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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.

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Dear Editor,

We submitted our final responses to the reviews of both Referees. The major change of the manuscript is the addition of a new figure (Fig. 1) and the discussion of it. This was motivated by the direct request for this figure by Referee 1 and a question touching the same topic by Referee 2. We also contacted Dr. Wickert to discuss his comment to our paper and included his point of view regarding the GFZ vs. CCR comparison (see below). However, following the suggestions of both Referees, we didn't remove the figure showing the GFZ vs. CCR comparison.

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These and further modifications of the manuscript are described and justified in detail in the final responses to the Referees and the response to Dr. Wickerts comment. The list below gives an overview on the changes (the references to the Referee's comments refer to the numbering in our final responses):

1. Introduction, second paragraph: A sentence was adapted following the specific comment (a) of Referee 2. It reads now:

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

2.2. High-altitude initialisation and statistical optimisation, last paragraph: We further clarify why we claim that the hydrostatic integral effectively needs no initialisation in our retrieval (general comment (b) and specific comments (a) and (i) of Referee 1):

"...yielding high-quality refractivity profiles up to high altitudes so that effectively no "2nd initialisation" is needed to initialize the hydrostatic integral subsequently. This follows from the fact that the initialisation of the hydrostatic integral with zero pressure at 120 km, compared to initialisation with pressure from the MSISE-90 climatology, has no noticeable effect on the retrieved temperature profiles at any height of interest below the stratopause. 120 km can be regarded as being outside of the atmosphere from a RO retrieval point of view and effectively no further a priori information needs to be introduced to the retrieval after statistical optimization of the bending angles. This strategy ingests less a priori information compared to most other RO retrieval schemes and allows clear tracing of the amount of non-observed information entering the retrieval (see Section 2.3). "

2.3 The CHAMPCLIM retrieval, third paragraph: The effect of using the altitudinal variance of the ionosphere-corrected bending angle profile instead of the root-mean-square (RMS) differences relative to the a priori as estimator for the observation error

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is described now (general comment (b) and specific comment (h) of Referee 1):

“Unlike several retrieval schemes that use the root-mean-square (RMS) differences relative to the a priori for this purpose we derive observation errors independently from the background by analysing the altitudinal variance of the ionosphere-corrected bending angle profiles at high altitudes, where it predominantly contains noise and the neutral atmospheric contribution to the signal is close to negligible. Compared to the RMS method, this generally reduces the observation error estimate by 10 to 20% (which does not necessarily mean that the lower value is more realistic). More important are single cases with severely biased background information. Depending on the quality of the background information, such cases can lead to a more than 50% overestimation of the observation error.”

2.3 The CHAMPCLIM retrieval, fourth paragraph: The typical observation error estimate is quantified (specific comment (e) of Referee 2):

“Typically, the observation error standard deviation is estimated to amount to 1 to 4 μrad.”

2.3 The CHAMPCLIM retrieval, fifth paragraph: Our strategy of coping with the fact that ECWMF assimilates RO data since December 2006 is described (general comment (c) and specific comment (g) of Referee 1):

“Due to ECMWF having started RO data assimilation as of mid December 2006, CCR is scheduled to use short-range forecasts instead of analyses as a priori information beyond 2006 in order to have available sufficiently independent, yet physical consistent a priori profiles with good error characteristics (any potential influence of this change on climatology fields will be checked).”

2.3 The CHAMPCLIM retrieval, fifth paragraph: The merging of ECMWF and MSIS at 65 km is further described (general comment (b) and specific comment (e) of Referee 1, specific comment (b) of Referee 2):

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“This was converted into a refractivity profile (Eq. (2)), expanded upwards from 60 km (the second-highest level of the ECMWF model) to 120 km using refractivity derived from the MSISE-90 climatology (Hedin, 1991) and half-Gaussian weighting (vertical scale length 7.5 km) to ensure a smooth transition, and transformed into a bending angle profile using the forward Abel transform (the inverse of Eq. (1); e.g. Rieder and Kirchengast, 2001; their Eq. (14)).”

