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Earth Sciences

Ten years after Hurricane Katrina: monitoring recovery in New Orleans and the surrounding areas using remote sensing

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Abstract Remote sensing data have been widely used in pre-hazard prevention/preparation, emergency response and post-hazard recovery monitoring. Hurricane Katrina caused serious damage to the environment, society and economy in the southern United States in 2005. On the 10th anniversary of Hurricane Katrina, we monitored the recovery process in New Orleans and the surrounding area based on remote sensing. Results from multi-source remote sensing data indicated that the average vegetation conditions of the affected areas have not fully recovered compared with the pre-disaster conditions, especially in the hurricane's landfall area. Analysis from moderate resolution Landsat data showed that many civil engineering works have been undertaken in the city of New Orleans to prevent future disasters. Frequent observation using high-resolution images recorded the progress of some of these civil construction projects (e.g. the 17th Street Canal pumping station) in New Orleans. In this case study, we illustrated the capabilities of remote sensing techniques in recovery monitoring following a natural disaster. International/institutional cooperation is suggested to improve Earth observation capability in hazard monitoring. More Chinese Earth observation data are expected to be used in international monitoring.

Keywords MODIS · Landsat · High-resolution images · Change detection · Natural hazard

1 Introduction

Hurricane Katrina (August 2005) was a major natural disaster that resulted in squalls, storm tides, the breaching of levees, and severe flooding in the United States. More than half a million people were forced to leave their homes and have not returned [1]. The hurricane destroyed important infrastructure and damaged the natural environment [2–5]. Remotely sensed images were used to rapidly assess the influence of this hurricane [6]. Damage to in situ assessment tools by flooding prevented their use, and hence remote sensing became the main data source for disaster evaluation [7].

Remote sensing sensors combine wide coverage, rapid response and repeat observations, and therefore have been widely adopted for tracking the influence of natural disasters over time [8]. A wide range of studies have been carried out to quantify the impacts of disasters such as earthquakes [9–12], floods [13–16], and hurricanes [2–4, 17–21]. Typical applications include the Bam earthquake (Iran, 2003), the Great East Japan Earthquake (Japan, 2011) [10], and the Tianjin chemical warehouse explosion (China, 2015). Images with different spatial and temporal resolutions provide varying details for monitoring natural disasters [5, 7]. Change detection is a commonly used approach to identify land surface changes pre- and post-disaster. Based on different disasters, various change

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indicators (e.g. spatial morphology [10, 11], vegetation indices [2, 3], and water indices [15]) have been employed to serve different applications. For example, Contreras et al. [9] integrated remote sensing, a geographical information system and in-site observations to monitor recovery after earthquakes in Italy. Reviewed multiple water indices and digital elevation models (DEM) with remotely sensed images to quantify the extent of flooding. Rossi et al. [22] used the enhanced vegetation index of Moderate Resolution Imaging Spectroradiometer (MODIS) datasets to estimate the forest damage after Hurricane Felix (2007) in northern Nicaragua. Wang and Xu [18] explored forest disturbance at a landscape scale after Hurricane Katrina. Post-classification is an alternative to these indicator-based approaches to identify the disturbed regions after a natural disaster [3, 4]. However, misclassification may reduce the ability to accurately distinguish actual change and pseudo-change.

Presently, most studies on natural disaster monitoring focus on a relatively short period of time between pre- and post-disaster, with multiple sequential images. The effect of a disaster such as a hurricane is noticeable within a short period. Nevertheless, quantifying the long-term influence of (or resilience to) a hurricane is of great importance to better understand ecosystem disturbance [23, 24]. Multi-temporal and multi-resolution remotely sensed images that cover a relatively long period are necessary to capture this disturbance and resilience at different scales. Images with different spatial and temporal resolutions provide varying details for monitoring natural disasters [5, 6]. For example, in addition to the natural recovery of ecosystems, artificial adaptation to reduce or prevent disasters in the future is crucial to reduce the influence of disasters on human society. This relies on fine-resolution images to identify new municipal facilities.

The 10th anniversary of Hurricane Katrina was in 2015. Here, we applied multi-source (multi-temporal and multi-resolution) datasets, including MODIS, Landsat and high-resolution images from Google Earth, to track the recovery of damage to New Orleans caused by Hurricane Katrina over the past decade (2005–2015). The specific aims of this study were: (1) what are the spatial and temporal patterns of natural recovery from Katrina, and (2) what we have learned and prepared to prevent similar damage by the next hurricane?

2 Study area and datasets

2.1 Study area

Our study area covers the whole region affected by Hurricane Katrina (Fig. 1). On 25 August 2005, this hurricane made landfall in Florida. Its destructive weather continued to influence the states of Louisiana, Mississippi, Florida, Georgia and Alabama until 31 August. The direct impacts of the hurricane caused the deaths of more than 1,800

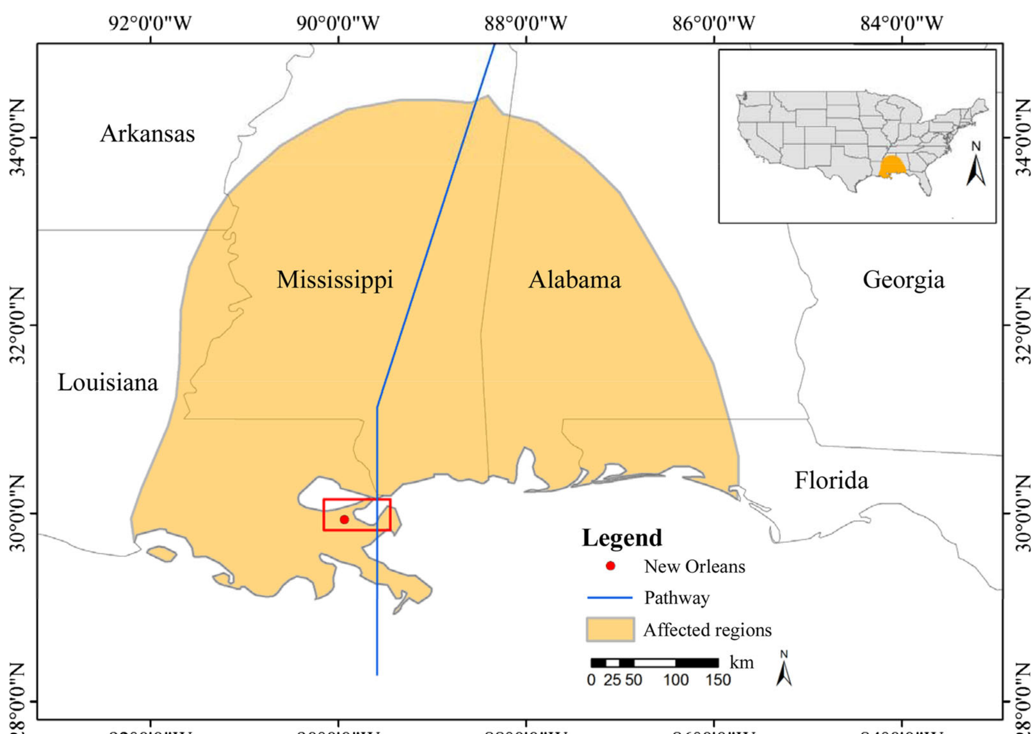

Fig. 1 Regions affected by Hurricane Katrina (Note: the yellow region was digitised by [5])