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Annual Progress Report for CN Davies Award 2017

Improving the Understanding of the Optical Properties of Atmospheric Aerosols

Atmospheric aerosols' interaction with radiation is one of the largest uncertainties in modelling our climate. There can be no doubt of our need to better constrain aerosols' optical properties with improved measurement techniques. Aerosols both scatter and absorb solar and terrestrial radiation. This interaction with light is described by refractive index, which is composed of a scattering, *n*, and absorbing component, *k*. In this work, single aerosol particles have been studied to gain precise information relating to aerosols' direct effect. This is achieved with a Bessel laser beam (BB) optical trap with concurrent cavity ring-down spectroscopy (CRDS) and elastic scattered light (or phase functions, PF) measurements which are described in detail elsewhere.[1,2,3]

This work presents the most precise and extensive parameterisation of aerosol refractive index as a function of relative humidity (RH) and wavelength to date. This was achieved by measuring the optical properties of individual atmospherically relevant aerosol particles (composed of aqueous NaCl, $NaNO_3$, Na_2SO_4, NH_4HSO_4 or $(NH_4)_2SO_4$) with CRDS and PF measurements. These measurements provide n_λ (where $\lambda = 405, 473, 532$ nm) as a function of relative humidity. Single aerosol particles were also measured with aerosol optical tweezers, providing n_{650}. The measured data were combined with literature aerosol n_{633} data and bulk n_{589} data.[4,5,6] A Cauchy optical dispersion model was fitted to the measured and literature data, which provided a parametrisation of the refractive index for each compound, Figure 1(a). The coefficients that govern the parameterisation can be included in global radiative transfer models in order to reduce the uncertainly associated with aerosols' direct effect on our climate.

Not only has the scattering behaviour of aerosols been looked at, weakly absorbing behaviour has been studied for the first time with this instrument. A single aerosol particle (composed of aqueous NaCl or $(NH_4)_2SO_4$) was optically trapped and intermittently irradiated with an infrared laser. The heating-induced size change for each droplet is precisely known, shown in Figure 1(b), allowing the absorption, *k*, to be calculated. Initial analysis has shown this method is very sensitive to small changes in *k*, values as small as $k_{1620} = 4.5 \times 10^{-6}$ for aqueous NaCl have been calculated. This technique is useful for studying weakly absorbing species, although alternative aerosol trapping methods will be required to investigate strongly absorbing species, which is an area of interest for future studies.

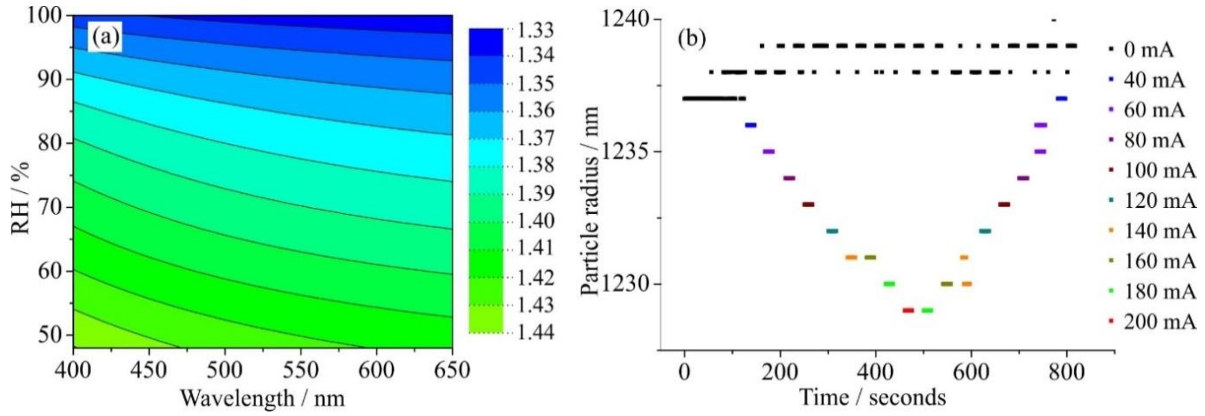

Figure 1: (a) Aqueous NaCl variation of refractive index (indicated in the key) with wavelength and relative humidity, (b) Heating-induced size change of aqueous NaCl as a function of 1620 nm laser power

Within the atmosphere aerosols are composed of a complex mixture of compounds, mainly organic species, therefore studying aerosols of increased complexity is an important step for the application of this research. Aerosols containing an organic mixture (of malonic acid, glutaric acid, lysine and glycine) have been studied. The measured n_{532} and n_{473} compared well with predictions from the molar refraction mixing rule,[7] further extensive studies of multicomponent systems will be carried out in order to thoroughly asses mixing rule predictions.

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