Global mass balance estimates of glacier using altimetry

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Research Objective

This study focuses on quantifying the long term mass balance of continental glaciers in the High Mountain Asia (HMA), Alps, Western Canada and Andes using Cryosat-2 and ICESat altimeter data. We have also identified spatial heterogeneity in mass balance within HMA which can give useful indication about either different climate conditions or different glacier responses to climate conditions.

Background

- Glaciers are considered Essential Climate Variables (ECV) because glacier geometry (areal extent, glacier tongue and elevation) and glacier dynamics are sensitive to changes in temperature and precipitation (Dyurgerov and Meier, 2005).
- Identifying the current state of the health of the continental glaciers is important as their variations may have direct impacts on processes of global importance such as global sea-level rise (IPCC 2013). the hydrology of mountain-fed rivers, the freshwater balance of the oceans, natural disasters, and even the shape and rotation of the Earth. Quantification of glacier mass balance provides the direct measure of glacier health as it is undelayed response of glaciers to atmospheric conditions.
- Even though mass balance plays a key role in monitoring strategies of the Earth climate system, quantification of mass balance is limited in many parts of the world such as High Mountain Asia because of labor, remote locations along with political issues.
- Geodetic methods which involves comparing Digital Elevation Models (DEMs) from at least two different times is one of the most important Remote Sensing technique for quantification of mass balance of glaciers.
- Altimeters such as ICESat have been successfully used to quantify mass balance at global scale for the period 2003-2009 (Gardner et al., 2013), however in order to extend the mass balance .results over longer time period, we have used Cryosat-2 data.
- Mass balance has been measured in terms of different units, here we use meter water equivalents or m w. eq.

Data and Methods

- In this study Cryosat-2 L2I (**L**evel-**2** **I**n-depth data in SAR Interferometric (SARIn) mode and ICESat GLAH06 and GLAH14 data were utilized over the period 2010-2016 and 2003-2009 respectively.
- Also. we used Shuttle Radar Topographic Mission (SRTM) DEM of year 2000 as a reference elevation surface. SRTM mission was flown during 11-20 February, 2000 and produced DEM worldwide at 30 m resolution. We used RGI version 6 as a source for glacier outlines.
- Initially we performed atmospheric correction, geoid correction, corregistration for ICESat and Cryosat-2 data, followed by differencing with the corregistered SRTM data to obtain elevation differences for each region.
- In Elevation difference trend figures created in this study, Red line indicates the elevation difference trend computed using elevation difference results of Autumn month by 'robustfit' regression method in MATLAB. The individual points represent median elevation differencesfor respective month(s)

High Mountain Asia (HMA)

HMA host the largest glacier concentration outside the polar regions and are important contributors to streamflow in one of the most populated areas of the world.

HMA region has wide variation in climate regimes leading to heterogeneity in mass balance results. Most glaciers in the eastern and central Himalaya belong to the "summer-accumulation type," gaining mass mainly from summer-monsoon snowfall whereas winter accumulation is more important in the northwest (Bolch et al., 2012). Affect of Climate variation on mass balance can be seen Fig. 1.

