We thank the reviewer for the thoughtful comments and hope that our responses adequately address the concerns, particularly regarding the impacts of absorbing aerosols on the bi-spectral CER retrievals via solution space non-orthogonality. Our responses to the general, specific, and technical comments are below.

General comments:

My main comment is about the potential presence of absorbing aerosol (smoke) above the clouds. As mentioned on page 3, 'ORACLES targeted the unique aerosol and cloud environment over the southeast (SE) Atlantic Ocean where an extensive biomass burning smoke layer overlies a quasi-permanent marine stratocumulus cloud deck. Indeed, on the main day of study, 20 September 2016, extensive smoke appears to have been present in the study region, with absorbing aerosol index (AAI) values (much) higher than 2 (see image below taken from https://www.temis.nl).
Surprisingly, no analysis of this aerosol layer is included in the paper, and it is not taken into account in any of the retrievals. Effects on COT and CER retrievals are discussed on page 17, and it is stated that 'CER retrievals, on the other hand, are substantially less biased, e.g., less than 5% on a monthly mean scale (Meyer et al., 2015), since the above-cloud aerosol spectral absorption is at a minimum in the SWIR and MWIR (de Graaf et al., 2012; Haywood et al., 2004). However, while it is true that absorption by smoke is minimal in the SWIR and MWIR, CER retrievals are affected through the coupling with COT. Haywood et al. (2004) find CER underestimates of up to 2 µm at 3.7 µm, 1 µm at 2.13 µm, and as much as 5 µm at 1.63 µm. In the context of this paper, these are significant biases, which must be taken into account. The authors either need to include these aerosols in the retrievals or – alternatively – demonstrate that no significant aerosol was present above the clouds in the cases studied.

The reviewer raises an important point on the non-orthogonality of the COT/CER solution space for these bi-spectral retrievals, particularly for those using 1.6x µm versus 2.x µm or 3.7 µm. As the reviewer correctly states, above-cloud aerosol absorption that attenuates only the VIS/NIR channels nevertheless can cause changes to CER retrievals when the reflectance observations lie in portions of the COT/CER solution space that are non-orthogonal. Non-orthogonality of the COT/CER solution space typically is dependent on the SWIR/MWIR wavelength (1.6x µm is the most non-orthogonal; 3.7µm is least) and on the COT of the cloud (non-orthogonality increases with decreasing COT). While we did consider the impacts of above-cloud absorbing aerosols using regional/seasonal retrieval statistics from previous studies focusing on the SE Atlantic biomass burning smoke, we quite frankly are embarrassed that we did not consider their impacts in the specific case studies shown here.

We now have included estimates of these impacts for the 9E Sawtooth and 10.5E Ramp probe comparison case studies in Section 4.2, and specifically only for the 1.6x and 2.x µm retrievals. While the reviewer correctly notes that Haywood et al. (2004) finds CER impacts up to 2 µm for the 3.7 µm channel (see Haywood's Fig. 3(b) and associated text showing impacts of above-cloud smoke), these strong impacts for the NIR/3.7 µm channel pair are evident only for larger CER, roughly apparent (i.e., retrieved) CER > 16 µm (note: the same cannot be said for the above-cloud dust case in Haywood's Fig. 4, where the 3.7 µm reflectance also changes, thus 3.7 µm CER retrievals show impacts throughout the solution space). In our two case studies, apparent CER is < 10 µm for the Sawtooth case and < 12 µm for the Ramp case, both squarely in the orthogonal portion of the solution space and, using Haywood's Fig. 3 (b) as a guide, likely to have little change when accounting for above-cloud aerosol absorption in the NIR 0.87 µm channel used for the eMAS retrievals in our study.

