We thank the reviewer for his/her thoughtful comments.

1. *A considerable effort has been made here to identify the contribution of subsurface bubbles to the lower boundary condition used for MODIS aerosol retrievals over ocean. The authors are honest in concluding that the likely magnitude of this contribution at wind speeds below 12 m/sec is negligible, and similarly for the southern ocean band of high-AOD retrievals on average. However, I'm not sure they take adequate account uncertainties in other aspects of the ocean surface model, specifically the wind dependent whitecap contribution. They develop what should be very useful machinery to study the impact of the ocean boundary condition on aerosol retrievals, but perhaps they could reach stronger conclusions if they applied it to the whitecap model itself, or to all the wind-dependent contributions (whitecap + subsurface bubbles) together as a single factor*.

   We thank the reviewer for these suggestions. We have yet to see other studies that try to study the effects of submerged bubbles on aerosol retrievals, and thus we believe it worth reporting. Submerged bubbles have not been considered in aerosol retrievals, yet, based on our study, it should be considered under high wind conditions. Thus, we try to single out the effects of oceanic bubbles on aerosol retrievals in a hope to remind the community about this missing component. Evaluating the combined contributions from both whitecaps and subsurface bubbles is a great idea. However, it takes a full study to carefully evaluate the issue and we believe the topic is subject to a future study. Still, we have added the relative contributions in between whitecaps and submerged bubbles in the revised version of the paper.

2. *Introduction, P12797, lines 19-21. According to the MISR Level 2 Aerosol Product Quality Statement, the First Look aerosol product uses climatology for the wind speed, but the Final product uses QuickScat and other sources to account for wind speed explicitly.*

   We have removed this sentence to avoid confusion.
   "Previous versions of satellite retrievals generally assumed a static climatological wind field with annual to monthly averages, and high wind events are unaccounted for."

3. *Introduction, P12798. A general question: If the wind is strong enough to create subsurface bubbles, it apparently would also produce surface bubbles. So wouldn't the conditions under which the longevity of subsurface bubbles matter most be those where the wind is initially strong, and then dies down? I'm wondering whether this would be very significant for satellite aerosol retrievals, as even those that take account of varying wind speed rely on three-hourly or coarser temporal resolution wind data. I agree that the greater uniformity of subsurface bubbles could have a larger impact on higher-spatial-resolution aircraft observation, as you mention.*

   We agree with the comment that "if wind is strong enough to create subsurface bubbles, it apparently would also produce surface bubbles". However, whitecaps and bubble rafts only cover a fraction of open oceans. In this study we have estimated the fraction of whitecap coverage based on Koepke [1984]. Within the area affected by whitecaps, the contribution of subsurface bubbles is assumed to be negligible, and the effects of submerged oceanic bubbles on aerosol retrievals are assumed to be from whitecap free regions. Again, subsurface bubbles are not considered in previous aerosol retrievals and we would like to report the effect of this missing component on aerosol retrievals.

4. *Introduction, P12799, lines 4-9. Another general question: I'd expect that subsurface bubbles could be a bigger issue for ocean color retrievals. For example, if subsurface bubbles are present but not accounted for, chlorophyll-a concentration deduced from light absorption by that species might be underestimated. I'm not familiar with the Zhang and Lewis work you cite, but is this discussed specifically in the ocean color retrieval literature? I guess another possibility is that ocean color retrievals are simply not done when wind speeds exceed some value, maybe 7.5 m/sec, i.e., when poorly calibrated whitecap models themselves tend to predict non-linearly increasing contributions to ocean surface reflectance, and with large uncertainties.*

   Yes, the subsurface bubbles are indeed an issue for ocean color retrievals. We simulated the absorption and scattering coefficients of bubbles in Zhang et al. 1998 and found bubbles themselves have negligible absorption (if any, it would come from the organic film absorbed onto the bubble surface) and exhibit spectrally flat scattering and backscattering. However, presence of bubbles does shift the color of the ocean towards green, and this is why ship wakes appear greener than the surrounding waters. This color effect is similar to phytoplankton but for different reasons. For phytoplankton, the green shift arises from the absorption by chlorophyll-a pigment in both the blue and the red wavelengths. For bubbles, the green shift is due to increased scattering by bubbles resulting in a relatively more green light reflected than blue light. Since the algorithm for estimating chlorophyll-a concentration is typically based on the color ratio, the effect of bubbles, if not corrected, would lead to an overestimation of chlorophyll concentration. It is expected that the stronger the wind, the greater the impact.
   Also, it should be noted, as the reviewer has recognized, that there is significant uncertainty in quantifying the relationship between wind and bubbles and whitecaps. For example, the concentration of bubbles is often related to the wind speeds through a power law. The exponent of the power law, mainly determined empirically, varies from 3.3 to 4.7 for different waters and conditions. For a wind speed of 10 m/s, the uncertainty of bubble concentration calculated by this power law would be over an order of magnitude. In our study, we limited this variability within a very constrained range of a factor of 2 to establish a conserved baseline. It is possible, however, the effect could be greater or lesser. Apparently, more research is needed in this area. We have added the discussion in the paper.
   .

