Description of simulated $\Delta^{14}C$ and $\delta^{13}C$ in atmospheric CO_2 in the Shared Socioeconomic Pathways (SSPs) for CMIP6

Heather Graven, November 2018, h.graven@imperial.ac.uk

Simulations for $\Delta^{14}C$ and $\delta^{13}C$ of atmospheric CO_2 were conducted following Graven (2015), using updated historical data and data for SSP1-1.9, SSP1-2.6, SSP2-4.5, SSP3-Baseline, SSP5-3.4-Overshoot and SSP5-Baseline. Historical atmospheric CO_2 concentration was specified by global annual mean data from Meinshausen et al. (2016). Historical fossil fuel CO_2 emissions data were given by the Community Emissions Data System (CEDS, Hoesly et al. 2018). Historical land use CO_2 emissions data were given by C4MIP (CMIP6_C4MIP_landuse_emissions.nc available at http://c4mip.net/index.php?id=3455). Global annual atmospheric CO_2 concentration data for the SSPs were retrieved from input4mips (https://esgf-node.llnl.gov/projects/input4mips/). The SSP fossil fuel and land use CO_2 emissions and the SSP bioenergy with carbon capture and storage (BECCS) data were gathered from the internal SSP database in October 2018 and provided by J. Rogelj (j.rogelj@imperial.ac.uk).

The $\delta^{13}C$ of fossil fuel emissions was specified by Andres et al. (2016) for 1850 to 2013 and then kept fixed at the 2013 value from Andres et al. (2016), -27.73 per mil, for the period 2013 to 2100 in all SSPs. Due to limitations in the data available about the SSPs it was not possible to accurately specify $\delta^{13}C$ in fossil fuel emissions in the SSPs, i.e. CO_2 emissions or time-varying emission factors (amount of CO_2 emitted per unit energy produced) for each fuel type were not reported for the SSPs. Sensitivity tests estimating future changes in $\delta^{13}C$ of fossil fuel emissions showed that the potential impact on simulated atmospheric $\delta^{13}C$ is likely to be small, less than ~0.4 per mil for simulated $\delta^{13}C$ in 2100.

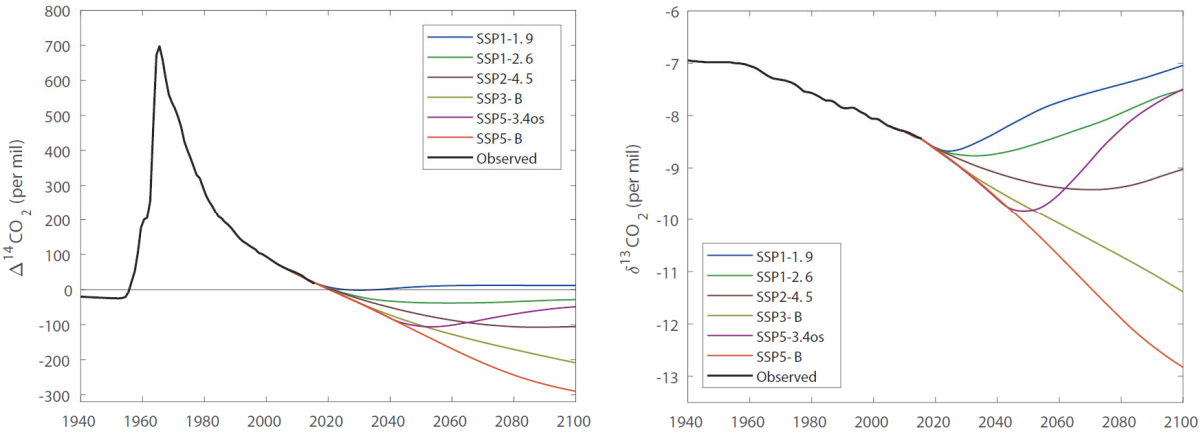
Simulations for 1850-2005 were conducted following a spinup period of 11850 years. Atmospheric $\Delta^{14}C$ and atmospheric $\delta^{13}C$ were specified by historical data from Graven et al. (2017) for 1850-2005 and then atmospheric $\Delta^{14}C$ and atmospheric $\delta^{13}C$ were simulated prognostically for 2005-2100.

Three changes were made to the model setup in comparison to Graven (2015).

First, a sensitivity of photosynthetic ^{13}C discrimination to atmospheric CO_2 concentration was included, following Schubert and Jahren (2015) and Keeling et al. (2017). The formulation for discrimination in Schubert and Jahren (2015)'s equations 3 and 4 was used, beginning from ^{13}C discrimination of 17 per mil in 1850. This leads to discrimination of 18.7 per mil in 2100 for SSP1-1.9 and 22.5 per mil in 2100 for SSP5-Baseline.

Second, sea surface temperature (SST) changes were included for both the historical and future period. The historical data used were annual, global data SST anomalies from HadSST.3.1.1.0 from 1850 to 2018 (https://www.metoffice.gov.uk/hadobs/hadsst3/data/download.html, accessed October 2018). A reference SST of 18°C in 1850 was assumed. Future SST was estimated from global mean temperature data for the SSPs retrieved from the internal SSP database. SST anomalies in the SSPs for 2020 to 2100 were estimated from global mean temperature by applying a scaling factor of 0.85, which derives from a regression of HadSST.3.1.1.0 SST anomaly data and HadCRUT.4.6.0.0 global annual near surface temperature anomaly data (https://www.metoffice.gov.uk/hadobs/hadcrut4/data/current/download.html, accessed October 2018). SST is used in the model in the calculation of the ocean carbonate system and in the specification of fractionation factors related to air-sea gas exchange.

Third, the formulation of the terrestrial biosphere model was changed from one to three boxes, following Naegler and Levin (2009). The initial masses and turnover times in the scenarios listed in Naegler and Levin (2009) Table 1 were investigated with other parameters in the model following the parameter ranges used in Graven (2015). Parameter sets were selected to match a global bomb excess ^{14}C inventory of 615 ± 35 x 10^{26} atoms and to match the change in atmospheric $\delta^{13}C$ between 2005 and 2014 to within ±0.05 per mil, resulting in 35 different accepted parameter sets. The mid-range values for simulated atmospheric $\Delta^{14}C$ and atmospheric $\delta^{13}C$ across the accepted parameter sets are used to specify the SSP forcing.



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