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Mathematical vector framework for gravity-specific land surface curvatures calculation from triangulated irregular networks

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Land surface curvature (LSC) is a basic attribute of topography and influences local effects of gravitational energy and surface material transport. However, the calculation of LSCs based on triangulated irregular networks (TINs) has not been fully studied, which restricts further geoscience studies based on TIN digital elevation models (DEMs). The triangular facets and vertices of a TIN are both expressions of the land surface; therefore, based on their adjacency relationship, the LSCs can be calculated. In this study, we propose a mathematical vector framework to enhance LSC system theory. In this framework, LSC can be calculated based on both triangular facets and vertices, and the selection of weighting methods in the framework is flexible. We use the concept of the curvature tensor to interpret and calculate the commonly used LSC, which provides a new perspective in geoscience research. We also investigate the capacity of the TIN-based method to perform LSCs calculations and compare it with grid-based methods. Based on a mathematically simulated surface, we reach the following conclusions. First, the TIN-based method has similar effects on the scale to the grid-based methods of EVANS and ZEVENBERGEN. Second, the TIN-based method is less error sensitive than the grid-based methods by the EVANS and ZEVENBERGEN polynomials for the high error DEMs. Third, the shape of the TIN triangles exerts a great influence on the LSCs calculation, which means that the accuracy of LSCs calculation can be further improved with the optimized TIN but will be discontinuous. Based on three real landforms with different data sources, we discuss the possible applications of the TIN-based method, e.g., the classification of land surface concavity–convexity and hillslope units. We find that the TIN-based method can produce visually better classification results than the grid-based method. This qualitative comparison reflects the potential of using TINs in multiscale geoscience research and the capacity of the proposed TIN-based LSC calculation methods. Our proposed mathematical vector framework for LSCs calculations from TINs is a preliminary approach to mitigate the multiple-scale problem in geoscience. In addition, this research integrates mathematical vector and geographic theories and provides an important reference for geoscience research.