Improving hydrological model representation of alpine snowcover depletion and snowmelt runoff generation

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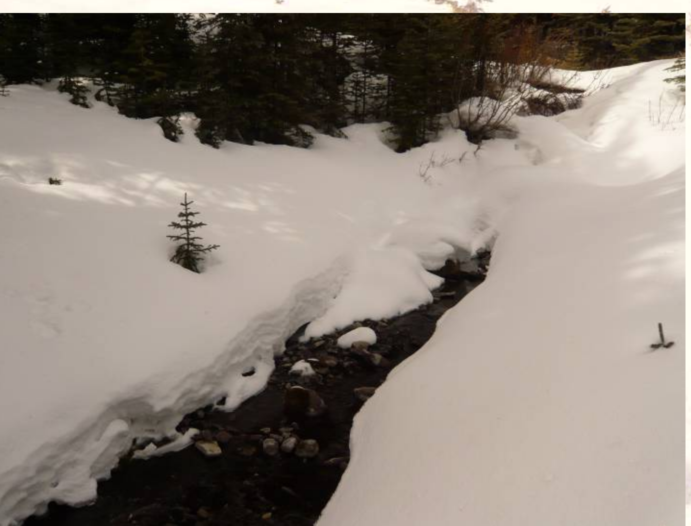
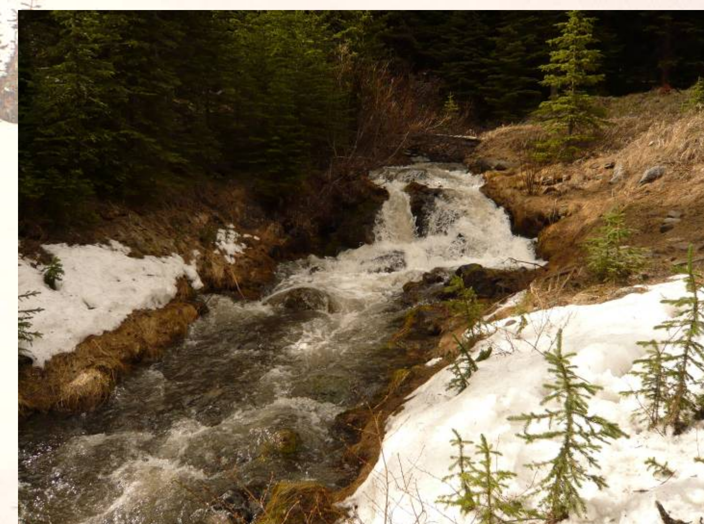




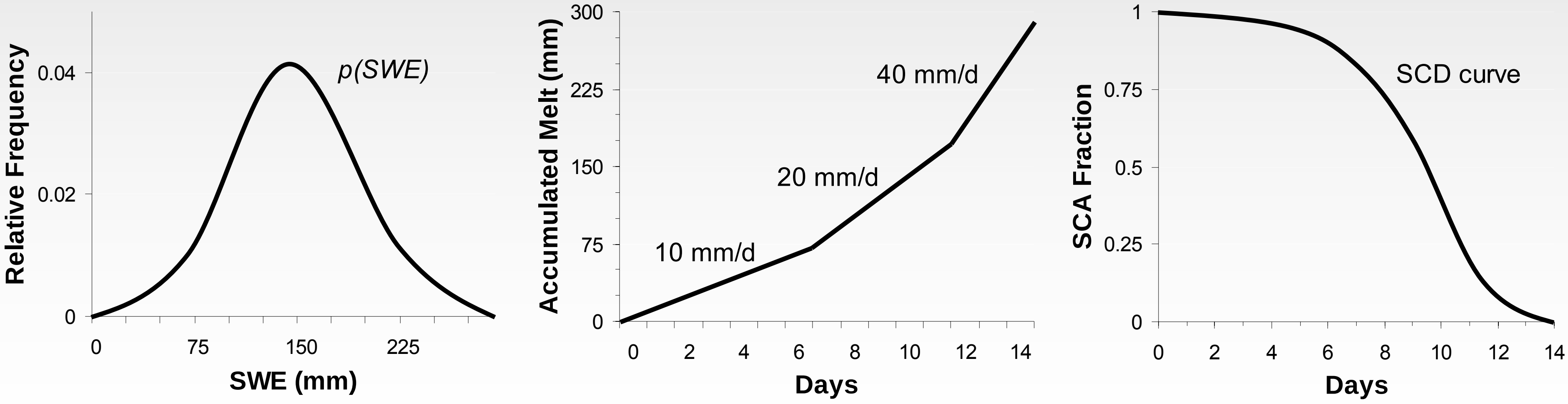
Background

- Late winter alpine snowcover has high spatial variability in depth, energy state, and SWE
- Together with spatial variation in melt energy, this leads to patchy snowcover and variable runoff contribution
- Important to represent this variability in hydrological models and land surface schemes
- Disaggregating terrain into slope and aspect based units can resolve much of the variability for modelling

Background

- Approach is to apply slope-corrected melt rates to SWE distribution on each landscape unit to derive snowcover depletion curve

