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Hydrology and Earth System Sciences
Discussions

Interactive comment on "Assessing various drought indicators in representing drought in boreal forests in Finland" *by* Y. Gao et al.

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We deeply appreciate referee V. Blauhut for his helpful and valuable comments in improving the readability and clarity of this manuscript. Our point-by-point response to all the comments are listed below, and corresponding modifications have been made for the manuscript. We hope our reply will satisfy the expectation from the referee.

The authors propose a novel comparison of commonly used drought indicators and their potential to indicate extreme drought conditions in order to indicate impact on forest health for Finland. The author therefore tested outcomes of the revised version of the JSBACH model with station data and tested drought indicators on their quality to identify drought events that do have an impact on forestry based on the reference year

of 2006. I highly appreciate the idea of this study to investigate for drought indicator specific thresholds. Nevertheless I think the study could benefit from several revisions in order to increase readability and understanding for the reader. (Please excuse missing reference recommendations, my citing program just broke and I'm on travelling, but in case you want them please contact me) .

My general suggestions are:

If I understood the methods right, the determined drought indicator thresholds indicate when impacts on forest health occur? This is a crucial point, but more detailed information to what the EDF is, what it is based on etc. is missing or not sufficient. To increase the value of this work I suggest to raise the point (emphasize in other part) of 'impacts on forest' health.

Authors response (AR): We agree with the reviewer's comments. It is crucial to explain what EDF is based on. Thus, we have added how we defined EDF in the abstract, introduction, and conclusion parts of the paper. We also added a brief introduction of the forest health observation data in Data section. Please find our revisions in the revised manuscript.

SPI and SPEI are standardized products that are aggregated for different timescales. In your study I do not see the application of this benefit.

AR: Finland is a high latitude country. The growing season in Finland is relatively short due to its climate. In spring, the snowmelt water normally saturates the soil and the rest of it produces runoff. Therefore, SPI/SPEI in longer aggregation period, e.g. 3 months, influenced by the amount of snow could be inappropriate to reflect drought in Finland. The 1 month SPI/SPEI reflects short-term climate conditions, thus it can be related to short-term soil moisture stress, especially during the growing season (World Meteorological Organization, 2012). A time frame of less than 1 month is not recommended as the strong variability in weekly precipitation may lead to erratic behavior in the SPI (Wu et al., 2007). However, the "moving window" of a minimum of 4 weeks

with daily updating is acceptable (World Meteorological Organization, 2012). Also, by using the monthly running SPI/SPEI, we can follow the development of meteorological drought more closely and investigate their relationship with daily variations of soil moisture indicators.

Furthermore I miss a clear definition of the aggregation time applied and chosen as best indicator.

AR: We have tried to improve the clarity of this message in the original section 2.4, P8100 L1-2, as "In this study, daily SMI was used. The SPI, SPEI and SMA were calculated with 4 week (28 days) aggregation time frame, but they were updated every day with running inputs over the 30 year period. Both 4 week aggregation time frame and 30 year study period are considered to be of sufficient duration climatologically under WMO guidelines (World Meteorological Organization, 2012)." The answer for the above comment shows our reasons for choosing this aggregation period. Those reasons are listed in P8102 L3-6 in the discussion paper also. According to the specific comments below, we have added the description of the aggregation time in the Conclusion part of the revised manuscript. Moreover, we have now made our conclusion more clear that SMI is chosen as the best indicator for indicating EDF.

