Climate sensitivity of terrestrial carbon exchange

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Airborne Stable Isotopes of Carbon from the Amazon

WAGENINGEN
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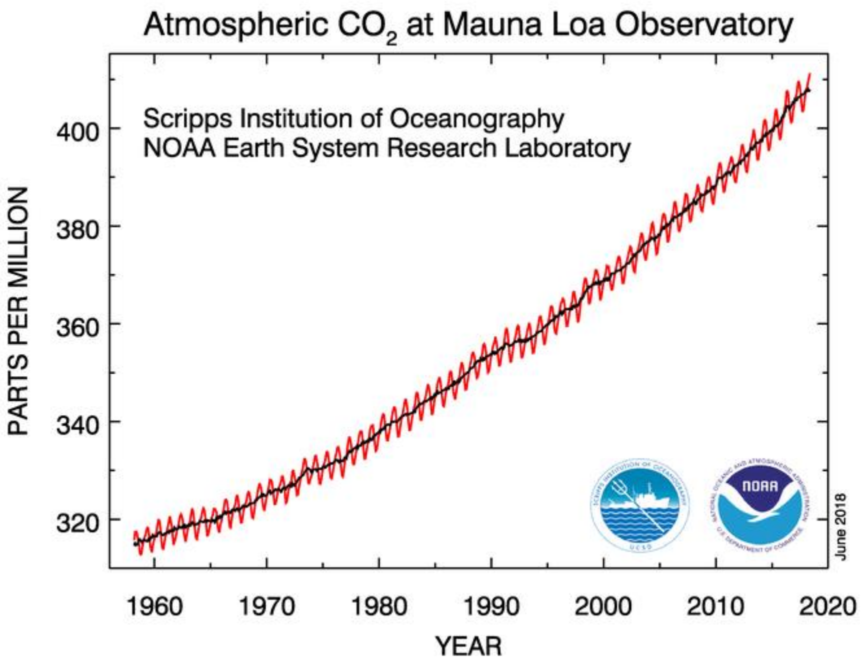
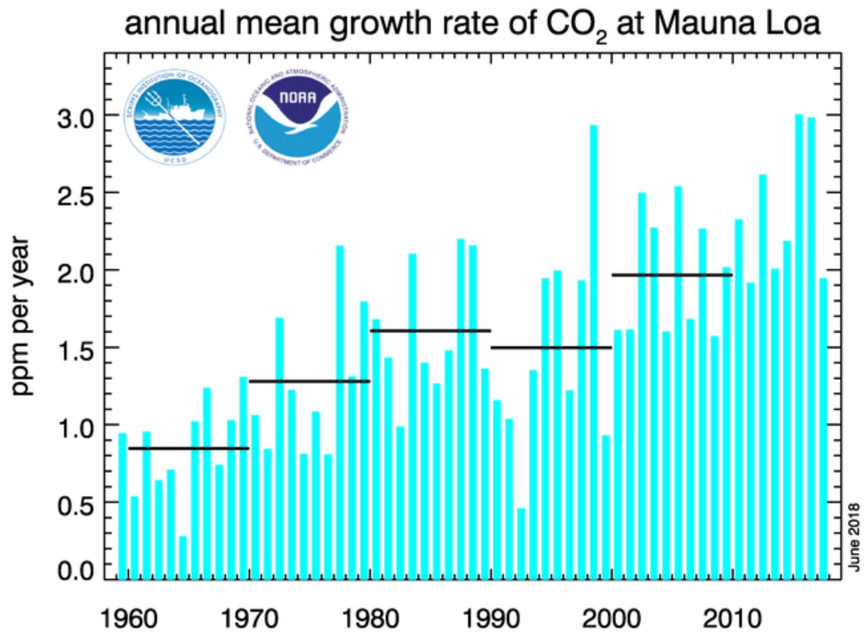
CO_2 at Mauna Loa

