Albedo change feedbacks to resulting shifts in vegetation under climate warming in Siberia

Tchebakova N.M. and Parfenova E.I.
Institute of Forest, Siberian Branch, Russian Academy of Sciences

Goals

- Evaluate possible effects of feedbacks of vegetation-induced albedo change to net radiation change and to accelerating/mitigating vegetation shifts over Siberia in a warmed climate

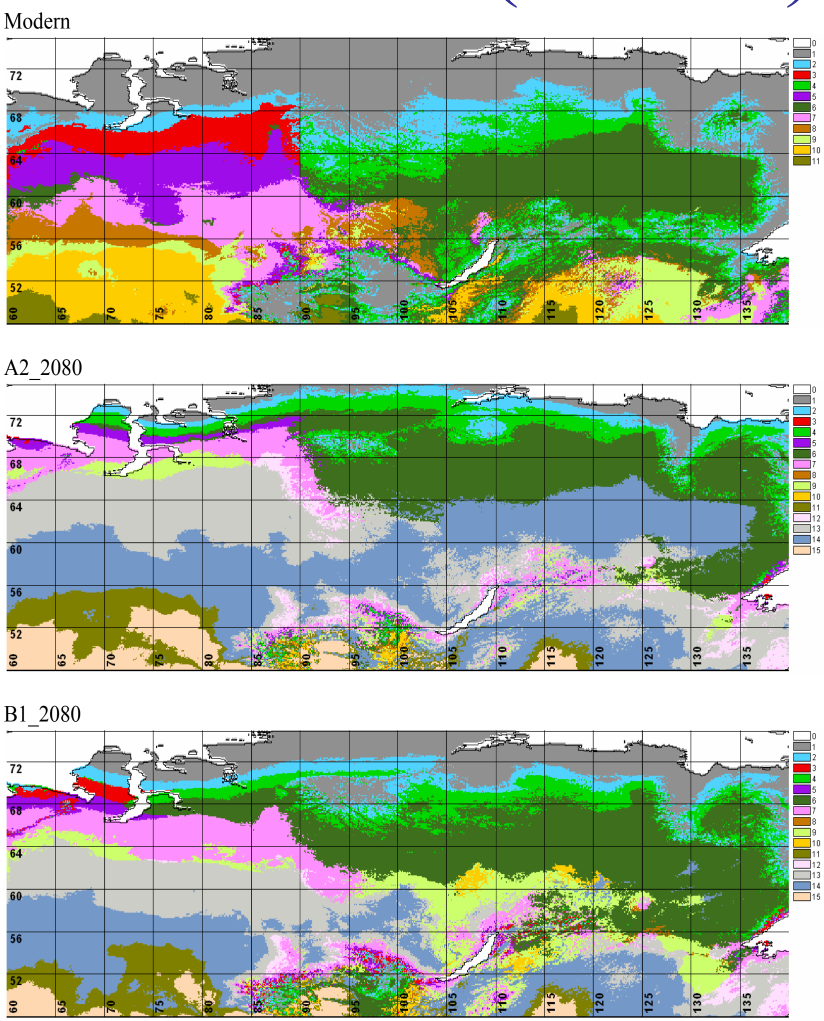
Study area

60-140°E and 48-72°N, 12 million square km

Methods

- To highlight possible vegetation change at 2080 we applied our Siberian bioclimatic model (SiBCliM) to the HadCM3 A2 (with the highest temperature increase) and B1 (with the lowest temperature increase) scenarios of the Hadley Centre (IPCC, 2007)
- SiBCliM predicts a biome (a zonal vegetation class) from three climatic indices (growing degree-days, negative degree-days, and an annual moisture index) and permafrost.

