Hydrological Storage and Pathways in Alpine Headwaters: Lake O'Hara Study Update

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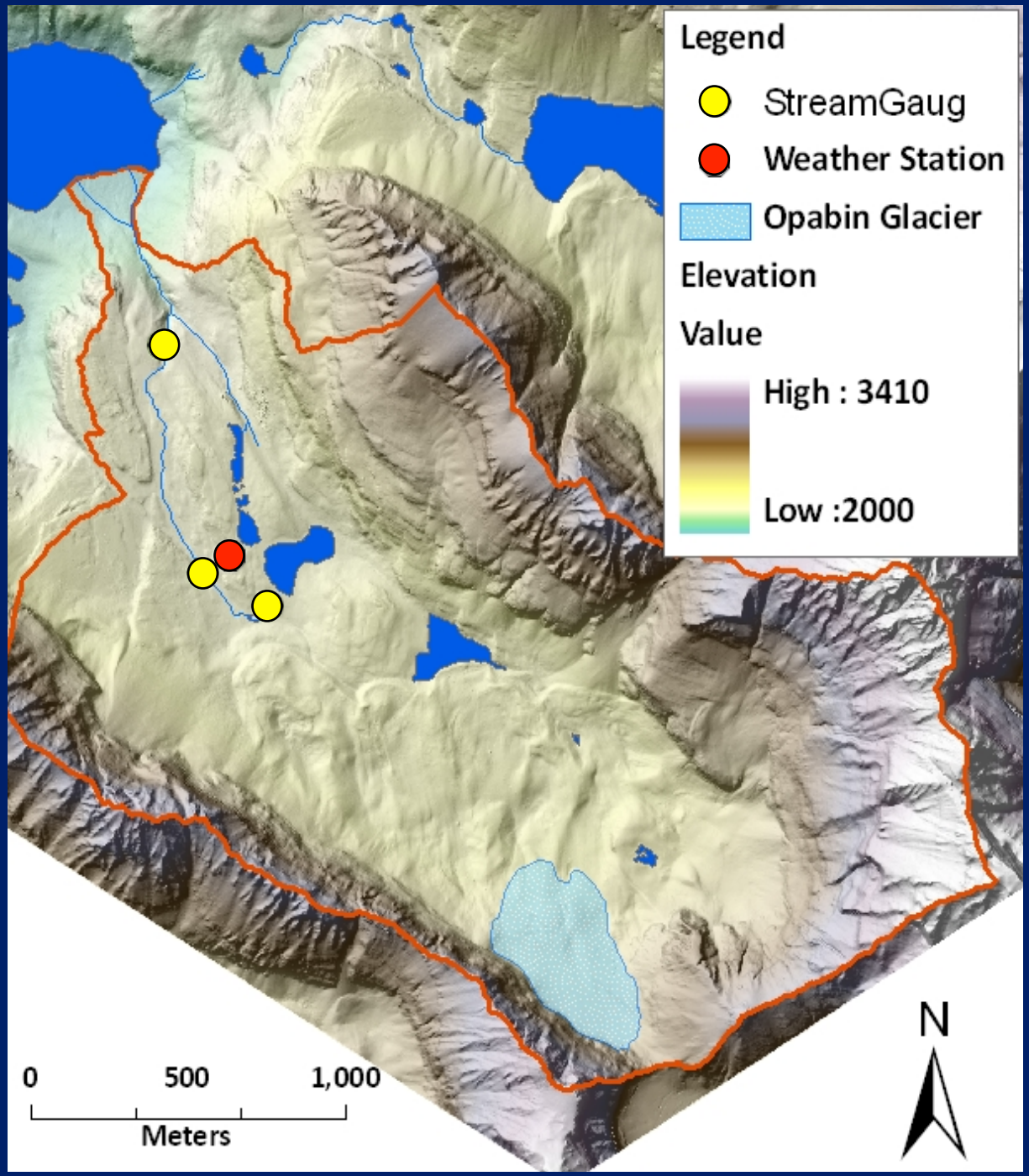
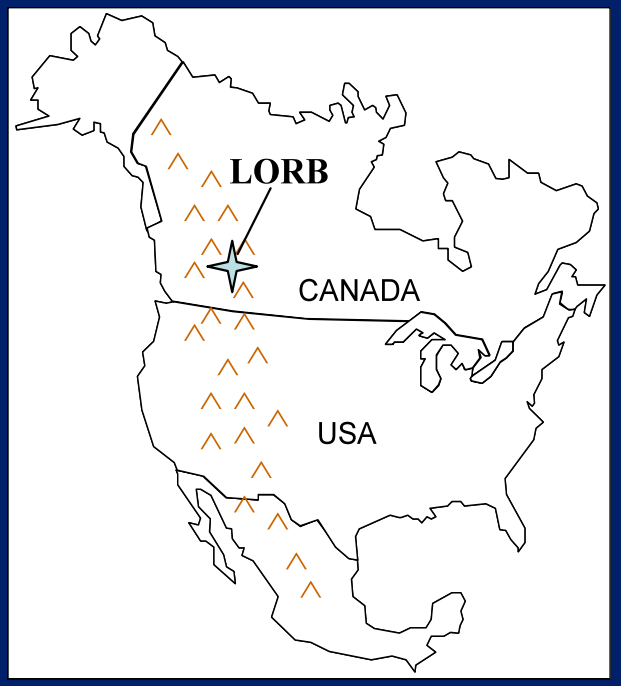
Unanswered Questions in Alpine Hydrology

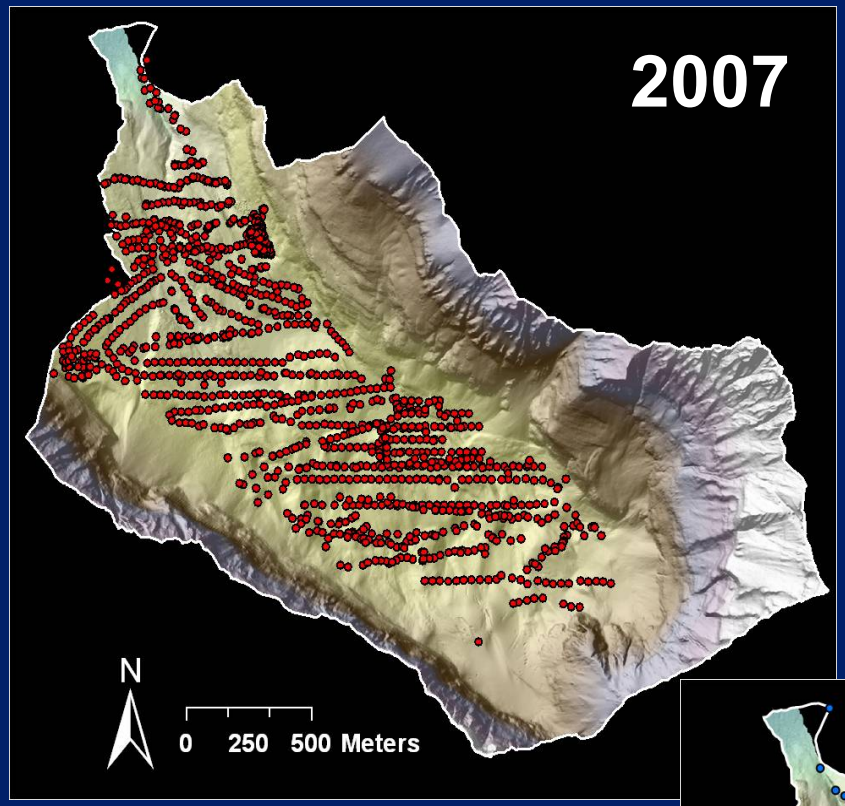
- Where is groundwater stored?
- How large is groundwater storage?
  10 mm? 100 mm?
- How long is groundwater stored?
  days? weeks? months?
- How can these be represented in basin hydrology models?

