Integrated firn elevation change model for glaciers and ice caps

Björn Saß
University of Erlangen (FAU), Institute of Geography,
bjoern.sass@fau.de

20°E 80°N

1 The Idea

My motivation is to address uncertainties which result from converting geodetic volume change into glacier mass balance. The uncertainties result from an inadequate conversion factor (density) which neglects altitude dependent firn density variations, firn layer thickness and not homogenous density variations with varying climate conditions. I am developing a transferable firn densification resp. elevation change model to minimize this systematic error and to raise the accuracy of glacier mass balances measured in geodetic manner.

What is the change in height by the densification of firn on glaciers and ice caps?

2 Data base

Input climate data:
- ERA-Interim/ MAR [1]
- AWS network [2]
- Model output statistics

Calibration & validation:
- In situ data archive of the IPY Kinnvika field campaigns between 2007 and 2010 (e.g. climate data, firn density profiles and ablation measurements) [2,3,4,9]
- Multimission satellite data between 2003 and 2015 to derive elevation data and the transient snow line (e.g. TanDEM-X, CryoSat-2, ICESat, Aster, ALOS Palsar)

3 The Model

Programming language: Python 2.7 (Open Source, GIS compatible, relatively easy)

Input

Physical model forcing by surface energy balance parameters: incoming shortwave radiation, air temperature, relative humidity, air pressure, wind speed, all-phase precipitation, cloud cover fraction.

Data format: NetCDF-4 | Default resolution: 2 - 3 km | Boundary conditions: subdaily reanalysis (e.g. MAR) [1]

Core

Based on: 1D COupled Snowpack and Ice surface energy and MAss balance model (COSIMA) (Matlab) (Huintjes et al. 2015)[5]

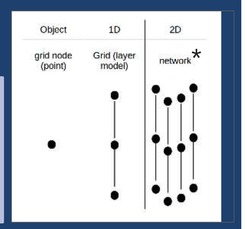
ADD NEW SNOWFALL & CHANGE SNOW COVER PROPERTIES
↓
HEAT FLUXES & SURFACE TEMPERATURE
↓
CHANGE PHASES OF WATER AT SURFACE: MELTING & REFREEZING
↓
DENSIFICATION BY OVERBURDEN PRESSURE & SNOW TEMPERATURE
↓
SUBSURFACE MELT, PERCOLATION & REFREEZING
↓
UPDATE DENSITY PROFILES & CHANGE REFERENCE HEIGHT

↰ time loop ↲

Output

2D/ 3D (distributed) grid network* containing the pixel based dh_{FIRN}/dt, firn density profiles and mean density values (ablation zone will be treated as bare ice).

Data format: ascii, NetCDF, GeoTIFF | One modeled pixel = one pixel of $DEM_{dh/dt}$

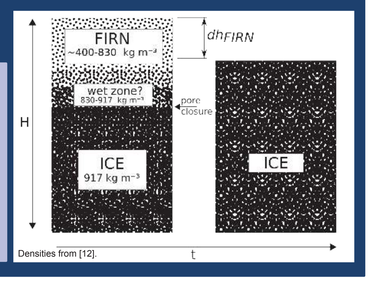


Mass balance correction

accumulation (acc) zone: $(dh / dt - dh_{FIRN} / dt) * A * \rho_{ICE} = dM_{acc} / dt$

ablation (abl) zone: $dh / dt * A * \rho_{ICE} = dM_{acc} / dt$

glacier wide: $dM_{acc} / dt + dM_{abl} / dt = dM / dt$ [e.g. G a^{-1}]



Densities from [12].

! Project frame

- PhD-Project: 2015 - 2017
- Supervisors: Prof Matthias Braun & Dr Tobias Sauter (both Erlangen)
- Observation period: 2003 - 2015

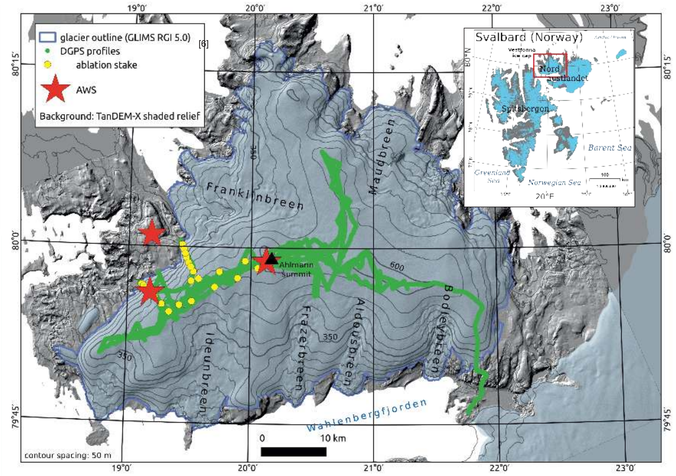
4 The test site

Vestfonna Ice Cap (VIC) (~2340 km²) on Nordaustlandet, north east of Svalbard.
- Vertical spanning: 0 - 630 m asl
- Mean elevation: 386 m asl
- Mean ELA: 380 m asl ($S^{E}_{m\,asl}$) [2]

General conditions:
VIC is a polythermal ice cap with a dome like shape and gentle slopes. Most outlet glaciers calve into surrounding seas.
Melting occurs up to summit in summer season and mass balance year starts in September, with ablation period from June to August. [2]

Glacier change:
VIC showed almost balanced conditions in the last two decades, while the outlets were steady retreating, with the exception of the re-advance of the largest outlet glacier towards NW (surge). [10,11]

Firn conditions on VIC:
Firn thickness was 1996 10 m at summit [7], recent studies suggest it to be 15 - 20 m thick [4].
Melt water percolation and refreezing play a major role on the ice cap.



5 To talk about

What I need

- GPR (stratigraphy/ layering/ pore closure) for VIC [8,9]
- A minimal model for fresh snow density

Further study sites with a magnificent in situ measurement archive are welcome:
- GPR (stratigraphy/ layering/ pore closure) and/ or
- Shallow (firn) cores (density and layering)
- Reanalysis climate data (subdaily) and
- AWS data (min.: T, rH, u/v, SSR; add.: p, Precip., CC,)
- Ablation measurements and/ or
- Snow height & Accumulation conditions (e.g. SR-50)

What I can provide

end of 2016
- Firn elevation change model output

Multimission remote sensing products:
- high resolution DEMs for specified dates (TanDEM-X, ICESat, CryoSat-2)

2017
- Transient snow line & seasonal melt pattern (TanDEM-X, Sentinel-1A, Aster, ALOS Palsar)
- Up to date glacier outlines (GLIMS, Optical and radar satellite missions)

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TanDEM-X data provided under DLR AO XTI_GLAC0264 and XTI_GLAC6770. Glacier outlines are taken out of the Global Land Ice Measurements from Space (GLIMS) Glacier Database (http://www.glims.org/). ICESat elevation tracks are published by NASA National Snow and Ice Data Center (NSIDC) Distributed Active Archive Center (DAAC). CryoSat-2 data are postprocessed by V. Helm (AWI Bremerhaven). Detailed Info of IPY Kinnvika on http://www.kinnvika.net

Abstract of resources:
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