Effective Radiative Forcing and adjustments in CMIP6 models


Eyring et al., 2016, GMD
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×CO₂ 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

<table>
<thead>
<tr>
<th>Forcing</th>
<th>ERF ± s.d. (W m⁻²)</th>
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<tbody>
<tr>
<td>4×CO₂</td>
<td>+7.98 ± 0.39</td>
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<tr>
<td>[Present-day CO₂]</td>
<td>[+1.81]</td>
</tr>
<tr>
<td>Well-mixed GHGs</td>
<td>+2.88 ± 0.19</td>
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<tr>
<td>Aerosols</td>
<td>-1.01 ± 0.23</td>
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<tr>
<td>Land-use change</td>
<td>-0.09 ± 0.13</td>
</tr>
<tr>
<td>Anthropogenic total</td>
<td>+2.01 ± 0.23</td>
</tr>
</tbody>
</table>
| [Residual, interpreted as O₃]                | [+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 \approx [stratospherically adjusted] RF.
• For aerosols, clouds dominate and ERF \neq RF.
• Due to aerosol effects on cloud adjustments, ERF \neq 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.

• $4\times\text{CO}_2$ 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-$4\times\text{CO}_2$ 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/](https://www.atmos-chem-phys-discuss.net/acp-2019-1212/)