Seasonal Variation of Global Stratosphere-Troposphere Mass Exchange

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1. Background

Air mass and trace constituents exchange between the stratosphere and the troposphere has long been a crucial problem in meteorology, climatology, and atmospheric chemistry. Since stratospheric air has high potential vorticity (PV), rich ozone and low water vapor and chlorofluorocarbons(CFC) compared with the troposphere, transport and mixing between the stratosphere and troposphere can lead to changes in the chemical and dynamical characteristics of the atmosphere. Large scale and long term calculations of CTME are absolutely essential in order to understand global CTME in seasonal, interannual and even decadal timescales.

2. Purpose

The purpose of the current study is to diagnose the global and regional distributions of the time averaged CTME. The roles of individual processes are examined, including horizontal movement of air at the tropopause, vertical movement of air at the tropopause, and the shift of the of the tropopause itself.

3. Data and methodology

ECMWF reanalysis data from 1958 to 2001 was used, with 2.5°by 2.5°horizontal resolution, 23 levels in the vertical and an interval of 6 hours each day. In the present study, Wei formula was used to calculate Cross Tropopause Flux (CTF) in pressure coordinate, where ω= P/ Dt is the vertical velocity, V the vector horizontal velocity, P_{tp} the tropopause pressure, F_{AM} the mass exchange caused by air movement, and F_{TM} the mass mass exchange by tropopause movement.

$$F(p) = -g^{-1}\left(\frac{dP}{dt} - \frac{\partial P_{tp}}{\partial_t} - V \cdot \nabla P_{tp}\right)$$
$$= \left[\frac{1}{g}(V \cdot \nabla P)_{tp} - \frac{\omega}{g}\right] + \frac{1}{g}\frac{\partial P_{tp}}{\partial_t} \qquad (1)$$
$$= F_{AM} + F_{TM}$$

Determination of P_{tp} the dynamical definition 3.5PV Unit pole-ward of 30°latitude and the thermal definition 380K equatorward of 10°latitude. The analysis in subtropics was based on a weighted average of dynamically and thermally derived tropopause pressure according to:

$$P = WP_{dynamical} + (1-W)P_{380K} \qquad (2)$$
$$W = A\sec h(\varphi) + B\varphi^2 + C \qquad (3)$$

The coefficient s in (3) are empirically derived such that W = 1 at ϕ= 30°, W = 0 at ϕ= 10°and W =0. 5 at ϕ= 20°

4. Rezults and summary

a. Indonesia, bay of Bangl and the mid-west coast of the South Africa are the main channels of the upward mass flux into the stratosphere. Upward and downward transport of mass at the middle and high latitude accompany with each other. Downward transport from the stratosphere to the troposphere mainly appears near the large scale troughs , while transport of mass to the stratosphere generally occurs down stream and pole-ward of the mid-latitude outflow regions. Mass transport into troposphere is stronger in autumn and winter than in spring and summer(fig.1,3,4,5,6).

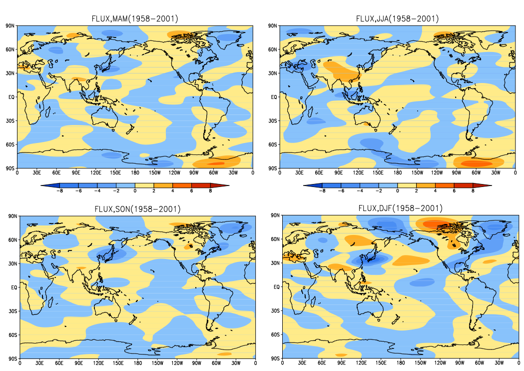

Fig. 1. Seasonal stratosphere2troposphere mass flux exchange for spring (MAM); summer (JJA) ; autumn (SON) and winter (DJF), Positive(negative) values indicate a time-mean mass flux from the troposphere (stratosphere) into the stratosphere (troposphere) (Contour interval: 10^{-4} kg·m^{-2}·s^{-1})

b. Strong downward cross tropopause mass flux appears in eastern Asia. Although the area of eastern Asia account s to only 5. 6 % of that of the NH , it s net mass exchange reaches 15. 83 % of that of the NH ,which means that CTME in eastern Asia is highly important to that of the NH and even the globe. Owing to the peculiar geographic situations and general circulation characteristics of eastern Asia and in peticular Qinghai Tibetan Plateau , it is worth researching on CTME of the two regions especially on the correlated mechanisms.(fig.2,5)

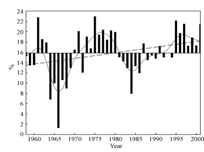

Fig. 2. Ratio of annual cross2tropopause mass exchange in eastern Asia to that of the NH (column bar). The dot dash line is the Gauss 92point filter curve of the ratio ; long dashed line indicates the tendency of the ratio.

