Lauren Andrews
6 May 2010
GEO 386G: GIS final project

Using Ice Thickness and Bed Topography to Pick Field Sites Near Swiss Camp, Greenland

Problem Formulation

My primary goal for this project is to map ice thicknesses and hydraulic potential in the vicinity of Swiss Camp, Greenland. This information will be used in conjunction with historic supraglacial lake bodies (included in a final map) to determine the most suitable locations for three boreholes in 2011. These boreholes will intersect the bed and will be instrumented with pressure transducers, tilt meters, and a several other instruments. The main focus of this research is understanding the characteristics of subglacial hydrology in the area. By having basal hydraulic potentials and ice thicknesses readily available, we will be able to better understand the conditions under which we will be drilling.

Data Collection and Preprocessing

In order to create the layers required for the maps, I used a combination of data that I gathered from various sources. The base map is a MODIS (Moderate Resolution Imaging Spectroradiometer) image of Greenland from 2001. These images are TIFF documents so I was able to import the image directly into ArcGIS. The most useful projection for Greenland is the Polar Stereographic projection, which uses the WGS 1984 datum. I determined that the use of the Polar Stereographic projection would be most effective for this project;

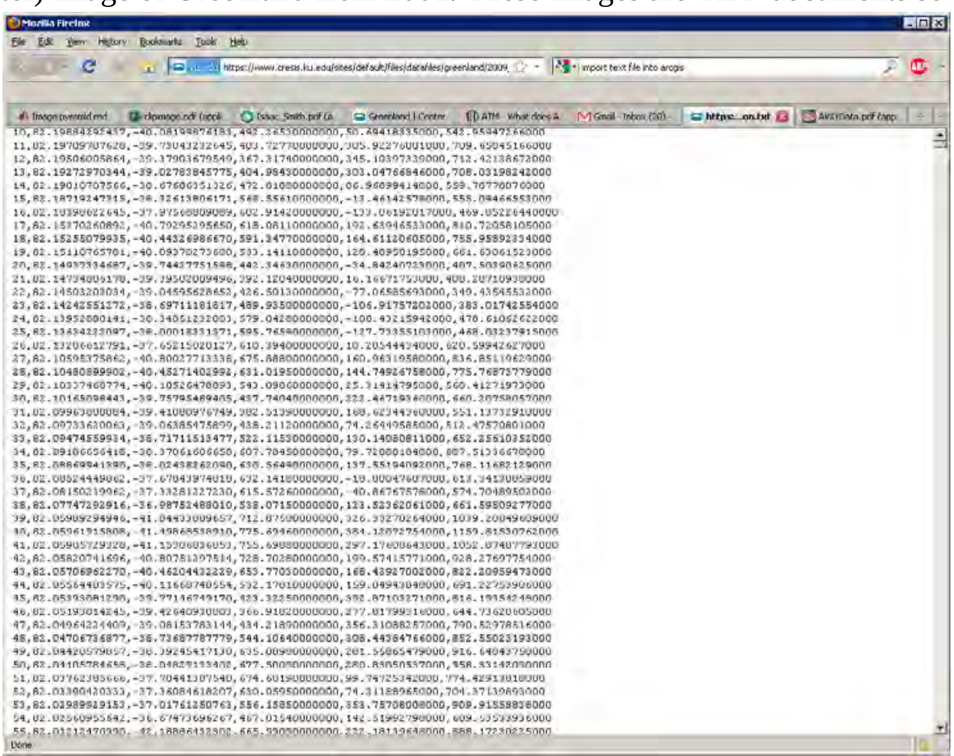


Figure 1. Ice thickness as text files available on the CReSIS website (https://www.cresis.ku.edu/). These data are eventually converted into raster data for analysis.

therefore, all layers, including the MODIS base map use this projection.

The next, and most difficult, step involved sorting, gathering, and importing CReSIS (Center for Remote Sensing of Ice Sheets) data. These data are extensive and difficult to process effectively. CreSIS determines the ice sheet thickness using radar to determine ice thicknesses. These data are available on the CReSIS webpage in text format (Figure 1). My first step was to import all the data into a text document (luckily, the data were already in decimal degrees) and then import the data into ArcMap using the import X-Y data. This process permitted me to establish the projection as Polar Stereographic. Upon importing these data, I realized that the amount of information was overwhelming and would significantly slow any data processing work (Figure 2). Therefore, I decided limit the amount of data I was importing by sorting and selecting the X-Y data by the appropriate longitude and latitude in Excel before importing into ArcMap. Once I limited the spatial extent of the data by manually selecting the data I needed, I was able to quickly import the data into ArcMap (Figure 3). However, the CReSIS point data did not contain the formatting needed for manipulation in ArcMap. To remedy this, the data

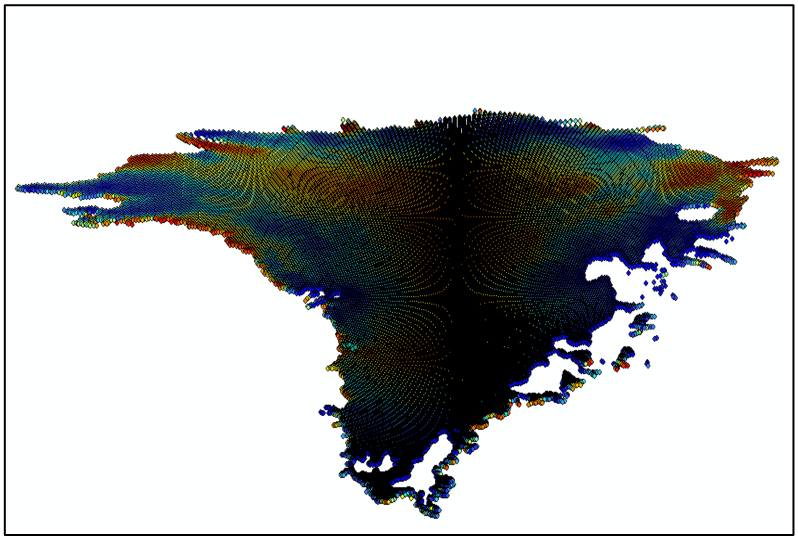


Figure 2. Projection of CReSIS data in ArcMap. The extensive amount of point data caused significant processing problems. Data was selected spatially in Excel to speed future data analysis.

