Taranaki seismic and ground deformation monitoring: July 2017 to June 2018

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EXECUTIVE SUMMARY

During July 2017 to June 2018, 215 earthquakes were located in the Taranaki region by GeoNet. This is similar to the annual numbers since 1994, and accounts for about 1% of the total number of earthquakes located in New Zealand in that period. Similar to the long-term trend, shallow earthquakes (less than 50 km deep) occurred west and north of Mt Taranaki, or north-east of Stratford; earthquakes to the south-east, near Hawera, are substantially deeper (greater than 100 km).

No earthquakes were located beneath Mt Taranaki, and we conclude that during the period July 2017 to June 2018 seismic activity on the Taranaki Peninsula was not significant in assessing the state of the volcano.

During the year, no changes were made to the seismograph network in Taranaki, and no substantial technical problems occurred.

Three GNSS[1] monitoring sites are operated near Mt Taranaki. These sites have recorded stable conditions, that is, no locally sourced deformation or obvious flank instability of the volcano has been observed since they were installed.

[1] GNSS = Global Navigation Satellite System. This includes GPS (the US Global Positioning System). These satellite signals are used for precisely measuring the position of a site, and also for navigation.

1.0 INTRODUCTION

This report summarises earthquake occurrence and ground deformation in Taranaki for the period 1 July 2017 to 30 June 2018. It compares the location and rate of earthquake occurrence in the last year with recent historical activity and also examines the ground deformation data. These are used in assessing the quiescent state of Taranaki volcano.

2.0 EVOLUTION OF THE SEISMOGRAPH NETWORK

The Taranaki Volcano-Seismic Network was commissioned by the Department of Scientific and Industrial Research in late-1993, with the first usable data being recorded in January 1994. Since that time data have been recorded almost continuously.

In 2001, GeoNet began improving the existing network for monitoring earthquakes in the whole of New Zealand. In 2005, work commenced to upgrade seismograph installations in Taranaki to a standard equivalent to that in other parts of New Zealand. The upgraded seismographs in Taranaki substantially improved the monitoring capabilities in the region.

The network upgrade in Taranaki was completed in 2010. The last change to seismographs in Taranaki occurred in October 2012, when a new instrument (NBEZ, Figure 2.1) was installed in a borehole to replace a noisy site nearby.

There are currently nine seismographs in the Taranaki area which continuously send data to GeoNet data centres for analysis. Data are sent via network hubs located at the Taranaki Emergency Management Office (TEMO) in New Plymouth; at Kahui Road west of Mt Taranaki; and at Eltham (Figure 2.1).

Several seismographs outside Taranaki record earthquakes that occur in Taranaki, and are usually required to locate earthquakes in Taranaki.

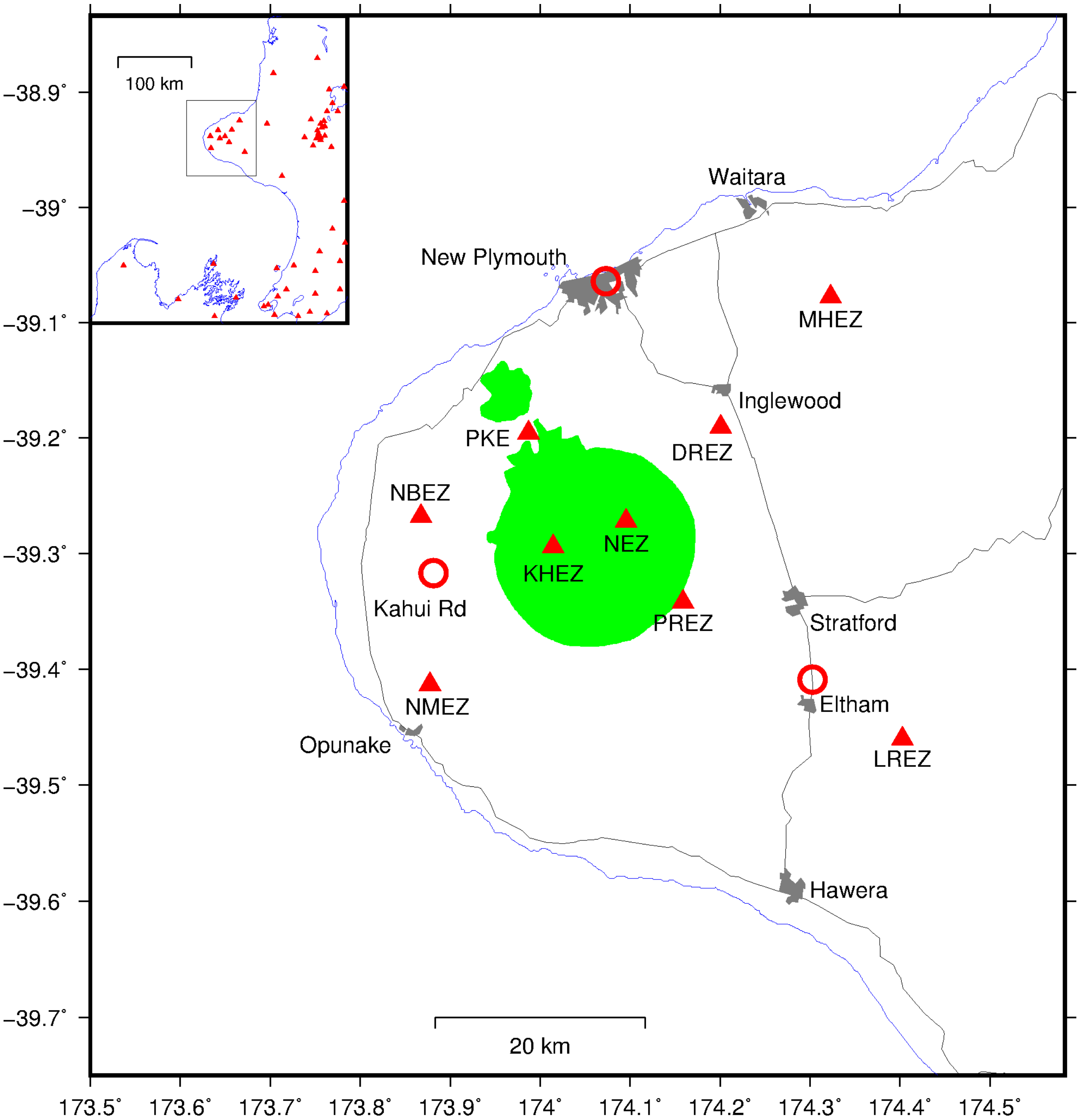

Figure 2.1 A map of the Taranaki seismographs as at 30 June 2018. Seismograph sites are indicated by red triangles and three or four-letter site codes. NEZ is North Egmont, NBEZ is Newall Road Borehole, and PKE is Pukeiti. DREZ is Durham Road, MHEZ is Mangahewa, and NMEZ is Namu Road. KHEZ is Kahui Hut, PREZ is Palmer Road, and LREZ is Lake Rotokare. Data connection (hub) sites are shown by red circles. Main population centres are shown in grey and named. The Egmont National Park is shown as a green area. Major roads are shown as black lines. The coastline is marked in blue. The inset shows Taranaki and nearby GeoNet seismographs (red triangles), some of which are used in locating earthquakes in the Taranaki region.

3.0 EARTHQUAKE DATA ANALYSIS

The Taranaki Research Group at Auckland University was responsible for analysis of data recorded by the network from January 1994 until June 1997. These analyses were regularly reported to Taranaki Regional Council (TRC), and data from the period January 1994 to March 1995 were summarised in Cavill et al. (1997). In July 1997, GNS Science took over responsibility for data analysis and annual reporting under contract to TRC.

Currently, seismic data from Taranaki are continuously transmitted to GeoNet data centres. In near real-time, an automatic earthquake analysis program (SeisComP3[2]) is used to search for signals that may be caused by earthquakes. When the signal from an earthquake is detected, the program estimates the arrival time of the earthquake waves at each of the seismographs (in Taranaki and elsewhere) and attempts to automatically locate the earthquake.

SeisComP3 is capable of automatically obtaining a location for all moderate size earthquakes within 1-2 minutes of an earthquake's occurrence. In most cases, the automatic locations are sufficiently accurate for rapid notification of these events to the public and responding authorities without requiring additional manual checking or analysis. SeisComP3 has been very successful in this regard, but there have been some shortcomings. Because of the way GeoNet has configured SeisComP3, it is less sensitive to smaller earthquakes in Taranaki than the system that operated before January 2012. This was discussed in detail in the 2012-13 report (Sherburn and Scott 2014) and highlighted in a presentation to the Taranaki Seismic and Volcanic Advisory Group in September 2013.

In compiling this report we have used data from the GeoNet earthquake catalogue[3], as it is the official record of seismicity in New Zealand. The catalogue currently comprises locations from the previous analysis system up to December 2011 and SeisComP3 locations from January 2012 to the present day.

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2 www.seiscomp3.org

3 www.geonet.org.nz/data/types/eq_catalogue

4.0 FACTORS AFFECTING THE RELIABILITY OF EARTHQUAKE LOCATIONS

The precision and reliability of earthquake locations determined from seismic networks depends on several factors. These include:

- The number of instruments at which an earthquake is recorded. Small earthquakes are often poorly recorded or recorded on only a few instruments. Locations for these earthquakes are not as well constrained as those for larger events which are well recorded at many more instruments distributed over a range of distances and directions.
- How far an earthquake is from the nearest seismographs. There is little control on the location of earthquakes well outside a network of seismographs so these earthquake locations usually come with large uncertainties; in the case of Taranaki this particularly applies to offshore earthquakes.
- Physical and electronic problems with a seismic network. Various problems can at least degrade data quality and at worst, may reduce the number of seismographs at which an earthquake can be recorded.

