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Interactive comment on "Aerosol properties and meteorological conditions in the city of Buenos Aires, Argentina during the resuspension of volcanic ash from the Puyehue-CordónCaulle eruption" by A. G. Ulke et al.

Anonymous Referee #2
Received and published: 18 March 2016

We thank the referee for the helpful comments and suggestions . We include here the referee comments in black *and our replies in blue. The paragraphs of the manuscript are quoted and included in normal font type.*

In this paper the authors analyze the resuspension episode occurred in mid-October 2011 which impacted the city of Buenos Aires and resulted in the closure of airports. Authors explore the meteorological conditions that led to the episode of volcanic ash resuspension and its transport to the city of Buenos Aires using measurements of aerosol properties carried out at Ciudad Universitaria. Moreover, they use the HYSPLIT model with the dust storm module to simulate the episode finding a good correlation. I recommend the publication after that the authors clarify some specific points:

1) Abstracts: the authors should add what are the implications of their study.

Answer: We agree with your suggestion, so we have modified the abstract as follows:

OLD ABSTRACT (P2 lines 1-20) in the submitted manuscript *nhess-2015-311-discussions-typeset_manuscript-version3 (nhess-2015-311-D-3)*:

"The eruption in June 2011 of the Puyehue-Cordón Caulle Volcanic Complex in Chile impacted air traffic around the Southern Hemisphere for several months after the initial ash emissions. The ash deposited in vast areas of the Patagonian steppe was subjected to the strong wind conditions prevalent during the austral winter and spring, experiencing resuspension over various regions of Argentina.

In this study we analyze the meteorological conditions that led to the episode of volcanic ash resuspension, which impacted the city of Buenos Aires and resulted in the closure of both airports on 16 October 2011. The thermodynamic soundings show the signature of "pulses of drying" associated with the presence of hygroscopic ash in the atmosphere that has been reported in similar episodes after volcanic eruptions in other parts of the world.

Measurements of aerosol properties that were being carried out in the city during the resuspension episode indicate the presence of an enhanced concentration of aerosol particles in the boundary layer. Reports of ash on the runway at the airport near the measurement site correlate in time with the enhanced concentrations. Since the dynamics of ash resuspension and recirculation is similar to the dynamics of dust storms, we use the HYSPLIT model with the dust storm module to simulate the episode that affected Buenos Aires. The results of the modeling agree qualitatively with satellite lidar measurements."

NEW ABSTRACT in the Revised Manuscript (RM):

"The eruption in June 2011 of the Puyehue-Cordón Caulle Volcanic Complex in Chile impacted air traffic around the Southern Hemisphere for several months after the initial ash emissions. The ash deposited in vast areas of the Patagonian steppe was subjected to the strong wind conditions prevalent during the austral winter and spring, experiencing resuspension over various regions of Argentina.
In this study we analyze the meteorological conditions that led to the episode of volcanic ash resuspension, which impacted the city of Buenos Aires and resulted in the closure of the two main airports in Buenos Aires area (Ezeiza and Aeroparque) on 16 October 2011. A relevant result is that resuspended material (volcanic ash + dust) imprint a distinguishable feature within the atmospheric thermodynamic vertical profiles. The thermodynamic soundings show the signature of "pulses of drying" in layers associated with the presence of hygroscopic ash in the atmosphere that has already been reported in similar episodes after volcanic eruptions in other parts of the world. This particular footprint, could be used to detect the probability of volcanic ash layers. This study also illustrates the alternative of using ceilometers not only to detect cloud base at airports, but also volcanic ash plumes at the boundary layer and up to 7 km altitude.
Aerosol properties measured in the city during the resuspension episode indicate the presence of enhanced concentrations of aerosol particles in the boundary layer along with spectral signatures in the measurements at the Buenos Aires AERONET site, typical of ash + dust advected towards the city. The mandatory aviation reports from the National Weather Service about airborne and deposited volcanic ash at the airport near the measurement site (Aeroparque) correlate in time with the enhanced concentrations. The presence of the resuspended material was detected by the CALIOP lidar overpassing the region. Since the dynamics of ash resuspension and recirculation is similar to the dynamics of dust storms, we use the HYSPLIT model with the dust storm module to simulate the episode that affected Buenos Aires. The results of the modeling agree qualitatively with satellite lidar measurements."

2) A detail description of the eruption features is lacking and should be added in the Introduction section or in a new paragraph.

*Answer: We have added a brief description of the eruption features together with updated references in the Introduction of the **RM**.*

OLD DESCRIPTION IN THE INTRODUCTION (P2 lines 22-26 P3 lines 1-8 in *nhess-2015-311-D-3*):
"After an inactive period of ca. 50 years the Puyehue-Cordón Caulle Volcanic Complex (PCCVC) in Chile (40.59°S, 72.11°W, 2.236m a.s.l.) erupted on 4 June 2011, ejecting a plume higher than 12km a.s.l. The earthquake activity and eruption events were monitored by the Chilean agency on geology and mining policies, Servicio Nacional de Geología y Minería (SERNAGEOMIN), which provides the periodic status reports of Chilean volcanoes. A detailed chronological description of the volcanic eruption and modeling of the volcanic ash dispersion during the main phase explosive events are reported by Collini et al. (2013). As a result of this eruption many airports were closed and flights cancelled in Chile, Uruguay and Argentina because of the potentially hazardous operating conditions. The PCCVC eruption also impacted air5 traffic throughout the Southern Hemisphere for several days from South America to Oceania, as prevailing winds at higher levels (300–600 hPa) over this region are strong and westerly."

NEW EXTENDED DESCRIPTION in the Introduction in the RM:
"At the end of April 2011, dozens of volcano-tectonic earthquakes mostly located at the Puyehue-Cordón Caulle Volcanic Complex (PCCVC, 40.59° S, 72.117° W, 2236m a.s.l) in the Chilean Southern Andes were detected by the Observatorio Volcanológico de Los Andes del Sur dependent of Servicio Nacional de Geología y Minería (SERNAGEOMIN) which is the Chilean agency on geology and mining policies, that monitors the volcanoes activity and reports the level alerts. The seismic activity at the PCCVC continued with an increasing magnitude and the eruptive process finally began at 2.45 p.m. of 4 June 2011. During the initial phase of the sub-plinian eruption a large plume of gases and ash particles were injected into the atmosphere up to ~12-14km height. The PCCVC volcanic activity declined its activity till March 2012 when the red alert level downgraded to orange and subsequently on 24 April 2012 decayed to yellow. This status alert remained until August 2012 when finally the alert level turned to green. A detailed chronological description of the volcanic eruption and modeling of the volcanic ash dispersion during the main phase explosive events are reported by Collini et al. (2013). A field-based reconstruction of the volcanic eruption, eruptive phases with a detailed characterization of the stratigraphy and deposit features during the entire eruption sequence is presented by Pistolesi et al. (2015) and the exact details of tephra sedimentation and grain size are presented by Bonadonna et al. (2015a).The determination of physical parameters during the main eruptive phase in relationship with the eruption classification and the characterization of the plume dynamics and spreading is also conducted by Bonadona et al. (2015b).
As a result of this eruption many airports were closed and flights were cancelled in Chile, Uruguay and Argentina because of the potentially hazardous operating conditions. The PCCVC eruption also impacted air traffic throughout the Southern Hemisphere for several days from South America to Oceania, as prevailing winds at higher levels (300–600 hPa) over this region are strong and westerly."

3) In the Measurements and methodology, a brief description of the instrumentation and data quality should be added, even if already reported in Ulke et al. (2011) and Raga et al. (2013). Moreover, the authors should give details on the properties that were measured. Perhaps a table with the type of measurements reported in the paper and their explanation could be useful.

Answer: We agree with your comment and as R1 suggested more explanation on this issue and a reorganization of the paper, these points are now clarified.

*In the **RM** we concentrated in the analysis of the ceilometer observations, PM_{10} concentrations, AERONET information and CALIPSO retrievals. We added the required information for the measurements that we finally included where/when suggested or necessary in the **RM** and in the answers to the referee comments.*

*The original paragraph: P5, L17 to L26 and P6 to P8 at **nhess-2015-311-D-3:***
"A detailed description of the instrumentation deployed at the Ciudad Universitaria (34°35' S, 58°22' W) during the field campaign to evaluate urban aerosol pollution is presented by Ulke et al. (2011) and Raga et al. (2013) and is only briefly described here. The particle properties measured were the number concentration of condensation nuclei (CN) larger than approximately 50 nm, the mass concentration of particle-bound polycyclic aromatic hydrocarbons (PPAH), the scattering (B_{scat}) and absorption (B_{abs}) coefficients at 530nm and the vertical profile of backscattered light from aerosols at a wavelength of 910

nm. For the purpose of studying urban pollution, the measurements of B_{abs} are converted to an equivalent mass concentration of black carbon (eBC) using a specific mass absorption coefficient of $6.5 m^2 g^{-1}$ (Bond and Bergstrom, 2006). The eBC concentration is an indicator of emissions from combustion by diesel engines, as are common in buses and trucks in Buenos Aires. Dust particles and volcanic ash (not only black carbon) can absorb radiation at 530 nm. However, the presence of dust and volcanic ash will typically not produce a PPAH signal, so the measurements can provide evidence of light absorbing particles that are not originated by diesel engines. The ceilometer backscatter measurements were converted to extinction coefficients using a least squares analysis with the in situ measurements of B_{scat} and B_{abs} (Raga et al., 2013). The vertical resolution of the ceilometer is 20m and the measurements are 10 min averages."

*Was replaced by the following one in the **RM:***
"The instrumentation deployed at Ciudad Universitaria (CU) (34.58° S, 58.37° W, 30 m a.s.l.) during the field campaign to evaluate urban aerosol pollution is described by Ulke et al. (2011) and Raga et al. (2013) including a discussion of uncertainties and limitations. However, for the purpose of this study, we will only concentrate on the data obtained with the Vaisala CL31 ceilometer, a remote sensing instrument located at the site that provides the vertical profile of backscattered light from aerosols at a wavelength of 910 nm. The vertical resolution of the ceilometer is 20 m, ranging up to an altitude of 7000 m. The measurement frequency of the instrument is 0.5 Hz, but the data was averaged over 10 min intervals. The ceilometer backscatter measurements were converted to extinction coefficients using a least squares analysis with the in situ measurements of scattering and absorption, as described in detail in Raga et al. (2013)."

