Comparison of the effect of using different precipitation data sources on VIC-3L model calibration

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Introduction

Macro-scale Hydrologic models are similar atmosphere-ocean general circulation models although they are mainly simulate runoff, river discharge or catchment water budget.
Macro-scale models operate in a distributed manner because of the physical basis.
These models with considering the major processes affecting the basin's energy and water balance are suitable for simulating of spatial distribution of runoff at the basin level, spatial distribution of evapotranspiration, soil moisture, soil temperature, and so on.
Macro-scale Hydrologic models are very similar to general atmospheric circulation models, but their main emphasis is on modeling of runoff, river flow and basin level water balance.
Among the many models available in this field, the VIC (Variable Infiltration Capacity) model is more popular among researchers all over the world.
Wood et al. (1992) presented the initial version of VIC model as one layer of soil with the inspiration of Xinangjiang model. The two-layer model was introduced in 1994, taking into account the two layers of soil, to determine the spatial variation of vegetation and evaporation in each cell. To modify the two-layer model, researchers considered a 10 cm layer on the upper layer to consider the moisture diffusion between the layers of the soil, and a three-layer VIC-3L model was introduced.
It should be noted that the VIC model now has the possibility of adding more layers.

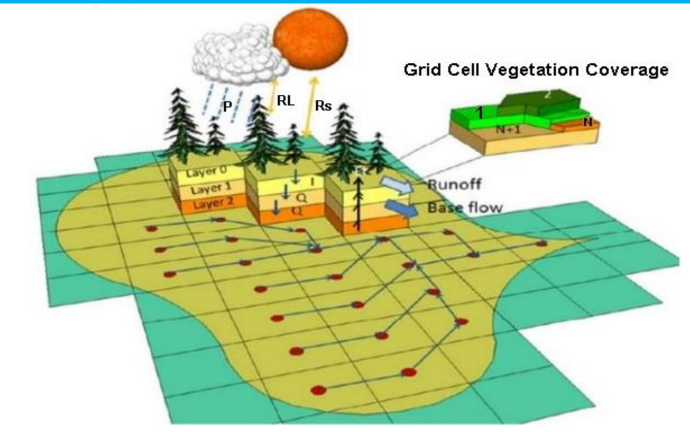
Aim

The purpose of this study is to compare the performance of the VIC-3L model under different rainfall databases.
Four precipitation databases were evaluated in present study:
•**ECMWF** with a spatial resolution of 0.125°,
•**GPCP** with a spatial resolution of 0.5°,
•**TRMM** with a spatial resolution of 0.25°,
•**PERSIANN CDR** with a spatial resolution of 0.25°

Method

Implementing the VIC-3L model requires the preparation of 5 files as inputs.

1. Meteorological data file: This file contains daily meteorological data for each cell in the study period. Meteorological file includes precipitation, maximum temperature, minimum temperature and wind speed.
2. Soil parameters file: In addition to determining the soil type in each cell, the specification of each layer of soil is also required. Some of these parameters are extracted according to the dominant texture from soil properties and library functions, some of these parameters are proposed by default by the model, and some of these parameters are obtained during the calibration process of the model.
3. Vegetation files: Two types of input files are defined in each cell for determining vegetation parameters.
   - **Vegetation parameter file** that includes number of vegetation per cell, percentage of cover for each vegetation, type and values of leaf area index, etc.
   - **Vegetable library file** determines some of the parameters of the vegetation types in the study area, such as the upper lid of vegetation, architectural resistance of vegetation types, etc.
4. File Control File: This file has the function of controlling or managing between the input and output files and executing the model. This file contains the location of the input and output files, total duration of the modeling and time steps.



Schematic view of the macro-scale VIC-3L model.

After running the VIC model, a routing model was implemented. The inputs for the routing model include the direction of the stream, the fraction file, the station location file and the model control file.

