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Modern spatial sea-ice variability in the central Arctic Ocean and adjacent marginal seas: Reconstruction from biomarker data

Xiaotong Xiao, Marie Méheust, Kirsten Fahl, Juliane Müller, and **Ruediger Stein**
Alfred Wegener Institute for Polar and Marine Research, Am Alten Hafen 26, 27568 Bremerhaven, Germany (E-mail: Xiaotong.Xiao@awi.de)

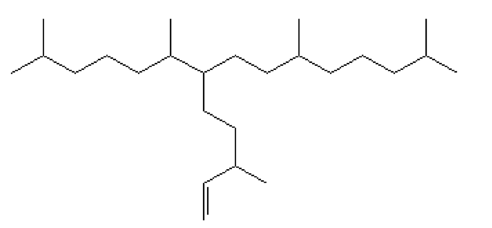
1. Introduction

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 related to the modern spatial (seasonal) sea-ice variability in the central Arctic Ocean and adjacent marginal 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.

New biomarker: IP_{25} (Belt et al., 2007)

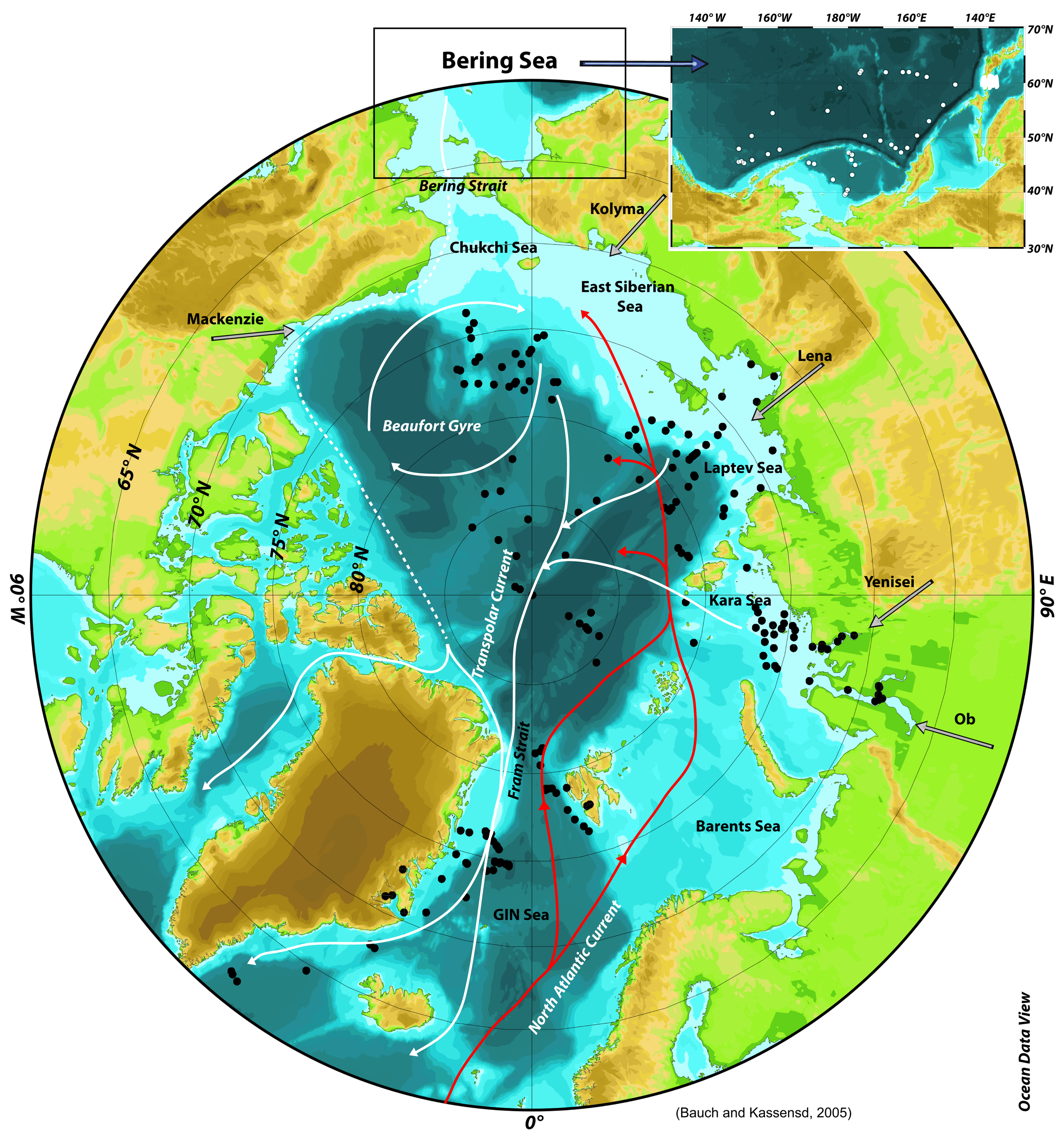


-- A C_{25} monounsaturated hydrocarbon used as ice proxy

--Highly branched isoprenoid

IP_{25} is biosynthesized specifically by sea-ice diatoms and has been used to reconstruct the past sea-ice distribution as a reliable proxy due to its stable preserve in sediments (e.g., Müller et al., 2009; Fahl and Stein, 2012).
The absence of IP_{25} either refers to ice-free conditions or a permanent ice cover.

2. Study area



Oceanographic setting in Arctic and sampling locations.

--Warmer, salty surface waters from the Atlantic (red arrows) enter the Arctic Ocean and are cooled as they move through the Greenland Sea and the Norwegian Sea. Cold and relatively less salty water (white arrows) enters the Arctic Ocean through the Bering Strait. A large volume of cold and fresh water (white arrows) crosses the Arctic in the Transpolar Current and enters the Fram Strait into the Atlantic.
--Four of the largest rivers: Yenisei, Ob, Lena and Mackenzie which transport a myriad of organic matter into the central Arctic and adjacent seas (Peterson et al.,2002; Stein and Macdonald, 2004).

