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Interactive Comment

Interactive comment on "The CM SAF ATOVS tropospheric water vapour and temperature data record: overview of methodology and evaluation" *by* N. Courcoux and M. Schröder

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Anonymous Referee #1

General comments This paper introduces a data set for tropospheric water vapour and temperature based on space-borne measurements for 1999-2011. In particular the vertically resolved tropospheric water vapour data constitute a very valuable data set. As stated in the paper, a strong motivation for considering tropospheric water vapour is the fact that it accounts for more than half of the present day green-house effect and is the most important gaseous source of infrared opacity in the atmosphere (Held and

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Soden, 2000; Schmidt et al., 2010). However, to avoid misunderstandings the paper should also point out in the introduction that atmospheric CO2 constitutes the principal "control knob" governing Earth's temperature, in the sense that atmospheric water vapour only makes the climate more sensitive to forcing by non-condensable greenhouse gases. It is also important for the paper to notice that water vapour at greater altitudes in the tropics particularly important (e.g., Dessler and Sherwood, 2009). However, in spite of its climatic importance, water vapour in the upper troposphere is only badly known (e.g., Hurst et al., 2011; Kunz et al., 2013), which makes the data set presented here particularly valuable. The authors might want to stress this point more strongly.

This is a valid point and we will include the following statements in the introduction, together with reference to the mentioned papers: At the beginning of the paragraph:" Although the atmospheric CO2 constitutes the principal "control knob" governing Earth temperature, water vapour plays a central role in the Earth's energy and water cycles by making the climate more sensitive to forcing by non condensable greenhouse gases." At the end of line 14, page 129: "However, despite of its great importance for climate, especially at high altitude in the tropics (Dessler and Sherwood, 2009), water vapour in the upper troposphere is not sufficiently known (e.g., Hurst et al., 2011; Kunz et al., 2013)".

The data on the specific humidity at 200 and 300 hPa might be of particular interest when the issue of the present day green-house effect is investigated using this data set. However, the existence of this product is not mentioned in the abstract and its validation is not mentioned there as well (in fact there is rather little effort to validate this data product in the paper). I suggest putting more weight on this data product in the presentation throughout the paper. One could for instance show vertical profiles of averages of the data set (e.g., northern and southern hemisphere mid-latitudes, tropics, Asian monsoon region etc).

The CM SAF ATOVS product suite contains a relatively large number of different pa-

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rameters. We have restricted the manuscript to a subset of these parameters in order to keep the manuscript readable. However, we also see the relevance of specific humidity at UT. We will add to the abstract: "...six tropospheric levels ranging from 1000 hPa to 200 hPa and ..." In order to solve this we will include a figure on regional averaged profiles (log scale) in section 2. The regions will be the northern and southern hemisphere mid-latitudes, the tropics, and the warm pool. Reviewer #2 wanted to see the difference between input and retrieval output as well as final product. This difference is analysed using profiles from the same regions. We will include a new figure with two panels and the following text in section 2, page 133, after second last paragraph (same answer as for reviewer #2): "Associated level 2 data is available on request. The level 2 data contains, among others, the specific humidity profiles at 42 pressure levels. The left panel of Fig. 3 shows exemplary profiles of specific humidity for four different regions (northern and southern hemisphere, tropics and warm pool) and for September 2007. The profiles are computed as arithmetic averages over valid observations at levels smaller or equal to the surface pressure. The specific humidity of the final product is also plotted as asterisks. The specific humidity generally decreases with height and this decrease is the strongest at 450 hPa and above. The warm pool exhibits largest specific humidity and the northern hemisphere is generally more humid than the southern hemisphere both between surface and 200 hPa. The final product is typically more humid than the averages based on Level 2 data in all regions and at all considered levels for reasons discussed in section 4.2.1. The maximum difference is 0.17 g/kg (at 850 hPa, northern hemisphere) which explains why the differences are hardly visible in Fig. 3. The average differences between the ATOVS and the ERA-Interim profiles are shown in the right panel of Fig. 3. It illustrates the adjustment made by the retrieval to the input profiles. At near surface layers the changes are minimal what is likely due to the rather low information content in the observation. Noticeable is that this extends up to 650 hPa in the southern hemisphere. Largest reductions of up to -83% are found in the upper troposphere. While moving downward this changes to local maxima in increase of up to 11%. These maximum values are found for the

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warm pool. Also shown is the difference between the final product and the input data. These differences generally exhibit very similar features as the difference between the averaged Level 2 data and the input. We conclude that there are substantial changes by the retrieval in the upper troposphere and, to a lower degree, also between 800 hPa and 550 hPa. Whether or not these changes led to an improvement in quality can hardly be judged because the radiosondes are assimilated in ERA-Interim and, more generally speaking, because a true reference with sufficient spatio-temporal coverage is not available."

