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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Balloon-borne radiometer measurement of Northern Hemisphere mid-latitude stratospheric HNO_3 profiles spanning 12 years" by M. Toohey et al.

M. Toohey et al.

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We thank the reviewers for their helpful comments on our paper. In the following, the reviewer's comments are repeated in italics, followed by our responses.

2-0: The attempt to quantify any significant

changes in the summer mid-latitude HNO3 profile since 1990 suffers from the poor quality of the 1990 balloon data. As long as the level of significance, with which the trend could be quantified from this data - given the systematic uncertainties of the measurements - is not demonstrated in the paper, the last sentence in the conclusions " This result may be taken as direct evidence that the - 2year HNO3 trend measured by the UARS-MLS instrument ..." is not justified.

We agree that the formulation of this sentence may have suggested a greater significance than is justified. We have modified this statement to a degree which we hope communicates 1) the scientific context (studies by Randel et al. and Rinsland et al.), 2) our conclusion of no significant measured change, while 3) explicitly stating that the uncertainty of our measurements precludes us

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from confirming or refuting the hypothesis of no long-term trend. The final sentence of the abstract has also been modified to better communicate this.

2-1: INTRODUCTION While there is credit to the very first HNO3 measurements by Murcray et al., the further selection of cited relevant publictaions seems rather arbitrary. I miss here for example reference to papers form other space and balloon-borne observaltions such as ATMOS, CLAES, CRISTA, ILAS, MARKIV and the various MIPAS deployments on balloons and on Envisat.

The references to early papers by Murcray and by Evans are motivated by the fact that these studies used instruments closely related to the emission radiometer used in this study. This is hopefully made clear by repeating the references in the discussion of the instrument history (Section 3).

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Concerning the more modern HNO_3 measurements, Santee et al. 2004 reference 12 satellite based instruments having measured HNO_3 profiles. There are at present at least two more such instruments on the AURA satellite. We have chosen to reference Santee et al. 2004 and references therein, rather than include references to each space-based instrument in order to improve the readability of the introduction. We have however added specific mention of (and references regarding) the MIPAS-B and MkIV balloon based instruments.

2-2: INSTRUMENT Nothing is said about potential non-linearity of the detectors used in the different instruments and how this was corrected for (if any). Although an absolute calibration was obviously provided during every flight, different detector properties could have affected the

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retrievals.

Detector linearity was implicitly assumed in the techniques we have used to perform absolute calibration using the blackbody scans. While laboratory blackbody calibration tests have shown that the instruments respond relatively linearly over most of their measurement range, recent close inspection has revealed that at very low radiance levels, the instrument response is indeed somewhat non-linear. Correction for non-linearity would require careful calibration tests on each of the instruments. Since the retrieval method was developed with the goal of being applicable to the 1990 data, for which the instruments are no longer available, we believe that non-linear instrument response is not an issue we can deal with directly within the context of this work. The effect of non-linear behaviour at low radiance levels would

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lead to biases at the highest altitudes, and indeed may be the source of the apparent low bias of the MANTRA retrievals compared to ACE above 30 km. We have added an explicit statement of our assumption of linearity in the description of the forward model used (Sec. 4.2). We have also discussed the likely effects of non-linear response in Sec. 4.4 in the context of the error analysis. Mention is also made of non-linearity in the description of the Results, specifically when pointing out the discrepancies between the retrievals during the double flights, and to the difference between the MANTRA retrievals and those by ACE at high altitudes.

2-3: RETRIEVAL The authors should explain why the instrument responsivity is changing with atmospheric parameters and why it is derived from the low altitude scans, which sounds a bit strange.

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Generally, the description of the ’first stage’ of the optimization (section 4.3) should be improved. The ’second stage’ describes a classical sequential onion peeling approach; it is not at all clear then, why the authors call this approach ’gobal fit’.

We have added: "The responsivity of the instrument changes as a function of altitude, most likely due to the fact that the detector does not reach liquid nitrogen temperature before launch, and continues to cool during the balloon ascent." Section 4.3, describing the retrieval algorithm, has been completely reworked, which we hope is much clearer in its description of the retrieval algorithm used.

2-4: ERROR ANALYSIS a) The temperature error of the external blackbody is estimated to within 2 K. Does this include inhomogenous temperature over the flap? What about blackbody emissivity

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smaller than unity? b) The HNO3 profiles of the various flights are displayed over altitude, but in the error budget any altitude error is not mentioned. c) Another error which obviously is not accounted for is the mutual interference of the CFC-12 and HNO3 bands which are overlapping in the spectral domain covered, given the bandwidth and low spectral resolution of the radiometer. Given the large errors of individual CFC profiles of up to 100% this error must not be neglected.

a) We assume a blackbody emissivity of unity, and have inserted a statement as such in the description of the instrument model (Sec 4.2). We have referred to the 2 K blackbody temperature error as a thermometer measurement error, which more accurately describes our intent. b) We have included errors in altitude based on an assumed random 1 hPa error in measured pressure, based

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on the results presented by Richner and Viatte (1995). Altitude error is included on plots of the resultant HNO3 profiles as vertical error bars in figure 4. The magnitude of this altitude error is quite small over most of the altitude range, but increases exponentially with height, reaching 2 km at 35 km. c) We have modified our error estimation procedure to take into account interference between the retrieved species. We now calculate the full Jacobian matrix resulting from perturbations to the retrieved mixing ratio profiles. The matrix inverse of the full Jacobian allows us to calculate the resulting retrieval error for one species given radiance noise at the radiance peak of all three retrived species (i.e., including the noise of the interfering species). The resultant error on our profiles (Figure 4) are accordingly somewhat larger than originally estimated. A

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description of the updated error estimation technique is included in Sec. 4.4.

2-5: RESULTS a) The scientific value of the retrieved profiles of the CFCs for this paper is questionable. CFC-12 should rather be treated as contaminant. Both CFCs appear to have a bias in the lowermost stratosphere when compared to ACE-FTS and also the shapes are not consistent. In Figure 5 both ACE-FTS data and MANTRA data should be plotted with the same level of confidence (either 1-sigma or 2-sigma. b) The authors should explain how the mean HNO3 profile has been calulated from the individual ones. Did they take into account the individual errors which obvioulsy differ from flight to flight? Did they treat the double flights of Aug 24, 1998 and Aug 29, 2000, respectively, as independent from each other? c) Figure 4: Please state in the

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caption if the error bars represent the total error or just the random part.

a) b) We have replaced the "MANTRA mean" in Figure 5 with profiles for each MANTRA year, which are weighted means for the two years having simultaneous measurements. This avoids the mismatch of confidence-level measures. This also makes the noisy nature of the retrieved CFC profiles even more apparent. While we choose to retain the retrieved CFCs as part of this figure, we aim to stress that they are retrieved not so much for their scientific value, but as interfering species in our retrieval. The CFCs are now introduced as "interfering species" in Sec. 4.3, and discussed as such in Sec. 6. c) The caption has been changed to make clear that the error bars represent the estimated total uncertainty.

Interactive comment on Atmos. Chem. Phys. Discuss., 7, 11561, 2007.