Snow Processes and Parameterisations

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Study Elements

- Processes (also see Marks talk)
  - Snow accumulation, structure and observation
  - Radiation effects on snowmelt under vegetation
  - Turbulent transfer to snow
- Parameterisations (also see Ellis, Essery talks)
  - Blowing snow over complex terrain
  - Sub-canopy snowmelt
  - Spatial associations between accumulation and melt
  - Contributing area for snowmelt
  - Areal infiltration and runoff generation
- Prediction (see Pietroniro talk)
  - Level of spatial complexity necessary in models
  - Snow modelling contribution to MESH

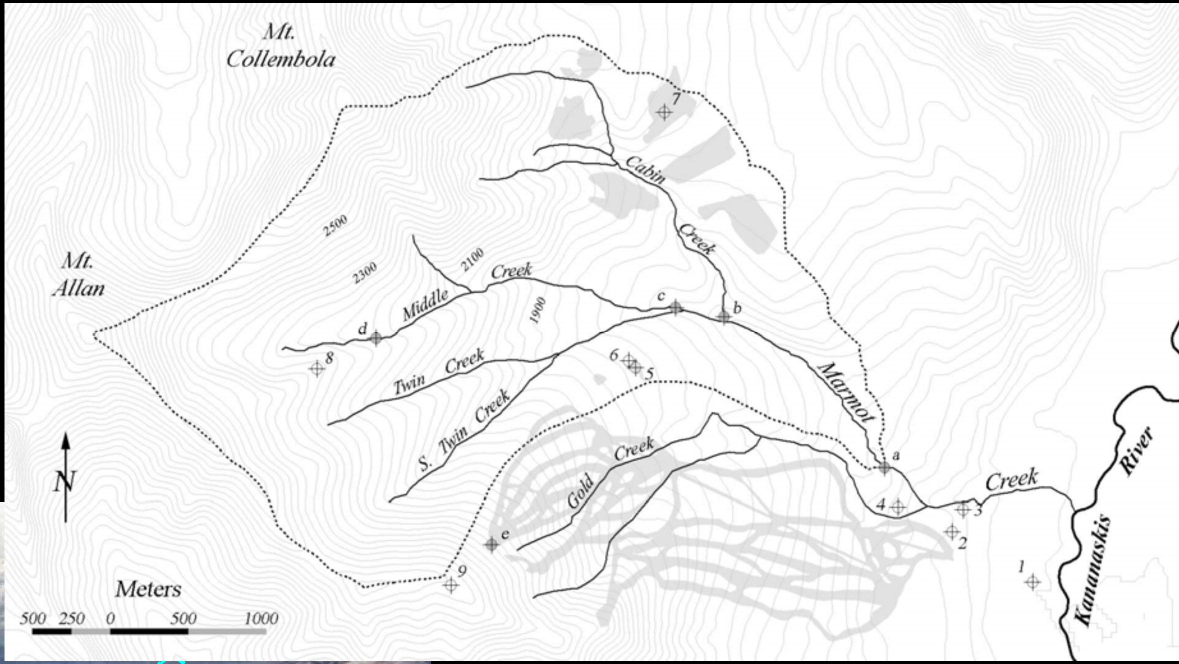
Marmot Creek

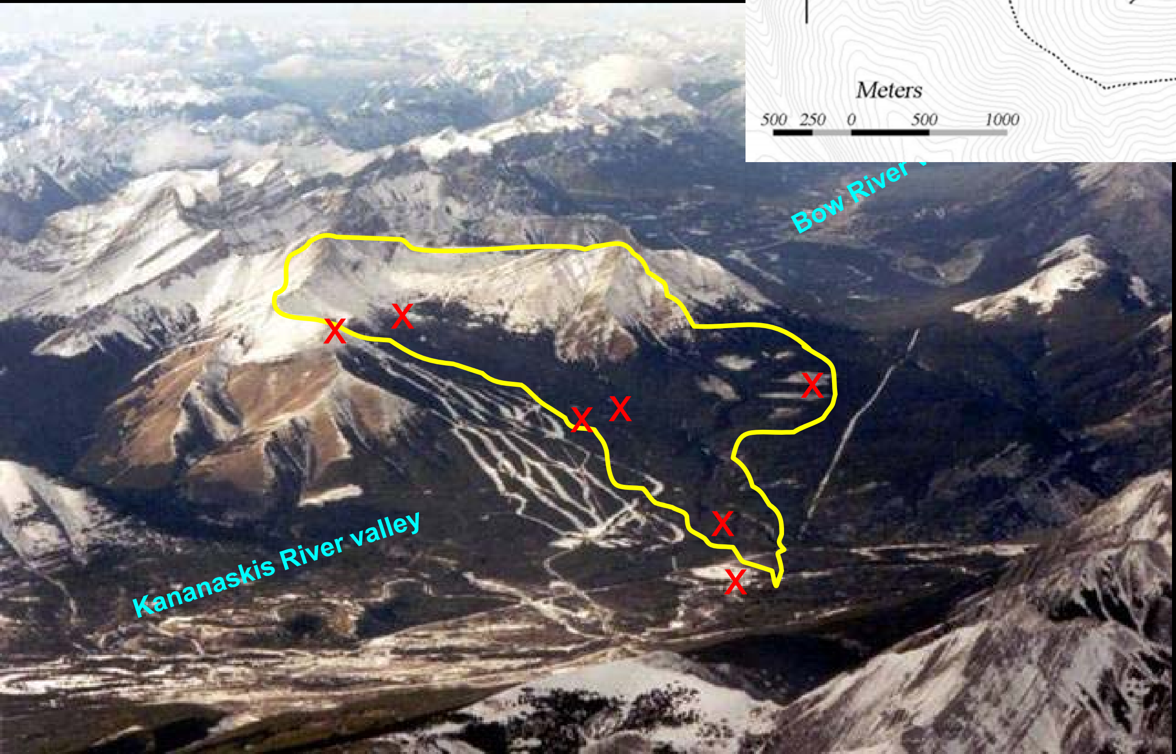
Marmot Creek, Alberta
-montane, subalpine forest
-alpine tundra
-steep alpine topography
-eastern slopes climate
-10 meteorological stations
-WSC streamflow gauge
-3 U of S streamflow gauges

Wolf Creek

Wolf Creek, Yukon
-boreal forest
-shrub and sparse tundra
-sub-arctic to arctic climate
-4 meteorological stations
-Snow pillow
-4 Yukon Environment streamflow gauges

