IMPORTANCE OF LITHOSPHERE-COVERSPHERE-ATMOSPHERE COUPLING TO EARTHQUAKE ANOMALY RECOGNITION

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ABSTRACT

The GEOSS under construction is providing space-, aero-, ground/sea-based multiple observations on planet Earth for the seismogenic process monitoring and earthquake precaution. The stress enhancement and energy accumulation in seismic activity area change locally the physical parameters of lithosphere with the developing of a series of effects that can comprise most of the following ones: initial cracks, the fracturing of rock, the changing of electromagnetic properties, the decreasing of dielectric constant, the re-activation of P-holes, the leaking of pore-gas, and the rise of water-level. The physical states of coversphere and atmosphere are to be affected due to the lithosphere-coversphere-atmosphere (LCA) coupling, and the signals from the underground, surface, and atmosphere to satellites are to be changed with parameter anomaly. We suggested that the LCA coupling is important for understanding GEOSS observations, especially for earthquake anomaly recognition (EAR). Using deviation-time-space-thermal (DTS-T) method for EAR, three recent major earthquakes (2009 Italy L’Aquila earthquake, 2010 China Yushu earthquake and 2010-2011 New Zealand earthquake sequence) are taken as typical cases for analysis to the multi-parameters anomalies, preceding the shocking, with quasi-synchronism and geo-consistency. The specific LCA coupling effects related with the earthquakes are also discussed in brief.

Index Terms—GEOSS, lithosphere-coversphere-atmosphere (LCA) coupling, earthquake anomaly recognition (EAR), multiple parameters

1. INTRODUCTION

The Global Earth Observation System of System (GEOSS) under construction is providing space-, aero-, ground/sea-based multiple observations on planet Earth for global change and earth system process researches. One of the most important applications of GEOSS in natural disasters is the seismogenic process monitoring and earthquake precaution. Resulted from the local enhancement of crust stress in seismic activity area, the preparation of an earthquake changes locally the physical parameters of lithosphere with the developing of a series of effects that can comprise most of the following ones: initial cracks, the fracturing of rock, the changing of electromagnetic properties [1], the decreasing of dielectric constant [2], the re-activation of P-holes [3], the leaking of pore-gas [4], and the rise of water-level [5]. The physical parameters of coversphere, such as the soil moisture, the water contents and the surface temperature, are to be affected henceforth by bedrock deformation, underground degassing and thermal fluid upwelling. Furthermore, the physical parameters of atmosphere, such as the gas contents, the air humidity, the air temperature, and the reflection-transmission capability, can be changed by water-phase transition, via a greenhouse effect. The couplings between lithosphere and coversphere and between coversphere and atmosphere, called in general as lithosphere-coversphere-atmosphere (LCA) coupling [6], are complex but less cared.

The LCA coupling changes not only the physical states of lithosphere, coversphere and atmosphere itself, but also the signals from the underground, surface, and atmosphere to satellites. Some of the changing signals due to an earthquake preparation can be observed by multiple sensors in underground, in water, on ground, above ground and on satellites [7-13]. Different from normal features and trend variations, the abnormal signals, although they are very weak, are of useful information for seismic activity and of potential message for earthquake precaution. It is a big issue to pick the weak messages out from massive observations with complex noise background. Referring to the analysis on the inherent relations between multiple thermal parameters in consideration of possible lithosphere-
coversphere-atmosphere (LCA) coupling, we have developed a deviation-time-space-thermal (DTS-T) method for earthquake anomaly recognition (EAR) and already successfully applied to three earthquakes [14].

With Remote Sensing Rock Mechanic (RSRM) [15-19] experiments on loaded rock to fracturing, the rock-water-gas coupling features were studied with detections on rock stress, rock deformation, rock humidity, rock acoustic emissions, rock surface infrared radiation temperature, and rock microwave radiation temperature. It was revealed that rock humidity is of great influence on infrared radiation, which is well related with rock stress, and on microwave radiation which is well related with rock fracturing. Also, the infrared and microwave radiations have staged features but inverse change patterns before rock fracturing. For Wenchuan earthquake, China, 12 May 2008, the satellite observed infrared/microwave brightness temperatures were compared and analyzed referring to the local LCA coupling along Longmenshan faults [20].

