A UV-Visible Broadband Cavity Enhanced Spectrometer for Ambient Aerosols

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1 | Introduction

Aerosols directly affect climate by scattering (= cooling) and absorbing (= warming) solar radiation. These are the aerosol direct effects and are a large uncertainty in climate models.

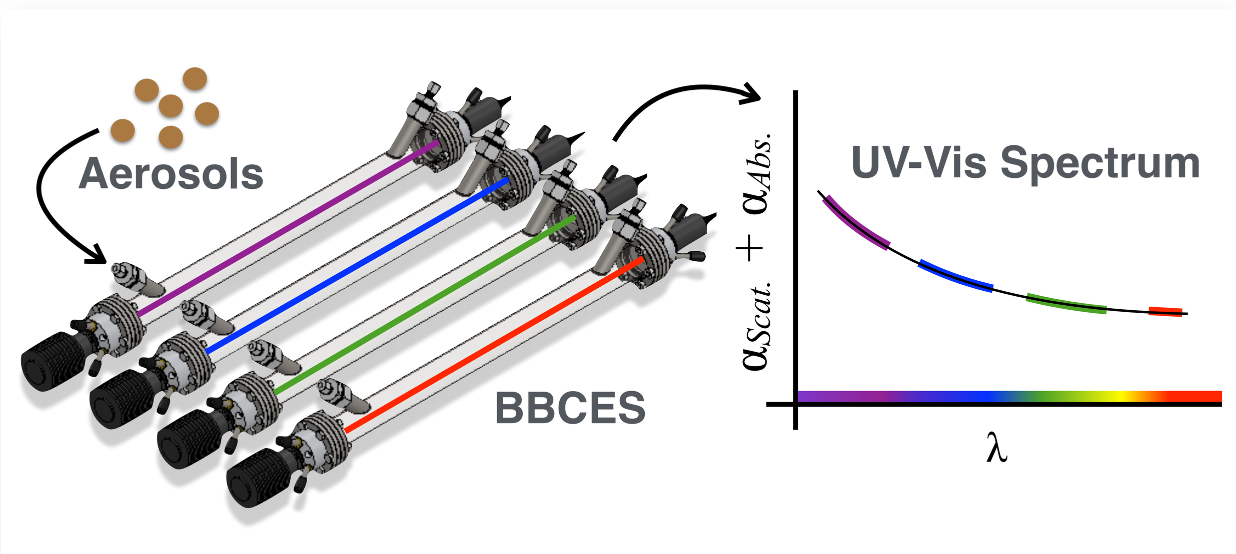
The wavelength dependence of aerosol extinction (scattering + absorption) is often inferred from two or three visible wavelengths and represented as the extinction Ångstrom exponent (EAE). The lack of wavelength coverage may lead to uncertainties in the measurement.

We have built a broadband cavity enhanced spectrometer (BBCES) that spans the UV-visible spectrum to provide hundreds of wavelengths for fitting and reduce uncertainty in EAEs.

