Response to Reviewer #2

We would like to thank the anonymous reviewer for these suggestion and relevant comments.

RC2-1: Abstract: First two lines fit well for an introduction. What is the overall major scientific problem regarding the goal of this manuscript should be first spelled out in the first part of the abstract, instead of generic information on surface temperature variability?

The first sentence presented in the abstract has been changed in order to present the major scientific problem and scope of the current study, as follows:

"*Local short-term temperature variations at the surface are mainly dominated by small-scale processes coupled through the surface energy balance terms, which are well known but whose specific contribution and importance on the hourly scale still need to be further analyzed*"

RC2-2: Intro: Authors should clearly mention the need for such a model which is based on a lot of observations. How can this model help develop and improve surface layer parameterization scheme. Etc

Now this is mentioned in the introduction in Line 579-588 as follows:

"The use of the model developed in the current study considers all the variables acting within the ABL and controlling surface temperature variations, all of them estimated almost exclusively from surface-based observations. Thus, it allows to study separately the influence of each SEB term in a local scale. This indeed allows to have a realistic and reliable estimation of the contribution of each term (radiative fluxes, turbulent heat fluxes, etc.) on hourly temperature variations, and it would be possible to have that at different sites since each term will present a different behavior and importance. These estimations could help improving the parametrizations already existing of the SEB terms and better understanding their spatial evolution as a function of local conditions. Furthermore, a comparison between multi-model regional climate simulations and these estimations can be performed to evaluate if the simulations are able to well reproduce these behaviors, in particular in a warming climate where these processes are expected to change."

RC2-3: Line 28: Azores?

We suppose the reviewer meant Line 27 from the original manuscript, and maybe there is an error of encoding in the PDF from the reviewers PDF viewer since it is written "Açores"

RC2-4: Line 55: This is result and too early to spell out here. Please remove.

It is modified since the reviewer #1 also suggested to remove the results in the introduction, in Line 592-593:

"Clouds are well known to modify directly near-surface temperatures and other near-surface variables in multiple time-scales (Parding et al., 2014; Broeke et al., 2006; Kauppinen et al., 2014)."

RC2-5: Line 65: Set an example for each with references for "climate variability and extreme local events". I suggest 2006 drought in EU

Three references are mentioned now that show extreme local events influenced by the presence of clouds: Chiriaco et al., (2014); Rebetez et al., (2009); Bennartz et al., (2013)

RC2-6: Line 72: Repeated. Delete please.

It is deleted and then slightly modified

RC2-7: Line 105: Which lidar and what is the temporal and vertical resolution of lidar instrument here. Some details could be found in Koffi et al. (Evaluation of the boundary layer dynamics of the TM5 model over Europe) on different EU sites on this.

It is now specified the type of lidar used as well as its vertical resolution, and it is now mentioned in Line 649-650 that further details can be found in Chiriaco et al., (2018) in Table 1 and Section 3.5. This is mentioned as follows:

"(…) retrieved from a LNA lidar (532 and 1064 nm) whose vertical resolution is 15 m (for further details, see Chiriaco et al., 2018), (…)"

RC2-8: Line 118: Unless it has been established before, this is too early in a manuscript. Please remove.

Indeed, it is too early to mention it, so this sentence has been removed.

RC2-9: Line 171: Please use the term "combined"

The sentence is changed as follows:

"… is retrieved using SIRTA-ReOBS combined with ERA5 dataset"

RC2-10: Line 182: "mixing with an atmosphere of higher levels….". If so, then how does it represent a high positive correlation coefficient found in other literature where the authors have performed regression analyses of MLD and surface temperature. See Seidel et al.2010, 2012 (Climatology of the planetary boundary layer over the continental United States and Europe). This has an important implication. Please clarify. I think above statement need to justified and corrected.

Seidel et al. (2012) showed a strong correlation between MLD and surface temperature (especially in warm seasons), but this correlation is found for radiosondes launched at 12:00 UTC. Moreover, both the temporal and spatial scales are different from those of ours. Seidel et al. (2012) looked at a continental scale with measurements retrieved from several observatories in North America and Europe, whereas our study focuses on a local scale. As for the temporal scale, they performed an annual cycle of MLD and T_{2m} and then found the strong correlation between these two variables. It is also expected that this high correlation is found for the rest of the day since the surface temperature keeps increasing as MLD does it as well. However, here we refer to the contribution of the HA to hourly surface temperature variations, not to surface temperature. The HA term presents a negative contribution to hourly surface temperature variations in the afternoon as shown in Figure A (figure not added to the manuscript) for all seasons, therefore we mention that the mixing of higher atmosphere levels indeed contributes to cool the surface. We change this sentence in Line 727-728 to clarify that we do refer to surface temperature variations, as follows:

"(..) meaning that the mixing with an atmosphere of higher levels contributes to decrease surface temperature variations, even if surface temperatures continue increasing along the day."

