Snow Hydrology and Modelling in Alpine, Arctic and Forested Basins

John Pomeroy

and collaborators

Richard Essery (Edinburgh), Chris Hopkinson (CGS-NS), Rick Janowicz (Yukon Env), Tim Link (Univ Idaho), Danny Marks (USDA ARS), Phil Marsh (Env Canada), Al Pietroniro (Env Canada), Diana Verseghy (Env Canada), Jean Emmanual Sicart (IRD France

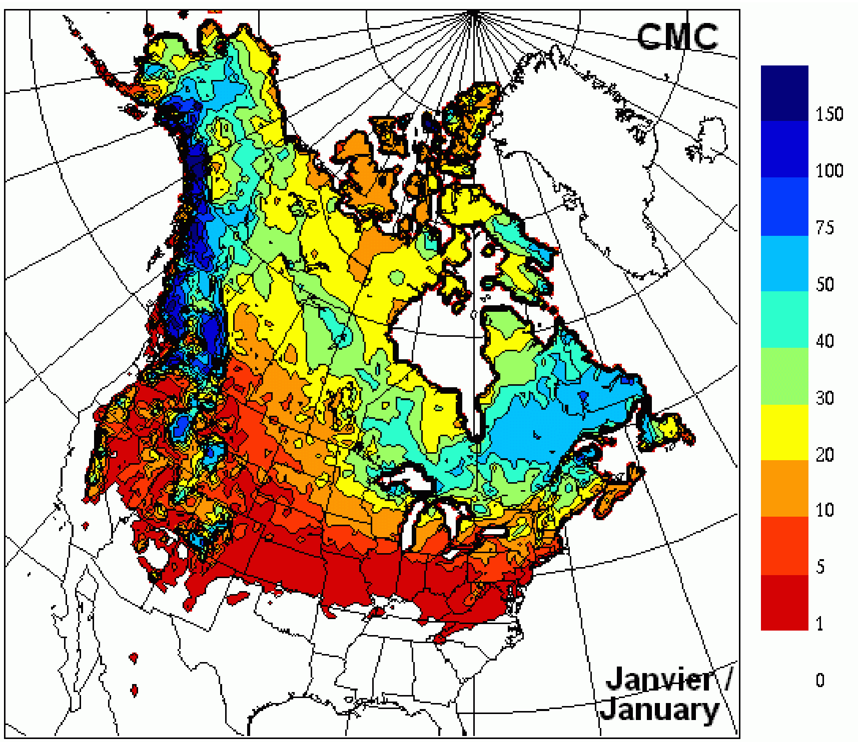
and Centre for Hydrology Faculty, Researchers and Students

Tom Brown, Kevin Shook, Warren Helgason, Chris DeBeer, Pablo Dornes, Chad Ellis, David Friddell, Warren Helgason, Edgar Herrera, Nicholas Kinar, Jimmy MacDonald, Matt MacDonald, Chris Marsh, Stacey Dumanski, Brad Williams, May Guan

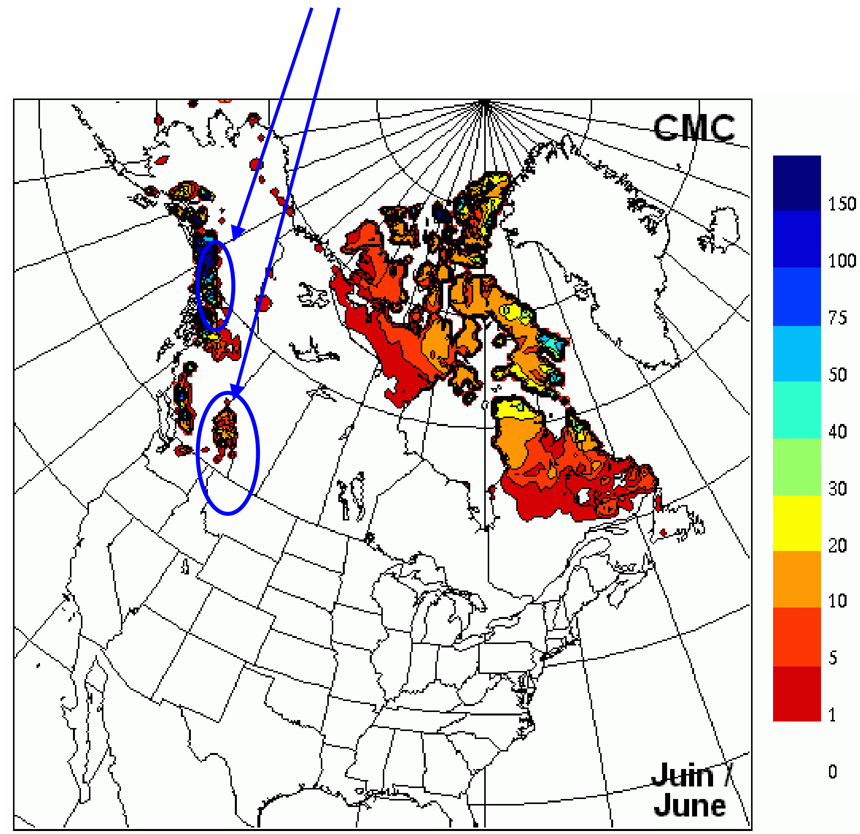
Mountain Snow

vast water reserves in winter snowpack

summer snow water reserves



Snow depth in January



Snow depth in June

Study Elements

- Processes
  - Snow accumulation, structure and observation
  - Turbulent transfer to snow
  - Radiation effects on snowmelt under tundra shrubs and evergreen forests

- Parameterisations
  - Blowing snow over complex terrain
  - Irradiance in complex terrain – longwave from terrain, shortwave shadows
  - Forest snow interception, unloading and sublimation
  - Sub-canopy snowmelt
  - SCA Depletion in complex terrain,
  - Contributing area for runoff generation in snowmelt period
- Prediction
  - Wind and atmospheric modelling over complex terrain
  - Level of spatial complexity necessary in models
  - Regionalisation of CLASS parameters
  - Snow modelling contribution to MESH
  - CRHM
    - Arctic and sub-arctic snow hydrology, Wolf Creek & Trail Valley Creek
    - Alpine snow hydrology, Marmot Creek
    - Montane forest snow hydrology, Marmot Creek

