Present-day land subsidence based on time-series InSAR for mapping potential building damage in Jakarta

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Abstract: According to [Abidin et al., 2015] findings, approximately 40 percent of Jakarta may be situated below sea level by 2050, encompassing a significant portion of the city's business districts. The necessity of considering these topographical changes points out that existing flood mitigation policies and urban plans lack provisions for addressing land subsidence. Several factors that can cause land subsidence over the Jakarta; natural compaction, groundwater extraction, heavy load from big buildings and houses, and sea level rise. Utilizing the persistent scatterer interferometry (PSI) technique and C-band SAR data from 2016 to 2024, time series analysis indicates maximum subsidence rate of 10–20 mm/year in the northern and western part of Jakarta. Available data from GNSS stations ensures the reliability of these findings.

Introduction

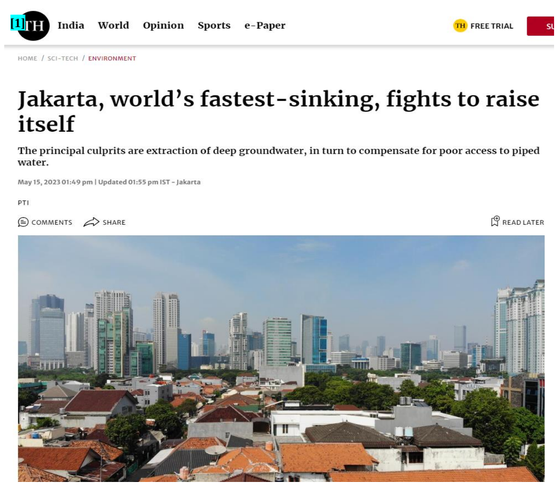


Figure 1. Land subsidence in Jakarta as reported in the media

Land subsidence is a significant issue in coastal cities and deltas globally, resulting from natural and or human activities, as observed in Jakarta, Indonesia. Several factors that can cause land subsidence over the Jakarta; natural compaction, groundwater extraction, heavy load from big buildings and houses, and sea level rise. Population density and massive infrastructure development in Jakarta can exacerbate land subsidence if no countermeasures are taken, leading to a negative impact on infrastructures (Cao., et al, 2021).

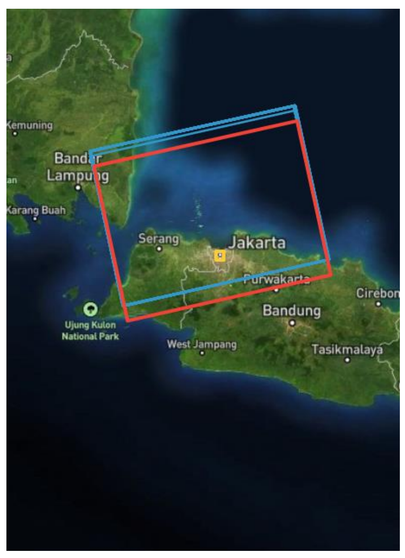
The objectives of this study are as follows: to determine the present-day land subsidence in Jakarta by using the PSI method, which overcomes limitations such as gap acquisition for time series processing and obtains potential non-linear deformation due to seasonal effect. This study aims to provide unequivocal evidence of the ongoing land subsidence in Jakarta and its impact on infrastructure.

Figure 2. Recent conditions in Jakarta due to land subsidence phenomena

地盤沈下は、インドネシアのジャカルタで観測されたように、自然活動や人為的活動によって生じるものであり、世界的に沿岸都市や三角州における重要な問題である。ジャカルタの地盤沈下を引き起こす可能性のある要因には、自然圧密、地下水の汲み上げ、大規模な建物や家屋による大きな荷重、海面上昇などがある。ジャカルタの人口密度と大規模なインフラ開発は、対策を講じなければ地盤沈下を悪化させ、建築構造物に悪影響を及ぼす可能性がある（Cao et al., 2021）。

本研究の目的は、時系列処理におけるギャップ取得などの制限を克服し、季節効果による潜在的な非線形変形を得るためのPSI法を用いて、ジャカルタにおける現在の地盤沈下を決定することである。また、本研究はジャカルタで進行中の地盤沈下とそのインフラへの影響について、明確な証拠を提供することを目指している。

Methodology



- Our study area is in Jakarta
- We used Sentinel-1 C-band in ascending direction
- Data observations spanning from 2016 to 2024
- Persistent Scatterer Interferometry (PSI) was applied to measure vertical displacement by employed SARPROZ software
- PSI identifies and analyzes stable radar targets, known as persistent scatterers, which consistently reflect radar signals back to the satellite

- 調査地域はジャカルタです。
- センチネル-1 Cバンドの上昇方向を使用しました。
- 観測期間は2016年から2024年です。
- パーシステント・スキャタラー干渉法（PSI）を用いて、SARPROZソフトウェアで鉛直変位を測定した。
- PSIは、一貫してレーダー信号を衛星に反射し続ける、永続的散乱体として知られる安定したレーダーターゲットを特定し、分析します。

