Interactive comment on "Atmospheric boundary layer dynamics from balloon soundings worldwide: CLASS4GL v1.0" by Hendrik Wouters et al.
Anonymous Referee #1
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General Comments
This is a well-written manuscript which documents a powerful new software tool which the authors are making publicly available. This tool should allow researchers to perform extensive experiments related to boundary layer growth and development, including sensitivity to land surface and atmospheric inputs and parameters. The input datasets are global and extend back to 1981, allowing for easy application of experiments across climate regimes and seasons, and allowing users to test the representation of boundary layer dynamics in climate and earth system models. The authors include analysis of an initial experiment to demonstrate the first-order performance of the model. This projects looks like it could be extremely beneficial to the broad scientific community. I am fully in favor of this manuscript being published in Geoscientific Model Development. I document a few very minor suggestions below.

We would like to thank the referee for providing their review of the manuscript, and we are very glad to note the appreciation of the software's potential. We also acknowledge their comments, especially for improving the clarity of used methodologies, input data and results, and we provide a point-by-point answer below. The changes to the manuscript are provided as quoted text, which will be included in the next revised version of the manuscript.

Minor Suggestions
1. Section 2.1, line 15: "for which one also adds the entrainment flux driven by shear": I'm not quite sure what this phrase means. Do you mean that the component driven by shear is included in the 0.2(buoyancy flux) term, or that it should be added to this term? If it's the latter, you should change the word "for" to "to".*

It is the latter, namely the component driven by shear is added to the buoyancy flux afterwards. Hence, we change "for" to "to". In the revised manuscript, it will read as: "Entrainment flux is calculated as a fixed fraction (0.2) of the buoyancy flux, **to** which one also adds the entrainment flux driven by shear."

2. Line 18: Which parameters in the Penman-Monteith and other empirical equations are fixed and which are locally and/or seasonally determined from the input datasets?'

Here is a table for the most important parameters in the Penman-Monteith and other empirical equations regarding to vegetation, soil and the air. It will be included as a second table in the revised manuscript:

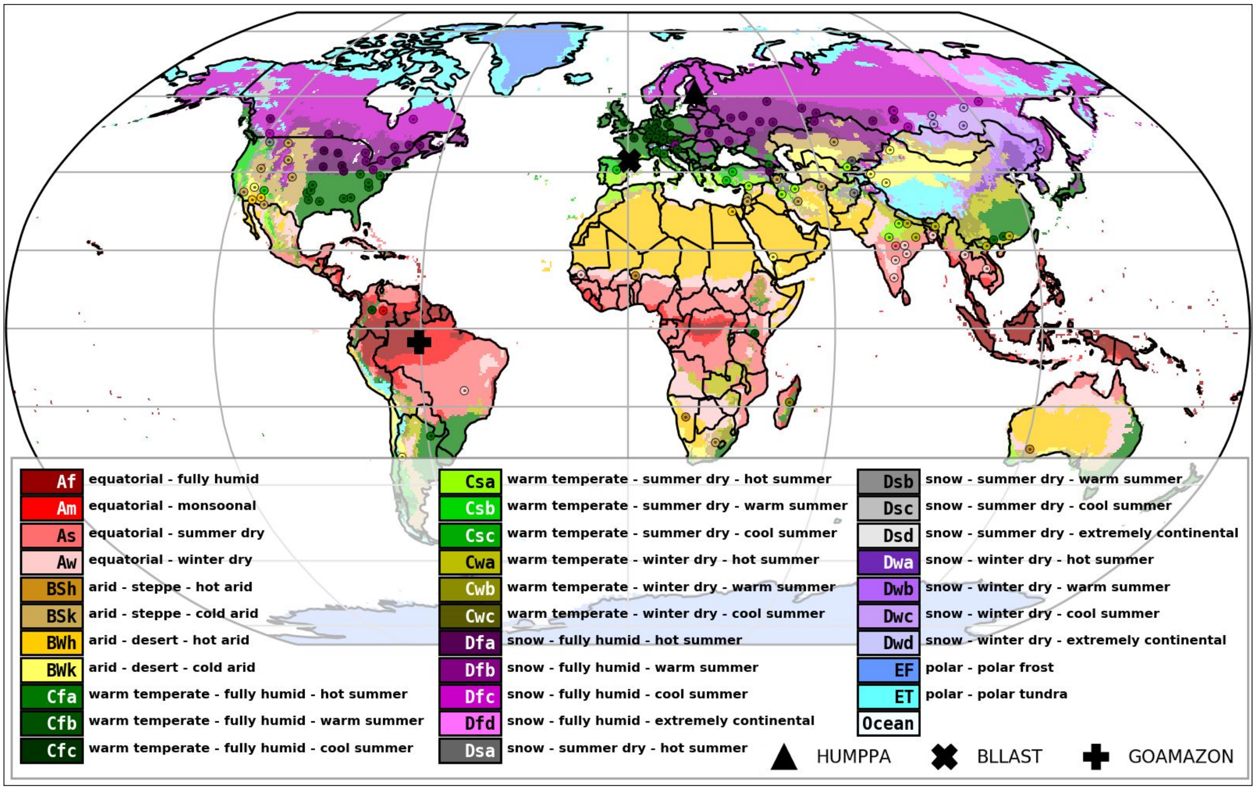
Vegetation			
Symbol	*Name*	*Unit*	*Default value or source*
LAI	Leaf area index of vegetated surface fraction	[-]	GIMSS
$r_{c,min}$	Minimum resistance transpiration	[s m^{-1}]	110
$r_{s,soil,min}$	Minimum resistance soil evaporation	[s m^{-1}]	50
g_D	Vapour pressure deficit correction factor for surface resistance	[-]	0
h_{can}	Canopy height	[m]	GLAS
z_{0m}	Roughness length for momentum	[m]	0.1 x h_{can}
z_{0h}	Roughness length for heat and moisture	[m]	0.1 x z_{0m}
α	Surface albedo	[-]	MOD44B
T_s	Initial surface temperature	[K]	ERA-Interim
$T_{soil.1}$	Temperature top soil layer	[K]	ERA-Interim
$T_{soil,2}$	Temperature deeper soil layer	[K]	ERA-Interim
ω_{sat}	Saturated volumetric water content	[m^3 m^{-3}]	IGBP-DIS
Soil			
Symbol	*Name*	*Unit*	*Default value or source*
ω_{fc}	Volumetric water content field capacity	[m^3 m^{-3}]	IGBP-DIS
ω_{wilt}	Volumetric water content wilting point	[m^3 m^{-3}]	IGBP-DIS
EF	Evaporative fraction	[-]	ERA5
$\omega_{soil,1}$	Volumetric water content top soil layer	[m^3 m^{-3}]	By iterative matching of EF
$\omega_{soil,2}$	Volumetric water content deeper soil layer idem		*Idem*
c_{veg}	Vegetation fraction	[-]	MOD44B
a	Clapp and Hornberger retention curve parameter	[-]	HWSD
b	Clapp and Hornberger retention curve parameter	[-]	HWSD
p	Clapp and Hornberger retention curve parameter	[-]	HWSD
C_{Gsat}	Saturated soil conductivity for heat	[K m^{-2} J^{-1}]	HWSD
$C_{2,sat}$	Coefficient force term moisture	[-]	HWSD
$C_{2,ref}$	Coefficient restore term moisture	[-]	HWSD
Λ	Thermal diffusivity skin layer	[-]	5.9
Air			
Symbol	*Name*	*Unit*	*Default value or source*
β	Ratio between buoyancy virtual heat and entrainment virtual heat	[-]	0.2

γ_θ	Initial lapse rate of potential temperature in the free atmosphere	[K m^{-1}]	From profile (IGRA)
γ_q	Initial lapse rate of specific humidity in the free atmosphere	[kg kg^{-1} m^{-1}]	*Idem*
γ_u	Initial lapse rate of zonal wind in the free atmosphere	[s^{-1}]	*Idem*
γ_v	Initial lapse rate of meridional wind in the free atmosphere	[s^{-1}]	*Idem*
$\Delta\theta_h$	Initial temperature jump between the mixed layer and free atmosphere	[K]	*Idem*
$\Delta\theta_q$	Initial specific humidity jump between the mixed layer and free atmosphere	[kg kg^{-1}]	*Idem*
$\Delta\theta_u$	Initial specific zonal wind jump between the mixed layer and free atmosphere	[m s^{-1}]	*Idem*
$\Delta\theta_v$	Initial specific meridional wind jump between the mixed layer and free atmosphere	[m s^{-1}]	*Idem*

Table2. Surface input parameters for CLASS4GL. The parameter specifications and source acronyms are explained in section 2.3, see also table 1.

