



Climatology of cross-tropopause mass exchange over the Tibetan Plateau and its surroundings

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The cross-tropopause mass flux (CTMF) and long-term trends in stratosphere–troposphere exchange (STE) over the Tibetan Plateau (TP) and its surroundings were analyzed using European Centre for Medium-Range Weather Forecasts reanalysis data. The gross CTMF (the sum of upward and downward mass flux) shows an evident wave train structure over the TP, which is mainly related to the horizontal exchange of air masses along the tropopause associated with the sharp meridional gradient in tropopause pressure or vertical discontinuity of the thermal tropopause in winter. The seasonal cycle of the STE over the TP shows that the gross mass flux is downwards in Northern Hemisphere (NH) winter and upwards in NH summer.

The gross CTMF over the TP accounts for 2.96% of the global total CTMF arising from STE processes resolved by Wei method. Both the upward and downward CTMF over the TP exhibit statistically significant positive trends in winter during the period 1979–2009. The strong positive trends of STE in winter over the TP are resulted from the combined effects of the rising tropopause height, enhanced westerlies and decreasing plateau winter monsoon. In summer, both the upward and downward CTMF exhibit statistically significant negative trends over the northern TP, while the trend in upward CTMF is positive over the southern TP, in accordance with the increasing intensity of Asian summer monsoon in recent decades. The sensitivity simulations with a climate model confirm that changes in the Asian monsoon can significantly affect the tropopause and the CTMF over the TP.