

FRAME DESIGN OF REMOTE SENSING MONITORING FOR VOLCANIC ACTIVITIES IN CHANGBAI MOUNTAINS

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ABSTRACT: Volcanic eruption is one of the most serious geological disasters, however, a host of facts have proven that the Changbai Mountains volcano is a modern dormant one and has ever erupted disastrously. With the rapid development of remote sensing technology, space monitoring of volcanic activities has already become possible, particularly in the application of thermal infrared remote sensing. The paper, through the detailed analysis of geothermal anomaly factors such as heat radiation, heat conduction and convection, depicts the monitoring principles by which volcano activities would be monitored efficiently and effectively. Reasons for abrupt geothermal anomaly are mainly analyzed, and transmission mechanism of geothermal anomaly in the volcanic regions is explained. Also, a variety of noises disturbing the transmission of normal geothermal anomaly are presented. Finally, some clues are given based on discussing thermal infrared remote sensing monitoring mechanism toward the volcanic areas.

KEY WORDS: thermal infrared remote sensing; volcanic activity; geothermal anomaly; Changbai Mountains

CLC number: P317.1; TP722.5

Document code: A

Article ID: 1002-0063(2003)04-0347-05

1 INTRODUCTION

The volcano of the Changbai Mountains, as an active volcano, is much concerned by many scholars, who have conducted a series of fruitful research for many years in the field of volcanic geology, volcanic dynamics, volcanic geomorphology, volcanic projection as well as volcanic effusive period and rule etc. On the other hand, many kinds of scientific methods have been used to monitor the changes of geophysical and geochemical phenomena, such as earthquake, terrestrial magnetism, terrestrial temperature and crust deformation. In recent years, spatial monitoring has been under way mainly on geothermal anomaly, geomagnetism anomaly and crust deformation, in which temperature survey has been viewed as a main source to be monitored in a convenient way. However, its transmission mechanism is so complicated that many problems have not been solved yet, especially disturbing noises in the transmission process of thermal information. This paper discusses these problems in detailed as well as heat radiation transmission, and through correction and removal of the noises, finds an effective

difference of temperature. The situation of volcanic activities will be analyzed by the means of spatial and temporal characteristics of bright temperature difference.

2 OCCURRENCES OF ABRUPT GEOTHERMAL ANOMALY AND ANALYSIS OF ITS TRANSMISSION MECHANISM

Volcano emanation is a form of strong release of substance and energy inside the Earth. When cold oceanic plates go down to one side of an island arc from oceanic trench, during the initial period, volcanic activity could not be caused in virtue of low temperature. Crush materials melt under the action of various stresses at a specified distance and depth of the plates (YOU *et al.*, 1998). Thus, melting substances erupt from rock faults or rupture belts by a high pressure (SONG, 1990; JIN and ZHANG, 1994). During the development of volcano, abrupt geothermal anomaly definitely occurs at repeated times, however, pocket of magma detained at a shadow crush is only an ideal spot hot source of geothermal anomaly in volcanic re-

Received date: 2003-05-14

Foundation item: Under the auspices of the Science and Technology Committee of Jilin Province (No. 980356)

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gion (BO *et al.*, 1999). Deep melting magma in the course of moving up by the high pressure excites pocket of magma. Therefore, the existed anomalous subterranean heat is aroused into the abrupt geothermal anomaly. Different types of volcanoes have different geothermal features. Studying different types of geothermal features and intensity of volcano activity is one of the studies on thermal infrared remote sensing monitoring and forecasting.

The deep terrestrial heat in volcanic region might be transmitted to the surface through various transmission mechanisms. During the dormant period of volcano, volcanic areas have a phenomenon of geothermal anomaly; while in mobile or forewarning period, geothermal anomaly would be more obvious than ever. In the course of transmitting to the surface, the deep terrestrial heat mainly transmits through electromagnetic radiation, conduction of terrestrial heat, convection of terrestrial heat etc. towards the surface, which makes the terrene's temperature rise.

2.1 Radiation Transmission

In the process of motion, morphological change and rupture of rock slabs, rock substances will adjust their inner structure and produce some physical and chemical phenomena. The inner mechanical energy will be transformed into heat energy, which appears as electromagnetic waves. As soon as the released electromagnetic energy comes across objects, whether or not solid, liquid and gas, interaction consequentially happens, in which partial energy absorbed by the object is transformed into the heat energy of the object itself. In the birth of volcano and earthquake, crust stress changes a lot, so that rock temperature will rise in a large area. The high energy released to space along with crack and rift results in temperature rising in a larger surface.

In addition, partial energy may penetrate through the surface, and directly enter into a lower layer of atmosphere. With earth substance temperature rising, inner electrons have enough motive energy to release out of rock surface, and enter into atmosphere. These free electrons affect the change of low atmosphere static field, and the electrons act with the protons released by the sun to make surface temperature rise. This kind of temperature rising mechanism has been proven by a lot of experiments.

