UNDERSTANDING THE GLOBAL SEISMICITY BASED ON MAPPING OF THE GLOBAL EARTHQUAKE ENERGY RELEASE

Q. Miao[1] and C.A. Langston[2]

[1] *Associate Professor, Earthquake Administration of Yunnan Province, Kunming, China*
[2] *Professor, Center for Earthquake Research and Information, University of Memphis, Memphis, USA*
Email: qingmiao.mem@gmail.com, clangstn@memphis.edu

ABSTRACT
We examine the location and magnitude parameters of 486,364 events of the NEIC earthquake catalog with magnitude equal to or greater than 1.0 over the time period from 1973 to 2007, with a focus to understand the global seismicity based on mapping of the global earthquake energy release. The spatial distribution of earthquake energy release is mapped using the standard empirical magnitude-energy relation. The global earthquake energy release map shows the basic patterns of global seismicity, which are generally consistent with plate tectonics. We also map the earthquake energy release in China and neighbors based on parameters of 48,066 events of China Seismograph Network catalog with magnitude equal to or greater than 0.7 from 1970 to 2007, in the range of 60°E-150°E longitude and 15°N-60°N latitude, to understand the seismicity in China and neighbors from a global point of view. Results show that a major part of intraplate earthquake energy release on the earth occurred in China and neighbors in the time period from 1970 to 2007. The relatively high energy release is usually occurred at shallow depths, and distributed close to places where moderate earthquake energy release occurred at relatively deep depths.

KEYWORDS
Global Seismicity, Earthquake Magnitude, Earthquake Energy Release

1. INTRODUCTION

Based on plate tectonics, the relative movement of plates is the cause of earthquakes (Cox and Hart, 1986). The spatial distribution of earthquakes, to some extent, may reflect the relative movement of plates in some way. However, when there are too many earthquakes to be plotted on a map with reasonable size, it will be difficult to understand the distribution of earthquakes around the earth in detail, if we plot the map using circles with different diameters proportional to the sizes of earthquakes, for many of the earthquakes occurred at relative deep depths will be covered by those occurred at relatively shallow depths. It is clear that this situation will become even worse with time. To solve this problem, we developed a technique to plot the spatial distribution of earthquakes using earthquake energy release (Miao and Langston, 2008).

In this paper, we will map spatial distribution of earthquake energy release for the whole earth based on parameters of 486,364 events of the NEIC earthquake catalog with magnitude equal to or greater than 1.0 over the time period from 1973 to 2007, China and neighbors, and Wenchuan and neighbors based on parameters of 48,066 events of China Seismograph Network (CSN) catalog with magnitude equal to or greater than 0.7 from 1970 to 2007, using the standard empirical magnitude-energy relation (Richter, 1958), to understand the Wenchuan M8.0 earthquake from global, regional and local scales, based on analyses of the global earthquake energy release, as we did for the New Madrid seismic zone (NMSZ) in the central U.S. (Miao and Langston, 2008). We will investigate the earthquake energy release distribution versus depth for Wenchuan and neighbors to understand the possible differences between the M8.0 earthquake hypocenter area and the neighboring areas. We will also investigate the published strain rate models (Kreemer *et al.*, 2000; Kreemer *et al.*, 2003) corresponding to the energy release maps to analyze the general correlations between earthquake energy release and strain rate.

2. WORLDWIDE EARTHQUAKE ENERGY RELEASE

The global earthquake energy release map (Figure 1) shows the basic patterns of global seismicity, which are generally consistent with plate tectonics (Turcotte, 1982). It can be seen from the map that the global seismicity is dominated by earthquakes occurring along the major plate boundaries. High energy release located along the subduction zones, and moderate energy release located along transform faults and spreading ridges. However, there are also earthquakes occurring in regions that are not located along the major plate boundaries, such as those in mid-North America, western Europe, southern Africa, and Australia.

Based on comparison between Figure 1 and Figure 2, it can be seen that the highest energy release is usually located at relatively shallow depths along the subduction zones, while moderate energy release located at relatively deep depths along the subduction zones. Energy release along the spreading ridges is usually located at shallow depths. Intermediate-deep seismicity in central Asia corresponds to moderate energy release. Yet, deep seismicity located at north boundary of African plate corresponds to relatively weak energy release, with moderate energy release located at nearby places.

