Understanding sources of contrail cirrus radiative forcing uncertainty using a new diagnostic contrail scheme for UKESM

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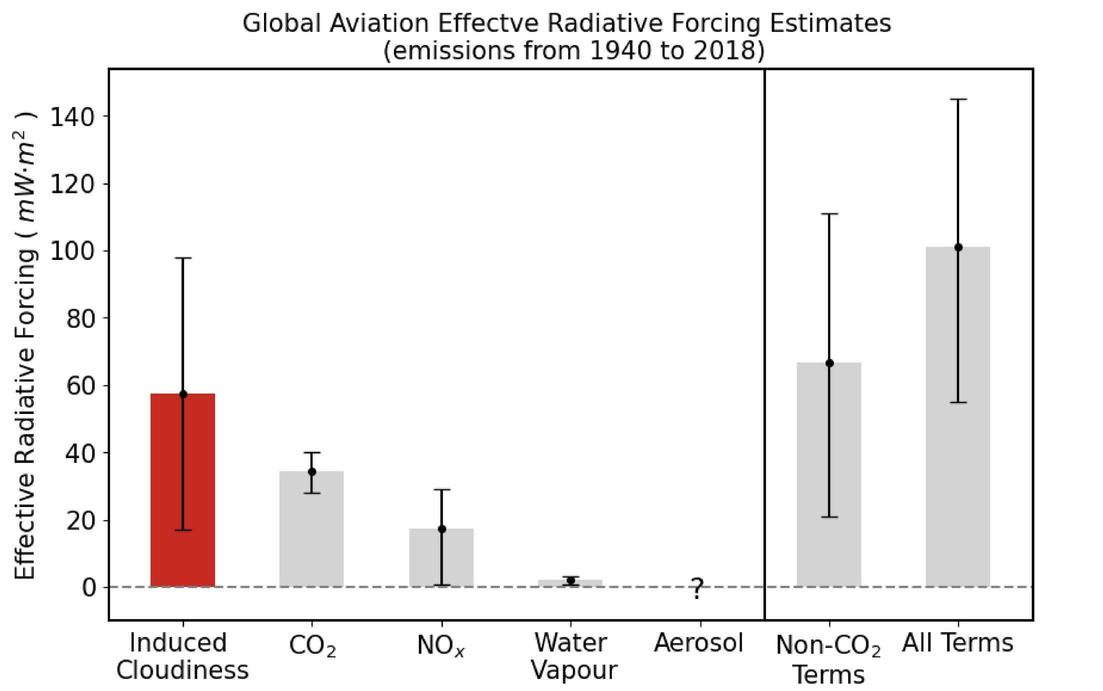
1. Introduction

Short-lived contrails Persistent contrails Contrail cirrus

Why do we care about contrails and contrail cirrus?

- The steady increase in air travel volume has led to concerns about the **growing impact of aviation on climate**;
- The **largest single contribution** to aviation radiative forcing (RF) corresponds to contrails and contrail cirrus, i.e. ~60 mW·m², with **high uncertainty**.



Data from Lee et al. (2021)

Uncertainty sources of contrail cirrus radiative forcing

- Differences and approximations in the **radiation schemes**;
- **Background cloud** field and its overlap with contrail cirrus;
- Assumptions about the **homogeneity of the contrail cirrus** field;
- **Only two existing climate models can simulate contrail cirrus.**

2. Objective

- Develop a new contrail parameterisation by adapting the contrail scheme in CESM Community Atmosphere Model (CAM) to the UK Met Office Unified Model (UM).
- **Evaluate the differences in contrail coverage and radiative forcing** estimated with the same scheme hosted by the UM and CAM, **exploring the differences caused by different host climate models**.

