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Comprhensive Approach to the Analysis of the 3D Kinematics Deformation with appliction to the Kenai Peninsula

Research Article

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Abstract:
The problem of analyzing surface deformation of the Earth's crust in three-dimensions is discussed. The isoparametric and Lagrangian formulations of deformation are extended from 2D to 3D. Analytical and numerical investigation of problem conditioning proves that analyzing the 3D kinematics of deformation can be an ill-posed problem. The required mathematical elements for solving this problem, including sensitivity analysis of the deformation tensor and regularization, are proposed. Regularized deformation tensors were computed using the method of truncated singular value decomposition (TSVD). The optimal regularization parameter was attained by minimizing regularization errors. Regularization errors were assessed using the corresponding 2D results of deformation analysis. The proposed methods were applied to the GPS network in the Kenai Peninsula, south-central Alaska, in order to compute the 3D pattern of postseismic crustal deformation in this area. Computed deformation in the vertical direction is compared to the existing pattern of vertical deformation obtained from the combination of precise leveling, gravity and GPS measurements from other studies on this area.

Keywords:
Deformation analysis • sensitivity analysis • principal component analysis • regularization • truncated singular value decomposition (TSVD) • GPS deformation

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1. Introduction

According to Berber et al. (2003), the earliest known publication on the application of geodetic techniques to the analysis of the deformation of the Earth's surface is Terada and Miyabe (1929). They use strain analysis for describing seismic surface deformation. Since then, repeated geodetic observations have been used to derive displacement fields and to analyze geodynamical phenomena. A variety of methods have been developed and proposed. Characteristic features of the geometric geodetic analysis of deformation have also been explored (Frank 1966; Welsch 1979; Bibby 1982; Chen 1991; Altiner 1999; Krumm and Grafarend 2002, Dermanis and Grafarend, 1981; Xu, 1995, 1997; Xu et al., 2000).

For geodetic networks without a connection to an external reference frame, free network adjustment are widely used to derive deformation parameters. It is now commonly accepted that absolute displacements cannot be uniquely determined unless the geodetic network is tied to an external reference frame (Segall and Matthews, 1988; Xu, 1997; Xu et al., 2000). The invariance of strain parameters have also been thoroughly analyzed (Dermanis, 1981, 1985; Dermanis and Grafarend, 1992; Grafarend, 1992; Biby, 1982; Lambeck, 1988 and Xu, 1994, 1995, 2000). It is also commonly accepted that components of the strain tensor are not all invariant and therefore cannot be uniquely determined. Xu et al., (2000) mathematically investigated the invariance of the deformation

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