Self-organized criticality of high temperature events

To cite this article: Zuhan Liu 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **289** 012005

IOP Conf. Series: Earth and Environmental Science **289** (2019) 012005 doi:10.1088/1755-1315/289/1/012005

Self-organized criticality of high temperature events

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Abstract. The high temperature events are frequently occurred due to global climate change, which is harmful to human existence, social and economic development, water resources and ecologic environment. The goal is to improve the ability of coping extreme weather events for the whole society and promote the sustainable development of national economy. Based on the self-organized critical and previous research, this paper explored the frequency-intensity distribution of temperature change satisfied Gutenberg-Richter power-law relation. Then, a numerical sandpile model with decay coefficient is constructed to reveal inherent dynamic mechanism of high temperature events based on the idea of sand model. The study on occurring mechanism, temporal evolution and inherent dynamic behavior of high temperature events, which could provide the scientific basis and important reference for effective establishing all kinds of emergency plan such as extreme weather disaster prevention, mitigation and relief.

1. Introduction

Self-organization is a process of internal organization, which increases its complexity without external guidance or management [1,2] . Therefore, if the system does not need to be adjusted by parameters and automatically reaches the critical state, it is called self-organized criticality, which is used to describe the inherent mechanisms of criticality, long-range correlation, $1/f^{\beta}$ noise and scale invariance (namely fractal) of unbalanced complex systems [3-5].

In the critical state, the measured values of the physical quantities of system will appear a power-law relation, which is as many phenomena found in nature, such as forest fires [6], earthquakes [7] and landslides [8]. Therefore, if a system had its manifested below three basic characteristics: the event size distribution being scale-invariant; it appearing as $1/f^{\beta}$ noise in the time domain and it having long memory, it tends to near critical stable state [9]. And the SOC behaviors may be the internal mechanism of system evolution.

There are many scholars who have studied some SOC behaviors of climatic factors sequence [10-

17]. So, whether has is SOC behaviors in high temperature events in Jiangxi Province or not? From the existed documents, temperature series have above three characteristics. So what is the root cause or mechanism of the phenomenon? A sandpile model is the most famous model for studying SOC phenomena. Therefore, this paper establishs a sandpile model for high temperature events to grasp the main characteristics of the time evolution of its change process from a macro perspective and explore the dynamic physical mechanism of its change.

2. Data and theoretical methods

In this paper, Jiangxi Province as the study area. And the research object is extracted high temperature data used percentile threshold method from January 1, 1961 to December 31, 2014. These data come from 83 ground meteorological observation stations in Jiangxi Province and American National Center for Environment Prediction (NCEP) global reanalysis data.

A numerical sandpile model with decay coefficient of high temperature events is constructed, which is primarily based on BTW sandpile model. The model is mainly divided into five steps, and its specific algorithm can consult the Reference [17]

The frequency-intensity distribution of pollution indexes are found to satisfy power-law relation that is similar to the Gutenberg-Richter law in the earthquakes study [18,19] , suggesting there is inherent dynamical connection between small and high events of air pollution.

3. The frequency-intensity distribution of high temperature event

Figure 1 shows the frequency-intensity distribution of high temperature events. We find the frequency of high temperature events exhibits a power-law decayed distribution with events' size. The scaling exponent and scale-invariant interval are respectively 1.72 and 0.72 with the least square method. The distribution is a significant Gutenberg-Richter power-law relationship, which is one of the most significant signs of SOC behaviors. Therefore, we believe that the mechanism of occurrence of high temperature events in Jiangxi Province has a self-organized critical feature. Moreover, its top is significantly deviated from the linear relationship, mainly because these statistical high temperature data ignore huge amounts of low temperature data during a statistical process. A loss of low temperature data lead to deviating off the linear relationship, and the same phenomenon occurs when Peters and Christensen studied precipitation process.