3. Figure 2: It took me a while to find the big X for the BLLAST experiment location, in part because much of the X is on top of country lines. Perhaps you can use a different Symbol.

The symbol for the BLLAST location is now replaced with a thick cross. It will now appear as follows, which should make it more traceable:



4. Section 3, line 3: When you first mention daytime tendencies, can you clarify what time period the resultant values are averaged over? I imagine it is from sunrise through the time of the second sounding.

The tendencies are averaged from the morning sounding to the afternoon sounding. This will appear explicitly in the revised text as follows:

"The evaluation is done by comparing the modelled daytime tendencies of the mixed-layer height (dh/dt), potential temperature (dθ/dt) and specific humidity (dq/dt) against the corresponding tendencies observed from the balloon sounding pairs. **Observed and modelled tendencies represent the mean diurnal change from the morning sounding to the afternoon sounding.**"

Since the local timing of this second sounding is at different times of day in different longitudes, might this introduce a spatial bias since BL growth rates are not uniform over the course of the day?

Ideally, one would always have a sounding at the same local time in the morning and in the afternoon. Since the launching times are based on UTC, this is obviously not the case. So we agree that the common local time of the sounding launch depends on longitude, and also that the ABL growth is certainly not uniform over the course of the day. However, the latter is taken into account, since the model is always initialized with the morning sounding for which the initial local model time is set equal to the sounding launch, and the same is true for the afternoon sounding. So it can be concluded that the expected tendency for each launch or site (depending on the local time window being considered in the computation of that tendency) is equivalent for observations and models, hence any biases related to launching times between the two are avoided.

This will be clarified with the following additional text (it will be located just after the previous text):

“It should be noted that the local time of the morning and afternoon soundings changes given that the launch times are often at 12 and 0 UTC, and that the boundary-layer tendencies are not uniform over the course of the day. The resulting variety in the tendencies is taken into account in the simulations, since the model is initialized with the morning sounding while the initial solar local time in the model is set equal to the sounding launch. The same happens for the end of the simulation at the time of the afternoon sounding. Hence, the expected tendency for each launch or site (depending on the local time window being considered in the computation of that tendency) is equivalent for observations and models, hence any biases related to launching times between the two are avoided”

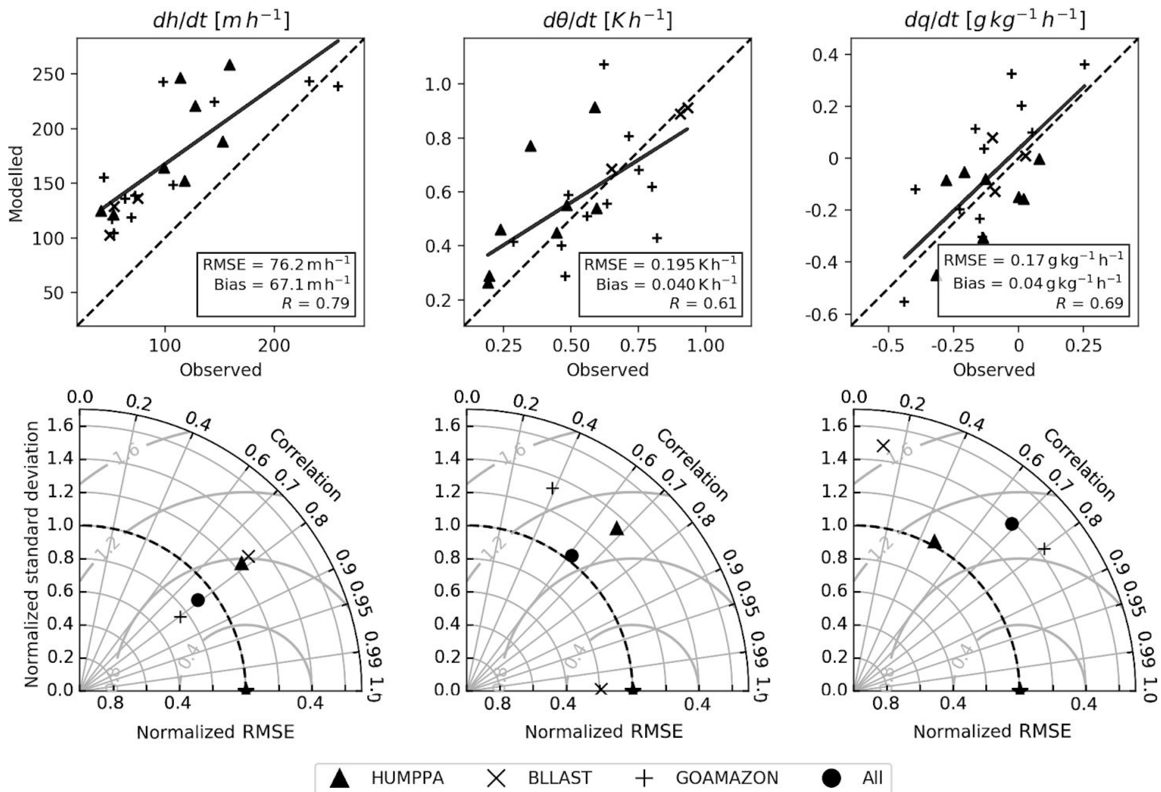
5. Page 12, line 2: Here you mention the observed daytime tendencies when you are discussing the results from the three intensive campaigns. Are the results you show actually subdaily averages since you have more than two soundings per day?

