DISTRIBUTION OF DINOFLAGELLATE CYSTS IN SURFACE SEDIMENTS FROM THE EAST SIBERIAN AND CHUKCHI SEAS AND THEIR RELATION TO THE PREVAILING HYDROGRAPHICAL CONDITIONS

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ABSTRACT

Thirty-four surface sediment samples from the East Siberian and Chukchi Seas, Pacific Arctic Ocean sector were investigated to determine the distribution, abundance and species composition of resting stages of dinoflagellates (dinoflagellate cysts). This study is the first to document the distribution of the dinoflagellate cysts in the area. A clearly distinguishable distribution pattern was observed in species diversity, concentration and taxa dominance varying along inner-shelf to outer-shelf gradient. The data presented here also reveal a clear longitudinal trend in the dinoflagellate cyst distribution such that subdivision into two domains is possible. The first, the Chukchi Sea area, is characterized by higher numbers and diversity of dinoflagellate cysts, with the assemblages dominated by *Operculodinium centrocarpum*, *Pentapharsodinium dalei* and *Spiniferites elongatus*. The second, the East Siberian Sea area, is characterized by high occurrence of the RBSC-type cysts that are brown in color with a distinct spheroidal and process-bearing shape. A particular note is for the recently described species, *Islandinium minutum* subsp. *barbatum* subsp. nov., which shows rather restricted distribution pattern in the shallow East Siberian Sea shelf area. This result tentatively suggests a potential use of dinoflagellate cysts in providing retrospective information on the long-term changes in the phytoplankton community in the study area. Our study also highlights the importance of further investigation to identify the main environmental drivers of the dinoflagellate cyst distribution patterns, several regional and in situ environmental parameters in the East Siberian and Chukchi Seas.

Distribution of dinoflagellate cysts in surface sediments from the East Siberian and Chukchi Seas and their relation to the prevailing hydrographical conditions

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Abstract

Twenty-two surface sediment samples from the East Siberian and Chukchi Seas, Pacific Arctic Ocean sector were investigated to determine the distribution, abundance and species composition of resting stages of dinoflagellates (dinoflagellate cysts). This study is the first to document the distribution of the dinoflagellate cysts in the area. A clearly distinguishable distribution pattern was observed in species diversity, concentration and taxa dominance varying along inner-shelf to outer-shelf gradient. The data presented here also reveal a clear longitudinal trend in the dinoflagellate cyst distribution such that subdivision into two domains is possible. The first, the Chukchi Sea area, is characterized by higher numbers and diversity of dinoflagellate cysts, with the assemblages dominated by *Operculodinium centrocarpum*, *Pentapharsodinium dalei* and *Spiniferites elongatus*. The second, the East Siberian Sea area, is characterized by high occurrence of the RBSC-type cysts that are brown in color with a distinct spheroidal and process-bearing shape. A particular note is for the recently described species, *Islandinium minutum* subsp. *barbatum* subsp. nov., which shows rather restricted distribution pattern in the shallow East Siberian Sea shelf area. This result tentatively suggests a potential use of dinoflagellate cysts in providing retrospective information on the long-term changes in the phytoplankton community in the study area. Our study also highlights the importance of further investigation to identify the main environmental drivers of the dinoflagellate cyst distribution patterns, several regional and in situ environmental parameters in the East Siberian and Chukchi Seas.

Study area- East Siberian and Chukchi Seas

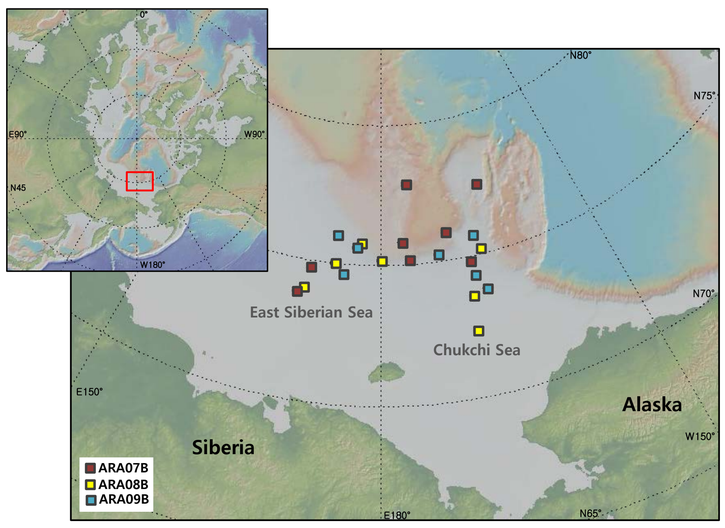


Figure 1. Map of study area, showing surface sediment sampling sites and the research cruises as indicated by the colored dots.

