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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Measurement of the tropical UTLS composition in presence of clouds using millimetre-wave heterodyne spectroscopy" *by* B. M. Dinelli et al.

B. M. Dinelli et al.

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We have repeated part of the comments of referee 1 and introduced our answers below. All typos spotted by the referee have been corrected

Referee: Unfortunately the authors do not fully convince in how the measurement capabilities of the new instrument are derived and discussed. The mainly employed diagnostical criterion is the "individual information content" of the measurements, based on the ratio of the apriori uncertainty (knowledge prior to the measurement) to the error of the retrieved volume mixing ratios. ..... For example, discussion of the relative error (with respect to a retrieved or climatological value) would give further insight concerning the usefulness of the new instrument for observing a particular target species and

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altitude range.

Answer: R1) The qualifier used for the assessment of the new information provided by the measurements does already provide the information that the Reviewer would like to see. The a-priori is the climatological profile (see Sect. 5.3 of the paper and reply R10) and the qualifier provides, therefore, the log of the ratio between the retrieval error and the error of the climatological knowledge. The use of the log to represent this ratio is a useful convention adopted according to Rodgers'; information content. One unit of this qualifier corresponds to one extra binary bit of information.

Referee: Concerning the rather limited information content found by the authors, a particular problem might lie in the weighting between measurement and apriori information used ....

Answer: R2) The weight of the Optimal Estimation is given by the a-priori errors used. The choice of the a-priori errors is discussed in section 5.3. We have added the following text in the section:'Since the OEM uses the errors associated with the a-priori profiles as the weight with which the a-priori information is combined with the measurement information, particular care should be used in their choice. For all the target species but temperature, in our analysis we have used the measured atmospheric 1-sigma variability that has been estimated by Remedios (1999) for the latitude band of Darwin and that is included in the IG2 database. Only for the temperature, whose knowledge is supposed to be better than the registered variability over the wide latitude band considered in the IG2 database, a 3 K constant error was used. In the altitude range of MARSCHALS measurements the size of the a-priori errors for water ranged from 10% at 23 km to 190% at 7 km; for ozone the a-priori errors ranged from 30% to 100% depending on the altitude and for HNO3 the errors ranged from 40% to 100%. '

Referee: Finally, systematic uncertainties of the instrument are only partly discussed. For example, whilst the critical uncertainties in pointing are described in detail, there is hardly any information about other critical parameters such as the antenna character-

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istics, among others .....

Answer: R3) Some general comments on instrument parameters: Antenna pattern: The antenna pattern has been measured at an antenna test range at University College London. The measurements have been performed in both polarisations down to +-90 degrees and from the measurements azimuthally collapsed antenna patterns ACAPs have been computed for both main axes. The dynamic range of the detector was ˜50dB, which means that sidelobes higher than -50dB have all been captured. This is a very low value. From our experience anything below -40dB is barely noticeable and even -45dB is still a very strict threshold! These measurements and the resulting antenna pattern have been reported to ESA in a MALSAC project report ('MARSCHALS Test & Characterisation Report', MAR-RAL-TCR-001, Issue 003, 28/02/2006, Technical Report to ESA, B. P. Moyna, M. L. Oldfield, D. N. Matheson, Rutherford Appleton Laboratory). The antenna patterns have been used in this analysis, so the antenna pattern knowledge is very high and consequently the impact on retrieval error is negligible. In any case, the systematic errors introduced by the antenna characteristics will affect the definition of the Field Of View function and are related therefore to the pointing uncertainty. These errors are taken care of by the pointing bias retrieval. The retrieved values suggest that those errors are negligible with respect to the instrumental noise Standing waves: In contrast to ground based radiometers MARSCHALS uses fully open to the atmosphere calibration loads, i.e. neither the thermal load at ambient temperature nor the cryogenically cooled load are hidden behind protective shields or immersed in liquid coolant. To prevent condensation on the cold load the cryostat is only opened once the very dry stratosphere is reached. Consequently, there are almost no standing waves present in the quasioptical system which could influence the measured spectral radiation. Lab measurements under a dry-air canopy performed on a gas cell have shown no signs above the NEBT threshold of baseline ripples (apart from the ones due to the cavity walls of the gas cell). If required we can add this considerations to the manuscript and the following and previous reference for more instrument details will be added to the manuscript: MALSAC - Phase 2 Report, 'Flights of the

