

Response to Referee #2

General Comments:

1) Methods to measure snow depth. The authors describe the snow course data, how is snow depth/snowfall measured at other stations? Is the method similar in the different countries?

Reply: All measurements at the meteorological stations across the Eurasian continent was set at the same standard by the former USSR after the World War II, including China in the 1950s. All snow depth measurements at these meteorological stations were conducted with the same kind of instruments, the same standard, and the same local time. Therefore, snow depth at all meteorological stations are all consistent. Snow courses were established and operated the same way as the snow depth measurements.

Choice of time window for analysis. The snow year was defined from July 1st to June 30th. Why this choice of period? Figure 3 shows that snow seems to begin accumulating in September but snow remains in June in northern Russia and the Tibetan Plateau. So the chosen analysis window may not be optimal and should probably begin, and end, later so as to capture the complete seasonal cycle over the studied area.

Reply: We checked that the snow cover extent is the smallest in July and August. We also conducted analysis about snow depth in July and snow was essentially gone based on the data we have. Snowfall can happen anytime of the year on the Qinghai-Tibetan Plateau but it only lasts from a few hours to a few days during summer months such as June through August. We believe it is safe to say that a snow-year from June 30 through July 1 would capture the entire seasonal snow cycle.

Trend detection. Trend detection in environmental time-series is a delicate topic and this is a big concern for this study, as the 'significant' trends reported could be cited in future works. The authors seem to have used ordinary linear regression (OLS) with classical hypothesis tests (Fisher or 'F-test' on the variance explained, and/or Student T test on regression coefficients). These parametric tests make the assumption that the data is normally and independently distributed. The authors have not reported on checking these assumptions, and I doubt that the time series presented in the figures are free of autocorrelation. As a result I question the validity of much of the 'significant' linear trends reported in this study and suggest the author should apply a statistical test which account for the serial correlation of time-series. A suggestion is given below.

If the data are normally distributed, OLS can be used but the degree of freedom for the significance test must be adjusted for the reduction in the degree of freedom caused by the auto- ('serial') correlation. If the data is not normally distributed, transformation or a non-parametric test is necessary. The Mann-Kendall trend test is commonly used on

non-normal data. Here again serial correlation must be accounted for. The authors could quickly apply a normality test and the Durbin-Watson statistic to the residuals of their regression to diagnose these problems. One possible approach to take the autocorrelation into account using OLS is outlined in Weatherhead et al. (1998):

Weatherhead, E. C., et al. (1998), Factors affecting the detection of trends: Statistical considerations and applications to environmental data, *J. Geophys. Res.*, 103(D14), 17149–17161, doi:10.1029/98JD00995.

Another possibility is to apply pre-whitening to the time series. A pertinent paper is:

Yue, S., Pilon, P., Phinney, B. and Cavadias, G. (2002), The influence of autocorrelation on the ability to detect trend in hydrological series. *Hydrol. Process.*, 16: 1807–1829. doi:10.1002/hyp.1095

Reply: Thank you very much for your comments and suggestions. Any trend analysis is an approximate and simple approach to obtain what has happened on average during the study period. Linear trend analysis provides an average rate of this change. Despite there is a nonlinearity, the linear trend analysis is also a useful approximation when a systematic low-frequency variations emerged (Folland and Karl, 2001; Groisman et al., 2006). The linear trend coefficient of snow depth was calculated to represent the rate of change at each station. We checked and found that the data were normally distributed. The Student T test was used to assess the statistical significance of the slope in the linear regression analysis and the partial correlation coefficients, and the confidence level above 95% was considered in our study. Meanwhile, to overcome the strong assumption in ordinary least squares (independent and normal distribution), we also added the Mann-Kendall (MK) test to identify the monotonic trend in snow depth. Confidence level above 95% was used to determine the statistically significant increase or decrease in snow depth. These two test methods could provide more robust and comprehensive information of the trend analysis.

Folland, C.K. and Karl, T.R. (2001), Observed climate variability and change. *Climate Change 2001: The Scientific Basis*, edited by: J. T. Houghton et al., Cambridge University Press, Cambridge, UK, 99–181.

Groisman, P. et al. (2006), State of the Ground: Climatology and Changes during the Past 69 Years over Northern Eurasia for a Rarely Used Measure of Snow Cover and Frozen Land, *J. Climate*, 19, 4933–4955.

The description of the wavelet analysis is very confusing and seems unnecessarily complicated, due to their limited role in the paper. It does not allow the reader to understand what was done to the data and to replicate the analysis. This section really cuts the flow of reading and should be reworked altogether in order to bring out the essential, with proper supporting references. Which wavelet transform was used in the end, a continuous or discrete? Which wavelet family/filter? From my understanding of this paragraph you applied a discrete wavelet transform, excluded the high-frequency components and then used the inverse transform to reconstruct the lower frequency signal. Or is it that you applied an averaging filter on the wavelet coefficient before reconstructing the signal with the inverse wavelet

transform?

Reply: We have revised the description of the wavelet analysis. As your comments, we applied a discrete wavelet transform, excluded the high-frequency components and then used the inverse transform to reconstruct the lower frequency signal. The new description as following:

“Wavelet analysis was performed to reveal the long-term low-frequency variations of snow depth over the study area as a whole. A wavelet is a wave-like oscillation with an amplitude that begins at 0, increases, and then decreases back to 0 (Graps, 1995). We applied a discrete wavelet transform, excluded the high-frequency components and then used the inverse transform to reconstruct the lower frequency signal.”

