An Analysis of Mechanical Constraints when Using Superconducting Gravimeters for Far-Field Pre-Seismic Anomaly Detection

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ABSTRACT

Pre-seismic gravity anomalies from records obtained at a 1 Hz sampling rate from superconducting gravimeters (SG) around East Asia are analyzed. A comparison of gravity anomalies to the source parameters of associated earthquakes shows that the detection of pre-seismic gravity anomalies is constrained by several mechanical conditions of the seismic fault plane. The constraints of the far-field pre-seismic gravity amplitude perturbation were examined and the critical spatial relationship between the SG station and the epicenter precursory signal for detection was determined. The results show that: (1) the pre-seismic amplitude perturbation of gravity is inversely proportional to distance; (2) the transfer path from the epicenter to the SG station that crosses a tectonic boundary has a relatively low pre-seismic gravity anomaly amplitude; (3) the pre-seismic gravity perturbation amplitude is also affected by the attitude between the location of an SG station and the strike of the ruptured fault plane. The removal of typhoon effects and the selection of SG stations within a certain intersection angle to the strike of the fault plane are essential for obtaining reliable pre-seismic gravity anomaly results.

Key words: Earthquake, Pre-seismic gravity anomaly, Superconducting gravimeter


1. INTRODUCTION

A superconducting gravimeter (SG) is a spring-type gravimeter that is used for long-term gravity observation. The mechanical spring is replaced by a magnetically levitated superconducting sphere (Goodkind 1999). The voltage signals indicate the sphere’s displacement from its null position, which is proportional to the gravity. Calibration is performed using parallel observations of an absolute gravimeter and the SG.

SGs are the most sensitive and stable instruments for gravity measurement (Iwano and Fukuda 2004). A 1 nano-Gal sensitivity and a 1 Hz sampling rate make SGs very useful for detecting internal gravity waves inside the earth, and thus for determining the influence of environmental effects on gravity (Ikeda et al. 2005). A series of co-seismic gravity perturbations were detected and analyzed using SGs to demonstrate their sensitivity, with results compared with those obtained by seismometers (Imanishi et al. 2004; Hwang et al. 2009; Kim et al. 2009; Nawa et al. 2009). The gravity signal of an SG is influenced by many natural events, including free oscillations of the Earth after a strong earthquake (Virtanen 1996; Park et al. 2005; Arora et al. 2008), seismic background noise (Virtanen 1998), the gravity effects of hydrological phenomena (Virtanen 2000, 2001), and variation in atmospheric mass (Virtanen and Mäkinen 2003; Virtanen 2004). SGs are suitable for long-term background gravity observation with fully automatic recording and data handling to reduce possible human error. For Global Positioning System (GPS) continuous tracking stations, long-time series of gravity readings are needed for outlier rejection to obtain more consistent analyses (Yang et al. 2007).

The search for earthquake precursors has been carried out for years. Studies have claimed that the ionosphere might be disturbed before strong earthquakes (Chuo et al. 2002; Liu et al. 2001, 2009; Zhao et al. 2009). Some studies suggested that pre-seismic surface vertical deformation detectable using InSAR may be linked to strong earthquakes (Shan et al. 2009). An amplitude increase and a phase-delay

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