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Solar EUV radiation effects on the early Martian upper atmosphere

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Evolution of the Martian atmosphere with regards to its CO_2 and H_2O inventory seems to have been strongly affected by thermal and non-thermal atmospheric loss processes of the lightest neutral and ionized constituents like H, H_2, O, C, CO, H^+, O^+, H_2^+, CO^+, O_2^+, etc., into space, as well as by chemical weathering of the planetary surface materials. The evolution of all the escape processes should have depended on the intensity of the solar X-ray and EUV (XUV) radiation and the solar wind density during the Solar system history. Thus, in this study the satellite data derived from observations of solar proxies with different ages within the Sun in Time program for reconstructing the Sun's radiation and particle fluxes from the present time to 4.6 Gyr ago have been used. A thermospheric model of the CO_2-rich Martian atmosphere exposed to intense XUV flux that was expected during the Sun's evolution has been developed to study its photochemistry and thermal balance that are essential for determining the atmospheric escape rates. During the first Gyr after the Sun arrived to the Zero-Age-Main-Sequence, high XUV radiation fluxes in a range from about 10 to 100 times the average flux of the present Sun were expected to be responsible for much higher temperature in the thermosphere and exosphere of the planet. The diffusive-photochemical and thermal balance model of the early Martian thermosphere and ionosphere has been applied for investigating the solar radiation impact due to photodissociation and ionization processes, heating in exothermic chemical reactions, and cooling by the CO_2 IR emission in the 15 μm fundamental band, as well as in some prominent CO_2 hot and isotopic bands. It has been found that high XUV radiation flux results in a hot and expanded early thermosphere with the exobase level as high as about 2000 km (4.5 Gyr ago). Our model simulations also indicate that the high temperature of the early Martian thermosphere could result in "blow-off" conditions for neutral hydrogen

atoms even for high CO_2 atmospheric mixing ratios of 96%. Furthermore, the results show that lower CO_2 / N_2 or CO_2 mixing ratios in general, or higher abundance of H_2O-vapor in the early Martian atmosphere could have had a dramatic impact on the loss of water and atmosphere from the early planet. The duration of this phase of high exobase temperature and thermal loss rates could have essentially depended on the mixing ratios of CO_2, H_2O, and N_2 in the early atmosphere. Lower CO_2 mixing ratios on early Mars shortly after its volatile outgassing, for example, might have had a major effect on the thermal loss of the major atomic atmospheric species (O, N, C) combined with intense impact erosion and nonthermal loss of hot O due to dissociative recombination of the O_2^+ ions in the dense early Martian ionosphere.