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Hydrology and Earth System Sciences Discussions

Interactive comment on "Long term variability of the annual hydrological regime and sensitivity to temperature phase shifts in Saxony/Germany" *by* M. Renner and C. Bernhofer

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The authors ahve made a thorough revision of the manuscript based on the critical and extensive reviews. In particular, the review of Boris Orlowsky has been very constructive for the final shape of the manuscript and is greatly acknowledged.

The paper is still a bit lengthy due to the chosen language style and some redundancy in the text. However, it can be accepted for HESS when a couple of remaining issues and technical corrections are applied:

Remaining issues:

- p3-l27: "sensitivity": unclear sensitivity of what variable with respect to what other quantity is implied here
- p4-l5: "Generally": this is not consistent with several analyses published in literature, like the one by Gedney et al (Nature 2006)
- p4-l21: do you mean the change of the variability of the annual cycle?
- p6-l6: already here I can intuitiviely feel that changes in a ratio are generally more emphasised than changes in the terms of a ratio. I think you should put a general consideration of this feature here, and reflect on it later in the text (see below)
- p6-l19: you say "filter the annual cycle from the data", but at this point it is not clear whether you will work with the filtered signal or with the residual that is left after removing the annual cycle
- p7-l9: I know that Stine et al (2009) has been critized. Please check the recent literature and refer to this criticism
- p7-l13: what is "demeaned"?
- p7-l25: "better": I don't see why this is better. RR contains all kinds of memory effects, certainly when calculated over subseasonal time scales. This may lead to low correlations between R and P.
- p8-l13: does ϕ refer to the peak of the cosine function?
- p9-l9: "large difference in some years": from this table it is already clear that $Q_{50} > \phi_{RR}$, but that (and the fact that ϕ is less variable than Q_{50}) is trivial given the fact that $RR \neq R$."
- p10-l20: it is unclear over what time interval CUSUM is calulcated. Apparently from the beginning of the record. Does this make the method sensitive to the actual starting date?

- p10-l20: CUSUM is *not* a process, but a statistical variable. Please delete the word "process" from *all* corresponding places in the text and figures (including axis labels in e.g. fig 6 and fig 10)
- p11-l21: what is C_i?
- fig 2: why don't you show the 4 elevation groups?
- p15-l11: "One explanation of this behaviour": I find this a strange argument. From the very beginning it is already clear that $R \neq RR$. So you need to put the argument in the next paragraph (l15-l16) up front, and add a discussion of the implications of the fact that $R \neq$RR.
- p16-l2: Unclear which year-to-year varibility you mean. I would say that the low elevation catchments have a higher σ. The comparison of high and low basins is limited to the change after 1960. However, also before 1940 the differences between the elevation bands were smaller. You should discuss this!
- p17-l3: explain what "positive" and "negative" shifts are (positive means delayed, negative means earlier)
- p17, discussion of fig 8: it appears that it is *not* ϕ_T that is the relevant variable here characterizing the different years, but the plain negative temperature anomaly during Jan-May. I think a lot more explained variance could possibly obtained when correlating RR to this quantity rather than ϕ_T. Please discuss.
- p20-l13: I find it strange that the low frequency behavious is not influenced by the change in station density, given its dependence on the Jan-May temperature anomaly
- p20-l24: I cannot follow the "explanation" and this sentence "...there is no limitation of winter precipitation"

- p21-l7 (and abstract and p24-l15): I cannot understand why a change in aerosol and the associated shortwave radiation change can lead to a *sudden* change of the hydrological regime. My feeling is that these air pollution changes occur gradually, not sudden. Please comment!
- p21-l20: the cyclic behaviour is unlikely to be affected, but CUSUM is designed to pick up this kind of changes. Please comment.
- -l26: unclear what "differences" and "averaged series" are implied here
- p22-l16: "estimates" of what?
- p23-l26: what do you mean by "linear effect"?
- p24-l19: "demonstrated": this demonstration (of the mountain effect) is not clear to me
- -l24: "...predictability ... may decrease": why? Lower snow amounts may well be associated with an improved predictability of stream flow

Technical corrections:

- p2-l3: "advanced timing" → "earlier seasonal peak of surface temperature"
- -l12: rephrase as "...to both mainly pluvial river basins and snow melt..."
- -l17: "as well as" → "and"
- -l21: delete ","
- -l22: rephrase as "While the timing of temperature increase in spring shifted backwards by 4 days..."

