An Approach to Understanding the Landscape Exposure Rate for the Post-Wisconsin Late Stage Glacial Melting on Long Island, New York using a Glacial Withdrawal Simulation

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Abstract

The Wisconsin Glacial Episode is the most recent glaciation event in the Pleistocene of North America. Although the Wisconsin Glacial Episode had an effect on the landscape of Long Island, we would like to examine the reverse phenomenon where a continuing drop in the elevation of the glacial surface and increasing exposure of the landscape may have stimulated an acceleration of melting of the Wisconsin glacier in the latest stages. Changes in the land surface exposure rate and the glacial ice cover caused by the albedo of the land surface and possible climate change may have sped up the rate at which the ice melted. For this study, a Digital Elevation Model (DEM) of Long Island was created in Global Mapper in order to run surface and volume simulations as a proxy to estimate the glacial withdrawal affected by the rate of landscape exposure. The calculations are based on simulations made by a horizontal plane applied to the current DEM of the Long Island landscape and bathymetry of Long Island Sound. This research seeks to model how the glacial withdrawal might be affected by the landscape exposure rate. Assuming that the glacial melting rate was constant then our model estimates a maximum rate of landscape exposure at 136 m^2 per 1 m elevation drop, and when such a rate occurred the albedo should have significantly changed.

1. Introduction

The Wisconsin Glacial Episode is the most recent glacial advance in North America, during the Pleistocene Epoch. Beginning over 150,000 years ago, this ice sheet advanced from Northern Canada (Mills, 1974). The movement of the ice sheet was slow, and the force of its destruction was ongoing, altering mountains, the course of rivers, and creating enlarged valleys. It took roughly 130,000 years for the glacier to move into the Connecticut basin. While sitting in the basin, it melted slowly, forming rivers and river deltas that empty into what is now the Long Island Sound (Mills, 1974). The initial melting of the Wisconsin glacier on Long Island began approximately 22,000 years ago and it continued to retreat, disappearing completely by about 11,000 years ago (Mills, 1974).

The initial advance of the ice sheet formed the backbone of Long Island, the Ronkonkoma moraine. The Harbor Hill moraine that parallels the entire north shore coast from Staten Island to Port Jefferson appears to have formed from a later readvance of the ice sheet around 20,000 years ago. The Roanoke Point moraine, which contains a very broadly lobate line of kame hills with a crest that defines the shoreline of the North Fork of Long Island from Mount Sinai east to Orient Point, may be a recessional moraine related to the Ronkonkoma advance or a product of the Harbor Hill advance (Bennington, 2003). As a result of these episodes of glacial advance and subsequent melting, distinctive topographic features were formed between the north and south shores of Long Island, including, but not limited to; tunnel valleys, moraines, and outwash plains and channels (Mills, 1974; Bennington, 2000). By approximately 18,000 years ago the ice margin had retreated close to the present shoreline of Connecticut (Stone et al., 2005). Considering that Long Island is adjacent to Connecticut, then it is reasonable to assume that melting should be at the same rate.

Our research focuses on the Post-Wisconsin glacial melting and the effect of land exposure based on the geomorphic make-up of present-day Long Island. The albedo of the land surface played a crucial role with the Wisconsin Glacial melt, which increased the rate at which the ice melted, leading to ever more exposure of the surface (Broccoli,1987). As the ice surface decreased in area, less energy was reflected into space, and the Earth's surface warmed up even more. Given that the highest point on Long Island, Jayne’s Hill (122m), shows evidence of Wisconsin glacial deposits and a glacial summit (Sirkin,1994) it is reasonable to assume that at some point glacial ice completely covered Long Island. Therefore the process of uncovering Long Island’s landscape may have played some role in the melting of the glacier, especially at the time interval of 20,000-18,000 years ago, that is over a 2,000 years time interval. The Bald Hill area in Suffolk County is the second highest elevation (102 meters) and is part of the Ronkonkoma Moraine, which runs east to west along the center of the Town of Brookhaven, and marks a significant location of ice stabilization.

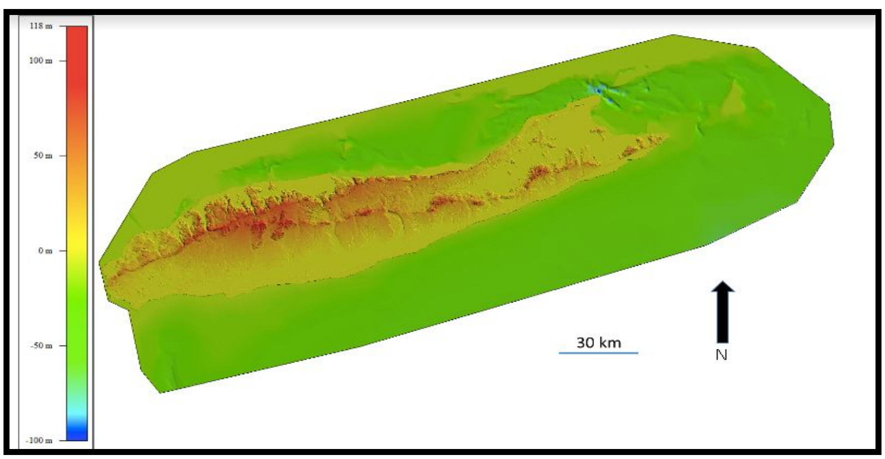

Figure 1: DEM reconstruction combining the Long Island landscape and bathymetry of Long Island Sound which was achieved by utilizing data retrieved USGS (bathymetric elevation data).

