

# The impact of aircraft engine emissions and alternative fuels on contrail formation



## Contrails induce a significant climate warming

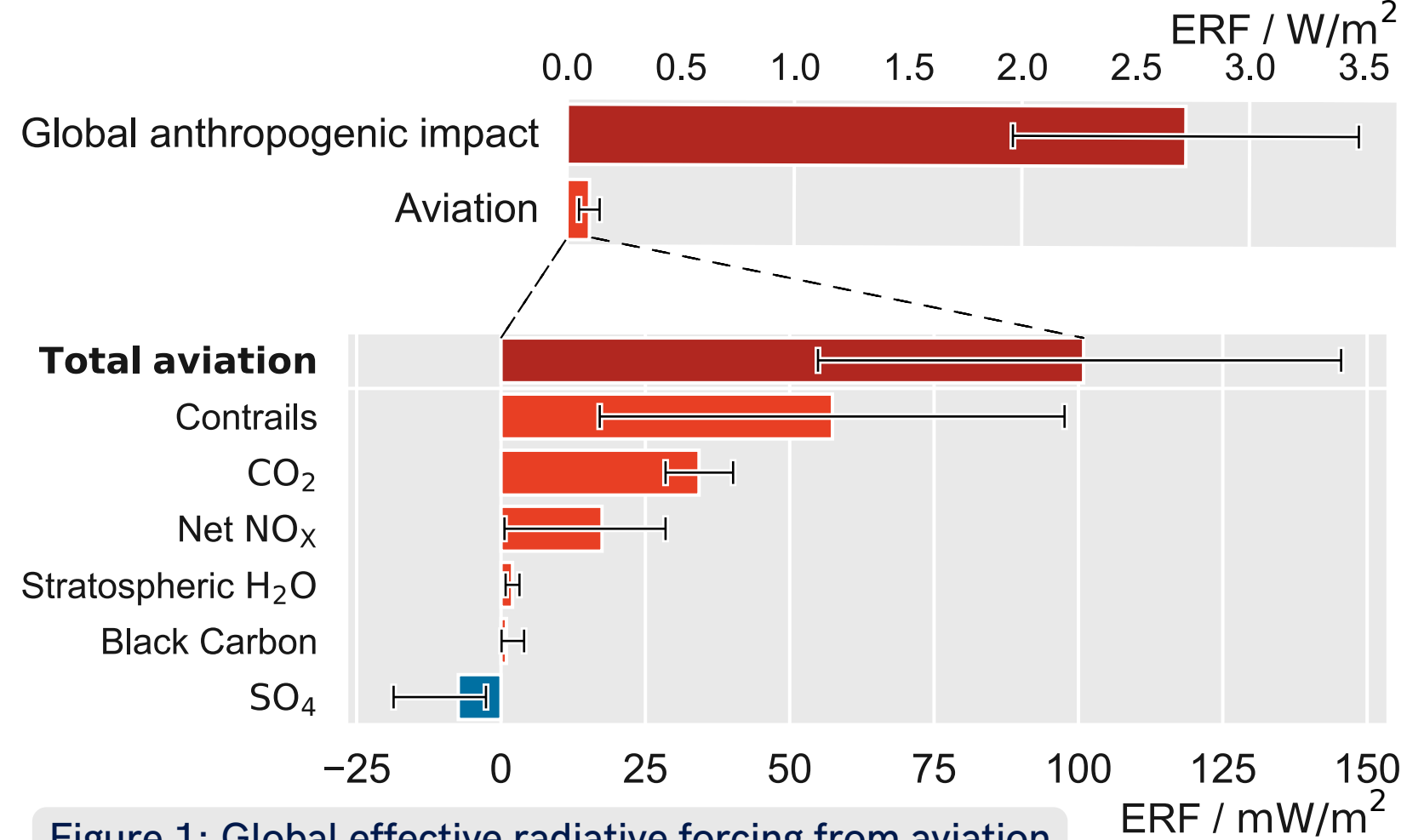


Figure 1: Global effective radiative forcing from aviation  
Based on data from IPCC 2021; Lee et al. 2021.

Contrail warming happens through their cloud greenhouse effect trapping terrestrial infrared.