Yes, as clarified above, the results reflect the diurnal tendencies averaged over the time span between the morning and afternoon sounding, hence depend on the sounding launch times. In case there are multiple soundings retained during a particular day which is especially the case for the campaigns, the sounding closest to sunrise is taken for the initialization in the morning, and the latest sounding for the validation in the afternoon. This was not mentioned explicitly in the text. This clarification will now be added in the methodology section ‘2.2. Automated balloon data mining’:

“... Finally, the afternoon radiosonde profile on the same day needs to occur between local noon and 1 h before sunset **(defined as the time when the incoming shortwave radiation at the top of the atmosphere becomes zero)**, and at least 4 h after the model initialization in the morning **so that a sufficiently large model time span is considered**. **In case there are more than two soundings retained during a particular day which especially occurs during the campaigns, the sounding closest to sunrise is taken for the initialization in the morning, and the latest sounding for the validation in the afternoon**. ...”

6. Figure 3: the correlation plots are quite busy, making it a touch hard to find the three symbols of interest. Maybe you can make the grey lines a little bit lighter grey so the symbols are easier to see.

The grid lines are now lighter which increased the visibility:

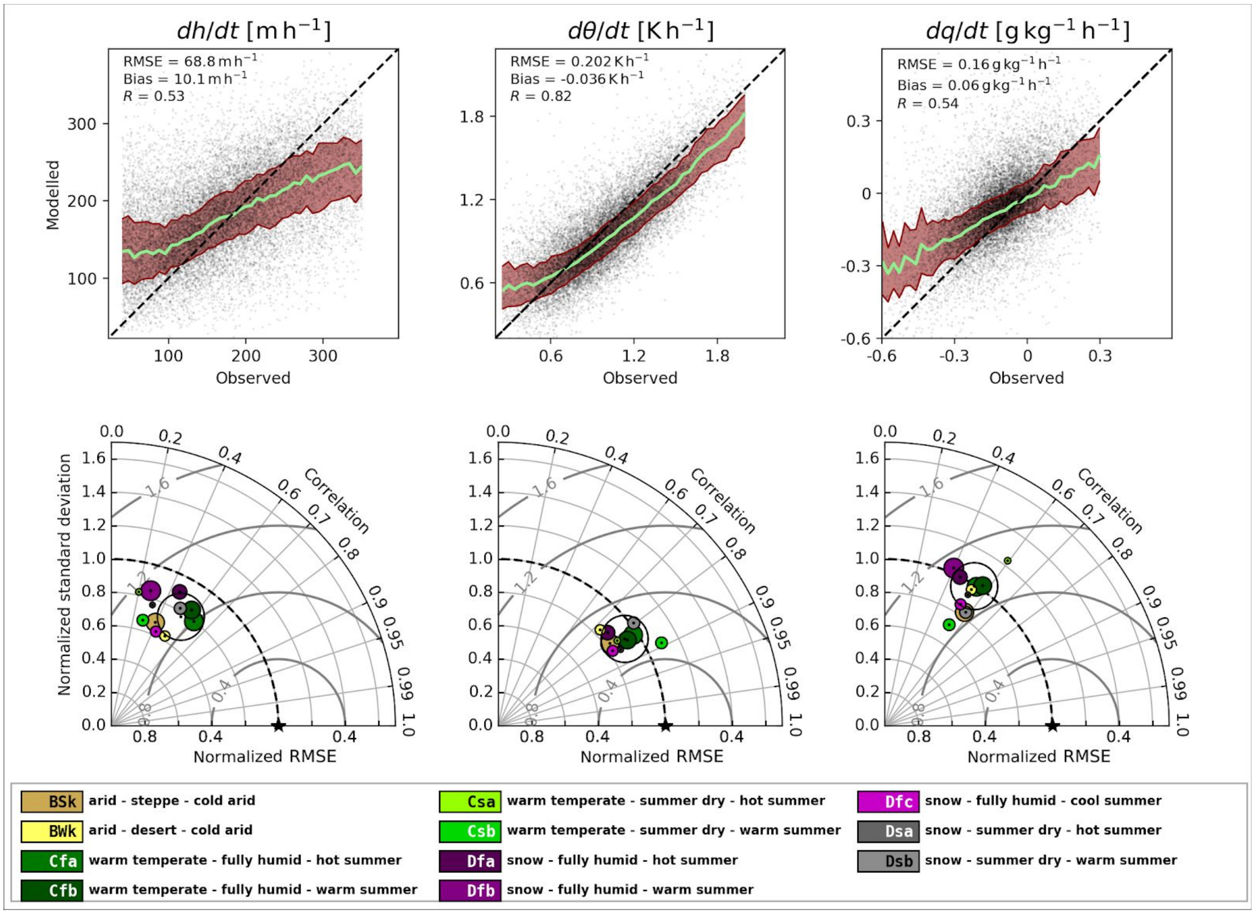


The updated figure will be included in the revised manuscript.

7. Page 13, line 8: It is not clear to me where the 22% value comes from. Please clarify.

