CLOUD FORMATION AND WATER TRANSPORT ON MARS AFTER MAJOR OUTFLOW EVENTS

D. L. Santiago[1,2] , A. Colaprete[2], M. Kreslavsky[1], M.A. Kahre[2], and E. Asphaug[1], [1]Earth and Planetary Sciences, University of California at Santa Cruz, Santa Cruz, CA 95064, USA dsantiago@ucsc.edu [2]NASA Ames Research Center, Moffett Field, CA, 94035, USA.

Introduction: The triggering of a robust water cycle on Mars might have been caused by the gigantic flooding events evidenced by outflow channels. We use the Ames Mars General Circulation Model (MGCM) to test this hypothesis, studying how these presumably abrupt eruptions of water might have affected the climate of Mars in the past. We model where the water ultimately went as part of a transient atmospheric water cycle, to answer questions including:

- Can sudden introductions of large amounts of water on the Martian surface lead to a new equilibrated water cycle?
- What are the roles of water vapor and water ice clouds to sudden changes in the water cycle on Mars?
- How are radiative feedbacks involved with this?
- What is the ultimate fate of the outflow water?
- Can we tie certain geological features to outflow water redistributed by the atmosphere?

Background: The surface of Mars has evidence for multiple outflow channels; many of them open into Chryse Planitia. Morphology of the outflow channels suggests that they were carved by floods with very large estimated water volumes [1,2,3]. Recent studies suggest that outflow channels formed with smaller, successive floods instead of a single, large flood [3,4,5,6]. The majority of outflow events seen in the geological record occurred early in Mars history, in the Hesperian, however the most recent of them occurred much later, even in the late Amazonian, such as associated with Cerberus Fossae [7].

Here we report on our investigation of climatic effects of the outflow events. We focus on the response of present-day climate. Previous work of interest includes a climate modeling study of responses of the climate system to changes in the spin/orbit configuration of Mars (see review in [6]). In particular, in [8] it has been shown that, at different times in Mars history, water from the North Polar Cap could have migrated to the Northern mid-latitudes. The immediate weather effects of water outflow have been explored in [9] on a regional scale; this study indicated very localized precipitation. Here we explore long-term global effects of outflows.

Approach: Our approach is to add water to the surface of Mars at an estimated outflow rate, similar to an expanding one-layer lake. Though we use estimated rates of the outflow, the events were nearly instantaneous in terms of Mars history. This enables us to study quantitatively how these outflow events influenced Mars climate, particularly the atmospheric water cycle. In our study we ignore short-term effects of intensive, immediate evaporation from released water. Lakes formed on the surface as a consequence of the outflow events are quickly covered with ice, and for the long-term climate effects the outflow is equivalent to the formation of a frozen lake.

We use the NASA Ames MGCM version 2.1 and other schemes that are part of the NASA Ames MGCM suite of tools. The MGCM 2.1 currently has a well-developed water ice cloud formation scheme [10,11], which includes calculation of cloud particle concentrations, nucleation, growth, and gravitational sedimentation.

The outflow is modeled as a frozen lake placed over Chryse Planitia (Figure 1), covering 1.4% of planet. The model is initialized with present day conditions in order to compare results with a known climate, and because some outflows may have occurred in the recent past [7], or under similar conditions. While individual outflows could be smaller, these initial conditions are chosen to test the large end of the climate response to outflows.

Preliminary Results: This work is in progress. The main interesting observations to date are:

- Post-outflow water ice clouds and water vapor may have transported water globally, leading to precipitation and deposition of surface ice around the planet.
- Water could be deposited not only in the cold traps of the polar regions, but also in the mid-latitudes.
- The atmospheric water cycle appears to reach a new equilibrium within the first few years after the outflow.
- The climate system is very sensitive to the surface ice albedo.

Figure 1 is a global map of Mars in simple cylindrical projection showing the amount of annually deposited water ice when the climate system reached a new equilibrium state after the outflow event. This case includes the radiative effects of water vapor and ice albedo feedbacks, but excludes the radiative effects of water ice clouds. The outflow water does not sublimate away during the run time (out to fifteen years), so acts as an infinite reservoir of water.

Figure 1 shows that water migrates from Chryse-Planitia and forms perennial deposits in wide polar areas, down to 70° in the southern hemisphere and 60° in the northern hemisphere. Ice also accumulates in equatorial Margaritifer Terra immediately to the south from Chryse Planitia, and in the Deuteronilus & Protonilus Mensae regions in the northern mid-latitudes at ~60º-90° E. The fact that the model yields deposition in the latter region is especially interesting, because this region contains geological evidence of extensive glaciation of Late Amazonian age [6].

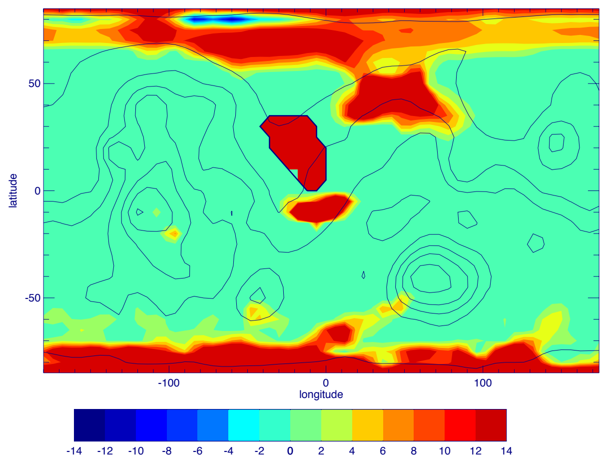

Figure 1: Color-coded annual deposition of the surface ice (in mm) in post-outflow equilibrated climate system, overlaid on topography contours. The model calculations include radiatively active water vapor, and do not include radiatively active clouds. Red polygon with dark blue outline shows the location of the modeled frozen lake resulting from the outflow event in Chryse Planitia.

Importance of Albedo: The sublimation of the ice is the main driver of what happens after the eruption of water, with the sublimation rate being particularly sensitive to the ground temperature. The importance of albedo feedback of the surface ice came into focus when the albedo feedback of ice was removed from the model. When more energy was absorbed by the surface in this no albedo case, a thirty-fold increase in the sublimation rate was observed. The albedo effects thus limits the amount of surface warming, and slightly decreases the amount of water that travels in the atmosphere as water vapor and water ice clouds. The effect of surface ice albedo warrants further studying. When the ice albedo feedback and the radiative effects of water vapor are included, there is a net global average cooling of 3 K on the surface.

Future Work: This work is in progress. Next steps in the modeling will include the important effects of radiatively active water ice clouds and latent heat. The effect of the geographic location of the outflow event will also be studied.

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