Supplementary Material

The SSP greenhouse gas concentrations and their extensions to 2500

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1 Supplementary Material

Note: All data and all scenario and individual gas visualisation for the SSP GHG projections under this study are available at **greenhousegases.science.unimelb.edu.au**

The supplementary material contains a comparison of our GHG concentration projections with those that are part of the IIASA SSP database as initial values using MAGICC6. Efforts are underway to update the IIASA database values with the GHG concentrations presented here. Also, this supplementary presents additional figures, such as those related to the methane gas cycle and nitrous oxide gas cycles.

1.1 Comparison to earlier SSP scenario data in IIASA database

Several Integrated Assessment Models (IAM) and the IIASA emission scenario database include the MAGICC6 model to produce atmospheric concentrations, radiative forcing and temperatures. Here, we compare our CMIP6 GHG concentration projections using the updated MAGICC7.0 model, with its CMIP6 default settings, to the concentration projections within the IIASA database, both the concentration projections from the harmonized and non-harmonized emission scenarios. The harmonisation process adjusted the various IAM group's emission scenarios to common starting values in 2015 (Gidden et al., 2018). In the case of CO_2, the difference between the harmonized and non-harmonized MAGICC6 concentration projections is generally small – given that most IAMs' recent historical CO_2 emission assumptions were relatively close to each other from

the start (see dashed and dash-dotted line in panel a of Supplementary Figure 4). A slightly more pronounced upward adjustment for the higher scenarios is due to the shift from the MAGICC6 default version to the MAGICC7 default version used in this study, predominantly due to the more sensitive carbon cycle setting used here. As illustration of this difference, we consider the non-harmonised SSP5-8.5 scenario from the REMIND-MAgPIE modelling group. Upper range 2100 CO_2 concentrations for the official CMIP6 recommendations resulting from this study are 1135 ppm, whereas the IIASA database lists 1089 ppm for the non-harmonized SSP5-8.5 scenario from the REMIND-MAgPIE modelling group (Supplementary Figure 4).

For CH_4, the overall concentration differences are somewhat more pronounced. For example, the effect of the scenario harmonisation for the SSP5-8.5 scenario (compare red dashed and dash-dotted lines in panel b of Supplementary Figure 4) is a substantial downward adjustment. See also Figure 7b in Gidden et al. (2019). This is partly offset by an upward adjustment that results from using the new MAGICC7.0 CH_4 cycle calibration (section 2.4.1). The MAGICC7.0 CH_4 gas cycle generally results in an upward adjustment of the projections from the harmonized emission dataseries, whereas the harmonization process itself resulted in both upwards and downwards adjustments. Similarly, for N_2O (panel c in Supplementary Figure 4), the updated gas cycle leads in slight upward adjustments of N_2O timeseries, whereas the harmonisation process resulted in both up and downwards adjustments.

1.2 Supplementary Figures - Captions

Supplementary Figure 1 – Calibration of MAGICC7's methane gas cycle to concentrations, lifetimes and natural emissions from Holmes et al. (2013), varying 10 of MAGICC's gas cycle parameters with the goodness of fit being a weighted mean squared error across the four variables (shown columns) and scenarios. MAGICC's CH_4 projections are emission driven from year 1900. The constant natural emissions assumed in MAGICC7 are calculated over the budgeting period from 1994 to 2004, whereas Holmes' et al. natural emission assumptions have a slight time-variation.

Supplementary Figure 2 – Calibration of MAGICC's N_2O concentration projections for the four RCPs and the concentrations projected by Prather et al. (2012) with natural N_2O emissions in left column of panels, the N_2O concentrations in the middle column of panels and the total N_2O lifetime in the right column of panels. Each row of panels refers to one of the RCP scenarios, with RCP2.6, RCP4.5, RCP6.0 and RCP8.5 shown in order from top to bottom.

Supplementary Figure 3 - One-year (2050) and cumulative emissions (2018-2050) and their relationship with mid-century concentrations for methane (panels a, b) and CO_2 (panels c, d) across the SSP, RCP and 475 other scenarios from the IPCC SR1.5 database. The considered scenarios are the same as in Figure 9.

Supplementary Figure 4 - Comparison of final CMIP6 recommendation datasets for CO_2 (panel a), CH_4 (panel b) and N_2O (panel c) concentrations with earlier derivations of concentrations using MAGICC6.