In GeoNet's configuration of SeisComP3, poorly constrained automatic earthquake locations were sometimes given an incorrect depth of 0 km (that is, sea level). Such a depth is, in most cases, both geologically unreasonable and results in unrealistically high predicted ground shaking values close to the earthquake epicentre. To prevent this problem, GeoNet has set some limitations on the minimum depth of earthquakes located. In effect, this means that any earthquakes that are truly shallower than 5 km will usually be assigned a fixed 5 km depth.

5.0 EARTHQUAKE RESULTS

Two hundred and fifteen (215) earthquakes were located in the Taranaki region by GeoNet between July 2017 and June 2018 (Figure 5.1). This accounts for about 1% of the total number of earthquakes located in New Zealand for the same period. The largest event was of magnitude 3.5 on 1 March 2018, located on the southern outskirts of New Plymouth, at 14 km depth. GeoNet received 727 felt reports for this event.

Shallow earthquakes (for the purpose of this report, those with a depth less than 50 km) were concentrated west and north of Mt Taranaki, and north-east of Stratford (Figure 5.1). Deep earthquakes (for the purpose of this report, those with a depth greater than 50 km) were mainly located in the Hawera region beneath south-east Taranaki (Figure 5.1).

The depths of earthquakes in Taranaki shallower than 50 km are shown in Figures 5.2A and 5.2B. Most earthquakes west of Mt Taranaki occurred between 5 and 20 km depth, and most located east of Mt Taranaki were at the deeper end of this range.

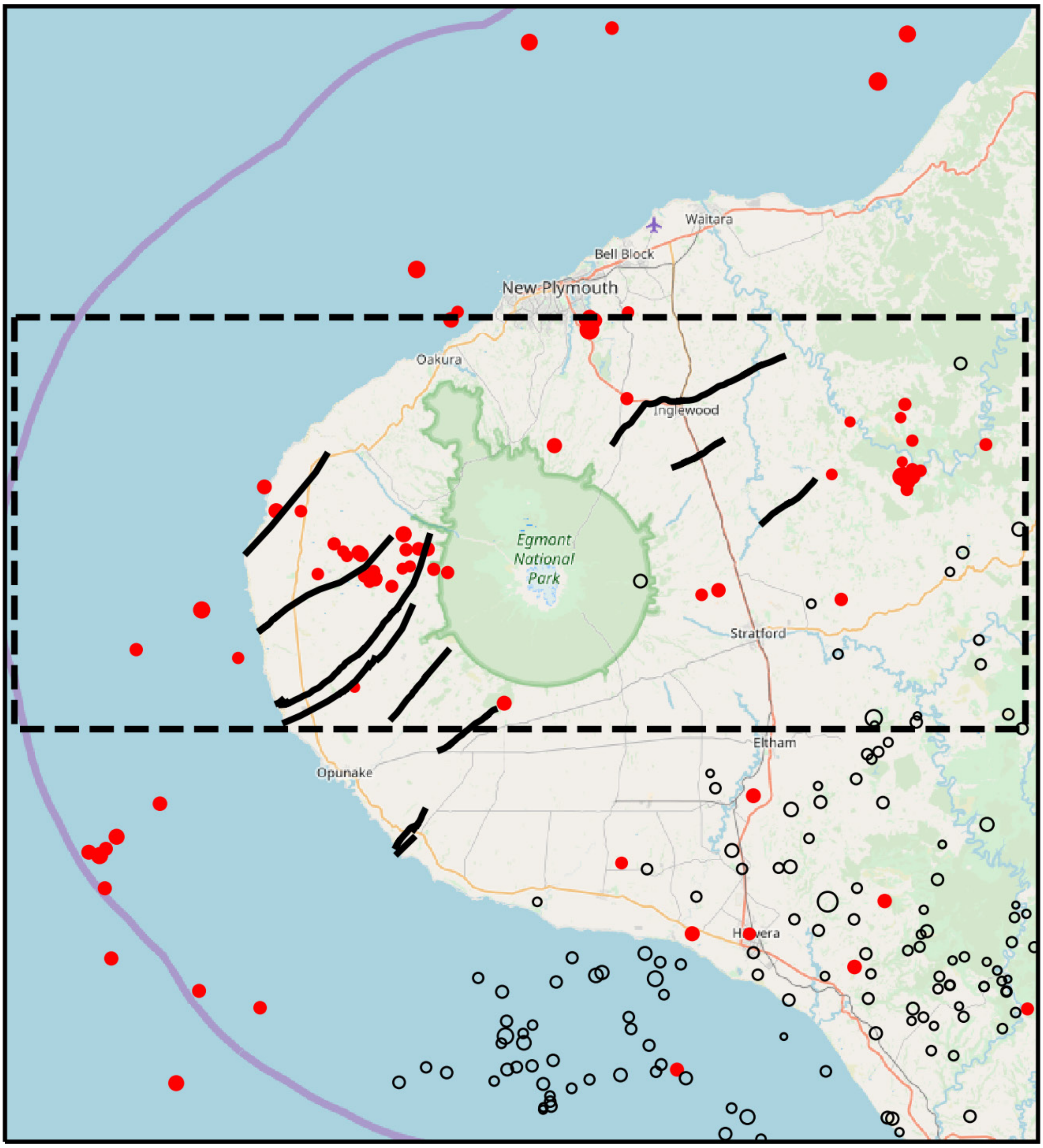

Figure 5.1 A map of all earthquakes located in Taranaki by GeoNet between 1 July 2017 and 30 June 2018. Red circles indicate earthquakes less than 50 km deep and open black circles those more than 50 km deep. The size of the symbol is proportional to the magnitude of the earthquake. Active faults (thick black lines) are from the New Zealand Active Faults Database (Langridge et al. 2016). The dashed box marks the area covered by the cross-section in Figure 5.2A. Map data © OpenStreetMap contributors.

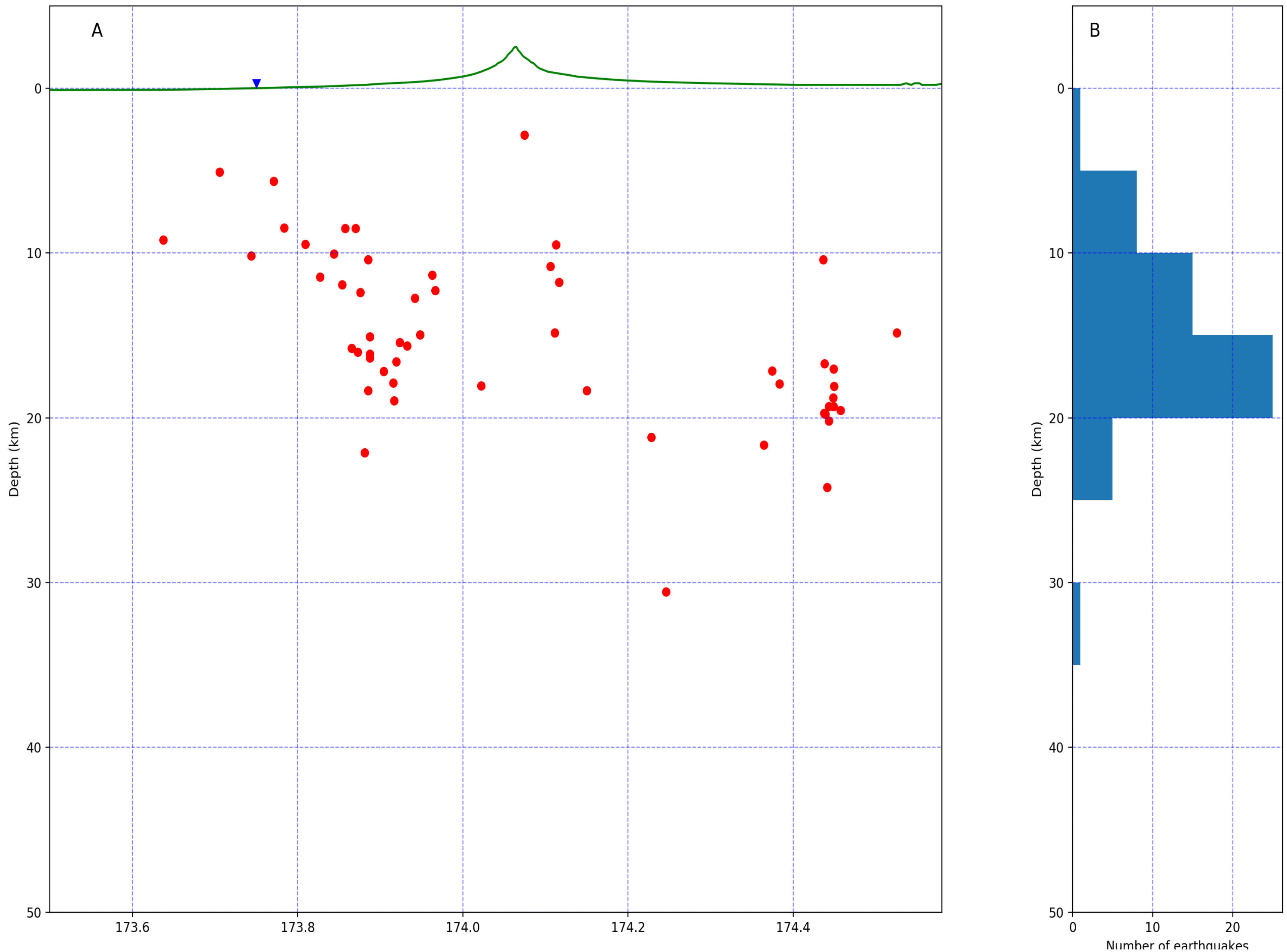

Figure 5.2 A. A projected west-east (left to right) cross-section showing earthquake hypocentres less than 50 km deep located in Taranaki between 1 July 2017 and 30 June 2018. This figure projects hypocentres within 20 km of the position of the cross-section onto the cross-section. The ground elevation is illustrated on upper part of the diagram (green line), with the inverted triangle marking the position of the coast at Cape Egmont. The horizontal:vertical scale is 1:1. The location of the cross-section is shown as a dashed box in Figure 5.1. B. Histogram of the depths of the earthquakes shown in Figure 5.2A.

