3.2 Snow Cover Melt and Runoff in Boreal and Tundra Ecosystems

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1. Objectives

The long-term objectives of this study are to:

- better understand the processes controlling snowcover melt and runoff;
- determine the magnitude of the individual components of the mass and energy balance for the boreal/tundra transition zone in the zone of continuous permafrost;
- develop process based algorithms of the energy and water fluxes during the spring melt and summer periods; and,
- incorporate and test these algorithms in distributed models at a variety of scales.

2. Progress and Collaborations

During the last year considerable effort has been expended on the collection of a high quality data set of the full water cycle for two research basins at the northern edge of the Mackenzie Basin boreal forest. Trail Valley Creek is predominantly tundra, while Havikpak Creek is dominated by black spruce boreal forest. Measurements at both sites included: monthly snow surveys throughout the winter (in cooperation with the Aurora Institute and with J. Pomeroy of NWRI); full weather station measurements, including air temperature, humidity, wind speed, net radiation, and incoming and outgoing solar radiation; precipitation, soil temperature, and soil moisture (in collaboration with CAGES enhanced surface observations), and stream discharge (in collaboration with Water Survey of Canada). As these stations are located at remote sites, certain measurements are unreliable during periods when the stations are unmanned. Additional measurements were made during the transition from late winter snowcover to early summer snow free. These included: full energy balance measurements at both early snow free and late snow covered sites; tower-based eddy correlation flux measurements; liquid water storage in the stream channels; snowcover and active layer changes in snowcover along various terrain transects; and basin-scale changes in snowcover as determined from multiple SPOT and LANDSAT images. The tower eddy correlation flux measurements were coordinated with the NRC Twin Otter flux measurement program. These measurements were aimed at obtaining a better understanding of the spatial variability in the fluxes and major processes.

3. Scientific Results

3.1 Flux Measurements

A significant effort was made during the CAGES period to provide estimates of the spatial variability in snowcover (obtained from snow surveys and SPOT and LANDSAT images, see Figure 1) and the associated fluxes of radiation and sensible and latent heat from both snow-covered and snow-free surfaces. Figure 2 shows the measured fluxes (with only minor quality control editing used in this version) at both Trail Valley (TVC) and Havikpak Creeks (HPC). Note the much larger fluxes of net radiation and sensible heat during early to mid-May at HPC when compared to TVC. These differences are obviously related to the effects of the forest canopy at HPC, while terrain around the TVC flux tower had a continuous snowcover with a high albedo. In addition to this difference between research basins, there are large spatial variations within each of the basins. For example, Figure 3 shows net radiation from a persistent snow site and an early snow-free site. Note the significantly larger net radiation at the early snow-free site. Such differences in net radiation result in large variations in the fluxes of sensible and latent heat. Related to this, are increases in sensible heat over the snow patches due to local scale advection (details have been provided in earlier MAGS reports). Ongoing work is aimed at developing appropriate physically based algorithms to model these variations in snowcover and fluxes.

3.2 Model Comparisons

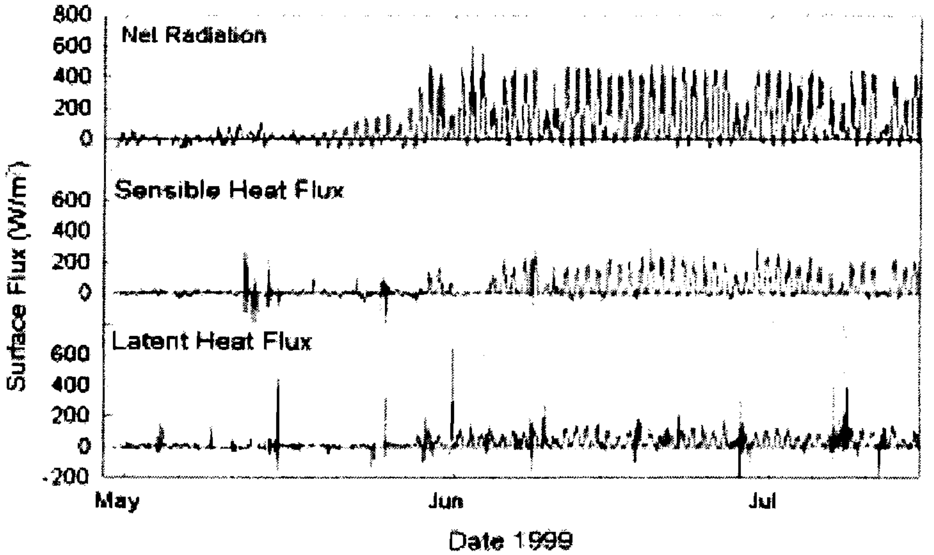
A major effort this year will be the comparison of a variety of models to observations during the CAGES period. Models used will include a variety of individual process models, basin-scale hydrological models (WATFLOOD), landsurface schemes (WATCLASS), weather prediction models (GEM) and climate models.

