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Dynamic and thermal processes of a surface low developed by a vortex aloft

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Over high-latitude oceans in winter, polar lows sometimes develop, whose typical size is a few hundred kilometers. Upper level trough is considered to be one of the important factors for development of polar lows. In this study, this type of process of development is focused: dynamical and thermal processes by which a vortical disturbance aloft excites a surface low are investigated through numerical simulations in an idealized atmosphere.

Some numerical studies in an idealized atmosphere for polar lows caused by upper level vortical disturbances have been conducted. In many studies, not only a vortex aloft but also a disturbance on the surface are located in the initial state, but it is reported recently that surface disturbances could be excited only by vortical disturbances aloft and some sensitivity experiments for such situations are carried out. However, the height of tropopause and upper level vortices are often set at 5000m to 6500m which is lower than real cases. Moreover, excitement of surface disturbances by upper vorticies are mainly investigated through dynamical processes and effects of thermal processes such as convections raised by weak stratification beneath the cold air aloft are not considered enough in idealized simulations.

Therefore, simulations in a zonally uniform baroclinic channel with a higher tropopause level are carried out. As a result, a comma-shaped polar low was simulated even when the upper level vorticies and tropopause is located at 8000m height level. However, it is revealed that in an early stage, the low was developed due to convective processes which are caused by destabilization of stratification rather than dynamical processes which are frequently mentioned in early studies. In order to understand the mechanism of the early stage of the development, simulations with various combinations of tropopause height and the stratification of the background atmosphere. As a result, the mechanism of the disturbance excitement could be classified into some patterns. Dynamical processes tend to occur when the height of a vortex and tropopause is low, and the stratification of the background is weak. In other cases, the low was excited by convective processes and in some cases with high tropopause height and strong stratification, the low was not developed. The condition of dynamical excitement of disturbances resembles that of Eady instability. A low will be emerged by interaction between vorticies when it is under the condition of instability of Eady model, but otherwise surface disturbances are developed convectively. The height which convective vertical flows can reach was calculated by using emagram and compared with the results of numerical simulation. When stratification is weak, the height of convection explains the result of the simulations well. There is, however, discrepancy when stratification is strong; it may be because potential temperature anomalies associated with vorticies and heat fluxes from sea surface are not taken into account.

Keywords: polar low, vortex aloft, stratification, convection