

## **Review of “Very high stratospheric influence observed in the free troposphere over the Northern Alps – just a local phenomenon?” by Trickl et al.**

### **General Comments:**

This paper presents the influence of stratospheric intrusions of high O<sub>3</sub> and low water vapor at/near Zugspitze summit station with surface, and O<sub>3</sub> and water vapor lidar data. The authors give several examples of the types and transport pathways of the intrusions, and summarize the frequency of the intrusions in ten years of data at Zugspitze. They find that 84% of days analyzed contained evidence of a stratospheric intrusion, which surprised both me and the authors. The pronounced summer maximum of “strong” intrusions (Fig. 14) was also counterintuitive. I think the authors will need to provide more evidence to support these extraordinary numbers, which seem to be at odds with many other studies, regardless of criteria used to identify intrusions (there is discussion of this in Section 4).

In particular, I strongly encourage the authors to at least perform a cursory intrusion analysis with the nearby Hohenpeissenberg ozonesonde data set (~3 profiles per week). That site is approximately 50 km north of Zugspitze, so the results should be very similar. Also, there should be more discussion on the peculiar summer maximum of “strong” intrusions. Is it possible to provide average lidar O<sub>3</sub> profiles on intrusion days, with the O<sub>3</sub> profile centered on the O<sub>3</sub> maximum (e.g. a profile in O<sub>3</sub>-maximum relative altitude coordinates)?

I enjoyed the presentation of Section 3.2, but at least one of the sections is unnecessary and mostly irrelevant to the current O<sub>3</sub> study (#6: Volcanic Influence for example).

Does the title of the paper refer to the fact that the authors find much more frequent stratospheric influence over Zugspitze compared to studies in other locations? Please clarify.

Overall however, the paper is written well, enjoyable to read, and there are few technical mistakes.

### **Recommendation:**

The paper itself requires mostly minor edits, but the authors first need to provide examples supporting the extraordinary frequency of stratospheric influence at Zugspitze cited here. This will take a more “major” effort.

### **Technical/Line-by-line Comments:**

Page 1, Line 32: Please cite the TOAR paper on O<sub>3</sub> trends by Gaudel et al. (2018).

Page 1, Line 37: As you mention later in this paper on Page 3, the Montsouris measurements are in serious doubt (Tarasick et al., 2019; TOAR “Observations” paper). They should not be used to estimate past influence nor changes to the stratospheric influence on tropospheric O<sub>3</sub> amounts.

Page 2, Line 34: What does “mostly of the northern hemisphere” mean? Please clarify and rewrite.

Page 2, Line 37: “does by far not match” does not make sense. Please rewrite.

Page 3, Line 11: Delete “this”

Page 3, Line 21: Change “clear” to “distinct”

Page 3, Line 30-35: This discussion could be rewritten without citing the Montsouris data.

Page 4, Line 8: Change “the privilege of” to “limited to”

Page 4, Line 9: Change “were” to “was”

Page 4, Line 11: Please rewrite “Below 50 N the stratospheric layers were limited to this range.”  
What does this refer to?

Section 2.1.3: Please provide a table summarizing the data sets used here including site, lat, lon, elevation, and period of data used in this study.

Section 2.2: A table could also clarify the multiple trajectory models and for what situations they are used here. It is currently confusing when and why each trajectory model is applied.

Section 2.2.2: For transport times >4 days, why not use LAGRANTO with archived ERA-Interim output? Again, the table would help clear up these questions.

Page 8, Line 15: Is this “reanalysis” data GDAS? What resolution (.5 or 1 deg?)

Page 8, Line 20: Please rewrite this sentence.

Page 9, Line 1: Please use “days” or some suitable substitution instead of “data files”

Figure 2: Why is the O<sub>3</sub> in the black profile so low above 12 km?

Figure 3: I find this very hard to interpret and have no idea what is going on in this figure. Is there a better way to present clusters of trajectories indicating where the air over Zugspitze at the time of the O<sub>3</sub> profiles originated?

Page 11, Line 8: Use of “dominates” in this title requires statistics for support.

Figure 7: Can you match the vertical scales of these plots so the altitudes are aligned?

Page 12, Line 1: Please reword this title i.e. “has been mostly high”

Page 12, Line 3: As mentioned in the General Comments, is it possible to calculate an O<sub>3</sub>-maximum centered average O<sub>3</sub> profile to indicate the general conditions on these days?

