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Atmospheric Chemistry and Physics Discussions

Interactive comment on "The impact of free convection on late morning ozone decreases on an Alpine foreland mountain summit" *by* J.-C. Mayer et al.

J.-C. Mayer et al.

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This is the cumulative response to the received reviews.

We are very grateful for the very useful comments and suggestions, provided by one anonymous referee (Ref #1) and Jenny Moody (Ref #2)

Concerning the general comments, we will quote the questions of the referees or summarize them where appropriate, and answer each of them individually.

The specific comments will all be implemented completely in the revised version. Only those which request (to our opinion) an explicit answer, will be addressed below.

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General comments:

Ref #1: The automated detection scheme does not give indication of the process behind the detected O3 drops.

Answer: This is true and was never claimed. However, we will weaken our conclusions in this respect and will emphasize, that the detection is only based on the phenomenon of the O3 drop and not on a certain process.

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Ref #1: It would be interesting to see, if and how frequent such phenomena occur also at other locations.

Answer: Evidence of such phenomena was recently found also for other locations (Eigenmann et al., 2008), although it was often not identified as active free convection (e.g. Hiller et al., 2008). These reference will be included in the revised version.

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Ref #1: It might be good to simplify the title to the following: The impact of free convection on late morning ozone concentrations upwind of a mountain summit.

Answer: We don't agree, because we have the impression, that this simplified title would rather focus on the upwind area of the summit than on the summit region, i.e. location of the drop event, were we focused on.

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Ref #2: One of the most seemingly relevant aspects of this event was the NO concentration, which spikes from what must be a few ppt to 12ppb, and then decays away. This begs the questions, was there a corresponding extreme increase in NO for each of these events? If so, that might be as relevant overall as the O3 observations.

Answer: We observed increases of NO during all 6 events (before/during, ppb): 30

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August: 0.2/0.7, 31 August: 0.4/6.1, 03 September: 0.1/1.4, 05 September: 0.1/12.7, 07 September: 0.1/4.1, 08 September: 0.2/0.7. These values will be added to the revised Table 2.

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Ref #2: There is also the question of whether in-situ chemical destruction of ozone is occurring as a result of the pulse of boundary layer air. It is certainly the case that the boundary layer ozone at the BASE site was fluctuating between 10 and 20 ppb, and yet, this extreme event at the TOP site resulted in a drop from 41ppb to 7ppb. In their discussion, the authors have implied that the processes which could lead to these O3 drop events are independent, and yet it seems fairly obvious that the injection of air up to the elevation of the TOP site, via free convection of air near the foot of the mountain will in fact result in a transient change of air mass, and more importantly, it could result in a temporally limited O3 sink at the mountain summit, a chemical sink. Chemistry and dynamics are not mutually exclusive.

Answer: Before the onset of the O3 drop event at the summit at the extreme day (05 September), the BASE O3 was at about 3 ppb. Chemistry and dynamics of course are not mutually exclusive. A transport of NO up to the summit, as observed, will certainly result in a temporally limited O3 sink at the summit. But this does neither alter the transport process, nor the link between the observed O3 drop events and the free convection phenomenon.

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Ref #2: The authors make the point that these free convection events were buoyancy driven by bubbles of warm, moist air rising during a period of light wind. Was there a corresponding increase in the water vapor mixing ratio observed at the TOP? This is implied by the increase in specific humidity as shown by the time height cross section of tether-sonde data from the BASE site. There should have been a corresponding increase in the RH, or a change in theta-e as measured at the TOP. Was this observed?

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Answer: Thank you especially for this remark. Yes, a corresponding increase in water vapour at the TOP was observed during the events. At 05 September, the specific humidity increased at the TOP from about 8.8 gkg-1 before the event to 11.1 gkg-1 during the event, which corresponds well with the value observed at the BASE. These values will be added to the revised Table 2, and a time series of specific humidity will be shown in Figure 4 instead of the air temperature at TOP for 05 September.

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Ref #2: Was the base site saturated earlier in the morning on all of these event days (RH=100% or almost 100%?).

Answer: Although earlier in the morning, rH ranged close to 100 %, it drops down from saturation on all days at least half an hour before the onset of the event. Patches of fog can be excluded by comparing the radiation temperature derived from downwelling longwave radiation, with the air temperature. In case of fog, both temperatures should be very close, as fog temperature and air temperature would be the same (the location where radiative energy transfer occurs would be the upper surface of the fog layer). For 05 September, we observed a downwelling longwave radiation temperature being about 20 K lower than the air temperature. This is indicative for clear skies. Furthermore, people being present at the BASE during the morning hours of 05 September did not observe fog or mist.

