

## **Response Review 2**

(black: Comments by reviewer)

(red: Answers)

(blue: Text from the paper; bold: Changed / Added text)

### **Response to major comments**

- (1) The discussion of the actual adjustment procedure was difficult to follow. Please try to provide more clarity and detail.

We agree that in the discussion of the adjustment, the different steps of the procedure should be described with more clarity. We revised Ch. 4.1 (see attached document).

- (2) Is the adjusted dataset publicly available? I strongly believe it should be made available with a summary of the mapping methodology and a comprehensive list of caveats. See below...

A dataset will be publicly available, and a doi and a direct link to the data (iagos website) will be provided within the paper as soon as the paper is accepted. This includes multi-annual climatologies for different regions (Atlantic, Europe, America, Asia) on Equivalent latitude – Relative to tropopause Coordinates (like Fig.11), and multi-annual means on different theta levels with a resolution of  $5 \times 5^\circ$  (like Figure 10). Additionally, a bias estimate will be provided.

A summary of mapping approach as well as a list of caveats will be added to the dataset. Caveats that have to be emphasized are

- (1) limitations of the adjustment itself (e.g. uncertainties up to 30 %)
- (2) differences in the temporal coverage between different regions and resulting differences in the climatologies

- (3) I find the statements regarding the “better resolution of temporal and spatial variability” to be misleading. The averaging in the adjustment process and derivation of the climatology limits the effective resolution of the product. In particular, the temporal resolution of this climatology is poor given that it relies on multi-annual monthly mean values. MLS, which provides daily, near-global profiles of water vapor from the UT to the mesosphere, has far superior temporal resolution, where monthly means from different years can be compared to examine inter-annual variability.

The statement that the data provide “better resolution of temporal and spatial variability” (L.467) was indeed formulated in a misleading way. We wanted to emphasize that the adjusted IAGOS data provide an advantage compared to the CARIBIC dataset only, which includes a better spatial resolution being possible, due to a much better temporal resolution. The temporal resolution of the adjusted dataset itself however is very poor, given that multi-annual means are derived. We revised that statement in the paper.:

The adjusted climatologies provide better resolution of the ~~temporal~~-seasonal and spatial variability of UT/LMS H<sub>2</sub>O compared to other in-situ or space-borne dataset.

- Also, any assessment of trends in water vapor concentrations/changes in dynamical processes, etc. over this 30-year period is likely impossible given the limitations of the dataset. This constraint should also be emphasized.

That is an important point that should be emphasized.

Given the limitation, water vapor trends are not possible to assess, since the uncertainties of the adjusted data often exhibit the scale of possible trends. We added a comment on this issue in the revised manuscript (Section 4.2.2):

**‘Due to the requirement for a substantial amount of data and the relative uncertainty exceeding 10% in the driest range, robust trend analysis cannot be reliably performed using the derived data set. Even in regions with sufficient data availability, the level of uncertainty reflects the potential magnitude of H<sub>2</sub>O trends.’**

## **Response to minor comments**

(green: corrected / considered)

- Lines 8/9 – data set or **dataset**?
- Line 8 – “applying” sounds a bit odd, maybe “utilizing” or “employing”?
- Line 9 – add a space here “hygrometer (ICH)”
- Line 26 – consider: “...and a corresponding total stratospheric water vapor radiative feedback parameter of 0.2 – 0.3 W/m<sup>2</sup> per 1 Kelvin of surface warming.” (?)
- Line 30 – consider: “...UT/LMS H<sub>2</sub>O, as well as trends at high temporal...”
- Line 38 – consider: “...passenger aircraft flights, enabling the resolution of strong...”
- Line 48 – consider: “In this context, the large quantity in-situ H<sub>2</sub>O measurements provided by IAGOS is important to improving the accuracy of...”
- Lines 52 and 53: spell out CORE and CARIBIC?

**Comment: No acronym for CORE**

- Line 55: “...measurements by a compact capacitive humidity sensor...” (replace all locations of humidity capacity sensor with capacitive humidity sensor)
- Line 58: “...were found to lose precision...”
- Line 63: “This lower detection limit for the ICH instrument was later determined to be 30 ppmv by means of a dedicated...”
- Line 78: “...H<sub>2</sub>O variability in the UT/LMS at northern mid-latitudes.”
- Section 2.1: please spell out all acronyms?
- Line 96: “...and derived H<sub>2</sub>O mixing ratios.”
- Line 110: spell out “PA” in “PA-laser spectrometer”
- Line 126: “...ERA5 data are used at reduced resolution...”
- Figure 2 caption: “...the probability density in coordinates relative...”
- Line 142: “measurement quantity” here is confusing... I believe what is meant is “magnitude of RH<sub>liq</sub> measured by the ICH” and not the quantity of measurements. So, consider: “...closely linked to the magnitude of RH<sub>liq</sub> measured by the ICH sensor.”
- Lines 171+: consider: “We use a measurement mapping method to evaluate MOZAIC&CORE with respect to CARIBIC, focusing on the primary variable measured by MOZAIC&CORE, RH<sub>liq</sub>.”
- Line 173: remove space after the open parenthesis (500 flights)
- Line 177: consider: “These factors particularly affect the UT...”
- Line 186: consider: “, and the corresponding H<sub>2</sub>O mixing ratio.”
- Line 231: “This trade-off factor shows that fewer measurements are needed to constrain... providing confidence in our approach.”

