The coastal temperate rainforests of Alaska receive large amounts of precipitation each year. Much of this precipitation falls as snow, and it is not uncommon for Alaska’s coastal mountains to receive hundreds of inches of snow each winter. As a result, extensive areas of Southcentral and Southeast Alaska are covered in glaciers and icefields. Globally, glaciers store about 75% of Earth’s freshwater. Glacier meltwater contributes substantially to runoff in many regions of the Alaska coastal mountains, and freshwater runoff rates from this region are among the highest on earth. This glacier runoff strongly influences the chemistry and ecology of freshwater and marine ecosystems along the Gulf of Alaska.

In Alaska, glaciers cover about 75,000 square kilometers or 5% of the state. Alaska has both land-terminating glaciers and ocean-terminating, or tidewater glaciers. Primarily due to warming climatic conditions, most of the glaciers in Alaska are undergoing a rapid mass loss. Glacier runoff currently accounts for about half the total runoff into the Gulf of Alaska, however future runoff rates may increase with increasing temperatures and/or seasonal precipitation changes over the region. Understanding the links between glacier mass loss and river discharge is essential to better manage freshwater and biological resources.

Despite great economic and societal importance, the linkages between climate, glacier runoff, and downstream marine ecosystems are not well understood. An improved understanding of the processes controlling glacier runoff will improve our ability to predict future changes in runoff and how they will affect coastal marine fisheries, biological productivity, sea level rise, hydropower generation potential, and municipal water resources in the region.

The objective of this study is to develop a quantitative understanding of freshwater runoff into the Gulf of Alaska. This research project will be carried out through a partnership between the U.S. Geological Survey (USGS), the University of Alaska Fairbanks Geophysical Institute, and the University of Alaska Southeast.
The Glacier Watershed System

Glaciers are formed when snow accumulates year after year in the same area without melting during the summer. Eventually, this accumulating snow is compacted into glacier ice. Like rivers, glaciers flow down slope eroding the landscape, transporting materials, and releasing freshwater as ice melts. Glaciers can greatly influence the surrounding landscape, and they interact with the atmosphere, rivers, land, and ocean systems in many ways. Changes in accumulation, ablation, ice flow, and iceberg calving can influence various components of the glacial watershed system. These changes have the potential to impact subsistence resources, infrastructure, economic activities, and recreational opportunities throughout Alaska’s glacierized coastal region.

STREAMS: The flow from glacial streams varies greatly from season to season, carrying cold water and nutrients into rivers and the ocean. Changes in flow rates and timing, temperature, and nutrients can affect freshwater and ocean ecosystems. Future reductions in glacier volume are expected to alter the temperature regime in hundreds of productive coastal streams and estuaries in this region.

OCEAN: Loss of glacier ice is a primary source of new water contributions to global sea level rise, and Gulf of Alaska glaciers are among the fastest changing ice masses on Earth. Additionally, recently developed understanding of ice-ocean coupling has shown that calving glaciers are acutely sensitive to ocean thermal forcing. Resolving dynamic ice-ocean feedbacks is essential to projecting near future sea level changes.

ATMOSPHERE: Glacier surfaces are highly reflective and they prevent incoming sunlight from warming the Earth’s surface. As glaciers retreat, they are less efficient at cooling the Earth’s surface, resulting in enhanced warming and additional glacier melt.

Numerous data sets are available to characterize changes of individual components of glacier, terrestrial, atmospheric and oceanographic systems in Alaska. The goal of this project is to integrate these data sets. Glacier mass balance, stream discharge, climate data, and remote sensing will be used to quantify total freshwater runoff into the Gulf of Alaska. In addition, data analysis and modeling techniques will be used to partition this runoff between glacier and non-glacier sources.

Satellite altimetry (ICESat), radar (TerraSAR-X) and gravimetry (GRACE) data will be used to quantify glacier mass variations. Radiance data measured by MODIS will be used to investigate Ocean productivity, temperature and other variables.

Numerous existing stream gage, weather station and glacier mass balance observations will be combined to build a comprehensive runoff database. Several field glacier mass balance programs will be expanded.

This figure illustrates the glacier watershed system and the methods used to quantify various components in this study.
Project Timeline

**PHASE I:**

- Data assembly and methodological development and testing. This includes regional upscaling using remote sensing and modeling.
- Determination of data gaps, key resources, and existing programs that should be leveraged.

**PHASE II:**

- Development of a biogeochemical nutrient transport model that can quantify biogeochemical fluxes and impacts of changing fluxes on the coastal ecosystem.
- Advance our ability to quantify total regional freshwater runoff and nutrient fluxes to the Gulf of Alaska.

**EXPECTED OUTCOMES:**

We expect to produce a strong foundation during Phase I that will allow progress towards a time series of variability in freshwater discharge through the past three decades. The potential to better understand the mechanics of the system in the future will result only after we develop the capacity to quantify past hydrological change. Our work will highlight the importance of glacier changes in the Gulf of Alaska region to important socioeconomic systems, including the highly productive salmon fisheries in the region. We anticipate developing new relationships between physical and biological science groups to enhance interdisciplinary research that supports project goals.

Learn more about this and other research projects supported by the Alaska Climate Science Center online at: http://csc.alaska.edu.

For more information contact: Shad O’Neel, Research Geophysicist
USGS Alaska Science Center | soneel@usgs.gov