New Numerical Model on the Radiation Field of Martian Atmosphere and Strategy of Radiative Field Observation in Mars Landing Mission in the Future

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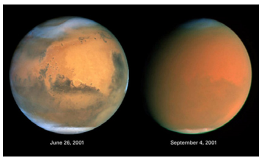
Purpose

We propose a new numerical model of Martian dust with a reasonable number of parameters which can be determined unambiguously by direct observation of radiation field from Martian surface. Thus we will propose the best way to observe the radiation field to determine the parameters, according to our model.



Mars without (left) and during (right) dust storm. Image Credit: NASA/STScl/AURA

Methods

In our model, the properties of Martian dust are parameterized by:
(1) imaginary part of refractive index of the substrate (feldspar etc.),
(2) volume mixing ratio of hematite,
(3) effective radius and (4) variance of size distribution,
(5) optical depth, and
(6) scale height of extinction coefficient.

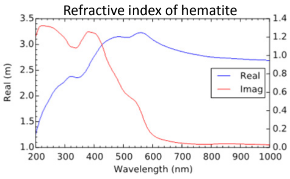
We assume non-spherical dust shape (spheroid) with a fixed aspect ratio distribution. The optical parameters are calculated using a look-up table prepared by the T-matrix code. Then, radiation condition at the Martian surface with wide range of parameters is simulated by using MODTRAN5 numerical code.

➢ Complex refractive index

The optical property of dusty Martian atmosphere is assumed to be expressed as a mixture of feldspar and hematite, i.e. according to Maxwell-Garnet relation,

$$n^2 = \frac{n_A^2+2n_0^2+2\rho_A(n_A^2-n_0^2)}{n_A^2+2n_0^2-\rho_A(n_A^2-n_0^2)},$$

where n_0 and n_A are the refractive indices for feldspar and hematite, respectively, and ρ_A is the volume fraction of hematite. The volume fraction of hematite is assume to be independent of height.



➢ Vertical Dust Distribution

The extinction coefficient, α_e, at an altitude, z, is given as:

$$\alpha_e(z) = \frac{\tau}{z_s}\exp\left(-\frac{z}{z_s}\right),$$

where τ is the optical depth from the space and z_s is the scale-height of dust distribution. We ignore horizontal heterogeneity in dust distribution for simplicity.

➢ Size distribution

Dust grains are assumed to be spheroidal shape with a fixed aspect ratio distribution. The size distribution of dust grains is given as:

$$\frac{dN(r)}{dr} = \frac{r^n}{\Gamma(n+1)(r_{eff}v_{eff})^{n+1}}\exp\left(-\frac{r}{r_{eff}v_{eff}}\right),$$

where
r_{eff} is the effective radius of a dust grain and v_{eff} is a variance of size distribution. The parameter n is equal to $(1-3v_{eff})/v_{eff}$.

The optical parameters of dust grains are calculated using a look-up table prepared by the T-matrix code.

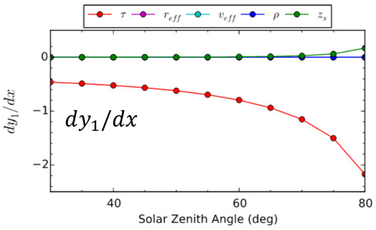
➢ Radiative field

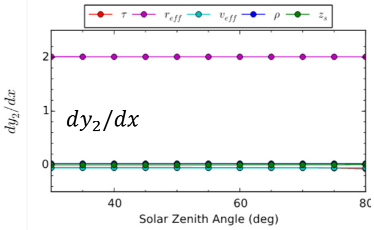
Under the models described above, a radiative field (an solar zenith angle- and elongation angle-resolved radiation intensity distribution) can be calculated as a function of 6 parameters and the solar elongation angle.

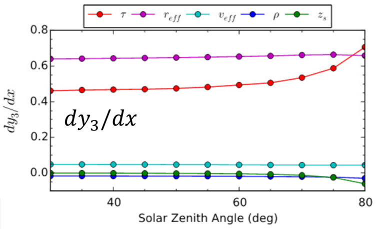
We use MODTRAN5 numerical code to simulate radiation condition for wide variety of solar zenith angle, elongation angle, and 6 parameters to clarify the sensitivity of the resulting radiative field on the 6 parameters. Then, finally we can find a best way of atmospheric observation to obtain the dusty properties of the Martian atmosphere.

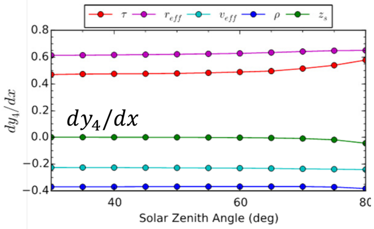
Results

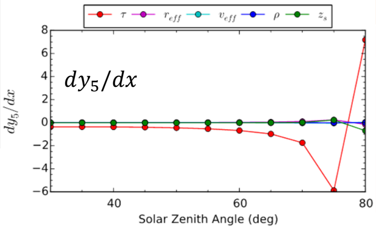
Based on a linear algebraic analysis of the numerical results, the sensitivity of our observation to the dust model parameters are evaluated. Especially observation of the radiation from the vicinity (~3 degree) of the sun contributed considerably to the sensitivity to the effective radius.







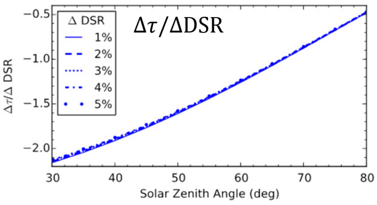


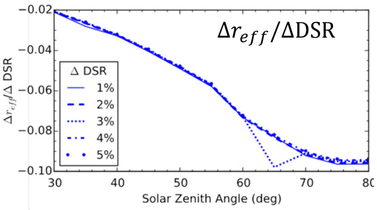


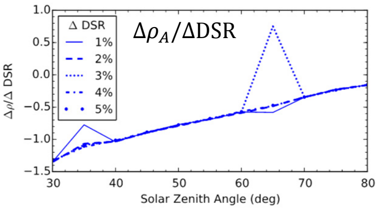
Definitions of Observed parameters y_i

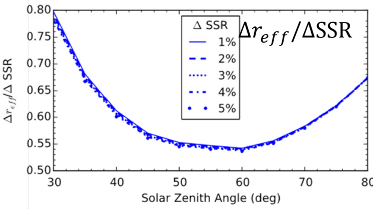
y_1 = DSR(550nm)
y_2 = SSR(675nm,3°)/SSR(675nm,10°)
y_3 = SSR(675nm,50°)/SSR(675nm,10°)
y_4 = SSR(450nm,50°)/SSR(450nm,10°)
y_5 = [SSR(675nm,$\chi_\uparrow$)－SSR(675nm,$\chi_\downarrow$)]/SSR(675nm,$\chi_\downarrow$)

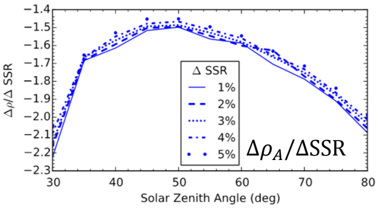
DSR: direct solar radiation, SSR: scatterd solar radiation











➢ Resulting proposal

We can determine τ with an error less than -0.5% if y_1 is obtained at a solar zenith angle about 80-degree. Similarly, r_{eff} and r_A are able to determined within 0.6% and 2% errors, respectively if observation take place at an solar zenith angle 50-60 degrees.