SUBSIDENCE MONITORING IN THE COASTAL REGION OF NIGERIA USING MULTI TEMPORAL INTERFEROMETRIC SYNTHETIC APERTURE RADAR (MT -INSAR)

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ABSTRACT

The uncontrolled exploitation of the groundwater, oil and gas in the Nigerian coastal geosyncline has led to progressive decline of the aquifer level and a continuous need for opening deeper drillings to exploit deeper aquifers.

From the analysis of the interferometric results derived from the application of Multi-Temporal Interferometry (MT-InSAR) technique, Lagos state appears to be subsiding conically up to -7 mm/yr. The velocity rates of subsidence in the surrounding cities like Lekki, Badagry, Ikorodu and Epe are much higher than in Lagos city. These preliminary investigation results reveal heavy structures, in particular buildings, that were seen constructed mostly on the sand filled areas where the sediments compaction rates is very high.

1. INTRODUCTION

Land subsidence is described as the gradual differential settling or sudden sinking of the ground surface due to the movement of ground materials [1] and is generally caused by human and natural activities such as alterations to the earth's surface and underground geologic processes. Some of the specific causes includes: underground mining of solid minerals and the collapse of such mines roofs; withdrawal of groundwater, oil and gas exploration; dewatering or drainage of organic soils; sinkholes, wetting of dry low density soil; and natural sediment compaction.

It has been reported by [2] that there were more than 150 major cities in the world, mostly coastal cities, where subsidence is a serious issue (e.g., Bangkok, Houston, Mexico City, Osaka, San Jose, Shanghai, Tokyo and Venice).

Nigerian coastal region is part of an activity subsiding geosyncline; a sequence of dead coralline banks in shallow waters off the Nigerian coast indicates stages in subsidence and rise in sea level during the past four thousand years [3]. In [4] it has been reported that all the subsidence (approximately 80 meters in about 15,000 years in the Northwestern flank of the Niger Delta) can be accounted for by eustatic sea level rise and isostatic adjustment to water load.

The Nigerian coastal geosyncline is subsiding not only because it was formed in a tectonic setting but because of the continuing dewatering and compaction of its sediments which were deposited rapidly. Subsidence in this area or region is presently been accelerated by the indiscriminate withdrawal of fluids, including oil and gas particularly in Warri and Port Harcourt from underground aquifers and reservoir strata. Subsidence associated with fluid withdrawal results from the reduction of fluid pressure in the reservoir or aquifer thus leading directly to an increase in effective stress in the system [5].

Available records also show some structural failures, particularly along the coastal region of Nigeria which are suspected to be caused by the sedimentary nature, excessive withdrawal of the underground water, oil and gas exploration in the coastal areas [6]. Moreover, the

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coastal cities of Nigeria are also highly populated and highly industrialized which is progressively increasing the need for water. Since surface water could not meet such needs, thousands of uncontrolled boreholes were drilled and wells were bored for water pumping in the last 40 years. In the time span between 1990 and 2006 more than 150,000 boreholes and about 376,000 hand dug wells are known to have been bored and dug. This uncontrolled exploitation of the groundwater has led to progressive decline of the aquifer level and a continuous need for opening deeper drillings to exploit deeper aquifers. Similarly, between 1991 and 2006, the mean aquifer head level dropped to between 20 and 70 meters with a maximum of 120 meters in some areas. Erection of heavy structures on sand filled areas exacerbated by the geology of the environment are also among the causes of subsidence in Port Harcourt city, as well as in Lagos (Fig. 1), the study areas, that experience subsidence due to the compaction of recent alluvium sediments.

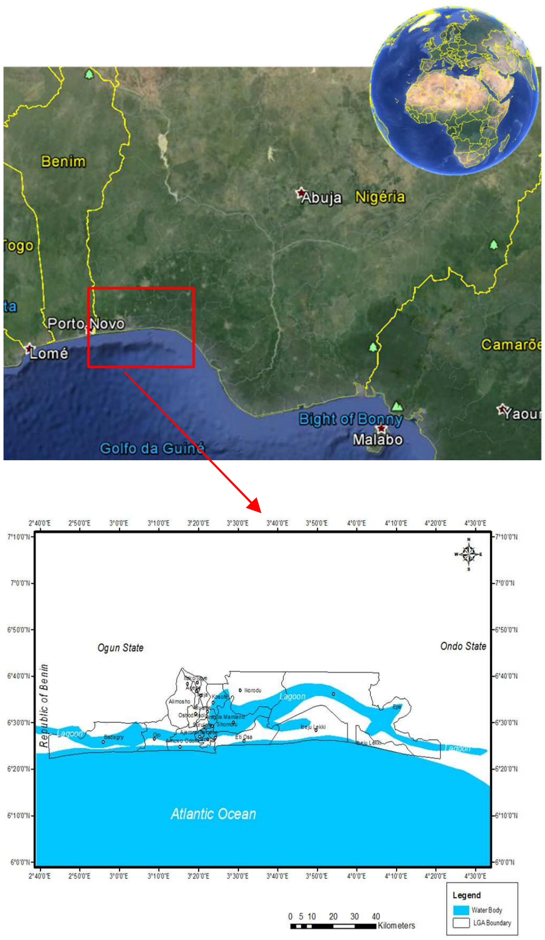

Figure 1. Location map of Lagos state.

