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# Modelling needs assessment for social adaptation to climate change in Siberia

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**Abstract**: Despite the common expectation that climate change may make Siberia a warm heaven, this would not be good for local people. Surprisingly the people of Siberia do rely on the winter cold. Warming may be a serious challenge here. Climate change threatens Siberian forests, lakes and permafrost. In the region where landscapes are unstable this implies the risks of losing the traditional means of subsistence, at least for a while. Social adaptation to climate change is becoming an urgent issue, as the first signs of warming are becoming noticeable to local people. This article reports an attempt to explore the gaps between the state-of-the-art and desired progress in environmental modelling with respect to the integrated assessment of the climate change impacts on Siberia.

***Keywords:*** climate change, environmental modeling, Siberia, reindeer herding, permafrost modelling

## 1. INTRODUCTION

For the past two decades, Siberian ecosystems were intensively studied to understand how they are functioning in present conditions and how they will be functioning in a warmer climate [Anisimov et al., 2002; Arzhanov et al., 2008; Demchenko et al., 2002; Maximov et al., 2008; Romanovskii and Hubberten, 2001]. These studies resulted in a relatively good understanding of major biophysical processes and their sensitivity to climate change. These studies also led to a conclusion that environmental changes induced by both socio-economic development of the region and climate change are dangerous. The rate of the changes would be too high to cope with their consequences in a business-as-usual way [Iijima et al., 2010].

There is an increasing understanding that a focus of research must be shifted to determine strategies for social adaptation [Ford and Furgal, 2009]. This challenge requires dramatic improvement of environmental models. Models should be able to forecast not only the environmental changes but also the potential impact of those changes on human well-being. Models also should respond to the questions of people potentially affected and provides direct support to political and management decisions.

This article is to emphasize the demand for the models that can adequately connect the scientific vision of future environmental changes to the real consequences for Siberian people.

## 2. DISCUSSION

### 2.1. How warm will Siberia be?

The answer to this question depends on the scenario of carbon dioxide emissions and the climate model in use.

The emissions scenarios that are used to run climate models are listed in the corresponding Special IPCC report [Nakicenovic and Swart, 2001]. This report was released in 2001, and scenarios were not updated since that time, although the growth rate of global emissions in 2000-2008 exceeded the conservative expectations. This does not undermine the confidence in the ability of these scenarios to predict the future, because the increase may be a short-term trend.

The large number of scenarios, however, makes it difficult to forecast the future climate. To forecast the future climate, we should first forecast the long-term trend of carbon dioxide emissions. Scenarios were not developed with this purpose in mind. They display the options for world development, and do not take into account the modern political tendencies towards stabilization of carbon dioxide emissions. The models that are used to create scenarios are not exactly the same that are needed to make a forecast of the long-term trend of carbon dioxide emissions and to update the forecast regularly proceeding from the observed rate of emissions and the state of emissions regulation efforts.

The SRES B1 (SRB1) scenario, that was used to run climate models for the Fourth IPCC Report, is perhaps the best candidate to the role of the emissions forecast. This scenario assumes the world to be more integrated and more ecologically friendly. The rapid growth will be accompanied with the rapid changes towards a service and information economy, towards the introduction of clean technologies, and towards global solutions for achieving socio-environmental stability.

Under this scenario, almost all parts of Siberia will be warmer by more than 2°C in sense of mean annual temperature, whereas northern parts will be warmer by more than 3.5°C (Fig 1). Projections for a particular region are model dependent, but in most cases vary in the same range.

The analysis of the 16 climate model outputs available at IPCC Data Distribution Center show significant discrepancies [IPCC 4th Assessment Report (2007), 2007]. Therefore, for constructing a model independent projection, one has to combine model outputs. This can be done either by simple averaging or by weighted averaging. In the latter case one need to develop criteria for assigning weights, which is not an easy task. Another option is to use a recently proposed method [Alexandrov and Matsunaga, 2008; Alexandrov and Matsunaga, 2009], which is based on the premises of evolutional epistemology [Bradie, 1994]. Since the number of climate models is quite large, development of methods for constructing model-independent projections become more important issue than improvement of any single model.