Results: Vegetation change in Siberia from current climate (upper) and climate change scenarios A2 (middle) and B1(lower) at 2080



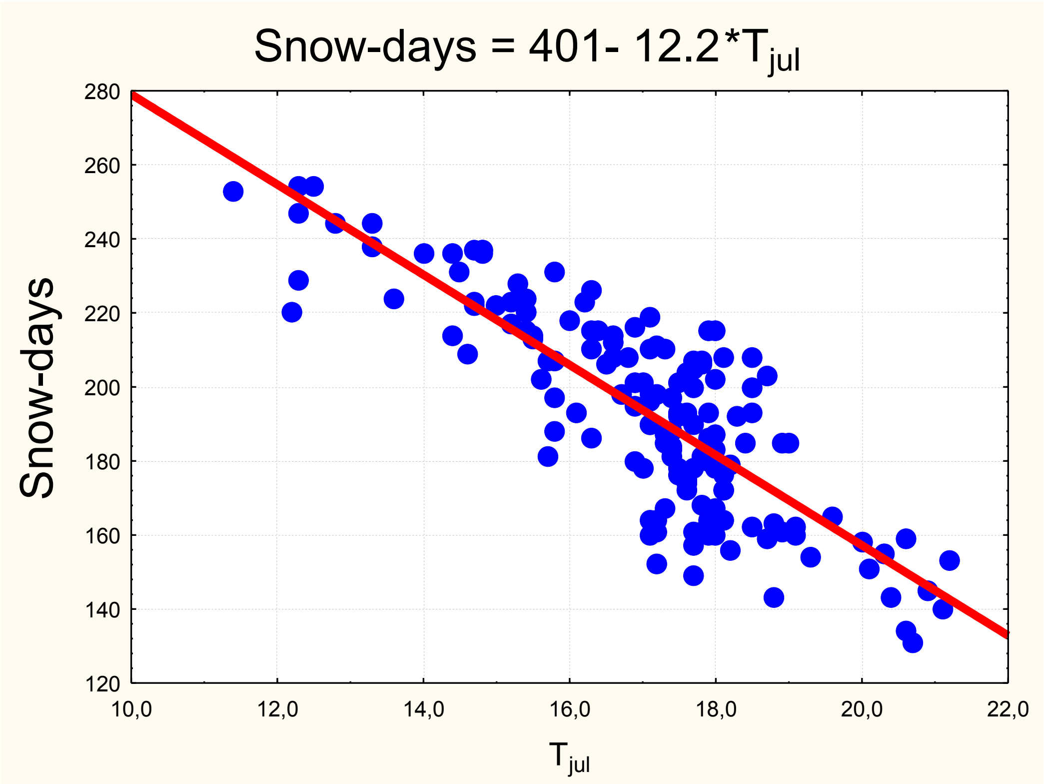
Our simulations indicate large changes in Siberian vegetation:

- northern vegetation types (tundra, forest-tundra, and taiga) would decrease from 81.5 % to 30-50%;
- southern habitats (forest-steppe, steppe and semidesert) would expand from 18.5% to 50-70%.