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MARSCHALS Instrument on November & December 2005 during the SCOUT-O3 Tropical Campaign in Darwin, Australia';, D.Gerber, A-S.Goizel, B.Kerridge, D.Matheson, B.Moyna, T.Nightingale,

Referee: c) Presentation Quality: fair The presentation quality is judged as "fair" since sections 2 and 3 could be considerably shortened if only the relevant information is presented. Another issue is the limited readability of some of the figures (axis labels) (see suggested technical corrections below).

Answer: R4) Figures will be modified. Sect. 3 will be reduced. Sect. 2 will be changed

Referee: 2) Specific comments Abstract: Please provide quantitative results, e.g. measurement capabilities in terms of altitude range, altitude resolution, measurement uncertainties for the studied target species.

Answer: R5) The following text has been added to the abstract 'Water has been measured from 10 km to flight altitude (˜18 km) with a 10% accuracy, ozone from 14 km to flight altitude with accuracy ranging from 10% to 60%, while the retrieval of nitric acid have been possible with an accuracy not better than 40% only from 16 km to flight altitude due to the low signal to noise ratio of its emission in the analyzed spectral region.'

Referee: Introduction: Limitations of present meteorological mm-wave nadir sounding capabilities (MHS, AMSU, IASI) in the middle and upper troposphere for the here relevant species could be briefly discussed in the introduction in order to set the scene for this study.

Answer: R6) We have a problem because here more discussion about existing instruments is asked while reviewer 2 asks to remove all the discussion about other instruments. We have decided to leave the discussion as it is as a compromise between the opposite requests of the reviewers. And please notice, IASI is a mid-infrared sounder.

Referee: Section 2 (2.2-2.4): The right balance (level of detail) needs to be found. For

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example, whilst the critical uncertainties in pointing are described in detail (section 2.4 might even be shortened slightly), there is hardly any information about other critical parameters for limb-sounding measurements such as for example the antenna characteristics. All typically important sources for systematic uncertainties of the measurement (related to pointing, antenna, optics, sideband filter, spectrometer, calibration, baseline ripple, etc) could here briefly be discussed and (if possible) quantified. This is so far only partly done.

Answer: R7) See answer R3 on this point

Referee: The impact on the retrieved profiles needs also to be addressed.

Answer: R8) The systematic errors introduced by the instrument are compensated in the retrieval by the fit of an additive offset and of a gain factor. The retrieved values suggest that those errors are negligible with respect to the instrumental noise

Referee: Section 3: The whole paragraph (3.0) about the Scout campaign could be considerably shortened. The relevant background information for the single successful flight with Marschals can easily be summarized in only one or two lines.

Answer: R9) We have shortened the section, retaining some details to explain why only data from one flight have been analysed

Referee: Section 4: (2. on "individual information content (IC)"): Since this quantity is used later in the manuscript as the main diagnostical tool, the authors should indicate which values of IC indicate a useful measurement, i.e. how large is IC when information is mainly from the measurement and not from the apriori information of a retrieval parameter..... The choice of the apriori uncertainty is therefore of primary importance and may have considerably affected the outcome of this study. This needs to be discussed and clarified in the manuscript.

