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WELCOME SPEECH FROM THE CHAIRMAN

RISM 17th International Surveying Conference for Undergraduates (ISCU 2025)

بسم الله الرحمن الرحيم السلام

عليكم ورحمة الله وبركاته

Greetings to all,

It is with great pleasure that I welcome you to the 17th RISM International Surveying Conference for Undergraduates (ISCU 2025), themed *"Embracing Construction Revolution 4.0: Transforming Malaysia's Built Environment."* On behalf of the Royal Institution of Surveyors Malaysia (RISM), I also wish to express our sincere appreciation to Universiti Teknologi MARA (UiTM), Perak Campus, for graciously hosting this significant event.

As we navigate the era of the Fourth Industrial Revolution (IR4.0)—or in our context, Construction Revolution 4.0 (CR4.0)—we are witnessing transformative advancements across the global construction sector. Technologies such as Building Information Modelling (BIM), the Internet of Things (IoT), artificial intelligence (AI), robotics, big data analytics, and cloud computing are redefining the way we build, manage, and interact with our built environment. For Malaysia, embracing CR4.0 is a strategic imperative to achieve our socio-economic and environmental goals.

This conference serves as a vital platform to unite surveying undergraduates from various disciplines, fostering critical dialogue on industry challenges, enhancing professional networking, and preparing a new generation of talent for the rapidly evolving construction landscape. It is also an opportunity for employers to engage with and inspire our future professionals.

I would like to extend my heartfelt thanks to all industry speakers, paper presenters, judges, and participants for their time, contributions, and support in making ISCU 2025 a success. I also commend the organising committee for curating a meaningful and dynamic conference experience.

May the knowledge gained, connections formed, and ideas exchanged during this event inspire all participants to lead and innovate in their future endeavours.

Wishing everyone a productive and memorable conference.

Prof. Ts Sr Dr. Adi Irfan Bin Che Ani'
Chairman, Universities' Partnering Committee
RISM Session 2024/2025
May 2025

WELCOME SPEECH FROM CO-CHAIRMAN

RISM 17th International Surveying Conference for Undergraduates (ISCU 2025)

Bismillahirrahmanirrahim.

السلام عليكم ورحمة الله وبركاته and greetings to all.

It is my great pleasure to welcome everyone to the 17th International Surveyor Conference for Undergraduates (ISCU 2025), proudly hosted by Universiti Teknologi MARA (UiTM) Perak Branch in collaboration with the Royal Institution of Surveyors Malaysia (RISM). This event is a meaningful platform for students in the built environment to share ideas, showcase innovations, and build professional networks. We are honoured by your presence and enthusiastic participation, with 135 accepted papers and 78 poster presentations this year.

UiTM Perak, home to the College of Built Environment, has long been a hub for academic excellence in architecture, planning, and surveying. Our commitment remains strong in nurturing competent graduates who meet industry demands and contribute to nation-building.

While you're here, we invite you to experience the heritage and culture of Perak Tengah from the architectural richness of Rumah Kutai to the historical towns of Pasir Salak, Bota, and Kampung Gajah.

To all presenters and winners, congratulations on your achievements. Let your work today be a catalyst for future success and academic growth. We hope this conference will inspire you to explore new ideas, foster collaboration, and make lasting memories.

My deepest thanks to the Royal Institution of Surveyors Malaysia (RISM) and the organising committee for making this event a success.

We hope your experience here will be rewarding and unforgettable.

Thank you. Selamat datang dan selamat berjaya.

Associates Professor Dr. Nur Hisham Ibrahim, *PMP*
Co-Chairman, Universities’ Partnering Committee
RISM Session 2024/2025
May 2025

WELCOME SPEECH FROM THE PROJECT DIRECTOR

RISM 17th International Surveying Conference for Undergraduates 2025

Alhamdulillah, all praise to Allah S.W.T. for His guidance and blessings in making the RISM 17th International Surveying Conference for Undergraduates (ISCU) 2025 a reality.

