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Interactive comment on "Validation of ENVISAT/SCIAMACHY columnar methane by solar FTIR spectrometry at the Ground-Truthing Station Zugspitze" *by* R. Sussmann et al.

R. Sussmann et al.

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We like to thank the anonymous referee very much for the effort to carefully go through the manuscript.

In final response, we thereafter provide positive point-to-point replies to all referee comments, and a list of all related manuscript changes we have performed.

"... I have serious doubts about the approach used to reach the conclusion that SCIAMACHY has the potential to capture the XCH4 atmospheric day-to-day variability and the annual cycle on spatial scales of the order of 2000 to 1000 km radius ..."

We are grateful for this hint, that our description of the validation approach, especially the strict logical separation between the single-site XCH_4 observations above the Zugspitze versus the 2000-km radius averages from SCIAMACHY, might have been presented not clear enough to the reader. We are sure, however, that our approach and the above mentioned conclusions drawn are valid. To clarify, we therefore inserted the following paragraph to section 3 (after the existing 3rd paragraph):

Since we are using selection radii of up to 2000 km around the Zugspitze, i.e., daily averages of XCH_4 values from all the SCIAMACHY pixels available within this radius for that day, the question arises how i) the absolute XCH_4 values, ii) the amplitude of their annual cycle, and iii) the day-to-day variability of the 2000-km averages compare to the corresponding quantities seen in the column time series above the center site (i.e., the Zugspitze). Ad i) we state that we expect no significant bias (i.e., less than a few percent) between the daily average column averaged mixing ratio above a single site (e.g., 47°N, 11°E), and an average over a 2000-km radius around that site on that day. The argumentation for this is as follows. First of all, we obtained a standard deviation of the individual SCIAMACHY column averaged mixing ratios of ≈5.2 % using all pixels per day within the 2000-km selection radius (section 4.2.3, Table 1). Using this value we derive an estimate of the standard deviation of the true individual XCH_4 values within the 2000-km radius of ≈4 % per day. This is obtained assuming a quadratic error superposition of the true scatter together with the known statistical SCIAMACHY error sources, i.e., instrumental noise causing an ≈1 % error (Buchwitz et al., 2005a) as well the so called-retrieval noise of ≈3 % (the latter resulted from a comparison to models in Buchwitz et al. [2005b]). We state that this variability of ≈4 % within the 2000-km selection circle is dominated by regional sources and sinks, and this scattering effect appears strongly reduced by a factor in the order of ≈10, considering the "standard deviation of the mean value" of all radius-2000-km values, as done in section 4.2.3 below (Table 1). From these considerations it is obvious, that we do not expect any significant bias between the column averaged mixing ratio obtained at the Zugspitze site (which shows a day-to-day variability of only ≈1 % and is located in

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the free troposphere and is therefore representative for a wider horizontal area), versus that obtained from the 2000-km radius average. In particular, it becomes clear that the current study focusing upon characterization of a time-dependent bias of SCIAMACHY in the order of ≈10 %, is not significantly affected by any possible bias due to the horizontal averaging. As an additional effect, the well known north-south gradient in the tropopause altitude results in an absolute tropopause increase of ≈2 km between the northern boarder and the southern boarder of our selection circle. However, this transfers only to a gradient of XCH_4 of ≈2 % expected between the northern and southern boarder. The underlying relation for the change of XCH_4 with the tropopause altitude was derived using an ensemble of radio-sonde pressure-temperature profiles with differing tropopause altitudes, together with a methane volume mixing ratio profile that was iteratively distorted according to varying tropopause altitudes (vertical scale linearly compressed or stretched below and above the tropopause, respectively, or vice versa). I.e., there is a small north-south increase of the columns within our selection radius on the ≈2 % level, but since it is to a good approximation a linear increase, this does not introduce any significant bias to the 2000-km average versus the center-site value, considering the magnitude of the effect we are investigating in this study, i.e., the ≈10 % time-dependent bias effects. Ad ii) we expect the amplitude of the annual cycle in the 2000-km radius daily averages to be very close to the magnitude of the amplitude at the center (Zugspitze) site. For an explanation, we make reference to the FTIR station at Iza$\tilde{n}$a (Teneriffa, 28°N, -16°E) which shows an amplitude of the annual cycle of ≈1 % (I. Kramer, personal communication, 2005), which is within the same order of magnitude as the Zugspitze amplitude of ≈1.6 % (see section 4.2.1), and shows the same phase. Since the annual cycles both at the center site (Zugspitze) and at the southern boarder site (Iza$\tilde{n}$a) are in the same order of ≈1-2 %, and they are showing the same phase, we conclude, that the amplitude of the annual cycle of the full 2000-km XCH_4 average is also within this same order of ≈1-2 %, i.e., it is by no means expected to be completely different in amplitude or phase. Ad iii) we state that the day-to-day variability of the 2000-km radius average is probably in the same order

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of magnitude as that above the center (Zugspitze) site (≈1 %), with a tendency to be smaller. We derive this from the consideration that day-to-day variabilities of column averaged methane are caused by tropopause movements due to synoptic planetary-wave activity, and this effect might be somewhat reduced due to averaging, when using the 2000-km radius mean XCH_4 values, compared to when using individual-site values.

