More perceived but not faster evolution of heat stress than temperature extremes in the future

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◊ **<u>What we do know</u> :**

- Global warming observed and projected until 2100 according to CMIP5 models (*Collins et al., 2013*) ;

- Associated hot extremes have increased and will increase in the future (e.g. *Horton et al., 2016*)

- The heat stress, defined as the combined effect of temperature and humidity of the human body (e.g *Kjellström et al., 2009*), will increase along with temperature but with different behaviours due to humidity changes (e.g. *Fischer and Knutti, 2013 ; Coffel et al., 2019 ; Brouillet and Joussaume, 2019*)

◊ **<u>What we want to know</u> :**

How global warming of heat extremes could be perceived by populations in the future ?

<u>Corresponding paper</u> : Brouillet A. and Joussaume S. (2020). More perceived but not faster heat stress evolution than temperature extremes in the future. Climatic Change (in revision)

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◊ **Selected indicators to investigate how climate change could be perceived** independently from physiological and psychological factors

→ A set of 12 Earth System Models is selected from CMIP5 projections to conduct climate data analyses from 1959 to 2100 (future scenarios : RCP8.5 and RCP2.6).

(1) Extremes are intuitively closer of what people feels of the climate than annual and seasonal means → **we analyse annual hot extremes** (defined as higher than annual 99th percentile) ;

(2) The heat stress can be considered as a “feels-like” indicator due to its definition and used → **we analyse the simplified Wet-Bulb Globe Temperature* (WBGT)**, a well-known heat stress index ;

(3) The climate change is analysed for each year as the difference between the last 20-years and the upcoming 20-y → **we quantify the speed of change with moving baselines** ;

(4) Yearly speeds are compared to each recent 20-y interannual variability to characterize how upcoming change will emerge from what people just experienced → **we compare speeds of change with the standard deviation of the last 20-y annual extremes.**

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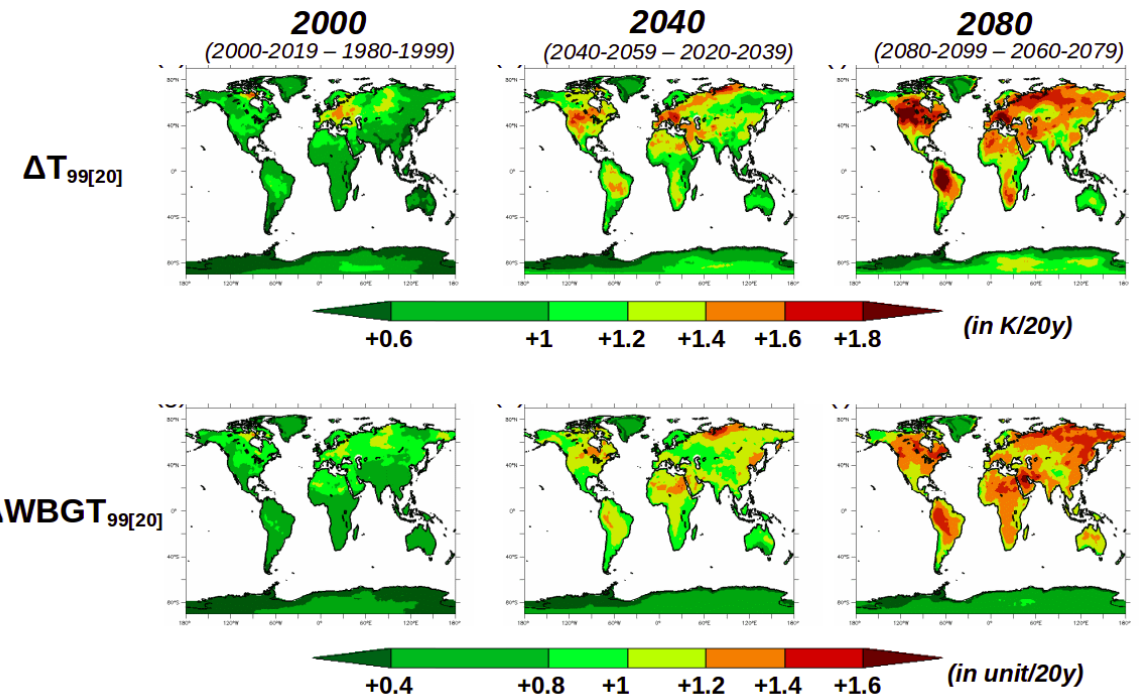
◊ **Results** :

=> Intensifications of both extremes of temperature (T_{99}) and WBGT ($WBGT_{99}$) accelerate in the future (RCP8.5).



