

Modeling the Projected Impact of Climate Change on Boukan Dam Inflow and Water Availability in the Zarrine River Basin of Iran

SWAT 2017

WARSAW Conference

Farzad Emami

Manfred Koch

UNI KASSEL VERSITÄT

Geohydraulik Kassel

Institut für Geotechnik und Geohydraulik

Contents

Introduction

- One in three people in the world is already facing sever water shortages. (CA, 2007)
- Parts of the arid Middle East region including western Iran lost freshwater reserves rapidly over the past decade.
  (Voss et al., 2013).
- Iran will be more likely facing a serious and protracted water crisis. This water scarcity is aggravated by increased climate variability due to global **climate change** reflected by droughts with drying lakes and rivers, declining groundwater resources and deteriorating water quality.
  (Madani, 2014).

Introduction

Climate change impacts will not only reduce available water resources, but also increase the water demands by crops, i.e. negatively impact agricultural production.
(Punkari et al., 2014)

The first unavoidable step to prepare ourselves for this water crisis, is the identification of the climate variations, followed by a prediction of the hydro-climatic conditions for future years, in order to evaluate these adverse water resources impacts.

Literature Review

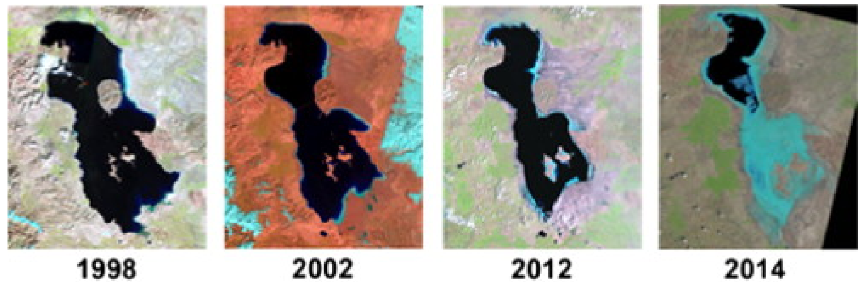
The impacts of changing climate on available water resources

(Abbaspour et al., 2009; Hashemi, 2011; Blanc et al., 2013; Koch and Cherie 2013; Chien et al., 2013)

SWAT Soil & Water Assessment Tool

GCM projections → **Statistical Downscaling** → Climate variables prediction → **Hydrologic simulation model** → Hydrologic changes prediction

Literature Review



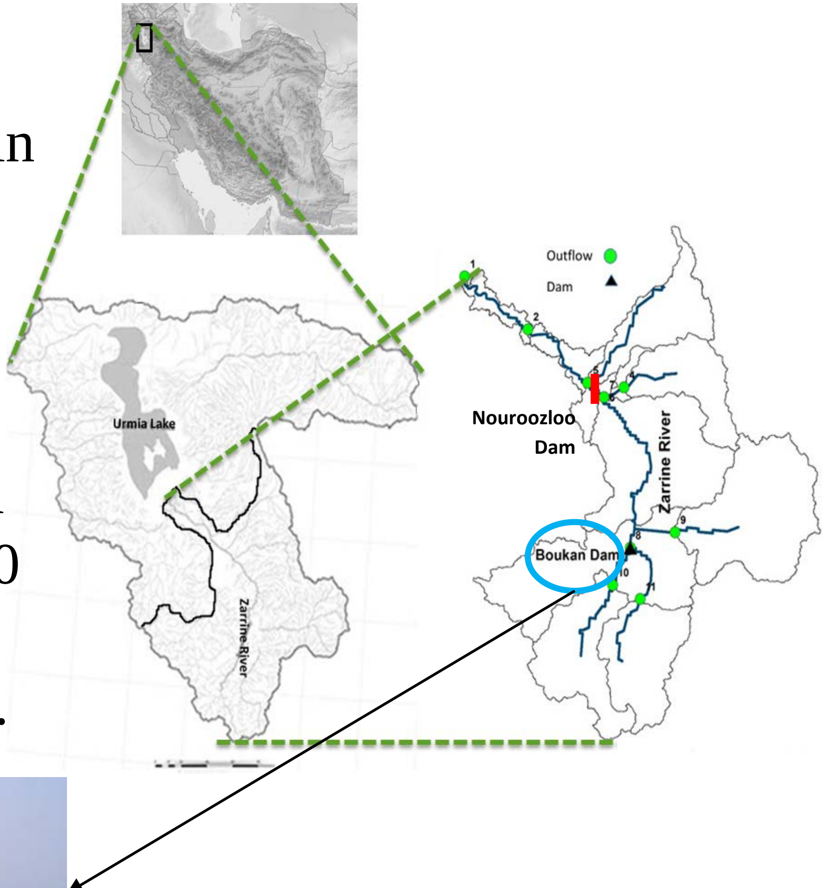
Substantial changes in area of Lake Urmia derived from LandSat imagery

the area of this Iranian lake has decreased by around 88% in the past decades. (Aghakouchak et al., 2015)

Case Study

The **Zarrine River Basin** is located in the southern part of the Lake Urmia.

The most important dam of the basin is the **Boukan reservoir dam**, the only dam located on the Zarrine River and serving with a storage capacity of 650 MCM much of the region's needs of potable and agriculturally used water.



