Dependence of Projected Future Change in the Arctic Oscillation on the Stratospheric Wave Activity among High-top CMIP5 Models

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1. Introduction

The Arctic Oscillation (AO) is a zonally symmetric mode of mass exchange (also, zonal-mean zonal winds) between the mid- and high-latitude in the Northern Hemisphere with a vertically equivalent barotropic structure (Thompson and Wallace 2000). The AO owes its existence to the wave-mean flow interaction in the mid-latitude westerly zone (Limpasuvan and Hartmann 2000). One of way of the wave-mean flow interaction is that the breaking or absorption of planetary waves (i.e., the convergence of Eliassen-Palm (EP) fluxes) locally changes the speed of zonal-mean zonal winds (Eliassen and Palm 1960), which should influence the AO phase.

In the present study, projected future AO changes are evaluated among historical and representative concentration pathway (RCP) scenario runs of the 5th phase Coupled Model Intercomparison Project (CMIP5) models (Taylor et al. 2012), in the context of the wave-mean flow interaction in the troposphere and stratosphere.

2. Data and Methods

The monthly geopotential height, horizontal and vertical winds, and temperature at multi-pressure levels from the historical and RCP scenario runs of CMIP5 models are used to evaluate the models' properties. The same variables from the ERA-Interim reanalysis of the European Centre for Medium-range Weather Forecasts (ECMWF) are also utilized to show the reference observations.

According to the EP theorem, the Eulerian time change of zonal-mean zonal winds depends on the divergence/convergence of the EP flux. In a midlatitude quasi-geostrophic system, the EP flux is represented as the following form: $\vec{F} = (F_{(y)}, F_{(p)})$ $F_y = -[u^*v^*]$ $F_p = f\frac{[v^*\theta^*]}{[\theta]_p}$ where vector F has meridional ($F_{(y)}$) and vertical ($F_{(p)}$) components, $F_{(y)}$ is a meridonal eddy flux of zonal momentum, $F_{(p)}$ is a meridional eddy flux of heat, the bracket and star respectively represent zonal-mean and deviation from zonal-mean.

3. Results

The CMIP5 models can be broadly grouped into two: one with lid height above 1 hPa ("high-top model") and the other with lid height below 1 hPa ("low-top model"). In the high-top model group, the projected future change of seasonal intensity of stratospheric wave absorption/breaking (measured by the EP flux divergence) is a systematic indicator for the AO change, because the two parameters are linearly related with each other among the models (Fig. 1). In contrast, the linear relationship is not found in the low-top model group. The results may imply that the more realistically resolved stratospheric processes in the high-top model group enhance the structural dependence of the AO changes on the stratospheric changes, which may, in turn, imply the increased role of stratosphere-troposphere coupling on the AO changes in the high-top models.

References

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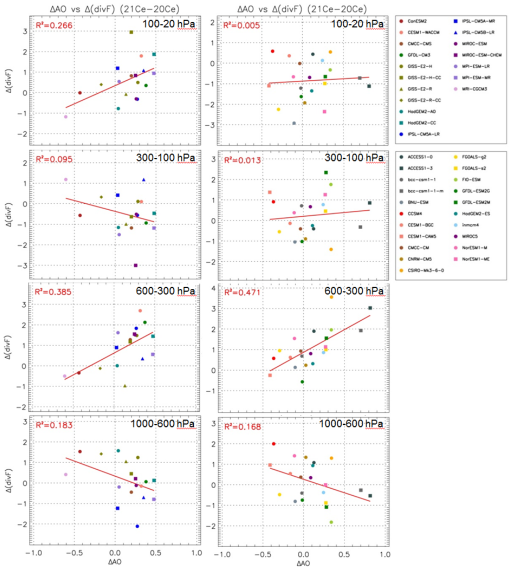

Fig. 1. Scatter diagrams between future changes (2080-2099 minus 1980-1999) of AO indices (x-axis) and Northern Hemispheric-mean divergence of EP fluxes averaged at different layers (1st row: 100-20 hPa, 2nd: 300-100 hPa, 3rd: 600-300 hPa, and 4th: 1000-600 hPa) among (left) high-top and (right) low-top CMIP5 models.