* Fastest warming of T_{99} in Europe during early 2000s, but all over mid-continental regions in 2080.

* Different patterns for $WBGT_{99}$. Fastest speed of increase in the northern hemisphere in 2000 and in Amazonia, Sahel to Arabia region and north-eastern Asia in 2080.

For a year t, the speed of change is calculated as :

$$\Delta X(t) = \langle X \rangle_{t+1,t+20} - \langle X \rangle_{t-20,t-19}$$

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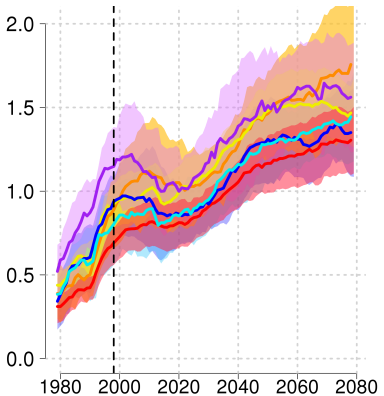
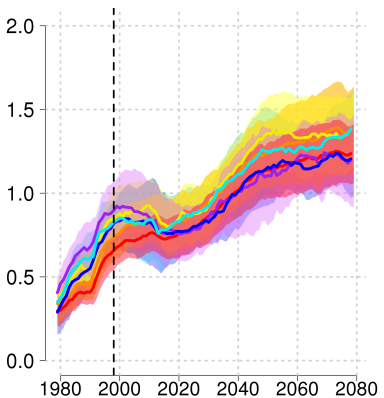
◊ **Results** :

=> Regional means between 1979 and 2100 confirm patterns of running speeds.

$\Delta T_{99[20]}$
(in K/20y)



$\Delta WBGT_{99[20]}$
(in unit/20y)



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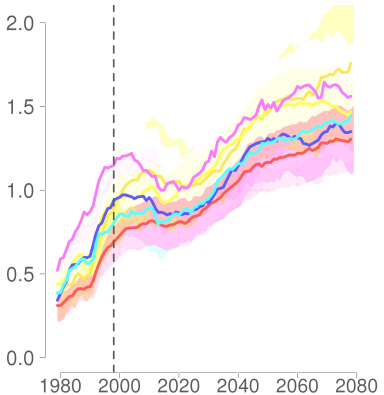
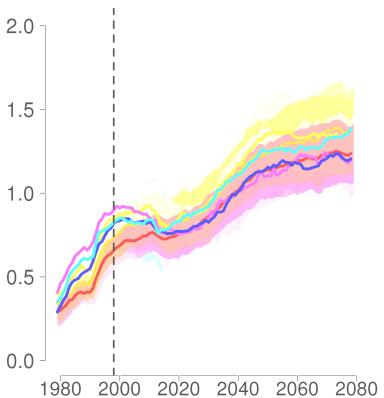
◊ **Results** :

=> **However**, both speeds cannot be compared due to different unit systems nor true physical quantity for WBGT. So :

$\Delta T_{99[20]}$
(in K/20y)

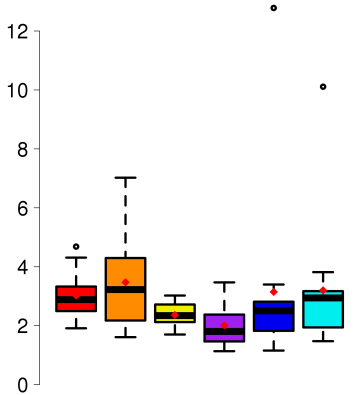


$\Delta WBGT_{99[20]}$
(in unit/20y)

