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SMILES観測で明らかになった中層大気オゾンの日変動
Diurnal ozone variations in the middle atmosphere as revealed with SMILES observations

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Diurnal ozone variations in the middle atmosphere are controlled by both photochemistry and dynamics. The global and quantitative understanding of diurnal ozone variations is crucial for trend analysis, intercomparison of different satellite observations made at different local times, validation of CCMs and so on. Previous studies mainly used in situ observations such as ozone lidars for detecting the diurnal variability; in contrast, global observations have been only possible by the two non-Sun-synchronous satellite observations, i.e., UARS/MLS and TIMED/SABER. However, the results from the two satellite observations are not consistent quantitatively at some altitude levels in the stratosphere. The Superconducting Submillimeter-Wave Limb-Emission Sounder (SMILES) onboard the International Space Station is another non-Sun-synchronous satellite, which achieved global observations of minor constituents in the middle atmosphere with a very high accuracy during the period from October 2009 to April 2010. The purpose of this study is to obtain a global picture of diurnal ozone variations in the middle atmosphere, by using SMILES data as well as other satellite and CCM data sets.

We analyze ozone mixing ratio from four different observation/model data sets: (1) SMILES Version 2.0 data, (2) TIMED/SABER Version 1.07 data from the 9.6 micro-meter band, (3) SD-WACCM data, (4) CCSR/NIES Nudging CTM. These data are analyzed for the period of the SMIELS observations. For the non-Sun-synchronous SMILES (SABER) observations, 30 (60) days are needed to cover a whole diurnal cycle. In order to avoid sampling issues due to the background ozone changes, the 30-day (60-day) running mean has been subtracted from the original data for data (1, 3-4) (data (2)) in advance. Then, every 5 degrees in latitude and every ˜3 km in altitude, the residuals from the running mean are binned and averaged in 1-hour local-time bins, which are considered as diurnal variations in this study.

Figure 1 shows vertical distributions of diurnal ozone variations averaged for 10S-10N, as derived from SMILES and SD-WACCM data. The diurnal variations shown here are the relative values to the daily-mean for the analysis period shown also in Figure 1. We discover that the results from the two data sets agree quite well. The results from SABER observations show a roughly similar phase pattern as in Figure 1 but with much larger amplitudes (approximately twice) at 30-50 km. These findings suggest that SMILES has allowed us to obtain the global picture of diurnal ozone variations for the first time. In other words, diurnal ozone variations in CCMs (e.g., SD-WACCM) have been validated for the first time. The observed results are summarized and interpreted as follows. At 20-30 km, the diurnal harmonic component is dominant with the amplitude of 2-3%. Its phase shows a downward progression with altitude. An analysis of dynamical fields (temperature and winds from MERRA) suggests that this diurnal component is mainly controlled by the vertical transport associated with diurnal tides. At 30-40 km, ozone minimizes after dawn and increases toward the maximum in the afternoon. The amplitude is 2-5%. The dawn minimum is caused by the depletion of odd oxygen associated with the NOx chemistry, while the afternoon maximum is caused by the production of odd oxygen through the photolysis of molecular oxygen as suggested by Pallister and Tuck (1983). At 40-50 km, we observe similar diurnal variations seen at 30-40 km and additional minimum of ˜5% about at noon. This additional minimum is probably caused by the depletion of odd oxygen due to the HOx chemistry as also suggested by Pallister and Tuck (1983). Finally, above 50 km, the ozone shows a simple day/night contrast with an amplitude of ˜100% at maximum. This is caused by the high [O]/[O3] ratio in the upper atmosphere; i.e., the odd oxygen resides as atomic oxygen so that ozone shows a strong depletion during the day.

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