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Study of Aftershocks of Gorkha Nepal Earthquake of 2015

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Abstract

Aftershock behavior of the April 25, 2015 Mw 7.8 Nepal earthquake is studied using EMSC catalog. Parameters studied are time and space variation as well as the b and p values. The aftershocks are confined to the rupture zone and have not spread out. The aftershock sequence has decayed slowly than normal for a Himalayan earthquake. Aftershocks of M4 have continued for several months. The normal b value of ~1 indicates the presence of normal stress level and a corollary of it may be that the major earthquakes have likely released the accumulated stress. As the aftershocks of Mw 7.3 May 12, 2015 major aftershock are located east of 86.1E while aftershocks of April 25 earthquake are rarely occurred east of 86.1E, the two major earthquakes appear to behave as independent earthquakes, the aftershock behavior of the two major earthquakes is studied separately also.

Keywords: Aftershocks, Nepal earthquakes, b-value, p-value

1. Introduction

A large earthquake Mw 7.8 struck central Nepal around Kathmandu at 28.15^{0}N, long 84.71^{0}E, depth 8-15 km, origin time 6:11 UT (EMSC) on April 25, 2015 (Fig.1). A major aftershock Mw 7.3 was stress triggered some 150 km east on May12, 2015 at 27.89^{0}N 86.17^{0}E, 7:05UT. Some researchers believed that the May 12 earthquake could be an independent main shock as the rupture zone of it was not within that of April main shock, rather adjacent to it. In this new rupture area very few aftershocks of the April earthquake had occurred. The May earthquake had its own aftershock sequence. Aftershock behavior of these two large earthquakes independently and also all of them taken together are studied using the EMSC catalog until September 2015 (Appendix 1). Parameters studied are temporal and spatial variations as well as the b and p values of the aftershock sequences. The b-value indicates ratio of smaller to larger earthquakes and the p-value indicates rate of decay of aftershocks. Epicentral maps and histograms of daily frequency are also presented.

2. Space and Time Distribution of Aftershocks

Epicenters of the two major earthquakes are located near the snow peaked Himalayan mountains close to Nepal-Tibet border (Fig. 1). The two major earthquakes show their own independent aftershock sequences.

Subsequent to the April 25 main shock (Mw 7.8), an aftershock of Mw 6.6 occurred half an hour after and another aftershock of Mw 6.7 occurred 25 hours after the main shock. Most of the aftershocks **(14 out of 16)** of Mw $\geq$ 5.0 occurred within 2 days, and 225 aftershocks of Mw ≥4.0 continued for over 5 months. The Mw 6.6 aftershock was experienced near the main shock at western end of the rupture zone, and the Mw 6.7 aftershock occurred 150 km east.

The May 12 large earthquake (Mw 7.3) had an aftershock of Mw 6.2, some 11 aftershocks of Mw 5-5.9 and 104 aftershocks of Mw ≥4 until September 2015. Rupture zones of both the earthquakes propagated to the east from their respective epicenters. These rupture zones are identified based on modeling of teleseismic seismograms, distribution of aftershocks and deformations observed by GPS as well as by Synthetic Aperture Radar. A review of these observations is made by Rastogi (2016). The April 25 main shock was at the northwestern end of its 150 x 55km rupture zone, while the May 12 earthquake occurred at the northeastern end of this rupture zone. Rupture zone as well as aftershock area of the May 12 earthquake is dominantly to the east of long 86°E, and the zone is about 50 km wide.

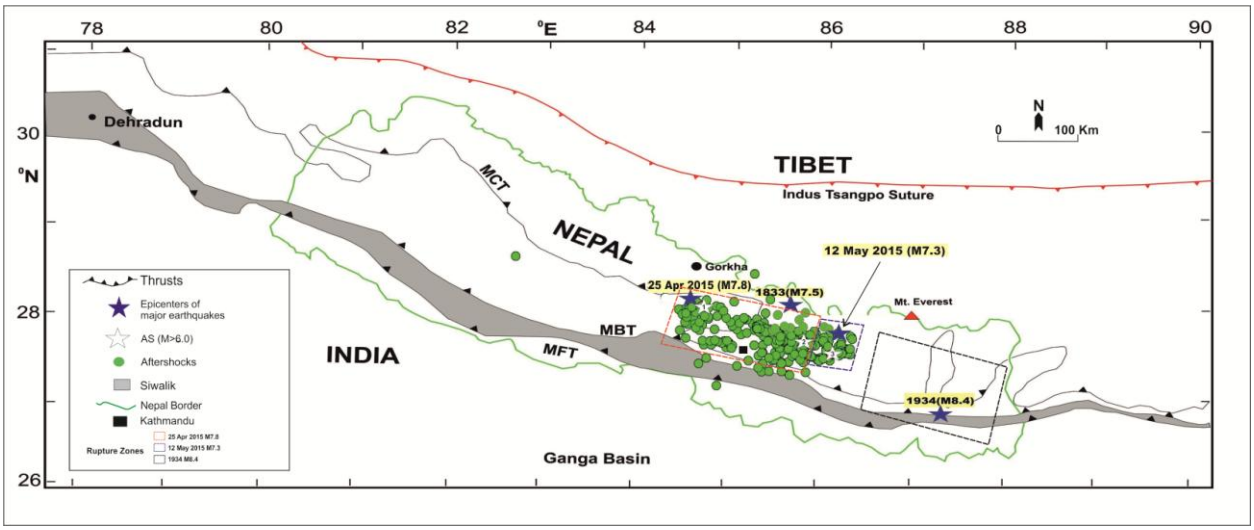


Fig. 1: Inferred Rupture zones of the Jan 1934, April 2015 and May 2015 earthquakes are shown by rectangles. Prior to May 12, the aftershocks of the earthquake of April 25, 2014 were largely limited to west of 86.1°E, hence, all the shocks east of 86.1°E are considered as aftershocks of May 2015 earthquake. The aftershocks reported until September 2015 by EMSC are considered.

Locations of the two aftershock sequences of the two major earthquakes of 2015 are shown in Figs. 2 a and b respectively, and all the aftershocks together are plotted in Fig 2c. It is observed that the boundary of the two rupture zones lies at 86°E. However, in the southern part it may go as west as 85.8E. Until August 2015 total number of aftershocks of Mw 6-7 is 3, Mw 5-5.9 is 26, and Mw ≥4 is 350. The last Mw 5 aftershock occurred on August 23, 2015 at 86.24°E and 27.96°N.

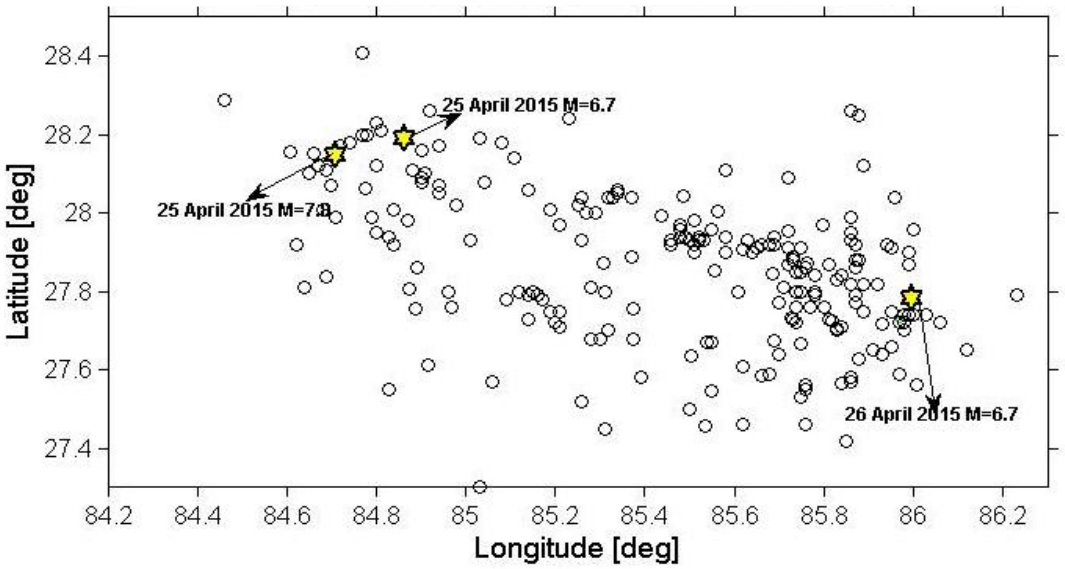


Fig. 2a: Epicenters of aftershocks of the Nepal April 25, 2015 earthquake along with those of stronger aftershocks (Mw > 6.0) during April to August 2015. Note that fewer locations are east of 86°E.

