Time-frequency analysis of the Sumatra 2004 earthquake impact on GPS stations displacements

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Abstract

In the article time-frequency analysis of the Sumatra 2004 earthquake impact on 5 Polish GPS permanent station are presented. The analysis has been performed on the stations coordinates obtained from kinematic processing and on the double difference residuals from static processing

Introduction

The Sumatra 26-12-2004 earthquake is one of the largest earthquakes in the world since 1900. The magnitude was reported as 9.1 on the Richter scale. The earthquake sets off a tsunami recorded on tide gauges nearly world-wide (http://neic.usgs.gov/, http://wcatwc.arh.noaa.gov/). The earthquake lasted more then 8 minutes and it caused the entire Earth to vibrate. In this article the observed impact of the earthquake on 5 Polish GPS stations is presented.

Analyzed stations (KATO, KRAW, ZYWI, WODZ, KLOB) are part of Polish Active Geodetic Network ASG-PL, and three of them (KATO, KRAW, ZYWI) provide data for EUREF Permanent Network. The stations are equipped with Ashtech UZ-12 receivers with ASH701945C_M SNOW antennas and data are recorded with 1 sec sampling interval. All the stations are located on the roofs of the buildings. Figure 1 shows the network of analyzed stations. Analysis has been performed on the horizontal coordinates time series (north and east component) obtained from kinematic solution. In the kinematic processing centrally located KATO station has been treated as a fixed station. Moreover the double difference residuals from baseline KRAW-KATO static solution have been also analyzed.

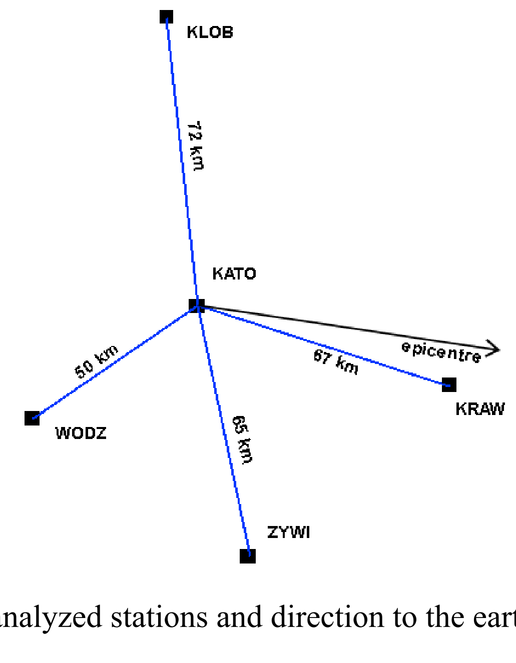

Fig. 1. Network of analyzed stations and direction to the earthquake epicenter.

Analysis of GPS data

The earthquake occurs at DOY361/2004 at 00:58:53 UT. In order to isolate the effect of earthquake on the GPS stations, 1-hour (1 UT – 2 UT) coordinates time series from 3 consecutive days DOY360, 361 and 362 have been compared. In the sample data from KRAW station the short period oscillations are clearly visible in both components (north and east) in the DOY361 time series. The oscillations are not present day before an after (Fig. 2). Day-to-day cross-correlation coefficients calculated between data from DOY360-361 and DOY361-362 indicates a maximum correlation at lag of 250 sec, close to the difference between sidereal and mean solar day. It proofs that the long-term oscillations in the time series are satellites constellation dependent (e.g. multipath). In the next step the oscillations with period longer then 4 minutes (arbitrary chosen) has been removed from the signal using the high-pass filter showing that the short period displacements in north component are of 3 cm (Fig. 3) After filter applying the time-frequency spectrum has been calculated using Gauss derivative wavelet.

