International collaboration in the East Siberian Shelf : present and future

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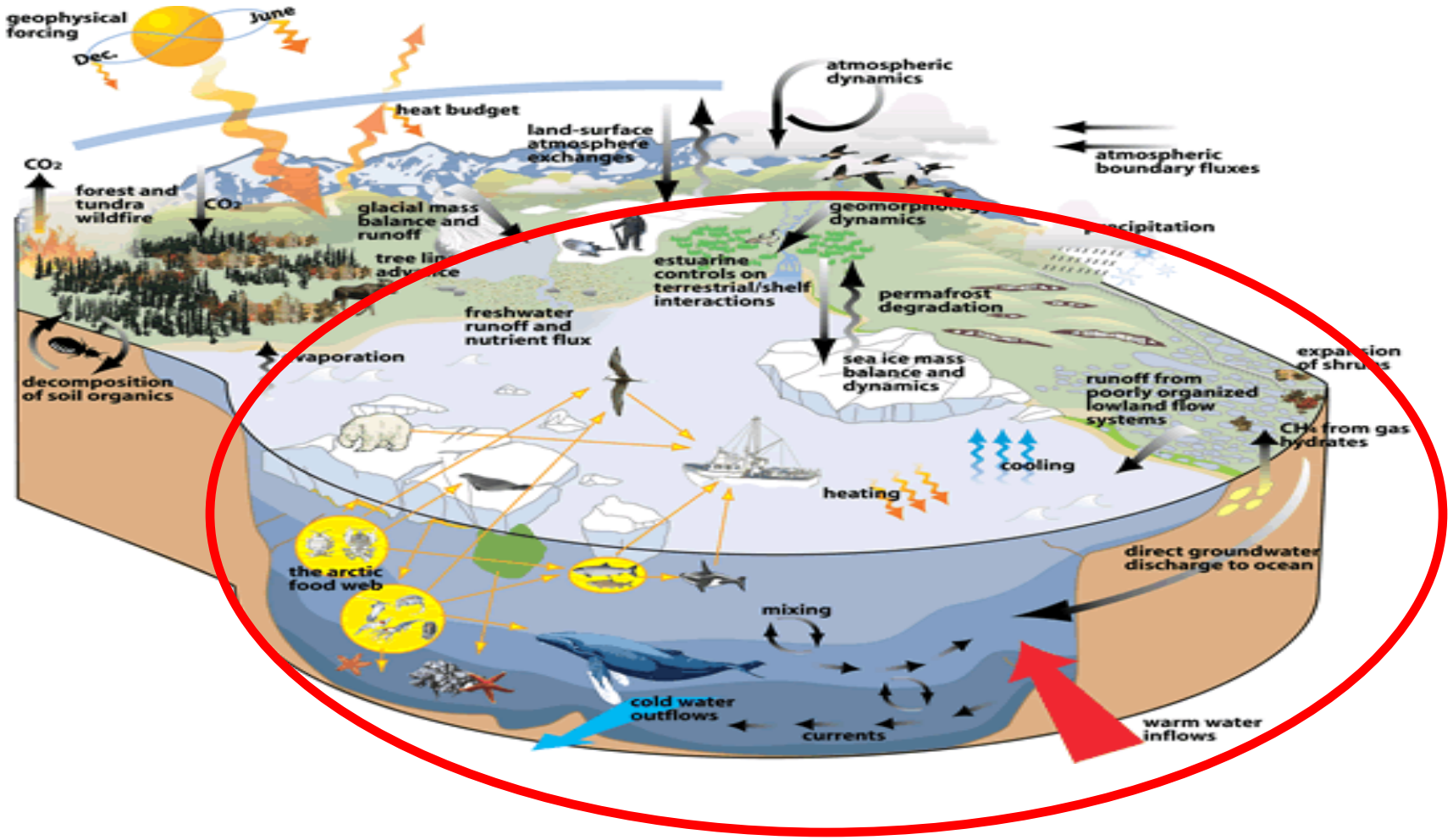
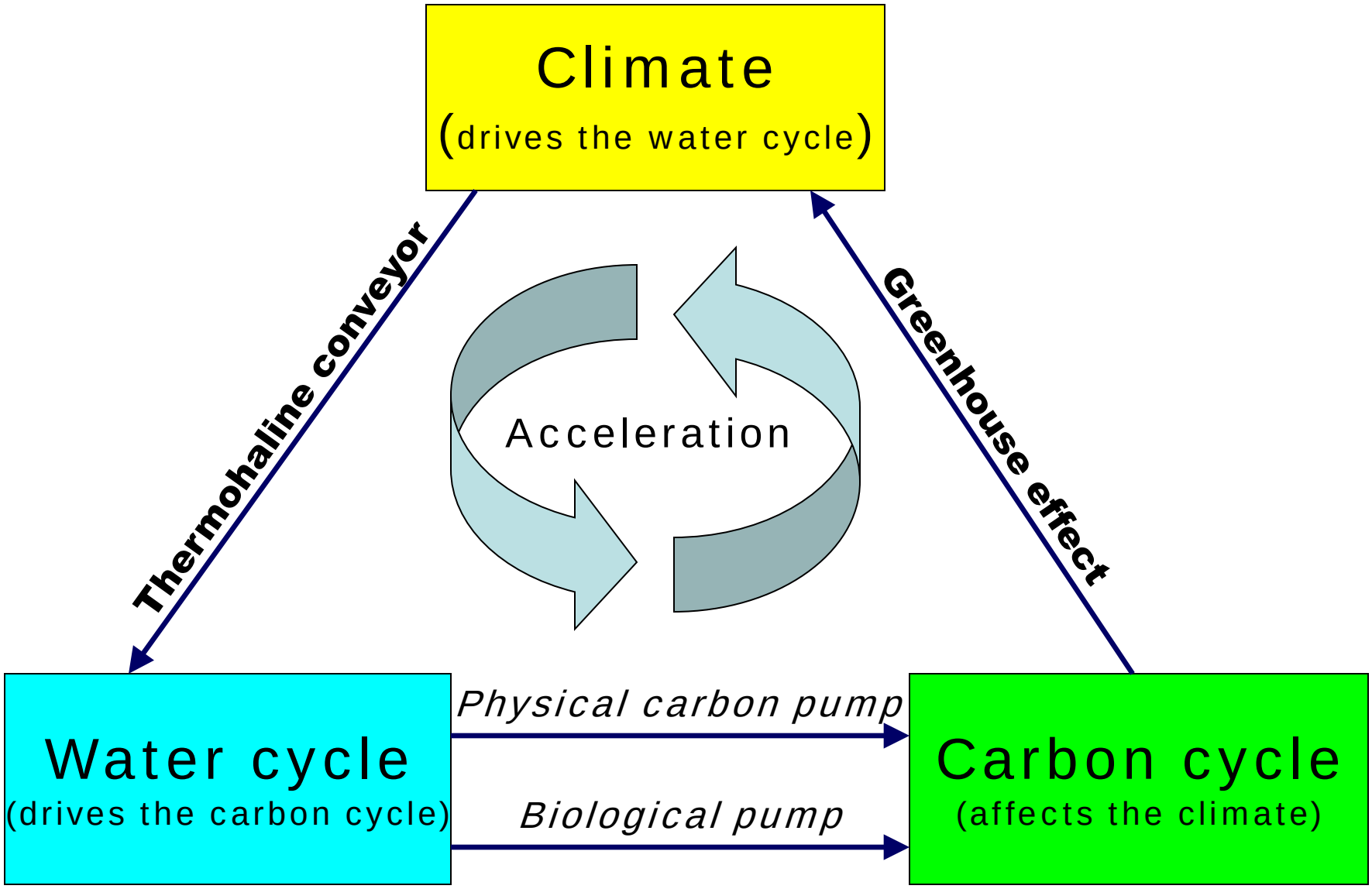
OUTLINE

