RADIATIVE TRANSFER CALCULATIONS FOR THE ATMOSPHERE OF MARS IN THE 200-900 NM RANGE. S. Deo[1,], R. Kalchgruber[1,3] and B. Mayer[2], [1]Oklahoma State University, Department of Physics, 145 PS II, Stillwater, OK, 74078, USA. [2]Deutsches Zentrum für Luft- und Raumfahrt (DLR), Institut für Physik der Atmosphäre, Oberpfaffenhofen, Germany. [3]email: kalchgr@okstate.edu .

Introduction: Due to the increasing interest in the climatic history of the planet Mars, efforts are made to develop a miniature dating device for in situ luminescence dating of Martian sediments [1]. In luminescence dating the time elapsed since deposition of a sediment layer is determined from the radiation-dose accumulated in minerals since the last bleaching event, and the dose rate due to naturally occurring radioactive nuclides and cosmic radiation. During sunlight exposure the sediments are mainly bleached by wavelengths between 200 and 900 nm. Due to the well known solar spectrum, the solar resetting under terrestrial conditions has been investigated extensively; no measured data exist, however, for the spectral irradiance at the surface of Mars.

Many radiative transfer calculations for the atmosphere of Mars focused on the UV range of the solar spectrum, due to its influence on lifeforms and atmospheric photochemical reactions (e.g. [2]). Extensive simulations, triggered by the data from TES, have also been carried out in the thermal IR (e.g. [3]). Almost no data however exist for the visible range.

We used the libRadtran software package for radiative transfer calculations in the 200-900 nm range. The calculation is based on a vertical atmospheric profile file and accounts for absorption by CO_2, O_2, O_3, and H_2O, as well as Rayleigh scattering. The Lambertian surface albedo and extinction by dust particles were also included. The libRadtran software package and the input parameters are presented and the results of the simulations will be compared to spectra on Earth.

The libRadtran Software Package: libRadtran is a library of C and Fortran functions and programs for calculation of solar and thermal radiation in the Earth's atmosphere. It has evolved from the uvspec radiative transfer model. The libRadtran software package is freely available from www.libradtran.org under the GNU General Public License. Minor changes were necessary to adapt the package for Martian conditions.

Input Parameters: The calculations account for the following parameters:

Atmospheric Profile. The vertical density, pressure and temperature profiles measured by the Viking landers [4] and the Mars Pathfinder [5,6] were used for the calculations. The concentrations of relevant atmospheric gases were 95.32 % CO_2 and 0.13 % O_2.

Absorption coefficients and Rayleigh scattering. Rayleigh scattering cross sections for a pure CO_2 atmosphere were calculated according to Bodhaine et al. [7], using the CO_2 refractive index given by Owens [8]. Absorption cross-sections for CO_2 were taken from Lewis and Carver [9] and for O_3 from Molina and Molina [10]. The data, given in each case for three temperatures, were fitted with a parabolic equation and temperature dependent cross sections were derived for each atmospheric layer. The absorption of O_2 in the Herzberg continuum was included using the coefficients derived by Amoruso et al. [11]. The pressure dependence was considered to be negligible.

Water and ozone. We used the vertical water and ozone profiles calculated by Lefevre et al. [12] for different latitudes and areocentric longitudes. Vertical profiles were scaled with an integrated column value for ozone [12] and the precipitable water in the atmosphere [13].

Aerosol particles. We assumed an exponentially decreasing dust profile with an optical thickness between 0.1 and 4, typical for each season [14]. For the wavelength dependent extinction coefficient, asymmetry parameter and single scattering albedo we chose the data from Ockert-Bell et al. [15].

Albedo. Wavelength dependent values for the Lambertian surface albedo were taken from the publications by Fox et al. [16] and James et al. [17].

Extraterrestrial spectrum. The calculated transmission values (diffuse and direct) were corrected for the Mars-Earth distance and multiplied with an extraterrestrial spectrum [18] to receive the spectral irradiance at the surface of Mars. Simulations were carried out for different latitudes and areocentric longitudes.

Results: Differences between the irradiances calculated with the Mars Pathfinder and Viking lander atmospheric profiles were only about 1 %.

Scattering by dust may cause a considerable fraction of diffuse radiation at the surface. For an optical thickness $\tau = 1$, the diffuse irradiance exceeds the direct component. At the same time the integrated total irradiance (200-900 nm) at the surface is 79 % of the value without dust, and can be as small as 32 % for $\tau = 4$.

A comparison of the total spectral irradiances for a clear day on Earth (solar zenith angle 20°) and typical summer an winter days on Mars is shown in Figure 1. We used the Mars Pathfinder atmospheric profile. Both spectra were calculated for a latitude of 20° and noon conditions. For the day in northern summer the areocentric longitude was 143°, solar zenith angle 5°,

$\tau_{dust} = 1$, 0.1 DU ozone and 0.02 mm precipitable water; (northern winter: areocentric longitude 250°, solar zenith angle 43°, $\tau_{dust} = 0.1$, 0.2 DU ozone and 0.01 mm precipitable water).

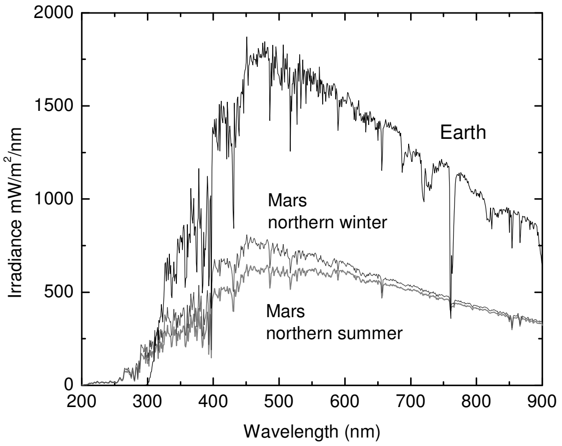

Figure 1: Comparison of spectral irradiances for Earth and two typical days in northern summer and winter on Mars.

The integrated (200-900 nm) total irradiance at the surface of Mars is similar for both seasons. The irradiance in northern summer amounts to 40 % of the value for Earth. Despite of the much smaller dust load in winter, the irradiance is only 45 % of the Earth-value due to the increased solar zenith angle. Whereas practically no radiation below 300 nm reaches the surface of Earth, sediments on Mars are exposed to UV radiation starting from 200 nm.

The simulations showed, that the lower irradiance and the far UV radiation are the major differences between Mars and Earth. Experiments on the bleaching behaviour of sediments on Mars, should focus on these issues.

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