UDC [551.24.08 : 528.2/.5 : 518.4].001.24

Maryna BATUR[1], Kateryna BABII[2]

[1] Istanbul Technical University, Department of Geomatics Engineering, Graduate School, Ayazaga Campus, Maslak, Istanbul, 34469, Turkey, e-mail: baturm20@itu.edu.tr, https://orcid.org/0000-0001-9284-8858
[2] M. S. Poliakov Institute of Geotechnical Mechanics of the National Academy of Sciences of Ukraine, 2a, Simferopolska, Dnipro, 49005, Ukraine, e-mail: babiyev@i.ua, https://orcid.org/0000-0002-0733-2732

https://doi.org/10.23939/jgd2022.02.006

TRENDS IN HORIZONTAL AND VERTICAL CRUSTAL DISPLACEMENTS BASED ON INTERNATIONAL GNSS SERVICE DATA: A CASE STUDY OF NEW ZEALAND

The study analyzes the coordinate time series of five permanent International GNSS Service (IGS) stations located in New Zealand. It also considers their annual movement from 2009 to 2018. The raw data in the form of Receiver Independence Exchange (RINEX) files were taken from IGS database and processes by means of online processing service AUSPOS. Using coordinate time series, horizontal and vertical displacement rates were calculated covering the ten-year study period. According to the results, stations located at the North Island of New Zealand revealed an uplift of 31–32 mm/yr. At the same time, stations placed on the South Island showed the 21–22 mm/yr. of positive vertical displacement. Regarding the horizontal displacements, their rates increase in North-South direction over the study region. In particular, two stations of North Island, located at the North-Western part, appeared in 24–25 mm/yr. displacement, and one station at the Southern part of North Island showed the 35 mm/yr. displacement rate. Stations, established at South Island, showed the horizontal displacement rates of 41–56 mm/yr. This research confirms the main contribution made to the field of crustal deformation studies, including the updated values of displacements along with their directions over the recent years. The results of this study can be used for further geodynamics investigations as well as for finding the most likely earthquake locations of the current study area.

Key words: crustal deformations; displacement; IGS data; time series; New Zealand; earthquake; seismic region.

Introduction

Every year, there are on average about 2000 earthquakes with magnitudes of 5.0 and more recorded around the World [Luginbuhl et al., 2019]. They include moderate earthquakes with M_W 5.0–5.9, strong earthquakes with M_W 6.0–6.9, major with M_W 7.0–7.9, and great seismic events with M_W>8.0. Around 20 major earthquakes occur yearly worldwide. Approximately 1–2 events of M_W with more than 8.0 usually cause a great surface rupture and ground displacements [Luginbuhl et al., 2019]. Even the most insignificant earthquakes lead to crustal deformations, including interseismic (interval between earthquakes), coseismic (directly time of earthquake), and postseismic (time following an earthquake) stages of seismic cycle, not even mentioning the major events. Active geological faults of New Zealand owe their existence to the tectonic boundaries between the Australian and the Pacific plates. This causes a large amount of tectonic squeezing. For example, one of the most devastating 2011 Christchurch earthquakes claimed the lives of 185 people and resulted in considerable structural damages and building collapses [Johnston et al., 2014]. Understanding the crustal deformations and ground displacements is important not only for the Earth observation studies, but also for taking the necessary steps on earthquake hazards mitigation, in earthquake potential and early warning research [Chetverik et al., 2017; Cremen and Galasso, 2020].

GPS/GNSS is currently one of the most cost-effective tools for monitoring and measuring crustal deformations. Recent improvements in the development of GPS/GNSS have been greatly contributed to the study of tectonic motion, fault zones, subduction mechanisms, volcanic processes, etc. The majority of prior research has applied GPS/GNSS velocities to analyze geodynamic processes. For instance, present-day crustal deformations using GNSS data over the Southern Patagonian Icefield region were studied in [Richter et al., 2016; Larson et al., 2004]. The research was conducted on crustal deformations measurements for Mexico. [Shen et al., 2001] did research around the Tibetan Plate; [Zheng et al., 2017] used 25 years of GPS observation data to study crustal deformations in India-Eurasia collision zone. A number of studies were focused on slip rate estimation using GPS measurements [Alif et al., 2020; Johnson, 2013; Metzger et al., 2011]. There have been numerous studies to investigate the crustal strain rates [Dumka et al., 2018; Ishchenko, 2017; Koulali et al., 2016; Tretyak and Brusak, 2022].

Geodetic studies carried out in New Zealand were mainly focused on ground deformations induced by large earthquakes, related to coseismic and postseismic stages of seismic cycle. Some of those studies are shown in Table 1, indicating the main objectives and key findings.

The purpose of this work is to study the geodynamic processes of tectonic plates in New Zealand and to obtain updated horizontal and vertical displacements of five permanent stations over the period of 2009–2018.

This research aims to investigate horizontal (X and Y) and vertical (Z) displacements from five IGS stations located in New Zealand. For this purpose, RINEX files were taken from the IGS database and processed using the online GPS processing service AUSPOS provided by the Australian Government. Data was taken for the time interval of 2009–2018 twice a year (the 1st of January and the 1st of June), covering the ten years period. As the result, coordinate time series were obtained for each axis separately and final displacement rates were calculated as the coordinate differences divided by the total observation time [Zuska, 2014]. The results of this study make a significant contribution to the latest displacement data that should be used when updating or improving the seismic hazard assessments in New Zealand.

The results of this study make a significant contribution to the general issue. It is revealed in the works of various geologists, surveyors, geographers, and earth scientists (see Table 1). They investigated the plate mass displacement processes and provided the present-day displacement data important for updating or improving the seismic hazard assessment in New Zealand.

