RATIC Arctic Infrastructure Science Talk Series

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Innovative permafrost monitoring and research directions for resilient Arctic civil infrastructure

Presenter: Ming Xiao, Penn State University

AI Summary (unedited)

The meeting discussed the impacts of climate change, particularly in the Arctic region, and the importance of infrastructure management. Ming Xiao presented research on the use of distributed fiber optic sensing techniques, airborne electromagnetic approaches, and hazard mapping in the Arctic region. The conversation ended with discussions on the need for smart sensing technologies, the development of digital counterparts of physical infrastructure, and the planning of an upcoming workshop in Boulder.

Climate Change and Arctic Infrastructure

In the meeting, Jana Peirce from the University of Alaska, Fairbanks, led the discussion with various participants from different backgrounds and locations. The participants included Nikita Kaplan, a candidate in traditional indigenous activities, Dima, a professor of geography and international affairs, and others. The discussion revolved around the impacts of climate change, particularly in the Arctic region, and the importance of infrastructure management. The participants also discussed the need for innovative monitoring approaches and future research for resilient civil infrastructure in the Arctic. The conversation ended with an introduction to the draft agenda for the upcoming workshop in Boulder.

Distributed Fiber Optic Sensing in Permafrost

Ming discussed the use of distributed fiber optic sensing techniques for understanding and forecasting long-term variations in permafrost conditions. He explained the process of using a data acquisition box to send laser pulses through a fiber optic cable buried in the ground or attached to infrastructure. The cable's deformation due to ground vibrations, such as footsteps or waves, is used to determine seismic properties like shear wave velocities. Ming presented results from a 2-kilometer-long fiber optic cable installed in the tundra, showing temperature variations over four years. The data revealed a clear distinction between the infrastructure area and the tundra, with the infrastructure area experiencing warmer temperatures. Ming also mentioned the potential for future research in this area.

Soil Hardness Analysis and Electromagnetic Methods

Ming discussed the analysis of data from a 100-meter long road, converting it into shear wave velocity of the soil. He noted that the soil's hardness could be inferred from the wave propagation rate, with colder soil being harder and warmer soil being softer. Ming also presented results from

three types of airborne electromagnetic approaches: Gp, EM induction, and GPR. He highlighted the advantages of these methods, including their ability to cover large areas and access difficult-to-reach locations. Ming shared preliminary results from a 50-meter grid flown near a NOAA facility in Gavik, showing the permafrost table and ice wedge polygons. He concluded by suggesting that these methods could be used to identify hidden ice wedges in the ground.

Arctic Hazard Mapping Approaches Discussed

Ming discussed two approaches to hazard mapping in the Arctic region. The first approach, the Arctic Coastal Hazard Index (ACHI), is an index-based method that considers seven parameters including habitat, shoreline type, relief, wind and wave, surge potential, and sea level rise. This method was adapted from a previously used approach in lower 48 temperature regions and incorporated an additional parameter, the permafrost thaw potential. The second approach is a high spatial resolution coastal hazard mapping for civil infrastructure, which identifies soil types and their bearing capacity. This method considers the loading of infrastructure on the soil and its impact on thaw subsidence. Ming concluded by presenting the results of these approaches, highlighting the higher coastal hazards and thaw subsidence when considering the loading of infrastructure.

Smart Sensing for Soil Monitoring

Ming discussed the need for smart sensing technologies in a multispatial temporal scale to monitor soil changes across larger spatial scales and over time. He also highlighted the need for advanced data analytics and machine learning approaches to analyze the large amounts of data collected. Ming suggested the development of digital counterparts of physical infrastructure, such as a digital twin of permafrost infrastructure systems, to monitor changes and predict future performance. He also acknowledged the challenges of incorporating salinity into hazard mapping due to lack of data and the need for a factor of safety in traditional engineering approaches. Ming shared his experiences conducting research in the Arctic, noting mixed reactions from communities and the need for more immediate results.

Cable Positioning and Data Collection

Jana, Ming, and Vladimir discussed the positioning and usage of a cable buried in permafrost for data collection. Ming clarified that the cable was initially placed at the permafrost table but has since moved due to the table's movement. Vladimir raised concerns about the cable's exposure to warmer temperatures, which Ming acknowledged as a good point. Ed added that the fiber optic cable technology is being used in other research locations, including Alaska and London. The team also discussed the high cost of the interrogator box, which Ming confirmed was around 100k.

Workshop, Presentations, and Upcoming Events

Jana expressed gratitude for the presentations and discussions, and mentioned that the recordings of the meeting would be available for those who couldn't attend. She also discussed the upcoming workshop in Boulder on March 24th, which would focus on research directions and priorities for the next 10 years. The team also discussed the possibility of Nikita presenting his work in about a month's time, with the help of Vladimir for translation. The idea of organizing an event outside of the Assw venue was also brought up. Lastly, Jana mentioned a planning

meeting that would be held to discuss the upcoming events and their fit into the overall schedule.

Next steps

- Nikita to translate one of the calculation methods into English and share it with the team in about a month.
- Vlad to help with the translation of Nikita's presentation on the economic losses calculation method.
- Nikita to prepare a presentation on the economic losses calculation method for the team in about a month.