<Author’s response>

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Referee #2

We appreciate the thoughtful comments from the reviewer, which have helped us to improve the original manuscript. We explain in detail how we responded to the reviewer’s comments, with line numbers referring to the revised manuscript unless otherwise noted.

Index		Comments
1	Referee review	Downscaling: the authors’ prior published BCSA Downscaling Method yields 3,000 precipitation realizations that are constrained to NLDAS-2 daily spatiotemporal statistical structure. It is not clear to me how this approach avoids acting like a low-pass stochastic filter for increasingly extreme temperatures, droughts, or floods. Specifically when contemplating more extreme quantiles that are rarely observed or have not been observed. The GCMs themselves are not strongly capable of capturing extremes. Moreover, limits in the observation record reduce the value for NLDAS-2 daily statistics in capturing extremes. Likewise, bias filtering also often eliminates extreme events. It is not clear to me how well the authors have even captured stationary extremes.
	Author’s response	We agree with the reviewer that GCMs are not particularly good at reproducing interannual climate cycles such as ENSO, or extreme temperature and precipitation events. We also agree that bias correction and downscaling methods cannot these correct problems, and will not produce climate events that are significantly outside the range of those that occurred during the historic period used for bias correction. Nevertheless previous research has shown that they are able to simulate broad features of the climate system and are useful for characterizing plausible projections of possible futures (Kundzewicz et al, 2008, 2009). The BCSA method used in this paper was developed by Hwang & Graham (2013). Hwang & Graham (2013) showed that BCSA performed better than BCCA, BCSD, or SDBC in reproducing the mean, variance and spatial correlation structure of daily precipitation over the state of Florida. Hwang and Graham (2014) showed that BCSA showed better performance than BCSD or SDBC in predicting retrospective streamflow and groundwater levels streamflow in the Tampa Bay Region when using the same INTB model used in this study. In particular Hwang and Graham (2014) showed that, when driven by GCMs downscaled using the BCSA method, the INTB model not only reproduced the mean and variance of daily streamflows but also accurately reproduced

		frequencies of extreme high and extreme low retrospective streamflows as well as 7Q2 and 7Q10 retrospective streamflows in the Tampa Bay region." The introduction of the paper was modified to include the following: "Although these bias correction and downscaling methods do not correct problems with large scale synoptic forcing, and are not particularly good at reproducing extreme floods or drought in retrospective period, previous research has shown that they are able to simulate broad features of the climate system and are useful for characterizing plausible projections of possible futures (Kundzewicz et al, 2008, 2009). Furthermore, previous work has shown that hydrologic models driven by bias-corrected downscaled retrospective GCM output adequately reproduce retrospective high stream flows (e.g. 7Q2 and 7Q10, as well as the long term mean and standard deviation of monthly flows (Hwang and Graham, 2014)." Section 2.4 of the paper was modified to include the following: "Hwang & Graham (2014) showed that BCSA showed better performance than other statistical downscaling methods (i.e .BCSD (Maurer et al, 2012) or SDBC (Abatzaglou and Brown, 2012)) in reproducing spatiotemporal statistics of both precipitation and daily streamflow in the Tampa Bay region. In particular, the INTB model, when driven by GCMs downscaled using the BCSA method, accurately reproduced frequencies of extreme high and extreme low retrospective streamflows as well as 7Q2 and 7Q10 retrospective streamflows in the Tampa Bay region." In addition the description of the BCSA method in Section 2.4 was improved.
2	Referee review	Human use scenarios: Although I understand that the authors are managing the computational demands of their work, the experiment being presented lacks a balance in how it treats humans versus climate in a manner that likely pre-ordains their attained results and ultimately may make them poorly representative of the uncertainties and impacts from the human decisions in the system. I found the human scenario justifications to be lacking in clarity and justification for their appropriateness. I suspect had the authors even done a basic parametric uncertainty for the aquifer conductivities that many of their claimed inferences would disappear into neglected parametric uncertainty effects. Moreover, the underlying "off/on"nature of the eight scenarios described in lines 237-271 mix mean behaviors and oddly unlikely human use combinations.
	Author's response	In response to comments from all three reviewers we have significantly revised the justification and explanation of the future water use scenarios, and added an analysis of each one's ability to meet future water demand and maintain or improve compliance with current water resource regulations. In short, the future scenarios were developed based on discussions with Tampa Bay Water staff, projected increases in public water demand (*Tampa Bay Water Water Demand Management Plan Final Report*, 2013), projected changes in agricultural land use and agricultural irrigation demand (*Florida Statewide Agricultural Irrigation*

