Development of a novel thermo-mechanical model for simulating permafrost demise and Arctic coastal erosion

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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 the terrestrial component of 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. The terrestrial component of the ACE model [1,4] is comprised of two main ingredients: (1) a solid mechanics model that calculates the three-dimensional (3D) stress, strain and displacement fields of the underlying permafrost developing in response to a frozen water content dependent plasticity model, and (2) a novel thermal model governing the 3D heat conduction and solid-liquid phase change occurring within the permafrost. These two physics sets are coupled via a sequential thermo-mechanical coupling scheme developed within the Albany LCM open-source finite element code [2]. Elements are dynamically removed from the underlying finite element mesh so as to simulate transient permafrost erosion events. 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. Unlike prior approaches, our modeling approach enables failure from any allowable deformation (block failure, thermo-denudation, thermo-abrasion); moreover, failure modes develop from constitutive (rather than empirical) relationships inherent in the underlying finite element model. Following a description of the key features of the ACE terrestrial model, I will present some results generated using this model, namely: (1) results of a sensitivity study performed using the model run in mechanics-only mode [3], and (2) results from a qualitative assessment of the model on a pseudo-realistic problem in which a slice of permafrost is exposed to realistic oceanic and atmospheric boundary condition data occurring at Drew Point, Alaska in late summer/early fall 2018 [1].

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