Interannual variation of spring total ozone and winter planetary-scale wave activity in re-analyses data

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INTRODUCTION

In the Northern Hemisphere, the stratospheric ozone is the most abundant in spring. The variability of ozone transport in polar region and lower stratospheric temperature are correlated because they are both driven by dynamical variability. The arctic polar lower stratospheric temperature in spring is primarily controlled by planetary-scale waves in late winter (Newman et al., 2001). In this study, we validate the lag correlation between spring total ozone in polar region and winter wave activity represented in each re-analysis data for monitoring of the spring ozone in polar region.

DATA AND ANALYSES

The column ozone data used here are obtained with the Ozone Monitoring Instrument (OMI) on Aura for 2005 and 2006, and the Total Ozone Mapping Spectrometer (TOMS) instruments using Version 8 of the TOMS processing algorithm from 1979 to 2004. Monthly averages are calculated from daily original data.

The products of the following four reanalyses are used as the atmospheric datasets in this study.

*Japanese 25-year Reanalysis (JRA-25) [Onogi et al., 2007] and JCDAS (1979-2006)
*ECMWF 40-year Reanalysis (ERA-40) [Uppala et al., 2004] (1979-2002)
*NCEP/NCAR reanalysis [Kalnay et al., 1996] and CDAS1 (1979-2006).
*NCEP/DOE reanalysis [Kanamitsu et al., 2002] and CDAS2 (1979-2006)

In the JRA-25, ozone observations are not assimilated directly in the data assimilation system. Instead a 3-dimensional daily ozone profile is separately produced in advance and provided to the forecast model. In the ERA-40 project, retrievals from TOMS and SBUV instruments on various satellites are directly assimilated. In NCEP/NCAR and NCEP/DOE, zonally averaged seasonal climatological ozone are used in the radiation computation.

Using these reanalyses, zonally averaged eddy heat flux is calculated to estimate the amount of planetary wave activity propagating into the lower stratosphere. The eddy heat flux is the vertical component of EP-flux which represents wave activities, and vertical component of residual circulation related to transport of ozone. The eddy heat fluxes are calculated from those reanalyses datasets and we calculated monthly means for the period 1979-2006.

RESULTS

Year-to-year variation of observed total ozone over arctic polar region in March and eddy heat flux over mid-latitude in late winter (Jan-Feb) which indicates tropospheric planetary wave activity are shown in Figure 1a. The monthly mean eddy heat fluxes at 100hPa are calculated using JRA-25. The eddy heat flux in late winter are correlated well ($r=0.63$) with the total ozone in March. Simultaneous relation between observed total ozone and eddy heat flux are shown in Figure 1b. There is no significant correlation ($r=-0.03$) between these two elements. The time lag correlation is larger than the simultaneous correlation. The strong lag correlation between total ozone in March and eddy heat flux in late winter are confirmed in JRA-25.

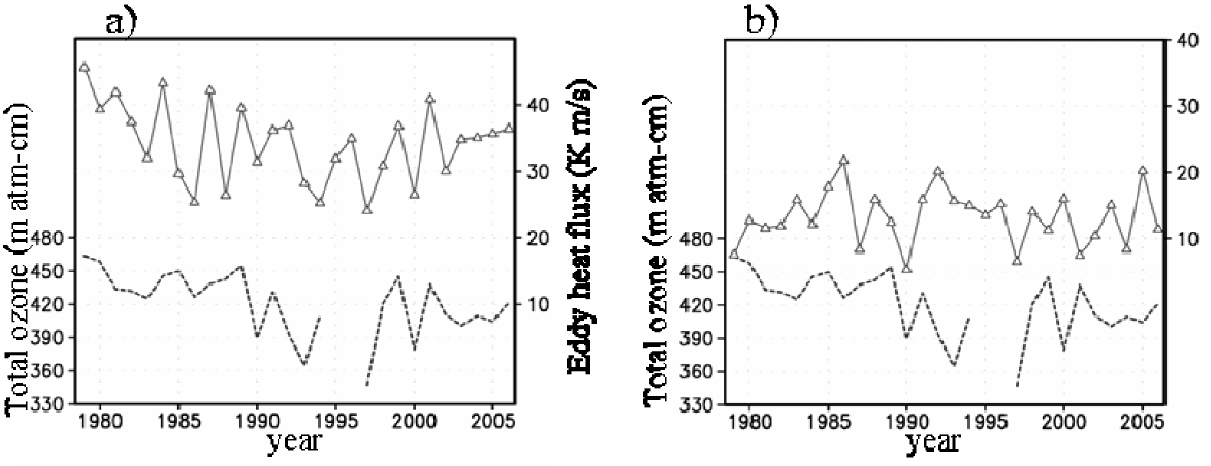

Figure 1 Time series of eddy heat flux (solid line) over 45N-75N at 100hPa in Jan and Feb (a) and in Mar (b). Broken lines indicate total ozone over polar cap region in March.

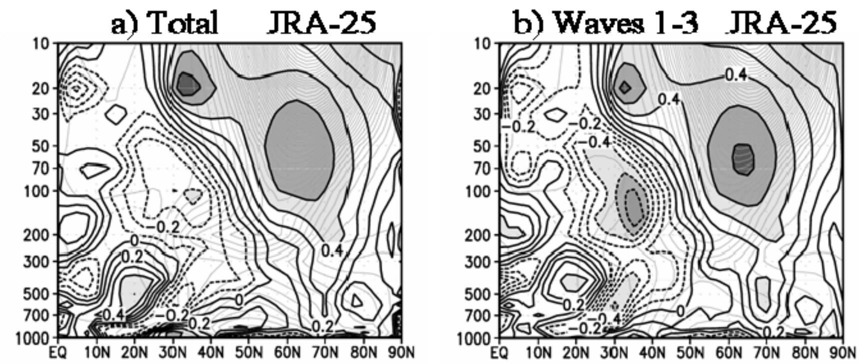

Figure 2 Correlation of March total ozone (60N-90N, 1979-2006) and total eddy heat flux (a) and wave 1-3 component of eddy heat flux during Jan-Feb in JRA-25.

