Characteristics of northern hemispheric wintertime cold extremes for 1951-2011 as revealed by a Markov analysis

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1. Introduction

According to the Intergovernmental Panel on Climate Change (IPCC, 2007), frequency of cold extremes generally decrease with global warming. However, deadly cold weather still occur over many regions unexpectedly in the recent winters (Blunden and Arndt, 2013). For instance, the record breaking low temperature appeared and lasted several days in the North America in 2013/14 winter. This occasional occurrence of cold extremes implies that our understanding on dynamical and physical drivers to induce the cold extremes remains quite unclear. To improve the understanding, firstly, characteristics of cold extremes should be analysed on the multilateral aspects. Namely, the analysis is for not only frequency that is focused in most previous studies, but also persistence and predictability that are related with degree of risks. Moreover, it is important to examine if the changes in multilateral characteristics of cold extremes are really associated with regional warming.

2. Data and Method

We use minimum air temperature from the gridded station data HadGHCND at 3.75°×2.5°resolutions based on 23,000 station produced by the Met Office Hadley Centre for 1950-2011. Also, percentile thresholds (Jones et al. ,1999) are used to define wintertime cold events (WCEs). In detail, we define the moderate WCEs as the events with the bottom 10% (WCE10p), and the rare WCEs as the events with the bottom 1% (WCE1p).

For analyzing the characteristics of WCEs on multilateral aspects, we applied the statistical method called the Markov analysis (Mieruch, 2010). From Markov analysis, three WCE descriptors such as frequency (Fr), persistency (Pe), and entropy (En) are attained; the Fr value is the average of WCE events; the Pe value is the average days of sequential WCE events; the En value is the average of entropy for WCEs and non-WCEs, indicating the unpredictability of WCEs.

3. Results and Discussion

According to the analysis of 60-year climatology (Table 1), the events of WCE10p occur about five times in the winter season, persist for about two days, and have unpredictability of about 0.3 on the average over the northern hemispheric land. In the spatial patterns in 60-year climatology, higher frequency, shorter persistence and higher entropy of WCE10p coincide.

Trends of all these descriptors on the average are negative. Thus, Fr, Pe and En for WCE10p experience to decrease with time, about −3.8 (events·winter^{-1} per century), -0.6 (days per century) and −0.19 (per century) respectively (Table 1). In the meantime, Fr and Pe (or En and Pe) do not have any similar spatial patterns to those shown in the 60-year climatology; the trends of Fr and En are negative regardless of region, whereas the trends of Pe vary with

regions.

As for WCE1p, values of three descriptors in 60-year climatology are about half of those for WCE10p (Table 1), but have the same spatial patterns as WCE10p. On the other hands, trends of WCE1p have two differences from those of WCE10p; (1) Pe for WCE1p seems to increase with time overall and (2) trends of the three WCE1p descriptors are inhomogeneous as well as insignificant (at 98% confidence level).

We related regional mean winter temperature to Fr, Pe, and En for moderate and rare extremes. Firstly, all the three WCE10p descriptors exhibit to decrease with regional warming, exponentially for Fr and En values, and less exponentially or semi-linearly for Pe values depending on regions.

On the other hand, the decreases in WCE10p descriptors with regional warming are not clearly shown those in WCE1p. Changes in Fr and En values of WCE1p are much weakly related with regional warming; the degree of changes per 1K warming are different from regions. Pe values over some regions, however, increase continuously with regional warming.

4. Summary

To sum up, we analyze characteristics of WCEs on the multilateral aspects in the northern hemisphere during 1950-2011. In the 60-year climatology, higher frequency, shorter persistence and higher entropy of both of rare and moderate WCEs spatially coincide. In the time variation analysis, the descriptors of WCE10p tend to decrease with time and regional warming, whereas those of WCE1p do not have the significant trends and relations with regional warming. The results suggest that rare WCEs are not likely to be affected by regional warming. Therefore, this study implies that governing dynamics to derive rare extremes could be different from those for moderate extremes.

References

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Table 1. the area-averaged values of the climatology and trend corresponding to WCE10p and WCE1p in the northern hemisphere.

Climatology	WCE10p	WCE1p
Frequency, Fr (events · winter^{-1})	5.1	2.1
Persistence, Pe (days)	2.3	1.6
Entropy, En	0.3	0.1
Trend	**WCE10p**	**WCE1p**
Frequency, Fr (events · winter^{-1}/century)	−3.8	−1.0
Persistence, Pe (days/century)	−0.6	1.2
Entropy, En (/century)	−0.19	−0.04