Atmos. Chem. Phys. Discuss., 7, S2055–S2062, 2007
www.atmos-chem-phys-discuss.net/7/S2055/2007/

Atmospheric Chemistry and Physics Discussions

Interactive comment on "Retrieval of temperature profiles from CHAMP for climate monitoring: intercomparison with Envisat MIPAS and GOMOS and different atmospheric analyses" *by* A. Gobiet et al.

A. Gobiet et al.

Received and published: 25 May 2007

Final Response to the Comments of Referee 2

(referee's comments are given in italics)

1. **Answer to General Comments**

   (a) *I feel that further information is missing that shows how much a priori information has entered the retrieved profile at stratospheric altitudes.*

   To quantify the amount of background information entering the retrieval, a plot (new Fig. 1 in Sect. 2.3) depicting the relative contribution of the background error to the retrieval error for two representative cases and a short discussion has been included in the paper. Please also refer to our answer to the specific comments (b) and (c) of Referee 1 for more details.

2. Answer to Specific Comments

(a) *page 3231: "data sparse regions" given that the main information in NWP models is these days provided by satellites, such regions do not really exist anymore. Radio occultation is rather complementary to other satellite observations.*

We indented to express the general advantage of satellite based remote sensing systems compared to ground based observations and the advantage of high vertical resolution of RO compared to most other satellite-based measurements. Since our sentence is indeed misleading, it has been reworded as follows (Sect. 1):

"Particularly the high accuracy and high vertical resolution in regions where so far predominantly rather low vertical resolution satellite-based data from nadir looking instruments is available (e.g., over remote oceanic areas and in polar regions) opens new possibilities."

(b) *page 3238-39: "As background information..." How is MSIS combined with ECMWF?*

Please refer to our answer to the similar specific comment (e) of Referee 1.

(c) *Are 91 ECMWF levels used for more recent periods and is there any effect on the obtained temperature profiles?*

Yes, we used the full 91-levels of the ECMWF analyses since they are available (Feb. 2006) but those data are not part of the paper. Comparisons with other datasets showed no significant change in the CCR temperature profiles. Remark: At the same time, considerable improvements in the ECMWF

ACPD

7, S2055–S2062, 2007

Interactive Comment

analysis, particularly in the tropical tropopause region, have been found (Borsche et al., 2007).

(d) *What will be the effect of improved ECMWF temperatures, e.g., the removal of the stratospheric cold bias in future analysis? Will this generate a fake trend at higher altitudes over time?*

In Section 4.4 we discuss the (in)dependence of CCR temperature profiles from the a priori (ECMWF). We show that CCR temperatures are insensitive to ECMWF biases of about 3 K up to 35 km and to large biases (about 10 K) up to 30 km. Such large biases are only found in the ECMWF Antarctic polar vortex region. We conclude that CCR is insensitive to improvements in the ECMWF analyses up to at least 30 km and don't expect any artificial trend below that altitude.

(e) *Could you further quantify the error of the observation and the background to see their individual contributions?*

A more detailed discussion of background, observation, and retrieval errors was indeed missing in the submitted version of the paper as Referee 1 noted as well. Please refer to our answer to the specific comments (b) and (c) of Referee 1 and the discussion of the new Fig. 1 in the paper (Sect. 2.3).

(f) *page 3239-40: "Finally a rough..." Could you provide further information on how many profiles are removed?*

Our quality control system removes about 10% of the profiles. An according note has been added at the end of Sect. 2.3:

"The entire CCR quality control system (including the rejection of technical corrupted data during the retrieval) removes about 10 % of the profiles entering the retrieval (GFZ level 2 data at phase delay level)."

(g) *"This yields no ..." von Engeln compared the full processing from orbit to temperature. Here, only level 1a (?) and upward is compared.*

ACPD

7, S2055–S2062, 2007

Interactive Comment

We only compare CCR to the operational GFZ retrieval starting from phase delays (level 2 in GFZ notation) as described in Sect. 2.3. This is indeed a difference to the study of von Engeln (2006) which is now clearly noted in Sect. 3.3.1:

“This yields no comprehensive information on the overall RO retrieval performance but rather estimates structural retrieval uncertainty starting from phase delays. Von Engeln (2006) performed a similar study for the entire RO retrieval process by comparing CHAMP data from two independent processing centres.”

