Response to the 1st Reviewer's Comments:

General Comments:

- "The most important feature still missing in the model - and the authors clearly mention it - is a good routing scheme for the major inflows. Without a routing scheme the Caspian Sea cannot respond properly to changes in the precipitation in the surrounding drainage basins. I'd strongly encourage the authors to pursue this work as announced in the discussion section."

  We plan to add a realistic river runoff/routing component to the coupled modeling system in the near future. We are investigating a wide range of river routing models from very basic ones (relies on the evaporation, precipitation and surface runoff balance) to the sophisticated ones such as Max-Planck's HD model and also SWAT.

- "The only confusion arises from SST and LST that are used synonymously, sometimes LST is used, in other places SST. I suggest the authors make this consistent and either talk about sea surface temperature or lake temperature"

  We will change the following lines to be consistent in the manuscript.

  Page 3908, Line 9: "lake surface temperature (LSTs)" will be modified as "Caspian Sea Surface Temperature (SST)"

  Page 3918, Line 17: "lake surface temperature (LST)" will be modified as "sea surface temperature (SST)"

  Page 3920 Line 25: "LST" will be modified as "SST"

  Page 3921, Line 6, 23, 26, 27, 28: "LST" will be modified as "SST"

  Page 3928, Line 20: "LST" will be modified as "SST"

Specific Comments:

- "Abstract: "The distribution of sea ice and its seasonal evolution are well captured." I don't really agree with that statement, the sea-ice extent is well captured, but definitely not the sea ice concentration (fraction)"

  Page 3908, Line 12, 13: The sentence "The distribution of sea ice over the shallow northern shelf of the Caspian Sea and its seasonal evolution are well reproduced." Will be modified as "The sea ice extent over the shallow northern shelf of the Caspian Sea and its seasonal evolution are well reproduced, however a significant negative bias in sea-ice fraction exists due to the relatively poor representation of the bathymetry."

  The detailed explanation of the bias in the sea-ice fraction can be found in page 3927 between lines 5-16.

- "Model description (sections 2.1-2.2): These sections list all possible options fro the different components, although only one of the options is selected for the model. For example all possible convection schemes are listed, but this information is not relevant in the context of this paper. Why not shorten these sections and only list the relevant options? Possibly this could be done in a table."

  We have shortened the first paragraph describing RegCM4, which now only mentions the specific options used for this study,

  "The dynamical core of the RegCM is based on the primitive equation, hydrostatic version of the National Center for Atmo- spheric Research (NCAR) and Pennsylvania State University mesoscale model MM5 (Grell, 1995). The model includes the Biosphere-Atmosphere Transfer Scheme (BATS; Dickinson et. al., 1989) along with the ocean/atmosphere flux parameterization of Zeng et al. (1998). The model also contains the nonlocal boundary layer scheme of Holtslag et al. (1990) (as augmented by Giorgi et al., 2011), the radiative transfer package of NCAR Community Climate Model Version 3 (CCM3; Kiehl et al., 1996), the explicit cloud/precipitation scheme of Pal et al., 2000), and the Grell cumulus convective scheme (Grell, 1993). More details about RegCM4 can be found in Giorgi (2011).

- "Coupling (section 2.3): Figs 1 and 2 didn't contribute to my understanding, rather confused me. Take Fig 1: does the process marked with a 1 (the black dot with a 1) run first, then stops and process 2 is done? Or do they go in parallel? I think this section needs some revision to better explain the workings of the coupling in this model."

