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Hydrology and Earth System Sciences
Discussions

Interactive comment on "Attribution of high resolution streamflow trends in Western Austria – an approach based on climate and discharge station data" *by* C. Kormann et al.

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The manuscript presents a trend analysis in hydroclimatic variables in Western Austria, and gives plausible explanations to changes in streamflow. The methods are good and plenty. I particularly liked the idea of trend timing, used in conjunction with other classical trend analysis methods. The topic is within the scope of HESS. But I have some serious criticisms concerning the manuscript.

I refer to the main drawbacks of the manuscript in the "General comments" section (ranked by importance).

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Interactive Discussion

Discussion Paper

I also have some specific comments that I would like the authors to address. However, I don't consider them mandatory except those related to the general comments. Some are mere suggestions, corrections, or things that might need better clarification.

I consider that the paper needs a major revision, focusing on solving the main four criticisms mentioned below.

GENERAL COMMENTS

1) A major problem is that the manuscript is overlapping with another paper written by three of the authors: Kormann C, Francke T, Bronstert A (2014) Detection of regional climate change effects on alpine hydrology by daily resolution trend analysis in Tyrol, Austria, J Water Clim Change (in press). Some results are simply duplicated: that paper deals with the very same region, some methods are identical, e.g., Mann-Kendall test, Sen's slope, 30-day moving average (30DMA), and the data series are quite the same (except that, in that paper, longer intervals were also considered); the effect of altitude on trend timing and magnitude is also discussed; some figures are similar, too. This affects the originality of the present manuscript (even if the authors write that one manuscript is only limited to trend "interpretation", while this one deals with trend "attribution").

2) The introduction lacks a proper literature review on streamflow trends in the region, and contains some statements that are misleading or false. I think this part has to be rewritten.

3) The streamflow data in particular have to be better described. Are the data series from independent basins? Is there any nested basin? A detailed map containing the river network and the dams and water withdrawals is necessary. A homogeneity test is recommendable in order to check for eventual anthropogenic influence on such small basins.

4) Finally, I think a paper dealing with trend attribution should have an in-depth, stand-

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alone Discussions section.

SPECIFIC COMMENTS AND CORRECTIONS

Slide 6883, lines 4-8: You write that temperature increase "is at least twice as strong in mountainous areas compared to the global average (Brunetti et al., 2009)". The statement in Brunetti et al. (2009) does not refer to the global average, but to the lower-elevated areas within the (same) HISTALP dataset. On line 8, I suggest to replace "." with ";"

Slide 6883, lines 12-13: Your statement "Although the credibility of observations is far stronger than that of the model results, only a few studies analyse trends in historical data." is simply not true. There are plenty of studies on with streamflow trends. See for example Stahl et al. (2010) for a comprehensive review on streamflow trend studies in Europe until 2010. There are many others after 2010 as well. For a global view, see Dai et al. (2009). For other hypotheses on hydrologic responses to climate change, see Jones (2011).

Slide 6883, lines 17-18: You write: "A lot of trend studies in Central Europe did not find significant changes in the water cycle (cf. Pekarova et al., 2006), which has also been reported about trend studies in alpine regions (Viviroli et al., 2011)." The phrase is misleading. Neither Pekarova et al. (2006), nor Viviroli et al. (2011) reported that. The paper of Pekarova et al. (2006) refers to 18 large rivers (10'000 to 1'380'000 km^2) in Europe, out of which 11 are in Central and Western Europe. The paper was published in 2006, before the vast majority of papers on streamflow trends in several European countries came out.

Slide 6883, lines 24-26: I think you are too harsh when claiming that studies based on indicators like centre of volume or annual peak flow day "should be revised".

Slide 6884, lines 25-27: You write "trends used for correlation analyses were mainly derived from annual or seasonal (3-monthly) totals (e.g. Birsan et al., 2005)". In Birsan

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et al. (2005), minimum, maximum and all deciles (i.e., 10th. 20th ... 90th percentiles) of the mean daily streamflow were involved in the correlation analysis, on a seasonal basis. Please rephrase (or remove the reference).