Some obvious correlations between the major plate tectonic features can be found when comparing the global earthquake energy release map (Figure 1) with the global strain rate map (Figure 3). At subduction zones, the energy release map shows the highest values, while the strain rate map shows relatively high but not the highest values. For the transform faults, the energy release map shows moderate values, and the strain rate map also shows moderate values. At spreading ridges, the energy release map shows moderate values, but the strain rate map shows the high-highest values.

Table 1 shows some the basic parameters for the global earthquake energy release. Since the Earth rotates around its own axis, we assume that the energy release on north hemisphere should be somewhat equal to that on south hemisphere. Results show that earthquake energy release on north hemisphere is a little higher than that on south hemisphere. The energy release on east hemisphere is much larger than that on west hemisphere. This phenomenon may be explained by the fact that more subduction zones located on east hemisphere than that on west hemisphere (Figure 1 and Figure 2).

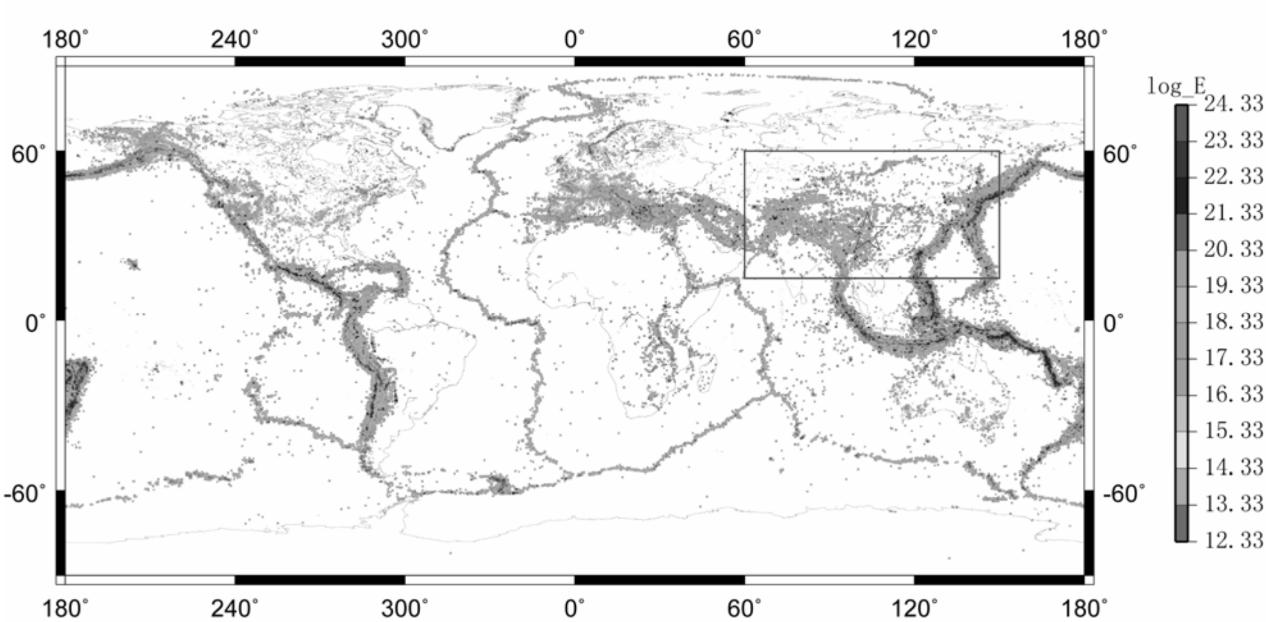

Figure 1. 0.2° x 0.2° global earthquake energy release based on NEIC earthquake catalog 1973-2007. Box indicates China and neighbors for this study. Star indicates epicenter of May 12th Wenchuan M8.0 earthquake.