$$SCA = \int_{M_a}^{\infty} p(SWE)dSWE$$



Background

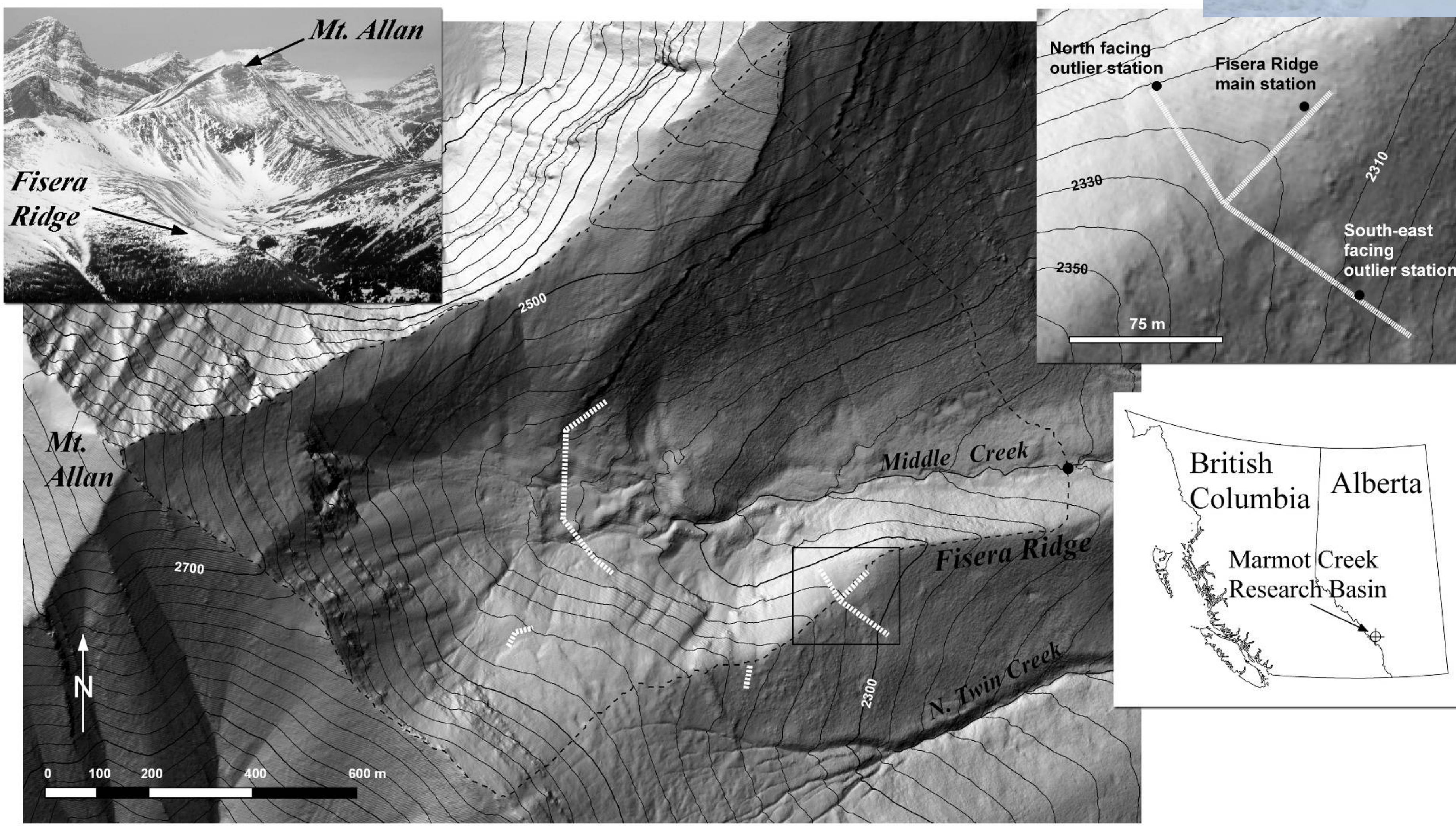
- However, melt timing and rates are non-uniform, even within a landscape unit
- Important to consider internal processes in the snowpack when applying the energy balance principle in physically based models
  - e.g., internal energy, refreezing overnight
  - Depends on depth and density, so varies over SWE distribution
- Oversimplifying to assume uniform melt and runoff generation over a distribution of SWE

Objectives

- Examine small scale variation in melt timing and rates due to variation in SWE depth in a sparsely vegetated alpine environment
- Determine the effect of this variation on simulated snowcover depletion and meltwater runoff generation
- Suggest an approach for improving the representation of small scale snowmelt variability in hydrological models