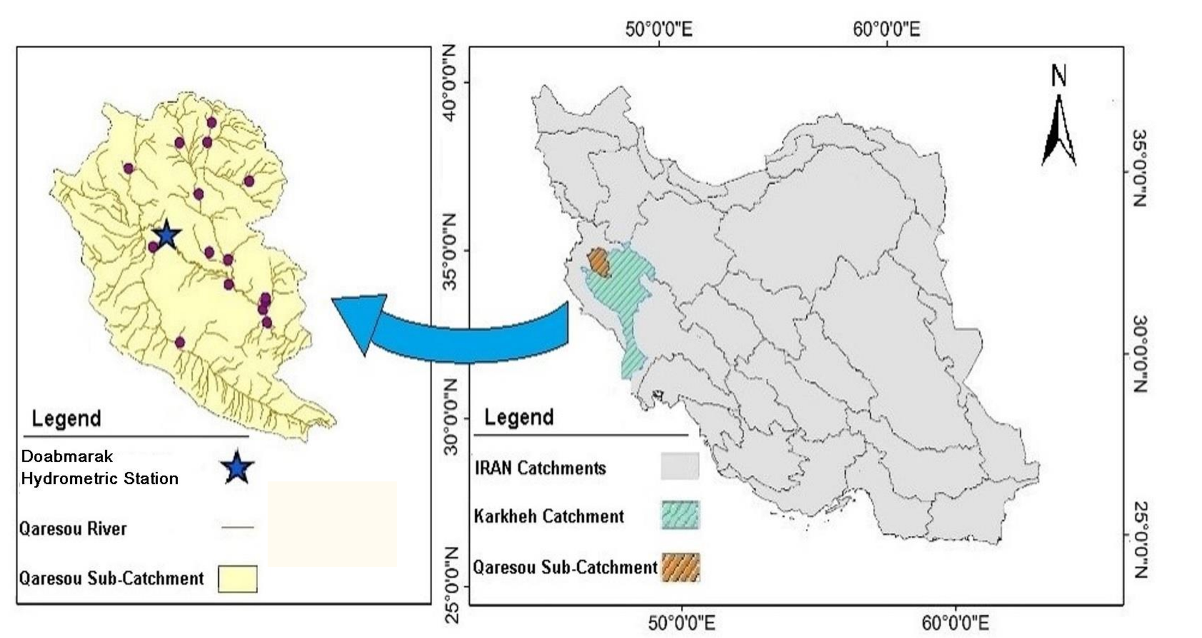
1. Flow direction file: This file determines how to connect each cell according to the flow path (streams). The output of each cell is a number that represents the direction of the flow. The output flow of each cell can exit in one of the eight main directions. In present research, ArcGIS 10.3 software was used to build the Flow direction file.
2. Fraction file: This file contains the percentage of each cell involved in streaming the flow into the basin. In this study, it is assumed that all cells are completely within the basin so that the participation rate of all cells is equal to one.
3. Location file: This file contains the name and location of the runoff simulation hydrometer station. The station's location is expressed as a row and column number. The Duabmarak hydrometric station, located in row 4 and column 3, was used as the outlet of the basin runoff.
4. The control file: It is similar to the VIC model as previously described.

Calibration of the VIC model: some of parameters can not be determined using direct measurement. These parameters are conceptual and have non-physical values. The important parameters that should be calibrated in the VIC model are related to the soil file, which are:

1. D_m : Maximum velocity of baseflow,
2. D_s : The fraction of Dm, where nonlinearly baseflow begins,
3. W_s : The fraction of the maximum soil moisture in the lower layer of the soil in which non-linear baseflow occurs,
4. B_{inf} : Variable infiltration curve parameter,
5. d2 and d3: which are related to the depth of the soil in the second and third layers.