2.3 The CHAMPCLIM retrieval, seventh paragraph: A new figure (Fig. 1) and a discussion related to error tracing and the relative contribution of the background error to the retrieval error has been added (general comment (a) and specific comments (b) and (c) of Referee 1, general comment (a) of Referee 1):

“For enabling the possibility to trace errors in CCR, transformation matrices for background (B), observation (O), and retrieval (R) error covariance matrices ($R = (B^{-1} + O^{-1})^{-1}$) have been implemented to derive temperature error characteristics from the bending angle errors following Syndergaard (1999). As a measure of the relative importance of the background and observed information after the statistical optimization, profiles of the square root of the ratio of the diagonal elements of the retrieval error and background error covariance matrices (q_r) were analysed, where the retrieval-to-background error ratio qr can be regarded to indicate the fraction of the retrieval error stemming from the background error following Rieder and Kirchengast (2001) (their equation 8). q_r allows to define background dominated (qr > 0.5) and observation dominated (q_r < 0.5) altitude ranges, with the transition height ($hq50$) between these two regimes at the altitude where qr equals 0.5. In CCR temperature profiles, $hq50$ typically lies between 40 and 55 km and it lies about 4 km higher for the corresponding bending angle profiles, the actual height primarily depending on the observation error estimate for each given CHAMP bending angle profile. Two exemplary profiles, one with $hq50$ = 40 km (“low” case) km and one with $hq50$ = 57 km (“high” case) are displayed in Fig. 1. These two cases mark the range of virtually all CCR temperature profiles for which error estimation as described above could be performed. However, about one quarter of all CHAMP phase delay profiles showed data weaknesses at high altitudes where the observation error is estimated (indicated by negative bending angles in ionosphere-corrected bending angle profiles above some height). In these cases we down-weighted the observation by assuming a large observation error (50 micro rad) which results in lowering $hq50$ to about 32 km. We regard a more sophisticated treatment of these profiles, part of on-going work on CCR upgrades, as a major possibility for further reducing the dependence of CCR from background information."

2.3 The CHAMPCLIM retrieval, last paragraph: The effect of our quality control system is quantified (specific comment (f) of Referee 2):

"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)."

3.3.1 Operational GFZ retrieval, first paragraph: The difference between our CCR vs. GFZ comparison and the comparisons of von Engeln (2006) is clearly noted now (specific comment (g) of Referee 2):

"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."

3.3.1 Operational GFZ retrieval, first paragraph: A clearer explanation of the effects of initialising the hydrostatic integral and a reference to J Wickert regarding the GFZ retrieval has been added (specific comment (j) of Referee 1).

"The GFZ retrieval employs statistical optimisation of bending angle profiles using the MSISE-90 climatology (Hedin et al., 1991) as a priori data and adds further a priori information derived from operational ECMWF analyses by initializing the hydrostatic integral at 43 km (i.e., the systematic and random error of ECMWF at 43 km is assumed

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to be zero). This results, similar to other double-initialisation schemes described in literature (e.g., Hajj et al., 2004), in overemphasis of ECMWF a priori information and physically inconsistent refractivity and temperature profiles near the "2nd initialisation" upper boundary. We note that an enhanced version of the GFZ retrieval is scheduled to be released later in 2007 (J. Wickert, personal communication, 2007)."

3.3.2 Envisat instruments MIPAS and GOMOS, second paragraph: The influence of ECMWF a priori information on the Envisat/MIPAS temperature retrieval is discussed (specific comment (k) of Referee 1 and specific comment (i) of Referee 2):

"Though ECMWF analyses are used as a priori in the retrieval process, MIPAS is not biased against ECMWF, since the latter data are used within a smoothness constraint matrix of the type $\gamma L_1^T L_1$, where γ is a scaling factor and L_1 is a first order finite differences operator. The use of the first order finite differences operator does not constrain the column information but only how this information is distributed over altitude (von Clarmann and Grabowski, 2007). For the focus of this study, inspection of biases, MIPAS can be regarded as independent from CCR and ECMWF for biases in those data being vertically resolvable by MIPAS."

4.1 Comparison to operational GFZ CHAMP temperatures, first paragraph: The differences between the GFZ retrieval and CCR are discussed including the information given by Dr. Wickert in his comment to the paper and in personal communication (general comment (d) and specific comment (l) of Referee 1 and specific comment (l) of Referee 2):

"Parts of this bias can be attributed to the treatment of a priori information in the GFZ retrieval (see Sect. 3.3.1). As will be shown in Sect. 4.4 later, the source of this bias is a general cold bias (except southern JJA high latitudes) in ECMWF temperatures above 30 km, to which the GFZ retrieval is more strongly attached than the CCR. Additional causes could be a numerical incorrectness found in the GFZ retrieval (J. Wickert, personal communication, 2007) and the influence of the MSIS a priori information used

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for statistical optimization in that retrieval."

References: A reference related to the discussion of the dependence of the MIPAS retrieval MIPAS on the ECMWF a priori has been added:

"von Clarmann, T., and Grabowski, U.: Elimination of hidden a priori information from remotely sensed profile data, Atmos. Chem. Phys., 7, 397-408, 2007."

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

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