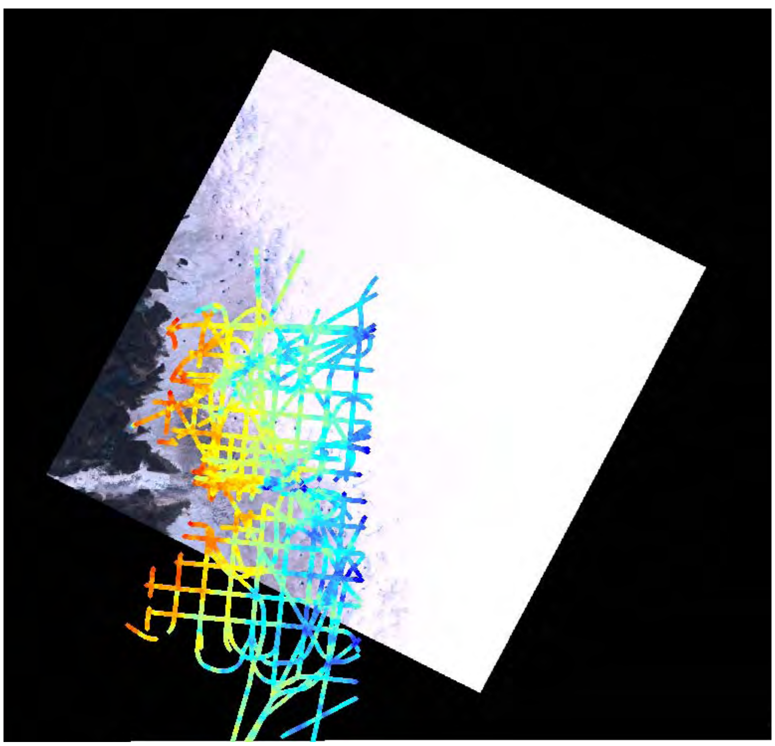


Figure 3. Limited CReSIS data imported into ArcMap and displayed using a Polar Stereographic projection.

were exported and saved both in my GIS_Lab file and as a layer in the current project.

After completing the preprocessing for the CReSIS data, it was necessary to complete the preprocessing for the bedrock topography. The bedrock elevation point data was also available via the CReSIS website. The CReSIS project completed the bedrock elevation data using ICEsat data. It was still necessary to complete the same steps that I completed with the ice thickness data. The amount of data was limited by sorting by longitude and latitude in the text document then the remaining data were imported into ArcMap, much like the ice thickness data.

GPS locations from the 2006-2007 field season, weather stations and the Swiss Camp base were imported into the project as well. A text file identifying the locations of each point was created and imported into the project. The layer was then exported and an editable point file was created at the same time. At this time, I also imported points marking historic supraglacial lakes previously identified (not by me) using ArcMap (Figure 4). All the layers that I needed to complete my analysis are now in a project and can be easily manipulated, more or less.

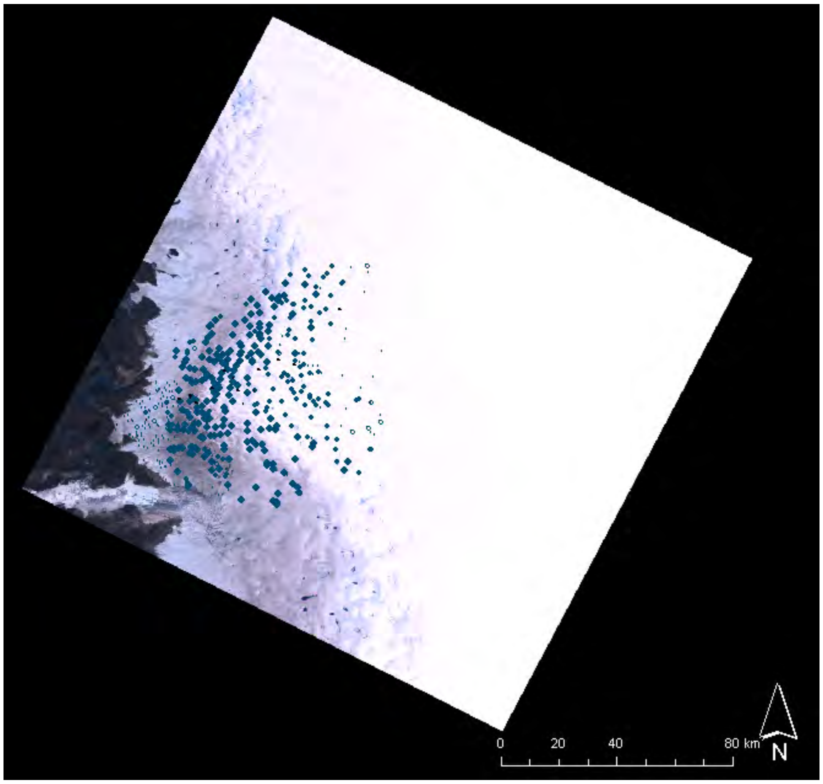


Figure 4. Supraglacial lake filling and drainage events through 2003.

ArcMap Processing

The primary components of ArcMap processing for this project include defining an area of interest for the data and MODIS image, creating raster data from the CReSIS and BEDMAP point data, and using map algebra to determine the ice sheet surface and the basal hydraulic potential.

Area of Interest

I decided to define an area of interest (AOI) for this project because relative to the initial data set, the area needed to complete the appropriate calculations is relatively small. In order to define an AOI to which I could clip the MODIS image and CReSIS data, I created a polygon shapefile in ArcCatalog and defined the projection as Polar Stereographic. Next, I added the shapefile to the ArcMap project and created a polygon defining my AOI using the editor toolbar. This AOI is a simple red box in which all the lake drainage events, GPS locations, and weather stations are contained (Figure 5).