During the day, contrails have an offsetting cooling effect by reflecting sunlight.

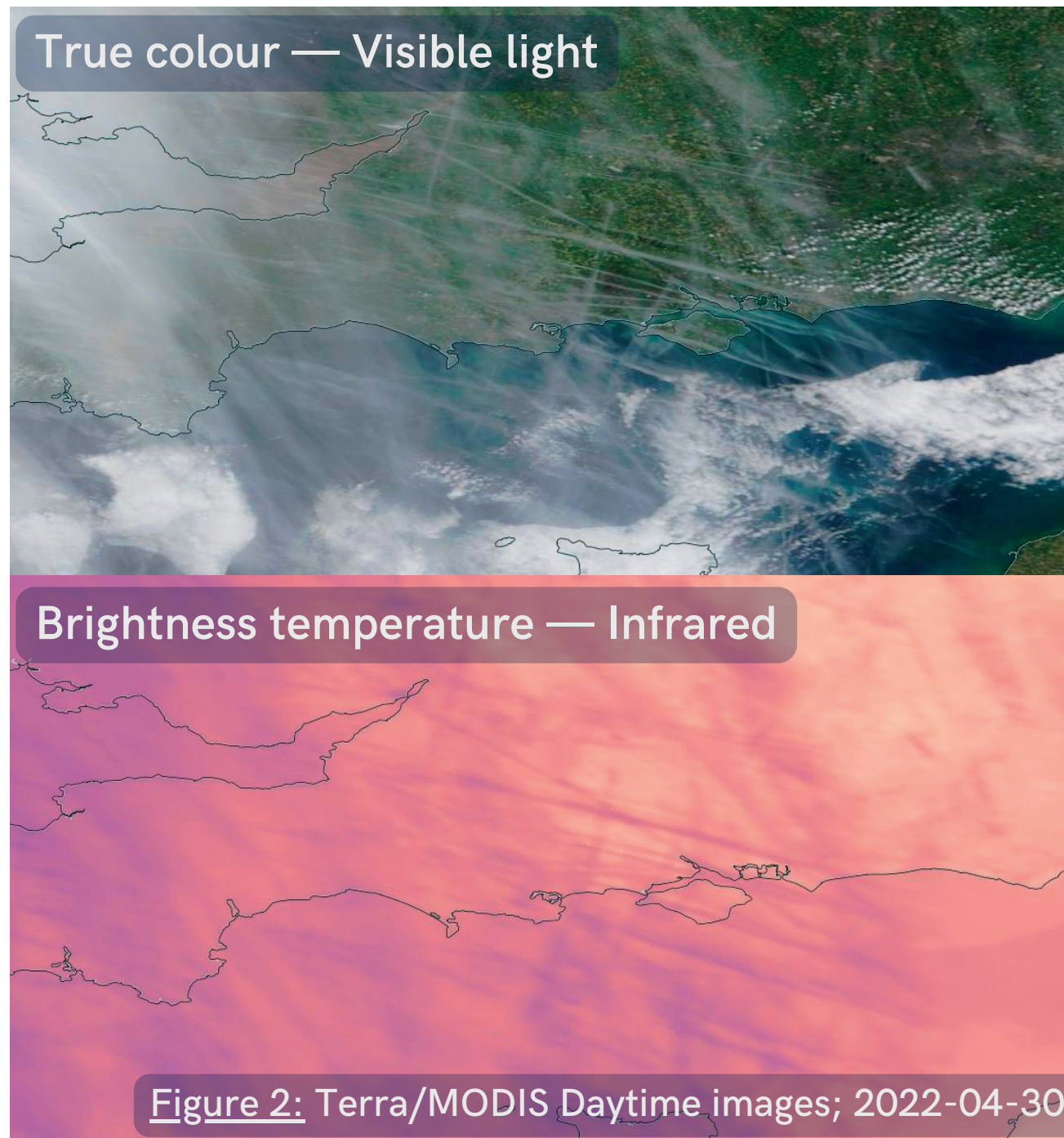


Figure 2: Terra/MODIS Daytime images; 2022-04-30

See also: Karcher et al. 2018.