2 | The Instrument

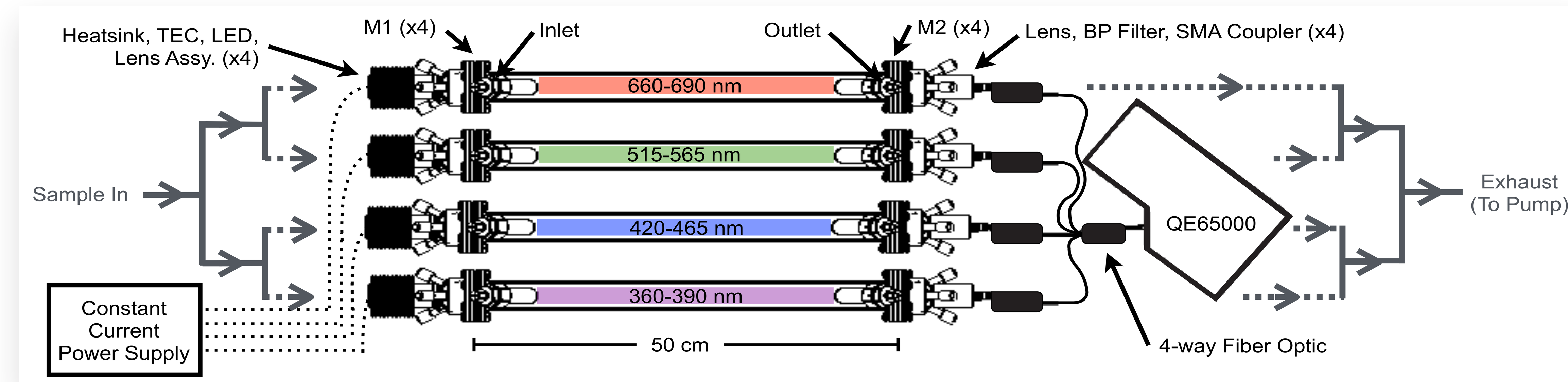
The UV-vis BBCES is composed of four channels. For each channel, light from a temperature-stabilized LED is coupled into an optical cavity bound by two highly reflective ($R \approx 99.99\%$) mirrors. Light leaking through the back mirror is focused onto a fiber optic and band-pass filtered, and the four fiber optics are combined into a single SMA connector on one end to allow direct coupling to a miniature grating spectrophotometer. The intensity loss measured with the spectrophotometer is proportional to total extinction.

Typical broadband instruments work over a narrow range of wavelengths (~50 nm, limited by the mirror reflectivity). [*Washenfelder + (2013)* AMT; Langridge + (2008) *Rev. Sci. Inst.*; *Zhao + (2014)* Anal. Chem.] To span the UV-visible spectrum, we use a custom fiber optic cable to combine the output from four parallel cavities (red, green, blue, and UV) with spectral ranges of ~50 nm each.



1 A four-channel BBCES allows for measurement of climate-relevant aerosol optical properties throughouth the UV-visible spectrum.

2 The 4 cells are coupled via a 4-core fiber optic into a single spectrophotometer for wavelength-resolved spectra.



3 | Application

Ambient aerosols were sampled in Athens, Georgia. A power law was fit via non-linear least squares to retrieve the EAE from the resulting spectra [*Kokhanovski (2008)* Aerosol Optics, *Springer*]:

$$\alpha_{Ext.} = \beta\lambda^{-EAE}$$

Though not included in the fit, a 355 nm Nd:YAG CRDS was used as a comparison to the BBCES.

4 | Impact

To demonstrate the utility of having a full-spectrum instrument, EAEs obtained from either the full spectrum or from individual points in various regions of the spectrum were compared.

A power law was fit to combinations of spectra acquired every second; on the same data, fits were performed with various single wavelength combinations to mimic a more traditional 2- or 4-wavelength CRDS.