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Ref #2: In fact, is that a significant part of these free convection events, the evaporative heat added to the lower boundary layer results in the subsequent destabilization?

Answer: The humidity, released into the boundary layer, creates buoyancy, which supports the free convection. This was taken into account by using the buoyancy flux in Equation (1).

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Ref #2: But have you explored the use of the Bowen Ratio for the base site for this time period, it would represent the ratio of the energy flux upward as sensible heat to the energy flux used for evaporation? Given the timing, it seems very plausible that you are burning off a mist or light fog, or dew in the vicinity of the lower forested site.

Answer: The Bowen Ration at the BASE was about 0.5 around the event time and decreased slowly towards noon. There was no pattern visible, which would indicated a burning-off of mist or dew (this would result in low Bowen Rations during the burn-off period).

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Ref #2: I recommend you add both NO data, and RH to Table 2 for the campaign events, these gases should also be changing. It would also strengthen your argument if you add something other than just wind and T, eg., add virtual temperature, equivalent potential temperature, or RH to figures 3 and 4.

Answer: We will add NO and rH to Table 2 and add temperature and specific humidity to Figure 3 (mean diurnal courses with ranges) and replace temperature by specific humidity in Figure 4.

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Ref #2: The authors have noted that the magnitude of these events vary temporally, is it possible to estimate the magnitude (size) of the freely convected eddy based on the duration of the depletion event and the local wind speed?

Answer: We intentionally did not try to estimated the size of the eddies based on event durations and local wind speeds, because a) the location of the eddy relative to the inlet for the trace gas analyzers is unknown, i.e. whether the eddy is analyzed completely or just its out edge, and b) there might occur severe horizontal distortion along the wind direction during ascent and transport of the eddy. Nevertheless, for 05 September, a vertical dimension of about 20 m can be derived from the tethered balloon profile.

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Ref #2: Finally, at the outset of this paper, the authors suggest this phenomenon should somehow be removed (filtered) from the data so as to not affect derived statistical descriptions of ozone. However, considering the fact that these events occur frequently, and are likely to occur at comparable sites, it would seem that this kind of data manipulation, i.e. filtering, would be unwise. The point is, long term observations, effectively monitoring data, should categorically not be filtered to remove specific natural events that cause fluctuations in the data (remember the ozone hole!). Scientific investigations, indeed, like this paper, that attempt to understand why significant data fluctuations occur, and try to determine the recurrence of particular types of events are in fact what is needed. More thoughtful, detailed investigations like this one that recognizes the interplay between chemistry and meteorology through marshalling a variety of different observations are exactly the kind of integrated analyses we need. But please, do not throw out the data!

Answer: We totally agree with you, that such data should not in general be filtered out, and in our paper, we explicitly used these periods with O3 excursions. To avoid any confusion, we will omit the filtering remark in the revised version.

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Specific comments:

Ref #1: p. 5456: l. 11: What do you mean by the altitude of the wind direction change? Doesn't the wind direction change at all altitudes at some point?

Answer: We agree with the referee, that the wind direction changes at all altitudes at some point (temporally spoken). In this sentence, we referred to the altitude, where the wind direction change was currently going on, i.e. the time of the transition from wind direction before to the wind direction after the establishing of the Alpine Pumping. This actual change occurred with an increasing delay with increasing altitude compared to the near ground measurements.

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Ref #1: p. 5459, l. 14 ff: How certain can you be in identifying similar phenomenon, when you don't have all the other observation but only the ozone concentration time series at the top of the mountain. Wouldn't it be possible that other processes than free convection may have been the cause of these drops?

Answer: The similarity of the detected O3 drop events to those observed during the campaign makes it very likely, that the same processes generated them. However, there is no 100 % certainty, that other processes could not lead to comparable O3 drop events.

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Ref #2: Page 18. Do you know that the drop is air temperature mentioned in point 1 is not the result of evaporative cooling from burning off of fog or mist? I think you should discuss this.

Answer: We are sure, that the air temperature drop is not the result of evaporative cooling, because the longwave radiation indicates clear sky and relative humidity had dropped well below 100 % at least half an hour before the temperature drop occurred.

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References

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