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A Case-study in Forecasting Low-lying Inversions and Stratocumulus Cloud Cover in the Bay of Biscay

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Many regional operational forecasting models struggle to simulate low-lying strong temperature inversions. In order to understand and begin to improve on this apparent deficit, we investigate the processes of inversion formation and their implementation. Next to the large-scale subsidence, the turbulent vertical mixing is a key dynamical process in the formation of inversions. In this case study we use the COSMO model, where turbulence is parameterised by the Mellor and Yamada (1974,1982) scheme, which is a state-of-the-art turbulence scheme used by many limited-area weather prediction and regional as well as global climate models. Here we investigate the sensitivities with respect to two key parameters (a prescribed minimum threshold for the vertical mixing and the maximum length scale of turbulent eddies) on forecasting shallow, cloud-topped marine boundary layers (MBLs) in the Bay of Biscay for January 2003. This particular period was characterised by an initial 10 – 12 K strong temperature inversion at a MBL height between 500 – 800 m with stratocumulus cloud cover below, which was slowly lifted by an impeding cold front. Furthermore we tested how well the model could form as well as maintain the inversion in 2-km and 12-km simulations with varied lead times of 12h – 72h and how the vertical cloud distribution was affected. The cloud microphysics was represented by the 2-moment scheme of Seifert and Beheng (2006), providing prognostic equations for cloud water as well as droplet number concentration and hence a cloud-droplet size distribution. We used the 2-moment scheme, as it leads to a more realistic representation of cloud drop activation and precipitation formation by autoconversion, which is crucial for maintaining the stratocumulus layer. Additionally, the 2-moment scheme will be needed for future work focusing on ship tracks, which were also observed during the period analysed in this study.

The key findings of this study showed that limiting the vertical mixing, as it is currently done in COSMO as well as other regional models, to at least $1 m^2/s$ considerably weakens the inversion and produces a much too dry MBL with little cloud cover. On the other hand little sensitivity was observed towards the prescribed maximum length scale of the turbulent eddies. Additionally, the pre-frontal lifting was found to increase with simulation time indicating stronger frontogenesis.