3.2 BIOME-SCALE REPRESENTATION OF SNOW COVER DEVELOPMENT IN BOREAL AND TUNDRA ECOSYSTEMS

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The storage and transformations of water as snow and water vapour are largely overlooked in the winter period by present hydrological and global circulation models, yet at high latitudes and altitudes the annual magnitude of the fluxes are large and quite sensitive to climate, vegetation and terrain. The primary processes that influence accumulation are interception of snow in coniferous forests and wind redistribution of snow in open areas. Sublimation is concomitant with these processes and presents a notable annual flux of water vapour to the atmosphere. Snow fluxes have been examined in recent campaigns conducted at four Canadian GEWEX "observatories" in the MAGS "domain" -

1) Southern boreal forest: Waskesiu, Sask. with pine, mixed-wood, burned, clear-cut and regenerating clear-cut sites,
2) Boreal-alpine transition: Whitehorse, Yukon with alpine, shrub-tundra, and forest sites in Wolf Creek,
3) Subarctic forest-tundra: Havikpak Creek, Inuvik, NWT and
4) Arctic tundra: Trail Valley Creek, north of Inuvik, NWT.

The measurements have been complemented by modelling of blowing snow and intercepted snow processes and initial linkages with land-surface models and GCMs. Recent results are highlighted by:

i) *Interception storage function.* Up to 60% of snowfall can be intercepted in mid-winter by conifers. A process-based model has been developed that represents snow accumulation in boreal forest canopies. Weighed conifers and comparative snow surveys validate the results.
ii) *Exposure parameterisation of intercepted snow*. Fractal geometry indexes the exposure of snow in the forest canopy for use in sublimation rate calculations. An exposure coefficient model has been developed for intercepted snow that in conjunction with the interception storage algorithms can provide the amount and degree of exposure of intercepted snow for use in energy balance evaporation/sublimation schemes.
iii) *Sublimation from intercepted snow*. Snow exposure, intercepted snow mass and within-canopy energy balance are used to determine snow sublimation from coniferous canopies using a single particle energy and mass balance scaled up to the forest stand canopy scale.. Sublimation losses are 30-35% of annual snowfall for conifers in the southern boreal forest, less in more northerly forests..
iv) *Energy balance of the winter boreal forest*. The latent heat flux can be notable and variable, its direction governed by conifer coverage and the load of intercepted snow. Radiation is extinguished and emitted by the coniferous canopy, affecting the energetics of snow beneath

and the atmosphere above. A canopy radiation model has been developed and its implications for snow ablation explored. Early results show that canopy alteration of the radiation regime extends the length of the snowmelt period 3 fold under dense canopies compared to adjacent open areas.

v) *Blowing snow transport threshold condition.* Two new algorithms predict the threshold wind speed for transport and the probability of occurrence of blowing snow. The algorithms permits application of physically-complete blowing snow algorithms to a variety of environments and data sets and solve the problem of scaling from point representations to larger snowfields.

vi) *Distributed Blowing Snow Model (DBSM*). Landscape classifications, a regional snow budget and blowing snow flux routines calculate blowing snow fluxes over complex land surfaces. The DBSM has been applied and tested in an Arctic and subarctic catchment. It realistically represents the distribution of snow water equivalent and matched basin snow accumulation within 6%. Sublimation losses were small for the subarctic basin, about 21% over the arctic basin and 30% from tundra surfaces.

vii) *Blowing snow in alpine terrain*. Fluxes of latent heat and snow particles along a northern alpine ridge crest suggest that small-scale advection of energy plays an important role in driving sublimation fluxes in mountain basins. Mass and energy balances are being calculated for alpine blowing snow and provision is being made for an implementation in SLURP of blowing snow routines for this environment.

The field and modelling results show that winter snow transformations are critical elements of the global cycle of water and energy in cold environments. Many of these transformation have been unrecognised before this study. As the field datasets mature, robust algorithms describing these processes are being developed for implementation in hydrological and land surface models that will contribute to GEWEX modelling efforts.

GEWEX Refereed Publications (numerous conference presentations and non-refereed publications are supplemental to this list)

Pomeroy, J.W., P. Marsh and D.M. Gray, 1997. Application of a distributed blowing snow model to the Arctic. Hydrological Processes In Press.

