

Dear Editor and Reviewer #2

We really appreciate the Anonymous Referee #2's time and comments which are precious to our manuscript. We have revised the entire manuscript incorporating the comments and questions by the reviewer as possible as we can. The following is our detail replies to specific comments by the reviewer.

1. (Page 3, line 7) It seems that the authors are using an em dash. Please replace it by an en dash and include a space character between the numbers and the dash; Do the same for periods of time (e.g. in page 13, line 19, please replace "2003-2004" by "2003 – 2004") and elsewhere in the manuscript;

All em dash has been replaced by en dash and included a space character between the numbers and the dash.

2. (Page 5, line 29 and page 13, line 9) The FWI codes and indices do not have a large-scale character but are being computed with large scale data; Please see (page 19, lines 7 – 8) in the conclusions where this is clear;

Page 5, line 29 identified the gap research in the application of large-scale FWI codes in fire risk management. Page 13, line 9 and page 19, lines 7-8 emphasized that our research evaluated the ability/performance Canadian fire weather indices using large-scale data.

3. (Page 6, line 15) Why do you use the ($1.875^{\circ} \times 1.92^{\circ}$) NCEP reanalysis product and no other with better spatial resolution?

Calculation of fire weather indices requires a number of input weather variables that are not always available to collect in local weather stations, particular in remote areas. NCEP reanalysis data are available for long time period. The use of this dataset in fire risk management has an important implication to understand the ability of coarse meteorological data in reconstructing historical fire weather as well as quantifying future fire risk since coarse resolution data are often available to users, such as data from NCEP, ECMWF, GEOS-4, and IPCC (see page 19, lines 21-24).

4. (Page 6, lines 23 – 24) Why do the authors "only used fire occurrence (number of fires) to represent of fire activity in relation to fire weather indices in the study area"? Burned area is not also an important aspect of fire activity and the most immediate consequence of fire? In many biomes, including boreal forests, larger burned area are due to a relatively small number of fires. In addition, can you obtain the exact number of fires from the MODIS data?

Our study mainly focused on studying of Canadian fire weather indices in the prediction and monitoring of fire risk and/or fire occurrence in Siberian region. There indices are calculated by weather conditions only and not being used to determine burned area in fire management systems. In fact, area burned (after fire ignition) is influenced by many factors such as local fire-fighting activities and policies, topography, vegetation types in coupling with weather conditions. It has been examined in many studies that (e.g. (Dimitrakopoulos et al., 2011; Tian et al., 2012; Harrington et al., 1983; Flannigan et al., 2005) fire weather indices are highly correlated with fire occurrence but poorly account for variation of burned areas (see page 18, lines 11-24). We don't say that burned area is not an important aspect of fire

activity. It is complicated aspect of fire activity and could not define by fire weather indices only, and thus it is not included in our study.

Active fire MODIS product is reliable remote sensing data on fire occurrence and has been widely used for fire monitoring all around the world (Giglio, 2010; Hantson et al., 2013). In order to enhance the confidence of fire occurrence identifying using MODIS data, we only selected fire pixels with the high confident level (fire-pixel value equals 9 in MOD14A2 product).

5. (Page 6, lines 25 – 27) So, you are saying the number of fires is only dependent on weather conditions? or, can you assure that all human initiated fires were excluded from the analysis? In this case, how was this performed? Please see page 16, lines 8 – 10) in the “Discussion” where is written that “more than 87 % of fires in boreal Russia are human-caused”; I suggest a different/better explanation for the decision of using the MODIS and the “number of fires” as a measure of fire activity.

We are not saying the number of fires is only dependent on weather conditions in these sentence (see our explanation in the above point 4). Weather condition is one of important factors that determine fire risk and fire occurrence. For example, if fuel is in dry condition (strongly depends on weather conditions), fire can occur without human cause. On the other hand, even with human cause, fire cannot occur if fuel contains high moisture content (again, strongly depends on weather conditions). As the application of Canadian fire weather indices, the system is mainly focus on weather conditions to predict and monitor fire risk and fire occurrence. Therefore, as scope of our study we also mainly focused on weather condition representing by fire weather indices to observe fire occurrence pattern in the study area. Page 16, lines 8-10 is to discuss and explain why the pattern of fire occurrence in Siberia if monitored (or identified) by Canadian fire weather system differs from real fire activity defined by MODIS fire occurrence (in this study). This will help (if there are some) fire managers consider application of Canadian fire weather indices to predict and monitor fire risk and fire occurrence in Siberian region. Again, number of fires extracted from MODIS active fire data is reliable enough to understand fire occurrence pattern in the region (see the above explanation).

