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Variability in atmospheric minor constituents in the mesosphere and lower thermosphere observed by the Superconducting Submillimeter-Wave Limb-Emission Sounder from the International Space Station

(国際宇宙ステーション搭載超電導サブミリ波リム放射サウンダによって観測された中間圏・下部熱圏の大気微量成分の変動)

Kota Kuribayashi

The mesosphere and lower thermosphere (MLT) is intermediate region between Earth’ atmosphere and space, and affected both from space and lower Earth’s atmosphere. High energy protons, produced by solar eruptions, reach to the MLT region and produce active radicals, such as nitric oxide and hydrogen oxide, which contributes to the natural ozone variability in the stratosphere. On the other hand, atmospheric waves induced in the lower atmosphere transports energy and momentum to the MLT region, which causes meridional and vertical circulations in the MLT region. The measurements of atmospheric minor constituents in the MLT region is difficult relative to one in the stratosphere, since the abundance of atmospheric minor constituents become smaller, and observation methods are limited. A quantitative understanding of the chemical, dynamical, and radiative behavior of minor constituents is required to improve the understanding of the atmospheric system in the MLT region.

The purpose of this thesis is to understand a feature and mechanism of chemical and dynamical behaviors of atmospheric minor constituents in the MLT region. The limb-emission spectra acquired by the Superconducting Submillimeter‐Wave Limb-Emission Sounder (SMILES) were used for this study. The SMILES spectra of ozone (O3) and hydroperoxy radical (HO2) were used to understand diurnal variations of hydrogen-oxygen chemistry in the MLT region, since O_3 and HO_2 are short-lived species in the MLT region. Moreover, the SMILES spectra of hydrogen chloride (HCl) were used to understand dynamics in the MLT region, since HCl is one of the long-lived species in the MLT region. The vertical, latitudinal, and seasonal variations of HCl are controlled by the dynamics in the MLT region. I developed the optimized retrieval algorithm for vertical profiles of O_3, HO_2, and HCl in the MLT region that includes (1) an improvement of an a priori profile and covariance matrix of target species using the Whole Atmosphere Community Climate Model version 4 driven with specified dynamical fields (SD-WACCM) calculations, (2) an optimization of spectral windows and retrieval altitude grid, and (3) an improvement of temperature and pressure profiles using the Ground-to-topside model of Atmosphere and Ionosphere for Aeronomy (GAIA) calculations. The vertical profiles of O_3, HO_2, and HCl in the MLT region were obtained with lower random and systematic errors compared with previous products.

I revealed the actual atmospheric conditions in the MLT region using SMILES observation data sets as follows: 1) Diurnal variations of HO_2 and O_3 from mesosphere to mesopause: The chemical mechanism of hydrogen-oxygen chemistry was qualitatively understood in MLT region including diurnal variation. 2) Vertical, seasonal, and latitudinal variations of HCl in the MLT region: The Cl atomic radical might open a new active chemistry in the MLT region after the anthropogenic chlorine injection into the atmosphere in the 1950s. Future investigations should be important for understanding what humans have done to the upper atmosphere.