

The ESSENCE project - Extreme temperatures in a future climate



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The ESSENCE project produced a large (17-member) ensemble of climate change runs. The ECHAM5/MPI-OM climate model was forced by the SRES A1b emission scenario for the period 1950-2100. The large ensemble gives a solid statistical basis to determine temperature extremes with a long return time. The 100-year return daily max temperature (T_{100}) rises much faster than the mean temperature. Even when corrected for present-day biases, T_{100} may reach dangerous levels in many densely populated areas by the end of this century. This aspect of climate change receives much too little attention.

1. Method - GEV fit

We divide the results of the 17 ensemble simulations into slices of 10 years and fit the resulting 170 annual maxima of T_{2m} in each slice to a Generalized Extreme Value (GEV) distribution,

$$G(x) = \exp\left[-\left(1 + \xi \left(\frac{x - \mu}{\sigma}\right)\right)^{-1/\xi}\right],$$

where μ , σ and ξ are called the location, scale and shape parameter, respectively. The return time $T(x)$ for level x is given by the $1 - 1/T(x)$ percentile of G ,

$$T(x) = \frac{1}{1 - G(x)}.$$

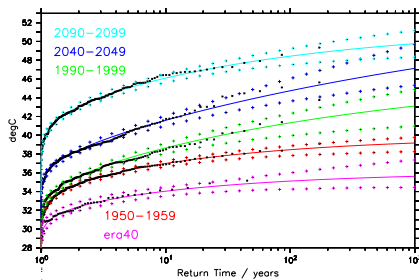


Figure A. GEV-fit for annual-maximum T_{2m} at $2^\circ E$, $42^\circ N$ (southern France) as a function of return time for different time slices, together with the values derived from ERA-40 for 1958-2002. The colored crosses give the 95%-confidence interval, based on a bootstrap with 1,000 repetitions. The black symbols are the simulated annual-maximum values.

The example in Fig. A shows that the fit represents the simulated maxima fairly well. The error bars are small, not exceeding 2 K for T_{100} . The same characteristics are found at other places.

2. Validation

The overestimation of extremes over land as compared to ERA-40 [1] is a general feature of the model (Fig. B).

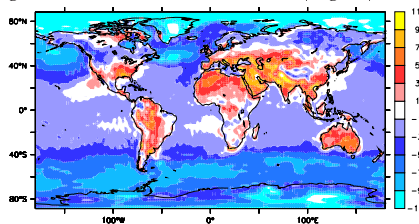


Figure B. Difference of T_{100} between ESSENCE and ERA-40 for the entire ERA-40 period (1958-2100).

It reaches more than 10 K in dry areas (Mediterranean, Middle East). Similar patterns and amplitudes are also found in other GCMs [2]. We will use the values of Figure B for a bias-correction of future T_{100} values.

3. Projections

Fig. C shows that the extreme temperatures rise faster than the means.

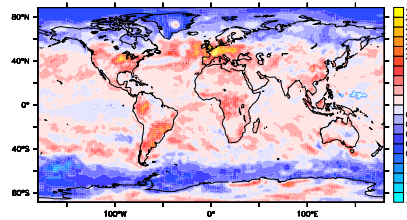


Figure C. Difference between 2090-2099 and 1990-1999 of T_{100} , expressed as a multiple of the ensemble mean temperature change during the same period. Red (blue) colors mean that T_{100} grows faster (slower) than the mean temperature.

Both μ and σ increase. The change in μ (Fig. D) reflects the fact that the climate becomes warmer. The change of σ (Fig. E) is positive over most land areas, indicating more variability, probably because of soils drying out. The change of T_{100} is largest where large changes of μ and σ coincide as over Europe and an area south of the Great Lakes (Fig. C).

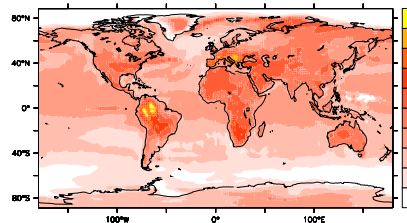


Figure D. Difference between 2090-2099 and 1990-1999 of μ (in K).

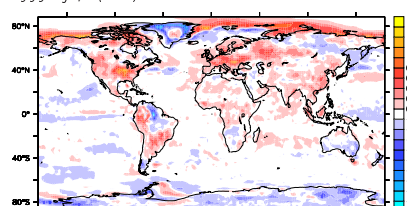


Figure E. Same as D, but for σ (in K).

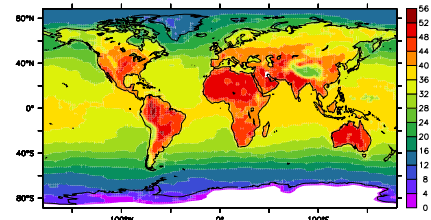


Figure F. T_{100} from ESSENCE for 2090-2100, bias-corrected using ERA-40 (Fig. B subtracted).

By 2100 T_{100} reaches values around $50^\circ C$ in heavily populated areas like India and the Middle East (Fig. F) and far exceeds $40^\circ C$ in most other densely populated areas. Such temperatures can be life-threatening. They are poorly understood (Fig. B) and need more attention.

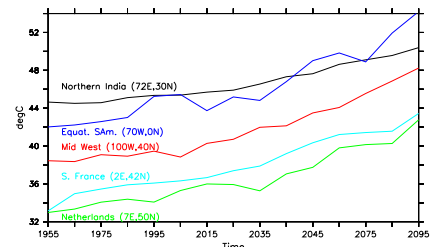


Figure G. Time series of T_{100} at a few 'hot spots' from Fig. F, bias corrected using ERA-40. Years denote the middle of the respective time-slice of ten years.

The regular increase of T_{100} in northern India (Fig. G) is mainly caused by global warming (increasing μ). The increase in hot extremes is accelerated by increasing variability (σ) in equatorial South America and the American Mid-West. The acceleration is slightly less in Europe, but still an increase of T_{100} of 7 K is modelled for the end of this century.

4. Conclusions

Hot extremes

- are overestimated in models
- rise faster than mean temperatures
- reach dangerous levels before 2100
- & their modelling need more attention

Acknowledgment

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References

- [1] Uppala et al. (2005) The ERA-40 reanalysis, *Quart. J. Roy. Meteor. Soc.*, 131, 2961-3012.
- [2] Kharin et al. (2005) Estimating extremes in transient climate change simulations, *J. Clim.*, 18, 1156-1173.

