using digital elevation models in glaciology

UNIS Glaciology Course

vår 2017

Today's Topics

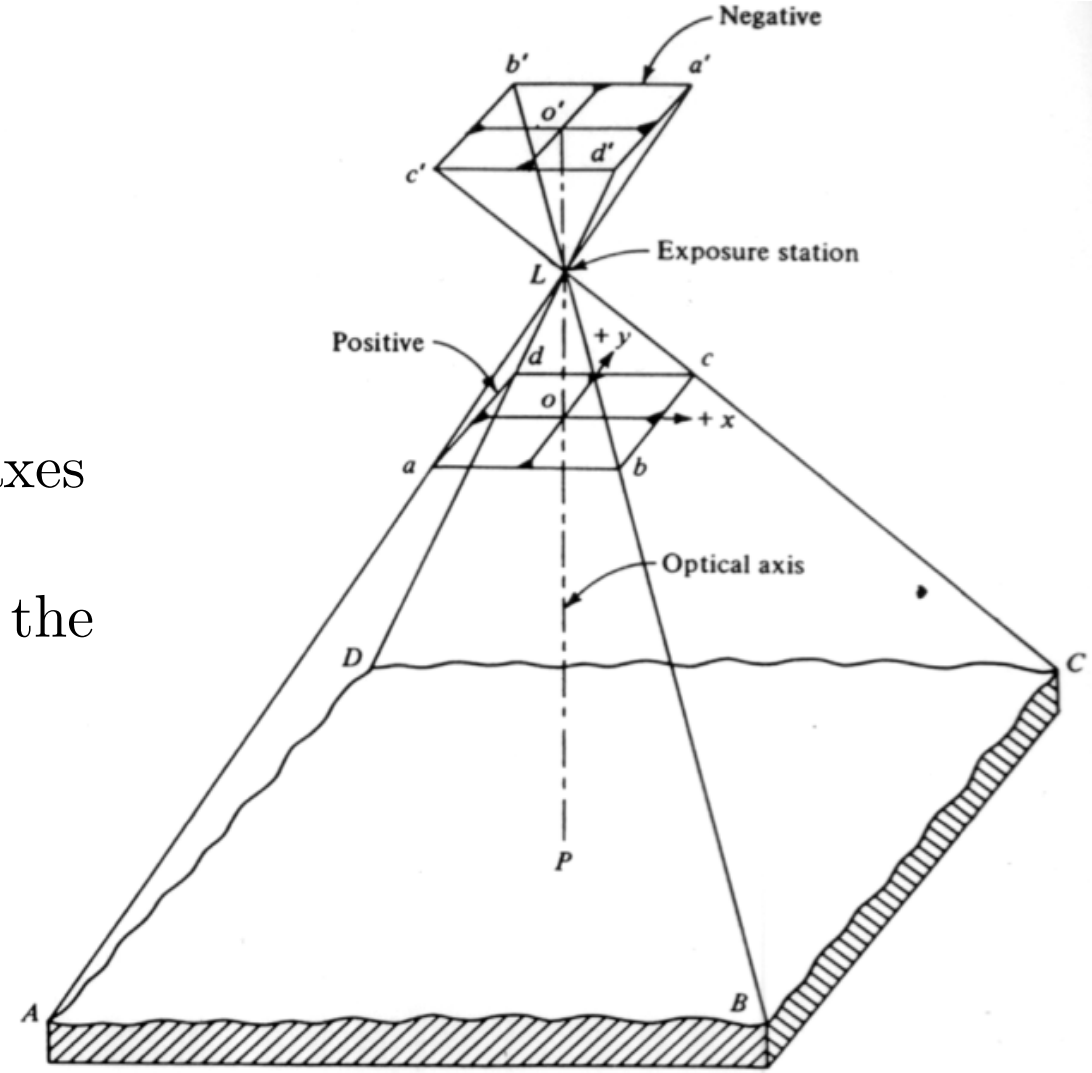
- principles of stereo photogrammetry
- dem co-registration
- dem differencing and geodetic mass balance
- uncertainty estimation

what is photogrammetry?

- photogrammetry: the technique of obtaining reliable measurements of objects from photographs
- stereo photogrammetry: the technique of determining 3-D coordinates of points in photographs taken from different locations
- with stereoscopic images, we can obtain:
  - precise x, y, z locations
  - digital elevation models (dems), digital terrain models (dtms), digital surface models (dsms)
  - orthophotos

image geometry

photographic coordinate axes x, y radiate from the principal point (center) of the photo



Wolf, DeWitt, Wilkinson, *Elements of Photogrammetry*

measuring distance in images

can measure distances in photographs in several ways:

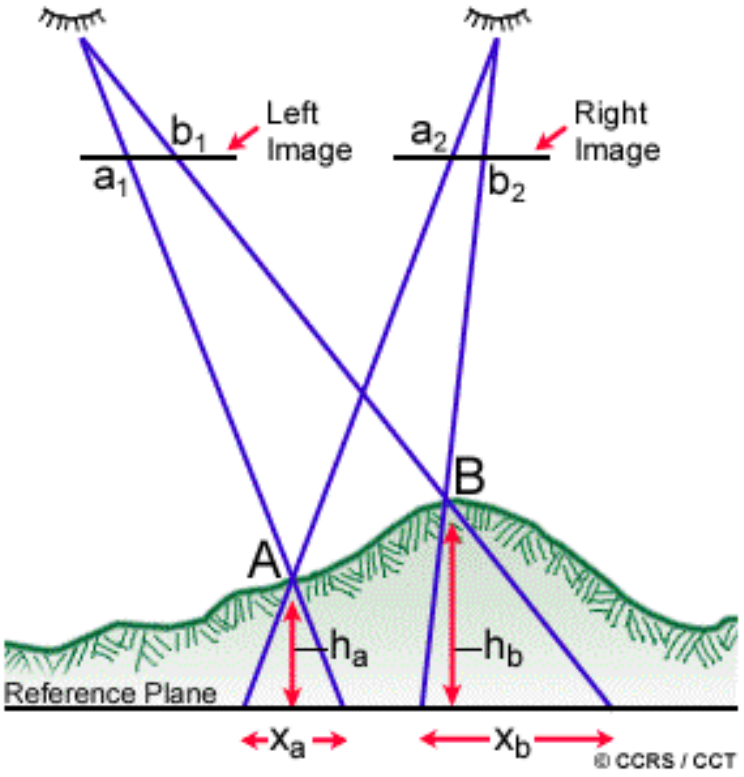
- comparing apparent size in image to known size on ground
- calculate scale based on camera properties, distance to target
- shadow length
- relief displacement

parallax

with two cameras (or eyes), we can calculate parallax:

