Rectification of Radar Images Using Stereo-derived Height Models and Simulation

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Abstract

One application of topographic height information derived from stereo-radar is for the rectification of the radar image. Using an analytical plotter one can plot contour-lines and planimetric features from radar stereo images that are presented on film in analog form. The stereo-derived heights serve as input to a specific rectification technique based on digital image processing. A simulation program generates a synthetic digital radar image to match the real digital image. This relates the addresses of the height values to each radar image pixel. Consequently an ortho-image can be created by resampling.

Introduction to the problem

The problem of precisely relating the gray values of an aircraft or satellite radar image to a corresponding map is solved by creating a geometrically corrected image. The result -- an image with the backscatter of a radar image but the geometric properties of a map -- is here denoted as "ortho-image". The radar rectification discussed here depends on the use of a digital elevation model and subsequent radar image simulation as it was proposed first by Kobrick (see Domik, Kobrick, Leberl, 1983)

The required input for a rectification, according to Leberl (1983) is

- a radar image
- interior orientation
- exterior orientation
- a digital elevation model

Digital rectification has also been done in the context of the SEASAT-mission. Curlander et al. (1981) have used digital SAR-images from SEASAT together with orbital data, and Naraghi et al. (1981) matched the SAR-data with a digital terrain model.

Rectification procedures

The digital elevation model (DEM) required for the rectification process might be available from maps or other sources. If a DEM model does not exist, (e.g. in exterrestrial areas), it might be derived from a radar stereo pair. The procedure of generating a DEM with radar stereo mapping and subsequent rectification of one of the radar images is only described shortly here. Emphasis is on the description of the results. References for more detailed information on the procedures are in Raggam and Leberl (1984) for stereo mapping and in Domik et al. (1984) for the rectification procedure.

Generation of DEM with radar stereo mapping

LaPrade (1963) first suggested radar stereo mapping. Flight configurations to obtain stereo pairs are e.g. same side flights with different look angles, opposite side flights or crossing flight paths. At the Research Center Graz a software system for the analytical plotter Kern DSR-1 was developed to set up, and plot from, radar stereo models. The stereo model set-up is realized in two steps. The first step is to relate the image x,y coordinates to the physical radar measurements of range r and time t. (Inner Orientation). The second step (exterior orientation) relates image and object space. The plotting is either directly on an xy pen plotter or results are entered into a digital data base for further processing.

Rectification of digital radar image

The DEM together with sensor and imaging parameters and backscatter curves enter into a simulation. The result is a

synthetic radar image, with the geometry close to the equivalent real image. Each image pixel has an address attached to it, relating the image coordinate with the DEM address from which it was mapped. The radar backscatter in the simulation process is only a function of the incidence angle; usually a homogenous, standard backscatter curve is used. The backscatter in the simulated image has only significance in helping to find homologue points in the real and synthetic image. These points enter into a registration procedure to match real and simulated image. After the registration each digital DN number of the corrected radar image is connected to one or more DEM addresses. In a final step the image grey values are resampled to their DEM addresses and thus the radar distortions removed.

Results with Greek Test Site

On Nov. 12, 1981, the SIR-A (Shuttle Imaging Radar-A) was launched aboard NASA's space shuttle. SIR-A was a left-side-looking SAR operated at L-band frequency with an elevation angle of approximately 50 deg. off nadir to the center of the imaging swath. SIR-A data were optically recorded.

Two images obtained in Europe from Data Take 32-33 and Data Take 37A, resp., were of special interest for stereo investigations. They showed two Greek islands, Cephalonia and Ithaca. Though SIR-A was not specially designed for stereo-investigations, these data takes from the crossing orbits proved to deliver fairly well stereo. The intersection angle of the imaged swaths was approximatley 34 deg.

The analog images were used to create a stereo-derived digital elevation model as explained above. The illuminated height model is shown in Fig. 1. For our investigations the images presented on film were scanned by an Optronics device to receive the data in digital form. The quality of the images after digitizing can be evaluated in Fig. 2 and Fig. 3. Data Take 37A (Fig. 2) was chosen for the rectification process.

