Evidence of localised Amazon rainforest dieback in CMIP6 models

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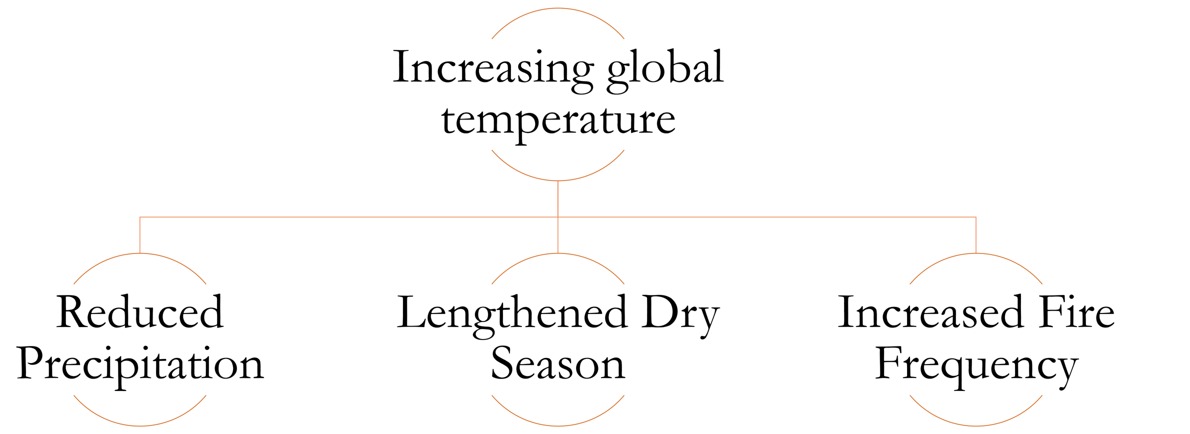
Background

Future tipping points pose a risk to both natural ecosystems and human activities, as they produce abrupt system-wide changes that are often difficult to reverse (Lenton et al., 2013).

The Amazon rainforest is at risk of dieback in response to rising global temperatures (Cox et al. 2004).
This may be caused by several factors (Malhi et al., 2009):



The fifth-generation of Earth system models (Coupled Model Intercomparison Project Phase 5, CMIP5) produced few examples of Amazon dieback under climate change (Chai et al., 2021).
This study investigates projections from the latest CMIP6 models for evidence Amazon dieback.

Methodology

CMIP models, experiment runs and data used

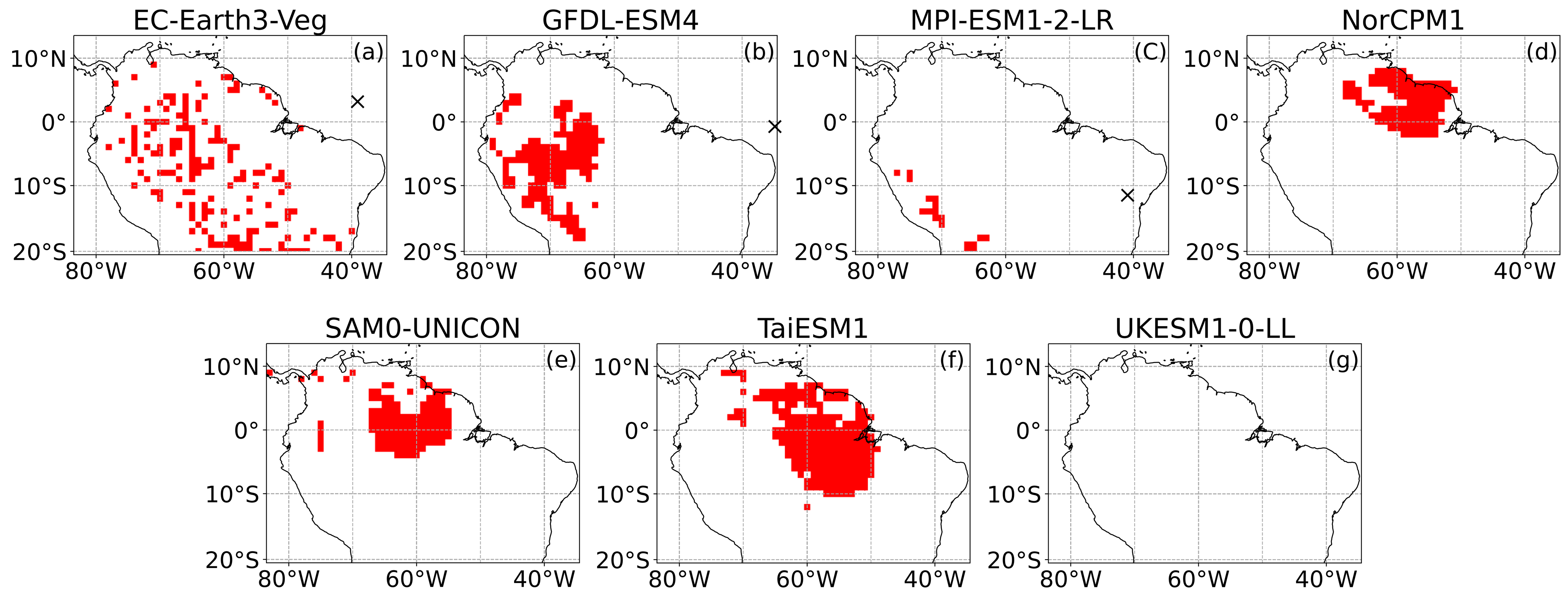
- Model output data of vegetation carbon and surface temperature from seven CMIP6 models were used.
- This study focused on the effect of climatic drivers alone, therefore used 1pctCO2 runs, where CO2 increases by 1% per year (Eyring et al., 2016).

