The Fractal Dimension Distribution of the Short–Term Climate System in China and It's Connection with the Monsoon Climate①

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ABSTRACT

By analyzing the Fractal Dimension(FD) distribution of the Short–range Climate system(SCS) in China, it is found that the FD varies in different region and this just agrees with the regionality of the monsoon climate in China. The FD of the SCS Lays between 2.0 and 5.0. In the vast eastern area of China, the FD almost grows gradually with the latitude. Line 4.0 is along the mountain chains from the Nanlin Mountain to the Wuyi Mountain. North of the line the FD varies only slightly and all are above 4.0. Only in coastal islands the FD is smaller than 3.0.

Key words: Short–range Climate System(SCS), Fractal Dimension(FD), Monsoon climate, Climate division

I. INTRODUCTION

It has been pointed out in many researches that many atmospheric systems of different time and space scale are nonlinear systems and have strange attractors. The dimension of a strange attractor not only depicts the special behaviour of this system but also shows the least independent variables needed to study the evolution of this system. Packard et al. (1980) proposed that phase space can be reconstructed by the time series of a single variable. Takens(1981) had demonstrated Packard's theory. Grassberger and Procaccia(1983) and Fraedrich(1986) respectively gave the method to estimate the FD from observational data. Their works and some other studies as by Eckman and Ruelle (1985) and Zeng, et al.(1992) estimated the FD of weather, climate system and atmospheric turbulent flow. In recent years, the FD of some single atmospheric systems has been studied in China, such as Zheng and Liu(1992) and Liu(1986), et al. Our work will give a systematic analysis of the FD of the SCS in China.

In Section II, the FD distribution of the SCS in China will be shown, using the time series of monthly average temperature during about 100 years of nearly 30 stations. In Section III, the internal feature of monsoon climate in China and its connection with the FD distribution will be discussed.

II. DATA METHOD AND RESULTS

The data used here are the monthly average temperature series from 1900 to 1986 in nearly 30 observational stations.

Detailed method of the FD calculation can be found in Lin(1993). Fig.1 shows the FD distribution of the SCS in China.

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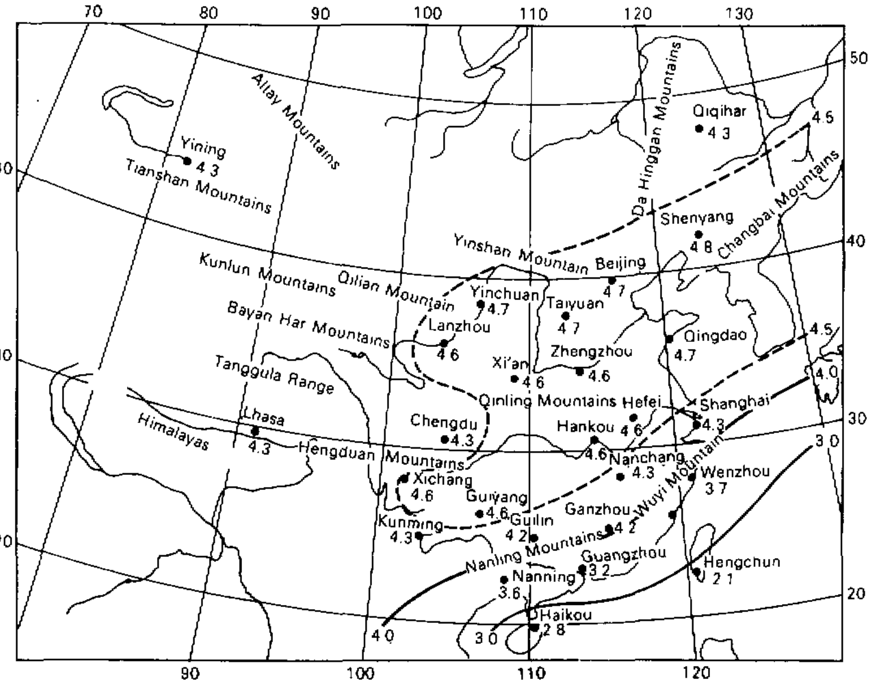

Fig.1. The fractal dimension distribution of the short–range climate in China.

It can be seen from Fig.1 that:

(1) The FD in each station is fractal. This proves that the SCS in China is chaotic. FD varies from 2.0 to 5.0 and in eastern China it grows qradually with latitude.

(2) Line 4.0 approximately lies along the Nanlin–Wuyi mountain chains. To the north of the line, the FD ranges from 4.0 to 5.0 although it is of differences in different areas, and this is the area with the most complex SCS change in China. On the other hand, to the south of the line, especially in the coastal islands, the FD is relatively small, and the SCS change is relatively simple there.

