Approach to Estimate Current and Future Destabilization Risk to Energy Facilities on Permafrost

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Abstract

Permafrost is permanently frozen ground that covers over 10% of the Earth's surface. Many northern regions have extensive infrastructure built on this hard, frozen ground. When permafrost thaws, the ground becomes a softer mix of soil and water, which can cause degradation and damage to critical infrastructure. Permafrost thaw has substantial economic, strategic, and environmental implications. While thawing permafrost due to climate change will affect energy infrastructure in many countries, this work focuses on Russia's current and planned arctic energy infrastructure. To quantify Russian energy infrastructure locations on permafrost, geospatial data was collected and mapped. Specifically, our analysis focuses on Russian gas and oil terminals and power plants. First, we determined the types of permafrost extents (e.g., continuous, discontinuous, sporadic, and isolated) on which each energy facility lies. Next, to evaluate the infrastructure hazard potential of permafrost thaw, we leveraged an existing analysis by [Karjalainen et al., 2019] in which data on ground conditions were weighted and aggregated to generate low, medium, or high hazard classifications under various greenhouse gas trajectories. For the time frame 2041-2060 and assuming greenhouse gas trajectories consistent with RCP 4.5, most facilities were found to be located in moderate and high hazard zones. A similar analysis was conducted for the years 2060-2081 under various climate conditions. Next, we generated supplemental analysis to define similar hazard classifications under current climatic conditions. The future climate scenario findings are compared with current conditions to identify potential variations in hazard zones, which could heighten infrastructure destabilization. Findings are applied to a targeted case study of the Yamal Peninsula to assess implications for Russia in the areas of energy capacity, foreign investment and supply chains, and future infrastructure construction projects. Citation: Karjalainen, O., Aalto, J., Luoto, M. et al. Circumpolar permafrost maps and geohazard indices for near-future infrastructure risk assessments. Sci Data 6, 190037 (2019). https://doi.org/10.1038/sdata.2019.37

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PRESENTED AT:

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PROJECT GOALS

- Assess the impacts of permafrost thaw on Russian energy infrastructure by using a quantitative, qualitative, and geospatial ap
- Develop a geospatial product to model current permafrost hazard conditions and conduct a comparative analysis between cur
Using the Yamal Peninsula as a case study, integrate open-source information with comparative analysis, to discuss geopolitic

METHODS

A) Analyzed future permafrost hazard model for years 2041-2060 and 2061-2081 from Karjalainen et al which is as follows: Ia = (groundtem 0.248) + (relative increase of ALT x 0.122) + (fine – grained sediment content x 0.071) + (slopegradient x 0.035)

B) Adapted above model to account for current conditions (slope gradient dropped)

