A SYSTEMATIC REVIEW OF SENSITIVITIES IN THE SWEDISH FLOOD-FORECASTING SYSTEM

2011-01-27

Göran Lindström/SMHI
Outline

- A SYSTEMATIC REVIEW OF SENSITIVITIES IN THE SWEDISH FLOOD-FORECASTING SYSTEM
- Berit Arheimer, Göran Lindström and Jonas Olsson
- Atmospheric Research, in press

- Project financed by SVC (Svensk Vattekraftcentrum)

- New S-HYPE version
Background

- HBV model was developed in the 1970s
- Large number of studies aiming at improving the model and forecasts
- Large amount of experience from model applications and use at the SMHI
- A quantitative synthesis of the knowledge was needed
The forecast chain

- Forecast quality is influenced by many factors
- Forecast chain at SMHI is quite complex
Questions

- What are the most sensitive steps in the forecast chain?
- What errors should we avoid in model applications?
- In what fields could there be room for further improvements?
Three categories

1. General runoff simulations
2. Spring flood forecasts
3. Short term forecasts
Comparing evaluation criteria

- Different numerical evaluation criteria have been used in different studies (e.g. NSE, mse, rms, mean absolute error,...)

- For each alternative model test an improvement compared to the reference was computed

\[ I = \left( E_{REF} - E_{ALT} \right) / E_{REF} \]

- Ex) From NSE = 0.80 to 0.90 means an improvement by 50% (NSE is based on mse)

- Some tests give poorer results (negative improvement)

- Improvements can not be added
### Reviewed Studies

<table>
<thead>
<tr>
<th>Type of hydrological forecast</th>
<th>Studied components in the production system</th>
<th>No</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>General runoff simulations and predictions</td>
<td>Model structure</td>
<td>1</td>
<td>WMO, 1986; Lindström et al., 1996; Brandt, 1987a.</td>
</tr>
<tr>
<td></td>
<td>Precipitation input pattern</td>
<td>4</td>
<td>Larsson and Lidén, 1996; Brandt, 1987b; Johansson, 2000; Johansson et al., 2007</td>
</tr>
<tr>
<td></td>
<td>Snow-pack data assimilation</td>
<td>8</td>
<td>Lindström and Ottosson-Löfvenius, 2000</td>
</tr>
<tr>
<td></td>
<td>Evapotranspiration equations</td>
<td>9</td>
<td>Gardelin and Lindström (1997)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10</td>
<td>Gardelin and Lindström (1997)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>11</td>
<td>Unpublished</td>
</tr>
<tr>
<td>Annual spring-flood forecasts</td>
<td>Up-dated precipitation &amp; temperature</td>
<td>12</td>
<td>Unpublished; Carlsson and Sjögren, 2003</td>
</tr>
<tr>
<td></td>
<td></td>
<td>13</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Meteorological forecasts</td>
<td>14</td>
<td>Unpublished; Carlsson and Sjögren, 2003</td>
</tr>
<tr>
<td></td>
<td></td>
<td>15</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Model calibration</td>
<td>16</td>
<td>Unpublished</td>
</tr>
<tr>
<td></td>
<td>Data assimilation of snow distribution (remote sensing)</td>
<td>17</td>
<td>Brandt 1991; Andréasson et al., 2001; Bergström and Brandt, 1984; Johansson et al., 2003</td>
</tr>
<tr>
<td></td>
<td></td>
<td>18</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>19</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Short-term forecasts</td>
<td>Up-dated discharge</td>
<td>22</td>
<td>Unpublished; Carlsson and Lindström, 2001</td>
</tr>
<tr>
<td></td>
<td></td>
<td>23</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Precipitation input</td>
<td>24</td>
<td>Unpublished</td>
</tr>
<tr>
<td></td>
<td>Ensembles of meteorological forecasts</td>
<td>25</td>
<td>Olsson et al., 2006;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>26</td>
<td>Unpublished</td>
</tr>
</tbody>
</table>
1. General runoff simulations

Model structure
Precipitation input pattern
Snowpack data ass.
Evapotranspiration (ET)

No. 1 2 3 4 5 6 7 8 9 10 11

Other models (WMO) vs. HBV
HBV-96 vs. HBV-76
PULS vs. HBV
One new rain gauge per basin vs. Original network
50% rain gauges vs. 100% of observation network
Optimal interpolation vs. Subjective weights
Radar precipitation vs. Only real-time rain gauges
Updating with measured snow depth vs. No updating
Priestley-Taylor vs. Thornthwaite
Corrected temperature anomaly vs. Original Thornthwaite
Penman-Monteith vs. Thornthwaite
The choice of model is important

WMO (1986)
Short term forecasting/updating

LUCHEM
Land use changes
Examples of using radar data

Lake water level, Vidöstern    Discharge, Lagan

Flood event 2004
2. Spring Flood Forecasts

Rather insensitive!
Analysis of evaluation of long range forecasts
Recalibration sometimes appropriate

Example: Tjaktjajaure, Luleälven
3. Short Term Forecasts
Example of evaluation of short term forecasts (Southern Sweden, 2004)

Simulation | Updated (effect decreases with time)
Ensemble forecasts vs deterministic forecasts

Which forecast should we believe in?
General runoff simulations and predictions were sensitive to

- Model structure and calibration
- Model equations (e.g. evapotranspiration expression)
- Precipitation input using radar data as a complement to station gauges.
Annual spring-flood forecasts could be significantly improved by

- Better seasonal meteorological forecast
- Re-calibration of the hydrological model based on long time-series
- Data assimilation of snow-pack measurements using georadar or gamma-ray technique.
Short-term (2 days) forecasts could be significantly improved by

- Updating using an autoregressive method for discharge
- Ensembles of meteorological forecasts using the median at occasions when the deterministic forecast is outside of the ensemble range.
General Conclusions and comments

- It is important to continuously evaluate the entire production chain.
- The presented method for harmonizing numerical performance-criteria provides a quantitative way of comparing the results from different studies.
- The study could be extended, to more models, other HBV versions etc.

- Complementary synthesis by Sten Bergström
New version of S-HYPE model is being finalized right now

- 38000 subbasins for all of Sweden
- Improvements in model formulation and set-up
- Snow depth stations included for evaluation and updating

Examples from evaluation of 2008 version of S-HYPE