Letter of Reply to Referee 2

Thank you for carefully reading the manuscript and providing useful suggestions to improve the paper.
Replies to your comments are given below.

General comments: The authors presented lidar detection and classification of pollen species (birch and spruce) mainly based on depolarization ratio of them. The data together with backscatter coefficient, extinction coefficient, lidar ratio and Angstrom exponent of pollen that they measured are very basic and useful parameters for lidar studies. However, more focused discussion on the local aerosol except for pollen is required for the paper to be accepted. Comments are given below.

Specific comments:

1 Title: "multi-wavelength Raman lidar" should be better to be changed to (for example) "multi-wavelength scattering lidar with several lidar parameters", because Raman data was only used to derive water vapor mixing ratio (is this correct?) that is not main point of the content.

The used lidar instrument is a multi-wavelength Raman polarization lidar. In addition to the determination of the water vapor mixing ratio, Raman measurements are also used to derive the lidar ratio, which is an important property for particle typing. We therefore prefer to keep the specification of our lidar system in the title. However the title was changed to "Detection and characterization of birch pollen in the atmosphere using multi-wavelength Raman polarization lidar and Hirst-type pollen sampler in Finland" to emphasis the synthesis of lidar and pollen collector.

2 Introduction: Please survey and show other methods/techniques of pollen detection such as CCD detection with imaging analysis, fluorescence lidars and others, so that authors can appeal features of their lidar to readers who are not only lidar researchers but also the wide range of them.

A paragraph about other pollen detection methods was added in the introduction, as:

"The majority of these stations operate Hirst-type volumetric air sampler. These traditional pollen traps are operated manually, which requires human resources and is time consuming. In the recent years, novel techniques have been developed to enable automated pollen monitoring and reduce workload. Those techniques use, for example, automated image recognition (Oteros et al., 2015) or fluorescence spectra (Crouzy et al., 2016) to identify pollen types and could enable a systematic pollen monitoring on ground level in near real-time."

3 Two cases: I want to know the reason why you selected only the two cases, the first period on 6 May 2016 between 23:00 and 01:00 and the second period on 15 May 2016 between 19:00 and 21:00. During 5-9 May, most of observations showed much higher concentration of birch pollen than that of first period you selected. And also, it seems better to discuss the influence of spruce pollen by using data in the morning on 13 May (13/05/16, Fig. 1) as spruce pollen concentration was higher than that in the second period.

The first case was chosen because we assume less contamination with anthropogenic aerosol during 6 May than during the period 8-9 May, when the concentration of birch pollen was much higher. During those days trajectories show that air masses travelled over the European continent e.g. Germany, which could have caused a contamination with anthropogenic aerosols. We want to show a case with minimal contamination of other aerosols. The second case study was chosen because we want to show Raman measurements (which are only possible during night time with less background light) with all lidar-derived parameters. 15 May was the only possible period suitable for lidar analysis (i.e. no low clouds and sufficient signal-to-noise ratio) although the spruce pollen concentration is higher on 13 May.

4 Aerosols: There are several descriptions for the possible existence of local aerosols other than pollen, p. 4 line 13, p. 5 line 22, p. 8, line17 and others. Nevertheless, the content of the paper seems to insist too much on the influence of pollen alone.

To check the background aerosol at our measurement site, lidar measurements during different times of the year have been checked. The particle depolarization ratio of the ground-near aerosol layer during the winter months of 2015 and 2016 are shown in Fig.1a. The winter time was selected to ensure the absence of pollen. Backward trajectories have been checked and measurements with distinct aerosol layers were omitted. The mean PDR during normal days without influence of pollen or other depolarizing aerosols is 4±1%, which is smaller than during the pollen-influenced period. Also pollen-free periods during spring and summer time, which means no pollen have been counted by the Hirst-type pollen collector, have been checked and are shown in Fig1 b, c. The mean values of PDR during those periods was 3.5±1% in March/May and 3.9±1% in July/August. However, during spring and summer the absence of pollen in the atmosphere cannot be confirmed with absolute certainty even if there are no pollen collected by the Hirst-type sampler.

