Implementation of a recursive numerical filter for updating individual flood hydrographs

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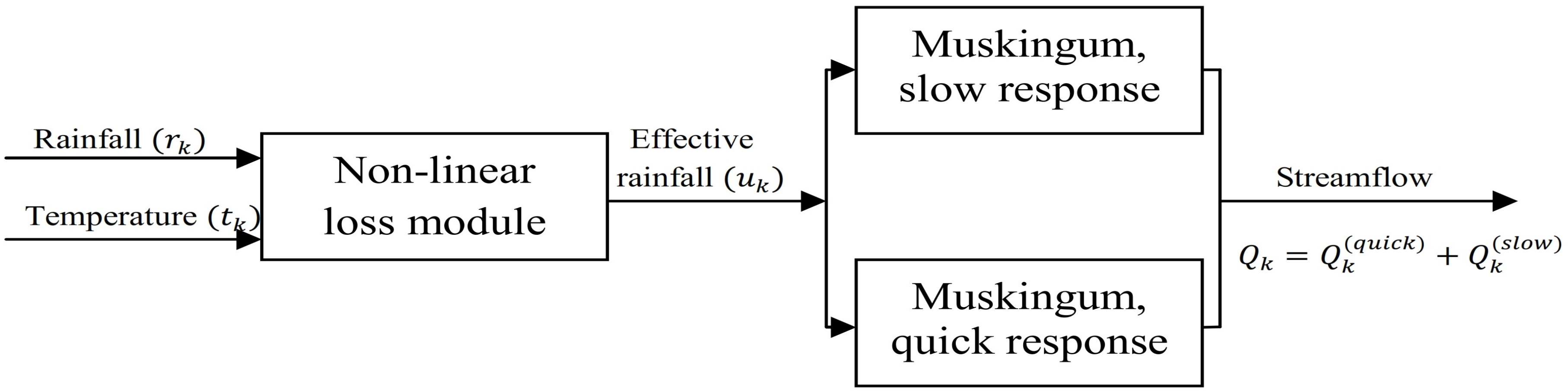
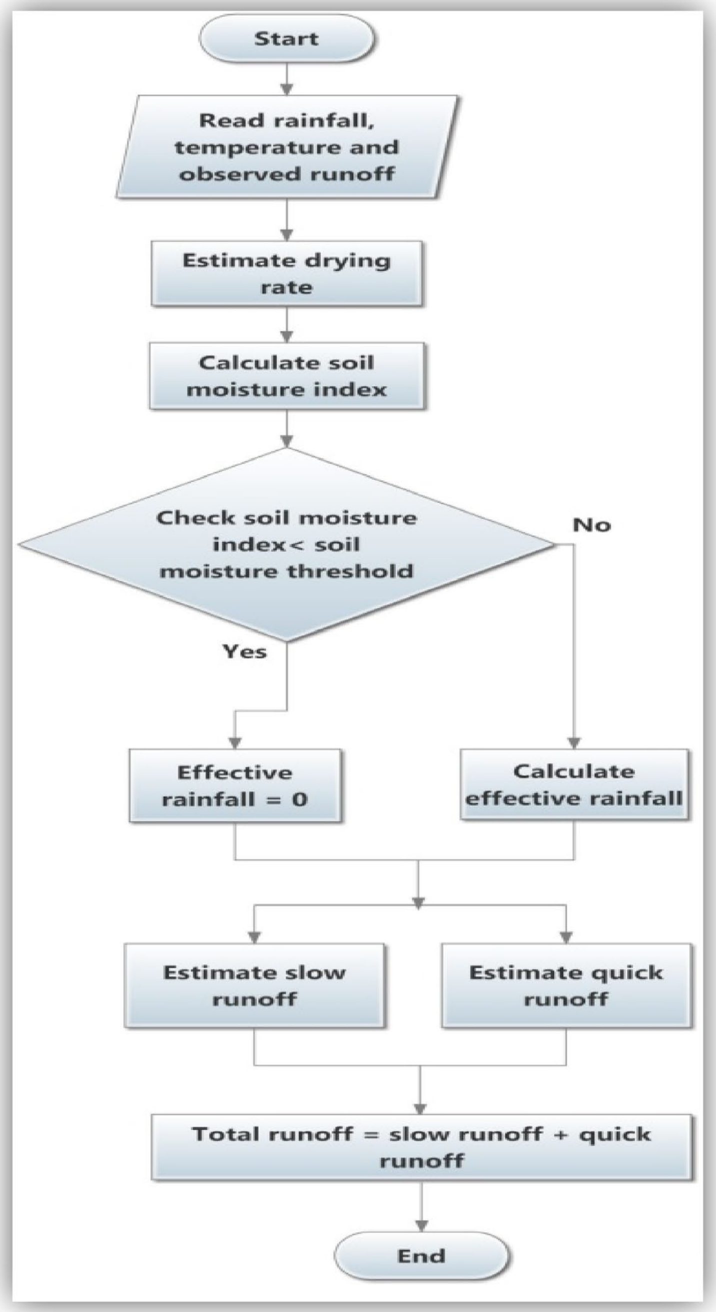
ERM model

