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A Preliminary Study on Plate Motion Measurements on the Korean Peninsula with the New Korean VLBI Array

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Abstract

Although the officially adopted global plate motion model in ITRF, the NNR-NUVEL-1A, assumes that the Korean Peninsula is located on the Eurasian plate (EU), many researchers now postulate that it is on a separate plate, called the Amurian plate (AM). In the near future, we will have 4 VLBI stations in Korea: a geodetic VLBI station and 3 astronomical/geodetic VLBI stations (Korean VLBI Network, KVN). This compact Korean VLBI array is capable of achieving a good determination of the plate motion parameters, as shown in our simulation with small VLBI arrays arranged on stable sites on the North American plate (NA). We estimated the precision of AM motion parameters with the Korean VLBI array. The results showed that the Korean VLBI array would verify the existence of AM, provided an observation precision of 0.2–0.5 mm/yr for station velocities was achieved. Therefore, the new Korean geodetic VLBI array can contribute to crustal deformation studies in East Asia. Moreover, the Suwon site can be an important reference point for defining the ITRF, if it indeed turns out to be a stable mid-plate VLBI station in East Asia.

1. Introduction

1.1. VLBI in Korea

In Korea, within a few years, there will be 3 VLBI stations for astronomical/geodetic purposes, KVN which will be composed of three 21m antennas, to be located in Seoul, Ulsan and Jeju, with 2/8, 22, 43, 86, and 129GHz receivers [7]. The National Geographic Information Institute (NGII) is planning to construct a geodetic VLBI station in Suwon. We will be able to measure the movement of the Korean Peninsula more precisely using these four stations (Figure 1).

1.2. Amurian Plate

The existence of the Amurian plate (AM), which covers the region from the Baikal rift to the Nankai trench, including the Korean Peninsula, was proposed first by Zonenshain and Savostin (1981) [11]. They used seismic data of the Baikal rift zone in order to determine plate motion parameters of AM. Recent developments in high precision space-geodetic measurements imply that it is difficult to explain motions actually observed at various sites on the Earth using only 12 major plates that have been assumed in NNR-NUVEL-1A [1][4]. Many authors divide the major plates into new small plates and blocks (micro-plates). One of them is AM in East Asia. The assumed AM includes the Korean Peninsula as a part of its stable interior. Therefore, precise geodetic measurements on the Korean Peninsula are best suited to determine the motion of AM, and judge if it is in fact a separate micro-plate, and not part of EU as assumed in NNR-NUVEL-1A. Large earthquakes often occur in East Asia causing many disasters. It is suspected that the

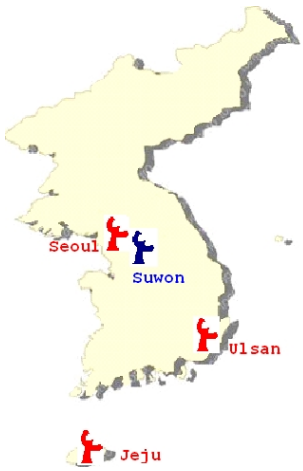

Figure 1. Site locations of the KVN and Suwon antennas in Korea.

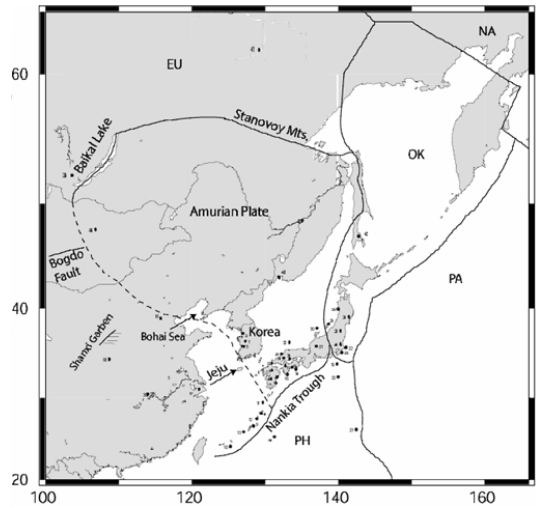

Figure 2. Amurian plate (Eastern Asia Joint Project, 2004).

majority of the recent large earthquakes in the East Sea and Japan Islands area are likely to have occurred along the eastern boundary of AM [6]. A more accurate plate motion model is needed in order to clarify mechanisms and recurrences of earthquakes in this region.

2. Previous Research on the Amurian Plate Using GPS

There were several GPS research projects on the AM. Figure 3 shows the pole positions of the estimated AM-EU relative plate angular velocities. For estimating the motion of the AM, all of the authors who used GPS data had only 3-5 stations located on the postulated AM [6][8][9][10]. This means that this area does not have enough data to estimate the plate motion, compared with other areas of the world. It is evident from Figure 3 that their results are inconsistent with each other, beyond estimated statistical errors, even though they usually used GPS data of the same stations. Hence it is difficult to draw a definite conclusion about the existence of the AM as a separate rigid plate in this region. At this point, we need another independent space geodetic technique in order to distinguish existing results on the Euler vector. In order to determine precise plate motion parameters in East Asia, geodetic VLBI, which has quite good accuracy [2], is desirable.

