We would like to thank the reviewer for the following constructive feedback on our manuscript and in aiding our progress towards publication. Our responses are given in blue text and any adjustments to the manuscript text are given in quotes and italics. Major changes to the updated manuscript text are highlighted.

Review of “Use of Lidar Aerosol Extinction and Backscatter Coefficients to Estimate Cloud Condensation Nuclei (CCN) Concentrations in the Southeast Atlantic” by Lenhardt et al., submitted to Atmospheric Measurement Techniques, 2022.

Overview:

This paper presents empirical relationships between remote sensing and in situ measurements of aerosol properties that were made during the NASA ORACLES project. The goal is to inform vertically-resolved CCN concentration retrieval algorithms that are heavily based on HRSL-2 data in the southeastern Atlantic airmasses dominated by smoke. The results presented in the form of correlation coefficients indicate that there is a strong relationship between HSRL-2 observations and the in situ CCN measurements from aircraft mounted sensors.

Review:

The paper is well organized and written. The figures complement the conclusions and are laid out appropriately. I do not find the conclusions to be overwrought because the authors state that the correlations described are limited to the SEA region and BBA type that was observed during ORACLES. However, there is a general reliance on the HSRL-2 observations without adequate caution. The authors are experienced with this system, so I recommend they include a more complete description of the limitations of the instrument on the airborne platform and the how the error propagates into the relationships derived herein, especially with regards to volume averaging extinction and backscatter coefficients. After the inclusion of such a discussion, I would find the paper suitable for publication.

We appreciate the kind feedback on the positive aspects of our paper. HSRL-2 uncertainty was not accounted for in the original regression, as officially reported HSRL-2 uncertainty values are only available for ORACLES 2016, because the instrument was located on a high-flying platform in this campaign, allowing for careful calibration with clear-air returns. However, upon receiving this question we reached out to the ORACLES HSRL-2 team and were advised on how to calculate approximate uncertainty values for 2017 and 2018 data. This was done using a spatial variability method that we describe in a new Section 2.3 titled “HSRL-2 Uncertainty Calculations” (lines 291-310). We take HSRL-2 observables from 5 profiles before and 5 profiles after each collocated data point (at the same altitude) and calculate the standard deviation across all profiles. This results in one HSRL-2 uncertainty value for each collocated data point.

We then compare our uncertainties calculated using this spatial variability method with the reported uncertainties available for September 2016 (Table 3). Through this comparison we show that our mean calculated uncertainties are on the same order of magnitude as officially reported uncertainties. However, our calculated values do span a wider range than reported uncertainties, suggesting that this method captures a possible upper-bound to HSRL-2 uncertainties. Since the means from our method match well with reported mean values and the ranges do not tend to underestimate uncertainty, we move forward with using our calculated values to depict HSRL-2 error via horizontal error bars on Figures 3 and 6. A plot is provided for the reader below to visualize the comparison between reported and calculated uncertainties. Section 2.3 and Table 3 read as follows:

"The forthcoming analysis develops a regression between HSRL-2 observables and CCN concentration, both of which are observed quantities measured with uncertainty. Therefore, we consider uncertainties associated with both measurements and with the slope of each regression. At the time of this analysis, reported HSRL-2 uncertainties were only available for September 2016. Therefore, we have taken a spatial variability approach to estimate uncertainties for HSRL-2 data from August 2017 and September-October 2018. This method uses backscatter and extinction coefficients in the same vertical bin from five profiles before and five profiles after the HSRL-2 profile associated with each collocated data point. We analyze the distributions of backscatter and extinction across these profiles to ensure no large variations in either coefficient, i.e., that we are accurately estimating instrument uncertainty and not including a large gradient due to aerosol spatial inhomogeneity. After this step we calculate the standard deviation across all eleven profiles to use as a measure of uncertainty.