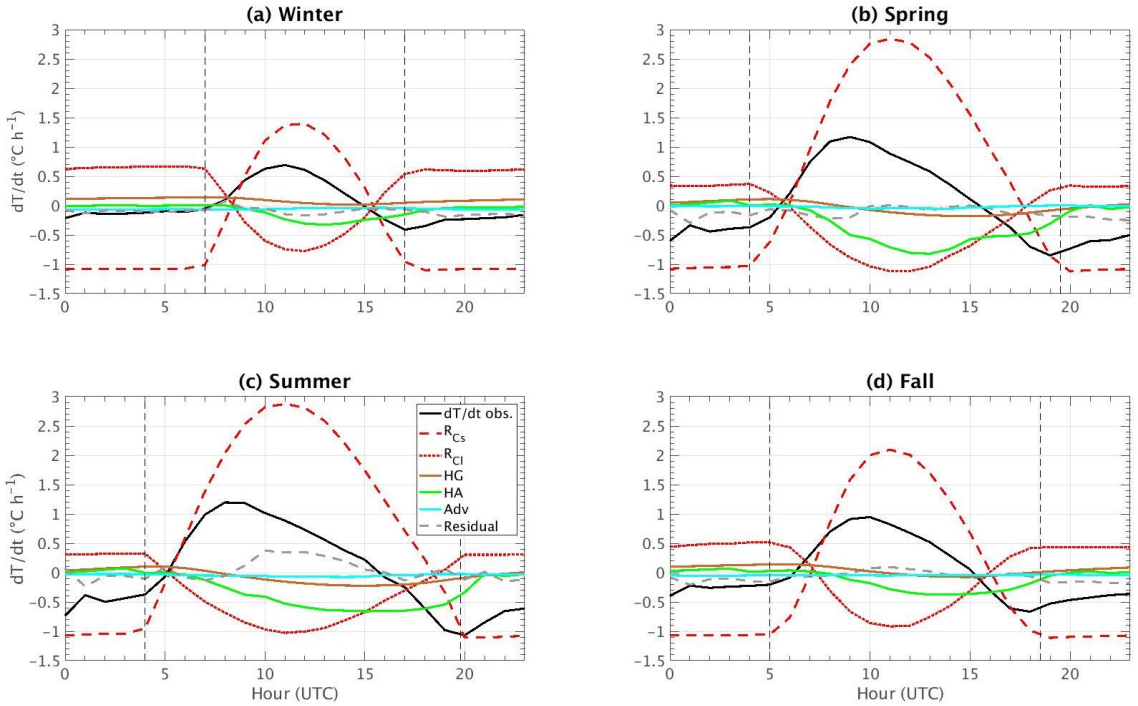

Figure A. Diurnal cycle of the five terms of our model, and the observed temperature variations, split into seasons.

RC2-11: Line 186: Please quantify (remains low).

This sentence is now corrected in Line 731-732:

"…: differences occur for cases where the temperature decreases during the hour, but this difference corresponds to some cases where the model presents more negative values than the observations, around -1 °C h^{-1}"

RC2-12: Figs. 2a and 2b: x-axes scale limits need to be symmetric; otherwise, one cannot justify the statements made in this regard.

Both x-axes on Figs. 2a and 2b have been modified and now they are symmetric

RC2-13: Line 189 and associated figure: Since observation is the reference here for the analytical model, please exchange the x and y axes of Fig. 2c.

Indeed, the linear regression that best fits the model for the observation is calculated and presented in Fig. 2c: y corresponds $\frac{\partial T_{2m}}{\partial t}_{obs}$ and x is $\frac{\partial T_{2m}}{\partial t}_{obs}$, so the best linear fit found is $\frac{\partial T_{2m}}{\partial t}_{obs} = p * \frac{\partial T_{2m}}{\partial t}_{mod} + b$, where p is the coefficient and b the intersection with the y-axis. We found therefore convenient to represent in the y-axis the observations and in the x-axis the model

RC2-14: Fig. 4: Units are missing on the color bar scale limits. Please use symmetric color bar scalelimits as well like in Fig. 4f

Units of the color bar are specified on figure caption. Using symmetric color bar scales limits do not allow to have a clear view of the contribution of each term, the idea is also to set red colors as a positive contribution and blue as negative contributions. We use the upper and bottom scale limits as the maximum and minimum value contribution of each term for a clearer interpretation.

RC2-15: Section 4.2: It will be important so that the authors should focus on the analyses of temperature variability during morning and evening transition periods which are the two most complicated phases of the diurnal cycle of temperature over land and this is also important for trace gas variability as well since the ABL interacts with upper layers in phases (e.g., Lee et al. Meteorological controls on the diurnal variability of carbon monoxide mixing ratio at a mountaintop monitoring site in the Appalachian Mountains).For the above, I suggest rather than each hour temporal variability, author could build a key temperature growth rate (between sunrise and 14 UTC) and compare that single parameter in different seasons and years (model vs obs).