		Demand Estimated Agricultural Water Demand, 2015-2040., 2017), potential agricultural adaption behaviors, and potential changes in groundwater regulations. The range of scenarios was designed to explore the largest range in possible future water uses that were consistent with these sources of information. In the early 2000s Tampa Bay Water was permitted to pump 158 MGD groundwater to meet public water supplies. However at that time local groundwater overdraft was adversely affecting wetlands and lakes in the area and leading to salt water intrusion. Thus in 2002 the permitted groundwater pumping capacity was reduced to 121 MGD in 2002 and further reduced to 90 MGD in 2008. To more clearly separate the impact of human water use versus climate change on the hydrologic system, three extreme groundwater use reduction scenarios were developed. As discussed in the revised manuscript, and shown in the new Figure 6, climate scenarios that project that future precipitation will be approximately equal to retrospective rainfall can only meet both 2045 public water demand and maintain existing compliance with groundwater level regulations for these extreme scenarios that completely eliminate groundwater pumping for public water supply purposes. In addition scenarios that increased groundwater pumping were also examined. In the most extreme of these scenarios pumping from the Tampa Bay Water's consolidated wellfields (CWFs) was increased from the current permitted 90 MGD to 130 MGD, which is less than the 158 MGD that was permitted in the early 2000s. Figure 6 shows that only the 2 wettest future climates projected by the GCMs used in this study can meet both projected public water supply demands and maintain or improve compliance with current ground water regulations if CWF pumping is increased to 130 MGD. The full improved justification and explanation of the future water use scenarios is included in Section 2.7 of the revised manuscript. The full analysis of the scenarios' ability to meet future water demand is included in Section 3.6 of the revised manuscript. Regarding model parameter uncertainty, the INTB model was calibrated and validated with data from the 1989-2006 time period. The results of this calibration/validation as well as basic parametric uncertainty and sensitivity tests are reported Geurink & Basso (2013). The goals of this study was to evaluate the impact of climate change and water use change using the existing calibrated model.
3	Referee review	Global sensitivity analysis: the authors claim a variance decomposition is being done, but by merit of their experimental design the core potential for generating variance in the model is strongly concentrated within their climate sampling. Variance decomposition is strongly influence by factor ranges and deterministic human scenarios are extreme a priori statistical assumptions that strongly under sample the human component of the work. Additionally, the authors report only 1st order indices, which is tacit to a One-at-a-Time analysis in only highlighting

