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Interactive comment on "Spatial and temporal characterization of SCIAMACHY limb pointing errors during the first three yearsof the mission" *by* C. von Savigny et al.

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General comments

The paper by von Savigny et al. investigates the limb pointing error, which is one of the most important error sources in the retrieval of atmospheric trace gas profiles using the limb scattering technique. As the main purpose of the paper is to contribute to the special issue of Atmospheric Chemistry and Physics in the frame of the geophysical validation of SCIAMACHY, the article mainly focuses on the spatial and temporal characterisation of the pointing error of the SCIAMACHY instrument. However, many of the

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findings are of importance for other current and future limb scattering missions as well, like OSIRIS, SAGEIII, SOLSE/LORE and OMPS. Therefore the present contribution is not only of interest to the SCIAMACHY community, but to scientists working with limb observing satellite instruments in general. In this regard the paper is well suited for publication in ACP.

The authors apply a spectrally extended knee-method algorithm to SCIAMACHY data in order to derive tangent height (TH) offsets. The knee-method uses a maximum in the measured limbscattered radiance in the UV-B spectral range, with the aim to retrieve the tangent height of the line-of-sight with high precision. For that purpose the authors use a spherical radiative transfer model combined with an optimal estimation scheme. The difference between the retrieved tangent height and the engineering tangent height, as given in the level 1 SCIAMACHY data file, is called the TH offset and therefore a measure for the apparent limb pointing error of the instrument. The authors restrict the application of the knee-method algorithm to measurements, which are performed within the range of 20 degree south and 20 degree north, in order to prevent that horizontal variations in the ozone concentration introduce artefacts in the retrieved TH offset. Subsequently, the derived and over latitude averaged TH offsets are assumed to be constant over the full orbit, i.e. they are applied to ozone profile retrieval also beyond the range of 20 degree south and 20 degree north. Based on this method, von Savigny et al. present an analysis of the temporal and spatial evolution of the TH offset during the first three years of the SCIAMACHY mission. In general, they find TH offsets of up to 2.5 km, with strong variations depending on season and location. These offsets may be decomposed in a linear and a sinusoidal contribution as well as in a constant component. After the correction of the orbit propagator model in December 2003 the seasonal variation in TH offset decreases significantly, however, the constant offset intensifies and reaches a value of approximately 1 km. Further, sudden limb pointing discontinuities occur daily with the update of the onboard orbit model. These points clearly show up in a longitudinal plot of TH offsets at 60 degree west and 100 degree east. Further, one observes a linear increase of the TH offset

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between these update locations.

The apparent limb pointing error has a severe influence on the retrieval of the vertical distribution of trace gases. Errors in the determination of the tangent height of up to 2 km can lead to errors in the determination of the ozone number density of up to 30%. In the presented case study the authors show that the pointing correction clearly improves the ozone profile retrieval. Here, the uncorrected and the corrected retrieved ozone profiles are compared to a reference ozone profile determined from lidar measurements. Due to the correction, the differences to the reference profile are reduced from approximately 30 % to less than 10 %. The precision of the TH retrieval achieves a few hundreds meter in addition to a constant offset of 1 km. The authors conclude, that in order to reduce the errors in ozone profile retrieval caused by pointing errors to less than 5%, the tangent heights have to be known to within 250 m.

Altogether, the authors present in a clear and convincing manner the evidence that there is an apparent mispointing in the range of up to 2.5 km. And that correcting for it leads to a significant improvement in the retrieval of ozone profiles.

As a general comment on their paper, I would like to suggest, that the authors should try to discuss more in detail the physical processes and model assumptions which might lead to the observed apparent limb pointing errors (thus, w.r.t. the instrument and the retrieval algorithm) and especially try to assess the reason for the remaining, constant TH offset of 1 km. In this regard, another important point is the fact, that it is very difficult to separate the instrumental effects from modeling artefacts. That is to say, it is a challenging task to distinguish between real mispointing due to the instrument or apparent mispointing due to model errors. In fact, the retrieval of the line-of-sight tangent height by inverse modeling could correct for inherent errors in the radiative transfer model and therefore improve the profile retrieval. One example for such an effect could be the used geometry. The engineering tangent heights are given for an elliptical coordinate system, whereas the radiative transfer model uses a spherical coordinate system. Differences in the calculated tangent heights due to different coordinate systems might be simply counterbalanced by a shift in tangent height itself (for details see also later in the specific comments). Finally the result will be the same; the correction of the identified TH offset leads to an improved ozone profile retrieval, despite there was no mispointing from the instrument in the first place. Thus, I suggest that the authors include a discussion on the difficulties to distinguish the effects of instrumental mispointing and model errors on the retrieved tangent height offset. Thus, putting weight not only on the description of TH offsets but also on their explanation, would further enhance the use of their article for other limb scattering missions.