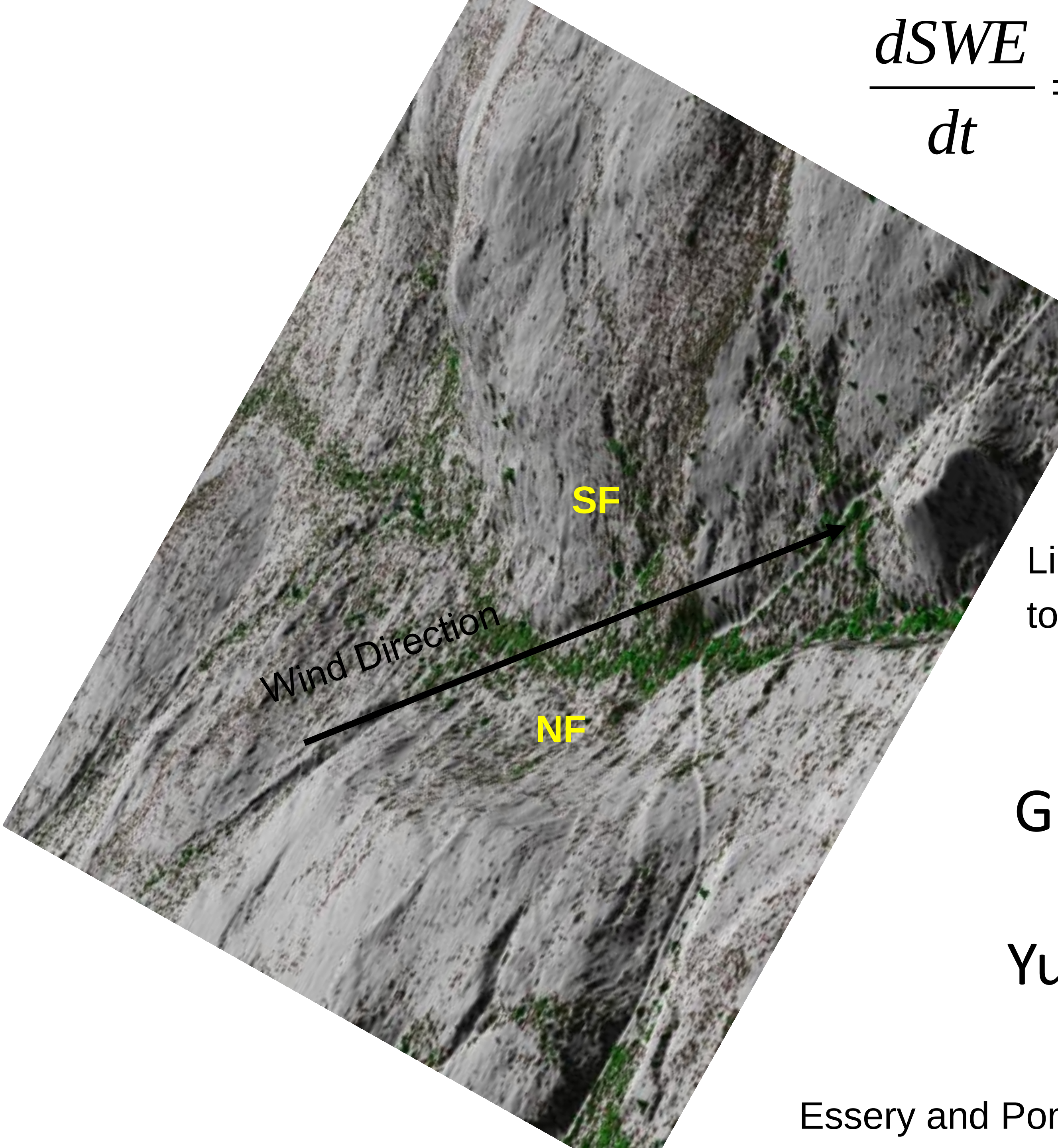
Blowing Snow in Complex Terrain

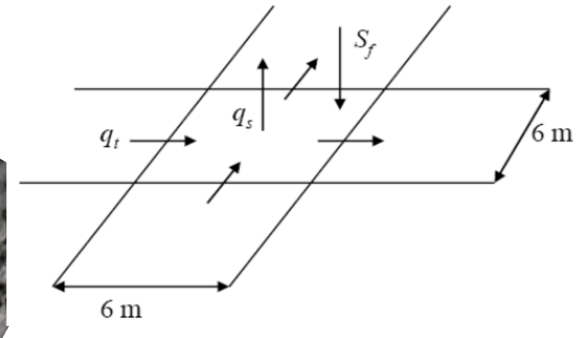
Inter-basin water transfer

Transport of snow to drifts

Supports glaciers, late lying snowfields, hydrological contributing areas

$$\frac{dSWE}{dt} = X_S - \nabla \cdot T - E_S$$



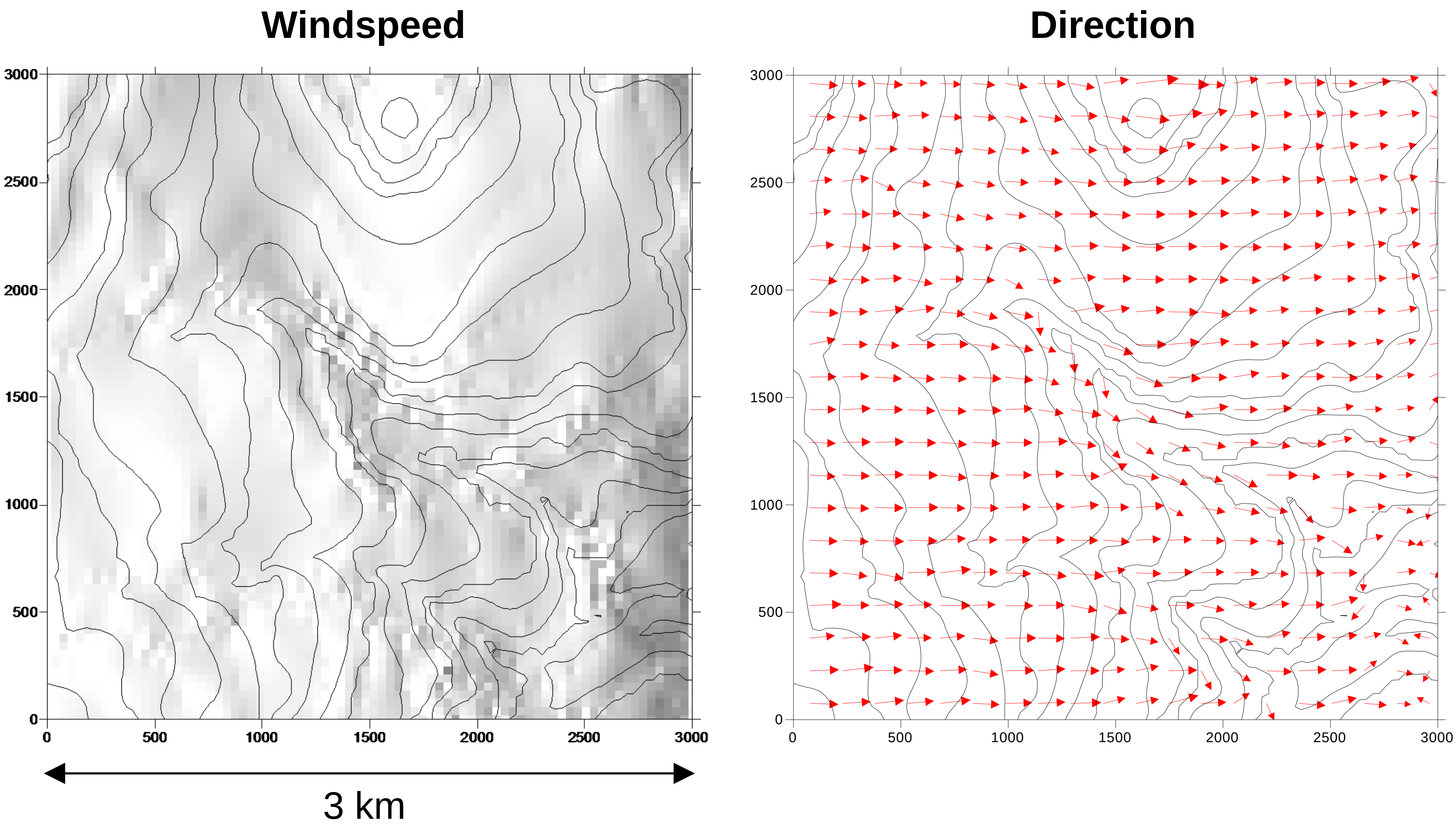


LiDAR used to develop topography and vegetation DE

Granger Basin, Wolf Creek, Yukon Territory

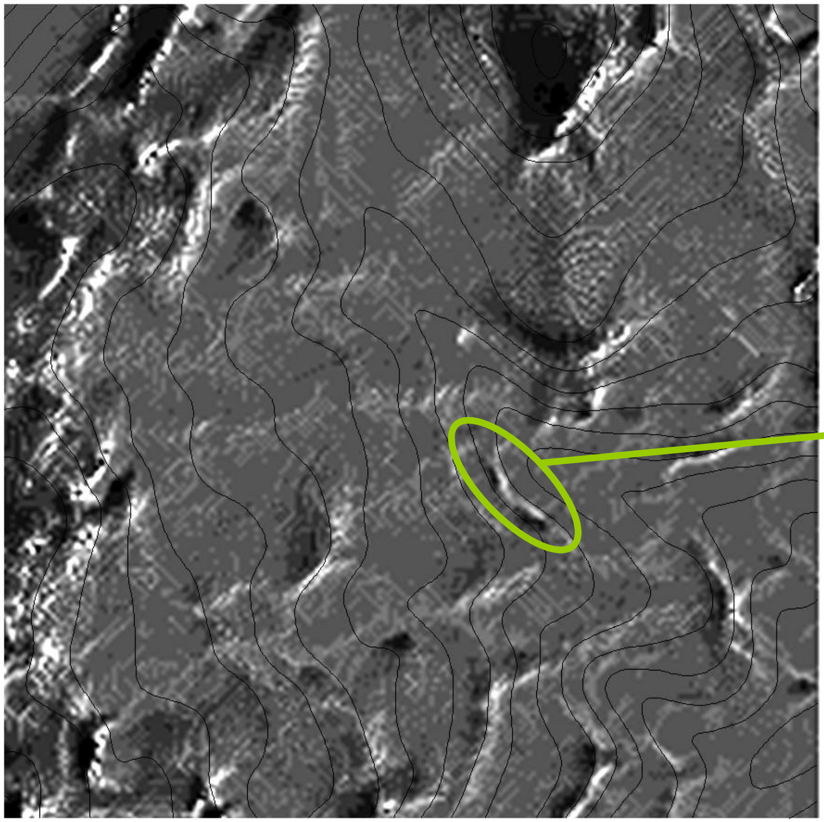
Essery and Pomeroy, in preparation

Computer simulation of wind flow over mountains



