# Nationwide urban ground deformation monitoring in Japan using Sentinel-1 LiCSAR products and LiCSBAS

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Ground subsidence in urban areas has an impact on human society and activity. Precise and continual monitoring of ground subsidence is important for early detection, taking a countermeasure, and control. Whilst leveling and GNSS surveys have been used for the monitoring, the density of the measurement points or the observation frequency are insufficient in most cases. InSAR can realize dense observation and now achieve the accuracy of mm/yr owing to recent development of time series analysis. Moreover, Sentinel-1 launched in 2014 by ESA and its frequent, constant, and global observations have greatly improved the situation.

LiCSAR and LiCSBAS have further facilitated exploitation of the abundant Seintinel-1 data. LiCSAR is an automated Sentinel-1 InSAR processing system and has published the products (e.g., unwrapped interferograms and coherence estimates) at a global scale. As of June 2020, ~280,000 interferograms are published mainly covering the Alpine Himalayan Belt and global volcanoes. LiCSBAS is an open-source InSAR time series analysis package integrated with LiCSAR. It allows easy and efficient execution of the time series analysis even for a non-expert user, and has demonstrated that displacement velocities and time series with an accuracy of ~2 mm/yr and <1 cm/epoch, respectively, can be derived.

In this study, I carried out the InSAR time series analysis in 73 all major urban areas in Japan using the LiCSAR products (~12,000 interferograms) and LiCSBAS, and detected deformation from 2014 to 2020. Owing to the efficient and automated algorisms in LiCSBAS, the processing successfully finished with almost no manual adjustment and took only about a day. Many deformations with various temporal and spatial features, such as linear subsidence in Hirosaki, Kujyukuri, Niigata, and Kanazawa, episodic subsidence in Sanjo, annual vertical fluctuation in Hirosaki, Yamagata, Yonezawa, Ojiya, and Nogi, unknown nonlinear uplift in Nara and Osaka, postseismic deformation in Kumamoto, have been precisely detected.

This approach using LiCSAR and LiCSBAS can be used for repeated monitoring since LiCSAR will continually update its products. As all data and tools used in this study are freely available, this approach is easily applicable to any urban areas in the world wherever sufficient LiCSAR products are available.