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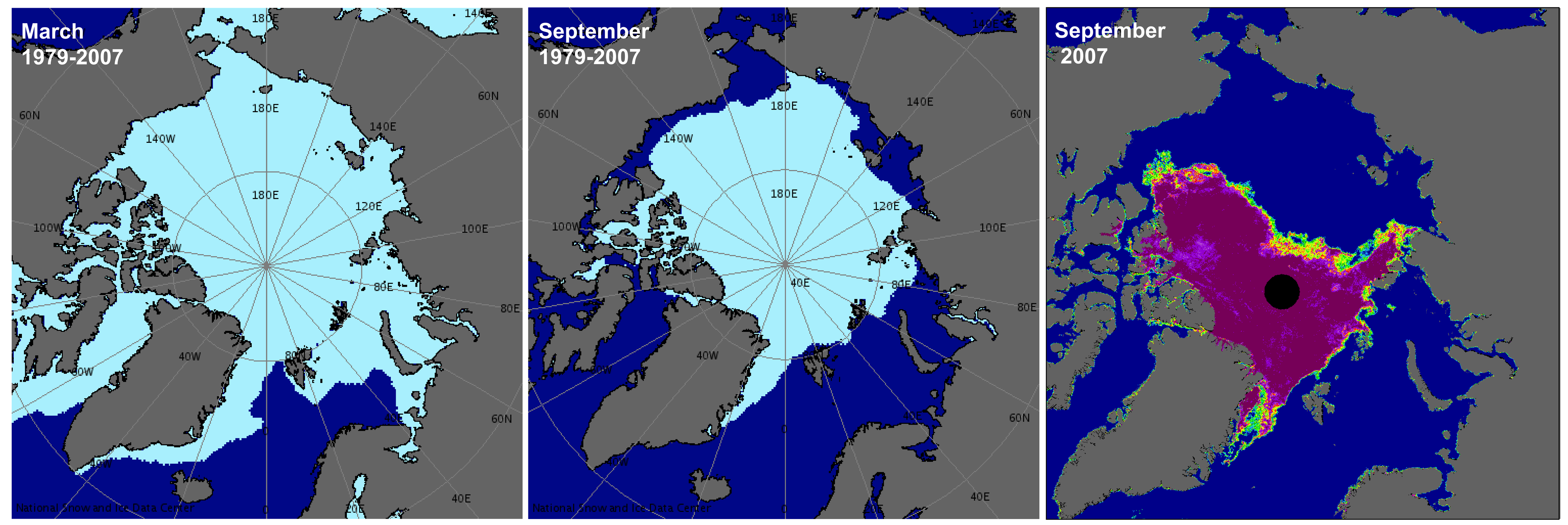
