INTRODUCTION

Over the last few decades, the Arctic has experienced a warming trend. Warming temperatures are rising unevenly for the engineering community, land use planners, and policy makers, as it may have a series of negative impacts on socioeconomic development and human activities in the northern regions, especially in 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 1 as partly included.

Land transportation: Since Arctic countries rely heavily on seasonal road networks, the changes in the operational period of winter/ice roads were evaluated through estimated potential annual 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 1 as partly included.

LAND TRANSPORTATION

Over the last few decades, the Arctic has experienced a warming trend. Warming temperatures are rising unevenly for the engineering community, land use planners, and policy makers, as it may have a series of negative impacts on socioeconomic development and human activities in the northern regions, especially in 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 1 as partly included.

The changes in the operational period of winter/ice roads were evaluated through estimated potential annual 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 mean date 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).

In order to quantify and 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 national 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 the operational period of winter/ice roads were evaluated through estimated potential annual 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 mean date 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).

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

1, Murmansk O; 2, Karelia; 3, Arkhangel'sk O; 4, Vologda O; 5, Nenets AO; 6, Yamalo-Nenets AO; 7, Khanty-Mansi AO; 8, Tyumen AO; 9, South AO; 10, Yakutia; 11, Chukotka AO; 12, Magadan O; 13, Khabarovsk K; 14, Primorsky K; 15, Sakhalin O; 16, Tyva. 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 50-90% (Figure 2), indicating that a majority of the population lives in cities such as Yakhtsy, Salekhord, Noviy Urengoy, Noviy Urengoy, Neryungri and Yakutsk. It is equally important to note that 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 50-90% (Figure 2), indicating that a majority of the population lives in cities such as Yakhtsy, Salekhord, Noviy Urengoy, Noviy Urengoy, Neryungri and Yakutsk. It is equally important to note that in all five study regions substantial decreases in a 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 Salekhord, Noviy Urengoy, Neryungri, Pevek, Anadyr; by 10-15% in Bilibino and Dudinka; by 5-10% in Neftek, Narynoggy, Shemy, Yakutsk, and Chersky. In the Arctic, the majority of the study area did not show any significant changes.

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 most pronounced change in energy consumption is found in northern and southeastern Yamalo-Nenets AO and northern Chukchi AO (Figure 4). In the heating season more than 1% were found predominantly in northern Yamalo in settlements such as Tomtom, but also in southern areas of Narynoggy and Sredne. However, the majority of the study area did not show any significant changes.

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

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

Land transportation:

The changes in the operational period of winter/ice roads were evaluated through estimated potential annual 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 mean date 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).

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

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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 warm 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 precipitation 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.