(3) We can judge the complexity of a certain nonlinear dynamic system by its FD. The least independent variables needed to study is INT (D)+1, the smallest integer larger than the FD. Hence we need at least 3 to 5 independent variables to study the SCS in China. To the north of the line 4.0 we need 5, and 4 to the south of it, and 3 for the coastal islands.

III. DISCUSSION

China has a large territory, the behaviour of climate system varies dramatically with different regions because the distribution of sea and land, complex terrains and the dominant atmospheric circulation system is different in different regions. Particularly China lies in the world most famous monsoon climate zone, the influence of monsoon is important to the complexity of the formation and evolution of the regional climate in China, thus we believe that the FD distribution shown in Fig.1 reflects the influence of the above factors, especially the regionality of the monsoon climate in China. The study of the relationship between the

FD distribution and monsoon climate can give synoptic and climatic significance of the FD calculation and also serve to be a criterion to the climate division in China.

It is shown in Fig.1 that the FD in the vast eastern area of China increases gradually with latitude. The monsoon climate division in China according to the position and movement of Polar Front pointed out that the eastern China lies in the tropical and subtropical monsoon area. In summer, July to August, when the average Polar Front moves to its northeast position, the ITCZ is also at its northeast position and serves to be division line of the tropical and subtropical climate. It can be easily found that this division line roughly corresponds to the line 4.0 in Fig.1. Many studies show that it is a distinct geographical climate division line of China. The tropical monsoon area in China lies in the southern area of that line. In winter, the monsoon is very weak and it doesn't maintain very long because of the protection of terrains such as mountains and the large thermal–inertia of the nearby tropical ocean, The southeast monsoon and western monsoon are all from tropical ocean and much similar in their nature, meanwhile northeast trade–wind and equatorial easterlies occasionally affect this area in winter. All these unique features make this area simplest in the SCS in China and the FD below 4.0, especially in the coastal island stations as Hengchun and Haikou both being smaller than 3.0.

However, in the subtropical area which lies to the north of line 4.0, the dominant atmospheric system is not always the same. The alternation of winter and summer monsoon is very significant. The summer monsoon comes from tropical oceans, causing damp, rainy and hot weather and the high cloud amount and relative humidity. When the winter monsoon is in control, its intensity differs with time, occasionally with the cold wave acting. The main climate features here cause not only the interannual difference of the large monthly average temperature but also the large temperature difference anomaly. This feature is quite different from the tropical monsoon area, we also found this area the most complex one in the SCS in China, thus it needs more independent variable.

Concerning the latitude, the distance from sea, the terrain, the dominant planetary circulation system, the stability of monsoon, the inner feature of the monsoon climate change and other factors, the subtropical monsoon area in China can be divided in more detail into 5 districts. They are the Northeast China Area, the Hetao (the Great Bend of the Yellow River) Area, the North China, the Sichuan Basin Area and the Area of the middle and lower reaches of the Yangtze River (see this division in Gao, 1990). Fig.1 also shows the difference in FD in different districts. For instance, the FD of Qiqihar in Northeast China Area is relatively small while in North China Area the FD is above 4.5. In the Sichuan Basin Area, monsoon climate is not significant because of the protection of huge terrains, the FD is much small.

From Fig.1 we can also see that, different from the monsoon climate in the eastern China, the FDs in Tibetan Plateau area and Westerlies Area are all between 4.0 and 4.5. Line 4.5 just consists with the north–south mountain range near 100°E which runs from Yinshan mountain Chain and extends northeastward. The Tibetan Plateau is more than 3000 km in height, it is dominated by upper planetary circulation. This is greatly different from the eastern area in China. Moreover the Westerlies Area is seldom influenced by the tropical monsoon. Therefore in the same latitude the FD of these two areas is lower than that of the eastern subtropical monsoon area.

In brief, from above discussion, we can conclude that the regionality of the monsoon climate is the main reason of the regional FD distribution of SCS in China. The line 4.0 in Fig.1, which is along with Nanlin–Wuyi Mountain Chains, is a very important geographical climate division line in China. Line 3.0 is consistent with the southeast coastline. The FD estimation also gives the least variables to study the SCS in China. We suggest taking 5 to the north of Nanlin Mountain Chains but 4 to the south of it including coastal island area. It is very important to reconstruct climate models using historical data as described in Lin(1993) and Huang and Yi(1991), and to study the dimension selection of phase reconstruction of the short–term climate in China. This paper is a preliminary discussion to the connection of the FD distribution and monsoon climate. It still deserves further study.

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