Interactive comment on "Seasonal variability of the Caspian Sea three-dimensional circulation, sea level and air-sea interaction" by R. A. Ibrayev et al.

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We thank G.Korotaev (Referee) for his constructive comments (shown in "quotes")

> "The paper of R.A. Ibraev et al. is subjected to the simulation of the Caspian Sea hydro thermodynamics with realistic atmospheric forcing and comparison of the model result with available observations. Rather sophisticated model is developed by authors to carry out simulations. It is based on the circulation model with free surface coupled with air-sea interaction module which allows adjust atmospheric fluxes to the sea state and sea-ice thermodynamics. Atmospheric forcing is slightly corrected ERA-15 reanalysis for 1982 which was selected as the annual sea level increase was smallest during that year according to observations. Simulations presented in the paper under the review to my knowledge are the best for the Caspian Sea."

No response required

> "The circulation model is well designed and clearly outlined. However models of sea ice and air-sea interaction are described very briefly with reference to other publications for more details. Probably it is better to provide broader description of both sub-models in the text of the paper and emphasis specific problems that were solved."

Response: Sub-models of sea ice and air-sea interaction, included in our model are used without modification with respect to the original publications of Schrum and Backhaus (1999) and of Launiainen and Vihma (1990). Therefore, we only give a brief description in our paper and refer to these papers for details.

> "I can also recommend authors to describe better how simulations were fulfilled. It is not clear how non-periodic boundary conditions (atmospheric forcing, river runoff) were used to reproduce 1982 seasonal cycle."

Response: We repeat our comments given to Anonymous Referee #1. Technically, modeling of the seasonal cycle implies integration of the model equations for several years subject to periodic annual atmospheric and river forcing, based on the assumption that the solution does not have a long term trend. If a climatological steady state exists, this assumption is valid. For the Caspian Sea it is rather difficult to find a 30-year period with stable sea level, especially after the 1950-es, when corresponding atmospheric observations have become more abundant. It should be noted that the sea level response is an integrated function of the forcing and internal dynamics. Use of forcing with trend in water balance will mean that the yearly net sea level change will not be zero. Consequently, the simulation with an inaccurate forcing (possibly with an unrealistic trend) for about 10 years (otherwise sufficient for getting a quasi-periodic solution for the relatively small Caspian Sea) will result in a solution that diverges from reality. The means to escape this are either i) to artificially balance the water budget of the basin; or ii) to adjust solution so as to have zero mean sea level at the end of every model year. Both of these methods have drawbacks. We have therefore chosen to force the model with data corresponding to a period with nearly balanced water budget.

One of the choices resulting from our approach would have been to force the system with climatic atmospheric forcing. This would have the above stated disadvantage of having an unrealistic trend in it, reflected in the observed evolution in sea level after the 1950-es. The other choice, which has been adopted, is to simulate a single year in which the net sea level change between the first and the last day is minimal. Our analyses, based on a literature search and discussion with experts showed 1982 to be a candidate satisfying the above criteria within the 1979-1993 period, corresponding to the ERA15 atmospheric re-analysis data that has been used. 1982 had been a balanced year with respect to water budget while the Volga river run-off (222.3 km^3/yr), was at a medium range that is still larger than 11 other years in the 37-year period from 1961 till 1997.

Considering the general lack of understanding of the Caspian Sea circulation and sea level variability pointed in Introduction section of our paper, we directed our attention to a single year with balanced water budget so as to investigate dynamical linkages of the system, and to establish a good starting point for future investigations. The one-year simulation obviously will not answer all the questions with respect to the multi-decadal climatic oscillations of the system, especially at the present level of availability of observational data, but we hope further studies will be made of the inter-annual variability aspects. One of the questions in this respect is the role of the changing volume and surface area of the Caspian Sea, modifying its response characteristics as a function of sea-level. This important aspect can only be answered by including flooding/drying processes in the models.

In the revised version we will give a better discussion of our choice for simulating a single year and describe the technique for simulation of the seasonal cycle.

> “It is not clear why the net heat flux during the last year of integration is almost equal zero? What about the net fresh water budget?”