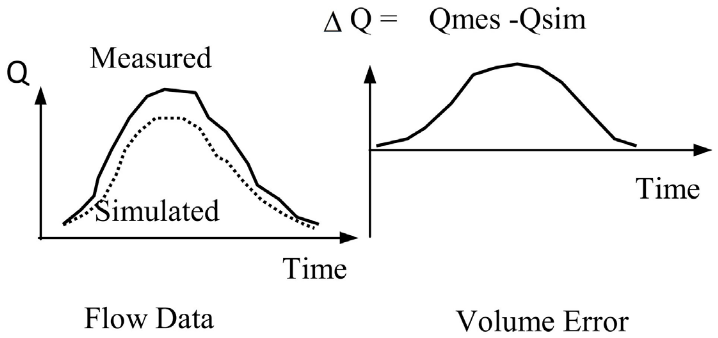
Based on the popular IHACRES model
Hybrid optimisation scheme (CNLO-GA)
Muskingum routing method



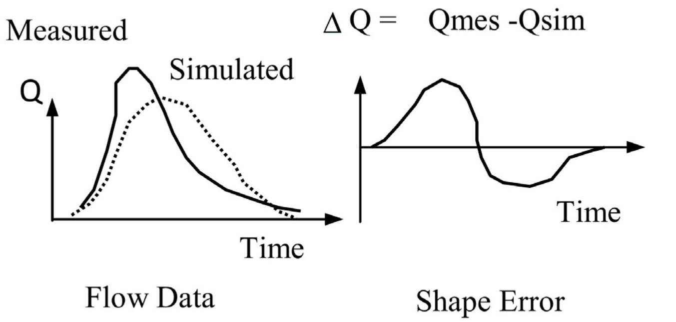
ERM model flwochart



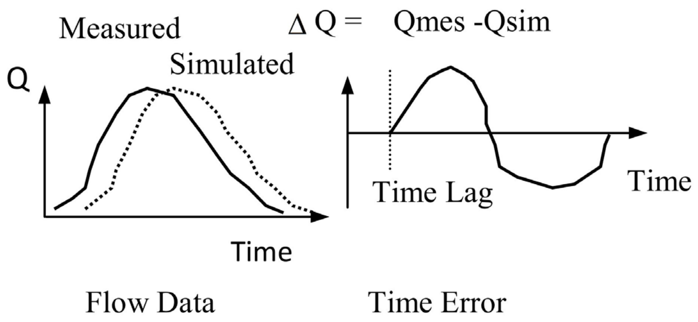
Hydrological modeling errors



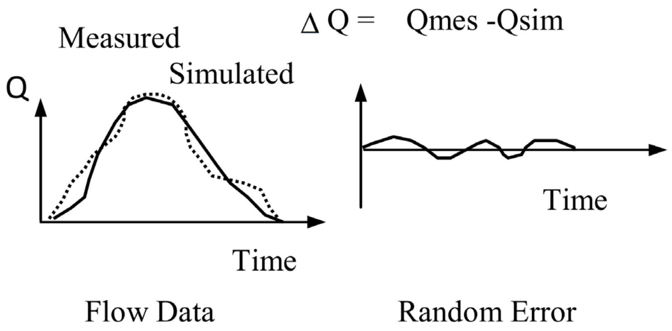
a) Volume Error



b) Shape Error



c) Timing Error



d) Random Error

Kalman filter and real-time flood forecasting

The filter works based on forecasting the model states and correcting (updating) the estimated state

Forecasting stage

Updating stage

Two noise terms are considered in the Kalman filter model as the process and measurement noise