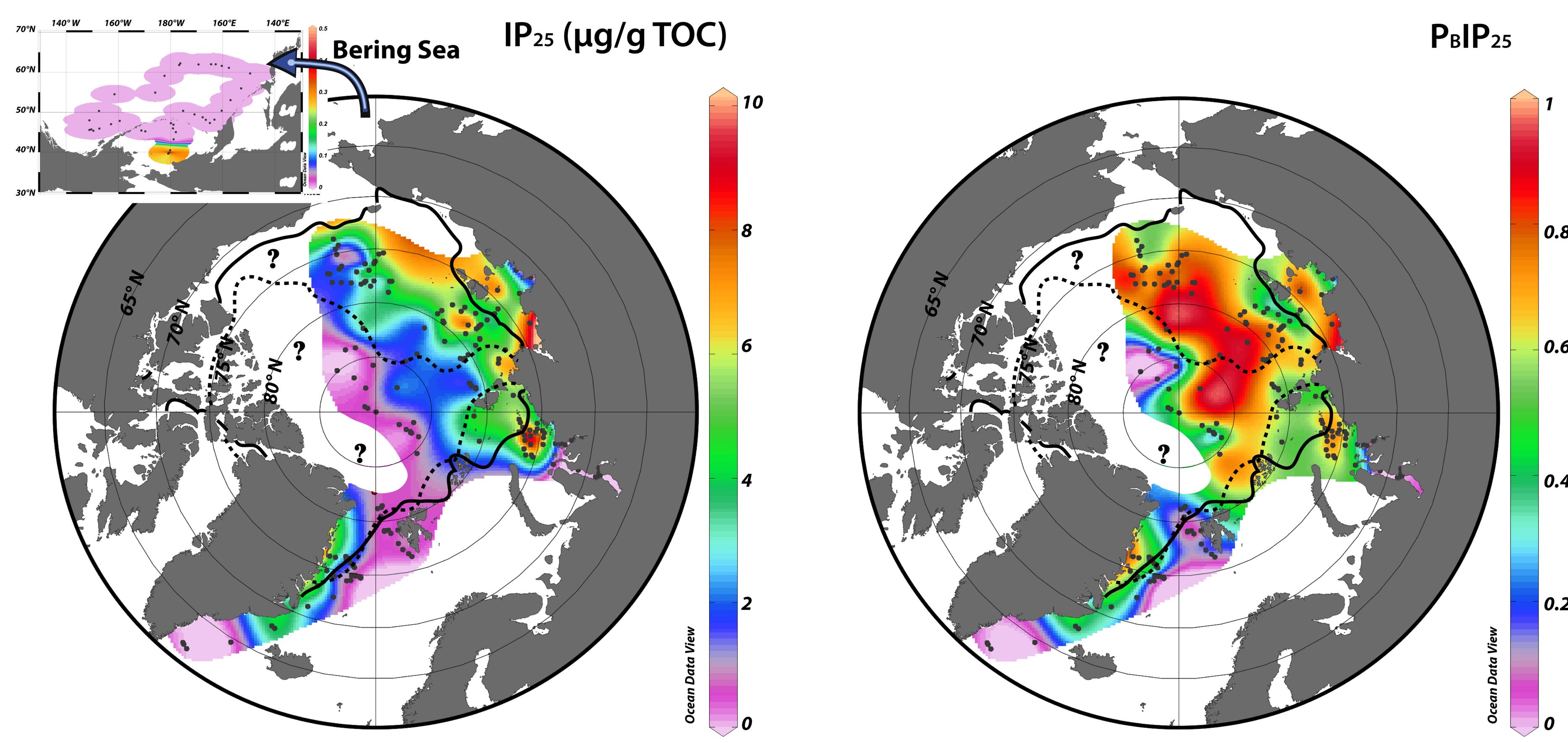
4. Sea-ice conditions and sea-ice indicators

