Effects of Surface Fluxes and Latent Heating on Extratropical Cyclones in an Idealised Linear Framework

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We use a linear extension of the Eady model to investigate the influence of surface fluxes associated with air-sea interactions on the development of midlatitude cyclones. Several studies have found that surface sensible heat fluxes reduce eddy available potential energy and thereby stabilise baroclinic instability. However, while the direct effect of surface sensible heat fluxes might be detrimental to individual baroclinic development, it is still unclear how surface fluxes modify latent heat release, which is the dominant diabatic contributor to cyclone development. For example, destabilisation of the cold sector via surface fluxes enhances convection and latent heat release, which leads to an increase of kinetic energy within the cyclone. Furthermore, latent cooling associated with evaporational effects at lower altitudes was recently found to affect the potential vorticity distribution within midlatitude cyclones. It is, however, still unclear if these evaporational effects have a significant impact on the overall development.

In our linear framework, surface fluxes and latent heating/cooling are separable, but can still directly affect each other. With the possibility to more clearly disentangle the different diabatic processes, we can gain insights into how these processes alter the intensification and structure of extratropical cyclones. With strong latent heating and/or surface fluxes, short and shallow instabilities that are comparable to Diabatic Rossby Vortices emerge. Above the latent heating, a negative potential vorticity anomaly forms for Eady-like instabilities, supporting downstream ridging. For moderate heating intensities, evaporational cooling barely affects the instabilities, despite the intensification of the positive low-level potential vorticity anomaly. For strong heating intensities, however, unstable modes at shorter wavelengths intensify with weak evaporation, but become neutral for intense evaporation. Our results show that surface fluxes are detrimental to the growth of Eady-like instabilities at longer wavelengths, but enhance shallow instabilities at shorter wavelengths and low altitudes, especially when latent heat release is weak.

Keywords: surface fluxes, air-sea interactions, baroclinic development, latent heating, Eady model