Study area

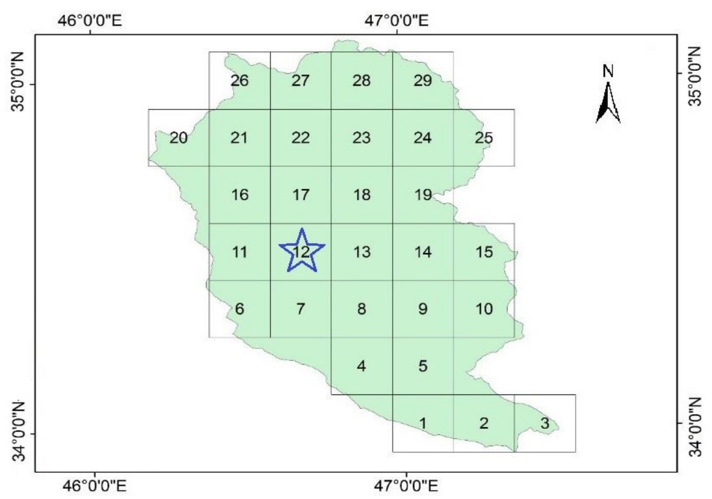
Qarasou sub-catchment is located in Kermanshah province and northwest of Karkheh catchment. It is located at 46° 22' to 47° 23' E and 34° 02' to 34° 56' N. The Total area is 5354 square kilometer, and the average rainfall is between 300 to 800 mm. The elevation is at least 1180 meters that reaches a maximum of 3346 meters above mean sea level.



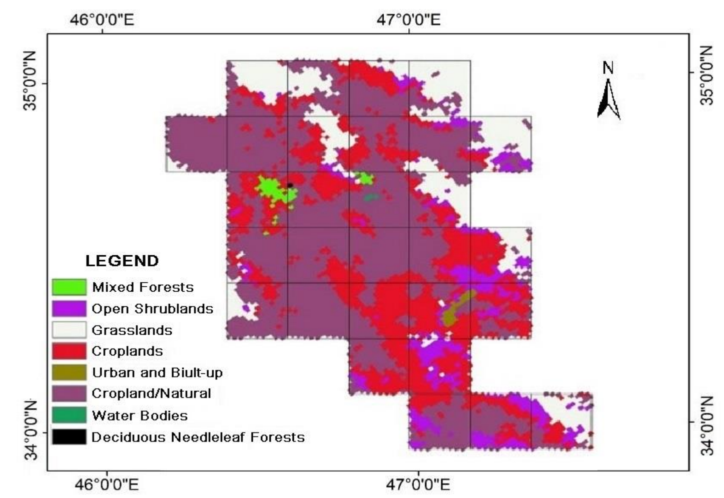
This figure shows the general location of the Karkheh catchment and Qaresou sub-catchment in west of Iran and the location of Doabmarak hydrometric station located on Qaresou River.

Results

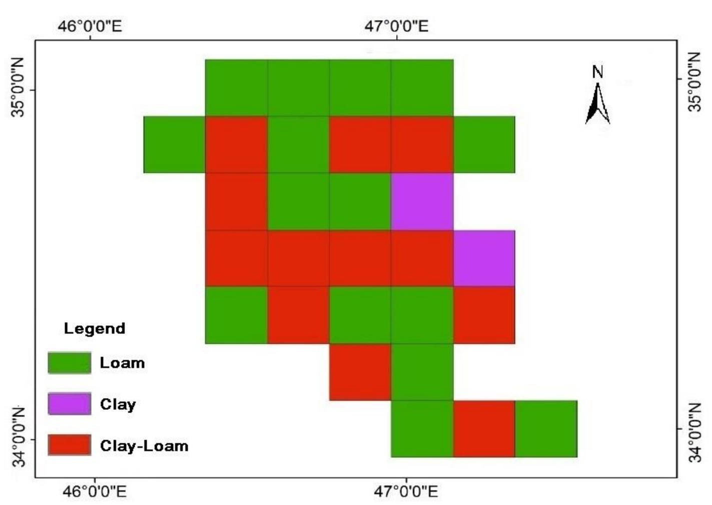
The most suitable spatial resolution for implementing VIC model was considered 0.125°*0.125° and total rainfall database data was downscaled using the ArcMap10.3 software.
It is noteworthy that other meteorological parameters including minimum and maximum temperature and wind speed were taken from the ECMWF database.



