ICE CAP SURFACE ELEVATION CHANGE PRODUCTS FROM ENVISAT RA2 AND ICESAT GLAS ALTIMETER DATA

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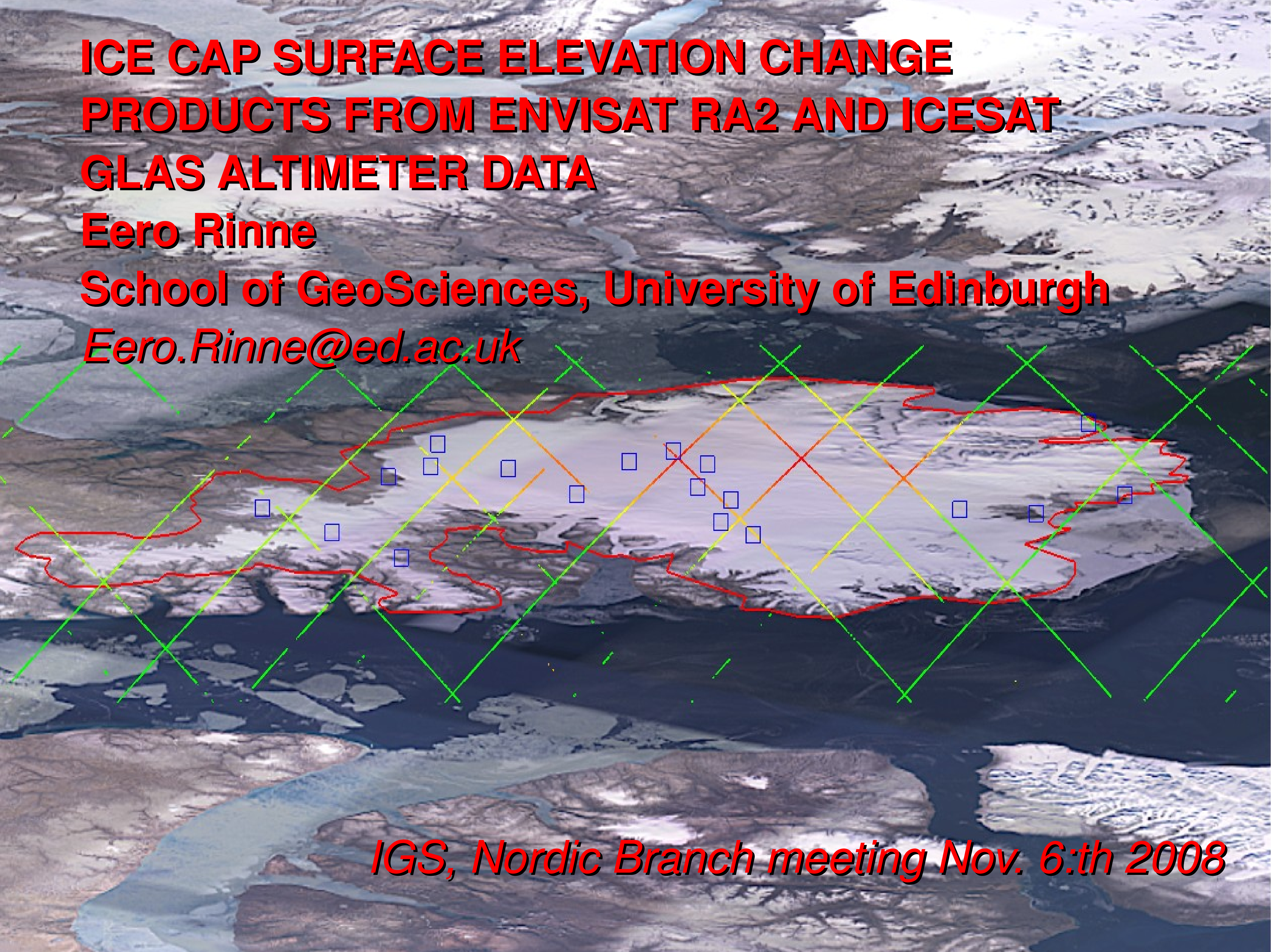


IGS, Nordic Branch meeting Nov. 6:th 2008

Outline

- What and why
  - What we want to achieve
  - Who's paying the bills?
  - Who cares?
- How
  - The data
  - Quick introduction of software and some technical talk
- Results and discussion
  - So what?
- Mandatory joke

What and why

What we want to achieve?

