Improving the efficient and robust uncertainty quantification in real-time flood forecasting using Polynomial chaos expansions and ensemble Kalman filter

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1. Motivation in hydrologic flood forecasting

- Quantifying the uncertain ranges due to many sources is indeed important but time consuming.
- Securing sufficient (golden) time plays a significant role in terms of flood warning and risk mitigation.

| Parameter | Range of \( \theta \) | NAM and PCE | Automatic updating of states and parameters by
|-----------|----------------------|-------------|------------------------------------------------|
| \( \theta \) | 3 minutes if 30 sec | 30 minutes | EnKF
| \( \theta \) | 50 minutes | 3 hours | GLUE
| \( \theta \) | 3 days | ~2 days | PCE
| \( \theta \) | ~5.7 years | ~5.7 years | PCE

2. Methodology

2.1. PCE model construction

- Effects of Experiment Design (N) & Polynomial degree (p) & Metamodel-PCE (Experiment design, N = 1000 and Polynomial Degree, p = 3)

2.2. Real-time flood forecasting based on PCE and Dual EnKF

- The result of model forecasting in real-time: Scheme 1 and 4 are NAM model and PCE model; Scheme 2 and 5 are NAM model and PCE mode with updated state using EnKF; Scheme 3 and 6 are NAM model and PCE model with dual parameter-state updated using Dual-EnKF.

3. Data and Scenarios analysis

| Scheme | Calibration | Forecast | Model update or update
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<tr>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>NAM</td>
<td>GLUE</td>
<td>EnKF - state updated</td>
</tr>
<tr>
<td>2</td>
<td>NAM</td>
<td>GLUE</td>
<td>GLUE - state updated</td>
</tr>
<tr>
<td>3</td>
<td>NAM</td>
<td>PCE</td>
<td>PCE - state updated</td>
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<tr>
<td>4</td>
<td>PCE</td>
<td>GLUE</td>
<td>GLUE - state updated</td>
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<tr>
<td>5</td>
<td>PCE</td>
<td>PCE</td>
<td>PCE - dual parameter</td>
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<tr>
<td>6</td>
<td>PCE</td>
<td>PCE</td>
<td>PCE - dual parameter</td>
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4. PCE model construction

5. Conclusions

- PCE model is able to efficiently quantify uncertainties caused by many sources with ten time faster than NAM model.
- The GLUE method can be used to generate the initial input for EnKF to improve efficient of forecasting.
- Results forecasted with a metamodel based on PCE method are as good as those by MIKE-NAM model through automatic updating of states and parameters by EnKF.