Proceedings of the VII Bulgarian-Serbian Astronomical Conference (VII BSAC)
Chepelare, Bulgaria, June 1-4, 2010,
Editors: M. K. Tsvetkov, M. S. Dimitrijević, K. Tsvetkova, O. Kounchev, Ž. Mijajlović
Publ. Astron. Soc. "Rudjer Bošković" No 11, 2012, 351-358

SECULAR PLATE DRIFT IN NORTH DIRECTION DETERMINED BY ASTROMETRICAL LATITUDE OBSERVATIONS AT OBSERVATORY PLANA

YAVOR CHAPANOV and TZVETAN DARAKCHIEV

National Institute of Geophysics, Geodesy and Geography of Bulgarian Academy of Sciences, Acad. G. Bonchev Bl.3, 1113 Sofia, Bulgaria
E-mail: chapanov@clg.bas.bg

Abstract. The secular plate drift at observatory Plana in North direction is determined by means of astrometrical latitude observations from zenith tube Zeiss 135/1750. The latitude variations due to the polar motion are determined from the solution C04 of the IERS for the pole coordinates. The time series of the mean latitude variations and mean polar changes of the latitude are determined by averaging in running 6-year window. The mean nonpolar latitude variations are determined as difference between these time series. The secular plate drift in North direction is estimated by the linear trend of the mean nonpolar latitude variations. The results are compared with the values from GPS measurements, provided by a permanent station, located nearby the observatory Plana.

1. INTRODUCTION

The geodynamical phenomena, related to the variations of the Earth shape, rotation and gravity field, are complex and often nonpredictable effects, determined by the structure and dynamical properties of the Earth. These phenomena are of special interest to the geosciencies, and particular to the geodynamics, the geophysics and the geodesy. These geophenomena are so complex, that it universal investigation is possibly only on the base of the utilization of various methods of observations. Such methods are the classical astronomical geodetic methods of determination of astronomical time - geographic longitude and geographic latitude. The latitude observations are connected directly to the vertical in the observation station, and due to it's high precision and long duration can be used to investigation of the permanent changes of the vertical in time.

The nonpolar latitude changes are connected to the changes of position of the vertical at the observation station. The last changes are within the nonpolar changes of the geographic latitude at the point, and that is the reason to derive the changes of the vertical from the latitude changes. Thus, investigation and determination of the nontidal changes of the vertical at a given point of earth surface is connected to investigation and determination of the changes of the geographic latitude of the observation station.

A part of nontidal changes of the vertical can be provoked by the deformations and motions of the earth plates. The nonpolar changes of the geographic latitude can be used as indicator of the horizontal and vertical changes at the observation station and for investigation of the local gravity field variations.

2. LATITUDE VARIATIONS AT OBSERVATORY PLANA AND ITS HOMOGENEITY

The latitude observation by zenith telescope Zeiss 1750/135 at observatory Plana are provided permanently since 1987.5. More than 20 000 observations of 72 star pairs in 12 groups are available (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).

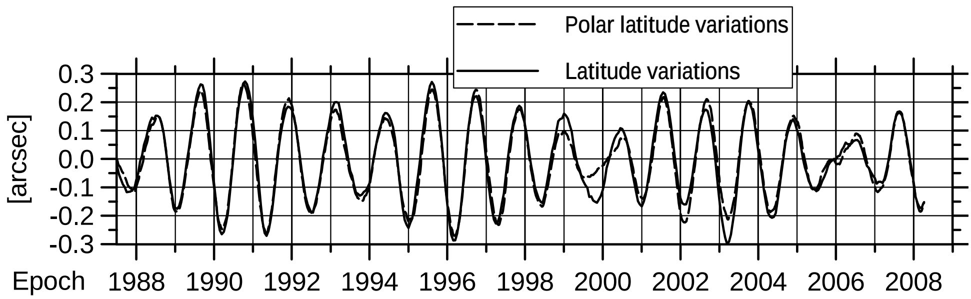

Figure 1. Smoothed time series of the latitude variations at observatory Plana, determined from observations with zenith telescope Zeiss 135/1750 and the polar latitude changes, determined from solution C04 of the IERS for the pole coordinates.