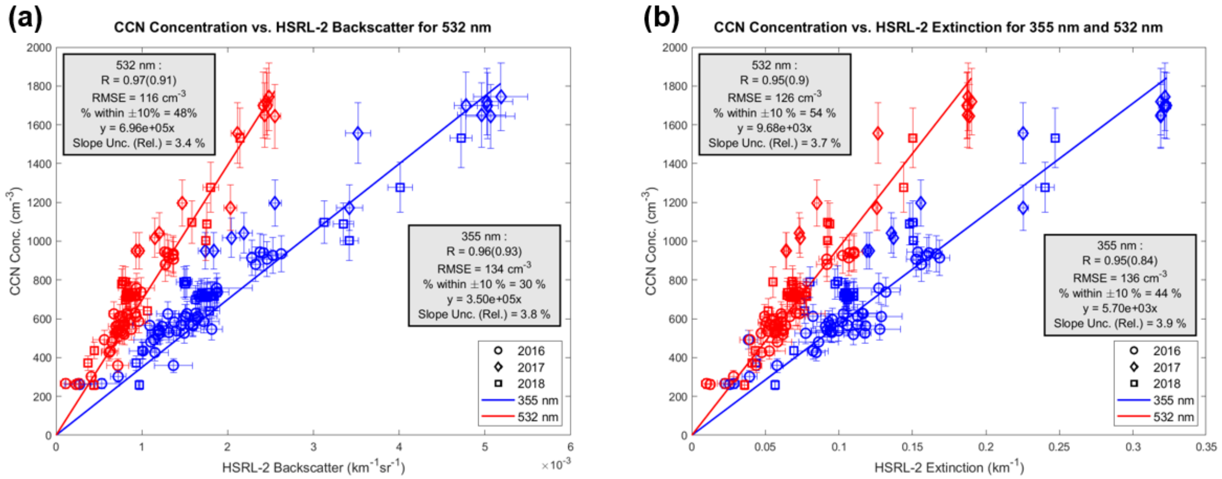
In Table 3 we present a comparison between HSRL-2 uncertainties calculated using this spatial variability method to the reported HSRL-2 uncertainties available for September 2016. In general, the mean uncertainties from both methods are on the same order of magnitude and very close in value. However, our calculated uncertainties span a wider range than reported uncertainties, suggesting that this method captures a possible upper-bound to HSRL-2 uncertainties. While this method only accounts for random uncertainties in backscatter and extinction measurements, systematic uncertainty for backscatter is reported as 5% for 355 nm and 4.1% for 532 nm while extinction is dominated by random error and has a small systematic error (Burton et al., 2015). Given the similar mean uncertainties and possible slight overestimation of HSRL-2 reported uncertainty (rather than consistent underestimation of error) using our spatial variability method, we use these values when considering uncertainty impacting the forthcoming regressions. Furthermore, we present this spatial variability method as a reasonable way to estimate HSRL-2 uncertainties in future studies."

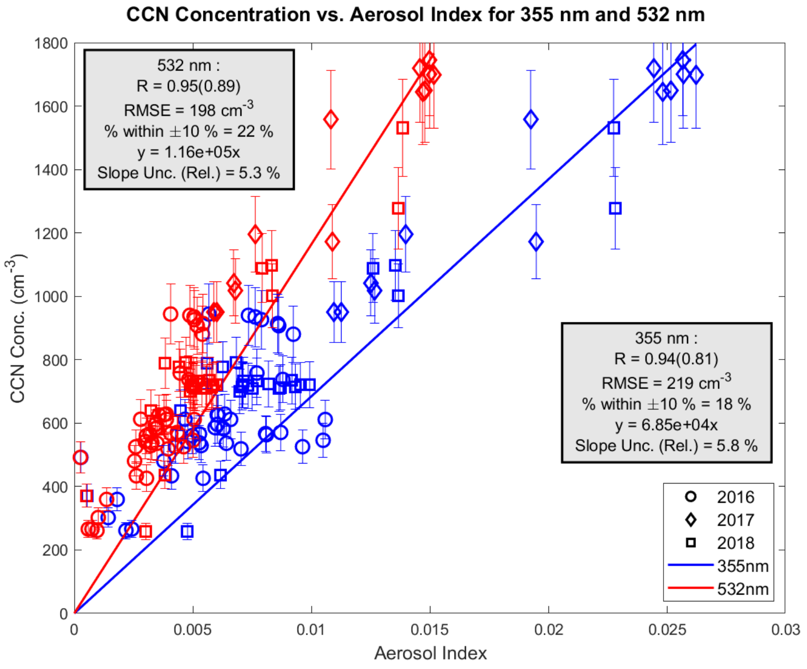
Table 3: Comparison of HSRL-2 reported uncertainty to uncertainties calculated using a spatial variability method for September 2016.