Answer: R10) The reviewer is right; the IIC value depends on the a-priori uncertainties chosen for the retrieval. The quantifier is used to indicate at what altitudes the mea-

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surements consent a gain in information with respect to the a-priori knowledge that we think to have of the atmospheric status. For this reason we have chosen to use as a-priori errors the measured variability of the targets (result of a dedicated study of J. Remedios) at the latitude of Darwin and to use as initial guess the best possible knowledge available. In this way we intended to give an absolute estimate of the gain in information provided by the measurements with respect to the expected composition of the atmosphere. Of course we could have used a smaller a-priori error that probably would have given lower gain but smoother results than the ones obtained, or a larger error that would result in a too optimistic measure of the information content gained with the measurements.

Referee: Section 5.5: The above mentioned issue is also important for the discussion of the retrieval results in Section 5.5 where changes are needed accordingly.

Answer: R11) Done

Referee: 3) Recommended technical corrections Title: in case this paper should be revised for ACP, I suggest publication as "technical note".

Answer: R12) We have no problem in publishing this as a technical note. We live the decision to the editor

Referee: Page 14170 l5: provide frequency range of Marschals OK

Page 14171 l1: inadequate citation "ricaud 2007"

Answer: R 13) reference removed

l13: 2 references for IASI, but other instruments need also to be briefly discussed (in a general way)

Answer: R14) Here we have a problem because reviewer 1 asks for more discussion in the introduction while reviewer 2 asks to remove all the discussion about other instruments. We have decided to leave the discussion as it is now as a compromise between

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the opposite requests of the reviewers.

Referee: l24: "since the majority of instruments are blinded by clouds ... in this region". Certainly incorrect, suggest to reformulate. Spatial resolution and sensitivity is also a limitation of todays satellite sensors.

Answer: R15) It is true, but those problems will affect also a new satellite instrument (maybe both resolution and sensitivity could be enhanced but up to a certain level only). Moreover the development of MARSCHALS was driven by the necessity of a new sensor that was not affected by the cloud coverage in the UTLS. This is why we stressed this point.

Referee: Page 14172 l17: "was not enough to" (?)

Answer: R18) OK changed into 'prevented to obtain a definte proof of'

Referee: l20: "ODIN". Explain acronym.

Answer: R19)It is not an acronym, should be written as Odin. Text changed accordingly

Referee: l10-20: All space sensors mentioned measured quite a large range of constituents, not only the few here mentioned species. This should be corrected. The authors may focus on the here relevant target species (H2O, O3, HNO3, temperature).

Answer: R20) We will modify the introduction accordingly

Referee: Page 14174 l2: aliased radiances (?)OK Text will be changed to better explain this point l15: Suggest to remove figure 2. Otherwise explain in more detail what the reader is supposed to see.

Answer: R21)The reader is supposed to see how the different instrument modules of MARSCHALS play together. This is nice to know from an engineering point of view, but it is not crucial for the understanding of the results presented in this paper. Furthermore, there is also a block diagram of the instrument elsewhere which shows things like the calibration mechanism, so if this figure is controversial in any respect, then

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there is no harm in leaving it out

Referee: Page 14175 l1: can present one of (?)OK Text will be changed to better explain this point Page 14176 l10-17,following page: please shorten. OK see answer R9 Page 14178 l9: explain "incoherent flight pattern"

Answer: R22)The flight pattern for the Hector flight (i.e. aimed at cloud sampling) features numerous and frequent turns and sharp alterations in flight altitudes. The lack of intervals of the order of one or more limb scan durations during which the instrument is consistently looking at a fixed direction at level flight altitude makes this flight pattern unsuited for remote sensing of the atmosphere. We changed the text into 'the particular flight pattern used for cloud sampling with numerous and frequent changes in direction and flight altitude made it particularly unsuitable for remote sensing applications'

Referee: l12-13: contradiction in statement "Marschals was compromised although the instrument was again operational"

