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Technical Document 1



GIS-IDEAS 2024

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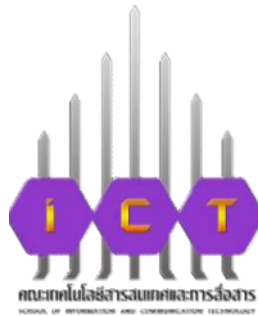
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Geoinformatics for Spatial - Infrastructure Development in Earth & Allied Sciences

The International Conference on Geoinformatics for Spatial-Infrastructure Development in Earth & Allied Sciences (GIS-IDEAS) provides a platform for sharing of knowledge and valuable experiences and help promote collaborations and scientific exchanges between not only between students, researchers and practitioners Japan, Vietnam and Thailand but also our other colleagues involved in developing and promoting Geoinformatics technologies. The conduct of GIS-IDEAS Conferences is based on the spirit of mutual cooperation and openness.

GIS-IDEAS is planned around a central theme which is decided in consultation with the host institution. Apart from Technical Sessions on Geoinformatics technologies and applications, Special sessions on different topics related to Geo-informatics are also held during the conference.

GIS-IDEAS is organized in collaboration with premier institutes located in Asia. GIS-IDEAS which was founded in 2002 to develop and promote Geoinformatics applications and foster cooperation in application of Information and Communication Technologies to problems and issues related to our natural and social environment. To achieve these aims, the conference aims to;

- ◆ support capacity building through organization of symposia, workshops and fieldwork.
- ◆ share information resources and know-how in Geoinformatics
- ◆ promote research collaborations and joint research in Geoinformatics
- ◆ promote exchange of information and academic publications
- ◆ develop a human resource network to support development and growth of Geoinformatics

Previous GIS-IDEAS Conferences were organized in collaboration with premier institutions like Can Tho University (VN), Danang University of Education (VN), Japan Geotechnical Consultant Association (JP), Japan Society of Geoinformatics (JP), Hanoi University of Mining and Geology (VN), Hanoi University of Natural Resources & Environment (VN), Ho Chi Minh City University of Technology (VN), Kyoto University (JP), Naresuan University Thailand, Osaka City University (JP), Osaka Metropolitan University (JP), Vietnam National University (VN) and others.

From the Conference Chairs

Our best wishes to the GIS-IDEAS Community for a Happy New Year! We are very happy to bring out this volume of the GIS-IDEAS 2024 Conference Proceedings, that was held from December 11–13 in the vibrant city of Chiang Rai, Thailand. As we look back at this exciting event, we feel immense satisfaction to continue the proud tradition of fostering global collaboration and innovation in geoinformatics that began with the establishment of the Japan-Vietnam Geoinformatics Consortium (JVGC) in 2001.

The GIS-IDEAS 2024 conference provided a unique platform to exchange ideas, share knowledge, and explore the latest advancements in spatial sciences, urban planning, and environmental sustainability. The beautiful and culturally rich Chiang Rai offered an excellent venue to discuss how Geoinformatics can address some of the most pressing global challenges. With a program that included inspiring keynote speeches, dynamic technical sessions, and hands-on workshops, GIS-IDEAS 2024 promises to deliver insights and solutions that will resonate well beyond the event.

We extend our heartfelt thanks to all the contributors whose research enriches the proceedings of this conference. Our deepest appreciation to our wonderful host the University of Phayao and to various conference committees, faculty, staff, and students who work tirelessly to ensure the event's success. Special acknowledgment is due to our sponsors and supporters, whose generous contributions enable us to create a collaborative and vibrant platform to showcase innovations and current trends in Geoinformatics research and application. We also express our thanks to the editors and manuscript reviewers and commend their hard work to bringing out the proceedings in a timely manner.

Together, we hope to kindle innovative ideas, foster meaningful collaborations, and deepen the connections that unite the Geoinformatics community worldwide. Your participation and support are integral to the success of GIS-IDEAS 2024, and we look forward to the insights, discoveries, and partnerships that this conference will inspire.

