Detection of seismic geoid changes by the 2004 Sumatra-Andaman earthquake from satellite altimetry

Yutaka Hayashi[1]; Nobuo HAMADA[2]; Tsurane Kuragano[3]; Toshiyuki Sakurai[4]; Hiromi Takayama[5]; Yohei Hasegawa[1]; Kenji Hirata[6]

[1] MRI,JMA; [2] JMA; [3] Office of Marine Prediction, JMA; [4] Climate and Marine Department, JMA; [5] Meteorological Research Institute, Japan Meteor. Agency; [6] JAMSTEC

1. Introduction

The 2004 Sumatra-Andaman earthquake caused the tsunami in the Indian Ocean on December 26. Standard seismological approaches were insufficient for precise knowledge on the main shock, because of some slow slip on a time scale beyond the seismographical band in the northern part of the fault (Ammon et al., 2005).

Although a coseismic geoid change has never been observed, geoid analysis with satellite altimetry data seems to be an inventive non-seismic approach for unraveling the mechanisms of huge earthquakes with slow slip beyond the seismographical band in the time scale. In general, a change in geoid height must be approximately equal to an average change in the sea surface height. It is predicted that a coseismic geoid change caused by an earthquake of magnitude 9 could possibly be detected by satellite altimetry through the change of sea surface height, because such a geoid change would theoretically be expected to reach the order of centimeters (Sun and Okubo, 1994).

2. Change of sea surface height from satellite altimetry

(1) Data

We analyzed sea surface height observed by satellite altimetry from Jason-1 and TOPEX/Poseidon from November 4, 2004 to February 16, 2005 except the day of the tsunami. Five cycles of of both before and after the earthquake are included. Sea surface height data are processes by NASA to eliminate the effects of geoid locality, ocean tides, air pressure, and atmospheric vapor.

(2)Method

We calculate the cange of sea surface heights before and after the earthquake at every sampling point with more than three observation values. Then, averaged change of sea surface heights every 10km from measured distance of -150 km to +300 km normal to the trench are calculated.

(3) Results

We estimated that the peak-to-peak change in sea surface height before and after the 2004 Sumatra-Andaman earthquake was 7+/-2 cm, and the positive peak was located at 70 km east from the Sunda Trench, and the negative one at 110 km. Such changes in sea surface heights were probably related to the coseismic geoid change caused by the Sumatra-Andaman earthquake.

3. Theoretical coseismic geoid change

When calculated with the equations formulated by Sun and Okubo (1994) from long shallow low-angled reverse fault models whose scalar moments were equivalent to that of an Mw = 9.3 earthquake, coseismic geoid changes had the following characteristics.

(a) The geoid change perpendicular to the trench was more significant than the change parallel to it.

(b) One positive peak and one negative peak of the geoid change were found perpendicular to the trench. The positive peak was nearer to the up-dip.

(c) The positive peak of the geoid change perpendicular to the trench was almost directly above the upper edge of the high-slipped area; the negative peak was almost just above the lower edge of the earthquake fault.

(d) The peak-to-peak geoid change reached several centimeters.

4.Conclusion

We concluded that the upper edge of a high-slipped area and the lower edge of the entire slipped area in the earthquake fault plane of the main shock were possibly located approximately 70 km and 110km east of the Sunda Trench.

To confirm our results, we must reanalyze sea surface height data from satellite altimetry over a longer period and compare it with other geodetic findings on the 2004 Sumatra-Andaman earthquake.

Details of our research are described in our submitted paper (Hayashi et al., 2006).

References

Ammon, C.J. et al., 2005, Science, 308, 1133-1139.
Hayashi et al., 2006, EPS, submitted.
Okubo, S., 1994, J.Geod.Soc.Jap., 40, 1-16.(in Japanese with English abstracts)
Sun, W. and Okubo, S., 1998, Geophy.J.Int., 132, 79-88.