Modeling-NAM Assignment

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Sub catchment: 4
Parameters (group a): U_{max}, CK_{12}, TOF

Introduction

1. **Model-NAM:** The NAM is consider as a rainfall-runoff model in this report, Because the analyze area in Belgium doesn't have snow, so we can ignore the influence of temperature and radiation.
2. **Catchment:** River Dender catchment, Belgium
   The study area of our group is Sub catchment Ruisseau D'Ancre, NO. 4, with the area 76.81 km2.
3. **Parameter:** group a - U_{max}, CK_{12}, TOF
4. **Model build up:** I changed the subarea to number 4, and prepare the calculation steps in the excel sheet, set the ε= 0.00000001. In figure 1, column A represent the range of the study period, column B is the observation data of the total flow, column C is the simulated total flow, the columns in yellow are the calculation steps, and the column in green are the results of each numerical criteria.

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
Time	Obs_TF(Oi)	Total flow	$O_t - S_t(\theta)$	$\bar{O}_t$	$O_t - \bar{O}_t$	$(O_t - S_t(\theta))^2$	$(O_t - \bar{O}_t)$ ^2	ε	$\log(O_t+\varepsilon)$	$\log(S_t(\theta)+\varepsilon)$	$\log(\bar{O}_t+\varepsilon)$	$(\log(O_t+\varepsilon) - \log(S_t(\theta)+\varepsilon))$^2	$(\log(O_t+\varepsilon) - \log(\bar{O}_i+\varepsilon))$^2	NSE	LNSE	PBIAS
2005	0.64	0.883979	-0.24398	0.63	0.010226	0.059525916	0.000104571	1E-08	-0.19382	-0.0535579	-0.2008153	0.019673467	4.89337E-05	0.429336	0.279625	17.85268
2005	0.64	0.883872	-0.24387		0.010226	0.059473433	0.000104571		-0.19382	-0.0536107		0.019658642	4.89337E-05			
2005	0.63	0.883755	-0.25375		0.000226	0.064391521	5.1084E-08		-0.20066	-0.0536682		0.021606429	2.42844E-08			

Figure 1 – calculation steps in excel sheet

Sensitivity Analysis

Steps: I set the 20 equally spread values of my 3 parameters (Table 1), then run each parameter value in NAM_setup.py, the output which is the simulated total flow will use to calculate the NSE, LNSE and PBIAS in my excel. Next, I created 3 graphs for each parameter to show the sensitivity of the model to changes in parameter values (Figure 3, 4, 5).

Table 1 - 20 equally spread values of the parameters U_{max}, CK_{12} and TOF

Parameters	Range	Values (total 20 values)						
U_{max} [mm]	5-35	5	6.5	8	…	30.5	32	33.5
CK_{12} [h]	3-48	4	6.3	8.6	…	43.1	45.4	47.7
TOF [-]	0-0.9	0.01	0.055	0.1	…	0.775	0.82	0.865