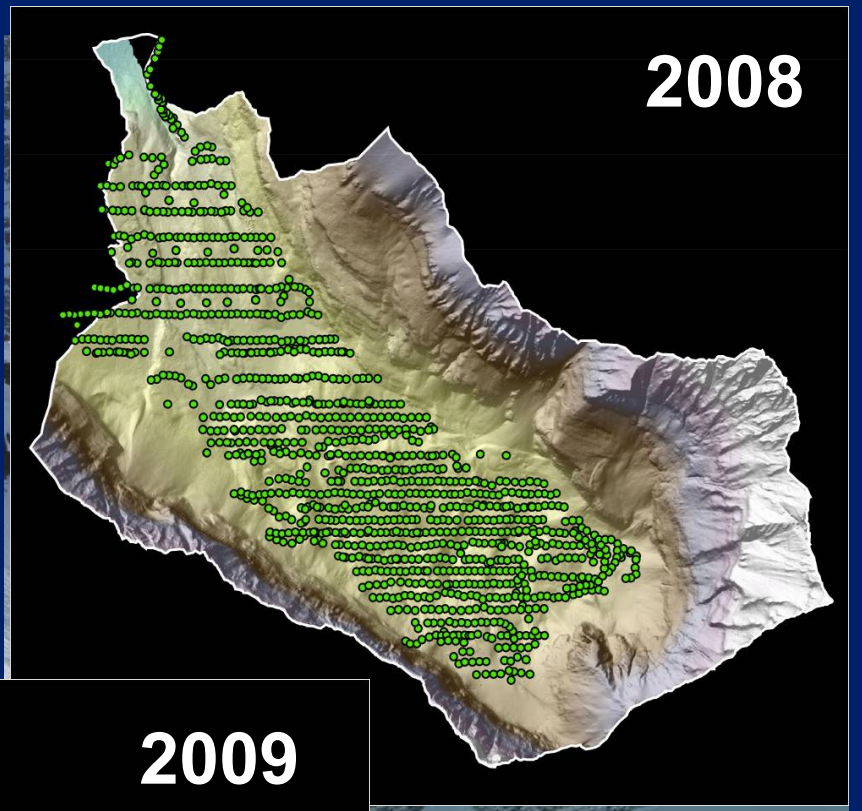
Opabin Sub-Basin in Lake O'Hara Basin

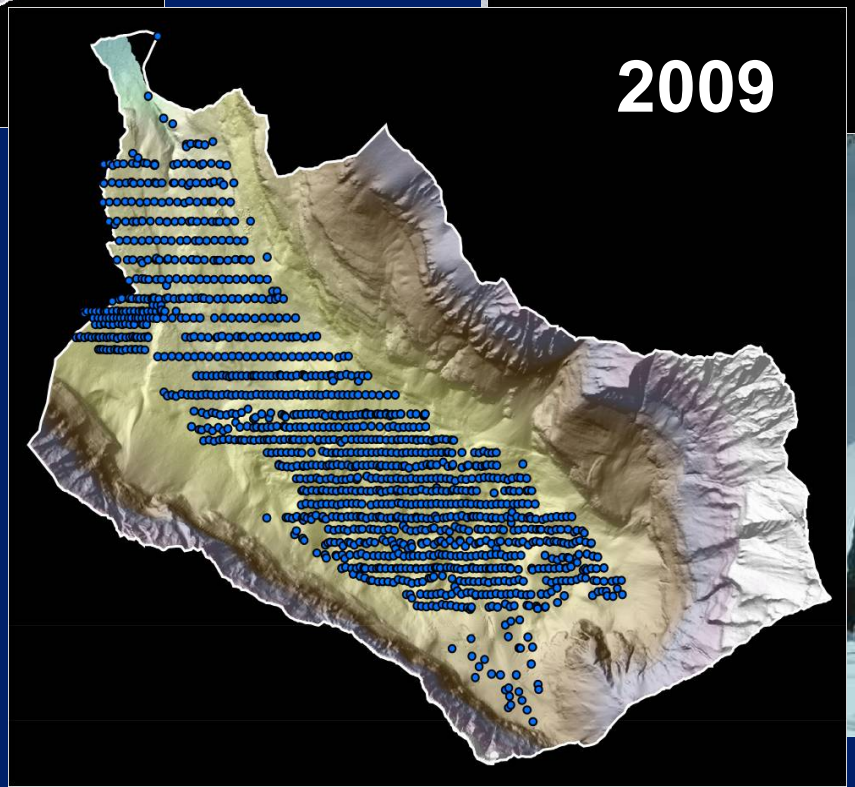




Annual Snow Survey, April 16-21



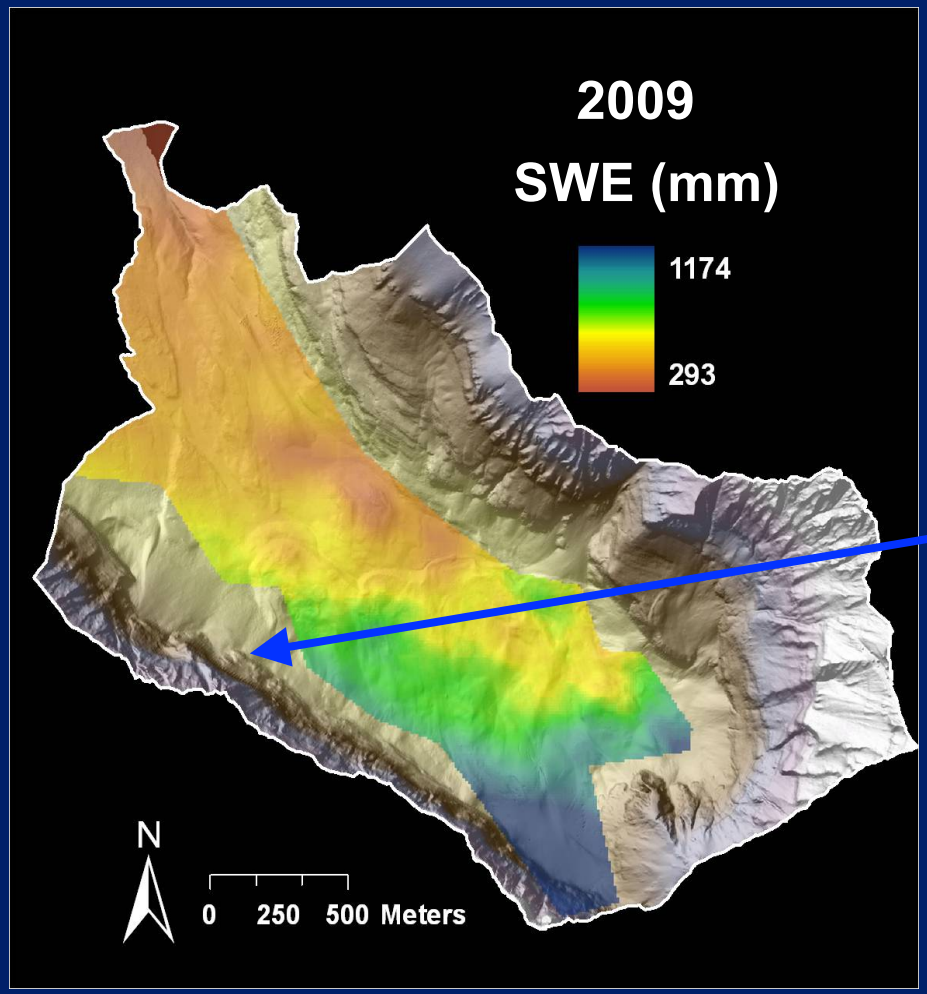




1,200-1,500 depth measurements.

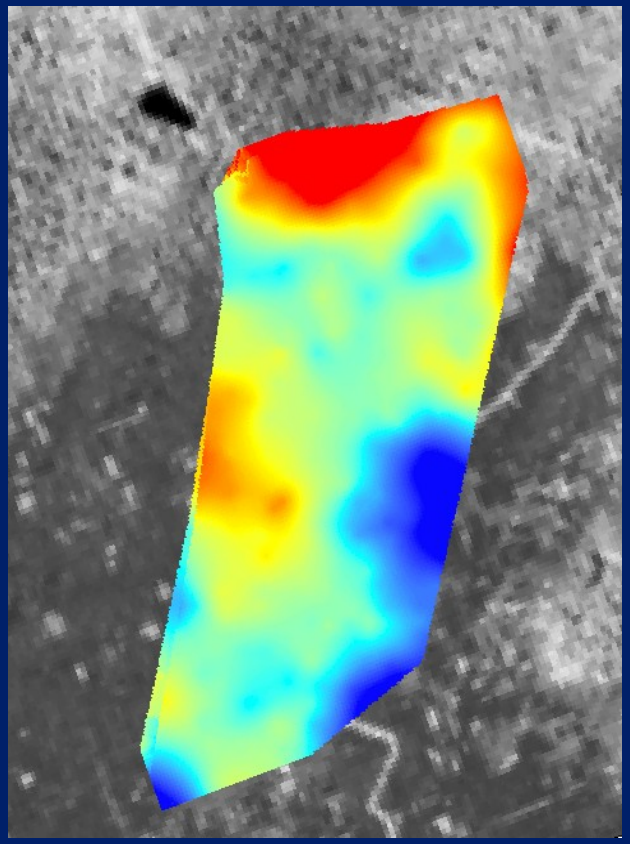