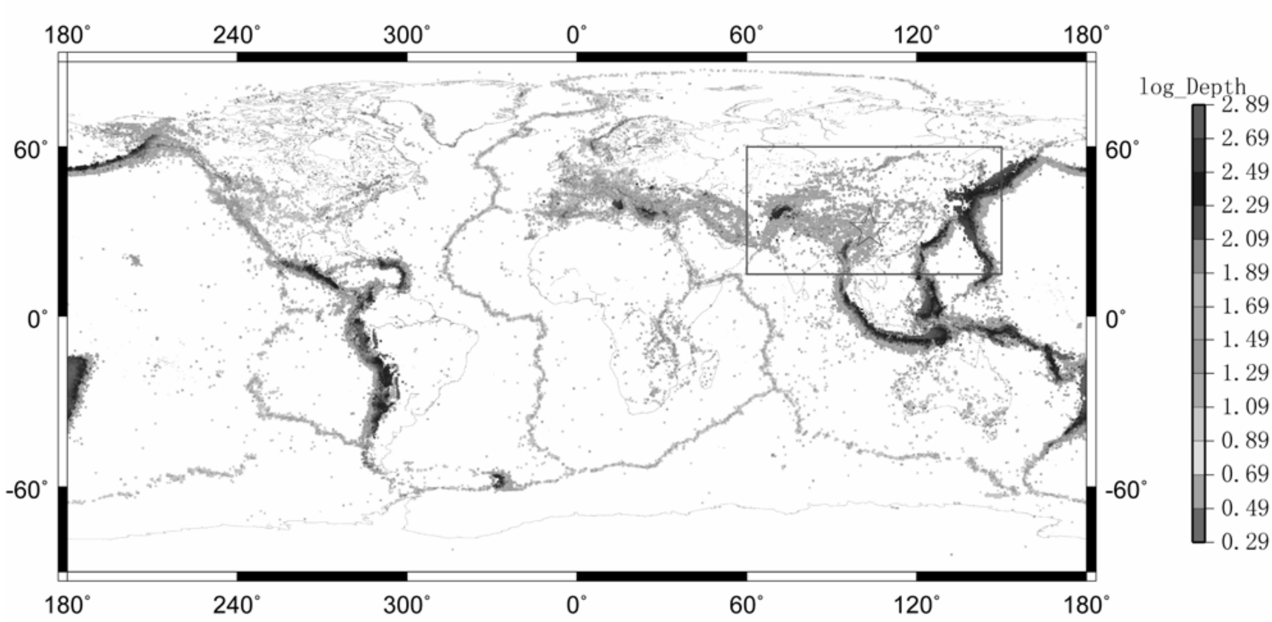

Figure 2. 0.2° x 0.2° global earthquake depth based on NEIC earthquake catalog 1973-2007. Box indicates China and neighbors for this study. Star indicates epicenter of May 12th Wenchuan M8.0 earthquake.