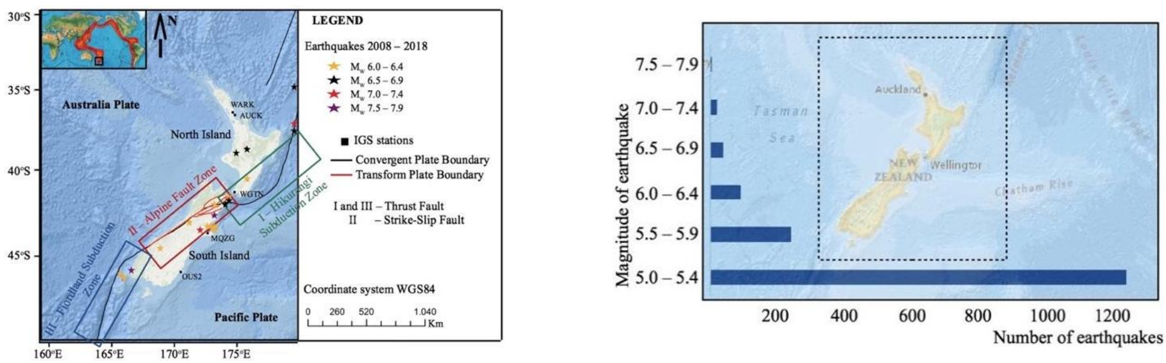
Table 1

Preliminary studies of crustal deformations in New Zealand using GPS/GNSS data

Author	Year of publication	Title of publication	Aim of the study and main findings
[Beavan et al., 2012]	2012	Fault slip models of the 2010–2011 Canterbury, New Zealand, earthquakes from geodetic data and observations of postseismic ground deformations	Crustal deformations were derived using GPS data after four different seismic events. It was possible to construct the fault model and to detect postseismic deformations
[Tenzer et al., 2012]	2012	A compilation of a preliminary map of vertical deformations in New Zealand from continuous GPS data	The main objective was to derive the vertical deformations for the region of New Zealand where these deformations are substantially different in its magnitude and rate compared to other regions of the country
[Bartlow et al., 2014]	2014	Time-dependent modeling of slow slip events and associated seismicity and tremor at the Hikurangi subduction zone, New Zealand	Hikurangi subduction zone was studied for the slip events over the period of 2010–2011 using daily GPS observations
[Beavan et al., 2016]	2016	New Zealand GPS velocity field: 1995–2013	Crustal deformations were derived for New Zealand over the almost 20-year period using observations from an extensive GPS campaign
[Hamling and Hreinsdottir, 2016]	2016	Reactivated afterslip induced by a large regional earthquake, Fiordland, New Zealand	The authors of this study combined GPS data with InSAR to calculate the coseismic and postseismic deformations after two independent seismic events of M_W 6.8 and 7.8 respectively
[Arnadottir et al., 2018]	2018	A preseismic strain anomaly detected before M6 earthquake in the South Iceland seismic zone from GPS station velocities	2001–2015 GPS campaign measurements were used to estimate the stations' velocities and calculate the strain rates. This study detected substantial velocity variations, indicating the increased strain rates for the study region
[Su et al., 2020]	2020	Coseismic and early postseismic deformation of the 2016 M_w 7.8 Kaikoura earthquake, New Zealand, from continuous GPS observations	It was possible to estimate the coseismic offset after the large earthquake using GNSS data

Tectonic settings and seismicity of New Zealand

New Zealand is an ocean located country with a total area of more than 250 000 km^2. Although the country consists of a large number of islands, there are two main land masses – North and South Islands (Fig. 1, *a*). The geographical location on the boundary of two World's major tectonic plates, the Australian and the Pacific one, makes New Zealand an active seismic country with more than 7.0 magnitude earthquakes. These plates are driving against each other causing one to be pushed past and beneath the other. In general, the territory of New Zealand can be divided into three main zones according to tectonic settings. The first zone represents the Hikurangi subduction zone – the narrow strip that stretches off the east coast of the North Island to the North-East of South Island. Along this line, the Pacific Plate is pushing under the Australian Plate, thus forming the convergent plate boundary. The second zone begins on the east coast of the South Island and crosses the island down to Fiordland. Here, the plates are sliding past each other forming the right-lateral strike slip fault – Alpine Fault, which refers to the transform plate boundary. In the Southern part of Fiordland, the Australian Plate subducts below the Pacific Plate. It forms the third zone, which is called Fiordland subduction zone. Similar to the first zone, this geological fault line relates to the convergent plate boundary where thrust faults occur. Besides, the country is located on the belt of active volcanoes named as the Ring of Fire that includes the greatest seismic and volcanic hot spots. Every year, thousands of earthquakes strike New Zealand. Most of them are too small to feel, but some earthquakes generate enough shaking to cause significant damage [Leite et al., 2013]. Fig. 1, *b* shows the number of earthquakes with the M_W 5.0 and more that occurred in the period of 1900–2022 in the vicinity of New Zealand. According to the graph, more than 75 % accounts for the events with M_W 5.0–5.4, 15 % falls on earthquakes with M_W 5.5–5.9, 6 % comes from M_W 6.0–6.4, and a very negligible part belongs to M_W 6.5–7.9.



a b

Fig. 1. Study area: a – tectonic settings of New Zealand (Earthquake data is taken from USGS; Tectonic Settings data is taken from UNAVCO; Rectangular map in the left upper corner shows the Ring of Fire); b – statistical data on earthquakes in New Zealand over the period of 1900–2022 (taken from USGS); rectangular area represents geographical region for which earthquakes were taken

Materials and methods

IGS was firstly established in 1994 by the International Association of Geodesy (IAG) with the purpose to support various scientific applications related to the earth, oceanic, and climatic observations. Nowadays, it is freely available for all users with more than 500 stations worldwide. It also has a great contribution to geodetic study of crustal deformations. Since its initial inception, the IGS network has been implemented by many scholars to support geodetic research of tectonic plates. In [Lee et al., 2008], authors used IGS data to study the station's displacement due to the earthquake that occurred in Indonesia; (Yildirim et al., 2014) used IGS data to study tectonic displacements due to 2011 Van earthquake in Turkey; and [Altiner et al., 2006] focused on the velocity estimations around the Adria plate using the IGS dataset. In this study, data was collected from the IGS database in the form of RINEX files from five stations located on both, North and South Islands, in New Zealand. Fig. 2 shows the monumentation of stations used in the study and Table 2 lists their geographical parameters. RINEX files were obtained for the ten-year period from 2009 till 2018. For each year data was taken for the same day, namely, the 1st of January and the 1st of June. Raw data was processed through the online processing service AUSPOS provided by Geoscience Australia. AUSPOS computes coordinates in Cartesian and Geodetic coordinate systems, as well as in UTM Grid system using GRS80

Ellipsoid. Phase preprocessing was carried out using triple-difference. Coordinate uncertainties were given relating to 95 % confidence level. In this study, the coordinates of stations were received in Cartesian International Terrestrial Reference Frame 2014 (ITRF2014). Displacements in point positioning along with their corresponding rates were calculated from estimated time series.

