# A PRELIMINARY STUDY ON THE CLIMATIC CHANGE OF THE HENGDUAN MOUNTAINS AREA SINCE 1600 A.D.

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Received October 22, 1987

ABSTRACT

Based on twelve tree-ring chronologies, two curves including the fluctuations of air temperature and the annual precipitation during last hundreds of years in the Hengduan Mountains area are drawn. Some significant cold/warm and dry/wet periods could be identified. A combined analysis between dendrochronologies and historical literature data of five classes helps us understand successive variations of each climatic pattern since 1600 A.D. In addition, the periodicities of some climatic features in the area have been studied in this paper.

## I. INTRODUCTION

The Hengduan Mountains area, located in Southwest China is a transitional zone from the Tibetan Plateau to the Yunnan-Guizhou Plateau and the Sichuan basin. In this area, the high mountains and deep gorges run generally S–N. The average altitude of this area is over 3,000 m a.s.l. with different topography and climate. However, it has rather rich floras and faunas. Some rare animals and plants, such as panda and dovetree, are also living here.

Due to the lack of data, historically climatic changes in this area have not so far been studied systematically. In early 1980's, Chinese Academy of Sciences organized a large scale multi-discipline investigation in this area. By field investigation, we have got a large quantity of tree ring specimens and other kinds of proxy data. The estimate of the climate change of the Hengduan Mountains of last several hundred years has been made from these data.

## II. DATA AND METHOD

Based on the basic principles of dendrochronology (Fritts, H.C., 1976, Wu Xiangding and Lin Zhenyao, 1987), the selected tree-ring specimens from the Hengduan Mountains can be divided into two classes. One is near upper tree limit to which tree growth is mostly sensitive to temperature; the other is from lower-altitude arid area where tree growth may mainly respond to precipitation. Through our practice, the former lies at the altitude of 3,800–4,200 m with the species of Sabina tibetica, Sabina wallichana and Abies forrestii in the mountains, while the latter, about 3,500 m or less with some species, such as Picea likiangensis, Larix gmeliai, etc. Generally speaking, their ring-width variations indicate the local climatic change based on the relationship between ring width and observed climate factors, temperature or precipitation in the past several decades.

All tree-ring chronologies adopted in this paper are built from many incremental cores except one chronology Ba 1. Some of them include multicores with more than one cross section. For example, the chronology Zhong 2 has 18-tree cores and two cross sections; Zhong 1 has 21-tree cores and three sections. This is because cross section can be used to detect some destruction within a tree and to check dating. In fact, it may be easier to

