Future socio-ecosystem productivity threatened by compound drought-heatwave events

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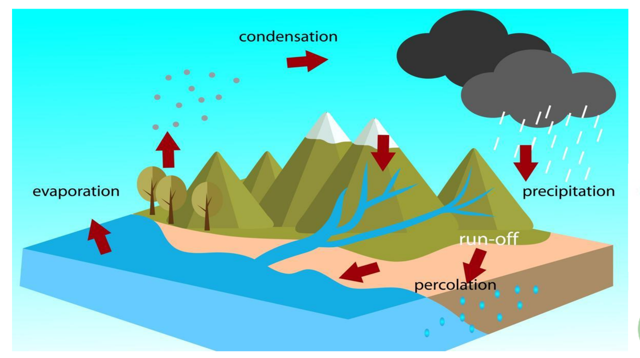
1 Introduction

- Compounding drought-heatwave events (**CDHW**) are now regarded as one of the worst climatic stressors for global sustainable development.
- The physical mechanisms behind CDHW remain poorly understood, especially in terms of the atmospheric dynamics under an intensified hydrologic cycle.
- The effects of changing terrestrial water storage (**TWS**) — a key determinant of global water and energy budgets — on CDHW and the resulting impacts on socio-ecosystem productivity remain unexamined.

2 Methods and Data



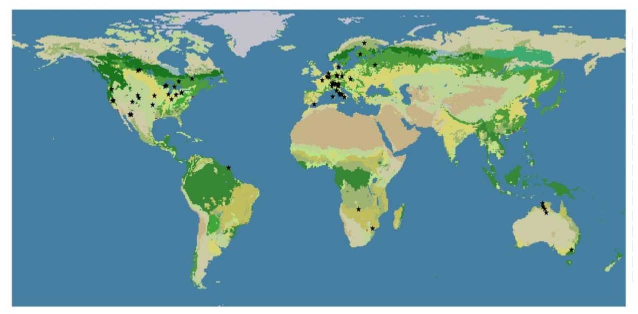
Atmospheric dynamics in water cycle

GRACE

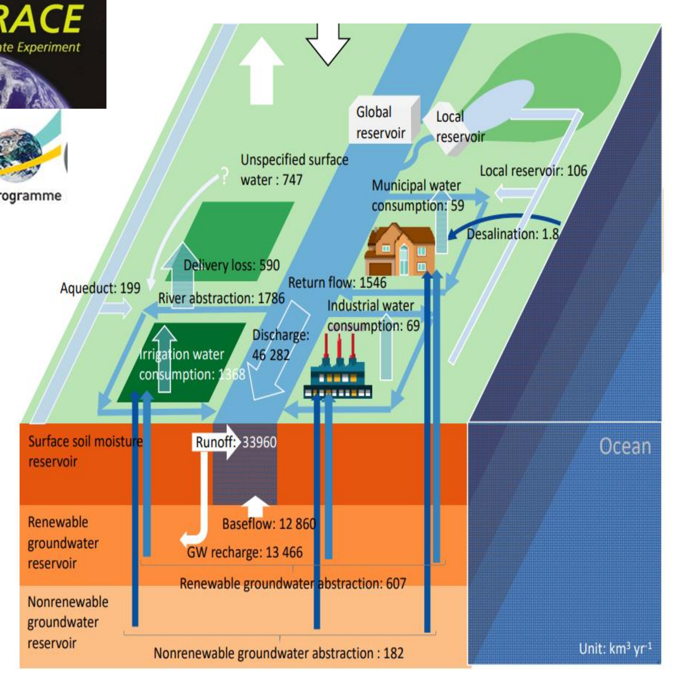
WCRP World Climate Research Programme

ISIMIP

ERA5

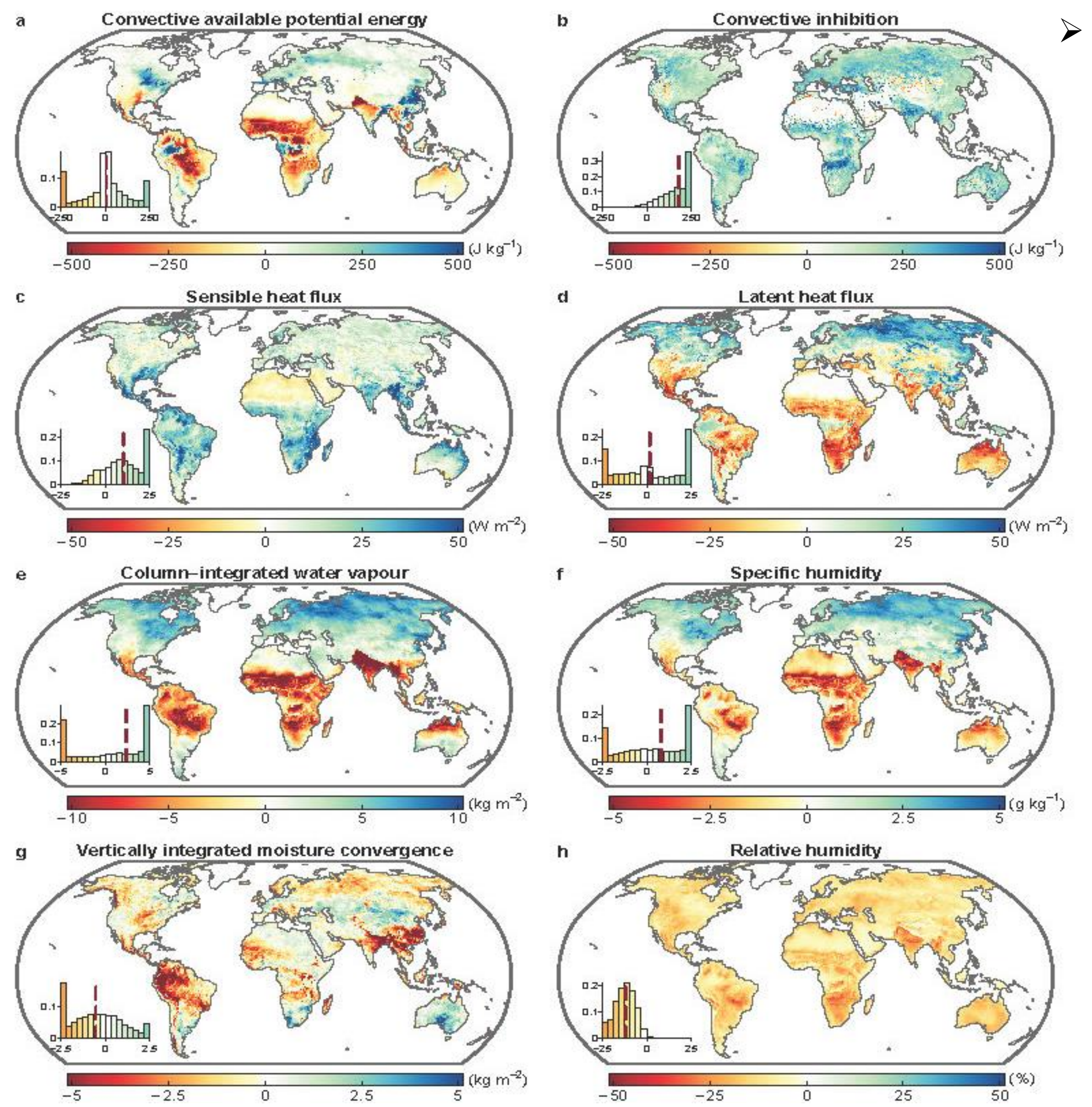


Global eddy-covariance flux towers



H08 (Global hydrological model)

