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Planetary boundary layer feedbacks in climate system

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A remarkable feature of the ongoing global warming is the asymmetry in trends of the daily minima, $\theta_{\min}$, and maxima, $\theta_{\max}$, of the surface air temperature (SAT): $\theta_{\min}$ increases faster than $\theta_{\max}$, so that the daily temperature range (DTR), $\theta_{\max}$–$\theta_{\min}$, basically decreases. The state of the art general circulation and climate models (GCMs) do not reproduce it and predict approximately the same change rates for $\theta_{\min}$ and $\theta_{\max}$. We propose that the difference in trends of $\theta_{\min}$ and $\theta_{\max}$ is caused by the strong stability dependence of the height, h, of the planetary boundary layer (PBL). Indeed, the daytime warming is associated with deep convective (C) PBLs (with the heights $h_C \sim 10^3$m), in contrast to the nocturnal and/or wintertime cooling associated with shallower mid-latitudinal nocturnal stable (NS) PBLs (with $h_{NS} \sim 200$m) and even shallower high-latitudinal long-lived stable (LS) PBLs (with $h_{LS} \sim$ 30-50m) developing during longer than night periods of the persistent surface cooling. As a result, one and the same increment, δQ_0, in the surface heat flux leads to only minor increment in $\theta_{\max}$ in deep C PBLs, but essential increments in $\theta_{\min}$ in shallow NS and especially NS PBLs. The latter type of the PBL has been discovered only recently and is not yet accounted for in modern GCMs. In the present paper, we derive theoretical estimates of the variations, $\delta\theta_{\min}$ and $\delta\theta_{\max}$, in the SAT minima and maxima associated with the stable and convective PBLs, respectively, and by this means explain the observed asymmetry in the growth rates of $\theta_{\min}$ and $\theta_{\max}$. To characterise the role of PBLs in the climate system, we introduce the concepts of local and general PBL feedbacks. Besides the strengths of feedbacks, we propose to take into account the reaction times of different mechanisms. The proposed concepts could be applied to different climate-change problems from global (as in this paper) to local, in particular, to those caused by the land-use modification.