Arctic infrastructure at high risk by 2050

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1. INTRODUCTION

Arctic permafrost environments are undergoing unprecedented changes[1,2]. In addition to the potential adverse effects on global climate and ecosystems[3], **thaw of permafrost may damage fundamental infrastructure**[4-7] (Fig. 1). This could threaten the sustainable development of Arctic communities, and the utilization of natural resources[6-9].

In this study, we **(i) identified infrastructure hazard areas** in the Northern Hemisphere's permafrost regions under projected climatic changes (focus on RCP4.5) and **(ii) quantified critical engineering structures at risk** by 2041–60 (hereafter 2050).

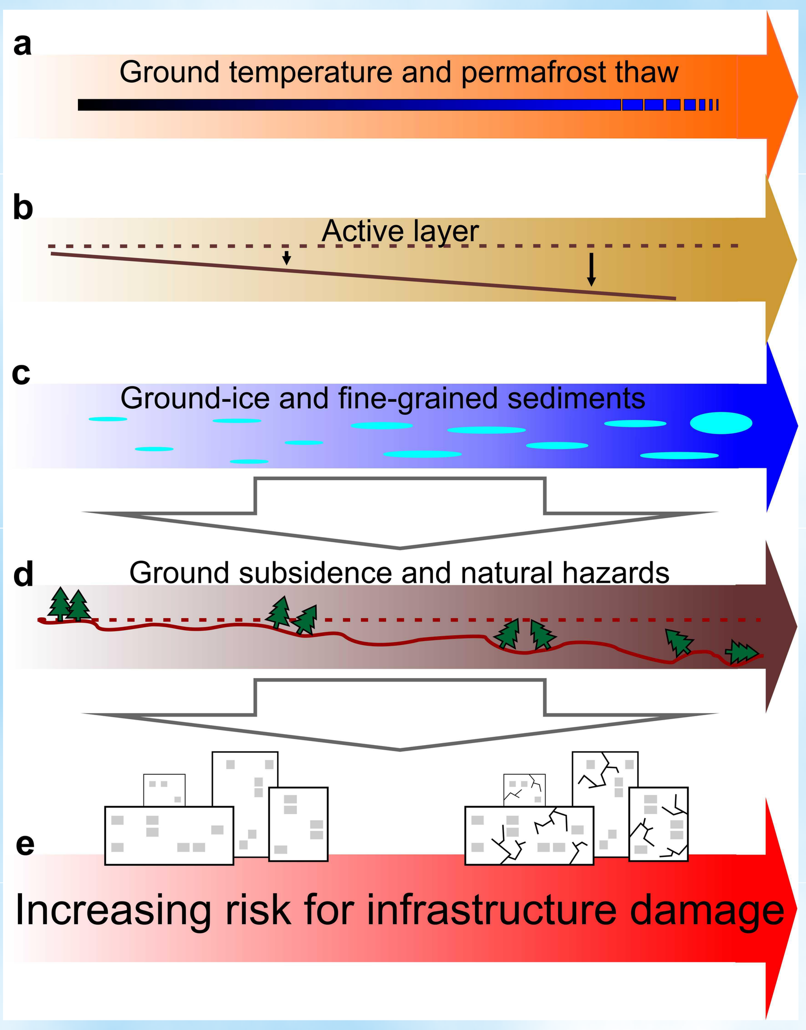

Figure 1. Key environmental factors causing ground instability and infrastructure hazards in the permafrost domain. Increasing ground temperature and thaw of near-surface permafrost (**a**), thickening of active layer (seasonally thawed surface layer atop permafrost) (**b**), or higher ground-ice and fine-grained sediment content (**c**) increase ground instability and natural hazards (**d**), which may lead to loss of structural bearing capacity and damage of human infrastructure (**e**).