Slide 6885, lines 14-17: You write that the objectives of the study are: "(1) to explain the spatially incoherent streamflow trends in Alpine regions based on annual sums; (2) to find drivers of streamflow trends in these areas, and finally (3) to attribute the streamflow trends in the study region with a high level of credibility." Why do you think the streamflow trends in Alpine regions in general are incoherent? I suggest rewriting the objectives of the paper, highlighting the value of the study, and clearly pointing out the differences between this manuscript and Kormann et al., 2014 (in press). The order of the objectives seems a bit strange, too: the 1st and 2nd objectives refer to interpretation of streamflow trends in Alpine regions in general, while the 3rd refers to the study area in particular; the 2nd objective seems a generalization of the 3rd. To me, the main purpose of the paper is to explain (physically-wise), the streamflow changes in Western Austria.

Slide 6885, line 18: I think it is Kormann et al., 2014 instead of 2013.

Slide 6885, lines 24-26: You write that Kormann et al. stated that "the timing of daily trends (i.e. the day of year when a trend turns up) potentially is a more robust measure than trend magnitude". Measure of what? Do you mean it could be a better indicator of change? The expressions "stated" and "potentially is" do not fit well together. A statement refers to a clear and sure affirmation. Maybe you could change "stated" with "concluded" or some other verb.

Slide 6886, lines 26-27 "In the present study, we assume that precipitation has no trend." This is not really an assumption, since you already did a trend analysis of precipitation in Kormann et al (2014) and found no significant trends.

Slide 6886, lines 5-6: You should provide a more detailed description of the region of study and its particularities, rather than referring to a paper from a low-level (closed-

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access) journal. Please indicate the exact elevation range.

Slide 6886, line 9: Are there any nested basins?

Slide 6886, lines 24-25: You write: "snow height changes have a much stronger effect on streamflow than those of snowfall". Please clarify. I guess you refer to the decreases in snow height in particular, as they translate into snowmelt.

Slide 6887, lines 14-15: You write that "the present analysis was carried out for the period 1980 to 2010". However, a 31-year period is close to the limits of acceptability for a streamflow trend analysis. Salas (1993) even recommends at least 40 years of data records. Longer intervals should also be considered – especially when concerned about streamflow attribution –, even if the number of gauging stations is small. As far as I noticed, there are at least 10 stations with records from 1950, according to Kormann et al. (2014). Also, runoff records might contain large scale periodic behaviour (e.g., Pekarova et al., 2003), and trend analyses should always be conducted on periods that span full cycles of this process if it exists.

Slide 6887, lines 20-21: You should relate the storage capacity of smaller dams to the basin area. The fact that the storage volume of a small dam "is very limited compared to that of large dams" is quite obvious, but that does not necessarily imply "that the impacts on the seasonal discharge behaviour are very limited as well". There are indeed a lot of small hydro power plants in the region. I suggest (at least) adding a column Table 1 with the total storage volume of upstream dams. I think this is extremely important since 20 out of 32 basins have a drainage area between 9 and 100 km2.

Slide 6888, line 8; Slide 6889, line 6; Slide 6909, line 6: Helsel (not Hensel).

Slide 6890, Section 3.2.1: What is the rationale for choosing a 30-day interval as moving average? That way you are in fact analysing monthly values, centred on each day of the year, i.e., 365 times for each station. Please cite Kim and Jain (2010) who used a similar approach, but with a 3-day moving average.

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TABLES AND FIGURES

Table 1. In the caption, replace "watersheds" with "gauging stations".

Table 2. I suggest showing plots, rather than show correlation coefficients – see Figure 2.1 from Helsel and Hirsch (1992), available at (page 18): http://pubs.usgs.gov/twri/twri4a3/pdf/twri4a3-new.pdf.

Figure 1 should be redone. Please make a clear map with the river basins, the river network, and also including the main anthropogenic interventions (hydropower plants, water withdrawals, etc. There is no need for a km bar if Lat / Lon coordinates are present. Please make use of colours.

Figure 2. Please clarify in the caption what "limits of minimal detectable trends" means.

Figures 3, 5 and 7. The "z axis" mentioned in the figure legend does not exist (these are 2D pots). Please just refer to colour legend only.

Figure 8. I suggest removing the word seasonal from the caption ("original seasonal hydrograph"). Is the earlier snowmelt the only cause of streamflow increase in March to mid-April? Isn't there also an increase in the rain/snow ratio? The figure seems to belong to a very small catchment, looking at the minimum and maximum streamflow. Also, the two volumes are not the same.

Figures 8 and 9 could be merged. It is not clear to me why you didn't plot the REAL hydrographs – for a handful of basins, at different elevations or with different glacier coverage.

MENTIONED REFERENCES:

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