- Integration into PAG science framework
- Background
- Major results achieved in 2007-10
- New challenges
- Future plans

Object of study: Carbon Cycle in the Arctic ocean system




Climate
(drives the water cycle)
Thermohaline conveyor
Acceleration
Greenhouse effect
Water cycle
(drives the carbon cycle)
Physical carbon pump
Biological pump
Carbon cycle
(affects the climate)

Contribution to PAG mission

The GOAL of the group is to study the changes observed in the Arctic Ocean **by using a combination of advanced observational methods.**

Reaching this goal is a necessary step for reducing uncertainties **in prediction of the future state of the Arctic climate through the integration and synthesis.**

During IPY (2007-2008) and beyond, ***the International Arctic Marine Observations Group focused on one from key components of the Arctic system*****:**

Carbon flux between the atmosphere, land, and shelf with emphasize on trace gas emission from/beneath thawing submarine permafrost, and transport/fate of eroded and river carbon across the shelf-shelf slope.

Research Highlights

- ***Significant release of methane and carbon dioxide from the East Siberian Arctic Shelf (ESAS) to the atmosphere was detected. ESAS is considered as a potential source of methane abrupt release to the atmosphere.***

- ***The average loss of DOC in the East Siberian Shelf was calculated to be ~50% for DOC from both below and above the halocline with a clear pattern of higher losses further east in the area where the FW component is oldest, while in the area with short FW residence time (heavily influenced by rivers) DOC behaviour is conservative (vs salinity)***

- ***The net ecosystem metabolism of the East Siberian shelves, is likely to function as the heterotrophic dominated ecosystem with net CO2 release into the atmosphere is about 19 Tg C- CO2, which roughly can "compensate" the air CO2 uptake by the most productive Arctic seas: the Barents and Chukchi seas.***

Background: Biogeochemical observational studies in the Arctic Ocean: **Carbon and Fresh Water**

The Arctic Ocean is an important component of the Arctic climate system in terms of heat and fresh water (FW) dynamics and is also linked to the rest of the globe biogeochemically via **carbon** (SEARCH, 2005).

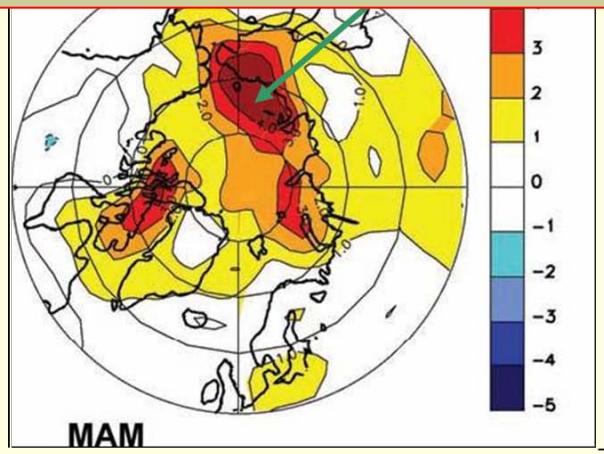
The Arctic Ocean is surrounded by offshore and onshore permafrost which is being degraded at increasing rates under warming. Degrading permafrost release a large amount of old terrestrial organic material (OM)