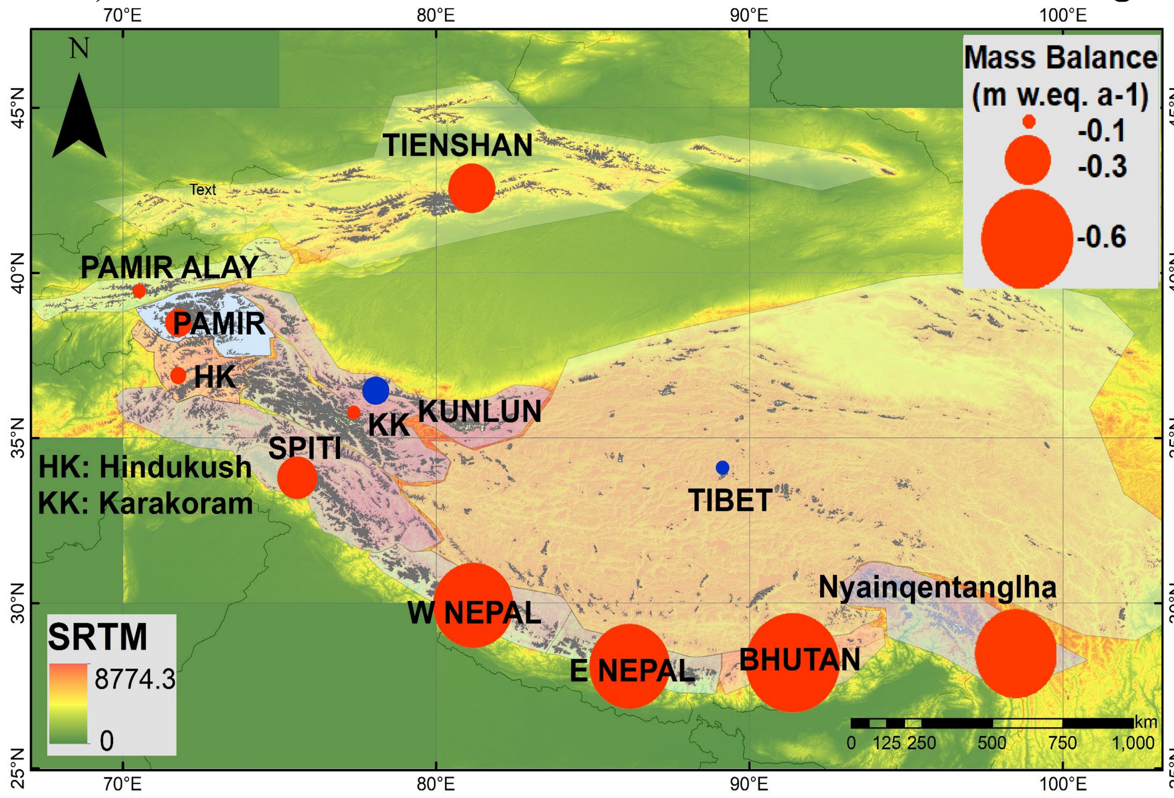
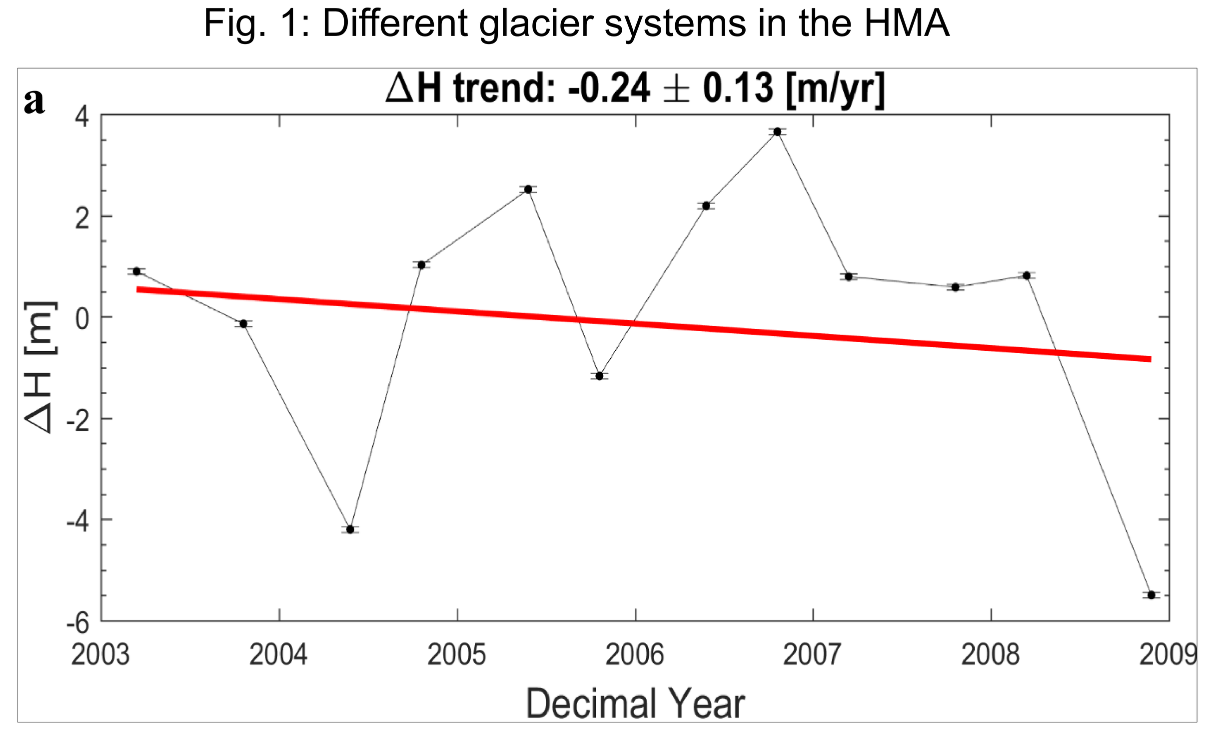


