Geophysical Research Abstracts
Vol. 19, EGU2017-10791, 2017
EGU General Assembly 2017

On the unsteady decline of atmospheric CFC-11: Bumps in the road to ozone recovery or variations in atmospheric transport and/or loss?

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Atmospheric mole fractions of the ozone-depleting and greenhouse gas CFC-11 have declined since 1995 owing to global controls on production associated with the fully adjusted and amended Montreal Protocol on Substances that Deplete the Ozone Layer. From 2002 to 2012, CFC-11 mole fractions in both hemispheres decreased at a near-constant rate of 2.2 $\pm$ 0.2 ppt/yr. Assuming a constant atmospheric loss frequency, these results suggest that CFC-11 emissions did not decrease over this 11-yr period. This conclusion is difficult to reconcile with an idealized model of emissions being sustained by leaks from a shrinking reservoir of CFC-11 (reported global production has been negligible since 2007). Even more surprising, from 2013 to 2015 the atmospheric decline slowed appreciably (mean global rate was –1.3 $\pm$ 0.1 ppt/yr) and the hemispheric difference (N – S) increased by 50%. Here we consider the implications of these atmospheric changes. When analyzed with a simple 3-box model and constant loss frequency or a 3-D climate model (WACCM) with specified dynamics, the observations suggest global CFC-11 emissions in 2014-2015 that were 30% (15 Gg/yr) larger in 2014 and 2015 compared to the 2002-2012 mean. Are emissions of this globally controlled Class 1 ozone-depleting substance actually increasing despite global reported production being negligible for nearly a decade? Or do anomalies observed for multiple trace gases during these periods suggest significant changes in stratospheric loss and mixing processes that are not captured by global models using estimates of actual meteorology?