Enhanced future changes in African humid heatwaves at the convective scale

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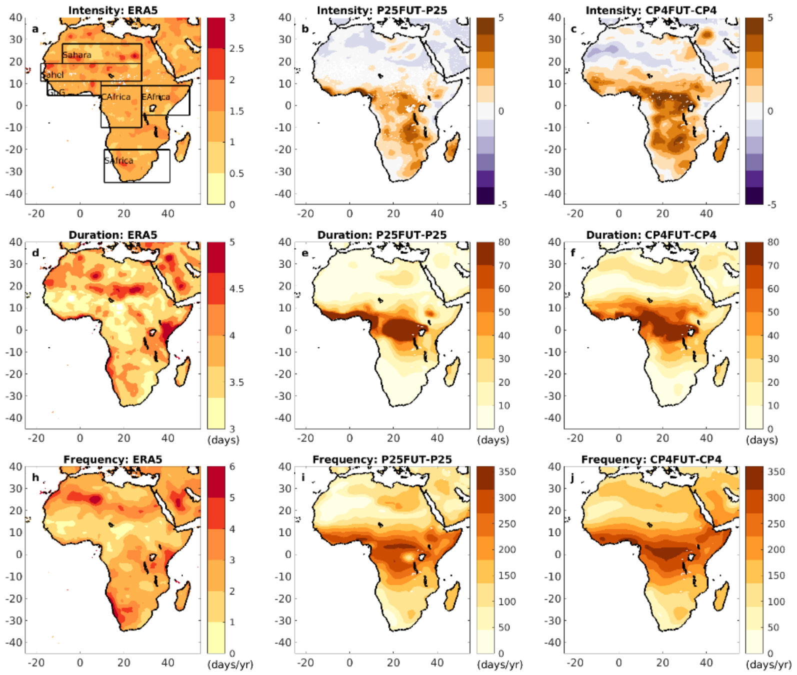

Figure 1 | Present day and future change in wet-bulb heatwave metrics. Present-day heatwaves in ERA5 (left) and the future change in P25 (middle) and CP4 (right).

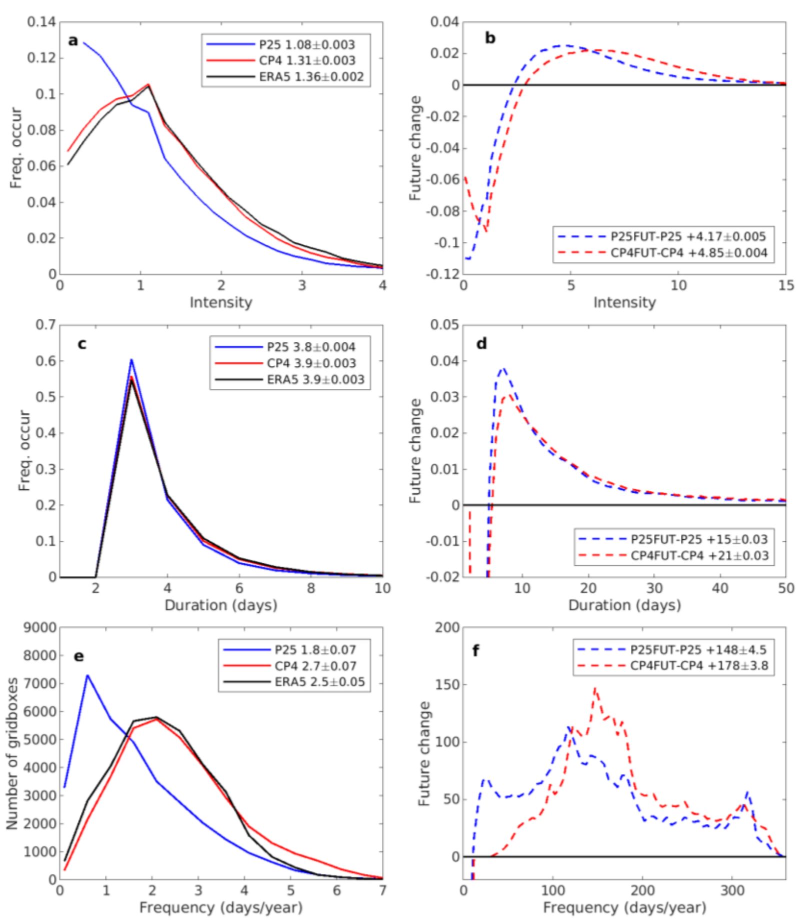

Figure 2 | Pan-African wet-bulb heatwave metrics. a,c,e, Present day metrics for ERA5, P25 and CP4. **b,d,f,** Future change in metrics in P25 and CP4. The numbers in the legends represent the mean and standard error of each distribution.

Background

- Mean temperatures and their extremes have increased over Africa since the mid-20th century and this trend is projected to continue
- Human heat stress is dependent on both temperature and humidity
- It is crucial that we understand the scale of the future increases in humid heatwaves, the driving mechanisms and the ability of climate models to represent them

Future change in humid heatwaves

- Large increases in intensity, length and frequency are projected by 2100 (Fig. 1)
- Frequency increases from 2 or 3 heatwave days per year to more than 145
- Hotspot of future change over central Africa, where frequency is up to 360
- CP4 present-day heatwaves are closer to ERA5 and it projects larger changes in all 3 metrics than P25 (Fig. 2)

Heatwave drivers

- The main drivers of humid heatwaves are increased moisture, cloud, evaporation and longwave heating (Fig. 4)
- In the observations, heatwaves occur on wet days (>1mm/day) 32% of the time, compared to wet days occurring climatologically 24% of the time (Table 1)
- In CP4 and P25, heatwaves occur on wet days 35% and 56% of the time respectively (i.e. there is a bias in P25 compared to observations)
- In the future, a larger fraction of heatwaves are associated with rainy days
- The future change in the main heatwave drivers is larger in CP4 (Fig. 4)

	ERA5	CP4	CP4FUT	P25	P25FUT
Dry <1 mm/day	**68** (76)	**65** (84)	**60** (86)	**44** (67)	**41** (66)
Wet >1 mm/day	**32** (24)	**35** (16)	**40** (14)	**56** (33)	**59** (24)

Table 1 | Percentage of heatwave events associated with wet and dry days. The climatological distributions of the rainfall categories, weighted for the months and locations in which the heatwaves occur, are in brackets.

