Lasers and geology: making LiDAR accessible to non-GIS users

By Christopher Maike

LiDAR (Light Detection and Ranging) is a prominent technology which has been fundamental in supporting various North Dakota Geological Survey (NDGS) missions. It is a remote sensing method that uses laser light technology to survey the surface of Earth. Figure 1 displays an example of the acquisition and processing operation of LiDAR data. A plane or drone is equipped with a laser system, GPS equipment, and software. Planes are used for larger missions, such as covering a county or larger area, whereas a drone is a more cost-efficient method for smaller LiDAR collections, such as a well-pad or at most hundreds of acres. As a plane flies over the target area, lasers are rapidly emitted towards Earth's surface and reflected back. The travel time of these lasers can be calculated, and the result is a high precision elevation, longitude, and latitude of a given point. Millions of these points are placed into what is called a point cloud; however, this is not a very usable set of data to the average person, so a digital elevation model (DEM) can be produced from the aggregate of points. A digital elevation

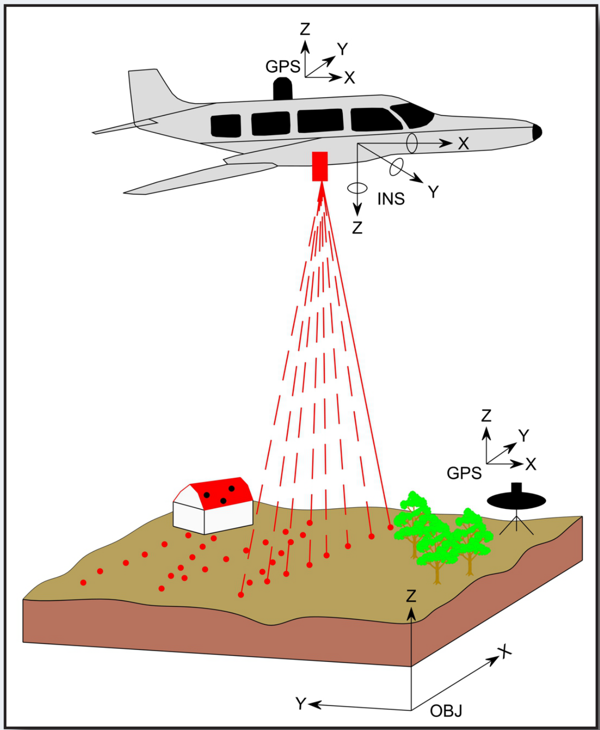

Figure 1. A schematic of an airplane is shown flying above the surface collecting LiDAR data. The xyz of the airplane GPS, airplane instrumentation, and ground-based GPS are pivotal in giving accurate high-resolution data. Adapted from http://www.asu.edu/courses/art345/pike_b/terrainmapping/lidar_files/image001.jpg (Date retrieved October 20, 2020).

model interprets the elevation between points to form a smooth surface (fig. 2; Zhang and others, 2020). For North Dakota, the NDGS is using a "bare earth" DEM. This means that vegetation is excluded from the data, creating a model of only Earth's surface without any "noise." This can be achieved through the collection of millions of points and the post-processing technical capabilities of software. In North Dakota, most horizontal resolutions are 1 to 2 meters apart giving a very smooth and high-end product.

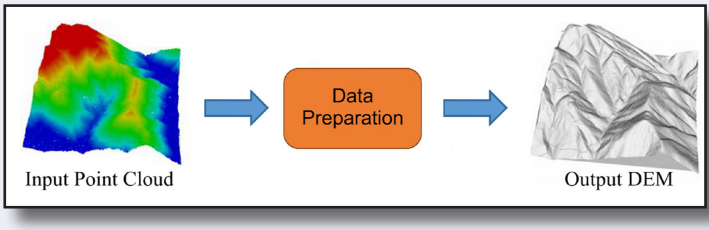

Figure 2. The graphic displays a rendering of the collection of several points versus the final model product. Software can accurately predict elevations between points, resulting in a smooth surface model. Adapted from Zhang and others (2020), https://www.mdpi.com/2072-4292/12/1/178 (Date retrieved October 20, 2020)

