AUSGEO news ISSUE 80 December 2005

Australian Government
Geoscience Australia

CRUSTAL DEFORMATION from the SUMATRA–ANDAMAN EARTHQUAKE

Geoscience Australia's analysis of the largest earthquake since the beginning of modern space geodesy.

Minghai Jia

The Global Positioning System (GPS) and a global network of receivers now enable detection of ground motion at the millimetre to centimetre level before, during and after earthquakes.

GPS data from the global network of more than 200 sites is routinely analysed for various research purposes, including the monitoring of global sea level, climate change, and crustal deformation in Southeast Asia, Australia, the South Pacific and Antarctica.

Long-term GPS time series analysis shows that the Australian and Indian plates move towards Sumatra–Andaman at velocities of five centimetres and four centimetres per year, respectively.

To assess the Sumatra–Andaman earthquake, Geoscience Australia used Bernese GPS Processing Software Version 5.0 to analyse data from more than 250 GPS sites, including the 200 global GPS sites and 50 local GPS sites in the region, including sites in Australia, Malaysia, Thailand, Indonesia, the Philippines, China, India and the Maldives.

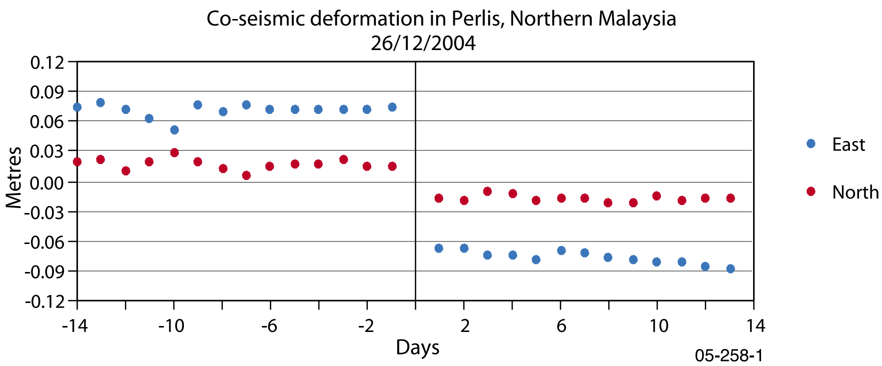
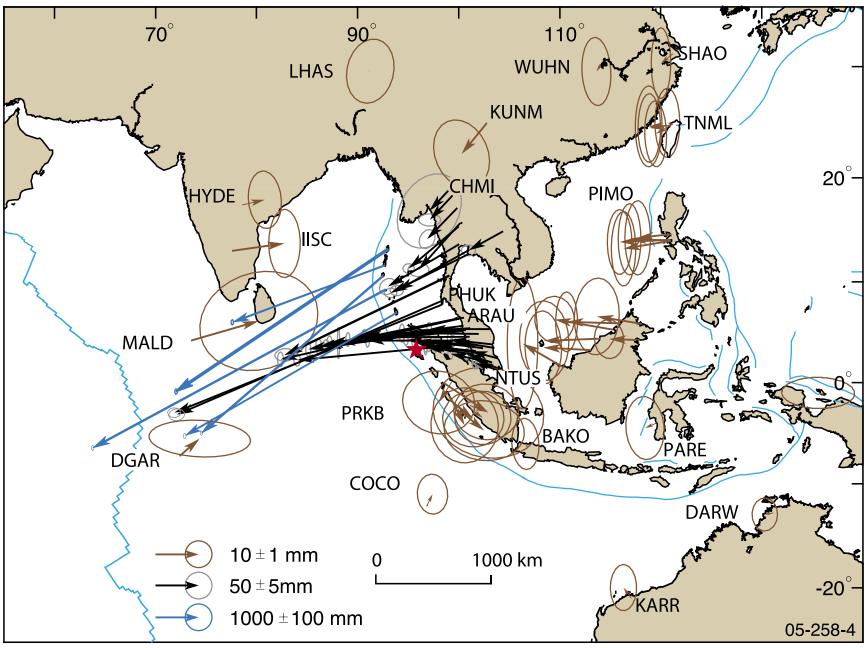


Figure 1. Co-seismic deformation at GPS site ARAU (Perlis, northern Malaysia).