A further potential of your work is the comparison of standardized indicators vs. SMI, which gives you 'real' condition estimates. I suggest to focus more on the different outcomes of these to (two) kind of indicators. As your results show, SMI shows less impacts in northern Finland than SPEI (?). So what is the reason for it? (I guess the standardisation background). Thus I suggest the reader could benefit from a conclusion that states e.g.: thresholds should be region specific, standardized drought indicators may show a drought, but in fact there has not been any impact. . ..Thus we suggest to a) or b)

AR: We have made our conclusion more clear and emphasized the differences between standardized indicators vs. SMI, for example: "To conclude, we recommend

to use SMI to indicate EDFs in boreal forest because it directly represents the plant available soil moisture, which is a synthesized result of the initial soil moisture content, soil properties, as well as climate conditions." and, "In boreal forests in Finland, EDFs indicated by SPEI and SMA often cannot lead to very low soil moisture that could be indicated as EDFs by SMI, due to the high initial soil moisture or presence of peat."

In general I suggest to revise the structure of the study. Methodological parts are found in the introduction, whereas very important applied methodologies are not described. A distinction between results and conclusion might ease the overview for the reader. By now, my feeling is that some important parts are not sufficiently explained and discussed or my benefit from some 'highlighting'.

AR: We have improved the structure of the paper accordingly. This includes: 1) separation of the original Data and Methods into two parts, 2) added a subsection in Data about Forest health observation data, 3) moved the methodological parts in results to Methods part, 4) shortened the methodological parts in introduction and 5) reformulated the Summary and Conclusion part, and make the summary and conclusions distinguishable.

Specific comments:

Abstract:

To increase readability I suggest to shorten the methodological of the abstract to a minimum, but therefore put more emphasize to your results and conclusion.

AR: We agree with the reviewer's comments. The abstract has been reformulated. We have shortened the methodological parts in the abstract and put more emphasize to our results and conclusion. Please find our reformulations in the revised abstract.

8092 27 last sentence: Please rephrase this sentence. Does your results suggest, or not? And: "..,an integrated analysis of projected drought with drought indicators is recommended" is nothing novel, and is not the key conclusion of your study (in my

opinion).

AR: We have clarified our conclusion and made it to be more specific with our study in the abstract: “Therefore, we consider SMI is more appropriate for indicating EDFs in boreal area. The selected EDF thresholds for indicators could be calibrated when there are more forest health observation data available. Furthermore, in the context of future climate scenarios, assessments of EDF risks in northern areas should, in addition to climate data, rely on a land surface model capable of reliable prediction of soil moisture.”

Introduction:

In general I suggest that the introduction would benefit from more homogenized information. For the part of the drought indicators, information is either very general of specific for your application. I suggest that a brief discussion of the benefits of each indicator, examples of application in Finland/ Scandinavia or its monitoring could raise more interest. I suggest it is crucial for the reader to easy grasp the research gap that is intended to be faced with this study. Furthermore, the objectives are a bit lost over the introduction. I suggest to finalize the section of introduction with a small paragraph on the successive objectives of your work.

AR: We have reconstructed the introduction to increase its homogeneity. The research gap and objectives of this study have been emphasized. Please find our revisions in the revised manuscript.

8093 1, very general statement which does not fit the point for either entire Europe and especially not Finland. Please revise.

AR: This sentence has been deleted because we think it does not fit the revised introduction.

8093 17, please revise your references, it is not Veit et al. 2015, it is Blauhut et al. 2015 ;)

AR: Sorry for the mistake! We have corrected this.

8093 23, please provide a reference for the previous sentence

AR: We have added (Hirschi et al., 2011) there.

8094 15, please provide a reference for the previous sentence

AR: We have added (Granier et al., 2007) there.

8094 16, please provide a reference for the previous sentence.

AR: We have revised this sentence as following to make it more precise: “Nevertheless, ground observed soil moisture is limited in time and space (Seneviratne et al., 2010).”

Data and Method:

In prior I suggest to increase the understanding for the reader to split up this paragraphs. I do not see the advantage of having them together. A separate section for methods might increase readability and increase the methods content.

AR: We have split the Data and Method part to improve the readability. We also added a subsection in Data about Forest health observation data and moved the methodological parts in results to Methods part. Please find our revisions in the revised manuscript.