Abrupt shift detection algorithm

1. **Absolute change** in vegetation carbon must be at least **2 kgCm⁻²** over a 15-year period.
2. This change must contribute to at least **25% of the overall change** in vegetation carbon.
3. The mean annual rate of change in the abrupt shift must be at least **3 times larger** than the variability in the rates of change in the **unforced control run** (piControl).

Results

Figure 1: Maps of abrupt shifts detected in the Amazon**.** Red grid points indicate abrupt dieback shifts. **Detected abrupt shifts appear to be clustered together in over half the models analysed.**



- Abrupt shifts in NSA area to experience abrupt shifts reflect **multiple grid points tipping at a similar time** (Fig. 2a).
- Model mean shows a smoother increase in fractional NSA area to undergo an abrupt shift compared to individual models.
- There is **no singular temperature threshold**; the risk of tipping increases approximately linearly
- Abrupt changes are not obvious in the NSA regional average , despite local abrupt shifts (Fig. 2b).
- Sensitivity of the **temperature seasonal cycle amplitude** to global warming is higher for grid points featuring an abrupt shift (Fig. 3).
- This means that sensitivity could potentially be used as a system-specific **early warning signal**.

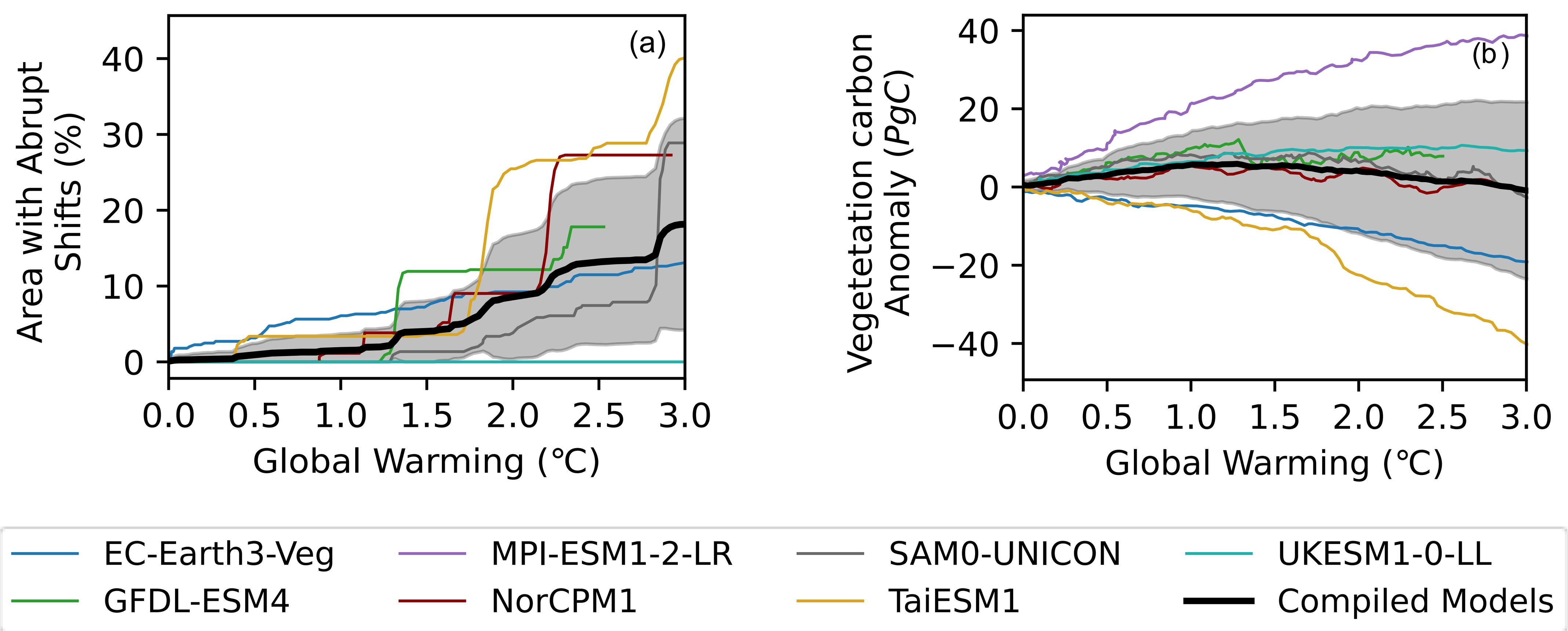


