Potential of ERS-1 Derived Orthometric Heights to Generate Ground Control Points

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ABSTRACT

In order fully to utilise the high number of valid returns from the ERS-1 altimeter over the earth's land surface during the geodetic mission, the precision to which altimeter derived heights can be generated over land surfaces must be investigated.

In this paper, Waveform Altimeter Product data retracked using an expert system (described elsewhere), to optimise the determination of individual heights have been used at two test sites, which include the whole of Zimbabwe, and part of the USA, to investigate the extent to which retracked altimeter data can be used to generate Ground Control Points for geodetic purposes. This paper presents results of both internal comparisons between spatially correlated returns from different orbit arcs near crossovers, and direct comparison with ground truth. The results obtained over these test areas have demonstrated that altimeter crossovers over land can be determined to an internal precision of better than one metre and show good agreement with ground truth.

1. INTRODUCTION

The orthometric height information derived by retracking ERS-1 land altimetry data from the geodetic mission has many potential applications. One possible use of such data is to generate ground control points. However, this can only be done if it can be demonstrated that under certain conditions the heights obtained are extremely accurate.

In order to investigate the behaviour of the retracked dataset, data over test areas has been analysed close to crossover points. This paper presents results of this analysis from two test areas; the whole of Zimbabwe, and part of the central USA. Comparison with ground truth is also presented.

2. DATA

Zimbabwe

A test area from Zimbabwe was chosen for the initial analysis, because of the varying nature of the terrain, which includes large areas of low to moderate slopes. Retracked altimeter data from the ERS-1 geodetic mission, previously transformed to orthometric heights referenced to the WGS84 ellipsoid, were selected over this area, at the full 20Hz resolution. Detailed discussion of the techniques used in producing this dataset can be seen elsewhere [1,2,3,4]. All crossovers where data points existed in close proximity were identified and graphed (Figure 2.11) to confirm the existence of a sufficiently dense network.

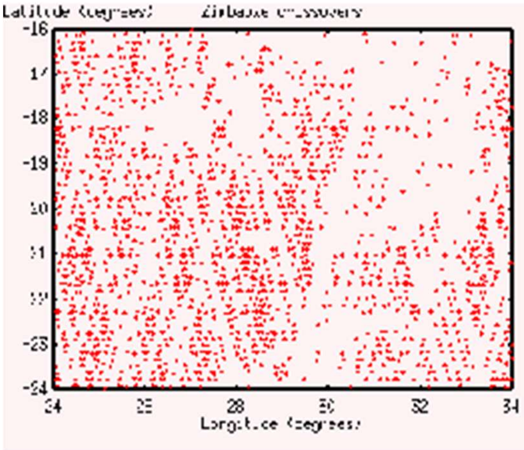

Figure 2.11 Crossovers over Zimbabwe

USA

An 8o x 8o test area in central USA, already being utilised for comparison with GLOBE global digital elevation model heights [2,8,9] was also used for this analysis as it contained areas of widely varying topographic roughness. Although data dropout was found to be significant over the most varying terrain, a usable number of crossovers satisfying the same constraints as for the Zimbabwe dataset were still found to be present (Figure 2.21).