The 22% value refers to the departure of the (normalized) standard deviation of the model output from the (normalized) standard deviation of the observations. This can be seen on the Taylor plots in Fig. 4 (figure pasted below) for which the centers of the open circles are between 0.78 and 1.22 of the normalized standard deviation. This will be made clear in the text as follows:

"In addition, the overall modelled range in dh/dt, dθ/dt and dq/dt agrees well with the observed range~~, with departures from the standard deviation of the observations below 22% – see Taylor plots in Fig. 4.~~**, for which the departure of the (normalized) standard deviation of the respective modelled parameters results from the (normalized) standard deviation of the observed parameters is below 22%. This can be seen on the Taylor plots in Fig. 4 for the centers of the open circles are between 0.78 and 1.22 of the normalized standard deviation.**"



dh/dt [m h^{-1}]
RMSE = 68.8 m h^{-1}
Bias = 10.1 m h^{-1}
R = 0.53
$d\theta/dt$ [K h^{-1}]
RMSE = 0.202 K h^{-1}
Bias = -0.036 K h^{-1}
R = 0.82
dq/dt [g kg^{-1} h^{-1}]
RMSE = 0.16 g kg^{-1} h^{-1}
Bias = 0.06 g kg^{-1} h^{-1}
R = 0.54
Modelled
Observed
Normalized standard deviation
Correlation
Normalized RMSE
BSk arid - steppe - cold arid
BWk arid - desert - cold arid
Cfa warm temperate - fully humid - hot summer
Cfb warm temperate - fully humid - warm summer
Csa warm temperate - summer dry - hot summer
Csb warm temperate - summer dry - warm summer
Dfa snow - fully humid - hot summer
Dfb snow - fully humid - warm summer
Dfc snow - fully humid - cool summer
Dsa snow - summer dry - hot summer
Dsb snow - summer dry - warm summer