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Atmospheric Measurement Techniques Discussions

Interactive comment on "Inversion of multi-angular polarimetric measurements from the ACEPOL campaign: an application of improving aerosol property and hyperspectral ocean color retrievals" *by* Meng Gao et al.

Anonymous Referee #1

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The paper uses data collected from two airborne multi-angle polarimeters (MAPs) flying together on the ER-2 over a SeaPRISM site off the southern California coast to investigate whether multi-angle polarimetry will improve atmospheric correction of a hyperspectral instrument. The question is important because of the NASA PACE mission scheduled to launch in less than three years. The flagship PACE instrument is a hyperspectral radiometer, but it will be flying with two MAPs. Will those MAPs improve the radiometer's ability to retrieve ocean-leaving radiance by constraining aerosol properties? The study is presented well, is backed up with real validation and comes to a

solid conclusion. There are a few points that I think should be considered before publication, but overall my take is that the revisions will be very minor.

Comments:

1. Addressing the lack of UV in the study.

For me the biggest challenge for atmospheric correction in PACE is not the hyperspectral, but the UV. The atmosphere in the UV range is thick with Rayleigh and with aerosol scattering/absorption, making atmospheric correction even more uncertain than it is even in the deep blue (410 nm). Yet, the ocean community is excited by the UV measurements by OCI and intends to exploit that data, which they absolutely will not be able to do without a better plan for UV atmospheric correction.

I fully understand that addressing UV is outside the scope of this paper, but there are small things that can be done here to clarify the limitations of this paper and express the need for a future focus on the UV. The authors would be doing the community a great service.

P3 Line 1. SPEXone has true UV measurements.

P4 Line 27. SPEX airborne does not have UV measurements

P3 Lines 21-22. "SPEX Airborne collects hyperspectral radiometry, and thus can be used as a proxy for OCI in developing hyperspectral ocean color algorithms." With the caveat that it is missing measurements in the true UV part of the range.

P20 Line 2. "The resulting hyperspectral water leaving reflectances agree well with the AERONET OC and MODIS OC products." But not below 470 nm. This has implications for the UV.

2. Cases at very low aerosol loading

The two cases examined in the study are at very low AOD. There are a few places in the paper where the low aerosol loading introduces some concerns. P5 Line 11. "For

AOD less than 0.2, uncertainties in the AERONET inversion properties. . .. (Dubovik et al., 2000)".

For what wavelength is AOD < 0.2?

Dubovik 2000 is a very old reference. I looked through the materials on the AERONET web site including this document.

https://aeronet.gsfc.nasa.gov/new_web/Documents/U27_summary_final.pdf

It seems to imply a different set of uncertainties that are actually larger than what is stated here, especially for refractive indices and SSA. Size distribution products can tolerate lower aerosol loading, but anything to do with absorption just falls apart when there is insufficient signal.

Also the implication by this statement on P5 is that the same uncertainties hold for all AOD 0.2 and less. This means that AOD = 0.04 has the same uncertainties as AOD =0.20, and the AERONET document, and especially the graphs at the bottom do not support this.

Now I find it interesting that the authors do mention the challenge of retrieving micro-physical properties when the aerosol loading is small. (P6 Line 15 and P16 Lines 6-8). Then why imply minimal uncertainty for these very, very low loadings of the cases studied in this paper? I am sufficiently distressed about trying to make retrievals of intrinsic particle properties when the AOD at 550 nm is less than 0.04, that I question the results of these retrievals in Figure 5 and Table 3, and some of the overall conclusions. Specific items that need to be addressed:

The statement on P5 should be updated.

In figure 5, the AERONET properties are plotted with their daily variation, but not their uncertainties. The uncertainties are larger than the range of the daily variation. This should be stated explicitly.

P16 Line 4, check those AERONET uncertainties again. I think they are too small.

P19 Line 16. The absolute values also agree better with the AERONET aerosol product. " This is not true for SSA. But. . . there are large uncertainties for SSA in AERONET because of the low AOD.

3. Systematic biases between airborne SPEX and RSP

Beginning on P6 Line 28, the paper mentions "systematic differences", but never describes which is higher, SPEX or RSP. This becomes important in the conclusion. P17 Lines 15-18. Here systematic differences between RSP and SPEXairborne are mentioned again, but which one is higher? And it isn't stated which one is right. So when speaking of impact on aerosol retrievals, how would these instrumental differences cascade into the aerosol retrievals? What should be expected from these differences, and why or why not were these expectations met? P17 Lines 21-23. Once again we are presented with differences, but are never told which instrument produces the higher result.

4. Theoretical retrieval uncertainty and validation against measurements

The authors to their credit address uncertainty from both the theoretical perspective and then also by comparing with ground-based measurements with well-defined uncertainty. The act of validation validates the magnitudes of the retrieved properties. In addition the act of validation validates the theoretical estimate of the uncertainties. The authors should explain explicitly in the paper when the theoretical polarimeter uncertainty is validated by the ground-based measurements and when it is not. I never believe the calculations of theoretical uncertainty until validation. On P17 Lines 11-12, "These reduced uncertainties in the aerosol micro-physical properties can help to determine aerosol type and its composition.." The authors here are discussing the theoretical reduced uncertainties. Have these reduced uncertainties been explicitly validated?