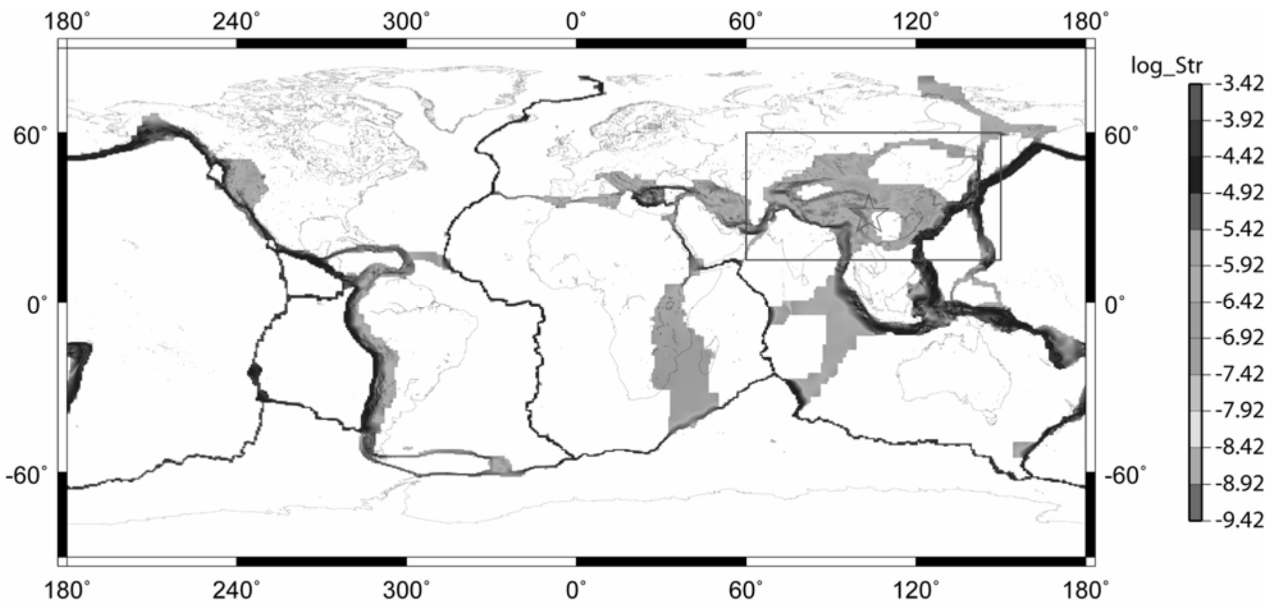

Figure 3. 0.2° x 0.2° global strain rate map based on second invariant of strain rate in the Global Strain Rate Map Project (Kreemer *et al.*, 2000; Kreemer *et al.*, 2003). Box indicates China and neighbors for this study. Star indicates epicenter of May 12th Wenchuan M8.0 earthquake.

Table 1. Global EQ Energy Release Based on NEIC Global Earthquake Catalog 1973-2007

Total Energy Release	1.378095E+26 (ergs)	Average/Year	3.937414E+24 (ergs)
Energy Release on North Hemisphere	7.034757E+25 (ergs)	Average/Year	2.009931E+24 (ergs)
Energy Release on South Hemisphere	6.746200E+25 (ergs)	Average/Year	1.927486E+24 (ergs)
Energy Release on East Hemisphere	1.023694E+26 (ergs)	Average/Year	2.924840E+24 (ergs)
Energy Release on West Hemisphere	3.544011E+25 (ergs)	Average/Year	1.012575E+24 (ergs)

