Referee 02

This paper evaluates 1-, 3-, and 7-parameter ocean bio-optical models using the Multi-Angular Polarimetric Ocean coLor (MAPOL) joint retrieval algorithm applied to data from the Research Scanning Polarimeter (RSP) in different types of water (clear and open water and turbid coastal water). The authors compare MAPOL retrievals to MODIS products.

The topic of this paper is interesting and the approach of this paper seems sound. However, it is unclear where the novelty lies in this paper. No new algorithms are developed, and the conclusion that the 3- and 7-parameter models are more versatile than the 1-parameter model is fairly intuitive. Furthermore, there are deviations between the MAPOL retrievals and MODIS retrievals which are not fully explained. Thus, I recommend acceptance with major revisions. I suggest that the authors further analyze the differences between MAPOL retrievals and MODIS retrievals and that the authors revise the paper to clarify the major novel contributions of this paper to the reader.

In general, I agree with the comments posted by Anonymous Referee #1 as RC1.

AC to general comments:

We appreciate your critical review which prompts us to further clarify the novelty of our manuscript. The main novelty of this work is to evaluate the performance of ocean bio-optical models with different free parameters in joint aerosol-ocean color retrieval algorithms and to provide recommendations on the optimal representation of the optical properties of coastal ocean waters. Though we carried out the research using MAPOL, the conclusions are applicable to any other joint retrieval algorithms of atmosphere and ocean systems, which makes its impact far-reaching in the Earth science community.

Gao et al. (2019) have partially touched on this subject by comparing the 1-parameter open water model and the 7-parameter coastal water model with MAPOL using multi-angle polarimeter (MAP) data. They concluded that the choice of bio-optical model affects the retrieval accuracy, and the 7-parameter model is more suitable for the coastal waters than the Case I model. What was not covered is whether seven parameters are necessary to represent coastal waters. In other words, are there other bio-optical models of coastal ocean water that have similar or superior performance? Though it sounds trivial, this question is indeed important to explore as the number of free parameters directly changes the number of forward model and Jacobian simulations, which as a consequence greatly affects the speed and stability of the least square fitting algorithms. Bio-optical models with fewer free parameters with superior or similar performance are highly desired, which makes it easier to develop operational algorithms for satellite sensors.

Hannadige et al. (2023) also showed that the multi-parameter models (3-parameter vs 7 parameters in combination with different parameterization schemes) have similar retrieval performances in the Rrs inversions with a semi-analytic algorithm, regardless of their number of free parameters. This demonstrated that the use of a 3-parameter bio-optical model is feasible. Note that Hannadige et al. (2023) used in-situ Rrs data. This has never been demonstrated in inverting airborne MAP measurements.

In this work, we extend the work by Gao et al. (2019) and Hannadige et al. (2023) and study the performance of different bio-optical models in joint retrieval algorithms of airborne MAP measurements, which is also applicable to satellite sensors. We confirmed that a simplified bio-optical model of 3 parameters performs equally well as the original 7-parameter model. In addition, we also revealed a number of important features which have not been published before. They include:

1. The 1-parameter model uncertainty is small, even when it fails to converge over coastal waters. This suggests that using the spread of the cost function to study the uncertainty of retrieval parameters is misleading. One has to ensure convergence first.
2. The multi-parameter (3 or 7) models can be used to represent open waters in joint retrieval algorithms, though the retrieval algorithm tends to converge to local minima which made the interpretation of the retrieval results difficult. It is preferable to develop a screening algorithm to divide open and coastal waters before performing MAP retrievals.
3. The 3-parameter model performs equally well with the 7-parameter model, which makes it preferable as fewer free parameters lead to significantly less processing time and more stable retrieval performance.

Based on the novelty we summarized above, we believe this work is innovative, impactful, and publishable. We have updated our manuscript by rewriting part of the abstract and introduction to better reflect the novelty. For details, please refer to the revised manuscript with tracked changes. We also address the following questions to further clarify this paper's goal, novelty, and clarity.

In order to clarify the novelty and the goal of this work, the following paragraph (line 92-104, hereafter all line numbers are referred to in the revised manuscript) has been updated.

"The goal of this study is to examine the overall impact of bio-optical models with different numbers of free parameters on the performance and uncertainty of joint retrieval algorithms for Case II waters. Hannadige et al. (2023) showed that multiparameter bio-optical models with 3 and 5 parameters show similar retrieval performances for the semi-analytical algorithm (SAA) based on 95 in-situ multi-band Rrs measurements. An independent study showed that the number of free parameters a retrieval algorithm might meaningfully retrieve is roughly four based on in-situ hyperspectral Rrs measurements (Cael et al., 2023). Here, for the first time, we have examined to which extent these conclusions hold for the joint retrieval algorithms using airborne MAP measurements, which have not been studied before. The quality of the retrievals in this study is evaluated with respect to the magnitude of the retrieval cost function values, the distribution of retrieval cost function values (Sec. 3) from the ensemble retrievals, and the sanity check with MODIS retrievals. We studied the uncertainty of the different bio-optical models based on the spread of ensemble retrieval cost function values which is important to understand the impact of the bio-optical models on the convergence behavior of the non-linear least squares fitting algorithms. This has not been examined in previous studies. Given the inherent problems associated with MODIS retrievals over optically complex scenes, we consider the MODIS products as merely a reference, rather than a validation dataset."

