Using JULES to Model the Congo Peatlands

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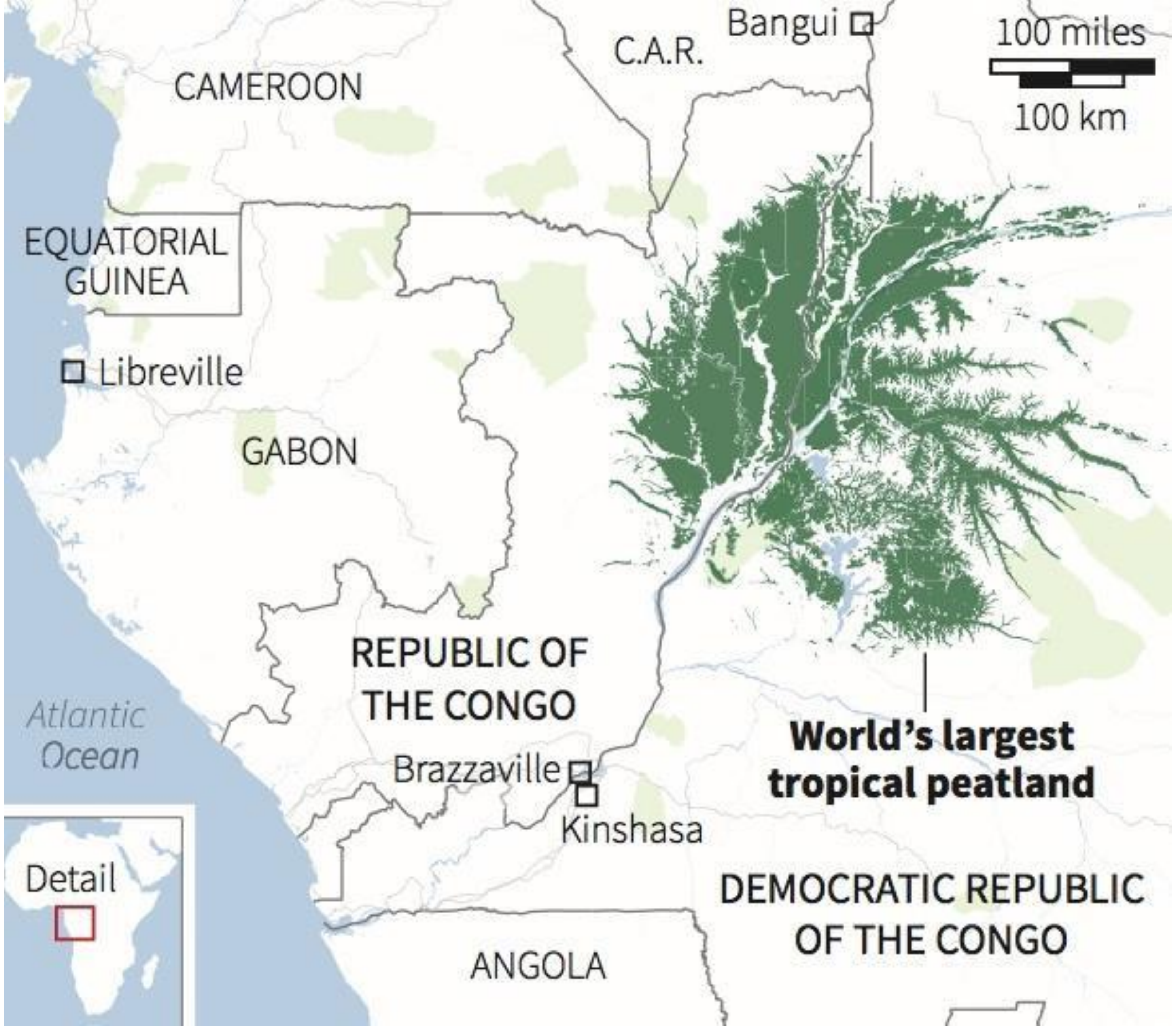
More information about CongoPeat is at: https://congopeat.net