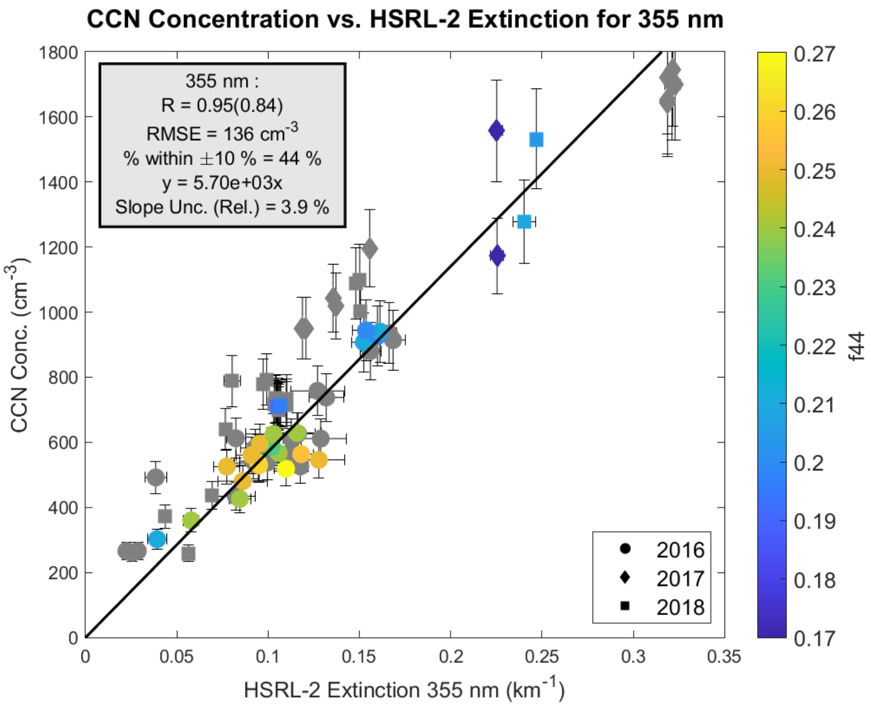
	Reported HSRL-2 Uncertainty		**HSRL-2 Uncertainty Calculated from Spatial Variability Method**	
	Range	Mean	Range	Mean
BSC355 (km^{-1}sr^{-1})	5.5E-05 – 2.1E-04	1.5E-04	6.3E-05 - 4.17E-04	1.4E-04
BSC532 (km^{-1}sr^{-1})	3.2E-05 – 7.3E-05	6.2E-05	2.9E-05 - 2.1E-04	7.0E-05
EXT355 (km^{-1})	4.7E-03 – 1.2E-02	8.8E-03	2.1E-03 – 1.5E-02	7.6E-03
EXT532 (km^{-1})	3.8E-03 – 5.6E-03	4.9E-03	1.9E-03 – 1.7E-02	6.4E-03

Figures 3, 4, and 6 are updated to include error bars in the manuscript and are shown below. Their captions have also been edited to reflect changes made to the plots. Note that

Figure 4 does not include horizontal error bars. This is due to the fact that extinction and Angstrom exponent are not independent of each other, there is no straight-forward way to calculate the propagation without estimates of error covariance, and the uncertainties in aerosol index are not further used in the manuscript.