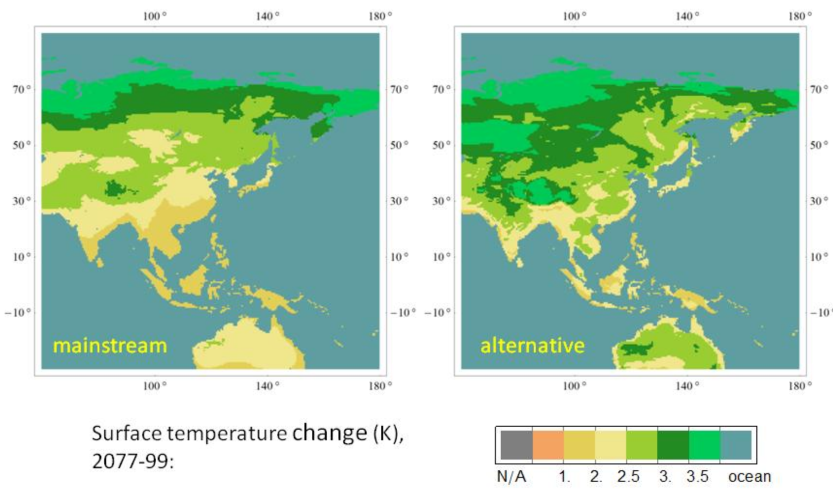


Figure 1. Anomalies in mean annual temperatures in the end of this century projected for SRB1 scenario: left pane – mainstream projection, right pane – alternative projection. Data source: outputs of sixteen climate models available at IPCC DDC. Method: inference tool of *Carbon Sink Archives*.

### 2.2. Will permafrost disappear?

Permafrost, in a broad sense, is ground remaining below freezing point of water for at least two years. The mean annual ground temperature (MGT) is usually higher than the mean annual air temperature (MAT), and therefore permafrost regions are the regions where mean annual air temperature is below -5°C. In these regions the temperature of ground at some depth remains below 0°C during the whole year, because the amplitude of seasonal variations decreases with the distance from ground surface.

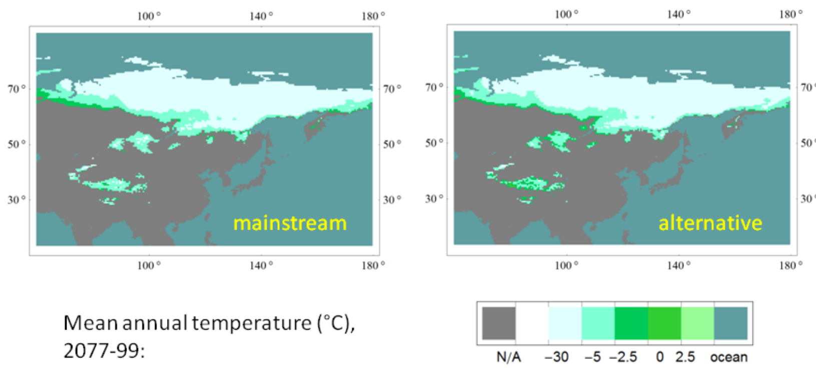


Figure 2. Mean annual temperatures in the permafrost regions (i.e., where MAT<-5°C in present) as projected by the end of this century for SRB1 scenario: left pane – mainstream projection, right pane – alternative projection. Data source: outputs of sixteen climate models available at IPCC DDC. Method: inference tool of *Carbon Sink Archives*.

The long-term records of ground temperature in permafrost regions show that the trends in MGT generally follow the trends in MAT. Both of them are increasing. However, the rates are not the same. MGT grows 1.5 times slower [Pavlov, 2008]. It would increase by 2°C when MAT would increase by 3°C. The area of the permafrost regions (that is, the regions where MAT<-5°C) would decrease by the end of the century, but they would still cover most of Siberia.

Since water keeps ground warm, the area of permafrost in permafrost regions may be sensitive to changes in hydrological regime, especially where the ice content in the ground is high. A depression in permafrost table tends to grow, because it accumulates water that makes ice melting. Hence, permafrost table is locally unstable. This property manifests itself in patterned landscape which is typical for permafrost regions.

Even in the regions of so-called continuous permafrost, permafrost covers about 80% of land. The other land is covered by taliks - year-round unfrozen ground. Taliks occur beneath lakes and rivers where deep water does not freeze in winter.

The percentage of taliks (and water bodies) at a given watershed reflects the water balance of this watershed, and may respond non-linearly to the warming. Perhaps permafrost may really disappear at some watersheds, even if MAT will remain below - 5°C. Thus, to assess changes of permafrost area within permafrost region one needs a spatially-distributed model of heat and water balance within a small watershed.

### 2.3. What happens to reindeer herders?

The modern Siberian "reindeer civilization" was formed somewhere in the 18th century, when the rapid expansion of semi-domestic reindeer population occurred [Krupnik, 2000]. This was supposedly the result of favorable environmental change that improved the quality of summer pastures and thus opened the "window of opportunity" for the socio-economic transformation.

Pasture quality is conventionally evaluated in terms of the amount and nutritional value of forage that the pasture produces. However, reindeer herders tend to evaluate summer pastures proceeding from other criteria [Istomin, 2004]. Herding reindeer flocks at the pastures covered with tall vegetation (or having complicated relief) is not as easy as at the pastures covered with short vegetation (or having flat relief). First, a flock more often breaks into small groups. Second, herders need more time to react on the changes in the flock behavior. The size of flock that can be managed by 1-2 herders depends on the pasture relief, the height of vegetation and some other factors having no direct relation to the pasture productivity. The best pastures allow 1-2 herders to keep under control the flock of 3000-3500 reindeers.

