MODIS albedo used to detect ELA on Svalbard glaciers

C13F-0689

Jack Kohler[1] (jack@npolar.no), C. Nuth[2], M. König[1], J.O. Hagen[2]

[1] Norwegian Polar Institute, Fram Centre, N-9296 Tromsø, Norway
[2] Dept. of Geosciences, U. of Oslo, Postboks 1047, N-0316 Blindern, Oslo

1. Motivation

Measuring mass balance in the field is time-consuming, expensive, and gives only a few local measurements. Remote sensing (RS) has the potential to provide data over large areas, but the challenge remains to find a RS technique which can be used to recovere mass balance parameters.

We use satellite albedo to track snow-line on four test glaciers in Svalbard, with snow-line serving as a proxy for the Equilibrium Line Altitude (ELA). While arctic glaciers may have extensive superimposed ice (SI) areas, the altitudinal range of the SI is relatively limited (ca. 50-100 m), so this potentially represents only a small bias.

2. MODIS albedo

The MODIS albedo product MCD43A3 comprises 16-day average albedo values, collated on ~500 m pixels at 8 day intervals. MODIS reflectance data are obtained for each pixel from multiple looks over a 16-day period, filtered to remove clouds, and then averaged using the semi-empirical BRDF (Bidirectional Reflectance Distribution Function). MCD43A3 comprises black- and white-sky albedos for 7 spectral bands and 3 broad bands at mean solar zenith of local solar noon. Data quality is assessed in the MODIS product MCD43A2.

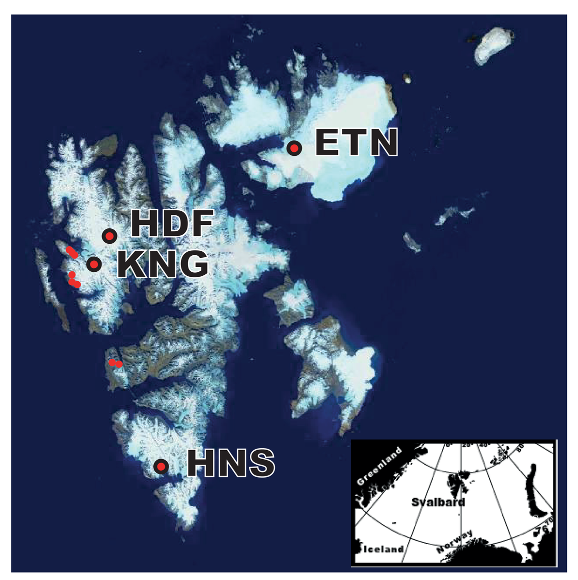
In this poster, we use black-sky visible albedo data covering Svalbard, for data flagged 0-3 in MCD43A2 in the period April 4 to Sept. 15. Data are interpolated for each year to fill data gaps; holes larger than one pixel in the temporal dimension or three pixels in the spatial dimension are left unfilled.

3. Svalbard

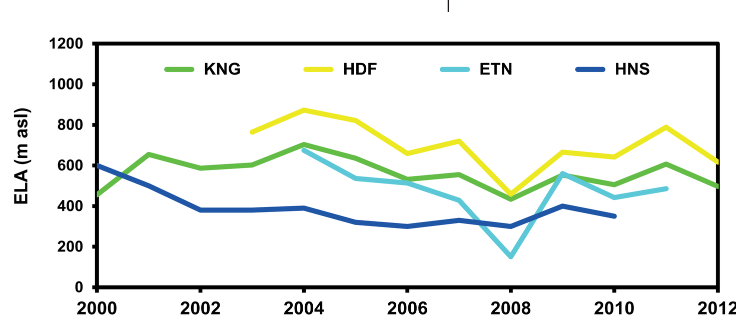
Total area of Svalbard is 60,000 km², of which 57% is covered by glaciers. Mean specific net balance is ca. -25 to -50 cm w.eq. a^{-1} and the total volume change is estimated between -5 and -10 km³ a^{-1}.

