The social costs of aviation CO_2 and contrail cirrus

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Problem and Purpose

Aviation contributes with approximately 3.5% of global anthropogenic climate forcing. Up to two thirds of this contribution can be attributed to contrail cirrus (*Lee, D. S. et al. 2021).* Contrail cirrus are artificially induced clouds evolved from the line-shaped clouds formed behind aircraft when the ambient air is cold and humid enough. As clouds they reflect incoming sunlight and trap outgoing heat radiation on the whole having a warming effect on earths climate.

The European Commission aims to propose legislative measures aimed at reducing aviation non-CO_2 forcers by January 1, 2028. The aviation climate impact of CO_2 is certain, homogeneous and long-lived while the climate impacts of contrail cirrus are uncertain, heterogeneous and short-lived. Efficient policy requires an understanding of the climate impacts of contrail cirrus vs. CO_2 emissions, addressing their inherent differences. Our main research questions:

- Can we use the social cost as a metric for comparing CO_2 and contrail cirrus climate impact?
- How does the social cost as metric compare to the Global Warming Potential of contrail Cirrus?

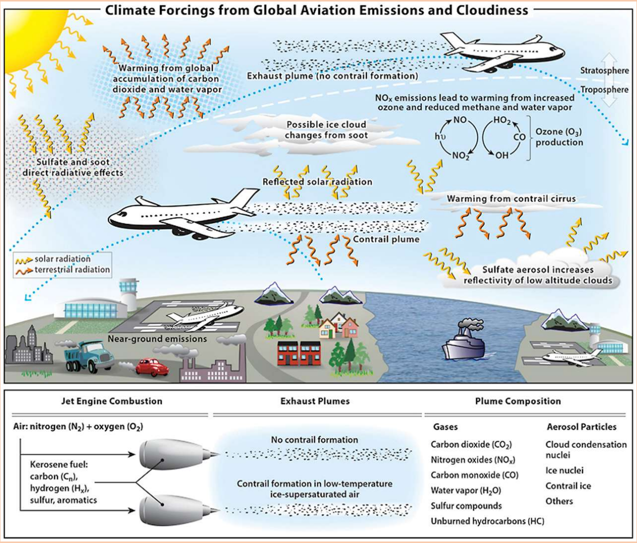
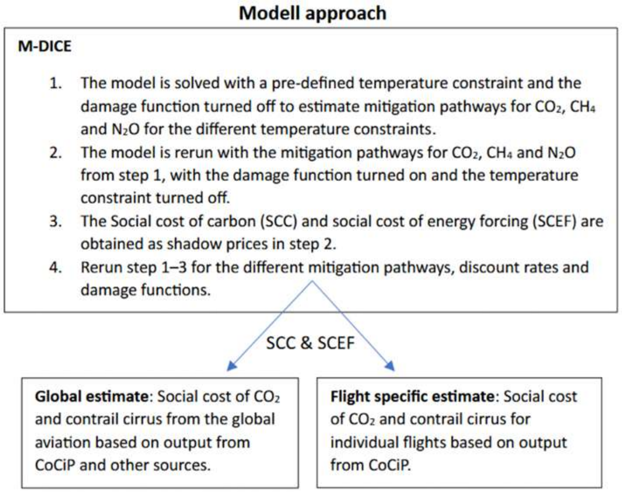


Figure 1: Schematic of aviation climate forcings (*Lee, D. S. et al. 2021)* .

Realization

To calculate the social cost of carbon (SCC) and contrail cirrus (SC-contrail) we use a modified version of the Dynamic Integrated Climate-Economy (M-DICE) model based on Hänsel et al. (2020) and Azar et al. (2023). We use the Contrail Cirrus Prediction (CoCiP) model Schumann (2012) to estimate the energy forcing of 477 923 flights over the North Atlantic in the year 2019.



