Methane and subsea permafrost studies in the East Siberian Arctic Shelf.
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<u>Phase 1: Activities accomplished (03.24.2014-04.18.2014)</u>

Recent studies show that significant quantities of methane are escaping the East Siberian Arctic Shelf (ESAS) as a result of degradation of submarine permafrost (Shakhova et al., 2009, 2010ab, 2014; Nicolsky et al., 2012). There remains substantial uncertainty regarding several aspects of CH_4 release from the ESAS. To accurately predict future CH_4 releases, we must understand the size of the reservoir (the amount of trapped CH_4 that potentially could be released), as well the processes that have kept it trapped and those that control its release.The main accomplishments to be considered here are related to:

Permafrost stability. Are changing ESAS thermal conditions causing the permafrost to thaw? Do accelerated rates of permafrost degradation lead to development of taliks that act as CH_4 vents to the overlying seawater and potentially to the atmosphere?

This short report describes field research accomplished during the complex biogeochemical and geophysical studies conducted during the April 2014 winter campaign in the shallow Laptev Sea (Fig. 1) as an extension of the field work accomplished in April 2011 and 2013, and in March-April 2012 (Fig. 2a). We also drilled new sites located within recently-submerged thermokarst lakes that are transforming into sea lagoons to evaluate predominant factors controlling subsea permafrost thermodynamic characteristics.

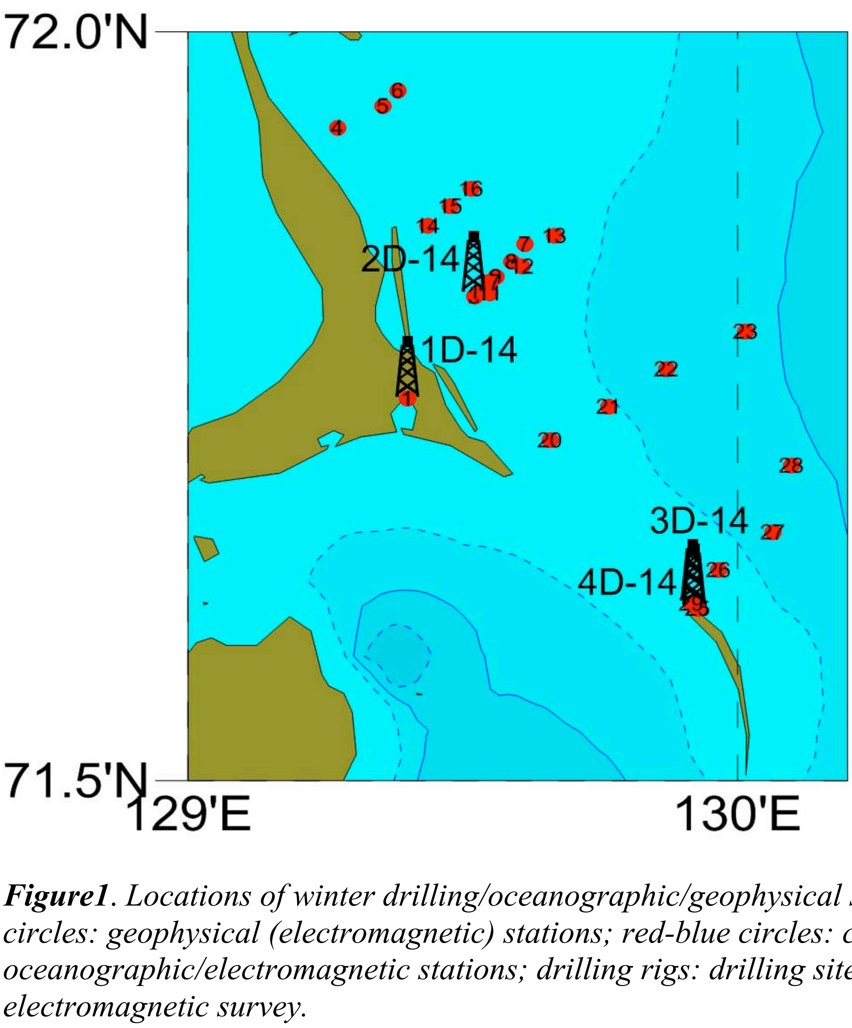

Figure1. *Locations of winter drilling/oceanographic/geophysical stations, April 2014: red circles: geophysical (electromagnetic) stations; red-blue circles: complex oceanographic/electromagnetic stations; drilling rigs: drilling sites accompanied by electromagnetic survey.*