It is with great honour and gratitude that I welcome all participants, guests, academicians, and industry professionals to this prestigious event, proudly organized under the Royal Institution of Surveyors Malaysia (RISM). This 17th edition of ISCU stands as a proud testament to our collective dedication toward academic excellence, professional collaboration, and youth empowerment in the field of surveying.

I extend my heartfelt appreciation to RISM for its unwavering support, to the hardworking ISCU 2025 Organising Committee, and to all 16 partnering universities across Malaysia for their commitment and contributions. Your efforts have shaped this conference into a dynamic platform for knowledge exchange, innovation, and professional growth.

To the academicians and practitioners present, your insights are invaluable in bridging the gap between academic theory and real-world practice. To our undergraduate participants, your passion, curiosity, and commitment are the very foundation of our future. May this conference not only deepen your academic journey but also ignite a spirit of leadership, integrity, and sustainable thinking.

Let this gathering serve as more than an academic milestone. May it foster lifelong networks, inspire transformative ideas, and chart new directions in our shared professional journey.

Wishing everyone a rewarding and inspiring conference experience.

Sr Dr. Nurul Fadzila Zahari
Project Director
RISM 17th ISCU 2025

ENHANCING DAM DEFORMATION MONITORING THROUGH THE INTEGRATION OF INSAR AND GNSS

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ABSTRACT

Dam infrastructures face ongoing environmental and operational pressures from hydrostatic pressure and geological activity. Even small-scale deformations that remain undetected can cause massive structural breakdowns in future which could lead to dam failures and result in economic and environmental disasters. Maintaining the long-term stability of a dam structure demands precise and continuous subsidence and structural deformation monitoring to prevent potential risks. The advanced geospatial methods which are InSAR and GNSS able to serve this purpose. InSAR able to produce large-scale deformation maps with millimetre-level precision, while GNSS delivers highly precise point-based measurements at high temporal resolution. This study proposes a conceptual framework that integrates InSAR and GNSS to enhance dam deformation monitoring by utilizing their combined advantages. The accuracy of structural assessments improves when extensive spatial deformation data from InSAR is combined with point-based measurements from GNSS. This approach using InSAR and GNSS presents a cost-effective and scalable solution for continuous monitoring which essential for detecting structural risks of dam infrastructure. Through theoretical analysis of this integration technique, it demonstrates how geospatial analysis can revolutionize safety dam monitoring. The conceptual framework introduced in this paper creates essential groundwork which supports and help future developer or research to develop scalable systems that manage sustainable infrastructure and continuously track dam deformation subsidence in a cost-effective manner.

Keywords: Dam Deformation Monitoring, GNSS, InSAR

I. INTRODUCTION

Structural stability is crucial for dams because these critical infrastructures provide essential services like water supply and hydroelectric power while also maintaining public safety and economic sustainability. Structural stability faces constant threats through forces such as hydrostatic pressure, geological activity and material degradation which may lead to both slow and rapid structural deformations (Nur et al., 2023). Undetected deformations risk triggering structural failures which produce significant economic damage and environmental harm. Traditional methods for monitoring structures like geodetic surveys and visual inspections deliver useful information yet require considerable labor and time while providing limited spatial and temporal data coverage. Modern geospatial technologies including Interferometric Synthetic Aperture Radar (InSAR) and Global Navigation Satellite System (GNSS) now serve as widely accepted solutions that deliver precise measurement capabilities to detect millimeter-scale displacements thus enhancing dam deformation monitoring accuracy and efficiency (Ansar et al., 2024).

The purpose of this conceptual paper is to establish a theoretical basis for combining InSAR with GNSS technologies to monitor dam deformations. This hybrid approach combines the strengths of InSAR and GNSS to enhance dam safety and sustainability while addressing possible challenges and measuring its future impact. Integrating these technologies will enable dam monitoring systems to operate more efficiently while saving costs and proactively reducing structural risks.

