Supporting Information for "Reconstruction and prediction of the global carbon cycle with an emission-driven Earth System Model"

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October 28, 2021, 9:19am

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References

Dlugokencky, E., & Tans, P. (2020). Trends in atmospheric carbon dioxide. *National Oceanic and Atmospheric Administration, Global Monitoring Laboratory (NOAA_GML)*. Retrieved from `https://gml.noaa.gov/ccgg/trends/`

Friedlingstein, P., Jones, M. W., O'Sullivan, M., Andrew, R. M., Hauck, J., Peters, G. P., . . . Zaehle, S. (2019). Global carbon budget 2019. *Earth System Science Data*, *11*(4), 1783–1838. Retrieved from `https://essd.copernicus.org/articles/11/1783/2019/` doi: 10.5194/essd-11-1783-2019

Marotzke, J., Müller, W. A., Vamborg, F. S., Becker, P., Cubasch, U., Feldmann, H., . . . others (2016). MiKlip: A national research project on decadal climate prediction. *Bulletin of the American Meteorological Society*, *97*(12), 2379–2394.

Table S1. Simulations based on MPI-ESM1.2-LR. Resolution Atmosphere: T63L47 Ocean: GR15L40. The design of the prediction simulations is according to previous study (Marotzke et al., 2016). The assimilation starts from the end of year 1958 in an uninitialized simulation. The nudging is strong therefore an assimilation starting from a different uninitialized simulation would end up with similar evolution of the climate and carbon cycle. The initialized simulations start from the assimilation yearly from October 31st and run freely for 2 months plus 5 years afterwards. We have 59 runs for one ensemble of initialized simulations starting from 1960 to 2019 annually and run for 5 years and 2 months each, i.e., Nov. 1960 - Dec. 1965 for starting year 1960, Nov. 1961 - Dec. 1966 for starting year 1961, and so forth until Nov. 2018 - Dec. 2023. The ensembles are generated with lagged 1-day initialization, i.e., the simulations start from 10 consecutive days from October 31st to November 9th. The ensembles for uninitialized simulations are generated by starting from different year of the control simulation.