6. (Page 7, lines 10 – 11) According to the Köppen–Geiger climate classification system “extremely continental” is not a main type of climate (see for example Kottek et al. 2006 or Peel et al. 2007). This is a three letter classification scheme where the first (A to E) define the main type of climate, the second is determined by the precipitation regime and the third by the temperature. The “extremely continental” is a subtype (identified by the third letter “d” of the group D (Continental/microthermal or snow climates), indicative of three or fewer months with mean temperatures above 10 °C and a coldest month temperature below -38°C;

We removed this sentence.

7. (Page 7, lines 16 – 17) In this study, is there any difference between wildfire and forest fire? This sentence may be confusing and should be rewritten;

The area is mainly covered by boreal forest. The sentence has been revised to make it clear.

8. (Page 7, line 19) The title of section 2.2 should be changed because satellite data is not necessarily different from weather data, i.e., weather data may include satellite data;

The section has been changed to “Datasets”

9. (Page 7, lines 20 – 25) The authors should explain how the 8 day MODIS active fire product (MOD14A2) was used in this study, namely to compute the monthly number of fires and to produce, for example, the Table 1;

Extracting number of fires from 8 day MODIS active fire product has been described more in this paragraph.

10. (Page 8, lines 1 – 8) There is some repetition in the introduction; In my opinion, the detailed description of the data and methods should be moved to section 2;

Page 4, lines 11-14 in the introduction very briefly introduced about FWI system. Detailed description of the data and methods to calculate FWI and fire occurrence currently include in section 2 (Materials and methods)

11. (Page 8, lines 9 – 10) The spatial resolution is unnecessarily repeated;

The sentence has been revised to avoid repetition.

12. (Page 8, lines 20 – 23) What is the definitions of burn trend? Why use trend and tendencies in the same sentence? This sentence should be rewritten;

The sentence has been revised

13. (Page 8, line 24 to Page 9, line 16) The FWI system is very well known and described in the literature; if the authors decide to present additional aspects of the indices and codes of the CFFDRS, citations/references are needed; if not the citation to a few studies (already in the list of references) are sufficient;

References have been added to these sentences

14. (Page 9, lines 19 – 24) Repetition;

Sentences in page 8, lines 11-15 have been removed to avoid the repetition.

15. (Page 12, lines 5 – 6) Please, explain the reader why WCS without normalization to the single wavelet power spectrum, this can produce mis-interpreting the relationship between two time series;

One more statement has been added to explain this. For example, if one wavelet power spectrum is locally flat and the other exhibits strong peaks, this can produce peaks in the cross spectrum using WCS, which may have nothing to say about relationship between two time series. More detail can be found at Maraun and Kurths, 2004.

16. (Page 13, lines 11 – 12) What was the test used? The (numerical) results must be presented;

As the requirement of wavelet analysis, time series variable should not be too far from normally distributed. That means it might be not normally distributed. Visual test using histogram is good enough in this case. However, the authors can include the numerical results of normal distribution test.

17. (Page 13, lines 11 – 12) Why? What are the potential consequences/limitations?

Non-normally distributed variables can distort relationships and significance test, which is similar to linear regression. According to (Grinsted et al., 2004), continuous wavelet transform of geophysical time series shows that series far from normally distributed produces rather unreliable and less significant results. In addition, transformation to normally distributed data also helps to remove outliers.

18. (Page 13, lines 18 – 19) Which results are on the basis of this sentence (Table 1, Figure 2, and/or Figure 4)? A mention to any of these Table/Figures must be included?

Table 1 and Figure 2 have been included in the sentence

What are the (mathematical/statistical) definitions of “severe” and “critical”? Without fire statistics for other periods, how can the reader know/confirm that “Wildfires in south central Siberia region were found to be severe for the last 14 years”?

Severe and critical terms used here to describe relative fire occurrence within observed years. The authors will add data and statement to compare with other regions (e.g. boreal forest in North America) to see how severe fire occurrence in Siberia. We don't have data for other periods.