The Cuvette Centrale Peatlands

- The Cuvette Centrale swamp forest in the central Congo Basin has the most extensive peatland complex in the tropics but was only discovered in 2014 by Leeds University researchers lead by Professor Simon Lewis
- With an area of 145,500 Km^2 (almost as large as England and Wales), in many places the peat is over 6m deep, the peatlands are estimated to contain 30 billion tonnes of Carbon (~3 years of global CO_2 emissions)
- Deepest peat is over 20,000 years old, measured by radio-carbon dating, but the peatlands seem to be very sensitive to changing conditions
- The international project CongoPeat, with researchers from the UK, the Republic of the Congo and the Democratic Republic of the Congo, studies how the peatlands formed, the ecosystems and possible threats
- Working with the local people who depend on the swamp forest
- Threatened by climate change and possible logging and oil prospecting, as any drop in the water table would lead to a rapid loss of peat


Bangui
C.A.R.
100 miles
100 km
CAMEROON
EQUATORIAL
GUINEA
Libreville
GABON
REPUBLIC OF
THE CONGO
Atlantic
Ocean
Brazzaville
Kinshasa
World's largest
tropical peatland
Detail
DEMOCRATIC REPUBLIC
OF THE CONGO
ANGOLA

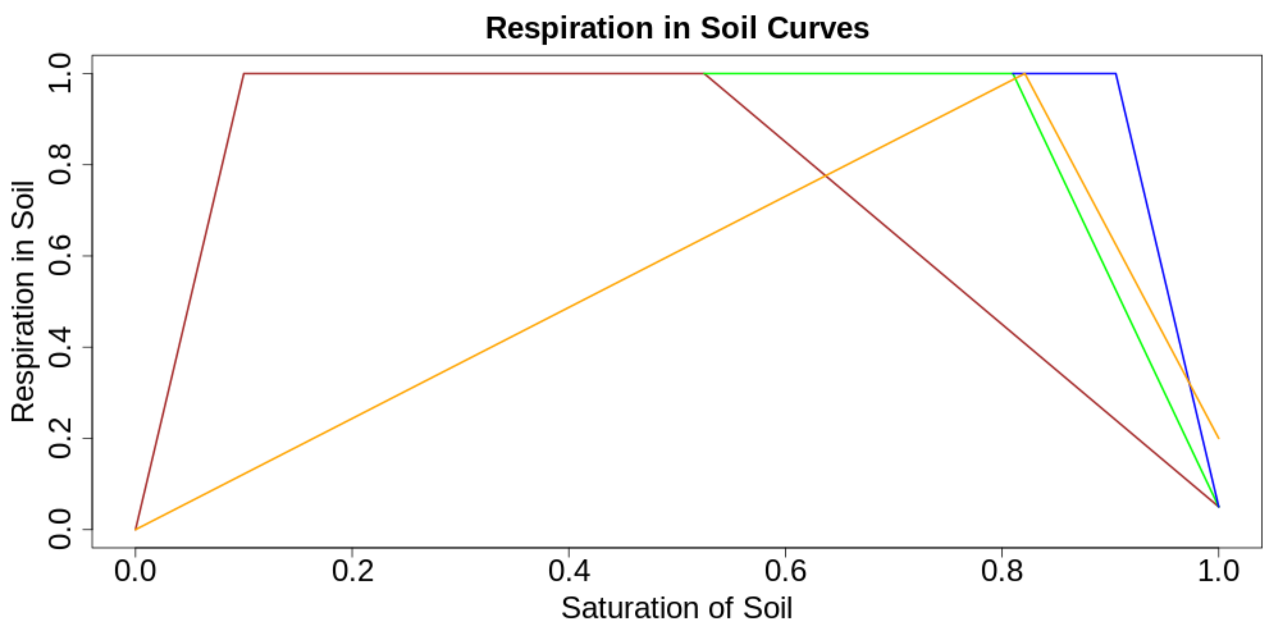
CongoPeat researchers obtaining a soil core

