EUREF and geodetic model of the Eurasian Plate Movement

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Abstract

The problem of the densification the permanent GPS existing network of Russia is discussed. To the existing eleven permanent sites in offered project fifteen (first stage) new sites are added. The new permanent network besides of geodetic tasks, will help to solve as well series of the geological-geophysical problems, in particular, to improve our knowledge about the boundaries between the main lithospheric plates and minor plates within the Eurasian plate. The extended permanent GPS network will allow also update the definition of Euler's parameters, describing the movement of Eurasian plate.

1. Introduction

Among thirteen main lithospheric plates the Eurasian plate is one from most interesting. On dimension it takes third place and bounds with seventh main plates: North-American, Pacific, Indian, Arabian, African, Australian and Philippine.

In its structure enters many minor plates. One of these minor plates – Anatolian – has strictly fixed by GPS measurement non consent, relative Eurasia, rotational movement [REILINGER et al., 1997, KAHLE et al., 1999; MCCLUSKY et al., 2000].

In the boundaries of the Eurasian plate there is precambrian Fennoscandian shield, experiencing the post glacial uplift. The geodetic study this phenomenon gives the possibility for the upper mantle viscosity definition [SJOBERG et al., 1994; KAKKURI, 1997].

The interaction of this plate with African, Arabian and Indian allows to study instrumentally the collision and subduction zones what gives the numerical data for the modelling of driving mechanism for the plate motion. Several zones of collision and subduction are located at the territory of Russia and former soviet republics.

The Caucasus region inhering to the Eurasian plate gives an interesting example of intensive vertical movements with very short period (20 – 25 years) of changing the sign and intensity of the movements.

In limits of the Eurasian plate on Russia territory there are several zones, for example Ural, Altay, which experienced the repeated orogenic processes in intraplate conditions [KHAIN, LOMIZE, 1995]. This regions were never studied instrumentality; it is time to do it now.

One more phenomenon of the Eurasian plate is the Baikal rifting zone. The GPS study of this region gives the valuable data for understanding the realization of continental rifting mechanism.

It is worse to mention once more that the huge spaces of Eurasian plate – Russia, Kazakhstan, Tadjikistan, China, Vietnam are extremely poorly covered by GPS networks, especially of permanent stations.

This shortage has a strong influence on the determination of the Euler Pole and angular velocity for Eurasian plate. Using the density GPS network located only at western part of plate may give the results which do not reflect properly the movement of the whole plate.

2. The scheme of the GPS permanent network on the territory of Russian Federation

The proposed project of the first stage densification of the permanent GPS network has aim to serve to the next three main tasks: a) to increase the numbers of permanent GPS sites for geodetic use; b) to help to solve some geological-geophysical problems; c) to serve as the IGS tracking stations (see fig.1). To the existing eleven permanent station on the territory of Russian Federation, fifteen station are added. Some geological-geophysical reasons for choosing the specific sites are given shortly below.

Sites Narjan-Mar, Salekhard and Uralsk together with an existing site Ekaterinburg are outlined the Ural mountain system. The data from all sites allow to make a conclusion about the activity of this ancient collision zone and peculiarities of movements for European and Asian flanks of the Ural system.

The sites Ulan-Ude and Severobaykalsk are selected for strengthening the existing non-permanent network [SAN'KOV et al., 1999] and GPS networks which will be established in near future for the more wide study of the Baikal rifting zone.

The observation on the newly installed sites Skovorodino, Komsomol'sk-na-Amure, Ayan, Evensk and existing sites Blagoveshensk, Magadan, Petropavlovsk will allow to verify the boundaries of Okhotsk and Amurian minor plates and to determine their velocities. The sites Deputy, Sredneko-lymsk, Pevek and Anadyr will serve for improvement our knowledge about the boundary between the North-American and Eurasian plates. The sites Murmansk, Novosibirsk and Tura are located on the stable parts of the Eurasian plate. They will help to better determination of Euler's parameters.

