Using a high-resolution ensemble modeling method to inform risk-based decision-making at Taylor Park Dam, Colorado

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Motivation

- Bureau of Reclamation responsible for dam safety at many facilities across western United States
- Stress tests on dams using rainfall-runoff model
- Reservoir inflow scenarios: dam failure?
- Inputs: Precipitation and temperature
- Estimates are inherently uncertain
- Reclamation partnered with Cooperative Institute for Research in Environmental Sciences (CIRES/NOAA) and the National Center for Atmospheric Research (NCAR) to improve probabilistic precipitation and runoff estimation
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• Rainfall-runoff model driven by area averaged precipitation ("lumped")
• **Storm templates** – spatial/temporal precipitation patterns from historical events
• Estimate precipitation uncertainty using modified storm templates – **maximization** and **storm transposition**
• Useful for decades, but new tools available for improvements
Proposed Improvements

1. **Generate storm templates using physically-consistent dynamic model**
   - Weather Research and Forecasting (WRF) modeling system
   - Produces high resolution realistic precipitation scenarios
   - Avoid maximization and storm transposition

2. **Produce a range of precipitation and runoff scenarios (ensemble)**
   - Precipitation: WRF - perturb atmospheric parameters
   - Runoff: WRF-Hydro - modify precipitation and land attributes
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Taylor Park Dam & Watershed

- Taylor Park Dam located in central Colorado – 9,300 feet
- Surrounded by terrain exceeding 10,000 feet
Test Case Selection

- Reclamation provided list of potential cases based on precipitation and reservoir inflow data
- Peak inflow (1962-2015) during May-July

**Test Case**

- **27 July 2014**
  1. Heavy precipitation
  2. Convective
  3. Seasonal forcing data available for WRF-Hydro
WRF Configuration

Simulation (96 hours)
- 00 UTC 25 July – 00 UTC 29 July 2014

Grid Spacing
- 4km
- Resolves terrain, key precipitation processes

18 Ensemble Members

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microphysics</td>
<td>Microphysics = Thompson, Eta, Lin, Morrison, Goddard, WSM6</td>
</tr>
<tr>
<td>Stochastic</td>
<td>Stochastically perturb temperature/streamfunction</td>
</tr>
<tr>
<td>Lateral Boundaries</td>
<td>Lateral boundaries perturbed (GEFS Reforecast)</td>
</tr>
</tbody>
</table>
WRF Ensemble: Spatial Distribution

25-29 July 2014

Microphysics
- Microphysics 1
- M2
- M3
- M4
- M5
- M6

Stochastic
- Stochastic 1
- S2
- S3
- S4
- S5
- S6

Lateral Boundaries
- Lateral 1
- L2
- L3
- L4
- L5
- L6

96 hr Accumulated Precipitation (mm)
WRF Ensemble: Temporal Distribution

25-29 July 2014

Microphysics

Stochastic

Lateral Boundaries

Watershed-Averaged Accumulated Precipitation (mm)
WRF-Hydro: Streamflow Simulations

- Preliminary seasonal analysis using downscaled precipitation observations
- WRF-Hydro streamflow vs. observed streamflow

Streamflow: 09107000 (TAYLOR RIVER AT TAYLOR PARK, CO.)

- Correspondence suggests skill – now generate spread
WRF-Hydro Streamflow Ensemble

Generate streamflow spread by altering observations and infiltration capacity

**Scenarios:**

1. Precipitation Increases
2. Infiltration Reduction
3. Forest to Shrub + 50% Infiltration Reduction

- 10% increase ~ default run
- Large spread with 100% increase – close approximation to WRF precipitation spread
WRF-Hydro Streamflow Ensemble

Generate streamflow spread by altering observations and infiltration capacity

- **Scenarios:**
  1. Precipitation Increases
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- Small spread between members
- Spring events enhanced, decreased summer peak
WRF-Hydro Streamflow Ensemble

Generate streamflow spread by altering observations and infiltration capacity

• **Scenarios:**
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• Spring events enhanced, summer peak flow signal lost
WRF-Hydro Streamflow Ensemble

Generate streamflow spread by altering observations and infiltration capacity

- **Scenarios:**
  1. Precipitation Increases
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- New runs will use WRF ensemble precipitation as input
Summary

- WRF and WRF-Hydro ensembles generate promising spread in precipitation and streamflow
- Best/worst case scenarios of use for Reclamation decision making
  - Can dam survive worst case scenario?

Moving Forward...

1. Use full WRF ensemble to increase streamflow spread in WRF-Hydro, existing Reclamation models
2. Create precipitation PDFs for use within WRF-Hydro
3. Generalize process to other cases and locations
4. Reclamation transition from lumped to WRF ensemble gridded input
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WRF Ensemble: Temporal Distribution

16-20 June 1995

Microphysics

Stochastic

Lateral Boundaries

Watershed-Averaged Accumulated Precipitation (mm)