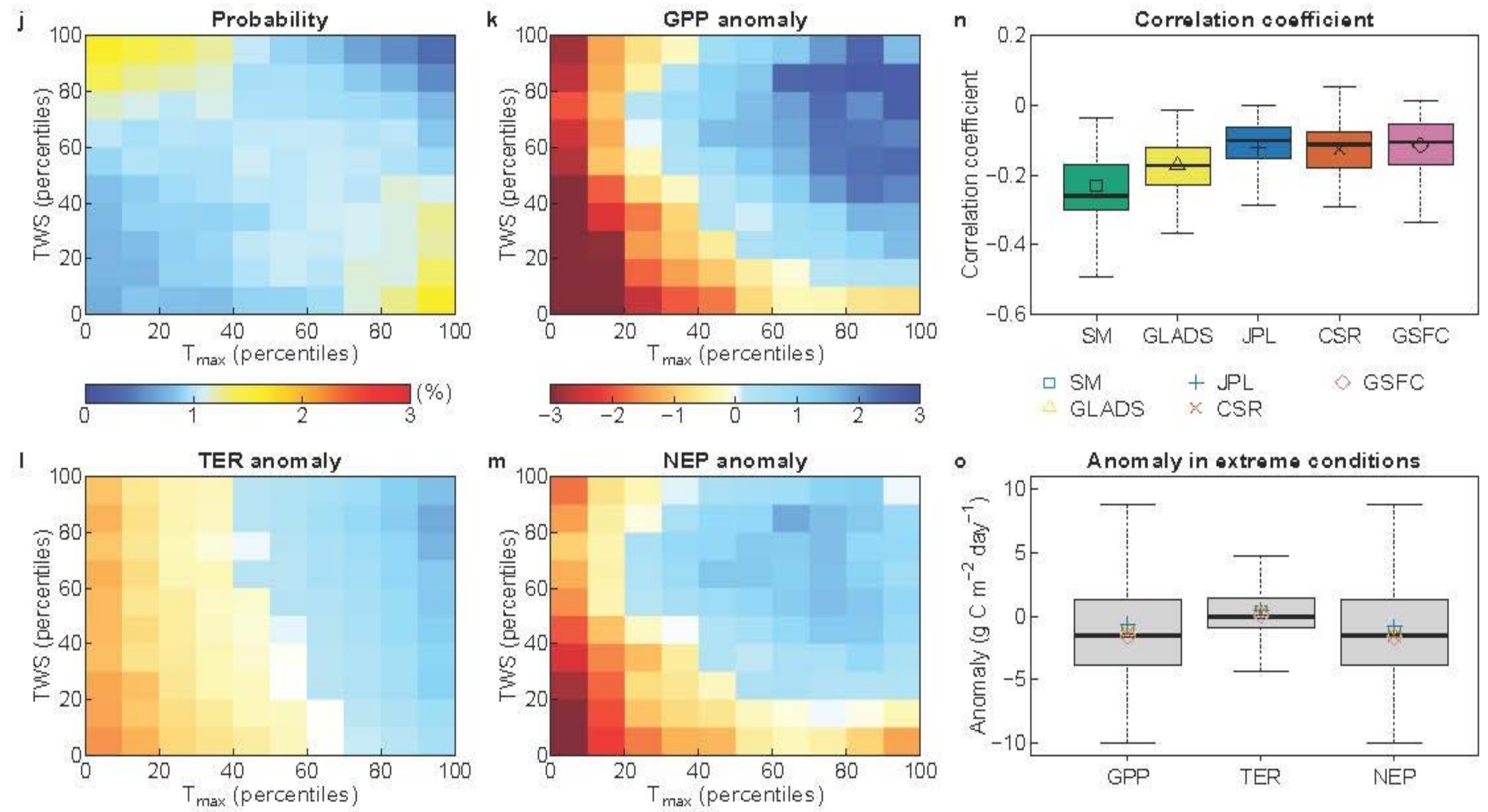
3 Water-heat coupling by vapor deficit and energy demand



- **Figure 1. Anomalies of composite water-heat flux variables in concurrent dry and heat extremes**. Anomalies of the variables are calculated as the difference between the daily values in extreme events and the mean daily values in the warm season in each grid cell. Insets in each figure show the histogram of these anomalies, with the dashed vertical line showing the median value. The concurring conditions are identified when extreme heat days occur during droughts (TWA-DSI< -0.8).

