GNSS CORS Processing using Automated Crustal Deformation Monitoring System in South Korea

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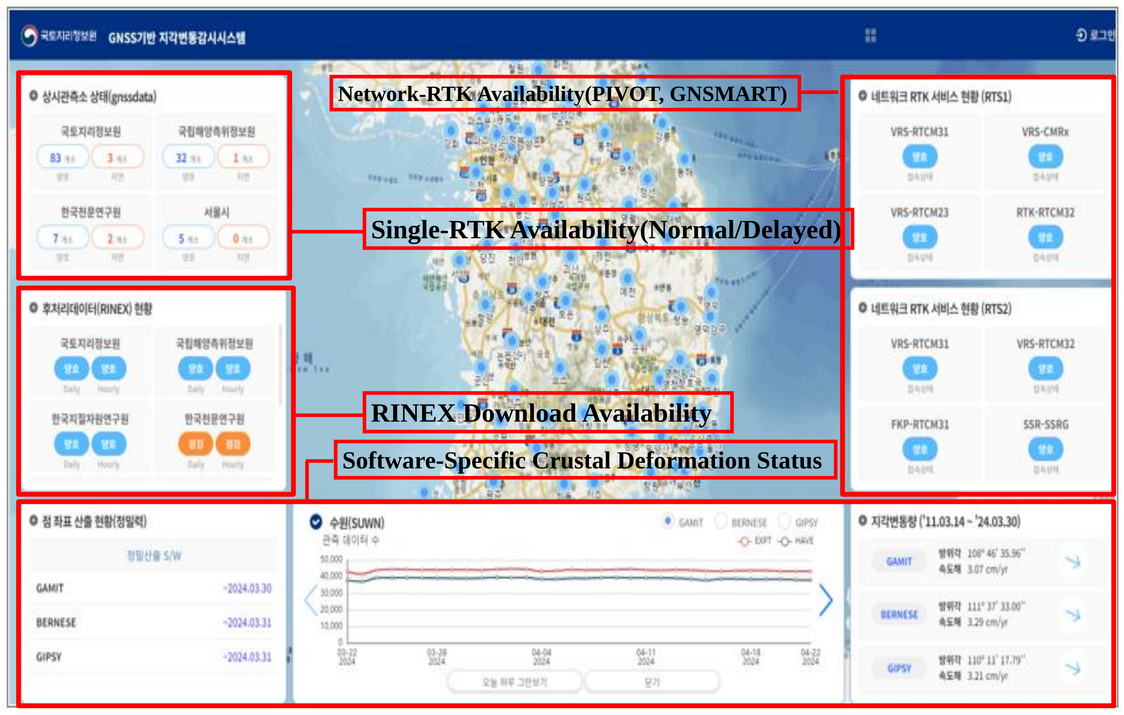
ABSTRACT

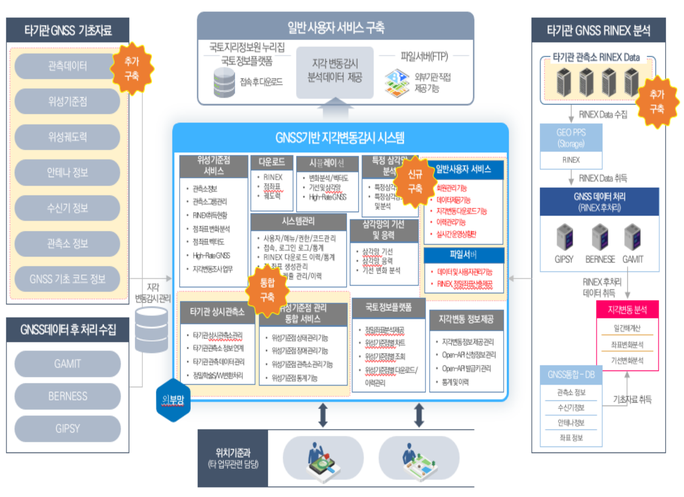
•The National Geographic Information Institute of Korea (NGII) established a Crustal Deformation Monitoring System (CDMS) using GNSS CORS data in 2020. This system automatically processes daily GNSS CORS positions using three GNSS processing software: GAMIT-GLOBK, Bernese 5.2, and GIPSY-OASIS. It calculates crustal deformation using accumulated time-series coordinates of CORS stations. NGII's Crustal Deformation Monitoring System collects RINEX data from CORS stations in Korea and abroad, automatically processes GNSS data using necessary orbits and models, and performs daily processing using Ultra-Rapid, Rapid, and Final orbit products. The system monitors sudden crustal deformations due to seismic events and earthquakes in Korea. Additionally, NGII provides real-time status updates on CORS and Network-RTK operations. This research analyzes crustal deformation in Korea from 2018 to 2023 using GNSS data processing, as well as the impact of the inland earthquake that occurred in Korea in 2023.