Thank you Chiang Rai!, and See you at GIS-IDEAS 2026!! Warm regards,

Phaisarn JEEFOO & Venkatesh RAGHAVAN

Chairs, GIS-IDEAS 2025

Dt: January 2025

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PROF. SONG XIANFENG



Prof. Song Xianfeng is a distinguished expert in Geographic Information Sciences (GIS) and Remote Sensing Hydrology, focusing on geospatial data mining using vehicle GNSS trajectories, cellular network signalling, and DVR data. He holds an MS in Remote Sensing Geology (1995) from China University of Mining & Technology, along with a PhD in GIS from the Chinese Academy of Sciences (1998). He is presently serving as a Professor at the University of Chinese Academy of Sciences since 2011, following roles as Associate Professor and Assistant Professor there and at Kyoto University. His industry experience includes managing IT for the Chinese Investment Corporation for Sciences and Technology.

The Keynote speakers

DR TRAN VAN ANH



Dr. Tran Van Anh is a lecturer at Hanoi University of Mining and Geology (HUMG). She obtained her Master's degree in Surveying and Mapping Engineering from HUMG, Vietnam, in 2001 and her PhD degree in Geoinformatics from Osaka City University (Japan) in 2007. Her field of study is remote sensing and GIS. She has working interests in Radar Interferometry (InSAR) for land deformation detections and optical images for air pollution (PM10) determination. Besides that, she also works on geospatial data research and builds predicting models. She has had more than 50 works published in prestigious domestic and international journals.

DR NATRAJ VADDADI



Dr. Natraj Vaddadi, an Executive Member of the Governing Council at the Centre for Education & Research in Geosciences, is a geologist specializing in Urban Groundwater Recharge through Rainwater Harvesting. He holds a Master's degree in Geology from the University of Pune and a Ph.D. in Natural Resources and Environment from Naresuan University, Thailand. With over three decades of teaching experience, he serves as a Visiting Professor in Petroleum Technology at Nowrosjee Wadia College and teaches postgraduate courses in Drilling Engineering and Production Operations at the University of Pune.

Dr. Vaddadi has conducted numerous workshops on Open-Source GIS in India, Thailand, and Vietnam and is the author of the internationally acclaimed book *An Introduction to Oil Well Drilling*. As a founding member of the Centre for Education & Research in Geosciences, he advocates for geoscience education, promoting its integration into environmental conservation and sustainability initiatives.

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INVESTIGATING LAND SUBSIDENCE BY PROCESSING MULTI-TEMPORAL SAR TIME SERIES ON GOOGLE COLAB: CASE STUDY IN CAMAU CITY, MEKONG DELTA, VIETNAM

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ABSTRACT

The phenomenon of land subsidence is widespread and complex in Ca Mau Province, stemming from both natural factors and human activities. Radar remote sensing technology has become an effective tool for monitoring and surveying land subsidence over large areas. The process of processing radar images to identify land subsidence not only requires specialized knowledge and experience but also necessitates powerful hardware systems to handle multi-temporal data. Therefore, this process can be costly and time-consuming. This study focuses on evaluating the application of the Google Colab online platform using the MT-SAR (Multi-Temporal Synthetic Aperture Radar) processing method to analyze a series of 24 Synthetic Aperture Radar images from January 2022 to December 2023 for Ca Mau City and surrounding areas. By comparing the results from Google Colab with field survey data, the study will assess the effectiveness and accuracy of land subsidence detection using the SBAS technique on the Google Colab platform, with results showing a correlation coefficient R^2 of 0.80 and RMSE of 4mm.

1. INTRODUCTION

The InSAR (Interferometric Synthetic Aperture Radar) technique is currently being explored for detecting land subsidence through various methodologies, including Differential InSAR (D-InSAR), Permanent Scatterers InSAR (PS-InSAR), and Small Baseline Subset (SBAS) techniques, as well as their combinations, across diverse global regions. Radar remote sensing was first applied to extract surface data of Venus and the Moon in 1969 (A. Rogers, 1969). By 1974, Graham removed the topographic phase from SAR images to map and detect surface displacement (Graham, 1974). Howard demonstrated that the D-InSAR method is affected by atmospheric noise and spatiotemporal conditions (H.A. Zebker, 1992). The PS-InSAR method was proposed by Ferretti et al. (A. Ferretti, 2000). However, this method has limitations when applied to areas with few stable scatterers, such as rural regions, forests, or deserts. In 2002, Berardino and colleagues introduced the SBAS method, which enables more effective monitoring in regions with rapidly changing ground conditions (P. Berardino, 2002). Since its development, SBAS has been employed for surface deformation detection across

various global locations. Notable studies include the monitoring of subsidence in Mexico City using the SBAS technique (S., 2020); the application of both PS-InSAR and SBAS technologies to detect land subsidence in Kunming City, China (Xiao, Zhao et al., 2022); Yuejuan Chen's work, which combined all three methods PS-InSAR, D-InSAR, and SBAS to identify Persistent Scatterers (PS) and Distributed Scatterers (DS) in Tongliao City, Inner Mongolia (Chen, Ding et al., 2024).

