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A GNSS-based near real time automatic Earth Crust and Atmosphere Monitoring Service for Turkey

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Abstract

Turkey is located in a highly active earthquake zone. Many geodynamic and seismic activities occur during a day, such as earthquakes, landslides, sinkholes and creep movements. In addition to seismicity, Turkey has unique physical features like being surrounded by seas on three sides, affected by different climate types. It is located on mid latitudes, which makes Turkey very suitable for atmospheric studies. For this reason, Turkey serves as a natural laboratory for geodesy, geophysical and atmospheric scientists. Therefore, Global Navigation Satellite System (GNSS) data are used in many areas. However, not all the scientists can reach or process the data for coordinate-based studies. Within the scope of the study, a GNSS-based Earth Crust and Atmosphere Monitoring Service is established at the Zonguldak Bulent Ecevit University. Using the results of the GNSS processing, time series of GNSS station positions are produced and used to infer strain solutions related to earthquakes. Estimates of the Precipitable Water Vapour (PWV) and the Total Electron Content (TEC) in the ionosphere are made available for tropospheric and ionospheric studies, respectively. Visualisation of the results are intended to be provided to the scientific community. Results show that the root mean square (RMS) differences of the PWV between GNSS and radiosondes are in the range of 1–3 mm. RMS differences of the TEC is in the range of 2–3 TEC units when comparing our GNSS estimates with the Global Ionospheric Maps (GIM) from the International GNSS Service (IGS). One of the main results obtained from the analysis centre is near

real-time strain rates and their relations to actual earthquakes. Results show that near real-time strain rates can be assessed as a precursor parameter for earthquakes.

Introduction

According to 2018 data, 10.400 people lost their lives due to natural disasters and the global economic loss reached 160 billion dollars (URL-1). As the world population increases, the number of people affected by natural disasters increases exponentially. It is estimated that the world's population will reach 8 billion by 2030 and 10 billion by 2055 (UNDRR, 2019). Table 1 presents a statistical analysis of natural disasters and loss of life caused by natural disasters. According to this, earthquakes are one of the leading disasters in the last 20years. This is followed by extreme temperatures, floods and storms associated with the climate. Scientists related with earth, climate and atmospheric studies are constantly researching to be prepared for disasters caused by climate change and earthquakes. In the last decades, Global Navigation Satellite System (GNSS) have become an important data source for scientists to understand geological and atmospheric phases. Although it is thought that human life will not be long enough to detect and understand the Earth's crust movements that cause earthquakes, the emergence of GNSS systems has made it possible to track ground movements and understand the tectonic mechanisms much more precisely.

In the early 2000s, conducted studies found that some earthquakes caused anomalies in the ionosphere layer before or after main shock (Liu et al., 2004, Masci and Thomas, 2015, Plotkin, 2003, Rolland et al., 2013). In addition to ionosphere, the amount of precipitable water vapour (PWV) in the troposphere layer can be determined by GNSS. It is more economical, faster, and provides much higher spatial and temporal resolution than other methods, thus making significant contributions to the forecasting of meteorological events (Baker et al., 2001, Bock and Doerflinger, 2001). In spite of these advantages provided by the GNSS for earth, climate and atmospheric scientists, the above-mentioned studies require advanced geodetic knowledge and complex academic software skills. However, it is not possible for every scientist from different disciplines to have this knowledge and skills. This situation makes it possible only for a limited number of scientists to benefit from the opportunities provided by GNSS systems and prevent its widespread usage.

As mentioned before, Turkey is located in one of the world's most troubled regions in terms of natural disasters and seismic activities. In fact, approximately 50% of the settlements in the country have been exposed to a natural disaster at least once between 1950 and 2008 (Gokce et al. 2008). It is an undisputed fact that this number has risen even higher nowadays.

In Turkey, 146 permanent GNSS stations, homogenously distributed all over the country about 80km distance between the stations that are tracking Global Positioning System (GPS) and Globalnaya Navigatsionnaya Sputnikovaya Sistema, form CORS (Continuously Operating Reference Station) network. Moreover, the 30s interval data of CORS-TR stations are available to scientists. This opportunity is a blessing for better understanding of natural disasters occurring in the country

and for developing country policies to mitigate harm. However, in Turkey, as is in the World, the number of qualified scientists are extremely limited to process these data and obtaining the final product. The lack of an online service infrastructure that serves end users by processing the data adversely affects the natural disaster-oriented use of the GNSS infrastructure. A GNSS-based Earth Crust and Atmosphere Monitoring Service has been established, to eliminate this aforementioned lack of service infrastructure and to support all scientists from different disciplines for their research or to support the authorities in their operational activities. The system automatically computes the daily crustal movements, parametric changes in the ionosphere and the troposphere on hourly and daily basis and provides online service. In this study, the evaluation strategy and the results of this service are discussed.

