CLASS with blowing snow algorithms: tests over alpine terrain

Matthew K. MacDonald, John W. Pomeroy and Alain Pietroniro
Centre for Hydrology, University of Saskatchewan,
117 Science Place, Saskatoon, Saskatchewan, Canada, S7N 5C8

Background

❖Snowcover over complex terrain is highly variable due to blowing snow redistribution

❖Field observations and modelling difficulties offer strong evidence that accounting for blowing snow transport and sublimation is necessary to simulate snowcover depletion and runoff in windswept terrain.

❖The current versions of CLASS and MESH do not include blowing snow sublimation, transport and redistribution algorithms.

Scope and Objectives

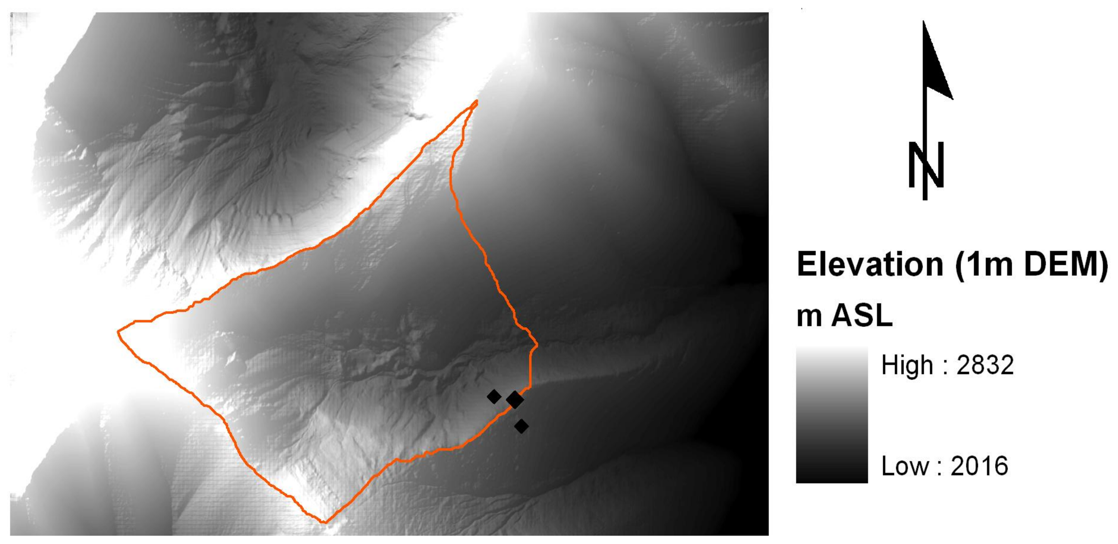
❖Blowing snow sublimation and transport algorithms from the Prairie Blowing Snow Model (PBSM) were incorporated in the Canadian Land Surface Scheme (CLASS) version 3.4.

❖Point simulation of snow depth using CLASS without and with blowing algorithms (CLASS and CLASS-PBSM, respectively) were compared to snow depth measurements.

❖The next step is to produce distributed snowcover simulations over mountainous terrain (i.e. over multiple landscape units).

