TOWARDS VALIDATION AND CORRECTION OF GLOBAL DIGITAL ELEVATION MODELS WITH ERS-1 ALTIMETRY

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ABSTRACT

The requirement for a global 1km Digital Elevation Model is currently being addressed by the compilation of several GDEMs such as the GLOBE dataset. However, the availability and quality of input ground truth varies widely over the earth's land surface. At this spatial scale, altimetry presents an attractive option for generation of an independent dataset, with the combination of near polar orbit and close track spacing during the ERS-1 geodetic mission providing data at a spatial scale of several km.

This paper presents the results of series of comparison studies between altimeter derived heights and the GLOBE GDEM, using orthometric heights derived from ERS-1 Waveform Altimeter Product data retracked using an expert system. Results over the USA show excellent agreement with the altimeter derived heights. It is intended that this work will be extended to evaluate the full GLOBE dataset.

1. INTRODUCTION

The geodetic phase of the ERS-1 mission resulted in the acquisition of large volumes of altimeter returns over non-ocean surfaces. Whilst data collected over ice have been the subject of considerable research, the land altimetry dataset has been much less studied. This is in part due to the complex nature of the echoes returned from the earthís land surface. The poor performance of previous altimeters over land, due to their inability to maintain lock over significant surface relief [1], and the extremely user-hostile format of the current dataset [2] are also contributory factors.

Details of the regional results obtained from retracking the ERS-1 land altimeter dataset, together with a discussion of the expert system approach, for waveform retracking over topographic surfaces to yield optimal estimates of orthometric height, have been presented elsewhere [6,7,9,10]. This paper presents results from a comparison between altimeter derived heights and the beta release of the GLOBE 30î Global Digital Elevation Model (GDEM).

This dataset, which is a compendium of ground truth survey data, contains values for about 60% of the earthís land surface. These height estimates are of variable, and in many cases unknown, quality. The purpose of this research is to determine the effectiveness of ERS-1 altimetry as a tool to validate and enhance the full release of the GLOBE dataset, as a contribution towards deriving a true Global DEM at 30î resolution.

2. DATA PROCESSING

A test area in the USA was chosen for the comparison analysis (Figure 2.1); over the USA data are believed to be fairly accurate as U.S. Defense Mapping Agency data were incorporated into the GLOBE dataset (Dunbar, pers. comm.). The area was chosen to contain significant terrain variation (at the lower left of the region) together with a region with significantly lower relief (upper right). Altimeter derived orthometric height data from the ERS-1 geodetic mission, referenced to WGS84, were used for this work [2,3,6,9]. Data at the full 20Hz resolution were binned at 30î, averaging all values within each cell to generate a mean elevation value. Null cells (primarily due to the cross-track spacing) were set to -100m. The resulting matrices were generated as 2^o x 2^o grids for comparison with the ground truth data.

Data from the GLOBE dataset were also combined into 2^o x 2^o grids for the test area; both datasets were then imported into the GRASS v4.1 GIS. As the

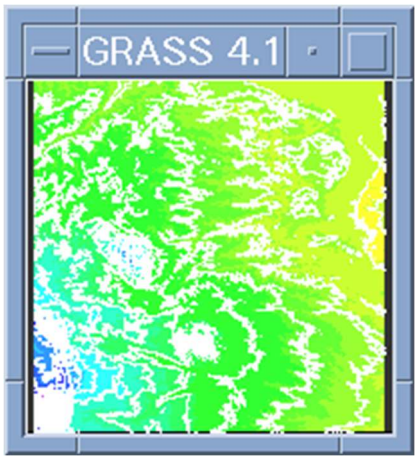
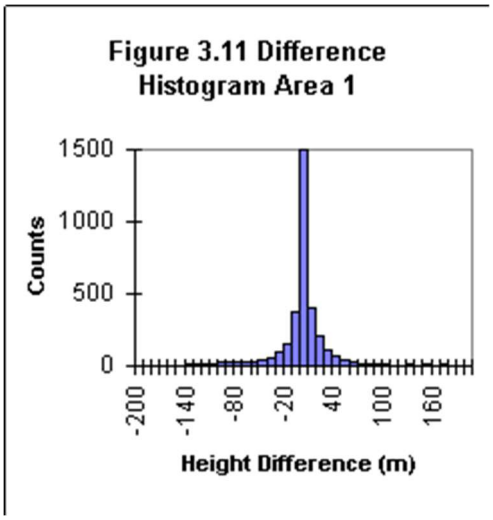


