Correlation of Radial Profiles Extracted from Automatic Detected Circular Features, in the Search for Impact Structure Candidates

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1. Introduction

Impact cratering is a common geological process in the Solar System and most planetary bodies display geomorphologies strongly influenced by impacts (Lowman 1997). Fresh impact craters are normally characterized by a circular morphology (Melosh 1989). This surface expression is modified on Earth by active geological processes. The variation of terrestrial impact structure expressions suggests a simple characteristic to use in automatic detection, usually the circular shape. Automatic techniques may detect candidates in regional data, but field and laboratory analysis are required to possibly confirm an impact origin by finding shock metamorphic effects or traces of meteorites (Koeberl 2004).

A first approach to detect candidates was conducted comparing typical impact crater morphologies and topography (Krøgli et al. 2007). Size-dependency scaling characteristics, e.g. relations of crater diameter, crater floor diameter and crater depth, have been established for heavily cratered areas like the Moon (Pike 1977). On Earth the catalog presently consists of 176 proven impact structures (Earth Impact Database 2009). Despite the low number, size-dependencies have also been established for terrestrial impact structures (e.g. Grieve and Pesonen 1992). To search crater-like circular depressions Krøgli et al. (2007) calculated correlations between circular templates, based on terrestrial and lunar size relations, and digital elevation models.

The geophysical properties of impacted target areas may also change during impact and can be found as anomalies in e.g. gravity and magnetic potential field data. Fracturing and brecciation of target rocks and the presence of low-density sedimentary infill cause a circular gravity low, while a central uplift of heavier rocks from deeper crustal levels may cause a circular gravity high (e.g. Grieve and Pilkington 1996). There has not been found a one to one relationship between shapes of magnetic anomalies and impact structures, but circularity may often be present (French 1998). An algorithm that detects circular orientations of slope values has been constructed to search impact structure candidates, treating regional gravity and aeromagnetic data as surface models. The algorithm, that also works on DEMs, examines only the outline of possible circular features.

Both methods (template matching and circular oriented slope values) detected features with different degrees of circularity. The number of detected features depends on the choice of threshold, but is usually large and requires further manual or automatic analysis to refine the number before field investigations. Results can be compared to maps of e.g. geology and drainage patterns and to additional methods and data (e.g. multispectral images). An approach to reduce the number of candidates is presented here as a filter technique, removing candidates from symmetry measurements.

2. Symmetry in Circular Features

The symmetry measurements are based on correlation coefficients between radial profiles in automatic detected circular features. For each circular feature the algorithm extracts eight profiles from the DEM or geophysical surface, radiating from centre to the length of the radius. These profiles are placed in a matrix consisting of a number of columns equal to the number of profiles (default eight) and a number of rows equal to the number of pixels in profiles (depending on radius). First only a part of the matrix, the first three pixels of each profile, is included in the correlation coefficient calculations. When counting pixels the first pixel of a profile is on the circular outline and the next pixel one step towards centre, and so on. A profile is marked if it does not correlate with any of the other profiles. The matrix then includes the pixels on the next step towards centre. Again a correlation coefficient calculation between profiles is performed, this time without marked profiles. This continues until all profiles are marked (no more correlation) or the end of profiles is reached (Fig. 1). Two profiles may then go the whole distance to the centre, even if situated at opposite sides. The percentage of pixels included in correlated profiles compared to total number of pixels in profiles is saved.

3. Results and Discussion

Fig. 2 displays the effect of symmetry filtering on automatic detected circular features. The reasoning behind equalizing two features having similar total profile distances is to keep features that have few but long correlation profiles, e.g. in just a corner or half of the circle. They may represent impact structures where only parts of the earlier circularity is present. Opposite, one could include a weight in order to reward if all the eight profiles are correlated a distance. The latter may exclude valleys, where two opposite ridges may have some of the characteristics of a partly circular feature. In the presented algorithm the profiles are extended from the rim an inwards, calculating correlation coefficients for each step, leaving out non-correlating profiles. This emphasizes the rim area and downgrades the middle area, which may be promising in an impact structure candidate detection. Initiating the calculations with a minor number of pixels could miss out profiles that would correlate at a later stage, if more pixels had been included. A future filter value might be calculated incorporating correlation results of profiles starting both from the outline and from the centre, or even including complete profiles. The choice of eight profiles, always with the same profile configuration, influence results. It is the profile shapes that are correlated, indicating that the profiles might be located at different elevations. Fig. 2 displays that the filter reduce the number of automatic detected impact structure candidate sites based on non-symmetrical characteristics.

