# The land contribution to natural carbon cycle variability

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(submitted to JAMES)

## Introduction

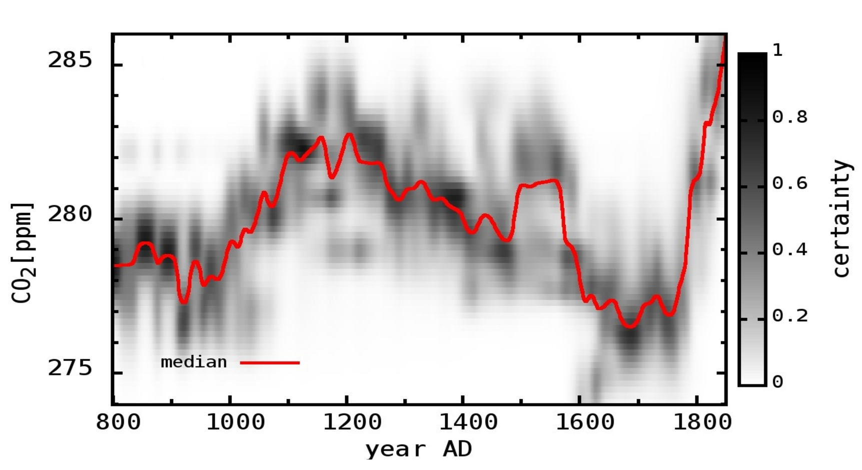


**Fig 1:** Atmospheric $CO_2$ reconstruction from 5 antarctic icecores.

The study presented here quantifies the potential land contribution to natural atmospheric $CO_2$ variations on time scales of centuries. During historical times $CO_2$ changes may partly be explained by long-term natural variations (besides the human impact or external forcing like vulcanism, Fig. 1).

The natural $CO_2$ variability depends on C-storage changes of land and oceans. Both are subject to high uncertainty, which is further enhanced by the interdependency between both compartments. Today the land C sink for atmospheric $CO_2$ shows a stronger variability than the ocean sink (Fig. 2).