Methods

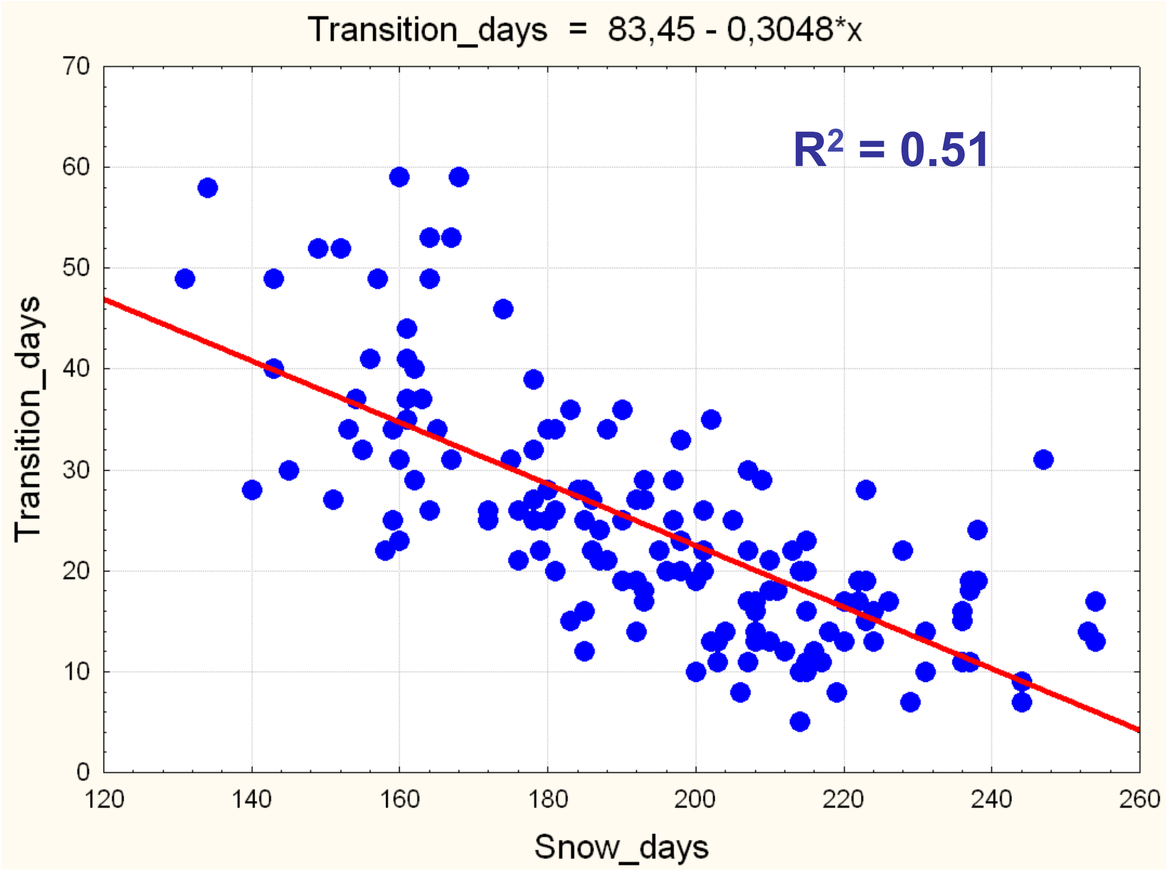
- Significant change in land cover would cause changes in the surface albedo;
- Albedo of current and the 2080 vegetation was calculated for each pixel as a sum of winter albedo (vegetation covered by snow), summer albedo (snow-free vegetation) and albedo of winter-to-summer and summer-to-winter transition periods;
- Albedo values for each year season were derived from Budyko (1974)

Relationships between a number of snow-days and July temperature



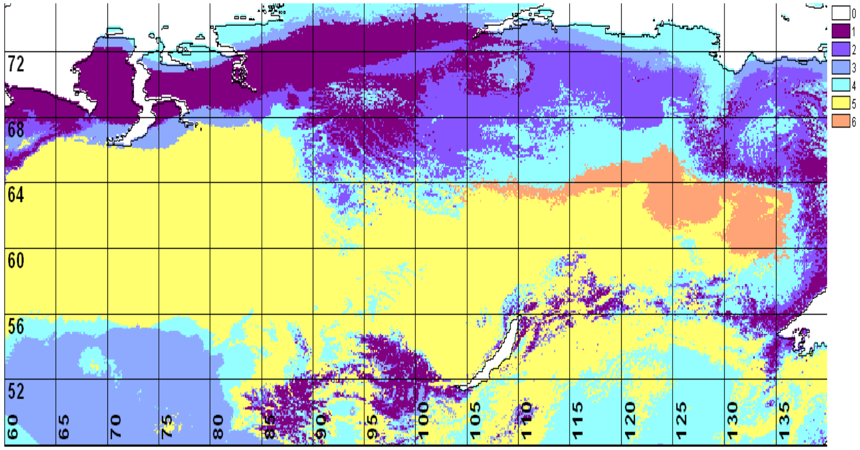
The snow period was calculated from the regression relating it to July and January temperatures(**R^2 = 0.72**)