The state of North Dakota now has statewide LiDAR coverage and is continually amassing more data. North Dakota is very fortunate to have statewide coverage with high resolution. The management and collection efforts for all this data, which were acquired in several regional projects (fig. 3), is administered by the North Dakota State Water Commission (SWC). Even though there is already statewide coverage for LiDAR, new, more refined datasets are continually being acquired. These updates are a great resource for people. The addition of higher resolution data is great but the ability to compare two different years of LiDAR is very useful. For example, it allows geologists to observe and model the advancement of a landslide feature from one year to another. The LiDAR point cloud data and ASCII grids can be accessed from the SWC website (https://lidar.swc.nd.gov) and brought into software, such as ArcGIS or QGIS. The NDGS saw an incredible amount of potential in the data and launched the LiDAR 1:24,000 (24K) and 1:100,000 (100K) map series in early 2016. The NDGS wanted this data to become more visual and accessible for the general public. The final product of the 24K and 100k map series includes, a DEM, hill shade, and a pdf (fig. 4). The DEM and hillshade are of greater use for power users such as geologists or GIS technicians, whereas, the PDFs are intended for more general use. These maps provide landowners, developers, planners, students, teachers, and other users valuable insight to understand Earth's surface of North Dakota. There has been

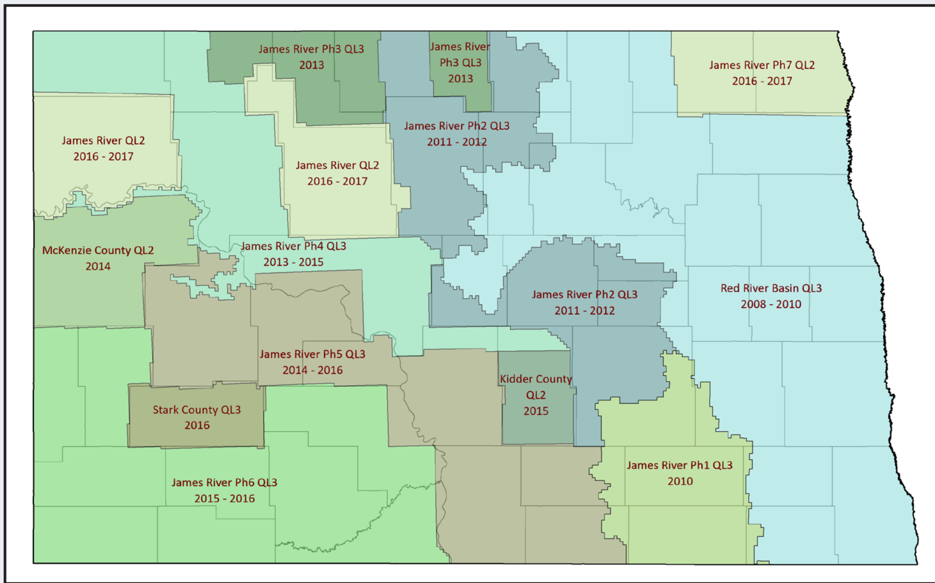

Figure 3. Location, quality, and years in which LiDAR was acquired throughout North Dakota. This was managed by the SWC.

great feedback as a result of making these maps available, whether it be consultants reaching out and asking for the whole dataset, or North Dakota State University professors using the maps to enhance their teaching in the classroom. The dataset was completed in late 2020. This feat could not have been made possible without the initial efforts of Elroy Kadrmas and the compilation completed by Steve Kranich and Navin Thapa.

The application of LiDAR can be used in a variety of industries. Geologists have many uses, including terrain modeling, surface geology mapping (landform identification), watershed delineation, geologic hazard mapping, paleontological dig surveying, wind and cellular tower placement, glacier volume and modeling, flood and erosion modeling, earthquake damage surveying, volume calculation in mining activities,

