TAGGING DUST AND WATER IN THE NASA AMES MARS GCM: A NEW GLOBAL VISION OF THE MARTIAN CLIMATE. T. Bertrand1, M. A. Kahre1, R. J. Wilson1, and A. Kling1, NASA Ames Research Center, Moffett Field, CA 94035, USA (tanguy.bertrand@nasa.gov).

Introduction: 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 answer these questions, we implemented the so-called tagging method in the NASA Ames Mars Global Climate Model (MGCM) [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 (α 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. 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 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. It has never been tested on Mars, and has plenty of promising applications.

<table>
<thead>
<tr>
<th>TAG</th>
<th>Criterion</th>
<th>Objectives</th>
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<tbody>
<tr>
<td>A1</td>
<td>Dust</td>
<td>Investigate the role of the reservoirs on the dust cycle and quantify the dust exchanges, considering finite/infinite sources</td>
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<tr>
<td>A2</td>
<td>Dust</td>
<td>Investigate the diurnal dependence of lifting and transport</td>
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<tr>
<td>A3</td>
<td>Dust</td>
<td>Estimate the global impact of scavenging on the current and past Martian climate, in particular during high obliquity periods</td>
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<tr>
<td>A4</td>
<td>Dust</td>
<td>Quantify the contributions of dust lifted by dust devils activity and surface wind stress when both schemes are active</td>
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<tr>
<td>A5</td>
<td>H2O ice</td>
<td>N. polar cap and outlayers Assess/compare the impact of the water ice reservoir located in the N. polar cap and in the outlayers on the climate</td>
</tr>
<tr>
<td>A6</td>
<td>Dust + H2O ice</td>
<td>Altitude Follow where high altitude aerosols tend to be transported</td>
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Current state of development: The tagging method has been implemented, tested, and validated. We are currently exploring the possible applications, summarized in Table 1, by running high resolution GCM simulations of Mars coupled with the tagging method. At the workshop, we aim to show the results concerning the first three applications (A1-A3), which are focused on the dust cycle.

First applications:
- **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, such as the storm zones of the northern plains [3], the highly eroded regions of the southern highlands, and the high/low albedo and thermal inertia regions [4]. By running different simulations with finite sources [5,6,7], 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.

- **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.

Table 1: Envisioned applications for the tagging method.
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.

Future 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 [8], 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).

We also would like to take the opportunity of this workshop to further develop the possible applications of this method to the existing issues related to the Mars climate.

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.