地理学报(英文版) 2001年第11卷第2期

Asynchronism-synchronism of regional precipitation in South-to-North Water Transfer planned areas

作者: ZHENG Hong-xing et al.

Abstract: This paper proposes a method on analyzing the asynchronism-synchronism of precipitation of different hydrol ogical regions regarding the S-to-N water transfer areas of eastern China. The general process of the analysis includ es three steps. Firstly, we created the rainfall series of the region concerned by calculating the regional average r ainfall of the stations in the area with the help of the classical Thiessen Polygon method. Secondly, the standards o f assessment indices for wetness or dryness are set according to Gamma distribution function with a certain probabili ty P 37.5% or 62.5% given respectively. Finally, the frequency of nine combinations are counted as the quantitative f eature of asynchronism and synchronism in three time scales, that is the yearly, seasonal and monthly scales. The asy nchronism-synchronism of two region pairs has been estimated. The results show that the frequency of precipitation as ynchronism in 1957-1998 is larger than the synchronism frequency for both the North China-middle and lower Yangtze Ri ver pair and for the North China-upper Hanjiang River pair. As for the synchronism phenomena, the frequency of Nd-Sd is rather low. As the combinations that are suitable for water transfers are Nd-Sw, Nn-Sw, Nd-Sn and Nn-Sn, the tota l frequency of these combinations for North China-middle and lower Yangtze River is 40% on an annual basis, but only 28% in spring when water shortages are most likely to occur. The total frequency of these combinations for North Chin a-upper Hanjiang River is about 24% on an annual basis, but 35% in spring and winter. It should be noted that if futu re precipitation patterns are similar to that of the period 1957-1998, it is very important to change the natural cha racter of asynchronism-synchronism by enhancing the capability of hydro-projects regulation and improving management of the water transfer project.

