MARTIAN DUST STORMS AND GRAVITY WAVES: DISENTANGLING WATER TRANSPORT TO THE UPPER ATMOSPHERE.

D. S. Shaposhnikov, *Moscow Institute of Physics and Technology, Moscow, Russia (shaposhnikov@phystech.edu)*, **A. S. Medvedev,** *Max Planck Institute for Solar System Research, Göttingen, Germany*, **A. V. Rodin,** *Moscow Institute of Physics and Technology, Space Research Institute, Moscow, Russia*, **E. Yiğit,** *George Mason University, Fairfax, VA, USA*, **P. Hartogh,** *Max Planck Institute for Solar System Research, Göttingen, Germany*.

Abstract

Simulations with the Max Planck Institute Martian general circulation model for Martian years 28 and 34 reveal details of the water "pump" mechanism and the role of gravity wave (GW) forcing. Water is advected to the upper atmosphere mainly by upward branches of the meridional circulation: in low latitudes during equinoxes and over the south pole during solstices. Molecular diffusion plays little role in water transport in the middle atmosphere and across the mesopause. GWs modulate the circulation and temperature during global dust storms, thus changing the timing and intensity of the transport. At equinoxes, they facilitate water accumulation in the polar warming regions in the middle atmosphere followed by stronger upwelling over the equator. As equinoctial storms decay, GWs tend to accelerate the reduction of water in the thermosphere. GWs delay the onset of the transport during solstitial storms and change the globally averaged amount of water in the upper atmosphere by 10-25% (Figure 1).

The presented MGCM simulations and comparison with ACS solidify the concept of the water "pump" mechanism of transporting vapor directly to the upper atmosphere. Model simulations also provide finer details and predictions, which can be later verified with observations, once more data become available.

Overall, our results highlight the wide-reaching implications of the GW-induced large-scale circulation and its potential role in modulating the distribution of water on Mars (Shaposhnikov et al., 2022).

Acknowledgments

The data supporting the MPI–MGCM simulations can be found at the repository (Shaposhnikov et al., 2021). The most recent model output can be accessed at `https://mars.mipt.ru`. The ACS MIR temperature and water data are available at the articles by Fedorova et al. (2020) and Belyaev et al. (2021), correspondingly. The MCS–MRO data are available at *MCS Data Archive* (2021).

The authors thank Denis Belyaev of IKI for assistance with the observational data and helpful discussions. The work was partially supported by the Russian Science Foundation grant 20-72-00110.

Figures

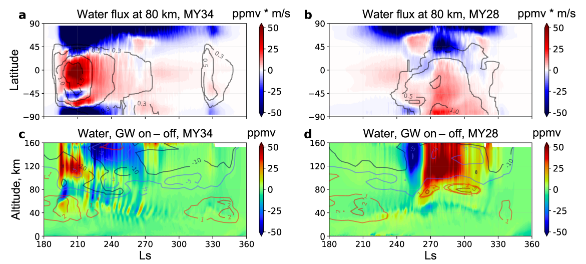

Figure 1: (**a**, **b**) Latitude-seasonal cross-sections of the zonally averaged vertical water vapor flux at 80 km (shaded) simulated with gravity waves (GW) included and the IR optical dust opacity (black contours). (**c**, **d**) Altitude-seasonal cross-sections of the globally averaged differences of water vapor (shaded) and temperature (contours) between the simulations with and without GWs. Left (**a**, **c**) and right (**b**, **d**) columns are for the MY34 and MY28 dust scenarios, correspondingly.

Abbreviations

- ACS MIR – Atmospheric Chemistry Suite middle-infrared echelle spectrometer onboard ExoMars Trace Gas Orbiter
- GW – gravity wave
- IKI – Space Research Institute, Moscow, Russia
- MCS–MRO – Mars Climate Sounder instrument onboard Mars Reconnaissance Orbiter
- MPI–MGCM – Max Planck Institute Martian general circulation model
- MY – Martian year

References

Belyaev, D. A., Fedorova, A. A., Trokhimovskiy, A., Alday, J., Montmessin, F., Korablev, O. I., … Shakun, A. V. (2021). Revealing a high water abundance in the upper mesosphere of Mars with ACS onboard TGO. *Geophysical Research Letters*, *48*(10), e2021GL093411. Retrieved from https://agupubs.onlinelibrary.wiley.com/doi/abs/10.1029/2021GL093411 doi: 10.1029/2021GL093411

Fedorova, A. A., Montmessin, F., Korablev, O., Luginin, M., Trokhimovskiy, A., Belyaev, D. A., ... others (2020). Stormy water on Mars: The distribution and saturation of atmospheric water during the dusty season. *Science*, *367*(6475), 297–300.

Mcs Data Archive. (2021). Retrieved 2021-12-02, from https://atmos.nmsu.edu/data_and_services/atmospheres_data/MARS/mcs.html

Shaposhnikov, D. S., Medvedev, A. S., Rodin, A. V., Yiğit, E., & Hartogh, P. (2022). Martian dust storms and gravity waves: Disentangling water transport to the upper atmosphere. *Journal of Geophysical Research: Planets*, e2021JE007102.

Shaposhnikov, D. S., Medvedev, A. S., Rodin, A. V., Yiğit, E., & Hartogh, P. (2021). *Martian Dust Storms and Gravity Waves: Disentangling Water Transport to the Upper Atmosphere.* Zenodo. Retrieved from https://doi.org/10.5281/zenodo.5749676 doi: 10.5281/zenodo.5749676