Response to Referee #2

By Sun S. et al.

General Comments:

In general the paper is well written and the subject matter represents a useful contribution to the journal. However, in my opinion the manuscript needs some significant revisions to make it a valuable contribution to the scientific literature. The following are the key problems with the manuscript. The representation of climate change is too simplistic to be useful from a policy guidance perspective. Specifically, the fact that the study only uses output from one GCM is problematic. There is a large degree of variability and uncertainty in GCM predictions particularly with respect to projections of precipitation patterns. Further, evidence to date suggests that inter-annual variability in precipitation is increasing with climate change. Such changes in variability are far more important with respect to their potential impacts on ecosystem productivity, forest health and water flow than trends in 30-year means. The analysis would be much improved by including additional scenarios using different GCMs and different assumptions with respect to annual variation in precipitation patterns. Accordingly, if this approach were to be followed, the results should focus on more than just changes in 30-year means.

Response: Thanks the referee's constructive comments. The reviewer correctly pointed out the likely issues of lacking GCM scenarios. We understand the large degree of variability and uncertainty in GCM predictions that our climate change community are facing. Our study is no exception. However, the major objective in this study is to link the process-based watershed scale ecohydrological model (i.e., the WaSSI model) with the dynamically downscaled climate data by the WRF model. We are hoping the methodology developed can provide a useful tool for assessing the potential impact of future climate change on hydrological and ecosystem fluxes.

The advantages of our study are that: (1) the simulation at natural watershed (i.e., 12-digit HUC watershed) can decrease the uncertainties of water balance due to the incomplete representation of key hydrological processes (e.g., lateral surface and subsurface flows) within the LSMs; and (2) the dynamic downscaling method with the WRF model is employed, which can also reduce the uncertainties of the WaSSI model inputs from effects of atmospheric dynamical processes. Additionally, to run the WRF model for dynamically downscaling climate scenario usually needs lager computational resource with lower computational efficiency, especially for the larger spatial extent (i.e., the CONUS) and the longer time span (i.e., 30 years).

To sum up, only one GCM climate scenario used in this study is mainly because of our major objective and the limited computational resource for dynamical downscaling. Of course, we admit that only one GCM output can also introduce some uncertainties into our results, and therefore, the next step for our study is to choose more GCMs output for evaluating future climate change impacts. Therefore we have also stated that "the study provides a potential scenario of likely impacts of future climate change on watershed hydrology and productivity across the CONUS, including 82,773 12-digit HUC watersheds. Although only one future climate scenario (the SRES A2 emission scenario) and one GCM (*HadCM3* model) was employed here, the methodology applies to other scenarios when more climate change scenarios generated from the WRF are

available" in the section of "5. Conclusions".

We agree with the referee's comments that climate variability is important for ecosystem productivity, forest health and water flow. It is also a key and interesting topic concerned by us. However, the WaSSI model is originally designed for simulating the key water (ET, Q and soil moisture storage) and carbon balances (GPP, ecosystem respiration and net ecosystem productivity) at the monthly scale, consequently that it has limited ability in estimating extreme climate impacts such as flood. In the next step, we will improve the WaSSI model ability through introducing hydrology and ecosystem responses to climate variability, and comprehensively explore climate change influences in water and carbon balances in the future works. In addition, as a specific case of climate variability, impacts of drought on ecosystem productivity, forest health and water flow have been discussed in this paper through citing other researchers' results (see the second paragraph of "4.1 Uncertainties").

In addition, the authors need to provide more detail with respect to the dynamic downscaling method employed. This method is highlighted as being a key objective yet little information is provided beyond citing Gao et al. (2011). **As mentioned above, it would be helpful if they provided more detail about how they are addressing inter-annual variation in precipitation patterns and temperature.** My recommendation is that the paper would only be acceptable if they were to adequately address these issues in a revised version.

Response: In this study, the dynamical downscaling method is performed by the regional climate model (i.e., the WRF model) with the GCM (i.e., the HadCM3 model) outputs as the forcing fields. Therefore, the detailed information about the dynamical downscaling method is the configuration of the WRF model. We have presented the WRF configuration in the fourth paragraph of "2.2 Dynamically downscaled climate by WRF".

Specific Comments:

The repetition of the phrase "82,773 12-digit HUC watersheds' throughout is tedious. I would suggest using a more descriptive name.

Response: Thanks for the referee's suggestions. We have revised the phrase in the revised manuscript.

Not sure why the Authors used the SRES scenarios as they were generated for the 3rd Assessment Report. We are now on AR5 and have new emissions scenarios and associated GCM runs. The authors need to justify why these were used instead of the newer ones from AR5.