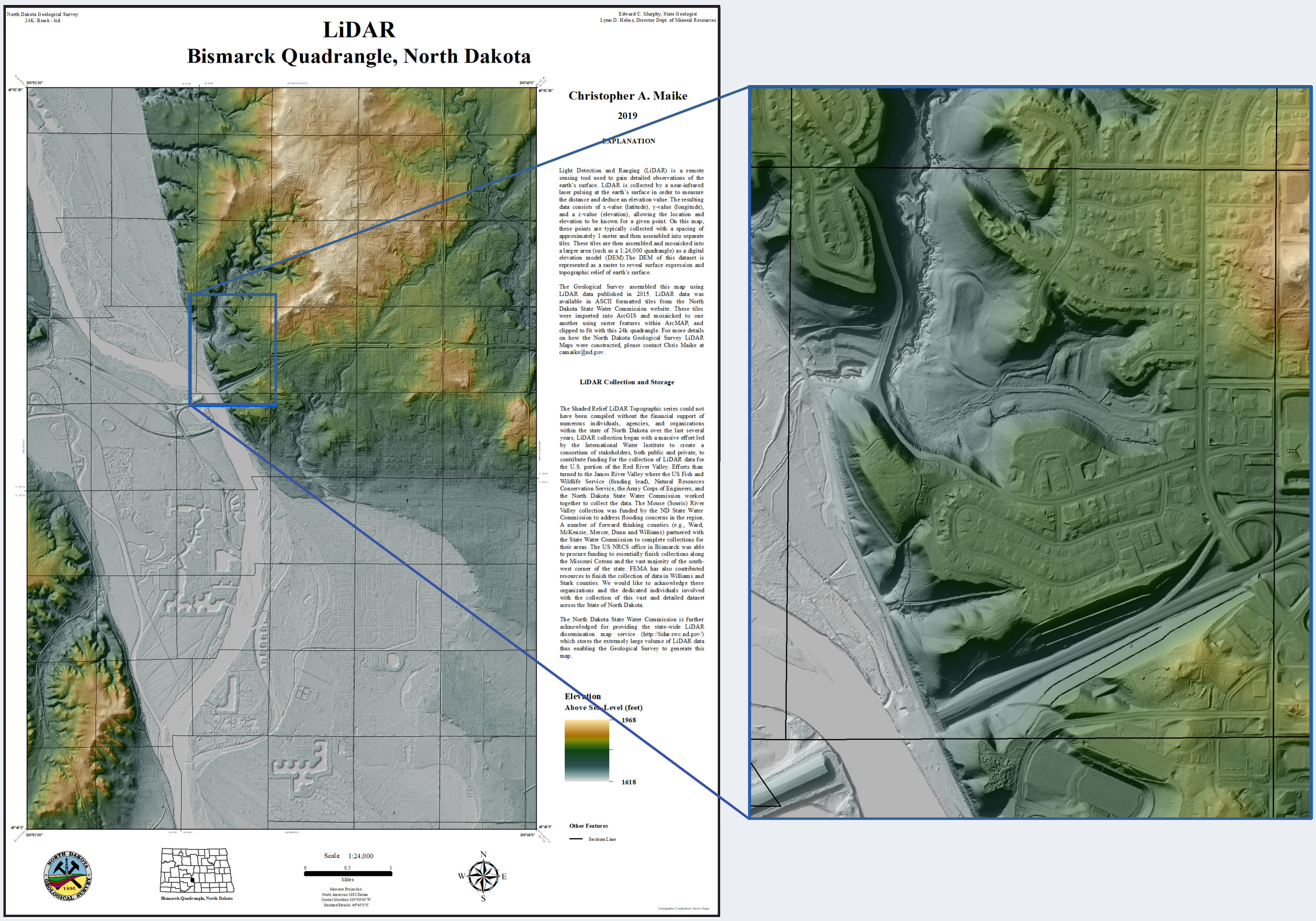

Figure 4. An example of a PDF LiDAR map made available by the NDGS. These are available to download and print. The NDGS can print these on request as well. This is a LiDAR map of the Bismarck Quadrangle, which displays the surface for a portion of the Bismarck/Mandan area.