  Actually, Fig. 1 shows the execution order of the different components of the coupled modeling system. According to the ESMF (Earth System Modeling) convention, each modeling component must have three subroutine, which control the initialization, run, and finalization phases. So, the step 1, 2, 3 and 4 will be parallel for the components. Then only atmospheric model processes (or PETs in ESMF terminology) will perform step 5. So, step 5 is also parallel but only for a subset of the PETs (from 0 to N-1). After running atmospheric model, step 6 will be distributed to the available processor (both atmosphere and ocean model PETs) because it preforms interpolation over the exchange fields such as surface momentum and heat fluxes. The step 7 is exactly same of the step 5 but in this case ocean model will run. This step is basically distributed only to the ocean model PETs and then interpolation will be performed in the reverse direction (step 8). Like step 6, step 8 interpolates data from ocean model to atmospheric model grid and all the available processor is used in this case. The step 5,6,7 and 8 will be repeated (in each coupling time interval which is defined as 3 hour in this case) until the coupled model reaches to the end of the simulation. Finally, all the ESMF components will be destroyed in step 9,10,11 and 12.

  The following changes will be made in the section 2.3:

  Page 3914, Line 7-8: The following sentence will be added "In this case, the processes are executed in parallel because there is no any dependency among the components in the model initialization phase. The reader also note that the step 1 and 2 only works on the specific subset of the PETs but step 3 and 4 distributed via all the available PETs because the coupler component will perform interpolation using all the PETs" after the sentence which begins in line 7.

  Page 3914, Line 8-10: The following sentence will be added, "Unlike initialization phase, the execution order will be sequential in this case due to the data dependency among model components (in both direction, forward and backward) but each component (models and the coupler) will run in parallel inside of their own MPI communication world (a subset of PETs)" after the sentence in line 8 (starts with "Then, ….").

  Page 3914, Line 12: The following sentence will be added, "The finalization phase (step 9-12) will be also sequential because ESMF needs to destroy the components in a specific order (first coupler component and then model components)" to the end of line 14.

- Atmospheric model (section 3.1): I am not an expert on lake models, but a vertical resolution of 1 m in combination with 50 km horizontal resolution seems to be odd. Please comment.

  The one-dimensional lake models can be assumed as a first order approximation to represent inland waters and lakes more realistically in the climate models. The three-dimensional models have some restriction in both horizontal related with the Rossby radius of deformation to represent the small-scale circulation features such as eddies but there is no any exchange between adjacent cells in the one-dimensional lake models so a 50 km horizontal resolution with a 1-meter vertical resolution is reasonable. Below are a few studies, which have successfully employed a 1-D lake model in the same manner.

- Small, E.E., L.C. Sloan, S. Hostetler, and F. Giorgi, 1999. Simulating the water balance of the Aral Sea with a coupled regional climate-lake model. Journal of Geophysical Research 104 (D6): 6583-6602.
- U.U. Turuncoglu, N. Elguindi, F. Giorgi, N. Fournier, G. Giuliani, 2013. Development and validation of a regional coupled atmosphere lake model for the Caspian Sea Basin, Climate Dynamics, DOI: 10.1007/s00382-012-1623-6
- Notaro, M., Holman, K., Zarrin, A., Fluck, E., 2012. Influence of the Laurentian Great Lakes on Regional Climate, Journal of Climate, DOI: http://10.1175/JCLI-D-12-00140.1

- "Ocean model (section 3.2): "The ratio of internal to external mode time step is defined as 20s." It's a ratio and should thus be unitless."

  It is correct. We will remove the unit from the ratio.

  Page 3916, Line 27: "step is defined as 20 s." will be changed as "step is defined as 20."

- "In this section it says that the wetting and drying scheme of ROMS are activated. Is that consistent with the statement on l.12 p.3912?"

  Yes. They are consistent.

- "The last paragraph of this section is unclear. Does your model need relaxation to maintain a stable climate after the spin-up? Or do you relax during the spin-up?"

  The relaxation is only applied to the spin-up simulation (standalone ocean model forced by output of the standalone atmospheric model, ATM.STD) to create initial condition for the ocean model. The OCN.STD and OCN.CPL (same run with ATM.CPL) use the result of the spin-up run as an initial condition and we did not apply relaxation to the both OCN.STD and OCN.CPL simulations.

