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Hydrology and Earth System Sciences Discussions

Interactive comment on "Development of streamflow projections under changing climate conditions over Colorado River Basin headwaters" *by* W. P. Miller et al.

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RESPONSE TO ANONYMOUS REFEREE #3 COMMENTS Streamflow Projections Under Changing Climate Conditions over Colorado River Basin Headwaters

Responses to Anonymous Referee #3 Comments

âĂć Comment 1: There is considerable effort in deriving sub-daily data sets, however,

all analysis concentrates on longer time periods. I am not sure I understand the effort of an sub-daily (even sub-monthly) time step given the presentation of the results - the authors need to elaborate on this.

Response to Comment 1: The authors appreciate this, and all, of Anonymous Referee #3's comments. Considerable effort was put into deriving sub-daily data sets because the NWS RFS model used by the CBRFC requires input climate data a 6-hour interval.

âĂć Comment 2: Oh boy, is this paper full of acronyms. For the first time as a reviewer I actually had to make a list myself just to remember them all. I urge the authors to reconsider in particular for readers who are not familiar with the area and institutional landscape. Please: (1) remove all acronyms from the abstract; (2) delete all acronyms which are not used in the further text (and there are a few); (2) reconsider creating acronyms which just make the text harder to read e.g. do you really need MAP, MAT or MAE (latter one gets easily confused with Mean Absolute Error)

Response to Comment 2: Thank you for the comment. We have revised the manuscript to try and limit the use of acronyms.

âĂć Comment 3: The paper omits any statistics on the performance of the model with respect to observations. If comparisons are plotted they obscure quality of the results (figure 5, 7 and 9)

Response to Comment 3: Unfortunately, because of the inability to use the calibration model that the NWS uses, we are unable present performance statistics with respect to the model and admit this is a limitation of the study. We have revised the manuscript to make this limitation more clear. In particular, section 2.2.1 page 15, lines 7-12 of the revised manuscript reads:

2.2.1 Calibration of Evapotranspiration Demand In practice, evapotranspiration demands, as well as other parameters, are adjusted by the CBRFC through the use of an external calibration model to more accurately represent observed streamflow condi-

tions. Although this study was unable to use the calibration model used by the CBRFC, calibration of streamflow projections was achieved through the use of a ratio method in post-processing of streamflow output (see Section 2.6 and 3.2).

âĂć Comment 4: I do not fully understand, the application of your post-run bias correction, which basically 'creates' or 'destroys' water and does not correct for any possible timing errors. You claim to see non-stationary, which will be also valid for your bias correction.

Response to Comment 4: The post run bias correction is done to compensate for the lack of having a calibration model. We would claim that we are not "creating" or "destroying" water; but rather, we are scaling the results of our modeling efforts to match the observed long-term (1976-2005) mean.

âĂć Comment 5: There are large assumptions in the computation of input fields of precipitation, temperature and evaporation. I would argue that the differences you see are smaller than the impact of the uncertainties in your assumptions.

Response to Comment 5: Thank you for your comment. It is a interesting point that would require future study and additional, considerable, effort. We feel this would be more suited to a following study. We hope that by investigating long-term decadal averages, rather than shorter-term periods, we mitigate the impacts of the uncertainty associated with the input files.

âĂć Comment 6: Please, put all units into the SI system

Response to Comment 6: All values are presented in the SI system. English units are provided in parenthetical to appeal to the audience that may be most interested in this work.

âĂć Comment 7: Why was the VIC model and the CBRFC RFS model used - why not just VIC?

Response to Comment 7: Reclamation is required to use the results of the RFS model

for short term forecasts, which makes this model particularly important to the region. We have tried to make this more clear in the revised manuscript. We have revised the manuscript to read on page 10, lines 8-10:

Reclamation is required to use streamflow forecasts by the CBRFC for input into operational and policy models; as such it is important for Reclamation, or any water manager, to evaluate potential impacts of climate change to streamflow forecasting tools.

âĂć Comment 8: p5578L2 I do not understand why there is a Reclamation in brackets?

Response to Comment 8: Reclamation is in brackets to abbreviate "US Department of the Interior, Bureau of Reclamation."

âĂć Comment 9: p5579L1 rephrase currently - your paper maybe read in 2020.

Response to Comment 9: Thank you for the comment, we have revised the manuscript to read on page 2, lines 14-15:

From 2000 through 2010, the Colorado River Basin has experienced the driest period on record and one the worst droughts in history (e.g, Timilsena et al. 2007).

âĂć Comment 10: p5579L5-10 Such fluctuations can be normal in other reservoirs and hence are no clear evidence for a drougth, please describe the hydro meteorological climatology of the area

Response to Comment 10: Thank you for the comment, we have revised the manuscript to describe the Colorado River Basin in more detail in the study area section. In particular, we have revised the manuscript to read on page 6, line 10-16:

Of the approximately 18,500 million cubic-meters (MCM) of inflow into the Colorado River Basin, approximately 17,900 MCM is currently allocated annually. The Colorado River Basin is unique from other water management systems in that it has the capability to store approximately four times (74,000 MCM) the average annual inflow; most of the storage is concentrated within the Lake Powell and Lake Mead reservoirs. Historically,

inflow into the Colorado River Basin is highly variable and typically driven by snowpack in the Upper Colorado River Basin.