5. *Introduction, P12800. You might consider mentioning how polarized observations might mitigate multiple-scattering effects at shorter wavelengths for this problem. The work of Chowdhary et al. might be relevant here. I'm thinking that many of the current aircraft instruments used for aerosol remote sensing have polarized channels.*

We might misunderstand the question. But a major difference between the ocean and the atmosphere in terms of optical remote sensing is that the absorption by the ocean is much greater than atmosphere. The strong absorption diminishes the total intensity as well as the polarization signature of the reflected light coming out of the ocean. This is the reason why the signal coming out of the ocean generally accounts for < 10% of the total radiance received by a satellite sensor. This is why it is critical to remove the atmospheric signal as accurately as possible in order to study the ocean. The use of polarized observation also serves this purpose.

However, the purpose of this study is not to achieve a good separation of atmospheric and oceanic signal. Instead, we try to evaluate the contribution by bubbles to the retrieval of aerosols. In other words, we need to be able to separate signals reflected by bubbles from the signals reflected by other oceanic constituents. This is the reason we choose 660 nm, where strong absorption by waters makes single-scattering the dominant mechanism reflecting incident solar radiation out of the ocean, allowing us to separate reflectance by bubbles from that by the background water. If we choose a shorter wavelength, it would be very difficult to separate the reflectance by bubbles from that by other particles due to multiple scattering among them, possibly even with the use of polarized light.

6. *Introduction, P12797, line 4. Come to think of it, you might also reference earlier on Kalashnikova et al., AMT 6, 2131–2154, 2013.*

   We thank the reviewer for their comments. Kalashnikova et al. 2013 has been added to the paper.

7. *Section 2.1, P12801, lines 12-24. I agree it is fair to compare with the MODIS C5 product due to the connection to previous analyses and prior claims. However, it seems more relevant, and more useful for future work, to compare with the MODIS C6 data, especially as C6 includes the better ocean surface model that you mention. I realize this represents extra work, but I think it will make the paper much more useful, as it will calibrate how effective the simpler wind-speed-dependent lower boundary whitecap condition in C6 also mitigates the subsurface bubble issue you raise.*

   Thanks for the suggestion. We have included the analysis using the MODIS C6 data.

8. *Section 2.1, P12803, line 5. It might be fair to reference Levy et al., AMT 6, 2989–3034, 2013 here as well. Also on P12808, line 17. And again for Collection 6 on P12809, lines 10-14.*

   We appreciate the comments from the reviewer. Further citation of Levy et al. 2013 has been added to the paper.

9. *Section 2.2, P12804, line 21. This should probably be: "red and near-infrared wavelengths: : :"*

   We thank the reviewer for their comments. This has been changed in the paper.

10. *Section 2.2, P12804, Equs. 1. (a) Is W a fractional or the total area, and should Ref_wc be multiplied by W? (b) More might be said about how the glint term is evaluated, as it can be significantly view-angle dependent. (For example, I see you assume a Lambertian surface in the next section; if used here, this might not be a good representation of the glint term for interpreting remote sensing radiance observations.) (c) Also, you seem to be assuming that other water-leaving reflectance terms are negligible where whitecaps are present; if so, this might be worth mentioning.*

    We thank the reviewer for their comments. Equation 1 is actually from Koepke [1984]. Koepke [1984] has explained each term in detail and thus it is unnecessary to explain the terms again in this paper. We try to explain the questions based on our understanding of Koepke [1984] and the 6S model below.

    a) W is a fractional area. Ref_wc is calculated by multiplying W by an effective reflectance (Ref_i). This is done because whitecaps of different ages have different albedos and reflectance properties. The effective reflectance is meant to take those characteristics into account. Therefore, Ref_wc is not multiplied by W because the whitecap coverage is already taken into account via how it is calculated. Details can be found in Koepke [1984] as well as the 6s model manual.
    b) In 6s, the glint term is computed based on Cox and Munk (1954). Therefore, viewing angles are considered.
    c) The reduction of water-leaving radiance due to white caps is considered. It is described in details in Koepke [1984] and thus is not repeated in this paper.

