Title: Biogeochemical observational studies in the Arctic Ocean

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Background

- Biogeochemical observations in the Arctic Basins, the Siberian Shelf Seas (SSS), the Chukchi Sea and the Bering Sea.

- In Arctic Basins and Chukchi Sea:
  * The distribution of Chl-a, and nutrients
  * Influence of water mass dynamics on these parameters
  * Investigating trace metals as water mass tracers

- In Siberian Shelf Seas:
  * Spatial-temporal variability of the marine carbon cycle components
  * Transport and fate of terrestrial OC
  * Methane and carbon dioxide marine fluxes to atmosphere
  * Chemical and physical shelf-basin interactions.

- In the Bering Sea:
  * Melting sea ice as a sources of Fe to surface waters, in particular to the Green Belt during spring bloom
Objectives

1. Investigate how changes in the sea ice regime affect the biogeochemistry and hydrology of the Arctic Ocean.

2. Investigate how changes in the hydrological cycle of surrounding land and alteration of terrestrial carbon cycles contribute to formation and propagation of halocline waters and affect hydrological and biogeochemical parameters of shelf water masses.

3. Investigate biogeochemical cycles in the Siberian shelf seas, especially in terms of CO$_2$ and CH$_4$, and their impact on the pan-Arctic ecosystem and climate.

4. Investigate physical and biogeochemical processes between arctic shelves and adjacent basins

5. Integrate observations toward understanding the effects of expected climate changes on the Arctic Ocean biogeochemical cycles and ecosystems
Methodology

1. Coordinated observations on the *R/V Mirai* Arctic cruise during 2009-2013 and collaboration on data analysis.

2. Joint exploration in the SSS and the Arctic Basins onboard icebreakers, e.g., Russian vessels: detecting carbon and freshwater changes over the SSS.

3. Combined analysis of observed data from Arctic Basins, SSS, Chukchi, and Bering seas.
R/V Mirai 2013 Cruise (MR13-06)

- Physical, chemical and biological joint observations in the Chukchi Sea
- Sea ice extent limited northward extent of cruise track
- Chukchi Shelf two-week fixed point observation station to study the impact of atmospheric events on the ocean stratification and the ecosystem
R/V Mirai fixed point observation during 11-25 Sep. 2013
Surface nutrient input and biological response

Wind velocity [m/s]

Wind stress [N/m²]

Phosphate [µmol/kg] @ surface 10 m

Log (Flux P) [mmol/m²/s]

Chl-a [µg/L]

Ocean Deep Year

Depth [m]

Sep 2013

AMSRR2 Sea ice and SST (Descending) for 2013.09.21

Sea ice

Fixed Point

Siberia

Alaska
R/V Mirai fixed point observation during 11-25 Sep. 2013
Sub-surface benthic boundary layer variability

Temporal and spatial variability of the benthic boundary layer at the fixed point observation station
R/V Mirai 2013: TM Profiles

Location of TM Stations

- Dissolved Pb (pM)
- Dissolved Cu (nM)
- Dissolved Fe (nM)
- Dissolved Ni (nM)
It is shown that the main source of terrestrial organic carbon in the ESAS is coastal and bottom erosion (Semiletov et al., BG, 2011, 2013; ERL, 2012; Vonk et al., 2012, Nature)

It is shown that the highest rates of CO2 emission (up to 500mM/m2/day) were found along the highly eroded ice complex bluffs (Figure 1)

Figure 1. (A) Rates of coastal erosion can be up to 25 m/yr and higher; (B) Contribution of terrestrial organic carbon (CTOM, %) in the ESAS surface sediment: 1) <40%, 2) 40-69%, 3) 69-98%, 4) 98-100%.

(C) Values of CO2 efflux approached 35 mM/m2/day over the shallow water which is significantly higher than CO2 emission from the nearest lakes (2-15mM/m2/day).

Highest CO2 release has been found from a plume of eroded material on the beach: up to 500 mM/m2/day (Semiletov et al., Biogeosciences, 2013)
SSS Results: Warming bottom water

Dynamics of the bottom water observed in the coastal zone of the ESAS (1999-2012). a) Position of oceanographic stations where the bottom water temperatures observed in summer are marked by red triangles; winter stations are marked by blue triangles; historical data are marked by green squares. b) Dashed lines reflect historical data\(^{17}\); black: annual mean bottom water temperature (MBWT); blue: winter MBWT; red: summer MBWT. Solid lines reflect modern MBWT: black for annual, blue for winter, and red for summer (Shakhova et al., Nature Geoscience, 2013).
Our latest modeling results allowed achieve better agreement with observational data.

Simulated areas of open taliks in the coastal area of the ESAS under different thermal regimes of sediments determined by bottom water temperature. a) Areas of taliks based on historical data sets describing bottom water temperatures. b) Areas of taliks based on historical data sets updated with modern data (1999-2009). c) Areas of methane hot spots observed in the coastal area.

(Shakhova et al., Nature Geoscience, 2013).
Summary Completed Fieldwork

Completed Cruises

• R/V Mirai 2013 – Chukchi and Beaufort seas, September 2013
• Research Drilling and Oceanographic Survey from fast ice in the near shore zone of the Laptev Sea (April/May)
• Biogeochemical/Hydrophysical Survey in the Laptev Sea and adjacent lagoons (September/October)

Expected outcomes from recent Fieldwork

• Joint papers from 2013 Mirai and SSS cruise results
• Presentations at international meetings from 2013 Mirai and SSS cruise results
Achievements

• Presentations at international meetings:

  • Aguilar-Islas, A. R. Rember, S. Nishino, T. Kikuchi, M. Itoh.
    Lateral transport of iron in the Canada Basin,
    2013 Aquatic Sciences Meeting, February 2013, New Orleans, Louisiana, USA.

  Nishino, S., T. Kikuchi, T. Hirawake, M. Yamamoto-Kawai, and M. Aoyama
  Biogeochemistry in the hotspots of the Chukchi Sea,
  ESSAS (Ecosystem Studies of Sub-Arctic Seas) Annual Science Meeting, January 2013, Hakodate, Hokkaido, Japan.

  Nishino, S., M. Itoh, W. J. Williams, and I. P. Semiletov
  Shoaling of the nutricline with an increase in near-freezing temperature water in the Makarov Basin,
  ISAR-3 (Third International Symposium on the Arctic Research), January 2013, Tokyo, Japan.

• Publications:

  Partitioning and lateral transport of iron in the Canada Basin. Polar Science, doi: 10.1016/j.polar.2012.11.001


Challenges and Concerns

• No joint cruises of R/V Mirai and Russian vessels to understand land – shelf – basin interactions and their impact on Arctic biogeochemical cycles and ecosystem

• The Russian sector of the Arctic Ocean is under sampled and should be targeted as biological activity in this area is expected to increase dramatically with the sea ice loss.

• IARC-based International Siberian Shelf Studies project is required to be extended to the entire East Siberian Arctic Shelf, because of no other biogeochemical and ecological studies are expected in the Russian sector of the Pacific Arctic in the near future.

• Limited trace metal sampling time on R/V Mirai cruises (#stations and depths) and inadequacy of Russian vessels for trace metal sampling operations

• Greater than expected sea ice extent in 2013 restricted sampling region