Comparisons of Brewer-Dobson Circulations

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1. INTRODUCTION

We are planning to make revised reanalysis of ozone by using a chemical transport model (CTM), where the CTM is driven by a general circulation model (GCM) assimilating the atmospheric reanalyses. In this system, reproduced distributions of minor constituents are considerably subject to the quality of atmospheric reanalyses. For stratospheric transport of minor constituents in a meridional plane, important is the Brewer- Dobson (BD) circulation as well as quasi-isentropic diffusions (Miyazaki and Iwasaki, 2005). In this work, we compare Brewer-Dobson circulation among JRA25, NCEP/NCAR and ERA-40, where the mean-meridional circulation is analyzed in terms of mass-weighted isentropic zonal means (MIM, Iwasaki, 1989).

Intercomparison study among the analyses is made of the climatological mean states of BD circulation and its interannual variabilityies. The secondary circulation of the southern hemispheric polar vortex (PV) is investigated based on the zonal mean variables.

2. CLIMATOLOGICAL MEAN STATES OF MASS STREAMFUNCTION

Figure 1 shows the mean-meridional circulation in boreal winter (DJF) and summer (JJA) averaging from 1979 to 2001. The MIM method diagnoses BD circulation-like poleward mass flux from all the reanalyses in the lower stratosphere. The stratospheric mean-meridional circulations diagnosed from reanalyses are, however, considerably different from each other particularly in JJA. ERA is much larger in the mass flux near the tropical tropopause than other reanalyses. The NCEP/NCAR and NCEP/AMIP have relatively large northern hemispheric mass flux with the southern hemispheric mass flux. JRA has unrealistic structure in the middle stratosphere.

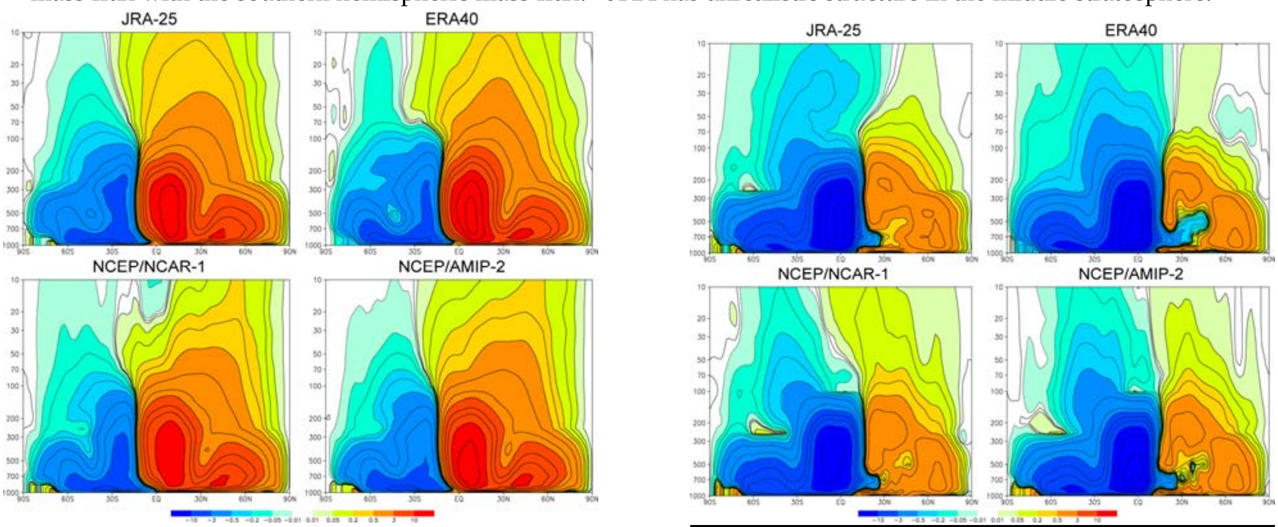

Fig. 1 Mass streamfunctions of JRA-25, ERA-40, NCEP/NCAR-1 and NCEP/AMIP2 averaging during December, January and February (DJF: on the left), and during June, July and August (JJA: on the right) 1979-2001 from 100hPa to 10 hPa. Unit: 10^{10}kg sec^{-1}.

3. INTERANNUAL VALIABILITY AND TREND

Figure 2 shows the year-to-year variations of winter mean mass streamfunctions at 100hPa of some latitudes, which indicate poleward mass flux above 100hPa. Note that negative values indicate poleward mass flux in the southern hemisphere. In low latitudes, the mass flux analyzed from ERA is the largest of those from the four reanalyses, while in the middle latitudes that from NCEP2 is the largest. Probably, such differences come from the physics parameterizations in the model. In the tropics, mean-meridional circulation is directly driven by latitudinal gradient of diabatic heating. In the extratropics, it is indirectly driven by wave-mean flow interactions, both effects of model resolvable waves and parameterized gravity waves.

