Propagation of wave packets from the stratosphere to the troposphere during cold spells

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Planetary waves propagate downward from the stratosphere to the troposphere, changing the tropospheric circulation and contributing to the occurrence of cold spells (e.g., Kodera et al., 2008; Matthias and Kretchmer, 2020). Matsuyama (2023) conducted the statistical analysis of downward propagation of planetary wave packets using the large ensemble data d4PDF (Mizuta et al., 2017) and presented that the location of cold spells might vary dependently on the longitudinal characteristics of downward propagation. In this study, we extract cold spell events in the Northern Hemisphere winter and investigate characteristics of the wave packet propagation during cold spells to clarify the contribution of downward propagation to the occurrence of cold spells. We use d4PDF with 2.5 x 2.5 latitude-longitude grid-spacing and calculate wave activity flux (WAF) of Plumb (1985). The analysis period is from December to March in the historical simulation.

We extract cold spell events on the basis of 500 hPa temperature anomalies from the climatological values averaged over the regions 40˚N through 70˚N over North America (112.5˚W through 45˚W) and Europe (22.5˚E through 67.5˚E). The "event days" are determined when the negative peaks occur below an appropriate criterion value for each region. Resultantly, we obtain 1451 events over North America and 1868 events over Europe, which approximately corresponds to a frequency once per five years.

Vertical components of WAF (WAFz) averaged over 50˚N to 80˚N at 30 hPa are used to evaluate the contribution of downward wave packet propagation. We extract cold spell events with a negative peak of WAFz below a criterion value from six days before the event day. As a result, about 30% of the cold spell events over North America and about 22% of the events over Europe have negative peaks of WAFz at 30 hPa, respectively.

Next, we conduct a composite analysis for the cold spell events extracted above. The composite results over North America have a negative peak of WAFz at 120˚W three days before the event day. The entrainment of cyclonic anomalies from the stratosphere into the troposphere occurs with the downward propagation of wave packets. Our composite results of the events over Europe have the negative peak of WAFz at 45˚W three days before the event day, and their longitudinal width of downward propagation is 90 degrees. In the events over Europe, wave packets propagate horizontally after the downward propagation which is located about 100 degrees longitude westward from the cold spell regions.

Keywords: stratosphere, planetary waves, wave activity flux, cold spell

