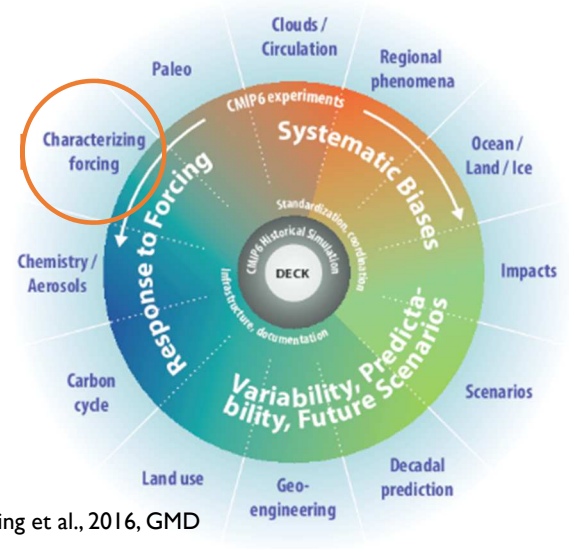
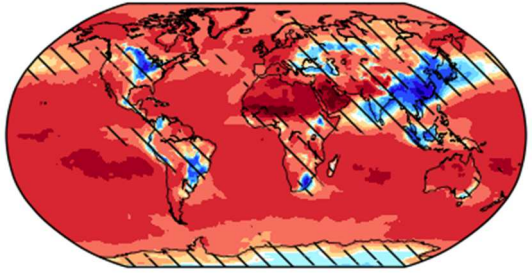
Effective Radiative Forcing and adjustments in CMIP6 models



Eyring et al., 2016, GMD

Chris Smith, Ryan Kramer, Gunnar Myhre, Kari Alterskjær, Bill Collins, Adriana Sima, Olivier Boucher, Jean-Louis Dufresne, Pierre Nabat, Martine Michou, Seiji Yukimoto, Jason Cole, David Paynter, Hideo Shiogama, Fiona M. O'Connor, Eddy Robertson, Andy Wiltshire, Timothy Andrews, Cécile Hannay, Ron Miller, Larissa Nazarenko, Alf Kirkevåg, Dirk Olivié, Stephanie Fiedler, Anna Lewinschal, Chloe Mackallah, Martin Dix, Robert Pincus, Piers Forster



CONSTRAIN

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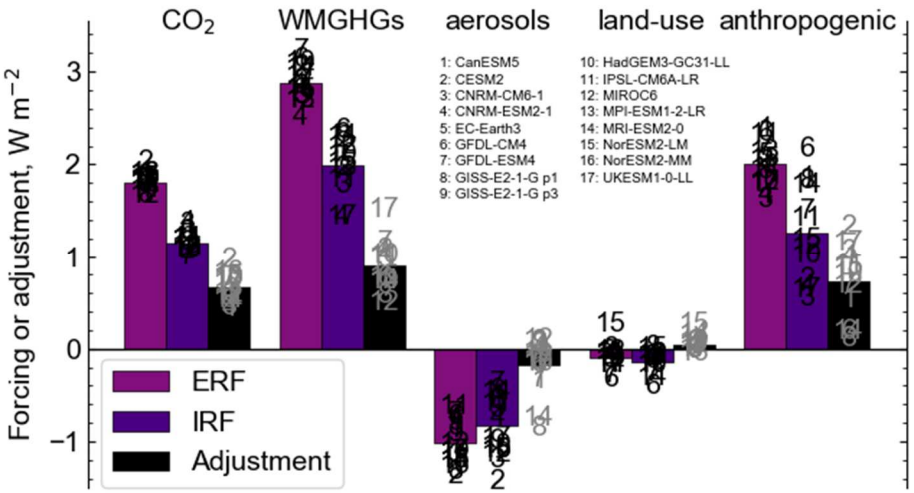
Effective Radiative Forcing in CMIP6 models