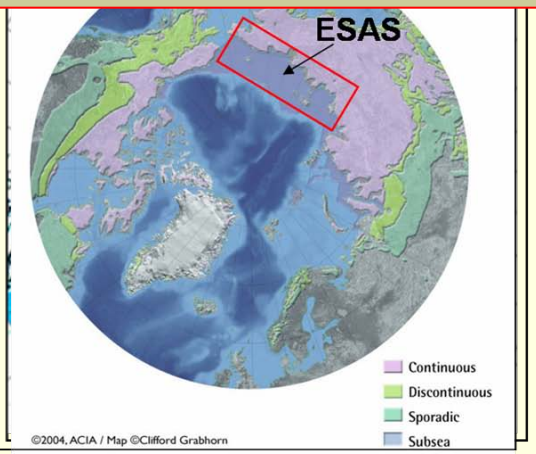
A- This warming is most pronounced in the East Siberian part of the East Siberian Arctic Shelf (**ESAS), which is the most undersampled area in the Eurasian sector of the Arctic Ocean**;

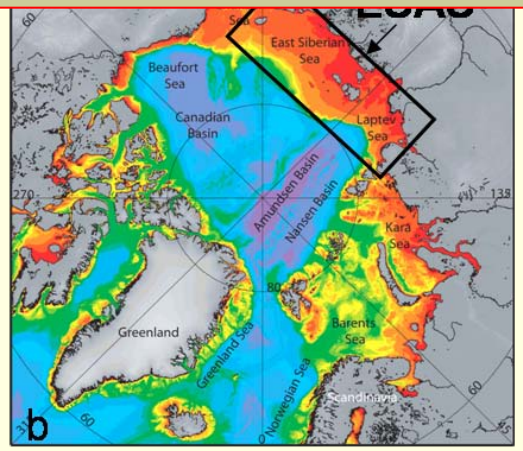
B- The ESAS includes almost 90% of the Arctic sub-sea permafrost which is the most fragile component of modern Cryosphere; *release of ~1% of expected hydrate deposits into the atmosphere can increase significantly the modern atmospheric methane burden.*

BC- The ESAS (>2 mln sq. km) represents broadest and shallowest shelf in the World Ocean which accumulates the fresh water (FW) and carbon signal from Eurasian continent via Great Siberian Rivers: Lena, Indigirka, and Kolyma. Those rivers integrate geochemical signal from their vast watersheds (>3mln sq km) located in changing permafrost zone. *Huge pool of vulnerable carbon in the ESAS (~1750Gt) is comparable with the carbon pool in the upper 3m onshore permafrost layer*. Increasing land-shelf pumping of carbon is expected. It might cause acidification because of the oxidation end-product is carbon dioxide.

A B C







International Biogeochemical Marine Group focuses on integration of observations towards understanding FW and carbon cycling across the Siberian Shelf (ISSS-Project) **and Continental Slope** (ODEN, NABOS, SSS, MIRAI, POLARSTERN)

Siberian Shelf Study: (2003-010)

Major Results


Яков Смирнитский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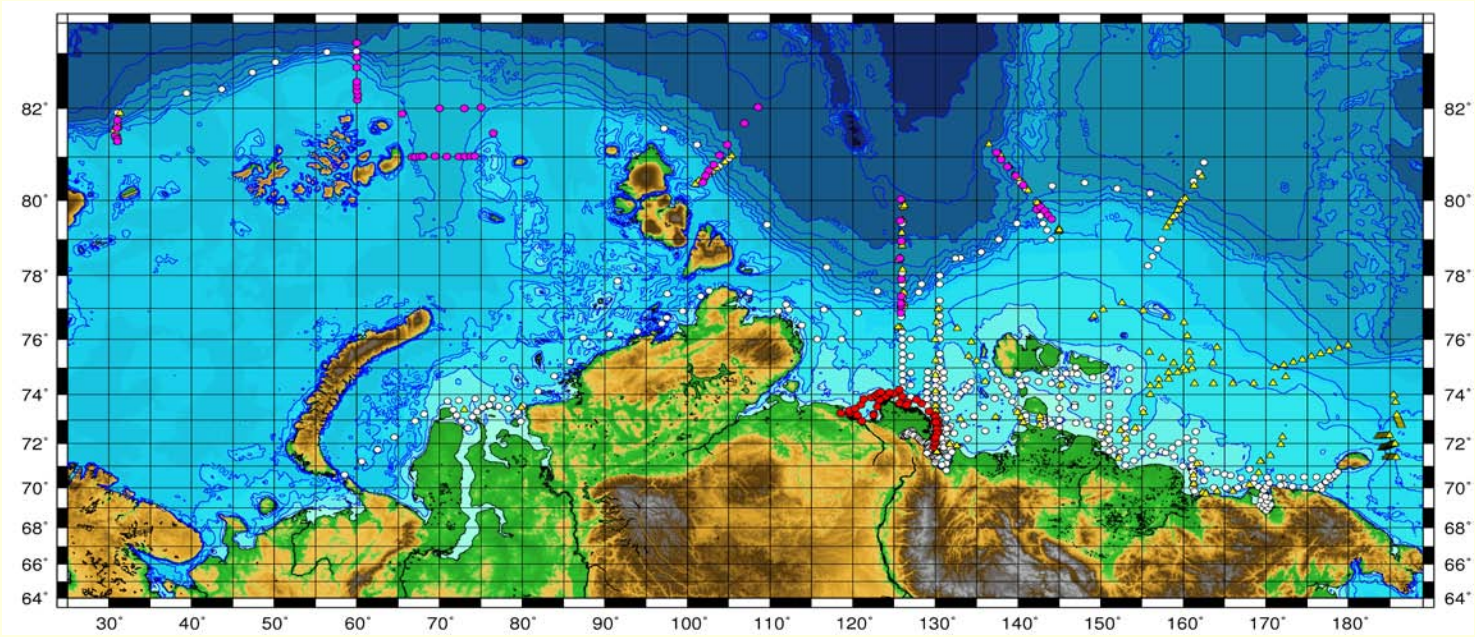


