Brewer-Dobson 循環の形成と age of air の変化のメカニズム

岡本功太[1]、佐藤薫[1]、秋吉英治[2]
[1] *東大院理*
[2] *環境研*

On the mechanism of the formation of the Brewer-Dobson circulation and the change in the age of air

Kota Okamoto[1], Kaoru Sato[1] and Shingo Hideharu Akiyoshi[2]
[1] *The University of Tokyo*
[2] *NIES*

The stratospheric meridional distribution of atmospheric minor constituents such as ozone is largely affected by the Brewer-Dobson circulation (BDC) consisting of upwelling in the low latitudes and downwelling in the middle to high latitudes of each hemisphere. This circulation is considered to be driven by the body force in the middle latitudes in the stratosphere induced by the breaking and/or dissipation of waves propagating mainly from the troposphere. Previous studies indicate that planetary waves are a main driver of the BDC. However, it is also recognized that the momentum deposition by synoptic-scale waves and gravity waves is important for the zonal momentum balance in the lower stratosphere. The purpose of this study is to quantify the relative role of each kind of waves to the BDC driving mechanism. The contribution of different types of waves to the BDC in the Center for Climate System Research/National Institute for Environmental Studies (CCSR/NIES) Chemistry Climate Model (CCM) for the present climate was diagnosed using the "downward control principle (DC)". Orographic gravity wave drag (OGWD) has a great influence on the BDC in middle latitudes of the lower stratosphere. In addition, OGWD is a dominant factor to form the ascent in the summer low-latitude part of winter circulation at all heights of the stratosphere. The DC analysis was also applied to the ERA-Interim data. The result is consistent with that of the CCM analysis. Thus, it is concluded that the gravity waves play an important role in maintaining the BDC.

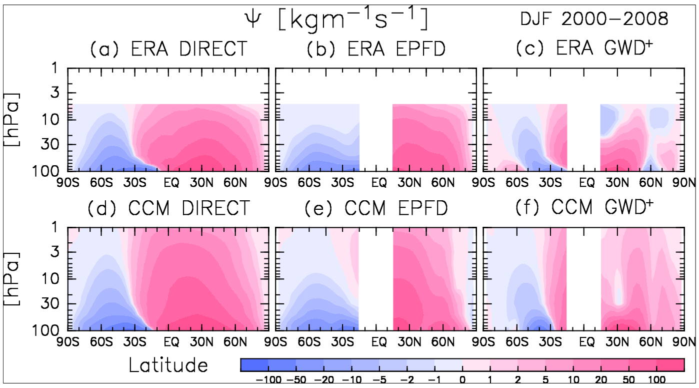

Figure 1. Meridional cross sections of the mass stream function in DJF for the result using (a)-(c) ERA-Interim data and (d)-(f) CCM data. EPFD ((b), (e)) and GWD ((c), (f)) show contributions of the resolved wave forcing and the gravity wave drag, respectively.

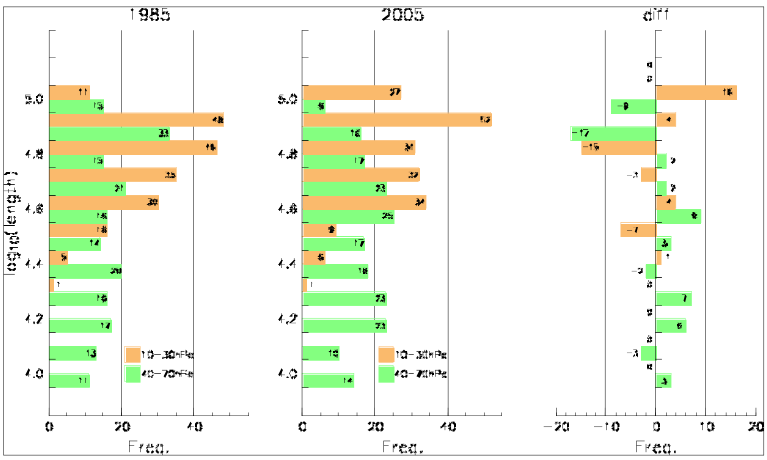

Figure 2. Histograms of the frequency of *Lz* in the latitudes of 45∘–80∘ for (a) 1985, (b) 2005, and (c) its difference. Orange shaded show the frequency in 10–30 hPa, and Green shaded show frequency in 40–70 hPa.

Moreover, we analyzed long-term changes of the BDC by comparing the "age of air" (AOA) using CCM data for the recent past (1985), present (2005) and future (2085) climates. In this study, the AOA was estimated by calculating backward trajectories from a given latitude and pressure level to the 100 hPa level in the residual velocity fields that were obtained using the CCM data. Since the mixing processes by subgrid-scale motions are ignored in the AOA estimates, the long-term change in the "AOA" should be explained by the change of the BDC. The AOA in the future is smaller than that in the present, which is consistent with the acceleration of the BDC as shown by simulations using most CCMs under the scenario of greenhouse gases increase. However, the difference in AOA between the past and present climates depends on the region. The difference is significantly positive in high latitudes of the middle atmosphere, while it is negative in the other regions of the stratosphere. In order to clarify the cause of the positive difference, namely larger AOA in the present climate than in the past, the trajectory characteristics were examined in detail. As a result, it turned out that the larger AOA in the present climate is mostly due to longer transport paths rather than slower speeds of the BDC. This result may explain the observational evidence of little or slightly positive AOA trend which is, at a glance, in contradiction to the positive trend in the BDC strength shown by most CCMs.