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# *Interactive comment on* "Verification of the AIRS and MLS ozone algorithms based on retrieved daytime and nighttime ozone" *by* Wannan Wang et al.

**Anonymous Referee #3**

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Review of "Verification of the AIRS and MLS ozone algorithms based on retrieved daytime and nighttime ozone" by Wang et al.

The authors evaluate ozone retrievals from two instruments well known to the scientific community; AIRS was launched on Aqua in 2002 and MLS on Aura in 2004. Both are nearing the end of their lifetimes in space and offer nearly two decades of continual global measurements. A comparison of their ozone retrievals can help differentiate AIRS and MLS observing capabilities and clarify how their products can contribute to science applications that characterize atmospheric ozone. The validation of space-based trace gas observations such as ozone is not straightforward, not least due to the



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Discussion paper

scarcity of in situ measurements (Nalli et al., 2013, 2018). In evaluating tropospheric ozone, Gaudel et al. (2018) found no two sources of space-based ozone observations to agree. We need to better understand different space-based ozone observing systems and we need novel methods with which to evaluate them to better understand their value in science and decision making. Recognizing this, Wang et al. used diurnal variability as a metric to evaluate AIRS and MLS ozone retrievals. While the focus of their work has scientific relevance and their method is reasonable, my assessment of the work they presented here is that it is not mature enough for publication yet based on (A) conceptual and scientific shortcomings as well as (B) technical issues. Throughout this review, I also cite papers that the authors should consider in their future work.

A. Conceptual issues.

- The authors compare total column ozone from infrared nadir measurements (AIRS) with stratospheric column ozone from microwave limb measurements (MLS) without sufficient acknowledgement of the effects instrument differences will have on their results. Top of atmosphere infrared radiances (AIRS) are sensitive to stratospheric and (to a lesser extent) tropospheric ozone (Nalli et al., 2018 and references therein). AIRS radiances have almost no sensitivity to ozone in the lower troposphere and boundary layer. Moreover, infrared measurements have strong sensitivity to clouds, which dominate the signal in channels sensitive to tropospheric variability. Microwave limb measurements (MLS), on the other hand, are sensitive to stratospheric ozone down to $\sim$200hPa, with almost no sensitivity to clouds in the upper troposphere (< 200hPa cloud top pressure). The authors compare AIRS total column ozone (troposphere + stratosphere) to MLS stratospheric column ozone (stratosphere only) and find that the former has higher diurnal variability. My sense, as reviewer, is that their results have limited value because they included tropospheric, and thus diurnal, variability into their AIRS values from the start. A scientifically more meaningful comparison would have been a comparison between stratospheric columns from both AIRS and MLS. One can easily calculate partial column totals from the AIRS Level 2 products, which are dis-

tributed as 100-layer profiles (Earth surface to top of atmosphere) for every retrieval scene.

- The authors attempt to draw a distinction between ascending/descending (MLS) versus day/night (AIRS) but this remains confusing throughout the paper. I recommend that the authors limit AIRS and MLS values to the exact same latitudinal zones and pressure zones to legitimize their comparisons and clarify their results.

- Infrared and microwave instruments have different observing capabilities for the same atmospheric variables. When comparing products from different instrument types, one has to account for inherent instrument limitations. E.g. ozone retrievals from AIRS will never have value in urban-scale air quality applications, because the AIRS infrared measurements lack sensitivity to boundary layer ozone. There is no retrieval algorithm that can extract boundary layer ozone from AIRS measurements because the signal is simply not there. Another example is that MLS ozone observations will have very limited cloud contamination (if any) because, by definition, microwave radiance measurements lack sensitivity to non-precipitating clouds. One has to acknowledge basic instrument capability when comparing products.