2.2 Conduction of Heat

Surveying shows that fissures and pocket of magma

exist in the Changbai Mountains region, which can provide a great deal of substance sources and dynamic sources stored up as a huge heat energy for volcanic activities. So geothermal anomaly often occurs in the region with modern volcanic activity. Geothermal anomaly is the phenomena that underground temperature and geothermal gradient increases much more in the area than its surroundings. Geysers and hot springs are generally found in above regions. During the violent volcanic activities or forewarning period of volcano eruption, abrupt geothermal anomaly comes out. Abrupt geothermal anomaly means that underground temperature on some spots as well as the affected temperature of surrounding area abruptly increases in a short time. Its geophysical properties represent the spatial and temporal features of current subterranean magma activity or crush movement intensity in the area, which contains much information for geology, geophysics and geo-dynamics. So the above information is very important to monitor and forecast temporary volcanic activity.

2.3 Convection of Heat

Most geothermal energy can be convected through the underground water and the magma motion. When hot sticky magma suddenly touches cold circulation layers, a great deal of volatile flux will be produced and underground water will be heated. In addition, while volcano is active, the temperature of original hot spring and crater lakes must be rising. In this case, heat transmission in water body mainly depends upon heat exchange. Produced volatile flux and heated gases such as vapor, hydrogen, HCl, CO₂, CO, H₂S, SO₂, HF etc. contained in magma and adjoining rocks will be released to air through movement faults and broken rock cracks. They not only bring heat to the surface, but also result in the hothouse effect in basin and low gully, which will make temperature rise in the area.

In summary, experiments prove that according to the above transmission mechanism, there is an obvious increase for surface's temperature in abrupt geothermal anomalous area in contrast to geothermal normal area during the forewarning period of volcano activity. In the view of formation cause and geothermal transmission mechanism of abrupt geothermal anomaly in the regions of volcano, rising range of temperature in anomalous area could be 3–6°C or more. This offers a basic condition for monitoring volcanic activities by thermal infrared remote sensing techniques.

3 INTERFERENCE NOISES IN GEOTHERMAL ANOMALY INFORMATION

It is imagined that if geothermal anomaly information could be monitored without interference, remote sensing monitoring for volcanic activities would be ideal and effective. In reality, there must exist many factors affecting the normal transmission of geothermal anomaly information, mainly concentrating on the following four aspects.

3.1 Geothermal Anomaly Caused by Factors of Non-volcanic Activity

Elements such as U, Th, ^{40}K etc. in crushed rocks are able to generate certain ground heat currents by decaying, which probably covers up the abrupt geothermal anomaly.

3.2 Distortion of Information Caused by Atmospheric Factors

In the process of the monitoring volcanic activities by thermal infrared remote sensing technology, the thermal infrared radiation information of the earth's surface has to penetrate atmospheric layer to reach sensors. So atmosphere interference probably affects information transmission, mainly appearing in four ways: atmosphere scattering, absorption, flicker and thermal infrared radiation itself.

3.3 Distortion Caused by Different Observation Angle

In general, the sensor of thermal infrared remote sensing adopts different observation azimuths. Since heat radiation of objects is different in monitoring by different directions, by the influence of atmospheric disturbances, heat radiation data of the earth's surface recorded by the sensor is also different. It inevitably affects the interpretation of heat anomaly in the earth's surface of the studied region.

3.4 Noises Produced by Non-boundless Projection of the Surface's Objects

Suppose the surface of the earth consists of well-distributed material without varied terrain, both acceptance radiation of the sun and projective thermal radiation are equal anywhere in a certain areas, such as parts of oceanic surface and desert. In this case, it may be regarded as the body of diffusion. But in fact the

earth's surface, especially land's surface, is composed of diversity of objects with up and down terrain. So the characteristics of thermal mechanics, the process of thermal mechanics and characteristics of thermal projection of every object as well as its heading condition are different, which is named as the bodies of non-diffusion. The non-diffusion characteristics of the surface heavily disturbed the thermal flows of the earth, which may block the real presentation of abrupt geothermal anomaly. Therefore, it is the main obstruction to identify abrupt geothermal anomaly and effectively monitor and predict earthquake and volcanic activity.

4 REMOVALS OF INTERFERENCE NOISES IN GEOTHERMAL ANOMALY INFORMATION

Obviously, there are different methods to remove the four noise sources mentioned above according to their interference mechanism, which are preprocessing, restoration processing, black-box handling and multi-source data processing.

4.1 Preprocessing

Some noises can not disturb the monitoring of thermal infrared remote sensing because they can be removed before the acquirement of remote sensing data, called preprocessing (BO and HUA, 1999). For the geothermal anomaly caused by non-volcanic activities, as its variation process follows certain rules or appears relatively slow, the difference between the anomaly and abrupt geothermal anomaly is quite obvious. In this case, these noises should not be considered in the practical monitoring.

Considering the distortion of thermal infrared information brought by atmosphere absorption, in general, those spectral widths with the intense atmospheric absorption are shunned as far as possible in selecting the thermal infrared remote sensing windows. In the meanwhile, the selected data sources should be cloudless or no cloud. Therefore, this problem is not a key technological one.

