ARTICLE IN PRESS
RSE-09261; No of Pages 16
Remote Sensing of Environment xxx (2014) xxx–xxx
Contents lists available at ScienceDirect
Remote Sensing of Environment
journal homepage: www.elsevier.com/locate/rse

Assessments of land subsidence in the Gippsland Basin of Australia using ALOS PALSAR data

Alex Hay-Man Ng, Linlin Ge *, Xiaojing Li

Geoscience and Earth Observing Systems Group (GEOS), School of Civil & Environmental Engineering (CVEN), The University of New South Wales (UNSW), Sydney, Australia

ARTICLE INFO

Article history:
Received 14 July 2014
Received in revised form 3 December 2014
Accepted 3 December 2014
Available online xxxx

Keywords:
InSAR
Land deformation
Time-series analysis
Gippsland Basin
Australia

ABSTRACT

In this paper, the land deformation in the Gippsland Basin, Victoria, Australia has been mapped using the interferometric synthetic aperture radar (InSAR) time-series analysis with the ALOS L-band SAR data. Land subsidence in the basin resulting from mining activities has already been known over the past few decades. There has been ongoing concern that irrigation and off-shore oil and natural gas extraction has significantly lowered groundwater levels on-shore, and that this may lead to further subsidence. Therefore it is important to map the land surface change in the basin in order to understand the actual impact of these activities. The total area of Gippsland Basin is approximately 46,000 km^2, where approximately one-third of the basin is located onshore. Because of the large area of the basin, ALOS PALSAR data from 4 different paths were used to map the land displacement over the basin. The InSAR result suggests that the land displacement at 98% of the measurement points in the basin was between −10 mm/year and 10 mm/year. The InSAR result has been compared to the ground survey data in several areas, collected with GPS and total station surveys. The comparison of results suggested that the InSAR measurement and the ground survey measurement agree with each other in general. The standard deviation of difference between the InSAR results and the ground survey data is approximately 4 mm/year near the coastal area and 15 mm/year near the mining sites. Several rapidly deforming areas have been identified at the mining sites and the surrounding areas. Deformation rate at up to −82.9 mm/year is observed in these areas. The deformation at the mining sites and the surrounding areas are expected to be resulted from mining activities and associated mine dewatering. Moreover, several minor displacement zones have been observed and investigated in the area between the Loy Yang Mines and the Gippsland coast as well as the area between Yanakie and Wilsons Promontory.

1. Introduction

Land subsidence has become a global problem and cases of subsidence have been identified in many places around the world (Abidin, Gumilar, Andreas, Murdohardono, & Fukuda, 2013; Chaussard, Amelung, Abidin, & Hong, 2013; Colesanti, Ferretti, Novali, Prati, & Rocca, 2003; Herrera et al., 2007; Ng, Ge, Li, & Zhang, 2012; Osmanoglu, Dixon, Wdowinski, Cabral-Cano, & Jiang, 2011; Tizzani et al., 2007; Zhang, Ge, Li, & Ng, 2013; Zhang et al., 2012). Environmental and structural hazards caused by land subsidence include: damage of bridges, buildings, roads, gas/water pipes and underground telecommunication optical cables; alteration of river and groundwater flow; failure of well casings; and increasing risks of inundation and inland sea water intrusion. These hazards could lead to massive economic loss and may even threaten human's life. Therefore it is essential to monitor the land subsidence so that the land surface change can be better understood and managed for minimising the associated loss and damage.

Australia is one of the countries with land subsidence problems, mainly due to anthropogenic activities including the use and extraction of natural resources such as iron-ore, gold, natural gas and coal (Australian Government Department of Resources, Energy and Tourism, 2005; Ng et al., 2010). The Gippsland Basin (Fig. 1), one of Australia's most productive hydrocarbon provinces, is an area attracting public attention. Localised subsidence is measured and well documented in the vicinity of the Latrobe Valley mining operations. The possible causes that might contribute to the land surface movements near the mines have been well studied (Victorian Goverment Department of State Development Business and Innovation, 2012). Unlike the areas near the mine sites, the possible subsidence mechanisms near the Gippsland coast are not well understood. Because of the uncertainties in these areas, there is a need to better understand the land surface condition along the coastal area for an accurate assessment of the potential impacts at regional and local scales.

