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# Unsupervised Machine Learning Algorithms to Detect CO2 Clouds on Mars

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The Mars Orbiter Laser Altimeter (MOLA) was an instrument aboard the Mars Global Surveyor spacecraft whose first goal was to dress a precise map of Mars'topography using laser altimetry. However, precisions of the range measurments were better than expected and allowed detection of features that could not be assigned to the surface. In particular, MOLA was the first instrument to detect polar winter CO2 ice clouds. Previous studies in the early 2000s showed that some laser returns were clearly clouds signatures coming from the atmosphere. These studies were limited due to the large amount of data to analyse that forced them to use very strict distinction criteria. Nowadays, modeling clouds is a huge challenge for the developed Mars Climate Models. Especially, CO2 clouds are exotic components of the Mars'atmosphere that imply rethinking our microphysical theories. Therefore, it would be important to acquire additional information from the rare, available datasets, leading to a better understanding of involved processes.

K-means clustering methods appear as good options to analyse MOLA data. We proceed by applying the method on a single data file (about 10 % of data) then enlarging to the whole data set. We first guess the best observed parameters among those given in the raw data to separate surface and clouds returns. Then we use three independant optimisation methods, elbow, gap statistic and average silhouette, to determine the best number of clusters. From those clusters, we can eventually plot geographical and temporal distribution of the different clusters separately.

Following the Neumann and al. paper (2003), we find that the product of surface reflectivity and two-way transmissivity of the atmosphere is the best parameter for distinguishing cloud and surface returns. Our three optimisation methods converge to an unique number of five clusters for our test case using only 10 % of the data. Plotting the clusters shows that one of them clearly identifies clouds returns. Another one could represent cloud boundaries or thinner clouds. The other clusters allow for identification of noise and surface returns. Our method allows us to find more clouds than previous studies due to less stringent detection criteria, and eventually new types of clouds. Geographical and temporal distributions resulting from this study should be more accurate and help us understanding cloud formation process on Mars. This dataset will be very important for comparing with microphysical model results in particular in the polar winter season.

## Field

Planetology (incuding small bodies and exoplanets)

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