Marmot Creek Research Basin

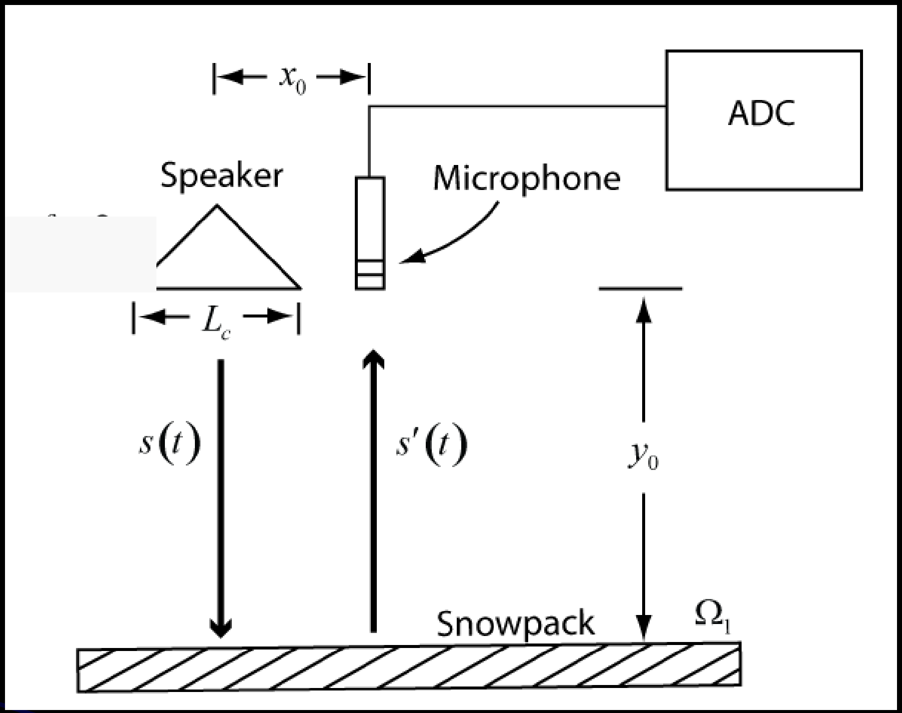




Snow Accumulation, Structure, and Observation

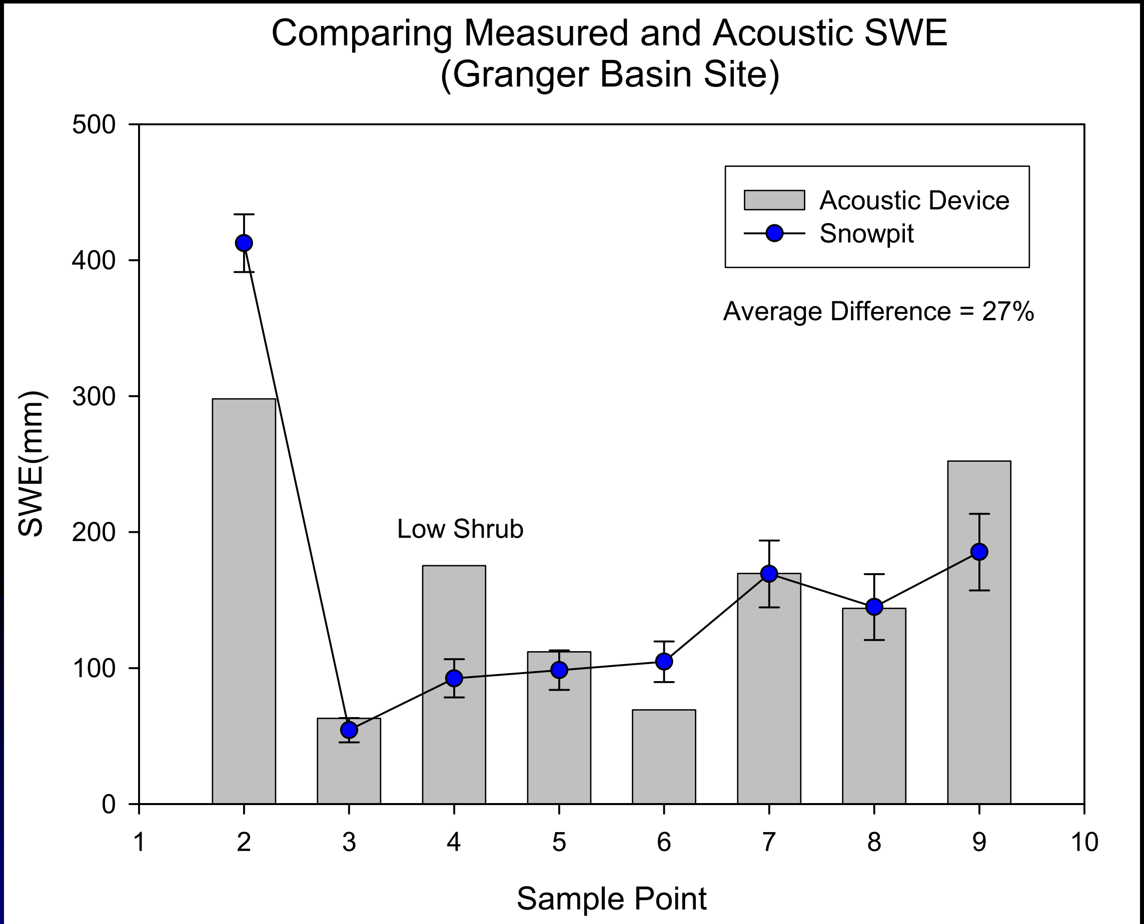
- Acoustic observation of depth, porosity and tortuosity from snow layers
- Interception and unloading of snow from mountain forests

Acoustic Determination of SWE



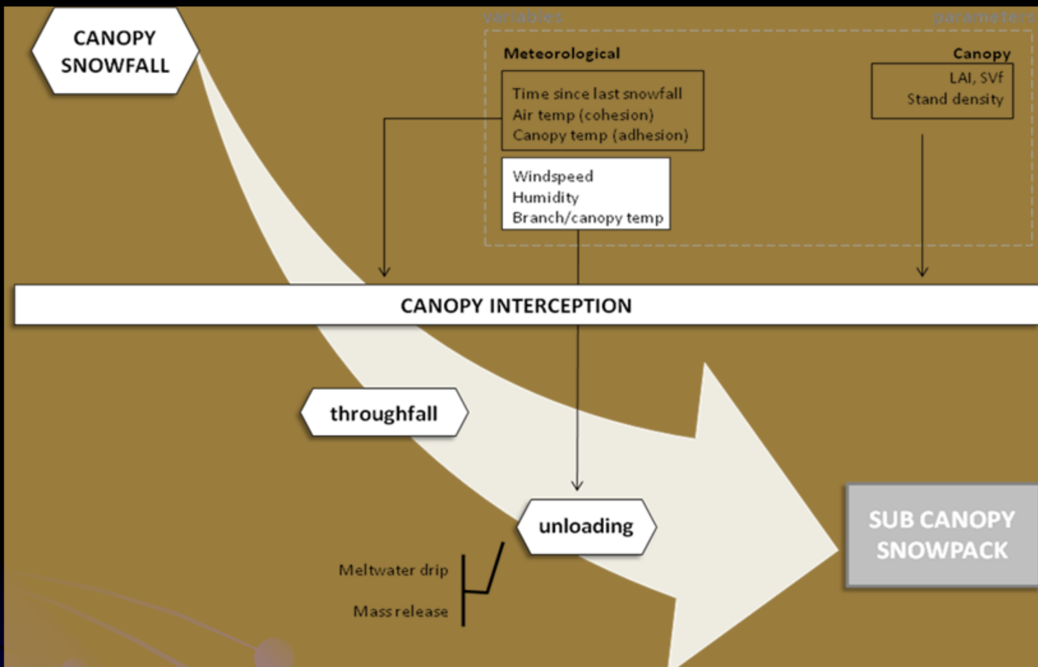
- Digital signal processing adapted from Frequency-Modulated Continuous-Wave (FMCW) Radar
- Continuous sound pulse in the audible frequency range (20 Hz to 20 kHz)
- Solution based on Biot's theory and Berryman's relationship
- Layer and total depth and porosity estimated from returned acoustic signal
- Non destructive sampling

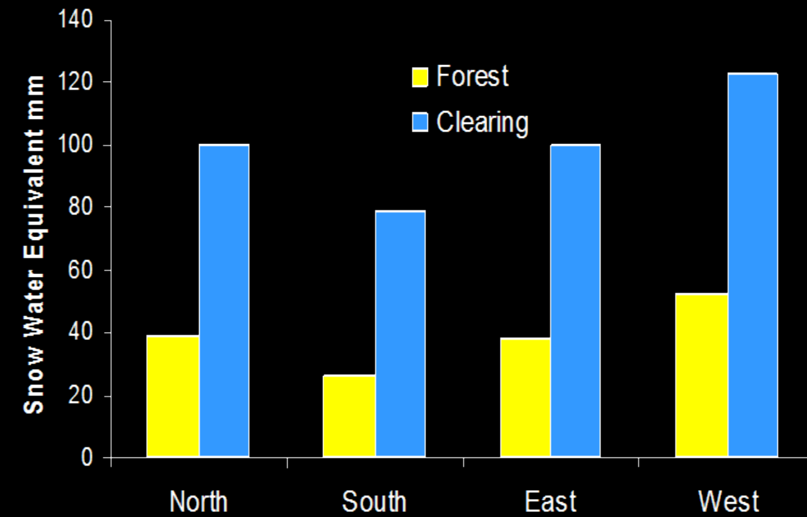
SWE Estimates Possible where Snow Tubes Fail