References

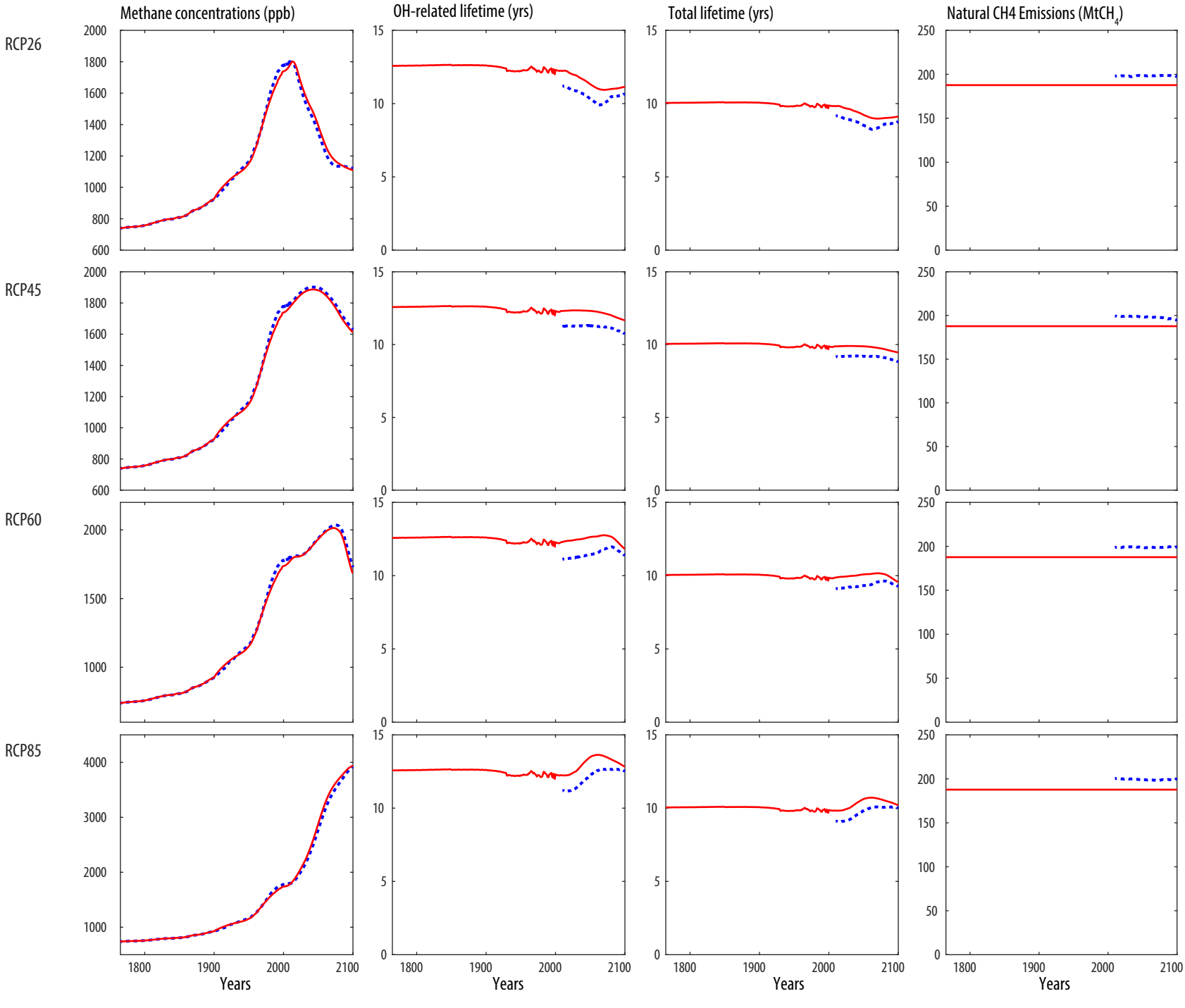
Gidden, M. J., Fujimori, S., van den Berg, M., Klein, D., Smith, S. J., van Vuuren, D. P., and Riahi, K.: A methodology and implementation of automated emissions harmonization for use in Integrated Assessment Models, Environmental Modelling & Software, 105, 187-200, https://doi.org/10.1016/j.envsoft.2018.04.002, 2018.

