**Sezione di Catania**
**Osservatorio Etneo**
Piazza Roma, 2
95125 Catania, Italy
Tel. +39 095 7165800
Fax +39 095 507390
http://www.ct.ingv.it

Istituto Nazionale di Geofisica e Vulcanologia

Catania, 30 November 2015

Dear Dr. **Emma Liu**,

Herewith, we report our answers to revisions regarding the manuscript "**$PM_{10}$ measurements in urban settlements after lava fountain episodes at Mt Etna, Italy: Pilot test to assess volcanic ash hazard on human health**" by Daniele Andronico and Paola Del Carlo for possible publication in **NHESS.**
The manuscript now comprises 20 double-spaced pages (submission item: "REVISION") and includes 10 figures and 1 table.

We made the revisions as requested modifying the text and figures 4 and 6, inverting figures 2 and 3, and adding the new figure 9 (with the previous 9 becoming now figure 10). In this letter we explain how and where the reviewer comments have been incorporated in the manuscript.

In our opinion, the main focus of this work is to prove the formation of PM10 during and immediately after the tephra fallout deposition in urban areas produced by Etna explosive activity. On this basis, our contribution would help guide future studies on the potential risk related to the exposure of PM10 particles in this area. Thus, in the revised version, we have stressed this point in order to convince the reviewers and the Editor that our results can represent a starting point to stimulate new studies about this much undervalued problem in the Etnean territory, as is clearly proved in a recent medical study that acute respiratory and cardiovascular diseases, and ocular disturbances, have significantly increased during the ash exposure caused by the 2002 Etna eruption.

We indicated the changes in an annotated version of the revised manuscript file (submission item "REVISION-changes marked").

I certify that the Co-Author Paola Del Carlo is aware of this revision.

Please address any correspondence to:

Daniele Andronico
INGV - Sezione di Catania
Unità Funzionale di Vulcanologia e Geochimica
Piazza Roma 2 - 95123 Catania, Italy
tel. ++39 0957165806fax ++39 095435801
e-mail: daniele.andronico@ ingv.it

Yours sincerely,
Daniele Andronico

**Answer to Emma Liu**

***General comments***

*Dear Authors,*

*This paper makes a very valuable contribution towards raising the awareness of the hazards posed by fine-grained volcanic ash. In particular, the observations presented highlight effectively the role of ash remobilisation in prolonging the longevity of ash hazards beyond the phase of primary fallout. I think this paper is very timely, and presents a very interesting dataset that forms an excellent foundation for future research.*

*The data is presented well, and the paper is very clearly written. However, I have several minor comments, which I hope you will find constructive:*

We are happy that Dr. Liu commented positively on some peculiar topics of our research. In the following we answer to the specific requests.

***Minor comments***

*Page 3926 Line 26: It may be useful here to define 'aerodynamic equivalent diameter', as not all readers may be familiar with this term.*

We agree and have added the definition, the new phrase now reads: "The finer particles, especially particulate matter with dimensions ≤10 μm or $PM_{10}$ in aerodynamic equivalent diameter (i.e., the diameter of a spherical particle with density 1000 kg/m$^3$ and the same settling velocity as the airborne particle considered)" (new lines 40-43).

*Page 3926 Line 26: Throughout the paper 'micron' and 'μm' interchangeably. Be consistent in the style of units.*

We preferred to replace "micron" with "μm" thus using the latter unit throughout the paper.

*Page 3930 Line 5: Should SEC be NSEC?*

We changed SEC into NSEC (new line 158).

*Page 3930 Line 24: The choice of sample names is very confusing (PM1, PM2, PM3), as they are in the same form as abbreviations for particle size ranges such as PM10 and PM4. I suggest modifying the sample names to make this distinction more clear.*

Yes, we agree and changed the previous sample names into NSEC1, NSEC2 and NSEC3, respectively.

*Page 3930 Line 28: Here you refer to grain size analysis at 1 2 phi intervals, and yet all other references to grain size in this paper are given in units of microns or millimetres. Perhaps either define the relationship between phi and mm here, or accompany measurements in mm with the equivalent phi values in brackets (and on Fig. 4).*

We have followed the first suggestion and added in brackets "($\phi$ being the $-\log_2 d$, where $d$ is the particle diameter in mm" (new lines 192-193).

