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Contribution of Contrail Cirrus to Aviation Induced Radiative Forcing and Surface Temperature Change

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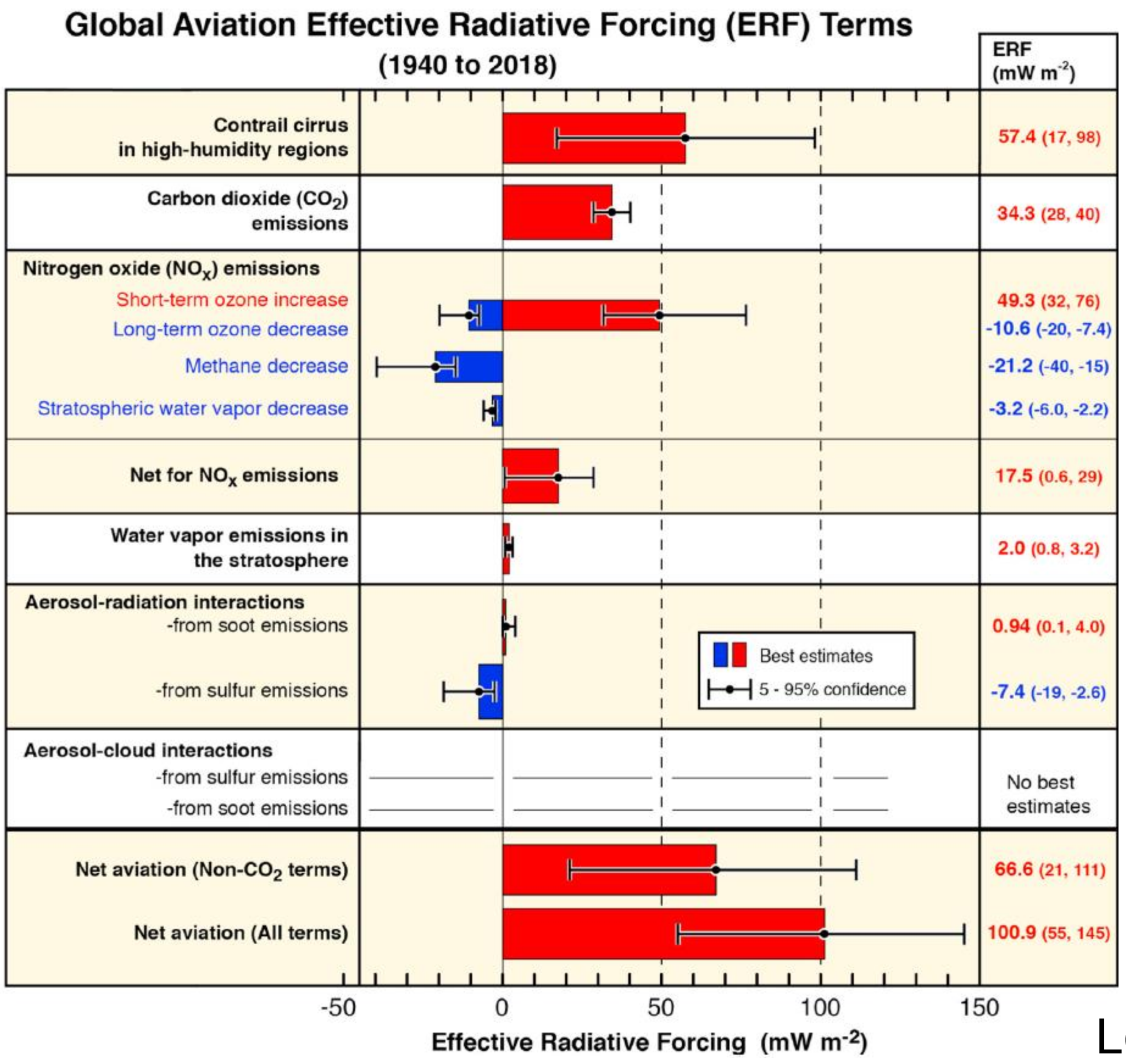
DLR

Climate impact of air traffic



Lee et al., 2021

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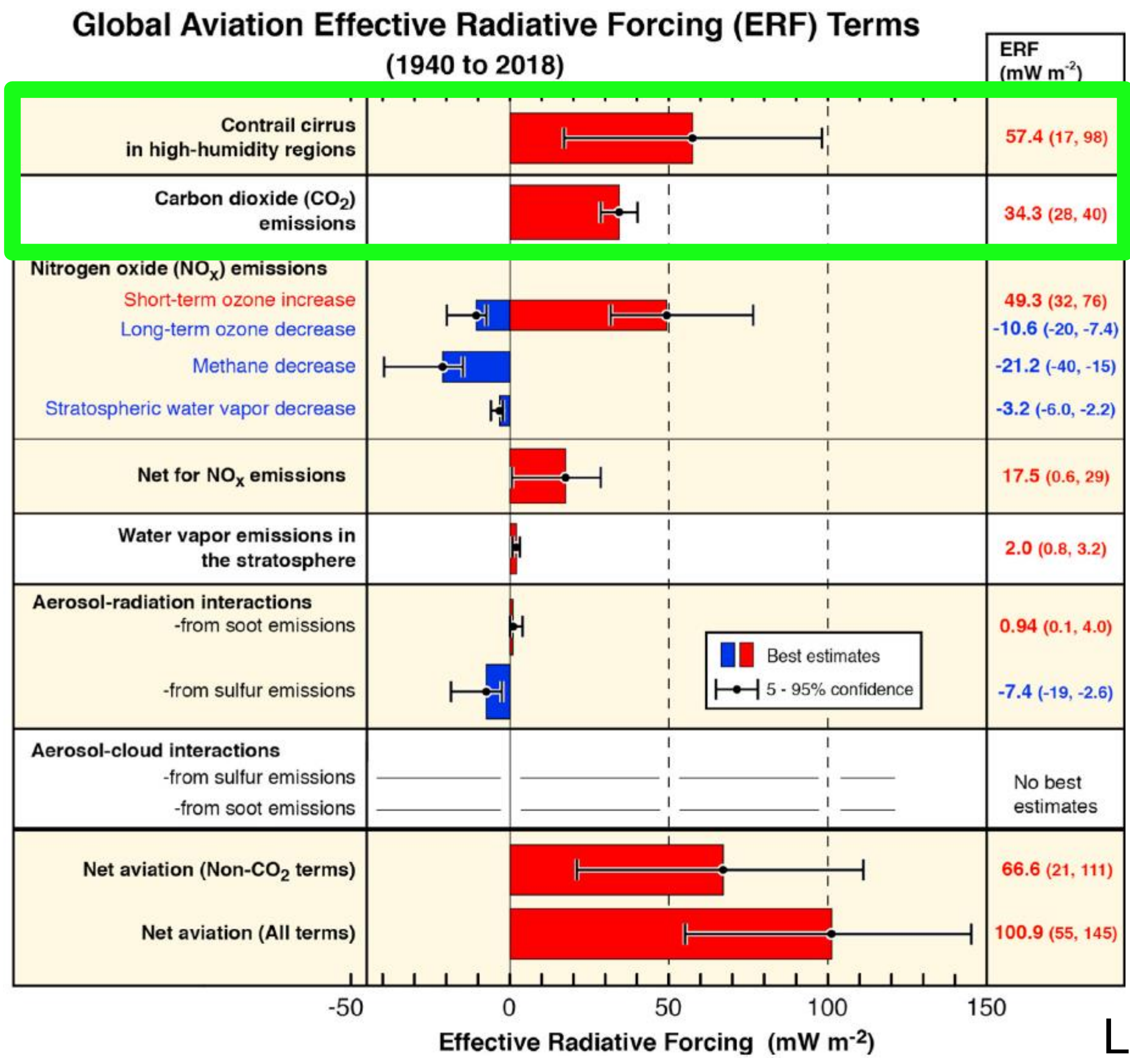

