Numerical simulation of permafrost thermal structure in West Siberia

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Permafrost strongly influences the processes that contribute significantly to both local and global climate on different time scales. In this study, the model for thermal and hydrolocal processes in the soil interior, the Deep Soil Simulator (DSS) [Arzhanov et al., 2007] is used to simulate numerically the evolution of permafrost soils in West Siberia over the last 200,000 years. The DSS is forced by the Climer-2 output as reported by Ganopolsi et al. [2016]. The results of the DSS simulations are compared to the data from the borehole drillings in the respective regions, and also to the results of another numerical simulations of the temperature field for the north of West Siberia [Chuvilin et al., 2013]. Despite the differences in degrees C, the geothermal gradients of simulation results agree well with those of the boreholes data.

For numerical simulations with DSS, the model of permafrost heat transfer mechanisms is used with respect to freezing-thawing cycles. This model was developed at IAP RAS, is based on the solution of the Stefan problem with several water-ice phase transitions boundaries [Arzhanov et al., 2007]. The upper boundary of the simulated area is taken land surface level or the snow cover level (if any), with boundary condition of the first kind established on it -- the near-surface temperature of the CLIMBER-2 data. A geothermal flow of 0.06 W/m^2 is set at the lowest boundary of the simulated area, which is at the depth of 1500 meters.

The results of simulations are temperature distributions in soils in the West Siberia and China. According to the simulations, the geothermal gradients for the selected area are 2.45 C/100 m and 2.53 C/100 m for different longitudes 47-57 N and 57-67 N respectively, at latitudes 90-120 E.

In order to verify how adequate the CLIMBER-2 model reproduces the temperature regime of the soil of West Siberia region, the results were compared to the instrumental data of borehole drilling for present time (Fig. 1). Temperature measurement were obtained from several boreholes in West Siberia at least 200 meters deep.

The geothermal gradients of instrumentally obtained data are 1.741 K/100 m at the location 55.17 N, 82.83 E [https://www.ncdc.noaa.gov/paleo/study/1000884]; 2.784 K/100 m at the location 49.08 N, 114.25 E [https://www.ncdc.noaa.gov/paleo/study/1000765]; 3.767 K/100 m at the location 37.88 N, 92.25 E [https://www.ncdc.noaa.gov/paleo/study/1001031]; 0.709 K/100 m at the location 66.42 N, 112.5 E [https://www.ncdc.noaa.gov/paleo/study/1000881]. The geothermal gradients calculated based on the results of CLIMBER-2 simulations fall within the range of the geothermal gradients of observational data.

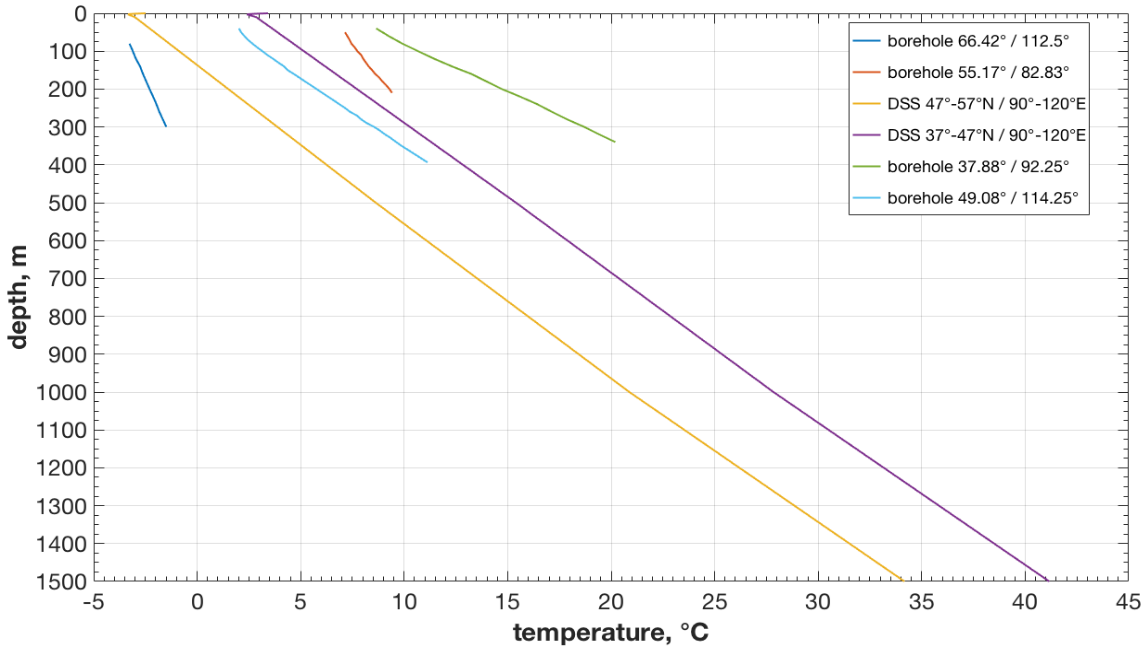

Fig. 1. Soil temperature profiles in West Siberia and China from the DSS simulations and borehole data.

Another comparison of the obtained DSS estimates with the results of numerical simulations of the temperature field for the north of Western Siberia [Chuvilin et al., 2013] illustrates that the model reproduces well a decrease in soil temperature during periods of glacial peaks, in particular about 200,000 years ago and in LGM (about 20,000 years ago), as well as an increase in temperature during the interglacial periods - the Eemian interglacial (120,000 years ago) and the Holocene optimum (from 10,000 years ago). The obtained values of the temperature at 1500 m for the current period are 34-42 C, which agrees well with the estimates of 35-45 C from [Chuvilin et al., 2013].

References

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