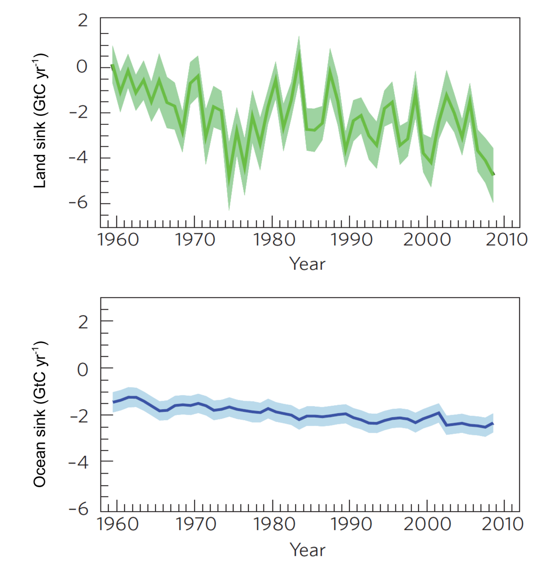


**Fig 2:** Sinks of anthropogenic $CO_2$ emissions[1]. Negative values correspond to uptake.

## Simulations and Results

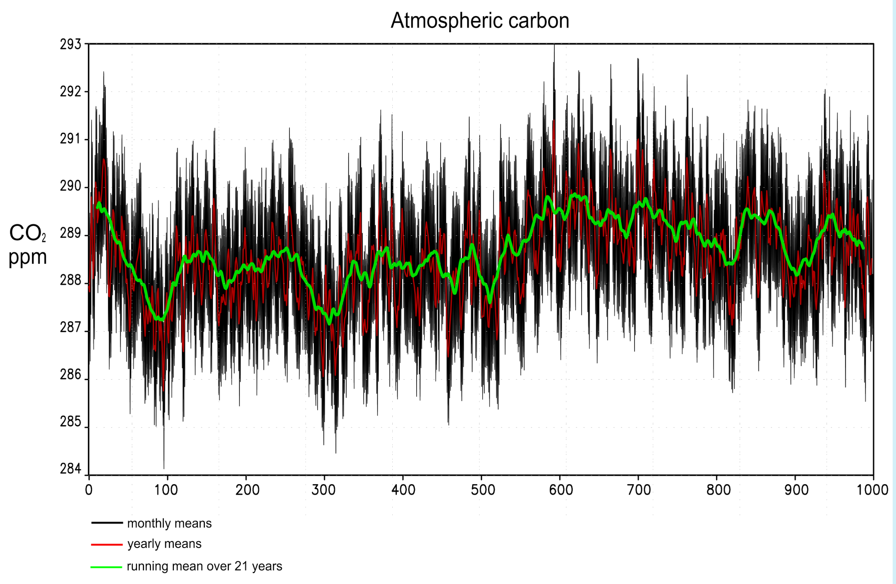


**Fig 3:** Atmospheric $CO_2$ in the CTL_freeCO2 simulation.

Our study is based on the MPI-M CMIP5 preindustrial simulations with the MPI Earth System Model (MPI-ESM-LR).

The first simulation (CTL_freeCO2), with a fully coupled C-cycle and driven with constant forcing of the year 1850 shows natural atmospheric $CO_2$ variations of about 2 ppm (Fig. 3). This is too small to explain the reconstructed historical $CO_2$ changes shown in Fig 1 (of about 5 ppm). However, the simulated atmospheric $CO_2$ variability would be higher if the effect of land C-storage variations on $CO_2$ would not be compensated by the ocean.

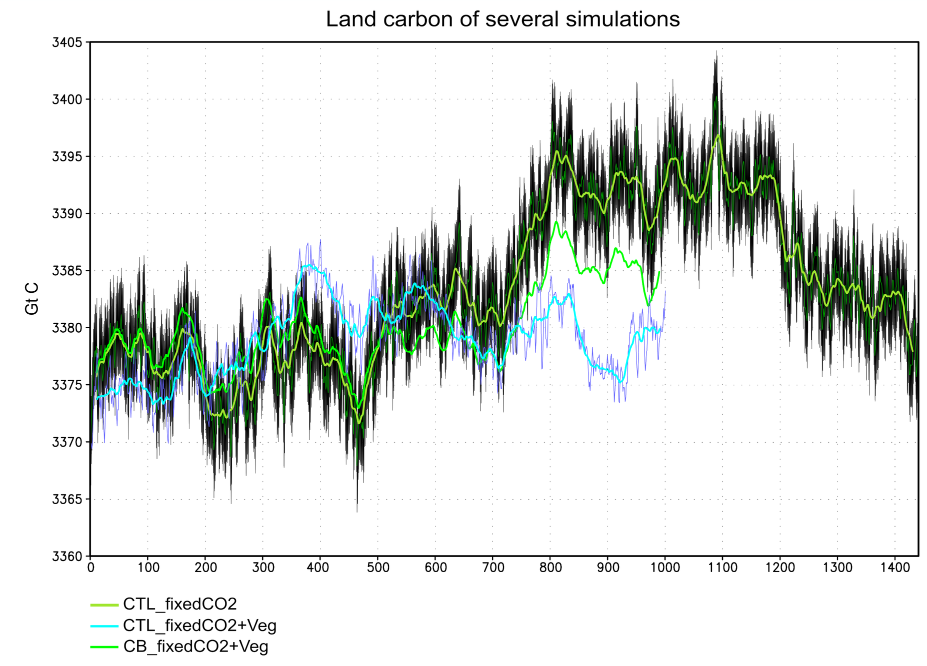


**Fig 4:** Global land carbon of the fixed $CO_2$ simulations.

In a second run (CTL_fixedCO2), with fixed atmospheric $CO_2$ concentration, the land C-storage variations emerge without the influence of atmospheric and oceanic storage variations. This run shows two times higher C-storage changes on time scales of centuries than the first simulation (Fig. 4).