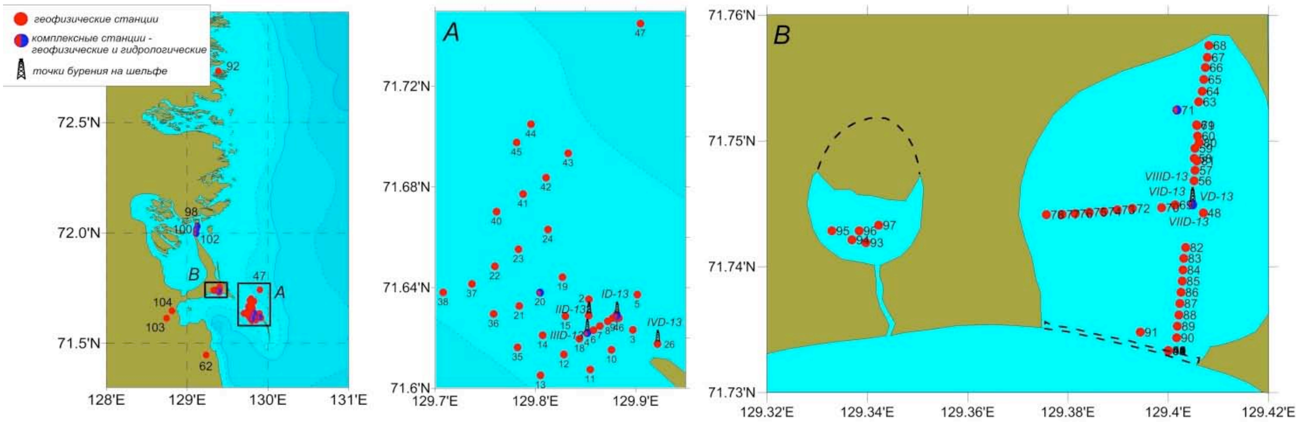

***Figure 2**. Locations of winter drilling/oceanographic/geophysical stations, April 2013: red circles: geophysical (electromagnetic) stations; red-blue circles: complex oceanographic/electromagnetic stations; drilling rigs: drilling sites accompanied by electromagnetic survey.*

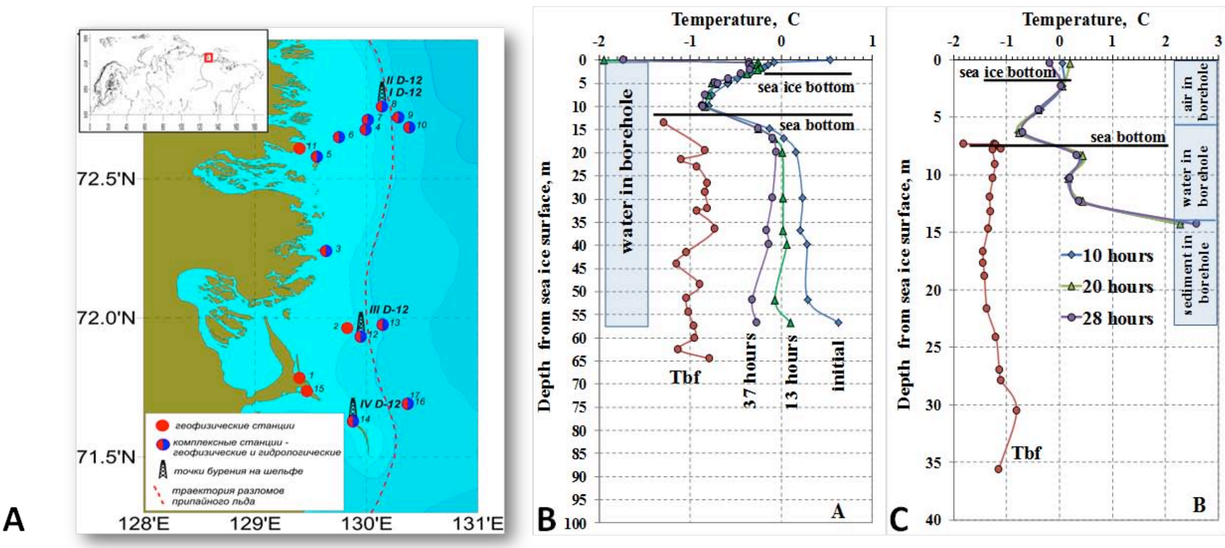

Figure 3. *A) Position of a borehole drilled in March-April 2012; B) measured temperature along the borehole and estimated freezing temperature in the borehole drilled in April 2011 (marked as 16/17 in A)); C) temperature in the borehole drilled in March 2012 (marked as 2D-12 in A)); "Tbf" means " temperature at beginning of freezing" (*Semiletov et al., 2014, in preparation).