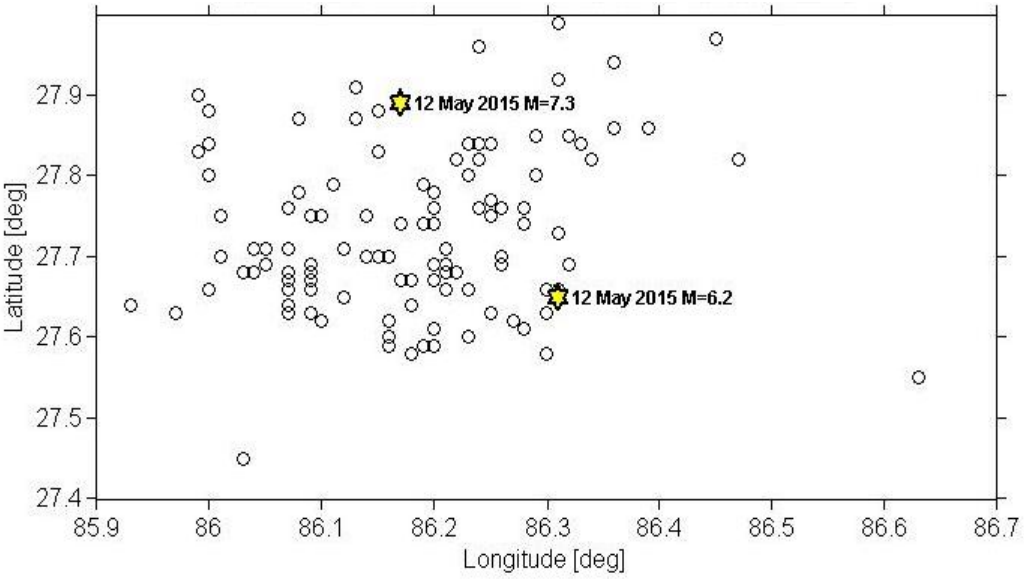


Fig. 2b: Epicenters of aftershocks of the May 12 earthquake, occurred mostly east of 86.1^{0}E (data until Sept 2015)

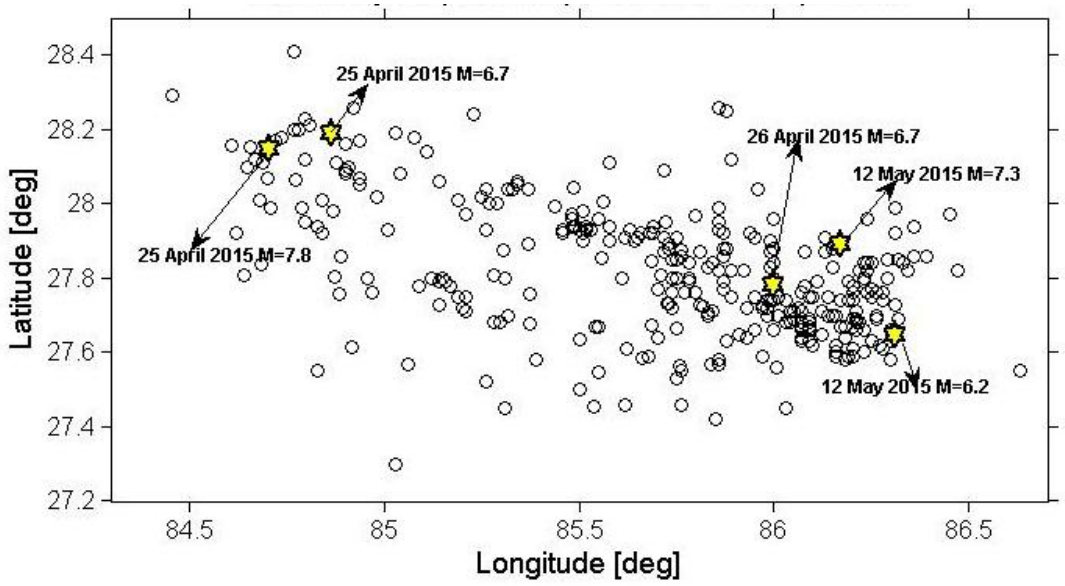


Fig. 2c: Locations of all the aftershocks of April 25 and May 12 earthquakes. Rupture zone of May 12 earthquake appears to be east of 86.1^{0}E, as evident from its aftershock sequence

Histograms of daily frequency of aftershocks are presented in Figs.3a, b and c. The Mw <5 aftershocks have continued for several months, more than 3 months as expected for an Mw7.8 earthquake in Himalaya (Srivastava and Kamble, 1972). An aftershock of Mw 5.1 occurred as late as on August 23, 2015.

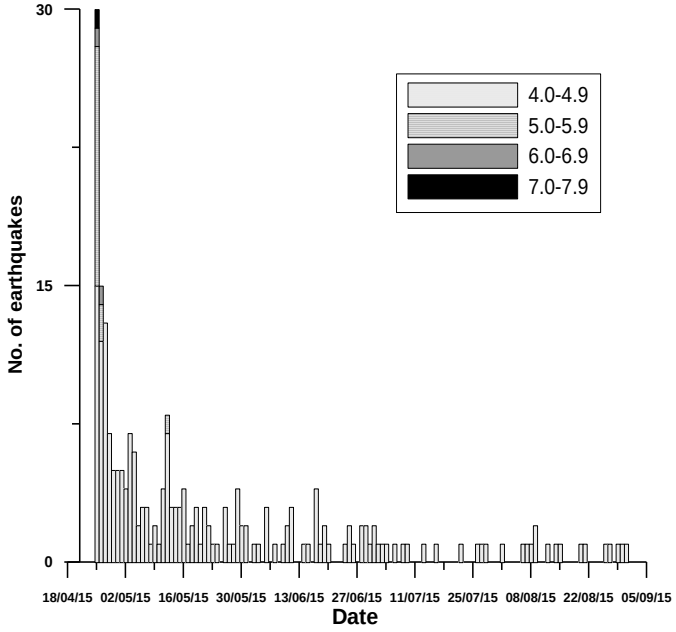


Fig. 3a: Daily frequency of aftershocks Mw ≥ 4.0 of the April 2015 earthquake, which occurred west of 86^{o}E. There were two shocks of Mw 6-6.9, sixteen of Mw 5-5.9 and 204 of Mw 4-4.9, totaling 222 until September 2015.

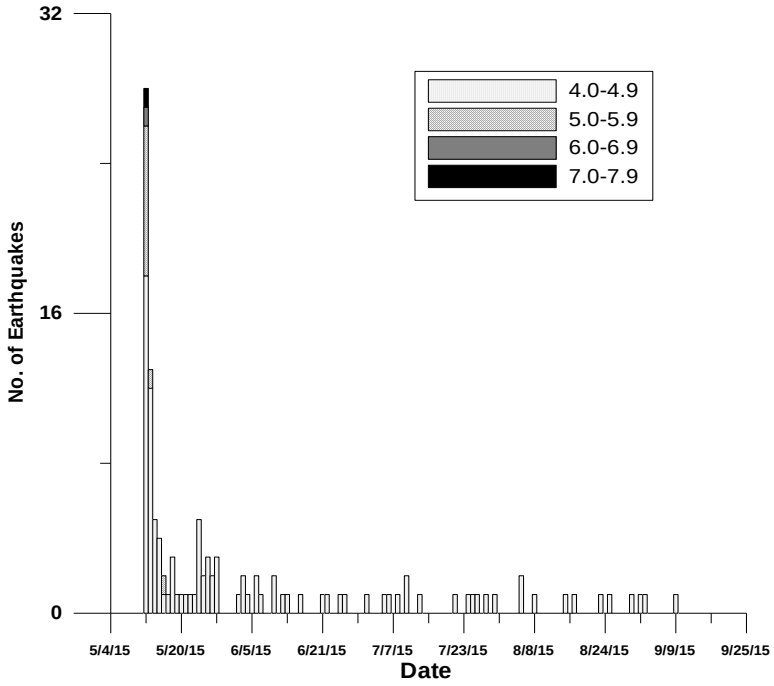


Fig. 3b: Daily frequency of aftershocks of Mw ≥4.0 for the May 12, 2015 earthquake, mostly occurring east of 86°E till September 6, 2015. One Mw 6.2, ten of Mw 5-5.9 and one hundred five of Mw 4-4.9 totaling 116 aftershocks occurred until Sept 2015

