Monitoring Activities of Permanent GPS Stations at Tide Gauge in South Korea

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Abstract

South Korea has about 80 permanent GPS stations, being used for a variety of applications such as DGPS, RTK, survey and geodesy. Some of them are installed in or near the coastal area for the purpose of maritime navigation. But, until recently, none of them are used for tide gauge benchmark monitoring. In order to monitor the absolute sea level changes, it is necessary to monitor the land uplift or subsidence occurring at tide gauge sites. It is a common practice to use GPS stations installed at tide gauges to determine absolute sea level. This collaborative efforts coordinated by IGS are called TIGA Pilot Project. Many countries including U.S., Canada, European Union nations, Australia and Japan are participating in TIGA, but South Korea is not a member yet. Recently, we established continuously operating GPS stations at tide gauges located in Incheon and Jeju to monitor the movement of tide gauges sites. This paper will introduce goals and progress of the efforts.

Keywords: GPS, Land subsidence, Ocean Tidal Loading, GIPSY, Tide guage.

1. Introduction

Relative mean sea level (RMSL) includes land movements, because it is based on the data recorded by tide gauge established on the ground expected to be stable. Absolute mean sea level (AMSL) is with respect to a global datum such as the International Terrestrial Reference Frame (ITRF) ellipsoid, so we can distinguish between land movements and true MSL changes. Rates of global MSL changes have been calculated by observing RMSL changes in the past. However, in order to get exact rates of global MSL change, we have to use AMSL.

In 1989, International Association for Physical Sciences of the Ocean (IAPSO) Commission recommended tide gauge benchmark (TGBM) coordinates conform to the ITRF frame (Carter et al, 1989). From 1991 to 1996, Institute Engineering Surveying and Space Geodesy (IESSG) and Proudman Oceanographic Laboratory (POL) established episodic GPS at tide gauge and carried out the study to monitor vertical land movements (Teferle, 2000). After that, International GNSS Service (IGS) organized Tide Gauge Benchmark Monitoring Pilot Project (TIGA-PP) that analyzes GPS measurements collected at tide gauge. TIGA-PP categorizes TIGA Observing Station (TOS), TIGA Data Centers (TDC), TIGA Analysis Centers (TAC) and TIGA Associate Analysis Centers (TAAC). About one hundred stations participated in TOS, but many countries like Korea, Russia, China and India are not participating yet.

A GPS station was established at Incheon tide gauge in order to join TIGA-PP as apart of TOS in 2005. In this paper, components of GPS stations at Incheon tide gauge are explained and the accuracy of GPS data evaluated by computing RMS errors in coordinate time series using the data recorded for a year.

Predicted site displacements due to ocean tidal loading (OTL) is compared with hourly GPS coordinates as the first step for analyzing OTL effects on Korean peninsula crust.

2. GPS Station at Incheon Tide Gauge

2.1 MSL Measurements at Inchon Tide Gauge

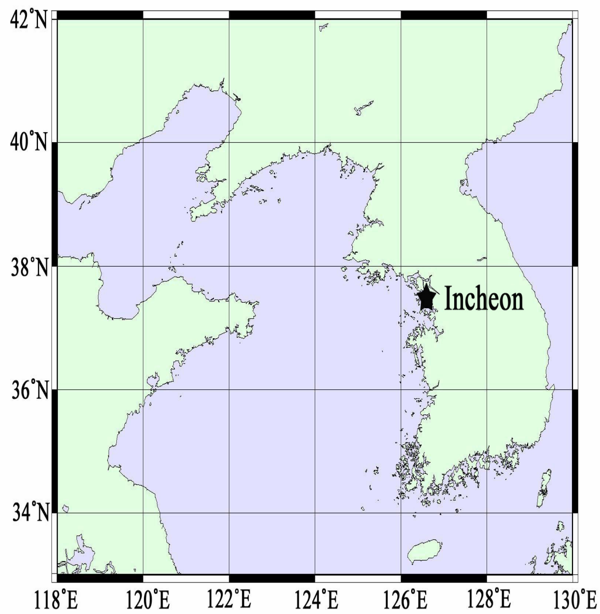

Figure 1. Location of Incheon tide gauge.