"*Changes in glacier surface elevation will be obtained ... from time-series of satellite (and partly airborne) altimetry data (e.g. RADAR, LiDAR). Additionally, methods for spatial extrapolation of point measurements to the entire glacier surface will be developed.*"

- GlobGlacier original project proposal

Goal is to create large number of surface elevation change estimates (and errorbars!) of ice caps and glaciers around the world.

Who's paying the bills?

- European Space Agency (ESA) is, via project GlobGlacier
- GlobGlacier attempts to establish a service for glacier monitoring from space, which aims at establishing a global picture of glaciers and ice caps, and their role as Essential Climate Variables
- Many WP:s, Edinburgh University is responsible for the one concerning elevation change
- If interested, check out http://globglacier.ch

Who cares?

- The GlobGlacier user group does:
  - National environmental agencies:
    - Natural resources (Norway's water resources and energy directorate, Norway)
  - International organisations
    - Risk assesement (International Centre For Integrated Mountain Development, Himalaya)
  - Universities
  - Research institutes

How

ICESat Geoscience Laser Altimeter System - GLAS 06 dataset

- Elevation [h] measurements
- Laser altimeter data → sees the air-snow interface
- Global coverage: 86 N – 86 S
- Density of ground tracks increases with latitude
- ~ 65 m footprint and 170 m spacing between measurements
- Precision ~ 15-50 cm depending on the surface slope
- 15 observation periods so far
  - first: 20 Feb. to 21 Mar. 2003
  - last so far: 17 Feb to 21 Mar 2008.
- Available for free from National Snow and Ice Data Centre website

edinburgh
earth
observatory

ICESat GLAS data challenges

- IceSat is optimized for large ice sheets with very small or zero surface tilt
- 91 day repeat orbit makes repeat measurement from same place scarce
- Creating timeseries is problematic due to surface tilt – elevation trend is very sensitive to processing parameters
- Using lower level data might provide better filtering tools but is really beyond scope of GlobGlacier
- If an elevation model is available, DEM correction results in better quality elevation change estimates

Nevertheless IceSat data has been used for studies of smaller ice bodies with complicated surface geometry – for example Malaspina Glacier, Alaska {Sauber et. al. 2005]

GlobGlacier processing chain for ICESat data

- Extract elevations for area of interest from GLAS06 global product (needs lat/lon box as input)
- Read data into Matlab
- Reproject if necessary
- Find crossover points inside outline (GLIMS or other GlobGlacier WP)
- interpolate elevation in exact crossover point or average elevations inside 100-500 m radius of crossover points for each operation period
- If a DEM is available, apply DEM correction
- Filter out bad data points:
  - 3-sigma clipping, too much temporal variation → discard data
- Calculate trend (by fitting a 1:st degree polynom to elevations at different times) and standard deviation of elevations over time at each crossover point
- Output is surface elevation [m] or elevation difference between ICESat and DEM (dH) at given times t, elevation trend [m/a] and std. of elevation [m] and timespan [a] of measurements inside given outline

DEM correction for ICESAT data

- Crossover points from different years can be as far as 500 m apart
- Instead of using icesat measured elevation value for trend analysis, we use the difference between measured elevation and DEM elevation
- Efficient as long as the resolution of DEM is enough to describe surface shape

