APPLICATION NOTE

NIKIRA LABS – AN01 - OEA

Nikira Labs

App Note Series: Optical Extinction Analyzers

10 Hz Measurements of Optical Extinction for Eddy Flux Applications

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Introduction

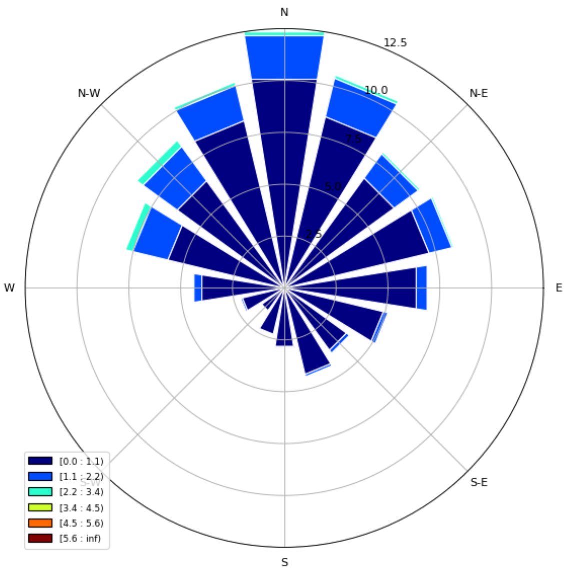
The Eddy flux (or Eddy covariance) technique has been extensively used to study evapotranspiration, latent heat transfer, and greenhouse gas cycling. The technique typically requires a fast (e.g., 10 Hz) analyzer to measure the species of interest, a sonic anemometer to measure windspeed and direction, and data logger to acquire and synchronize the two data streams. Extending this technique to aerosol studies is promising due to their impact on radiative forcing as well as their effect on terrestrial gas fluxes. Moreover, by correlating aerosol concentrations with wind direction, particulate sources can be localized.

In this brief application note, we demonstrate the use of a Nikira Labs OEA-532EC Fast Optical Extinction Analyzer coupled with a RM Young 81000V Sonic Anemometer to localize an aerosol source and determine the aerosol flux via the eddy covariance technique.

Experimental Setup

The OEA-532EC was placed at a height of ~1 meter above the ground. The sonic anemometer was located adjacent to the analyzer, and a humidifier was placed 1.5 meters away from the analyzer. The latter served as a continuous point source of aerosols by producing mist and humidifying existing aerosols in the air. The OEA-532EC was configured to directly log the sonic anemometer, obviating the need for a data logger of post-synchronization of the data.

The histogram of measured azimuthal wind speeds and directions is shown in Figure 1. Note that, due to the geometry of the deployment in an urban environment, winds were limited in their azimuthal direction.



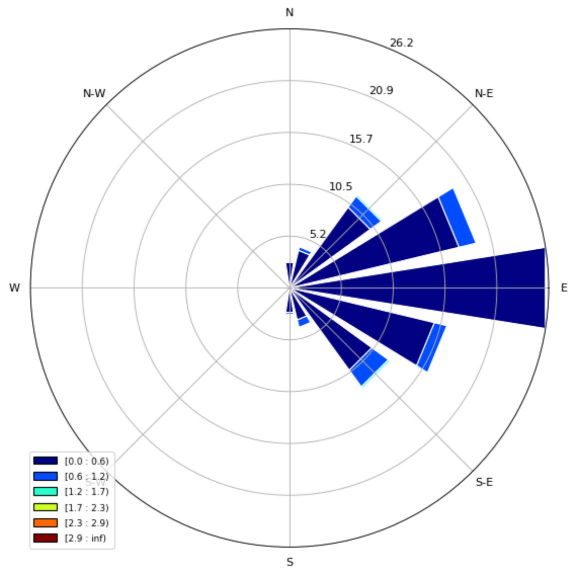


Figure 1: (left) Wind rose showing azimuthal wind direction and magnitude.

Figure 2: (right) Wind rose showing vertical wind direction (90 degrees corresponds to no vertical component) and magnitude.

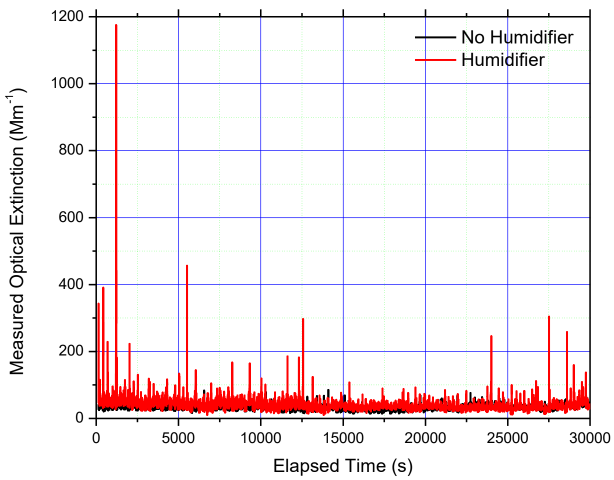
The complementary measurements of vertical wind speed and elevation angles are shown in Figure 2. Note that the upwind and downwind components are relatively equal and small in magnitude.