2) Results and discussion

Physiographic and climatic control on spatial variability of snow depths. The analysis of the factors controlling the spatial variability of snow depths is somewhat limited in breadth. The authors show a general increase in snow depth with latitude and a general decrease in snow depth with increasing altitude. Large-scale control on snow depth will be mainly dependent on the interplay between latitude and altitude but also distance to moisture sources (continentality) and position relative to orographic barriers. Together these will determine the snowfall rate. For such a large and topographically contrasted region as the Eurasian continent, ignoring these last two effects does not allow a clear understanding of large-scale snow depth spatial variability in the region. The negative (but poor) relationship between snow depth and altitude shown by the authors is largely explained by the continentality and rain shadow effect of the high Tibetan Plateau, while at higher latitude snow depth does seem to increase with altitude in response to orographic enhancement of snowfall. The authors should try to incorporate quantitatively the effects of continentality and barrier effect into their analysis, or at least provide a more in depth discussion of their results in the light of known large-scale physiographic control on the snow cover, with proper supporting references.

Reply: Thank you very much for your comments and suggestions. We indeed conducted analysis on impact of continentality on snow depth over the study area. To our surprise, the correlation between the two are not significant. However, we strongly agree with the reviewer that at local and regional (less than continental) scales, topography can play key roles. In Section 4.2, we added more discussions about topographical effects on snow depth, especially on Tibetan Plateau (TP). The Tibetan Plateau's largest snow accumulation occurred in the winter, but the snowfall during winter months is the smallest of the year. This was mainly due to the terrain factors: the water vapor from the east and west was blocked by the Hengduan Mountains and Nyainqentanglha Mountains, respectively, which resulted in less snowfall. Although there was more snowfall in spring, snow cover was not easy to accumulate with higher temperatures. Therefore, snow depth was shallow on TP in general. In addition to topographic factors, spatial distribution of snow depth was also affected by atmospheric

circulation. We will discuss this issue in the future studies.

Relationships between mean (Eurasian) climate and snow depth over time.

The authors revealed interesting increases in snow depth, SWE, temperature and snowfall rates over the study period. However the analysis and interpretation of these tendencies remains somewhat superficial. This section could be enhanced by quantitative analysis, i.e. by performing correlation analysis, and/or multiple correlation/regression analysis to highlight the respective influence of temperature and snowfall changes on mean Eurasian snow depth and SWE. Even more interesting would be to see this analysis done spatially, perhaps in a future study. This would probably highlight the effect of continentality and position relative to orographic barriers on the response of the snow cover to climate.

Reply: We have added the quantitative analysis by the partial correlation analysis between snow depth, SWE, air temperature and snowfall. The results showed that the significant negative correlation ($p \leq 0.05$) between snow depth and air temperature presented in most areas of European Russia and the southern Siberia (Fig 13a). The stations with negative effects of air temperature on SWE were fewer, and there were no statistically significant correlation in the northern Siberia (Fig 13b). It was because the air temperature was below 0°C in most areas of Siberia during December through March, the increasing temperature did not have an obvious effect on snow depth. Consistent with the interannual variation, changes in snow depth and SWE were more affected by snowfall in most areas across the former USSR from December through March. The greater partial correlation coefficients (>0.6) between snow cover and snowfall appeared in the northern European Russia, the southern Siberia, the northeast and southeast of the Russian Far East. Variations in snow depth and SWE were more sensitive to snowfall and snowfall rate in these areas.

Specific comments and editorial changes:

- 1) P3, L13. Although snow cover extent reduced with climate warming, snow depth still increased in northern Eurasia (Kitaev et al., 2005; Bulygina, 2011). Over which period?

Reply: The sentence is revised as “Although snow cover extent reduced with climate warming, snow depth still increased in the northern Eurasia during 1936 to 1995 (Kitaev et al., 2005) and 1966-2010 (Bulygina et al., 2011).”

- 2) P3 L23, 'a' thin snow cover results...

Reply: We deleted the third paragraph in P.3 and the second paragraph in P.4 according to the suggestion of referee #1.

- 3) P3 L24. Frauenfeld et al. (2004) indicated that in permafrost areas the maximum snow depth by the end of winter has a significant influence on the active layer depth during the following summer.

Reply: We deleted the third paragraph in P.3 and the second paragraph in P.4 according to the suggestion of referee #1.

- 4) P3, L28. The numerical modeling results showed that the rate of mean annual ground surface temperature increase with the increasing maximum snow depth was about 0.1 °C cm⁻¹ for the maximum snow depth at 15 cm. This sentence is convoluted and hard to understand, please rephrase more clearly. Maybe: The numerical modeling results showed that the mean annual ground surface temperature increases with increasing snow depth at a rate of 0.1 °C cm⁻¹ until up to a snow depth of 15 cm...?

Reply: We deleted the third paragraph in P.3 and the second paragraph in P.4 according to the suggestion of referee #1.

- 5) P4, L2, ...also increased with snow depth.

Reply: We deleted the third paragraph in P.3 and the second paragraph in P.4 according to the suggestion of referee #1.

- 6) P4, L5: Furthermore, snow accumulation an important freshwater resources and has direct impacts on the hydrological cycle.

Reply: We deleted the third paragraph in P.3 and the second paragraph in P.4 according to the suggestion of referee #1.

- 7) P4, L11. Adam et al. (2009) suggested that the variations in snow depth will significantly affect the hydrological regime of the Arctic in the future.

Reply: We deleted the third paragraph in P.3 and the second paragraph in P.4 according to the suggestion of referee #1.