Land subsidence information can be very useful for interpreting and explaining any possible physical causes of the land deformation and hence to predict the consequences. An accurate assessment of the potential causes and impacts of land subsidence often require time-series of observations, preferably for a long period of time.

* Corresponding author. Tel.: +61 (0)423 287 219 (mobile).
E-mail address: l.ge@unsw.edu.au (L. Ge).

http://dx.doi.org/10.1016/j.rse.2014.12.003
0034-4257/© 2014 Elsevier Inc. All rights reserved.

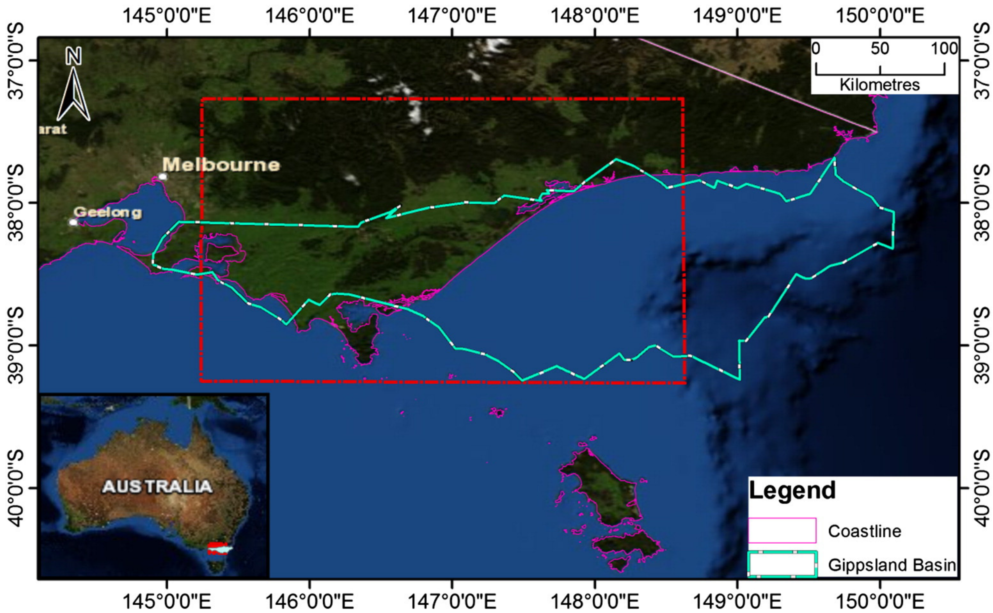

Fig. 1. Location map of the Gippsland Geological Basin. The extent of the Gippsland Geological Basin was digitalised from the Gippsland Basin regional setting and location map from Geoscience Australia. The extent of Fig. 2 is highlighted by the red box.

Unfortunately, slow gradual lowering of land is often difficult to be detected. The undetected gradual sinking of landforms can become serious problems after some period of time if they are not being properly dealt with. Conventional techniques such as GPS and levelling have been used for land subsidence monitoring in the Latrobe Valley and coastal area in Gippsland (Department of Primary Industries, 2007; GHD, 2010). Although these techniques can provide precise measurements, they are time consuming, labour intensive and costly. Because of these, the previous monitoring work could only be conducted with limited extent and resolution in both temporal and spatial domains. In this study, the magnitude and spatial pattern of land displacement in the Gippsland Basin between 2007 and 2011 are derived and investigated using InSAR time-series analysis. Wang et al. (2012) has already demonstrated the importance to identify areas with subsidence comparable with local sea level rise using InSAR time-series analysis. The capability of InSAR for precisely mapping land displacement at a regional scale has also been demonstrated in other studies (Blanco, Mallorqui, Duque, & Monells, 2008; Chen et al., 2010; Ferretti et al., 2011; Ge et al., 2008; Ng, Ge, Li, Abidin, et al., 2012; Reeves et al., 2011; Zhang et al., 2013). These studies have shown that InSAR time-series analysis is able to provide high resolution in time and/or spatial scale. Therefore the results obtained can be used to complement the measurements obtained from the conventional techniques.