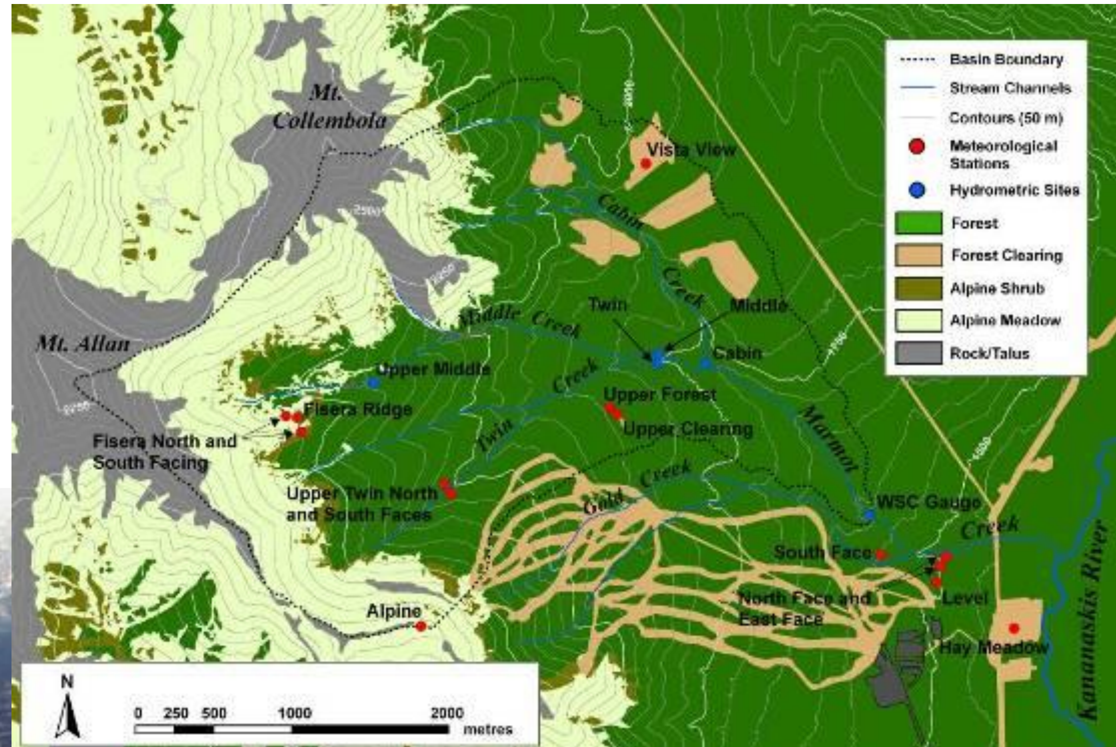
Granger Basin, Wolf Creek, Yukon

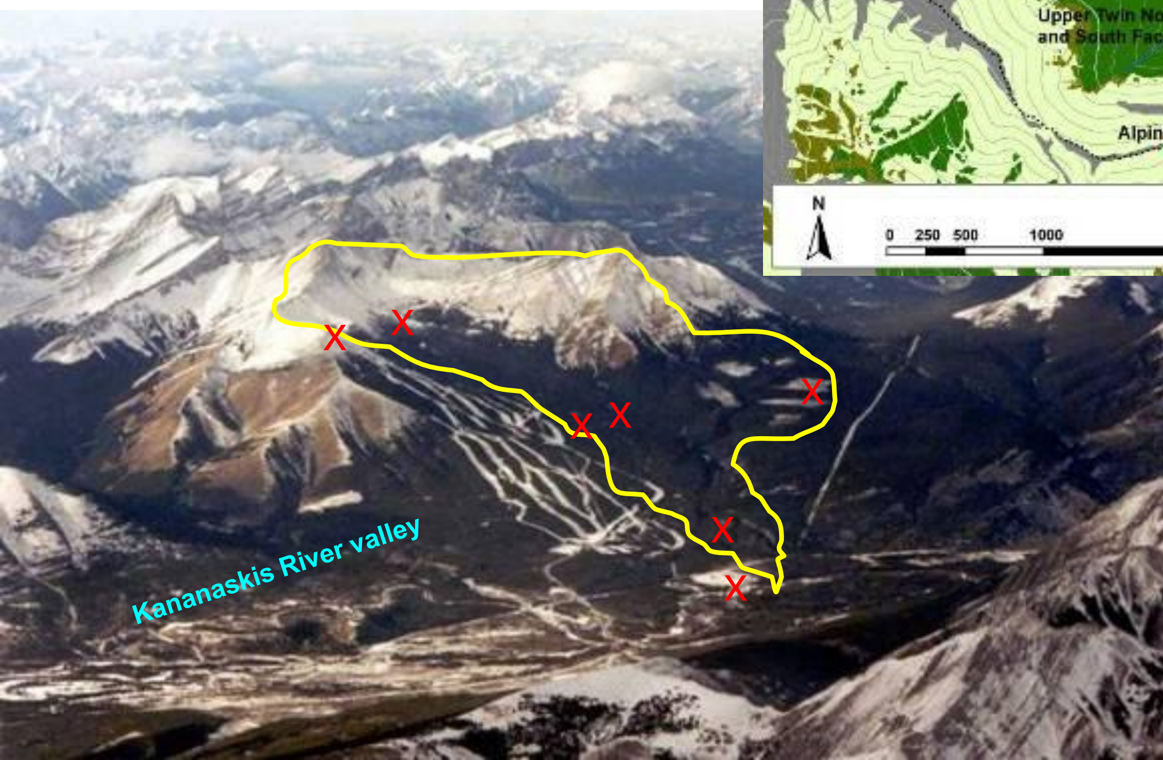
Simulation of Hillslope Snowdrift



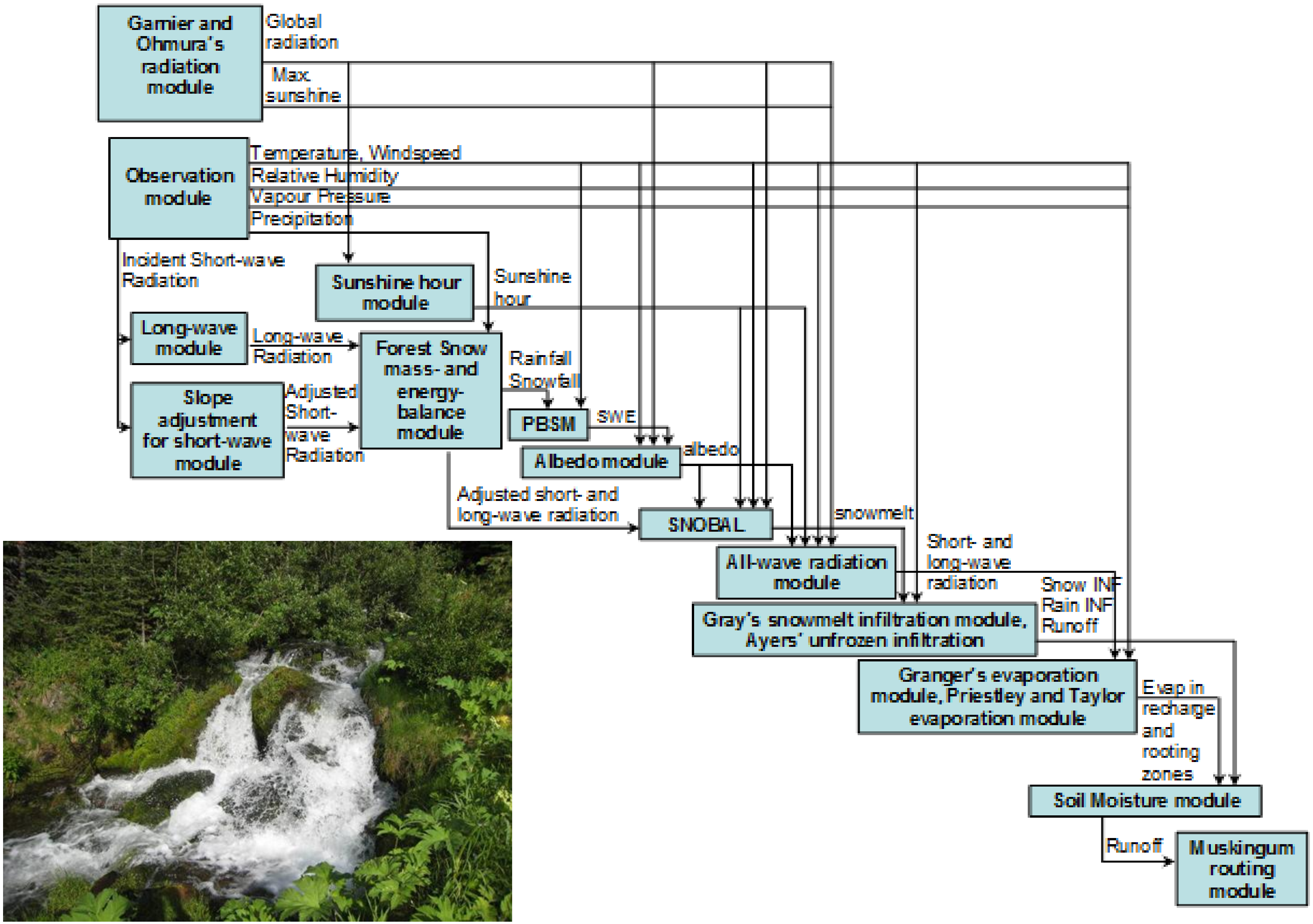
3 km

Marmot Creek Research Basin

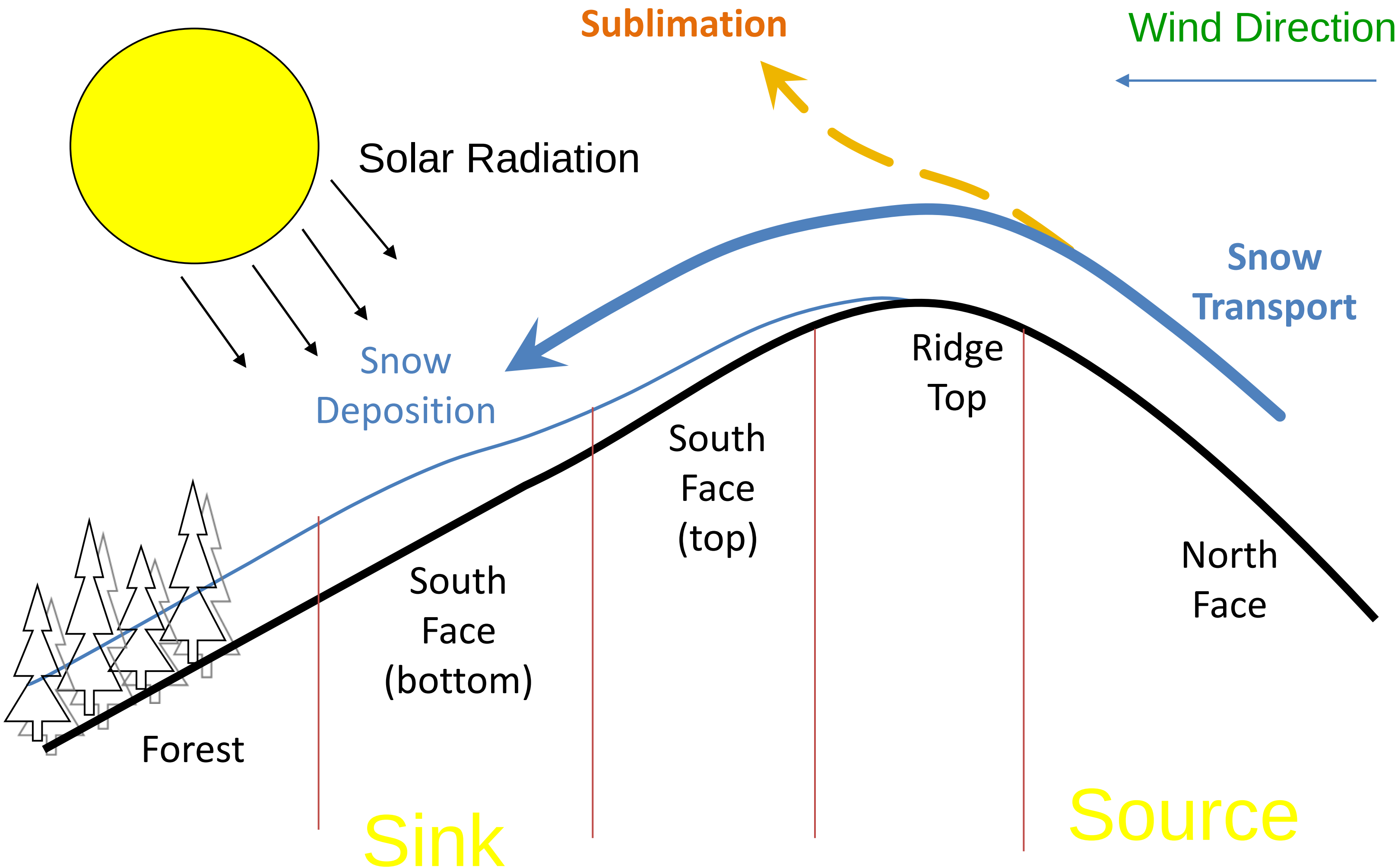




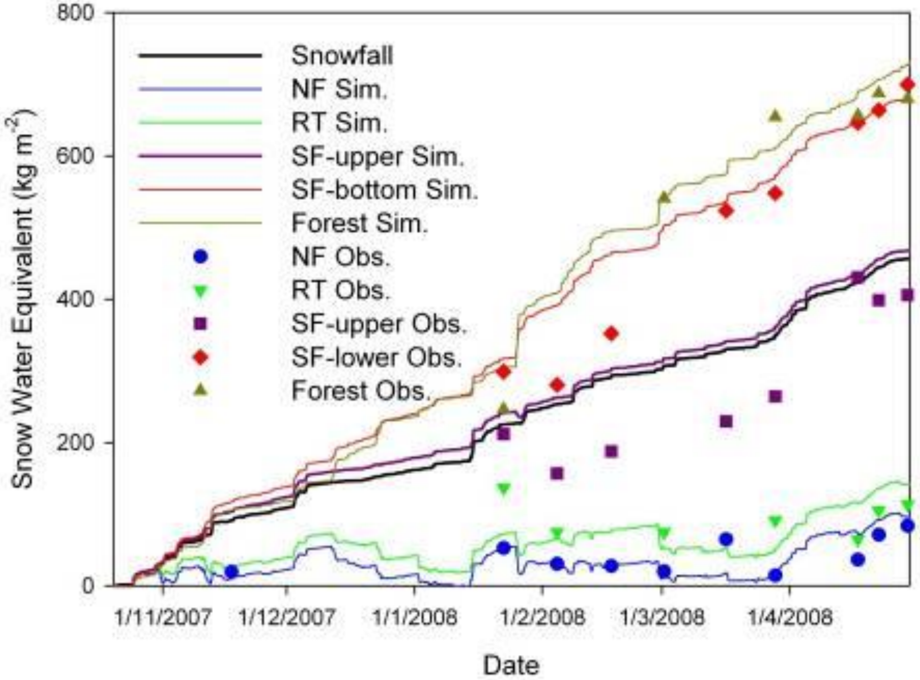
CRHM Mountain Structure

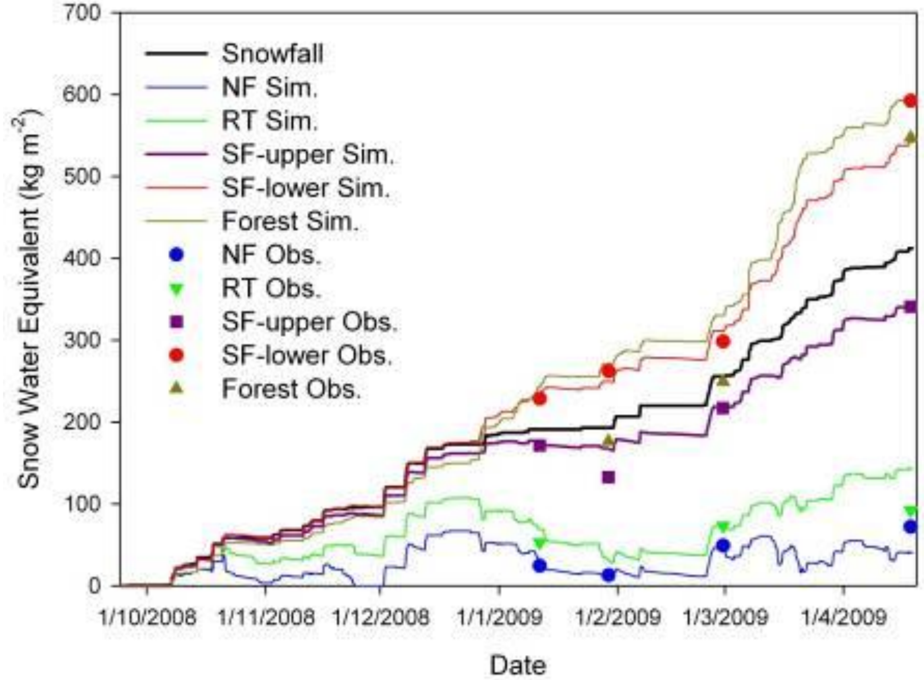


Alpine Hydrological Response Units

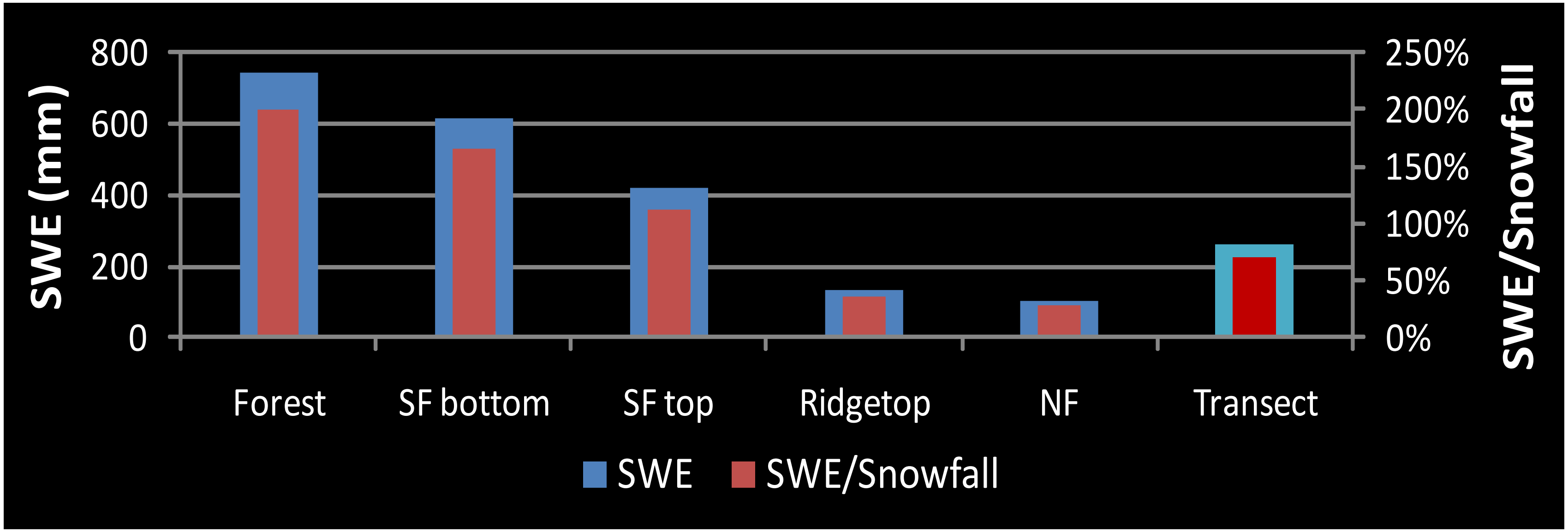


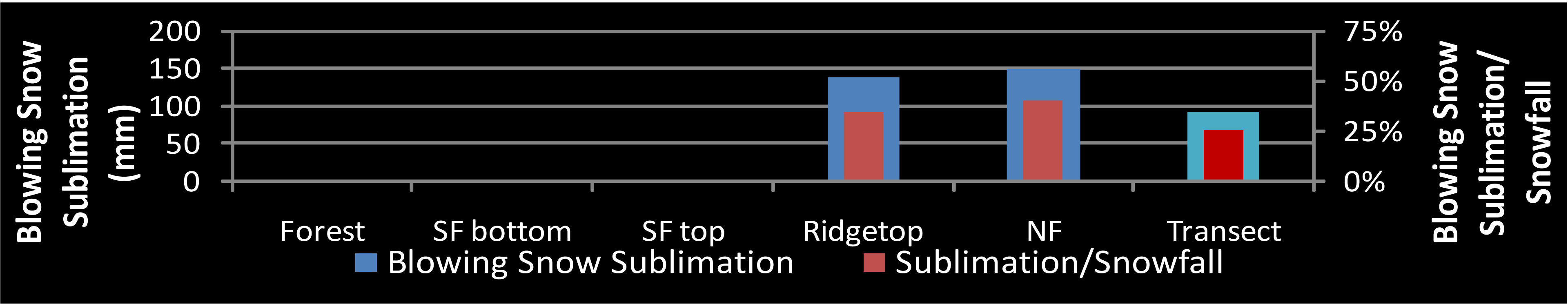
Winter Snow Redistribution Modelling