Two runs were performed, the first with the humidifier on and the second with the humidifier off.

The humidified run was limited to ~8 hours by the humidifier lifetime, whereas the dehumidified run lasted ~25 hours.

Results & Discussions

The measured optical extinction versus time over the first 8 hours is shown for both runs is shown in Figure 3. Note that the data presented during humidification shows occasional sharp spikes. Moreover, an expanded view of such features (Fig. 4) shows how the high 10 Hz data rate of the instrument is able to clearly capture these aerosol extinction events with multiple points. Note that the small shift in overall baseline (~15 Mm^{-1}) cannot be clearly attributed to humidification as the runs were performed on different days and the background aerosol optical extinction may not be constant.



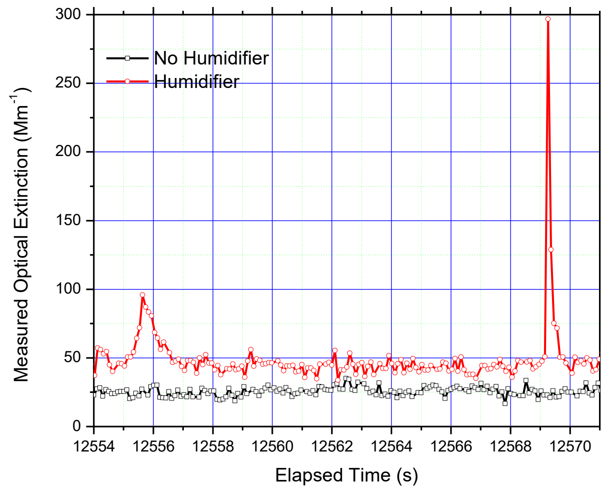


Figure 3: **(left panel) Measured optical extinction versus elapsed time with the humidifier on (red) and off (black).**

Figure 4: **(right panel) Expanded view of a two select aerosol extinction spikes shows how the 10 Hz data rate allows for clear quantification of such events.**

A set of wind roses was then generated for both datasets with different optical extinction thresholds: 0 Mm^{-1}, 20 Mm^{-1}, 100 Mm^{-1}. Data below threshold was removed from the plot. The data without humidification is shown in Figure 5. Note that the 0 Mm^{-1} shows all of the measured data points. Only ~2.3% of the data has optical extinction values that exceed 20 Mm^{-1}. This data shows rough directionality. Finally, without the humidifier, there were no measured optical extinction values that exceeded 100 Mm^{-1}.

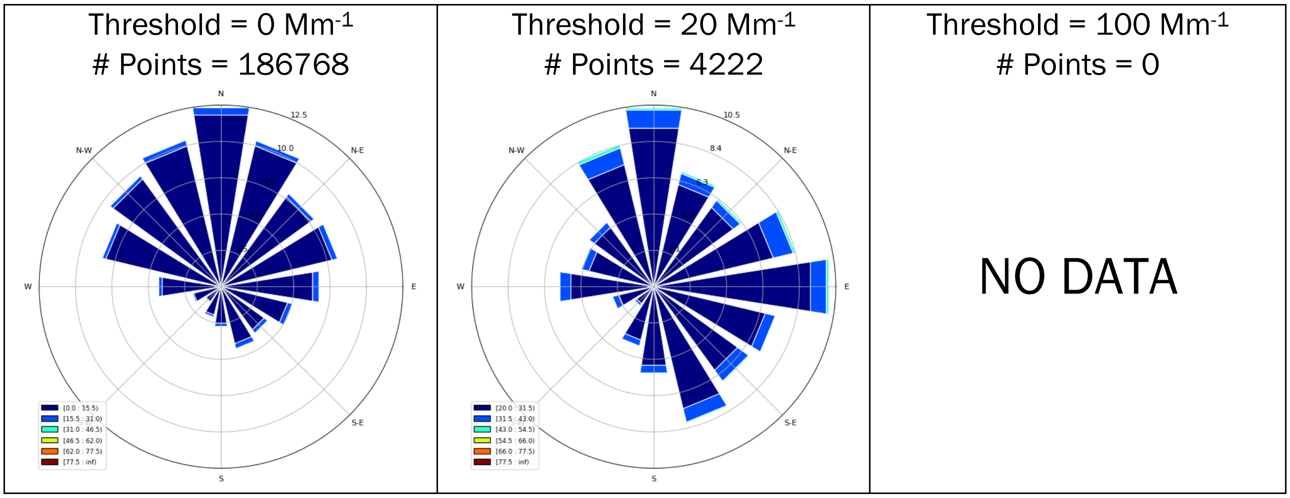


Figure 5: **Data with humidifier off and different thresholds. The polar length of the polar histogram bars shows the number of measurements taken at a specific angle. The bar colors indicate the measured optical extinction.**