  Page 3917, Line 23: We will add the following sentence, "The reader also note that the three-dimensional temperature and salinity relaxation is activated only in the spin-up run not in the OCN.STD and OCN.CPL simulations."

- Observational datasets (section 3.3): I miss a description of Ibrayev's climatology that is used later. In particular, this dataset could warrant a discussion of the fact that these data d not cover the same time as the model simulations. Given the large fluctuations of CSL this could be a rather strong caveat.

  The Ibrayev's climatological dataset is based on distinct in-situ measurements (i.e. CTD) and do not cover the same period as the model simulation. To clarify this point, we add the following sentence to the description of the dataset found in section 3.3 at the end of paragraph 3,

  "However, it should be noted that the Ibrayev's climatology is based on the unknown years (we could not get the Ibrayev's original paper that includes detailed information about the climatological data), which is different from our model climatology (1999-2008). While a comparison between the two climatologies is not ideal, it can nonetheless give an idea of the general model performance."

- Results: l.21 p.3919: why do you think the excessive vertical heat transport is inherited from the driving ERA interim analysis at the boundaries? The Caspian Sea shouldn't be influenced by the boundary conditions, or?

  In the current version of the coupled model setup, the size of the domain of the atmospheric model component is not enough to produce large-scale systems inside the

RCM domain and those features are inherited from the driving dataset (in this case ERA-Interim). Indeed, ERA-Interim has a significant warm bias in the northeastern portion of our domain (over land, not over the Sea), and this warm bias is transmitted to the regional model via the boundaries. During the winter, this region is characterized by very cold, stable conditions near the surface. We have found that the planetary boundary layer (PBL) scheme is not able to reproduce well these very stable conditions, which results in too much mixing in the lower PBL and thus warmer temperatures.

- Figure 6 and discussion: I wouldn't plot precipitation bias in an absolute scale, rather the ratio model/observation - 1 (relative bias). The reason is that precipitation varies a lot, and small differences can be significant in dry regions but mean nothing in areas were precipitation is abundant. The precipitation differences you show in Fig.6 are of similar order of magnitude than the observations, and therefore I wouldn't call the biases small in the text.

According to your suggestion, we will change the Fig. 6 with the following one. In this case, the plot shows the relative bias rather than the absolute differences. The text in the manuscript will be modified based on this change.

