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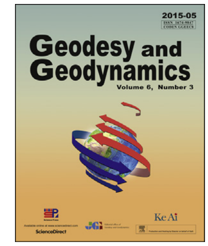

Influences of crustal thickening in the Tibetan Plateau on loading modeling and inversion associated with water storage variation

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ABSTRACT

We use the average crustal structure of the CRUST1.0 model for the Tibetan Plateau to establish a realistic earth model termed as TC1P, and data from the Global Land Data Assimilation System (GLDAS) hydrology model and Gravity Recovery and Climate Experiment (GRACE) data, to generate the hydrology signals assumed in this study. Modeling of surface radial displacements and gravity variation is performed using both TC1P and the global Preliminary Reference Earth Model (PREM). Furthermore, inversions of the hydrology signals based on simulated Global Positioning System (GPS) and GRACE data are performed using PREM. Results show that crust in TC1P is harder and softer than that in PREM above and below a depth of 15 km, respectively, causing larger differences in the computed load Love numbers and loading Green's functions. When annual hydrology signals are assumed, the differences of the radial displacements are found to be as large as approximately 0.6 mm for the truncated degree of 180; while for hydrology-trend signals the differences are very small. When annual hydrology signals and the trends are assumed, the differences in the surface gravity variation are very small. It is considered that TC1P can be used to efficiently remove the hydrological effects on the monitoring of crustal movement. It was also found that when PREM is used inappropriately, the inversion of the hydrology signals from simulated annual GPS signals can only recover approximately 88.0% of the annual hydrology signals for the truncated degree of 180, and the inversion of hydrology signals from the simulated trend GPS signals can recover approximately 92.5% for the truncated degree of 90. However, when using the simulated GRACE data, it is possible to recover almost 100%. Therefore, in future, the TC1P model can be used in the inversions of

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hydrology signals based on GPS network data. PREM is also valid for use with inversions of hydrology signals from GRACE data at resolutions of approximately 220 km and larger.

1. Introduction

A new interdisciplinary research field that combines hydrology and geodesy (referred to here as hydro-geodesy) is emerging because of the innovative application of space-borne gravimetry and Global Positioning System (GPS) techniques to enable the monitoring of near-surface water storage variation and their trends [1,2]. This new approach has considerable advantages over that of the more traditional approach, which uses micro-wave remote sensing, because it enables continuous measurements for the total amounts of regional or global water storage variations on both the Earth's surface and in deeper aquifers. Furthermore, the measurements can be performed in all weather conditions.

Hydro-geodesy measures the hydrology signals via inversion using observed gravity variation and surface radial displacements, with the assumption that the Earth's structure and material properties are well known [1,3]. It is therefore possible that use of an inappropriate earth model or the selection of inappropriate parameters could cause a bias in the inverted hydrology signals [4].

According to a newly released crustal model (CRUST1.0) [5], the Tibetan Plateau has an average crustal thickness of 65 km, and a maximum thickness of 80 km. Furthermore, the laterally averaged densities and P-wave and S-wave velocities within the top 65 km greatly deviate from those in the commonly used Preliminary Reference Earth Model (PREM) [6] (Fig. 1). It is therefore considered necessary to investigate the effects of earth model parameters on the estimated hydrology signals on the Tibetan Plateau [4].

Wang et al. [4] investigated the effects of crustal differences on the inversion of water trend rates on the Tibetan Plateau using the simulated Gravity Recovery And Climate Experiment (GRACE) and GPS data. They found that the effects of crustal differences on the inversion of hydrological trends were negligible when using simulated GRACE data, but were very prominent when using simulated GPS data. Note that the assumed hydrological trends were derived from the WaterGAP Global Hydrology Model (WGHM) [7], which considered major hydrological processes occurring between August 2002 and March 2011. However, it is now doubtful that the WGHM could reflect long term trends of water storage variation because unlike in North America and Scandinavia [1], surface hydrology observations are sparsely distributed in the Tibetan Plateau. For example, the WGHM interpreted larger trends of water level rises in the west and central Himalayan Mountain range, which may not be accurate [4]. Therefore, the Global Land Data Assimilation System (GLDAS) model [8] is used in this study, even though it does not include groundwater [1]. Jia et al. [9] investigated how radial displacements that are induced by the hydrological trends inverted from GRACE data (from 2003 to 2012), may be affected when using CRUST2.0 [10] instead of PREM to describe the average crustal structure in mainland China, with differences as large as 4% in mainland China, and 10% in the Tibetan Plateau.

In this study, we implement an extensive investigation with the aim of first gaining an understanding of the sensitivity of GPS-inferred surface radial displacements and surface gravity variation from terrestrial gravimetry on crustal structures. It is considered that this knowledge could then be used to correct for hydrology effects in the observed crustal movement and gravity variation [11,12]. And we describe the differences between the two selected earth models, TC1P and PREM; analyse the loading effects derived from the two earth models. Also, the effects of the earth model selection on the inversion of hydrology signals are presented. We aim to discern to what extent the crustal structure impacts the inversion of hydrologic signals as seen by the GLDAS hydrology model [8], and also the hydrological trend seen by GRACE.

2. Earth models and assumed hydrology signals

In this section, we compare the parameters of the two earth models used, their load Love numbers (through which

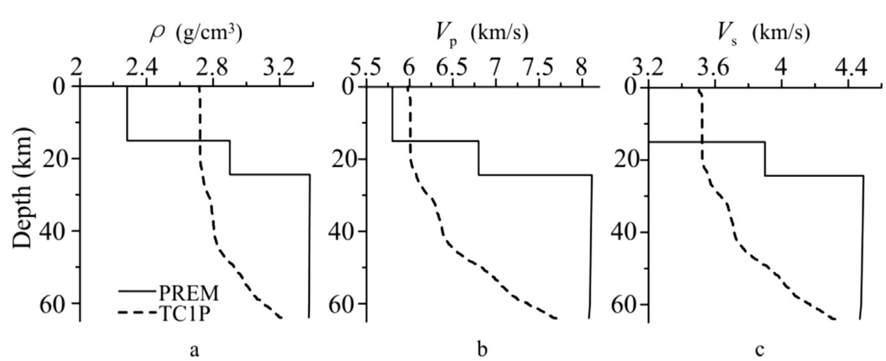

Fig. 1 – Comparisons of density and velocity profiles from surface to a depth of 65 km between the realistic TC1P model for the Tibetan Plateau and the global model PREM. ρ is density, and V_p and V_s are P-wave and S-wave velocities.