Case Study

The region's climate:

semi- wet cold or wet- cold, in the mountain areas with annual precipitation of up to 800mm/a, but changes to semi- dry in the vicinity of Lake Urmia, where the precipitation is only about 200mm/a

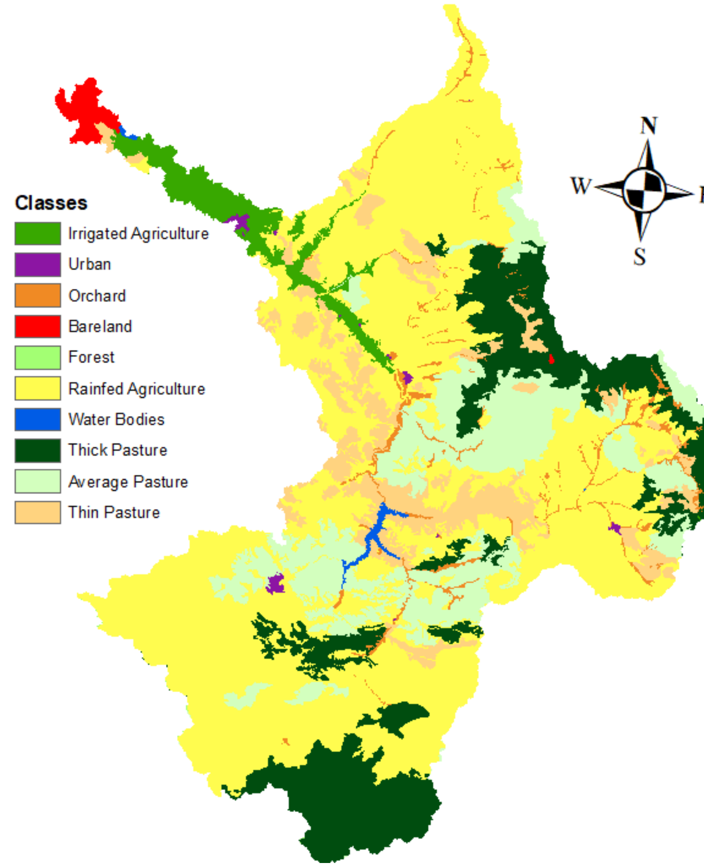
Total area of the basin: 12,025 km^2

Length of main channel: 300 km

Average annual Rainfall: 390 mm

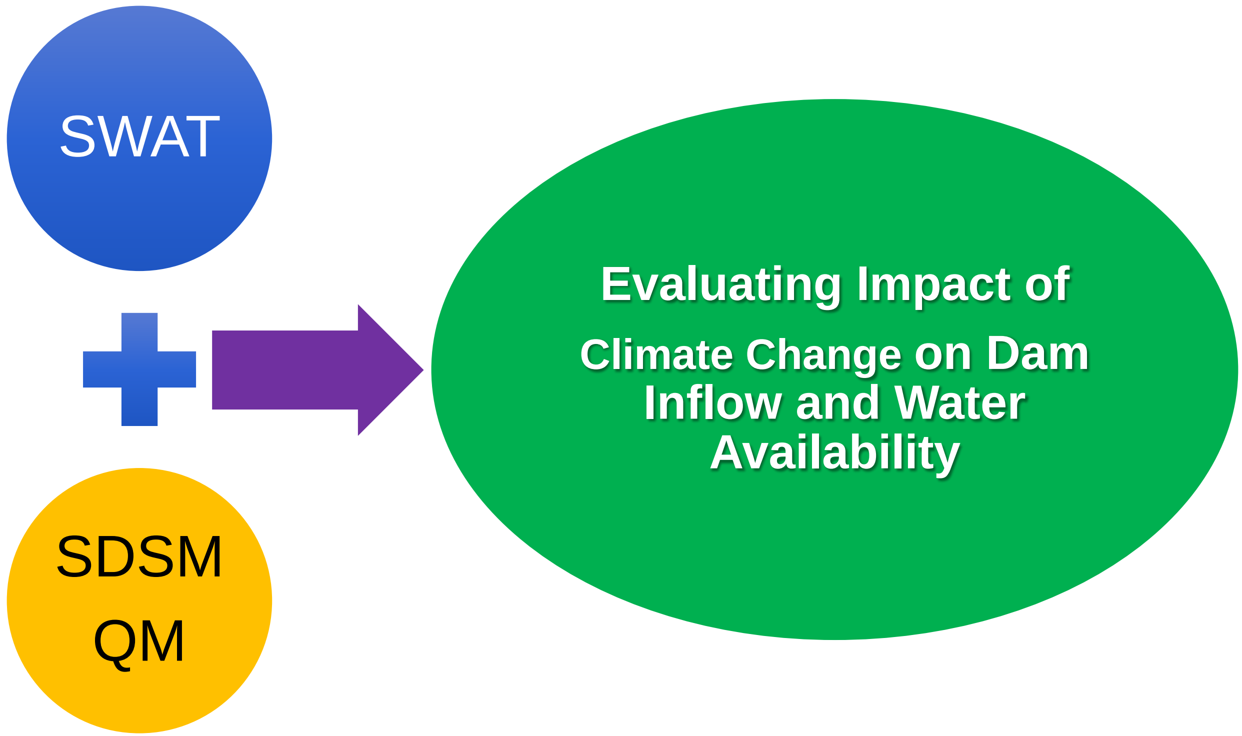
Land Use of the basin:

10 landuse classes



Methods

Integrated hydrologic model



Downscaling model
using GCM projections

Methods

The Soil and Water Assessment Tool (SWAT)

physically-based integrated semi-distributed hydrological model (Arnold et al., 1998; Nietsch et al., 2001)

- Digital elevation model (DEM)

Iranian surveying organization with a spatial resolution of 85 m

- Land use map of the watershed

MOJA (2007) with a resolution of 1000 m and 10 land use classes

- Soil map of watershed

FAO digital soil map of the world at spatial resolution of 10 km for this area includes 8 types of soil with two layers

- climatic weather input data

daily precipitation

21 stations from the Iran Ministry of Energy (MOE)

daily max. and min. temperatures

GCM- predicted (0.5º x 0.5º grid) Climate Research Unit (CRU)

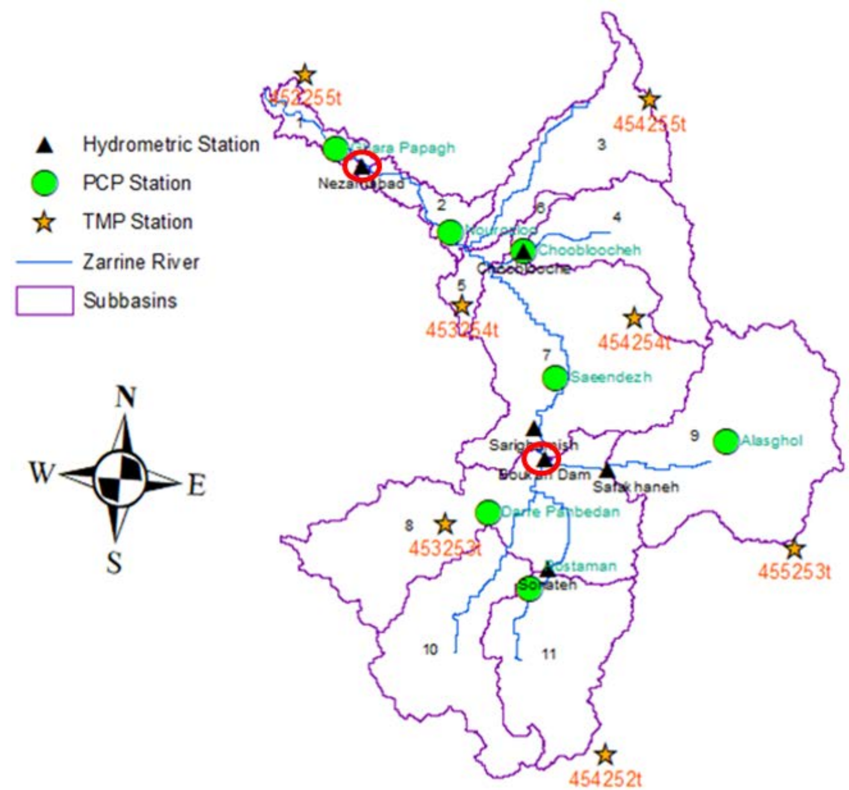
- River discharge data

7 hydrometric stations from MOE

Methods

Calibration, Validation and Sensitivity Analysis

SWAT-CUP (Calibration and Uncertainty Program)
(Abbaspour et al., 2004; Abbaspour, 2011)
SUFI-2 (Sequential Uncertainty Fitting) Algorithm



Methods

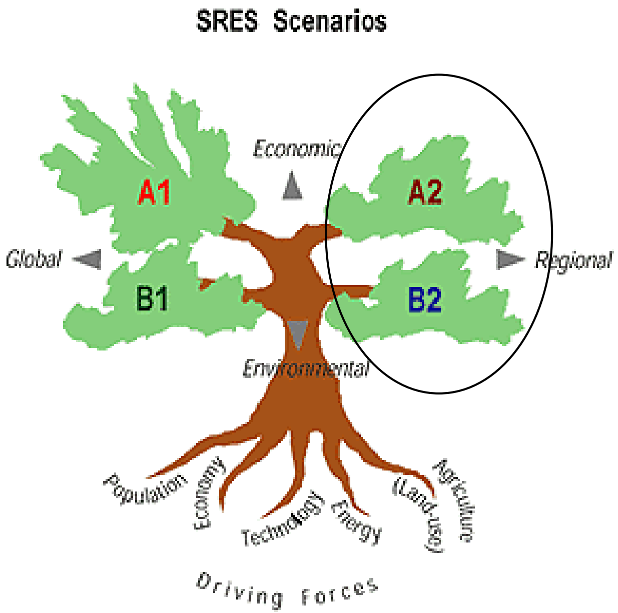
Climate change scenarios and predictions

SDSM- downscaling of HADCM3- historical temperatures

HadCM3-GCM's (2.5° x 3.75° grid)

Prediction Scenarios:

the extreme emission scenario (SRES)
A2 (promoting further regional economic development) and the more benevolent
B2 (with emphasis on an ecologically sustainable development). 2006- 2029



Predictand max temperature
NCEP Predictors ncep_p500 and ncep_temp

Predictand min. temperatures
NCEP predictors ncep_mslp, ncep_shum and ncep_temp

Methods

QM- downscaling of MPI-ESM-LR precipitation predictands

Quantile Mapping (QM) Downscaling method Monthly, Daily
statistical technique using two bias correction methods with some modification (Themeßl et al., 2011; Miao et al., 2016)