Real-time flood forecasting by coupling the ERM with the Kalman filter

Schreider et al., 2001

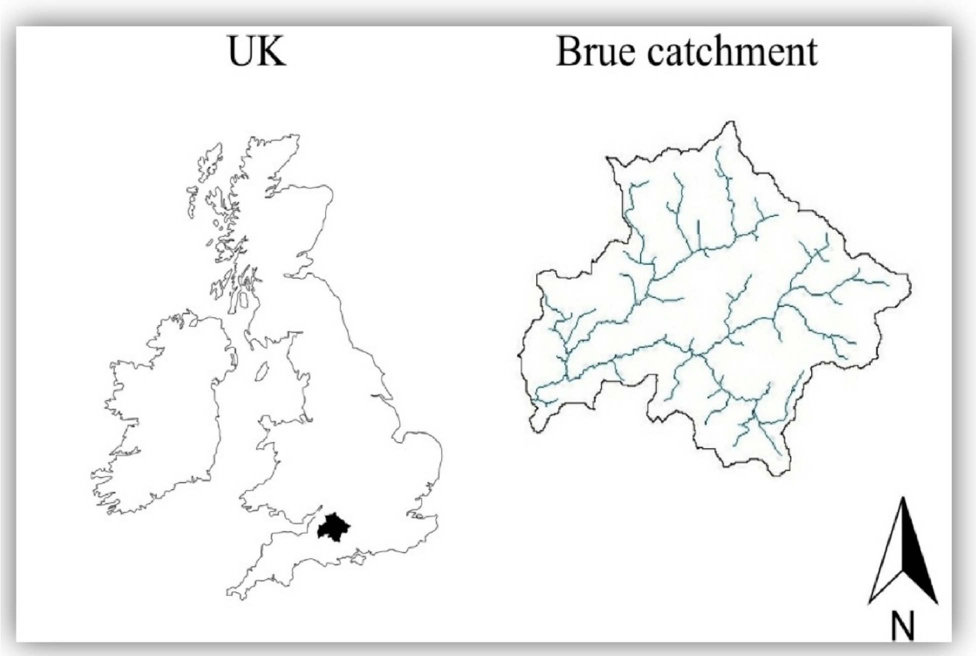
- If the n step ahead forecast is required, then the correction step
is eliminated n times (by IHACRES model)

- Applied on nine catchment and the method was sufficient

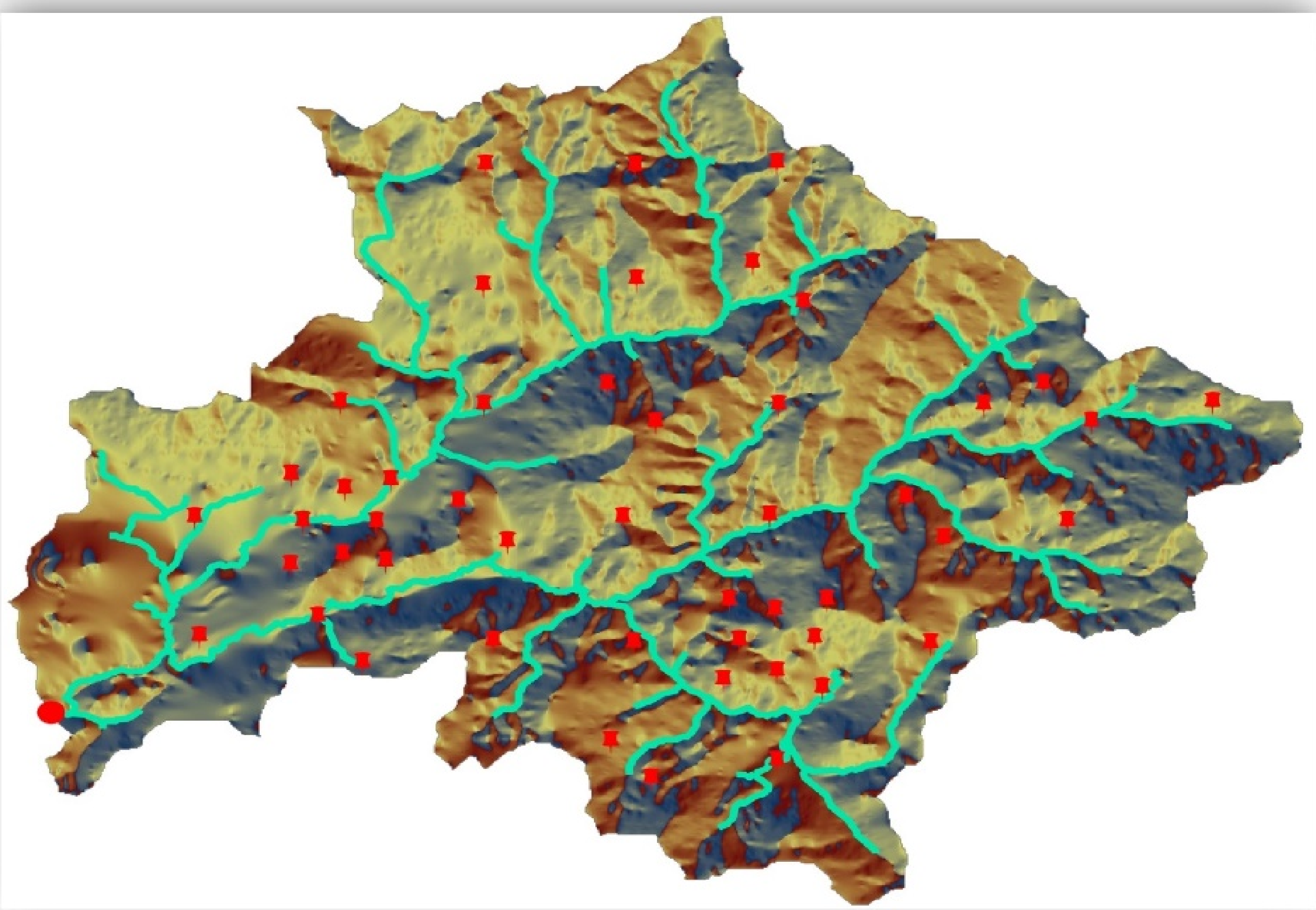
- The implementation of such the model on the ERM model is possible due to the linear form of the Muskingum model.

