AGU Fall Meeting 2019 – A31N: Diagnosing the Components of Radiative Forcing and Addressing Its Sources of Intermodel Spread – Poster A31N-2737

Bounding aerosol radiative forcing of climate change

Review of Geophysics, https://doi.org/10.1029/2019RG000660

Introduction

Aerosol radiative forcing plays an important role in the attribution of past climate changes, estimates of future allowable carbon emissions, and the assessment of potential geoengineering solutions. Substantial progress made over the past 40 years in observing, understanding, and modeling aerosol processes helped quantify aerosol radiative forcing, but uncertainties remain large.

In spring 2018, under the auspices of the World Climate Research Programme's Grand Science Challenge on Clouds, Circulation and Climate Sensitivity, thirty-six experts gathered to take a fresh and comprehensive look at present understanding of aerosol radiative forcing and identify prospects for progress on some of the most pressing open questions. The outcome of that meeting is a review paper, Bellouin et al. (2019), soon to be published in Reviews of Geophysics.

This review provides a new range of aerosol radiative forcing over the industrial era based on multiple, traceable and arguable lines of evidence, including modelling approaches, theoretical considerations, and observations. A substantial achievement is to focus on lines of evidence rather than a survey of past results or expert judgement, and to make the open questions much more specific.

Key points

- An assessment of multiple lines of evidence supported by a conceptual model provides ranges for aerosol radiative forcing of climate change;
- Aerosol effective radiative forcing is assessed to be between −1.60 and −0.65 W m^{-2} at the 16-84% confidence level;
- Although key uncertainties remain, new ways of using observations provide stronger constraints for models.

Aerosol-radiation interactions — Adjustments to ari — Twomey — Adjustments to Twomey

$$E = \Delta\tau_a \left[S_\tau^{\text{clear}}(1 - c_\tau) + S_\tau^{\text{cloudy}} c_\tau + \frac{dR}{dR_{\text{atm}}} \cdot \frac{dR_{\text{atm}}}{d\tau_a} \right] + \Delta \ln N_d \left[S_N \cdot C_N + S_{C,N} \cdot c_C + S_{L,N} \cdot C_L \right]$$

Industrial-era changes in aerosols and clouds

- Estimating industrial-era changes in aerosol optical depth ($\Delta\tau_a$) and cloud droplet number concentration ($\Delta \ln N_d$) is a difficult problem because preindustrial aerosols have not been observed.
- Observational inferences like the one shown in Figure 1 provide possible ways to estimate industrial-era changes. They suggest that aerosol optical depth likely increased by 15-30% and cloud droplet number concentration likely increased by 6-18% since 1850.