Approaches:
Empirical Cumulative Distribution Function (ECDF)
Kernel Density Function (KDF)

GCM Model:
MPI-ESM-LR (ECHAM-6)
1.86^{o} x 1.87^{o} grid resolution
RCP 2.6 & RCP 4.5

Results

Calibration, Validation and Sensitivity Analysis

General parameters of the basin and the final calibrated values

Rank	Parameter	Final value	Rank	Parameter	Final value
1	SFTMP.bsn	1	5	SMFMX.bsn	7.95
2	SMTMP.bsn	0.5	6	SMFMN.bsn	0.73
3	SNO50COV.bsn	0.3	7	SNOCOVMX.bsn	463.9
4	TIMP.bsn	0.71			

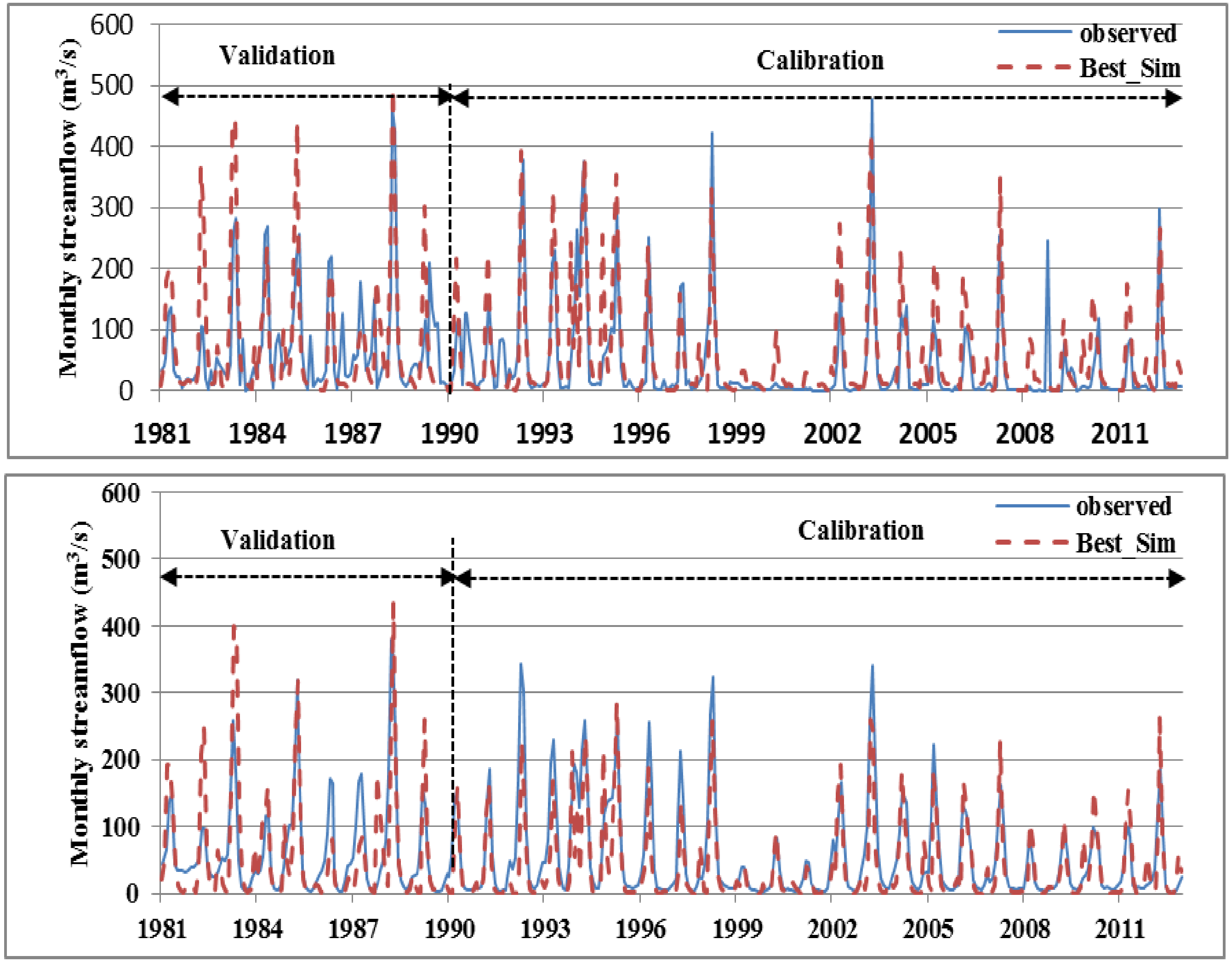
Sensitive SWAT- input parameters by rank used in the calibration process

Rank	Parameter Name	Initial Range	Subbasin groups	Rank	Parameter Name	Initial Range	Subbasin groups

1	CN2.mgt	-0.3 to 0.3	Sub 1,2
			Sub 3
			Sub 4
			Sub 5,6,7
			Sub 8
			Sub 9
				9	SOL_AWC(..).sol	-0.3 to 0.3	Sub 10
							Sub 11

2	SOL_BD(..).sol	-0.3 to 0.3		10	ALPHA_BF.gw	0 to 0.4	
3	SOL_Z(..).sol	-0.3 to 0.3		11	REVAPMN.gw	1 to 500	
4	ALPHA_BNK.rte	-0.3 to 0.3		12	GW_SPYLD.gw	0 to 0.05	ALL
5	GWQMN.gw	1000 to 2500		13	CH_K2.rte	0.01 to 0.5	ALL
6	ESCO.hru	0.9 to 1		14	RCHRG_DP.gw	0.0 to 0.1	ALL
7	SOL_K(..).sol	-0.3 to 0.3		15	CH_N2.rte	0 to 0.016	ALL
8	GW_DELAY.gw	15 to 31					

Results Calibration, Validation and Sensitivity Analysis



Observed and simulated hydrographs for outlet station 8 (bottom) measuring inflow to the Boukan dam and the main basin outlet station 2 (top) namely Nezamabad.

