Proc. VI Serbian-Bulgarian Astronomical Conference, Belgrade 7-11 May 2008,
Eds. M. S. Dimitrijević, M. Tsvetkov, L. Č. Popović, V. Golev
Publ. Astr. Soc. "Rudjer Bošković", No. 9, 2009, 293-300

LATITUDE VARIATIONS FOR THE PERIOD 1987.5-2008.3 AT OBSERVATORY PLANA AND THEIR INERPRETATION

YAVOR CHAPANOV and TZVETAN DARAKCHIEV

Central Laboratory for Geodesy of Bulgarian Academy of Sciences,
Acad. G. Bonchev Bl.1, 1113 Sofia, Bulgaria
e-mail: chapanov@clg.bas.bg

Abstract. Latitude variations at Geodetic Observatory Plana, located near to Sofia, are determined permanently since July 1987 by means of zenith telescope Zeiss 135/1750. More than 18350 observations of 72 star pairs are available now for scientific investigations. The most essential results and interpretation of the latitude variations and oscillations of the vertical at observatory Plana for the period 1987.5-2008.3 are pointed out. Some changes of the latitude and vertical at observatory Plana are explained by the earthquakes, long-period variations of the gravity and solar activity cycles.

1. INTRODUCTION

The geodynamic phenomena, related to the Earth rotation, the inner Earth mass forming and motion, the Earth plates deformations and motions, earthquakes, core-mantle interaction, etc., are complex and often no predictable effects, determined by the structure and dynamical properties of the Earth. These phenomena are of special interest to the geosciences, and particular to the geodynamics, the geophysics and the geodesy, because the inner Earth structure, the effects and processes in earth's womb, over earth's surface and earth's closing space reflect on them. These geophenomena are so complex, that it universal investigation is possibly only on the base of the utilization of many and various methods and means of observations.

Such methods are the classical astronomical geodetic methods and means of determination of universal time-geographic longitude and geographic latitude, known as astrometrical methods of determination of universal time and latitude.

These observations are connected directly to the vertical in the observation station, and due to its high precision and long duration can be used to investigation of the permanent changes of the vertical in time.

The change of the latitude at the observation station, as well the natural lows, by which this change develops, can be find out by means of permanent astrometrical observations of geographic latitude.

The changes of the geographic latitude are polar and nonpolar. The changes of nonpolar character are connected to the changes of direction of the vertical at the observation station.

The changes of the vertical can be provoked by the deformations and motions of the earth plates and the local formations in them, the forming and moving of the mass into the earth, over it surface, and in the atmosphere; by the dynamics and interconnection between the mantle and the core; by the earthquakes and the volcano activity; by the changes of the levels of the big water basins and underground water; by the variations of earth rotation; and by the other reasons. The results, obtained by means of permanent observations of geographic latitude correspond to these geodynamical phenomena, thus these results can be used to investigate a great part of them. Inclusive to investigate the earthquake predictions and the earthquake nature. The nonpolar changes of the geographic latitude can be used for investigation of the local gravity field variations.

2. LATITUDE OBSERVATION AT OBSERVATORY PLANA

The latitude observation by zenith telescope Zeiss 1750/135 at observatory Plana are provided permanently since 1987.5. More than 18 000 observations of 72 star pairs in 12 groups are available in 2008 (Fig. 1). For processing of the latitude observations and investigation of the oscillations of the vertical in the Central Laboratory for Geodesy are developed several methods for determination of some instrumental constants and specific systematic errors (Darakchiev and Chapanov, 2003; Chapanov and Darakchiev, 2005).

The nonpolar latitude changes (Fig. 1) are determined as differences between the observed latitude values and polar latitude variations, computed by the solution C04 for pole coordinates of the International Earth Rotation Service (IERS).