C) Acquired data for each variable from open-source databases

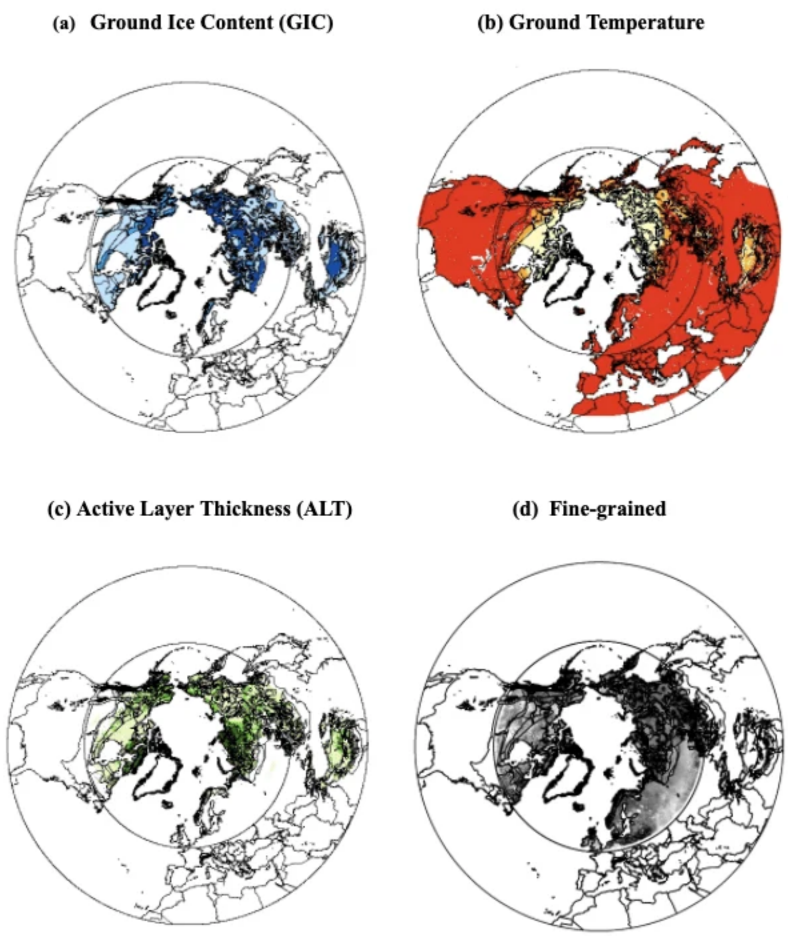
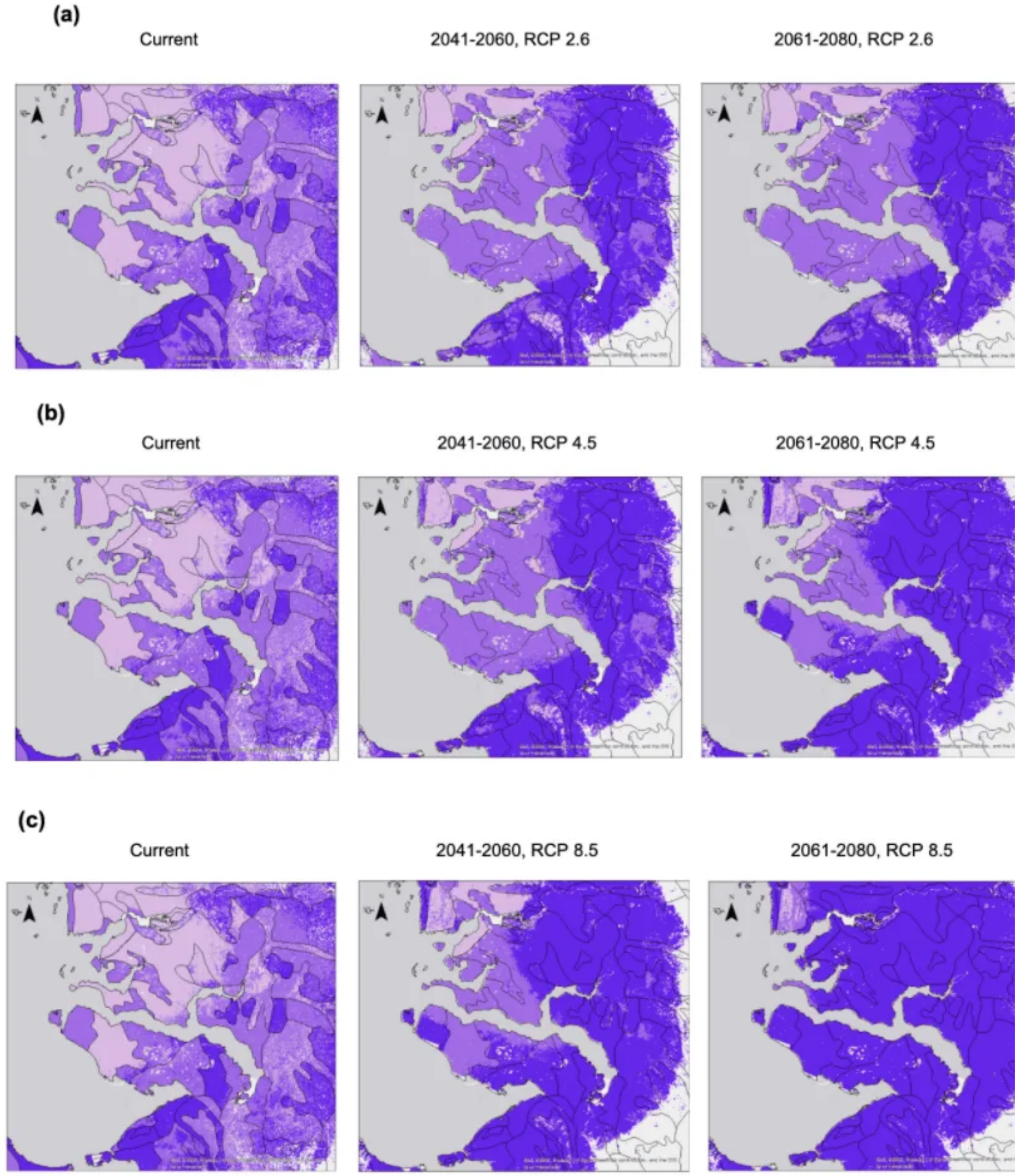


Figure 2. Ground Ice Content (GIC), Ground Temperature, Active Layer Thickness (ALT), and Fine-grained sediment layer uploaded into ArcMap.

