IMPLICATIONS OF CLIMATE CHANGE IN THE RUSSIAN ARCTIC:

ENERGY CONSUMPTION, LAND TRANSPORTATION, FOUNDATION STABILITY

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INTRODUCTION

Over the last few decades, the Arctic has experienced a warming trend. Warming temperatures are raising concerns for the engineering community, land use planners, and policy makers, as it may have a series of negative impacts on socio-economic development and human activities in the northern regions, especially on Russia. Majority of Russian territory is considered to be northern to at least some extent with some regions largely occupied by permafrost (Figure 1). Recent delineations identify 16 federal subjects as fully included in the Russian North and 11 as partly included.

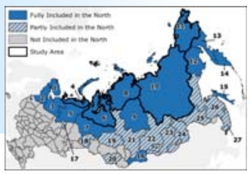

Figure 1. Federal Subjects fully or partly included in the Russian North in 2000.

1, Murmansk O; 2, Karelia; 3, Arkhangel'sk O; **4, Nenets AO**; 5, Komi; **6, Yamalo-Nentes AO**; 7, Khanty-Mansi AO; **8, Taymyr AO**; 9, Evenk AO; **10, Yakutia**; **11, Chuckchi AO**; 12, Magadan O; 13, Koriak AO; 14, Kamchatka O; 15, Sakhalin O; and 16, Tyva. Federal subjects partly included in the Russian North include: 17, Komi-Permiak AO; 18, Tiumen O; 19, Tomsk O; 20, Altai; 21, Krasnoiarsk K; 22, Irkutsk O; 23, Buriaria; 24, Chita O; 25, Amur O; 26, Khabarovsk K; and 27, Primorsk K. Bold-faced subjects in this note are the federal subjects included in the study area of this analysis.

While population in the Arctic is generally sparse, the Russian Arctic population is heavily urbanized. Data from the 2002 Russian Census showed that in five Russian Arctic administrative regions urbanization ranged from 59-94% (Figure 2), indicating that a majority of the population lives in cities such as Vorkuta, Salekhard, Nadym, Noviy Urengoy, Noril'sk, Magadan, Yakutsk.

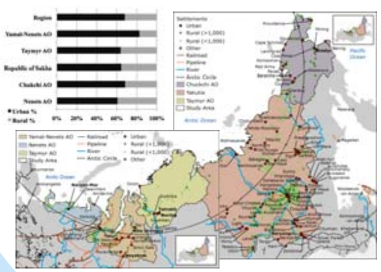

Figure 2. Percent of the total population that was urban or rural in 2002 for specific administrative regions.

METHODOLOGY

In order to quantitatively address impacts of climate change on human infrastructure in the Arctic, the historical changes of three vital, climate-dependent types of economic activity were considered for analysis: stability of foundations, energy consumption, and land transportation.

Energy consumption: The majority of the Russian Arctic population live in buildings with a centralized heating system. The local and municipal governments establish standardized location-specific requirements on building insulation and heating load. As a result the heating degree-days (HDDs) and the length of the heating season can be used as proxies for energy consumption. According to Russian government standards the beginning of heating season starts on a day following the five consecutive days with temperatures below 8°C and does not end until the temperature exceeds five consecutive days of 8°C.

Land transportation: Since Arctic countries rely heavily on seasonal road networks, the changes in land transportation were evaluated through estimated potential annual operational period of winter/ice roads. Russian construction norms do not implicitly use climate (e.g. air temperature) as a parameter determining suitability of winter road operation. We have relied on North American regulations which indicate that an accumulation of more than 300 degree-days of freezing (DDF) can be used to estimate the onset of winter road construction. The mean daily temperature of more than 0°C determines the closing date of safe winter road operation. The operational period was estimated by counting days between the beginning of construction (> 300 DDF in the fall) and closing date (daily air temperature >0°C in spring).

Foundation stability: Urban architecture in the Russian arctic is predominantly represented by mixture of prefabricated panel or standard-design brick five to nine-floor buildings. The majority such structures on permafrost are built using piling foundations according to passive principle. To assess changes in potential stability of Arctic infrastructure we have used the bearing capacity (ability to support load) of the standard, 0.35x0.35x10 m concrete foundation pile. Such an approach is frequently used in Russia for preliminary assessments of large territories. Changes in permafrost parameters (e.g., active-layer thickness, permafrost temperature) were estimated using spatially distributed equilibrium model of permafrost-climate interactions.