*In the submitted manuscript: (**nhess-2015-311-D-3**), we have referenced our previous paper (Raga et al., 2013) <u>only for brevity</u> because Table 2 presents the information of the array of instruments deployed at the research site.*

Table 2 (from Raga, G.B., Baumgardner, D., Ulke, A. G., Torres Brizuela M. M. and Kucienska, B., The environmental impact of the Puyehue-Cordon Caulle 2011 volcanic eruption on Buenos Aires. Nat. Hazards Earth Syst. Sci., 13, 2319-2330, doi:10.5194/nhess-13-2319-2330, 2013) is the following one:

Table 2. Description of instrumentation deployed at the research site at the Facultad de Ciencias Exactas y Naturales, Universidad de Buenos Aires (FCEN, UBA). The acronym UNAM corresponds to Universidad Nacional Autónoma de México.

Parameter	Instrument	Institute	Detection limit	Accuracy	Frequency
Temperature, RH, pressure	Davis Inc. Weather Station	UBA	-50° to $+50^{\circ}$ 0 to 100 % 100 to 1024	$\pm 1^{\circ}$ ± 5 % ± 1 mb	1 Hz
Horizontal winds	Davis Inc. Weather Station	UNAM	0 to 50 m s^{-1}		1 Hz
Condensation nuclei	TSI CPC 3010	UNAM	0.02 µm	± 15 %	1 Hz
Particle-bound polycyclic aromatic hydrocarbons	EcoChem PAS 1000 photoelectric aerosol sensor	UNAM			0.3 Hz
Absorption coefficient	Radiance research particle soot absorption photometer (PSAP)	UNAM	1 M m^{-1}	± 25 %	1 Hz
Scattering coefficient	Radiance research nephelometer	UNAM	1 M m^{-1}	± 25 %	1 Hz
Backscattering vertical profile	Vaisala ceilometer CL-31	UNAM	20 m to 7000 m, with 20 m resolution		0.5 Hz

4) In the modelling approach, an improved description of sensitivity tests carried out in the paper will be valuable.

Answer: Thanks. This issue has been addressed in the RM and in this document.

5) Several sentences reported in the discussion section show results plotted in figures. They should be moved to a new section and deleted from the discussion.

Answer: We agree with your comments and as R1 also suggested a re-ordering of the different sections to a better comprehension for the readers, we have reorganized the sections as follows;

1. INTRODUCTION
2. MEASUREMENTS AND METHODOLOGY
2.1. Geographical location
2.2. Datasets
3. ANALYSIS OF THE METEOROLOGICAL CONDITIONS
3.1. Vertical Profiles
3.2. Synoptic Analysis
4. ANALYSIS OF AEROSOL PROPERTIES
4.1. Surface-based measurements
4.2. Satellite measurements
5. ANALYSIS OF HYSPLIT SIMULATIONS
5.1 Methodology and setup
5.2 Analysis of modeling results
6. DISCUSSION
7. CONCLUSIONS

The Figures will be re-organized accordingly and following this scheme.

Figure N° submitted manuscript	***Figure N° revised manuscript***
Figure 1	Corrected **Figure 1**
Figure 2	Corrected **Figure 2**
Figure 3 (extinction from ceilometer)	**Figure 5 (a)**

Figure 3 (surface wind speed)	**Figure 4** (surface wind speed and direction)
Figure 4	**Figure 3**
Figure 5	corrected **Figure 5 (b)**
Figure 6	Suggested replace by a new **Figure** as **5 (c)**
Figure 7	Corrected **Figure 7**
Figure 8	**Figure 6**

6) The discussion should be rewritten. Many sentences of the discussion can be moved to the Results section. A comparison with results reported in Folch et al. (2014) should be also reported.

*Answer: We agree with your comments and as R1 also suggested a rewritten discussion and the re-ordering of the different sections, we prepared a **RM** with the new scheme of Sections shown in the previous response (5)). In consequence, in the **RM**:*

- *all the results were removed from the old Discussion section.*
- *we have extended the comparison with the results reported in Folch et al. (2014), but please keep in mind that regarding the HYSPLIT model results, the comparison is qualitative because we used the public version, which has some limitations.*
- *in the following paragraph of the answer we have included the comments on specific figures from Folch et al. (2014) to make the required comparison, but we have not included their Figures in our **RM** because it seems to us inappropriate. We only include in the **RM** our HYSPLIT Figures at the times corresponding with CALIPSO overpass.*
- *to illustrate the comparison of selected Figures of Folch et al. (2014) with our HYSPLIT outputs at similar times we have included **supplementary material** (**SupplementaryMaterial.pdf**).*

OLD PARAGRAPH (Page 19, lines 9-17 in *nhess-2015-311-D-3*):
"Although the goals of our study are not to compare HYSPLIT dust module results with other model simulations, a qualitative comparison with Folch et al. (2014) for 16 October 18:00UTC is done. In fact, Folch et al. (2014) study was focused on the calibration of a new resuspension module. The horizontal particle distribution depicted at Fig. 7g is quite similar to their results (see their Fig. 7d and e) obtained with the oldest resuspension schemes. Comparing model estimates with proxy data obtained from visibility reports from the SMN, they mentioned that best results were obtained with the simplest scheme, but the horizontal fields of accumulated material were not included."

NEW PARAGRAPH (Section 5. ANALYSIS OF HYSPLIT SIMULATIONS, sub-section: 5.2 Analysis of modelling results in the RM):
"Although the goals of our study are not the comparison of the HYSPLIT dust storm module results with other model simulations, a brief qualitative comparison with results reported by Folch et al. (2014) for 16 October 18:00UTC is done. We compared the horizontal distribution of particles as well as the time of arrival of the ash+dust over the aiports were we have information (METAR/SPECI). Folch et al. (2014) study was focused on the calibration and evaluation of their new resuspension module within a refined numerical modelling system WRF–ARW/FALL3D, specially designed for volcanic eruptions and dispersion of volcanic-origin material. The FALL3D model can predict the field of volcanic material concentrations. They evaluated the performance of different resuspension modules with derived quantities (total

suspended particles derived from visibility data which is reported by the SMN weather stations) using as control case the measured PM_{10} concentrations in Buenos Aires city. Analyzing their fields of mass concentration (see their Figures 7) and comparing with our HYSPLIT simulation at similar times and keeping in mind that our fields are "horizontal particle distributions" a similar behavior of the horizontal distribution is evident and the better agreement is with their SH new scheme."

*(The comparison is provided in the document **SupplementaryMaterial.pdf**).*

NEW PARAGRAPH (Section 5. ANALYSIS OF HYSPLIT SIMULATIONS, sub-section: 5.2 Analysis of modelling results in the RM):
"As previously mentioned, Folch et al. (2014) calibrated the resuspension in the FALL3D model analyzing the performance of three parameterizations originally developed for dust particle resuspension. In their calibration, they used visibility reports in Aeroparque (see their Fig. 6) and afterwards, they made a comparison with the remaining proxy data (estimated concentrations from 15 meteorological stations and plume arrival times (see their Figs. 8 and 9). Their found an underestimation of concentrations in the far field stations with all resuspension schemes. Afterwards, they compared the characteristic arrival time in terms of the decrease of the concentration to half the maximum value, with similar results for the 3 schemes. Focusing on the PM_{10} concentrations in the same event that we are analyzing in our paper, Folch et al. (2014) mention that the schemes that rely on the emission strength and friction velocity (the more sophisticated ones, MB and SH) widely underestimate the measured concentrations at CABA. They concluded that this results are due to the underestimation of the friction velocity by the meteorological model (WRF-ARW) that provides the input meteorological field to FALL3D. In fact they show that the MB and SH schemes need the friction velocity provided by the meteorological model which in turn is strongly depend on soil moisture field in the same meteorological model. They found best agreement when their predicted concentrations considering dry soil were compared to PM_{10} CABA measurements (see their Figure 11). In consequence, our results are consistent with their findings in spite of the more simple modelling strategy we have applied. As we mention in the introduction, the driving mechanisms of the dust storm module in HYSPLIT are the near surface wind speed and the soil type. The deposited ash was already in an arid region (the Patagonian steppe) which is frequently a source of wind-blown dust. In addition, in this particular event, the soil conditions were dryer than the climatological values as documented in the SMN reports."

TECHNICAL CORRECTIONS

Abstract

We agree with your comment and the Abstract was modified according your suggestions (see Pages 1-2 this document).

P3L9. What airports? Two or more? Specify.
*We think that the correct mentioned page number is **2, line 9.***
We agree with your correction as this paragraph is not clear, so we have modified it (see pages 1 and 2 this document) Moreover, from the noon all airports in Argentine were closed by the authorities (Secretary of Transport) for security reasons.

P3L9. Add the location where the thermodynamic soundings and measurements of aerosol properties were done.
*We agree with your comment and we can add a Table (Table I) with the geographical coordinates of all the locations. The text in the **RM** and **Figure 1** were modified including all the locations as well.*

Table I Location of the sites

Site ID	Name	Latitude (º)	Longitude (º)	Altitude (m)
1	PCCVC - Chile	40.59° S	72.11° W	2236
2	CU - CABA	34.58° S	58.37° W	30
3	Santa Rosa - La Pampa	36.57° S	64.27° W	190
4	CEILAP- BA -Buenos Aires	34.57° S	58.5° W	10
5	Ezeiza - Buenos Aires	34.82° S	58.53° W	20
6	Aeroparque - CABA	34.56° S	58.42° W	6
7	La Boca - CABA	34.62° S	58.36° W	11
8	Centenario - CABA	34.61° S	58.43° W	27
9	Córdoba - CABA	34.60° S	58.39 ° W	35
10	Córdoba - Córdoba	31.42° S	64.18 ° W	448
11	Rosario - Santa Fe	32.95° S	60.65 ° W	25
12	Santa Fe - Santa Fe	31.63° S	60.68 ° W	25
13	Carrasco - Montevideo	34.84° S	56.03° W	32

P3L15. Were the reports available only for one airport?
*We think that the correct mentioned page number is **2, line 15.***
We agree with your comment and we have modified the Abstract. In fact we have considered the reports of the airports in the area of our study.