Asynchronism-synchronism of regional precipitation in South-to-North Water Transfer planned areas ZHENG Hong-xing, LI U Chang-ming (Institute of Geographic Sciences and Natural Resources Research, CAS, Beijing 100101, China) 1 Introduc tion The geographical feature of China is quite complex with an obvious spatial heterogeneity. At the sense of spatia l distribution of precipitation, under the impacts of the relative position of land to ocean and the monsoon climat e, the amount of precipitation tends to decrease from south to north and from southeast to northwest. According to th e hydrological regionalization, the North China Plain, one of the social and economic centers of China[1,2], is a reg ion short of water resources with annual precipitation less than 600 mm, whereas in the middle part of the plain the precipitation is even less than 500 mm. The amount of water resources per unit area is only 3765m3/ha, which is just 1/5 of the mean level of the whole country. On the other hand, along with rapid economic development of the region i n recent years, the amount of water demand is increasing continuously, which has resulted in a more serious water cri sis[3]. Transferring water from the middle and lower reaches of the Yangtze River to North China, which is the so-cal led South-to-North Water Transfer Project, has been planned for a long time in order to eliminate water resources cri sis in North China. However, on the discussion about the feasibility of the project, the attention is mainly paid to the aspects such as technical constraint, economic rationality and environmental safety[4]. In fact, for such a proje ct concerning the redistribution of water resources among different basins, it is of great importance to discuss the synchronism features of water resources for the region concerned by taking both the spatial heterogeneity and tempora l fluctuation into account. For the synchronism features of the two regions concerned is the basis for trans-basinal water distribution, it is one of the most important parameters for project planning and designing, which may affect t he reliability of the water distribution project. In this research, we try to provide the rational basis for the Sout h-to-North Water Transfer Project planning and designing by analyzing the water resources synchronism features for North China versus the middle and lower reaches of the Yangtze River and North China versus the upper reaches of the Hanjiang River. Usually, the water resources of a certain region are estimated according to its natural runoff. The features of the runoff, however, have been distorted greatly due to the impact of human activities. The synchronism features should be obtained by analyzing precipitation rather than by natural runoff series. We regard precipitation as the original water resources for a certain region and use it as the basis for water resources synchronism analysis. 2 Data collection and processing On analyzing the synchronism features by precipitation series, we have employed the meteorological data from China Meteorological Bureau. The data used in the research covered a spatial scope from Nanchang to Beijing in the longitudinal direction and from Hanzhong to Shanghai in the latitudinal direction. The time series of data used are the monthly precipitation data from 1957 to 1998. On the basis of the materials, the synchronism features of every two regions concerned are shown in three different time scales (monthly, seasonally and yearly). In general, the process of synchronism analysis includes three main steps as follows. Firstly, the mean precipitation of the region concerned is estimated in different time scales. Secondly, the standards are set for classifying the precipitation series which should be divided into three categories: dryness, normal and wetness. And thirdly, we may calculate the frequency of each combination type for regions concerned (water export region and water import region) on the basis of classification in the series. Table 1 F-test and T-test for different annual rainfall series of representative stations (?=0.05) 2.1 Test of precipitation data series Precipitation synchronism analysis is based on the synchronous observation data. However, with the constraint of data availability, the monthly series of the stations from 1957-1998 in the study area are selected. To ensure the reliability of the research, it is necessary to test the data series. The representation of the data series can be confirmed by hypothesis testing. In this research, F-test and T-test have been called in analyzing different features, especially the mean value and standard error, between any two series of three controlling stations, that is Beijing, Hankou and Hanzhong. Table 1 shows the results of testing. From Table 1, it can be seen that the two time series of different length can be accepted as the representative one. In addition to the hypothesis testing, the representation of the series selected can be confirmed by other researches[5], which show that there is a 36-year wetness oscillation in eastern China. For the length of the time series we selected is longer than 36 years, the series selected may reflect the features of precipitation variation. 2.2 Calculation for regional mean precipitation The mean precipitation of a region concerned is the basis for further analyzing precipitation synchronism features. To calculate the mean value of precipitation, the Thiesson polygon method is introduced in the research. According to the method, the region concerned is divided into several polygons from stations selected. Then the relative area of every polygon region is estimated. We can get the mean precipitation of any region by the formula (1) shown below: where Xi(t) is the mean precipitation of the i hydrological region; Xij(t) is the observed precipitation of the j station in the i region; Aj is the controlling area of station j; n is the number of stations in a certain region; and t means different time scales, that is the yearly, seasonal and monthly scales. In this research, the periods of spring, summer, autumn and winter are from March to May, June to August, September to November and December to February respectively. As for the upper reaches of the Hanjiang River, there are not so many meteorological stations available for Thiesson polygon method, thus the mean precipitation is the average precipitation of the stations in the region. Figure 1 shows the calculated annual rainfall of the three regions we focus on in the research. And Table 2 gives some important parameters of the regions˘ rainfall series. Figure 1 Annual rainfall of North China, the middle and lower reaches of the Yangtze River and the upper reaches of the Hanjiang River (1957-1998) Table 2 Statistical characters of precipitation series of the study areas 2.3 Definition of wetness and dryness The precipitation synchronism of every two regions concerned can be described as the probability of a certain climate condition that when one region is in a condition of wetness, dryness or normal, the frequency of wetness, dryness or normal of the other region. In such a sense, we need to define wetness, dryness or normal firstly. Ordinarily, the standards given to define wetness or dryness are set according to the probability distribution of precipitation. By the maximum-likelihood method, we can estimate the parameters of the probability density function on the basis of the time series