6.0 EARTHQUAKE DISCUSSION

In this section we compare the seismicity for 1 July 2017 to 30 June 2018 with the total of recorded and located seismic activity in Taranaki since 1994. We include a discussion of long-term similarities, differences and trends. We assess the volcanic significance of the recent data and comment on the network's effectiveness.

6.1 Long-term Data

6.1.1 Larger Earthquakes

In previous reports we summarised the occurrence of all earthquakes located in the Taranaki region since January 1994. However, a seismic network can only permit location of all earthquakes above a certain magnitude and can locate only some of the earthquakes of lower magnitudes[4]. Summarising all earthquakes is a little ambiguous because apparent differences in the distribution might partly reflect differences in location threshold, rather than the actual number of earthquakes that occurred. For an area similar to that shown in Figure 2.1, but excluding earthquakes more than 20 km offshore, Sherburn and White (2005) showed that for the period 1994-2001 the GNS Science catalogue was complete down to magnitude 2.7[5]. In summarising earthquakes located since 1994 we therefore acknowledge network limitations and separately show all earthquakes (Figure 6.1) and those above the magnitude 2.7 threshold (Figure 6.2).

Earthquakes located immediately west of Mt Taranaki appear to dominate the catalogue, but this is partly an artificial effect of the location threshold onshore being substantially lower than that offshore. Considering only earthquakes of magnitude 2.7 and larger (Figure 6.2), there is not as much difference between the apparent level of activity onshore west of Mt Taranaki and that offshore of the Taranaki Peninsula.

6.1.2 Long-term Distribution

In terms of the distribution of earthquakes, the events from 1 July 2017 to 30 June 2018 (Figure 5.1) are similar in geographic spread to all events located since 1994 (Figures 6.1 and 6.2). The earthquakes west of Mt Taranaki represent energy release in part of the Cape Egmont Fault Zone, a region of seismically active faulting. The deep earthquakes in the Hawera region represent the top of the Pacific plate subducting beneath the North Island. The cluster of earthquakes north-east of Stratford is the western part of a band of activity that continues almost to Mt Ruapehu. All of these are documented features of Taranaki seismicity. Their persistence implies that the underlying causes have remained nearly unchanged since detailed monitoring in Taranaki began in 1994.

As illustrated in Figure 6.1 there are more than 100 earthquakes located beneath Mt Taranaki, which gives the impression that there is a low, but notable, level of seismicity beneath the volcano, and raises questions about the possible volcanic origin of these events. However, the majority of these earthquakes occurred in the 1990s, when locations were less reliable than now, and we hypothesise that many may have been mis-located and in fact, occurred in the area immediately west of Mt Taranaki (highlighted in Figure 5.1).

[4] This is called the location threshold or magnitude of completeness, and can depend on the area considered, the time interval, and on the analysis procedures used.

[5] For the area east of Mt Taranaki, more recent work has shown that the completeness threshold is now closer to magnitude 2.0. However, for the sake of comparison with previous reports we will continue to use a threshold of magnitude 2.7

6.1.3 Long-term Rate

We use two measures to show the long-term rate of shallow (depth less than 50 km) seismicity in the Taranaki region: the number of located earthquakes each month (Figure 6.3) and the cumulative number of earthquakes and energy release since 1994 (Figure 6.4).

An apparent reduction in the rate of activity since 2012 is most likely an artefact following GeoNet's change to its earthquake analysis system and introduction of SeisComP3.

In terms of seismic energy release (Figure 6.4), it is the larger earthquakes that dominate. In Taranaki, these are events with high magnitude 4 or low magnitude 5 values, and most have occurred west of Mt Taranaki, in the Cape Egmont Fault Zone.

6.2 Volcanic Significance of Earthquake Data

While there are no strict rules for assessing whether or not an earthquake or group of earthquakes are significant as a possible harbinger of volcanic unrest, the number of earthquakes, their magnitude and the presence or absence of low-frequency earthquakes (McNutt and Roman 2015) are criteria that are often considered. None of the earthquakes located in Taranaki in 2017-18 are considered by GNS Science to be of volcanic origin.

6.3 Seismic Network Effectiveness

In the past, the effectiveness of the network has been significantly compromised by technical problems. The seismograph network upgrade between 2005 and 2010, and the borehole instrument (NBEZ) added in 2012 means that it is now much more reliable and technical problems are rare. There are occasional and usually minor technical issues with any network, but no problem had a substantial effect on Taranaki seismic data, or monitoring effectiveness in 2017-18.

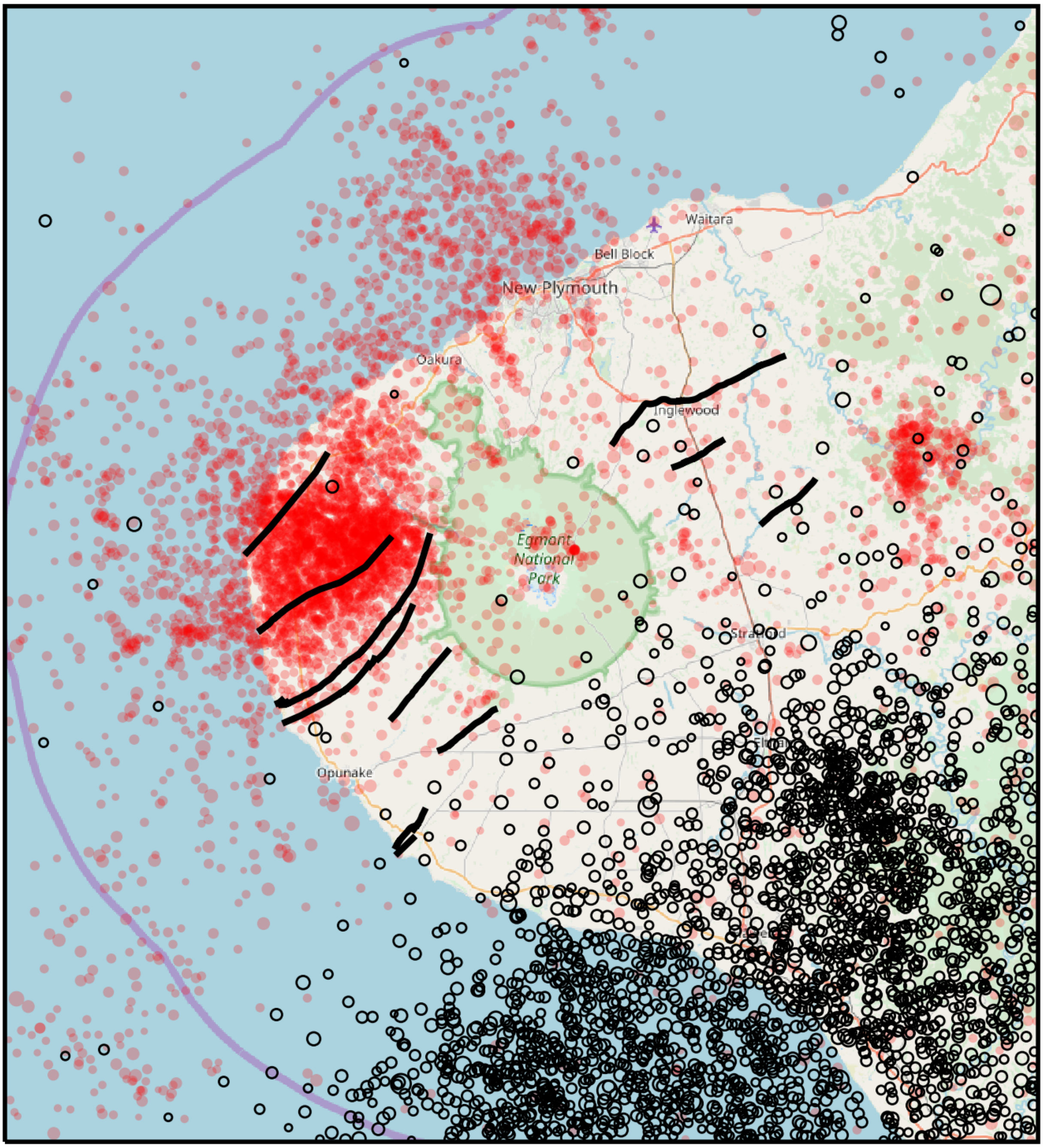

Figure 6.1 A map of all earthquakes located in the Taranaki region between January 1994 and June 2018. Symbols for earthquakes shallower than 50 km (red) are shown partially transparent to show more structure in the distribution west of Mt Taranaki. Other aspects of the symbols are as described in Figure 5.1.