Study Site

Fisera Ridge, Marmot Creek Basin, Kananaskis Country, Alberta

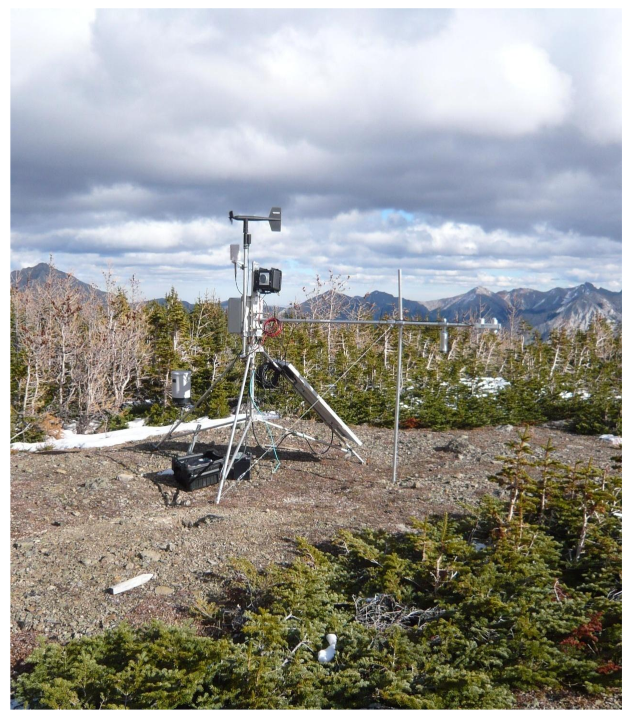


Location:
50º 57' N, 115º 10' W

Mean Elevation:
2310 m ASL

Mean Annual Precipitation:
900 mm (60-75% snow)

Mean Temperatures:
-8 to -5 ºC
(September-April)



❖Landcover: 25% needleleaf shrubs, 25% grass, 50% bare ground/rocks

Data

❖Three years of simulations: 2006/2007, 2007/2008, 2008/2009

❖Meteorological and sonic now depth data was obtained from a hilltop station located on Fisera Ridge.

❖Precipitation data was obtained from a GEONOR precipitation gauge at 1845 m ASL (2006/2007 and 2007/2008) and at Fisera Ridge (only 2008/2009).

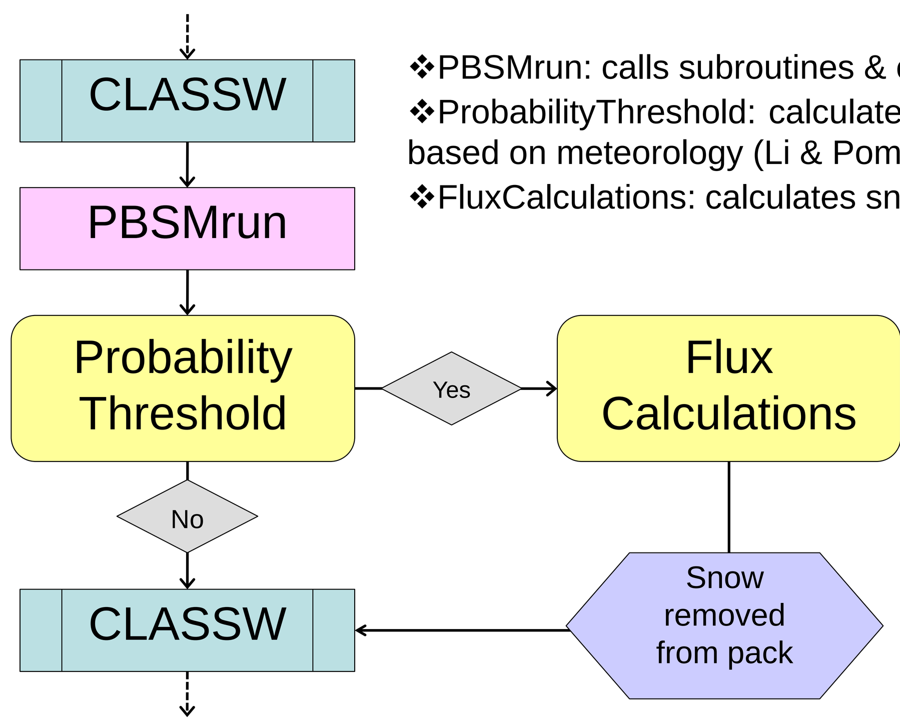
❖Model runs were initialized using soil temperature measurements made at 1845 m ASL

Model Structure

❖PBSM algorithms (Pomeroy et al., 1993; Pomeroy and Li, 2000) were coded into the water budget calculation routine (CLASSW).

❖Blowing sublimation and transport calculations were performed for two of the four CLASS subareas: snow-covered ground and canopy over snow.

❖PBSM calculations were separated into three subroutines.



❖PBSMrun: calls subroutines & calculates changes to snowpack
❖ProbabilityThreshold: calculates probability of blowing snow occurrence based on meteorology (Li & Pomeroy, 1997)
❖FluxCalculations: calculates snow transport & sublimation rates

❖Thermodynamic feedback due to blowing snow sublimation is addressed empirically in PBSM vertical atmospheric profiles.

❖No changes were made to surface energy balance calculations (CLASST) at this stage.