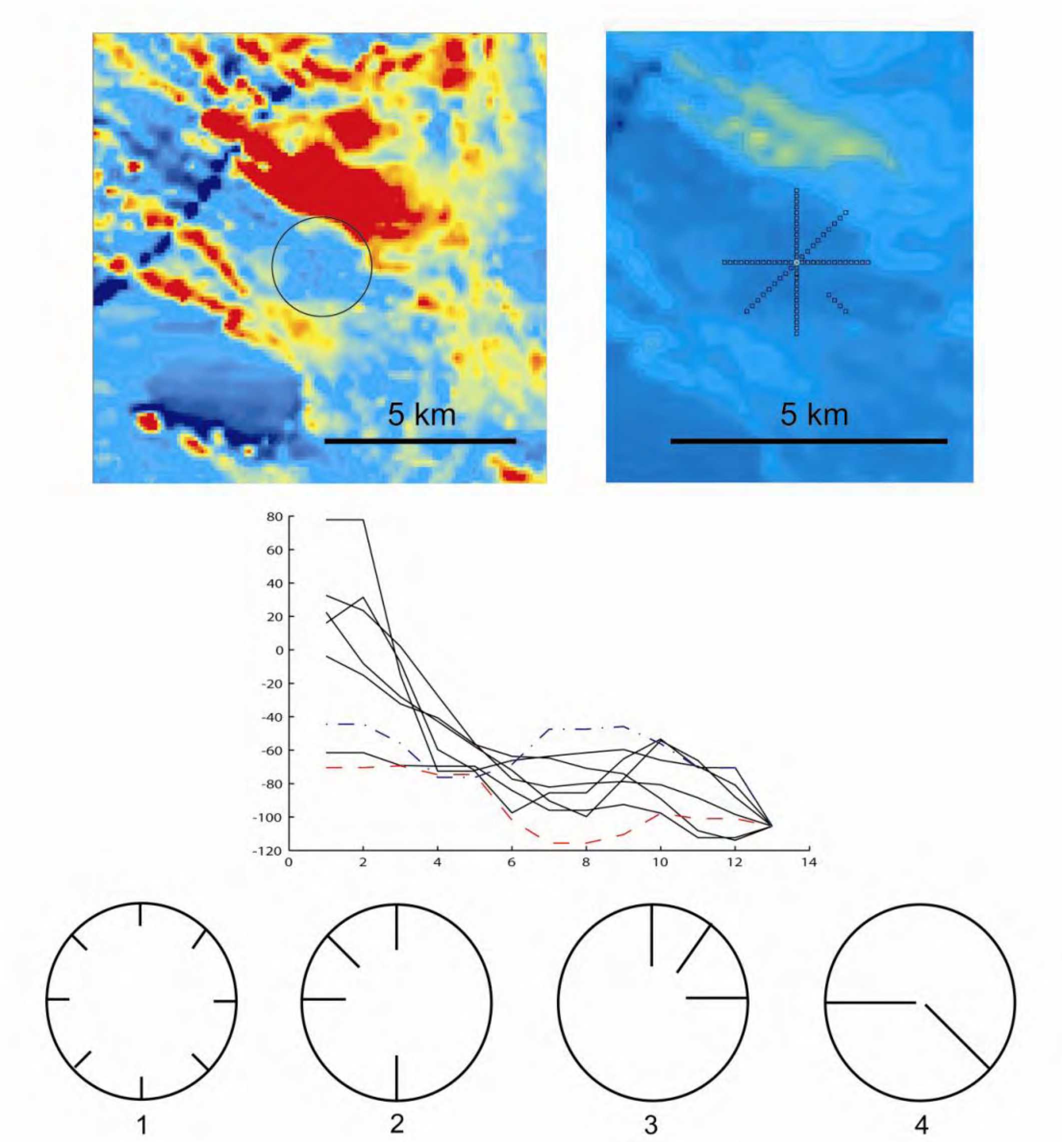

Figure 1. (Above left) Automatic detected circular feature in aeromagnetic potential field data (100 m spatial resolution, Finnmark, northern Norway). (Above right) Length of profile correlations for feature on left image. Correlation threshold 80%. Six profiles correlate the whole distance. The north-west profile does not correlate with any other. There is a gap in the circular border at that place. The south-east profile stops correlating after a while. (Middle) The eight profiles. The dashed (red) profile is the one not correlating with the others, while the dash-dotted (blue) profile stopped correlating at step 5. The y-axis is exaggerated. (Below) Four circles that display equal total profile correlation distances. If a few profiles correlate a longer distance, e.g. in a quarter of the circle (#3), it will get the same value as if all profiles correlate a smaller distance (#1). Fig. 1 is marked in Fig. 2d.