*Page 3932 Line 17: Figures 5 and 6 show ash particles several hundred microns to a millimetre in size. It may be useful to include SEM images of the finer size fractions for comparison, especially when you later discuss the possibility that the PM10 material is derived from breakage of coarser grains.*

We have included a new SEM image of the finer fraction of the deposit in the figure 6 (frame d), and commented this at new lines 241-242.

*Page 3933: Section 5.1 is for the most part a review of previous literature; consider placing some of this information in the introduction as it sets up quite nicely the motivation for this study.*

We agree and placed it in the Introduction chapter. Furthermore, we reorganized this section by adding information from a previously uncited paper (Lombardo et al., 2013) which supports our thesis on the potential risk for human health caused by the exposure to ash deposited in the Etnean inhabited settlements after tephra fallout.

*Page 3932 Line 27: Should be 24 h for consistency?*
In the revised version, we used only 24 hours replacing all the previous "24 h".

*Page 3935 Line 5: The phrasing of this sentence does not make sense to me, I suggest rephrasing for clarity (e.g., 'The grain size distributions of collected tephra show that X % of the mass is coarser than 1mm: : :' or words to that effect). Also, the values given here for the percentage of material <1 mm do not seem to agree with those given earlier in Section 4.2?*
We rephrased the whole sentence as follows: "The grain-size distributions of collected tephra show that 99.8 % and 94.8 % of the volume for samples NSEC3 and NSEC2 (respectively) is coarser than 1 mm, and all the samples are composed of particles coarser than 10 μm." (new lines 290-293).

*Page 3936 Line 13-15: I am not sure what you mean by the sentence 'We are aware that the methodology adopted does not: : :.' Please clarify this sentence or provide additional detail.*
This sentence sought to highlight that we know well that our PM10 measurements needed to be carried out more rigorously and systematically, i.e. with similar conditions of height from the ground and longer duration. So, due to the fact that also other reviewers raised some doubts on the methodology and asked to report the limits of our measurements in the text, we deleted the previous phrase in the "Conclusion" chapter and moved it to the "Methods" chapter (3.1 DustTrak measurements) adding a few sentences describing the limits of our procedure at new lines 175-183.

*Page 3936 Line 24: You make the good point here that enhanced vehicular or foot traffic may amplify the airborne PM10 concentrations. Just a thought on this: : : do you think that in areas of very high traffic, the resulting intense remobilisation could actually reduce the time of exposure by redistributing (and therefore removing) ash deposits on the ground?*
The question is very interesting. In our experience we have observed that it depends on the mass of tephra per square meter. So, if the cover is not continuous on the ground, car traffic can enhance the remobilization, otherwise if the cover is continuous, car traffic is not able to significantly remove the ash and it remains over the same areas.

*For comparison, it may also be worthwhile to consider some of the literature on ash remobilisation in Iceland (see suggested references), which discuss the influence of deposit remobilisation on local and regional PM10 concentrations.*
*E.g: 1. Leadbetter, S. J., Hort, M. C., Löwis, S., Weber, K., & Witham, C. S. (2012). Modeling the resuspension of ash deposited during the eruption of Eyjafjallajökull in spring 2010. Journal of Geophysical Research: Atmospheres (1984–2012), 117(D20).*
*2. Thorsteinsson, T., Jóhannsson, T., Stohl, A., & Kristiansen, N. I. (2012). High levels of particulate matter in Iceland due to direct ash emissions by the Eyjafjallajökull eruption and resuspension of deposited ash. Journal of Geophysical Research: Solid Earth (1978–2012), 117(B9).*
*3. Arnalds, O., Thorarinsdottir, E. F., Thorsson, J., Waldhauserova, P. D., & Agustsdottir, A. M. (2013). An extreme wind erosion event of the fresh Eyjafjallajokull 2010 volcanic ash. Scientific reports, 3.*
Thank you very much for suggesting these interesting papers, we used them in the Discussion chapter.