EPSC Abstracts
Vol. 9, EPSC2014-426, 2014
European Planetary Science Congress 2014

Seasonal variation of HDO/H_2O ratio in the atmosphere of Mars observed by SUBARU/IRCS and MEX/PFS

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Abstract

We present the seasonal variation of HDO/H_2O ratio caused by sublimation-condensation process in a global view of the Martian water cycle.

It is well-known that water on Mars exists as vapor (in the atmosphere) and ice (ice clouds, surface ice, and possibly subsurface ice), and its phase change occurs via sublimation-condensation process. Mapping of HDO/H_2O ratio could provide the information to discriminate these physical processes. The key theory here is that the condensation process induces an isotopic fractionation on water vapor due to the difference in their vapor pressures, i.e., the heavier HDO vapor preferentially condensates compared to the lighter H_2O vapor [1], whereas there is no isotope fractionation during sublimation due to very slow molecular diffusion within ice. Indeed, general Circulation Model (GCM) predicted that HDO/H2O ratio changes by a factor of 2 due to condensation-induced fractionation in the polar region [2].

So far, distribution of HDO/H_2O ratio has been investigated by only a few ground-based observations. They found that HDO/H_2O ratio was not constant but varied in the range between 2 and 10 wrt VSMOW [3,4]. In addition, latitudinal gradients of HDO/H_2O ratio probably due to condensation of HDO vapor over high latitude at the middle of the northern spring was suggested [4]. However, it is still open question that what causes the un-uniform distribution of the HDO/H_2O ratio due to lack of its seasonal behavior. In order to answer the question, we investigated the HDO/H_2O ratio at two different seasons, the northern spring (Ls=52°) and summer (Ls=96°), and revealed the seasonal variation.

The HDO/H_2O ratio was retrieved from ground-based observations by high-dispersion echelle spectroscopy of Infrared Camera and Spectrograph (IRCS) [5] onboard Subaru telescope and the coordinated joint observation by Planetary Fourier Spectrometer (PFS) [6] onboard Mars Express (MEX) spacecraft. The observations were performed at middle of the northern spring (Ls=52°) and beginning of the summer (Ls=96°) in the Mars Year 31. We retrieved H_2O abundances with the spring observation using the absorption lines at 3035.78356 cm^{-1} and 3216.52218 cm^{-1} and HDO abundances from the lines at 2672.59294 cm^{-1} and 2677.71967 cm^{-1} of SUBARU/IRCS data. On the other hand, the PFS measurements were used to derive H_2O abundances in order to investigate HDO/H_2O ratio for the summer observation since the abundances of H_2O could not be retrieved from the IRCS data because of the high terrestrial humidity during the Subaru observation.

Figure 1 shows the retrieved latitudianl distribution of HDO/H_2O ratio at the nothern spring and summer. The averaged HDO/H_2O ratios were 4.1 ± 1.4 (Ls=52°) and 4.6 ± 0.7 (Ls=96°) times larger than the terrestrial Vienna Standard Mean Ocean Water (VSMOW), which was consistent with previous observations. The HDO/H_2O ratio showed a large seasonal variation especially at high-latitudes. The HDO/H_2O ratio is significantly increased from 2.4 ± 0.6 wrt VSMOW at Ls=52° to 5.1 ± 0.7 wrt VSMOW at Ls=96° over the polar region (70°-80°N). This can be explained by preferable condensation of HDO vapor in the northern spring, and sublimation of the seasonal polar cap in the northern summer.

Figure

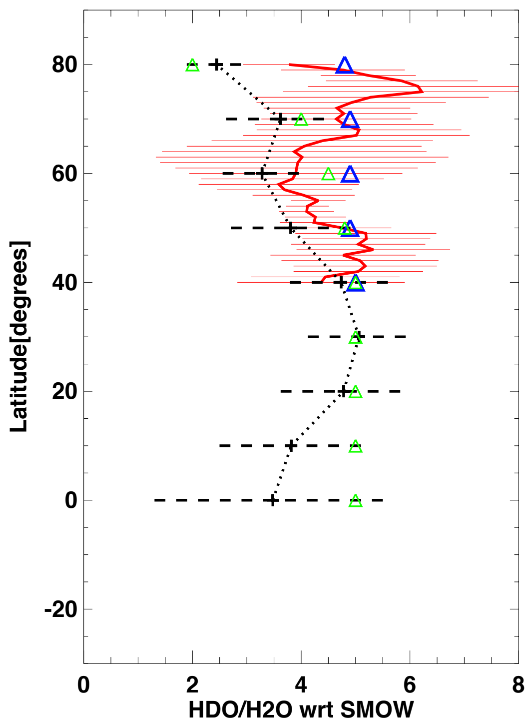

Figure 1: Seasonal variation of HDO/H_2O ratio (relative value to VSMOW). The red curve shows the longitudinal mean values of HDO/H_2O ratio observed at Ls=96° and the black curve represents the ones at Ls=52°. The error bars correspond to the standard deviations of longitudinal mean. For the Ls=96° data, we could not be retrieve the ratio with enough accuracy below 40°N due to the high terrestrial humidity during the ground-based observation. The green and blue triangle symbols show the predicted values for Ls=52° and Ls=96° by GCM. The values are extracted from the zonal averaged map of HDO/H_2O ratio shown in Fig. 2 of Montmessin et al. (2005).

Acknowledgements

The presented analysis is based on data collected at Subaru Telescope, which is operated by the National Astronomical Observatory of Japan. PFS activities are funded by ASI in the context of Italian participation to the ESA Mars Express mission.

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