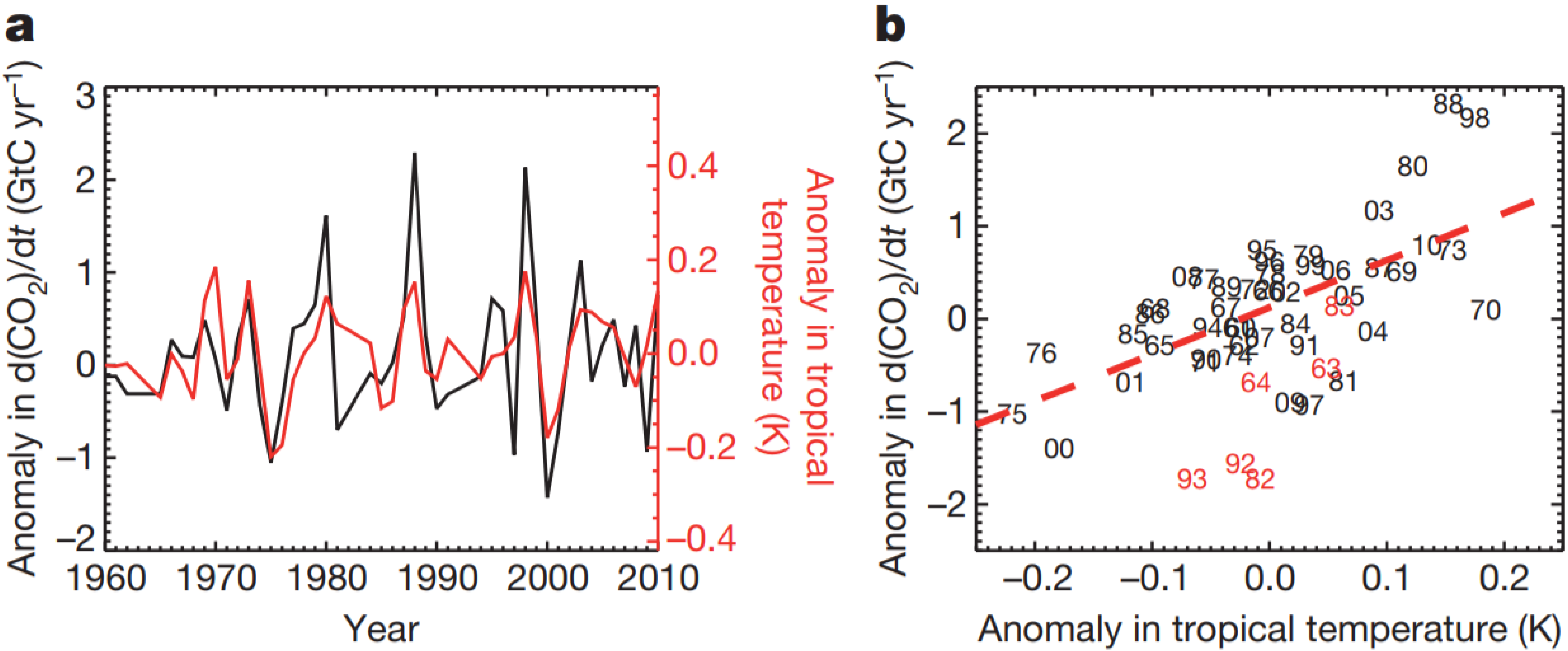




- High growth rate of CO_2 mixing ratios following El Niño events (e.g. 2015/2016) and droughts in the Amazon (2005, 2010)

- Reduced CO_2 growth rate after volcanic eruptions

Climate sensitivity



- Anomalies in growth rate of CO_2 correlate with anomalies in tropical temperature (Cox et al., Nature, 2013)

Aims

1 Reduce computational expense of biospheric CO_2 fluxes (input for forward TM5 simulations or prior information for CarbonTracker)

- SiBCASA runs with 10 minute time step, 0.5° x 0.5° spatial resolution
- SiBCASA requires NDVI and meteo input