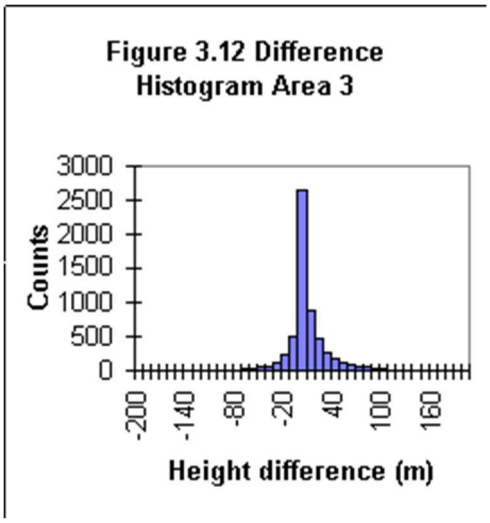
Figure 2.1 Test Area

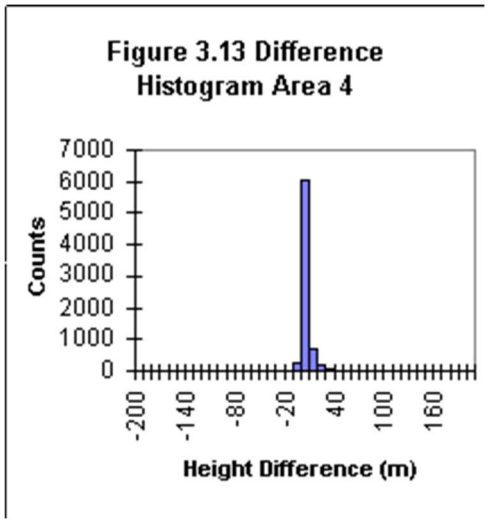
GLOBE dataset contains, in addition to a mean height for each pixel, an estimate of the maximum and minimum height per pixel, these data were also imported for use in this study.

3. COMPARISON
3.1 Difference Histograms

By latticing the GLOBE dataset within GRASS to retain only those GLOBE pixels where valid altimeter data were present, a difference dataset was created for the area, and histograms generated for all 2° x 2° subsets. Sample results are given in Figures 3.11 to 3.13, with a key to sample areas in Figure 3.14. The samples included here were selected to show comparisons over a range of terrain relief. As all valid altimeter pixels were included in the analysis the altimeter dataset is a spatially uneven subsample of the DEM. It is clear that the histogram sets show generally very good agreement, particularly in Area 4, where the vast majority of the data lies within 2 - 5 m of the GLOBE mean height. The effects of missing data where the altimeter lost lock on the surface are also evident, particularly in test Area 1, which contains the most severe terrain relief.







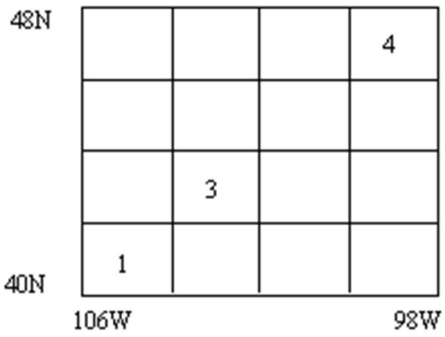


Figure 3.14 Sample Area Key

3.2 Profiles

A series of comparison profiles were taken over the test area, selected to overfly varying terrain. Samples are given in Figures 3.21 to 3.23, with the GLOBE mean height plotted against the altimeter height. GLOBE maximum and minimum heights are also included.