Specific details on this additional analysis have been added to Section 4.2 (and updates to Figs. 11 and 15), along with smaller text additions at the end of Section 4.1, in the Section 5 discussion, and in the Section 6 summary. We also have replaced Figure 12 with a new figure showing the COT/CER solution spaces for a cloud only and a cloud with overlying aerosol having AOT defined by co-located HSRL-2 retrievals. The upshot is that for the 9E Sawtooth case, we estimate that the CER retrievals can increase by roughly 3.3 and 4.1 µm for the 1.62 and 1.66 µm channels, respectively, and by roughly 1.0 µm for all 2.x µm channels, when accounting for the above-cloud aerosol absorption in the NIR only. These findings are consistent with Haywood et al. (2004). For the 10.5E Ramp case, however, the 1.62 and 1.66 µm retrievals increase only by 1.1 and 1.5 µm, respectively, while the impacts on the 2.x µm retrievals are less than 0.2 µm, or essentially negligible. In both cases, the above-cloud AOT from HSRL-2 is near 0.6, which cannot explain the differences in the aerosol impacts between the two cases. Rather, the 10.5E Ramp case is optically thicker (COT ~23.3) such that the observed spectral reflectance is in the more orthogonal portion of the solution space (thus smaller impacts), while the 9E Sawtooth case is optically thinner (COT ~9.4) such that the observations are in the less orthogonal portion of the solution space.

We sincerely thank the reviewer for this insightful comment on an important omission from our study!

Specific comments:

Fig. 2: The Aqua MODIS comparisons appear to suggest a much larger eMAS degradation than the RSP comparisons. Can you comment on that? Also, a symbol appears to be missing for the Aqua MODIS comparison of the 2.13 micron channel on 20 September.

The reviewer has a good eye! The MODIS comparisons do appear to suggest a larger degradation, though we note that these comparisons are done only for the small geographic region where the ER-2 was spatially/temporally co-located with the Aqua nadir ground track, thus are a small sample size that may have larger day-to-day variability. Nevertheless, we historically have chosen MODIS as our radiometric benchmark given our desire for consistency between the eMAS retrievals and their spaceborne MODIS counterpart, and the comparison itself involves iterating the eMAS calibration until COT/CER retrieval consistency is achieved for the co-located near-nadir observations. The comparison against RSP, on the other hand, involves reflectance comparisons that do not account for spectral response differences (thus cannot be used as absolute radiometric benchmarks), but that do use data sampled from each entire science flight that inherently includes a wider variety of scenes and geographic sampling and that can provide a relative degradation curve covering the entire campaign. We further note that, while an eMAS-RSP retrieval comparison approach similar to the eMAS-MODIS approach is possible, it may yield calibration adjustments that do not enable COT/CER retrieval consistency with MODIS.

Regarding the 20 September 2.13μm comparison, the CER retrievals used for the iterative calibration adjustment approach had some outliers that muddied the results. Therefore we excluded this day for this channel only, which explains the missing symbol in Fig. 2. That said, we expect similar behavior in this channel as in the 1.62μm channel (i.e., no degradation between 18 and 20 September) given that both are on the same focal plane; the VNIR channels that do show day-to-day degradation are on a separate focal plane.

Fig. 4: I am somewhat surprised by the large difference in retrieval uncertainties between the spectral channels. In particular, the 3.7 μm CER has a relatively very low uncertainty. Could it be that uncertainties related to estimating the thermal emission contribution to the observed radiance as well as the error of 5% in the solar component (compared to 7% error in the reflectance for the other channels) are judged too optimistically? A related question is that, if I am not mistaken, these uncertainties are not included in the further analysis. For example, in Fig. 11 the whiskers denote spatial variability but single-pixel retrieval uncertainty is not accounted for. If the retrieval uncertainty of the 1.6 μm CER is really as large as 50% (which seems to be the case in Fig. 4) – corresponding to about 4 μm and likely a combination of systematic and random errors – this puts the results in Fig. 11 in a different perspective. Can the authors comment on this?

This is a great observation. Since we're using the same code base as the MODIS MOD06 and MODIS/VIIRS CLDPROP optical property retrievals, the uncertainty handling in the eMAS retrievals shown here is identical to those satellite products and, for the 3.7 μm channel, does include thermal emission removal uncertainty components, specifically the solar irradiance and surface/cloud temperatures (see Section III/F in Platnick et al. (2017)). The 3.7 μm uncertainties are smaller largely due to the mostly orthogonal solution space, in particular for the COT/CER ranges observed in this scene. We note that similar differences between the 3.7 and 2.1μm CER retrieval uncertainties are found in the MOD06 uncertainties (see Fig. 14, Platnick et al. (2017)), though perhaps are less extreme since the MODIS radiometric uncertainty has less spectral variation than the 5% vs 7% uncertainties used here for eMAS. The rationale for the different SW vs MWIR radiometric uncertainty assumptions is an attempt to account for the different calibration sources for each spectrum; the SW, as described in our answer above and in the text, uses lab sphere calibrations and comparisons with other imagers, while the MWIR, like the thermal

IR, is calibrated using an onboard blackbody that is expected to have greater stability. The reviewer is indeed correct that the pixel-level uncertainties are not included in the further analysis.

