Helmholtz-Zentrum Geesthacht
Centre for Materials and Coastal Research

GERICS Climate Service Center Germany

Session ITS3.2/NH10.7
Climate Extremes, Tipping Dynamics, and Earth Resilience in the Anthropocene

Future compound climate extremes and exposed population in Africa

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Objectives

- How will the occurrence of coincident and sequential compound extremes in Africa change to the end of the century?
- What are the most affected regions with the highest total exposure to compound climate extremes?
- What compound climate extreme causes the highest change in total exposure?
- Which effect contributes at most to the change in total exposure?

Data and Methods

- Reference data: ERA5 (1981-2010), ISIMIP2b (1981-2005)
- Regional climate model data from CORDEX-CORE Africa ensemble (five members):
  - MPI-ESM-LR/REMO2015, HadGEM2-ES/REMO2015, NorESM1-M/REMO2015, HadGEM2-ES/RegCM4-7, NorESM1-M/RegCM4-7
  - Spatial resolution: 0.22°, temporal resolution: daily
  - Emission scenarios RCP2.6 and RCP8.5
  - Reference period: 1981-2010, scenario period: 2070-2099
- Socioeconomic projections: SSP1 and SSP3, spatial resolution: 5 arc-minutes (~0.083°), (Jones and O'Neil, 2016, 2017)
- Indices:
  - *Heat waves* (three or more consecutive days with a temperature above the 95th percentile of the daily maximum temperature of the reference period, but at least above 25°C)
  - *Droughts* (five or more consecutive days with a daily precipitation less than 1 mm)
  - *Extreme precipitation* (precipitation above the 95th percentile of precipitation on wet days (>= 1 mm) of the reference period)
- Two kinds of compound events were analyzed:
  - *Coincident occurrence* (takes place when two different climate extremes overlap one or more days)
  - *Sequential occurrence* (starts within seven days after the termination of a precedent extreme event)

Data and Methods

Total change exposure ΔE defined by Liu et al. (2017):

$$\Delta E = P_R \times \Delta C + C_R \times \Delta P + \Delta C \times \Delta P$$