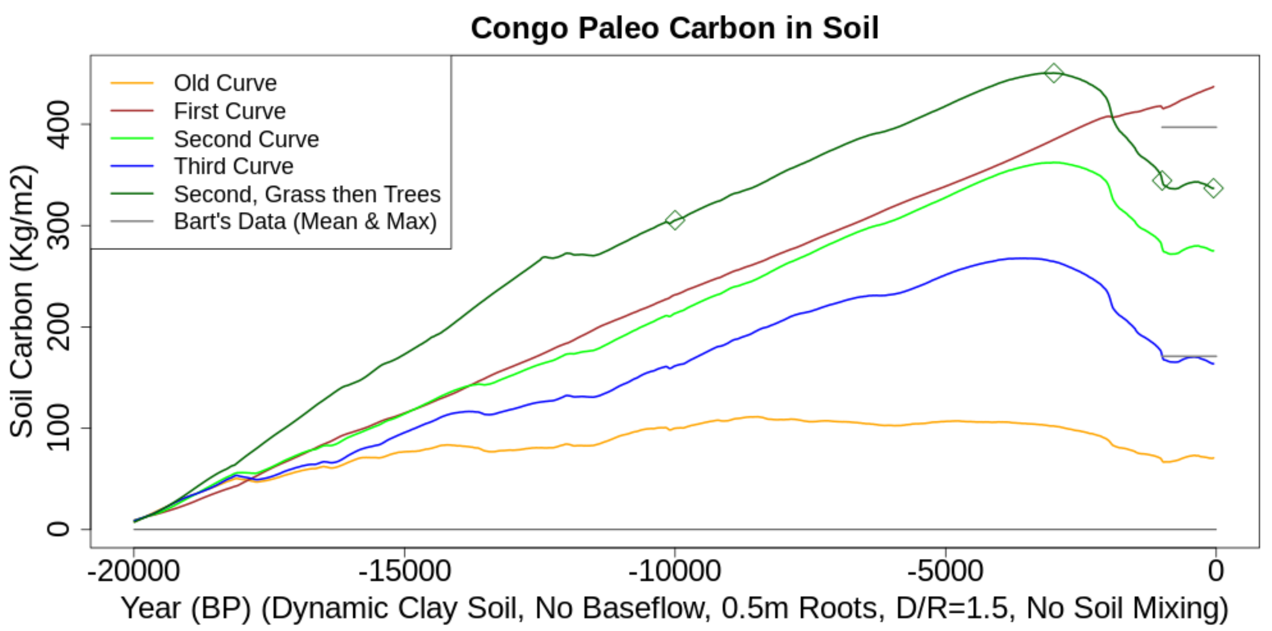
JULES CongoPeat Paleo Runs

- Aiming to accurately simulate the formation and development of the Cuvette Centrale peatlands, as soil core measurements imply that a lot of peat was lost during drier conditions a few thousand years ago
- 20,000 year model runs at a single location (0N 18E) during which vegetation cover is established and Carbon accumulates in the soil
- Using a paleo rainfall reconstruction obtained from leaf wax data
- Other meteorological inputs from a HadCM3 paleo climate run
- Starting with zero vegetation and zero soil Carbon, JULES is run with dynamic vegetation (interactions between the different vegetation types) and dynamic soil (the soil properties change as Carbon accumulates)
- All runs include complex Nitrogen cycles which can limit the vegetation growth, would otherwise produce too much and too young Carbon
- Not using fully saturated soil as this would be unrealistic