Regarding the 1.6x µm uncertainties, the reviewer makes an important point. Correctly understood, these retrieval uncertainties essentially are sensitivities to changes in spectral reflectance such that, all error sources being equal across retrievals, more non-orthogonal solution spaces will have higher retrieval uncertainties. As such, all the results in this paper should be interpreted in light of these uncertainties. Thus, along with the text additions describing the above-cloud aerosol impacts, we have added statements on the higher uncertainties associated with the 1.6x µm retrievals that, like the impacts of the above-cloud aerosol absorption in the NIR, are directly related to its less orthogonal solution space (e.g., P25, L613-616).

P29, 647-648: I am not sure what this statement means. The inter-wavelength differences seem to be comparable between the two cases:

- Sawtooth: PDI 7.9-8.3 um, CAS 6.5-6.7 um
- Ramp: PDI 9.0-9.4 um, CAS 7.7-7.9 um

Good catch. This statement on the PDI adiabatic signature differences between the two case studies referred to an older iteration of the data/table that we later found to be in error. We have removed the statement from the text.

P43, Fig. 21: I do not see how CER at 1.62 micron can increase as a result of doubling above-cloud water vapor. Can you explain?

This result does indeed differ from what one might expect, and we will admit it also caused us to scratch our heads upon first seeing it. However, the explanation lies in spectral water vapor absorption differences coupled with the non-orthogonality of the solution space for the VNIR/1.62 µm retrievals. First, water vapor is only weakly absorbing in the 1.62 µm channel and is stronger in the other SWIR channels and the 0.87 µm channel used for COT retrievals. For the NIR/1.62 µm channel pair only, the atmospheric correction acts to increase the 0.87 µm reflectance, with only a small increase in the 1.62 µm reflectance, thus moving the observation point more "right" than "upwards/rightwards" in the solution space. Using the LUT plot in Fig. 12 (a) as a guide, this rightward movement paradoxically yields larger CER retrievals. For all other retrieval channel pairs, the atmospheric correction has larger impacts on the SWIR channels, thus yielding larger SWIR reflectance and smaller CER.

Technical comments:

P7, L204: remote -> remotely

Done.

P19: There is some duplication between text and caption. In general, content of the figure is best described in the caption. Suggest to transfer some of the description to the caption (e.g., arrows, labels, blue boxes).

Done.

P30, L677: spectral -> spectrally

Spectral in this case refers to the weighted CEV for each spectral channel; the CEV itself is vertically weighted. We have changed the text to clarify this.

P35, L785-787: It would be good to include the meaning of the vertical dotted lines also (or only) in the caption of Fig. 19.

We have added the explanatory text to the Fig. 19 caption.

P42, L909: Prefer: 'it is'.

Changed.

P43, Fig. 21: Please indicate for clarity what the dotted boxes refer to. I guess these are the ‘default’ retrieval results from Figs. 11a and 15a?

The reviewer is correct, these correspond to the “default” retrieval results in Figs. 11(a) and 15(a). We have added explanatory text to the figure caption.

P44, L954: ‘bias difference’ sounds strange and ‘double’. Consider to replace with ‘difference’.

Changed.

P47, L1051: Incomplete reference

This reference refers to an online document at the Ames ASF website for eMAS, whose url apparently does not get included when using the Zotero bibliography template for Copernicus publications. We will add this by hand.

P48, L1087: n/a-n/a. Correct and include doi

Fixed.

P49, L1103: n/a-n/a. Correct and include doi.

Fixed.

P51, L1185: ldots. Correct and include doi.

Fixed.

P52, L1211: Incomplete reference

See comment above on our use of the Copernicus template with Zotero. We will add the url by hand.

P53, L1248: Incomplete reference

We will add the url by hand.

P53, L1260: Incomplete reference

Fixed.

P54, L1290: n/a-n/a. Correct and include doi.

Fixed.