		separable single factor effects (e.g., Table 4 clearly indicates that a Total Order index in contrast to the 1st order index should be analyzed).
	Author's response	We used variance-based global sensitivity analysis (Saltelli et al., 2008, 2010) to apportion the variance in projected changes between future and retrospective streamflow and groundwater level onto the three input factors: GCM selection, ET_0 method and water use scenario. The first-order sensitivity coefficients were presented which represents the fraction of the total variance attributed solely to each factor, not accounting for interactions among factors. As the reviewer points out this analysis showed that differences among GCM projections drive the results presented in this study, for example the first order sensitivities of change in streamflow to GCM ranged from 87-96%. However the sums of first-order sensitivities range from approximately 96% to 98% for streamflow and 82% to 90% for groundwater level, indicating very small interactions among factors. Thus we not understand why the reviewer believes that Table 4 indicates that a total order index (in contrast to the 1st order index) should be analyzed Mean changes in precipitation projected by GCMs used in this study ranged from -68 mm/year to 293 mm/year over the 2030-2060, and from 154 mm/year to 400 mm/year over the 2070-2100. Mean changes in ET_0 ranged from 24 mm/year to 137 mm/year over the 2030-2060 and from 122 mm/year to 351 mm/year over the 2070-2100. Groundwater pumping scenarios ranged from 0 mm/year to 74 mm/year which we agree is much lower than the variation over P or ET_0. However, as explained above, this range in future groundwater pumping is plausible, and based on discussions with Tampa Bay Water staff, projected increases in public water demand (Tampa Bay Water Water Demand Management Plan Final Report; 2013), projected changes in agricultural land use and agricultural irrigation demand (Florida Statewide Agricultural Irrigation Demand Report, 2017), potential agricultural adaption behaviors, and potential changes in groundwater regulations .
4	Referee review	Introduction: at several points in the text (see lines 36-39; 49-53; 59-61; 75-80) the authors declaratively enumerate the existence of literature without any analysis for connection to this work and its novel contributions. Simple listing citations is not the same as providing readers with a guided narration of strengths, weaknesses, needs, and clarifying your own contribution.
	Author's response	We edited introduction to more clearly present the connection of referenced literature to this work and clarify the contribution of this paper.
5	Referee review	At several points in the Methods it was not clear what was new or novel in this work relative to prior published work.
	Author's response	We significantly revised the abstract, introduction and conclusions of the paper to more clearly point out the new contribution which we believe is the use of downscaled GCMs to drive regional hydrologic models in order to understand the likelihood of meeting future projected water demand while complying with water resource regulations over a range of possible climate and water management futures. In particular section 3.6 was added that includes a scenario discovery analysis (Tariq et al., 2017) that investigates which combinations of climate and water use scenarios are able to meet future water demand and maintain or improve compliance with current water resource regulations. This provides a framework for water management agencies to use GCM and water use projections to

		prioritize actionable, low risk water management strategies that are robust across a wide range of possible futures. We believe study will be useful other regional water management agencies who seek to develop water management plans that incorporate future climate risks.
6	Referee review	In terms of sensitivity analysis results, I would encourage the authors to improve their work by bootstrapping and reporting the confidence of their reported variance decomposition.
	Author's response	As mentioned above variance-based sensitivity analysis (Saltelli et al., 2008, 2010) was used to apportion the variance in projected changes between future and retrospective streamflow and groundwater level onto the three input factors: GCM selection, ET_0 method and water use scenario. Using the variance-based GSA method the variance-based first order effect is expressed as: $$V_{X_i}\left(E_{X_{\sim i}}(Y\|X_i)\right)$$ Where V is the scalar model output (i.e., streamflow or groundwater level), and X_i are the factors causing variation in the model output (i.e. choice of GCM, ET_0 method, water use scenario). The expectation operator $E_{X_{\sim i}}(Y\|X_i)$ indicates that the mean of Y is taken over all possible values of X except X_i (i.e., $X_{\sim i}$) while keeping X_i fixed. The variance, V_{X_i} , is then taken of this quantity over all possible values of X_i . The first-order sensitivity coefficient is $$S_i = \frac{V_{X_i}(E_{X_{\sim i}}(Y\|X))}{V(Y)}$$ where $V(Y)$ the total variance of Y over all X_i. S_i is a normalized index varying between 0 and 1, because $V_{X_i}\left(E_{X_{\sim i}}(Y\|X_i)\right)$ varies between 0 and $V(Y)$ according to the identity (Mood et al., 1974): $$V_{X_i}\left(E_{X_{\sim i}}(Y\|X_i)\right) + E_{X_i}\left(V_{X_{\sim i}}(Y\|X_i)\right) = V(Y)$$ In this study the variances and expected values in the equations above were calculated over the full ensemble of 8GCM*3ET0 methods*8water use scenarios = 192 samples of 24 year time series in the retrospective period, or 30 year time series in the future period. We did not sub-sample the ensemble, but used the entire set of model outputs generated by all possible combinations of input factors. Section 2.8 was revised to better explain how the variance based sensitivity analysis was performed in this study,
7	Referee review	I found the figures poorly designed and difficult to interpret. Even Zooming to 200%, many of the claimed insights were not easily interpretable.
	Author's response	All figures were edited to improve clarity.
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