climate effect population effect interaction effect

$P_R -$ population in the reference period

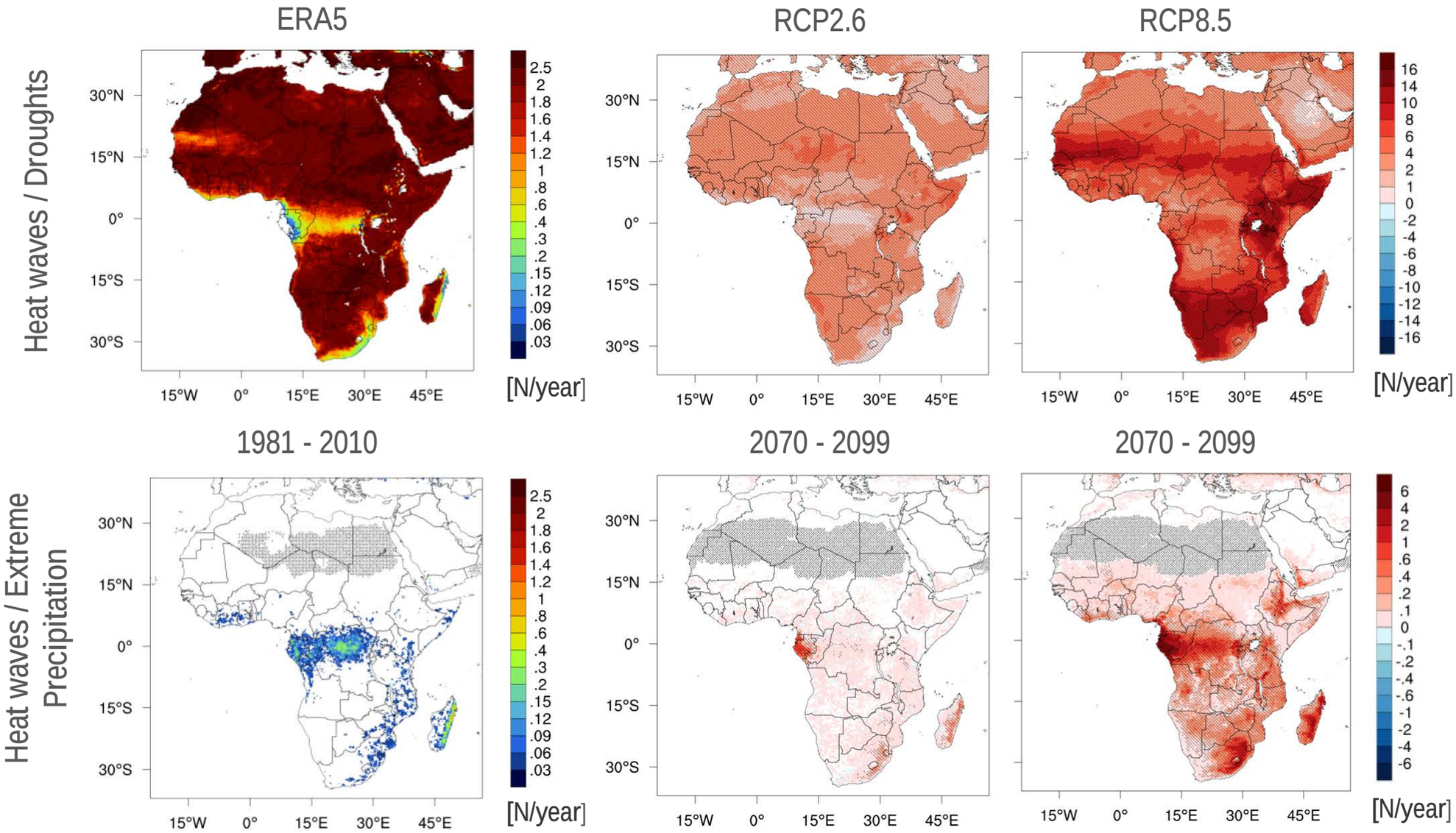
$C_R -$ climate in the reference period

$\Delta C -$ climate change in the scenario period

$\Delta P -$ population change in the scenario period

The climate effect describes the influence of climate exposure and the population effect measures the influence of the population exposure. The interaction effect considers the combined impact of climate change and population change, i.e. how many more (less) compound climate extremes will affect more (less) population in the future.

Number of Coincident Events



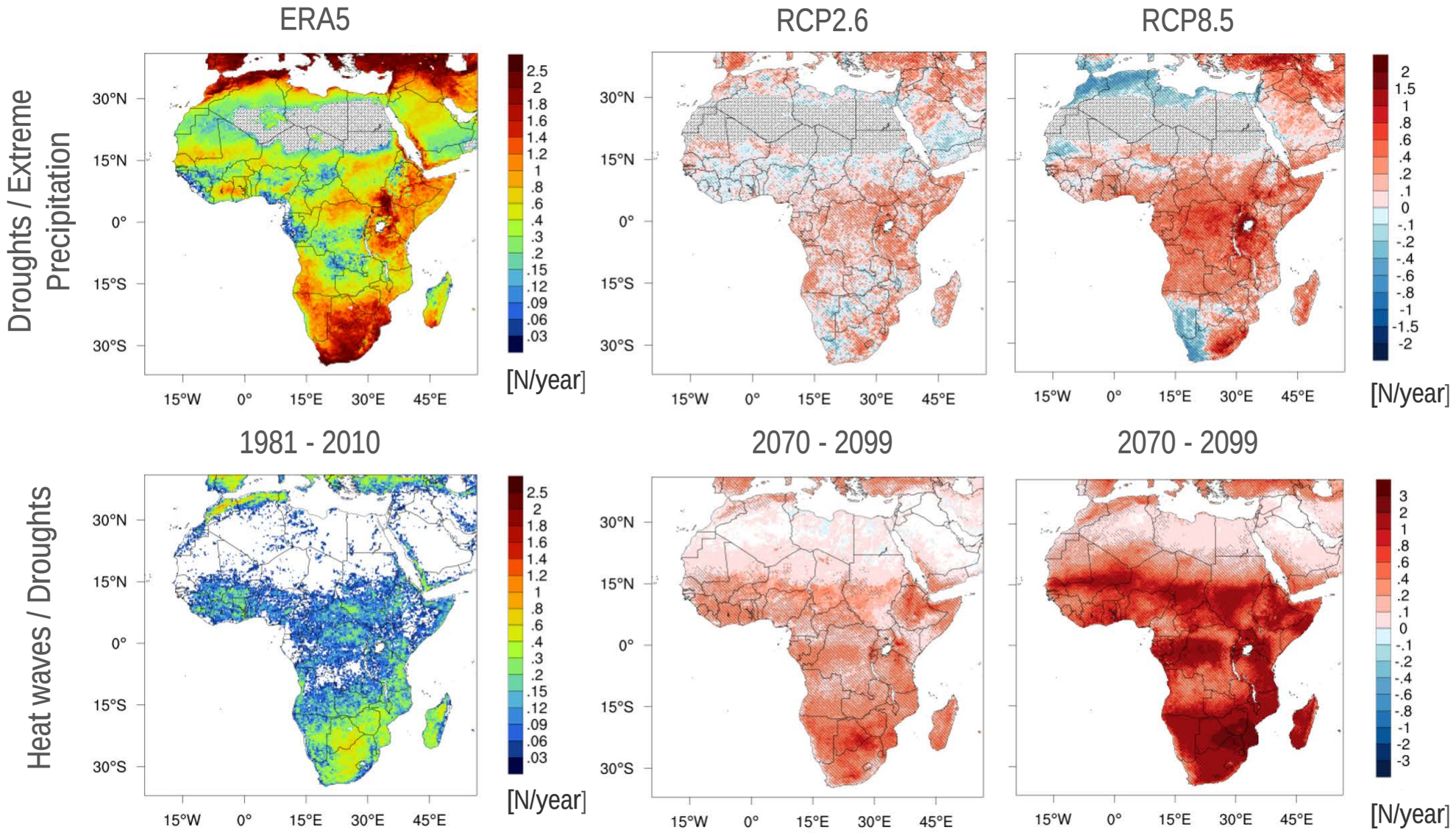
Mean annual coincident climate extremes were calculated from the ERA5 data set for the reference period 1981-2010.