Similar data with the humidifier on are shown in Figure 6. The no threshold data again shows a good wind direction distribution. Both the 20 Mm^{-1} and 100 Mm^{-1} thresholds show strong directionality that points towards the humidification source, clearly showing the source location.

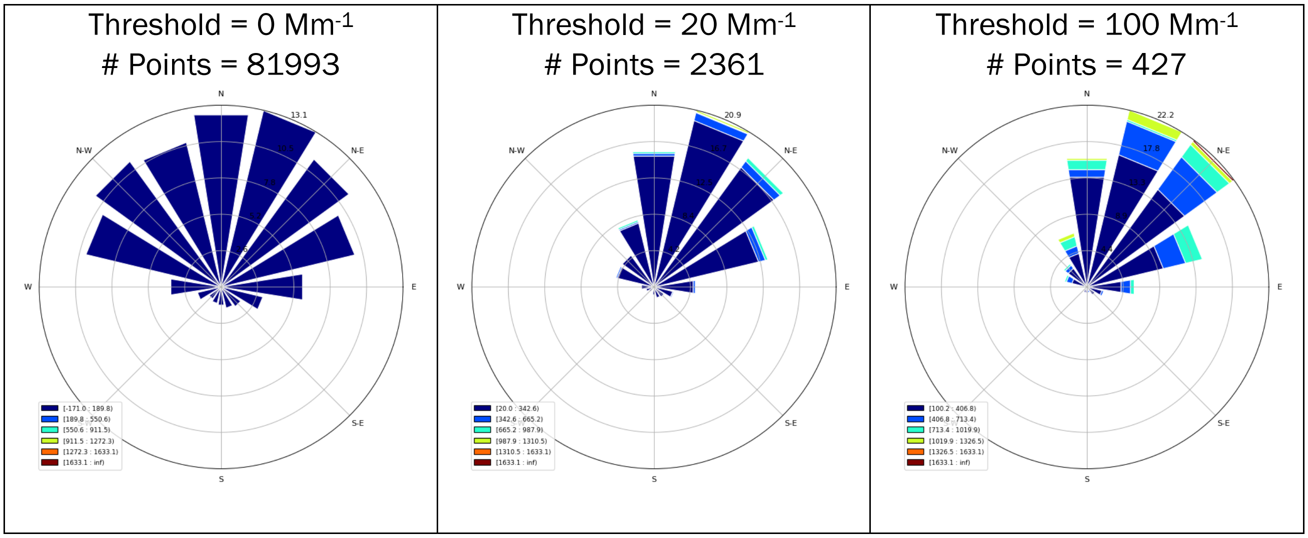


Figure 6: Data with humidifier on and different thresholds. The polar length of the polar histogram bars shows the number of measurements taken at a specific angle. The bar colors indicate the measured optical extinction.

The cross correlation between the vertical wind magnitude and measured optical extinction (Fig. 7) were examined as a function of time shift for both data sets, akin to conventional eddy flux methodologies. The data clearly shows that the humidified data is more strongly correlated with vertical wind direction. Note that a true eddy flux calculation would require better placement of the analyzer and a more homogenous source.