D) Classified each variable into (low medium high) using benchmarks from Karjalainen and nested mean procedure. Reclassified to produce

E) Raster calculator to compute calculation and produce final layer depicting current hazard conditions


(a)
Current
2041-2060, RCP 2.6
2061-2080, RCP 2.6
(b)
Current
2041-2060, RCP 4.5
2061-2080, RCP 4.5
(c)
Current
2041-2060, RCP 8.5
2061-2080, RCP 8.5

FINDINGS

- The total reserves and resources in the Yamal Nenets region account for 1/5th of Russia's total reserves and supplies 90% of Russian domes

- Russia's LNG production will shift toward increasingly high permafrost hazards as soon as 2041. Approximately ¼ of Russia's LNG is e in 2061-2080 under RCP 8.5. (Slide R1)

- The Yamal Peninsula is currently characterized by low and medium hazard zones. Future projections under severe conditions indicate that a subset area and the surrounding areas, will consist of high hazard zones. (Slide R2)

- Permafrost hazards to pipelines varies across space. By 2040-2060 under RCP scenario 4.5, 49% of the Yamal pipeline will be in a portion 8.5, roughly 90% of the Yamal pipeline will be under high hazard conditions. (Slide R3)

- As a part of its Polar Silk Road initiative, China has invested heavily in the Yamal LNG facility. The China National Petroleum C shareholder of the Yamal LNG project as it owns 20% of the project (CNPC). (Slide R4)

DISCUSSION

- Given the strategic importance of the Yamal Peninsula and Russia's increased focus on LNG, Russia will invest significant scientific and ec permafrost related infrastructure degradation
- Russian companies will seek foreign investment and tech for arctic infrastructure, particularly from China, to assist in covering the high cos resilient infrastructure.
- LNG can be a bargaining chip for Russia in international negotiations as well as provide a vehicle for Russia to develop new potential allie
- Given the permafrost hazard risks associated with natural gas transportation via pipeline, as well increased demand from distant markets in via the Northern Sea Route.

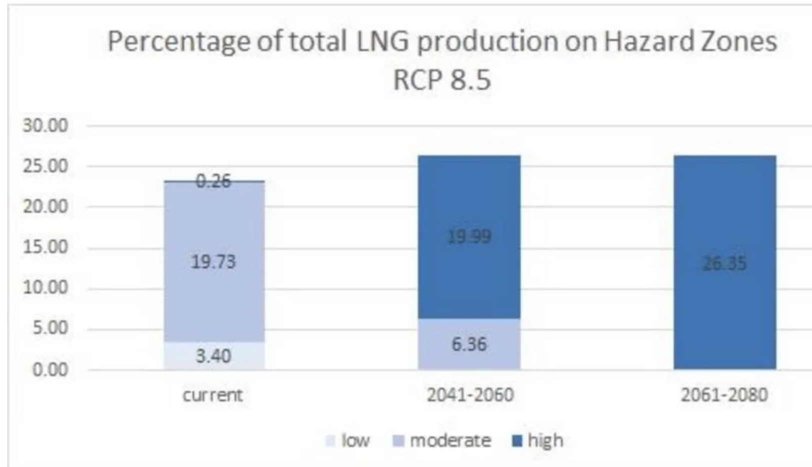


Figure 5. Graph displaying percentage of total LNG production on Hazard Zones
RCP 8.5

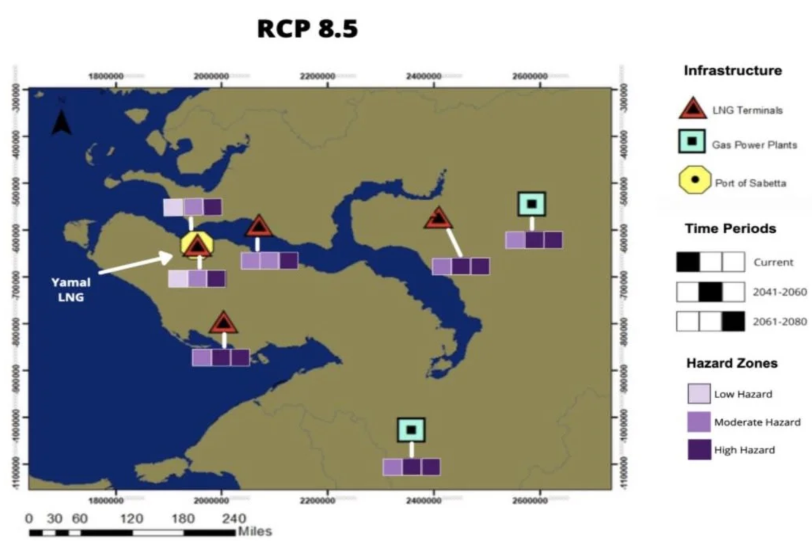


Figure 6. Map displaying infrastructure points and their hazard level for current and fut
periods

