Historical Climate Change Impacts on the Hydrological Processes of the Ponto-Caspian Basins

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Drivers of Pontocaspian Biodiversity Rise & Demise: An EU Horizon-2020 Innovative Training Network 2015-2019

Introduction

The Ponto-Caspian region (Figure 1) is one of the largest area globally, composed of a closed basin (Caspian Sea) and open basin connecting to the global ocean (Black and Azov Sea). Connections between the seas have occurred numerous times, with the possibility of exchange of biotic and abiotic materials, which influenced the distribution and diversity of marine fauna in the region (Yanina, 2014; Figure 2).

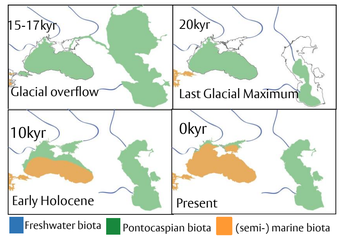

Figure 2: Black, Caspian and Azov Seas connectivity history (Frank Wesselingh©)

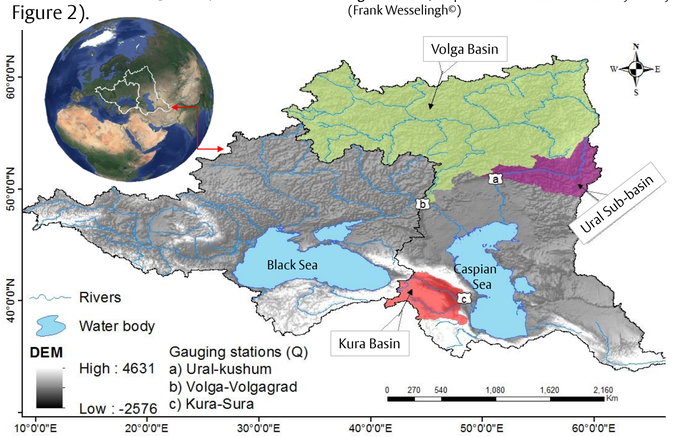

Figure 1. Study area: Volga, Ural and Kura basins are used for validating GCM and reanalysis runoff product with observation

During the last century Caspian Sea levels (CSL) have varied between −25 and −29mbsl (Figure 5-a), resulting in considerable changes to the area of the lake. Therefore, understanding long-term lake system evolution and hydrological connectivity between these seas are important to understand how/where/when biodiversity was likely to have experienced large changes. Furthermore, given projections of future climate change and the importance of the Caspian Sea for fisheries, agriculture, and industry, it is vital to understand how sea levels may vary over different period of time. The study focus is to model the surface hydrological processes and lake levels of the Caspian Sea and understand the main driving mechanisms of lake level change.

References

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2. Yanina T. A., (2014). The Ponto-Caspian region: Environmental consequences of climate change during the Late Pleistocene. Quaternary International 345, 88-99.

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Research Method

In this study, the Terrestrial Hydrological Model (THMB) (Coe, 2000) is applied and evaluated to investigate the hydrological processes of the Ponto-Caspian basin for the historical period 1900 to 2000. The model has been forced using observational reanalysis datasets (ERA Interim Land, ERA20c) and historical climate model data outputs (from CESM and HadCM3 models) to investigate the variability in the Caspian Sea level and the major river discharges (Figure 3).

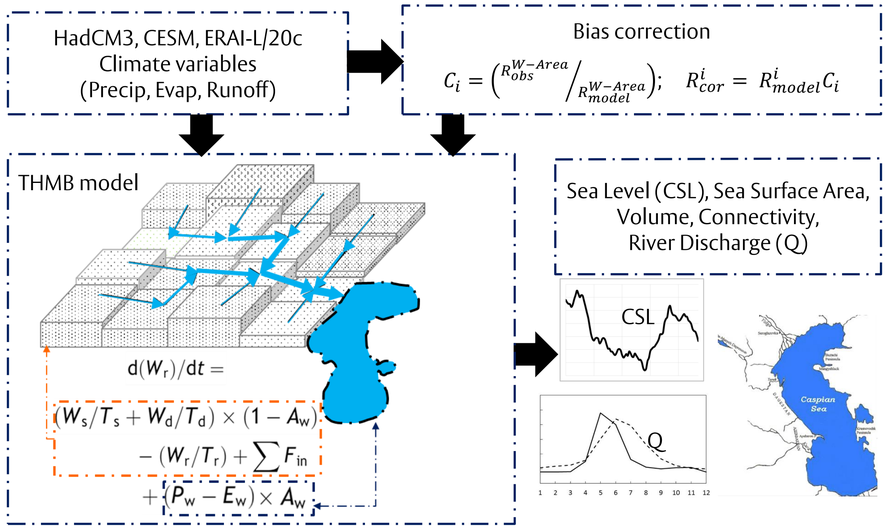


Figure 3: Research method and THMB model (Where: A_w is the predicted fractional water; T_r, T_d, and T_s are the residence times; P_w and E_w are the precipitation and evaporation rates (m^3s^{-1}); and F_{in} is the water fluxes (m^3s^{-1}); river water reservoir (W_r), surface runoff pool (W_s), and subsurface drainage pool (W_d))