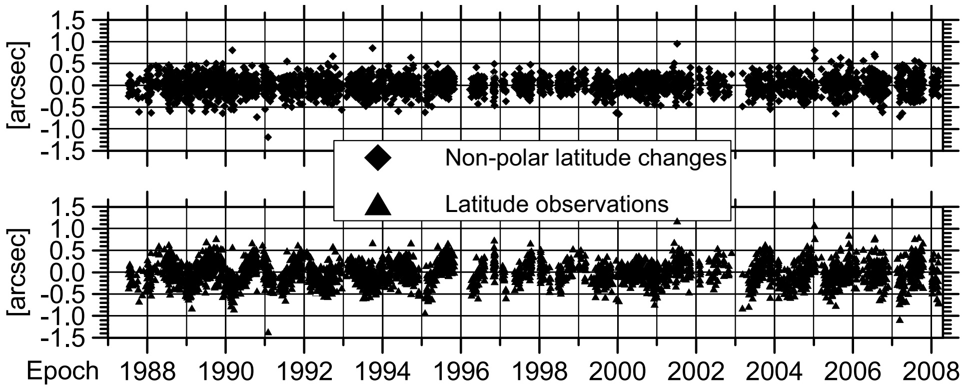

Figure 1: Latitude observations at observatory Plana (low graph) and non-polar latitude changes (upper graph).

3. OSCILLATIONS OF THE VERTICAL AT OBSERVATORY PLANA

The time series of the nonpolar latitude change are determined by normal points at 0.05a (Fig. 2). The normal points are computed by means of the robust Danish method (Kubik, 1982; Juhl, 1984; Kegel, 1987). This method allows to detect and isolate outliers and to obtain very accurate and reliable solution for the nonpolar latitude changes and the oscillations of the local vertical in the meridian plane. Other parameters of the latitude changes and oscillations of the vertical are estimated by means of robust Hampel's method (Hampel 1973, 1974) in modification of Somogyi (1987). The processing of the astrometrical observations by robust methods allows reliable detection of the gross errors in observations, as well as more reliable account of the outliers near the limits of 3σ (Poits, 1988).

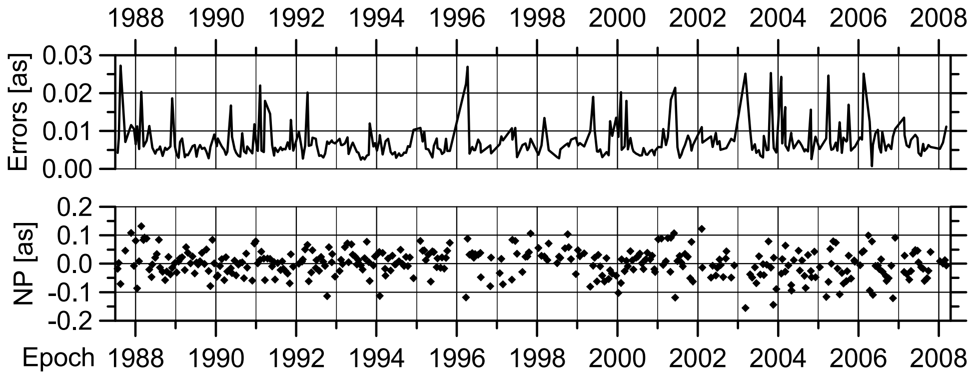

Figure 2: Normal points (NP) of non-polar latitude changes at observatory Plana at 0.05a (low graph) and their RMS errors (Root Mean Square), whose mean level is about 7mas.

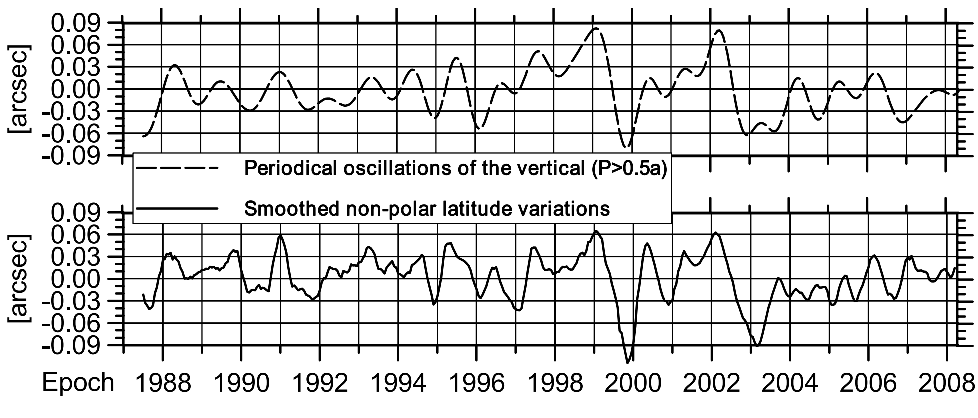

Figure 3: Periodical oscillations at observatory Plana with periods above 0.5a and smoothed time series of the nonpolar latitude changes.