- apparent displacement in object position caused by shift in the position of observation
- depends on distance between observation point and object
- can use triangulation to determine distance to various objects
- can use stereo photos to measure topography

calculating topography from stereo



- x_a, x_b are the parallax shifts of a,b
- h_a, h_b are the heights of a,b
- using baseline separation P of acquisition locations:

$$h_a = (H - h)\frac{x_a}{P + x_a},$$

where $H - h$ is the aircraft height above the ground

calculating topography from stereo images

in practice we no longer do this manually

- with two images, find and process tie points
- use correlation to find best matches
- use knowledge of camera/sensor parameters, orientation, positions
- as with velocities, contrast is good

generating dems

can generate dems from single-camera images if we can change the viewing angle

- satellite imagery (e.g., ASTER, SPOT, Worldview, Planet)
- aerial photography
- structure from motion with aerial/terrestrial photos

errors/uncertainty

sources of error and uncertainty in dems include, but are not limited to:

- satellite/sensor motion (jitter)
- inability to see features (i.e., snow/ice washes out image)
- resampling topography
- georeferencing errors

dem differencing

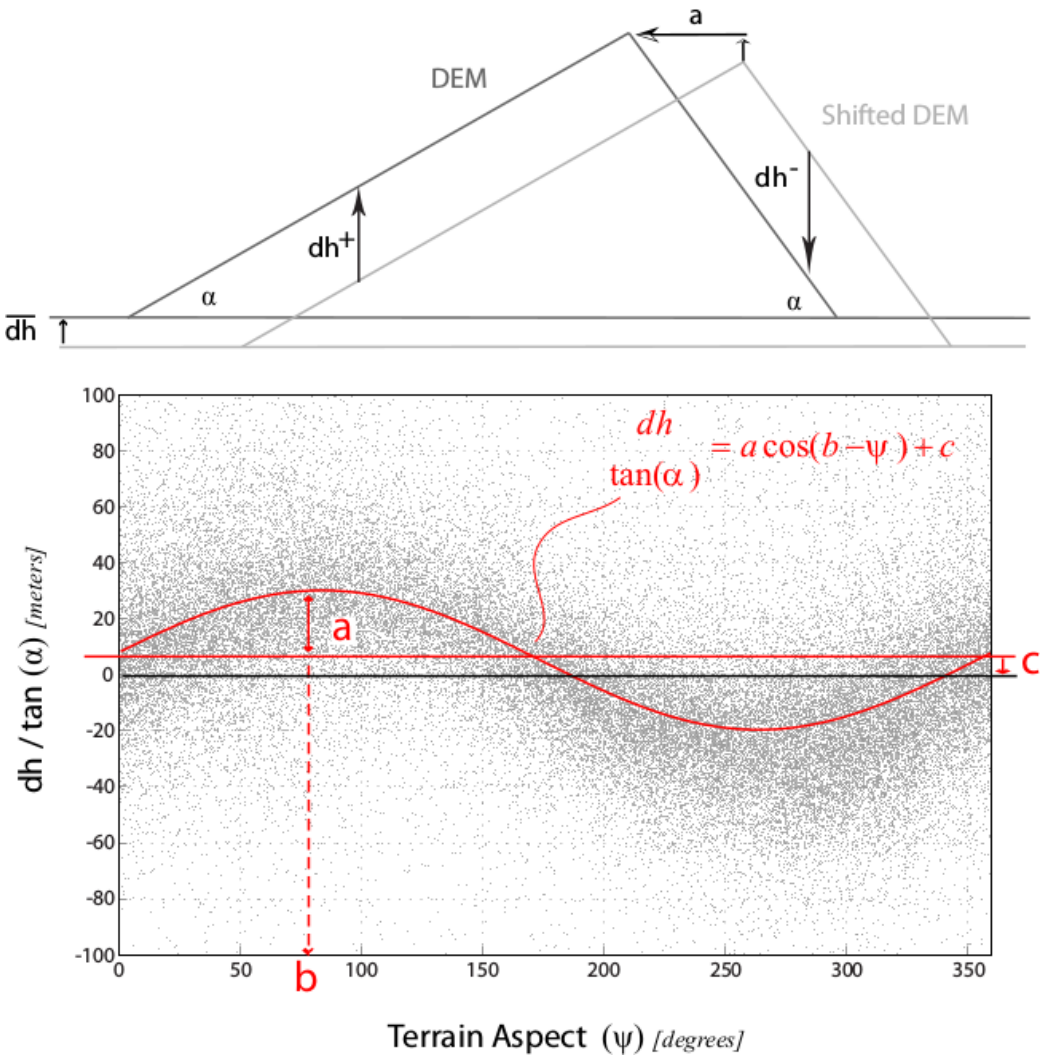
- we want to use multiple dems of glaciers to estimate volume change, mass balance
- have to select dems separated enough in time to see signal
- separation depends on:
  - how much the surface is changing
  - how good our dems are
- typically, $\sim$5 years is a good rule