Brue Catchment

- Catchment located in the Somerset (51.075° North and 2.58° West)
- South-west England with an area of 135 square Kilometer
- average annual rainfall 867 mm and the average river flow 1.92 cumec



Rain gauges around the Brue catchment



Study periods

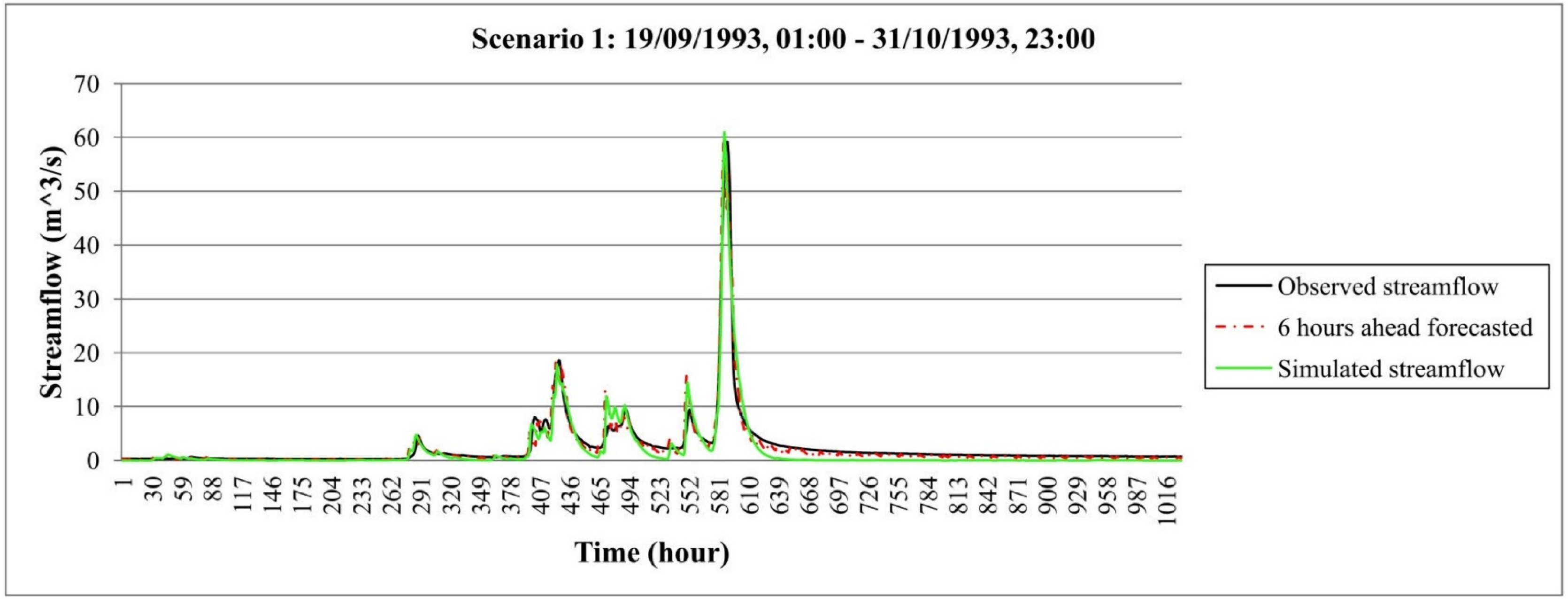
Events	Starting date	Ending date
Scenario 1	19/09/1993, 01:00	31/10/1993, 23:00
Scenario 2	13/06/1997, 01:00	08/09/1997, 12:00
Scenario 3	10/09/1999, 12:00	21/10/1999, 16:00