Results and Discussion

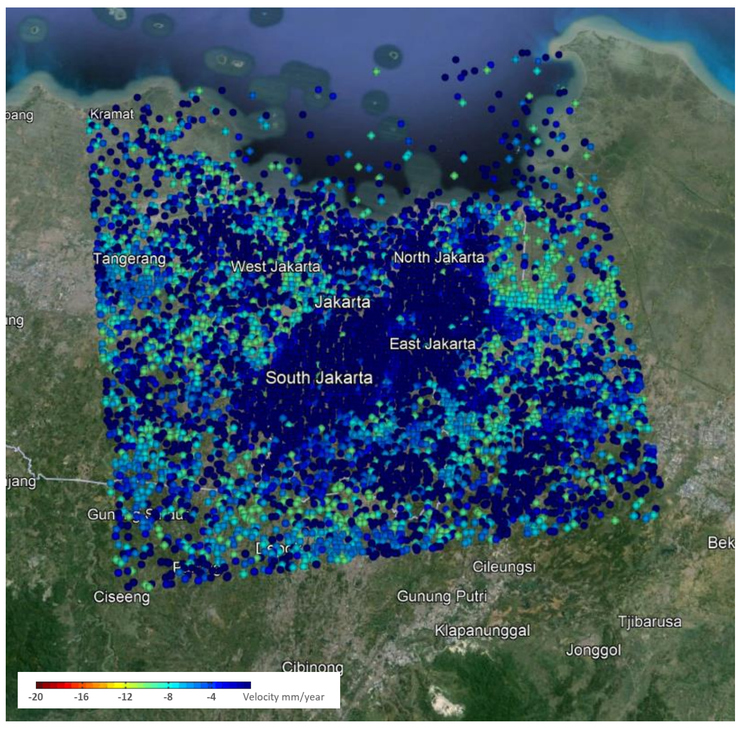


Figure 3. Displacement velocity rate over Jakarta in ascending

At this initial stage of the study, the attractive subsidence rate denoted light blue on the velocity bar where occurred along the line of sight (LOS). The results of time-series processing in Jakarta indicate maximum subsidence rates of around 10-20 mm per year. The most severe land subsidence is located in northern Jakarta, followed by western Jakarta. The spatial subsidence tends to expand to the East Jakarta and southwest of Jakarta as shown in Fig. 3.

Furthermore, Fig. 4 demonstrates that selected point InSAR velocities revealed a consistent subsidence pattern with continuous GNSS monitoring around 8 mm/year. The phenomenon of land subsidence will affect the reliability of urban infrastructure (Cigna, F., & Tapete, D. 2021; Amedeo, C et al., 2023)

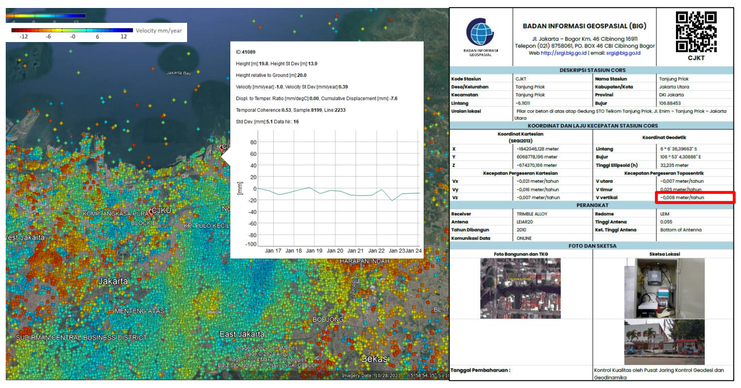


Figure 4. Comparison results between InSAR and GNSS site at North Jakarta (CJKT)

研究の初期段階では、視線（LOS）に沿って発生した沈下率は、速度バー上で水色で示されています。ジャカルタでの時系列処理の結果、最大沈下率は年間約10〜20 mmであることが示されています。最も深刻な地盤沈下はジャカルタ北部で発生し、その次にジャカルタ西部が続いています。図3に示すように、空間的な沈下は東ジャカルタおよびジャカルタ南西部に拡大する傾向があります。さらに、図4は、選択した地点のInSAR速度が、継続的なGNSSモニタリングにより、年間8mm前後の一貫した地盤沈下パターンを示していることを示している。 地盤沈下現象は都市インフラの信頼性に影響を与える（Cigna, F., & Tapete, D. 2021; Amedeo, C et al.）

Future Work

- We will process the descending orbit in a time-series analysis
- Calculate the vertical and horizontal components of the displacement using the combined data from both orbits
- After the urban-scale evaluation, conduct a deeper analysis of displacement relative to the specific building object. We must be careful in selecting the area, taking into account the high coherence value

- 下降軌道を時系列分析で処理する。
- 両軌道のデータを組み合わせて、変位の鉛直成分と水平成分を計算する。
- 都市スケールの評価後、特定の建物オブジェクトに対する変位をより深く分析する。コヒーレンス値が高いことを考慮し、エリアの選定には注意が必要である。

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