Pomeroy, J.W. and R.J. Granger, 1997. Sustainability of the western Canadian boreal forest under changing hydrological conditions - I- snow accumulation and ablation. In (ed. D. Rosjberg) Sustainability of Water Resources under Increasing Uncertainty. IAHS Publ No. __. IAHS Press, Wallingford, UK. In press.

Granger, R.J. and J.W. Pomeroy, 1997. Sustainability of the western Canadian boreal forest under changing hydrological conditions - 2- summer energy and water use. In (ed. D. Rosjberg) Sustainability of Water Resources under Increasing Uncertainty. IAHS Publ No. __. IAHS Press, Wallingford, UK. In press

Li, L and J.W. Pomeroy, 1997. Estimates of threshold wind speeds for snow transport using meteorological data. Journal of Applied Meteorology. In press.

Pomeroy, J.W. and E. Brun. 1997. "Physical properties of snow" In, (eds. Jones, Pomeroy, Walker and Hoham) Snow Ecology Handbook. Cambridge University Press. In Press.

Marsh, P., J.W. Pomeroy and N. Neumann 1996. Sensible heat flux and local advection over a heterogeneous landscape at an arctic tundra site during snowmelt. Annals of Glaciology. In press.

Pomeroy, J.W. and B.E. Goodison. 1996. "Winter and Snow", In. The Surface Climates of Canada, McGill-Queen's Univ Press. In press.

.Pomeroy, J.W. and K. Dion, 1996. Winter radiation extinction and reflection in a boreal pine canopy: measurements and modelling. Hydrological Processes, 10. 1591-1608.

Marsh, P. and J.W. Pomeroy, 1996. Meltwater fluxes at an arctic forest-tundra site. Hydrological Processes , 10. 1383-1400.

Harding, R.J. and J.W. Pomeroy. 1996. The energy balance of the winter boreal landscape. Journal of Climate, 9. 2778-2787.

Pomeroy, J.W. and H.G. Jones. 1996. Wind-blown snow: sublimation, transport and changes to polar snow. In, (E. Wolff and R.C. Bales, eds) Chemical Exchange between the Atmosphere and Polar Snow. NATO ASI Series I 43. Berlin, Springer-Verlag. 453-489.

Pomeroy, J.W. , P. Marsh, H.G. Jones and T.D. Davies. 1995. Spatial distribution of snow chemical load at the tundra-taiga transition. In, (K.A. Tonnessen, M.W. Williams and M. Tranter, eds.) Biogeochemistry of Seasonally Snow-covered Catchments. International Association of Hydrological Sciences No. 228. IAHS Press: Wallingford, UK. 191-206.

Pomeroy, J.W. and D.M. Gray. 1994. Sensitivity of snow relocation and sublimation to climate and surface vegetation. In, (H.G. Jones, T.D. Davies, A. Ohmura and E.M. Morris Eds.) Snow and Ice Covers: Interactions with the Atmosphere and Ecosystems. International Association of Hydrological Sciences No. 223, IAHS Press, Wallingford, UK, 197-213.

Pomeroy, J.W., D.M. Gray and P.G. Landine. 1993. The Prairie Blowing Snow Model: characteristics, validation, operation. Journal of Hydrology, 144, 165-192.

Pomeroy, J.W., P. Marsh and L. Lesack. 1993. Relocation of major ions in snow along the tundra-taiga ecotone. Nordic Hydrology, 24, 151-168.

Shook, K., D.M. Gray and J.W. Pomeroy. 1993. Temporal variations in snowcover area during melt in Prairie and Alpine environments. Nordic Hydrology, 24, 183-198.

Pomeroy, J.W. and R.A. Schmidt. 1993. The use of fractal geometry in modelling intercepted snow accumulation and sublimation. Proceedings of the Eastern Snow Conference, 50, 1-10. *Honour Paper Award*

Marsh, P. and J.W. Pomeroy. 1993. The impact of heterogeneous flow paths on snowmelt runoff chemistry. Proceedings of the Eastern Snow Conference, 50, 231-239.

Shook, K., D.M. Gray and J.W. Pomeroy. 1993. Geometry of patchy snowcovers Proceedings of the Eastern Snow Conference, 50 89-98.

Pomeroy, J.W. and D.H. Male. 1992. Steady-state suspension of snow. Journal of Hydrology, 136, 275-301.

GEWEX BOOK

Pomeroy, J.W. and D.M. Gray 1995. *Snowcover Accumulation, Relocation and Management*. NHRI Science Report No. 7. Supply and Services Canada. 134 p.