Crustal Deformation Monitoring System

Since the March 2011 Japan earthquake (magnitude 9.0), the September 2016 Gyeongju earthquake (magnitude 5.8), and the November 2017 Pohang earthquake (magnitude 5.4), public interest in earthquakes has increased significantly in Korea. As a result, the national policy importance of disaster and safety management has risen. Therefore, since 2017, the NGII has formulated basic plans for establishing a permanent GNSS reference point-based Crustal Deformation Monitoring System (CDMS) around major fault zones. In 2020, NGII internally established the GNSS CORS for crustal deformation monitoring, and as of 2024, it provides real-time velocity vector calculations of current crustal deformations as a public service through the monitoring system. The purpose of the Crustal Deformation Monitoring System is not only to continuously monitor ground movements based on GNSS but also to provide rapid information on positional changes in the event of sudden crustal deformations such as earthquakes. Additionally, NGII offers services for CORS and Network-RTK operational statuses. Currently, there are a total of 213 permanent observation stations under continuous analysis, including NGII's satellite reference points and those from other institutions such as the Korea Hydrographic and Oceanographic Agency, Korea Institute of Geoscience and Mineral Resources, and Korea Astronomy and Space Science Institute.



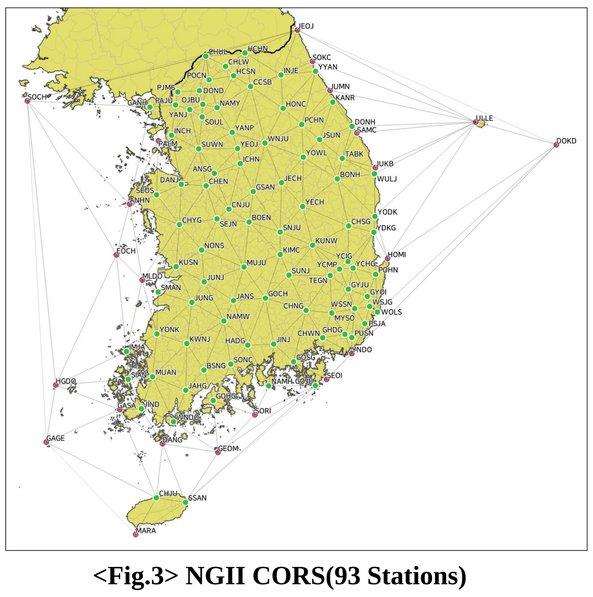
<Fig.1> Initial Screen of Crustal Deformation monitoring System(geodesy.ngii.go.kr)



<Fig.2> System diagram of CDMS

Partner Agency	Quantity
NGII *Korea Space Weather Center	93
NMPNT *National Maritime Positioning, Navigation and Training Office	32
KIGAM *Korea Institute of Geoscience and Mineral Resources	17
KASI *Korea Astronomy & Space Science Institute	7
NMSC *National Meteorological Satellite Center	24
Seoul-City	5
KSWC *Korea Space Weather Center	5
LX *Korea National Land Information Corporation	30
Total	**213**

<Table.1> Number of CORS Site of CDMS



<Fig.3> NGII CORS(93 Stations)