The periodical oscillations of the vertical are determined by the first 42 terms of the Fourier approximation of nonpolar latitude changes (Fig. 3), which include all oscillations with periods larger than 0.5a.

4. LATITUDE VARIATIONS OF OBSERVATORY PLANA

The time series of latitude variations of observatory Plana are determined as sum of the smoothed time series of nonpolar latitude changes and polar latitude values, computing from the solution C04 for the pole coordinates of the IERS (Fig. 4).

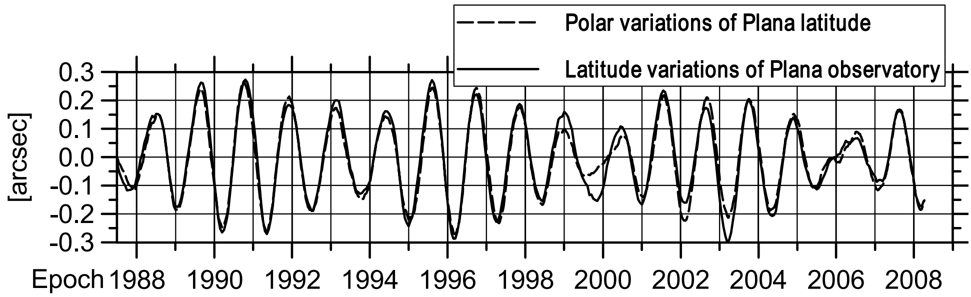

Figure 4: Smoothed time series of the latitude variations at observatory Plana, determined from observations with zenith telescope Zeiss 135/1750 and the polar latitude changes, determined from solution C04 of the IERS for the pole coordinates.

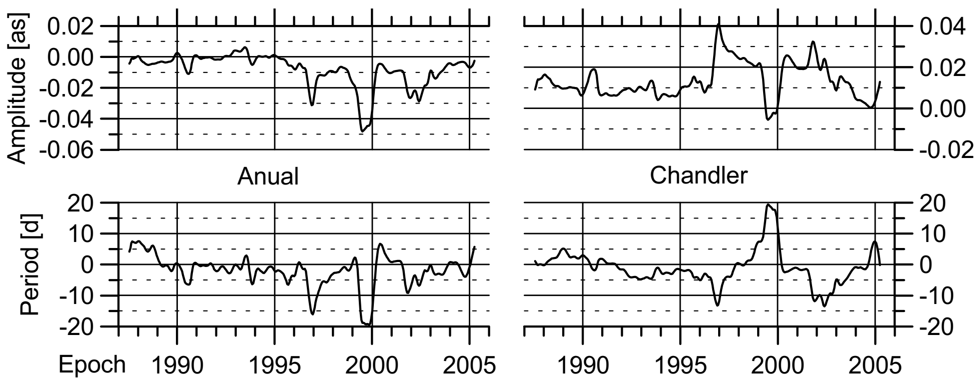

Figure 5: Variations of the seasonal (left) and Chandler (right) periods and amplitudes, due to the local and regional geodynamic events in the Balkans.

The periodical oscillations of the polar motion consist of two main components – seasonal and Chandler. Its phases and amplitudes vary in time and their time series are determined by the Least Squares Method (Chapanov, 2004c). The variations of phases and amplitudes of smoothed time series of the latitude changes at observatory Plana are determined first, as well as the phases and amplitudes variations of the polar latitude changes, and differences between the corresponding series next. As the result, the variations of the seasonal and Chandler periods and amplitudes, due to the local and regional geodynamic events in the Balkans are determined (Fig. 5).

Strong local disturbances of the seasonal and Chandler periods and amplitudes variations occur three times - around the epochs 1997.0, 1999.5-1999.9 and 2002.0-2002.5. The first one is connected with the switching over the 5.5-year oscillations of the vertical to the 3-year oscillations, according the long-term behavior of the vertical position (Fig. 7). The next two disturbances are connected with the ends of 3-year cycles of the oscillations of the vertical.