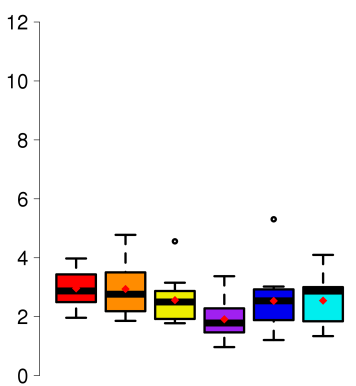


We normalize yearly ΔT_{99} and $\Delta WBGT_{99}$ with their speeds averaged over 1979-1998 to characterize accelerations (i.e. $R_{\Delta X}$) :

$R_{\Delta T99}$ in 2080



$R_{\Delta WBGT99}$ in 2080



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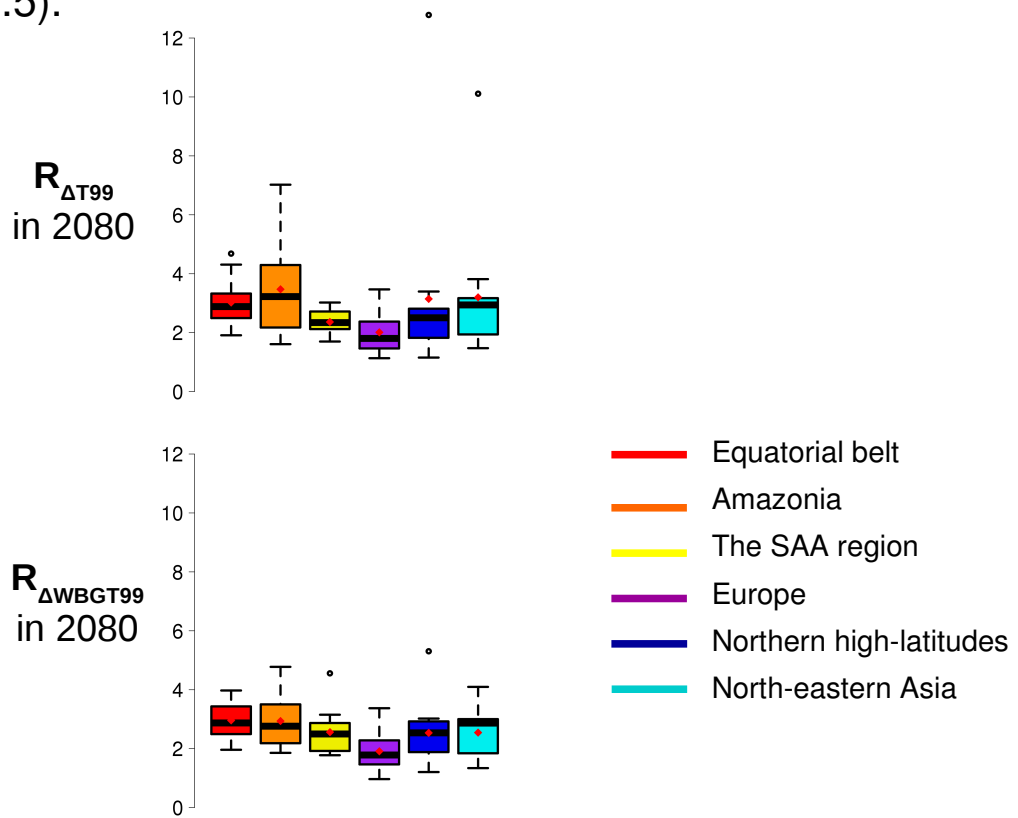
◊ **Results** :

=> The corresponding accelerations of running intensifications are very similar between T_{99} and $WBGT_{99}$ region per region (RCP8.5).

* Despite the fastest ΔT_{99} in Europe in 2080, the slowest acceleration is projected in this region in 2080. The largest acceleration is projected in the tropics.