What are the meaning of defining the “critical periods” as “2003–2004, 2006–2008, and 2010–2012”? This means “2003 and 2004; 2006, 2007 and 2008; and 2010, 2011 and 2012” or the transition (some months in 2003 and other months of 2004, ...? The second option cannot be true because of Figure 3 and the following paragraph (page 13, line 24 to page 14, line 3); the first either, because of the results presented in Table 1 and Figure 4 (assuming that the missing values in Table 1 for the months of January, February, November and December are negligible in comparison with the value for the other months). For example, according to this table, both the annual number of fires and burnt area in 2004 (844 fires and 346 km² burnt) were much smaller, just about 20% of the number of fires and 7% of the burnt area in 2002 (3956 fires and 4844 km² burnt), not considered a “critical” year! Results for 2010 are slightly higher but also much smaller than for 2002; why include 2004 in the list of the critical periods but exclude 2013 when occur much more fires and burnt area (970 fires and 1266 km² burnt)? This must be clarified and changes must include the conclusions (page 19, lines 1 – 2);

This has been corrected. Critical periods should be 2002 – 2003 (2002 and 2003), 2006-2008, and 2010-2012. 2004 was excluded from results.

19. (Page 13, lines 19 – 22) Results presented in this sentence cannot be easily drawn solely from Figure 2; According to this figure, the highest value of the number of fires were obtained for 2008 while the highest values of the FWI indices was never on 2008; the year with the second highest number of fires was 2003 and the indices with an higher value in this year are DMC and BUI; most of the indices present higher values in the last years (2010, 2011 and 2012) when, according to Figure 4, the number of fires were only in “relatively” high in 2012 and 2011 but much smaller than in 2003 and 2006; in fact, values

for the great generality of the indices were very small for 2006; Apparently, the indices were only able to rate adequately the fire danger in 2003!

The authors agree that Figure 2 only helps to see the general pattern but not enough to account for how many of fires in one year. As in 2008, the highest number of fire can be observed but this is for 8 days period in May 2008 only. However, the total number of fires in 2008 was lower than other years (e.g. 2003, 2011, and 2012), because number of fires in other 8-days periods lower than the other. Table 1 has been included in this sentence.

20. (Page 13, line 23 to page 14, line 3) What is the number of fires and burnt area in the months not considered in Table 1?

The number of fires and burnt area in the months not considered in Table 1 was 0 as observed from MOD14A2 data. This is out of fire season. Therefore, they are not included in the table 1.

What is the need/objective to define “non-regular” seasons, using the same names of the calendar seasons and/but with different durations (Spring 4 months, summer and winter both with 2 months)? If June was considered a summer month (as usual) the percentages of number of fires will be very different; if these seasons are fire seasons, what was the criteria used to define them?

We used calendar seasons that have been commonly used in Siberian boreal forest from the literature ((Farukh et al., 2009). This is similar to North American boreal forests (Buermann et al., 2013; de Groot et al., 2012). These also based on seasons of vegetation phenology in the study area (Chu and Guo, 2012).

Please see Conclusions (page 19, lines 5 – 6) where the reader may be confused; What is and why was not present and discussed the intra-annual variability of the burnt area? This is particularly important because it seems that there are “large burned areas (> 1000 ha) within the study area”, help to understand the option of “only used fire occurrence (number of fires) to represent of fire activity in relation to fire weather indices in the study area” and help to determines the relevancy of this study and its findings; the reason cannot be because the “correlation between FWI components and burned areas was poor and varied depending on ecozone” (page 18, lines 20 – 21);

As we explained in the points 4 & 5 above, burned area is not mainly driven by fire weather conditions. Our objective is to focus on application of fire weather indices in the prediction and monitoring fire risk as well as fire occurrence in the study area. Analysis of burned area and its driving factors will be presented in another research.

21. (Page 14, lines 1 – 3) “In the primary fire season, May was the most severe month of fire activity accounted for 48 % of total fires during fire season. Two other peaks of fire activity were in July and September annually (Fig. 3)”. For me, it does not make much sense to define 3 consecutive fire seasons (with decreasing “magnitude”), two of them with just 2 months and, in addition, identify fire peaks in these two fire seasons; In my opinion you only have 1 fire season with a prominent peak in May with almost 50% of total number of fires;

Because fire activity strongly relates to weather conditions, 3 consecutive fire seasons were defined in order to see how fire regime changes within a year with respects to weather conditions and vegetation

phenomenon. The authors agree that there is one fire season within a year in which spring fire, summer fire, and autumn fire can be seen as sub- fire seasons. If we compare fire activity inter-annually, then fire season can account for 1. If we compare fire activity intra-annually, then there might be 3 fire seasons with respects to weather/calendar seasons (spring, summer and autumn).

