For the moment, we respond only to the major comments of the first reviewer, mainly about the calibration of the cross-polarized channels of the lidar.

1) The separation of lidar signals in two channels, based on depolarization, is in general affected by the following undesired effects: [a] laser output not fully polarized; [b] laser polarization not fully aligned to the receiver channels, i.e. a rotation; and [c] imperfect separation of signals at the receiver. In the present form of the paper (section 2.2), only the latter aspect is taken into account. The authors should discuss and quantify the contribution of effects [a] and [b], describe how they are minimized during instrument design, and provide the corrections that need to be used to cancel them during data analysis.

Yes, we agree that the main causes of uncertainty are the ones cited by the reviewer. In the paper, we have only discussed the third cause because the other ones have been considered to be negligible. Indeed, the laser is presented to be perfectly polarized by the manufacturer QUANTEL. We have discussed several times with this company about this and the response has always been the same: the laser ULTRA is totally polarized in the direction p (parallel). We have no capability in our lab to check this and we trust Quantel. Nevertheless, we have performed measurement with and without a Glan-prism placed at the exit of the laser and we have not observed significant differences on the depolarization ratio. About the second cause of uncertainty, the emission and reception paths are on the same integration plate to ensure that emission and reception optical axes are parallel. The orientations of the two Brewster plates are adjusted so as to maximize the backscatter signal on each channel. Moreover, the support of the Brewster plate are machined to within 2 degrees to accommodate the Brewster plates, the residual clearance is for adjustment in the laboratory. Hence, the dominant error source is due to the characterization of the plate transmission.

In the revised version we will add this discussion for clarification

2) Equations 2 and 3 are formally correct (although they only account for the effect [c] discussed above). However, it is easy to verify that some terms are negligible. In equation 2, the second term in the denominator is less than 0.1% of the first term, and in equation 3 the first term in the denominator is less than 0.1% compared to the second term (try substituting VDR=0.5, for instance). Similarly, (1-T1perp)(1-T2perp) is almost 1 (0.2% error). You should therefore either simplify the equations, or at least say clearly in the text that those terms are negligible. Otherwise you confuse the reader on what is really important and what is not.

We are agree that

$$S(r) \approx \frac{S^1(r)\cdot\left(1+VDR(r)\right)}{C^1\cdot T_1^{//}} \qquad (2)$$

$$VDR(r) \approx \frac{T_1^{//}\cdot S^2(r)}{R_c\cdot S^1(r)} - \left(1-T_1^{//}\right)\cdot\left(1-T_2^{//}\right). \qquad (3)$$

But we think it is worth starting with the “correct” equations for clarity purposes, the simplified equations being then given in a second step (considering the values of the transmissions of the Brewster plate).

3) Once your equations are simplified as discussed above, it is easy to see that the important term controlling the imperfect separation of your channels is (1-T1par)(1-T2par) and is equal to ~0.05 and ~0.01 for the two systems respectively. This evaluation is based on the transmission of each Brewster plate, considered separately. However, it will be affected by the angle of incidence of light onto each plate. I would assume that the transmission values Tpar and Tperp given in the paper are valid for a perfect positioning of the plates (Tperp minimized). How can you be sure that your Brewster plates are correctly positioned? Please describe the method used to position and align the plates, and how the transmissions Tpar and Tperp are determined.

The positioning of the Brewster plates in the lidar has been explained in our response to comment 1. The characterization of the Brewster plate has been done in the laboratory on a specific optical alignment bench where the Brewster plate is mounted on a support at 56° (specifically machined). We use a continuous laser at 355 nm with a Glan-prism after the emission. A half wavelength plate is used to rotate the polarization. The same interferential filter as the one of the lidar is used on the bench. To assess the plate transmission, the laser beam is measured with and without the Brewter plate. The uncertainty, evaluated using 10 repetitive measurements, is 35% on Tper and 1% on Tpar. We will add this complementary information in the revised manuscript.

4) Atmospheric calibration of the depolarization channel (determination of Rc – lines 9-10 after equation 3): is this done on each vertical profile separately, or do you determine this constant once and assume it does not vary after that during each flight? Later (bottom of page) you say that Rc varies with laser temperature; what is your uncertainty on Rc after accounting for these thermal variations? Are you monitoring temperature constantly?

The calibration coefficient is estimated during each flight by looking at lidar signals acquired in aerosol-free volumes. Note that it is not necessary on the profiles used to retrieve the optical properties of ash. The ± given on the Rc value characterizes its variability on different profiles. During the first flight, the air conditioner in the aircraft was out of service, but for the other flights, the temperature was stable at about ~18°C in the cabin. This information is given in the paper. We have not performed a specific study about the evolution of Rc against the ambient temperature.

5) If you can prove that all the above have been done correctly, then we can start believing your findings. If you can't prove it, however, it is easy to show what may be the consequence on an incorrect evaluation. Let me first write equation 3 in a simplified form: VDR = [(T1par S2) / (Rc S1)] - (1-T1par)(1-T2par). When you do your atmospheric calibration, therefore: Rc = (T1par S2_m) / {S1_m [VDR_m + (1-T1par)(1-T2par)]}. If for instance you have overestimated (1-T1par)(1-T2par), you will underestimate Rc. In return, this underestimated Rc will give you an overestimated depolarization. Moreover, you can see from equation 2 that this will also result in a larger signal in the ash layer (but not in the molecular layers). Therefore you will overestimate backscattering but not extinction (extinction is estimated from the attenuation of the molecular layers), i.e. you will get an underestimated lidar ratio. I do not say that this is necessarily happening, but it is another possible explanation of your results. It is therefore really important to prove that everything has been done for a correct evaluation of the (1-T1par)(1-T2par) term.

We hope that you can believe our findings as the one of other previous authors where no information is given about the calibration of the polarization. We agree with your demonstration if (1-T1par)(1-T2par) is overestimated. Nevertheless, the overestimation is less than 2% and cannot explain the difference with certain previous publications. It is important to note that similar LR has been retrieved over Paris using N2-Raman lidar and the coupling between sunphotometer and backscatter lidar during several days.

6) In section 4.1.1 you assess the potential bias for aerosols at the lower reference altitude, but ignore the possible bias at the higher altitude (line 15). The latter would probably result in a larger bias because it is at the near side. I recommend assessing this uncertainty as well.

Yes, this point has to be assessed on the same way. It will be done for the revised paper.

7) Conclusions need to be expanded. Compare your estimated concentrations to dispersion models and/or simultaneous satellite estimates, and explain the impacts that your methods may have on future research. Is there any synergy with data from other instrumented aircrafts?

Yes, we will discuss this point. We agree that it is important for further airborne experiments. Note that it is not so easy to couple in situ and lidar measurements, in particular in such a crisis condition. It is preferable to use two aircrafts. The coordination was not so efficient between the European countries, likely due to the crisis conditions.