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Characterizing Potential Radiative Forcing on the North Slope of Alaska Field Campaign Report

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Acronyms and Abbreviations

AAE	absorption Angstrom exponent
AAOD	absorption aerosol optical depth
AERONET	Aerosol Robotic Network
AMF	ARM Mobile Facility
AOD	aerosol optical depth
ARM	Atmospheric Radiation Measurement
BC	black carbon
BrC	brown carbon
CSPHOT	Cimel sun photometer
DOE	U.S. Department of Energy
EC	elemental carbon
MAE	mass absorption efficiency
NASA	National Aeronautics and Space Administration
NIOSH	National Institute for Occupational Safety and Health
NSA	North Slope of Alaska
OC	organic carbon
PI	principal investigator
QFF	quartz fiber filter
UV	ultraviolet
WSOC	water soluble organic carbon

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1.0 Summary

The goal of the campaign was to quantify black carbon (BC) and brown carbon (BrC) and their contributions to absorption for two coastal sites on the North Slope of Alaska (NSA). This field campaign was intended to expand on PI Sheesley's successful 2012-2013 U.S. Department of Energy (DOE) Atmospheric Radiation Measurement (ARM) Climate Research Facility campaign, the Barrow Black Carbon Source and Impact Study field campaign. The two sites selected for this campaign were the Barrow, Alaska (now known as Utqiagvik) observatory and the ARM Mobile Facility at Oliktok Point. The purpose of having two sites was to better assess regional extent and impacts of regional and long-range sources on NSA BC and BrC, and allow a more comprehensive determination of regional aerosol absorption coefficients and regional hygroscopicity and regional aerosol optical depth (AOD) and absorption AOD (AAOD). AOD is a parameter used for determining atmospheric aerosol loading since AOD data from a sun photometer is highly accurate. AAOD provides information to determine the absorption component of aerosol radiative forcing for the total air column, including aerosol at both the surface and aloft.[1]

Set up began on June 12, 2016, at Barrow. A high-volume sampler was set up on top of one of the towers (Figure 1). The sampler was calibrated and ARM technician Jimmy Ivanoff was trained on the filter-change protocol. Jimmy Ivanoff was the primary technician for this sampler and contributed significantly to the success of the campaign. Quartz fiber filters (QFF) were stored onsite in a freezer and a specific area of the shelter was set up for filter changes. Sampling began on June 15, 2016. Samples were collected for one-week durations. The sampler was stopped three times due to inclement weather for up to a day each. There was one instance of snow collecting on the filter. In total, 619,415 mins were sampled for a total of 699,108 m^3 of air collected, for a total of 63 samples which were acceptable for analytical use.

Figure 1. The high-volume air samplers set up at Barrow, Alaska (left) and Oliktok Point, Alaska (right).

Due to a parallel ARM campaign that took place in summer 2016, an aethalometer was not set up onsite until the end of September 2016. Once set up, ARM technicians sent the data collected from the instrument to a graduate student once a week. Set-up began on June 15, 2016, at Oliktok Point. A high-volume air sampler was set up on top of the AMF3 facility (Figure 1). The sampler was calibrated and the

technicians were trained on filter change protocol. Multiple technicians were responsible for the sampler at Oliktok. The QFFs were stored in a freezer in the AMF3 and a specified area was set up for filter changes. Sampling began on June 15, 2016. Samples were collected for a duration of one week, with the exception of those collected during a parallel campaign occurring in August-September 2016 where filters were changed more frequently by Moffett, who was on-site from Baylor. The flow controller on the sampler broke in mid-November as a result of snow entering the sampler body, and two weeks of sample collection were lost as the technicians awaited the arrival of a replacement. The sampler was shut down on three occasions due to inclement weather. In total, 589,969 mins were sampled for a total of 668,241 m^3 of air collected for a total of 64 samples, of which 62 were acceptable for analytical use. An aethalometer was run at Oliktok Point during August-September 2016 as part of a parallel ARM field campaign. The ARM CIMEL sun photometers (CSPHOT) were used to assess AAOD and aerosol characteristics in the vertical column at both Barrow and Oliktok Point during months of sunlight (spring-fall).

