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Abstract

The main theme of this work is the development of a simplified model of the martian circulation suitable for conducting computationally fast long term simulations of the martian climate system. In particular, we are looking for causes of the irregular occurrence of the martian global dust storms (GDSs). The low-order model (LOM) is constructed by Galerkin projection of a 2D (zonally averaged) general circulation model (GCM) onto a truncated set of basis functions. The resulting low-order model consists of twelve coupled nonlinear ordinary differential equations (ODEs). The forcing of the model is described by simplified physics based on Newtonian cooling and Rayleigh friction. The atmosphere and surface are coupled: atmospheric heating depends on the dustiness of the atmosphere, and the surface dust source depends on the strength of the atmospheric winds. Parameters of the model are tuned to fit output of the NASA Ames GCM.

The model performance is examined for different seasons and dust opacities and it is found that the simulated mean meridional circulation and temperature fields compare well with the more sophisticated GCM. The time of occurence and duration of the global dust storms produced by the model compare well with observations by Viking Landers (VLs). The intensity of the meridional circulation as simulated by the LOM during northern summer is stronger than that predicted by the GCM. The situation can be improved if the Rayleigh friction varies seasonally. The LOM uncoupled from the dust source can be further simplified to form the Lorenz system with forcing.

The model is applied to the problem of interannual variability of martian global dust storms. Basic hypotheses of the intrinsic and of the extrinsic irregularity of the martian climate system are tested. The intrinsic irregularity hypothesis implies that the system under consideration is chaotic, so that small variations in initial conditions make the behavior of the system essentially unpredictable. Different paths

taken by the system in state space would correspond to years with and without a GDS. The extrinsic irregularity hypothesis, on the other hand, implies that without noise the system behaves periodically, but stochastic forcing of the system causes it to behave irregularly. It is concluded that the observed variability of GDSs is more easily explained by extrinsic irregularity. The stochastic forcing ("noise") could be provided by transient weather systems or some surface process, like size sorting or redistribution of the sand particles in the "active" (i.e., storm generating) zones on the surface. The results are very sensitive to the value of the saltation threshold, which hints at the possible feedback between saltation threshold and dust storm activity. According to this hypothesis, the saltation threshold has adjusted its value so that dust storms are barely able to occur.

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List of Abbreviations

2D Two dimensional.

3D Three dimensional.

EOF Empirical orthogonal functions.

GCM General circulation model.

GDS Global dust storm.

LDS Local dust storm.

LOM Low-order model.

NH Northern hemisphere.

ODE Ordinary differential equation.

PSD Particle Size Distribution

SH Southern hemisphere.

VL1 Viking Lander 1.

VL2 Viking Lander 2.