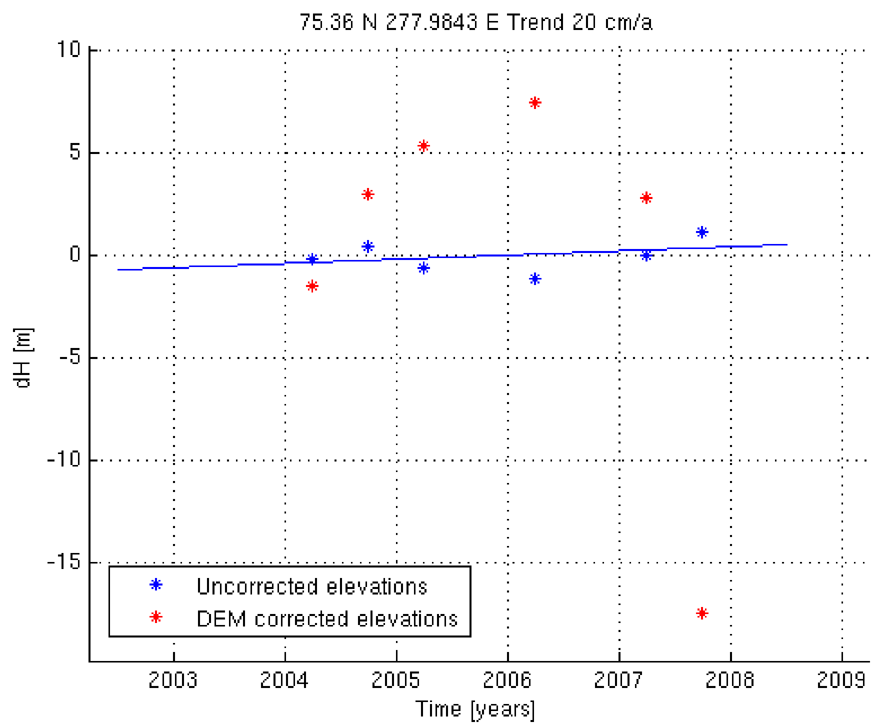


Figure: ICESAT measured elevations at the high altitude area of Devon Ice Cap Uncorrected ICESat (red), DEM corrected ICESat (blue)

EnviSAT RA2 (radio altimeter) data

- Radio altimeter → sees the snow ice interface (if the snow is dry). If the snow is not dry, no-one really knows...
- ~ 3 km footprint
- Data available since late 2002 to present
- RA2 copes better with land ice surface elevation than RA1 did (that is, does not lose lock when retracking surface as easily).
- Covers Arctic land areas > 65N (similar dataset for Antarctic areas will be available later)
- Elevation difference (dH) at every orbital crossover point
- Elevation values from one orbit is designed to act as a reference track to be used as zero when calculating dH for other orbits
- dH values are binned to reduce noise and errors
- Processed from lower level data by UCL, London

GlobGlacier processing chain for RA2 data

- Read data into Matlab
- Reproject if necessary
- Find crossover points inside ice cap outline
- Combine elevation values measured using different reference tracks
- Filter out bad data points
  - 3-sigma clipping, too much temporal variation
- Calculate trend (by fitting a 1:st degree polynom to elevations at different times) and standard deviation of elevations over time at each crossover point
- Output is surface elevation trend [m/a] and std. of elevation of RA2 orbital crossover points inside given outline [m] and measurement timespan [a]

Results

Method development area – Devon Ice Cap

- Relatively large ice cap (14000 km^2) relatively north (75 N) → multiple RA2 and GLAS orbital crossover points
- Shape and flow is well documented and an airborne DEM is available by Dowdeswell et al.
- Elevation 0-2000 m.
- ASIRAS radio altimeter data from CryoSAT validation experiment campaigns available (tools to process this have been made but data has not been yet used.)
- Has areas with complicated geometry and a rather simple dome structure