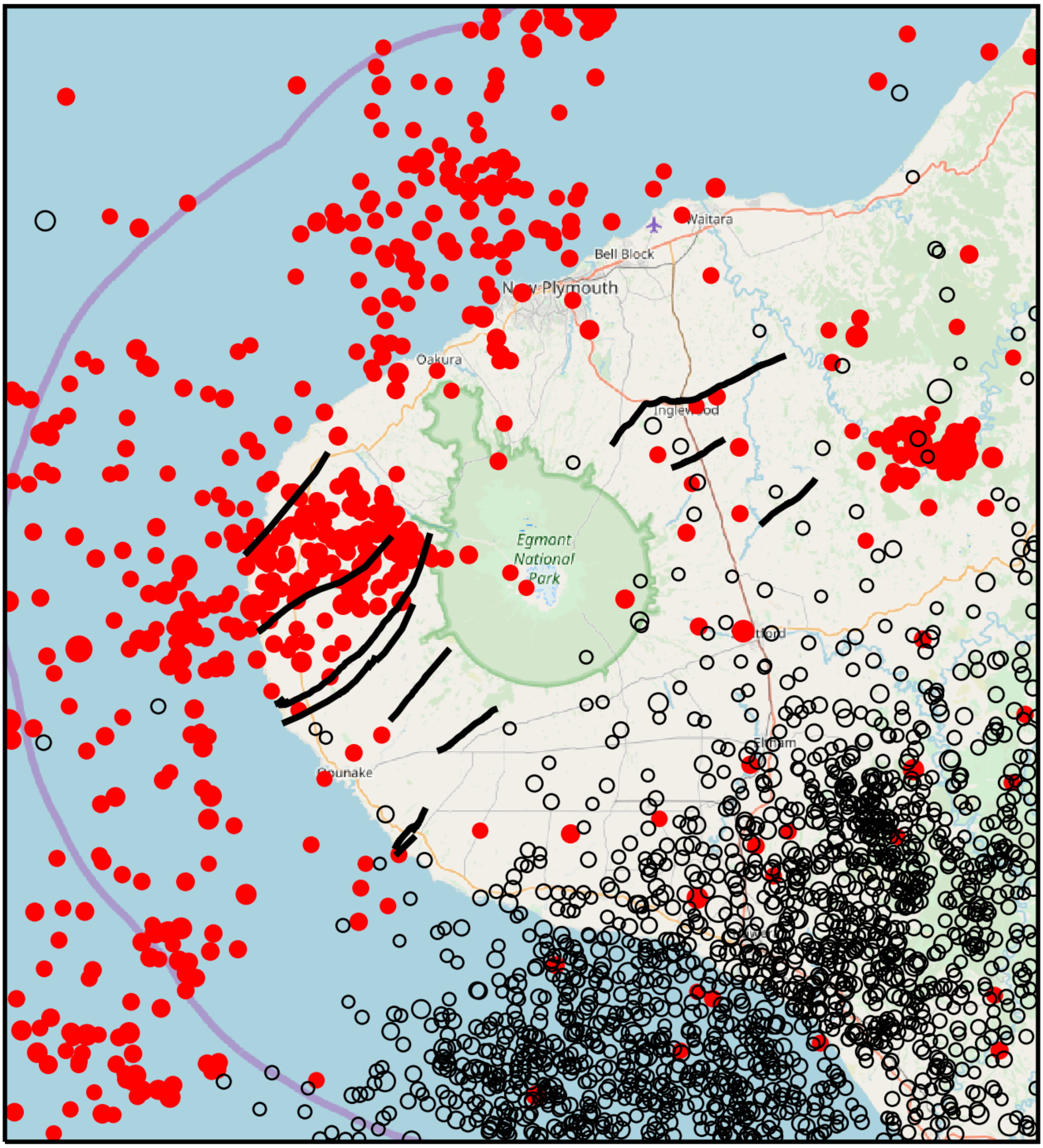

Figure 6.2 A map of earthquakes of magnitude 2.7 and larger located in Taranaki between January 1994 and June 2018. Symbols are as described in Figure 5.1.

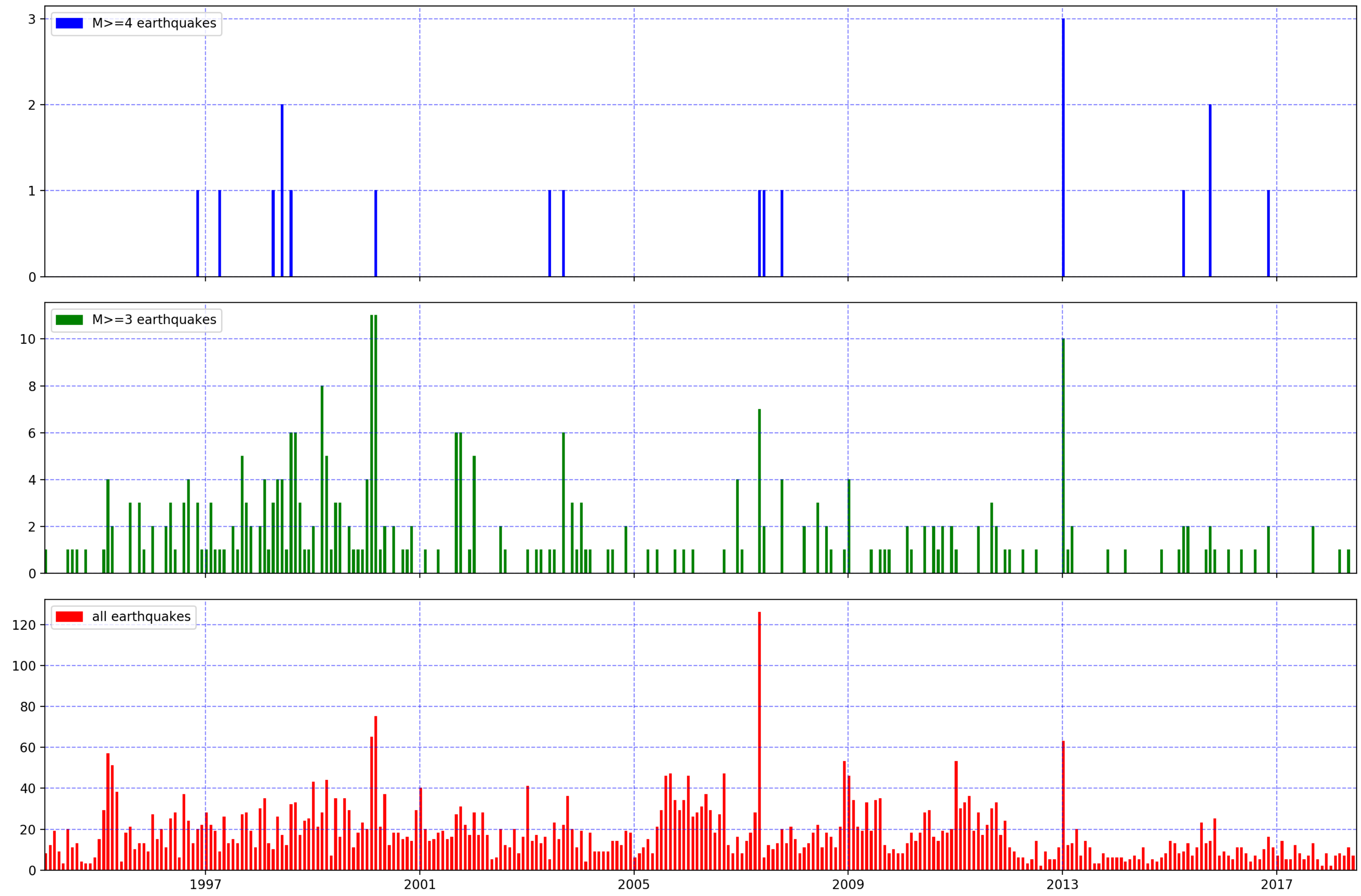

Figure 6.3 Histograms of the number of earthquakes less than 50 km deep that have occurred each month between January 1994 and June 2018 in the area shown in Figure 2.1. Three separate histograms are shown: all earthquakes (bottom), those of magnitude 3 and above (centre) and those of magnitude 4 and above (top). Data up to December 2011 are from the previous analysis system, and those from January 2012 onwards are from the SeisComP3 system.