In Vietnam, the D-InSAR, PS-InSAR, and SBAS methods have also been studied and applied for land subsidence detection in several regions. Early research in Vietnam focused on monitoring subsidence in Hanoi (Van Anh, 2016; Dang, 2014; Bui, 2020). In the Mekong Delta region, including Ca Mau, a study by Erban applied InSAR technology using stacking methods to determine average phase displacement (Erban, Gorelick et al., 2014). The PS-InSAR method was utilized to detect land subsidence in the Mekong Delta (Philip S. J. Minderhoud, 2020). With the same method, Anh V.T. conducted studies in the Ca Mau area (Anh, 2021; Anh T. V., 2023).

These studies predominantly utilize software platforms such as StaMPS/MTI (Stanford Method for Persistent Scatterers/Multi-Temporal InSAR), ESA SNAP (European Space Agency's Sentinel Application Platform), and SARscape (Synthetic Aperture Radar Scape) that operate on computer systems with adequate configuration and storage capacity, particularly for processing multi-temporal radar image series over extensive areas. To overcome these limitations, online platforms leveraging server resources from major technology companies like Google and Microsoft have been developed, enhancing performance and cost-effectiveness for processing large datasets. Google Colab, a widely used online platform provided by Google, offers significant advantages for remote sensing data processing (Johary, Révillion et al., 2023). This study utilizes the SBAS method on the Google Colab platform to process a series of 24 multi-temporal radar images to monitor land subsidence in Ca Mau City and surrounding areas from January 2022 to December 2023.

2. RESEARCH METHODOLOGY

2.1 Study area

The study area includes the entire city of Ca Mau and several neighboring communes within the districts of Dam Doi, Cai Nuoc, Tran Van Thoi, U Minh, and Thoi Binh, located in Ca Mau province in the southern territory of Vietnam (Figure 1). This region is predominantly flat, with an average elevation ranging from 0.4 to 0.6 meters above sea level. Some areas have elevations around 0.2 meters in low-lying regions and between 0.8 to 1.1 meters in higher regions. The topography gently slopes from north to south and from northeast to northwest. The area features a complex network of rivers and canals, facilitating agricultural irrigation. The eastern and southern parts are mainly used for intensive and semi-intensive shrimp farming, while the northern and western parts are primarily used for double-crop rice cultivation, vegetables, and freshwater agriculture.

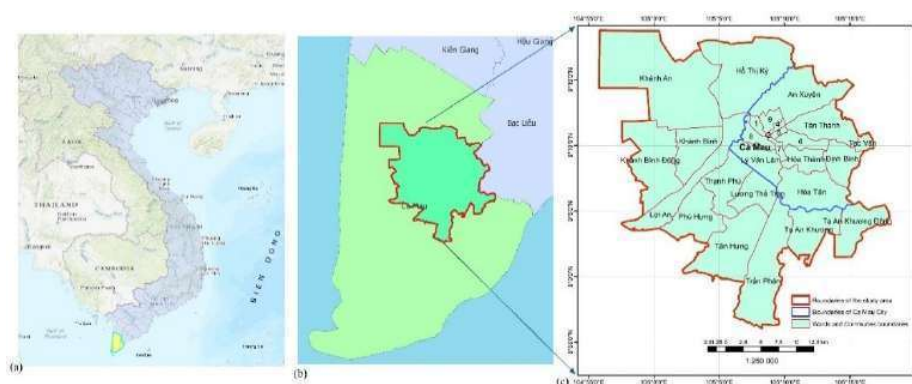


Figure 1. (a) Location of Ca Mau Province in Vietnam, (b) Location of the study area within Ca Mau Province, (c) Boundaries of wards and communes in the study area.