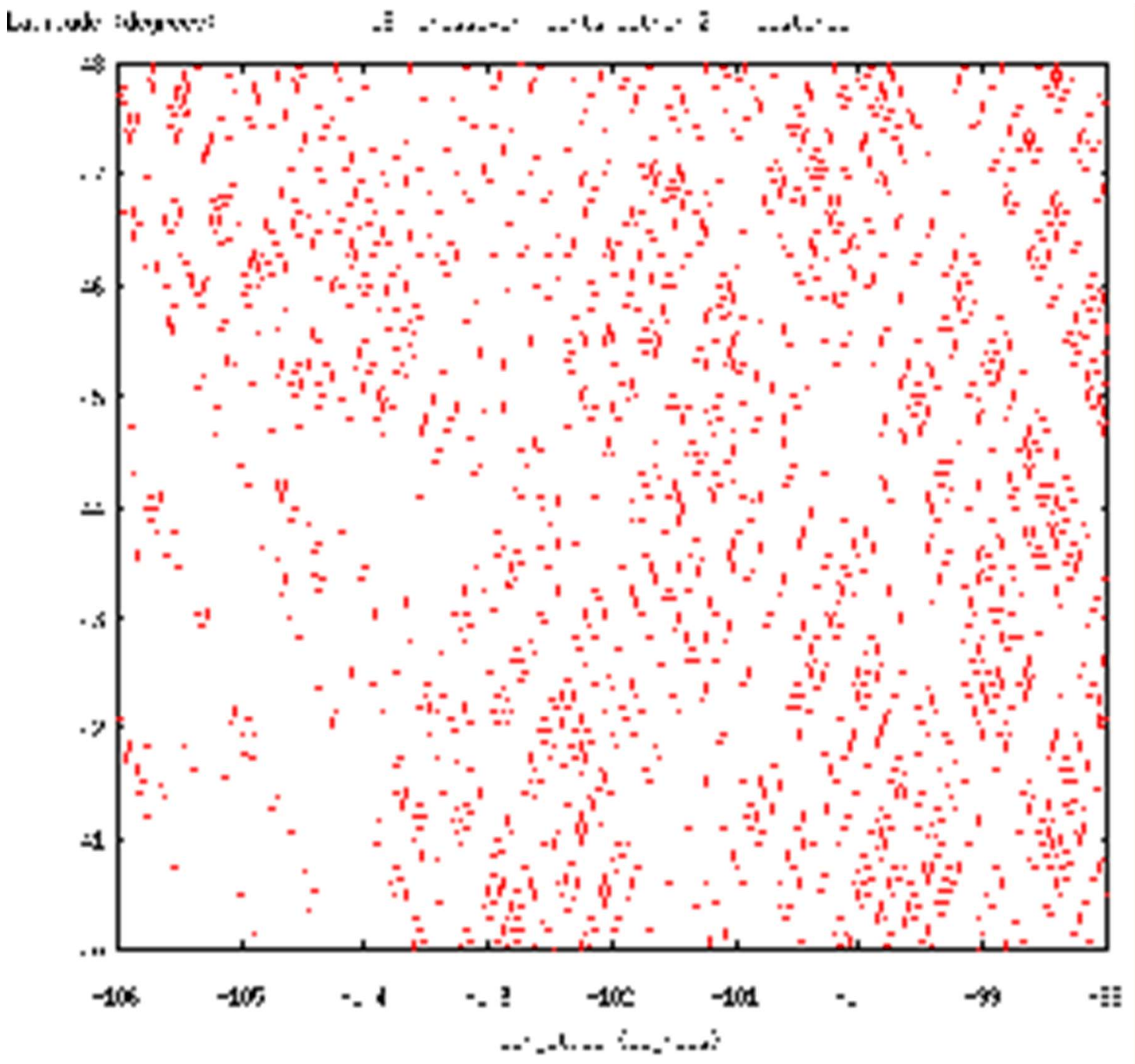

Figure 2.21 Crossovers over USA Test Area

3. ANALYSIS

Over the ocean, crossover point analysis is a well-understood and widely used technique for assessing the quality of altimeter data. However, the fundamental assumption - that the height from ascending and descending tracks should be the same when interpolated to a crossover point - is evidently invalid over land. Here, crossover points are used as a means of identifying orthometric heights from different arcs that result from echoes from the surface lying in close spatial proximity.

For the geodetic mission data, the density of crossover points means that a data driven approach rather than a global solution is more appropriate for crossover point detection. For this research, crossover points are calculated for each test area from the actual data, and all data points within a certain radius of the crossover point are identified.

In this work, the six closest pairs of points to each crossover point have been considered. The separations were calculated, and the height differences obtained. One advantage of this approach is that errors in the geoid model used to convert to orthometric heights do not appear in the height differences. This is of relevance as there are known errors in high order terms of the OSU91 geoid model.

3.1 Zimbabwe Results

For all closest data pairs whose nominal separation (calculated from the waveform latitude and longitude) did not exceed 200m, the height differences were calculated and statistics generated. Results are summarised in Figure 3.11 for all 1820 crossovers satisfying the constraints. It is evident that for 70% of the crossover pairs, agreement is reached to within 2m. This extremely good result is clearly in part a function of the comparitively gentle terrain relief over much of Zimbabwe and the surrounding area. Detailed plots of the spatial distribution of crossover pair differences over the region confirmed the clear relationship between terrain relief and crossover pair agreement. However, even in the most severe terrain, many data pairs agreed to within a few metres.

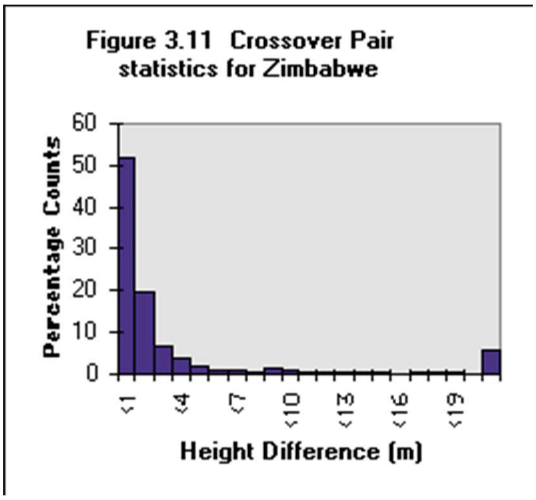

Figure 3.11 Crossover Pair statistics for Zimbabwe

USA Results

In order to examine the behaviour of altimeter data over varying terrain, data from the USA test area were analysed, using the same constraints as for the Zimbabwe dataset. Statistics for the crossover differences are summarised in Figure 3.21.