* Accelerations are very similar between T_{99} and $WBGT_{99}$ intensifications. This stands in contrast with the expected faster heat stress increase due to Clausius-Clapeyron relation.



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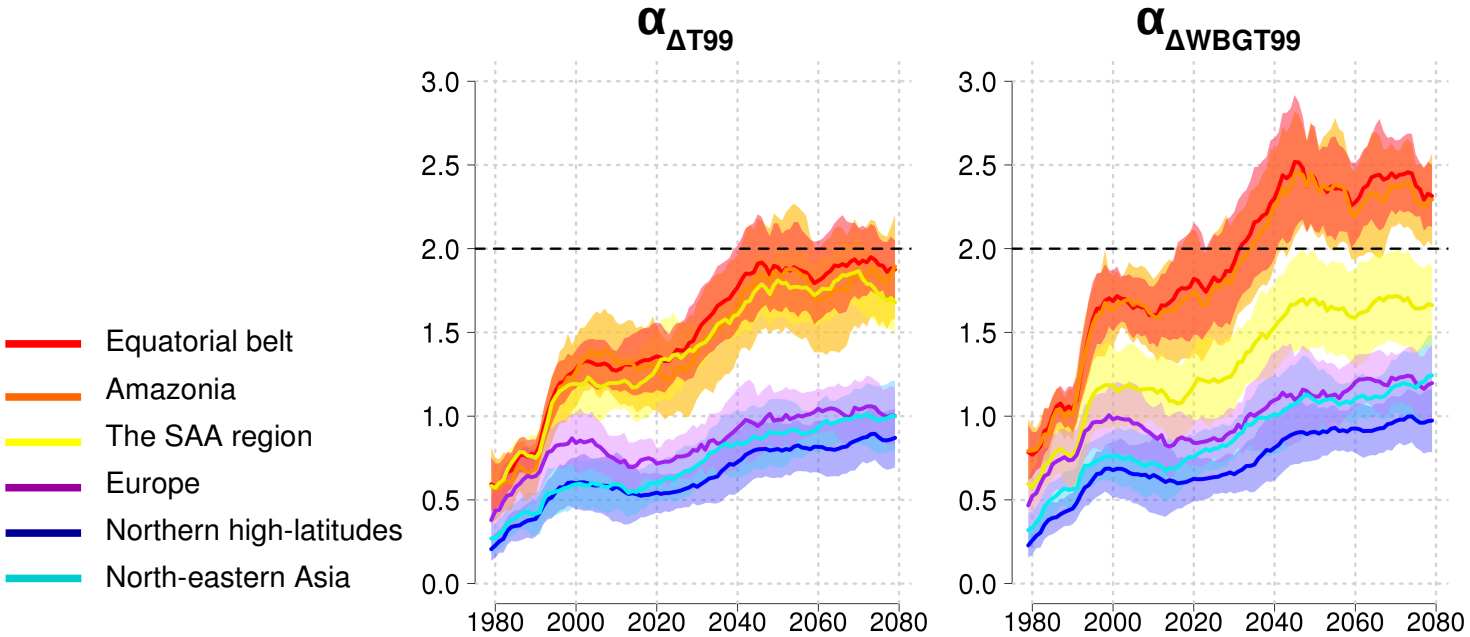
◊ **Results** :

=> Normalized speeds with each recent 20-y interannual variability (i.e. $\alpha_{\Delta x}$) show a more emergent $WBGT_{99}$ intensification than T_{99} between 1979 and 2100 for all latitudes but particularly in the tropics (RCP8.5).



* $\alpha_{\Delta WBGT99}$ will be stronger than $\alpha_{\Delta T99}$ for all regions until 2080. Upcoming changes will be more and more emergent from what people just experienced, especially in $WBGT_{99}$ compared to T_{99}.

* Tropics will experience larger $\alpha_{\Delta X}$ than mid-latitudes, exhibiting more emergent upcoming intensifications of extremes in these regions, despite the larger warming projected in northern mid- and high-latitudes.

