

# Spatiotemporal slip distribution around the Japanese Islands deduced from Geodetic Data

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## Abstract

Recent development of the continuous GPS network has extended the possibility for data assimilation in earthquake simulations. Precise daily station coordinates are analyzed to estimate the spatiotemporal slip distribution of a silent event in Boso Peninsula, Japan, providing important constraints on the modeling of such an event. Traditional leveling data are also analyzed to estimate slip distribution during a complete earthquake cycle by applying viscoelastic response functions. Kinematic conditions on plate interfaces can be deduced by means of geodetic inversion, but mechanical interpretation of the kinematic results is not straightforward and requires thoughtful consideration.

## Introduction

The physical processes involved in earthquake generation are highly complex and nonlinear. Therefore in order to simulate earthquake phenomena, especially for the purpose of prediction or forecast, it is crucial to incorporate observational information. Simulation programs need to be able to use observational data in real time. Data assimilation techniques are applied for this purpose. The major objectives of data assimilation are not only to give quantitative constraints on model parameters, but also to remove erroneous observations. Data assimilation techniques have been developed in the field of meteorology and oceanography, where 4-dimensional quasi-real time data is used. In earthquake studies, we are trying to develop an analogue of the weather forecasting system based on a physical model of the earthquake generation cycle and real time observations.

## Geodetic data assimilation

In earthquake cycle simulations, several kinds of observational data can be assimilated. Seismic data covers almost all of the regions of interest with high accuracy. This data is very important because seismic data is considered to be closely associated with changes in stress. A problem with seismic data is that it is highly dependent on regional effects and the related physical process is not well understood.

On the other hand, deformation data can be easily interpreted in terms of fault slip by using dislocation theory. Sagiya et al. (2000) presented mathematical formulation of geodetic inversion using viscoelastic response functions.

An important aspect of geodetic data is the recent installation of continuous GPS arrays in many locations around the world. Among the arrays, the Japanese GPS network maintains the largest number of continuous sites and has provided data for many scientific studies (e.g. Heki et al., 1997, Sagiya et al., 2000). Recently, not only the horizontal but also the vertical displacement rate has been reasonably estimated from GPS daily coordinate data (Figure 1). The continuous GPS network makes it possible to monitor deformation and assimilate the data into earthquake simulations in a real time manner.

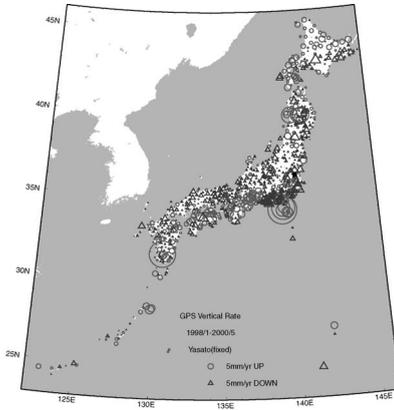


Figure 1: Distribution of vertical displacement rate estimated from GPS daily coordinate data during January 1998 to May 2000. Yasato station (denoted as solid square) is assumed to be fixed.

## Examples of Analysis

As an example of analysis using data assimilation, we discuss a silent earthquake event that occurred in the coastal region of Boso Peninsula, central Japan.

The Boso Peninsula silent earthquake occurred in May 1996. Several GPS stations were displaced to the southeast by up to 20mm in about a week. It is interesting to point out that the onset time of the transient deformation varies among stations, possibly indicating rupture propagation (Figure 2). Using calculations of the daily change in position, the daily evolution of slip distribution was estimated (Figure 3). The estimated silent slip region and previously estimated slip deficit region (Sagiya, 1998) are complementarily distributed. On the other hand, the depth of the estimated silent slip region is 10-20km, which is usually considered to be the depth range of the locked region of the crust. Slip at this depth could indicate lateral heterogeneity of the plate interface. Such a result can be utilized in simulation studies of the physical processes of the silent event.