Results

Calibration, Validation and Sensitivity Analysis

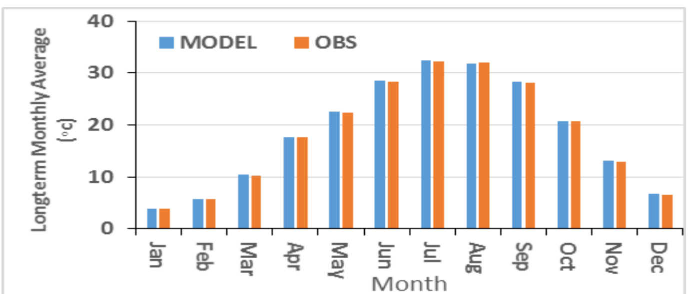
Statistical measures for the SUFI-2 - optimized objective functions for calibration and validation periods for various sub-basin outlet stations.

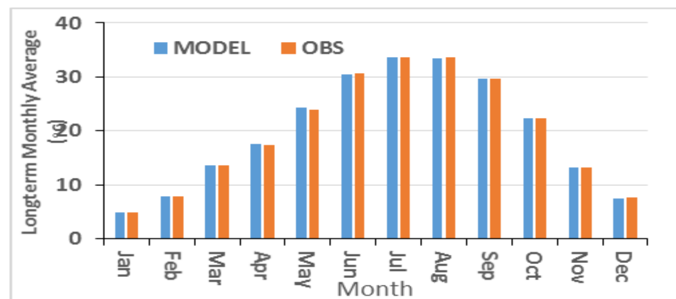
Outlet #	Station	Calibration			Validation
		R^2	NS	bR^2	bR^2
2	Nezamabad	0.72	0.65	0.66	0.50
4	Chooblooche	0.60	0.30	0.60	0.56
7	Sarighamish	0.68	0.55	0.67	0.52
8	Boukan Dam	0.76	0.72	0.58	0.54
9	Safakhaneh	0.66	0.40	0.62	0.55
11	Sonateh	40.6	0.42	0.63	0.30
Average		0.68	0.51	0.63	0.50

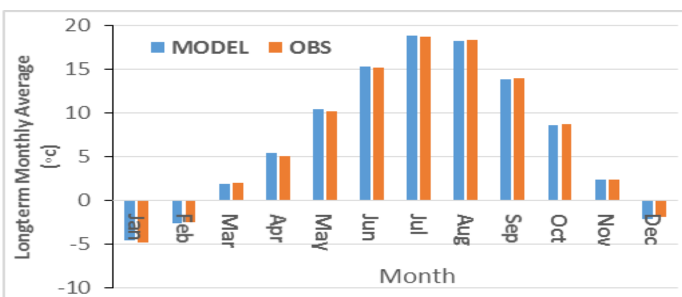
Results

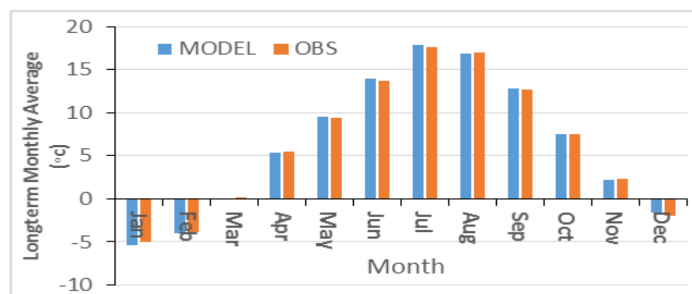
Min and Max temperatures

Parameter	Station Name	R^2		SE	
		Calibration	Validation	Calibration	Validation
Min. Temperature	452255t	0.63	0.72	2.05	1.67
	453253t	0.56	0.61	2.48	2.1
	453254t	0.61	0.68	2.2	1.82
	454252t	0.54	0.59	2.55	2.19
	454254t	0.60	0.70	2.2	1.76
	454255t	0.64	0.74	2.06	1.62
	455253t	0.57	0.65	2.34	1.88
Max. Temperature	452255t	0.73	0.78	2.04	1.81
	453253t	0.77	0.7	1.78	2.20
	453254t	0.72	0.79	2.07	1.75
	454252t	0.68	0.77	2.21	1.81
	454254t	0.71	0.78	2.16	1.79
	454255t	0.72	0.78	2.11	1.82
	455253t	0.69	0.77	2.17	1.84
Average		0.66	0.72	2.17	1.86