By analyzing multi-parameters anomalies, this paper synthetically shows the local LCA coupling process related to three typical earthquakes (2009 Italy L’Aquila earthquake, 2010 China Yushu earthquake and 2010-2011 New Zealand earthquake sequence).

2. CASE STUDY

2.1. 2009 L’AQUILA EARTHQUAKE, ITALY

For the L’Aquila earthquake, Italy, 6 April 2009, surface air temperature, relative humidity, water vapor, SLHF, Gutenberg-Richter b-value and geomagnetic field are investigated based on space-, aero-, ground- and sea-based multiple observations. The results show that: a) Abnormal temperature, relative humidity and water vapor appeared near the epicenter around 1 week before the mainshock; b) Abnormal surface latent heat flux (SLHF) appeared near the epicenter on March 16 2009, i.e. 22 days before the mainshock; c) The entropy of earthquakes, related to b-value, has evolved in 3 phases: a generalized increase in preparation phase, a sudden jump 6 days before the mainshock in concentration phase and a decrease “after” the mainshock in diffusive phase [21]; d) Entropy analysis of the transfer functions from the geomagnetic components, points out clear temporal burst regimes of a few distinct harmonics about one year before the main shock, with subsequent occurrences 10 and 6 months earlier than the mainshock. Together with the various published anomalies [22], we conclude that multi-parameters anomalies appeared quasi-synchronously about 2-8 days before the earthquake, and SLHF is an intermediate parameter between atmosphere and ionosphere anomalies. Referring to the existing mechanisms [24, 25], the local LCA coupling process can be explained using a possible physical model. Firstly, the long-term tectonic activity is enhanced in the latter period of the seismogenic process, leading to multiple effects including piezoelectric effect, radon leaking out and alpha particles emitting, P-holes activating and recombining, and hence causing air ionization at the ground-air interface. Secondly, the uplift of ion lead to the generation of additional electric field and then the excitation of atmosphere molecules, causing stimulated IR emission and a subsequent increase in VLF wave activity in the magnetosphere. Thirdly, when the nucleus of water gets attached to the ions, latent heat will release and hence result in local SLHF increases. Finally, the cold water vapor forming the clouds is heated and becomes invisible, and hence produces the dry zone on the cloudiness background (or called earthquake cloud).

2.2. 2010 YUSHU EARTHQUAKE, CHINA

For the Yushu earthquake, China, 13 April 2010, surface air temperature, infrared/microwave brightness temperature, SLHF and VLF are analyzed and compared based on space-, aero-, ground- and sea-based multiple observations. The results show that: a) On 16 March 2010, there were a short-term strip-shaped zone of enhanced TIR and a dry layer on the cloudiness background (or called earthquake cloud) geographically overlapping the regional faults in the seismogenic zone; b) Abnormal peaks in the time-series of near-surface air temperature and infrared/microwave brightness temperature from the epicenter pixel all appeared on 16 March 2010; c) Abnormal SLHF firstly appeared to the west of the epicenter on March 16, and then enhanced forming two areas on both sides of the epicenter on April 9. Together with the report that VLF magnetic field perturbations above the epicenter and its south conjugate point during the night of 9 April, 2010 [23], we conclude that multi-parameters anomalies appeared quasi-synchronously about 28 and 4 days before the earthquake, and SLHF is an intermediate parameter between atmosphere and ionosphere anomalies. Referring to the existing mechanisms [24, 25], the local LCA coupling process can be explained using a possible physical model. Firstly, the long-term tectonic activity is enhanced in the latter period of the seismogenic process, leading to multiple effects including piezoelectric effect, radon leaking out and alpha particles emitting, P-holes activating and recombining, and hence causing air ionization at the ground-air interface. Secondly, the uplift of ion lead to the generation of additional electric field and then the excitation of atmosphere molecules, causing stimulated IR emission and a subsequent increase in VLF wave activity in the magnetosphere. Thirdly, when the nucleus of water gets attached to the ions, latent heat will release and hence result in local SLHF increases. Finally, the cold water vapor forming the clouds is heated and becomes invisible, and hence produces the dry zone on the cloudiness background (or called earthquake cloud).