The first, second, third, and fourth winter transport caravan expeditions were accomplished in April of 2007 and 2011, March-April 2012, and April-May 2013. The overarching goal of the firth such expedition to the southeastern Laptev Sea, in 2014, was to gain new data for determining rates of subsea permafrost degradation, in order to answer the following questions:

1) Are changing East Siberian Arctic Shelf (ESAS) thermal conditions causing the permafrost to thaw? Do accelerated rates of permafrost degradation occur in the areas that were more strongly affected by the thermokarst process prior to inundation during the Holocene?

2) Is talik (thaw bulb beneath a body of water) sediment gas content much higher than in other areas without taliks?
3) Do developing taliks act as methane (CH_4) vents to overlying seawater and, potentially, the atmosphere?
A new goal of this drilling campaign was to begin to study lagoons, submerged thermokarst lakes/taliks which may play a significant role in accelerating subsea permafrost degradation (Nicolsky and Shakhova, 2010; Nicolsky et al., 2012). Downward salinization might increase vertical subsea degradation and talik formation rates, increasing vulnerability of the gas hydrate stability zone located within/beneath subsea permafrost over the vast ESAS (Soloviev et al., 1987; Romanovskii et al. 2005; Shakhova et al., 2009, 2010b). Transformation of thermokarst lakes into sea lagoons led to the formation of indented coastlines, increased shore length subjected to thermoerosion of coastal ice complexes, and accelerated shelf submergence, especially after 7.5 ka BP (Romanovskii et al., 2004). This process continues in the nearshore zone, specifically at Bykovsky Peninsula, the southwestern end of Buor-Khaya Bay. Thermokarst lakes and newly-formed lagoons are characterized by very low mineralization and high content of CH_4 in sediments which can be released during drilling in concentrations higher than 4 % v/v, which allows the CH_4 to be burned (Fig. 4)

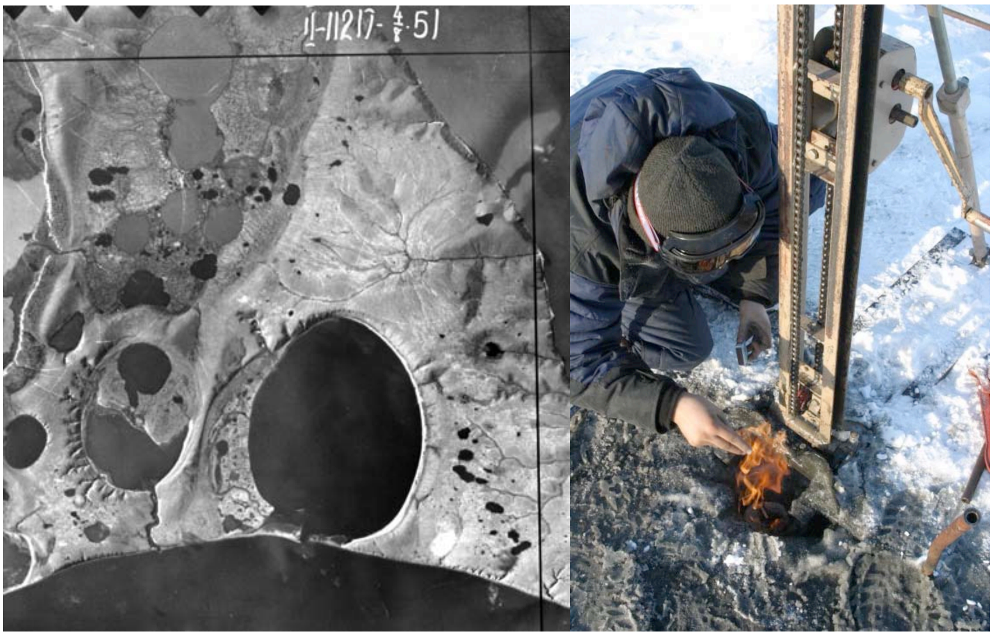

Figure 4. *Left: bird's eye view of the largest lagoon of the Bykovsky Peninsula; right: flame indicating burning CH_4 which has escaped from the shallow borehole accomplished in 1999 (photo by V. Tumskoy)*

Another goal of the spring 2014 field program was similar to those of the spring 2011, 2012, and 2013 campaigns: to apply a complex approach, including seismo-profiling (in summer), electromagnetic survey (in summer and winter)- Fig.5, and drilling from fast ice, and to study the vertical structure of the sediments with emphasis on the location of the permafrost table and the mechanisms responsible for forming gas migration pathways within the seabed underlain by permafrost.

