Modern spatial (seasonal) variability in sea ice cover of the Kara and Laptev seas: Reconstruction from new biomarker data determined in surface sediments

Xiaotong Xiao, Kirsten Fahl and Rüdiger Stein E-mail: Xiaotong.Xiao@awi.de

Alfred Wegener Institute for Polar and Marine Research, Am Alten Hafen 26, 27568 Bremerhaven, Germany

1. Introduction

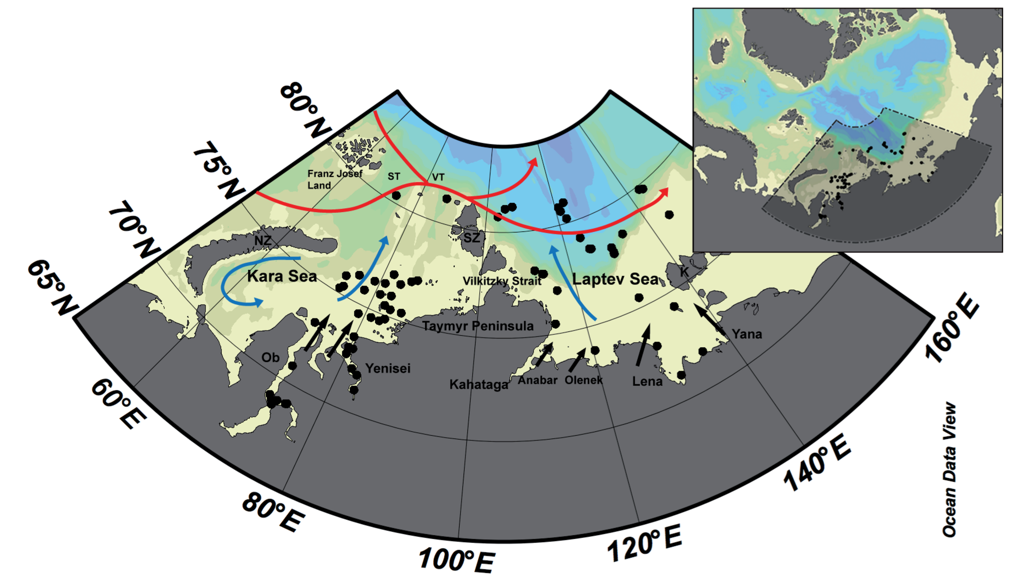
Sea ice is a fundamental component of Earth's climate system, contributing to heat reduction (albedo) and deep-water formation.

Here, we present new biomarker data from surface sediments and related to the modern spatial (seasonal) sea ice variability in the Kara and Laptev seas. We determined concentrations of

--the sea ice diatom-derived biomarker „IP_{25}“ (isoprenoid with 25 carbon atoms),
--phytoplankton-derived biomarkers (brassicasterol and dinosterol),
--terrigenous biomarkers (campesterol and ß-sitosterol)

to estimate recent sea ice conditions in the study area.