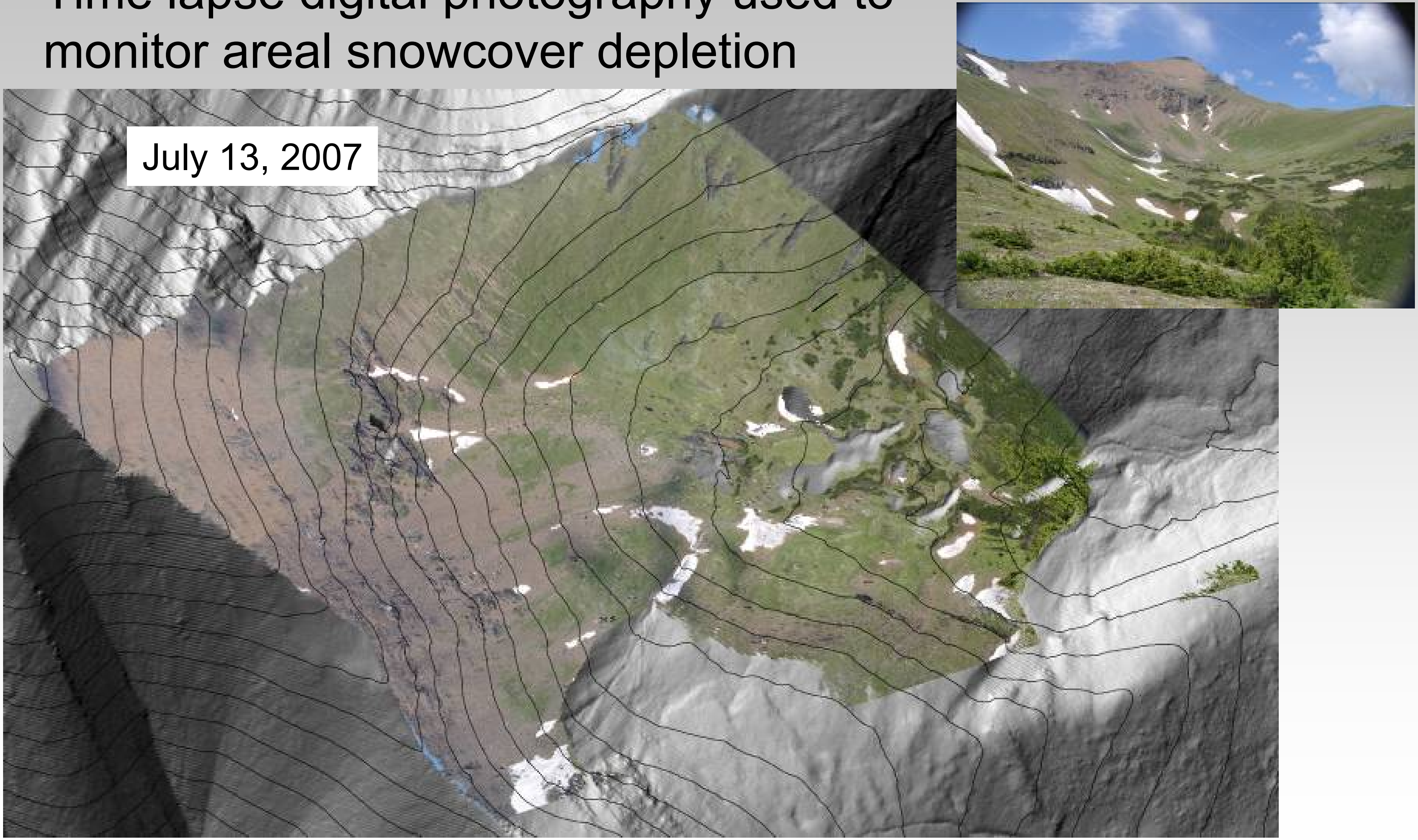
Study Site

- Fisera Ridge and Upper Middle Creek Basin



Areal Snowcover Observations

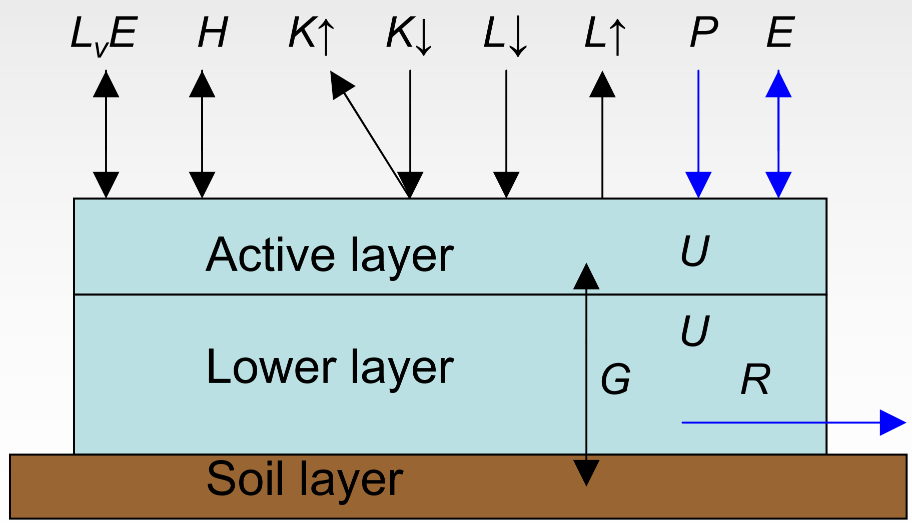
Time lapse digital photography used to monitor areal snowcover depletion



Snowmelt Modelling and Validation

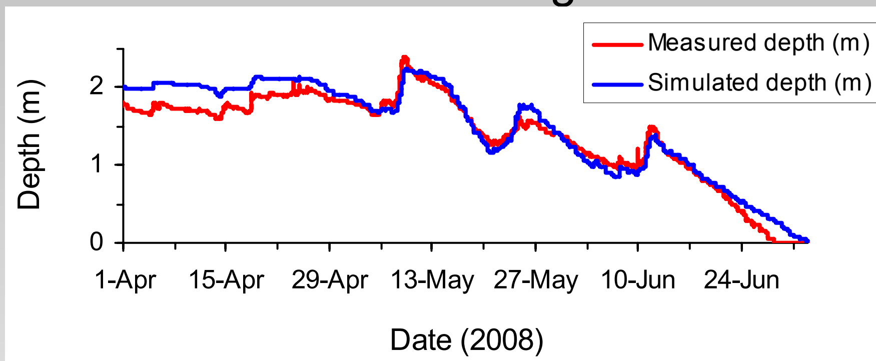
- Point location snowmelt modelling and observation
  - snow depth and temperature monitoring on slopes

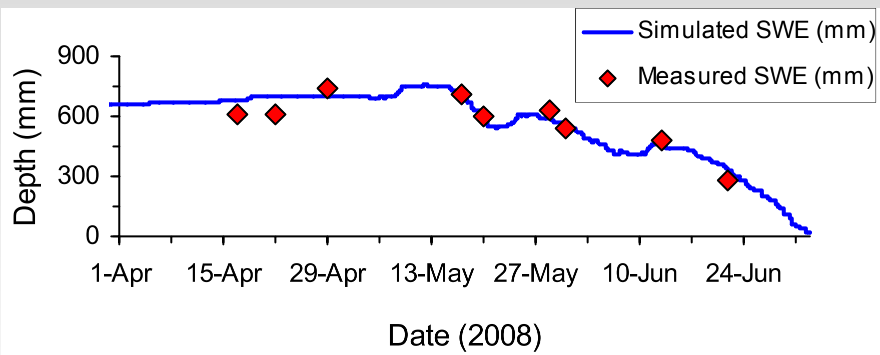
– Melt rates simulated using *Snobal* module in Cold Regions Hydrological Model ($Q_m = L_V E + H - K\uparrow + K\downarrow + L\downarrow - L\uparrow + G - dU/dt$)