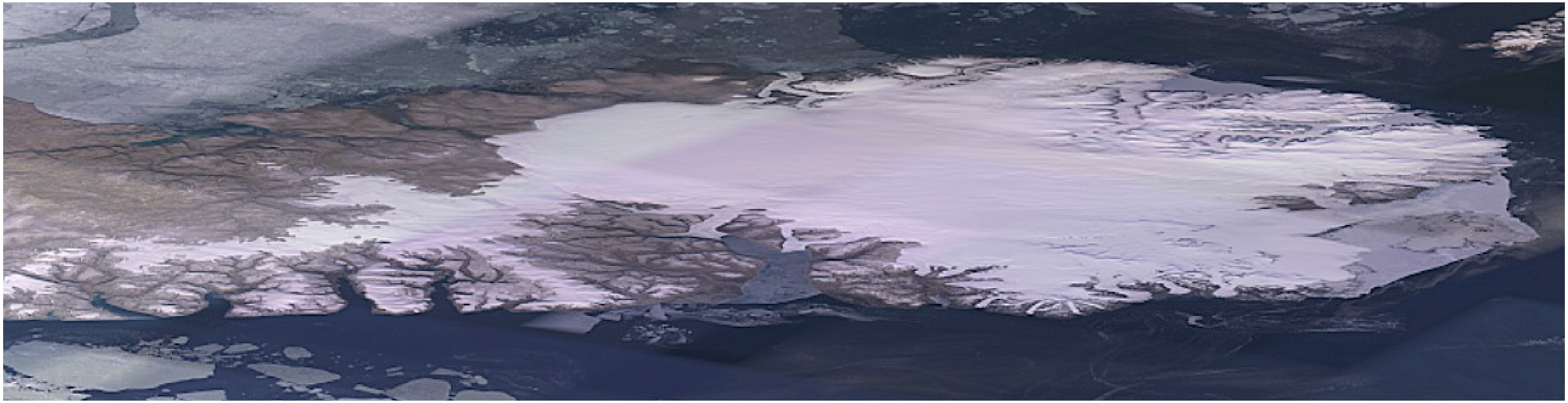
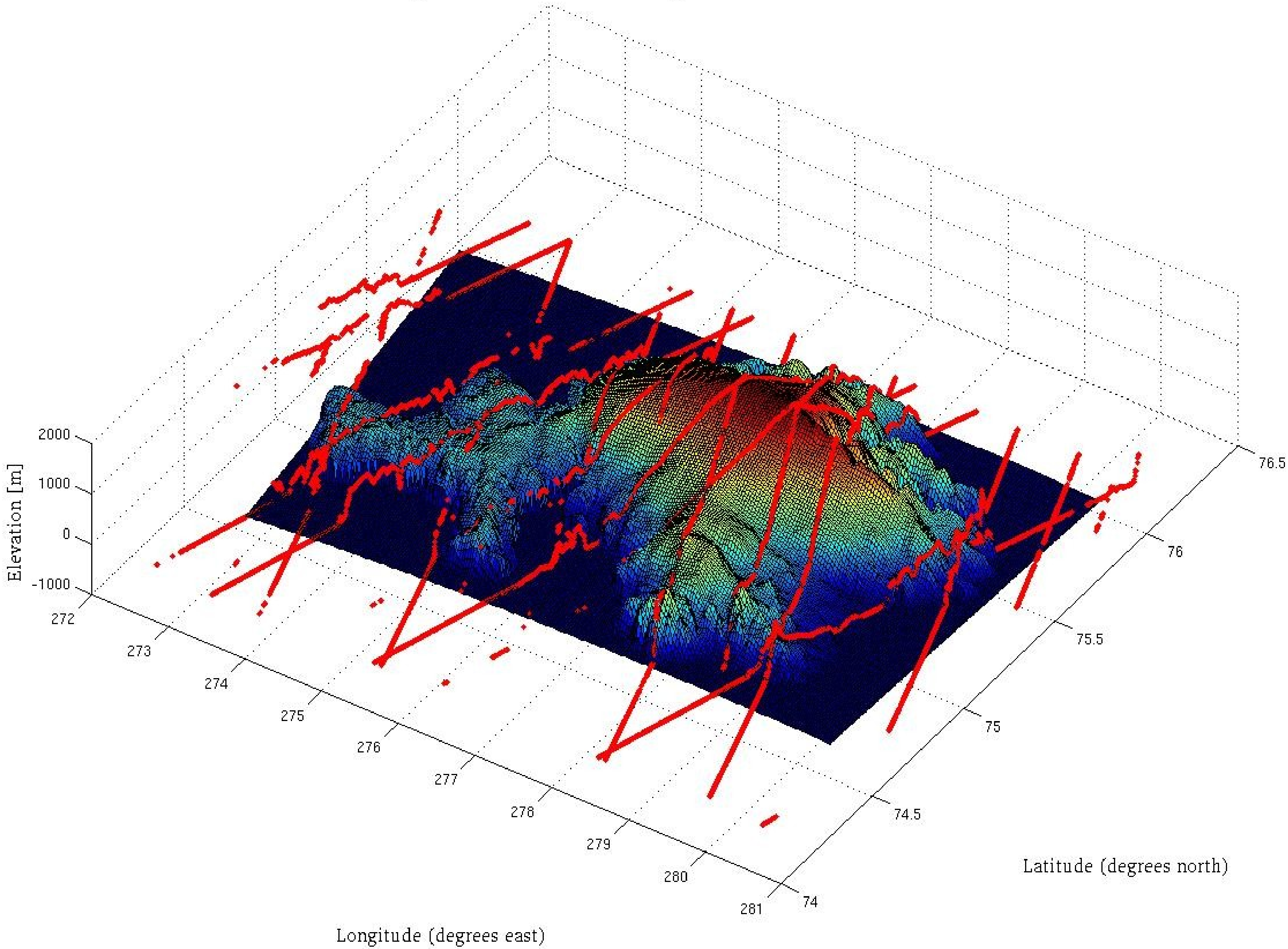
