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Winds and Waves on Mars' atmosphere using ExoMars/TGO CaSSIS

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Currently, there is a considerable effort from the science community to study planetary atmospheres, in order to understand the role of climate change in planetary evolution. In particular, for Mars, climate history plays a key role in understanding the conditions that could have allowed the presence of liquid water in the past and its consequences for comparative planetology and potential past habitability. However, knowledge of the mechanisms that dominate the atmospheres of planets is still limited. Current research projects have contributed significantly to understand the temporal and spatial variability of winds on Mars, the role of cloud formation, dust storms and gravity waves in atmospheric circulation [1]. The goal of this work was, then, to detect clouds in the ExoMars/TGO CaSSIS stereo camera dataset, measure cloud altitudes [2] and cloud structure, retrieve wind velocities and related wind fields, and to
detect and characterize atmospheric gravity waves in the atmosphere of Mars, in order to improve our understanding of the planet's atmospheric dynamics. Gravity waves have already been detected by Mars Express [3], although there is still an important dataset from ExoMars/TGO CASSIs completely unexplored. Through this, we aim to build a catalogue of winds and atmospheric gravity waves using data from ExoMars' CaSSIS enabling the comparison with Mars Express cameras' data, namely OMEGA and HRSC. In order to have the most complete cloud catalogue possible, a Machine Learning (ML) algorithm was considered, besides manual verification, to go through the CaSSIS dataset.

Through the CaSSIS Observations website and the CaST (CaSSIS Suggestion Targeting) tool, manual verification of almost 9000 CaSSIS images – including basically all stereo pairs – was made, in order to check for the existence of clouds in each one. In the future, to complete out catalogue, the Yolov5X algorithm [4] will be trained with 1500x1500 tiles, where cloud detections were annotated with recourse to Roboflow, and then deployed on the CaSSIS dataset to signal other possible cloud images. ML has already been deployed effectively in similar research projects [5,6], so the potential in this case is exciting as we intend to present. Altitude measurements will be performed based on a work by Scholten et al. (2010) [7] and developed and fine-tuned in Brasil et al. (2024) [2], while wind measurements were made via cloud tracking in stereo pairs. Both the former and latter procedures, as well as the characterization of waves were facilitated through the navigation and processing of the images in ArcGIS Pro.

Through manual verification, to date, we have detected clouds in over 200 CaSSIS images, including more than 80 that belong to one of over 40 stereo pairs. These detections were mostly made in the northern hemisphere (Fig. 1 & 2), suggesting a contribution from the higher humidity related with a larger permanent polar cap [8], although most CaSSIS stereo pairs can be found in the southern hemisphere [9]. The peaks in cloud detection happen around the northern and southern spring equinoxes (□□! = 0□ and □□! = 180□, respectively) possibly related with an intensification of the water ice and vapour sublimation cycle, whereas it dips just after the beginning of the summer season in the northern (□□! = 90□) and southern (□□! = 270□) hemispheres (Fig. 2.), possibly due to lesser weather activity [10].

There could also be an observational bias during the second half of the Martian year related with the Dust Storm season, with CaSSIS being actively directed away from regions with ongoing weather activity, fog or dust lifting.
We intend to continue our work in completing our cloud image catalogue, adding the images suggested by the ML model in development. Navigation of stereo pairs and wave images will be made in order to perform the measurements described earlier and to make available new data from an unexplored dataset which will enable us to better constrain our interpretation of temporal and spatial variations in the Martian atmosphere.

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