WATER RESOURCES RESEARCH GRANT PROPOSAL

TITLE: Geomorphological Controls on Hydrological Processes in the Alaskan Arctic

FOCUS CATEGORIES: CP, G&G, HYDROL

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CONGRESSIONAL DISTRICT: Alaska

INTRODUCTION

It has been acknowledged that arctic regions of the world are critical components of earth's climate and that hydrology plays a very important role in the transfer of energy. From the discovery of oil in the late 1960s until the start of the LAII Flux study, resource development, rather than scientific interest primarily dictated hydrologic studies in the Alaskan Arctic. As part of the LAII Flux study, the nested watershed study in the Kuparuk River basin was the first truly scientific study conducted in the United States Arctic at a large scale where all the major hydrologic elements were examined. The scientific investigation of arctic hydrology is in its infancy. During the past five years we have made considerable progress (see results in prior research section below), however there are still many areas of profitable research. Future progress can be made in the science of arctic hydrology in Alaska by continuing some ongoing facets of existing work and carrying out similar studies over a period of two to three years in different settings. There are numerous aspects of arctic hydrology which have not been previously studied and present obstacles to developing a complete understanding of arctic system science. We will address several of those topics in this proposed research. Internationally, comparative studies with researchers in other countries is probably the most efficient method for developing a circumpolar understanding of arctic hydrology.

Our previous research has been directed at characterizing hydrologic and thermal processes occurring in North Slope watersheds and developing the tools to accurately simulate these processes and their interactions with other components of the ecosystem. In this phase of the research program we intend to focus upon the hydrologic controls on the riparian system (including channel network) and how this system will respond to changing climate. Most research tasks in this project will be associated with determining how the drainage network will evolve with a changing climate or with determining how the hydrologic regime will respond with a different channel network. Understanding how these riparian areas evolve is a critical component of understanding the arctic system. A second thrust of this proposal is to expand the understanding of hydrologic processes that we have developed in the Alaskan Arctic to the Circumpolar Arctic.

The central theme of this proposal is that climatic warming is occurring in the Alaskan Arctic, that this will result in a thicker active layer (the layer of soil near the surface which proceeds through freeze and thaw each year) with more shrubs and that the present hydrology will undergo changes in the future. These changes may be most pronounced in riparian zones, which are dominant regions of physical and biological activity in watersheds. We hypothesize that the present drainage network of water tracks and incised channels represents an immature system restricted from further development by the shallow active layer over permafrost; as the thickness of the active layer changes in response to climate change, the drainage patterns will also change. Further, we hypothesize that:

1) The hydrologic drainage patterns have major influence on the spatial distribution of soil moisture and that an increase in the number of incised channels will result in a reduction in surface area of poorly drained or wet soils.

2) Present areas contributing flow to the incised streams include those areas of enhanced soil moisture adjacent to the water tracks; changes in the contributing area of flow will alter the characteristics of the flow regime, water chemistry and sediment transport.

3) On the low gradient Alaskan Coastal Plain, changes in drainage pattern will both arise from and cause drainage of shallow thaw lakes. Summer stream flows will increase along with areas of improved drainage (reduction in wetlands). Portions of this proposal have been funded under an existing grant from the National Science Foundation. This proposal requests support to cover salary and tuition for one M.S. graduate student to assist in the research activities described below.

OBJECTIVES

The overall objective of this proposal is to improve our understanding of the scientific role that riparian areas of the arctic perform in the hydrologic cycle and how this affects arctic ecosystems. Riparian areas defined here are zones of enhanced soil moisture within a watershed. In the foothills, they include water tracks and streams, plus adjacent areas with elevated soil moisture. In the coastal plain, they include those areas where positive soil water pressures occur in the active layer. Hydrologically, these areas are important because this is where most of the wind distributed snow collects and where the runoff is produced. More robust plants are associated with a deeper active layer in these riparian areas. Large animals (bears, moose, musk-oxen and caribou) prefer these areas for food and habitat.

Within this broad theme we would like to address the following issues:

1. Examine potential changes in the drainage network of arctic watersheds in response to climatic warming. We have hypothesized that the shallow nature of the active layer has resulted in an immature drainage network; however, a mature network could replace the present water track/linear stream network if a deeper active layer prevails.

2. Explore how changes in the drainage network could impact soil moisture. There exist a strong correlation between vegetation/snow distribution/soil moisture in arctic watersheds. Changes in the drainage network could alter the spatial and temporal distribution of soil moisture. This may alter vegetation distribution and subsequently snow distribution.

3. Continue to improve our ability to determine spatial soil moisture distribution by remotely sensed methods. Hydrologic studies, CO_2 and CH_4 flux estimates, surface energy balance estimates all require soil moisture distribution at the watershed scale. SAR (synthetic aperture radar) is potentially the best tool for obtaining this data. Although it was not part of our original LAII flux work plan in 1992, we initiated work in this area because of our own validation data needs and the urgent need for this data from others in the present LAII Flux study.

4. Apply our physically based, spatially distributed hydrologic model to other areas. We have applied our model to Imnavait Creek and the Upper Kuparuk River (Zhang et al., 1999) and will apply it to the entire Kuparuk River basin this fall. We would like to verify this model on a coastal watershed such as the Putuligayuk River (456 km^2) near Prudhoe Bay and a river basin in Western Alaska, such as the Kuzitrin River on Seward peninsula. The Putuligayuk was selected because of the low gradient; it was gauged for 15 years by the U. S. G. S. through 1985 and is contained in our present meteorological network. The watershed in Western Alaska would require at least two meteorological stations and it is assumed that it would be selected in the first year of the study. Although an arctic environment with continuous permafrost, it is warmer, has more shrub vegetation and receives considerable more precipitation.

5. Continue to monitor the existing hydrologic and meteorologic stations in the Kuparuk River basin to examine inter-annular variation in hydrologic processes at the basin scale. Both the Upper Kuparuk and the Kuparuk Rivers have been monitored for the last five years; stream flow measurements have been made since the early 1970s on the Kuparuk River, but no measurements of rainfall or snow water equivalent were made at that time.