Caption of Fig. 3: "Average profiles of specific humidity from ATOVS (left panel) and mean difference (bias) between ATOVS and ERA-Interim (right panel) for September 2007. The regions are defined as follows: northern hemisphere (NH) - within 20°N and 50°N, southern hemisphere (SH) - within -20°S and -50°S, tropics – within -20°S and 20°N and warm pool – within -15°S and 15°N and within 90°E and 150°E. Specific humidity and bias are plotted only if the number of valid observations exceeds 75% of the value in the upper troposphere (a minimum of 230,000 for the warm pool)."

We further propose to include the following paragraph after the discussion of figure 6 in which we now mention the quality of profiles of specific humidity: "In view of the results shown in Fig. 3 we briefly want to characterise the relative bias of the ATOVS specific humidity product (not shown). The relative bias increases with height and ranges from 4% at 1000 hPa to approximately 90% at 200 hPa, with this latter value being three times and more larger than the values of the other levels and with ATOVS being more humid than the radiosondes. This may again partly be explained by the dry bias in radiosondes. However, the relative bias is of similar order than the maximum values given in Fig. 3. This may point to a wet bias in the ATOVS product in the upper troposphere. However, a verification is hard to accomplish due to the lack of fully independent and high quality reference data. "

A further issue that needs more attention is the vertical resolution of the data sets. Table 1 list layers and pressure levels on which the data are reported, but this is not

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necessarily the true vertical resolution of the data set. I assume that in the optimal estimation algorithm used here, information on the vertical resolution should be available as averaging kernels. Why are those not discussed in section 2? Why are the averaging kernels not part of the provided data set? I suggest showing a figure presenting the averaging kernels.

We have not discussed averaging kernels because they are not part of the data record, despite their value for in depth analysis. The averaging kernels depend on atmospheric conditions and thus each instantaneous profile is associated to a different averaging kernel. Strictly speaking this should affect the definition of the vertical grid as well – on pixel level. However, in addition to the horizontal grid we prefer to have a fixed pressure grid to ease utilisation. During more than 10 years of operation we did not receive a user request to include averaging kernels thus far. We agree that it is adequate to sensitise this aspect explicitly. We will thus include the following text in section 2, page 133, line 24: "The ATOVS data is provided on a fixed vertical grid to ease utilisation. However, the actual vertical resolution of an individual retrieval differs from pixel to pixel and time to time because the information content is a function of local surface and atmospheric conditions. The origin of the observed radiation is best described by so called Jacobians, and in addition to atmospheric conditions these are a function of the instrument characteristics. Exemplary Jacobians are given in Li et al. (2000) for AMSU-A and HIRS and in Kleespies and Watts (2006) and Bühler et al. (2004) for AMSU-B."

References: Buehler, S. A., M. Kuvatov, V. O. John, U. Leiterer, and H. Dier (2004), Comparison of microwave satellite humidity data and radiosonde profiles: A case study, J. Geophys. Res., 109, D13103, doi:10.1029/2004JD004605. Kleespies, T. J. and P. Watts, 2006: "Comparison of simulated radiances, jacobians and linear error analysis for the Microwave Humidity Sounder and the Advanced Microwave Sounding Unit–B," Q. J. R. Meteorol. Soc., Volume 132, Issue 621C, Date: October 2006 Part C, Pages: 3001-3010.

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There is also relatively little discussion of the ATOVS temperature data set in the paper. In contrast to the water vapour products, no attempt is made to quantify the uncertainties of the data set. A possible reason could be that the temperature data set is considered here only as an add-on, while superior temperature data exist. But if this is the case, then this point should be explicitly be made in the paper. Likely, the authors would then like to remove the term 'temperature' from the title of the paper.

