The Sun and the climate on Venus and Mars

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The planets Venus, Earth and Mars orbit in close proximity to the Sun (0.7-1.5 AU). This makes them subject to intense solar radiation- and solar wind forcing. Their chemical composition is rather similar, but certain dissimilarities like the intrinsic magnetization have made them evolve in different ways. Under the assumption that all Earth-like planets accreted from matter of essentially the same chemical origin, the differences we observe today must have been due to differences in their evolution. A particularly important item is the evolution of volatiles on a planet. The Earth is the only planet of the three with a significant hydrosphere and the climate has remained beneficial for advanced biological life. The questions are therefore: what happened with the water on Venus and Mars? Specifically, why did the atmosphere and climate evolve so different? What are the mechanisms responsible for the differentiation observed in the atmosphere of the Earth-like planets?

Water and CO_2 , the most abundant molecules on the Earth-like planets, are major constituents in their climate control. Venus has a dense (90 Bar) atmosphere dominated by CO_2. The Venus surface is fiercely hot (≈750 K) due to a running greenhouse effect. Mars also has a CO_2 dominated atmosphere, but the density is very low (≈0.07 Bar) and the surface temperature is generally below 250 K. On the Earth CO_2 is a minor species, water vapor being the main greenhouse gas. The present water based greenhouse effect in the Terrestrial atmosphere is ideal (300 K) for advanced life forms.

Several theories exist on the loss of water from Venus and Mars. A theory put forward in recent years is that the solar wind interaction with the topside atmosphere and ionosphere leads to a long-term change of planetary atmospheres. The Earth is well protected against solar wind erosion by an intrinsic magnetic dipole – a “magnetic umbrella”. For planets lacking magnetic shielding, like Venus and Mars, the solar wind have direct access to the topside atmosphere, causing fast erosion of ionized volatiles there. The large outflow of H^+, O^+ and O_2^+ measured near Mars is evidence for such an ongoing dehydration.

The abovementioned planetary properties illustrate the importance of an intrinsic magnetic field in protecting and maintaining the hydrosphere on a planet near the Sun. We have also learnt that the solar activity and the variability of the heliospheric magnetic field modulate the Terrestrial ionospheric outflow, the outflow being highest during solar maximum. An active Sun, in particular the early Sun, is therefore related with high planetary volatile erosion rate.

Issues like solar wind erosion, solar activity, and magnetic shielding discussed in this report is important for the evolution of volatiles and the climate on Mars and Venus. These issues are also expected to be important for the evolution of the long-term climate on the Earth.