Results

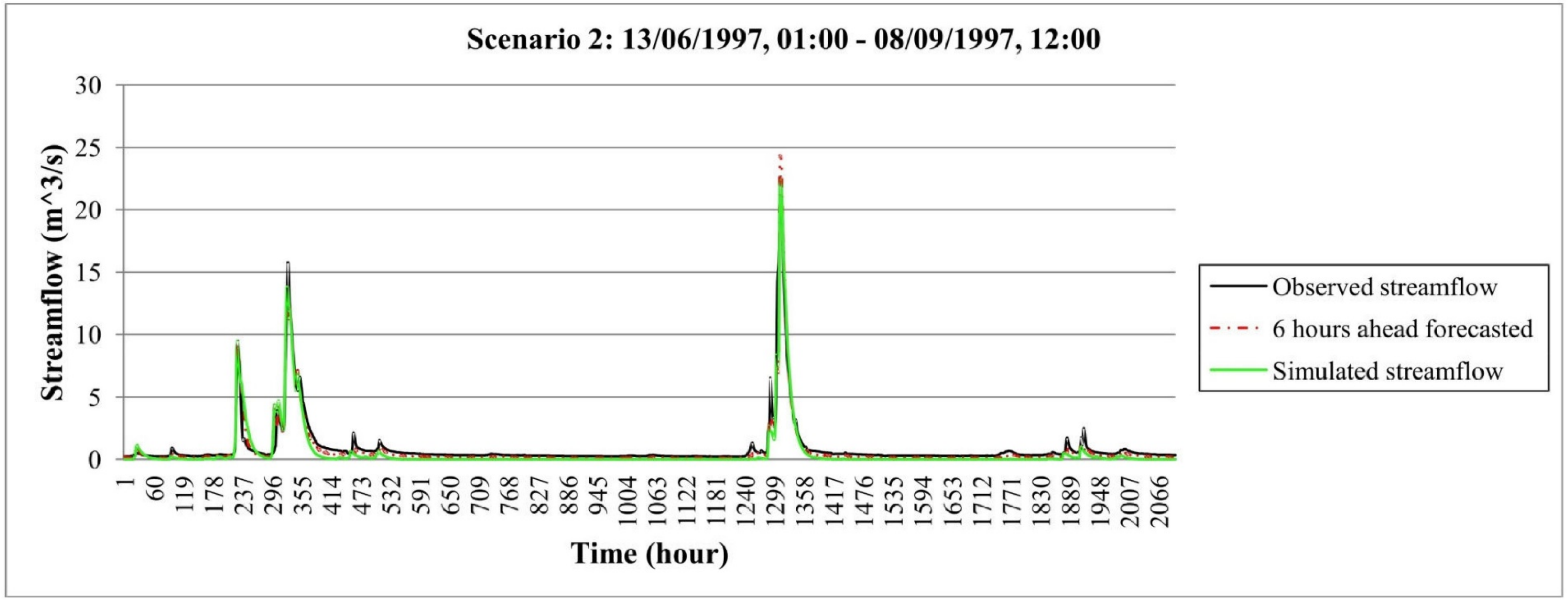
- Two numerical terms, R^2 and RMSE have been selected to compare the hydrographs.

	Simulated runoff		6 hours ahead forecasted	
	R^2	$RMSE$	R^2	$RMSE$
Scenario 1	0.91	1.645	0.94	1.352
Scenario 2	0.89	0.658	0.93	0.548
Scenario 3	0.88	1.955	0.95	1.346