- 8) P4, L14-26: here you describe trends in snow cover and other variables. Please mention the period over which these changes were observed for respective studies

Reply: Thank you very much for your suggestion. We added the period over these changes for respective studies:

“overall, the annual mean snow depth decreased in most areas over North America during 1946 to 2000 (Brown and Braaten, 1998; Dyer and Mote, 2006), and increased in Eurasia and the Arctic during the recent 70 years (Ye et al., 1998; Kitaev et al., 2005; Callaghan et al., 2011a; Liston and Hiemstra, 2011) but there was regional differences (Bulygina et al., 2009, 2011; Ma and Qin, 2012; Stuefer et al., 2013; Terzago et al., 2014). Changes in snow depth were primarily affected by air temperature and precipitation. Ye et al. (1998) and Kitaev et al. (2005) showed that higher air temperatures caused an increase in snowfall in winter from

1936 through 1995, thus greater snow depth was observed in northern Eurasia in response to global warming. Furthermore, snow depth distribution and variation are also controlled by terrain (i.e., elevation, slope, aspect, and roughness) and vegetation (Lehning et al., 2011; Grünewald et al., 2014; Revuelto et al., 2014; Rees et al., 2014; Dickerson-Lange et al., 2015). Snow depth is also closely related to other large-scale atmospheric circulation indices, such as the North Atlantic Oscillation /Arctic Oscillation (NAO/AO) indices. For example, Beniston (1997) found that the NAO played a crucial role in fluctuations in the amount of snowfall and snow depth in the Swiss Alps from 1945 to 1994. Kitaev et al. (2002) reported that the NAO index is positively related to snow depth in the northern part of the East European Plain and over western Siberia during the period 1966-1990;”

- 9) P4, L28. Snow depth is also closely related to other large-scale atmospheric circulation indices, such as the North Atlantic Oscillation /Arctic Oscillation (NAO/AO) indices. For example, Beniston (1997) found that the NAO....

Reply: We have revised the sentence.

- 10) P5, L8. In order to obtain a wider range of snow depth...Wider range is imprecise. In order to increase the spatial coverage? and/or spatial resolution?

Reply: We revised it with “increase the spatial coverage”

- 11) P5, L18. Ground-based snow measurement remains the basis for verification of remote sensing and instrumental data...

Reply: We replace “is” with “remains”

- 12) P6, L1. 'TP' = Tibetan Plateau I presume, but I don't think it was defined before.

Reply: We have defined it in P.5, line7.

- 13) P6, L15. on a daily basis.

Reply: We inserted it.

- 14) P6, L15. Suggested change: Historical snow course data over the former USSR from 1966 to 2011 were also used in this study

Reply: We revised it.

- 15) P6, L17 snow surveys performed throughout the accumulation season

Reply: We revised it.

16) P6, L19. Snow surveys were conducted over 1–2 km-long transects.

Reply: We revised it.

17) P6, L20. Snow depth was measured every 10 m in the forest, and every 20 m in open terrain.

Reply: We replace “each” with “every”

18) P6, L22. SWE: define once

Reply: We have defined it in P.3, line7.

19) P6. L25 ... over the former USSR. Why only over USSR? Maybe complete sentence with ... 'where SWE data are available...'

Reply: We added it.

20) P6 L25. SWE was measured every 100 m along the 0.5-1.0 km courses and every 200m along the 2 km course.

Reply: We replace “each” with “every”

21) P6, L27. Precipitation data were divided proportionally into daily solid and liquid data, and the solid-to-liquid fraction was determined according to daily mean temperature (Brown,2000). I suggest replacing by: Daily precipitation was partitioned into a solid and liquid fraction, based on daily mean temperature (Brown,2000). You then describe the partitioning equation in the following sentence. Srat : whatdoesratstandsfor...?

Reply: Thank you very much for your suggestion. We replaced this sentence.

22) P7, L9. Quality control steps. (1) daily snow depth observations (equal to or greater than 0 cm, not including missing data) for <15 days in one month were omitted; This is confusing. Do you mean that months having less than 15 days with snow depth data were omitted from the analyse? If that so rephrase in that sense. (2) snow data from stations with <20 years of measurements during 1971-2000 were excluded; I suggest replacing by: Stations with less than 20 years of data during the 1971-2000 period were excluded from the analysis. 3) data exceeding two standard deviations compared with the annual average value during 1966-2012 were omitted. Add: 'At each station,' before the sentence.

Reply: We rephrased this sentence as “Months having less than 15 days with snow depth data were omitted from the analysis”

23) P7, L16. We defined a snow year as the period from July 1st of a current year to June

30th of the following year. Why this choice of period..? maybe add short complement to the sentence: '... so as to insure that the complete seasonal snow cycle is captured across the study region...' Also, I note in Figure 3 that snow remains in June in some areas, and seems to begin accumulating in September. So the chosen analysis window may not be optimal and should probably begin and end later.

Reply: Thank you very much for your suggestion. The snow cover extent is smallest during July to August, in order to capture the beginning of snow cover, we defined a snow year as the period from July 1st of a current year to June 30th of the following year. We have added the explanation of the choice of time window before we defined the snow year.

24) P7, L17. Because the procedures for taking snow observations have changed over the course of the studied period, there were some inhomogeneities in the data.

Reply: We revised it.

25) P7, L25....World Meteorological Organization (WMO) climatological products. A reference would be needed here.

Reply: We added the reference "World Meteorological Organization (WMO) climatological products (Ma and Qin, 2012)"

26) P7, L25. A threshold of 15 days was selected because the snow cover duration in some areas of China was less than one month, and the data for 15 days' snow depth in a month were relatively stable. Do you refer to the previously defined quality control step 1? If this is the case this sentence should go in the quality control paragraph. You can here recall it in short sentence.

Reply: Thank you very much for your suggestion. We moved this sentence to the quality control paragraph.

27) P8. L2. In order to capture the primary...