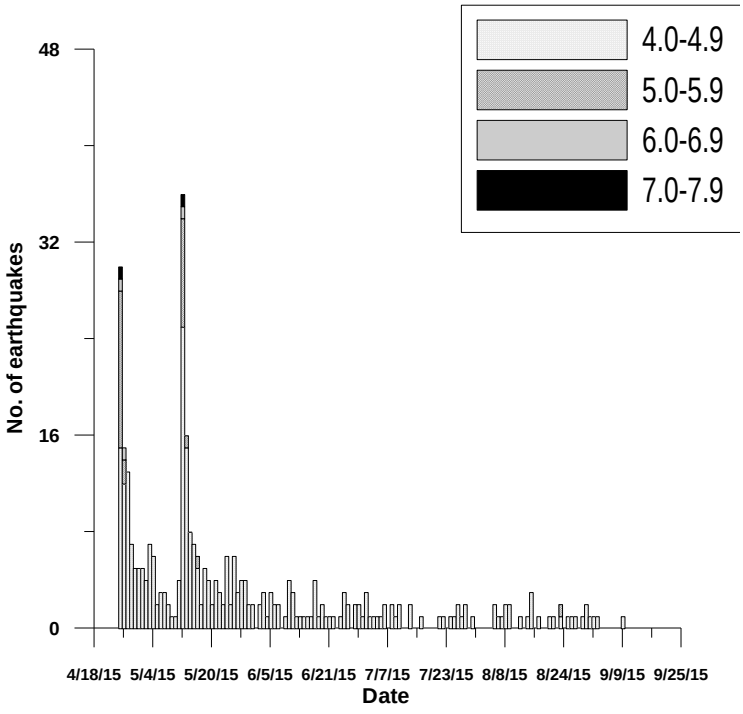


Fig. 3c: Daily frequency of all aftershocks Mw ≥4.0 of the two Nepal 2015 large earthquakes. There were two main shocks (Mw 7.9 and 7.3) , three aftershocks Mw 6-6.9, 27 aftershocks Mw 5-5.9 and 306 of Mw 4-4.9, totaling 338 until Sept 2015

The cumulative number of aftershocks with time is examined. It shows a linear increase of the curve and saturates after three months or so (Fig. 4). We have also presented a histogram of total number of aftershocks recorded at different magnitude ranges (Fig.5). It shows maximum number (306) of aftershocks are recorded for Mw range of 4.0- 4.9, 27 for Mw 5.0-5.9, three for Mw 6.0-6.9. This sequence is observed against two large shocks Mw 7.8 and 7.3 in April and May 2015, respectively.

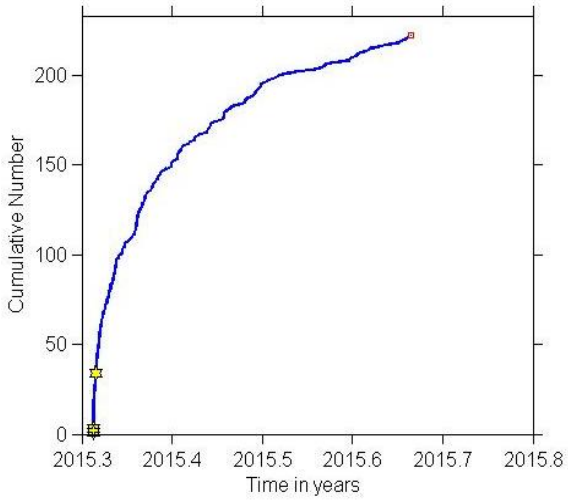


Fig. 4: Cumulative no. of all the aftershocks plotted with time. Rate of occurrence reduced after 3 months

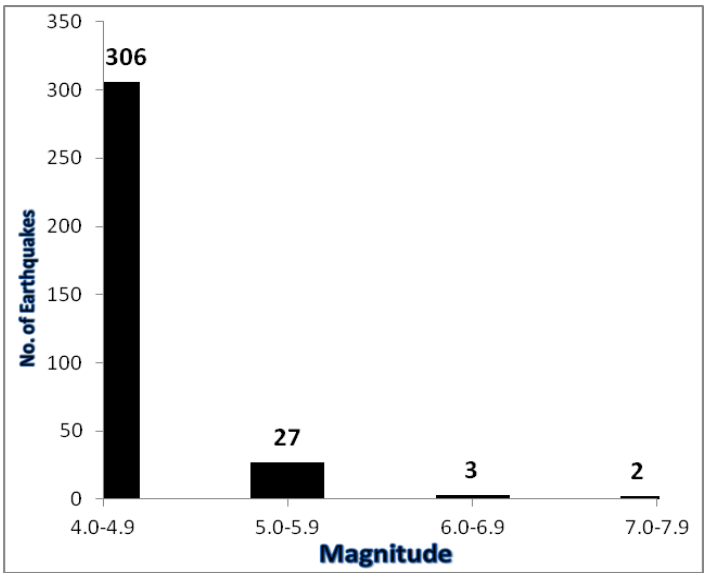


Fig. 5: Magnitude distribution of two major earthquakes and aftershocks until 10 Sept 2015

3. The b-Value: Slope of the Relation Between Magnitude and Number of Earthquakes

Gutenberg-Richter power law (Gutenberg and Richter, 1954) has been used to estimate the b-value, which is slope of a log-linear relation between magnitude and cumulative number of earthquakes as given below:

$$\log_{10} N = a - bM \quad (1)$$

where, **N** is cumulative number of earthquakes, **a** is a constant that indicates seismicity level, M is magnitude of earthquakes, and b-slope or b-vale is the seismic characteristics of the studied area. The b-value is calculated for shocks of magnitude ≥ Mc (magnitude of completeness), which indicates the magnitude above which all the earthquakes can be detected (Wiemer and Wyss, 2000).

In this study, we have calculated the *b*-value using equation (1).

For a larger range, say Mw < 4.0 to *Mw* >7.0, the frequency decreases more rapidly than linearly. This is because less number of smaller magnitude shocks due to lack in detectibility, while larger magnitude shocks may suffer saturation in magnitude scales. To overcome these difficulties, we have calculated the *b*-value above the M_c and biggest earthquake in our catalogue is *M* 6.7. Thus our estimate is within the magnitude range Mw 4.0 - 6.7, where linear relationship is maintained.

The estimated b-value for the aftershock sequence of April 2015 is 0.98 (Fig. 6a) and for the sequence of May 2015 earthquake is 1.07 (Fig. 6b). The b-value for all the aftershocks taken together (Fig. 6c) is 0.98.

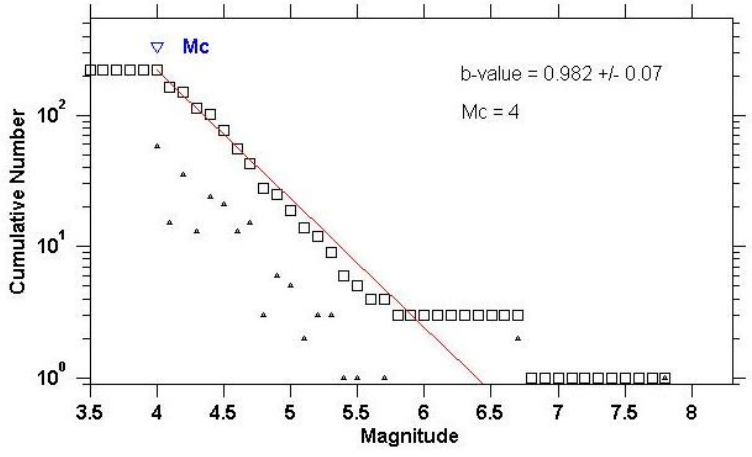
The 'b' value for M≥4.5 was obtained 0.862 by Goda et al. (2015)