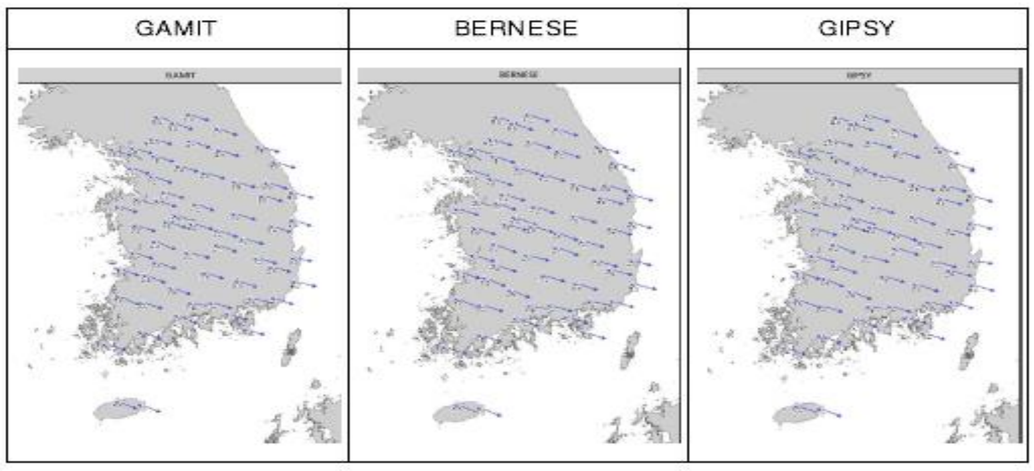
<Fig.4> IGS CORS Sites in Korea

Analysis of Ground Movements on the Korean Peninsula

From 2018 to 2023, using GNSS processing software (GAMIT-GLOBK, Bernese 5.2, GIPSY-OASIS), NGII has calculated velocity vectors for 59 GNSS CORS reference points. These results show an average movement direction towards the southeast (110.55°) at approximately 3.18 cm/year. Similarly, velocity vectors were calculated for 57 permanent observation stations from other institutions, showing an average movement towards the southeast (109.9°) at approximately 3.14 cm/year. These results closely resemble the crustal deformation quantities analyzed using NGII's satellite reference points. Additionally, analysis using NGII's Sejong VLBI system indicated a similar ground movement of 2.9 cm/year towards 122.6°. The table and figure below illustrate the velocity vectors calculated using NGII's 59 satellite reference points. This suggests consistency in the crustal deformation measurements across different methodologies and reinforces the reliability of NGII's monitoring systems in tracking ground movements over time.

Division		GAMIT	Bernese	Gipsy	Average
Second Half in 2023 ('18.1~'23.12)	Velocity	3.09 cm/year	3.26cm/year	3.19cm/year	3.18 cm/year
	Azimuth	108° 51′39.4″	112° 20′19.0″	110° 27′24.6″	110° 33′07.7″
First Half in 2023 ('18.1~'23.06)	Velocity	3.09 cm/year	3.28cm/year	3.20cm/year	3.19 cm/year
	Azimuth	108° 41′42.8″	111° 31′14.5″	110° 12′13″	110° 08′23.4″

<Table.2> Velocity Vector Values using NGII CORS by Software



<Fig.5> Velocity Vector Values using NGII CORS by Software

Analysis of Ground Deformation Caused by Domestic Earthquakes

In 2023, NGII analyzed the coordinates of GNSS satellite reference points located closest to the epicenters of three inland earthquakes with magnitudes of 3.0 or higher. The analysis covered coordinates for one month before and after each earthquake occurrence. Based on this study, NGII found minimal horizontal differences (East, North) of less than 0.5 cm and vertical differences (ellipsoidal height) of less than 1.0 cm. Consequently, NGII concluded that there was virtually no crustal deformation associated with these earthquakes. This assessment underscores the precision and sensitivity of GNSS technology in detecting even subtle changes in ground positions, thereby providing valuable insights into seismic activities and their impacts on the Earth's crust.

Epicenter	Date of Earthquake	Magnitude/Depth	Distance from CORS	Analysis Resulting
Jangsu	'23.07.29	3.5 / 6km	JANS / About 18km	No Ground Deformation
Gongju	'23.10.25	3.4 / 12km	NONS / About 18km	No Ground Deformation
Gyeongju	'23.11.30	4.0 / 12km	GYJU / About 3km	No Ground Deformation

<Table.3> Analysis of Ground Deformation Resulting from the 2023 Domestic Earthquake

<Fig.6> The Epicenter of Jansu

<Fig.7> The Epicenter of Gongju

<Fig.8> The Epicenter of Gyeonju

Future Plan

NGII defines and manages South Korea's Reference Frame, overseeing infrastructure such as VLBI, GNSS CORS, and national benchmarks. The Crustal Deformation Monitoring System introduced in this study utilizes GNSS CORS to monitor national ground movements and seismic-induced crustal deformations. Currently, it provides services to the public and will continue to evolve. In the future, NGII plans to ensure stable operation of the system and expand processing capabilities to include GNSS CORS operated by other institutions. Additionally, it aims to leverage other outputs from GNSS data processing, such as tropospheric delays and ionospheric TEC, to monitor global changes like climate change. This ongoing effort reflects NGII's commitment to advancing geospatial monitoring technologies and their applications in understanding and responding to global environmental changes.