In middle latitudes of both winter hemispheres, we have weak increasing trends of the mass streamfunctions at 100 hPa, corresponding to intensification of Brewer-Dobson circulations. The trend during 20 years is, however, smaller than interannual variability. It is also smaller than differences between the two of reanalyses. In the southern hemisphere, its rates analyzed from individual reanalyses have considerable discrepancy. All of those suggest that we are unable to make full discussions on the trend of Brewer-Dobson circulation.

Interannual variability seems to be fairly correlated with each other. Correlations of detrended interannual variability are shown in Table 1. The correlation is better in the extratropics than in the tropics. It indicates that mean-meridional circulation is primarily driven by wave-mean flow interactions of resolvable waves. This will be checked directly by Eliassen-Palm flux and its divergence in the reanalyses. The correlation is worse in the southern hemisphere than in the northern hemisphere. The sparsity of the observation data degrades the quality of reanalyses in the southern hemisphere.

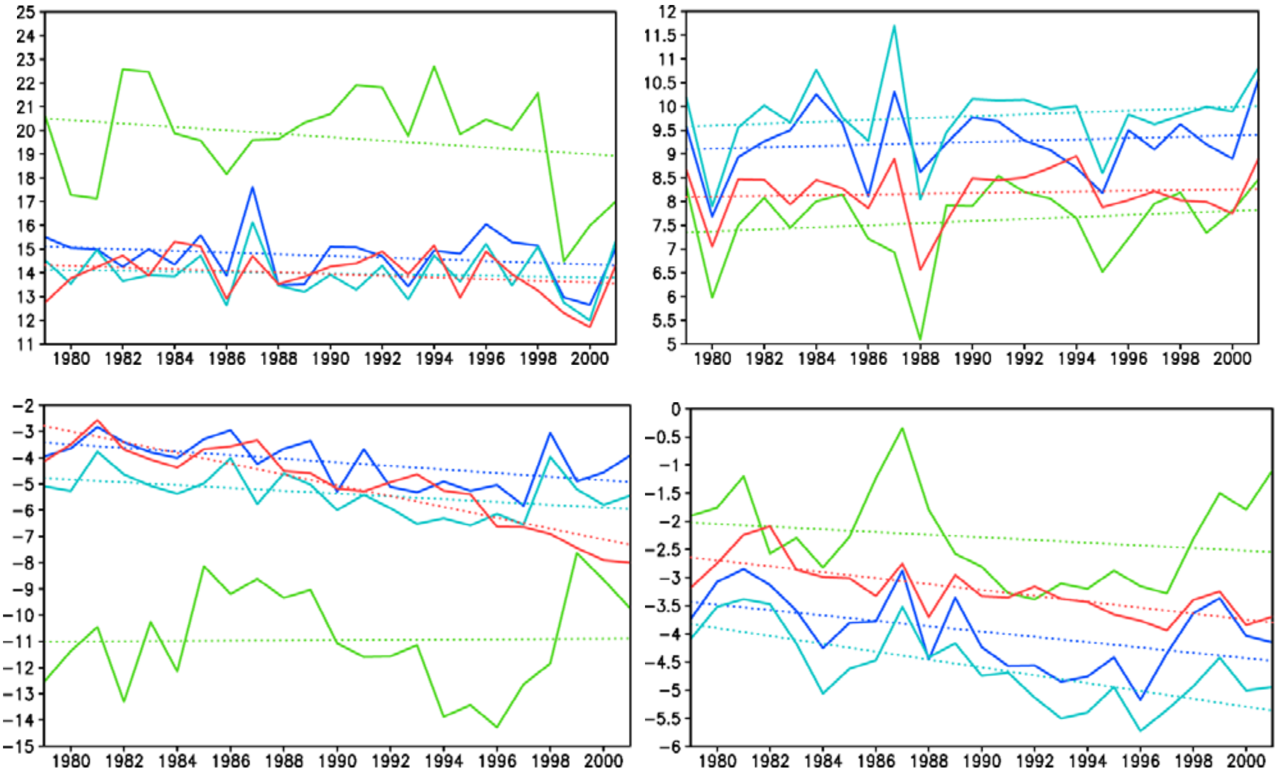

Fig. 2. Year-to-Year variations of mass streamfunctions at 100 hPA in the winter hemisphere. Note that negative values indicate poleward flux in the southern hemisphere. Upper left, Upper right, lower left and lower right panels are values at 15N for DJF, 45N for DJF, 15S for JJA and 45S for JJA, respectively. Colors of red, green, blue and light blue indicate **JRA, ERA, NCEP** and NCEP2, respectively. Unit: 10^{9}kg sec^{-1}.

