Responses to Reviewer 1

We would like to thank Reviewer 1 for his interesting suggestions and comments which will certainly improve the quality of the manuscript.

General comment

The manuscript would benefit from improved organization to highlight the specific theoretical explorations of this work as compared to several similar previous publications from the same group: it is at times difficult to discern which are the new developments and motivations (some specific suggestions below).

The end of the introduction from L17 is modified in the following way:

In this context, the main objectives of the paper are to investigate the theoretical foundations of the combination equation, applied to a canopy of leaves, and to examine the different ways of aggregating the in-canopy resistances (surface and air) in a general single-source formulation of canopy evaporation, both under dry and wet conditions. This examination follows previous works made on the formulation of evaporation from heterogeneous and sparse canopies (Lhomme et al., 2012, 2013). Indeed, it appeared that the generalized formulation derived by Lhomme et al. (2013, Eq. 12) for multi-component canopies could be extended to a simple canopy, the individual leaves and the soil surface making the different components and the general formulation being rewritten in a form similar to a combination equation. The basic principles are similar to those developed by Shuttleworth (1978) in his simplified description of the vegetation-atmosphere interaction. The whole canopy (soil surface included) is supposed to be subject to the same vapour pressure deficit D_m at the mean source height z_m ($d + z_0$), as in the original Penman-Monteith model and in two-source models (Shuttleworth and Wallace, 1985). Given that the modeling process accounts for all the surface and boundary-layer resistances within the canopy, the issue of aggregating the component resistances, as discussed in Lhomme et al. (2012), is indirectly dealt with, together with the question of the exact location of the canopy source height and the corresponding problem of the excess resistance. Finally, the errors made when applying simple equations of the Penman-Monteith type instead of the more general ones are numerically assessed.

The conclusion is also slightly amended:

> The present paper sets a theoretical framework for canopy evaporation through the development of two generalized combination equations, one for completely dry canopies (Eq. 7) and the other for partially wet canopies (Eq. 28), the former being included in the latter. These general equations are derived assuming that all the exchange surfaces are subject to the same vapour pressure deficit at canopy source height. In this sense, as already said, the modeling approach is different from the common multi-layer approach, where the whole canopy is divided into parallel layers, each one subject to a different air saturation deficit, with an additional aerodynamic resistance in relation to the vertical transfer of heat and mass. Comprehensive combination equations have been derived using this approach (Lhomme, 1988a, b), but they are more complex than the equations derived here. Despite their relative simplicity, the present generalized combination equations cannot be easily applied in an operational way, since the available energy partition (within the canopy and between wet and dry surfaces) is required as input. To provide equations easier to handle, assumptions and approximations can be made. In this down-grading process, one of the basic assumptions is to consider that the available energy is equally distributed amongst the exchange surfaces. This hypothesis appears to be rather unrealistic, both in dry and wet conditions, but it leads to simple formulations of the Penman-Monteith type (Eqs. 13 and 33, respectively), which have been successfully used up to now. The numerical simulations, based on a simple one-dimensional model, confirm that the Penman Monteith equation performs well in dry conditions, when the soil surface does not evaporate. In partially wet conditions, a discrepancy with the comprehensive formulation exists, but it tends to be nil when the canopy becomes completely wet.

Specific comments

1. **The abstract should provide conclusions about the behavior of the formulation rather than simply indicate that simulations are carried out. I suggest the most important are P10958L14 and P10958L19.**

The end of the abstract has been modified in the following way:

Numerical simulations are carried out by means of a simple one-dimensional model of the vegetation-atmosphere interaction to compare formulations and to assess the concept of excess resistance. In dry conditions, there is a large discrepancy between the generalized formulation and its simpler forms of the Penman-Monteith type when the soil surface resistance is low. In partially wet conditions, the discrepancy is maximal when the canopy is half wet and decreases when it becomes drier or wetter.

