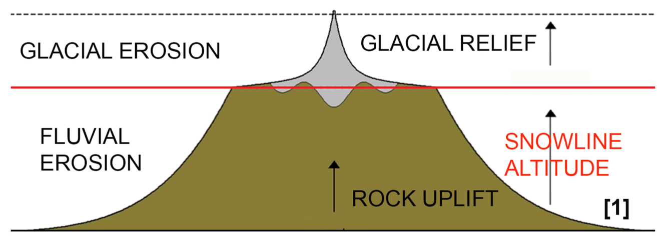
GEOMORPHOLOGY OF GLACIAL- AND NON-GLACIAL LANDSCAPES IN MOUNTAIN REGIONS; TESTING OF FORMATION PROCESSES USING GIS CHARACTERIZATION

Alexandra Jarna 1,2, Ola Fredin 2
1 VŠB- TU OSTRAVA, Inštitút geoinformatiky; 2 Geological Survey of Norway, Trondheim, Norway
Email: jar225@vsb.cz

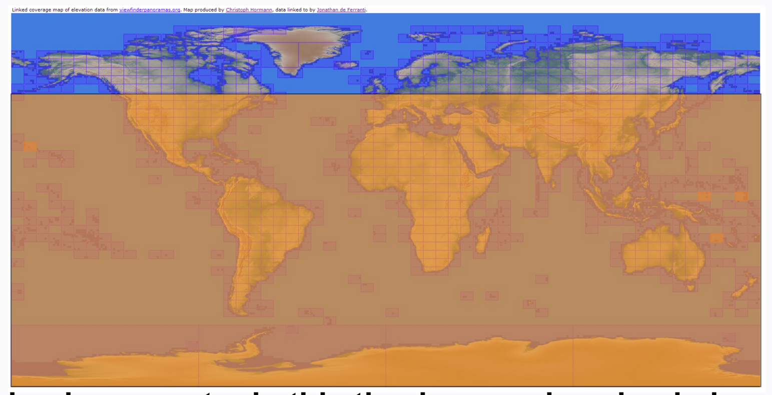
INTRODUCTION



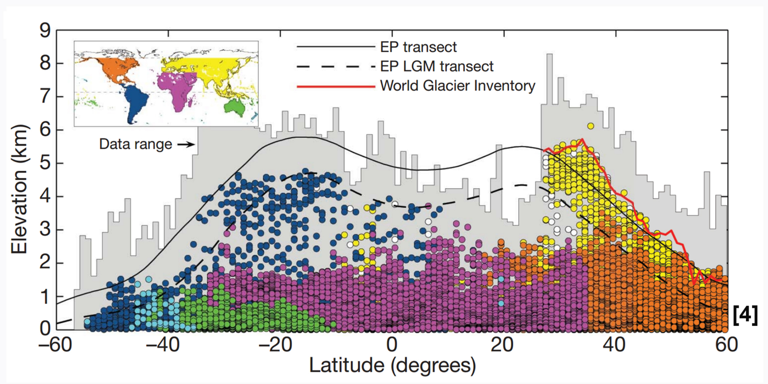
The presence of the ice sheets during the Pleistocene ice ages have had a major influence on local climate and environment, and is an important factor in shaping landscapes. It is generally thought that glacial erosion is selective and erodes deep troughs, while at the same time not affecting intervening uplands. This view implies increased alpine relief in glaciated regions where ice carves deep valleys while at the same time mountain peaks and plateaus remain. A recent competing hypothesis (The ICE hypothesis) maintains that upland plateaus also are created by glacial erosion, in effect decreasing alpine relief. To test how glacial erosion affect first order geomorphology in mountain regions this project will use GIS tools to classify and characterize topography in selected glaciated mountain ranges. In this project were used global analyses of topography in order to show variation in maximal mountain altitude located in the northern hemisphere (50°-85° N) in comparison with ELA- Equilibrium-line altitude. The competing theory of glacial buzzsaw saying that the height of mountain ranges is limited by the sum of the snowline altitude of glacial relief above the snowline, but the amplitude of glacial relief is generally under the 1500m according to a global topographic analysis.

The term paleic surface or old surface was firstly used by Reusch (1901) [2] in Norway to denote low relief surfaces high in the landscape. The first to mention these surfaces was in 1820 Keilau who wrote about Norwegians wide upland ('vidde'), described as surfaces with small differences in altitude in relation to the horizontal distances.