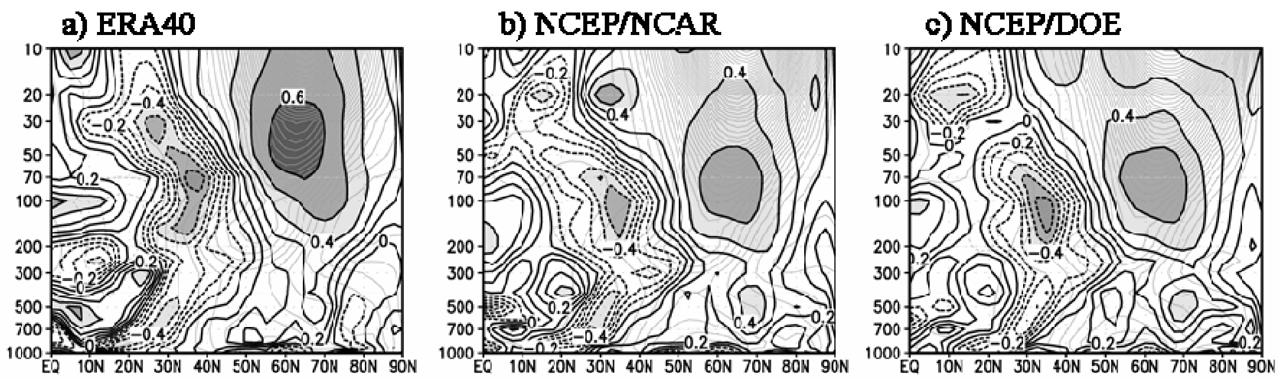

Figure 3 Correlation of March total ozone (60N-90N, 1979-2006) and wave 1-3 component of eddy heat flux during Jan-Feb.
Same map as Fig.2b but for a) ERA40, b) NCEP/NCAR, c) NCEP/DOE.

To see the spatial distribution of the correlation in JRA-25, 28-year-average March total ozone over polar region is correlated with each latitude and height of zonal mean eddy heat flux field in late winter represented in JRA-25. Figure 2a shows the correlation between March total ozone and total eddy heat flux in late winter and Figure 2b shows the correlation between March total ozone and eddy heat flux for waves 1-3 in late winter. The maximum correlation is found at around 60N and 70hPa. The correlation of the polar ozone with the zonal mean waves 1-3 eddy heat flux is slightly improved than the total eddy heat flux. The eddy heat flux time series and its interannual variation are dominated by planetary-scale waves in stratosphere.

Figure 3 shows same correlation maps as Figure 2b, but by using other reanalyses. Large positive correlations over polar lower stratosphere are commonly found in other reanalyses. However the maximum value of correlation in ERA40 is greater than that of JRA-25, and the correlation in NCEP/NCAR and NCEP/DOE are less than that of JRA-25.Differences among correlation patterns may be due to the difference of ozone assimilation method.

Figure 4 shows the year-to-year variation of waves 1-3 component of eddy heat flux in each reanalyses. The inter-annual variation of eddy heat flux well matches among these reanalyses after 1992. However they do not match during 1979-1991. The correlations among the reanalyses are shown in table 1. The correlation between JRA-25 and ERA40 is 0.82 and the correlation between JRA-25 and NCEP/NCAR is 0.97. The inter-annual variation of eddy heat flux in JRA-25 well matches both ERA-40 and NCEP/NCAR.

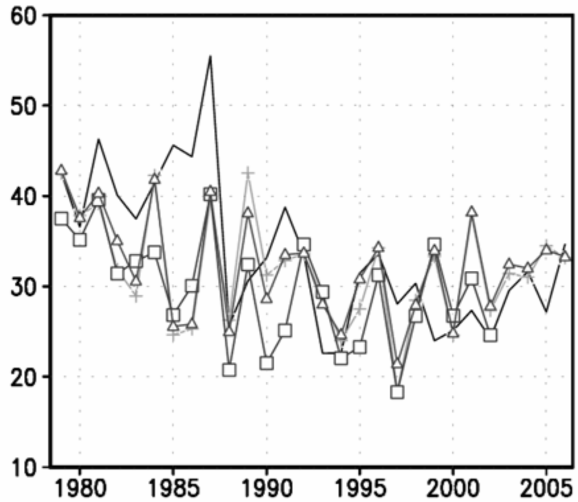

Figure 4 Time series of eddy heat flux (45N-75N, wave 1-3) at 100hPa in Jan-Feb
Triangle: JRA-25, Square: ERA40, Cross: NCEP/NCAR, None: NCEP/DOE

Table 1. Correlation coefficient among the year-to-year variation of eddy heat flux at 100 hPa over 45N-75N in each reanalyses

	JRA-25	ERA40	NCEP/NCAR
ERA40	0.82		
NCEP/NCAR	0.97	0.78	
NCEP/DOE	0.49	0.58	0.41

SUMMARY

The results are summarized as follows:

1) The variation of the lower stratospheric eddy heat flux in late winter in JRA-25 is correlated well with the observed total ozone over arctic region in March.

2) These correlations were confirmed by 4 major reanalyses.

3) The inter-annual variation of eddy heat flux in JRA-25 well matches both ERA40 and NCEP/NCAR.

It is confirmed that the variation of total ozone over the polar region in spring can be diagnosed and/or predicted by using the eddy heat flux of JRA-25 in winter, same as ERA40 and NCEP/NCAR.

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