co-registration

errors in co-registration can occur

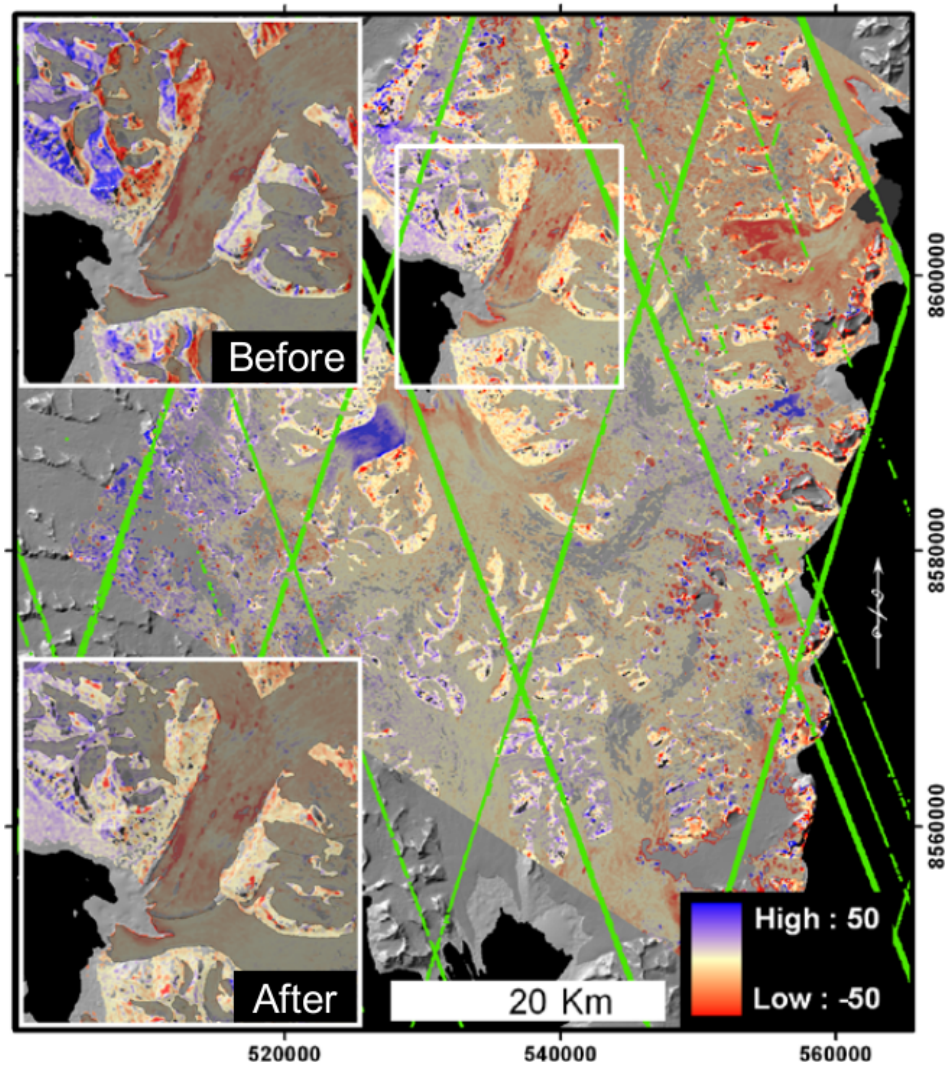
- these errors become very obvious in difference image
- dem difference map will resemble hillshade
- can use offsets, slope, aspect to co-register