The nonpolar latitude changes 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). 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. The smoothed time series of the latitude variations at observatory Plana and the polar latitude changes, determined from solution C04 of the IERS for the pole coordinates are shown in Fig. 1. The comparison between the curves points out excellent agreement of the amplitudes and phases of the annual and Chandler oscillations due to the polar motion. Visible disturbances of Plana latitude variations after 1999 are due to the oscillations of the vertical, dominated by 3-year oscillations (Fig. 2).

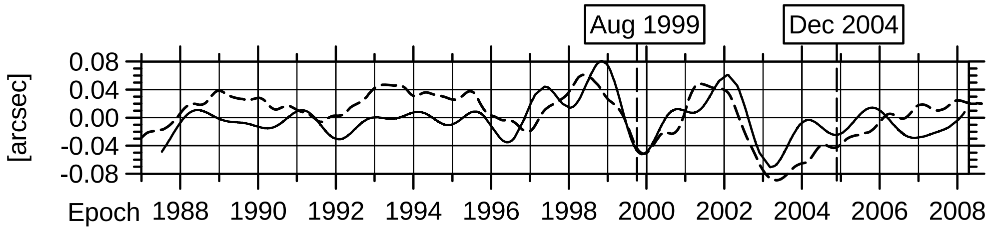

Figure 2. Interannual (with solid line) and long-term (with dashed line) variations of the vertical in observatory Plana and disaster earthquakes in Turkey in 1999 and Sumatra in 2004. The interannual curve is composed by oscillations with periods below 3.5a. The long-term curve is determined by running average in 1-year window.

The interannual oscillations of the vertical at observatory Plana consist of 3.5-year and 5.5-year cycles. The 5.5-year cycles are visible till 1997 and 3.5-year cycles – after that. Correlation relationships between 3.5-year oscillations of the vertical at observatory Plana and disaster earthquakes in Turkey in 1999 and Sumatra in 2004 exist (Chapanov and Darakchiev, 2008). These earthquakes occurred after the end of the 3.5-year cycles of the local gravity, so they are probably connected with some strong geodynamical disturbances after 1999. These geodynamical events disturbs interannual oscillations of the gravity and it long-term behavior. We determine the long-term behavior of the local gravity and corresponding trends of the variations of the vertical by means of Vondrák-Whitaker filtration (Vondrák, 1969, 1977) of the latitude variations of Plana observatory and polar variations of Plana latitude determined with different smoothing factors (ε=0.01, 0.1, 1.0, Figures 3-5). The difference between the filtered time series of the variations of Plana observatory and polar variations of Plana latitude is positive for the first part of the observed time span and negative for the second part. The positive values of the nonpolar latitude variations at Plana observatory occurred before 1999.7 – 2001.4, so the quite period of vertical oscillations is approximately before 2001.5 and disturbed period, due to significant 3-year gravity oscillations – after 2001.5. According this, the trend of the vertical changes at observatory Plana for the period 1987.5-2001.5 represents the secular plate drift in North direction, while the vertical changes after 2001 are dominated by strong geodynamical disturbances.

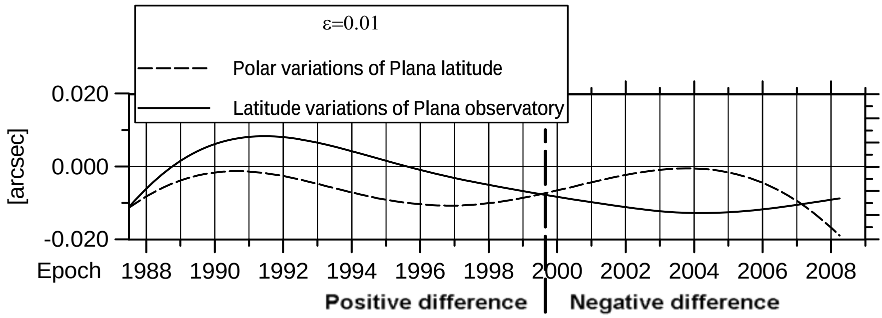

Figure 3. Vondrák-Whitaker filtration of the latitude variations of Plana observatory and polar variations of Plana latitude determined with smoothing factor ε=0.01. The nonpolar latitude changes are positive before 1999.6 and dominating negative after.

