20TH CENTURY PRECIPITATION TRENDS IN THE YANGTZE RIVER CATCHMENT

by

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PREFACE

Research on climate trends in China has been carried out within a co-operation of the Justus Liebig Universities Department of Geography and Zentrum für internationale Entwicklungs- und Umweltforschung (ZEU) and Chinese colleagues of the Nanjing Institute of Geography and Limnology (CAS) and Nanjing University. Earlier Sino-German studies of this co-operation focused on historical climate variability (CHEN et al. 1997; CHEN et al. 2001). Climate trend analysis with observed data was started in 2002 during exchange programmes of the Chinese co-authors which were funded by the German Academic Exchange Service (DAAD) and the International Bureau of the Federal Ministry of Education and Research (BMBF-IB). The exchange was part of the project on "Sustainable Land Use, Flood Risks and Watershed Ecosystem Management" of the ZEU's section 1.

The results of the author's precipitation and temperature trend research has been published as BECKER et al. (2003a), BECKER et al. (2003b), BECKER et al. (2003c), and GEMMER et al. (2003). Furthermore, the results were presented in poster sessions at following international conferences: International Symposium on Climate Change (ISCC), 31 March - 3 April, 2003, Beijing, China, and Chinese-German Workshop on Climate Change and Yangtze Floods. 4-8 April 2003, Nanjing, China.

The paper in hand presents yet unpublished materials which came into being while working out the international publications. It is supposed to give a closer glance at actual research activities at the Department of Geography and the ZEU.

1 INTRODUCTION

Flooding, waterlogging, and drought are the most severe natural disasters in China based on terms of economic losses, damaged farmlands, and casualties (TAO, LI & WANG 1998b: 60; DING et al. 1998; CHINA STATE STATISTICAL BUREAU & MINISTRY OF CIVIL AFFAIRS 1995; KING, GEMMER & METZLER 2002). It is beyond controversy that human factors such as soil erosion, regulations of the river courses and wetland reclamation are more important for aggregating floods (KING, GEMMER & WANG 2001) than precipitation variation (ZHANG 1998). However, drought and flood events in the Yangtze river catchment are caused by precipitation extremes. They regionally occur in China almost every year since China's climate is influenced by the south-east and south-west summer monsoons and the Siberian north-west winter monsoon. Due to the mei-yu event, inter-annual variability of precipitation is very high. Weather abnormalities such as null mei-yu seasons with hardly any precipitation in summertime or heavy rainfall events in the Yangtze river catchment are generally related to abnormal characteristics of the monsoons. Examples are severe floods such as in 1954, 1991, 1996, and 1998 or the droughts in 1955 and 1962.

Heavy monthly precipitation occurred regularly in the 20th century but summer precipitation in the Yangtze river catchment in the 1990s is claimed to be higher than in earlier decades (LI, CHEN & WANG 1999). The Yangtze river flood event in 1998 also started a new discussion on possible implications of climatic change. An increase of rainfall over eastern China without decrease of the number of dry years has been predicted for the actual decade (GONG & WANG 2000; YANG & YUAN 1996).

It is common knowledge that precipitation has been unusually high in the last decade (IPCC 2001a,b). Studies on precipitation time series in China or elsewhere in the world have always revealed cycles of relatively wet and dry periods. It is, however, yet an open question, whether a precipitation situation like in the 1990s has taken place before in the Yangtze river catchment. The analysis of precipitation trends and cycles during the last 100 years will enable the evaluation of the 1990s precipitation. The focus will not only be on the absolute annual precipitation amounts but also on the inner-annual variability of rainfall and the monthly precipitation amounts, as they are important factors in the understanding of summer flood events.

2 DATA ACQUISITION, PREPARATION AND ANALYSIS METHODS

The data of 16 stations with long-term precipitation data sets which are spread widely over the Yangtze river catchment have been analysed in this study. Data of the Yangtze source area are unfortunately not available for the first half of the 20th century. The location of the stations with precipitation time series which have been used for the present study can be seen in **figure 1.**

The selection represents all stations in the Yangtze catchment where monthly precipitation data were available for the greater part of the last century. Data gaps are partly due to circumstances during civil war and Japanese occupation. The data sets contain monthly precipitation values with time series starting in Shanghai e.g. in 1872. Data starting in the 19th century are taken from the Global Historical Climatology Network (GHCN) project version 2 (VOSE et al. 1992; PETERSON et al. 1998). They have been provided by the Chinese Academy of Sciences (CAS) and collected at the Carbon Dioxide Information Analysis Center for the use in several studies (KAISER et al. 1995; TAO et al. 1997). Original data from CAS have been used in earlier studies such as WANG et al. 2000. They are mainly available until 1993. The station data were individually tested and visually inspected for the presence of spurious trends and jumps by KAISER et al. 1995. The US Department of Energy's (DOE) Carbon Dioxide Information Analysis Center (CDIAC) has conducted a quality assurance (QA) review of the data, checking them for completeness, reasonableness, and accuracy .

Figure 1: Location of the precipitation stations in the Yangtze river catchment

Precipitation data have been published for the province capitals in the China Statistical Yearbooks (CHINA STATE STATISTICAL BUREAU 1988-2001) since the founding of the P.R. China. Data gaps in the GHCN time-series from 1988 to 2000 have been filled in with data from these yearbooks or data from YANGTZE RIVER WATER RESOURCES COMMISSION 2000. The Kolmogorov-Smirnov test was applied in this study to confirm the approximate normal distribution of the data. The homogeneity of the precipitation records was analysed by calculating the von Neumann ratio (N), the cumulative deviations ($Q/n^{-0.5}$ and $R/n^{-0.5}$), and the Bayesian procedures (U and A) (BUISHAND 1982). The data sets of most stations proved to be homogeneous with a significance beyond the 95% confidence level. Only data sets of Chengdu, Guiyang, and Zhijiang stations show homogeneity with a significance slightly less than the 95% confidence level according to some of the applied criteria. Annual and monthly precipitation sums, inter- and inner-annual variabilities, and decadal fluctuations have been assessed and linear trend analysis as well as the Mann-Kendall trend test have been applied to evaluate precipitation changes or trends.