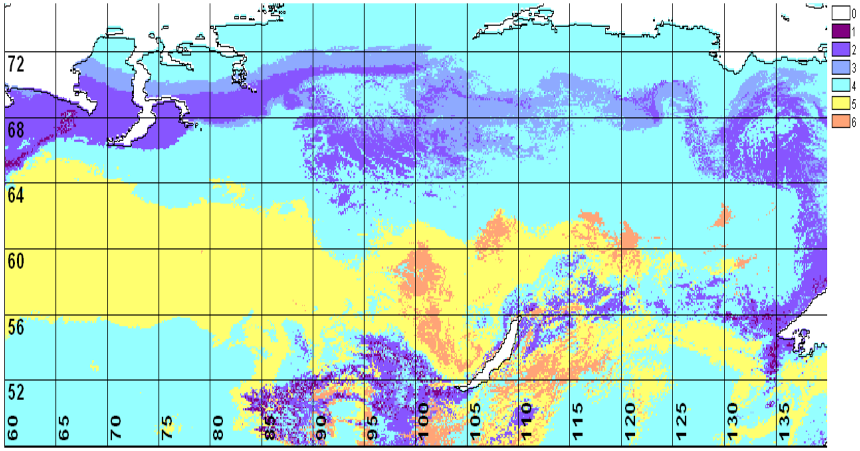
Relationship between a number of transition days and snow-days



The winter-to-summer & summer-to-winter snow transition period was calculated from the regression relating this period to the snow period

RESULTS: Vegetation-induced albedo change in the **A2** (left) and **B1** (right) climate at 2080





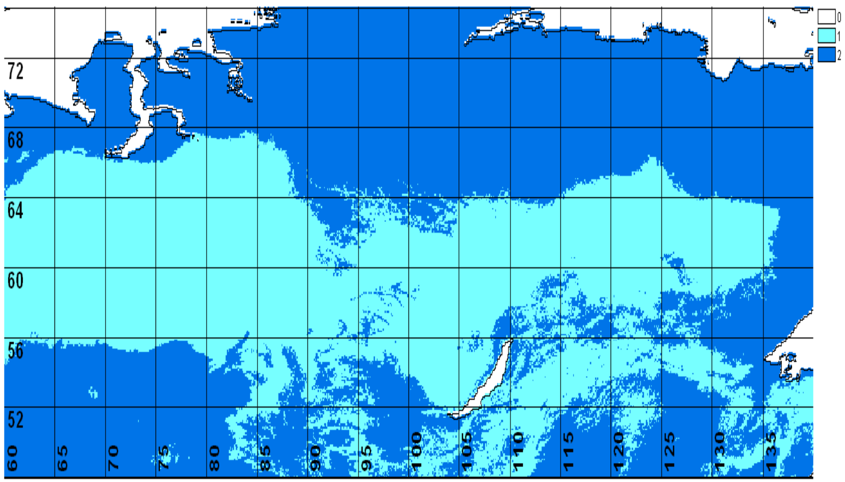
Shades of **Blue** is albedo decrease

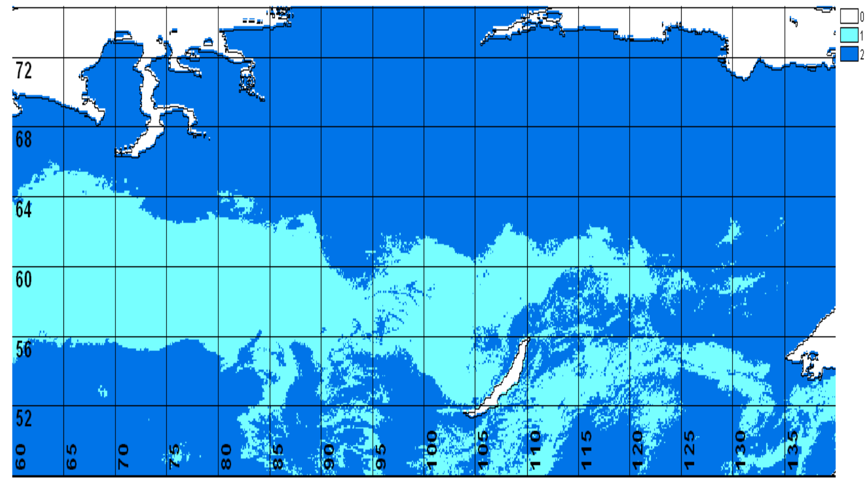
Shades of **Yellow** is albedo increase

According to the warmer A2 scenario, albedo would increase over 45% of the area and would decrease albedo in 55% of the area

According to the moderate scenario B1, albedo would increase over 30% of Siberia and would decrease in 70% of the area

RESULTS: Albedo-induced net radiation change in the **A2** (left) and **B1** (right) climate at 2080





Albedo change would feedback to Net Radiation;

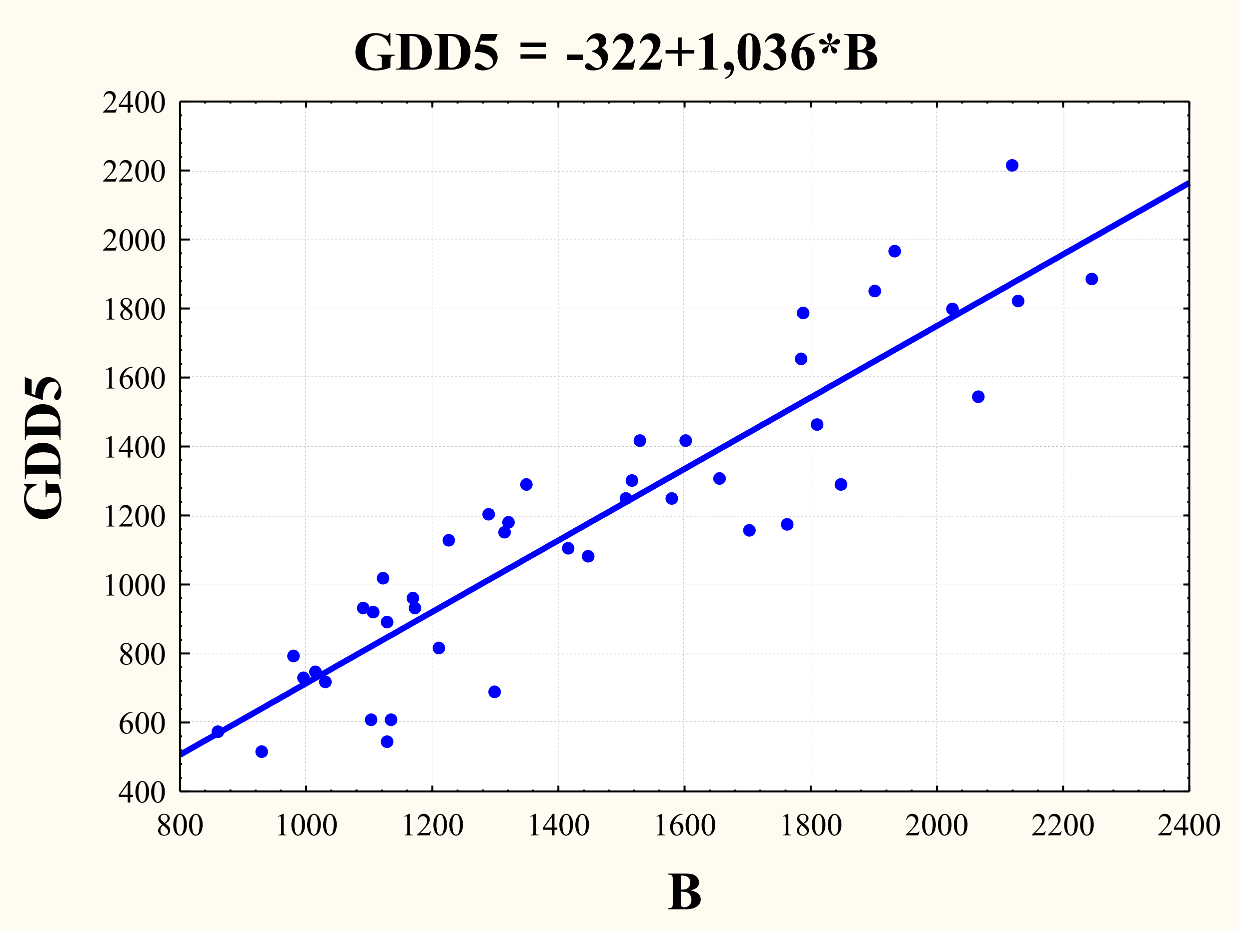
- Under a greater warming (A2) net radiation balance would increase by $220*10^{13}$ MJ/yr in a half of the area and would decrease by $70*10^{13}$ MJ/ yr in another half of the area totaling in $150*10^{13}$ MJ per year over the entire Siberian window;
- Compared to the annual net radiation 1000-2000 MJ*m^{-2} in current climate, this change is about 10% in the A2 climate and 6% in the B1 climate;

Methods

- to estimate albedo-induced net radiation feedbacks to vegetation, net radiation was transformed to growing degree-days, GDD, the climatic constrain we use in our SiBCliM;

- a linear regression model relating net radiation and GDD was developed for Siberia from observed data

The relationship between net radiation (B) and growing degree-days (GDD) in Siberia



R^2= 0.83, n-45, st.er. = 193;

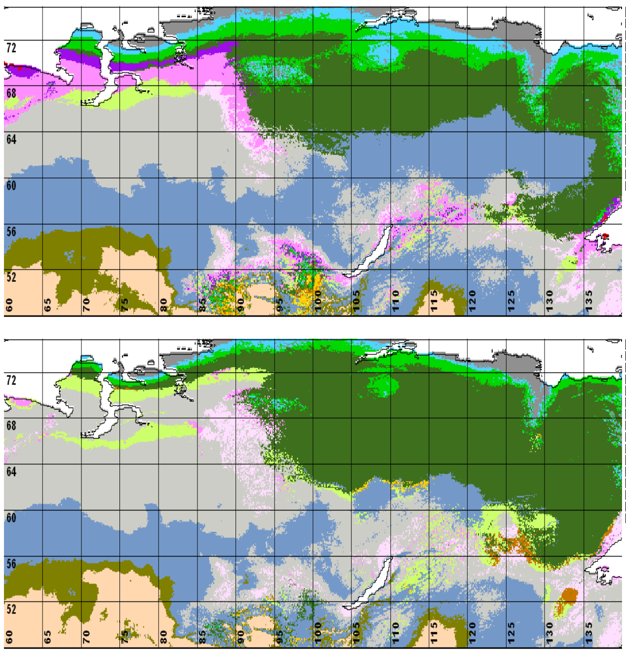
Methods

- albedo-induced corrections for growing degree-days were calculated coupling this regression with the net radiation maps in the A2 and B1 climates at 2080;

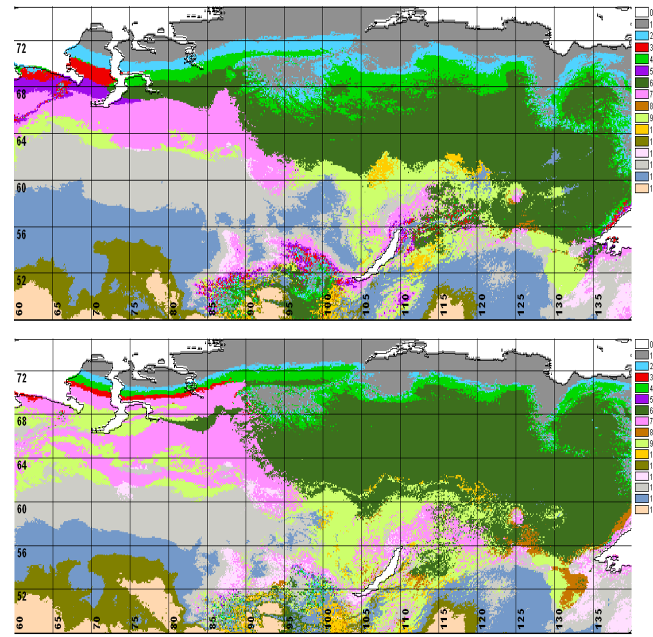
- SiBCliM was run again for the A2 and B1 climates to insight how vegetation would shift with regard the predicted feedbacks

RESULTS: Vegetation distribution in 2080 predicted with no albedo feedbacks (left) and corrected for albedo feedbacks *(right)*

HadCM3 A2



HadCM3 B1

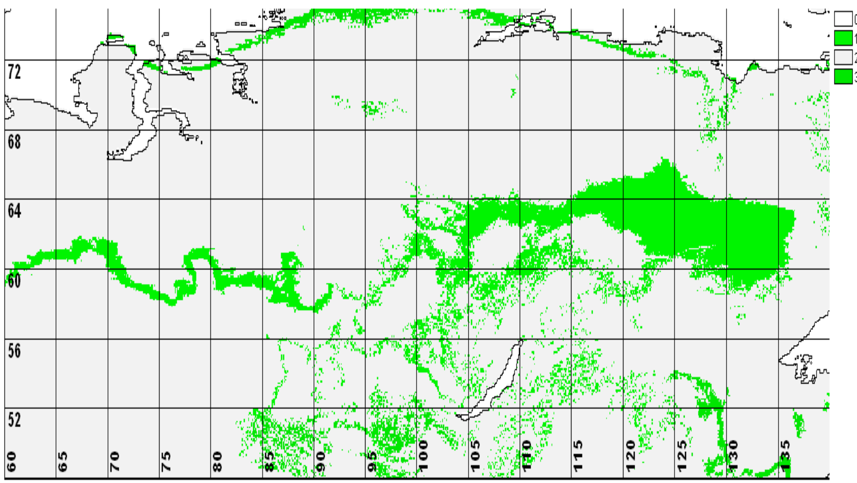


Potential albedo feedbacks due to land cover change predicted from IPCC scenarios, may result in:

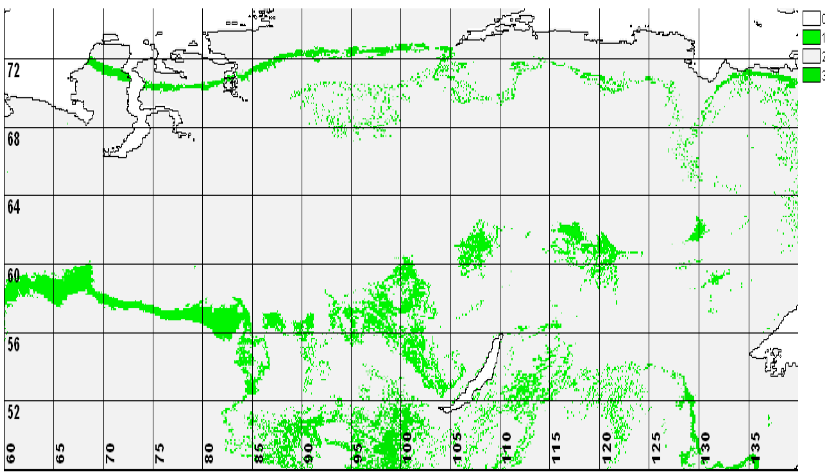
- additional warming in the north promoting the further forest advance northwards;
- some cooling in the forest-steppe ecotone promoting the forest return in the south;

RESULTS: Forest portion (green) may increase at 2080 due to albedo feedback effects

HadCM3 A2



HadCM3 B1



The forest may additionally gain back in its area about 1% of tundra and 6-8.5% of grasslands

Conclusions

The pattern of land cover change predicted from IPCC climate change scenarios and followed by albedo-induced feedbacks suggests accelerating warming and the further forest advance into tundra in the north and mitigating warming and the forest return into steppe in the south resulting in up to 8% of increased forest area.