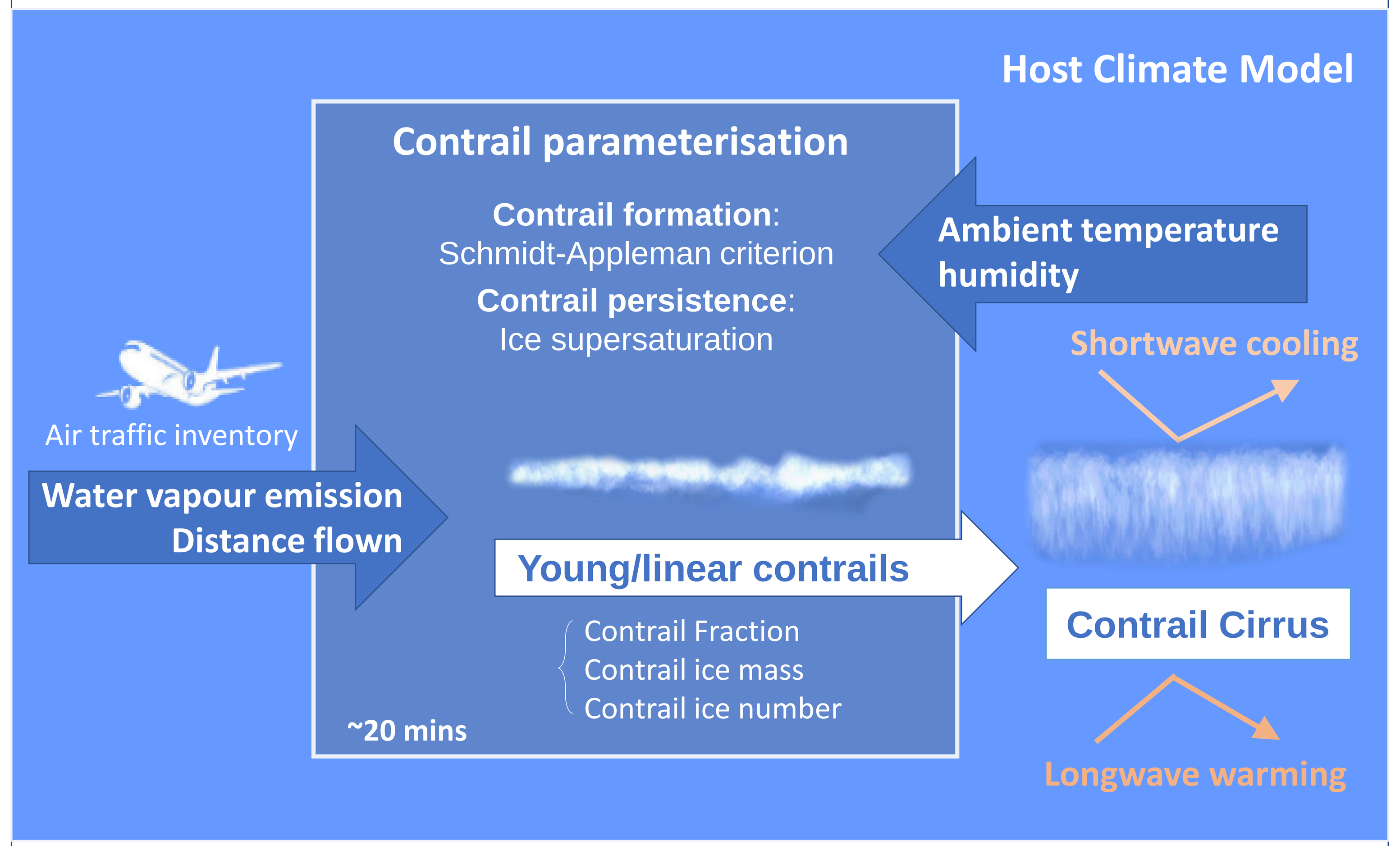
References

Lee et al. (2021) The contribution of global aviation to anthropogenic climate forcing for 2000 to 2018. Atmospheric Environment.

Gettelman et al. (2021) The Climate Impact of COVID19 Induced Contrail Changes. Atmospheric Chemistry and Physics.

3. Methodology

How does the contrail scheme work in climate models?