2. Study area



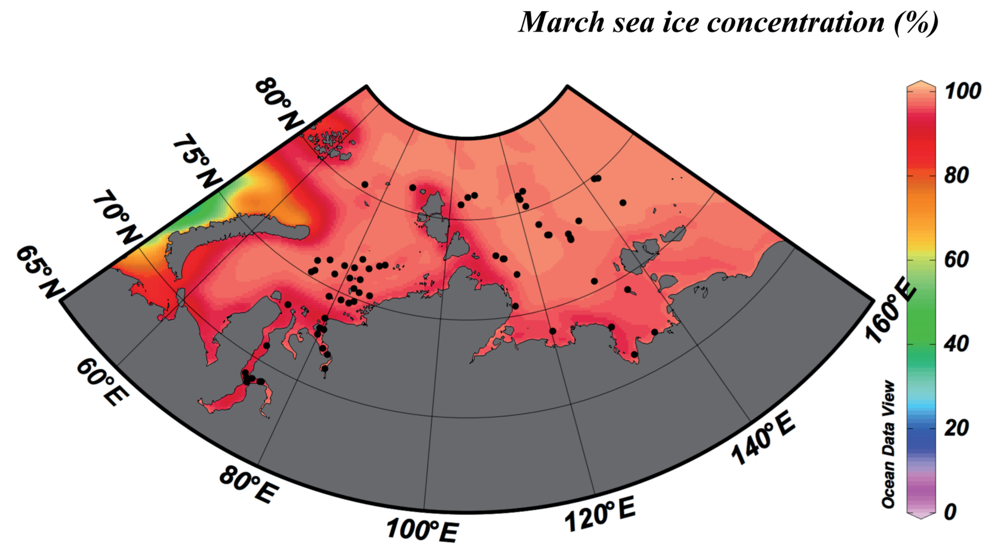
--Currents: warm Atlantic waters (red arrows) and cold, fresh river input (blue arrows).
--Three of the largest rivers: Yenisei, Ob and Lena, which transport a myriad of organic matter into the Kara and Laptev seas.
--This region also includes several archipelagos on the shelf, which are glaciated at present: Novaya Zemlya, Severnaya Zemlya, and Kotelnyy.

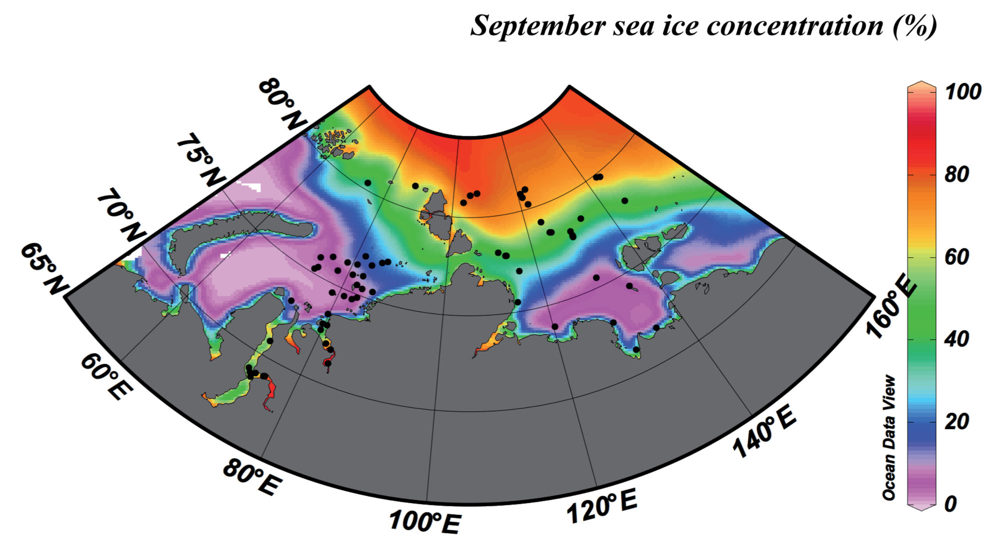
3. Sediment sampling

The surface sediment samples from the Laptev Sea shelf and slope were taken in 1993 during the RV Polarstern expedition ARK IX/4, the Transdrift I expedition with RV Ivan Kireyev and during RV Polarstern expedition ARK XXVI/3 in 2011.

