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The effects of degassing on the long term evolution of the Martian atmosphere.

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We study the long term evolution of the conditions on the surface of Mars through the modeling of the effects of volcanic degassing and atmospheric non-thermal escape during the last four billion years. We propose to use the recent advances due to observation and modeling to constrain possible evolutions of the atmosphere of Mars with the help of isotopic data from Carbon, Nitrogen and Argon. CO2 is the main object of our study. In our calculation, we do not consider early impact erosion, hydrodynamic escape or carbonate formation. ASPERA (Analyzer of Space Plasma and EneRgetic Atoms) measurements and modeling of the escape rates produced by ionic escape, sputtering and dissociative recombination constitute the sink of volatiles. For the sources, we use two different ways to model the volcanic degassing. First, an estimate of the volcanic degassing is obtained from observation of the surface, lava flows and comparison with published data and models. In a second part, we model directly the evolution of the stagnant-lidded Martian mantle with the use of the StagYY numerical code for realistic mantle convection (with mineralogical phase transition, partial melting, for example; Tackley, 2008 ; Keller and Tackley, Icarus 2009, for Mars). By combining atmospheric escape, volcanic production and lava composition, we can operate a integration backward in time, starting with the present day state of the atmosphere, to investigate its past. Our model is able to reproduce present day 36Ar abundance and 40Ar/36Ar ratio. We also show that the present-day atmosphere of Mars is likely to be constituted by a large part of volcanic gases. With a low CO2 concentration in the magma (150 ppm), present atmosphere is constructed of 50% of volcanic gases emitted since 3.7 billion years ago, which corresponds to an age of 1.9 to 2.3 Gyr. The variations of CO2 pressure over this period seem relatively low (50 mbars at most) when we only take into account degassing and non-thermal escape. This seems in line with the assumption of a heavy loss of volatiles during the first 500 Myr. The evolution of the isotopic ratio of Nitrogen allow us to hypothesize that it decreased from high primordial values to its present state due to atmospheric escape and that what nitrogen is left in the atmosphere of Mars is old. On the contrary, the CO2 would be much younger and volcanic degassing would have had a strong effect on the CO2 isotopic ratio over the last four billion years. Finally, water is abundant on Mars during the whole 4 billion years evolution (between 30% and 150% of the present day water) but is unlikely to reside in the atmosphere or in liquid form.