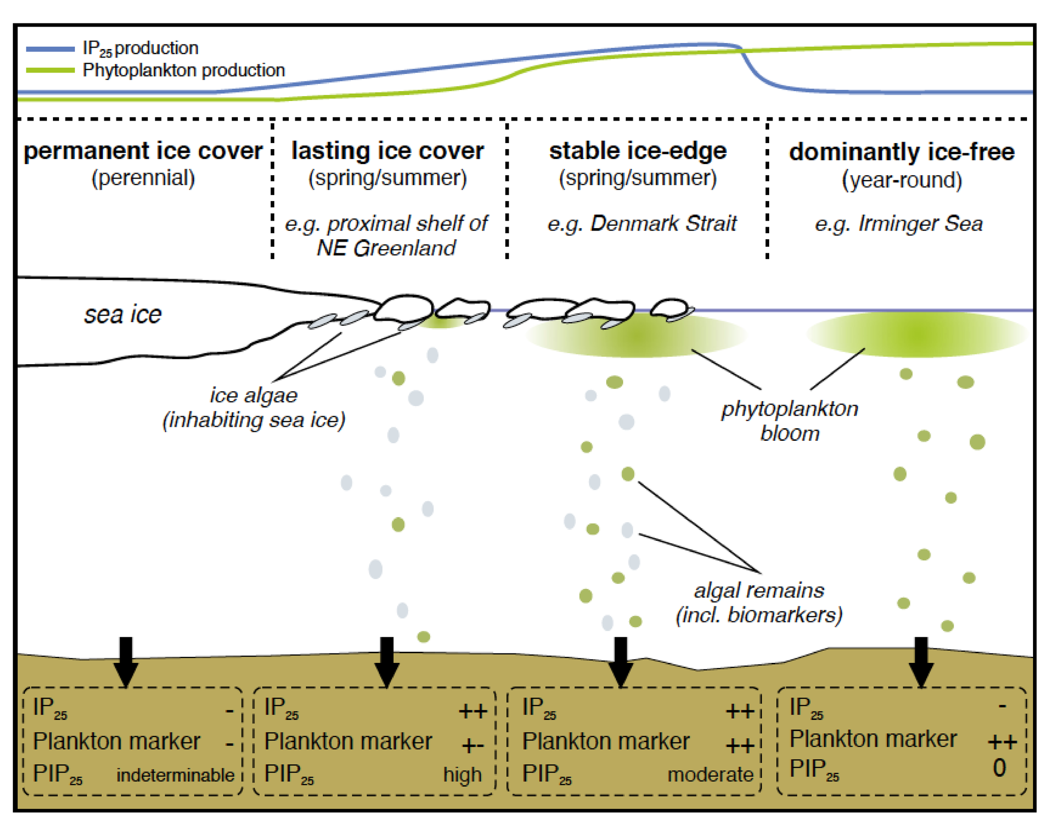
Maximum average sea-ice extent | Minimum average sea-ice extent | Minimum sea-ice extent



(http://nsidc.org/data/atlas/ National Snow and Ice Data Center)