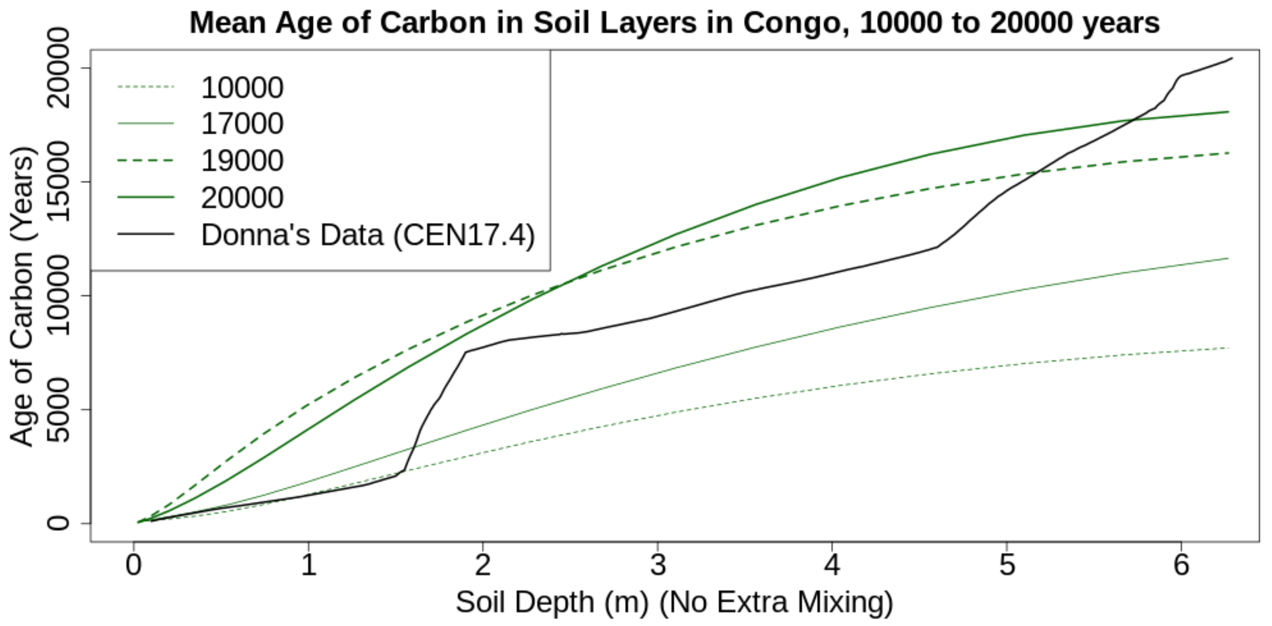
JULES Set Up Using Measurements

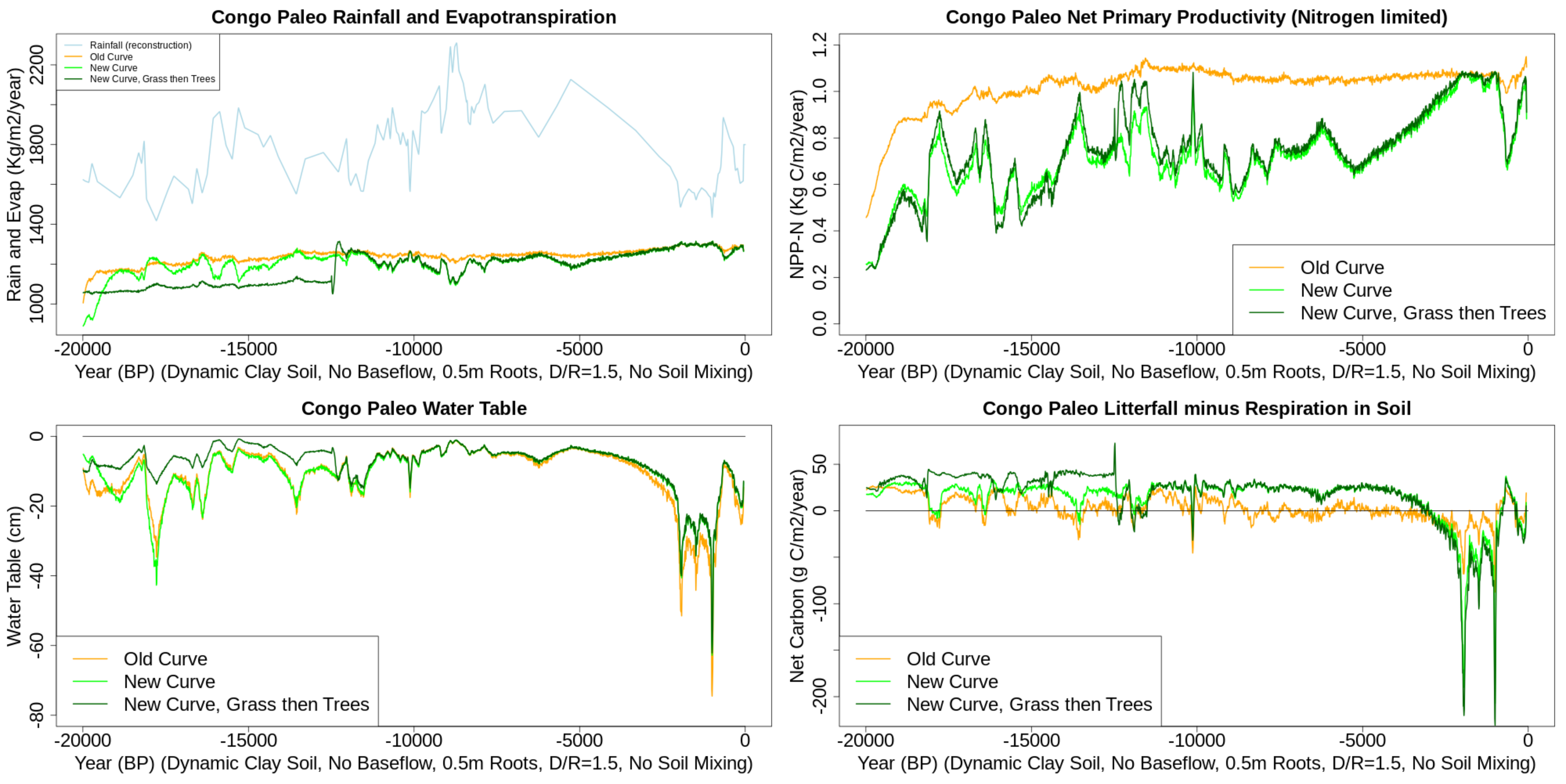
- Both the rainfall seasonal cycle and the temperatures from the HadCM3 model are reduced to match recent measurements
- Using clay soil, as measured in the Congo Basin, with no baseflow
- Short (0.5m) roots on all vegetation as in a swamp forest, with most litter put in near the surface (“tau_lit” is increased to 5)
- Using litter as measured (60% Decomposable and 40% Recalcitrant)
- No extra mixing in the soil from biological processes
- Then trying new curves of peat decay (microbial respiration in the soil vs saturation)
- Runs have mixed vegetation throughout (mostly trees), or grasslands for 7500 years (as measured in some soil cores) followed mixed vegetation





