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ON THE POLE TIDE EXCITATION OF SEISMICITY

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Abstract. The NEIC seismic database up to 2012.0 was used for search of pole tide influence on the intensity of seismic process. The pole tide is generated by the centrifugal effect of polar motion on the chandler and annual frequencies (0.84 – 1.0 cpy) with the radial displacement up to 2 cm. Their beat frequency is equal to 0.16 cpy. These frequencies (for chandler wobble in doubled frequency) were revealed in series of seismic intensity calculated for the 0.05 year time span. These long-period components in seismic intensity are robust to the change of interval (up to 0.2 year) and to minimal used magnitude (from 3.0 to 4.5). It is known that seismic failure time t_n in any region is depend on energy of seismic event $t_n \sim E^{1/3}$ and hence depend on seismic magnitude. For magnitude up to 5.5 t_n is usually equal from one to some years. This failure time correlates with the oscillating stress. The degree of correlation between failure time and the phase of the driving stress depends on the amplitude and frequency of the stress oscillation and on the stressing rate. So pole tide influence on the intensity of seismic process could be revealed in the regions where its amplitude is maximal (latitudes 30° - 60° in both hemispheres). The response of seismic intensity on the value of pole tide radial displacement was researched for various zone of seismic activity. It was revealed that pole tide influence on seismicity is approximately the same for various seismic zones and is detectable for phase of pole tide with radial displacement more than 6 mm. The dependence on minimal used magnitude and depth of seismic event was not revealed.

INTRODUCTION

The intensity of seismic events has some low-frequency regularity marked in many papers (Gamburtsev et al., 2004; Levin, Sasorova, 2002). The spectrum of these variations of seismic intensity has significant lines in the pole tide frequency band as it was revealed and investigated in our previous paper (Gorshkov, Vorotkov, 2004). The direct pole tide modulation of slow sleep seismic events was researched in (Zheng-Kang Shen et.al., 2007) for Pacific subduction zones. The majority of searched in this paper events (14 from 20) were closely associated with maximal phase of pole tide for event coordinates.

The power spectrum of earthquake series preliminary averaged in 30 days are shown in Fig.1 (from Gorshkov, Vorotkov, 2004). Other time span for averaging and magnitude cutting were also used for spectrum estimations but the ~ 6 and ~0.6 years lines are always present at spectrum. The more probable explanation of these spectrum lines is display of pole tide excitation of seismicity.

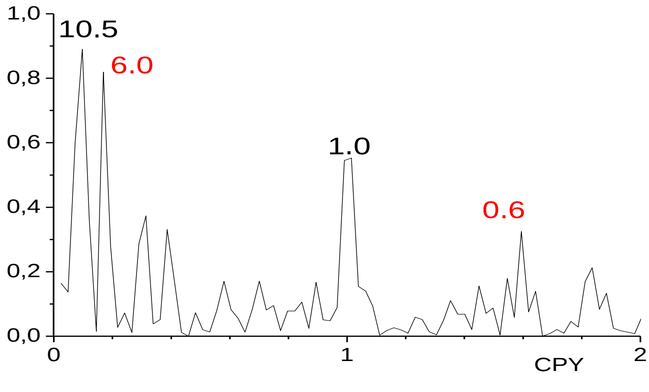

Figure 1. Low-frequency band of power spectrum of intensity of seismic events from NEIC data-base (1973 -2010). There are used all events with magnitudes M > 3. The time interval for seismic events averaging before spectrum calculation is equal 30 days. The marked picks in spectrum are in years, the red of them are probably excited by pole tide.