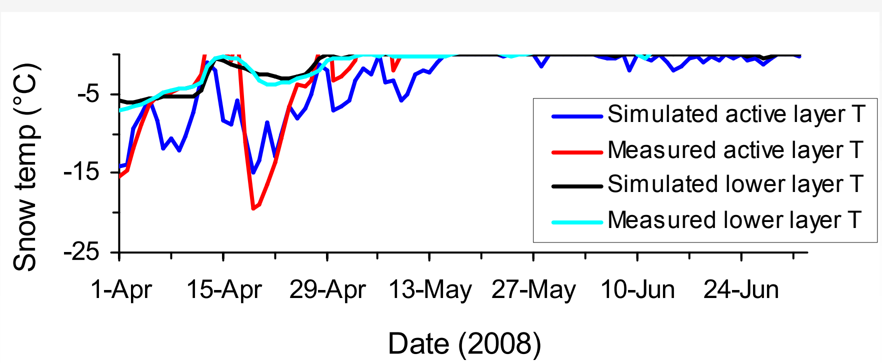


Snowmelt Modelling and Validation

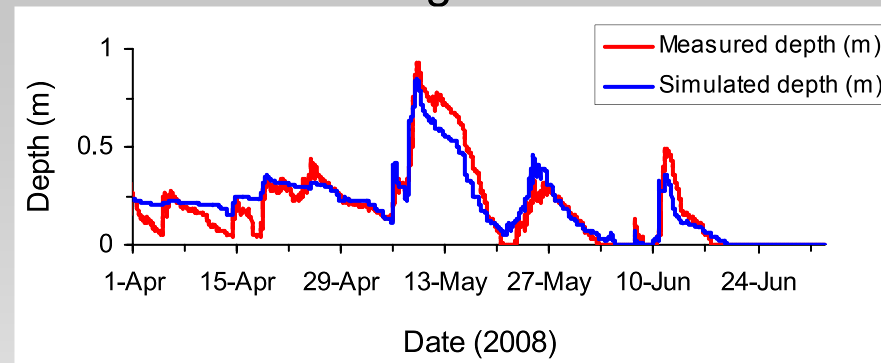
South-east facing site

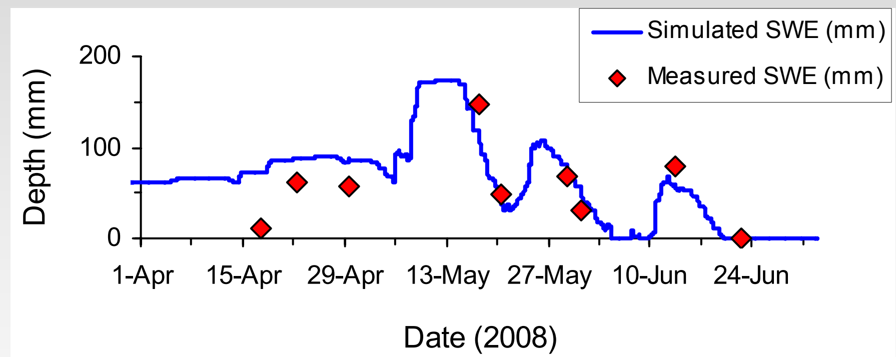


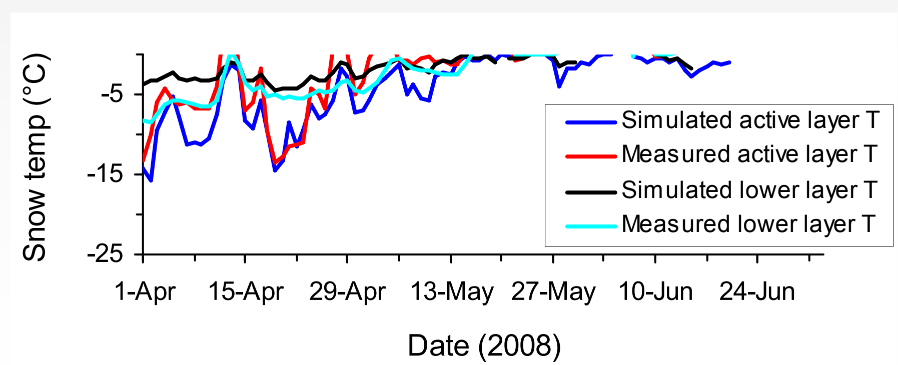




North facing site



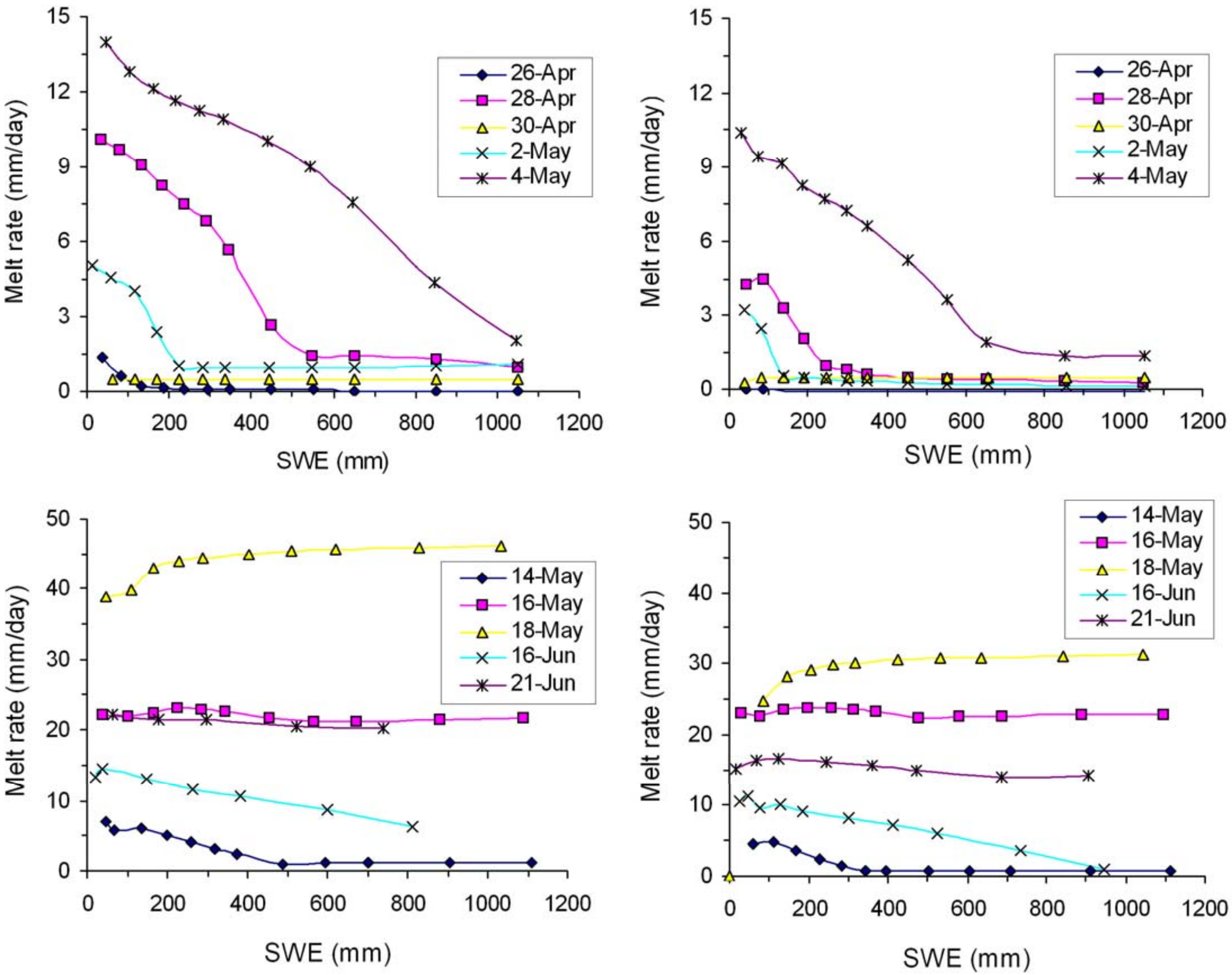




Simulated Snowmelt Variation

South-east facing site

North facing site



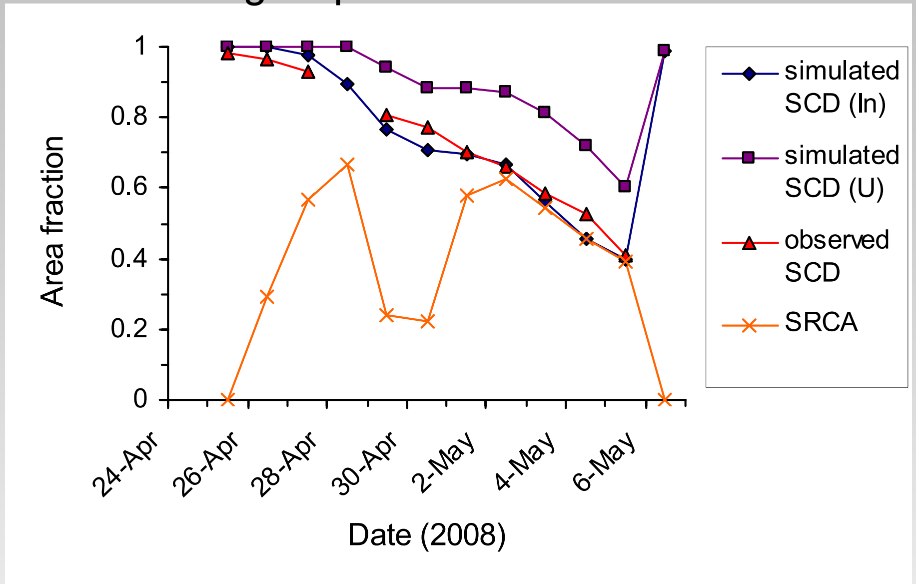
Time-dependent small scale associations between melt rate and SWE due to more rapid warming of shallow snow.