- Line 241: "...serve as a reference..."
- Line 288: what does the (2) refer to?  
**Comment: Equation 2; now clear in the text**
- Line 292: "...for which this intercomparison is valid."
- Figure 7 caption: "...the plots (c) and (d) show the derivation..." (delete "exemplary")
- Line 329: "...consist of a large number of measurements on the order of..."
- Line 330: "...state." (delete comma)
- Line 336: "For every one..." or "For each..."
- Line 359: "...is calculated."
- Section 4.2: There are a lot of separate paragraphs here, is that intentional?  
**Comment: We restructured Section 4.2**
- Line 374: consider: "The adjusted MOZAIC&CORE-based H<sub>2</sub>O climatology offers the advantage of a longer record and greater spatial and seasonal sampling than the datasets of CARIBIC and JULIA, enabling more detailed analysis of the drivers of H<sub>2</sub>O variability. However, the adjustment of mean values requires... ."
- Line 379: "." (?)
- Line 383+: consider: "Despite the good agreement shown in Figure 8, the adjusted MOZAIC&CORE H<sub>2</sub>O incorporates uncertainties associated with (1) the measurement itself and (2) the adjustment methodology."
- Line 387: "...is on the order of..." ("on" not "in")
- Line 388: consider: "Uncertainties in the mapping method result from the small number of..."
- Line 390: "...despite the fact that the sampling strategy should reduce the impact of uncertainties..."
- Line 392: consider: "The uncertainty of the mapping method is determined as follows: The bias derivation... is performed for each season separately. In the next step, ...from the four seasonal means. Finally, these standard deviations are used to do derive the mean standard deviation as a function solely of RH<sub>liq</sub>."
- Figure 9 caption: (dashed line) not (solid line)
- Line 397: "The uncertainty... varies depending on the.."
- Line 407: clarification: "...same geographic latitudes."
- Section 4.3: Again, there are a lot of separate two-sentence paragraphs here, is that intentional?  
**Comment: We restructured the text.**
- Line 409+: consider: "From fall to spring the highest values in the mid-latitudes... . Higher H<sub>2</sub>O amounts occur over the Atlantic than over continental regions during the winter half of the year, associated with greater low pressure activity over this area, and the resulting large scale uplift of moist and relatively warm airmasses (UT)... ."

- Figure 10: Is the red box in panel (a) meant to highlight the isentropic mixing of moist air into the LS?

The red box highlights the area further studied in Figure 11. Description added in the capture.

- Line 415: "...Figures 11a-d show adjusted multi-annual monthly means of adjusted H<sub>2</sub>O, plotted in coordinates of..."
- Line 417: extra space before 100 ppmv?
- Line 419+: The wording here is clunky and the discussion is perhaps too simple. In addition to the seasonal change in H<sub>2</sub>O along the 340 K potential temperature surface, there is a distinct shift in the tropopause height, such that 340 during the summer/fall it is near the tropopause level and during the winter/spring it is >20K above. Also, I see H<sub>2</sub>O for Jan in the range from 10-20 not 5-10? Perhaps I'm not reading the color bar correctly?

We added: 'This pattern can strongly be related to the increase of the tropopause Theta level during summer and the subsequently stronger influence of (isentropic) transport of H<sub>2</sub>O from the subtropical regions into the mid-latitude LMS. Generally, layers in the LMS close to the TTP ( $\Delta \Theta < 10$  K) are moister during the summer season. A key question here is to what extent this increase can be attributed to local transport from the underlying upper troposphere (UT) or to large-scale transport, particularly from monsoon-influenced regions. Further trajectory-based analysis is essential to quantify the contributions of the different transport mechanisms involved.'

- Line 423: mid-latitude not mid-latitudinal (?)
- Figure 11 caption: extra space after H<sub>2</sub>O and before (e-h)
- Line 432+: consider: "Finally, we examine how well sampled the UT/LMS is over the North Atlantic, given..."
- Line 436: "Overall, good coverage is found."
- Line 441: ...adjust H<sub>2</sub>O climatologies (?) or H<sub>2</sub>O data (?)

'Climatologies' might be a inaccurate, we wanted to make clear from the beginning of the summary that only mean values can be adjusted with our method. We rephrased the first sentence.

- Line 447: consider: "For the comparison, a mapping approach was utilized, where measurements were grouped into bins with similar dynamical origins and properties. Consideration of equivalent latitude, season, and height..., were used to derive mean RH<sub>liq</sub> values..."
- Line 455: "...showed good agreement in the..."
- Line 456: distance to the tropopause is hard to parse here... consider: "However, in the LMS, the average values were generally biased, with the magnitude of the bias increasing with distance above the tropopause, reaching relative differences of 300% for H<sub>2</sub>O at around 5 ppmv."