SNOW-17 a priori parameterization
Update

Naoki Mizukami, Victor Koren and Michael Smith

DOH Science Conference
July 17, 2008
Outline

1. Background
2. MFMAX & MFMIN parameterization
3. UADJ parameterization
4. Snow-17 run with new parameters
5. Planned work
Point snow accumulation & ablation model and later applied to basin-wide through lumped model

Conceptual model to simplify energy balance in snow pack

Use 12 parameters

Two input variables (air temp and precipitation)
Distributed SNOW-17

- SNOW-17 runs at each HRAP pixel (~4km).
- Other parameters need to be generated based on physiographical and/or climate properties as a starting point (a priori parameter).
  - e.g.
    - MFMAX/MIN can be related to latitude, slope, aspect, forest, wind climatology.
    - UADJ and SCF can be related to wind climatology.
## Background

### Current status of a priori parameterization

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>A Priori grids available for CONUS?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Major</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SCF</td>
<td>Snow Correction Factor</td>
<td>In progress</td>
</tr>
<tr>
<td>MFMAX</td>
<td>Maximum Melt Factor</td>
<td>Yes 1</td>
</tr>
<tr>
<td>MFMIN</td>
<td>Minimum Melt Factor</td>
<td>Yes 1</td>
</tr>
<tr>
<td>UADJ</td>
<td>Ave. wind function during rain-on-snow</td>
<td>Yes 2</td>
</tr>
<tr>
<td>SI</td>
<td>Areal SWE above which there is always 100% snow cover</td>
<td>No</td>
</tr>
<tr>
<td>ADC</td>
<td>Areal Depletion Curve</td>
<td>Removed or simplified as straight line</td>
</tr>
<tr>
<td>Minor</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NMF</td>
<td>Negative Melt Factor</td>
<td>No</td>
</tr>
<tr>
<td>TIPM</td>
<td>Antecedent snow temperature index</td>
<td>No</td>
</tr>
<tr>
<td>MBASE</td>
<td>Base temperature for non-rain melt factors</td>
<td>No</td>
</tr>
<tr>
<td>PXTEMP</td>
<td>Temperature that separates rain from snow</td>
<td>No</td>
</tr>
<tr>
<td>PLWHC</td>
<td>Percent liquid water holding capacity</td>
<td>No</td>
</tr>
<tr>
<td>DAYGM</td>
<td>Daily Ground Melt</td>
<td>No</td>
</tr>
</tbody>
</table>

### Notes:

1. ½ hrap available
2. Monthly grid
3. Looking for DEM & forest grid data for Alaska
MFMAX & MFMIN parameterization

MFMAX & MFMIN overview

- Melt rate \([\text{mm}/\Delta t]\) computation in no-rain condition
- Temperature index eq. with melt factor \((M_f : \text{mm}/6\text{hr}/^\circ\text{C})\)

\[ h_C = M_f \cdot T \]
\[ M_f = f(M_{\text{MAX}}, M_{\text{MIN}}) \]
MFMAX & MFMIN parameterization

Physiographic & Climate Grids

Topography
- DEM
  - Aspect
  - Slope
- GRASS script
  - Solar radiation

Wind climatology
- NARR Wind (1978-2006)
  - Monthly wind climatology

Forest
- type
- percent
**MFMAX & MFMIN parameterization**

**Methods**

1. Based on recommended values (Anderson, 2002)

<table>
<thead>
<tr>
<th>Forest Cover</th>
<th>MFMAX</th>
<th>MFMIN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coniferous forest /persistent cloud cover</td>
<td>0.5 -0.7</td>
<td>0.2 - 0.4</td>
</tr>
<tr>
<td>Mixed forest Coniferous plus open and/or deciduous</td>
<td>0.8 – 1.2</td>
<td>0.1-0.3</td>
</tr>
<tr>
<td>Predominantly Deciduous</td>
<td>1.0-1.4</td>
<td>0.2- 0.6</td>
</tr>
<tr>
<td>Open Areas flat terrain</td>
<td>1.5-2.2</td>
<td>0.2-0.6</td>
</tr>
<tr>
<td>Mountainous terrain</td>
<td>0.9-1.3</td>
<td>0.1-0.3</td>
</tr>
</tbody>
</table>