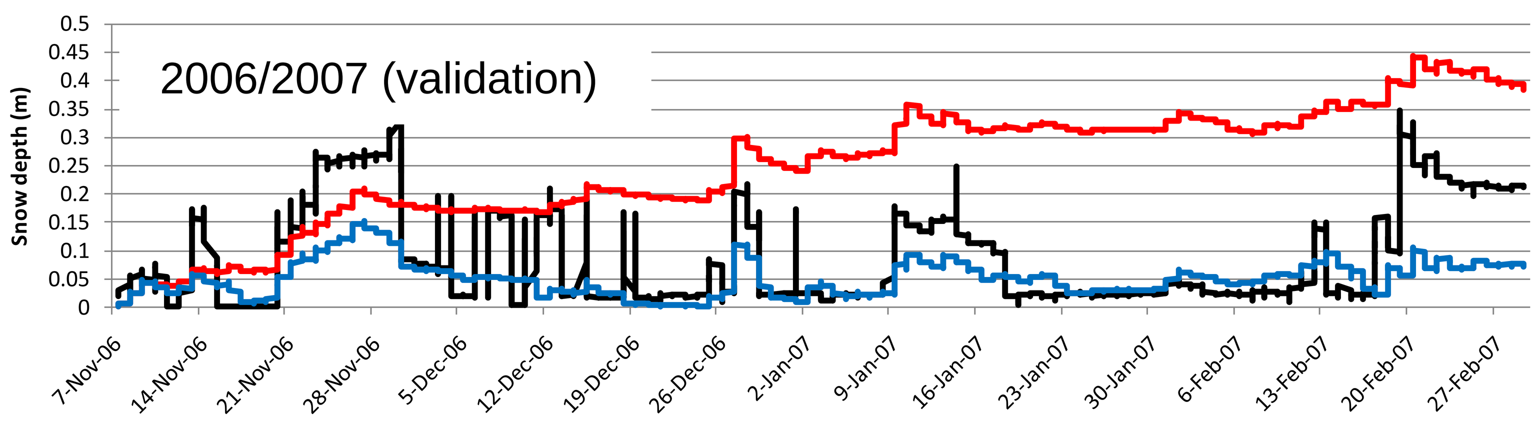
Modelling Strategy

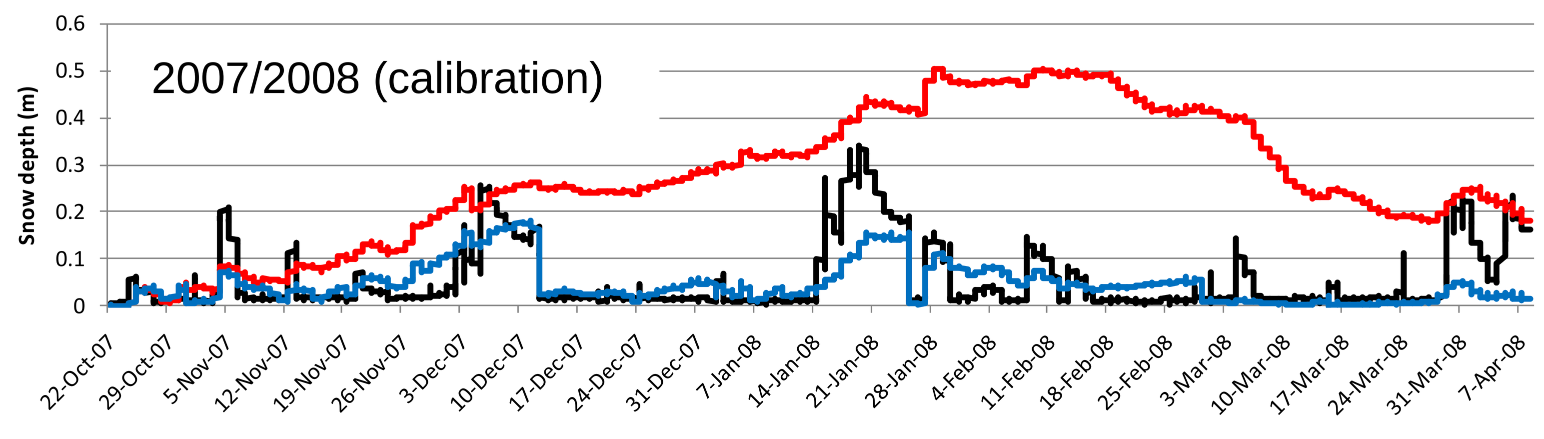
❖ CLASS and CLASS-PBSM were calibrated using the Dynamically Dimensioned Search algorithm (DDS; Tolson and Shoemaker, 2007) to SR50 sonic snow depth measurements for 2007/2008 and validated for the other years.

