PROJECT TITLE: Exploring the Climate Impacts of More Accurate Representations of Aerosol Surface Properties
DTP Research Theme(s): Changing Planet
Lead Institution: University of Bristol
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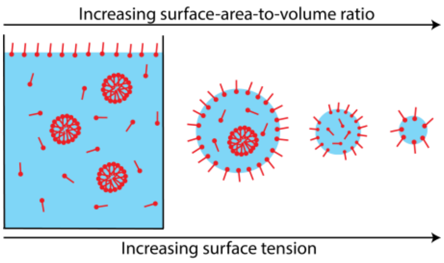
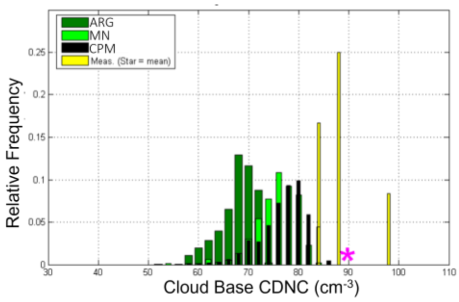
Project keywords: aerosol, chemistry, climate, clouds, surface tension, surfactants



Aerosol surface tension is droplet size dependent, making it challenging to incorporate into climate models.



Cloud droplet activation models (dark and light green) and a cloud parcel model (black) do not match measurements (yellow). Surface tension assumptions could explain these differences.

Project Background

Atmospheric aerosols impact global climate and represent the largest uncertainty in climate change estimates. Aerosols are also a major component of air pollution, which is responsible for 7 million deaths globally per year. Surfactants have emerged as common but poorly understood components of aerosol composition. Aerosol surface properties are key to governing their atmospheric chemistry and impacts [1]. For instance, aerosol droplet surface tension strongly influences the fraction of aerosol that activates into cloud droplets and impacts climate. Moreover, because they sit at the aerosol-air interface, surfactants play key roles in the chemical reactivity of ambient aerosols. Sea spray aerosol, the largest global aerosol source, is often enriched with surface active molecules that are thought to undergo unique reactions that differ from those in macroscopic solutions. However, accurately predicting the surface properties of aerosol droplets is challenging because their high surface-area-to-volume ratios can alter surface-bulk partitioning.

Project Aims and Methods

This exciting project will explore through experiments and models how the surface tensions of surfactant-containing droplets differ from those of the macroscopic solutions that produce them, and how these differences ultimately feed through to climate impacts. A widespread climate model assumption is that aerosol surface tension is equivalent to that for pure water. This assumption is directly at odds with field measurements of aerosol composition, which show a significant surfactant component that would be expected to reduce surface tension well below the value for water. We developed a unique instrument to directly measure the surface tensions of 3-10 µm radius droplets and demonstrated that surfactants can significantly reduce finite-sized droplet surface tension below the value for water. However, this reduction is droplet size-dependent and does not correspond exactly to the macroscopic solution value [2].

In this project, the student will extend our initial studies to explore the surface tensions of droplets containing surfactant mixtures, which begin to approach the chemical complexity inherent in atmospheric aerosols. With collaborators at University of Minnesota and University of Oulu (Finland), the student will use these measurements to refine thermodynamic models describing the size dependence of aerosol surface tension. Finally, with Dr. Partridge, the student will develop the Pseudo-Adiabatic bin-micRophySics university of Exeter Cloud parcel model (PARSEC) to include a more detailed representation surface tension effects on cloud droplet formation, which will be used assess the extent to which a more accurate incorporation of surface tension influences climate model predictions.

Opportunities exist for the student to be involved in the design of the project, including on the research direction.

Candidate requirements

This project includes a significant experimental and modelling component and would best suit a student with a strong background in chemistry or physics. We welcome and encourage student applications from under-represented groups. We value a diverse research environment.

Project partners

This project is a collaboration with Dr. Daniel Partridge, a climate modeller at University of Exeter whose research improves climate model representation of aerosol-cloud interactions by developing novel frameworks for transferring knowledge from small scale processes to the larger scale of climate model grid-boxes [3]. Dr. Partridge will make available the branch of the UK Met Office Earth System Model UKESM1 (https://ukesm.ac.uk/) that includes the PARSEC model and will provide support for including improved representation of surface tension into PARSEC. Initially, these developments will be performed offline from UKESM1 to enable efficient incorporation of more complex representations of surface tension (ST) (e.g. size and composition-dependent effects). Once completed, the additions associated with the improved model (PARSEC-ST) can be efficiently passed to UKESM1 to perform Atmospheric Model Intercomparison Project (AMIP) style simulations to assess the global impact of surface tension on cloud microphysical and radiative properties. Finally, a computationally fast parameterisation of the improved PARSEC-ST will be created in the form of an emulator to be used within UKESM1 to improve the existing parameterisation for droplet formation and reduce current uncertainties in the representation of aerosol-cloud-climate interactions.

Training

This project will embed the student in a research group that studies microscopic aerosol particles, which have unique physical and chemical properties compared to macroscopic materials. The student will have access to a training curriculum developed to teach aerosol science to postgraduate students with backgrounds from any discipline. The student will also take NERC NCAS courses providing training to work with UKESM1 and gain familiarity with climate modelling. The student will also work closely with collaborators in the US and Finland, potentially conducting a research visit to these institutions as thermodynamic models are tested and revised following the experimental measurements.

Background reading and references

[1] Bzdek et al., “Open questions on the physical properties of aerosols”, *Commun. Chem.*, **2020**, *3*, 105.
[2] Bzdek et al., “The surface tension of surfactant-containing, finite volume droplets”, *PNAS*, **2020**, *117*, 8335-8343.
[3] Lowe et al., “Key drivers of cloud response to surface-active organics”, *Nat. Commun.*, **2019**, *10*, 5214.

Useful links
http://www.bristol.ac.uk/chemistry/courses/postgraduate/

Bristol NERC GW4+ DTP Prospectus:
http://www.bristol.ac.uk/study/postgraduate/2024/sci/phd-great-western-four-doctoral-training-partnership-nerc/

How to apply to the University of Bristol:
http://www.bristol.ac.uk/study/postgraduate/apply/
Please note: If you wish to apply for more than one project please contact the Bristol NERC GW4+ DTP Administrator to find out the process for doing this.

The application deadline is Tuesday 9 January 2024 at 2359 GMT. Interviews will take place from 26 February to 8 March 2024.

For more information about the NERC GW4+ Doctoral Training Partnership please visit https://www.nercgw4plus.ac.uk

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