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Earth System Dynamics
Discussions

Interactive comment on "A dynamical and thermodynamic mechanism to explain heavy snowfalls in current and future climate over Italy during cold spells" *by* Miriam D'Errico et al.

Anonymous Referee #1

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GENERAL COMMENTS

This paper first uses reanalysis data to document the large-scale circulation conditions that have led to heavy snowfall events together with low temperatures in Italy between the years 1954 and 2018. After this, an intermediate complexity climate model (PlaSim) is used to explore how the occurrence of such events might change in a warmer future climate.

The paper has its positive aspects but also severe limitations. To start with the former, it includes a valuable compilation of 32 major snowfall / cold spell events that have affected Italy since the mid-20th century. The analysis of the corresponding circulation

anomalies in the NCEP reanalysis also makes good sense. Furthermore, the paper is written in good English.

On the other hand, there are many problems in the PlaSim simulations and in the interpretation of their results. The first is, obviously, the coarse ($2.8^\circ \times 2.8^\circ$) resolution of the model. Simulations at such a resolution give very little direct information on snowfall in Italy. In the control simulation, the (country mean) snow water equivalent anomalies in the identified extreme cases are of the order of 2 mm, which is at least an order of magnitude smaller than the observed local snowfalls. Therefore, in practice, the analysis mainly gives information on the atmospheric circulation events that resemble the circulation during the observed snowfall extremes.

A second important problem is that the severity of the cold spells is only analysed based on the magnitude of the 850 hPa cold anomalies relative to the climatological mean values. These anomalies are found to (more or less) retain their earlier magnitude, leading to the suggestion that such events in the future will be no less severe than those observed this far. Yet the warmer mean climate in these simulations also means that the actual temperatures during the cold spells will become higher. In the RCP8.5 scenario, this change is large enough to nearly eliminate all snowfall in Italy. Thus, a cold anomaly with the same magnitude will not have the same effects in a warmer climate.

In addition to the simulation based on the RCP8.5 forcing scenario, the study uses another simulation in which the sea surface temperature (SST) has been uniformly increased by 4 K, without changing the atmospheric composition. Such a simulation may be useful for process studies but does not represent a plausible future. Increasing the SST without increasing atmospheric greenhouse gas concentrations creates an artificial energy source at the sea surface, which distorts the dynamics of the climate system. The finding that the simulated snowfall extremes increase under such conditions is therefore difficult to interpret.

Aside from these scientific issues, the selection of figures requires consideration. For example, Figure 8 is hardly at all discussed in the text, suggesting that it is redundant. Figure 4 is also a candidate for deletion (see comment 17 below). On the other hand, to aid the reader to assess how severe the simulated future cold spells are, figures and/or other information on the average winter warming would be needed.

In conclusion, large improvements are still needed in this paper.

SPECIFIC COMMENTS

1. L131. What is the length of the cold spells and their analogues? Does it vary from case to case, and if so, how is the length determined?

2. L156-157. How much does the average winter T850 in Europe / in Italy increase relative to CTRL in RCP8.5 and 4SST?

3. L163-168 and Fig. 8. If there is nothing more to say about Fig. 8, the figure and this paragraph can be deleted. To me there are two main messages: (i) the zero-lag correlations between the observed events are not very strong ($\sim$0.3) suggesting that there is actually quite a lot of case-to-case variability, and (ii) the correlations in PlaSim are stronger, indicating that there is less case-to-case variation in the model.

4. L179-181. Although the anomalies remain similar, the absolute temperatures must be higher (how much higher?) in RCP8.5 and 4SST than in CTRL. I don't see anything particularly counterintuitive in your results.

5. L179-181. Are these differences in the average magnitude of the cold anomaly statistically significant in comparison with the inter-event variability?

6. L181. Warmer mean temperatures are expected, but not necessarily smaller warm or cold anomalies (the latter depends on location and season).

7. L193-194. Is this really cooler than in CTRL in terms of the absolute temperature?

8. L196-197. There is nothing about the lapse rate in Eq. (1). Delta_T is the tempera-

ture tendency caused by the parameterized condensation of water vapour.

9. L197-199. If the colour scale in Fig. 11 is correct, then there is less convective precipitation over the northern parts of the Mediterranean (including surroundings of Italy) although more in the south.

10. L211-212. Although a similar frequency of the analogue events (in terms of the SLP and T850 anomalies) occurs, the absolute values of T850 during these events are higher. Therefore, the sentence (This mean that . . .) is misleading.

11. L215-217. Overinterpretation of a very subtle difference. Even if the difference were larger, why would the decrease in the frequency of good circulation anomalies in 4K-SST indicate that dynamic processes are more favoured than thermodynamic processes?

12. L222-224. The 4K-SST increase without increasing greenhouse gases is not a physically consistent possibility in the real world.

13. Figure 7d. The values of T850 in CTRL (particularly) in Italy seem surprisingly high compared with those in NCEP (Fig. 5b), RCP8.5 and 4SST (Figs. 7e-f). Are they correct? In particular, given the 8 K increase in the global mean temperature in RCP8.5 (Fig. 4), a much larger difference between CTRL and RCP8.5 would be expected.

COMMENTS ON PRESENTATION

14. L29. Dynamics of compound extreme cold and snowy events?

15. L35. the Great Lakes

16. L89. deteriorates the realism of the resulting climate?

17. L117. Figure 4 seems unnecessary. Just mention how much the global mean temperature increases in your RCP8.5 simulation and how much it increases in the CMIP5 simulations by the end of the century.

18. L125. +3.5 K . . . under which scenario?

19. L139. western half of Eurasia

20. L164. at time lags up to +/- 60 days

21. L207. SLP, not SPL

22. L254. main characteristics 23. Table 1. Write T850 and Z850 (rather than a) and b)) directly in the table.

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