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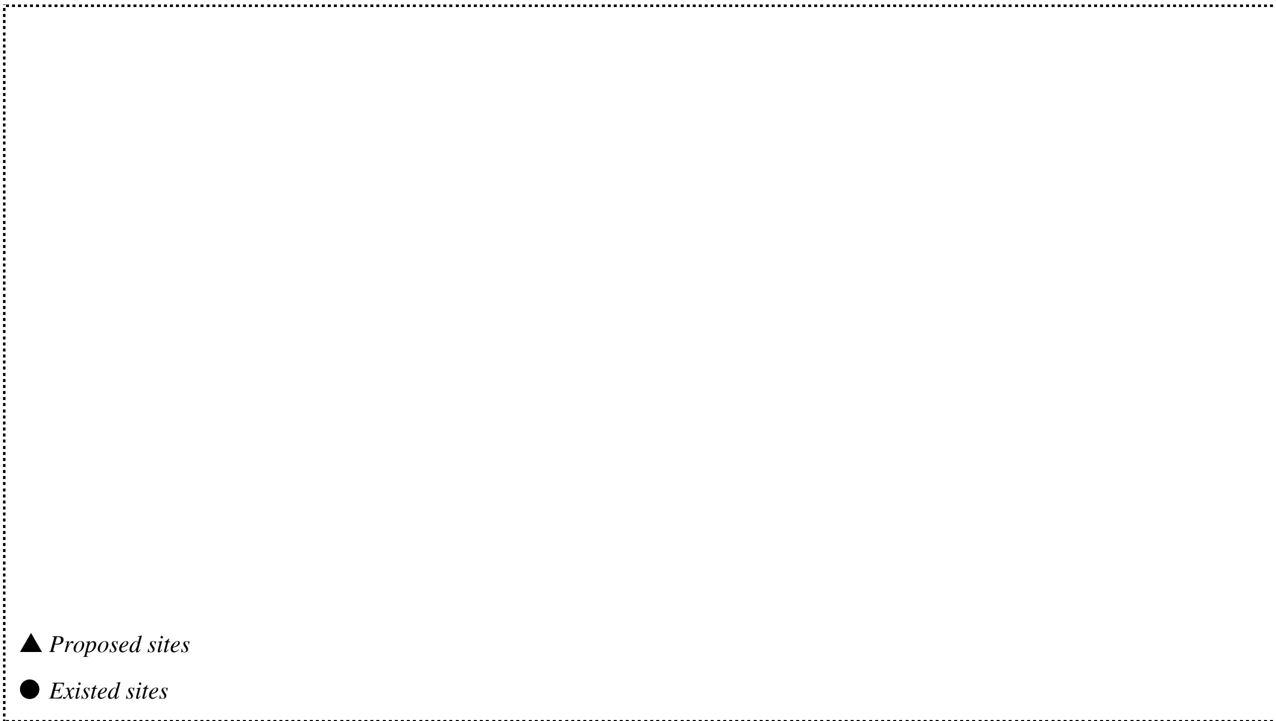

Fig.1: Scheme of the permanent GPS sites for the Russian Territory

The discussed permanent GPS network and its further modification in near future "will paint over a white spot" on a map of IGS and ITRF sites concerning the Russian Federation and will approach us to solve the problem, whether it is possible to speak about common Euler's parameters for whole Eurasian plate or it is necessary to determine Euler's parameters for different parts of the Eurasian plate.

3. Geodetic model of the Eurasian plate motion

Several "paleomagnetic" models describing the movements of the global lithospheric plates. are known. We would like to mention here the models RM-1,2; AMO2 [Minster, Jordan, 1978], which have broad application earlier. The most known resent "paleomagnetic" model for absolute motions is NNR NUVEL-1A [Argus, Gordon, 1991]. For determination of Euler's parameters of this model were used the different data: the velocities of ocean ridge spreading, the values of transform faults' azimuths during earthquakes. In spite of two first data cover the time intervals 3-5 million years and the third data – only a few tens years (quite comparable with geodetic study of plate motions), in the literature the opinion is fixed that "paleomagnetic" models reflect motions for the first 3-5 million years.

In the latest time the publications have appeared where the Euler's parameters are determined using only geodetic data (SLR, VLBI, GPS, DORIS) [Larson et al., 1997; Sillard et al., 1998]. Here we will discus the data for Eurasian plate only. In the first case [Larson et al., 1997] for the deriving the Euler's parameters only 7 IGS sites located on western part of the plate were used.

In second case [Sillard et al., 1998] about 80 sites were used, but again overwhelming majority of them were located on western part of the plate. This non-uniformity of the covering the plate by observation sites could have an effect on determination of Euler's parameters for the Eurasian plate.