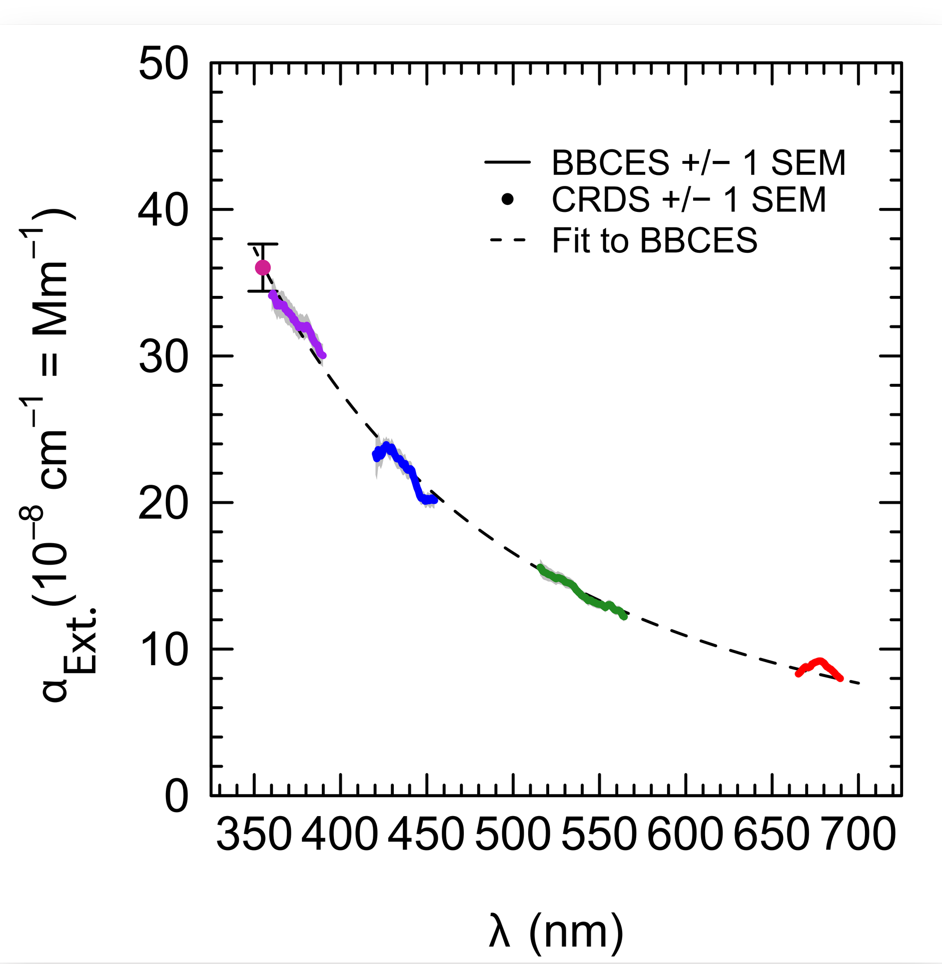
The availability of the full spectrum averages out noise between EAEs and narrows the distribution of the data; further, the median EAEs varied based on the combination of data used in fitting.

5 | Summary

We argue this 4-channel BBCES provides reduced uncertainty in EAE measurements compared to 1- or 2-channel instruments.

