Authors response to:

Interactive comment on “Sensitivity of water balance components to environmental changes in a mountainous watershed: uncertainty assessment based on models comparison”

Anonymous Referee #1
Received and published: 16 November 2013

Referee comments:

The manuscript presents a modelling study about possible hydrological changes in the future brought about by climate change and land-use changes in northeast Spain. The authors use three climate models (global-regional) that drive two hydrological models under several climate and land-use changes scenarios.

I found the manuscript in general terms clearly written and interesting. I particularly liked the use of several models to highlight the risks of relying in just one simulation with a particular model. in my view the authors focus most strongly on the hydrological, somewhat glossing over some of the uncertainties inherent to the climate simulations they have used.

My main concern is related to the regional climate simulations. The most important hydrological variables, such as evaporation, depend non-linearly on the absolute temperature, and not just on the simulated temperature changes. In this study the authors assume that the regional climate models are able to simulate the present climate without biases, and thus the simulated climate changes can be used to drive the hydrological models directly. However, this is not always true, and unfortunately regional and global climate models may display large biases with respect to the observed climate that may attain values of 2-3 K. For precipitation the biases may be even more severe from the physical point of view. The manuscript does not indicate whether or not

climate simulations by the regional modes are close to the observations. Their validation of the regional simulations is limited to Table 3, showing some correlations between simulations and observations, but it is not clear what Figure 3 is actually displaying. Figure 3 contains a Taylor diagram, showing the correlation and ratio of variances between observation and simulations. It is not clear to me what this correlations mean. Are they the correlations between the observed and simulated annual cycles of the area-average temperature (and precipitation) ? are these the spatial correlations between the mean annual mean temperature fields from observations and simulations?

In any case, this figure does not include the possible bias, i.e. the difference between the mean simulated and mean observed temperature in the present climate. Figure 3 also includes the centred RMS errors- I interpret that for the calculation of the RMS the bias has been eliminated, and I suspect that the authors did so because the bias is large. The manuscript does not include references to a description and analysis of this simulations either , so that the reader cannot assess by themselves whether there biases are large or small. A glimpse into similar simulations (e.g. the project Prudence; Jacob et al. Climate Change 81, 31 (2007) strongly suggests that the biases can easily be as large as the simulated climate change signal. I would strongly suggest to include a figure showing the model bias for winter and summer, for temperature and for precipitation, for all three models. If the authors deem that this figure may get too loaded with information, an alternative would be to include this information in a table for the climate variables averaged over the spatial domain, although the complex topography may render the spatial averages more difficult to interpret. Th manuscript should also include a discussion about the possible influence of the systematic errors of the regional models on the results achieved here. For instance, if a regional model displays a systematic error of 2 K in the present climate in this region, how robust are the simulated changes in evapotranspiration? How robust is the simulated changes in the annual cycle of snow-pack, etc.? The contents of Figure 3 should be much more clearly explained. Table 1 is also poorly described. Are the numbers in Table 1 the area-average changes between the present climate (which period) and the future period (2021-2050)? Please consider that many readers will later want to have a quick look at the tables and figures and they would like to find this information in the figure/table caption.

Authors general comment:

The authors want to express their gratitude to the referee for expressing his/her sincere opinion about the manuscript and for highlighting what he/she thinks is the biggest drawback: the lack of explanation of climate models biases and how they could affect the obtained results in terms of hydrological simulation. We agree with the referee that RCM biases can sometimes be of great magnitude (sometimes as large as the predicted future changes), and therefore they must be considered when using RCM's outputs for any kind of forecasting. However, we certainly believe that this is an issue of misunderstanding derived from insufficient explanation, especially concerning the procedure to calculate changes in climate variables as input for the hydrological model.