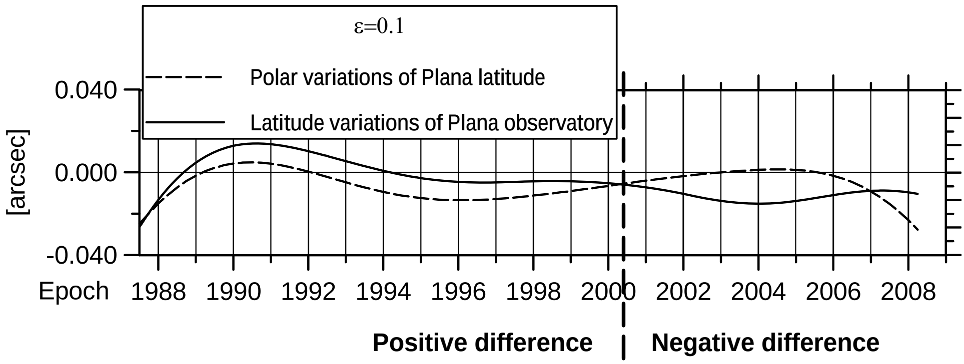

Figure 4. Vondrák-Whitaker filtration of the latitude variations of Plana observatory and polar variations of Plana latitude determined with smoothing factor ε=0.1. The nonpolar latitude changes are positive before 2000.4 and dominating negative after.

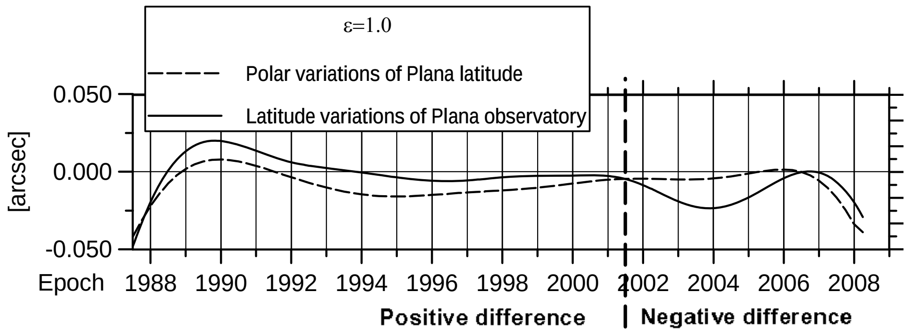

Figure 5. Vondrák-Whitaker filtration of the latitude variations of Plana observatory and polar variations of Plana latitude determined with smoothing factor ε=1.0. The nonpolar latitude changes are positive before 2001.3 and dominating negative after.

3. IMPROVED METHOD OF 6-YEAR AVERAGING

The method is similar to the method for determination of the polar motion components (Chapanov, 2004). The first step of the method includes solving the system

$$x = x_0 + \frac{dx}{dt} t + \sum_{i=1}^{n} a_{yi} \sin i\omega_y t + b_{yi} \cos i\omega_y t + \sum_{i=1}^{m} a_{ci} \sin i\omega_c t + b_{ci} \cos i\omega_c t, \quad (1)$$

for the following unknowns – the mean coordinates of the current six-year span $\hat{x}_0$, the velocities of the linear trend $d\hat{x}/dt$, the harmonic coefficients of the seasonal component $\hat{a}_{yi}, \hat{b}_{yi}$, $i = 1,\ldots,n$ and the harmonic coefficients of the Chandler component $\hat{a}_{cj}, \hat{b}_{cj}$, $j = 1,\ldots,m$. The observations for the first step are the coordinates x from the current six-year span.

