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Hydrology and Earth System Sciences
Discussions

Interactive comment on "Climate change impacts on hydroclimatic regimes and extremes over Andean basins in central Chile" *by* Deniz Bozkurt et al.

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General response for reviewers 1 and 2:

We appreciate the thoughtful comments by the reviewers. All of them are taken into consideration in our responses. The reviewers raised two major concerns, namely: i) lack of model performance evaluation and ii) the choice of spatial resolution for VIC model simulations.

We agree with both reviewers in that the model setup and simulation protocol adopted in this study may not be suitable for a comprehensive characterization of the hydrological processes within the four basin evaluated. However, we would like first to recall

that the main goal here is to make use of the VIC capabilities to get future basin-wide projections in key hydroclimatic variables (e.g. ET, SWE) that are consistent with the imposed changes in precipitation and temperature. Yet, given the general lack of this type of assessment in central Chile, we considered as a reasonable starting point to extend the work done by Demaria and colleagues over the Mataquito basin to three other basins of the same region (Rapel, Maule and Itata).

For instance, the spatial resolution of 0.25 degree follows the forcing available at the time of performing our simulations (we adopted the one of Demaria et al. 2013). This grid is indeed too coarse to evaluate processes at the scale of secondary and tertiary watersheds in Chile ($\sim$100 to 1000 km2). Aware of this, our group is working on a higher resolution (5km) meteorological forcing for regional hydroclimate research in Chile. This dataset is still in evaluation and will not be used in the present study. The 25km-resolution of the Demaria et al. forcing, although at the limits regarding the main basins assessed in this study ($\sim$10000 km2), is however useful for the general purposes above mentioned.

Understanding the limitations of our study, notably the resolution and the use of the VIC-parameters calibrated for Mataquito for the whole domain, we have considered the reviewer suggestions and improved the model evaluation by adding more statistics such as NSE, KGE, PBIAS. We have found that the VIC model adequately captures relevant information contained in these evaluation metrics, which gives further confidence in the use of this model for hydroclimate change projections in central Chile. Results of those evaluations are given in a separate file as a table.

We think that with these changes, and clearer statement of the goals of the paper will improve the manuscript. Please, find below our point-by-point response to the reviewers' comments.

1. The model evaluation and its satisfactory performance are prerequisites for impact assessment. However, it was not done properly in this study. The authors refer to

another study, by Demaria et al. (2013), where "reasonable agreement of VIC model" for this region was shown (from the manuscript is not clear - was it done for one basin, or for all 4 basins). However, the paper by Demaria et al. used 12 GCMs from CMIP3 "to evaluate climate-attributed changes in the hydrology of the Mataquito river basin in central Chile, South America", and not all four catchments. That is why this reference is not fully eligible. Besides, it is not clear, whether the authors used the model setup and parametrization from the former study, or not.

Response: We acknowledge your comments in this crucial point. Let us first recall that Demaria et al. (2013a) produced a gridded dataset of observed climate (1948-2008) for four basins (Rapel, Mataquito, Maule and Itata) in central Chile. In that study, the VIC model was calibrated to monthly stream flows for the Mataquito basin, and then they applied the same VIC-calibrated parameters in the four basins, as we also did in this study. Demaría et al (2013a) stated that the the rationale for using the same calibrated parameters for the entire domain is to avoid the possibility of allowing extensive calibration to hide the deficiencies of meteorological forcing fields. Demaria et al. (2013a) then validated the VIC model using three gauge sites (one in Mataquito and two in Maule) and based on the calibration/validation statistics they concluded that the VIC model can realistically capture the flow albeit with some biases for high and low flows. Following the same study, Demaria et al. (2013b) used the same validated VIC model to assess the climate change impacts on the hydrology of the Mataquito basin in central Chile through a comparison between 12-member ensembles of CMIP3 and CMIP5. In our study, we follow a similar approach of Demaria et al. (2013b). We used the same model setup and parameterization and extended hydroclimate change projections in central Chile by including three more basins (Rapel, Maule and Itata) and 26 CMIP5 models.

As we have used the same model configuration and parameterization, we did not consider it fundamental to repeat the validation process. Based on your comments and given the fact that the audience of HESS would be interested in seeing more evalu-

ation statistics rather than referring to Demaria et al. (2013a, b), we have expanded the model evaluation and added more evaluation statistics such as NSE, KGE, PBIAS (results included in table in separate file). Furthermore, we have included two more stream gauges of Itata and Rapel basins so that we could provide a detailed validation statistic for each basin. Finally, we have clarified in the text that we used the same model setup and parameterization of Demaria et al. (2013a).

Demaria, E. M. C., Maurer, E. P., Sheffield, J., Bustos, E., Poblete, D., Vicuñna, S., and Meza, F. (2013a): Using a gridded global dataset to characterize regional hydroclimate in central Chile, J. Hydrometeor., 14, 251–265, doi:10.1175/JHM-D-12-047.1.

