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Interactive comment on "Future hydrological extremes: the uncertainty from multiple global climate and global hydrological models" *by* I. Giuntoli et al.

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Anonymous Referee 4 Received and published: 3 March 2015

General Comments The authors present a study that investigates the projected changes in hydrological extremes from 6 global hydrological models. The study is robust, both in terms of the statistical techniques used and the size of the ensemble (although the authors can easily extend the number further). The results of the study further our understanding of uncertainties global climate and hydrological models in simulating in future hydrological extremes.

Answer We thank the reviewer for the positive review and helpful suggestions.

Comment-1 My main concern is with the authors' use of multi-model ensemble mean. Although effort has been made to provide some information on the inter-model spread (e.g. variance), the manuscript can make a significant contribution to our understanding of the projections and modelling uncertainty of each GHM-GCM combination. In these respect, Figures 1, 3 and 4 can be provided as added illustration in the manuscript (or as appendix) by showing the changes in frequency of days under high and low flows from every GHM-GCM combination. In addition, given the focus of the study, I have strong recommendation on the use of winter half-year and summer half-year periods which is more representative of the relationship between rainfall and runoff, instead of climatologically defined seasons such as DJF and JJA.
Answer We understand the reviewer's concern with the use of the multi-model ensemble mean, but we must keep in mind that the main goal of this study is to provide a comprehensive synthesis of multi-model ensemble hydrological projections and variance within (i.e. uncertainty). Considering single GCM-GHM combinations would mean annexing 60 mean changes maps (30 for high and 30 for low flows) on maybe 5 or 6 A4 pages. It's probably too much space devoted to the behavior of each model combination given the core focus of this study.
We acknowledge the value of using winter half-year and summer half-year periods, however, having looked at the four seasons (DJF, MAM, JJA SON), our choice went for seasons for which changes are more marked (as shown in Fig.1). This time scale also facilitates direct comparisons with similar studies.

Specific Comments The authors should also address the following comments for added clarity to improve the manuscript.

Comment-2 3:13-15 : The authors cited several studies which assessed future changes in the global water cycle and argued that the lack of GHMs in these studies presents a limitation. The authors went on to say that GHMs provide more uncertainty. What is the authors' point on the relationship between the utility of more GHMs and uncertainty? Are the authors referring to the range of uncertainty (i.e. ensemble spread) that is produced given the use of large number of GHMs? This should be made clear. In addition, the authors should explain: the types uncertainties by GHMs and if there are merits in using GHMs (with input from GCMs) compared with using solely GCMs for assessment of future hydrological extremes.
Answer As the reviewer points out, when considering the inclusion of more GHMs in relation to uncertainty we refer to capturing a comprehensive range of uncertainty.
Terrestrial water cycle processes in GCMs can be simulated at a coarser resolution and with less detailed processes than in GHMs. This is why a cascade of GCMs-GHMs model ensembles are currently used to undertake global climate impact studies in hydrology. As detailed in our reply to Ref.2, our text relating to the uncertainty captured within the ISI-MIP ensemble will be revised in the new manuscript.

Comment-3 4:12-13 : The cited studies – Dankers et al. (2013), Schewe et al. (2013), Davie et al. (2013) and Prudhomme et al. (2014) – do not amplify how "GCMs and GHMs uncertainty contribute to the spread in projected changes in hydrological cycle". Reference to these studies should describe the regions where there is consistency as well as uncertainty in the projected changes of hydrological extremes.
Answer This has partly been addressed in the Discussion and conclusion Section, but we will make sure we have a comprehensive reference to these studies as of where the results agree i.e. changes in consistency and uncertainty occur.

Comment-4 5:9 : Is there any reason why the authors use the Koppen-Geiger climate classification over other classifications such as Giorgi-Francisco regions (2002) or

Mahlstein-Knutti's (2010) cluster analysis-based regions?
Answer The aim of using regional classifications was to sort land (gridcells) into homogeneous regions to help summarize and examine results regionally. Giorgi-Francisco (2002) and Mahlstein-Knutti (2010) regions could be an option too, but we opted for the Koppen-Geiger classification because it is based on hydro-climate homogeneity, and it is a well known and referenced classification, which we thought would provide the best regional frame of reference for our study.
The Mahlstein-Knutti (2010) regions are very similar to the Koppen-Geiger ones (which are also based on temperature and precipitation), but their partitioning, in addition to present, also incorporates projected changes in the simulated variables (using CMIP3 models). The adoption of the MK2010 classification, would require to update the region boundaries by undertaking a new regional clustering this time using the data set at hand (i.e. CMIP5 models).

Comment-5 5:19 : What variables from GCMs were used as inputs to GHMs?
Answer The GHMs vary in the use of all or some variables as input, as listed in Table 1 of the manuscript "Meteorological Forcings". They include: Surface air temperatures (Tavg, Tmin, Tmax); Precipitation (snow and rainfall separately); Surface radiation (short and longwave downwelling); Near-surface windspeed (total); Surface air pressure; Near-surface relative humidity; CO2 concentration. The last two variables have not been bias corrected. All of the variable have daily and monthly frequency except CO2 concentration (annual).
These variables, as reported in the ISI-MIP Protocol, consist of biasâĂŘcorrected climate data from the GCMs participating in the CMIP5 and cover the time period from 1950 to 2099 (1950-1970 are usually used for spin-up).