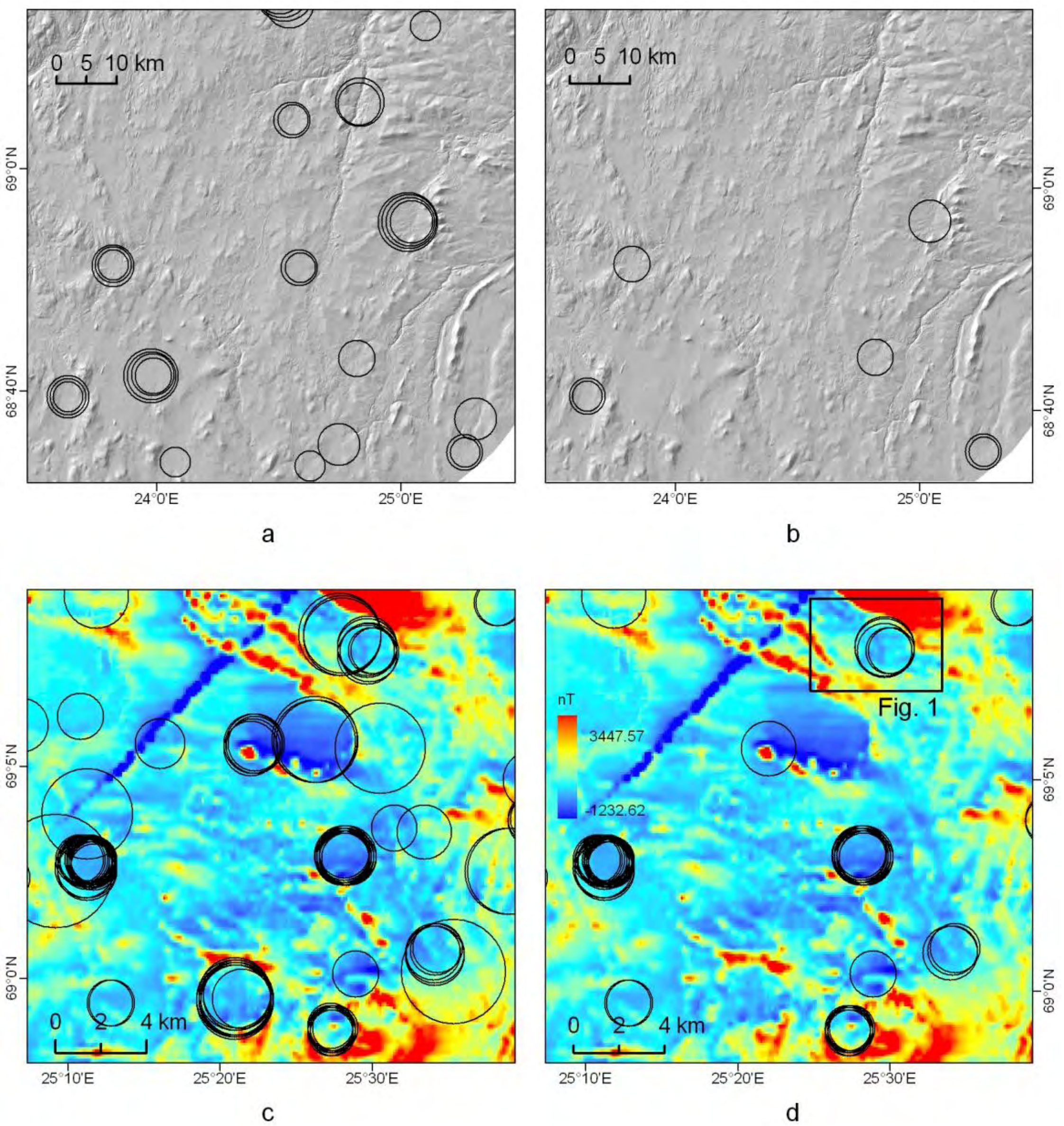

Figure 2. Figures (b) and (d) display features with a symmetry value higher than 75%, and are the filtered results of the automatic detected circular features in (a) and (c). The circular features are found by the methods of template matching on a DEM (a) and the circular outline algorithm on aeromagnetic data (c). (a) and (c) display two different areas of Finnmark, northern Norway. Both models have a spatial resolution of 100 m. The location of Fig. 1 is shown in (d).

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