On the Role of Missed Components of Carbon Cycling in the East Siberian Arctic Shelf

I. Semiletov *, N. Shakhova*, Mikhail Grigoriev+, I. Pipko, and O. Dudarev****

**International Arctic Research Center, University Alaska Fairbanks,(igorsm@iarc.uaf.edu); +Yakutsk Permafrost Institute, Siberian Branch, Russian Academy of Sciences, **Pacific Oceanological Institute, Far East Branch of Russian Academy of Sciences*

Motivation:

• Artic Ocean is small (~4% from total World Ocean), but it is unique because one is surrounded with **onshore and underlain with offshore permafrost which contains a huge reservoir of organic matter and trapped methane**, including methane in form of free gas and hydrates;
• **Area of subsea and land permafrost** (near 14mln km²) **is equal to the total area of the Arctic Ocean**, *Figure 1L*;
• East Siberian Arctic Shelf Shelf (**ESAS**) is the **broadest and shallowest shelf in the World Ocean and is the most strongly impacted by warming**, *Figure 2R*
•ESAS (area > 2 mln km²) is **accumulating an integrated signal of the terrestrial organic matter (OM) export from the vast riverine watersheds and eroded coastal ice-complex.**

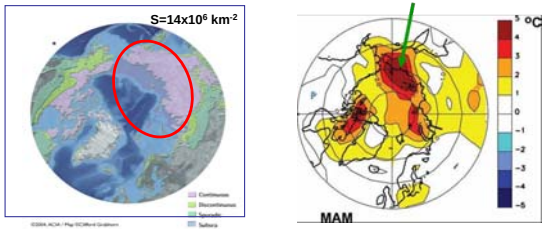


Figure 1. Left: distribution of subsea and onshore permafrost in the arctic region;
Right: temperature anomalies over the East Siberian region (indicated by the green arrow)

• **Permafrost is warming and thawing**
that causes an increase of transport of fluvial carbon, (and FW), and eroded carbon (due to coastal and bottom erosion); other consequence is **thawing of sub-sea permafrost and destabilization of gas-hydrates/leaking of methane.**
Unknown part of fluvial and eroded carbon transforms to CO2, *Figure 2*.

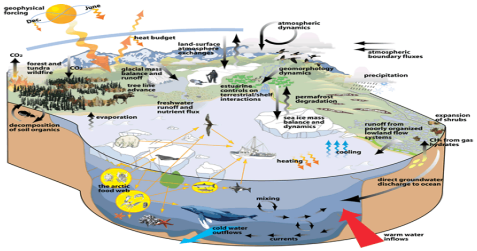


Figure 2. **Arctic System**: Climate drives the Water cycle, the Water cycle drives the Carbon cycle, the Carbon cycle affects the climate

Major uncertainties constructing the marine carbon budget are:

1) current estimates of riverine solid runoff, used for budget estimations, does not reflect the fact that majority of riverine TOC settles in delta channels and never reach the shelf , *Figure 3.*

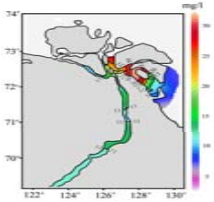
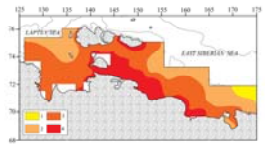


Figure 3. Particulate material distribution, mg l-1 in the lower stream/delta of the Lena River June-July 2003. Using the mean PM concentration of 20 mg l-1 and an annual river discharge of 525 km3 we calculate the "mean" solid discharge to be 10.5 Tg delivered to the delta channels. Annual discharge of POC may be equal to 0.38 Tg if we use a mean POC value of 0.75 mg l-1, which was obtained in 2003 along the Lena River during flooding (moderate or high estimates). If we accept *Lisytsin's* (1994) statement concerning the precipitation of 85-95% of total PM (and POC) on the marginal "filter", then only **about 1Tg of PM, and 0.03-0.04 Tg of POC reaches the Laptev Sea from the Lena River** [Semiletov et al., in preparation].

