The 2004 Sumatra Earthquake as a critical phenomenon and an accelerating seismicity along the Indian-Eurasian plate boundary zone

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Seismic activity in broad area prior to large earthquakes can be seen as fracture phenomena evolving toward a critical point in heterogeneous media due to the interacting stress field. Accelerating cumulative seismic energy release of earthquakes in a broad area can be expressed by a power law time-to-failure relation based on damage mechanics model (Bufe and Varnes, 1993). The log-periodic oscillation driven in case of the heterogeneous structure with hierarchical fault network is added to the power law time-to-failure relation (Sornette & Sammis, 1995; Saleur et al., 1996), which is useful to constrain the final rupture time for the oscillatory fluctuation phenomena of crustal activity approaching critical point. Associated with critical feature of seismicity various investigation and empirical relations have been examined and derived during the last dozen years or so (e.g., Bowman et al., 1998; Jaume & Sykes, 1999; King & Bowman, 2003). In view of this situation, the great Sumatra earthquake of 26 December 2004 with moment magnitude Mw9.3 (Stein & Okal, 2007), the second largest event among the five Mw 9 class events since 1900, is the only great earthquake occurred in low-latitude region in the Indian ocean in recent year. The location and time of the 2004 Sumatra earthquake may be closely linked with crustal activities in a considerably large area and over a long period of time centered on the focal location and the origin time. We examine the critical feature of seismicity prior to the 2004 event based on the Global CMT catalog (Harvard catalog), mainly by calculating the cumulative Benioff strain as a function of time. We also examine the accelerating tendency of recent seismicity in and around the Indo-Himalayan collision zone and Tibet plateau.

From the relation between the critical area and the magnitude of the oncoming main shock (Bowman et al., 1998; Jaume & Sykes, 1999), the critical area of Mw 9.3 corresponds to a circular region radius about R=2800 km centered at the epicenter. Considering this, we investigate accelerating patterns of cumulative strain release curve in circular areas by varying both the center and radius and applied a non-linear least-square method to fit the power-law increase model to the data. One suitable circular region obtained for earthquakes with Mw=6.5 and larger and depth of 60 km or less is a radius R=3000km centered at three degrees westward the epicenter. In the critical region, a remarkable clustering of seismicity in wide area around 2000 is noteworthy. They include the rarely occurred large events near the epicenter of the coming 2004 event; June 4, 2000 Sumatra Mw 7.8 and the succeeded June 18, 2000 Indian Ocean Mw 7.9. If we take a broader area, large intraplate events such as January 26, 2001 western India Mw 7.7 and November 14, 2001 Xizang, China Mw 7.8 can be seen as moderate earthquakes in critical region prior to the 2004 earthquake. The frequency-magnitude distribution of earthquakes in the critical area exhibit that the Gutenberg-Richter relation extend systematically to larger magnitude range for earthquakes in the later period before the 2004 event. These observations may reflect the development of correlation length of interacting stress field toward the critical point of the 2004 final rupture.

We also observe a remarkable long-term periodicity between the quiescent and active period of large earthquakes in the Himalayan collision zone and Tibet plateau. A tentative estimate of the cumulative strain release of shallow earthquakes with Mw=6.5 and larger in a circular area centered at central portion of the Himalayan collision zone with radius R=2000 km shows a clear accelerating increase from around latter half of 1990s. It is important to clarify the influence of the critical area of the 2004 Sumatra earthquake on the intracontinental seismicity.