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Discussions

Interactive comment on "Unravelling the impacts of precipitation, temperature and land-cover change for extreme drought over the North American High Plains" *by* Annette Hein et al.

Anonymous Referee #2

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The paper titled "Unravelling the impacts of precipitation, temperature, and land-cover change for extreme drought over the North American High Plains" uses the ParFlow-CLM model and a set of synthetic climate scenarios to investigate the role of different extreme climate conditions and their interactions in the severity of drought. The novelty in the paper is in its objective to quantify how comprehensively integrating subsurface flow into the modeling of the land surface acts to enhance or reduce drought conditions and the role that temperature, precipitation, and land cover play in those emergent conditions. The paper is appropriate for HESS and I believe it will eventually be suitable for publication. However, the scenarios need to be revisited and rerun before publication.

Main issues: The meteorological scenarios used in this study are physically inconsistent. One cannot just add or subtract from the temperature without accounting for how that impacts the rest of the meteorological states or fluxes. For example, downward longwave radiation is very strongly correlated to temperature and specific humidity is strongly connected to temperature. As such, if you are modifying one you have to modify the others. If not, the meteorology with which you force the model is mostly fantasy and not realistic. There are methods out there to deal with this. This needs to be addressed before publication by first making physically consistent meteorological scenarios and then rerunning the simulations.

Other comments:

Abstract, Line 10 - physically based equations? A lot of land surface and hydrologic models have physically-based equations. I really don't understand the need to use this terminology here. ParFlow is indeed an advanced groundwater model that uses our best understanding of how to model the flow of subsurface water over regional scales. However, that does not mean that other models do not use physically based equations. As long as models are not just complete black boxes, they will always have physically based equations. Those equations might be over-simplistic but they are still physically-based. In my opinion, the better analogy of ParFlow is the "superparameterization" term used in climate models. Anyway, I don't say this to lessen the value of ParFlow but using this terminology distracts the reader from the real strengths of ParFlow.

Abstract, Line 13 - I don't think there was a need to run such a complex model to prove that decreases in precipitation will cause the largest negative anomalies in the evapotranspiration, soil moisture, streamflow, and water table levels. The only flux that would compete with precipitation would be shortwave radiation. However, fortunately for us, the sun is not going anywhere anytime soon.

Page 1, Line 22 - There are studies over the past few years that show that drought recurrence has changed very little over the past half century. Droughts have devastating impacts regardless of if we consider climate change or not. The value of studying the impact of subsurface flow on droughts is critical regardless of the impact of climate change.

Page 3, Line 6 - It is true that the different meteorological factors are strongly interconnected. However, there is a reason for that. The states and fluxes are inherently interconnected. You can't think about precipitation without thinking about temperature. And you especially can't think about specific humidity, radiation fluxes, among others without thinking about temperature. As such, although separating them is a nice thought experiment it is not any realistic representation of what is going on in the observed physical system.

Page 3, Line 27 - Could we move away from the term "fully integrated hydrologic model"? I understand that you are reemphasizing the coupled groundwater, land surface model, surface flow advantages of the model. However, "fully integrated" has a very comprehensive meaning that leads to expecting too much from ParFlow-CLM and leads to stronger criticisms for the model than there should be. Fully integrated would mean a complete characterization of urban hydrology, water management, dynamic coupling with the ecosystem processes (i.e., ecohydrology), complete representation of flooding dynamics, among many many other processes. Again, ParFlow-CLM has significant advantages that should not be discounted or disregarded over more simplistic approaches and those should be emphasized. But you can do that in a more direct way instead of broad terminology such as "fully integrated".

Page 4, Line 23 - Van Genuchten functions should be Van Genuchten water retention curve. Also, it would be a good idea to cite the corresponding VG paper.

Page 5, Line 2 - It is certainly true that VIC does not model the lateral flow between macroscale grid cells and this is a feature that should have been addressed a long time ago. Thankfully most land surface models are finally moving in the right direction and starting to include groundwater flow between macroscale cells. In any case, VIC does

account for sub-grid flow of water even though it only does so implicitly in the variable infiltration curve. Stating that there is no lateral flow at all is not entirely accurate.

Page 5, Line 7 - I agree with this statement to a certain extent. Although it is fairly comprehensive down to the 1km scale grid scale (if we disregard the role of faults and karst terrain in the regional flow), it still completely disregards finer scales. There are plenty of hydrologic processes that play a fundamental role in ecosystem functionand structure that are far below the spatial resolution that you capture in ParFlow. As a result, there is still an underlying need to parameterize meter-scale coupling between the water, energy, and biogeochemical cycles. CLM does that somewhat but it is certainly still far from the objective.

Page 6, Line 6 - This should say sink-filled instead of processed. However, why is this necessary? The sinks in elevation maps can be real features. For example depressions in the landscape certainly exist. This is one of the large advantages in my opinion of ParFlow vs more simplified models since it allows you to directly model those depressions through subsurface redistribution or through accumulation over the surface and redistribution. Maybe I am misunderstanding something here. Please clarify.

Page 6, Line 17 - This is problematic. You can't assume pre-industrial conditions in water management but then use land use change from the past 30 years. They are fairly inconsistent. The agriculture over the plains is inherently dependent on irrigation. If you are going to have one you shouldn't throw out the other especially given the argument of a fully integrated approach. As you revisit the scenarios I would recommend also trying to address this inconsistency.

Page 6, Line 25 - Recursively? Do you mean repeatedly? Recursively has a very specific meaning in computing that doesn't make much sense here.

Table 2 - It is important to realize that the moment that you start varying the climatic conditions you will start also varying the response of the biogeochemical cycles. Certain plant species will die while others will flourish. As a result, the land use scenarios

that you use are inconsistent with what would actually occur with your prescribed forcing. I don't expect you to account for this because this is actually a problem in climate models. However, it might be a good topic to address this explicitly in the discussion section.

Page 13, Line 23 - I would say not strongly correlated. "Independent" is too strong of a word here.

Page 22, Line 16 - I would stay km-scale instead of small scale. That term is fairly nebulous and means different things to different communities. For example, small scale in watershed hydrology is cm to meter scale.

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