The graduate student involved with the project gained valuable experience in planning and carrying out a high latitude sampling campaign. She was able to travel to the DOE ARM facilities in Barrow and Oliktok Point several times to set up of the samplers and train technicians. She also managed the campaign from Baylor and was in routine contact with technicians from both sites and Hi-Q, the sampler manufacturer.

The concentrations of organic carbon (OC) and elemental carbon (EC) were determined using the weekly QFF using a Sunset Lab Carbon Analyzer with the NIOSH 5040 protocol.[2] The samples were also analyzed for absorption using a UV-Vis spectrophotometer and analyzed for water soluble organic carbon (WSOC). The data was then used to calculate the mass absorption efficiency at 365 nm (MAE_{365}) and the absorption Angstrom exponent (AAE), which gives information about the wavelength dependence of WSOC absorption. Some samples were extracted together in a composite due to area of filter available, in addition, some did not contain enough WSOC to produce a strong signal during analysis by UV-Vis.

For the aethalometer, BrC ambient concentrations are calculated at a wavelength of 370 nm and the BC ambient concentrations are calculated at a wavelength of 880 nm.

The Cimel Sun-Photometer data were collected by DOE as part of the ARM Climate Research Facility and processed by the National Aeronautics and Space Administration (NASA)'s Aerosol Robotic Network (AERONET). The AOD and AAOD for two wavelengths, 440 and 870 nm, was calculated for this campaign for the available dates, i.e., clear-sky dates.

2.0 Results

Barrow had low concentrations of both OC and EC (Figure 2). There is an increase in EC ambient concentrations in the winter months which is consistent with previous long-term studies in Barrow where the highest concentrations are during the winter and the lowest are in the summer, with spring and fall as transitional periods.[3] The average ambient concentration of OC was 0.18 ± 0.01 μg m^{-3} and the average ambient concentration of EC was 0.016 ± 0.008 μg m^{-3}. Oliktok Point also generally had low ambient concentrations of OC and EC with the exception of a few periods of high OC. While it also displayed higher EC in the wintertime, following the trend at Barrow, there were also periods in other seasons

where EC was high. The average ambient concentrations of OC and EC were 0.35 ± 0.03 μg m^{-3} and 0.05 ± 0.01 μg m^{-3} respectively.

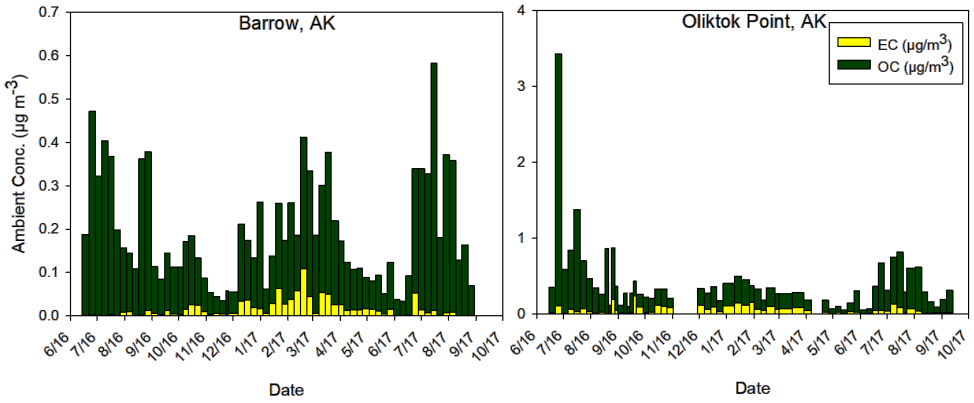

Figure 2. The OC and EC ambient concentrations for Barrow, Alaska and Oliktok Point, Alaska for the duration of the sampling campaign.

Seasonal averages for each site were also calculated for summer (June-August), fall (September-November), winter (December-February), and spring (March-May) which can be found in Table 1. Oliktok Point had higher average ambient concentrations of OC in all seasons except spring, where the averages were the same, and had higher average ambient concentrations of EC in all seasons. This can be attributed to the sites proximity to oil and gas extraction and exploration activity. Additional chemical characterization of the OC constituents would facilitate better apportionment.

Table 1. Seasonal averages for ambient concentrations of OC and EC at both sites.

