

Object: Response to comments on “Atmospheric Brown Clouds in the Himalayas: first two year of continuous observations at the Nepal-Climate Observatory at Pyramid (5079 m)”, by P.Bonasoni et al.

Dear Editor,

Please find below the responses to the specific comments raised in the 2 reviews. We believe all comments have been addressed and we have followed all the suggested changes. Modifications with respect to the original manuscript are clearly highlighted in this letter. In particular, also following Referee 2’s suggestions, the paper has been considerably shortened.

We hope the manuscript now meets ACP scientific standards for publication.

Sincerely,

Paolo Bonasoni

Anonymous Referee #2

General Comments:

This article analyzes a data set of meteorological parameters, ozone, black carbon and particulate matter collected at the Nepal Climate Observatory – Pyramid (NCO-P) at 5079 masl in Himalayas. Initially, a descriptive analysis of the seasonal changes on weather conditions is performed, by combining in-situ data with back-trajectories and meteorological fields determined by mesoscale modelling. In a second step, the influence of long range transport and of seasonal weather conditions (with special emphasis on monsoon) on the variability of some pollutants is performed. The paper is of high interest for the atmospheric scientist community and is within the scope of ACP. I have some general comments about the manuscript.

The authors thank the referee for the valuable comments that which have enabled to improve the paper for a better focus of the results. All remarks were accurately evaluated and point-to-point discussed in our answer.

1.1 When reading the manuscript it is not clear what findings are results of this paper and what findings are results of other companion papers.

- *In order to better focus on the results of this study, the manuscript has undergone further improvement. New parameters describing atmospheric composition at NCO-P have been added (aerosol scattering coefficient and PM1), and an analysis of AOD derived by MODIS on north IGP – Himalayas foothills has also been inserted in order to better characterize and identify the presence of ABC at the NCO-P (Par. 4.1). The final result provides a preliminary assessment of the impact of direct transport of ABC (i.e. events when ABC polluted air masses are transported to the site by up-valley breeze circulation). In this paper the abstract, introduction and conclusion have been significantly revised also with the purpose to better clarify the paper outcomes.*

In order to provide a more focalized and detailed presentation of this new analysis and to avoid an excessive length of paper, we have removed part of the modelling (Section 2.4 and analyses in Section 3.4 of ACPD paper) investigation presented in the ACPD manuscript. In particular, regional-scale WRF simulations have been moved to the supplementary material. The detailed analysis of atmospheric compound variations as a function of different synoptic air-mass circulations (Sect. 4.2.2 of ACPD paper) will be the subject of a further, specific, paper.

As reported in the paper, specific results concerning the analysis of aerosol properties and their behaviours, as well as of surface ozone, can be found in the companion papers of this special issue: Cristofanelli et al., 2010; Decesari et al., 2010; Gobbi et al., 2010, Marinoni et al., 2010, Marcq et al., 2010, Sellegri et al., 2010 and Duchi et al., 2010.

In some sections, the most relevant results are accompanied by a reference to a paper that is (in most of times) in preparation.

Some examples: section 4.1 Atmospheric composition during the monsoon period. The results of this section are that very low BC, O₃ and coarse particles are typically recorded during the monsoon period. When discussing the data a reference is performed to other three papers that analysed the same data base: Marinoni et al. (2010), Sellegri et al. (2010) and Decesari et al. (2010). In the reference list these appear as papers "in preparation". The question is: what is new in this article?. A similar situation is found in section 4.2, with references to Marinoni et al. (2010) and Decesari et al. (2010). Also 4.2.1, with several references to Marinoni et al. (2010).

- *Because the most relevant results are now better defined and focused in line with the title of the manuscript, and this work does not seek to introduce other papers, many of the references and linkages to other companion papers (already presented in this special issue) have been cut.*

1.2. In Section 2 (Measurements and Methodologies), a detailed description of the measurements program at the NCO-P site is performed. However, most of these data are not analysed in this paper. For example, DMPS/SMPS, Scattering coefficient, Aerosol Optical Depth and aerosol chemical composition, data are not used in this study. The description of the measurements techniques makes confusion.

