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OPENFOAM NUMERICAL ANALYSIS OF THE DIURNAL CYCLE OF THERMALLY-DRIVEN WINDS ON MARS

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ABSTRACT

The study of Martian winds holds significant scientific interest and potential practical applications. For instance, understanding the dynamics and behaviour of Martian winds is crucial in order to properly evaluate and select landing sites for missions to Mars [1]. The study of wind patterns is also critical in determining the capacity of Martian winds to remove dust from solar panels, thereby improving their performance and longevity [2]. Furthermore, Martian winds' effects on dust are fundamental to comprehending the planet's weather and climate [3], and finally, studying regional-scale sand transport and dune formation can contribute to gain a deeper understanding of Martian geological processes [4]. Therefore, the investigation of Martian winds represents a multidisciplinary approach with meaningful repercussions for planetary science and space exploration.

This work focuses on analysing the formation of thermally-driven winds, which are typically observed in inclined regions, examining their implications for the production of renewable wind energy. While wind energy may not be ideal for initial stages of human settlement on Mars, due mainly to the low density of the Martian atmosphere, it has the potential to serve as a renewable energy source in the long term and as a backup for solar energy [5]. Thermally-driven winds can attain considerably high velocities for steep slopes (values of up to 17 m/s [6]), exerting a dominant influence on the near-surface wind. The study of maximum velocities (Fig. 1) and the heights at which these velocities typically occur could be of particular interest for determining the optimal placement of wind energy resources (such as wind turbines) for future energy production on planet Mars.

Within the scope of this study, 2D simulations of slope winds on Mars are achieved using the open source computational fluid dynamics (CFD) code OpenFOAM. Several slope angles (ranging from 5º up to 20º) are considered. Following [7], the incompressible Navier-Stokes equations with Boussinesq approximation with a conventional k–ε turbulence model are used. The impact of slope angle on the creation of thermal winds for both anabatic (up-slope) and katabatic (down-slope) flows is analysed: velocity and temperature profiles are presented for each slope angle along with the position of the maximum velocity. The numerical simulations shown in this work can serve as a cost-effective initial approximation, particularly when evaluating numerous configurations, while computationally more expensive techniques like Large Eddy Simulations (LES) or Direct Numerical Simulations (DNS) could be used in the future for validation and further exploration of final configurations.

Keywords: computational fluid dynamics (CFD), OpenFOAM, slope winds, thermally-driven winds, anabatic, katabatic

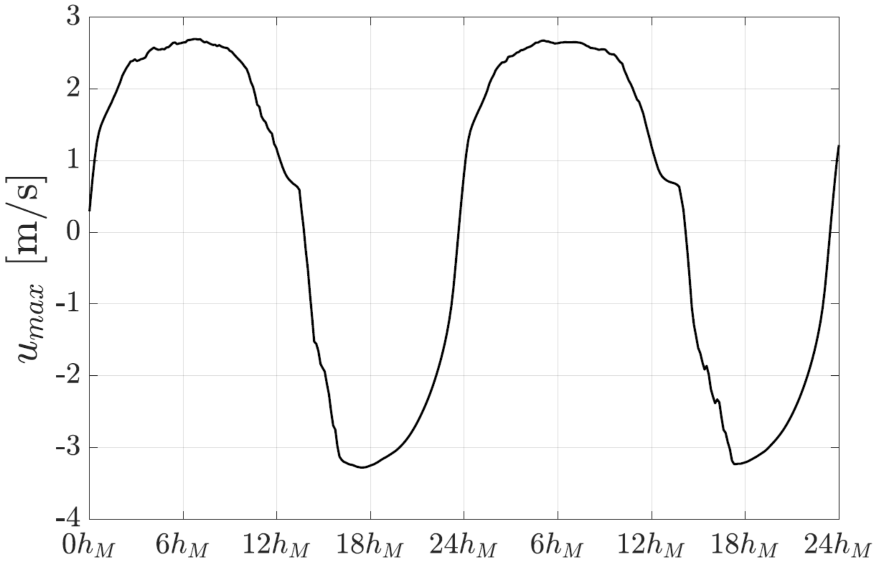

Fig 1. Maximum along-slope velocity u_{max} vs. time (in Martian hours) for 2 consecutive Martian sols and for an angle slope of 20º. Positive and negative velocities correspond to katabatic (down-slope) and anabatic (up-slope) flows, respectively.

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