Thank you for your thoughtful review of our manuscript. We appreciate your comments and questions and we have responded below (in boldface) to each item. Line numbers refer to the original manuscript.

This is a useful analysis of the heating rates derived for biomass burning aerosols over the south-east Atlantic during the ORACLES campaign. The dependence of the heating rates on various driving factors is isolated by making use of a newly conceived parameter, the "heating rate efficiency" or HRE. This parameter removes the linear dependence on aerosol extinction coefficient and incoming solar flux in each layer (i.e. the main drivers for the heating rates) by dividing the heating due to aerosols by these factors. The remaining dependencies on underlying cloud albedo, aerosol single-scattering albedo, and path length for the direct solar beam are then readily observed.

Whilst HRE provides a useful intermediary in determining the relationship between heating rates and various parameters, I'm not convinced of its utility as a general purpose parameter (for reasons outlined in the comments below). Despite that, this is a well written and useful study that I would recommend for publication subject to fairly minor revision after addressing the following comments.

1) The method used to segregate the contribution to heating rates from different components is only really applicable for small perturbations caused by the removed component. For example, if you remove aerosol from the whole profile and then recalculate the heating rate at layers below the aerosol layer, the heating in those layers is likely to be higher than before because more direct flux would have penetrated to that depth. This would lead you to conclude the aerosol has a negative heating rate at these altitudes. These issues should be explained. A different approach would be to calculate the component's contribution to the heating rate layer-by-layer by only removing the component from a single layer each time, and therefore leaving the flux arriving at the layer principally unaltered. Was this considered?

This is a good point. We calculated the component-specific HR in two steps: 1) Total heating rate, 2) Turn off components (e.g., aerosols, water vapor, other gases) one by one, and calculate the heating rate without that component, then take the difference. This allows us to partition the HR layer by layer. Your statement is true: When turning off a component, the HR of all the *other* components located below the (now missing) layer that would normally attenuate the radiation is higher than when the component is turned on.

However, this is effect is small. The difference in downwelling irradiance at the bottom of the aerosol layer is only ~18 W/m2 as shown in the figure below. This is less than 2% of the total irradiance at that level, and below the uncertainty in SSFR instrument (3%–5 % across the spectral range) used to derive the aerosol intensive properties.

Therefore, we have chosen to keep the results as they stand but have included the following text at lines 200-201:

"While minimal for our cases, very thick absorbing aerosol layers may induce shading effects on the downwelling irradiance."

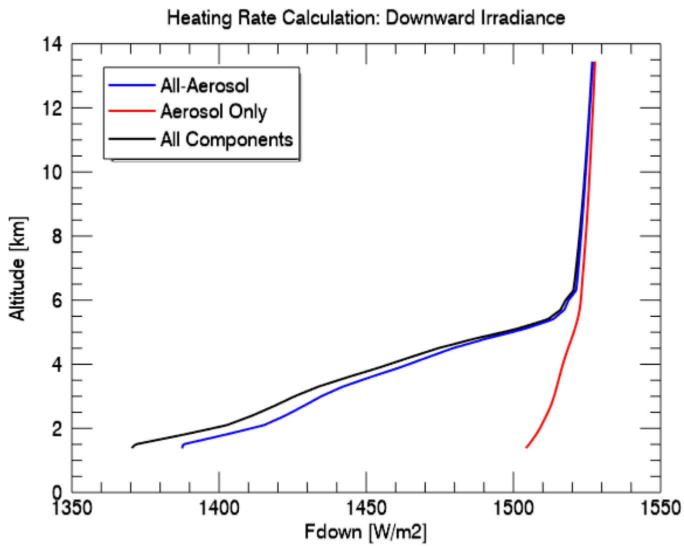

Figure 1. Downward irradiance at 532 nm for different heating rate radiative transfer calculations for case 20160920 #2. The black line shows Fdown for the full atmosphere with all components, the blue line shows Fdown for the full atmosphere without the aerosol, and the red line shows Fdown for an aerosol-only atmosphere.

2) The description of the way heating rates are segregated by absorber is a bit disjointed. The explanation of this in lines 156-166 would be better left to section 3 (along with a discussion of the issues highlighted in comment 1 above).

We chose to present the methodology description in this way to introduce the general method of calculating heating rates (applicable to both the spiral and the wall analyses) prior to the explaining the detailed method of each type of analysis. Because of this, we would like to preserve the section layout as is. However, as noted above, we included a discussion regarding shading effects on lines 200-201.

3) The heating rate efficiency has been defined to make use of the available observations, but these are inconsistent in wavelength: the heating rates are for the total heating over all wavelengths, the extinction is defined at 532nm and the fluxes are for the range 350 - 2100nm. The HRE parameter cannot therefore be ascribed any physical meaning and is not generally applicable, which I suspect will limit its usefulness in a wider context. You state one future use of the parameter (around line 382) would be to translate extinction profiles into heating rates. To do this you would also need not only cloud albedo, SSA and solar zenith angle but also the downward fluxes at each level between 350 - 2100nm (which is not stated). Is the intention for HRE to be used specifically with the instruments that cover the required wavelengths?