The overall *goal* of the project is to provide a quantitative, observationally-based assessment of the dynamics of different components of the East Siberian Arctic Shelf (ESAS) carbon cycle under conditions of changing climatic and environmental conditions

Key Objective is to quantify the area-scaled ESAS contribution of CH4 and CO2 to the atmosphere.

1. DOC. The estimated stock in the Laptev and East Siberian seas, out to 200m depths at the continental slope, was ~ 99 Tg DOC .

The average loss of DOC was calculated to be ~50% for DOC from both below and above the halocline with a clear pattern of higher losses further east in the area where the FW component is oldest

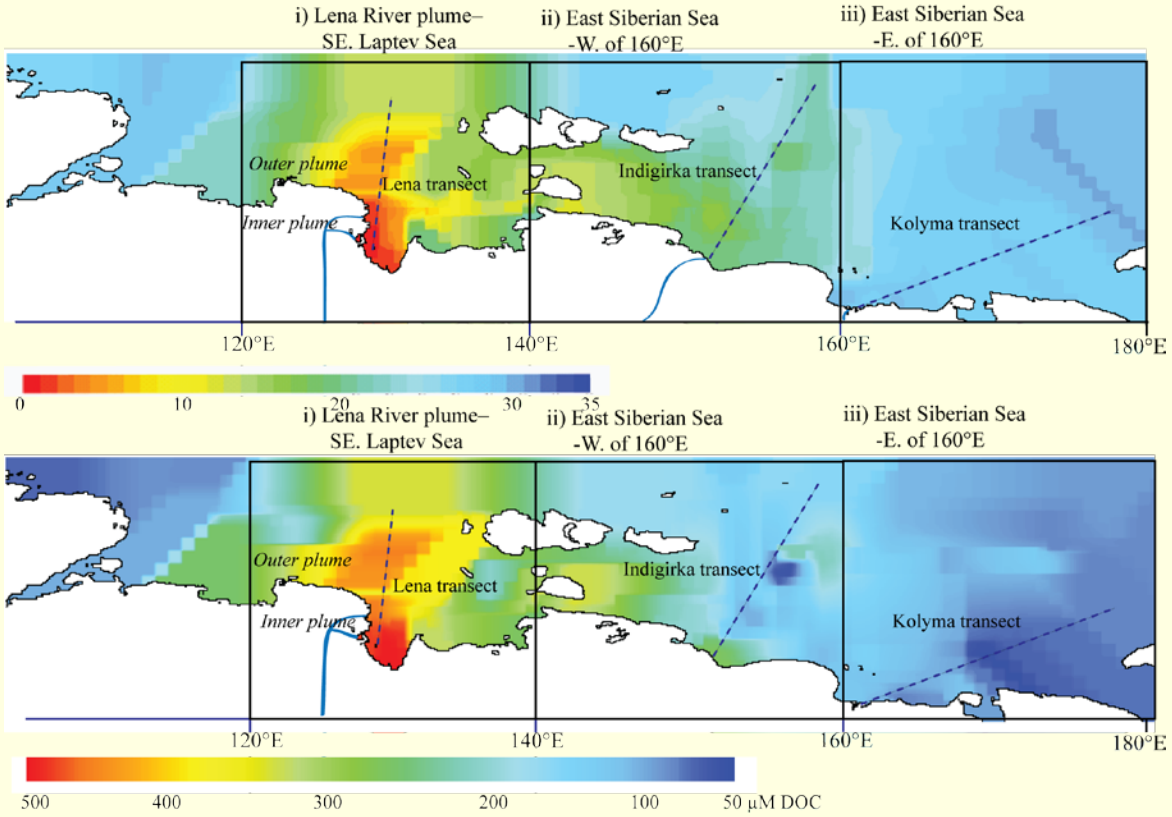


Figure . Top: Surface salinity; Bottom: Surface DOC (µM) in the Laptev and East Siberian Sea during the ISSS-08 cruise (adopted from *Alling et al., Global Biogeochemical Cycle, 2010*)

2. East Siberian Arctic Shelf (ESAS) as a Source of Greenhouse Gases (carbon dioxide and methane) into the Atmosphere

1. Several studies show that transport of coastal eroded material into the Laptev and East Siberian seas ranges between 40-70 Tg. Annual transport of eroded terrestrial organic carbon onto the ESAS is evaluated as ~ 4Tg [Grigoriev, 2010], which is a value about two orders of magnitude higher than the Lena River POC discharge into the sea (Semiletov, Shakhova et al., in preparation)
2. The dominant role of coastal erosion in offshore POC transport and its fast degradation to carbon dioxide in aerial and sub sea environment is illustrated by Figure 1(abc)

