Potential climate-induced vegetation change in Siberia in the 21st century

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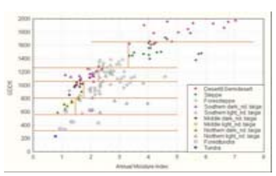
Study area. *Siberian window (60-140⁰ E and 50-75⁰ N) on the background of the Eurasian continent*

Goals

Regional studies in Siberia already registered a change in climate at the end of the 20th century. A mounting body of evidence of the changes in Siberian vegetation and in the forests in particular related to climate warming is available in the literature*.

The objective of this study was to examine the potential effect of two climate change scenarios on the spatial vegetation redistribution across Siberia for more than a century (from 1960 to 2080) and identify locations where predicted changes in climate would create new habitats for vegetation change



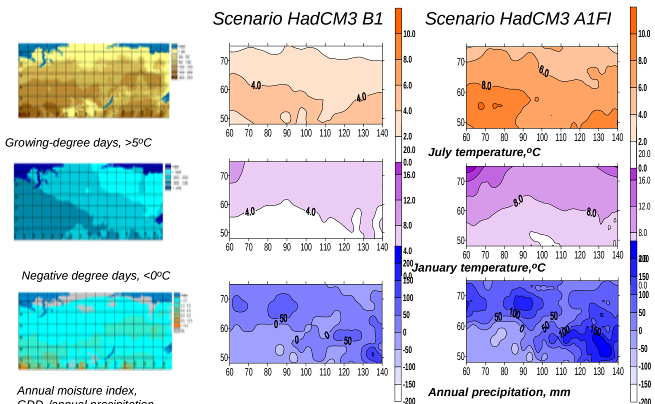
Siberian bioclimatic model.

* Some evidence of climate-caused vegetation change in Siberia

- *At the northern treeline, the forest shifted into tundra and open forests and become more stocked (Kharuk et al., 2005);*
- *In Evenkia, in the permafrost zone dominated by only L. dahurica, undergrowth of Siberian cedar, fir and spruce of some 40 years old was found (Kharuk et al., 2005; Ivanov 2004) probably because of permafrost melting;*
- *Upper treeline shifts 40-100 m uplope was registered in the mountains in the south: Altai (Timoshok, et al. 2003), Ovchinnikov et al., 2002), in the Sayans (Vlasenko 2000, Istomin, 2002), in Kuznetsky Alatau (Moiseev, 2002) and even in the north in Putorana Plateau (Abaimov et al., 2002);*
- *At the lower treeline, the P. sibirica seed production significantly decreased in the West Sayan for 1990-1999 possibly because of the cone damage by the moth Dioryctria abietella (Schft.) that may produce two generations for a longer vegetation period (Ovchinnikova and Ermolenko (2003).*

Methods. We used our bioclimatic vegetation model for predicting vegetation zones (zonobiomes) across Siberia. Our model is an "envelope-type" model (Box, 1981) that determines a unique vegetation class (unique climatic limits for a vegetation class) from three bioclimatic indices: GDD_5, representing plant requirements for warmth tolerance; and AMI characterizing; GDD_0 characterizing plant cold plant drought tolerance. Vegetation predicted only from climatic variables was then corrected for permafrost which is the primary factor controlling the vegetation and tree species distribution over Siberia.

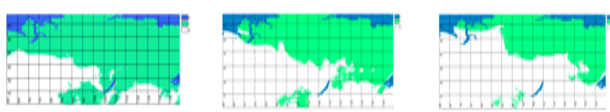
Current climate **Climatic anomalies by 2080**



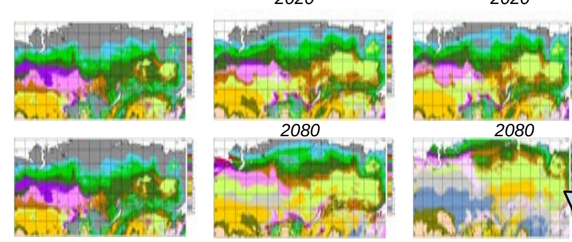
Methods

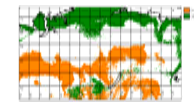
Data from about 1000 Siberian weather stations were used to map climatic variables and indices. Hutchinson's (2000) thin plate splines were used to produce climate surfaces on DEM grids (1 km) for monthly temperature and precipitation.

Climatic anomalies from 1990 to 2020, and from 1990 to 2080 were derived from two climate change scenarios the HadCM3 A1FI and B1 of the Hadley Centre in the U.K. based on the Special Report on Emission Scenarios (SRES). These scenarios reflect opposite ends of the SRES range, the largest temperature increase from the A1FI scenario and the smallest temperature increase from the B1 scenario.



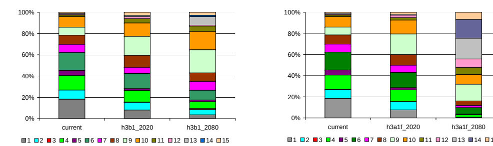
Permafrost distribution over Siberia from 1960 to 2080 calculated from Stefan's theoretical formula





New forest habitats (green) at the expense of tundra and new steppe habitats (orange) at the expense of forests at 2080. White – no change in vegetation

Vegetation change from 1960 (left) to 2020 (center) and to 2080 (right) in Siberia was mapped for all scenarios by coupling our bioclimatic vegetation model with maps of bioclimatic indices and of the permafrost border driving the model.



Vegetation classes:

***Boreal**: 1 – Tundra; 2 – Forest-Tundra; Northern Taiga: 3 – darkleaf, 4- lightleaf; Middle taiga: 5 – darkleaf, 6 – lightleaf; Southern Taiga: 7 – darkleaf, 8 – lightleaf; 9 – Subtaiga and Forest-Steppe; 10 – Steppe; 11 – Semidesert;*

***Temperate**: 12 – Broadleaved; 13- Forest-Steppe; 14 – Steppe, 15 – Desert, 0 – Water;*

•Results.

- **Siberian vegetation will be perturbed by 2020 and especially by 2080;**
- **Because of a predicted dryer climate, forest-steppes and steppes rather than forests would dominate over half of Siberia;**
- **Biomes and major tree species may shift northwards as far as 600-1000 km;**
- **Despite of a large predicted warming, permafrost will not thaw deep enough to support dark taiga which require 1-2 m of the active layer depth (ALD). Over plain Siberia, the larch (*Larix dahurica*) taiga withstanding shallow ALD will stay the dominant zonobiome;**
- **Our model also show that new habitats for some temperate vegetation types (broadleaf forest and forest-steppe) would occur by 2080;**
- **Melting permafrost and fire are the principal mechanisms that facilitate equilibrium between the vegetation and the climate across Siberian landscapes.**

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