Answer: R23) This sentence is referring to the flight of 6th November 2005. During this flight the antenna pointing system was not working. The pointing controller was constantly resetting the scanning mirror and so no atmospheric measurements where made (the scan mirror kept spinning). This was the reason that for later flights the EPROM of the pointing controller has been replaced with the spare module, which in turn only allowed the use of fixed pointing angles. On the other hand OCM cloud data have been acquired during the whole flight, and also the full set of housekeeping data, geo-location data and aircraft UCSE data. In earlier campaigns we had problems with the aircraft power supply and during these flights the instrument was basically switched off and no data was recorded whatsoever. In contrast to this previous case, all systems where powered on during the 6th Nov flight and doing something; but because the scan mirror could not be stabilised no actual integration period for atmospheric spectra was ever started. We changed the text into 'MARSCHALS was recording a full set of OCM cloud measurements, geo-location, housekeeping and aircraft UCSE data but, due to

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an error in the antenna controller, the scanning mirror could not be stabilised and no atmospheric data were measured'

Referee: Page 14180- l5-16: please provide quantitative results (for MIPAS-STR error budget for the here relevant species).

Answer: R24) We changed the paragraph and we give absolute values for the individual errors in the text. Also we put a reference to Fig. 17, where the errors are given with the profiles.

Referee: Page 14182 l16: per limb view ?

Answer: R25) an OCM frame is taken during each atmospheric integration cycle (in contrast to the calibration views hot/cold during which no OCM image are taken).

Referee: Page 14183 l2: NET=4k, 250ms, 200MHz gives roughly a Trec of 28000K. Please check and make consistent throughout paper.

Answer: R26) The table lists Trec=20’000K, which is the receiver noise temperature derived from a single hot-cold measurement (the so called y-factor). This does not include effects from the IF chain, mainly the first amplifier immediately after the mixer, or indeed from calibration. The system noise temperature Tsys which is related to the smallest possible difference in Brightness Temperature the instrument can detect (according to the radiometric formula deltaT=Tsys/sqrt(b*t)) will indeed be of the order of 28’000K depending on channel. We will update the table in question and we shall also better discriminate between Trec and Tsys in the text.

Referee: Page 14185 l11: define/explain "external continuum"

Answer: R27) The definition of it has been already explained in section 4

Referee: l12: short definition/explanation of pointing bias, instrumental offset, gain correction factor needed Answer: R28) We have added to section 4 the following text: 'Besides the vertical profiles of the selected atmospheric quantities (tempera-

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ture, VMRs, external continuum absorption coefficient) MARC can retrieve instrumental scalar quantities in the form of single values for all the spectra of the same scan: one pointing bias value to account for the errors in determining the real pointing of the antenna, a radiometric offset value to be added to all the spectra of the same scan and a correction factor to be multiplied to all the spectra of the same scan to account for detector non-linearity.'

Referee: Page 14186 l2: guarantees (?)

Answer: R29)OK changed into 'ensure'

Referee: l6: among the sweeps of the same scan (?)

Answer: R30) MARSCHALS sweeps sometimes share the same calibration, so in principle the errors among them should be correlated. We decided not to introduce this correlations in the VCM of the observations.We have changed the sentence into:' among sweeps that share the same calibration'

Referee: l9: removed from the analyzed data set (?)

Answer: R31)OK the sentence has been changed into: 'Spectra that after a first run of the retrieval had a chi-test value higher than 20 have been removed from the analysis"

Referee: l11: as a compromise between the details (?)

Answer: R32)OK changed into 'number of altitudes needed for a correct representation of the vertical profile'

Referee: l19: temperature was retrieved. Why is it "NOT a target"?

Answer: R33)FIR measurements are not too sensitive to temperature. This makes the errors on the temperature measurements too high for a scientific exploitation of the temperature data. The retrieval of temperature is performed in any case to compensate for systematic effects. We have added a clarification in the text

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Referee: Page 14187 l6: spectrally averaged noise (?)

Answer: R34)OK changed into: 'single noise value for each sweep used '

Referee: l15: external continuum (?)

Answer: R35)Already explained in section 4.

Referee: l23: "indicating a good radiometric performance". Good linearity?

