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Interactive comment on "UTLS water vapour from SCIAMACHY limb measurements V3.01 (2002–2012)" *by* K. Weigel et al.

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We thank referee #1 for the time and effort spent on reading the paper and providing the comments. Below please find the reply to every comment.

Answers to specific comments:

Page 7960:
In the description of the averaging kernels and the assessed vertical resolution I see an inconsistency between different definitions of vertical resolution. Taking the FWHM of the rows of the averaging kernel, one gets the values described here, with the best

vertical resolution at altitudes where the tangent point of the observation is. Here the resolution is in the range of the vertical field of view, indicating that most of the signal at these altitudes rally originates from the measurements at these altitudes. However, the vertical resolution is also determined by the vertical spacing with 3.3 km between the tangent altitudes. Looking at the sensor response, which is around 1 for all altitudes in the selected vertical range this means that all altitudes contribute to the signals. In my understanding the vertical resolution can only be as good as the spacing of the measurements if the field of view is smaller than the vertical spacing of the measurements. This explanation could be improved. Especially as the origins of the measured signal and smoothing are discussed later (see my comment further down).

The vertical resolution is calculated as inverse of the information content, i.e. the inverse of the diagonal elements of the AVK, as described at P7960, L15-17. That the resolution can be better than the sampling is because it is not directly dependent on the sampling and calculated independently for each height of the retrieval grid. It describes how the value at one particular altitude is influenced by the measurements at the same and other altitudes. The best possible resolution is about 2.5 km, limited by the size of the FOV. Theoretically one single LOS can lead to this resolution at one height. But together with to the regularization the vertical sampling plays a role of for the resolution at heights inbetween the measurement altitudes. With 3.3km the sampling is coarser than the vertical extent of the field of view. At the lowest altitudes the real difference between two measurement altitudes is increased to even more than 3.3km due to refraction. For most other limb instruments the vertical sampling is rather higher than the vertical extent of the field of view. In this usual case the result is always clearly influenced by neighbouring measurement altitudes. For the lower altitudes in this retrieval the influence of the neighbouring altitudes is rather low, therefore these higher resolutions are possible. The drawback is, that the resolution between two measurement heights is clearly influenced by both, leading to the zigzag shape in the resolution profile. We agree with the referee that the description of the resolution should be improved and will change it to:

In combination with the regularization, the extent of the FOV, and the vertical sampling yield the height dependent resolution of the retrieved water vapour profile, shown in the right panel of Fig. 1. As in Hoffmann et al. (2008), it is calculated as reciprocal values of the diagonal elements of the averaging kernel matrix multiplied by the retrieval grid spacing. This method to calculate the resolution is based on the concept of information density (Purser and Huang, 1993) and yields comparable results to the Backus and Gilbert approach (Backus and Gilbert, 1970) used e.g. in Rozanov et al. (2011) for V3 of the water vapour from SCIAMACHY limb measurements. The lowest part of the profile shows the best vertical resolution of about 2.5 km. Here, the result is mainly influenced by one measurement, therefore resolutions close to the FOV size are possible. The resolution becomes coarser with increasing height and between the measurement heights at about 11.6, 15, 18.3, 21.6, and 24.9 km, where local minima in the vertical resolution are seen. For all SCIAMACHY limb profiles the measurements are taken at about the same heights, leading to a systematic variation of the resolution with altitude in the data set. The coarser resolution at higher altitudes is caused by a lower SNR combined with the increased smoothness coefficient. At 22 km, the resolution is clearly coarser than the 2.5 km FOV width also at the grid point closest to measurement height because due to the regularization and the lower SNR at 22 km this height is influenced by the measurement below at about 18 km.

Page 7980, Line 3-5:
I cannot follow the explanation on the annual cycle. In my understanding, either the SCIAMACHY datasets catch the annual cycle while the others do not or vice versa, while the annual cycle in the differences is much weaker for polar latitudes. Rewording probably makes this point clearer. In line 9/10, the explanations are getting clearer.

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We agree with the referee that the explanation needs to be improved. It was meant that all other instruments but SCIAMACHY agree in their annual cycle in the mid latitudes. To clarify this we will change P7980 L3-5 to:

This is similar for the NH mid latitudes (Fig. 17, right panel). Additionally, here a concordant annual cycle is found in the differences between SCIAMACHY and the other instruments which is not seen as distinctly in the polar regions.

Page 7984 Line 24-25:

I think this sentence could be improved by rewording. It is not completely clear what you mean by the fact that measurements at higher altitudes are a "mixture of measurements at about 18.3 and 21.6 km altitudes." Even the with sentence before, about SNR at 24.9 km, is not clear to me. The influence on what part of the profile is smaller?

It is always the lower part of the profile (with better SNR), which influences the upper part. To improve the explanation about the resolution we changed the description for the resolution (see answer to **Page 7960:**). Additionally, we will change this sentence to:

Therefore, the retrieval result above 19 km is influenced by the measurements at about 18.3 and 21.6 km altitudes, i.e. the measurement at 18.3 km influences all altitudes above because there the SNR decreases and the smoothing constraint increases.

Page 7986 Line 14:

The statement concerning the increase in water vapour in the tropical lower strato-

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sphere is very strong. By stating that "... it is real", it seems that this is a common result, found and supported by other sources. In that case you have to support this by an independent reference to other studies. Otherwise, I propose to weaken the statement by writing e.g. " ... the measurements discussed here indicate (suggest) that this increase in water vapour is real."