2 Estimate climate sensitivity γ for different regions/ecosystems

3 Get a better constraint on tropical regions with sparse coverage of CO_2 observations

- Better attribution of fluxes to tropical America/Africa/Asia

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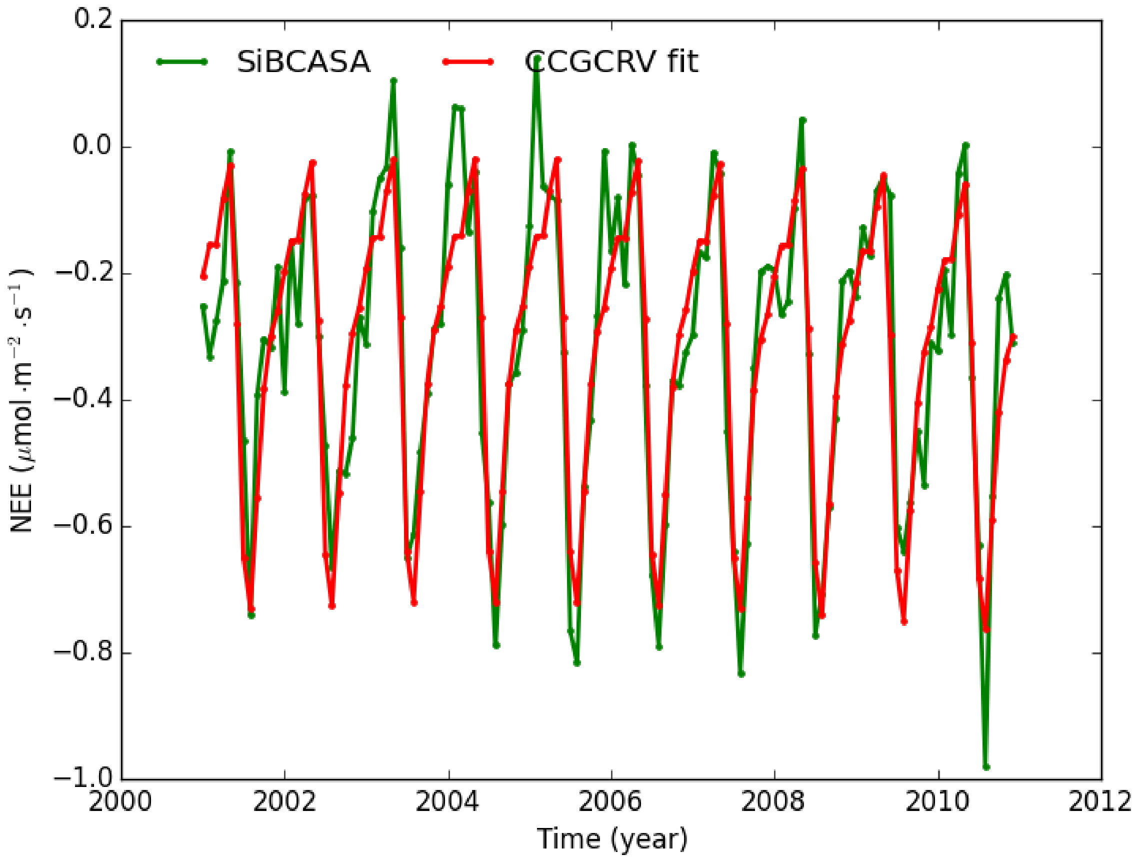
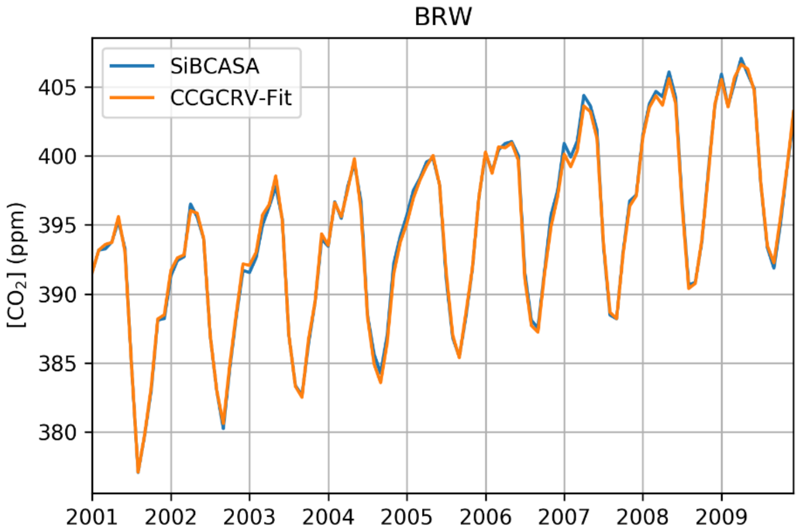
SiBCASA CCGVRV-fit

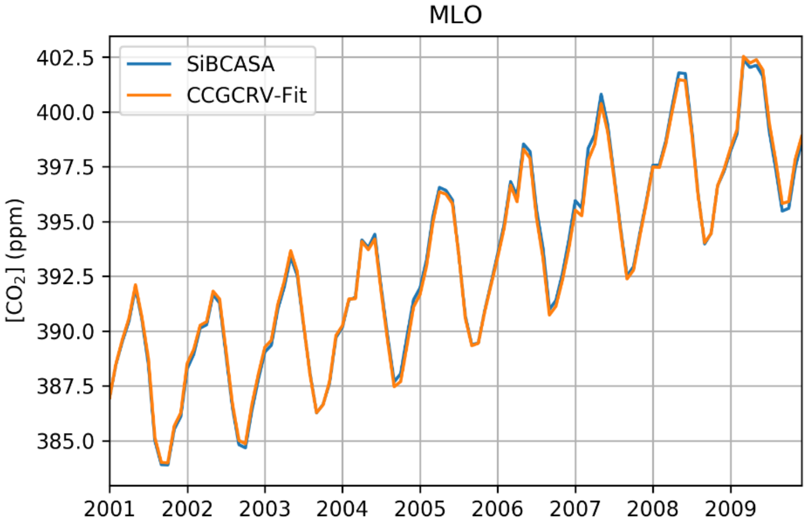


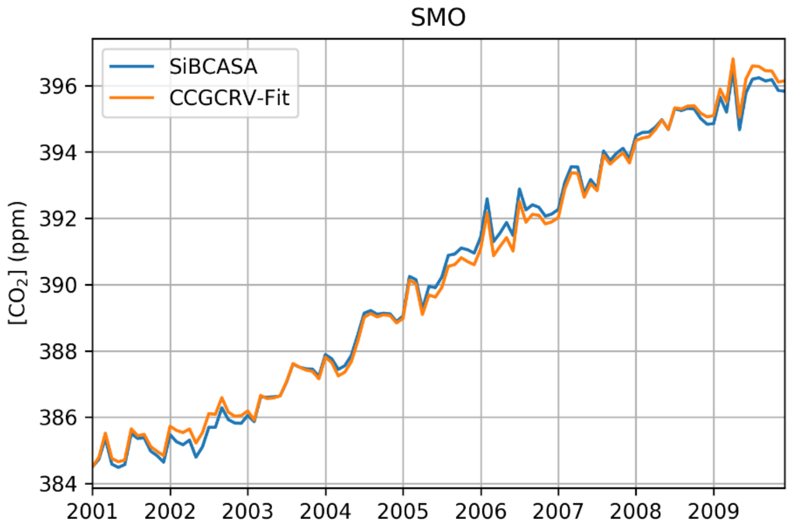
- NEE fluxes from SiBCASA for Amazon region over 10 year period
- Negative NEE means uptake of CO_2 by the biosphere
- CCGCRV function for NEE (originally developed for CO2, Thoning et al., 1989) with polynomial part and harmonics

