Project: **1124**
Project title: **CCiCC**
Principal investigator: **Tatiana Ilyina**
Report period: **2021-05-01 to 2022-04-30** (*Text: maximum of two pages incuding figures.)*

I. Reconstruction and prediction of the global carbon budget

Reconstructions based on the MPI-ESM emission-driven prediction system by assimilating observational products capture the observed global carbon budget variations in the past decades. Such a fully coupled decadal prediction system with interactive carbon cycle enables representation of the global carbon budget within a closed Earth system and therefore provides an additional line of evidence for the ongoing assessments of the anthropogenic global carbon budget (Fig.1 left and middle column panels).

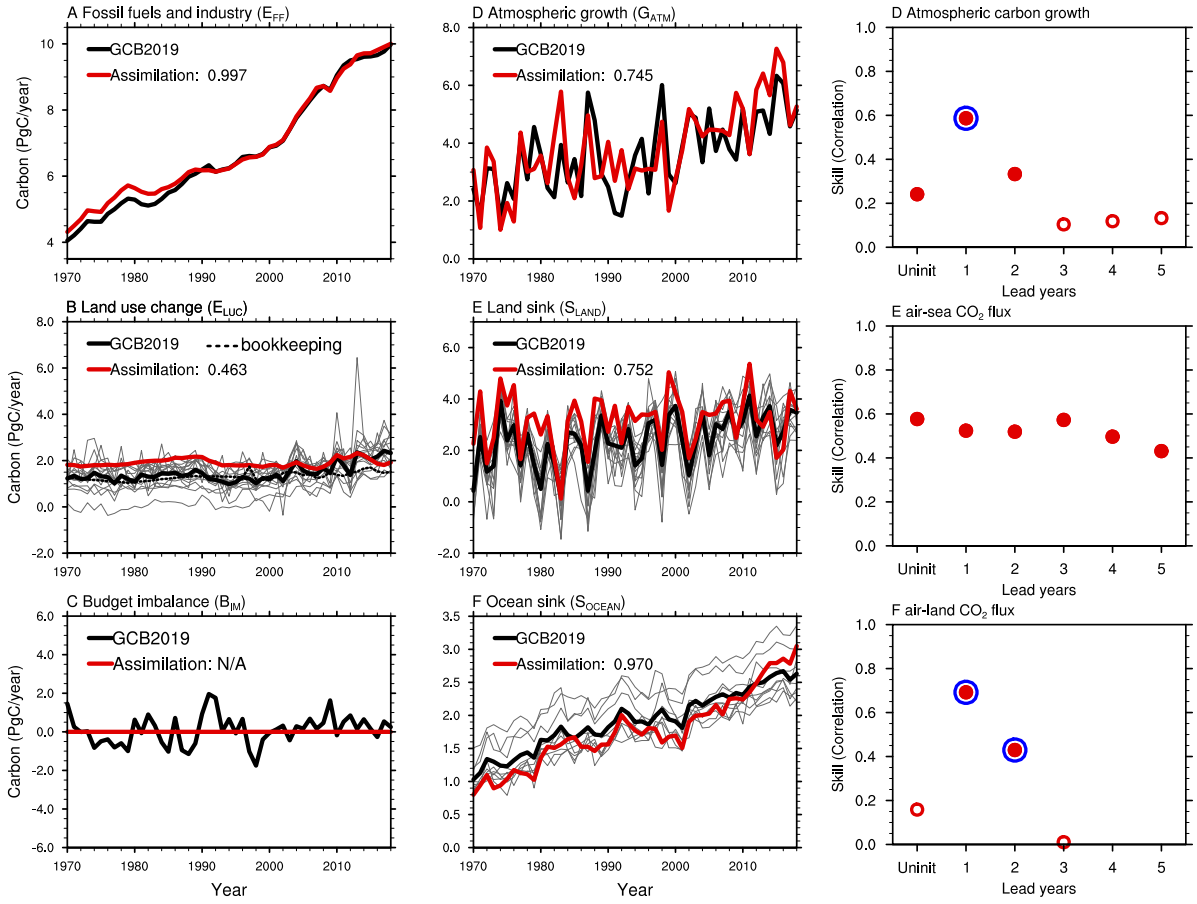

Fig.1 Left panels: Time series of fossil fuel and industry CO_2 emissions (EFF, top), emissions from land use change (ELUC, middle), and the budget imbalance (BIM, bottom) that is not accounted for by the other terms. Middle panels: Time series of atmospheric carbon growth rate (GATM, top), the natural terrestrial carbon fluxes (SLAND, middle), and air-sea CO_2 fluxes (SOCEAN, bottom) from MPI-ESM1.2-LR assimilation in comparison with Global Carbon Budget (GCB 2019, Friedlingstein et al., 2019). Right panels: Predictive skill of atmospheric carbon growth rate, i.e., GATM (top), air-sea CO_2 fluxes, i.e., SOCEAN (middle) and net air-land CO_2 fluxes, i.e., ELUC+SLAND (bottom) reference GCB 2019. The filled red circles on top of the open red circles show that the predictive skill is significant at 95% confidence level and the additional larger blue circles indicate improved significant predictive skill due to initialization in comparison to the uninitialized simulations. We use a nonparametric bootstrap approach (Goddard et al., 2013) to assess the significance of predictive skill. The results are based on annual mean data for the time period from 1970-2018.

