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The latitudinal shift of the midlatitude atmospheric circulation in response to climate change and the role of midlatitude diabatic heating

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Previous studies showed that the midlatitude atmospheric circulation generally shifts poleward in response to climate change induced by increased greenhouse gas concentration, including the midlatitude storm track and the eddy-driven jet. The magnitude of this shift varies widely between different climate models and depends on the season, hemisphere and longitude. In this study we aim to reexamine the connection between the shifts of the sensible eddy heat flux and the eddy-driven jet in response to climate change and the role of diabatic heating and latent eddy heat flux in this relation. Our approach is to use the constraints of the zonally averaged heat and momentum budgets in order to connect the eddy-driven jet latitude to the heat budget terms. First, we examine the relation between the eddy-driven jet latitude and the eddy heat flux latitude in the inter-model spread of CMIP6 models. We find that the latitudinal separation between the eddy heat flux and eddy-driven jet depends on the amount of diabatic heating in the midlatitude midtroposphere, which varies widely between different models. This relation is explained based on the heat and momentum budgets.

Next, we use an idealized general circulation model with interactive water vapor and full radiation. We customized the model with different levels of saturation vapor pressure by increasing CO_2 concentration and by increasing the humidity factor in the Clausius-Clapeyron relation. We found that in both the cases the atmospheric circulation responds in a similar way and the heat budget terms shift upward and poleward, signifying an upward and poleward shift of the storm track. We found that when the diabatic heating rises upward and strengthens enough over the midlatitude mid-troposphere in response to climate change, the adiabatic cooling by the Ferrel cell rising branch balances the diabatic heating and an equatorward shift of the eddy driven jet and the Ferrel cell is observed. These results provide further insight to the relation between the responses of the midlatitude circulation and the poleward energy flux terms to climate change.