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Spectral observation of mesospheric CO_2 ice clouds in the Martian mid-low latitude using PFS onboard Mars Express

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Mars is the only known planet where CO_2 ice clouds can be observed. CO_2, main component of Martian atmosphere, can condense and form 'CO_2 ice clouds' in the coldest region; in the troposphere above polar night and in the mesosphere around equator. CO_2 ice has narrow spectral emission peak feature at 4.3 um. Unfortunately, polar cloud in the lower altitude is below thick atmosphere and this spectral feature can not be detected by strong CO_2 gas absorption. However, mesospheric cloud in low-mid latitude is enough high. Dayside nadir observation of OMEGA aboard the Mars Express spacecraft first detected such feature.

In this study, we attempted to detect the spectral feature of mesospheric CO_2 ice clouds in low-mid latitude at 4.3 um band by Planetary Fourier Spectrometer (PFS) onboard Mars Express. In this wavelength, its spectral resolution is ~1,000, about 10 times higher than that of OMEGA. It enables us to resolve the spectral features of CO_2 ice clouds with enough resolution to estimate their particle size comparing with synthetic spectra. We confirmed that PFS could detect this spectral profil on the orbits where OMEGA detected CO_2 ice clouds. In the PFS spectral resolution, we identified two spectral types, i.e., 'single-peak case' at 4.25 um and 'double-peak case' at 4.25 and 4.28 um, which were not resolved by OMEGA.

Based on this confirmation, we statistically surveyed the CO_2 ice features in all PFS data in 2004-2014 which covers MY 27-32. We identified 272 single-peak cases and 9 double-peak cases. Spatial and seasonal distributions of CO_2 ice clouds agreed with the previous studies. In spatial distribution, CO_2 ice clouds were detected in the latitude range of 20 degS to 20 degN and the longitude range of 100 degW to 30 degE and around 170 degE. In seasonal variation, almost all of CO_2 ice clouds were detected just after spring equinox (L_s: 0-30 deg).

In these samples, the spectral peak in the single-peak case and the first peak of double-peak case was centered at 4.252 um. From this observed feature, we derived the typical particle size of CO_2 ice clouds by the comparison with the synthetic spectra derived by a radiative transfer model with the assumption that cloud particles were made of pure CO_2 ice and had spherical shape. Refractive index of CO_2 ice is from experimental one. Although the observed single-peak feature was reproduced by the model, the peak wavelength appeared at ~4.27 um, shifted to 0.02 {¥mu}m longer position than the observed one. Such shift of the peak position could not be reproduced by various particle parameters, including radius, size variance, and column density. In addition, the synthetic spectra could not reproduce the double-peak structure observed by PFS. We proposed three possible cases to explain these discrepancies; (1) the uncertainty of the refractive indices, (2) non-spherical particle shape, and (3) different core material in CO_2 ice. For (1), we simply assumed that the model refractive index could be shifted 20 nm toward shorter wavelength. After that, we got satisfied agreement between the observed and model spectrum. Based on the matching of both spectrum, effective radii of observed CO_2 ice cloud were constrained in the range between 0.63 to 1.0 um. This is the first quantitative estimation of the CO_2 ice clouds using 4.3 um feature of CO_2 ice. The effective radii obtained by our model follows the line of CRISM observation (0.5-2.0 um) but slightly small compared with that of previous works. For (2) and (3), they can potentally produce double-peak features observed by PFS. It means that non-spherical haze with a core material might be actual characteristics of the Martian mespheric CO_2 ice cloud.