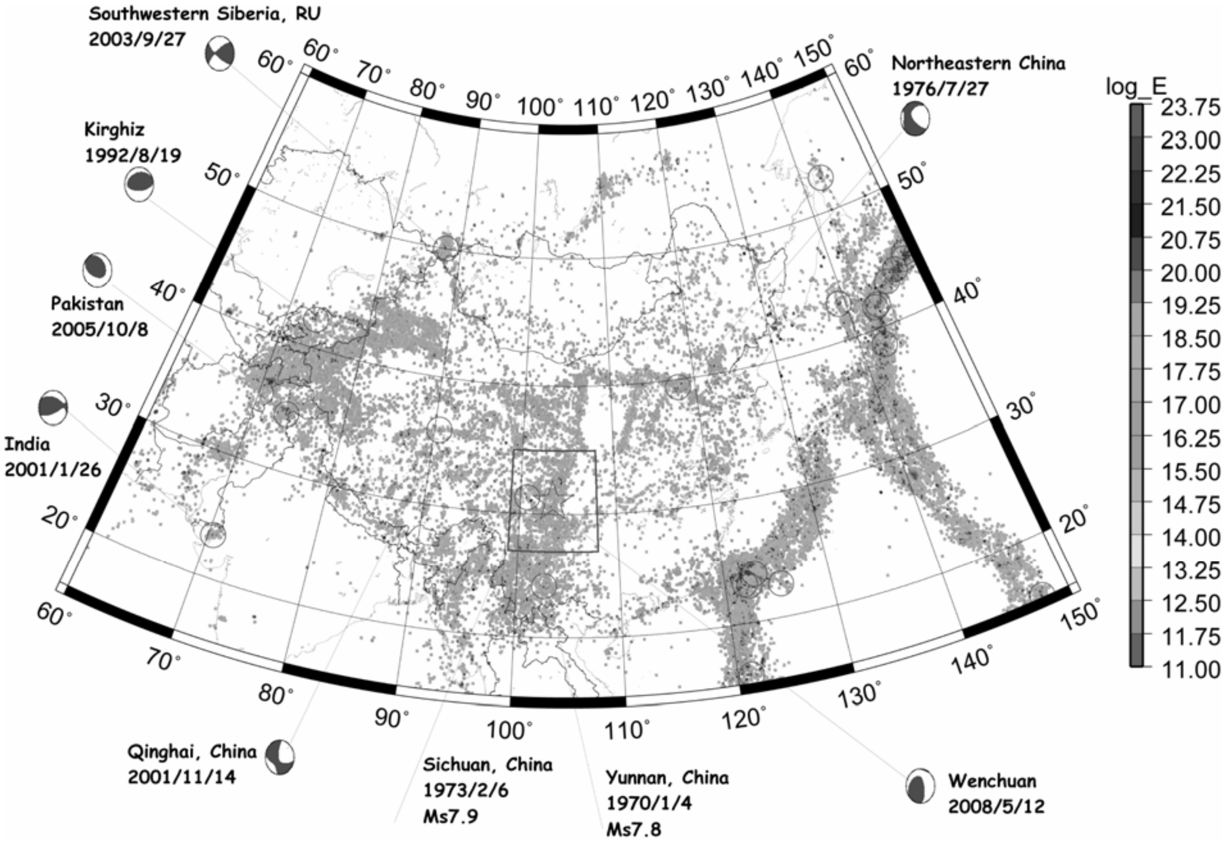

Figure 4. 0.05° x 0.05° China and neighbors earthquake energy release based on CSN earthquake catalog 1970-2007. Box indicates Wenchuan and neighbors. Star indicates epicenter of May 12th Wenchuan M8.0 earthquake. Circles indicate earthquakes with magnitudes equal to or greater than M7.5 based on CSN earthquake catalog. Focal mechanisms are from CMT earthquake catalog.

2. EARTHQUAKE ENERGY RELEASE IN CHINA AND NEIGHBORS

From a global point view, earthquake energy release in the range of 60°E-150°E longitude and 15°N-60°N latitude (Figures 1) is dominated by intraplate earthquakes on the west side and interplate earthquakes on the east side (Figure 5). A major part of intraplate earthquake energy release on the earth occurred in this region. On the east side, high energy release, corresponding to high strain rate (Figure 3), located along the subduction zones; on the west side, moderate energy release, corresponding to intermediate-lower strain rate, located at shallow depths, except the deep seismicity in central and south-east Asia, where energy release located at relatively deep depths (Figure 2).
From a regional point of view, Earthquake energy release in China and neighbors shows a complicated pattern. The east and south-east sides are controlled by high energy release (Figure 4) and high strain rate (Figure 6) along the subduction zones. On south-west side, moderate energy release distributed in Tibetan plateau area. Two areas with intermediate-deep seismicity located at the north-west and south-east of Tibetan plateau (Figure 5), which may be related with the collision of the Indo-Australian Plate with Eurasia plate along the Himalayas.
The other feature of earthquake energy release in China and neighbors is the relatively low energy release belt, with shallow depth, running from north to south at the middle of China. Most of the historic large earthquakes in China occurred on this belt (Ming *et al.*, 1995).

3. EARTHQUAKE ENERGY RELEASE IN WENCHUAN AND NEIGHBORS

Earthquake energy release in Wenchuan and neighbors is dominated by earthquakes occurred along the active faults, such as the Longmenshan fault, Xianshuihe fault, and Litang fault (Figure 7; Yao *et al.*, 2008). From a global point of view, Wenchuan M8.0 earthquake occurred near the eastern boundary of a huge earthquake energy release block located in western China and neighbors (Figure 1); from a regional point of view, Wenchuan M8.0 earthquake occurred near the middle of an earthquake energy release belt, running from north to south (Figure 4); from a local point of view, Wenchuan M8.0 earthquake occurred near the cross point between the Longmenshan fault and Xianshuihe fault (Figure 7). Earthquake energy release from aftershocks displays a linear distribution. Some of the energy release at north-east edge has never occurred in the past 38 years before the M8.0 event.
Figure 8 shows the earthquake energy release with depth for Wenchuan and neighbors. Around the Wenchuan M8.0 earthquake hypocenter area, the relatively high energy release distributed near the boundary between the upper and middle crust. Meanwhile, some of the weak and moderate energy release was also found located in the lower crust.

4. DISCUSSION AND CONCLUSION

The use of energy release from earthquakes gives a different view of seismicity, particularly for understanding intraplate earthquakes, such as those in the NMSZ of the central U.S., and those in China and neighbors. Energy release depth distributions give a different view of crustal strength and we suggest that they may be a better indicator of the physical conditions of the crust.
The global earthquake energy release map shows the basic patterns of global seismicity, which are generally consistent with plate tectonics. The global seismicity is dominated by earthquakes occurring along the major plate boundaries. High energy release distributes along the subduction zones, and moderate energy release distributes along spreading ridges and transform faults. However, there are also earthquakes occurring in regions that are not located along the major plate boundaries, such as those in mid-North America, western Europe, southern Africa, and Australia. Earthquake energy release on north hemisphere is a little higher than that on south hemisphere.
The seismogenic lithosphere at a ridge is very thin that is simply inefficient in producing earthquakes. Most subduction zones, however, occur where relatively old plates subduct at continental margins or island arcs where there is a relatively thick seismogenic layer. Transform faults are generally intermediate in efficiency since they are usually associated with relatively young portions of oceanic plates between adjacent spreading ridges.