OLD SENTENCE in the Abstract:
"Reports of ash on the runway at the airport near the measurement site correlate in time with the enhanced concentrations."

NEW SENTENCE in the Abstract:
"The mandatory aviation reports from the National Weather Service about airborne and deposited volcanic ash at the airport near the measurement site (Aeroparque) correlate in time with the enhanced concentrations."

In the following we explain what these mandatory reports are:
The METAR (meteorological airport reports), SPECI (special meteorological airport reports) correspond to mandatory International Civil Aviation Organization (ICAO) meteorological airport reports which in the METAR case are provided every hour and SPECI reports are emitted when the meteorological conditions could be risky for the aviation. These reports are generated by the meteorological offices located at airports (dependent from the National Weather Service).

P3L15. Add the location of the airport.
Answer: With the Table I and the new Figure 1, this item was solved.

Introduction

P3L24. Add references about eruption description.

We agree with your comment about an enrichment of the description of the volcanic eruption and we have added a new paragraph within the Introduction following your suggestion.

P4L12. Specify the four case studies that were analyzed.
*We think that the correct mentioned page number is **3, line 12.***

Answer: We have modified the paragraph.

OLD PARAGRAPH
"Four case studies were analyzed and evaluated that were coincident with the arrival of the ash plume over the Buenos Aires area and that led to airport closures. Vertical profiles of aerosol backscatter, measured with a ceilometer, clearly identified the presence of the volcanic ash."

NEW PARAGRAPH
"In Raga et al. (2013) four case studies were analyzed and evaluated that were coincident with the arrival of the ash plume over the Buenos Aires area and that led to airport closures. On these cases the vertical profiles of aerosol backscatter, measured with a ceilometer, clearly identified the presence of the volcanic ash."

P4L13. 'Vertical profiles of aerosol backscatter, measured with a ceilometer, clearly identified the presence of the volcanic ash'. Is it the result of this study? If yes, delete from the Introduction section.
*We think that the correct mentioned page number is **3, line 13.***

Answer: As the identification of the presence of ash with the ceilometer data was a result of the previous paper Raga et al. (2013), we have modified the paragraph (the immediately previous paragraph) for a better understanding.

P5L19. The moisture content is not present in the Result section. Add the graph or delete from the Introduction.
*We think that the correct mentioned page number is **4, line 19.***

Answer: Thanks for your observation. As it was an important result of our investigation it was included within the Results section. The corresponding graphs are the thermodynamic soundings (Figures 2) explained at Section 3, within the subsection 3.1 (Vertical Profiles). The analysis of these figures was not deleted but the text was modified considering the broader audience of the Journal. Please see our new paragraph at page 20 this document.
*In addition, Figure 2 in **nhess-2015-311-D-3** did not include the values of the variable that indicates moisture content, and this mistake was corrected.*

2. Measurements and Methodology

P6L11. How do the authors identify volcanic ash from the dust by MODIS images? May they add some other analysis (T2-T1 difference channels? e.g. Corradini et al. (2010)) or some references from other satellite studies?

*We think that the correct mentioned page number is **5, line 13***

Answer: We agree with your comment, so we modified this paragraph according the satellite study from Pujol et al. (2013), which confirms the resuspension event. The paragraph was modified as follows;

OLD SENTENCE
"The resuspended volcanic ash is seen in the Moderate Resolution Imaging Spectroradiometer (MODIS), 1km resolution visible data on 15 October in Patagonia (Fig. 1b)."

NEW SENTENCE
"The resuspended volcanic ash is seen in the Moderate Resolution Imaging Spectroradiometer (MODIS), 1km resolution visible data on 15 October in Patagonia (Fig. 1b).The results presented by Pujol et al. (2013) helped to confirm the volcanic origin of the detected aerosol layer. To identify the source of the ash/dust plume they used the concept based on reverse absorption (Prata, 1989) and 3.9 /11 /12 µm bands empirical algorithm (Ellrod et al., 2003)."

P6L11. What is it reported in this technical report?. Add more data or delete the sentence.
Answer: The report analyses the spatial distribution of the ash over the Patagonian steppe after 6 months of the initial eruption, the relationship amongst the particle sizes, the soil and vegetation types. They also considered in their analysis the precipitation regimes and the soil moisture content. This data are relevant in the resuspension or remobilization of the deposited ash and the maps did also contribute to locate the deposited ash in our simulations

We included this results in the RM.

OLD SENTENCE:
"A technical report from the Instituto Nacional de Tecnología Agropecuaria (Gaitan et al., 2011) based on field measurements depicts the deposition zone (isopachs) in the same area."

NEW SENTENCE:
"A technical report from the Instituto Nacional de Tecnología Agropecuaria (Gaitan et al., 2011) based on field measurements depicts the deposition zone (isopachs) in the same area. The report analyses the spatial distribution of the ash over the Patagonian steppe after 6 months of the initial eruption, the relationship amongst the particle sizes, the soil and vegetation types. They also considered in their analysis the precipitation regimes and the soil moisture content. This data are relevant in the resuspension or remobilization of the deposited ash "

P6L21. 'Condensation nuclei (CN) larger than approximately 50 nm'. what is the greatest size that can be detected?
*Answer: We have followed the **R1** recommendation about displaying/describing only the main and distinguishable aerosol features of this event, so the CN comments and Figure were eliminated as they are not significant for the analysis.*

P6L10. All the locations reported in the text should be added in the map (e.g.Figure1a).
*We think that the correct mentioned page number is **5, line 10.***

Answer: We agree and all the locations were added in the new Figure 1 and also within the Table I.

P6L15. What multiple wavelengths could the AERONET sun-photometer give?

*Answer: Regarding AERONET information we have not included the detailed information for brevity because it is available at their site http://aeronet.gsfc.nasa.gov/. We only mentioned (P15, L16 at **nhess-2015-311-D-3**) that the information is the*

LEVEL 2 CEILAP-BA AERONET data. In order to facilitate the interpretation of the results, we included more information in the ***RM.***

The original paragraph: P6, L10 to L19 at ***nhess-2015-311-D-3:***
"Additional information on aerosol optical properties was obtained from the AERosol RObotic NETwork (AERONET) sun photometer (Holben et al., 1998), maintained and operated by personnel at Centro de Investigaciones en Láseres y Aplicaciones (CEILAP-BA 34 39' 35" S; 58 28' 08" W), located approximately four kilometers west of the Ciudad Universitaria measurement site. Although the AERONET sun-photometer measures at multiple wavelengths, only the aerosol optical depth (AOD) at 500 nm was selected for analysis. This wavelength is closest to the 530nm wavelength used in the instruments that measured the B_{scat} and B_{abs} and the 550nm used by MODIS that is carried on the Aqua (Parkinson, 2003) and Terra satellites. MODIS images were used to identify the resuspension events."

Was replaced by the following one in the ***RM:***
"Additional information on aerosol optical properties was obtained from the AERosol RObotic NETwork (AERONET) site CEILAP-BA (34.57°S; 58.5°W, 10m a.s.l.) which is maintained and operated by personnel at Centro de Investigaciones en Láseres y Aplicaciones and is located approximately four kilometers west of the CU site. AERONET is a global network of surface-based stations that provide continuous information for the study of aerosol properties. It was established by the National Aeronautics and Space Administration (NASA) and PHOTONS (PHOtométrie pour le Traitement Opérationnel de Normalisation Satellitaire; Univ. of Lille 1, CNES, and CNRS-INSU) and currently there are numerous collaborators worldwide. The data along with the detailed information on detection limits, limitations and assumptions for the retrieval, inversion algorithms and quality-control procedures is freely available at http://aeronet.gsfc.nasa.gov/.
The observations are made with sun photometers of type CIMEL at multiple wavelengths (340, 380, 440, 500, 670, 870, 1020 and 1640 nm) (Holben et al., 1998). The measurements are provided for three quality levels (level 1: unscreened; level 1.5: cloud-screened and level 2: cloud-screened and quality-assured after a seven-steps procedure) and their uncertainty ranges from 0.01 to 0.02 (Eck et al., 1999, Smirnov et al., 2000). Data intermittence is mainly due to cloudiness over the site and/or the detection of anomalous values on the basis of their temporal variance.
The Aerosol Optical Depth (AOD) is a measure of the extinction of a beam intensity by the presence of aerosols in an atmospheric layer through which the light is traveling and indicates the columnar aerosol load in the local atmosphere. Several quantities are obtained from the measurements using inversion algorithms based on the AOD spectral dependence (e.g. aerosol size distributions, single scattering albedo, refractive indices and asymmetry parameter, among others).
The Ångström exponent (Alpha) shows the variation of the AOD with the wavelength (λ) of incident light. The 440-870 nm Ångström exponent ($Alpha_{440-870}$) is computed from linear regression of ln AOD versus ln λ for all AOD data available between the wavelengths of 440 and 870 nm and provides important information on the particle size distribution (Dubovik et al., 2002). The larger Ångström exponents are due to higher spectral variation in AOD and are associated to smaller particles. Contrarily, the lower values of Alpha indicate dominance of coarse aerosol. Aerosol particles in the fine fraction are typical from urban/anthropogenic pollution (combustion products from fossil fuel or biomass burning) whereas those associated to natural sources belong to the coarse fraction (dust, marine aerosol, volcanic ash, bioaerosol).
The AERONET fine mode fraction AOD_{500nm} product (FMF) is the ratio of fine to total AOD obtained with the spectral deconvolution algorithm (SDA) using the measurements from 380 to 870 nm. The detailed information and evaluation of the SDA along with the assumptions and errors is fully documented in O'Neill et al. (2001a,

b, 2003). Specifically, the FMF is an estimation of the optical effects of the fine-mode particles based on the spectral curvature in the observed optical depths instead of a cutoff radius. It is more robust because it could be applied in the cases of mixed aerosols (e.g. desert dust + combustion aerosols, clouds + smoke, etc).
The quantities that were selected for analysis were the AOD_{500nm}, the FMF AOD_{500nm} and the Ångström exponent ($Alpha_{440-870}$) level 2 data."