Lee et al., 2021

Metrics for assessing global climate impact

→ **So far:** Climate impact has been predominantly quantified, and the individual components ranked, on the basis of Radiative Forcings

→ **Requirement:** Climate sensitivities (λ) of the different forcers have to be approximately the same size

$$\Delta T_{surface} = \lambda \cdot RF$$

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→ **Requirement:** Climate sensitivities (λ) of the different forcers have to be approximately the same size

$$\Delta T_{surface} = \lambda \cdot RF$$

→ **But:** Deviations have already been confirmed for linear contrails (Ponater et al., 2005) and various other forcers (Richardson et al., 2019)

→ Magnitude of deviation is expressed by climate efficacy (r):

$$r = \frac{\lambda_{\text{Contrail cirrus}}}{\lambda_{CO_2}}$$

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Model setup

- EMAC / MESSy climate model, resolution 2.8° (horizontally), ~600m (vertically)
- Contrail cirrus parameterization of Bock and Burkhardt (2016)
  ↳ „Two-moment cloud scheme“ (Ice water content and ice crystal number conc.)
- AEDT 2050 air traffic dataset 12x scaled (air traffic density and water vapor emissions)

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FSST simulations:

- sea surface temperatures fixed by climatology (FSST)
- Radiative forcings (RF_{inst}, RF_{adj}, ERF)
- Rapid radiative adjustments

$$\lambda = \frac{\Delta T_{surface}}{RF}$$

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→ see Bickel et al. (2020)

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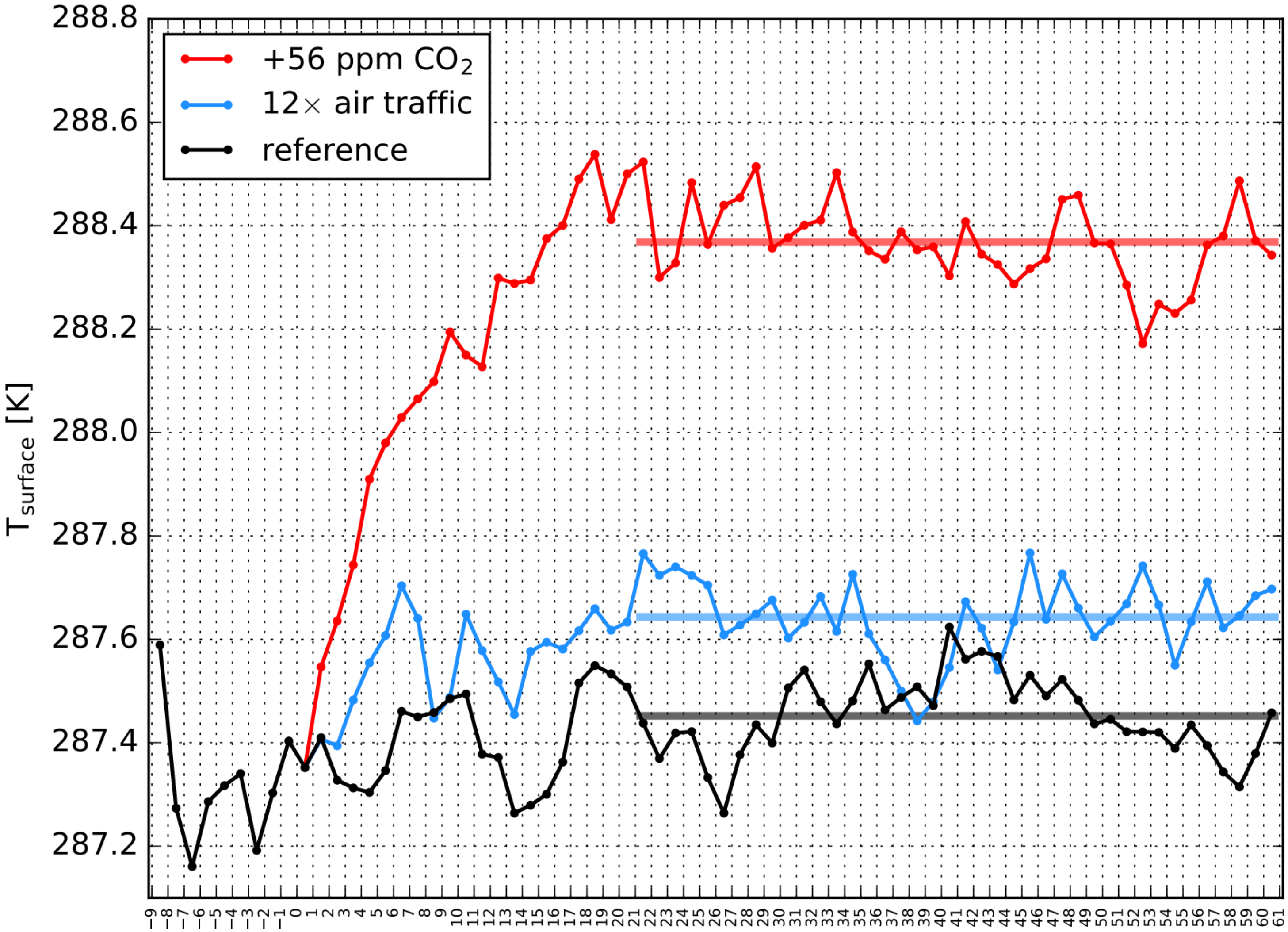
MLO simulations:

- Coupled mixed layer ocean (MLO)
- surface temperature change
- Slow feedbacks

$$\lambda = \frac{\Delta T_{surface}}{RF}$$

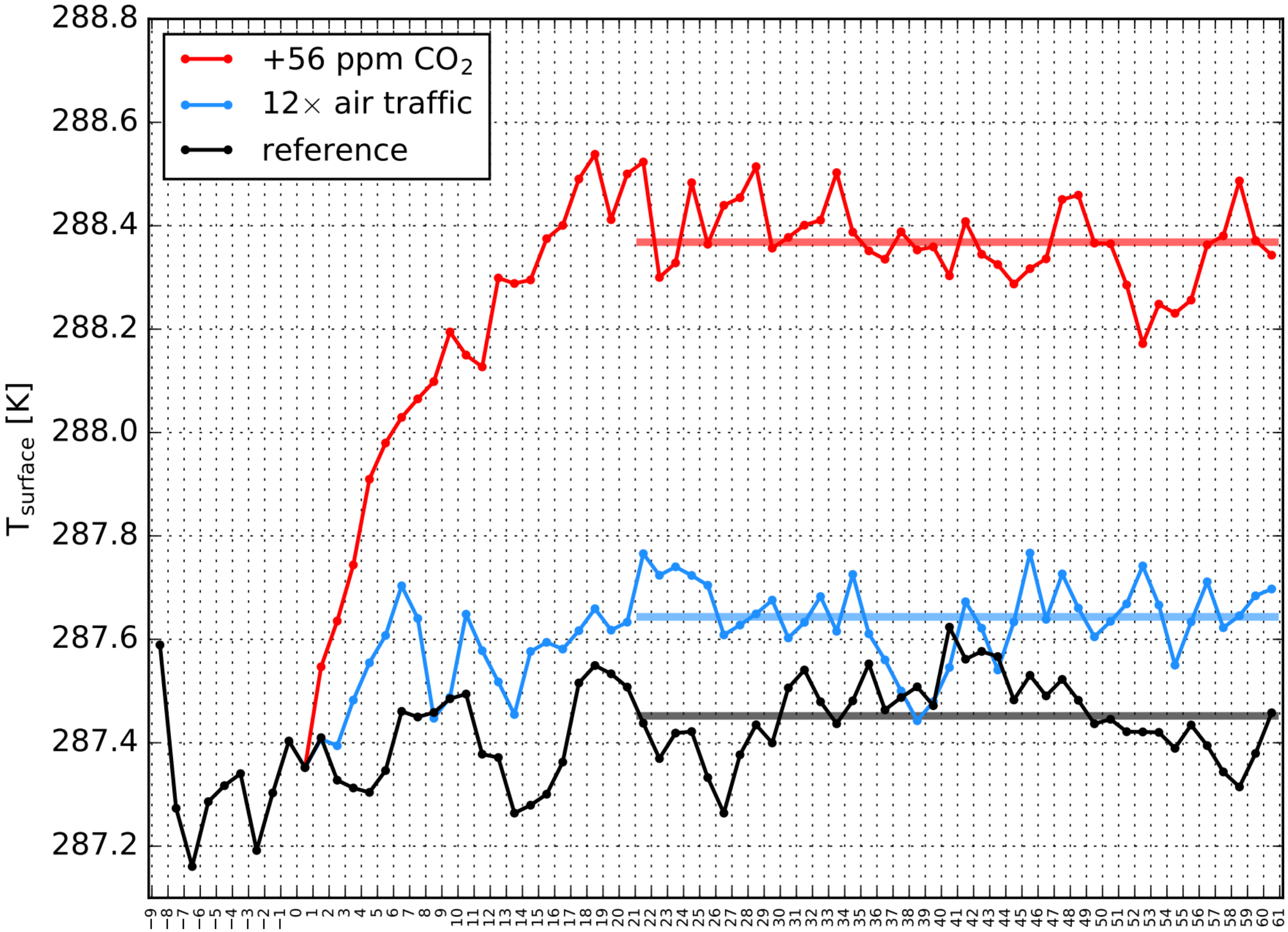
Surface temperature change



+56 ppm CO_2:
RF: 854 mW/m²

Contrail cirrus:
RF: 858 mW/m²

Surface temperature change



+56 ppm CO_2:
RF: 854 mW/m²
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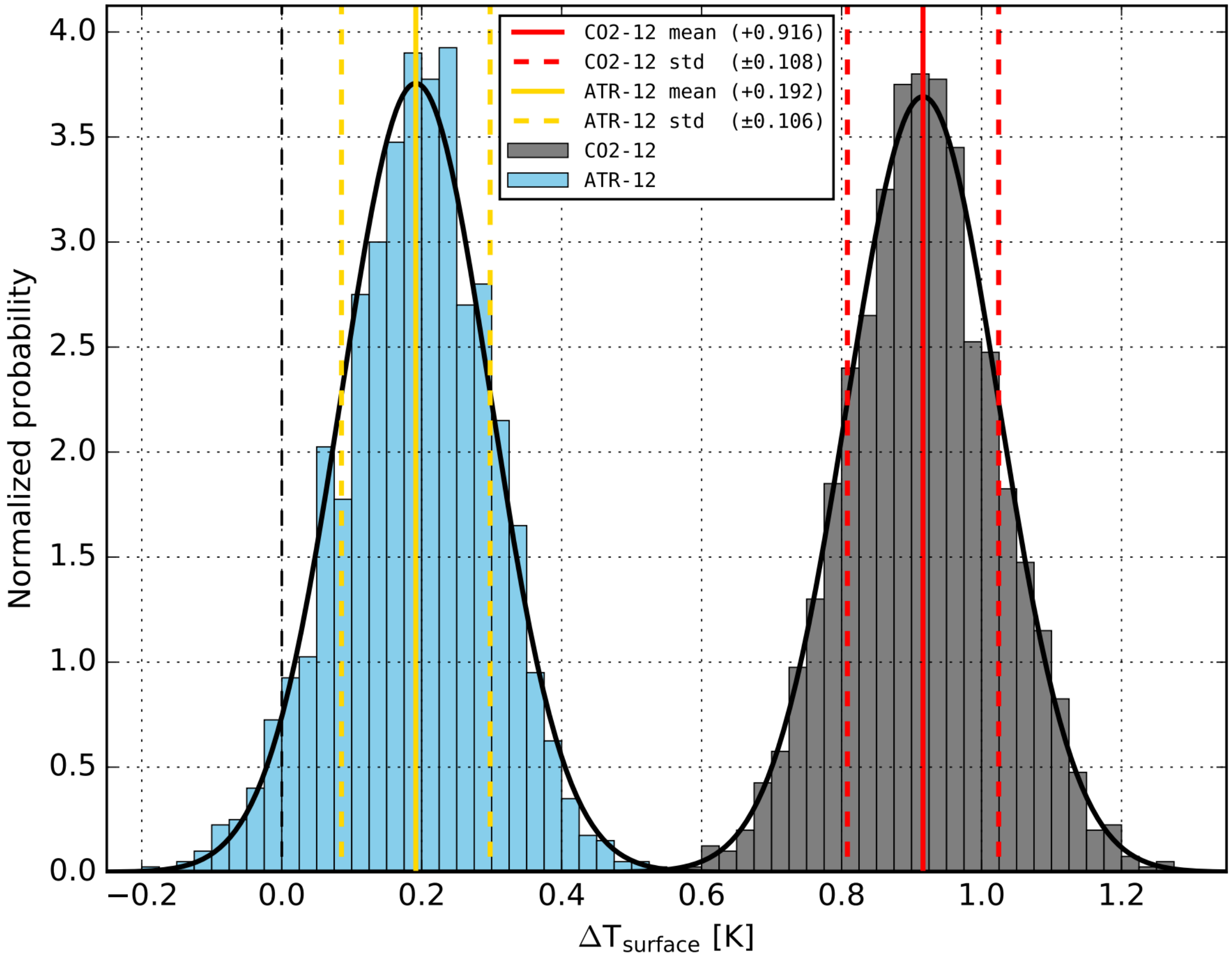

Contrail cirrus: +0.2 K

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Climate sensitivity and climate efficacy (ERF framework)

