Rain on Snow Flooding

Photo: National Park Service,
2006 Flood Mt. Rainier National Park

The major washout on the Nisqually Road
Melting Snow
(Less than 25%)

Heavy Rain
“Typical” Storm

- SNOWFALL
- RAINFALL

No runoff production

Area contributing overland runoff to stream

Elevation $Z_1$

Runoff

Slide by Mark Raleigh
Photo credit: Flickr.com User: Lucas – K Lu
Rain-on-Snow Event

(1 week later)

Snowcover exposed to warm, windy weather

Rain-on-Snow event produces Larger AREA contributing overland runoff to stream

Elevation \( Z_1 \)

Elevation \( Z_2 \)

ΔZ

RAINFALL

SNOWFALL

RUNOFF

RUNOFF

RUNOFF

Photo credit: Flickr.com User: Lucas – K Lu

Slide by Mark Raleigh
A common Myth about what a Rain-On-Snow event is...

• “Rain on snow is a miserable thing because it washes the snow away” – Edmonton Journal, June 2013

• “…snow gets melted by the rain falling on it and that compounds the situation and makes it even worse” – Global News, June 2013
A brief aside about rain on snow:

HOW MUCH WARM RAIN DOES IT TAKE TO MELT SNOW DIRECTLY?

• Each gram of liquid water contains about 4 J of heat per degree C above freezing
• To melt a gram of ice requires about 333 J of heat

--> Ice melted $\sim 1/80$ gram per gram of rain per degree C above freezing
So what does melt the snow?
You need energy to melt snow

“Snow” = Ice, liquid water, and air

- Melting snow requires a phase change from ice to liquid.
- The phase change breaks bonds.
- The amount of energy required to break these bonds is called the Latent heat of fusion
- It takes 334000 Joules to melt 1 kg of ice
Sources of energy for the snowpack

Total Energy = \( (S_{in} - S_{out}) + (L_{in} - L_{out}) + (H_{flux}) + (L_{e flux}) + (P) + (G) \)
Solar Radiation

During a clear day Solar Radiation is the primary energy input into a system.
Terrestrial Radiation

Clouds, Trees and anything that has a temperature emits radiation, including you!
Net Longwave Radiation

• Cloud cover makes a big difference

Total Energy Emitted = $80T^4$

CLEAR DRY AIR, $T = 0^\circ$C

Net Energy Loss From Snow Pack

SNOW, $T = 0^\circ$C

No Net Energy Loss From Snow Pack

CLOUD, $T = 0^\circ$C

Emissivity

<table>
<thead>
<tr>
<th>Material</th>
<th>Emissivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air</td>
<td>0.60 - 0.70</td>
</tr>
<tr>
<td>Water, Ice, Snow</td>
<td>0.92 - 0.97</td>
</tr>
</tbody>
</table>

Credit: Dr. J. Lundquist
Total Energy = \((S_{in} - S_{out}) + (L_{in} - L_{out}) + (H_{flux}) + (L_{e_{flux}}) + (P) + (G)\)

**Sensible Heat Flux**

- Think Convection (hair dryer)
- Warm and windy conditions = larger sensible heat flux
Total Energy $= (S_{in} - S_{out}) + (L_{in} - L_{out}) + (H_{flux}) + (L_{eflux}) + (P) + (G)$

**Latent Heat Flux**

- **Water Vapor**
- **Condensation**
- **Liquid**
  - Latent heat released
  - Heat melts snow!

Warm, windy, and **HUMID** conditions = larger latent heat flux
Total Energy \( = (S_{in} - S_{out}) + (L_{in} - L_{out}) + (H_{\text{flux}}) + (L_{e_{\text{flux}}}) + (P) + (G) \)
How will Rain-on-snow Floods change in the future?

ΔZ

SNOWFALL

ΔZ

RAINFALL

RUNOFF

RUNOFF

RUNOFF

RUNOFF