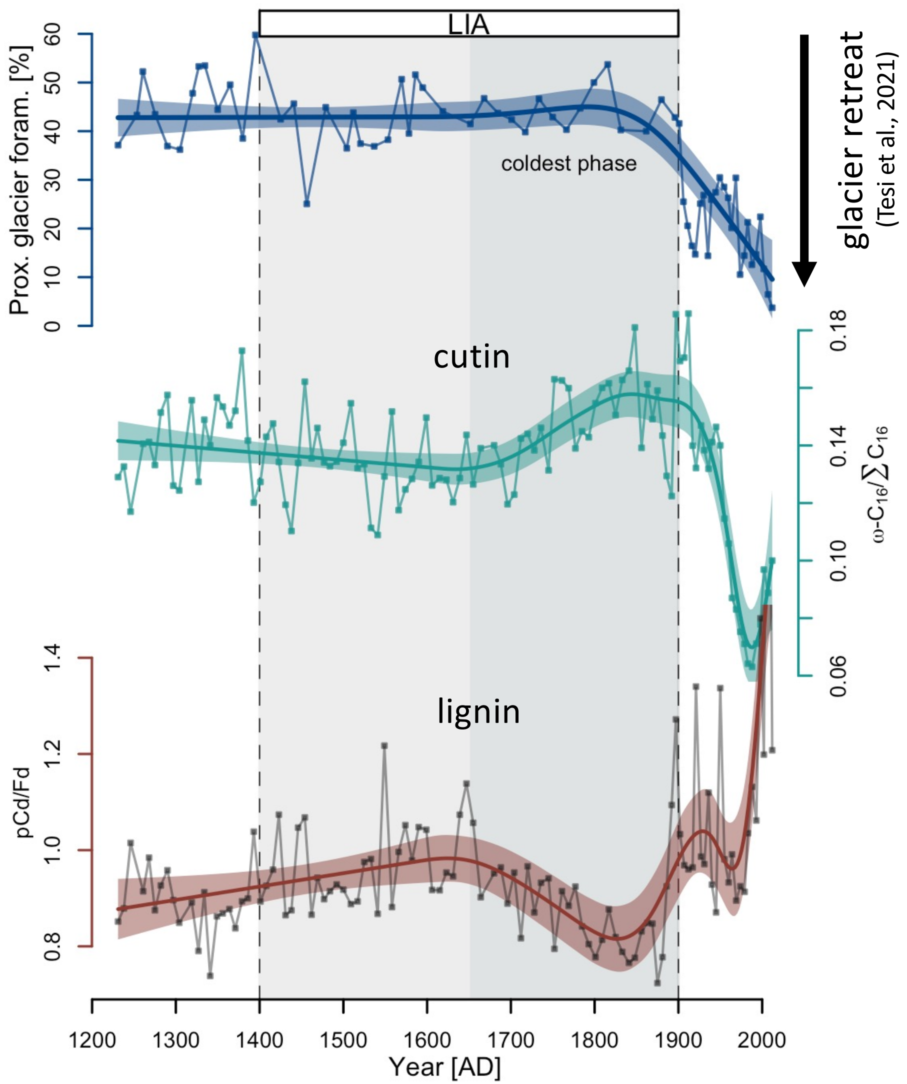


HMW n-alk & acids

Wax lipids are present in epidermal cells of most terrestrial plants

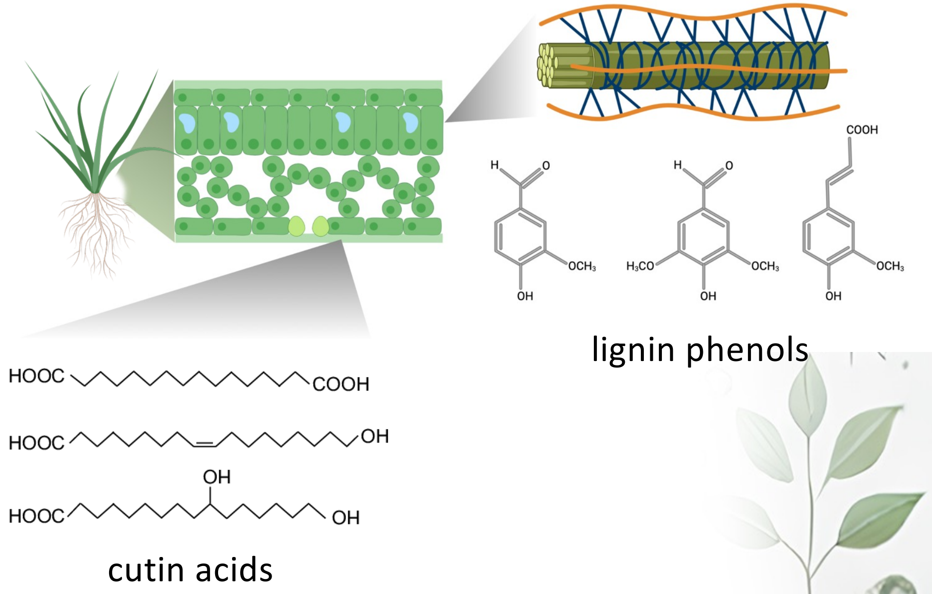


- affected by fossil sources (permafrost, IRD, etc.)
- the estimated trends are complex and do not provide useful information