Contrail cirrus

ERF: 568 mWm^{-2}

$\Delta T_{surface}$: +0.2 K

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ERF: 1034 mWm^{-2}

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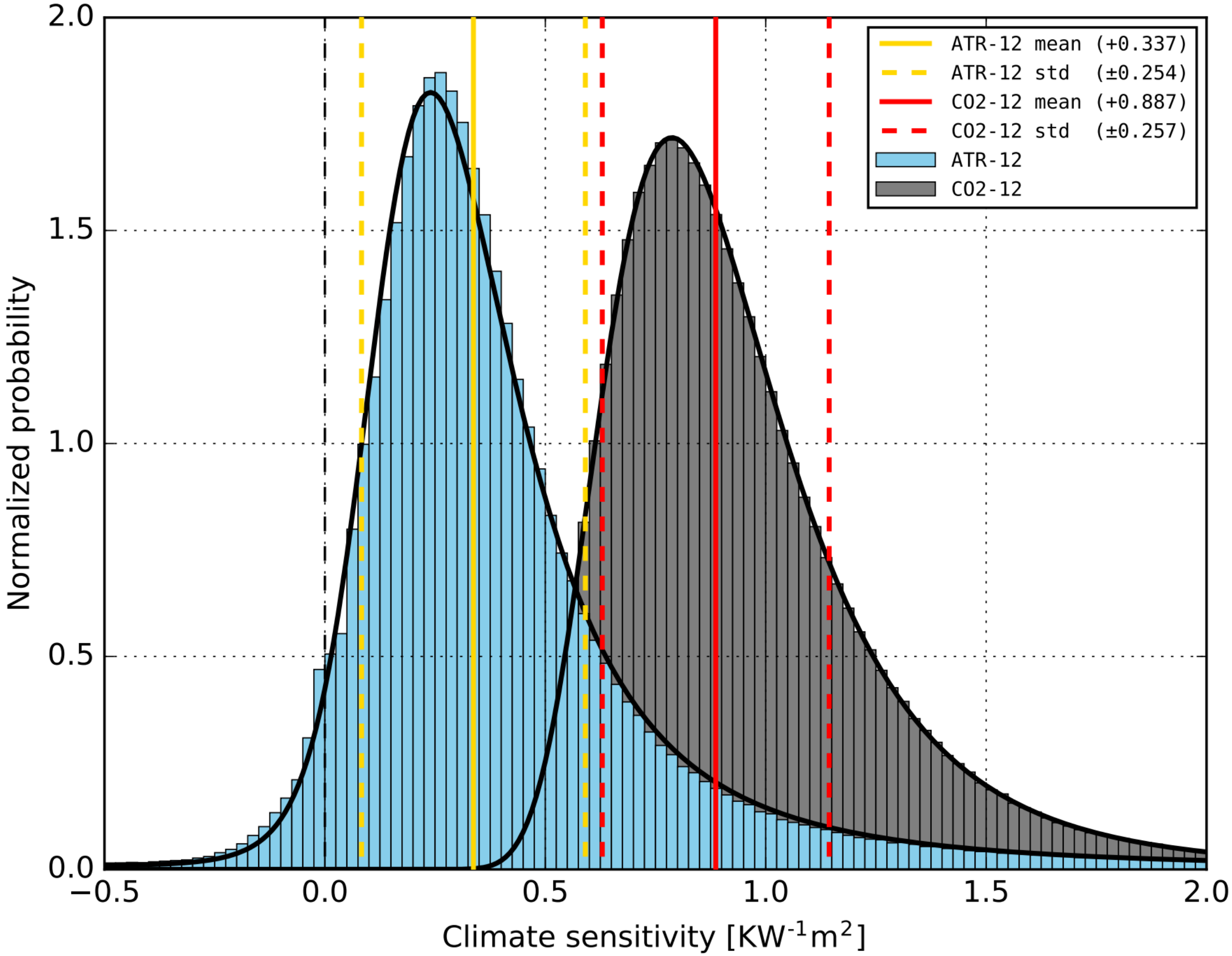
$$\text{Climate sensitivity:} \quad \lambda = \frac{\Delta T_{surface}}{\text{ERF}}$$

Contrail cirrus – **λ:** 0.33 $KW^{-1}m^2$

+56 ppm CO_2 – **λ:** 0.89 $KW^{-1}m^2$

Climate sensitivity



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λ: 0.89 $KW^{-1}m^2$

$$\text{Climate efficacy:} \quad r = \frac{\lambda_{\text{Contrail cirrus}}}{\lambda_{CO_2}}$$

$r_{\text{Contrail cirrus}}$: 0.38

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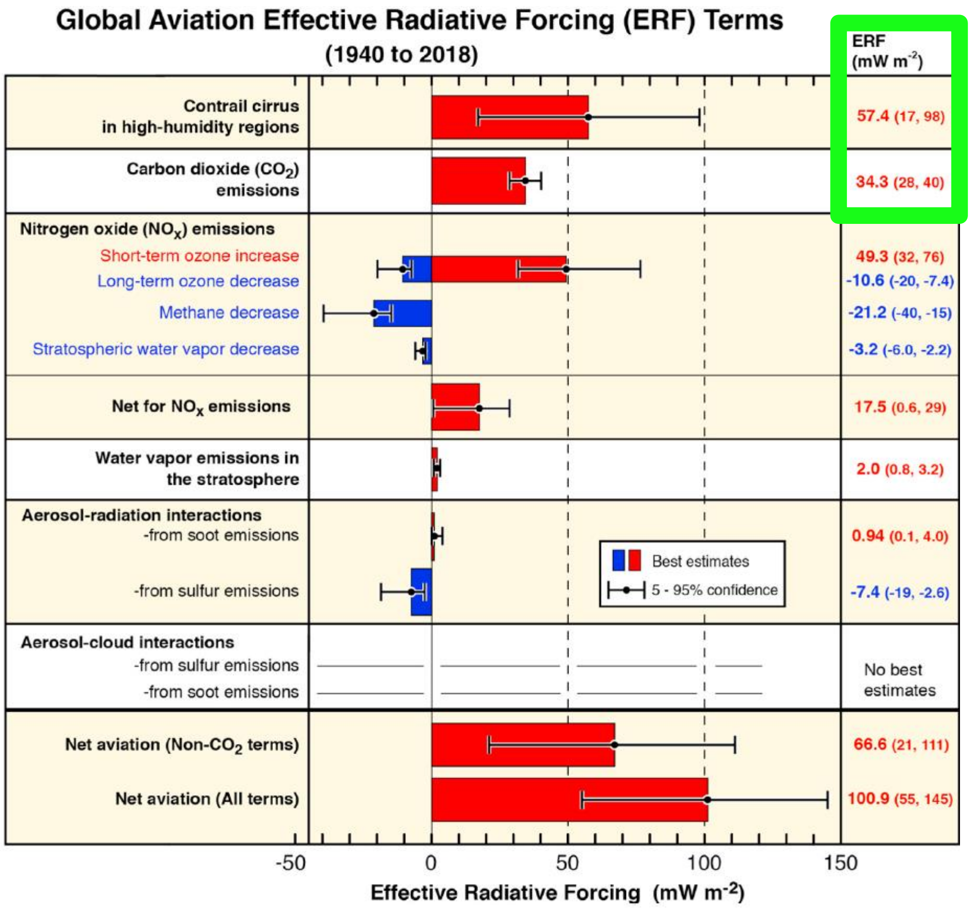
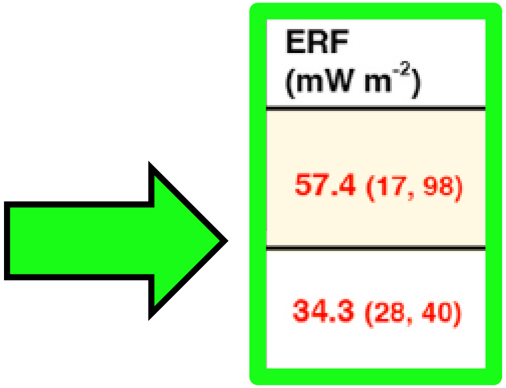
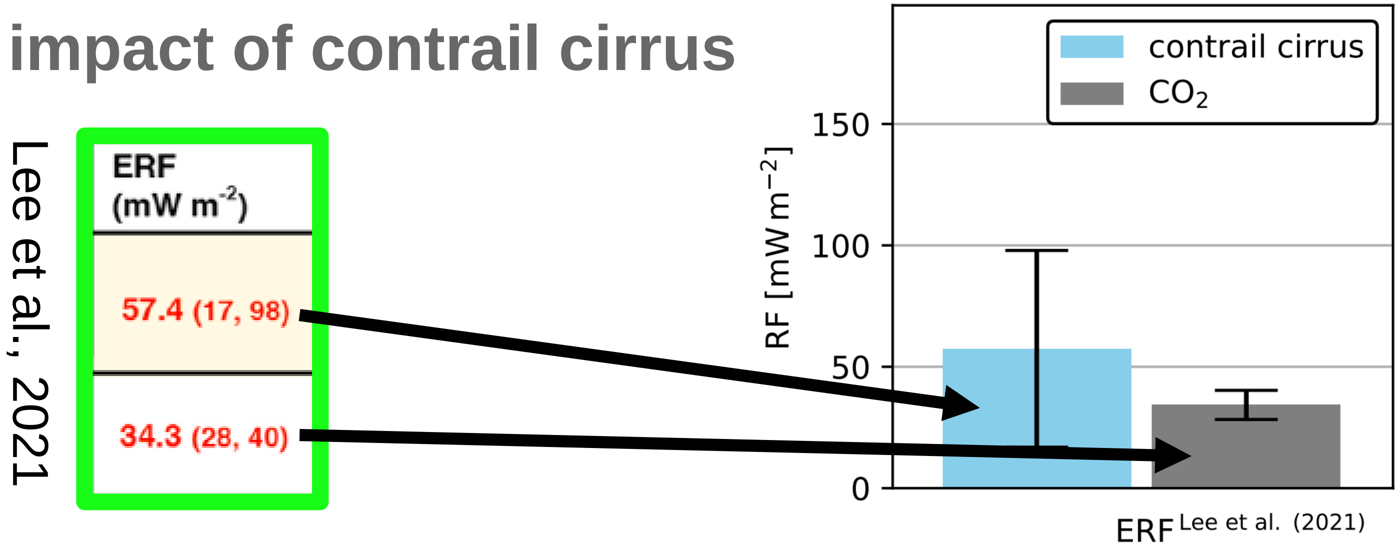
Climate impact of contrail cirrus