Reply: We revised it.

28) P8, (4) Linear trend coefficient of snow depth: the linear trend coefficient of snow depth for each station was obtained by linear regression analysis with respect to time, and thus represents the rate of change in snow depth for a period of time. Replace 'for a period of time' by 'over time'? Or by: 'for a >20 year time period'. Statistical test on linear trend: see main comments...

Reply: We replaced it. And the analysis of the statistical test on linear trend is answered in the main comments.

29) P8, L23. ...each station and averaged the anomalies for all stations to the anomalies for the whole Eurasian continent. : 'averaged the anomalies for all stations to obtain mean anomalies for the whole Eurasian continent'.

Reply: We revised it.

30) P8, L26 -. Description of wavelet analysis. See main comment on this. You need to include at least once key reference.

Reply: Thank you very much for your suggestion. We have revised the description of the wavelet analysis. As your understanding, we applied a discrete wavelet transform, excluded the high-frequency components and then used the inverse transform to reconstruct the lower frequency signal. The new description as following:

“Wavelet analysis was performed to reveal the long-term low-frequency variations of snow depth over the study area as a whole. A wavelet is a wave-like oscillation with an amplitude that begins at 0, increases, and then decreases back to 0 (Graps, 1995). We applied a discrete wavelet transform, excluded the high-frequency components and then used the inverse transform to reconstruct the lower frequency signal.”

31) P9, L12. We used an averaging filter for wavelets analysis. Using this method, values that are too small or too large may be excluded; This description is really unclear. Please simplify and add proper references so that the interested reader can find further explanations on the technique used, if wanted.

Reply: We deleted this sentence.

32) P9, L15. obtained from filtering. Remove extra space.

Reply: We deleted the space.

33) P9, L26. increased with the latitude... A maximum annual mean snow depth... in the west of the Yenisey River

Reply: We replace “the” with “A”

34) P9, L28. ...were observed in some areas of China. 'some areas' is rather vague, can you be more descriptive?due to wind speed, topography, underlying ground surface, and climatic conditions (refs). This is a rather very general statement which does not bring any insights. Of course snow depth will vary everywhere due to these factors... if you do analyse in a later section how these factors affect the spatial variability, mention it. 'The relation between these factors and spatial snow depth variability is further investigated in section xxx'...

Reply: We added more description L28: “in some areas of the south of Yangtze River in China”. We deleted “due to wind speed, topography, underlying ground surface, and climatic conditions (Gray and Male, 1981; Sturm et al., 1995, 2001; Callaghan et al., 2011b).”

35) P10, L5. The regions with the smallest annual mean snow depth (<5 cm) were located in most areas of the Caucasus Mountains. This is a bit surprising given the high elevations. Is there an elevation bias here? (snow stations are at low elevations?)

Reply: The stations with the smallest annual mean snow depth are located in the eastern and western areas of the Caucasus Mountains, close to the coast of the Caspian Sea and the Black Sea, where the elevations are below 2000 m. We have added the specific location in the text: “were located in the eastern and western areas of the Caucasus Mountains”

36) P10, L13. varied with the latitude

Reply: We deleted “also”

37) P10, L15. . (201.8 cm) :here as elsewhere in the text you can should round the snow depth to the nearest centimeter, as this is the probably accuracy of the measurements.

Reply: The maximum value is calculated using the average values of annual maximum snow depth. The average is kept one decimal place, so it is an approximation.

38) P11, L4.... in northern Siberia. Remove extra space between in and northern

Reply: We removed the extra space.

39) P11, L21. ...the increasing rate of snow depth. increasing rates of snow depth

Reply: We replaced “rate” with “rates”

40) P11. L19-22: linear trends and results plotted on Figure 4: were trends computed on annual anomalies or on the wavelet filtered series? You must provide a trend test that accounts for the autocorrelation of time-series (see main comment).

Reply: The trends were computed on the annual anomalies. Any trend analysis is an approximate and simple approach to get what has happened on average during the study period. Linear trend analysis provides an average rate of this change. Despite there is a nonlinearity, the linear trend analysis is also a useful approximation when a systematic low-frequency variations emerged. The linear trend coefficient of snow depth was calculated to represent the rate of change at each station. The Student T test was used to assess the statistical significant of the slope in the linear regression analysis and the partial correlation coefficients, and the confidence level above 95% was considered in our study. Meanwhile, to overcome the strong assumption in ordinary least squares (independent and normal

distribution), we also added the Mann-Kendall (MK) test to identify the monotonic trend in snow depth. Confidence level above 95% was used to determine the statistically significant increase or decrease in snow depth. These two test methods could provide more robust and comprehensive information of the trend analysis. We have added the MK test and compare the results of the two methods:

“The Mann-Kendall statistical curves of annual and maximum snow depth were consistent with the linear trend analysis (Fig. 5). The increasing trend of annual snow depth reached to the 0.05 confident level in the late 1980s and from the early 1990s to the mid-1990s; it reached to the 0.01 confident level in the late 1990s. The decreasing trend reached to the 0.05 confident level from the early 2000s through the mid-2000s. The intersection of the UF curve and UB curve appeared in the mid-1970s, it indicated that the rising trend was an abrupt change during this period. The abrupt change point of the maximum snow depth was in the mid-1980s, then it increased significantly ($p \leq 0.05$) from the early 1990s through the mid-1990s, and it reached to the 0.01 confident level from the late 1990s to the early 2010s.”