Answer: R36)OK we have changed the text into 'indicating that the detector response had no deviations from linearity'

Referee: Page 14188 l1-25: Clearly, a quantitative discussion is required for each retrieved species, evaluating diagnostics such as information content, absolute and relative retrieval errors as well as altitude resolution. What is the lower limit for the information content required for a retrieved parameter being determined by the measurement, and not by the apriori information? Which is the altitude range where the information content is high enough and at the same time the relative error sufficiently small (say, below ˜50% of a climatological value)? How many independent levels can be retrieved in this range, considering the altitude resolution provided in Fig. 16?

Answer: R37)The quantitative discussion is already reported Table 2 where the following information is summarised for each retrieved species: - Number of retrieved altitudes (please note that with the Optimal Estimation Method it is possible to use a grid of retrieved altitudes with more points than the Degrees Of Freedom) - The Degrees Of Freedom which tells us how many independent levels are actually retrieved - Altitude range where useful information is obtained, which together with the Degrees Of Freedom provides information about the vertical resolution - Variability of the relative accuracy in the useful altitude range.

Referee: l6: information content (for T) is larger than 1 from 8-9 to 16-17km (please check). OK l12: down to about 8-10km, depending on the scan. OK l19: A possible reason for the low information content for HNO3 is the insufficient signal-to-noise ratio

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of the measurement (limited sensitivity), related to the assumed climatological (apriori) uncertainty.

Answer: R38)OK we changed the text into:' The HNO3 profiles (Figure 12) are always poorly determined (its accuracy is never better than 40% - see table 2) due to the low signal to noise ratio of its emission in the analysed spectral region,'

Referee: l29: suggest to reformulate "the boundaries of the apriori errors applied to the initial guess profile"

Answer: R39)This will be done in the revised text

Referee: l9, l20: time (UTC, x-axis) could be indicated for the sake of simplicity OK l20: "clouds were not detected at millimetre waves" (reformulate) l23-24: suggest "... cloud coverage, detected by OCM, MIPAS-STR, and the Falcon lidar." (or similar)

Answer: R40)OK We have changed the text in 'the clouds, whose presence was reported by other instruments such as the OCM imager, MIPAS-STR and the lidar on board the Falcon aircraft, were not affecting the millimetre waves measurement. The loss of sensitivity at about 10 km occurs because of the high absorption of water vapour in the tropical region and not because of the detected cloud coverage.'

Referee: Page 14190 l2: indicate time of scan OK l11: It is certainly incorrect to name this single comparison "validation" (which would require much deeper analysis). Suggestion: "Intercomparison with MIPAS-STR"

Answer: R41) OK. The results have been validated during the ESA study reported in Dinelli et al. 2007 not only with MIPAS measurements but also with the results obtained with in-situ instruments on board the M55 during the flight. We decided to use MIPAS measurements only because it was the only instrument using the same observation geometry (limb views) of MARSCHALS. We have changed the initial part of the paragraph into: 'The results of our analysis have been validated with measurements of in-situ instruments on board the M55 during the flight. The outcome of this exercise

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is reported in Dinelli et al. 2007. Here we limit the validation exercise to the comparison of the results obtained from MARSCHALS scans with the profiles obtained by MIPAS-STR (the only limb viewer instrument on board the M55) during the same flight.'

Referee: l23: profiles within their error bars

Answer: R42) OK text changed into 'the profiles never differ for more than their retrieval error (shown in the figure)'

Referee: Page 14191: l7 (and Figure 17): Was Marschals water vapour retrieved as log(VMR), in contrast to MIPAS-STR water vapour? the symmetric error bars in the log-plot seem to suggest this. Please clarify or correct possible inconsistencies!

Answer: R43)Marschals water was not retrieved as log(VMR). We checked the numbers appearing in the figure, they are the correct values. It happens that their size makes almost impossible to see the asymmetry. However if you look at the lowest retrieved point, where the error bar is huge, you can see that the error is asymmetric

Referee: l27: spectral error (radiometric error? statistical error?, noise?)

