Anonymous Referee #1

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In this manuscript, satellite observations of the isotopic composition of free tropospheric water vapor are used to investigate the processes shaping the moisture budget over the subtropical North Atlantic in summer. The study highlights the importance of the Saharan Heat Low in facilitating the uplift and westward transport of moisture from the continental boundary layer to the oceanic free troposphere. The isotope data are used to shed light on seasonal, interannual and spatial variations in the associated moisture transport and mixing processes. In my view, this is a convincing study that provides important mechanistic insights into the subtropical water cycle and demonstrates the usefulness of isotope observations for such process investigations. I still have quite a few comments that mainly relate to the presentation of the methods and results, which in my opinion could be improved at several places. Nevertheless, most of these comments should be easy to resolve for the authors. Note that the manuscript contains several minor language errors, and I do not attempt to list all of them (I think these could be eliminated in the copyediting stage).

We are grateful to Referee #1 for his/her positive and attentive review. His/her numerous comments have been very useful to improve the manuscript. Our answers to referee's comments are shown in blue and changes in text are shown in grey.

Specific Comments:

Title: I think the wording of the current title is a bit awkward. What about 'Importance of the Saharan Heat Low in controlling the North Atlantic free tropospheric humidity budget deduced from IASI dD observations'?

We now follow your suggestion, thank you.

Abstract/Introduction: The last part of the abstract (from line 7) and last part of the introduction are a bit unconnected to the rest (read more like a report, first we did .., then . . .). I'd try to improve the connection between the different parts (SHL, interannual and spatial variability).

Changes have been made to improve the connection.

Abstract: One a²dditional sentence on the more general implications of the work would be good.

Added:

> "More generally, our results demonstrate the utility of δD observations obtained from the IASI sounder to gain insight into the hydrological cycle processes in the West African region."

Page 2, lines 3-4: 'the dryness of...': I don't understand this. Also in a moist atmosphere the humidity can be variable (even more in absolute terms).

We meant to refer to the logarithmic dependence of the OLR to changes in specific humidity where in dry area a small change of specific humidity has a great influence on the OLR (greater than a small change in humid areas). But this is now removed for sake of simplicity.

> ~~"and as the dryness of the subtropical atmosphere allows for important variations of the humidity "~~

P 2, 21: 'representation' is probably not the correct word; 'understanding'?

We changed to 'understanding'

P 2, 29-30: ‘the seasonal cycle . . . in summertime’ is a bit contradictory

This has been changed to:

> “(..) the Saharan Heat Low (SHL) - which is a key component of the West African Monsoon system - has a large influence on the budget of water isotopologues above the North Atlantic in summertime, when the SHL is most active, leading to a strong seasonality of δD.”

P 3, 19: ‘filtered based on the residual fit’: What does this mean?

This is related to the retrieval procedure that requires the fitting of computed spectra on the measured spectra. The residual is the difference between the final computed spectra and the measured one. The sentence needs more details to be properly understood and is not of prime importance, we thus removed it

> ~~“The retrievals are also filtered based on the residual of the fit.”~~

Section 2.1: Please add some information on the averaging procedure. For instance, above Izana, do you first calculate daily means by averaging over the individual observations and then monthly means? May there be a bias due to the diurnal cycle? Do you weight the isotope observations by moisture content?

We now add information on the averaging. IASI overpasses are around 9.30 AM and 9.30 PM local time and are likely to induce a bias if there is a strong diurnal cycle.

> “These data are used at different time scales from the individual observation to monthly averages. Daily means are obtained by averaging individual observations from morning and evening IASI measurements which is likely to introduce a bias if there is a diurnal cycle. Monthly averages are obtained from the daily averages.”

Section 2.3: More details on the trajectory setup would be helpful. At which altitude and time of the day are the trajectories initialized? May there be a bias due to temporal mismatches between observations and trajectories? Wouldn’t it be good to quantify also the uncertainty due to different starting altitudes (by using more than one trajectory per day), since also the satellite observations do represent a vertically extended layer?

More details are now given. Referee is right mentioning potential temporal and spatial mismatches between observations and trajectories. We thus tested if trajectories arriving at different altitudes representative of the IASI sensitivity layer have similar patterns and we also tested the temporal differences. The outcome of this test is that the situation presented is generally valid. We provide the different trajectory analyzes in appendix.

P 4, 11: Which reanalysis data set do you use (add reference)?

This is now specified:

> (..) we use backward trajectory calculations from the Hybrid Single Particle Lagrangian Integrated Trajectory model (HYSPLIT) (Stein et al., 2015) where NCEP GDAS (Global Data Assimilation System) re-analyses (Kleist et al., 2009) have been used as the meteorological fields

P 4, 14 and P5, 8: Does q denote specific humidity or mixing ratio? Please use a consistent nomenclature.

q is the mixing ratio. This has been corrected.

P 5, 14-15: ‘intense convective activity’: I’d be more specific at this point. As I understand the Worden-paper, it is the recycling/evaporation of precipitation that leads to this increased depletion.

This has been changed to:

> Noteworthy, intense convective activity act to over deplete water vapor through rain-drop re-evaporation and δD-q pairs can be found below the Rayleigh distillation model (Worden et al., 2007).

P 5, 23: There is also a relatively abrupt increase in q. In my view, the differences in autumn are more pronounced.

The now corrected Figure 2 (see next answer) better highlights a difference between the enrichment (in June) and the progressive moistening (from April).

Figure 2: From inspecting this figure, the individual values (e.g, for July) shown in panel b do not seem to average to the value shown in panel a. Do you weight by q? Is this really what one should do when calculating such a multi-annual mean value?