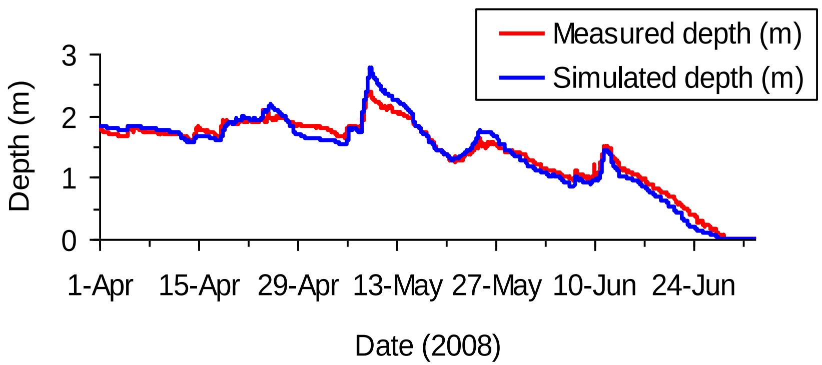
Winter Snow Redistribution and Sublimation

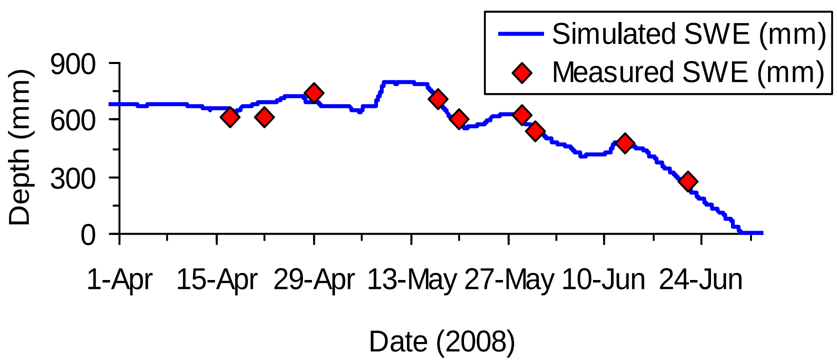


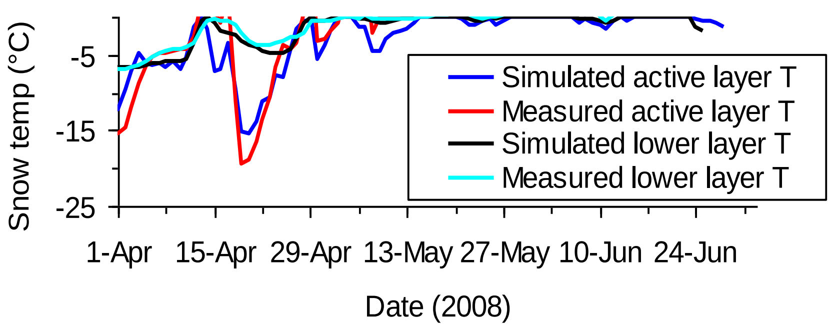


Point Evaluation of Snowmelt Model

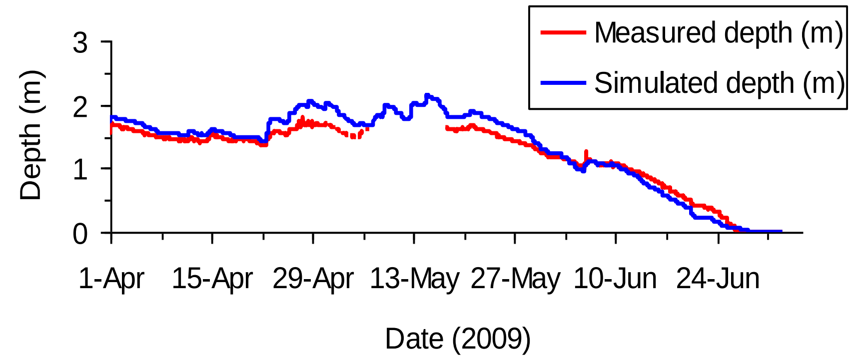
2008

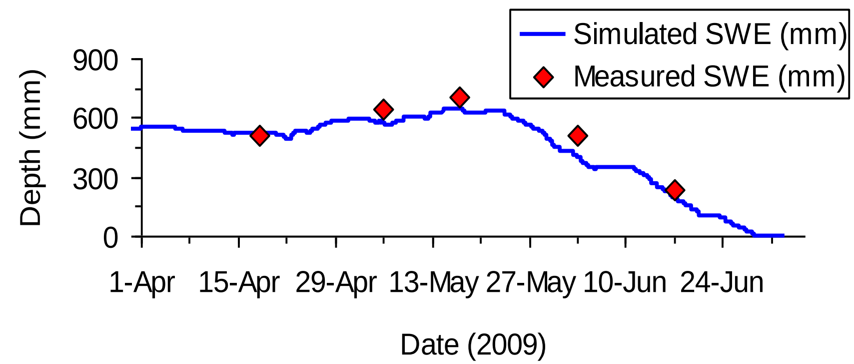


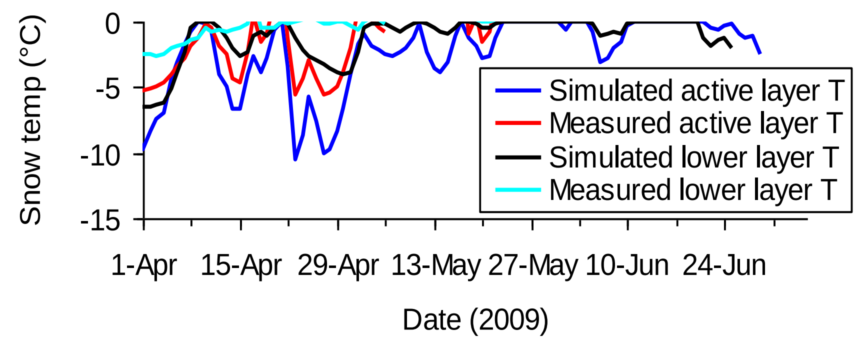




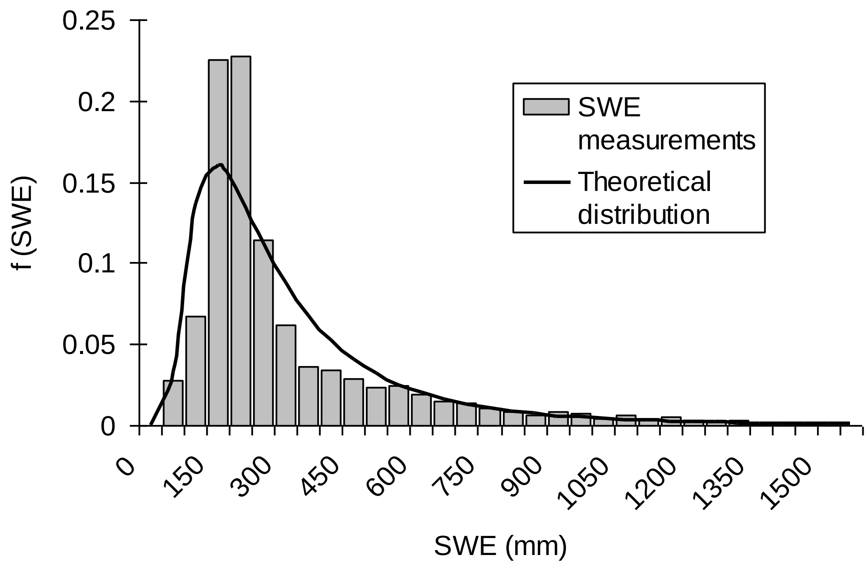
2009

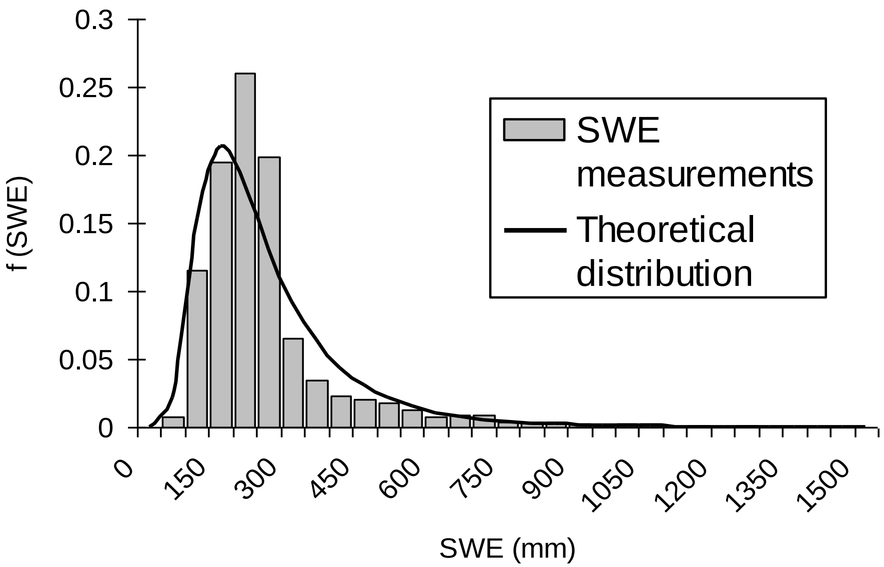






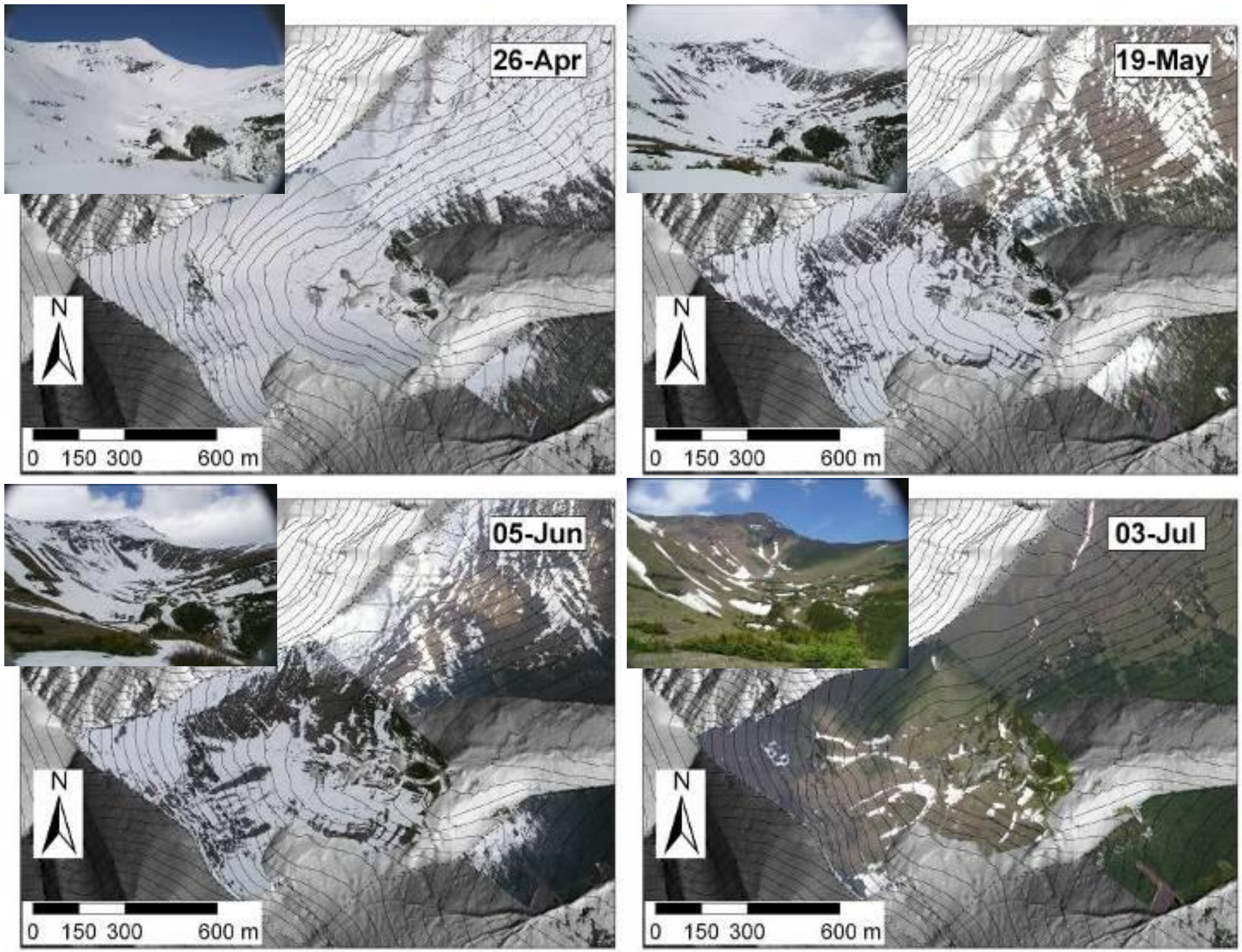
Frequency Distributions of SWE from LiDAR Depths and Measured Density