GLOBAL HYPSOMETRY

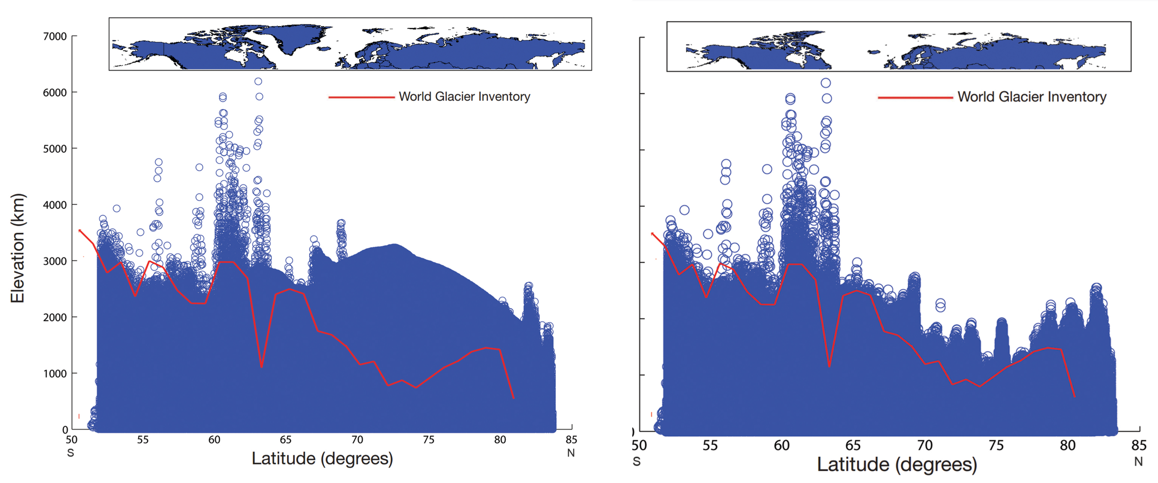


Hypsometry is a measure of land elevation in relation to sea level. Specifically we have studied hypsometrical maxima, large land areas at similar elevation, in relation to snowline altitude or glacier equilibrium line altitude (ELA). Data used for showing hypsometry in this thesis were downloaded from http://www.viewfinderpanoramas.org/ [3]



According the V.K.Pedersen (2009) [4] the presence of a hypsometric maximum indicates that dynamic processes (tectonic, deposinitional or erosional) concentrate surface elevation within a narrow altitude interval. So the high density of hypsometric maximum at low elevation reflects fluvial erosion and deposition by the sea level.

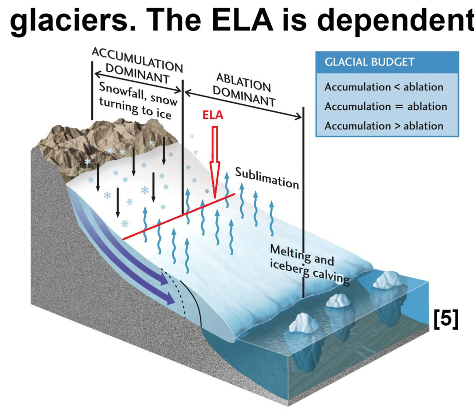
The plots shows global distribution of hypsometric maxima as a function of latitude and elevation. Each hypsometric maximum is represented by a circle. Snowline altitude is represented by red line, based on 132890 modern snowline observations from the World Glacier Inventory, calculated as a maximal bin at each 1°latitude where data was available.

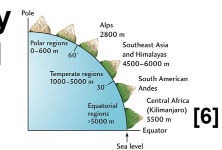


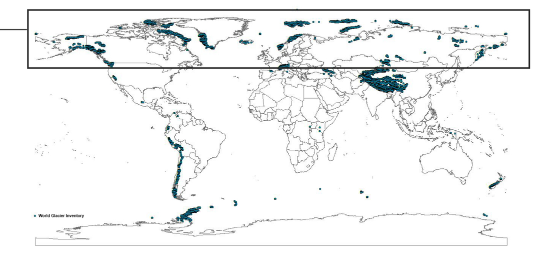
The plot to the left shows hypsometry including the Greenland ice sheet, while the right hand plot excludes the Greenland ice sheet.