Fig. 2. IGS stations used in the study (Source: IGS)

Table 2

IGS stations' coordinates in ITRF2014 reference frame

Station	Latitude, decimal degree	Longitude, decimal degree	Elevation, m
WARK	–36.434	174.663	111.000
AUCK	–36.603	174.834	132.711
WGTN	–41.323	174.806	26.060
MQZG	–43.703	172.655	154.680
OUS2	–45.869	170.511	26.100

Results

The station's position differences were calculated by taking the stations' latitude, longitude, and height of the 1st of January 2009 as the reference epoch and the 1st of January 2018 as the final epoch in ITRF2014 reference frame. Fig. 3–7 illustrate the time series plots of IGS stations' positions in North, East, and Up directions for each of the stations. On these figures, the green rectangle contains information regarding the maximum, minimum, and mean displacements and blue graphs show the cumulative displacements for the entire time period. The period between 2009 and 2018 reveals almost similar results – a linear model of time series, with the exception of MQZG station in North time series, where the deviations increase dramatically, and except the point of 1st of June 2011 for WARK station in East time series. It can also be noticed from cumulative plots. In case of MQZG station, such deviations from the straight line of the model can be considered quite explanatory because of geological settings of study area and due to presence of coseismic deformations. As for the WARK station, such displacement can be clarified by the large positional uncertainty during the data processing, which was 0.053 m. The estimated longitude coordinate has precision outside of the boundary of 95 % confidence level and can be counted as outlier. In all the other cases, positional uncertainties were obtained in the range of 0.002–0.009 m for latitude and longitude, and in the range of 0.007–0.013 m for the altitude. Fig. 8 shows the box plots of positional uncertainties for the whole study period and in all directions.

As it is seen from time series plots, two stations located at the North Island (WARK and AUCK) were displaced at South-West direction with uplift at 310 mm and 303 mm respectively. Three other stations included the one located at the North Island (WGTN), and two others located at South Island (MQZG and OUS2). They were shifted at a South-East direction with uplifts of 303 mm, 203 mm, and 211 mm respectively. Maximum displacement for X-axis (North-South direction) were found on WGTN station – 255 mm, the highest value for Y-axis (East-West direction) were detected on OUS2, that is 31 mm, and the highest uplift were revealed on WARK station – 310 mm. Table 3 shows the displacement rates calculated on each station along with the uncertainty rates for the period of 2009–2018. Fig. 9 demonstrates the horizontal and vertical displacement rates over the study period. From the horizontal rates, it can be observed that the Australia Plate is pushing the Pacific one along the lower part of the South Island in South-West direction at the rate of H50 mm/yr. and slowing down at upper part of the same island at the rate of 35 mm/yr. in the sharper Southern direction. These displacement patterns reflect the complex tectonic settings in the upper part of the island, where the right-lateral Alpine strike-slip fault diverges into several branches and smoothly turns into Hikurangi subduction zone. The stations' displacements at the top of North Island exhibits South-West direction with very smooth western inclination at the rate of 24 mm/yr. This shows the evidence for the subduction of the Pacific Plate under the Australia Plate.

Table 3

IGS stations' horizontal (D_N and D_E) and vertical (D_U) displacement rates with their corresponding uncertainty rates in ITRF2014 reference frame over the period of 2009–2018

Station	Displacement rates, mm/yr.			2D displacement rates D_{NE}, mm/yr.
	D_N	D_E	D_U	
WARK	–24±0.1	–2±0.1	32±0.1	24
AUCK	–25±0.2	–2±0.1	31±0.1	25
WGTN	–27±0.4	22±0.3	32±0.6	35
MQZG	–10±0.2	56±0.1	21±0.3	57
OUS2	–14±0.3	39±0.3	22±0.6	41