3. Future VLBI Array in Korea

3.1. Determination of Plate Motion Parameters with the Compact VLBI Array

In order to examine whether the compact VLBI array, such as the one expected in Korea, can determine plate motion parameters to the needed extent, we performed a simulation using existing VLBI stations on the North American plate (NA). We selected two small networks, each consisting of 3 stations, as shown in Figure 4. The positions and velocities of the stations are published in IERS Technical Notes No. 31 as VLBI ITRF2000 station positions at epoch 1997.0

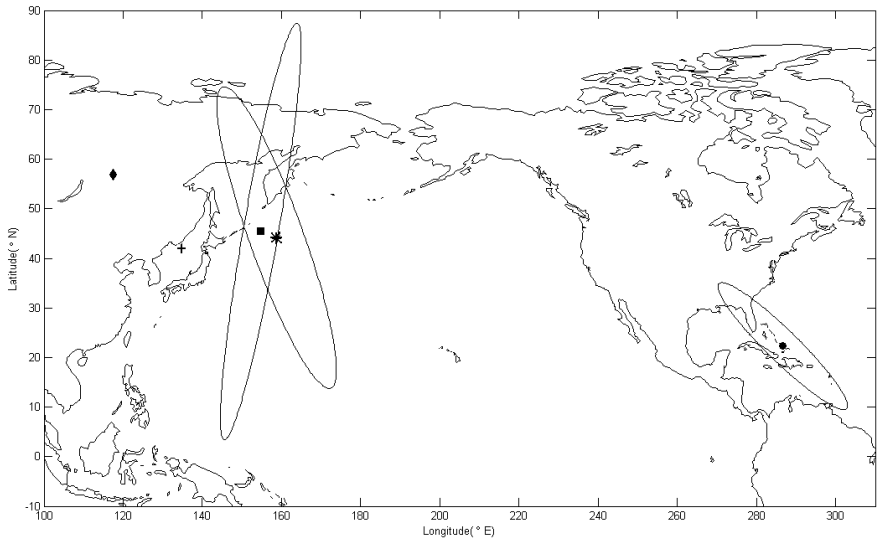

Figure 3. The pole positions and their error ellipses of the plate angular velocities of the AM with respect to the EU in previous research works. ◇ : Zonenshain & Savostin (1981), seismic data, o : Heki *et al.* (1999) GPS, ∗ : Sella *et al.* (2002) GPS, + : Steblov *et al.* (2003) GPS, □ : Prawirodirdjo & Bock (2004) GPS. The error ellipses of Zonenshain & Savostin (1981) and Steblov *et al.* (2003) are not available.

and velocities. From the data, we estimated the rotation vector of NA relative to ITRF2000 with the weighted least squares method. Table 1 shows that the rotation vector of the small array in the East Coast relative to ITRF2000 is almost the same as the Euler vector of the North American plate listed in the IERS Technical Notes No. 31 [3] on the basis of many space geodetic data for NA. The result is also very close to Prawirodirdjo and Bock's (2004) result derived from data of 22 GPS stations in NA. Differences in the estimated vectors are smaller than statistical errors in the present calculation. Hence, the statistical error estimation seems to be reasonable. In the case of the West Coast stations: Fort Davis, Pietown and Los Alamos, the agreement of the rotation vector obtained from these stations with the reference values is fairly good (20% in rotation rate). Accordingly, even a small VLBI network with a small number of stations is able to give a well determined rotation vector of a plate, if the stations are located in the stable interior of the plate. The Korean Peninsula is known to be away from plate boundaries, and seismic activity is quite low in Korea. We can expect that the Euler vector of the plate, which the VLBI stations of the Korean Peninsula form part of, will be well estimated and therefore will allow to verify the existence of AM as a separate plate.

3.2. Error Estimation for the Euler Vector of the AM Relative to ITRF

We estimated the errors of the plate motion parameters expected for the Korean VLBI array, assuming that the errors in the observed velocities are uniform and equal to 0.5 mm/yr for both the NS and EW components, which is typical in present day geodetic VLBI observations. Results are shown in Table 2. It does not seem to be too difficult to achieve a velocity precision of 0.2 mm/yr through geodetic VLBI observations over several years. Then, with several years of

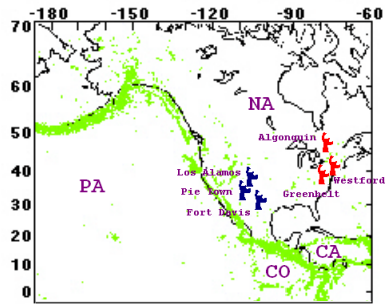

Figure 4. Seismic belts as the boundaries between NA and PA (Pacific plate), NA and CO (Cocos plate), and NA and CA (Caribbean plate), and two small VLBI arrays on NA for the determination of plate motion parameters.