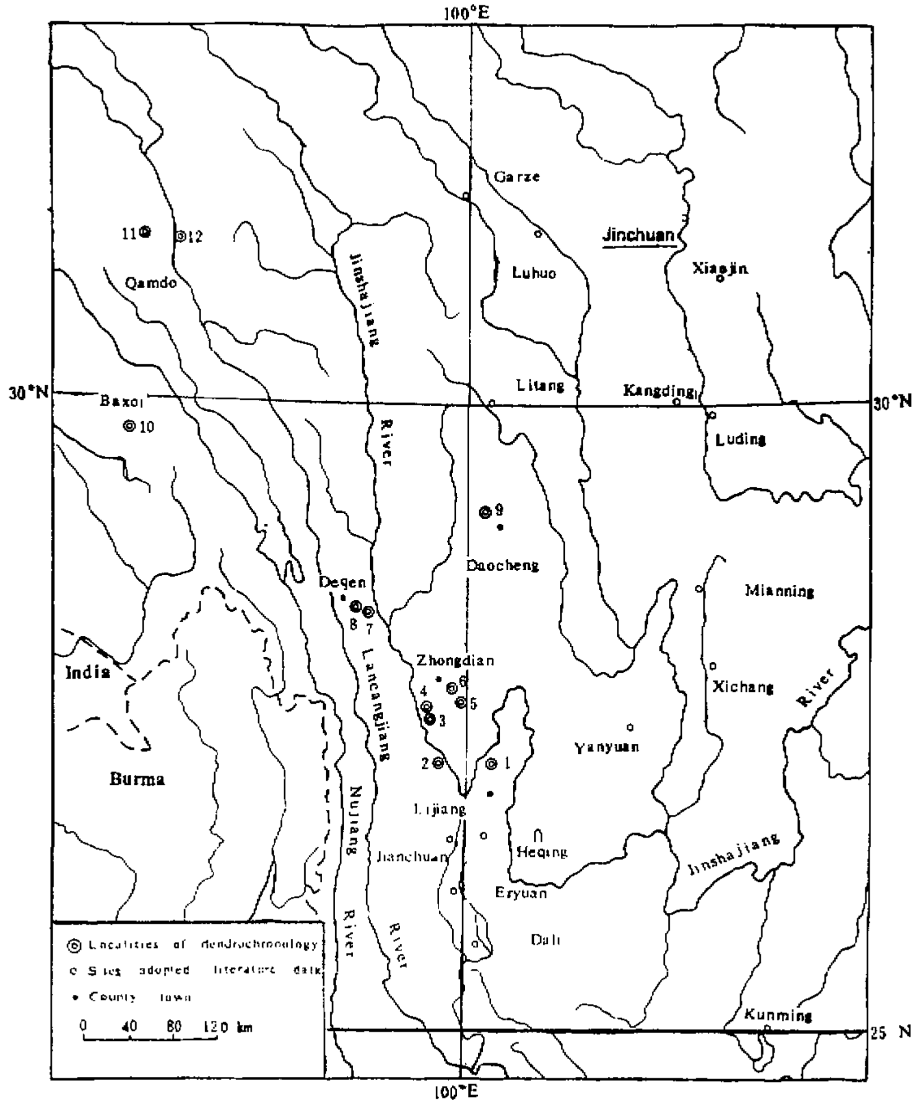


Fig. 1. Distribution of the dendrochronologies and the sites based on literature data in the Hengduan Mts.

find local absent or double ring by a cross section than by two cores from one tree.

Following basic processes: measuring, dating, curve fitting, and some statistical calculations, a tree-ring width series can be converted into an index series. Then a tree-ring chronology can be built. The detail of calculation procedure is omitted in this paper, for it has been discussed elsewhere in detail (Wu Xiangding and Lin Zhenyao, 1978, 1981a, 1983). As for the mean sensitivity and exponential curve fitting, we just follow the popular definition in dendrochronology (Fritts, H. C., 1976, Hughes, M. K. et al., 1982). Of course, some adjustments have been adopted for selecting the specimen in our present study. For example, each tree-ring width series in which the mean sensitivity is less than 2.0 or the correlation coefficient between ring width and climate factor is less than 95% and confidence level can not enter the master series (Wu Xiangding and Lin Zhenyao, 1983).

Through comparison and selection, 12 tree-ring chronologies have been built in the *Hengduan Mountains*. The localities, covering from 27°10′ to 31°12′ N and from 89°57′ to 100°15′ E, of these chronologies are shown in Fig. 1 and listed in Table 1.

The shortest chronology is of 125 years and the longest length, of 710 years. On the basis of the relationship between annual variations of tree growth and climate factors in nearest meteorological station, all 12 dendrochronologies can be divided into two classes. One is mainly in response to local precipitation, including Nos. 3,5,7 and 12; the other includes 8 chronologies except Nos. 3,5,7 and 12 and may indicate local temperature change.

Table 1. Summary of Some Dendrochronologies in the Hengduan Mts.

| No. | I.D. | Lat. (N) | Long. (E) | Elevn. (m) | Species | Length (yr.) |
|---|---|---|---|---|---|---|
| 1 | Li 1 | 27°15′ | 99°50′ | 3900 | Abies forrestii | 198 |
| 2 | Li 2 | 27°10′ | 100°15′ | 3600 | Abies forrestii | 254 |
| 3 | Zong 3 | 27°46′ | 99°41′ | 3300 | Picea likiangensis | 245 |
| 4 | Zhong 2 | 27°47′ | 99°41′ | 3900 | Abies forrestii | 378 |
| 5 | Zhong 1 | 27°48′ | 99°43′ | 3750 | Larix gmelini | 383 |
| 6 | Zhong 4 | 27°49′ | 99°43′ | 3550 | Sabina tibetica | 266 |
| 7 | De 2 | 28°16′ | 89°58′ | 3500 | Picea likiangensis | 199 |
| 8 | De 1 | 28°18′ | 89°57′ | 4200 | Sabina tibetica | 332 |
| 9 | Dao 1 | 29°13′ | 100°10′ | 4200 | Sabina tibetica | 315 |
| 10 | Ba 1 | 29°38′ | 96°48′ | 4000 | Sabina tibetica | 710 |
| 11 | Qam 7 | 31°12′ | 96°52′ | 3800 | Sabina wallichiana | 125 |
| 12 | Qam 301 | 31°12′ | 96°59′ | 3250 | Picea likiangensis | 227 |