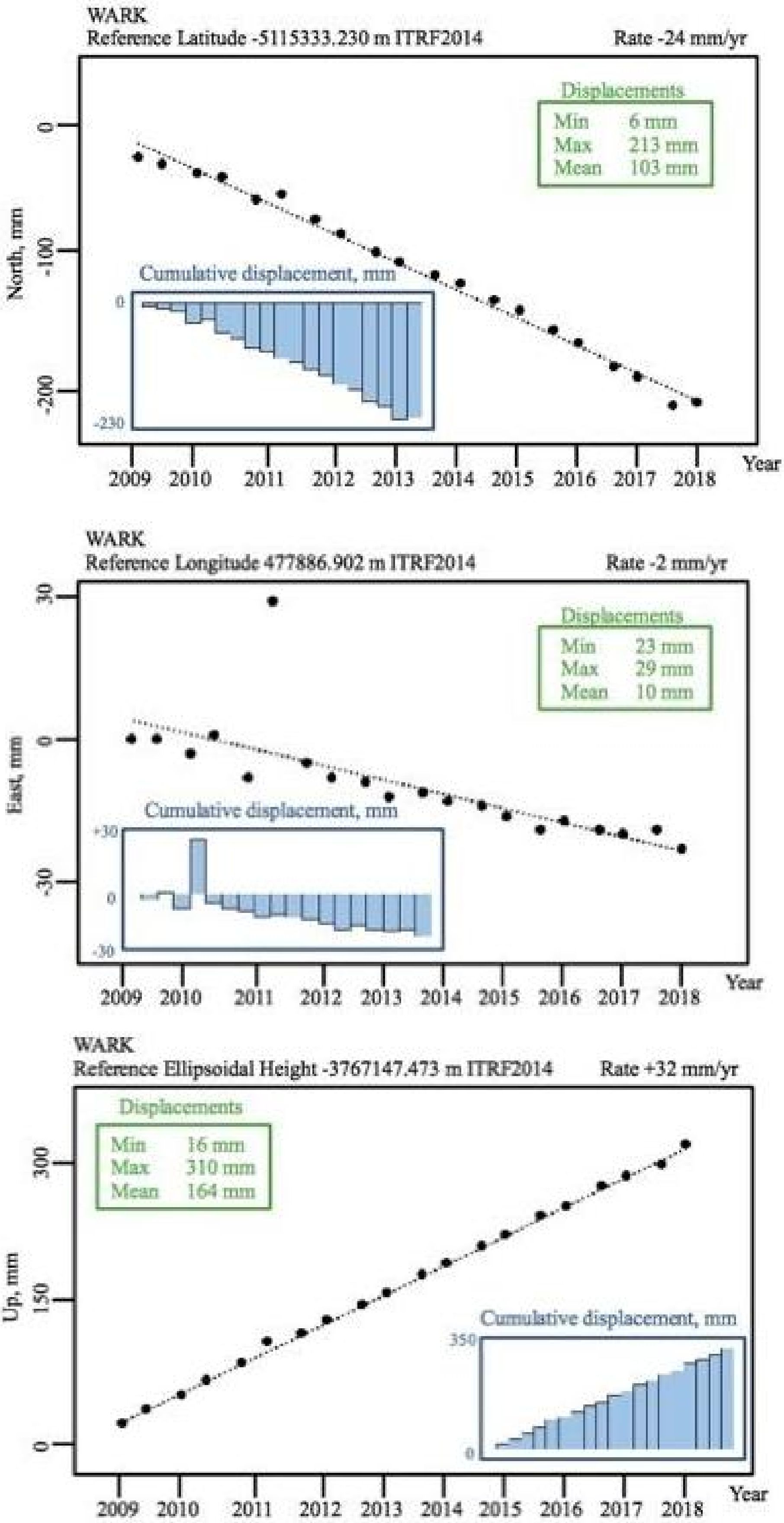


Fig. 3. Time series plots of WARK stations' positions

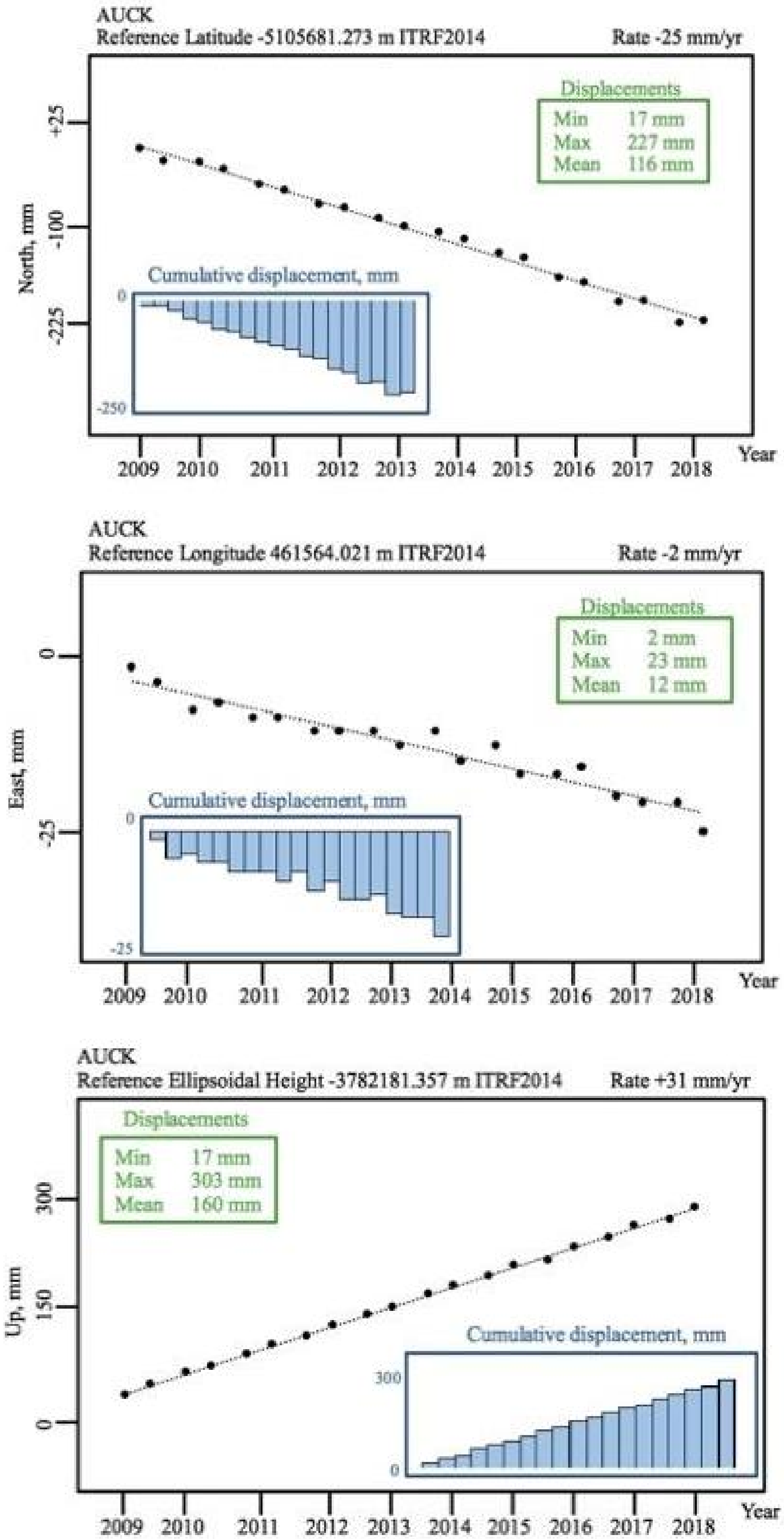


Fig. 4. Time series plots of AUCK stations' positions

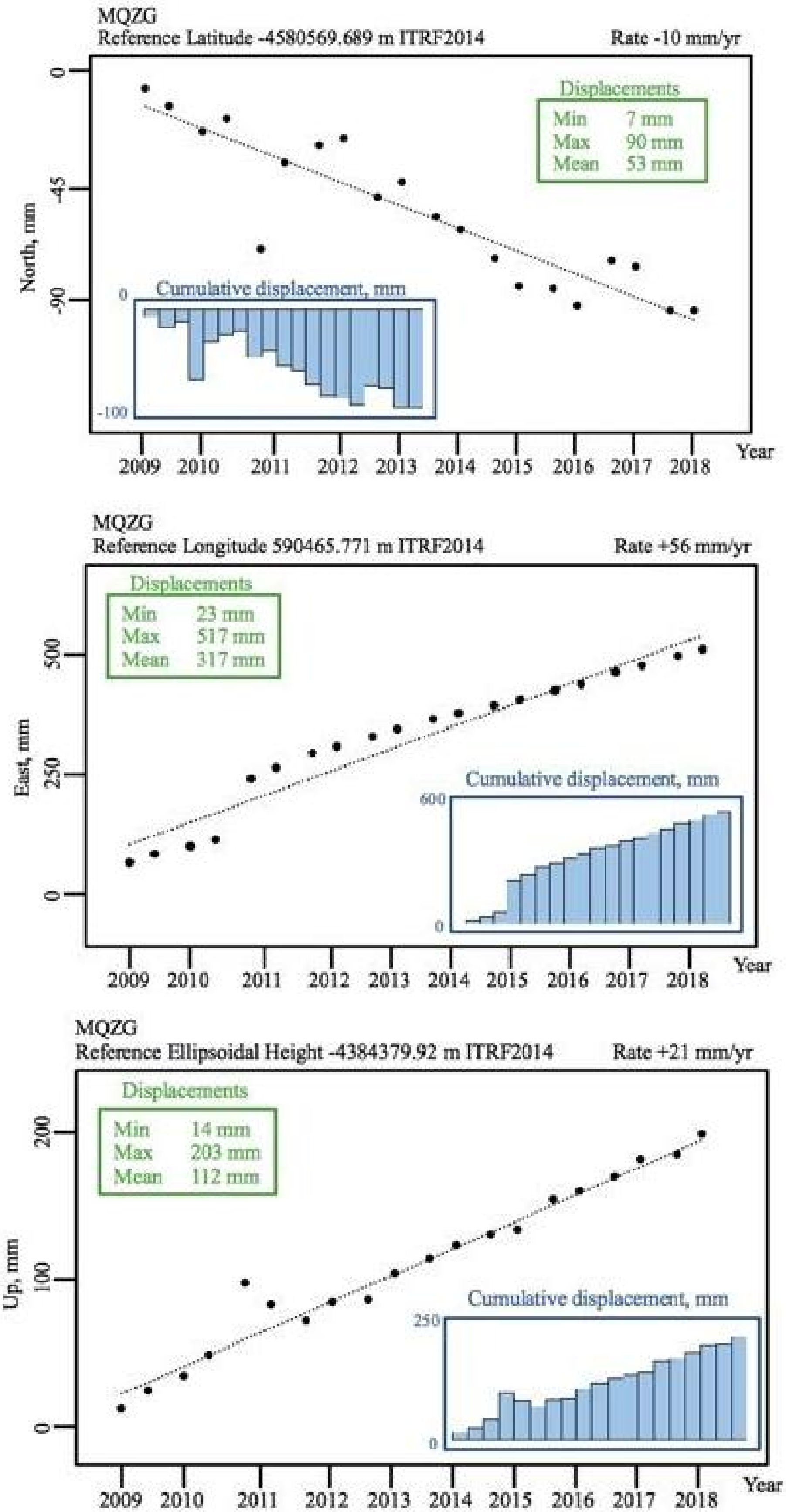


Fig. 5. Time series plots of MQZG stations' positions

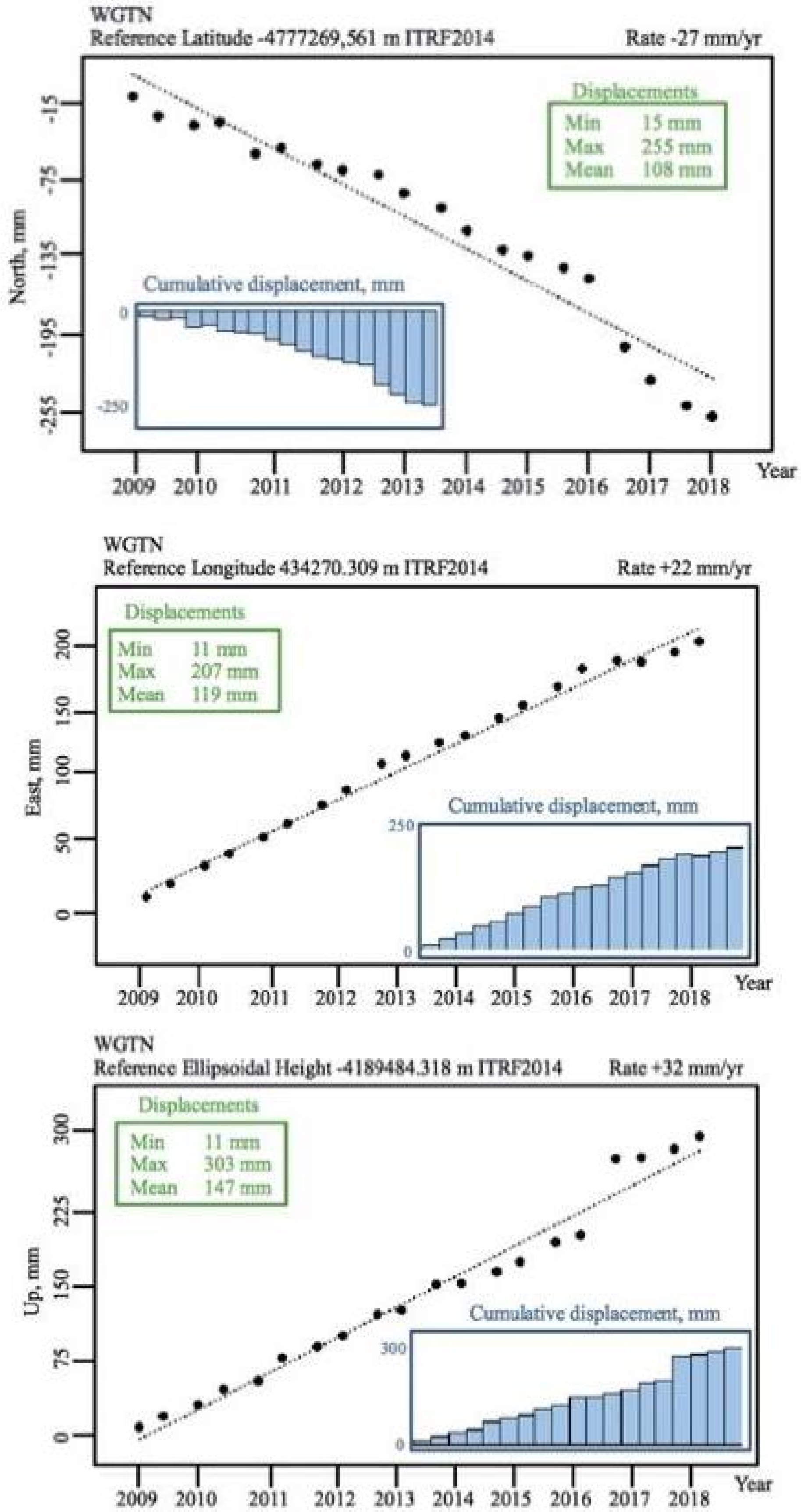


