ICESAT LIDAR AND GLOBAL DIGITAL ELEVATION MODELS: APPLICATIONS TO DESDYNI/TANDEM-L

Claudia Carabajal[1] *& David Harding*[2]

[1] Sigma Space Corp. @ NASA Goddard Space Flight Center, Planetary Geodynamics Lab., Code 698, Greenbelt, MD 20771, USA.

[2] NASA Goddard Space Flight Center, Planetary Geodynamics Lab., Code 698, Greenbelt, MD 20771, USA.

1. INTRODUCTION

Geodetic control is extremely important in the production and quality control of topographic data sets, enabling elevation results referenced to an absolute vertical datum. Global topographic data with improved geodetic accuracy achieved using global GCP databases enables more accurate characterization of coastal inundation hazards and land surface changes related to solid Earth processes, natural hazards and climate change. The Ice, Cloud and land Elevation Satellite (ICESat) has acquired globally distributed laser altimetry profiles (± 86°) since February of 2003 [1, 2]. They provide a consistently referenced elevation data set with unprecedented accuracy and quantified measurement errors that can be used to generate GCPs with sub-decimeter vertical accuracy and better than 10 m horizontal accuracy. Although ICESat only sampled the Earth's surface at discrete points illuminated by ~ 50 m laser footprints spaced 175 m along profiles, its capability to record a waveform, representing the elevation distribution of surfaces illuminated in the laser footprint, allows for comparisons with respect to the highest, centroid (average) and lowest elevations observed by ICESat [3]. Furthermore, lidar measurements are the most direct measure of the height and the vertical structure of forests. In regions of vegetation cover, the waveform measures the vertical distribution of vegetation and the underlying ground where illuminated through canopy gaps thus providing a unique means to generate topography geodetic control in areas of dense vegetation cover.

2. DEVELOPMENT OF A GLOBAL ICESAT GEODETIC CONTROL DATABASE

Using ICESat data we are producing a global set of GCP's in a project supported by NASA's Earth Surface and Interior Program. We apply stringent editing criteria in order to produce the highest quality ground control. This dataset will contribute to a global, coordinated and integrated DEM database produced from different sources, embedded into a consistent, high accuracy, and long term stable geodetic reference frame. They will be a key means to establish a much needed global topography reference frame to facilitate interoperability among DEM data sets. A precise digital elevation model (DEM) is useful for myriad of earth-surface studies and science applications as well as processing of Interferometric SAR interferograms used to precisely determine small changes in surface elevations. To date we have used ICESat geodetic controls to characterize and quantify spatially varying elevation biases in DEMs produced by the Shuttle Radar Topography Mission (SRTM) (Figure 1) and the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) [4, 5, 6]. This data set will be particularly useful in Northern and Southern latitudes above and below ±60°, where other high-resolution global topographic data assets are not available, and topographic control is scarce. In addition, by incorporating global land cover databases, such as that produced by MODIS, evaluation of elevation biases and reported error statistics can be done in the context of land cover types and various topographic relief conditions globally.

3. FUTURE SPACE-FLIGHT LASER ALTIMETER MISSIONS

The methodologies developed to use ICESat data for global geodetic control purposes are a pathfinder for similar use of data to be produced by ICESat-2, with a target launch date of 2015, and the lidar component of the DESDynI/TANDEM-L mission. The DESDynI Lidar waveform data will be analogous to ICESat data but employing 25 m laser footprints sampled every 30 m along five profiles spaced across track by 850 m. This substantially improved sampling, as compared to ICESat, will provide a more comprehensive set of global GPS's and enable DEM control using multi-beam elevation profiles, rather than simply single points. The ICESat-2 mission plans to employ a new measurement approach, micropulse single-photon ranging whereby single photons yield ranging precision of ~10 cm. Sampling will depend on the probability of detecting a photon return for a laser pulse, but typically along-profile sampling distances of a few meters should be achieved. Like DESDynI Lidar data will be acquired simultaneously along multiple profiles spaced cross-track. This data will be akin to point clouds generated by discrete return laser altimetry. The ICESat-2 data will provide an opportunity to evaluate and control DEMs with highly resolved, geodetically referenced elevation profiles.

