Climatology and origin of small-scale vertical structures in stratospheric ozone

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To understand the small-scale transport and mixing in the stratosphere which are not resolved by assimilated meteorological data, the climatology and origin of vertical structures (less than 2 km) of stratospheric ozone are investigated. The data used are the global data of the routine ozonesonde observation in the lower stratosphere and the optical ozonesonde data obtained in the upper stratosphere at Sanriku (39.16N, 141.83E) during about ten years mainly in summer.

Vertical structures of ozone in the lower stratosphere can be attributed to dynamical processes, i.e. vertical advection and horizontal advection, since ozone lifetime exceeds several months in the lower stratosphere. A powerful method to distinguish between vertical advection and horizontal advection as the cause of ozone laminae is to investigate the correlation between the fluctuations of ozone mixing ratio and potential temperature. Positive correlation indicates that vertical advection is responsible for the ozone fluctuation, while no correlation means that horizontal advection is responsible for the ozone fluctuation. It was found that the correlation increases with decreasing latitude and such a latitude dependence is not a local but a global feature. In the midlatitude, there exists a distinct seasonal variation of the correlation with a maximum in late summer and a minimum in late winter. The results of the correlation coefficient, the mixing ratio variability and the gravity wave activity in the midlatitudes suggest that horizontal advection becomes active and overwhelms vertical advection in late winter, thereby lowering the correlation in this season.

The contribution of shear instability and convective instability to the irreversible vertical mixing of ozone was demonstrated based on a case study with the aid of meteorological data obtained by ozonesondes. Statistical studies showed that the vertical mixing under the condition of shear instability occurs frequently in the lower stratosphere.

In the upper stratosphere, the contribution of vertical advection to ozone fluctuations is limited. Photochemical processes also cannot explain the observed ozone laminae: the ozone fluctuations expected by the observed temperature fluctuations are much smaller than the observed ozone fluctuations. These results suggest that horizontal advection will be the principal process of creating ozone laminae structures in the upper stratosphere, although the process could not be confirmed with assimilated meteorological data.