300-500 density measurements.

Snow Water Equivalent (SWE) Distribution



Remote Survey of Steep Slopes

Laser Range Finder: Poor man's LiDAR



Validation Procedure

"Model" the depth distribution using Laser data.

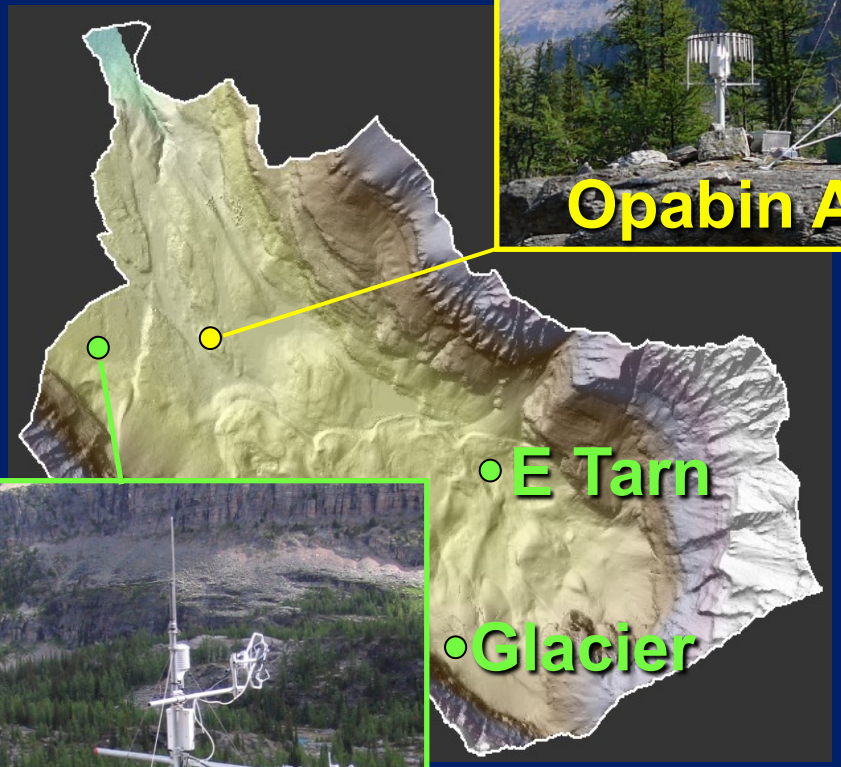
Measure the depth using conventional probes.