2.2 Data

In this paper, the dataset utilized consists of a series of 24 images from the Sentinel-1A satellite, covering the period from January 2022 to December 2023 in the Ca Mau Province region. Sentinel-1A imagery is a product of the Copernicus Earth Observation program of the European Space Agency (ESA), equipped with a C-band Synthetic Aperture Radar (SAR) with a 12-day repeat cycle in Interferometric Wide Swath (IW) mode with VV polarization (Table 1). The Sentinel-1A datasets were obtained from the Alaska Satellite Facility's database (<https://search.asf.alaska.edu/>). Additionally, the study employs SRTM DEM (Shuttle Radar Topography Mission) data provided by NASA with a ground resolution of 30 meters.

Table 1. Parameters of Sentinel-1A Satellite Images in the Study.

Parameter	Value
Flight Direction	Descending
Data Acquisition Mode	IW (Interferometric Wide Swath)
Polarization	VV
Band	C
Wavelength (cm)	5,6
Spatial Resolution	20m
Swath Width	250km
Number of Images	24
Observation Period	01/2022 – 12/2023

2.3 Proposed Method

MT-SAR (Multi-Temporal Synthetic Aperture Radar) is a method for analyzing synthetic aperture radar (SAR) data using multi-temporal observations to measure and monitor surface deformation with high accuracy. It is one of the techniques used in long-term analyses, enabling the monitoring of phenomena such as land subsidence, mountain deformation, or changes in the height of architectural structures over time. MT-SAR can estimate ground surface movement with millimeter precision. Key MT-SAR techniques include PS-InSAR (Persistent Scatterer Interferometry SAR) and SBAS (Small Baseline Subset). In this study, we focus on using the SBAS method to determine subsidence in Ca Mau City, Ca Mau Province, Vietnam.

SBAS is an advanced method used in Synthetic Aperture Radar (SAR) image processing for monitoring and measuring surface deformation, proposed by Berardino in 2002 (Berardino P, 2002). This method relies on analyzing subsets of SAR images with small baselines to minimize errors related to observational conditions and signal noise.

The process of applying SBAS technique to process multi-temporal Synthetic Aperture Radar (SAR) images for surface deformation monitoring consists of the following main steps:

(1) SAR data acquisition: Collecting 24 SAR images from the Sentinel-1A satellite from January 2022 to December 2023.

(2) SAR image pre-processing: Utilizing geometric correction methods to ensure precise alignment of all SAR images and applying filters to remove noise.

(3) Creating interferometric image pairs: Computing interferometric pairs of SAR images with small spatial and temporal baselines to minimize geometric errors. Subsequently, performing interferometric phase processing on these pairs to determine phase differences between two image scenes. Applying methods to mitigate atmospheric phase variation and geometric errors.

(4) Phase unwrapping: Employing algorithms such as SNAPHU (Statistical-Cost Network-Flow Algorithm for Phase Unwrapping) (Zebker, 2000) to unwrap the phases of the interferometric pairs, converting from wrapped phase to absolute phase.

(5) Time-series deformation analysis: Using Digital Elevation Model (DEM) data to correct for terrain effects on the interferometric pairs. Then, applying the SBAS method to analyze the time-series of unwrapped interferometric phases to determine surface deformation over time.

2.4 Google Colab online platform

Google Colab (Google Collaboratory) is a free online platform offered by Google that facilitates the editing and execution of Python code in a notebook environment. Leveraging Google's cloud infrastructure, Google Colab eliminates the need for high-performance local computing resources. Users can access this platform with a Google account and a stable internet connection, allowing them to operate it seamlessly across various devices. The processing of radar image time series is a resource-intensive and complex task. By utilizing Google Colab, users benefit from sufficient computational power and storage capacity. In this study, the PyGMTSAR library is utilized on the Google Colab platform to collect, process, and analyze



3.1 Subsidence detection on Google Colab

The graph displays the distance from the ground to the light source (m) on the y-axis (ranging from -50 to 250) against the photograph date on the x-axis (ranging from 2022-01 to 2024-01). The 'Đường ánh' series is represented by a blue line with circular markers. The path is highly irregular, with a significant peak in early 2023 reaching approximately 250m. Other notable points include a low point near -50m in mid-2022 and another low point near -70m in mid-2023.