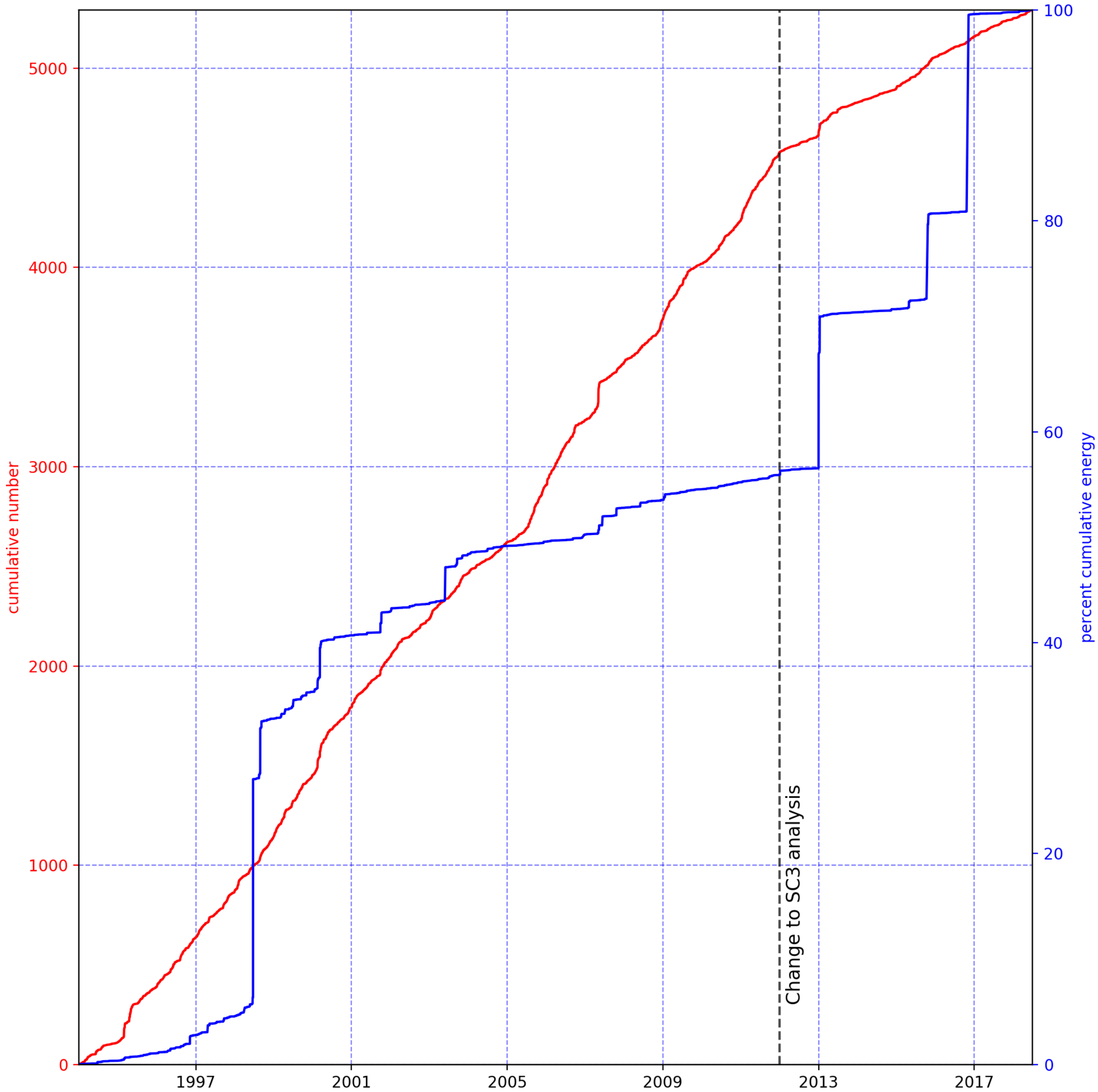

Figure 6.4 The cumulative number (red line) and energy release (blue line) of all earthquakes less than 50 km deep located in the area shown in Figure 2.1 between January 1994 and June 2018. SeisComP3 data are from January 2012 onwards and this corresponds to a reduction in the rate of located earthquakes.

7.0 GROUND DEFORMATION MONITORING

In 2003, GeoNet installed a GNSS site on German Hill (station code NPLY) as part of a National geodetic framework. In 2014, two further sites (station codes PGKH and PGNE) were established on the volcano thus enabling the monitoring of local ground deformation.

Figure 7.1 shows the locations of the three GNSS sites on or near Mt Taranaki. All sites show long-term eastward, northward, and vertical displacements (Figures 7.2 to 7.7). This movement is also observed at sites outside Taranaki and is the result of tectonic movement of the North Island of New Zealand.

Substantial ground displacement occurred in New Zealand as a result of the November 2016 Kaikoura earthquake. GNSS sites in Taranaki were also displaced by this earthquake, moving to the north-east (see pronounced red line steps in Figures 7.2 to 7.7).

One technique to subtract the regional tectonic movements from the local GNSS site data is to calculate the distance between sites (Figure 7.8). This has routinely been used as a ‘first pass’ monitoring tool for GNSS data in volcanic regions. However, GNS Science recognises that the deep ground at each site responds to regional tectonic movements to a different extent, and this can lead to changes in the distance between sites that can be incorrectly interpreted as locally sourced or volcanic deformation. A clear example of site response is a slight change in the line lengths PGKH-PGNE and PGNE-NPLY evident at the time of the 2016 November Kaikoura earthquake. This is not a result of locally sourced deformation, but instead was caused by each of the GNSS sites responding slightly differently. For this reason, plots of changes in the distance between sites must be interpreted with caution and should not be analysed without reference to the original three-component displacement data and knowledge of any substantial regional tectonic events.

Data from three GNSS monitoring sites in Taranaki show no locally sourced deformation or obvious flank instability of the volcano since monitoring became possible in 2014.

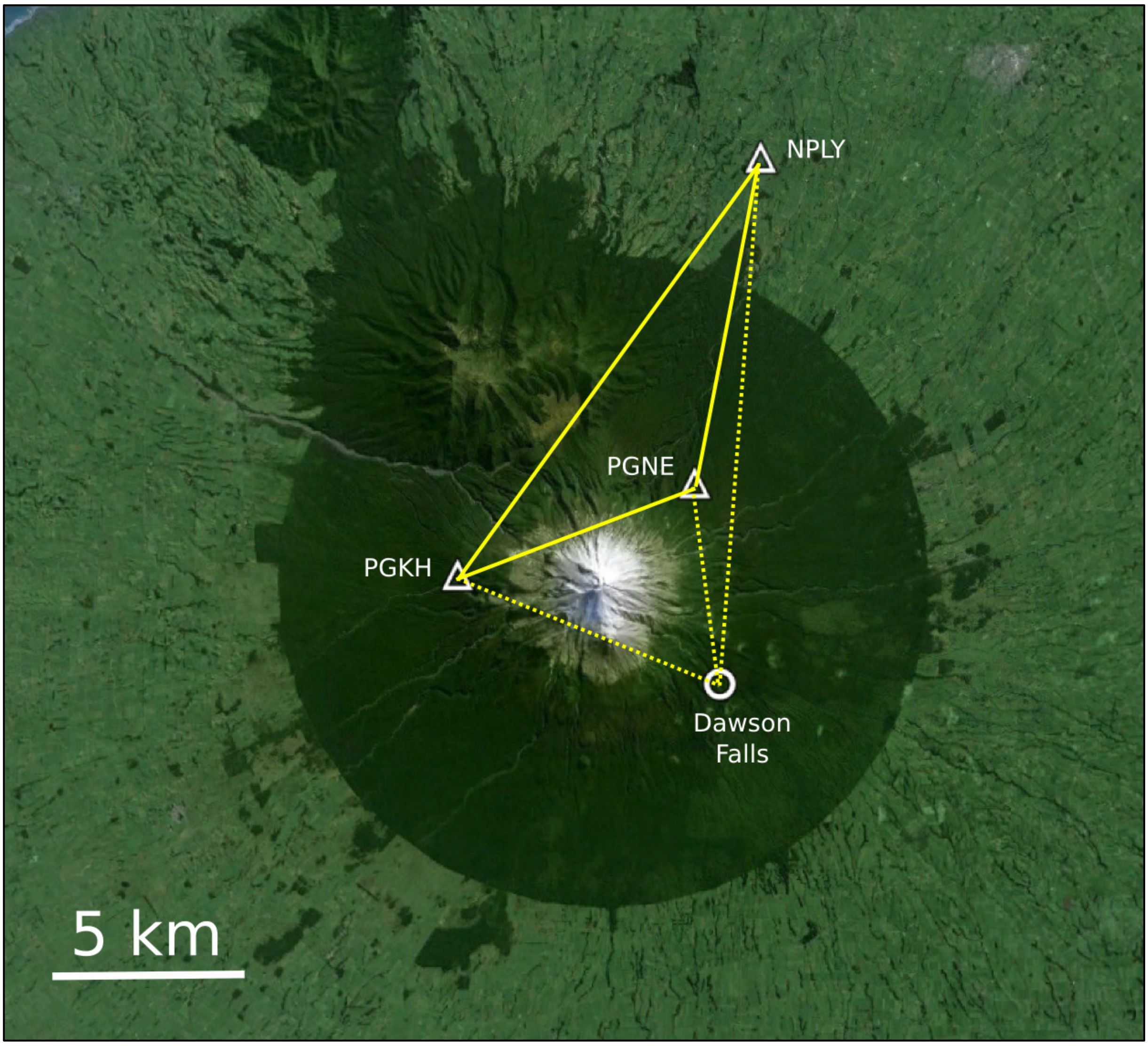

Figure 7.1 Locations of GeoNet GNSS sites on and near Mt Taranaki. Sites are labelled by their 4-letter site codes. NPLY is New Plymouth (located on German Hill), PGKH is Kahui Hut and PGNE is North Egmont. The intention is to also install a site at Dawson Falls once redevelopment work planned in that area is completed. Solid lines indicate line lengths currently able to be monitored. Dashed lines can be monitored when instruments are installed at Dawson Falls. The base map is from Google Earth.