$$NEE(t) = a_0 + a_1 \cdot t + a_2 \cdot t^2 + \sum_{k=0}^{n} A_n \sin(2\pi \cdot nt + \varphi_n)$$

Simulated CO_2 at NOAA baseline stations

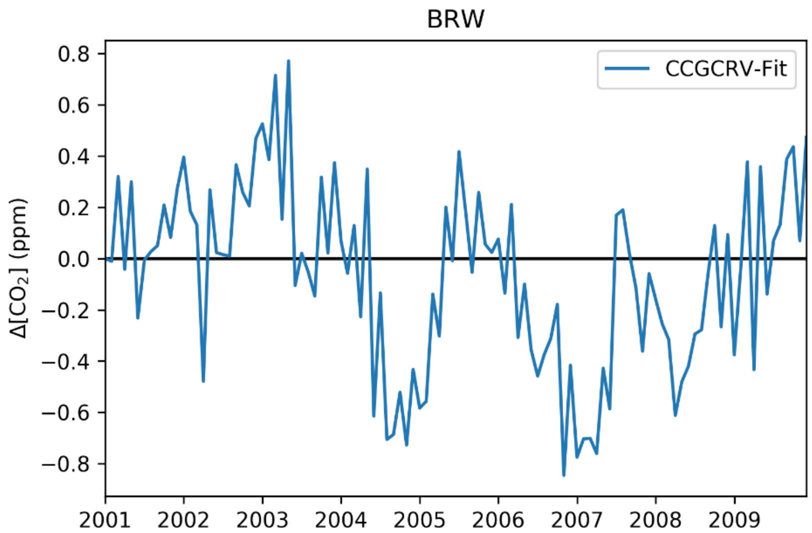


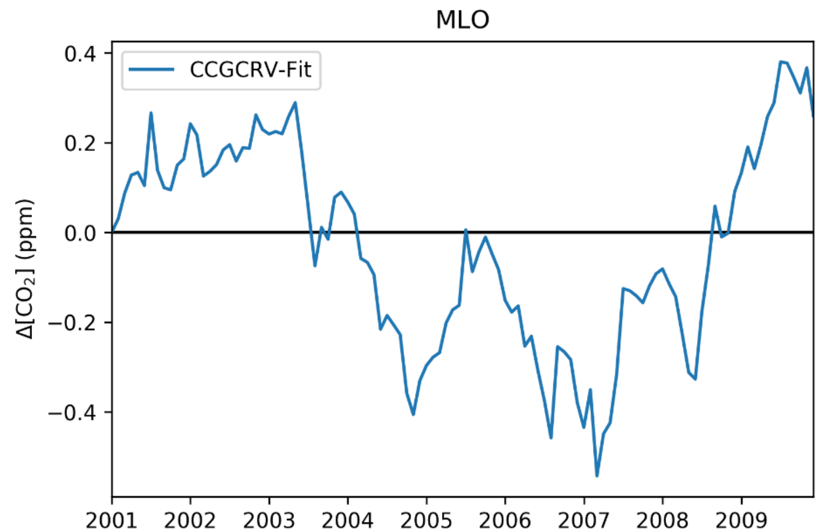


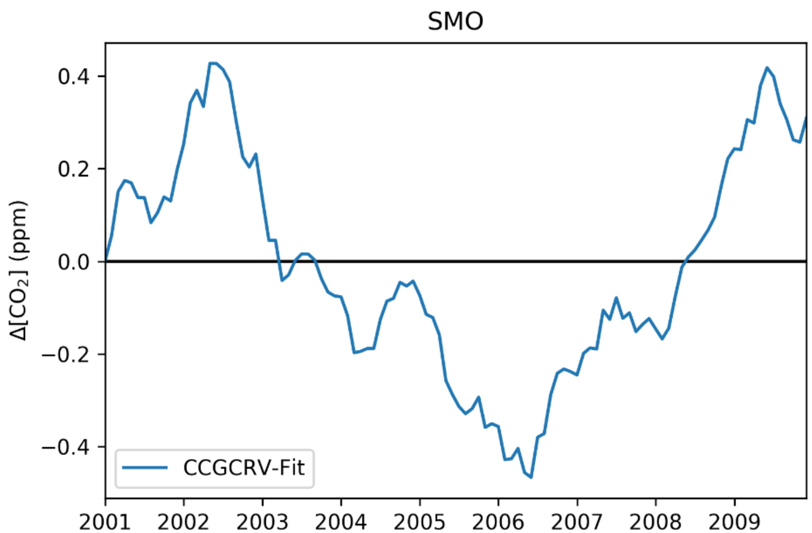


- Forward TM5 simulations at 6° x 4° with 25 vertical layers
- Biosphere fluxes from SiBCASA or CCGCRV fit from SiBCASA fluxes
- Also including fossil fuel emissions, biomass burning and ocean fluxes

