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Influence of global dust storms on the mesosphere and lower thermosphere of Mars

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Abstract

Simulations with a general circulation model (GCM) demonstrated that wind and temperature above the Martian mesopause (~100 km) respond to global dust storms as intensively as in the lower atmosphere. During the equinoctial dust storm, temperature decreased above 100 km by up to 30K, except in the northern high latitudes, where it increased by ~15 K. At the solstitial dust storm, temperature dropped by 40 K in the winter hemisphere, by ~15 K in the summer hemisphere, and increased by 30-40 K in tropics. Zonal wind jets intensified throughout the atmosphere at all heights. The changes are the result of altering the meridional circulation by atmospheric waves of different scales.

1. Introduction

Global-scale effects of dust storms in the lower atmosphere of Mars are numerous. This presentation addresses the least studied aspect of dust storms - their manifestation and consequences in the upper atmosphere. The most comprehensive observational data set to date of upper atmospheric densities during dust storms was presented by Withers and Pratt [2013]. We use the MPI Martian General Circulation Model (MGCM) extending from the surface to the lower thermosphere (~150-160 km) to simulate the atmosphere during the equinoctial and solstitial major dust storms occurred in Martian years 25 and 28 (MY25 and MY28), correspondingly.

2. Scenarios of dust storms

Two particular major planet encircling dust storms were chosen for the scenarios. One occurred around the Martian equinox (MY25), the other around the solstice (MY28). The corresponding scenarios in the form of zonally averaged latitude-time distributions of the total dust optical depth in IR from the MGS-TES and MEX-PFS are shown in Figure 1

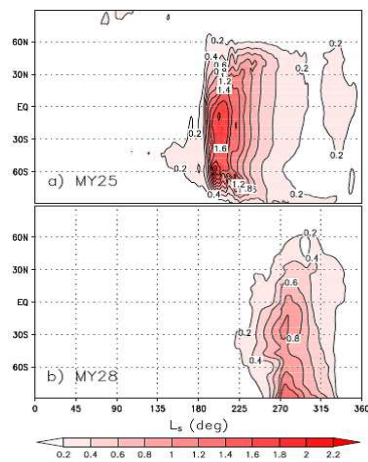

Figure 1. The observed dust total optical depth (in IR) during a) MY25 (31 May 2000 to 17 April 2002) and b) MY28 (21 January 2006 to 18 Dec 2007).

3. Simulations: equinoctial storm

There is an unexpectedly strong cooling of the middle and upper atmosphere (above ~70–80 km, pressures below 0.5–0.1 Pa) away from North Pole. The temperature above the mesopause drops by up to –30 K, that is, by the same amount as it rises in the lower atmosphere, even though it is not directly affected by the dust storm. Zonal mean simulated temperature during the storm and its deviation from the undisturbed state (simulation with the total dust optical depth τ=2 in the IR) are plotted in Figure 2.

3. Conclusions

Simulations with a Martian general circulation model (GCM) extending from the surface to the lower thermosphere (~160 km) show that wind and temperature in the upper atmosphere above 100 km respond to dust storms as intensively as in the lower atmosphere. These changes are the result of the altered meridional overturning circulation induced by resolved and unresolved waves. Atmospheric density during dust storms enhances in average by a factor of 2 to 3 in the mesosphere and lower thermosphere, which agrees well with observations.

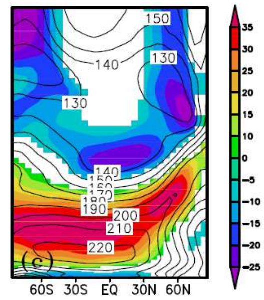

Figure 2. Simulated zonal mean temperature during a major dust storm between L_s=190 and 200^O (contours), and its deviation from the undisturbed state (shaded).