

FaIR v2.0: a generalised impulse-response model for climate uncertainty and future scenario exploration, integrated assessment, and teaching

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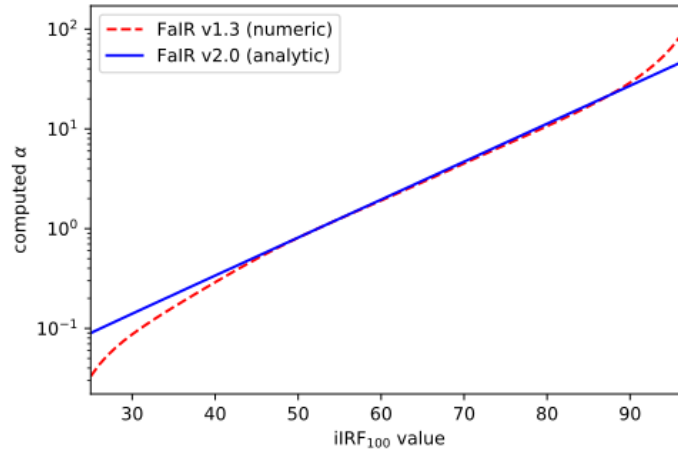


Figure 1: Numerical solution for α in FaIR v1.3 versus analytic solution in FaIR v2.0. This highlights the reason for the lowered r_0 parameter in FaIR v2.0 compared to FaIR v1.3 (Smith et al., 2017) or v1.0 (Millar et al., 2017), as we see that for pre-industrial α values (0.12 in v1.0 or 0.16 in v1.3), the analytic solution requires a lower iIRF_{100} than the numeric. Since both solutions are near identical once iIRF_{100} values reach 45 (close to the present-day value), this could lead to FaIR v2.0 systematically simulating lower CO_2 concentrations through a lower α than FaIR v1.3 or v1.0. However, this will be compensated to a certain degree by the slight increase in default r_t and r_u parameters.