Projected changes of annual coincident climate extremes were calculated as ensemble mean using RCP2.6 and RCP8.5 for the scenario period 2070-2099/1981- 2010.

The dotted areas show not sufficient (n <100) wet days in 30 years to determine the 95th percentile precipitation. The hatched areas indicate a high model agreement (n >= 4) of the sign of the climate change signal.

(Weber et al., submitted to Earth's Future)

Number of Sequential Events



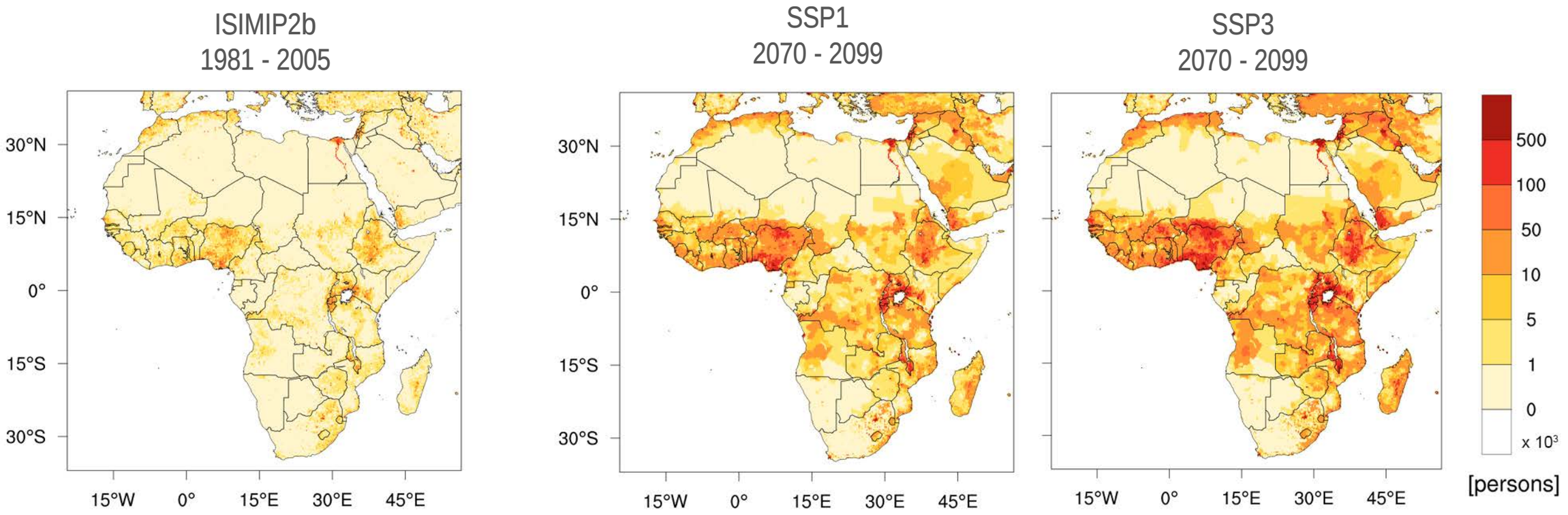
Mean annual sequential climate extremes were calculated from the ERA5 data set for the reference period 1981-2010.