Retrospective predictions initializing from the assimilation simulation show high confidence in predicting the next year global carbon budget in supporting the Global Carbon Project. The predictive skill is even higher up to 5 years for the air-sea CO_2 fluxes, and 2 years for the air-land CO_2 fluxes and atmospheric carbon growth rate (Fig. 1 right panels). A paper based on the results are in revision on Geophys. Res. Lett.

This initialization is based on nudging of ECMWF reanalysis data, but the ocean reanalysis ORAS4 stopped updating. Further simulations were done to test another assimilation method, i.e., ensemble kalmann filter, to have the reconstruction towards EN4 ocean profile data until the most recent day, i.e., 2021, therefore enable real predictions. The first simulations show comparable results as the nudging simulations.

II. Adaptive emissions scenario

With an objective to quantify future CO_2 emission pathways over this century and beyond that are consistent with Paris agreement's temperature targets (that is reducing anthropogenic GHG emissions to stay well below 2°C above preindustrial levels), we use an emission-driven version of the MPI Earth System Model (MPI-ESM), allowing free exchange of carbon dioxide between atmosphere, ocean and land. To calculate an emission pathway that reaches a given temperature target, e.g., 1.5°C and 2°C, we apply the adaptive emission reduction approach (AERA) that stepwise adapts future greenhouse gas emission pathways every five years based on the stock take mechanism implemented in the Paris Agreement (Fig. 2). Results indicate that we need strong emission decline by 2037 to keep up with 1.5°C target, while stabilizing global mean temperature at 2°C target allows for emission rise up to 2033, and then emission decline by the end of the 21st century is needed.

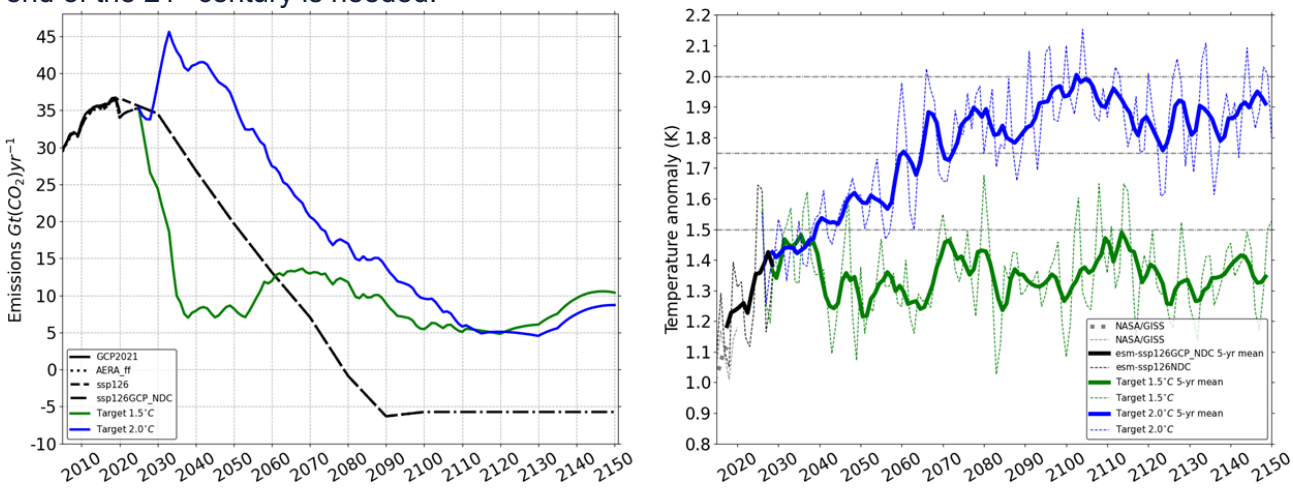

Fig.2: Time series of adaptive fossil fuel CO_2emissions (left), and global mean temperature anomaly (right) for 1.5°C (green) and 2°C (blue) above pre-industrial average temperature targets.

Publication: Li, H., Ilyina, T., Loughran, T., Spring, A., and Pongratz, J. (2022). Reconstructions and predictions of the global carbon budget with an emission-driven earth system model. Geophysical Research Letters, in revision, https://www.essoar.org/doi/10.1002/essoar.10508552.1

Georgievski, G., Brovkin, V., Terhaar, J., and Frölicher, T.J. (2022). Adaptive emission scenario simulations with the MPI Earth System Model (Poster session at Scenarios Forum, Vienna 2022)

References

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

Goddard, L., Kumar, A., Solomon, A., Smith, D., Boer, G., Gonzalez, P., . . . others(2013). A verification framework for interannual-to-decadal predictions477experiments.Climate Dynamics,40(1-2), 245–272.