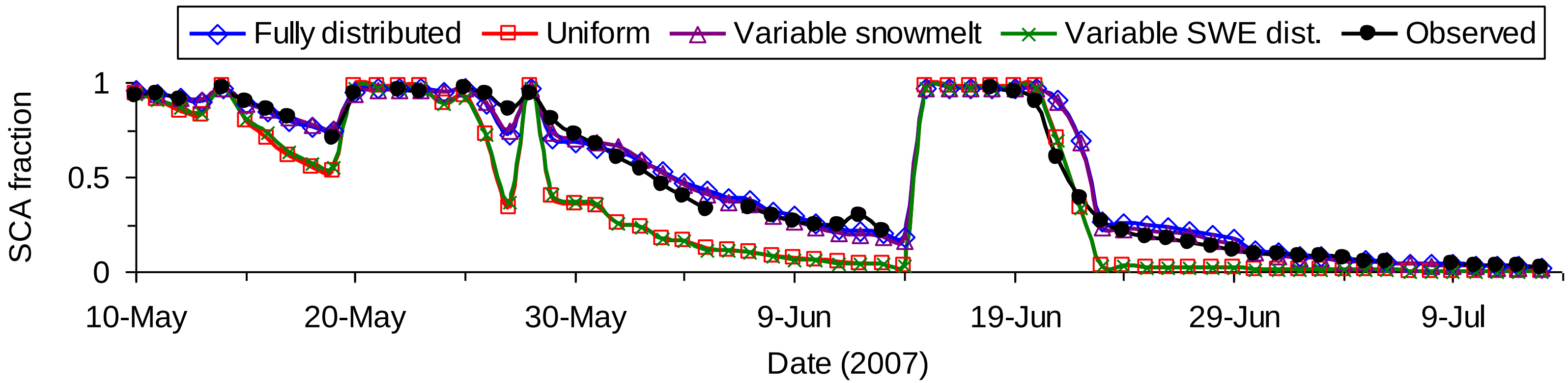
SWE distribution within HRU fit log-normal density distribution

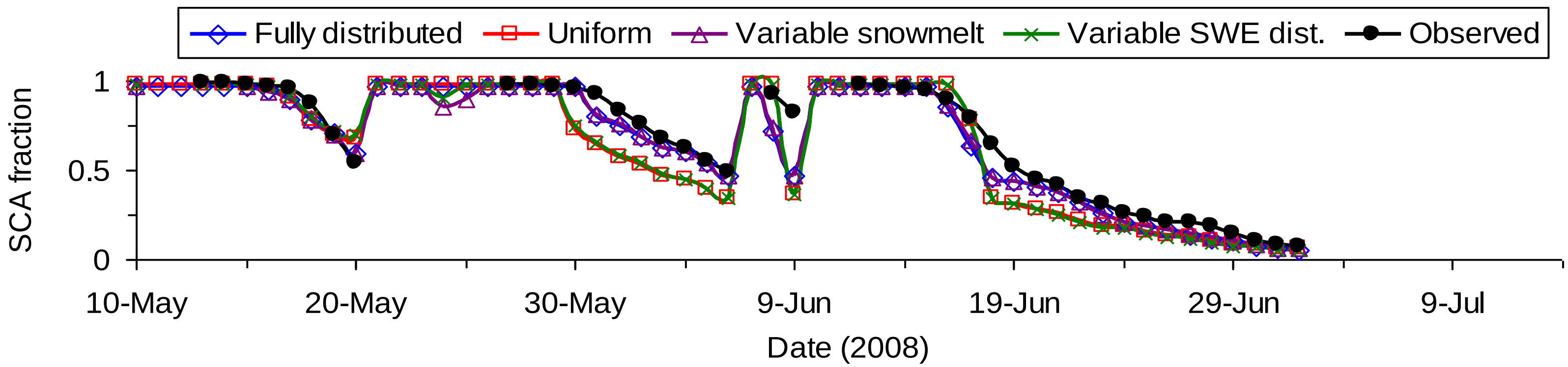
Snowcovered Area from Oblique Terrestrial Photographs, Aerial Photographs and LiDAR DEM



Snow-covered Area Depletion Modelling

Four HRU (NF, SF, EF, VB) with modelled melt applied to SWE frequency distributions.





Observed – using oblique photography

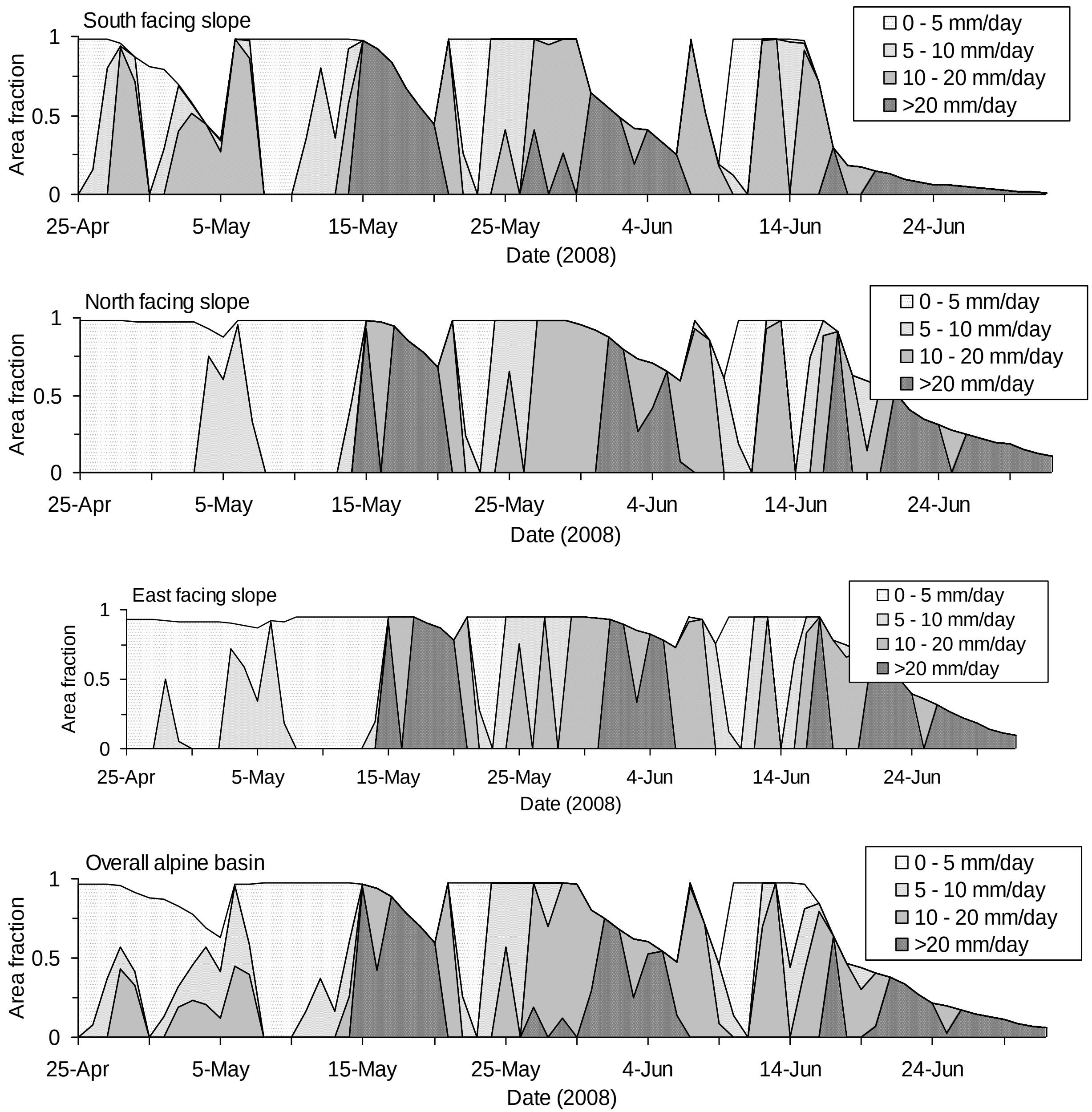
Uniform – spatially uniform SWE distributions and applied melt rates for each HRU

Variable SWE dist. – each HRU has a distinct distribution of SWE

Variable snowmelt – each HRU has a distinct melt rate applied

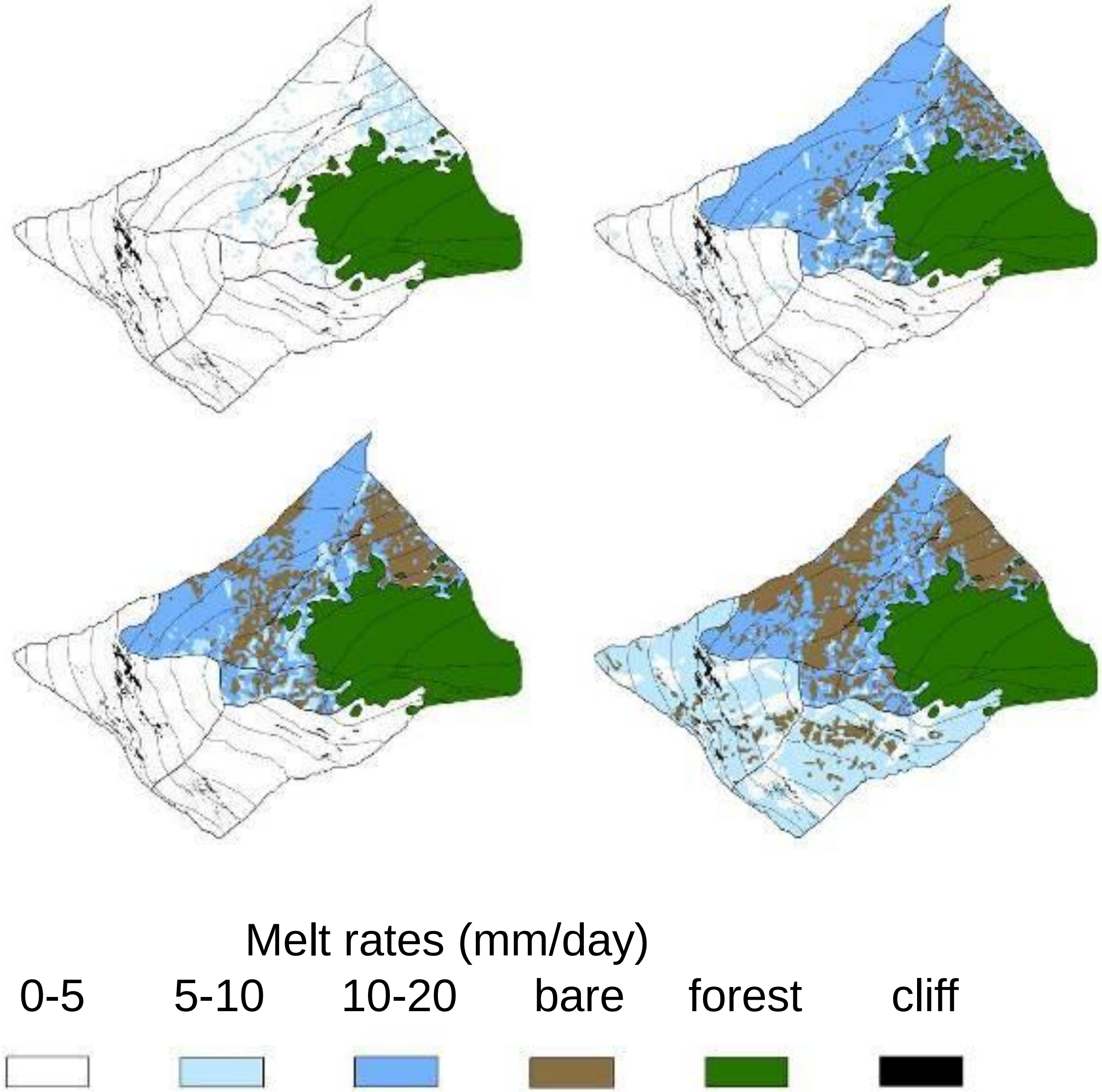
Fully distributed – each HRU has a distinct distribution of SWE and applied melt rate

