DI

IMAGE PROCESSING TO BUILD A MULTITEMPORAL VEGETATION ELEVATION ECOSYSTEM MODEL OF THE GREAT LAKES BASIN

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EXECUTIVE SUMMARY

Over a period of two-and-a-half years, the research team has acquired, processed, and created high-resolution, multitemporal vegetation elevation ecosystem models (MTVEEM) across the entire Great Lakes Basin (GLB) using stereo, submeter, optical satellite imagery obtained over the last 15 years. The team continues to process new imagery and has added processing steps to monitor changes in ecosystems and water extent over time. By providing this critical data set to stakeholders, both the understanding of the complex processes at work in the GLB and the ability to address adverse changes to the world's largest freshwater ecosystem will vastly improve. The amount of data processed and analyzed in the GLB is well beyond the capacity of most academic, private, and government systems; the team could not have done this work without a leading-edge petascale resource such as Blue Waters.

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RESEARCH CHALLENGE

Ecosystem management requires knowing the type, size, structure, and density of vegetation over time. These important features need to be mapped repeatedly. Stereo submeter, optical satellite imagery, and derived surface vegetation models can be used to better characterize these features and their changes over time, with the added dimension of height.

High-resolution vegetation surface canopy mapping over large geographic regions such as the Great Lakes Basin (GLB) has never been obtained from either aerial or satellite surveys. Additionally, the binational management by Canada and the United States of the GLB limits consistent, repeatable coverage by either country working independently. While a few scattered vegetation surface models exist from expensive airborne active laser sensors within the GLB, these data sets represent single time points and were not planned as continuous, basinwide acquisitions. Having high-resolution multitemporal information in three dimensions enables the kind of science that can address a multitude of critical questions that surround the ecosystems of the GLB.

These research questions remain: How are the ecosystems of the GLB changing and what can we as a society do about it? Continuous monitoring of surface elevation will detect both natural changes (such as flooding, forest blowdown, fire, insects, and disease outbreaks) and anthropogenic changes (such as harvest and land cover change). Further, MTVEEM will improve habitat and biological modeling. Finally, MTVEEM will be used binationally to better visualize canopy change in forested habitats and freshwater wetland resources within the Great Lakes Basin.

METHODS & CODES

Stereo-mode image acquisition through Digital Globe over the entire GLB began in 2016 and continues through 2019 as clouds and other higher-tasking priorities permit. The research team has processed over 150,000 stereo pairs, where each job consists of converting the input imagery into a standard format (GeoTIFF) and then calls the elevation extraction software (SETSM) [1]. The team expects 50,000 additional satellite image stereo pairs in the GLB each year going forward. Each stereo pair task is run on a single node, submitted in batches of two to 100 tasks per job on the low queue to maximize the scheduler throughput. Complete processing of one stereo pair to 2 meters takes an average of 12 node hours (charged as six node hours owing to using the low queue), totaling 300,000 node hours. Additionally, the researchers estimate it will take 150,000 to 200,000 node hours to process ortho-images and explore producing classifications based on the total number of image pairs they will have in hand.

RESULTS & IMPACT

As the data are processed, the resulting surface canopy models will be openly available in 2019 initially through the University of Minnesota. Other partners' online distribution systems, such as the National Oceanic and Atmospheric Administration's Digital Coast and the Great Lakes Observing System, will also be used. The final product, a seamless and registered surface elevation ecosystem model (MTVEEM) of the GLB will enable a large range of science activities at substantially higher resolution than currently available (current status shown in Fig. 1). These canopy maps and change detection products will provide positional accuracies of less than a couple meters with the added ground control points. The team is assessing semidecadal changes in priority GLB areas where light detection and ranging-derived digital surface models from six to nine years ago are available. They are also assessing intraseasonal differences by processing and differencing surface models from satellite stereo image pairs within a single growing season. The preliminary results continue to show great promise for providing valuable data to myriad coastal and terrestrial ecosystem science researchers and decision-makers across the entire GLB [2,3].

The research team's primary concentration will continue to be the GLB with extended temporal and geographical footprints as efficiencies and capacities improve. Though they will continue to make significant progress in the GLB, the team will also explore habitat types and terrain characteristics in depth that are not found within the pilot study areas. This will allow for process adjustments and quality control checks, enabling the team to scale the project to much larger geographic regions. In addition, the team has begun to process pilot areas at a one-half meter spatial resolution.

Figure 1: Great Lakes Basin digital surface model (DSM) production status as of May 2019. The source of the stereo imagery used to produce these DSMs spans the archive, starting in about 2008 to early 2019 (2019 DigitalGlobe NextView License).

WHY BLUE WATERS

Stereo satellite imagery allows for the generation of highly accurate surface elevation models; the researchers have already tasked stereo-mode acquisition through Digital Globe over the entire GLB. Each stereo pair is about 1.25 GB; the total number of pairs processed to date is about 120,000 and soon will exceed 150,000. The amount of stereo imagery in a study area the size of the GLB and the computational burden to process each of these image pairs is well beyond those resources available from standard academic, private, and government systems. This is precisely why this project requires a leading-edge petascale resource such as Blue Waters.