INVESTIGATING THE ROLE OF RADIATIVELY ACTIVE CLOUDS ON WIND STRESS BASED DUST LIFTING DURING NORTHERN HEMISPHERE SUMMER ON MARS.

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Introduction: The Martian atmosphere contains dust throughout the year but the atmospheric dust load varies with season. A background haze of atmospheric dust is maintained throughout northern hemisphere spring and summer and the dust activity is heightened during southern spring and summer. In the absence of regional or global storms, dust devils and local storms maintain the background dust loading during the non-dusty season. Mars Global Surveyor (MGS) Mars Orbiter Camera (MOC) observations indicate that small regional dust events persist throughout northern spring and summer. Observational surveys of dust devils [13], [4] and general circulation modeling results [1] suggest that it is likely that dust devils are responsible for the presence of atmospheric dust during these seasons. However, a quantitative understanding of the relative contribution of dust devils and local dust storms has not yet been achieved.

Here we present preliminary results from an investigation that focuses on the effects of radiatively active water ice clouds on dust lifting processes. Radiatively active water ice clouds influence the thermal structure of the Martian atmosphere and can thus affect dust lifting through radiative-dynamic feedbacks. We show that radiatively active clouds increase the efficiency of wind stress dust lifting during NH spring and summer by strengthening the mean overturning circulation [10],[18],[19]. This work will further our understanding of how the background atmospheric dust haze is maintained during NH spring and summer by focusing on how clouds affect local dust storm generation.

Methods: The primary tool for this work, the NASA Ames Legacy GCM, is a 3 dimensional model that has been used for investigations of the past and current climate of Mars [6],[7],[8],[9]. The NASA Legacy GCM runs on an Arakawa C-grid with a normalized sigma coordinate vertical grid. A horizontal resolution of 5° in latitude and 6° in longitude is used for the study. The model has surface properties that include MOLA topography, and albedo and thermal inertia maps that have been derived from the Viking and Mars Global Surveyor (MGS)/Thermal Emission Spectrometer (TES) observations.

It has been suggested by observations of local and regional dust lifting events that the momentum imparted to the surface by winds is one mechanism responsible for lifting dust off the Martian surface [2]. While wind speeds on Mars are not predicted to be strong enough to lift dust sized particles, simulated near-surface wind speeds do exceed the experimentally derived threshold for sand-sized particles to enter into saltation [5]. The GCM has routines for representing the physics of lifting, transport and sedimentation of radiatively active dust [9]. Wind stress based dust lifting and dust devil lifting are the two parameterizations used for dust lifting. The dust devil scheme is based on the thermodynamic theory of dust devils developed by [16]. In this scheme, the lifted dust flux depends on the magnitude of the sensible heat exchange between the surface and atmosphere, and the depth of the planetary boundary layer. The wind stress dust lifting parameterization from [9] is used for this study with a threshold wind stress of τ = 22.5 mN m-2. The KMH scheme was originally formulated by [17] for Earth-based dust lifting. The wind-stress lifting scheme is tuned with a multiplicative ''efficiency'' factor to produce reasonable dust loadings throughout the Martian year.

The airborne dust that interacts with solar and infrared radiation acts as ice nuclei and goes through gravitational sedimentation as free dust and as cores of water ice cloud particles. The microphysical processes of nucleation, growth, and settling of radiatively active water ice clouds and sublimation from the north residual cap are also included in the simulated water cycle [11], [12], [14], [15].

The lognormal particle size distributions of dust and cloud are represented by a spatially and temporally varying mass and number, and a constant effective variance. This method takes into account the complex processes of cloud microphysics through cloud and dust particle size evolution and is computationally efficient.

Experimental Simulations: Three simulations that included wind stress dust lifting were executed for a period of 5 Martian years: a case that included no cloud formation, a case that included radiatively inert cloud formation, and a case that included radiatively active cloud (RAC) formation.

Water ice clouds are known to affect atmospheric temperatures directly by absorption and emission of thermal infrared radiation. They also affect the temperatures indirectly through dynamical feedbacks. The aphelion cloud belt and the polar hood clouds are two prominently observed types of clouds. The aphelion cloud belt is composed of optically thin clouds that form above 10-15 km at low latitudes during northern spring and summer (Ls~50-135^o; [3]. Polar hood clouds are optically thick and may or may not extend down to the surface [3]. We focus on NH spring and summer to study how radiatively active water ice clouds in the aphelion belt and in the polar hoods impact atmospheric heating and cooling, atmospheric circulation, and the pattern and magnitude of wind-stress dust lifting.

Results: Figure 1 shows a comparison of the globally averaged wind stress dust lifting rates for all three simulations during NH spring and summer. It is evident that the inclusion of radiatively active clouds in the simulation enhances the global dust lifting rates by approximately an order of magnitude. This enhancement is the result of radiative/dynamic feedbacks due to water ice clouds. Radiative heating by clouds in the aphelion cloud belt warms the atmosphere aloft at low latitudes while low-lying polar clouds radiatively cool the low-level polar atmosphere. This increased equator-to-pole thermal gradient drives an enhanced overturning circulation. The stronger overturning circulation produces an enhanced low-level flow in the Hadley cell return branch, which in turn produces higher surface stresses and increased dust lifting in those locations.

Figure 2 shows a comparison of the global average dust visible column opacities for all three simulations. Although the simulation with radiatively active clouds produces a higher dust loading during NH spring and summer, the difference is not substantial. We thus preliminarily conclude that, while radiatively active water ice clouds increase dust lifting by wind stress during these seasons, dust devil lifting still dominates the maintainance of the background dust haze.

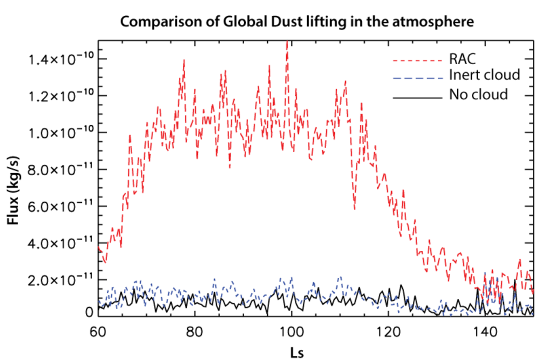

Figure 1: Globally averaged dust lifting rates for simulations without clouds, with radiatively inert clouds, and with radiatively active clouds.

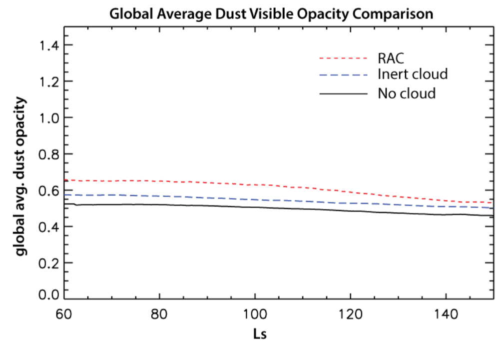

Figure 2: Globally averaged dust visible column opacity for simulations without clouds, with radiatively inert clouds, and with radiatively active clouds.

Conclusions: Our results suggest that with radiatively active clouds included, radiative-dynamic feedbacks generate a stronger mean overturning circulation and more pronounced wind stress dust lifting and a slightly higher overall dust loading during NH spring and summer. These results suggest that wind stress lifting may contribute more to maintaining the background dust haze during NH spring and summer than what previous studies have shown. However, dust devils are still important for maintaining the background haze in the atmosphere during that time of the year.

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