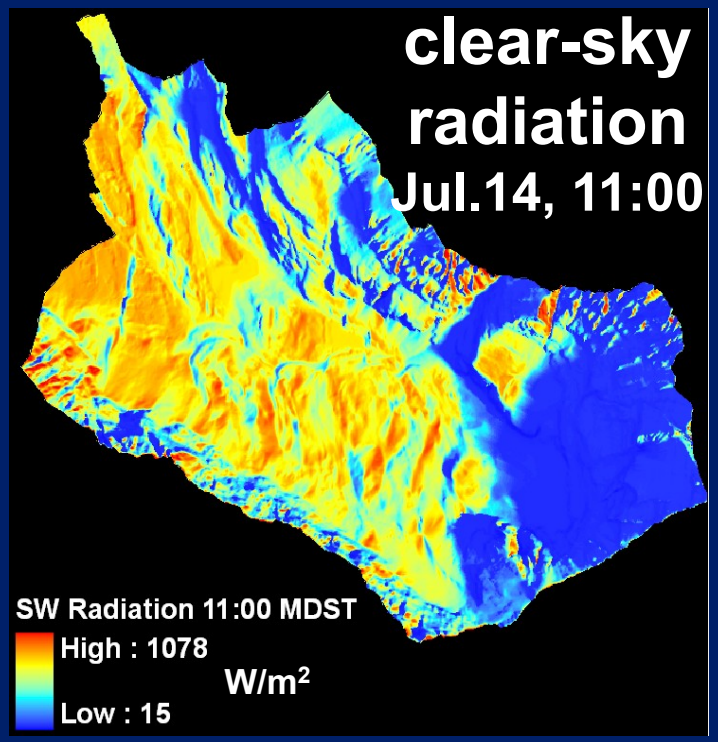
Results

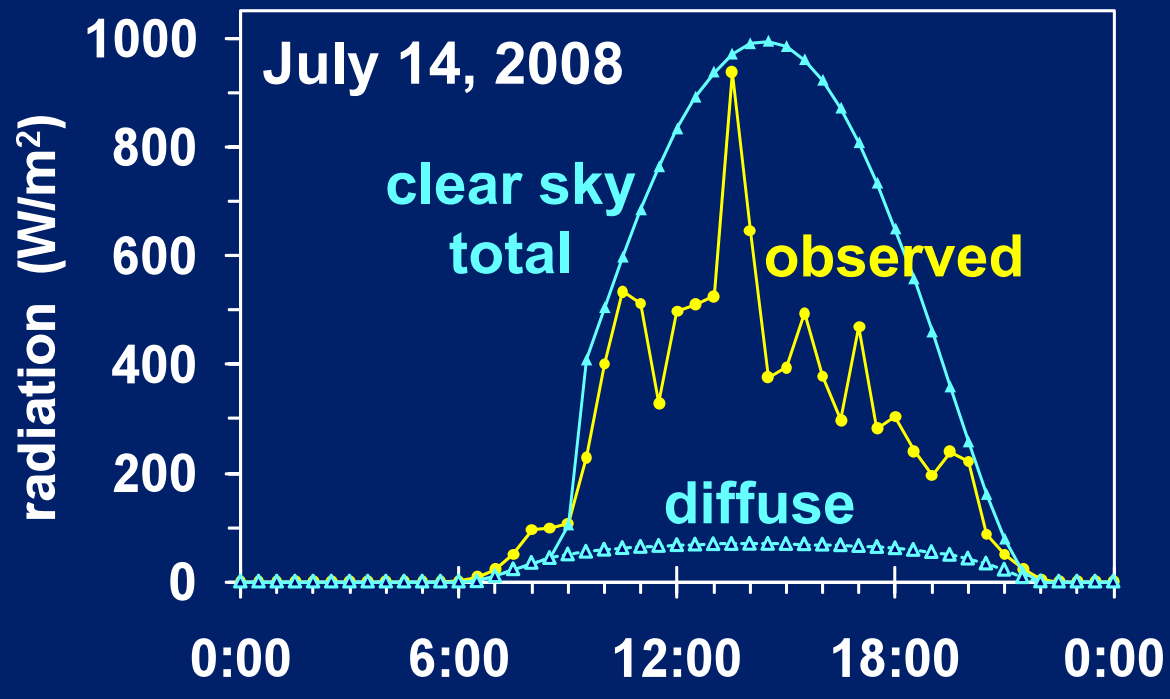
Average measured snow depth = 1.74m

RMS error of modeled vs measured = 0.27m

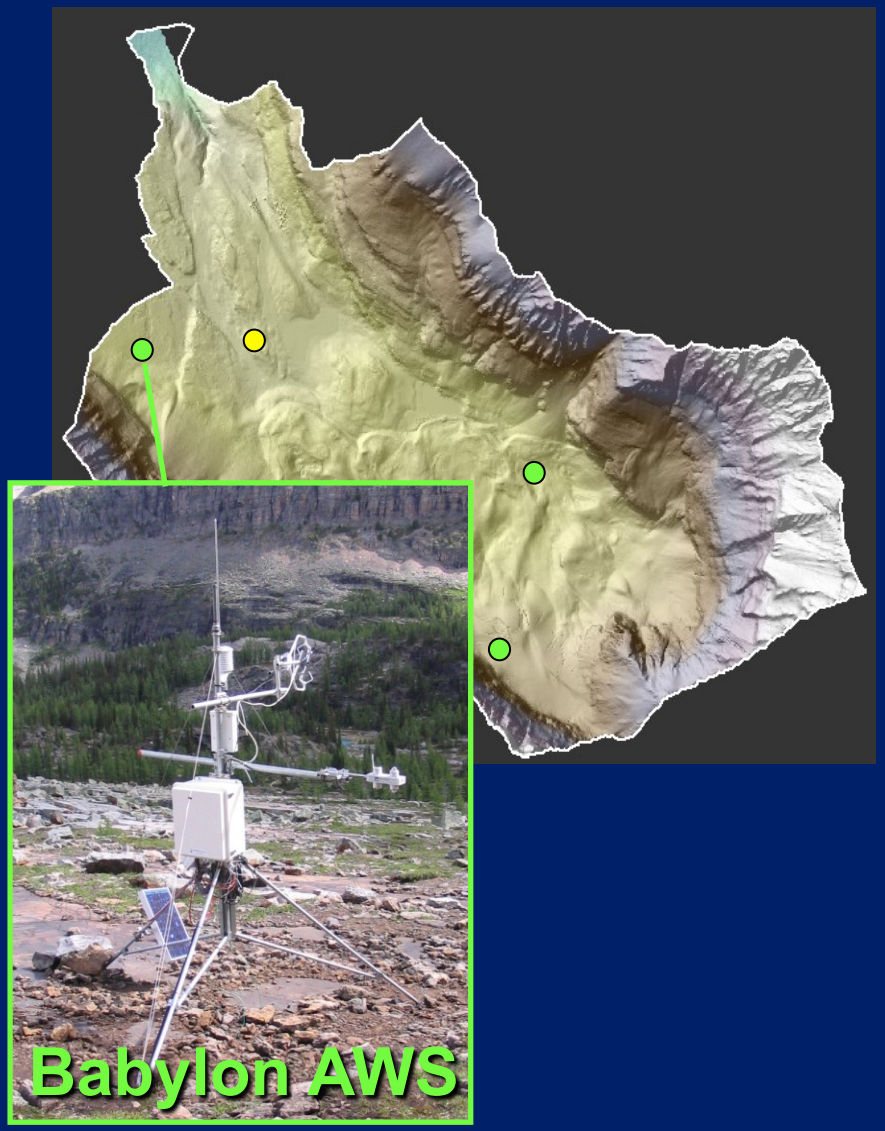
SW Radiation: ArcGIS Solar Radiation Tool