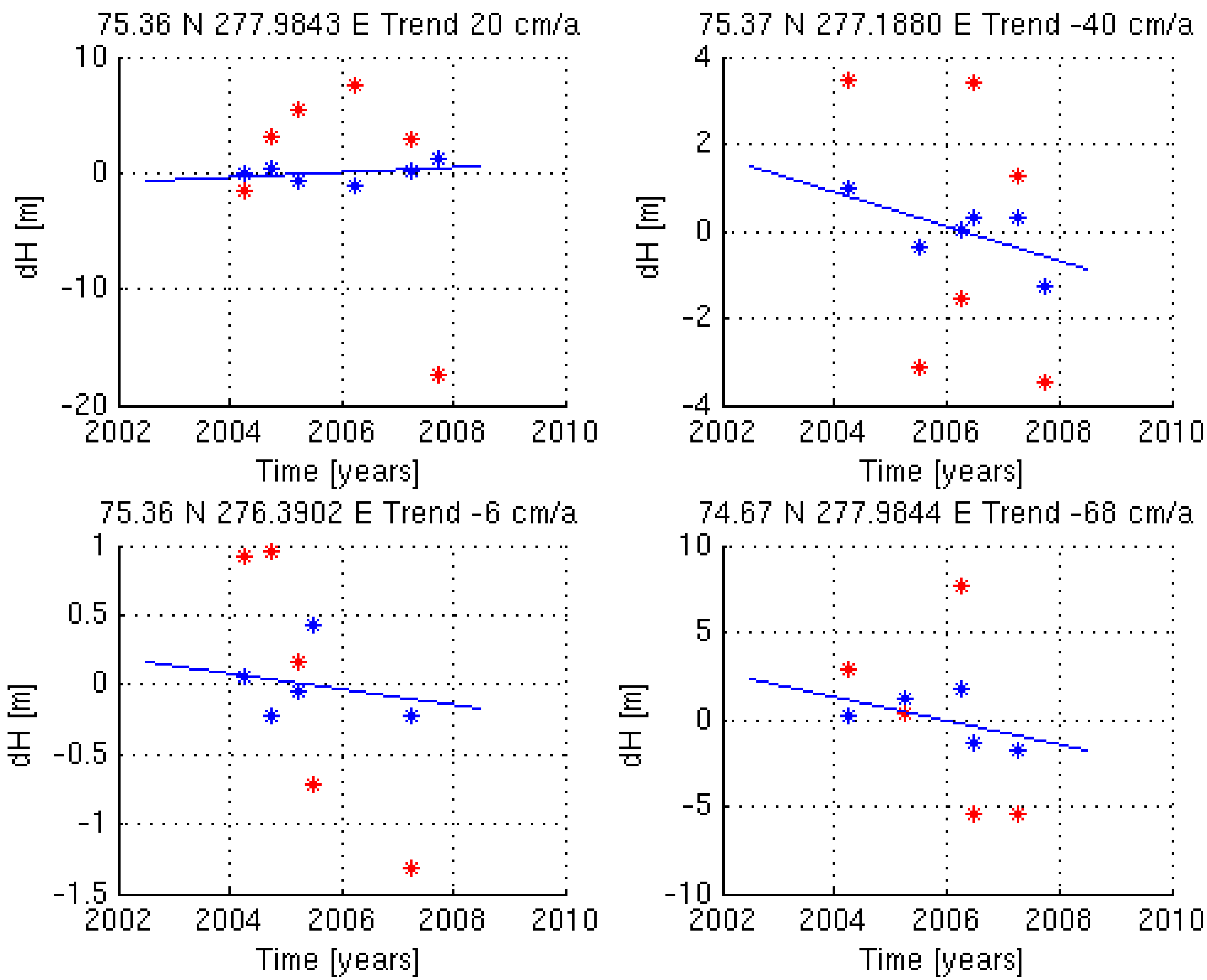