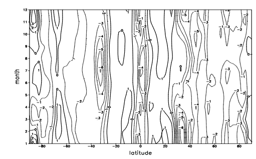

Fig. 3. Seasonal variation of monthly mean and zonal mean cross tropopause mass flux. Positive (negative) values indicate a time-mean mass flux from the troposphere (stratosphere) into the stratosphere (troposphere) . Contour interval: 10^{-4} kg·m^{-2}·s^{-1}. Positive (negative) values in abscissa present northern (southern) latitude, 0 is the equator.of annual cross tropopause mass

c. Contribution of HMA horizontal mass exchange is the largest between 5°S and 5°N , while VMA vertical mass exchange is the biggest poleward of 10° in the tropics in both hemispheres. CTMF at middle and high latitude is the difference between HMA and VMA with opposite phase but nearly the same order of magnitudes

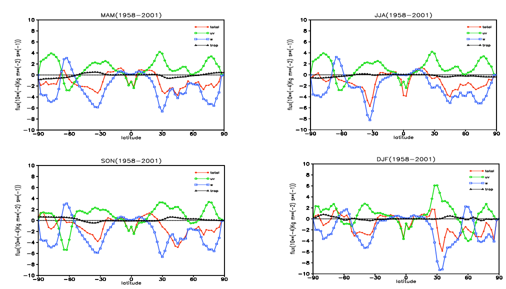

Fig. 4. Seasonal mean and zonal mean cross2tropopause mass flux exchange (total) and that caused by the horizontal movement of air (uv) , vertical movement of air (w) , and the movement of the tropopause itself (trop) for spring (MAM); summer (JJA); autumn (SON); and winter (DJ F). Positive (negative) values indicate a time-mean mass flux from the troposphere (stratosphere) into the stratosphere (troposphere). (Contour interval: 10^{-4} kg·m^{-2}·s^{-1})

d. It is noted by Gettelman[28] that it is essential for accuracy of the prognosticated data and the assimilated data in order to use Wei method. Biases from data may lead to obvious deviation from the result s. From our analysis , net cross tropopause mass exchange CTME is from stratosphere to troposphere , which is probably caused by systematic errors of the assimilated data and the persistent ascent of the tropopause height .CTME negatives in the equator may be due to the persistent cooling on equipotential temperature surface in the assimilated data.(fig.3)

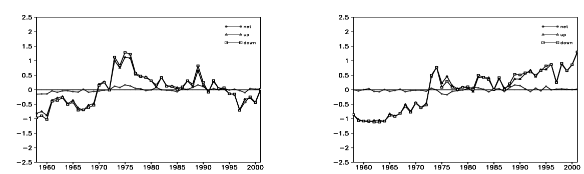

Fig. 5. Annual cross tropopause mass exchange anomaly in NH (a) and SH (b) . Dot solid line indicates net exchange , and triangle2 solid (square) line is the exchange from the troposphere (strato2 sphere) into the stratosphere (troposphere)) (unit : 1017 kg) .

e. Contributions of the mass exchange and the mass flux exchange in NH and SH to their latitudes increase from equator to pole , with larger contributions in the NH. Mass exchange and mass flux exchange per area are larger at high latitudes than at low latitudes , which implies greater mass exchange efficiency at high latitudes. It should have become a very critical issue for the study on CTME in the polar regions.(fig.7,8)

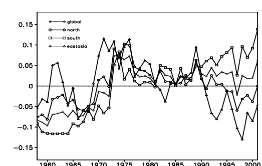

Fig. 6. Percentage of the balance between the total transportation (upward and downward) and 442year averaged transportation in 442 year averaged transportation.

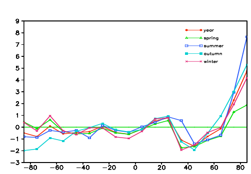

Fig. 7. Latitudinal ratio of the net mass flux exchange to theri ar2 eas (unit : 10 - 16 kg·m- 2·s - 1) . Positive (negative) values in ab2 scissa represent northern (southern) latitude ; 0 is the equator.

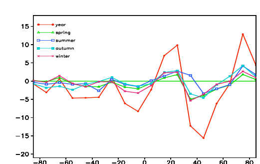

Fig. 8. Latitudinal ratio of the net mass exchange to their areas (103 kg ·m- 2) . Positive (negative) values in abscissa represent northern (southern) latitude ; 0 is the equator.