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Annular-mode-like variation in a multi-layer QG model

Y. Zhang (1), X. Yang (1), Y. Nie (1), and G. Chen (2)

(1) School of Atmospheric Sciences, Nanjing University, Nanjing, China (yangzhang@nju.edu.cn) , (2) Department of Earth and Atmospheric Sciences, Cornell University, Ithaca, USA

Eddy-zonal flow interactions in the annular modes are investigated in this study using a beta-plane multi-layer QG channel model. Our study shows that the anomalous zonal winds in the annular modes can organize the eddy feedback through the resulting critical line variations. Eddies with different critical line distributions response to the zonal wind anomalies differently. For eddies with higher phase speed (high frequency) and a critical layer at lower levels at the center of the jet, they dominate the eddy momentum forcing on the zonal flow, feeding back positively to the zonal wind anomalies. For eddies with lower phase speed (low frequency) and a more 'barotropic' vertical distribution of the critical line, they enhance the lower-level baroclinicity at the jet center, which prevails over the eddy mixing of the high-phase-speed eddies and eventually extends the latitudinal shifts of midlatitude jets. Thus, our study suggests a baroclinic mechanism through which the high-phase-speed and low-phase-speed eddies work symbiotically maintaing the annular-mode-like variations.

The importance of the lower-level critical line distribution in the zonal wind variability is further demonstrated in the sensitivity runs, in which the surface friction on eddies is increased thus the length scale and the critical line distribution of the energy-containing eddies are varied. For simulations in which the low-phase-speed eddies become inactive, the leading mode of the zonal wind variability shifts from the position fluctuation to a pulsing of the jet intensity. Further studies indicate that the activity of the low-phase-speed eddies and the resulting response of the lower-level baroclinicity to the zonal wind anomalies can be crucial in maintaining the annular-mode-like variations of the zonal winds.