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A data-driven approach in the search for Antarctic meteorites

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Meteorites provide an unparalleled view on the origin and evolution of the solar system. Antarctica is the most productive region for collecting meteorites, as the visually contrasting meteorites are easily detectable and tend to concentrate at specific areas exposing blue ice. Blue ice areas act as meteorite stranding zones if the flow of the ice sheet and specific geographical and climatological settings combine favorably. Previously, possible meteorite stranding zones were identified by chance or through visual examination of remote sensing data, which limits the discovery of new locations for future meteorite searching campaigns.

In this study, various state-of-the-art datasets are combined in a machine learning approach to estimate the likeliness of a blue ice area to be a meteorite stranding zone. Input data for a generative classifier consists of ca. 13,000 reprojected meteorite finding locations (positive observations) and 2,000,000 unlabeled observations, for which the presence of meteorites is unknown. Four features have been selected, representing the typical conditions in which meteorites are found: exposure of blue ice (radar backscatter), cold surface conditions and negative surface mass balance (surface temperature and surface slope), and almost stagnant ice flow (surface velocities). With these features, the probability of the presence of meteorites is computed for each unlabeled observation at blue ice areas. These probabilities are computed by evaluating the multidimensional density distributions of the observations on the unlabeled observations and combining these with the prior probabilities of the two classes (positive and unlabeled). As the set of training data does contain only positive and unlabeled observations, the prior probabilities are scaled. The amount of scaling is decided by maximizing the harmonic mean between precision and sensitivity, which are estimated in a cross-validation using negative observations of sites known to be absent of meteorites. In the post-processing, the pixels that likely contain meteorites are clustered, resulting in several hundreds of meteorite stranding zones.

Results show that the first continent-wide meteorite stranding zone classification is ca. 70-80% accurate (first estimate, based on independent test data). The post-processed results reveal the existence of major unexplored meteorite stranding zones, some of which are in close proximity to existing research stations. The quest to collect the meteorites remaining at the surface of the ice

sheet, the number of which is estimated to exceed those already collected to date, will greatly benefit from our newly provided meteorite map.