# Mass circulation variations due to seasonal and longer term variations in the middle atmosphere circulation

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Keywords

Middle Atmosphere, Seasonal Variations, Mass Circulation, Numerical Simulation

## 1. Background

Air mass flows from the troposphere in low-latitudes into the middle atmosphere, where there are meridional flows from low-latitudinal region to both polar regions(Brewer, 1949; Dobson, 1956), and there occurs counter outflows from the middle atmosphere to the troposphere in mid- and high-latitudes. This indicates that the middle atmosphere plays an important role in the global circulation of trace gases such as ozone, ozone depleting chemicals, carbon dioxide. The detail of this circulation, however, is still not well understood partly because of the scantness of observations. Then model simulations are expected to be reliable tools, as a complement of observations, to investigate the global mass circulation.

## 2. Objective

This study is to explore the role of middle atmosphere on the global mass circulation by making and using general circulation models, which can well reproduce the characteristics of the middle atmosphere. This year, passive-tracer transport experiments are made using high vertical resolution GCMs, which can represent sharp stability gradient near the tropopause.

## 3. Model

The model used in this study is a global circulation model (GCM), which is a spectral transform model, extending from the surface to the middle mesosphere (top 0.05 hPa). It is a parallelogramic truncation model, *i.e.*, truncated zonally and meridionally at wavenumbers of 13 and 74, respectively, (referred to henceforth as R74), and hence has a maximum total wavenumber of 87. The horizontal resolution is about 1.4°(latitude) by 7.5°(longitude), and the vertical resolution is about 700 m with 92 layers(R74L92). The physical processes are nearly the same as in the previous GCM version (Shibata and Chiba, 1990). To avoid the noise originating from fine topography and to make stable time integration, the semi-implicit time integration is used with the reduction of the topographic resolution to be nearly equivalent with that in rhomboidal 31 truncation model. The biharmonic diffusion constant is set to be $3.25 \times 10^{14} m^4 s^{-1}$, which gives an e-folding time of about 1 day at the maximum total wavenumber 87.

## 4. Off-line transport experiment

Passive tracer transport experiments are made using the R74L92 simulated winds data sampled every 12 hours.

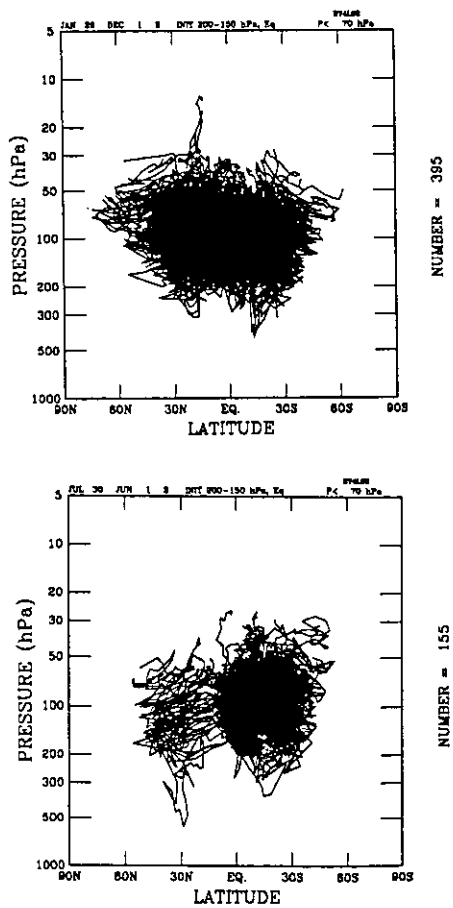


Figure 1. Trajectories projected on the meridional plane for the the particles situated higher than 70 hPa on January 31(upper) and July 31(lower).

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Ten thousand particles are used as tracers and their trajectories are calculated with time step of one hour. Initially, one thousand particles are isotropically distributed in a box region of 1° by 1°, extended from 200 to 150 hPa, and ten boxes are located equally-spaced, *i.e.* 36° apart from adjacent boxes, on the equator. Initial date is the first day for every month, and integrations of two months are made for two and half years, that is, 30 integrations of two months are made.

The trajectories of the particles, which are situated higher than 70 hPa, which is in the overworld (Hoskins, 1991), on the last day are shown in Fig.1. The two panels, though there are different features, show a prominent common feature that major cross-tropopause transport occurs not in the vicinity of the equator but in 10-30 latitude regions. Cross-isentrope transport is due to updraft, which is diabatic heating in the isentropic coordinates(Andrew et al., 1987). Meridional cross section of diabatic heating show that maximum axes is around 25 degrees in the middle and lower stratosphere(not shown), being different from the trajectories.

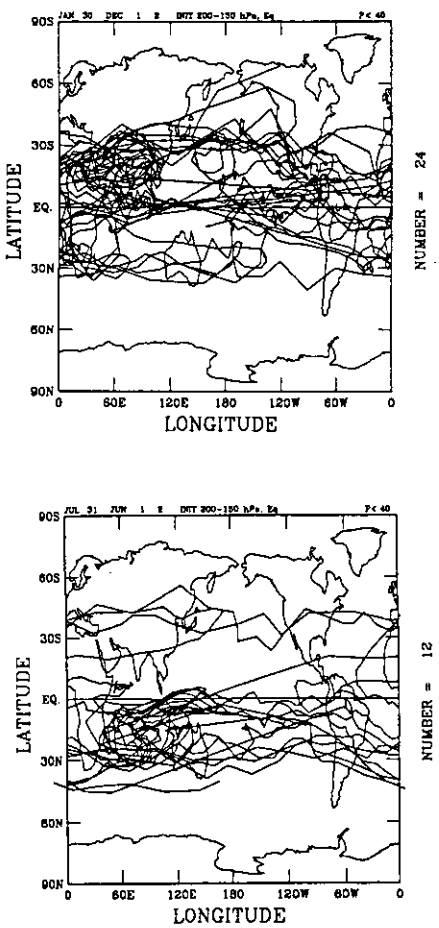


Figure 2. Trajectories projected on the geographical plane for the particles situated higher than 40 hPa on January 31(upper) and July 31(lower).

It should be noted that these trajectories do not well agree with those expected from the residual meridional circulation patterns(not shown).

Figure 2 shows the over-world particle(higher than 40 hPa at the last day) trajectories projected into the horizontal surface for winter case(upper panel) and for summer case(lower panel). There are large difference between summer and winter. In summer virtually no particle is transported in northern hemisphere, while in winter there are similar numbers of particles in both hemispheres. This feature also contradicts with the residual meridional circulation patterns, in which a certain number of particles are expected to exist in both hemispheres, irrespective of seasons.

5. Summary

Off-line transport experiments of two months integration are made with R74L92 GCM using two and half years data. The major results are as follows: (1) In northern summer and autumn the cross-tropopause transport in low-latitudes shows non-symmetric pattern with respect to the equator, and it is much larger in southern hemisphere than in northern hemisphere; (2) In winter and spring the transport is nearly symmetric; (3) The particle number transported into the stratosphere is the smallest in summer, intermediate in autumn and winter, and the largest in spring with the ration spring to summer exceeding 3; (4) There are favorable regions for the transport, where large diabatic heating and weak wind are both occurred.

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