Fig. 1: Different glacier systems in the HMA



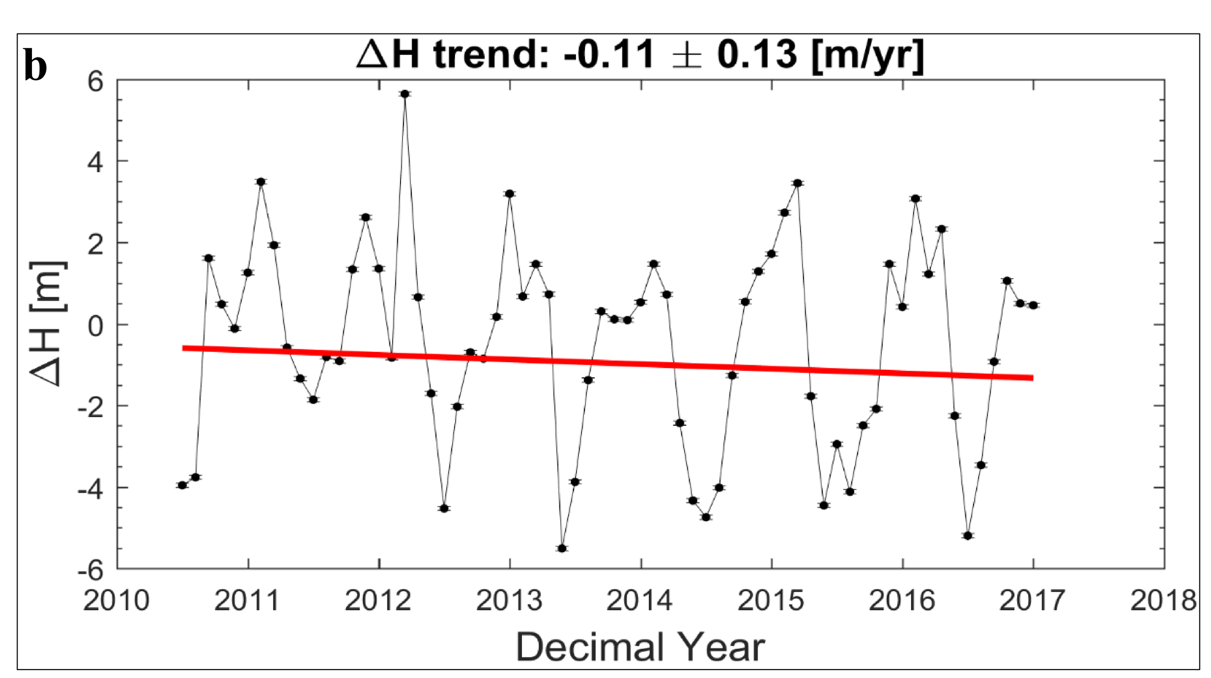
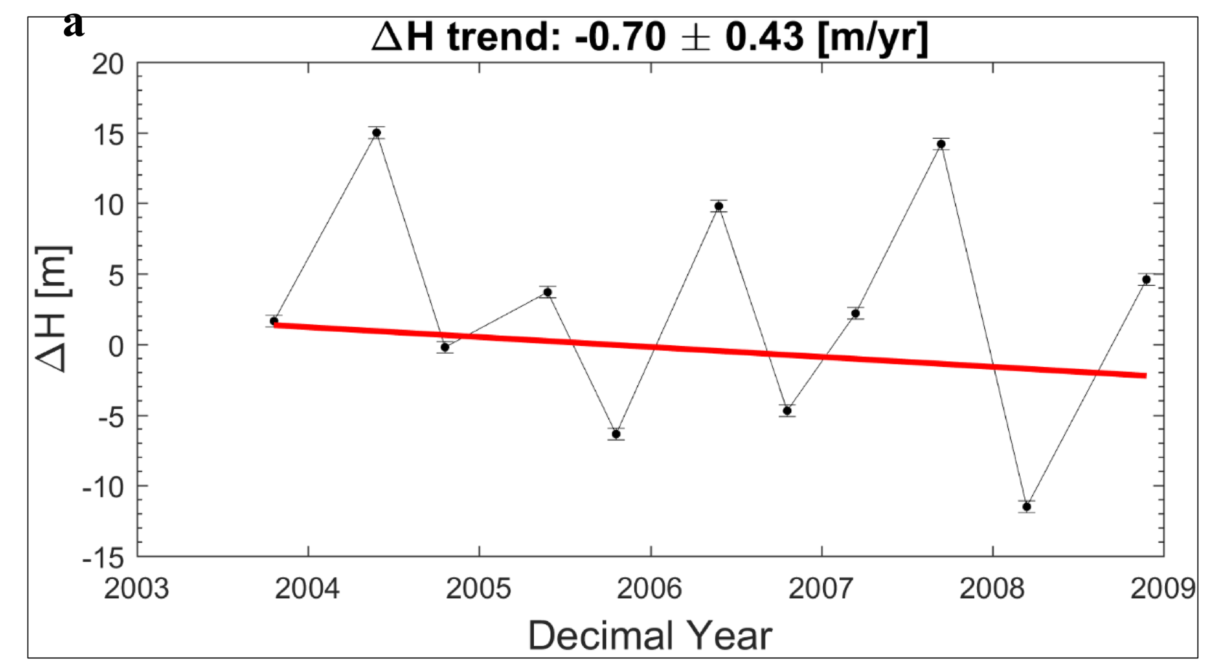


