The impact of aerosol on convective clouds

Dr Edward Gryspeerdt (Imperial, Physics), Dr Helen Brindley (Imperial, Physics)

Clouds have a central role in the energy budget of the Earth; small changes in the amount and properties of clouds can have a large effect on global temperature and precipitation patterns. By emitting aerosols (particles nanometres to around a micron is size), human activities have increased brightness of clouds, cooling the climate and offsetting some of the warming from greenhouse gases. However, the magnitude of this effect is the most uncertain component of the human forcing of the climate system (IPCC, 2013), limiting how accurately the response of the atmosphere to greenhouse gases can be determined (Andreae et al, 2005).

The response of convective clouds to aerosols is a significant unknown. It has been hypothesised that aerosols could invigorate convective storms (Rosenfeld et al., 2008; Thornton et al., 2017), increasing the size and height of convective anvils. However, observing and measuring the impact of aerosols is difficult due to the complexity of the processes involved. Ships provide an ideal 'experiment of opportunity' into cloud processes, as they are large sources of aerosol that are independent from local meteorological factors (such as humidity).

Recent advances in satellite data collection record the location of all large ships across the globe. In collaboration with the UCL Energy Institute, you will link the aerosol emissions from these ships to satellite observations of cloud properties, providing a complete picture of the aerosol-cloud system. At Imperial College, we have already been using this new dataset to investigate the properties of low oceanic clouds. The role of this PhD project would be to investigate the impact of aerosol on convective clouds and storms.

In this project, you will use state of the art earth observation data to isolate and quantify the impact of aerosols on convective clouds. By linking new datasets on ship emissions to these satellite observations, you will be able to detect even the weakest perturbations to the cloud field. Analysing these relationships at a global scale, you will build a new understanding of how aerosols affect the properties of important cloud types and how this depends on the local meteorological situation. The will also be the option to compare these results to atmospheric models, identifying potential areas for improvement. Given the upcoming regulations in shipping fuel, there is also the potential for a direct policy connection through this project.

For further details, contact Dr Gryspeerdt (e.gryspeerdt@imperial.ac.uk)

References

Andreae, M. O., C. D. Jones, and P. M. Cox (2005), Strong present-day aerosol cooling implies a hot future, Nature, 435(7046), 1187–1190, doi:10.1038/nature03671.

Rosenfeld, D., U. Lohmann, G. Raga, C. O'Dowd, M. Kulmala, S. Fuzzi, A. Reissell, and M. Andreae (2008), Flood or Drought: How Do Aerosols Affect Precipitation?, Science, 321, 1309, doi:10.1126/science.1160606.

Thornton, J. A., K. S. Virts, R. H. Holzworth, and T. P. Mitchell (2017), Lightning enhancement over major oceanic shipping lanes, Geophys. Res. Lett., doi:10.1002/2017GL074982.

PhD student plan

Question: *What is the impact of aerosol on convective clouds?*

1. Shallow cumulus – they are some of the most common clouds, although they have a low cloud fraction, due to their significant coverage, a small change in cloud amount could have a large effect on the energy budget. Aim to study using:
    a. Ships tracks in shallow cumulus fields – previous studies have looked at shiptracks in stratocumulus, but with information on ship locations, we could identify them is much weaker cases (and much faster). This would help to test some hypotheses on shallow cumulus processes, including
        i. Shallow cloud invigoration (Koren, Dagan etc.)
        ii. Increases/decreases in cloud fraction (Seifert, Small etc.)
        iii. Changes in liquid water path (Toll etc.)
        iv. Can shallow cumulus shiptracks be used to retrieve ship emissions? (potential industry links)
    b. Comparisons to models – probably first looking at small scale models/LES. There are a couple of possible routes for this, the Met Office would be nice (given that this could then feed into their parametrisation development), but there are other options for this part (Cambridge, NOAA/ESRL). A second part could then involve looking at global models, using a shiptrack diagnostic developed as part of the fellowship, perhaps a multi-model experiment using AeroCom or something similar.

2. Deep convective clouds – The ability of aerosol to impact storms is highly uncertain, but may provide a missing positive climate forcing from aerosols that could offset a large cooling from low clouds. This would necessarily aim at smaller systems, rather than MCSs, due to the limited nature of the aerosol perturbation. Deep convective clouds would be investigated through:
    a. Links between lightning and ship locations. Thornton et al. (2017) showed a strong increase in lightning near shipping lanes. If this is the case, it should be possible to see the change in lightning associated with individual ships.
    b. Changes to convective cloud development in regions of increased aerosol. This builds on previous work looking at cloud development, but could benefit from new satellite instruments (particularly geostationary).
    c. Looking at the ice crystal number in convective outflow, using the new DARDAR Ni retrieval, can this be related to the droplet number concentration at earlier stages in the storms development?
    d. Comparisons to models are harder here, but still possible, perhaps in a more idealised sense using WRF-Chem or similar modelling setups.

Funded PhD Studentship in aerosol-cloud interactions at Imperial College London

A funded (Home/EU) PhD studentship is offered at Imperial College London, starting as soon as possible after October 1st 2019.

In this project, you will combine the latest satellite datasets with new data on aerosol emissions of individual ships to investigate the 'experiments of opportunity' provided by shipping emissions, with a particular emphasis on convective clouds.

The impact of aerosols on clouds is a significant outstanding uncertainty in the human forcing of the climate system. Without the ability to vary aerosol at a large scale, it is difficult to identify its influence on clouds. As large isolated sources of aerosol, ships provide an ideal 'experiment' enabling you to control for known variables in the aerosol-cloud system and detect even very subtle changes to cloud properties.

You will have considerable freedom to choose the pathway of the project, including using atmospheric models and working with industry.

This studentship will be in the space and atmospheric physics group at Imperial, which conducts a wide range of research into atmospheric and oceanic physics. Opportunities also exist for collaboration through the Grantham Institute for the Environment at Imperial and the wider London, UK and international research communities.

The ideal candidate will have 1st or 2.1 degree in physics or a related numerate field. To apply, please send a CV and short cover letter outlining your motivation and background to Edward Gryspeerdt (e.gryspeerdt@imperial.ac.uk). Please contact me at the above address with any informal enquiries.