- Highly sensitive to climate variability, which affects its atmospheric and oceanographic linkages with the Pacific Ocean.
- The atmospheric circulation is mainly controlled by a low-pressure system in the North Pacific (Aleutian low), which interacts with polar air masses and strongly affects meteorological conditions in the western Arctic.
- The oceanographic connection between the Arctic and the Pacific oceans through the Bering Strait transports Pacific waters and organisms to the Chukchi Sea shelf and adjacent basins.
- The overall shallow (mostly <100 m deep) shelf region is characterized by a complex system of currents originating mostly from the inflow of relatively warm and fresh Pacific waters via the Bering Strait.
- Extensive sea-ice formation in the Chukchi Sea is enhanced by Arctic river discharge and relatively fresh Pacific inflow providing low-salinity surface water into this region.

Methodology

Sample collection

- ARAON cruises during 2016~2018
- Twenty-two surface samples using a box corer

Palynological analysis

- The standarzied palynological preparation protocol
- Counts of dinocysts and other palynomorphs

Statistical approach

- Multivariate statistical analyses test (e.g. CANOCO)
- Environmental data: the World Ocean Atlas 2013 V2 and the National Snow and Ice Data Center

Results: dinoflagellate cyst analysis

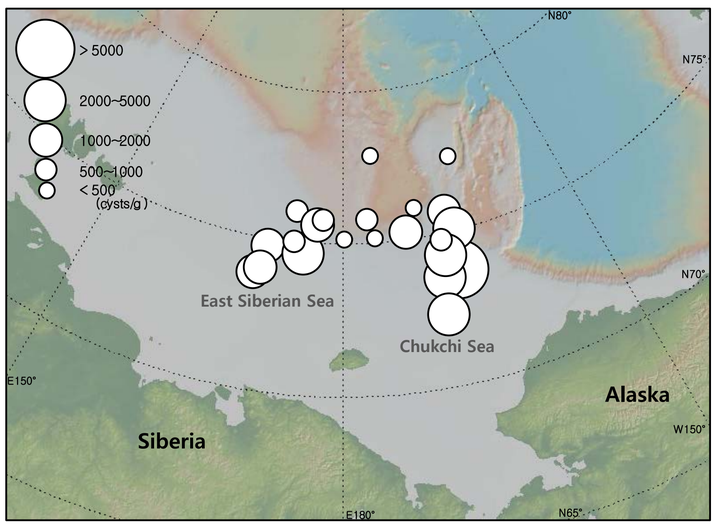


Figure 2. Distribution of total dinoflagellate cyst concentrations (cysts/g) in the Eastern Siberian and Chukchi Seas.