As mentioned above we have not discussed the temperature product in detail in order to keep the paper readable. We agree that this is in conflict with the title and will thus remove "temperature" from the title.

One further point is that the paper should be more accessible to the non-specialist. One major problem here is the excessive use of acronyms, for example there are already 14 acronyms used in the abstract. The title mentions "CM SAF"; the information content of these letters is zero for the nonspecialist. The excessive use of acronyms makes the paper very difficult to read in certain sections. I understand that the names of many satellites are acronyms (e.g., ATOVS or AIRS). But the usage in the paper goes much beyond this points and forces the reader to constantly translate acronyms while reading the paper. As an example, followers of particular sports might not be confused about the use of terms like "Hibs and Hearts", "Gunners and Blues", or "05er and Kickers" when reading a text, but other people will have to constantly check again what is meant here. And you even introduce FCDR in the last sentence of the manuscript.

We understand the point and will reduce the number of acronyms by either simply avoiding them or when used only once or twice we will not introduce the acronym. For example we will not introduce "FCDR" in the last sentence but speak of carefully recalibrated radiances.

In summary, this paper needs work in the sense that the presentation should be reworked throughout the paper. There could be a somewhat better motivation for improved water vapour products, the issue of the vertical resolution of the data should

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be better addressed and the balance between the presentation of the different data products should be improved. Also the quantification of the error estimates for the different data products presented here should be more balanced. However, I believe that a substantially revised paper on the ATOVS data products could be a very valuable contribution to ESSD.

Comments in detail Title: the title should be changed: remove “CM SAF” (see comments above) and introduce the information of vertical resolution of tropospheric water vapour into the title.

Our understanding is that the objective of ESSD is the publication of papers related to data records. The data record name is “CM SAF ATOVS data record”. This way a unique name is provided. We thus propose not to remove “CM SAF” from the title. Following this comment and the comment given above we propose to change the title into: “The CM SAF ATOVS data record: overview of methodology and evaluation of total column water and profiles of tropospheric humidity.”

Abstract, l. 1: The information about the release of the data should be dropped from the abstract.

The DOI has to appear in the abstract, it is a ESSD requirement.

Abstract, l. 15/16: it would be important to list the layers here explicitly. Or alternatively, give some impression of the vertical resolution and of the vertical range covered.

We will add line 15, page 128: “. . .for five tropospheric layers between the surface and 200 hPa.” And the same line 16, page 128 : “. . .at six tropospheric levels between 1000 and 200 hPa”.

Last part of the Abstract: Only TWP comparison with sonde data is reported here; also the comparison for LPW should be given here. Further, the measurement geometry and spectral range (say IR and microwave) of ATOVS could be briefly mentioned here.

True. We extend as follows: “For LPW, the maximum absolute (relative) bias and

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RMSE values decrease (increase) strongly with height. The maximum bias and RMSE are found at the lower layer and are -0.7 kg/m2 and 2.5 kg/m2, respectively." And slightly adapt as follows: "ATOVS observations from the three infrared and microwave sounders from the National Oceanic and Atmospheric Agency (NOAA)-15..."

p. 129., l. 15: Give a bit more background about what GCOS is, who stands behind it?

It now reads: "The Global Climate Observing System (GCOS) is a long term and user driven operational system which role is to ensure availability of global observations for monitoring the climate system, detecting and attributing climate change, assessing impacts of and supporting adaptation to climate variability and change, and supporting climate research. The GCOS has been established in 1990 as an outcome of the second World Climate Conference, it is sponsored by international and intergovernmental organisations such as the World Meteorological Organization, the Intergovernmental Oceanographic Commission, the United Nations Environment Programme, and the International Council for Science."

p. 129., l. 21: water vapour is more than just one of 44, discuss the prioritises in the essential climate variables.

It now reads: "The GCOS Second Adequacy Report (GCOS-82, 2003) established a priority list of 44 essential climate variables and called for integrated global analysis products. The GCOS essential climate variables are classified in three domains, atmospheric, oceanic, and terrestrial and within the atmospheric domain a distinction is made between the surface, the upper air, and the composition variables. Water vapour is one of the atmospheric surface and upper air essential climate variables because of its key role for the radiation budget, the structure of tropospheric diabatic heating, the water cycle and atmospheric chemistry."

p. 130., l. 27: there are also retrieval schemes that do not use optimal estimation and those that do not use a-priori.

