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Pre-Processing of Planetary Image Data for Photometric Model Creation by Spatial Context Functions

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Abstract

Images of planetary surfaces are influenced by the distribution of topographic features on scales ranging from well resolved objects down to microscopic structures. To account for these a photometric correction is usually applied based on topographic and photometric models. However, fine structures near the spatial resolution limit are the cause for systematic errors of the photometric correction. We propose a class of methods which account for these by the determination of functions which characterize these influences and lead to statistically cleaned input data for the subsequent standard photometric modeling and correction.

1. Introduction

Exact identification of parameters like geometric albedo, or roughness, which enable a consistent and meaningful analysis of spatially resolved data is essential in planetary science, in particular for atmosphere-less bodies. The models are based on the assumption of reliable information of the incidence and emission angle and the weights of the contribution to the whole photometric data set. The weights are frequently treated statistically, in particular assuming a uniform distribution of albedo and surface roughness. However in general, systematic effects are present, which are caused by structures like ejecta blankets, impact craters or rocks on the surface whose characteristic shape deviate from the assumption of uniformity. Consequently problems will arise, if the parameters of the photometric analysis are related to the composition of the surface material, or if they are used in a predictive way for extrapolation beyond the range of observed phase angles.

2. Spatial Context Functions

In the case of impact craters of different sizes it is obvious that their characteristic shape, slopes and associated shadows change the phase curve derived for a specific surface region in a systematic way. Other topographic features, such as linear rift structures show a different scaling behavior. On the output side, the accuracy of derived parameters will reflect the structures associated with the input data and those of the chosen model. Our test calculations demonstrate the sensitivity of parameters assuming isotropy such as the roughness.

While being identifiable at large scales, the influence of such features requires a specific analysis at scales near or below the limit of spatial resolution. The characteristic behavior can be described by an ample variety of mathematical tools. These methods are termed as spatial context functions. Usually the amount and accuracy of photometric input data will impact on the best choice of the type of such functions such as algebraic, geometric, statistical etc. The representations of the functions may be histograms or analytical expressions like trigonometric series.

For illustration of their relationship to photometric parameters, some applications of spatial context functions for input improvement of photometric models and their significance will be shown. The first one explores the topographic structures by comparing the pixels of maximum brightness gradients and their mutual spatial distances. This is an extension of an approach described by Belongie et al. [1]. This way craters or linear structures can be characterized independent of their individual size, if a self-similar (fractal) scaling is assumed. A second example is the evaluation of the interaction of shadows casted by objects of different shape under various illumination conditions and different size distributions [2].

Obviously a crucial issue is the behavior at different scales. The phase curve is quite sensitive to erroneous determinations of the illumination geometry: If the integrated effect of slopes of craters change the distribution of the average incidence angles, its level and slope will be systematically in error. Successive averaging of the photometric data will help to identify the correct scaling behavior at least down to the resolution limit.

Regarding individually specified pixels the result of an analysis by spatial context functions is meaningless. However if applied in a statistical way, for example, by increasing the values of a specific fraction of the pixels of a sufficiently large selected area according to a derived distribution, the accuracy of the integral of the photometric input data will be improved. So this seemingly manipulative process is not a corruption of the information as long as it is identifiable and no conclusions based on individual pixels are drawn. On the other hand, photometric parameters always describe the properties of some integrated area. If systematic influences have been removed by the proposed method, formal error statements of derived photometric parameters become more reliable.

Once the local photometric parameters have been determined, a local characterization is ready for a test with its neighbors. Roughness properties associated with down-slope motion, for example, may have different signatures in different geologic units which are less conspicuous or represented by other observables there. This may require other modeling details. But in general it is another way for verifying the significance of this new correction process. Our intention is to apply this method for the data returned from the Dawn mission to Vesta and Ceres.

3. Summary and Conclusions

An improvement of input data for photometric modeling on a statistical basis may be feasible by the application of spatial context functions selected in accordance with the specific topography. Since the proposed method is closely related to error analysis, the identification and determination of statistical and systematic errors has to be handled with enhanced care.

References

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