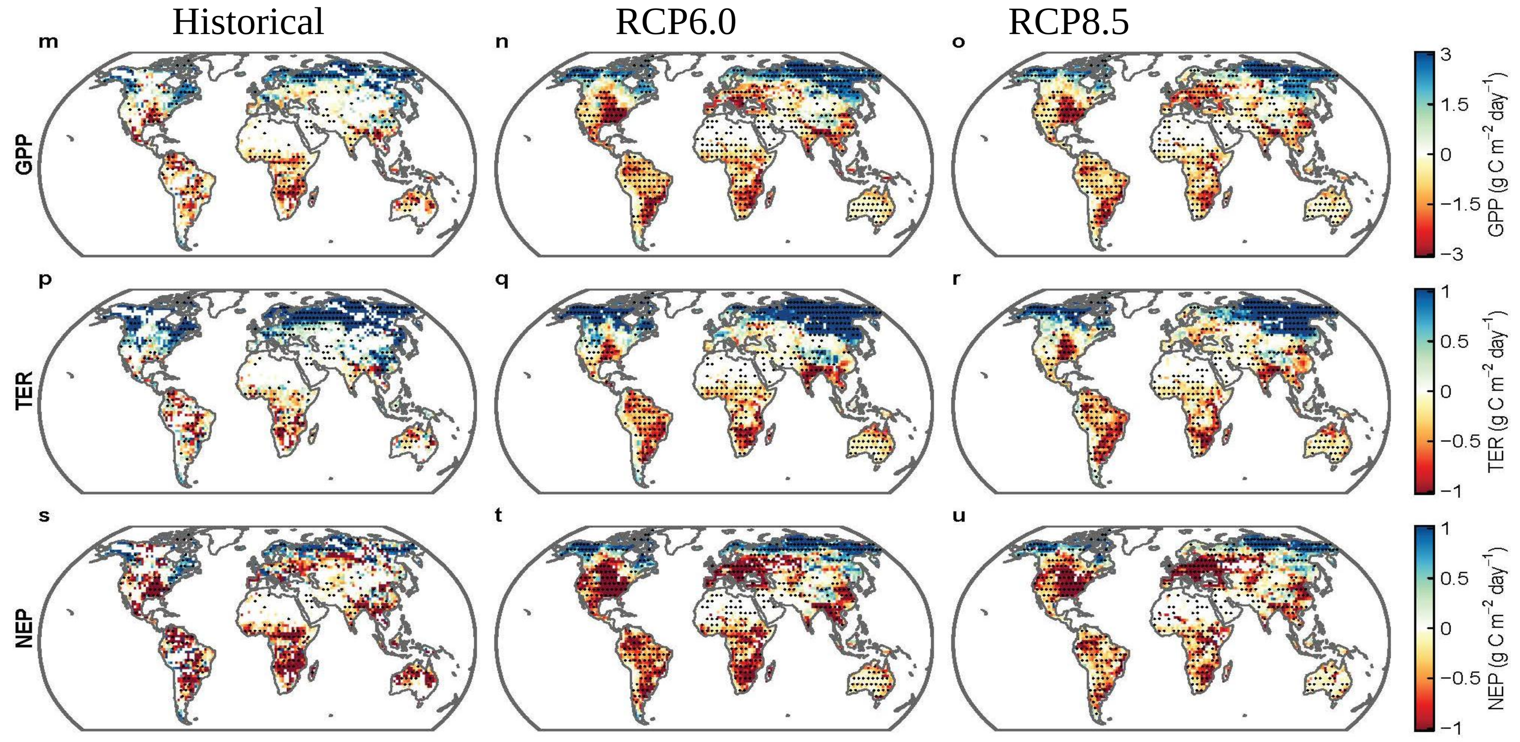
By combining satellite observations, field measurements and reanalysis, we show that terrestrial water storage and temperature are negatively coupled, likely driven by similar atmospheric conditions (e.g., water vapor deficit and energy demand).