Comments

1. Figure 4: At a wavelength of 470 nm, it seems like the MAPOL retrievals significantly underestimate AOD when compared to MODIS. Generally, MODIS retrievals are outside of the error bars for MAPOL retrievals. The authors note this (in lines 310-311) but do not explain it -- what are the potential causes? This also appears to be an issue at 550 nm and 670 nm, but at these wavelengths, MODIS retrievals are at least generally within 1-sigma error bars for MAPOL retrievals.

In this pre-print version, we used MODIS dark target (DT) aerosol data product. In the revised version we replaced the DT AOD with those from the atmospheric correction algorithm of ocean color, for a better interpretation of the consistency between AOD and remote sensing reflectance Rrs. The MODIS AOD and Rrs values we have shown in the plots are relatable to each other. Based on the OBPG AC algorithm, larger AOD values lead to smaller Rrs values (which is similar to the MAPOL algorithm as well). The differences in MODIS and MAPOL results are attributed to the differences in measurement capabilities and algorithm differences. Please refer to Figure 5, which shows the comparison of AOD at 532 nm with MODIS and HSRL-2, which are mostly similar.

2. Figure 5: It might improve clarity to include a line on the plot showing where the coast actually is, or make the x-axis the distance from coast rather than longitude. At first glance, it can be difficult to understand where the coast is.

Each figure caption states where the coast is in each plot (to the right or to the left). For the NAAMES-Coastal case, the RSP leg is located along the coast of Delaware Bay. We added a sentence to the figure caption to indicate this. Using distance from the coast as the x-axis instead of the longitude can reduce the readability of the plots. To make it consistent throughout the manuscript we chose to use longitude as the x-axis.

3. Figure 6: I recommend including the full figure caption (and see above comment about deviations from MODIS).

All the figure captions are updated following your recommendation.

4. Figure 9: At 410 nm, spectral remote sensing reflectance from MODIS is consistently lower than from MAPOL (and is sometimes negative). Why is this?

Based on the updated AOD figures, the MODIS AOD at 410 nm is larger than that from MAPOL. The larger the AOD the smaller the Rrs is. Hence MODIS Rrs is smaller than that from MAPOL. Due to the underlying assumptions in the AC process of NASA OBPG algorithm (black pixel assumption), MODIS Rrs can become negative over turbid (coastal) waters.

5. Figure 9: Please include the full figure caption.

All the figure captions are updated.

6. General note on figures: I recommend including the full figure caption for all figures.

All the figure captions are updated.

7. Lines 123-124: I recommend further explanation of POLYAC and this paper's relevance to POLYAC. Perhaps POLYAC performance improvements can be used to motivate this paper (if it can be shown that novel contributions in this paper improve MAPOL retrievals).

POLYAC is an AC scheme for hyperspectral radiometers which can be used as an alternate scheme for heritage AC algorithms to derive hyperspectral Rrs when optically complex scenes such as coastal waters are involved. Accurate hyperspectral Rrs is required for ocean color studies such as for differentiation of phytoplankton functional types. POLYAC utilizes collocated MAP retrievals from MAPOL to estimate hyperspectral path radiance where its accuracy directly depends on the accuracy of the water-leaving signal estimated from MAPOL. We added the following paragraph (line 123-127) to better reflect the impact of this work to POLYAC.

"This study also expects to improve the performance of the POLYnomial-based Atmospheric Correction (POLYAC) algorithm (Hannadige et al., 2021) which is an AC algorithm for hyperspectral single-view radiometers applied over optically complex scenes, such as over coastal waters. POLYAC relies on collocated MAP retrievals from the MAPOLalgorithm to estimate the hyperspectral path radiance to calculate hyperspectral Rrs which is crucial for retrieving phytoplankton functional types (IOCCG, 2014)."

8. Lines 316-322: Why does MODIS estimate higher spectral remote sensing reflectance than MAPOL for pixels other than the ones closest to the coast?

The differences in MODIS and MAPOL results are attributed to the differences in measurement capabilities and algorithm differences. In this case, the estimation of AOD from the AC algorithm is higher than the MAPOL retrieval (Fig. 4), which leads to higher Rrs. In the first version, this was not clear as the MODIS dark target data were used, which are not consistent with the Rrs data. In the revised manuscript, we updated all AOD data from the AC algorithm so that all MODIS remote sensing data are physically consistent.

9. Line 327: The authors note that the uncertainty for AOD is less than 0.01 at all wavelengths -- but is the uncertainty adequately capturing error/differences from MODIS retrievals (especially noting the differences between MODIS and MAPOL)?

Based on the updated AOD figure, MODIS AOD from most of the cases falls within the uncertainty of the 3 bio-optical models. A small difference is seen for the NAAMES-Coastal case (Fig 8) at 410 nm, where the MODIS AOD only falls within C1P1 uncertainty. Given the overall performances, the difference between MODIS AOD and the uncertainty from C2P3 and C2P7 are insignificant.