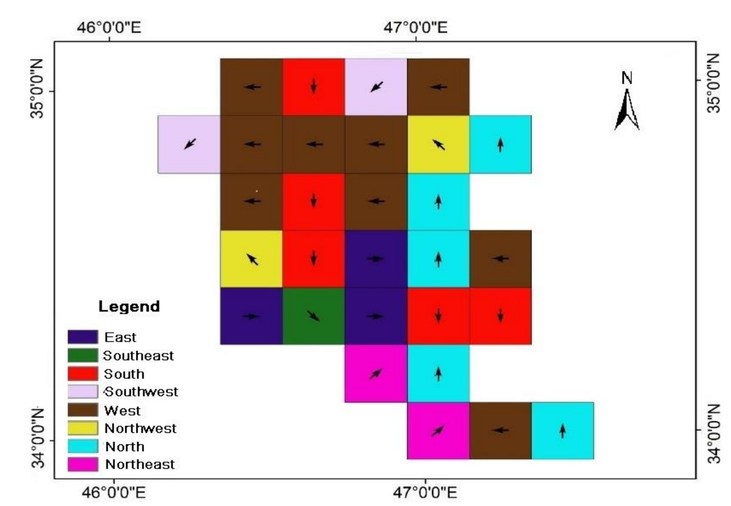
The study area has been gridded according to the Digital Elevation Model (DEM) and divided into 29 cells with spatial resolutions of 0.125°×0.125° (13.75×13.75 km^2). The Doabmarak hydrometric station located on row 4 and column 3 (cell No. 12) was used as a runoff outlet.



*One kilometer scale of GLCC maps has been used to determine the vegetation of the area.
In GLCC maps, vegetation is classified into 17 classes using the IGBP technique.
As it is evident, the most type of vegetation is a type of land with a natural agricultural cover, and the lowest is related to the water levels, which is very small.*



In this figure, Spatial distribution of different soil texture in the study area is shown. the FAO map of the one kilometer scale has been used to create the soil file. Also, for determining the parameters of leaf area index and albedo coefficient, MODIS satellite images were used. As it is seen in this figure, the dominant texture of this basin is Loamy with 51.72%, followed by Clay-Loam with 41.38% and Clay with 6.8% minimum.