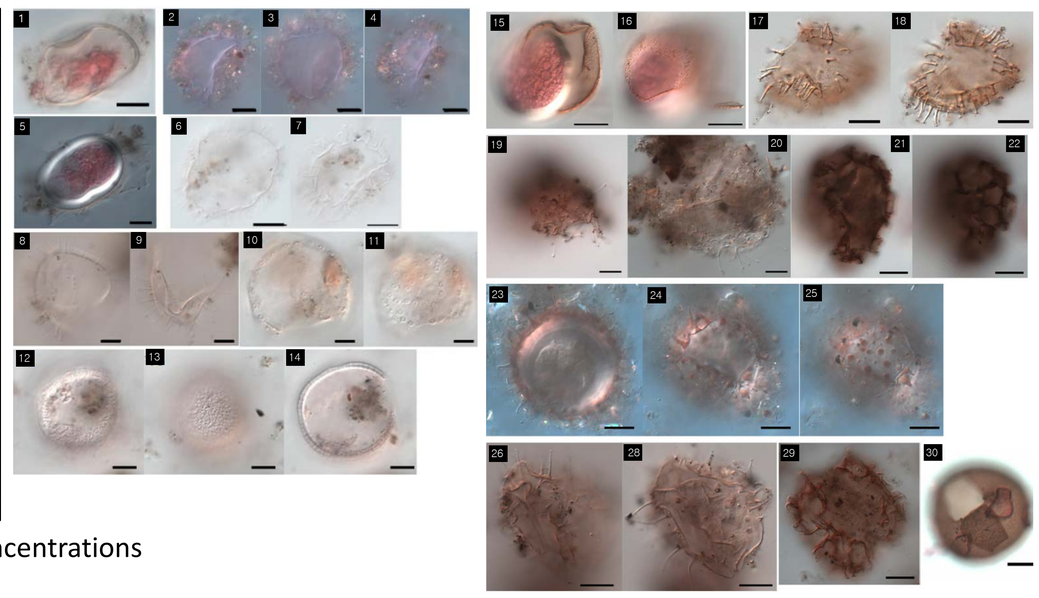
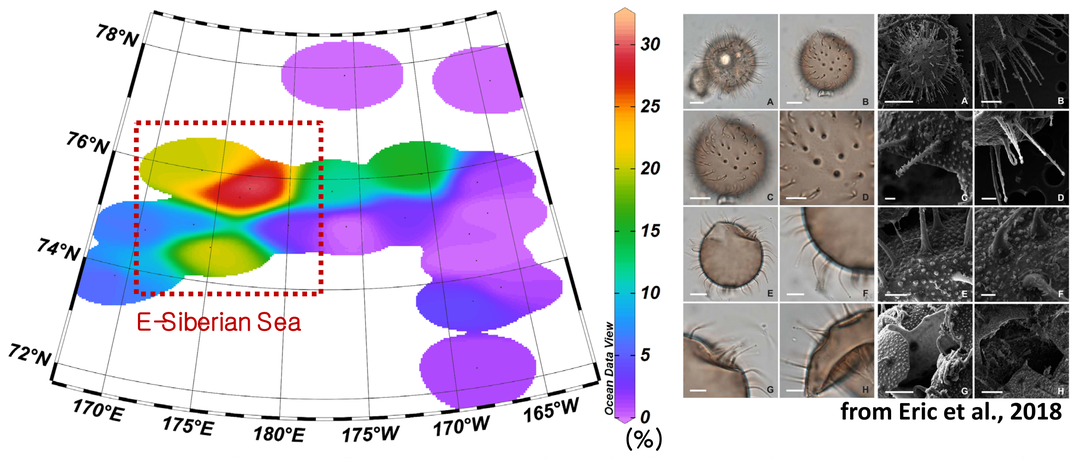


Figure 3. 1) *Alexandrium* spp., 2-4) *Pentapharsodinium dalei*, 5) *Spiniferites elongatus*, 6-7) *Nematosphaeropsis labyrinthus*, 8-9) *Operculodinium centrocarpum*, 10-11) *Operculodinium centrocarpum*-Arctic morphotype, 12-14) *Bitectatodinium tepikiense*, 15-16) *Islandinium brevispinosum*, 17-18) *Islandinium cezare*, 19-20) *Islandinium cezare* morphotype 1, 21-22) *Polykrikos schwartzii*, 23-25) *Echinidinium karaense,* 26-27) *Islandinium barbatum*, 28) *Polykrikos* sp. Arctic morphotype, 29) *Brigantedinium* spp. (Scale bar = 10 ㎛)

Results: previous studies & the working hypothesis

New subspecies *Islandinium minutum* subsp. *barbatum* subsp. nov.

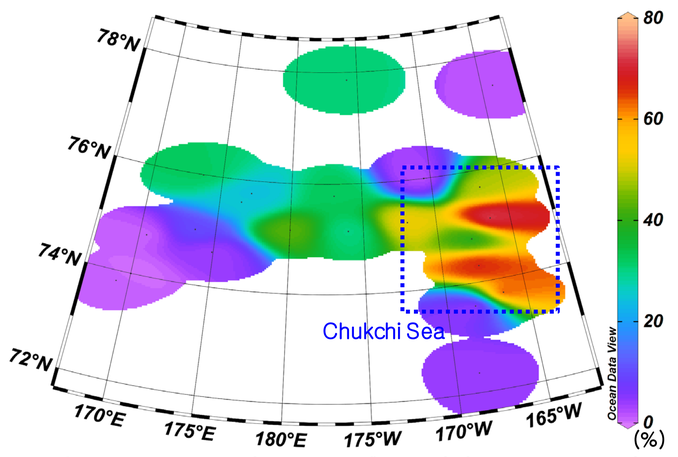


from Eric et al., 2018

Figure 4. Distribution of *I. minutum* subsp. *barbatum* subsp. nov., expressed in percentages.