Mass balance is measured annually on 15 glaciers (small red circles, right); most are relatively small (less than 10 km²), and all but one are in western Svalbard.

We use stake data from the 4 largest glaciers (large red circles, right) to determine ELA along each glacier's centerline.

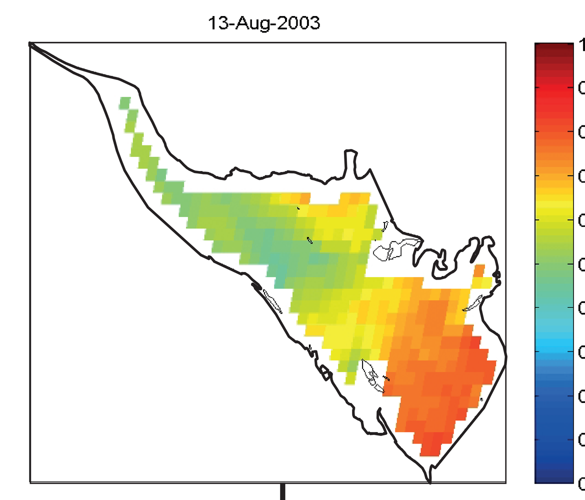


	Glacier	Area	Mass balance data available
KNG	Kongsvegen	110 km²	1987-2012
HDF	Holtedahlfonna	295 km²	2003-2012
ETN	Etonbreen	640 km²	2004-2011
HNS	Hansbreen	64 km²	1989-2010



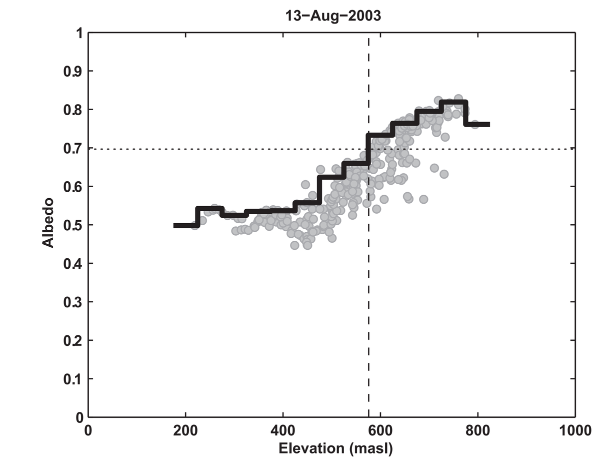
4. Method

Albedo data are cropped to the glacier masks, and trimmed by one pixel. Plot to right shows albedo for the 16-day period starting 13-Aug-2003

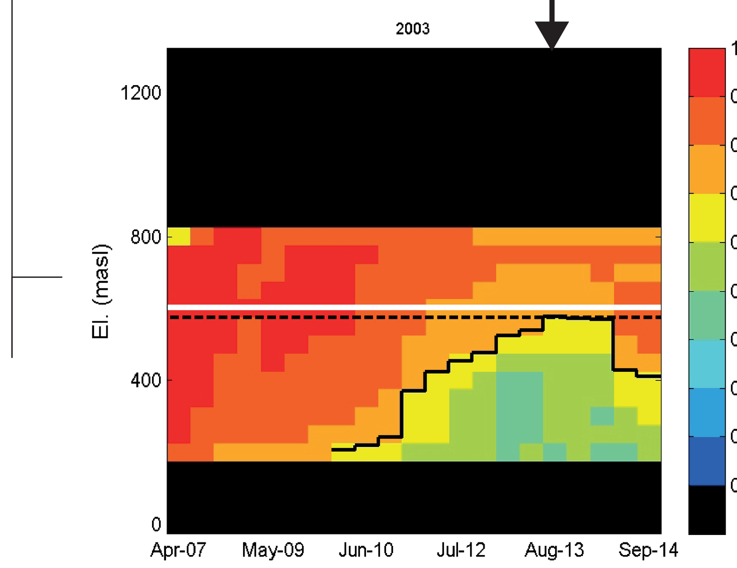


For each 16-day block we group albedo by elevation, and determine the maximum albedo in 50-m bins using 95th percentile values (heavy black line).

