Global-scale mapping of periglacial landforms on Earth and Mars using deep convolutional networks

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We will develop a machine learning system based on high-resolution airborne and satellite images of Earth and Mars for classifying periglacial landscape features, detecting their temporal changes, and assessing their global distribution as well as their potential as indicator for climate conditions and changes. Earth periglacial landscape phenomena such as ice wedge polygons, thermo-erosional gullies, blockfields, and rock glaciers, are closely linked to permafrost dynamics including permafrost aggradation and degradation, repeated freeze-thaw cycles, and the presence of water and ice in the subsurface. Ice wedge polygons, which are widespread in Arctic lowlands, constitute an important indicator for ground ice content. Ground ice makes permafrost vulnerable to thaw and subsidence, thus leading to massive changes in topography, hydrology, and biogeochemical processes [Liljedahl et al., 2016]. On Mars, large volumes of excess ice exist in the shallow subsurface of mid-latitude regions [Dundas et al., 2018], where various young landforms resemble glacial and periglacial ones on Earth. A major debate focusses on whether Martian surface dynamics resulted in landforms indicating active freeze-thaw processes, such as ice-wedge polygons, in the geologically recent past. If true, this would be conflicting with the current Martian environment, which ostensibly prevents the generation of liquid water, and would therefore have implications for the recent hydrologic past of Mars. While local studies have demonstrated that these features as well as their changes can be observed with remote sensing, quantification of periglacial features on regional- to global-scale has not been done for either of the planets so far. Big data approaches relying on high-resolution imagery, highly automated image processing, machine learning classification, and feature detection now allows scaling of these mapping efforts to very large regions. For Earth we have access to historical and modern high-resolution aerial photo and satellite image datasets (<1 m resolution) from periglacial regions in Alaska, Siberia, and Canada with a total area of several 100000 km^2 of Arctic tundra. For Mars we can use tens of thousands of images of the northern mid-latitudes with resolutions of up to 0.25 m. In this new project we are developing a machine learning system in order to identify the most appropriate image features characteristical for each landform. Amongst the available machine learning methods, deep convolutional networks achieve the best performance, given that the amount of training data suffices. Ice wedge polygons are morphologically very similar on both planets, which may provide the possibility to combine training datasets from both planets. To maximize the amount of training data, these databases will be expanded through data augmentation by transforming the available images as well as by including synthetic data. Our project explores the potential for a deep convolutional network and of data augmentation with synthetic data to detect periglacial phenomena by exploiting big datasets available for large regions of Earth and Mars. The resulting near global-scale mapping of ice wedge polygons, gullies and blockfields will provide insights regarding the distribution of ground ice, freeze-thaw process dynamics, and the permafrost vulnerabilities to changing climates on Earth, as well as about the recent role of liquid water on Mars. The former are linked to life and biogeochemical processes on Earth, while the latter to the evolution of climate and potential habitability of Mars.

References

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