	Barrow, AK				Oliktok Point, AK			
Season	**OC (μg m^{-3})**	**OC unc.**	**EC (μg m^{-3})**	**EC unc.**	**OC (μg m^{-3})**	**OC unc.**	**EC (μg m^{-3})**	**EC unc.**
Summer	0.25	0.02	0.006	0.007	0.55	0.04	0.043	0.010
Fall	0.09	0.01	0.009	0.008	0.20	0.02	0.074	0.014
Winter	0.18	0.02	0.040	0.011	0.24	0.02	0.091	0.012
Spring	0.13	0.01	0.019	0.008	0.13	0.01	0.032	0.008

The aethalometer shows similar trends of both BrC and BC to EC ambient concentrations at Barrow. Concentrations of BrC and BC are low in the summer and fall months and increase in the winter and spring which follows previously reported trends for BC.[3] Data was collected at 20 minute intervals in order to ensure sufficient loading for a measurement. Figure 3 shows the daily average ambient concentrations for both BrC and BC at Barrow from October 2016 through August 2017.

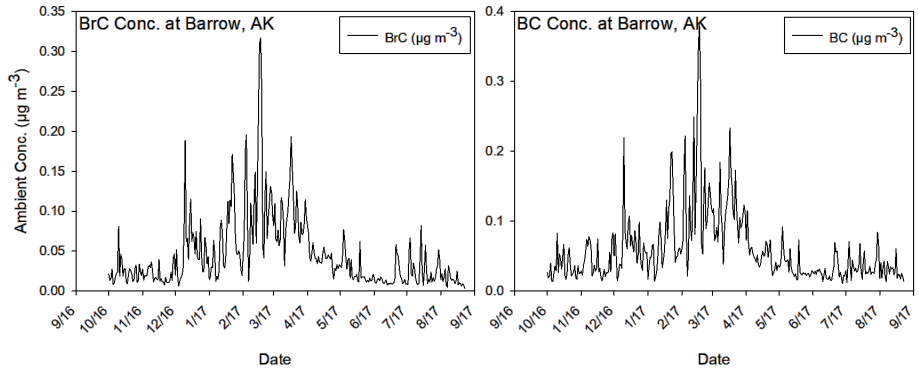

Figure 3. The BrC and BC daily average ambient concentrations in Barrow, AK, from October 2016 through August 2017. BrC concentrations are calculated at 370 nm and BC concentrations are calculated at 880 nm.

In Barrow, Alaska, WSOC ambient concentrations ranged from 0.05 to 0.43 µg m^{-3} (Figure 4), which is similar to previously reported values.[4] Average seasonal MAE_{365} values were 0.42 ± 0.05 m^2 g^{-1} in the fall, 0.35 ± 0.2 m^2 g^{-1} in the winter, and 0.11 ± 0.1 m^2 g^{-1} in the spring. MAE_{365} values were not available for the summer season due to low loading on the filters. There were two time periods at Barrow where the WSOC and MAE_{365} appear to trend together and two time periods where when the WSOC was high the MAE_{365} was low and vice versa. At Oliktok Point the WSOC ambient concentrations ranged from 0.08 to 2.9 µg m^{-3}. When WSOC ambient concentrations were high, the MAE_{365} was relatively low, and when WSOC concentrations were low, the MAE_{365} tended to be high. The average MAE_{365} value was 0.23 ± 0.19 m^2 g^{-1} in the summer, 0.46 ± 0.18 m^2 g^{-1} in the fall, 0.42 ± 0.19 m^2 g^{-1} in the winter, and 0.25 ± 0.28 m^2 g^{-1} in the spring. Previous studies have shown that higher MAE_{365} values may result from WSOC emitted from biomass burning, primary and secondary organic aerosols from coal burning, and secondary organic aerosol produced from aromatic hydrocarbons.[4-7] Those time periods with lower MAE_{365} values are likely due to more contemporary biogenic sources. The results found in this study in Oliktok Point show more biomass burning and fossil fuel combustion sources in the late fall and winter, and more biogenic sources in the summer and spring.

