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Long-term changes in mean age of air and stratospheric chlorine

Stratospheric trace gases like HCl and N2O show a hemispheric asymmetry, with trends over the last two decades having opposing signs in the Northern Hemisphere (NH) and Southern Hemisphere (SH). Some of this difference is due to hemispherically asymmetric changes in the rate of transport by the Brewer–Dobson circulation (BDC). Mean age of air (AoA) is a common proxy for the transport rate by the BDC in models; however, it cannot be directly measured. Long term changes in transport, and thus AoA, also complicate the analysis of trends in stratospheric chlorine when compared to changes in surface emissions of ozone depleting substances (ODSs) regulated by the Montreal Protocol.
Here we use N2O as a proxy for the stratospheric circulation to calculate long-term trends in trace gases and AoA. First, N2O observations from ACE-FTS are combined with results from CLaMS simulations driven by 4 different reanalyses to derive AoA anomalies. We find that, irrespective of which reanalysis is used, air in the NH aged by up to 0.3 years per decade relative to the SH over 2004–2017. The maximum hemispheric difference in aging occurs in the middle stratosphere, near 30 hPa. We also show that the aging rate in the NH becomes smaller when the analysis is extended to 2021. Furthermore, we use the N2O proxy to analyze how much of decrease in stratospheric chlorine is related to transport variations and how much is driven by the reduction in chlorinated long-lived ODSs. We show that the observed decrease in stratospheric chlorine is 25%–30% smaller than expected based on trends of long-lived ODSs alone. This can be explained by the increase in chlorinated very short-lived substances, which offsets the long-term reduction of stratospheric chlorine by up to 30%.

Topic

Atmospheric composition (Earth and planets), chemistry and transport

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