Associations change later in melt period as all snow is ripe.

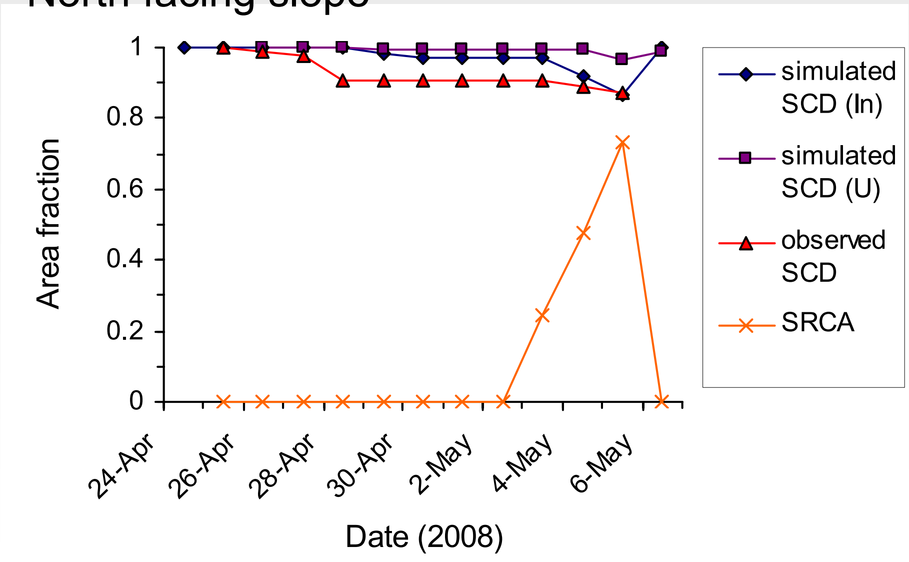
Effects on SCD and Runoff Contributing Area

- Simulated Melt rates used to predict SCD in adjacent cirque basin
- SWE distributions measured by surveys and repeat LiDAR
- SCD simulated by applying both uniform melt and in-homogeneous melt for different SWE classes
- Snowmelt runoff contributing area defined as fraction of basin generating runoff > 5 mm/d