Flight and imaging information to be entered into the simulation were gained from (Cimino and Elachi 1982): Latitude and longitude for the center of the swath as well as flight altitude were recorded only for each minute, so the flight path was approximated by a straight line at the height of about 264 km (slightly descending). The STC position and the interpulse period were used to calculate the sweep delay to the near edge of the swath. The image presentation was in slant range. Through

the simulator a synthetic radar image was created from the stereo-derived DEM together with an additional address file (Fig. 4). The registration resulted in Fig. 5 by removing the differences (see registration grid in Fig. 6) between real and simulated image. The final ortho image (Fig. 7) was created by resampling the radar image grey values at their corresponding DEM addresses.

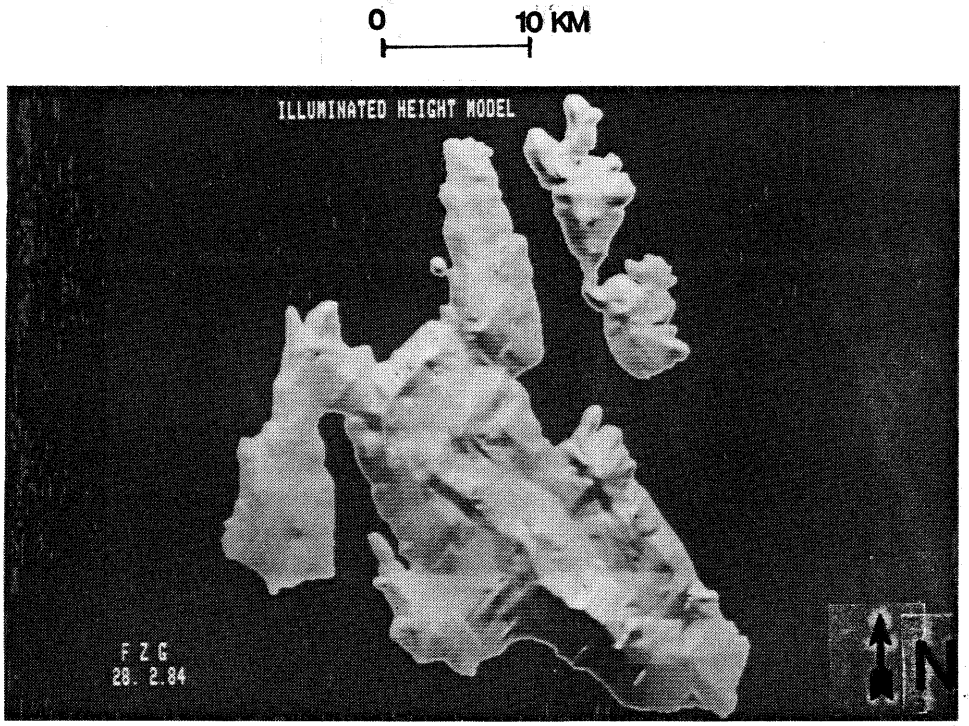
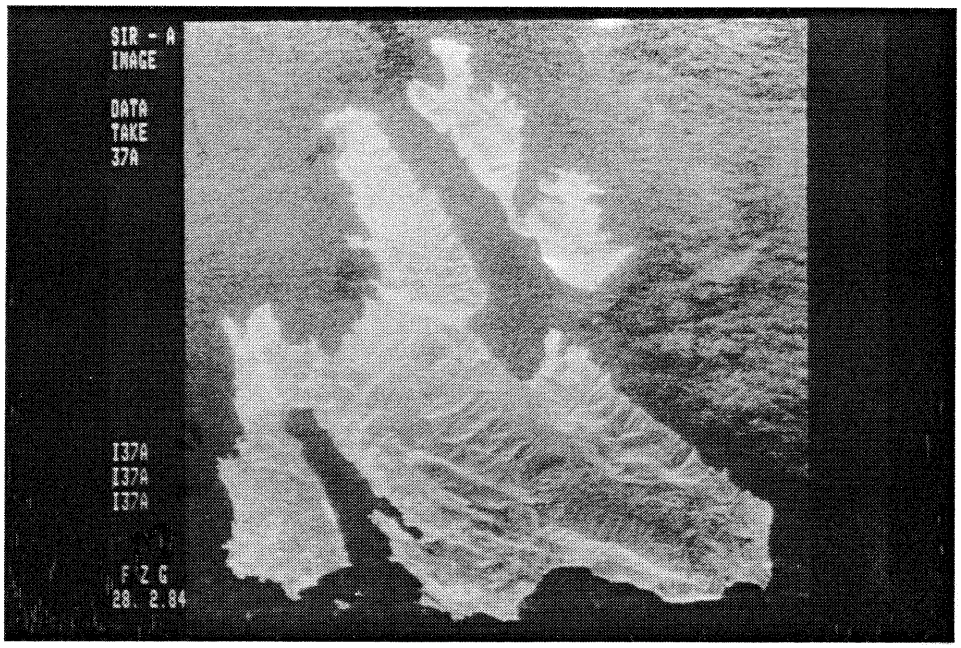


