Responses to the interactive comment on "The effect of low density over the "roof of the world" Tibetan Plateau on the triggering of convection" by Jun-Ichi Yano (Referee)

Authors

The reviewer made the following comment regarding the change of surface flux with a change of air density:

"The authors do not provide any sensible argument to justify this experimental design. However, a following simple simply consideration on a principle of the bulk surface-flux formulation suggests that it is rather the vertical eddy flux rather than the heat flux, *H*, itself that remains overall invariant with a change of air density."

Our response is the following:

A more physical approach to evaluate how the sensible heat flux $\boldsymbol{H} = \boldsymbol{\rho C_p \overline{w'\theta'}}$ at the Earth's land surface varies with air density *ρ* is to consider the surface energy budget,

$$R_{net} = H + LE + G, \qquad (1)$$

where R_{net} is the surface net radiation, *LE* is the latent heat flux, and *G* is conduction into the ground. We assume that each of these components is independent of the altitude of the surface, which is approximately the case for identical land surfaces with the same incoming solar radiation and mean atmospheric temperature structure. This is the basis for assuming that *H*, which is proportional to the air density, *ρ*, is independent of altitude. Buoyancy flux, $\boldsymbol{(g/T)\overline{w'\theta'}}$, does not depend on *ρ*. Hence it follows that an increase in altitude means a decrease in *ρ*, and thus an increase in $\boldsymbol{\overline{w'\theta'}}$ to compensate, which then increases the buoyancy flux.

The increase of buoyancy flux with altitude has been documented observationally by Wu et al., 2017) who found that *H* increases as the elevation increases from 2000 m to 4000 m over the TP and by Wang et al., 2016 who showed that for unstable stratification in daytime, $(\boldsymbol{g}/\boldsymbol{T})\overline{\boldsymbol{w}'\boldsymbol{\theta}'}$ over the TP is significantly larger than at lower elevation.

Finally, the derivation of (A10) follows closely the derivation of Tennekes (1973) whom we reference (although with an erroneous date. The date given in the manuscript (1984) is incorrect; it is actually 1973, the same year that Betts independently published a similar relation.). The solution (A11) is a slightly generalized form of his solution that allows for arbitrary values of the entrainment coefficient β.

References

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