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THE REFERENCE ELEVATION MODEL OF ANTARCTICA

Allocation: Innovation and Exploration/1,200 Knh
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EXECUTIVE SUMMARY

The goal of this project is to create the Reference Elevation Model of Antarctica (REMA), a continuous, high-resolution (8 m), high-precision (accuracy better than 1 m) reference surface for a wide range of glaciological and geodetic applications. REMA will be constructed from stereo-photogrammetric Digital Elevation Models (DEM) extracted from pairs of sub-meter resolution Worldview satellite imagery and vertically registered using ground control from both GPS (Global Positioning System) surveyed points and coordinated airborne LiDAR (Light Detection and Ranging) surveys by Operation IceBridge of the U.S. National Aeronautics and Space Administration. The Worldview imagery is archived and provided at no cost from the Polar Geospatial Center (PGC), which will also openly distribute REMA through its web data portal. REMA processing will be done using fully automated DEM extraction and coregistration software on the Blue Waters supercomputing system.

RESEARCH CHALLENGE

Accurate surface elevation is an essential dataset for glaciology, required for mapping bed topography from ice thickness; measuring ice thickness changes; constraining ice flow and geodynamic models; mapping glacial geomorphology, terrain corrections, and filtering of remote sensing observations; and many other science tasks. It is also critical for mapping ice traverse routes, landing sites, and other field logistics planning. Continuous DEMs of the continent, however, have spatial resolutions of hundreds of meters or more, accuracies of tens of meters in coastal and mountainous areas, and no definitive time stamping for change detection, limiting their utility. The growing archive of sub-meter stereo imagery held by the Polar Geospatial Center is arguably among the most underutilized collections of satellite data in existence, with nearly complete coverage of the polar regions below 85° of latitude. The project will be the first continental-scale application of these data for terrain mapping, upscaling an established processing and distribution system that has been used to map large regions of the Arctic successfully, and will be the next step toward eventual global mapping

METHODS & CODES

In collaboration with PGC, our team has spent three years developing an efficient algorithm for constructing photogrammetric DEMs from satellite imagery with the objective of creating a fully automated system capable of handling large amounts of data. Development of the Surface Extraction from TIN-based Search-space Minimization (SETSM) algorithm was begun to facilitate an automated processing pipeline for the PGC operations. SETSM DEMs have been extensively validated; SETSM is node parallelized using OpenMP and has been applied to processing large-area DEM mosaics in proof-of-concept studies. SETSM's structure uniquely eliminates the need for an existing (i.e., "seed") DEM for *a priori* constraint or any data-specific, user-defined search parameters, making it a truly automated algorithm. SETSM is called from a single command line with the only required inputs being the filenames of the two stereo images and the RPC (Rich Photorealistic Content) file, typically provided in XML (eXtensible Markup Language) format. SETSM is written in stand-alone C code with no external dependencies and requires no libraries, ensuring simple, multi-platform installation, support, and optimization. SETSM is available as open source on Github.

RESULTS & IMPACT

Antarctica's ongoing rapid changes—and potential for near-future change—are of global concern due to increased rates of sea level rise. REMA will provide a benchmark for detecting these changes. It will be useful for a wide range of applications beyond glaciology, ranging from geodynamics to logistics planning.

As we near the end of the first year of the project, we are well ahead of schedule in our activities thanks to receiving a 1.2-million node-hour "innovation award" allocation for the Blue Waters supercomputer at the National Center for Supercomputer Applications (NCSA). This allocation has allowed us to complete a full, double-coverage processing of the entire Antarctic continent and subantarctic islands to 8-m resolution, totaling nearly 0.5 million individual DEMs, and resulting in 98% coverage prior to filtering. Using the remaining allocation, we are now selecting gaps in coverage due to both prior data unavailability or cloud cover, and we are processing additional coverage to fill gaps.

