Dynamics of a Diabatic Layer in the quasi-geostrophic framework

Rupert Klein\textsuperscript{1}, Lisa Schielicke\textsuperscript{2}, Stephan Pfahl\textsuperscript{2}, and Boualem Khouider\textsuperscript{3}
\textsuperscript{1}Freie Universität Berlin, Mathematik & Informatik, Berlin, Germany (rupert.klein@math.fu-berlin.de)
\textsuperscript{2}Freie Universität Berlin, Meteorologie, Berlin, Germany
\textsuperscript{3}Dept. of Mathematics, Univ. of Victoria, Victoria, CA

Quasi-geostrophic (QG) theory describes the dynamics of synoptic scale flows in the troposphere that are balanced with respect to both acoustic and internal gravity waves. Within this framework, effects of (turbulent) friction near the ground are usually represented by invoking Ekman Layer theory. The troposphere covers roughly the lowest ten kilometers of the atmosphere while Ekman layer heights are typically just a few hundred meters. However, this two-layer asymptotic theory does not explicitly account for substantial changes of the potential temperature stratification due to diabatic heating associated with cloud formation or with radiative or turbulent heat fluxes, which, in the middle latitudes, can be particularly important in roughly the lowest three kilometers. To alleviate this constraint, this work extends the classical QG plus Ekman layer model by introducing an intermediate, dynamically and thermodynamically active layer, called the “Diabatic Layer” here. The flow in this layer is also in acoustic, hydrostatic, and geostrophic balance but, in contrast to QG flow, variations of potential temperature are not restricted to small deviations from a stable and time independent background stratification. Instead, within this layer, diabatic processes are allowed to affect the leading-order stratification. As a consequence, the Diabatic Layer modifies the pressure field at the top of the Ekman layer, and with it the intensity of Ekman pumping seen by the quasi-geostrophic bulk flow. This leads to a new model for the coupled dynamics of the bulk troposphere, the diabatic layer, and the Ekman layer when strong diabatic processes substantially change the stratification in the lower part of the atmosphere.