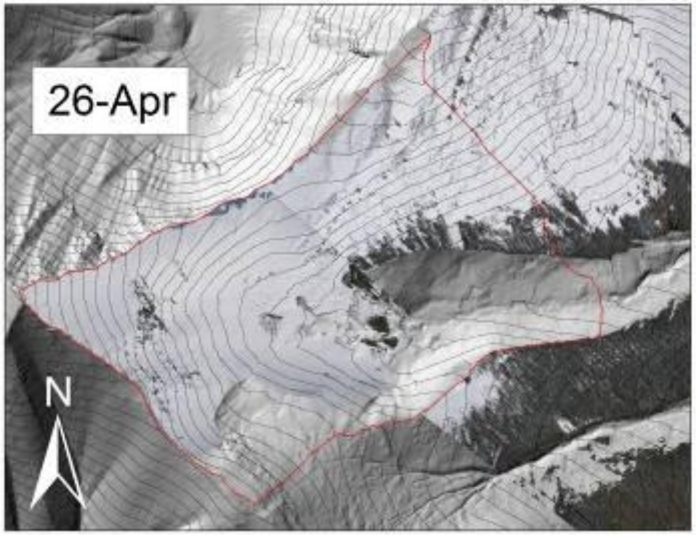
Snowmelt Runoff Intensity by HRU

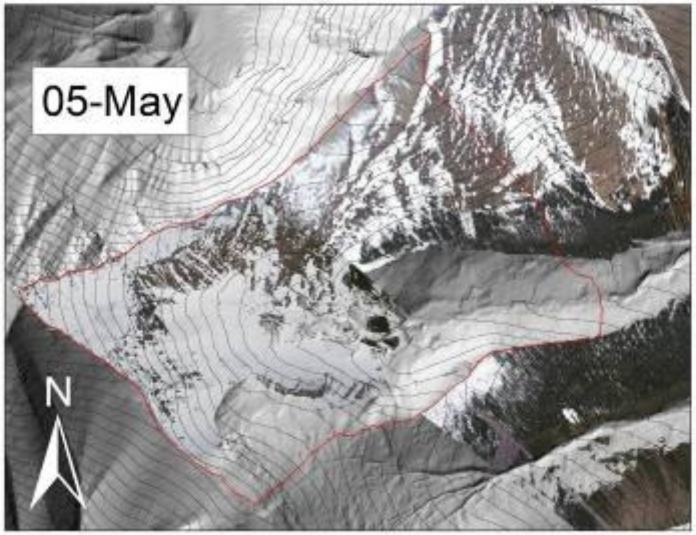


Visualisation of Snowmelt Runoff Intensity

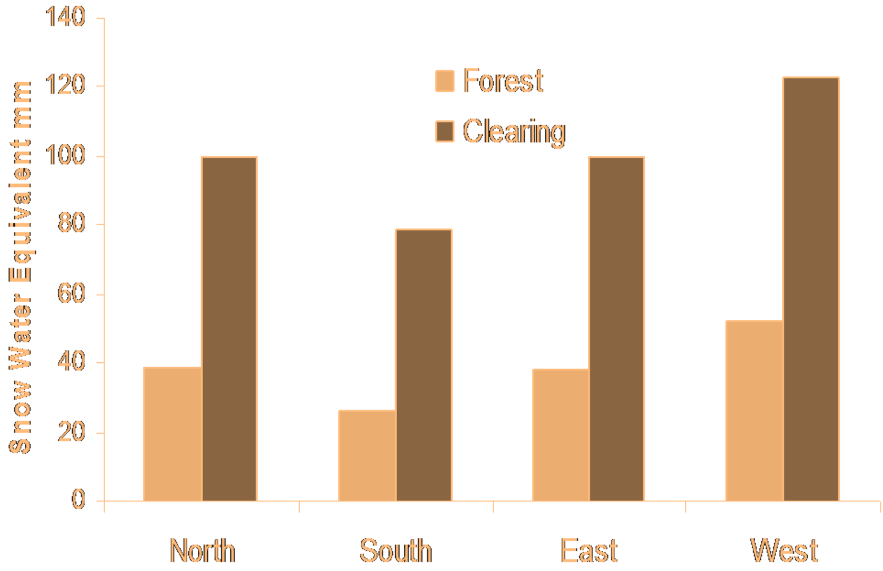
Early Snowmelt Period - 2008



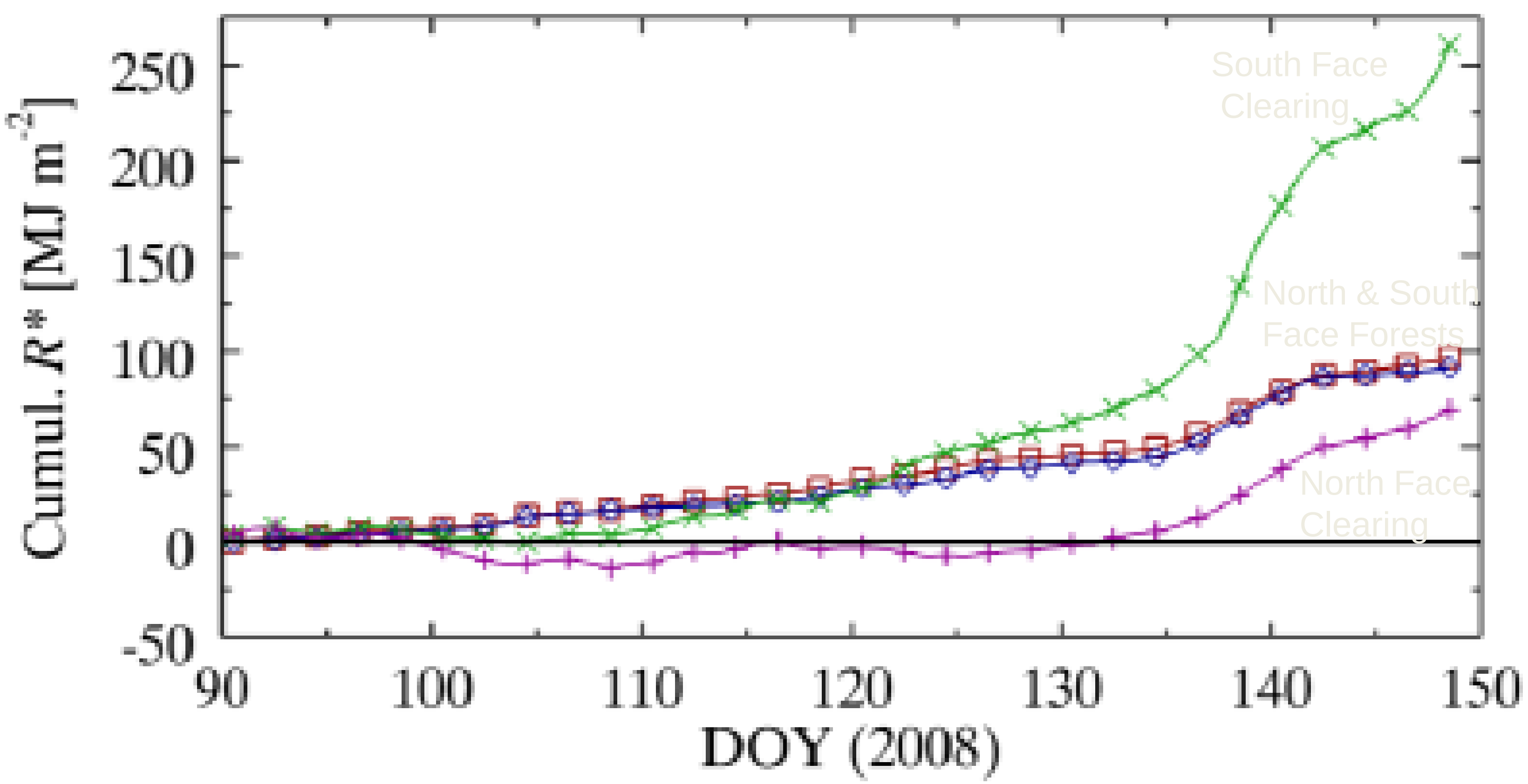




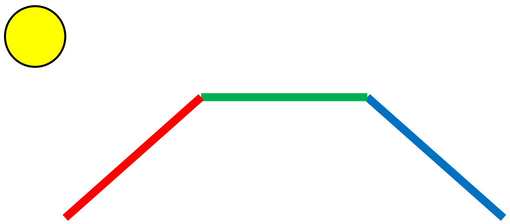
Snow Interception & Sublimation

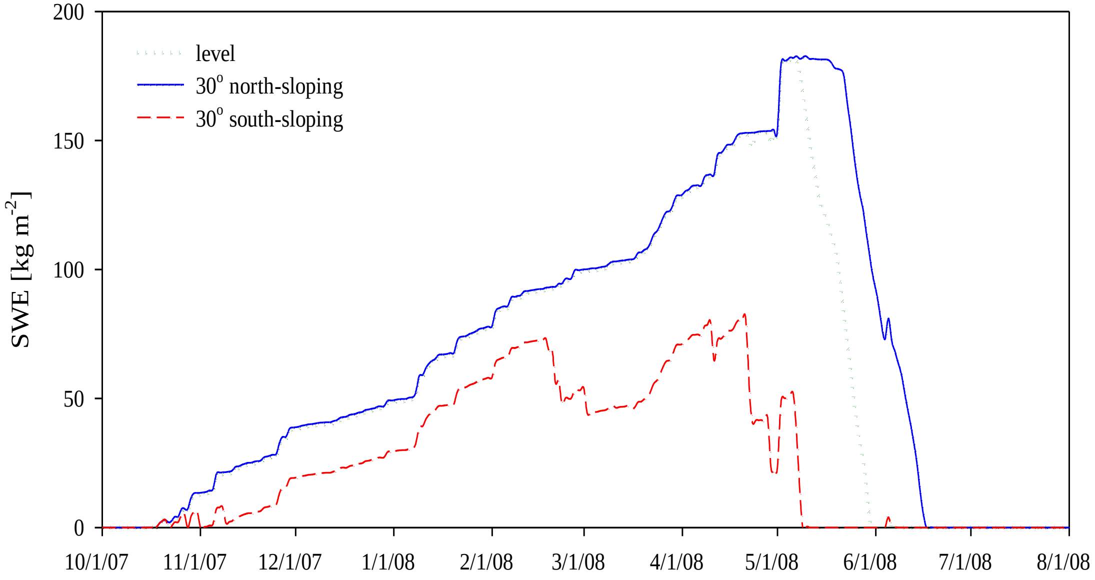


Net Radiation to Forests: Slope Effects

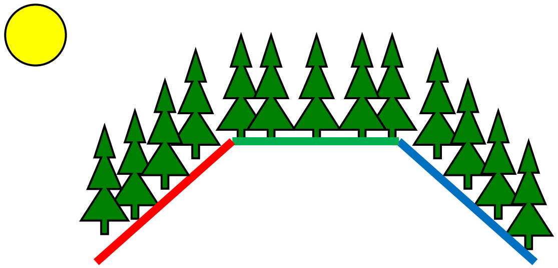


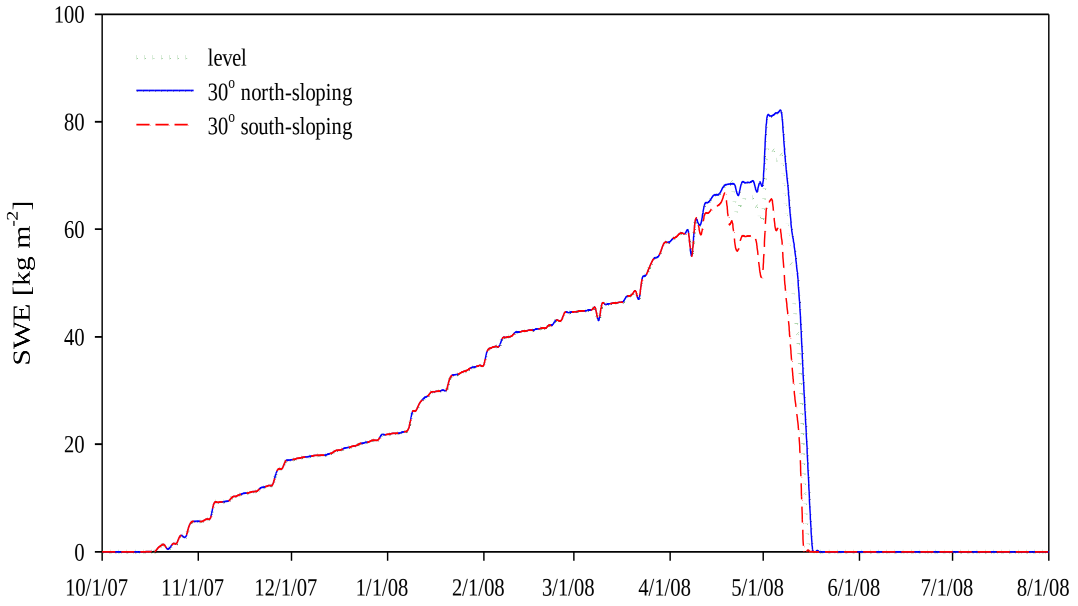
