Mixing at the extratropical tropopause as characterized by collocated airborne H2O and O3 lidar observations

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This paper presents novel measurements of a 2-D cross-section of ozone and water vapour across a jet stream, identifying regions of mixed air using tracer-tracer distributions. There is considerable literature in this field drawn from in situ and satellite observations, and the methodology used in the paper follows previous work. The novelty therefore rests on the unique co-located lidar measurements that extend the previous studies into high-resolution 2-D curtains.

The study is certainly worthy of publication but I struggled with it in its present form. My main criticism is that the paper is much too long, with a wealth of detail presented at all turns that obscures the scientific argument. I sit necessary, for instance, to give a blow-by-blow description of each of the figures? Surely what is needed is to point out the features that feed into the scientific argument of the paper. As there is no conclusions section, the conclusions of the paper are included in the narrative, which means it is not clear what parts of the paper are necessary. It seems that the authors have applied all the analysis methods ever used in the past regardless of whether they bring new insight on the problem.

The difficulties start with the Introduction, which provides a comprehensive summary of previous work but does not identify the scientific problem that needs addressing – instead we are told '*For a more detailed characterization of the influence of the dynamics in individual synoptic situations on the distribution of trace gases in the ExTL, an observation capability for the instantaneous two-dimensional distribution of relevant trace gas along cross-sections through individual weather systems is required.*' Well yes, but why is a more detailed characterisation required? I'm not saying it isn't, I'm saying that clearly identifying the problem that needs to be addressed will help focus the remainder of the paper and allow un-necessary detail to be removed.

Section 2.2 is one of the areas that would benefit from considerable reduction in length. It reads like a review article on tracer-tracer correlations. What is the information that is relevant to the analysis in this paper?

What is the point of fig.4 and the accompanying text? Why not press straight on to the tracer-tracer correlations as these are the heart of the paper?

Again, I could not understand the point of fig.6 and the accompanying discussion – whereas fig 7a is a real highlight, comprehensively demonstrating the power of the combined lidar observations.

But 7b, the mixing factor analysis, doesn't seem to me to be telling us anything new. That may be because of the confusing way the diagnostic is described – e.g l.414-420 seem to be trying to say something important but whatever it is makes no sense to me. The authors should either remove this analysis altogether, or rewrite is much more clearly and concisely so that it comes to a conclusion that advances the scientific argument in the paper.

I thought fig.9 worked well, and followed on nicely from 5c and 7a.

What is the purpose of section 3.5, 'Isentropic trace gas gradients'? Is it to calculate the dynamical tropopause? If so, the section heading would be better as 'Comparison of the dynamical tropopause with isentropic trace gas gradients'. It seems that the key sentence in this section is that on l.511 '*The PV-gradient tropopause follows the regions of highest isentropic trace gas gradients much better than the 2-PVU isoline, especially in case of the O3 gradients, which confirms Kunz et al (2011b)*'. However, I don't agree with this sentence. First of all, the subjective 'much better' is not a scientific statement – by what criterion is it better, and how much better by this criterion? Secondly, the 2 PV contour in fig. 10f doesn't do too badly at all below 340 K. I don't think the tracer gradients support any particular definition of the dynamical tropopause, and challenge the authors to come up with a convincing diagnostic to show that they do.

The summary needs to set out more clearly what the conclusions of this work are, and how they advance our understanding of the tropopause region. There is a very good paper in here but the authors need to sharpen their arguments and dispense with superfluous detail in order to let it blossom.

Minor comments

l.16 'allows to identify' -> identifies (you can't use the construction '*subject* allows to *verb*' in English, it needs to be '*subject* allows *object* to *verb*'.) On line 150 I have suggested the latter construction; here and on l. 538 the 'allows to' is superfluous.

l.18 'surroundings'

l 18, 218 and 268 'indicative of'

l.20 'confirm that the mixing is strongest'

l.21 'the strongest'

l.23 'Although the methods do not allow conclusions to be drawn either on the individual mixing process or on the location and time of the event'

l.24 'allows the formation … T-T space to be discussed and hypotheses to be developed about mixing on ..'

l.25 'The 2-D lidar data presented'

l.49 'However, the DIAL they used was not capable of accurately measuring'

l.95 '..EXTL in the context of the'

l.125 'ratio of both signals as a function of the time taken to pass through the atmosphere, and knowledge about the exact absorption characteristics'

l.150 'allowed the mixing layer to be delineated'

l.200 what do you use as a definition of the dynamical tropopause? (I know you answer this question later but it helps the reader to know your definition at this point)

l 223 'tropospheric air'

l.229 'both in situ' (no comma)

l.234 'meridional' (not zonal)

l.338 '*high potential temperatures that increase towards lower ozone, which corresponds to vertically decreasing ozone values*' Fig. 3b shows a range of ozone values between 100 and 500 ppb for θ > 360 K, which is not consistent with this sentence

l.386 This paragraph makes specific reference to the dynamical tropopause. How does this differ from the thermal tropopause well to the north of the jet?

l.406 'Please note......' This sentence does not make sense –please rewrite

l.41 surroundings

l.429 the callout '(fig 9b)' is in the wrong place

l.430 missing figure callout '()'

l.463 the sentence 'In dynamic…' has no verb in the second clause and does not make sense

l.486 what does 'angular' mean?

l.492 Below the jet maximum your PV tropopause is displaced towards lower, not higher PV

l.538 'allowed to identify' -> identified

l.539 'losing'