Image: Devon Island from Landsat global mosaic (NASA)

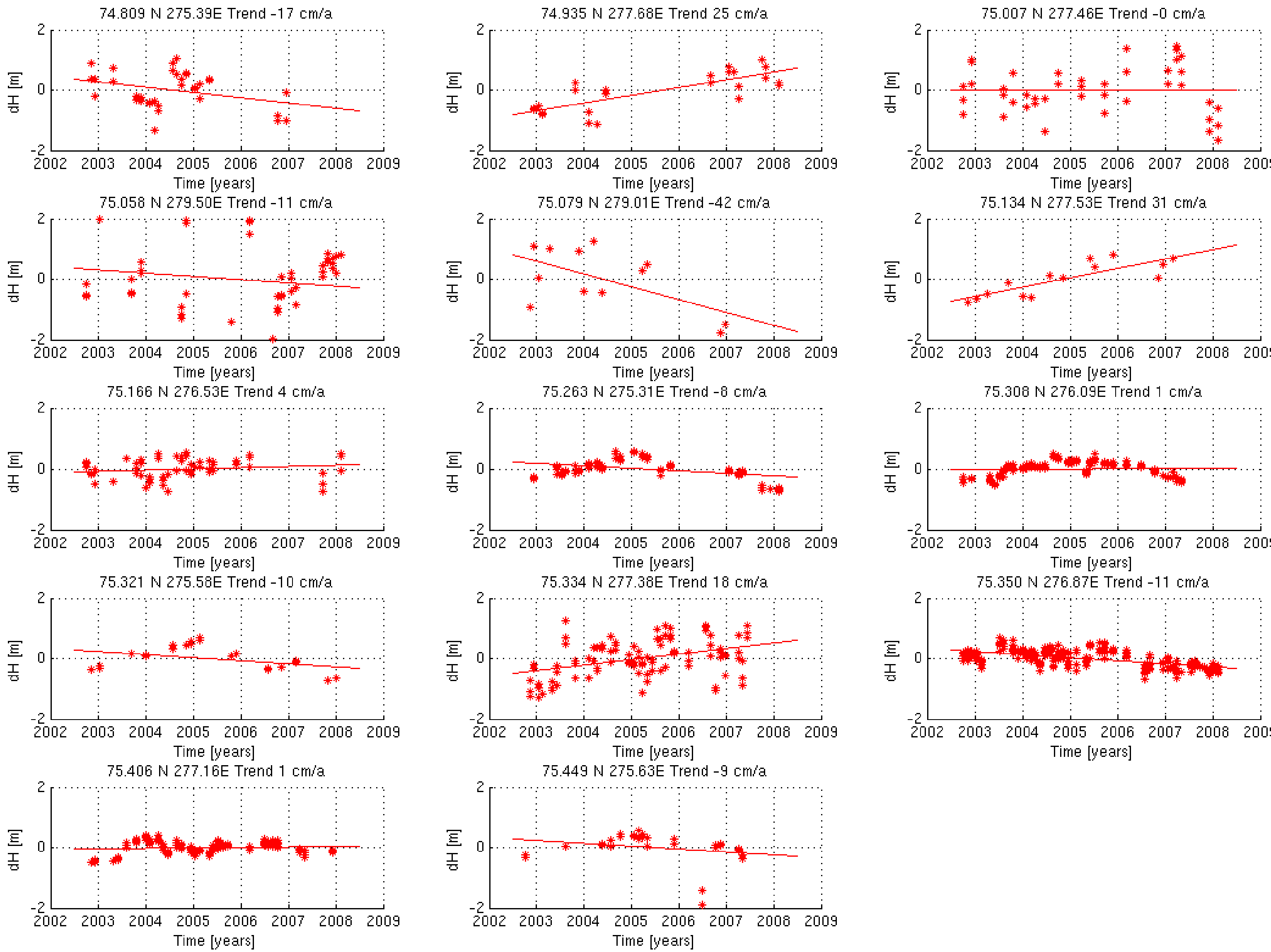
Devon Ice Cap DEM and example of IceSat GLAS elevations