In addition, some historical documents are adopted in this analysis. Total 15 sites where the systematic literature can be used as other kind of proxy climate data have been marked in Fig. 1; most of them are located in the eastern part of the Hengduan Mountains. The data are accepted from "Yearly Charts of Dryness/Wetness in China for the Last 500-Year Period" (Central Meteorological Bureau, 1981) and deduced from other local historical literature. Although most document-data series have the length of about 100 years, several can reach no more than 300 years, such as Dali, Xichang and Kangding. This kind of document data have been generally divided into five grades, which are defined as: 1=very dry or cold, 2=dry or cold, 3=normal, 4=wet or warm, and 5=very wet or warm.

We will consider the tree-ring chronologies, along with document series in analyzing the climatic change of the Hengduan Mountains of the last hundreds of years.

## III. RESULTS

Two classes of tree-ring chronologies have been used to reconstruct past local temperature and precipitation respectively for the Hengduan Mountains. In order to facilitate the comparison, we examine the time series spanning 1600–1981 A.D., in which two chronologies have the same length of 382 years.

By carrying out low-pass filter with Gaussian method of wave-filtration weighting, two trend curves on fluctuation of air temperature and precipitation reconstructed from tree-ring data in the Hengduan Mountains during last 400 years are shown in Figs. 1, 2, and 3, respectively. Some characteristics of the climatic change in this area will be stated as follows.

### 1. *Variation of Air Temperature*

According to Fig. 2, some cold and warm periods can be determined. For example, it lasted for a long cold period in the Hengduan Mountains from the early 17th century through 1650's. And the coldest period might be in last 400 years. Temperature, then, increased quickly and it had kept warm until 1740's, so that a long warm period appeared in this area. More obvious cold and warm periods came one after another, but the fluctuation amplitude was smaller and successive time of these periods was shorter than those of the first two periods before 1740's. In the present century, two cold periods were obvious but it has been warm since 1970's.

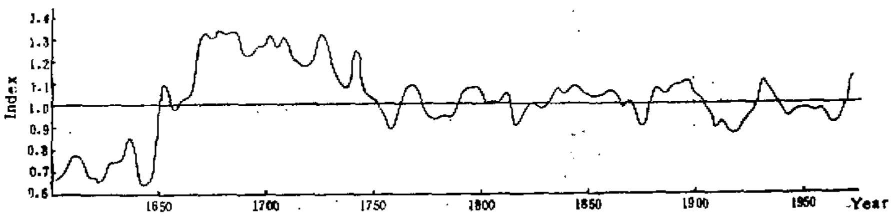


Fig. 2. Fluctuation of air temperature indicated by tree-ring data.

The famous mountain, Diancangshan, is located near the Dali city, facing the beautiful Erhi Lake, and has the highest peak of 4,100 m or more. Many geographers and travelers have been there and made some records in snow season in accumulated snow mountain, including investigation report, poem and other travel notes. For example, in historical books and annual of local histories, there are quite a few records of snow cover that existed in summer season during 1520s–1630s. Xu Xiake, a famous ancient geographer investigated the mountain in the spring of 1638 and described the wide-spread snow cover on the third peak of Diancangshan, the three-tower temple in the suburb of the Dali city and some gorges. However, now there is no snow cover around the peak, temple and gorges in spring season. Meanwhile, we can not see any permanent snow cover on the peaks of Diancangshan in summer season. There is an evidence that there had been a strong cold period by 1630's.

Seen from other literature records, the variation of snow cover in this area is generally coincident with the fluctuation trend deduced from tree-ring chronologies in Fig. 2.