Original (orange) and new (brown, green and blue) peat decay curves (microbial respiration vs saturation) with the resulting development of the Cuvette Centrale peatlands and the development of the Carbon age profile (run starting with grass only) with measured values





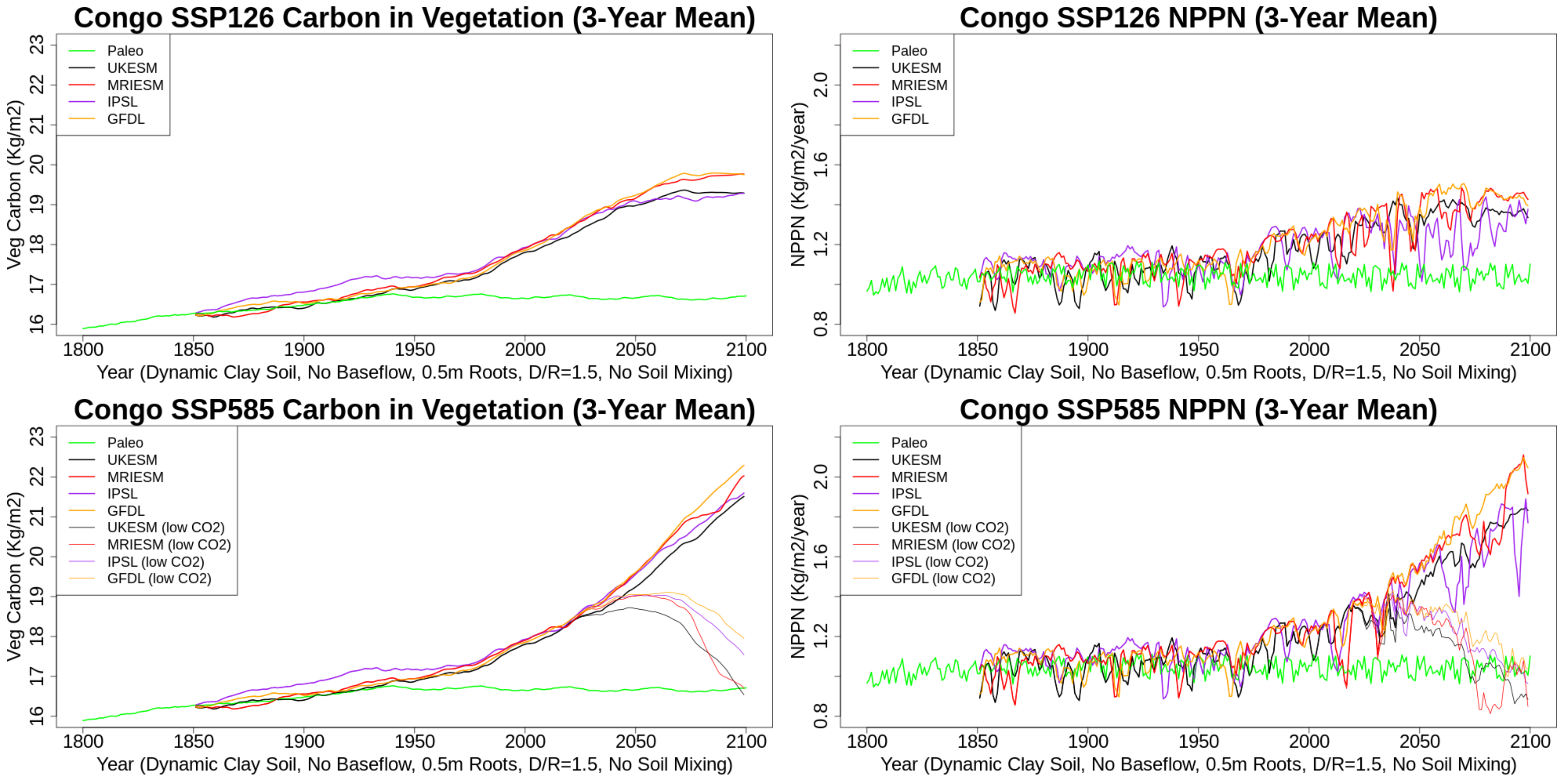
Decadal mean values during the JULES paleo runs