Projected changes of annual sequential climate extremes were calculated as ensemble mean using RCP2.6 and RCP8.5 for the scenario period 2070-2099/1981-2010.

The dotted areas show not sufficient (n <100) wet days in 30 years to determine the 95th percentile precipitation. The hatched areas indicate a high model agreement (n >= 4) of the sign of the climate change signal.

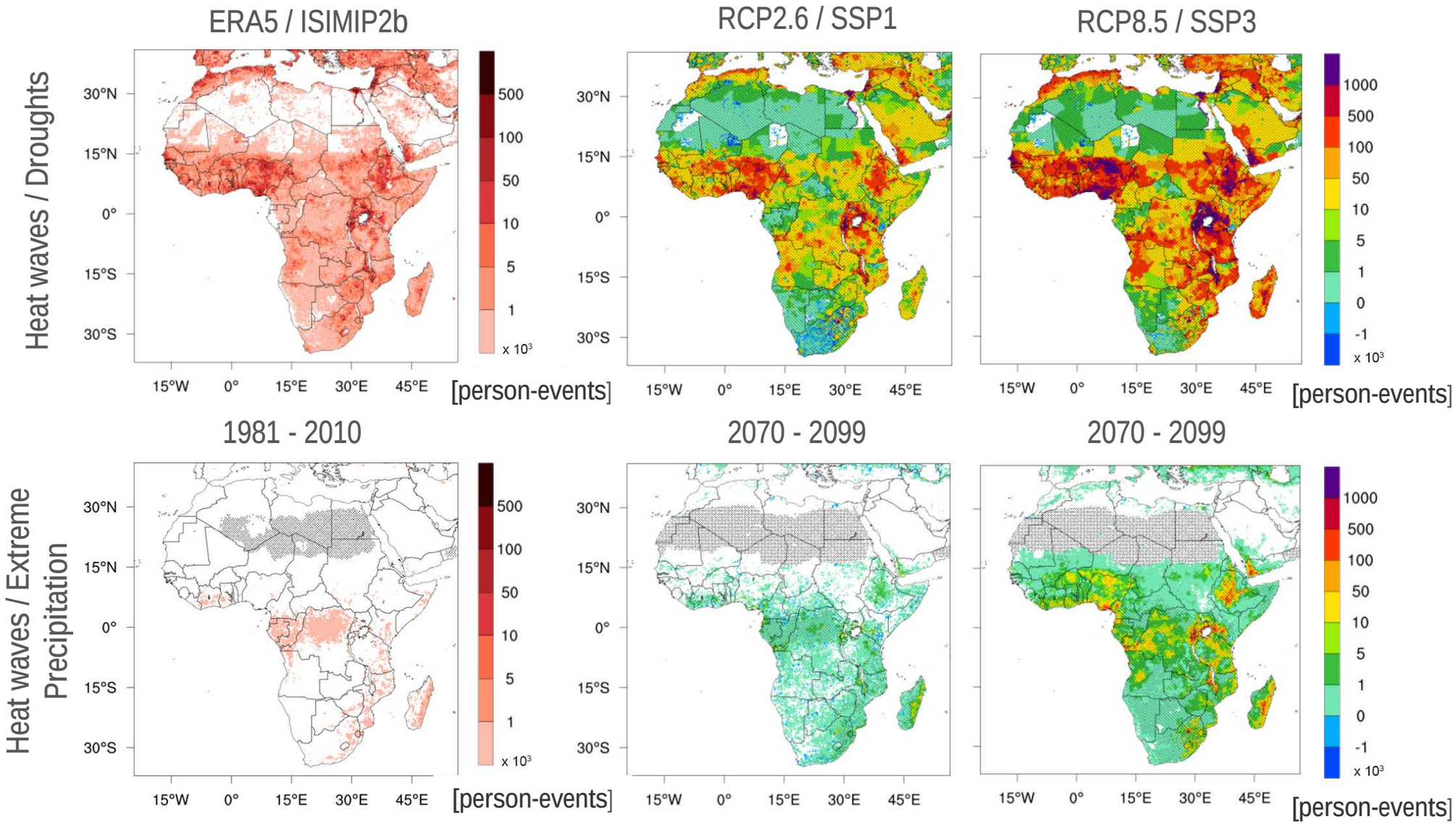
(Weber et al., submitted to Earth's Future)