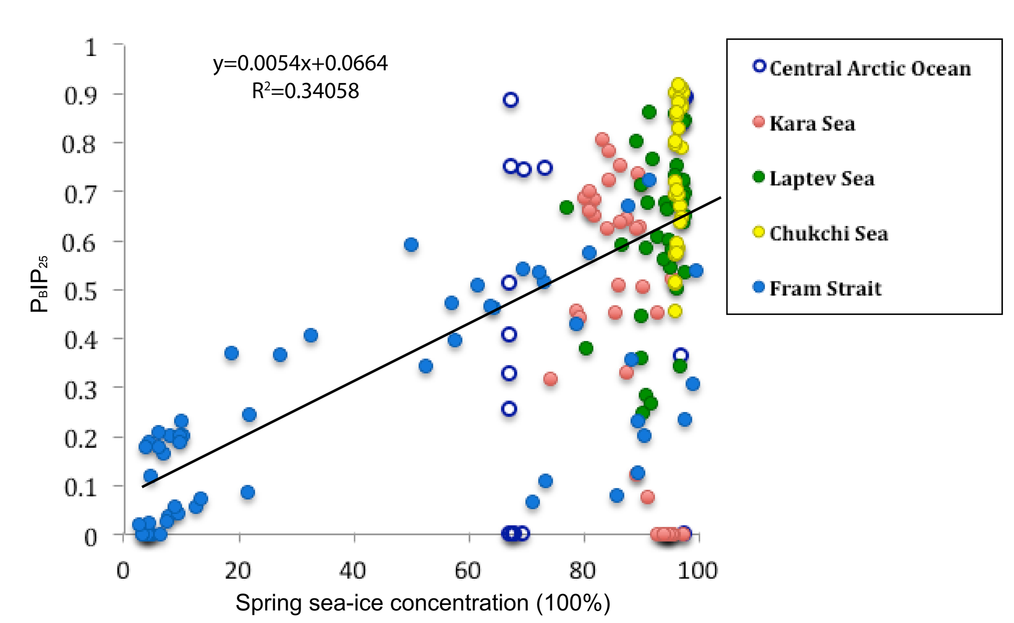
Figure shows the permanent sea-ice cover in the central Arctic Ocean with its strong seasonal variabilities in adjacent marginal seas.
A minimum sea-ice cover was observed in September 2007, which is about 40% less than that of 1979.





(Müller et al., 2011)