Figure 1 shows the location of Incheon tide gauge and a complicated structure of the coastline. It is difficult to model ocean tides due to the low depth of water and complicated structure of the coastline.

Figure 2 shows MSL change rates based on the data recorded at Incheon tide gauge from 1979 to 2005. The MSL height is relative to the datum level that is determined by approximately lowest low water.

A0 is the annual mean sea level of tide data and Z0 is MSL value calculated using the four principal tidal constituents from the harmonic analysis of tides. Two data sets agree within 4 mm. When you exclude the 1995 data, the MSL rate is about 4.8 mm/yr. It is different from the global rate of 1.0 ~ 2.0 mm/yr published by Intergovernmental Panel on Climate Change (IPCC).

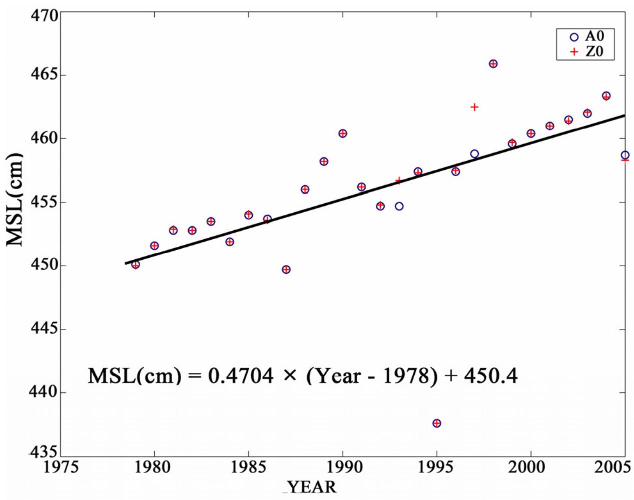

Figure 2. Mean Sea Level changes from 1979 to 2005.

While the value suggested by IPCC a result of a very-long term analysis (>100 years), the rate components in Figure 2 is based on the data recorded for only about 20 years. So it couldn't be a fair comparison. The rate of 4.8 mm/yr is considered to reflect a lack of a long-term analysis observation and a mud accumulation due to a reclamation project in 90's. By monitoring the crust movement of the tide gauge site using GPS measurements, more accurate tide gauge data and be obtained.

2.2 Components of the GPS Station at Incheon Tide Gauge

There are about eighty permanent GPS stations in Korea, but they are not designed to monitor vertical movements on the tide gauge. For the first time in Korea National Oceanographic Research Institute (NORI) established GPS station to monitor vertical land movements at the tide gauge in September, 2005 (Figure 3).

Figure 3. GPS site at Incheon tide gauge.

The Incheon tide gauge is inside a one-story wooden building and the GPS antenna is 1 meter far from a stilling well. The antenna is Ashtech 701945E_M, which is a Dorne-Margolin choke ring type. A SCIGN hemispheric radome is mounted on the antenna because the GPS antenna needs to be protected from the elements, birds, insects, etc. An Ashtech iCGRS receiver is used and received data is transmitted to the NORI server via FTP. The name of the site is ICNW that stands for Incheon West.

ICNW has started operating on September 19, 2005 and has been storing observation data for about a year. Although it is a short-term data, we analyzed the data and evaluated its accuracy.

3. Estimating GPS Station Velocity

Daily coordinates of ICNW were computed with GIPSY-OASIS II developed by Jet Propulsion Laboratory (JPL). The period of the data is from September 19, 2005 to July 15, 2006 and Figure 4 shows a time series of the north, the east and the vertical coordinates. The following models were used to correct systematic error.

