Three-dimensional numerical simulation of displacement and stress fields after the 1944 Tonankai and the 1946 Nankai earthquakes

Shoichi Yoshioka

Department of Earth and Planetary Sciences, Faculty of Science, Kyushu University, Fukuoka, Japan (e-mail: yoshioka@geo.kyushu-u.ac.jp, phone: +81-92-642-2646, fax: +81-92-642-2684).

Abstract

I constructed a three-dimensional finite element model to simulate displacement and stress fields after the 1944 Tonankai and the 1946 Nankai earthquakes. They were great interplate earthquakes that occurred most recently at the Nankai subduction zone. Taking the three-dimensional configuration of the subducted Philippine Sea plate into account, I constructed a realistic model with lateral heterogeneity of viscoelastic structure. I assigned a variable slip distribution on the plate boundary obtained from inversion analyses of coseismic geodetic data and interseismic GPS data. In this presentation, the calculated spatio-temporal variations in displacement and stress fields will be discussed in detail, in comparison with postseismic geodetic and seismic data.

Introduction

It is well known that large thrust-type earthquakes have occurred along the Nankai trough with a recurrence interval of 100 and 150 years. The most recent major interplate events were the great 1944 Tonankai (M 8.0) and the 1946 Nankai (M 8.1) earthquakes. Coseismic fault parameters for these events have been proposed by several investigators using seismic waves, aftershock distributions, crustal deformations and tsunami data.

Following these events, spatio-temporal peculiar changes in geodetic and seismic data were observed. To be more concrete, postseismic crustal deformations which persisted for a couple of decades on Shikoku island and Kii peninsula were observed. The vertical deformations are characterized by subsidence in the northern parts of both and uplift in the southern parts of both except slight subsidence around the southernmost parts of both. The observed principal strain field for twenty years following the events indicates the dominance of contraction in the NW-SE to NNW-SSE directions. The spatial distribution of the postseismic crustal deformation is almost opposite that of the observed coseismic one.

The temporal changes in the direction of the compressive stress from N-S to E-W beneath the Kii channel and the eastern part of Shikoku were observed after the two earthquakes. Thirty seven days after the 1944 Tonankai earthquake, the 1945 Mikawa earthquake (M 7.1) occurred 160 km northeast of the source region of the Tonankai event. In 1948, a large unique earthquake (M 7.0) with the focal mechanism of normal faulting occurred near the deeper extension of the fault plane of the 1946 Nankai earthquake which was low-angled thrust faulting. On the other hand, in the Wakayama region, drastic decrease in seismicity was observed just after the 1944 Tonankai earthquake.

In order to elucidate physical mechanisms of the observed postseismic geodetic and seismic data, I constructed a numerical model, employing the three-dimensioned finite element method. The total numbers of the finite elements and nodes used here are 34,980 and 38,556, respectively. The solution for the unknown nodal displacements of 115,668 enables us to reveal detailed and accurate viscoelastic deformations associated with variable slips on the plate boundary. The horizontal distances of the model are 600 km in length and 450 km in width and the region from the earth's surface down to a depth of 150 km is modeled. I modeled the complicated three-dimensional configuration of the upper surface of the subducted Philippine Sea plate, which was estimated from spatial distribution of subcrustal micro-earthquakes. Recently, on the basis of data of bathymetry and thickness of marine sediments in and around the Nankai trough, Yoshioka and Itoh (1995) [1] demonstrated that the elastic thickness of the Philippine Sea plate becomes thinner from Kyushu toward Kii peninsula along the Nankai trough. Based on the result, the thickness of the oceanic plate is assumed to change linearly from 47.5 km at the western boundary to 20 km at the eastern rim of the model space. Recently, Sagiya and Thatcher (1996) [2] obtained coseismic slip distributions of the 1944 and the 1946 events through inversion analysis of geodetic data in Shikoku and Kii peninsula. In our model, I assigned the slip distributions on the plate boundary using the split node technique (Melosh and Raefsky, 1981 [3]), and calculated elastic and viscoelastic responses. Also, inverting recent GPS data for the last two years, Ito et al. (1998) [4] obtained back-slip distributions on the plate boundary. Here, assuming that the distributions have been constant in time since the two great earthquakes, I assigned the distributions on the plate boundary as annual rates of interplate coupling. In the model, the continental lithosphere and the oceanic Philippine Sea plate are assumed to be elastic, while the upper mantle is Maxwell viscoelastic.