We use a threshold value (dotted horizontal line) to differentiate winter snow from the underlying surface. The threshold varies slightly from glacier to glacier (see below), but is held constant for all years. The intersection (dashed vertical line) of the maximum albedo and threshold gives the snow-line elevation.



Raster plot showing the maximum albedo values in 50-m elevation bins (heavy black line in figure above) for each time block, during one year, together with the elevation at the threshold value (solid black line), and the highest elevation attained each summer (dashed black line). The latter is the MODIS-determined snow-line elevation, our proxy for the ELA. For comparison, the observed ELA is also shown (white line).



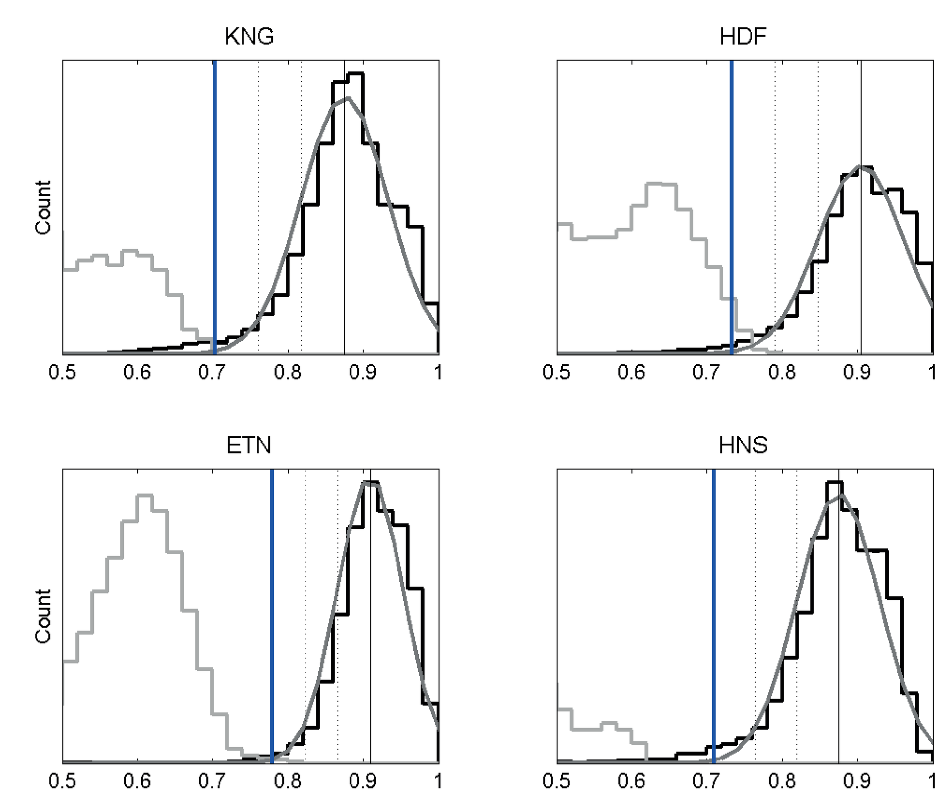
5. Threshold