Simulated CO_2 at NOAA baseline stations

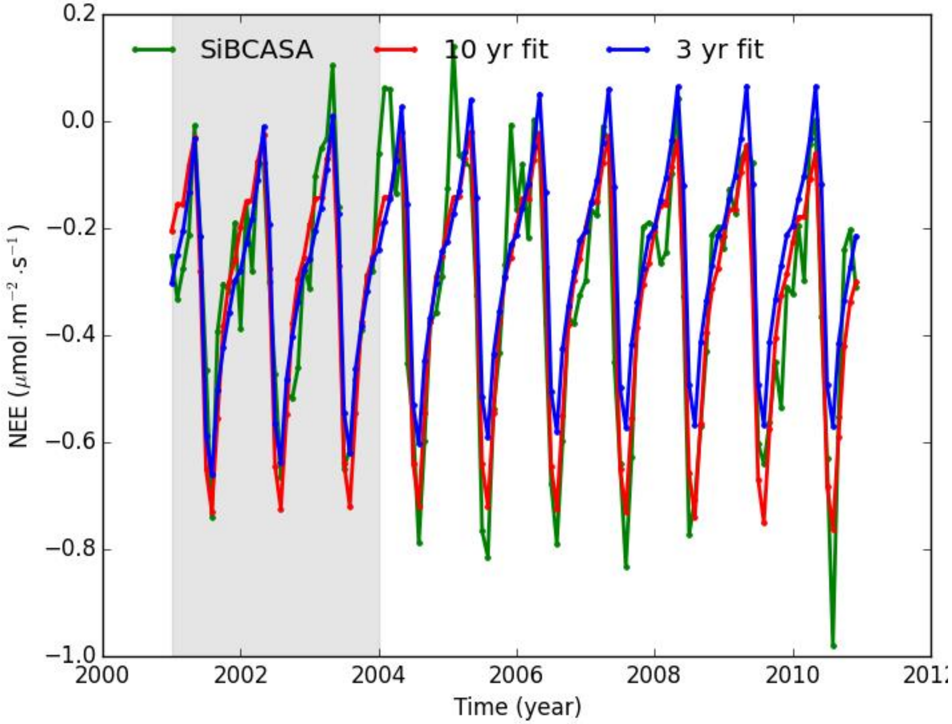


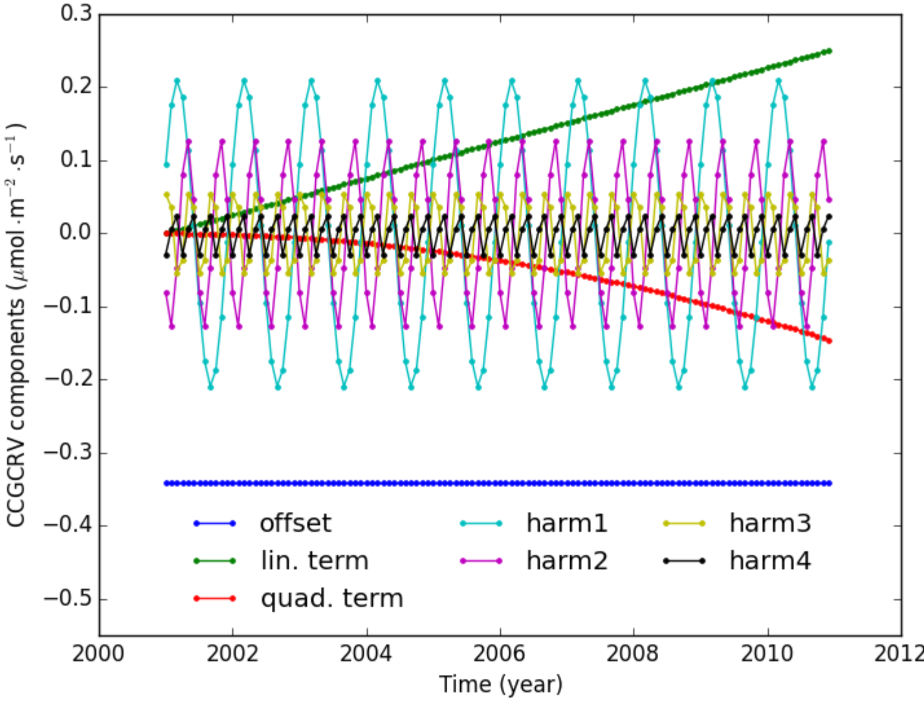




- Difference of simulated CO_2 using CCGCRV fit relative to CO_2 simulated from SiBCASA fluxes
- Difference is in the order of 0.5 ppm (This is the 'best we can get', using the full SiBCASA fluxes to 'train' CCGCRV)