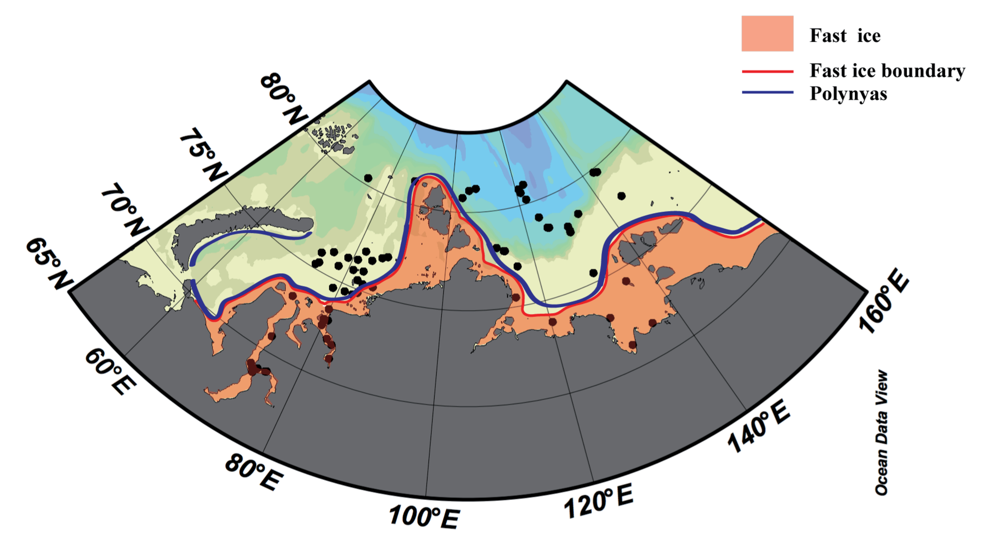
The surface sediment samples from the Ob and Yenisei transects and the inner Kara Sea shelf were taken during the Akademik Boris Petrov expeditions in 2000, 2001and 2002.

4. Sea ice conditions





Sea ice data are collected from http://nsidc.org
National Snow and Ice Data Center

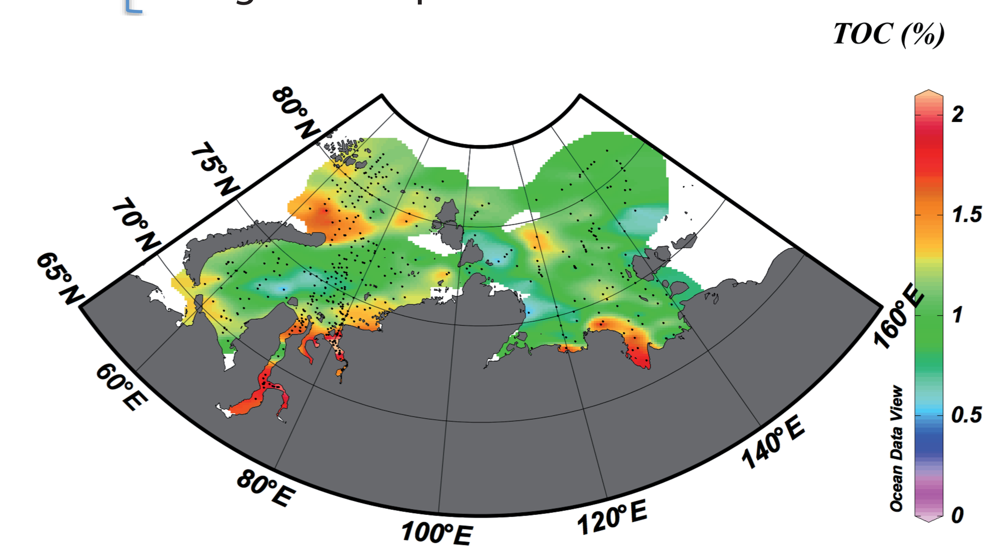


The Kara and Laptev seas present a complex sea-ice system.

--Mean sea ice cover extends the maximum in March and reaches the minimum in September.
--The ice realm is characterized by strong seasonal and interannual variability, comprising a variety of sea ice conditions such as drift ice, fast ice, ice massifs and coastal polynyas (Parkinson et al., 1999; Bareiss and Görgen, 2005).
--In summer ice will be transported to the Kara and Laptev Seas from the Arctic Basin, whereas in winter ice is exported to the Arctic Basin (Mironov et al., 2007).