âĂć Comment 11: p5579L16 you describe impacts on changes in timing and your paper uses a sub-daily time step, but non of your analysis refers to this or shows it

Response to Comment 11: Thank you for the comment. The statement regarding timing changes to runoff in the Colorado River Basin is simply provided to give the reader introductory information regarding the current hydrology and research efforts in the basin. Because of significant downscaling and limitations of the model, we feel it would be inappropriate to examine sub-decadal impacts in this study.

âĂć Comment 12: p5579L16 Please make more clear what your paper adds in respect to the paper by Christensen and Lettenmaier, 2007

Response to Comment 12: Thank you for the comment. We feel this paper presents a methodology that is flexible enough to integrate various hydrologic models and data sources, as opposed to being limited to a particular hydrologic model (e.g., VIC). But we do very much appreciate the work by Christensen and Lettenmaier, 2007. We have revised the manuscript on page 13 lines 4-14 to include the following, which we hope addresses your concern:

Evapotranspiration within the VIC model has been extensively studied (e.g., Christensen and Lettenmaier 2007, Hamlet et al. 2007, Hurkmans et al. 2008, Hurkmans et al. 2009, Lakshmi and Wood 1998, Nijssen et al. 1997). Of particular importance to this study Hamlet et al. (2007), indicated that evapotranspiration trends within VIC were driven by trends in precipitation and temperature; concurrent work indicated that evapotranspiration significantly influenced projected streamflow response within the VIC model (Christensen and Lettenmaier 2007). An advantage of the VIC model, and other hydrologic models discussed, over the NWS RFS utilized by the CBRFC is that these models allow for the user to account for evapotranspiration as a function of changing conditions within the model. The NWS RFS utilized by the CBRFC is depen-

dent on user-defined evapotranspiration demand that is unique to each month; that is, evapotranspiration demand in any given month is identical throughout the length of the model run.

âĂć Comment 13: p5580L5 This is a hydrology journal, please, spell out AMO, PDO and SOI

Response to Comment 13: Thank you for the comment. We have defined the AMO, PDO, and SOI acronyms in the revised manuscript.

âĂć Comment 14: p5581 Please make more clear what the novel contribution of your paper is

Response to Comment 14: We hope that our response to comment 12 addresses this concern satisfactorily.

âĂć Comment 15: Figure 2: Difficult to place on the world (unless you know it). Add lat, long Or a small map of north America

Response to Comment 15: Thank you for the comment, we have shown the lat/long coordinates of Denver, CO in the caption of Figure 2.

âĂć Comment 16: p5582L5-11 Please consider relevance to scientific objective of this paper

Response to Comment 16: Thank you for the comment. We feel that this introductory information speaks to the importance of the study area.

âĂć Comment 17: p5586L9-10 acronyms in these lines seem to be unused

Response to Comment 17: Thank you for the comment. We have removed the unnecessary acronyms from the manuscript.

âĂć Comment 18: p5586L13 Please give some performance statistic of the model using this calibration. Is this calibration a error updating method? Please provide

reference.

Response to Comment 18: Thank you for the comment. We understand this is a limitation of our study and have tried to make that more clear in the revised manuscript. Unfortunately, without access to the NWS calibration model, we cannot provide this.

âĂć Comment 19: p5587L18-21 Please provide evidence (beyond personal communication) for the values in the equations. A quick check of GTS stations in the area seem to suggest some uncertainties on these values. They are important for you climate projections in particular for your evaporation. Please indicate impact of these assumptions.

Response to Comment 19: Despite our best effort, these values from the equation are not documented by the CBRFC. There is undoubtedly uncertainty in these values. We have revised the manuscript to read on page 16 lines 5-7:

Because of the empirical nature of these equations, it should be noted that under climate change, there is uncertainty as to how valid these equations are for long-term forecasting.

âĂć Comment 20: p5590Section 2.5 I do not understand your post-run bias correction. It will severely damage the water balance and have no influence on the temporal structure of the hydrographs. Please provide some performance indicators of your bias correction (beyond the once you have) e.g. Nash-Sutcliffe. I am uncertain, why a model in which the parameters are well calibrated is in need of such a correction. You do establish non-stationarity, which will also be impacting your bias correction. Please present a plot of the bias correction factors.

Response to Comment 20: The model is calibrated to data derived by the CBRFC over the period from 1976-2005. By using BCSD CMIP3 data, this calibration no longer applies. Since we do not have access to the NWS calibration model, we apply a post-bias correction. We are not damaging the water balance computed by the hydrologic model,

we are simply scaling the output to more match the long-term, historical average. Each of the 112 climate projections has a separate bias correction factor; while we would be happy to provide these bias correction factors to any interested party, plotting them is impractical for this study.

âĂć Comment 21: Figure 3 are these differences statistical significant? (also a question for figure 6)

Response to Comment 21: Because we do not have access to the calibration model used by the CBRFC, it is difficult to do a fair statistical test on this data. We have provided the magnitudes as it represents a measure of the impact that adjusting for evapotranspiration may have on the model.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 7, 5577, 2010.