5. OSCILLATIONS OF THE VERTICAL AND SOLAR ACTIVITY

The response of the oscillations of the vertical at observatory Plana to the 11-year solar cycles is determined by superposition of 10.3-year and 2-year oscillations (Fig. 6). The comparison of the resulting curve with the smoothed Wolf's numbers W_n shows significant correlation, when the time series of W_n variations are shifted 1 year back in time (Fig. 6). Similar behavior of the oscillations of the local verticals at other observatories exists (Chapanov, 2003; Chapanov et al., 2005). Such advance of the gravity response to the sunspot cycles is possible by intermediation of the liquid earth core only, where the solar-terrestrial magnetic influences precede sunspot variations.

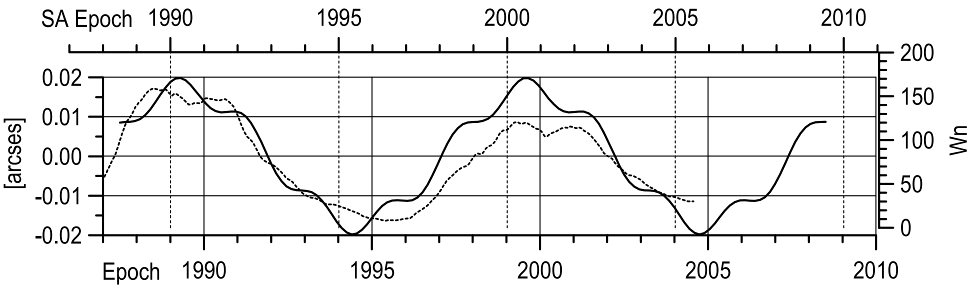

Figure 6: Comparison between the 11-year cycles of nonpolar latitude changes (solid line) and smoothed variations of the solar activity index - Wolf's numbers.

6. 5.5-YEAR OSCILLATIONS OF THE VERTICAL AND GRAVITY

The oscillations of the vertical at observatory Plana (Fig. 3) consist mainly of irregular seasonal variations, but the spectral analysis shows the presence of two additional oscillating components - one with period of 500 days and another - with period of 5.5 years. The seasonal and 500d oscillations are filtrated by averaging in the running window with a span of 1.4 years. The residual long-periodical oscillations of the vertical at observatory Plana (Fig. 7) consist of two 5.5-year cycles. The first cycle is not complete and the last one is interrupted by two cycles with duration about 3 years. The long-periodical oscillations of the vertical at observatory Plana are highly correlated with 5.5-year oscillations of the gravity at observatory Brussels, determined by super-conducting gravimeter, for the period

1987.5-1998.5 (Fig. 7). The coefficients of correlation vary between +0.57 and +0.92 for different part of the above time series (Chapanov, 2004d). The phases of the 5.5-year oscillations at both observatories are very close.

It is remarkable the differences between the epochs of the minimums of the corresponding graphs in Fig. 7 for the period 1990-1998. For observatory Plana the epochs of minimums are 1991.6 and 1997.0, and for observatory Brussels - 1992.0 and 1997.4. So these two minimal values of the relative changes of the vertical at observatory Plana and the gravity at observatory Brussels occur with a delay of 0.4 year. According to the longitudinal difference between Plana and Brussels, which is 19 degrees, the value of phase difference corresponds to the angular velocity 1/8 cpy (Chapanov at al., 2005).

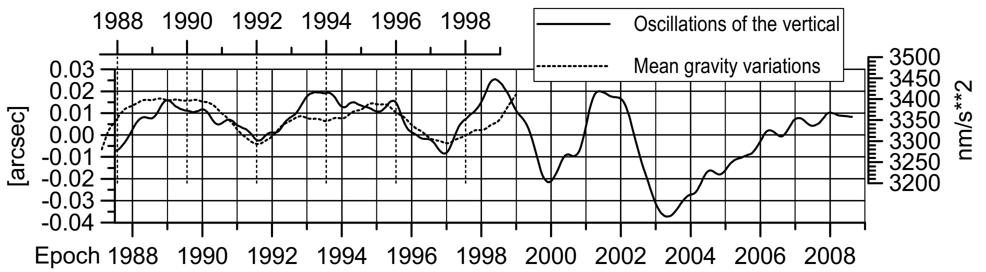

Figure 7: Comparison between the long-periodical oscillations of the vertical at observatory Plana and the gravity at Brussels for the period 1987.5-1997.5.