Comment-6 5:22 : There should be a description on how well the climates of CMIP5 GCMs have been bias-corrected. For example, can the authors identify regions where

there is high confidence in the simulation of climate after bias correction? The same can be said for regions which still suffer from poor simulation of climate after bias correction. (cf. 6.26)
Answer The regional variability in the performance of bias-correction is an interesting aspect of climate change science but we don't think it is relevant to our analysis because all GHMs were driven by the same bias-corrected climate forcing. In addition, more than one variables have been bias corrected and fed to GHMs, so the confidence in the simulation after bias-correction will vary according to the variable considered. We provide reference to the published material regarding the bias-correction method and invite the interested reader to refer to this body of work (Hempel et al., 2013).

Comment-7 6:21-24 : The binary assignment – 0 or 1 – to no low/high flows and low/high flows is confusing. In the example of high flows, if the runoff value of the cell exceeds the Q95 value, then the cell is assigned either 0 or 1. There should be separate criteria to distinguish a 0 flag from a 1 flag.
Answer This issue was also raised by Ref.2. As replied to Ref.2, we will rephrase the binary assignment as follows: "For HFD, a value of 1 (high flow) is assigned to each cell if the cell's runoff exceeds the Q95 value, otherwise a value of 0 (no high flow) is assigned"; and similarly for LFD.

Comment-8 6:26 : On the aspect of "screened-out" areas – While the screened-out gridcells are located in arid or frozen regions, could they also be regions where there is considerable modelling uncertainty GHMs and/or GCMs? (cf. 5:22)
Answer Areas have been screened out on the basis of veto rules (described in Appendix B) applied to the HF and LF threshold curves (e.g. gridcells with null variance). Can these areas coincide with regions with considerable uncertainty i.e. considerable variance? They can, because the screening indicates large pools of zero-runoff but one GHM is sufficient to have that to impose the screening to the whole

ensemble, while the remainder of the GHMs could show considerable variance. In general however, the screening pattern is similar across all model combinations.

Comment-9 8:13 : Referring to Figure 2, the authors state that "the mean change vary spatially in magnitude". However, there is no information in Figure 2 to highlight spatial differences. In addition, it is not clear how the mean changes are derived. Are these spatially averaged changes? Can the authors clarify these two points?
Answer This figure was crafted to provide a visual on the magnitude of mean changes that are mapped in e.g. Fig.1a of the manuscript. As written on the reply to Ref.2 we will update Figure 2. We provide in this document an updated version (Fig.1), which includes the seasons MAM and SON, in support to our reply to comment-1 on the choice of sub-annual windows of analysis.

Comment-10 8:14-19 : The description in the lines 14-19 should be referenced to Figure 1.
Answer We will amend as suggested.

References

Hempel, S., Frieler, K., Warszawski, L., Schewe, J., and Piontek, F.: A trend-preserving bias correction – the ISI-MIP approach, Earth Syst. Dynam., 4, 219–236, doi:10.5194/esd-4-219-2013, 2013.

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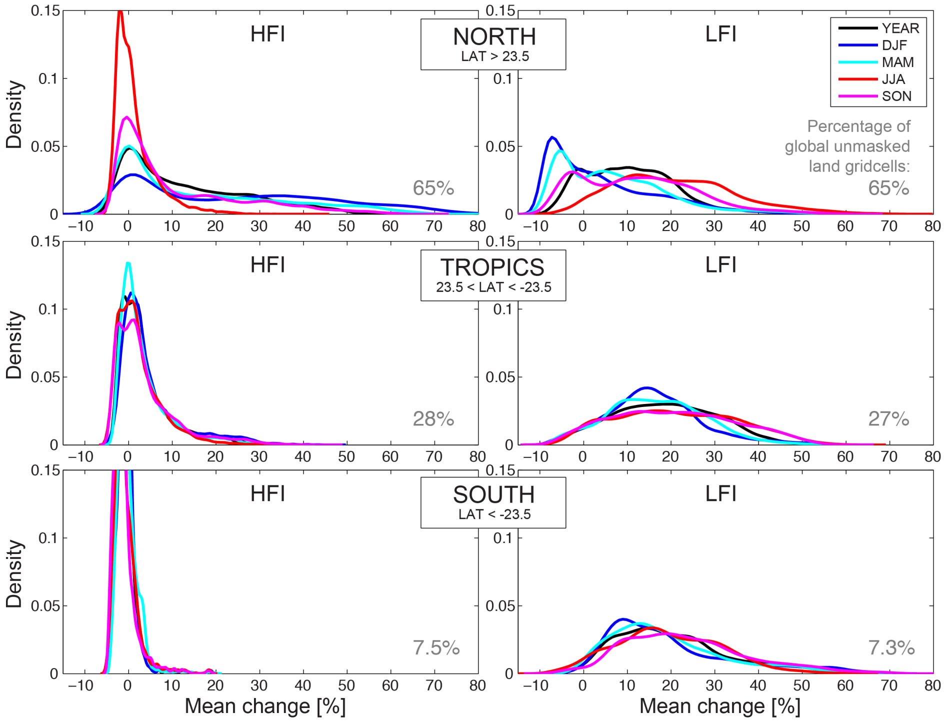

Fig. 1. PDFs of mean changes in high (HFI) and low (LFI) flows, annually and per season (DJF, MAM, JJA, SON) referring to North, Tropics and South latitude bands.