4. Rate of Decay of Aftershocks

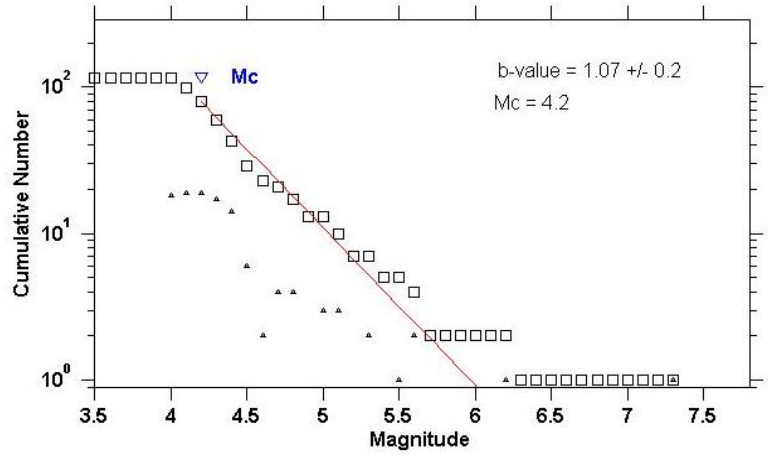
An important property of aftershock sequences is the rate of decay. The number of aftershocks in a sequence will drop as time progresses. Expressed mathematically, this relation is commonly known as Omori's Law:

$$n(t) = K/ (t+c)^p$$

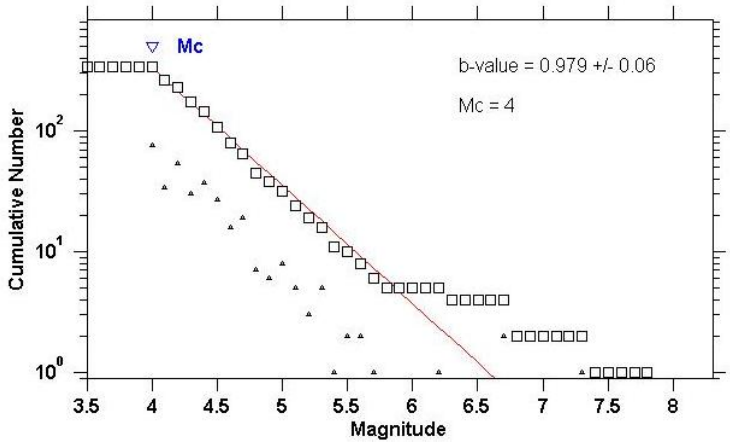
where, p is the decay rate and typically falls in the range 0.9–1.5, n(t) is the frequency of earthquakes per unit time, at time t after the main shock, and K and c are constants. It states that the number of aftershocks occurring at a given time *t* after the main shock will be proportional to that time *t* taken to the negative power of *p*, a constant. This means that the decrease in aftershock numbers will be rapid at first, then gradually until it wanes off to the background seismicity rate. Normally p value is found to be 1 for tectonic earthquakes. It increases with structural heterogeneity of the area.



(a)



(b)



(c)

Fig. 6: Estimated b-value of (a) aftershocks of the April 25, 2015 earthquake to the west of 86E (b) aftershocks of the May 12 earthquake (c) all the aftershocks taken together. Period considered is until September 2015

The p-value for the April earthquake aftershock sequence is 0.73 (Fig. **7a**), 0.81 for the May earthquake aftershock sequence (Fig. 7b) and 0.63 for all the aftershocks taken together. Goda et al. obtained p = 1.049 for initial 20 days which is near normal.

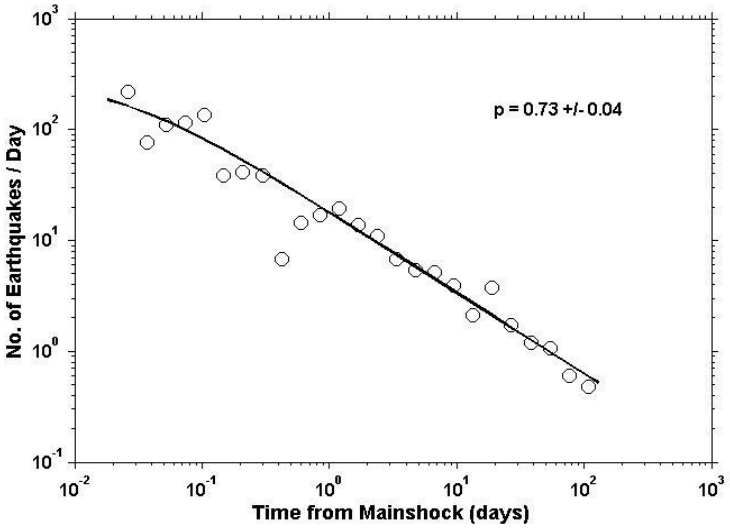


Fig. 7a: Decay rate of aftershocks of the M7.8 earthquake of Apilr 25, 2015 west of 86E and during March to July 2015

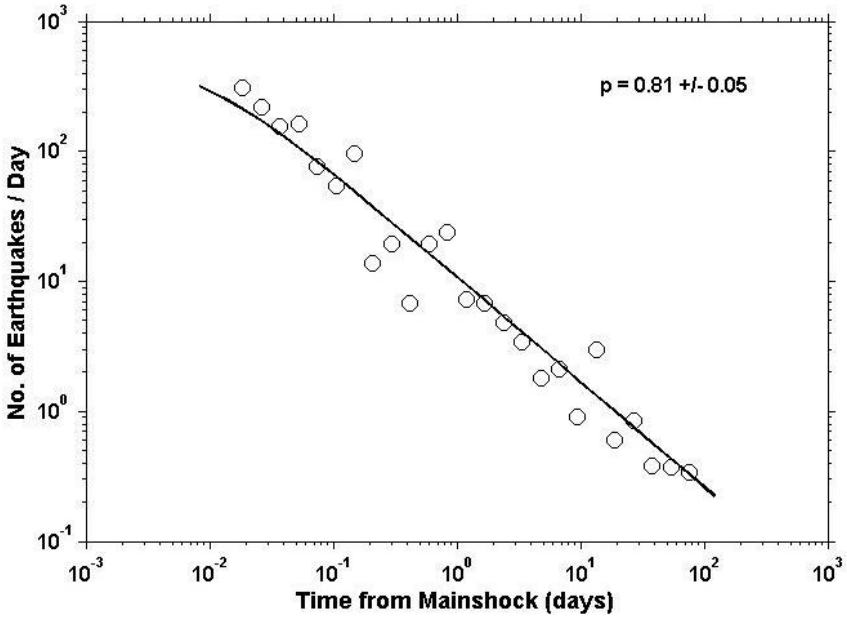


Fig. 7b: The p-value for aftershocks of the earthquake Mw 7.3 of May 12 until July 2015

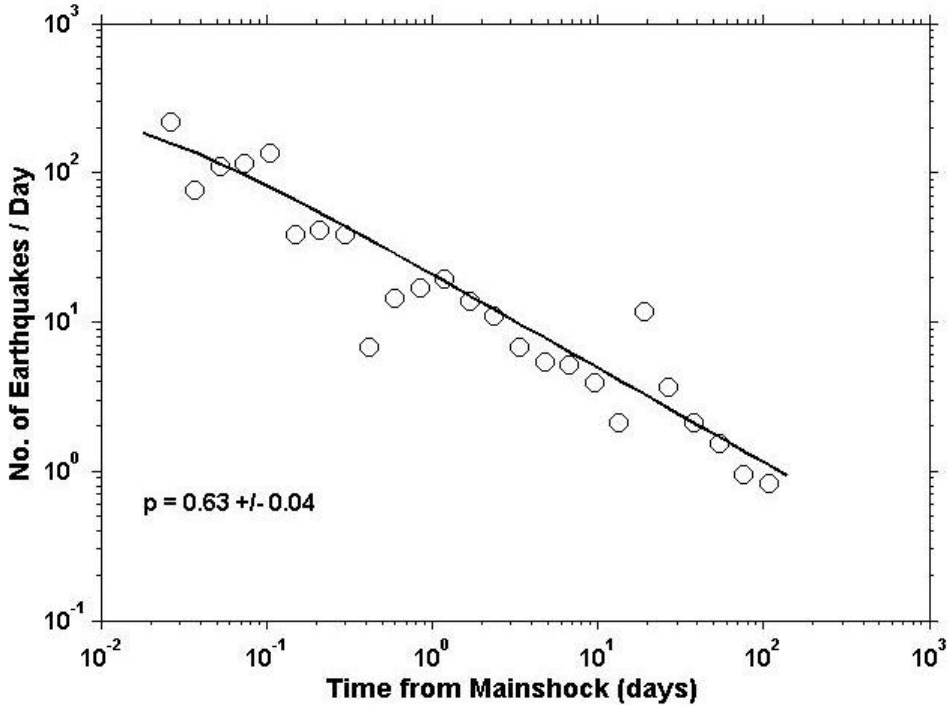


Fig. 7c: The p-value for all aftershocks of April 25 and May 12 earthquakes

5. Results and Discussion

Seismicity in Himalaya is the result of continental collision of Indian and Eurasian plates, which are converging at a relative rate of 40-50 mm/yr, nearly 50% of which is accommodated in Himalaya and rest in Eurasia. The Indian plate underthrusts northward beneath Eurasia. The surface expression of the plate boundary is marked by the east-west trending Himalaya Front.

