A mesoscale parameterisation of snow redistribution by wind

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Background

❖Snowcover over complex terrain is highly variable due to blowing snow redistribution from windward slopes with bare and sparsely vegetated surfaces to leeward slopes, topographic depressions and to more thickly vegetated surfaces.

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

Scope and Objectives

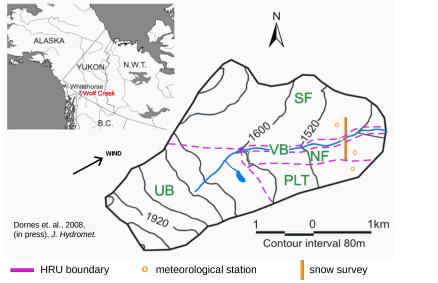
❖The effects of topography and vegetation on numerical simulations of inter-tile snow transport and the resulting snow accumulation are examined for a mountain tundra basin during winter 1998-1999.

❖Simulated snowcover results from a physically-based blowing snow model and a parametric version are compared to snow survey measurements.

❖The long term objective is to develop and test a parameterisation of inter-tile snow transport and sublimation suitable for land surface schemes.

Study Site

Granger Basin, Wolf Creek Research Basin, Yukon



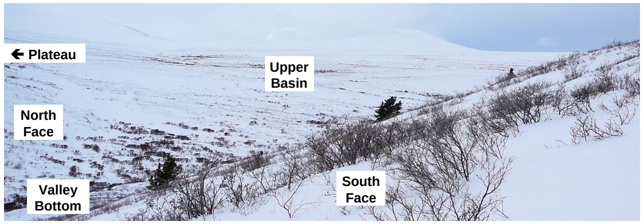
Location:
60° 31' N, 135° 07' W

Basin Area:
8.0 km^2

Elevation Range:
1405 to 2080 m a.s.l.

Mean Annual Precipitation:
300 to 450 mm (40% snow)

Mean Temperatures:
-3 °C (Year); –16 °C (January)



❖Five hydrological response units (HRUs) were used to represent Granger Basin

HRU Name	Area (km^2)	Aspect	Slope (°)	Vegetation Height (m)
Upper Basin (UB)	3.1	E/NE	15	0.1
Plateau	0.8	-	0	0.25
North Facing Slope (NF)	0.6	N	20	1
South Facing Slope (SF)	3.2	S	20	1
Valley Bottom (VB)	0.3	-	0	1.5

Data

❖Meteorological data was obtained from stations located on PLT, NF, SF and VB.

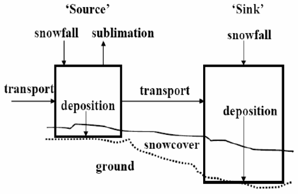
❖PLT data was also used to drive UB simulations

❖Precipitation data was obtained from the Whitehorse Airport Nipher Snow Gauge (elev. 706 m).

Blowing Snow Modelling

❖ Two blowing snow models were employed and the results were compared

❖Prairie Blowing Snow Model (PBSM; Pomeroy et al., 1993; Pomeroy and Li, 2000)
❖Simplified Blowing Snow Model (SBSM; Essery et al., 1999)



❖PBSM is a physically-based model that calculates transport and sublimation rates for blowing snow over uniform terrain (i.e. an HRU) given measurements of air temperature, humidity and wind speed.

❖SBSM approximates the complex numerical integrations performed by PBSM with considerably less computational exertion.

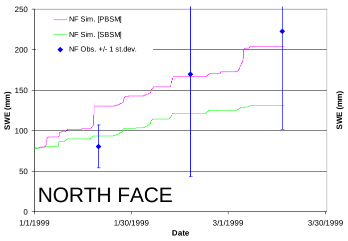
❖The snow redistribution allocation fraction (α) allocates the fraction of snow blown from one HRU to other HRUs i.e. from 'source' to 'sink'.

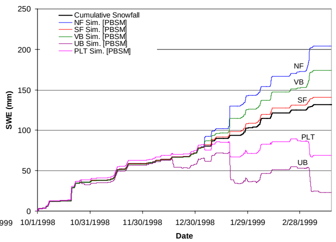
❖snow transport from HRU A to HRU B is essentially the fraction of the interface distance of A and B (d_{AB}; normal to the predominant wind direction) to the sum of all interface distances over which A transports snow is transported from (d_{Ai}).

