Geophysical Research Abstracts
Vol. 16, EGU2014-1693, 2014
EGU General Assembly 2014

Biases in the surface climatology from Global Climate Models due to the representation of the Planetary Boundary Layer

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This study assessed 36 Global Climate Models (GCMs) that contributed to the latest phase of the Coupled Model Inter-comparison Project (CMIP5) for their ability to reproduce the mean climate and climate change of the surface air temperature (SAT) in the historical scenario. The model results were assessed individually through comparison to a reanalysis product (ERA-Interim), and collectively by assessing the inter-model mean and spread. We have demonstrated that the models perform worse, both individually and collectively, under conditions of stable stratification – related to shallow boundary layers. The models generally under-estimate the SAT trends and variability in stably-stratified conditions, where they have a bias towards deeper PBLs.

These results are interpreted within the framework of the PBL response mechanism. GCMs use a variety of parameterizations to represent the PBL, and these result in different climatologies of the PBL depth. These models have difficulty reproducing the observed climatology of the PBL with a general bias towards over-estimating the depth of the PBL, especially in stably-stratified conditions. The PBL depth is linearly related to the effective heat capacity of the atmosphere, which modulates SAT response to forcing. This effect is especially important in shallow PBLs due to the reciprocal relationship between the strength of the changes to the SAT (the trend and variability) and the effective heat capacity of the atmosphere (the PBL depth). Therefore, structural problems in a GCM's ability to describe the PBL may be expected to lead to errors in the climatology of the SAT. When a model over-estimates the PBL depth we may expect it to under-estimate the strength of SAT trends and variability, and vice versa. These errors are expected to be most apparent in shallow PBLs where the models have large errors in their climatology of the PBL and (since the shallow layers most strongly effect the SAT response to forcing) this leads to large errors in the SAT.