Here, I show an example of the calculation. The figure below represents coseismic surface deformations obtained giving the variable coseismic slips of the 1946 Nankai earthquake on the plate boundary. The calculated horizontal and vertical deformations naturally explain well the observed ones.

In this presentation, a variety of calculated spatio-temporal patterns on displacement and stress fields will be demonstrated in detail, in comparison with the observed ones.

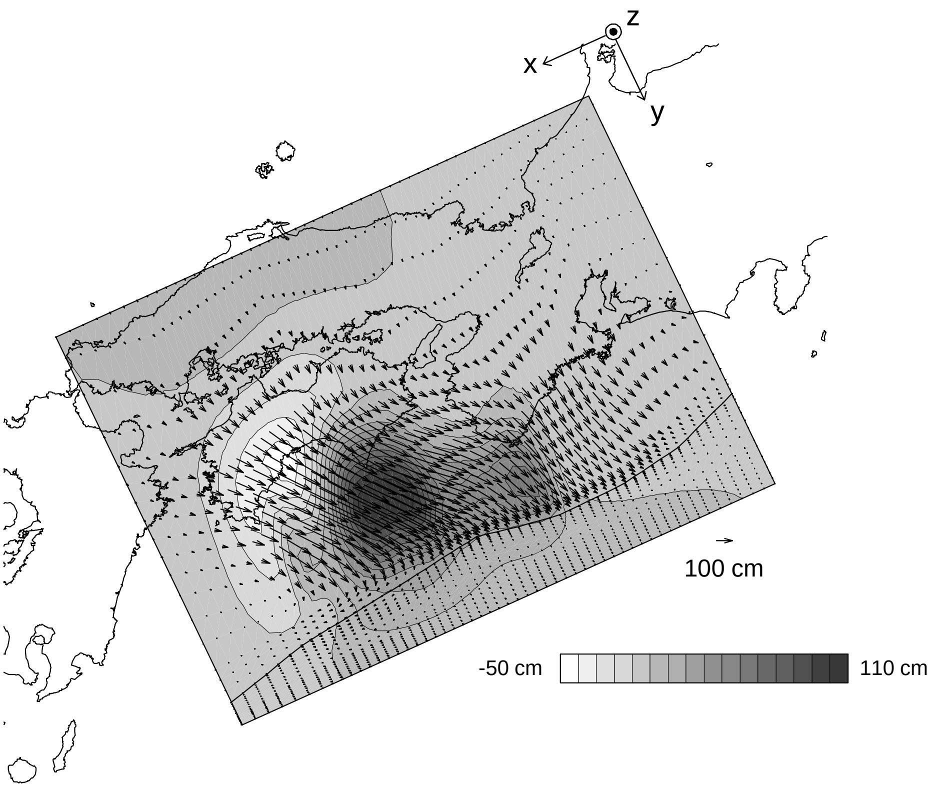

Figure 1: Calculated coseismic surface deformations associated with the 1946 Nankai earthquake. The arrows and the contours represent horizontal and vertical displacements, respectively. The positive and negative values for the vertical displacement correspond to uplift and subsidence, respectively. The contour interval is 10 cm.

References

[1] Yoshioka, S., and Itoh, Y., 1995, *Estimation of Elastic Thickness and Bending Moment of the Philippine Sea Plate along the Nankai Trough,* Abstr. Seismol. Soc. Jpn. **2**, B21 (in Japanese).

[2] Sagiya, T., and Thatcher, W., 1996, *Interseismic Deformation and Coseismic Slip Resolution Along the Nankai Trough, Southwest Japan,* EOS, Transactions, American Geophysical Union, 1996 Fall meeting, **77**, G12B-09.

[3] Melosh, H. J., and Raefsky, A., 1981, *A Simple and Efficient Method for Introducing Faults into Finite Element Computations,* Bull. Seismol. Soc. Am. **71**, 1391-1400.

[4] Ito, T., Yoshioka, S., and Miyazaki, S., 1998, *Interplate coupling in southwest Japan deduced from inversion analysis of GPS data,* submitted to Phys. Earth Planet. Inter.