Response: It is both hard and easy to answer. We can’t say if the net heat flux is balanced, then we reached a periodic solution, because the net water budget is not zero, see Table 2, while the sea level increment is equal to 7.0 cm. We only point out the fact that the model was able to correctly simulate the seasonal cycle of heat and water fluxes.

> “The paper presents general description of the seasonal cycle of currents, temperature, salinity, sea ice and sea level. Special attention is paid to the seasonal variability of air-sea fluxes. It follows from the paper that the agreement between model results and that what is known from observations or another model studies is quite reasonable. This is very important characterization of the model quality if 3D state of the basin is formed only by air-sea fluxes and river runoff. However the model starts from climatic state of November and it is not clear from the text how sensitive simulation results to the initial conditions.”

Response: This is a valid point. In preliminary runs of the model starting from climatic temperature and salinity data, we have verified that the solution is independent of the initial conditions after few years of integration, especially in the upper part of the water column.

> It is shown by authors that the Caspian Sea is a very delicate basin rather sensitive to input parameters. Sensitivity study presented in the paper permits to evaluate qualitatively possible distortion of the simulation results due to uncertainties in the

fluxes on the sea surface, river runoff, etc.

At the same time it seems for me that it is possible to present broader comparison of simulations and observations. I do not understand why nothing was done to compare simulated temperature and salinity fields with climatic data base or at least with simulations of Ibraev et al. (2001). Maps of SST distribution can be compared with SST maps retrieved from the space IR measurements to show how the model reproduces spatial SST distributions. Such comparison is useful to show the quality of radiation and heat fluxes on the air-sea interface."

Response: Yes, we agree that more comparison with observations is necessary for validation of the model. At this stage of our continuing studies, we only have compared the solution with a number of climatological norms concerning hydrodynamics. We plan to present the results of a more rigorous validation procedure in the following paper, where we will analyze meso-scale dynamics of the Caspian Sea, with increased resolution of the computational grid and atmospheric forcing.

"Probably there is a reason to extend analysis of the sea level evolution during a year. Authors mention on page 1917 that the sea level oscillations during a year reflect annual variability of the net water budget. Therefore a major part of the signal shown on Fig. 19 can be obtained from a simple water balance equation $S \cdot \frac{d\bar{\varsigma}}{dt} = W$ (S - sea surface area, $\bar{\varsigma}$ - sea level averaged over the basin area and W - net water bud- get. This means that the comparison of simulated and observed sea level variability on Fig. 19 characterize mainly the quality of the river runoff, precipitation and evaporation data. Only deviation of the sea level evolution on every of four sites from the sea level evaluated by the water balance equation is important to show circulation model skill. I recommend authors to provide such comparison with observations. Other case Fig.19 is just misleading."

Response: It is true that the major part of the signal shown on Fig. 19 can be obtained from a simple water balance equation. On the other hand, there are rather large differences of sea level connected with circulation dynamics at each site as we have endeavored to show, that reflect the deviations of the sea level from the one predicted by the water balance equation. We point out the local effects of hydro- and thermodynamics, resulting in widely varying values of net sea level change: 18 cm in Makhachkala, 25 cm in Baku and 32 cm in Krasnovodsk.

"The paper contains a set of conclusions which clarify the Caspian Sea hydrothermo- dynamics (fronts, gyres and their evolution, spatial variability of temperature). The most interesting of them is an explanation of a warm water tongue along the eastern coast which appears due to a warm water transport to the north by sub-surface current though surface currents are directed often to the south. Those conclusions are of great interest and prove the expediency of the paper publication."

Response: No response required

"However an advantage of numerical simulations if to compare with observations consists in the possibility provide full analysis of the most interesting phenomena.

Validation of some model results by observations justifies a need to extend interpretation of simulations. Therefore it is pity that authors restrict themselves mainly by the analysis of processes manifested on the sea surface or close to surface. I think that it is interesting to pay attention to the deep sea ventilation and water mass formation in the Caspian basin. Usually deep basins have restricted areas of convection penetrated to the bottom. Sometimes this process is intermittent with time. I believe that it is important to clarify what is the process of deep water formation in the Caspian Sea according to the presented model simulations in spite of the sort time of integration.

It is also interesting to show peculiarities of the meridional heat and salt fluxes in the basin with emphasis of relative importance of vertical overturning and lateral transport. I am not sure that authors are able to include proposed aspects to this paper but may be they will consider them later.