Fig. 2: (a) Elevation difference trend for the period 2003-2009 computed using ICESat GLAH06 and GLAH14 data products. (b) Elevation difference trend for the period 2010-2016 computed using Cryosat-2 data. The estimated mean mass balance of -0.13 ± 0.13 m w.e. yr−1 compares favorably with −0.18 ± 0.04 m w.e. yr−1 (Brun et al., 2017)

Central Europe

According to European Environmental Agency majority of Alps are in retreat. And they have lost half of their volume since 1900, with more accelerating trend since 1980s.



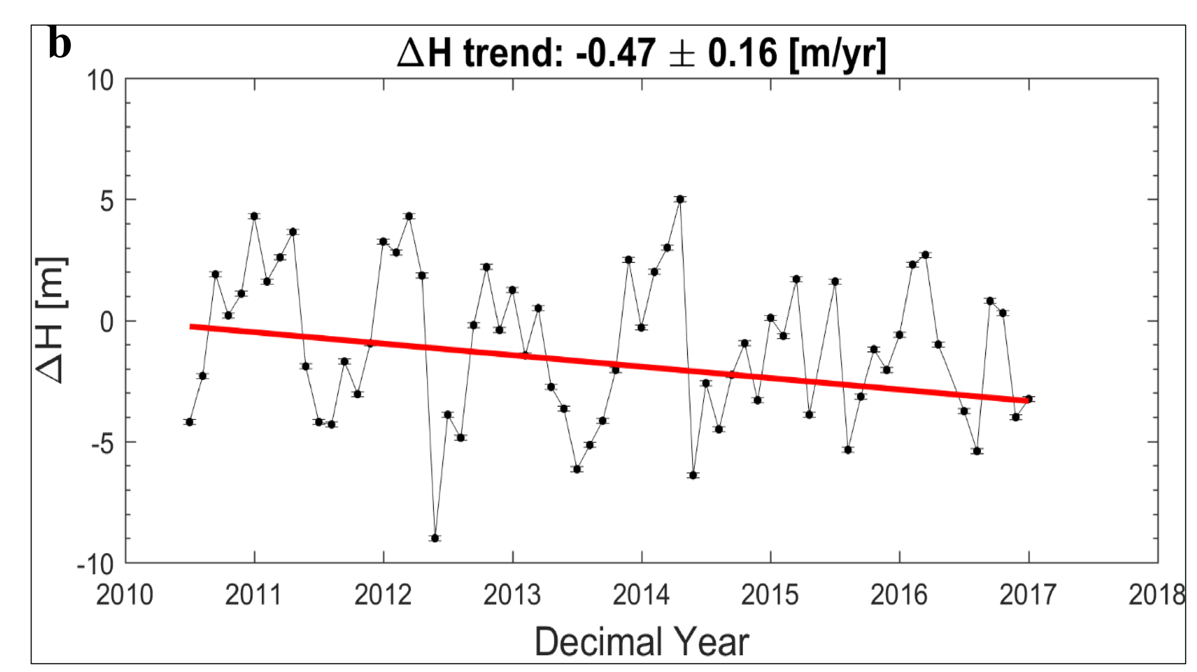


Fig. 3: (a) and (b) The computed elevation differences are consistent among the two periods..

Western Canada/United States

This region has the second largest area under permanent ice in the world, after Antarctica. It is projected that by year 2100, the volume of glacier ice in western Canada will shrink by 70 ± 10% relative to 2005 (Clarke et al., 2016)