Collision of India with Asia started 50 million years ago. Crustal thickening and burying of rocks to 35 km depth in Himalaya occurred between ~35-30 Ma. During the Miocene (~25-18 Ma) time the Main Central Thrust (MCT) developed. About 10 million years ago the Main Boundary Thrust (MBT) became active bringing Lesser Himalayan rocks southwards over Siwalik foreland sediments. These Himalayan thrusts root into a major blind detachment called the Main Himalayan Thrust (MHT) that represents the present day plate margin, where India is underthrusting the Himalaya. The zone covered by different thrusts south of Tibet is locked and episodically produces large earthquakes along the MHT. The Gorkha earthquake is part of this process. Rupture zones of large earthquakes in Himalaya are about 150-200km. From a convergence rate of 2 cm/yr a strain enough for 4m slip and a great earthquake may be accumulated every 200 years in such stretches (Bilham et al. 2001; Ader et al., 2012).

The aftershocks of April 25 earthquake are found to spread throughout the rupture zone of 150kmx55km. The May 12 aftershock and its aftershocks define adjacent 50km wide rupture zone further east. Most of these shocks are along the MHT extending from near surface at the Himalayan front to about 20km. Deeper shocks are noticed at some portions of Himalaya due to doubling of the subducting plate boundary (Kayal et al., 1993) but no such shocks have been recorded here. For the April earthquake the aftershocks are less in the area where slip amount is more. Aftershock sequence decays faster in Himalaya

than in intra plate region of India (Richa,2003). However, the Nepal 2015 aftershock sequence had a slow decay. As expected for a Himalayan earthquake, larger aftershocks occurred for two days after the major earthquakes but M4 aftershocks for some months. The distribution of aftershocks and their b and p values are given in Table 1.

The parameter b is believed to depend on the stress regime and tectonic character of the region (Allen et al., 1965; Mogi 1967; Scholz 1968; Tsapanos 1990). General "global" average value of the b parameter is close to be 1 which indicates ten times higher number of shocks for one unit lower magnitude. Regionally, changes in b-value are believed to be inversely related to changes in the stress level (Bufe 1970; Gibowicz 1973, Kanamori 1981, Urbancic et al., 1992) or heterogeneity of the area. A smaller b-value means high stress or homogenous area.

The estimated b-values for aftershocks of April 2015 and May 2015 earthquake as well as for all of them taken together are about 1.0 indicating that stress in the rupture zone after the major earthquakes is normal. The 'b' value for M≥4.5 = 0.862, p = 1.049 for 20 days (Goda et al. 2015).

Low b-value would have indicated presence of accumulated stress. The p-value for all the aftershocks taken together and individually for April and May earthquakes are 0.63, 0.73 and 0.81, respectively indicating slow decay rate as compared to normal decay rate of 1.

Table 1: Parameters of aftershocks

Parameter	Apr	May	All
B	0.98	1.07	0.98
P	0.73	0.81	0.63
Nos.	M6=2,M5=16,M4=204 Total=222	M6=1,M5=11,M4=104 Total=116	M6=3,M5=11,M4=306 Total=338
Area	150kmx55km	50kmx50km	180kmx55km

6. Conclusions

The aftershocks of the two major earthquakes have remained confined to the rupture zone. They have not spread out with time. The M4 aftershocks have continued a little more time (more than 5 months against the expected duration of 3 months. The rate of decay 0.6-0.8 is found to be slower than expected 1. The normal b-value of 1 indicates presence of normal stress after the two major earthquakes. Behavior of the aftershocks of the two major earthquakes is similar and it is also the same for all the aftershocks taken together.

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Appendix 1: List of aftershocks of 2015 Nepal earthquake of Mag 7.8 till 10.09.2015 totaling 336 (Source: EMSC)

DATE	(HH:MM) (UTC)	Long.	Lat.	Mag.	Place
25.04.2015	6:11	84.7079	28.1473	7.8	34 km ESE of Lamjung
25.04.2015	6:37	85.8182	27.7239	5.3	28 km SSW of Kodari
25.04.2015	6:45	84.8645	28.1927	6.7	49 km E of Lamjung
25.04.2015	6:56	85.6501	27.91	5.7	25 km NNE of Nagarkot
25.04.2015	7:13	85.5502	27.5458	5	5 km SE of Panaoti
25.04.2015	7:16	85.2694	28.002	5	33 km N of Kathmandu
25.04.2015	7:39	85.7483	27.6659	4.5	22 km E of Banepa
25.04.2015	7:47	85.5572	27.8549	5.3	15 km NNE of Nagarkot
25.04.2015	8:05	85.7304	27.7307	4.7	20 km E of Nagarkot
25.04.2015	8:16	85.6878	27.6733	5	17 km ENE of Banepa
25.04.2015	8:20	85.7219	27.9528	4.7	22 km W of Kodari
25.04.2015	8:29	84.7097	27.9903	5.1	41 km SE of Lamjung
25.04.2015	8:49	84.8874	27.7579	4.5	39 km NNW of Hitura
25.04.2015	8:55	85.5029	27.6364	5.4	1 km WNW of Banepa
25.04.2015	9:03	85.3069	27.8741	5	19 km N of Kathmandu
25.04.2015	9:30	85.437	27.9938	5.1	31 km NNW of Nagarkot

25.04.2015	10:23	85.762	27.8732	4.2	20 km WSW of Kodari
25.04.2015	10:40	85.8384	27.5667	4.9	32 km E of Panaoti
25.04.2015	10:53	85.8701	27.7719	4.4	21 km SSW of Kodari
25.04.2015	12:01	85.4854	28.0438	4.2	36 km N of Nagarkot
25.04.2015	12:17	85.5638	28.0049	4.6	32 km N of Nagarkot
25.04.2015	12:44	84.6587	28.1513	5.2	29 km ESE of Lamjung
25.04.2015	13:30	85.89	27.7476	4.7	23 km SSW of Kodari
25.04.2015	14:10	85.6622	27.5843	4.7	14 km E of Panaoti
25.04.2015	17:42	85.6175	27.9087	5.3	23 km NNE of Nagarkot
25.04.2015	18:58	85.3739	27.6781	4.2	5 km ESE of Kathmandu
25.04.2015	20:32	85.7583	27.5632	4.4	24 km E of Panaoti
25.04.2015	21:07	85.7266	27.732	4.9	20 km E of Nagarkot
25.04.2015	23:12	86.0062	27.5606	4.3	27 Km NNW of Ramechap
25.04.2015	23:16	84.8744	27.8052	5.5	41 km WNW of Kirtipur
26.04.2015	2:48	84.6095	28.156	4.6	24 km ESE of Lamjung
26.04.2015	3:21	85.536	27.4563	4.4	14 km S of Panaoti
26.04.2015	4:58	84.6866	27.8362	4.5	30 km NE of Bharatpur
26.04.2015	7:09	85.9971	27.782	6.7	19 km SSE of Kodari
26.04.2015	07:26	85.8284	27.707	5	29 km SSW of Kodari
26.04.2015	7:36	85.929	27.7189	4.7	25 km S of Kodari
26.04.2015	8:40	85.6858	27.8449	4.6	21 km NE of Nagarkot
26.04.2015	8:46	85.6782	27.591	4.7	16 km E of Panaoti
26.04.2015	13:11	85.3745	27.7571	4.6	8 km NE of Kathmandu
26.04.2015	14:44	85.7493	27.532	4.7	24 km ESE of Panaoti
26.04.2015	14:57	84.6702	28.1203	4.5	31 km ESE of Lamjung
26.04.2015	16:26	85.7704	27.7612	5.2	25 km ENE of Nagarkot
26.04.2015	18:54	84.7757	28.0627	4.5	43 km ESE of Lamjung
26.04.2015	20:39	85.7964	27.9696	4.5	15 km W of Kodari
26.04.2015	22:32	85.6194	27.4597	4.6	17 km SE of Panaoti
27.04.2015	0:39	84.9165	27.6128	4.5	23 km NNW of Hitura
27.04.2015	2:33	85.55	27.67	4.2	23 km E of Kathmandu
27.04.2015	4:14	85.23	28.24	4.3	60 km N of Kathmandu
27.04.2015	4:20	85.86	27.93	4	59 km NE of Kathmandu
27.04.2015	9:32	85.12	27.8	4	23 km NW of Kathmandu
27.04.2015	14:57	85.92	27.82	4.1	61 km E of Kathmandu
27.04.2015	15:51	85.14	27.73	4.5	18 km W of Kathmandu
27.04.2015	16:54	85.89	27.82	4.2	58 km E of Kathmandu
27.04.2015	17:45	85.03	28.19	4	61 km NW of Kathmandu