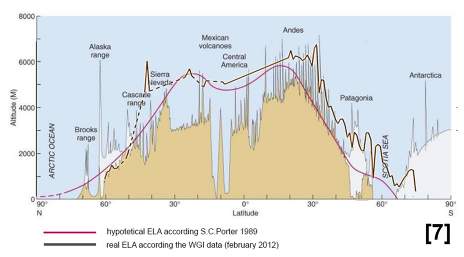
ELA - Equilibrium-line altitudes

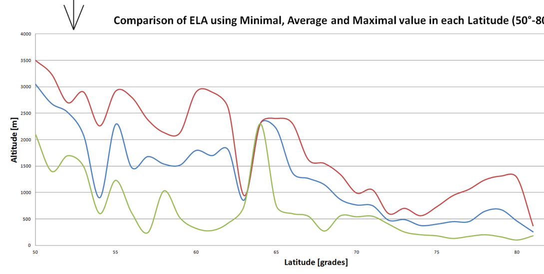
ELA shows where annual accumulation and annual ablation are equal on glaciers. The ELA is dependent on the local climate, particularly on summer air temperature and winter precipitation.











Comparisons of Porter's hypothetical ELA from 1989 and modern ELA.

CONCLUSION

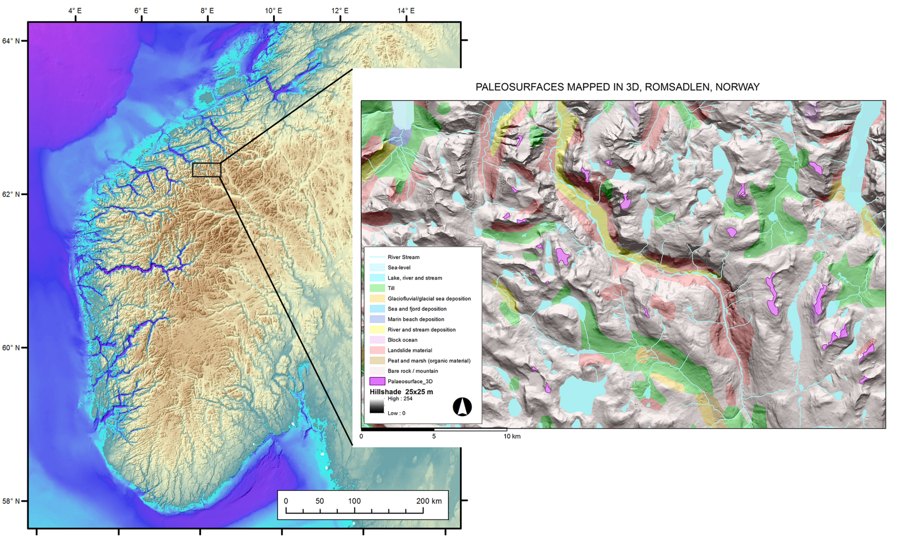
1. We have tested whether glacial processes can shape large flat surfaces (glacial "buzz-saw") on a global- and local scale. From a global perspective the relationship between ELA and hypsometric maximum breaks down north of 60°. Past continental ice sheets in these areas have had ELA, essentially down at sea level, during glacial maxima. It is thus clear that high elevation surfaces have not been formed by glacial erosion by these ice sheets.

2. North of 60° there are, and have been, permafrost conditions implying past and present glaciers with basal temperature below the pressure melting point, hence not eroding their substratum. This is contrary to glaciers in temperate and tropical areas, which largely have basal temperatures at the pressure melting point, and thus eroding their substratum. We must thus be careful in comparing temperate/tropical glaciers with polar glaciers.

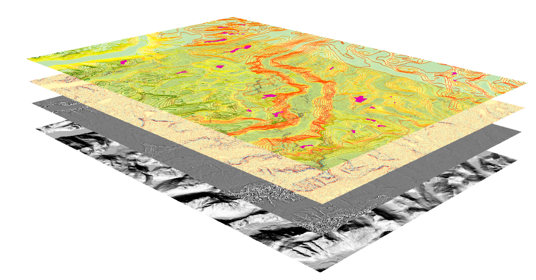
3. Paleic surfaces were mapped using 3D aerial photographs in a small area in west-central Norway. Careful topographic analysis was made on these surfaces showing that surface slope, profile curvature, surface roughness and zonal statistics could be used as parameters for automatic GIS classification of paleic surfaces.