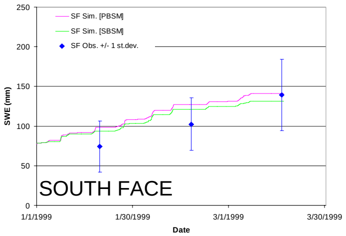
❖α changes as HRUs are progressively filled with snow to vegetation height.

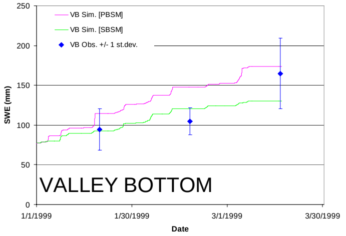
	Snow Redistribution Allocation Fraction				
HRU filled	UB	PLT	NF	SF	VB
UB	-	0.3	0.1	0.6	0
PLT	0	-	0.5	0.35	0.15
NF	0	0	-	0.1	0.9
SF	0	0	0	-	0
VB	0	0	0	0	-

$$\alpha_{A\rightarrow B} = \frac{d_{AB}}{\sum d_{Ai}}$$









Measured SWE

❖SWE (NF) > SWE (VB) > SWE(SF)

❖NF is a leeward slope: a blowing snow 'sink'

❖VB is a depression with relatively taller vegetation: a 'sink'

❖SF is a windward slope: a 'sink' and 'source'

Simulated SWE

❖ Simulated end-of-winter SWE corresponds to measurements.

❖Simulated SWE on NF, SF and VB exceeded cumulative snowfall.

❖Simulated SWE on UB and PLT was below cumulative snowfall.

PBSM vs. SBSM

❖ PBSM and SBSM simulated similar seasonal SWE for SF.

❖Different simulated SWE for NF and VB was due to difference in how vegetation height is handled.

Topographic and Vegetation Controls

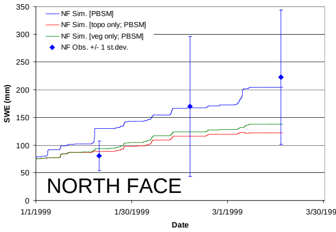
❖ PBSM was then used to simulate snowcover considering the effects of

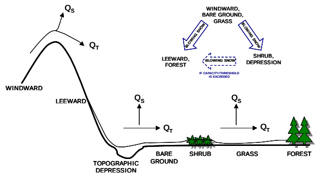
1. both topography and vegetation
2. only topography (vegetation height = 0 for all HRUs)
3. only vegetation (slope = 0; no aspect; "flat surface" wind speed used for all HRUs)

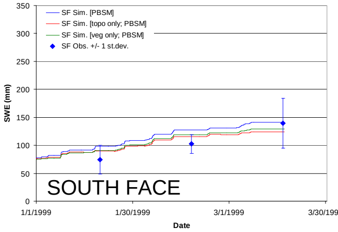
❖Flat surfaces and windward slopes have relatively higher wind speeds, therefore relatively more snow is eroded.

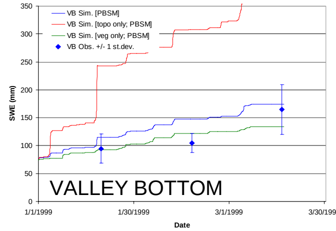
❖Leeward slopes and topographic depressions have relatively lower wind speeds, therefore relatively more snow is deposited.

❖Vegetation "traps" snow as it blows across a landscape.









❖ Best simulations resulted from including parameterisations of both topography and vegetation.

❖ For NF, end-of-winter SWE was severely underestimated when not including either topography or vegetation.

❖For SF, all simulations produced similar SWE.

❖For VB, SWE was grossly overestimated when not including vegetation effects

❖In reality, vegetation on NF traps snow, reducing snow transport to VB.

❖For VB, simulated SWE for January and February improved when not including topographic effects.

❖Vegetation has a relatively stronger control on snow accumulation regimes when there is less snow.

Conclusions

❖ The physically-based and parametric blowing snow models produced very different snowcover. PBSM simulated observations well. An improved parameterisation of shrub height and density is required for SBSM.

❖Both topography and vegetation exert a strong control on snow accumulation regimes in mountainous tundra environments. Both should be included in blowing snow parameterisations.

❖A parameterisation of inter-tile snow transport and sublimation must include a representation of the spatial arrangement of HRUs to estimate seasonal snowcover.

Acknowledgements

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