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Insights from ACRUISE (Atmospheric Composition and Radiative forcing changes due to UN International Ship Emissions regulations) from aircraft, modelling, and satellite perspectives

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Ship exhausts have historically been significant sources of sulfur dioxide and aerosols to the marine atmosphere and some global models suggest the emissions cause a large negative radiative forcing by modifying cloud properties. International Maritime Organisation (IMO, an agency of the UN) regulations require that ships in international waters reduce their sulfur emissions from a maximum of 3.5% to 0.5% from January 2020. The ACRUISE project, taking advantage of this unique large-scale aerosol perturbation, investigates the impacts of the IMO's 2020 sulfur regulations on aerosols, clouds, and radiation in the North Atlantic and globally. Here I summarise our findings so far from intensive aircraft observations, high-resolution model simulations, and deep learning-based satellite cloud analysis.

Aerosol-cloud interaction near shipping lanes was studied from an aircraft in the northeast Atlantic in 2019 as well as in 2021. Aerosol chemical and physical properties were markedly different between the two years, with much lower sulfur content, smaller, and less hygroscopic aerosols in 2021. A detailed analysis of the aerosol and cloud microphysics observations within/immediately outside the ship plumes will be performed to determine whether some clouds appeared to be strongly impacted by ship plumes, while other clouds were not. To help interpret the aircraft data and provide context, we ran nested regional domain simulations of the Met Office Unified Model for all flight campaigns. These high-resolution simulations (few hundred metres) show a generally diffuse pattern of perturbed trace gases and aerosols that are not apparent as individual ship tracks, suggesting that analysis of tracks alone may underestimate the climatic effects of ship emissions.

We have trained a deep learning model to detect ship-tracks in satellite imagery with good skill and applied it to the whole MODIS mission in order to develop a global climatology. We will discuss the spatial and temporal distribution of shiptracks relative to the underlying ship emissions, and particularly focus on the effects of the IMO regulation as well as the global COVID-19 pandemic. Ongoing work that combines airmass trajectory modelling with known positions of ships will enable us to assess the impact of ship emissions on all pixels, and not just those identified as ship tracks.