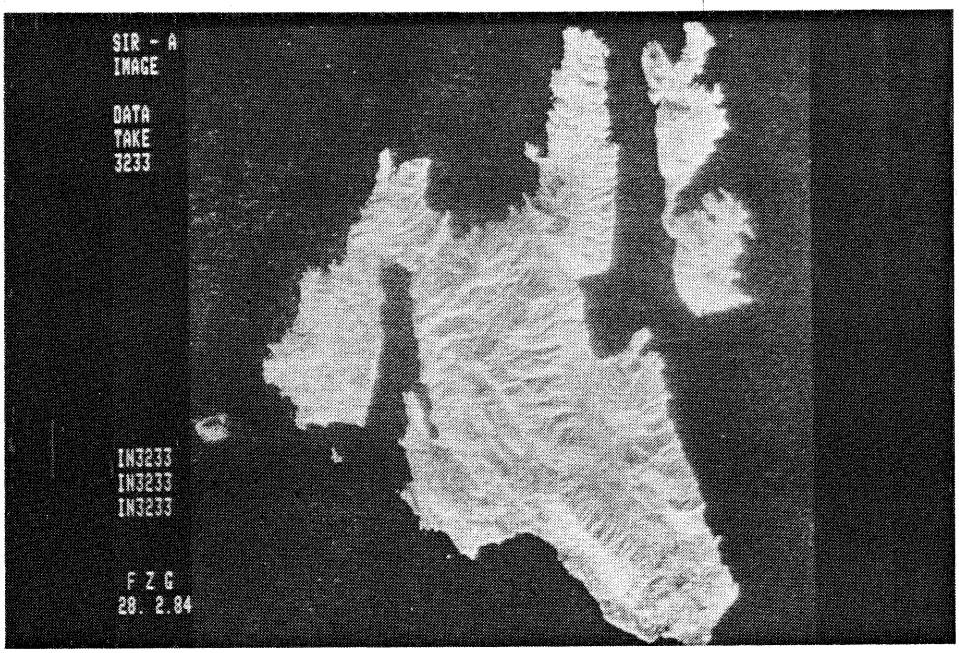
Fig. 1 : Digital elevation model of the greek islands Cephalonia and Ithaca with radar illumination. Data is stereo - derived using an analytical stereoplotter.



N

Fig. 2 : Data Take 37A

0 10 KM



N

Fig. 3 : Data Take 32-33

Fig. 2 + 3 : Space Shuttle Imaging Radar SIR-A stereo radar image pair of the Greek islands Cephalonia and Ithaca, taken at 34 deg. angle between flight lines at 50 deg. elevation angle.