- *To avoid confusion, section 2 has been shortened, inserting the references to specific papers for a more detailed description of instruments used for data analysis. However, the general experimental setup is still described here, in order to give an overview of the station, which is also useful for the other companion papers. More measurements are now taken into account in the analyses presented in the text (e.g. PM₁ and aerosol scattering coefficient), calling for a complete description of measurements.*

1.3. After reading the paper and taken into account the comments above (#1 and #2), it seems that authors tried to do an general analysis of the data, with alternative treatment to those performed in the companion papers. If this is the case, I then suggest to authors to say it directly at the end of the Introduction. To say clearly what the objective of this paper is, and to say what is different in this paper with relation to the companion papers. I think it is necessary to state clearly the objectives.

- *We thank the Referee for this remark. Following the Referee's suggestion, the objectives of the paper have been better clarified and discussed. The general analysis of the data concerns the meteorological aspects (with the identification of season transitions and cloud classification) as well as local and*

large scale circulation description, all material useful for this paper and for the companion papers.

The more detailed analysis concerns the specific objective of this paper: “the identification and observation of brown cloud at NCO-P”, and is now more clearly introduced, focused and discussed.

2. Specific Comments

2.1 Section 2.2 Measurements and sampling procedures. When describing the measurements with the MAAP, it is said that a value of 6.6 m²/g was used for the mass absorption coefficient. This is the standard value provided by the manufacturer. My question: Did the authors determine the “mass absorption coefficient” experimentally for the type of aerosol / mixing of aerosols, present in the study area?, because they have EC determined by analysis on filter they may determine this value. This could provide more realistic data of BC. Previous studies have shown that the “mass absorption coefficient” may exhibit values very different to that provided by the manufacturer. For example, Petzold et al. (Atmos. Chem. Phys., 8, 407–423, 2008) observed values of 7.6 and 11.1 m²/g in the Alps.

- *A fraction of filters sampled at NCO-P for chemical characterisation have been analysed also with a thermo-optical method (OC/EC analyzer, Sunset laboratory Inc.) providing the Elemental Carbon concentration. This allows us to determine the “mass absorption efficiency” ($\sigma_{me, BC}$), assuming that elemental carbon (EC) is equivalent to BC. An averaged value of $10.7 \pm 5.6 \text{ m}^2 \text{ g}^{-1}$ was obtained over the entire period (2 years) presented in the paper. However, because of the large variability and the limited period sampled by filters (only concentrated in few seasons), the $\sigma_{me, BC}$ value used throughout this work was $6.6 \text{ m}^2 \text{ g}^{-1}$ as recommended by Petzold et al (2002). We plan a more depth investigation on this point, in order to determine the real mass absorption efficiency coefficient and its seasonal dependency.*

2.2. The objective of the manuscript is to study the Atmospheric Brown Clouds. The measurements program at the NCO-P includes a number of parameters, most of them not analysed in this study. Authors have only studied the behaviour of BC and O₃ (and of PM₁ and coarser particles in some sections). My question is: is there any definition for Atmospheric Brown Clouds?, why Atmospheric Brown Clouds are only studied with BC and O₃?

- *As also reported in the answers to Referee#1, and taking into account these observations: “it should keep in mind that the unambiguous definition of Atmospheric Brown Cloud hot spot concerns the seasonal values of AOD larger than 0.3 with absorption contribution larger than 10%” (as also reported in the “Introduction” of this paper). This definition is clearly not suitable for a high altitude site where the reduced integrated atmospheric columnar path (e.g. 5 km of difference between NCO-P and Indo-Gangetic Plains) makes the identification of brown cloud hot spots problematic by in-situ AOD measurements, also considering that the brown cloud covering the South Asia and the IGP is usually confined to altitudes lower than 5000 m asl. For this reason, in order to define the ABC influence to NCO-P, in the revised paper, we investigate the behaviour of black carbon, aerosol mass – PM₁ and aerosol scattering coefficient, which are able to provide quantitative information about the presence of brown cloud at the site, also presenting information on coarse particles (dust) and ozone concentration. The measurements concerning aerosol mass (PM₁) and scattering coefficient have now been included and discussed in the manuscript and, together with other*

measurements continuously carried out at this Observatory, they better describe the atmospheric composition behaviour at the site, also characterising the presence of brown clouds.

2.3. Some parts of the manuscript could be shortened.

- *Also in line with this remark, the manuscript has been considerably shortened. Particular reduction concerns the following paragraphs: "Introduction", "Measurements and sampling procedures", "Large scale circulation". The new paragraphs 4 and 4.1, concerning respectively "Atmospheric composition at NCO-P" and "Influence of direct transport of brown cloud on atmospheric composition at NCO-P" have been redrafted in keeping with the main focus of the paper.*