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Modeling of detached dust layers with a parametrization of the dust entrainment at the top of sub-grid scale mountains

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Abstract

The aim is to reproduce the detached dust layers observed in the atmosphere over the whole martian year. We implement a new parametrization of the entrainment of dust by slope winds at the top of sub-grid scale topography in the GCM of the LMD. Although the altitude of the dust concentration peak remains too low in comparison to the observations, detached dust layers are obtained, in particular during the clear season.

1. Introduction

The dust cycle is a key component of the martian atmosphere, which General Climate Models (GCMs) attempt to accurately reproduce. The GCM of the Laboratoire de Météorologie Dynamique (LMD) predicts a well-mixed distribution of dust in the lower atmosphere and its decrease as a function of pressure up to the top of the atmosphere [1], [2]. However, many observations display the presence of detached dust layers all over the martian globe and all along the martian year [3, 4, 5, 6, 7, 8]. These detached dust layers are characterized by peaks of dust concentration located in the troposphere around 30-50 km altitude above the surface, whereas first layers near to the ground remain free of dust, accounting for the "detached" aspect of the dust distribution. The mecanism responsible for the formation of these detached dust layers is still under investigation. Thanks to mesoscale simulations, the process of "rocket dust storm" has been observed and proposed to be responsible for the generation of in the detached dust layers [9]. In a nutshell, concentrated dust is quickly entrained vertically by the action of radiative warming. A parametrization of the rocket dust storm process has been developped and implemented in the LMD GCM [10]. Although results display some similar features as detached dust layers, these only occur during the dusty season (Northern Hemisphere Winter), i.e. when the dust is in large amount available in the atmosphere. Another approach consists in invoking the effect of the sub-grid scale topography, in which slope winds created by buoyancy forcing during the day entrain the dust above a mountain's summit [11]. Such a process is now pointed out to play a major role in the dust rise processes leading to the detached dust layers formation [12]. In the continuity of [10], our work has been focused on the development of a parametrization of the entrainment of dust by slope winds. This parametrization is presented here.

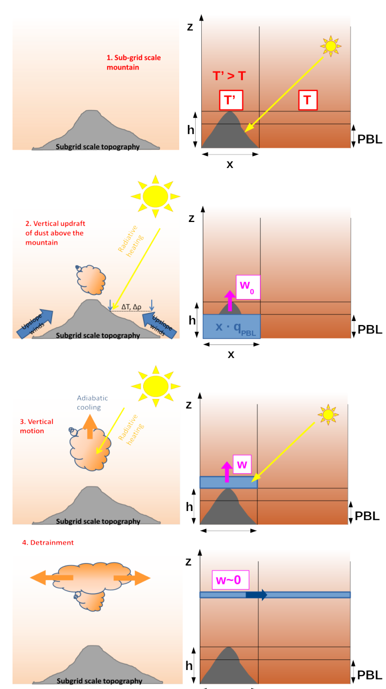

Figure 1: Main steps of the parametrization of the entrainment of dust at te top of a sub-grid scale mountain. 1-Subgrid scale mountain; 2-Vertical updraft of dust above the mountain; 3-Vertical motion; 4-Detrainment

2. Methods

The height of the sub-grid scale mountains is determined over the whole martian globe. We also define a fraction x of the mesh-grid within which the dust is entrained, i.e. where the rising dust is concentrated. The difference of temperature between the top of the mountain and the environment creates a buoyancy force (see Figure 1-1). The dust is entrained from the boundary layer and injected above the mountain with a vertical velocity resulting from this buoyancy force (see Figure 1-2). Once the dust has been entrained from the boundary layer up to the top of the mountain, it undergoes the same process as a rocket dust storm: concentrated dust is radiatively warmed and rises vertically up to the altitude, where the vertical velocity becomes null (see Figure 1-3). Then, the concentrated dust eventually detrains in the background dust (see Figure 1-4). The vertical velocity is tuned according to the one obtained by mesoscale simulations [13], where the maximum velocity reached above Olympus Mons is about 3 m s $^{-1}$.

3. Results

The implementation of the parametrization allows to obtain dust structures comparable to detached dust layers during the clear season as seen for example in Figure 2, where MCS data are compared to the GCM results obtained both with and without the new parametrization. The displayed dust density-scaled opacity (DSO) is calculated from the dust mixing ratio as in [5]. Locally the dust can reach altitudes as high as 30-50 km, however the zonal mean of the dust DSO remains under the altitude level reached by the MCS observations.

4. Summary and Conclusions

A new parametrization of the entrainment of dust at the top of sub-grid scale mountains has been developped and implemented in the martian GCM of the LMD. First results are very promising as detached dust layers are obtained during the clear season, which the rocket dust storm parametrization was failing to obtain. The altitude of these detached dust layers remains too low in comparison to the observations and parameters have to be further tuned. The combination of both parametrizations of rocket dust storm and entrainment by slope winds has also to be further explored and is currently under test and investigation. Furthermore, a perspective is to apply the entrainment generated by slope winds to not only the dust but also to all other tracers, in particular water vapour and ice.

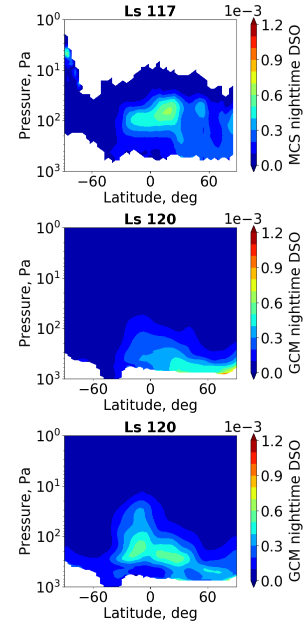

Figure 2: Night-time zonal mean of the dust DSO at Ls 120°. From the top to the bottom: MCS data, GCM results without the new parametrization, and GCM results with the new parametrization.

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