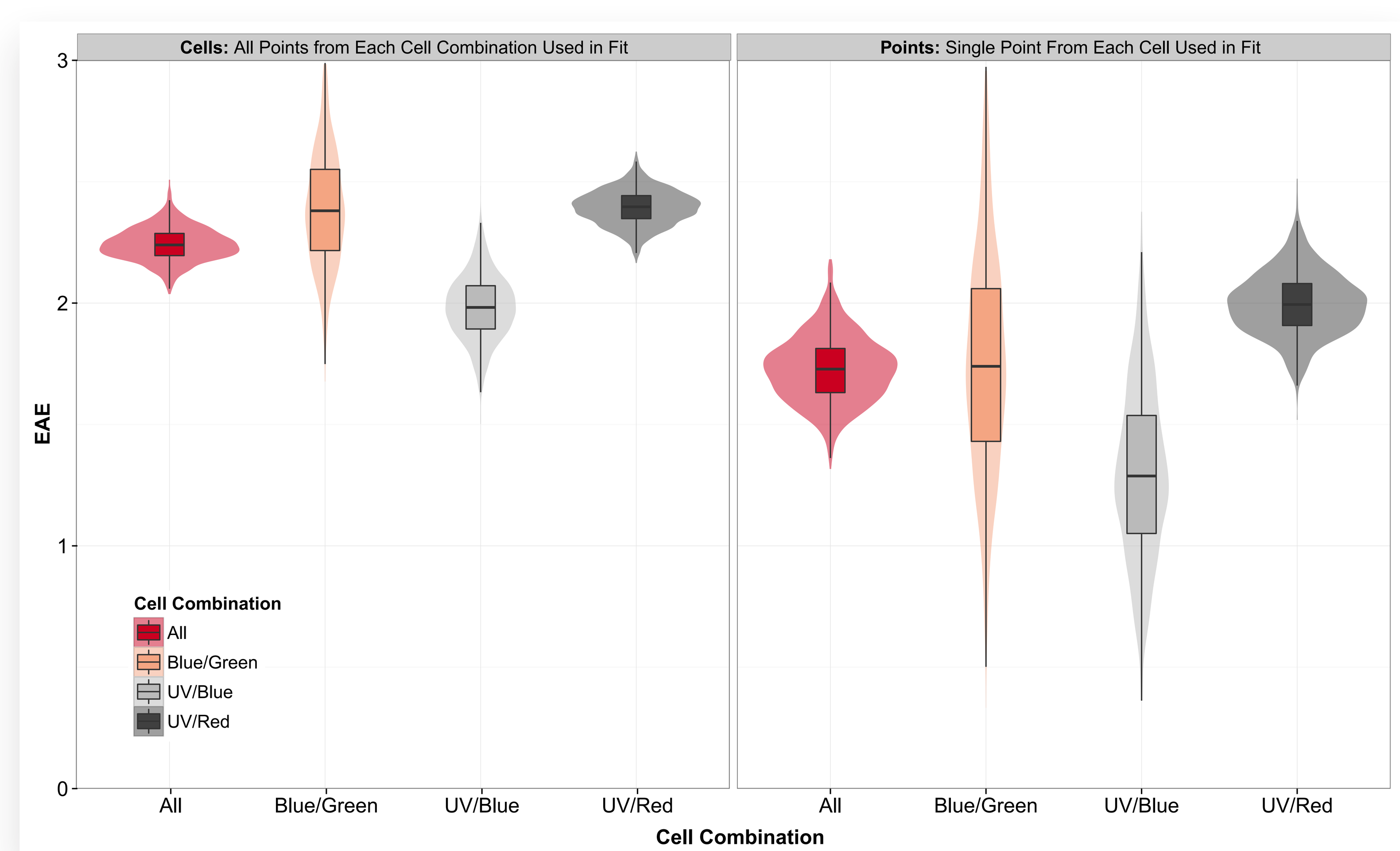
Future directions include combining the instrument with a UV-visible photoacousitc spectrometer [*Wiegand + (2014)* Anal. Chem.] to provide an instrumental system capable of retrieving extinction and absorbtion directly, and scattering indirectly. This system will be compared to a nephelometer for full closure.

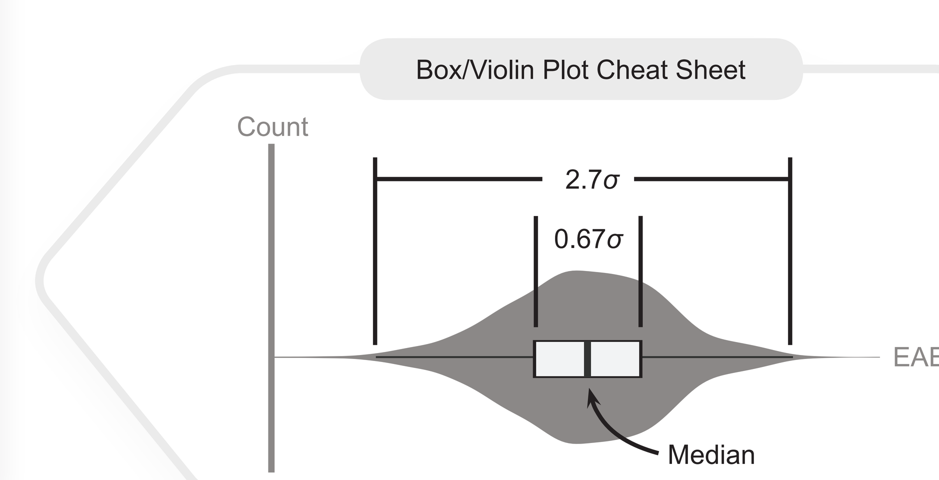
The instrument was designed with field work in mind, and components were selected to be robust and portable. We ultimately aim to deploy this system in the field.



3 A power law is fit to the spectra from all four cells to retrieve an EAE and infer a UV-visible spectrum. Qualitatively, the wide wavelength coverage allows visual examination of goodness of fit.

4 The numerous points anchor the fit and improve measurements compared to dual point fits by "averaging" fluctuations in the retrieved EAE.





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