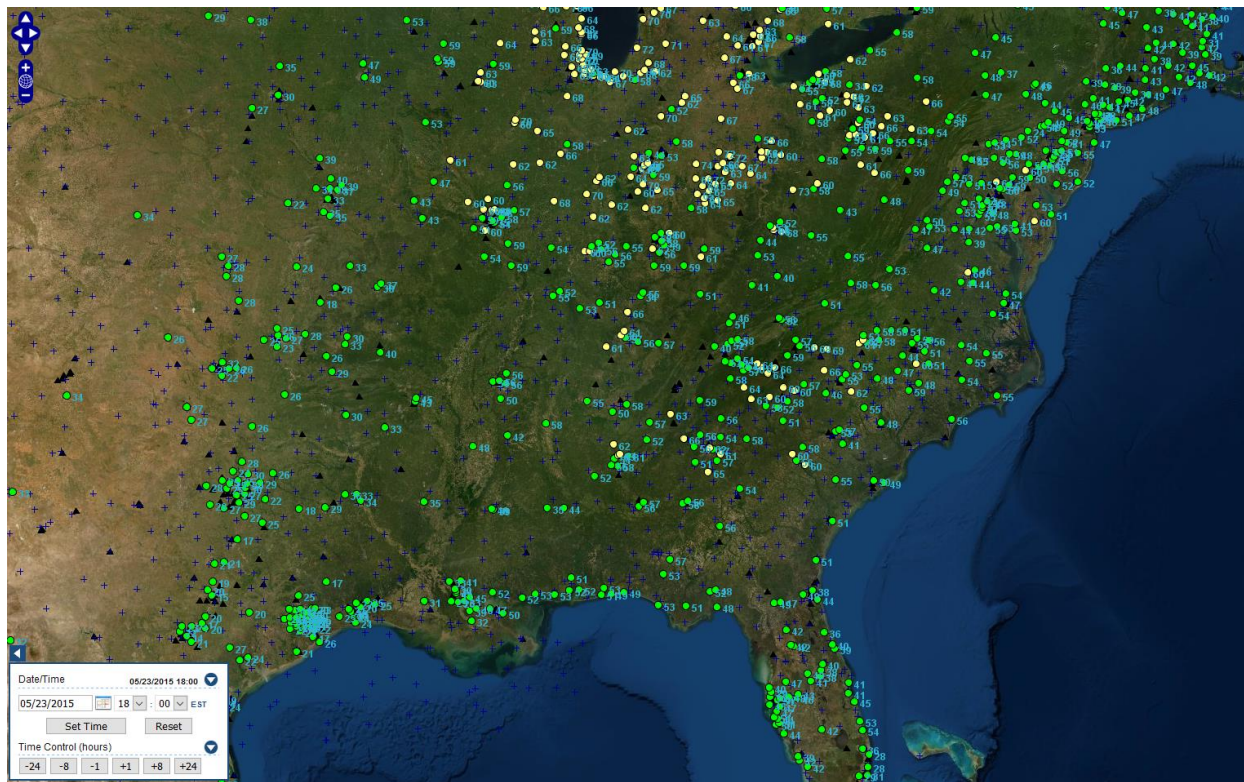
Page 12, Line 9 (#6): This section seems out of place and could probably be removed.

Page 12, Line 27: I do not follow this logic. How have you shown that O<sub>3</sub> layers are more likely to descend toward the ground at night?

Page 13, Line 1: Please rewrite “just eight-day.” What is FLEXTRA? Another trajectory model?

Page 13, Lines 1-2: Delete “during already”

Page 13 and Figs 11 and 12: Running HYSPLIT ensemble back trajectories for a single altitude over Zugspitze would be more convincing than single trajectories over this very long timescale. The same can be said for other HYSPLIT examples used in this paper. Also, a model should not be used to indicate high O<sub>3</sub> values over the US. In fact, the actual observations show that O<sub>3</sub> was not particularly high near the surface ([www.airnowtech.org](http://www.airnowtech.org) data from 0z 24 May 2015):



The Huntsville, AL, ozonesonde from 23 May 2015 at 18z also shows that O<sub>3</sub> in the boundary layer was generally ~60 ppbv. Please rethink the supporting arguments for this example.

Page 14, Line 11: Change “similarly” to “similar”

Page 14, Line 13-15: I’m not sure what this sentence means or is trying to argue.

Page 14, Line 22: This factor of 20 difference between two studies is part of what needs to be explained more as mentioned in the General Comments.

Page 15, Line 11: This is the most surprising result of the paper. I did not expect a summer maximum, and I certainly did not expect the intrusions to be mainly of the “strong” (as you define it) variety.