

Reply to comment by Ben-Zvi and Givati on 'First super-high-resolution model projection that the ancient "Fertile Crescent" will disappear in this century'

Akio Kitoh¹, Akiyo Yatagai² and Pinhas Alpert³

¹Meteorological Research Institute, Tsukuba, Japan

²Research Institute for Humanity and Nature, Kyoto, Japan

³Tel Aviv University, Tel Aviv, Israel

Ben-Zvi and Givati (2008 hereafter BZG) raised two points on model's ability to reproduce current climatology and hydrology used in Kitoh *et al.* (2008 hereafter KYA): one is reproducibility of present-day precipitation amounts and its spatial distribution in the model, and the other is the streamflow that is highly affected by human intervention in reality.

Ability to reproduce current climate by global numerical models is steadily increasing in the past decade (IPCC 2007; Reichler and Kim 2008). BZG pointed out that the area with simulated annual precipitation > 1000 mm in KYA is much larger than the area observed and the area with simulated annual precipitation < 200 mm is substantially larger than the area observed. In the previous global models, such as those that had provided climate projections in IPCC AR4 (Reichler and Kim 2008), regional geographical details have not been resolved due to their coarse resolution. Our 20-km mesh global model, however, has for the first time the sufficient resolution to resolve orographic rainfall well. Exact contour lines of the model simulation in KYA do not fully match with the observations, but desert climate where annual precipitation < 200 mm is rather well reproduced in the Middle East. This is in contrast to the other aforementioned climate projections with coarser resolution.

Another aspect is that, while the model results contain uncertainties, the observed climatology dataset used in KYA to validate the model is also subject to uncertainties. In general, rain-gauge observation is more reliable than that of satellite-derived precipitation estimates over the land. Hence, we used a gauge-based precipitation climatology dataset, which was developed with many more rain-gauge observations over this area (Turkey, Israel and Iran), and have compared to other monthly precipitation products and satellite-based precipitation data. See Yatagai *et al.* (2008) for details. However, the quality of rain-gauge-based precipitation dataset depends on the density and distribution of rain-gauge network. For example, the rain-gauge network is very sparse over a part of the Fertile Crescent area, particularly over the high mountains and vast unpopulated desert areas. These limitations certainly caused uncertainties in this precipitation dataset, and then had created a part of the differences between the modeled and observed precipitation presented in KYA.

Second point is that in our model simulation we do not account for any human intervention such as reservoir and groundwater use. In order to project actual streamflow at each of the targeted basins, we need to know about future change in anthropogenic water use, but this was not sought in KYA for the reasons stated below. There are some attempts in the modeling com-

munity to incorporate anthropogenic water usage, such as a reservoir operation scheme, in climate models to reproduce present streamflow. By doing that, current streamflow reproducibility should become better. For this purpose, however, scenarios for how this anthropogenic water usage will change in the future are needed, which contains further uncertainties of societal nature. Therefore, in order to avoid further complexity, we focused on the future change in natural climate system and its effect on regional streamflow. The difference in the simulated streamflow between the present-day and the future climate can be interpreted as a first approximation of the streamflow change caused by the global warming.

In spite of all the shortcomings mentioned, our projections are the first ever of naturally-driven streamflow changes in the region, which may suffer a lot from global warming as suggested by most (nearly all) of recent IPCC (2007) AR4 models. At the same time, this is an extremely sensitive area to lack of water. Some of the struggles or even wars in the region had to do with problems related to water. Hence, it is tremendously important to start a serious scientific dialogue on global warming impacts on water in this region and we hope our Letter served in this positive direction.

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Correspondence to: Akio Kitoh, Meteorological Research Institute, 1-1 Nagamine, Tsukuba, Ibaraki 305-0052, Japan. E-mail: kitoh@mri-jma.go.jp. ©2008, Japan Society of Hydrology and Water Resources.