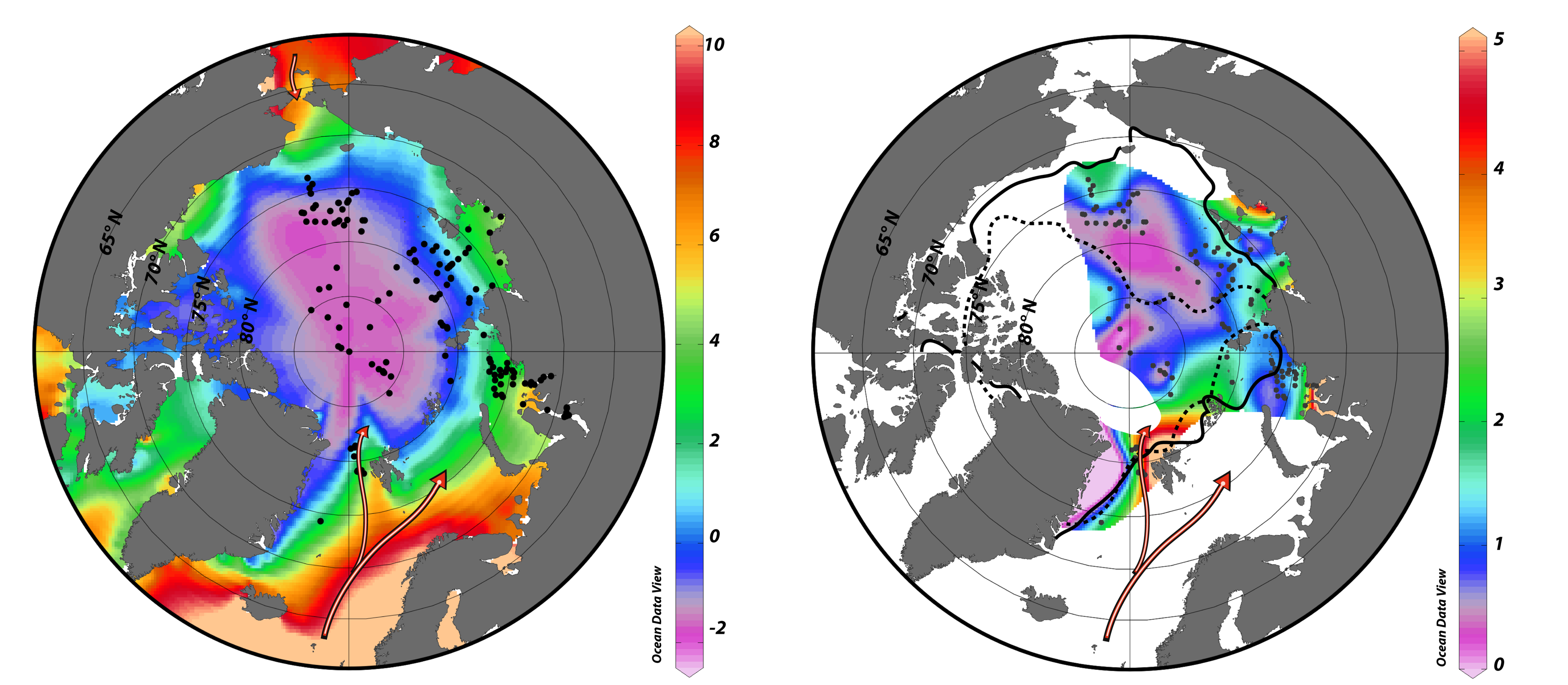
$PIP_{25} = IP_{25}/ (IP_{25} + \text{phytoplankton marker} \times c)$
c = mean IP_{25} concentration/ mean phytoplankton biomarker concentration



IP_{25} is produced by sea-ice diatoms. The minimum values are restricted to the central Arctic Ocean, Siberian estuaries, eastern Fram Strait, Irminger Sea and Bering Sea (Müller et al., 2011; Méheust et al., 2012; Xiao et al., 2012), indicating permanent ice cover or open-water conditions. The maximum values were found along the continental shelves (ice edge), reflecting suitable living conditions for ice algae.

The PIP_{25} has been calculated using the concentrations of IP_{25} and phytoplankton biomarkers (Müller et al., 2011). The PIP_{25} index indicates the spring/summer algal productivity beneath the sea ice (mainly ice algae), at the ice edge (ice algae and phytoplankton), and in the open water (phytoplankton) and gives a rough estimate of the spatial and temporal extent of the ice cover (Müller et al., 2011).
In contrast to the good correlation between IP_{25} and PIP_{25} with sea-ice concentration derived from satellite data described for the Fram Strait area (Müller et al., 2011), our data set does not show this correlation. This may be explained by the more complex environmental situation in the whole Arctic Ocean, influenced by sea ice and fast-ice formation, occurrence of ice massifs, Transpolar current and river discharge.

