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Decadal changes in ozone and ozone-depleting substances and their link to stratospheric circulation changes

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Monthly zonal mean distributions of ozone, ozone-depleting substances, and age of stratospheric air have been derived from ten years of global observations with the MIPAS/Envisat instrument. They reveal systematic decadal variations, showing up as hemispherically asymmetric patterns if characterized as linear trends. This has been demonstrated recently from MIPAS observations (Stiller et al., 2012; Haenel et al., 2015; Eckert et al., 2014; Kellmann et al., 2012; Chirkov et al., 2016), but also from independent measurements (Mahieu et al., 2014; Nedoluha et al., 2015; Harrison et al., 2015). We demonstrate that these patterns can be explained by a shift of the stratospheric circulation over the time of the MIPAS observation period. We show that the subtropic mixing barriers were shifted southward by about 5 degrees from 2002 to 2012, resulting in a shift of the global distribution patterns. The southward shift can explain the changes in ozone, CFC-11, CFC-12, HCFC-22, N2O, NO_y, and age of air. If trends of ozone or trace gases are calculated without taking into account the variation in circulation as demonstrated here, unrealistic and inconsistent trends are derived as a consequence. As an example, the observed increase of tropical lower stratospheric ozone around 20 km might be interpreted as a sign for a slow-down of the Brewer-Dobson circulation, however it comes together with an decrease of the age of stratospheric air at that location (i.e. acceleration). This discrepancy is solved if the shift of the circulation pattern is taken into account.

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