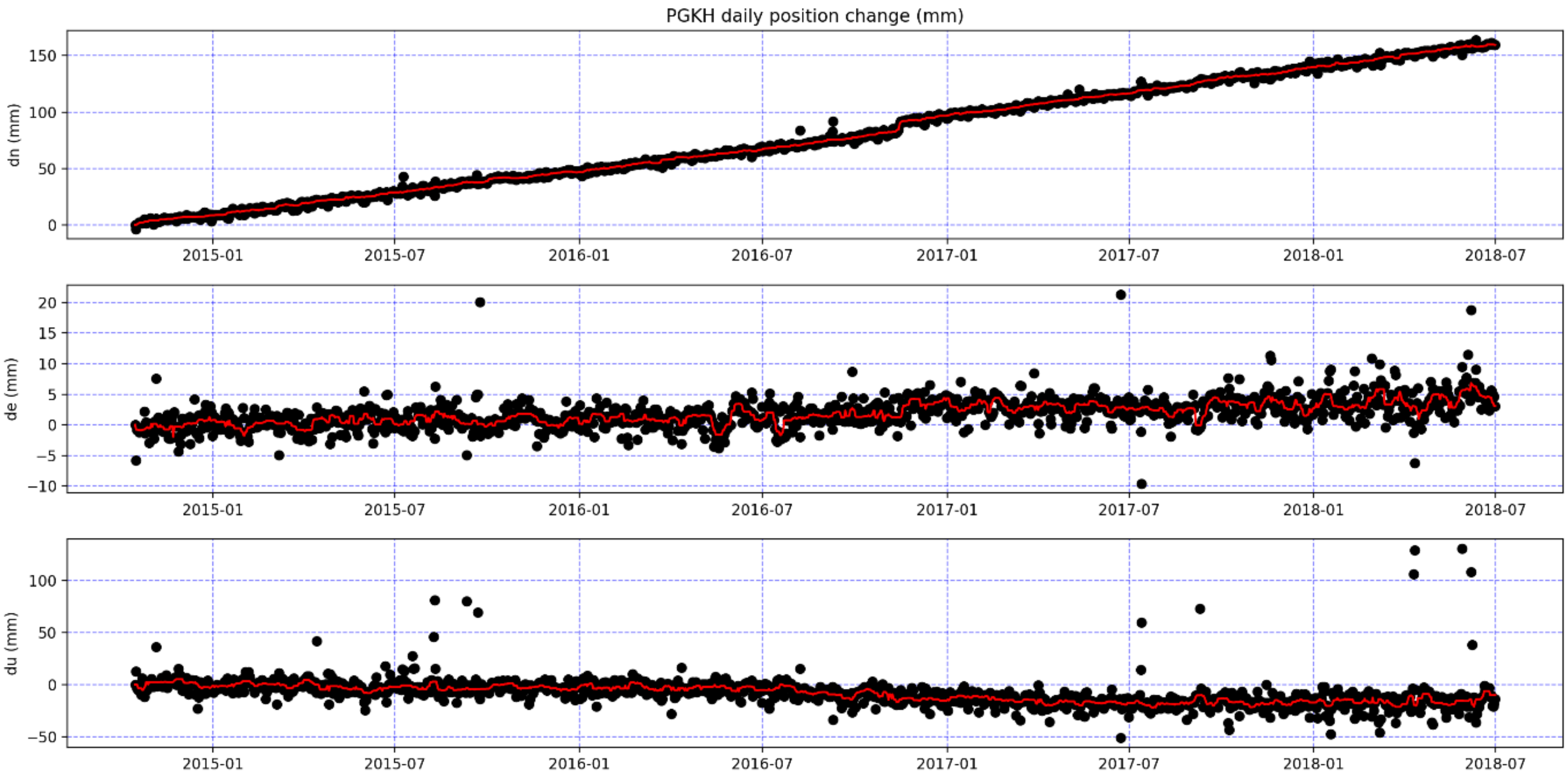

Figure 7.2 The displacement of the GNSS site PGKH at Kahui Hut on Mt Taranaki for 2014 to 2018. Displacements in the north-south (dn), east-west (de), and up-down (du) directions are shown. All positions are relative to the initial position when the sites were installed, and thus represent a displacement from the initial position. The black circles represent smoothed daily displacements. The red lines are the smoothed daily displacement curves. The Kaikoura earthquake occurred on 14 November 2016.

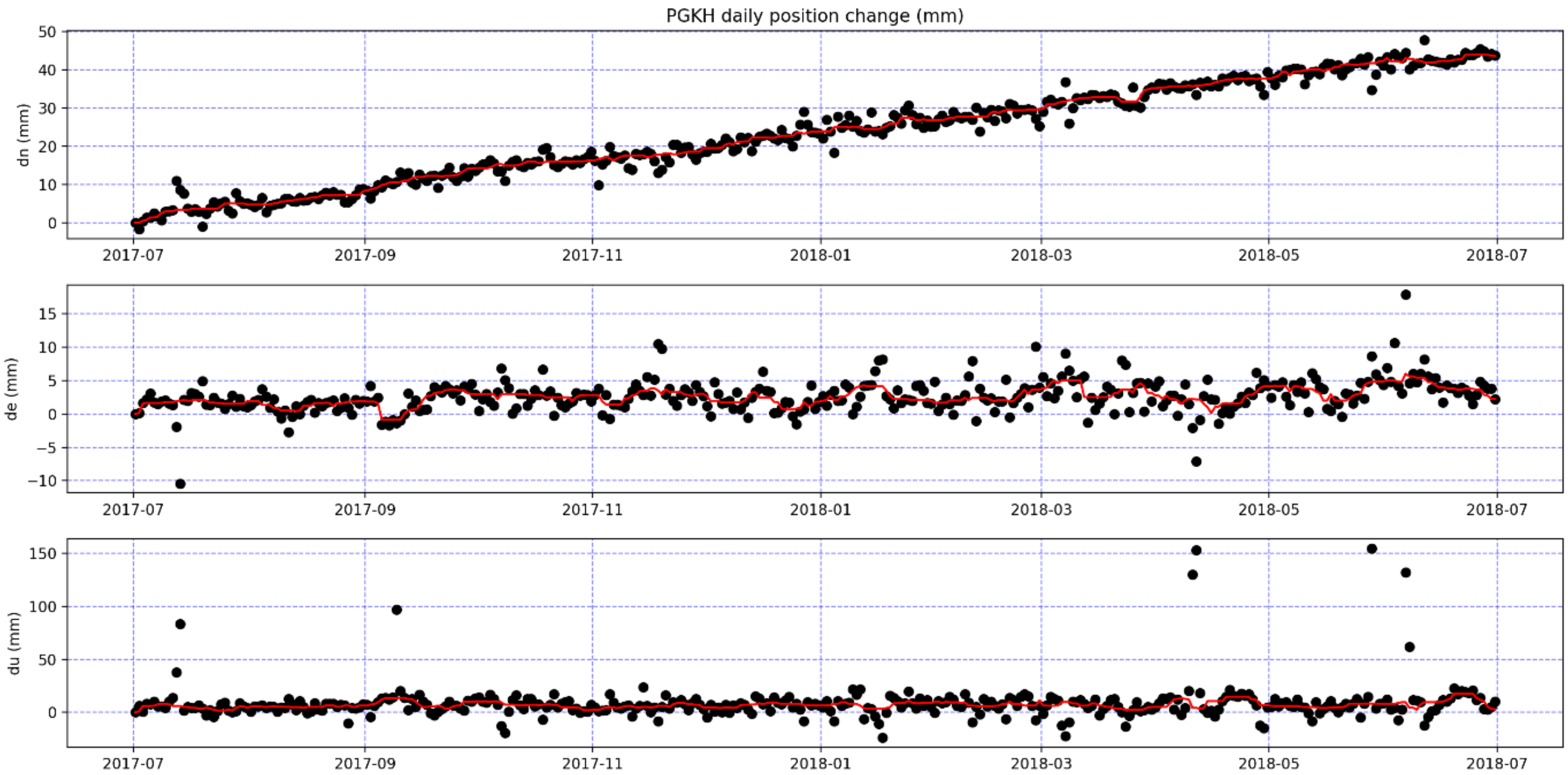

Figure 7.3 The displacement of the GNSS site PGKH at Kahui Hut on Mt Taranaki for 2017 to 2018. For further details refer to Figure 7.2.