It is clear that, over most of the altimeter tracks, good agreement is obtained between the altimeter and GLOBE height values. Whilst the altimeter heights appear to tend towards a minimum rather than a mean height estimate, this trend is limited; the apparent effect is primarily due to the failure of the altimeter to track over the more severe terrain, which tends to be represented by the higher height values. Where the terrain slopes are most severe, to the extent that considerable data dropout occurs in

the altimeter dataset due to both failure to return a valid waveform (missing leading edge) or actual loss of lock, a systematic effect is occasionally observed, where the altimeter profile appears to be displaced laterally with respect to the ground truth. Several of the profiles selected for this paper have been chosen because they display this effect. The most probable reason for the displacement is off-ranging of the altimeter in the presence of high slopes. However, this effect is seen only intermittently even in the presence of steep mean slope values. A fuller discussion of this issue is presented elsewhere [10]. Off-ranging is not apparent as a significant contributor to the error budget over the majority of profile data in the test area.

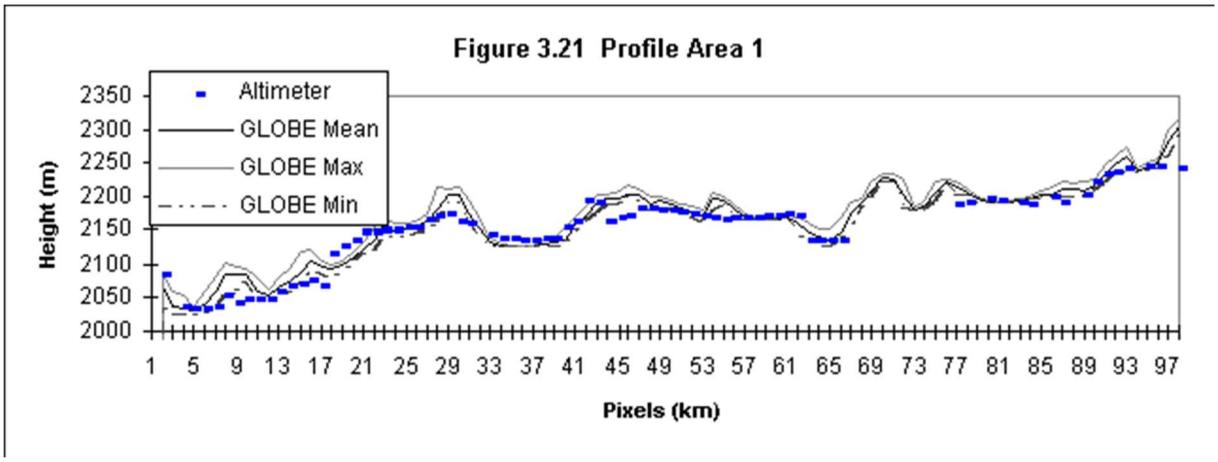