27.04.2015	21:14	85.51	27.92	4.2	31 km NE of Kathmandu
27.04.2015	21:27	85.74	27.76	4.4	42 km E of Kathmandu
27.04.2015	22:26	84.65	28.1	4.2	79 km NW of Kathmandu
27.04.2015	23:20	85.26	27.93	4.4	26 km N of Kathmandu
28.04.2015	2:55	85.8	27.76	4	48 km E of Kathmandu
28.04.2015	6:23	85.55	27.96	4	36 km NE of Kathmandu
28.04.2015	9:25	85.83	27.83	4	52 km E of Kathmandu
28.04.2015	10:59	85.17	27.78	4	17 km NW of Kathmandu
28.04.2015	11:18	85.88	27.88	4.2	59 km E of Kathmandu
28.04.2015	16:22	84.78	28.2	4	77 km NW of Kathmandu
28.04.2015	23:04	85.63	27.93	4	40 km NE of Kathmandu
29.04.2015	0:09	85.14	27.79	4.2	20 km NW of Kathmandu
29.04.2015	7:32	85.37	28.04	4	38 km E of Kathmandu
29.04.2015	9:39	84.89	27.86	4.5	46 km NW of Kathmandu
29.04.2015	11:27	85.52	27.93	4.6	32 km NE of Kathmandu
29.04.2015	17:16	85.66	27.92	4.4	41 km NE of Kathmandu
30.04.2015	0:37	84.62	27.92	4.3	73 km W of Kathmandu
30.04.2015	2:46	85.34	28.05	4.7	39 km N of Kathmandu
30.04.2015	17:34	85.87	27.92	4.3	59 km NE of Kathmandu
30.04.2015	19:13	85.98	27.7	4.2	65 km E of Kathmandu
30.04.2015	21:11	85.3	27.68	4	3 km SW of Kathmandu
01.05.2015	4:50	85.95	27.75	4	62 km E of Kathmandu
01.05.2015	5:43	85.33	28.04	4.5	38 km N of Kathmandu
01.05.2015	11:52	85.99	27.74	4	66 km E of Kathmandu
01.05.2015	14:42	85.87	27.88	4.2	58 km E of Kathmandu
01.05.2015	18:14	85.32	28.04	4	37 km N of Kathmandu
02.05.2015	3:47	85.5	27.93	4.2	31 km NE of Kathmandu
02.05.2015	5:28	85.74	27.72	4	41 km E of Kathmandu
02.05.2015	5:35	84.77	28.41	4.9	95 km NW of Kathmandu
02.05.2015	21:44	85.88	27.63	4.5	56 km E of Kathmandu
03.05.2015	0:02	85.04	28.08	4	50 km NW of Kathmandu
03.05.2015	2:15	84.87	27.98	4.1	54 km NW of Kathmandu
03.05.2015	5:01	84.83	27.94	4.5	55 km NW of Kathmandu
03.05.2015	11:35	84.97	27.76	4.5	35 km W of Kathmandu
03.05.2015	14:42	85.72	28.09	4.2	58 km NE of Kathmandu
03.05.2015	16:54	84.94	28.05	4	54 km NW of Kathmandu
03.05.2015	23:14	85.83	27.7	4.4	50 km E of Kathmandu
04.05.2015	1:15	86.12	27.65	4.5	67 km E of Kathmandu

04.05.2015	4:09	85.21	27.97	4.2	32 km N of Kathmandu
04.05.2015	7:32	84.8	28.12	4	69 km NW of Kathmandu
04.05.2015	9:55	85.86	27.95	4.4	60 km NE of Kathmandu
04.05.2015	10:29	86.23	27.79	4.7	90 km E of Kathmandu
04.05.2015	12:17	86	27.74	4.2	67 km E of Kathmandu
05.05.2015	11:15	86	27.96	4.2	73 km NE of Kathmandu
05.05.2015	11:18	86.03	27.74	4.3	70 km E of Kathmandu
06.05.2015	12:17	84.68	28.01	4.2	72 km NW of Kathmandu
06.05.2015	16:34	85.26	28.04	4	38 km N of Kathmandu
06.05.2015	21:56	85.19	27.75	4.2	14 km NW of Kathmandu
07.05.2015	2:11	85.16	27.79	4	19 km NW of Kathmandu
07.05.2015	16:30	85.46	27.92	4	28 km NE of Kathmandu
07.05.2015	20:34	85.58	27.94	4	37 km NE of Kathmandu
08.05.2015	00:32	86.06	27.72	4.9	73 km E of Kathmandu
08.05.2015	21:23	85.01	27.93	4	40 km NW of Kathmandu
09.05.2015	20:05	85.96	28.04	4.2	73 km NE of Kathmandu
10.05.2015	5:23	85.25	28.02	4	36 km N of Kathmandu
11.05.2015	2:50	85.86	27.99	4.2	62 km NE of Kathmandu
11.05.2015	18:09	85.75	27.91	4	48 km NE of Kathmandu
11.05.2015	18:22	84.91	28.1	4	66 km NW of Kathmandu
11.05.2015	20:23	84.9	28.16	4.1	66 km NW of Kathmandu
12.05.2015	7:05	86.17	27.89	7.3	86 km E of Kathmandu
12.05.2015	7:17	86.31	27.99	5.6	103km E of Kathmandu
12.05.2015	7:34	86.36	27.94	5.5	106 km E of Kathmandu
12.05.2015	7:36	86.31	27.65	6.2	98 km E of Kathmandu
12.05.2015	7:43	86.27	27.62	5.1	94 km E of Kathmandu
12.05.2015	7:48	86.63	27.55	5	130 km E of Kathmandu
12.05.2015	8:01	86.04	27.68	4.3	71 km E of Kathmandu
12.05.2015	8:06	86.24	27.76	5.1	91 km E of Kathmandu
12.05.2015	8:21	86.36	27.86	5.3	87 km E of Kathmandu
12.05.2015	8:24	86.11	27.79	5	78 km E of Kathmandu
12.05.2015	8:35	86	27.88	4.7	70 km E of Kathmandu
12.05.2015	8:39	86.21	27.69	4.7	88 km E of Kathmandu
12.05.2015	8:59	86.31	27.73	5.3	83 km E of Kathmandu
12.05.2015	9:29	86.01	27.7	4.2	68 km E of Kathmandu
12.05.2015	10:04	86.03	27.68	4.4	70 km E of Kathmandu
12.05.2015	10:15	86.09	27.75	4.3	77 km E of Kathmandu
12.05.2015	10:31	86.05	27.69	4.2	72 km E of Kathmandu