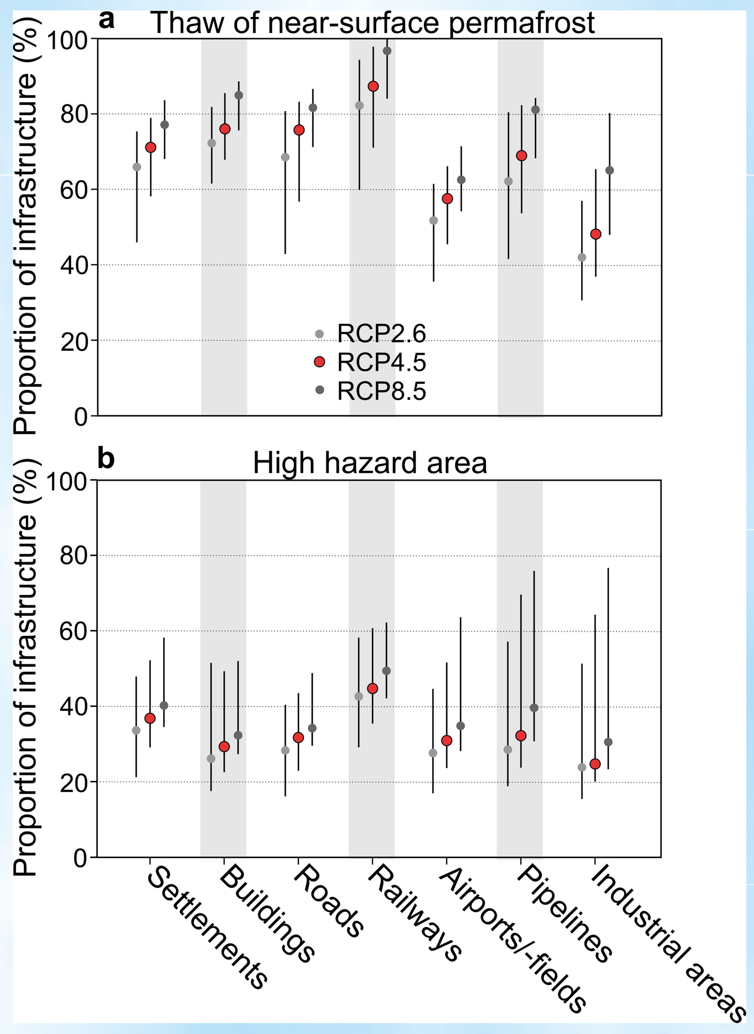

Figure 2. Proportion of infrastructure elements in areas of near-surface permafrost thaw (**a**) and high hazard (**b**) in pan-Arctic permafrost area by 2050. The uncertainty ranges (bars) were determined using 95% uncertainty in the mean annual ground temperature (**a** and **b**) and active layer thickness predictions (**b**).

2. DATA AND METHODS

We used observations of ground thermal regime, geospatial environmental data, and statistically-based ensemble methodologies to model the current and future permafrost conditions[10,11]. Using the forecasts of ground temperatures, geohazard indices, and GIS-based infrastructure data we mapped hazard areas at unprecedentedly high (~1 km) spatial resolution and quantified the amount and proportion of engineering structures in areas where ground subsidence and loss of structural bearing capacity could damage infrastructure[12].