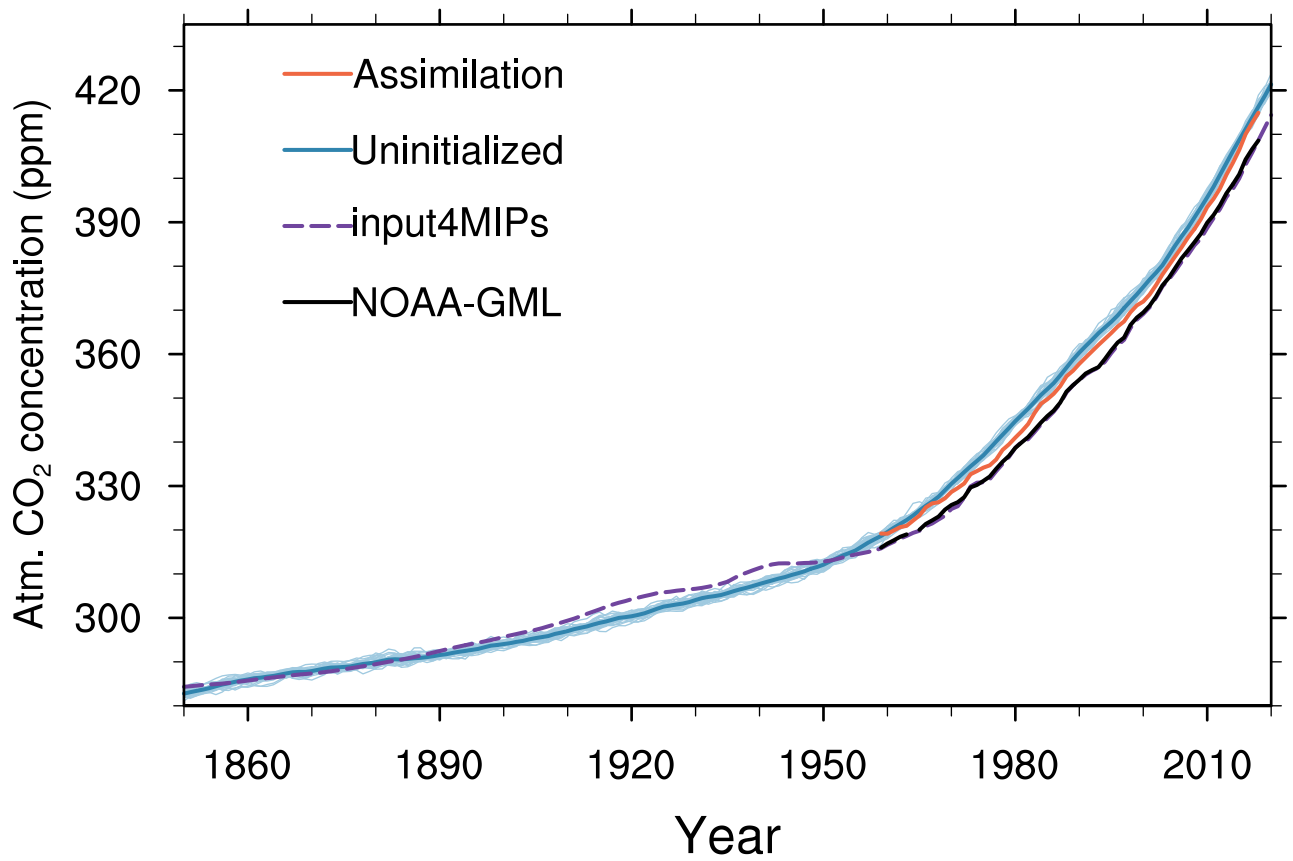| Simulations	Ensemble members	Nudging	Initial condition	Time period
Uninitialized	10	N/A	Preindustrial	1850-2099
Assimilation	1	Atm.: ERA Ocean: ORAS4 anomalies (without 5N-5S band) Sea Ice: NSIDC	Uninitialized	1959-2018
Initialized	10	N/A	Assimilation	1960-1965 ... 2018-2023

