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Atmospheric Measurement Techniques Discussions

Interactive comment on "Comparison of Optimal Estimation HDO/H_2O Retrievals from AIRS with ORACLES measurements" *by* R. L. Herman et al.

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Final Author Comments to reviewers of amt-2019-195, To anonymous Referee #4 We thank the referee #4 for constructive comments on the manuscript amt-2019-195, "Comparison of Optimal Estimation HDO/H2O Retrievals from AIRS with ORACLES measurements." We have addressed all comments from the referee.

Below are (1) comments from the referee, (2) our author's response and (3) author's changes in the manuscript.

Specific comments

Comment 1:

(1) Lines 92-93: Is AMSU used in the retrieval in any way? Not sure you really need to include its introduction here as you are not using the golf ball configuration (9xAIRs + 1xAMSU IFOV).

(2) The reviewer is correct that the AIRS HDO retrieval does not use AMSU.

(3) Section 2.1 text has been modified to remove the 2-sentence introduction to AMSU. Instead, one sentence defines the horizontal resolution: "These footprint observations have a horizontal resolution of approximately 13.5 km at nadir."

Comment 2:

(1) Line 116: The reference for WISPER, if still in preparation are there any additional technical reports etc that could also be added?

(2) The reference for WISPER is still in preparation. AMT allows the gray literature (e.g. conference proceedings) if nothing else is available so we additionally cite an AGU abstract, Henze et al. 2017.

(3) New citation added: Henze and Noone, 2017, Henze, D., and Noone, D.: The Dependence of Entrainment and Drizzle in Marine Stratiform Clouds on Biomass Burning Aerosols Derived from Stable Isotope and Thermodynamic Profiles, AGU Fall Meeting, New Orleans, Louisiana, United States, Abstract A11C-0048, 2017.

Comment 3:

(1) Table 1: Why are there some large discrepancies between the number of collocations and others have lower or no reduction in matchups when the tighter lat/lon constraint is applied? Maybe some additional information for context in the table header would be useful for readers unfamiliar with the ORACLES campaign.

(2) The reviewer has a good point. It should be better explained here that the loose constraint is a large rectangle aligned with parallels of latitude and meridians of longitude. All flights except two (Sep 2, 2016, and Sep 14, 2016) had large rectangles

because the aircraft flew along the diagonal of the rectangle (see Figure 2). Sep. 2 and Sep. 14, 2016, had different flight patterns so we used smaller latitude/longitude shapes to constraint AIRS data on those days. The tighter constraint is matched AIRS geolocations and aircraft FOVs within 0.3 degrees of each other.

(3) New text has been added to the body of Sec. 4.1: We have replaced the text "Within each flight are several profiles each spanning 1 to 3 degrees (or $\sim$ 100 to 300 km), so measurement pairs are typically within 3 degrees (Fig. 2)." With the revised text: "The loose constraint (Table 1 column 1, Fig. 2 open circles and Fig. 4a) is that, for an aircraft vertical profile ($\sim$ 100 to 300 km in length), all AIRS geolocations within the same rectangle of maximum to minimum latitude and maximum to minimum longitude are selected. The only exceptions were the aircraft flights of 9/2/2016 and 9/14/2016, which had different flight patterns and smaller shapes were used to constrain AIRS geolocations. The tighter constraint (Table 1 column 2, Fig. 2 closed circles and Fig. 4b) is to match only AIRS geolocations within 0.3 degrees (30 km) of the aircraft flight track."

Comment 4:

(1) Line 222-223: Do you get 1 DOF between 750-350 hPa?

(2) Yes, most retrievals have approximately 1 DOF between 750-350 hPa. Most of the sensitivity of AIRS to HDO is at pressure levels of 750 hPa to 350 hPa so most of the information is coming from these levels.

(3) No change to text.

Comment 5:

(1) Line 239: Is the DOF threshold for a sub-column between 750-350 hPa?

(2) No, the DOF threshold is for the total column of AIRS HDO/H2O. This DOF threshold is used merely as a way to filter for the retrievals with the highest information content.

(3) New Text added to Section 4.1: "Following Worden et al. (2007) and Brown et al. (2008), we filter data for a reasonable threshold of standard nadir data product DegreesOfFreedomForSignal (DOFS) > 1.1, but include all values of AverageCloudEffOpticalDepth. Data product DOFS is the trace of the averaging kernel, and is a measure of the number of independent parameters for the retrieved HDO/H2O profile. AverageCloudEffOpticalDepth is the retrieved cloud mean optical depth at wavenumbers from 975 to 1200 cm-1 from the final retrieval step (e.g., the same for all species) (Kulawik et al., 2006)."

Comment 6:

(1) Line 240: Where does the cloud optical depth information come from? Is it a retrieval output? Is there any uncertainty information associated with the cloud information, if so is it propagated?

(2) The cloud optical depth is standard retrieval output, retrieved for a non-scattering cloud reported from the values at the final sequential retrieval step. The uncertainty information associated with the cloud is propagated. The AIRS cloud optical depth is retrieved the same way as the TES cloud optical depth, new citation: Kulawik, S. S., Worden, J., Eldering, A., Bowman, K., Gunson, M., Osterman, G. B., Zhang, L., Clough, S., Shephard, M. W. and Beer, R.: Implementation of cloud retrievals for Tropospheric Emission Spectrometer (TES) atmospheric retrievals: part 1. Description and characterization of errors on trace gas retrievals, J. Geophys. Res., 111, D24204, doi:10.1029/2005JD006733, 2006.

