MONITORING THICKNESS CHANGE OF THE DONGKEMADI GLACIER ON QINGHAI-TIBETAN PLATEAU USING SRTM DEM AND MAP-BASED TOPOGRAPHIC DATA

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1. INTRODUCTION

Space-borne techniques are the only method to ensure sustainable, global-scale monitoring of glaciers. Whereas space-borne methods have been developed and successfully applied for detecting glacier area change and glacier movement, the major current gap in glacier monitoring from space lies in the measurement of glacier thickness or volume change for their contribution to sea-level change and as sensitive indicators of local climate. The necessity of extensive field work for laser altimetry and problems of DEM generation on featureless snow fields using satellite photogrammetry limit the widespread use for glacier thickness change monitoring in remote alpine areas[1,2]. The Shuttle Radar Topography Mission(SRTM) acquired in Feb, 2000, resulted in a global DEM of land area between 60 N and 54 S. The nominal vertical accuracy is 6m relative and 16m absolute, and the nominal horizontal accuracy is 15m relative and 20m relative(90%)[3]. Therefore, it could be used as a reference point for local and regional glacier thickness change studies.

Here we measured the long-term thickness change of the Dongkemadi Glacier on Tanggula Mountain, Qinghai-Tibetan Plateau, using SRTM C-band data(2000) and a digital elevation model(DEM) generated from topographic map(1969). In this paper, first we check the accuracy of SRTM DEM by comparison at 16 random independent points in non-glacier area below 5500m a.s.l., then we focus on an analysis of the glacier's surface thickness change features and a validation of the results using GPS survey data (2007) and DEM(1969) in Xiaodongkemadi Glacier(XDG). The result shows XDG decreased by an average of 6.15m, or 0.20 m a^{-1} between 1969 and 2000. We estimate the error of annual thickness change rate to be on the order of 5%, compared to the result of field measurement. And DDG decreased by an average of 20.74m or 0.67m a^{-1}(1969-2000) using the same method.

2. STUDY SITE AND DATASETS

The Dongkemadi glaciers (33.08N,92.09E) is continental glacier, which is located in the head region of the Buq river, on the northern slope of the Tanggula Mountain in the central part of the Qinghai-Tibetan Plateau. A nunatak separates the glacier into two branches, DDG and XDG. The DDG branch is 5.4 km long, with an area of 14.63 km^2. The XDG is 2.8 km long, and is a small valley glacier with an area of 1.76 km^2[4].

The SRTM DEM acquires an absolute vertical accuracy of 6.2m and horizontal accuracy of 8.8m in Eurasia[5]. The topographic map was derived from aerial photographs acquired in 1969 by the Chinese military geodetic service. The systematic errors were < 11m over slopes <15° and < 19m over slopes >25° [4]. DEM(1969) is produced by digitizing the 20m interval contours from the map, interpolated and filtered with 10m cell size. Then it is re-projected and transformed to the WGS84/EGM96 geoid, the same as SRTM DEM using seven-parameter transform model with an error <0.002m.

3. RESULTS AND ANALYSIS

The glacier vector is extracted from a Landsat ETM+ image(July, 8th, 2001). The elevation change (1969-2000) is computed for each points in the glacier area. The results of differentiating GPS survey data(2007) in XDG and DEM(1969) from topographic map is shown. And then one profile in the middle of XDG is extracted and the curve of the elevation change vs. elevation on that profile is given. (Figure. 1) The elevation change of DDG (1969-2000) is presented using this method. (Figure. 2)

The 16 random independent points in surrounding non-glacier area below 5500m a.s.l. were chosen to estimate the systematic differences between SRTM DEM and DEM(1969). Due to the sensitivity of SAR to high topography, the slope of the site that we chose is under 15° , which is the same as that of XDG. The result shows that the elevation differences(1969-2000) are from -10.0 to 6.0m (the mean is -2.8m and the standard derivation is 5.1m). It didn't show apparent dependence of elevation differences with elevation. So the mean elevation error is accounted for as an overall correction to the mean elevation differences. We find XDG decreased by an average of 6.15m(1969-2000), or 0.20 m a^{-1}, compared with the result of field GPS measurements, decreased by 7.92m(1969-2007) in average, or 0.21m a^{-1}[4], with an error of 5% for annual thickness change rate.