2. Methodology

For this study, a digital elevation model (DEM) of Long Island and Long Island Sound in New York was created. A Geographical Information System (GIS) software package called Global Mapper was used to construct the DEM of the Long Island Sound and Long Island (Figure 1) utilizing SRTM data (Shuttle Radar Topographic Mission; with a spatial resolution of 30 meters). Simulations were applied to obtain the volumetric and surface calculations between an imagery surface, which is the glacial surface starting from the highest assigned elevation where we have evidence from the glacial deposits and the landscape surface. Simulations were implemented in Global Mapper using a flooding surface the glacial surface elevation to obtain the incremental ice volume and land surface calculations during the glacial withdrawal process (Figure 2). As ice volume decreases, high albedo ice area decreases, and low albedo land area increases. We assume that the DEM (Figure 1) reconstruction of the Long Island Sound and Long Island is very similar to the 20,000-year-old landscape with no more than 10% of erosion (Cook, 2020) of the recent landscape to justify the results by reconstructing what Long Island looked like 20,000 years ago. In addition, we did not take into consideration any sea-level change, while we based on the assumption that the glacial melting rate is constant to simplify the model.

We simulated the glacial retreat as an imagery surface that drops in elevation as the glacial withdraws. As the elevation of the glacial surface drops due to melting the area of the exposed land surface increases, and a new volume and area calculation takes place. Approximately, 123 volumetric and surface calculations were determined.

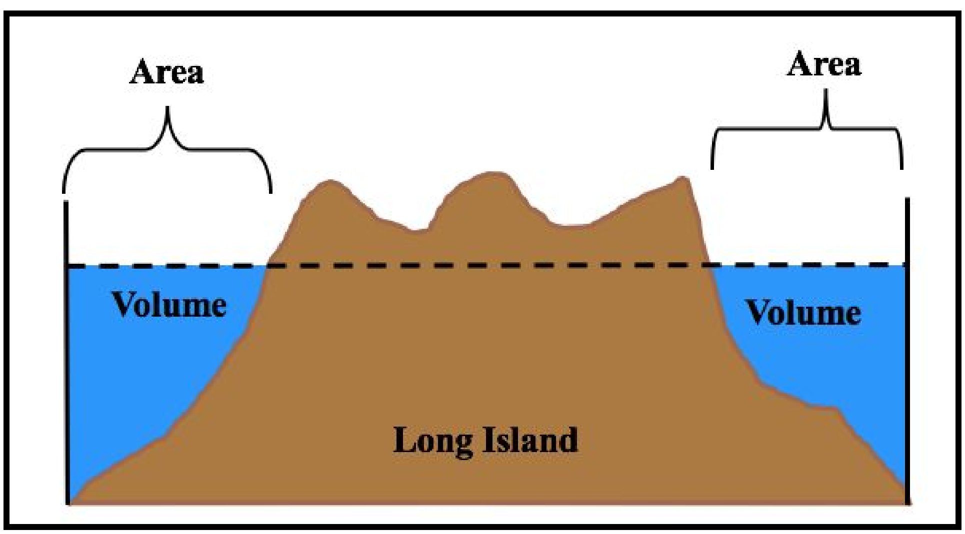

Figure 2: An illustration showing the volume and area calculated at incremental elevations of the ice surface (dashed line) with respect to the landscape of Long Island, New York exposed during withdrawal of the glacier. The dashed line represents the

glacial surface at the time of melting. The volume of the glacial ice is represented by the blue shaded area.

The rate of land surface exposure with respect to the level of the glacial surface was then plotted to examine the landscape exposure evolution on the latest stages of glacial melting. Glacial melting and rate of landscape exposure were plotted (Figure 3) to examine the landscape effect on the latest stages of glacial melting.

3. Results

The surface incremental calculations have shown a simulation of the Wisconsin glacial surface withdrawal with specific criteria such as a constant rate of melting, no significant sliding, or/and erosion. The related elevation drop of the Wisconsin glacial surface at various heights (Figure 3) shows that there is a high rate of exposed land during the latest stages of the glacial withdrawal, which is at low elevations close to the shoreline when the glacial thickness was low. Lower rates of exposed land were found at a higher elevation at which thickness of the glacial was high. Assuming that the glacial melting rate was constant then there is a 136 km^2/m high rate of glacial melt during the latest stage.

