STATUS REPORT
DECEMBER 2010

Project Title: Yosemite's Melting Glaciers **Project Start Date:** January 2009
Project Manager: Greg Stock, Park Geologist, Yosemite National Park
PI: Robert Anderson, University of Colorado, Boulder

OVERVIEW:
Yosemite's remaining glaciers are rapidly retreating, with consequences for ecosystem health and visitor experience. This project is a three year study of the Lyell and McClure glaciers, the largest glaciers in Yosemite, with the goal of understanding the climate patterns forcing their retreat. Melting glaciers are a critical source of late-season cold water, and the impending loss of these glaciers will have profound impacts on ecosystems in and around the upper Tuolumne River.

Our research combines traditional glacier measurements with new techniques to evaluate the health of these glaciers. Goals include characterizing the present area and thickness (volume) of both glaciers, documenting their winter snowfall accumulation and summer melt patterns, measuring their movement, and determining the amount of water delivered from the glaciers to the upper Lyell Fork of the Tuolumne River. The project is being conducted collaboratively between Dr. Greg Stock (Park Geologist), Dr. Robert Anderson (University of Colorado, Boulder glaciologist), and Kali Abel (University of Colorado, Boulder Ph.D. student).

The only major change to the project has been a positive one. Graduate student Kali Abel has expertise in extracting paleoclimate records from tree rings, and was excited by the prospect of extracting such records (without harm to the trees) from the spectacular lodgepole pine forests below the glaciers. The addition of alpine tree ring paleoclimate records will help to establish the climate context for the past several hundred years of glacier advance and retreat. More on these records below.

ACCOMPLISHMENTS:
The year 2010 was productive on several fronts. Three trips to the glaciers allowed us to measure meteorological and stream conditions, document snow depth fields, measure ice motion, and collect tree cores. These efforts are summarized below.

We made three field visits at critical points in the year: one in June at the start of the melt season, one in August at the end of the melt season, and another in September. Each trip had different objectives. The trip in June allowed us to document snow depth – the key "input" for glacier growth - for both glaciers. On the Lyell Glacier we dug two snow pits with depths of 3.4 meters and 3.5 meters (11.2 and 11.5 feet, respectively). Surprisingly, the Maclure Glacier snow pit reached only 1.9 meters (6.2 feet), roughly half as deep as those on the Lyell Glacier. This significant difference likely indicates the influence of windblown snow and the differing efficiencies of the headwalls of Mt. Lyell versus Mt. Maclure in collecting such snowfall. While assessing snow depth, we placed light- and temperature sensors for collection in the fall. These sensors were buried under the current snowpack and recorded the exact date at which the glacial ice was exposed (and snowpack gone). We also conducted reconnaissance for tree ring work in order to assess the viability of building a tree-ring chronology near the glacier headwaters.

Figure 1. (left) Maclure Glacier cloaked in snow in June 2010, (right) 11.5-foot deep snow pit on the Lyell Glacier.

As with virtually all scientific projects, we experienced some technical glitches, primarily with the power supply (solar panel and/or battery) of our meteorological (met) station, which failed during the 2009/2010 winter season. Fortunately, redundant instrumentation allowed us to capture most of the key data. We are presently troubleshooting the power supply of the met station, but have installed full backup sensors on the station and thus do not anticipate losing any data over the 2010/2011 winter season.

Figure 2. Graduate student Kali Abel extracts a tree ring paleoclimate record.

On the August trip, we had the assistance of mules in getting motion stakes and the backpack-able steam drill up to camp. On this trip we added two more motion stakes on the Lyell Glacier and measured ice thickness in two locations. This year proved an interesting one in terms of weather, as even in August there was still a thick snow cover (~1 m, or 3.3 feet) over the ice. On this trip we also cored nearly 40 trees (a total of 70 cores) from the stand of lodgepole pine on the ridge at upper base camp. The aim in collecting tree ring cores is to reconstruct a local climate history as recorded by nearby altitude-stressed trees. GPS coordinates were taken at each tree, opening the door for future work to understand changes in this alpine environment based on factors such as aspect, elevation and shading.

