Out-of-season water escape during Mars' northern summer triggered by a strong localized dust storm

Adrián Brines[1]*, Shohei Aoki[2]*, Frank Daerden[3], Michael S. Chaffin[4], Samuel A. Atwood[5,6], Susarla Raghuram[6], Bruce A. Cantor[7], Yannick Willame[3], Loïc Trompet[3], Geronimo L. Villanueva[6], Michael J. Wolff[8], Michael D. Smith[6], Christopher S. Edwards[9], Ian R. Thomas[3], Giuliano Liuzzi[10], Lori Neary[3], Manish R. Patel[11], Miguel Angel López-Valverde[1], AnnCarine Vandaele[3], Armin Kleinböhl[12], Hoor AlMazmi[13], James Whiteway[14]

[1]Solar System Department, Instituto de Astorfísica de Andalucía (IAA-CSIC), Granada, Spain.
[2]Department of Complexity Science and Engineering, University of Tokyo, Kashiwa, Japan.
[3]Royal Belgian Institute for Space Aeronomy (BIRA-IASB), Brussels, Belgium.
[4]Laboratory for Atmospheric and Space Physics (LASP),University of Colorado Boulder, Boulder, USA.
[5]University of Maryland Baltimore Country, Maryland, USA.
[6]NASA Goddard Space Flight Center, Maryland, USA.
[7]Malin Space Science Systems, California, USA.
[8]Space Science Institute, Boulder, USA.
[9]Department of Astronomy and Planetary Science, Northern Arizona University, Arizona, USA.
[10]School of Engineering, Università degli Studi della Basilicata, Potenza, Italy.
[11]School of Physical Sciences, The Open University, Milton Keynes, UK.
[12]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California, USA.
[13]United Arab Emirates Space Agency, Abu Dhabi, UAE.

*Corresponding authors: Adrián Brines (adrianbm@iaa.es), Shohei Aoki (shohei.aoki@edu.k.u-tokyo.ac.jp)