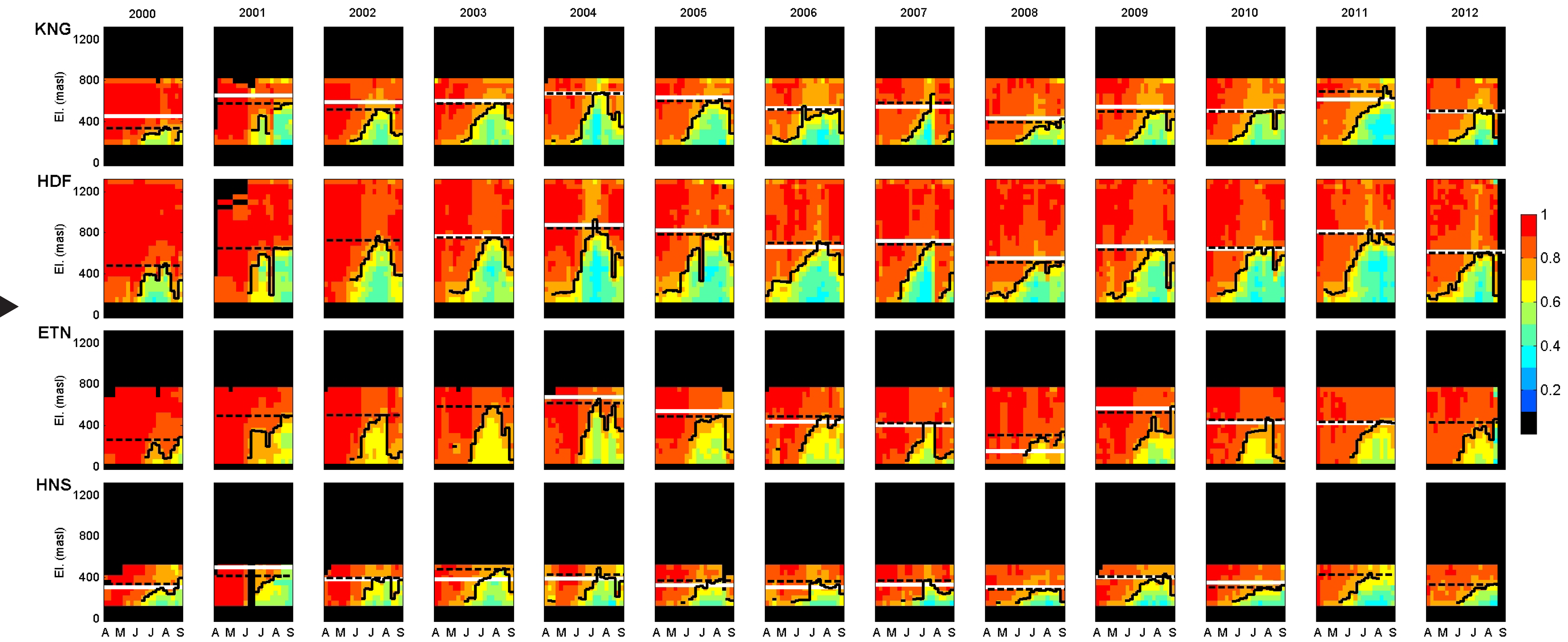
A threshold value must be determined for each glacier, to account for geometrical factors such as e.g. surface undulations at different length scales that will vary from glacier to glacier.

We extract all winter albedo values in the upper half of each glacier (black line), fit a gaussian distribution to the resultant histograms (grey line), and take the 3-σ value (vertical blue line) as the threshold between snow and underlying surface.

For comparison, minimum albedo values for the lower half of the glacier are also shown (light grey line).

Threshold values determined (0.70-0.78) fall in the range expected for differentiating dry snow (0.80-0.97) or wet snow (0.66-0.88) from firn (0.43-0.69) or ice (0.34-0.51) [Patterson: Physics of Glaciers, 2001]



