**Review of "Present and future synoptic circulation patterns associated with cold and snowy spells over Italy", version 9.3.2022, by M. D' Errico et al.**

## GENERAL COMMENTS

This is my fourth review of this manuscript. I believe that most of the major problems have been settled, but I still need to return to the bias correction issue. The authors do wisely when not applying it to Z500 and SLP, but the results in their Figs. 8-9 suggest that they should seriously reconsider the cases of T850 and T2M as well.

In particular, Figures 9g-h show a completely unrealistic pattern with 2-m winter temperatures exceeding 25°C in Greenland, combined with an abrupt shift to more reasonable (5-10°C) values to the north-west of Iceland. Spurious local hotspots also appear elsewhere in the same maps, for example over the Gulf of Finland. I am convinced that the patterns in the original PlaSIM data are much smoother and more physically reasonable.

The likely cause of this problem is the standard deviation correction included in the bias correction method. I assume that the transformation

$$T_{corr} = (\bar{T}_{obs} - \bar{T}_{ctrl}) + \frac{s_{obs}}{s_{ctrl}}(T - \bar{T}_{ctrl})$$

has been used, where $T$ is the original and $T_{corr}$ the corrected temperature, $\bar{T}_{obs}$ and $\bar{T}_{ctrl}$ are the mean values in the observations and the control simulation, and $s_{obs}$ and $s_{ctrl}$ are the corresponding standard deviations. The problem is that the latter term, which is needed to ensure that the standard deviation in the control simulation agrees with observations, also affects the mean climate change in the model if $s_{obs}$ and $s_{ctrl}$ differ. Denoting the temperatures in a future RCP simulation as $T_{RCP}$, their mean value after the bias correction becomes

$$\bar{T}_{RCP,corr} = (\bar{T}_{obs} - \bar{T}_{ctrl}) + \frac{s_{obs}}{s_{ctrl}}(\bar{T}_{RCP} - \bar{T}_{ctrl})$$

whereas the mean for the control simulation is simply

$$\bar{T}_{corr} = \bar{T}_{obs}$$

Taking the difference, we get

$$\bar{T}_{RCP,corr} - \bar{T}_{corr} = \frac{s_{obs}}{s_{ctrl}}(\bar{T}_{RCP} - \bar{T}_{ctrl}) - \bar{T}_{ctrl} = (\frac{s_{obs}}{s_{ctrl}} - 1)(\bar{T}_{RCP} - \bar{T}_{ctrl})$$

For example, if the standard deviation in the control simulation is too small, ($s_{ctrl} <$

$s_{obs}$), the bias correction amplifies the change in the mean temperature and, therefore, also the highest temperatures. I suspect that the extremely high temperatures in (e.g.) Greenland in Figs. 9g-h result from this effect.

To avoid this problem, a mean-conserving version of the bias correction should be used instead. When the corrected daily temperatures in the RCP simulations are defined as

$$T_{RCP,corr} = (\bar{T}_{obs} + \bar{T}_{RCP} - \bar{T}_{ctrl}) + \frac{s_{obs}}{s_{ctrl}}(T_{RCP} - \bar{T}_{RCP})$$

then

$$\bar{T}_{RCP,corr} - \bar{T}_{corr} = (\bar{T}_{obs} + \bar{T}_{RCP} - \bar{T}_{ctrl}) - \bar{T}_{obs} = \bar{T}_{RCP} - \bar{T}_{ctrl}$$

just as expected.

Alternatively, the problems associated with the standard deviation correction could be avoided simply by omitting this correction, i.e., by only correcting the time mean bias.

**SPECIFIC COMMENTS**

1. L122. Why 18? On L120 the numbers 22 and 10 are mentioned.
2. Figure 4. The small numerical values indicate that the units are not as given in the figure headers (m and hPa). I assume that the values are non-dimensional.
3. Figure 5. Same comment as for Figure 4.
4. L179-180. Earlier (L172-173) ten levels were mentioned, but here only five. Which is correct?
5. L241. Z500 anomaly or standardized Z500 anomaly?
6. L248. $p_1$ or $\pi_{1,r}$? Table 1 seems to report both alternatives.
7. L281-283. Do you see similar "winter heat waves" without using bias correction? The fields for T2M in Fig. 9 look so unphysical (particularly for RCP8.5) that I strongly suspect that they are an artifact of the standard deviation adjustment in your bias correction technique (see the general comments).
8. L293. Consider putting Figures 11-15 in an Appendix or in Supplementary material. They take too much space from the main article compared with their information content, or the amount of text devoted to them.
9. Figures 11-15. It seems that the values are dimensionless, and not in the units indicated in the figure headings.
10. Caption of Figure 11. Root mean square difference in standardized geopotential height [standard deviations]? The same also applies to captions of Figs. 12-15.

**TECHNICAL COMMENTS**

1. L54. Section 4
2. L55. "Cold" with capital C

3. L99. Section 2.1
4. L102. Put "Jézéquel et al. 2018" in parentheses.
5. L141. hPa
6. L159. by high uncertainty
7. L197. the the
8. L232. persistence
9. Table 1. Why are 6-7 decimals used for RCP2.6, instead of just 4?
10. L297. “Similar” with capital S
11. L317. to be
12. L322. Temperatures are only shown in Figures 8-9.