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Transport of short-lived species into the Tropical Tropopause Layer

M. J. Ashfold (1), N. R. P. Harris (1), E. L. Atlas (2), A. J. Manning (3), and J. A. Pyle (1)

(1) Department of Chemistry, University of Cambridge, Cambridge, UK, (2) Rosenstiel School of Marine and Atmospheric Science, University of Miami, Miami, USA, (3) Met Office, Exeter, UK

Very short-lived substances (VSLS) could be the source of around a quarter of the bromine that destroys ozone in the lower stratosphere. However, the size and distribution of VSLS sources, and the rate and paths of their transport from surface to stratosphere remain uncertain. Aircraft measurements up to the tropical tropopause layer (TTL), which might help to reduce these uncertainties, are limited and exhibit significant variability. It is also questionable how representative of the larger-scale reality any particular set of such VSLS measurements might be, but modelling techniques should help to place the observations in context. We use NAME, a trajectory model, to investigate the conditions that could have influenced one such set of measurements, made during the SHIVA campaign, which took place in Borneo during November 2011. We examine the routes and timescales over which air parcels reach the TTL above Borneo during three previous years, with the aim of assisting the planning of the aircraft campaign. The method we use, and the results outlined below, should prove useful in planning and interpreting measurements made during other similar campaigns.

We first study the TTL above Borneo in November 2008, under neutral El Nino/Southern Oscillation (ENSO) conditions. Air parcels (trajectories) arriving in the lower TTL (below $\sim$15km) are most likely to have travelled from the boundary layer (BL; <1 km) above the West Pacific. Few air parcels found above $\sim$16 km travelled from the BL in the previous 15 days. We then perform similar calculations for moderate El Nino (2006) and La Nina (2007) conditions and find year-to-year variability consistent with the phase of ENSO: under El Nino conditions fewer air parcels travel from the BL to the TTL above Borneo; during the La Nina year, more air parcels travel from the BL to the mid and upper TTL (above $\sim$15km) than in the ENSO-neutral year and again they do so from the BL above the West Pacific. We also find variability within each of the studied months, with day to-day differences of up to an order of magnitude in the fraction of an idealised short lived tracer travelling from the BL to the TTL above Borneo. Finally, to validate our approach, we consider measurements made in two previous campaigns. The features of vertical profiles of short-lived species observed in the TTL during CR-AVE and TC4 are in broad agreement with calculated vertical profiles of idealised short-lived tracers.