Variation in instantaneous lifetimes of ozone depleting substances, in relation to stratospheric circulation

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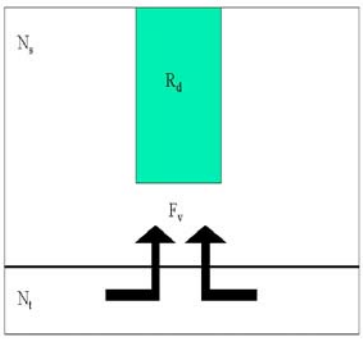
It is vital to anticipate how the lifetimes of Ozone Destroying Substances (ODS) will develop in the future. This will enable the prediction of the rate at which the reduction of ODS in the stratosphere (and consequently the recovery of the ozone layer) will proceed. To provide an insight into the link between ODS lifetimes and general circulation, the 3-D offline chemical transport model MEZON is used[1]. The results of multi-year simulations, using input fields from both ERA-40 and UKMO assimilations, are presented and a correlation between variation in the instantaneous lifetimes of ODS and changes in aspects of the stratospheric circulation over the last 10 years is sought. A good correlation between tropical vertical mass flux and instantaneous lifetimes of several ODS is found.

Lifetimes



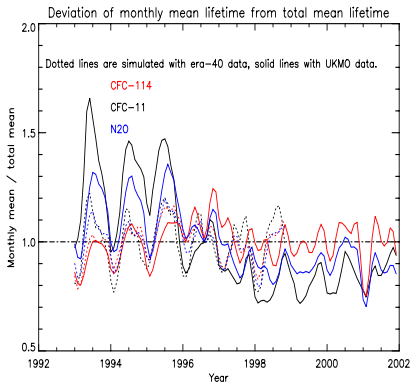
What affects the lifetimes of ODS? The ODS are transported at a rate N_t*F_v from a reservoir region into a region where they are broken down at some rate N_s*R_d. Here N_s and N_t refer to the ODS concentration in the destruction and reservoir regions respectively. F_v and R_d are transport and destruction rates.

The **steady state** lifetime is then given by :

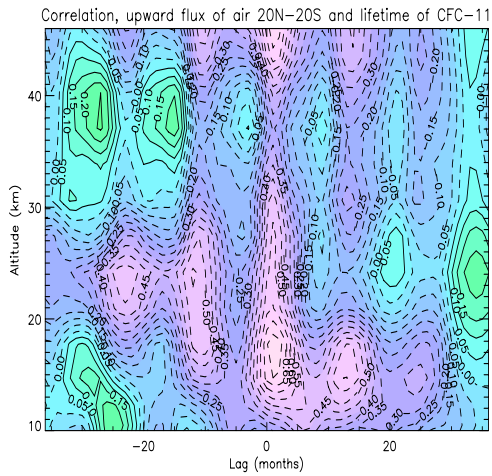
$$T=(1/R_d)+ (1/F_v)$$

Thus, those ODS with relatively short lifetimes (i.e. large R_d) will have a lifetime which is highly dependant on the rate of transport into the region of destruction.

Simulated lifetimes with the new ERA-40 wind and temperature fields show some differences from the lifetimes simulated using the UKMO data. Most notable is the absence of a substantial decline in lifetime after about 1996 when ERA-40 data is used.



Correlation of lifetime with mass flux



The plot above shows the correlation between zonal mean mass flux F_v (20°S – 20°N) and global instantaneous lifetime of CFC-11 at various altitudes. The "pumping" by the Brewer-Dobson circulation is clearly visible with strongest anti-correlations at ~ 17 km, just above the tropical tropopause. The region of highest photolysis for CFC-11 is between 18 km and 34 km. The lag between the lifetime and the transport rate of ~ 2 months corresponds to the time needed by an air mass to ascend from the tropopause to the region of maximum photolysis. The correlation for CFC-114 (not shown), which is longer lived than CFC-11 (steady state lifetimes of about 45 and 300 years, respectively[4]) is much weaker after about 1996.

Conclusions

Although there is a clear correlation, we find it difficult to quantify the effect of changes in vertical mass flux on lifetimes of ODS. For the longer lived species (such as CFC-114) meridional transport out of the area where photolysis occurs, may have a significant impact on the lifetime. This is not as important for shorter lived species such as CFC-11, which is destroyed lower in the atmosphere.

The variations in lifetimes, shown in the first figure, correspond to variations in destruction of ODS. Thus, it may be reasonable to expect that the same processes, which affect the lifetimes of ODS, cause variations in stratospheric chlorine loading, and therefore chlorine catalysed ozone destruction. We intend to examine this issue in the near future.

[1] E.V. Rozanov, V.A. Zubov, M.E. Schlesinger,F. Yang, N.G. Andronova, *The UIUC three-dimensional stratospheric chemical transport model: Description and evaluation of the simulated source gases and ozone*, JGR, Vol. 104, No. D9, 11755-11781, May 20 1999

[4] IPCC, 2001: *Climate Change 2001: The scientific basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change* [Houghton, J.T., Y. Ding, D.J. Griggs, M. Noguer, P.J. van der Linden, X. Dai, K. Maskell, and C.A. Johnson (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 881pp.