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Invisible Ship Tracks as Opportunistic Experiments for Aerosol Cloud Interactions

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Cloud reflectivity changes due to anthropogenic aerosol remain a source of significant uncertainty in our understanding of climate change. Ship tracks, long lines of polluted clouds that are visible in satellite images, have been used widely as opportunistic experiments for quantifying aerosol-cloud-interactions. However, only a small fraction of the clouds polluted by shipping show ship tracks, potentially introducing a sampling bias when extrapolating such studies to a wider range of environmental conditions.

To overcome this issue, we develop a novel method to investigate all clouds polluted by shipping, regardless of whether they exhibit visible ship tracks. While previous studies are limited to on the order of thousands of tracks, we use on the order of two million equivalent ship paths. Combined with reanalysis winds and trajectory modelling, these paths enable us to identify clouds that are exposed to pollution and compare them to unpolluted ones nearby. This way we show that formerly invisible ship emissions change cloud properties considerably: cloud droplet numbers increase even when no ship tracks are visible, with the anomaly roughly half as large as in visible tracks. These “invisible” ship tracks also show a more positive liquid water response. For the first time, we directly detect shipping-induced cloud property changes in the trade cumulus regions of the Atlantic. These regions also show stronger liquid water responses than the stratocumulus regions previously studied for ship tracks. We estimate the global radiative forcing from liquid water adjustment to be between (-1.89, -0.30) W m^{-2}, well outside the equivalent IPCC estimate of (0.0, +0.4) W m^{-2}. We also show that only 30 days of satellite observations are needed to confidently detect changes in cloud droplet number from known shipping, with implications for potential marine cloud brightening experiments.

Our results indicate that earlier studies of ship tracks may be suffering from selection biases by focusing only on visible tracks from satellite imagery. The strong liquid water path response we find translates to a larger aerosol cooling effect on the climate, potentially masking a higher climate sensitivity than observations would otherwise suggest. Further work is in progress to evaluate the dependency of aerosol effects on environmental factors such as atmospheric stability and sea surface temperature, as well as extending the analysis to cloud top height and, if possible,

to cloud fraction.