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Climate factors of the high-latitude planetary boundary layer

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The global earth system models (ESMs) are widely used to study the earth's system climate and its future change in climate forcing scenarios. However, the coarse spatial resolution of the state-of-the-art ESMs requires parameterization of the small-scale climate dynamics and the essential physical processes in the climate system. The vertical turbulent exchange in the planetary boundary layer (PBL) is one of the key small-scale dynamical processes with large and non-trivial effect on the earth's climate. The PBL effects are particularly significant in high latitudes where the PBL is shallow and sensitive to the changes in the surface and cloud properties. This study highlights four climate factors linked to the high-latitude PBL:
1. Amplification of the climate forcing signal and the natural variability in the shallow PBL
2. Asymmetric response of the PBL on warm and cold advection events
3. Suppression/enhancement of the vertical mixing by PBL structures over heterogenic surface
4. Indirect effect of the PBL variability on larger climatologic spatial and time scales
Recent research efforts revealed that the direct turbulent coupling between the atmosphere and the ocean or land surface as expressed through the flux-gradient approximation is not adequate on both the large climatologic scales and the small turbulence scales. On the large scales, the aggregated PBL effects depend on the degree of adjustment between the component of the climate system, e.g. between the atmospheric circulation and the ocean heat content anomalies. On the small scales, the flux-gradient approximation is not appropriate to describe the non-local turbulent mixing dynamics and the aggregated effects of the turbulence self-organization. Any state-of-the-art ESM includes a number of physical and bio-geochemical processes with the aggregated climate impact determined by the details of the turbulence dynamics. It justifies the efforts towards systematic studies of the climate factors sensitive to the asymmetric and indirect aggregated effects of the PBL.