II. ROLE OF INSAR IN MONITORING

InSAR represents a remote sensing approach that is commonly used to track dam subsidence and deformation. The main advantages of InSAR are its wide spatial coverage that enables large-scale deformation mapping and millimeter-level precision that makes it possible to detect minimal structural movements (Wang et al., 2020). InSAR offers a cost-effective and non-intrusive monitoring solution because it uses satellite data instead of requiring numerous ground-based instruments. This technology can track past deformation patterns by analyzing data from previous satellite images. However, InSAR has several limitations, including atmospheric disturbances that introduce errors, as well as temporal decorrelation caused by vegetation changes, human activities, long temporal baselines, and soil moisture variations. Moreover, InSAR can only measure relative deformation since its reference point is within the monitored area and is assumed to remain stable.

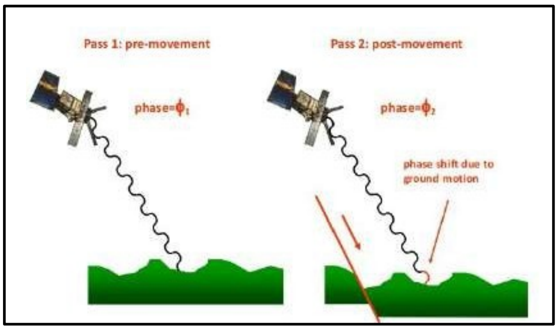

Figure 1.0 How InSAR Works [3]

Figure 1.0 shows how satellite sends and receives a single radar wave to the same point on the ground before and after (COMET, 2017). So, the radar phase differences detected by InSAR make it essential for monitoring subsidence and deformation because it reveals small ground movements over time. It is because InSAR produces interferograms which show deformation patterns that help to detect settlement, tilting, or movement which can point to structural weaknesses. The changes can be caused by hydrostatic pressure along with geological shifts and material degradation. Moreover, the InSAR technique serves as an important tool to observe movement in reservoir banks and nearby slopes which might undergo changes because of variations in water levels or seismic events (Li et al., 2023). InSAR delivers precise deformation information regularly which enhances early warning systems enabling engineers to implement preventive steps to avoid serious structural failures (Ma et al., 2024).

III. ROLE OF GNSS IN MONITORING

GNSS provides real-time monitoring of dam deformation by precisely tracking structural movements. The GNSS system excels in providing precise displacement measurements at designated points and enables continuous monitoring of structural changes with high temporal resolution. The ability of GNSS to function under any weather condition establishes its reliability for extended monitoring periods. However, GNSS technology is limited from irregular spatial data coverage since it relies on fixed monitoring stations and requires expensive ground-based receivers for operation and maintenance. Besides, GNSS is not suitable for dam monitoring in hazardous areas due to safety risks and accessibility challenges.

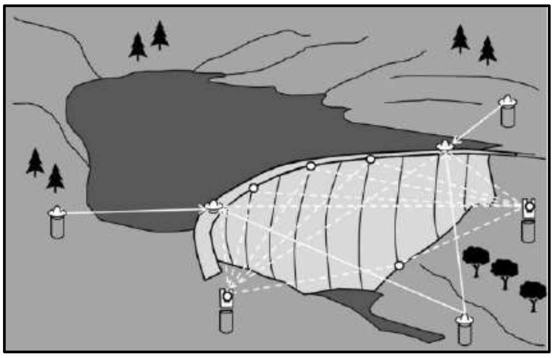

Figure 2.0 GNSS Observation for Monitoring Dam Deformation [7]

Figure 2.0 shows the monitoring network consists of reference points on pillars around the dam and object points on the dam for monitoring deformation. Because of that, GNSS serves as an essential method for monitoring subsidence and deformation through its capability to detect small positional changes across three dimensions including vertical, horizontal and height (Teunissen et al., 2020). The continuous measurement of displacement through GNSS enables identification of both slow and quick movements resulting from hydrostatic pressure changes, geological shifts, or material degradation. Monitoring critical dam points like the crest, abutments, and foundation helps identify structural changes that could reveal potential risks (Caldera et al., 2022). The real-time monitoring functions of GNSS improve early warning systems which allow engineers to promptly react to structural changes for preventing potential problems (Farolfi et al., 2018).

