# PETASCALE POLAR TOPOGRAPHY PRODUCTION

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## EXECUTIVE SUMMARY

Surface topography is among the most fundamental earth science data sets, essential to a wide range of research activities that include hazard assessment and mitigation, hydrologic modeling, solid-earth dynamics, and many others. Change in surface topography provides critical information about surface processes such as plate tectonics, erosion and subsidence, glacier mass balance, and mass balance of woody vegetation. Over most areas of the globe, however, the spatial resolution (tens of meters) and accuracy (greater than 10 meters) of openly available topographic data sets are insufficient for many of these research activities. Even fewer areas have repeated high-precision elevation measurements for observing change.

## RESEARCH CHALLENGE

There is a lack of high-resolution, consistent, high-quality elevation data available for the Earth. In 2000, the Shuttle Radar Topography Mission acquired Synthetic Aperture Radar data for the Earth that was processed into an elevation model with a 30-meter horizontal resolution. While invaluable for temperate regions, this mission was not repeated and had a limited resolution. The National Geospatial–Intelligence Agency, DigitalGlobe, and the Polar Geospatial Center have built up a near-seamless archive of polar submeter stereo imagery that consists of hundreds of thousands of stereo pair strips from the Worldview-1, -2, and -3 satellites. Using photogrammetric algorithms, the research team is able to construct digital elevation models (DEMs) from the stereo pairs, allowing for mapping of surface features at the two-meter scale. These data are already being used by the research community to support activities that include transportation, national defense, land management, sustainable development, and scientific studies. Further, most geographic areas include repeated coverage with a frequency of months or even days. Such temporal coverage can be used for change detection with applications ranging from studies of land use to resource management and environmental change.

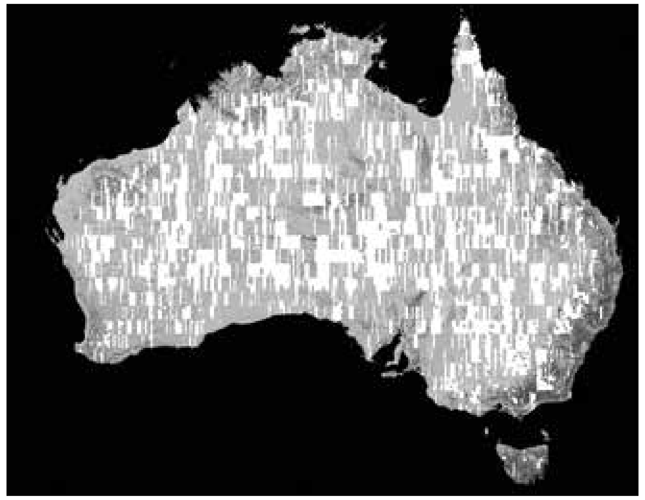

Figure 1: Map of the topography of the current production status of Australia. Each strip of elevation data is acquired in a single pass by Worldview-1, -2, or -3 and is processed on Blue Waters.

## METHODS & CODES

The research team has spent seven years developing an efficient algorithm for constructing photogrammetric DEMs from satellite imagery with the objective of creating a fully automated pipeline capable of handling large amounts of data. The Surface Extraction from TIN-based Search-space Minimization (SETSM) algorithm, initially designed to extract elevation data over ice sheets, has been refined and optimized to handle stereoscopic imagery over any land cover [1,2]. Unlike other DEM extraction algorithms, SETSM's structure eliminates the need for an existing (*i.e.*, "seed") DEM for *a priori* constraints or any data-specific, user-defined search parameters, making it a truly automated algorithm. After an initial preprocessing step that corrects the source imagery for sensor-specific detector alignment artifacts, SETSM takes the two source images and derives increasingly detailed elevation models using its pyramid-based approach. The DEM extraction workflow runs on a single node for efficiency, and several thousands of these single-node tasks are bundled together using the Swift workflow management package to effectively submit jobs in 100- to 1,000-node batches.

## RESULTS & IMPACT

Thus far, the research team has processed the stereo imagery into topography for the poles for all of 2018 as well as the first half of 2019. In addition, they have produced DEMs for 126,000,000 $km^2$ of the land surface of the Earth from 60°N to 60°S with additional focus on North America, Australia, Western/Northern Africa, and Central Asia. On average, the poles are covered eight to ten times, with some areas having several hundred unique DEMs for a given location. These data are also processed into continuous mosaics for over 99% of the 20,000,000 $km^2$ Arctic and the 15,000,000 $km^2$ Antarctic. The polar data have been released to the science community and the public through ArcticDEM.org, and Esri has developed web services and an interactive viewer. These data are now being used by scientists, national institutions, and regional and local governments for a broad range of scientific, civil engineering, and mapping applications. Three hundred scientific publications have used ArcticDEM and 27 of the Reference Elevation Model of Antarctica data sets since the data were first released.

Figure 2: Shaded relief image of the region around Paris, France. Note the meandering of the Seine River and the layout of the streets. If you look closely, the roundabout surrounding the Arc de Triomphe can be seen.

## WHY BLUE WATERS

Currently, no other academic computer has comparable capacity or large allocations. Over 1.5 billion core hours were required to process the archive of stereoscopic imagery over the life of the Arctic, Antarctic, and nonpolar elevation projects. Additionally, the Blue Waters' staff were invaluable in adapting the system to handle the single-node, high-throughput ArcticDEM workflow. With their help, the researchers adopted a strategy that enabled ArcticDEM jobs to use primarily backfill nodes on a low-priority basis, increasing overall system utilization and minimizing impact on other projects.

## PUBLICATIONS & DATA SETS

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