Indeed RCM's outputs were not used as inputs in the hydrological models (as could be inferred from the original manuscript). We have only used RCM projections as a reference, in order to have a range of possible and reliable long-term variations in climate variables. From the RCM's outputs we calculated the seasonal changes (deltas, depicted in table 1) in temperature and precipitation between the periods 1961-1990 and 2021-2050, and applied these changes (delta method) to our observed climate series. Therefore the climate change series used as inputs in the hydrological models are not affected by any bias derived from RCM's, they only contain the deltas calculated between the aforementioned periods. This was not explained in the manuscript (clearly a big miss), and we make sure in the revised manuscript to include this information, in the next paragraph:

From the three RCMs, seasonal changes (deltas) in precipitation and temperatures between the periods 2021-2050 and 1961-1990 were calculated (Table 1). The obtained deltas were applied on a daily basis to our observed climatic series and these series were used as inputs in the hydrological models for simulating climate change conditions. In this way we made sure to provide plausible changes in the climate variables, preventing our analyses to be influenced by any bias that the RCMs may present. For informative purposes we show the statistical agreement of the three RCMs with observations (regional average of the 15 climatic series) for the control period (Figure 3). The Taylor diagram shows the model's performance with respect to observations in terms of their long-term correlation, ratio of variances, root-mean-squared error, and their percent bias. For precipitation, only DMI is capable of reproducing the statistical characteristics of the

observations, whereas C4I and SMHI present poorer performance. For temperatures the three RCM show good performance in terms of correlation, variances and RMS error with respect to observations, however, minimum temperatures simulated by models present a large bias (nearly 60%). An assessment of ENSEMBLES RCMs performance for precipitation over Spain can be found in Herrera et al. (2010). It must be emphasized that these biases and errors of RCMs are not propagated in the hydrological simulations due to the use of deltas rather than the actual RCM series.

Figure 3 was included in the paper for informative purposes to show the statistical agreement between models and observations, but the value of the statistics shown (pearson's correlation, ratio of variances and RMS error) do not have a direct effect in hydrological simulations. A better description of this figure is provided in the new paragraph above.

It must be clarified that this work is not an attempt of evaluation of climate models performance for hydrological purposes. More exactly, it is an evaluation of hydrological simulations under plausible scenarios of environmental conditions in the future, and the RCM are only used as a reference that provide ranges of variations in climate variables, to see how the hydrological models respond within these ranges.

We believe that with this explanation we clarified most of reasons of concern of the referee; however, some specific referee's comments are addressed with more detail in the following. (Please, note that for a better tracking of changes, referee's comments are shown in italics and authors responses are in normal font)

Referee*: Figure 3 contains a Taylor diagram, showing the correlation and ratio of variances between observation and simulations. It is not clear to me what this correlations mean. Are they the correlations between the observed and simulated annual cycles of the area-average temperature (and precipitation) ? are these the spatial correlations between the mean annual mean temperature fields from observations and simulations?*

Authors: The three statistics (correlation, ratio of variances and root mean squared error) are calculated for the monthly 1961-1990 series of RCMs in the 25 km^2 pixel lying on the studied watershed, and the observations series, which correspond to a regional average series calculated from the 15 climatic stations located within or near to the watershed. This information is explained in the figure caption of the revised manuscript.

***Referee**: In any case, this figure does not include the possible bias, i.e. the difference between the mean simulated and mean observed temperature in the present climate.*

Authors: As explained before, there is no necessity for considering model's biases as RCMs outputs are not used directly in the hydrological simulations. However, in order to give more information on the agreement between RCMs and observations, we have included the percent bias (symbol size) in the Taylor diagram, which shows that especially minimum temperatures are largely overestimated by the RCMs.

***Referee**: Figure 3 also includes the centred RMS errors- I interpret that for the calculation of the RMS the bias has been eliminated, and I suspect that the authors did so because the bias is large*

Authors: The calculation of RMS error was done on the original series and the Bias was not removed for doing so.