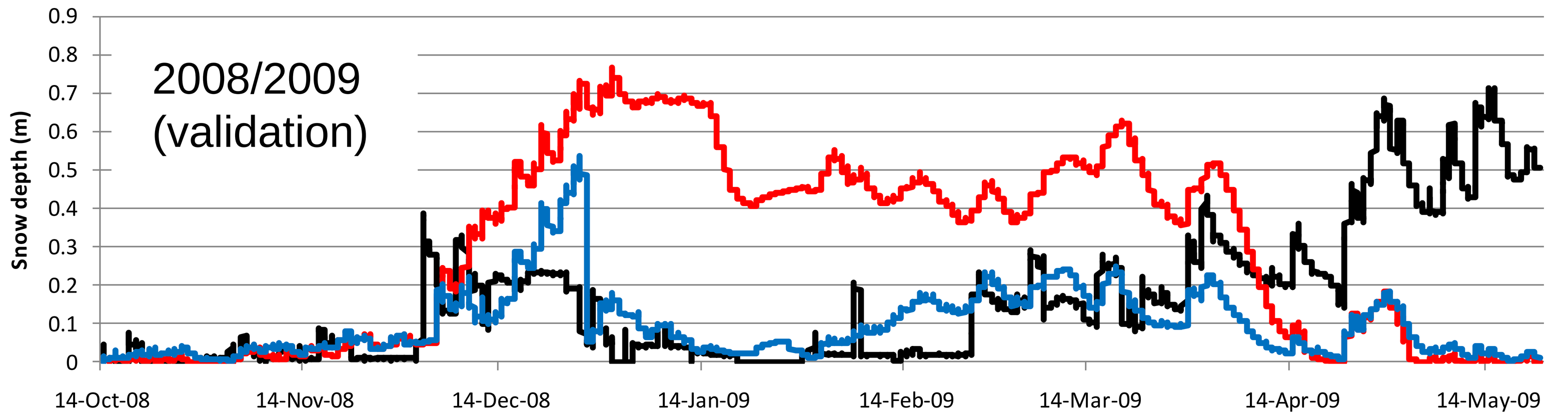
❖CLASS parameters calibrated: vegetation albedo, roughness length, minimum and maximum LAI, and D100 limiting snow depth

❖Additional PBSM parameters calibrated: vegetation height and density

Results







Observed   CLASS   CLASS-PBSM

Discussion

❖ CLASS-PBSM provided significantly better simulated snow depth than CLASS.

Year	Snow transport (mm)	Blowing snow sublimation (mm)
2006/2007	17.8	67.4
2007/2008	35.4	117.1
2008/2009	38.6	208.0

Year	RMSE (cm)		MB	
	CLASS	CLASS-PBSM	CLASS	CLASS-PBSM
2006/2007	20.2	7.7	1.82	-0.43
2007/2008	26.1	5.4	4.03	-0.14
2008/2009	35.8	19.2	0.86	-0.37