Gidden, M. J., Riahi, K., Smith, S. J., Fujimori, S., Luderer, G., Kriegler, E., van Vuuren, D. P., van den Berg, M., Feng, L., Klein, D., Calvin, K., Doelman, J. C., Frank, S., Fricko, O., Harmsen, M., Hasegawa, T., Havlik, P., Hilaire, J., Hoesly, R., Horing, J., Popp, A., Stehfest, E., and Takahashi, K.: Global emissions pathways under different socioeconomic scenarios for use in CMIP6: a dataset of harmonized emissions trajectories through the end of the century, Geosci. Model Dev., 12, 1443-1475, 10.5194/gmd-12-1443-2019, 2019.

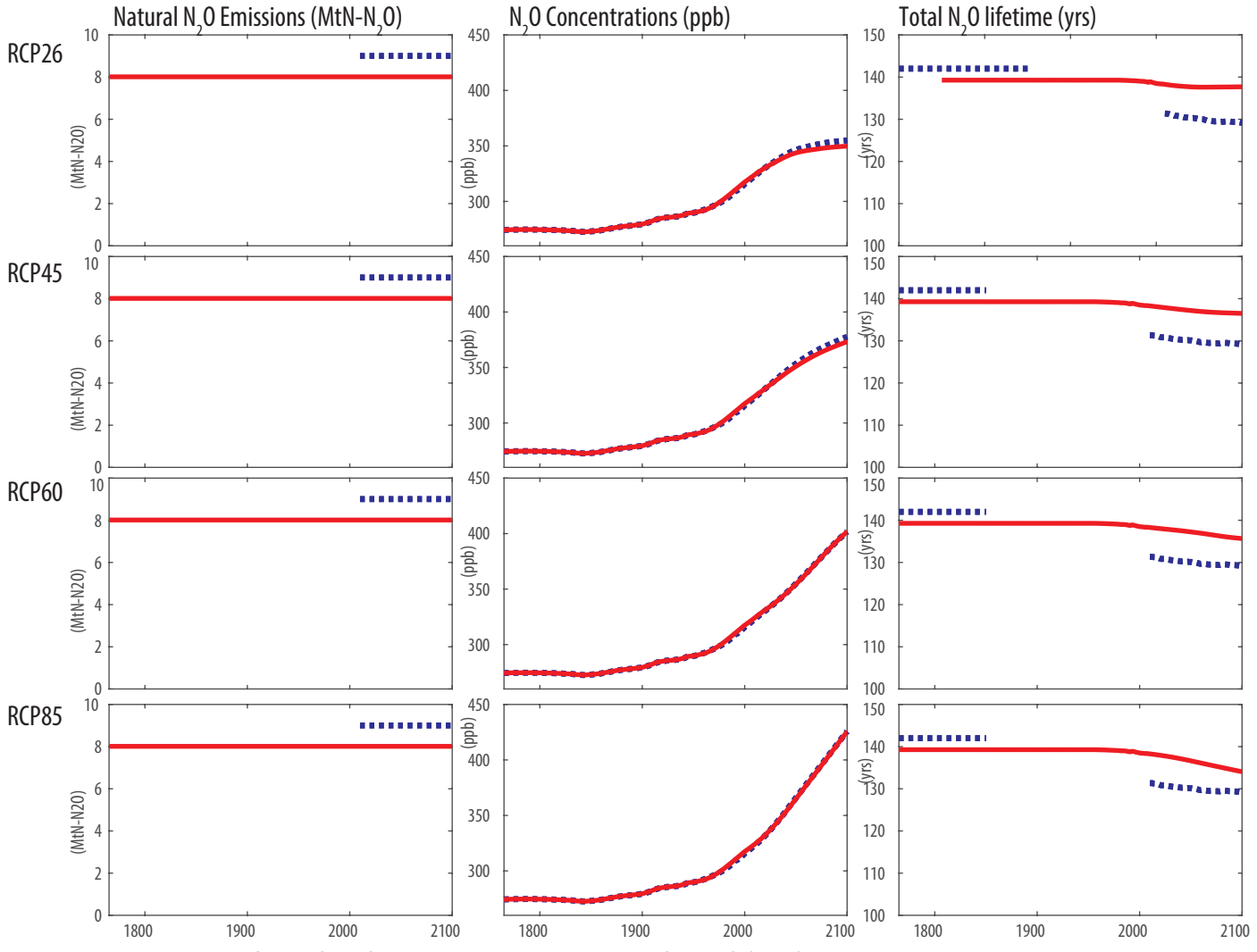
Holmes, C. D., Prather, M. J., Sovde, O. A., and Myhre, G.: Future methane, hydroxyl, and their uncertainties: key climate and emission parameters for future predictions, Atmospheric Chemistry and Physics, 13, 285-302, 2013.

