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Surface Heave Detection related with CO₂ Injection by DInSAR at In Salah, Algeria

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Abstract

Surface deformation related with CO₂ injection at In Salah Gas Plant, Algeria, was analyzed using satellite-borne Synthetic Aperture Radar (SAR) data. In Salah Gas project is widely known as long term CO₂ storage project, of which injection has been performed since August 2004, with the injected amount of 1 million tons CO₂ per year. Surface deformation around three injection wells was analyzed by Differential Interferometric SAR (DInSAR), a remote sensing technique to detect the surface displacement at an order of millimeters, using 30 scenes of ENVISAT ASAR. DInSAR results of 56 interferometry pairs, which met with requirements of perpendicular baseline between two observations less than 300m, the observation interval longer than 1.5 years and less phase noise of tropospheric turbulence, were stacked to derive the surface deformation rate with reducing the influence of atmospheric delay and phase noise. The result of stacking shows that the surface heave rate of 7 mm/year was detected around all of the three injection wells, whereas a subsidence rate of 3 mm/year for the gas-producing wells. Moreover, the analysis of the deformation series has revealed that each injection well has experienced different deformation histories. All of the surface heave for injectors and the subsidence for producers show a NW-SE trending elongation pattern which is the direction of the anticline axis in the field, suggesting certain relationship between the structural feature and the distribution of injected CO₂. It is obvious that DInSAR stacking process using satellite-borne SAR data successfully detected the surface deformations associated with CO₂ injection. This technique will hopefully provide us with a powerful and a cost-effective tool for monitoring of behaviors of the injected CO₂.

Introduction

InSAR, standing for Interferometric Synthetic Aperture Radar, has been proved as a promising remote sensing technique for mapping of topography and monitoring of ground displacement at an order of centimeters or millimeters. Several spaceborne SAR systems including ALOS PALSAR, JERS-1 SAR, ERS1/2 AMI, ENVISAT ASAR and Radarsat SAR, have been widely used for mapping of surface deformation. These are referred to as the active type sensors which transmit radar pulses towards the earth and receive echoes back off the Earth's surface. Because of the nature of radio wave, spaceborne SAR systems have the observation capability at all weather, day and night conditions, which is suitable for monitoring of Earth's surface. Although many InSAR application examples related with earthquakes, volcanic activity, landslide, glaciers motion, and ground subsidence have been reported in the past decade [1][2], to date there is no examples concerning with the monitoring of CO₂ injection. The primary objective of this paper is to examine the applicability of satellite-borne InSAR technique to the monitoring of surface deformation at CO₂ injection site, by applying the technique on the actual project being operated at In Salah, Algeria (Figure 1).

In Salah Gas Project is well known as one of huge CCS (Carbon dioxide Capture and Storage) projects in the world, as well as the Sleipner Project, Norway and Weyburn Project, Canada. The CO₂ is separated from natural gas produced from three fields of Krechba, Reg, and Teguentour, and is injected into underground at three wells down-dip from the Krechba natural gas accumulation. The field is located in the rocky desert where ground surface is vegetation free. In such a dry area, radar signal scattered at surface objects is generally quite coherent for different observations, which is suitable for the InSAR processing. Natural gas produced in the project contains 3-9% of carbon dioxide which is captured by a regenerative amine system [3] then is injected into the Carboniferous reservoir at a depth of 1,900m, from three injection wells of KB-501, 502 and 503 [4]. Monitoring at In Salah Gas Project is considered to be crucial for developing a detailed understanding of