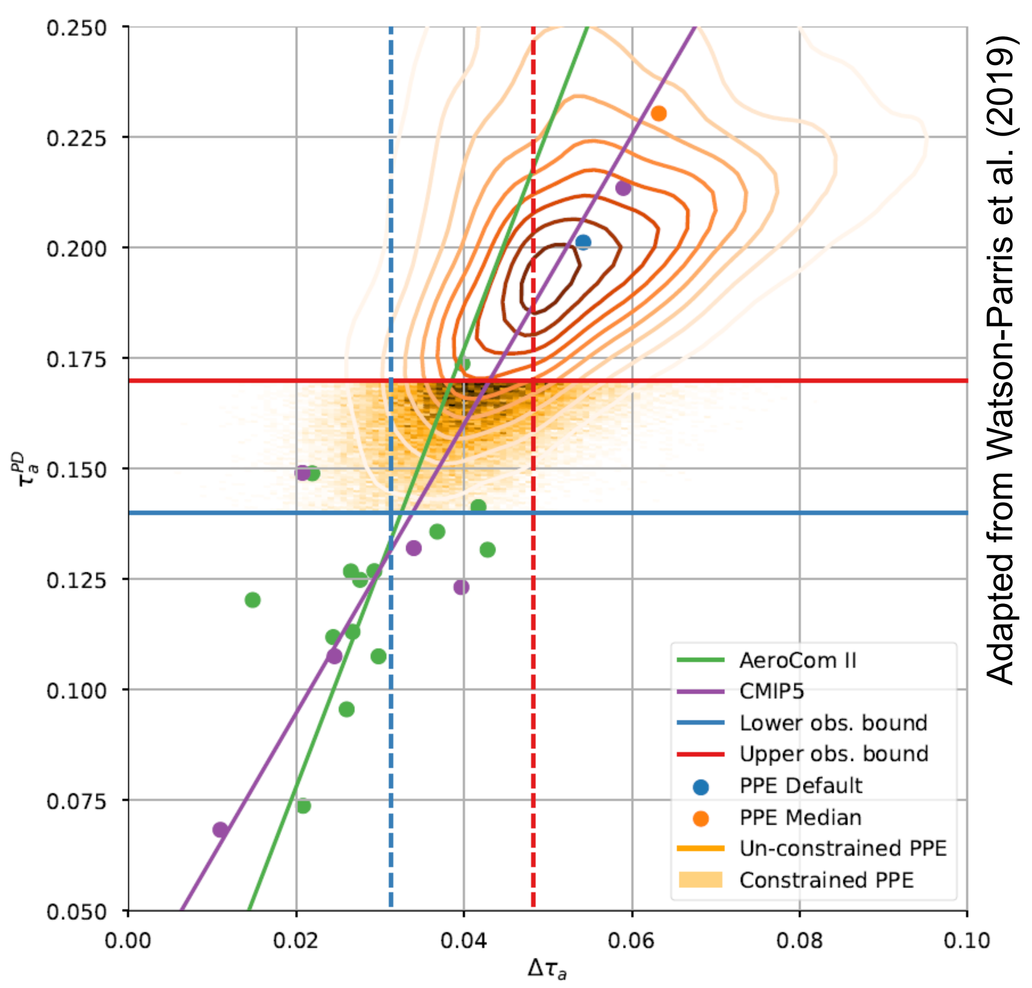


Figure 1: Distributions, standard deviation and best-fit lines of the present-day aerosol optical depth τ_a^{PD} against the industrial-era change in aerosol optical depth at 0.55 µm, $\Delta\tau_a$ between 1850 and present-day.

- Question marks remain on human influences on mineral dust emissions through land use change, on changes to biogenic aerosol emissions through interactions with anthropogenic aerosols, and on whether humans increase or suppress fires globally.

Sensitivities

- It is challenging to obtain properly weighted global averages of the radiative forcing and adjustment sensitivities (S and $\frac{dX}{dY}$ terms) from process-level lines of evidence like in-situ obs and large eddy simulation.
- So weaker lines of evidence, like global modeling or large-scale satellite studies, had to be used instead.
- The sensitivities of ice clouds to aerosol perturbations are unknown. But there is also little evidence of a large-scale perturbation of ice clouds by aerosols.

Effective cloud fractions

- For aerosols to exert a radiative forcing, there needs to be an aerosol perturbation, a sensitivity of top-of-atmosphere radiation to that perturbation, and, for adjustments, a sensitivity of temperature, moisture and cloudiness.
- In the equation above, those elements are expressed as effective cloud fractions (the c terms). Figure 2 shows distributions of effective cloud fractions for aerosol-cloud interactions.