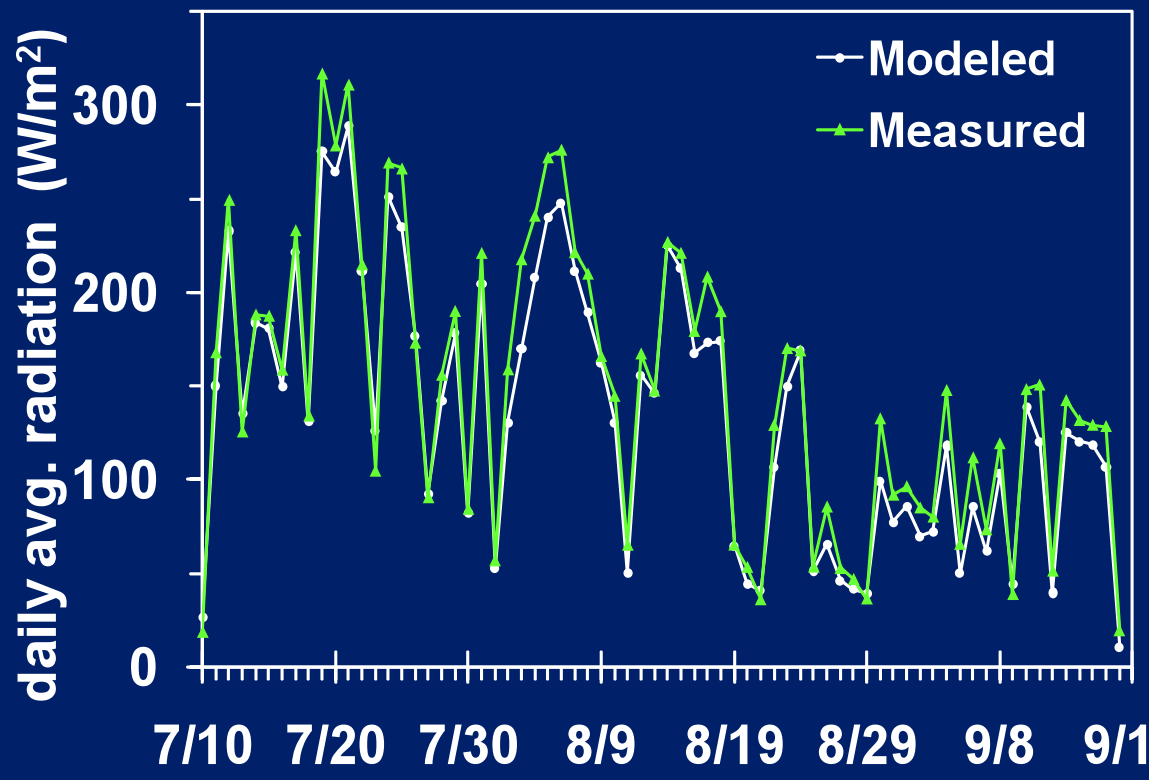




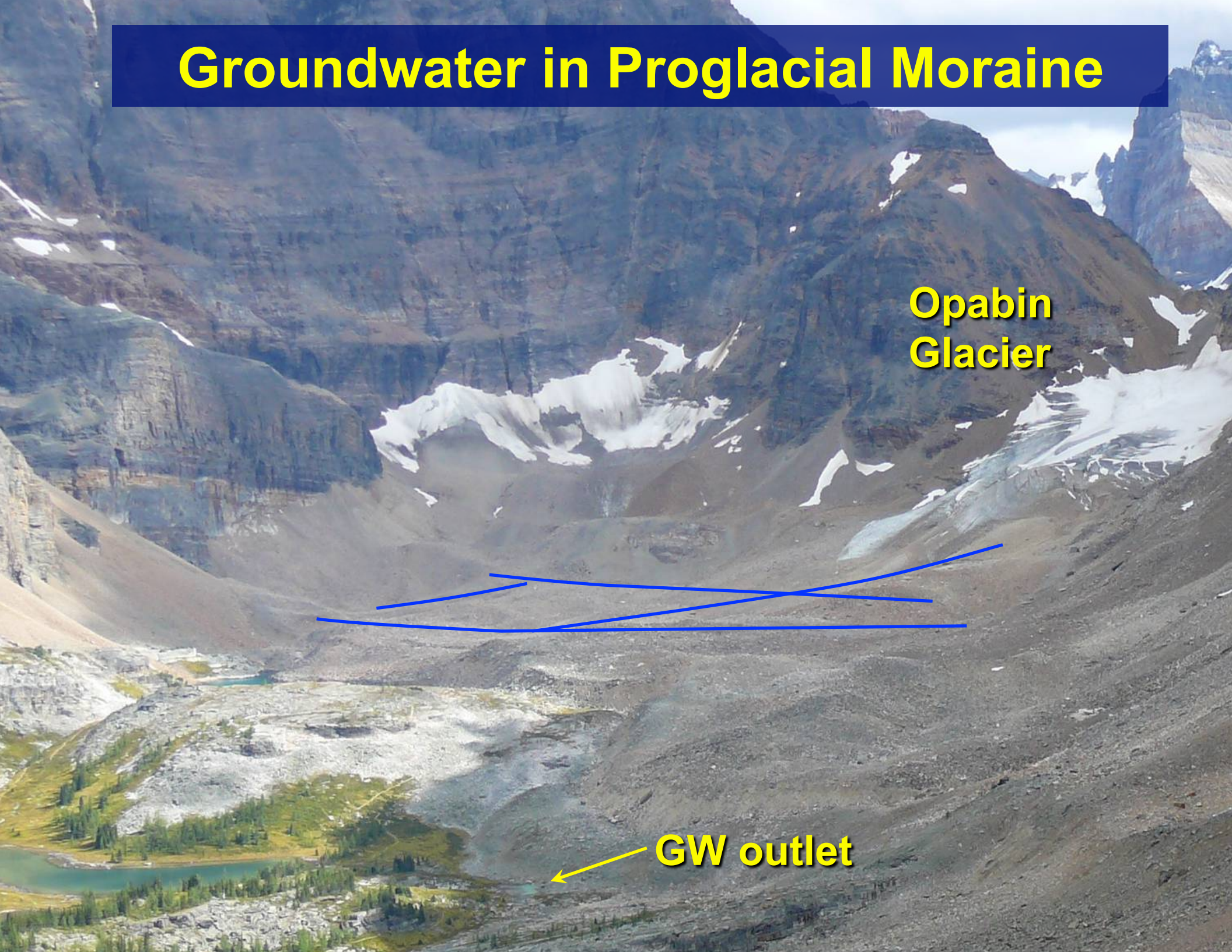


Validation of SW Radiation: Babylon Site



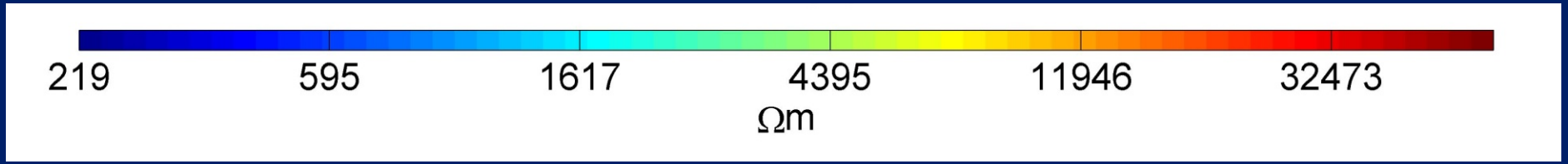