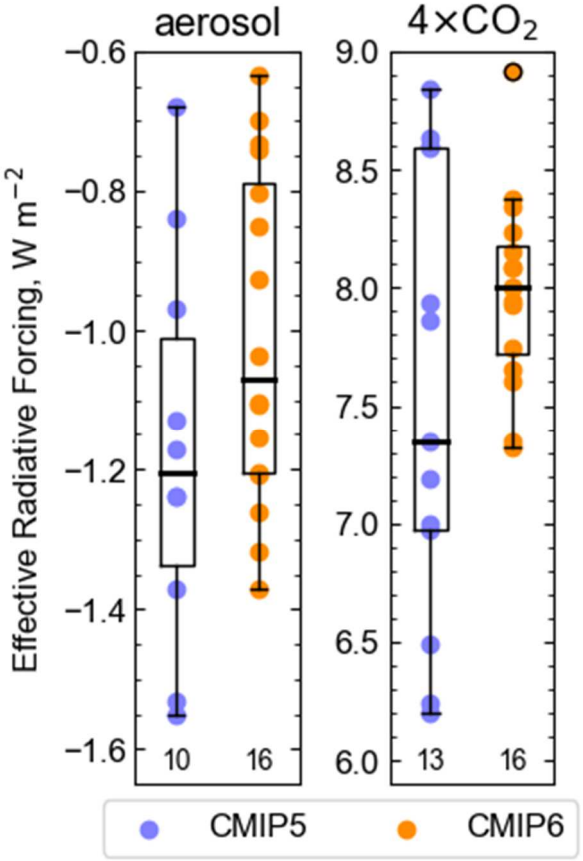
- We report results from the Radiative Forcing Model Intercomparison Project (RFMIP) tier 1
- Effective Radiative Forcing (ERF) from 4×CO_2 and present-day GHGs, aerosols, land use and total anthropogenic forcing using 30-year time slice experiments with climatological SSTs
- Using radiative kernels we can break down ERF into instantaneous (IRF) and adjustments



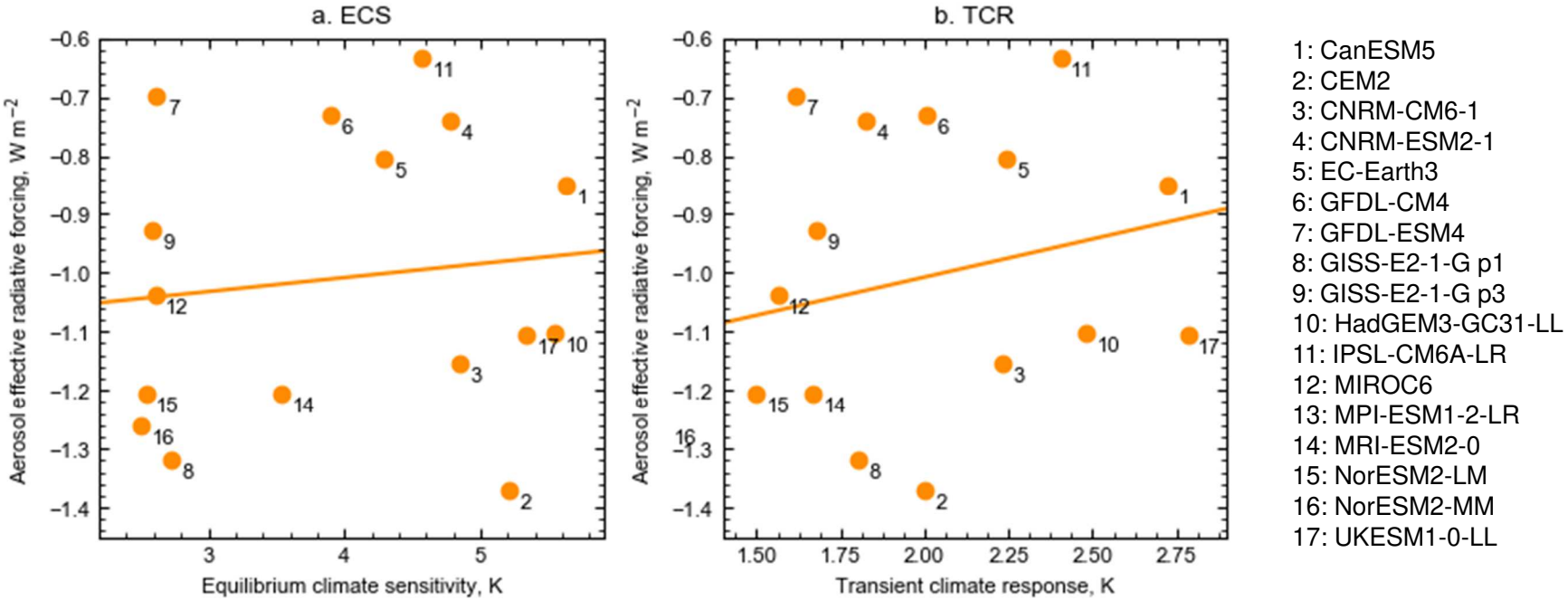
Forcing	ERF ± s.d. (W m^{-2})
4×CO_2	+7.98 ± 0.39
[Present-day CO_2]	[+1.81]
Well-mixed GHGs	+2.88 ± 0.19
Aerosols	-1.01 ± 0.23
Land-use change	-0.09 ± 0.13
Anthropogenic total	+2.01 ± 0.23
[Residual, interpreted as O_3]	[+0.23]