Answer: R44)OK changed in 'noise'

Referee: Page 14192 l2: acquisition (integration? averaging?)

Answer: R45)OK changed into 'measurement'

Referee: l10: retrieval of an absorption profile (define terms such as "absorption profile", "unaccounted continuum", "external continuum")

Answer: R46) OK changed into 'external continuum absorption profile'

Referee: l15: The information content does not depend on the constituent abundances, just on their uncertainties!

Answer: R47) If the signal produced by the constituent abundance is below the noise level, the information content of the measurements is very low. Here we analyse limb

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measurements and sometimes the observed signal at a certain tangent altitude comes entirely from the molecules located above flight altitude!

Referee: l18: consistent with expectation (which expectation?)

Answer: R48) We have changed the text into:' the results expected from the theoretical retrieval study (Dinelli et al., 2007)'

Referee: l25-27: Capabilities of the retrieval system? Is this relevant for ACP?

Answer: R49) Sentence removed

Referee: Table 1: The receiver noise temperature during the flight should be clearly stated in the table, since this is a key engineering quantity. See answer R26 Instantaneous bandwidth (of the spectrometer?): 12 GHz (appears to be inconsistent with width of spectral bands given above?)

Answer: R50)The frequency ranges given in the table are the RF "target" frequency ranges (they are named as such). This means that they are the minimal frequency ranges which have to be covered to comply with ESA requirements and to achieve the target science objectives. They are the band specifications on which the science studies and retrieval simulations are based. Notice that they are different for each band. Band B, which targets ozone, requires a large bandwidth to include a large number of spectral lines. Band D on the other hand can do with a narrow bandwidth as the main target species CO only features a single, narrow spectral line at the band centre. Since we measure all bands in turns with the same set of spectrometers, the total instantaneous bandwidth of the spectrometers is dictated by the widest band, which in our case is band B with 11.5 GHz. The final value of 12 GHz reflects the smallest even number of channels of 200 MHz individual bandwidth to cover the minimal required instantaneous bandwidth. Technical details: 3 spectrometers x 20 channels each x 200MHz bandwidth each = 12 GHz instantaneous bandwidth

Referee: Table 2: The table provides a column for accuracy. How was this derived? I

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did not find where this was discussed in the manuscript.

Answer: OK we have added a discussion about the accuracy that was derived from the retrieval errors reported in the figures.

Referee: Number of retrieved altitudes (parameters): add 3 for the scalar quantities and sum up (58 parameters were retrieved, 31 degrees of freedom). OK All figures, with exception of Fig. 1,4,7-9, are hard to read.....it is required that axis labels are enlarged to be readable in the final version. OK Figure 2: Is this figure really required for this paper? Figure Removed Figure 4: Please indicate latitude and longitude (coordinate system). Answer: OK. We replaced the figure by the same with coordinate system

Figure 5: Indicate date, time, latitude, longitude for this snap-shot in the caption. Moreover, it would be highly useful if the MIPAS-STR cloud index data would be presented in a similar way and for the same time, allowing to directly compare mm-wave, midinfrared and near-infrared sensitivity to clouds.

Answer: OK. We added a figure similar to that from the cloud imager, but with the MIPAS CI values

Regrouping of Figs. 7-9 would reduce the overall number of figures and allow to have all the retrieval diagnostics in one plot.

Answer: We have grouped figs 7 and 8, (now figure 7) but retained figure 9 because of readability of numbers and plots

Figure 10-14: replace "biased error" or define/explain in the manuscript. OK

Figure 17: It would be much better is only the relevant data with sufficient information content were plotted (please blank out not relevant parts of the profiles, for better readability of the figure). Answer: OK the figure will be changed

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Interactive comment on Atmos. Chem. Phys. Discuss., 8, 14169, 2008.