The distance between the observatories Brussels and Plana is more than 2000km, therefore the possible common reason for the presence of the two cycles of 5.5a oscillation with close phases has a regional or global origin. Moreover, this common reason affects as the value of the mean gravity acceleration (at the observatory Brussels), as the direction of the gravity acceleration (or the vertical at the observatory Plana). Thus, this points out to a regional gravity oscillation of the Earth with a period of 5.5 years. An explanation of the six-year oscillations of the gravity and vertical at different points of the Earth surface can be maid by means of existing theoretical models of the geophysical processes at core-mantle boundary and the mantle convective flows (Hide et al. 2000; Kuang and Chao, 2001, 2003; Mound and Buffett, 2003). Probably the six-year oscillations of the gravity are due to the core-mantle interaction and corresponding redistribution of the heavy and light masses in the mantle convective flows and these oscillations are observable over the Earth surface.

7. 3-YEAR OSCILLATIONS OF THE VERTICAL AND EARTHQUAKES

The 5.5-year oscillations of the vertical at observatory Plana are interrupted by 3-year cycles. The end of the first 3-year cycle is centered over the epoch of the disaster earthquake in Turkey in 1999 with magnitude 7.8, while the end of second 3-year cycle precede by 1.7 years the Sumatra earthquake in 2004 with magnitude 9.0 (Table 1, Fig. 8). The interannual oscillations of vertical at observatory Plana from different frequency bands, shown in Fig. 8, also contain similar 3-year cycles. The possible explanation of the 1.7-year delay between the end of the second 3-year cycle of the oscillations of the vertical at observatory Plana and Sumatra earthquake in 2004 is eastward phase drift of the 3-year cycle. The velocity rate of this phase drift is 42.9 deg/a, or 1 revolution per 8.4a, which is comparable with the phase drift rate of the 5.5-year cycle in opposite direction (47.5 deg/a, or 1 revolution per 7.6a).

The possible explanation of 3- and 5.5-year cycles phase drift is core-mantle interaction with a regional manifest. The hypotheses about the interconnection between the 3-year cycles of the gravity and disaster earthquakes is, that at the end of 3-year cycles, some resonant effects increase the magnitude of earthquakes above 8, while without 3-year gravity cycles these earthquakes should have less magnitude.

Table 1. Earthquakes in Turkey in 1999 and Sumatra in 2004/2005, according to the data of the USGS National Earthquake Information Center.

Year	Month	Day	Latitude	Longitude	Magnitude
1999	08	17	40.7	29.9	7.8
1999	11	12	40.8	31.2	7.5
2004	12	26	3.3	96.0	9.0
2005	03	28	2.1	97.1	8.6

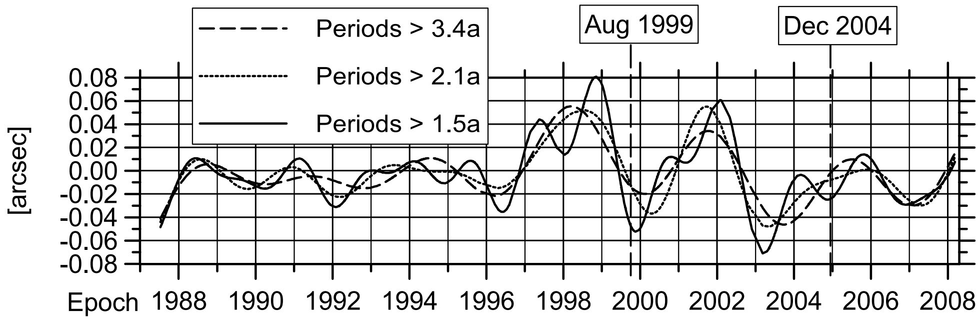

Figure 8: Interannual oscillations of vertical at observatory Plana from different frequency bands and epochs of disaster earthquakes in Turkey and Sumatra.