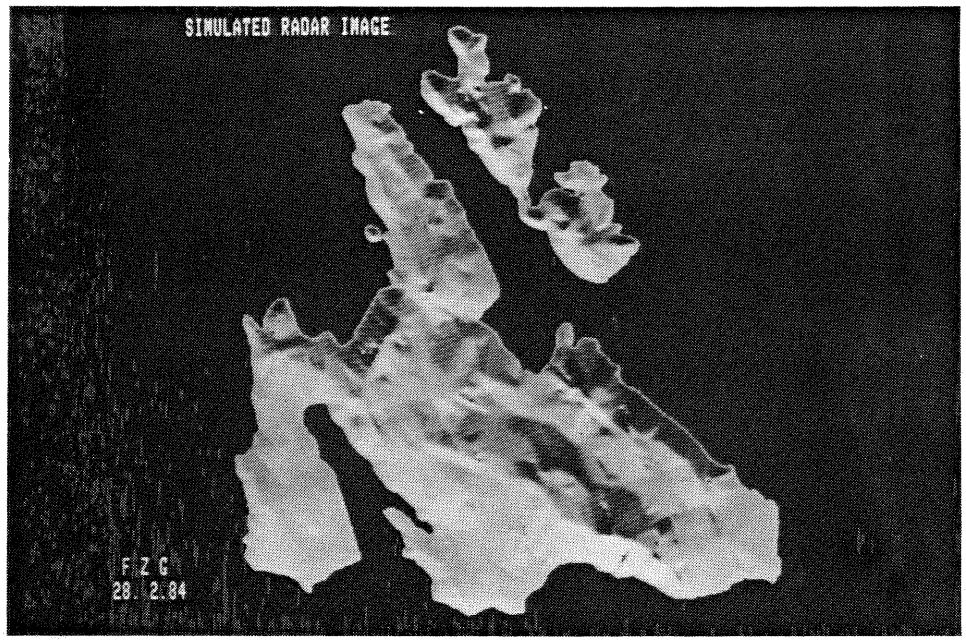


Fig. 4 : Simulated radar image using imaging and sensor parameters from SIR-A recordings and stereo-derived digital elevation model.

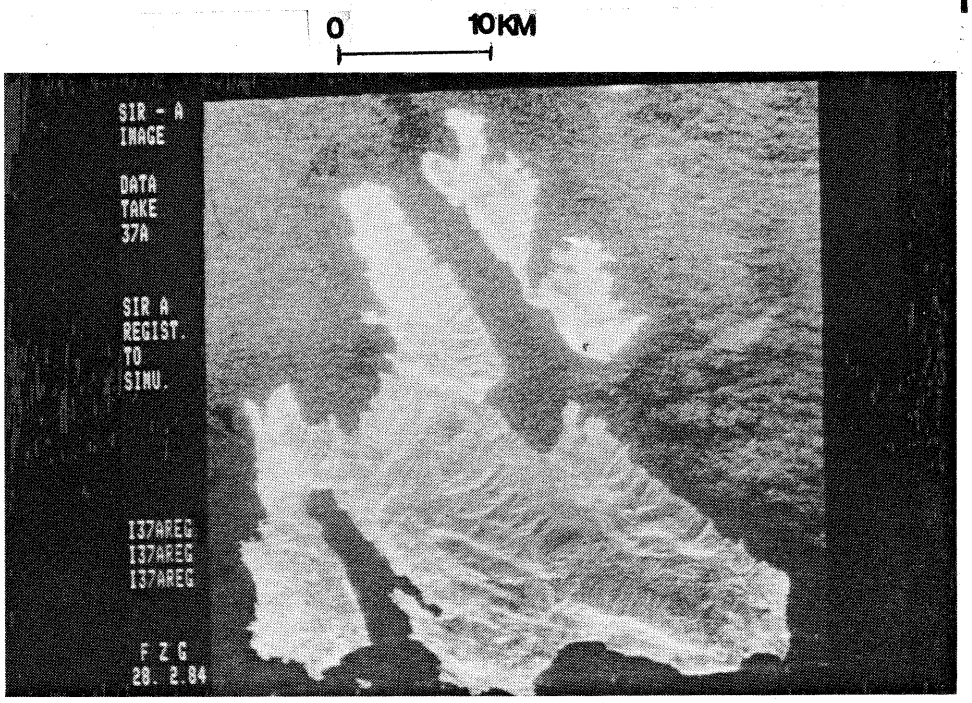


Fig. 5 : SIR-A image registered to simulated image.