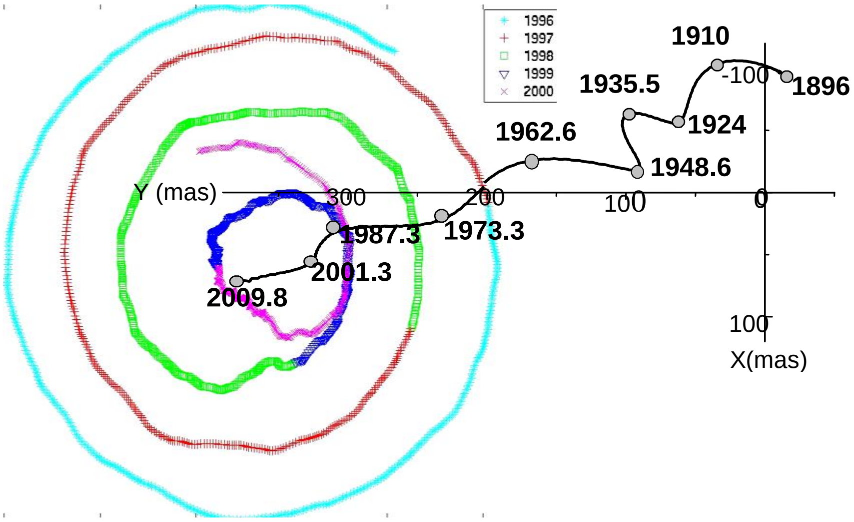

Figure 2. Real motion of instantaneous Pole *{Xp,Yp}* in 1996-2000 years (colored) and slow drift of mean Pole *{Xm,Ym}* from the beginning of International Polar Motion Service (1896).

The Pole tide is generated by the centrifugal effect of Polar Motion $PM = Xp - iYp$. The trend (mean) components of *PM* have to be subtracted before assessment of Pole tide effect:

$$\{X,Y\} = \{Xp - Xm, Yp - Ym\} \approx \{Xcw + Xan, Ycw + Yan\}.$$

Both components of Polar motion are shown in Fig.2. The residual series *{X,Y}* is mainly composed of two *PM* components – the most power Chandler wobble (*CW*) with period $P_{cw} \approx 1.2$ year and annual variation $P_{an} \approx 1$ year. The mean amplitude of *CW* is equal approximately 0.2″ (200 mas) and annual is a half. The beat variation of *PM* $P_{beat} = P_{cw}P_{an}/(P_{cw}-P_{an}) \approx 6$ year is also observable as it can be seen in Fig.3.

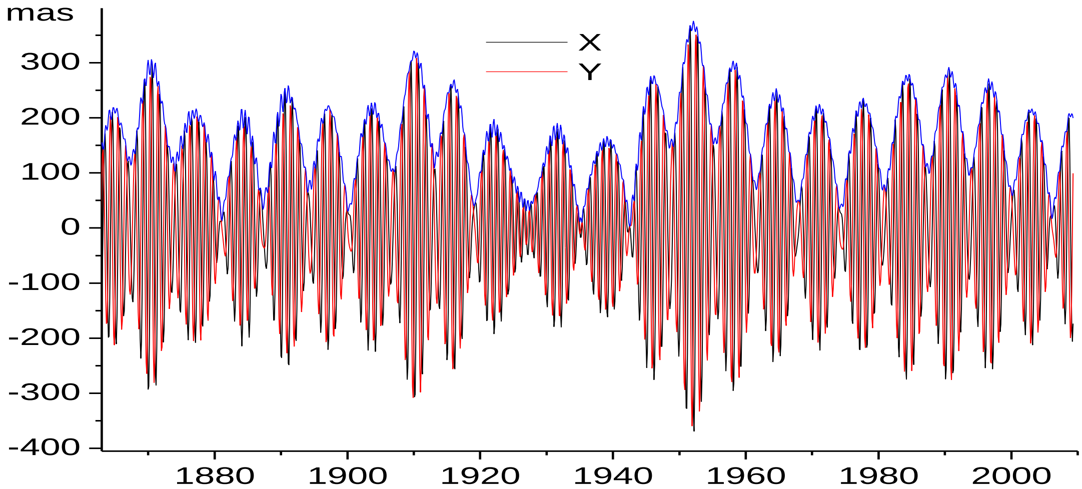

Figure 3. Black and red curves are *{X,Y}* series and blue is variation of *PM* polhode radius.

The centrifugal perturbation in the potential ΔV because of *PM* (Wahr, 1985) is equal:

$$\Delta V(r,\theta,\lambda) = -0.5\,\Omega^2 r^2 \sin 2\theta\,(X\cos\lambda + Y\sin\lambda),$$

where Ω - the mean angular velocity of rotation of the Earth, r - geocentric distance to the station, λ, θ - longitude and colatitude (π/2 - φ) of the station. The radial displacement S_r (positive upwards) due to ΔV is equal:

$$S_r = h_2 \Delta V/g = -32 \sin 2\theta\,(X\cos\lambda + Y\sin\lambda) \text{ mm},$$

where h_2 - loading Love's number and $\boldsymbol{g}$ – mean equatorial gravity.

It is obvious from Fig.3 that amplitude excursion of *{X,Y}* did not exceed 400 mas and hence variations of $\boldsymbol{S_r}$ didn't exceed 2 cm. Why we can see pole tide trigger earthquake effect (stress changed up to 1 kPa according (Zheng-Kang Shen et al., 2007)) but it is almost impossible to reveal more power sun-moon tide (solid Earth tide) which cause daily stress oscillation in the crust, on the order of several kPa?

