Lessons from Snow Model Intercomparisons and Ensembles

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Snow Model Intercomparison Projects

<table>
<thead>
<tr>
<th>Points</th>
<th>PILPS2d</th>
<th>SnowMIP</th>
<th>SnowMIP2</th>
<th>Catchments</th>
<th>PILPS2e</th>
<th>Rhône-AGG</th>
<th>Global</th>
<th>GSWP-2</th>
</tr>
</thead>
<tbody>
<tr>
<td>PILPS2d</td>
<td>22 models</td>
<td></td>
<td></td>
<td>PILPS2e</td>
<td>28 models</td>
<td>Rhône-AGG</td>
<td>GSWP-2</td>
<td>24 models</td>
</tr>
</tbody>
</table>
Example SnowMIP Results

Snow Model Intercomparison Projects

- models capture broad features of snow accumulation and ablation
- broad spread between models, particularly in warmer conditions
- there is no “best” model
- model performance is not clearly related to model complexity
- driving and evaluation data errors are hard to separate from model errors
- interpretation of results complicated by different interpretation of instructions and different degrees of calibration
Example SnowMIP2 Results

MOSES version 2.2
JULES version 1.0

A Different Idea …

Single model combining many hypothesized process parametrizations in all possible configurations


Essery, Martin, Douville, Fernández and Brun, 1999. A comparison of four snow models using observations from an alpine site. *Climate Dynamics* 15


AGU fall 2012 joint Cryosphere / Hydrology session proposal: “Innovative methods to diagnose modeling deficiencies” Convenors Martyn Clark, Richard Essery, Danny Marks
Snow Thermal Conductivity

Conductivity parametrizations:
- Quadratic function of density
  e.g. SAST, SNTHERN, CLM
- Power function of density
  e.g. Crocus, HTESSEL, ISBA
- Constant
  e.g. MAPS, MOSES, SECHIBA

Fresh Snow Density and Compaction

Fresh snow density options:
- function of temperature and wind
- function of temperature
- constant density

Snow compaction options:
- physical parametrization
- empirical parametrization
- constant density
Albedo and Snow Cover Fraction

Snow albedo options:
- function of prognostic grain size
- empirical function of age
- function of surface temperature

Snow cover options:
- low coverage for given depth
- intermediate coverage
- high coverage

Snow Hydrology and Turbulent Fluxes

Turbulent flux options:
- Monin-Obukhov similarity theory
- function of Richardson number
- constant exchange coefficient

Snow hydrology options:
- low liquid holding capacity
- high liquid holding capacity
- no liquid holding capacity
Comparison with SnowMIP Results


Long-term Snow Measurement Sites

<table>
<thead>
<tr>
<th>Site</th>
<th>Coordinates</th>
<th>Elevation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reynolds Creek (RME snow pillow)</td>
<td>43°N, 117°W, 2050 m a.s.l.</td>
<td></td>
</tr>
<tr>
<td>Col de Porte</td>
<td>45°N, 6°E, 1325 m a.s.l.</td>
<td></td>
</tr>
</tbody>
</table>


SWE Simulation Errors

Col de Porte

Reynolds Creek
SWE Simulation Errors

Col de Porte

SWE Simulation Errors

Col de Porte

Reynolds Creek

1983-1984
1999-2000

2003-2004
2005-2006

2003-2004
2005-2006

2005-2006
2003-2004
Comparison Between Sites

Col de Porte Model Calibration

Parameters of each model selected to minimize rms errors for 2005-2006
Col de Porte Model Calibration

2005-2006: cold

2006-2007: warm

2007-2008: typical

2005-2008 combined

Parameter Transfer to Reynolds Creek

Some good models degraded
Bad models improved
Best models unchanged
Conclusions

• multi-physics ensemble modelling reduces intercomparison “noise” and makes it easier to attribute model difference “signal”

• there is no best model, but some models are much better than others

• more physically-based parametrizations generally perform better, with a few surprises

• warmer winters are not necessarily harder to simulate
  – a model that can’t capture interannual variability is a bad model

• calibration helps bad models more than good models, but it is still better to have a good model

• SWE alone does not contain enough information to constrain surface energy balance partitioning – getting the right answer for the right reason requires multi-criteria evaluation

• across catchments, many other things are important for snow dynamics