Reviewer response for AMT-2017-473 "Remote sensing of aerosols with small satellites in formation flight" Kirk Knobelspiesse and Sreeja Nag.

Response to reviewer #2

The paper by Knobelspiesse and Nag performed a systematic information content analysis to evaluate the performance of using multiple small satellites for aerosol and surface (land + ocean) remote sensing. As one of the major advantages, small satellites have the flexibility of multiple path location and being replaceable when necessary. The information content analysis demonstrates that such a flexibility results in a similar accuracy as achieved by setting the same number of view angles with a single instrument on a single platform (such as MISR on Terra). Moreover, it is found that the information content does increase with the increase of number of viewing angles.

This work provides important theoretical support to the design and development of multi-platform sensors for aerosol remote sensing and is highly appropriate for AMT. I have the following comment for the authors to consider and clarify.

We are grateful for the reviewer's helpful and constructive thoughts on our manuscript.

1. *Page 10: The authors correctly pointed out three pre-assumptions for applying information content analysis. Should there be another one that "The relationship between measurement errors and retrieval uncertainties are assumed to be linear around the solution" ?*

Yes, and we added this to the document. This was mentioned it elsewhere in the paper as a uniform assumption of the error propagation technique proposed by Rodgers, but it is good to also mention it again.

2. *Earlier work performed by O. Hasekamp et al. 2010 (theoretical study), L. Wu et al. 2015 (using RSP data), and F. Xu et al. 2017 (using AirMSPI data) used direct retrieval test (alternative to information content analysis) and found a significant gain of AOT retrieval accuracy when the number of viewing angle increases from 2 to 5 and then a limited gain once the number of viewing angles exceed 5. Though the number of viewing angles in this work starts from 3, it will be helpful to add into simulation the 2-angle case and compare these earlier work the retrieval uncertainty as a function of view angles (such as Fig. 7, but plotting absolute AOT error), and comment the difference if there is. This may help the readers be aware of the errors caused by using different analysis approach.*

Although we plotted the analysis in figure 7 in terms of relative uncertainty, one can observe a decrease in uncertainty consistent with the work you quote, that tapers off around 5 viewing angles. This is most obvious for the lower simulated AOT's, which is part of our motivation for plotting relative AOT uncertainty. The ability to retrieve aerosol optical properties is directly related to AOT… in other words, better aerosol retrievals if there are more aerosols. It would be nice to add 2 viewing angles to this study, but that would involve starting over from the beginning in terms of orbit design and information content, and wouldn't modify an assessment of our core hypothesis, to compare 9 angle views on a single satellite vs nine single angle satellites.

3. *Do I understand correctly that the authors conclude the specific location of viewing angle (or "observation geometry" as in the paper) has very limited impact on aerosol/surface retrieval accuracy as long as their number are same ? If so, I'm confused. For a certain number of viewing angles, the spread of the degree of freedom (DOF) in Fig 6 spans a range that can cover the difference in mean DOF caused by varying 4-5 view angles. This is indeed a huge impact. Please clarify.*

Yes, specific viewing geometries have highly variable information content, and you correctly note the evidence for this in the range of DFS in fig. 6. However, satellites flying in formation do not maintain a specific measurement geometry, rather, this varies throughout the orbit. So, in aggregate over the entirety of an orbit, the number of viewing angles defines the information content of a scene (assuming they are well dispersed within the observing geometry, as is the case for the orbit simulations we used).

4. *Page 19, paragraph 2, it is not easy for readers to capture these remarks from Figure 6. It is better to add another plot showing the delta_DOF as a function of number of viewing angles. Moreover, I see from the bottom right panel of Fig 6 a gradual increase of DOF from using 5-6 angles, 6-7 angles, and then 7-8 angles. And convergence seems not achieved by use of 9 angles. I suggest the authors setting more angles for test and plot delta_DOF to justify the convergence. Even claimed as "seven or eight satellite configuration" are capable enough, it is different than earlier finding that AOT retrieval accuracy gain converges at five angles. This needs some comments.*

We revised our statement "For scenes over the ocean, in fact, the DF S tends to level off after five or six satellites. This would indicate that only that many view angles are required, at least as expressed by the DFS" to "For reflectance-only scenes over the ocean, in fact, the DFS tends to level off after five or six satellites, indicating diminishing returns with more angles. Polarimetric ocean, and both reflectance-only and polarimetric land scenes benefit from additional viewing angles, although the DFS increase becomes more gradual."

Ultimately, we address our primary hypothesis by comparing the 9 view / 1 satellite to the 1 satellite / 9 view case, which shows equivalent DFS (and parameter uncertainties) for the two systems.

5. *The authors correctly uses the chain rule to calculate the AOT uncertainty. To be more complete, please describe more explicitly after Eq.(2) that the square root of the diagonal term of S matrix represents the uncertainty of the retrieval parameters. This would be better than describing it in the figure caption.*

The sentence following equation 2 is: "The diagonals of this square matrix correspond to squared uncertainties associated with each parameter in x, while off diagonal elements are the covariances between them."

6. *P23, Section 4,5, the authors are trying to use the off-diagonal terms of the retrieval error correlation matrix (Eq.6) to analyze the cross-contamination between different retrieval parameters. It is stated that "large off diagonal values indicate a smaller volume in retrieval State space, an indication of higher information content for that pair of parameters." Please be more explicit about the physical interpretation behind the relation between diagonal and off-diagonal terms. For example, does the author mean in contrast to the diagonal term, large off-diagonal term means retrieval error of the two quantities are less correlated and therefore easy to decouple ?*

This is a subtle issue that we've attempted to describe in more detail in this version of the manuscript. We use the example of the anti-correlation present in the AOT and effective radius (for the same size mode). Physically, these parameters should be uncorrelated, (one is extrinsic, the other intrinsic). Here's what we put: "All scenes demonstrate a strong anti-correlation between AOT and the effective radius of the same size mode. Physically, these parameters should be uncorrelated, since effective radius is an intrinsic optical parameter, while AOT is an extrinsic parameter expressing total column extinction. Thus, our assumption of no correlation between these parameters in the a priori error covariance matrix, S_a in Equation 2 is probably valid. This would thus indicate that the source of the anti-correlation is the nature of parameter space expressed in the Jacobians. In practice it would not indicate a relationship in the retrievals of the parameters, but that if one retrieved parameter were wrong, we could expect the other parameter to also be wrong (but in the direction of the opposite sign)."

7. *In addition to the DOF and retrieval uncertainty analysis for the AOT (e.g. Figs 6 - 7), could the authors add a similar analysis for aerosol single scattering albedo (and maybe an extra case for smoke or dust aerosols) This will help the readers understand the role of using polarization in constraining aerosol single scattering albedo retrieval.*

This is probably most appropriate for a subsequent study with a wider scope beyond comparing the 9 view / 1 satellite to the 1 satellite / 9 view case. That said, the fine mode imaginary refractive index (related to SSA) was a free parameter for the land scenes, although Figure 9 shows low averaging kernel values for that parameter (indicating low sensitivity). Although we have done so in the past, we wonder if Single Scattering Albedo, bounded between 0 and 1, is an appropriate parameter to examine within the Rodgers style formalism, which requires gaussian error distributions. An alternative metric that might work better could be the absorption optical depth.