EPSC Abstracts,
Vol. 2, EPSC2007-A-00072, 2007
European Planetary Science Congress 2007
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Evolution of the ancient Martian atmosphere and plasma environment studied by 3d hybrid simulations

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A three dimensional hybrid code for simulation of the solar wind interaction with the ionosphere of Mars using curvilinear coordinate systems has been developed. In this code the ions are represented by macroparticles, whereas the electrons act as a massless, charge neutralizing fluid. The code was successfully applied to the interaction of the solar wind with weak comets, Mars and Titan. For simulation of Mars the neutral oxygen profile was calculated by a thermospheric model, which is self-consistent with respect to the neutral gas temperature and several other heating processes. We have modeled a three dimensional ionosphere by a Chapman layer model. The ionospheric ion production is calculated by a Monte Carlo method including chemical reactions. The 3d hybrid model allows an analysis of the ancient Martian plasma environment as well as non-thermal loss rates of O^+, O_2^+, CO_2^+ and H^+. The three main loss processes by ion pick-up, plasma-clouds and momentum transfer are automatically included. We compare several scenarios between 1 EUV and 100 EUV for average solar condition: The present situation corresponds to 1 EUV and the case 4 billion years ago (end of Noachian period) corresponds to the 10 EUV case. This comparative study illustrates that the structure of the interaction region and the ionospheric loss rates are not only highly sensitive to changes in the solar EUV intensity, but an important role must be ascribed to the solar wind parameters (magnetic field, density and velocity) as well. Therefor we use data from the observation of solar proxies with different ages and a

Weber-Davis solar wind model. Especially the strength of the IMF controls the value of the Martian induced magnetic field which protects the atmosphere against the interaction with the solar wind and influences on the other side the loss rates again. First simulations for the present case and 3.5 billion years ago have shown that only an amount of water equivalent to a global ocean with a depth of 7m have been lost. This means that Mars may have lost the majority of its water inventory in a time period before 3.5 billion years by hydrodynamic escape and impact erosion.