Lee et al., 2021

Climate impact of contrail cirrus



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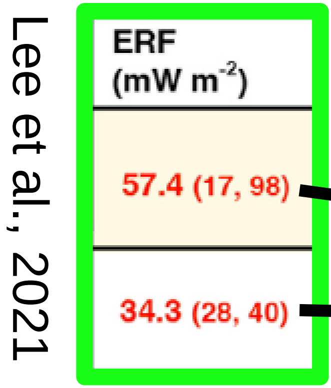
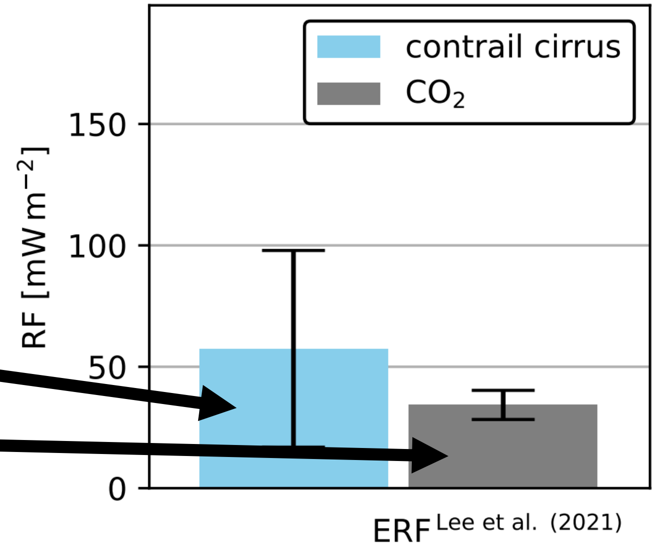


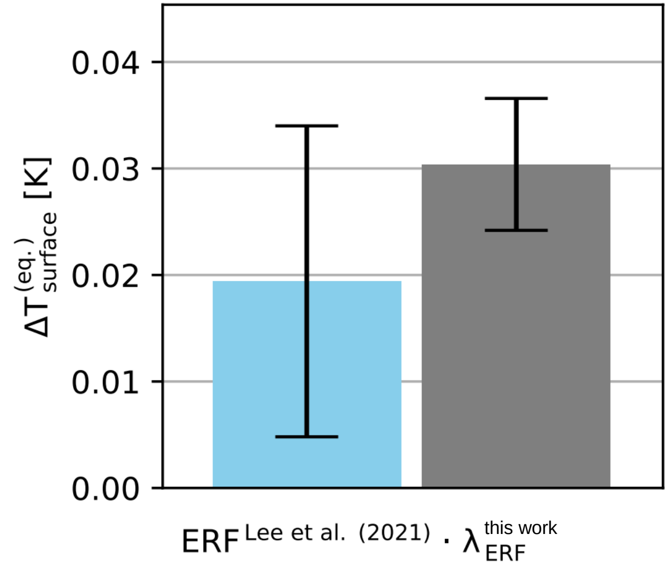


Contrail cirrus:

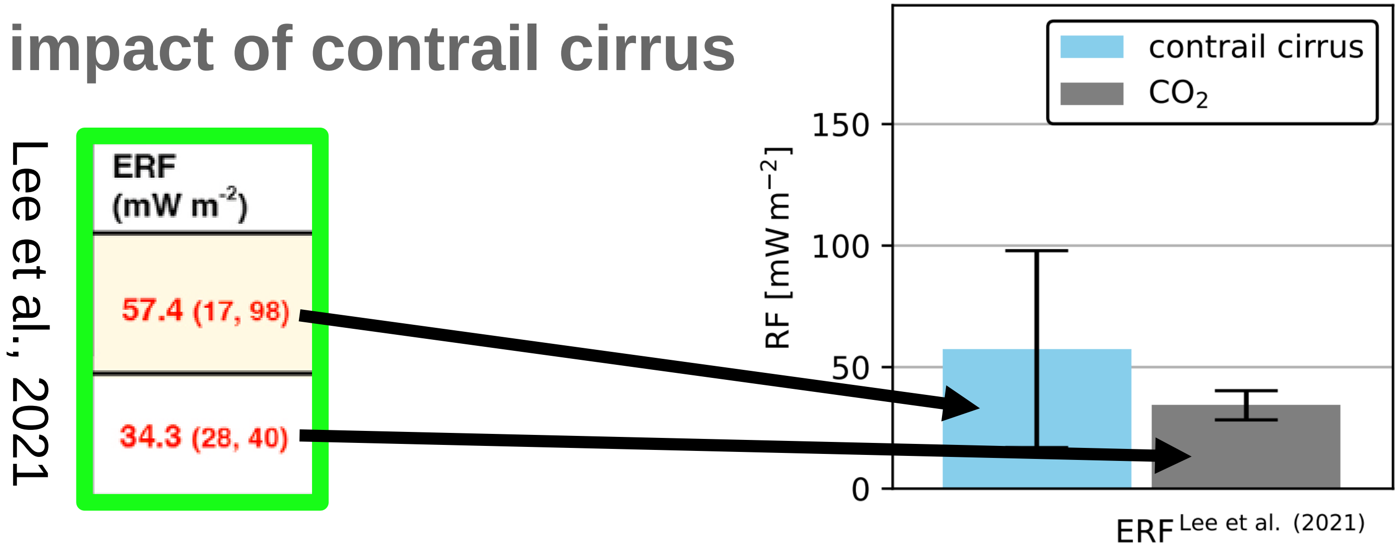
ERF_{Lee} • 0.33 KW^{-1}m^2 = **+0.019 K**

CO_2:

ERF_{Lee} • 0.89 KW^{-1}m^2 = **+0.031 K**



Climate impact of contrail cirrus



Contrail cirrus:

$ERF_{Lee} \cdot 0.33\ KW^{-1}m^2 = \mathbf{+0.019\ K}$

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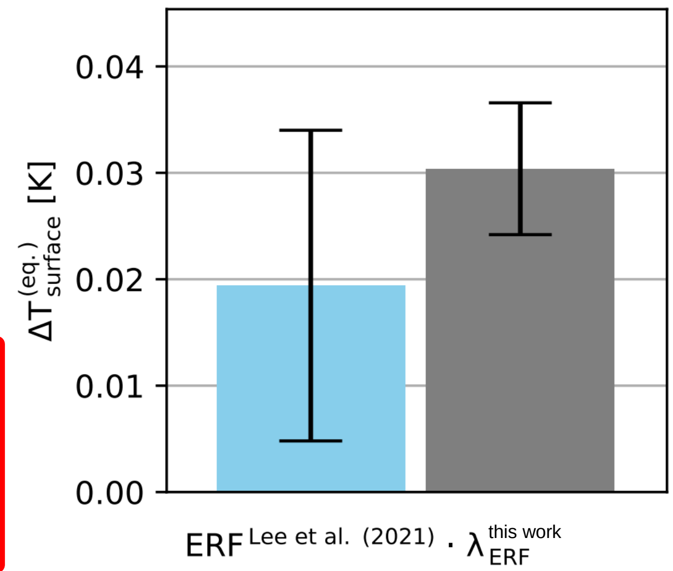
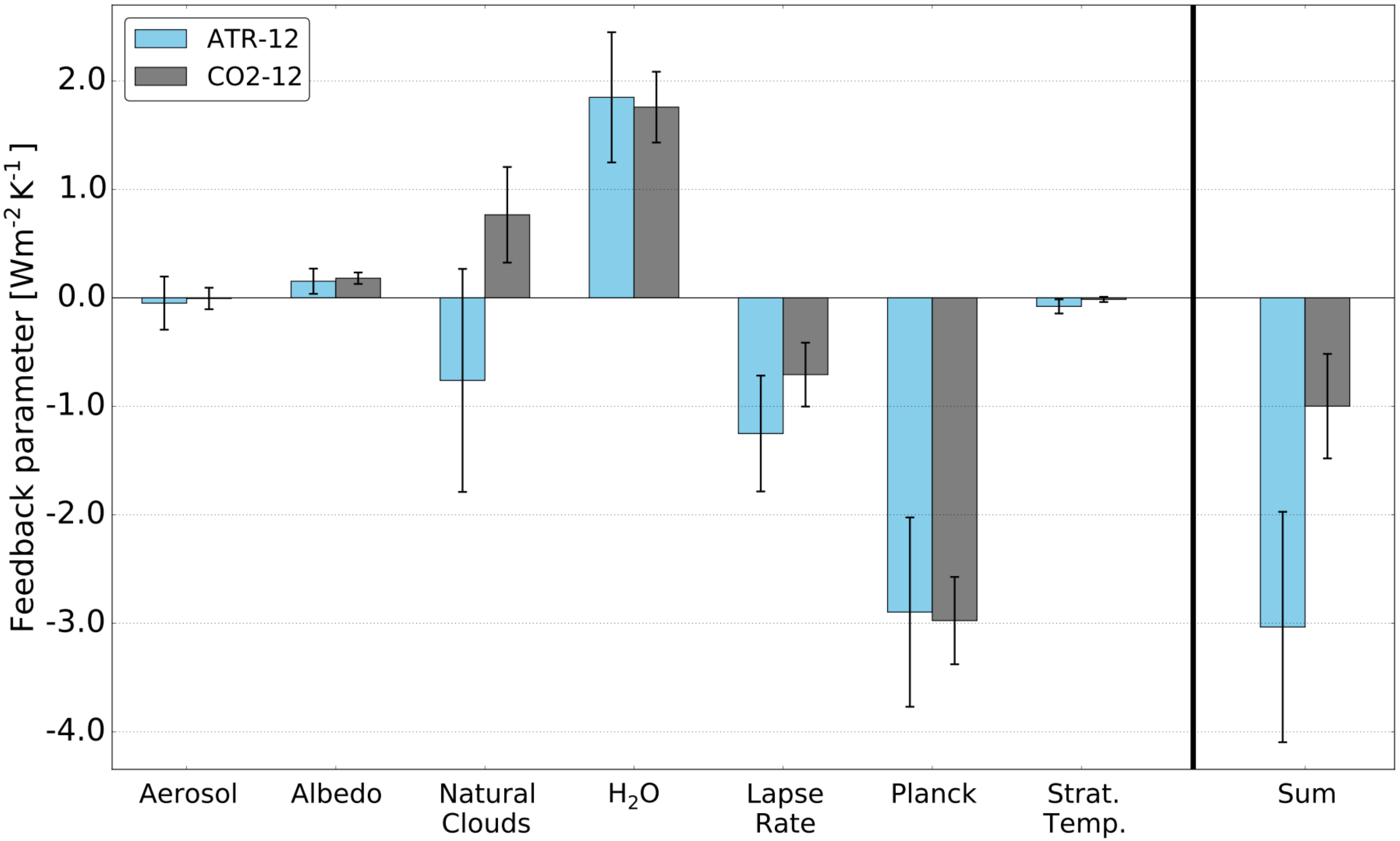


ERF may be an inappropriate metric for contrail cirrus to assess the impact on surface temperature

Feedback analysis to identify the physical origin of the reduced climate efficacy



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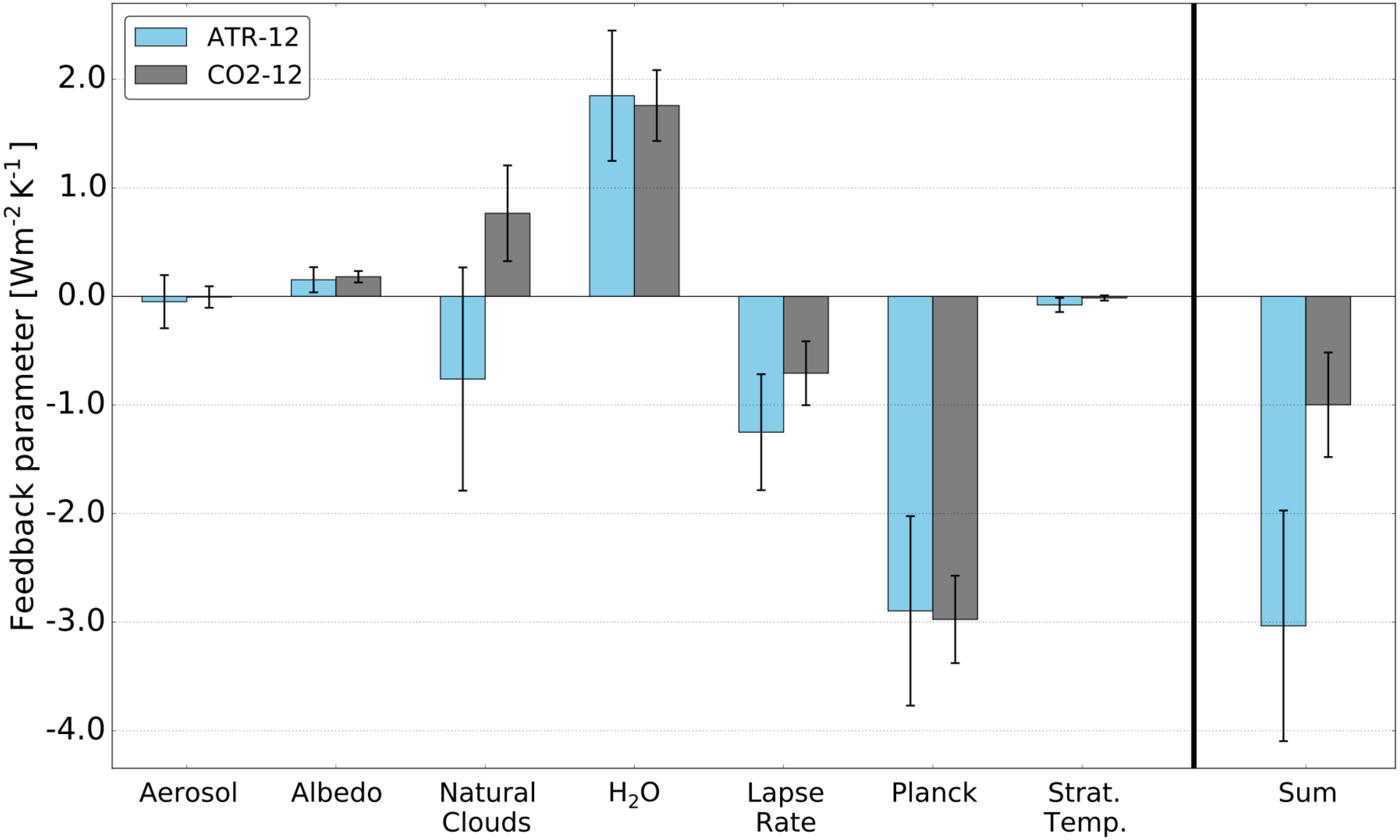