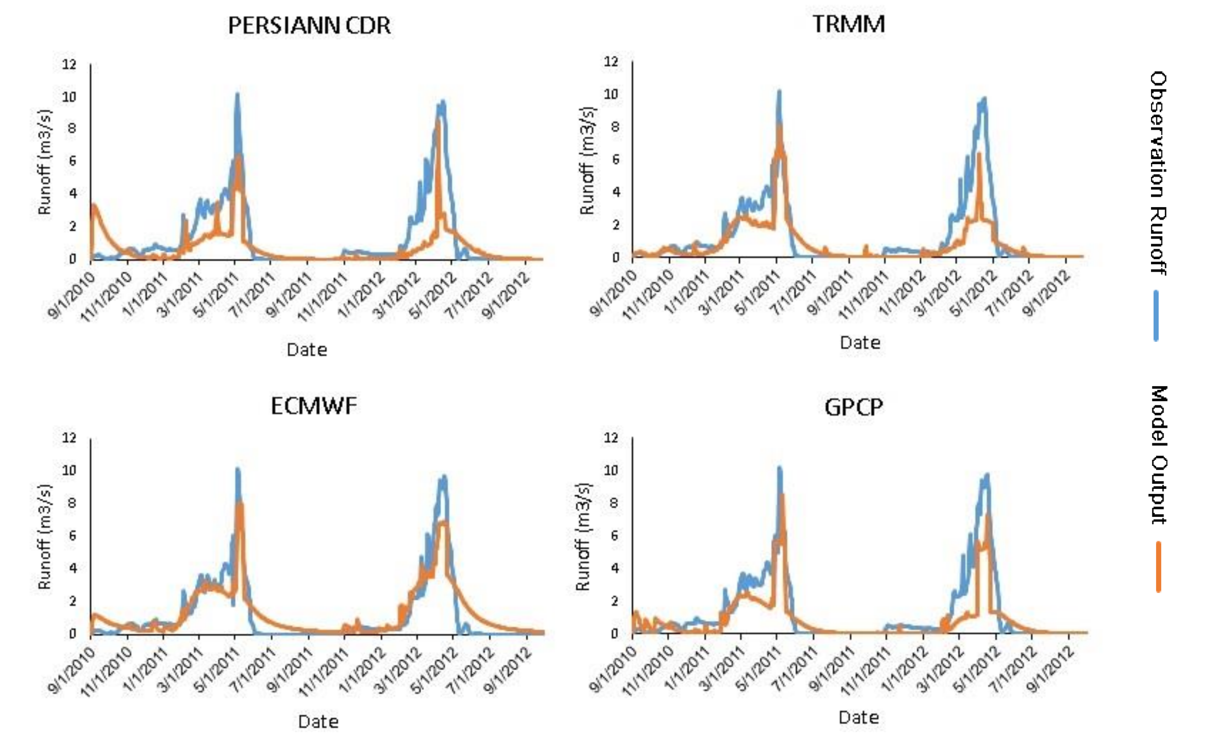


According to this figure, each color represents flow direction in each cell, which can have 8 direction.

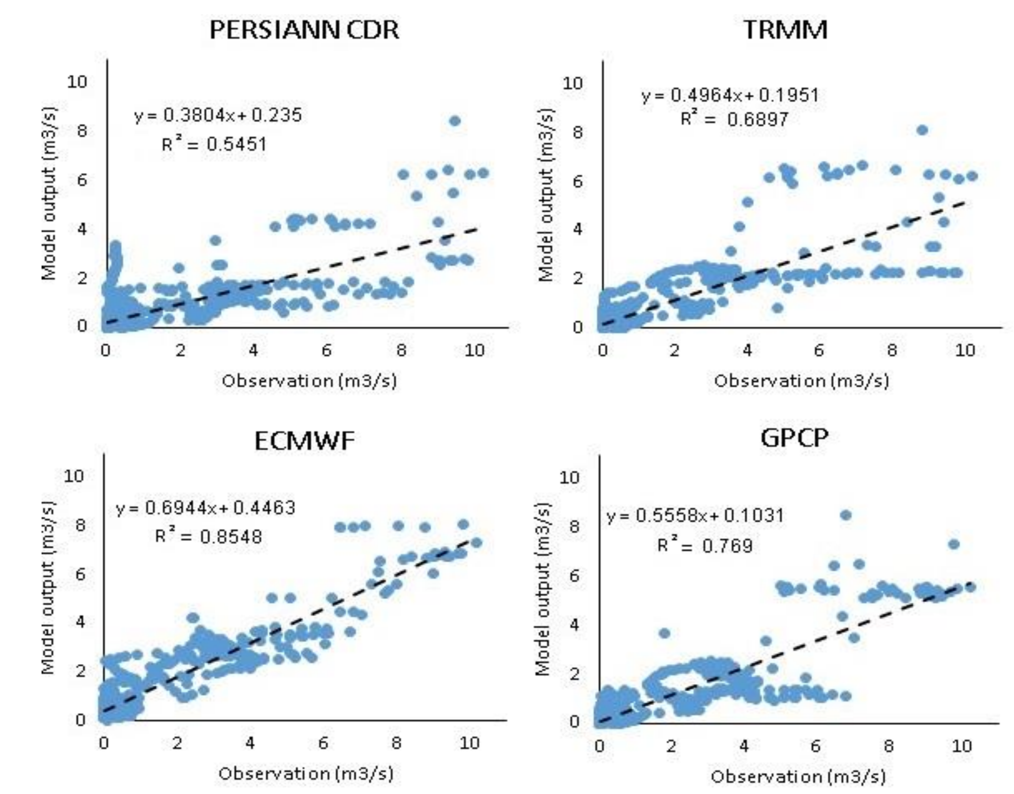
Calibration of the VIC model for 4 precipitation databases was conducted between years 2010 to 2012. Furthermore, Daily runoff data of Doabmarak station was compared with the output data of the model.