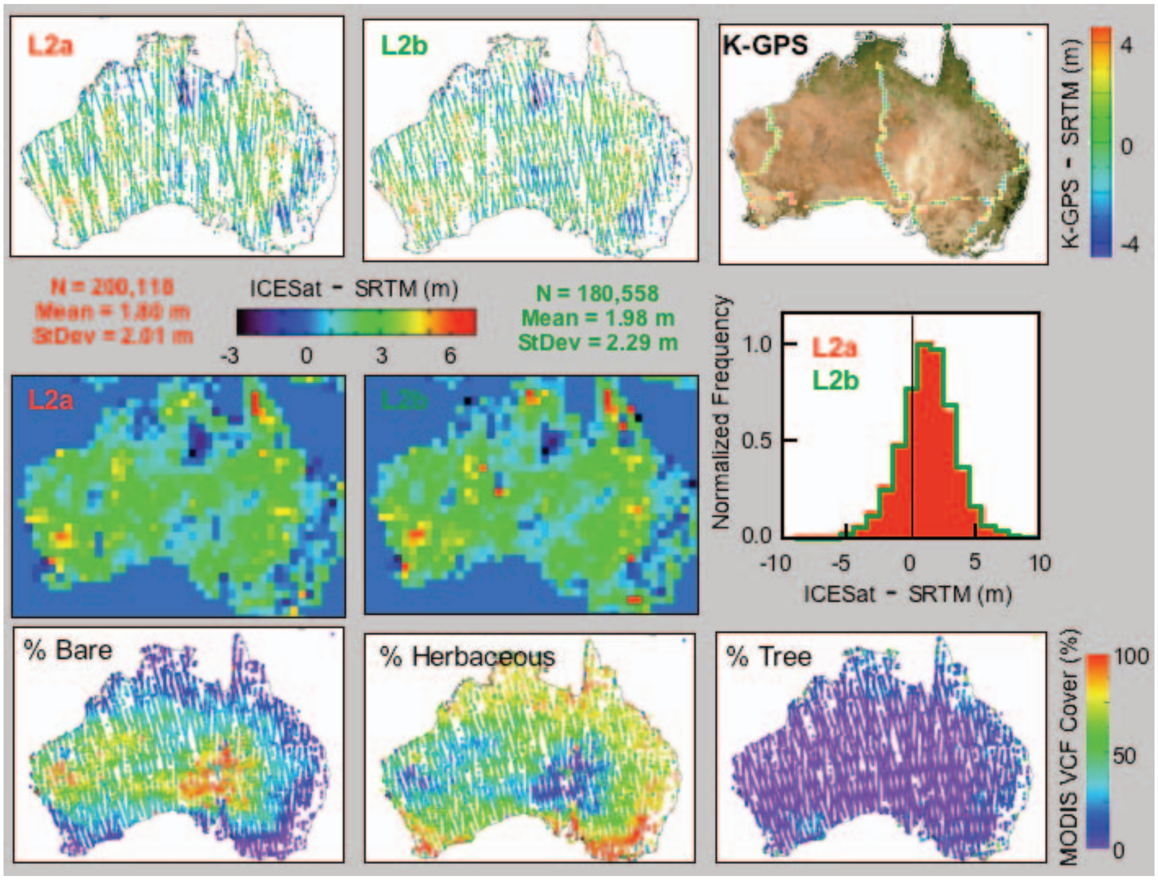

Figure 1. ICESat minus SRTM differences for two observation periods (L2a and L2b) were studied using selected ICESat data well suited to be used as GCPs. Maps on the top left show the location of the differences at the ICESat-I GCP locations, and mean differences within a 1°x1° grid cell (center left). Summary histograms (center right) and statistics show that SRTM as a whole for Australia is biased low by nearly 2 m. A long wavelength elevation error structure varying form -3 m to 7 m is observed, which agrees with the long wavelength elevation biases observed in the kinematic GPS transects used as the primary validation for SRTM elevation models (top right). The pattern of long wavelength biases is not correlated with vegetation cover, as represented in the Vegetation Continuous Fields product derived from MODIS, indicating the aerial percent of bare ground, herbaceous and tree cover in 500 m pixels (bottom).

4. SELECTED REFERENCES

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