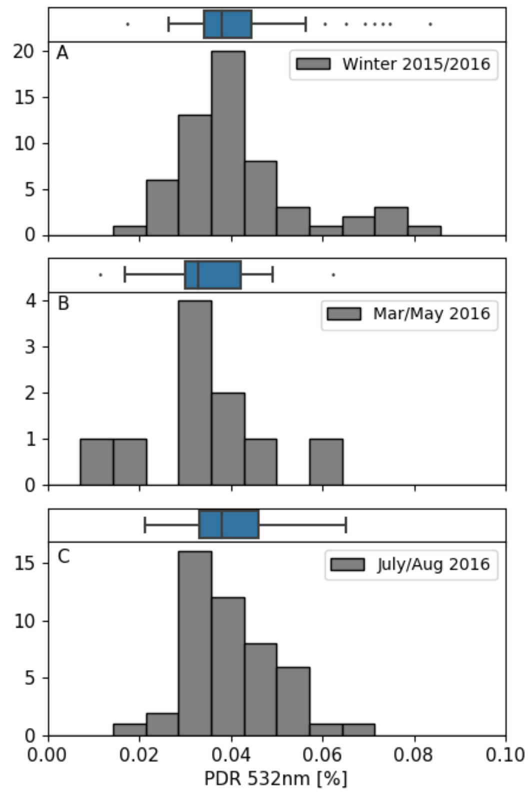

Figure 1 Histograms of mean PDR within the lowest aerosol layer during January 2015 and 2016 (A) and pollen-free cases during March/May 2016 (B) and July/August 2016 (C)

As the depolarization ratio of cases without detected pollen on ground-level or other depolarizing aerosol is below 4% and therefore significantly lower than during the presented pollination period, the particle depolarization ratio can be used to detect the presence of pollen in the atmosphere.

Information about background aerosol was added in section 4.2., as:

"*However the effect of the background particles has to be considered. Lidar measurements during the winter months of 2015 and 2016 and during pollen-free periods in spring and summer 2016 have been analyzed to determine the effect of background aerosol at our measurement site. During winter time the absence of pollen can be ensured, but there is a possibility that pollen also have been present in the atmosphere during spring and summer when no pollen were detected by the Hirst-type sampler on ground. Nevertheless, values of mean PDR at 532 nm are below 4% during all analyzed periods with no observed pollen concentration. Since the PDR during the pollination period is significantly higher than the PDR of the background aerosol, the depolarization ratio can be used as an indicator for detecting the presence of pollen.*"

5 Hirst-type volumetric air sampler: Relating to #3, please describe the detailed results about solid particles, except for pollens, found/collected with the air sampler. There may be much amount of particles generated from the ground around the local area where the lidar measurements were done. Couldn't you find any particles which showed depolarization? I think these particles are more important to understand the lidar results than airmass derived with backward trajectories.

The analysis of the collection tape of the Hirst-type air sampler only involves the examination of pollen grains. Other particles are not counted or analyzed. During the selected pollination period no other instruments measuring the depolarization were available. It is therefore not possible to make any statements about other depolarization particles close to the ground. However, the effect of depolarizing particles originating from the ground, can be considered negligible at the latitudes the lidar data is used. Also if such depolarizing particles were frequently present, this would be visible in the PDR values of days without pollen.

6 Range: The line 4 in page 5 describes "we only consider the lowest layer in the following analysis". It was at around 1 km. But Fig. 3 showing range up to 2.5 -3 km makes readers confused. Authors also described that data can be retrieved down to around 500 m. That data is important for comparison with the sampler data.

The lowest layer is used because the highest amount of local pollen is likely located in the layer closest to the ground. However our profiles cannot be extended down to ground-level. Theoretically profiles can be determined with overlap correction down to 500 m. However in this study the lower limit of our profiles is at around 800 m with a vertical smoothing of 25 bins (750 m) and a time average of 2 hours. Data below could not be used for comparison with the sampler data. The profile ranges used for calculation of mean values (pollen layer) is marked grey in Fig.3. Nevertheless the profiles are shown up to 3 km to give more information about the vertical aerosol distribution. A comment about the pollen layers shown in grey was added to the caption of Fig.3 and clarification that profiles are only reliable starting from 800 m in this study was added in the section 2.1, as:

“In this study, the lower limit of reliable profiles of vertically smoothed and temporally averaged optical properties is at around 800 m.”

Technical comments: Technical word and its prefix, such as particle depolarization ratio and PDR, lidar ratio and LR, frequently appears at random to each other, please unify them through the whole paper.

Technical words and their abbreviations have been unified.