Processed data are undergoing manual quality control by our student assistants. In addition, we are implementing automated filtering and processing methods to improve the efficiency and consistency of the filtering. We have also finalized our algorithms for mosaicking data into seamless elevation model tiles for distribution. As a test, we produced a prototype set of tiles for the Thwaites Glacier area.

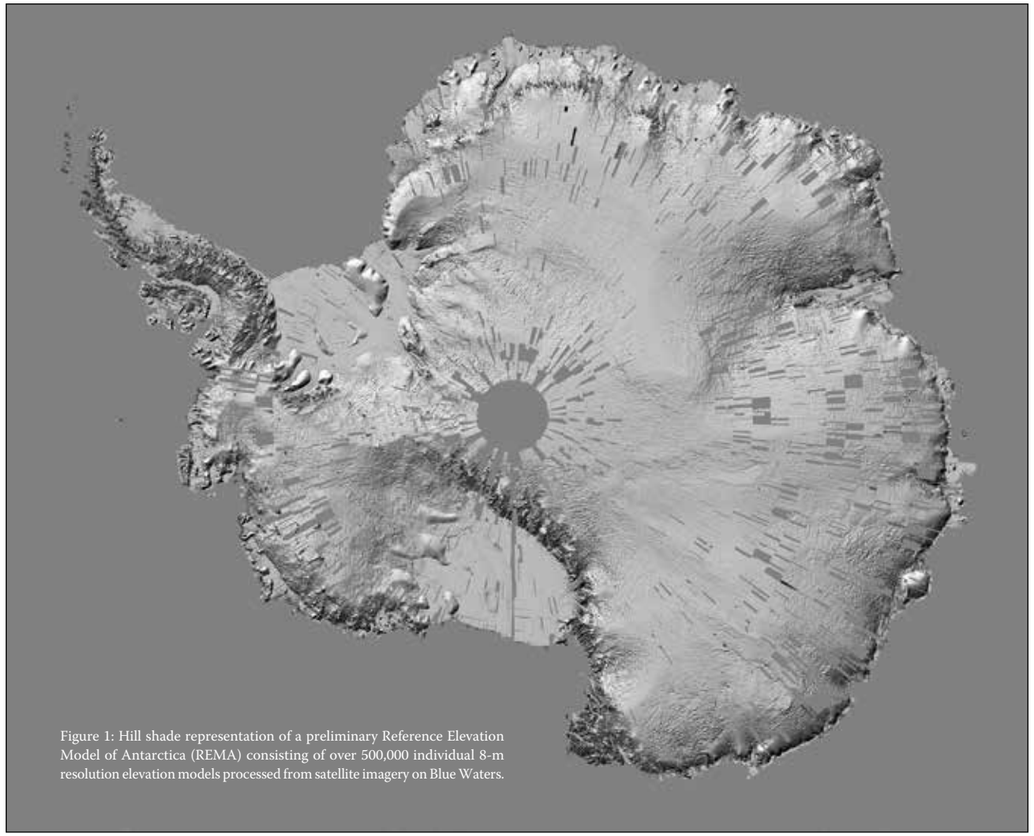

Figure 1: Hill shade representation of a preliminary Reference Elevation Model of Antarctica (REMA) consisting of over 500,000 individual 8-m resolution elevation models processed from satellite imagery on Blue Waters.

In collaboration with colleagues at the University of Washington, we have successfully implemented a method for registering the DEMs to Cryosat-2 radar altimetry, providing an elevation accuracy within the 1-m specification for REMA. Cryosat-2-derived registration has been tested against airborne LiDAR elevations. The spatial and temporal coverage of Cryosat-2 makes it an ideal source of DEM registration.

Finally, we have worked with the PGC to develop a web distribution system that will be implemented soon.

WHY BLUE WATERS

Our processing requires scheduling and rapid throughput of thousands of individual jobs, each with highly variable and unpredictable wall times. Only Blue Waters has the capacity to provide efficient throughput of this job volume. Further, our processing was able to take advantage of Blue Water's backfill scheduling capabilities, further increasing efficiency and system utilization.