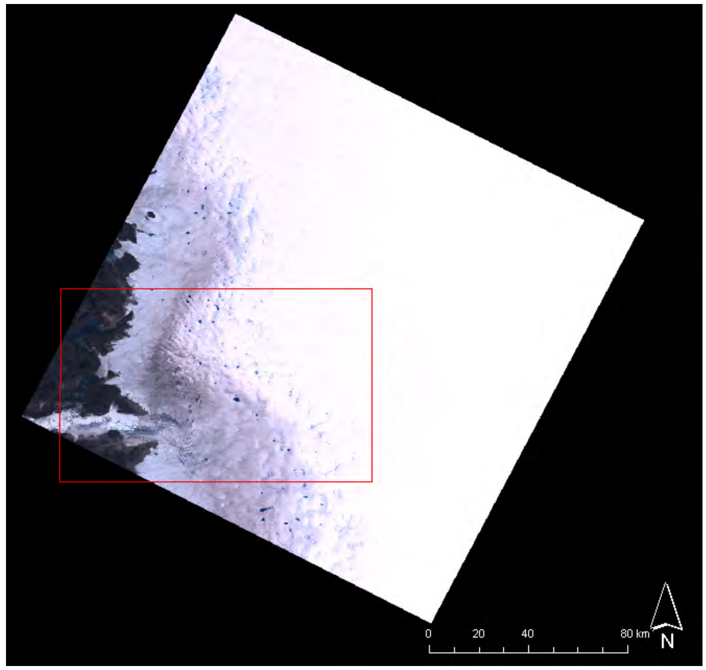


Figure 5. AOI created by editing a shapefile created in ArcCatalog. The area was limited to the area near Jakoshavn Isbre.

Clipping the Data

I decided to clip the MODIS image using the Clip tool in the Raster toolset of the Data Management Toolbox. I define the input raster as the MODIS image and used the newly created AOI as the boundaries of the clip.

In order to clip the ice thickness and bed topography point data, I used the Clip tool of the Analysis toolset in the Coverage toolbox. The input files were the point data and the clip was defined by the AOI (Figure 6). This could also be completed using the Selection tool. First select the points by location (within the AOI polygon). Next, the points would need to be extracted and added as a new layer in the project. I found that using the clip tool was more efficient and decided to use it throughout the process.

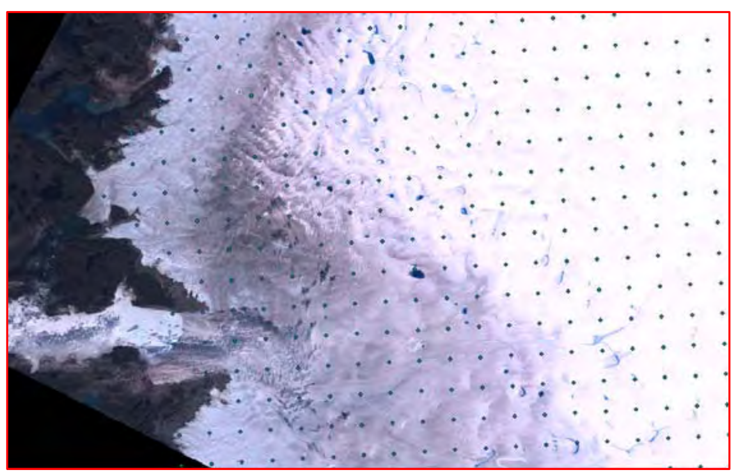


Figure 6. Clipped bed elevation data. All files were clipped to the AOI in order to more easily manipulated in ArcMap and to represent the field area.

Raster Creation

Once I limited the size of the data sets by clipping them to my AOI, I created rasters from the bed topography and ice thickness point data. Spatial interpolation is needed to create appropriate rasters. Because the data are elevation data, I believe using the spline method is most appropriate. In order to convert the point data to a raster file I used the Spatial Analyst toolbar. In the drop down menu, I chose “Convert to Raster.” Each time I completed this process (once each for the CReSIS data sets) I selected the input layer and the spatial interpolation method (Figure 7; Figure 8). I saved these new layers in my GIS_Lab folder.