- Corrections for Ocean Tidal Loading: M2, S2, N2, K2, K1, O1, P1, Q1, Mf, Mm and Ssa based on the NAO.99b model (Matsumoto et al, 2000).
- Corrections for relative antenna phase center variations.
- Corrections for Solid Earth Tides.
- Modeling of the 'dry' zenith troposphere delay using the Niell model
- Estimation of the 'wet' zenith troposphere delay using the Niell model

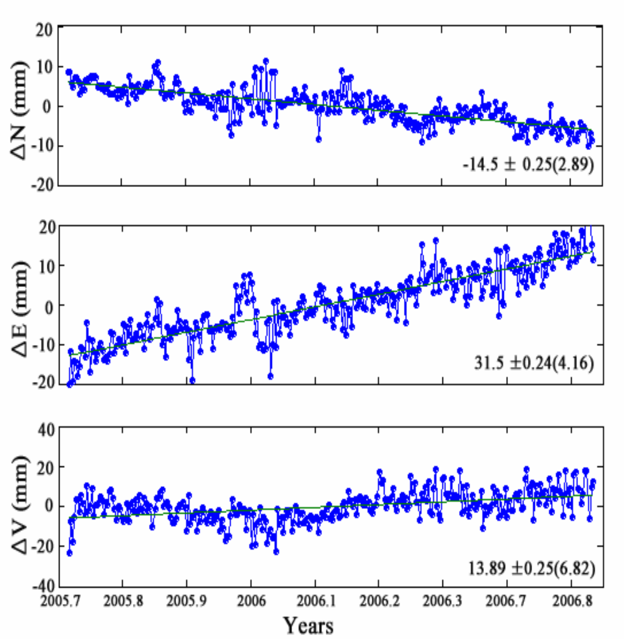

Figure 4. Coordinate time series for ICNW GPS Station.

Because the time series are too short for a meaningful analysis, we mention the errors associated with a linear regression. RMS errors were 2.89 mm to the north, 4.16 mm to the east and 6.82 mm to the vertical directions.

4. Comparison of Ocean Tidal Loading models with GPS measurements

The ocean tide occurs periodically due to the gravitational attractions of the Moon and Sun, and in turn the solid Earth responds periodically due to the change in the mass distribution of the water of the ocean. The appeared periodic phenomenon on the GPS measurement is problematic in case that the session length is shorter than 24 hours and precise positioning required. Recently, many of ocean tidal loading models were developed, and they are more precise than the old ones by using TOPEX/Poseidon altimetry data since 1992. Even with a remarkable progress in the space geodesy technique, the complexity of structure and the narrow depth of water around the coast still cause the difficulty in modeling ocean tides.

The test performed for the verification of the OTL effects on the ICNW site. The GOTIC2 program calculated the predicted crust displacements due to the OTL using the NAO.99b model. And the GIPSY program determined the vertical crust deformation without the correction of OTL effects.

Figure 5 shows vertical displacements predicted by GOTIC2 (solid line) and GPS-observed ones (red dots). The RMS difference is 19 mm and the amplitude of the OTL signal is about ~ 30 mm. According to Figure 5, GPS-observed displacements match pretty well with OTL-predicting, but some specific parts have maximum difference of 80 mm. After we got rid of these noticeable misfits, we could see the phase and amplitude are similar.

5. Conclusion

We introduced continuous GPS station at tide gauge in the Korean Peninsula, which was established in September, 2005. The purpose of the site is to provide absolute mean sea level for calculation of global mean sea level through monitoring vertical movements at tide gauge.

We confirmed an accuracy of the coordinates and a magnitude for site displacements due to ocean tidal loading at the tide gauge through data processing. RMS errors of the coordinate time series were 2.89 mm to the north, 4.16 mm to the east and 6.82 mm to the vertical directions. And the results for a comparison of predicted OTL and observed GPS indicated 19 mm in RMS error.