2. DATA AND METHOD

The study area (Fig. 1) is covered by two Envisat ASAR tracks, the descending track 122, from 07/01/2004 to 22/09/2010 and the descending track 351, from 19/12/2003 to 03/09/2010. Fig. 2 shows the location of these tracks over the study area. For this preliminary processing 24 and 28 SLC scenes were selected for tracks 122 and 351, respectively.

Figure 2. Satellite tracks 122 and 351 over Lagos state.

In this study, Stanford Method for Persistent Scatterers/Multi-Temporal InSAR (StaMPS) [7, 8], that combines both persistent scatterer (PS) and small baselines (SB) methods, allowing the identification of scatterers that dominate the scattering from the resolution cell (PS) and slowly-decorrelating filtered phase (SDFP) pixels, was applied.

In addition to the PS analysis that consists on the detection of temporally coherent of natural reflectors in SAR images, detected due to their correlated phase behavior over time, the SB analysis aims to detect pixels whose phase decorrelates little over short time intervals. The SB method searches to make phase unwrapping easier by selecting small baselines interferograms and filtering the phases. StaMPS combines both sets of results to improve phase unwrapping and the spatial sampling of the signal of interest.

Both configurations graphs for the datasets used in this study, PS and SB, are presented in Fig. 3.

3. RESULTS

The MT-InSAR results show that Lagos state is subsiding conically at the velocity rates of between -4.0 to -7.0 mm/yr (Fig. 4 and 5). The subsidence rate increases centered in Ikeja city to all directions.

The most highly industrialized populated areas like Lekki, Badagry, Victoria Island and Lagos south are subsiding at higher rates mostly due to the ocean tide loading and compacting sediments. Moreover this subsidence phenome is connected to the excessive water withdraw and compacting sediments due to heavy structures built and filled areas towards the coast and lagoons.

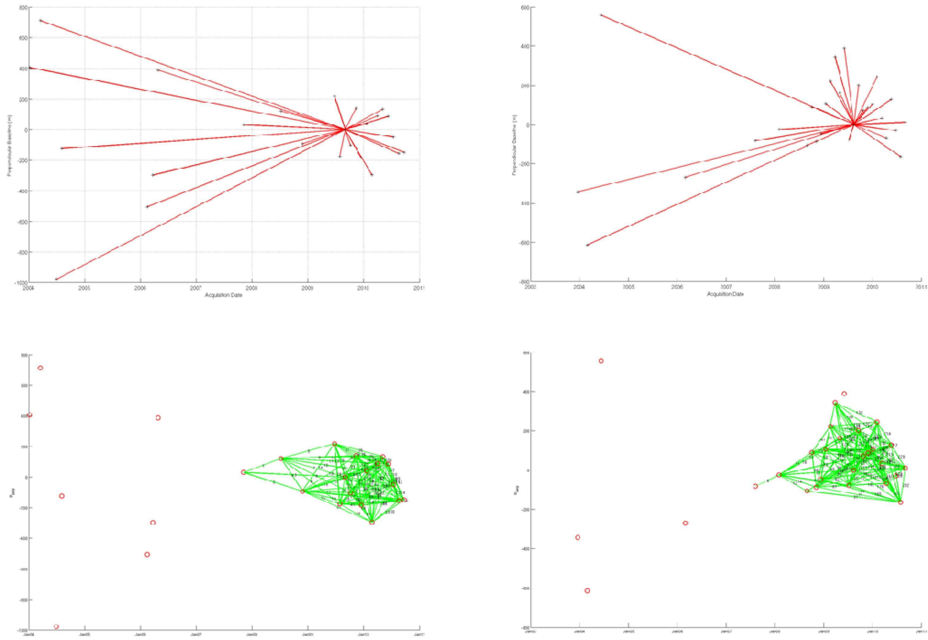

Figure 3. PSI vs. SBAS baselines for track 122 (left) and track 351 (right).