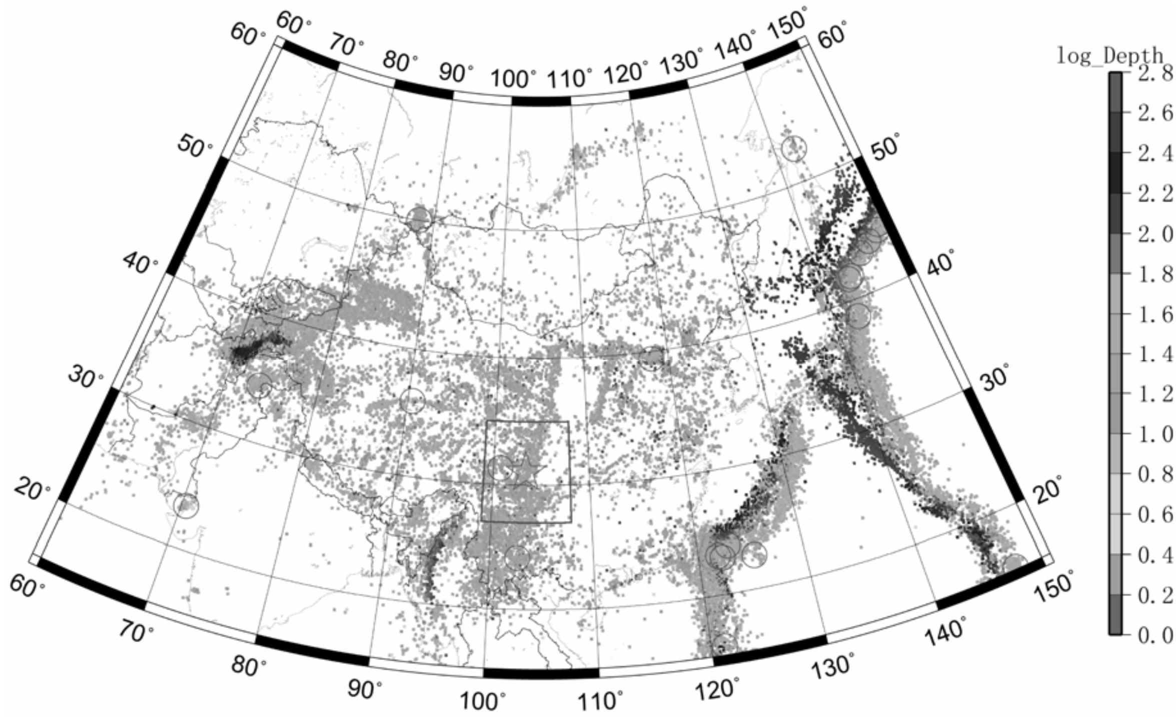

Figure 5. 0.05° x 0.05° China and neighbors earthquake depth based on CSN earthquake catalog 1970-2007. Box indicates Wenchuan and neighbors. Star indicates epicenter of May 12th Wenchuan M8.0 earthquake. Circles indicate earthquakes with magnitudes equal to or greater than M7.5 based on CSN earthquake catalog.