Comparison with CMIP5

- ERF has better model agreement in CMIP6 compared to CMIP5 where comparable experiments exist
- For CO_2 there is evidence that model radiative transfer parameterisations have improved
- Lesser spread and overall less negative aerosol forcing with more models. Reduction in mean could be CMIP5 (2000) v. CMIP6 (2014) emissions dataset.

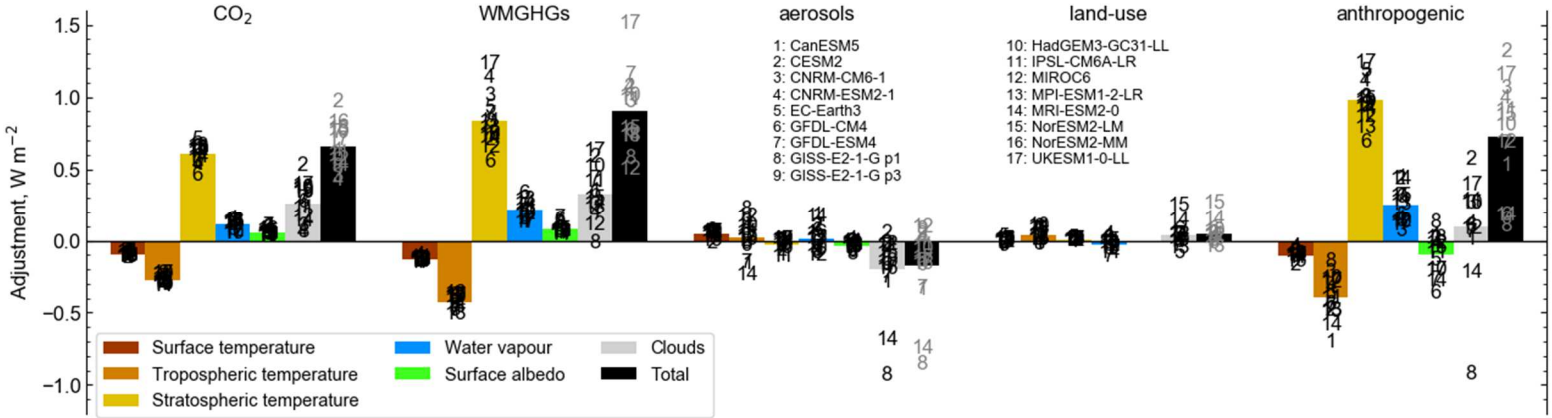


- However, aerosol forcing does not constrain climate sensitivity.
- The corollary of this is that modelling groups are not using correspondence of their CMIP historical runs to observed temperature as an explicit tuning constraint.
- We would expect a significant negative correlation between aerosol ERF and TCR especially.