3 ANALYSIS OF THE ANNUAL PRECIPITATION

3.1 Background

Climatic predictions and paleo-climatic research have been carried out within the framework of global change studies in China (CNC-IGBP 1998). Climatic cycles in China with strong variations are investigated over the last 20.000 years. For the past 500 years three major so-called principal periodicities have been detected, which are based on quasi-biannual, 3-5 year, and 11 year cycles (WANG, GONG & ZHU 2001). This study also points out the hypothesis, that the 20th century produced the least amount of rainfall in east china within the last 1000 years.

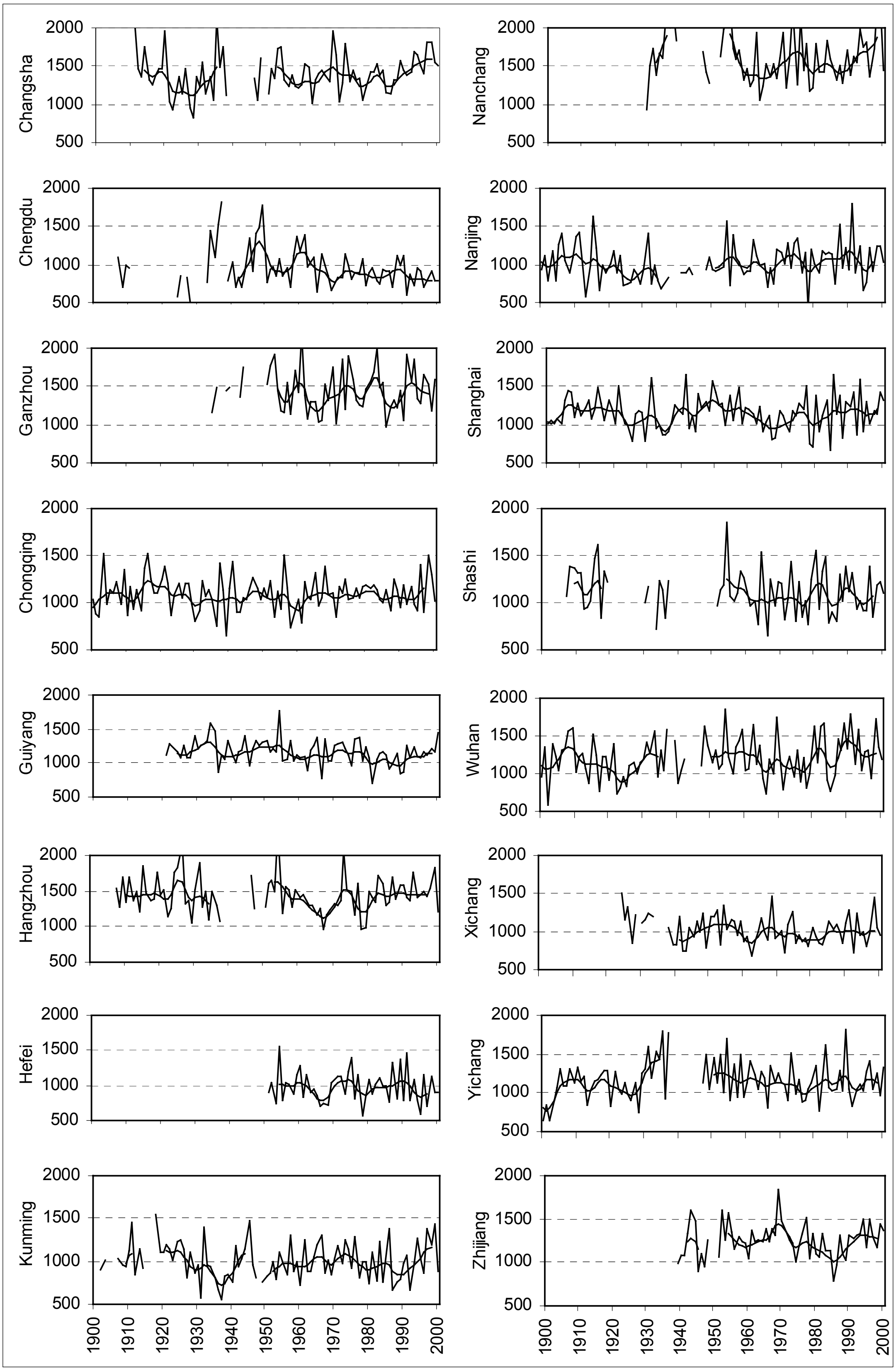
The average annual precipitation in the Yangtze river catchment has been published in various papers. Three major sequences with wet and dry conditions have been detected in the 20th century. A quasi-70-years and a quasi-20-years oscillation in the precipitation time series has been observed by WANG et al. (2001). SCHAEFER (2001) points out inconsistent annual precipitation trend patterns in the Yangtze river catchment with positive trends some parts of the middle and lower catchment since 1951.

3.2 Description of the time series

The annual precipitation sums of the last century of 16 stations are presented in **figure 2.** It becomes apparent that the annual precipitation sums in the Yangtze river catchment do not show any significant long term trend during the last century. This is confirmed by T/N relations of linear trend tests which reveal no significant trends for any of the stations in the 20th century due to the high inter-annual variability of the annual precipitation sums.

However, decadal-scale fluctuations of precipitation are apparent and considerable differences between the stations can be observed regarding absolute values, variations and temporal courses. Chongqing, Guiyang, Shashi, Xichang, and Nanjing show relatively constant smoothed values (Gauss low pass filtered values). A relatively distinct periodicity can be observed at Ganzhou, Shanghai and Wuhan whereas no recognisable periodicity can be found at all other stations which may partly be due to missing data.