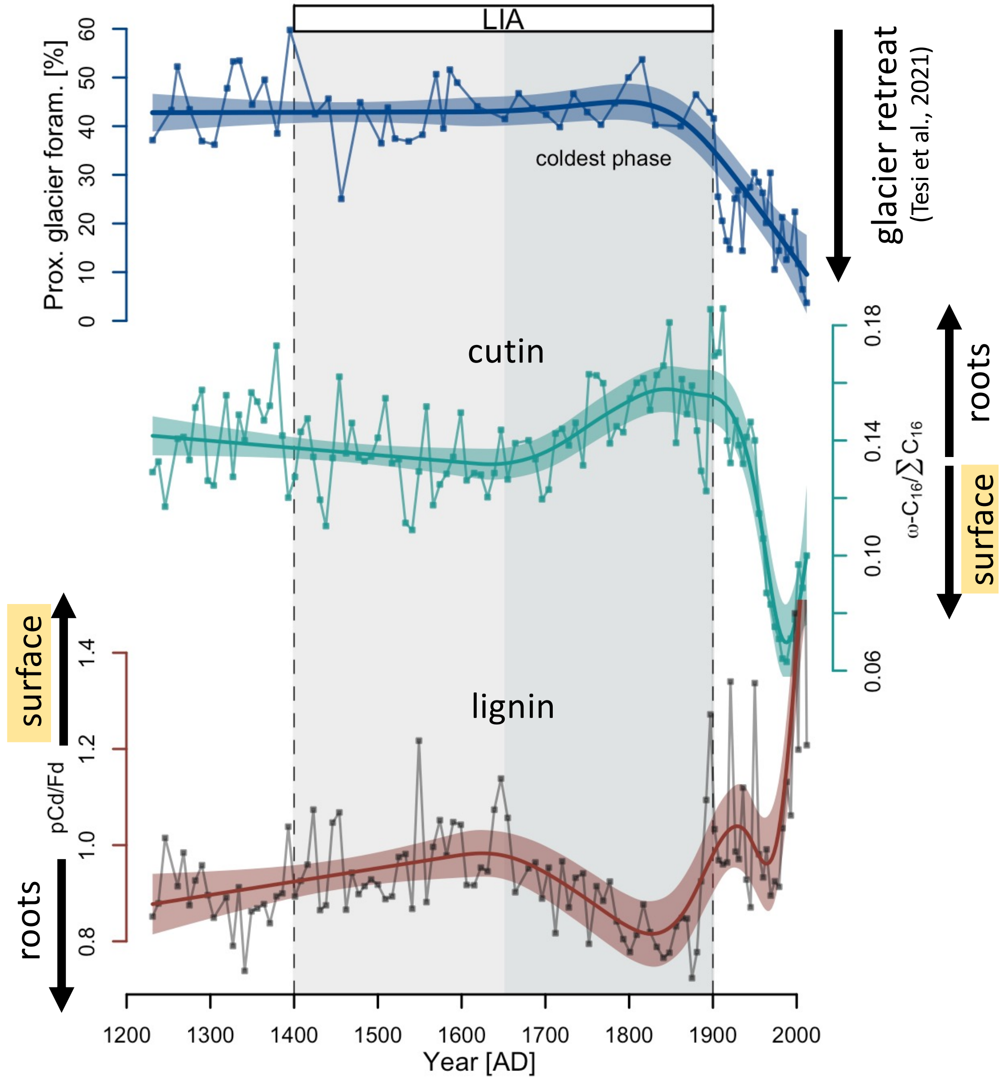


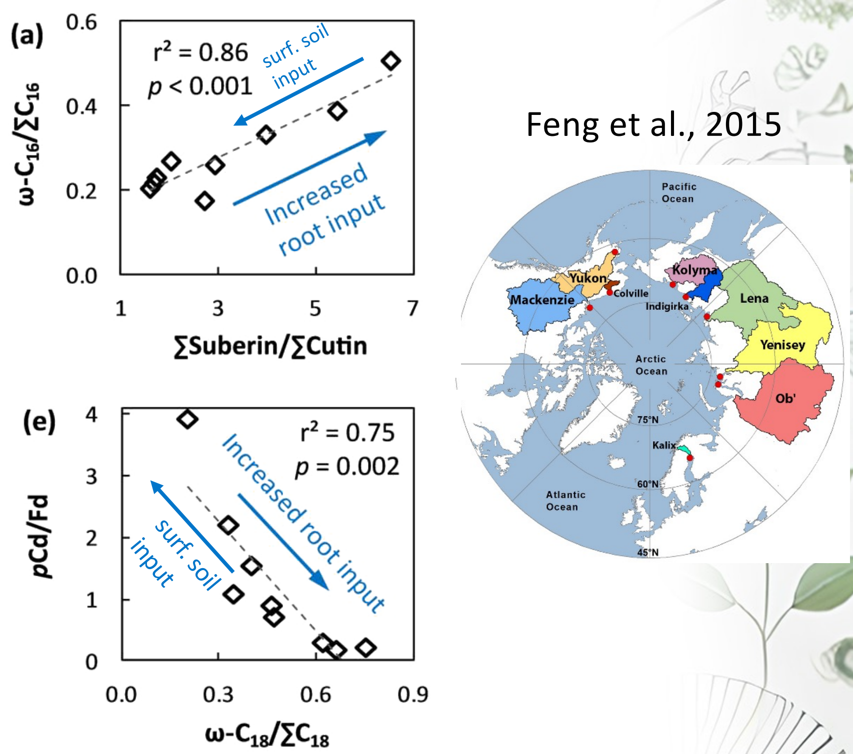
Plant specific biomarkers