Forest Snow Regime on Slopes



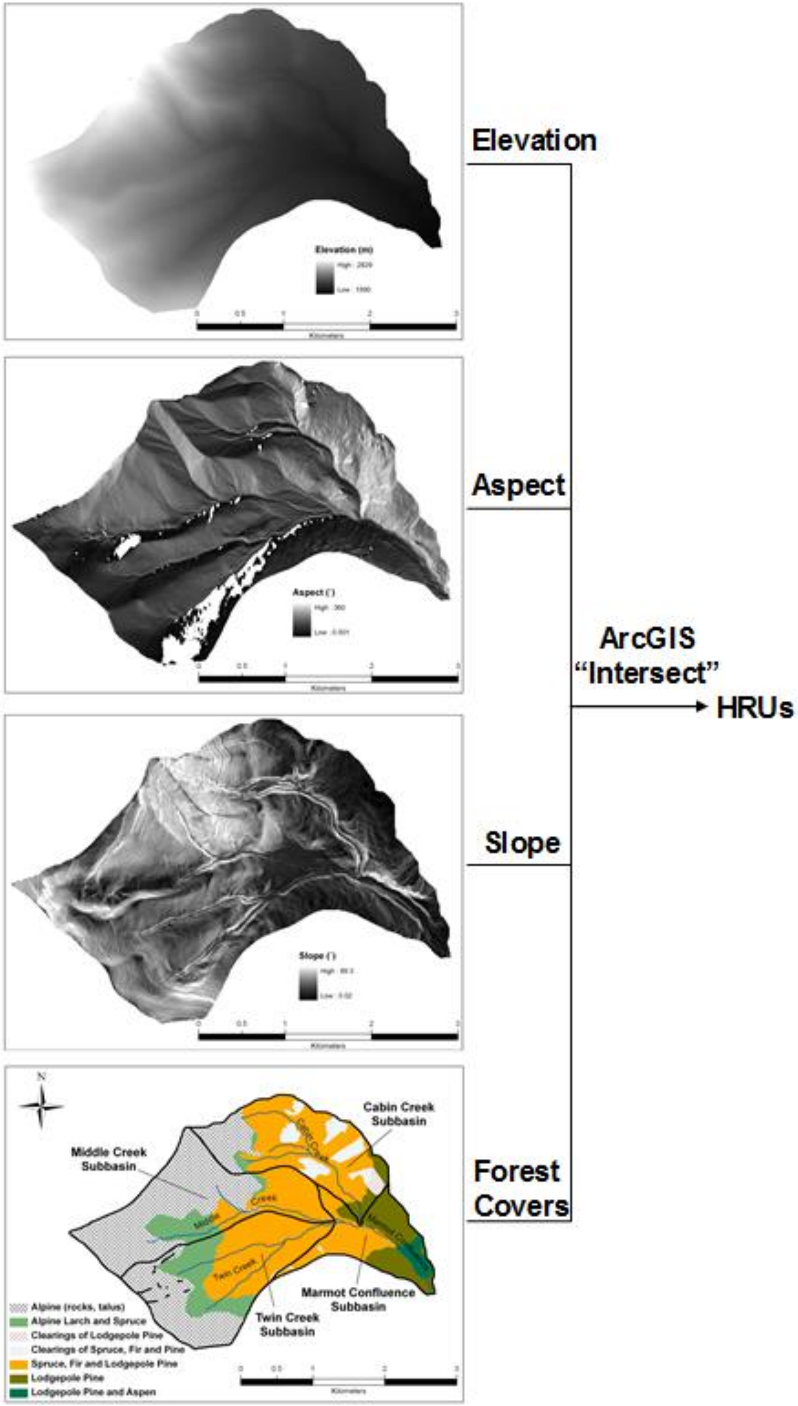


Open slopes highly sensitive to irradiation difference, forests are not



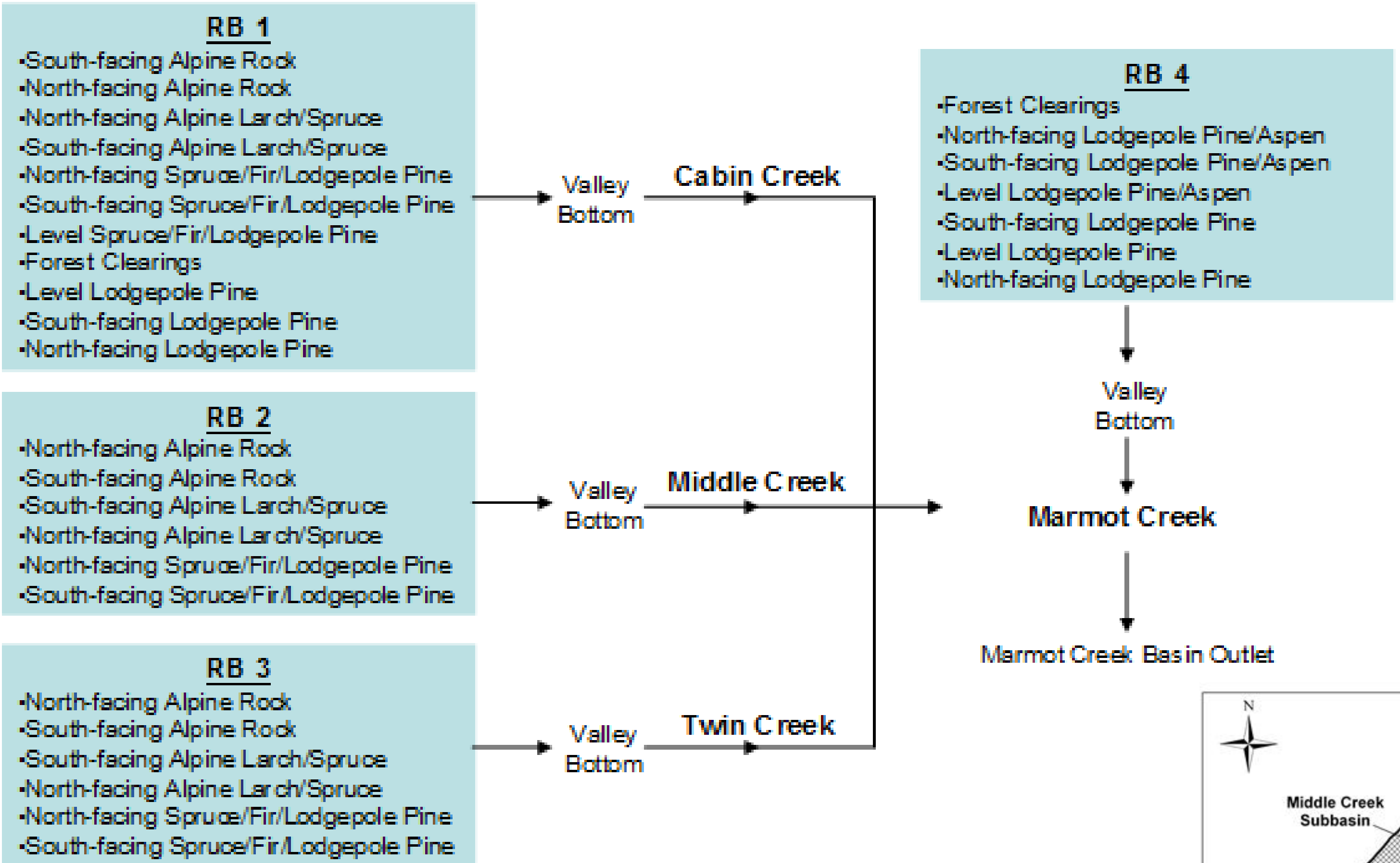


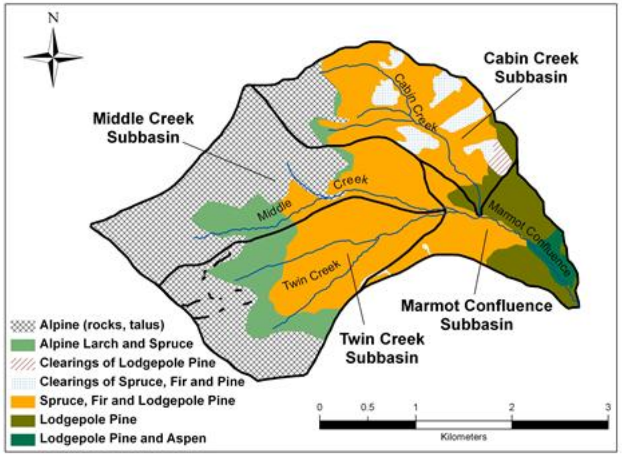
HRU Delineation



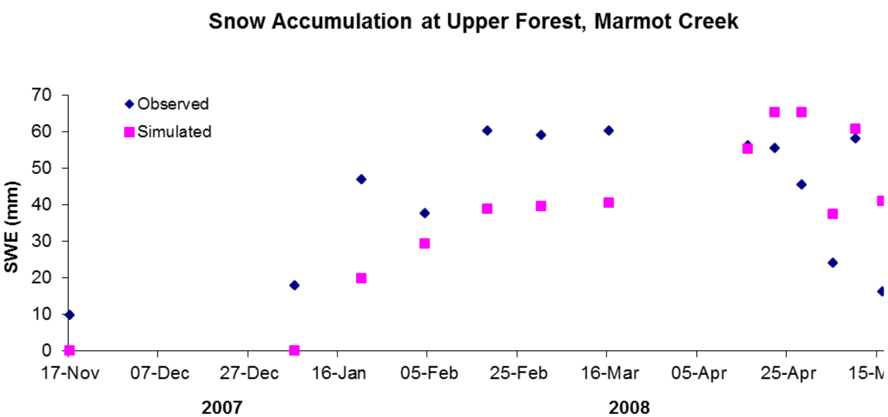
- Driving meteorology: temperature, humidty, wind speed, snowfall, rainfall, radiation
- Blowing snow, intercepted snow
- Snowmelt and evapotranspiration
- Infiltration & groundwater
- Stream network