22. (Page 14, lines 4 – 8) I believe that the authors have three options: (1) remove this sentence from the manuscript, (2) include a citations/reference for these results ; or (3) describe the data and the methodology used to obtain these results;

We calculated based on 2000 landcover map. Data and methodology have been added to section 2.

23. (Page 14, lines 9 – 10) “In general, higher number of fires resulted in larger burned area, except for fires in 2007 and 2008 (Fig. 4)” This kind of sentences cannot be accepted! What is the meaning of “In general”? It means in any place of the world? It means that the fires in the study regions have approximately the same size? How can this sentence result from the analysis of Fig. 4? Why the exception of 2007 and 2008? Why not 2002 and 2009?

This sentence results from Fig. 4 and Table 1. This is a relative comparison of fire characteristics among observed years between 2000 and 2013. The term In general has been removed from the sentence, and Table 1 has been added to the sentence.

24. (Page 14, lines 9 – 12) “Visual interpretation of fire activity during this period, almost all fires occurred in the flat and low elevation areas that resulted in the high rate of fire spread and thus larger burned patches even small number of fires”. The authors cannot expect that such a sentence be accepted easily. The reader do not have the possibility to verify the obtained results. Once again the authors have three options: (1) remove this sentence from the manuscript, (2) include a citations/reference for these results; or (3) describe the data and the methodology used to obtain these results; the same type of sentence appear in the discussion (e.g., Page 18, lines 14 – 16);

The authors can add slope and/or elevation map overlaying on burned areas to see how 2007 and 2008 burned areas differed from the other. “During this period” has been changed to between “2007 and 2008”.

25. (Page 14, lines 12 – 15) “Both fire occurrence and burned area data showed a cyclic pattern of about 4–5 years interval in south central Siberia region with the severe fire/burn years in 2003, 2008 and 2012 (Fig. 4)” what was the methodology used to obtain these results? What is the (statistical) significance?

This result derived from visual interpretation of Fig. 4. We can see highest burned area and fire in 2003, 2008, and 2012, lowest in 04-05 and 09-10, showing the cyclic pattern of fire activity and areas burned.

26. (Page 16, lines 8 – 10) For me, it is not clear why the fact that “more than 87 % of fires in boreal Russia are human-caused” is consistent “with the spring-dominated fire season found in this study” even with the potential explanations provided in the Discussion section (Page 16, lines 10 – 16);

That is our discussion and prediction on the relationship between spring-fire activity and causes of fire based on the literature review. It seems existing a relationship between spring fire and human activity.

Further investigation on either number of human-caused fires or number of lightning-caused fire for our study area is necessary to confirm this assumption.

27. (Page 16, line 19) Please present a definition of burn trend which is not shown in Figure 4;

See our explanation on point 25 above. A general pattern of burned area between 2000 and 2013 can be seen as a burn trend for the area.

Tables and figures

28. Table 1 needs much work. It is not clear what is shown. Only after some calculations it is possible to find that the monthly values are of the number of fires; replace “ ” by “ ” ; replace “ ” by “ ” ,

Total or Sum; in fact the intra-annual variability of the burnt area is not shown and the caption should be changed;

More description on the table 1 has been added. E.g. Σ Fire changed to Σ Fire/year; Σ monthly changed to Σ fire/month. More description has been added to the table caption.

29. Please include the latitude and longitude ranges in Figure 1.

The latitude and longitude have been added to Fig. 1

30. Used the same name for the NCEP reanalysis product in both Figure 1 and Figure 2 “reanalysis-2”;

This has been corrected

31. In Figure 3, what is the definition of “Trend of fire occurrence”? Please replace

“Number of fire” by “Number of fires”;

Trend of fire occurrence has been derived from moving average method, showing the trend in time series data. This description has been added into the Figure’s caption.

32. Figure 4 is not necessary because exactly the same information is presented in

Figure 7;

These two figures will be reorganized into one figure.

Technical corrections

1. Do not start a figure caption (e.g., of Figure 2 and Figure 3) with a numeral;

2. Used the same name (“NCEP reanalysis-2”) for the NCEP reanalysis product in the captions of both Figure 1 and Figure 2.

3. To be coherent, please uniform the reference “de Groot et al. 2012” or “De Groot et a. 2012” in the text (line 3, page 4 and line 10, page 16) and in the reference list (page 21, line 4);

4. (Page 7, line 20) Replace “tile h23v03and tile h23v03” by “tile h23v03 and tile h23v03”;

All these have been corrected in the manuscript

References

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