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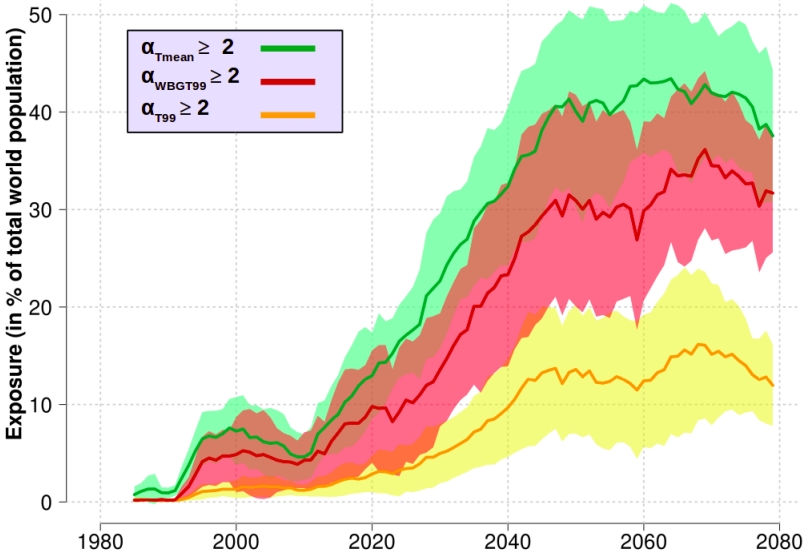
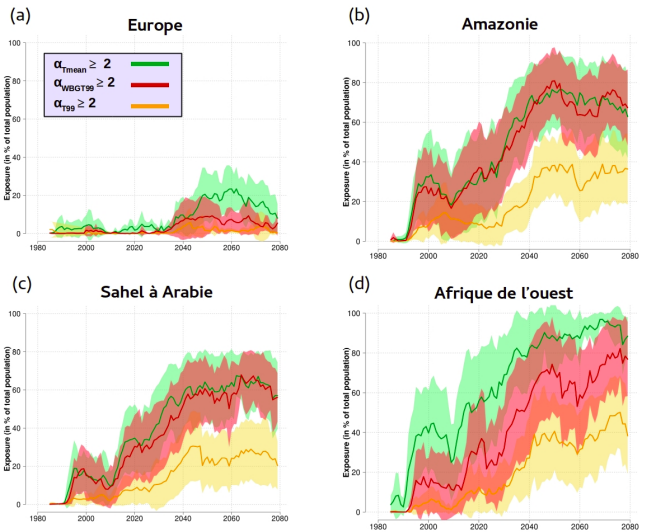
◊ **Results** :

=> More than 30% of the global world population will experience a $WBGT_{99}$ change at least twice larger than the recent interannual variability (less than 15% of the population for T_{99}). For Amazonia and western-equatorial Africa, exposures will be larger than 80% in $WBGT_{99}$.



*Exposure of **world population** (in %) for α > 2 (i.e. speed of change larger than twice the last 20-y interannual variability)*

*Exposure of **regional populations** (in %) for α > 2*



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◊ Conclusions

=> Intensifications of both temperature and WBGT extremes accelerate in the future (RCP8.5). Nevertheless, corresponding accelerations are very similar between both heat extremes intensifications region per region (for RCP8.5) ;

=> Normalized speeds with each recent 20-y interannual variability show more emergent $WBGT_{99}$ increases in the future than in T_{99}, particularly in the tropics (for RCP8.5, confirmed under the RCP2.6 scenario).

=> More than 30% of the global world population will experience a $WBGT_{99}$ change at least twice larger than the just experienced interannual variability (less than 15% of the population for T_{99}). For Amazonia and western-equatorial Africa, exposures will be larger than 80% in $WBGT_{99}$.

=> These results suggest that the global warming will be more perceived in tropical regions than in mid-latitudes and particularly in heat stress compared to temperature.

=> *Brouillet A. and Joussaume S. (2020). More perceived but not faster heat stress evolution than temperature extremes in the future. Climatic Change (in revision)*

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Further reading

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