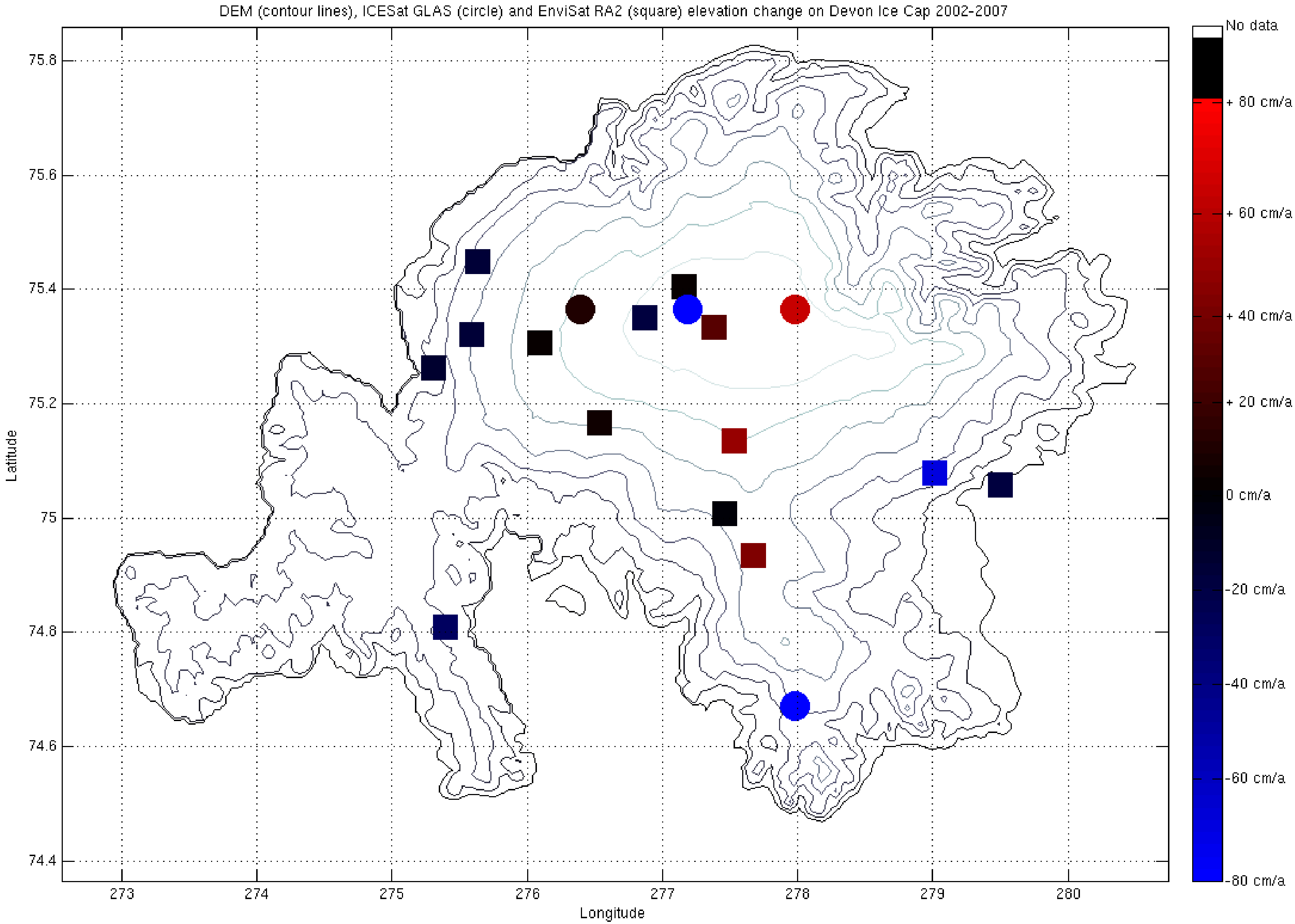


ICESAT GLAS data elevations and trends, Devon IC
Uncorrected (red) and DEM corrected (blue) elevations