Extrapolated fluxes





- Quadratic term will ultimately limit realistic extrapolation window
- Interpolation in space and time can also reduce computational expense

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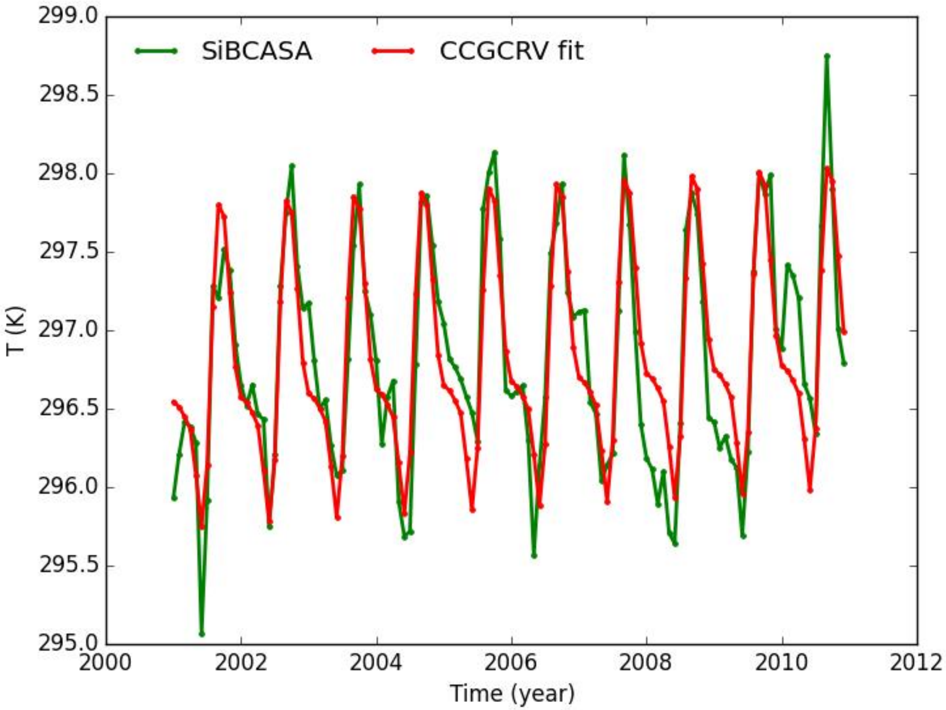
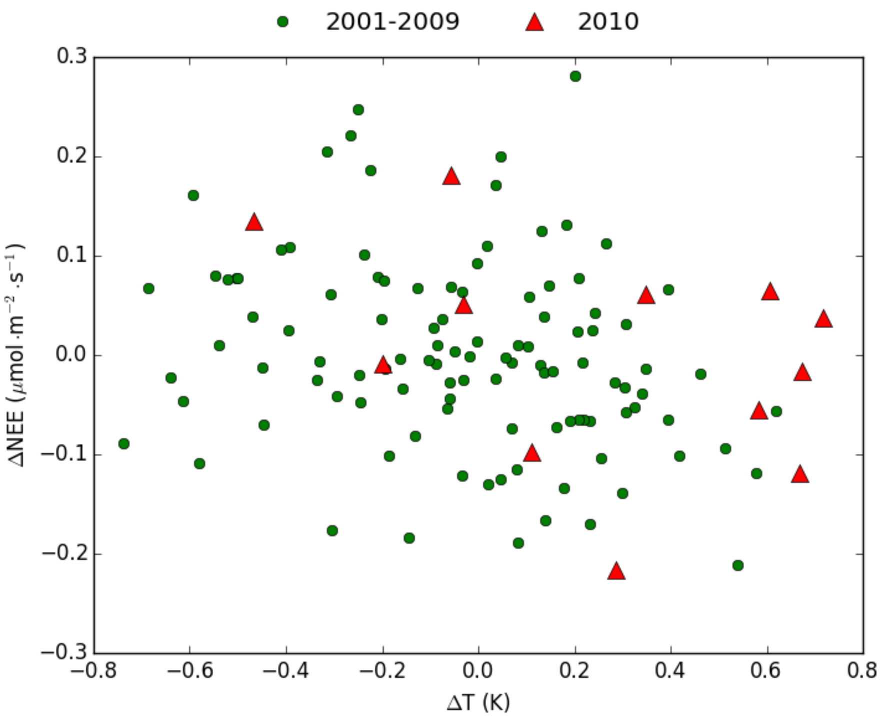
Climate sensitivity