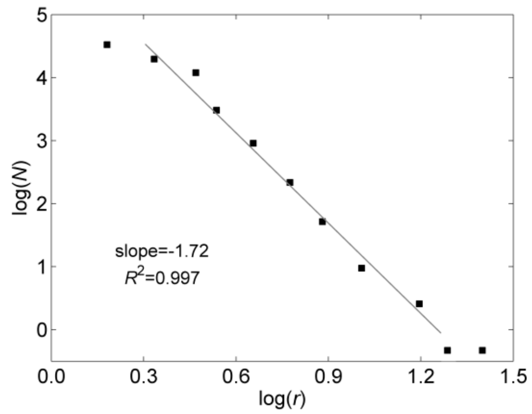

Fig. 1. The number density of temperature change events per year N, with size greater than or equal to r, versus change event size r on a double logarithmic scale.

So, there is no reason to believe that high and low temperature events have a completely different production mechanism and fully independent in the constant scale section. In other words, they are possible to have the same dynamic mechanism.

Quantitative and qualitative discussions about the above the self-organized criticality of high temperature events are made. In order to understanding how high temperature events itself form self-organized criticality, it needs to be established a sandpile model of high temperature events.

4. The numerical sandpile model of high temperature events

In order to ensure that the calculation has a strict statistical significance, and truly reflect the evolution trend of the numerical sandpile system, two-dimensional 50×50 grid scale with initial assignment 0 is selected, and a million dual-time stepping are counted when it reaches 100,000 times to start counting. The main aim of initial 100,000 times is to enter critical stable state.

In the near attenuation k =0.011, different k values 0.09, 0.01and 0.012 are selected for the constructed numerical sandpile model of high temperature events and its frequency-intensity relation is simulated. And satisfactory results have been obtained through many parameters debugging calculations. In the double logarithmic degree distribution as shown in the Figure 2, there exist a markedly power-law relation between sollapse size high temperature events *s and its statistical frequency* $P(s)$, which can be described by $P(s)\propto s^{-\alpha}$. Its fitted index or scaling exponent is 7.87, and the scale invariant interval is 0.72. Compared to Figure 2, we find that the numerical simulation results are in good agreement with the frequency-intensity relation of temperature events, viz. its self-organized criticality is shown significantly.

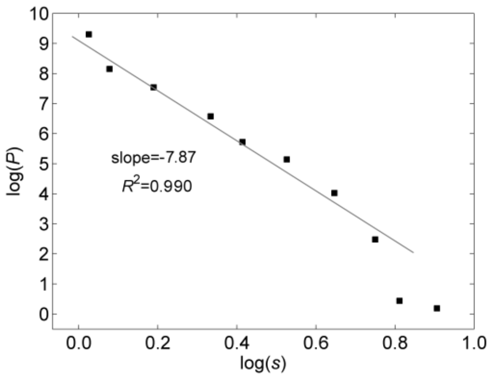

Fig. 2. Avalanche size distribution for the sand model of high temperature events when k=0.01.

5. Discussions and conclusions

The temporal evolution and its inner dynamic behaviors were studied based on SOC in this paper. We combined the qualitative and quantitative analysis to explore self-organized criticality of high temperature events. Specifically, the Gutenberg-Richter power-law relation of its frequency- intensity relation was firstly authenticated. Then, a numerical sandpile model with decay coefficient is constructed based on the concept of sandpile model. The results have important theoretical significance application value to emergence plans for extreme climate events.

Acknowledgments. This work was supported by the China Postdoctoral Science Foundation (2016M600515), Jiangxi Graduate Innovative Special Fund Project (2017KY48), Opening Fund of Key Laboratory of Poyang Lake Wetland, Watershed Research (Jiangxi Normal University) Ministry of Education (PK2017002), Jiangxi Postdoctoral Daily Fund Project(2016RC25), Science and

Technology Project of Jiangxi Provincial Department of Education (GJJ180926) and the National Natural Science Foundation of China (61703199 and 51669014).

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