Figure 2: Annual precipitation (scale in mm) and filtered values Gauss low pass filter, based on 10 years time steps)



It can also be seen that the annual precipitation sums in the 90s at all stations are not exceptional in relation to the last century. Both, the annual sums and the filtered data of the 90s are well within the ranges of the preceding decades. Changsha, Chongqing, Guiyang, Kunming, and Nanchang show a remarkable increase of the values which started in the late 80s or early 90s. However, 90s peaks at these stations have been superseded in previous decades with regard to annual sums and filtered values. The values of the 90s have been superseded in Changsha in the early last century as well as during the 70s, in Chongqing during the 10s and 50s, in Guiyang during the 30s and 50s, in Kunming during the 10s and 40s and in Nanchang during the 50s and 70s. These findings compliment the findings of the study from QIAN & ZHU (2001) who observed excessive above normal annual precipitation in east and central China between 1900 and 1910 and after the 1980s. ZHAI et al. 1999 describe an above normal annual precipitation during late 1950s through early 1960s and since 1980s with an increasing number of rain storms and strong annual variations in East China (YANG & YUAN 1996) whereas the annual precipitation in the 1970s was low. JIANG, ZHANG & FRAEDRICH (1997) detected precipitation sequences that vary in different regions and change over the decades and centuries (GONG & HAMEED 1991, JIANG 1991).

3.3 90% quantiles, dry and wet years

Extreme years based on annual precipitation can be detected all over the 20th century. In the following, a “wet year” will be defined as a year with annual precipitation beyond the 90% quantile of all the station’s data. At least one year with extremely high annual precipitation can be found during most decades at each station, see **table 1.** More than one wet year per decade occurred during the 50s in Nanjing and Zhijiang; during the 60s in Ganzhou, Guiyang, and Nanchang; during the 70s in Ganzhou, Guiyang, and Nanchang; during the 80s in Shashi, Wuhan, and Yichang and during the 90s in Changsha, Chongqing, Hangzhou, Kunming, Nanchang, Wuhan, and Xichang.

No underlying regional distribution pattern can be detected but it becomes obvious that the 90s take on an exceptional position, as more than one wet year occurred during this decade at comparatively many stations. A comparison with the 30s and 40s is not possible due to the considerable data gaps during these decades, however, these decades already show comparatively many wet years based the available data sets. The sum of the numbers of wet years regarding all stations takes on a maximum in the 90s which is followed by the 50s. Years with extremely low annual precipitation (values not exceeding the 10% quantile, “dry years”) did not occur regularly every decade at most stations as it was found for the wet years. More than one dry year per decade occurred during the 50s in Chongqing only, most other stations do not even show one dry year. During the 60s we find more than one dry year in Chengdu, Ganzhou, Guiyang, Hangzhou, Hefei, Nanchang, Shanghai, Shashi and only Zhijiang does not show a dry year.

Table 1: Number of dry and wet years per decade

	Number of years per decade which exceed the 90% quantile of annual precipitation							Number of years per decade which fall below the 10% quantile of annual precipitation						
Station	**30s**	**40s**	**50s**	**60s**	**70s**	**80s**	**90s**	**30s**	**40s**	**50s**	**60s**	**70s**	**80s**	**90s**
Changsha	2	0	1	1	1	0	2	3	1	0	1	2	0	0
Chengdu	3	3	0	1	0	0	0	0	2	1	2	0	0	2
Chongqing	1	1	1	2	0	0	3	3	0	2	1	1	0	0
Ganzhou	0	0	1	1	2	1	1	0	0	0	3	1	1	1
Guiyang	2	1	1	1	2	0	0	1	1	0	2	0	3	1
Hangzhou	1	1	1	0	1	1	2	2	0	0	2	3	0	0
Hefei	0	0	1	1	1	1	1	0	0	0	2	1	0	2
Kunming	1	1	1	1	1	0	2	3	0	0	1	0	2	1
Nanchang	2	0	1	0	2	0	2	0	0	0	3	4	0	0
Nanjing	1	0	2	1	1	1	1	2	0	1	1	1	1	1
Shanghai	1	2	1	0	1	1	1	1	0	0	2	2	2	1
Shashi	0	0	1	1	1	3	0	1	0	0	2	2	1	0
Wuhan	0	0	1	2	0	2	2	0	1	0	1	2	2	0
Xichang	1	2	1	1	0	0	2	0	3	0	1	1	0	2
Yichang	3	0	1	0	0	2	0	0	0	1	1	3	1	1
Zhijiang	0	1	2	1	1	0	1	1	2	0	0	1	2	0
Sum	**18**	**12**	**17**	**14**	**14**	**12**	**20**	**17**	**10**	**5**	**25**	**24**	**15**	**12**

During the 70s we find more than one dry year in Changsha, Hangzhou, Nanchang, Shanghai, Shashi, Wuhan, and Yichang and one year at most other locations. Almost half of the stations do not show any dry year in the 80s and the 90s; whereas at least one dry year appeared in Guiyang, Kunming, Shanghai, Wuhan, and Zhijiang in the 80s and in Chengdu, Hefei, and Xichang in the 90s. The 60s and 70s show approximately twice of the 90s number of dry years regarding all stations and only for the 50s we note a lower number of dry years than for the 90s.

Summing up these findings it becomes obvious that many wet years and few dry years occurred in the Yangtze catchment during the 50s and 90s whereas the opposite is applicable in the 60s and 70s.

