VALIDATION OF THE NEW SRTM DIGITAL ELEVATION MODEL (NASADEM) WITH ICESAT/GLAS OVER THE UNITED STATES

Marc Simard[1], Maxim Neumann[1], Sean Buckley[1]

California Institute of Technology, Jet Propulsion Laboratory, Pasadena, California[1]

ABSTRACT

A new version of the digital elevation model (DEM) generated from Shuttle Radar Topography Mission (SRTM) data is to begin release in 2016. The so-called NASADEM results from re-processing the raw radar echoes and telemetry, guided by global measurements of topography from the ICESat's Geoscience Laser Altimeter System (GLAS). Significant improvements in accuracy were obtained thanks to the removal of large-scale systematic biases due to a variety of arte-facts ranging from residual boom oscillations to the presence of vegetation.

Index Terms— DEM, SRTM, interferometry, radar

1. INTRODUCTION

The current SRTM DEM is (per byte) the most popular data set distributed by the EROS Data Center with more than 2 TB of SRTM DEMs downloads each month. This corresponds to an average of on 1^ox1^o tile downloaded every second of every day. In February 2000, SRTM flew for 11 days on the orbiter Endeavour with the objective to generate a DEM of 80% of the landmass between latitudes 60^oS and 60^oN. To date, three official versions of the SRTM DEM have been released with incremental improvements. The NASADEM is the latest and most likely, last version. This is also the only update with complete re-processing of the data from radar echo and telemetry. While SRTM version 2 addressed delineation of water bodies, and was distributed with a spatial resolution of 90m, version 3 provided a global dataset with 30m resolution and was void-filled. Other alternative and improved versions have been produced by other institutions (e.g. CGIAR).

The ICESat/GLAS, a spaceborne laser altimeter, acquired about 1.9 billion measurements between 2003 and 2009. It recorded full return waveforms enabling measurements of elevation as well as forest canopy height within its 70 meter footprint. The altimeter provided discrete measurements along its orbit track every 172m in cloud-free conditions and with separations of tens of kilometers between tracks. Nonetheless, the large amount of data proved sufficient to cover all SRTM's elevation measurements. Thus, GLAS data is the ideal dataset to assess and even improve the SRTM DEM.

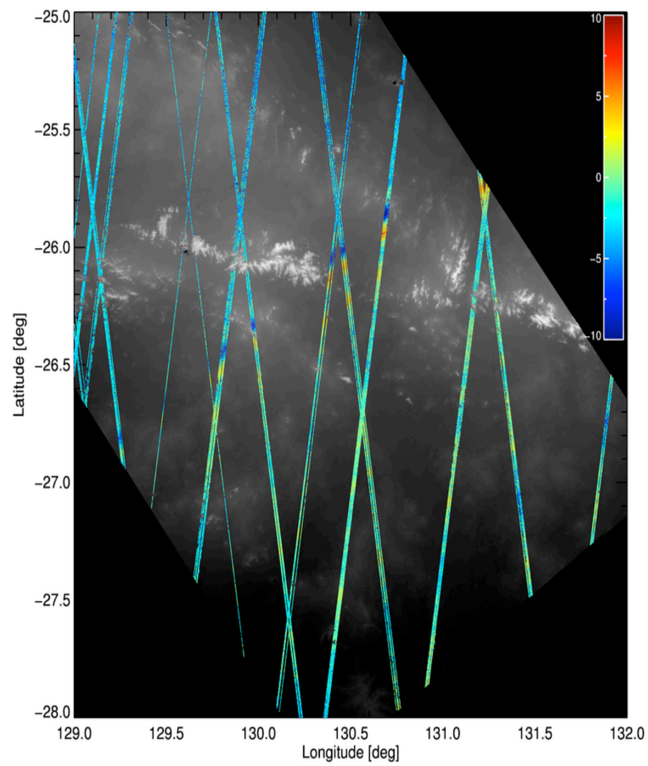

Figure 1: SRTM DEM strip with an overlay (colored transects showing the error (difference between GLAS and SRTM elevation measurements.

In this paper, we discuss the use of the ICEsat/GLAS dataset to calibrate and validate the NASADEM. We show the GLAS data enables correction of SRTM boom oscillations that could not be corrected during previous processing iterations.

2. DATASET ASSESSMENT

2.1. SRTM

The required SRTM data accuracy was to be better than 16 meters absolute relative to the center of the Earth, with data points spaced every 1 arcsecond in latitude and longitude (~30m at the equator). However, until 2015, the 30m version was released publically only for the United States and was released globally with a spatial resolution of 90m.

First assessments of SRTM accuracy reported overall errors of ~8m [1][2][3] based on global GPS transects and point measurements. Relative accuracy, the ability to detect and map small scale changes on the surface elevation, was ~7m [1]. It was also observed that ripple arte-facts most obvious in flat and large terrain, contaminated the DEM [4]. These ripples were caused by uncompensated boom oscillations that slightly changed the interferometric baseline roll angle. Moreover, these ripples were combined during the averaging of SRTM strips to produce the DEM mosaics, resulting in crisscross patterns of ripples. This made correction very difficult as a post-production step. In fact, corrections can only be compensated at the strip level in radar slant range geometry.