## Models suggest new fuels will reduce contrail RF

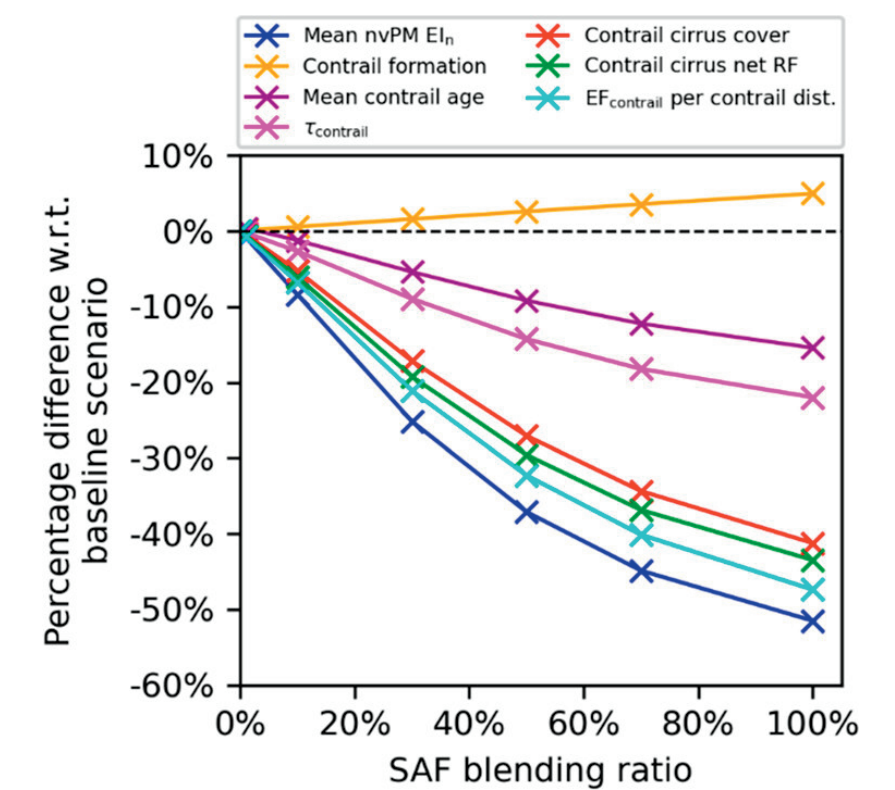


Figure 3: CoCiP-modelled impact of sustainable aviation fuel  
(Reproduced from Teoh et al. 2022)

Reduced impact: less soot → fewer, larger crystals → shorter-lived contrails.  
(CoCiP model — Schumann 2012)  
Are contrail models accurate enough to make these claims?

