

**Faculdade de Ciências**

**DEGGE**

**Project Title**

Final report

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**Mapping vertical land movement in Singapore using InSAR and GNSS**

Final Report

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**Executive Summary (exemplo)**

LandMov was a two year Project under a contract research agreement between National University of Singapore (NUS) and Instituto D.Luiz, University of Lisbon (IDL-UL). Blá, blá, blá.... The BCA project aims to address the concerns surrounding coastal protection in the light of climate change and sea-level rise over the next 100 years.

The objective of LandMov was to provide support on processing multi-dated Interferometric Synthetic Aperture Radar (InSAR) data to map past and present day vertical ground deformation of Singapore territories. For that, a set of archived ERS1 and ERS2 SAR images, from 1995 to 2000, and new acquisitions of TerraSAR-X (TRX), from 2011 to 2013, were interferometricaly processed and combined with GNSS velocities determined from 5 continuous GNSS stations in Singapore. The persistent scatterers technique was applied to the interferogram time series to derive the vertical displacement. For ERS data set, the estimated velocity field covers the entire Singapore mainland territory whilst for TRX the west part is not covered.

The results show a consistent pattern of subsidence in the order of -1.5mm/yr, which was detected consistently by combined InSAR and GPS analysis. On some localized areas, a significant subsidence with subsiding rates of -15 mm/yr was detected. Highest subsiding rates are near the shore on low flat land, above 5m. The result seems to be reliable and consistent with the geologic setting. The scatter pattern of the deformation indicates anthropogenic causes related with consolidation of built and/or reclaimed areas, rather than natural causes. Together with sea level rise, this can pose significant risks to the coastal areas of Singapore.

Keywords: Climate Change, Subsidence, InSAR, Singapore

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# 1. Introduction (Motivação, racional: qual o problema?)

Changes in climate with the associated sea level rise and subsidence of populous coastal cities, have major impacts on the economy, environment, societal and human utilization; and represent one of the significant natural hazards [e.g., IPCC Working Group II Report, Bijlsma, 1996]. The Asia-Pacific region, which has the highest concentration of human population in the world, represents one of the larger areas on Earth being threatened by the rise of sea level. Recent studies indicate the rate of average land subsidence, for example in Pingtung Plain, southern Taiwan, is more 3 cm/yr from 1995 to 2000 (Hsieh et al., 2011). Singapore has undergone relative subsidence which created the many small islands. Submergence also accelerates coastal erosion because it facilitates greater inland penetration of storm waves e.g. observed accelerated erosion in East Coast of Singapore.

The movement of ground can be attributed to natural processes or to human activity – and such movements can often be sufficient to cause coastal hazards and risk to coastal infrastructure. These ground movements are traditionally monitored on-site with traditional geodetic instruments and with GNSS. In recent years, repeat-pass space-borne Synthetic Aperture Radar Interferometry, (InSAR) has been applied to monitor ground subsidence in urban areas, mostly related to the construction of important engineering structures. First experiences with SAR data of the European Remote Sensing satellites ERS-1, ERS-2 and ENVISAT, characterized by a spatial resolution of 20m and revisiting cycle of about 35 days pointed out both potentialities and drawbacks of this technique mainly related to atmospheric phase delay (Fruneau and Srati, 2000). In the last few years, the spatial resolution of SAR sensors has improved drastically. COSMO-Sky-Med and TerraSAR-X have a spatial resolution of up to 1 m in very high-resolution spotlight mode and around 3 m in stripmap mode (Eineder et al., 2005). Of course this enhances the quality of subsidence maps in urban areas obtainable by InSAR data.

In this project we used InSAR Persistent Scatterers technique to determine the spatial variation in vertical land motion (VLM) along the coast of the Singapore over the past decade, and combined PS results with CGPS (continuous GPS) observations, to examine the impact of spatially variable VLM on relative sea level trends. Our approach has taken advantage of the synergistic aspects of these techniques, GPS providing long-term stability, good resolution of horizontal motions and broad scale control on rates and patterns of deformation and InSAR providing high spatial resolution and high sensitivity to vertical motions.

# 2. Objective (o objetivo tem de ser conciso)

The objective of this project was to investigate the spatial variation in vertical land motion (VLM) along the coast of Singapore over the past two decades and to examine the impact of spatially variable VLM on relative sea level trends.

# 3. Methodology

Qual a metodologia usada no projecto?

Descrição genérica e justificada com referências sobre a metodologia usada. Porque é usada esta metodologia e não outra. Porque usa o software A e não o B?

Eventualmente poderá haver uma secção anterior com o estado da arte.

# 4. Project Implementation

Descrição detalhada da implementação do projecto com resultados, figuras e tabelas. Os resultados deverão ser comentados.

**5. Conclusions**

Apresentação das conclusões do projecto.

**References**

Gabriel, K., Goldstein, R.M:, Zebker, H.A, 1989. Mapping small elevation changes over large areas: differential radar Interferometry. J. Geophysical Research, 94.