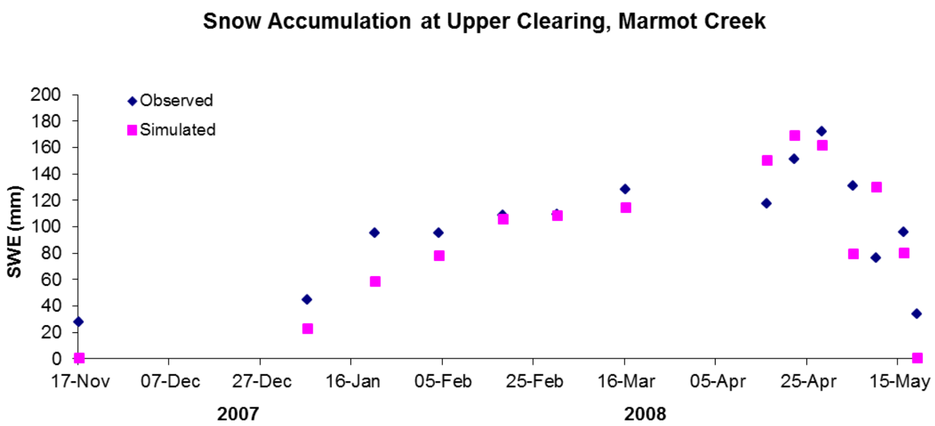
Model Structure

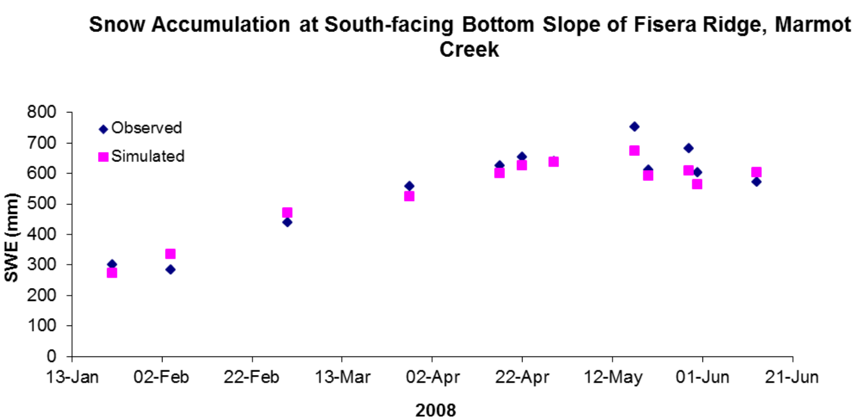


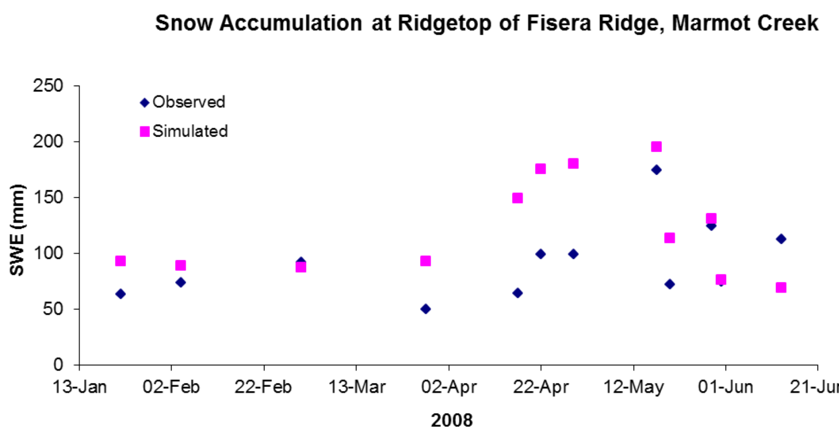


Model Tests - SWE

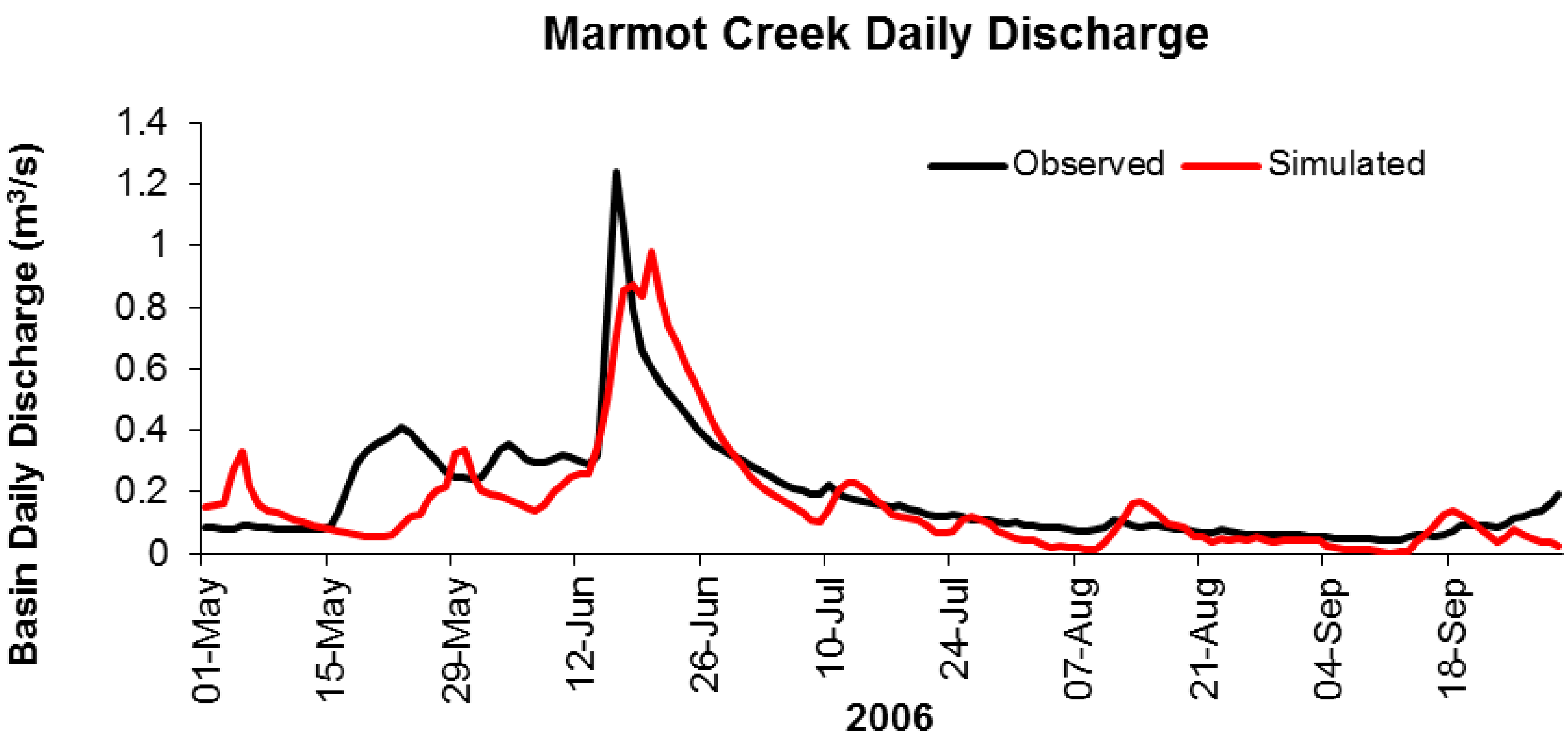


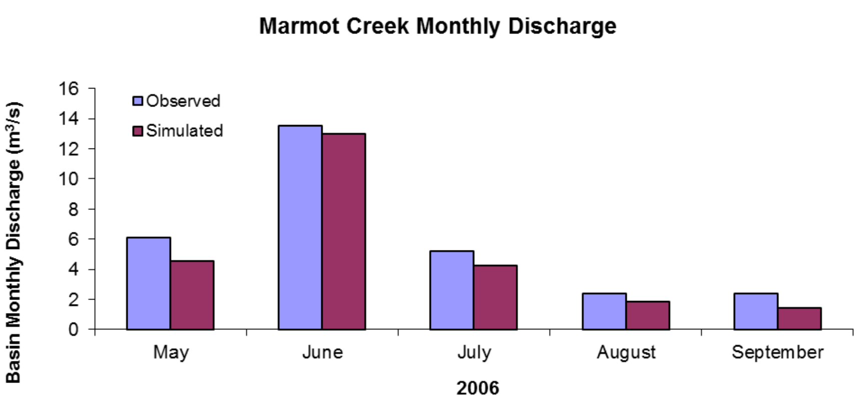






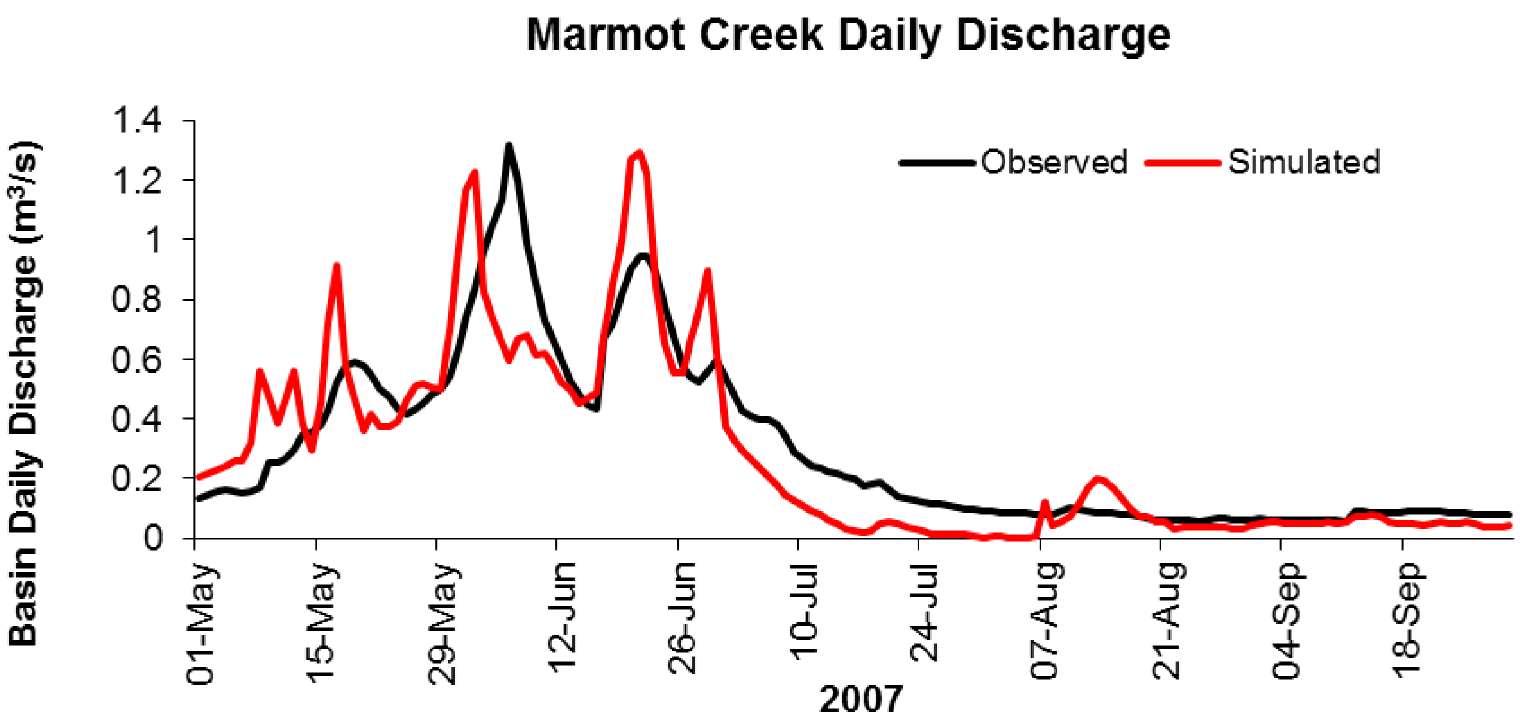
Streamflow Prediction 2006

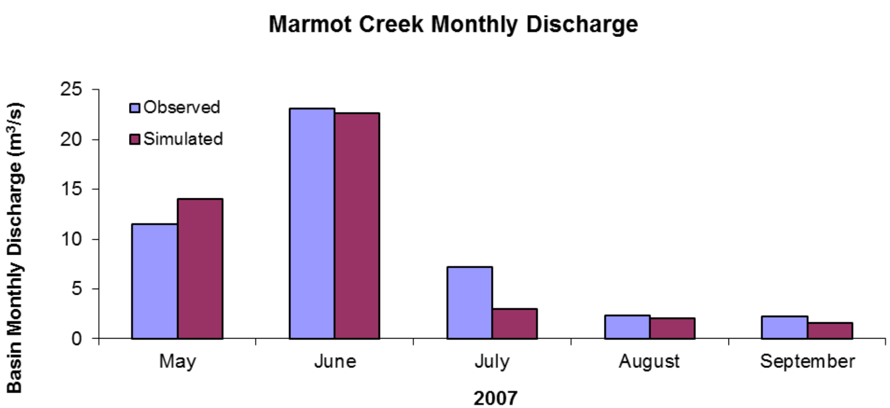




Mean Bias = -0.13
all parameters estimated from basin data

Streamflow Prediction 2007





Mean Bias = -0.068

all parameters estimated from basin data

Conclusions

- Appropriate process based models driven by enhanced remote sensing and good observations can be used to achieve adequate hydrological prediction in the alpine.
- Model process and spatial structure must be appropriate to the complexity of the energy and mass exchange processes as they operate on the landscape.
- It is possible to test for the most appropriate structure for balance between model complexity and predictive ability.