The HRE depends on the heating rate (a broadband quantity; all wavelengths integrated to obtain the broadband heating), the downward fluxes (broadband) and the extinction at 532 nm (narrowband). To translate from extinction profiles to heating rates, the first step would be to develop a full HRE parameterization, which would require the full spectra of cloud albedo, SSA, etc. However, once the parameterization has been developed than the user is only required to have these parameters at 532 nm, which are generally readily available. It may seem like a lot of required parameters, but requiring only one narrowband value is a significant improvement over requiring the full spectrum.

In addition, while you are correct that one application of the manuscript is the potential for future simplification (through the development of a full parameterization), another important application of the HRE is that it facilitates more convenient and consistent comparisons of heating rates across models, papers, study regions, etc. Currently, comparing heating rates is a major challenge due to the huge variability of contributing parameters. With the HRE, that large variability is significantly decreased.

4) The HRE parameter appears to be a fairly arbitrary intermediary parameter. It is useful to remove the linear dependence on extinction to expose the remaining dependencies. The division by downward flux, however, hides the dependence on the state of the atmosphere above as well as the solar illumination at the top of the atmosphere. Why stop there? You could have divided through by (downward + upward) flux which would have removed the dependence on the state of the underlying atmosphere (i.e. the cloud albedo), leaving the dependence on SSA and path length, etc.

In theory, this is an excellent suggestion. However, we chose not to go further in this manuscript because the relationship of HRE to the albedo is not exactly proportional. We have added text describing Figure 10 (HRE vs. Albedo) starting at line 366 to describe this more extensively:

"From the fit line, it is apparent that the HRE increases by approximately a factor of 2 across the full albedo range from 0 to 1. This can be understood intuitively, considering that the layer at an albedo of 1 is essentially illuminated "twice" – from the top and from the bottom. Of course, the heating of the layer is not exactly doubled since the illumination from the bottom (the upwelling) is less than from the top (the downwelling) due to the partial attenuation of radiation."

If we continue this work to develop a full parameterization in the future, we would need to consider the slight non-linearity of the scene albedo, in addition to other dependencies for which linearity cannot be assumed. For example, the dependence on the co-albedo (1-ssa) is only approximately linear (at ssa=1, the HRE=0 as can be seen in Figure 10b).

5) Paragraph starting at line 79 indicates HSRLs will be able to provide extinction profiles directly. Can you provide a reference / explanation for how this is done? This paragraph goes on to state that HREs could be used to translate these extinction profiles directly in to aerosol heating rates. How can this be done without knowing the downward fluxes at each level?

We have included the following citations at line 80:

Hair, J. W., Hostetler, C. A., Cook, A. L., Harper, D. B., Ferrare, R. A., Mack, T. L., Welch, W., Izquierdo, L. R., and Hovis, F. E.: Airborne high spectral resolution lidar for pro- filing aerosol optical properties, Appl. Optics, 47, 6734–6752, https://doi.org/10.1364/AO.47.006734, 2008.

Hu, Y., Vaughan, M., Liu, Z., Powell, K. and Rodier, S.: Retrieving Optical Depths and Lidar Ratios for Transparent Layers Above Opaque Water Clouds From CALIPSO Lidar Measurements, IEEE Geosci. Remote Sens. Lett., 4(4), 523–526, doi:10.1109/LGRS.2007.901085, 2007.

The downward flux would still need to be known at each level, but that should be a relatively straightforward radiative transfer calculation if the extinction profile is known. We admit this may not be as straightforward as we want, and that a full parameterization may need to be built without reliance on the downwelling irradiance and instead rely only on SZA, etc. Since these details are still to be explored, we didn't go further into the development of the full parameterization in this manuscript.

6) At lines 240, 292 and various other places you have used the terms 'extensive' and 'intensive'. It's not clear to me what these terms mean in this context. Could you please define your usage of these words or perhaps use an alternative description.

Extensive properties scale with the amount. Here, heating rate is an extensive property because it's proportional to extinction coefficient, which depends on number concentration of scatters and absorbers. However, if we normalize by the extinction coefficient, then HRE becomes intensive (similar to mass (extensive) vs. density(intensive.)) We have update the text starting at line 239 to the following:

"**This challenge is one of the motivations for the development of the heating rate *efficiency* (Section 5) which turns the heating rate (an extensive parameter proportional to the extinction) into an intensive quantity."**

Typo's and minor adjustments:
1) Abstract line 27: I think the term "curtains" needs explaining on first use.
We have updated the text on line 29 to first define a curtain as a vertical cross section.
2) Tables and figures are not referenced in order.
Thank you for pointing this out. The order of the tables and figures have been updated to be referenced in the appropriate order.
3) line 224: day^1 -> day^-1
Updated
4) line 337 & 338: sentence is repeated
Deleted duplicate sentence
5) line 352: and -> an
Updated