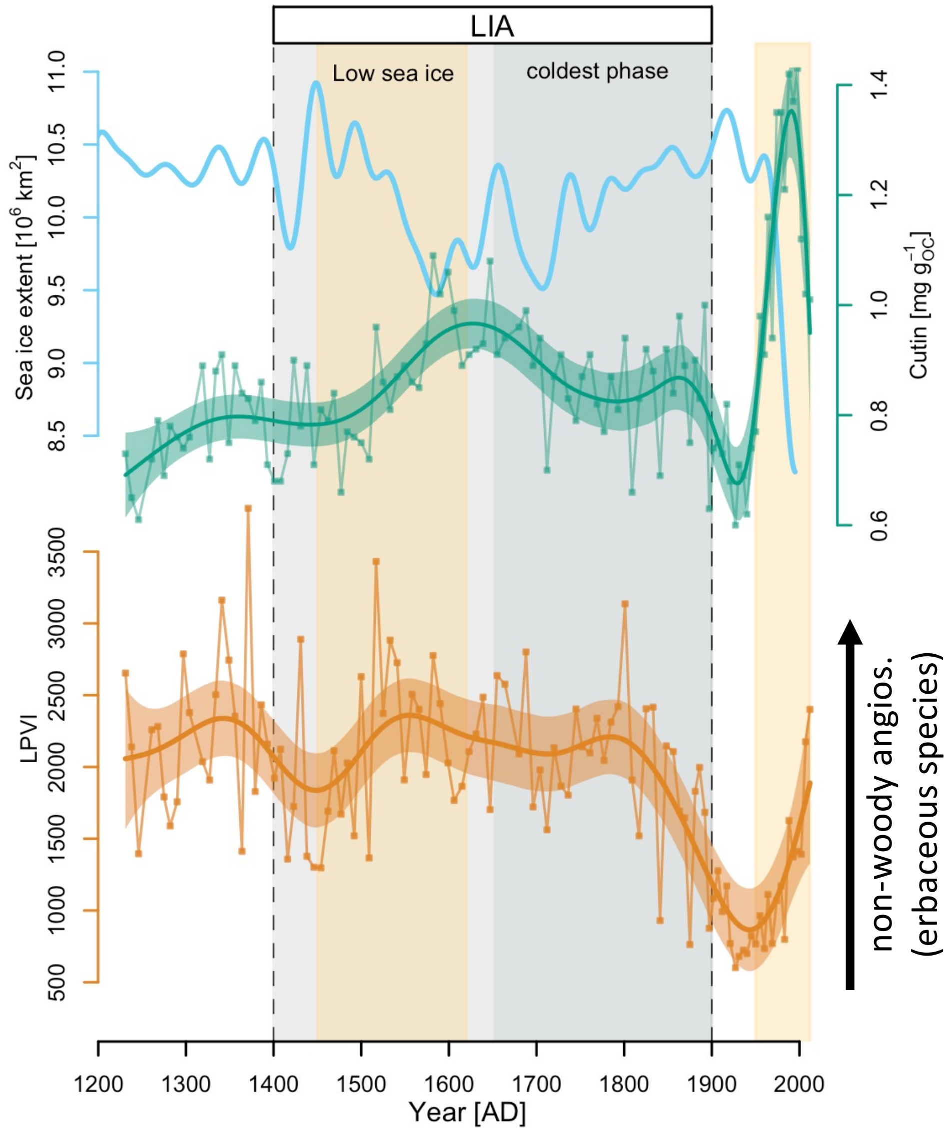
lignin and cutin are biopolimers present both in leaves and roots the terrestrial vascular plants