co-registration



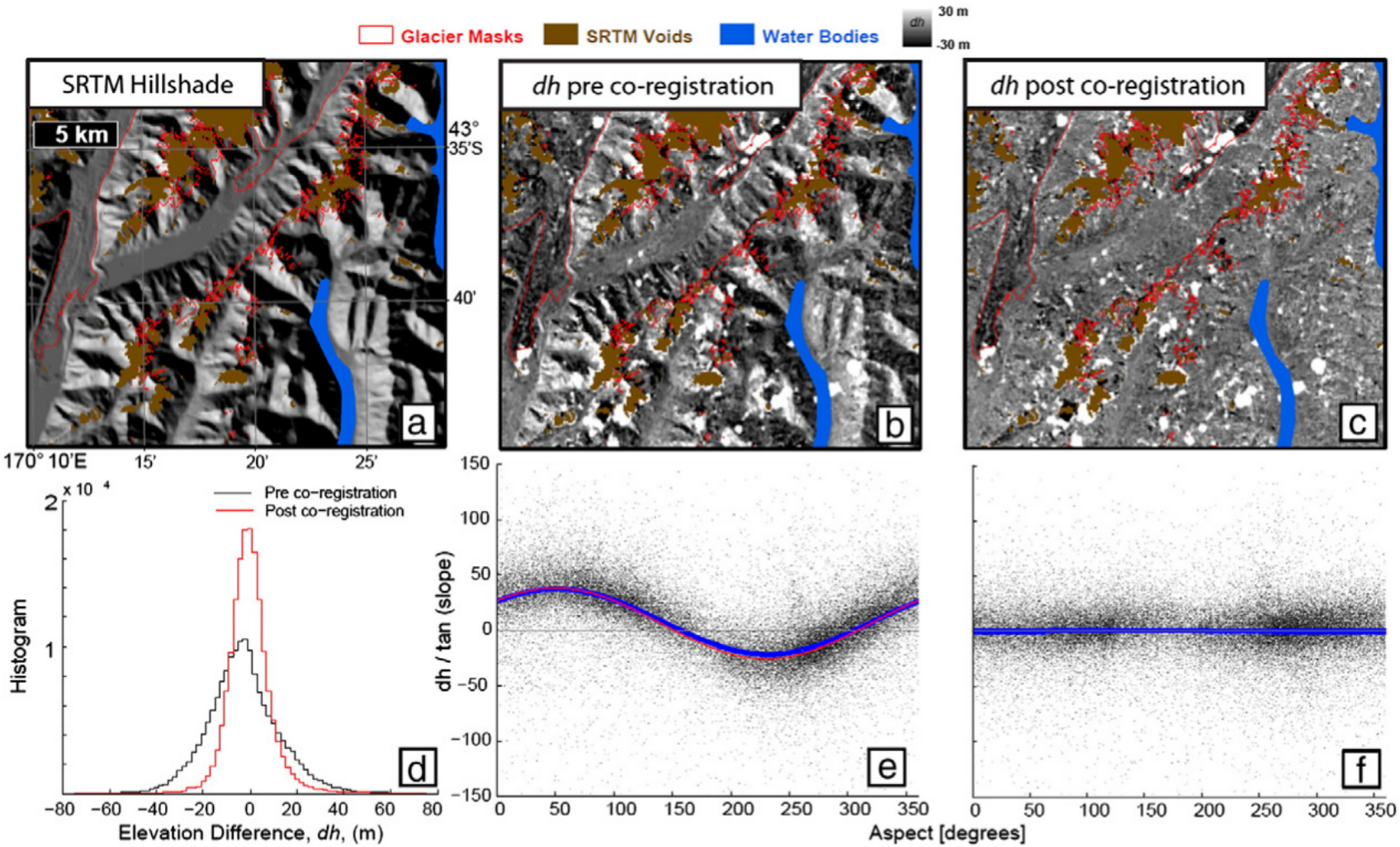
Nuth and Kääb, 2011

co-registration



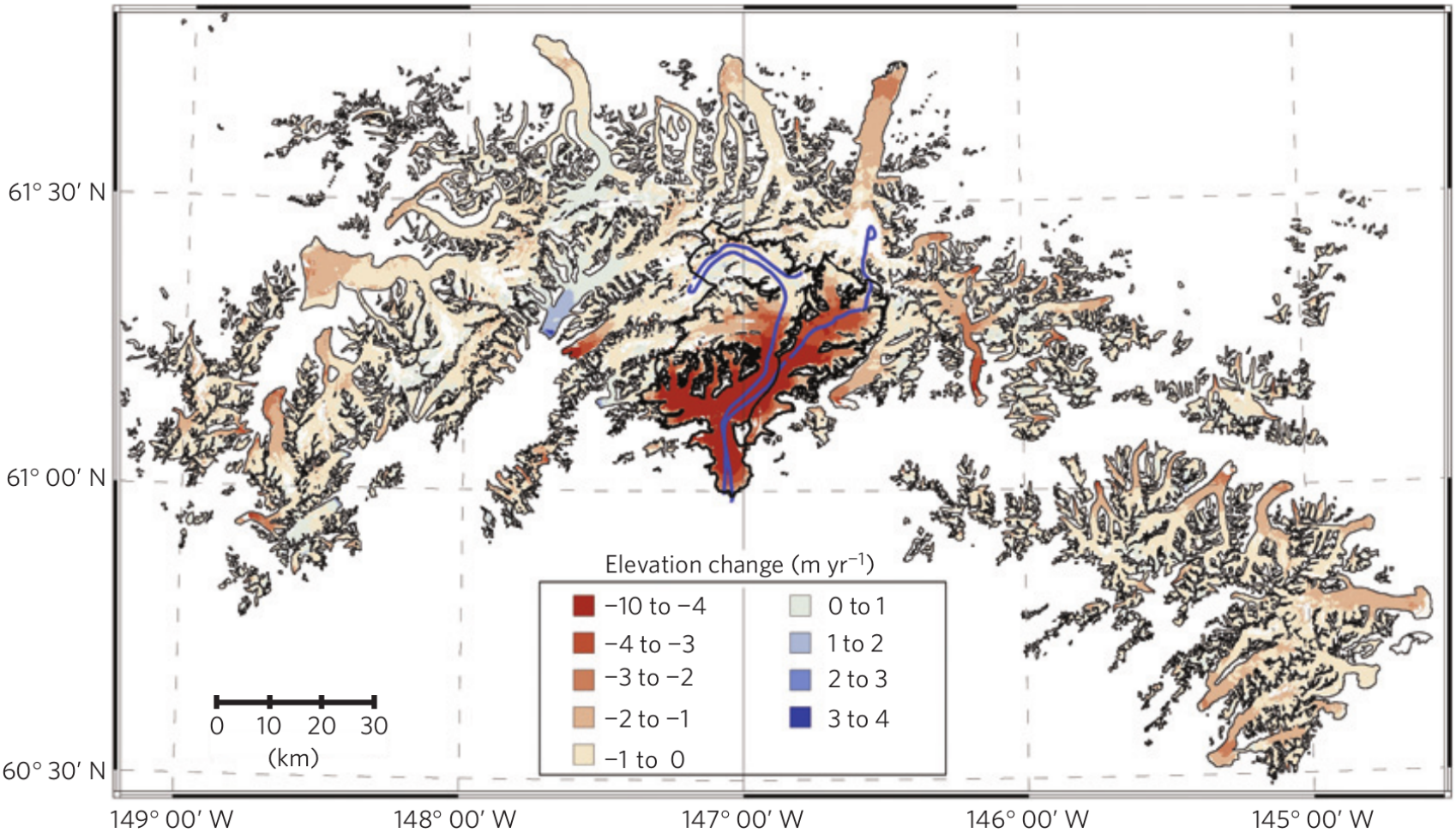
Nuth and Kääb, 2011

co-registration



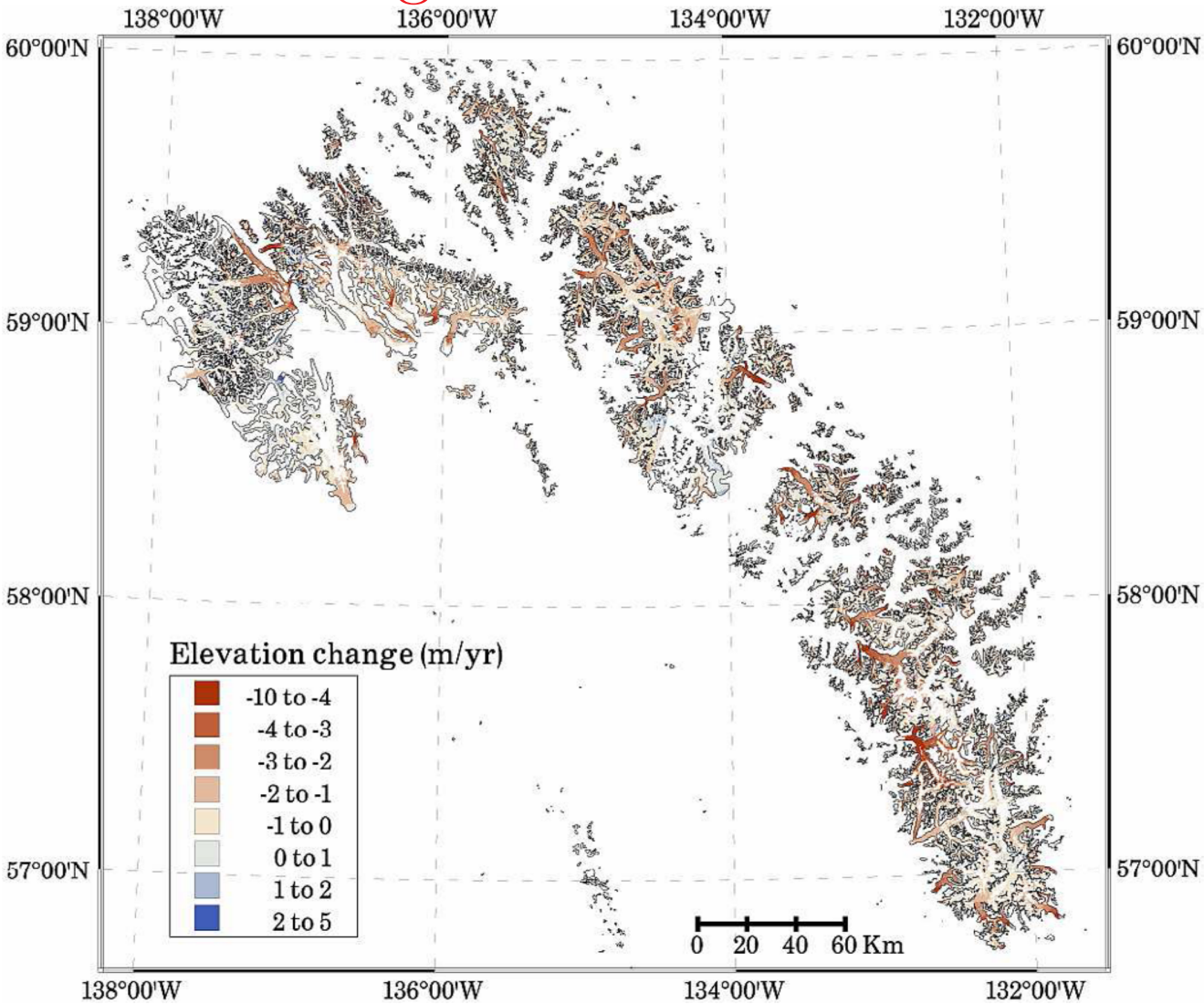
Paul et al., 2015