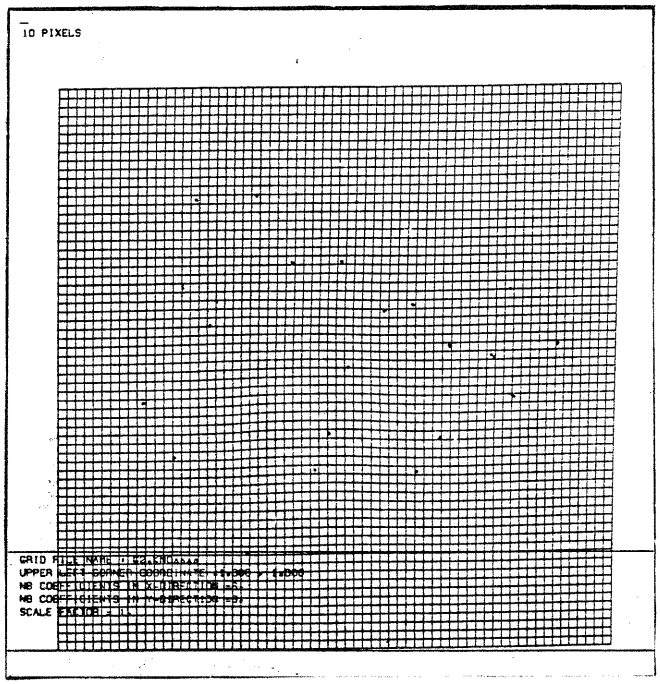


Fig. 6 : Distortion grid between real and simulated image. One grid cell length corresponds to 10 pixels. Anchor points and residual vectors are plotted in the grid.

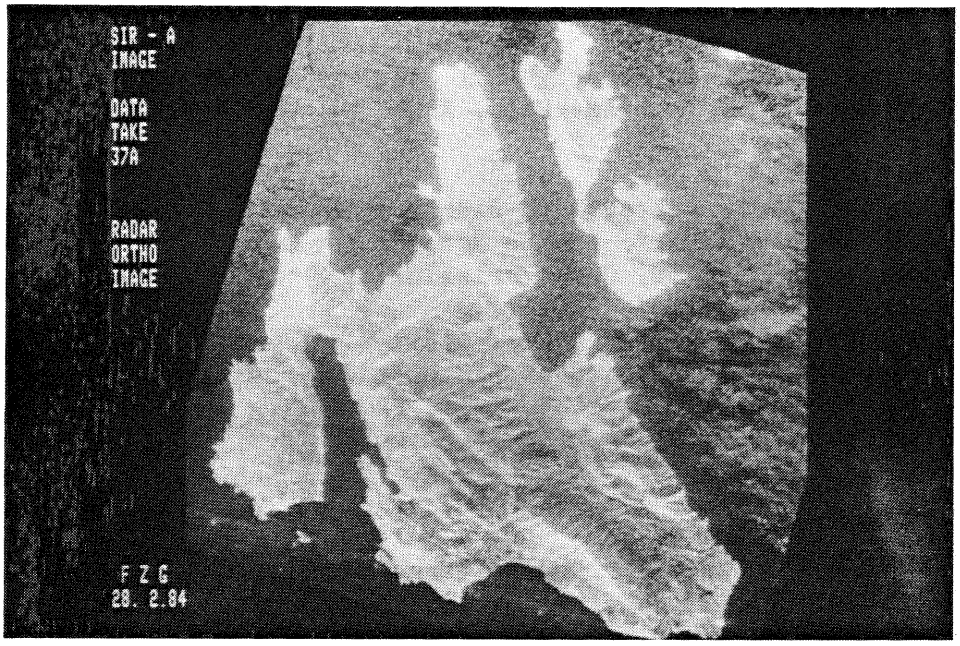


Fig. 7 : Radar ortho-image created from a SIR-A image (Data Take 37A) using the height model derived from the radar stereo pair of two SIR-A images with a crossing swath (Data Take 37A and 32-33).

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