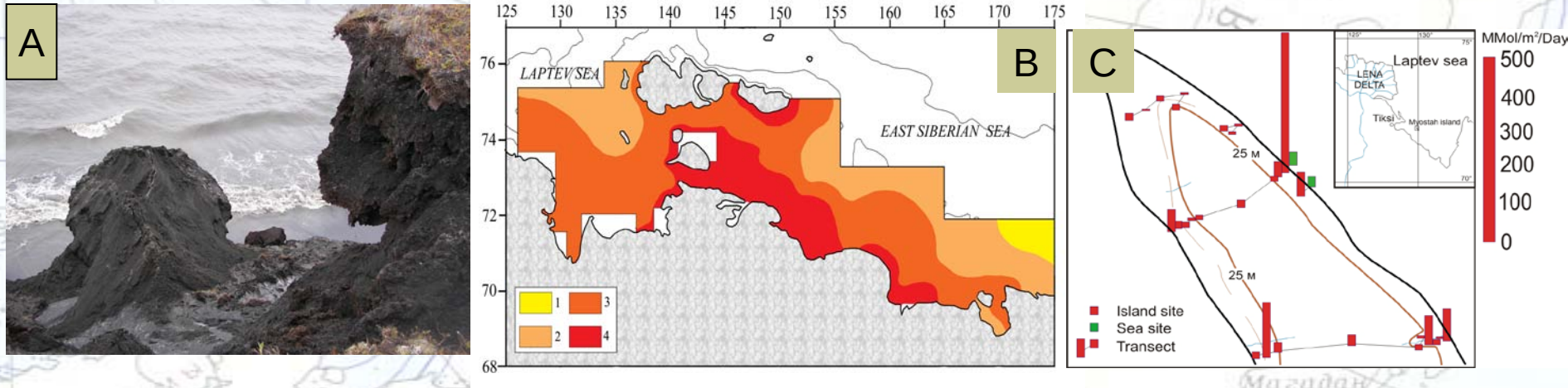


Figure1. (A) Rates of coastal erosion can be up to 25 m/yr and higher;
(B) Contribution of terrestrial organic carbon (CTOM, %) in the ESAS surface sediment: 1) <40%, 2) 40-69%, 3) 69-98%, 4) 98-100%.
(C) Values of CO2 efflux approached 35 mM/m2/day over the shallow water which is significantly higher 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, Shakhova et al., in preparation*)

3. Our evaluations of the combined **CO2 summertime evasion from the Laptev Sea and the East-Siberian seas** is ~**19 Tg C-CO2** (moderate estimate). Estimate given by Macdonald et al (2008) shows that ***annual marine carbon burial in the Arctic Ocean*** **is much lower, about *3.6 Tg C.*** This value is below the lower estimate for CO2 summertime emission from the ESAS indicating on high rates of terrestrial POC oxidation in water column and OC in the surface sediment.