- The authors posit that one of the possible reasons for diurnal variability in AIRS total column ozone is due to a mis-characterization of surface emissivity. While this may be true for boundary layer temperature or water vapor, it should have minimal effect on ozone retrievals because AIRS radiance channels lack sensitivity to lower tropospheric ozone. By far a stronger effect on the retrieval product is the a-priori. AIRS V6 is an optimal estimation retrieval system that uses a non-linear regression as a-priori for temperature, water vapor and ozone (Milstein and Blackwell, 2016; Smith and Barnet, 2019, 2020; Susskind et al., 2014). This regression algorithm uses all available AIRS channels to retrieve a host of atmospheric variables simultaneously, thus propagating their spectral correlation into the retrieved products. In optimal estimation retrieval systems, the a-priori functions as a stabilization factor, such that wherever the radiance channels lack sensitivity, the a-priori will fill the result will default to the a-priori. My

sense is that the diurnal variability observed in AIRS V6 total column ozone probably originates from the regression a-priori. The authors can test this because the a-priori (or first guess) values are distributed with the retrievals in the Level 2 file. The authors can also test their hypothesis that clouds affect total column ozone values by correlating AIRS ozone with cloud fraction and cloud top pressure, both retrieved from AIRS radiances and available in the Level 2 file (AIRS Science Team/Joao Texeira, 2013).

B. Technical issues

Lines 9-12 and Lines 56-59: "Based on knowledge of the chemistry and transport of O3. . ." The premise of the work is unclear to me. I recommend that the authors rephrase their argument for evaluating diurnal changes in O3, to clarify the scientific meaning of their results.

Line 59: The references listed here for ozone retrievals from infrared radiances, predate the launch of AIRS. Since this paper is about AIRS ozone retrievals, I recommend that the authors reference more recent papers.

Line 60: "calibration procedures between day and night". . .This sentence implies that radiometric calibration varies diurnally for all instruments. This is not true, of course. Can the authors be more specific here?

Lines 64-65: "There are infrared satellite instruments, like AIRS and MLS. . ." MLS is not an infrared instrument.

Line 69: "near the polar day terminator in the upper troposphere" Can the authors explain what they mean here?

Lines 75-79: Personally, I think this level of detail about the chemical reactions of O3 (and its precursors) is irrelevant to the discussion here.

Line 110: I would suggest that the authors write out "TCO" to make this title less cryptic.

Line 114: Can the authors provide a reference and perhaps doi number for the AIRS

V6 level 3 data products?

Line 140: What is considered a “small positive bias” in lower stratospheric MLS O3 data?

Line 141: “Comparisons with expectations and other observations. . .” What do the authors mean here?

Lines 145-147: “. . .and the decline over land is larger than over oceans indicating differences in surface loss.” Can the authors clarify this statement?

Line 153: Can the authors give an example of what they mean by “atypical earth surface properties”?

The titles for Section 3.2 and 3.2.1 are cryptic and almost exactly the same. I recommend the revise these to distinguish the two sections.

Line 184: “When this flag has a value of plus one or minus. . .” Rephrase.

Lines 186, 187, 189: “14 may” should be “14 May”

Line 198: “scientifically reliable values” Could the authors elaborate on what they mean here?

Line 264: “Timescale becomes low enough”. What do the authors consider a “low” timescale?

Line 265: “Figures $1 to $4” should be “Figures 1 to 4”

Line 266: “O3” should be a subscript “3”

Lines 266-267: “small day-night differences of tropospheric O3 are hard to discriminate comparing day/night TCO.” This sentence needs revision.

Line 268-269: “we found that the frequency and intensity of low O3 regions between 60ËŽS and 60ËŽN was higher at night by AIRS and MLS” What do the authors mean here?

Line 270-273: “whether the more serious low region at night are due to the problem of the algorithm itself or the atmospheric physical and chemical factors different from that in the daytime, we compared both MLS and AIRS at day and at night. It is necessary to verify day-night differences by infrared TCO observations for retrieval aspect first. Our results show that maintaining the quality of the satellite observations of stratospheric O3 is therefore highly relevant.”

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