2.2. ICESat/GLAS dataset

The GLAS dataset has been used to derive DEM's in environments with smooth environments, to determine snow accumulation or loss and even to measure water levels. One popular use of the data has been to investigate forest structure, and to produce large-scale map of forest canopy height (e.g. [5]).

3. METHODOLOGY

Strip elevation data (slant range projection) were generated using raw radar echoes and telemetry data acquired in February of 2000. While there are several strips covering a sing geographical area, the analysis and comparison with ICESat/GLAS estimates of ground elevation was performed on single strips to monitor ripples along-track. The GLAS data was projected into SRTM's viewing geometry. The amount of GLAS measurements was found to be sufficient to cover SRTM elevations nearly continuously along-track. Figure 1 shows an example of a SRTM strip with the GLAS tracks overlaid. The colors indicate the difference between SRTM and GLAS. It is this difference that was used in the SRTM strip direction to quantify and model the impact of boom oscillations (ie. the elevation ripples) on the data.

The SRTM collected data in 4 beams and the impact of boom oscillation (baseline roll) caused ripples with a ramp in the slant range direction. To remove the observed ripples, a residual interferometric baseline angle was estimated that would account for the observed elevation errors throughout the 4 beams. Finally the estimated residual roll angle was added to the baseline angle, and the SRTM was completely reprocessed.

In addition to the ripples removal, the absolute error difference with GLAS was subtracted from the SRTM elevation to effectively correct any elevation bias.

4. RESULTS

The results were compared to the previous SRTM version 3. Figure 2 shows the difference between NASADEM and SRTM. The ripples that have been removed in the NASADEM version are clearly observable. The crisscross pattern is due to multiples SRTM strips being mosaicked to produce the final DEMs.

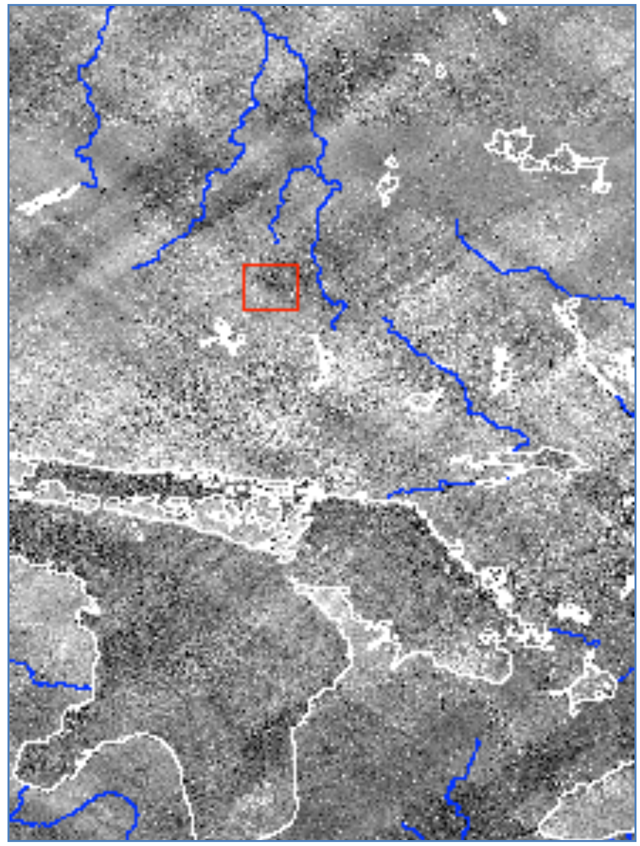

Figure 2: Difference image between NASADEM and SRTM in the North of the Great Lakes (white lines) region.

Figure 3 shows the elevation errors as defined by the difference between SRTM and GLAS elevation measurements. At large scale, systematic biases observed in the SRTM version 3 have been removed in the NASADEM version. It is unclear of the origin of these errors. Figure 4 shows a scatterplot of the elevation measured by GLAS and NASADEM which is used to determine overall error and residual bias. A fit with a slope of 1.0 was found and a small bias of about 10cm. The final RMS error was 2.3m which is significantly better than the original assessments [1][2][3].

These results hold only for the current iteration (as of January 2016) over the continental United States. We expect updated and final results over North America by summer 2016. Other regions will be processed later and released on a continent by continent basis.

In the near future, we will assess the NASADEM product relative to DEM products from TanDEM-X and ASTER missions.