observed precipitation. Then we can induce the standard according to a certain probability P. The standard may be described as the value that the integral probability of precipitation less than it is just equal to P. And the standards can be calculated according to expression (2) shown as follows: where xp is the value of the standard. Some results show that the best probability distribution of precipitation is the Gamma distribution function[6], especially in northern China[7]. The density function of such a probability distribution can be described as expression (3): where ? (>0) and ? (>0) are called scale parameter and shape parameter respectively. Figure 2 shows the correlation between the experiential probability and the expected probability. It is true that the Gamma distribution funct ion is quite fit for describing the distribution features of the precipitation series of all the three regions. So we may adopt this to define the standard. According to the standards we can classify the precipitation into several types. In the research here we just set 3 types in classifying the precipitation series, that is the wetness, normal and dryness, where the probability P for wetness and dryness standards setting is 62.5% and 37.5% respectively. Thus, we can define the type of precipitation during a certain period according to expression (4). From the above discussion, we can get the assessment standards of different regions in a different period just as shown in Table 3. Table 3 Index value of dryness and wetness of the study areas (Xp=0.625, Xp=0.375, Equation 4, mm) Figure 2 Gamma P-P plots for annual rainfall of North China (a), the middle and lower reaches of the Yangtze River (b) and the upper reaches of the Hanjiang River (c) 2.4 Synchronism and asynchronism analysis With the help of the indices we set in Table 3, we have assessed the precipitation type of the three regions in a certain time scale. The result for any two regions indicates the asynchronism-synchronism frequency of the regions concerned. Table 4 shows the results for North China and the middle and lower reaches of the Yangtze River, and for North China and the upper reaches of the Hanjiang River for the period 1957-1998. Because three rainfall classifications?dryness (d), normal (n) and wetness (w)?are used, nine possible combinations, i.e., Nw-Sw, Nw-Sn, Nw-Sd, Nn-Sw, Nn-Sn, Nn-Sd, Nd-Sw, Nd-Sn and Nd-Sd are shown for each pair of the regions. Here, N and S represent north and south respectively, and w, n and d are wetness, normal and dryness respectively. In Table 4, N denotes North China and S denotes the Yangtze River or the Hanjiang River. Table 4 Asynchronism-synchronism frequency of rainfall between different regions Figure 3 Rainfall asynchronism-synchronism frequency for North China against middle and lower reaches of Yangtze River /% 3 Results 3.1 Precipitation synchronism for North China vs. the middle and lower reaches of the Yangtze River In Figure 3, more details about the asynchronism-synchronism of North China (water import region) vs. the middle and lower reaches of the Yangtze River (water export region) are given. From Figure 3 and Table 4, we can find that: 1) In view of the yearly scale, the synchronism frequency is 45%. In the seasonal scale, there is a synchronism frequency higher than 40% except for summer (31%). Especially in spring, when water is very important for agriculture, the frequency is up to 47%. In the monthly scale, there is a synchronism frequency higher than 40% except for March, July and August. Of all the twelve months, the frequency of November and December is the highest (57%), whereas that of July is the lowest (26%). 2) Among the three types of synchronism, that is Nn-Sn, Nd-Sd and Nw-Sw, the frequency of Nd-Sd is rather low. In the yearly scale, it is only 14%, whereas the frequency of Nw-Sw is the highest (19%). In the seasonal scale, the frequency of Nd-Sd is the highest in spring whereas that of the other seasons is lower than 20%, especially in summer, it is lower than 10%. However, the frequencies of Nd-Sd in summer and autumn are the highest, which may account for 62% and 53% of the total synchronism frequency respectively. 3) As for the asynchronism, in the yearly scale, the total frequency of Nd/n-Sw/n (i.e. Nd-Sw, Nd-Sn and Nn-Sw) is just about the same to that of Nw/n-Sd/n (i.e. Nw-Sd, Nw-Sn and Nn-Sd), while the former is a little higher. Of all the 6 types, the frequency of Nd-Sw, Nw-Sd and Nw-Sn is the highest, each occupying 22% of the total frequency of asynchronism. However, in spring and winter, the frequency of Sw-Nn is the highest, which is about 14% and 17% respectively. In summer, the frequencies of Nd-Sw (17%) and Nw-Sd (21%) are higher than the other combination types. In autumn, the Nd-Sn and Nn-Sd occur more frequently than the others. In general, the total asynchronism frequency of Nd/n-Sw/n is higher in summer and winter whereas that of Nw/n-Sd/n is higher in spring and autumn. In the monthly scale, the frequency of Nd/n-Sw/n goes to the highest in October (40%) and the lowest in April and November (19%), whereas the frequency of Nw/n-Sd/n is at the highest in July (43%) and at the lowest in October (12%). 4) Considering the South-to-North Water Transfer Project, of all the 9 combinations, the four types of combinations such as Nd-Sw, Nn-Sw, Nd-Sn and Nn-Sn are more situable for this project operation. For the other combinations, the condition that the water export region has not enough water to be transferred and the water import region do not need water transferring may happen. For the two regions considered, in the yearly scale, the total frequency of these four combinations is about 40%, but in spring it is only 28%. Figure 4 Rainfall asynchronism-synchronism frequency for North China and the upper reaches of the Hanjiang River in 1957-1998 (%) 3.2 Asynchronism-synchronism for North China vs. the upper reaches of the Hanjiang River The asynchronism-synchronism of the North China Plain and the upper reaches of the Hanjiang River pair is shown in Figure 4 and Table 4. The following points are identified. 1) In the yearly scale, the synchronism frequency of the region pair is higher than 45%, whereas in the seasonal scale, the frequency is higher than 45% except summer, and that of winter is the highest (57%). Concerning the monthly scale, the frequency of December is the highest (71%). 2) Of the three types of synchronism, the frequency of Nd-Sd is lower than 20% in the yearly scale and it is only 24% in spring in the seasonal scale, whereas the frequency of Nw-Sw is relatively higher (> 20%) in summer, autumn and winter. 3) For the asynchronism of the region pair, the total frequency of Nd/n-Sw/n is about the same as that of Nw/n-Sd/n but the latter is a little higher. The three combinations of Nd-Sw, N w-Sn and Nn-Sd are higher than the others are in the yearly scale. In the seasonal scale, in spring, Nd-Sn and Nw-Sn occur more frequently than others do, whereas in summer Nd-Sw and Nw-Sd occupy a larger percentage. Respectively, in autumn and winter, the facts of Nn-Sd and Nw-Sn occur more frequently. On the whole, the total frequency of Nd/n-Sw/n is higher in spring and summer, whereas that of Nw/n-Sd/n is higher in summer and autumn. Both are nearly 30%. 4) The total frequency of the four combinations, which are suitable for water transfer, is 24% in the yearly scale. But in spring and winter, it is higher than 35%.