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We agree that his sentence can be misleading and propose to change into: “The error characteristics of the retrieval or analysis will critically depend on the utilised a-priori or training data.”

p. 133, l. 26: why was the reprocessing stopped in the year 2011 rather than continuing the time series?

The ATOVS reprocessing was carried out within EUMETSAT CM SAF which has a planning horizon of 5 years. Originally the release was planned for 2012. Due to delays in reprocessing, in combination with the documentation, the doi approval, and the external review process the submission of the paper was delayed. The operational version is still running but due to input constrains differs slightly from the reprocessing version. The goal of this paper is to describe the available reprocessed data record.

p. 134., l. 13: this basic information should be given in the introduction already.

Done: The Television and Infrared Observation Satellite (TIROS) Operational Vertical Sounder suite (TOVS) onboard the TIROS-N and NOAA-6 through NOAA-14 satellites consists of three sounders, one infrared sounder, the High Resolution Infrared Radiation Sounder (HIRS), and two microwave sounders, the Microwave Sounding Unit (MSU) and the Stratospheric Sounding Unit (SSU).

p. 135., l. 6: the HIRS 6.7-μm water vapour channel was changed to 6.5-μm for HIRS/3 (Shi and Bates, 2011); is this shift important for the time series presented here?

This is not relevant for the time series presented. We use only data from NOAA15 onwards. HIRS/2 was replaced by HIRS/3 starting with NOAA15. We do not use any HIRS/2 data.

p. 135., l. 19, 20: please clarify: there is no wind retrieval here, so winds at 10 km cannot have been used as a-priori.

This is correct. Wind is not used as input to the IAPP retrieval and we will adapt the text accordingly.

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p. 137, l. 24: does this mean that surface pressure is a retrieval product? This is nor clear from the discussion in the paper so far. I suggest providing a list (or table) of all the retrieval products in above (e.g. in section 3.3).

We propose to mention all products that are either part of the product or mentioned in the manuscript in section 2. We also separate between the final product as defined in the doi and side products as part of the IAPP Level 2 output. So on page 133 before line 18 (after the list of the CM SAF data record products list), we will add:" Furthermore, the outputs of the IAPP are: temperature retrieval, water vapour retrieval, and dew point temperature retrieval on the 42 IAPP level, using the CO2 slicing method, microwave emissivity, cloud top pressure, cloud top temperature, clear cloudy index and effective cloud amount are retrieved, using the O2 slicing method, cloud top pressure, cloud top temperature, and effective cloud amount are retrieved, total ozone, cloud fraction, total precipitable water and rainfall are also part of the IAPP output. However this output is not part of the CM SAF ATOVS data record."

We further add in section 3.4, after "surface pressure": "on basis of input data".

p. 138, l. 17: the GUAN sondes are used here for testing the satellite data set. But how reliable are the GUAN sondes especially at greater altitudes, where water vapour concentrations are low, but where the concentrations matter most in terms of climate, as discussed in the introduction.

This is discussed in section 4.1.1 and references therein. From Daan (2002): The minimum requirement for specific humidity is 2% of present climatological average and the target requirement is 1% of present climatological average (this should include the bias due to the change in local environment). See also next point.

p. 140., l. 3: what is the impact of not applying the corrections? Are they unimportant?

We slightly extend the uncertainty discussion, prior to "A series of ...": "Among the strongest impacts is the dry bias caused by solar radiation (Vömel et al., 2006) which

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would lead to significant underestimations of humidity in the upper troposphere if not corrected".

p. 142, l. 1, 2: reference for the TPW annual cycle?

We propose to add: "Schröder and Lockhoff (2013) show that the strength of the annual cycle is a function of region: strongest annual cycles are associated with the monsoon regions and the propagation of the ITCZ, largest regions of minimum strength are found over the southern oceans and land areas typically exhibit strong annual cycles. The former explains the presence of an annual cycle in the satellite data due to the imbalance in strength between the northern and the southern hemisphere and the latter in combination with the asymmetric sampling between the northern and the southern hemisphere explains the annual cycle in the GUAN data." Strictly speaking all local annual cycles at each station need to be considered. We think that this goes into too much detail in view of the comment from reviewer #2 to remove this figure (but to keep the discussion).

