Changes in Late Quaternary circum-Arctic ground ice and soil organic carbon simulated by a simple numerical model

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Permafrost is a large reservoir of soil organic carbon (SOC; about half of all the terrestrial storage). Therefore, its degradation (i.e., thawing) under global warming may lead to a substantial amount of additional greenhouse gas (GHG) release. However, understanding of the processes, geographical distribution of such hazards, and implementation of the relevant processes in the advanced climate models are insufficient yet so that variations in permafrost remains one of the large source of uncertainty in climatic and biogeochemical assessment and projections. Knowledge on the “vulnerability distribution” as the high potential areas of ice-rich permafrost degradation is important for assessment and projections. However, the information from the currently accessible data is limited. On the other hand, the development of ice-rich permafrost has a long timescale (i.e., on the order of hundreds to tens of thousands of years), gone through varying stages under changing ambient conditions since the Last Interglacial period (c. 130 thousand years ago, or 130ka). This study, conducted as a part of three-year research project (2-1605, ERTDF of ERCA) aims to understand the evolution of the vulnerability distribution, we developed a simple numerical model to simulate the dynamics of ground ice and SOC in the circum-Arctic region (north of 50° N). The model has two compartments, above-ground and ground; the former is driven by annual air temperature and total precipitation (Figure 1) to calculate the carbon input (i.e., litter fall) and thermal conditions, and the latter calculates subsurface carbon and water budget, including ice content (Figure). The driving data and boundary conditions are taken from literatures, open data, and outputs from global climate models, such as Paleoclimate Model Intercomparison Projects (PMIPs). The preliminary model results at 8 characteristic circum-Arctic points for the transient changes in ground ice (mm) and soil carbon content (gC m-2) from 26ka to the present successfully simulate the contrasting difference between the glacial and post-glacial periods (Figure 2). For the full period (0-130ka), the driving data is now under preparation. Further validation and calibration, including evaluations on simulated geographical distributions, are to be conducted.

Keywords: terrestrial soil organic carbon, permafrost, glaical-interglacial, simple numerical model, Arctic