Supplementary Figures

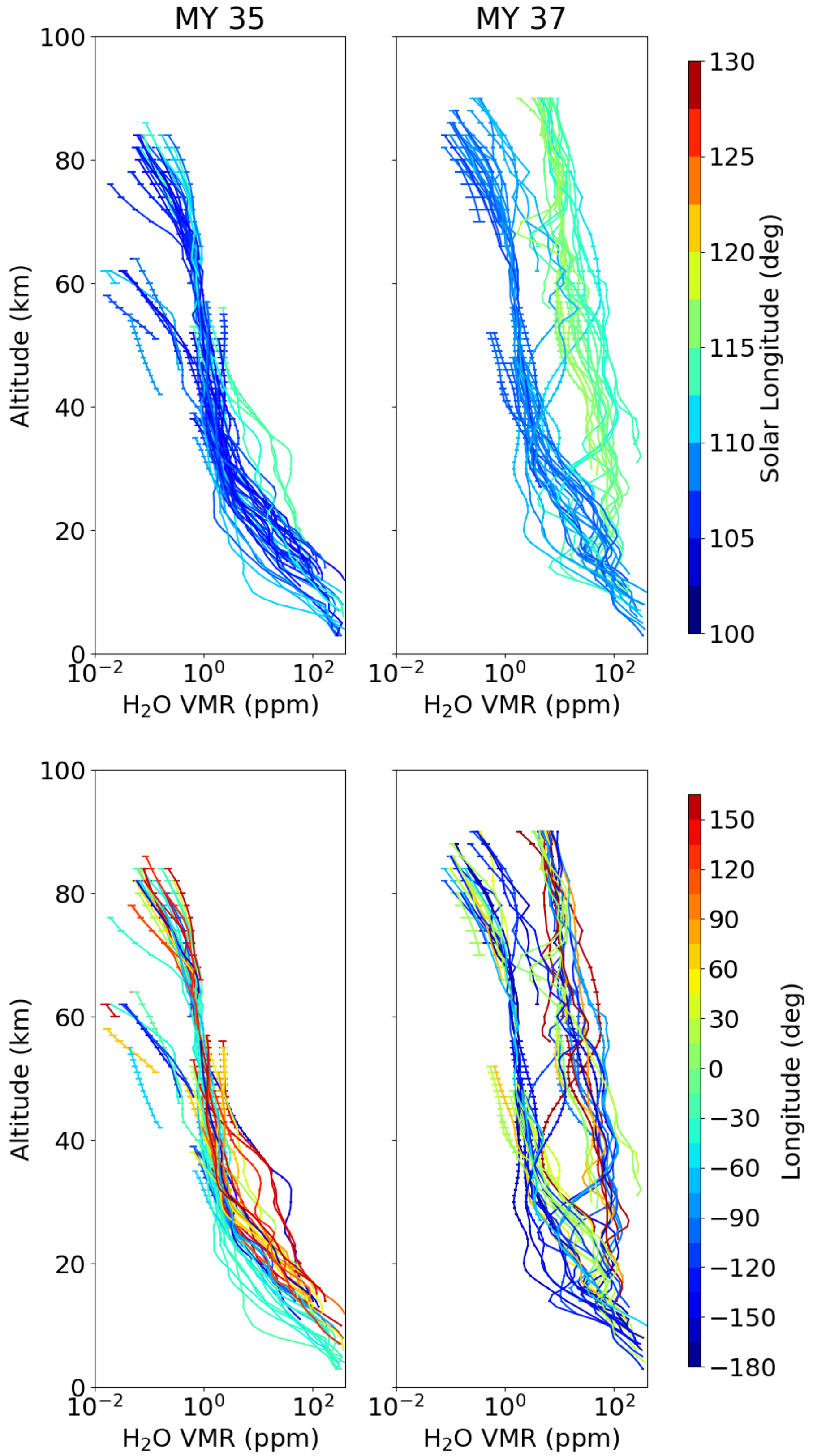

Fig. S1: Water vapor vertical profiles as observed by NOMAD SO at latitudes above 50º N during L_S=110º-130º for MYs 35 (left) and 37 (right). Top panels show the profiles colored by solar longitude while bottom panels are colored by longitude of the observations.