***Referee**: The manuscript does not include references to a description and analysis of this simulations either, so that the reader cannot assess by themselves whether there biases are large or small. A glimpse into similar simulations (e.g. the project Prudence; Jacob et al. Climate Change 81, 31 (2007) strongly suggests that the biases can easily be as large as the simulated climate change signal. I would strongly suggest to include a figure showing the model bias for winter and summer, for temperature and for precipitation, for all three models. If the authors deem that this figure may get too loaded with information, an alternative would be to include this information in a table for the climate variables averaged over the spatial domain, although the complex topography may render the spatial averages more difficult to interpret.*

Authors*:* Models bias have been included (symbol size) in Figure 3, although only for informative purposes as above explained. A reference that evaluate ENSEMBLES RCMs in Spain for precipitation has been as well included (Herrera et al., 2010).

***Referee**:The manuscript should also include a discussion about the possible influence of the systematic errors of the regional models on the results achieved here. For instance, if a regional*

model displays a systematic error of 2 K in the present climate in this region, how robust are the simulated changes in evapotranspiration? How robust is the simulated changes in the annual cycle of snow-pack, etc.? The contents of Figure 3 should be much more clearly explained.

Authors*:* this kind of discussion would have a lot of sense if the RCMs outputs were used as inputs for the hydrological models. Since it was not done that way, the errors are not influencing the results, therefore it is not necessary to discuss them.

Referee*: Table 1 is also poorly described. Are the numbers in Table 1 the area-average changes between the present climate (which period) and the future period (2021-2050)? Please consider that many readers will later want to have a quick look at the tables and figures and they would like to find this information in the figure/table caption.*

Authors: We agree that Table 1 needs a better description. We provided it in the caption, as follows:

Table 1.Climate and land-use scenarios considered in the study. (a) Changes (deltas) in seasonal temperature (T) and precipitation (P) projected for the RCM's between the periods 1976-2007 and 2021-2050. These deltas were applied to the observed climate series for creating the climate change inputs for the hydrological models. (b) Absolute and relative extension of the land-uses classes in the current and hypothetical land-use scenarios. Only shown classes subject to change

Some minor points:

Referee*: 'is related to the increase of wildfires in the Mediterranean region. Specifically in Spain wildfires have experienced a significant increase since the 70s due to climate and land-use changes as demonstrated by Pausas (2004)' This conclusion cannot be derived from the work of Pausas. Pausas shows that the number of fires is negatively correlated with summer precipitation, but that paper also shows that summer precipitation shows no statistically significant trend in the last decades. Pausas argues that it is reasonably to think that higher temperatures may have contributed to soil dryness and thus to the increase of fires in the last decades. However, in that study no correlation between temperature and number of fires is indicated, and therefore this conclusion, though plausible, has not been 'demonstrated'. Pausas demonstrates a link between the interannual variations of precipitation and fires, but not a link between climate change and fires.*

Authors: We agree that the word “demonstrated” is not the most suitable word for this assertion. Pausas 2004, discusses about the plausible relation of increasing fires with summers becoming dryer and warmer, as well as with changes in landscapes due to abandonment of rural areas. We changed the sentence as follows:

Specifically in Spain wildfires have experienced a significant increase since the 70s, and this is possible due to climate and land-use changes, as discussed by Pausas (2004)

***Referee**: 'Zaragoza and Lleida'. These are the names of these cities in Spanish and Catalan, respectively. It seems to me more logical that, being this a text written in English, the English names should be used (Saragossa and Lerida)*

Authors: Names were changed into English as suggested

References:

Herrera, S., Fita, L., Fernández, J., and Gutiérrez, J. M.: Evaluation of the mean and extreme precipitation regimes from the ENSEMBLES regional climate multimodel simulations over Spain, Journal of Geophysical Research: Atmospheres (1984–2012), 115, 2010.

Pausas, J.: Changes in Fire and Climate in the Eastern Iberian Peninsula (Mediterranean Basin), Climatic Change, 63, 337-350, 10.1023/B:CLIM.0000018508.94901.9c, 2004.