South facing slope



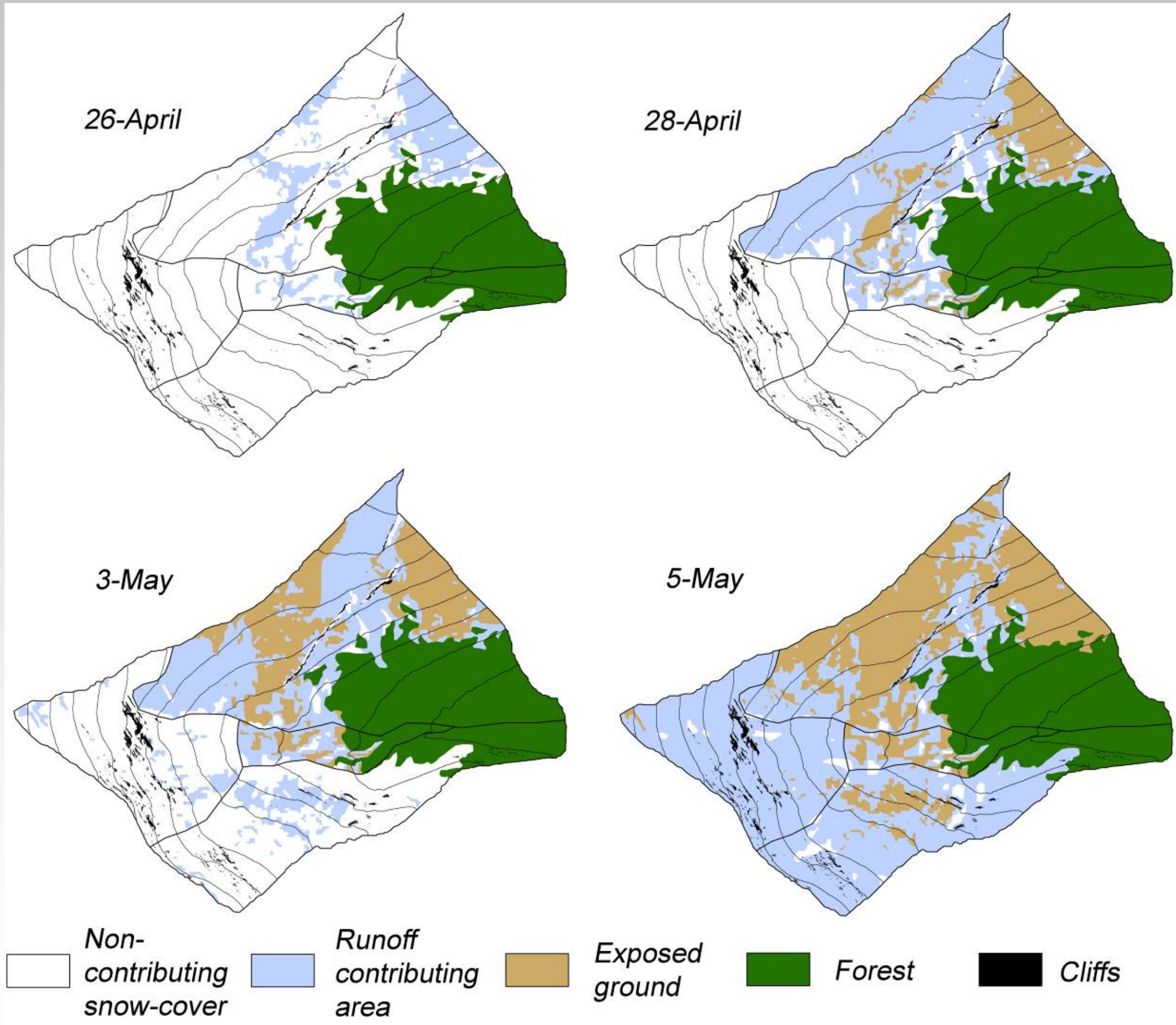
North facing slope



Effects on SCD and Runoff Contributing Area

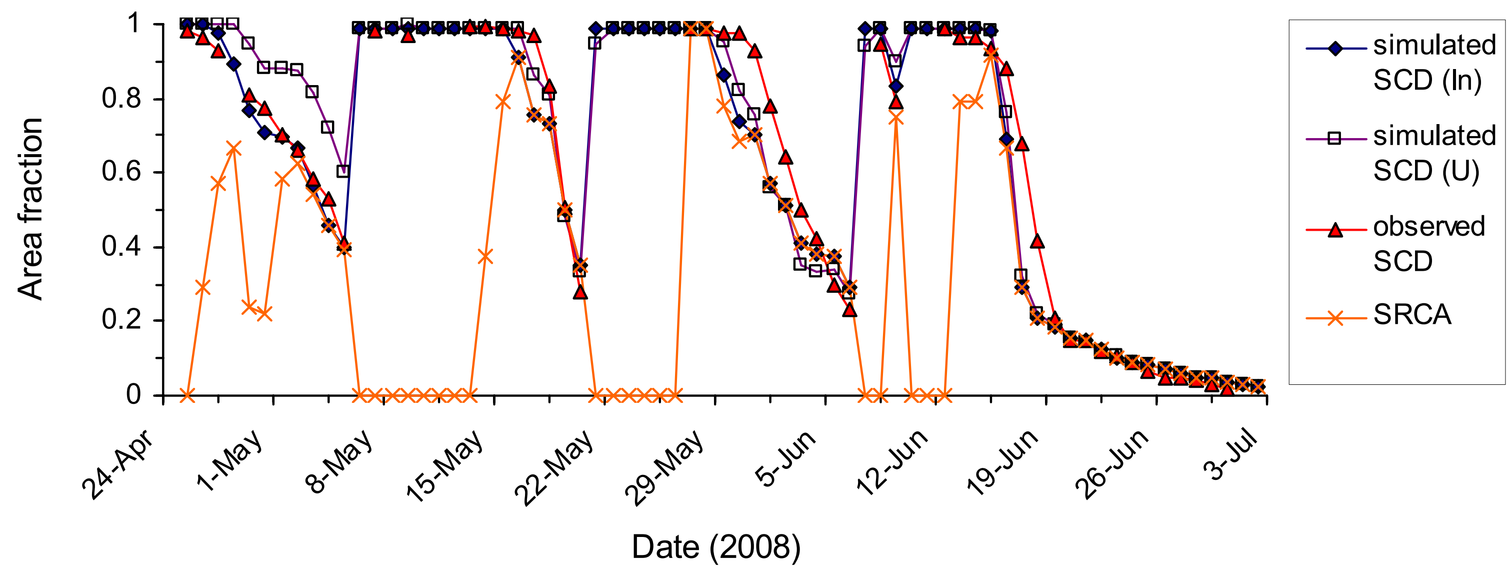
- Spatial distributions of snow depth from LiDAR used to map spatial patterns of SCD and SRCA