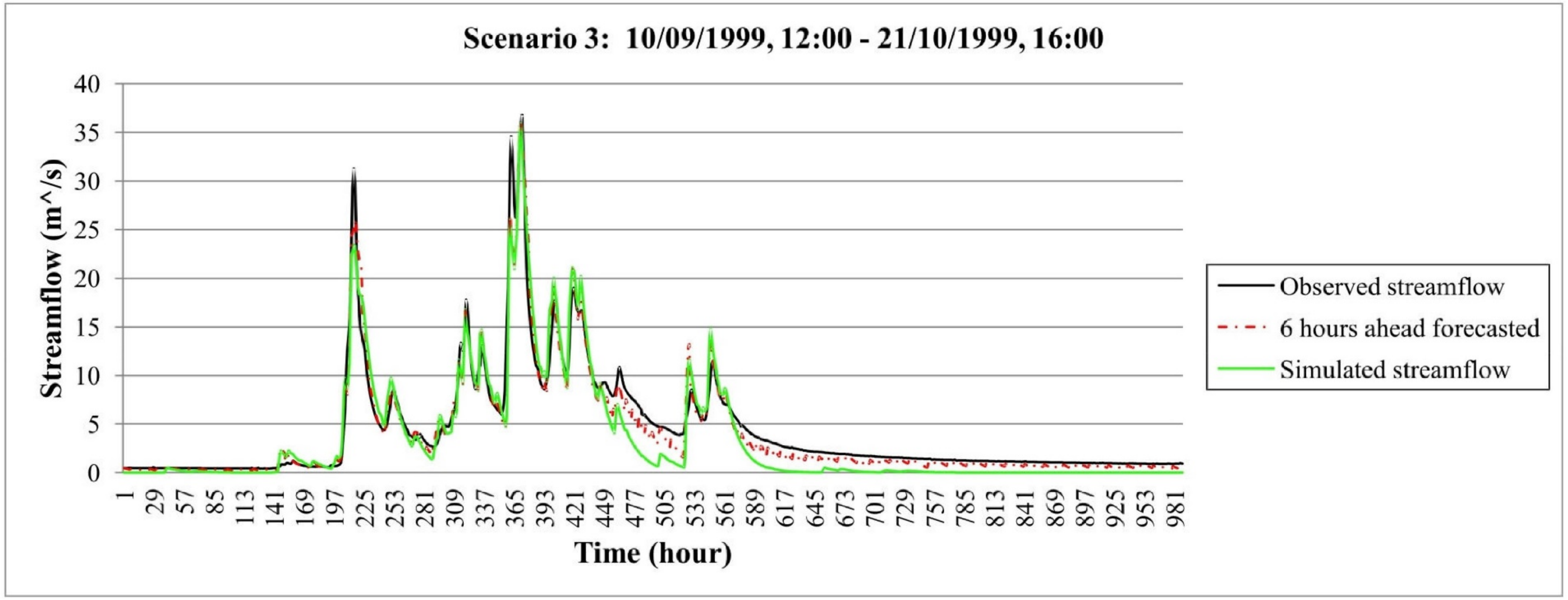
Results (Scenario 1)



Results (Scenario 2)



Results (Scenario 3)



The stability of Kalman filter

- **Question**

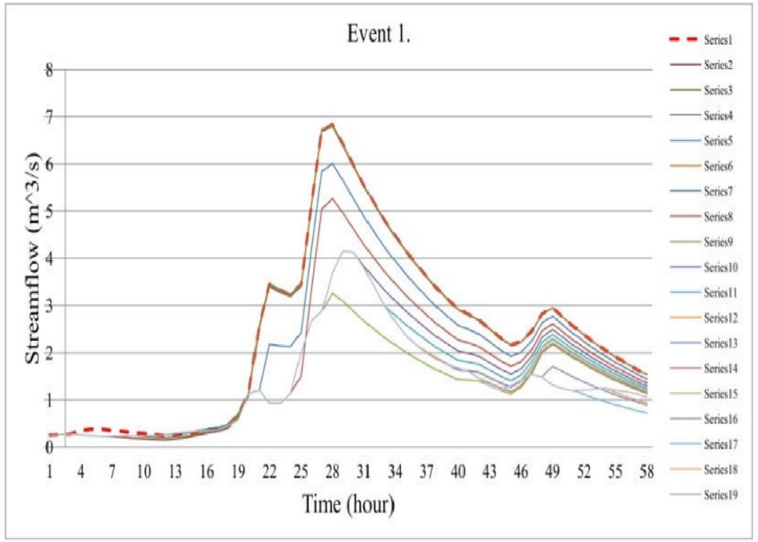
how much the Kalman filter is stable over a time?

10 events are selected from the Brue catchment data base and the Kalman filter and the ERM model will be applied for forecasting purposes