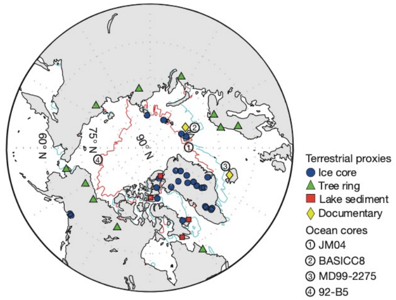
Plant specific biomarkers







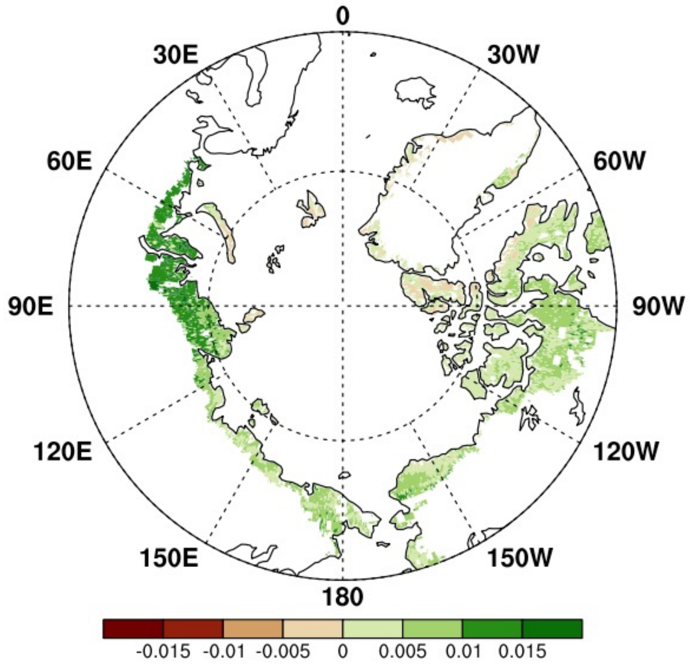
Plant specific biomarkers



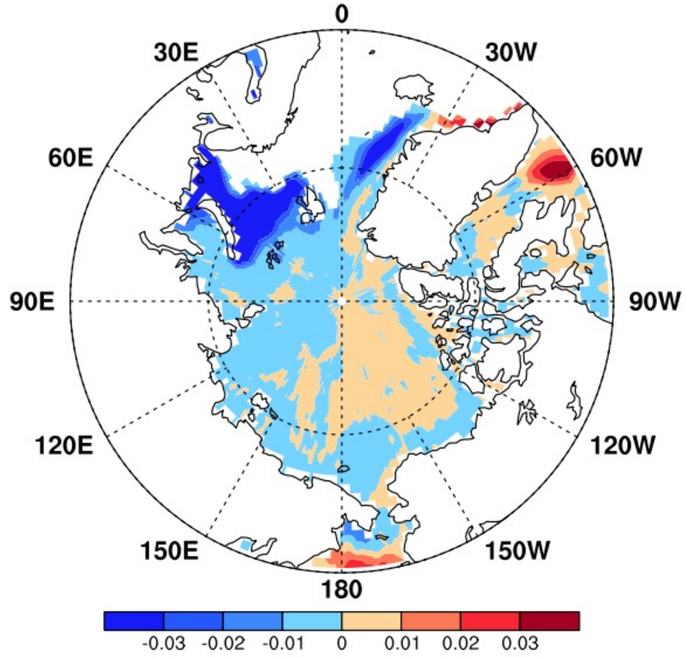
Reconstruction of summer sea ice extent (Kinnard et al., 2011)

An early signal of greening of the western Svalbard that started at the beginning of the 20th century associated with the general sea ice collapse

Arctic tundra growth associated with sea ice decline



NDVI during 1982–2021



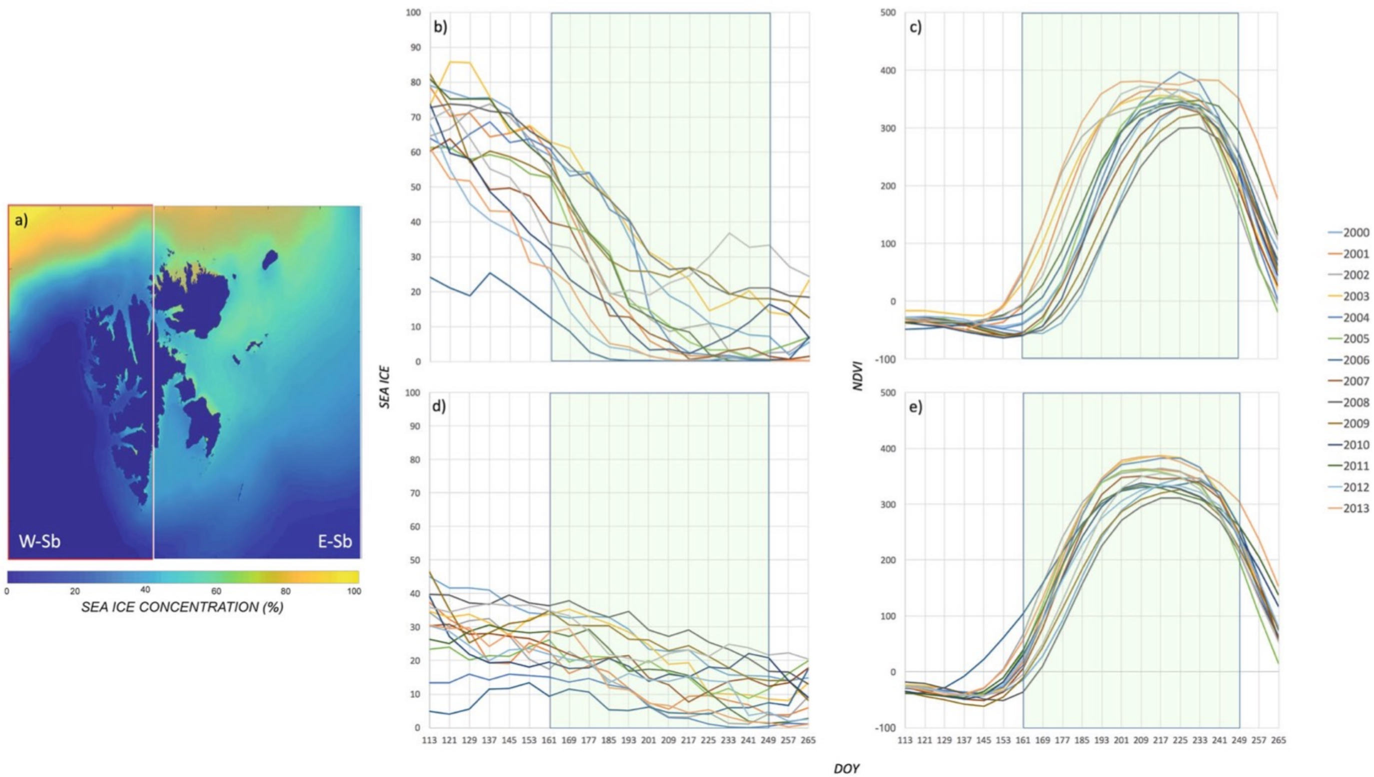
Sea ice concentration during 1982–2021

Satellite records indicate a widespread interannual linkage between Arctic vegetation NDVI increase and sea ice retreat (Ji et al., 2024)