Table 1. Correlations of detrended interannual variablities of the mass streamfunctions at 100 hPa in winter hemisphere

	(JRA v.s. ERA)	(JRA v.s.NCEP)	(NCEP v.s. ERA)
15N for DJF	0.50	0.49	0.32
30N for DJF	0.45	0.73	0.40
45N for DJF	0.73	0.59	0.58
60N for DJF	0.77	0.78	0.75
15S for JJA	0.08	-0.08	0.41
30S for JJA	0.24	0.16	0.40
45S for JJA	0.19	0.64	0.70
60S for JJA	0.03	0.50	-0.03

4. SECONDARY CIRCULATION OF SOUTHERN HEMISPHERIC POLAR VORTEX

The polar vortex (PV) surrounded by very strong polar night jet stream is a unique structure in the stratosphere. Its secondary circulation, which plays important roles in the transport of minor constituents, is of great concern to the stratospheric dynamics and chemistry. The vertical velocity is so weak that we hardly estimate it accurately. Furthermore, the northern hemispheric PV can not be analyzed by means of zonal mean variables, because it is to a certain degree axially asymmetric. Thus, our discussions are focused on the southern hemispheric PV.

Figure 3 shows a GCM diagnosis based on MIM (Iwasaki, 1989), where the model is the MRI/JMA 1998 GSM (Shibata et al., 1999). The left and right hand side panels are diagnosed in the dynamical way from meridional wind with the continuity equation and in the diabatic way from radiative heatings with the thermodynamic equation. The vertical velocity obtained with the two different data is very consistent with each other and indicates its reliability (Miyazaki and Iwasaki, 2008). Note that the transformed Eulerian Mean (TEM) provides too strong downward velocity outside of PV and too weak one (sometimes upward) inside. It is interesting that the major downward branch of the Brewer-Dobson circulation is located just outside of the polar night jet stream (Iwasaki, 1992), as far as the model atmosphere is concerned.

Figure 4 shows the seasonality of the mean vertical velocity at 50hPa. In the GCM, the downward branch of Brewer-Dobson circulation is located in middle latitudes and it slightly moves with season. On the other hand, the reanalyses are too noisy to see seasonality of the vertical velocity. JRA has a similar seasonality to the GCM but it is still subject to large noises. Actual secondary circulation of the polar vortex is an important matter to be studied in the future reanalyses.

5. CONCLUDING REMARKS

The reanalyses are still too noisy for us to use them for the assessment of Brewer-Dobson circulation. They also have some discrepancies of trends. Considering the smoothness of GCM output, assimilation processes of observation data cause noises and discrepancies in the reanalyses. Model biases are most responsible for discrepancies among reanaleses. For stratospheric analyses, we should improve parameterization schemes of radiation and gravity wave drag. Data assimilation causes dynamical imbalances which cause gravity wave noises. Such imbalance may be removed by advanced data assimilation technique.

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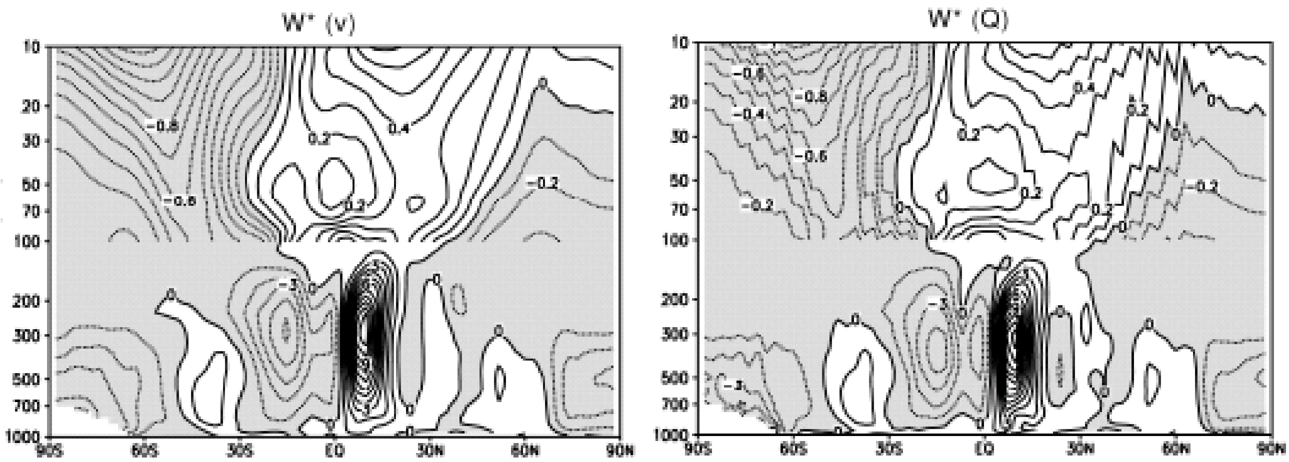

Fig. 3 Mean vertical velocity reproduced in the GCM for JJA（mm sec^{-1}）.
Left panel is dynamically derived from meridional velocity and right panel is thermodynamically derived from diabatic heatings.