Reference: Schröder, M., and M. Lockhoff: Intercomparison of trend results. Presented at the 3rd G-VAP workshop at CIRA, CSU, CO, USA in October 2013, available at http://gewex-vap.org/?page_id=529.

p. 143, top paragraph: what are the error estimates for the TPW values? Are these differences significant?

The differences are not significant when a t-test is applied with the ratios of the bias and the standard deviation as input and when a significance level of 0.05 is applied. We hesitate to include this information in the manuscript because it is misleading. The kriging systematically increases the average TPW. In view of a time series analysis this leads to a significant break point at the time the kriging is turned off. In our case this break is observed in early 2001.

p. 144: Why is the specific humidity product at 6 pressure levels not compared to the

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GUAM sondes in section 4.2.2.

The CM SAF ATOVS product suite contains a relatively large number of different parameters. We have restricted the manuscript to a subset of these parameters in order to keep the manuscript readable. CM SAF monitors the usage of the product and the number of users of the LPW is ∼30% larger than that of the specific humidity product. Thus and because we also consider TPW we decided to analyseTPW and LPW. We also see the relevance of specific humidity at UT and have enhanced the manuscript in this direction (introduction, new figure plus discussion and a brief discussion of the uncertainty of specific humidity, see above).

p. 149, l. 24: is there a reference for the SSM/I TPW product?

Yes. We will add Andersson et al. (2010): Andersson, A., Fennig, K., Klepp, C., Bakan, S., Graßl, H., and Schulz, J.: The Hamburg Ocean Atmosphere Parameters and Fluxes from Satellite Data – HOAPS-3, Earth Syst. Sci. Data, 2, 215–234, doi:10.5194/essd-2-215-2010, 2010.

p. 151: Section 4 ends here but without discussing a the temperature product at all. Why is there no discussion on the temperature data set (which is even mentioned in the title)?

The word “temperature” will be removed from the title. We were not considering the temperature as it would add another dimensions to the paper plus a duplication (almost) of the number of figures. For readability reasons we did not discuss temperature.

p. 153, l. 8: it is not a conclusions that contributors have been discussed. Or is the conclusion that the bias remains unexplained in spite of the discussion?

True. We change into: “The bias can to a large extend be explained by ...”.

Figures: The figures could be improved by dropping the dashed vertical lines which are present in many plots. I do not consider them useful. In any case they should not intersect with the legends. Probably the most easy solution is dropping them.

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We will drop the vertical lines.

References Dessler, A. E. and Sherwood, S. C.: A Matter of Humidity, Science, 323, 1020–1021, doi: 10.1126/science.1171264, 2009. Held, I. M. and Soden, B. J.: Water Vapor Feedback and Global Warming, Ann. Rev. Energy Environ., 25, 441–475, doi:10.1146/annurev.energy.25.1.441, 2000. Hurst, D. F., Oltmans, S. J., Vömel, H., Rosenlof, K. H., Davis, S. M., Ray, E. A., Hall, E. G., and Jordan, A. F.: Stratospheric water vapor trends over Boulder, Colorado: Analysis of the 30 year Boulder record, J. Geophys. Res., 116, D02306, doi:10.1029/2010JD015065, 2011. Kunz, A., Müller, R., Homonnai, V., Jánosi, I., Hurst, D., Rap, A., Forster, P., Rohrer, F., Spelten, N., and Riese, M.: Extending water vapor trend observations over Boulder into the tropopause region: trend uncertainties and resulting radiative forcing, J. Geophys. Res., 118, 11 269–11 284, doi:10.1002/jgrd.50831, 2013. Schmidt, G., Ruedy, R., Miller, R., and Lacis, A.: The attribution of the present-day total greenhouse effect, J. Geophys. Res., 115, D20106, doi:10.1029/2010JD014287, 2010. Shi, L. and Bates, J. J.: Three decades of intersatellite-calibrated High-Resolution Infrared Radiation Sounder upper tropospheric water vapor, J. Geophys. Res., 116, D04108, doi: {10.1029/2010JD014847}, 2011.