Low Shrub

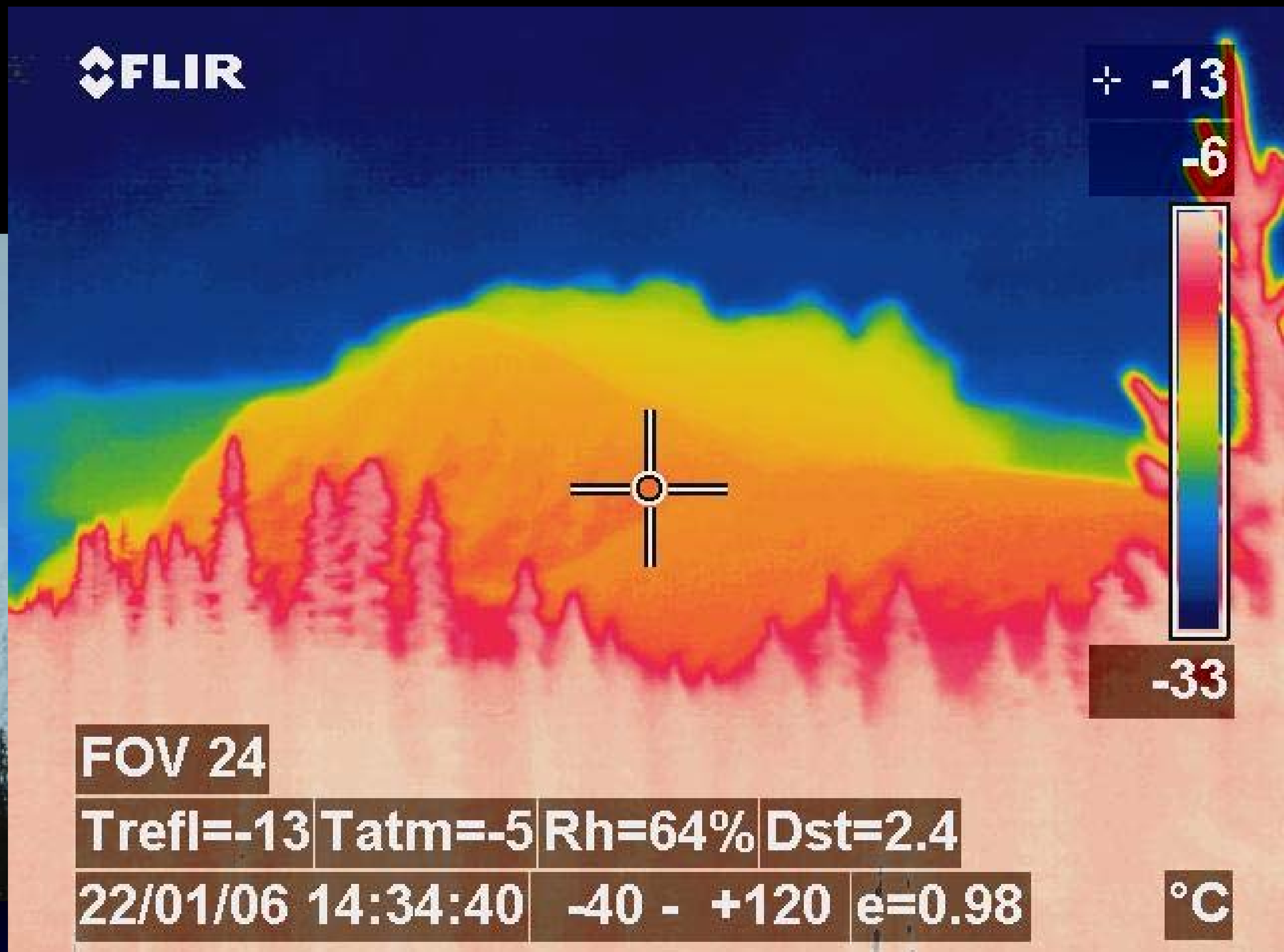
Snow Interception & Unloading



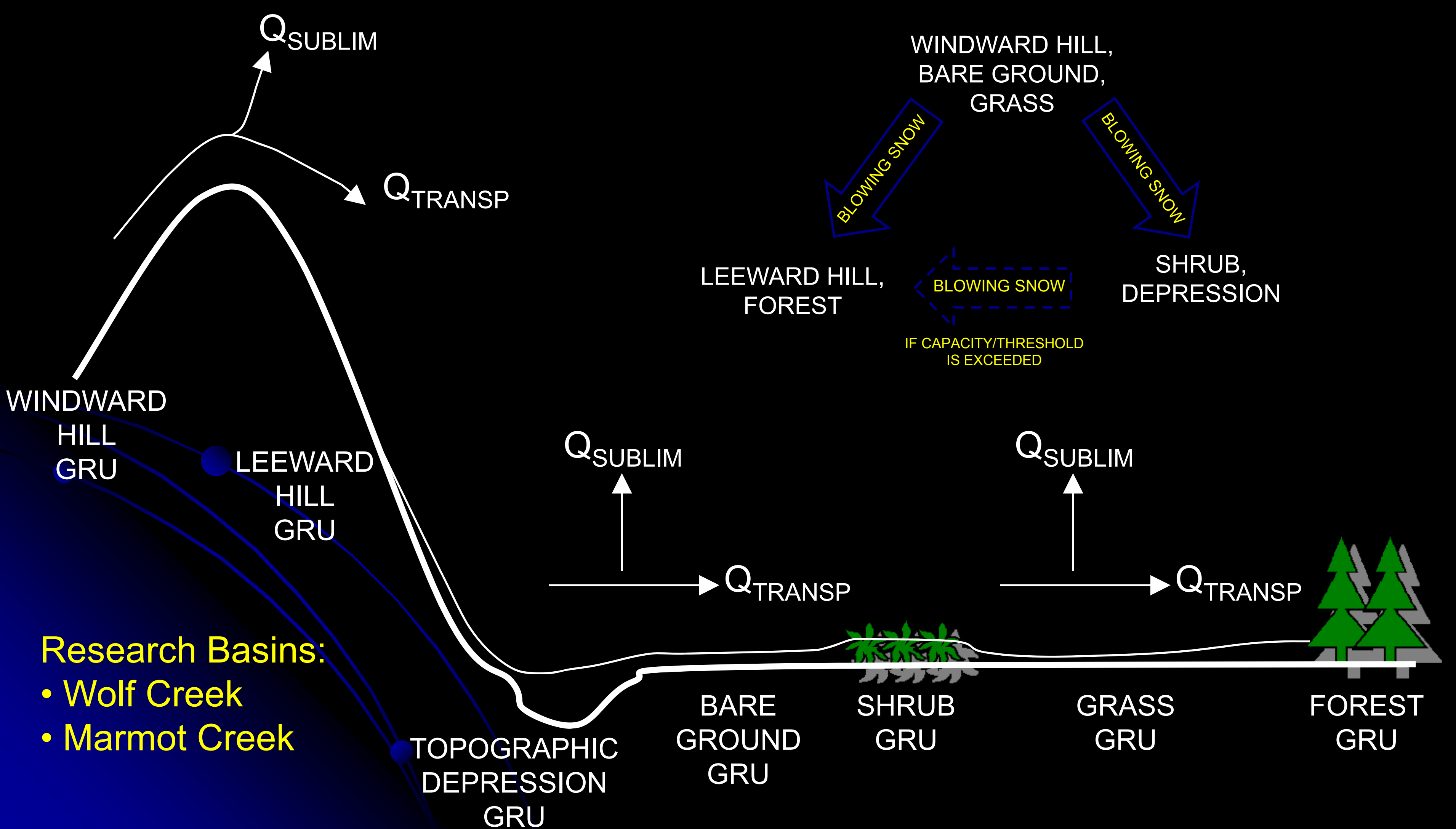


-Greater interception than observed elsewhere
-Frequent unloading events in mountains
-Current model might be wrong…….
-Unloading during wind gusts

Alpine Blowing Snow: Flow Separation



GRU-to-GRU Blowing Snow Transport Over Complex Terrain for MESH



Research Basins:

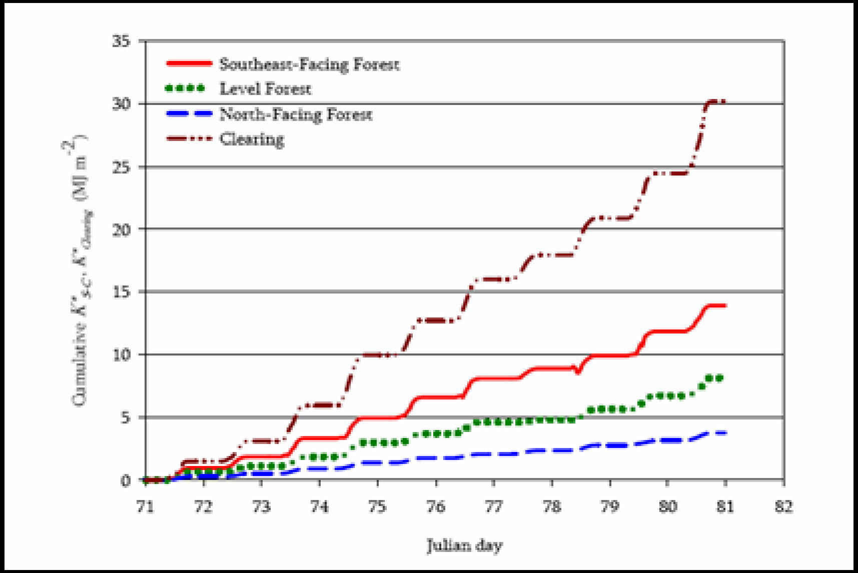
- Wolf Creek
- Marmot Creek

Radiation Effects on Snowmelt under Vegetation

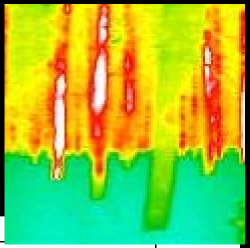
- Longwave radiation from shrubs, tree trunks and needles
- Shortwave extinction by shrubs, and forests on slopes
- Radiation in sparse canopies and gaps
- Associated sub-canopy turbulent transfer

