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# Understanding $NO_2$ and $O_3$ changes in tropical mid-stratosphere by means of a chemistry-transport model

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The decline in the atmospheric abundance of halogenated Ozone Depleting Substances (ODS) is a successful outcome of the Montreal Protocol (and amendments) and is expected to result in a global ozone ($O_3$) recovery. Nevertheless, there are other factors that affect the abundance of $O_3$ in the atmosphere, such as non-halogen chemical species, changing climate with its natural forcings, volcanic activities, solar effects etc. Hence, stratospheric $O_3$ is expected to demonstrate dynamical and chemical variability over many timescales, which needs to be understood in order to have confidence in recovery from ODSs.

An unexpected negative change in $O_3$ has been observed in the tropical stratosphere at altitudes around 30-35 km within the period 2004-2012. An analysis of trends from the SCanning Imaging Absorption SpectroMeter for Atmospheric CHartographY (SCIAMACHY) showed a decrease in $O_3$ concentrations, which is associated with an increase in $NO_2$ concentrations. This coupling between stratospheric $O_3$ and $NO_2$ is well recognized, with the latter being the major ozone-depleting substance in the altitude range 25-40 km. However, the driver for the observed change in $NO_2$ is not yet clearly identified.

To analyze possible and plausible causes of the observed changes in $O_3$ and $NO_2$ we use TOMCAT/SLIMCAT Chemistry-Transport Model (CTM) with different chemical and dynamical forcings to quantify their impacts. The model is driven by European Centre for Medium-Range Weather Forecasts (ECMWF) ERA-Interim reanalyses to specify the atmospheric transport and temperatures and calculates the abundances of stratospheric species using a detailed chemical scheme.

The model generally does well in capturing features of the observed variability in tropical $NO_2$ and $O_3$. Our simulations show that the +7%/decade trend in $NO_2$ is due to a similar positive trend in reactive odd nitrogen ($NO_y$), which is associated with a decrease (5 %/decade) in $N_2O$.

In this presentation, we discuss the impact of both dynamical features (via age-of-air simulations) and chemical processes that could lead to the change in the tropical mid-stratospheric $N_2O$ from model simulations, which in turn, indirectly impacts $O_3$.