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Feasibility of anomaly occurrence in aerosols time series obtained from MODIS satellite images during hazardous earthquakes

Mehdi Akhoondzadeh *, Fatemeh Jahani Chehrebargh

Remote Sensing Department, School of Surveying and Geospatial Engineering, College of Engineering, University of Tehran, North Amirabad Ave., Tehran, Iran

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Abstract

Earthquake is one of the most devastating natural disasters that its prediction has not materialized comprehensive. Remote sensing data can be used to access information which is closely related to an earthquake. The unusual variations of lithosphere, atmosphere and ionosphere parameters before the main earthquakes are considered as earthquake precursors. To date the different precursors have been proposed. This paper examines one of the parameters which can be derived from satellite imagery. The mentioned parameter is Aerosol Optical Depth (AOD) that this article reviews its relationship with earthquake. Aerosol parameter can be achieved through various methods such as AERONET ground stations or using satellite images via algorithms such as the DDV (Dark Dense Vegetation), Deep Blue Algorithm and SYNTAM (SYNergy of Terra and Aqua Modis). In this paper, by analyzing AOD's time series (derived from MODIS sensor on the TERRA platform) for 16 major earthquakes, seismic anomalies were observed before and after earthquakes. Before large earthquakes, rate of AOD increases due to the pre-seismic changes before the strong earthquake, which produces gaseous molecules and therefore AOD increases. Also because of aftershocks after the earthquake there is a significant change in AOD due to gaseous molecules and dust. These behaviors suggest that there is a close relationship between earthquakes and the unusual AOD variations. Therefore the unusual AOD variations around the time of earthquakes can be introduced as an earthquake precursor.
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Keywords: Aerosols; Earthquake; Remote sensing; Anomaly; Atmosphere; MODIS

1. Introduction

The earthquake is a natural disaster that a lot of human and financial losses are results of that. This damage can be prevented with earthquake prediction. The earthquake prediction has become one of the most important issues of the 21st century's science. The first successful prediction of large earthquakes was in 1975, that scientists could predict strong Haicheng earthquake in China (Wang et al., 2001; Wang et al., 2006). But one year later, scientists could not predict Tangshan earthquake, which was a great earthquake, and the result of that earthquake was the 250,000 killed and 164,000 wounded (Alarifi et al., 2011).

To date, different algorithms have been suggested to predict the earthquake, but there is not one unique algorithm that could be able to predict each earthquake around the world. Therefore earthquake prediction issue has not solved yet. Although earthquake prediction remains continues to be challenging, but recent studies show that physical and geochemical parameters are closely related to the earthquake (Pulinets and Boyarchuk, 2004; Molchanov and Hayakawa, 2008; Akhoondzadeh, 2011).

Earthquake is a dynamic phenomenon that usually occurs because of the Earth's crust movements. When an earthquake occurs, energy released and transferred

* Corresponding author. Tel.: +98 21 61114522; fax: +98 21 88008837.
E-mail address: makhonz@ut.ac.ir (M. Akhoondzadeh).

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between the environment and resource. Released energy can effect on the lithosphere, atmosphere and ionosphere. Various parameters of the lithosphere, atmosphere and ionosphere, are known as precursors of earthquake that pointed out the impending of earthquake (Saradjian and Akhoondzadeh, 2011).

Studies have shown that there are many parameters when the earthquake occurs, abnormal changes occur, such as changes in weather, the formation of earthquake clouds, changes in animal behaviors, changes in land surface temperature and etc. Nowadays, remote sensing data are used to show time series of earthquake precursors.

Remote sensing data showed that they have close relationship with earthquake occurrence, and there are parameters in remote sensing data that have anomalies when the earthquake occurs. Therefore with analyzing the time of these anomalies, the approximate time of the earthquake can be predicted, and the relationship between the precursors and earthquakes can be found.