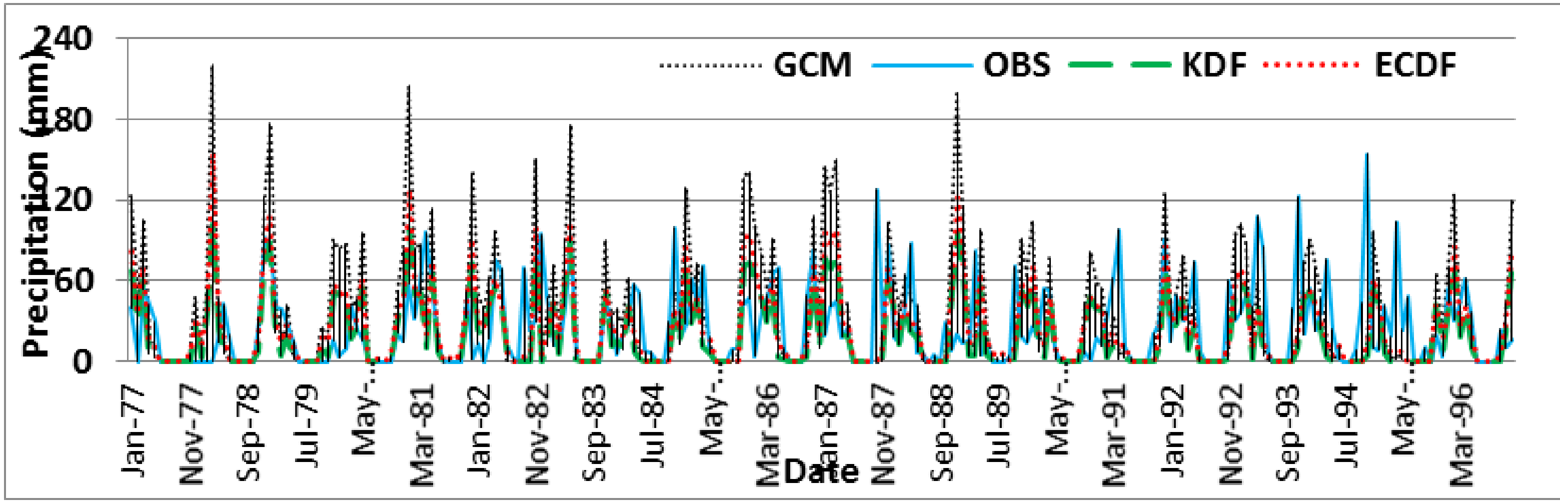






Results

Observed and raw vs QM- downscaled precipitation



Monthly observed and QM- downscaled (bias–corrected with ECDF and KDF) precipitation at Nouroozloo station for 1977 to 1996.

Best QM-method for bias correction in each quantile bias together with success rate of that method and average of the resulting bias.

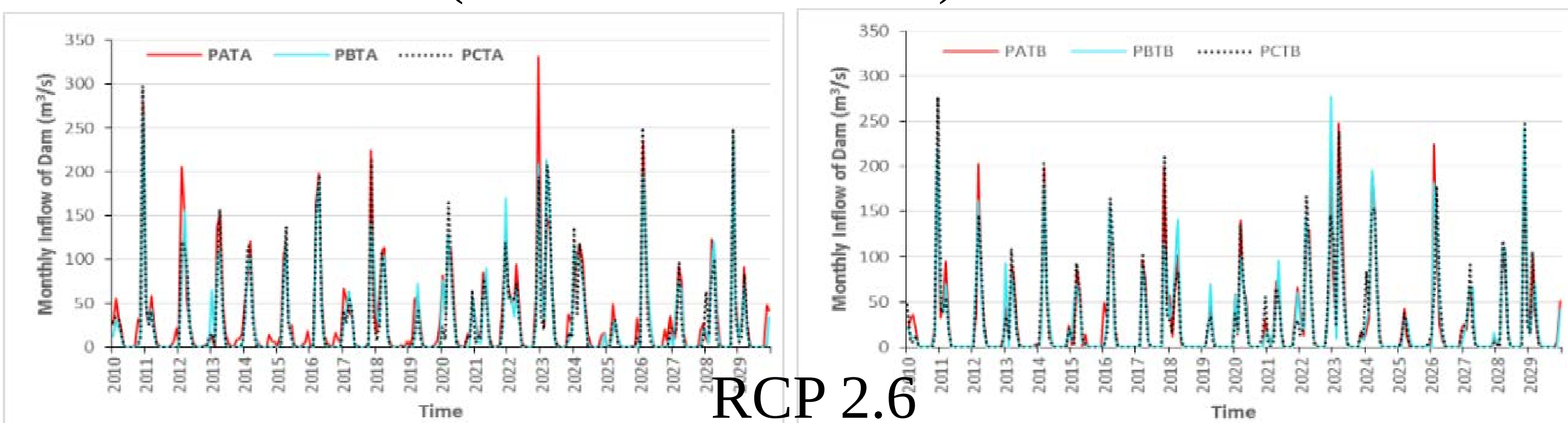
Percentile	QB_t			Bias Correction Success	Bias Reduction
	GCM	KDF	ECDF		
25%	1.39	0.69	0.91	80%	30%
50%	1.15	0.57	0.76	73%	28%
75%	0.86	0.43	0.57	59%	14%
Average	1.13	0.56	0.75	70%	24%