Preliminary comparisons between observations and GEM output have been carried out. Figure 4 shows examples for air temperature and precipitation at Trail Valley Creek compared with the nearest GEM grid point. The general trends in air temperature are reproduced by GEM, however, as shown in the insert, the GEM output is only within +/- 10°C of observed. In terms of precipitation, the GEM results are very good during the first 200 days of the comparison when a total of only 60 mm of precipitation fell. Major problems occurred around day 280, when the GEM model "missed" a major precipitation event. This storm was likely a convective precipitation event.

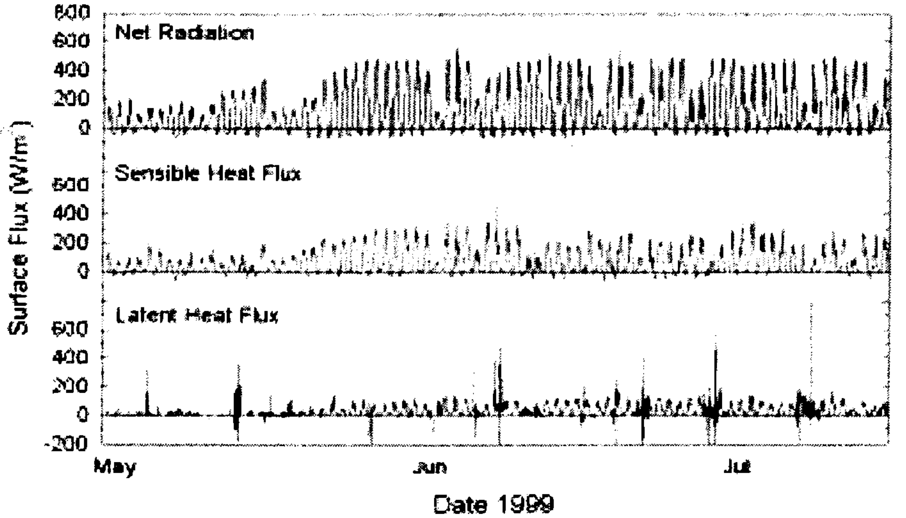
WATFLOOD has been set up to run at 1km grid squares for the study basins. Figure 5 shows preliminary results for Trail Valley Creek in 1996. Note that the modelled discharge begins, and rises to a peak, earlier than the observed. Ongoing work is aimed at determining the reasons for this discrepancy, and will consider if similar problems occur when using WATCLASS. In addition to considering only discharge, a full range of parameters such as snowcover, soil moisture, fluxes and full water balance will be considered.

Figure 1 **SPOT image of Trail Valley Creek (basin border shown along with outflow direction) during the melt period when the snowcover is patchy.** In order to better understand the spatial variability in the fluxes and major processes, a series of spatially distributed observations were carried out over the 1999 spring melt period. These include: snow surveys distributed by landcover, SPOT images to obtain estimates of snowcover distribution, flux measurements (dark square) and estimation of fluxes from bulk aerodynamic methods at sites typical of late lying snow and early emergant bare ground (light squares). Similar measurements were obtained at Havikpak Creek. These observations were coordinated with the NRC Twin Otter aircraft program.

(A) Trail Valley Creek



(B) Havikpak Creek



ure 2 **Net radiation, sensible heat flux and latent heat flux at Trail Valley Creek (A) and Havikpak Creek (B) during May, June and July of 1999.** The Trail Valley Creek site is an upland tundra location, while the Havikpak Creek measurements were taken above a sparse Black Spruce forest canopy.

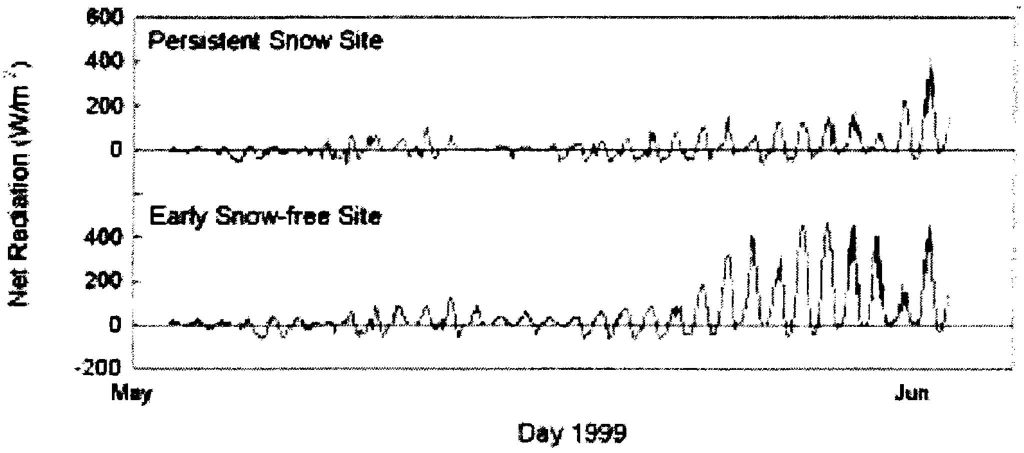


Figure 3 **Example of net radiation from a persistent snow site and an early snow-free site.** Such measurements will allow a proper representation of the spatially variable fluxes during the melt period. Note the large increase in net radiation at the early snow-free site when the ground became snow-free.