IV. METHODOLOGY

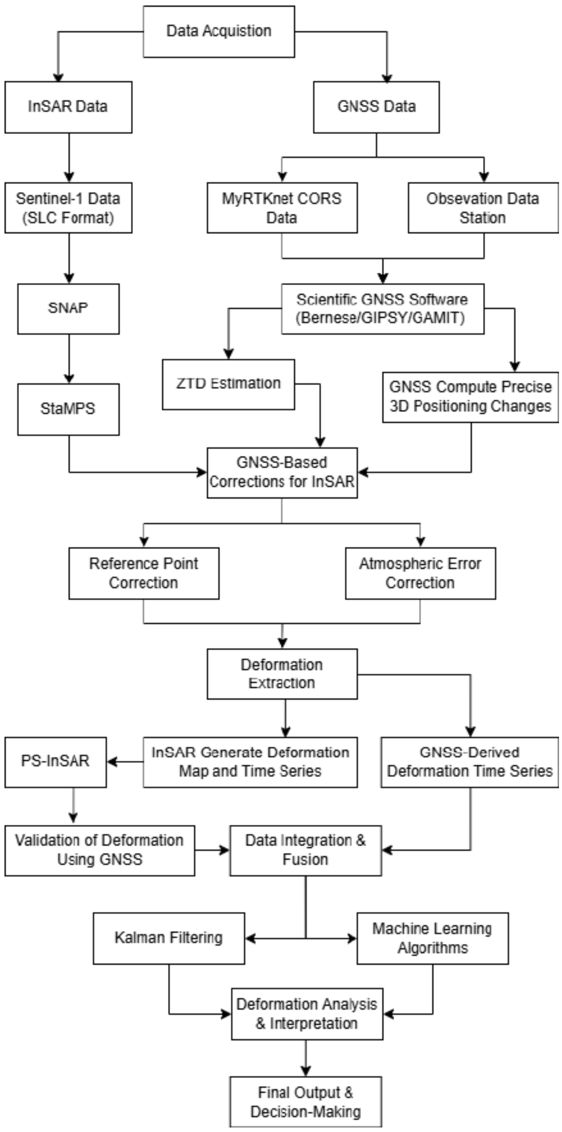

Figure 3.0 Framework for Integration of InSAR and GNSS

Figure 3.0 illustrates the framework for integrating InSAR and GNSS. The data acquisition phase starts with InSAR gathering satellite imagery to measure large-scale surface deformation followed by GNSS which delivers displacement measurements at specific points. InSAR provides extensive spatial coverage yet encounters limitations due to satellite revisit intervals while GNSS achieves high temporal precision but does not provide complete spatial coverage (Wang et al., 2023). The InSAR processing stages include co-registration, interferogram generation, selection of Persistent Scatterer (PS) points, and phase unwrapping for accurate deformation analysis. Meanwhile, GNSS data undergoes orbital, clock, and atmospheric corrections before resolving phase ambiguities to enhance accuracy and ensure consistency before integration. The accuracy of InSAR data is greatly improved through two key corrections provided by GNSS. Reference point correction transforms InSAR relative measurements into absolute deformation by utilizing GNSS control points. Atmospheric error correction uses GNSS-derived Zenith Total Delay (ZTD) data to reduce tropospheric distortions in InSAR measurements. Figure 4.0 displays the visualized map output for interpolated MyRTKnet-ZTD (Mohd Sidek, 2022). Additionally, validating InSAR data involves comparing high-temporal-resolution of GNSS displacement measurements with InSAR-derived deformation to ensure accuracy and reliability.