Groundwater in Proglacial Moraine

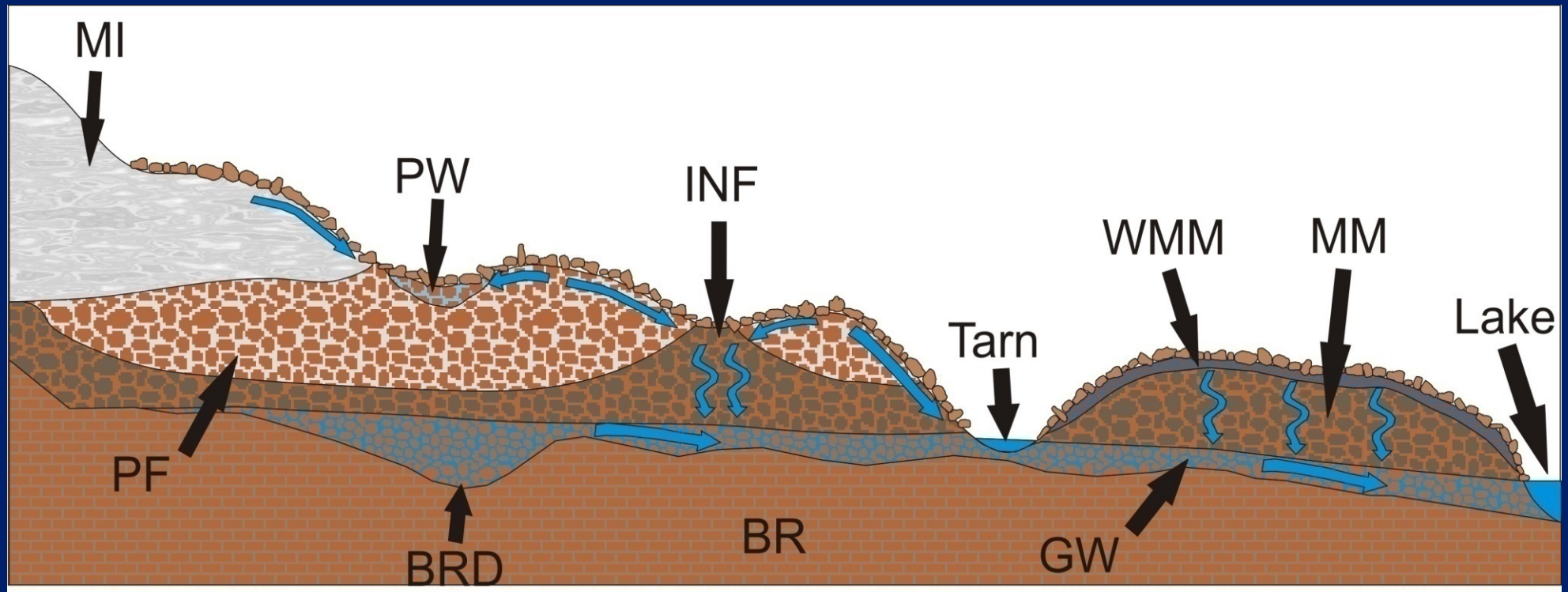


Results

Ice ridge
Tarn
Permafrost
Elevation (m)
2350
2300
2250
2200
1600
1400
1200
1000
800
600
distance (m)
600
700
800