African Population Growth



(Weber et al., submitted to Earth's Future)

Total Exposure of Coincident Events



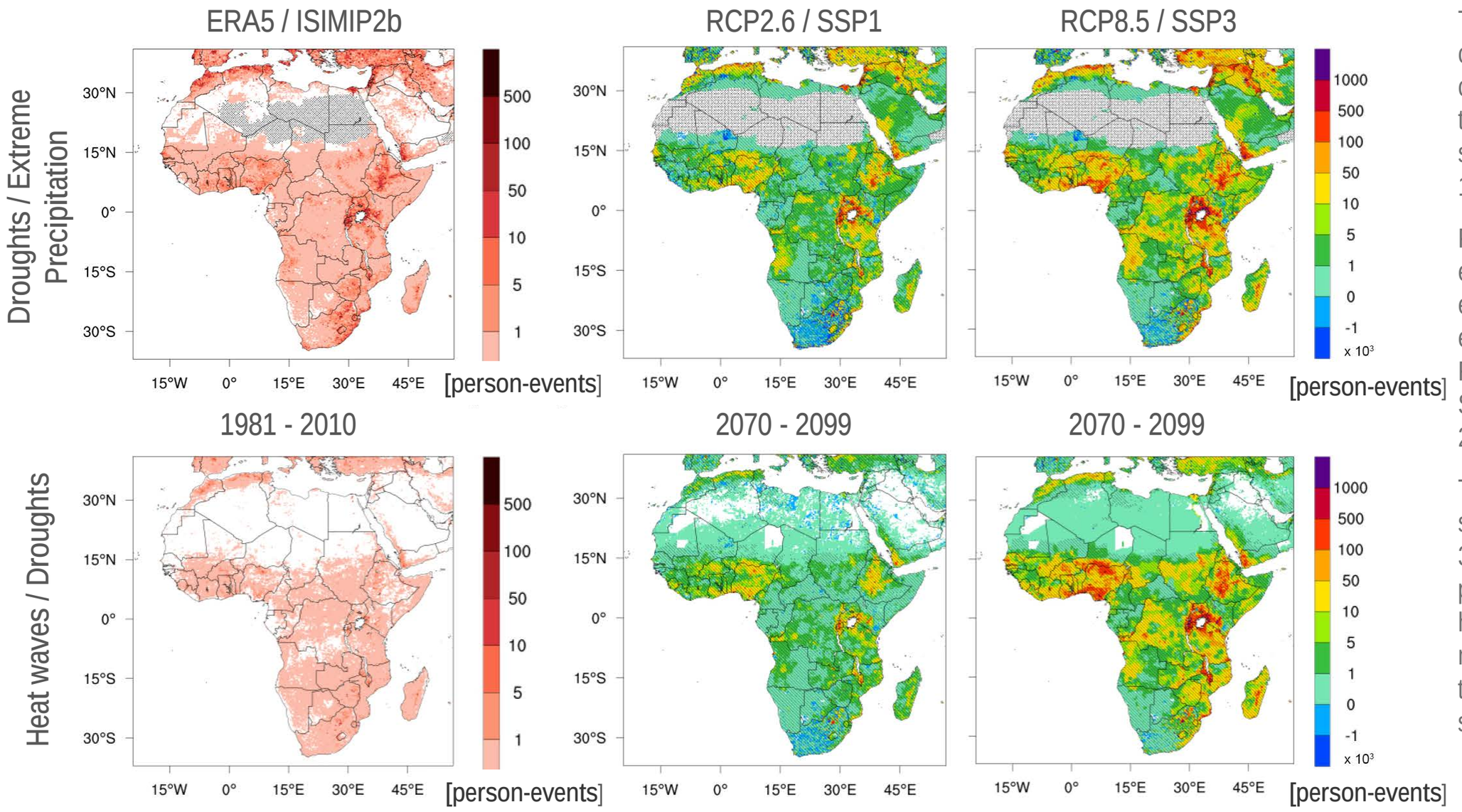
Total exposure of coincident climate extremes were calculated from the ERA5 and the ISIMIP2b population data set for the reference period 1981-2010.