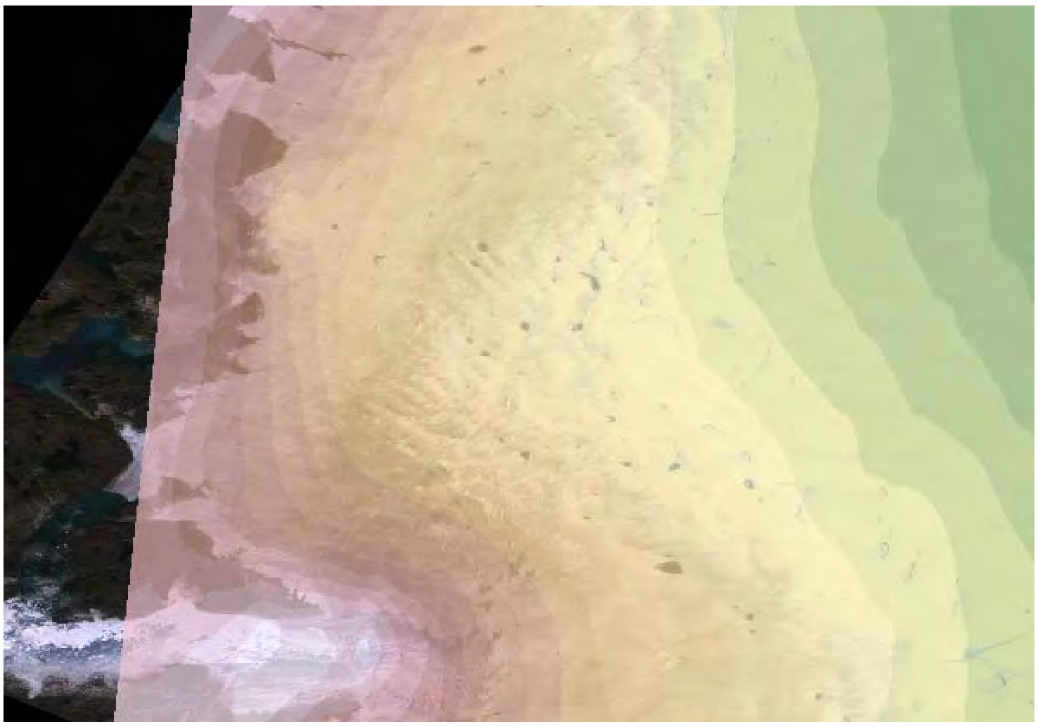


Figure 7. Raster of ice surface elevations derived from the clipped point data.

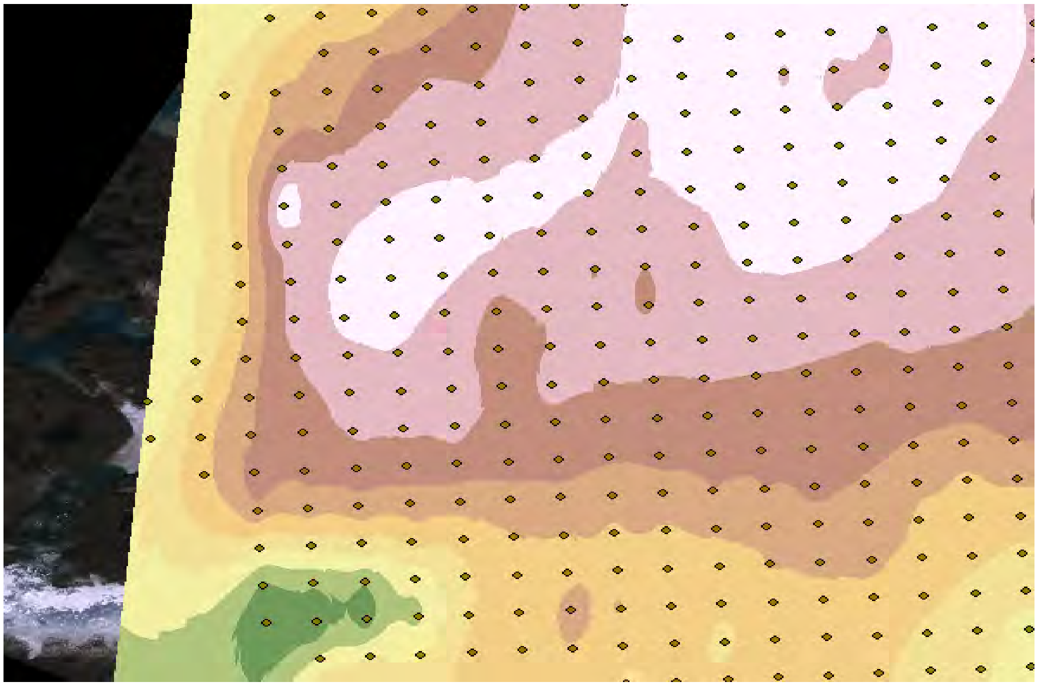


Figure 8. An opaque view of the bedrock raster data. It is overlain by the point bedrock data.

Map Algebra

In order to complete my final maps, I constructed two new rasters using the raster calculator. First, I created an ice surface elevation raster by adding the ice thickness raster and the bedrock elevation raster. Next, I created a raster that displays the hydraulic potential using the following equation:

$$\phi = \rho_w gB + \rho_i g(H - B)$$

In this equation, the acceleration due to gravity, g, is a constant at $9.81 m/s^2$, the density of water, $\rho_{w,}$ is approximately 100 kg/m^2, the density of ice, ρ_i, is approximately 900 kg/m^2. For the purposes of this equation, B represents the bedrock elevation raster and H represents the ice surface elevation raster. The resulting raster was then converted into contour lines using the Raster to Polyline tool in the Conversion toolbox (Figure 9).

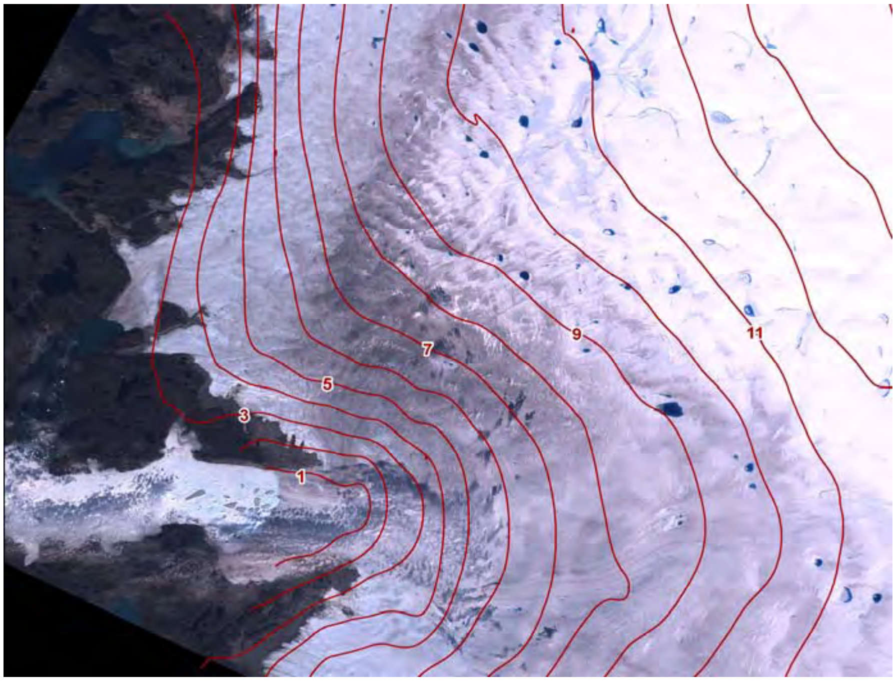


Figure 9. A screen capture of the basal hydraulic pressure contour lines. The lines are only an approximate of hydraulic potential; however, they do provide an idea of the water flow direction under the ice sheet.