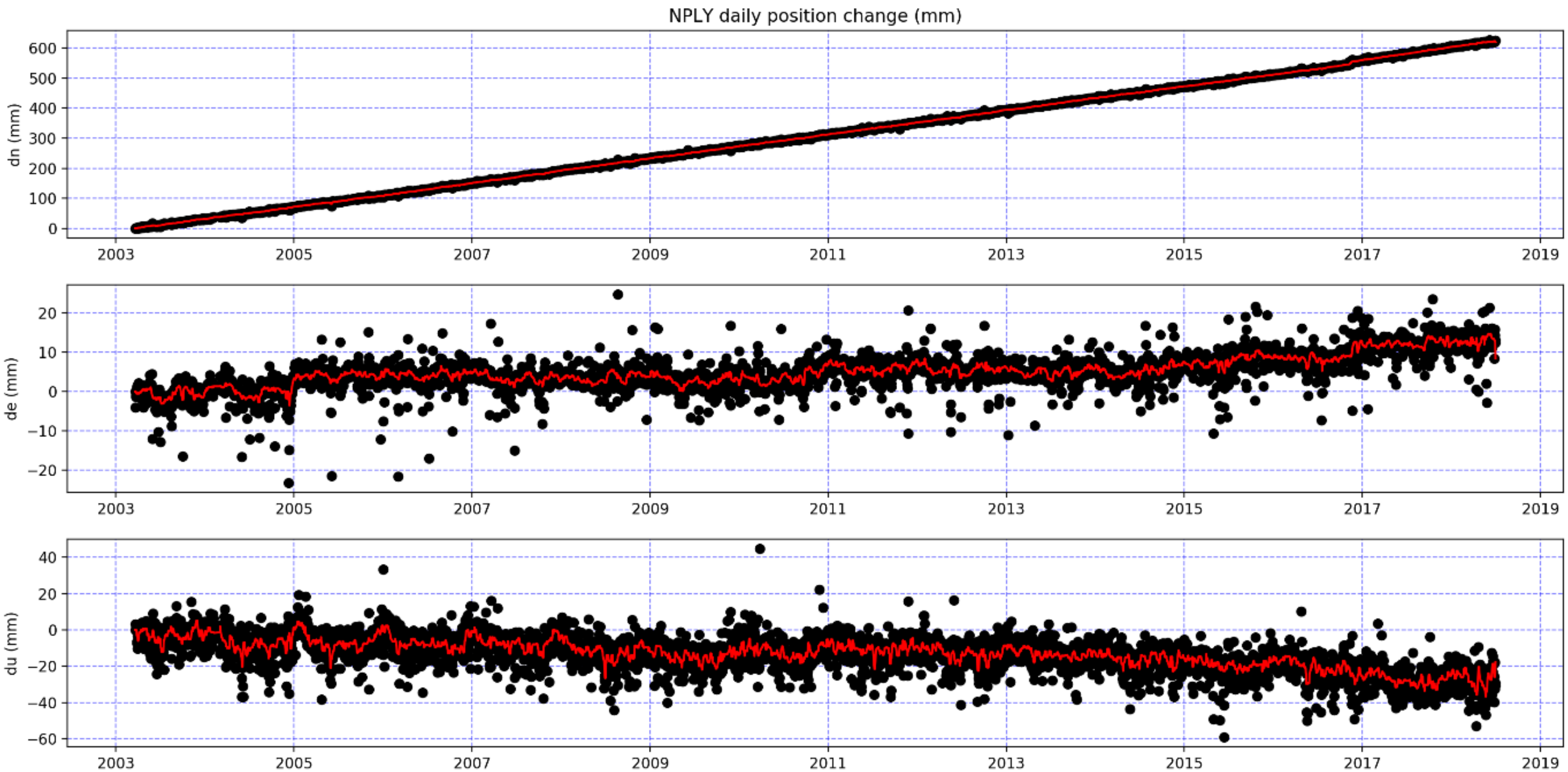

Figure 7.4 The displacement of the GNSS site NPLY at German Hill for 2003 to 2018. For further details refer to Figure 7.2.

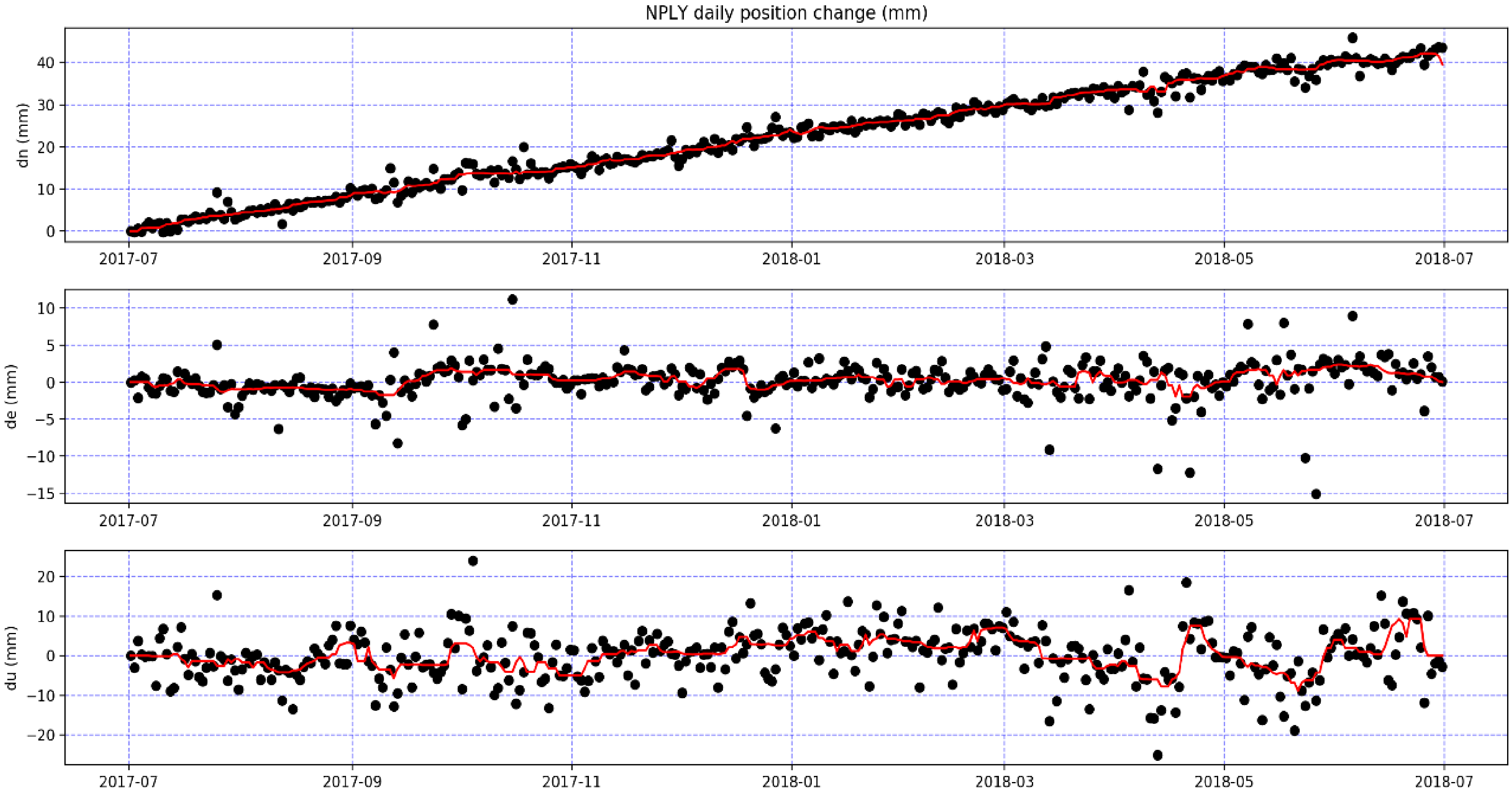

Figure 7.5 The displacement of the GNSS site NPLY at German Hill for 2017 to 2018. For further details refer to Figure 7.2.

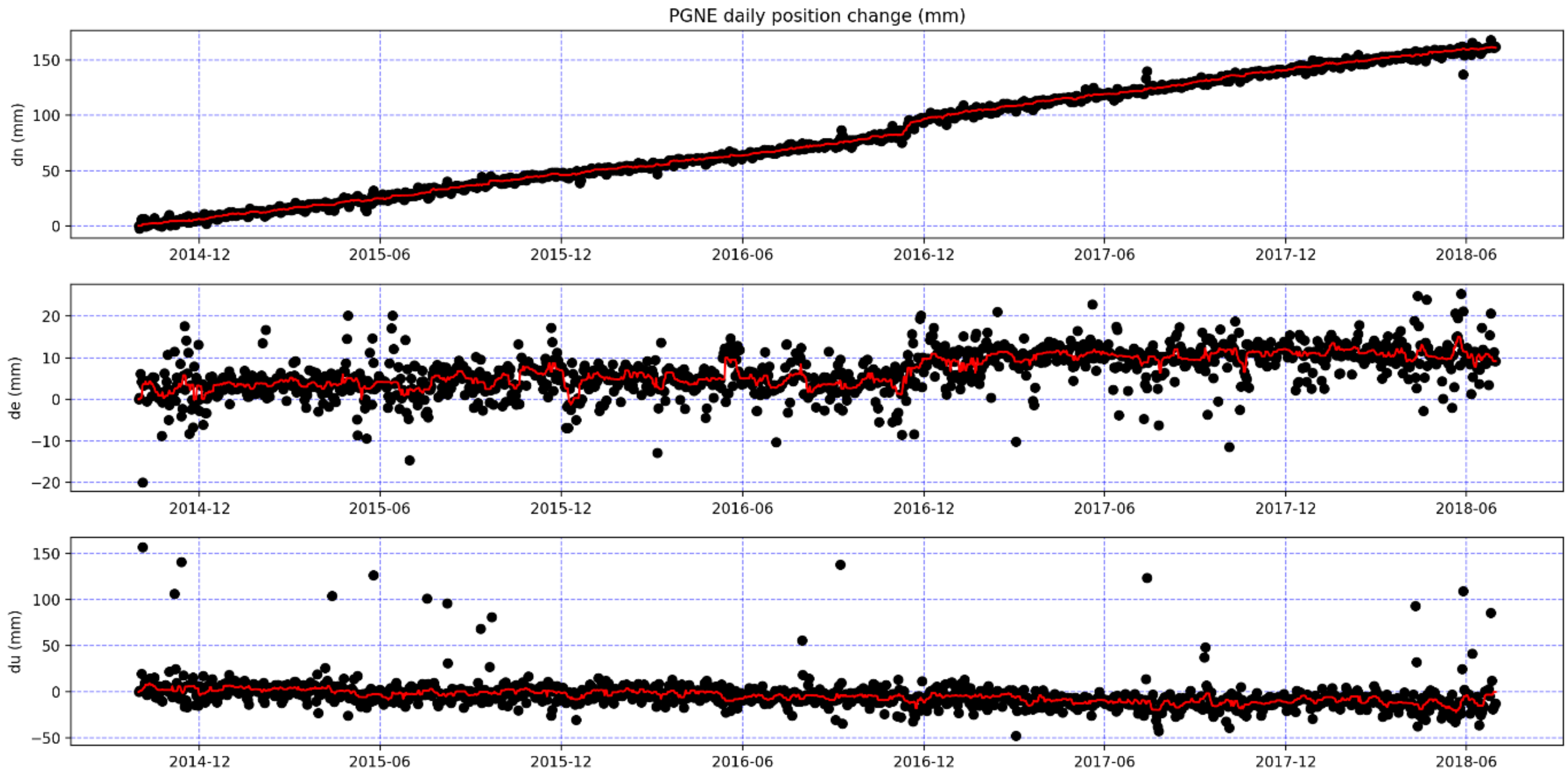

Figure 7.6 The displacement of the GNSS site PGNE at North Egmont on Mt Taranaki for 2014 to 2018. For further details refer to Figure 7.2.

