New analysis of shipping emissions reveals that air pollution has a larger effect on climate than previously thought

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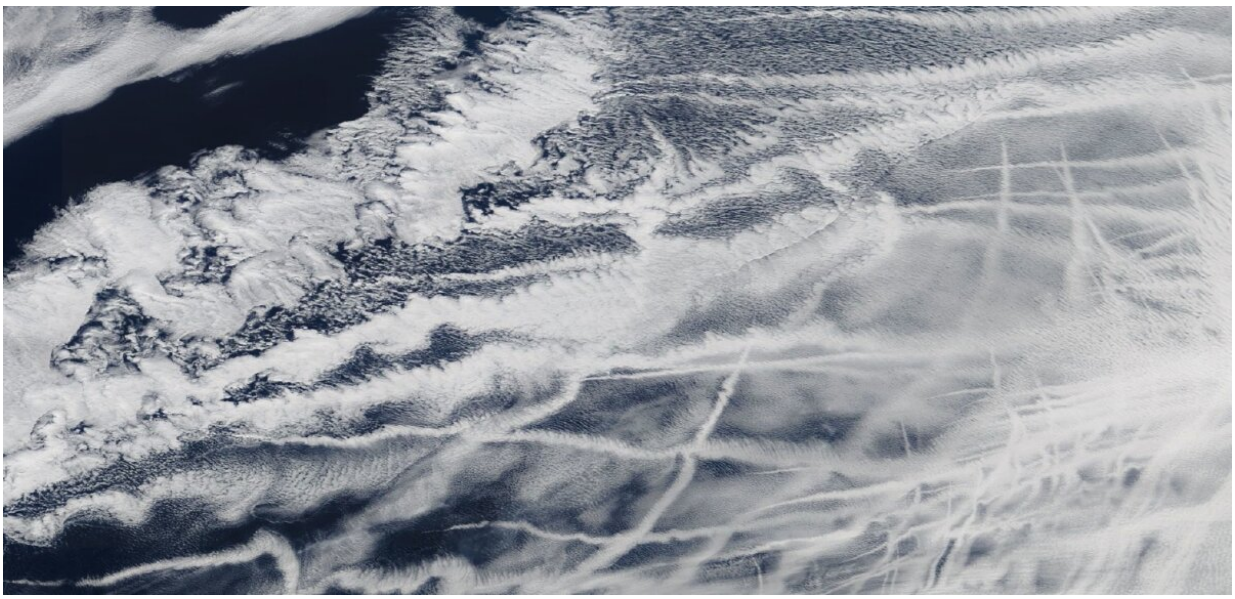

A satellite image with visible shipping emissions seen as tracks. Credit: NASA WorldView / D Watson-Parris

A group of researchers based at Oxford University's Climate Processes Group has used novel methods of analyzing satellite data to more accurately quantify the effect of human aerosol emissions on climate change. The results are published today in the journal *Nature*.

Human aerosol emissions have a cooling effect on the planet, because they can make clouds brighter by providing extra condensation nuclei on which cloud droplets form. Brighter clouds reflect more of the sunlight that strikes them, deflecting it from the earth's surface. However, it is currently unclear how large this cooling effect is, particularly if the cloud brightness change cannot be seen in satellite images. This could be when the emissions are diffuse, such as from a city's traffic, or when there are winds that disperse them. The cooling effect offsets some of the warming effect of greenhouse gasses, and provides the largest uncertainty in human perturbations to the climate system.

To investigate this, the research team analyzed data on ship emissions as a model system for quantifying the climatic effect of human aerosol emissions in general. Sometimes, when a ship passes underneath a cloud, its aerosol emissions brighten the cloud in a long line, similar to a contrail. These so-called ship tracks have been studied previously, however the vast majority of ships leave no visible tracks. This was the first study to provide a quantitative measure of the impact of invisible ship tracks on cloud properties, and thus their cooling effect.

Key findings:

- Invisible shipping tracks had a clear impact on the properties of clouds they polluted.
- Surprisingly, the specific effects were different to those of visible shipping tracks.
- Invisible ship tracks showed a smaller increase (roughly 50% less) in the number of droplets in the clouds, but the amount of water increased more, compared to the effect of visible tracks. This implies that for a given increase in droplets, the increase in water is larger than thought, equating to a greater cooling effect.
- The same may be true for aerosol emissions more generally—clouds may react more strongly to air pollution than

previously thought, getting brighter and having a stronger cooling effect.

Ship emissions often occur in remote ocean environments, and so provide unique opportunities to study the effects of aerosols in isolation of other human-induced factors that affect the climate. This new study, led by DPhil student Peter Manshausen, used a global database of ship routes containing the locations of almost all ships at a given time: more than two million ship paths over six years.

Combining these with historical weather observations, the researchers then simulated where all these ships' emissions were carried by the wind and entered the cloud. Studying these locations in satellite data allowed them to measure the number of droplets and the amount of water in the polluted and unpolluted clouds. Importantly, this method does not depend on the ship emissions being visible in satellite images.

According to the research team, the findings indicate that human health policies to reduce air pollution must be carefully considered when forecasting future climate change scenarios. In a recent study, the Climate Processes Group also found that ship tracks reduced by around 25% almost immediately after the International Maritime Organization introduced strict new fuel regulations in 2020 to reduce air pollution caused by global shipping. This analysis used a machine learning approach to automatically measure more than one million visible ship tracks from satellite images over a 20 year period.

Professor Philip Stier (who leads the Climate Processes Group in the Department of Physics, Oxford University), a co-author for the study, said, "These techniques show the value of combining novel data science approaches with the huge amount of earth observational data now available. They will allow us to transform the analysis of climate processes in earth observations from case studies to global monitoring,

providing entirely new observational constraints on our understanding of the climate system and future climate models."

The study, "Invisible ship tracks show large cloud sensitivity to aerosol," has been published in *Nature*.

More information: Peter Manshausen et al, Invisible ship tracks show large cloud sensitivity to aerosol, *Nature* (2022). DOI: 10.1038/s41586-022-05122-0

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