Linking climate change and human systems: A case study of Arctic pipelines

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Background

- Thousands of kilometers of oil and gas transmission pipelines in the Russian Arctic are built on degrading permafrost
- The study estimates the associated economic risk over the period 2020-2040

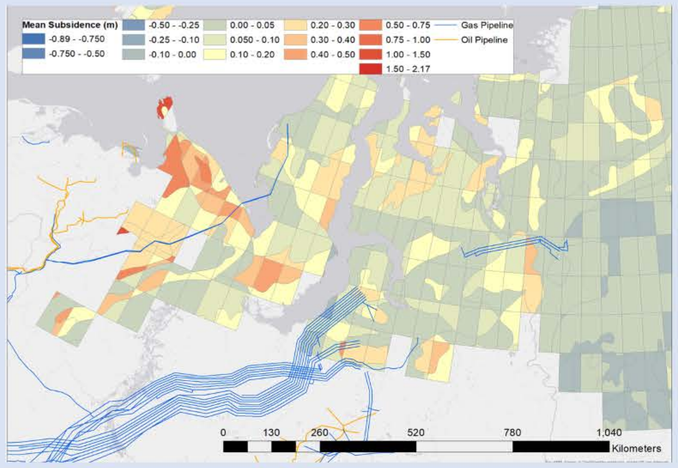
Upheaval of buried Urengoi-Center pipeline in western Siberia. (Brouchkov et al., Pipelines on Russian North: review of problems of interaction with permafrost)

Methods

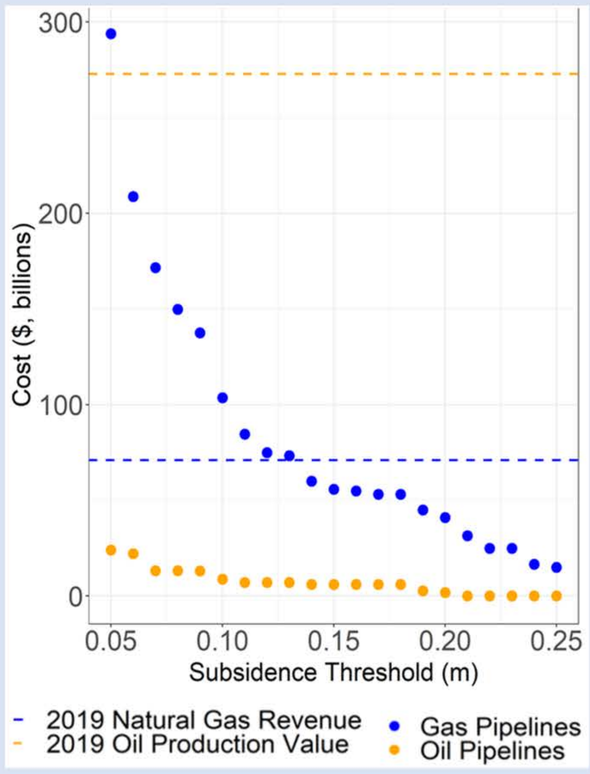
- Generated permafrost thaw-induced ground subsidence projections over the period 2020 to 2040 with a quantification of uncertainty, using pan-Arctic simulations of permafrost thaw-depth from the Community Land Model version 4.5 and ground ice characteristics
- Identified at-risk pipelines by overlaying Russian oil and gas transmission pipeline networks over ground subsidence projection in ArcGIS
- Selected range of subsidence thresholds likely to damage pipelines based on expert opinion and engineering analysis
- Estimated range of pipeline replacement costs over study period with uncertainty analysis on cost, subsidence tolerance, and permafrost thaw

Results

- Permafrost thaw-induced ground subsidence poses significant threat to oil & gas pipelines in the Russian Arctic
- The central estimate for pipeline replacement cost was $100 billion over the study period
- Gas pipelines are especially vulnerable to ground subsidence due to their positioning; the 20-year central estimate for gas pipeline replacement exceeded Russian natural gas 2019 revenues



Map of oil and gas pipelines and thaw induced ground subsidence projections over the period 2020-2040 on the Yamal Peninsula



Replacement cost estimates vs assumed subsidence threshold over period 2020-2040.

	Permafrost projection percentile (5^{th},mean, 95^{th})	Cost multiplier (3, 5, 7)	Replacement threshold (25cm,10cm,5 cm)	Combined
Low, Billion USD	44	62	14	4.0
Central, Billion USD	100	100	100	100
High, Billion USD	350	150	290	1100

Uncertainty analysis for gas pipeline replacement costs

Conclusions

- Reduced pipeline viability
  - Maintaining pipelines under changing ground conditions will be expensive and incidents more will become more frequent
  - Pipelines will need to be buried deeper to reach stable permafrost or built above ground
  - Much of the Russian oil and gas industry depends on frozen ground conditions for construction – it will become difficult to maintain construction routines in warmer conditions
  - Costlier technologies such as access mats will become increasingly necessary
- Reduced pipeline viability has implications at the global scale
  - Economic
  - Environmental
  - Geopolitical

The study highlights the need for additional research to better understand how changing Arctic conditions will affect infrastructure and the associated implications for broader systems

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