P6L18. Already written in the previous paragraph. Again, how do the author distinguish volcanic ash from dust? Channels at 11 and 12 micron are usually used to identify volcanic ash.

Answer: We have deleted the sentence: "MODIS images were used to identify the resuspension events." and we have referenced Pujol et al. (2013) study to identify the resuspension event (see previous comment within Methodology).

P8L15. May the authors give detail on color ratio and why this type of measurement is useful?
*We think that the correct mentioned page number is **7, line 15.***

*Answer: The color ratio is one of the CALIPSO retrievals, all of them were described at **nhess-2015-311-D-3** from P6 L20 to P8 L10 (in the section 2.2) and from P16 L17 to P18 L28 (in the section 5). After your question, we realized that our wording was misleading in some paragraphs and they were changed in the **RM**. We hope that the changes in these paragraphs and the reorganization of the manuscript will contribute to better present the procedures and outcomings of our work.*
In fact, we used the products provided by the Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) freely available at http://www-calipso.larc.nasa.gov/. The products are distributed by the NASA Atmospheric Science Data Center and are listed in detail in the CALIPSO Data Products Catalog (Powell et al., 2013). A summary of the measurement uncertainties and capabilities and spatial resolution is also available at their site, which also provides the detail of the publications in journal articles, technical papers and manuals.

*The original paragraph: Page 6, L20 to L21 at **nhess-2015-311-D-3:***
"Measurements obtained by the Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) are also analyzed."

*Was replaced by the following one in the **RM:***
"Products obtained from the observations of the Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) are also analyzed. The products are distributed by the NASA Atmospheric Science Data Center and are freely available at http://www-calipso.larc.nasa.gov/. The detail of the products can be found in the CALIPSO Data Products Catalog (Powell et al., 2013)."

*In our analysis we use the browse images (Version 3.01) available in the CALIPSO web site and we applied a similar approach than Winker et al (2012) that was explained in P7 L23 to L28 (**nhess-2015-311-D-3**). That means that we identified the ash+dust by visual inspection of the CALIPSO browse images and considered in our analysis the values reported in the cited literature in the manuscript.*

The definitions of the variables from CALIOP lidar in the CALIPSO browse images that we use in our analysis are included here:

The total attenuated backscatter signal 532 nm (TAB) is the sum of the 532 nm parallel and perpendicular return signals. The volume depolarization ratio is the ratio of the

perpendicular to parallel components of the TAB. The total attenuated color ratio is the ratio of the total attenuated 1064nm and 532nm backscatters.
The integrated attenuated backscatter is

$$\gamma' = \int_{\text{top}}^{\text{base}} \beta(z) T(z)\, dz,$$

where β is the total (molecular + particulate backscatter) and T is the atmospheric transmittance due to both molecules and particles, z is altitude and the subscripts "top" and "base" refer to the top and base of the feature as determined by the layer detection algorithm (Vaughan et al. 2009).
For further details please refer to:
http://www-calipso.larc.nasa.gov/resources/calipso_users_guide/browse/index.php.

*The definitions were included in modified paragraphs in the section 2.2 of the **RM**.*

*The original paragraph in P7 L9 to 15 at **nhess-2015-311-D-3:***
"To determine aerosol type, these algorithms use the integrated attenuated backscatter and the volume depolarization ratio measurements, as well as surface type and layer altitude. The volume depolarization ratio is used to identify aerosol types with a substantial mass fraction of aspherical particles (e.g., a mixture of smoke and dust). The integrated attenuated backscatter is used to discern instances of transient high aerosol loading over surfaces where this is not usually expected. The total attenuated color ratio is an independent quantity because it is not used in the subtyping algorithm."

*Was replaced by the following one in the **RM:***
"To determine aerosol type, these algorithms use the volume depolarization ratio (the ratio of the perpendicular to parallel components of the TAB) and the integrated attenuated backscatter (the vertical integral of the product of the backscatter and atmospheric transmittance due to particles and molecules between the base and the top of the detected layer), along with information on surface type and layer altitude. The volume depolarization ratio is used to identify aerosol types with a substantial mass fraction of aspherical particles (e.g., a mixture of smoke and dust). The integrated attenuated backscatter is used to discern instances of transient high aerosol loading over surfaces where this is not usually expected. The total attenuated color ratio (the ratio of the total attenuated 1064nm and 532nm backscatters) is not used in the subtyping algorithm and is an independent quantity that contributes to classify the features."

*The original paragraphs in P16 L17 to P17 L21, P18 L1 to 11 and L16 to L28 at **nhess-2015-311-D-3** will be in section 4.2 in the **RM**.*

*The original paragraphs in P16 L17 to L21 at **nhess-2015-311-D-3:***
"Figure 8 includes for each selected period a map that indicates the trajectory, the total attenuated backscatter (TAB) at 532nm and the derived aerosol subtype.
The TAB signal strength has been color coded such that cirrus clouds appear 20 in gray/red/yellow colors and mid- and low altitudes clouds in white/gray/red colors.
Aerosols show up as green/yellow/orange/red colored features".

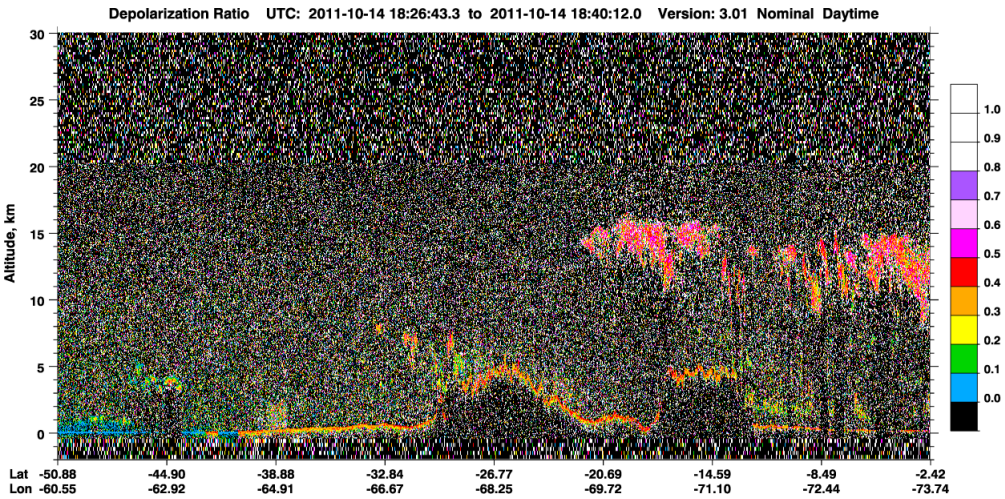
*Was replaced by the following one in the **RM:***
"Figure 6 shows the CALIOP images corresponding to the total attenuated backscatter (TAB) at 532nm and the aerosol subtype for the times of the overpass of the satellite over the region of the present study. The TAB signal strength is provided by the CALIPSO team in a color code such that cirrus clouds appear in gray/red/yellow colors

and mid- and low altitudes clouds in white/gray/red colors. Aerosols show up as green/yellow/orange/red colored features."

The original paragraphs in P17 L15 to L21 at ***nhess-2015-311-D-3:***
"On 14 October, the CALIPSO revealed a zone with TAB ranging from 2.5 x 10^{-3} to 4 x 10^{-3} km^{-1} sr^{-1} located over the Patagonian steppe (~39° S and 65° W, reaching 2 km height) (Fig. 8b). The vertical feature mask clearly discriminates this feature as aerosol and the aerosol subtype is dust (Fig. 8c). This zone displayed volume depolarization ratios between 0.3 and 0.4 and color ratios near 0.5 (not shown). This behavior is in agreement with the findings of Vernier et al. (2013) and Winker et al. (2012) for volcanic ash."

Was replaced by the following one in the ***RM:***
"On 14 October, the CALIPSO revealed a zone with TAB ranging from 2.5 x 10^{-3} to 4 x 10^{-3} km^{-1} sr^{-1} located over the Patagonian steppe (~39° S and 65° W, reaching 2 km height) (Fig. 6a). The vertical feature mask (not shown) clearly discriminates this feature as aerosol and the aerosol subtype is dust (Fig. 6b). This zone displayed volume depolarization ratios between 0.3 and 0.4 and color ratios near 0.5 (not shown). This behavior is in agreement with the findings of Vernier et al. (2013) and Winker et al. (2012) for volcanic ash."