Figure 3.21 Profile Area 1

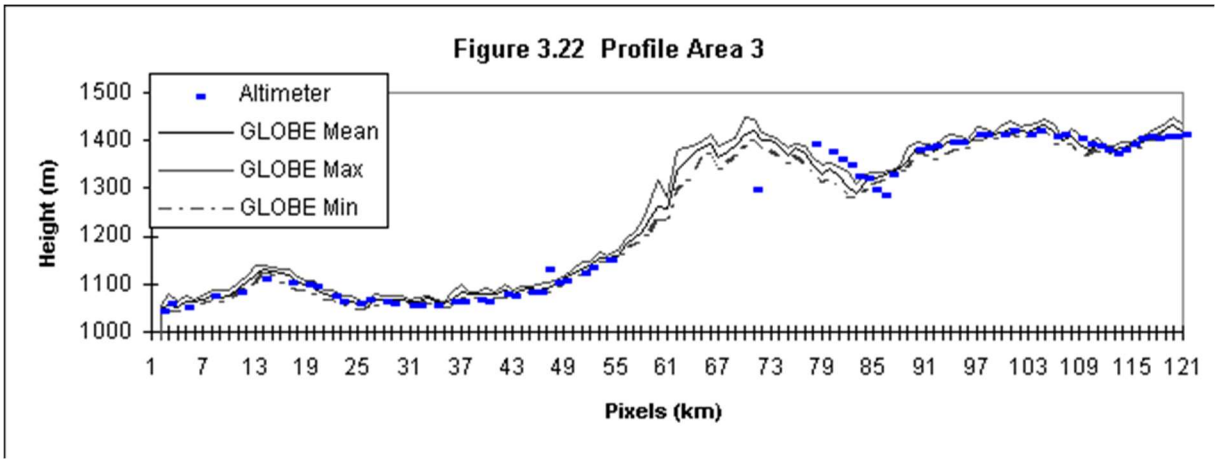


Figure 3.22 Profile Area 3

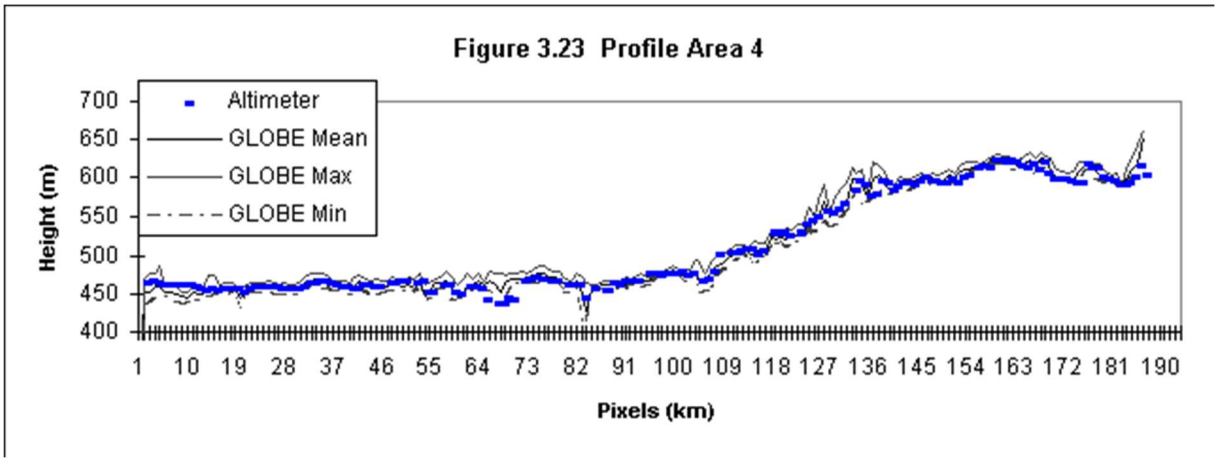


Figure 3.23 Profile Area 4

4. DISCUSSION

The initial results are extremely promising. Excellent overall agreement is seen with the GLOBE dataset, over an area where the GLOBE data are expected to give a good representation of the real terrain. Systematic offsets which could be attributable to off-ranging appear to be confined to parts of the profiles where slopes are very high and data dropout is considerable.

5. FURTHER WORK

The overall level of agreement between the two datasets indicates that altimeter derived height values can be used to provide a valid comparison dataset for the existing GLOBE data. Accordingly, the altimeter dataset will be reprocessed using the latest version of the Expert System [10]. Based on the full results from comparison with ground truth over a number of test areas, each altimeter data point will be graded for probable accuracy by the expert system during reprocessing, and this completely independent dataset will be used for global evaluation of the GLOBE GDEM. It is expected that the results of this work will be available later in 1997.

6. ACKNOWLEDGMENT

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