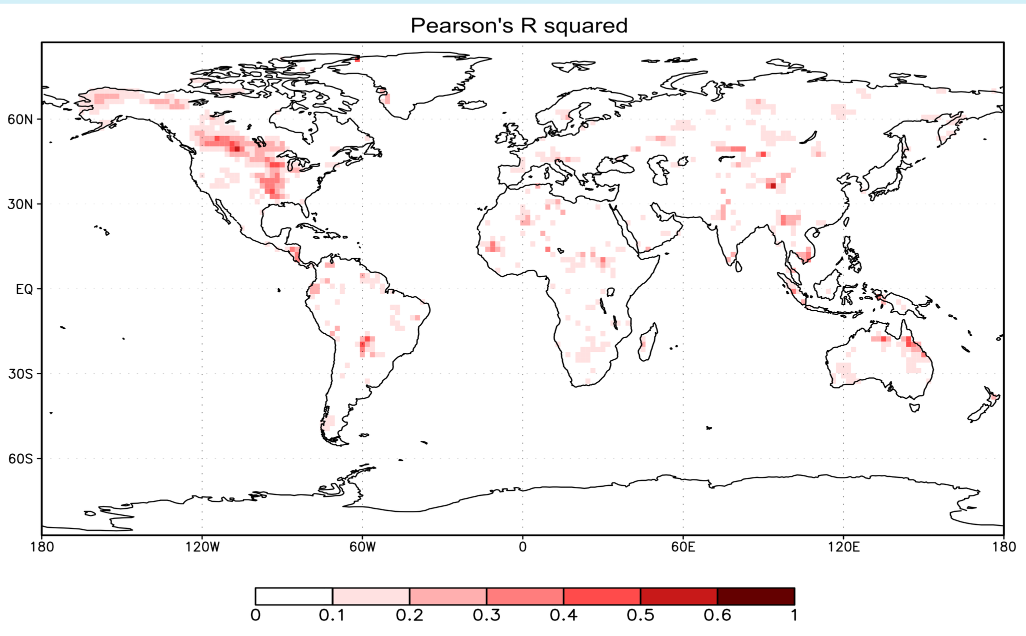


**Fig 5:** Correlation coefficients of total carbon between the single grid cells and the global average.[1]

We quantified the contribution of single grid cells to the long-term global C-storage changes.[1] The map of the correlation strength (Fig. 5) exhibits that the long term variability of land C originates from regions all over the globe with a strong contribution from North-America.

To separate storage effects coming from climate variability and from vegetation dynamics, a third run (CTL_fixedCO2+veg) with additionally fixed vegetation cover was performed. The results exhibit that the C-storage variability is mainly caused by direct climatic variations (Fig. 4).

The main reason for long-term land storage variations are fluctuations in Net Primary Production (NPP) caused by climatically driven variations of the leaf area index (LAI). However, several climate variables cause the LAI variability. Fig. 6 shows the climate dependency of the LAI.