2.3. 2010-2011 NEW ZEALAND EARTHQUAKE SEQUENCE

For the New Zealand earthquake sequence 2010-2011, multi-parameters including surface air temperature, SLHF, GPS displacement and soil moisture are investigated by using a long-term statistical analysis method. It shows that local thermal and deformation anomalies appeared quasi-synchronously not only about one month before the Sept. 3, 2010, Mw 7.1 mainshock, but also appeared ten days before the Feb. 21, 2011, Mw 6.3 aftershock [6]. The special LCA coupling processes are interpreted initially referring to the regional tectonic geology (http://all-geo.org/highlyallochthonous/), geo-thermal hydrology, local meteorology and tectonic motion...
The specific LCA mechanisms include (Fig.1): a) magmatic-hydrothermal upwelling fluids via convection heat the upper-lying ground layers; b) soil moisture increment, due to the rise of ground water level, alters the physical properties of land surface, and thereby affects the different components of the surface energy balance; c) the underground pore gases leaking to the atmosphere absorb more Earth’s infrared radiation due to greenhouse effect, and thus led to the accumulation of heat near the surface; d) The positive holes activating and recombining, and thus led to a stimulated electromagnetic emission in the TIR window and the heating of a thin surface layer.

3. CONCLUSION AND DISCUSSION

In general, the results of the above case studies show some common features: a) the anomalies of different parameters have quasi-synchronism (i. e., the number of anomalies of different parameters might be more or less, but at least two parameters appear almost at the same time before the shocking); b) the anomalies of different parameters have geo-consistency (i. e., the different anomalies appear almost in the same place, and are spatially related with the tectonic structure and/or active faults in the seismogenic zone). The quasi-synchronous multi-parameters anomalies and their geo-spatial relationship allow us to interpret initially the specific LCA coupling processes. In turn, the number of multi-parameters being effective for a certain earthquake, the quasi-synchronism and the geo-consistency of multi-parameters anomalies can vary according to the different seismogenic zone and local coversphere/ atmosphere conditions. Hence, a deeper study on the mechanisms and localized processes of LCA coupling will be helpful. We suggest that the LCA coupling is important for understanding GEOSS observations, especially for EAR.

It is reasonable to think that the occurrence of quasi-synchronous multi-parameters anomalies with geo-consistency anticipates a great change in the solid earth and LCA, in the sense that the final happening of the earthquake might be preceded with several occurrences of quasi-synchronous multi-parameters anomalies with geo-consistency. For 2009 L’Aquila Earthquake, there were two occurrences of quasi-synchronous multi-parameters anomalies, one is 2-8 days (b-value, TIR, temperature, relative humidity, water vapor, VLF, ULF and Vp/Vs ratios) before the mainshock, and the other is in the prior 22 days (foF2, SLHF). For 2010 Yushu earthquake, there were also two anomalies: one is about 28 days (near-surface air temperature, infrared/microwave brightness temperature, and SLHF) before the earthquake, the other is 4 days (SLHF, VLF). For 2010-2011 New Zealand earthquake sequence, there was one occurrence one month and ten days before the Sept. 3, 2010, Mw 7.1 mainshock and the Feb. 21, 2011, Mw 6.3 aftershock, respectively. The number of occurrence of quasi-synchronous multi-parameters anomalies with geo-consistency, and the number of parameters as well as the parameter properties, should depend on the specific lithosphere and coversphere conditions.

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5. REFERENCES


Fig. 1. A schematic plot of the LCA coupling mode interpreting the quasi-synchronous multi-parameter anomalies associated with the 2010-2011 New Zealand earthquake sequence. Firstly, the magmatic-hydrothermal fluids upwelled via convection from the deep crust and mantle had increased the geotemperature in particular zones, which were connected with subsurface fluids. Secondly, soil moisture increased due to the rising in ground water level had altered the physical properties of the land surface (i.e., thermal conductivity, albedo and evaporation), which led to local differences in latent heat flux and ground heat flux. Thirdly, the leaking out of trapped pore gases from underground to lower atmosphere had produced local greenhouse effect, which resulted in more net radiation locally. Finally, positive holes in rockmass were activated by stresses and recombined at the surface, which led to a stimulated electromagnetic emission in the TIR window and the heating of a thin surface layer (from K. Qin et al., 2012)