Results and Discussion

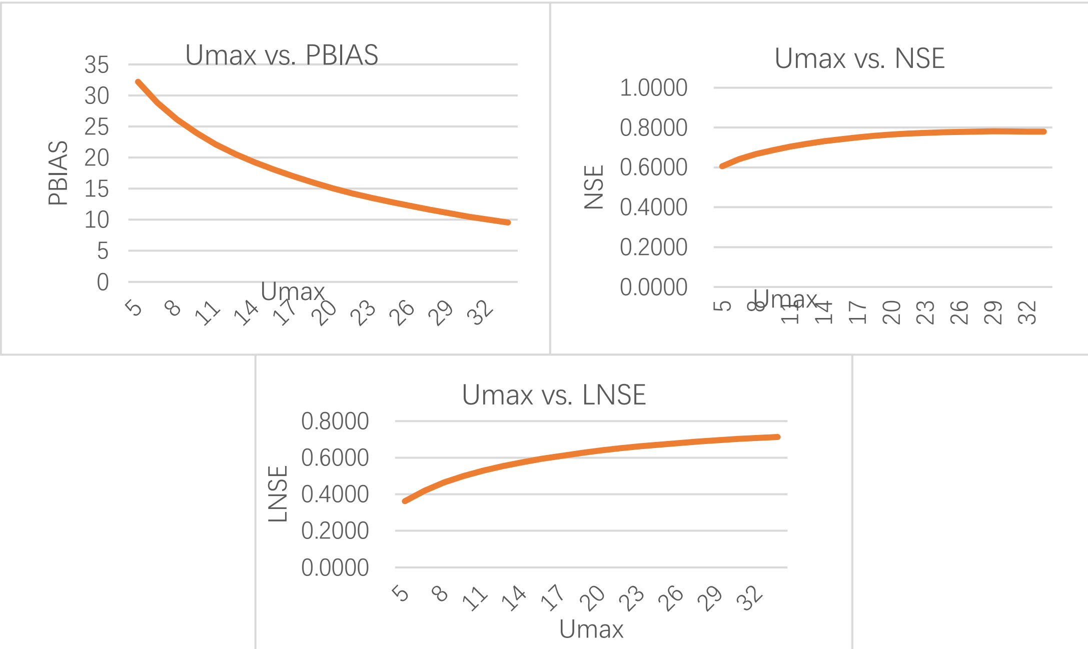

Figure 2 - Graphs of the parameter U_{max} VS. PBIAS, NSE and LNSE

For the parameter U_{max}, we can read from the graphs that the PBIAS and LNSE are more sensitive to change in U_{max} than NSE, because the lines of them are more slanted, especially PBIAS, decreased more than 60% with the increasing of U_{max}. Additionally, because for PBIAS, the smaller the absolute value, the value is more recommended, for NSE and LNSE are the closer to 1, the value is more recommended, so the graphs reflected all 3 criteria recommended bigger U_{max} value.

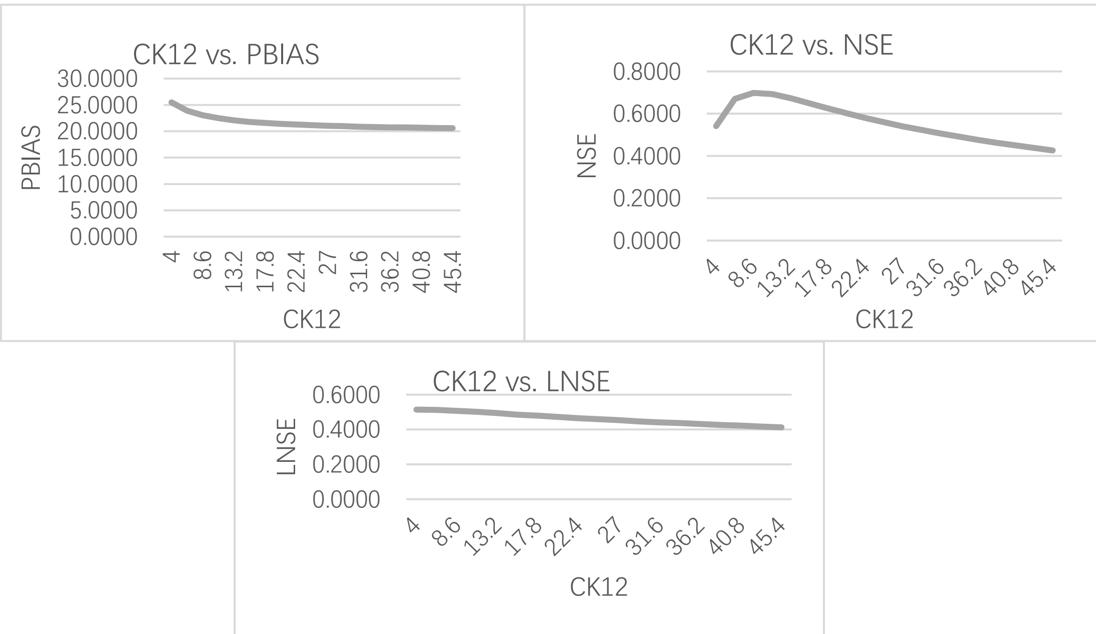

Figure 3 - Graphs of the parameter CK_{12} VS. PBIAS, NSE and LNSE

For the parameter CK_{12}, it shows that the line of NSE has the biggest slope, and the line of PBIAS is most horizontal, which means NSE is most sensitive for changes of CK_{12}, especially when CK_{12} around 10, and for PBIAS and LNSE, even they are not that sensitive, but can still show that the smaller CK_{12}, the value of the parameter is more recommended.