Fig. 6. Time series plots of WGTN stations' positions

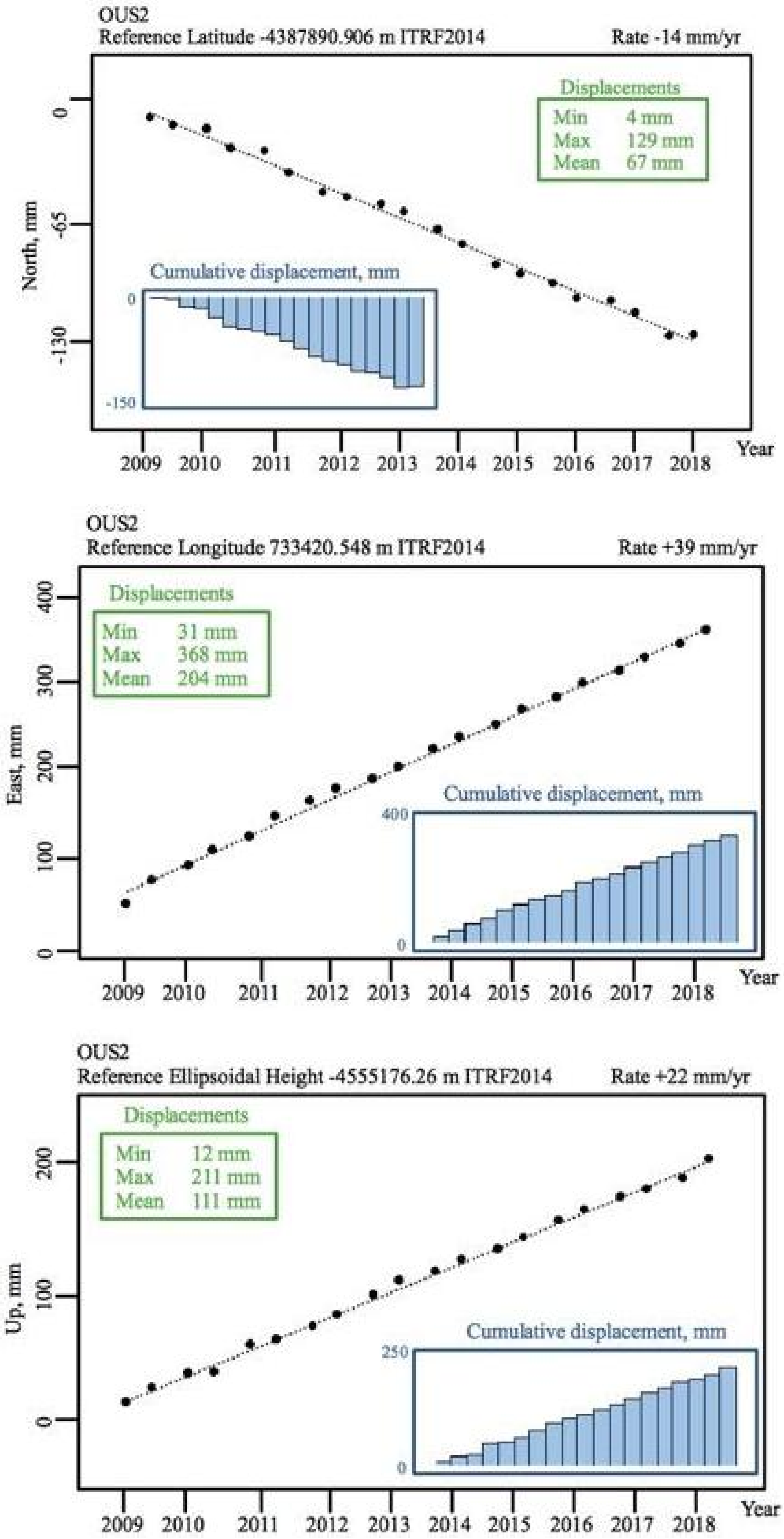


Fig. 7. Time series plots of OUS2 stations' positions

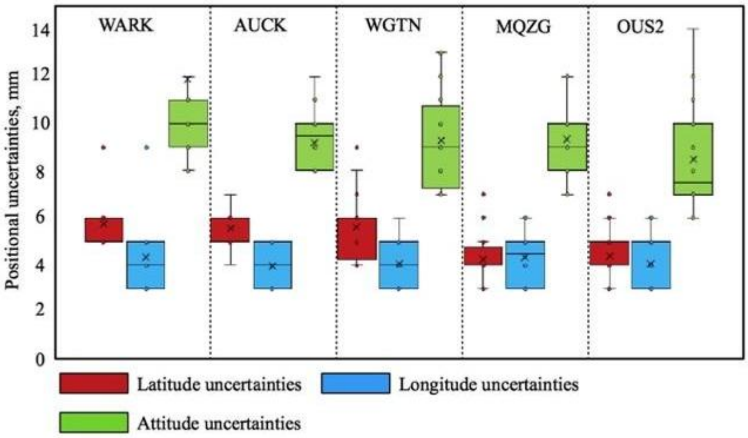


Fig. 8. Box plots of coordinate uncertainties in terms of the 95 % confidence level

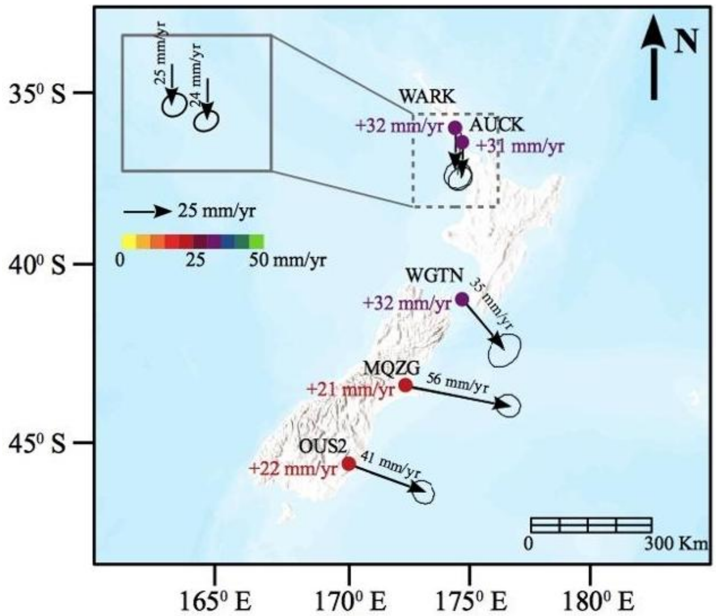


Fig. 9. Horizontal and vertical displacement rates of IGS stations in ITRF2014 (2009–2018). Black arrows indicate horizontal displacement vectors; error ellipses with 95 % confidence level are shown at the end of each displacement vector; colorful circles at each station mean vertical displacement rates

