Response to Anonymous Referee #2

General comment. The manuscript describes in detail the phenomenon of aerosol transport from the Po basin into the Aosta valley, investigated both by a fairly comprehensive instrumentation and from a modeling perspective. This effect is of universal importance for air quality dynamics in Alpine valleys. While the study does not reveal significant new findings about the phenomenon, it adds another valuable data set and discussion to the scientific literature. The manuscript is well structured and written coherently, the scientific questions are clearly set at the beginning and the analysis is focused on the their respective answers in the conclusions. Three case studies are investigated thoroughly with respect to available measurements and models. Besides some very minor comments below, I do not see any further obstacle on the way for publication in ACP.

We thank the reviewer for taking the time to revise our manuscript and for his/her pertinent comments. Our reply to these is given hereafter (the text in italics represents a citation of the revised manuscript and the figure references follow the updated numbering).

Referee's comment 1. p9, Fig. 4 and all subsequent figures showing heat maps. The blue-yellow-red color maps (diverging color maps) are not ideal for the sequential type data of e.g. backscatter ratios. Sequential color maps with monotonous increase in luminance would be a better alternative here.

Author's response 1. Following the reviewer suggestion, we now use a more appropriate colour map starting from Fig. 3 (new numbering) and for all subsequent figures. The new colormap (which is similar to the "Parula" one used in Matlab) is sequential, perceptually uniform, colorblind safe and print/photocopy safe.

RC2. p20, l12pp. If only daily averages from August 26 until August 31 are considered, as for the hourly data in Fig. 4, the increase is less pronounced.

AR2. The reviewer is right. Following this comment, and similar remarks from referee #3 (RC1 and 10) and referee #4 (RC6), we expanded (and homogenised) former panels 4, 10 and 13 (old numbering) to include the same number of days. At the same time, we also paid attention at introducing into the sequence a "clear" day in order to better show the effect of the advections. We thus opted to show one week of measurements in each of these figures, as a compromise between completeness and detail (e.g., of the wind velocity field). The new plots extend from 25 to 31 August 2015 (case 1), from 24 to 30 January 2017 (case 2) and from 24 to 30 May 2017 (case 3), respectively. This allows to better appreciate the difference between event- (clear) and non-event (polluted) days.

Finally, for each episode, the information on the respective seasonal average concentrations were added to the text to provide reference values. Also note that a rigorous assessment of the long-term impact of the phenomenon presented in this part 1 is indeed the purpose of our companion paper (Diémoz et al., 2019) based on a statistical analysis of the complete dataset (2015–2017).

RC3. p22, Fig. 9b. The red/blue contours are really difficult to distinguish, but I also acknowledge this might be a hard visualization task.

AR3. Thank you for your suggestion. We made the contour lines thicker now and the revised figure looks better (Fig. 8).

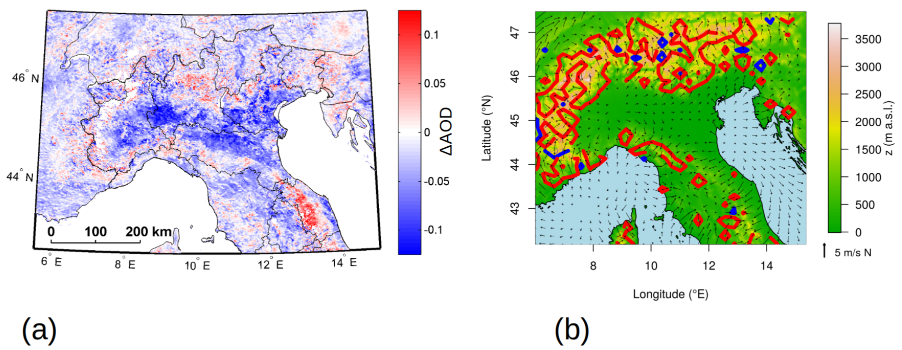

Figure 8: (a) Average difference between AOD estimated from Aqua and Terra satellites during days 27–31 August 2015 using the MAIAC algorithm. (b) Horizontal wind velocity from COSMO (arrows), vertical velocity (red/blue contours, $\pm 0.1\,\mathrm{ms}^{-1}$) over the same domain and the same hours as in Fig. (a).

RC4. p22, l5pp. The winter study seems a little more complex than the summer/spring studies. As the authors point out, the synoptic wind from the Po basin is mainly above the very stable PBL, so are the Aosta aerosols really all advected and mixed down to the surface?