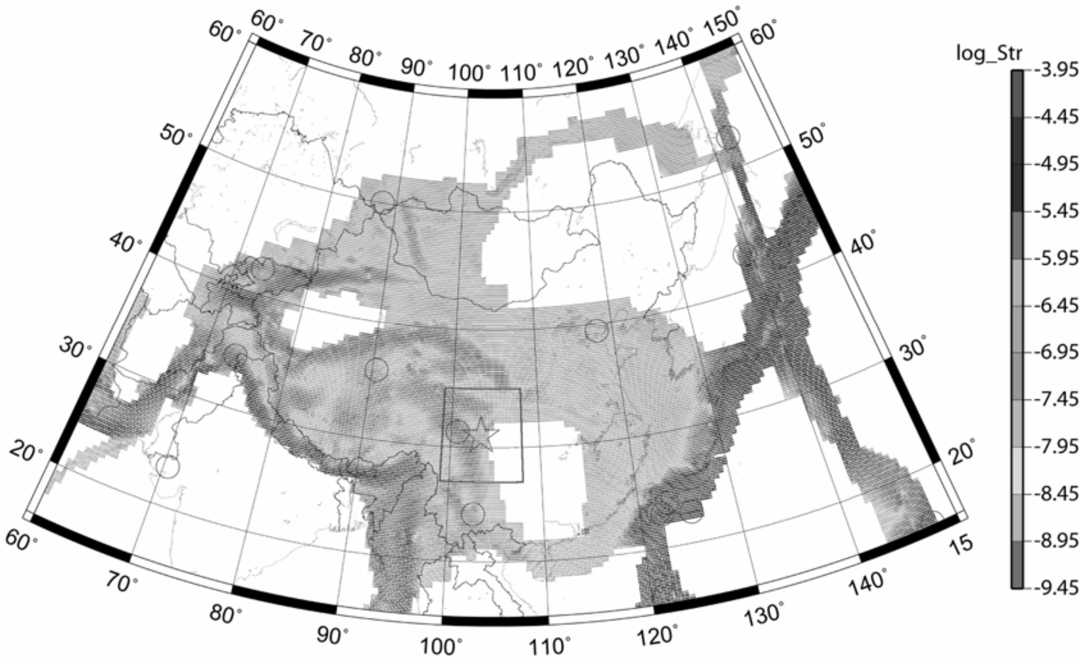

Figure 6. 0.2° x 0.2° China and neighbors strain rate map based on second invariant of strain rate in the Global Strain Rate Map Project (Kreemer *et al.*, 2000; Kreemer *et al.*, 2003). Box indicates Wenchuan and neighbors. Star indicates epicenter of May 12th Wenchuan M8.0 earthquake. Circles indicate earthquakes with magnitudes equal to or greater than M7.5 based on CSN earthquake catalog.

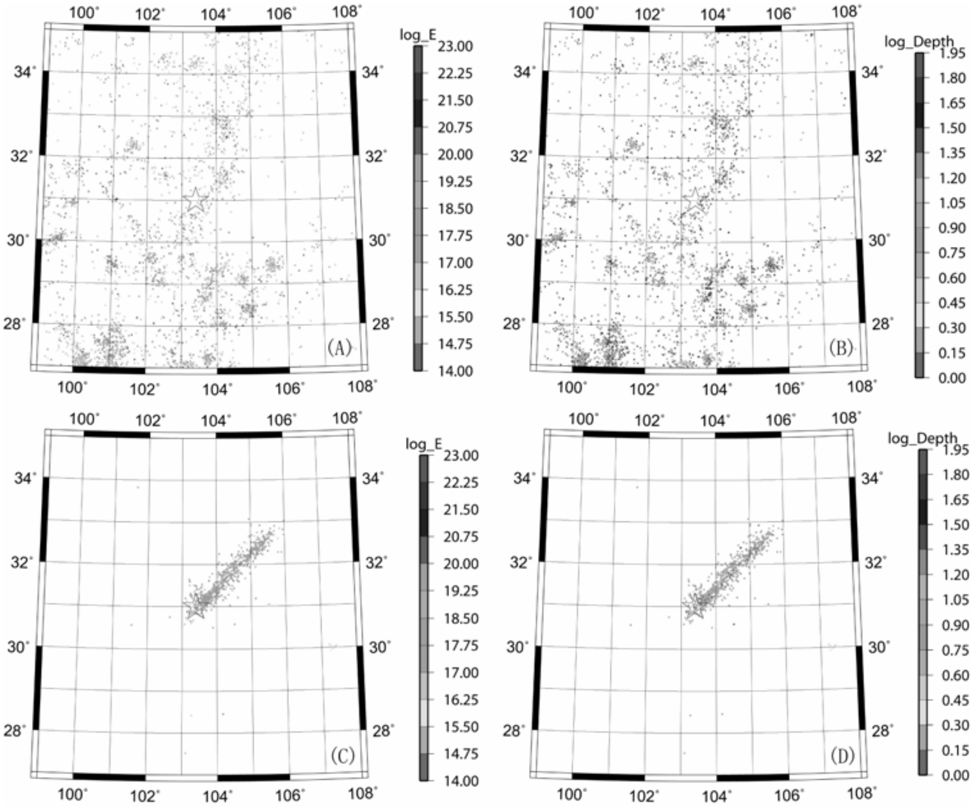

Figure 7. 0.01° x 0.01° Wenchuan and neighbors earthquake energy release and depth. (A) Energy release based on CSN earthquake catalog 1970-2007. (B) Depth based on CSN earthquake catalog 1970-2007. (C) Energy release based on NEIC earthquake catalog, between May 12 (after the mainshock) and July 24. (D) Depth based on NEIC earthquake catalog, between May 12 (after the mainshock) and July 24.