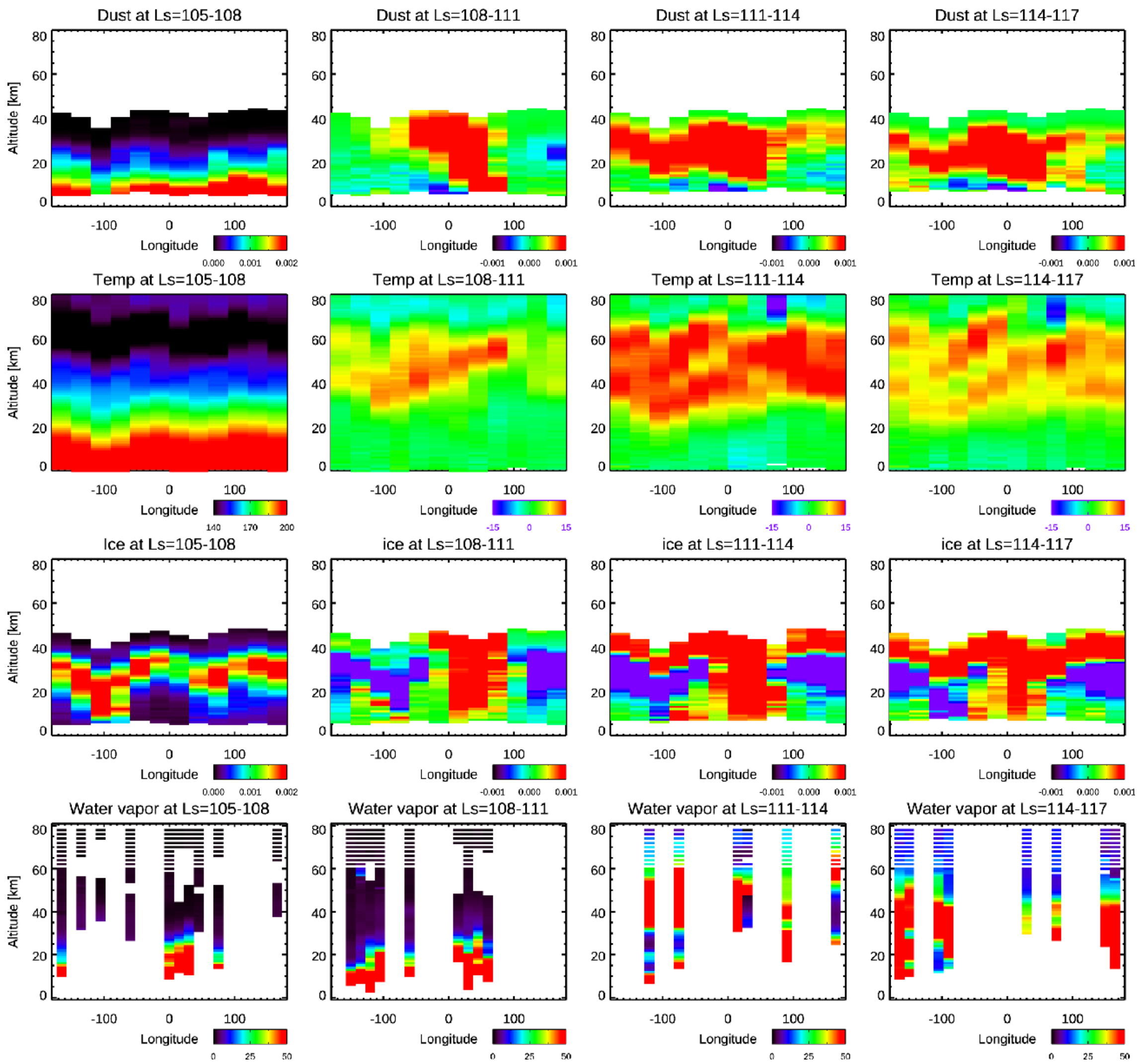

Fig. S2: Longitudinal distribution of dust extinction [1/km] (top), temperature [K] (second row), water ice extinction [1/km] (third row) as measured by MCS, and water vapor Volume mixing ratio [ppmv] (bottom) as measured by NOMAD, from L_S=105° to L_S=117° for observations at latitudes 30°N-45°N. Each panel shows the distribution within L_S periods of 3°. For MCS results (three top rows), the first period L_S=105°-108° (first column) shows absolute values, whereas the rest of the periods (second, third and fourth columns) show differences with respect to the first one. Bottom panels show absolute water vapor abundances in all columns. NOMAD and MCS vertical profiles have been averaged within bins of 15° and 30° longitude respectively. The reference wavelength for the dust and water ice extinctions are 461 cm^{-1} and 843 cm^{-1}, respectively.