Conclusions and Final Maps

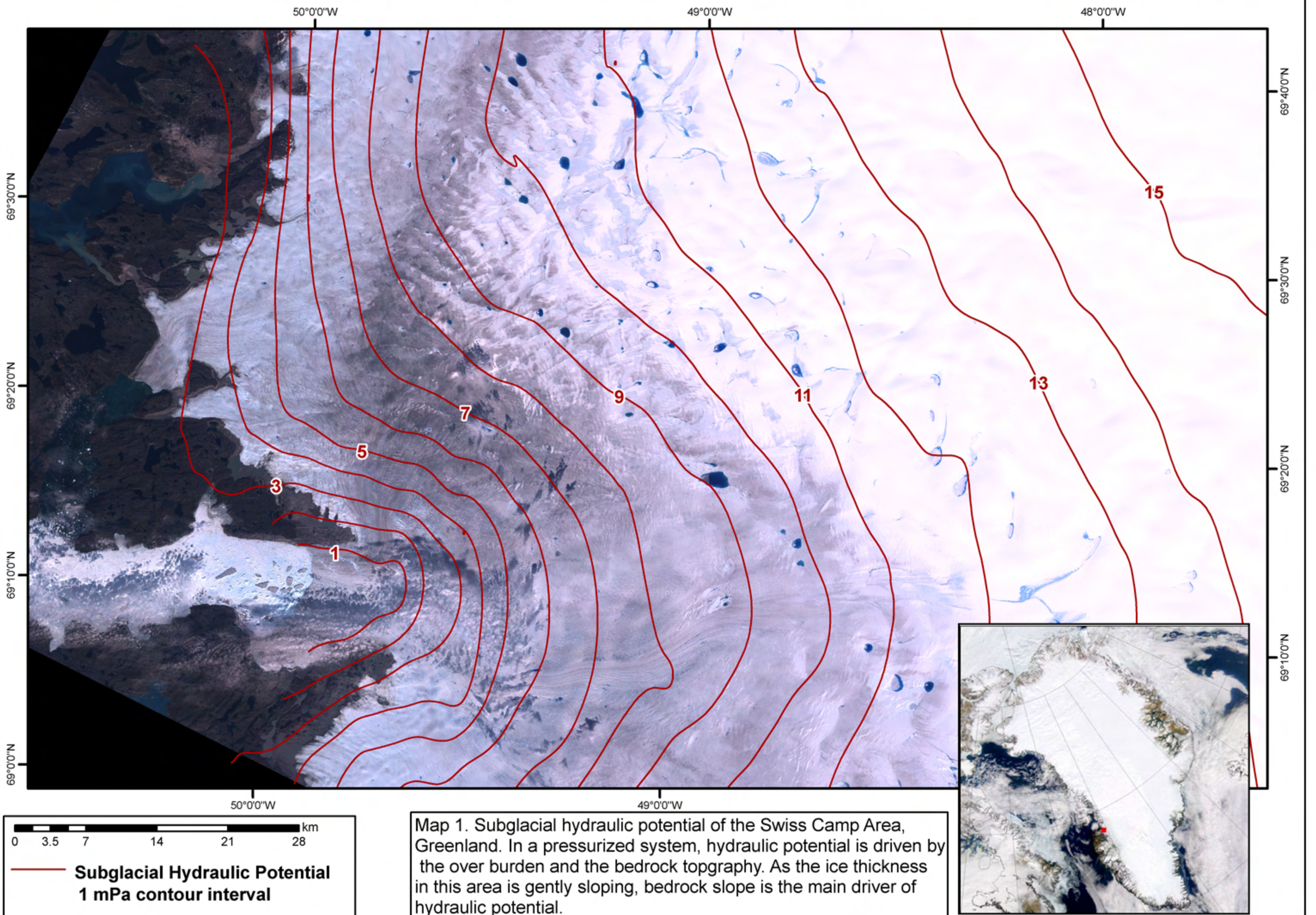
Using the final maps I completed, I determined several locations that may be suitable as drill sites. These locations are chosen on the original CReSIS lines because here the data is not interpolated; therefore, there is less uncertainty in what ice thickness to expect. However, having the ice thickness and hydraulic potential throughout the region will be useful in the event a new drill site needs to be found. There are some other interesting characteristics present in the map. Of note is the significant over-steepening of the bed under Jakoshavn Isbre. The significant elevation change is likely one of the causes of the significant ice velocities in the region. In addition, much of Jakoshavn's bed is below sea level, which could make it more susceptible to rapid retreat.

The final maps resulting from this project are included as attachments to this document.

I consider this project the first iteration of these maps. After completion of my project, I realized that there are several things that I could have done differently to improve the results. The first would be to digitize the coast line of Greenland. This would allow me to clip the raster files that I created by the coast line. The raster files currently do not line up nicely with the coast line due to the timing difference between the MODIS and CReSIS data and the resolution of the CReSIS data. In addition, I believe displaying bed and ice surface elevation as a raster is relatively ineffective, I should have displayed them as contour lines. However, I attempted create contours from the raster data and I was consistently given an error stating that the raster data was not in the correct format (it was floating point). I could not figure out how to change the format of the raster data or to recreate the raster in a different format.