Acknowledgement

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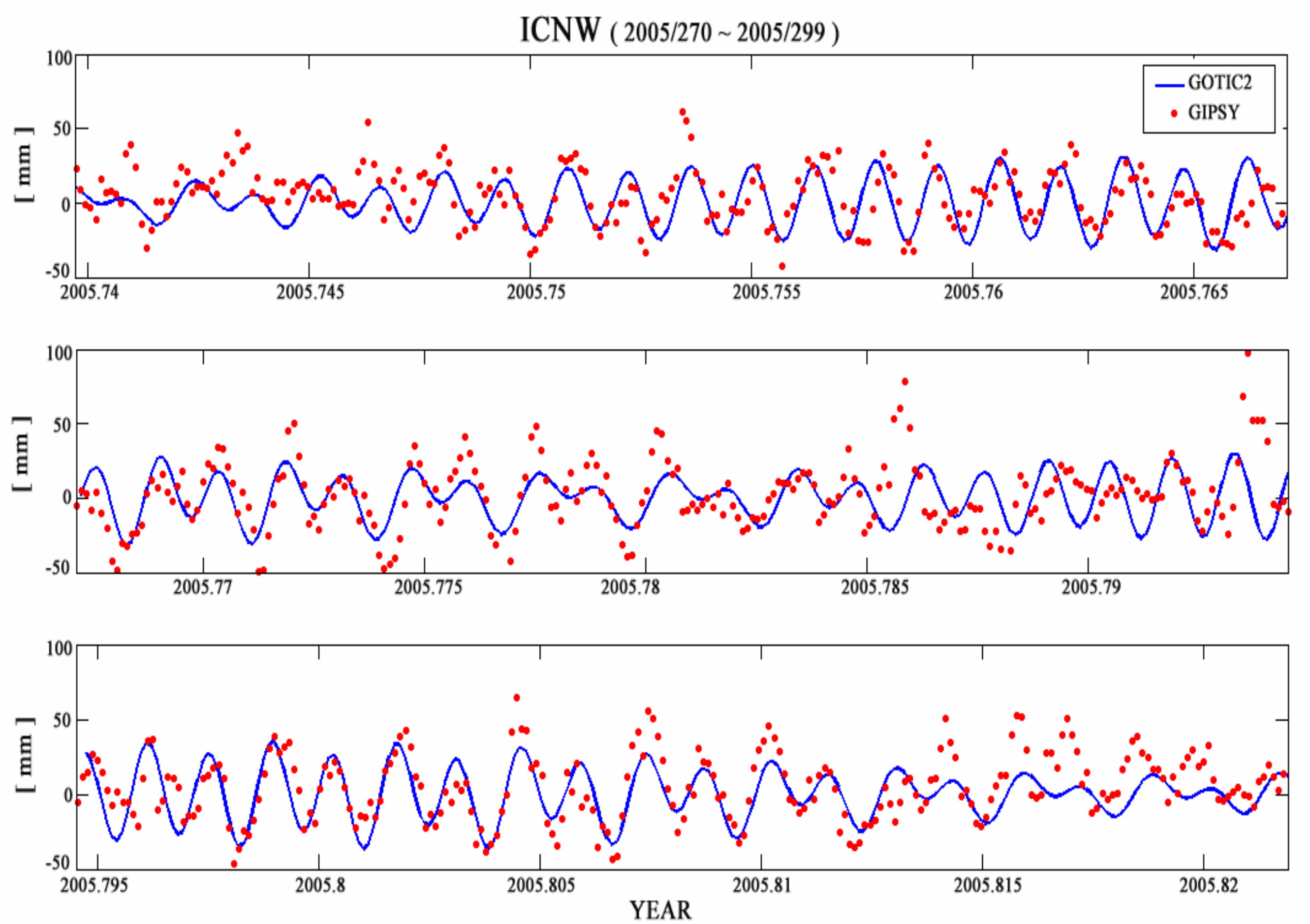

Figure 5. Comparison of GPS-observed (red dot) .vs. OTL-predicted deformations (solid line).

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