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Variation of CO/CO_2 profiles in the Marian mesosphere and lower thermosphere retrieved from TGO/NOMAD

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CO is produced by the photodissociation of CO_2 and recycled to CO_2 by the catalytic cycle involving HOx in the Martian atmosphere [e.g., McElroy & Donahue, 1972]. In the mesosphere and lower thermosphere (MLT) region of Mars, the number density of CO is determined by photodissociation, diffusion, and atmospheric circulation. The increase of the CO mixing ratio in the MLT region and further enhancement in the polar region due to the transport of CO-enriched air via meridional circulation are predicted in the 3D models [Daerden et al., 2018; Holmes et al., 2019]. On the other hand, the decrease in the CO mixing ratio in the MLT region during a global dust storm is detected by TGO/ACS, which suggests that the increase in the hygropause altitude leads to the increase in the vertical range over which OH becomes available to convert into CO_2 [Olsen et al., 2021]. Additionally, a substantial variation of the homopause altitude has been investigated [Slipski et al., 2018; Jakosky et al., 2017; Yoshida et al., 2020], which suggests that the order of magnitude changes in the eddy diffusion coefficient at the homopause [Slipski et al., 2018], and then variations in the profile of CO mixing ratio in the MLT region. However, the effects of change in the eddy diffusion coefficient on the profile of CO mixing ratio have not been investigated. The variability of the CO mixing ratio profiles can be a clue for understanding the dynamical coupling between the lower and the upper atmospheres.

To clarify the contributions of photochemistry, diffusion, and atmospheric circulation to the CO/CO_2 profiles in the MLT region, we use the Nadir and Occultation for MArs Discovery (NOMAD) instrument aboard Trace Gas Orbiter (TGO). NOMAD solar occultation is designed as the combination of the Acousto Optical Turnable Filter and echelle grating [Neefs et al., 2015; Thomas et al., 2016]. NOMAD solar occultation operates in the wavelength range of 2.2 - 4.3 μm (2320 to 4350 cm^{-1}) with a high spectral resolution ($\lambda/d\lambda$ = 20000) [Vandaele et al., 2018]. It provides us CO and CO_2 spectra below 100 km and 180 km altitudes, respectively.

In this study, we applied the equivalent width technique [Chamberlain and Hunten, 1987; Krasnopolsky, 1986] to derive a new set of CO and CO_2 column densities, respectively, with the observed atmospheric transmittance spectra by NOMAD solar occultation. The absorption lines

centered at 4285.0, 4288.2, and 4291.5 cm^{-1} for CO (2-0) band and 3358.7, 3364.9, and 3366.4 cm^{-1} for CO_2 (21102-00001) band are carefully selected for retrievals due to the contribution of nearby and central orders [cf. Liuzzi et al., 2019]. It is noted that the line strengths of the selected CO_2 have high sensitivity to the background temperature. In this study, we applied the vertical profiles of temperature simulated in the GEM-Mars model [Neary et al., 2018; Daerden et al., 2019]. We retrieve the CO and CO_2 slant column densities between 60 and ~100 km altitudes because those slant opacities are saturated below 60 km altitude. The CO and CO_2 spectra observed from April 2018 to September 2020, corresponding to from MY 34 Ls ~ 150 to MY 35 Ls ~ 280, are investigated.

We found that the retrieved CO/CO_2 ratio between 60 and ~100 km increases with altitude. A behavior of the decrease in the CO/CO_2 ratio during the global dust storm corresponds to the previous observations [Olsen et al., 2021]. However, the CO/CO_2 profiles also vary with season and latitude. For interpretation, the 1D photochemical model will be compared with newly obtained CO/CO_2 profiles, especially in order to discuss the contributions from the variations in eddy diffusion coefficient and photochemistry in the MLT region on Mars.