…especially in the Fram Strait

Arctic tundra growth associated with sea ice decline

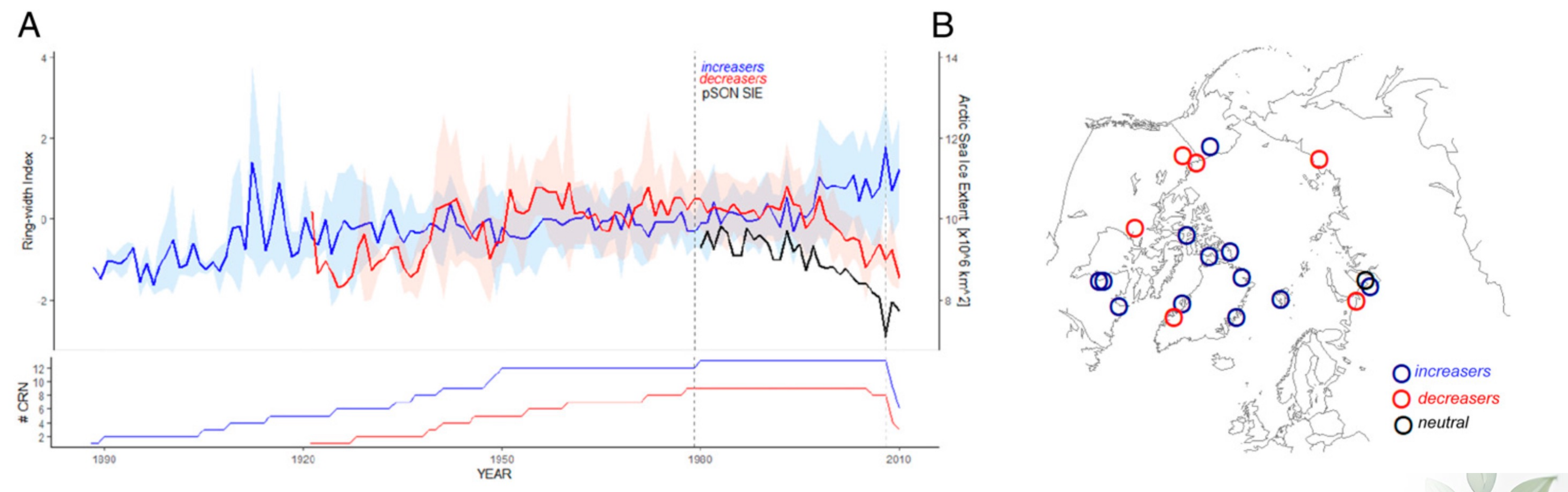
Sea ice decline **Tundra productivity increase**



Data 2000 – 2013

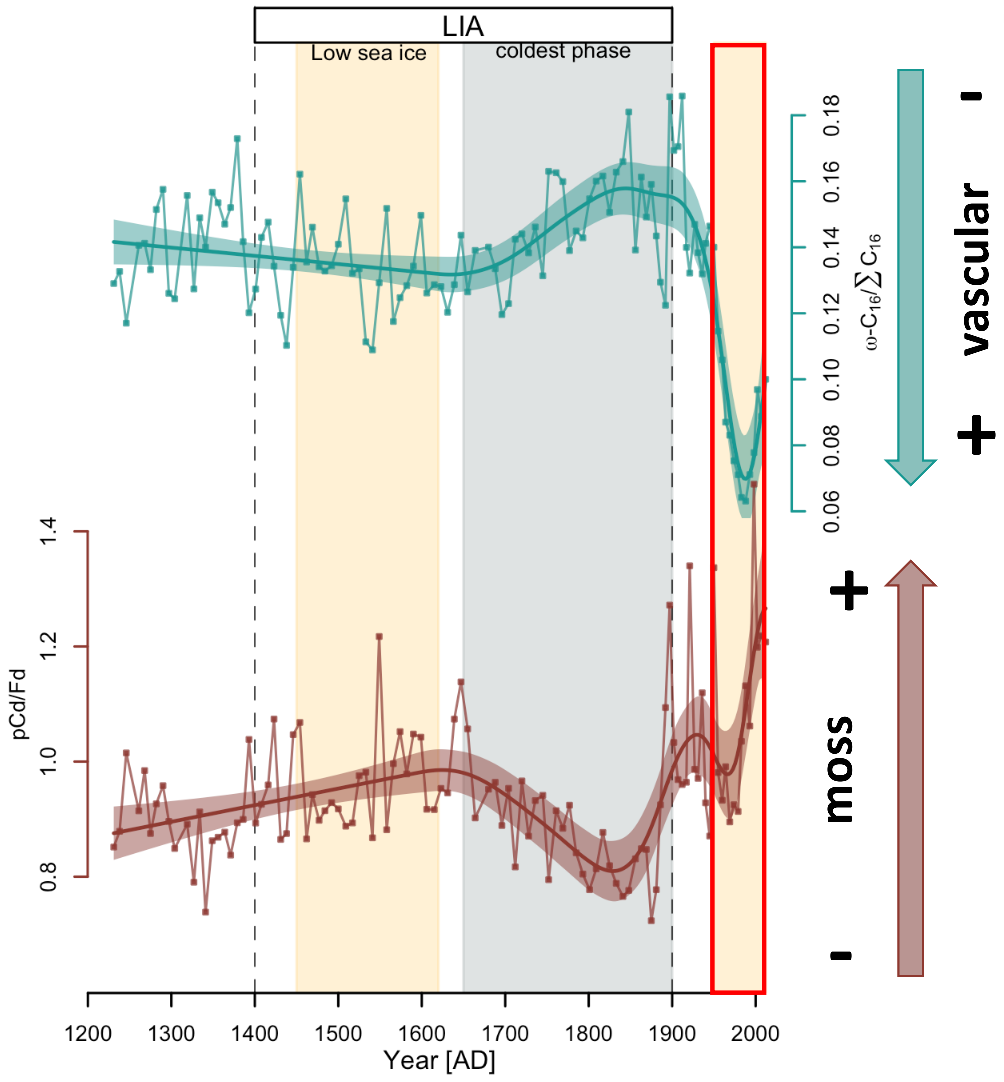
For Svalbard an explicit relationship between sea ice decline and tundra productivity increase have been reported for the last decades (Macias-Fauria et al., 2017)