Projected changes in total exposure coincident climate extremes were calculated as ensemble mean using RCP2.6/SSP1 and RCP8.5/ SSP3 for the scenario period 2070-2090/1981-2010.

The dotted areas show not sufficient (n <100) wet days in 30 years to determine the 95th percentile precipitation. The hatched areas indicate a high model agreement (n >= 4) of the sign of the climate change signal.

(Weber et al., submitted to Earth's Future)

Total Exposure of Sequential Events



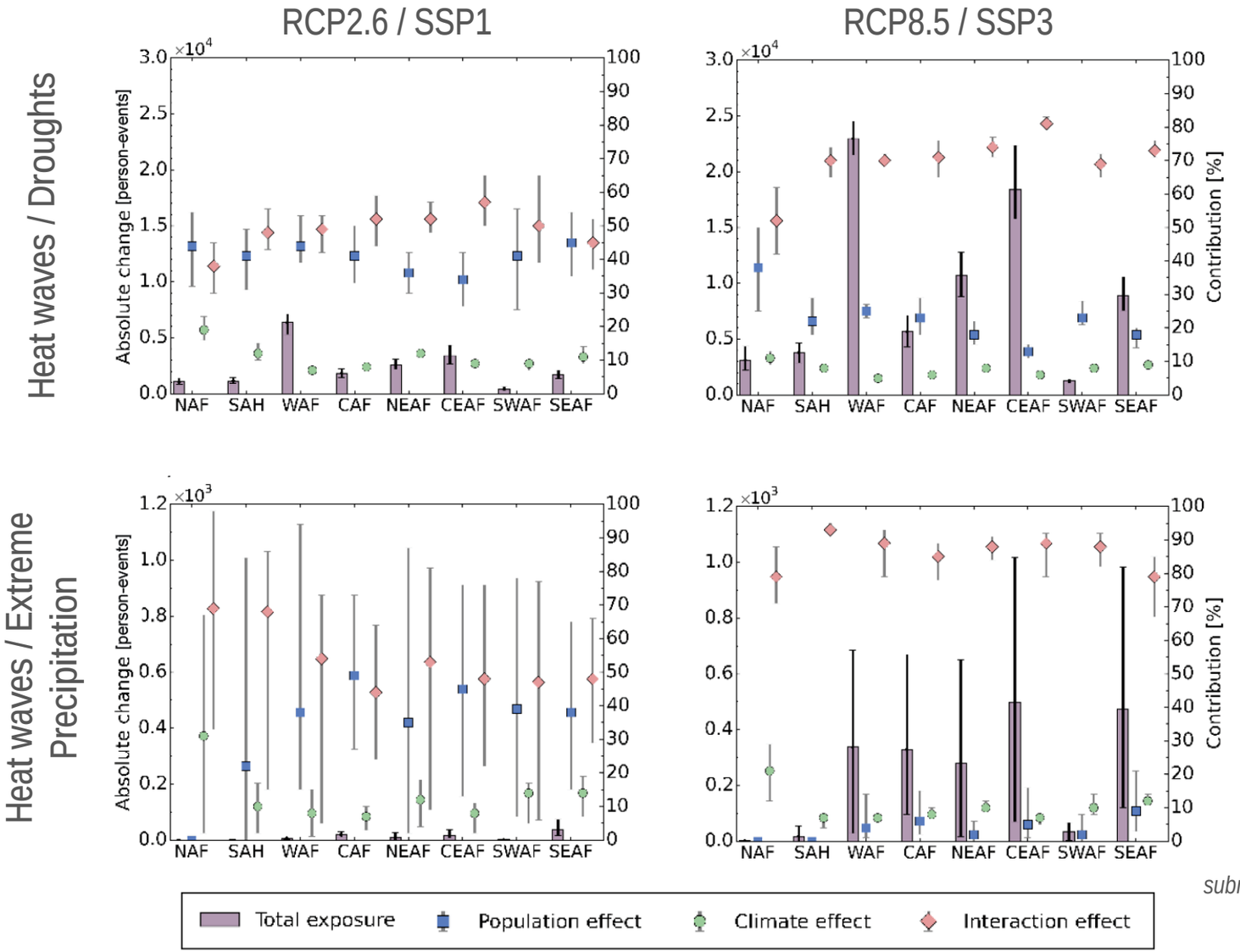
Total exposure of sequential climate extremes were calculated from the ERA5 and the ISIMIP2b population data set for the reference period 1981-2010.