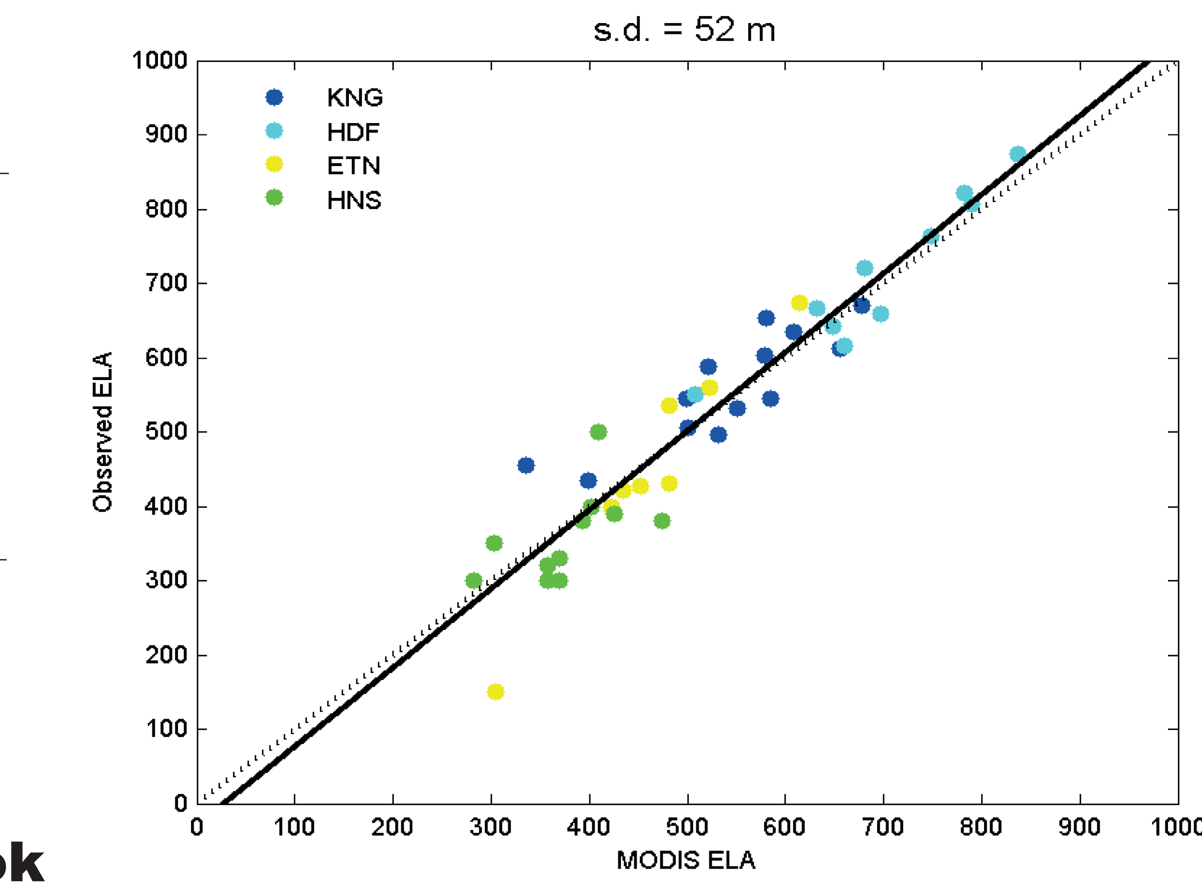


6. Results

Comparison of the MODIS-derived and observed ELA for all four test glaciers shows that, with one exception (ETN, 2008), the agreement is excellent (figures above, right).

The black line (figure, right) is the best-fit line to all the data, while the dotted line shows the 1:1 line.

The spread of values around the best-fit line (1-σ = ca. 50 m) is comparable to what is expected from errors in determining the ELA from mass balance data, or from variability of the ELA across the glacier surface, away from the glacier centerline.



7. Conclusion, future outlook

We have developed a method that successfully retrieves an ELA proxy for the test glaciers, with no calibration to in situ data beyond determination of an appropriate threshold. While the threshold varies for individual glaciers, it is kept constant across all years, and the algorithm is the same for all test glaciers.

Application to all large glaciers (>50 km²) on Svalbard is ongoing. While there are problems in determining individual years on some glaciers, for example low-lying glaciers in years with very negative mass balance, the pattern of the mean for all years is similar to other estimates of archipelago-wide ELA [Hagen et al, Arct. Antarct. Alp. Res. 2003].