ULTRAVIOLET RADIATION ON THE SURFACE OF MARS. D. C. Catling[1], C. S. Cockell[2], and C. P. McKay[1]. [1]M/S 245-3, NASA Ames Research Center, Space Science Division/Planetary Systems Branch, Moffett Field, CA 94035 (catling@humbabe.arc.nasa.gov), [2]M/S 239-20, Exobiology Branch, NASA Ames Research Center, Moffett Field, CA 94035.

Introduction: An evaluation of the ultraviolet (UV) flux incident on the Martian surface is important for a number of issues. UV-induced photolysis of water changes the chemistry of the soil and atmosphere, inducing its oxidizing nature [e.g., 1]. Alternatively, UV may directly affect surface chemistry by generating silicate defects [2]. UV also rapidly degrades organic material delivered by meteoritic infall [3]. Consequently, UV affects the overall chemistry of the Martian surface and atmosphere. The extent of UV breakdown of organic molecules is also relevant to concerns regarding contaminants on lander or rover surfaces that could interfere with life-detection experiments causing “false positives”.

The radiation flux at a point on the surface of Mars depends on factors such as cloud cover, atmospheric dust loading, season, local time, and latitude [4]. Previously, the UV spectrum incident on the surface of Mars has been calculated from a simple radiative transfer model [5]. Limitations of this earlier model include no accounting for the effect of dust, which may be a perennial constituent of the atmosphere [6], and also the use of gas absorption data measured at room temperature that overestimate absorption for lower Martian temperatures. We present an updated model for UV radiation (200-400 nm) that incorporates dust and more recent data for the solar spectrum, gas absorption, and UV surface albedo.

Methodology: High altitude aircraft, balloons, and satellites have defined the solar extraterrestrial UV spectrum [7]. Variations in solar intensity over the solar cycle are ~10% at 190 nm, ~5% at 200 nm and <1% for wavelengths >210 nm. For Mars, we scale the flux for a given orbital position. The Lambertian surface albedo in the UV is taken as ~ 0.02-0.03 from spectropolarimetry measurements [8], assuming a surface not covered with ice. Atmospheric CO_2 absorbs and Rayleigh-scatters UV. In general, the temperature dependence of the UV absorption cross-section of CO_2 is relatively weak at small UV wavelengths and increases with wavelength. For fixed wavelengths above 190 nm, the cross-section can decrease by a factor of ~2 to 6 if the temperature is lowered from 300 to 200 K [9].

On Earth, the biosphere is shielded from UV by the ozone (O_3) layer, which absorbs in the Huggins bands (300-360 nm) and Hartley bands (200-300 nm). For Mars, the latter bands are the only significant absorption, because of the much smaller O_3 column abundance, ~2% of typical terrestrial levels even at maximum Martian abundance. Indeed, ozone is essentially absent in the summer at low latitudes. There is a weak temperature dependence of the O_3 absorption cross section near the Hartley peak at 250 nm [10,11]. Compared to CO_2 and O_3, the effects of other gases on the surface flux in the range 200-400 nm are very minor.

Dust absorbs and scatters UV. However, studies in this region of the spectrum have generated a range of dust optical properties unlike the properties in the visible where there is reasonable agreement. On the basis of refractive index data from Mariner 9 UVS data [12,13], we use Mie scattering to calculate the wavelength dependence of the optical properties in the UV. This assumes spherical particles, which may cause some error [14], but is necessary in the absence of any certain information concerning the dust shape distribution. Mariner 9 UVS data seem to indicate that Martian dust is absorbing around 200-220 nm [13] perhaps due to a small component of TiO_2 or magnetite [15]. Wolff et al. [16] also found that dust was necessarily absorbing in the UV to obtain good fits to data taken from the Hubble Space Telescope (HST).

Surface irradiation is calculated by using the Delta-Eddington approximation [17] for diffuse flux.

Results and Discussion: CO_2 absorption is significant at wavelengths < 204 nm and effectively provides a shield below ~190 nm. Above 204 nm, the CO_2 extinction cross-section is equivalent to the Rayleigh scattering cross-section, i.e., there is negligible CO_2 absorption. If the Martian atmosphere were to be cleansed of dust, the dominant effect on attenuating the UV flux reaching the surface would be CO_2 Rayleigh scattering, except for high latitude winter locations where O_3 absorption may become significant. Indeed, if it were the case that Mars had an early, thick CO_2 atmosphere ~ 1 bar, then it is plausible that the Martian UV environment may have been more benign than on Archean Earth, which lacked an ozone layer.

On present day Mars, the total integrated UV flux over 200-400 nm, is comparable to the Earth’s. However, on Mars the shorter wavelengths contribute a much greater proportion of this UV flux. These wavelength ranges, such as UVC (200-280 nm) and UVB (280-315nm) are particularly biologically damaging.

Dust, if present, contributes substantially to attenuating the UV flux reaching the surface. For (mean visible) dust optical depths >1, the calculated diffuse UV flux at the surface exceeds the direct flux. Even for small optical depths ~0.1, dust still contributes significant extinction comparable or exceeding the effect of CO_2 Rayleigh scattering across the UV spectrum. In this regard, it is interesting that some HST UV observations have been interpreted as requiring dust optical depths < 0.1 unlike the Viking years [18], a result perhaps counter-intuitive on dynamical grounds. Recently, a possible explanation has been put forth that the dust may be concentrated in a layer beneath cloud [19].

Outstanding issues of uncertainty include the dust optical constants across the UV spectrum as well as the effects of cloud cover on the UV. The proposed Beagle 2 Lander on Mars Express [20], which is baselined to include UV sensors, affords a possible opportunity to help resolve these issues. A miniature UV spectrometer, or a several transducers, each sensitive to a specific wavelength, could measure the actual UV surface spectrum. Combined with camera measurements of the visible optical depth of dust, this would open up a valuable part of the solar spectrum to study from the surface.

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