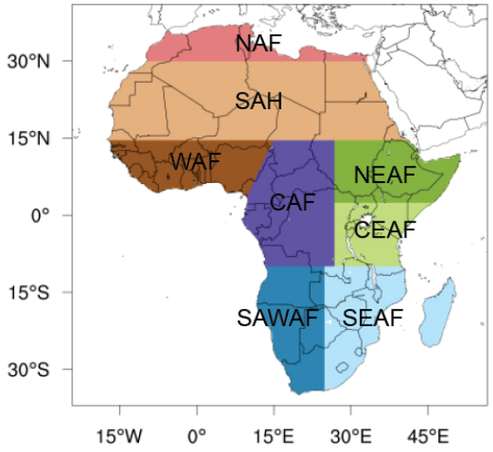
Projected changes in total exposure sequential climate extremes were calculated as ensemble mean using RCP2.6/SSP1 and RCP8.5/ SSP3 for the scenario period 2070-2090/1981-2010.

The dotted areas show not sufficient (n <100) wet days in 30 years to determine the 95th percentile precipitation. The hatched areas indicate a high model agreement (n >= 4) of the sign of the climate change signal.

(Weber et al., submitted to Earth's Future)

Total Exposure Change of Coincident Events





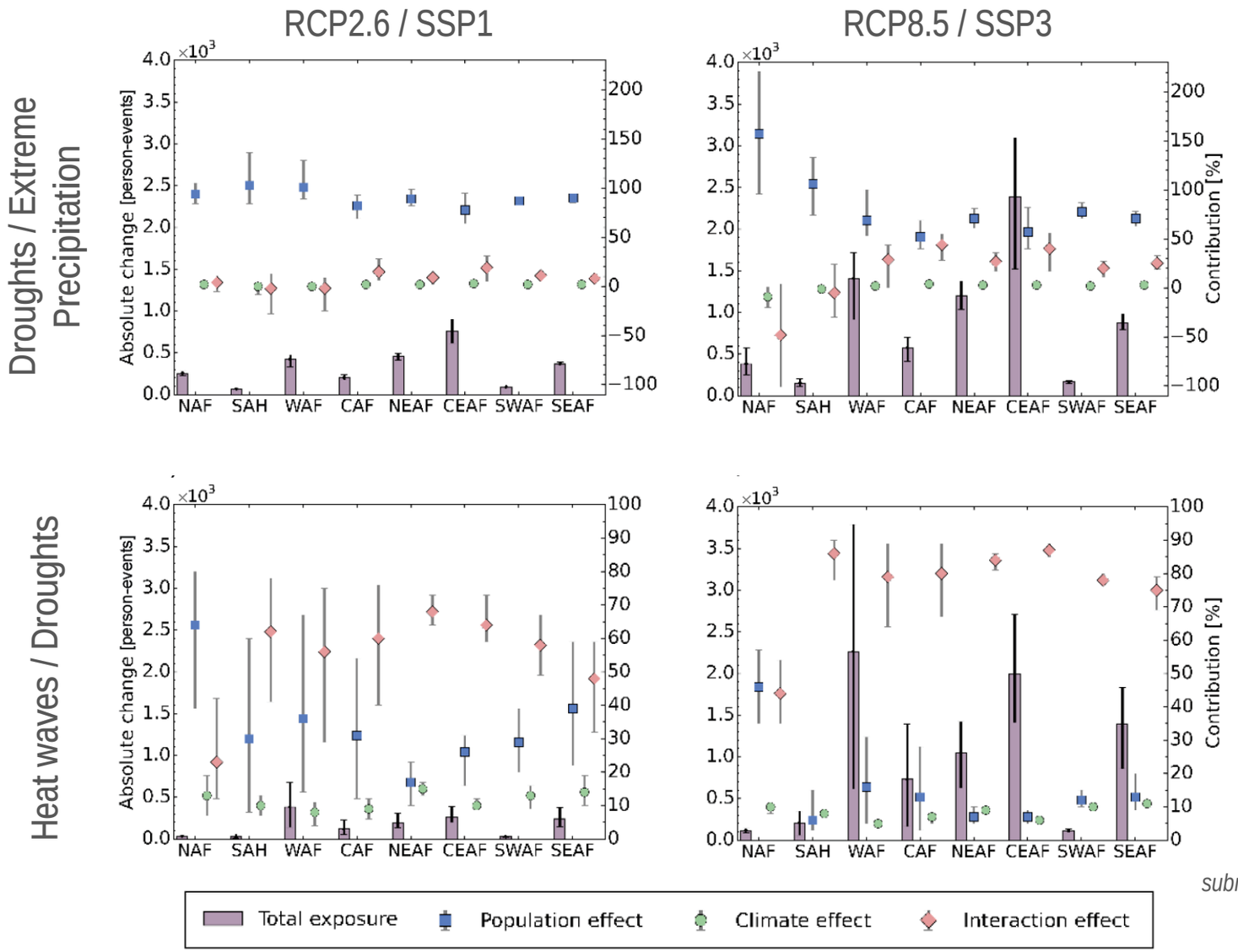
(Weber et al., submitted to Earth's Future)