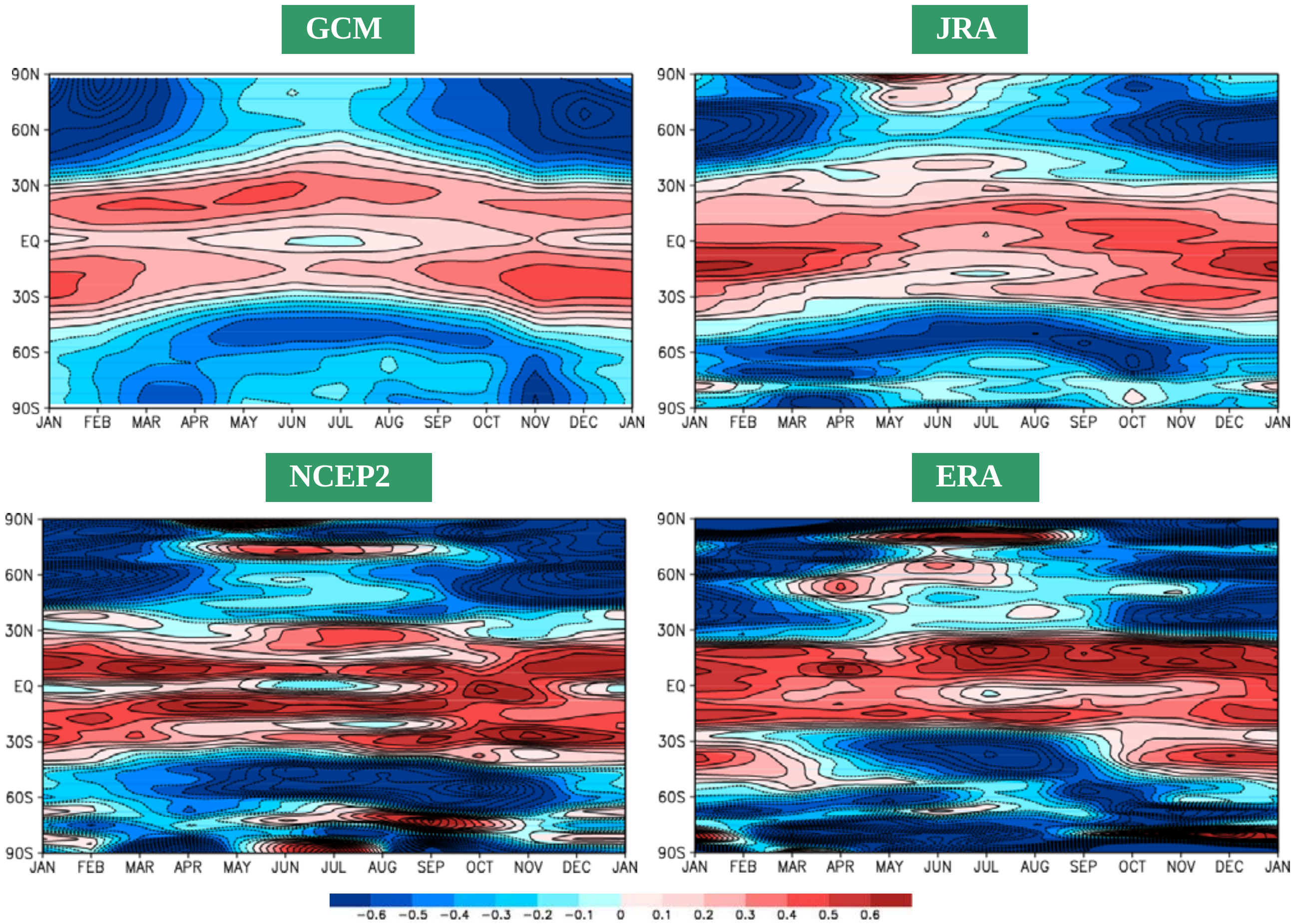

Fig. 4 Seasonality of mean vertical velocity at 50 hPa（mm sec^{-1}）.
Upper left, upper right, lower left and lower right panels are analyzed from GCM, JRA, NCEP2 and ERA, respectively.