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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 #2

General Comments

The paper investigates the important issue of the vertical transport of pollutant in mountain terrain. In particular the mechanisms connected with exchanges of air masses between the Atmospheric Boundary Layer (ABL) and the Free Troposphere (FT). The analysis is conducted by mean of a mass budget analysis based on air flight measurements, using aerosol lidar measurements, radio sounding, and a forward trajectory model. While the analysis of the lidar results and the forward trajectories are interesting, as well as the conceptual model presented in Fig. 13, the mass budget

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analysis need to be discussed more critically and some aspects need to be clarified (see following points).

AUTHORS REPLY TO GENERAL COMMENTS

We would like to thank the referee for the comments on our paper. We have to admit that parts of the description of the mass budget analysis might be misleading and might be misunderstood. We will renew this part in the final paper and clarify the specific comments.

Specific Comments

1) From the text and the figure captions it seems that the mass flux measurements at the two sections of the valley were taken at two hours distance one from the other. The authors say that the stationarity assumption is justified because the ground measurements oscillate around 16

2) The measurements presented in Fig. 2 and 3., do not cover the lower 500 m of the valley. How did the authors consider this layer in their budget analysis? Did they neglect the flow in this part of the valley?

3) The authors confuse in the text the net vertical mass flux, with the amount of valley air leaving the valley. To be clear, net vertical mass flux = upward flux (e. g. by slope winds or thermals) - downward flux (e g. sinking in the center of the valley). The amount of air leaving the valley (which is what is interesting for air pollution studies) is linked only with the flux due to upward motions. The net vertical mass flux can give only a lower limit to this value. This should be discussed in the text.

4) It is impossible to generalize the conclusion from the mass flux analysis to all the Alps (as it is done in section 4). Firstly because the budget analysis gives only the net mass flux, and NOT the amount of valley air leaving the valley atmosphere, and second,

ACPD
3, S2272–S2275, 2003

because measurements recorded in other Alpine Valleys show different patterns. In some cases with a divergence along the valley axis (downward net vertical flux of mass, Freytag, 1987). Even if the phenomena described in the paper are certainly very important, I think it is very dangerous to generalize (in a quantitative way) to all the Alps results obtained for two specific valleys.

5) The paper can be better structured. I suggest to add a paragraph at the end of section one explaining explicitly how the measurements will be used in the following, in order to build the scheme of Fig. 13, and the role of the modeling trajectory study.

AUTHORS REPLY TO SPECIFIC COMMENTS

1) Our paper might confuse some parts of the mass flux analysis. To clarify the final version will be renewed. Mass flux measurements at two *subsequent* sections were taken within approximately 20-30 minutes. Mass flux measurements at the *same* section were repeated after two hours. The change of the horizontal mass flux during this two hour period is estimated. For the budget calculation the trend in the mass flux is considered for the time difference between measurements at the two subsequent sections. The wind speeds in the valley flow layer are assumed to be rather stationary at a time scale of 0.5 to 2 hours but the depth of the valley flow layer is usually increasing with time.

2) For the lowermost part of the valley an average wind speed per height is assumed according to a logarithmic wind speed increase with height with a fixed z0 of 10 m, which is suitable for mountainous terrain (Stull, 1988). This assumption does not have a strong influence on the total horizontal mass flux because the cross sectional area is rather small at the valley bottom. Therefore the fraction of the mass flux through this bottom layer is also rather small, on average 6% of the total horizontal mass flux.

3) Average vertical wind speeds in the valley are too small to be measured. The vertical temperature profiles in the valley center show two counteracting processes. On one

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hand subsiding motion should be seen in subsiding temperature structures (inversions, etc.) on the other hand convection starting from the valley floor anticipates further subsidence. An inversion layer build up during the night did usually not disappear during the day and remained rather unaltered in altitude or slightly rose during the afternoon hours. We therefore assume that the downward flux plays only a minor role for our budget analysis. If the downward flux would be larger the flux within the slope wind layer would also be larger. Based on the directly measured slope wind speed the depth of the slope wind layer necessary to balance the net vertical mass flux was calculated (page 5215, line 4f). A larger flux within the slope wind layer would result in a larger slope wind layer depth. Since our result for the slope wind layer depth is in the range of other studies we conclude again that the downward flux in the valley center is much smaller than the upward flux within the slope wind layer.

4) We are aware and agree with the referee that our estimation of the export potential is only a very crude number. But topography like in the two investigated valleys is typical for 25% of the Alpine terrain. Most NO_x emissions in the Alpine terrain take place along the major transalpine traffic routes, especially at sections with strong ascending slope. Therefore we considered all NO_x emissions to undergo the exchange process. The study by Freytag (1987), is done in a different environment (broad Inn valley, without strong incline of the valley ground and far away from the end of the valley) and there are additional uncertainties arising in their study due to the presence of tributary valleys and thus necessary assumptions. If one assumes that the upward flow in the slope wind system is the same for the Inn valley and the Leventina and Mesolcina valley the exchange rate (percentage of up-valley-wind layer air) in the Inn valley would be ten times smaller than the one measured in the Leventina or Mesolcina valley. Therefore, the net vertical flux would be within the uncertainty of the method.

5) We will consider this suggestion for the final paper.

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