CLASSIFICATION

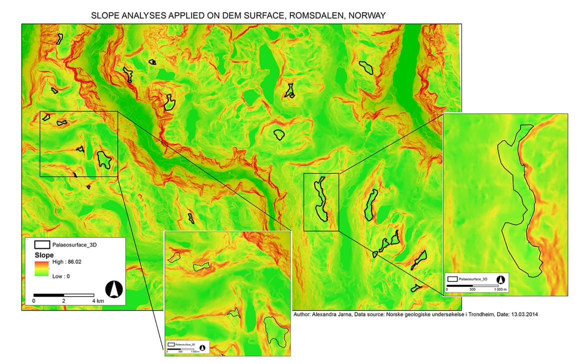
MANUAL CLASSIFICATION OF PALEIC SURFACES

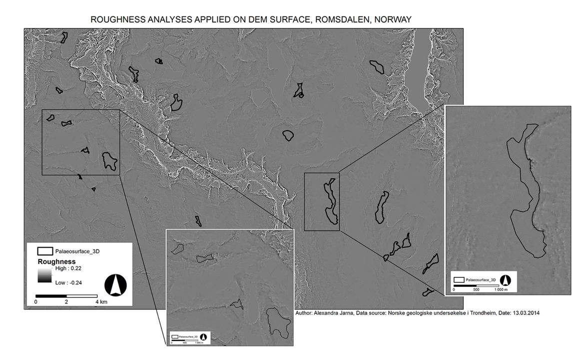


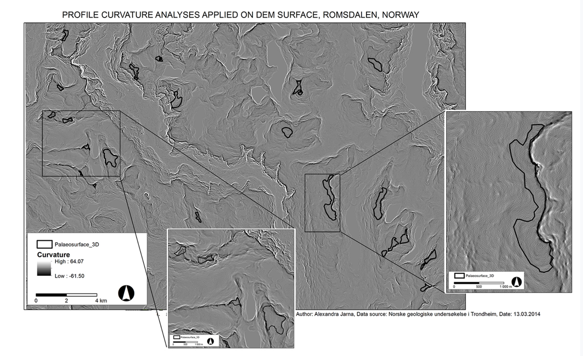
Paleic surfaces in the Romsdalen area, west-central Norway, was manually mapped and digitized using 3D aerial photography. The surfaces are easy to distinguish from landscape elements exhibiting influences of glacial-, slope- and fluvial processes.



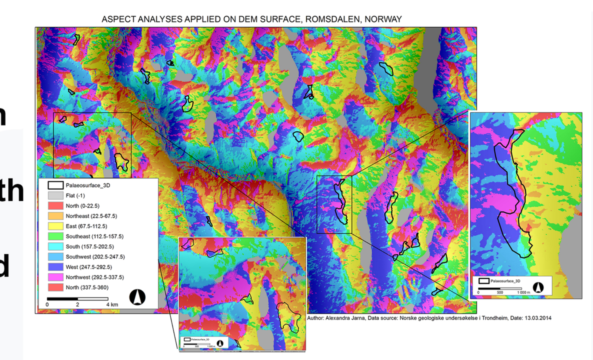
- paleosurfaces
- slope and curvature
- profile curvature
- roughness
- hillshade

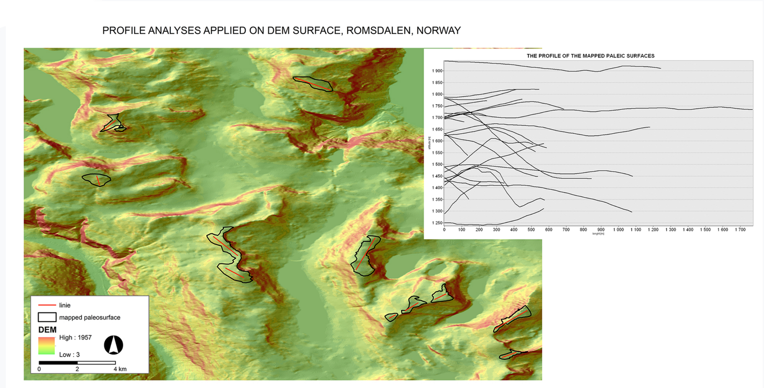






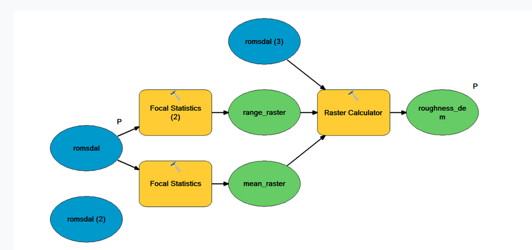
Key topographic features of paleic surfaces:
- •Fairly low gradient slopes
- •Roughness calculations shows very strong correlation with paleic surfaces
- •Profile curvature shows that paleic surfaces are smooth
- •The paleic surfaces have weak correlation with aspect
- • Profile shows most of the surfaces as a flat, correlated in same altitude