## Observation is needed to test the limits of contrail models

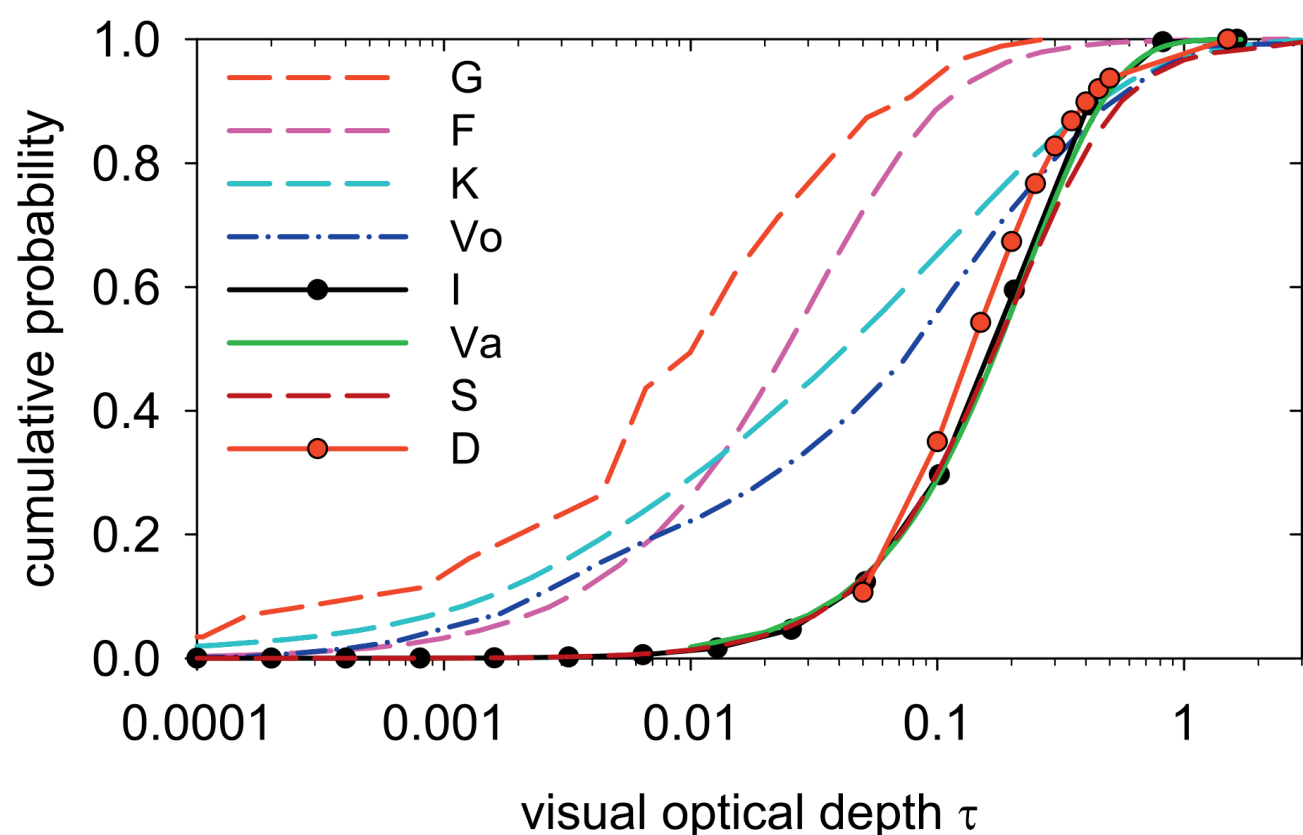


Figure 4: Contrail optical depth distributions across studies  
Reproduced from Schumann & Heymsfield, 2017

There is a significant spread in contrails predicted by models (dashed lines in Figure 4).

**Objective: validate contrail models' use when for estimating RF associated with alternative fuels**

Test contrails forecast against contrails observed:



Observation competes with optical depth limits of detection.

We need to improve on existing observational techniques to enable this work.

**Objective: Use observation to determine the extent of effects not contained in models**

- How do contrail remnants behave?
- How big is the optical depth enhancement of embedded contrails?

## Policy and industry

- Industry against policy: "Science not robust".
- Personal impact: removed from Google Flights due to uncertainty.
- Beginnings of policy implementation: EU Emissions Trading Scheme.

**Key requirement: accurate models to estimate the impact of individual flights.**

*Aviation chiefs rejected measures to curb climate impact of jet vapours*

— The Observer | 2023-03-18

*Google 'airbrushes' out emissions from flying, BBC reveals*

— BBC News | 2022-09-26

## Modern geostationary satellites, with other techniques, enable observation for model validation

### Advantages

- Wide field of view
- Time resolution: 5-10 min
- Single instrument

### Challenges

- Spatial resolution: 0.5-2 km
- Optical depth limit of detection
- Background

- The limit of detection of existing techniques (Mannstein 1999; Meijer 2022) is not well defined. Extended objects should be more easily detectable than single pixels.
- Additional information: flight matching, other retrievals.

**Objective: Establish a ground truth contrail detection dataset**

Apply statistics and radiative transfer models to establish real confidence values.

Tools:

- GOES-R & MTG satellites meteorological satellites.
- LibRadTran & RTTOV radiative transfer models
  - The cloud, background, meteorology, and satellite.
- Flight tracking and advection models.
  - Research group knowledge using ship tracks.
- Lidar/Radar: DARDAR retrievals of ice crystal properties.
- Flight inventories.