Paleo Run Results

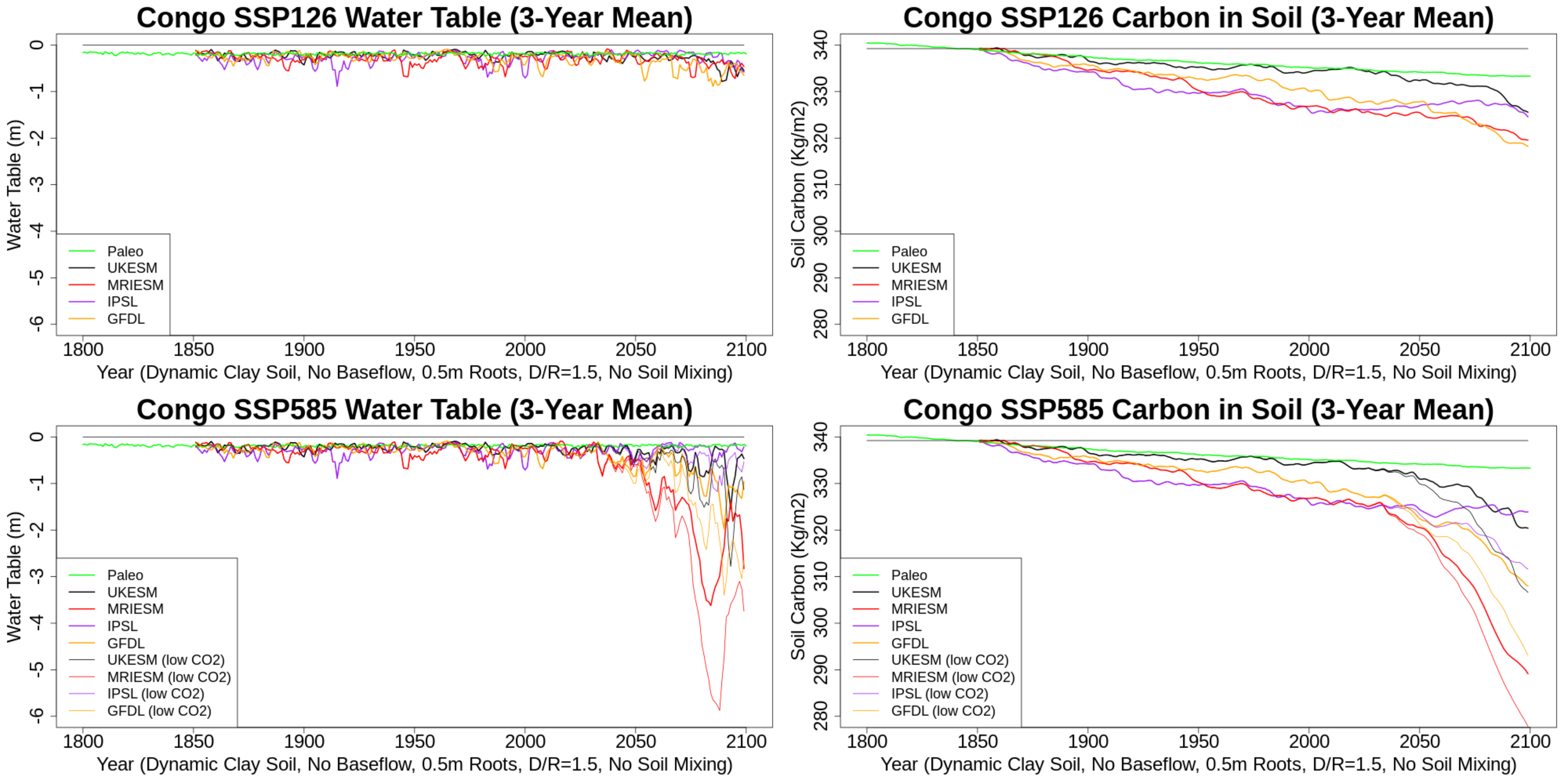
- In our simulations we need a strong build up of peat, but also a strong response to changes in the climate so that Carbon is gained in wetter conditions then lost in drier conditions, with a big decline near the end
- Using new curves, with more peat decay in drier soil and less in wetter soil, leads to less vegetation and productivity due to complex Nitrogen feedbacks, but does result in more peat with a greater response to climate, a bigger decline near the end, and greater mean ages of Carbon
- Adjusting the new curve to give more peat decay in wetter soil leads to more productivity and a greater response to climate, but also a lower water table and less peat in total, so a balance has to be made here
- When there is grass only evapotranspiration is less and the water table higher so there is less decay and more peat builds up, then later on there is a bigger decline in peat and still greater mean ages of Carbon

