Reply to Reviewer #1

March 26, 2018

The referee's insightful comments are greatly appreciated. Our responses are detailed below.

The authors of this paper found the sources of water conservation error in E3SM atmosphere model that leads to long-term sea level rising and proposed the remedies to resolve them. This paper describes the error sources and fixing methods, as well as provides the sensitivity analysis of the water conservation error to model resolutions. Conservation is one of the most important issues scientists should pay attention to when developing the model. It is a hidden threat to long-term simulation. Although the fixing methods in this manuscript are somewhat remedies and bugfixes instead of root cures, the contribution this manuscript represents is an important achievement to E3SM development. The solution this manuscript proposed can be applied to any other model. The manuscript is well-organized and the conclusion is convincing. I would suggest accepting with revisions based on the following comments.

Specific Comments

In the introduction section, there is little to no evidence/literature showing the relationship between water conservation error and sea level rising. The literature mentioned is too weak to support this connection. The authors may need to provide some strong evidence on it.

The relationship between water conservation error and sea level rising is indeed not entirely clear. The revised introduction acknowledges this, and puts the emphasis of discussion on conservation error instead of sea level prediction. We clarify that the reported "equivalent sea level rise" is the depth of liquid water that would accumulate at the Earth's surface if the increased water amount in the atmosphere were converted to precipitation and distributed evenly over the surface of the globe.

Equation (6): The meaning of "W" is vertically integrated total atmospheric water with a unit of kg/m^2. After multiplying "A", the grid cell area, and dividing by liquid water density, the result should be volume, but not height. I think the area of ocean is missing in the equation. Assume this equation is corrected. It is possible that some local spurious water source/sink stay in the atmosphere, leading to less sea level rising. So, it may not have that large effect on the actual

sea level rising.

Thanks for pointing this out. Equation (6) in the discussion paper is missing a denominator, and what we used was the surface area of the entire globe. The reported "equivalent sea level rise" is the depth of liquid water that would accumulate at the Earth's surface if the atmospheric water from spurious sources was converted to precipitation and distributed evenly over the surface of the globe. As the referee pointed out, part of the spuriously created water might stay in the atmosphere, resulting in less amount reaching the surface than we reported, although our analysis suggested that the long-term global-mean net surface flux $(P - E)$ was close to the spurious water source $\Delta W/\Delta t$. Another point to consider is that in reality, the increased precipitation is likely to end up in the oceans and in reservoirs over land such as lakes, ice caps and glaciers, hence the division in Eq. (6) by the surface area of the entire globe is likely to underestimate the change in sea level. To provide an accurate assessment of the impact of the conservation error, one should conduct a pair of coupled model simulations with and without the fixes discussed in our paper, and compare the simulated sea levels. Unfortunately we did not have sufficient resources to conduct such simulations to evaluate the impact of water conservation in isolation. (The coupled simulations presented in the paper contained various other changes that have impact on the simulated sea level.) The "equivalent sea level rise" reported in our paper is essentially a measure of water conservation error, not the actual sea level drift in E3SM. This is clarified in the revised manuscript after Eq. (6) is presented.

Line 18: I am not sure whether you can cite an unpublished paper: Rasch et al, 2017.

Our current plan is to replace this citation by a reference to the E3SM public website, and will update the information when E3SM V1 is released.