Originality

The horizontal and vertical displacements were derived for New Zealand considering the period of 2009–2018. In addition, the displacement rates were calculated, which provide a comprehensive understanding of crustal movements within the study area and over the particular time period.

Practical significance and future work

Crustal deformations refer to the Earth's surface changes due to strain that is accumulated in the crust and then released in the form of an earthquake. In this work, dynamic processes of the Pacific and Australian Plates' movement were studied.The results of the research confirm the presence of active zones. Understanding these surface changes and the details of deformations as well as their effect on the existing geological faults, is crucial for deducing which parts of faults are most likely to produce the next earthquake. Besides, the amount of displacement due to earthquakes or during the coseismic period allows one to better understand the crustal kinematics, thus, making a great contribution to the study of tectonic plate movement. This illustrates the significance of the current study. The results of this paper have important core findings for further research on the crustal movements of New Zealand.

This study was limited to several GPS stations, but could be extended for the whole New Zealand's territory. It may be also useful to study particular geological zones to investigate the potential dynamic processes behind these deformations.

Conclusions

In this study, the linear time series models were obtained in horizontal and vertical directions for the five IGS monitoring stations located in the seismic zone of North and South Islands, New Zealand. The analysis of the obtained results regarding the displacement parameters of IGS stations allowed us to determine the movement direction of tectonic plates, the stability of dynamics processes, the magnitude of horizontal and vertical plate displacements, and their rate.

On the North Island (WARK and AUCK stations), the offsets are established in the south-west direction. Whereas on the South Island (MQZG and OUS2 stations), displacements revealed the south-east direction. These spatial differences are explained by stations belonging to the Australian and Pacific plates respectively. The maximum horizontal displacement along the X-axis (North-South direction) was detected at WGTN station – 255 mm. The largest value of displacement along the Y-axis (East-West direction) was found at OUS2 and was equal to 31 mm.

As for the vertical displacements, WARK and AUCK stations were found to be elevated at 310 mm and 303 mm, while WGTN, MQZG, and OUS2 stations were uplifted at 303 mm, 203 mm, and 211 mm respectively. The maximum vertical displacement (Z-axis) was detected at the WARK station which was 310 mm. This is explained by using the map of tectonic settings (see Fig. 1, ***a***), where it can be seen that all stations are located in areas of active rising.

The map of horizontal and vertical displacement rates was designed indicating the direction of stations' movement. The results showed a clear shift to the south-east at the South Island and a small shift to the south-west at the North Island for the whole study period. The horizontal displacement rates were calculated as 24, 25, 35, 57, and 41 mm/yr. for WARK, AUCK, WGTN, MQZG, and OUS2 stations respectively, and the vertical displacements were found to be 32, 31, 32, 21, and 22 mm/yr. for the same stations respectively.

References

Alif, S. M., Fattah, E. I., Kholil, M. (2020). Geodetic slip rate and locking depth of east Semangko Fault derived from GPS measurement. *Geodesy and Geodynamics*, 11(3), 222–228.

Altıner, Y., Bačić, Ž., Bašić, T., Coticchia, A., Medved, M., Mulić, M., Pavlides, S. (2006). Present-day tectonics in and around the Adria plate inferred from GPS measurements. *Postcollisional tectonics and magmatism in the Mediterranean region and Asia*, *409*, 43–55.

Árnadóttir, T., Haines, J., Geirsson, H., Hreinsdóttir, S. (2018). A preseismic strain anomaly detected before M6 earthquakes in the South Iceland Seismic Zone from GPS station velocities. *Journal of Geophysical Research: Solid Earth*, *123*(12), 11–091.

Bartlow, N. M., Wallace, L. M., Beavan, R. J., Bannister, S., Segall, P. (2014). Time dependent modeling of slow slip events and associated seismicity and tremor at the Hikurangi subduction zone, New Zealand. *Journal of Geophysical Research: Solid Earth*, *119*(1), 734–753.

Beavan, J., Motagh, M., Fielding, E. J., Donnelly, N., Collett, D. (2012). Fault slip models of the 2010–2011 Canterbury, New Zealand, earthquakes from geodetic data and observations of postseismic ground deformation. *New Zealand Journal of Geology and Geophysics*, *55*(3), 207–221.

Beavan, J., Wallace, L. M., Palmer, N., Denys, P., Ellis, S., Fournier, N., Denham, M. (2016). New Zealand GPS velocity field: 1995–2013. *New Zealand Journal of Geology and Geophysics*, *59*(1), 5–14.

Chetverik, M., Bubnova, O., Babiy, K., Batur, M. (2017). Technogeneous earthquakes and mining operation safety. *Geotechnical Mechanics*, 136, 127–146 (In Russian).

Cremen, G., Galasso, C. (2020). Earthquake early warning: Recent advances and perspectives. *Earth-science reviews*, 205, 103184.

Dumka, R. K., Kotlia, B. S., Kothyari, G. C., Paikrey, J., Dimri, S. (2018). Detection of high and moderate crustal strain zones in Uttarakhand Himalaya, India. *Acta Geodaetica et Geophysica*, 53(3), 503–521.

Hamling, I. J. and Hreinsdóttir, S. (2016). Reactivated afterslip induced by a large regional earthquake, Fiordland, New Zealand. *Geophysical Research Letters*, *43*(6), 2526–2533.

Ishchenko, M. V. (2017). Determination of crustal strain in the northern region of Ukraine based on the analysis of GNSS observations. *Kinematics and Physics of Celestial Bodies*, 33(6), 302–308.