Atmosphere flicker could be getting worse under the status of quite a big temperature difference. In fact, there is a little temperature difference between the anomaly and normal regions during the forewarning period of volcanic eruption. So it will not be included in our consideration.

The information distortion of objects' thermal radiation caused by the thermal infrared radiation of atmo-

sphere itself mainly happens at the time of having a large volume of clouds, therefore, the remote sensing sources should be selected with no clouds or less.

4.2 Restoration Processing

The thermal radiation information distortion brought by atmosphere scattering has an impact on reducing the contrast of objects on the image, even worse in a short wave. However, the remote sensing data without clouds have no obvious influence on the aspect in the spectrum of thermal infrared. In general, geothermal normal and anomaly regions have the equivalent scattering under the condition of the same atmosphere. Also, the required value in monitoring is the temperature difference, not absolute one. Consequently, this kind of information distortion is so tiny that the correction between normal and anomaly atmosphere in the remote sensing data could reach the goal of restoring information, even better if adding the ground calibration parameters.

The distortion through an observation angle change can be solved by the two ways: one is to select the data with a higher altitude angle; the other is to make a naturalization handling between the observation angle and the sun angle.

4.3 Black-box Handling

The mechanism of some noises occurrence is quite complicated (BO *et al.*, 2001), but an effective way to remove them, called black-box handling, was come up with.

The interference noise produced by the thermal character of different objects and different terrain is called system noise as a result of having both certain timing order and spatial rule. For example, the spatial distribution of coverage area of water, bare land and vegetation can not be obviously changed in the short time; freezing and melting of water and growth order of crops have their natural laws. In the case, these kinds of noises could be easily removed. An easy, practical method of removing noise is to establish the basic database of thermal infrared of the meteorological satellite, which contains chronological records of the meteorological satellite. After image restoration processing at the same condition for the database and the real data, reversing the basic data, then conducting gray balance processing, geometric mosaic and overlapping, whether there exists anomaly thermal radiation information can be known through the above

analysis. Those noises formed by different emissivities of objects may be removed by using this black-box handling. The emphasis is placed on strict image restoration and gray balance processing between two images (Fig. 1).

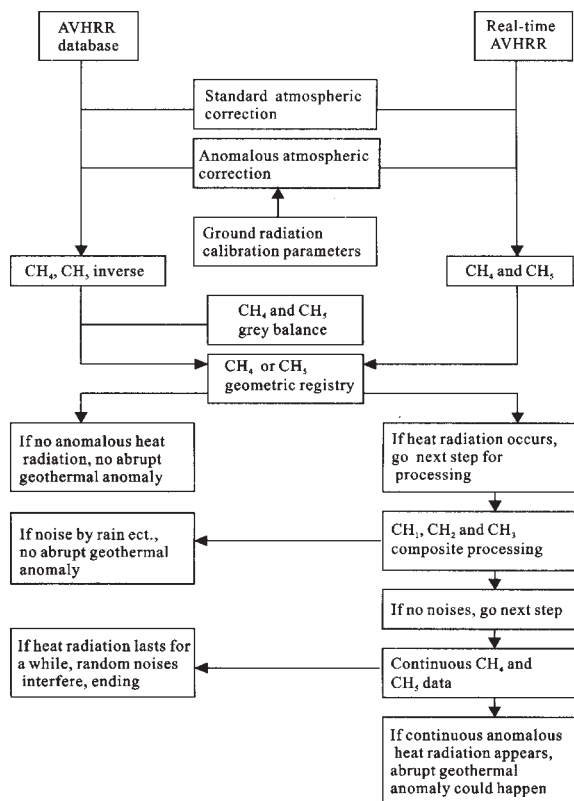


Fig.1 Flow chart of monitoring abrupt geothermal anomaly in volcanic region by meteorological satellite

4.4 Multi-source Data Processing

In order to remove some noises, multi-source remote sensing data computing must be adopted (BO, 2002). A series of abrupt events such as local rainfall, local cold and hot wind, manpower irrigation, large area pollution etc. are no rule to follow, called random noises, which not only cause an obvious variation of local thermal radiation information, but also brings on an evident change of reflection spectrum information. After the above step-by-step processing, if there still exists anomaly thermal radiation information, it is required to conduct data handling of both NOAA AVHRR reflection band and mid-infrared band to make an analysis and find if there exist random noises. If any, it makes certain that the variation should be caused by thermal radiation information; if not, it must be abrupt geothermal anomaly. As for the

change of local thermal radiation information produced by a cold and hot wind, since it lasts for a very short time, it is easier to eliminate this kind of noise only to analyze thermal infrared remote sensing of day and night for continuous several days.

5 CONCLUSIONS

Volcano monitoring involves the recording and analysis of volcano phenomena. The rapid development of space technology offers scientists a good chance of conducting a series of remote sensing technique researches. Meteorological satellite as a popular surveying device is an ideal tool to monitor abrupt geothermal anomaly during the forewarning period of volcanic eruption. Both Chinese scholars and foreign scientists have studied the Changbai Mountains volcano located in Jilin Province for a long time. At present, besides meteorological satellite monitoring, global position system (GPS) is also used to monitor crust deformation occurred before eruption.

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