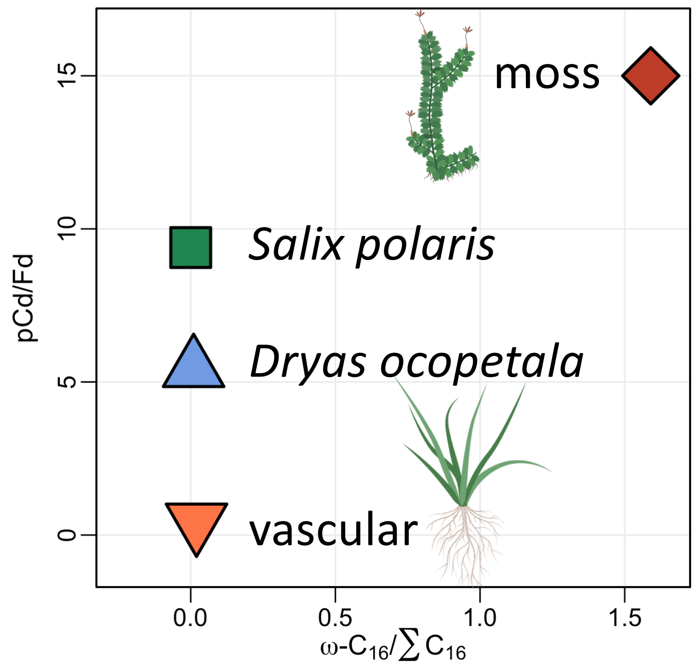
Arctic tundra growth associated with sea ice decline



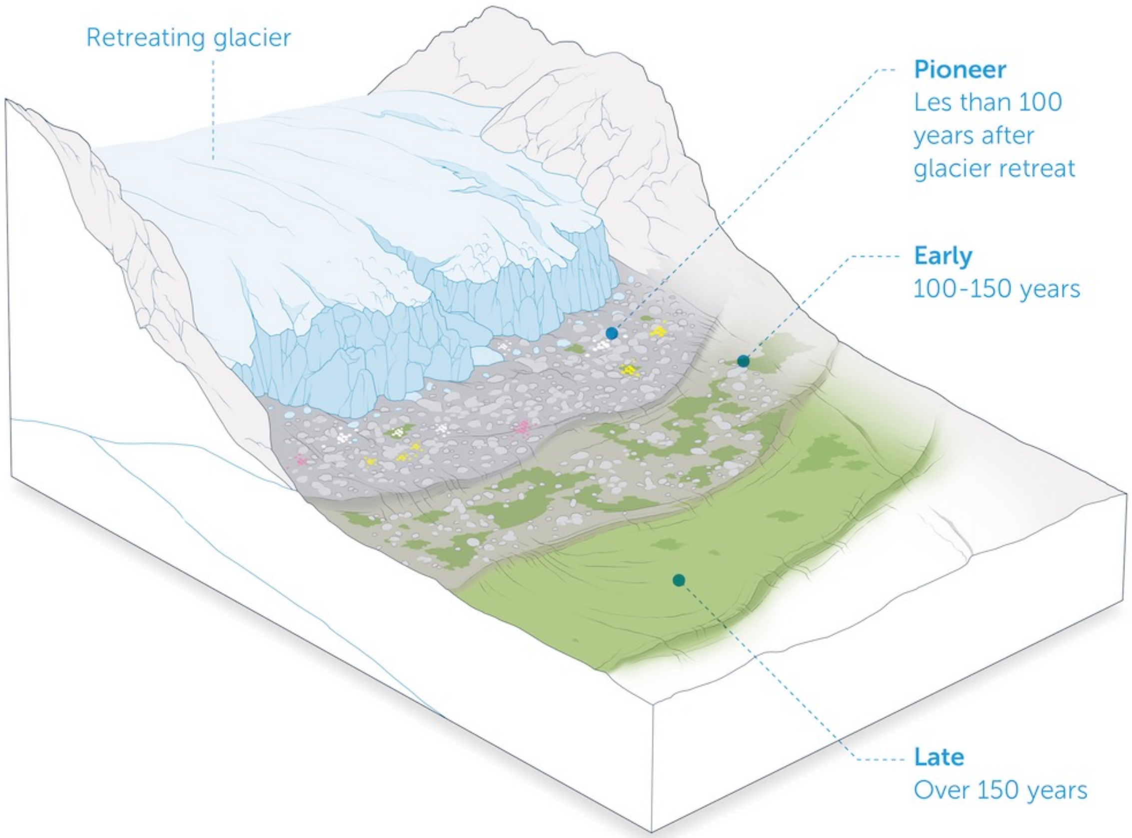
Specific in-situ reconstructions (tundra shrub-ring chronologies) suggest that tundra productivity increase with summer sea ice decline in the Svalbard (Buchwal et al., 2020).