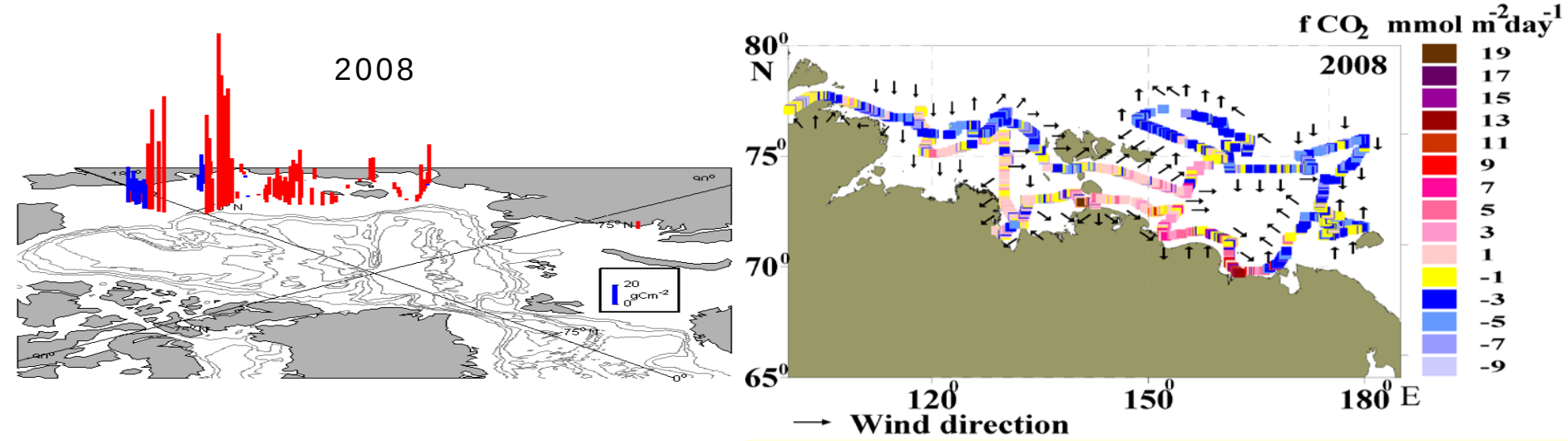
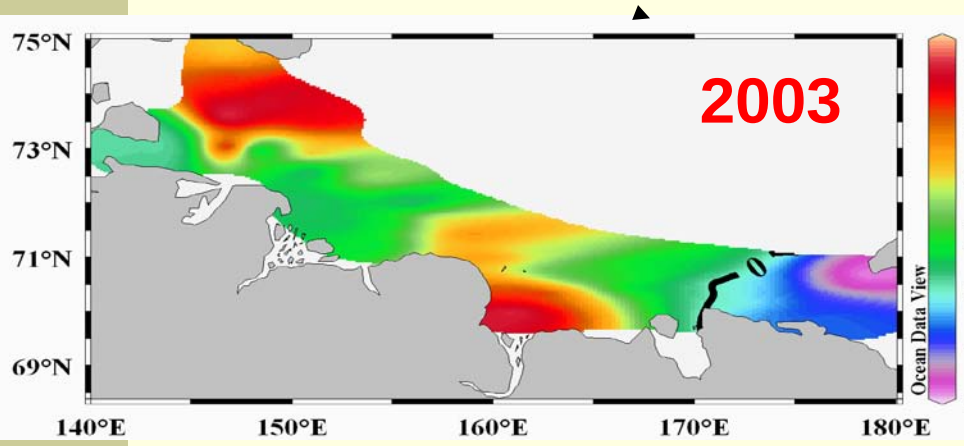
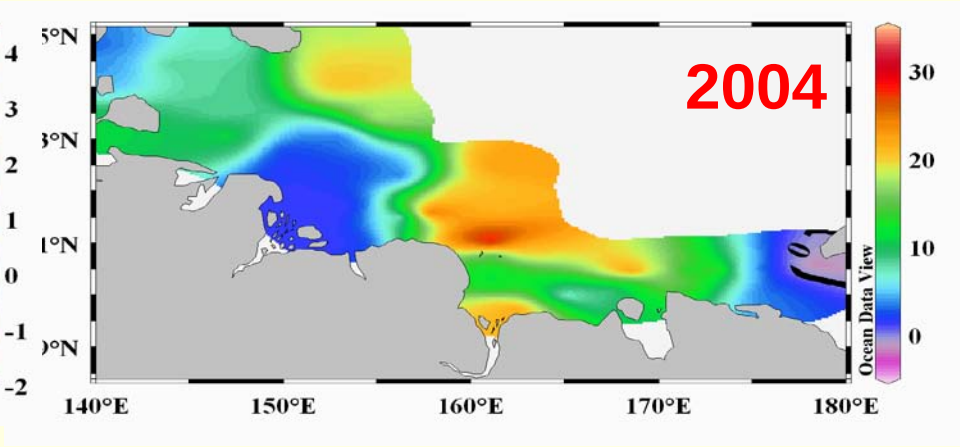
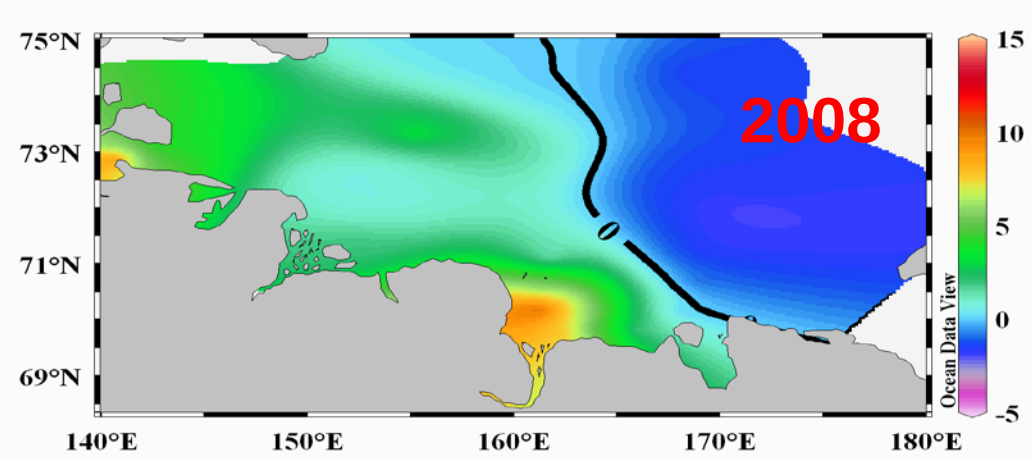


Fig. 1. Excess carbon (~20 Tg C) in the Laptev and East Siberian seas , red color, (g C m-2) relative to *f*CO2 = 385 µatm, integrated through the whole water column (after Anderson et al., 2009); (Right): turbulent air-sea CO2 fluxes in the ESAS in 2008 (Semiletov et al., in preparation)

