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Using the informational Fisher–Shannon method to investigate the influence of long-term deformation processes on geoelectrical signals: An example from the Taiwan orogeny

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HIGHLIGHTS

- Time dynamics of geoelectrical signals could be linked with deformation processes.
- Three sites in Taiwan with different amounts of crustal deformation are investigated.
- The three sites are discriminated by using the Fisher–Shannon method.
- The differential strain intensity is correlated with the Fisher–Shannon quantities.

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ABSTRACT

The time dynamics of geoelectrical signals measured at three sites in Taiwan were investigated by using the Fisher–Shannon method in order to investigate the possible correlation between their properties with deformation processes. The three sites are located along an almost perpendicular direction to the orogenic collision zone where each site experiences different amounts of crustal deformation. Our findings point out to a clear discrimination of the three sites on the basis of the informational properties of the recorded geoelectrical signals. In particular a relationship is found between the differential strain intensity of the sites where the geoelectrical stations are located and the Fisher–Shannon quantities.

1. Introduction

The plate configuration near Taiwan is characterized by the oblique convergence of two plates, namely the Philippines Sea Plate (PSP) and the Eurasian Plate (EUP) at a rate of 8 cm/year in a direction of N310E [1] (Fig. 1). The Taiwan orogeny is the direct consequence of this convergence expressed by the collision of the Luzon volcanic arc in the PSP and the Chinese continental margin in the EUP which began 3–6 Ma [2–4]. This collision results in high crustal deformation and seismicity rates which are most intense along the eastern part of the island and progressively dissipate once one moves towards the

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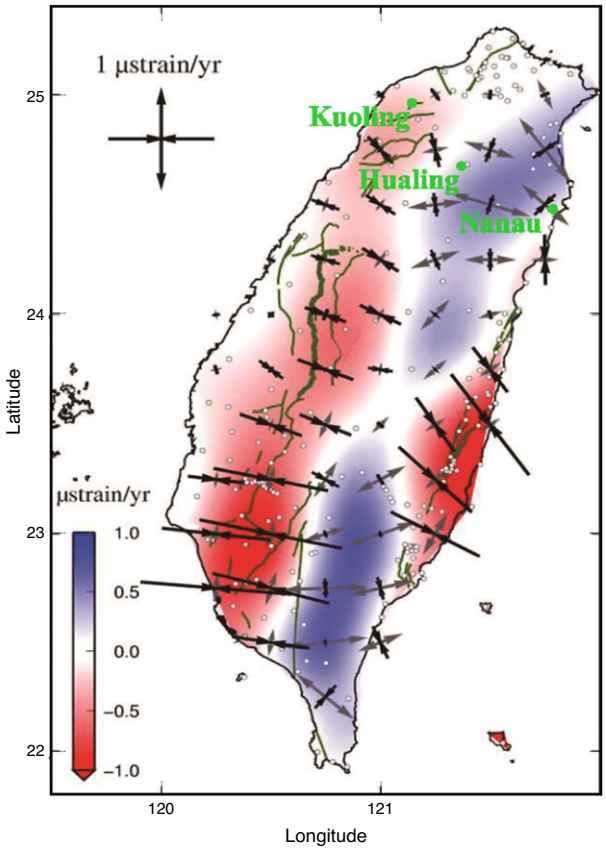

Fig. 1. Map of geoelectrical stations with strain rate field of Taiwan from GPS data between 1993 and 1999 (after Hsu 2009).

west. Present day deformation in Taiwan has been studied using both campaign and continuous GPS data augmented by geological observations [1,5–7] leading to a relatively detailed mapping of the stress/strain field.

Geoelectrical prospecting has long been used in geophysics for tectonic (e.g., faults) and environmental (e.g., in mapping waste disposal areas) applications by means of locating structures that exhibit anomalous electrical conductivities [8–10]. A more controversial application is the identification of anomalous patterns in geoelectrical signals prior to the occurrence of large earthquakes [48,11–19]. These patterns are thought to result from the deformation of the rock during the nucleation stage of the earthquake [45,20,21], thus it has been argued that they could be used as a short-term precursor [22–28]. If these short-term deformation variations are indeed reflected in the properties of geoelectrical signals, then this poses the question of whether longer term deformation variations have any influence on their properties as well.

Vallianatos and Tzanis [48] already investigated the proportionality between the electric field and the deformation rate. Our study extends such idea by elucidating the informational properties of geoelectrical signals recorded for a period of six months at three sites that span the deformation front of the Taiwan orogeny (Fig. 1). First, we give an overview of the data recording and their spectral characteristics. Then we proceed with the application of two methodologies, namely the Fisher Information Measure (FIM) and the Shannon Entropy that can provide information about the degree of order in observational data. Finally, the results along with the discussion follow.

2. Data

We measured the continuous self-potential (SP) data with 15 Hz sampling rate and GPS time correction at three sites across northern Taiwan from May to November 2012 (Fig. 1). These sites form a profile along a NW–SE direction where the crustal deformation varies in intensity and gradually switches from extensional in the area of the Ilan plain to compressional along the NW coastal plain of Taiwan [7]. The SP measurements at each site were the potential difference of two dipoles in North–South and East–West directions with length 1.89 and 3.57 km in Kuoling (Coastal Plain), 4.29 and 1.83 km in Hualing (Central Range), and 0.99 and 1.93 km in Nanau (south of Ilan plain). The daily fluctuations of NS and WE direction at Kuoling were 11.4 and 20.7, at Hualing were 147.3, 121.5 and Nanau were 30.5 and 43.1 mV/km. Those non-polarized electrodes ($Pb/PbCl_2$) were buried at 1 m depth and connected with the local telephone cable to each recording office. Then, the SP signals were converted to electric field and the minute averages were calculated (Fig. 2). In order to study the frequency