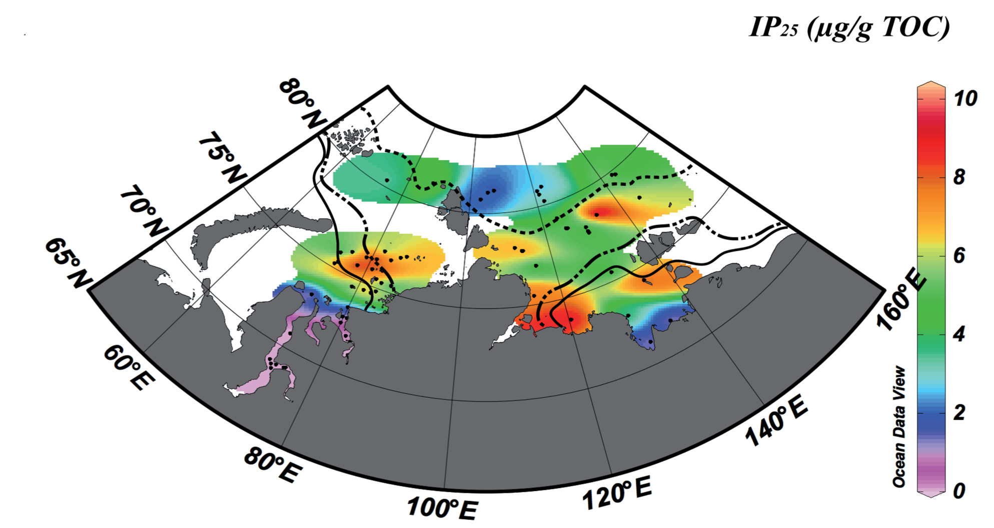
5. TOC (Total Organic Carbon)

TOC { primary production
terrigenous input

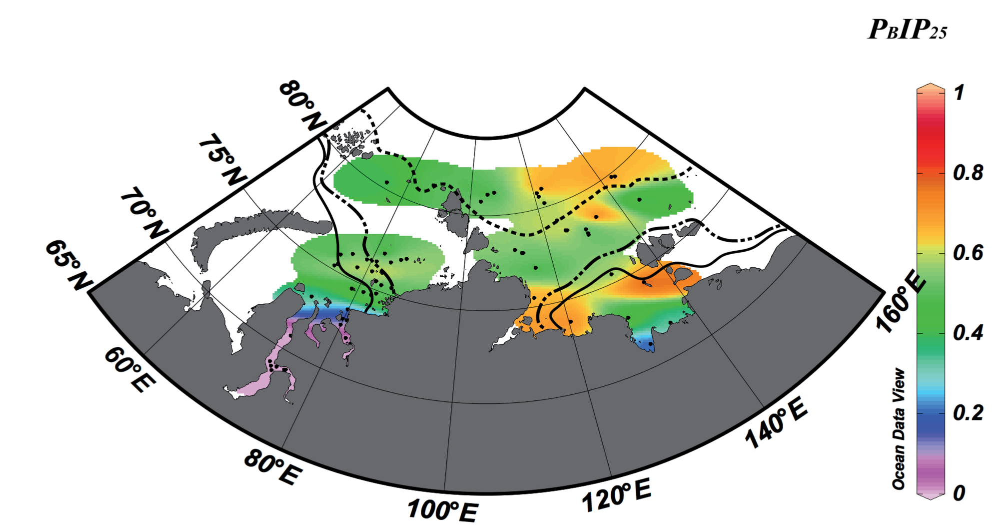


The seasonal variability in sea ice extent induces the organic carbon source.
We determined both marine and terrigenous biomarkers.

6. IP_{25} and phytoplankton-IP_{25} index



IP_{25} is produced by sea-ice diatoms. The minimum values are restricted in the deep sea and rivers, respectively. The maxima are found in the central Kara and Laptev seas.