Results

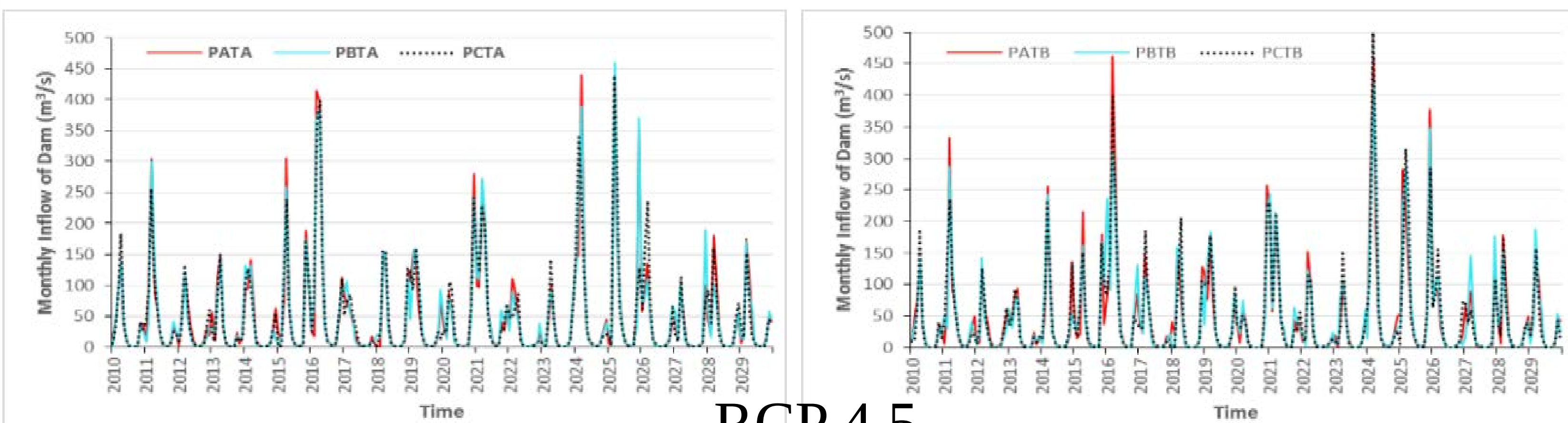
SWAT future dam inflow simulations

PCP PA: the less PB: the average PC: the most predicted rainy days

TMP A2 and B2 (named here TA and TB)



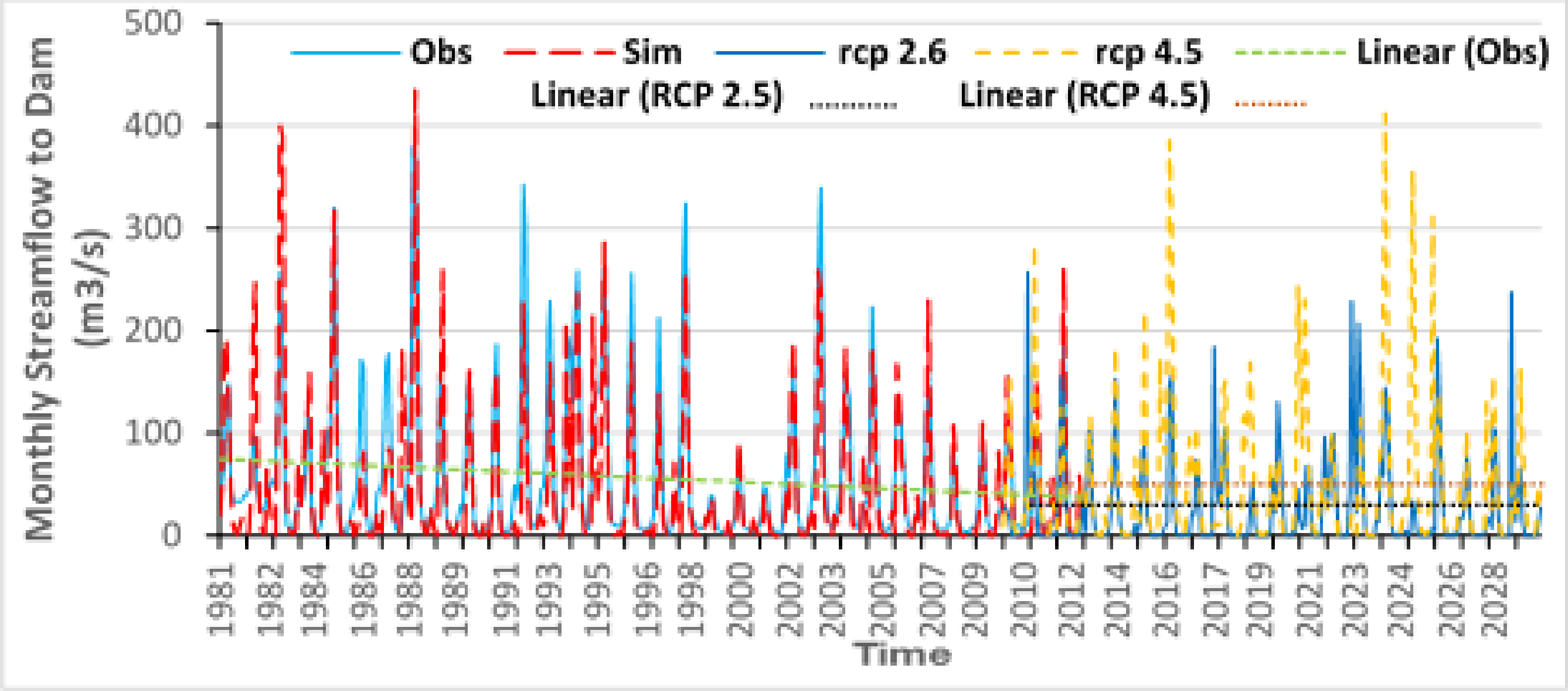
RCP 2.6



RCP 4.5

Results

SWAT future dam inflow simulations



Monthly observed (historical), simulated (historical) and future predicted inflow into the Boukan dam based on average of RCP 2.6 and RCP 4.5 climatic scenarios, together with trend lines