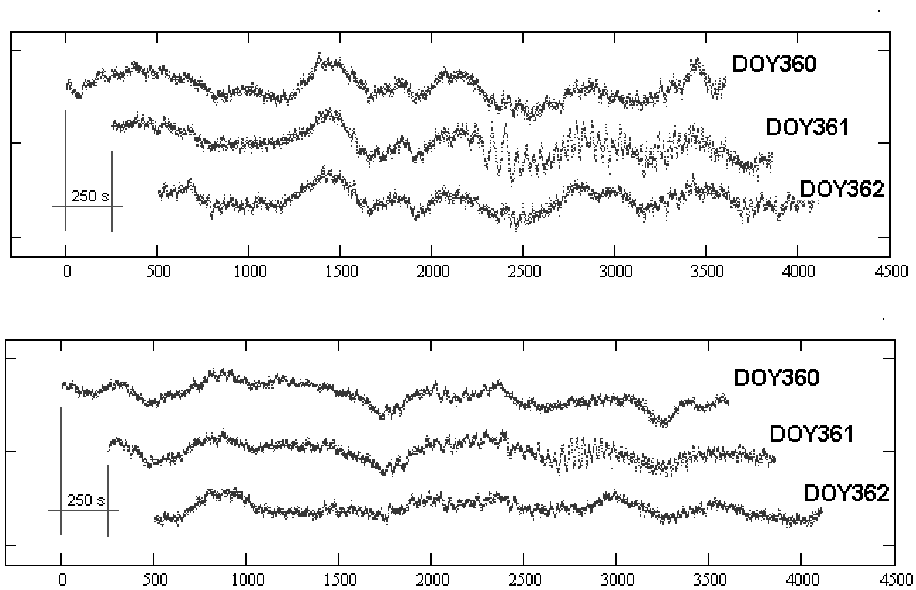

Fig. 2. KRAW station north (top) and east (bottom) components from days DOY360, 361, 362/2004 shifted by 250 seconds.

The impact of Sumatra earthquake is clearly visible in the KRAW and WODZ spectra of north and east components (Fig. 5). First oscillations in north component start at 1:33 TU and lasts about 20 minutes with frequency increasing from 0.015 Hz to 0.035 Hz. In the east component oscillations starts at 1:40 TU, lasts 6 minutes and frequency is between 0.020 Hz and 0.035 Hz. Due to baseline orientation nearly perpendicular to the seismic wave direction and differential processing of the data the impact on the ZYWI and KLOB stations is less visible (Fig. 4).

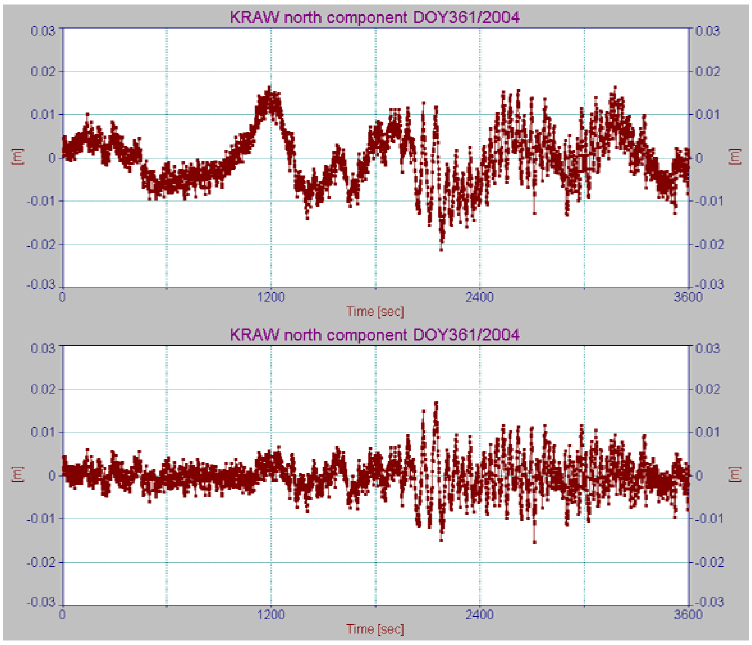

Fig. 3. KRAW station north component before (top) and after (bottom) applying the high-pass filter.