4. Air-Sea CO_2 Fluxes





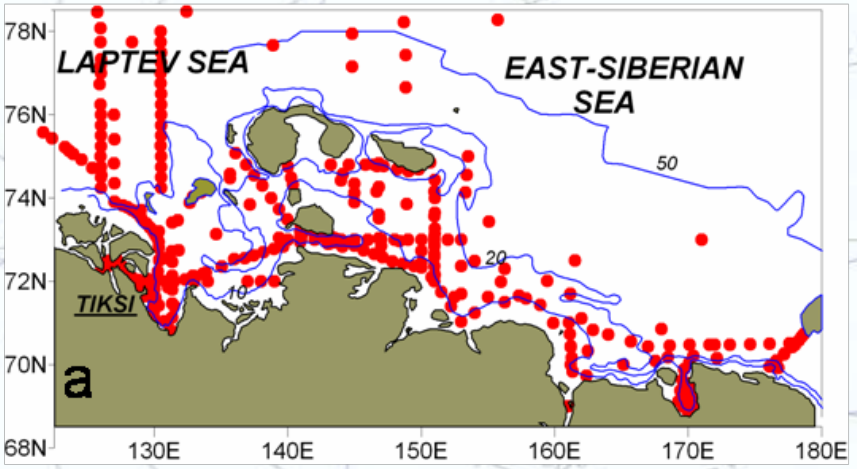


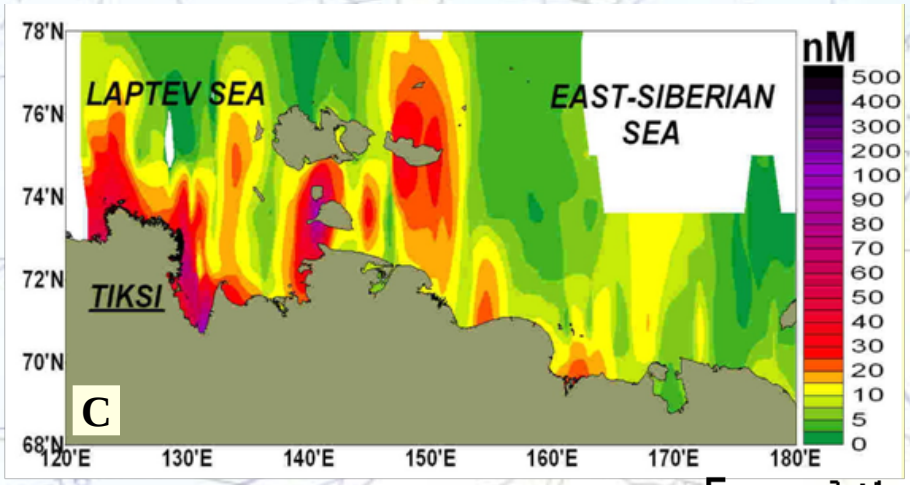
<u>Interannual variability of CO_2 fluxes</u> is determined by complex interaction between the wind-driven circulation, FW regime, and export of bio-available terrestrial organic carbon

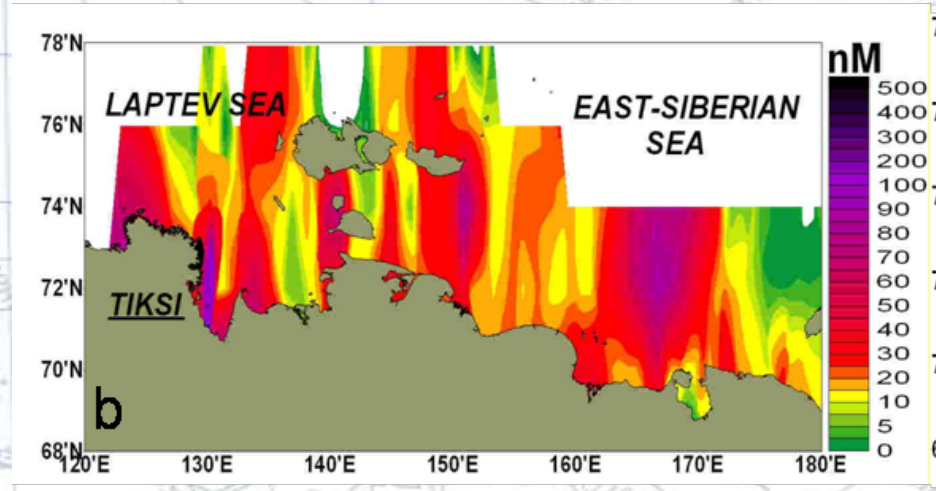
↑ *-Evasion*

↓ *- Invasion*

5. The current atmospheric methane emission from the East Siberian Arctic Shelf of ~8Tg/yr is on par with previous estimates of methane venting from the entire World Ocean.