In addition, the authors should respond to the following specific comments.

Specific comments:

page 3704, line 4: How has it been recognized that the TH information provided in the data files contains errors? In addition to the given references, it would be satisfying for the reader to receive some insight into the decision process at this point. When do you classify a given TH to be correct and when erroneous? If you define a wrong TH to be the one which yields incorrect retrieved ozone profiles, so it would be interesting to know if different retrieval algorithms detect the same wrong TH? Did you perform tests with different algorithms? Second, a short description of possible physical error sources, which cause the mispointing, and how accurately they can be determined would complete the discussion. I can imagine that temperature variations of the optical bench, positioning errors of the satellite, the pointing accuracy of the mirror, etc. may have a crucial influence on the mispointing of the instrument. What is the expected, i.e. precalculated, pointing error?

page 3705, line 8: You determine the TH offset by substracting the retrieved TH from the given engineering TH. However, the two quantities are calculated in two different coordinate systems. The engineering TH uses an elliptical coordinate system (reference ellipsoid), whereas the radiative transfer model uses a spherical geometry. Please as-

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sess the impact of the different coordinate systems on the determination of the TH offsets. Compare e.g. the technical note from Gijs van Soest, 'Sciamachy limb observation geometry, differences between ellipsoidal and spherical atmosphere', SRON, 2005. How large are the expected variations due to the different coordinate systems in the range 20 degree south to 20 degree north? Are they bigger/smaller than random variations in tangent height? Perhaps a plot of the retrieved TH offset for one orbit (or many orbits averaged over longitude) in north-south direction could reveal a systematic deviation? (See for example Fig. 4 in Kaiser et al., Satellite Pointing Retrieval from Atmospheric Limb Scattering of Solar UV-B Radiation, Can. J. Phys., 82, 2004. The figure shows a wave-like pattern between 20 degree south and 20 degree north.)

page 3705, line 19: What might be the influence of calibration errors of the SCIAMACHY instrument on the results of the knee-algorithm? Suppose the given pointing data in the level-1 file would be correct, but the radiance calibration of SCIAMACHY would experience a constant offset or even some tangent height dependent variations (e.g. introduced by spatial straylight, which is not taken into account in the level-0 to level-1 data processor). In my opinion, this could have the effect that the maximum value, i.e. the knee in the radiance measurements shifts to another altitude. Thus, more radiation from another tangent height than the given one reaches the detector. This in turn would result in a detection of a TH offset, despite the fact that there is no real mispointing. Please, try to estimate the effects of an imperfect calibration on the retrieved TH by adding a small, with altitude 1.) constant and 2.) increasing radiance offset to the measured radiances (as higher tangent heights receive relatively more straylight than lower tangent heights).

page 3706, line 20: The improvement of the orbit propagator model onboard the Envisat spacecraft resulted in a reduction of the seasonal variation of the TH offsets. As the orbit propagator model has such a big influence, could you explain in a few words the mode of operation of such a model? And what were the changes? Is there a difference between the onboard orbit model (page 7, line 3) and the orbit propagator model?

If yes, how does the pointing update work?

page 3708, line 16: Could the remaining seasonal variation in TH offsets result from the used ozone climatology? The inconsistency between the different coordinate systems in the orbit propagator model (Duesmann et al., 2004) has been removed, so there must be another reason. How does the uncertainty in the absorption cross sections of ozone influence the knee-retrieval? Furthermore, errors in the temperature profile of the used climatology could influence the refractive index of the atmosphere, leading to a different light path, which in turn would result in a TH offset. How would the retrieved TH offset change by using a different radiative transfer model (e.g. Sciatran).

page 3710, line 10: In addition to the single case study, that you present in this section, please include a statistical overview, which shows the average possible improvement of the ozone profile retrieval due to the pointing correction.

page 3711, line 9: You state, that 'In order to reduce the retrieval error due to pointing errors to less than 5%, the TH accuracy has to be better than 250 m.' Can an TH accuracy of better than 250 m be achieved? How realistic is it given the remaining error sources? Are there other limb observing satellite instruments, which achieve this accuracy (e.g. OSIRIS)?

Technical corrections:

1 typo; page 3710, line 23. Should be 1.13 km instead of 1.31 km.

Interactive comment on Atmos. Chem. Phys. Discuss., 5, 3701, 2005.