RESULTS AND DISCUSSION

Climate data show that the majority of the studied areas experienced warming, with the exception of the western part of Nenets AO and Northern Yakutia (Figure 3).

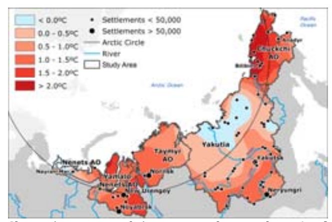

Figure 3. Changes in mean annual air temperature between the 1970 and the 2000 periods.

Energy consumption:

The most pronounced change in energy consumption is found in northern and southeastern Yamal-Nenets AO and northern Chuckchi AO (Figure 4). Increases in the heating season more than 1% were found predominantly in northern Yakutia in settlements such as Tommot, but also in southern areas of Neryungri and Aldan. However, the majority of the study area did not show any significant changes.

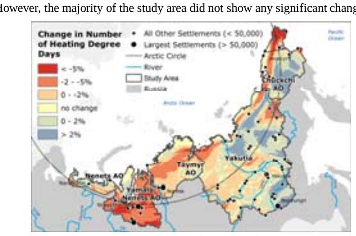

Figure 4. Temporal changes in percent of number of heating degree-days between the 1970 and the 2000 periods.

Land transportation:

Our results indicate that changes in the potential operational length of winter roads have already occurred. These changes, however, are not uniform in space. Some regions, such as Yakutia, show an increase in operational road length while West Siberia is characterized by a significant decrease. It is important to note that the decrease in the period of potential winter road operation was found in areas of intensive oil and gas exploration and development, including areas around Noyabrsk, Noviy Urengoy, and Nadym. Other economically vital regions with a decrease in potential land accessibility include areas along the Yenesey River north of Igarka up to Dickson; around Cherskiy in North-Eastern Yakutia; and Pevek and Anadyr in Chuckchi AO (Figure 5).

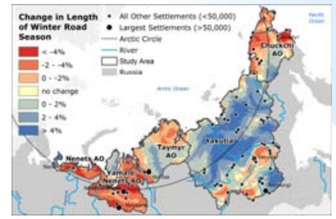

Figure 5. Temporal changes in winter road operable days between the 1970 and the 2000 periods.

Foundation stability:

Our results indicate that observed climate warming has the potential for decreasing bearing capacity of permafrost foundations built in the 1970s in majority of settlement cases in all five study regions. Substantial decreases in potential foundation bearing capacity occurred in regions of eastern Chukotka, southern parts of Yamalo-Nenets AO and Sakha Republic (Figure 6). According to our estimates the climate-induced decreases of bearing capacity by 15-20% occurred in Salehkard, Noviy Urengoy, Nadym, Pevek, Anadyr; by 10-15% in Bilibino and Dudinka; by 5-10% in Noril'sk, Neryungri, Mirny, Yakiusk, and Cherskiy. Noyabrsk and Provideniya experienced a decrease of more than 20%.

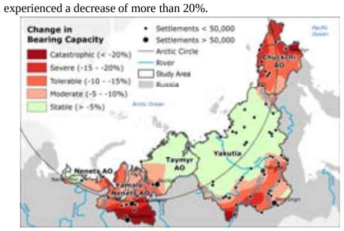

Figure 6. Temporal changes in foundation bearing capacity between the 1970 and the 2000 periods.

SUMMARY

Geographic assessment of potential impacts of observed climate change on several economic parameters representing infrastructure, transportation and energy consumption indicate that negative changes due to observed climate warming may exceed those that have a positive economic impact. Decrease of length of heating season is almost negligible despite warmer temperatures. Decreasing operational time of winter road networks reduces accessibility of remote regions resulting in negative consequences, especially for small, isolated Arctic communities. The most profound climate change impact is associated with the increase in permafrost temperature and the active-layer thickness and thus promoting the decrease in bearing capacity of foundations. Projected warming is likely to enhance observed trends and to further deteriorate living conditions in the Arctic. The effect will be most significant for highly urbanized Russian arctic communities.

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