While we now consider HSRL-2 and CCN uncertainty using bisector regression, error bars, and a measure of slope uncertainty, we do not propagate all sources of uncertainty into one value to be used as an estimate of uncertainty associated with lidar-derived CCN concentration. This is again because not all sources of error within these regressions are independent of each other – error in the slope is dependent on both HSRL-2 and CCN uncertainty. That is, the assumptions of error propagation do not hold when trying to incorporate each of these sources of error into one value. Therefore, we do not calculate a propagated error value applicable to our lidar-derived CCN concentrations. However, we acknowledge that we use a simplified methodology with multiple possible sources of uncertainty. We discuss all sources of uncertainty in a new Section 4.3 titled “Sources of Uncertainty” that aims to qualify the performance of these regressions in light of the aforementioned sources of uncertainty. Section 4.3 reads as follows:

“As previously mentioned and taken into consideration via bisector regression, both CCN and HSRL-2 are observations made with uncertainty. Relative CCN uncertainty is 10% and our spatial variability method of calculating HSRL-2 uncertainties resulted in mean values of 1.4E-04 km^{-1}*sr*$^{-1}$ *and 7.0-E-05 km*$^{-1}$*sr*$^{-1}$ *for backscatter at 355 and 532 nm, respectively, and 0.0076 km*$^{-1}$ *and 0.0064 km*$^{-1}$ *for extinction at 355 and 532 nm, respectively (Table 3). In addition, uncertainty is introduced as a result of the regression itself. Relative slope uncertainties range from 3.0-3.6% (Figure 3). We discuss each of these sources of error separately due to their dependence on one another. Uncertainties in both CCN concentration and HSRL-2 observations will impact uncertainty in the slope of each regression. Therefore, the assumption of each source of error being independent that is required for error propagation calculations does not hold. Rather, we present our method of deriving CCN concentration from lidar observables with such explanation of the various sources of error that will impact results.*

In addition to observational and regression-based uncertainties, another possible source of error when applying this method stems from the specific characteristics of the data set used to develop the regression equations. The relationships analyzed in this study are specific to BBA in the SEA. Additionally, they are specific to ambient conditions with low RH (≤40-50%), S≥0.2%, and aerosol ages represented by f44 values between about 0.17-0.27. While these conditions are characteristic of the high-altitude SEA smoke plume, they will not hold in all regions and for all aerosol types. Therefore, without careful consideration of the ambient conditions and aerosol types to which the regressions derived here are applied, increased uncertainty will be introduced in lidar-derived CCN concentrations. Despite the strict conditions under which our regressions are applicable, we will explore their performance on a larger portion of the collocated data set in the following section."

In terms of volume-averaging extinction and backscatter coefficients in our collocation method, we provide standard deviation values in the table below. These values represent the standard deviation of HSRL-2 coefficients vertically averaged that go into each collocated data point. Depending on the year, approximately 3-6 values are vertically averaged.

	Standard Deviation of Volume-Averaged HSRL-2 Coefficients	
	Absolute Mean	**Relative Mean**
BSC355	9.3E-05 $km^{-1}sr^{-1}$	6.5%
BSC532	4.4E-05 $km^{-1}sr^{-1}$	5.9%
EXT355	3.4E-03 km^{-1}	3.4%
EXT532	2.3E-03 km^{-1}	4.6%

We provide these values in comparison to the HSRL-2 uncertainty values given in the previous table to show that our vertical averaging of HSRL-2 coefficients into each collocated data point results in standard deviations comparable to or lower than our approximate HSRL-2 calculated uncertainties. Therefore, the volume averaging step of our collocation method does not result in averaging over highly variable backscatter and extinction coefficients.

Minor comments:

In the second line of the Figure 9 caption, ".0.5" should be replaced with "0.5"

Figure 9 was adjusted based on comments from Reviewer 1. Therefore, this issue was resolved as the caption was also changed.