UTILITY OF SATELLITE DERIVED TRANSIENT SNOWLINE MIGRATION RATES IN MASS BALANCE ASSESSMENT ON ARCTIC GLACIERS

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Here, we explore the utility of satellite imagery derived transient snowline (TSL) migration rates throughout the ablation season for mass balance assessment on four individual glaciers in Alaska and Greenland using Landsat imagery. Three of the glaciers have ongoing mass balance field data that is submitted to the WGMS to utilize in conjunction with the TSL observations; Taku Glacier (TG) and Lemon Creek Glacier (LCG), Southeast Alaska, are monitored by the Juneau Icefield Research Program (JIRP). Mittivakkat Gletscher (MG), Southeast Greenland is monitored by the Department of Geography and Geology, University of Copenhagen, Denmark. Here we test the use of MODIS imagery for TSL observation on Taku Glacier and Narssap Sermia in Southwest Greenland.

For LCG and MG the snow ablation rates were calculated based on both the TSL-mass-balance-gradient method and the snow-pit-satellite method. For the TSL-mass-balance-gradient method ablation at the TSL is the product of the field observed balance gradient and the TSL rate of rise (Pelto, 2011). For the snow-pit-satellite method, the snow ablation rates were calculated based on observed snow loss in snow pits, from the date of excavation to the date when the TSL reaches the snowpit. For example, if the snowpack depth on July 1 in a snow pit was 1.4 m w.e., and on August 12 the TSL reached the snow pit, then it took 42 days to ablate 1.4 m w.e. of snow, yielding the snow ablation rate. At TG and LCG snow pit excavations were conducted for the years 1998 and 2003–2012 and at MG for the years 1999, 2000–2002, 2006, 2008, and 2012.

The TSL for TG and LCG has been observed for 19 time periods where satellite observations are at least 15 days apart. For MG there are 11 time periods of at least 15 days. On LCG positive TSL migration rates varied from 2.9 ± 0.9 m d-1 to 5.2 ± 0.0 m d-1 (Figure 1) with a mean for all ablation periods of 3.8 ± 0.6 m d-1. On TG the TSL migration rate ranges from 3.1 m d-1 to 4.8 m d-1 with a mean of 4.2 ± 0.5 m d-1. On MG the observed positive TSL migration rates varied from 4.0 ± 0.1 m d-1 to 10.6 m d-1 with a mean for all ablation periods of 6.9 ± 5.2 m d-1.

For LCG, based on the TSL-mass-balance gradient method the ablation rates varied from 0.023 to 0.039 m d-1, averaging 0.028 ± 0.004 m d-1, whereas ablation rates based on the for snow-pit-satellite method varied from 0.025 to 0.038 m d-1, averaging 0.031 ± 0.004 m d-1 (Figure 2). JIRP ablation measurements for LCG during the ablation seasons from 2004–2010, over a total period of 162 days, yield a mean ablation rate of 0.031 m d-1, which is in accordance with calculations: The similarity of the TSL and field ablation rates supports the concept that remote sensing TSL observations, which can be extended over longer time periods and are not simple point measurements, offering a useful approach of estimating annual ablation rates, which are important in assessing changes in glacier mass balance in the Juneau Icefield region.

On Taku Glacier the balance gradient from probing between 900 and 1070 meters is 4.5 mm m-1. The mean daily TSL rise is ranges from with a mean of 4.2 m d-1, the TSL-mass-balance gradient method derived mean daily ablation is 0.019 m d-1 water equivalent for the July-September period in the vicinity of the TSL during July-early September.

For MG the snow ablation rates showed more variability, with rates in the range from 0.037 to 0.072 m w.e. d-1, averaging 0.051 ± 0.018 m w.e. d-1 based on the TSL-mass-balance-gradient method, and 0.028 to 0.073 m w.e. d-1, averaging 0.047 ± 0.019 m w.e. d-1 based on the snow-pit-satellite method (Figure 3). At MG no direct field snow ablation measurements have been conducted for validation of the estimated snow ablation values, but in future mass balance model simulations the calculated snow ablation rates has the potential for being compared against simulated ablation rates. However, Mernild and others (2006) simulated daily snow and ice melt rates using the modeling software package SnowModel for the period 1999–2004, and these simulated rates (0.03–0.04 m w.e. d-1) were in average slightly lower than the estimated snow ablation rates presented in this study.