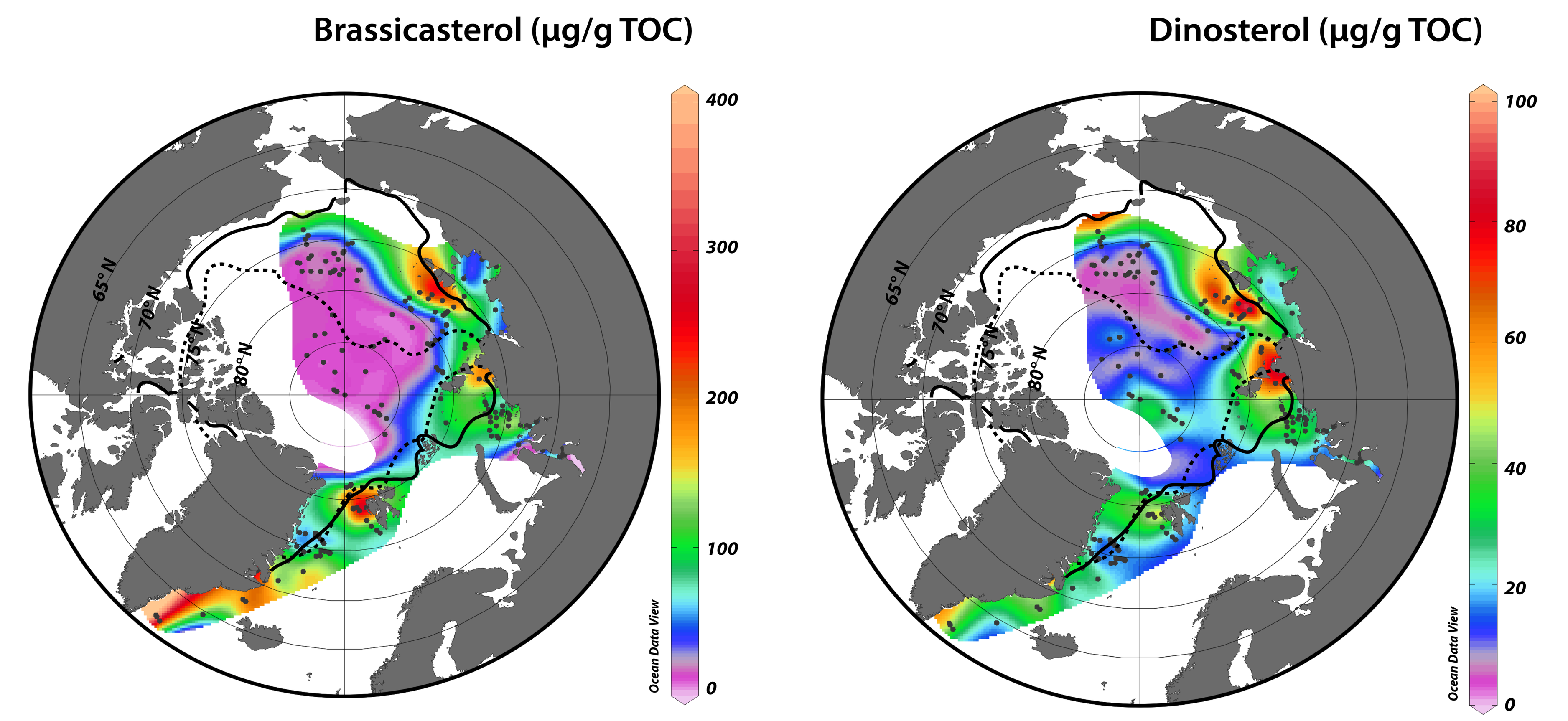
5. SST and diene/IP_{25}



The extent of unsaturation in HBIs (highly-branched isoprenoid alkenes) depends on the growth conditions and culture temperatures (Belt et al., 2000; Rowland et al., 2000).The unsaturation increases with increasing temperature. The diene/IP_{25} ratio seems to correlate positively with sea-surface temperature in our study area.