12.05.2015	10:35	86.08	27.78	4.5	75km E of Kathmandu
12.05.2015	10:41	86.24	27.76	4.4	91 km E of Kathmandu
12.05.2015	11:06	86.16	27.62	4.7	83 km E of Kathmandu
12.05.2015	11:21	86.14	27.7	4.2	81 km E of Kathmandu
12.05.2015	11:58	85.86	27.58	4.3	55 km E of Kathmandu
12.05.2015	12:28	85.95	27.66	4.5	62 km E of Kathmandu
12.05.2015	13:08	85.97	27.72	4.0	64 km E of Kathmandu
12.05.2015	13:43	85.81	27.73	4.5	48 km E of Kathmandu
12.05.2015	13:57	86.23	27.84	4.4	91 km E of Kathmandu
12.05.2015	15:28	86.45	27.97	4.8	115 km E of Kathmandu
12.05.2015	16:55	85.97	27.73	4.4	64 km E of Kathmandu
12.05.2015	17:28	86.31	27.66	4.8	98 km E of Kathmandu
12.05.2015	19:34	86.09	27.68	4.3	76 km E of Kathmandu
12.05.2015	19:37	85.88	28.25	4.5	82 km E of Kathmandus
12.05.2015	20:22	85.06	27.57	4.5	30 km SW of Kathmandu
12.05.2015	20:44	86.22	27.82	4	90 km E of Kathmandu
12.05.2015	21:25	84.64	27.81	5.2	68 km W of Kathmandu
12.05.2015	22:53	86.47	27.82	4.3	114 km E of Kathmandu
12.05.2015	23:39	85.99	27.83	4	67 km E of Kathmandu
13.05.2015	2:23	86.21	27.71	4.1	88 km E of Kathmandu
13.05.2015	2:43	86.25	27.75	4.4	92 km E of Kathmandu
13.05.2015	4:48	86.19	27.79	4.6	86 km E of Kathmandu
13.05.2015	6:26	86.32	27.69	4.8	101 km E of Kathmandu
13.05.2015	6:37	85.98	27.74	4.6	65 km E of Kathmandu
13.05.2015	6:49	86.25	27.84	4.6	93 km E of Kathmandu
13.05.2015	6:53	86.18	27.64	4.7	85 km E of Kathmandu
13.05.2015	8:45	86.16	27.6	4.3	84 km E of Kathmandu
13.05.2015	9:52	86.29	27.85	4	97 km E of Kathmandu
13.05.2015	10:59	85.99	27.87	4	67 km E of Kathmandu
13.05.2015	15:36	85.7	27.64	4	38 km E of Kathmandu
13.05.2015	15:51	86.15	27.7	4.1	82 km E of Kathmandu
13.05.2015	18:31	86.31	27.92	4.3	100 km E of Kathmandu
13.05.2015	21:28	86.07	27.66	4.1	74 km E of Kathmandu
13.05.2015	21:38	86.15	27.88	5	84 km E of Kathmandu
14.05.2015	3:07	85.85	27.42	4.4	61 km E of Kathmandu
14.05.2015	3:21	86.15	27.83	4.5	83 km E of Kathmandu
14.05.2015	9:35	85.86	27.57	4.3	55 km E of Kathmandu
14.05.2015	13:58	86.14	27.75	4	81 km E of Kathmandu

14.05.2015	15:05	86.04	27.71	4	71 km E of Kathmandu
14.05.2015	15:55	85.84	27.84	4	53 km E of Kathmandu
14.05.2015	21:53	86.25	27.63	4.1	92 km E of Kathmandu
14.05.2015	22:21	86.09	27.69	4.3	75 km E of Kathmandu
15.05.2015	1:42	84.9	28.09	4.9	55 km E of Kathmandu
15.05.2015	5:06	84.84	27.92	4	53 km E of Kathmandu
15.05.2015	9:24	86.2	27.61	4.5	87 km E of Kathmandu
15.05.2015	17:13	86.17	27.74	4	84 km E of Kathmandu
15.05.2015	20:30	84.7	28.07	4	73 km NW of Kathmandu
15.05.2015	22:43	86.12	27.65	4.1	79 km E of Kathmandu
15.05.2015	22:53	86.09	27.66	4.1	76 km E of Kathmandu
16.05.2015	0:26	85.48	27.97	4	34 km NE of Kathmandu
16.05.2015	3:39	85.84	27.71	4.8	51 km E of Kathmandu
16.05.2015	3:50	85.31	27.45	4.2	28 km S of Kathmandu
16.05.2015	11:34	86.3	27.58	5.6	98 km E of Kathmandu
16.05.2015	14:59	86.21	27.68	4.3	88 km E of Kathmandu
16.05.2015	23:15	85.98	27.72	4.4	65 km E of Kathmandu
17.05.2015	5:45	85.76	27.46	4.4	51 km SE of Kathmandu
17.05.2015	14:55	86.24	27.84	4.4	92 km E of Kathmandu
18.05.2015	3:26	86.07	27.71	4.2	74 km E of Kathmandu
18.05.2015	5:39	86.2	27.69	4	93 km E of Kathmandu
18.05.2015	12:42	84.88	28.11	4.1	63 km NW of Kathmandu
18.05.2015	22:49	85.93	27.64	4.4	61 km E of Kathmandu
18.05.2015	23:39	85.93	27.64	4.4	61 km E of Kathmandu
19.05.2015	5:44	85.99	27.9	4	70 km E of Kathmandu
19.05.2015	6:24	85.99	27.9	4	70 km E of Kathmandu
19.05.2015	10:59	85.86	27.82	4.3	55 km E of Kathmandu
19.05.2015	21:02	85.26	27.52	4.4	21 km E of Kathmandu
20.05.2015	5:25	86.33	27.84	4.2	101 km E of Kathmandu
20.05.2015	9:02	85.03	27.3	4.4	53 km SW of Kathmandu
21.05.2015	1:45	84.98	28.02	4	49 km NW of Kathmandu
21.05.2015	8:26	86.32	27.85	4.2	29 km E of Kathmandu
21.05.2015	9:11	85.46	27. 93	4	100 km E of Kathmandu
21.05.2015	13:45	84.98	28.02	4	49 km NW of Kathmandu
22.05.2015	9:00	85.14	27.79	4.2	20 km NW of Kathmandu
22.05.2015	11:45	86.03	27.45	4.4	75 km E of Kathmandu
22.05.2015	13:04	85.09	27.78	4	61 km E of Kathmandu
23.05.2015	7:29	86.2	27.74	4.2	87 km E of Kathmandu

23.05.2015	16:41	85.51	27.9	4.4	29 km NE of Kathmandu
24.05.2015	1:21	86.18	27.67	4.2	85 km E of Kathmandu
24.05.2015	4:53	86.28	27.76	4.4	95 km E of Kathmandu
24.05.2015	6:01	86	27.84	4.2	69 km E of Kathmandu
24.05.2015	7:10	86.29	27.8	4.4	96 km E of Kathmandu
24.05.2015	17:30	86.26	27.76	4.3	93 km E of Kathmandu
24.05.2015	21:38	84.77	28.2	4.4	77 km NW of Kathmandu
25.05.2015	5:15	86.07	27.71	4.1	74 km E of Kathmandu
25.05.2015	16:31	86.19	27.74	4.4	86 km E of Kathmandu
26.05.2015	8:26	86.24	27.84	4.3	92 km E of Kathmandu
26.05.2015	12:03	86.3	27.63	4.1	97 km E of Kathmandu
26.05.2015	12:54	86.05	27.71	4.4	72 km E of Kathmandu
26.05.2015	17:07	85.08	28.18	4.6	58 km NW of Kathmandu
26.05.2015	21:22	84.79	27.99	4	61 km NW of Kathmandu
26.05.2015	21:55	84.8	27.95	4	58 km NW of Kathmandu
27.05.2015	6:18	86.2	27.59	4.2	88 km E of Kathmandu
27.05.2015	7:30	85.53	27.93	4.5	33 km NE of Kathmandu
27.05.2015	23:44	86.25	27.77	4.2	92 km E of Kathmandu
28.05.2015	5:51	86.19	27.59	4.2	87 km E of Kathmandu
28.05.2015	6:29	86.16	27.59	4.1	84 km E of Kathmandu
28.05.2015	18:52	86.34	27.82	4.2	10 km E of Kathmandu
28.05.2015	23:35	84.94	28.07	4.2	55 km NW of Kathmandu
29.05.2015	2:45	84.72	28.17	4	79 km NW of Kathmandu
29.05.2015	6:45	84.84	28.01	4.8	58 km NW of Kathmandu
29.05.2015	10:00	84.9	28.08	4.8	59 km NW of Kathmandu
29.05.2015	20:07	85.21	27.75	4	12 km NW of Kathmandu
30.05.2015	14:50	85.19	28.01	4	37 km N of Kathmandu
30.05.2015	16:28	84.83	27.55	4.4	51 km W of Kathmandu
31.05.2015	8:09	84.46	28.29	4.2	107km NW of Kathmandu
31.05.2015	22:50	85.51	27.98	4	36 km NE of Kathmandu
02.06.2015	5:03	86.2	27.78	4	81 km E of Kathmandu
02.06.2015	21:00	85.78	27.84	4.1	48 km E of Kathmandu
03.06.2015	7:52	85.87	27.79	4.5	55 km E of Kathmandu
03.06.2015	8:54	86.07	27.76	4.2	74 km E of Kathmandu
03.06.2015	11:53	86.26	27.7	4.5	93 km E of Kathmandu
04.06.2015	10:30	86.2	27.76	4	87 km E of Kathmandu
05.06.2015	4:17	85.78	27.79	4.1	46 km E of Kathmandu
05.06.2015	8:31	85.21	27.71	4	11 km W of Kathmandu