3.4 Comparison of the 90s with previous decades

The deviation of the average annual precipitation of previous decades from the nineties is described in **figure 3**. Higher average annual precipitation in the 90s in comparison to all other decades can be observed for Changsha, Chongqing, Kunming , Nanchang, and Wuhan and in comparison to most other decades for Ganzhou, Xichang, Zhijiang, Hangzhou, Nanjing, and Shanghai. Lower average precipitation sums in the 90s in comparison to all other decades can be observed in Chengdu only and in comparison to most other decades for Hefei and Yichang. Precipitation at most stations was relatively low in the 60s and 70s compared to the 90s, e.g. Changsha, Hangzhou, Nanchang, Shanghai, and Wuhan. The 80s were dryer than the 90s at 11 stations while precipitation in the 80s exceeded the 90s distinctively only in Hefei. A regionalisation of these findings reveals relatively high annual precipitation sums for the 90s in the south and relatively low ones in the north.

3.5 Relative variability of annual precipitation

WANG, GONG & ZHU 2001 relate high rainfall variabilities to high annual averages in contrast to the observations of DOMROES 2001. No overall systematic relation can be found between the relative variability **(figure 4)** and the absolute amounts of the annual precipitation sums within the present study. Stations with high annual precipitation for example do not necessarily show low variability values or vice versa. A regional subdivision regarding this aspect can be found by neglecting the coastal station Shanghai in the east and the high mountainous station Kunming in the south-west. Apart from these exceptions we find a higher variability in the northern section (Chengdu, Hefei, Shashi, Nanjing, Wuhan) where only Chengdu and Hefei show relatively low average annual precipitation sums below 1000 mm. The stations in the south (Changsha, Guiyang, Hangzhou, Nanchang) are characterised by lower relative variabilities, only Chongqing does not fit into this characterisation.

The variability of the annual precipitation sums is illustrated by the Gauss high pass filtered values **(figure 5).** The darker lines represent the absolute averages of the decades. Relatively high variations can be found e.g. in the seventies in the eastern region (Changsha, Ganzhou, Hangzhou, Nanchang, Nanjing); in the eighties in the coastal and in the central region (Shanghai, Shashi, Wuhan, Yichang) and in the nineties at several locations without a recognisable underlying regional pattern (Chongqing, Hefei, Kunming, Nanjing, Xichang, Ganzhou).

So far it is clearly visible, that there is no general increase or trend of the annual precipitation and its variability in the Yangtze river catchment. However, decadal-scale fluctuations of precipitation are apparent and the 90s are distinguished by relatively wet conditions. In the following the data will be analysed on a monthly basis.

Figure 3: Deviation of the average annual precipitation of the 50s, 60s, 70s and 80s from the 90s average

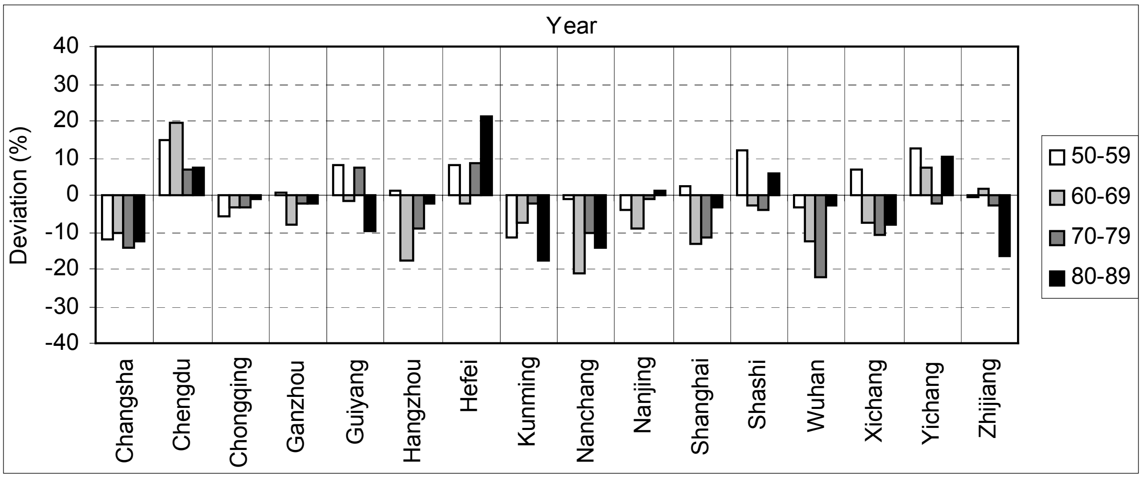


Figure 4: Relative variability of the annual precipitation sums from 1930 to 1999 in the Yangtze catchment