glacier elevation changes



Berthier et al., 2010

glacier elevation changes

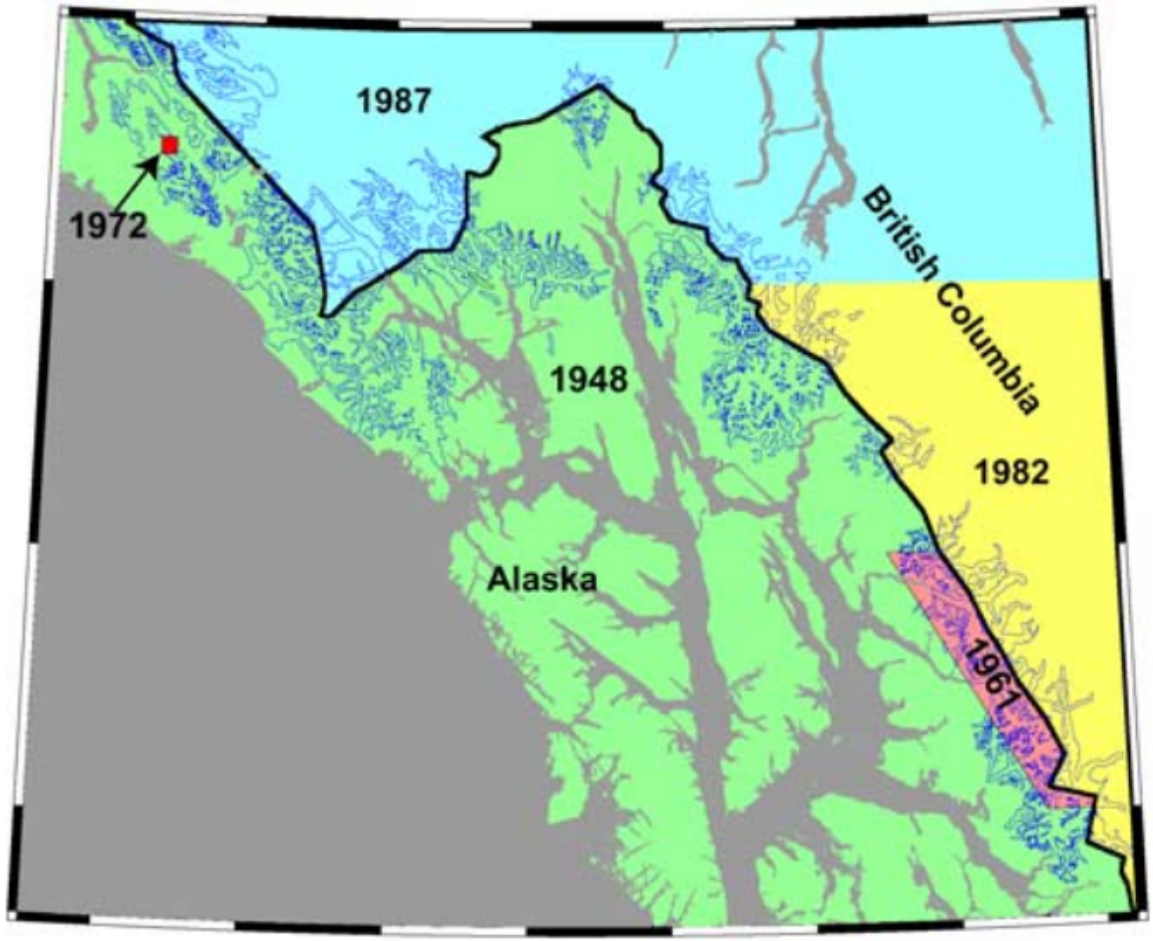


Berthier et al., 2010

calculating volume changes from elevation changes

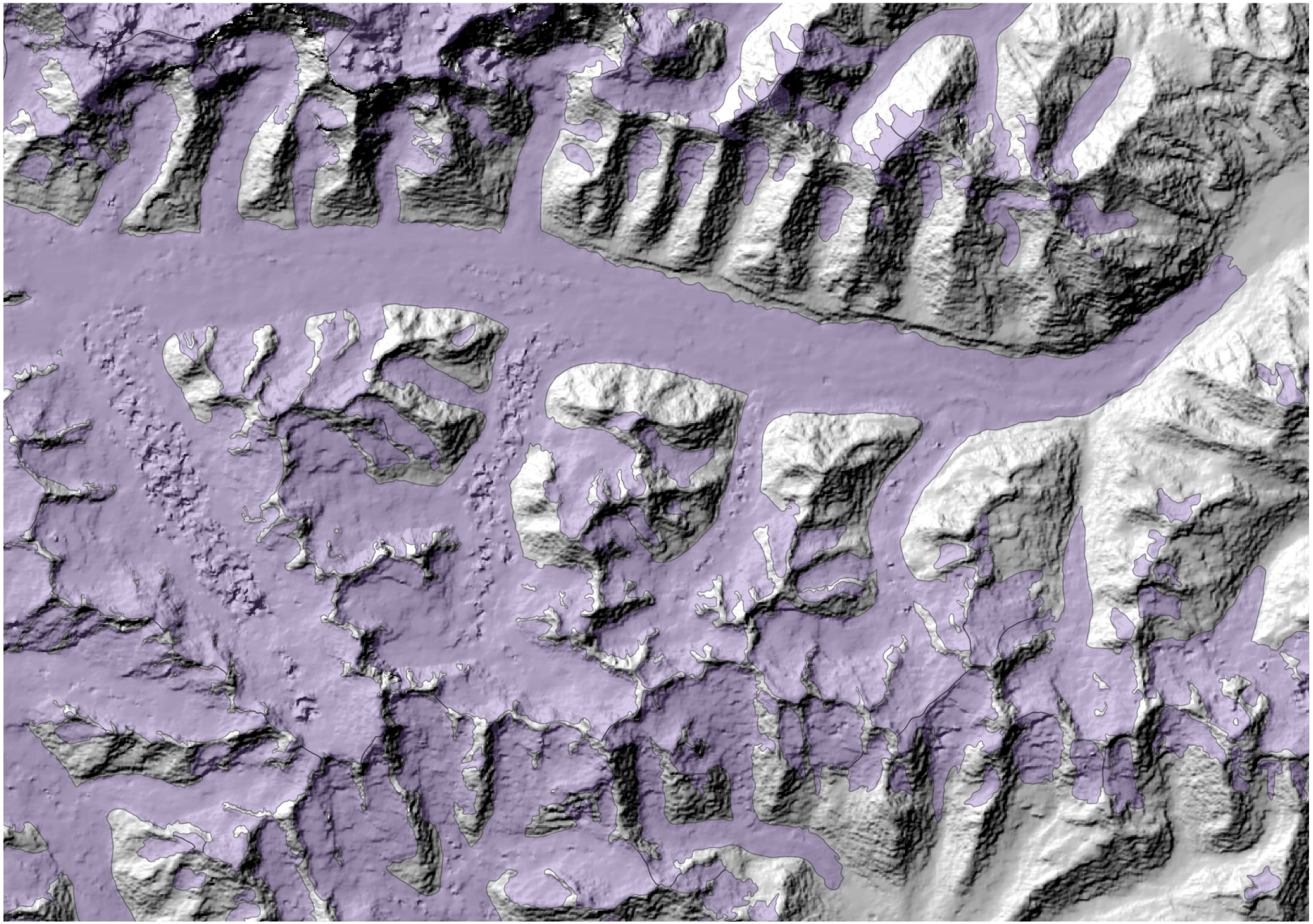
- dem differencing gives most straightforward way to estimate volume change of glaciers
- essentially, integrate elevation change map over glacier surface
- in practice, sum up dH, multiply by pixel area
- can still have errors