Figure 2: **(a)** Evolution of the percentage of the NSA region to experience an abrupt shift with global warming. **(b)** Evolution of vegetation carbon anomaly relative to the mean of the first 10 years with global warming. Plumes indicate error in the averaged line (black).

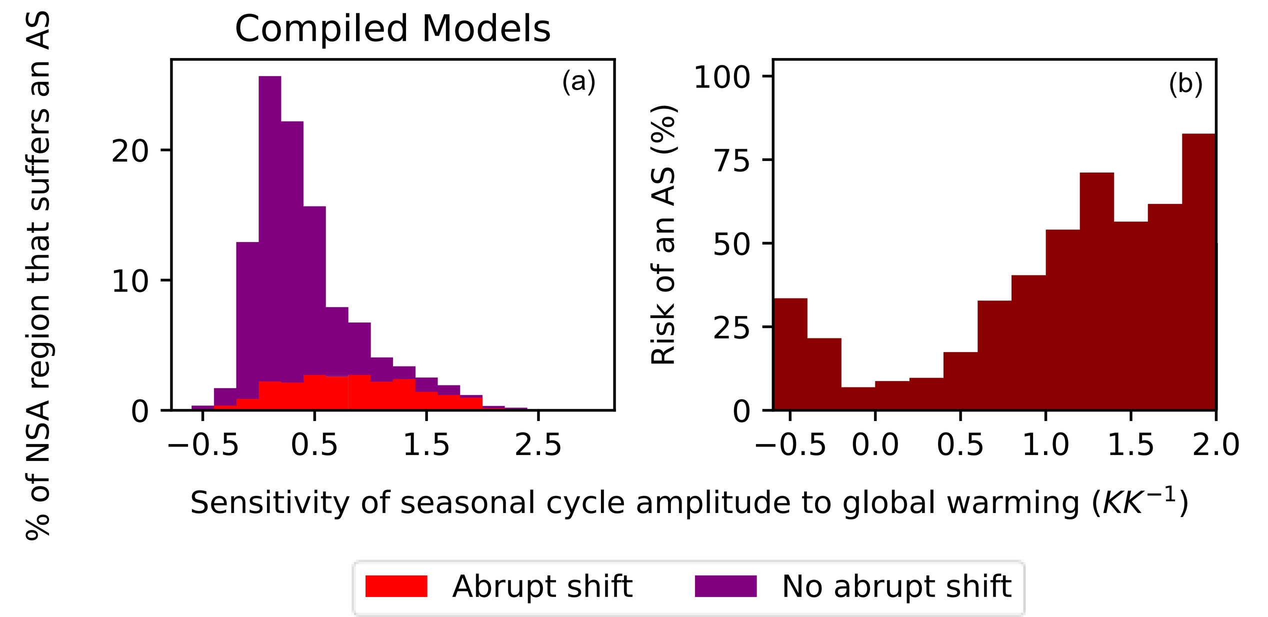


Figure 3: Efficacy of the temperature seasonal cycle amplitude (TSCA) at assessing risk of abrupt dieback. **(a)** Histogram showing percentage area of NSA region with different sensitivities of the TSCA to global warming. **(b)** How risk of a dieback shift changes with increasing sensitivity to TSCA.

Conclusions

- **Anthropogenic climate change could result in localised tipping events occurring in the Amazon Rainforest** with severe consequences for local communities and ecosystems.
- **7 +/-5%** of the NSA region would experience abrupt downward shifts in vegetation carbon **per degree of warming above 1.5°C.**
- Further research could assess the risk of tipping events under climate change and identify forewarning methods.

Further information

Acknowledgments

We acknowledge the World Climate Research Programme's Working Group on Coupled Modelling, which is responsible for CMIP, and we thank the climate modelling groups (listed in Table 1 in the Methods section of the attached paper) for producing and making available their model output.

References

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