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Polar low formation: ambient environments and the role of moisture

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Polar lows are maritime cyclones occurring during cold air outbreaks in high latitudes. Previous studies have shown that wind shear, baroclinicity, latent heat release, and surface fluxes are important factors during formation and intensification, yet their relative contributions and importance are still not fully understood.

We use the ambient atmospheric conditions during polar low genesis to provide dynamical insights to the intensification and formation mechanisms for polar lows. We identify the characteristics of the ambient pre-polar low environment utilising an existing polar low database and ERA-Interim reanalysis data. Classification of these environments is based on the the direction between the thermal wind and the mean flow in the lower troposphere, where environments are classified as 'reverse shear' if the thermal wind and mean flow are in opposing directions and 'forward shear' if they are in the same direction. The two types of pre-polar low environments exhibit distinctly different features in terms of synoptic scale patterns, baroclinicity, configuration of the sea-surface temperature, as well as depth and stratification of the troposphere. These clear-cut differences hint at different dynamical pathways for the formation and intensification of polar lows for different shear environments.

We also explore the role of latent heating during polar low formation utilising an idealised baroclinic channel model. The experimental design resembles a typical forward-shear moist-baroclinic environment at high-latitudes. Cyclogenesis is triggered by a weak, low-level thermal perturbation in hydrostatic and geostrophic balance. Our experiments show that significant disturbance growth is possible in absence of upper level forcing, surface fluxes, and radiation. The relative importance of diabatic versus baroclinic processes for the generation of eddy available potential energy is used to differentiate between the dynamical processes contributing to disturbance growth. The experiments indicate that sufficient latent heat release in the north-eastern quadrant of the cyclone is crucial for rapid disturbance intensification, where environmental relative humidity, baroclinicity, and static stability modulate the relative importance of latent heat release. Furthermore, the relative shallowness of the perturbation at high-latitudes increases the effectiveness of latent heat release on cyclone amplification.