Response: The deep-sea ventilation of the Caspian Sea is a poorly understood process. In this study, we concentrate our attention on the thermo-hydro-dynamics of the upper 100-200 meter depths of the sea. We hope to learn more about climatic mechanisms that affect ventilation of the Caspian Sea deep waters in following studies of inter-annual variability.

I think that the paper addresses scientific questions concerning to the seasonal cycle of the Caspian Sea fields. In spite regional significance of the paper it is relevant to the scope of OS to my understanding."

Response: No response required

"Introduction contains brief review of the current state of the Caspian Sea investigations and permits to distinguish new original contributions by authors.

The title clearly reflects the contents of the paper. May be according to the weight of different sections of the paper it is possible slightly correct it like this: "Air sea interaction, sea level and circulation. . . " "

Response: Possibly the reviewer is right. Because we have put more attention on air-sea interaction and sea level dynamics, we will slightly modify the title.

"The abstract provide a concise and complete summary. The overall presentation is well structured and clear in spite it is too brief sometimes. References are good enough. The language is also good for me but I am not an expert in English"

Response: No response required

Some particular remarks:

"1.Page 1917 lines 11-13. The sentence should be edited: One third of entity has the same order of magnitude as an entity itself! Also the sentence sates in fact that the sea level grows continuously as evaporation compensates river runoff and precipitation is big enough."

Response: Yes, we will correct the sentence, though we only tried to give orders of magnitudes for components of the water budget. The exact values are given in Table 2.

"2. Page 1917 last line: fluxes across the SEA surface, not ocean surface"

Response: Yes, it will be corrected.

"3. Page 1918. I do not understand the meaning of the last line."

Response: It will be corrected.

(ii) to study the seasonal variability of the circulation and sea level, and in particular the processes controlling the sea level.

"4. Page 1921 equation 10. Density ρ_f never defined."

Response: It is defined on next line at page 1922.

"5. Page 1923 line 3 ". . . model has. . . outflow.." Where is outflow? Lines 5 and 6 on the page 1929 do not clarify the question, for my mind."

Response: Yes, this comment may be misleading and will be corrected. The general numerical model formulation is described in part 2, with respect to inflow or outflow open boundaries. The model results are not affected, because the outflow to Kara-Bogaz-Gol Bay was closed during 1982.

"6. Page 1925 line 2-3. It is not clear why ". . . bottom topography and coastline correspond to the conditions during 1940 – 1955. . . "? Why it was not possible to specify them for 1982?"

Response: This is a valid point. The answer is that it was impossible to find actual coastline data corresponding to 1982.

"7. Page 1930 lines 5, 6. It is a little bit strange that cyclonic and anticyclonic eddies are evident on the monthly mean map of currents. It means that they are quasi-permanent. What is the mechanism of their formation?"

Response: As interpreted in the paper, they are clearly wind driven.

"8. Page 1935lines 15, 16. Can you comment that your simulation of air sea fluxes is better than estimated with balk formulae?"

Response: See Launiainen, J. and Vihma, T. (1990)

"9. Page 1937. The title of paragraph 4.3.1. is Mean sea level, though in the following discussion the sea level variability is considered in four points. What is the meaning of the word "mean"?"

Response: We discuss the seasonal cycle of mean sea level (spatial average), though we illustrate its spatial variability by sea level dynamics at four stations along the coast.

“10. Page 1938. I do not understand last sentence of paragraph 4.3.2. Fig. 19 shows that amplitude of annual sea level variability is only about 25 cm.”

Response: Sea level variation differs along the coast, from 18 cm at Makhachkala to 32 cm at Krasnovodsk. The spatial range of 15 cm being about half the seasonal range of sea level variation at any point.

“11. Page 1945. Something is wrong on the line 15”

Response: Yes. It should be:

Akhverdiev, I.O., and Demin, Yu.L. O structure sinopticheskih techeniy Kaspiiskogo morya v letniy sezon po rezultatam diagnosticheskih raschetov. In *Kaspiiskoe more. Struktura I dinamika vod, edited by* A.N. Kosarev. Nauka, Moscow, USSR, 5-15, 1989.