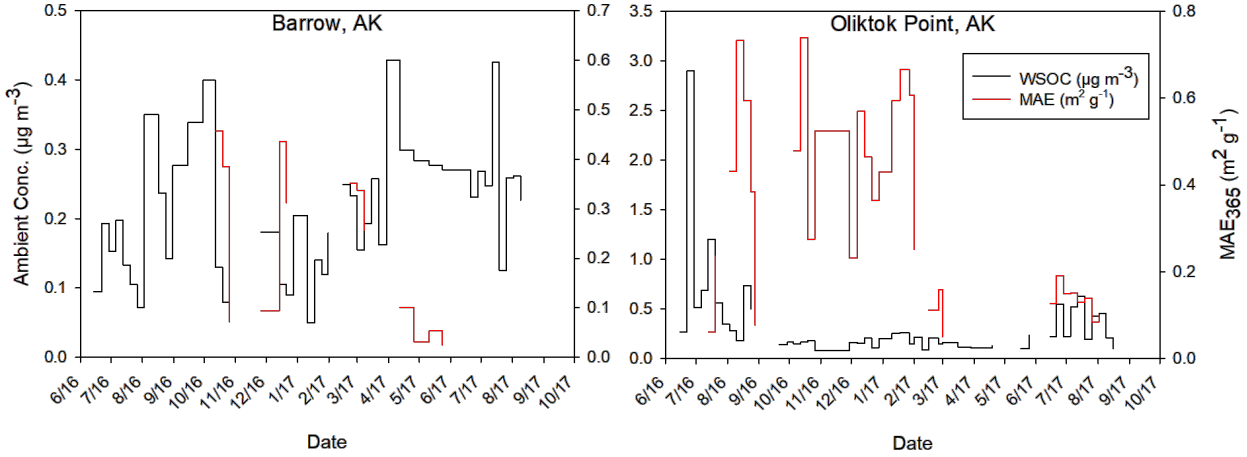

Figure 4. The WSOC ambient concentrations and calculated MAE365 values for both sites from June 2016 through August 2017.

The AOD and AAOD for two wavelengths, 440 and 870 nm, are shown in Figure 5. At both sites when MAE365 was high, the AOD and AAOD were relatively low. At Barrow, there is insufficient data for the summer and fall of 2016 to compare to MAE365 values. In summer 2017 at Barrow, it appears as though when the MAE365 is lower, the AOD and AAOD are higher. At Oliktok Point, AOD and AAOD values appear to be high when MAE365 values are low in the spring and summer months and are lower when MAE365 values are higher in the fall. All these are comparisons among MAE365 and then among AOD and AAOD; in other words, relative to the entire campaign, the MAE365 were low or high. Barrow tended to have higher AOD and AAOD values in summer 2017 than Oliktok Point, for the few measurements that were made. There is insufficient data to compare the two sites to each other for the summer and fall of 2016. Since AOD and AAOD are total column measurements while the MAE365 is a boundary-layer/ground-based measurement, they would only vary together if absorbing aerosol was dominated by the boundary layer.