Thank you for the in-depth inspection of the Figure, there was indeed something wrong. We realized that the monthly averages were not properly done from daily averages. This is now corrected and has been double checked: monthly averages are computed from daily means and composites are derived from monthly averages. The seasonality is thus less pronounced that previously stated, so that this is now also corrected in the revised MS.

P 6, 15: ‘before...’: I don’t understand this insertion. Is it really required? At least you don’t need the acronym.

Agreed, we have simplified the discussion here.

Figure 4: Axis labels should be added to the first row. ‘daily variations’ is unclear; do you show daily averages or individual observations?

We show individual observations, this is now stipulated in the legend and axis labels have been added.

Are the Rayleigh and mixing models the same as in Fig. 1 (with the same end members)? Over which levels has the temperature lapse rate been computed? This lapse rate is currently not discussed in the main text (but should be, I think).

They weren’t exactly the same, now they are.

We now add the information on the temperature gradient:

> The colour indicates the gradient of temperature computed between 5.5 and 1.5 km.

And is briefly discussed in the text. But this is more discussed in the following section.

P 9, 10: What is the data source for the precipitation amount? Also the reanalysis, which would mean that it’s actually a model forecast? What is the accumulation period? This should be mentioned, as it may introduce some uncertainty.

Yes, the precipitation also come from the reanalysis.

The average precipitation amount (computed from the re-analysis at a time step of 3 hours)

Figure 5: 'Daily variations': see above. Please specify how the Richardson number is calculated. The vertical velocity is not discussed and could thus be removed. Potential temperature could be shown as an alternative (which would probably also illustrate the deep mixed layer for the green box).

It is now stated that these are daily variations and not individual observations. Richardson number is from MERRA re-analysis. We removed the vertical velocity panel and choose to not add the potential temperature for sake of simplicity.

Section 3.4: In my opinion, this section disturbs the flow of the paper. I would shift it after section 4, as it provides a transition to the detailed spatial analysis in section 5.

We agree that it could fit before the spatial analysis (it was there in a previous section) but we prefer to have it in Section 3 "Seasonal variations: Influence of the SHL on _D in the subtropical North Atlantic" since we use the seasonality to derive the spatial influence.

P 11, 20 – P12, 2: I don't understand this sentence (the connection between the seasonality in q and the mixing processes).

The bottom panel of Figure 6, which shows the seasonality for the specific humidity (in percent), reveals a different behaviour. The observed maximum in δD wich does not correspond to the maximum of humidity can also be interpreted as the signature of the SHL, as mixing processes produce a stronger isotopic signal for a given specific humidity than any other hydrological processes (Galewsky2010,Noone2012).

Figure 7: The two upper panels could be combined by adding the red line to the uppermost panel.

We now combine the two panels.

Figure 9: The caption says that the ratio in b and c was normalized by the number of air masses from the African continent, but the main text and the axis label suggest that it is normalized by the total number of air masses.

Thank you, it is the ratio of #of western air-massess/# total number

P 14, 7: The wording of the first sentence is unclear.

Changed to:

> In this section we translate the control of the airmass origins in terms of mixing fraction of the mixing.

P 14, 17: 'very similar values' instead of 'always the same value' (it does vary a bit due to changes in SST)

Yes referee is right, this has been corrected.

Figure 11: Note that each point represents one location over the North Atlantic. Why do the arrows indicate linear pathways (your simple models describe curved paths in the q-dD space)?

The idea of the figure was to show that the δD-q pairs distribution can be decomposed into different pathways from three different points (sources). The arrows have no physical meaning here.

P 16, 12: 'can easily be distinguished': This is a bit subjective. How do you do this? Are the circles just positioned subjectively?

We try to be less subjective:

> "The latter are identified as the moist members of the different branches visually identified of the δD-q pairs scatter plot."

Are all data points within the circles shown in panel a of Fig. 12 (this should be explicitly mentioned in the caption)?

The circles were "drawn by hand" and some contours on q and δD were arbitrarily defined. The contours are now better defined. See also our answer to your last comment.

P 17, 25: 'processes . . . are horizontal': I don't think that this can be concluded from the present analysis. I'm pretty sure that the descent or ascent of air masses is important for shaping these patterns (as you have demonstrated, e.g., for the SHL).

Agreed. This is conclusion was a bit simplistic as the stronger subsidence is likely to contribute to the depletion and drying Northward. This has been removed and we now just mentioned:

> "Note that the sources show quasi constant δD and q values while the dehydration pathways, on the other hand, show an important variability . The dehydration and depletion is mainly latitudinal."

Figure 12: S2 and S3 are interchanged in panel c. Why are there gaps in the geographical locations of the pathways in the tropics in panel d? More general: Are the pathways defined in geographical or in the q-dD space? Why and how? For instance, in panel c there are some green points (P3) that I would visually attribute to P4.

The S2-S3 swap is now corrected, thank you.

The best would have been to dissociate the different pathways from their position in the q-δd diagrams. However to simplify the procedure, we sometimes used the geographical locations of the q-δd pairs. This is why the geographical limits between the different pathways are sometimes sharp. This is now explicitly stated. We could indeed think that some green point are related to P4 however their geographical position prevent us to link them to P4.

P 19, 3: Figure 12e instead of 11

ok

Section 5.2: I think some discussion should be added to this section. How unambiguous is the definition of the different pathways? Basically, one could reach every position in the q-dD space (in between your simple models of Fig. 1) by combining different Rayleigh and mixing lines.

The analysis proposed here suggest that the combined observation of water vapor and its isotopic composition can be very useful to identify the different sources of humidity, which are key actors of

the hydrological and dynamical cycle of the region, and their interactions. It is however impossible to unambiguously assess the processes responsible of the position of δD-q pairs as combination of different processes can lead to a same δD-q position. Nevertheless, the coherence of our interpretation with the actual understanding of the SHL dynamic suggest that it is a reasonable interpretation.