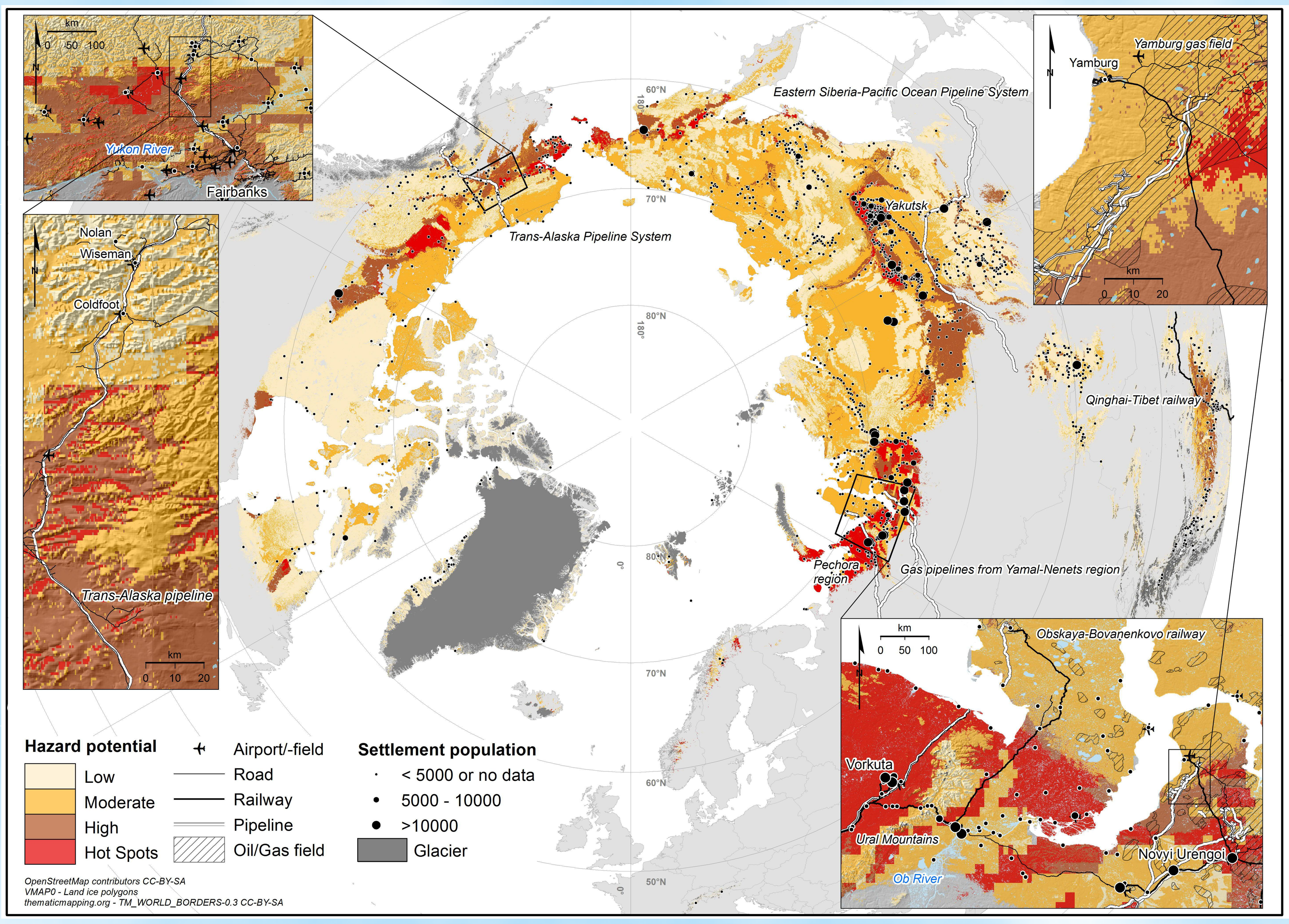

Figure 3. Pan-Arctic infrastructure hazard map with close-ups from central Alaska and northwestern parts of the Russian Arctic. A consensus of three geohazard indices (settlement index, risk zonation index, and analytic hierarchy process-based index) showing hazard potential by risk level (low–high) for infrastructure damage by the middle of the century (2041–2060). Hot spots indicate areas where all three indices showed high potential for infrastructure damage.

3. KEY FINDINGS[12]

(1) Nearly four million people live in areas with high potential for thaw of near-surface permafrost by 2050.

- This is over 70% of the current population in the Northern Hemisphere permafrost area.

(2) Substantial amount of infrastructure is located in areas where ground subsidence could severely damage constructions (Fig. 2).

- More than 36,000 buildings, 13,000 km of roads, and 100 airports occur in high hazard areas.

(3) The potential threat to hydrocarbon extraction and transportation in the Russian Arctic is considerable (Fig. 3).

- A total of 45% of the hydrocarbon extraction fields in the Russian Arctic are in high hazard zone.

(4) Fundamental Arctic infrastructure will be at risk by 2050, even if the Paris Agreement target is achieved.

- After 2050, attainment of the Paris Agreement could make more difference in terms of potential damage to infrastructure.




4. MAIN CONCLUSIONS

To successfully manage climate change impacts in sensitive permafrost environments, a better understanding is needed about **which elements of the infrastructure** are likely to be affected by climate change, **where they are located**, and **how to implement adaptive management** in the most effective way, considering the changing environmental conditions.

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