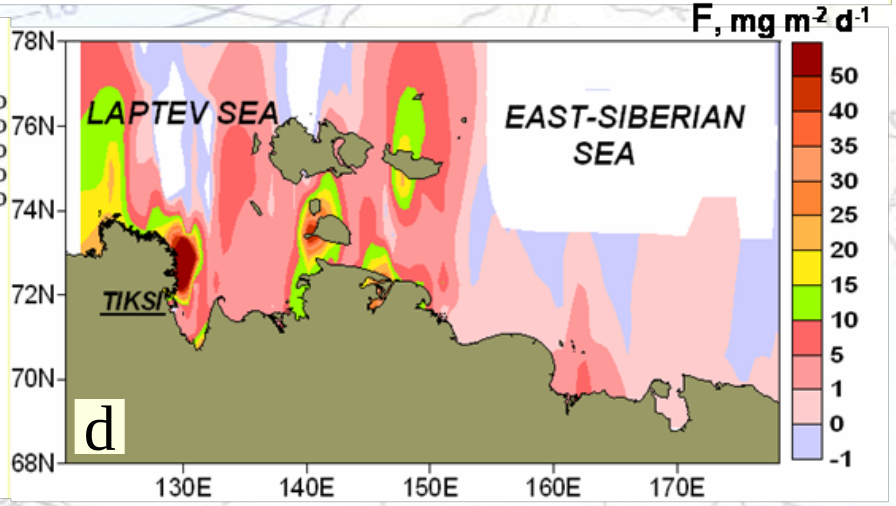
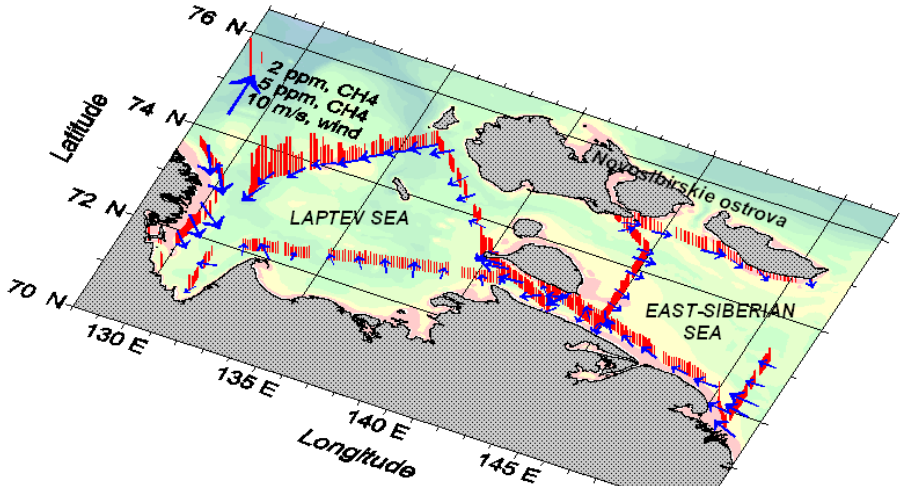
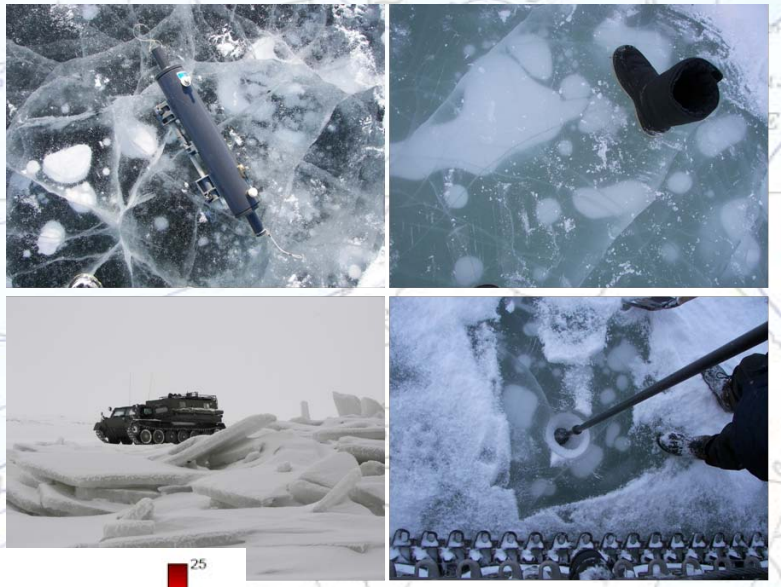
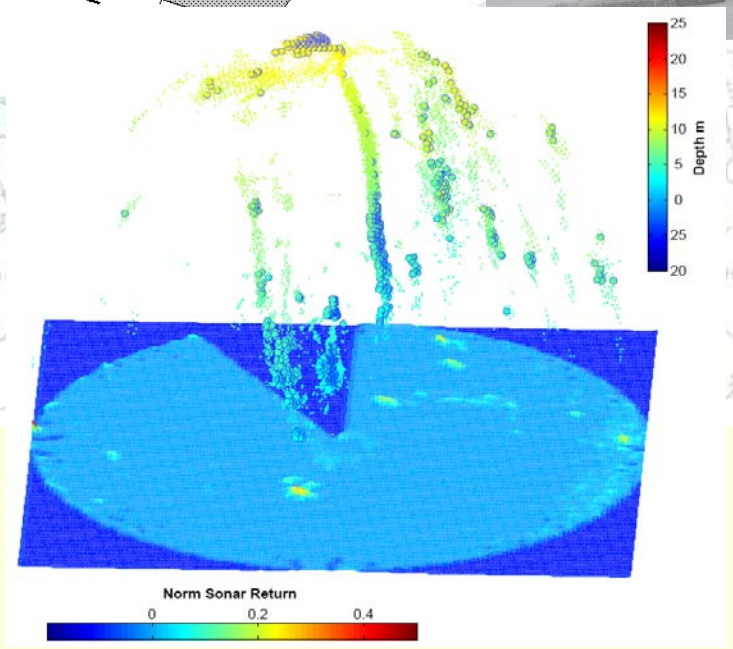


Figure . Summertime observations of dissolved methane in the East Siberian Arctic shelf: (a) positions of oceanographic stations in the eastern Laptev Sea and East Siberian Sea; (b) dissolved methane in bottom water; (c) dissolved methane in surface water; (d) fluxes of methane venting to the atmosphere over the ESAS (*Shakhova et al., Science, 327, 2010, 1246-1250*)

Evidence of ebullition: 1) air CH4 over the ESAS is highest ever measured in the Arctic Ocean; 2) CH4 bubbles entrapped by fast ice; 3) Sonar/lander observations







In 2007-10 researchers from the International Siberian Arctic marine 'observations' group:

- published >*30* papers in refereed journals (including accepted for publication), and *7* chapters in per-reviewed books.

- made >*50* presentations at professional meetings including international conferences

New Challenges

- Monitor changing conditions in the atmosphere-ice-ocean-land system with emphasize in the ESAS.
- Reveal the links and feedbacks between the warming ocean and shrinking/thinning ice cover, thawing of submarine and land permafrost, transport and fate of terrestrial carbon to the ocean, and greenhouse gas release to the atmosphere.

- Quantify changes in water, energy and carbon fluxes in the atmosphere - land – shelf – deep ocean system in the warmer climate

- Forecast future methane flux potential of sediments and thawing permafrost over the Arctic shelves

- Enroll junior scientists (all level students) and postdocs to deal with the scientific tasks of the group

Future plans