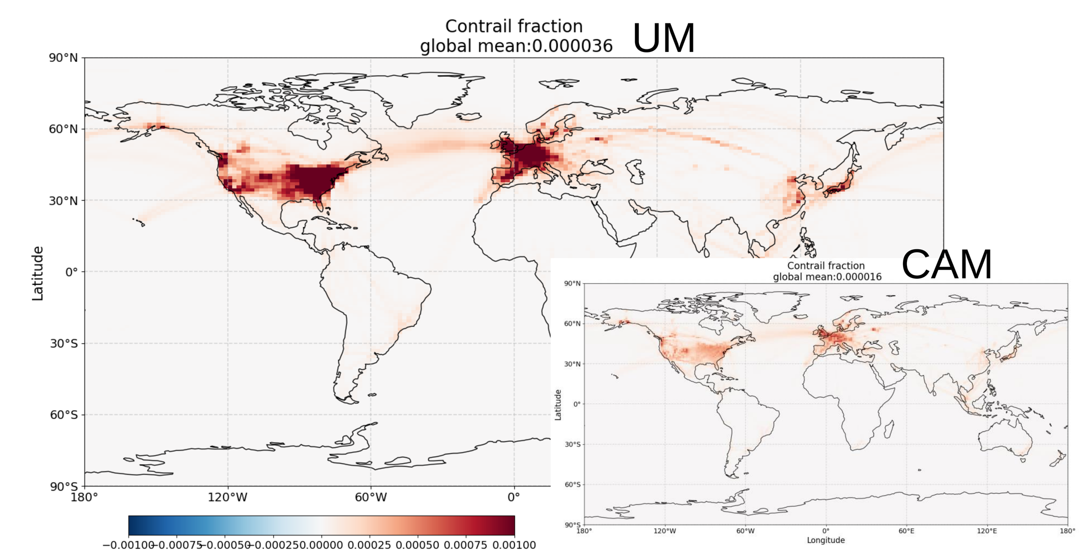


Persistent contrails form when the ambient temperature is below a critical temperature and the ambient air is above ice saturation, water vapour emissions turn into ice along with the ambient humidity above ice supersaturation within the volume swept out by aircraft.

Two climate models are used in this study: **UM and CAM**.

- They have **different** background meteorology conditions and cloud micro-physics scheme.
- The **AEDT air traffic inventory** for the year 2006 has been incorporated into both the UM and CAM for contrail simulations

4.1. Initialised Contrail Fraction



geographical distribution of contrail fraction diagnostics simulated with UM (left) and CAM (bottom right)

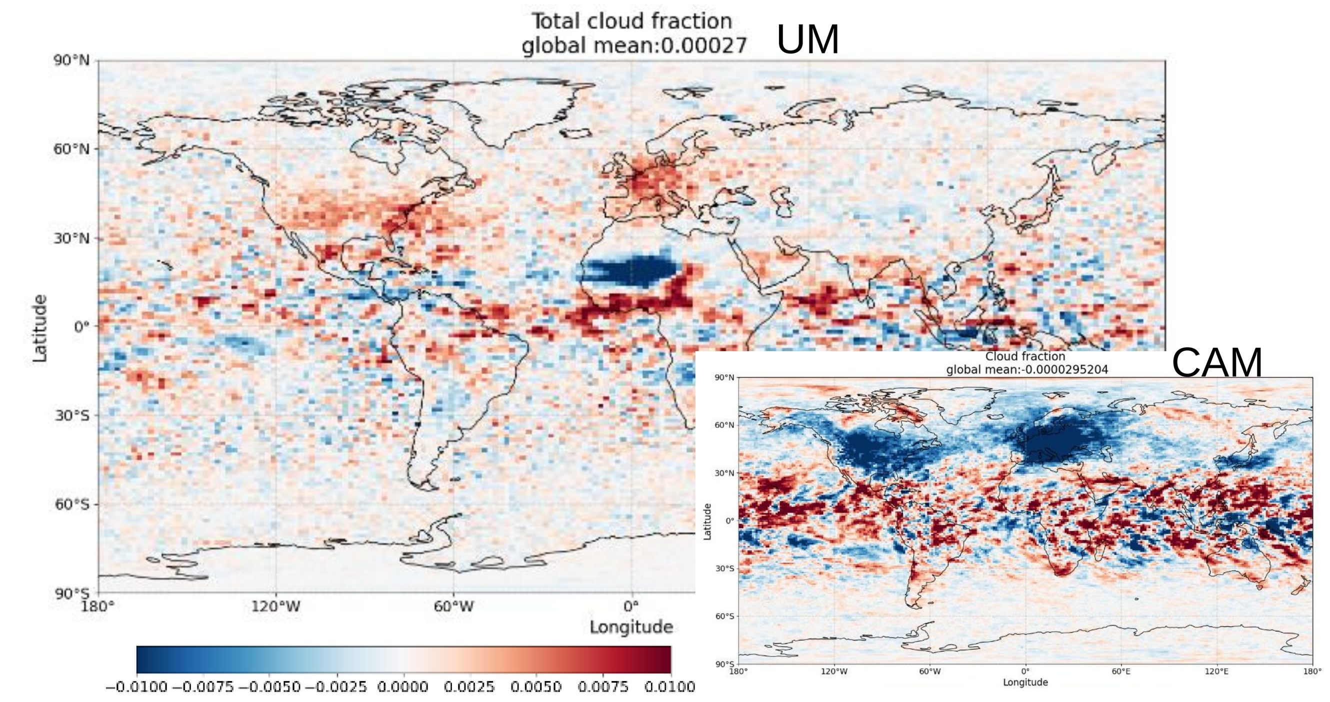
Similar geographical distribution pattern.