219
595
1617
4395
11946
32473
Ωm

Emerging Conceptual Model



Dry moraine material **(MM)**

Debris covered massive ice **(MI)**

Degrading Permafrost **(PF)**

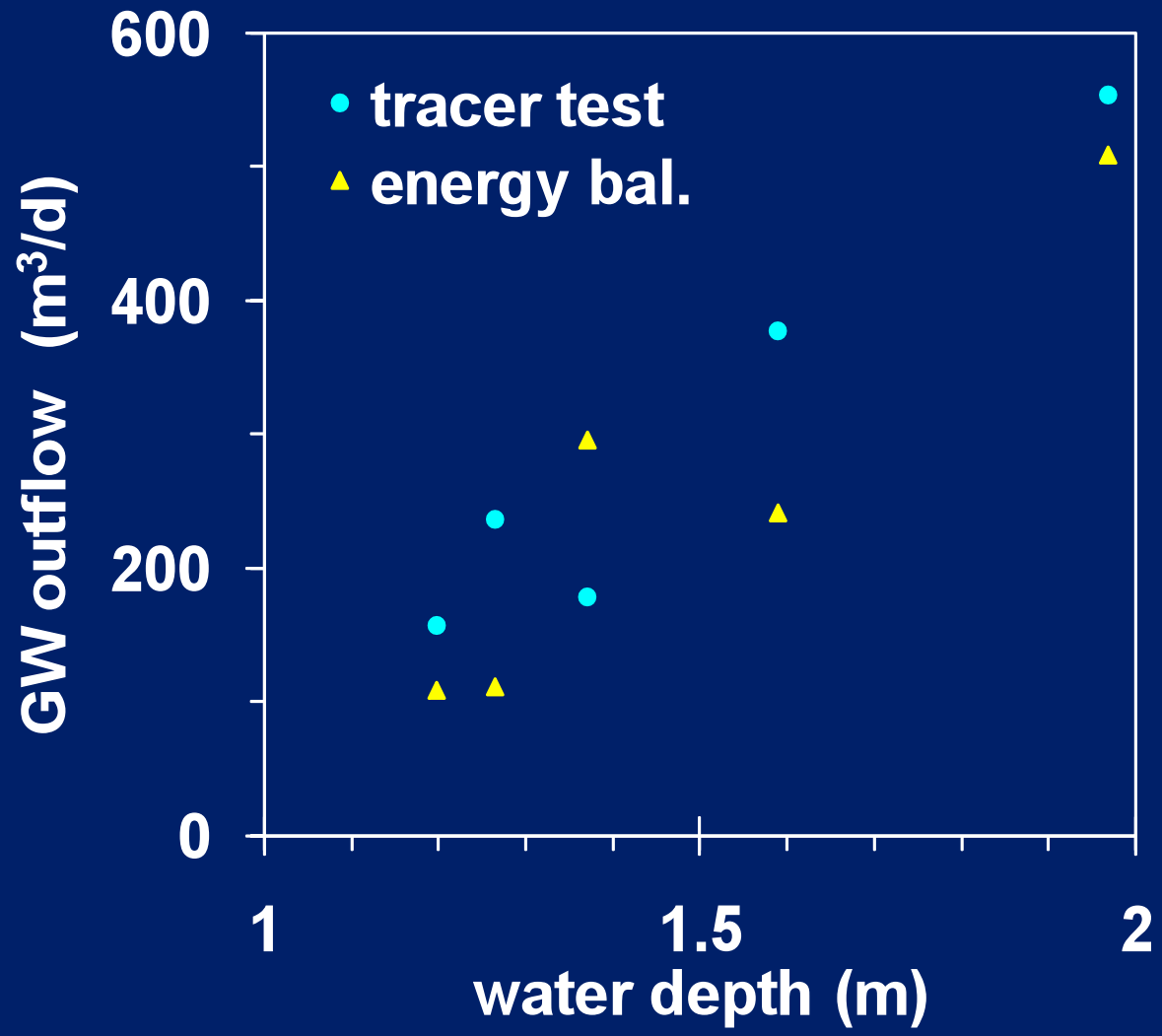
Saturated Moraine Material **(GW)**

Bedrock **(BR)**

Wet Moraine Material **(WMM)**

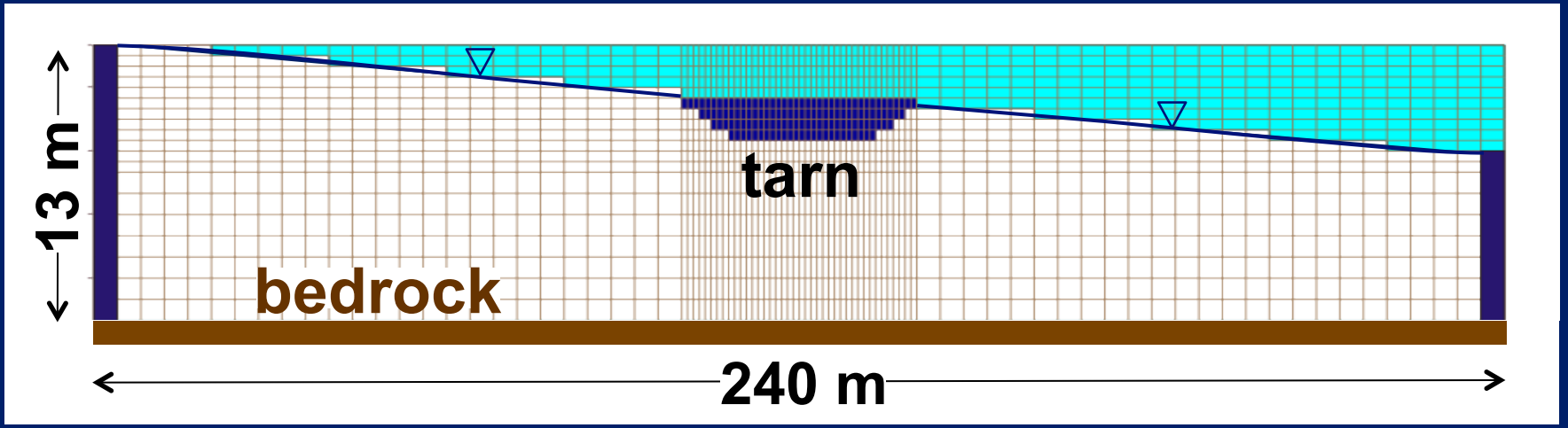
Tracer Dilution Experiment, Aug. 2008

- 44 kg of NaCl released
- Concurrent energy-balance study



Estimation of Hydraulic Conductivity

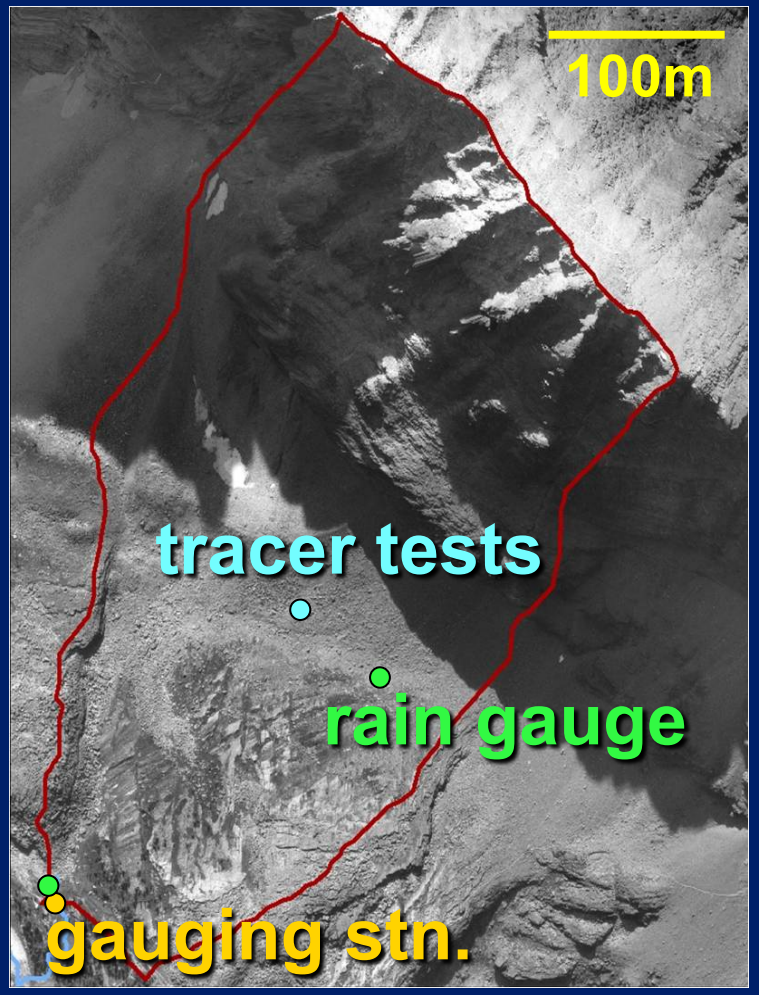
- Use a 3D groundwater flow model, MODFLOW.
- Simulate the steady-state exchange of groundwater with the pond.
- Inverse determination of best-fit conductivity.