4 Discussion

The results show that, for both the region pairs, the frequency of asymchronism is higher than that of synchronism. Of the three combinations of synchronism, the frequency of Nd-Sd is rather low. However, with regard to the region pair for North China and the middle and lower reaches of the Yangtze River, the total frequency of the four combinations, which is suitable for south to north water transfer, is 40% in the yearly scale. But it is only 28% in spring when the North China region is in a condition of water resources deficit. Comparatively, for the North China and the upper reaches of the Hanjiang River pair, the frequency of the four combinations is only 24% in the yearly scale but higher in spring and winter (35%). On this account, it is of great importance to take the adjustment capacity of the water transfer project into account during project planning and designing. Moreover, the adjustment projects must be well collocated and managed to change the natural asymchronism-synchronism of the regions concerned, which may enhance the reliability and the profit of the water transfer project. Through the process of synchronism analysis, it can be seen that the assessment of the precipitation series is an important step. Though there are many methods for the wetness or dryness assessment, the Gamma distribution function as the rational one is adopted and the probabilities of 62.5% and 37.5% for classification are set. As the assessment may be different due to different index standards, the results of synchronism analysis may be different correspondingly. Furthermore, it should be pointed out that the asynchronism-synchronism analysis on dryness or wetness of the precipitation series is not the same as the analysis on drought or waterlogging. The wetness or dryness assessment is in view of water resources, which focuses on the amount of water. However, the drought or waterlogging assessment is on the base of geographical disasters. The difference is confirmed by the results of synchronism assessment on drought and waterlogging on the basis of the drought/waterlogging information of the recent 500 years in China[8]. Take the region pair for North China and the middle and lower reaches of the Yangtze River for example, the asynchronism frequency of drought/waterlogging is 67% higher than that of dryness/wetness (55%), whereas the synchronism frequency of the former is lower than that of the latter. However, for both assessment results, the asynchronism frequency is higher than the synchronism one, which means that the two assessments are closely related to each other. Finally, it must be noted that the asynchronism-synchronism analysis on precipitation series of two different regions just offers the climatic background information of the water transfer regions concerned. The purpose of the analysis is to provide helpful physio-geographical parameters for the South-to-North Water Transfer Project planning. Furthermore the rainfall of a region may not be regarded as the whole water resources, which may also be affected by the groundwater and the water inflow from other regions. However, the necessity of the water transfer project mainly depends on the balance between water supply and water demand in northern China, especially in the North China Plain.

5 Conclusions

With reference to water resources deficit in North China, especially in the North China Plain, the South-to-North Water Transfer Project has been under consideration for several decades. For such a project concerning the redistribution of water resources among different basins, it is of great importance to study the asynchronism-synchronism of water resources for the regions concerned by taking both the spatial heterogeneity and temporal fluctuation into account. The asynchronism-synchronism of regions concerned is one of the most important physio-geographical parameters for project planning and designing, which may affect the reliability of the water distribution project. A general process on analyzing the asynchronism-synchronism of the regional precipitation has been discussed in details. According to the process, with the help of the time series precipitation of the stations in the study area in 1957-1998, the frequency of the asynchronism or synchronism of the region pairs in three time scales is estimated, that is the yearly, seasonal and monthly scales. The results show that in 1957-1998 the asynchronism frequency is higher than the synchronism frequency for both the North China-middle and lower Yangtze River pair and for the North China-upper Hanjiang River pair. As for the synchronism phenomena, the frequency of Nd-Sd is rather low. The combinations that are suitable for water transfers are Nd-Sw, Nn-Sw, Nd-Sn and Nn-Sn. The total frequency of these combinations for North China-middle and lower Yangtze River is 40% on an annual basis, but only 28% in spring when water shortages are most likely to occur. The total frequency of these combinations for North China-upper Hanjiang River is about 24% on an annual basis, but 35% in spring and winter. It should be noted that if future precipitation patterns are similar to the 1957-1998 period, it will be very important to change the natural characteristics of asynchronism-synchronism by enhancing the capability of hydro-project regulations and the promotion of the water transfer project management.

References

关键词： synchronous frequency; asynchronous frequency; South-to-North Water Transfer