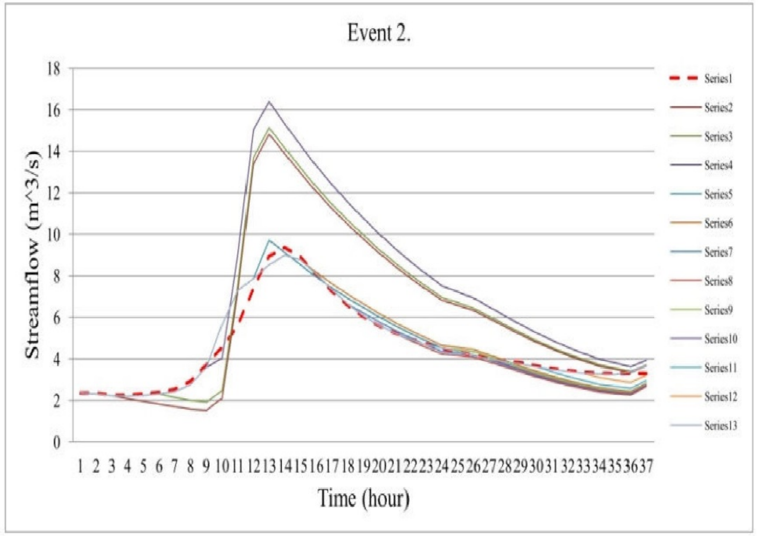
Events

10 events selected from HYREX study

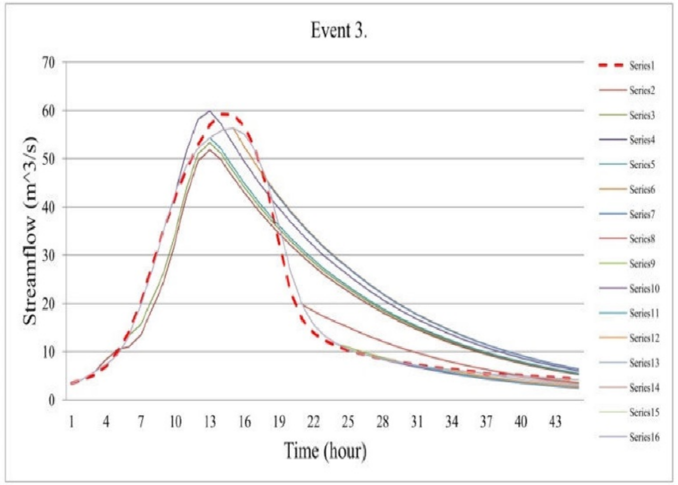
Event ID	Start date	End date
1	29/09/93 – 21:00	02/10/93 – 08:00
2	11/10/93 – 12:00	12/10/93 – 22:00
3	13/10/93 – 00:00	14/10/93 – 20:00
4	07/12/93 – 04:00	09/12/93 – 13:00
5	14/12/93 – 17:00	17/12/93 – 02:00
6	27/12/93 – 14:00	29/12/93 – 23:00
7	09/01/94 – 12:00	11/01/94 – 21:00
8	12/01/94 – 10:00	14/01/94 – 19:00
9	24/01/94 – 12:00	26/01/94 – 21:00
10	27/11/94 – 10:00	29/01/94 – 19:00



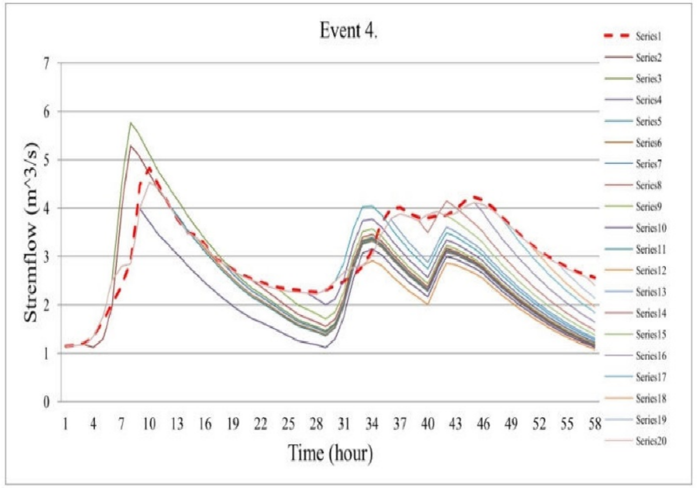
Event 1.
Streamflow (m^3/s)
Time (hour)
0
1
2
3
4
5
6
7
8
1
4
7
10
13
16
19
22
25
28
31
34
37
40
43
46
49
52
55
58
Series1
Series2
Series3
Series4
Series5
Series6
Series7
Series8
Series9
Series10
Series11
Series12
Series13
Series14
Series15
Series16
Series17
Series18
Series19



Event 2.
Streamflow (m^3/s)
Time (hour)
0
2
4
6
8
10
12
14
16
18
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37
Series1
Series2
Series3
Series4
Series5
Series6
Series7
Series8
Series9
Series10
Series11
Series12
Series13