Aerosols play such an important role in the Earth's radiation balance and climate changing (D'Almeida et al., 1991; Charlson et al., 1991). These air suspended particles reflect or absorb sun lights and cause the change in measurement reflection from the surface by the sensor (Bhaskaran et al., 2011). Aerosols do not affect only the climate during the reflection or absorption of sun lights, but also impact on air quality and human health (Li et al., 2007; Myhre et al., 1998; Penner et al., 1994; Pope et al., 2002).

Aerosol Optical Depth (AOD) is one of the aerosol parameters that can give useful information about aerosols. Over the years, various methods using satellite remote sensing data have been developed to estimate aerosols.

AOD is calculated by measuring the absorption of light at specific wavelengths of the visible spectrum. To use a wide variety of AOD, absorption at wavelength of 550 nm is recommended.

Scientific reports show that the amount of aerosols in different time intervals before and after the great earthquake have anomalies (Pulinets and Ouzounov, 2011; Pulinets et al., 2014).

Okada and his colleagues in 2004 obtained aerosol parameters (optical thickness and angstrom coefficient) from SeaWiFS sensor data, these collected data relate to before and after the Gujarat earthquake (which took place on 26 January 2001). Different values of aerosol parameters show significant changes after the Gujarat earthquake (Okada et al., 2004).

Qin et al. (2004) using AOD data showed that a significant change can be seen seven days before the Wenchuan earthquake that occurred on 12 May 2008. They compared their results with other atmosphere and ionosphere anomalies, which were obtained by other studies, and ultimately they also attempted to acknowledge their results using LAI (Lithosphere–Atmosphere–Ionosphere) coupling mechanism (Qin et al., 2004).

Akhoondzadeh (2015) attempted to acknowledge AOD seismo-atmospheric anomalies around the time of the Chile earthquake of 27 February 2010 using a multi-precursors analysis. An increase in AOD was clearly observed 2 days before the earthquake.

2. Data

Aerosol parameters are obtained through various methods such as ground stations, using satellite sensor products and solving algorithms such as Dark Dense Vegetation (DDV) (Kaufman et al., 1997), Deep Blue Algorithm (DBA) and SYNTAM method (SYNergy of Terra and Aqua Modis) (Tang et al., 2005).

In this study, aerosol variations have been analyzed using one of the atmosphere daily global 1degree products deduced from MODIS Terra and Aqua daily level-3 data. This product which is named "Aerosol Optical Depth at 550 nm" is available via: http://gdata1.sci.gsfc.nasa.gov/daac-bin/G3/gui.cgi?instance_id=MODIS_DAILY_L3.

For a detailed review and having maximum accuracy, 16 earthquakes from around the world are selected that their magnitude are greater than 6.4 Richter.

Information about these earthquakes areshown in Table 1 that the geographic coordinates, date and time, magnitude and depth of the earthquake are expressed.

3. Methodology

Optical properties of aerosols (such as optical depth) can be achieved using satellite images such as AVHRR, MODIS, MISR, Sea WIFS, POLDER, TOMS, and MISR. So far, many algorithms have been introduced to obtain the Aerosol Optical Depth, such as DDV, Deep blue and SYNTAM.

Dark dense vegetation (DDV), which was presented by Kaufman in 1997, today is one of the most important algorithms for processing AOD. This algorithm has shown well performance for MODIS data. It determines dark pixels in the mid-infrared band and then estimates its reflectivity, after that, reaches the AOD. But this method has limitations. The algorithm was related to dark pixels, these pixels can be found in wet areas or areas with vegetation and water and ice.

SYNTAM method was introduced by Tang et al. in 2005. This algorithm was able to remove limitation of DDV method by using integration of MODIS images of TERRA and AQUA satellites and be introduced as an efficient way to obtain the AOD. The results of this method are compared with ground-based data from AERONET and have shown good results.In this paper MODIS data on TERRA platform was used. There are various ways to find anomaly on AOD time series, such as the median/interquartile, wavelet transform, Kalman filter and so on (Akhoondzadeh, 2013).

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