The initial values of the seasonal (annual) frequency ω_y^0 and Chandler frequency ω_c^0 are determined by

$$T_y^0 = 365.2422\,d, \ T_c^0 = 1.2\,T_y^0, \ \omega_y^0 = \frac{2\pi}{T_y^0}, \ \omega_c^0 = \frac{2\pi}{T_c^0}, \quad (2)$$

where T_y^0 and T_c^0 are the initial values of the annual and Chandler periods. The estimates are obtained from (1) by the Least-squares method. In the second step the unknowns from the first step are improved and corrections of the seasonal and Chandler periods are determined. The coordinates x^c are computed by (1) with aid of the observation time and the obtained estimates. The linear system is solved

$$\begin{aligned} x - x^c = {} & \delta x_0 + \delta \dot{x} t + \sum_{i=1}^{n} \delta a_{yi} \sin i\omega_y^0 t + \delta b_{yi} \cos i\omega_y^0 t \\ & + 2\pi i t \left(T_y^0\right)^{-2} \delta T_y^x \left(\hat{b}_{yi} \sin i\omega_y^0 t - \hat{a}_{yi} \cos i\omega_y^0 t\right) \\ & + \sum_{i=1}^{m} \delta a_{ci} \sin i\omega_c^0 t + \delta b_{ci} \cos i\omega_c^0 t \\ & + 2\pi i t \left(T_c^0\right)^{-2} \delta T_c^x \left(\hat{b}_{ci} \sin i\omega_c^0 t - \hat{a}_{ci} \cos i\omega_c^0 t\right), \end{aligned} \quad (3)$$

for unknowns δx_0, $\delta\dot{x}$, δa_{yi}, δb_{yi}, i=1,…, n; δa_{cj}, δb_{cj}, j=1,…, m, which are the corrections of the estimates from the first step; $\delta \mathbf{T_y}^{\mathbf{x}}$, $\delta \mathbf{T_c}^{\mathbf{x}}$ are the corrections of the annual and Chandler periods for the coordinate **x;** and $\delta \mathbf{T_y}^{\mathbf{y}}$, $\delta \mathbf{T_c}^{\mathbf{y}}$ - for the coordinate **y** of the pole. Next iterations with the corrected values of the unknowns can be made, if it is necessary.

4. MEAN VARIATIONS OF THE LATITUDE AT OBSERVATORY PLANA.

The mean variations of the latitude and polar latitude of observatory Plana are determined by the improved method of 6-year averaging (Fig.6 - 7).

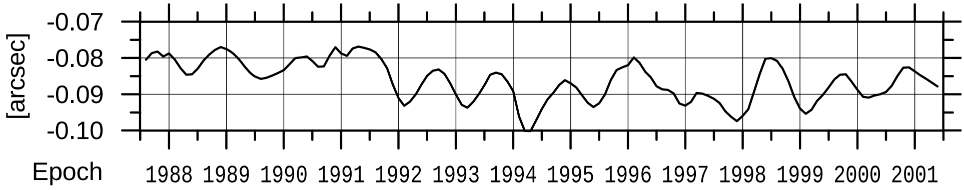

Figure 6. Mean latitude variations determined by the improved method of 6-year averaging. The rms errors are below 5mas.

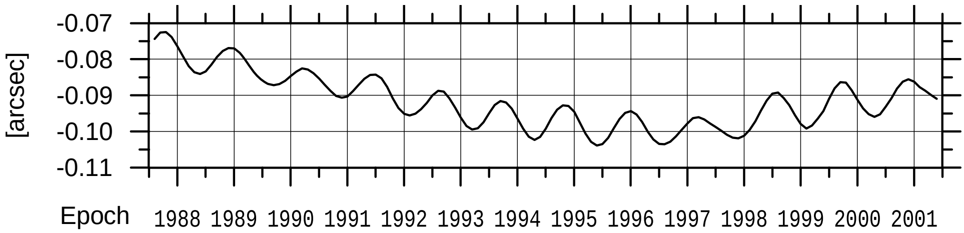

Figure 7. Mean polar latitude variations, determined by the improved method of 6-year averaging. The rms errors are below 3mas.