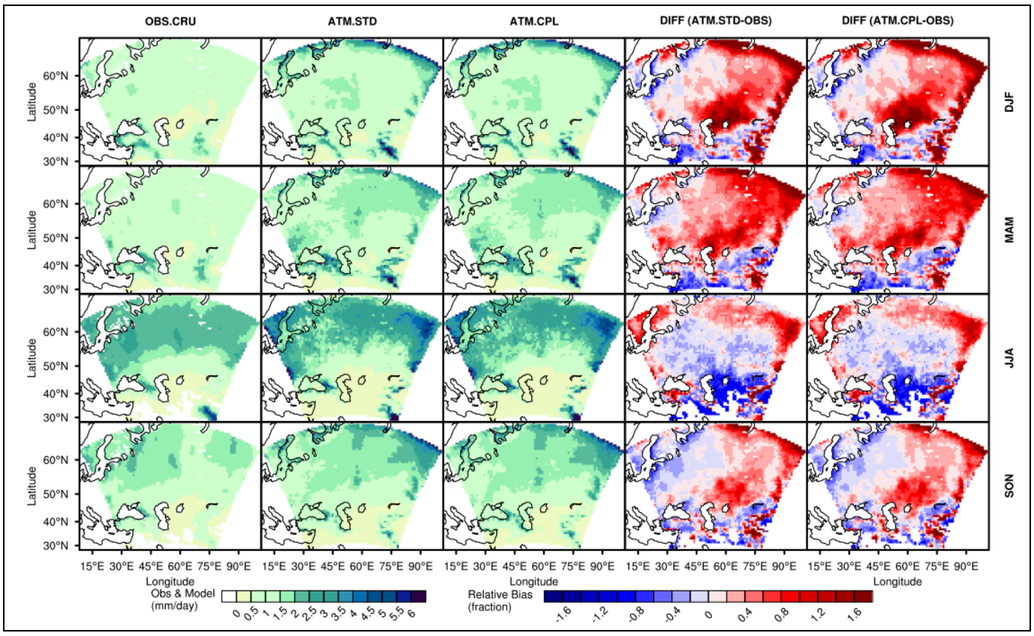

Figure 6 Seasonal precipitation climatology of ATM.STD, ATM.CPL simulations and observation (CRU version 3.10), along with the corresponding relative biases for the period 1999-2008.

- "l.15ff p.3924: you mention a few caveats for the OAFlux dataset. Do you have a reference for these statements?"

Actually we contacted directly the data providers of this dataset to get this information. The detailed information about the possible error sources in the OAFlux dataset can be found in the following papers,

Yu, L., and X. Jin (2012), Buoy perspective of a high-resolution global ocean vector wind analysis constructed from passive radiometers and active scatterometers (1987–present), J. Geophys. Res., 117, C11013, doi:10.1029/2012JC008069.

Also, this reference will be added to the end of the sentence in page 3924 and line 19.

- "l.10 p.3925: You conclude that a 3-d ocean model is essential for the simulation of the evaporation. But, where is evaportation computed? Isn't it done in the atmosphere model? If so, how would the 3-d ocena model improve the representation of the evaporation?"

The latent heat (or evaporation) is calculated by atmospheric component. Basically, latent heat is a function of the sea surface temperature or ground temperature in the land points. The ocean model updates the SST over Caspian Sea and the updated SST information is used to calculate latent heat in the atmospheric model. So there is two-way interaction between coupled model components and this also affects the sea surface evaporation. The sea surface circulation and temperature also affects the rate of evaporation over Caspian Sea. As can be seen from the Fig. 13, the strong circulation in the central Caspian Sea reduces the evaporation due to the mixing. The 1-d lake model is not capable of representing this kind of complex mixing features because there is no interaction between adjacent grid cells.

- "l.21ff p.3925: does it really make sense to include Figure 15 and comments given the fact that no river routing is included and all inflow is based on climatology? The conclusions are rather limited."

  The CSL calculations are based on the modeled precipitation, evaporation and observed monthly river runoff not monthly climatology. We agree that we don't have a real river runoff component in the designed modeling system but we think that the included CSL calculations can give a crude estimation about the actual performance of the coupled modeling system, and in particular it evaluates how well the model reproduces net evaporation (P-E) over the Sea which is a large component of the water budget. At this stage, we prefer to keep Figure 15 in the manuscript, however, if the reviewer strongly objects we will gladly remove it.

- "l.1ff p.3927: Similar temporal pattern? My eyes tell that the modeled annual cycle has a larger amplitude than the observations in Fig.16."

  Page 3927, Line 1: The sentence "As it can be seen from the figure, all the simulations shows very similar temporal pattern and produces % 10–20 less cloud cover than the observational data but correlation of the simulated and observed cloud cover as high as 0.91." will be modified to "As can be seen from the figure, all of the simulations capture the observed seasonal cloudiness cycle and have correlations which are around 0.91, however the models have a significant negative bias, producing 10–20% less cloud cover than the observational data."

<u>Technical Comments:</u>

- "Some figures contain empty spots, for example in Fig.1 the spring pictures for ATM.CPL is missing. Is that on purpose or did just some of the figures disappear when producing the pdf?"

  We checked but we could not see such kind of empty spots in the figures. Probably it could be related with the PDF reader client. Also, there is no ATM.CPL label in the Fig. 1, which demonstrates the general structure of the coupled modeling system. If you provide detailed information about it (figure number, specific part etc.), it would be helpful for us to find the problem in the figures.