The environmental conditions determine two parameters of the reindeer civilization – the size of total semi-domestic reindeer population and the size of the flock that can be handled by a family. The latter determines how wealthy the reindeer civilization may be. In the case of indigenous way of life, the minimum size of a flock is 25-30 reindeers per capita [Galanin and Galanina, 2004; Yoshida, 1997]. In the modern social-economic conditions, a herder needs a flock of 250-300 reindeers to ensure his family's well-being. On the south margins of the reindeer civilization (i.e., in the forest zone), the typical size of the flocks is much smaller, 30-50 reindeers, and therefore the other traditional sources of subsistence (like fishing and hunting) become more important [Yoshida, 1997].

Although climate change would make summer pastures more productive, this would not be good for herders, because warming may seriously reduce pasture quality. The summer pastures are vulnerable to the breaks in the vegetation cover and the upper layer of soil. The vegetation cover and upper layer of soil protect ground from thawing and permafrost table from melting. Due to instability of permafrost table even relatively small disturbances may turn a flat pasture into a patterned piece of land. Herders keep flocks moving to reduce the risk of losing summer pastures. The larger the flock the faster it should move. Warming may seriously decrease efficiency of herder's labor – that is, make herders working more hard or being poorer.

### 2.4. Modelling needs

The carrying capacity of a summer pasture may be defined as the number of reindeer that would stay there within one day without causing long-term damage to pasture productivity. The carrying capacity depends not only on the productivity of the pasture but also on the intensity of trampling damage to vegetation and soil cover. Disturbing local heat and water regime, the trampling damage to vegetation and soil cover may initiate thermokarst development (or differential thawing) and turn a flat pasture into a patterned piece of land not suitable for herding large flocks.

The ability of the pasture to withstand trampling damage depends on whether heat and water balance at the watershed scale may "diffuse" the local disturbances of the heat and water regime. Since local disturbances are of small size, one needs a 3-dimensional permafrost model of fine spatial resolution to address such a question.

The climate change studies have been concentrated on the thickness of active layer (i.e., the depth of permafrost table) [Arzhanov et al., 2008; Lunardini, 1996; Malevsky-Malevich et al., 2001; Romanovsky et al., 1997; Smith and Riseborough, 1996; Stendel et al., 2007]. Since this research question may be adequately addressed by one-dimensional models simulating the vertical profile of ground temperature, the development of models needed for simulating differential thawing and formation of patterned-ground landscapes was not a priority. Nevertheless, there were efforts in this direction [Nishimura et al., 2009; Pohl et al., 2009; Riseborough et al., 2008; Smith and Riseborough, 2010; Thomas et al., 2009; Woo et al., 2004; Woo et al., 2008], and therefore development of a 3-dimensional permafrost model mentioned above is a feasible need.

## 3. CONCLUSION

It is not an easy task to develop models responding to the questions of people potentially affected by climate change. Most of models developed in connection to climate change studies were to provide discovery of the changes that *might* take place. Today, in a world that is aware of its responsibility for planetary changes and planning globally concerted actions, environmental modelling is expected to provide forecasts of changes that *would* take place and affect human well-being. Therefore, modelers have to mobilize themselves and develop new kind of models.

This article emphasizes the demand for coming from plural scenarios of regional climate change to a single "official" forecast that can be used as the basis for developing adaptation strategies. Will Siberia become permafrost free by the end of this century? There are worries that this *might* happen, but there is no forecast that this *would* happen.

The next problem is how to evaluate the consequences of permafrost retreat for Siberian people. This article concentrates on reindeer herders whose well-being depends on the availability of land suitable for pastures, identifies constraints for future development of the Siberian reindeer civilization, which may be imposed by permafrost melting, and formulates the direction in which permafrost models should be improved.

The recent social studies [Forbes and Stammler, 2009; Takakura, 2010a; Takakura, 2010b] demonstrate that one should employ a holistic approach to understand the adaptive capacity of the Siberian reindeer civilization: "…the daily practice of tundra nomadism involves permanent processes of negotiating one's position in a changing environment, which is why "adaptation" is woven into the society, and cosmology as a whole, rather than being separable into distinct "bodies" of knowledge or Western-designed categories", [Forbes and Stammler, 2009]. The resilience of the reindeer civilization is based on the complex use of land area and freshwater resources. For example, fish always remains an important component of dietary culture of reindeer herders despite the size of the flock [Yoshida, 1997]. In other words, to simulate the future development of Siberian reindeer civilization we need not only models of environmental processes but also an agent-based model reflecting the way in which reindeer herders percept their role on the land.

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