WATER ICE CLOUDS IN THE MARTIAN ATMOSPHERE: A COMPARISON OF TWO METHODS.

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Introduction: Over the past decade there has been an increased interest in water-ice clouds in the Martian atmosphere and the role they may play in the water cycle. Water-ice clouds in the Martian atmosphere have been inferred, historically, through observations of “blue” and “white” clouds [1], but the first positive confirmation of water-ice in the atmosphere came during the Mariner 9 mission, through the Infrared Interferometer Spectrometer experiment [2]. Despite these observations of water-ice clouds, they were not thought to be a significant player in the climate or water cycle. Even through the Viking era (mid-1970’s), the true extent and ubiquity of water-ice clouds on Mars was not appreciated.

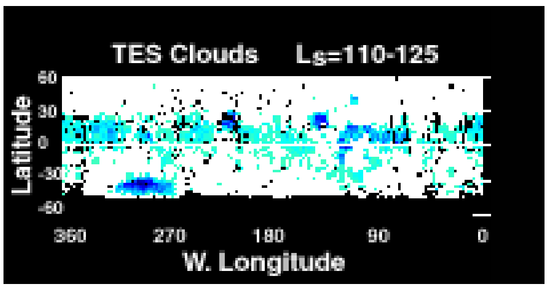
More recently, work has suggested that clouds forming in a low-latitude belt during the northern spring/summer time frame (the aphelion cloud belt) may be retaining water in and scavenging water to the northern hemisphere [3,4]. This cloud belt forms as a result of the cross-equatorial Hadley circulation, which has its upwelling branch in the northern hemisphere, during northern spring/summer. At the current epoch, Mars’ northern spring/summer timeframe coincides with aphelion (L_s=71°), causing the atmospheric temperatures to be lower in this season, allowing water-ice clouds to form more readily than during the perihelion season. Ice particles in the clouds may gravitationally settle, confining water to the northern hemisphere. This settling may also remove dust acting as cloud condensation nuclei, decreasing the radiative heating potential of the atmosphere further. This is a powerful mechanism to explain why Mars’ northern hemisphere contains substantially more water than the southern hemisphere.

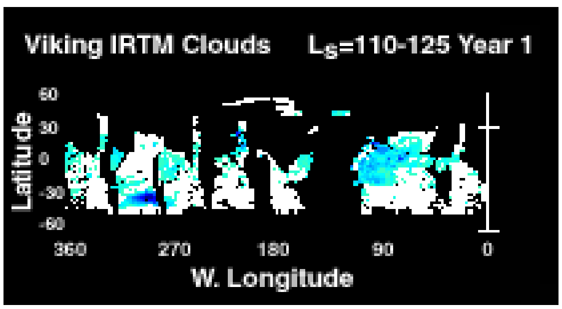
Furthermore, the aphelion cloud belt was not originally recognized as an annual feature in the Martian climate and was originally proposed to be due to a climate change since Viking [3]. However, Viking data did show the aphelion cloud belt over two Martian years [5], as well as widespread and frequent water ice clouds throughout the Martian year. Water ice clouds, and specifically the aphelion cloud belt, have also been seen through the MGS TES data set [6-10]. Since this belt is now seen as most likely an annual feature of the Martian climate, it is desirable to understand its characteristics, such as its spatial and temporal extent, and variations in opacity, temperature, and altitude. To date, the only two data sets offer the potential to examine year-to-year changes in cloud features over an entire Martian year: the Viking Infrared Thermal Mapper (IRTM) data set [5] and the Mars Global Surveyor (MGS) Thermal Emission Spectrometer (TES) data set [6-10]. We have examined the TES data in the same way in which we examined the Viking IRTM data [5; 9-10] This provides water-ice cloud information separated in time by 12 Martian years. Since the data are analyzed with the same method, we obtain a very accurate “apples to apples” comparison, and can generate a historical record of the subtleties of this annual event. However, the methodology used in our retrievals of water-ice clouds from TES data differs from the methodology used by [6-8]. Consequently, it is desirable to compare their results to ours to see what differences exist

Method: To assess the true extent of the interannual variability in water-ice cloud formation, a direct and robust method for comparing these different data sets and time periods has been used [5]. The water-ice cloud retrieval technique developed to analyze the broadband Viking IRTM channels [5] has been applied to the TES data. To do this, the TES spectra are convolved to the IRTM bandshapes and spatial resolutions, enabling the same processing techniques as were used in Tamppari *et al.* [5]. The resulting cloud maps are therefore directly comparable to those created for the Viking time period. Figure 1 a and b show a typical result. Others [6-8] have determined water-ice opacities from the TES spectra by first computing a column integrated opacity for pure atmospheric absorbers as a function of wavenumber, and then estimating the water ice contribution by simultaneously fitting predetermined spectral shapes for atmospheric dust, water ice, as well as non-unit surface emissivity. Though these methods are quite different, both show similar results for the same seasons, and analysis of the correlation between TES derived water ice opacities and Tamppari’s cloud signatures is ongoing.

Conclusions: While the data coverage is much greater in the TES data set, water-ice cloud maps from the same seasons have similar characteristics to those seen in the Viking dataset. In particular, the aphelion low-latitude cloud belt can be seen well in the TES data with both Tamppari's temperature difference technique and water ice opacity retrieval. Analysis of the differences and similarities between the results generated by each technique is ongoing. Due to gaps in data coverage, this aphelion cloud belt is not as well seen in this particular Viking map (figure 1b), but it is clearly present. In addition, a strong cloud signature in Figure 1a, indicating either a colder or thicker water-ice cloud, is present over Elysium Mons, over the Tharsis volcano region, and over the northern part of Hellas basin. Furthermore, Figure 1 can be compared to Plate 2 in Pearl *et al.* [8], which covers a similar areal extent between L_s=106°-141°. Their Plate 2 shows increased opacity at the same locations as the strongest cloud signatures shown in Figure 1, for example over the volcanoes. This may indicate that water-ice clouds over volcanic features in the Viking IRTM data set are of a higher opacity than those in the aphelion cloud belt, for example, and not just colder/higher altitude clouds.

Figure 1





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