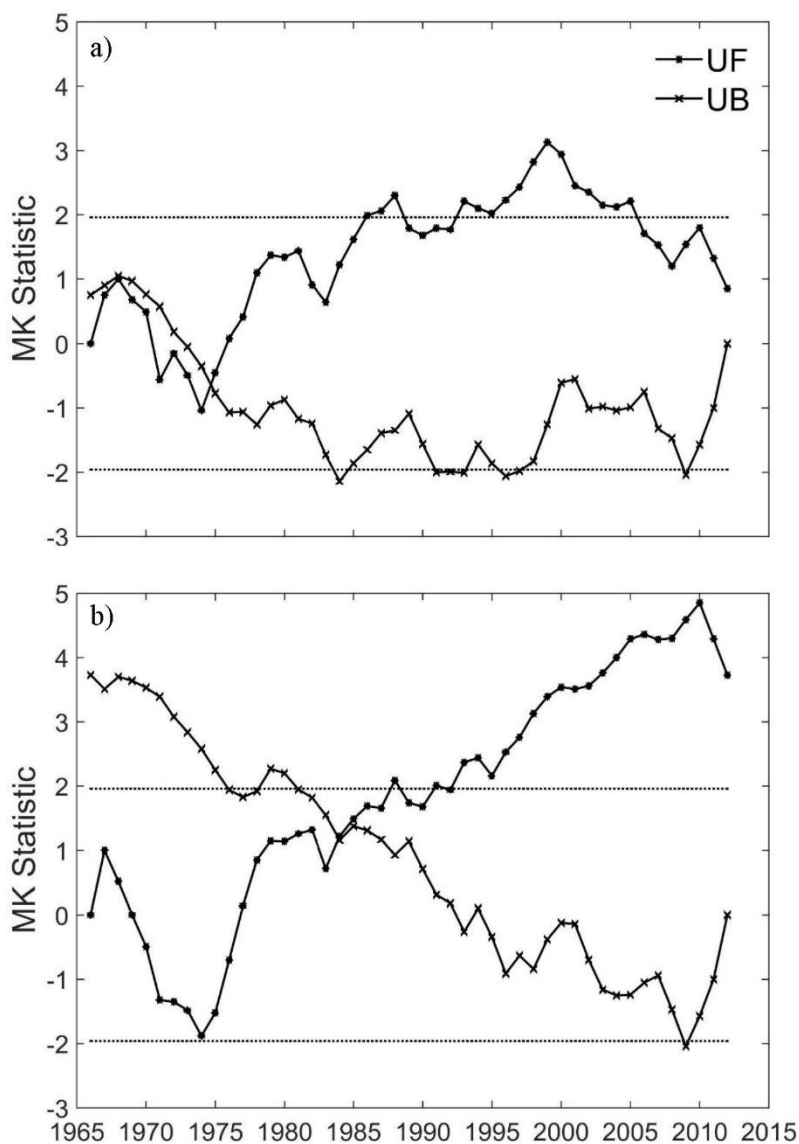


Figure 5. Mann-Kendall statistical curve of annual mean snow depth (a) and maximum snow depth (b) from 1966 through 2012 across the Eurasian continent. Straight line presents significance level at 0.05.

“In order to identify the monotonic trend in monthly snow depth, we conducted the MK test (Fig. 7). In October, snow depth represented a decreasing trend and it reached to the 0.05 confident level only after 2010. The statistically significant changes of monthly snow depth in November during the period of the late 1980s through the early 2000s, though it was not statistically significant with the linear regression. From December through March, there were increasing trends in monthly snow depth and the abrupt change point appeared in the mid-1970s. In the linear regression analysis, the variation of snow depth was not significant in December. However, the results of M-K test showed that the increasing trend of monthly snow depth reached to the 0.01 confident level during the mid-1980s through the late 1990s, and then it decreased during the 2000s. From January to March, monthly snow depth increased significantly ($p \leq 0.01$) from the mid-1980s to the early 2010s. In April, the statistically significant increase was found from the late 1990s to the late 2000s, and it reached to the 0.01 confident level after 2000. Consistent with the linear regression, the trend in monthly snow depth was not significant in May.”