In comparison with other results, including the tree-ring analysis of the Wolong (Liu Chuanzhi, 1982) and the Tibetan Plateau (Wu Xiangding and Lin Zhenyao, 1978), the general trend of air temperature variation in the Hengduan Mountains is similar to that in the bordered areas, Wolong region and Tibet.

2. *Variation of Precipitation*

From Fig. 3, it can be clearly seen that several dry and wet periods appeared alternately during last 400 years, but the distinct dry periods appeared in 1610s–1620s, 1660s–1670s, 1690s, 1730s, 1750s–1770s, 1790s–1820s, and 1910s–early 1940s. Other intervals can be called wet periods. The length of each wet period, is generally about 10 years; the longest is no more than 20 years.

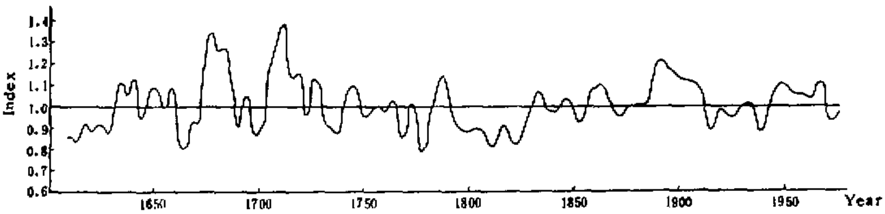


Fig. 3. Fluctuation of annual precipitation indicated by tree-ring data.

In comparison with the fluctuation of flood and drought in Tibet (Lin Zhenyao and Wu Xiangding, 1986), the circumstances of precipitation in the Hengduan Mountains seem a little complicate. Although there are some similar dry and wet periods in both areas, a quite obvious difference can be found. We have tried to deduce the periodicity of precipitation within the Hengduan Mountains. In fact, there is a periodicity with long-term fluctuation, lasting for 10 years. However, the obvious difference may occur between two sites, only a few kilometers apart, as the annual variation is considered. This may be caused by complicate topography and various weather system in this area.

In the present stage a dry period is for this area. With reference to the result from tree-ring analysis (Wu Xiangding and Lin Zhenyao, 1983), we have pointed out that the mean value of annual total precipitation of last 400 years is about 80 mm higher than that of last 30 years in the middle part of the Hengduan Mountains. Similarly, characteristic variation can also be found in other parts of the Hengduan Mountains.

3. *Alteration of the Climate Pattern*

With similar treatment mentioned above, two tree-ring series can be respectively converted into a new series with five grades corresponding to document data. We only use four values: $-2.5s$, $-1.5s$, $+1.5s$ and $+2.5s$ ($s$=mean deviation of a series) as precise criteria (Wu Xiangding and Lin Zhenyao, 1981a) for dividing each tree-ring series into five grades. Then, all graded document data can be merged with the tree-ring data at the same year. Finally, two graded series can indicate variations of temperature and precipitation in the whole Hengduan Mountains.

Five climate patterns have been derived from the two graded series, and each year could correspond with one of the five patterns. They are: dry-cold pattern; wet-cold pattern; normal pattern; dry-warm pattern and wet-warm pattern. Taking the area as a whole, the occurrence frequency and percentage of each climate pattern for the Hengduan Mountains within fifty years, short of the latest time interval of 32 years, have been given in Table 2.

Obviously, the dry-cold pattern was quite current and accounted for 58% of all during the first half of the 17th century. In the same period, the pattern with respect to warm climate would never appear. We can imagine how low air temperature was at that time. In the second half of the 17th century and the successive 50 years, the climate became warm and wet. The wet-warm pattern accounted for 20% or more. From 1850s to 1940s, the wet-cold pattern concerning glacial activity appeared frequently.

In fact, it corresponds with the active glacier advance occurring during the 19th century (Li Jijun et al., 1983). It should be noticed that the dry-warm pattern has been increasing from 4% (1900–1949) to 15.5% (1950–1981). This has become an important trend of the climatic change for this area.

