Glacial and Climate Controls on Tide-Water Glacier Calving Dynamics: A PASSCAL Seismic Experiment on the Columbia Glacier, Southeast Alaska

Dan E. McNamara • *U.S. Geological Survey, Golden*

Tad Pfeffer, Shad O'Neel • *INSTAAR, University of Colorado*

Columbia Glacier is a large tidewater glacier, ending at an iceberg-calving terminus in Prince William Sound, 35 km west of Valdez, in south-central Alaska. It is presently one of the world's fastest glaciers with an annual average speed at the terminus of approximately 11 km/yr (30 m/day). The glacier is discharging ice into Prince William Sound at rates in excess of 10 km3/yr (O'Neel et al., in press). The retreat is driven by iceberg calving that exceeds incoming ice flux at an average rate of 0.74 km/yr (Pfeffer et al., 2002). This value does not include rapid dynamic thinning that exceeds 7.4 m/yr averaged over the entire glacier area, and 20 m/yr at the present terminus (O'Neel et al., in press; Arendt at al. 2002). Such retreats are irreversible until the terminus reaches a location where the bed rises above sea level, and may be analogous to the rapid breakup of historical ice sheets such as the Laurentide.

In June 2004, we deployed an array of 10 high-frequency and 1 broadband digital seismometers around the lower 10 km of the glacier channel. Seismic sensors, power systems and recording equipment were obtained through the IRIS consortium PASSCAL program. The goal of the one-year study is to characterize small seismic events (icequakes) due to iceberg calving, fracturing and crevassing within the glacier and basal sliding. Our main interest is understanding the temporal and spatial distribution characteristics of icequakes and their relation to the retreat of Columbia Glacier. The type of passive-source seismic field experiment proposed here is relatively rare in glaciology, especially for temperate glaciers. In June of 2005, we will also deploy several high-frequency seismic sensors on the glacier itself and record a minimum of two active-source explosions with the goal of better defining ice velocity and thickness as well as the local rock velocity.

The main objective of the proposed project is to gain a better understanding of the interactions between tidewater calving mechanics and fracture mechanics, and the mechanisms that may force retreats such as climate change and buoyancy instabilities. Since Columbia Glacier is the last of the Alaskan tidewater glaciers to begin rapid retreat, and has a 30+ year observational record, it is imperative that this type of study be conducted before the rapid retreat ends and this natural observatory disappears.

We anticipate that results from this proposed project will be highly pertinent to the glacier/climate interaction debate. In addition to increasing our understanding of fundamental ice-processes, results from the proposed project have implications for important societal issues such as global climate change and hazards related to calving icebergs in shipping seaways and should be addressed by rigorous scientific study. Also, given the rapid changes in Greenland and Antarctica, this study will help our understanding of potential ice sheet instability.

It is evident that the relevant processes cannot be studied with our Columbia Glacier seismology field experiment alone. For this reason an integrated approach involving additional studies in global climate change, geology, and glaciology, are planned. The proposed studies include continued photogrammetric observations to monitor the retreat of the terminus of the Columbia Glacier (Pfeffer et al., 2002), co-located GPS stations to monitor active ice flow and additional sensors to monitor tide levels, barometric pressure, temperature and precipitation.