Database	TRMM	PERSIANN CDR	ECMWF	GPCP
R^2	0.689	0.545	0.855	0.769
NASH	0.592	0.429	0.824	0.663
RSME	1.312	1.553	0.863	1.193

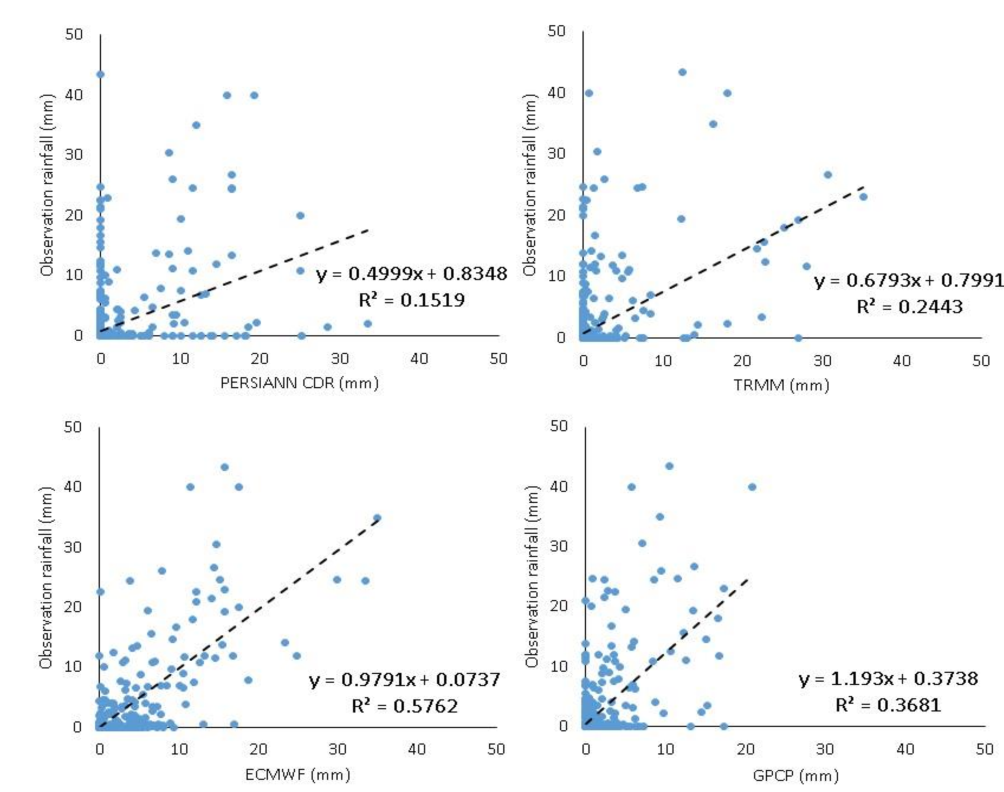
Coefficient of determination, NASH and RMSE indicate better performance of the ECMWF data than other databases. The GPCP, TRMM, and PERSIANN CDR are ranked next, respectively.



The above figure shows the simulated hydrograph and the observed flow during the calibration period under all four rainfall databases. These diagrams indicate that the VIC-3L model has the ability to simulate data in most cases, although the weakness is to simulate peak flows.



Above charts show the comparison of model output data under various rainfall dataset and observation data of the Doabmarak Hydrometry Station.



The charts shows the comparison of rainfall for the four rainfall databases with the Kerendgharb station data which located in cell 12. The ECMWF database are in better agreement with the observed data, which indicates that the ECMWF is more accurate in the study area.

References

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