Section snippets

The Turkish CORS network

The project of Turkish CORS Network (TUSAGA-Aktif in Turkish) utilised in this study was started in 2006 jointly by General Directorate of Land Registry and Cadastre (GDLRC) and General Directorate of Mapping (GDM). The system is operational to users all over the country since 2009 (Eren et al., 2009) (Fig. 1). As mentioned above, the main goal of this network is to establish network-based CORS-TR stations functioning 24/7 with RTK capabilities at centimetre accuracy level using 146 GNSS …

Data and methodology

The analyses involved five main sequential phases such as, data acquisition, processing, atmospheric parameter estimation, visualizing the results and transmitting the results to the end user on the web (Fig. 2). In the data acquisition phase, using file transfer protocol websites, hourly GNSS data belong to IGS and CORS-TR networks, and ultra-rapid ephemeris products from IGS are downloaded.

TEQC software is being used for quality check for downloaded data. After the data are checked, the GNSS …

Near real-time coordinates variations

After each processing, hourly solutions are kept and time series of coordinate components are updated per station. At the end of the day, daily solutions are processed and time series, which include daily coordinates, are updated. With both the hourly and the daily solutions available, users can obtain different kinds of data with respect to their needs. Using hourly and daily solutions,

hourly and daily displacements are computed. Using daily solutions, cumulative displacement vectors for a …

Conclusions and future work

Fully automatic near real-time GNSS-based Earth Crust and Atmosphere Monitoring Service is established and operational since 1 January 2019 at the Zonguldak Bulent Ecevit University. The capability of the new system is shown with different examples of products. Accuracy assessments of by-products such as PWV and TEC parameters have been done.

Apart from atmospheric parameters, cumulative strain rates for axes and planes obtained from hourly displacements also complies with the current physical …

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. …

Acknowledgement

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Reference (35)

H.C. Baker *et al.*
Ground-based GPS water vapour estimation: potential for meteorological forecasting
J. Atmos. Sol. Terr. Phys. (2001)

O. Bock *et al.*
Atmospheric modeling in GPS data analysis for high accuracy positioning
Phys. Chem. Earth Part A. (2001)

H.S. Kutoglu *et al.*

The 3-D strain patterns in Turkey using geodetic velocity fields from the RTK-CORS (TR) network

J. Afr. Earth Sc. (2016)

C. Shi *et al.*

An improved approach to model ionospheric delays for single-frequency precise point positioning

Adv. Space Res. (2012)

B. Aktuğ *et al.*

Türkiye Ulusal Temel GPS Ağı Güncel Koordinat ve Hızlarının Hesaplanması (Computation of the Actual Coordinates and Velocities of Turkish National Fundamental GPS Network)

Harita Dergisi (2011)

D.J. Allain *et al.*

Ionospheric delay corrections for single-frequency GPS receivers over Europe using tomographic mapping

GPS Solutions (2009)

J. Askne *et al.*

Estimation of tropospheric delay for microwaves from surface weather data

Radio Sci. (1987)

N. Bergeot *et al.*

Impact of the Halloween 2003 ionospheric storm on kinematic GPS positioning in Europe

GPS Solutions (2011)

N. Bergeot *et al.*

Near real-time ionospheric monitoring over Europe at the Royal Observatory of Belgium using GNSS data

J. Space Weather Space Clim. (2014)

M. Bevis *et al.*

GPS meteorology: remote sensing of atmospheric water vapour using the global positioning system

J. Geophys. Res. (1992)

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Cited by (9)

Fault displacement analysis using a multidisciplinary approach on the Gerede Segment of the North Anatolian Fault Zone

2023, Soil Dynamics and Earthquake Engineering

> *Citation Excerpt :*
>
> ...Numerous researchers have focused on the NAFZ's seismic activity, including [9,26,37,38,57]; and [48]. The Global Navigation Satellite System (GNSS) technique is frequently used in studies on geodynamics and kinematics of earth crust movements, as well as cartography studies, in determining the deformations in earthquake periods and is a source of data in defining geological and atmospheric phases [2,10,29,41,53,72]. Horizontal and vertical displacements in topography during an earthquake can be modeled according to the horizontal and vertical displacements measured along the surface rupture....

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On variations of the decadal precipitable water vapor (PWV) over Turkey

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> *Citation Excerpt :*
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> ...The continuously operating reference station (CORS-TR) network consists of 146 permanent GPS stations. It was commissioned in 2009 (Gurbuz et al., 2020). During the operation of the CORS-TR, some stations were renamed due to receiver upgrade or malfunction....

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