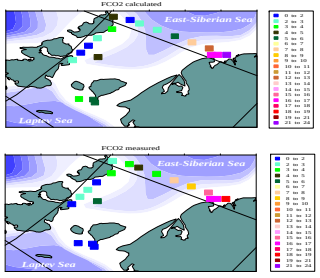
2) current estimates of eroded material entered the ESAS are showing that it is significant, but transport and fate of eroded carbon in the East Siberian Sea has not been studied yet.



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 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 et al., in preparation]. *Figure 4* illustrates the dominant role of coastal erosion in offshore POC transport

Figure 4. Contribution of terrestrial organic carbon (CTOM, %) in the ESAS surface sediment: 1) <40%, 2) 40-69%, 3) 69-98%, 4) 98-100% [Semiletov et al., in preparation]

3) Majority of the ESAS is a strong source of CO2 into the atmosphere, which reflects oxidation of terrestrial OM [Semiletov, 1999; Semiletov et al., 2007; Anderson et al., 2009] Semiletov et al., in preparation].



Carbon dioxide flux between air and sea is changed in values and directions from invasion ~5mM/m²/day in the in the Barents Sea, to evasion ~15mM/m²/day in the Laptev Sea (September-2006), and up to 24-32 15mM/m2/day in the East-Siberian Sea [Semiletov et al., in preparation]. Interannual variability of carbon dioxide fluxes is high, up to 10 times [Pipko et al., in preparation].

It is illustrated by ***Figure 5***. Summertime release of CO2 from the shallow ESAS to the atmosphere can reach up to 10 Tg C-CO2 and even higher [Semiletov et al., in preparation].

Figure 5. Distribution and values of calculated (a) and measured (b) fluxes are agreed well; the best correlation among them has been found for the calculated data using the cubic relation to the mean day wind speed (R=0.93)

4) current estimates of coastal erosion input does not reflect the fact that significant part of eroded organic carbon transforms to CO2 and releases to the atmosphere

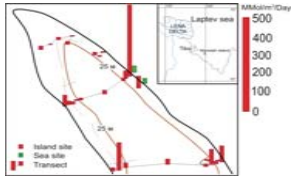
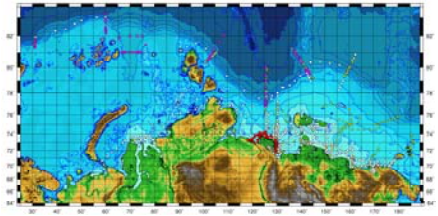


Figure 6. Direct CO_2 flux measurements (chamber technique) across the Muostakh Island show that a significant portion of eroded carbon escaped into the atmosphere (as CO_2) crossing onshore transit area. Values of CO_2 efflux approached 35 mM/m2/day over the shallow water which is significantly higher than CO_2 emission from the nearest lakes (2-15mM/m²/day). Highest CO_2 release has been found from a plume of eroded material on the beach: up to 500 mM/m2/day [Semiletov et al., in preparation]

5) annual methane outgassing from the shallow ESAS of ~8 Tg C-CH4 is comparable with total methane emissions from all coastal seas of the World Ocean (Shakhova et al., 2010; Shakhova et al., ***State of the Arctic, this poster session***)

Conclusions:
All existing carbon balance estimations for the Arctic Ocean are incomplete because:

1) they reflect lack of knowledge on the critical region of the Arctic marine system, which is the East Siberian Arctic Shelf composing ~30% of the total Arctic shelf area;
2) annual budgets do not reflect spatial and temporal variability of carbon fluxes;
3) TOC efflux accounted for the budget does not apportion processes, which accompany its transformation within land-shelf system;
4) gaseous components of carbon cycling (CO2 and CH4) were not incorporated into the budget.
Incorporating theses components into the current biogeochemical budgets could drastically change our understanding of processes ongoing over the Arctic Shelf and the entire Arctic Ocean.



Conclusions are based on multi-year studies accomplished by authors and their collaborators in (2003-2009)

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