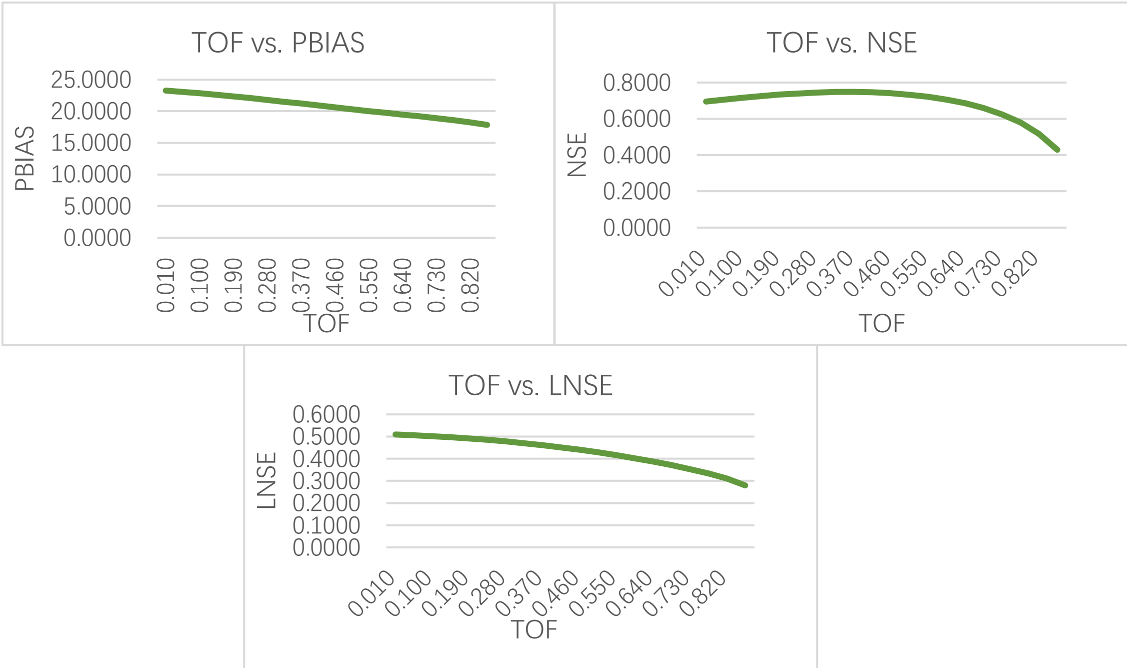

Figure 4 - Graphs of the parameter TOF VS. PBIAS, NSE and LNSE

As the parameter TOF increase, the line of LNSE decreases most sharply and the line of PBIAS is relatively slow. Which draws attention is the line of NSE, the first third of the line is almost horizontal, but then it decreases significantly. So we can observe the criteria LNSE is most sensitive to the changes of TOF. The interesting point is PBIAS recommended the smaller TOF but both NSE and LNSE recommended bigger TOF, although the overall performance of TOF is not good in PBIAS and LNSE.

Model calibration

1. Calibration period: 2005-2011 (2002 until 2004 is warm-up period)
   Validation period: 2012-2014 (2009 until 2011 is warm-up period)
2. First round calibration: I changed the parameter values by analogy, compare the criteria for determined the satisfied values of the first round of calibration for parameters: U_{max}, L_{max}, CQOF, CK_{12} and CKBF.
3. Second round calibration： I keep the values of first calibration default, and changed the parameter TOF, TIF and TG, then I compare the criteria, the hydrographs and residual plot to find the best matches values (Fig 5).
4. I applied the new parameters after second calibration to my validation period, the hydrograph and residual plot shows in (Fig 6). Additionally, I perform a zoomed hydrograph and residual plot in the validation period (Jan. to Feb. 2020) (Fig 7).
5. In summary, the calibration results show in (Table 2).