Results and Discussion

Uncertainty analysis of input boundary condition and model evaluation

- Modelled precipitation from CESM, ERA20c and ERA Interim are within the observations uncertainty estimates of GPCC gridded observation product except for GPCP based bias corrected (ERA Interim Land) and HadCm3 (Figure 4-a),

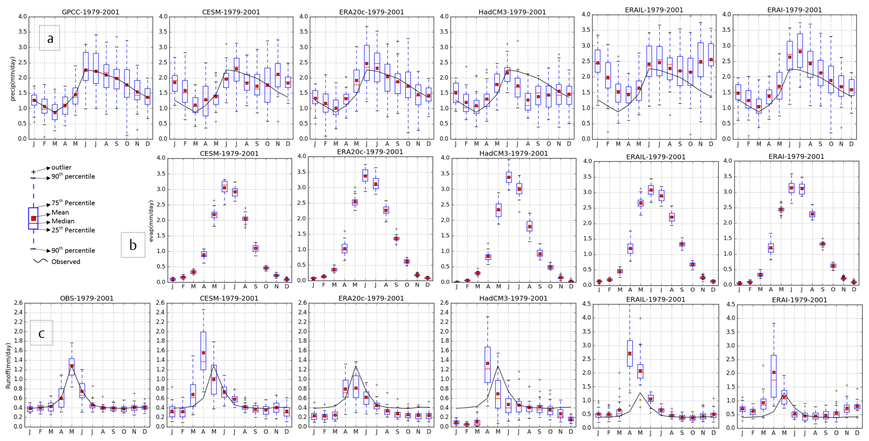


Figure 4: Mean seasonal cycle of precipitation (mm day-1) (a-top panel), evaporation (b-middle) and runoff (c-bottom) for Volga basin.

Results and Discussion cont.

- Unlike the precipitation and runoff, evaporation estimates are similar in all models (figure 4-b). The amount and timing of high flow do not match with observed runoff for all the model considered in this comparison (Figure 4-c). This could be related to how snows are attributed in the GCM model runoff simulation component,
- 20 century Caspian Sea Level (CSL) simulation as shown on Figure 5-a are based on GCM model (ERA20c ad CESM-1degree) climate variables forcing without bias correction. The overall pattern looks promising as the simulated CSL trend is similar to the observed.

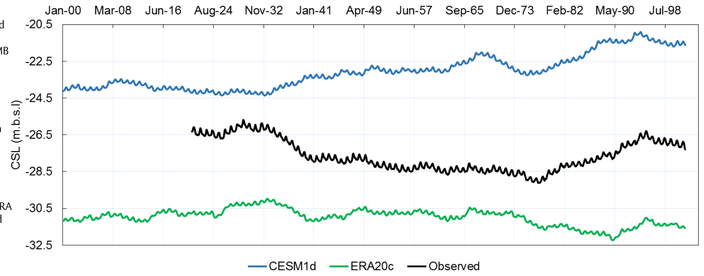
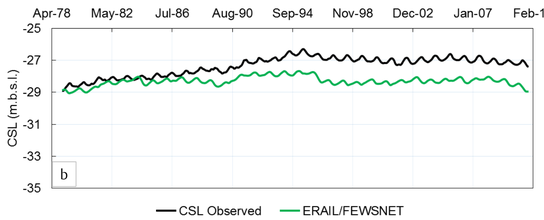


Figure 5: a) Observed (Black line) and simulated (Blue and green line) Caspian Sea Level by THMB Hydrological Routing Algorithm using climate variables (runoff, precipitation and evaporation) from Community Earth System Model (CESM 1-degree); and 20 century ECMWF Reanalysis (ERA20c); **b)** Caspian Sea level when climate fields from ERA Interim (precipitation), ERA Interim Land (runoff) and FEWSNET (potential evaporation) used



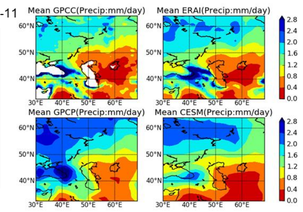


Figure 6: Mean spatial precipitation (mm day-1)

THMB model performed well in routing Volga river discharge and simulating the Caspian Sea level when climate fields from ERA Interim (precipitation), ERA Interim Land (runoff) and FEWSNET (potential evaporation) are used (Figure 5-b).

The mean precipitation from model estimates compares well with the observed (GPCC) in indicating the general pattern of low (south-east of Caspian sea) and high precipitation receiving area (Figure 6).

Conclusion and Way Forward

- Evaluation of THMB model has been made and the performance in routing Volga river and simulating the Caspian Sea level is promising, however, there is still question on how to attribute the GCM-runoff lead time magnitude case to reconstruct CSL similar to the observation (Figure 5-a).
- Model estimate of precipitation and evaporation shows increasing trend whereas the runoff decreased over the last century (20-C).
- Next step will be bias correcting the GCM-runoff over monthly time-step, which composite for the time lag and magnitude of the runoff product from the GCM models
- Future work will focus on millennial and multi-millennial time-scales simulations during the Quaternary (last 2.5Myrs), which looks at the hydro-climate and topographic changes.