Assessing permafrost erosion and infrastructure destabilization using the Arctic Coastal Erosion (ACE) coupled thermo-mechanical model

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ABSTRACT

Although the Arctic is warming at a rate of 4 times the rate of the rest of the globe, current tools for quantifying permafrost erosion fail to explain the episodic, storm-driven erosion events occurring in the region. This talk will describe the development, calibration and validation of a new thermo-mechanics-based ACE (Arctic Coastal Erosion) model [1] for the simulation of permafrost erosion off the Arctic coast of Alaska, towards understanding the impacts of Arctic warming on permafrost degradation. The ACE model integrates two key components: a solid mechanics model that calculates 3D stress, strain, and displacement in permafrost using a plasticity model dependent on frozen water content, and an innovative thermal model that governs 3D heat conduction and the solid-liquid phase transitions within the permafrost. These components are sequentially coupled through a thermo-mechanical scheme, implemented in the open-source Albany/LCM finite element code. The ACE model has several unique characteristics, including: (1) the ability to predict failure from any allowable deformation (block failure, thermo-denudation, thermo-abrasion); (2) the ability to predict failure modes from constitutive (rather than empirical) relationships; (3) the capability to perform mesh adaptation by removing elements from the underlying finite element mesh based on specified erosion criteria; and (4) the incorporation of realistic oceanic and atmospheric boundary conditions obtained from stand-alone oceanic simulations and observational data, respectively.

Following a description of the key features of ACE, we will study the model's ability to reproduce erosion behavior observed during a summer/fall 2018 field campaign at Drew Point, Alaska. Time permitting, we will additionally describe some recent work in employing the ACE model to study impacts of Arctic warming on critical infrastructure built on top of Arctic permafrost, focusing on an exemplar involving a runway in Paulatak, Northwest Territories, Canada.

REFERENCES

[1] J. Frederick, A. Mota, I. Tezaur, D. Bull. "A thermo-mechanical terrestrial model of Arctic coastal erosion", *J. Comput. Appl. Math.* 397 113533, 2021.