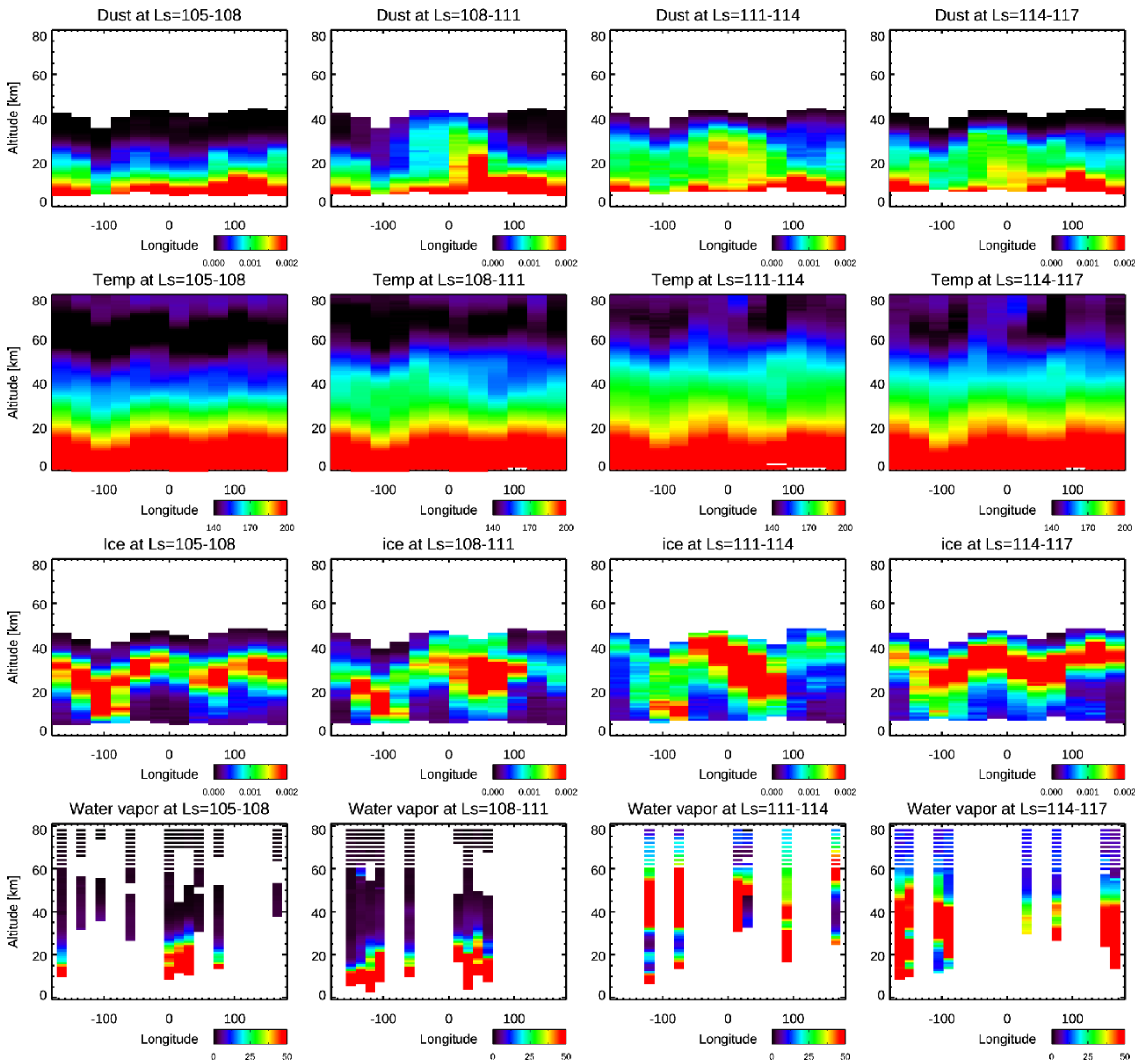

Fig. S3: Same as Figure S2 but absolute values for dust, water ice extinctions, and temperature are shown for all of the panels.