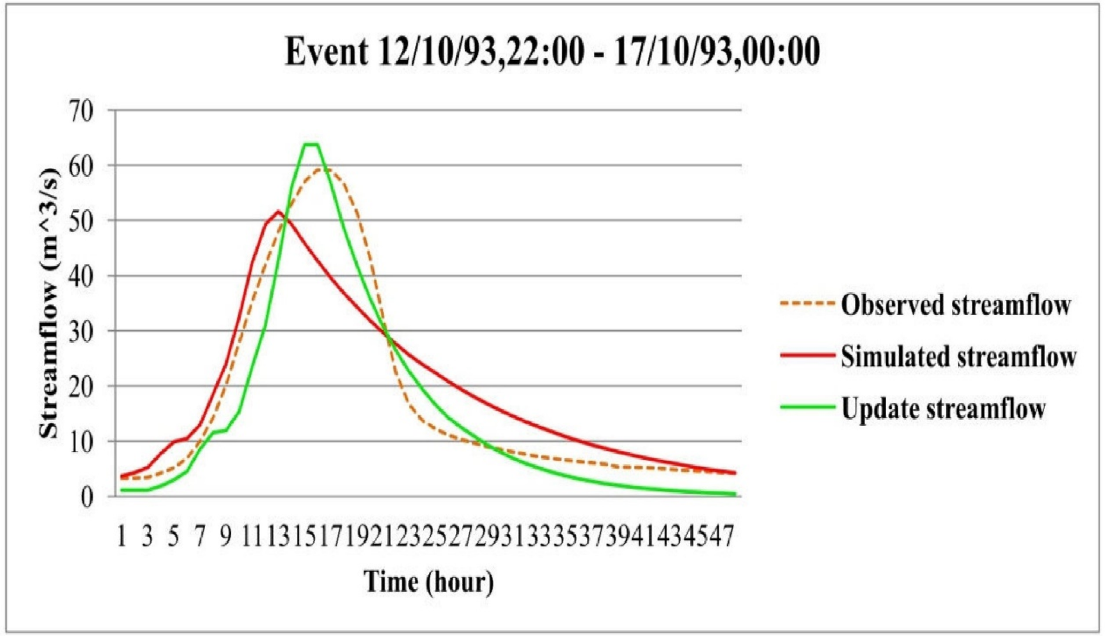


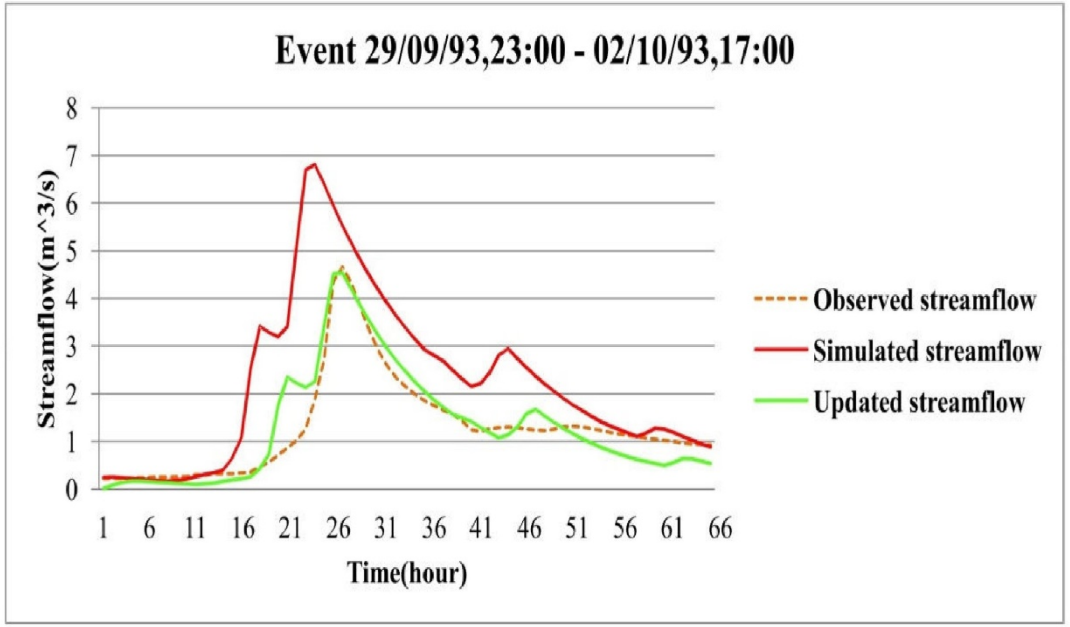
Event 3.
Streamflow (m^3/s)
Time (hour)
Series1
Series2
Series3
Series4
Series5
Series6
Series7
Series8
Series9
Series10
Series11
Series12
Series13
Series14
Series15
Series16



Event 4.
Stremflow (m^3/s)
Time (hour)
Series1
Series2
Series3
Series4
Series5
Series6
Series7
Series8
Series9
Series10
Series11
Series12
Series13
Series14
Series15
Series16
Series17
Series18
Series19
Series20

Single event updating





Conclusion

- The ability of the Kalman filter is acceptable to predict flood events for 6 hours ahead
- The model could be considered as a reliable forecasting model to use in real-time flood forecasting
- The stability analysis proves that, the model is not capable to forecast the certain shape of hydrograph for the leading events.
- The ERM and Kalman filter also have acceptable performance to update and forecast single flood events.

Related papers

- M Baymani-Nezhad and D. Han (2018) ERM model analysis for adaptation to hydrological model errors, Acta Geophisica, ISSN: 1895-6572
- M Baymani-Nezhad and D.Han (2013) Hydrological modelling using Effective Rainfall routed by Muskingum method (ERM), Journal of Hydroinformatics, ISSN: 1464-7141

Thank you for your attention