Use forest density and type, aspect and slope grids

2. Based on Energy balance model (new)

- Use computed solar radiation
- Use monthly wind climatology
- Use forest density and type
Snowmelt from simplified energy balance equation (non-rain)

\[ h_c = \left[ 1.03 + 2.04 + 0.42 \cdot u \right] \cdot T \]

- **\( h_c \):** melt rate [mm/°C/day]
- **\( T \):** daily average air temperature [°C]
- **\( u \):** Wind speed 10m above surface [m/s]

**Assumption**
- Clear sky
- Spring time
- Flat and no forest
- Snow albedo = 0.5
MFMAX & MFMIN parameterization

Account for topography & forest effect on radiation

\[ h_c = [1.03 \cdot (1 - g) \cdot R_{DB} + 2.04 + 0.42 \cdot u] \cdot T \]

Forest effect on radiation
\( g \): Forest percent

Topography effect on radiation
- Flat area: \( R_{db} = 1 \)
- Shaded area: \( R_{db} < 1 \)
- Exposed area: \( R_{db} > 1 \)
MFMAX & MFMIN parameterization

Simplified energy equation = SNOW-17 equation

\[
MFMAX = \frac{1.03 \cdot (1 - g) \cdot R_{DB} + 2.04 + 0.42 \cdot u}{2(R + 1)}
\]

\[
MFMIN = R \cdot MFMAX
\]

Need to determine “R” and “R_{DB}”
MFMAX & MFMIN parameterization

Derivation of $R_{DB}$ Grid

$R_{DB}$: Ratio of radiation with topo to radiation with no topo

Daily solar radiation (3/21) $\div$ Daily solar radiation no topo (3/21) $\Rightarrow$ $R_{DB}$

Unit: Wh/m$^2$/day
MFMAX & MFMIN parameterization

Derivation of R grid

R: Ratio of winter radiation to summer radiation

Daily radiation (12/21)

Daily radiation (6/22)

R

Unit: Wh/m^2/day Unit: Wh/m^2/day No Unit

CA NV CA NV CA NV

0 2244 4489 6733 8977

0 2641 5282 7924 10565

0.00 0.36 0.73 1.09 1.45

CONUS
MFMAX & MFMIN parameterization
MFMAX & MFMIN – Resolution effect

MFMAX

MFMIN

MFMAX & MFMIN

½ hr

MFMAX & MFMIN

½ hr
MFMAX range

- u = 0 m/s
- u = 0.5 m/s
- g = 0%
- g = 25%
- g = 50%

Dense forest
MFMIN range

Dense forest

- $g=0\%$
- $g=25\%$
- $g=50\%$

Wind conditions:
- $u=0$ m/s 
- windy 
- $u=0.5$ m/s
UADJ parameterization

- $\text{UADJ} = 0.002 \times U$ (Anderson, 1976)

  where $U$: 6hr. wind travel (km) at 1m above snow surface

- Used monthly wind climatology (10 m above surface) from NARR

- Adjust wind speed at 1m above surface using a wind profile (Golubev et al. 1992)
Run Snow17 at SNOTEL sites
- Input: SNOTEL T and P
- Parameter: From parameter grid
Snow17 simulation

19L03S
Slope 16.6 degree
Forest 42.8 %

<table>
<thead>
<tr>
<th></th>
<th>MFMAX</th>
<th>MFMIN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Method 2</td>
<td>1.21</td>
<td>0.43</td>
</tr>
<tr>
<td>Method 1</td>
<td>0.7</td>
<td>0.4</td>
</tr>
</tbody>
</table>
19L06S
Slope 18.2 degree
Forest 85.3 %