(3) New text, New sentence added: "Interference errors are due to CH4, N2O, surface emissivity, effects of temperature, and clouds." And also new text in Section 4.1, "Following Worden et al. (2007) and Brown et al. (2008), we filter data for a reasonable threshold of standard nadir data product DegreesOfFreedomForSignal (DOFS) > 1.1, but include all values of AverageCloudEffOpticalDepth. Data product DOFS is the trace of the averaging kernel, and is a measure of the number of independent parameters

for the retrieved HDO/H2O profile. AverageCloudEffOpticalDepth is the retrieved cloud mean optical depth at wavenumbers from 975 to 1200 cm-1 from the final retrieval step (e.g., the same for all species) (Kulawik et al., 2006)."

Comment 7:

(1) Figures23: A little colour/shading would be useful to help distinguish land/ocean. It is difficult to see the aircraft track through the AIRS IFOV markers. How many aircraft profiles are each subfigure?

(2) We will modify the Figures 2 and 3 to be easier to read. There are typically 3 to 6 aircraft profiles per subfigure. They overlap spatially as the aircraft flies the same diagonal path.

Comment 8:

(1) Figure 4: Subfigure headings are missing (a,b).

(2) We have added the subfigure headings (a) and (b) to the figure.

(3) Revised Figure, now renumbered as Figure 3.

Comment 9:

(1) Line 288: Little or no difference to a priori between 800 hPa-surface, is AIRS really adding anything here in the PBL? Is the averaging kernel not setting the difference between (x − xa) residual to/or close to zero?

(2) The reviewer has an excellent point. In most cases AIRS does not have much sensitivity to the PBL deuterium content. Any differences between the PBL a priori will therefore reflect the diagonal of the averaging kernel, plus the cross terms that describe the sensitivity of the PBL estimate to the true state in the rest of the atmosphere.

(3) Since in most cases AIRS does not have much sensitivity to PBL HDO, we have modified the line 343-344 in the manuscript, "We have shown that AIRS-only retrievals

have sensitivity to HDO from the middle troposphere to the boundary layer." to: "We have shown that AIRS-only retrievals have sensitivity to HDO in the middle and lower troposphere."

Comment 10:

(1) Section 5: Is this a description of the a posteriori error? When you say you are characterising the error budget I would expect some account of the collocation/ representativeness uncertainty due to the mismatch with the aircraft. I think you might just need to change the wording on line 305 to make this clearer.

(2) Our response to the reviewer is, yes, we are referring to the a posteriori error. We will make the wording on lines 305 and 325-327 clearer as detailed below.

(3) At the start of Section 5. Error Estimation, we will modify: "... we characterize the error budget for AIRS and assess this error by comparison with the ORACLES aircraft measurements." To: "... we characterize the a posteriori error budget for AIRS HDO/H2O and assess this error by comparison with the ORACLES aircraft measurements."

At lines 325-327, discussing differences between the estimated error from OE and empirical error from the comparison, we will modify "These differences are likely due to atmospheric variability as we do not have exact matchups between the AIRS data and aircraft measurements." To: "These differences between the OE estimated error and the empirical error are likely due to uncertainties in atmospheric variability in space and time and in the collocation between satellite retrieval and aircraft measurements. The instrument operator (Eq. 1) accounts for error due to the mismatch in *vertical* sensitivity between the satellite retrieval and aircraft in situ vertical profiling. In the cases where AIRS is compared to in situ measurements without the instrument operator, there is an additional smoothing error (Table 2). The instrument operator does not account for error due to *horizontal* mismatch. The close coincidences are all within 30 km (0.3 degrees), but given time differences, and the AIRS 15-km nadir footprint and limited in situ measurement, the satellite and aircraft are not necessarily measuring the same airmass. There is a collocation error on the order of ∼10 per mil due to horizontal collocation/representativeness uncertainty."

Technical Comments

(1) Line 206: in situ – should be in italics

(2) We have made in situ italicized every time it appears in the manuscript.

Interactive comment on Atmos. Meas. Tech. Discuss., doi:10.5194/amt-2019-195, 2019.

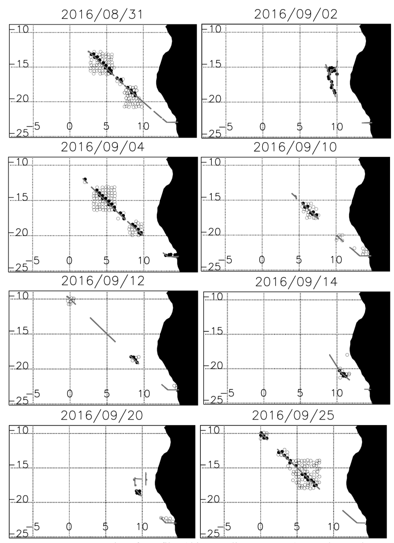

Figure 2. ORACLES aircraft profiles (thin grey line segments) over the southeast Atlantic Ocean to the west of Africa are matched to AIRS fields of view (FOVs) in loose spatial match (open circles) and tight spatial match within 30 km (closed circles) for eight

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Fig. 1. Revised Figure 2

flights in 2016.

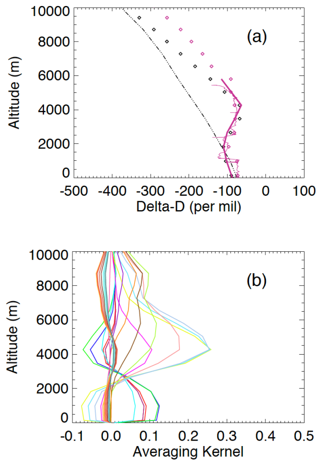

Figure 3. (a) Sample comparison of the δD profiles by aircraft and satellite over the southeast Atlantic Ocean during ORACLES on 31 August 2016: shown are AIRS δD (black diamond symbols), the prior δD (black dash-dot-dot line), nearest WISPER δD

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Fig. 2. Revised Figure 3