8. CONCLUSIONS

Strong local disturbances of the seasonal and Chandler periods and amplitudes variations occur three times around the epochs 1997.0, 1999.5-1999.9 and 2002.0-2002.5. The first one is connected with the switching over the 5.5-year oscillations of the vertical to the 3-year oscillations. The next two disturbances are connected with the ends of 3-year cycles of the oscillations of the vertical.

The observed variations of the geographic latitude and the oscillations of the vertical at observatory Plana for the period 1987.5-2008.3 are strongly affected by periodical cycles of the gravity changes from interannual to decadal scale.

The 5.5-year cycles of the variations of vertical at observatory Plana and gravity at observatory Brussels, determined by super-conducting gravimeter, are correlated with time delay about 0.4a.

Possible influence between the 3-year gravity oscillations and some disaster earthquakes exists. The end of the first 3-year cycle of the variations of vertical at Plana correlates with the epochs of the disaster earthquakes in Turkey in August and November 1999. The end of the second 3-year cycle of the variations of vertical at Plana precedes the disaster Sumatra events in December 2004 by 1.7a.

It is possible to explain the time delay of the 5.5-year cycles of the gravity between Plana and Brussels by phase drift of the corresponding core oscillations with a constant rate of about 47.5 deg/a or 1 revolution per 7.6a in East-West direction and the time delay between the end of the second 3-year cycle of the variations of vertical at Plana and the disaster Sumatra events in 2004 by phase drift of the 3-year core oscillations with a rate of about 42.9 deg/a or 1 revolution per 8.4a in West-East direction.

Further investigation of the interconnection between the 3-year oscillation of the gravity and earthquakes need increasing of the number of modern astrometrical instruments with permanent location and significant improving of the star catalogues, where the accuracy of star proper motions is most critical parameter.

References

Chapanov, Ya.: 2003. *Int. symp. on "Modern technologies, education and professional practice in the globalizing world"*, Sofia, 168.

Chapanov, Ya.: 2004a. *Proc. "3-rd Balkan Geoph. Congr. and Exhib."*, Sofia, 333.

Chapanov, Ya.: 2004b. *Proc. "3-rd Balkan Geoph. Congr. and Exhib."*, Sofia, 335.

Chapanov, Ya.: 2004c*, Proc. Int. symp. on "Modern technologies, education and professional practice in geodesy and related fields"*, Sofia, 167.

Chapanov, Ya.: 2004d, *Kinematics and Phys. of Celest. Bodies*, Suppl. Ser. **No5**, 347.

Chapanov, Ya., Darakchiev, Tzv.: 2005, *Proc. Int. symp. on "Modern technologies, education and professional practice in geodesy and related fields"*, Sofia, 280.

Chapanov, Ya., Srebrov, B., Darakchiev, Tzv.: 2005, *Proc. Int. symp. on "Modern technologies, education and professional practice in geodesy and related fields"*, Sofia, 270.

Darakchiev, Tzv., Chapanov, Ya.: 2003, *Geodesy* **16**, 71.

Hampel, F. R.: 1973, *Z.Wahrscheinlickeitstheorie verw. Geb.* **27**, 87.

Hampel, F. R.: 1974, *Journal of the American Statistical Association* **69**, 383.

Hide, R., Boggs, D. H., Dickey, J. O.: 2000, *Geoph. Journal International*, **143**, 777.

Juhl, J.: 1984, *XV ISP Congress proc.*, *Comm. III*, Rio de Janeiro.

Kegel, J.: 1987, *Vermessungstechnik*, **35**, № 10.

Kuang, W. and Chao, B. F.: 2001, *GRL*, **28**, No. 9, 1871.

Kuang, W. and Chao, B. F.: 2003, *Geodynamics Series*, **31**, AGU Monograph, 193.

Kubik, K.: 1982. *ISP Symposium, Comm. III*, Helsinki.

Mound, J. E. and Buffett, B. A.: 2003, *JGR*, **108**, No. B7, 2334.

Poits, H.: 1988, *Vermessungstechnik*, **36**, № 6.

Somogyi, J.: 1987, *DGK*, Reihe A.