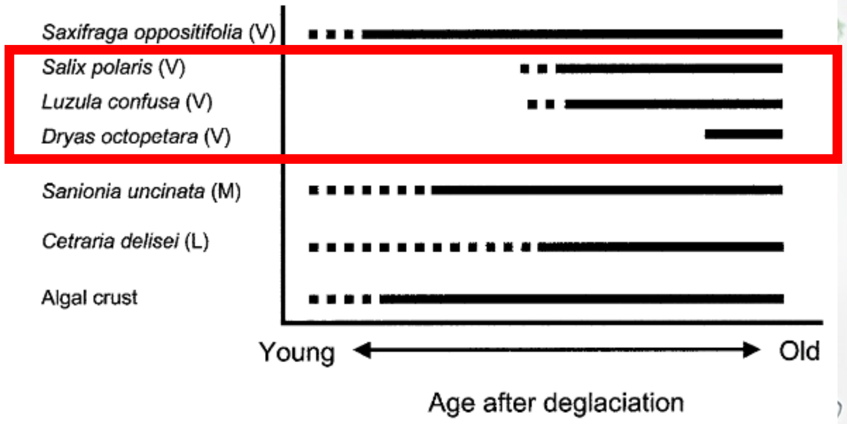
Change of the plant species composition





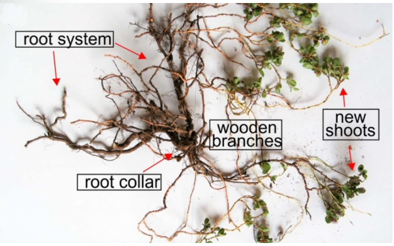
Plant successional series in the deglaciated area

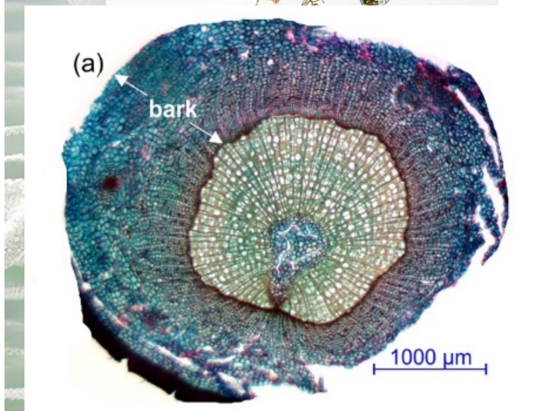


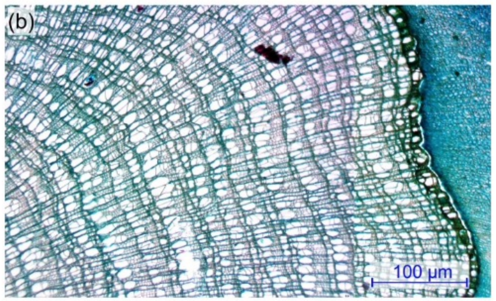


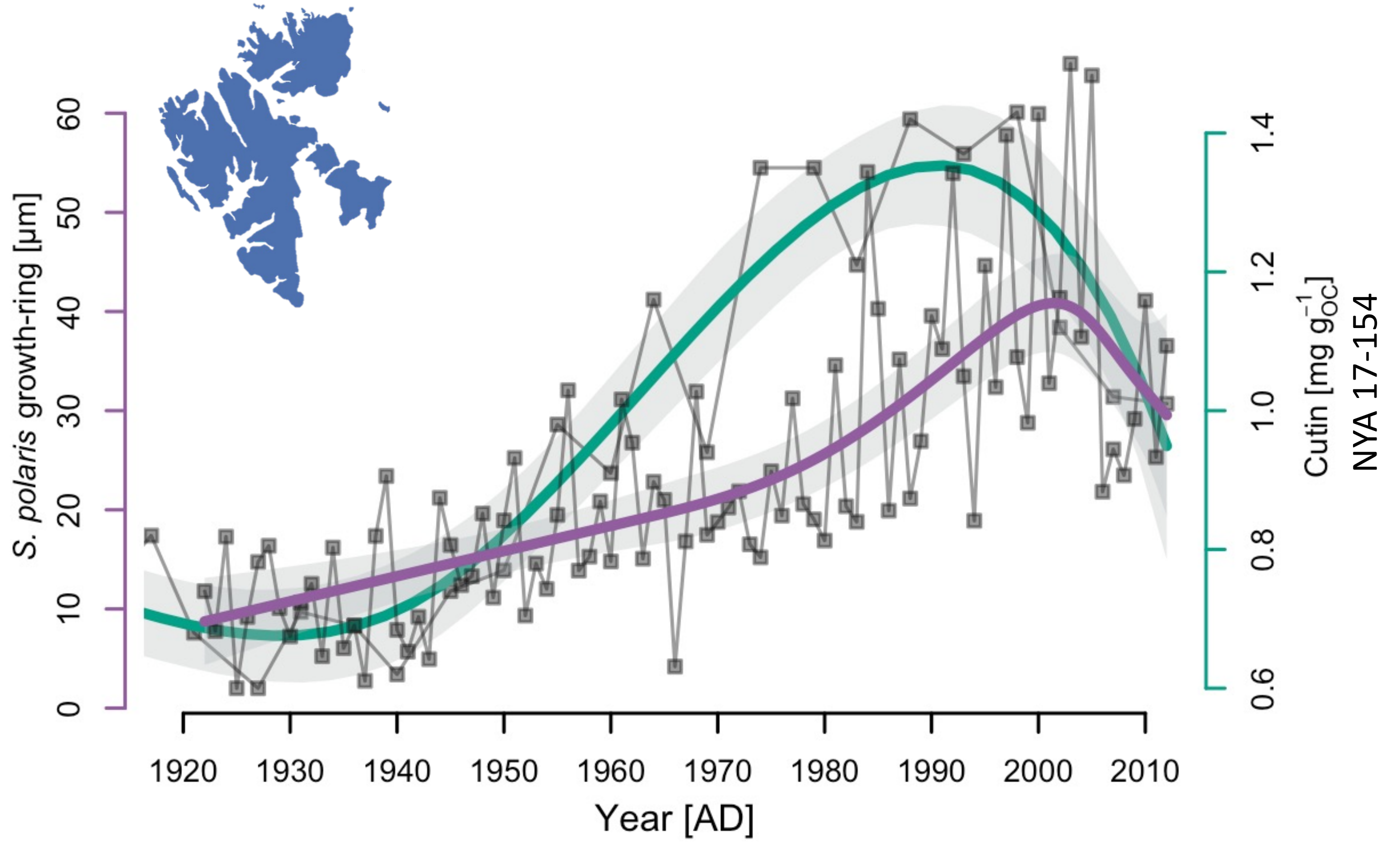
Salix polaris and *Dryas octopetala* predominate in the later stages of succession (Nakatsubo et al., 2005).

