Global Water Futures

Modelling High Mountain Central Asia

Water resources in high mountain central Asia are highly sensitive to climate change as they strongly depend on snow and glacier melt. The lack of physically based glacio-hydrological models in the region, however, limits our understanding of the hydrological systems and their vulnerability to climate change. In this study, we set up Environment and Climate Change Canada's MESH model (Wheater et al., 2021) for the Ala-Archa River Basin in Kyrgyzstan (near the capital city Bishkek). MESH is a physically based hydrological land surface scheme with representation of cold regions processes such as glacier energy balance and ablation, blowing snow, energy balance snowmelt and frozen ground. The drainage area of the Ala-Archa River Basin is 236 km^2, approximately 15% of which is dominated by glaciers. The Ala-Archa Basin is the major water source for the irrigation and water supply for the country.

To drive MESH model in the Ala-Archa River Basin, we have combined the EM-Earth (0.1°) (Tang, G., et al. 2021) and ERA-5 (0.25°) (Hersbach, H., et al. 2020) datasets. The precipitation rate and air temperature data were acquired from EM-Earth, while the incoming shortwave radiation, incoming longwave radiation, wind speed, barometric pressure and specific humidity were obtained from ERA-5. Most of the model parameters were set based on the previous studies in the region, as well as previous MESH modelling applications for Canadian basins. A limited model calibration has been performed on some parameters related to evapotranspiration, soil and routing. The model performance for simulating streamflow was evaluated by the Kling-Gupta Efficiency (KGE) using the Dynamically Dimensioned Search (DDS) algorithm. Simulated streamflow was compared at the outlet of the catchment for the calibration (1990-2000) and validation (2000-2010) periods. KGE is above 0.9 and precent bias (PBIAS) is below ±1% over both calibration and validation periods. The cumulative mean streamflow shows a good performance with a mean bias of -0.15% at the end of the water year.

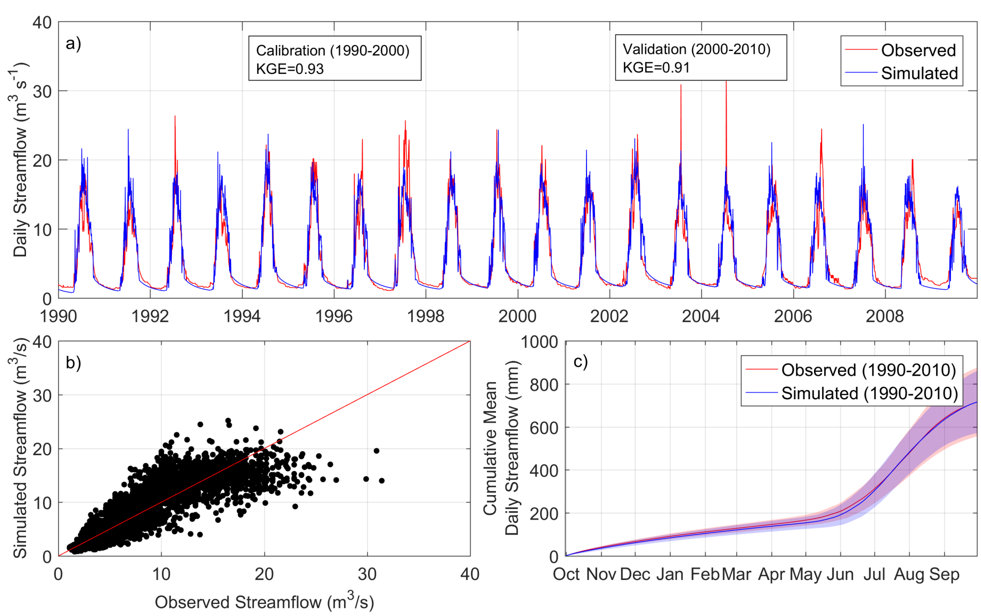

Figure 1. Assessment of the MESH model performance in simulating streamflow at the outlet of the Ala-Archa by comparing (a) daily streamflow, (b) scatter plot of streamflow, and (c) cumulative mean daily streamflow. The shades around the average values in panel (c) represent the inter-annual variability.

The simulated basin average snow cover fraction was compared against the processed NOAA-Advanced Very High-Resolution Radiometer daily images of snow cover fraction over the snowmelt periods for the 1997-2010 period (Figure 2). The simulated snow cover area (SCA) was found to be matching well with the satellite images for most of the years, while showed visible deviations from the satellite SCA in some years such as 2006 and 2007. Uncertainty of the satellite SCA could be one of the reasons for the deviations, when looking on the sharp increases of satellite SCA in the melting season.

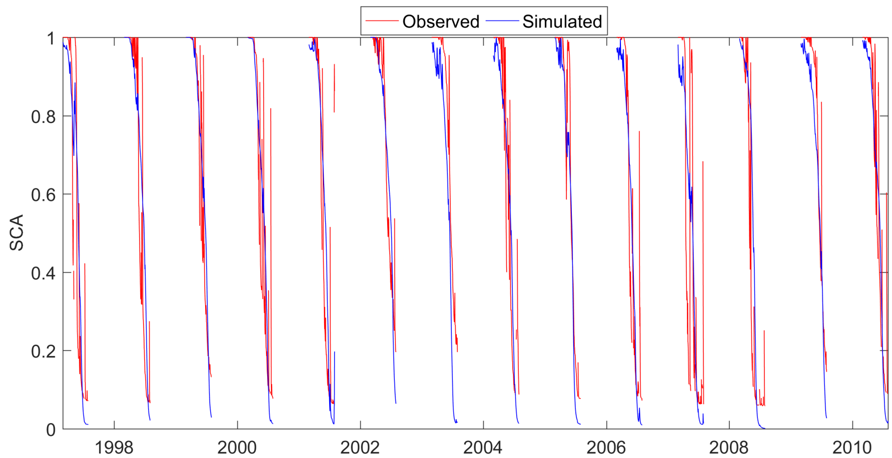

Figure 2. Comparison of basin scale simulated SCA with NOAA-Advanced Very High-Resolution Radiometer (AVHRR) SCA daily image products over the snowmelt period (March-August) (1997-2010).

Given the successful model performance in simulating streamflow and snow cover, our next step is to set up the MESH model for larger domains in the region such as Syr Darya River Basin where the model results can be helpful in local and regional water management. This work is part of the Global Water Futures Planetary Water Prediction Initiative—for more information see https://gwf.usask.ca/core-modelling/modelling-domain/planetary-water-prediction-initiative.php.

References

- Hersbach, H., Bell, B., Berrisford, P., Hirahara, S., Horányi, A., Muñoz-Sabater, J., ... & Thépaut, J. N. (2020). The ERA5 global reanalysis. *Quarterly Journal of the Royal Meteorological Society, 146*(730), 1999-2049.
- Tang, G., Clark, M.P. & Papalexiou, S.M. (2021). EM-Earth: The Ensemble Meteorological Dataset for Planet Earth. *Manuscript in preparation.*
- Wheater, H., Pomeroy, J., Pietroniro, A., et al. Advances in modelling large river basins in cold regions with Modélisation Environmentale Communautaire - Surface and Hydrology (MESH), the Canadian hydrological land surface scheme. Authorea. July 27, 2021. DOI:10.22541/au.162738548.88997933/v1. https://www.authorea.com/doi/full/10.22541/au.162738548.88997933