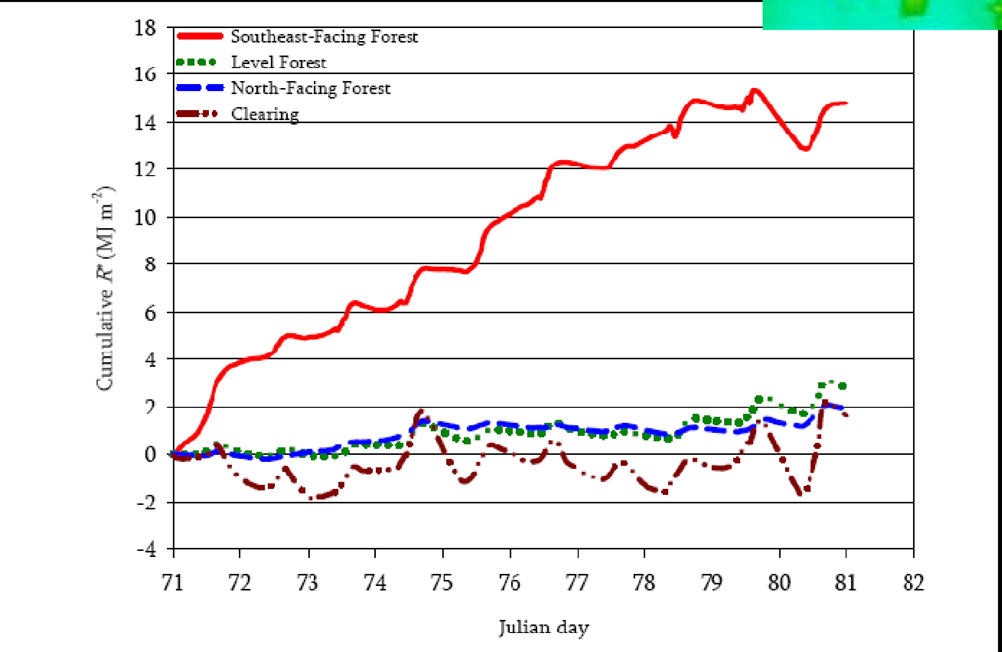
Radiation to Snowmelt on 25º Forest Slopes, Marmot Creek Research Basin, Alberta

Net Shortwave Radiation

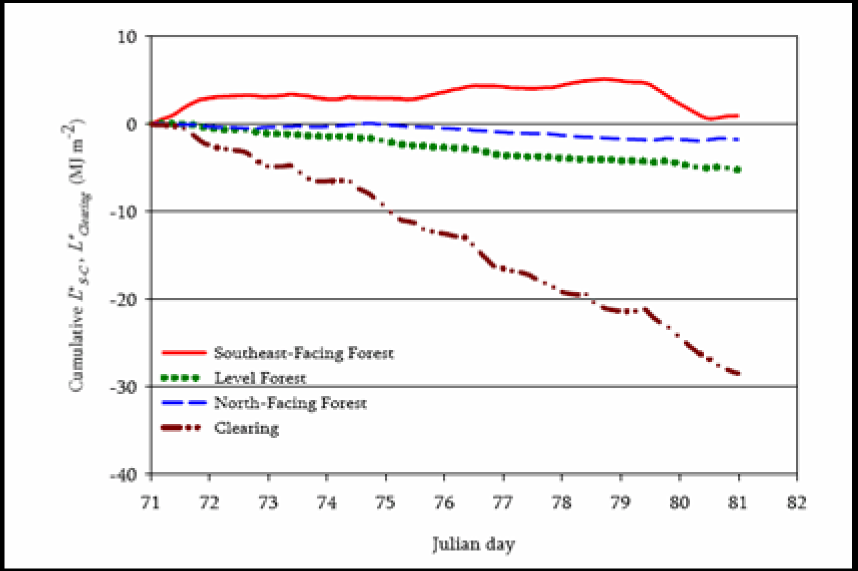


Net Allwave Radiation

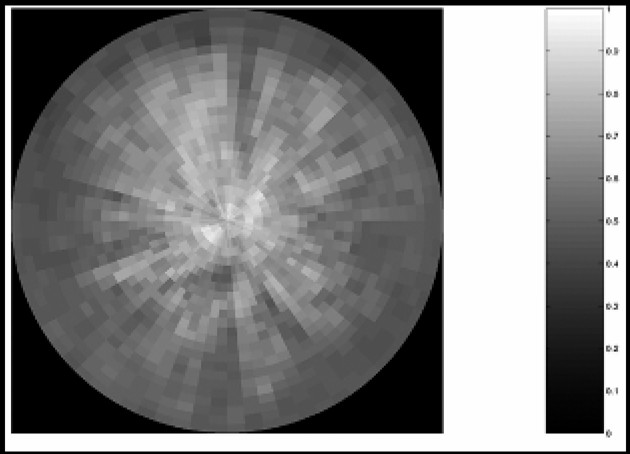




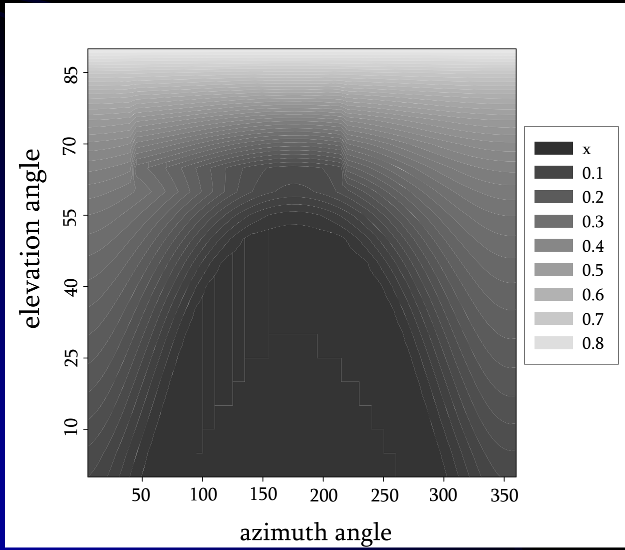
Net Longwave Radiation



Slope Forest Transmissivity

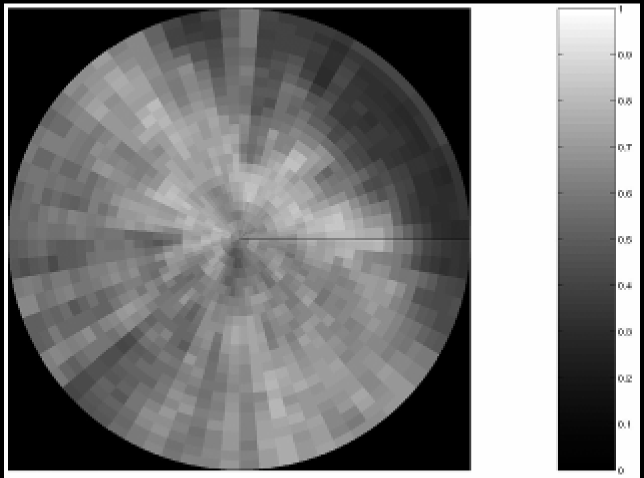


North Face Forest

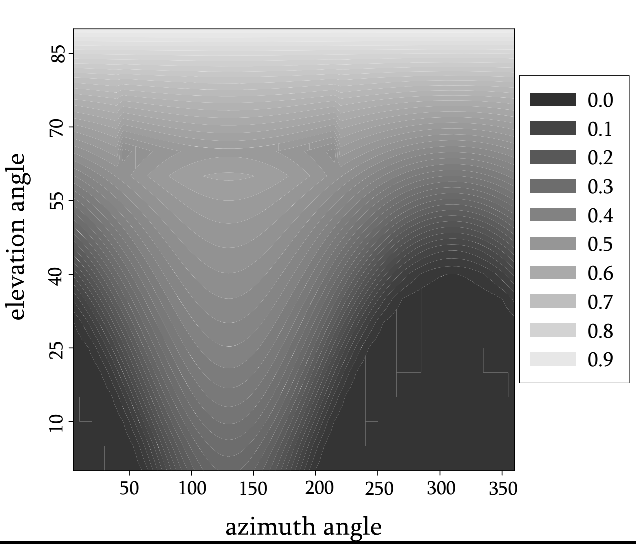


τ a function of
LAI,
Foliage inclination
Crown coverage
Slope,
Aspect,
Solar azimuth,
Solar elevation

Model of solar radiation transmission through continuous evergreen canopy on slopes