Thời gian chụp ảnh	Khoảng cách đường ánh (m)
2022-01-10	0
2022-02-15	20
2022-03-11	25
2022-04-16	0
2022-05-10	30
2022-06-15	90
2022-07-09	-50
2022-08-14	10
2022-09-19	140
2022-10-13	120
2022-11-18	10
2022-12-12	-30
2023-01-17	250
2023-02-10	70
2023-03-18	110
2023-04-11	-50
2023-05-17	-70
2023-06-22	150
2023-07-16	-60
2023-08-21	110
2023-09-14	60
2023-10-08	10
2023-11-13	10
2023-12-07	50

Figure 4. Typical interferogram.

Following data acquisition, the images were aligned with precise orbit files and cropped to accurately match the study area. The interferometric processing of the image pairs involved applying the Goldstein filter to mitigate noise, thereby producing clear interferograms with topographic phase effects removed. Additionally, the Minimum Cost Flow (MCF) technique was utilized for phase unwrapping. Out of the 24 image scenes, 50 filtered interferograms were generated. Figure 4 presents four selected interferograms with distinct fringes, highlighting the deformation within the study area.

After employing noise filtering techniques to obtain the clearest 50 interferograms, phase unwrapping using the Minimum Cost Flow (MCF) algorithm on the SNAPHU software, implemented on the Google server, finally utilized SBAS analysis to calculate the deformation over the 24-time series as shown in Figure 5.

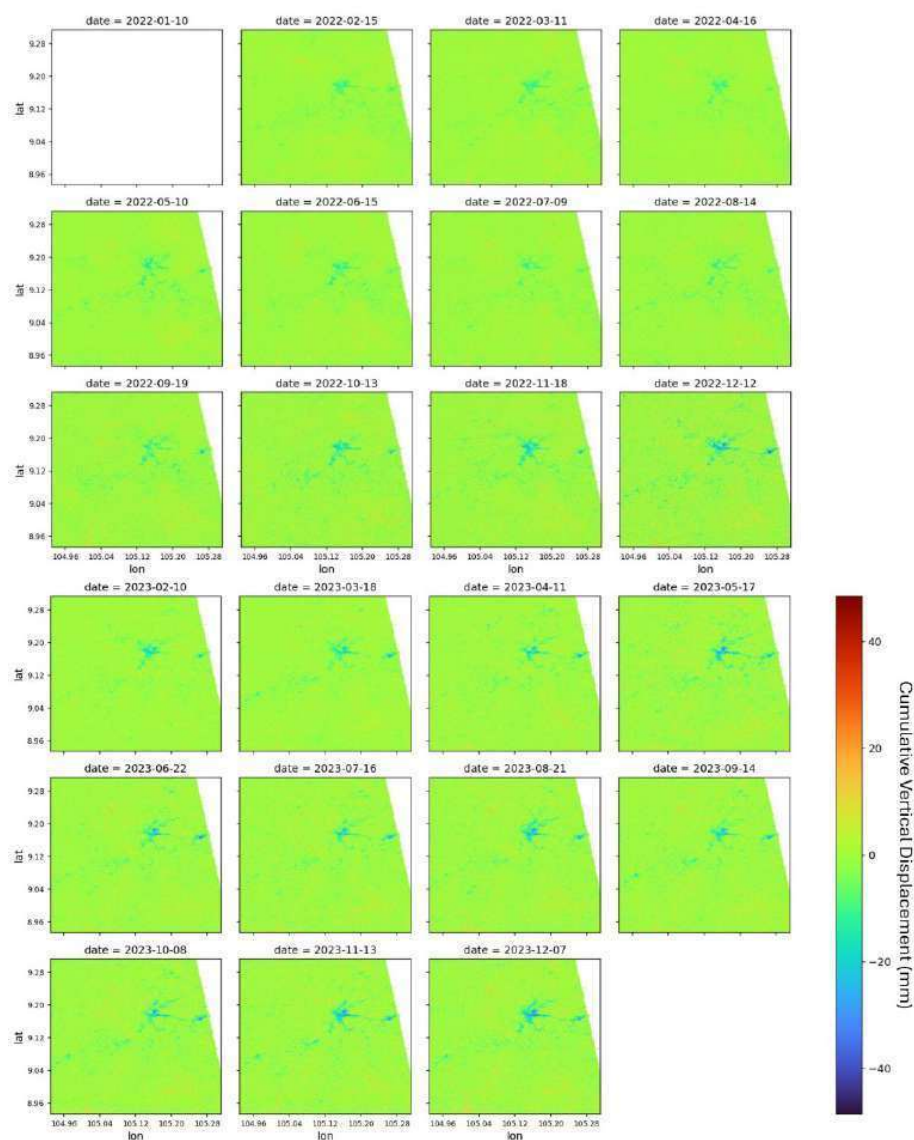


Figure 5. Deformation analysis sequence using SBAS on Google Colab.