Envisat RA2 data elevations and trends, Devon IC

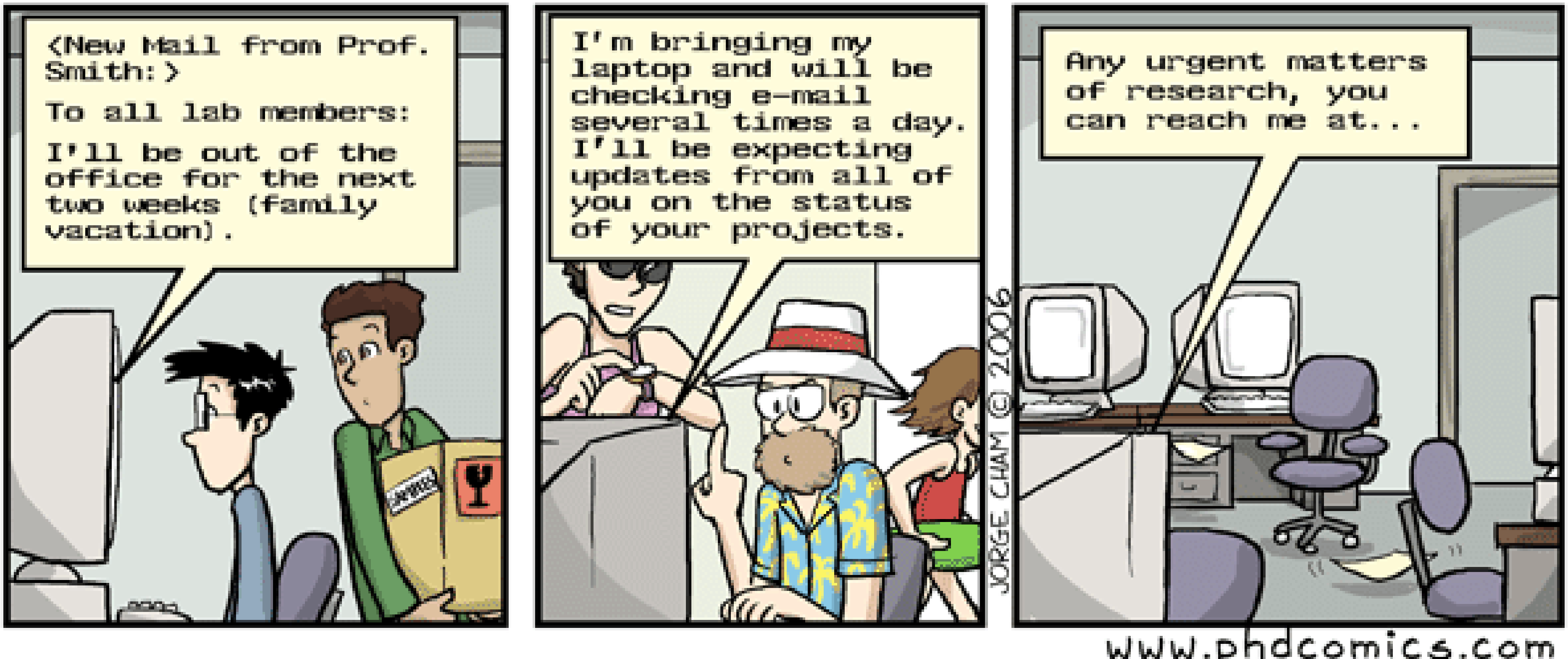



DEM (contour lines), ICESat GLAS (circle) and EnviSat RA2 (square) elevation change on Devon Ice Cap 2002-2007
Latitude
Longitude
75.8
75.6
75.4
75.2
75
74.8
74.6
74.4
273
274
275
276
277
278
279
280
No data
+ 80 cm/a
+ 60 cm/a
+ 40 cm/a
+ 20 cm/a
0 cm/a
-20 cm/a
-40 cm/a
-60 cm/a
-80 cm/a

Conclusions

- Most of the Devon Ice Cap surface has stayed put from 2002 to 2007.
- However there are some areas of non-zero elevation change.
- Both ICESat and RA2 data can be used for elevation change assessment of ice caps, although without a DEM ICESat can be at the limit of usability
- GlobGlacier is starting to create elevation change products this year
- Total of 1000 products (individual shapefiles) to be made until end of project in 2010
- Elevation change products will complement other GlobGlacier products:
  - Glacier outline
  - DEM
  - Snow line

The joke I promised



Mine is out doing fieldwork in Antarctica as we speak!