11. *Section 2.2, P12804, lines 24 ff. It might be worth mentioning the estimated level of uncertainty in these factors. (I guess this applies specifically to Equs. 2.) This would also address in part whether half and double bubbles (P12806, top paragraph) are the appropriate limits to use.*

    See our responses to question 5.

12. *Section 3.1, P12807, Figure 3. Given the scatter of points in Fig. 3a (especially north of 30S), and the relative contribution of the surface shown in Fig. 3b, is this approach really sensitive enough to assess the contributions of subsurface bubbles to TOA radiance? Perhaps you are in a position to put some constraint on one or more of the larger terms.*

    We appreciate the comments from the reviewer. The purpose of this figure is not necessarily to assess the contributions of ocean bubbles, but rather to analyze the performance of the 6S model as compared to Aqua MODIS. We wanted to be sure that the RTM is functioning before doing further analysis on the subsurface bubbles.

    We understand that other factors affect the simulation of TOA radiance. However, based on our knowledge, the contribution of submerged bubbles to aerosol retrievals has not been evaluated before. Therefore, the purpose of this paper is to evaluate the impacts of submerged bubbles to aerosol retrievals using a RTM modeling based approach by fixing other variables. Our study did seem to suggest that submerged bubbles are not important

for aerosol retrievals under low wind conditions, but do matter when wind speed is high (e.g. 15m/s).
To avoid confusion, we have removed Figure 3b based on the suggestion from reviewer 1.

13. *Section 3.2, P12807, line 12. Is the Koepke [1984] whitecap model good enough to apply at wind speeds greater than maybe 10 or 12 m/sec in this context?*

    It is not the goal of this paper to evaluate Koepke [1984]. However, observations with wind speeds larger than 10-12 m/s have been used in Koepke [1984].

14. *Section 3.2, P12807, paragraph 2. Certainly by changing one forcing term in one direction, you would expect to produce a systematic difference compared to the no-bubble case. However, in terms of practical application, it would help to address whether these differences rise above the uncertainties in the system as a whole. Similarly, you plot the average values in Fig. 4, but some measure of the spread would also be of interest, because satellite retrievals for a given location and season tend to be performed over a limited range of angular values. (BTW, I think I know what "AZM" is, as distinct from "SAZM," but I did not notice the former defined in the text.)*

    Points are taken. For low wind speed cases, the effects of bubbles are insignificant. However, for high wind speed cases (e.g. wind speed of 15m/s), "20% of the wind related uncertainty for the MODIS DT products over remote oceans can be attributed to subsurface bubbles." Such discussions are actually already presented in the paper (page 12808, line 20-22).

    Also, as suggested, we have discussed data spread in the paper. We have added the following discussion in the text:
    "The standard deviations of the variations, although not shown here, are on the order of 10-20% of the mean values for wind speeds larger than 10m/s for the SZA =0° case, and are on the order of 30-40% and 50-70% for SZA of 30° and 60° cases respectively."

    We have defined AZM (relative azimuth angle) in the paper.

15. *Section 3.2, P12808, lines 20-22. Does this consider uncertainty (as distinct from the variation) in the Koepke [1984] whitecap model itself?*

    The uncertainty in the Koepke [1984] whitecap model is not considered as the purpose of the paper is to single out the effects of bubbles on aerosol retrievals. In fact, evaluating of the uncertainty in the Koepke [1984] is a non-trivial task and deserves a full study of its own and we leave this topic for a future study. Still, to clear the reviewer's concern, we have added the following discussion in the text.

"Note that this conclusion is derived without considering uncertainty in the Koepke [1984] whitecap model (e.g. the area of whitecap coverage). We leave this issue for a future study."

16. *Section 3.2, P12809, line 4. At wind speeds in excess of 10 m/sec, or even less, uncertainties in any satellite-retrieved AOD would be much greater than 0.01 anyway.*

Agreed.