<table>
<thead>
<tr>
<th></th>
<th>MFMAX</th>
<th></th>
<th>MFMIN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Method 2</td>
<td>0.76</td>
<td>Method 1</td>
<td>0.55</td>
</tr>
<tr>
<td>Method 2</td>
<td>0.35</td>
<td>Method 1</td>
<td>0.25</td>
</tr>
</tbody>
</table>

UADJ = 0.04
Snow17 simulation

Slope 18.6 degree
Forest 79.8%

UADJ = 0.09

<table>
<thead>
<tr>
<th>MFMAX</th>
<th>MFMIN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Method 2</td>
<td>Method 1</td>
</tr>
<tr>
<td>0.76</td>
<td>0.55</td>
</tr>
</tbody>
</table>
Planned Work

- Continue a priori parameterization
  - MFMAX/MIN, UADJ (suggestions are welcome for improvement)
  - SCF
  - Minor parameters
  - Parameterization for Alaska/Hawaii

- Evaluation
  - A priori grid vs. RFC calibrated parameters
  - Evaluation on basin-wide SWE and SCA
    - Distributed SNOW-17 SWE vs. SNODAS product
    - Distributed SNOW-17 SCA vs. MODIS SCA
  - Evaluation on streamflow in snowmelt dominated basin
    - Conduct basin study for different climate regions (East, West and continental)
      - comparing flow from the distributed and calibrated lumped model.

- Calibration
Appendix Slide
Background

Research Distributed hydrologic model (RDHM) overview

Features:
- Modular and flexible system
- Gridded structure
- Independent snow and rainfall-runoff models for each grid cell
- Hillslope routing and channel routing of runoff

ET → P & T → SNOW-17 → SAC-SMA

- Melt & rain

Surface runoff → Base flow

Hillslope routing → Channel routing

Q → UZFWC, LZFWC, SCA, SWE etc.
MF parameterization

Method 1

1. Forest type at each HRAP: mixed, conifer, deciduous, open.
2. A pixel is open if the forest % < 20%.
3. Depending on the forest type, recommended ranges of MFMAX and MFMIN values are selected from the table (Anderson, 2002).
4. From the selected range, a parameter value is determined based on the dominant aspect.
   - The highest value assigned to a south facing pixel,
   - The lowest value assigned to a north facing cells.
   - For other aspect, values linearly increase starting from north to south.
   - Median value assigned to flat (slope <1 %), facing west or east.
Topographic effect on clear sky solar radiation

Aspect effect on solar energy flux

Topographic shadow
Wind adjustment

Adjustment factor – depends on forest % and type

Forest density

- Dense (g >70%)
  - Conifer dominant: 9 - 6
  - Deciduous dominant
- Medium (50<g<70%)
  - Conifer dominant: 3 - 5
  - Sparse Conifer dominant: 3 - 5
- Open (g < 30%)
  - Conifer dominant: 1 - 1.5
  - No adjustment

Apollov et al. (1974)
R~0.3 -> Flat & no topographic shadow around Sierra Nevada, CA
Energy input for non-rain cond.

\[ Q_i - Q_r + Q_a - Q_s + Q_h + Q_e + Q_m + Q_g = \Delta Q \]

Minimal heat from ground
Energy input for Rain-on-snow cond.

\[ Q_i - Q_r + Q_a - Q_s + Q_h + Q_e + Q_m + Q_g = \Delta Q \]

- \( Q_i \): Incident solar heat
- \( Q_r \): Reflected solar heat
- \( Q_a \): Absorbed solar heat
- \( Q_s \): Emitted longwave heat
- \( Q_h \): Sensible heat
- \( Q_e \): Latent heat
- \( Q_m \): Heat from rainwater
- \( Q_g \): Ground heat

Snow

- \( Q_{m} \): Heat from rainwater
- \( Q_{h} \): Sensible heat
- \( Q_{e} \): Latent heat
- \( Q \): Heat content of snow

Soil

Minimal heat from ground
CONUS R

Radiation (12/21) ÷ Radiation (6/22)

Unit: Wh/m²/day

No Unit
1 Wh = 3600 J: the amount of energy transferred if work is done at an average rate of one watt for one hour