Different magnitude: UM contrail fraction has a **larger** global mean (0.0036%) than CAM (0.0016%) – **Different model background meteorology**.

*The results shown in section 4 are based on the UM and CAM 1 year simulations with nudging and 4 ensemble members.

4.2.1. Induced Perturbation in Cloud fraction

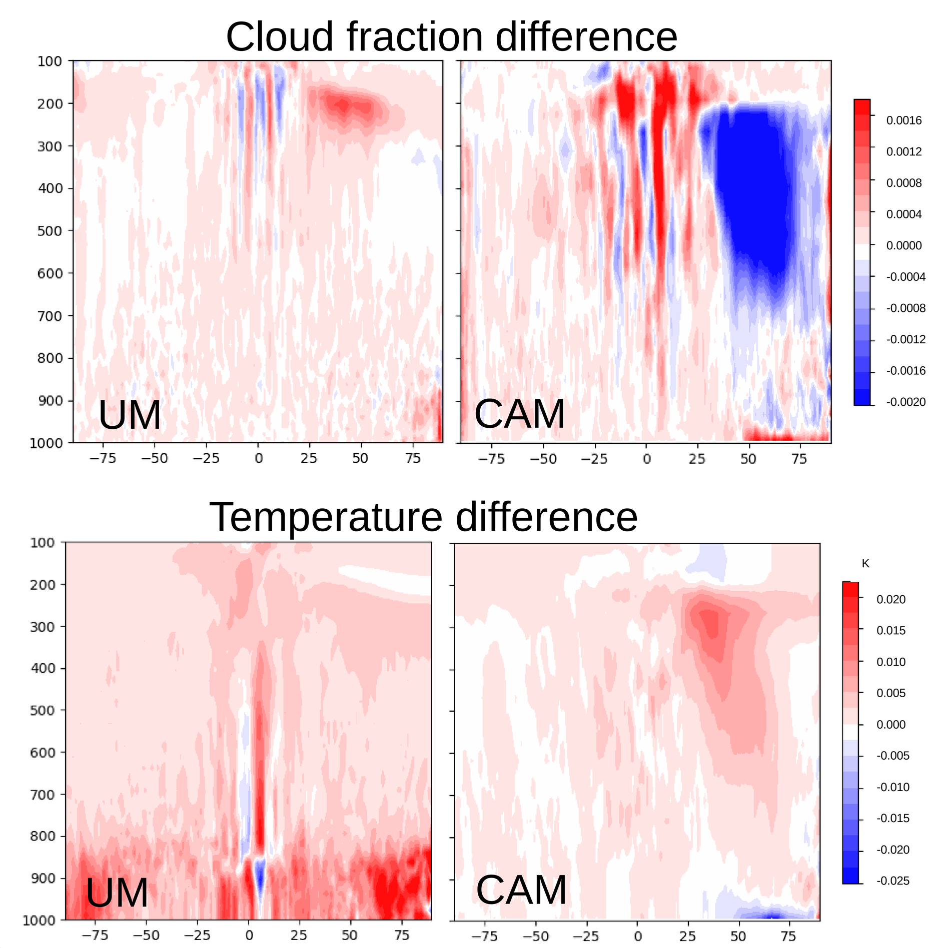
Opposite cloud fraction response:
Increase in UM, decrease in CAM



Geographical distribution of the differences in contrail coverage simulated with UM and CAM

The large noise in the tropics is caused by **model internal variability**, which can be reduced by increasing the number of ensemble members.

Why is there a reduction in total cloud fraction in CAM?



The **increase in temperature and cloud ice**, some of which comes from forming contrails in supersaturated air and the subsequent uptake of environmental water, **results in decreasing relative humidity** and, hence, **decreases cloud fraction.**

Gettelman et al. (2021)