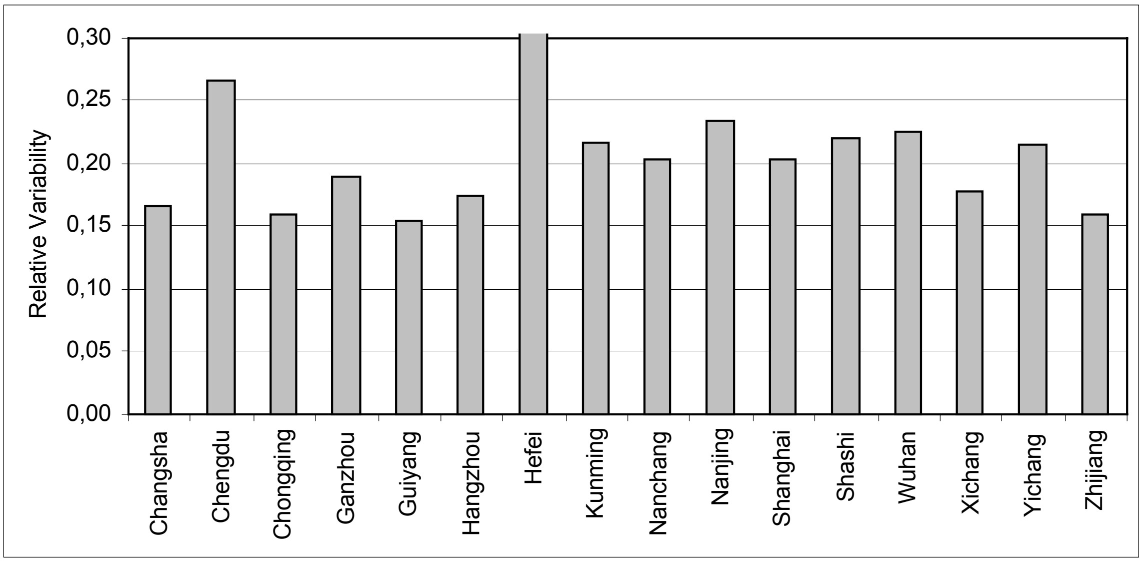
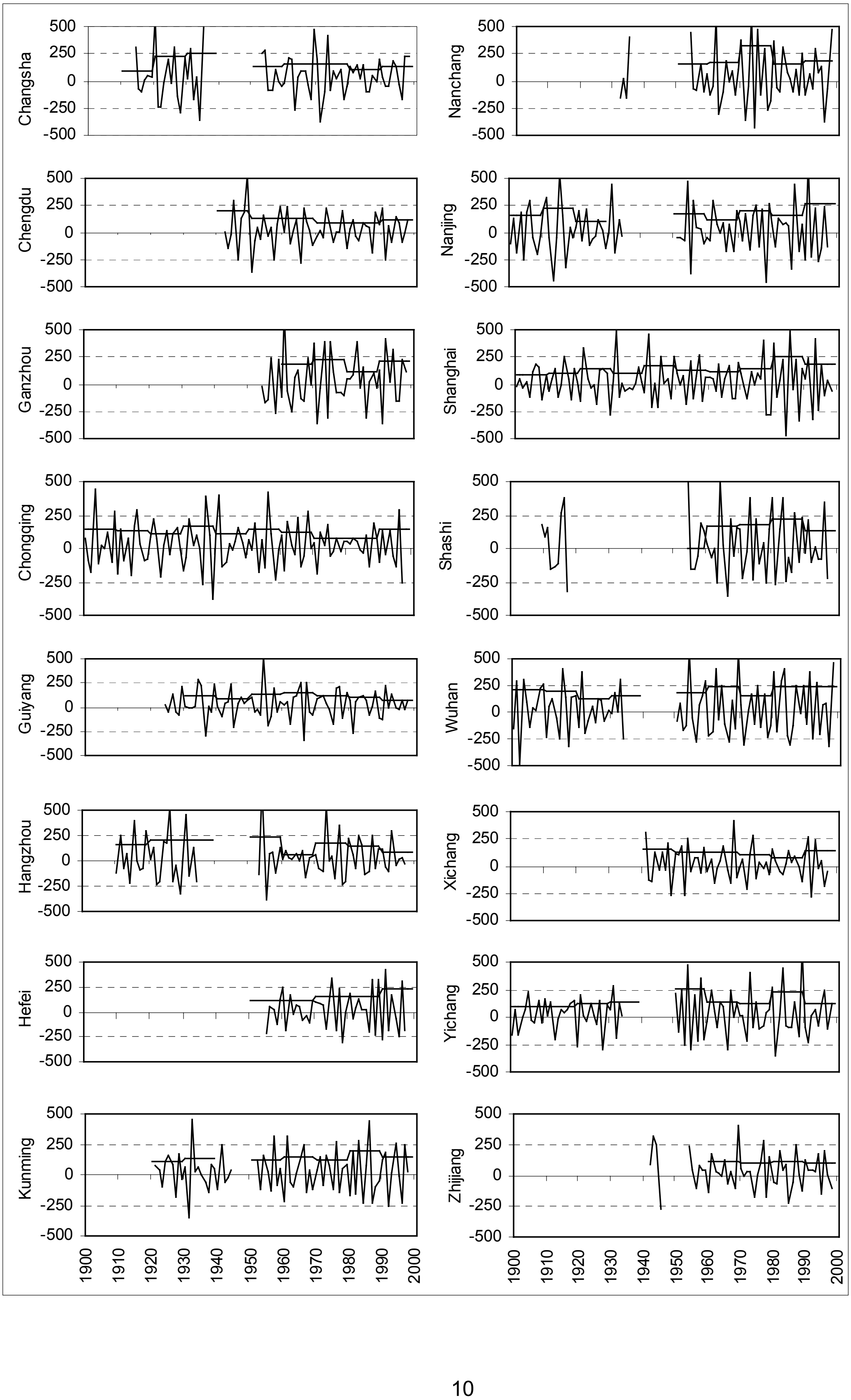


Figure 5: Gauss high pass filtered data of the annual precipitation (in mm, based on 10 years time steps), and their absolute decade averages (darker line)



4 MONTHLY PRECIPITATION ANALYSIS

4.1 Background

Much attention has been paid to the evaluation of the summer precipitation (May-August) in the Yangtze river catchment as these data are strongly related to flood risks (GONG, ZHU & WANG 2001; ZHU & WANG 2001). LI, CHEN & WANG 1999 and QUN 2001 suggest that the summer precipitation in the Yangtze River Catchment was higher in the 90s than in previous decades, except for some stations in the 50s. Simultaneously the north of China became much drier according to GONG, ZHU & WANG 2001 and XU 2001. Various trends of summer precipitation amounts, such as a negative trend for east China from 1954-76 and a positive trend between 1977 and 1988 have been detected by GONG & WANG (2000). QIAN & ZHU (2001) observed an increase of summer precipitation in northern China for the same period. FU & WEN (1999) mentioned a change in east Asia’s monsoon characteristics that started in the 1920s which might contribute to the explanation of those findings. Predictions of the east Asia monsoon are important for disaster precaution, since it is closely related to flood and drought events. Precipitation in the lower and middle reaches of the Yangtze River is below average and deficient in a strong summer monsoon year such as 1992 or 1997 whereas it is sufficient in the same area during weak monsoon years such as 1991 and 1998 (LI, LONG & ZHANG 2001; ZHANG & TAO 1998). In general, the rainbelt moves faster northward during a strong summer monsoon year.