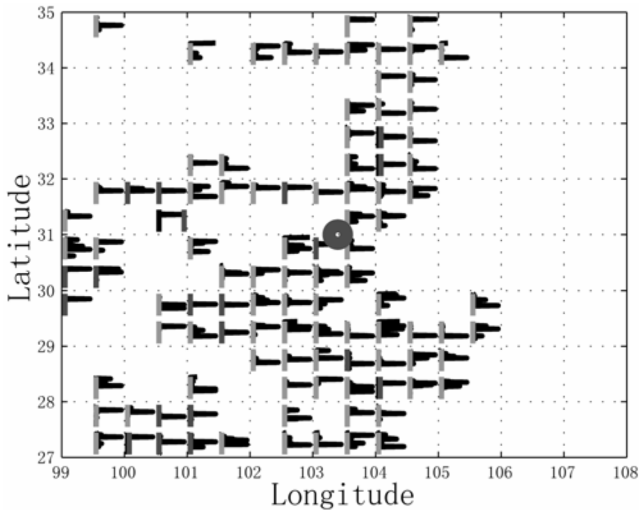

Figure 8. 0.5° x 0.5° Wenchuan and neighbors earthquake energy release with depth 0-50 km, based on CSN earthquake catalog 1970-2007. Circle indicates epicenter of May 12[th] Wenchuan M8.0 Earthquake.

We suggest understand particular earthquakes, such as the large earthquakes in the NMSZ of the central U.S., and the Wenchaun M8.0 earthquake at the boundary between Tibetan plateau of south China block, from a global, regional, and local point of view.

5. ACKNOWLEDGMENTS

We thank NEIC for making the NEIC catalog available. We also thank the Global Strain Rate Map Project for use of the global strain rate data (Kreemer *et al.*, 2000; Kreemer *et al.*, 2003). Use of the Generic Mapping Tool (Wessel and Smith, 1998) program is gratefully acknowledged. This research was supported by the Earthquake Administration of Yunnan Province and Center for Earthquake Research and Information, University of Memphis.

REFERENCES

Cox, A., and Hart, R. B. (1986). Plate Tectonics – How It Works, Blackwell Scientific Publications, Oxford, 392 pp.

Kreemer, C., Haines, A. J., Holt, W. E., Blewitt, G. and Lavalée, D. (2000). On the determination of a global strain rate model, *Earth Planets Space* **52**, 765-770.

Kreemer, C., Holt, W. E. and Haines, A. J. (2003). An integrated global model of present-day plate motions and plate boundary deformation, *Geophys. J. Int.* **154**, 8-34.

Miao, Q. and Langston, C. A. (2008). Spatial distribution of earthquake energy release in the central United States from a global point of view, *Seism. Res. Lett.* **79**, 33-40.

Ming, Z.Q., Hu, G., Jiang, X., Liu, S. C.and Yang, Y. L. (1995). Catalog of Chinese historic strong earthquakes from 23 AD to 1911 (in Chinese), 514 pp., Seismol. Press, Beijing.

Richter, C. F. (1958). Elementary Seismology, W. H. Freeman and Co., San Francisco, 578 pp.

Turcotte, D. L. and Schubert, G. (1982). Geodynamics: Applications of Continuum Physics to Geological Problems, John Wiley, New York, 450 pp.

Wessel, P. and Smith, W. H. F. (1998). New, improved version of Generic Mapping Tools released, *EOS Trans.***79**, 579.

Yao H., Beghein, C. and Van der Hilst, R.D. (2008). Surface-wave array tomography in SE Tibet from ambient seismic noise and two-station analysis: II – Crustal and upper mantle structure, *Geophys. J. Int.* **73**, 205-219, doi: 10.1111/j.1365-246X.2007.03696.x.