5. LINEAR TREND OF THE MEAN VARIATIONS OF THE VERTICAL IN NORTH DIRECTION

The linear trend of the mean variations of the vertical in North direction at observatory Plana are determined as a difference between the time series of the latitude and polar latitude variations (Fig.8). The secular plate drift in North direction is estimated by the linear trend from the Fig.8. This estimate is compared with the result obtained by the GPS data for the period 1997.5-2009 from station Sofi, located near the observatory Plana (Fig.9, Table1).

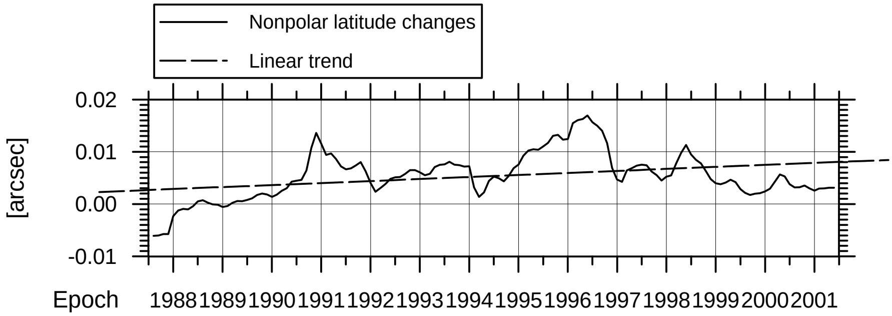

Figure 8. Mean variations of the vertical in North direction at observatory Plana. The linear trend is an estimate of the secular plate drift in North direction.

Table 1: Estimates of the secular plate drift in North direction, determined by latitude and GPS data.

	Linear trend of the vertical [mas/a]	Secular plate drift [mm/a]
ZT Plana	+0.39 ±0.09	+11.6 ±2.8
GPS Sofi		+11.97 ±0.01

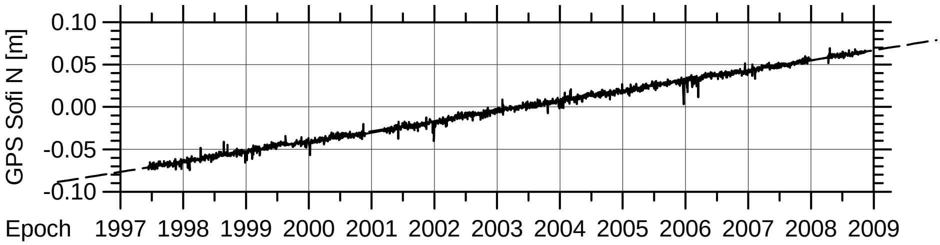

Figure 9. The time series of variations in North direction of the GPS station Sofia, located nearest to observatory Plana.

6. CONCLUSIONS

The trend of the vertical changes at observatory Plana for the period 1987.5-2001.5 represents the secular plate drift in North direction, while the vertical changes after 2001 are dominated by strong geodynamical disturbances.

The secular plate drift in North direction, determined by linear trend to the mean non-polar latitude observation at observatory Plana for the period 1987.5-2001.5, is +11.6 ±2.8mm/a, which is with excellent agreement with the value of

+11.97 ±0.01mm/a, determined by GPS measurements for the period 1997.5-2009 from station Sofi, located near the Sofia.

Acknowledgments

The present was supported by contract DO 02-275 with the Bulgarian NSF.

References

Chapanov, Ya.: 2004, Proc. Intern. Symp. on “Modern technologies, education and professional practice in geodesy and related fields” Sofia, 04 – 05 November, 167-177.

Chapanov, Ya., Darakchiev, Tzv.: 2005, Proc. Int. symp. on "Modern technologies, education and professional practice in geodesy and related fields", Sofia, 280-289.

Chapanov, Ya., Darakchiev, Tz.: 2008, VI Serbian-Bulgarian Astronomical Conference, Belgrade 7-11 May 2008.

Darakchiev, Tzv., Chapanov, Ya.: 2003, *Geodesy*, **16**, 71-80.

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

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

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

Vondrák, J.: 1969, *Bull. Astron. Inst. Czechosl.*, **20**, 349−355.

Vondrák, J.: 1977, *Bull. Astron. Inst. Czechosl.*, **28**, 84−89.