- p3-l9: intert "early" after "winter and"
- -l17: delete ","
- -l20: "has" → "have"
- p4-l11: "effect" → "affect"
- -l19: move "e.g. warm spells ... precipitation" to after "synoptic events"
- section 1.3: mention to which major river system the studied catchments belong (Elbe?)
- p5-l26: insert "and trends" after "variability"
- p6,l13: insert "mean" after "annual"
- p6-l22: "the" → "a"
- p8-l8: delete "as grey line": line styles etc are described in the figure caption, not in the main text
- -l11: same for "are depicted as bold blue line and are" and "as dash dotted line"
- -l16: delete "To filter the annual cycle signal"
- -l20: "with" → "when"
- -l25: delete "Then". Rephrase as "...date is defined as the day that 50
- p10-l2: rephrase as "$\alpha_0 = atan(C2/C1)$, where $C1$ and $C2$ are the regression coefficients derived using ordinary least squares from the expression:"

- p11-l5: rephrase as "...test statistic is a threshold level (dependent on the chosen significance level) that needs to be crossed by the CUSUM estimate to indicate a significant deviation from stationarity"
- -l8: "boundary lines" → "threshold levels"
- -l13: delete ","
- -l25: rephrase as "If the process under consideration changes positively, the residuals are negative and a negative CUSUM peak is shown".
- p12-l10: "how this was done" → "of these processing steps"
- -l19: delete ","
- p13-l22: put "as an example" at beginning of sentence
- p14-l3: insert "by this fit" after "explained"
- next sentence": delete "Compared to RR_3" and add "of RR_3" after "variability"
- p14-l5 and l5 and l12 and l18: delete ","
- -l14: "1-1" → "1:1"
- -l26: delete "Then"
- p15-l8: delete "in average timing"
- p15-l15: delete ","
- -l25: bring "The shaded band ... group mean" to the caption of the figure.
- p16-l2: "has been" → "is"

- -l3: rephrase as "In contrast to the low basins, there is trend towards earlier timing in the higher basins since the late 1960s". Delete "Lower basins do not show... noted"
- -l5: delete "The employed approach ...individual months."
- -l8: rephrase as "...while decreasing discharge is observed from April...". Delete "From the perspective of an annual cycle"
- -l19: delete "been"
- -l21 and l26: delete ","
- p17-l6: delete "it is recommended ... are required": this is a conclusion/discussion item, not appropriate here.
- -l8: -l8: delete "would"
- -l11: move this sentence "A standard ... runoff" in between "Thomson, 1995)" and "So,..."
- -l17: insert "between the basin groups" after "difference"
- -l19: insert "positive" before "linear"
- -l25: insert "also" before "is shown", and delete "as an orange band... values"
- p18-l2: start new sentence at "However"
- p18-l8: delete "Differences between ... For display in Fig 8" and "have been selected"
- -l11: "compared to" → "than in"

- -l14: delete "And"
- p19-l4 and l5 and l26: delete ","
- -l19: Rephrase as "Winter average snow depths and snow cover are poorly correlated to the annual phase of runoff. For the basin Lichtenwalde and station data at Fichtelberg, ρ_{c-l} is not very high and ... duration). However, the average snow depth in March"
- p20-l2: "delete second "," and "if" → "whether"
- -l3 and l7: insert "mean" after "annual"
- -l5: delete "process"
- -l7: "graph" → "range"
- -l15: insert "(Fig 6)" after "runoff ratio"
- p20-l23: delete ","
- p21-l2+3: delete "as there are ... management": out of scope here
- p21-l3, l5: delete ","
- -l6: delete "see e.g."
- p21-l16: delete "When dealing ... into play"
- -l20: insert "series at a given location" after "mean", and add "systematically" at the end of the sentence.
- p22-l1: "Beside" → "Apart from"
- -l8: "evaluated" → "quantified" and "by looking at" → "by calculating"

- -l13: "Last" → "Finally" and delete ","
- -l14: delete "set" and rephrase following as "The range within a group is a measure of the accuracy of our estimates. As these ranges were generally smaller thatn the temporal variability, we can conclude that the averaging method was robust."
- -l26: "and which only requires" → "of"
- p23-l4: rephrase as "A climatology of the timing of the dimensionless runoff ratio (RR)"
- -l10: rephrase as "...we observed a shift of peak RR values towards..."
- -l15: "than" → "as"
- -l19: delete "certain range of" and add "between elevation groups" at end of sentence.
- -l21: "in" → "at"
- -l22: rephrase as "As expected, the annual timing of peak temperature..."
- -l27: delete ","
- p24-l2: insert "of RR" after "variability"
- -l3: delete "The evaluation ... clear, that"
- -l5: "part" → "fraction"
- -l6: "frequent" → "frequency"
- -l19: delete ","

- -l26: rephrase as "This underlines..."
- Fig 2: add "White catchments are not gauged". The (black) bold numbers in this figure are difficult to read.
- Fig 5: Move last sentence of caption "All other basins ... both groups" to the main text.
- Fig 6: The quantity on the Y-axis is unclear. It is not a process, but some kind of statistical measure. What is it, and what units does it have?
- Fig 7: Rephrase second sentence as "Orange shading: the range ...of all basins (units on right axis).". You refer to "basin temperature" here but it is unclear what basins are actually implied.
- Fig 8: Explain what you mean with "without outliers". I think you mean "4th" quartile instead of "3rd"
- Fig 10: delete "The CUSUM ..different time series". This does not belong in a figure caption.

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