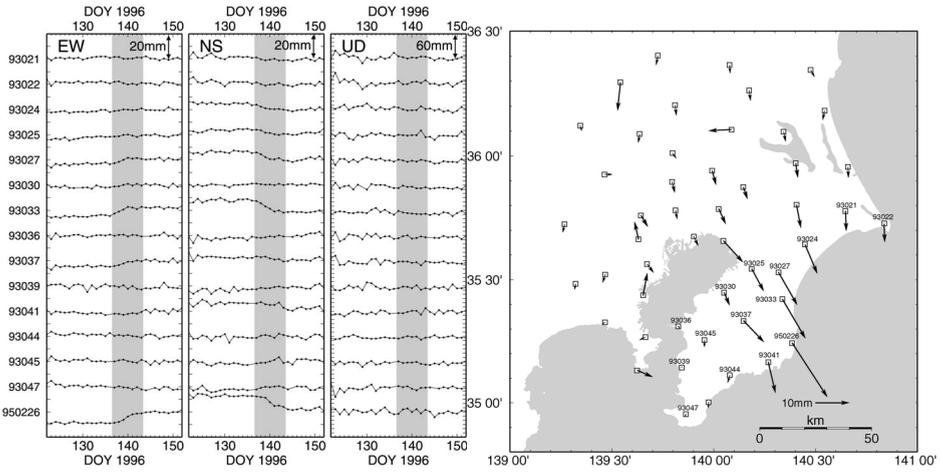


Figure 2: (left) Daily position change of GPS stations. Shaded period indicates the occurrence of the silent event. (right) Total displacement during the slow event

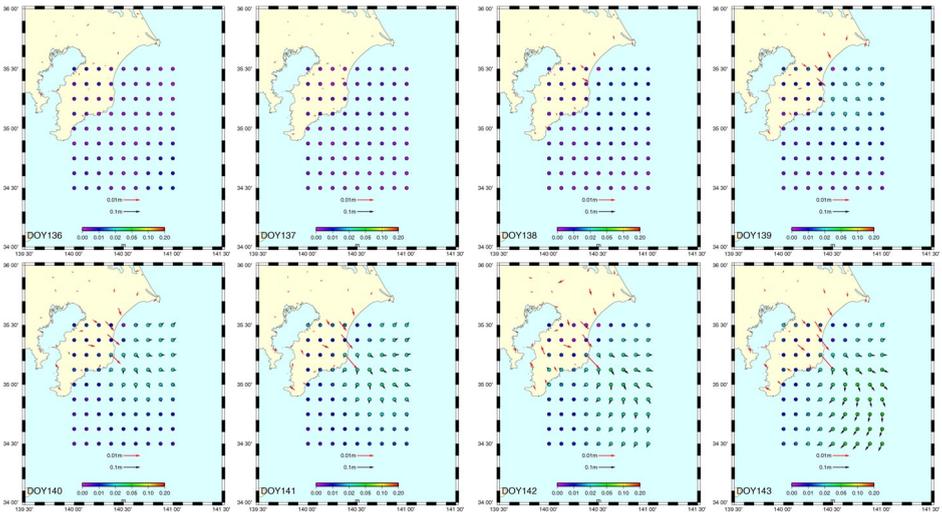


Figure 3: Daily evolution of slip distribution during the silent event.

A second example uses leveling data of the Shikoku Island, which is located landward of the western Nankai Trough. Magnitude eight earthquakes have repeatedly occurred at intervals of about 120 years along the Nankai Trough. Leveling data provides detailed uplift/subsidence patterns almost every ten years, spanning the whole earthquake cycle. By applying viscoelastic response functions we estimated spatiotemporal slip distribution at the plate interface. The present result is still preliminary and a refined result will be discussed in the future.

## Discussion: interpretation of slip distribution

It is worthwhile to point out that the slip distribution estimated from geodetic data gives kinematic constraints but tells nothing about mechanics of the plate interface. The mechanical problem must be treated in simulations where mechanical models are actually incorporated. For example, estimating a significant slip deficit at some location on a plate interface during an interseismic period does not imply that the point is mechanically locked. It is possible that a silent slip event like the one in Boso occurred in the mechanically unlocked area where the slip deficit exists (Figure 4). Such a possibility will be studied using continuous GPS data.

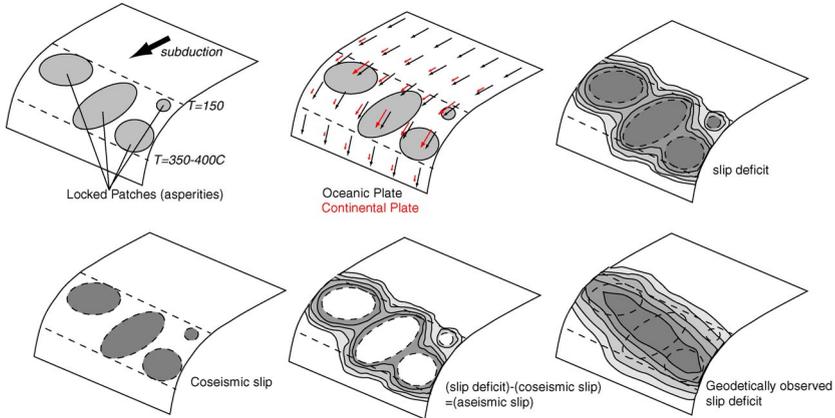


Figure 4 A physical interpretation of the slip deficit and the silent event.

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