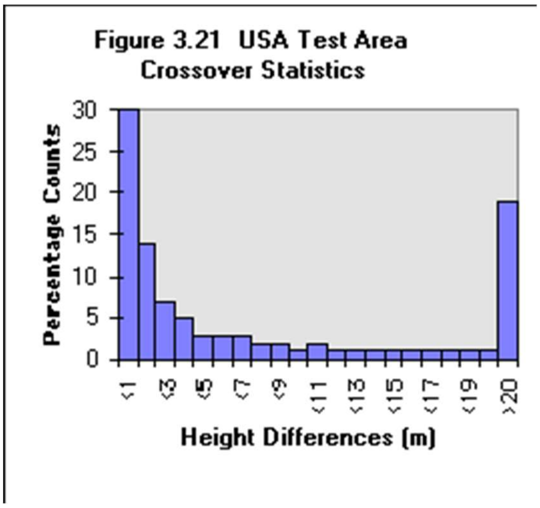

Figure 3.21 USA Test Area Crossover Statistics

It is clear that, whilst very good agreement is found for a significant proportion of the crossover pairs, the difference distribution is less good than for the Zimbabwe dataset. Analysis of the crossover pair distributions with height difference over the test area showed a very non-uniform distribution. Accordingly, statistics were calculated for each 2o x 2o subset of the area. Sample graphs are shown in Figure 3.22.

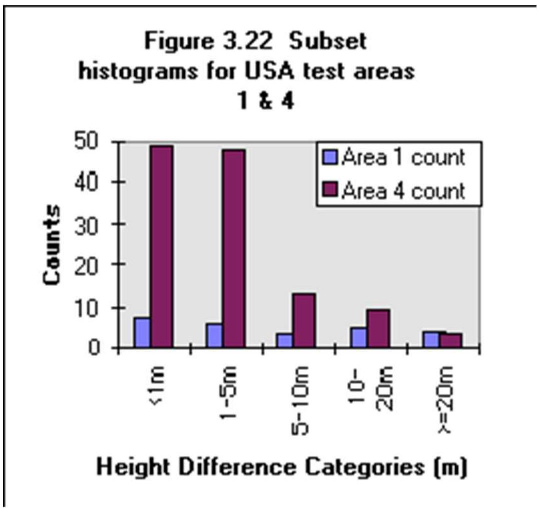

Figure 3.22 Subset histograms for USA test areas 1 & 4

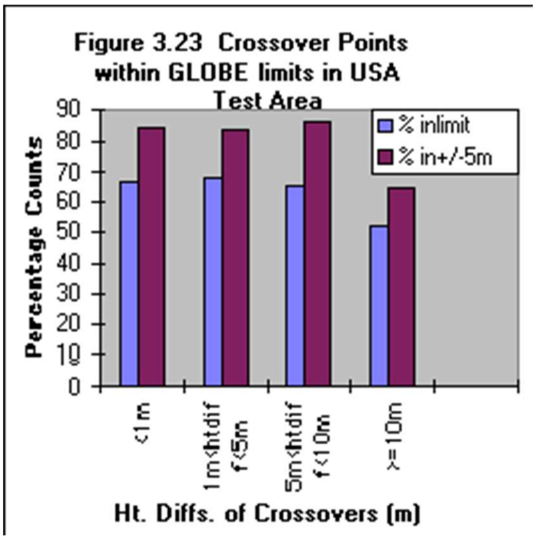

Figure 3.23 Crossover Points within GLOBE limits in USA Test Area

The availability of the GLOBE dataset enabled additional comparisons to be carried out with ground truth. It should be noted that the GLOBE dataset consists of 1km mean, maximum and minimum height pixel values with an estimated accuracy of +/- 5m at best. GLOBE heights for each crossover point (maximum, minimum and mean) were compared against the altimeter heights (higher, lower and average for each data pair) and grouped according to the crossover pair height difference. As in many cases all three GLOBE heights were found to define a very narrow height band, it was decided to relax the constraint to allow for the known inaccuracy in the GLOBE dataset and calculate all statistics for both comparison criteria. A sample output is included in Figure 3.23; this demonstrates clearly the effect of relaxing the GLOBE constraints, and also illustrates the good agreement obtained with the ground truth. More detailed comparisons with GLOBE are presented elsewhere[8, 9].

DISCUSSION

It is clear that the agreement between values on ascending and descending tracks can be extremely good in areas of varying terrain. Discrepancy does not of itself imply error, since over rough terrain the actual height distribution illuminated may vary appreciably between returns spatially adjacent. In this context, further analysis of the altimeter performance over varying terrain is clearly required; results to date from the evaluation of the contribution of off-ranging errors are very encouraging [2,5,6,7,9]. Detailed investigation to identify those parts of the surface which have contributed significantly to the return waveform is continuing.

The proportion of results where the nearest pair of points agree to within 1m is very high for both test sites. The extremely close agreement found generally (with over 70% of closest pairs agreeing in height to within 2m over Zimbabwe, together with the good results for GLOBE comparison at crossover points) also has implications for the current processing chain used for orthometric height determination. Whilst errors in atmospheric and instrument corrections, and radial orbit error have previously not been considered to add appreciably to the error budget for the majority of land altimetry data the finding that for some data consistent measurements over land can be made to high accuracy means that this approach needs to be re-addressed. It may well also prove necessary to consider regional geoid solutions rather than a global model.

FURTHER WORK

Currently direct comparison of results against GPS measurements over test areas are being made. Results from the research will then be incorporated in the decision process of the expert system used for altimeter retracking, to enable the generation of accurate ground control points.

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