Toward improved process-based pan-Arctic prediction of land surface moisture and energy fluxes

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The strength of the coupling between the ocean, land and atmosphere in the Arctic basin is particularly important to global climate due to the role of the Arctic in the global climate system as a net sink for energy, and a net source for freshwater. Runoff from the land surface represents the single largest input of freshwater to the Arctic Ocean. However, the dynamics of land-surface hydrology in the Arctic basin are not well understood due to their dependence on unique features such as the control of extreme seasonal runoff by snowmelt and ice break-up, large-scale redistribution of snow and the effects of ephemeral and permanently frozen soils. Furthermore, the paucity of observed data complicate understanding of the water balance of the region. Development of better understanding of, and ability to predict, the cycling of water in the Arctic region is directly responsive to the overarching objective of NASA's GWEC research them, "to improve the understanding of the global water cycle to the point where useful predictions of regional hydrologic regimes can be made".

An ongoing convergence of research activity in the arctic land region comes about in large part because of recognition that the arctic climate is highly dynamic, and changes there could have global implications. Most climate models, notwithstanding inconsistencies in projections for the mid-latitudes, indicate that substantial warming should occur at the high latitudes over the next century. Various studies, including analyses of long-term temperature records, as well as various ancillary data, including dates of breakup of lake and river ice, extent and thickness of sea ice, permafrost active layer depths, and carbon accumulation rates in arctic soils, suggest that this warming is already underway. Furthermore, there is evidence that the discharge of many of the major arctic rivers has been increasing, especially during the cold months. In short, the climate of the Arctic is changing in ways, and with implications, that are not well understood.

This proposal will address the following science questions that are central to better understanding of the interaction of the land, ocean, and atmosphere in a changing arctic environment. First, what is our ability to estimate runoff and other hydrologic fluxes and state variables in gauged and ungauged catchments within the Arctic drainage basin? Second, how do changes in snow cover, and permafrost active depths affect the space-time distribution of runoff production, and the discharge of arctic rivers? Third, to what extent are water and energy fluxes modulated by storage of surface water in lakes and wetlands, and by seasonal snow cover within the Arctic, and how might those processes change under a warmer climate? Our approach will be centered around a macroscale hydrology model, key component processes of which will be parameterized using a) field data at primary sites within the Kuparuk River basin of Alaska and the Torne-Kalix River basin of Sweden and Finland, b) transferability testing at secondary sites in Canada, Alaska, and Russia, and c) output from high resolution process based models applicable to tundra and boreal forest environments.

The proposed research will draw heavily on past work in two areas. The first is nested catchment studies, and associated high-resolution process-based models of runoff processes in the arctic coastal plain and the boreal forest of Alaska. The second is macroscale water and energy flux models, which will be the vehicle to evaluate the implications of process-based representations over large areas. Through both direct use of observed moisture and energy fluxes, and high resolution process-based models, existing and new parameterizations of three key processes controlling large area moisture and energy fluxes over the Arctic drainage basin will be evaluated and improved. These three processes are: 1) permafrost and frozen ground; 2) lake and wetlands surface storage, and 3) snow redistribution and ablation. Improvements to the macroscale VIC (Variable Infiltration Capacity) model will be implemented to better represent these processes. Testing of the improved model parameterizations will be undertaken in the Torne-Kalix and Kuparuk River basins. Subsequently, integrated testing of the improved model will be performed for large Arctic rivers, probably the Mackenzie and Ob, as well as the entire Arctic drainage basin. Diagnostic studies multi-decadal model output from the pan-Arctic model implementation will provide the basis for addressing the science questions posed by the proposal.