### GOES-EAST imagery

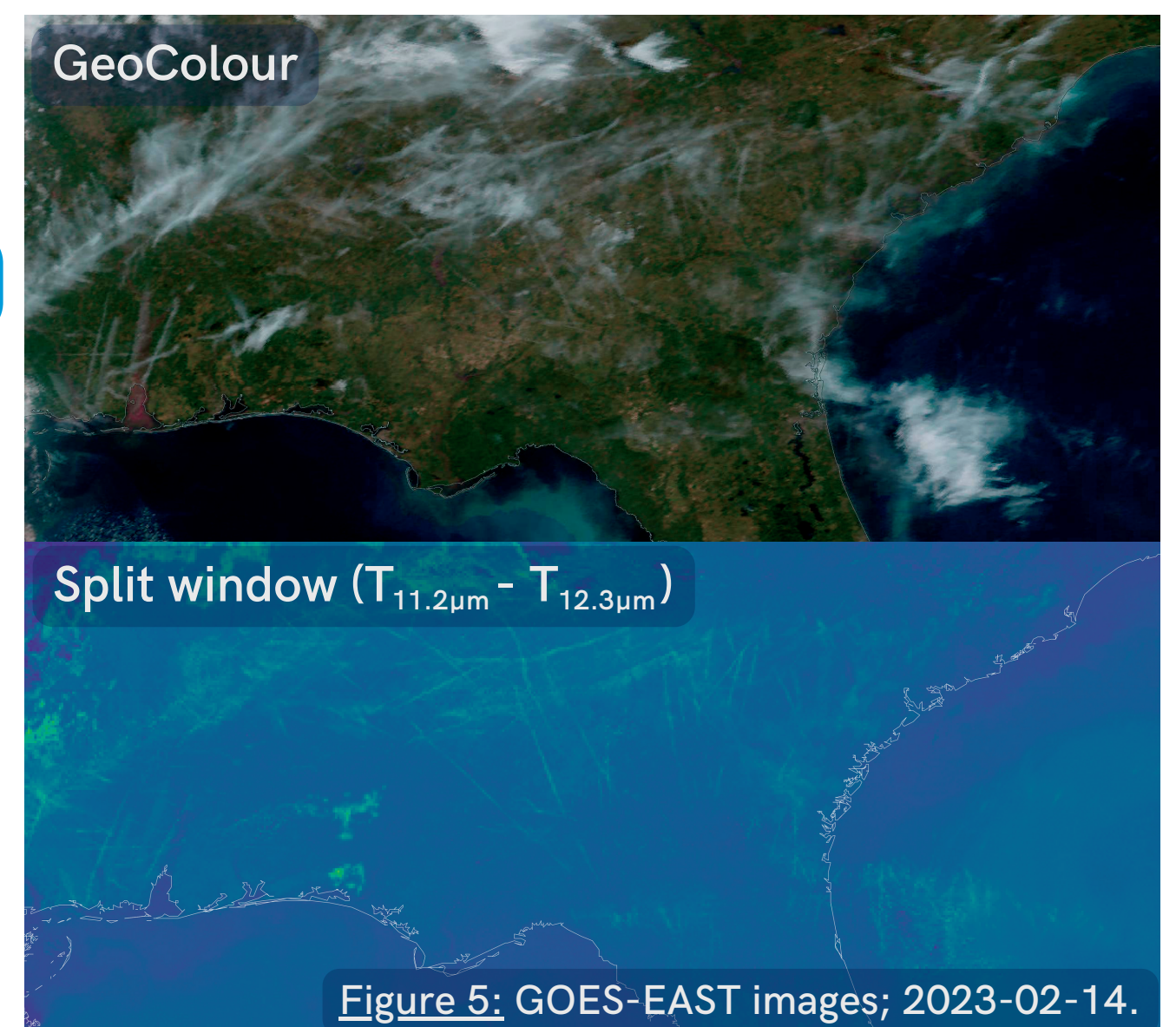


Figure 5: GOES-EAST images; 2023-02-14.



A contrail cirrus outbreak over London on 2022-10-07 (likely overlapping with some natural clouds).

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The header graphic is adapted from an image by the user Upl56 on Freepik.com

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