HAMLET How to Apply Machine Learning to Experimental & Theoretical PHYSICS
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Global glacier ice thickness inversion with supervised learning

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Accurate knowledge of ice volumes is essential for predicting future sea level rise, managing freshwater resources, and assessing impacts on societies, from regional to global. Efforts to better constrain ice volumes face challenges due to sparse thickness measurements, uncertainties in model input variables, and limitations in ice flow traditional model parameterizations. Glaciers currently account for approximately 20-30% of global sea level rise. Modeled glacier volume estimates vary widely, especially in arid regions such as the Andes and the Himalayan–Karakoram ranges, where billions rely on glacier-fed freshwater. On ice sheets, despite Synthetic Aperture Radar enabling unprecedented mapping of surface ice velocity from space, thickness inversion methods still yield significant errors - especially along coastal regions where complex bathymetry and fjord systems hinder mass conservation approaches, thus often requiring spatial interpolation techniques. Improved ice thickness estimates and bedrock mapping near grounding lines at the glacier termini of Greenland and Antarctica are crucial to improve ice flow models and reduce the uncertainties in future sea level rise projections. Over decades of surveys, millions of sparse thickness measurements have been collected across Earth's glaciers and ice sheets: approximately 4 million for glaciers worldwide, 20 million in Greenland, and 80 million in Antarctica, largely due to NASA's Operation IceBridge. Despite the wealth of data, machine learning has seen limited use in harnessing its full potential. To help bridge this gap, we've developed a global machine learning system capable of estimating the thickness of every glacier on Earth. The model combines two gradient-boosted decision tree schemes trained on numerical features. It integrates both traditional physics-based variables, such as ice velocity and mass balance, and geometrical features commonly used in area-volume scaling approaches. We find that the system outperforms existing models almost everywhere, and by up to 30-40% at high latitudes where most ice is stored, and generalizes well in the ice sheet peripheries. I will present the rationale, benefits, and limitations of our machine learning approach, along with an envisioned strategy towards a machine learning-based map of the Greenland and Antarctic ice sheets.

Broad physics domain

Geophysics, Physics of glaciers

AI/ML technique(s) to be presented

Gradient-boosted Decision Trees

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