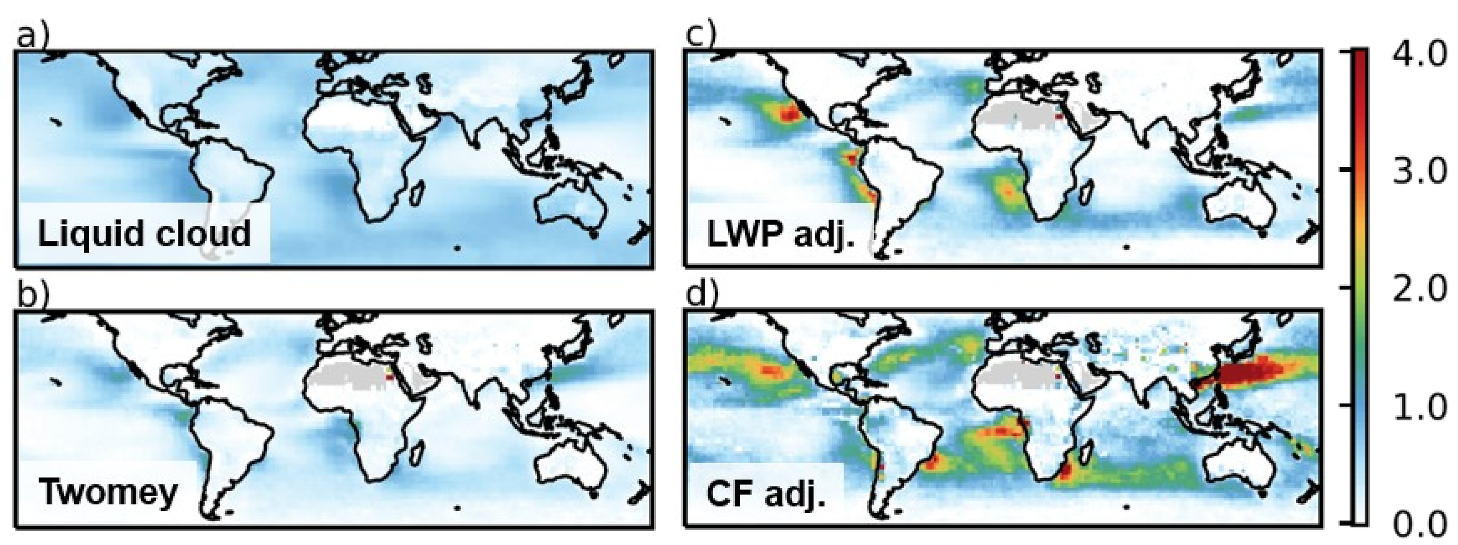
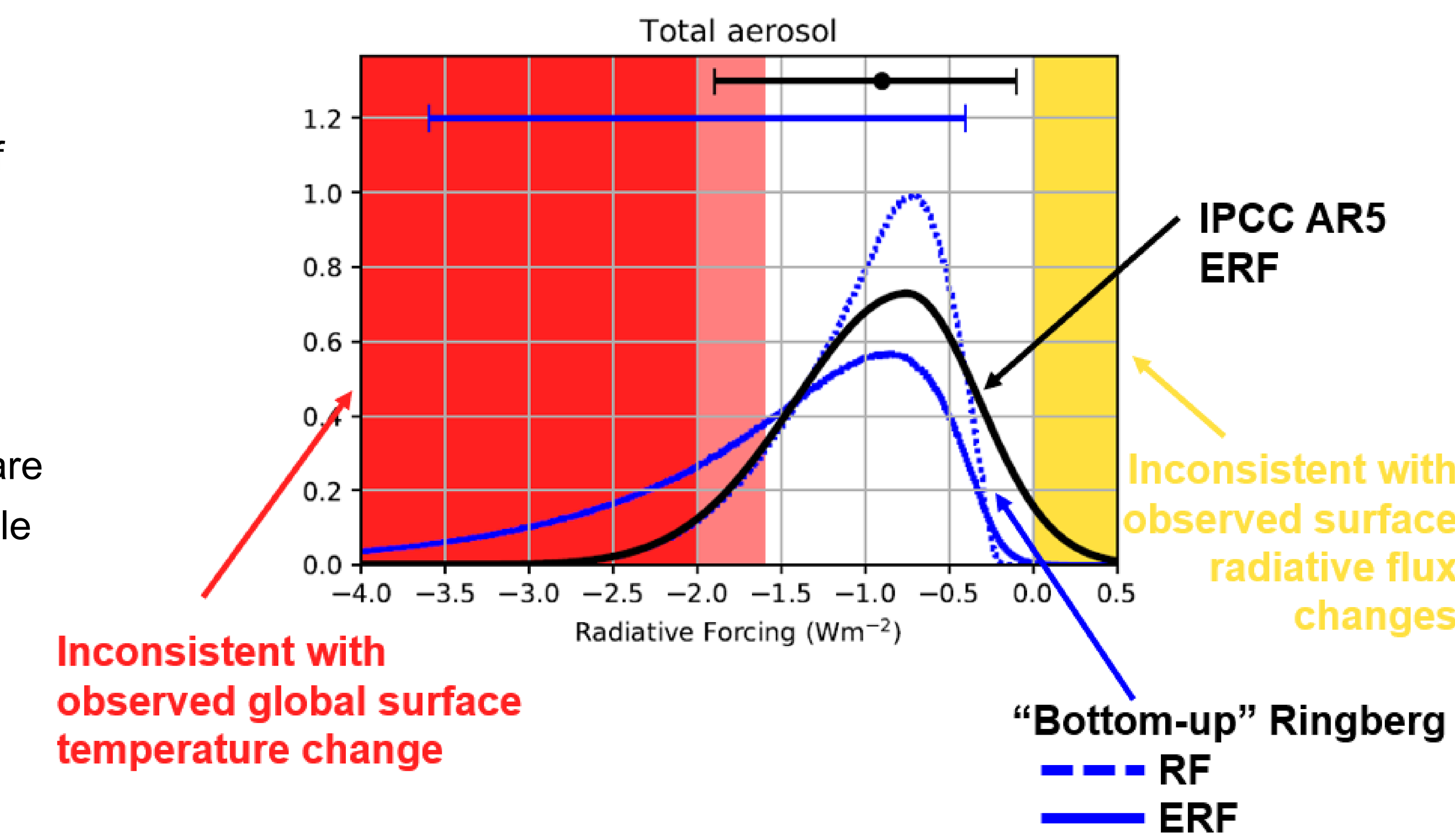


Figure 2: (a) Liquid cloud fraction, multiplied by 2 to be legible on the shared color scale. (b–d) The effective cloud fractions for b) the radiative forcing of aerosol-cloud interactions (C_N), c) rapid adjustments in liquid water path (C_L) and d) rapid adjustments in liquid cloud fraction (C_C).

Outcome



Reference

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Acknowledgements

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