EPSC Abstracts
Vol. 13, EPSC-DPS2019-708-1, 2019
EPSC-DPS Joint Meeting 2019

EPSC
EPSC-DPS Joint Meeting 2019
15–20 September 2019 | Geneva, Switzerland

Simulation of the 2018 Global Dust Storm on Mars Using the NASA Ames Mars GCM: A Multi-Tracer Approach

Tanguy Bertrand (1), R. John Wilson (1), and Melinda A. Kahre (1)
(1) NASA Ames Research Center, Moffett Field, CA 94035, USA (tanguy.bertrand@nasa.gov).

1. Introduction

Global dust storms (GDS) on Mars are the largest spatial-scale dust lifting events and represent one of the most puzzling phenomena of the Mars dust cycle. The most recent of these events, the 2018/MY34 GDS, was observed by several instruments, including the Mars Color Imager (MARCI) on-board Mars Reconnaissance Orbiter (MRO), which produced daily global maps of Mars during this period [1], and by the Mars Climate Sounder (MCS) which produced profiles of temperature and aerosol. Although the 2018/MY34 GDS was monitored by these instruments, many fundamental issues remain unsolved regarding its evolution and the sources of dust lifting (and more generally the evolution of the present-day dust cycle on Mars), which calls for modeling efforts of the dust storm. In particular: *What controls and triggers the onset of GDS or other regional storms? Why and by which mechanisms do they stop expanding? Where and how is dust lifted and transported in the atmosphere?*

In order to provide new insights on these questions, **we model the 2018/MY34 GDS with the NASA Ames Mars GCM (MGCM).** The MGCM now employs the NOAA/GFDL cubed-sphere finite-volume dynamical core with the Legacy MGCM physics implemented as described in [2]. We make use of the available gridded MCS opacity maps of the MY34 GDS [3] to aid in identifying lifting centers and accounting for 3-D dust transport. We perform an analysis of the dust sources, sinks, and transport and discuss the results by comparing with the available observations.

Additionally, we use a multi-tracer approach [4], which is a promising method recently developed for the MGCM that allows for the exploration of a large number of scenarios for dust lifting and transport.

2. The Multi-Tracer Approach

Recently, the dust cycle in the MGCM has been fitted with a multi-tracer capability. The following updates have been made:

(1) **Multiple and simultaneous aerosol size distributions have been implemented,** including dust bins AND two-moments populations. Both schemes and each population have their own set of parameters, but only one selected population is radiatively active.

(2) **Multiple and simultaneous parameterizations for dust lifting have been implemented**, including assimilated dust (following a prescribed dust scenario) AND non-assimilated dust (dust is lifted following equations describing convective and wind stress lifting processes [5-7]). The application of these dust lifting schemes is very flexible and can be applied differently for each tracer population.

(3) **The tagging method has been implemented**. This method “tags” or “labels” dust according to a chosen criterion (e.g. location / local time / type of lifting, amplitude of the dust source or wind stress, reached altitude, etc.), and enables us to keep track of the labeled dust during the entire simulation. Each dust tag is transported by the model as a tracer and behaves like the dust tracer they follow but remains completely passive and does not alter the predictions.

3. Modeling the 2018/MY34 GDS

3.1. Reference simulation

In the model, dust is lifted off the surface and transported by model winds. The amplitude of the dust source is calculated so that the model tracks observed dust column opacities, taken from the daily gridded 9.3 μm absorption maps constructed by [3][8], with a recent update (v3-2_beta) derived from special MCS v3.2 retrievals (dust scenario).

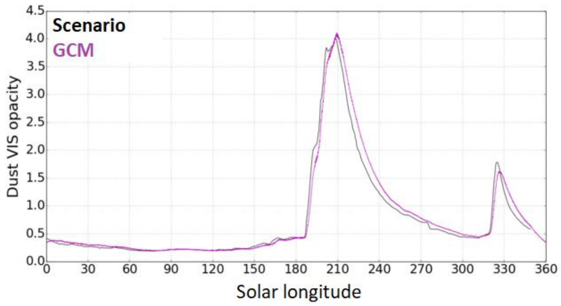

Figure 1. Evolution of the global mean column dust VIS opacity in the GCM and in the dust scenario.

We will present our best-case simulation of the global dust storm, analyze the sources and sinks of dust and compare with available observations (e.g., dust opacities from absorption maps and 15 μm brightness temperatures (depth-weighted at ~30 Pa) as seen by MCS. Note that a companion abstract focuses on the analysis of the surface pressure record observed by the MSL Curiosity in Gale crater during the dust storm and the comparison of this dataset with GCM results [9]. We will also highlight the discrepancies between the observations and the model results.

3.2 Discussion and further analysis of the storm using the multi-tracer approach

As some discrepancies in temperatures and opacities are obtained between model results and observations, we investigate how to improve the realism of the GDS simulation. First, we apply changes to the prescribed dust scenario by removing the predictions of opacities leading to an extreme and unrealistic dust lifting. Second, we prevent dust lifting in the simulation at the location where we think no dust is available (e.g. high thermal inertia terrains).

Finally, we investigate further how limited dust reservoirs and surface wind stress control the onset and evolution of the storm. Indeed, during the decay phase of the GDS, our simulations show that surface stress still increases at many locations, because it is mostly driven by the Hadley cell return branch circulation. This suggests that negative feedbacks, such as limited dust reservoirs, take place to limit dust lifting during this period and trigger the decay phase.

To do this, we derive a multi-tracer simulation from the reference assimilated dust simulation. The analysis of sources and sinks of dust in the reference simulation helps to define the spatial evolution and strength of the source regions that appear to be necessary to capture the observed life cycle of the dust storm. We use this source scenario as a basis for injecting dust in the model using parameterizations of dust devils and wind stress in order to derive/detect a reasonable description of how the dust lifting evolved during the storm, and how atmospheric transport shaped the dust field and so influenced the thermal structure. We also consider how parameterized lifting (stress, with finite availability of dust) account for the life cycle of dust lifting.

Acknowledgements

T. B. is supported for this research by an appointment to the National Aeronautics and Space Administration (NASA) Post-doctoral Program at the Ames Research Center administered by Universities Space Research Association (USRA) through a contract with NASA. The estimated column dust opacities (v5.3) were provided by the MCS team.

References

[1] Malin, M. C., et al.: MRO MARCI weather report, Malin Space Science Systems Captioned Image Release, MSSS-532. Retrieved from http://www.msss.com/msss_images/2018/05/30/

[2] Kahre, M. A., et al. : High Resolution Modeling of the Dust and Water Cycles with the NASA Ames Mars Global Climate Model, American Geophysical Union, Fall Meeting 2018, abstract #P33B-01

[3] Montabone, L., et al.: Eight-year climatology of dust optical depth on Mars, Icarus, Volume 251, p. 65-95, 2015.

[4] Bertrand, T., et al., Tagging Dust and Water in the NASA Ames Mars GCM : a New Global Vision of the Current and Past Martian Climates, American Geophysical Union, Fall Meeting 2018, abstract #P33B-06.

[5] Basu, S., et al.: Simulation of the Martian dust cycle with the GFDL Mars GCM, JGR, 109:E11, 2004.

[6] Kahre, M. A., et al.: Modeling the Martian dust cycle and surface dust reservoirs with the NASA Ames general circulation model, JGR, 111, 2006.

[7] Newman, C. E. et al.: The impact of surface dust source exhaustion on the martian dust cycle, dust storms and interannual variability, as simulated by the MarsWRF General Circulation Model, Icarus 257:47, 2015.

[8] Montabone et al., this issue.

[9] Wilson et al., this issue.