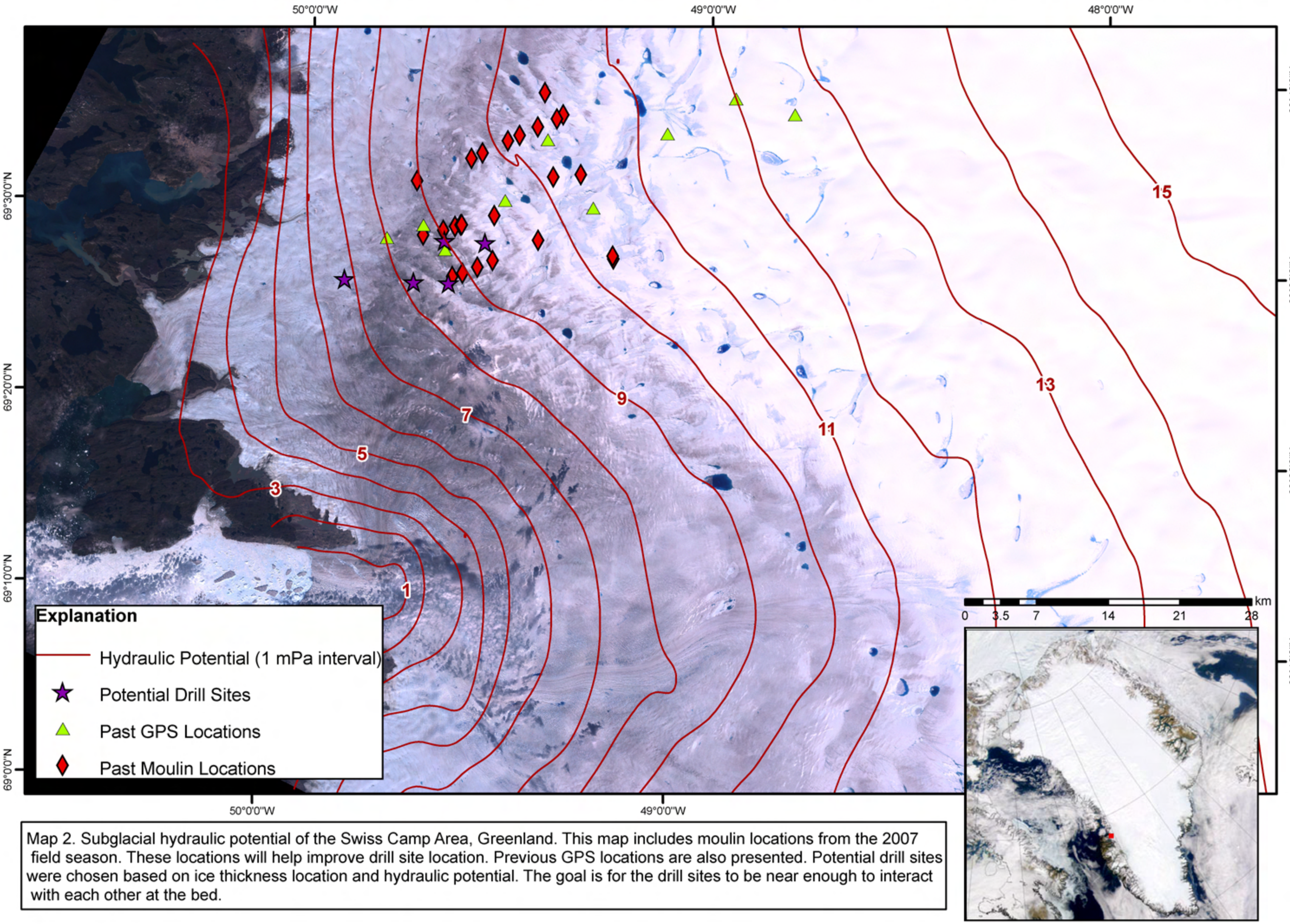
I plan on adding to this project this summer by using higher resolution data and picking the lake drainage events from 2003 to present. In addition, we just received very high resolution satellite Quick Bird imagery of our field site and plan to use this data to improve the location of drill sites and identify surface features that persist through the years.