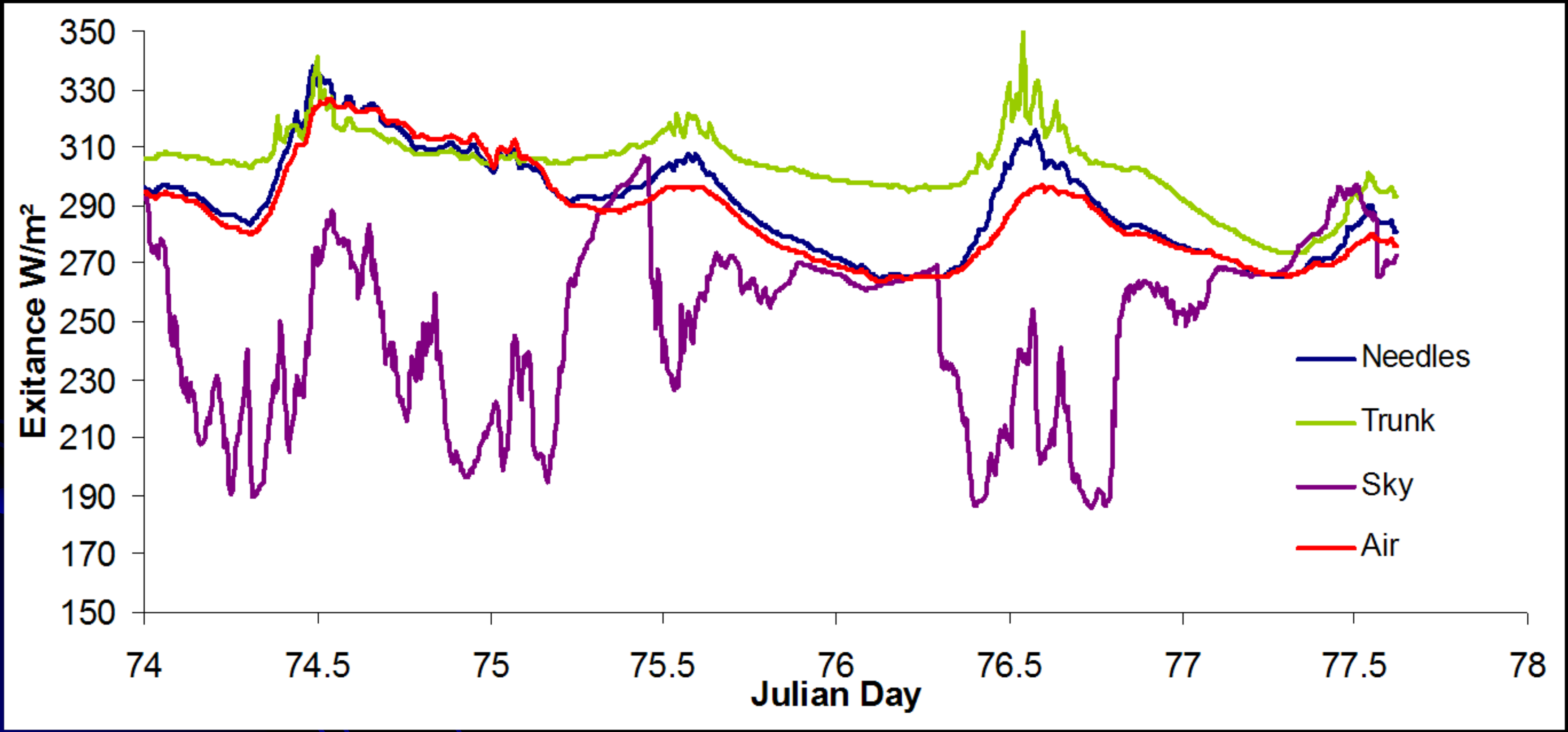
South Face Forest



Hot Trees

- Longwave radiation is an important component of snowmelt energy
- Longwave from trees dominates longwave in forests
- High melt rates are observed close to tree trunks in sparse forests
- Many assume that the tree temperature is equal to the air temperature during snowmelt
- This assumption has not been well tested……

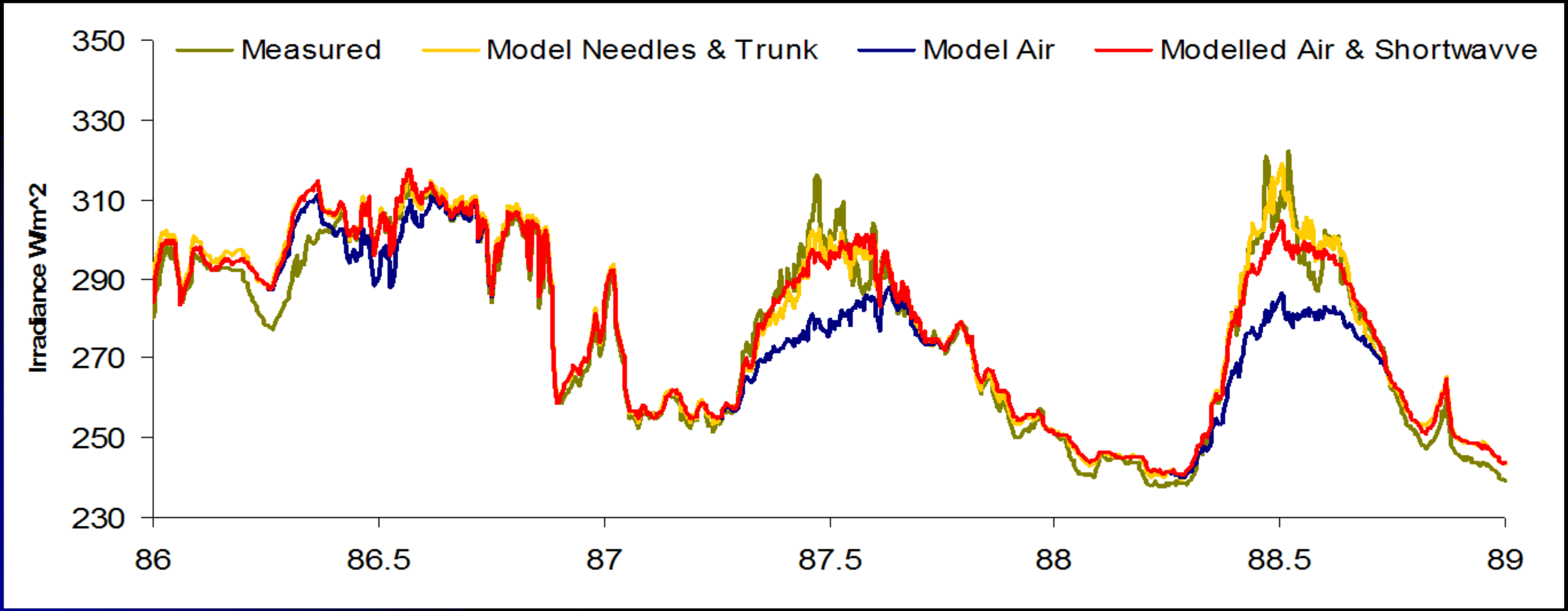
Longwave Exitance Pine Stand



Estimating Canopy Contribution to Downward Longwave

Air Temperature Model: all temperatures are air temperature, segregate by sky view V_f and emissivity ε

Air Temperature & Shortwave Extinction Model: common temperature at air temperature with shortwave extinction term B K^*_H that accounts for shortwave conversion to longwave

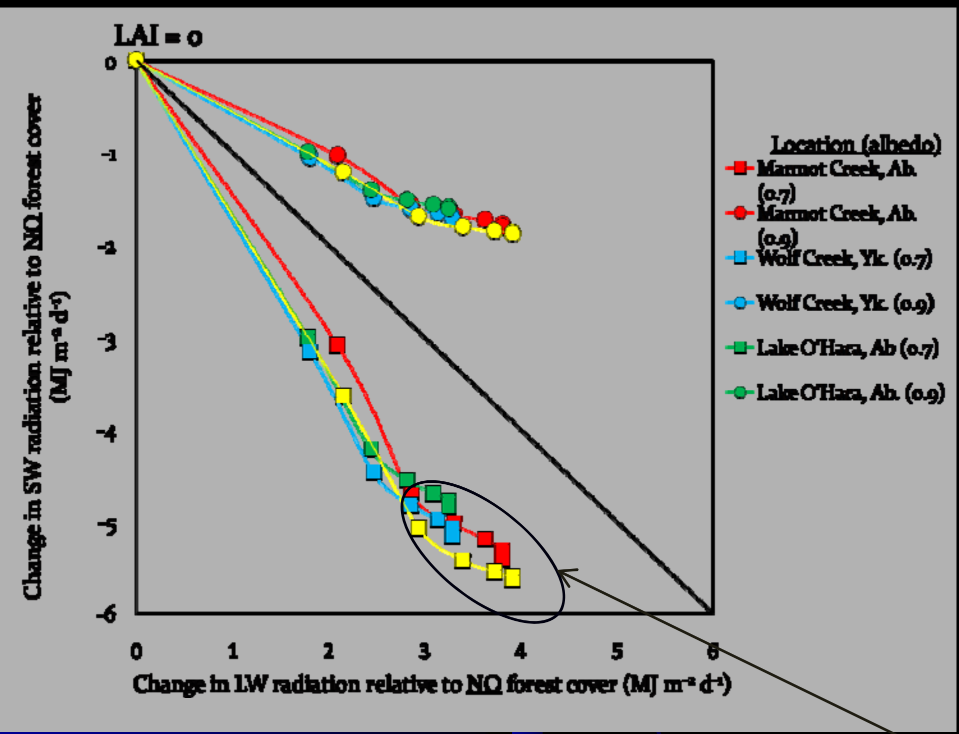


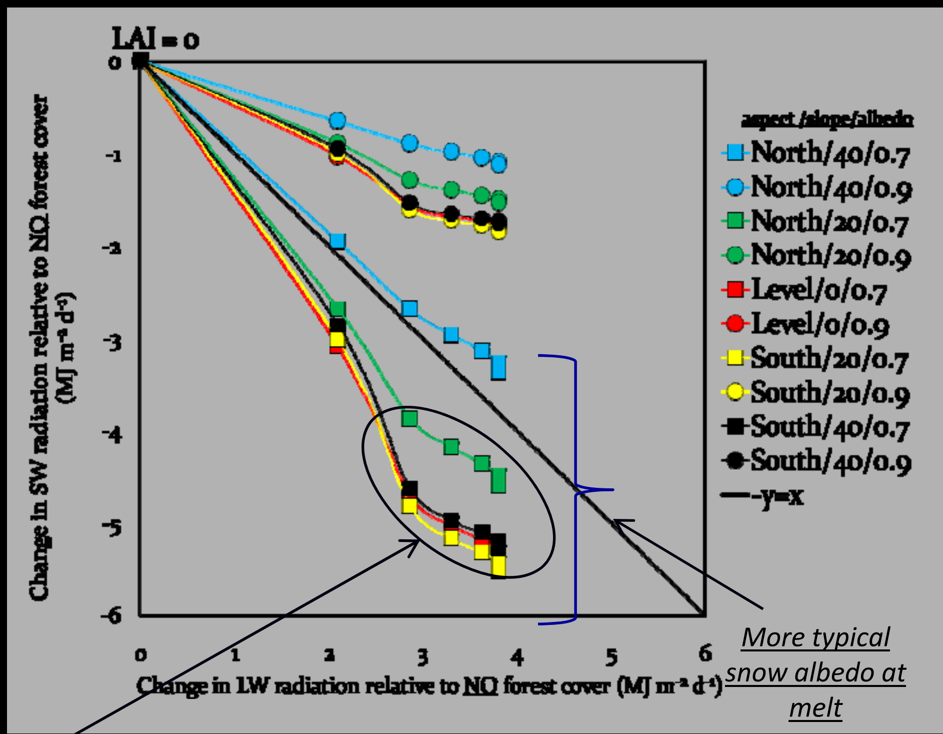
Radiation Paradox for Snowmelt: Albedo and Slope Effects