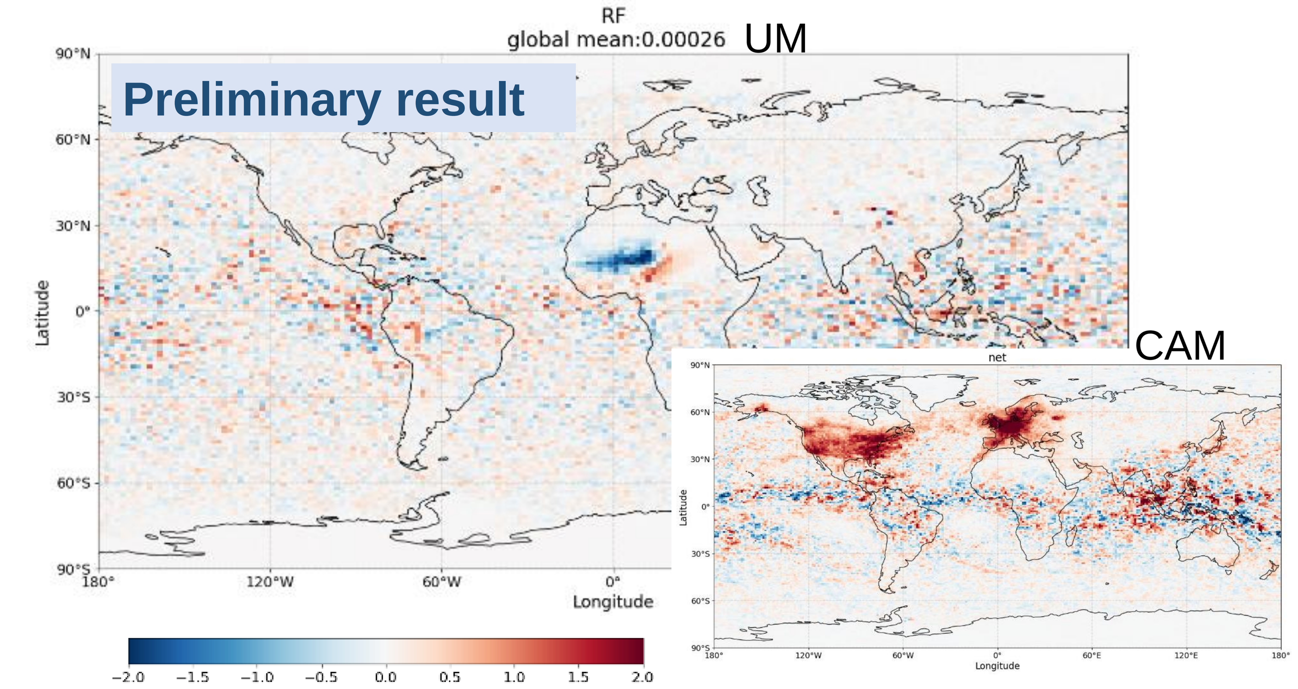
5. Summary

The host climate model meteorology and cloud scheme strongly affect the simulated contrail cirrus RF.

- Different magnitude of contrail fraction caused by different model background meteorology;
- Opposite changes in cloud fraction due to different temperature and cloud ice changes in the two models;
- Much smaller radiative forcing of contrail cirrus in the UM due to short contrail lifetime and large contrail ice particle size.
- Next steps: scale contrail ice mass to account for the large contrail ice size due to the one moment scheme in the UM.

4.2.2. Induced Perturbation in Radiation

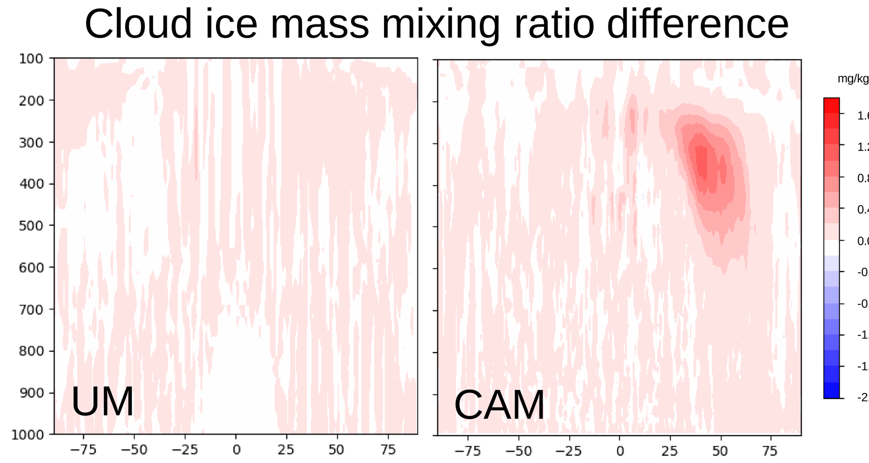
Different magnitude of radiative forcing:
Much smaller radiative forcing in UM over intense air traffic areas



Geographical distribution of the radiative forcing simulated with UM and CAM

Why is the contrail cirrus RF so small in UM?

1) Contrail ice particles in the UM have very **short lifetime**



Annual zonal mean latitude height plots differences in cloud ice mass mixing ratio simulated with UM (left) and CAM (right)

2) Increase in contrail radius reduces contrail cirrus RF: **Large particle size of contrails in the UM** due to the one moment cloud microphysics scheme