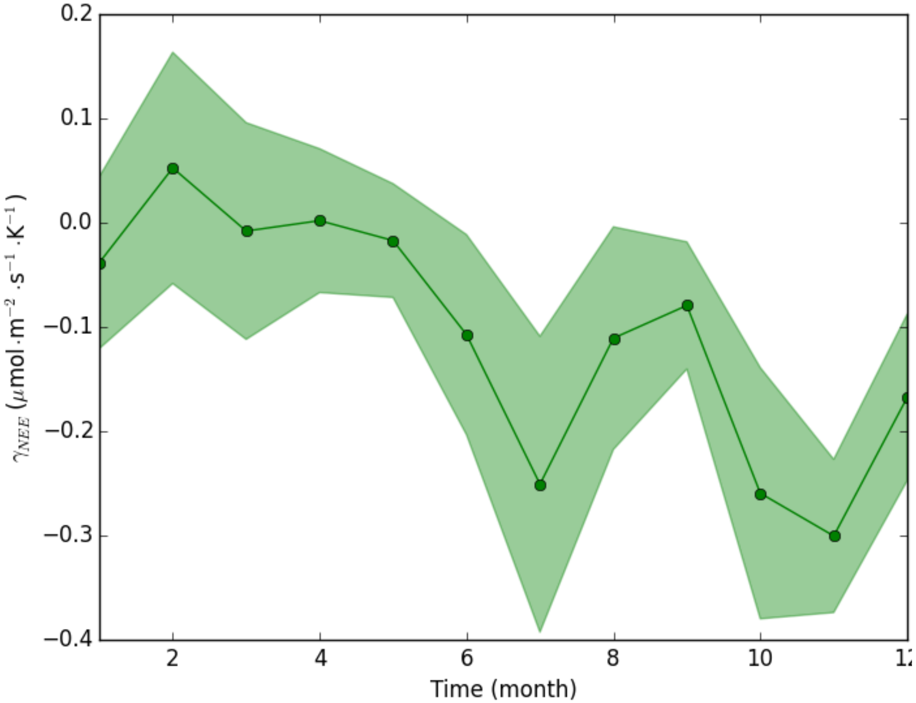


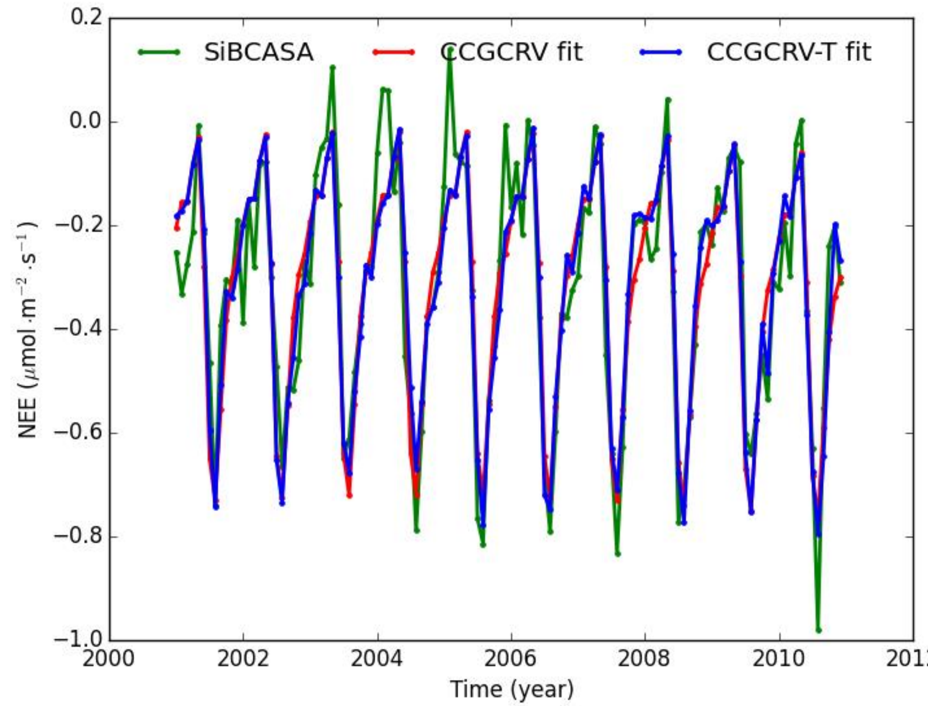
- Applying the CCGCRV routine to temperature data for the Amazon region to get a temperature fit (and hence also temperature residuals)

- Include climate sensitivity term for NEE (similar to Rödenbeck et al., 2018)

