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Dynamics of the nocturnal boundary layer in direct numerical simulation

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The evening transition to stable conditions in the nocturnal boundary layer (NBL) is poorly understood. The concept developed in the past decade (e.g. van de Wiel et al. 2007, 2012) provides an explanation for the existence of two regimes in the NBL (e.g. Mahrt 1998): the continuously turbulent (weakly stable) boundary layer and the 'quiet' (very stable) boundary layer. However, the concept still relies on closure assumptions (i.e. flux-profile relations) to describe the turbulent motions. To eliminate the use of such assumptions we use so-called direct numerical simulation (DNS). DNS directly solves the discretised Navier-Stokes equations up to the Kolmogorov length scale. Thus this method is without any assumptions regarding turbulence, in contrast to RANS (parametrisation of all scales of turbulence) or LES (parametrisation of the small scales of turbulence). The model system is a cooled Couette flow. It consists of two parallel plates, moving in opposite direction with velocities $\pm U_0$ to drive the flow. The distance between the plates is $2h$ and the at both bottom and top plate a negative heat flux is prescribed (to mimic net radiative heat loss). This results in a Reynolds number $Re = U_0 h/\nu = 2500$. This value, far below the atmospheric practice, is a result of the trade-off for solving all scales of turbulence. The results, however, are qualitatively similar to the conceptual model and field observations (e.g. van Hooijdonk et al. 2015). This signifies that elements of evening boundary layer dynamics can be understood from an idealised, controlled model system. From this the appearance of two qualitatively different regimes in the NBL can be explained.