EUROPEAN COMMISSION
JOINT RESEARCH CENTRE
Institute for Environment and Sustainability
Climate Risk Management Unit

To the Editor of the *Hydrology and Earth System Sciences*
Bart van den Hurk
KNMI, Atmospheric Research
P.O. Box 201
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Netherlands

Ispra, 29 October 2013

Dear Dr. van den Hurk,
Please find enclosed an electronic copy of the revised manuscript (hess-2013-378) entitled:

Ensemble projections of future streamflow droughts in Europe by G. Forzieri, L. Feyen, R. Rojas, M. Flörke, F. Wimmer and A. Bianchi

We have revised our manuscript in accordance with the comments and suggestions received from two reviewers. A 'response-to-reviewer' document is provided along with this revised submission. We believe we have properly addressed all concerns and added the necessary material to the text and figures to strengthen our manuscript. The material contained in this manuscript is not under consideration in any other publication.

Please let me know if I should provide any additional information. I look forward to your response.

Kind regards,

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Responses to comments on "Ensemble projections of future streamflow droughts in Europe" (hess-2013-378)

G. Forzieri, L. Feyen, R. Rojas, M. Flörke, F. Wimmer and A. Bianchi

Revised for *Hydrology and Earth System Sciences*

Please consider that corrections are marked in red fonts in the revised document and sentences in "Response and Actions Taken" (see right field in the following tables) marked in italic are part of the revised manuscript.

Responses to the first Referee's report (Anonymous Referee #1, report received and published on HESSD 3 September 2013)

Referee Comment	Response and Actions Taken
This is a nice study dealing with the evolution of lowflows in Europe until the end of the century. I think this topic is very important as water scarcity is projected to aggravate with climate warming. Therefore, an accurate assessment of temporal and spatial patterns of the respective changes is of crucial importance to local decision makers. I especially like this study as it also assesses several sources of uncertainties of the lowflow projections and hence their robustness, which is also a critical information for decision makers. <u>General comments:</u> The paper needs only minor revisions. It is nicely written and well structured. The presentation of the results is very clear and easy to follow and to understand.	We thank the reviewer for his/her positive evaluation and appreciation of our work, as well as for the constructive comments and valuable suggestions to further improve the manuscript.
page 10720 line 3: change "global change" to "climate change"	According to the reviewer's suggestion, we have corrected the text in the revised manuscript.
page 10720 line 23: remove "virtually" –> Droughts (if defined as *comparatively* dry conditions can occur everywhere)	According to the reviewer's suggestion, we have corrected the text in the revised manuscript.
page 10720 lines 24-26: mention increased ET as another potential cause of droughts	According to the reviewer's suggestion, we have included in the revised manuscript the increased ET demand as potential cause of drought.
page 10727 lines 17-18: this is an important assumption, since I could imagine that during dry periods (weeks-months) when water availablity is low anyway, the demand may increase even stronger than on the annual average –	We agree with the reviewer, the seasonal dynamics of water uses – in combination with the natural variability of water availability - may play a critical role in intensifying drought conditions, especially in dry periods.

> this would mean the water scarcity may be even more intensified by human water use, especially during dry conditions	While water consumption for the domestic, energy production, and manufacturing sectors can be reasonably considered constant within the year (Aus der Beek et al., 2010; Flörke et al., 2012; Schaldach et al. 2012; Flörke et al., 2013) withdrawals for agricultural irrigation may present strong seasonal fluctuations. Irrigated crops usually require more water during higher temperature months (dryer periods) to sustain photosynthetic activity. The seasonal variability of agricultural water use consumptions is taken into account into WaterGAP and properly downscaled to the LISFLOOD daily temporal resolution. We have described this in the Methodology (Section 2.1. and 2.2.). Intensification of droughts due to seasonal water demand for water irrigation is evident over Mediterranean regions. *Water use abstraction will exacerbate minimum low flow conditions by ca. 10-30% over the Mediterranean regions, especially where maximum rates of seasonal water demand of irrigated crops overlaps with drier periods (see e.g. stations Seros, Lugo, Ponte Lago and Beaucaire in Figure 6).* We have emphasized the concept expressed by the reviewer in Section 3.3. of the revised manuscript when interpreting the results.
page 10734 lines 1-3: Please explain.	*Control climate simulations do not reproduce the historical weather of the 1961–1990 period, but only the average climate conditions. This does not allow a day-to-day or event-to-event comparison. Instead, we evaluate the accuracy of the LISFLOOD simulations by comparing observed and simulated low-flow indices over 1961-1990 through statistical measures.* We have clarified this in the revised manuscript.
Would the hydrological model perform similarly well if plain daily streamflows would be considered instead of 7 day average minimum flows?	The use of the 7-day moving average on the original daily discharge time series serves to reduce short-term fluctuations. This approach is largely applied for the analysis of the low-flow indices to focus on the general behavior of data (Tallaksen and van Lanen, 2004). We did not quantify the accuracy of LISFLOOD in reproducing low-flow conditions in the case of daily streamflow discharges (without the 7-day moving average). However, we retain that results could be negatively affected by day-to-day flow variations, which are often arbitrary or artificial in low-flow periods (Lehner et al., 2006), and would not reproduce properly the dynamics of streamflow droughts. We have clarified this in the revised manuscript (see Section 2.3.).
page 10740 line 14: replace "more rare" with "extreme"	According to the reviewer's suggestion, we have corrected the text in the revised manuscript.

page 10740 lines 15-19: I cannot follow this argumentation. (I find the explanation on page 10744 lines 4-11 easier to understand)	We have rephrased this part of the revised manuscript as in the following: *In North-eastern regions summer and to a lesser extent also autumn precipitation is projected to rise, resulting in subsurface storages that are relatively larger at the start of the frost season. The extreme or very rare minimum flows are therefore expected to show a relative increase that is less pronounced than for more moderate low flow conditions.*
page 10745 line 14: replace "Balkans" with "Balkan"	According to the reviewer's suggestion, we have corrected the text in the revised manuscript.
page 10749 line 6-7: why 60-38% instead of 38-60%?	According to the reviewer's suggestion, we have corrected the text in the revised manuscript.
page 10750 line 5: replace "southern most" with "southernmost"	According to the reviewer's suggestion, we have corrected the text in the revised manuscript.
Figure 1: Is there no water management in the considered catchments? Or do you account for this in the model to achieve such good agreement with observations?	We have not taken into account in the modeling setup water management practices. In particular, *we recognize the potential importance of reservoirs and flow regulation for hydrological low-flow analysis, particularly in smaller catchments. This is relevant especially in light of the increasing number of reservoirs becoming operational in the catchments during last decades (Svensson et al., 2005). However, such structures have not been implemented in our assessment due to the lack of suitable information on dams, artificial reservoirs and their current and future operation.* We have better emphasized this in the modeling setup in Section 2.2. Hydrological modelling. Even if LISFLOOD generally shows good performances in reproducing streamflow droughts, the afore-mentioned modeling limitations may partially explain strong deviations between simulated and observed low flow statistics at some stations, a behavior that is more pronounced with decreasing catchment size (see Section 3.1.).
Figures 9&13: replace "80s" with "2080s"	According to the reviewer's suggestion, we have corrected the labels in the figures of the revised manuscript.
	We believe we have properly addressed all concerns and added the necessary material to the text and figures in order to strengthen our manuscript. We thank the reviewer for his/her constructive comments.