INVESTIGATING THE TIMING AND EXTENT OF SEASONAL SURFACE WATER FROST ON MARS WITH MGS TES.
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Introduction: The Mars Global Surveyor (MGS) Thermal Emission Spectrometer (TES) visible/near-infrared and thermal infrared bolometers measured planetary broadband albedo and surface temperature for more than three Mars years. As seasons progress on Mars, surface temperatures may fall below the frost point of volatiles in the atmosphere (namely, carbon dioxide and water). Systematic mapping of the spatial and temporal occurrence of these volatiles in the Martian atmosphere, on the surface, and in the subsurface has shown their importance in understanding the climate of Mars. However, few studies have specifically investigated seasonal surface water frost and its role in the global water cycle. We examine zonally-averaged TES daytime albedo, temperature, and water vapor abundance data [1] to map the presence of surface water frost on Mars. Surface water frost occurs in the polar and mid latitudes, in regions with surface temperatures between 150-220 K, and can significantly increase surface albedo relative to the bare surface.

Methods: The majority of this work focuses on data retrieved by TES aboard MGS. TES consisted of a spectrometer, a visible/near-infrared bolometer (0.3-2.7 μm) and a thermal infrared bolometer (5.5-100 μm). We focus mainly on bolometer data. TES data cover an approximately 3x6 km^2 footprint and is useful for mapping broader scale processes. Bolometer data was restricted to MY24 (Ls=104°) to MY27 (Ls=360°). MY28 was omitted due to gaps in nadir observations during that phase of the mission. To ensure high quality data, emission angles are restricted to 0°-20°, incidence angles restricted to 0°-80°, and local solar times of 1200-1600 hours.

The raw albedo data shows a variety of processes that affect the planetary albedo of Mars but can be difficult to interpret (Fig. 1). In order to identify the contribution from seasonal processes (e.g. dust, surface frost), it is useful to subtract the raw albedo data from a summertime average albedo, respectively for each hemisphere, and plot the difference (Fig. 2). To do this we calculated the mean albedo around L_s=~90° for the north and L_s=~270° for the south. We assume this best represents an “ice-free” surface.

Results: In the northern hemisphere seasonal water frost is most apparent in autumn/early winter, before the onset of carbon dioxide frost. Unfortunately, dust storms occurring near northern winter solstice affect TES albedo and prevent us from putting a latitudinal lower limit on the water frost in the northern hemisphere. Viking 2 Lander observations show that seasonal water frost occurs at least as low as 48°N in Utopia Planitia, beginning at L_s=~230° [2]. Daytime surface water frost was also observed at the Phoenix Lander site (68°N) beginning at L_s=~160° [3]. The timing of albedo variations observed by TES agree relatively well with lander observations of seasonal frost.

In the southern hemisphere autumn seasonal water frost is not detected. A potential explanation for this is the difference in atmospheric water vapor abundance between the two hemispheres. The frost point temperatures for water vapor in the southern hemisphere are ~5-10 K lower for the corresponding season and latitude in the north [1]. This inhibits the stability of water frost on the surface in the southern hemisphere and also lowers the maximum thickness of a water-frost layer, potentially limiting its effect on surface albedo.

Discussion: Seasonal evolution of water vapor in the northern hemisphere of Mars involves extensive deposition of water frost, similar to the behavior of the seasonal carbon-dioxide ice deposit. Surface water frost and subsequent mixing of vapor back into the atmosphere likely plays an important role in the global water cycle. Therefore, mapping the geographical extent, timing, and impact of water frost on surface albedo provides insight into the processes controlling the present Martian climate.

Variation in albedo on seasonal timescales can affect surface temperatures, which will propagate to the subsurface. This is important because near-surface ground ice is prevalent poleward of ~50° in both hemispheres on present-day Mars [4]. The stability and depth of ground ice is intimately linked to the mean-annual surface temperature and vapor pressure [5]. Seasonal frost may lower surface temperatures and/or increase surface vapor pressures and extend the boundary of stable ground ice equatorward. This may potentially explain recent observations of impact craters which expose near-surface, putatively unstable, ground ice [6].

