REVIEWER 1:

This paper developed an integrated water demand and water availability model where the climate change and water demand projections are based on the same socioeconomic development. This is interesting and important since water demand and availability projections are usually conducted separately. This integrated model reflects the interconnection of socio-economics, water demand, and climate. I have some questions which need to be clarified.

Line 10 page 3329: "integrated assessment model of energy, agriculture, and climate (GCAM)". Add references for GCAM?

We have added the following four references:

> *Edmonds J., and J. Reilly, Global Energy: Assessing the Future, Oxford University Press, New York, 1985.*
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> *Brenkert M., S. Smith, S. Kim, and H. Pitcher, Model Documentation for the MiniCAM, PacificNorthwest National Laboratory, Richland,Washington, 2003.*
>
> *Kim S., J. Edmonds, J. Lurz, S. Smith, and M. Wise, The object-oriented energy climate technology systems (ObjECTS) framework and hybrid modeling of transportation in the MiniCAM Long-term, global integrated assessment model, Energy J. 27 (2006) 63–92.*
>
> *Clarke L., J. Lurz, M. Wise, J. Edmonds, S. Kim, H. Pitcher, and S. Smith, Model Documentation for the MiniCAM Climate Change Science Program Stabilization Scenarios, Pacific Northwest National Laboratory Richland, WA, USA, 2007.*

Line 27 page 3329: "Furthermore, any quantification of climate change impacts on water resources is incomplete without also incorporating human demands of water. . ." Why? Should be "..climate change impacts on water stress. . ."?

Changed 'water resources' to 'water stress', Thanks!

Line 14 page 3330: "Oki et al. (2001,1999)" to "Oki et al. (1999,2000)"

Changed 'Oki et al. (2001,1999)' to 'Oki et al. (1999, 2001)'. There is no Oki et al. 2000

Lines 14-19 page 3330: are these models implemented in GCMs? Otherwise, "incorporated" in line 7 needs to be changed (to "coupled"?).

Changed to 'coupled', thanks!

Lines 22-28 page 3330: What are the differences between this group of water balance model and the hydrologic models in the previous paragraph? Model structure or the way of coupling with GCMs?

We have rephrased the sentence this:

> *For assessment of climate impacts on water, general circulation models (GCMs) and their representation of the hydrologic cycle are often used to provide spatially and temporally explicit quantification of changes in the water system over the upcoming century.*

Lines 10-11 page 3331: "soil water content thresholds are set at which irrigation is triggered". Are "soil water content thresholds" the lower bounds of soil water content? Not clear.

We are referring to the soil moisture threshold at which a crop model assumes that irrigation is applied. The sentence now reads:

> *In several of the models that focus on agriculture, soil moisture thresholds are set at which irrigation is triggered.*

Lines 1-12 page 3333: The GCAM model is described briefly in this section. It seems that the GCAM model includes the component of climate model (Figure 1). Are precipitation and temperature projections up to 2095 generated by the component of "Climate System"? If this is the case, what's the time step for projected rainfall and temperature? If it is monthly, please clarify "runs in five-year time steps" (line 5 page 3333). GCAM is like an integrated climate and socio-economic model.

GCAM uses the Model for the Assessment of Greenhouse-gas Induced Climate Change (MAGICC) as its representation of the atmosphere, ocean and climate systems. MAGICC itself is a reduced-form of the climate model and is often used to emulate global-mean results from most complex general circulation models. Thus, MAGICC does not provide any of the gridded monthly climate forcings necessary to derive the hydrology module in GCAM, and such information is taken from GCMs while ensuring that the total radiative forcing trajectory is consistent between the GCM forcings and the GCAM representation of climate as described in the paper.

Lines 18-23 page 3333: There is no river routing in the hydrologic model. Please add some discussions on its impact on monthly runoff at the spatial resolution of 0.5 degree. The missing of river and reservoir routing may be important at the monthly scale.

We agree with the reviewer that adding river routing is an important feature. But given that the focus here is to simulate annual quantities over very large basins, river routing becomes less important. We explain this in the manuscript:

> *River routing is generally an important feature to achieve accurate monthly estimates of runoff, but it is less crucial when accounting for water on an annual basis and over very large first order basins that drain directly to non-fresh water bodies.*

Line 3 page 3334: specify the time period of "historical streamflow observations".

The historical streamflow observations span different periods within the historical simulation period (1901-2002). Table S2 provides a detailed list of the observations periods for the individual basins.

Line 16 page 3334: what's the water scarcity indices of Falkenmark (1989) and Raskin (1997)?

We have added:

> *Falkenmark (1989) assumes that a country or region experiences water stress when annual water supplies drop below 1,700 cubic meters per person per year, and faces water scarcity when they drop below 1,000 cubic meters per person per year. Raskin et al. (1997) compare total water demand to the total amount of renewable water available, and define extreme water scarcity in any region as demand in excess of 40% of total water availability; Wada et al. (2011) provide a detailed summary of previous studies that have used the definition of Raskin.*

Lines 27-28 page 3334: “a gridded monthly water balance model with a resolution of 0.5×0.5â°U ˛ e” which repeats the previous sentence.

This is the first sentence in the paragraph. It is not clear what the concern here is!