Following this comment and a comment from referee #2 we changed the text at P7986 L13–14 to:
Therefore, our study indicates that the increase of water vapour mixing ratios in the tropical lower stratosphere is real. It agrees qualitatively with the increase seen in Urban et al. (2014) as well as with an an observed temperature increase in the TTL after 2001 and an increase of water vapour near the stratopause between 2004 and 2013 (Nedoluha et al., 2013).

Answers to minor/technical comments:

Page 7956, Line 3:
Check placing of comma. "... minimum in water vapour mixing ratios, the hygropause, is located (see.e.g...."

We will correct the text.

Page 7956, Line 4:
"Therefore, it is challenging... " Why is it challenging? Because the low temperatures and low mixing ratios lead to signals close to the detection limits for most observation techniques?

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Yes, in the case of SCIAMACHY it is challenging mainly because of low mixing ratios leading to a low SNR, for emission and in situ measurements the low temperature plays a role, too. For in situ measurements this altitude is also difficult to reach for measurements. To clarify this, we will change the sentence to:

Here, a minimum in water vapour mixing ratios, the hygropause, is located (see e.g., Gettelman et al., 2011). Due to these low water vapour mixing ratios, which are often close to the detection limit of the instruments, it is challenging to measure water vapour in these altitudes,...

Page 7957, Line 1:
Check placing of comma. ”... European satellite Envisat, provided ... ”

We will correct the text.

Page 7964, Line 5:
Are the errors ”higher” in the sense of altitude of appearence? Or larger in the sense of magnitude. In case of the second alternative, I propose to use ”larger” errors.

We agree with the referee and will replace ”higher” with ”larger” there.

Page 7967 Line 22:
”... profile is taken into account.” (remove comma)

We will correct the text.

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Interactive
Comment

Page 7969 Line 5-6:

Looking at figure 7, the region without data due to the SAA appears to be rather between 90 W and 5 E (not 5 W and 90 E).

We agree with the referee and will replace 90°E–5°W) with 90°W–5°E).

Page 7974 L 4-6:

Here the filter criterion is unclear. Are measurements with AVK less than 0.03 in the diagonal used (which would not make sense)? Or are these neglected? Also it would be good to mention what visibility flag 0 means. Additionally, it would be good to mention that the MIPAS data are the reduced resolution after 2005 (you mention it on p7980 l 25/26, but it would help here, too, as the reader is not necessarily familar with the version numbering) It would be good to make clear which data are used. The filter requirement used for ACE-FTS is similarly unclear.

We agree with the referee and change the corresponding sentences to:

Here, we use the reduced resolution data starting in January 2005, data version V5R. The data are filtered to omit profiles with visibility flag equal 0 (indicating clouds) and diagonal elements of the AVK smaller than 0.03, as described e.g. Lossow et al. (2011). We excluded all profiles with these values between 10 and 25 km height.

and

ACE-FTS data are filtered to exclude profiles where relative errors larger or equal 1 occur between 10 and 25 km height.

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Page 7979:
The paragraph discussing comparisons with other satellite data is very dense, containing a lot of information. I suggest to split this paragraph into several paragraphs. E.g. split up by instruments or latitude bands, for better readability.

For better readability we will split the corresponding paragraph for the different height ranges discussed and change it to:

Figure 16 shows the comparison with collocated profiles from the other satellite instruments averaged over different latitude bands. All comparison data sets are smoothed with SCIAMACHY AVKs. It should be noted, that due to the differing collocation criteria (Table 1), a direct comparison between the instruments used for the SCIAMACHY comparisons is difficult. Because the characteristics of the observed differences depend on the height, we discuss them for three different height ranges: the upper part of the profile above 19 km, the middle part between about 14 and 19 km and the lower part below 14 km.

For most latitude bands the SCIAMACHY limb water vapour V3.01 is drier in the upper part of the profile compared to the other data sets. This difference is largest in the NH high latitudes (about 10 to 30 %) and smallest in the tropics (about 0 to 10 %).

In the middle part of the profile (about 14–19 km) SCIAMACHY data agree well with most data sets. The agreement is best in the NH mid latitudes and in the SH outside the tropics. In the NH high latitudes SCIAMACHY water vapour V3.01 is drier compared to most data sets down to about 16 km. In the tropics, the SCIAMACHY limb water vapour is wet compared to several other instruments and agrees best to ACE-FTS and MIPAS in the middle part of the profile.

In the lower, mainly tropospheric part of the profile the spread of differences to the various data sets and the standard deviation for each difference profile are comparably large in all latitude bands. However, the SCIAMACHY profiles are mostly wetter than the other data sets. In the lower part of the profiles the best agreement is again found to ACE-FTS and MIPAS, usually the difference is smaller than 10 % in the SH high latitudes and in the NH. In the NH high latitudes the agreement to SAGE II is comparably good. In the tropics and the SH mid latitudes SCIAMACHY data are more than 20 % wetter than all other instruments below 12 km. MLS and HALOE are drier compared to SCIAMACHY for the lower part of the profile for all latitude bands with up to 50 % (MLS) and up more than 100 % (HALOE).

Page 7985, Line 6:
".. because they does not show..." : shouldn't this be plural and thus "do"?

Yes, we will replace "does" with "do".

Figure 16:
I suggest to see over the layout for Figure 16. The overlapping y-labels should be removed.

We will change Fig. 16 and removed the overlapping y-labels.

Literature

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