Impacts of precipitation interpolation on hydrologic modeling in data scarce regions

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1. Motivation

1. Precipitation is one of the most important model inputs

2. Precipitation patterns are important, particularly for spatially distributed modeling

3. Precipitation measurements are scarce in many regions of the world

Suitable interpolation method is required
1. Objective

Which interpolation method is most suitable for hydrologic modeling with SWAT in data scarce regions?

- Thiessen polygons
- Ordinary kriging
- Regression approach
2. Study area

Kumbheri

18.60°N, 73.41°E

3564 mm

687 m

Pune

18.53°N, 73.85°E

746 mm

24.7 °C

560 m

18.53°N, 73.85°E

746 mm

24.7 °C
2. Study area: Rain gauges

Gauge density: (gauges/1000 km²)

<table>
<thead>
<tr>
<th>Study area</th>
<th>~ 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>India</td>
<td>~ 2</td>
</tr>
<tr>
<td>Germany</td>
<td>~ 9</td>
</tr>
</tbody>
</table>
2. Data preparation

1. Consistency and homogeneity check using double mass curves
2. Removal of questionable data
3. Filling of measurement gaps and of removed questionable data
4. Correction of systematic measurement errors (e.g. wind loss; Richter 1995)
2. Interpolation methods

Thiessen polygons

Ordinary kriging

Regression approach

1 km² point grid
2.1 Thiessen polygons
2.1 Thiessen polygons
2.1 Thiessen polygons
2.1 Thiessen polygons
2.2 Ordinary kriging

Requirements

<table>
<thead>
<tr>
<th>Local conditions</th>
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<tbody>
<tr>
<td>Large number of measurement locations</td>
</tr>
<tr>
<td>Careful analysis of semivariograms</td>
</tr>
</tbody>
</table>

Local conditions

<table>
<thead>
<tr>
<th>16 rain gauges</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daily timestep</td>
</tr>
</tbody>
</table>

Pooling of mean daily values for every month and year

- 312 data sets (21 years * 16 gauges – missing values)
- 12 semivariograms

### Rain Gauge: Pune

<table>
<thead>
<tr>
<th>Month</th>
<th>Mean daily rainfall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jul 1988</td>
<td>10.2</td>
</tr>
<tr>
<td>Jul 1989</td>
<td>6.4</td>
</tr>
<tr>
<td>Jul 1990</td>
<td>8.5</td>
</tr>
<tr>
<td>Jul 1991</td>
<td>6.7</td>
</tr>
<tr>
<td>Jul 1992</td>
<td>4.7</td>
</tr>
<tr>
<td>Jul 1993</td>
<td>6.0</td>
</tr>
<tr>
<td>Jul 2005</td>
<td>11.3</td>
</tr>
<tr>
<td>Jul 2006</td>
<td>13.7</td>
</tr>
<tr>
<td>Jul 2007</td>
<td>10.1</td>
</tr>
</tbody>
</table>
2.2 Ordinary kriging

Semivariogram for July

June – September: *Ordinary kriging*

October – May: *Inverse distance weighting (IDW)*
2.3 Regression method
2.3 Regression method

Precipitation decreases with distance in wind direction from the Ghat.

X-coordinate represents this downwind fetch.
2.3 Regression method

X-coordinate shows high correlation with precipitation

\[ R^2 = 0.92, \ p < 0.001 \]
2.3 Regression method

1. Calculation of regression equation for every day, using a mean precipitation value for 7 days (+ - 3 days)

2. Validity test of daily
   a) significance (p<0.1)
   b) negative correlation (W-E decline of rainfall)
2.3 Regression method

Regression valid:

a) Calculate mean rainfall by regression equation
b) Interpolate the residuals with IDW
c) Add mean rainfall and interpolated residuals

Regression not valid:

Inverse distance weighting (IDW)
2.4 Evaluation

1. Cross-validation: Ability to reproduce measured precipitation data

2. Differences in model results:
   - water balance
   - runoff dynamics
2.4 Evaluation

SWAT model by Wagner et al. 2011, with different precipitation input

Sub-basin precipitation input was derived as an average from 1 km² grid
3. Results

Cross-validation: Ability to reproduce measured precipitation

Regression method is most accurate, used as reference
### 3. Results

#### Catchments’ water balance

<table>
<thead>
<tr>
<th>Interpolation scheme</th>
<th>Precipitation</th>
<th>Water yield</th>
<th>Evapo-transpiration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thiessen polygons</td>
<td>2285 mm</td>
<td>1523 mm</td>
<td>691 mm (-2.0 %)</td>
</tr>
<tr>
<td></td>
<td>(-2.3 %)</td>
<td>(-2.4 %)</td>
<td></td>
</tr>
<tr>
<td>Ordinary kriging</td>
<td>2321 mm</td>
<td>1545 mm</td>
<td>706 mm (+0.1 %)</td>
</tr>
<tr>
<td></td>
<td>(-0.7 %)</td>
<td>(-1.0 %)</td>
<td></td>
</tr>
<tr>
<td>Regression</td>
<td>2338 mm</td>
<td>1560 mm</td>
<td>705 mm</td>
</tr>
</tbody>
</table>


3. Results

Runoff dynamics: Comparison with regression model run

Nash-Sutcliffe efficiency at gauges

<table>
<thead>
<tr>
<th>Interpolation scheme</th>
<th>G1</th>
<th>G4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thiessen polygons</td>
<td>0.96</td>
<td>0.92</td>
</tr>
<tr>
<td>Ordinary kriging</td>
<td>0.99</td>
<td>0.98</td>
</tr>
</tbody>
</table>
3. Results

Runoff at G1 in rainy season 2004
4. Conclusions

- More complex methods perform better
- Catchment's modeled water balances is less affected by the interpolation method
  - *Thiessen polygons are sufficient*
- Runoff dynamics are more affected by the interpolation method
  - *Complex methods should be used*
- Kriging based on pooled variograms performed almost as good as the regression approach
  - *Alternative for application in other catchments*
Thank you very much for your attention!

Questions welcome...

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