Modeling extreme rain-on-snow melt responses in the Sierra Nevada snowpack:

When do you need a more sophisticated model?

California Extreme Precipitation Symposium
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Major Topics

- Controls on ROS response
- Calibrating a model
- Sensitivity during ROS events
- Choosing models for different purposes
Controls on ROS response

Fig. 4. Temporal trajectory of the ratio between cumulative snowpack runoff and cumulative rain input at hourly time steps for three ROS event patterns.

Research Question

How well do models of differing complexity predict liquid water drainage during ROS events?
Hypothesis

More complex models, that calculate the snowpack energy balance using field measured data, will better predict liquid water drainage through the snowpack.
Methods

2 models- SNOWPACK and something like SNOW-17

3 sites- SNOTEL monitoring network, along an elevation gradient

2 storm events- Oroville Dam flood (2017)
   Valentines day (2019)
Models

CONCEPTUAL

SNOW-17

PHYSICAL

SNOWPACK
SNOTEL Site: Independence Camp
State: California
Site Number: 539
County: Sierra
Latitude: 39 deg; 27 min N
Longitude: 120 deg; 18 min W
Elevation: 6980 feet
Reporting since: 1978-10-01
# Oroville Dam flood event

00:00 February 4, 2017 to 00:00 February 13, 2017

<table>
<thead>
<tr>
<th>Independence SNOTEL</th>
<th>Elevation (m)</th>
<th>Snow on the ground (cm)</th>
<th>Precipitation accumulation (mm)</th>
<th>Change in snow water equivalent (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lake</td>
<td>2541</td>
<td>400</td>
<td>250</td>
<td>325</td>
</tr>
<tr>
<td>Camp</td>
<td>2128</td>
<td>175</td>
<td>250</td>
<td>90</td>
</tr>
<tr>
<td>Creek</td>
<td>1962</td>
<td>100</td>
<td>180</td>
<td>0</td>
</tr>
</tbody>
</table>

*ballpark summary*
Valentines day 2019, 6 day storm  
00:00 February 11, 2019 to 00:00 February 17, 2019

<table>
<thead>
<tr>
<th>Independence SNOTEL</th>
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<td>320</td>
</tr>
<tr>
<td>Camp</td>
<td>2128</td>
<td>200</td>
<td>160</td>
<td>290</td>
</tr>
<tr>
<td>Creek</td>
<td>1962</td>
<td>150</td>
<td>130</td>
<td>75</td>
</tr>
</tbody>
</table>

*ballpark summary*
Calibrating ‘not SNOW17’

Daily forcing data:
- precipitation
- temperature

Parameters:
- Shuffled Complex Evolution (SCE-UA) Method
- “General purpose global optimization program”
- Efficient and effective calibration of hydrologic models
Calibrating SNOWPACK

Hourly forcing data:

• air temperature
• relative humidity
• snow depth
• ground surface temperature
• incoming long wave solar radiation
• windspeed
• precipitation

Parameters:

• water transport model
• snow surface roughness [0.5mm to 0.02m]
• atmospheric stability model
• ground surface temperature
• advective heat transfer
• shortwave radiation absorption scheme
• rain threshold temperature
Calibrating SNOWPACK

Independence Camp 2019

- Observed SWE
- Simulated SWE (default)
- Simulated SWE (calibrated)

Hourly snow water equivalent (mm)

Nov Dec Jan 2019 Feb Mar Apr May Jun
## Calibration

<table>
<thead>
<tr>
<th></th>
<th>RMSE Not SNOW-17</th>
<th>RMSE SNOWPACK</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lake</td>
<td>168.94</td>
<td>709.72</td>
</tr>
<tr>
<td>Camp</td>
<td>56.04</td>
<td>309.87</td>
</tr>
<tr>
<td>Creek</td>
<td>14.93</td>
<td>241.39</td>
</tr>
</tbody>
</table>
Low elevation site, Oroville Dam flood storm
Middle elevation site, Oroville Dam flood storm
High elevation site, Oroville Dam flood storm
Low elevation site, Valentines day storm
Middle elevation site, Valentines day storm

- Observed daily SWE (mm)
- Not SNOW-17 simulated daily SWE (mm)
- Not SNOW-17 accumulated RAIM (mm)
- SNOWPACK simulated daily SWE (mm)
- SNOWPACK accumulated virtual lysimeter (mm)
High elevation site, Valentine's Day storm
Results and discussion

- Calibration accuracy: RMSE for SNOWPACK was larger than Not SNOW-17 for all three sites
- Model complexity did not provide better results in this case
- Can we calibrate to rain-on-snow events?
- Adding additional data, better data to improve calibration
What makes liquid drainage more or less sensitive?

• Improving model calibration and validation for rain-on-snow storms
• An analysis of many, many storms (rain on snow and not)
Thank you!

Questions?