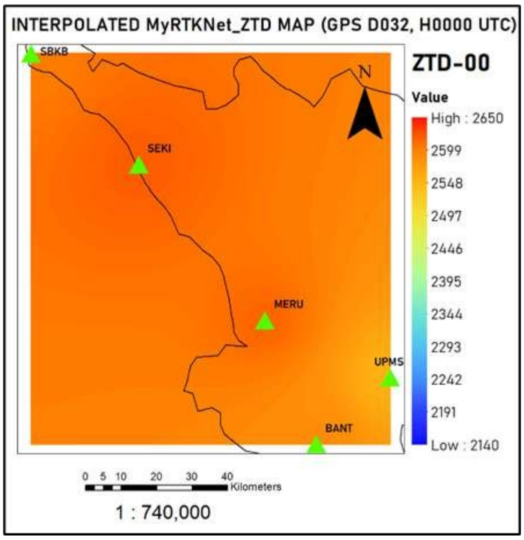

Figure 4.0 Interpolated MyRTKnet-ZTD [11]

After applying corrections, InSAR generates deformation maps and displacement time series in the slant-range direction, while GNSS provides precise 3D positional changes for comprehensive deformation analysis. The integration of large-scale deformation monitoring from InSAR with precise point-based measurements from GNSS leads to a comprehensive understanding of dam surface movements. Furthermore, InSAR relies on strong reflectors, such as PS points, which may be absent in certain dam areas. Therefore, GNSS can complement InSAR by providing reliable measures in vegetated regions or areas affected by decorrelation due to human activities.

InSAR data and GNSS measurements are aligned by converting InSAR slant-range displacement into the vertical component, allowing for direct comparison with GNSS measurements. Figure 5.0 and figure 6.0 show monitoring results in different areas of the dam body from another researcher (Pang, et al., 2023).

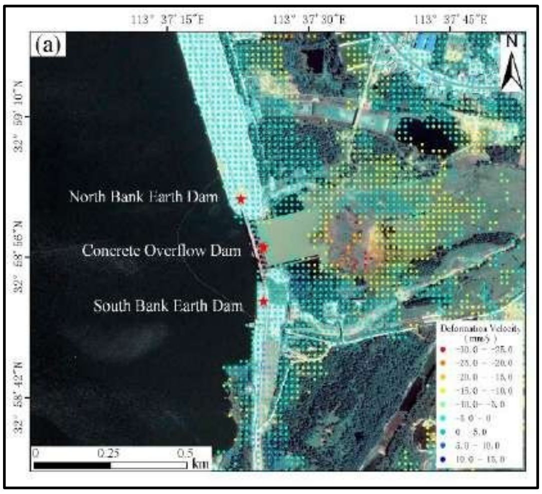

Figure 5.0 Example of Deformation Velocity of The Dam Body from Past Researcher (Pang, et al., 2023).

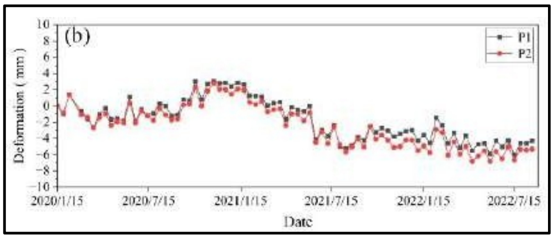

Figure 6.0 Example of The Time-Series Displacement of The Dam Body from Past Researcher (Pang, et al., 2023)

Through the use of data fusion techniques including Kalman filtering and machine learning algorithms deformation monitoring accuracy improves by merging InSAR comprehensive spatial deformation data with GNSS exact point-based measurements (Pang, et al., 2023). The Kalman filtering method which functions as a repetitive estimation approach successfully diminishes noise while improving measurement precision and handling uncertainties present in multiple data sets.

Meanwhile, Machine learning algorithms such as neural networks, support vector machines (SVMs) and deep learning models improve data integration capabilities by detecting complex deformation patterns and eliminating systematic errors (Li, et al., 2024). Through the use of GNSS data for training purposes these models improve InSAR displacement readings and time-series forecasts while enabling real-time error adjustments (Tasan, et al., 2024). Because of that this method helps to combine InSAR and GNSS to achieve higher accuracy, reduce data uncertainty and improve dam stability monitoring which supports early warning systems and risk management.

During the final steps deformation analysis and interpretation take place which includes the identification of deformation trends and their cross-validation to evaluate structural risks. Data accuracy is refined through comparisons with independent ground truth measurements during result validation and accuracy assessment. The generation of risk assessment maps and reports along with early warning indicators completes the process to enable proactive management of dam safety. Figure 7.0 and Figure 8.0 show a validation of InSAR-derived result with ground GNSS measurement from another researcher (Zhou, et al., 2024).

