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# Pathways and Timescales for Troposphere-to-Stratosphere Transport via the Tropical Tropopause Layer and their Relevance for Very Short Lived Substances

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At tropical latitudes, convection rapidly lifts air from the planetary boundary layer (BL) into the tropical tropopause layer (TTL). Much of this air subsequently descends back into the mid troposphere. However a fraction is transported to the stratosphere. Very 'deep' convection may penetrate the tropopause and inject air from the BL directly into the stratosphere. Either way, if troposphere-to-stratosphere transport (TST) is sufficiently rapid, an appreciable fraction of very short lived substances (emitted in the BL) may reach the stratosphere and contribute to the depletion of ozone.

We have carried out a number of tracer experiments using a chemistry transport model (CTM) and trajectory experiments to investigate TST via the TTL in January 2001. The following picture emerges: most transport (approximately two thirds) from the BL to the TTL takes place near-vertically above the Indian Ocean, Indonesia and the West Pacific. In contrast, we find no preferred region for subsequent transport to the stratosphere: we do not observe a 'stratospheric fountain'. Moreover, this transport is dominated by quasi-isentropic transport into the extratropical lowermost stratosphere (ELS) as opposed to ascent into the 'overworld'.

From the base of the TTL, air is transported to the ELS on an e-folding timescale of approximately 100 days. In contrast, transport to the 'overworld' takes place on a

timescale of approximately 1000 days. These average timescales are long since most air from the base of the TTL (approximately three quarters) descends into the mid troposphere. However, an average timescale is not necessarily the most useful measure. For example, that transport which does take place into the ELS, does so on a much shorter timescale (approximately 4 weeks) and therefore represents an important route by which very short lived substances may reach the lower stratosphere and contribute to the depletion of ozone.

In addition to studying the pathways and timescales on which TST takes place, we have compared transport in the tropical upper troposphere and lower stratosphere as modelled using a relatively low resolution CTM and high resolution trajectories. The two approaches yield very similar results and suggest that CTMs can capture the details of transport in this region sufficiently well for the purposes of chemical assessment modelling with reference to the role of very short lived substances.