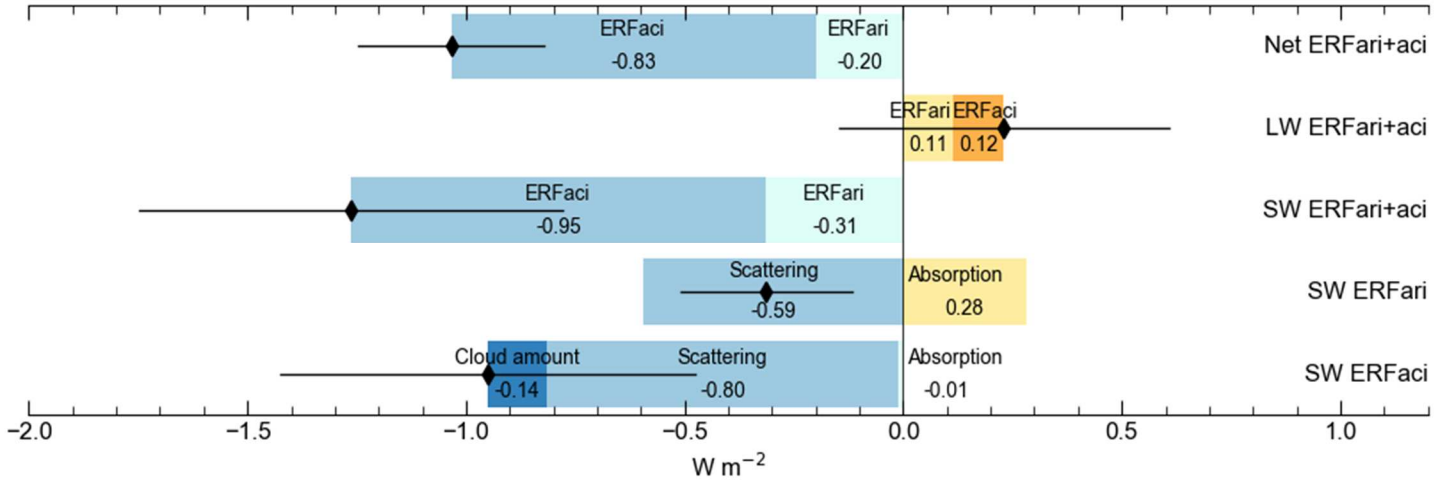
Radiative adjustments

- Using radiative kernels we can diagnose radiative [rapid] adjustments.
- We then define IRF = ERF – adjustments.
- For greenhouse gases, stratospheric adjustments dominate. Tropospheric and surface adjustments sum to near zero so that ERF ≈ [stratospherically adjusted] RF.
- For aerosols, clouds dominate and ERF ≠ RF.
- Due to aerosol effects on cloud adjustments, ERF ≠ RF for the anthropogenic total.



