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

GENERAL COMMENTS

The manuscript has been extensively revised from its first version. The catalogue of combined heavy snowfall and low temperature events in Italy between the years 1954 and 2018 is retained, but large changes have been made to the rest of the paper. First, a cluster analysis has been used to divide the observed cold spells to two clusters based on the associated sea level pressure (SLP) fields. Second, the analysis of the intermediate complexity PlaSim climate model simulations has been refocused on the search of situations that are analogous to the 32 identified cold spells in terms of the SLP and the 850 hPa temperature (T850) distributions.

The refocusing of the PlaSim analysis from snowfall to the atmospheric dynamical features has improved the manuscript, since the model is clearly more suitable for the simulation of the latter than the former. Furthermore, the revised manuscript is honest in acknowledging that cold spells in warmer future climate will produce less snow.

However, I still have some questions and concerns related to the interpretation of the main results. The analysis of the PlaSim simulations suggests that the frequency of SLP circulation states that resemble those in the observed cold spells is increasing strongly in the RCP8.5 scenario, whereas the corresponding change resulting for an artificial 4 K warming of the sea surface temperatures is negligible. To me this result is counterintuitive, and its physical significance is difficult to assess without further information on what the increase in RCP8.5 results from. Specifically, the increase in the frequency of circulation analogies could be associated with

1. A change in the winter mean SLP field that makes the average SLP distribution more similar to that observed during the cold spells, or
2. A change in the variability of SLP around its mean state, resulting in a larger frequency of SLP anomaly fields that resemble the SLP anomaly fields during the cold spells.

These two possibilities could be distinguished by repeating the cluster analysis for SLP anomalies relative to the observed or simulated (present-day and RCP8.5 separately) DJFM mean SLP field. If the increase in frequency is still seen when the mean state change has been eliminated by focusing on the anomalies, if must originate from changes in the simulated variability. If it disappears, then the change in the mean SLP field is the key.

Furthermore, if the change in the mean SLP field turns out to explain the increase in the frequency of the circulation analogies, a follow-up question is how and where the

mean state changes. In which parts of the (rather large) analysis domain (22.5-70°N, 80°W-50°E) does the new mean state approach the SLP fields during the observed cold spells?

Finally, biases in the simulated present-day winter mean SLP field might affect the change in the frequency of the circulation anomalies in a non-intuitive way. To check for this possibility, it would be prudent to repeat the analysis after also applying the simple linear scaling bias correction to SLP, not only to T850 as was apparently done.

I also have some concern about the ability of the clustering algorithm to identify good circulation anomalies in the model simulations. There appear to be quite large differences between the observed (Fig. 3) and the simulated (Figs. 8-9) SLP fields for both two clusters of the cold spell cases. Furthermore, the difference between the two clusters appears much smaller for the simulations. I wonder if this might be improved by selecting a somewhat smaller domain in the search of the circulation analogies.

Aside of this issue, the figures need improvement. All the maps (Figs. 3-5 and 7-9) use a very fine-grained colour scale, resulting in weak contrasts between the individual shades. Therefore, it is difficult to estimate any quantitative values from the maps. At least for SLP and T850, traditional isoline plots with labelled contours (with or without colours superimposed) would most likely be more informative.

More detailed comments follow below.

SPECIFIC COMMENTS

1. Figure 1. Please provide an absolute scale for the duration of the events
2. L277. Where was -23°C observed, if it was even colder in Marcesina?
3. L325. The lowest temperature in Finland in February 2012 was -42.7C (https://www.ilmatieteenlaitos.fi/lampimin-ja-kylmin-paikka-vuosittain)
4. L434-435. respectively 12 and 20 for k = 1 and k = 2?
5. L436. the 20 events in cluster 2
6. Figure 2. y axis labels are only partly visible
7. L503. (expected to lead to ~+3.5 K SST) This kind of numbers are meaningless without mentioning the emission scenario. From reading Adloff et al. (2015), this number most likely represents the high SRES A2 scenario.
8. L585-587. Are "decreased", "increasing" and "unchanged" the right words, when comparing PLASIM with the real world (NCEP) frequencies? Rather "smaller", "larger" and "the same"?
9. Caption of Table 1: cold spell SLP analogues?
10. Caption of Figure 7. Is this really a natural logarithmic scale from 0 to -15? Exp(-15) would mean about $3*10^{-7}$ kg m^{-2} of snow, which seems incredibly little even in Southern Europe (equivalent to having one day with 1 kg m^{-2} of snow

once in 27000 winters!).

11. L604-605. Can you explain how we get the number 179? Is this number the same for all the events, or is it an average?
12. Figs. 8-9. The SLP fields in these two figures seem much more similar with each other than those for the NCEP reanalysis clusters in Fig. 3. From a visual comparison, it is not even clear that PlaSim cluster 1 more similar to NCEP cluster 1 than 2, and vice versa for PlaSim cluster 2 (although comparison is complicated by the different map areas). Can you comment on why this is the case?
13. L631-632 (much more frequent configurations). As discussed in the general comments, more information would be needed on the dynamical origin of this difference.

TYPOs and minor linguistic issues

14. L92. main characteristics
15. L96. information … is repeated
16. L164. A very cold
17. L259. dropped to zero
18. L369. caused / was causing
19. L404. The previous snowfall in Rome
20. L502. one reason / one of the reasons
21. L564. consider as cold spell analogues
22. L592. RCP85
23. Captions of Figs. 8 and 9: in the analogies
24. L622. according to two?
25. L646. this type of events