MODIS imagery has a lower resolution but higher availability than Landsat. A comparison of overlain MODIS and Landsat, from the same day, indicates that TSL identification using MODIS indicates a mean difference of 110 m + 80 m in horizontal TSL position versus Landsat, which corresponds to a vertical difference of 3-5 m on Taku Glacier and Narssap Sermia. For Narssap Sermia TSL was evident in 2011 on 11 days with MODIS imgagery and 4 Landsat image dates. In 2012 there were 13 MODIS dates and 4 Landsat dates where TSL was identifiable. More details will be ready on this last part of the study by the conference date.

Mernild, S.H., G.E. Liston, B. Hasholt and N.T. Knudsen. 2006, Snow distribution and melt modeling for Mittivakkat Glacier, Ammassalik Island, SE Greenland: Journal of Hydrometeorology, v. 7, p. 808–824.

Pelto, M. 2011, The utility of late summer transient snowline migration rate on Taku Glacier, Alaska: The Cryosphere, v. 5, p. 1127–1133.

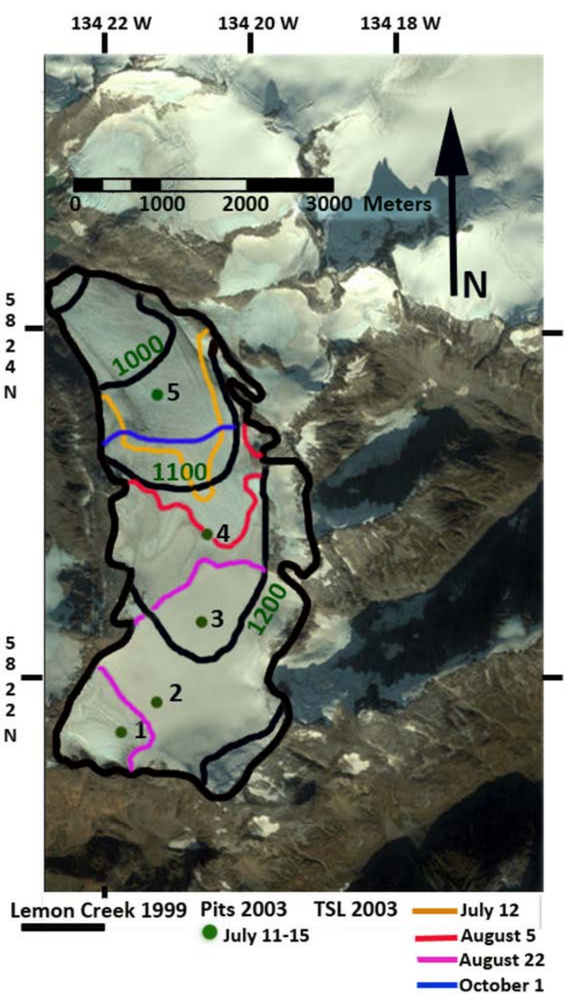

Fig 1. Satellite image of the Lemon Creek Glacier (11.6 km2) (the inset figure in the upper right corner indicates the general location of the glacier in Southeastern Alaska), with 100-m contour intervals. The green dots (one to five) indicate standard snow pit locations from 2003, and the colored bold lines the seasonal locations of snowlines during the 2003 ablation season. The glacier boundary is for 1999 and estimated from Global Land Ice Measurements from Space (GLIMS; www.glims.org).