2. **(P10947L13) The definition of Ai would benefit from clarification. This is the available energy at element i within the canopy, correct? Table A1 uses the words "energy of" but I think it is better to say energy "at" to indicate incoming (external energy).**

The corresponding text (starting from P10947L11) has been modified:

The elementary evaporation …. of the Penman-Monteith type. It involves the saturation deficit of the air at canopy source height (D_m) and the available energy (A_i) for element *i* within the canopy (Lhomme et al., 2012)

Eq. (3)

In Eq. (3), for the canopy leaves, A_i is the net radiation per unit area of leaf, $r_{s,i}$ is the leaf stomatal resistance (one side) per unit area of leaf and $r_{a,l}$ is the corresponding leaf boundary-layer resistance for sensible and latent heat. For the soil surface symbolized by subscript $i = s$, A_s is the net radiation minus the soil heat flux per unit area of soil, $r_{s,s}$ being the soil surface resistance ……

3. **(P10950L16) Theta is a critical concept and could be made more clear. First, if I understand it correctly, it seems it would be more appropriate to write it as theta (i) to indicate it is a smooth function evaluated at element i. As written now it implies there is a theta for every i. Second, it would be valuable to describe what you envision to be the likely structure of theta. For example is it simple theta = exp (kx) as in Beer's law? How can we estimate theta in the real world, which is to say, how can we ever measure something to test whether this assumption is correct? I suspect theta is not a simple function and probably requires a stochastic formulation.**

The corresponding text has been modified:

The variable A_i giving the partition of available energy within the canopy is assumed to be in the form $A_i = A\ \Phi(i)$, where A is the total available energy for the whole canopy and $\Phi(i)$ is a function resulting from the radiative transfers within the canopy and depending on canopy structure and leaf area distribution. Beer's law, which is commonly used to express the attenuation of net radiation within the canopy, is typically a function of this kind. This assumption on the repartition of available energy is certainly a crude approximation, but it is required to mathematically derive a Penman-Monteith type equation from the generalized form of Eq. (7). This means that it is implicitly included in the common Penman-Monteith equation.

4. **(P10956L22) Multiple-layer formulations have already been published. I would like to see how this new element-based discretization can perform outside the layer concept. I do not immediately see how to do that, but perhaps some comments about the possibility are appropriate.**

The following comment has been added (P10957L3):

…. plus the soil surface. This modeling approach is different from the classical multi-layer approach (Waggoner and Reifsnyder, 1968) in the sense that each layer is subject to the same saturation deficit (D_m) without the inclusion of aerodynamic resistances in relation to the vertical transfer of sensible heat and water vapour. The parameterizations used ….

5. **I suggest leading the Results (4.2) with the statement P10958L12-13. However, I also think it is worded too strongly. Neither the theoretical basis of Eq 7 nor Fig 2 itself are tested with field data, so it is better to refer to differences among predictions as hypotheses.**

   Section 4.2 now begins with:

   The differences among the predictions in relation to different formulations are assessed.

6. **Another caveat for interpretation (P10959L6-10) is that the evaluation was done without addressing sensitivity to assumed canopy conditions. I also think by collapsing the canopy element concept to layers, the simulations are in a restricted theoretical space: that could be discussed in more detail.**

   The following caveat have been added:

   (i) the fact of representing canopy elements by layers necessarily restricts the theoretical space, (ii) the model used for simulating the vegetation-atmosphere interaction is itself relatively crude, (iii) the evaluation was done without addressing sensitivity to assumed canopy conditions, (iv) the equation defining $r_{a,c}$ (Eq. 20) is a simplified version …

   Technical:

7. **P10956L25. The way this is worded it implies Shuttleworth (1978) assumed D was homogeneous throughout the canopy. Suggest rewording "In our model, ...";**

   In fact, Shuttleworth (1978) did assume that D was homogeneous throughout the canopy in his "Simplified General Model"(his Figs. 4 and 5). So, we did not reword the text.

8. **P10951L16 I do not follow how the substitution in the numerator is possible.**

The text above Eq. (18) is replaced by:

Substituting Eqs. (16) and (17) into Eqs. (14) and (15) leads to the following approximate expressions for bulk canopy resistances:

9. **The other technical amendments will be made directly in the manuscript.**