(h) *page 3234: “Since CCR uses... ” Taking into account the remarks made by J. Wickert, is the selection of profiles affected by this processing problem at GFZ? What kind of profiles are removed in the quality control and will this change once the processing problem has been removed?*

Our quality control system (QCS) removes physically inconsistent data (negative bending angles after ionospheric correction) and data not passing the quality criteria regarding refractivity and temperature in comparison with reference data as described in Sect. 2.3 of the paper. Only changes in the GFZ retrieval prior to the phase delay level could affect the removal of profiles in our QCS. Correction of a numerical incorrectness in the GFZ retrieval part from phase delay onwards (thats what we understood from GFZ where the correction will be) will thus have no effect.

(i) *page 3244: “since the latter data...” Just because MIPAS uses a smoothing constraint with ECMWF data does not mean it is independent of ECMWF. It just uses a different cost function.*

This point has also been addressed by Referee 1. Please refer to our answer his/her specific comment (k) and the references therein.

(j) *page 3245: “In addition... ” has there been any attempt made to compare bending angles directly? They should be less affected by structural uncer-*

ACPD

7, S2055–S2062, 2007

Interactive Comment

tainty.

No systematic comparisons of CHAMP and GOMOS bending angles have been performed. However, since the presented GOMOS retrieval uses a scheme based on CCR to transform bending angles to temperatures, we don't expect any added structural uncertainty.

(k) *page 3250: Discussion of Figure 2: All plots show a bias of up to 0.5K at altitudes below about 13km. Water vapor does not seem to be the cause, low latitudes show a smaller bias than high latitudes. What is the reason for this bias?*

We don't have a final answer to this question but two factors might contribute: First, GFZ combines a dry temperature profile above 15 km with a temperature profile from a moist air retrieval below 15 km. This combination is a non-trivial task and could lead to differences. Second, the L2 phase delays in CCR are extrapolated using the stronger L1 signal below 15 km (a commonly used technique). This is a further potential difference to the GFZ retrieval at altitudes $<$ 15 km. Currently on-going upgrades to the CCR processing are intended to look closer into these issues.

(l) *page 3251: "Such a large bias [the bias between CCR and ECMWF in the JJA 2003 polar vortex region]..." This part (and others) needs to be reworked with respect to the comment made by J. Wickert. Otherwise one would expect this bias also to affect GFZ retrievals.*

It is not expected that an oscillatory temperature bias in ECMWF affects the GFZ retrieval in the same way as CCR, since CCR uses ECMWF in the statistical optimisation of bending angles above 30 km. In that case, the oscillatory structure of the bias is ingested into the optimised bending angle profile to some degree (with exponentially decreasing weight downwards) and subsequently transformed to a bias of similar shape in the temperature profile. Quite contrary, GFZ picks up the ECMWF temperature at one spe-

ACPD

7, S2055–S2062, 2007

Interactive Comment

cific altitude (43km) and only the ECMWF bias at that specific altitude enters the retrieval (exponentially decreasing with height, no oscillatory structure). This means that an oscillatory a priori bias may effect the GFZ retrieval strongly (if the initialisation height coincides with the height of the maximum bias amplitude) or not at all (if the initialisation height coincides with an altitude where the bias crosses the zero-line).

(m) *It is also surprising to find this bias between CCR to GFZ AND CCR to MIPAS, leaving the impression that this is an atmospheric feature not picked up by CCR - and GFZ is doing a better job albeit their processing problem mentioned earlier.*

The polar vortex feature can clearly be attributed to an ECMWF bias and is no “real” atmospheric feature as discussed in Gobiet et al. 2005 and even better demonstrated by the fact the CCR to GFZ and CCR to MIPAS (and CCR to all other analyses than ECMWF) comparison show biases of *opposite* sign in the 30-35 km region than the CCR to ECMWF comparison. CCR is warmer than ECMWF but colder than the other datasets. This leads to the conclusion that the ECMWF polar vortex bias between 30 and 35 km is even larger than indicated by the CCR to ECMWF comparison (10K or more).