-Longwave radiation model (Sicart et al 2004)
-Shortwave Radiation Model (Pomeroy & Dion, 1996)
-Driven by IP3 Basin data

By Location: radiation to snow strongly controlled by albedo; little difference in total radiation between sites of differing elevation and/or latitude.

By Topography: radiation to snow also strongly controlled by albedo but also by topography. Increased forest cover results in grater total radiation to steep north-facing forests regardless of albedo.

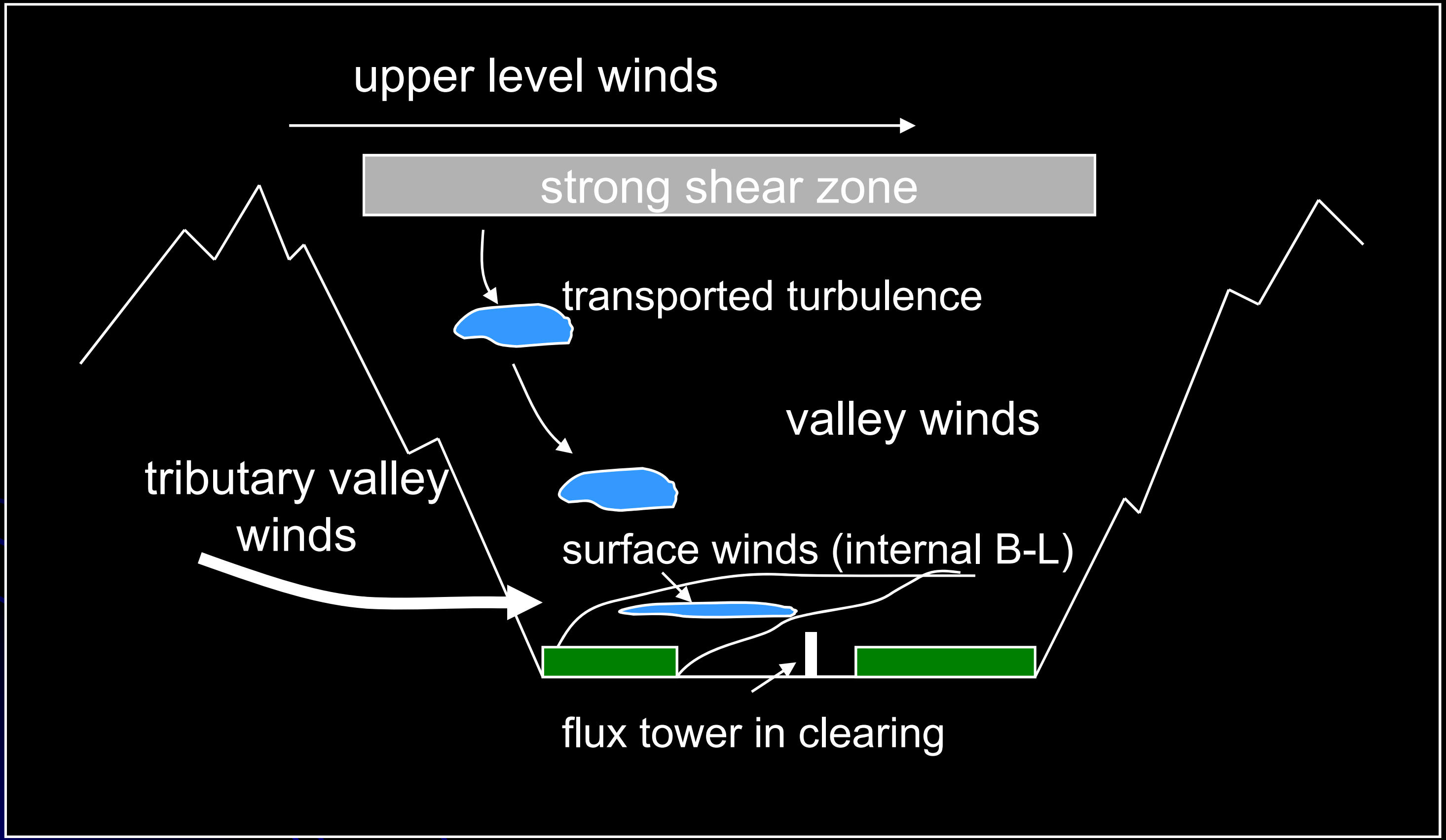




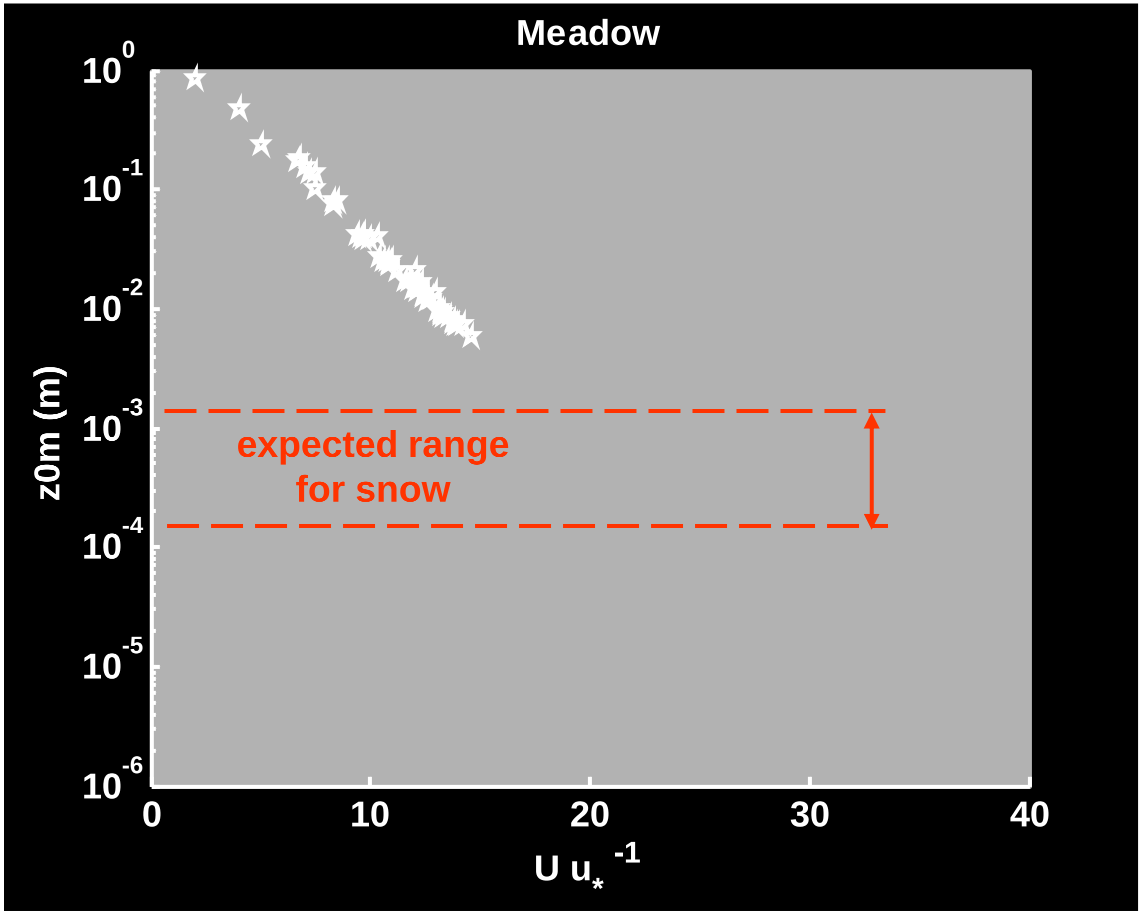
More typical snow albedo at melt

Slight gains in radiation at higher forest cover densities

Turbulent Exchange: Mountain generation mechanisms



Roughness Length (z_{0m})



$$\frac{U}{u^*} = \frac{1}{k}\left[\ln\left(\frac{z}{z0m}\right) - \psi_m(\zeta)\right]$$