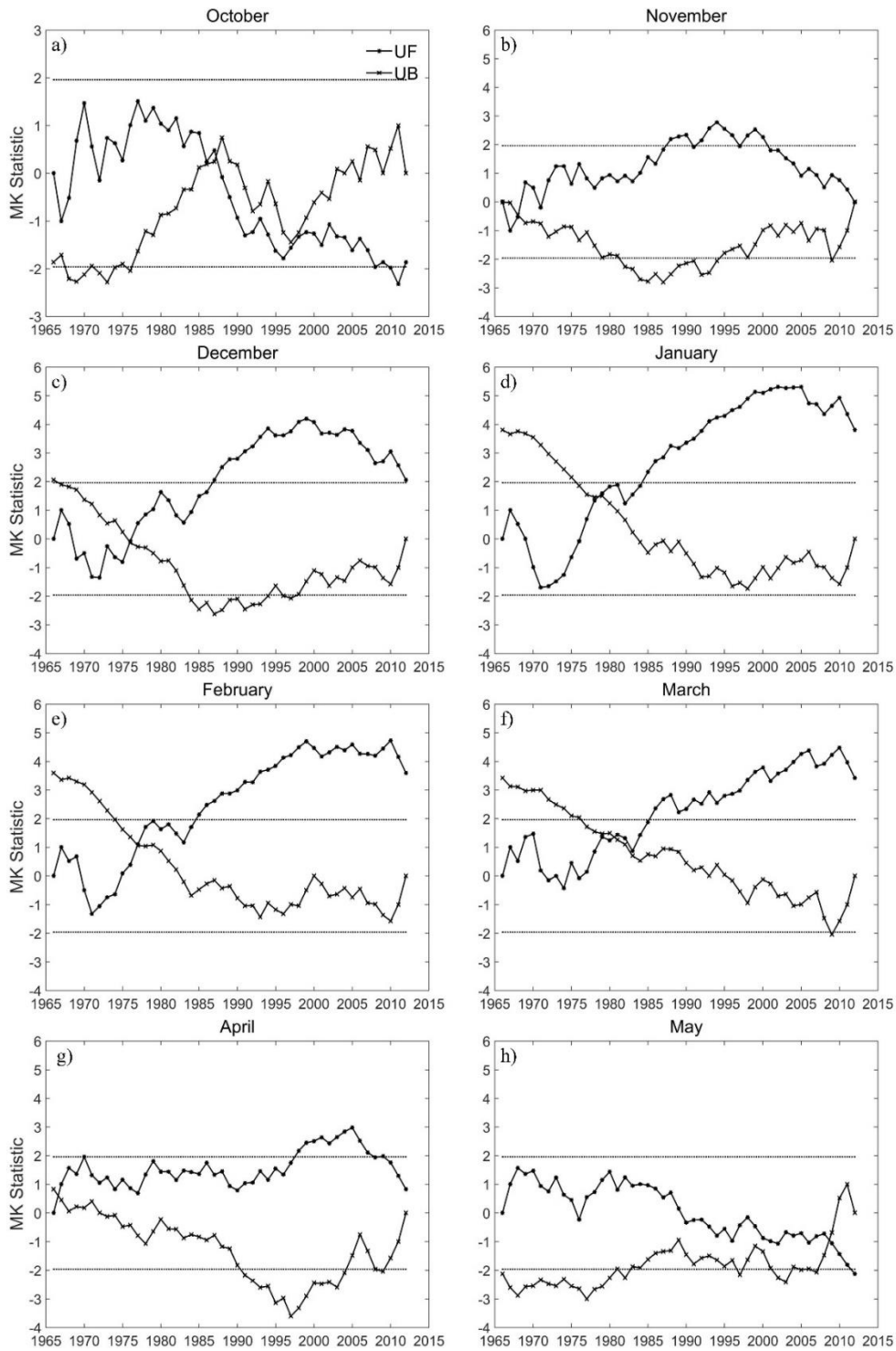


Figure 7. Mann-Kendall statistical curve of monthly mean snow depth (from October to May) from 1966 through 2012 across the Eurasian continent. (a) October, (b) November, (c) December, (d) January, (e) February, (f) March, (g) April, (h) May. Straight line presents significance level at 0.05.

41) P12, L1. There was a sharp increase of 3.5 cm in the maximum snow depth during the 1970s, then fluctuated from the late 1970s to the early 1990s. : then fluctuations from... Perhaps be more precise: what type of fluctuation?

Reply: There is no significant increase or decrease trend in fluctuation. We revised it as “then it fluctuating changed from the early 1990s through the early 2010s.”

42) P12, L20. the rate of increase being about 0.6 cm decade

Reply: We replaced “was” with “being”.

43) P14, L2. in monthly mean snow depth decreased,

Reply: We replaced “fell” with “decreased”.

44) P14, L3. Changes in monthly mean snow depth were consistent with the trends in winter over the former USSR but more stations with the decreasing trends in the southern Siberia. Do you mean: ‘but more stations with decreasing trends were found in southern Siberia’?

Reply: We revised it with “but more stations with decreasing trends were found in southern Siberia”

45) P14, L5. There were few stations with statistically significant trends of snow depth across China; for these, monthly snow depths tended to decrease at most stations.

Reply: We added “; for these,”

46) P14, L11. To explore the spatial variability of snow depth,

Reply: We replaced “features” with “variability”.

47) P14, L15. snow depth to the north of 40°N

Reply: We deleted “mean”.

48) P14, L23. because a snow depth. remove extra space between ‘a’ and ‘snow’

Reply: We deleted the extra space.

49) P14. This result indicates that elevation is an important factor affecting snow depth in these regions. I find this statement and the preceding analysis a bit over simplistic. At large scales the snow cover can be thought to depend on latitude, altitude and distance to moisture source (continentality). I feel you are missing the third factor in our analysis. The poor, and generally negative relationship between elevation and snow depth is interesting because it is contrary to what would be expected from orographic effects on precipitation amounts and phase. What you show is that the high elevation of the TP does not cause larger snow depth compared to surrounding lower lands. Continentality seems to be the main driving factor here: the TP is in the rain shadow of the Himalaya and as

such is moisture-deprived. This should be better discussed, and analysed in the paper. This effect could be investigated, perhaps using a simple continentality index (e.g. <http://glossary.ametsoc.org/wiki/Continentality>). These indices rely on temperature annual ranges. You could use the closest distance to coast as another simple index.

Reply: We indeed conducted analysis on impact of continentality on snow depth over the study area. To our surprise, the correlation between the two are not significant. However, we strongly agree with the reviewer that at local and regional (less than continental) scales, topography can play key roles. In Section 4.2, we added more discussions about topographical effects on snow depth, especially on Tibetan Plateau (TP). The Tibetan Plateau's largest snow accumulation occurred in the winter, but the snowfall during winter months is the smallest of the year. This was mainly due to the terrain factors: the water vapor from the east and west was blocked by the Hengduan Mountains and Nyainqentanglha Mountains, respectively, which resulted in less snowfall. Although there was more snowfall in spring, snow cover was not easy to accumulate with higher temperatures. Therefore, snow depth was shallow on TP in general. In addition to topographic factors, spatial distribution of snow depth was also affected by atmospheric circulation. We will discuss this issue in the future studies.

50) P15: section 3.4.