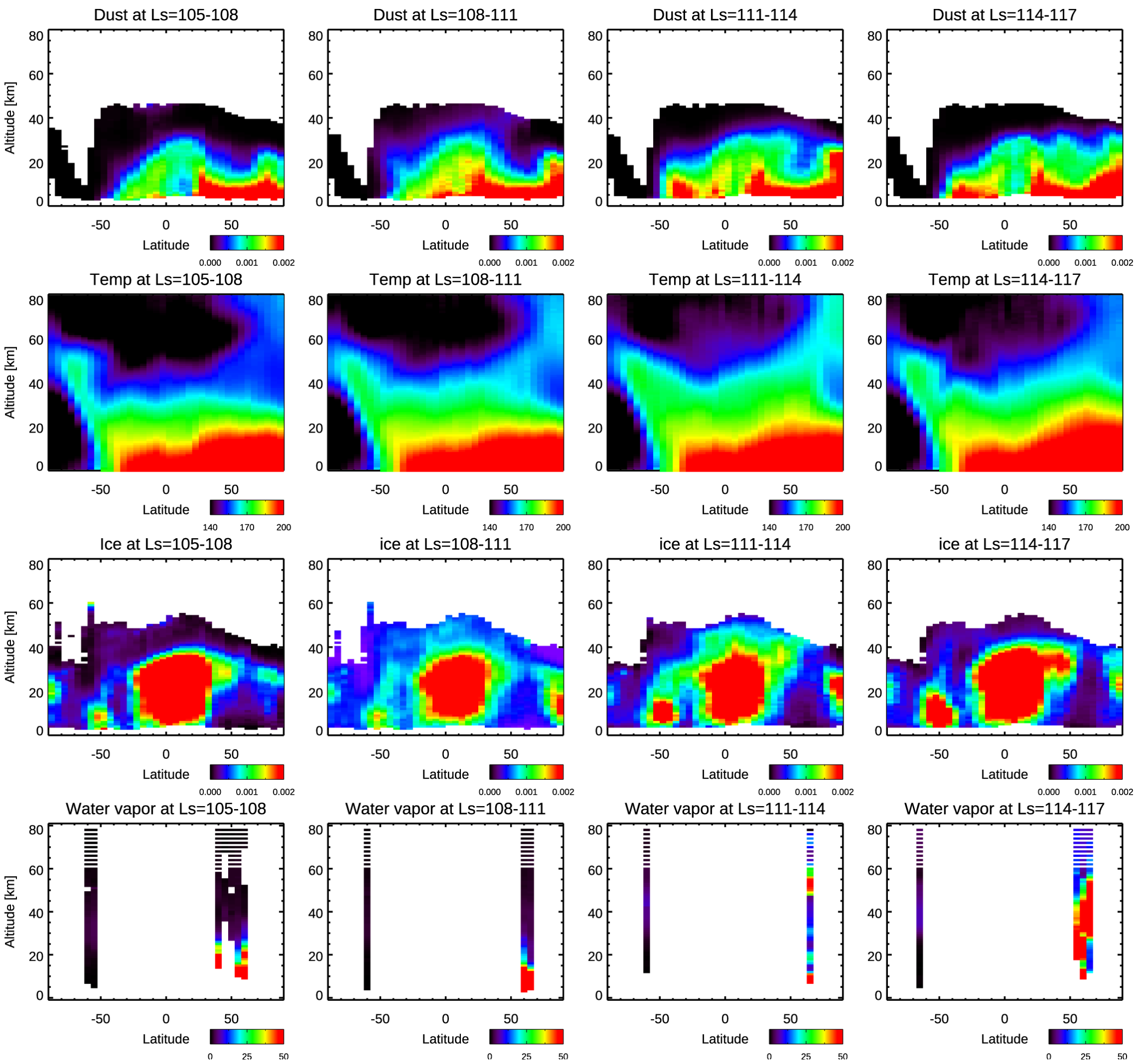

Fig. S4: Same as Figure 5 but absolute values for dust, water ice extinctions, and temperature are shown for all of the panels.