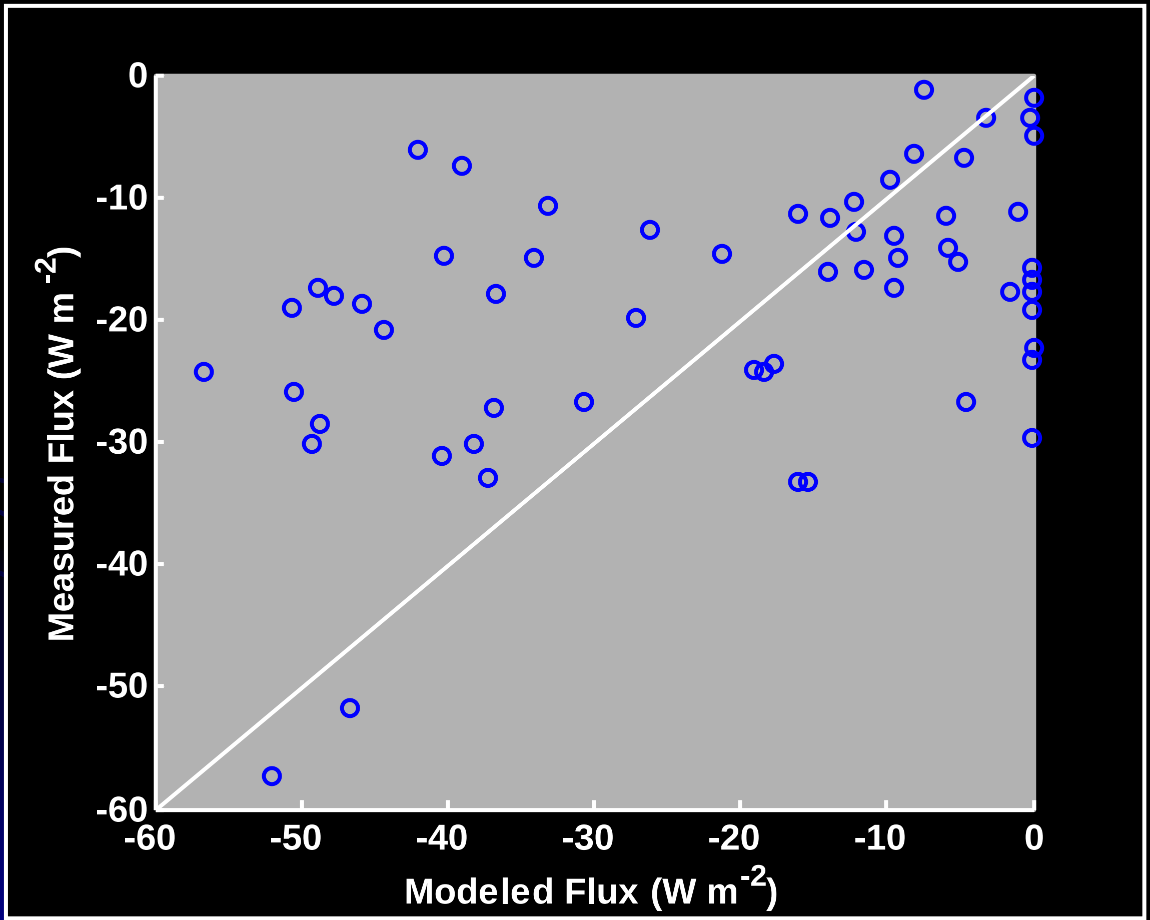
$0 < \zeta < 0.1$

Enhanced roughness in mountain valleys due to horizontal component of turbulence from surrounding terrain

Flow has intermittent turbulence at open prairie site typical of tundra plains

Typical Bulk Transfer Estimation Results

Sensible heat flux in meadow site (mountain valley)

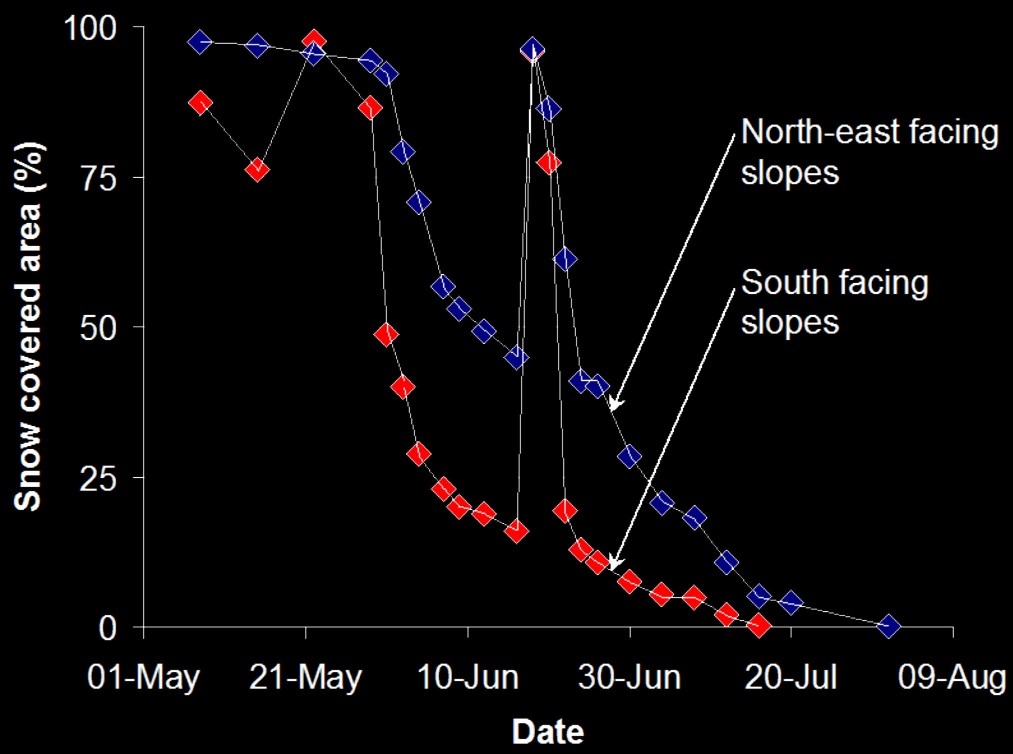


Horizontal component of turbulence adds momentum without contributing to vertical transport, causing failure of normal stability parameterisations of turbulent transfer in mountain valleys

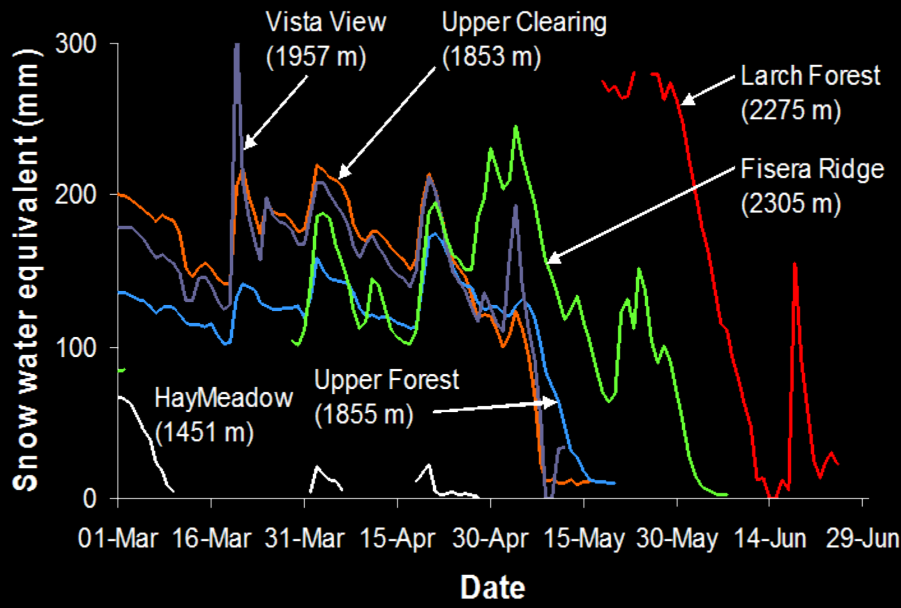
Basin Snowmelt and Areal Depletion

- Variable SWE
- Variable Melt Rate
- Spatial Associations between the two
- Modelling Implications