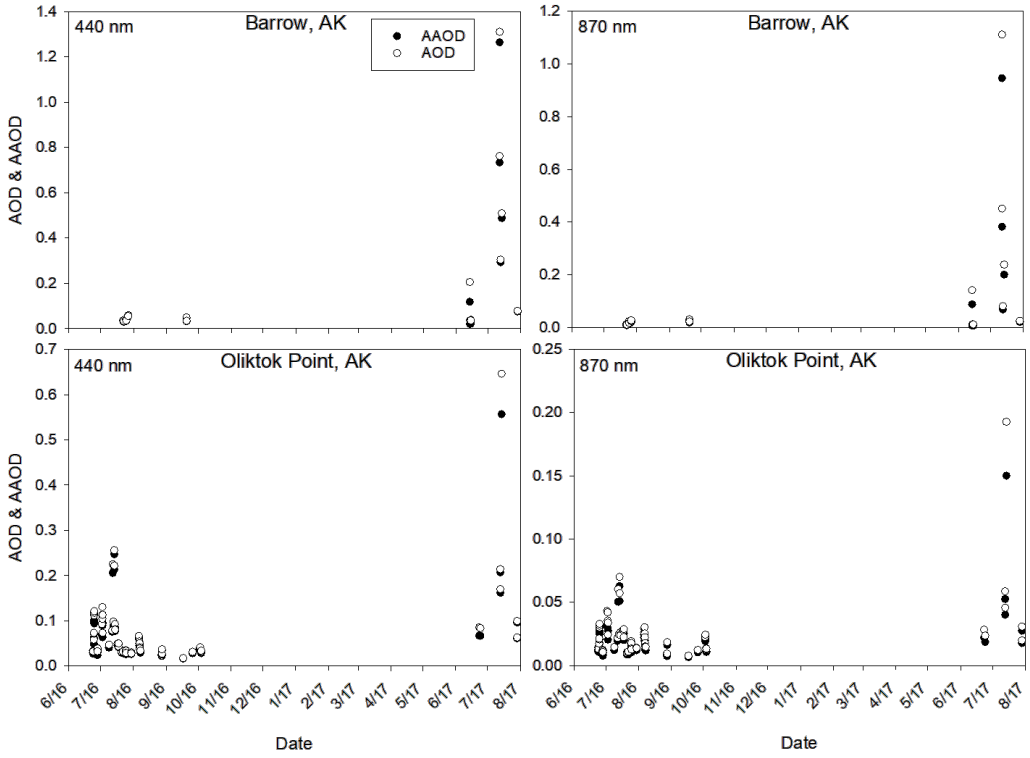

Figure 5. The AOD and AAOD values for Barrow and Oliktok Point for June 2016 through August 2017.

3.0 Conclusion

The goal of the campaign was to quantify BC and BrC and their contributions to absorption for two coastal sites on the NSA. The OC ambient concentrations at Barrow were lower than those at Oliktok Point over all seasons except spring where their average concentration was the same. Barrow EC ambient concentrations were also lower than those at Oliktok Point for all four seasons. Both sites experienced high concentrations in EC during the winter months and low concentrations of EC during the summer. WSOC ambient concentrations at the two sites varied with Oliktok Point having significantly higher

concentrations in the summer, likely due to events of high OC. MAE365 values at Oliktok Point tended to be higher than those at Barrow, indicating that they have a higher contribution from biomass burning and fossil fuel combustion. The results from this study indicate that Barrow and Oliktok Point have divergent sources for absorbing carbon, including both BrC and BC. There were very few clear days for AOD and AAOD measurements in Barrow in the summer of 2016, while Oliktok had a larger dataset. The AOD and AAOD at Oliktok did not seem to trend with the MAE365 based on preliminary evaluation.

4.0 Publications and References

4.1 Presentations

1. Moffett, CE, TE Barrett, MJ Gunsch, KA Pratt, and RJ Sheesley. 2017. "The relationship between organic carbon and methanesulfonic acid at two sites on the North Slope of Alaska over four summers." American Geophysical Union 50th Annual Fall Meeting.
2. Moffett, C., TE Barrett, MJ Gunsch, KA Pratt, and RJ Sheesley. 2017. "Biogenic and fossil contributions to organic aerosol at two sites on the North Slope of Alaska." European Geophysical Union 14th Annual General Assembly.

4.2 References

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5.0 Lessons Learned

A few lessons were learned during the campaign. After the 2012-2013 ARM campaign, the Barrow Black Carbon Source and Impact Study field campaign, new high volume samplers were purchased as the samplers used in the 2012 campaign were older and required consistent motor maintenance in the field. The new samplers contained newer technology, such as electronic flow controllers, and were insulated to protect from the cold. The samplers operated considerably better, with much improvement in motors and the flow recording and control.

Precautions were made for motor failure in the field by taking an extra motor to each site; however, extra electronics were not sent as the flow controller was not expected to break. This was an issue at the Oliktok Point site when snow entered the sampler body and affected the flow controller. The samplers also needed to be better protected from the snow. While they were insulated from the cold, there were a few instances of snow entering the lid of the sampler and affecting the filter. A net was placed over the samplers to keep snow out after the initial problem. In the future this should be placed on the sampler before snow becomes an issue.

Modifications to the training of technicians in the field might be considered in the future. At Barrow, there was one technician who would be changing filters and handling sampler maintenance. This made the communication of information easy and straightforward. At Oliktok Point there were multiple technicians who would be handling filter changes and sampler maintenance. During the training, only one technician was trained and the information was passed on to other technicians. In the future, it might be better to schedule set-up and training around the time when technicians are switching shifts to facilitate operation and communication.


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