The changing trend over the whole glacier is consistent with the results from GPS measurements. The elevation change is from -33.0(±3) to -5.0(±3)m under 5500m a.s.l as the elevation increases. It maintains relatively stable from 5500m a.s.l. to 5650m a.s.l., where the equilibrium line altitude (ELA) position is, with an elevation change of zero. Above 5650m a.s.l. it is accumulation region. The differences at the top of the glacier are a little large due to the large slope and elevation at the top of XDG. The largest decrease of 46.2(±3)m is at the tongue while the largest increase of 19.1(±3)m is at the two sides of XDG(1969-2000), compared with a largest decrease of 63.5m and increase of 30.2m(1969-2007)[4]. We estimate the smaller thickness changing range of SRTM-derived result due to following reasons: one is the accelerating decrease at the tongue during recent 7 years from 2000 to 2007 as the global temperature increases, the other one is the error caused by radar penetration at the C-band frequency in dry snow with a maxim of 9m, and it is in the phase of winter snow accumulation when SRTM DEM acquired in Feb, 2000[3]. As the closeness of DDG and XDG, the same mean error is then corrected for DDG. From figure.2, we find DDG decreased by an average of 20.74m (1969-2000) or 0.67m a^{-1}.

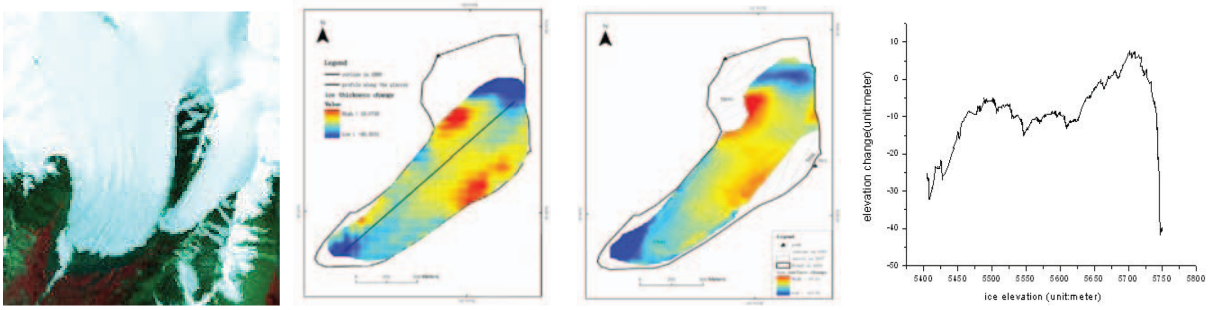

Figure. 1, Dongkemadi Glacier of Landsat/ETM+ image on July, 8th, 2001(left), ice-elevation change based on SRTM DEM(Feb, 2000) and DEM(1969) of XDG(middle left), ice-elevation change based on GPS RTK measurement and DEM(1969)[4] (middle right), elevation change vs. elevation along the profile indicated as black line on XDG (right)

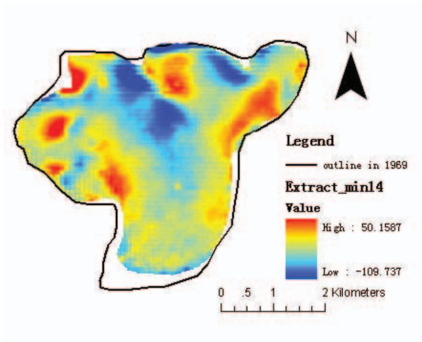

Figure. 2, ice-elevation change based on SRTM DEM(Feb, 2000) and DEM (1969) of DDG

4. CONCLUSION AND DISCUSSION

Our test study shows that XDG decreased by an average of 6.15m(1969-2000), or 0.20 m a^{-1}. From comparison with the result of field GPS measurements and DEM(1969), we estimate the error of annual thickness change rate to be on the order of 5%. And DDG decreased by an average of 20.74m(1969-2000) or 0.67m a^{-1} using the same method.

It is proved that using SRTM DEM and map-based topographic data is a viable method for measuring thickness change of the Qinghai-Tibetan Plateau valley glaciers over long time intervals. It offers the potential for cost-effective regional assessments of glacier thickness or volume change of major glaciated areas in mid latitude and low latitude if previous topographic data can be achieved. In the future we will combine the ASTER GDEM released on June, 2009 and SRTM DEM to improve the accuracy of glacier thickness change further.

5. REFERENCES

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