

This animation shows the meridional projections of Sample 8 air parcels migrating backward in time driven by three-dimensional wind of ERA-Interim, ACTM-NUDG, and ACTM-FREE meteorological fields. It runs for one year since the initialization on 27 February 2015. The black contours represent the residual stream function at  $\pm(0.1, 0.2, 0.5, 1, 2, 4, 8, 15, 30, 50)$   $\text{kg m}^{-1} \text{s}^{-1}$ ; solid and dashed contours are positive and negative values, respectively. The air parcels and the contours of zonal mean potential temperature are colour-coded. The thick red lines are the zonal mean potential vorticity ( $2 \times 10^{-6} \text{ m}^2 \text{ s}^{-1} \text{ K kg}^{-1}$  (PVU) in solid and 4 PVU in dashed lines) as proxies of the extratropical tropopause drawn outside of  $15^\circ$  latitude.