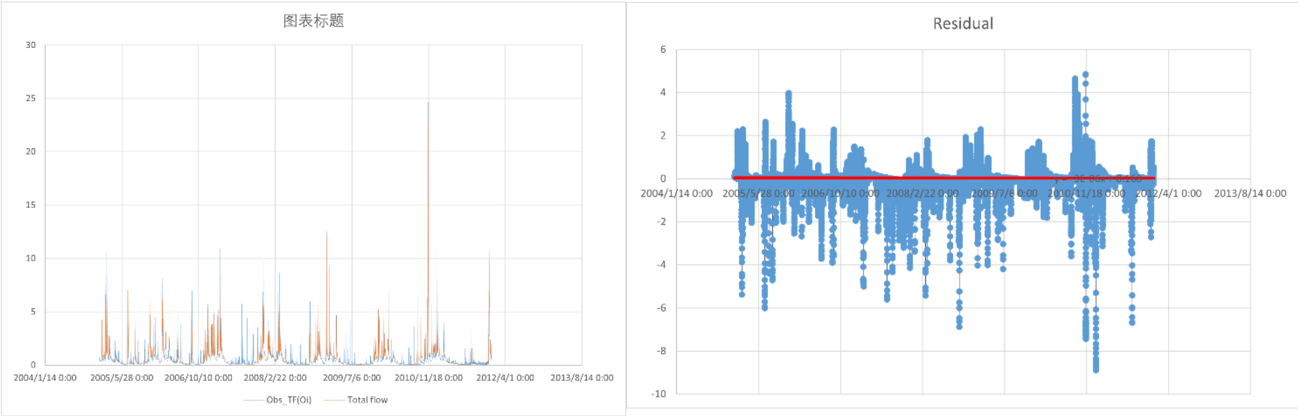

Figure 5 – Hydrograph (left) and residual plot (right) of the second-round calibration in period 2002-2011 (Calibration period)

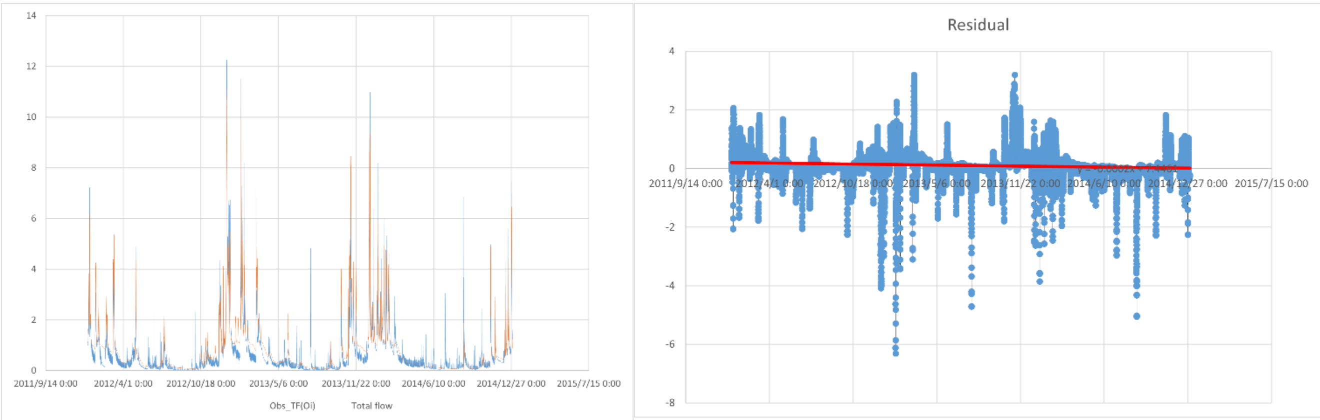

Figure 6 – Hydrograph (left) and residual plot (right) of the second-round calibration in period 2012-2014 (Validation period)