Modell approach

M-DICE

1. The model is solved with a pre-defined temperature constraint and the damage function turned off to estimate mitigation pathways for CO_2, CH_4 and N_2O for the different temperature constraints.
2. The model is rerun with the mitigation pathways for CO_2, CH_4 and N_2O from step 1, with the damage function turned on and the temperature constraint turned off.
3. The Social cost of carbon (SCC) and social cost of energy forcing (SCEF) are obtained as shadow prices in step 2.
4. Rerun step 1–3 for the different mitigation pathways, discount rates and damage functions.

SCC & SCEF

Global estimate: Social cost of CO_2 and contrail cirrus from the global aviation based on output from CoCiP and other sources.

Flight specific estimate: Social cost of CO_2 and contrail cirrus for individual flights based on output from CoCiP.

Figure 2: Conceptualization of modell approach.

Social cost of contrail cirrus is funded by Transport Area of Advance

Results

The global average values of the SCC are larger than SC-contrail for all cases. Additionally, there is a larger dependence on the choice of discount rate and climate stabilization level for SCC than for the SC-contrail due to the shorter life-span of the latter.

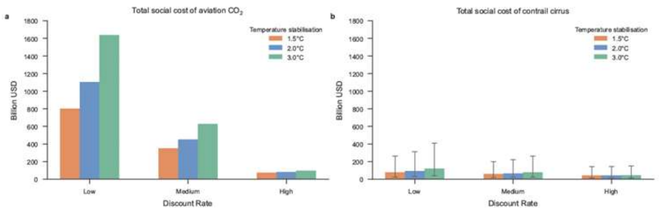
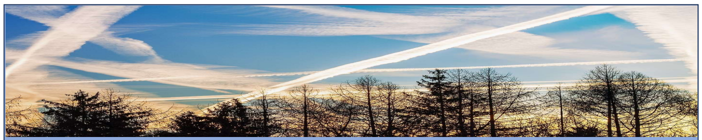


Figure 3: Social costs for aviation CO_2 and social costs for contrail cirrus for the emissions and forcing levels in year 2019 based on social cost estimates for 2020.



The time horizon in the GWP meausure plays a role that is closely related to the discount rate (specifically the inverse of effective discount rate). Note that, using a short time horizon when calculating, for example 20 years, is not consistent with any of the discount rates used here. Furthermore, the median view among economists and philosophers (Medium discount range) suggest the GWP-100 gives too high a relative value for contrail cirrus in a welfare maximizing context.

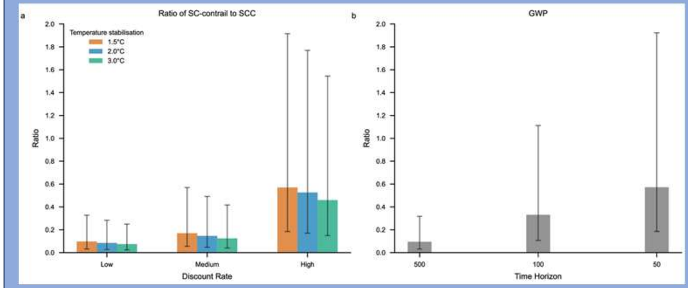


Figure 4: Ratio of social cost of contrail cirrus to social cost of CO_2 and GWP values for aviation contrail cirrus.

Some flights are strongly cooling even considering the joint impact of contrail cirrus and CO_2, while for other flights, the warming impact of contrails is several orders of magnitude larger than just the CO_2, see Johansson et al. (2025) for details.

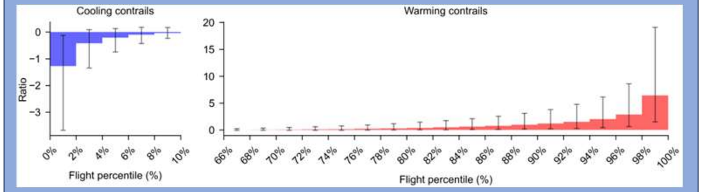


Figure 5: The ratio of SC-contrail caused by a flight to the SCC caused by the same flight ordered from lowest to highest ratio for 477 923 flights over the North Atlantic in the year 2019 and then divided into bins representing 2% of the total number of flights.

References

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