Conclusions

- The convective-scale model produces more extreme and frequent future humid heatwaves, with larger anomalies in the main heatwave drivers of humidity, longwave heating and evaporation
- Parameterised-convection climate models (e.g. CMIP6) may underestimate humid heatwaves due to known biases in their representation of convective rainfall
- It's critical to use a representative diurnal cycle of specific humidity when computing T_{wbmax}, rather than the daily mean, as this has a large impact on the computed value of T_{wbmax} and the heatwave metrics (not shown). Most previous studies use daily mean humidity to compute T_{wbmax}.

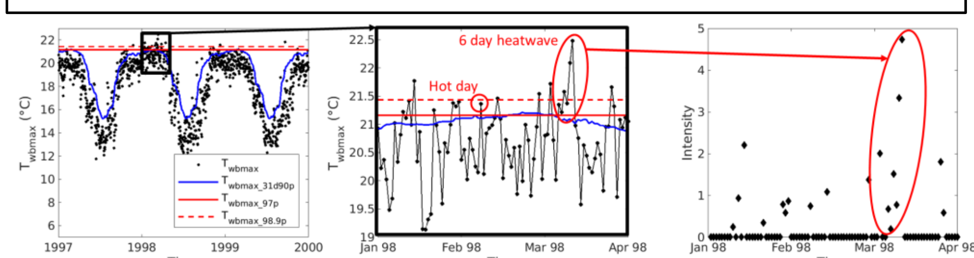

Figure 4 | Heatwave identification method for one arbitrary gridbox in CP4. The middle and right panels are zoomed in views of the left. The dots in the right panel show the unit-less intensity on each identified hot day.

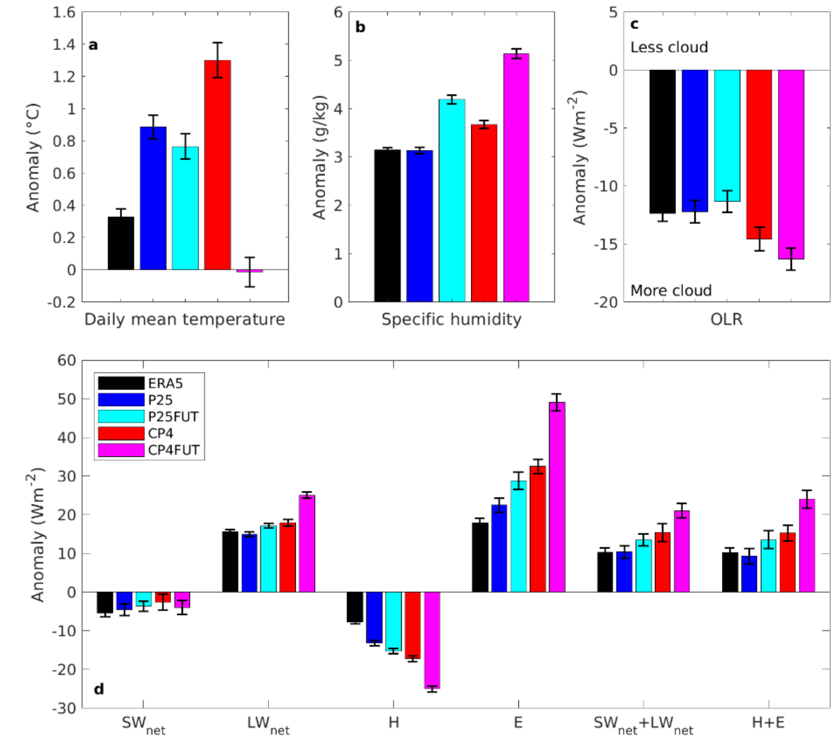

Figure 4 | Anomalies relative to climatology of key variables during wet-bulb heatwaves. All variables are averaged over the first 3 days of each heatwave and are presented as anomalies from the climatology at the relevant time of year. All variables are at the (near-)surface apart from Outgoing Longwave Radiation (OLR).

Data and methods

- 10-year pan-Africa climate simulations for present day and 2100@RCP8.5:
  - Convective-scale model (CP4,CP4FUT)
  - Parameterised convection model (P25, P25FUT)
- ERA5+GPM rainfall observations for comparison
- Humid heatwaves based on daily maximum wet-bulb temperature (T_{wbmax})
- Gridbox by gridbox percentile-based approach, where heatwaves are defined as 3+ consecutive 'hot days' (Fig. 4)
- Three metrics analysed:
  - Intensity (unit-less, based on distance above 97th percentile of T_{wbmax})
  - Duration (in days)
  - Frequency (number heatwave days per year)
  - Allows direct comparison of different African climates and models with differing mean temperature and humidity climatologies

FUTURE CLIMATE FOR AFRICA

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