EPSC Abstracts
Vol. 12, EPSC2018-596, 2018
European Planetary Science Congress 2018

Tagging dust and water in the NASA Ames Mars GCM: a new global vision of the Martian climate

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

Abstract

Many fundamentally issues remain unsolved regarding the current dust and water cycles on Mars. In particular: *What are the role and impact of the different reservoirs of dust and water on the cycles? What controls and triggers the regional and global dust storms? Where and how is dust lifted and transported in the atmosphere? What is the current global dust and water budget and how has it evolved over time and space?* In order to provide new insights on these questions, we implemented the so-called tagging method in the NASA Ames Mars Global Climate Model (MGCM) [1]. Below we describe this method and some of its promising applications.

1. The tagging method

The MGCM simulates the atmospheric transport of dust particles, water vapor and water ice. The tagging method "tags" or "labels" these transported constituents according to a chosen criterion (Figure 1). As an example, if dust particles are the tagged constituent (« dust tagging ») and the criterion is its geographic origin (e.g., the low thermal inertia regions), this means that during the entire simulation, we keep track of the dust that originated in the selected regions of Mars. Each tag is transported by the model as a tracer and behaves like the constituents they follow, but is completely passive and does not alter the predictions.

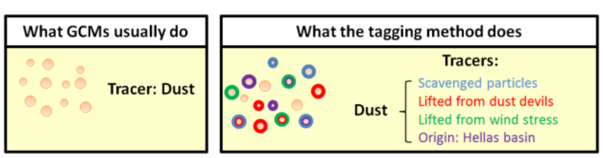

Figure 1: Illustration of the tagging method for the dust tracer. Instead of one unique tracer describing the dust population, the tagging method produces many tracers allowing us to keep track of its history.

This technique enables us to track not only the origin of a given atmospheric constituent, but also the physical processes it goes through (e.g., scavenging, ice cloud, storm, frost, etc.), or the different environments it has encountered since its emission (crater, mountains, dusty atmosphere, poles, etc.).
This powerful method, never tested on Mars, was first implemented in the NASA/GISS GCM [2] to identify the origin of the precipitation in various regions of the Earth, and is now widely used for detailed studies of the Earth water cycle.

2. Possible applications

The tagging method has been implemented, tested, and validated. We are currently exploring the possible applications, summarized in Table 1. At the conference, we aim to show the results concerning the first three applications (A1-A3), which are focused on the dust cycle.

2.1 Application A1

We tag dust depending on its geographic origin. We divide the Martian surface into different geographic areas, including the main regions of dust lifting [3][4] and the high/low albedo and thermal inertia regions [5]. By running different simulations with finite sources [6,7], we also investigate the role and contribution of each reservoir on the dust cycle and quantify their dust exchanges. We are also able to isolate the contribution of each region to the formation of global dust storms, providing insight into the main pathways dust particles take during the formation of a global dust storm. In addition, the simulations reveal the regions where dust is deposited after the decay of such a storm. On a multidecadal time scale, the simulations using this tagging method also constrain the mass balance and equilibrium state of the dust cycle.

Table 1: Envisioned applications

	TAG	Criterion	Objectives
A1	Dust	Geographic origin of lifting	Investigate the role of the reservoirs on the dust cycle and quantify the dust exchanges, considering finite/infinite sources
A2	Dust	Local time of lifting	Investigate the diurnal dependence of lifting and transport
A3	Dust	Scavenged by water ice	Estimate the global impact of scavenging on the current and past Martian climate, in particular during high obliquity periods
A4	Dust	Lifting scheme	Quantify the contributions of dust lifted by dust devils activity and surface wind stress when both schemes are active
A5	H_2O ice	N. polar cap and outliers	Assess/compare the impact of the water ice reservoir located in the N. polar cap and in the outliers on the climate
A6	Dust + H_2O ice	Altitude	Follow where high altitude aerosols tend to be transported

2.2 Application A2

By tagging dust depending on the local time it has been lifted and lofted in the atmosphere, we investigate how the diurnal cycle affects the dust lifting and transport. With this method, we provide insight into the contribution of upslope and downslope winds on the dust cycle.

2.3 Application A3

We tag dust particles that have been scavenged by water ice clouds. This enables us to assess the global impact of scavenging on the current and past Martian climate, in particular during the high obliquity periods where this process is thought to have been more efficient than it is today.

2.4 Other Applications

By tagging dust depending on the type of lifting, we can also quantify the contributions of dust lifted by dust devils activity and surface wind stress when both schemes are active, and determine where each type of dust tends to accumulate and influence the surface reservoirs (A4). By tagging water depending on its sublimation source, the northern polar cap or its outliers, we can assess the impact of both reservoirs on the current climate, and investigate their exchange of ice and global budget. This study can also be applied to past climates, where other reservoirs of water ice may be stable (A5). By tagging the aerosols depending on the altitude they reach, we can probe where the different levels tend to transport the aerosols (A6).

3. Summary and Conclusions

The potential of the dust, water and water ice tagging method in the GCMs opens the door to many powerful results regarding the long-term evolution of the dust and water cycles. We expect this method to fill many gaps in the understanding of the current and past Martian climate and provide insights on the development of global dust storms, the influence of the scavenging of dust particles during both the present-day and past climates, the exchanges between the different dust and water reservoirs and the long-term mass balance and equilibrium state of the cycles.

Acknowledgements

T. B. was 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.

References

[1] Kahre, M. A., et al.: Coupling the Mars dust and water cycles: The importance of radiative-dynamic feedbacks during northern hemisphere summer, Icarus, 260:477, 2015.

[2] Koster, R., J., et al.: Global sources of local precipitation as determined by the Nasa/Giss GCM, GRL, 13:121, 1986.

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

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

[5] Ruff, S. W., Christensen, P. R.: Bright and dark regions on Mars: Particle size and mineralogical characteristics based on Thermal Emission Spectrometer data, JGR (Planets), 107:E12, 2002.

[6] 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.

[7] M. A. Kahre, et al.: Investigations of the variability of dust particle sizes in the martian atmosphere using the NASA Ames General Circulation Model, Icarus 195:576, 2008.