Subglacial Hydraulic Potential of the Swiss Camp Area, Greenland



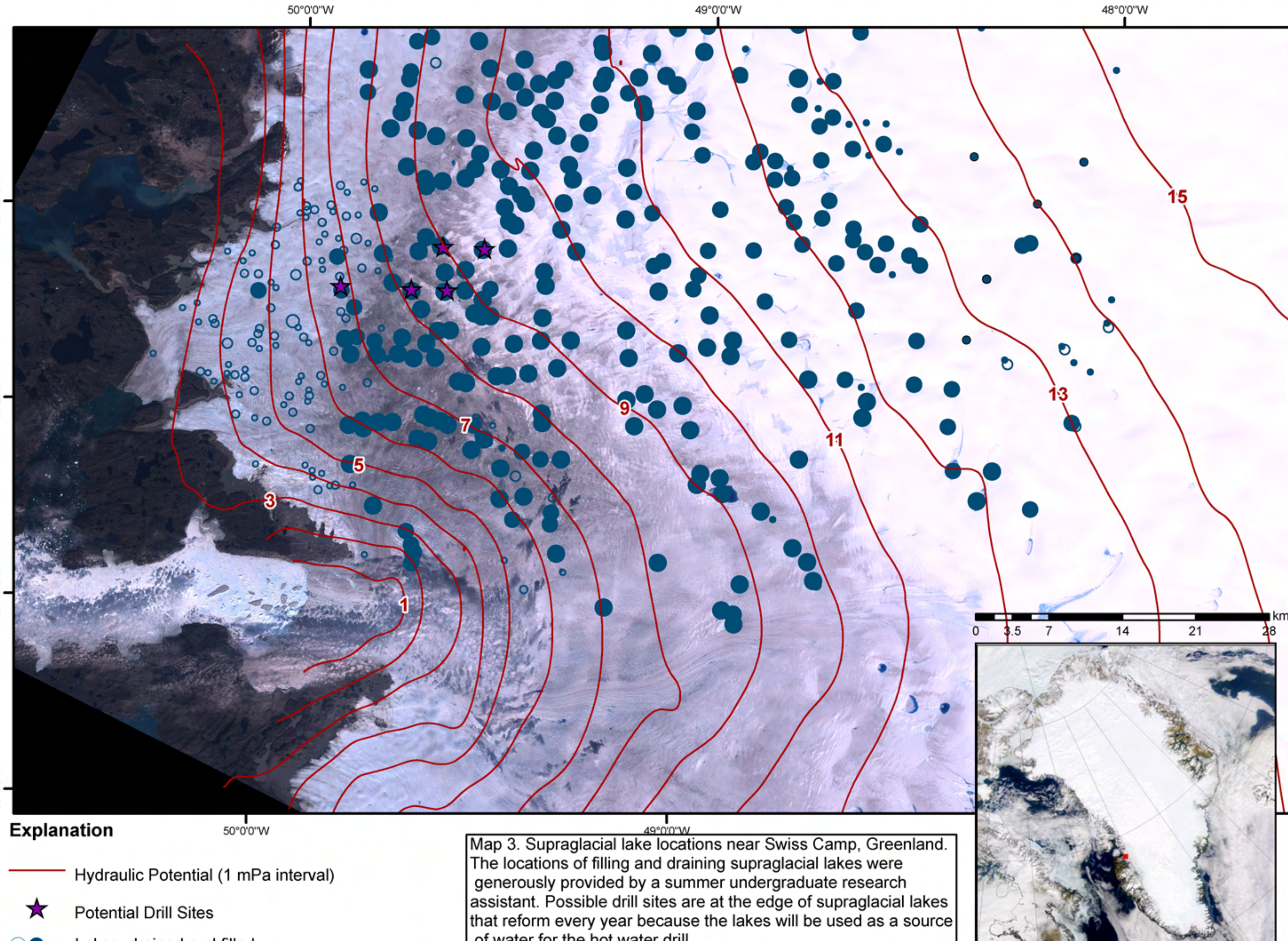
Map 1. Subglacial hydraulic potential of the Swiss Camp Area, Greenland. In a pressurized system, hydraulic potential is driven by the over burden and the bedrock topgraphy. As the ice thickness in this area is gently sloping, bedrock slope is the main driver of hydraulic potential.

Subglacial Hydraulic Potential of the Swiss Camp Area, Greenland



Map 2. Subglacial hydraulic potential of the Swiss Camp Area, Greenland. This map includes moulin locations from the 2007 field season. These locations will help improve drill site location. Previous GPS locations are also presented. Potential drill sites were chosen based on ice thickness location and hydraulic potential. The goal is for the drill sites to be near enough to interact with each other at the bed.

Subglacial Hydraulic Potential of the Swiss Camp Area, Greenland



Explanation

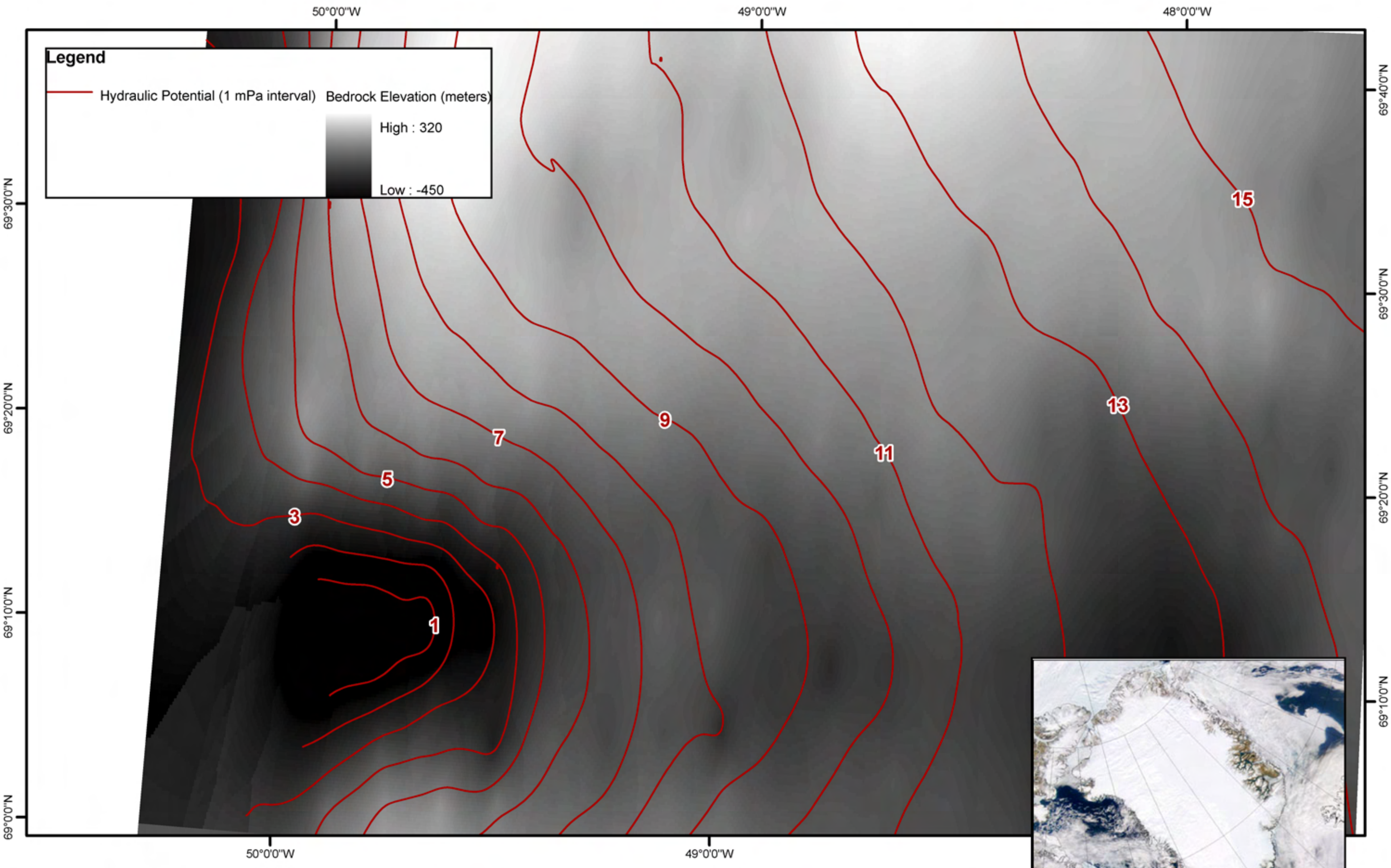
Hydraulic Potential (1 mPa interval)