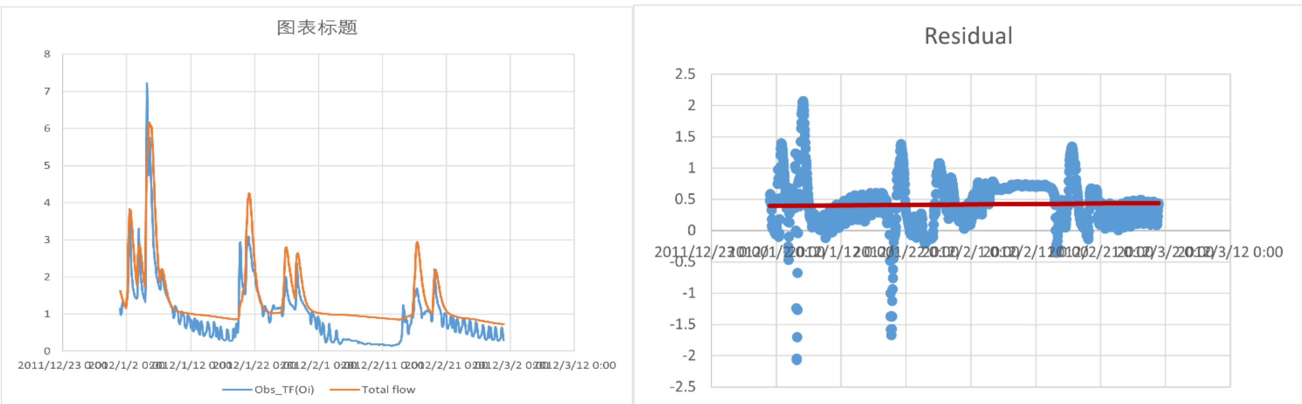

Figure 7 – Zoomed hydrograph (left) and residual plot (right) of the second-round calibration in period 2012.01.01-2020.02.29 (Validation period)

Table 2 – The calibration period and validation period results of NSE, LNSE and PBIAS

Result

		Umax	Lmax	CQOF	K12	CKbf	TOF	TIF	TG	NSE	LNSE	PBIAS
Calibration	first round	35	100	0.6	10	2000	0.0	0	0.0	0.7863	0.7563	5.1485
	Second round	35	100	0.6	10	2000	0.5	0.5	0.5	0.7996	0.7667	2.1794
validation		35	100	0.6	10	2000	0.5	0.5	0.5	0.8141	0.7797	3.2392

Discussion

As we know, when the values of criteria NSE and LNSE in the range of 0.75-1, and the values of criteria PBIAS in the range of 1-10% means the performance of the model is very good. After the first round of calibration, the values of NSE, LNSE and PBIAS is 0.7863, 0.7563, 5,1485 separately, means all 3 criteria all satisfy the “Very good” performance rating. Among all the parameters, the U_{max} and L_{max} are crucial, the change of them have significant influence to the result of criterial.

In the second round of calibration, I change the values of parameters TOF, TIF and TG mainly by the observation of hydrographs, such as the changes of height and volume of peaks, thus, to make the result of the model more accurate. The hydrograph in Fig 5 shows the peaks of the observation total flow are mostly overlap with the peaks of simulated flow. And the trend line of the residual is almost horizontal, no shift, no trend and no variable variance, which indicate it’s an accurate model.

When I applied this model to the validation period, the results of the criteria NSE, LNSE and PBIAS are 0.8141, 0.7797 and 3.2392 separately, the performance is not only “very good” but even better than in the calibration period. So it indicate it is an excellent and widely applicable model.

As a NAM model, the advantages are its real-time hydrological forecasting, easy to understand, and can achieve better accuracy when calculating runoff, but it also has some disadvantages, such as the accuracy is limited because its semi-empirical, and due to its lumped model, so unavailable analyze the rainfall distribution in spatial, besides, it cannot analyze the influence between the parameters on model.

Additional, from my observation, the default value ε also has influence to the model, it should as small as possible, if I set too big value such as 0.1, could affect the value of LNSE, decrease the accuracy of the model.

Conclusion

In summary, the NAM model is a very handy model for the rainfall-runoff process, people can adjust the values of the parameters to modify the accuracy of the model by both calculation and observation, but it also has limitations, for instance, when calculate, it always take the average values, even its easier to understand, but it ignore more details than the distributed model, besides, because the spatial distribution is not considered, the applicability of this model is limited, and a model that performs well in one area may not be applicable to another area.