Demaria, E. M. C., Maurer, E. P., Thrasner, B., Vicuñna, S., and Meza, F. (2013b): Climate change impacts on an alpine watershed in Chile: Do new model projections change the story?, J. Hydrol., 502, 128–138, doi:10.1016/j.jhydrol.2013.08.027.

2. The demonstrated results of model evaluation (Figs. 4, S2, S3) are not convincing: - discharge with the monthly time step: results not clear from the graphs, please add criteria of fit, e.g. NSE, PBIAS, RMSE, - seasonal dynamics (Fig. 4 and Fig. S3): runoff is notably overestimated for two catchments of four, ET is underestimated in all four, criteria of fit are missing. For the seasonal dynamics please use Pierson coef. of correlation and bias in standard deviation (see Gudmundsson et al., (2012). Such model evaluation in a regional-scale study with quite weak performance cannot serve as a basis for climate impact assessment, and should be improved.

Response: Please see our response to your previous point (1). Furthermore, based on your recommendation of Gudmundsson et al. (2012) and also another study of Moriasi et al. (2007), we created a table of evaluation statistics (results included in table in separate file) including the pearson correlation coefficient (r), ratio of RMSE to the standard deviation of the observations (RSR), percent bias (PBIAS), Nash-Sutcliffe efficiency (NSE) and Kling-Gupta efficiency (KGE). Please note that all these statistics are based on monthly and annual time series. Overall, the VIC model performance

is very good in Itata basin and adequate for Maule and Mataquito basins. These results for Maule and Mataquito basins are similar to those in Demaria et al. (2013a, b). On the other hand, the model simulation for Rapel basin shows a poorer performance albeit with low PBIAS and NSE value greater than 0. The reason for this is most probably related with the catchment characteristics of the Rapel basin as it has the highest amount of snow water equivalent among the four studied basins and corresponds to a snowmelt-dominated basin. As noted by Demaria et al. (2013a), while these evaluation statistics do not demonstrate that the best hydrologic model was developed for each basin, we think that the VIC model generally meets the criteria for satisfactory performance and can be used for climate change impact assessment.

Gudmundsson L, Tallaksen LM, Stahl K, Clark DB, Dumont E, Hagemann S, Bertrand N, Gerten D, Heinke J, Hanasaki N, Voss F, Koirala S (2012): Comparing large-scale hydrological model simulations to observed runoff percentiles in Europe. J Hydrometeorol 13:604–620

Moriasi, D. N., J. G. Arnold, M. W. V. Liew, R. L. Bingner, R. D. Harmel, and T. L. Veith (2007): Model evaluation guidelines for systematic quantification of accuracy in watershed simulations. Trans. ASABE, 50, 885–900.

3. The accepted spatial resolution of 0.25 degrees for catchments from 6.300 to 21.100 km2 seems to be too rough for setting up the model and checking its performance. Besides, it is not clear from the manuscript, whether the sub-grid parameterization was done and how. Such a rough spatial resolution could be also a reason for poor model performance. It is recommended to apply a finer disaggregation scheme for the model calibration (despite that the GCM data for further application is available at 0.25 degree resolution).

Response: As we note in the general response above, our selection for spatial resolution is merely based on the data availability of meteorological forcing fields at the moment of performing these simulations. Although clearly not desirable for sub-basins

analyses, we think the grid used is still useful for the purposes of this study.

4. The ignored river routing could be also a reason for poor model performance. It is recommended to add it.

Response: A central objective of the present work is to analyze the projected changes in hydroclimate in central Chile using the basin averages of the grid-based runoff (not routed to basin outlet). In this regard, we aim to illustrate the change in the water balance components (precipitation, runoff and ET) in each basin. As we noted in the manuscript, the region of interest does not include large-scale basins, therefore the summed runoff field does not differ majorly from the river routing (e.g., Shukla and Wood, 2008). Indeed, evaluation statistics for Mataquito and Maule basins in our study are similar to Demaria et al. (2013a) that used a river routing scheme. Please see our response to your previous points 1 and 2 for the detailed model performance evaluation.

Shukla, S. and Wood, A. W (2008).: Use of a standardized runoff index for characterizing hydrologic drought, Geophys. Res. Lett., 35, L02 405, doi:10.1029/2007GL032487.

5. Description of how the bias-correction of GCMs was done is missing.

Response: Our manuscript indeed lacks of exhaustiveness in this point. A more detailed description of the bias-correction methodology will be included in a resubmitted version.

6. Language should be checked by/with a native speaker.

Response: We will check the manuscript for English edits in order to improve its readability.

Please also note the supplement to this comment:
http://www.hydrol-earth-syst-sci-discuss.net/hess-2016-690/hess-2016-690-AC2-supplement.pdf

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