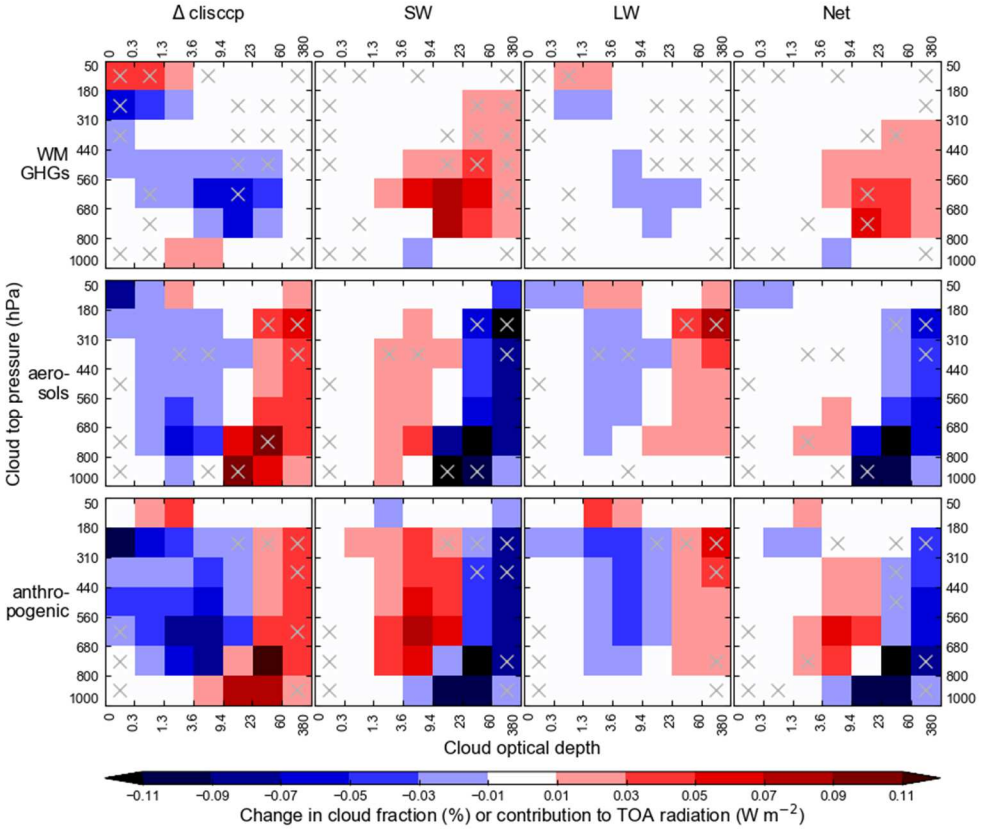
An alternative view of aerosol forcing

- We can diagnose the aerosol-radiation and aerosol-cloud interaction components of ERF (ERFari and ERFaci) using the Approximate Partial Radiative Perturbation method
- ERFari+aci is -1.03 (± 0.22) W m^{-2}, made up of -0.20 W m^{-2} ERFari and -0.83 W m^{-2} ERFaci
- Most of the Scattering contribution to ERFaci is the Twomey effect, which is part of the IRF. The adjustment component is made up of the cloud amount change + a small part of the Scattering contribution from cloud liquid water path change



Cloud responses using the ISCCP cloud kernel

- Many models included the ISCCP simulator diagnostics, allowing use of ISCCP cloud kernel (Zelinka et al., 2012)
- For greenhouse gas forcing, a warming troposphere results in a reduction in low and mid-level clouds, reducing planetary albedo and leading to a positive SW adjustment.
- For aerosols, the Twomey effect is clearly visible: an increase in cloud optical depth at all altitudes, with negative SW radiative effect.
- The negative forcing from aerosol-cloud interactions tends to outweigh the positive adjustment from GHGs in the anthropogenic sum.



Conclusions and further work

- Present-day aerosol forcing is less negative and more narrowly distributed than in CMIP5, and does not explain high ECS in CMIP6 models.
- 4xCO_2 forcing is shows much better agreement between models. The fixed SST method used here agrees quite well with the first 20 years from a Gregory regression of abrupt-4xCO2 but with a much lower standard error.
- More models are still incredibly welcome to perform these experiments: overhead is modest (180 years of atmosphere-only integrations for Phase 1, plus a piControl sea surface temperature climatology to spin from).
- Phase 2 model integrations on time-varying forcing are especially welcome, particularly for historical aerosol forcing, and designed to mirror DAMIP runs.
- **Paper in review:** Smith et al., 2020: Effective Radiative Forcing and adjustments in CMIP6 models. Atmos. Chem. Phys. Discuss., https://www.atmos-chem-phys-discuss.net/acp-2019-1212/