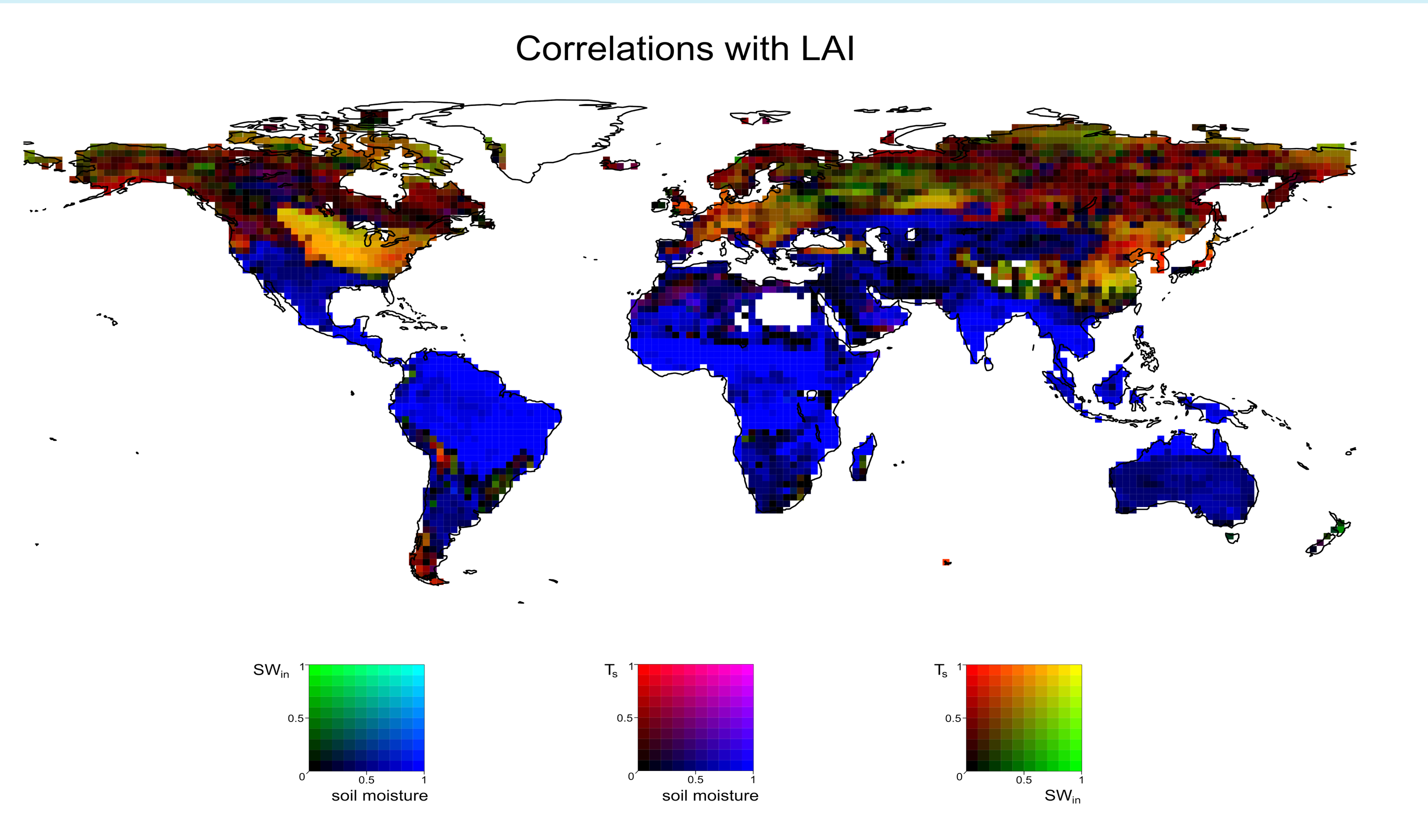


**Fig 6:** Map of positive correlations between climatic variables and the LAI in CB_fixedCO2+veg. Each color in the plot is a combination of red, green and blue. The intensity of red represents Spearman's rho correlation coefficient between surface temperature and LAI for the corresponding grid cell. The intensity of green represents respectively Spearman's rho between incoming shortwave radiation at the surface and LAI. The intensity of blue represents Spearman's rho between relative soil moisture and LAI.

## Summary and Conclusions

- Our model results indicate a natural atmospheric $CO_2$ variability of about 2 ppm on time scales of 250 yrs
- Without the compensatory effect of the ocean, the land induced $CO_2$ variability would be even higher
- The terrestrial C storage changes arise globally but are clustered in sensitive regions (N-America)
- The terrestrial C storage changes are caused by natural climate variability (vegetation dynamics is unimportant)
- Climate variability causes changes in the LAI, which leads to NPP changes inducing the C-storage variations

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1 Le Quéré C., Raupach M.R., Canadell J.G., Marland G. et al. (2009). Trends in the sources and sinks of carbon dioxide. Nature Geosciences. DOI: 10.1038/NGEO689.

2 We applied the following method: We calculated the time series for each grid cell in the CB_fixedCO2+veg simulation, built the 21 years running mean and used polynomial detrending. The same was done for the global average. Based on these results, we calculated the correlation coefficient $R^2$ (Pearson) between the single grid cells and the global averages.

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