- Occurs at locations where the heterotrophic dinocyst community is well represented and the RBSCs are observed in higher concentrations.
- Preferential affinity for environmental conditions characterizing the inner shelf area of the East Siberian Sea.
- While *I. minutum* subsp. *minutum* is currently associated with sea ice (de Vernal et al. 2013), information on the distribution of *I. minutum* subsp. *barbatum* is insufficient to determine whether this subspecies is also related to sea ice.

Pentapharsodinium dalei in the eastern Chukchi shelf sediments



from Mudie et al., 2017

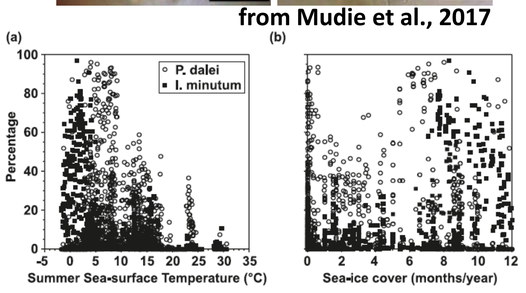
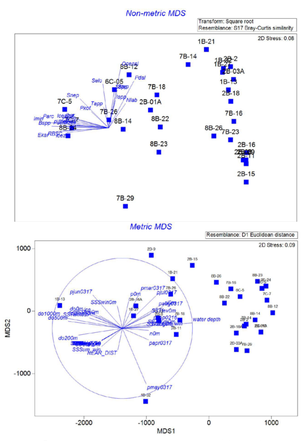


Figure 6. Relationship between the percentages of *P. dalei* and *I. minutum* and (a) summer sea-surface temperature and (b) sea-ice cover (Mckay et al., 2008).

Figure 5. Distribution of *P. dalei,* expressed in percentages.

- Abundant in the arctic front (Northern Hemisphere), particularly dominating the Barents Sea and the Chukchi Sea in the Arctic Ocean (up to 95%).
- Occurs at locations where can be covered by sea ice for up to 9 to 12 months a year with a slight negative relationship between its relative abundance and annual ice cover can be distinguished.
- Increase of *P. dalei* shows a strong affinity to warming in surface waters and increased water stratification (Mckay et al., 2008).

Application of the modern analogue technique



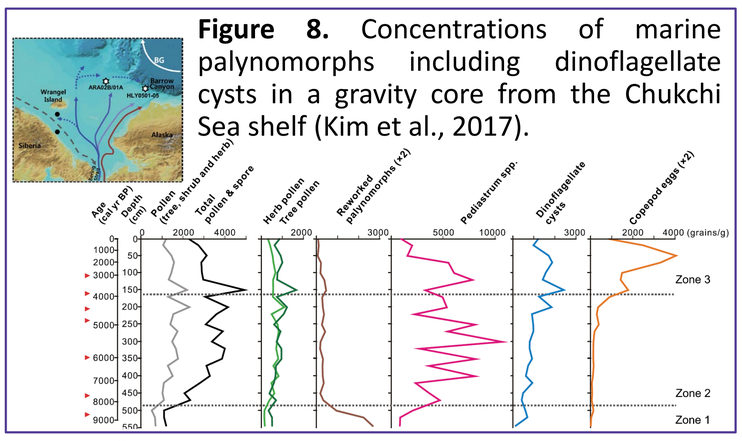


Figure 8. Concentrations of marine palynomorphs including dinoflagellate cysts in a gravity core from the Chukchi Sea shelf (Kim et al., 2017).

Figure 7. A preliminary result of multivariate analyses using the ARAON surface sediment sample database.

- Higher dinoflagellate cyst abundances in the mid- to late Holocene sediments of the Chukchi Sea shelf sediments may reflect changes in the hydrographic structure, which could affect biological production (Kim et al., 2017; Fig. 8).
- An increase in the content of P. dalei cysts starting from ca. 5000 yr BP, can be tentatively associated with warmer temperatures (McKay et al., 2008). This issue requires further investigation based on statistical approach.

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Aknowledgements

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