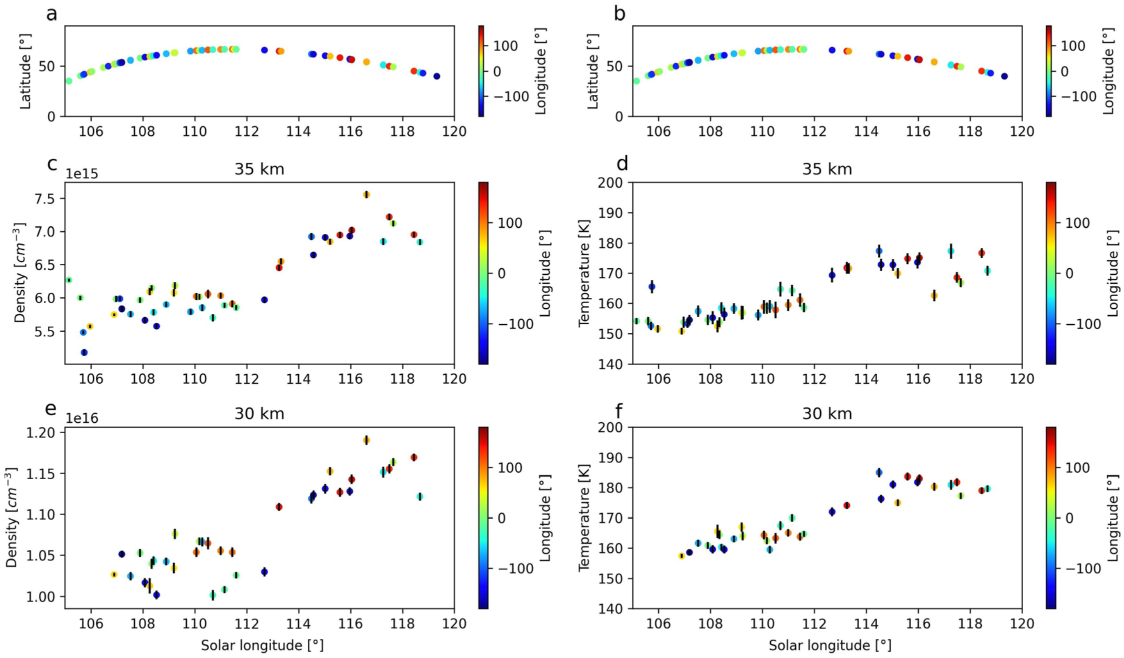

Fig. S5: Seasonal variation of CO_2 density (left) and temperature (right) at 35 km (panels c and d) and at 30 km (panels e and f) as measured by NOMAD during L_S=105º-120º in MY 37. Top panels show the latitude of the observations. Colors indicate the longitude of the observations.

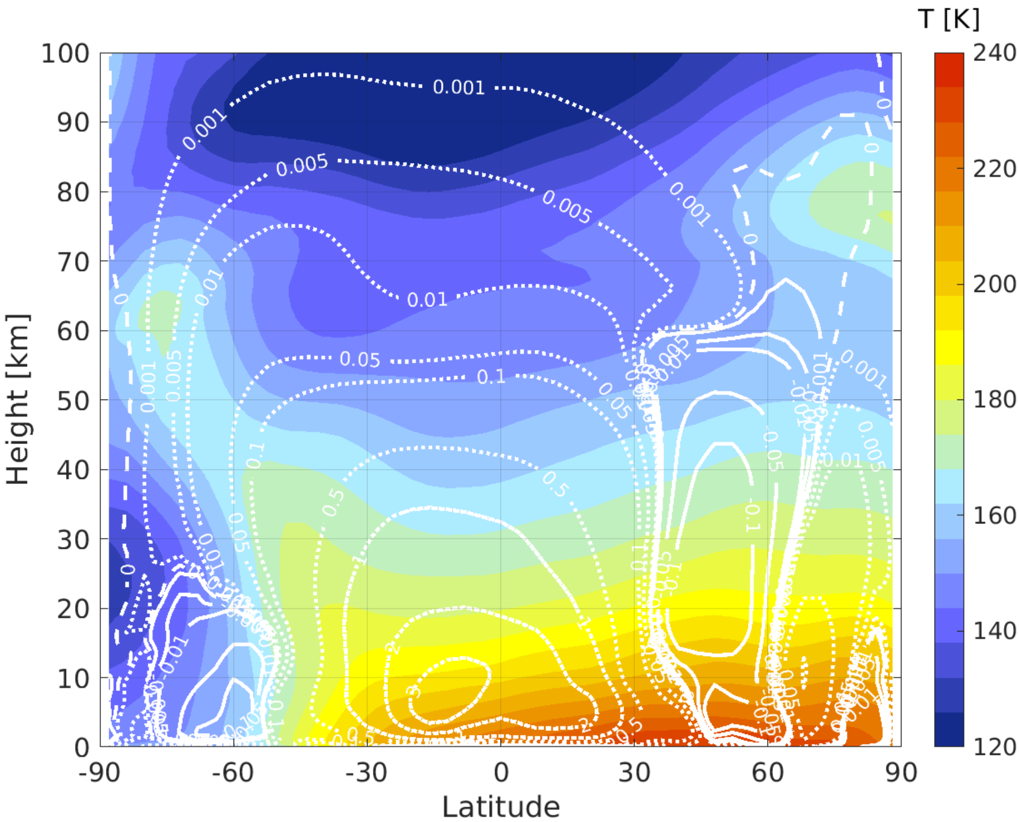

Fig. S6: Zonally averaged mass stream function (×10^9 kg/s, white contours) simulated in the GEM-Mars GCM (Daerden et al., 2019), averaged over 5 sols centered on L_S=110º. Full lines represent clockwise movement, and dotted lines represent counterclockwise movement of air. The color shading represents the temperature.