Data:

Study area

Please revise the content of this section. I suggest to reduce the content of the very general (and partly wrong) aspects climatological aspects and focus on the characteristics that drive drought. I like your map information on soil depth. Furthermore I suggest to provide a map for land use as described in CORINE. I guess both information suite on one page.

AR: The general description (P8096 L5-12) about the geographical characteristics of Finland has been removed.

The soil map shows the soil depth that has been used as one surface parameter in JSBACH. Finland is predominantly covered by forests, and we are trying to indicate the extreme drought affecting forest health. Therefore, we consider it is more suitable to show the forest cover fraction, which includes forest related PFTs, instead of the CORINE land use map. We also added the introduction about PFTs and forest cover fraction in the section about JSBACH land surface modelling: “Diversity of vegetation is represented by plant functional types (PFTs). A set of properties are attributed to PFTs with respect to the various processes JSBACH is accounting for.” and, “ Finland is a country predominantly covered by forests. The forest cover fraction over Finland in JSBACH derived according to the Corine land over 2006 data are shown in Fig. 1 (a). ”

You described the composition of species detailed. Please provide information on changes of species compositions over time.

AR: In this study, the land cover distribution is fixed, following Corine land cover 2006. We briefly introduced the peatland forestation happened in the past there prior to the simulated period (P8097 L6-9), for the aim to explain the history of forests located on peatlands. Changes of species composition, that in Finland are controlled by intensive forestry, is not central. To improve the clarity of the text, we reworded the sentence.

Observational data I’m missing explicit information on forest health. What is reported? Who and how. I recommend to the author to give more attention to this data, since you base your results on it.

AR: We have added a brief introduction of the forest health observation data as Section 2.3.

I would like to get more information on the choice of ‘summer’ month? Drought impacts on forestry are not only driven by summer month climate conditions. Especially early year conditions do have great impact on leaf production? Furthermore is the effect of JSBACH land surface modelling I’m not familiar with the details of the JSBACH model.

I feel confident with the amount of information here.

AR: The growing season is relatively short in Finland due to its climate. In spring, the snowmelt water often saturates the soil and the rest of it produces runoff. Drought does not normally take place in spring in Finland. The two multiyear site soil moisture observation data series used in this study – Hyytiälä and Sodankylä – also imply filling of the soil water storages during snow melt period by reaching maximum values is each spring. Therefore, we chose summer months for our analysis.

To make the title to be more clear, we have modified it to “ Assessing various drought indicators in representing summer drought in boreal forests in Finland”. However, the JSBACH land surface model simulations are continuous throughout the 30 year period and thus the spring weather is accounted for in the gradual processes such as leaf development.

8099 16, is Figure 1 really showing soil types? I’m doubting on the terminology here.

AR: Indeed, the terminology here was a bit simplified as mineral soil can be classified according to the ratio of soil particle sizes, such as sandy, loamy, clay, silt, and so on, while peat is a sub-class of organic soil. However, the main differences of soil parameters in JSBACH model exist between mineral and peat soils. In Finland, the mineral soil area is mainly covered with one soil type - loamy sand, as described in the FAO soil type distribution map (FAO/UNESCO, 1971-1981). Therefore, in this study, soil types over Finland is generally introduced with mineral soil and peat, but not with the detailed soil types.

In the caption of Fig. 1, “ the soil type distribution” has been changed to be “the peatland and mineral soil distribution”.

Drought indicators From your description I assume that you decided on some kind of monthly values with running mean inputs. I would appreciate if you could explain your decision for this (at least for SPI and SPEI) rather short aggregation periods. Diverse

authors suggest longer aggregation periods (full vegetation period) to indicate drought effects on vegetation, especially forestry.

AR: This is the same question with the general question 2. Please find our answer there.

Furthermore I recommend to put a more emphasis to the difference between 'normal' and standardised indicators.