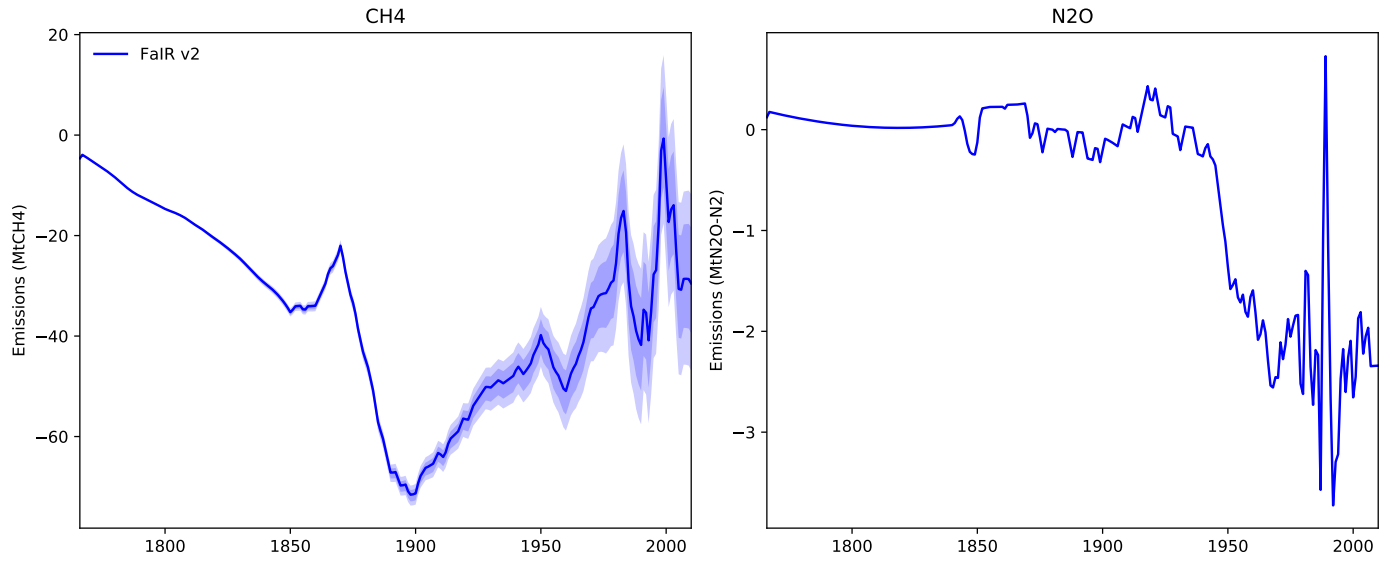


Figure 2: Differences between historical diagnosed emissions in FaIR v2.0 and the RCP database emissions for CH_4 and N_2O . This displays high similarity to Figure 2 from Smith et al. (2017), demonstrating that FaIR v2.0 and v1.3 are not systematically very different, but have simply been approached differently.