Table 2. Frequency and Percentage of Each Climate Pattern in the Hengduan Mountains. (N=frequency; %=percentage)

| Period | Dry-Cold | | Wet-Cold | | Normal | | Dry-Hot | | Wet-Hot | |
|---|---|---|---|---|---|---|---|---|---|---|
| | N | % | N | % | N | % | N | % | N | % |
| 1600–1649 | 29 | 58 | 8 | 16 | 13 | 26 | 0 | 0 | 0 | 0 |
| 1650–1699 | 4 | 8 | 3 | 6 | 25 | 50 | 6 | 12 | 12 | 24 |
| 1700–1749 | 4 | 8 | 6 | 12 | 23 | 46 | 7 | 14 | 10 | 20 |
| 1750–1799 | 2 | 4 | 8 | 16 | 36 | 72 | 1 | 2 | 3 | 6 |
| 1800–1849 | 5 | 10 | 7 | 14 | 36 | 72 | 1 | 2 | 1 | 2 |
| 1850–1899 | 7 | 14 | 10 | 20 | 22 | 44 | 1 | 2 | 10 | 20 |
| 1900–1949 | 9 | 18 | 12 | 24 | 23 | 46 | 2 | 4 | 4 | 8 |
| 1950–1981 | 7 | 22 | 4 | 12.5 | 14 | 44 | 5 | 15.5 | 2 | 6 |

4. *Periodicity*

The power spectrum analyses of various series, which are successive tree-ring chronologies in the Hengduan Mountains, have brought to light many cycles. We can know that principle cycles involved almost in every series are of 2 years or so. Apart from the marked "quasi biennial pulse", there are also quasi-cycles of about 11 or 22 years in a number of cases, and these are in harmony with two principal cycles of relative sunspots. A number of these tree-ring series also have cycles of thirty odd years, which are in agreement with the well known "Bruckner Cycle".

There are other cycles in some series, such as 80 years of more, 125 years or so, 'etc. We will not discuss them in this paper.

## IV. CONCLUSIONS

In summing up the above analyses, we can, on the whole, arrive at the following views concerning climatic change for the Hengduan Mountains during the last 400 years or more.

1. The temperature fluctuation during the last four hundred years in the area is similar to that in the Tibetan Plateau, and the coldest period occurred in the first half of the 17th century.

2. The long-term oscillation of precipitation is more obvious compared to air temperature.

3. For the present century, the statistical features show, on the average, lower temperature and lower precipitation, but the climate pattern with high temperature and low precipitation has been increasing since 1950s.

4. By carrying out anlysis of various series, some periodicities have been found, such as "quasi biennial pulse", 11 or 22 year, thirty odd years and so on.

REFERENCES

Central Meteorological Bureau (1981), Yearly Charts of Dryness/Wetness in China for the Last 500-Year Period, Cartographic Publishing House, 332.

Fritts, H. C. (1976), *Tree Ring and Climate*, Academic Press, London, 567.

Hughes, M. K. et al. (1982), *Climate from Tree Rings*, Cambridge University Press, Cambridge, 223.

Li Jijun et al. (1983), *Investigation of glaciers on the Gongga Shan, Study of Tibetan Plateau*, 140–153, Yunnan Press, Kunming.

Lin Zhenyao and Wu Xiangding (1986), A preliminary analysis of the regularity in flood, drought and snowstorm in Tibetan Plateau during Historical Time, *Acta Meteorologica Sinica* **44** (3): 257–264.

Liu Chuanzhi (1982), Tree-ring in the Wolong region and climatic variation of west Sichuan Province in recent century, *Meteorological Monthly*, **5**: 18–20.

Wu Xiangding and Lin Zhenyao (1978), A preliminary analysis of climatic variation during the last hundred years and its outlook on Tibetan Plateau, *Kexue Tongbao*, **23** (12): 746–750.

Wu Xiangding and Lin Zhenyao (1981a), Climatic change during the last 2000 years in Tibet, *Proceedings of Symposium on Climatic Change*, 18–25, Science Press, Beijing.

Wu Xiangding and Lin Zhenyao (1983a), *The climatic change and tree-ring analysis in the Hsiao Zhongdian area of the Yunnan Province, Study of Tibetan Plateau*, 206–213, Yunnan Press, Kunming.

Wu Xiangding and Lin Zhenyao (1987), *Sampling in Tibet, Methods of Dendrochronology I.* eds, L. Kairiukstis et al., WOSI, Warsaw, Poland, 23–33.