You begin the section by stating that 'Variations in snow depth are closely related to climate change'. But what is investigated is the influence of spatially variable climate factors (mean temperature and mean snowfall) on snow depth, and NOT the effect of time-varying climate on snow depth. To do so you would have to test the influence of changing temperatures and snowfall/precipitation on snow depth over time. Rephrase the introduction of the section to clearly explain that you investigate spatial relationships between mean temperature and snowfall on mean snow depths. The spatial relationship between air temperature and snow depth will be undoubtedly complex when considered an area as big and topographically diverse as the Eurasian continent. Your analysis is till interesting as it shows that snowfall is the main factor driving spatial variability in snow depth, at this spatial scale. However snowfall rates and air temperature must also be somewhat correlated, as snowfall depends on precipitation and temperature (precipitation phase). I suggest that you also calculate and report the partial correlation coefficients, i.e. to show the influence one variable while removing effect of the other, on snow depth. You do examine the effect of changing climate on snow depth and mass in Figure 10 for the composite Eurasian and Russian records. This analysis is qualitative and hile interesting and valuable, it could be enriched by calculating and presenting the correlation coefficients between series. Especially for the SWE series, how much of the variance can be respectively explained by air temperature and snowfall? Even more constructive would be to perform this analysis on a station basis and map the results. We would then learn about the spatially variable climate control on snow.

Reply: Thank you very much for your suggestion. We have added the quantitative analysis by the partial correlation analysis between snow depth, SWE, air temperature and snowfall. The results showed that the significant negative correlation ($p \leq 0.05$) between snow depth and air

temperature presented in most areas of European Russia and the southern Siberia (Fig 13a). The stations with negative effects of air temperature on SWE were less, and there were no statistically significant correlation in the northern Siberia (Fig 13b). It was because the air temperature was below 0°C in most areas of Siberia during December through March, the increasing temperature did not have an obvious effect on snow depth. Consistent with the interannual variation, changes in snow depth and SWE were more affected by snowfall in most areas across the former USSR from December through March. The greater partial correlation coefficients (>0.6) between snow cover and snowfall appeared in the northern European Russia, the southern Siberia, the northeast and southeast of the Russian Far East. Variations in snow depth and SWE were more sensitive to snowfall and snowfall rate in these areas. Variations of snow depth were explained by air temperature and snowfall in most areas of the European Russia and some regions of the southern Siberia, the effects of the two factors on SWE only appeared in some of these areas; however, snowfall was the main driver force of the variance of snow depth and SWE in the former USSR.

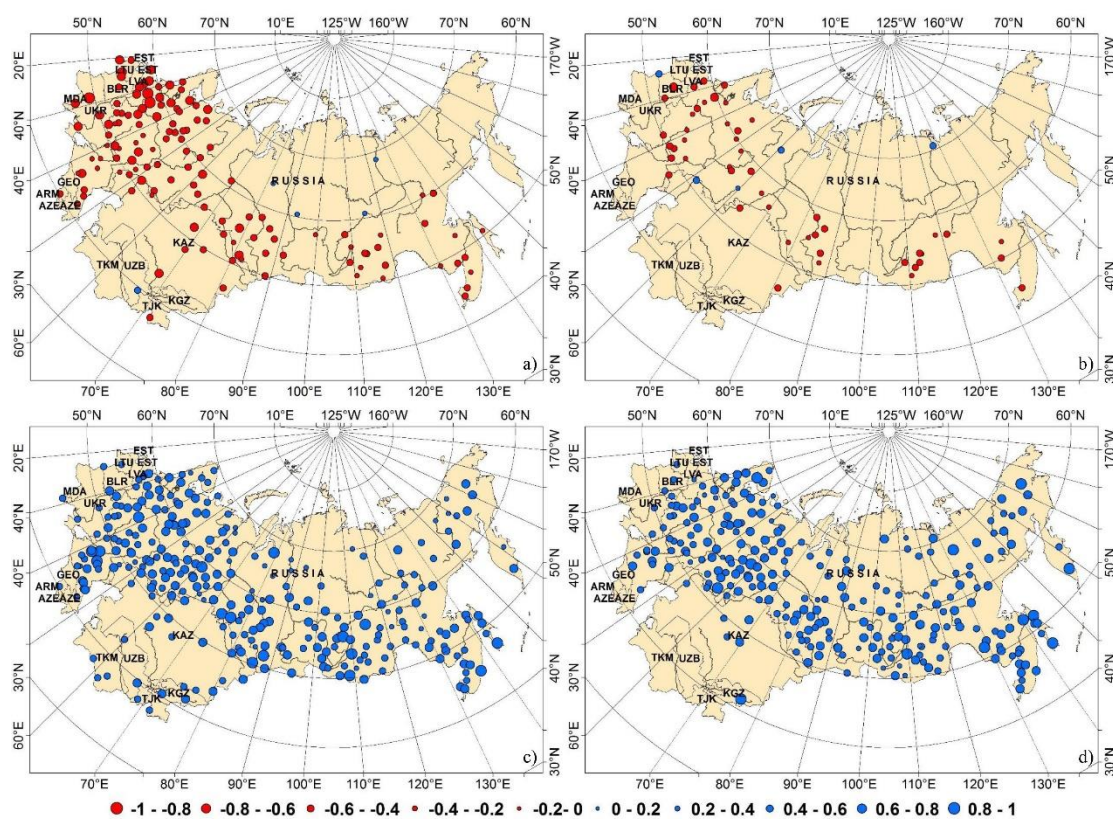


Figure 13. Spatial distributions of partial correlation coefficients of snow depth and air temperature (a), snow depth and snowfall (b), SWE and air temperature (c), SWE and snowfall from November through March during 1966-2009. The coefficients reaching to 0.05 confident level are displayed. Red circles represent a negative relationship, and blue circles indicate a positive relationship.