DATA AND METHOD

The answer that question is obvious at a glance – the most power components of solid Earth's tide are semi-diurnal and diurnal with amplitudes up to several tens *cm* but which have very short period in comparison with failure time t_n (the mean time for earthquake preparation). It is known (Sadovsky, Pisarenko, 1991) that the failure time in any region is proportional $t_n \sim E^{1/3}$ and hence for magnitude up to $M \sim 5$, $t_n < 10$ years. The long time sun-moon tide components ($P > 1$ year) have the amplitudes some *mm* and couldn't excite earthquake trigger effect.

This problem was accurately explored in (Beeler, Lockner, 2003) on the base of laboratory experiments in which faults are loaded by the combined action of a constant stressing rate, intended to simulate tectonic loading, and a small sinusoidal stress, analogous to the Earth tides. Correlation that is consistent with stress threshold failure models, e.g., Coulomb failure, results when the period of stress oscillation exceeds a characteristic time t_n. The degree of correlation between t_n and the phase of the driving stress depends on the amplitude and frequency of the stress oscillation and on the stressing rate. When the period of the oscillating stress is less than t_n, the correlation is not consistent with threshold failure models, and much higher stress amplitudes are required.

We try in this work to assess the trace of pole tide influence for various seismic regions by using global seismic data base NEIC (http://earthquake.usgs.gov/regional/neic/) and Earth's rotation parameters from IERS (http://hpiers.obspm.fr/eop-pc/).

There was used for research only region with latitudes between 30–60˚ in both Earth's hemispheres because of small influence of pole tide (S_r) in other zones. The main method was to search the dependence of quantity of seismic events on phase of pole tide radial component $N(S_r)$ after normalization by random (even) distribution of seismic event for each region N/N_e. This dependence is strongly conditioned by presence of for- and aftershocks in earthquake series as they give in the same time interval amplification of events. So we try as far as it's possible to eliminate for- and aftershocks in selected seismic region.

RESULTS AND CONCLUSION

The result of research of these dependences for some regions are presented in Fig. 4-6.

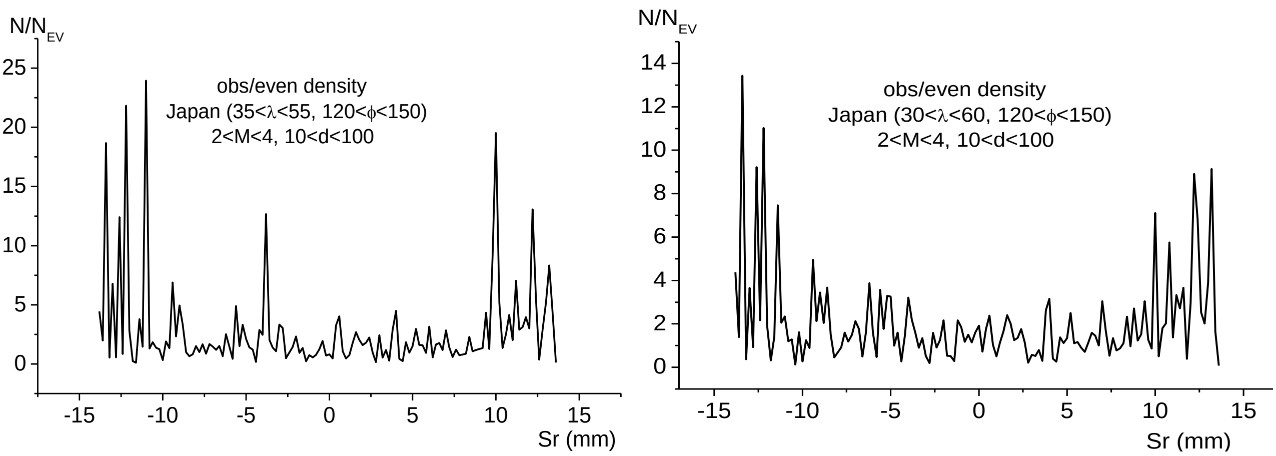

Figure 4. Normalized on the even distribution quantity of earthquake in dependence on pole tide phase in Japan region (subduction zone). Left – with presence of aftershocks sequence of Tohoku earthquake.

One can see that the influence of pole tide triggering effect excitation of earthquakes rises with amplitude of S_r in the majority of region. In addition as it can be seen for Japan region (Fig.4) the large earthquake and its aftershocks fall on *PT* phase with amplitude near and larger 0.5 cm.