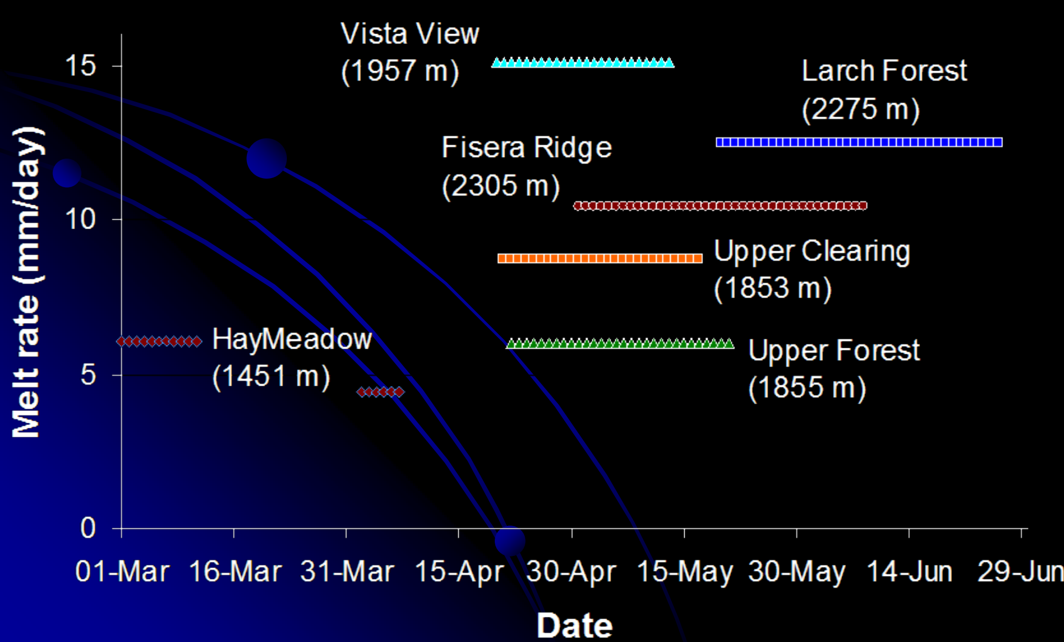
Snowcover Depletion in Alpine Basins

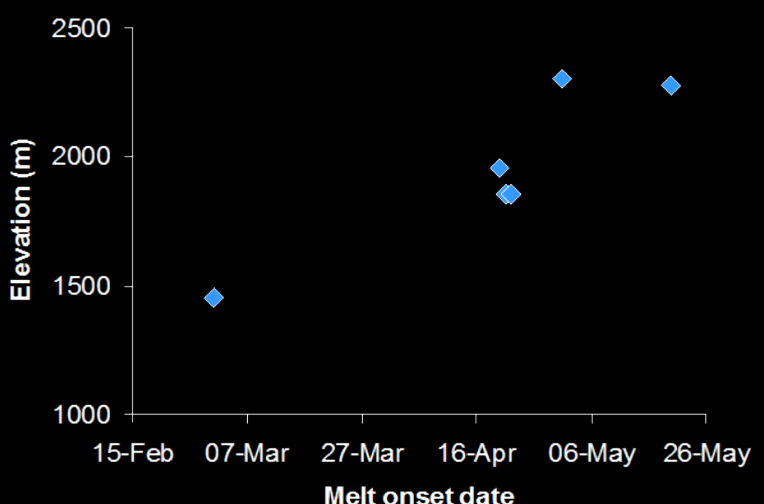


- Temporal snow cover depletion patterns differ considerably between slopes within ~1 km^2 cirque basin
  - Single SCD curve cannot be applied even for relatively 'small' scales in mountain terrain

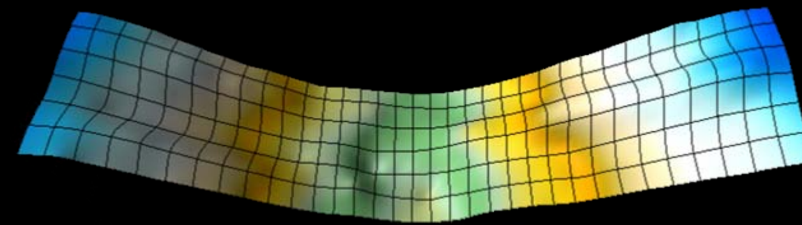


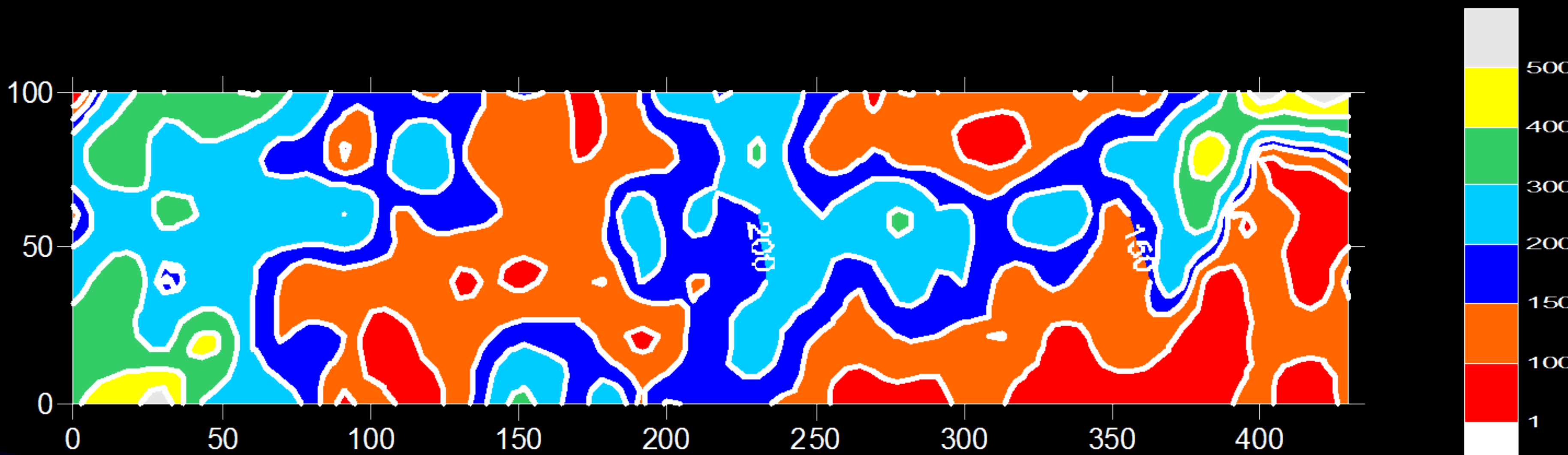
- Spatial association between SWE, melt rates, and melt timing.
  - Greater end-of-winter SWE at higher elevations,
  - Earlier melt onset at lower elevations,
  - Higher melt rates later in spring when deep snow at higher elevations is melting.



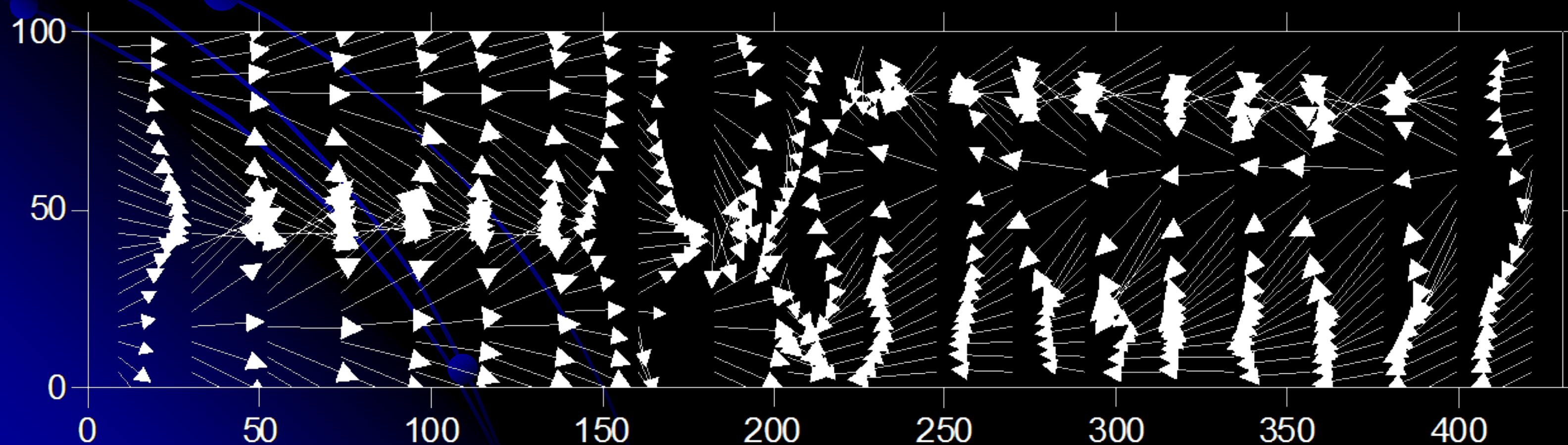


Snowmelt Runoff





North Face Valley Bottom South Face



Next Steps

- Multi-layer snow physics model
- Snow Interception and Unloading in Mountains
- Blowing snow parameterisation for CLASS/MESH
- 3-D Blowing Snow – small, medium and MEC scale
- Snow-atmosphere exchange parameterisation
- Complex Terrain Forest Melt Algorithms
  - Sparse canopy
  - Full integration of warm vegetation canopy effects
- Sub-grid distributions of accumulation, energy, melt for complex terrain
- Quantify and Correct for the Effect of Spatial Associations on Runoff Contributing Area from Melt in Complex Basins
- CRHM basin modelling and interface to MESH