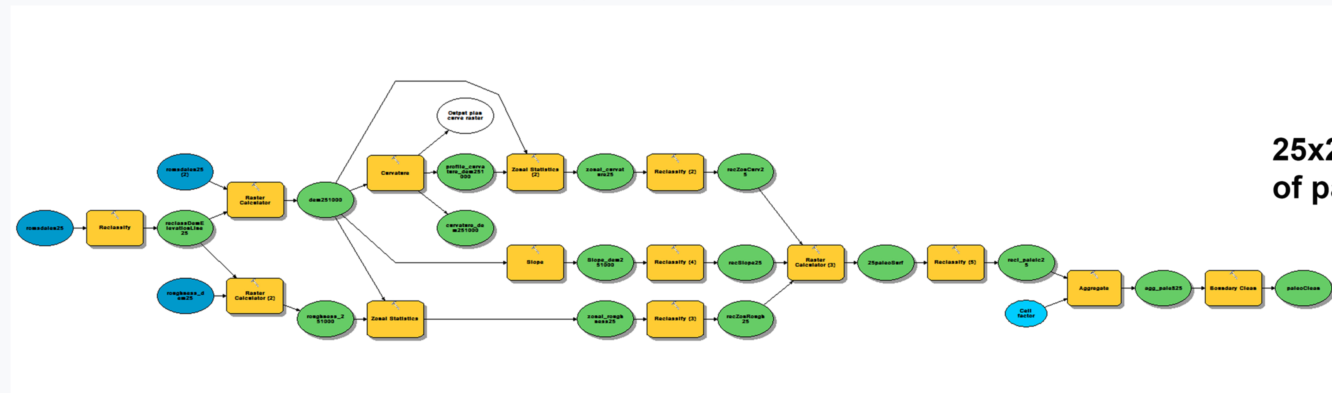
AUTOMATIC CLASSIFICATION OF PALEIC SURFACES

- • toolbox for roughness calculation



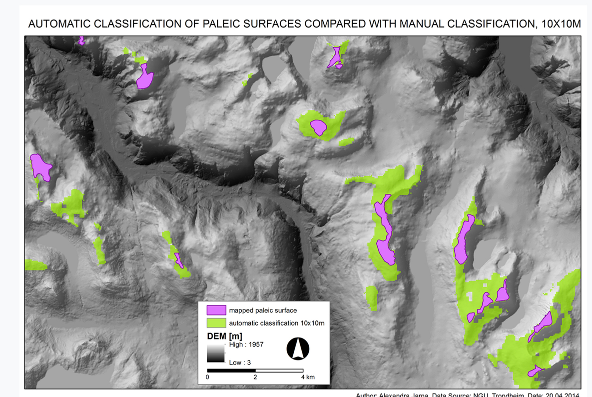
Calculated as standard deviation of elevation:
(mean elevation raster - original elevation raster)/ raster containing range of elevation values

- • based on the topographic characteristics of paleic surfaces an ArcGIS model was constructed to automatically classify paleic surfaces.

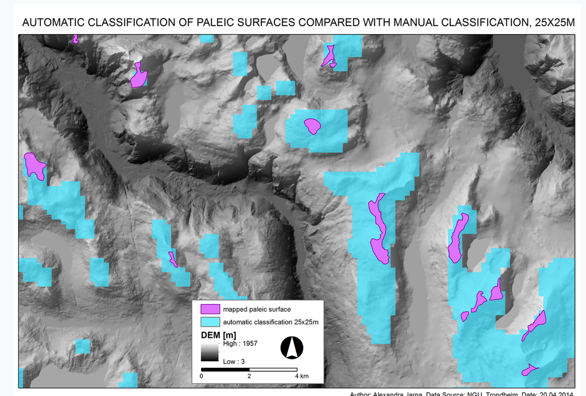


RESULTS OF CLASSIFICATION

10x10 m DEM (result shows the highest likelihood of incidence of paleic surfaces by green colour)



25x25 m DEM (result shows highest likelihood of incidence of paleic surfaces by blue colour)



REFERENCES

[1] https://www.youtube.com/watch?v=ILfM1FB58yA
[2] Reusch, H., 1901. Nogle bidrag til forsstaaelsen af hvorledes Norges dale og fjelde er blevne til. Norges Geologiska Undersøkelse 32, 124–263.
[3] http://www.viewfinderpanoramas.org/
[4] Pedersen, V.K., Glacial effects limiting the mountain height. Nature, Vol 460, 2009.
[5] http://bc.outcrop.org/images/glaciers/press4e/figure-16-10.jpg
[6] http://bc.outcrop.org/GEOL_B10/lecture27.html
[7] Porter, S.C., Some geological implications of average Quaternary conditions, Quaternary Research, 32 (1989), pp. 245–261