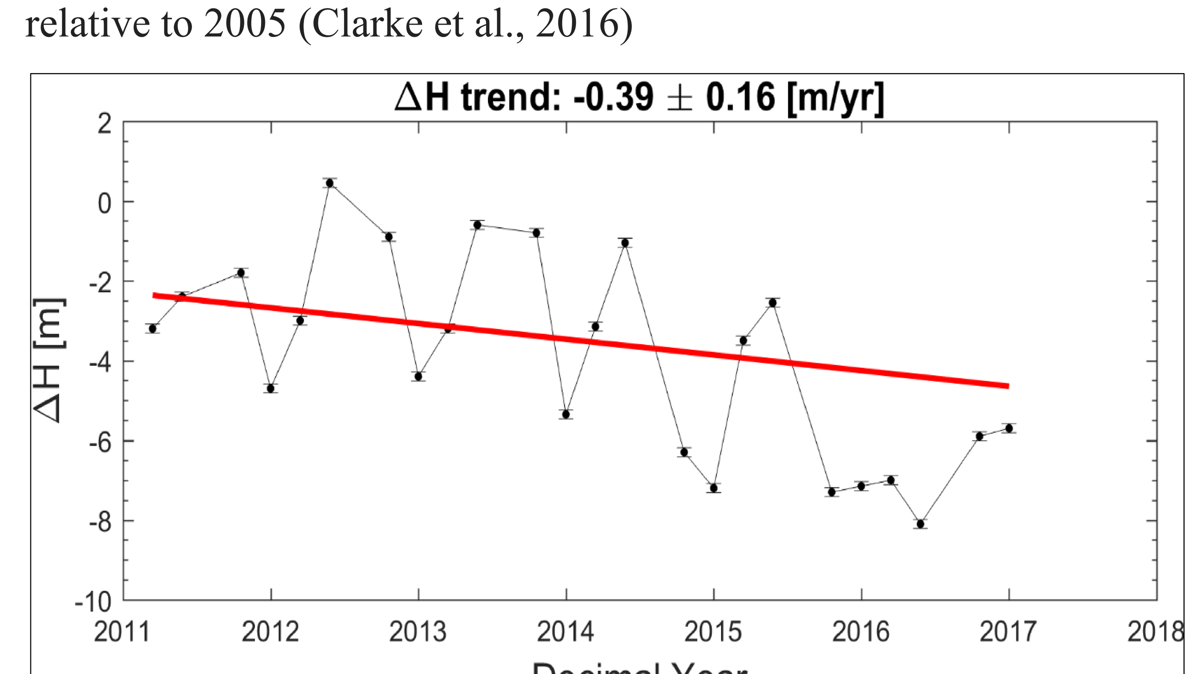


Fig. 4: Elevation difference trend for the period 2010-2016 computed using Cryosat-2 data. The trend of elevation differences is negative; seasonal signal is also clear. Here, the median elevation difference was computed quarterly due to noisy data

Southern Andes

Glaciers in South America contain the largest ice volume in the Southern Hemisphere outside Antarctica In particular, The Andes cordillera glaciers and ice fields are the biggest contributors to sea level rise per unit area.

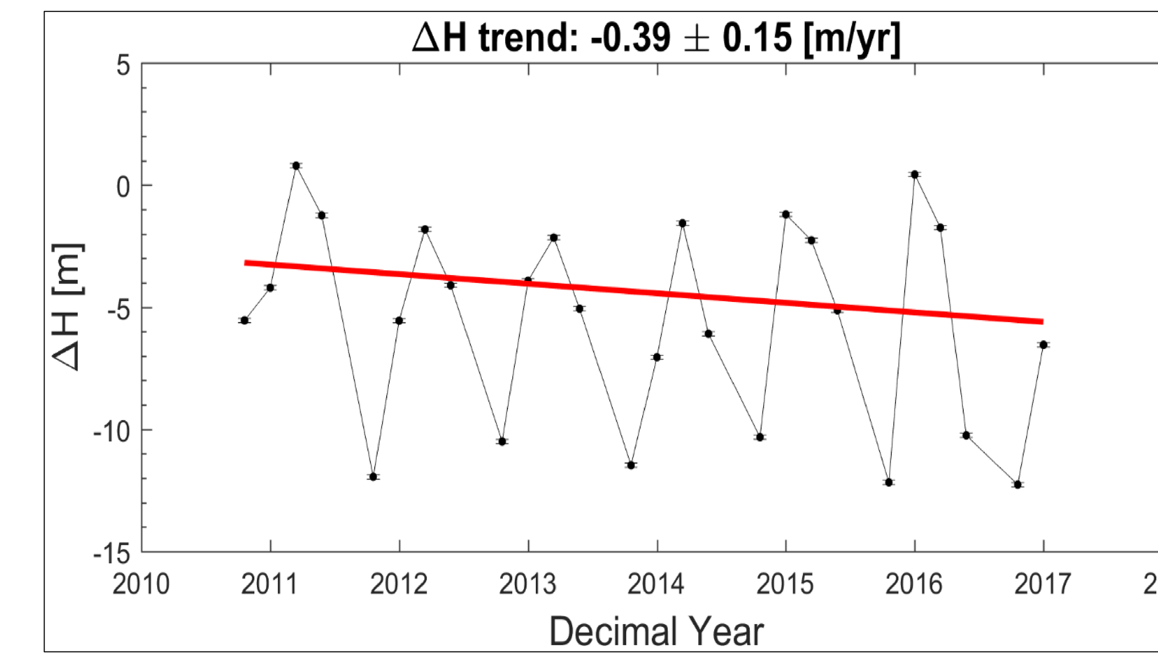


Fig. 5: Elevation difference trend for the period 2010-2016 computed using Cryosat-2 data for Andes. Elevation difference trend is similar to previous case, it is computed using summer months in Southern hemisphere.

Conclusions

The combined use of ICESat and Cryosat 2 altimetry data can help to establish a long term trend of mass balances over large glacier regions which can also help us to understand contribution of glacier melting to sea level rise which has been a subject of intense study. We also propose to extend this study by incorporating data from ICESat-2 satellite as it gets launched. Another innovative approach will be to interpolate and compare nearby points (distance <250 m) of Cryosat-2 data which will enable us to generate more data for mass balance results. Problem of noisy data can also be solved by averaging the data suitably as has been done in this study.

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