Comparison of Lower Tropospheric Water Vapor Vertical Distribution Measured with Raman lidar and DIAL and Their Impact of Data Assimilation in Numerical Weather Prediction Model

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To evaluate the performance of water vapor lidar for measuring the vertical distribution in the lower troposphere and its potential utility for numerical weather prediction, the vertical distributions of water vapor mixing ratio (w) were measured with a Raman lidar (RL) developed by the Meteorological Research Institute (MRI) and a differential absorption lidar (DIAL) that is being developed by Vaisala. The measurements were made continuously over two months in the summer of 2020 at Tsukuba, Japan. We compared the lidar-derived w with those obtained with radiosondes that were launched 80 m from the lidar twice daily (9 and 21 LST). The result of the comparison showed that the mean bias (and root-mean-square deviations, RMSD) of w were 0.075 g/kg (1.45 g/kg) and −0.20 g/kg (0.79 g/kg) for RL and −0.17 g/kg (0.80 g/kg) and −0.10 g/kg (0.97 g/kg) for DIAL at 9LST and 21LST, respectively, with correlation coefficients higher than 0.99. Notably, the RL-derived w values were mostly 0.2–0.5 g/kg higher than those obtained with the radiosonde at an altitude of 0.1 km, possibly because of the inaccurate correction of the overlap between the laser beam and receiver's field of view. The DIAL-derived w values were 0.6–0.7 g/kg lower than those derived obtained with the radiosonde below 0.5 km and 1−2 g/kg higher above 1 km. The probable reasons for that were the problems of algorithm of the software computing w from the lidar signal and the parameter setting of the hardware and software according to the manufacturer.

We assimilated the lidar-derived w in the initial condition of the mesoscale model (MSM) developed by the Japan Meteorological Agency (JMA) by means of a four-dimensional variational (4D-Var) method to study impact of the lidar data on the water vapor field predicted by the model. The results of the assimilation experiment showed that the w values predicted by MSM got closer to the radiosonde-derived values by assimilating RL and DIAL data. The correction by assimilating RL data was slightly better than DIAL data. The mean bias (and RMSD) of w predicted by MSM from those observed with the radiosondes between 0 and 2 km in altitude were −0.13 g/kg (1.04 g/kg) and −0.25 g/kg (1.08 g/kg) by assimilating RL data and DIAL data, respectively, whereas they were −0.4 g/kg (1.2 g/kg) without assimilation of the lidar data. Possible reasons for the difference in the corrections were the differences in bias and RMSD of the RL and DIAL data. These results showed that 1) assimilating the lidar water vapor data in the model can correct the predicted water vapor field and 2) the measured data with smaller bias and RMSD have a better impact on the prediction of water vapor field.