What the reviewer asked us to do is not possible to perform because we don't have the surface temperature estimated by the model. Nevertheless, to analyze if the model well reproduces the observed temperature variations,
contours indicating sunrise and sunset hours were added in all the subfigures in Figure B (Figure 4 in the manuscript). Our model seems to reproduce on average quite well $\frac{\partial T_{2m}}{\partial t}$ both at sunrise and sunset since the residual is low at these times (Fig. Bf). This is also corroborated again in Fig. A that show us that the residual is on average weak (gray dashed line) at these transition hours (marked as the vertical black dashed lines) for all the four seasons. A new paragraph is added in Section 3.3, which is consecrated to evaluate these transitions periods (Line 815-818):

"*Focusing on the transition periods (sunrise and sunset, black lines in Fig. 4), the residual presents low values at these times. Indeed, there is a slight underestimation of the model of about -0.13 °C* h^{-1} *for some months (e.g. February) at sunrise hours, whereas a low overestimation with close-to-zero residual mean values are found for May and June. For the sunset, a similar behavior is found (with very similar values for the residual term). Therefore, a good agreement is found between the model and the observations for these specific hours."*

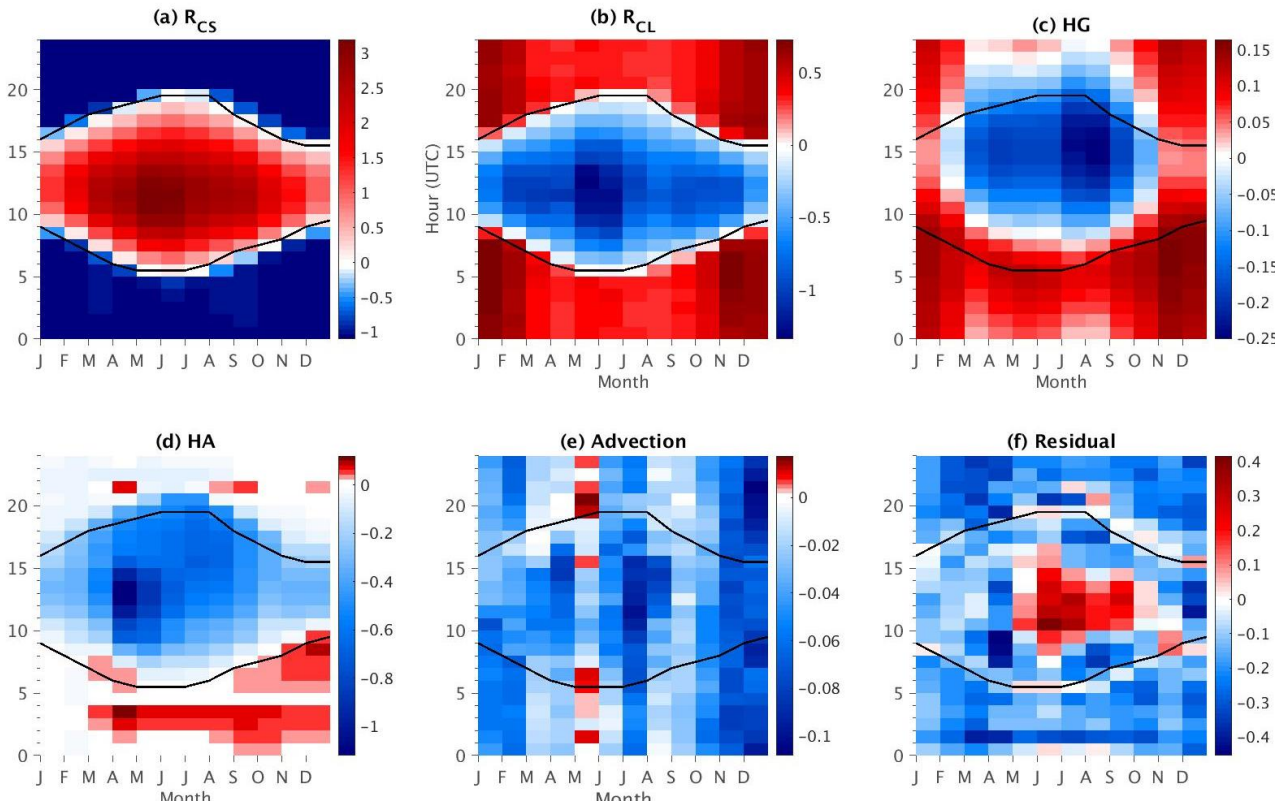

Figure B: Monthly-hourly mean values for (a) R_{CS}, (b) R_{CL}, (c) HG, (d) HA, (e) Adv and (f) the residual (i.e. difference between the model and the observations). Units on the color bars are all in °C h^{-1}, and their scale is different for each subfigure. The black contour line on each figure corresponds to sunrise (bottom line) and sunset (top line) approximative hours.