Summary

- The climate sensitivity of contrail cirrus is significantly smaller than that of a CO_2 perturbation with similarly sized radiative forcing
- Climate efficacy of contrail cirrus is strongly reduced (0.38) in the ERF framework and is even smaller (0.21) in the conventional RF framework
- Determination of the physical origins using feedback analysis reveals different response of the cloud and lapse-rate slow feedbacks between contrail cirrus and CO_2
- Effective radiative forcing (ERF) of contrail cirrus might be an inappropriate metric for assessing or comparing the impact on global mean surface temperature

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Literature

Bickel, M., Ponater, M., Bock, L., Burkhardt, U., & Reineke, S. (**2020**). Estimating the Effective Radiative Forcing of Contrail Cirrus, Journal of Climate, 33(5), 1991-2005. Retrieved Mar 10, 2022, from https://journals.ametsoc.org/view/journals/clim/33/5/jcli-d-19-0467.1.xml

Bickel, M. (**2023**): Climate impact of contrail cirrus. Dissertation, LMU München: Fakultät für Physik https://edoc.ub.uni-muenchen.de/32411/

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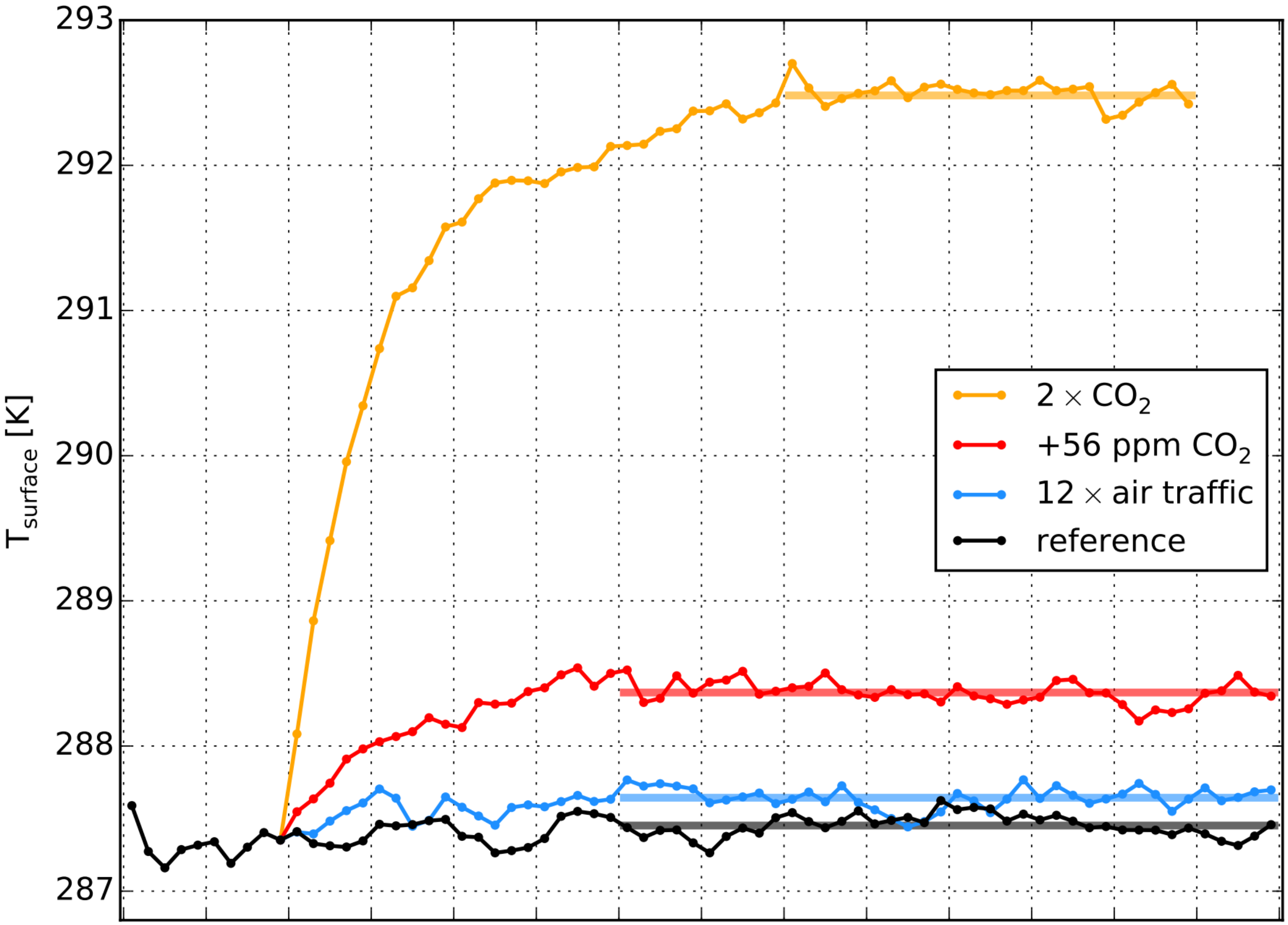
Ponater, M., Marquart, S., Sausen, R., and Schumann, U. (2005), On contrail climate sensitivity, Geophys. Res. Lett., 32, L10706, doi:10.1029/2005GL022580.