Table 1. Comparison of plate angular vectors relative to ITRF2000 with small VLBI arrays

	Latitute °N	Longitude °E	ω deg/Myr	σ_ω deg/Myr	Error Ellipse, deg		
					σ_{maj}	σ_{min}	Azimuth[a]
IERS Technical Notes No. 31	-83.144	-5.036	0.194	0.003	–	–	–
Prawirodirdjo and Bock [2004]	-84.702	-3.583	0.200	0.003	0.87	0.25	101
East	-83.452	-4.606	0.192	0.010	3.46	0.44	81
West	-88.642	1.981	0.236	0.016	2.68	0.39	27

[a]Azimuth of the semi-major axis in degrees measured clockwise from north

VLBI observations, the value of the error will become remarkably smaller. Therefore, if the high precision of station velocities, 0.2-0.5mm/yr, is realized, any systematic movements of the Korean VLBI stations can contribute to determine the plate angular velocity of the AM and verify the existence of the AM as a separate rigid plate.

4. Conclusion

We compared results of previous research works, by Heki *et al.* (1999), Sella *et al.* (2002), Steblov *et al.* (2003) and Prawirodirdjo and Bock (2004) for the plate motion of East Asia, reducing them to a common platform. The results of the comparison showed that movements derived by the above authors are inconsistent with each other, even though they applied the same technology (GPS) for the same area (East Asia).

We performed a simulation study for plate parameter determination, using measured velocities of several VLBI stations in North America. The results of the simulation showed that even small VLBI arrays are able to well determine the plate motion parameters, if the arrays are located in a stable area (e.g., Westford–Greenbelt–Algonquin array in NA).

We estimated the accuracy of the plate motion parameter to be determined with the new VLBI stations in Korea (KVN and Suwon sites). The results showed that the Korean VLBI array will

Table 2. Error estimation for the plate angular velocity of the AM relative to ITRF.

	σ_ω deg/Myr	Error Ellipse, deg		
		σ_{maj}	σ_{min}	θ_{maj} [a]
0.5 mm/yr[b]				
Seoul–Ulsan–Jeju–Suwon	0.0240	12.21	0.44	-52.17
0.2 mm/yr[c]				
Seoul–Ulsan–Jeju–Suwon	0.0096	4.88	0.17	-52.17

[a]The azimuth of the semi-major ellipse axis in degrees clockwise from north
[b]The assumed velocity errors both in NS and EW directions typical for modern VLBI stations.
[c]The assumed velocity errors after several years of regular geodetic VLBI observations.

be able to provide accurate plate motion parameters, and verify the existence of AM as a separate rigid plate, if the observation accuracy of 0.2-0.5 mm/yr for station velocities is realized.

References

[1] Argus, Donald F., and Gordon, Richard G., "No-net-rotation model of current plate velocities incorporating plate motion model NUVEL-1," *Geophys. Res. Lett.*, **18**, 2039-2042, 1990.

[2] Altamimi, Z., P. Sillard, and C. Boucher, "ITRF2000: A new release of the International Terrestrial Reference Frame for earth science applications," *J. Geophys. Res.*, **107**(B10), ETG 2-1 - ETG 2-19, 2002.

[3] Boucher, C., Z. Altamimi, P. Sillard, and M. Feissel-Vernier, The ITRF2000(IERS Technical Note No. 31), IERS ITRS Centre, 2004.

[4] DeMets, C., R. G. Gordon, D. F. Argus, and S. Stein, "Effect of recent revisions to the geomagnetic reversal time scale on estimates of current plate motions," *Geophys. Res. Lett.*, **21**(20), 2191-2194, 1994.

[5] Hamdy, M., Park, P., Lim, H., Park, K., " Present-day relative displacements between the Jeju Island and the Korean peninsula as seen from GPS," *Earth Planets and Space,* **56***(9), 927-931, 2004*

[6] Heki, K., S. Miyazaki, H. Takahashi, M. Kasahara, F. Kimata, S. Miura, N. F. Vasilenko, A. Ivashenko, and K. D. An, "The Amurian plate motion and current plate kinematics," *J. Geophys. Res.*, **104**(B12), 29,147-29,155, 1999.

[7] Minh Y. C., Roh, D. G., Han, S. T., and Kim, H. G., "Construction of the Korean VLBI Network(KVN)," *ASP Conference Series*, **306**, 2003.

[8] Prawirodirdjo and Bock, "Global plate motion model from CGPS," *J. Geophys. Res.*, **109**, B08405, doi:10.1029/2003JB002944, 2004.

[9] Sella, G. F., T. H. Dixon, and A. L. Mao, "REVEL: A model for recent plate velocities from space geodesy," *J. Geophys. Res.*, **107**(B4), 2081, doi:10.1029/2000JB000033, 2002.

[10] Steblov, G. M., M. G. Kogan, R. W. King, C. H. Scholz, R. Burgmann, and D. I. Frolov, "Imprint of the North American plate in Siberia revealed by GPS," *Geophys. Res. Lett.*, **30**(18), 1924, doi:10.1029/2003GL017805, 2003.

[11] Zonenshain, L. P., and L. S. Savostin, "Geodynamics of the Baikal rift zone and plate tectonics of Asia," *Tectonophysics*, **76**, 1-45, 1981.