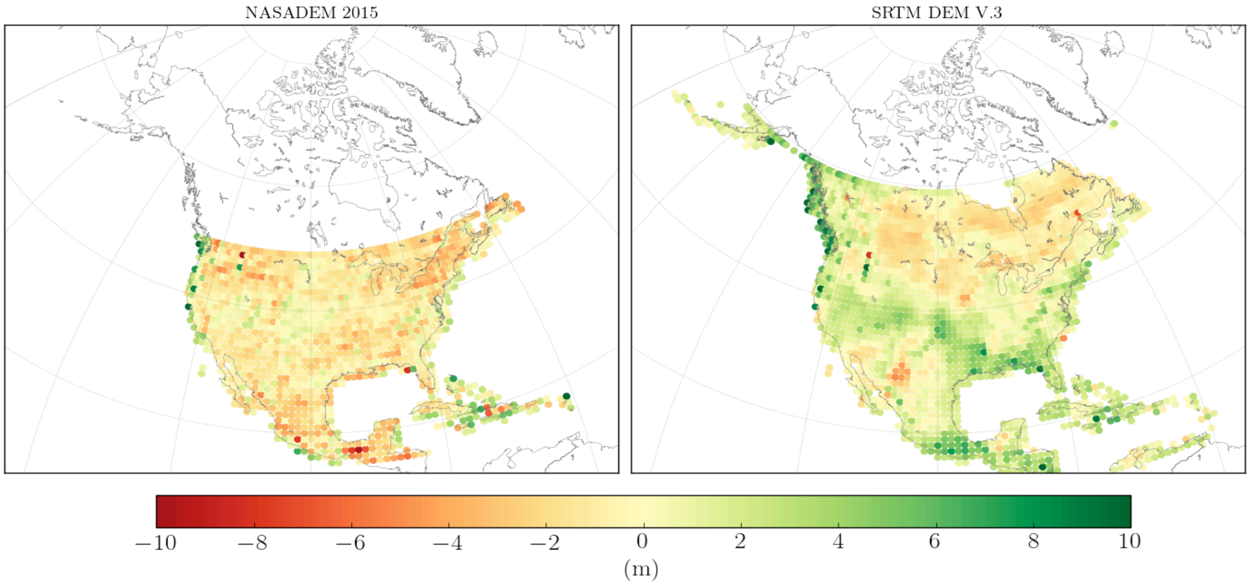

Figure 3: Error relative to ICESAT/GLAS elevation measurements in bare ground areas found in the NASADEM and SRTM DEM version 3. Large scale error patterns have been significantly removed in the NASADEM version.

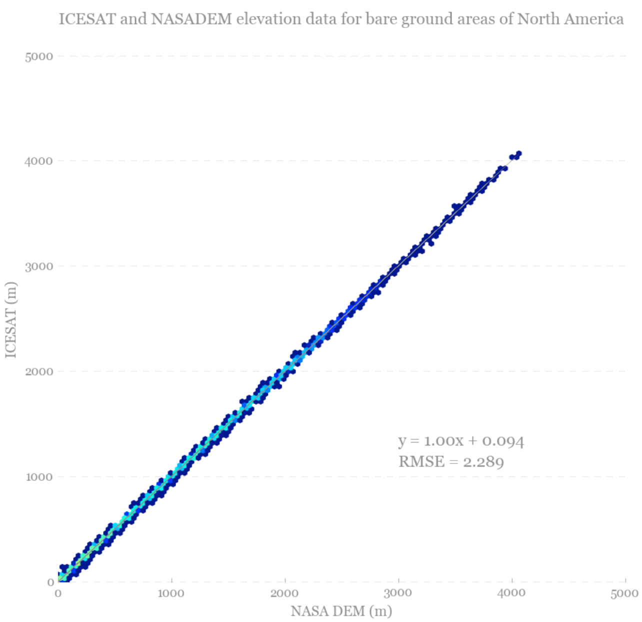

Figure 4: ICESat/GLAS versus NASADEM elevation estimates over the United States.

11. REFERENCES

[1] Rodriquez, E., C. Morris and J. Belz, "A global assessment of the SRTM performance," Photogram. Eng. and Rem. Sens., 72(3), 249-260, 2006.

[2] Carabajal, C. and D. Harding, "ICESat validation of SRTM C-band digital elevation models," Geophys. Res. Lett., 32, L22S01, doi:10.1029/2005GL023957, 2005.

[3] Carabajal, C. and D. Harding, "SRTM C-Band and ICESat Laser Altimetry Elevation Comparisons as a Function of Tree Cover and Relief," Am. Soc. Photogram. Rem. Sens., 72(3), 287-298, 2006.

[4] Gallant, J.C. and A. Read, "Enhancing the SRTM Data for Australia," Proceedings of Geomorphometry 2009, Zurich, Switzerland, 31 August - 2 September, 2009.

[5] Simard, M., Pinto, N., Fisher, J., Baccini, A., (2011), "Mapping forest canopy height globally with spaceborne lidar", Journal of Geophysical Research, VOL. 116, G04021, 12 PP., 2011, doi:10.1029/2011JG001708