Prather, M. J., Holmes, C. D., and Hsu, J.: Reactive greenhouse gas scenarios: Systematic exploration of uncertainties and the role of atmospheric chemistry, Geophysical Research Letters, 39, 2012.

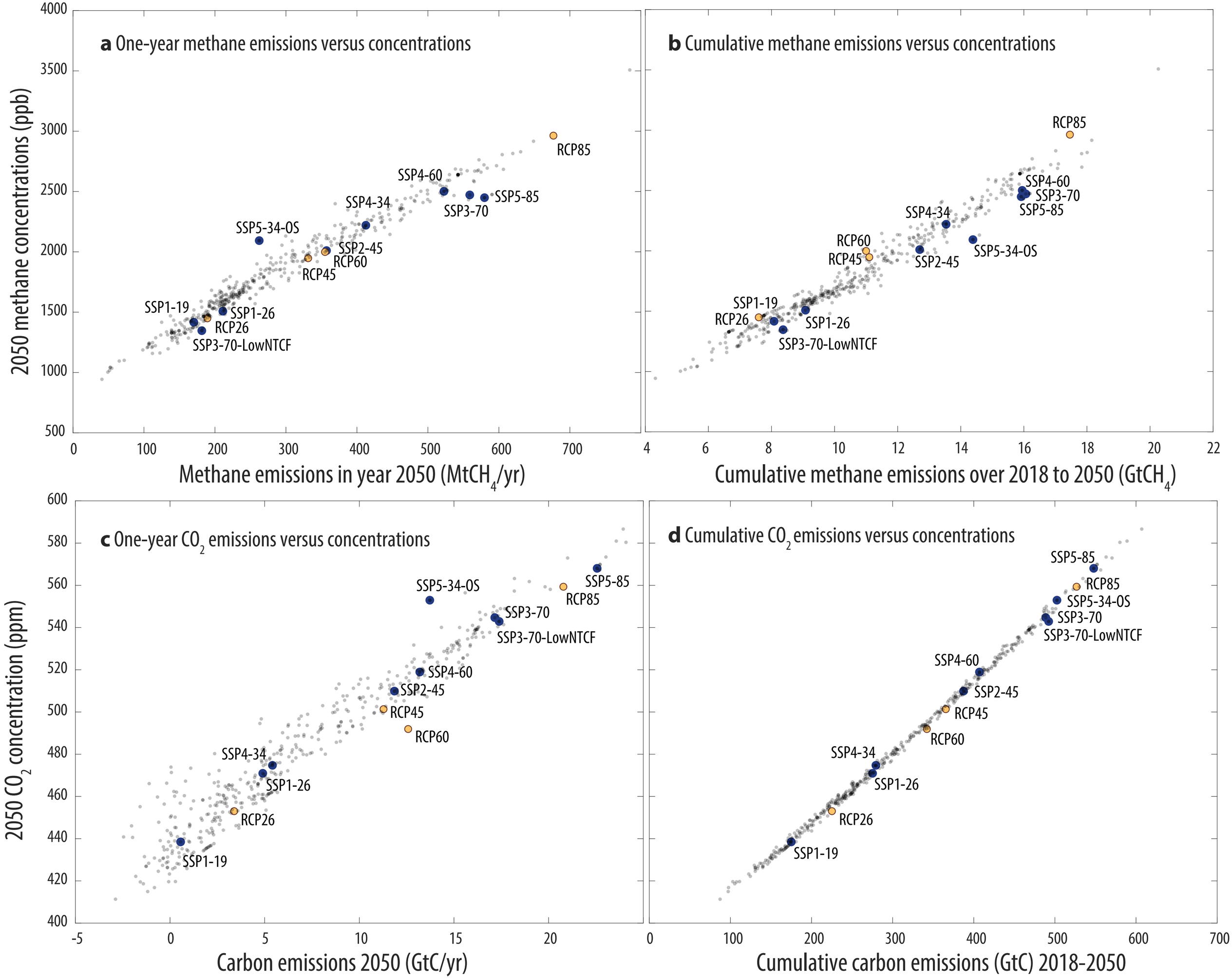
Supplementary Figures



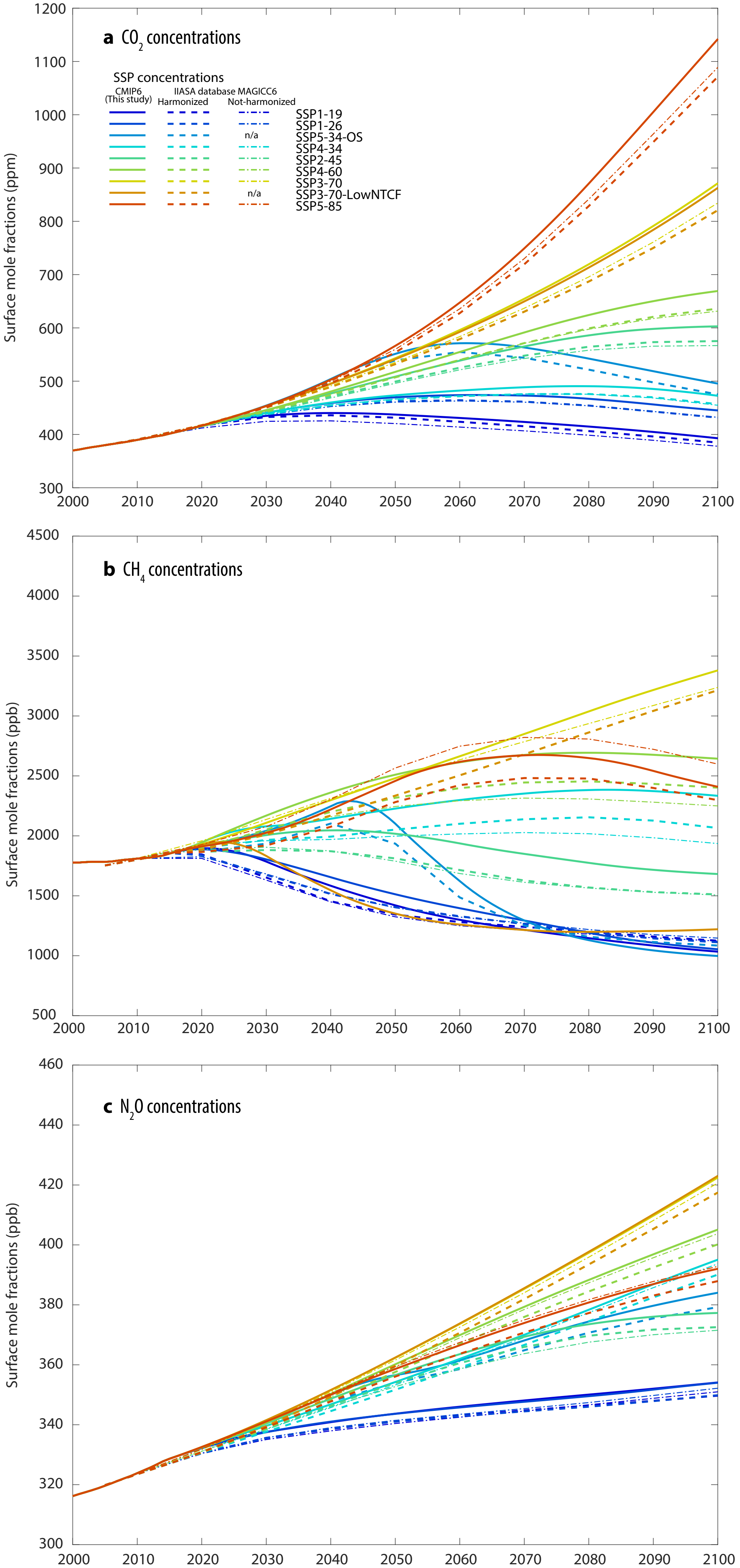
Supplementary Figure 1



Supplementary Figure 2



Supplementary Figure 3



Supplementary Figure 4