Co-seismic deformation

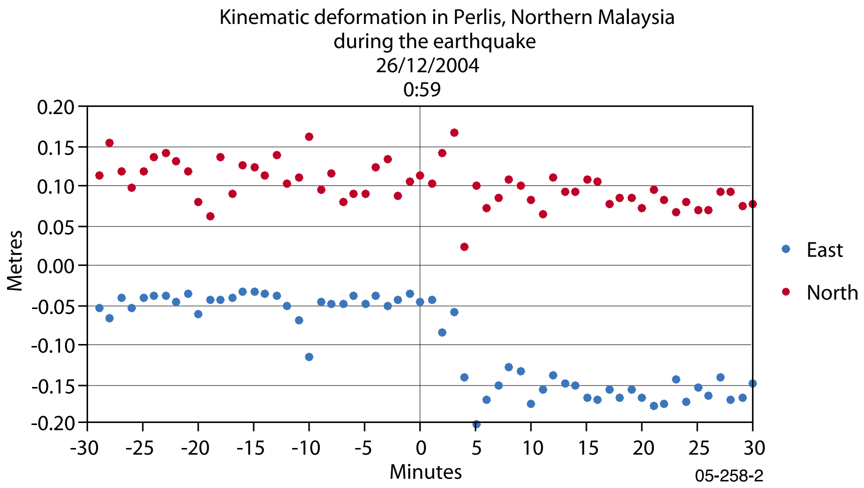
Co-seismic displacements were computed from two combined seven-day solutions—one before and one after the earthquake. Displacements of the sites were calculated as the difference between the two solutions. As an example, Figure 1 shows the co-seismic deformation at GPS site ARAU (Perlis, northern Malaysia). Displacements of 15 centimetres in the east and three centimetres in the north occurred at the site.

The displacement field and error ellipses for all GPS sites in the earthquake region are shown in Figure 2.

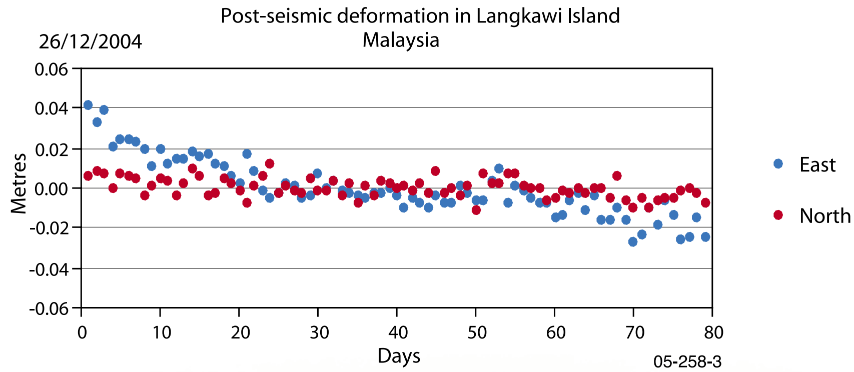
The displacement detected by GPS varies with location. Displacements vary from three to six metres in the Andaman and Nicobar Islands, indicated by the blue arrows. The black arrows show displacements at sites in Thailand, Malaysia and Sumatra. Almost 28 centimetres displacement was detected at GPS site PHUK (Phuket Island, southern Thailand near northern Malaysia), decreasing gradually towards the north and south.

Displacements reduced to two centimetres at the NTUS site (Singapore) and three centimetres at the CHMI site (northern Thailand). Deformation of around 10 millimetres was detected at large distances, indicated by brown arrows. Deformations from these sites, except for sites southeast from the epicentre, were also generally towards the epicentre or the great Sumatra fault, even though they were relatively small compared with their error ellipses.

Figure 2. Displacement field for the earthquake region determined by GPS. The red star represents the epicentre, and the green lines show plate and fault boundaries.



▲ **Figure 3.** Kinematic deformation at GPS site ARAU (Perlis, northern Malaysia) during the earthquake, which occurred at about 0:59 on 26 December 2004.



▲ **Figure 4.** Post-seismic deformation at GPS site LGKW (Langkawi Island, northern Malaysia).

The southeast sites seem not to have been impacted by the earthquake, which implies that the stress along the subduction zone plate interface of southern Sumatra was not released. This is the likely reason for the Simeulue–Nias earthquake on 28 March 2005.

The determination of co-seismic deformation is very useful for further investigation of fault slip models and of other seismic features of the earthquake.

Kinematic deformation

Kinematic coordinate solutions, computed from stations near the earthquake every 30 seconds over 30-minute periods before and after the earthquake (0:59, 26 December 2004), show the progression of the rupture.

Figure 3 shows the kinematic deformation of 10 centimetres at GPS site ARAU. Deformation was detected when the surface waves began to hit the site two minutes after the earthquake; four minutes later, positions at the site were relatively stable again.

Earthquake progressions of this type enable scientists to better understand the fault rupture process. In the near future, the determination of real-time deformation may also benefit tsunami warning systems, such as the Australia Tsunami Warning System, by allowing us to make more reliable assessments of the likelihood of tsunami events.

Post-seismic deformation

Using a long-term GPS time series after the earthquake, we can also examine the post-seismic deformation process. As an example, Figure 4 shows the deformation at GPS site LGKW (Langkawi Island, Malaysia), which declined continuously over time after the earthquake. An eastward deformation of more than six centimetres was determined during the 80-day period after the earthquake.

Such post-seismic deformation information from all available GPS sites in the earthquake region can help scientists analyse likely elastic, poroelastic and viscoelastic deformation, and plastic flow of the Earth's crust in the earthquake region, giving a better understanding of crustal relocation and redistribution after the earthquake.

For further information, phone Minghai Jia on +61 2 6249 9045 (email minghai.jia@ga.gov.au)