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Figure S1. Time series of atmospheric CO_2 concentration from model simulations and observation from 1850-2020. The assimilation and uninitialized simulations are shown with orange and blue solid lines, respectively. The CMIP6 input4MIPs atmospheric CO_2 concentration forcing and the NOAA_GML observation (Dlugokencky & Tans, 2020) are shown with blue dashed line and black solid lines, respectively.
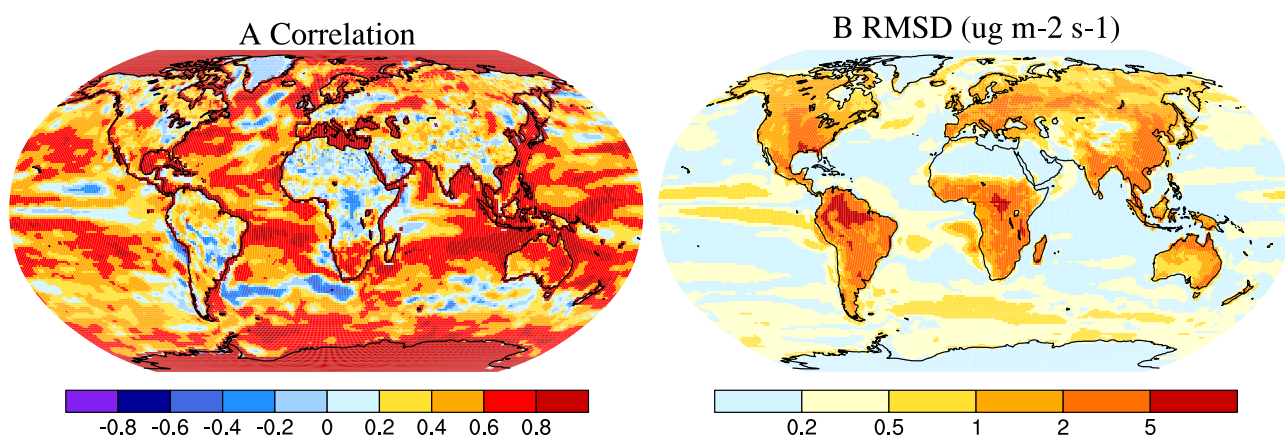
Figure S2. Spatial distribution of correlation and root mean square difference (RMSD) in air-sea and air-land CO_2 fluxes between Global Carbon Budget (GCB 2019 (Friedlingstein et al., 2019)) multi-model mean and MPI-ESM1.2-LR assimilation. The statistics are based on annual mean time series for the time period from 1960-2018.
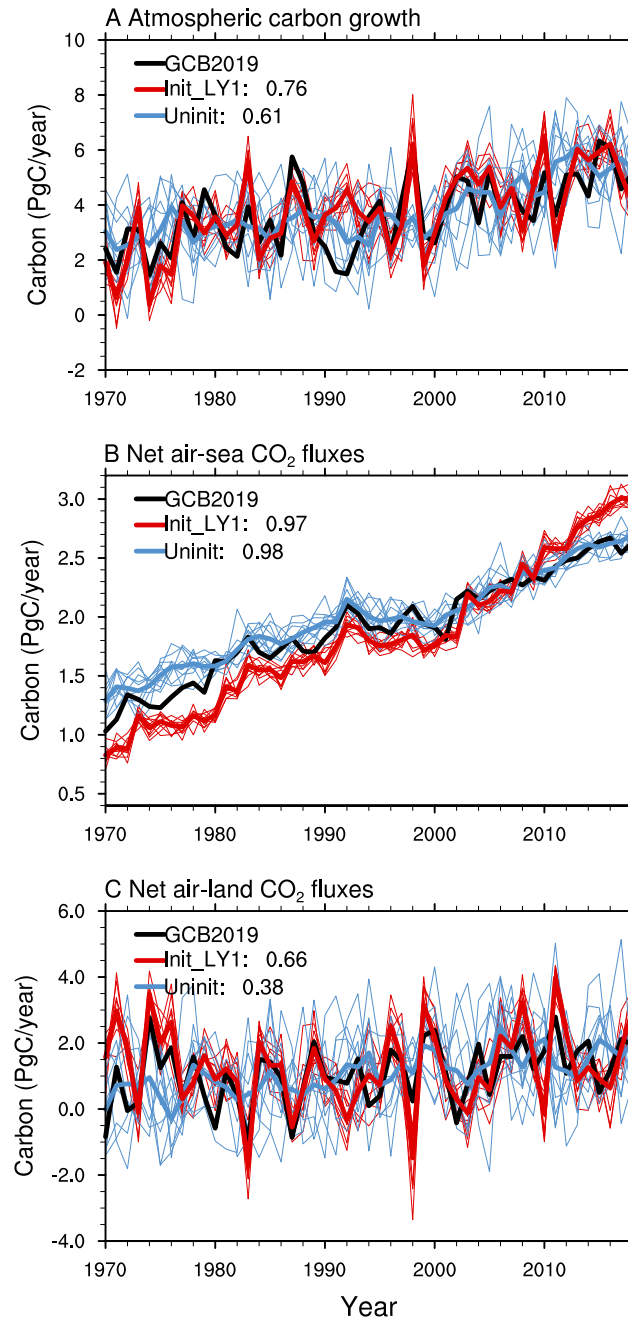