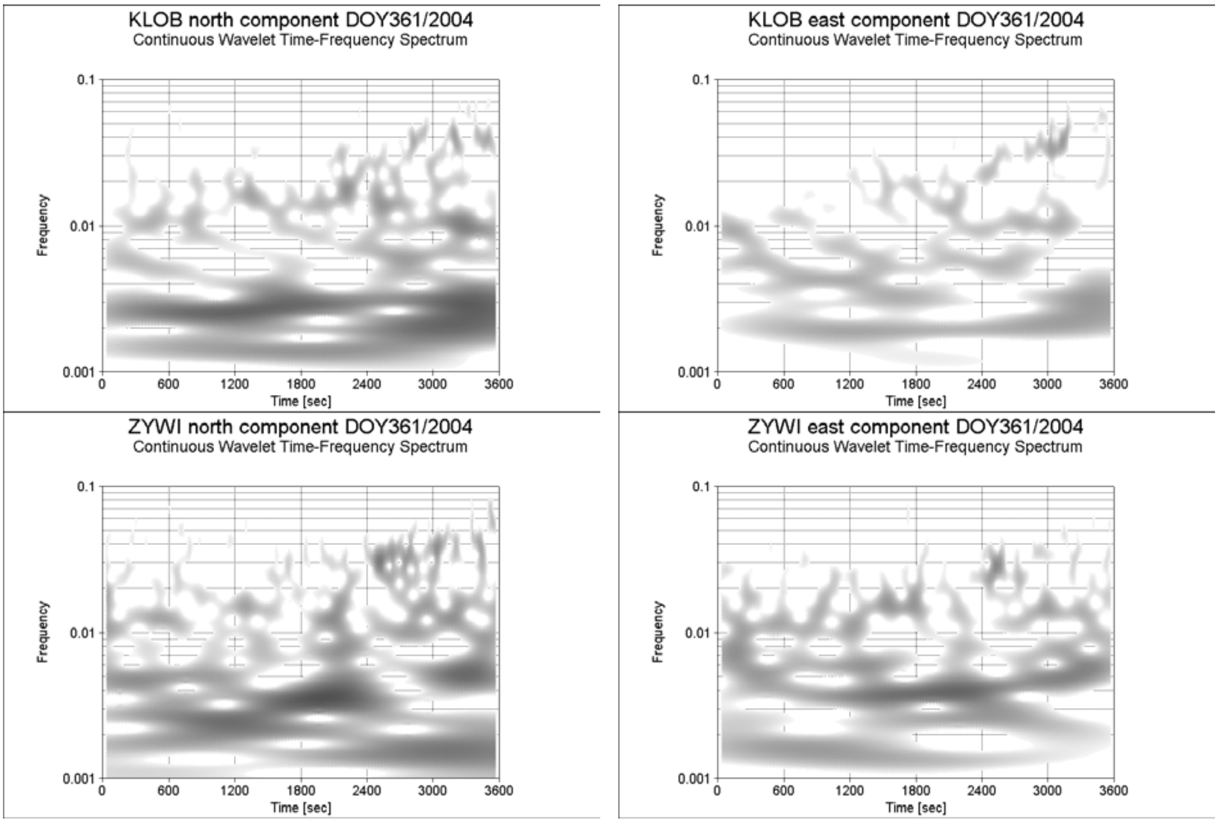

Fig. 4. Time-frequency spectra of the KLOB and ZYWI stations coordinates.

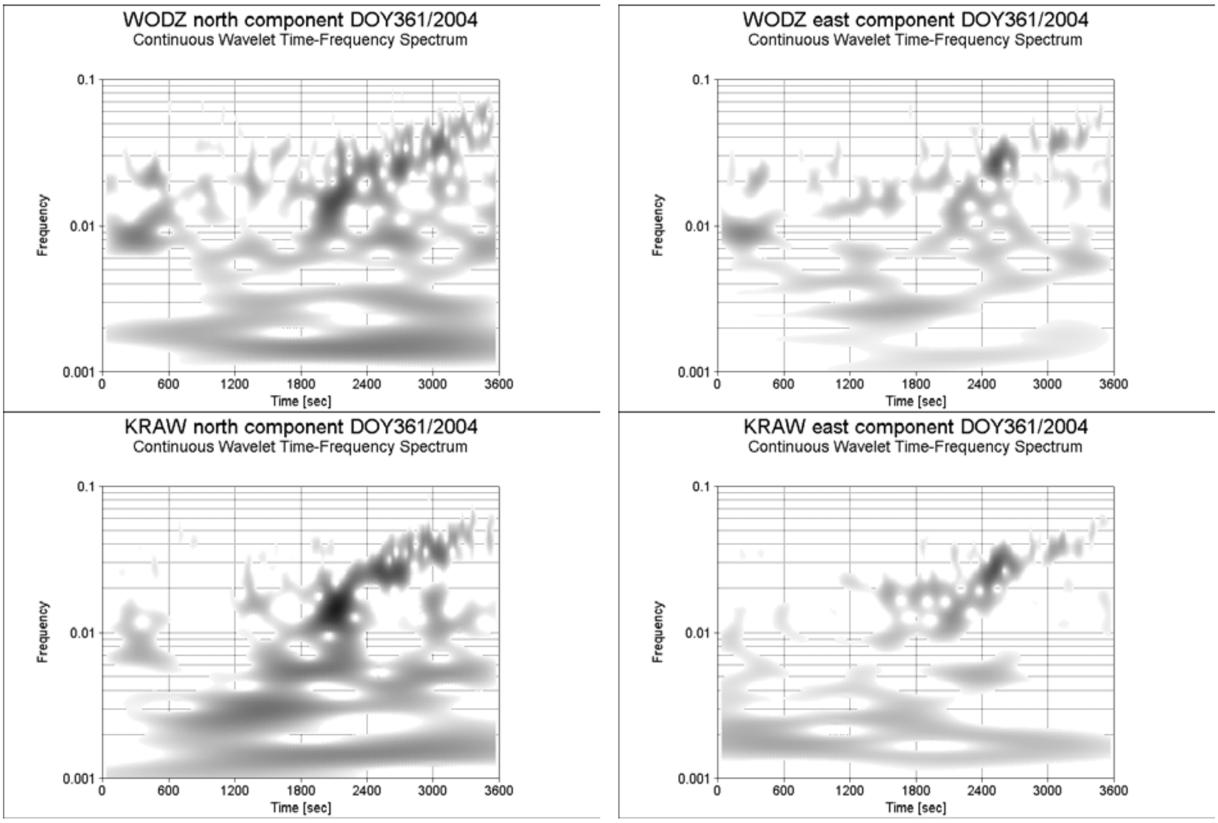

Fig. 5. Time-frequency spectra of the WODZ and KRAW stations coordinates.