In Fig. 6 with overall hemispheric results one can see double-peak smoothed red curves which reproduce global pole tide triggering effect in symmetric position between 5 and 10 mm of S_r for upward and downward motion of pole tide waves.

We can conclude that *PT* influence on seismic intensity begins observable when phase of vertical component of pole tide exceed 0.5 cm. So it will be advisable to search more detail the influence of excited by pole tide stress in various zones of seismicity.

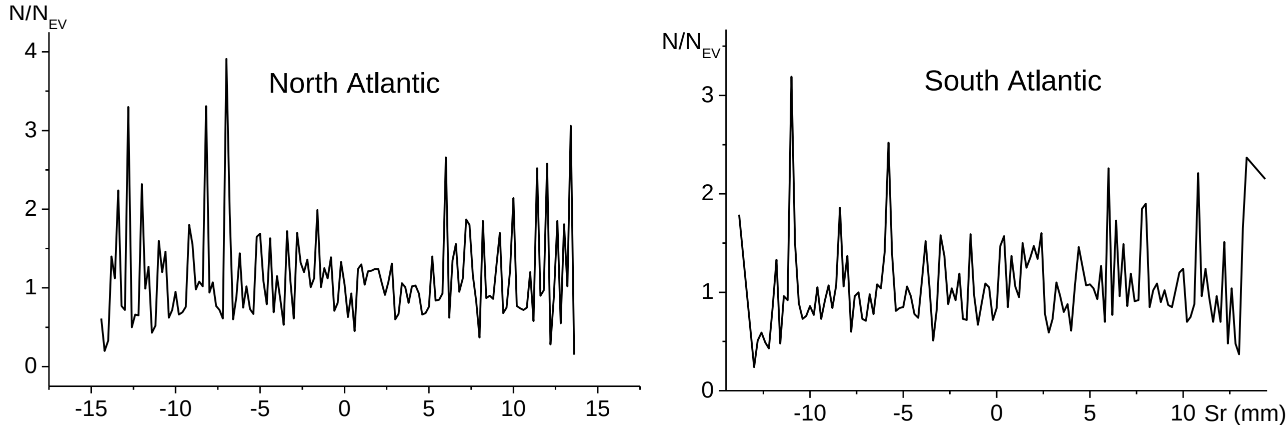

Figure 5. The same as Fig.4 for Atlantic region (spreading zone) with magnitude 2 < M < 6 and depth 10 < d < 200 km.

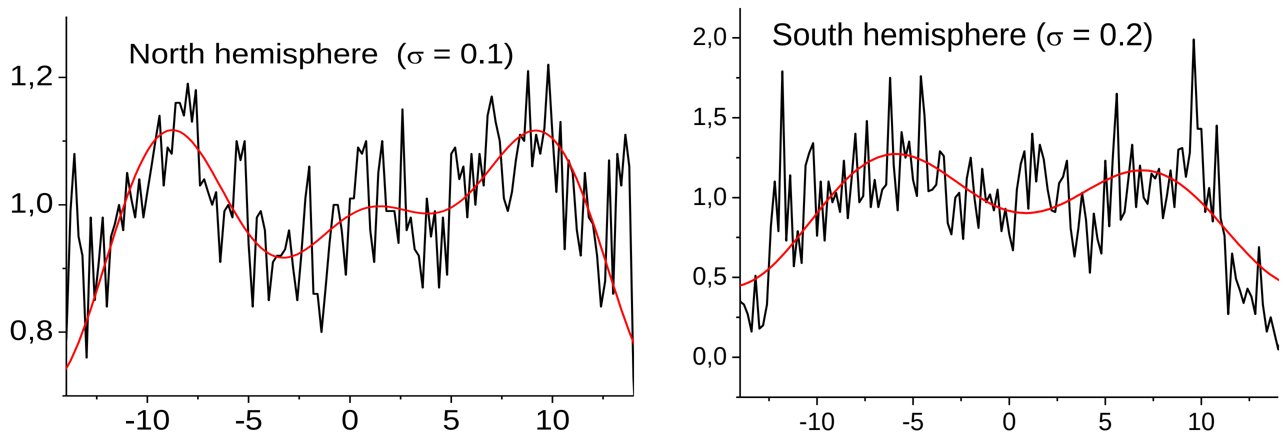

Figure 6. The same as Fig.4 for whole hemisphere North and South. Red curves are smoothed ones.

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