Development of a Strongly-coupled Thermo-mechanical Model of Permafrost for the Simulation of Arctic Coastal Erosion

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Abstract

Accelerating Arctic coastal erosion rates have put critical infrastructure and native communities at risk due to a number of changes in the Arctic environment. Although the Arctic comprises one-third of the global coastline, current tools for quantifying permafrost erosion are unable to explain the episodic, storm-driven events.

This presentation will describe a new thermo-mechanics-based model known as ACE (Arctic Coastal Erosion) for the simulation of the erosion of permafrost off the Arctic coast of Alaska. The ACE model is intended to inform our scientific understanding of coastal erosion processes, contribute to estimates of biogeochemical and sediment loading, and facilitate infrastructure susceptibility assessments.

At the heart of ACE are partial differential equations (PDEs) governing the mechanical and thermal behavior of a combination of ice and frozen soil are solved monolithically using the finite element method using the Albany open-source multi-physics code. Advancing Albany for permafrost/coastal erosion modeling involved the development of 3D stress/strain fields via a frozen water content dependent plasticity model, as well as the addition of a thermal evolution model of the permafrost bluff via a 3D heat conduction model which incorporates phase change. Oceanographic boundary conditions are provided by a numerical modeling suite comprised of a circum-Arctic Wave Watch III model forcing a two-way coupled SWAN-Delft3D-FM local model. Combined with atmospheric conditions, this suite produces time-dependent surge and run-up output to force the Albany terrestrial model.

A major advance in the ACE Model is that the failure mechanism of the coastal permafrost bluffs is not pre-determined or empirical, but results from any allowable deformation (block erosion, slumping, etc.). A parallel field campaign (summers of 2018 and 2019) at Drew Point, Alaska will validate and calibrate ACE Model parameters. Following a description of the ACE model and its implementation within the Albany code base, we will present the results of modeling representative geometries devised from field surveys and data collected from the Northern Alaskan coast, towards a formal validation study using observational data collected as part of the aforementioned field campaign.

References

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