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Figure S3. Time series of initialized simulations at lead time of 1 year in atmospheric carbon growth rate, i.e., G_{ATM} (A), net air-sea CO_2 fluxes, i.e., S_{OCEAN} (B) and net air-land CO_2 fluxes, i.e., $E_{LUC}+S_{LAND}$ (C) together with Global Carbon Budget (GCB 2019 (Friedlingstein et al., 2019)). The shown time series are based on annual mean data for the time period from 1970-2018. Positive values in B-C refer to CO_2 fluxes into the ocean or land. The numbers in the legend show the correlation coefficients between the simulations and GCB2019, the ensemble mean data is used for the calculation.
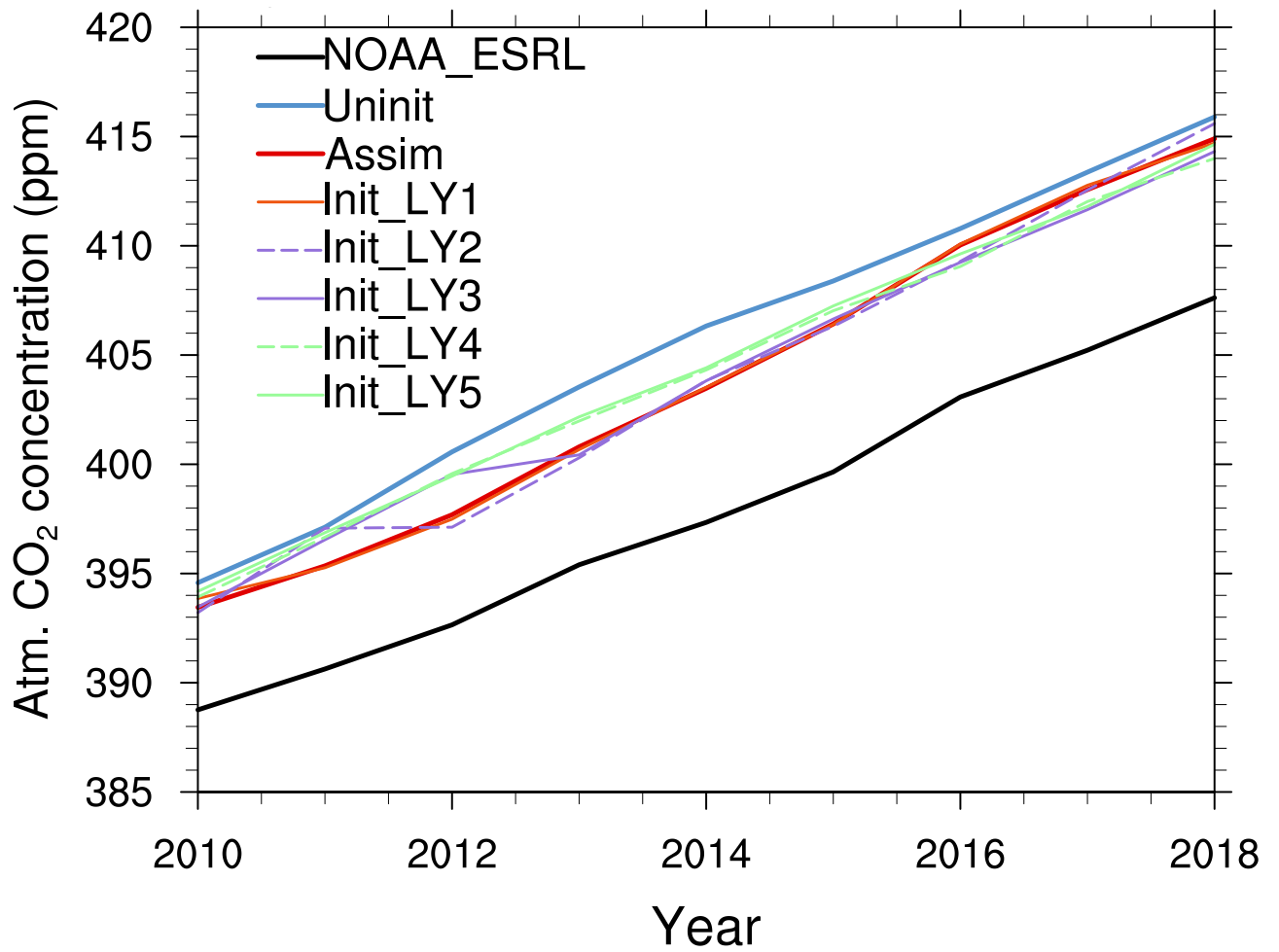
Figure S4. Atmospheric CO_2 concentration from the assimilation and initialized simulations together with NOAA_GML observation (Dlugokencky & Tans, 2020) in the last 10 years. The time series are original model outputs and connected according to the lead time of years.