Results

Annual SWAT-modeled water balance of the ZRB

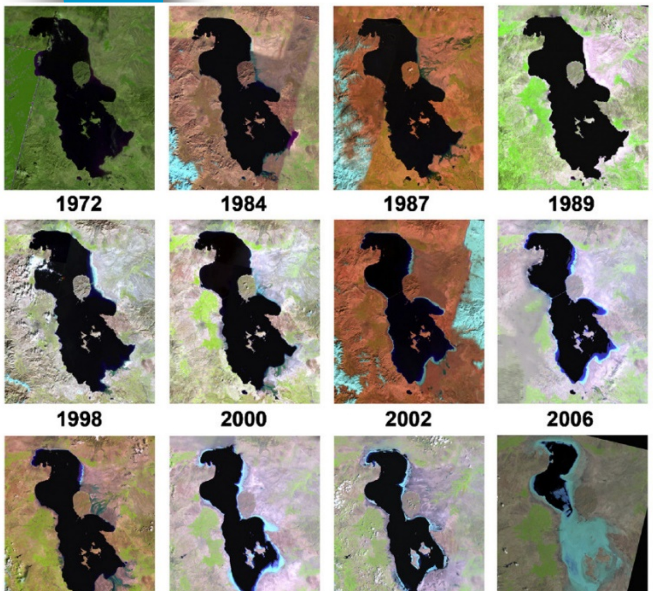
Water Balance Parameter (mm)	Historical		RCP 2.6						RCP 4.5					
	Val	Cal	TA-PA	TA-PB	TA-PC	TB-PA	TB-PB	TB-PC	TA-PA	TA-PB	TA-PC	TB-PA	TB-PB	TB-PC
PRECIPITATION	454.6	393.1	↓ 328.1						↓ 312.5					
SNOWMELT	105.9	79.7	↓ 57.5	↓ 60.0	↓ 65.5	↓ 61.7	↓ 64.7	↓ 63.5	↓ 61.4	↓ 56.2	↓ 60.9	↓ 56.6	↓ 56.4	↓ 60.4
SURFACE RUNOFF	61.1	39.8	↓↑ 46.8	↓↑ 45.9	↓↑ 45.6	↓↑ 46.5	↓↑ 45.9	↓↑ 45.3	↓↑ 49.5	↓↑ 50.9	↓↑ 47.9	↓↑ 53.1	↓↑ 50.5	↓↑ 49.0
LATERAL FLOW	29.7	25.2	↓ 20.5	↓ 20.0	↓ 19.7	↓ 19.4	↓ 19.4	↓ 18.8	↓ 24.5	↓ 24.2	↓ 24.4	↓ 22.9	↓ 23.3	↓ 23.5
GWQ Aquifer	133.2	101.0	↓ 61.4	↓ 61.0	↓ 60.3	↓ 58.8	↓ 58.1	↓ 57.9	↓ 79.4	↓ 78.4	↓ 80.6	↓ 78.9	↓ 76.8	↓ 78.0
Aquifer Recharge	177.1	140.3	↓ 99.8	↓ 99.8	↓ 98.8	↓ 97.0	↓ 96.8	↓ 95.4	↓ 105.1	↓ 105.4	↓ 106.5	↓ 100.6	↓ 104.1	↓ 103.7
Water Yield	221.7	164.3	↓ 127.4	↓ 125.7	↓ 124.3	↓ 123.4	↓ 122.1	↓ 120.6	↓ 152.2	↓ 152.4	↓ 151.7	↓ 149.6	↓ 149.5	↓ 149.2
ET	254.8	252.1	↓ 225.4	↓ 226.3	↓ 228.3	↓ 230.7	↓ 230.4	↓ 232.4	↓ 194.1	↓ 193.9	↓ 194.6	↓ 196.8	↓ 196.4	↓ 197.0

Conclusion

- The surface runoff changes of the basin and the dam inflows calibrated and validated with a satisfying performance using SWAT model and SWAT-CUP package.
- The Quantile Mapping method with two approaches, KDF and ECDF, as downscaling methods decreased remarkably the biases of GCM-simulated precipitation.
- The long-term river discharge and inflow of the dam is more likely to be decreased in the near future which is more severe in RCP 2.6, as same as the water yield, the groundwater contribution to the main channel and groundwater recharges.
- The results indicated that the models are compatible in this approach and can be used for assessing the impacts of climate change on available water resources and water balance in arid and semi-arid areas.

Conclusion

- These projected inflows can also be used as an input to dam operation model in order to optimize the operating policies of the reservoir and water supply.
- Considering the future water demands increase due to the agricultural and other development plans and the lack of available water resources, this situation emphasizes on the necessity of an adaptation plan to mitigate the negative impacts of climate change on the streamflow and the water balance of the river basin.
- The modelling approach in this study could be used for a high-resolution analysis of water resources system and as a prerequisite for managing available freshwater resources with a sustainable river basin management approach.



THANK YOU FOR YOUR ATTENTION