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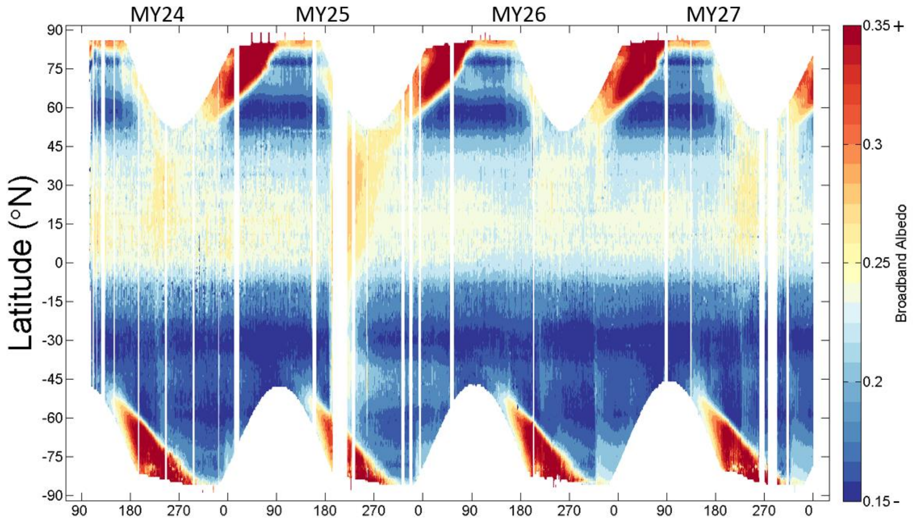

Figure 1. Raw, zonally-averaged, daytime, bolometric albedo data from TES. Prominent features include the global dust storm in MY25, seasonal polar caps, and global-scale latitudinal variation.

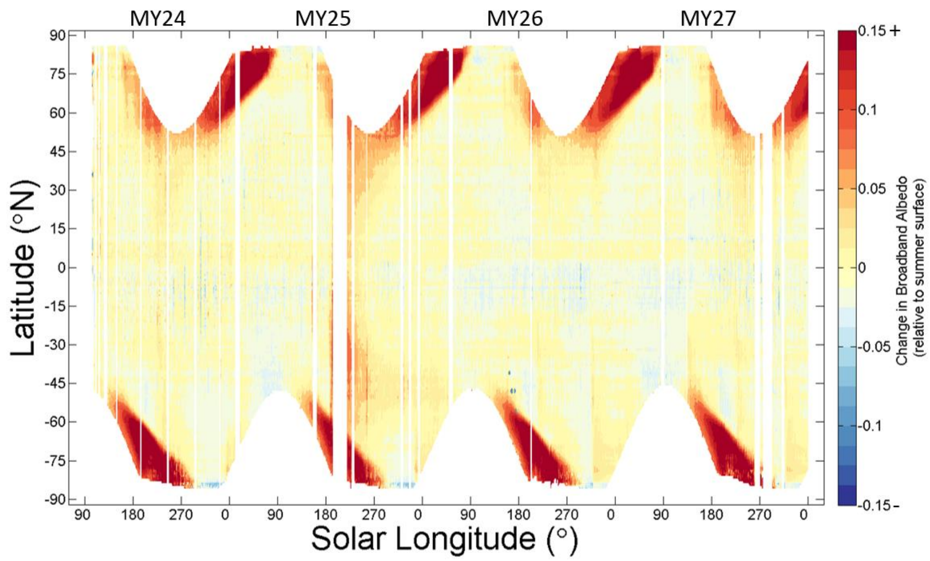

Figure 2. Raw bolometric albedo subtracted from a summertime mean. Prominent features still include the spring retreat of seasonal CO_2 cap. However, a new feature becomes more apparent: a northern autumn albedo anomaly. We interpret this anomaly to be surface water frost.