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Unsupervised Machine Learning Analysis of lead (Pb) Isotopes in Third Pole Ice Cores

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The use of Machine Learning (ML) in fields such as geoscience and environmental pollution has increased rapidly over the last decade due to the increase of available datasets, the development of specialized hardware and the introduction of large number of software packages with improved techniques, models, and toolboxes. In this presentation, we will show how we applied ML algorithms to discrete, high-dimensional Pb-isotope datasets from three ice cores, and we will present the resulting clusters and insights revealed by these analyses.

Outside of the Arctic and Antarctica, the glaciers in the Kunlun Mountains, along with those in Tibet and the Himalayas, are the largest reservoir of ice on the globe and are commonly referred to as the "Third Pole." As snow accumulates over centuries to millennia to form glaciers, it entraps and preserves atmospheric information that can later be recovered from ice cores. To track the variability of Pb sources before and after the Industrial Revolution in the Third Pole, we measured the Pb isotope composition (^{204}Pb, ^{206}Pb, ^{207}Pb, and ^{208}Pb) with an MC-ICPMS in discrete samples from ice cores recovered from the Guliya ice cap in Northwestern Tibet, the Puruogangri ice cap in central Tibet, and the Dasuopu glacier in the Himalayas. These three datasets are analyzed with unsupervised ML techniques to classify the ice core samples into distinct groups. It is expected that the samples are classified according to their Pb sources, such as anthropogenic or region-specific natural sources. However, because ML can extract hidden patterns, additional groups may emerge, providing new information from the high-dimensional Pb isotope datasets. Additionally, we will also present a feature-importance analysis to evaluate how the ML algorithms formed the groups and to determine the Pb isotope ratio(s) ranking contribution to the classification.