$K_{sat} = 2 \times 10^{-4}$ m/s

Groundwater Storage and Flow in Talus

Babylon Creek



Gauging Station

Tracer tests

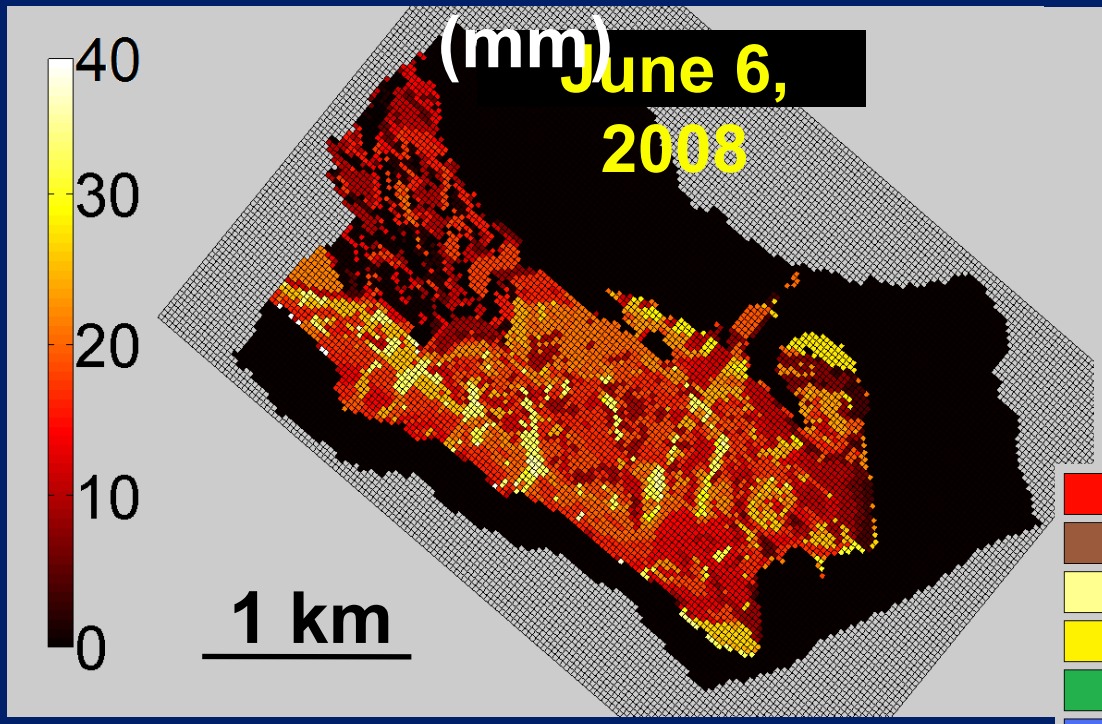
Groundwater Storage and Flow in Talus

Preliminary Analysis

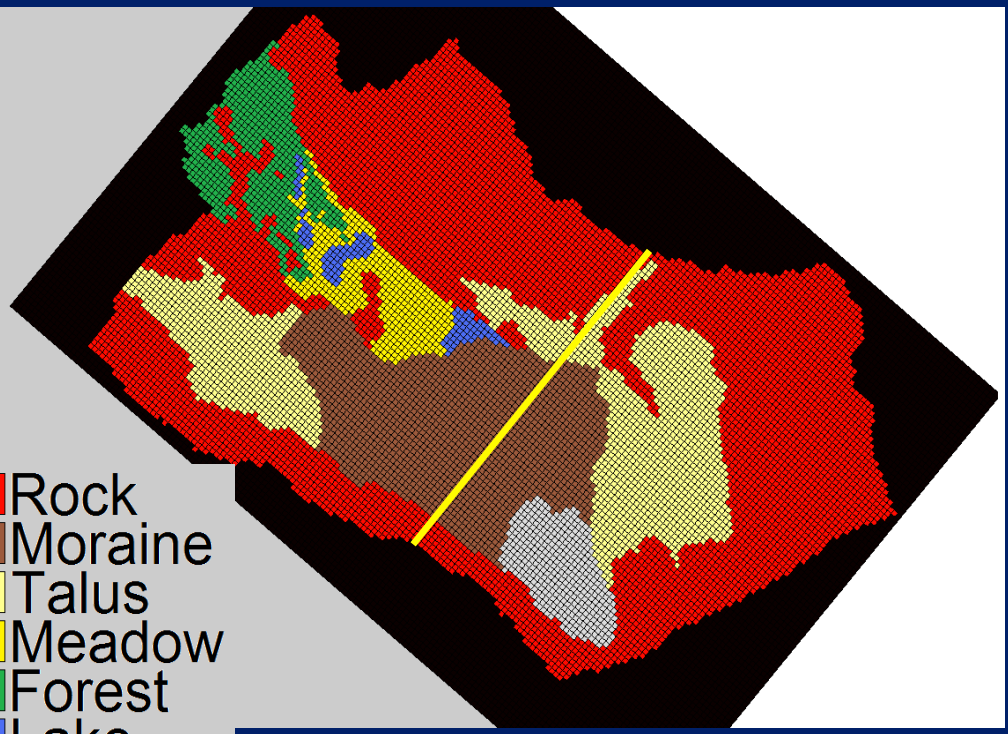
- Storage time in the talus is in the order of < 1 week.
- High hydraulic conductivity (10^{-2} m/s) for loose sediments.
- Moderate conductivity (10^{-5} m/s) for a second "reservoir" – fractured bedrock??

Coupled Surface-Groundwater Model

Daily snowmelt



Hydrologic landscape units

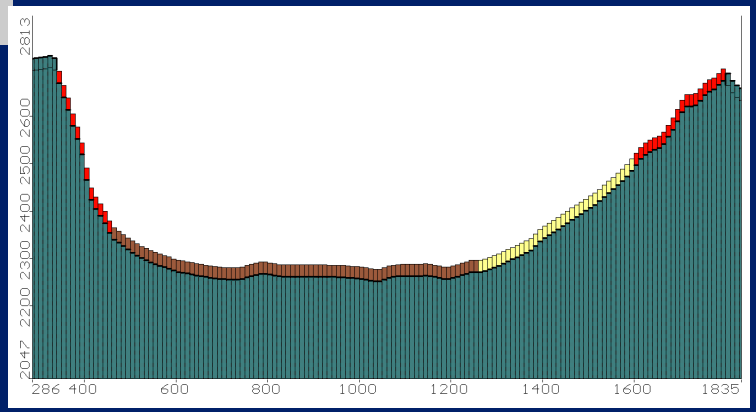


Distribute water inputs.

Couple with GW flow model.

Simulate basin outflow.

HBV–MODFLOW for this example.



Acknowledgements

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