Depends on satellites elevation and azimuth it is possible to detect the similar oscillations in the double difference residuals of static processing. Since reference satellite PRN27 is at high elevations, pseudorange and phase measurements to this satellite are not sensitive to horizontal oscillations (Fig. 6). Satellites at lower elevations are sensitive to oscillations in only one direction (e. g. east-west oscillations in case of PRN13) or both north-south and east-west oscillations (PRN10). As an example the time-frequency spectra of PRN10-27 and PRN13-27 double difference residuals of KRAW-KATO baseline are presented (Fig. 7, 8).

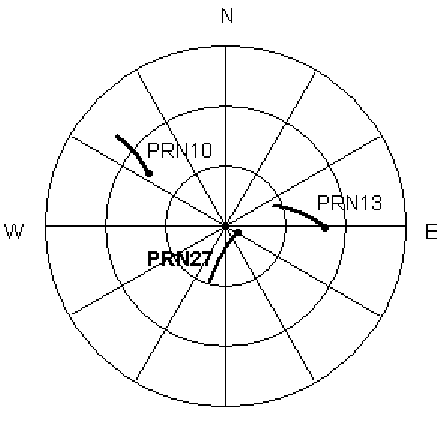

Fig. 6. Sky plot of chosen satellites visible at the KRAW station.

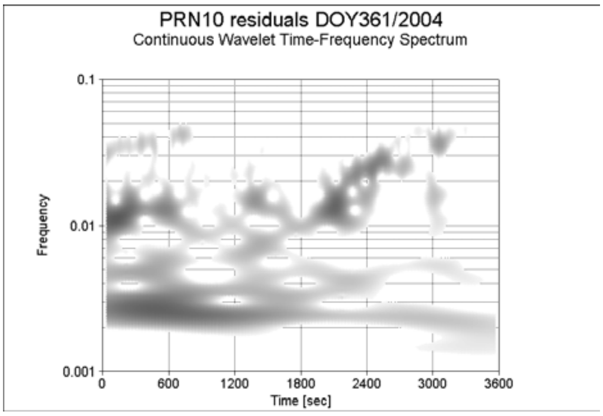

Fig. 7. Time-frequency spectrum of the double difference residuals PRN 10-27

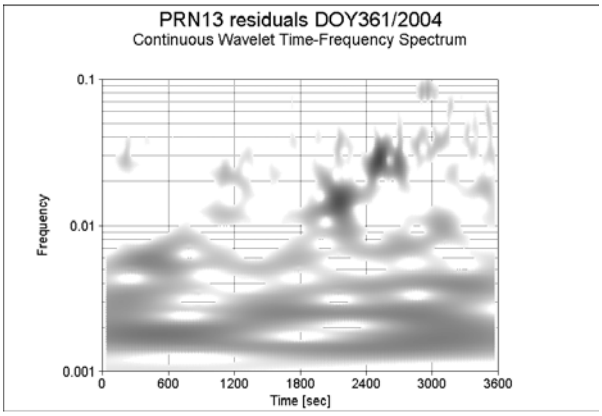

Fig.8. Time-frequency spectrum of the double difference residuals PRN 13-27

Conclusions

The Sumatra 2004 earthquake impact on GPS stations at distance of 9000 km from epicenter is detectable in both kinematic data and double difference residuals. Due to differential processing of the data, in some configurations of the GPS stations the effects are less visible.

Acknowledgment

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References

National Earthquake Information Center web page - http://neic.usgs.gov

West Coast & Alaska Tsunami Warning Center web page - http://wcatwc.arh.noaa.gov

R. Dach, U. Hugentobler, P. Fridez, M. Meindl; *User manual of the Bernese GPS Software Version 5.0*, Astronomical Institute, University of Bern, January 2007

W. Söhne, W. Schwahn, J. Ihde; *Earth surface deformation in Germany following the Sumatra Dec 26, 2004 earthquake using 1 Hz GPS data*; Presented at Euref Symposium 2005 in Vienna, Austria, June 1-4 2005.