Potential Drill Sites

Lakes, drained and filled

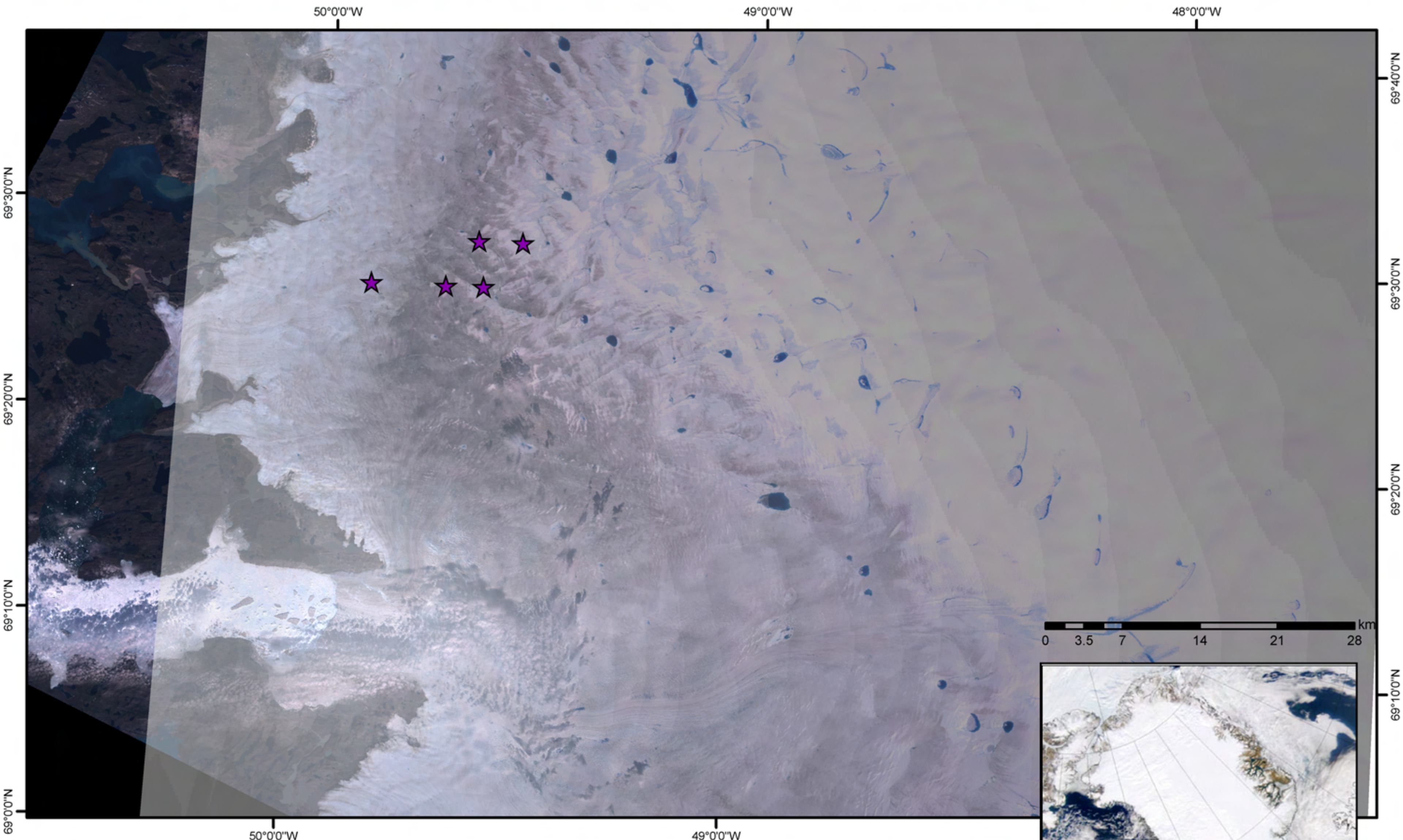
Map 3. Supraglacial lake locations near Swiss Camp, Greenland. The locations of filling and draining supraglacial lakes were generously provided by a summer undergraduate research assistant. Possible drill sites are at the edge of supraglacial lakes that reform every year because the lakes will be used as a source of water for the hot water drill.

Bedrock Elevations of the Swiss Camp Area, Greenland



Map 3. Contour map of the bedrock topography. Unfortunately, the hillshade does not work effectively; however, this image provides an ample picture of what the bedrock topography looks like.

Ice Surface Elevations of the Swiss Camp Area, Greenland



Legend

★ Potential Drill Sites

Ice Surface Elevations (meters)

41 - 129, 130 - 204, 205 - 271, 272 - 326, 327 - 380, 381 - 447, 448 - 522, 523 - 589, 590 - 657, 658 - 725, 726 - 792, 793 - 867, 868 - 935, 936 - 1,002, 1,003 - 1,077, 1,078 - 1,144, 1,145 - 1,212, 1,213 - 1,280, 1,281 - 1,347, 1,348 - 1,415, 1,416 - 1,483, 1,484 - 1,550, 1,551 - 1,618, 1,619 - 1,692, 1,693 - 1,767

Map 5. Ice surface elevations on the Greenland ice sheet near Swiss Camp. Ice thickness decreases toward the west at a relatively constant rate. Only near Jakoshavn Isbre do thicknesses change raipdly.