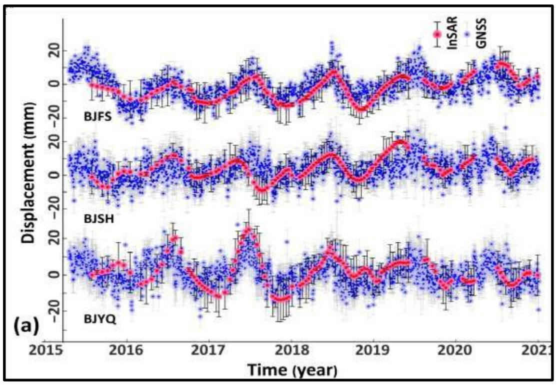

Figure 7.0 Example of Validation of InSAR-derived Result with Ground GNSS Measurement from Past Researcher (Zhou, et al., 2024).

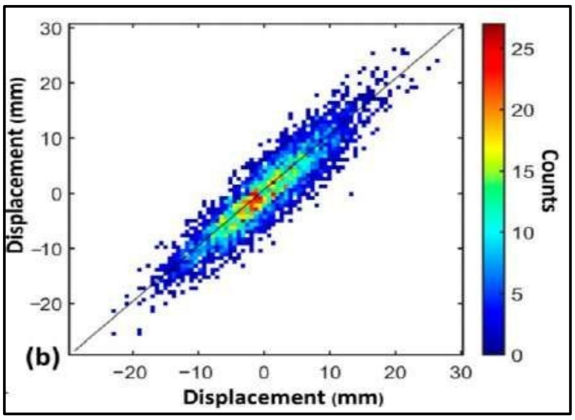

Figure 8.0 Example of Cumulative Displacement Comparisons of Insar and GNSS

(Zhou, et al., 2024).

The hybrid combination between these technologies able to strengthen early warning capabilities and improve structural risk analysis which allows engineers to detect minor deformations before it becomes major problems. Moreover, combining InSAR and GNSS technologies together enhances measurement precision while transforming dam monitoring into a more affordable scalable and uninterrupted process which guarantees proactive risk management and sustainable infrastructure for the future (Roque, et al. 2021). The utilization of historical satellite data combined with GNSS positioning establishes a reliable monitoring system for detecting both slow subsidence and sudden structural changes that improves dam safety and reliability.

V. POTENTIAL ADVANTAGES OF THE INTEGRATION

Dam deformation monitoring becomes more accurate through the combination of InSAR and GNSS which allows the systems to utilize their respective advantages while mitigating their individual weaknesses. It is because InSAR delivers precise millimeter-scale deformation observations across extensive regions which makes it effective for identifying slow ground movement patterns (Bekaert, et al., 2020). However, InSAR monitoring faces several difficulties including atmospheric disturbances, temporal decorrelation issues, and limited accuracy in measure vertical displacements. On the other hand, GNSS provides precise real-time and three-dimensional displacement information, its reliance on ground stations results in restricted spatial coverage and increase expenses. Furthermore, InSAR needs 12-day intervals between data collections meanwhile GNSS provides ongoing displacement data with better temporal resolution.

The combination of InSAR extensive spatial monitoring capabilities with GNSS precise point measurement accuracy results in a monitoring system that delivers enhanced reliability and accuracy. The pixel-based InSAR generates dense deformation maps across space while GNSS point-based measurements improve these results. The combined system leverages both spatial and temporal resolution to deliver widespread coverage while providing regular updates on structural variations. In hazardous environments where GNSS station installation proves challenging, InSAR stands out as an essential technology for monitoring inaccessible and dangerous sites (Carla, et al., 2019).

Combining InSAR with GNSS enhances dam deformation monitoring through the simultaneous utilization of spatial coverage, precision measurements, and real-time tracking capabilities (Wang, et al., 2022). Table 1.0 shows how each aspect of advantages integration of both technologies to enhance monitoring capabilities.

