A data-driven approach to quantifying Antarctic blue ice areas and the presence of meteorites

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Most of the surface of Antarctica is covered by snow. However, in certain areas, blue-coloured glacial ice is directly exposed at the surface. These blue ice areas, scattered over the continent, account for ca. 1.5% of the total surface (e.g., Hui et al. 2014). Blue ice areas are of great scientific interest, as they contain (very) old ice that is easily accessible for paleoclimatic studies. Moreover, some blue ice areas bear high concentrations of meteorites, which provide an unparalleled view on the origin and evolution of the Solar System. In this contribution, we use data-driven approaches to (i) explain why we find blue ice at the surface at certain locations and (ii) distinguish meteorite-rich blue ice areas from those absent from meteorites.

(i) The presence of blue ice strongly relates to the local surface topography: the subsurface topography is expressed at the surface (e.g., Leong & Horgan 2020), the ice flow velocity relates to surface slope, and topographic features govern katabatic wind patterns that prevent snow accumulation in blue ice areas. However, the exact configuration of the features that lead to the exposure of blue ice has never been quantified on a continental scale. Here, we aim to predict the presence of blue ice over the whole of Antarctica by relying on a digital elevation model and machine learning. As contextual patterns are leading in the prediction, we use a convolutional neural network. Labelled data exists (Hui et al. 2014), but suffers from considerable uncertainties introduced by the areas' sensitivity to temporal aspects such as temporary snow covers. Initial results show that with surface elevation alone, we can predict the presence of blue ice relatively well. However, errors in the prediction persist, especially when applying the trained neural network to independent test data. To reduce these errors, we explore how other data can be used (e.g., visual data), and involve the temporal aspect of blue ice areas (such as seasonal variations and temporary snow cover).

(ii) To predict which blue ice areas are meteorite-rich, we use indirect properties of the ice sheet, as meteorites are too small (on average 2.5 cm) to directly detect from remote sensing imagery. After an exhaustive feature selection, four properties arise: the surface temperature, the ice flow velocity, the intensity of radar backscatter, and the surface slope. By comparing data from meteorite-free areas (documented in the literature after unsuccessful search campaigns) to a random sample of locations, it appears that the former two properties (surface temperature and ice flow velocity) allow to distinguish meteorite-rich areas from areas that were unsuccessfully visited. The latter two properties (radar backscatter and surface slope) separate meteorite-rich areas from randomly selected ones, which include snow-covered and rock-exposed areas. Through our data-driven approach, we provide the first continent-wide estimates of the probability to find meteorites at any given location. The resulting set of meteorite-rich blue ice areas, with an estimated accuracy of over 80%, reveals the existence of unexplored zones, some of which are located close to research stations.

REFERENCES

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