Diffusive separation of major atmospheric components in the stratosphere over Indonesia

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In the atmosphere over the turbopause (about 100 km), the mole fraction of heavier molecules decreases with increasing altitude due to diffusive separation in Earth's gravitational field. Recently, Ishidoya et al. (2013) reported such gravitational separation of the atmosphere is also found in the middle to lower stratosphere (about 15-35 km) over Japan from high precision measurements of the composition of the atmospheric major components. To investigate whether gravitational separation is also detectable over the equatorial region or not, we carried out collection of the stratospheric air using a balloon-borne cryogenic air sampler over Biak, Indonesia during February 22-28, 2015. For the observation, we used a Joule-Thomson minicooler, developed by Morimoto et al. (2009), as the cryogenic air sampler, and succeeded to collect 8 air samples at heights of 17-29 km. The collected air samples were analyzed for delta(Ar/N_2), delta(O_2/N_2), delta^{15}N of N_2, delta^{18}O of O_2 and delta^{40}Ar by using a mass spectrometer (Ishidoya and Murayama, 2014), and the measured values showed small but significant decrease with altitude probably due to gravitational separation. The amount of gravitational separation, evaluated as delta values for the mass number difference of 1 (e.g. delta for $^{15}N^{14}N/^{14}N^{14}N$), is found to be 11 per meg at the height of 29 km. Based on the observed gravitational separation and a 1-dimensional steady state eddy diffusion/molecular diffusion model, we estimated 1-dimensional vertical eddy diffusion coefficients (K_z) over the equatorial region. By using the average K_z from the surface to the middle stratosphere, we calculated a timescale of the vertical diffusion for a length scale from the surface to the middle stratosphere assuming simple Fickian diffusion. We found that the calculated timescale agrees with the elapsed time since the stratospheric air passed an upper boundary of the tropical tropopause layer (TTL), estimated from tape recorder signals of stratospheric water vapor (Mote et al., 1996), which is significantly smaller than the mean age of air estimated from CO_2 concentration (CO_2 age). This discrepancy may be due to insensitivity of gravitational separation to mixing processes in Brewer-Dobson circulation, of which variations change the mean age of air significantly.

References

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Keywords: gravitational separation of atmospheric components, cryogenic air sampler, stratosphere over Indonesia