4 Observed carbon constraint by climatic extremes



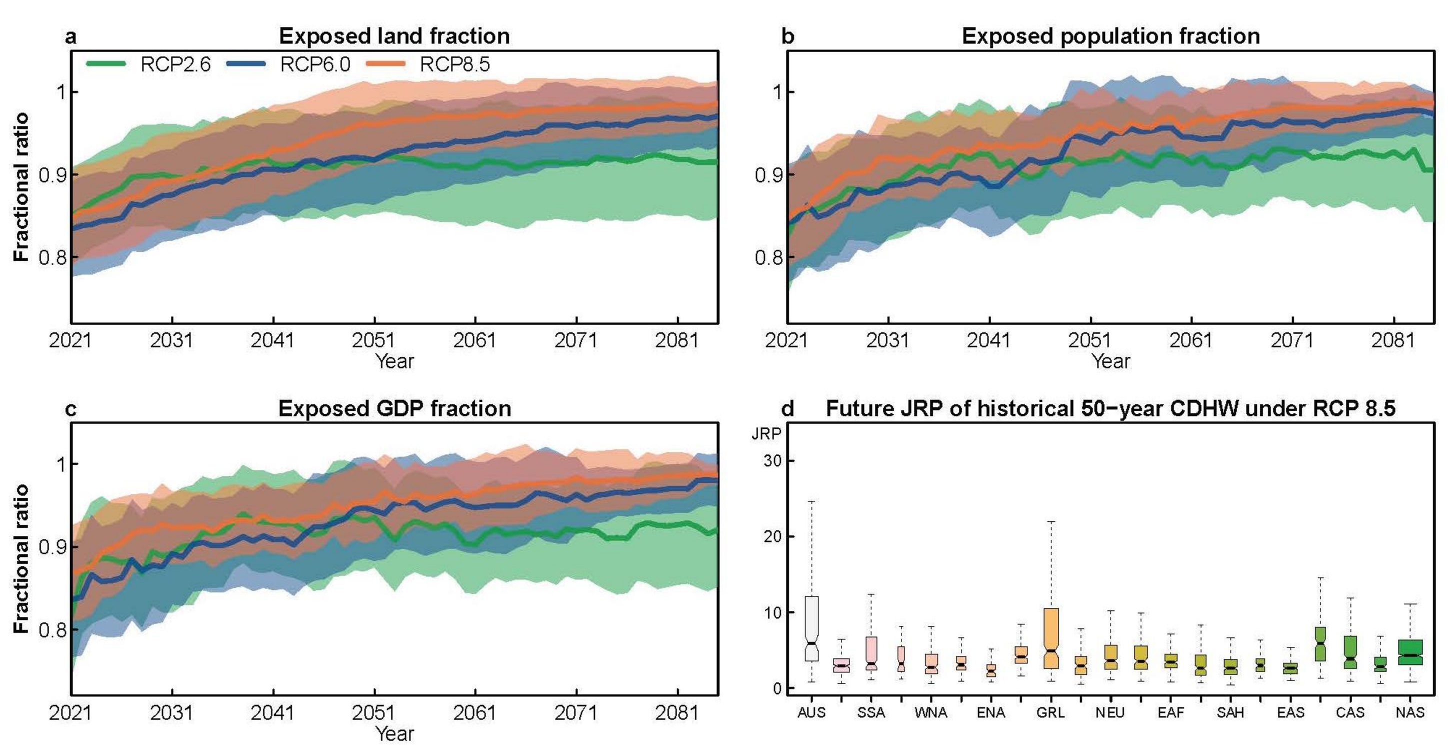
- **Figure 2. Anomalies of carbon variables during extreme climate extremes**. **j**, Mean probability of each percentile bin of T_{max} and daily GLADS TWS across 73 flux tower sites. **k-m**, Mean anomalies of GPP (**k**), TER (**l**), and NEP (**m**) for each percentile bin across 73 flux tower sites. **n**, Pearson's correlation coefficient between T_{max} and TWS (or SM). **o**, Anomalies of GPP, TER, and NEP above high T_{max} and dry TWS (or SM).

