Thinning of Glaciers in the Khumbu Himal from 1955 to 2008

Adam D. Barker[1], Bernard Hallet[1]

[1] Department of Earth and Space Sciences, University of Washington, Seattle, WA 98195, USA, adbarker@uw.edu

The change of Himalayan glaciers is of considerable interest in terms of sea level change and regional climate change impacts including, in particular, altered runoff in Himalayan catchments (Nakawo and others, 1986). Glacial geologic evidence clearly document that glaciers throughout the Himalaya fluctuated during the late Pleistocene and Holocene (Owen and others, 2009). Documentation and understanding of glacier fluctuations are important components in the assessment of climate change consequences at temporal scales relevant to society (Dyurgerov, 2001). Recently, considerable scrutiny, from both scientific and public groups, has shed light on the dearth of measurements characterizing the mass balance of Himalayan glaciers. Clearly, the Himalaya and, in particular, Mt. Everest are extreme elements of topography on our planet, yet they and their glaciated catchments remain some of the least studied and poorly understood places on Earth.

This study on rates of glacier thinning in the Khumbu Himal bypasses the difficult logistics of field work in remote sites through the use of remotely-acquired satellite data. In particular, we focus this study on the Khumbu Glacier, a debris-covered glacier originating on the south face of Everest in the Nepalese Himalaya. We chose the Khumbu not only because large debris-covered glaciers are one of the most striking morphological features on the southern slopes of the higher Himalaya, but because it is one of the very few Himalayan glaciers with a wealth of existing glaciological observations and measurements. Additionally, the glacier's proximity to Mt. Everest and the logistical support that comes with being a large tourist attraction make this site an attractive location to launch a related study to determine rates of erosion and debris flux in a glaciated catchment. The work presented in this study augments this field-based study. Herein, we report estimates of glacier thinning and volume loses for the Khumbu Glacier and surrounding region using a comparison of a suite of satellite derived data and earlier cartographic maps based on photogrammetry.

To calculate glacier thinning rates, we difference the glacier elevation from a digitized and geo-referenced cartographic map made in 1955 and from satellite derived digital elevation models (DEMs). Three different DEMs are used, including two ASTER DEMs and one SRTM DEM. The ASTER DEMs represent a single day in 2003 and an average from 2000-2008 from the recently released global DEM. SRTM DEMs were collected during a single Space Shuttle mission in 2000. A summary of the difference analysis is shown in Figure 1. Below the Khumbu icefall (at ~5400 m), comparison between the ASTER GDEM and 1955 map shows an average thinning of 44 m and thinning rate of 0.8 m/yr. Above the icefall, the glacier continues to thin until ~5900 m. Thickening (34 m average) of the glacier occurs at elevations between 6000 and 6600 m. Overall, we calculate a volume loss of about 0.5 km^3 in 53 years.

In the late 90's, the ice thickness was measured with a ground-based radar system along several transverse transects in the ablation zone of the Khumbu Glacier (elevations < 5400 m). Figure 1, on the left side, shows that this region has the largest fraction of the total area of the glacier. Gades and others (2000) measured thicknesses of about 450 m near the icefall and decreasing to about 20 m near the terminus with an average ice thickness of about 180 m. If we make the simplistic assumption that the thinning rate remains 0.8 m/yr indefinitely, it will take approximately 225 years for the lower portion of this glacier to disappear.

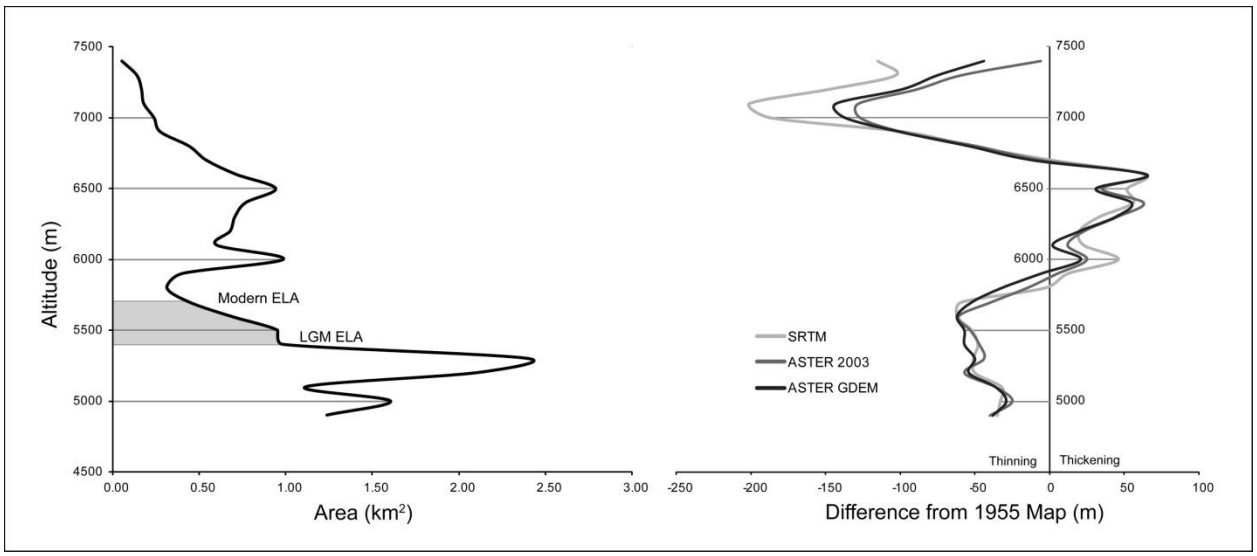

Figure 1. At left, area-altitude distribution of the Khumbu Glacier. The light gray box defines the approximate range of the modern and LGM equilibrium line altitude (ELA) (Owen, 2008). The peak in area just below 5500 m reflects the extensive debris covered ablation zone of the glacier. At right, each curve shows the difference in glacier elevation between one satellite derived DEM and the 1955 map. Below the icefall (at ~5400 m), for example, comparison between the ASTER GDEM and 1955 map shows an average thinning of about 44 m in 53 years, amounting to an average thinning rate of ~0.83 m/yr.

References

Dyurgerov, M.B., 2001, Mountain glaciers at the end of the twentieth century: global analysis in relation to climate and water cycle, Polar Geog., 241-338.

Gades, A., Conway, H., Nereson, N., Naito, N. and Kadota, T., 2000, Radio echo-sounding through supraglacial debris on Lirung and Khumbu Glaciers, Nepal Himalaya, in: Debris-covered Glaciers, IAHS Publ.

Nakawo, M., Iwata, S., Watanabe, O., and Yoshida, M., 1986, Processes which distribute supraglacial debris on the Khumbu Glacier, Nepal Himalaya, Ann. Glac., 8, 129-131.

Owen, L.A., 2008, Latest Pleistocene and Holocene glacier fluctuations in the Himalaya and Tibet, Quaternary Sci. Rev., 1-15.

Owen, L.A., and others, 2009, Quaternary glaciation of Mount Everest, Quaternary Sci. Rev., 28, 1412–1433.

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