One of the important applications of the geodetic models is using for calculation of the annual velocity vectors by the interpretation of the observed deformation fields tectonically active territories. We may call this vectors as reference-vectors. If the reference-vectors are used there is no necessity to solve a difficult task of choosing the unmovable point of the network. The Euler's parameters of lithospheric plate under study can be incorporated into the software package when the deformation field is analyzed.

Such vectors also are convenient for numerical comparison of different models. Such comparison of discussed geodetic models can be made using the numbers of table, where we calculated the modules of annual rate vectors are given for 5 GPS sites. Three sites ZELB, ANKR, SOXO belong to the Mediterranean–Caucasian project [Reilinger et al., 1997, Prilepin et al., 1997, McClusky et al., 2000], site IRKT represent a central part of the Eurasian plate and KMCH – its eastern part.

The data of the table allow to make the following conclusions. The modules of the reference vectors geodetic models (2) and (3) differ for chosen sites up to 6 mm/year and the difference has a systematic character. The systematic character is stipulated, first of all, by errors in angular velocities of both models. It is clear from comparison of the angular velocities these two models with NUVEL–1A.

The average values of geodetic models and NUVEL–1A are very close to each other, because $S(w_2+w_3) \approx w_1$ (the impact of the Pole positions differences is much smaller). Taking into account that in [SILLARD et al., 1998] much more comprehensive data were used in compare with [LARSON et al., 1997], we give the preference to the [SILLARD et al., 1998] parameters.

The differences in modules of annual velocities for NUVEL-1A and [Sillard et al., 1998] for our sites does not exceed 3 mm/year, so we may conclude that the precision of recent geodetic reference-vectors is on the level 2 mm/year. The differences in azimuths of these models lie in limits of 25°.

Fig. 2 Euler`s Pole position and residuals for three versions of data processing

Table. Modules of the reference vectors of annual velocities

Model	Position of Pole Angular Velocity	Modules in mm/year				
		ZELB	ANKR	SOXO	JRKT	KMCH
		44 N 42 E	40 N 33 E	41 N 23 E	52 N 104 E	50 N 160 E
NUVEL-1A [ARGUS, GORDON, 1991] (1)	51 W 112 W 0.23	25.4	25.4	25.3	24.5	20.3
[SILLARD et al., 1998] (2)	49 N 120 W 0.207	23.0	23.0	23.0	22.0	17.5
[LARSON et al, 1997] (3)	56 N 103 W 0.26	28.0	28.2	27.7	27.1	23.3
(4a)	56 N 128 W 0.18	20.3	20.4	20.3	–	–
(4b)	67N 92W 0.31	–	–	–	25.7	16.8

To understand, whether it is possible to describe the movement of Eurasian plate by one set of Euler's parameters, the attempt was made to determine these parameters in three variants: a) using only 5 European IGS sites; NY-ALESUND, TROMSOE, ONSALA, GRASSE, ZWENIGOROD; b) using 5 Asian IGS sites: KITAB, SELEZASCHITA, IRKUTSK, YUKUTSK, WUHAN. In the third variant we use all 10 sites together. The position of Euler's Poles and residuals is shown on the fig.2.

In fig.2 following signs are adopted: The Pole position for the variant 4a (European sites) – triangle, 4b (Asian sites) – star, variant 3 – empty circle. The values of the reference-vectors for the variant (4a) and (4b) also are given in table.

We treat the models (4a) and (4b) as the preliminary due to small number of sites and unreliability some data, as the residuals show for site Yakutsk (see fig.2).

The variants 4a and 4b do not give the clear evidence for the conclusion that the eastern part moves differently comparing with western part of Eurasian plate. We need more dense network and long period of observations on eastern part of the plate to solve the problem.

4. Conclusion

Models of movements of the lithospheric plates allow to calculate the annual velocity vectors of motion for every point within the concrete plate. These vectors play important role in the interpretation of the observed deformation field of tectonically active regions.

The comparison of most advanced "paleomagnetic" and geodetic models shows that for Eurasian plate the annual velocities have systematic differences which may reach 3 mm/year and further improvements of both models is needed. Concerning the geodetic model for Eurasian plate we see the main task in densification of the GPS permanent network on the Asian part of the plate.

In perspective there will be possible to create one model using "paleomagnetic" and geodetic data together.

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