5 Future CDHW socio-ecosystem effects



- **Figure 3.** Using 111 climate-hydrology model members, the CDHWs are projected to increase by ten-fold globally under the highest emissions scenario, along with a disproportionate negative impact on vegetation and socioeconomic productivity by the late 21st century.

6 Future bivariate CDHW and uncertainty



- **Figure 4.** By late of the 21st century, more than 90% of the world's population and gross domestic product is projected to be exposed to increasing CDHW risks in a warmer future climate, even under the lowest-emission scenario.

7 Socioeconomic inequality due to climate change

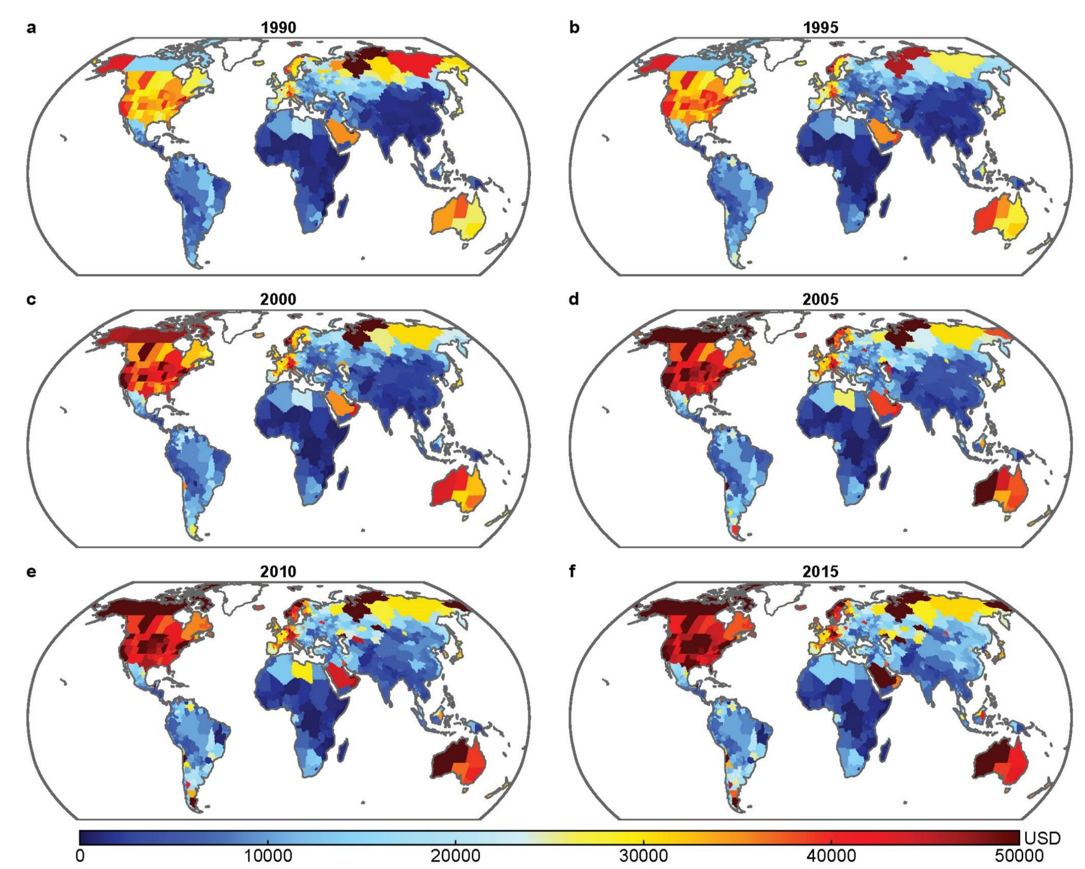


Figure 5. Gridded GDP per capita (purchasing power parity) in constant USD

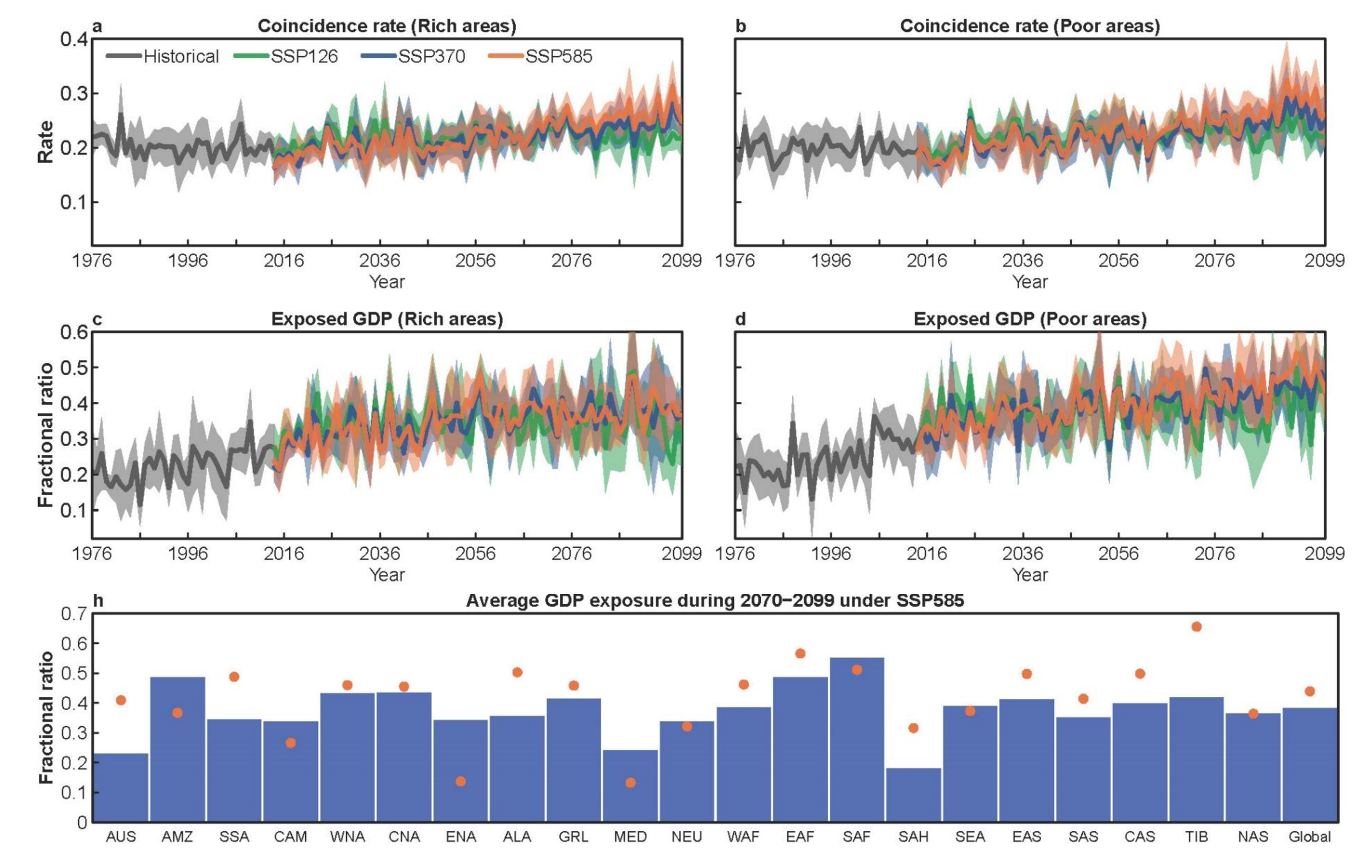


Figure 6. CDHWr and socioeconomic exposures in rich versus poor areas.