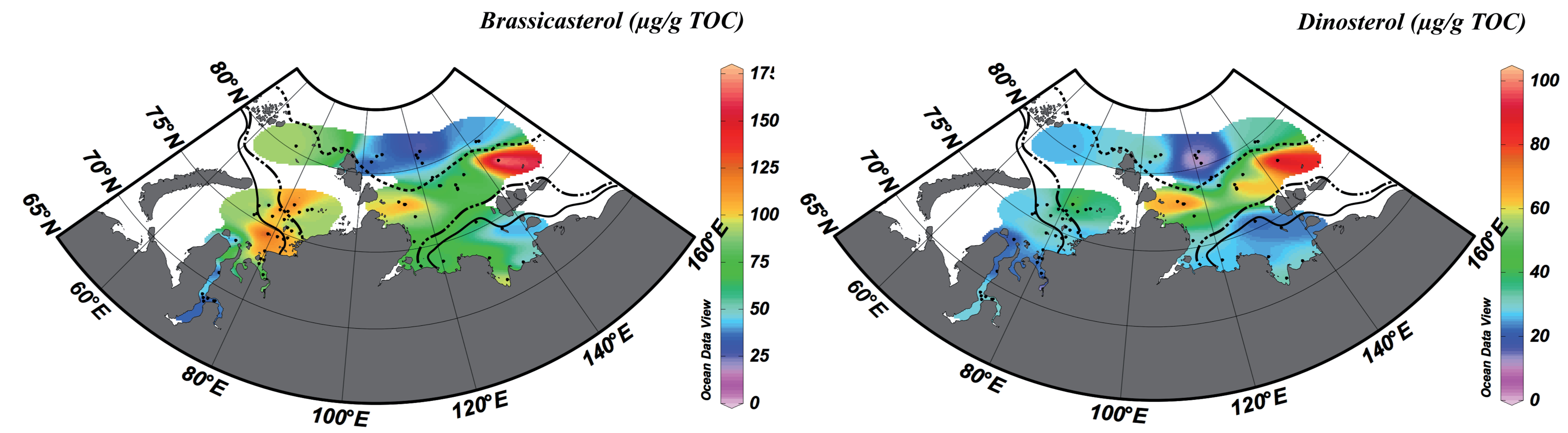


The PIP_{25} has been calculated using the concentrations of IP_{25} and phytoplankton biomarkers (Müller et al., 2011), which indicates the sea ice more quantitatively.

$PIP_{25} = IP_{25} / (IP_{25} + \text{phytoplankton marker} \times c)$
c = mean IP_{25} concentration/ mean phytoplankton biomarker concentration