Here we include the images corresponding to the ***volume depolarization ratio****,* ***color ratio*** *and* ***vertical feature mask*** *in order to show the mentioned values. We did not include them in our manuscript* *<u>for brevity</u>* *and because they are freely available at the CALIPSO homepage.*



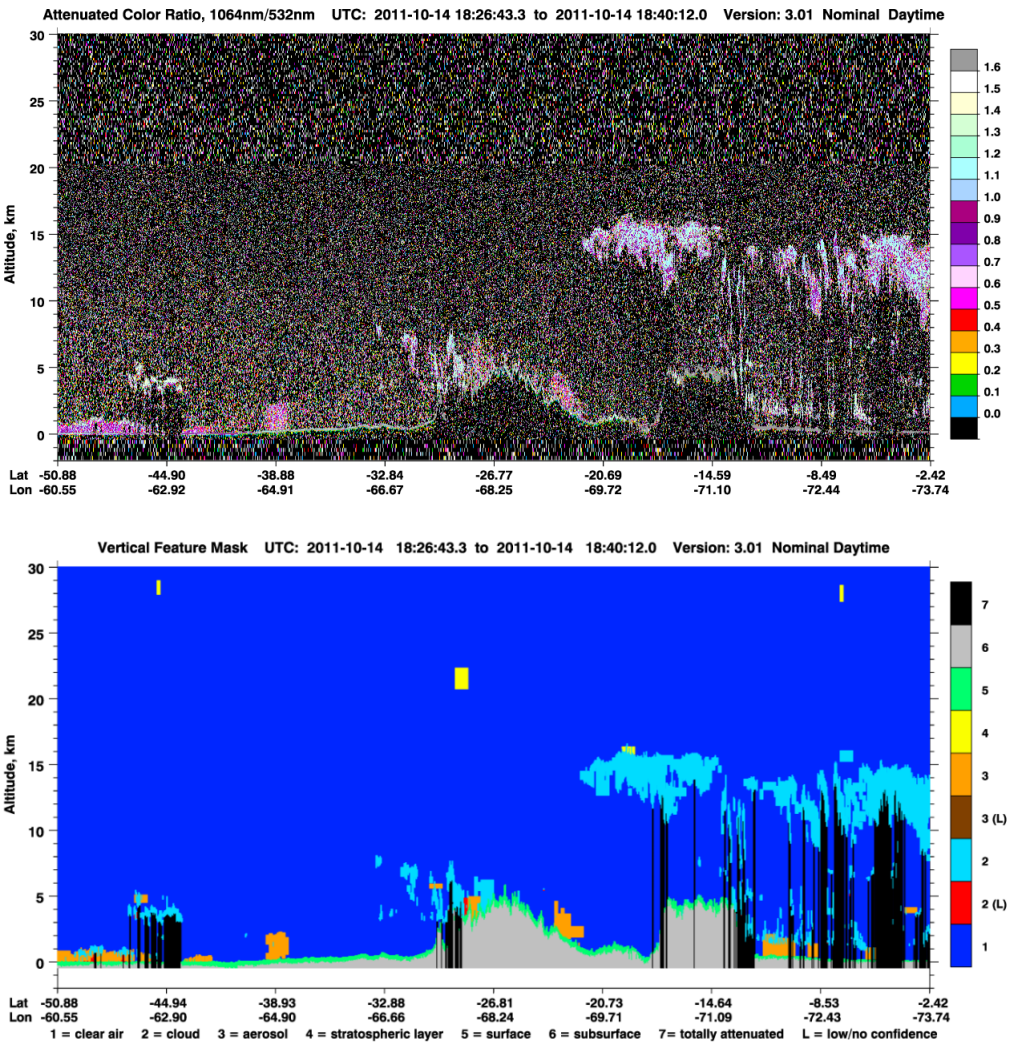


Figure I. Volume depolarization ratio (upper panel), attenuated color ratio (middle panel) and vertical feature mask (VFM) (bottom panel) from CALIOP along the track over the region of study on 14 October from 18:26:43 UTC to 18:40:12 UTC.

The original paragraphs in P18 L1 to L11 at ***nhess-2015-311-D-3:***

"The CALIOP lidar observations during the nighttime satellite route on 15 October depict TAB values ranging between 7 x 10^{-4} and 3 x 10^{-2} km^{-1} sr^{-1} at ~ 40° S; 64.5° W to 34° S; 63° W, rising up to 3 km above ground (indicated with the white arrow in Fig. 8e).

The depolarization ratios range from 0.1 to 0.5, where the predominant values are between 0.3 and 0.4 with a heterogeneous structure. The attenuated color ratio exhibits a majority of values around 0.5–0.6, but they also show magnitudes around 1, consistent with the presence of mixed clouds (water/ice) at southern latitudes, in coincidence with the vertical feature mask (VFM) (not shown). After applying the corresponding aerosol inversion algorithms, these features correspond to mostly dust, polluted dust and polluted continental as shown in Fig. 8f."

Was replaced by the following one in the ***RM:***

"The CALIOP lidar observations during the nighttime satellite route on 15 October depict TAB values ranging between 7 x 10^{-4} and 3 x 10^{-2} km^{-1} sr^{-1} at ~ 40° S; 64.5° W to 34° S; 63° W, rising up to 3 km above ground (Fig. 6c). The depolarization ratios (not shown) range from 0.1 to 0.5, where the predominant values are between 0.3 and 0.4

with a heterogeneous structure. The attenuated color ratio (not shown) exhibits a majority of values around 0.5–0.6, but they also show magnitudes around 1, consistent with the presence of mixed clouds (water/ice) at southern latitudes, in coincidence with the vertical feature mask (VFM) (not shown). Fig 6 d) shows that these features decoded by the CALIPSO aerosol inversion algorithms correspond to mostly dust, polluted dust and polluted continental."

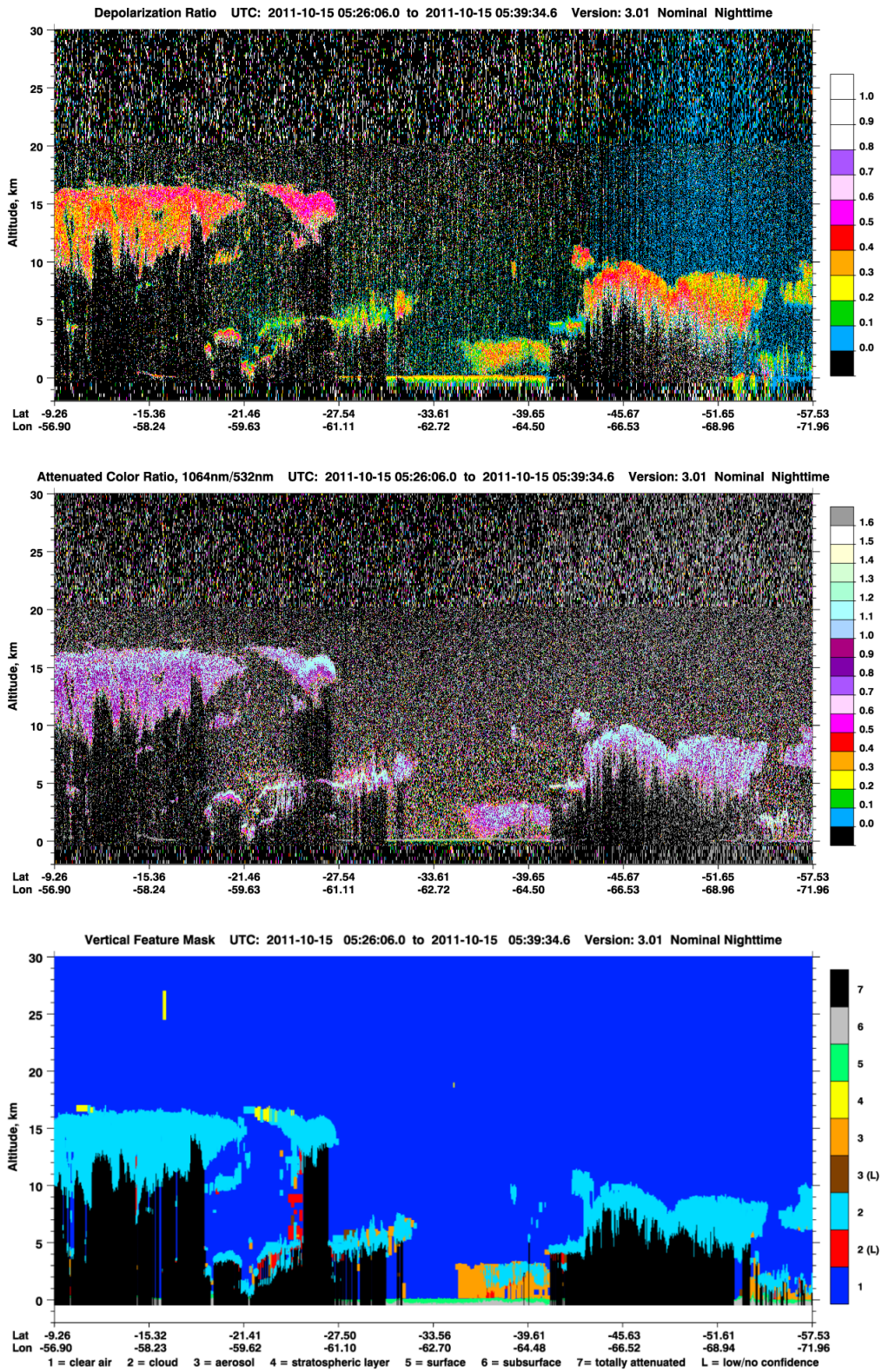


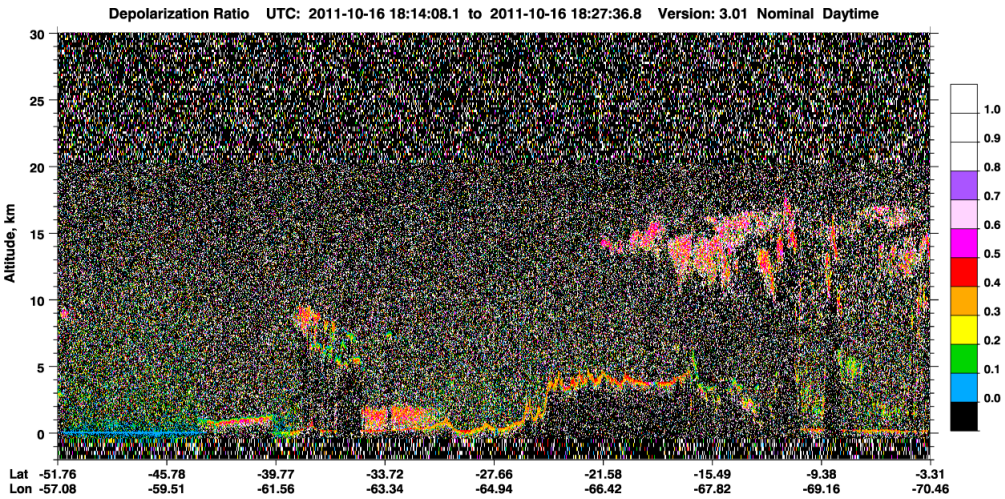
Figure II. Volume depolarization ratio (upper panel), attenuated color ratio (middle panel) and vertical feature mask (VFM) (bottom panel) from CALIOP along the track over the region of study on 15 October from 05:26:06 UTC to 05:39:34 UTC.