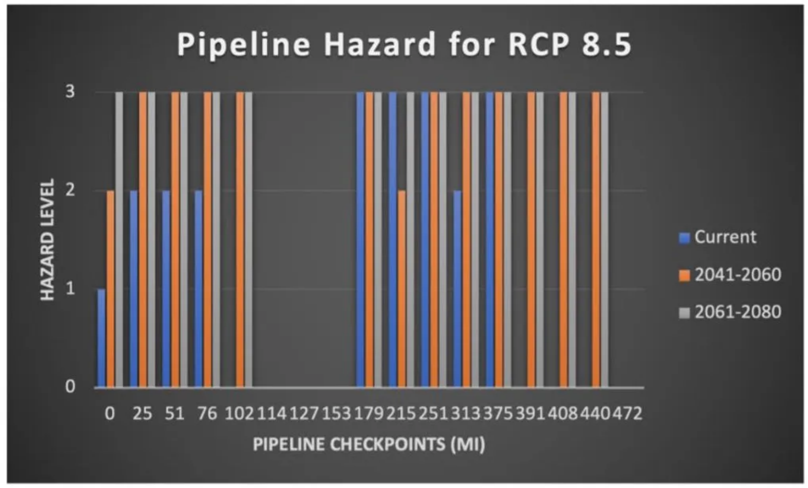
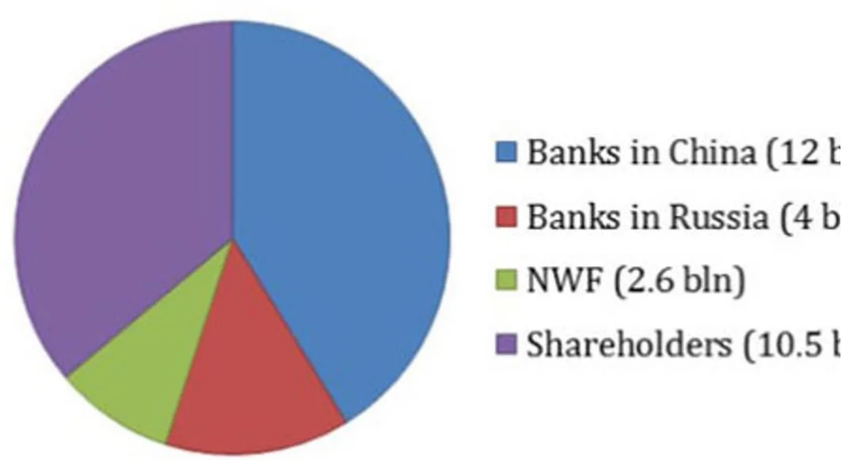


Figure 8. Graph displaying the Yamal Pipeline that transports natural gas. Pipelin
was split into mile segments in order to indicate which portions of the pipeline ar
different hazard levels under each time period for RCP 8.5



AUTHOR INFORMATION

Jason Koehn is a graduate student at Johns Hopkins SAIS. He is currently studying international conflict management and economics.

Alexia

Jefferson Antwi-Agyei is a graduate of George Mason University, obtaining a B.S in Criminology, Law, and Society with minors in Intelligence Analysis and Geographic Information Systems (*cum lade*). Jefferson was fortunate to intern this past summer at the Applied Research Laboratory for Intelligence and Security at the University of Maryland, College Park where he and his fellow interns tackled problems posed by IC members. Currently, Jefferson is an Open-Source Analyst for a private security company in Arlington, Virginia.

ABSTRACT

Permafrost is permanently frozen ground that covers over 10% of the Earth's surface. Many northern regions have extensive infrastructure built on this hard, frozen ground. When permafrost thaws, the ground becomes a softer mix of soil and water, which can cause degradation and damage to critical infrastructure. Permafrost thaw has substantial economic, strategic, and environmental implications. While thawing permafrost due to climate change will affect energy infrastructure in many countries, this work focuses on Russia's current and planned arctic energy infrastructure. To quantify Russian energy infrastructure locations on permafrost, geospatial data was collected and mapped. Specifically, our analysis focuses on Russian gas and oil terminals and power plants. First, we determined the types of permafrost extents (e.g., continuous, discontinuous, sporadic, and isolated) on which each energy facility lies. Next, to evaluate the infrastructure hazard potential of permafrost thaw, we leveraged an existing analysis by [Karjalainen et al., 2019] in which data on ground conditions were weighted and aggregated to generate low, medium, or high hazard classifications under various greenhouse gas trajectories. For the time frame 2041-2060 and assuming greenhouse gas trajectories consistent with RCP 4.5, most facilities were found to be located in moderate and high hazard zones. A similar analysis was conducted for the years 2060-2081 under various climate conditions. Next, we generated supplemental analysis to define similar hazard classifications under current climatic conditions. The future climate scenario findings are compared with current conditions to identify potential variations in hazard zones, which could heighten infrastructure destabilization. Findings are applied to a targeted case study of the Yamal Peninsula to assess implications for Russia in the areas of energy capacity, foreign investment and supply chains, and future infrastructure construction projects.

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