AR4. First of all, we updated the introduction of this case study to highlight that indeed the winter episode is more complex than the other ones:

Although local emissions (e.g., residential heating and traffic, additionally worsened by the temperature inversion), might have also increased in this period, the influence of pollution transport from the Po basin is unambiguous. As a result of the advection, the PM concentrations measured in the Aosta Valley were found to be significant in the whole region (e.g., PM_{10} >100 $\mu g m^{-3}$ in Aosta–Downtown and Donnas), even at some remote measuring sites (e.g., PM_{10} ~70 $\mu g m^{-3}$ in Antey, Sect. 4.2.3, and remarkably higher *than the average concentrations in the same period (e.g., 33 $\mu g m^{-3}$ for PM_{10} and 23 $\mu g m^{-3}$ for $PM_{2.5}$ in Aosta–Downtown in 2015–2017).*

Then, to further support our analysis and data interpretation, we also changed former Fig. S5 in the Supplement. The new figure shows the vertical gradient of *pseudo-equivalent potential temperatures (e.g., Freney et al., 2011) at different altitudes [...], thus providing a rough indication of the vertical extent of the mixed layer.* For this second episode, *the arrival of a different air mass is revealed by the temperature/humidity sensors along the mountain slope. Pseudo-equivalent potential temperatures at different altitudes are shown in Fig. S5. As clearly noticeable, the spread among the series recorded at 550 m a.s.l. and the ones at higher altitudes remarkably, and quickly, decreases on 26 January, especially during the night, suggesting that the strong (and very shallow) temperature inversion weakens and mixing of the upper aerosol layers down to the surface is favoured.*

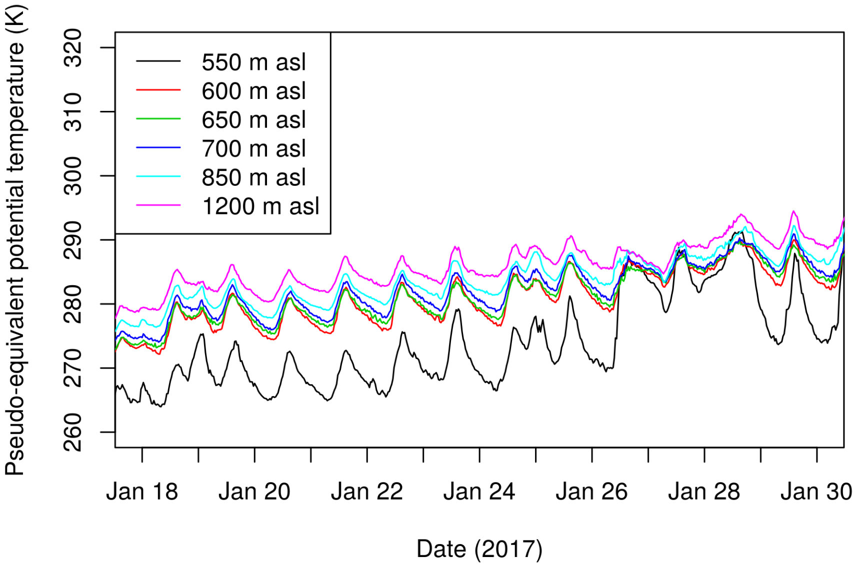

Figure S5: Profile of pseudo-equivalent potential temperature measured along the mountain slope on January 2017. A weakening of the temperature inversion, and a more mixed boundary layer, are clearly detected from 26 to 28 January, i.e. during the advection episode.

RC5. Maybe the contribution of local emissions is of more significant relevance here? Indeed, the daily cycles of measured PM10 surface concentration in Aosta seem to be influenced by local emissions (traffic, heating, etc.).

AR5. We agree that the daily cycle of measured PM_{10} may be partly influenced by local emissions during this episode as well as during other advection events. In this respect, in the companion paper, we indeed study the typical daily cycle of PM concentrations in different conditions (e.g., no aerosol layer detected by the ALC, aerosol layer arriving in the afternoon or leaving in the morning), based on statistical analyses of the long-term dataset. The PM daily cycles in these cases are represented in Fig. 10 (from companion paper). Although the overall daily tendency may vary as a function of the day type (e.g., increasing trend in case of a layer arriving in the afternoon, decreasing trend in case of a layer leaving in the morning), a common, typical feature of all plots is a double daily peak, resulting from both increased local emissions in the morning and late afternoon, and the evolution of the mixing layer height. The daily cycle of Polycyclic Aromatic Hydrocarbons (PAHs), detected at the same site, is also plotted. In fact, as demonstrated in “part 2” of the study (using Positive Matrix Factorisation), PAHs are related to (and are a good proxy of) the local emissions (e.g., traffic, combustion).