This paper is organised as follows. The location and geological settings of the Gippsland Basin are first presented, followed by the data used in this study. Next, the method used to estimate the linear and non-linear term displacement parameters is summarised. The displacement results obtained using ALOS PALSAR data is then presented. Subsequently, the analysis of the displacement results for five selected locations is provided. Finally, some concluding remarks are given.

2. Study area

The Gippsland Geological Basin is a large sedimentary basin that situated in south-eastern Australia and is about 200 km east of Melbourne (Fig. 1). The sediments are over 1000 m thick onshore extending to over 3000 m thick offshore (Hatton, Otto, & Underschultz, 2004). These sediments are composed of sequences of unconsolidated sands, clays, limestone and brown coal seams that contain large amount of coal, oil, gas and groundwater. The total area of the Gippsland Basin is approximately 46,000 km^2, where approximately one-third of the basin is located onshore. The primary production in Gippsland includes mining, power generation, oil and natural gas extraction and farming. The basin has one of the world's largest brown coal deposits and Australia's largest deposits of oil and gas. Most hydrocarbons discovered are stored within the siliciclastics of the Upper Cretaceous to Paleogene Latrobe Group. Remaining reserves are estimated at 400 MMstb (Million Stock Tank Barrels) oil and 6 Tcf (Trillion Cubic Feet) gas, with 2–4 Tcf of gas and up to 600 MMstb of liquids yet to be discovered (Australian Government Department of Resources, Energy and Tourism, & Geoscience Australia, 2011a). Almost all oil production and the majority of the gas production for Victoria are derived from the basin, mostly from the offshore area (Fig. 2). The basin is bounded to the north by Paleozoic basement of the Eastern Uplands, to the west by uplifted Lower Cretaceous fault-blocks and to the southwest by the Bassian Rise, which separates it from the Bass Basin to the west. Although the Gippsland Basin is well-explored compared to other Australian basins, it is relatively under-explored compared to many other prolific basins around the world (Australian Government Department of Resources, Energy and Tourism, & Geoscience Australia, 2011b).

The population of Gippsland basin is approximately 240,000. Although the population density is low in most parts of the basin, there are a number of populated cities. As a result, the region is connected by an extensive array of road. The pipeline network is well-developed for oil and gas transportation across the basin.

There are three main aquifer systems in the Gippsland Basin. (1) The Latrobe Group Aquifer System is the deepest and most extensive aquifer systems. (2) The Latrobe Valley Group, which lies on top of Latrobe Group, is best developed in the Latrobe Valley Depression (thickness of up to 400 m) and Seaspray Depression (thickness of up to 200 m). The Latrobe Valley Group is hydraulically connected to the Latrobe Group. The limestone serves as a major aquitard over the Latrobe Group. (3) The shallow aquifer system consists of unconfined to semi-confined systems of sand, clay and coal units on the onshore parts of the Basin with up to 150 m thick (Hatton et al., 2004). The groundwater in the Latrobe Aquifer System is extracted for three main purposes: (1) depressurisation and dewatering for open-cut mines in the Latrobe Valley and cooling for power generation (Latrobe Valley Group); (2) as part of oil and gas extraction in Bass Strait (Latrobe Group); and (3) -domestic and stock, town, irrigation and industrial use (both) (Victorian Government Department of Sustainability and Environment,

Please cite this article as: Ng, A.H.-M., et al., Assessments of land subsidence in the Gippsland Basin of Australia using ALOS PALSAR data, *Remote Sensing of Environment* (2014), http://dx.doi.org/10.1016/j.rse.2014.12.003