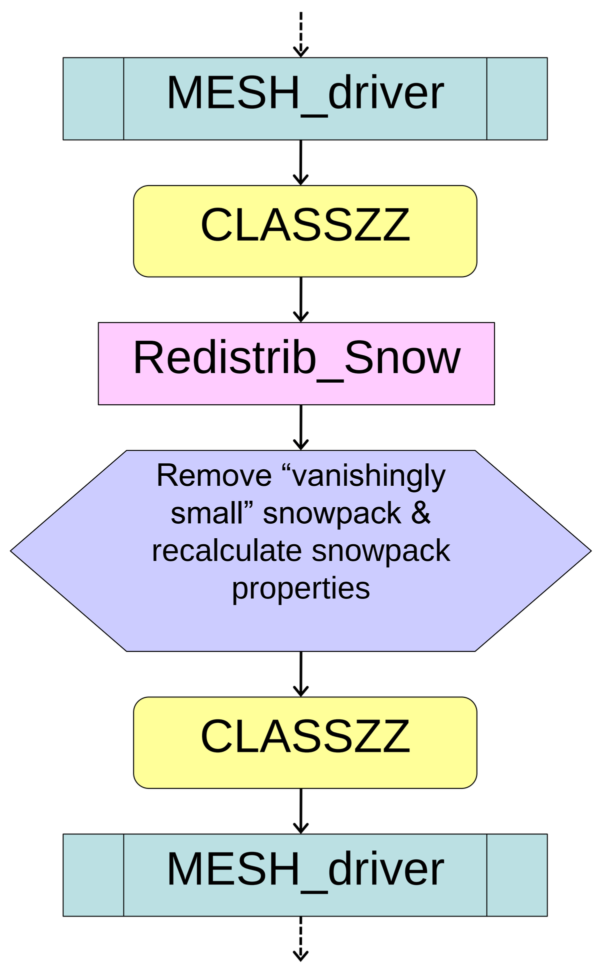
❖ Difficulties remain with rapid snowmelt, particularly during late winter and spring.

Framework for inter-tile snow redistribution

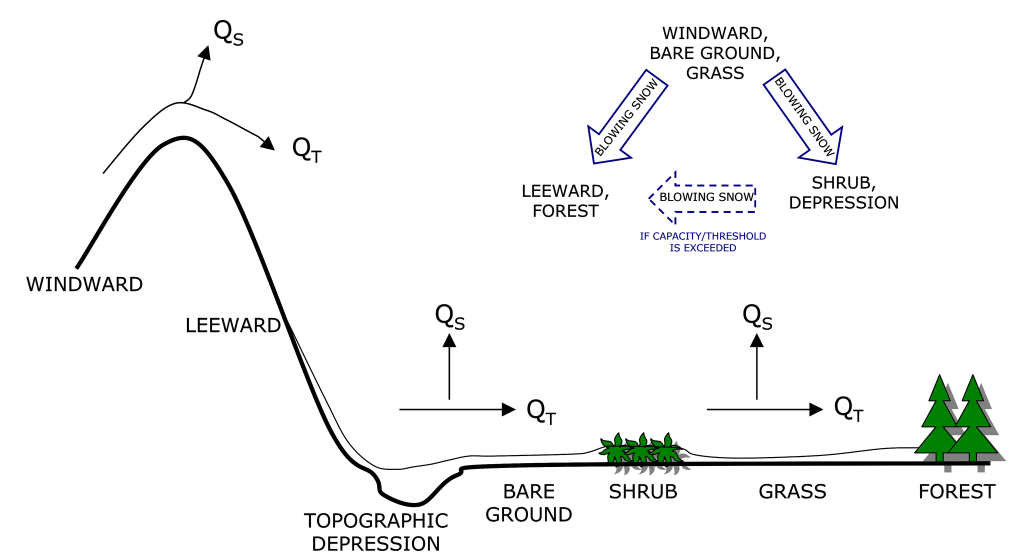
❖ There is now a framework within MESH to redistribute snow transport amongst multiple landscape units with a grid square.

❖The inter-tile snow redistribution parameterization requires one parameter per landscape unit.

❖*Snow redistribution factor*: percent of aggregated calculated snow transport that is to be deposited within a given landscape unit.



❖MESH_driver: calls all MESH routines including data reading, CLASS and hydrologic routing
❖CLASSZZ: performs energy & water balance checks
❖Redistrib_Snow: redistributes blowing snow mass, calculates changes to snowpack properties



❖This *redistribution factor* algorithm can be generalized and applied to other hydrological fluxes (e.g. overland flow between landscape units).

Conclusions

❖ CLASS simulations over windswept terrain are significantly improved when including physically-based blowing snow sublimation and transport calculations.

❖Difficulties remain in simulating snowmelt in this environment. Snow transport may be underestimated due to overestimated melt.

❖A framework now exists within MESH to distribute blowing snow transport amongst multiple landscape units. This inter-tile transport framework can be generalized for other hydrological fluxes (e.g. overland flow).

Acknowledgements

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