Response: Yes, we used the SRES scenarios (AR4) from the 3rd Assessment Report, mainly because we did not have the dynamically downscaled GCM climate data of the AR5 in 2014. Now, we have finished the collection of the AR5 dataset, and are processing them.

In addition, we have reviewed some literatures (van Vuuren et al., 2007, 2011; Haensler et al., 2013; van Garderen and Ludwig, 2013) about the emission difference between the AR4 and the AR5. Comparing all the potential emission scenarios (Fig.1), it is not difficult to find that the highest emission scenario is the RCP8.5 of the AR5, followed by the second highest of the SRES A2 of the AR4. Despite of the slight lower emission level of the SRES A2 than that of the RCP8.5 (the maximum difference of ~5 GtC in 2060), this suggests that the selected SRES A2 emission scenario in our study generally represented the higher climate changes. Therefore, from an impact and adaptation point of view, if one can adapt to a larger climate change, then the smaller climate changes of the lower end scenarios can also be adapted to.

Moreover, because of the limited dynamically downscaled future climate scenario, we think that the SRES A2 is the best selection for our study objective at the beginning of our research.

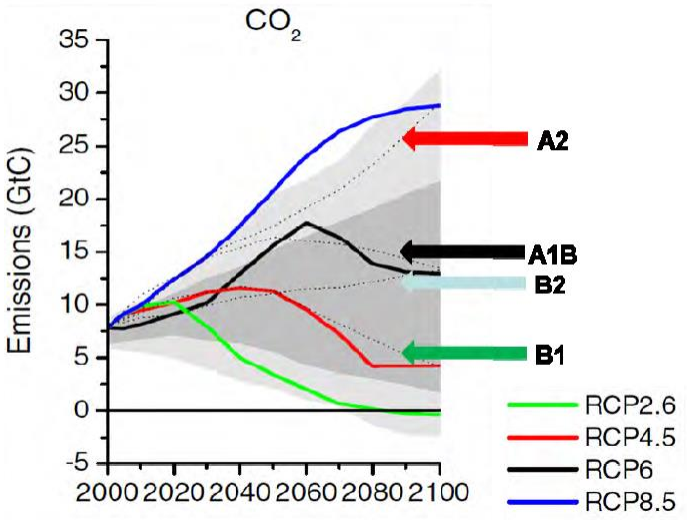

Fig.1 Comparison of emissions in the SRES (AR4) and the RCP (AR5) emission scenarios (Haensler et al., 2013).

References:

Haensler, A., Saeed, F., Jacob, D., 2013. *Assessment of projected climate change signals over central Africa based on a multitude of global and regional climate projections*. In: Climate Change Scenarios for the Congo Basin. [Haensler, A., Jacob, D., Kabat, P., Ludwig, F., (eds.)]. Climate Service Centre Report No. 11, Hamburg, Germany, ISSN: 2192-4058.

van Garderen, Ludwig, F., 2013. Climate change adaptation options for the Congo Basin countries. *In: Climate Change Scenarios for the Congo Basin.* [Haensler, A., Jacob, D., Kabat, P., Ludwig, F., (eds.)]. Climate Service Centre Report No. 11, Hamburg, Germany, ISSN: 2192-4058.

van Vuuren, D. P., Den Elzen, M. G. J., Lucas, P. L., Eickhout, B., Strengers, B. J., van Ruijven, B., Wonink, S., van Houdt R., 2007. Stabilizing greenhouse gas concentrations at low levels: an assessment of reduction strategies and costs. *Climatic Change*, 81(2):119-159.

van Vuuren, D. P., Edmonds, J., Thomson, A., Riahi, K., Kainuma, M., Matsui, T., Hurtt, G. C., Lamarque, J-F., Meinshausen, M., Smith, S., 2011. Representative concentration pathways: an overview. *Climatic Change*, 109:5-31.

Technical Comments:

Page Line 3 70 In comparison to the period between 1986-2005, the : : :

Response: "Comparing to" has been replaced by "In comparison to".

3 78 During what period of time?

Response: "In response, the hydrological cycle and ecosystems have been markedly changed through various physical, chemical and biological processes (Labat et al., 2004; Milly et al., 2005; Dai et al., 2009; Harding et al., 2011; Sedláček and Knutti, 2014)." has been replaced by "In response, the hydrological cycle and ecosystems have been markedly changed through various physical, chemical and biological processes during the past century (Labat et al., 2004; Milly et al., 2005; Dai et al., 2009; Harding et al., 2011; Sedláček and Knutti, 2014).".