Greening signal VS. *S. polaris* growth-ring reconstruction









Owczarek et al., 2021

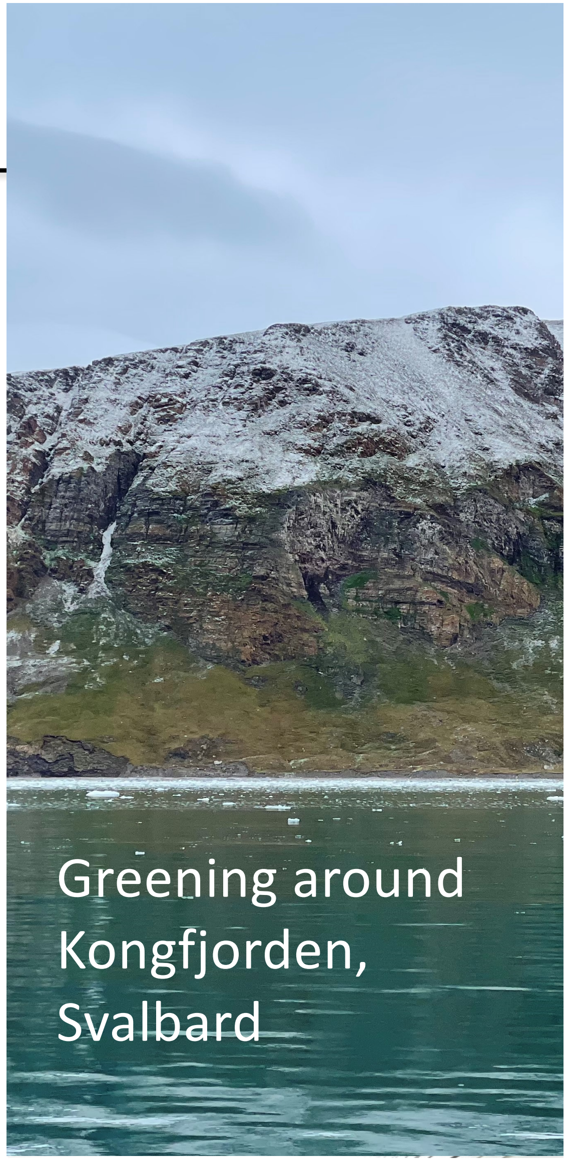
Conclusions

- **Not all terrestrial organic proxies are suitable** for describing the past greening events: n-alkanes and n-alkanoic acids

- **Lignin phenols are cutin acids are more promising** and consistent with the pan-Arctic reconstruction of sea ice

- In Northern Svalbard, **greening began soon after the end of the LIA** in the early 20th century

- **Signals of tundra vegetation shift** toward mature successional stages and vascular species adapted to milder climate (likely *S. polaris* and *D. octopetala*).

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Article

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Greening of Svalbard in the twentieth century driven by sea ice loss and glaciers retreat

Check for updates

Gianmarco Ingrosso[1,2,6], Chiara Ceccarelli[3], Federico Giglio[1], Patrizia Giordano[1], Jens Hefter[4], Leonardo Langone[1], Stefano Miserocchi[1], Gesine Mollenhauer[4,5], Alessio Nogarotto[1], Mathia Sabino[1,2] & Tommaso Tesi[1]

The greening of previously barren landscapes in the Arctic is one of the most relevant responses of terrestrial ecosystem to climate change. Analyses of satellite data (available since ~1980) have revealed a widespread tundra advance consistent with recent global warming, but the length is insufficient to resolve the long-term variability and the precise timing of the greening onset. Here, we measured plant-derived biomarkers from an Arctic fjord sediment core as proxies for reconstructing past changes in tundra vegetation during the transition from the Little Ice Age to modern warming. Our findings revealed a rapid expansion of the tundra since the beginning of the twentieth century, largely coinciding with the decline of summer sea ice extent and glacier retreat. The greening trend inferred from biomarker analysis peaked significantly in the late 1990s, along with a shift in the tundra community towards a more mature successional stage. Most of these signals were consistent with the biomolecular fingerprints of vascular plant species that are more adapted to warmer conditions and have widely expanded in proglacial areas during recent decades. Our results suggest that the greening of Arctic fjords may have occurred earlier than previously thought, improving our mechanistic understanding of vegetation-climate-cryosphere interactions that will shape tundra vegetation under future warming projections.