51) P15, L7. Snow depth significantly decreases with increasing air temperature ($P \leq 0.05$),

Reply: We replaced “decreased” with “decreases”

52) P15, L17. Increases

Reply: We replaced “increases” with “increasing trends”

53) P15, L21. The significant increasing snowfall can explain the sudden drop in snow density observed from the mid-1990s through the early 2000s (Zhong et al., 2014): fresh snow with low snow density. Explain the last statement better in a separate statement. Why does increasing snowfall decreases snow density? Is it the mean density of the snowpack? Increasing snowfall in response to warmer temperature should increase the density, both of fresh snow, and perhaps of the whole snowpack due to faster metamorphism and increased compaction...

Reply: The snow density means the bulk snow density of the snow profile. Increasing snow fall should decrease the density of the surface snowpack, which lowed the whole density of snowpack.

54) P15, L26. increasing trend of changes in snow depth. trend in snow depth? or trend in the rate of change?

Reply: It means the trend in snow depth. We deleted “of changes”.

55) P15, L27. In fact, the climatology of snow depth not only influenced by air temperature and precipitation, but also with other climatic factors and atmospheric circulation. Poor formulation, rephrase.

Reply: We have deleted the sentences and added the analysis of the partial correlation coefficients between snow cover and air temperature, as well as snow cover and snowfall.

“The partial correlation coefficients between snow cover and air temperature, as well as snow cover and snowfall were calculated to discuss the spatial relationship between them (Fig. 13). The significant negative correlation ($p \leq 0.05$) between snow depth and air temperature presented in most areas of European Russia and the southern Siberia (Fig 13a). The stations with negative effects of air temperature on SWE were less, and there were no statistically significant correlation in the northern Siberia (Fig 13b). It was because the air temperature was below 0°C in most areas of Siberia during December through March, the increasing temperature did not have an obvious effect on snow depth.

Consistent with the interannual variation, changes in snow depth and SWE were more affected by snowfall in most areas across the former USSR from December through March. The greater partial correlation coefficients (>0.6) between snow cover and snowfall appeared in the northern European Russia, the southern Siberia, the northeast and southeast of the Russian Far East. Variations in snow depth and SWE were more sensitive to snowfall and snowfall rate in these areas.”

56) P16. L7. These discrepancies may result from differences in the time frame

Reply: We replaced the first “differences” with “discrepancies”.

57) P16. L26. during the different study periods.

Reply: We revised it.

58) P16. L.26-28. The sensitivity of snow cover to air temperature and precipitation for each station showed regional differences (Fallot et al., 1997; Park et al., 2013). The amount of snowfall can be affected by climate change, and leading to differences in snow depth at different times (Ye et al., 1998; Kitaev et al., 2005). This is why simple spatial relationship between air temperature and snow depth do not exist...

Reply: We added a sentence after it.

“The results of our study showed that there was significant negative relationship between snow depth and air temperature in the southern Siberia, however, it did not exist in the northern Siberia. This may explain the difference in the results of these studies.”

59) P17, L5. and is the main reason. Extra space between 'and' and 'is'

Reply: We deleted the extra space.

60) P17, L10. Therefore, we will select a typical climate zone to research the climatology and variations of snow cover. This rather vague... your study looks at large scale control on snow cover and this is what this dataset allows. Studying small scale (topography, vegetation) effects on the snow cover requires other kind of data, sampled at a higher spatial resolution. I would remove this sentence.

Reply: Thank you very much for your suggestion. We removed the sentence.

61) You should better discuss your results in the light of what is known about large-scale control on snow cover: latitude, altitude and continentality are the main geographical factor which drive snowfall rates and hence snow depths. I find your analysis and the discussion on page 17 somewhat incomplete in this respect.

Reply: We have analyzed the relationship between snow depth and continentality. But the correlation coefficient was not high ($r=0.1$). This indicated that the continentality is not an important driving factor of snow cover climatology over Eurasia. However, we strongly agree with the reviewer that at local and regional (less than continental) scales, topography can play key roles. In Section 4.2, we added more discussions about topographical effects on snow depth, especially on Tibetan Plateau (TP):

“Some important questions that are not addressed in the current research should be resolved in the future. Topography is an important factor affecting the climatology of snow depth, and

is the main reason causing the inhomogeneity of data. Previous studies have analyzed the representation of snow depth for single stations to solve the issue (Grünewald and Lehning, 2011, 2013; Grünewald et al., 2014). However, in the present study, we did not discuss this question because of the complexity of spatial difference. But we still got some interesting conclusions: There was a closely relationship between snow depth and elevation at the local scale. However, compared with latitude, the correlation between them was not so significant in the whole Eurasian Continent. Moreover, the continentality did not play a great role in spatial distribution of snow depth, especially on TP. The previous studies showed that the Tibetan Plateau's largest snow accumulation occurred in the winter, but the snowfall during winter months is the smallest of the year (Ma, 2008). This was mainly due to majority of annual precipitation occurs during the summer monsoon season on TP which cause very less snowfall during winter half year (or snow accumulated season). Furthermore, the water vapor from the east and west was blocked by the Hengduan Mountains and Nyainqentanglha Mountains, respectively, which resulted in less snowfall. Although there was more snowfall in spring, snow cover was not easy to accumulate with higher temperatures. Therefore, snow depth was shallow on TP in general. In addition to topographic factors, spatial distribution of snow depth was also affected by atmospheric circulation. We will discuss this issue in the future studies.”