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New planetary boundary layer parametrization in ECHAM5-HAM: Dynamical refinement of the vertical resolution

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Marine stratocumulus-capped boundary layers exhibit a strong net cooling impact on the Earth-Atmosphere system. Moreover, they are highly persistent over subtropical oceans. Therefore climate models need to represent them well in order to make reliable projections of future climate. One of the reasons for the absence of stratocumuli in the general circulation model ECHAM5-HAM (Roeckner et al., 2003; Stier et al., 2005) is due to the limited vertical resolution. In the current model version, no vertical sub-grid scale variability of clouds is taken into account, such that clouds occupy the full vertical layer. Around the inversion on top of the planetary boundary layer (PBL), conserved variables often have a steep gradient, which in a GCM may produce large discretization errors (Bretherton and Park, 2009). This inversion has a large diurnal cycle and varies with location around the globe, which is difficult to represent in a classical, coarse Eulerian approach. Furthermore, Lenderink and Holtslag (2000) and Lock (2001) showed that an inconsistent numerical representation between the entrainment parametrization and the other schemes, particularly with the vertical advection can lead to the occurrence of 'numerical entrainment'. The problem can be resolved by introducing a dynamical inversion as introduced by Grenier and Bretherton (2001) and Lock (2001). As these features can be seen in our version of ECHAM5-HAM, our implementation is aimed to reduce the numerical entrainment and to better represent stratocumuli in ECHAM5-HAM.

To better resolve stratocumulus clouds, their inversion and the interaction between the turbulent diffusion and the vertical advection, the vertical grid is dynamically refined. The new grid is based on the reconstruction of the profiles of variables experiencing a sharp gradient (temperature, mixing ratio) applying the method presented in Grenier and Bretherton (2001). In typical stratocumulus regions, an additional grid level is thus associated with the PBL top. In case a cloud can be formed, a new level is associated with the lifting condensation level as well. The regular grid plus the two additional levels define the new dynamical grid, which varies geographically and temporally. The physical processes are computed on this new dynamical grid, Consequently, the sharp gradients and the interaction between the different processes can be better resolved.

Some results of this new parametrization will be presented. On a single column model set-up, the reconstruction method accurately finds the inversion at the PBL top for the EPIC stratocumulus case. Also, on a global scale, the occurrence of a successful reconstruction, which is restricted in typical stratocumulus regions, occurs with a high frequency. The impact of the new dynamical grid on clouds and the radiation balance will be presented in the talk.

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