According to XU (2001), a southward move of the monsoon rain belt started in the late 1970s and led to a trend of decreasing summer precipitation in the North and increasing summer precipitation over the Yangtze river catchment (QUN 2001). JIANG & YOU 1996 describe an abrupt reduction of the summer rainfall from the 1960s to the 1980s in middle China and a somewhat weaker jump from a dry to a wet period in the middle and lower Yangtze river catchment which started in the 1970s. Nevertheless, below average rainfall appeared in the same area e.g. between 1981 and 1985 (YANG & YUAN 1996). SCHAEFER (2001) found positive trends of summer precipitation in the south east of China and negative trends in the north since 1951. The underlying question of the following analyses is whether there is a significant change of summer precipitation towards the 90s and how the 90s can be evaluated in the scope of last century?

Monthly precipitation averages (**figure 6**) show maximum amounts in the summer months June, July, and August.

Figure 6: Monthly precipitation averages (mm, 1930 – 1999)

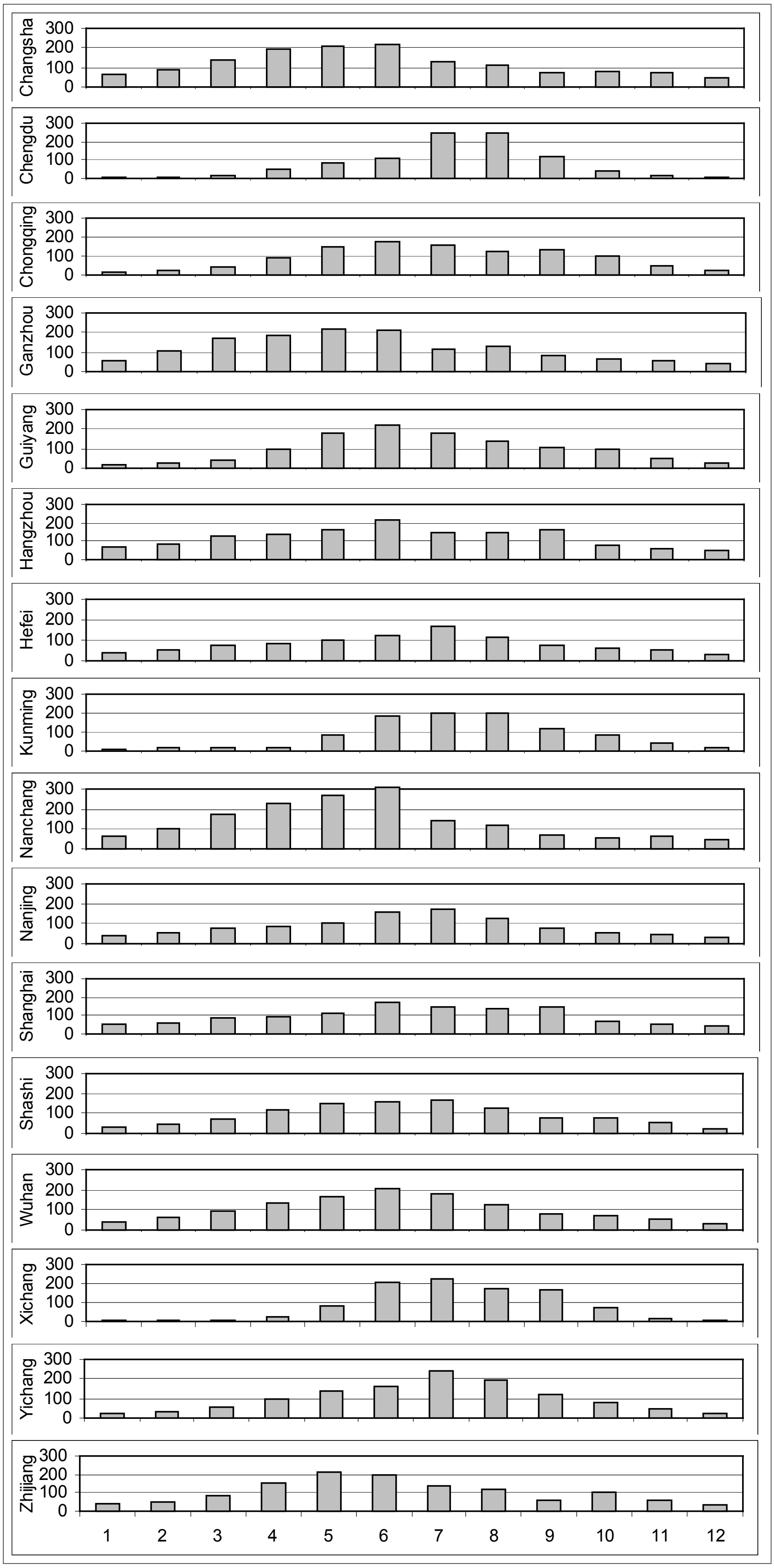
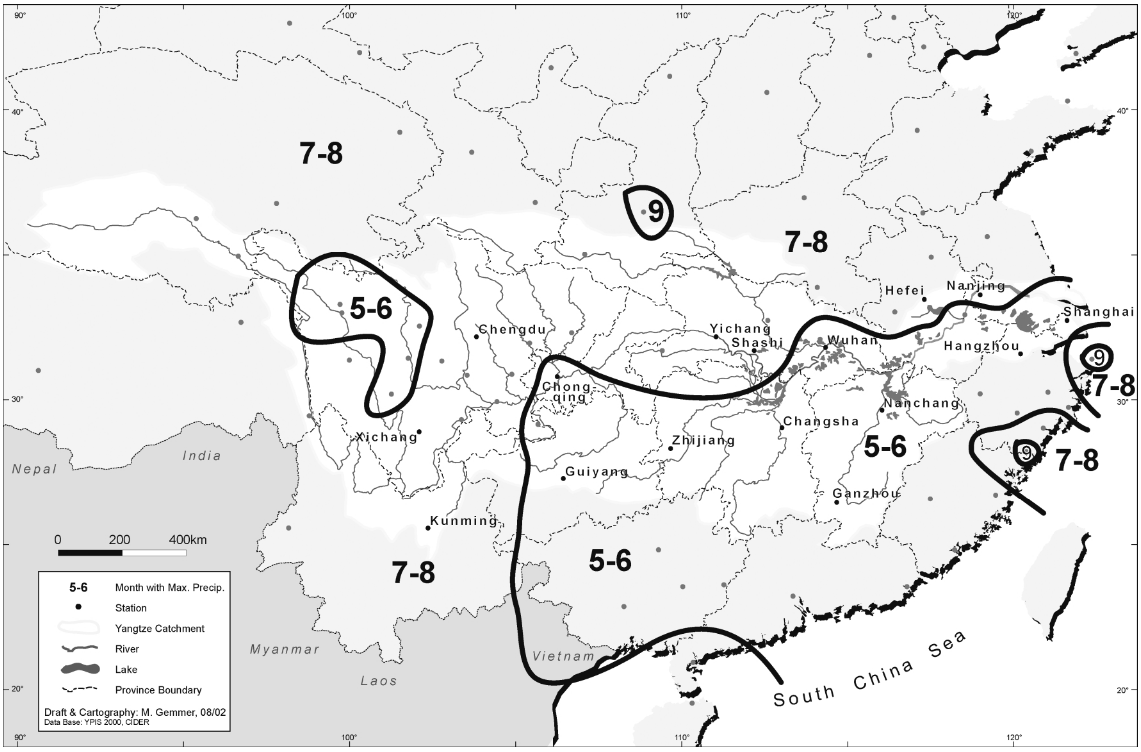