Our specific point-to-point replies thereafter are all given in direct reference to our manuscript extension presented above:

"A circle with radius 2000 km around the Zugspitze (the location of the reference FTIR data set) encompasses the whole of Europe, up to high polar latitudes, down to North Africa, eastwards well in Russia and westwards over the Atlantic Ocean. It is clear that within this large region CH4 is not homogeneously distributed, and total column gradients from one region to another may be as large as 5 to 10 %."

We have given evidence in our manuscript extension that the changes in individual XCH_4 values within the 2000-km radius are in the order of ≈4 % within a day (standard deviation).

"The statistics underlying the conclusions suppose that all samples in the 2000 or 1000 km radius area are drawn from the same population which is no more the case."

We had clearly stated in the manuscript, that population changes do occur within the 2000-km radius domain (see, e.g., section 3, paragraph 4: "...source and sink regions may be more and more included into the ensemble, ..."). Within our manuscript extension (see above) we have now even more detailed the relevant population changes (i.e., we quantified source/sink scatter to be ≈4 %, as well as the north-south increase to be ≈2 %, see above). So it should be clear now, that we are not neglecting these issues, but they cancel out for our conclusions by reasons given in detail in our manuscript extension.

"Moreover, what is the sense of using the Zugspitze data, at one single site, as the

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reference to compare the 2000km radius averaged SCIAMACHY data with? For example, what is the meaning of the so-called bias (section 4.1.1) if one is not comparing comparable quantities?"

Averaging columns within a stepwise increased selection radius does not at all introduce any significant bias in a magnitude which could mask our conclusions upon the time- dependent-bias issue of SCIAMACHY, which is in the order of ≈10 %. This due to symmetry reasons (approximately linear north-south increase of the columns, see our manuscript extension above), as well as due to averaging of local source/sink effects within the 2000-km average (see our manuscript extension).

"The same question holds true for the comparison of the scatter: how can one compare the day-to-day variability at the site of the Zugspitze, dominated by local tropopause variations, with the residual scatter on the SCIAMACHY data that represent averages over such a large area as the whole of Europe?"

We never intended to directly compare but, rather, discuss in analogy, as can be clearly seen, e.g., in our last sentence of section 4.3.1: "Therefore the conclusion from our statistical numbers given above can only be, that WFMD data have the potential - as to their precision - to retrieve natural variabilities down to the 0.3 % level for a 2000 km- selection radius and down to the 0.6 % level for a 1000-km selection radius if all systematic type time-dependent drifts would/could be eliminated."

In fact the Zugspitze day-to-day variability of ≈1 % is an upper limit for the day-to-day variability expected for the 2000-km average, see explanation in our manuscript extension above. In order to address this consequently, we made the following additional manuscript changes:

Abstract, last sentence was changed: Old version: Therefore, the natural variability could be captured under the prerequisite of further advanced time-dependent bias corrections, or the use of other channels, where the icing issue is less prominent.

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Changed now to: Therefore, the annual cycle as well as possibly the day-to-day variability could be captured under the prerequisite of further advanced time-dependent bias corrections, or the use of other channels, where the icing issue is less prominent.

In Section 4.2.3, end of second paragraph counted backwards from the end we added: Note, that this is now close to the day-to-day variability of $\approx$1 % observed at the Zugspitze site. However, as stated earlier, an even smaller true day-to-day variability is expected for a 2000-km mean value due to the averaging effect (section 3). I.e., there appears to be still some potential for further improvements.

Conclusion, last sentence we changed: Old version: This means that the XCH_4 atmospheric day-to-day variability and the annual cycle can be captured under the prerequisite of further successful advanced time-dependent bias corrections, or possibly the use of other channels, where the icing issue might be less prominent.

Changed now to: This means that the XCH_4 annual cycle as well as possibly the atmospheric day-to-day variability could be captured under the prerequisite of further successful advanced time-dependent bias corrections, or the use of other channels, where the icing issue might be less prominent."

End of Final Response

Interactive comment on Atmos. Chem. Phys. Discuss., 5, 2269, 2005.