The September trip allowed for the locations of motion stakes placed in the glaciers in 2009 and 2010 to be re-measured. This revealed that the Maclure Glacier stake – and thus the Maclure glacier itself – had moved 6 meters (20 feet) downslope over the past year, a somewhat surprising result given how small the glacier is. This measurement is of

the same sort made on the Maclure Glacier by John Muir in 1872. Although the measurements are somewhat different (Muir measured movement over only 47 days, whereas we are measuring over the entire year), we find that the rate of movement appears to be roughly similar between Muir's time and today, with an average movement of slightly less than one inch per day. Data from the temperature and light sensors placed both at the met station and buried on the glaciers was also collected, providing the date of last snow cover at each location, and to assure temporal coverage at the station.

On all trips we were able to take repeat photographs of the glaciers from the same photo positions used as far back as the late 1800's. These also document the dramatic change in snow cover between the start and end of the melt season. These photos especially lend themselves to outreach and helping others to understand how glaciers respond to local climate changes.

Figure 2. Glacier motion stake in the Lyell Glacier.

NEXT STEPS:

Since the end of the field season, graduate student Kali Abel has successfully built a full tree ring chronology, providing the long-term context for the climate history of upper Lyell canyon. We can now see in high (annual) resolution a picture of the local climate back through the Little Ice Age when the glaciers were last at their maximum extent. The chronology extends back into the late 1500's, making it the longest such record in the area. We will now use this climate chronology to drive numerical models of the glaciers through their Little Ice Age advances and subsequent retreats. This "calibrating" of the glacier history will allow us to forward model the ongoing retreat, to predict when the Lyell and Maclure glaciers will disappear entirely.

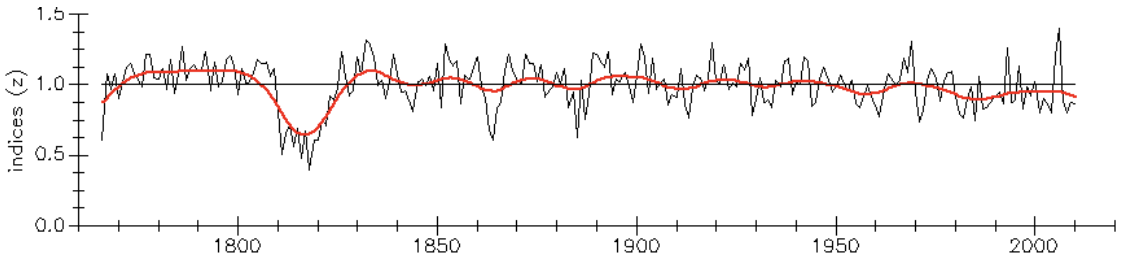

Figure 3. Preliminary tree ring chronology for lodgepole pines in the upper Lyell basin.

We are also beginning the planning for field trips in 2011, which will again consist of an early season (May or June) trip to download meteorological data and document snow depths, and a late season trip (August and/or September) to download stream data and

measure stake positions and ice extent. 2011 will be the final season for deploying field instrumentation.

ANALYSIS OF PROJECT:
Despite the minor technical glitches with the met station, overall the project is proceeding as planned. We are collecting the data needed for our intended analyses, are repeating historic surveys, and are very excited by the prospect of the new tree ring records to improve our understanding of how these glaciers respond to changes in climate. At the conclusion of the 2011 field season we anticipate having all of the information needed to estimate the future longevity of Yosemite's melting glaciers. We are pleased with the status of this project so far.

We are also pleased with the results of our outreach efforts this year. The September survey trip was highlighted in Episode 12 of the Yosemite Nature Notes video series, "Glaciers". This eight-minute long video, which has already been viewed thousands of times on YouTube, presents the setting of the Lyell and Maclure glaciers, our ongoing research of these glaciers, and what we might expect when the glaciers disappear. We have reached our scientific colleagues as well; Kali Abel presented our preliminary results at the Geological Society of America annual meeting in November 2010.

EXPECTED COMPLETION DATE:
We are on target for a project completion date and submission of a final report on December 31, 2012, and anticipate submission of a peer-reviewed scientific journal soon thereafter.