Line 1 page 3335: “maximum soil water storage capacity (a function of land cover). . .”. But in lines 10-11 page 3335, “The maximum soil moisture storage capacity . . ... and soil properties. . .”. The computation of Sm, which is a very important parameter for your monthly water balance model, is described Lines 11-17. This part should be described with more details, such as Sm= root depth *(field capacity-wilting point value)? How are root depths computed?

These are not dynamically calculated, but rather taken as an input to the model. As already described in the manuscript, this is obtained from the soil map of the world (FAO, 1998, 2003)

> *The maximum soil moisture storage capacity (S_m) with a resolution of 0.5x0.5 degrees is obtained from the soil map of the world and soil properties (FAO, 1998, 2003). Information with regard to the "maximum soil moisture storage capacity" in mm/m is derived from the "Derived Soil Properties" of the "Digital Soil Map of the World" which contains raster information on soil moisture in different classes (FAO, 1998, 2003). Maximum available soil moisture is estimated from estimates of root depth, field capacity, and wilting point values (typically ranges between 15-350 mm/m). The root depth estimate is itself a function of land cover and water stress conditions. In this study, a static S_m map over time is assumed.*
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> *FAO: Digital soil of the world and derived soil properties, Rome, 1998.*
>
> *FAO: Water Resources and Irrigation in Africa, Initially published in "Atlas of Water Resources and irrigation in Africa (CD-ROM)", FAO, Rome, 2001.*

Figure 2: It is difficult to read the numbers in the legend. If the purpose is only to present the model structure, the diagram is not quite informative since it only shows the inputs and outputs of the monthly water balance model. “. . .renewable water resources (i.e., annual flow of rivers and recharge of aquifers). . .” How is recharge of aquifers computed? No description of the recharge in the description of model structure such as Figure 2 and equation (1).

We have dropped figure 2 and updated the numbering of all the following figures.

The model does not account for any groundwater recharge from the soil column downward to aquifers. We have corrected the statements in the manuscript to clarify this point.

Lines 25-26 page 3335: “. . .the amount of water available (St−1+Pt−PETt). . .” It is not clear for me that PETt is used here for defining available water.

We have dropped “(St−1+Pt−PETt)”. What the sentence meant to say is that water availability is affected by these terms.

Lines 17-18 page 3337: “. . .from the Tyndall Centre for Climate Change Re- search (TYN SC 2.1, Mitchell and Jones, 2005). . .” Are the monthly climatic inputs in the future taken from TYN SC 2.1? Is TYN SC a component of GCAM? If not, how the interaction and feedback between human water use and socio-economic and climate systems are quantified in the GCAM?

The GCM data employed in this study came from the Climate Research Unit (CRU TS 2.0) and from the Tyndall Centre for Climate Change Research (TYN SC 2.1). The Tyndall data is not a component of GCAM. As we discussed earlier, GCAM uses the Model for the Assessment of Greenhouse-gas Induced Climate Change (MAGICC) as its representation of the atmosphere, ocean and climate systems. MAGICC itself is a reduced-form of the climate model and is often used to emulate global-mean results from most complex general circulation models. Thus, MAGICC does not provide any of the gridded monthly climate forcings necessary to derive the hydrology module in GCAM, and such information is taken from GCMs while ensuring that the total radiative forcing trajectory is consistent between the GCM forcings and the GCAM representation of climate as described in the paper.

Lines 5-15 page 3338: The difference of estimation methods may also contribute to the difference of runoff estimation.

We do list modeling approach as one of the factors that contribute to the difference.

Lines 17-20 page 3339: it seems that rainfall and temperature based on GCM are feed into the developed hydrologic model. Then how is the socioeconomic feedback to water availability shown in Figure 1 is included in the modeling framework?

The arrows are from the land use and climate systems to the water availability component. The land use arrow is reflective of the representation of land use, which governs the runoff-generation process. The climate arrow dictates that the climate forcing used to simulate the hydrology are consistent with the emissions computations in the climate system in GCAM.

Lines 21-23 page 3340: "In this study, socioeconomic characteristics and emissions prices are adjusted so that the GCAM output for radiative forcing matches that associated with the SRES A1Fi emission scenario. . ..". This is important. The socio-economic scenario of water demand matches the emission scenario of climate change. I think this is the strength of the integrated model of this paper.

Thanks.

Lines 22-23 page 3341: ". . .Assuming that population density maps remain static over time within each GCAM region. . ." not clear. Why does population density remain static with the increase of population?

This is simply to guide the downscaling step necessary to transform the water demand results to grid scale. When population is used to downscale from a particular region to grid scale, the way we distribute within a region stays the same – that is, the distribution of where people live within that regions stays the same over time even though population itself will be changing.

Line 12 page 3343: How to quantify "total water availability (TWA)" in the developed hydrologic model? Mean annual runoff? Is the future water demand projected by the population growth? The virtual water by goods trade such as food can mitigate the water scarcity regionally. This may be included in the discussion.

Yes, it means Mean Annual Runoff. The projection of water demands is not only a function of population, although population is an important factor. The issue of virtual water is important but is beyond the scope of the current study.

The length of the paper may be reduced. From example, the number of figures can be reduced.

We have dropped figure 2 (as suggested by reviewer 1) and figures 3, 10-14 (as suggested by reviewer 2).