Figure 6 shows the cumulative subsidence from January 2022 to December 2023, as synthesized and analyzed using the SBAS method. The blue areas indicate the most significant subsidence within Ca Mau City. The results from the map reveal that the main subsidence occurrences are concentrated in Wards 2 and 5, as well as in the adjacent areas of these wards with Wards 1, 4, 6, 7, 8, and 9. The maximum subsidence recorded over the entire area using SBAS is -48 mm, while the average subsidence across the study area is -20 mm.

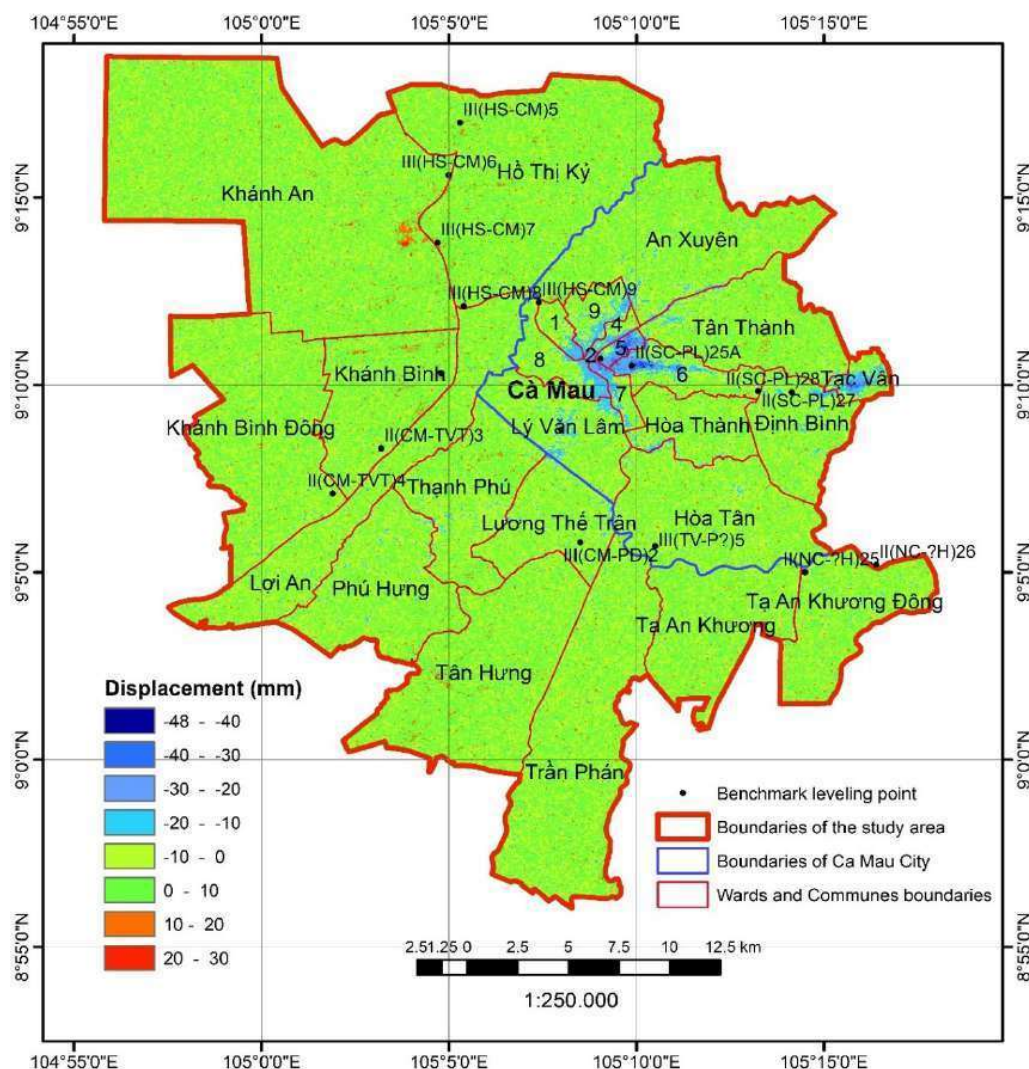


Figure 6. Map of Cumulative Vertical Displacement from January 2022 to December 2023.