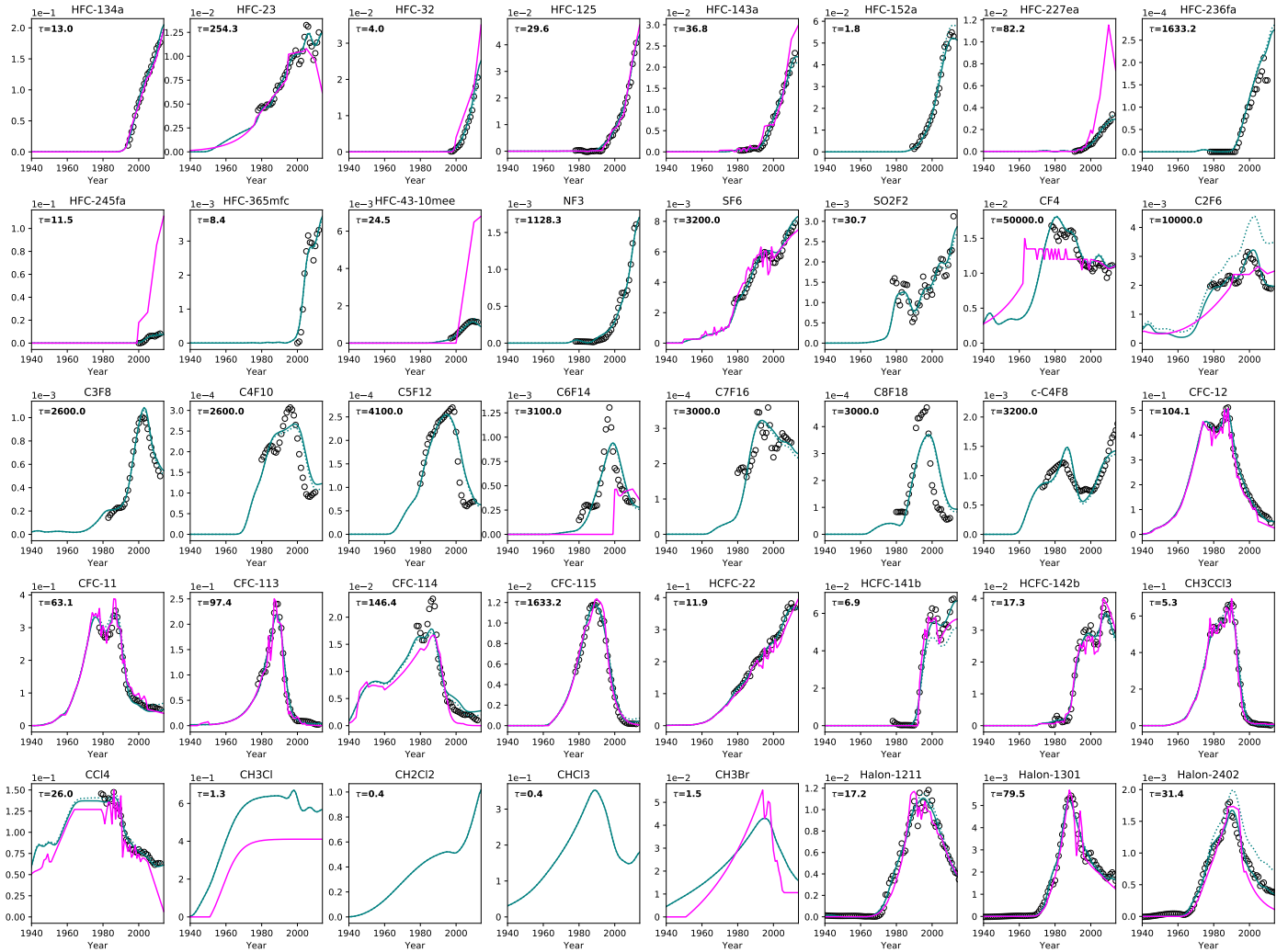


Figure 3: Best-estimate annual emissions from a more complex atmospheric model inversion Rigby et al. (2014), FaIR v2.0 inverse emissions and RCP database emissions from inversion of the MAGICC6 SCM. Open black circles show inverse emissions from a 12-box model Cunnold et al. (1994); solid green lines show inverse emissions from FaIR v2.0 with tuned parameters; dotted green lines show inverse emissions from FaIR v2.0 with lifetimes taken from Hodnebrog et al. (2013), and solid pink lines show emissions from the RCP database. Inset text shows the tuned species lifetime.