AR: We have added the following content in Section 3.2 to emphasis the differences between normalized and standardized indicators: "The SPI, SPEI and SMA are standardized indicators that show the degree of anomalies to long-term means over the aggregation period, while SMI describes the instantaneous soil moisture status normalized with total soil moisture storage available to plants. In this study, daily SMI was used. The SPI, SPEI and SMA were calculated with 4 week (28 days) aggregation time frame, but they were updated every day with running inputs over the 30 year period. Both 4 week aggregation time frame and 30 year study period are considered to be of sufficient duration climatologically under WMO guidelines (World Meteorological Organization, 2012)."

8102 16, 'The SPEI is similar to SPI', please rephrase and be more specific.

AR: We have rephrased this section. Please find our modifications in section 3.2.4.

8102 22, " a wide range of climates" , I recommend to give some indication of its application for northern climates, since SPEI was 'more less' built for dry climates.

AR: SPEI is a globally applicable indicator (Vicente-Serrano et al., 2010). "a wide range of climates" here refers to the FAO-56 Penman-Monteith equation. We have rephrased this sentence to make it more clear: "In this work, ET0 was calculated according to the FAO-56 Penman–Monteith equation (Allen et al., 1994; Beguería and Vicente-Serrano, 2013), which is predominately a physical-based method and has been tested over a wide range of climates (Ventura et al., 1999; López-Urrea et al., 2006). "

Results:

8103 'Simulated soil moisture corresponds well..', I recommend not to brush up the results of the model too much. The model performance well, but underestimation and delay or absences (2006) of signals should be explored to guarantee a full understanding of the underlying model processes.

AR: We reformulated this sentence to tone down the confirmation with model data, "In general, the timing of dry spells in summer in most of the years of the simulated soil moisture corresponded well with the observations at the three sites (Fig. 2).".

In this study, we are aiming to assess different drought indicators for their ability to represent drought in boreal forests in Finland. We used JSBACH soil moisture as the input for soil moisture indicators (SMI and SMA). Thus, we compared the dynamics of simulated soil moisture with the observations rather than deeply explore the reasons for the deficiencies in the model.

8103 23-28, Here you indicate the usage of two different soil type classifications, why did you not consider to harmonize these input?

AR: For the regional simulation, soil type in an individual grid box is homogenized according the soil type with the highest coverage in the grid box. For the site simulation, the soil type at the site is used for better agreement with the measurement data. The processes of heterogeneous or stratified soil types in a model grid box can not be simulated by JSBACH at present. This could be a point for future model development.

8104 25, '. . . good agreement', Please explain the 'good' agreement, this might become discussable.

AR: We reformulated the original sentence to be, "Overall, the timing of summer dry spells and the winter characteristics of the observed soil moisture at the three sites are well captured by the simulated soil moisture, although the simulated soil moisture shows larger amplitudes and a faster response to changes in water inputs."

8105 9 ‘grid boxes’, please rephrase

AR: We have changed “gridboxes” to “grid boxes” throughout the paper.

8106 1, ‘(data no shown)’, it might increase the understanding for the reader to add this data as an appendix

AR: We will provide those regional results as figures in the supplement.

8106 23, ‘relatively higher change’, relative to what?

AR: We deleted the inappropriate “relatively” in the sentence.

8107 23-5, This chapter was a bit confusing for me. Quiring explicitly stated that thresholds should be region specific, hence I wonder why you did not separate between at least North and South. Furthermore I do not understand the reason of 2% of SPEI, since it already is standardised. If you derive different values for North and South you probably have some noise in your data. By definition, it should be equal, everywhere, for each grid cell.

AR: We have derived the thresholds of SPEI for southern and northern Finland. They are very close, -1.843 for southern Finland and -1.857 for northern Finland. Thus, we decided to use the averaged thresholds, -1.85, for Finland. For SMI and SMA, their thresholds were derived according to the available forest observation data, which mainly showed forest damages over southern Finland.