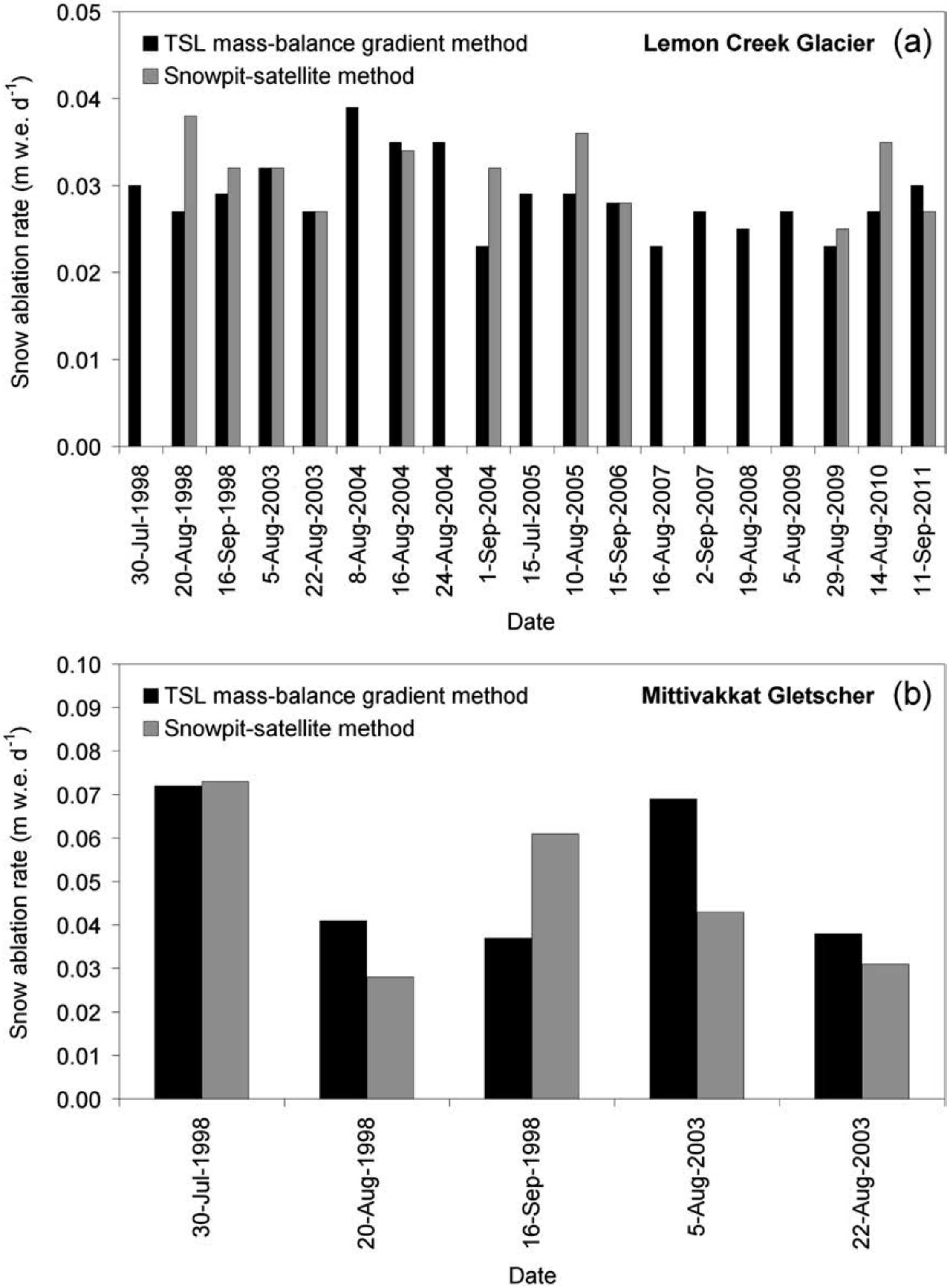

Fig 2. (a) Estimated snow ablation rates for Lemon Creek Glacier; and (b) for Mittivakkat Gletscher based on the TSL-mass-balance-gradient method and the snow-pit-satellite method.