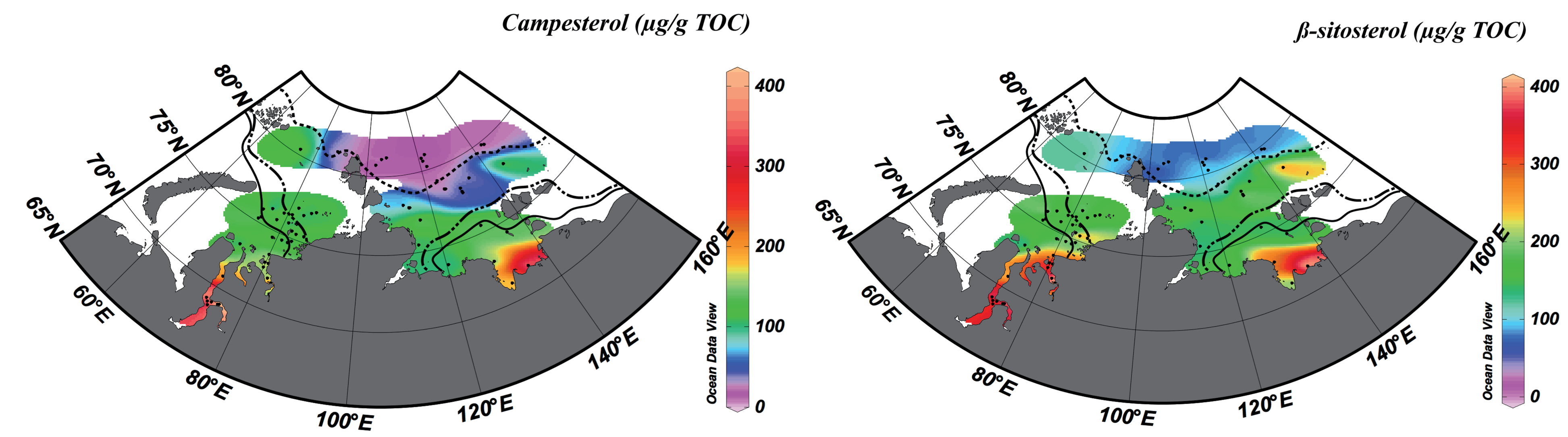
7. Sterols

Open-water phytoplankton biomarkers

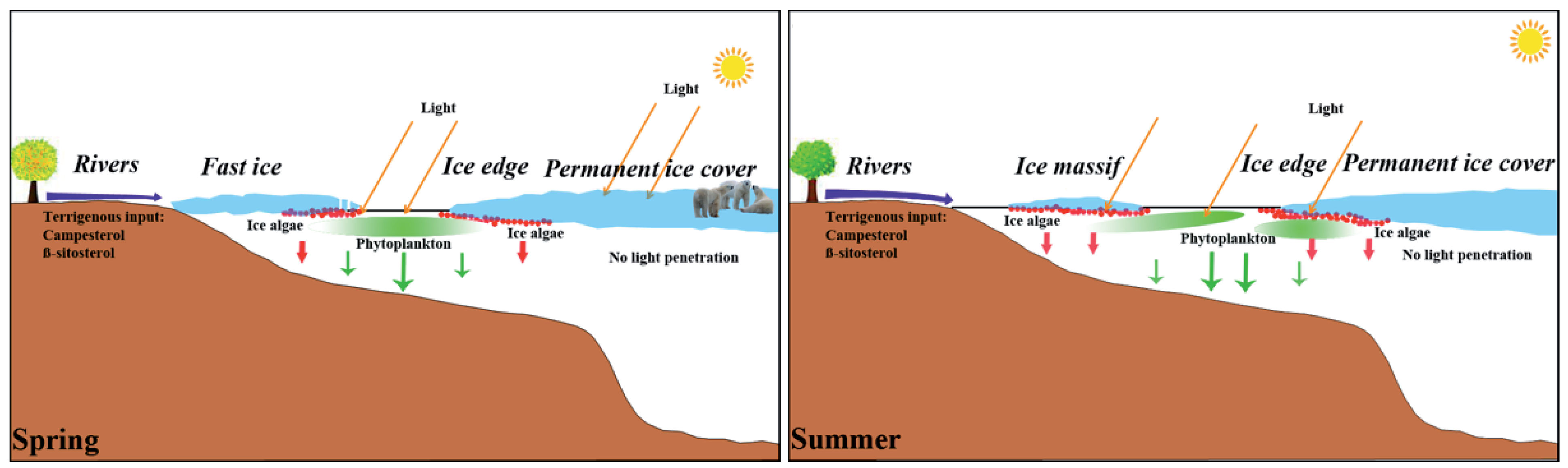


--Minimum concentrations of phytoplankton biomarkers occur in the adjacent continental margin, accompanied by low concentrations of IP_{25}, indicating a permanent ice cover.
--In contrast, the occurrence of increased values of IP_{25} and open-water phytoplankton biomarkers along the northern shelf of the Kara and Laptev seas, suggesting a stable ice edge in summer.
--Furthermore, high concentrations of marine biomarkers in the Kara Sea and Laptev seas are along the polynyas positions.
--Both IP_{25} and phytoplankton biomarkers concentrations diminish towards the river mouths, indicating less sea ice. In these areas, the seasonal sea-ice cover starts melting in spring and summer.

Terrigenous biomarkers



In general, the terrignous contents decrease towards the north, consistent with the distributions of TOC and long-chain *n*-alkanes.
Combined with the absence of IP_{25} and low concentrations of phytoplankton biomarkers, high values of terrigenous biomarkers can be used to indicate the riverine environment under ice-free conditions in summer.



We illustrated the seasonal sea ice variabilities by means of a schematic diagram, showing the general sea ice melting process in the siberian marginal seas during spring and summer.
Additionally, it reveals the variable terrigenous input and productivity of ice algae and phytoplankton during different seasons.

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