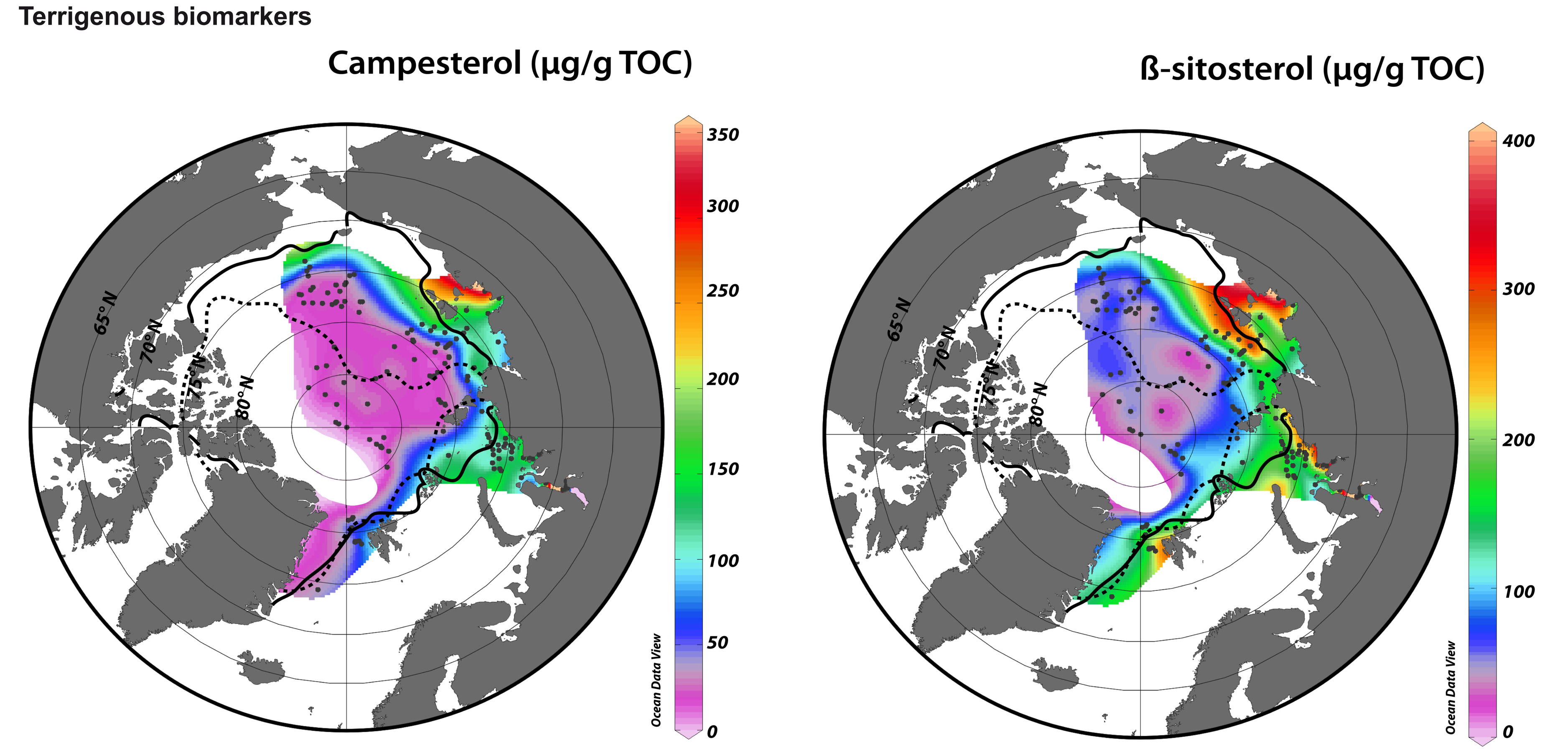
6. Sterols

Open-water phytoplankton biomarkers



Minimum concentrations of phytoplankton biomarkers occur in the Central Arctic and 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 phytoplankton biomarkers along the shelf suggests a stable ice edge in summer.

Terrigenous biomarkers



In general, the content of terrigenous OC decreases towards the central Arctic from the shallow shelves. Sediment organic matter can be incorporated into the sea ice during ice formation on the shallow shelf and then transported to the open ocean via sea-ice export to the Arctic Basin (Nürnberg et al., 1994; Eicken et al., 1997; Pfirman, 1997).