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Mars and the IsotopiC Ratio Of water: Budget and Evolution

DURATION
15/12/2019 – 15/03/2024

BUDGET
390 201 €

PROJECT DESCRIPTION

Today's Mars is known to be extremely arid and inhospitable. However, significant evidence indicates that the early Mars was much wetter and large areas were covered by liquid water, allowing the planet to be most likely included in the habitable zone billions of years ago. Since then, most of the initial water is believed to have escaped to space.

Several ongoing Mars missions are providing valuable information in this respect. On the one hand, ESA's TGO and NASA's Curiosity rover are observing the distribution of H_2O and HDO in the atmosphere and in situ, respectively. On the other hand, NASA's MAVEN orbiter is focusing on the upper atmosphere and the escape of their by-products to space. However, the observations alone are not sufficient and the support of models is crucial to fill the gaps in space and time so to complete the global picture. Yet, the last related model studies were conducted almost 15 years ago. Therefore, there is an urgent need to develop a model from the subsurface to the exobase, including all relevant processes to better understand the current evolution of water, which is prerequisite for the estimation of the total loss to space and the initial amount of water on the early Mars.

The study of the current isotopic composition of water (H_2O and HDO) helps to estimate how much water Mars lost in its history. Both isotopes are involved in physicochemical processes that produce isotopic fractionation effects. Moreover, the photochemical by-products of both isotopes can reach the upper atmosphere and escape to space. However, as deuterium (D) is twice as heavy as the more common isotope (H), the latter process results in an additional isotopic fractionation and eventually in a net enrichment in the heavier isotope on Mars.

In this project, we will develop a sophisticated 1-D model with the aim of better understanding the evolution of the two water isotopes from the regolith to the exobase. This will require to include all processes relevant to the evolution of water and its isotopic composition on Mars. A first step will consist of implementing routines currently used in the GEM-Mars General Circulation Model (GCM), developed at BIRA-IASB, into a 1-D atmospheric model. Here, we can refine and test the implementations of the dominant mechanisms affecting the diurnal cycle and transport of water and HDO in the lower atmosphere. A recently developed 1-D model describing the regolith-atmosphere interaction of water isotopes will be coupled to our atmospheric model.

Expanding into the upper atmosphere, the photochemistry involving neutral and ionic species will be developed referring to the existing literature. The amount of water that can diffuse into the upper atmosphere is essential to constraining the escape rates of hydrogen and deuterium. The escape rates are observed to be highly variable, so we will construct many scenarios in the lower atmosphere to force water into the upper atmosphere. In this way we will investigate the important reservoirs and processes that limit the presence of water into the upper atmosphere of Mars. Finally, an exospheric model will be used to study the escape processes, which strongly affect the fractionation of hydrogen and deuterium. All relevant improvements will then be provided to the GCM.

The development of the model will be carried out in close contact with the Mars mission teams mentioned above with the aim of constraining the model with observations and better understanding the processes at work and evolution of water isotopologues on Mars.

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The project will provide a valuable support to the numerous missions to Mars. Additionally, it will contribute to the understanding of the fate of water and the habitability of Mars in the past. In this respect, it comes within the general scope of the search for the conditions required for the emergence of life. Furthermore, the improvements made in the 1D model will then be integrated in the 3D GCM. This project will thus strengthen the theoretical expertise of the Planetary Aeronomy division of BIRA-IASB and consolidate the team as an important international partner in this field of research.

Our work will be presented regularly at European and international scientific conferences, and in a series of research articles. We are continually involved with current space missions observing Mars' atmosphere, and interact with their science and operations teams.

CONTACT INFORMATION

Coordinator

Justin Erwin
Royal Belgian Institute for Space Aeronomy (BIRA-IASB)
Planetary Aeronomy Department
justin.erwin@aeronomie.be

LINKS

https://microbe.aeronomie.be