Johnson, K. M. (2013). Slip rates and off fault deformation in Southern California inferred from GPS data and models. *Journal of Geophysical Research: Solid Earth*, 118(10), 5643–5664.

Johnston, D., Standring, S., Ronan, K., Lindell, M., Wilson, T., Cousins, J., Bissell, R. (2014). The 2010/2011 Canterbury earthquakes: context and cause of injury. *Natural Hazards*, *73*(2), 627–637.

Koulali, A., Susilo, S., McClusky, S., Meilano, I., Cummins, P., Tregoning, P., Syafi'i, M. A. (2016). Crustal strain partitioning and the associated earthquake hazard in the eastern Sunda-Banda Arc. *Geophysical Research Letters*, 43(5), 1943—1949.

Larson, K. M., Lowry, A. R., Kostoglodov, V., Hutton, W., Sánchez, O., Hudnut, K., Suárez, G.

(2004). Crustal deformation measurements in Guerrero, Mexico. *Journal of Geophysical Research: Solid Earth*, 109(B4).

Lee, E. S., Lee, Y. W., Park, J. H. (2008). Displacement analysis of the GPS station of Sampali, Indonesia. *Earth, planets and space*, *60*(5), 519–528.

Leite, J., Lourenco, P. B., Ingham, J. M. (2013). Statistical assessment of damage to churches affected by the 2010–2011 Canterbury (New Zealand) earthquake sequence. *Journal of Earthquake Engineering*, 17(1), 73–97.

Luginbuhl, M., Rundle, J. B., Turcotte, D. L. (2019). Natural time and nowcasting earthquakes: are large global earthquakes temporally clustered? In *Earthquakes and Multi-hazards Around the Pacific Rim, Vol. II*, 137–146. Birkhäuser, Cham.

Metzger, S., Jónsson, S., Geirsson, H. (2011). Locking depth and slip-rate of the Húsavík Flatey fault, North Iceland, derived from continuous GPS data 2006–2010. *Geophysical Journal International*, 187(2), 564–576.

Richter, A., Ivins, E., Lange, H., Mendoza, L., Schröder, L., Hormaechea, J. L., Dietrich, R. (2016). Crustal deformation across the Southern Patagonian Icefield observed by GNSS. *Earth and Planetary Science Letters*, 452, 206–215.

Shen, F., Royden, L. H., Burchfiel, B. C. (2001). Large scale crustal deformation of the Tibetan Plateau. *Journal of Geophysical Research: Solid Earth*, 106(B4), 6793–6816.

Su, X., Meng, G., Su, L., Wu, W., Liu, T. (2020). Coseismic and early postseismic deformation of the 2016 Mw 7.8 Kaikōura earthquake, New Zealand, from continuous GPS observations. *Pure and Applied Geophysics*, *177*(1), 285–303.

Tenzer, R., Stevenson, M., Denys, P. (2012). A compilation of a preliminary map of vertical deformations in New Zealand from continuous GPS data. In *Geodesy for Planet Earth*, 697–703. Springer, Berlin, Heidelberg.

Tretyak, K., Brusak, I. (2022). Modern deformations of Earth crust of territory of Western Ukraine based on "GEOTERRACE" GNSS network data. In *Geodynamics*, 1(32), 16–25.

Yildirim, O., Yaprak, S., Inal, C. (2014). Determination of 2011 Van/Turkey earthquake (M = 7.2) effects from measurements of CORS-TR network. *Geomatics, natural hazards and risk*, *5*(2), 132–144.

Zheng, G., Wang, H., Wright, T. J., Lou, Y., Zhang, R., Zhang, W., Wei, N. (2017). Crustal deformation in the India-Eurasia collision zone from 25 years of GPS measurements. *Journal of Geophysical Research: Solid Earth*, 122(11), 9290–9312.

Zuska, A. V. (2014). Kinematic model of landslide slopes: monograph. Donetsk: National Mining University, 140 (In Russian).

Марина БАТУР[1], Катерина БАБІЙ[2]

[1] Стамбульський технічний університет, докторант кафедри інженерної геоматики, Кампус Аязага, Маслак, Стамбул, 34469, Туреччина, e-mail: baturm20@itu.edu.tr, ORCID 0000-0001-9284-8858

[2] Інститут геотехнічної механіки ім. М. С. Полякова Національної академії наук України, вул. Сімферопольська, 2а, Дніпро, 49005, Україна, e-mail: babiyev@i.ua, ORCID 0000-0002-0733-2732

ТЕНДЕНЦІЇ ГОРИЗОНТАЛЬНИХ І ВЕРТИКАЛЬНИХ ЗМІЩЕНЬ ЗЕМНОЇ КОРИ НА ОСНОВІ ДАНИХ МІЖНАРОДНИХ СЛУЖБ GNSS: ПРИКЛАД НОВОЇ ЗЕЛАНДІЇ

Часові ряди координат п'яти постійних станцій Міжнародної служби GNSS (IGS), розташованих у Новій Зеландії, проаналізовано щодо їх річного переміщення за 2009–2018 рр. Неопрацьовані дані у формі файлів Receiver Independence Exchange (RINEX) взято із бази даних IGS і процесів за допомогою служби онлайн-обробки AUSPOS. Із використанням часових рядів координат розраховано швидкості горизонтального та вертикального зміщення за десятирічний період дослідження. Згідно з результатами, розташовані на Північному острові Нової Зеландії станції зафіксували підняття земної кори в середньому на 31–32 мм/рік, тоді як за даними станцій, розміщених на Південному острові, встановлено 21–22 мм/рік позитивного вертикального зміщення. Швидкість горизонтальних переміщень у регіоні дослідження зростає у напрямку північ – південь. Зокрема, дві станції, розташовані в північно-західній частині Північного острова, виявили зміщення 24–25 мм/рік, а одна станція в південній частині цього острова – швидкість зміщення 35 мм/рік. Станції, встановлені на Південному острові, показали швидкості горизонтальних зміщень 41–56 мм/рік. Це дослідження підтверджує основний внесок, зроблений у вивчення деформації земної кори, тобто оновлені параметри зміщень разом із їх напрямками за останні роки. Результати можуть бути використані для подальших геодинамічних досліджень, а також для пошуку найвірогідніших місць землетрусів на поточній території дослідження.

Ключові слова: деформації земної кори; зміщення; дані IGS; часові ряди; Нова Зеландія; землетрус; сейсмічна область.

Received 02.09.2022