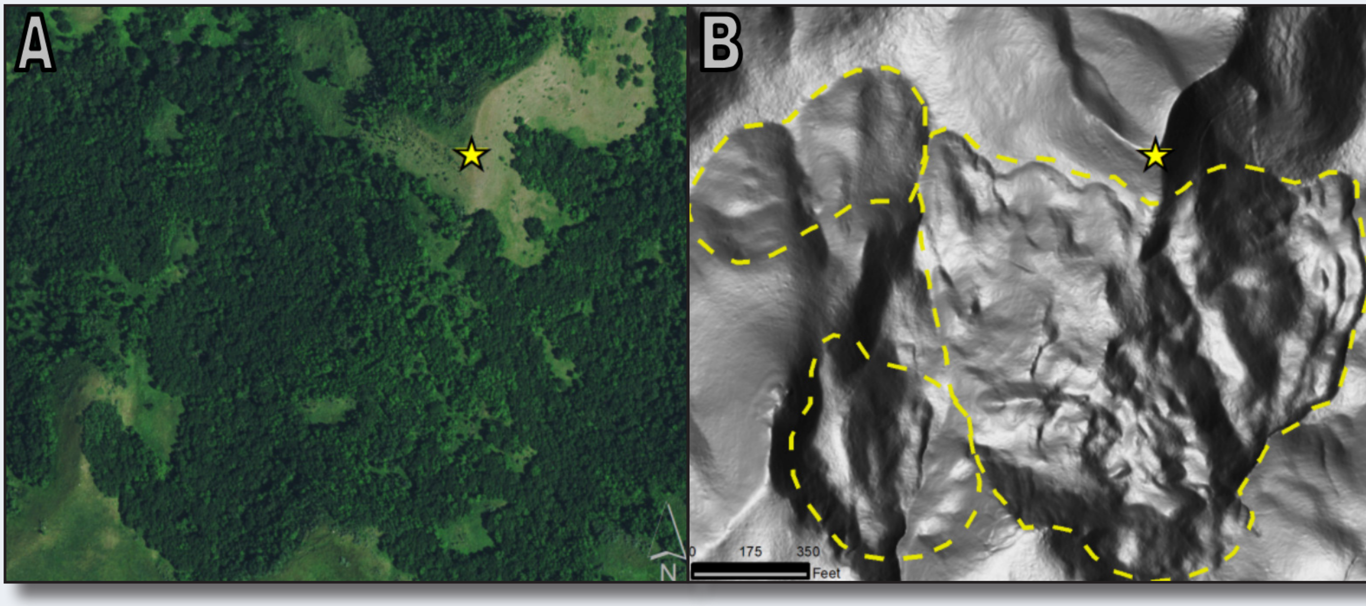

Figure 5. Comparison of (A) Landscape viewed with satellite imagery and (B) the same landscape viewed with LiDAR. On side B, the dashed lines indicate a geologist's interpretation of a landslide (Moxness, 2020).

and countless others. LiDAR has become a buzz word in the media in recent years. Autonomous vehicles are equipped with LiDAR systems that are constantly scanning their surroundings for lane keeping, collision avoidance, adaptive cruise control, and obstacle detection. In addition to cars, new Apple iPhone and iPad models are equipped with LiDAR sensors. These sensors allow detailed measurements to be taken with a phone or iPad from up to about 16 feet (5 meters) away. This is a huge step for handheld technology and will enhance many applications and uses of augmented reality. LiDAR has become a major technology which is used in the daily lives of people all around.

LiDAR has been a cornerstone in the NDGS hazard mapping program. In the last few years, surface geologists at the NDGS have completed hundreds of landslide maps. The addition of LiDAR propelled this program. Historically, geologists used satellite imagery and stereoscopic aerial photos to examine the landscape and map landslides; however, it was very difficult to accurately map in heavily vegetated areas. LiDAR has made this much more manageable (fig. 5). Pre-LIDAR mappers recognized an impressive number of these features, considering the only reference they had in many cases was the 1950s and 1960s 1:20,000 stereoscopic aerial images. On many of these early maps, updates with LiDAR offer the chance to refine the analog mapping boundaries and add smaller slope failures previously obscured in forested areas. On maps with the heaviest tree cover, LiDAR updates have increased the number of mapped slides from a few dozen to several hundred.

Many of the state's problematic landslides occur in western North Dakota and along waterways throughout the state. The addition of LiDAR not only allows geologists to identify more landslides, but also enables more accurate mapping as everything is completed digitally. Historically, mapping was completed with geologists looking at satellite imagery and stereoscopic photos and then mapped landslides on a paper topographic map. This map would then be scanned and digitized by a technician. At the time, this was the only way to complete the maps; however, those steps create margins of error. Present day geologists observe satellite imagery and LiDAR in software and map directly within that program. This eliminates a substantial amount of time and greatly increases accuracy of the map product.

It is clear that LiDAR technology is being used all around us. There are many other applications of LiDAR that are not touched upon in this article; however, that does not make them any less important. The NDGS will continue to be proactive and will be using any technologies available to create high-end and efficient mapping products. To access the available NDGS LiDAR products please go to dmr.nd.gov/ndgs/, click on "LiDAR Maps" on the pane located on the left hand side of the page, click "24K Maps" or "100K Maps" for your desired scale. A new window should pop up, please give it a few moments to load. Now you can click on the location you desire and choose between a PDF (static viewable map) or Data Files (DEM and hill-shade files), which are more directed for power users. For any questions regarding the NDGS LiDAR series or geologic hazard mapping, please contact Chris Maike (camaike@nd.gov). For questions about the SWC LiDAR data, please contact Rod Bassler (rbassler@nd.gov).

References

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