JULES CongoPeat Future Runs

- Also examining the effects of future climate projections on the Cuvette Centrale peatlands, without any other disruption of the swamp forest
- Starting with a reasonable peat profile (339 Kg/m^2) and stable vegetation in 1850, JULES was driven with 251 years of data (1850-2100) from 4 ISIMIP GCM's (global climate models), each having 3 climate projections (SSP126, SSP370 and SSP585), and using the associated CO_2 concentrations and Nitrogen depositions
- Also examining the CO_2 fertilization effect on the vegetation by runs using a high climate projection (SSP585) but lower CO_2 (SSP126)
- The 4 global climate models are: the UK Met Office Hadley Centre Earth System Model (UKESM), the Meteorological Research Institute of Japan Earth System Model (MRIESM), L'Institut Pierre-Simon Laplace in France (IPSL), and the NOAA Geophysical Fluid Dynamics Laboratory in the USA (GFDL)



Changes in vegetation Carbon and NPPN from paleo run and four GCMs



Changes in water table and total soil Carbon from paleo run and four GCMs

Future Run Results

- All of the future runs show a drop in the water table and a decline in the amount of soil Carbon
- Though the end of the paleo run also has a slow decline in soil Carbon
- For two of the GCM’s the high projections (SSP370 and SSP585) have a decrease in rainfall, leading to larger drops in the water table and greater declines in soil Carbon
- The runs using a high projection (SSP585) but low CO_2 (SSP126) show that increased vegetation and productivity are largely due to increased CO_2 and the drops in the water table and declines in soil Carbon would be even greater without the vegetation responses to increased CO_2
- Hence peat loss occurs in-spite of the increased vegetation and litterfall due to the fertilisation from increased CO_2, and in-spite of some reduction in plant transpiration also due to increased CO_2

Summary

- Long paleo climate runs by JULES, using a reconstruction of past annual rainfall, have produced results which are close to the measurements from the Cuvette Centrale peatlands
- Both a strong build up of peat and a strong response to changing climate have been obtained, including a considerable loss of peat in the drier conditions a few thousand years ago, mostly by using litter as measured and a new curve of peat decay (microbial respiration vs soil saturation)
- The large loss of peat and then some build up of young peat near to the surface at the end of the run produces a much steeper age-depth profile
- Future climate runs mostly show a loss of soil Carbon, even in the low projections, in-spite of increased CO_2 increasing the vegetation and litter while reducing the plant transpiration, implying that the Cuvette Centrale peatlands remain sensitive to drying or disruption of the swamp forest