CCR picks up a part of ECMWF’s cold bias (this is the reason of CCR’s cold bias compared to the other datasets) but still is considerably warmer than ECMWF due to the decreasing influence of the a priori with decreasing height. Above 35 km CCR is closer to ECMWF due to the stronger influence of the a priori at that altitude. Comparisons to the other datasets indicate another “oscillation” in the ECMWF bias above 35 km (ECMWF being too warm again).

The GFZ retrieval might do a slightly better job in this particular case, probably due to the fact that it fortuitously picks up the ECMWF temperature at an altitude where the oscillatory ECMWF bias is small. This is no indica-

ACPD

7, S2055–S2062, 2007

Interactive Comment

tion however that the oscillatory differences between CCR and ECMWF are caused by a “real” atmospheric feature not picked up by CCR.

(n) *In addition, remarks made earlier on the low-sensitivity of the chosen initialisation to a priori biases seems to be proven wrong here. Could you provide some profiles with different a priori biases and how they affect the CCR retrieval? The impact of a priori data should decrease exponentially with decreasing altitude, but in Fig. 2 and 3 it seems to be more linearly decreasing*

Our conclusion that CCR is insensitive to the a priori below 30 km in any case of this study and below 35 km in all cases except the JJA polar vortex case and the related large a priori biases is based on the Figures under discussion showing no indication of background dependence below 30 km. So we think our related remarks are adequate.

Regarding the second part of the Referee’s comment, we note that the shape of the JJA bias in Figs. 2 and 3 roughly corresponds to an exponentially decreasing oscillatory bias as can be expected when using an oscillatory biased a priori profile in the statistical optimisation of bending angles (please also refer to our response to question (l) above).

Temperature profiles retrieved with CCR using a different (non-oscillatory) source of a priori information show the expected exponential bias decrease. Examples can be found in Gobiet and Kirchengast (2004) and Gobiet (2005).

(o) *Is such a high bias of ECMWF likely, e.g., when compared to other measurements at these altitudes?*

Compared to MIPAS and analyses (GEOS-4, MetO, NCEP/CPC) the ECMWF stratospheric polar vortex bias (particularly between 30 and 35 km) seems to be even larger than indicated by the CCR to ECMWF comparison. Please consider our Figures 3 and 6 in combination with Fig. 5. Additional

ACPD

7, S2055–S2062, 2007

argumentation can be found in Gobiet et al. (2005).

References

Borsche, M., Kirchengast, G., and Foelsche, U.: Tropical tropopause climatology as observed with radio occultation measurements from CHAMP compared to ECMWF and NCEP analyses, Geophys. Res. Lett., 34, L03702, doi:10.1029/2006GL027918, 2007.

Gobiet, A., Kirchengast, G.: Advancements of GNSS radio occultation retrieval in the upper stratosphere for optimal climate monitoring utility, J. Geophys. Res., 109, D24110, doi:10.1029/2004JD005117, 2004.

Gobiet, A.: Radio occultation data analysis for climate monitoring and first climatologies from CHAMP (Ph.D. thesis), Scientific Report No. 6-2005, 140 pp, Wegener Center Verlag, University of Graz, Austria, 2005.

Gobiet, A., Foelsche, U., Steiner, A.K., Borsche, M., Kirchengast, G., and Wickert, J.: Climatological validation of stratospheric temperatures in ECMWF operational analyses with CHAMP radio occultation data, Geophys. Res. Lett., 32, L12806, doi:10.1029/2005GL022617, 2005.

We want the thank the Referee for his/her instructive comments that considerably helped to improve the paper!

A. Gobiet and co-authors.

Interactive comment on Atmos. Chem. Phys. Discuss., 7, 3229, 2007.