3 85 “greenness phenology” is vague, “timing of bud burst” or something more specific would be better.

Response: “Comparing to” has been changed with “timing of bud burst”.

4 96 remove “the”

Response: “The” has been deleted.

4 97 “was the warmest on record”

Response: “the nation’s warmest on record” has been replaced with “was the warmest on record”.

4 99 Remove “The”

Response: “The” has been deleted.

4 103 remove “consequently”

Response: “consequently” has been deleted.

4 111 remove both “the”

Response: “The” has been deleted.

4 112 sentence is inverted, consider revising to start with “Tools are..”

Response: Done

5 130 “This approach..” instead of “this type of methods”

Response: “This approach” has been replaced with “this type of methods”.

5 136 Need to come up with a more clear description of the resolution to be explored. 12 digit HUC watershed will be meaningless to most

Response: We have added some information about the resolution of 12-digit HUC watershed into the section of “2.1 Study area”.

“Among these HUC watersheds, the size ranges from 0.16 km^2 to 9238.44 km^2, with the median and the mean values of 88.18 km^2 and 94.97 km^2, respectively. Moreover, area of the overwhelming majority of the watersheds (>80,000) is between 50 km^2 and 170 km^2.**”**

5 138 how can you examine future changes in the past (1979-2007). Please clarify

Response: The word of “examine” may inappropriate here. Therefore, we have changed “examine” with “evaluate”.

5 139 “using dynamically downscaled climate projections from the WRF model”

Response: “using WRF (Weather Research and Forecasting) dynamically downscaled climate data” has been changed with “using dynamically downscaled climate projections from the WRF model”.

5 140 “changes of Q, ET, and GPP for the study area by..”

Response: “changes of the CONUS water yield (Q), ET, and GPP by” has been changed with “changes of Q, ET, and GPP for the study area by”.

5 147 “The research area includes the conterminous continental US with a representation of 82,773 : : :”

Response: “The research area includes 82,773 12-digit HUC watersheds within the 18 Water Resources Regions (WRRs) over the CONUS” has been replaced by “The research area includes the conterminous continental US with a representation of 82,773 12-digit HUC watersheds within the 18 Water Resources Regions (WRRs)”.

6 158 remove “The” from the start of the sentence

Response: “The” has been deleted.

6 161 the percentages don’t provide much information eg. > 33% or < 33%

Response: This sentence has been rewritten as “The WRRs in the east generally had higher forest (including mixed, evergreen and deciduous forests) percentages (>33%) than the southwest (<30%).”.

6 176 It makes more sense to describe the GCM you selected before going into details about downscaling.

Also need to specify which emission scenarios were run with HadCM3 (only A2?)

Response: We have added some information about the HadCM3 model in the revision, and showed the related literatures.

In this study, we have specified the emission scenario (SRES A2) for running the HadCM3. Please see the sentence of "Therefore, the SRES A2 emission scenario was selected in this study.".

7 192 It's not clear what the authors mean by "six-hour HadCM3 input"

Response: For clarity, "six-hour HadCM3 input" has been replaced with "HadCM3 inputs with 6-hour time resolution".

7 201 RCM is never defined

Response: Thanks. We have defined "RCM (Regional Climate Model)" in the revised manuscript.

8 212 include

Response: "includes" has been replaced with "include".

10 279 Would make more sense to list the units going from large to small (12 digit HUC < WRR)

Response: We have showed the resolution of 12-digit HUC watershed. Please see the revised manuscript.

10 289 Section 3.1 could be removed. Nothing new here, just a summary of historical climate data. At least reduce in length.

Response: We have simplified the description of historical data

10 293 (with the exception of the Pacific Northwest)

Response: Changed

10 296 Sentence beginning with "Q with" needs a beginning statement

Response: Corrected

17 483 There are many better references for this

Response: We have added a few better references.

Figures

Fig. 5 Units in Fig 5 should be per month not per year.

Response: We have redrawn these figures in the revised version.

Fig. 6 I don't think this figure is useful. The same information is relayed more clearly in Figures 2 & 3.

Response: These figures present the number of the WRR within a given difference interval for **monthly** ET/Q/GPP, which would be useful for understanding their monthly changes in the future. These figures provide the readers information about the magnitude of monthly ET/Q/GPP changes for each WRR, and the spatial extent given monthly ET/Q/GPP changes. The figure 2 and 3 only show annual ET/Q/GPP variations. Therefore, we think Fig. 6 is useful and necessary, and would like to keep it in the revised manuscript.