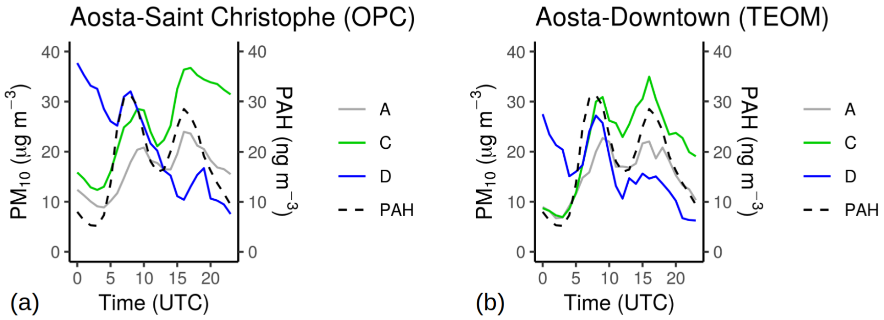

Figure 10 (companion paper): (a) Daily PM_{10} cycle sampled by the OPC in Aosta–Saint Christophe during non-event days (class A) and days with arriving and leaving aerosol layers (classes C and D), plotted together with the daily evolution of PAH as a proxy of the local sources (dotted line, right vertical axis, in $ng\,m^{-3}$). (b) Same as (a) using the TEOM in Aosta–Downtown.

During case study 2 (Fig. A), this typical daily cycle in Aosta–Downtown is visible in non-event days, i.e. Thursday 26 and Sunday 29 January 2017, but is missing during event days, i.e. on Friday 27 and Saturday 28 January, where the correlation between PM_{10} and PAHs is lost. We ascribe this behaviour to the advection of non-local, secondary aerosol from the Po Valley, such as ammonium nitrate. In fact, the chemical analyses show a remarkable increase of this compound, which we demonstrate (in the companion paper) to be a clear marker of the typical aerosol transported from the Po basin. This implies that local emissions are not the main effect modulating the PM_{10} concentrations in the winter case study.

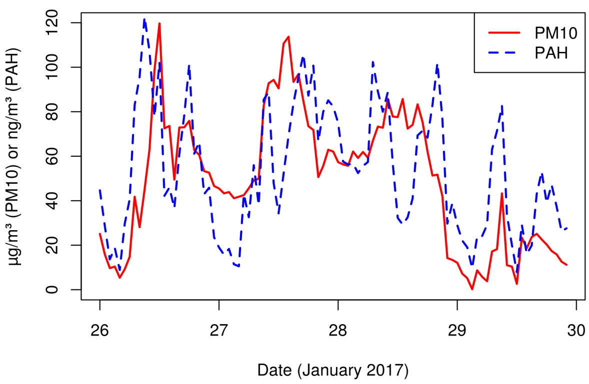

Figure A: PM_{10} and Polycyclic Aromatic Hydrocarbons (PAH) concentrations measured in Aosta–Downtown during case study 2.

RC6. However, I am no expert in atmospheric chemistry to evaluate the significance of the Nitrate and Ammonium percentages during Jan 27 and 28 in Aosta as an indication for air mass origin.

AR6. This topic will be thoroughly and rigorously discussed in the companion paper using the Positive Matrix Factorisation (PMF) technique coupled with the SR profiles from the ALC. There we demonstrate that nitrates (mostly in winter), sulfates (mostly in summer) and ammonium are indeed good markers of the advections from the Po basin. Also, locally-produced secondary aerosols are expected to be *minor contributors to* PM_{10}*, owing to missing sources of precursors in the Aosta Valley.*

RC7. p34, l17. Maybe the two cases for air quality degradation could be distinguished more clearly here, i.e. thermally driven winds in summer/spring and synoptic winds in winter in stable PBL conditions with no surface wind.

AR7. Right. This was mentioned in the revised conclusions:

We show that these advections are due to thermally-driven winds (especially in the warm period of the year, e.g. case studies 1 and 3) or synoptic flows (mainly in the cold season, e.g. case 2) from the east (Po basin) to the west. A more systematic analysis of the flow regimes and their impacts on transport based on comprehensive statistics are provided in the companion paper (Diémoz et al., 2019) exploiting the full 3-year record of ALC measurements.

RC8. p16, l11. ... in a few hours.

AR8. Done.

RC9. p34, l29. ... regime is established.

AR9. Done.

References

Diémoz, H., Gobbi, G. P., Magri, T., Pession, G., Pittavino, S., Tombolato, I. K. F., Campanelli, M., and Barnaba, F.: Transport of Po Valley aerosol pollution to the northwestern Alps. Part 2: long-term impact on air quality, submitted to Atmos. Chem. Phys., 2019.

Freney, E. J., Sellegri, K., Canonaco, F., Boulon, J., Hervo, M., Weigel, R., Pichon, J. M., Colomb, A., Prévôt, A. S. H., and Laj, P.: Seasonal variations in aerosol particle composition at the puy-de-Dôme research station in France, Atmos. Chem. Phys., 11, 13 047–13 059, doi:10.5194/acp-11-13047-2011, 2011.