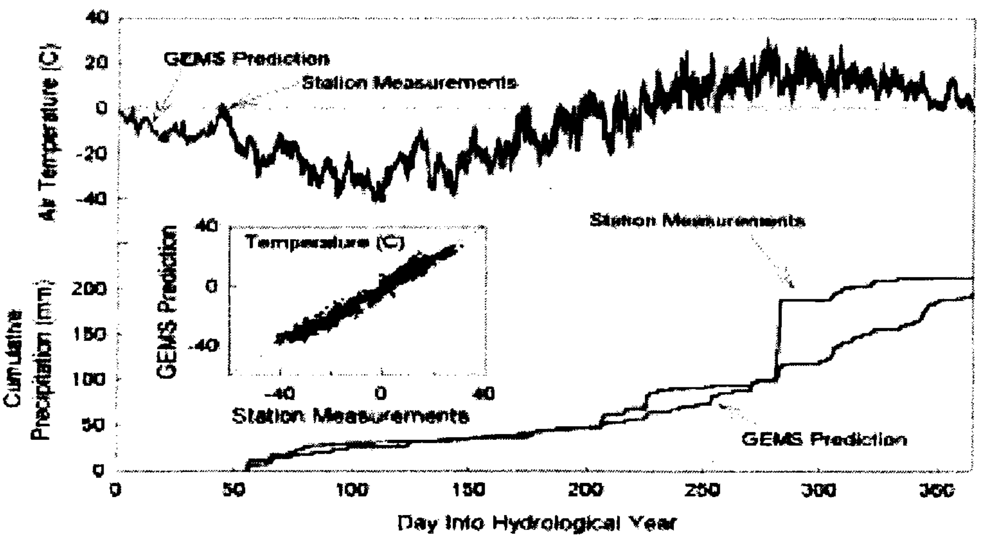
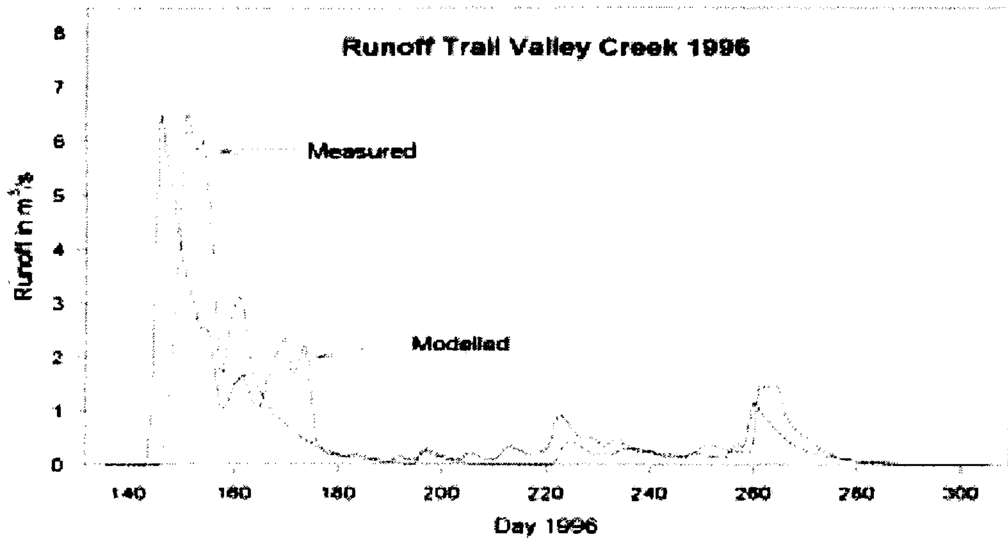


Figure 4 **Comparison of station measured air temperature and precipitation at Trail Valley Creek to the GEM predictions for the nearest grid point.** Note that the time scale is in days from October 1, 1998 - the start of the hydrologic water year.



;ure 5 **Comparison of measured and modelled (using WATFLOOD) runoff for Trail Valley Creek.** Ongoing work will focus on the CAGES period and will compare WATFLOOD and WATCLASS estimates of runoff, as well as other parameters and fluxes, to measured.

Summary

Ongoing studies are considering the wide range of processes controlling the fluxes of water and :rgy at the arctic treeline. Field and modelling studies have demonstrated the role of variable wind :ed and local scale advection of sensible heat in controlling the spatial variation in melt. When nbined with predicted variations in snowcover, this will allow an improved prediction in the change in ›w-covered area over the melt period, the flux of sensible and latent heat to the atmosphere, albedo, l snow melt runoff. In addition, improved physically based algorithms for routing meltwater through snowpack and horizontally from the uplands and hillslopes to the stream channel are being 'eloped. Physically based models of these processes, WATFLOOD, GEM and, when available, \TCLASS will be compared to measured water balance terms for the study areas. This will lead to ommendations for improving WATFLOOD, WATCLASS, and GEM for use in these arctic 'ironments.

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