Table 1.0 Advantages Integration of InSAR and GNSS

Advantages	Integration of InSAR and GNSS
High Accuracy	More accurate, reliable and trustworthy data output for deformation monitoring.
Wide Spatial Coverage	Able to ensure both large-scale monitoring and localized precision able to be archived.
Long-Term Monitoring	Able to improve trend analysis and early warning system.
Cost Equipment Used	Offering cost-saving monitoring solution by combining InSAR low-cost wide area monitoring with GNSS observation at critical locations only.
Early Warning and Risk Mitigation	The integration enhances early warning systems which enable prompt maintenance and reinforcement measures.
Better Decision-Making	Able to receive better structural risk assessments from the combined dataset which aids in making data-driven decisions.

The combination of InSAR and GNSS technologies leads to enhanced precision and efficiency in dam deformation monitoring which enables proactive management and early detection of risks to ensure dam safety. The hybrid approach improves structural monitoring practices while supporting sustainable infrastructure maintenance which lowers the chances of catastrophic failures.

VI. POTENTIAL CHALLENGES FROM THE INTEGRATION

Combining InSAR and GNSS improves dam deformation monitoring capabilities though it introduces multiple technical and operational difficulties. Although InSAR excels at large-scale monitoring efforts it suffers from atmospheric interference and geometric errors which reduce vertical measurement precision. Additionally, the effectiveness of InSAR-derived deformation data reduces when faced with coherence loss through vegetation interference, water surface changes or rapid surface variations.

On the other hand, GNSS delivers real-time high precision 3D positional data while its application remains restricted to particular observation locations which limits its capability to detect large-scale deformation patterns (Ruya et al., 2019). Operational expenses increase for GNSS stations due to the need for constant power supply and stable communication links combined with regular calibration especially in hard-to-reach dam locations (Maltese, et al., 2021).

The integration of these technologies demands sophisticated data fusion methods, precise alignment between coordinate systems and error correction for both sets of data. Proper mitigation strategies enable the benefits of integration to be maximized while reducing risks from data inconsistencies and processing complications. Table 2.0 explains challenges and impact integration for both technologies.

Table 2.0 The Table of Challenge Faced

Challenge	Impact Integration of InSAR and GNSS
Data Acquisition and Availability	The integration of both methods enhances temporal resolution yet depends on the availability of data and inconsistent datasets can reduce monitoring accuracy.
Atmospheric and Environmental Effects	GNSS used for correcting atmospheric distortions in InSAR demands extra computational models which results in greater processing complexity.
Geometric Limitations and Accuracy Issues	The combination improves accuracy but spatial inconsistencies between broad area coverage by InSAR and GNSS point data demand advanced fusion algorithms for effective dataset alignment.
Data Processing and Computational Complexity	The complexity of data fusion demands specialized software and expert knowledge to merge and interpret datasets.

CONCLUSION

Combining InSAR and GNSS improves dam deformation monitoring through wide-area detection capabilities and precise continuous measurements. This method enhances early warning systems while also improving structural assessments and risk mitigation measures. The advancement of data fusion methods along with AI- driven analysis will enable future research to boost monitoring precision and operational performance.

FUTURE DIRECTIONS

Research moving forward in InSAR-GNSS integration for monitoring dam deformations must prioritize better data fusion methods that will lead to more precise and dependable measurements. Real-time monitoring systems require cloud-based processing improvements along with automated data integration to support continuous deformation tracking through advanced development. The integration of InSAR and GNSS with geodetic sensors including LIDAR and ground-based accelerometers enables a more thorough evaluation of structural stability [22]. The accuracy of measurements can be improved by developing better correction models and optimizing satellite imaging angles to overcome atmospheric and geometric restrictions in difficult terrains. The development of low-cost GNSS receivers alongside open-source InSAR processing methods can create scalable solutions to extend global access to these monitoring technologies. The integration of geospatial monitoring outcomes into decision-making systems enables dam authorities to carry out proactive maintenance that minimizes structural hazards while boosting infrastructure durability.

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