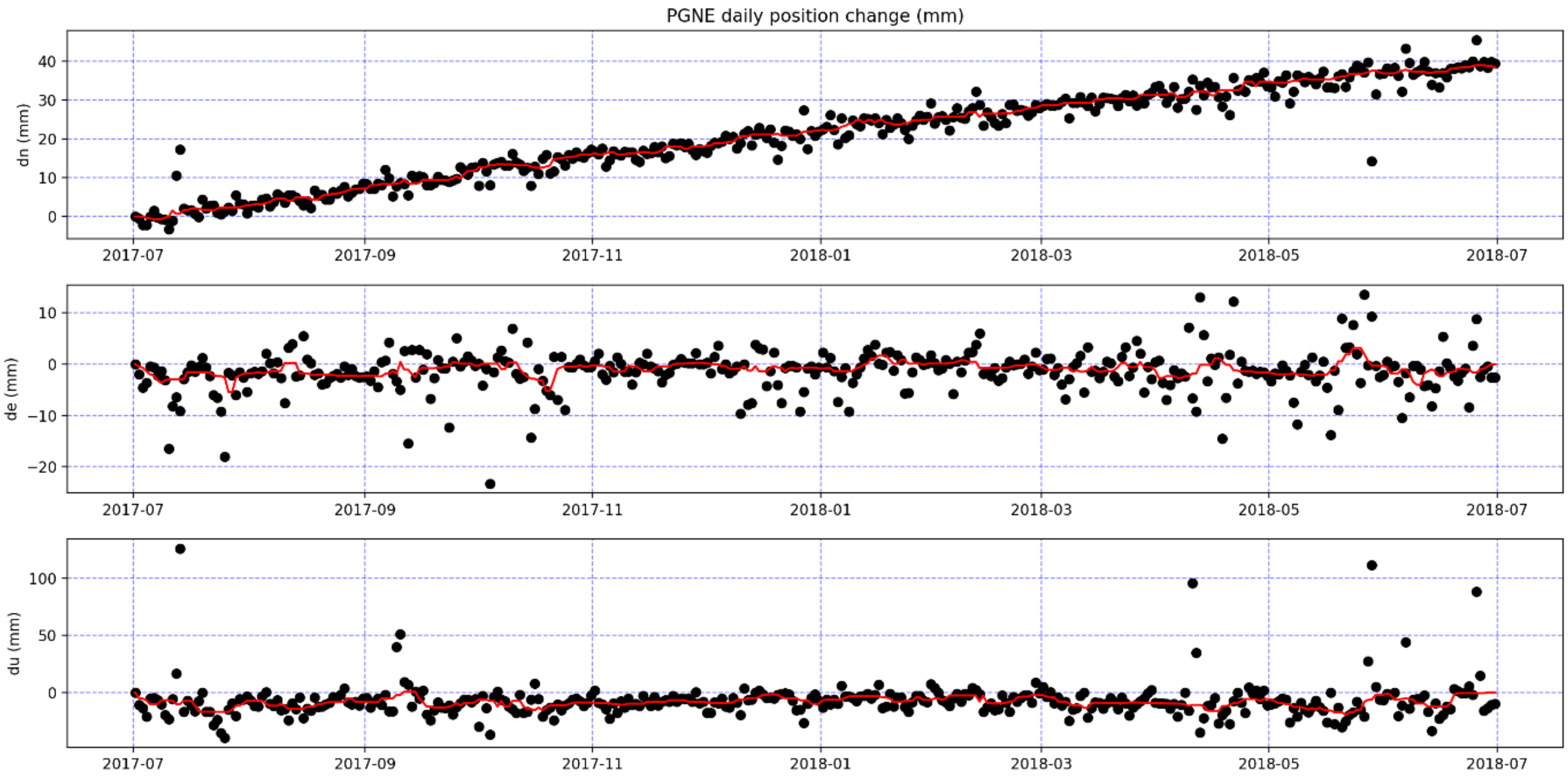

Figure 7.7 The displacement of the GNSS site PGNE at North Egmont on Mt Taranaki for 2017 to 2018. For further details refer to Figure 7.2.

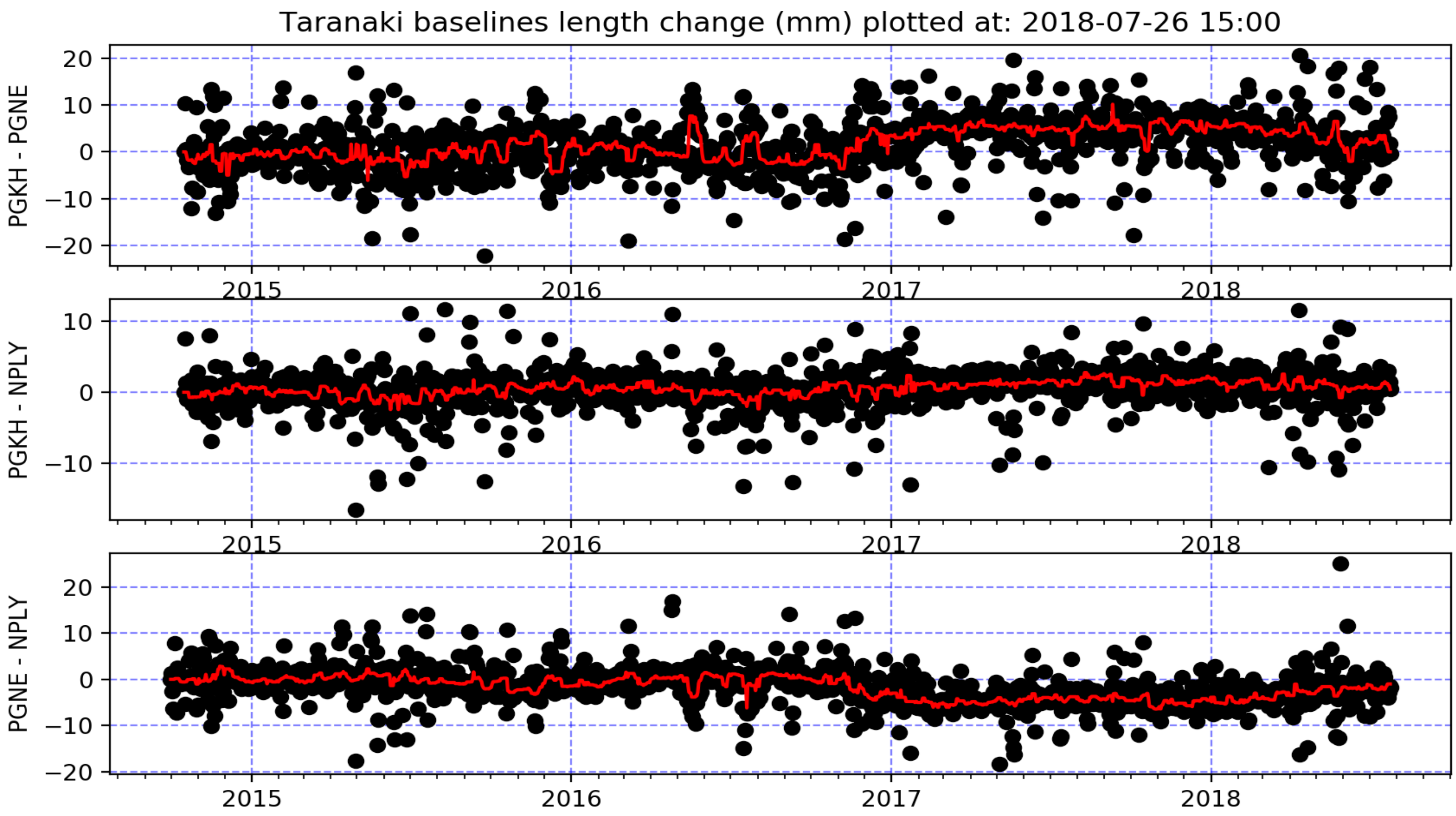

Figure 7.8 The length of lines between GNSS monitoring sites in Taranaki. The black circles represent daily line lengths and the red line a smoothed average. A slight change in the line lengths PGKH-PGNE and PGNE-NPLY is evident in late-2016. This occurred at the time of the 2016 November Kaikoura earthquake. It is not a result of locally sourced deformation, but was caused by each of the GNSS sites responding slightly differently to that distant tectonic movement.

8.0 CONCLUSIONS

Seismic activity on the Taranaki Peninsula continues to be dominated by shallow (<50 km) earthquakes west of Mt Taranaki. No earthquakes have been recorded that might indicate volcanic processes or volcanic unrest at Mt Taranaki. We infer that during the period 1 July 2017 to 30 June 2018 seismic activity on the Taranaki Peninsula was purely tectonic in origin and not of relevance to volcanic surveillance.

Data from three GNSS monitoring sites in Taranaki show no locally sourced deformation or obvious flank instability of the volcano since monitoring became possible in 2014.

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