The original paragraphs in P18 L20 to L28 at ***nhess-2015-311-D-3:***

"For the daytime CALIPSO pass of 16 October, the lidar reported 532 nm total attenuated backscatter ranging from 1.5 x 10^{-3} to 2 x 10^{-2} km^{-1} sr^{-1} located at ~ 34° S; 63°W to 29° S; 64.5° W, with a vertical extent reaching 2500m (indicated with the white arrow in Fig. 8h). The gray colors are associated with clouds. The depolarization ratio is dominated by values around 0.4–0.5 (not shown) and the attenuated color ratio in the upper part of the signature, mostly corresponds to water (1) and below this layer a mixture of values from 0.5 to 0.7 is observed in coincidence with water and unknown values (the VFM has low confidence in discriminating the features/aerosols).The aerosol layer is identified as dust and polluted dust as shown in Fig. 8i."

Was replaced by the following one in the ***RM:***

"For the daytime CALIPSO pass of 16 October, the lidar reported 532 nm total attenuated backscatter ranging from 1.5 x 10^{-3} to 2 x 10^{-2} km^{-1} sr^{-1} located at ~ 34° S; 63°W to 29° S; 64.5° W, with a vertical extent reaching 2500m (Fig. 6e). The gray colors are associated with clouds. The depolarization ratio is dominated by values around 0.4–0.5 (not shown) and the attenuated color ratio (not shown) in the upper part of the signature, mostly corresponds to water (1) and below this layer a mixture of values from 0.5 to 0.7 is observed in coincidence with water and unknown values (the VFM (not shown) has low confidence in discriminating the features/aerosols). The aerosol layer is identified as dust and polluted dust as shown in Fig. 6f."



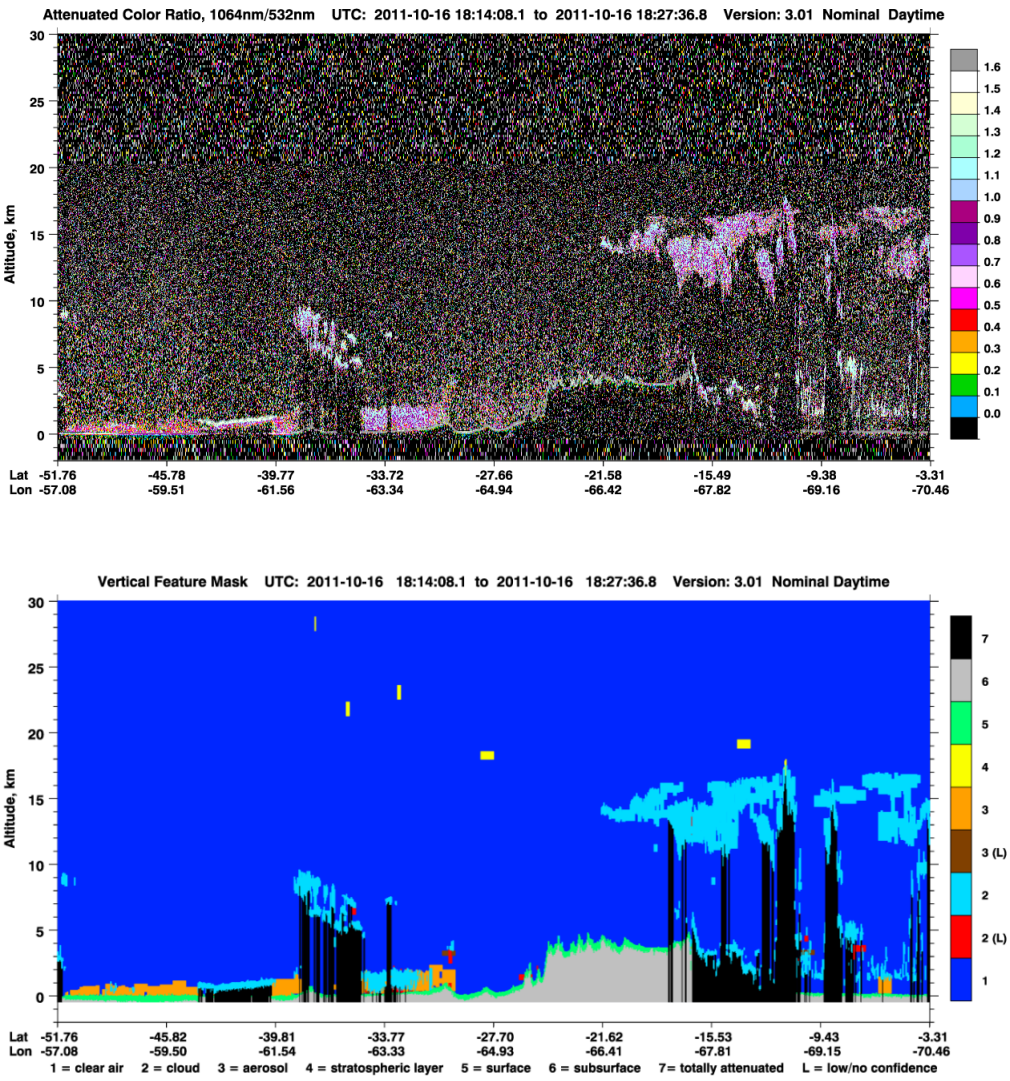


Figure III. Volume depolarization ratio (upper panel), attenuated color ratio (middle panel) and vertical feature mask (VFM) (bottom panel) from CALIOP along the track over the region of study on 16 October from 18:14:08 UTC to 18:27:36 UTC.

P8L23-P9L10. Are the authors using the same method? If yes, improve the method description used in this analysis.
*We think that the correct mentioned page numbers are 7**,** line 23 to 8 line 10. We hope that the previous explanation responds the question.*

P9L8-9. Delete the sentence. No pertinent with the Measurements and methodology section.
Answer: The sentence was deleted.

P9L20. Add the location in Figure 1a.
*We think that the correct mentioned page number is **8, line 20.***
Answer: We agree and the location was added in the new Figure 1 and also within the Table I.

P9L20. Specify the meaning for METAR, SPECI, TAF, SIGMET.
*We think that the correct mentioned page number is **8, line 20.***

Answer: We agree with your comment about a brief explanation for this reports which are commonly used by the meteorological and aviation community, and we also deleted TAF and SIGMET, as we did not use this information.
The reports definition are:

- **METAR** is an aviation routine weather report issued at hourly or half-hourly intervals. It is a description of the meteorological elements observed at an airport at a specific time.
- **SPECI** is an aviation special weather report issued when there is significant deterioration or improvement in airport weather conditions, such as significant changes of surface winds, visibility, cloud base height and occurrence of severe weather.

We have modified the old paragraph giving a brief explanation of them as follows:

OLD PARAGRAPH
"The surface data from synoptic stations located at the Buenos Aires airports, Ezeiza and Aeroparque, and also METAR, SPECI, TAF, SIGMET reports and upper air observations at 12:00UTC (09:00 LST) were provided by the SMN."

NEW PARAGRAPH
"The surface data from synoptic stations located at the Buenos Aires airports, Ezeiza and Aeroparque, and also the aviation weather reports (scheduled/not scheduled) METAR/SPECI, and upper air observations at 12:00UTC (09:00 LST) were provided by the SMN."

P9L21.What is SMN for?
We think that the correct mentioned page number is 8, line 20
Answer: We agree with your correction, because the acronym of SMN was not previously explained within the entire paper, so to make it clear, when we first mention of SMN at ***nhess-2015-311-D-3*** **page 5** line **8**, we modified the paragraph.

OLD PARAGRAPH
"It is worth mentioning that the climatological analysis (SMN Climatological reports, accessed at http://www.smn.gov.ar/serviciosclimaticos/on December 2011) indicated a dry period during 2011."

NEW PARAGRAPH
"It is worth mentioning that the climatological analysis provided by the National Weather Service (SMN Spanish acronym of ServicioMeteorologico Nacional) on its Climatological reports, accessed at: http://www.smn.gov.ar/serviciosclimaticos/ on December 2011 indicated a dry period during 2011."

P9L22. Add Ezeiza location in Figure 1a.
We think that the correct mentioned page number is 8, line 22
Answer: We have corrected this item with the new version of Figure 1 and a new Table I which includes all the locations.

P10L3. What approach are the authors using in their analysis?
We think that the correct mentioned page number is 9, line 3.

Answer: On this paragraph we are only giving a general/brief description of the HYSPLIT model, and the approach we have used is the DUST STORM module as we detailed in the Section regarding HYSPLIT our simulations. For more information, please refer to the READY HYSPLIT web site (http://www.arl.noaa.gov/) and Stein et al. (2015).

P10L4-6. Why don't the authors compare data taken in their measurement station.
We think that the correct mentioned page number is 9, lines 4-6.
P10L10. What do you mean for 'the optimum setup'?
We think that the correct mentioned page number is 9, line 10.
P10L10. How was the default land use file modified?
We think that the correct mentioned page number is 9, line 10.
P11L4. May the authors add the main differences between the default land use file and the new one?
We think that the correct mentioned page number is 10, line 4.

Answer:

*As regards the in-situ measurements, we considered the R1 comments about the magnitude of the measured peaks and we concluded that these measurements indeed did not give relevant information to justify their inclusion in the **RM**. Accordingly, we only kept the ceilometer profiles and their analysis.*

For the comments related to HYSPLIT runs we add the followings explanations.