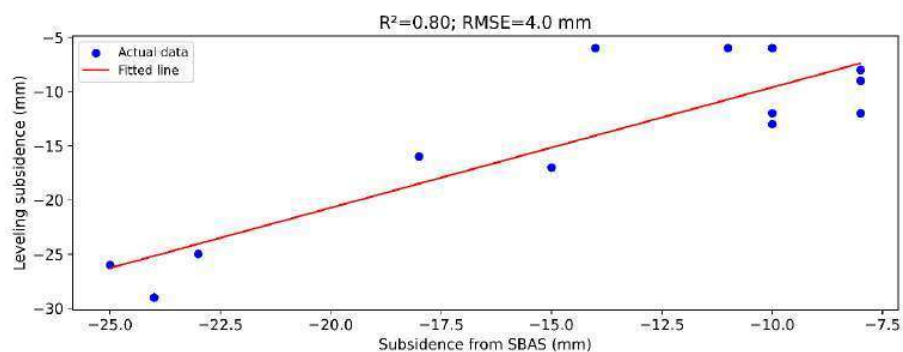
3.2 Accuracy assessment

To assess the reliability of the subsidence results determined using the SBAS method implemented on Google Colab, we compared these results with subsidence measurements at 13 benchmark points, which were determined using precise leveling methods by the Department of Survey, Mapping and Geographic Information Vietnam (Tran, 2024) (Figure 6). The comparison results are presented in Table 2, where subsidence values obtained using the SBAS method were extracted from Figure 6 at the 13 subsidence benchmarks and compared with precise leveling measurements.

Table 2. Comparison of subsidence between SBAS and levelling survey.

STT	Point name	Vertical Displacement from SBAS (mm)	Leveling-Measured Subsidence (mm)	Difference (mm)
1	II(CM-TVT)3	-6	-10	-4
2	II(CM-TVT)2	-6	-11	-5
3	II(NC-H)25	-16	-18	-2
4	II(NC-H)26	-8	-8	0
5	II(SC-PL)24	-26	-25	-1
6	II(SC-PL)25A	-25	-23	-2
7	II(SC-PL)27	-29	-24	-5
8	II(SC-PL)28	-17	-15	-2
9	III(HS-CM)5	-9	-8	-1
10	III(HS-CM)6	-12	-8	-4
11	III(HS-CM)8	-13	-10	-3
12	III(HS-CM)9	-6	-14	-8
13	III(TV-PU)5	-12	-10	-2

Using a linear regression model to assess the correlation between subsidence results obtained by SBAS and levelling survey, the study yielded $R^2 = 0.80$ and $RMSE = 4$ mm (Figure 7).

**Figure 7. Assessment of correlation between subsidence data from SBAS and levelling survey.**

4. CONCLUSION

The study employed the Small Baseline Subset (SBAS) method on the Google Colab

platform, utilizing 24 SAR images. The subsidence monitoring results for Ca Mau City and its surrounding communes reveal that subsidence is predominantly concentrated in the central areas of Ca Mau City, particularly in Wards 2 and 5, as well as adjacent areas including Wards 1, 4, 6, 7, 8, and 9. The average subsidence for the entire study area from January 2022 to December 2023 was found to be -20 mm. Compared to in-situ leveling measurements, the subsidence results obtained using the SBAS method on Google Colab demonstrated a high level of accuracy, with an R^2 of 0.80 and a Root Mean Square Error (RMSE) of 4 mm.

Additionally, the processing of the multi-temporal radar image series using the SBAS method on Google Colab was completed within 30 minutes, utilizing 75 GB of cloud memory provided by Google's servers. This demonstrates that Google Colab can effectively handle multi-temporal radar image processing, offering several advantages such as being free, easily accessible, and providing robust computational resources that significantly accelerate processing times. Moreover, integration with Google Drive facilitates efficient data management, and the online collaboration feature enables seamless sharing and teamwork. However, Google Colab has some limitations, including constraints on resources and runtime, as well as variable performance during peak usage periods when many users are active.

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