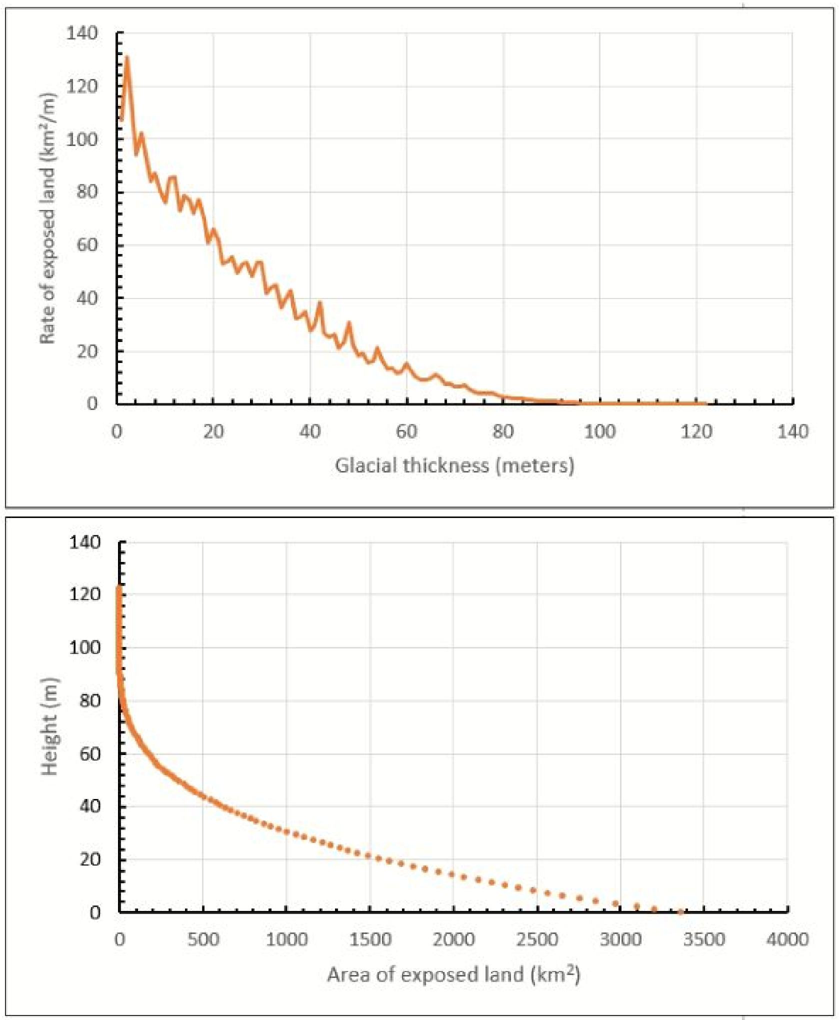

Figure 3: The graphs show the incremental surface calculations of the data derived by the simulations in Global Mapper with the DEM reconstruction. The top graph shows the loss of glacial thickness (in meters) against the rate of exposed land. The bottom graph shows the determined area of exposed land with respect to the height of the imagery surface that acts as the glacial surface.

4. Discussion

Based on the data that was collected and analyzed through the utilization of Global Mapper simulations on surface area and volume of the Wisconsin Glacial retreat on Long Island, we have investigated the landscape exposure rate of Long Island, New York that may possibly influence the melting processing of the Wisconsin Glacial Episode. "As the ice surfaces decrease in area, less energy is reflected into space, and the Earth surface will warm up even more," (Broccoli, 1987). Although albedo may have influenced the withdrawal of the glacial, there is a prominent fluctuation of the rate of exposed land between 40 and 60 meters of thickness. This is based on the pre-existing landscape of Long Island.

The albedo of the exposed land surface may have increased the rate at which the ice melted. Of course, at times of climate change rest, surface processes may have played a significant role in the glacial withdrawal. However, we have kept our model simple considering a constant glacial melting and no significant erosion of the pre-existing landscape. With the knowledge that Long Island's location rests on a passive continental margin, there is evidence that Long Island was shaped mostly by the last documented glacial movement. Therefore, glacial melting should be affected mostly by no tectonic reasons, and increased levels of landscape exposure rate may have been a significant factor when climate change rests.

We would like to note that this methodology may reveal various landscape exposure rates in different glacial settings. A pre-existing landscape may range from a relatively flat and low-relief topographic anaglyph like Long Island to a relatively high-relief topographic anaglyph with steep slopes. We expect that such flat surfaces on the pre-existing landscape should be exposed in a shorter time, and surfaces with a steep slope and higher relief would require more time to get exposed. A significant change of albedo and related effect should occur on flat surfaces with gentle slopes while less change of albedo should develop at more rough topographic relief with steep slopes. Long Island exposes a fairly flat and very low-topographic anaglyph, thus this region should have expressed the highest albedo effect on the glacial withdrawal.

5. Conclusion

Our methodology may reveal various landscape exposure rates in different glacial settings. Long Island reveals a relatively flat region with low-topographic anaglyph, and the process of the Long Island surface exposing as the glacial fill area decreases may have affected the Wisconsin Glacial Episode withdrawal process. The glacial withdraw was accelerated in Long Island during 20,000-18,000 years ago as previously has stated, and assuming that the glacial melting rate was constant then our model estimates a maximum rate of landscape exposure at 136 m^2 per 1 m elevation drop, and when such a rate occurred the albedo should have significantly changed.

6. Acknowledgement

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