Quiring (2009) showed that even though the SPI is a standardized index, the objective drought thresholds derived according to percentiles vary spatially and differ from those standard thresholds. The variation of drought thresholds among different areas increases slightly with drought severity because the lowest SPI values are influenced by a small number of extreme events. This also suits for SPEI, which is similar to SPI mathematically.

8109 5, ‘shallow soils’. . .maybe it is just personal interest, but especially these ‘shal-

low’ soils are highly interesting.

AR: Shallow soil have less storage room for water, therefore those areas are easier dried out or saturated than other ’normal’ areas, and their inclusion would distort the statistics and would not really present the frequency of extreme droughts. Therefore, we decided to exclude the shallow soil area in accounting the extreme drought indicated by drought indicators.

Despite the fact that I appreciate the approach, I’m missing on some discussion of different drought events. By now you base your results on the 2006 events? I know your data is rather limited for this, but it is a point that should clearly be raised, since these thresholds will vary enormous, depending on the event. Please also consider to point out the potential of this kind of analyses for future work.

AR: We have added this point in the discussion about future work, “In this study, the EDF thresholds for those indicators were selected only according to the statistics of the forest health observation in 2006. This might induce some uncertainties when they are used for future predictions of EDFs. The method for selecting EDF thresholds for drought indicators could be adopted and the EDF thresholds could be calibrated, when there are more observation data about forest damages induced by drought available.”.

In total I miss some closing overall discussion. For me it is still not clear if it is better to use standardised indicators or SMI, and why is it so? Does the standardised show higher percentage of EDF because of it is a better indicator or because it is standardised and thus and threshold that was derived for southern Finland cannot be used for northern Finland .

AR: We have added some closing overall discussion in this part, “Overall, the SMI is considered to be more capable in indicating EDFs because it directly reflects the plant available soil moisture. In boreal forests in Finland, EDFs indicated by SPEI and SMA often cannot lead to very low soil moisture that could be indicated as EDFs by SMI, due to the high initial soil moisture or presence of peat.”.

Conclusion:

In order to increase the understanding for 'brief readers' I recommend to give a little warp up of why you decided for the 2006 event and what the EDF is. I recommend to stay more close to research gaps filled (if there has been any) and objectives faced with in the work. I miss some more clear recommendations. What did you do in general (no numbers or results needed here.). What did your work enhance for the drought and forestry science. In order to open your work to a broader audience I recommend to phrase some line on: What are your recommendations for future work, with regard to modelling, monitoring of climate and vegetation conditions. Impact monitoring? → how to improve all that?

AR:We have revised the conclusion according to this general comment and the specific comments below. Please read our revisions in the revised manuscript.

8110 1, '1', good agreement, is it really good? Then please provide indication for that in the results

AR: The is the same comments with 8104 25. We have rephrased this sentence.

8110 9, to increase readability, please repeat the aggregation time of SPI and SPEI

AR: We have repeated this information in the conclusion part.

8110 21, for me the question that should be answered here (or maybe better more explicit in discussion) is does SMI over or under estimate EDF, Does a higher amount of EDF days indicate a higher sensitivity or is it 'just' a wrong signal (due to standardisation) → again, please discuss the differences between the kind of indicators.

AR: We have revised this part to make our conclusion more clear, as "To conclude, we recommend to use SMI to indicate EDFs in boreal forest because it directly represents the plant available soil moisture, which is a synthesized result of the initial soil moisture content, soil properties, as well as climate conditions.". The differences between the kind of indicators has also been discussed in the first paragraph of the Conclusion

section.

8111 7, Good. Please also raise also consider to mention that indicators without a linkage to past impacts are 'meaningless' and only indicate climate conditions, whereas the majority is interested in when impacts will happen etc. Thus, a better impact monitoring is essential.

AR: We have added the discussions regarding to this comments in the last two paragraphs in the revised conclusion.

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Please also note the supplement to this comment:
http://www.hydrol-earth-syst-sci-discuss.net/12/C5026/2015/hessd-12-C5026-2015-supplement.pdf

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