Diurnal Cycle Climatology of Planetary Boundary Layer Parameters in the Atmospheric Component of the GFDL Global Climate Model

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This study describes the performance of two developmental versions of the atmospheric component of the Geophysical Fluid Dynamics Laboratory global climate model in simulating the diurnal cycle climatology of PBL parameters. The main difference between the two versions is in the PBL parameterization: one uses a prescribed K-profile PBL scheme with an explicit entrainment parameterization, and the other employs a turbulent kinetic energy scheme. The simulated diurnal cycles are compared with those in the reanalysis ensemble, generated from ERA-20C, ERA-Interim, NCEP-CFSR, and NASA-MERRA.

Overall, the two versions reproduce the general patterns of the near-surface temperature, wind speed, and the PBL height, but several systematic biases are found. To identify the sources of the biases, the link among the biases, surface fluxes, and the turbulent mixing in the PBL is further studied for the two selected regions — the Sahara and Antarctica. The following is a list of the key findings.

The two versions underestimate 2-m temperature in most continents and the Arctic, while slightly overestimating it in dry regions. On the other hand, its diurnal amplitude is underestimated (overestimated) over land in the low and middle latitudes (in the high latitudes). The analysis for the Sahara region reveals that the vertical mixing in the dry convective boundary layers is weaker in the model than in the reanalysis, resulting in the warm bias. The 10-m wind speed and its diurnal amplitude are underestimated over land, with a systematic error in phase. The errors are attributed to the insufficient momentum mixing in the PBL. In Antarctica both versions hardly capture the daytime mixed layers in summer, due to the coarse vertical resolution near the surface. The heat from the surface is confined to the first model layer and hardly transported to the upper levels, resulting in the warm bias near the surface.