The concern I have is that the authors believe their theoretical calculations of uncertainty too much. P16 Lines 3-5. “Note that AERONET aerosol product uncertainties are approximately 0.01 for AOD, 0.05 for refractive index, and 0.05-0.07 for SSA as mentioned in Section 2, which are comparable with the results for 7rho_t but larger than the ones from 7rho_t +5rho_t . “ The implication is that RSP is more accurate than AERONET. There might be argument that RSP SSA retrievals are more accurate than AERONET inversion, but there is no way the RSP retrievals of AOD are going to be better than the AERONET direct sun measurements.

The point is that theoretical uncertainty calculations can only calculate the uncertainty that is known and when a retrieval is made in the real world, then the uncertainty that cannot be quantified theoretically, enters the picture and the actual accuracy of the retrieval is less good than the theoretical calculation.

5. The results question the ability of PACE to produce Rrs at short wavelengths

P20 Line 2. “The resulting hyperspectral water leaving reflectances agree well with the AERONET OC and MODIS OC products.” Well, not towards the blue, near 470 nm. Hasn’t this always been the problem? Ocean biology products need water leaving radiance at the short wavelengths, and they are going to want the UV also. Here the authors show that towards the blue, the hyperspectral retrieved water leaving radiance deviates from AERONET and MODIS products by a lot. At 470 nm for the 10/23 case, the SPEX airborne retrieved remote sensing reflectance is half of what AERONET-OC measured. This does not bode well for the ability to use the blue and UV from the PACE hyperspectral Ocean Color Instrument in any reliable, consistent fashion. The authors examine two cases. In one out of the two cases the atmospheric correction fails at shorter wavelengths for the hyperspectral retrieval. This needs to be stated explicitly when describing Figure 6, but also explicitly in the Conclusions.

6. Smaller items, but some are still substantial

Abstract Line 4. “aerosols properties” should be “aerosol properties”

P6 Line 19. “water leaving reflectance”. Is the same as Remote Sensing reflectance mentioned on Line 16? The terms seemed to be used interchangeably, and I’m not sure that is correct.

Figure 6 caption. What do the error bars signify?

P8 Line 8. “uncertainties” is misspelled.

P9 Line 9. Does the rho_Sensor need a ‘w’ subscript?

P9 Lines 13-15. That statement, “_Sensor w represents the water leaving signals originating from scattering in the ocean, and can be derived from the atmospheric correction process by subtracting the reflectance contribution of atmosphere and ocean surface from the measurement at the aircraft (Gao et al., 2019).” This statement warrants an explicit equation so that the reader does not need to look up the reference. Maybe repeat from the Mobley reference also.

P9 Lines 26-27. “The total amounts of water vapor and oxygen are computed from minimizing the difference between measurement and simulated SPEX Airborne measurement over all the bands. “ This statement could be expanded upon to provide greater clarity.

P9 Line 32. “Each parameter was varied within a boundary as specified in Gao et al. (2018).” Could we have the details repeated here? The authors draw heavily upon references to their previous publications, which is fine, but these details need to be repeated here to make this paper complete in its own right.

P10 Lines 5-6. “viewing angles on the glint side, and the negative viewing zenith angles refer to the sun side.” Isn’t the glint and the sun on the same side? Glint is forward scattering. This confusion continues throughout. The paper needs this clarified.

Table 3 caption. “parenthesis” should be parentheses. Plural.

P15 Lines 10-12. “The coarse mode SSAs are of 0:7 _ 0:8 for both days and both cost

function options. Moreover, including polarization in the retrievals, the uncertainties for refractive index, SSA and AOD become 0:02 _ 0:03 for refractive index, 0:02 _ 0:04 for SSA, and 0:004 for AOD, which are reduced nearly by one half." Because these two sentence run one after the other, the second sentence appears to refer to the coarse mode, but the numbers seem to represent the conditions of the fine mode.

P16 Line 13. "in situ measurements". The MODIS retrievals are certainly not in situ measurements, and it is debatable whether we should be calling the AERONET SeaPRISM measurements "in situ". Possibly for SeaPRISM.

P17 Lines 5-6. "The difference of the MODIS and SPEX Rrs at wavelengths smaller than 500 nm may be related to the measurement uncertainties where the effects are larger for the same percentage uncertainties due to the larger total measurement values." I did not understand this sentence at all.

P18 Line 7. VIS is never previously defined. Just write out "visible"

P18 Line 10-11. "Meanwhile, we have shown polarization information can help to improve accuracy in the retrieval of aerosol optical depth, fine mode refractive index and SSA as shown in Fig. 5." I actually see the opposite in Figure 5 for SSA, at least the retrieval without polarization gets closer to AERONET retrievals, but really how can we believe any of it when AOD is less than 0.04?

P18 Lines 21-23. Do the authors really believe this? I find it very far-fetched that they are trying to assign type to an aerosol with AOD less than 0.04. Really? The Russell study was using a data base where the entries all had significant loading. Whatever they found would have no relationship to the cases of the present study, because the present study is way outside of the Russell study's dynamic range. This speculation should just be removed from the paper.

Figure 7 is never referenced in the text.

P19 Line 16. "The absolute values also agree better with the AERONET aerosol prod-

uct." Not true for SSA.

P19-20 Lines 20-2. "In order to apply the retrieved aerosol properties from the MAP measurements to hyperspectral atmospheric correction, the principal components of the aerosol refractive index spectra are interpolated into the bands specified for SPEX airborne. The retrieval parameters from MAP measurements can be used directly with the hyperspectral measurements without interpolation." The two sentences are contradictory. The first states that the refractive index spectra have to be interpolated into hyperspectral. The second states that no interpolations is necessary.

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