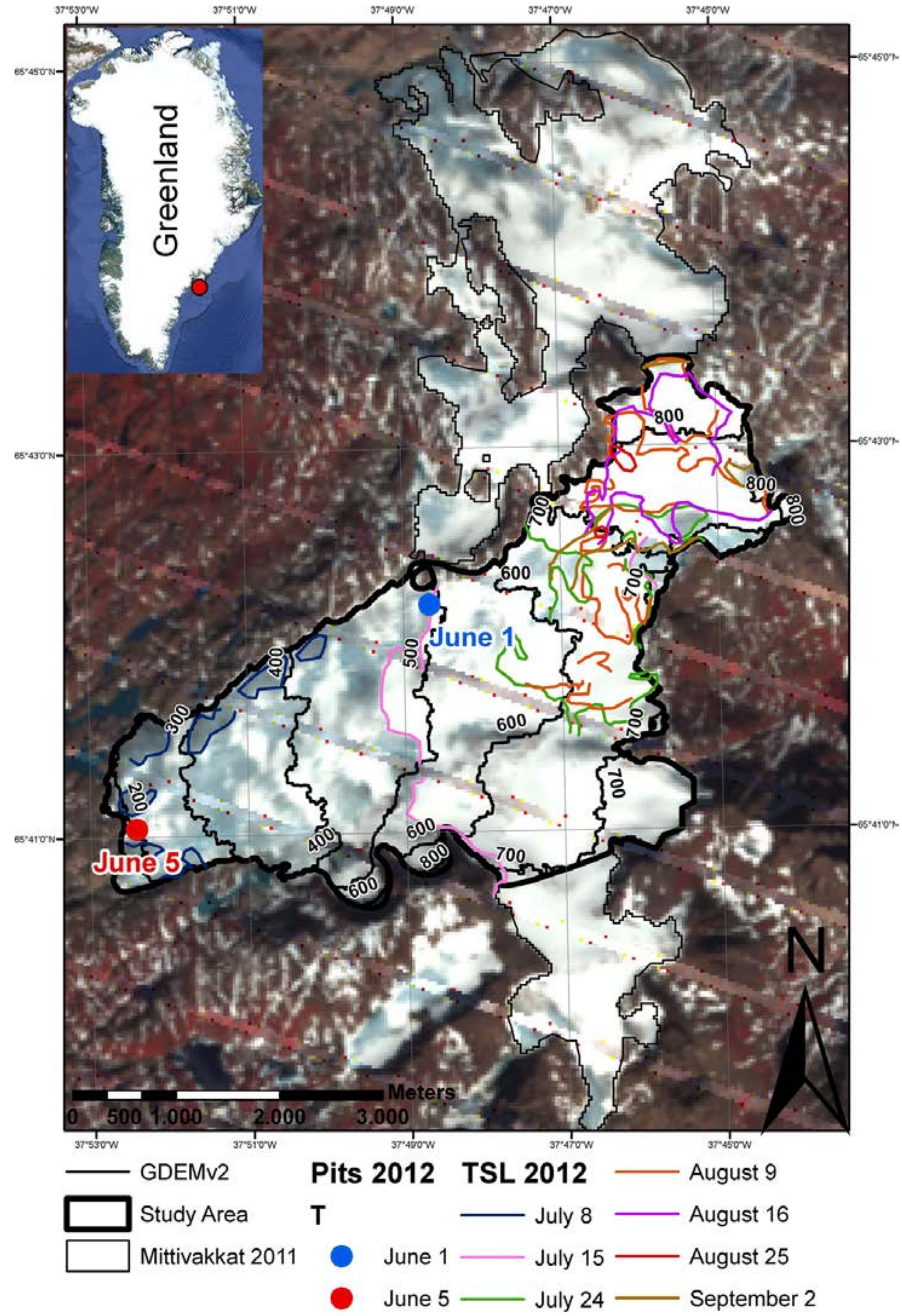

Fig 3. Satellite image of the Mittivakkat Gletscher (26.2 km2 in total in 2011, and 15.9 km2 for the observed Ba study area) (the inset figure in the upper left corner indicates the general location of the glacier in Southeast Greenland), with 100-m contour intervals. The red and the blue dots indicate an example of snow pit locations from 2012 and the colored bold lines the seasonal locations of snowlines during the 2012 ablation season. The glacier boundary is based on Landsat 7 ETM+ Mosaic imagery (1 August 2009 and 14 August 2011).