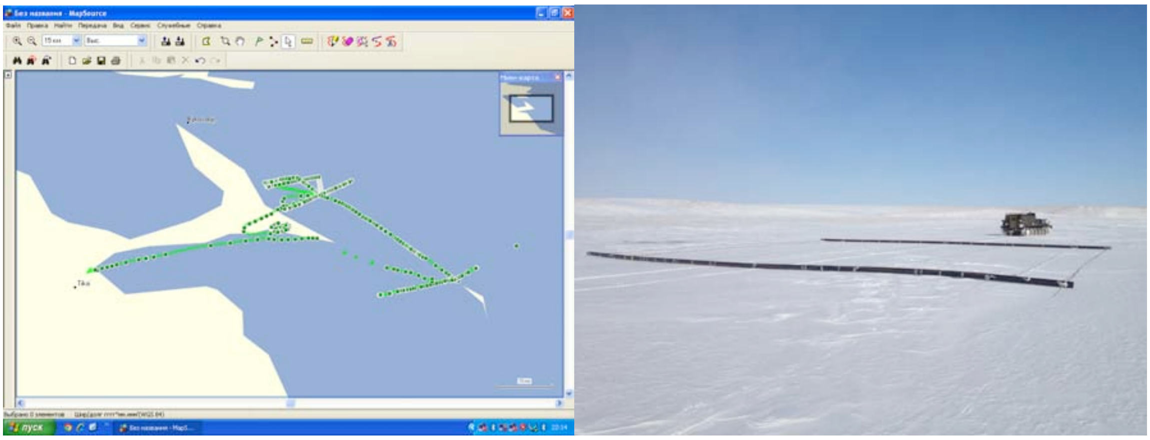

Figure 5. *Electromagnetic (EM) survey validated by boreholes (penetrrated throughout thaw-permafrost sediment) is a new and powerful tool to survey the table of subsea permafrost. Left: tracks of the EM survey -2014; right: the EM system ttawed by the all-terrain vehicle.*

The 24-day expedition (15 days on the fast ice: from April 1st through April 15th) was organized and led by I. Semiletov and N. Shakhova, in collaboration with a team of Russian scientists from the Pacific Oceanological Institute, Far Eastern Branch of the Russian Academy of Science (POI FEBRAS), and the Geological Department of Moscow State University. New drilling equipment including steel cases and pipes with a total weight ~7tons was delivered from Ekaterinburg to Yakutsk-Tiksi by railway and winter road along the Lena River in the mid-March. Team members arrived to Yakutsk from Vladivostok and Moscow on March 26th, and then travelled to Tiksi arriving there on March 28th. The expedition transport caravan was the same as those used in 2011, 2012, and 2013 and included two heavy caterpillars (T-150s), a drilling rig (URB-4T), two mobile houses on sledges, an all-terrain vehicle, and two cargo sledges, with a total weight exceeding 180 tons. The transport started from Tiksi (Fig. 6). Snapshots of winter field work in the Laptev Sea are shown in Fig.7.

Figure 6. Left*: Transport caravan in Tiksi;* ***Right****: transport caravan moving to the study area (photos by I. Semiletov)*

Figure 7. *Snapshots of winter field work in the Laptev Sea (2011-2014, photos by I. Semiletov& A. Koshurnikov).*

The core material extracted from four boreholes-2014 with total weight ~1,100 kg was divided into three categories: 1) for geochemistry including isotope analyses, microbiology, and geochronology research; 2) for investigating geological and physical cryogenic features ; 3) frozen samples for possible future analyses, stored in Vladivostok at POI FEBRAS under the PIs' control.   Note that in total almost 4,000 kg of unique samples taken from 14 boreholes (Figs. 1, 2) preserve not only exclusive information about the origination and migration of CH_4, but paleo-oceanographic records that extend through the Pleistocene and probably the Neocene.

Selected References

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