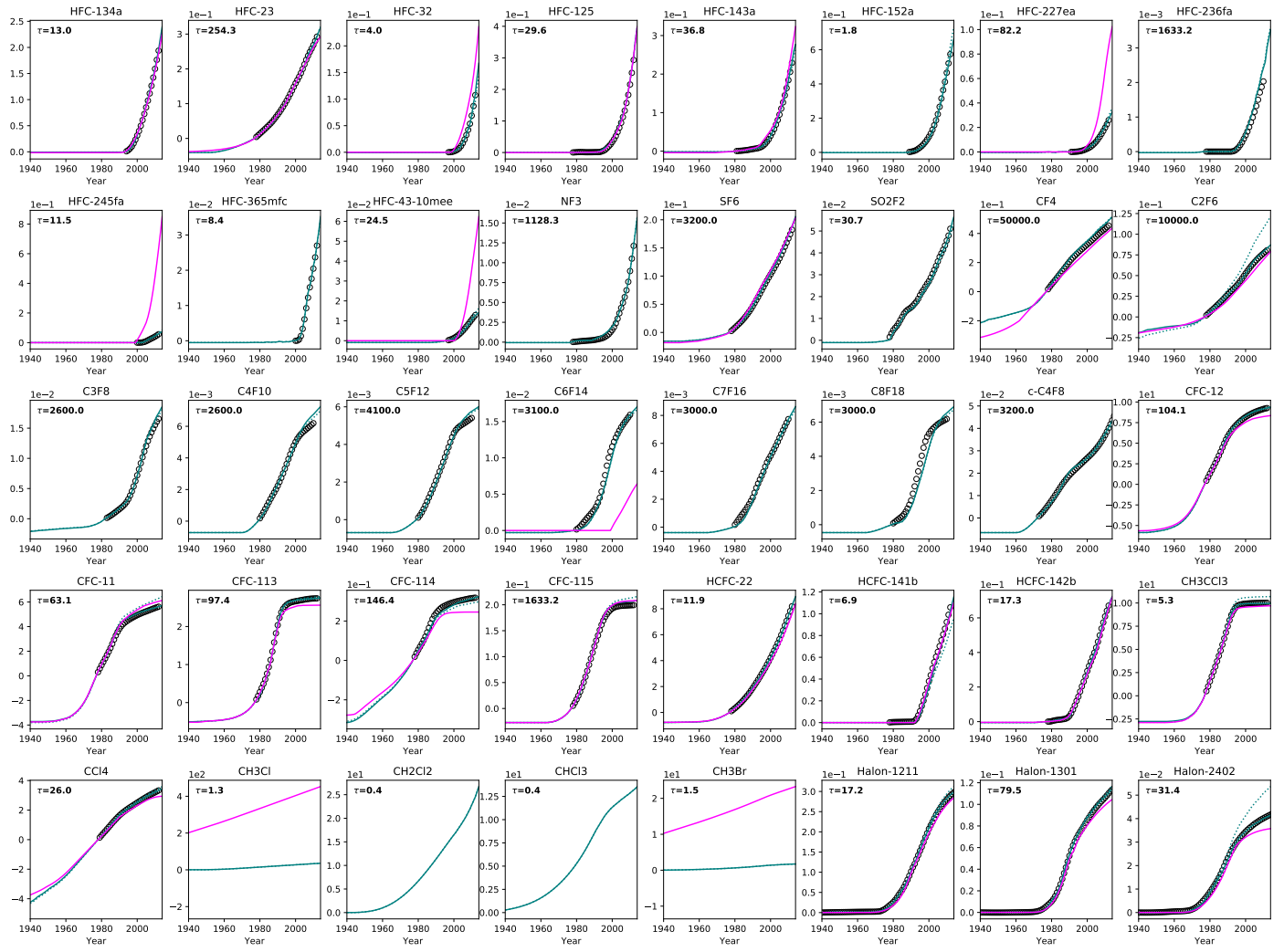


Figure 4: As Figure 3, but for cumulative emissions which are more relevant for the long lived ($\tau > 50$ years) species.