handling temporally inconsistent data

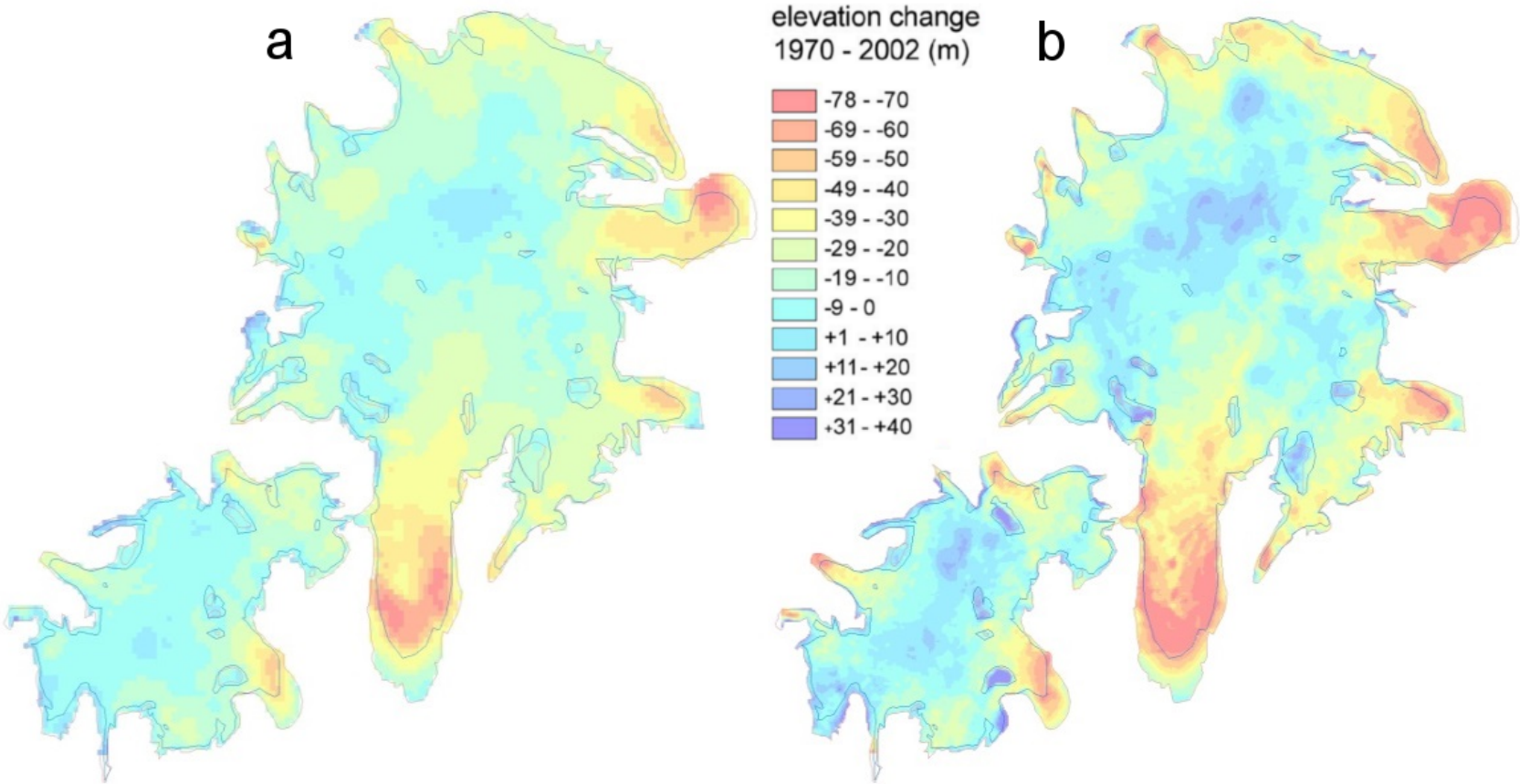


Larsen et al., 2007

handling spatially incomplete data

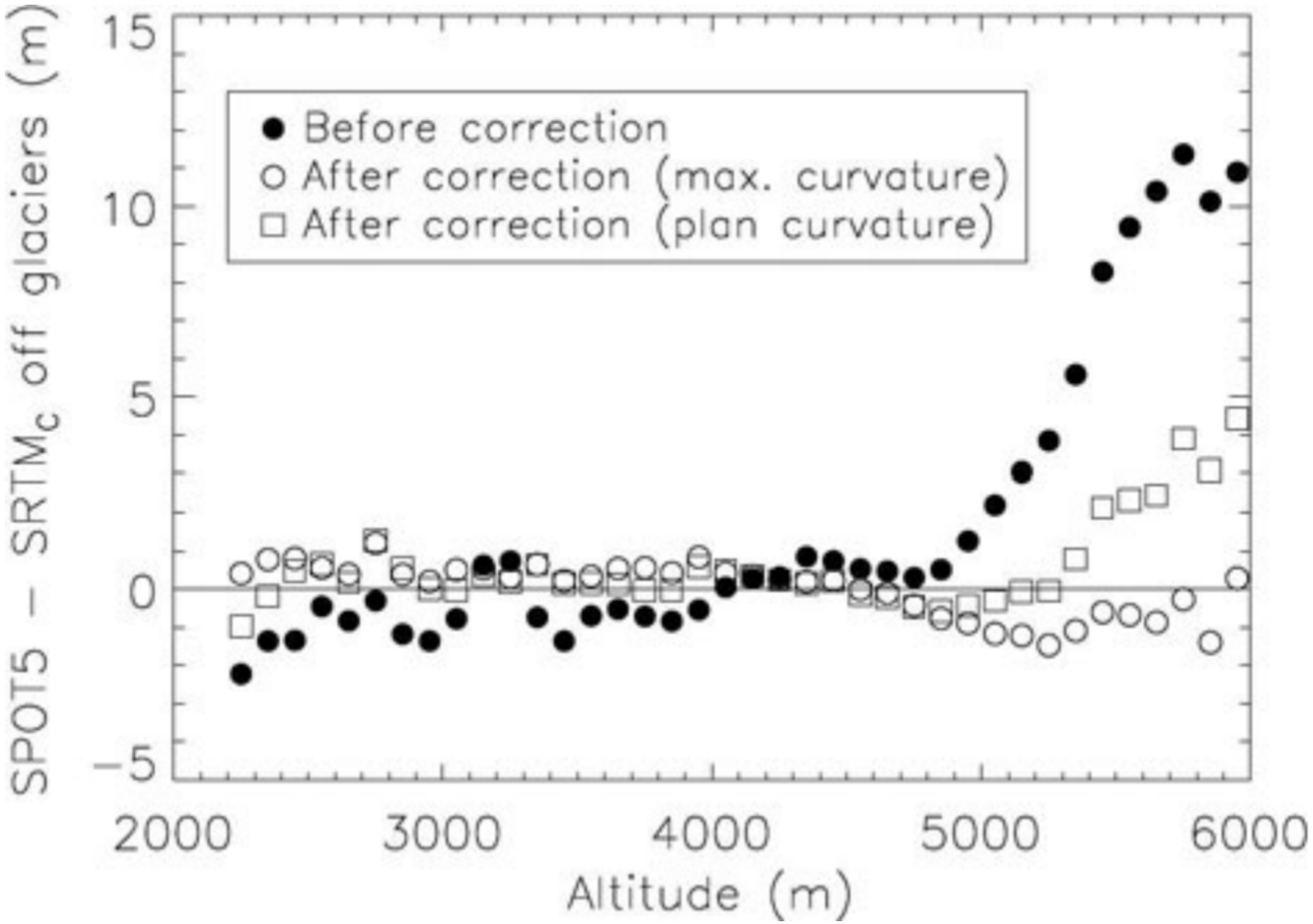


handling spatially incomplete data



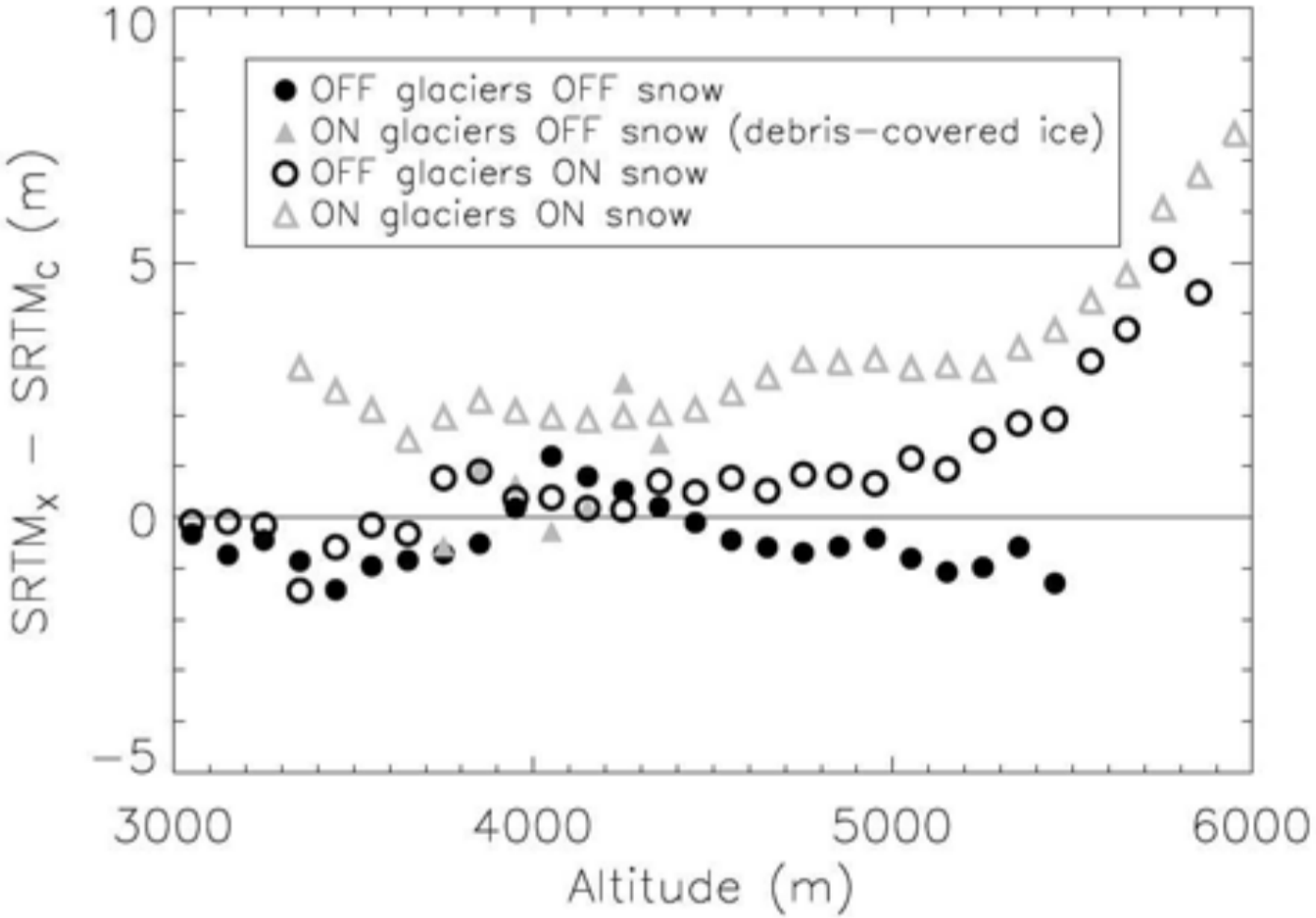
After Kääb, 2008

curvature errors



Gardelle et al., 2012

radar signal penetration



Gardelle et al., 2012

estimating uncertainties

- compare to a high-resolution dem (if available)
- compare off-glacier elevations to ICESat elevations
- if no external data available, estimate RMSE in off-glacier areas from difference map

questions?