$$NEE(t,T) = NEE(t) + \gamma \cdot T_{IAV}$$

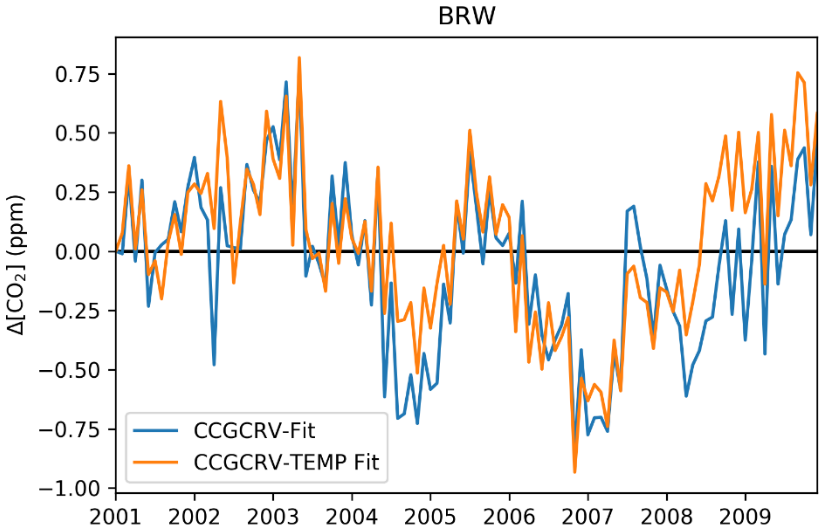
Climate sensitivity

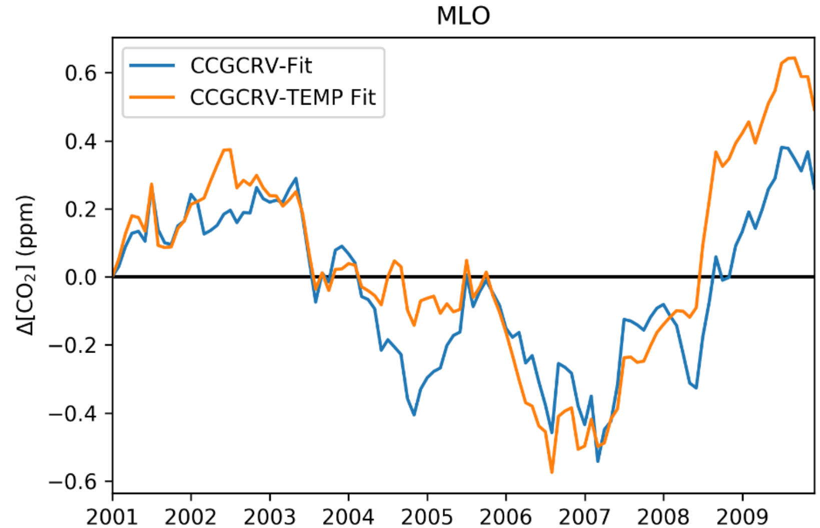


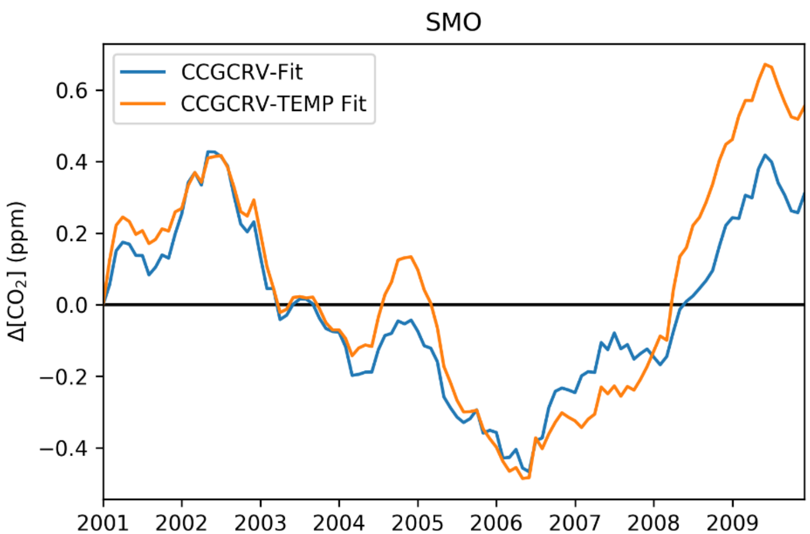


- Seasonal variation of climate sensitivity (e.g. increased temperature in summer has different effect than higher temperature in winter)
- According to SiBCASA higher temperatures in the Amazon lead almost always to more uptake (contrary to e.g. Cox et al., 2013)
- Temperature fit has lower RMSE w.r.t. SiBCASA than CCGCRV fit

Simulated CO_2 at NOAA baseline stations







- Difference of simulated CO_2 relative to CO_2 simulated from SiBCASA fluxes
- Although the TEMP-fit fluxes are closer to SiBCASA for each cell (lower RMSE), the resulting CO_2 mixing ratios are worse than CCGCRV-fit (high bias)

Conclusions

1 Reduce computational expense using CCGCRV

- CCGCRV can be used to partially replace SiBCASA
- Effect on simulated CO_2 mixing ratios is approx. 0.5 ppm
- Interpolation/extrapolation is possible but higher differences w.r.t. SiBCASA are expected

2 Estimate climate sensitivity γ for different regions/ecosystems

- Climate sensitivity in SiBCASA appears to ‘go in wrong direction’
- CCGCRV might not be suited for determining anomalies
- CO_2 inversions can be used to estimate climate sensitivity from observations

3 Better attribution of CO_2 fluxes for tropical regions

- Still to be done, likely using sun-induced fluorescence (SIF)