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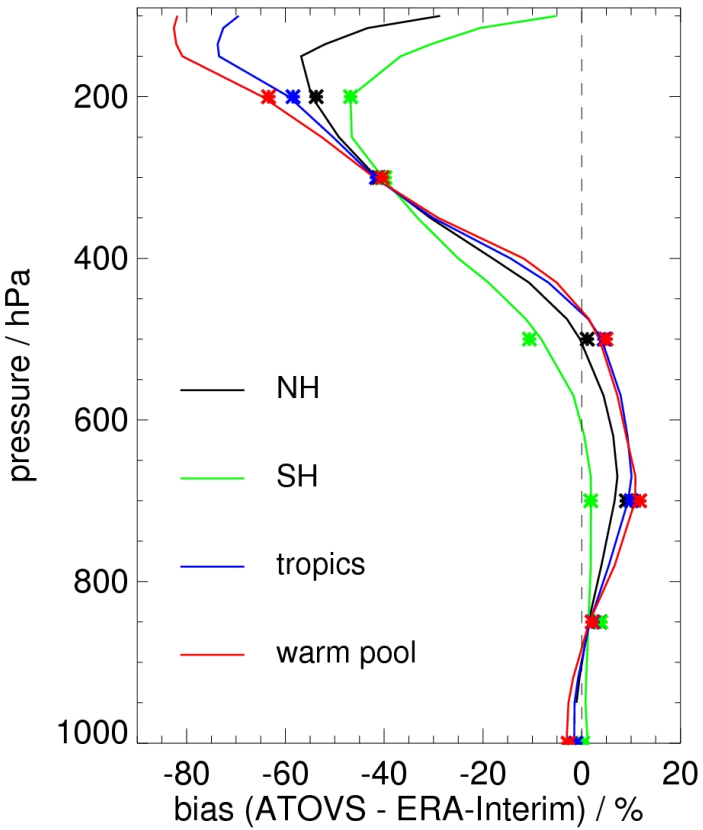

Fig. 1. Average profiles of specific humidity from ATOVS (left panel) and mean difference (bias) between ATOVS and ERA-Interim (right panel) for September 2007. The regions are defined as follows: northern he

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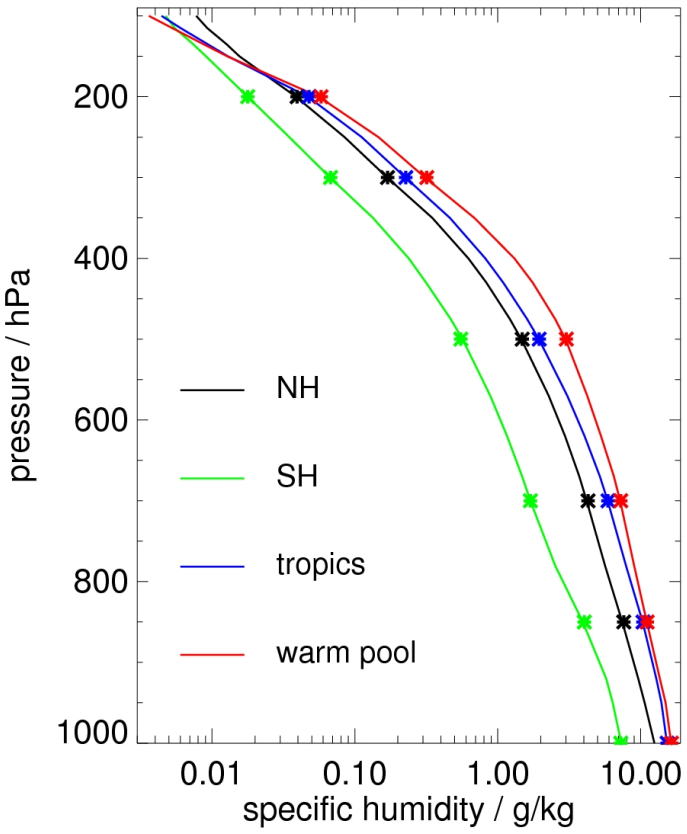

Fig. 2. Average profiles of specific humidity from ATOVS (left panel) and mean difference (bias) between ATOVS and ERA-Interim (right panel) for September 2007. The regions are defined as follows: northern he

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