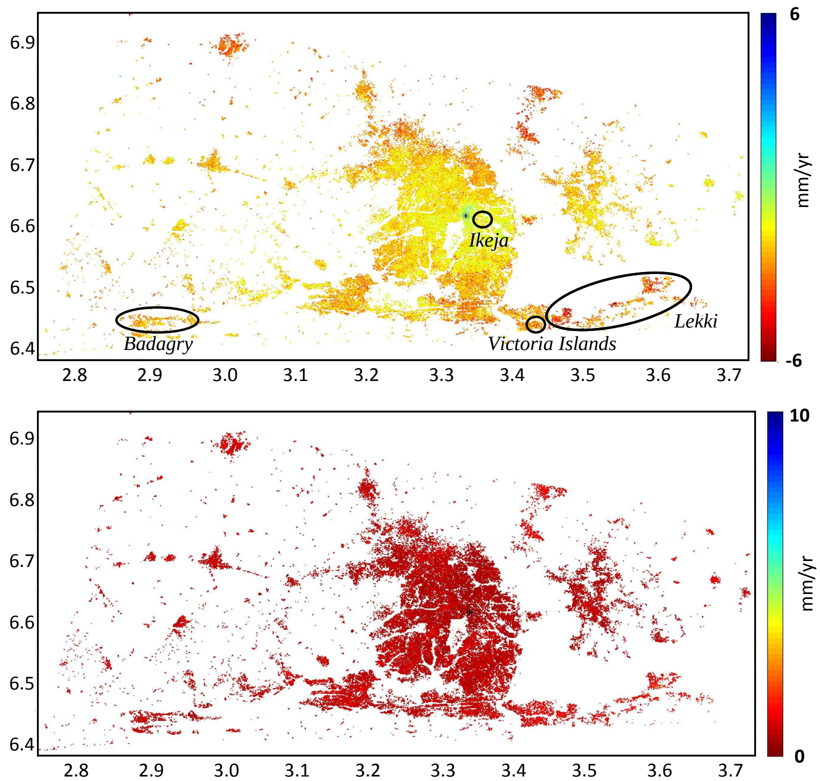

Figure 4. PSI mean LOS velocity (top) and standard deviations (bottom) for track 122 over Lagos state.

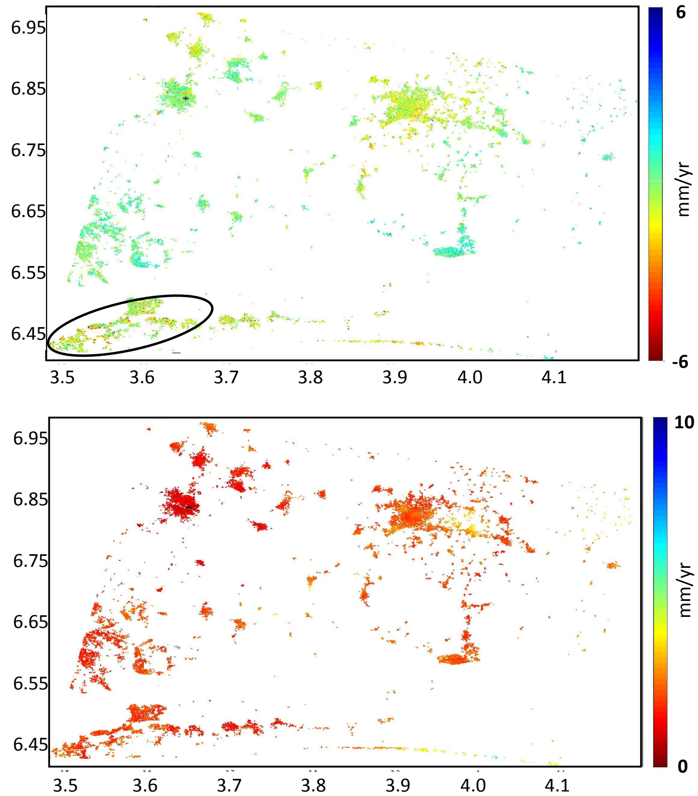

Figure 5. PSI mean LOS velocity (top) and standard deviations (bottom) for track 351 over Lagos state.

4. CONCLUSIONS AND FUTURE WORK

In this work we present the first interferometric results retrieved in the Lagos area, Nigeria. Several subsidence phenomena have been found for the first time in this region with velocity rates up to -7 mm/yr. It is therefore recommended that the concerned authorities, particularly, Lagos state government, Federal Ministry of Niger Delta and Niger Delta Development Corporation to collaborate with the Centre for Geodesy and Geodynamics, Toro, Bauchi state under National Space Research and Development Agency (NASRDA) mandated with this responsibility, for continuous monitoring of this phenomena (subsidence) in all the coastal cities of Nigeria for the safety of lives and properties.

With the already ongoing ESA Sentinel-1 mission and free accessible near real-time data archive as well as with the X-band CosmoSky-Med data already received under the scope of the ASI 237 CAT-1 project , the future processing will highlight the benefits that satellite radar interferometry can bring over this area.

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