- Differences in melt and SWE distributions control the spatial development of the snowmelt runoff contributing area

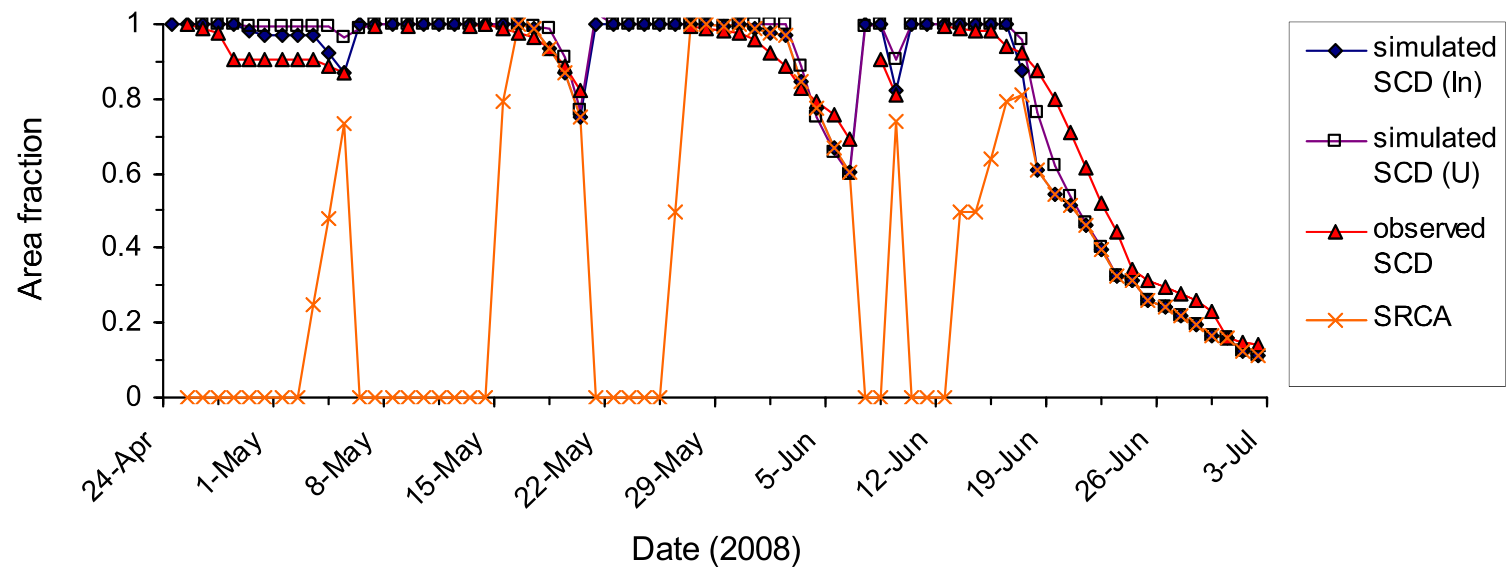


Effects on SCD and Runoff Contributing Area

South facing slope

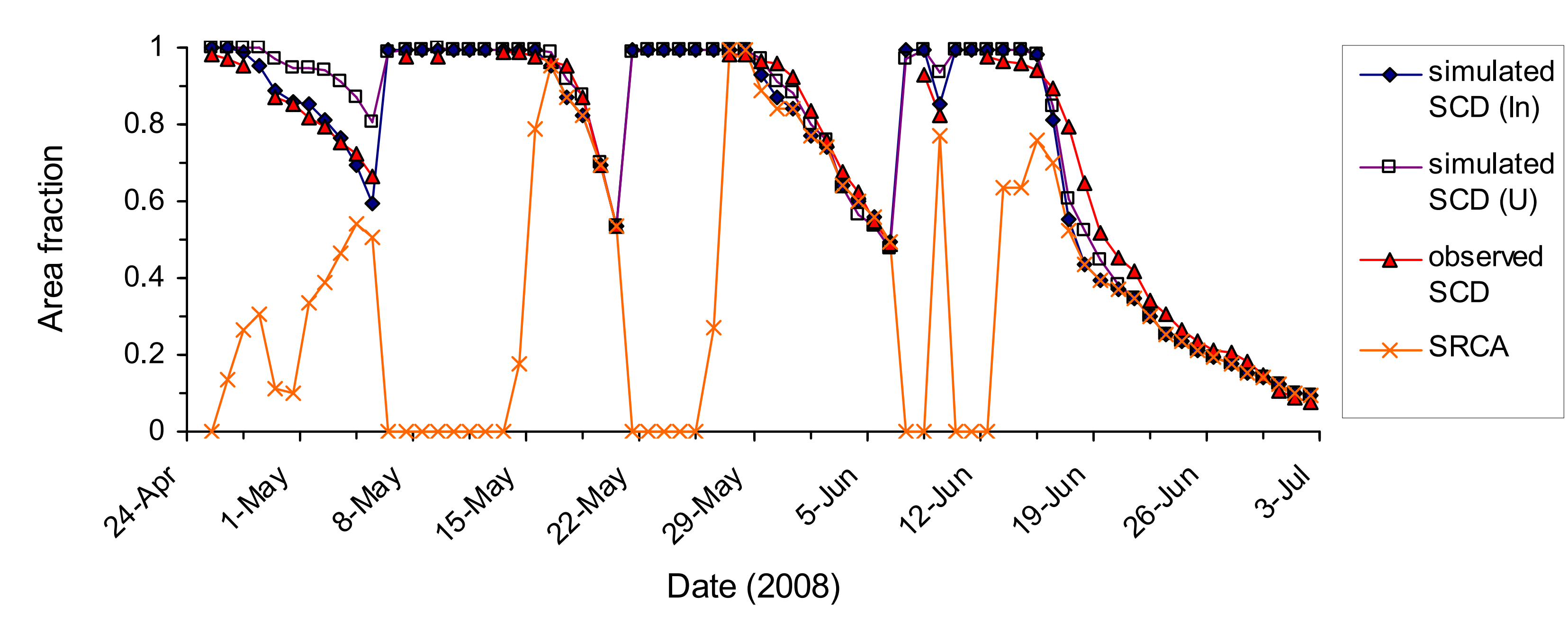


North facing slope



Effects on SCD and Runoff Contributing Area

- Results from each slope were aggregated to derive basin scale snowcover depletion and runoff contributing area

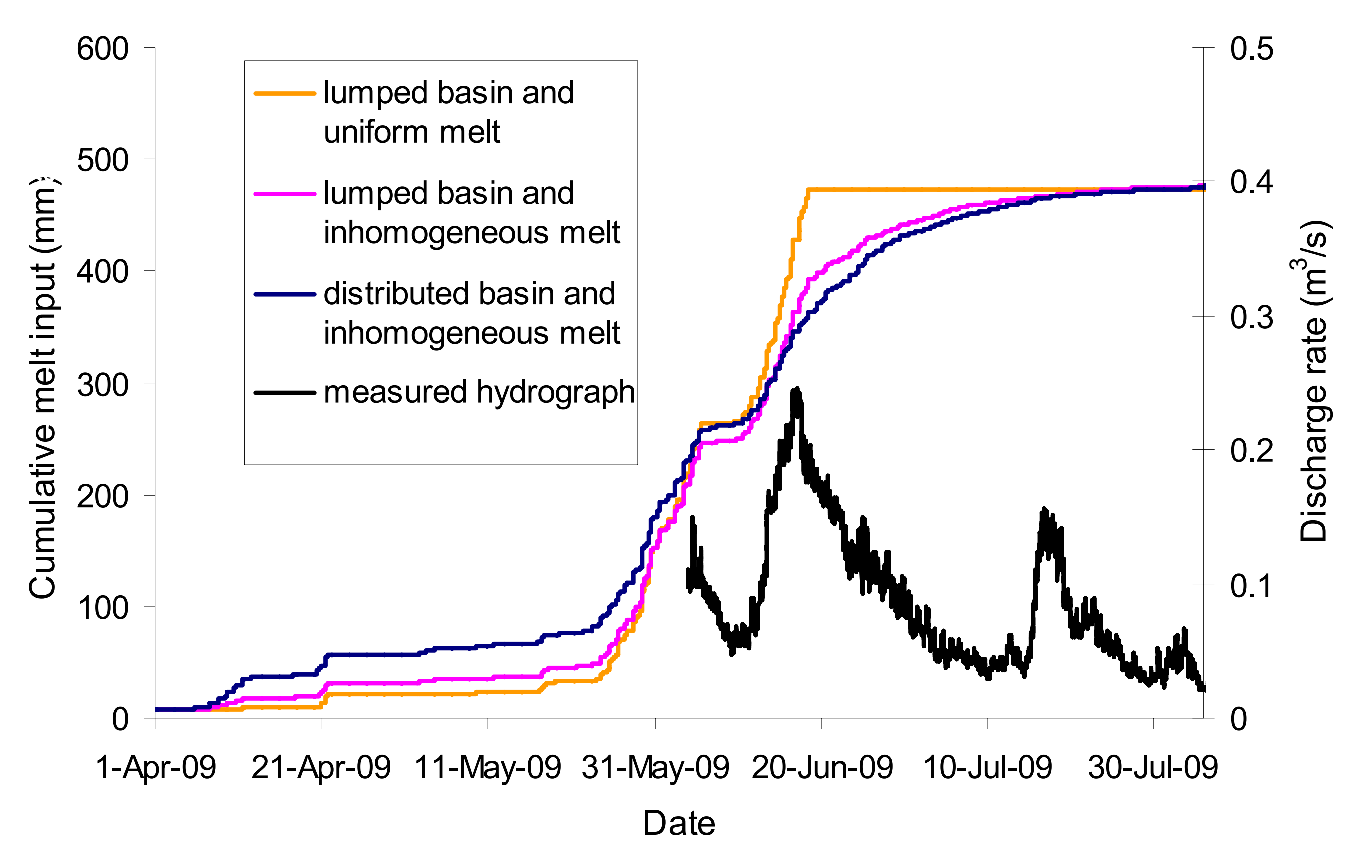


Snowmelt Runoff Simulation

- This framework can be applied to simulate the meltwater inputs over the basin
  - Inputs to each slope computed by running the model in point mode for various initial SWE depth classes over the distribution
  - Simulated outflow from the base of the pack weighted by the fraction of the total distribution in each SWE class, and aggregated on each slope unit

Snowmelt Runoff Simulation

– Rate and timing of melt input over the basin is sensitive to approach, with significant implications for the snowmelt hydrograph



Conclusions

- Snowmelt timing and rate is non-uniform, even within individual landscape units, due to differences in the internal energetics and ripening of the snow
- Effect of initial SWE depth on melt rates is pronounced in early melt period with major implications for areal SCD
- Simulations of areal snowcover depletion and snowmelt runoff generation can be improved by considering separate SWE classes on individual slopes
- By improving the representation of melt inputs over the landscape, the snowmelt hydrograph can likely be more accurately simulated