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Modeling Early Mars Climate

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Mars is presently cold and dry but geomorphological, sedimentary and mineralogical observations indicate the presence of liquid water on its surface [*Baker*, 2001; *Squyres et al.*, 2004; *Poulet et al.*, 2005]. Taking into account the expected dimmer early sun, an optically thick atmospheric greenhouse is required to reach a thermal balance optimal for the existence of liquid water on Mars. Infrared scattering by CO_2 clouds [*Kasting*, 1991], compensates for their shortwave cooling effect [*Forget and Pierrehumbert*, 1997] but a variety of climate models, from simple one-dimensional radiative-convective columns to full global circulation models, still require several bars of CO_2 to reach near-melting conditions [*Forget et al.*, 2012; *Wordsworth et al.*, 2012]. *Yung et al.* [1997] suggested that trace amounts of volcanically emitted SO_2 would inhibit CO_2 condensation, allowing a surface temperature increase capable of supporting liquid water. *Halevy et al.* [2007] modeled the coupled sulfur and carbon cycles to explore the effects of ppb to ppm levels of SO_2 on the climate and surface chemistry of early Mars. Subsequent global climate model simulations [*Johnson et al.*, 2008] support the suggestion that strong greenhouse warming by SO_2 increased early surface temperatures. In addition to gases, the effect of various aerosols, such as mineral dust, organic hazes and sulfur-bearing particles, remains unexplored. We have developed a rapid 1-D radiative transfer code using correlated-k distributions of gaseous absorption, instead of a computationally demanding line-by-line model. The radiative transfer backbone of the model is based on the line-by-line model of *Halevy et al.* [2009], as well as the high-resolution absorption spectra used to generate the k-coefficients required for the new, efficient model. The model allows calculation of simultaneous absorption and multiple-scattering at all wavelengths and is, therefore, especially suitable for exploring the effect of atmospheric particles on the radiative transfer. With this model we explore a range of atmospheric compositions, which can maintain a climate capable of sustaining liquid water at the Martian surface. We also explore the effect that mineral dust may have had in Mars' early climate.