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 flowchart

Start

Read rainfall, temperature and observed runoff

Estimate drying rate

Calculate soil moisture index

Check soil moisture index < soil moisture threshold

No

Yes

Effective rainfall = 0

Calculate effective rainfall

Estimate slow runoff

Estimate quick runoff

Total runoff = slow runoff + quick runoff

End
Hydrological modeling errors

\[ \Delta Q = Q_{mes} - Q_{sim} \]

- **a) Volume Error**
  - Flow Data
  - Measured vs. Simulated
  - Time

- **b) Shape Error**
  - Flow Data
  - Measured vs. Simulated
  - Time

- **c) Timing Error**
  - Flow Data
  - Measured vs. Simulated
  - Time Lag

- **d) Random Error**
  - Flow Data
  - Measured vs. Simulated
  - Time
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

<table>
<thead>
<tr>
<th>Events</th>
<th>Starting date</th>
<th>Ending date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scenario 1</td>
<td>19/09/1993, 01:00</td>
<td>31/10/1993, 23:00</td>
</tr>
<tr>
<td>Scenario 2</td>
<td>13/06/1997, 01:00</td>
<td>08/09/1997, 12:00</td>
</tr>
<tr>
<td>Scenario 3</td>
<td>10/09/1999, 12:00</td>
<td>21/10/1999, 16:00</td>
</tr>
</tbody>
</table>
Results

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

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Simulated runoff</th>
<th>6 hours ahead forecasted</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$R^2$</td>
<td>RMSE</td>
</tr>
<tr>
<td>Scenario 1</td>
<td>0.91</td>
<td>1.645</td>
</tr>
<tr>
<td>Scenario 2</td>
<td>0.89</td>
<td>0.658</td>
</tr>
<tr>
<td>Scenario 3</td>
<td>0.88</td>
<td>1.955</td>
</tr>
</tbody>
</table>
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

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