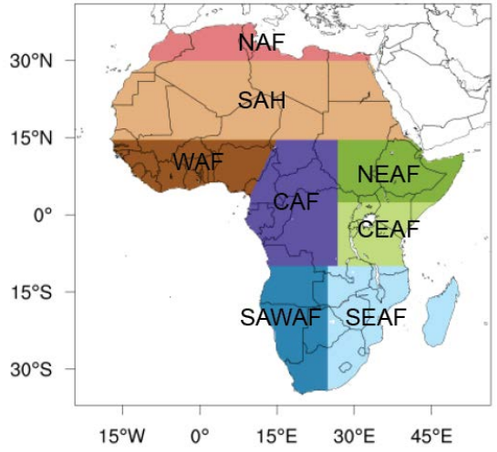
The field average of total exposure change of coincident climate extremes is depicted for different African sub-regions (bars, left axis) and the relative contribution of the population, climate and interaction effect of the total exposure change (marker, right axis).

The left column shows the RCP2.6/SSP1 and the right column RCP8.5/SSP3 for scenario period 2070-2099/1981-2010.

Bandwidths showing the ensemble minimum and maximum are denoted by error bars.

Total Exposure Change of Sequential Events





(Weber et al., submitted to Earth's Future)

The field average of total exposure change of sequential climate extremes is depicted for different African sub-regions (bars, left axis) and the relative contribution of the population, climate and interaction effect of the total exposure change (marker, right axis).

The left column shows the RCP2.6/SSP1 and the right column RCP8.5/SSP3 for scenario period 2070-2099/1981-2010.

Bandwidths showing the ensemble minimum and maximum are denoted by error bars.

Conclusions

- Projections show a small increase under the low emission scenario (RCP2.6), but a distinct increase under the high emission scenario (RCP8.5) for most coincident and sequential compound extremes in sub-Saharan Africa for the end of the century.
- In general, the total exposure change is higher in RCP8.5/SSP3 than in the RCP2.6/SSP1 scenario.
- Most affected regions with the highest total exposure to compound climate extremes are mainly West Africa (WAF), Central-East Africa (CEAF) and South-East Africa (SEAF).
- Simultaneous appearance of heat waves and droughts produces the highest change in total exposure of all analyzed compound events.
- Major contribution to total exposure change comes from the combined impacts (interaction effect) of African population growth and increase in frequencies of compound climate extreme events.
- For coincident heat waves and extreme precipitation as well as for sequential heat waves and droughts, projections produce high uncertainties (broad bandwidths) in the absolute total exposure change and/or the relative contribution effects.