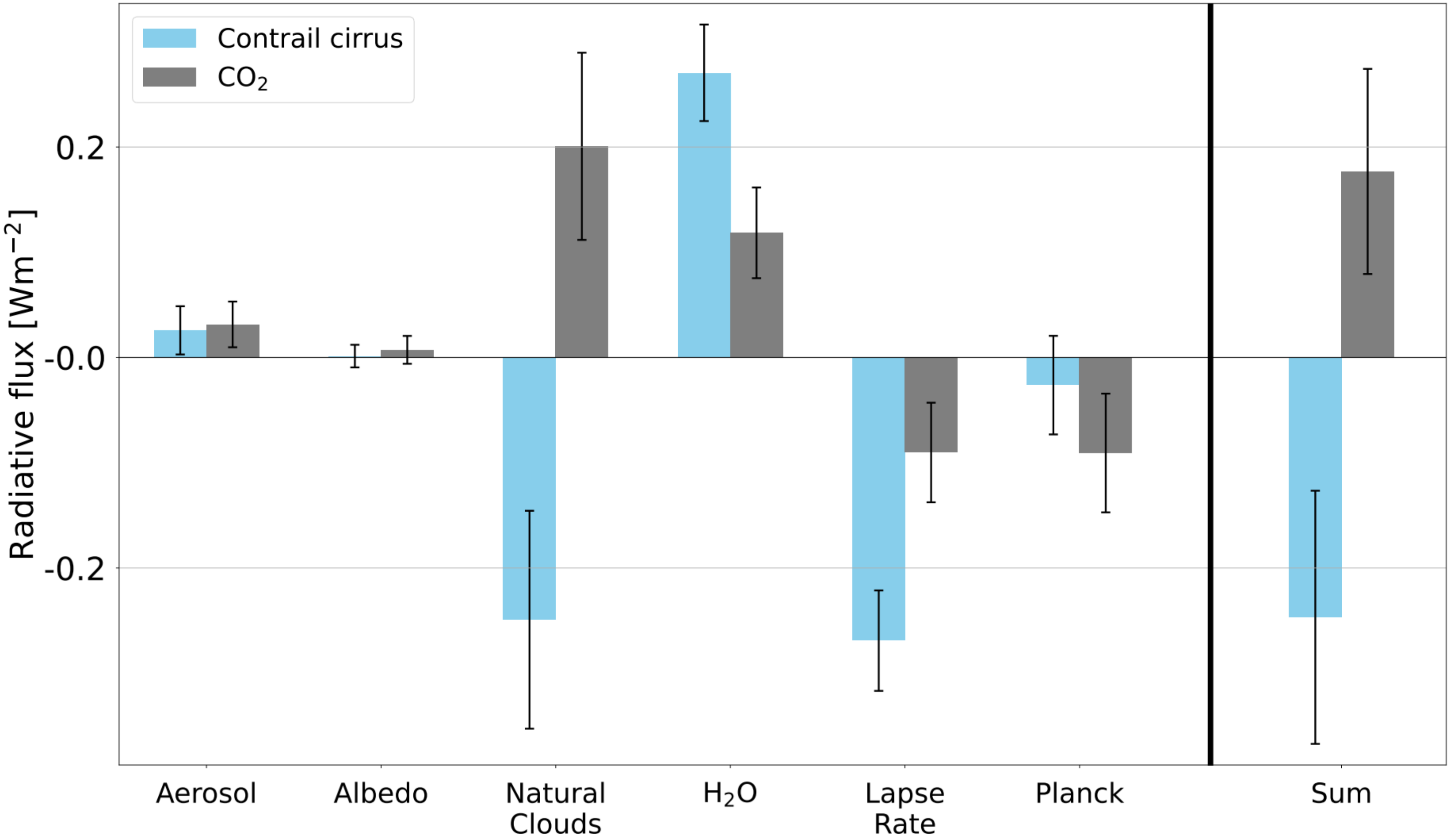
Richardson, T. B., Forster, P. M., Smith, C. J., Maycock, A. C., Wood, T., Andrews, T., et al. (2019). Efficacy of climate forcings in PDRMIP models. Journal of Geophysical Research: Atmospheres, 124, 12824– 12844. https://doi.org/10.1029/2019JD030581

Questions?

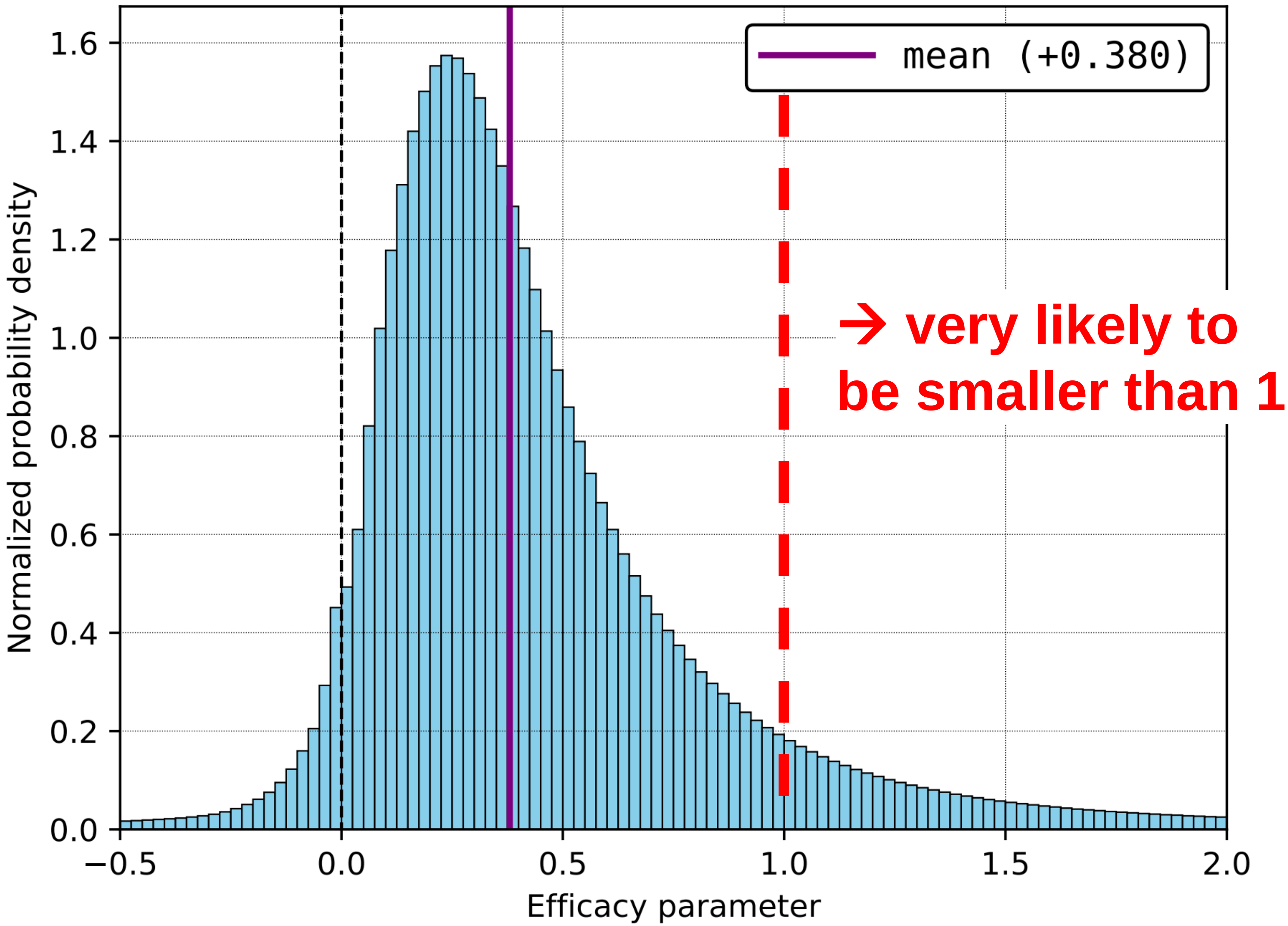
Surface temperature change



Rapid radiative adjustments



Distribution of Contrail cirrus efficacy (r)



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