- *Our previous experiments with the **HYSPLIT DUST STORM** module were carried out using the NCEP reanalysis (2.5°x2.5° resolution). The modeled results did not reproduce the observed ash+dust plume pattern and also the modelled particle plume did not arrive at the cities of Buenos Aires, Cordoba, Rosario and Santa Fe (as documented by the satellite images and METAR reports). Hence, we decided to use GDAS 1°x1° meteorological data as is commonly implemented in the SH and documented in published research in our region (please see Stein et al., 2015 and references therein). Although we were confident on the GDAS representation of the meteorological conditions, unfortunately, we obtained similar results with the **HYSPLIT DUST STORM** module as the one with the NCEP meteorological fields.*
- *After this failure, we tried with the **Matrix Configuration** Module (running **HYSPLIT** in concentration mode), where we specified the emitting cells, filled each concentration grid with the required features for the particles using the coarsest meteorological field resolution (NCEP, 2.5°x2.5°) and the results were promising. In conclusion, we understood that the real problem we had in using the **DUST STORM** module was the miss representation of the soil type in the default-file (LANDUSE.ASC), within the Patagonian Steppe for this resuspension event.*
- *Hence, we modified the default land-use file (that has a similar resolution 1°x1° than GDAS meteorological fields) with the inclusion of desert soil grid points where appropriate (that means: in the location of the deposited ash). After modifying this file the experiment was successful in representing the displacement of the ash+dust particle plume. In order to illustrate the crucial inclusion of land-use modification, we show in a **supplementary document (SupplementaryMaterial.pdf)** the corresponding Figures) comparing the HYSPLIT results with and without this readjustment of the original file.*

The purpose of using the HYSPLIT model is related to its portability on Windows PC Systems. Technical personnel from different government agencies (e.g. Road Safety,

National Parks, Civil Defense, County Offices, etc) could be trained in order to be prepared for this hazardous and not unusual event at the Patagonian Steppe. We want to remark that our numerical results were only qualitative as we do not have a dual-polarization lidar network or a dense air quality monitoring network to quantitatively evaluate the model results.

*We hope that our explanation would clarify the points about our approach. The original paragraphs regarding HYSPLIT model setup and simulations were modified in the re-organized **RM** in order to better explain the details of the model runs. Additional references were also included.*

P12L12. How much dryer?
We think that the correct mentioned page number is 11, line 12.

Answer: We agree that this needs an explanation for the broader audience of the journal.

Figs. 2 are Skew-T diagrams. These aerological diagram are extensively used by the meteorological community, and provide a graphical display of the thermodynamic vertical structure of the atmosphere. The vertical coordinate is pressure, the temperature are the grey sloping lines and the curved green lines represent the adiabatic temperature. On this diagram are also superimposed with the turquoise dashed lines the humidity mixing ratio in units of g/kg, which means the water vapor content (g) per unit of dry air (kg). We also have re-drawn the figures highlighting the mixing ratio values.

We modified their analysis in the RM:

OLD PARAGRAPH
"The humidity profiles show a dryer atmosphere than the mean decadal values (Fig. 2b) and this feature is more noticeable on 16 October, which shows a dry layer from the surface up to 1.8km. The layer from the surface up to 400m experienced an extreme drying (from 8.5gkg^{-1} down to 3.5gkg^{-1}) also associated with static stability, and coinciding with the presence of resuspended material over Buenos Aires."

NEW PARAGRAPH
"As the difference between the temperature (T) and the dew point temperature (T_d), at fixed levels is proportional to the relative humidity, a dryer atmosphere than the mean decadal values (Fig. 2b) is evident. This feature is prominent on 16 October, which shows a dry layer from the surface up to 1.8 km and an extreme drying in the layer from the surface up to 400m. The mixing ratio decreased from 8.5 gkg^{-1} to 3.5 gkg^{-1} (Figure 2b). This drying is also associated with static stability coinciding with the presence of the resuspended material over Buenos Aires."

P13L21. What is METAR/SPECI?
We think that the correct mentioned page number is 12, line 21.
Answer: We have already clarified this point.

4. Analysis of the measurements from the field campaign

P14L6. Add the location of the research site in Ciudad Universitaria.
We think that the correct mentioned page number is 13, line 6.
Answer: With the Table I and the new Figure 1 added within the paper, this item was solved.

P14L15. May the authors add the value of the correlation coefficient?
We think that the correct mentioned page number is 13, line 15.
Answer: We have eliminated the analysis of eBC and PPAH as these variables did not contribute to the analysis.

P15L4. The value of 240 gm^3 is not reported in the La Boca station in Figure 5.Why?
We think that the correct mentioned page number is 14, line 4.
P15L9. Add the hourly value maximum of PM10.
We think that the correct mentioned page number is 14, line 9.

*Answer: Many thanks for your helpful comments and suggestions. La Boca PM_{10} hourly measurements and long term mean were included in a corrected **Fig. 5 (b)** (see below). We made the **new Fig. 5 (b)** using the measured hourly values recently given to us by the Environmental division of CABA Government upon our request because the data we needed are not available from the web site. The previous Figure 5 in **nhess-2015-311-D-3** was done with the data extracted from the web page, which depicts the moving average over 8 hours minus the moving average over 8 hours during the previous 24 hours, and this is what the agency has to report according to the regulations. We realized that our estimates from the digitized data were incorrect after revising the original Figure and also comparing with the values plotted in Figure 11 in Folch et al (2014).*

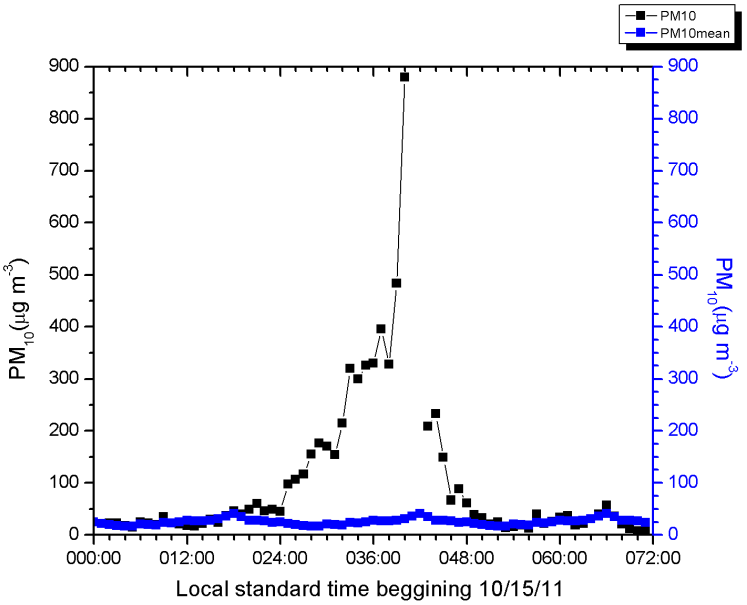


Figure 5. (b) Time evolution (LST) for the 3 day period from 15 to 17 October of the hourly PM_{10} concentration (black line and markers, in μgm^{-3}). The blue line and markers indicate the typical urban October mean values (in μgm^{-3}).

*The original paragraph (page P14, L5to 12 in **nhess-2015-311-D-3**):*
"Note that the PM_{10} concentration at La Boca, located ~ 13 km south of the research site, starts to increase earlier on the evening of 15 October, consistent with the resuspended ash plume arriving into the city. The average value of PM_{10} at this station for all other days during the month of October is only about 40 μgm^{-3}. The hourly maximum of PM_{10} is observed between midnight 15 October and 1 a.m. 16 October (see Fig. 5b), a time not associated with high pollution, and is further evidence of the presence of the aged ash in Buenos Aires."

*Was replaced by the following one in the **RM**:*
"Note that the PM_{10} concentration at La Boca, starts to increase around midnight on 15 October, consistent with the resuspended ash plume arriving into the city. The average value of PM_{10} at this station for all other days during the month of October is only about 25 μgm^{-3}. The hourly PM_{10} concentrations show an important and fast built up on 16 October, from around 100 μgm^{-3} at 1 a.m. LST reaching the maximum in the afternoon and persisting until midnight. This behavior is consistent with the ceilometer measurements and that reported by Folch et al. (2014) for Córdoba-CABA monitoring site (see their Figure 11)."

P15L26. May the authors show in the figure the "filament-like" plumes?
We think that the correct mentioned page number is 14, line 26.

Answer: We have added within the **Figure 5 (a)** an arrow indicating this filament and we have also written in the figure caption, what is pointing this arrow.

P16L1. Add the Aeroparque location in Figure 1a.
We think that the correct mentioned page number is 15, line 1.
Answer: With the Table I and the new Figure 1 added within the paper, this item was solved.

P16L20. What is the implication about coarse and fine mode?
We think that the correct mentioned page number is 15, line 18-20.

Answer: The implication is that the AERONET independent data confirm that the particles in Buenos Aires city are dust + ash (in the coarse fraction) and not typical urban pollution which is in the fine mode fraction.

*We have included the comments on Fig. 6 (**nhess-2015-311-D-3**) in a modified paragraph in the text of the **RM**.*

*The following sentence in P15, L15 to L20 in **nhess-2015-311-D-3:***
"Moreover, Level 2 AERONET measurements from CEILAP-BA indicate a significant contribution of the fine mode to the total AOD (Fig. 6) on 15 October, whereas the next day, the AOD data (only available at noon because of the obscuration by the ash layer), indicate that the coarse mode dominates in accordance with those reported by Papayanis et al. (2012) over Europe after the Eyjafjallajökull eruption."

*Was replaced by the next one in the **RM**:*
"Moreover, level 2 AERONET measurements from CEILAP-BA indicate a significant contribution of the fine mode to the total AOD on 15 October (the fine mode fraction (FMF) varies from 0.48 to 0.89, with a mean value of 0.69), whereas during the following days, the AOD data (only available at noon because of the obscuration by the ash layer), indicate that the coarse mode dominates (FMF ranged from 0.29 to 0.32 with a mean value of 0.30 on 16 October and between 0.37 and 0.47 with a mean of 0.40 on 17 October). On 16 October a few AOD level 2 data (from 07:00 to 08:00 LST) are available due to the presence of clouds + ash + dust over the site. These results are in accordance with those reported by Papayanis et al. (2012) over Europe after the Eyjafjallajökull eruption."