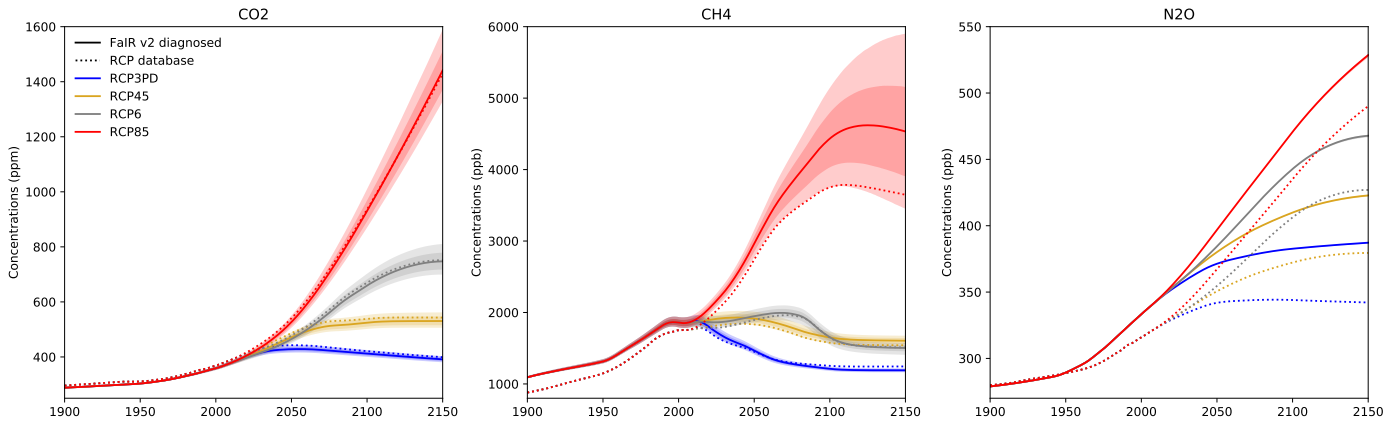


Figure 5: Simulated concentrations when

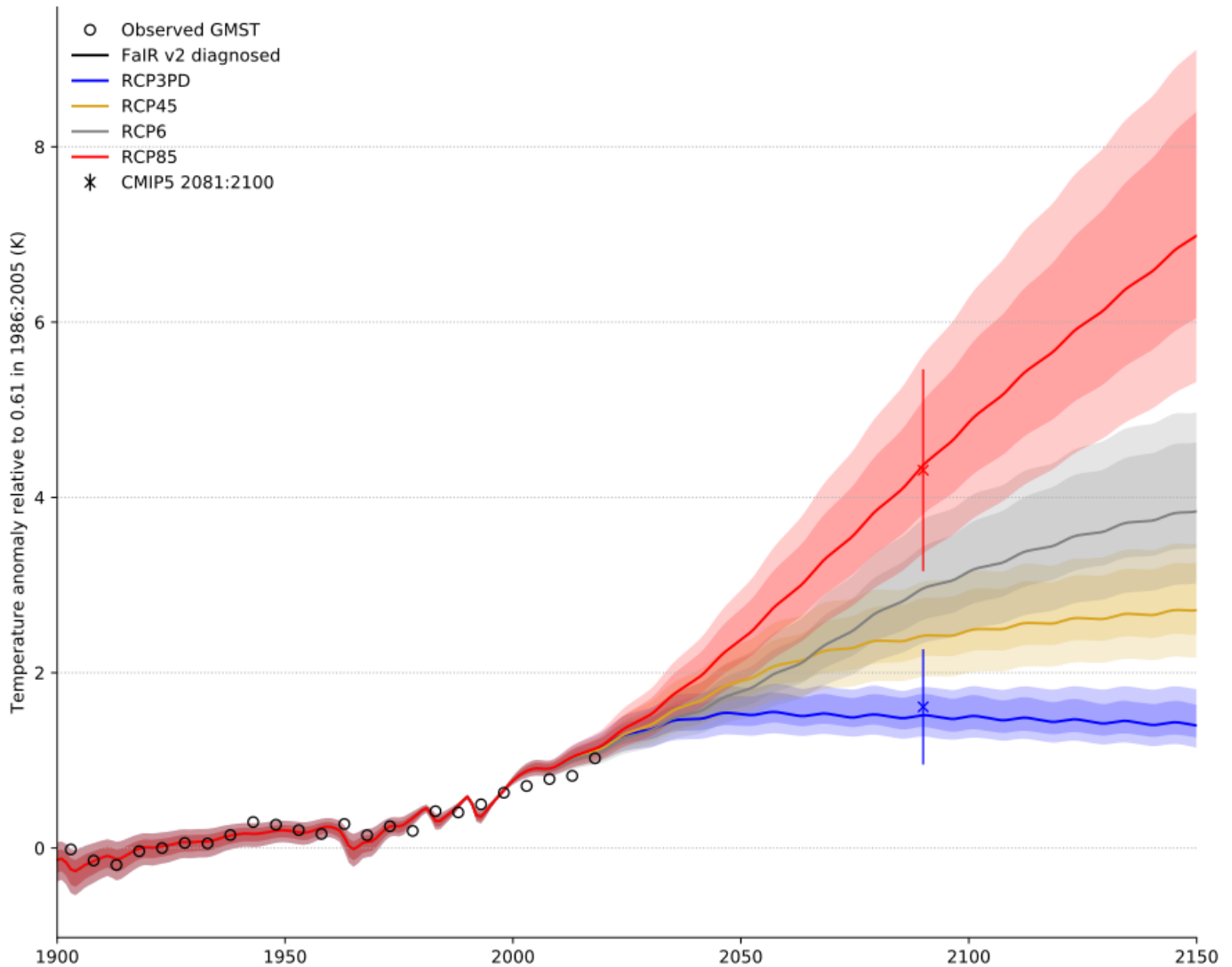


Figure 6

References

- Cunnold, D. M., Fraser, P. J., Weiss, R. F., Prinn, R. G., Simmonds, P. G., Miller, B. R., Alyea, F. N., and Crawford, A. J. (1994). Global trends and annual releases of CCl₃F and CCl₂F₂ estimated from ALE/GAGE and other measurements from July 1978 to June 1991. *Journal of Geophysical Research*, 99(D1):1107.
- Hodnebrog, O., Etminan, M., Fuglestad, J. S., Marston, G., Myhre, G., Nielsen, C. J., Shine, K. P., and Wallington, T. J. (2013). GLOBAL WARMING POTENTIALS AND RADIATIVE EFFICIENCIES OF HALOCARBONS AND RELATED COMPOUNDS: A COMPREHENSIVE REVIEW.
- Millar, R. J., Nicholls, Z. R., Friedlingstein, P., and Allen, M. R. (2017). A modified impulse-response representation of the global near-surface air temperature and atmospheric concentration response to carbon dioxide emissions. *Atmospheric Chemistry and Physics*, 17(11):7213–7228.
- Rigby, M., Prinn, R. G., O'Doherty, S., Miller, B. R., Ivy, D., Mühle, J., Harth, C. M., Salameh, P. K., Arnold, T., Weiss, R. F., Krummel, P. B., Steele, L. P., Fraser, P. J., Young, D., and Simmonds,

P. G. (2014). Recent and future trends in synthetic greenhouse gas radiative forcing. *Geophysical Research Letters*.

Smith, C. J., Forster, P. M., Allen, M., Leach, N., Millar, R. J., Passerello, G. A., and Regayre, L. A. (2017). FAIR v1.1: A simple emissions-based impulse response and carbon cycle model. *Geoscientific Model Development Discussions*, (December):1–45.