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Interactive Comment

Interactive comment on "Quantification of topographic venting of boundary layer air to the free troposphere" *by* S. Henne et al.

S. Henne et al.

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Anonymous Referee #1

General Comments

The paper is well written and presents a thorough discussion of the vertical export of air masses from the atmospheric boundary layer to the free troposphere aloft due to the thermal circulation in a deep Alpine valley. Based on aircraft measurements as well as sodar and radiosonde soundings the mass fluxes horizontally along the valley and vertically along the slopes and across the top of the BL are well illustrated, leading to a very nice schematic draft which summarises the daytime atmospheric structure and the pollution transport processes in and above the Alps.

Quantification of the mass exchange driven by the valley winds and up-slope winds is undertaken with mass budget calculations based on the experimental wind data. Finally, the main pathways of the pollutants (which are exported from the Alpine valleys) are investigated by trajectory analysis. This discussion focuses on the regional to synoptic scale while the main topic of the paper is on a rather local scale Ű giving information about the typical exchange quantities above two specific deep valleys in the Swiss Alps.

An extrapolation of the export rates derived for these valleys to the whole Alpine region is undertaken which requires further discussion (see specific comments). The connection between the investigations for specific deep valleys and the conclusions and transport studies concerning the whole Alpine region in this paper need further clarification - e.g. in the description of the methodology.

AUTHORS REPLY ON GENERAL COMMENTS

We thank the referee for his useful comments. We agree that the extrapolation of the export rates needs further discussion. This is done in the answer to the specific comments and will be included in the final paper.

Specific Comments

1) How is the amount of N-emission from the valleys (section 2.1) estimated? As the NOx-emission factor for trucks is roughly 5 g/km per vehicle, the values are plausible, but should be explained or referenced.

2) The maximum vertical range of the PA2 sodar is usually around 800m at undisturbed sites. Fig. 9 is restricted to this height and reveals a lower range around noon (as usual in neutral stratification). I suggest to give this range instead of "up to 1km" at the end of section 2.1.

3) According to section 2.1, the mean uncertainty of horizontal mass flux calculations is

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about 7 % due to wind measurement uncertainties. Error estimates are important for a proper quantification, thus, some more details about the measurements uncertainties and how this percentage is determined would be helpful.

4) section 3.1: What are the reasons that the vertical mass flux is twice as high in June that in July and August? Do the measurements reveal that the atmospheric stability is weaker in June than in July and August? How can this be explained? Do the formation of convective clouds or synoptic subsidence play a role? This finding needs clarification.

5) section 3.2: "The convective boundary layer is visually indicated by constant to decreasing theta with height ..." If theta stands for the potential temperature, theta is INcreasing at the top of the CBL!

6) Discussion: If the total NOx export over the Alps should be part of this paper, the "calculation that considers advection from the forelands, accumulation of nighttime emissions in the ABL" must be shown in detail or be supported by references if available. On the whole, quantification of the pollution fluxes is not essential for the discussion of your findings as the title of the paper is restricted to topographic venting i.e. air mass fluxes only.

7) Figures: Fig 3 It is not clear to me, why the wind profiles are depicted not as single value per height, but as bars, although horizontally averaged.

Fig 4 The thin black line is not explained. Mixing height? Top of boundary layer? The line suggest that these are horizontally flat across the valley which is certainly not the case.

Fig 4, 5, 6 What do the arrow and N stand for in these vertical cross-sections from west to east?

AUTHORS REPLY TO SPECIFIC COMMENTS

1) The N-emissions are calculated for the traffic load using an emission factor for an average truck fleet (2.23 gN/km = 7.33 g/km NO_x as NO_2) and an average incline of $\pm$ 4 % (Emission factors taken from: BUWAL and UBA, 1999: Handbook Emission Factors for Road Transport).

2) 1000 m is the maximal range declared by the manufacturer, but we agree that the PA2 is usually restricted to 800 m.

3) The error of the wind speed at an individual altitude within the section was taken as the standard deviation of all samples at this altitude range. Error propagation was considered for the horizontal mass flux calculation. This yields an uncertainty for each horizontal mass flux calculation. 7 % is the average of all individual horizontal mass flux errors.

4) We could observe that the atmospheric stability (up to 4000 m asl) was lower in the cases for June than for August and July. Since we have only a limited number of measurement days, a final conclusion on atmospheric stability being the major factor influencing the vertical mass flux can not be drawn. Other factors like cumulus formation, different surface Bowen ratio and different synoptic forcings might play an important role. But again their influence can not be investigated with the limited data set.

5) Theta stands for potential temperature. In a CBL, superadiabatic lapse rates (i.e., decreasing theta) often occur close to the ground, where air gathers in thermal plumes and starts to rise, whereas theta increases at the top of the CBL, where entrainment occurs. However, the entrainment zone extends only through about 20 % (depending on definition) of the CBL, whereas the bulk of the CBL has a close to neutral stratification (i.e., constant theta). Our remark about theta referred to this part of the CBL.

6) The extrapolation of the local measured export rate to the whole Alpine terrain and the resulting pollutant budget is not one of the main results of our study but only a rough

estimation to underline the potential of topographic venting. As also criticized by the second referee, there are some crude assumptions in the estimation. 1. We assume that all Alpine terrain above 1500 m shows similar exchange rates than the ones found for the Leventina and Mesolcina valley. This is partly justified because major emissions take place in or close to valleys that show similar topographic characteristics as the valleys investigated. 2. No chemical processes are accounted for. 3. No pollutant accumulation lasting for more than one night is considered. The neglected processes are thought to counteract one another, so that our estimation should still be in the proper order of magnitude. If one wants to be even more precise, it is worth to mention that oxidation products of NO_x like PAN can act as a reservoir for NO_2 that can be released at later times.

7) Fig 3: The bars indicate the standard deviation of all samples at an individual height. Standard deviations are used for error propagation calculation (see also 3)

Fig 4: The thin black line indicates the average mixing height as taken from the radiosoundings and the lidar measurement. The mixing layer top varies along the cross section as well as from one cross section to the other.

Fig 4: The arrow indicates the direction towards north. We agree that a 3D vector arrow would be more suitable for a better understanding.

TECHNICAL CORRECTIONS

All technical corrections will be considered in the revised version of the paper.

Interactive comment on Atmos. Chem. Phys. Discuss., 3, 5205, 2003.

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