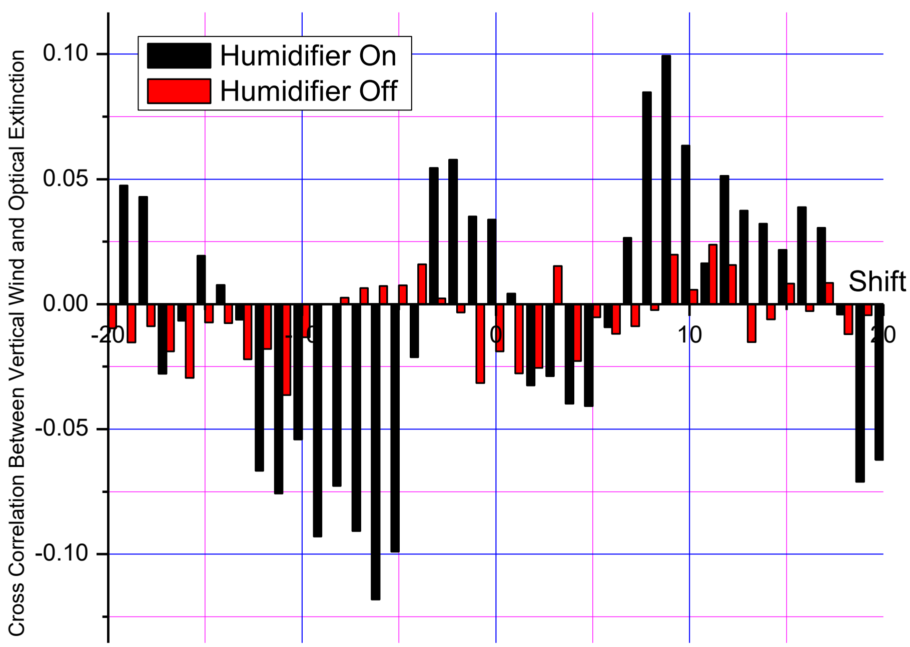


Figure 7: Cross correlation between vertical wind vector and optical extinction for both humidified and dehumidified datasets.

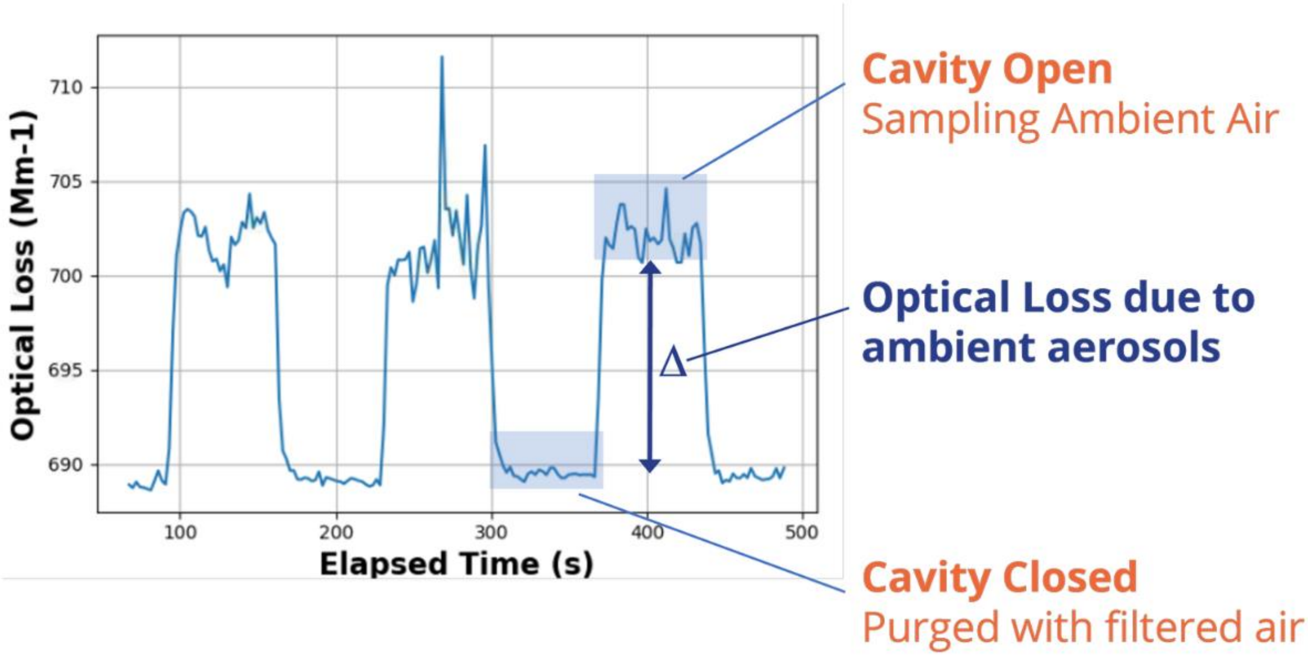
Further Work

This work can be extended in a variety of ways, including:

- Proper deployment for eddy flux studies (open area, higher tower, more homogenous source).
- Extinction measurement at multiple wavelengths to better characterize the particulates.
- Particle source modulation to gauge the effect on the baseline extinction values.
- Implementation of a dry aerosol generator to make particles of a known size and composition.
- Correlations between aerosol optical extinction and greenhouse gases (e.g., CO_2).

How Does the OEA Work?

1. Ambient air is pulled through a duct by fans at a speed of ~1 m/s.
2. Open-path cavity ringdown spectroscopy is used to make a direct measurement of the optical extinction coefficient (beta) in the sample.
3. The duct is periodically closed and the cell is purged with filtered air to a background measurement.
4. The difference between the open and closed duct values provides a direct, calibration-free measurement of the aerosol optical extinction.



The OEA Harnesses 3 Technologies: