Earth Sciences Sector

Reducing Canada's vulnerability to climate change

Changes in soil thermal status in Canada during the 20th century

A model assessment of climate change impact

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Introduction

Air temperature at high latitudes increased at a higher rate than the global mean during the 20th century. Climate warming could induce to permafrost thaw, deepen active layer thickness, reduce seasonal frost depth, and release soil carbon. Here we report our recent results about the responses of soil thermal status to climate change in Canada during the 20th century simulated by a process based model for northern ecosystem soil temperature (NEST).

Method and data

We simulated ground thermal dynamics based on energy and water transfer in soil-vegetation-atmosphere systems, and explicitly considered the effects of climate, vegetation, snow, organic layers, soil texture, and soil moisture on ground thermal dynamics (Fig. 1). The model was validated against the measurements of energy fluxes, snow depth, soil temperature, and thaw depth at four sites in Canada (Zhang et al., 2003).

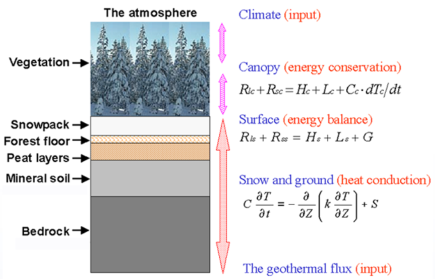

Fig. 1 The structure of the model

The model inputs include information about vegetation, ground and climate. Vegetation types were determined based on the land cover map of Canada. LAI was derived from AVHRR 10-day composition images. Soil texture, bulk density and organic content were extracted from the soil organic carbon digital database of Canada (Tarnocai and Lacelle, 1996). Excess ice content was estimated based on Heginbottom et al. (1995). The geothermal flux was interpolated from the measurements at about 250 sites (Pollack et al., 1993). The climate data were from New et al. (2000), which include global monthly climate data from 1901 to 1995 at 0.5-degree latitude/longitude spatial resolution. The monthly data were down-scaled to half-hourly during the simulation (Chen et al., 2003). The initial conditions were determined by iteratively running the model to equilibrium.

Results and analysis

Fig. 2 shows the spatial distributions of soil thermal status and its change during the 20th century. Panels 2D-G also show the boundaries of permafrost zones delineated by Heginbottom et al. (1995) for comparison. Fig. 3 shows comparisons between simulated and measured values of soil temperature and active layer thickness. Fig. 4 shows the temporal variations in soil thermal status averaged for the whole country.

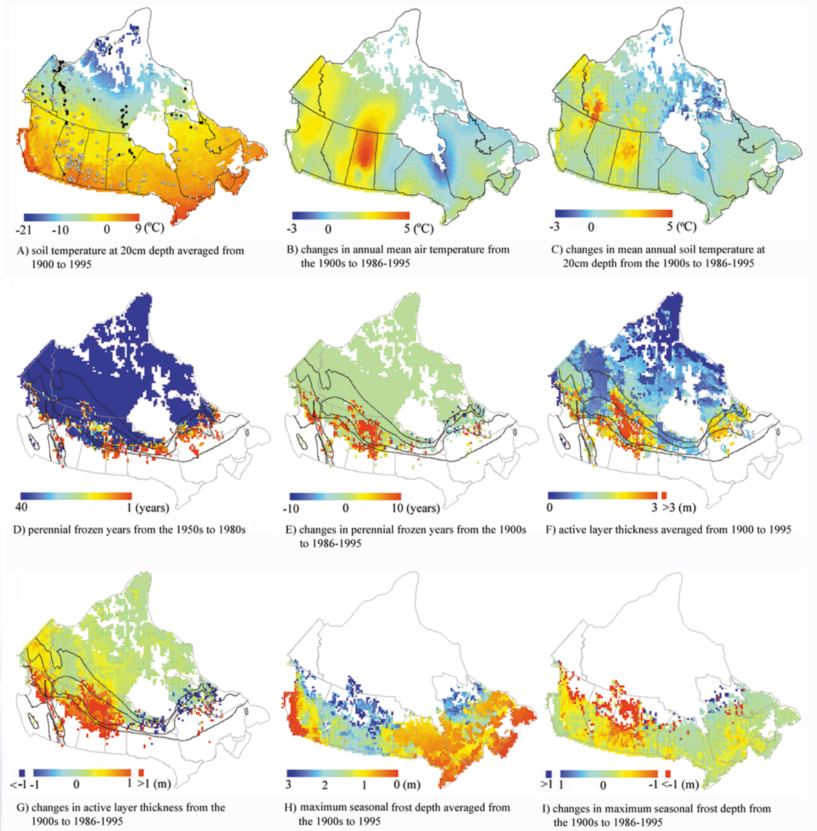

Fig. 2 Spatial distributions of soil thermal status and its change during the 20th century.

In panel A, the circles and dots are the locations of measurements of soil temperature and active layer thickness, respectively. The curves in panels D-G are the boundaries of permafrost zones delineated by Heginbottom et al. (1995). Perennial frozen here means a frozen layer exists for a whole year.

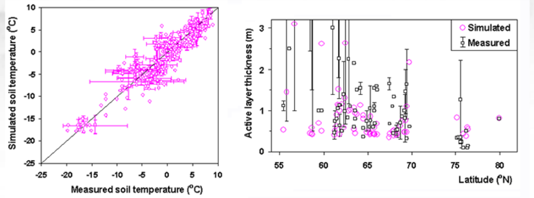

Fig. 3 Comparisons between simulated and measured values of soil temperature and active layer thickness. The masurement sites are shown in Fig. 2A.

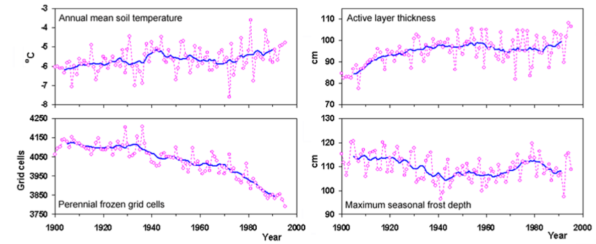

Fig. 4 Temporal variations of soil thermal status in Canada during the 20th century (annual means of the whole country and 10-year running averages)

Conclusions

This study simulated the transient response of soil thermal status to climate change during the 20th century. On average for the whole Canada, soil temperature at 20 cm depth increased by 0.6 °C; perennial frost areas reduced by 6.7%; active layer thickness increased by 18.1%; and seasonal frost depth reduced by 5.3%. Changes in soil temperature and air temperature were different, and the distributions of soil thermal status and its change were more spatially heterogeneous than that of air temperature.

References

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