05.06.2015	20:48	85.86	28.26	4.2	82 km NE of kathmandu
06.06.2015	5:00	86.18	27.58	4	86 km E of Kathmandu
06.06.2015	17:00	86.18	27.58	4	86 km E of Kathmandu
07.06.2015	5:17	85.64	27.9	4.6	38 km NE of kathmandu
07.06.2015	16:50	86.13	27.87	4.1	82 km E of Kathmandu
09.06.2015	21:05	85.81	27.87	4.1	52 km E of Kathmandu
10.06.2015	7:51	85.61	27.8	4.3	31 km E of Kathmandu
10.06.2015	9:06	86.1	27.62	4.2	77 km E of Kathmandu
10.06.2015	18:41	86.07	27.67	4	74 km E of Kathmandu
10.06.2015	19:36	84.81	28.21	4.6	75 km NW of Kathmandu
11.06.2015	4:17	85.78	27.8	4.6	47 km E of Kathmandu
11.06.2015	16:12	85.72	27.91	4.9	46 km NE of Kathmandu
11.06.2015	19:37	84.69	28.11	4.4	77 km NW of Kathmandu
12.06.2015	4:34	86.09	27.67	4.4	76 km E of Kathmandu
13.06.2015	1:18	86.07	27.68	4.8	74 km E of Kathmandu
14.06.2015	0:14	85.15	27.8	4.2	20 km NW of Kathmandu
15.06.2015	10:07	85.72	27.87	4.1	44 km NE of Kathmandu
16.06.2015	16:11	86.16	27.7	4.1	83 km E of Kathmandu
17.06.2015	00:13	85.28	27.68	4.4	5 km SW of Kathmandu
17.06.2015	0:29	85.37	27.89	4.3	21 km N of Kathmandu
17.06.2015	0:41	85.58	27.9	4	34 km E of Kathmandu
17.06.2015	2:15	85.58	28.11	4.7	64 km NE of Kathmandu
18.06.2015	2:39	85.11	28.14	4.1	53 km NW of Kathmandu
19.06.2015	8:05	84.92	28.26	4	73 km NW of Kathmandu
19.06.2015	20:55	84.94	28.17	4.2	64 km NW of Kathmandu
20.06.2015	12:23	82.78	28.75	4.7	275km NW of Kathmandu
21.06.2015	13:41	86	27.8	4.3	68 km E of Kathmandu
22.06.2015	7:34	86.17	27.67	4	84 km E of Kathmandu
24.06.2015	9:14	85.75	27.85	4	45 km E of Kathmandu
25.06.2015	15:22	85.28	27.81	4	13 km N of Kathmandu
25.06.2015	18:04	86.21	27.66	4.1	88 km E of Kathmandu
25.06.2015	18:06	85.49	27.94	4.2	31 km NE of Kathmandu
26.06.2015	9:00	85.39	27.58	4.1	15 km SE of Kathmandu
26.06.2015	12:17	86.28	27.74	4.2	95 km E of Kathmandu
28.06.2015	16:16	85.66	27.92	4.3	41 km N of Kathmandu
28.06.2015	23:57	85.95	27.91	4.7	66 km NE of Kathmandu
29.06.2015	17:42	85.73	27.88	4	45 km E of Kathmandu
29.06.2015	21:46	85.76	27.55	4.4	47 km E of Kathmandu

30.06.2015	21:48	85.74	27.8	4	43 km E of Kathmandu
01.07.2015	3:27	86.12	27.71	4	79 km E of Kathmandu
01.07.2015	9:49	85.14	28.06	4	44 km NW of Kathmandu
01.07.2015	23:41	85.54	27.67	4.1	22 km E of Kathmandu
02.07.2015	1:56	85.31	27.8	4.5	11 km N of Kathmandu
03.07.2015	20:04	84.96	27.8	4.7	37 km W of Kathmandu
04.07.2015	19:42	85.87	27.86	4.4	57 km E of Kathmandu
05.07.2015	4:22	86.2	27.67	4.2	87 Km E of Kathmandu
06.07.2015	5:03	86.2	27.69	4.3	87 Km E of Kathmandu
06.07.2015	15:29	85.69	27.94	4.2	45 km NE of Kathmandu
08.07.2015	4:10	85.68	27.92	4.2	43 km NE of Kathmandu
08.07.2015	4:34	86.23	27.6	4.1	90 Km E of Kathmandu
09.07.2015	12:14	85.73	27.89	4.4	45 km NE of Kathmandu
10.07.2015	20:43	86.23	27.8	4.4	90 Km E of Kathmandu
10.07.2015	21:13	86.1	27.75	4.3	77 Km E of Kathmandu
13.07.2015	10:16	85.34	28.06	4	40 km N of Kathmandu
13.07.2015	11:54	86.09	27.63	4.2	76 Km E of Kathmandu
16.07.2015	23:24	84.74	28.18	4	78 km NW of Kathmandu
21.07.2015	2:24	86.39	27.86	4.3	107 Km E of Kathmandu
22.07.2015	16:29	85.32	27.7	4.6	0 km S of Kathmandu
24.07.2015	18:20	86.28	27.61	4.3	95 Km E of Kathmandu
25.07.2015	14:19	86	27.66	4.5	67 Km E of Kathmandu
26.07.2015	3:45	86.22	27.68	4.1	89 Km E of Kathmandu
26.07.2015	4:18	85.75	27.85	4	45 km E of Kathmandu
27.07.2015	12:38	85.48	27.94	4.2	31 km NE of Kathmandu
28.07.2015	3:36	85.75	27.8	4.1	44 km E of Kathmandu
28.07.2015	12:53	86.04	27.68	4	71 Km E of Kathmandu
30.07.2015	14:33	86.09	27.66	4.5	76 Km E of Kathmandu
01.08.2015	1:37	85.71	27.81	4.2	40 km E of Kathmandu
05.08.2015	8:14	86.07	27.64	4.3	74 Km E of Kathmandu
05.08.2015	11:53	86.07	27.63	4.1	74 Km E of Kathmandu
06.08.2015	14:51	85.76	27.86	4.1	47 km E of Kathmandu
07.08.2015	6:12	85.5	27.5	4.4	29 km SE of Kathmandu
08.08.2015	0:39	85.7	27.77	4	38 km E of Kathmandu
08.08.2015	15:40	86.26	27.69	4.1	93 Km E of Kathmandu
09.08.2015	2:10	85.52	27.94	4.1	33 km NE of Kathmandu
09.08.2015	22:30	84.8	28.23	4.2	78 km NW of Kathmandu
12.08.2015	20:04	85.2	27.72	4	12 km W of Kathmandu

14.08.2015	13:02	85.97	27.59	4.3	65 km E of Kathmandu
15.08.2015	4:25	86.08	27.87	4.1	77 Km E of Kathmandu
15.08.2015	5:42	87.84	27.57	4.6	178 Km W of Kathmandu
15.08.2015	18:11	85.91	27.65	4.7	58 km E of Kathmandu
17.08.2015	22:23	86.13	27.91	4.2	83 Km E of Kathmandu
20.08.2015	6:02	85.29	28	4.6	33 km N of Kathmandu
21.08.2015	6:36	85.48	27.96	4	33 km NE of Kathmandu
23.08.2015	9:02	86.24	27.96	5.1	95 Km E of Kathmandu
25.08.2015	9:23	86.22	27.68	4	89 Km E of Kathmandu
26.08.2015	19:06	85.74	27.85	4.2	44 km E of Kathmandu
27.08.2015	0:22	85.89	28.12	4.1	63 km NW of Kathmandu
29.08.2015	21:24	85.94	27.92	4.3	45 km NW of Kathmandu
30.08.2015	2:41	86.23	27.66	4.1	90 Km E of Kathmandu
30.08.2015	13:17	85.62	27.61	4.7	31 km E of Kathmandu
31.08.2015	17:48	85.69	27.92	4.2	44 km NE of Kathmandu
01.09.2015	23:06	86.3	27.66	4.1	97 Km E of Kathmandu
02.09.2015	23:25	86.01	27.75	4.3	68 Km E of Kathmandu
09.09.2015	12:38	86.24	27.82	4.0	92 Km E of Kathmandu