*In order to better depict the effect of the ash+dust plume on the aerosol features in Buenos Aires, we have prepared a new Figure (Fig. V) (which might be considered as **Fig. 5(c)** in the **RM**), that includes additional information along with the typical values (long term means and standard deviations of the AERONET information, in this case the AOD_{500nm} and the Ångström exponent.*

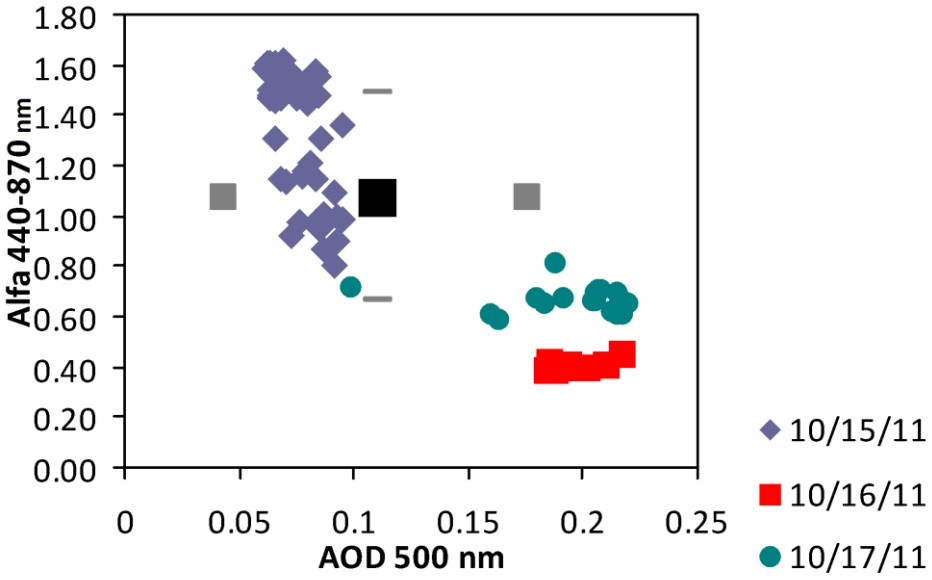


Fig. V. variation of the Ångström exponent (Alfa440-870nm) with the AOD_{500nm} from 15 to 17 October. The black square indicates the relation amongst the October long term means (1999 to 2012, excluding 2011). The grey squares indicate the AOD_{500nm} standard deviation and the grey slash the $Alfa_{440-870nm}$ standard deviation.

Figure V indicates that on 15 October the values of the Ångström exponent and AOD_{500nm} are typical of anthropogenic (mostly urban) sources, in coincidence with the greater proportion of fine aerosols. Contrarily, from 16 to 17 October, the small Ångström exponents are related to coarse mode aerosols in agreement with the fine mode fraction behavior. The elevated AOD_{500nm} coincides with the presence of the resuspended ash+dust on the atmospheric column over Buenos Aires. It is noteable how both parameters fall outside their mean values and standard deviations, particularly on 16 October. These results show similar behavior than those reported by Papayanis et al. (2012), Eck et al., (2005), (2010), Kim et al., (2011), Lyamani et al., (2015), among others).

*We consider that the inclusion of Figure V in the **RM** and the corresponding discussion would better support our study and its implications.*

5. Discussion

P17L15. Figure 7 is not well described. A description of the input run in the HYSPLIT simulation is necessary.
We think that the correct mentioned page number is 16, line 15-16.

*Answer: We agree with your comments and in the reordering of the **RM** the Methodology and the Analysis of modeling results in Section 5. ANALYSIS OF HYSPLIT SIMULATIONS, are closer and the manuscript will flow better.*

We included within the new sub-section 5, the new sentences already included in this document in pages 6 to 7, and the following paragraphs:

Analysis of modeling results

The HYSPLIT dust algorithm has clearly located the emission cells over the arid zone over the Patagonian steppe and as this zone was coincident with the CALIPSO overpass, so in the analysis we also use the resulting cross sections.

The simulated horizontal plume (Fig. 7a) is consistent with the synoptic environment and the advection of the particles is carried out by strong near surface SW winds veering clockwise (cyclonic circulation for the SH) and reaching the Atlantic Ocean (not shown). The simulated particle cross sections around the time of the satellite overpass highly resemble the lidar measurements in location (~35°S, 69°W) and also in the height of the plume near 3km (compare Fig. 7b, c with Fig. 6b, c).

The HYSPLIT particle plume displacement follows the strong SW winds over the southern Buenos Aires province. The divergent feature of the plume (Fig. 7g) over the Atlantic Ocean is consistent with the 1000hPa field pattern (see Fig. 3c). The model reproduces the dust plume being advected from the steppe into the Buenos Aires Metropolitan Area and the highly populated cities of Cordoba (31°25°S, 64°110°W), Rosario (32°57°S, 60°^{0}39°W) and Santa Fe (31°38°S, 60°41°W). In addition to the evidence from the CALIOP measurements, the METAR information reported volcanic ash at those locations, as well.

The purpose of using the HYSPLIT model is related to its portability on Windows PC Systems. Technical personnel from different government agencies (e.g. Road Safety, National Parks, Civil Defense, County Offices, etc) could be trained in order to be prepared for this hazardous and not unusual event at the Patagonian Steppe. We want to remark that our numerical results were only qualitative as we do not have a dual-polarization lidar network or a dense air quality monitoring network to quantitatively evaluate the model results.

P17L17. Add from CALIPSO.
We think that the correct mentioned page number is 16, line 17.
Answer: This issue was addressed.

P17L20. May the authors highlight the area where aerosol are retrieved in Figure 8? It is not clearly visible.
*Answer: We agree your correction and we have re-drawn all Figure 8 (Figure 6 in **RM**) including the missing white arrows.*

P17-L28. Large size respect to what?
We think that the correct mentioned page number is 16, line 28.
Answer: Aerosols particles might be classified according several criteria. In relation with their size, the most applied ones are the particle number distribution, the particle surface distribution and the particle volume distribution, being the latter linked to their mass concentration. In general, due to the wide variety of airborne aerosols these distributions have a number of modes (peaks in their frequency distributions as a function of their aerodynamic diameter). This kind of classification is basically related to a cutt-off in measurement devices and to their impacts or effects (for more details please see Seinfeld and Pandis, 1998).

P17L10-L2. Those sentences should be moved from the Discussion to the Result Sections.
We think that the correct mentioned page number is 16, line 10-16.
P18L15-L19. Those sentences should be moved from the Discussion to the Result sections.

We think that the correct mentioned page number is 17, line 15-19.
P18L22-P19L28. Those sentences should be moved from the Discussion to the Result sections.
We think that the correct mentioned page number is 17, line 22-P18, line 28.

*Answer: Addressed in the **RM**.*

P19L9. Explain the vertical feature mask. Add this feature in the plot.
We think that the correct mentioned page number is 18, line 9.
P19L10. May the authors describe the corresponding aerosol inversion algorithms that they used?
We think that the correct mentioned page number is 18, line 9-11.
Answer: We consider that this has been addressed in the present response document.

P19L28. Figure 8e?
We think that the correct mentioned page number is 18, line 28.
Answer: When uploading the manuscript we have done a mess with the letters in Figures 8, the right indication for the Figures 8 (now Figures 6) are: Figure 6a to f.

5. Conclusions

P20L25. How much far?
We think that the correct mentioned page number is 19, line 23-25.

OLD SENTENCE
"Some of that material was later resuspended by low-level winds, similar to particles in a dust storm, and transported far from the emission source."

NEW SENTENCE
"Some of that material was later resuspended by low-level winds, similar to particles in a dust storm, and transported around 1400-1700km from the emission source. "

P21L10. Add references.
We think that the correct mentioned page number is 20, line 10.

OLD SENTENCE
The analysis of thermodynamic soundings indicated that the presence of the resuspended ash resulted in a drying of the lower troposphere, an effect already reported in studies elsewhere as a result of the composition of the ash.

NEW SENTENCE
The analysis of thermodynamic soundings indicated that the presence of the resuspended ash resulted in a drying of the lower troposphere, an effect already reported in studies elsewhere as a result of the composition of the ash (Lathem et., al 2011, Schumann et al., 2011 and Miffre et al., 2012)

Figures and Tables

Figure 1a. To be improved including the bar scale. All the locations reported in the text should be added in Figure 1. May the authors identify volcanic ash with some standard techniques (e.g. Corradini et al., 2010)?

Answer: We have improved the Figure 1 with all the locations and the bar. The figure 1b is only qualitative as we have re-written the paragraph (within the Methodology section).

NEW SENTENCE

"The resuspended volcanic ash is seen in the Moderate Resolution Imaging Spectroradiometer (MODIS), 1km resolution visible data on 15 October in Patagonia (Fig. 1b).The results presented by Pujol et al. (2013) helped to confirm the volcanic origin of the detected aerosol layer. To identify the source of the ash/dust plume they used the concept based on reverse absorption (Prata, 1989) and 3.9 /11 /12 µm bands empirical algorithm (Ellrod et al., 2003)."

Figure 2. The size of characters are small. Explain the legend.
Answer: We agree and modified the corresponding Figure.

Figure 3. In the caption, add that the wind speed is plotted with the white line.
Answer: We modified the Figure 3 and also added a new (Figure 4) (please see the Table relating the Figures in the old and new manuscript) in order to be more clear.

Figure 4. Are the Figure 4 (b), (d) and (f) necessary? I suggest to delete or improve them.
Answer: Yes, these Figures are necessary, so we have improved them.

Figure 5. BC in the legend is for eBC?
Answer: We have deleted all comments about PPAH and eBC as they did not contribute with relevant information for the paper, as well as the Figure.

Figure 6. The plot should be improved.
Answer: We agree and we have replaced with a new Figure 6 which provides more information.

Figure 7. May the authors change the blue color with another colour (e.g. green?). The integrate particle cross-section could be deleted.
Answer: We are using the public version of HYSPLIT for Windows on this version the output colors are by default. We consider that the color does not change the message given by the figure.

Figure 8. All the maps of the CALIPSO overpassing should be redone. The size of the characters in the x and y scales are small. In the caption Figure 8b is lacking.
Answer: We have re-plotted the Figure 8 (now, renamed as Figure 6) and modified the captions accordingly.

In general, may the authors change the doy scale with UTC time?
Answer: We have deleted DOY scales as it is confusing, we have only referred the figures to UTC times in the Analysis of Meteorology fields and the thermodynamic profiles, CALIPSO images and HYSPLIT SIMULATION. The surface wind, ceilometer and PM_{10} evolution are analyzed and plotted with Local Standard time.

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