Figure 7: Months with maximum precipitation



The maxima at the stations in the north and west of the catchment (Chengdu, Hefei, Kunming, Nanjing, Xichang, Yichang) occur comparatively late in July or August, at all other stations they occur earlier in June **(figure 7)**. This phenomenon is due to the south east Asia summer monsoon that is described in DOMROES & PENG 1988; JU & SLINGO 1995; TAO; LI & WANG 1998a, and ZHANG & TAO 1998.

4.2 Inner-annual precipitation variability

The inner-annual variation varies considerably from station to station. The highest values (average > 1.0) can be found at the stations in the west (Chengdu, Kunming, Xichang), the lowest values (average < 0.8) are noted for the stations in the south-east of the catchment (Shanghai, Hangzhou, Ganzhou). The course of the inner-annual variations is drawn in **figure 8.** Most stations show a slight increase of the inner-annual variability from the 80s to the 90s, a considerable increase can be noted for Hangzhou and Shanghai. However, the values in the 90s were often superseded in earlier decades. Trend analysis for the inner-annual precipitation for time-series between 1950-1999 and 1970-1999 was performed by using the Mann-Kendall trend test considering confidence levels of 90%, 95%, and 99%.

Figure 8: Inner-annual variability (s/x)

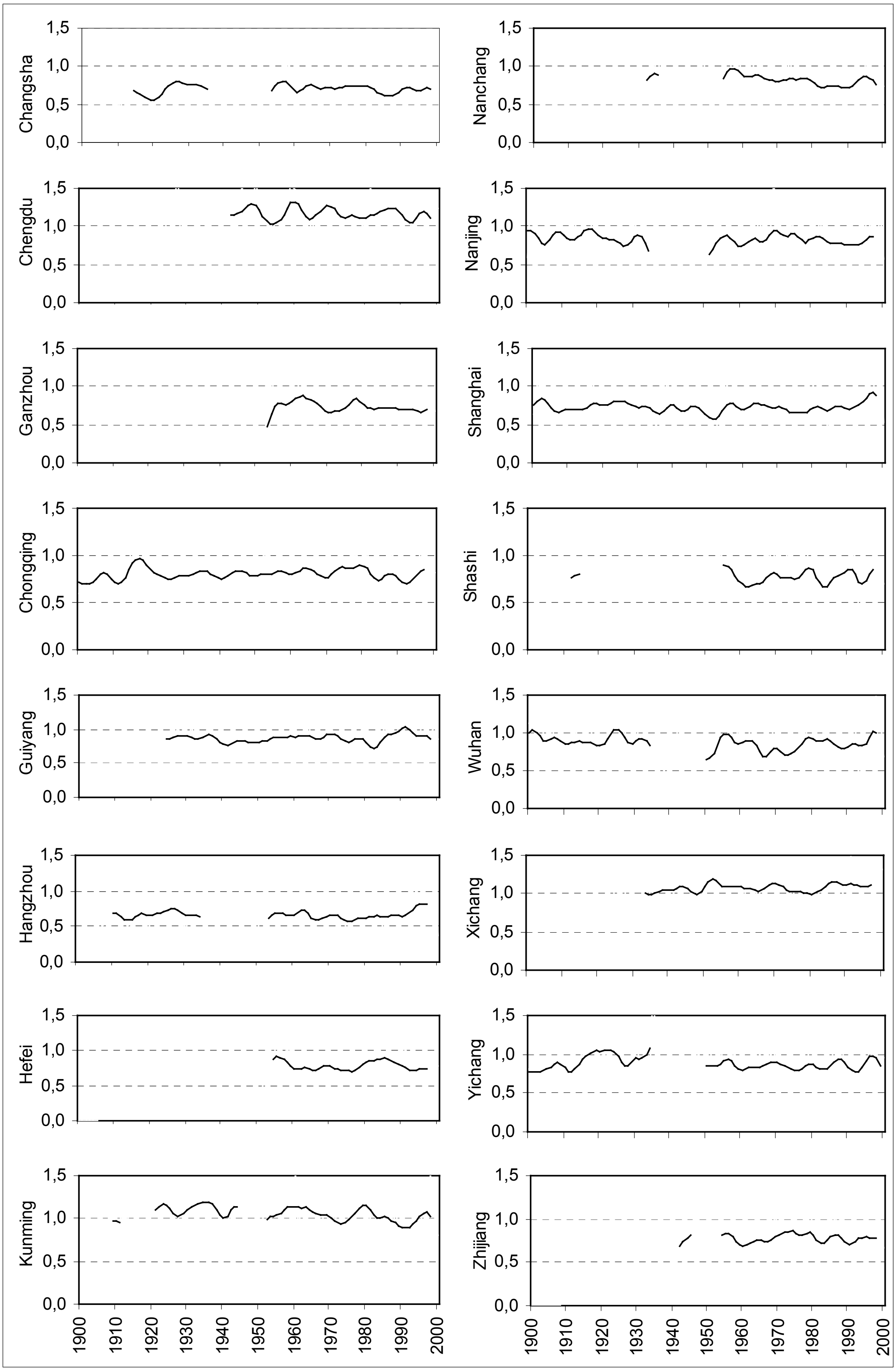
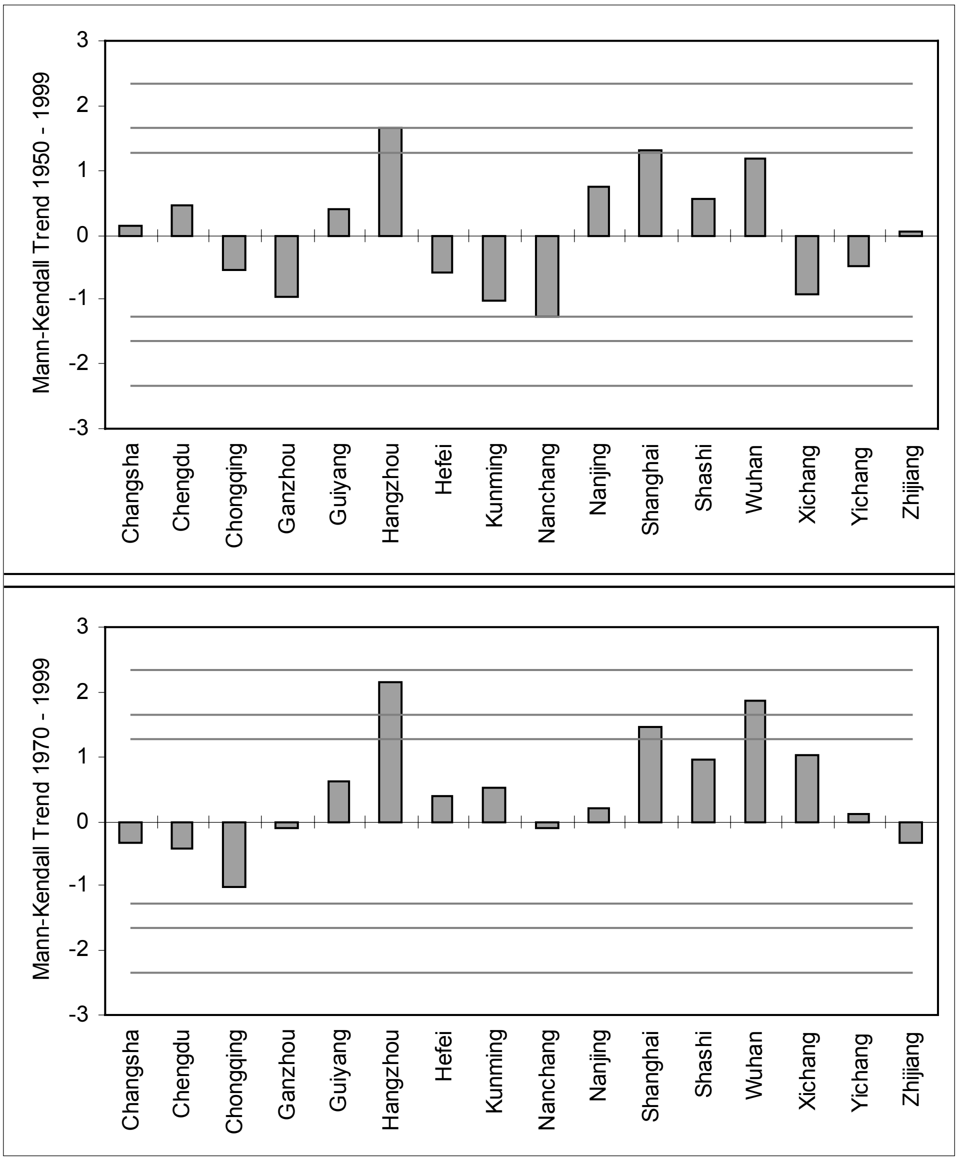


Figure 9: Mann-Kendall trend test for the inner-annual variability from 1950 to 1999 (upper graph) and from 1970 to 1999 (lower graph). The three lines above and below the abscissa represent the 90%, 95%, and 99% confidence levels of the trend tests.



The results displayed in **figure 9** show no overall trend for the region. Positive trends from 1950 to 1999 at the 90% confidence level prevail only at the eastern stations Shanghai and Hangzhou with corresponding negative trends only in Nanchang. No significant negative trends exceeding the 90% confidence level are detected between 1970 and 1999. Significant positive trends are identified in Shanghai, Hangzhou, and Wuhan, whereby significance does not exceed the 95% confidence level in Shanghai. It becomes obvious that only 3 of 16 stations show significant trends regarding inner-annual precipitation distribution patterns starting in the 70s. The absolute monthly deviations and trends for summer precipitation are investigated in the following.

4.3 The 90s summer precipitation compared to previous decades

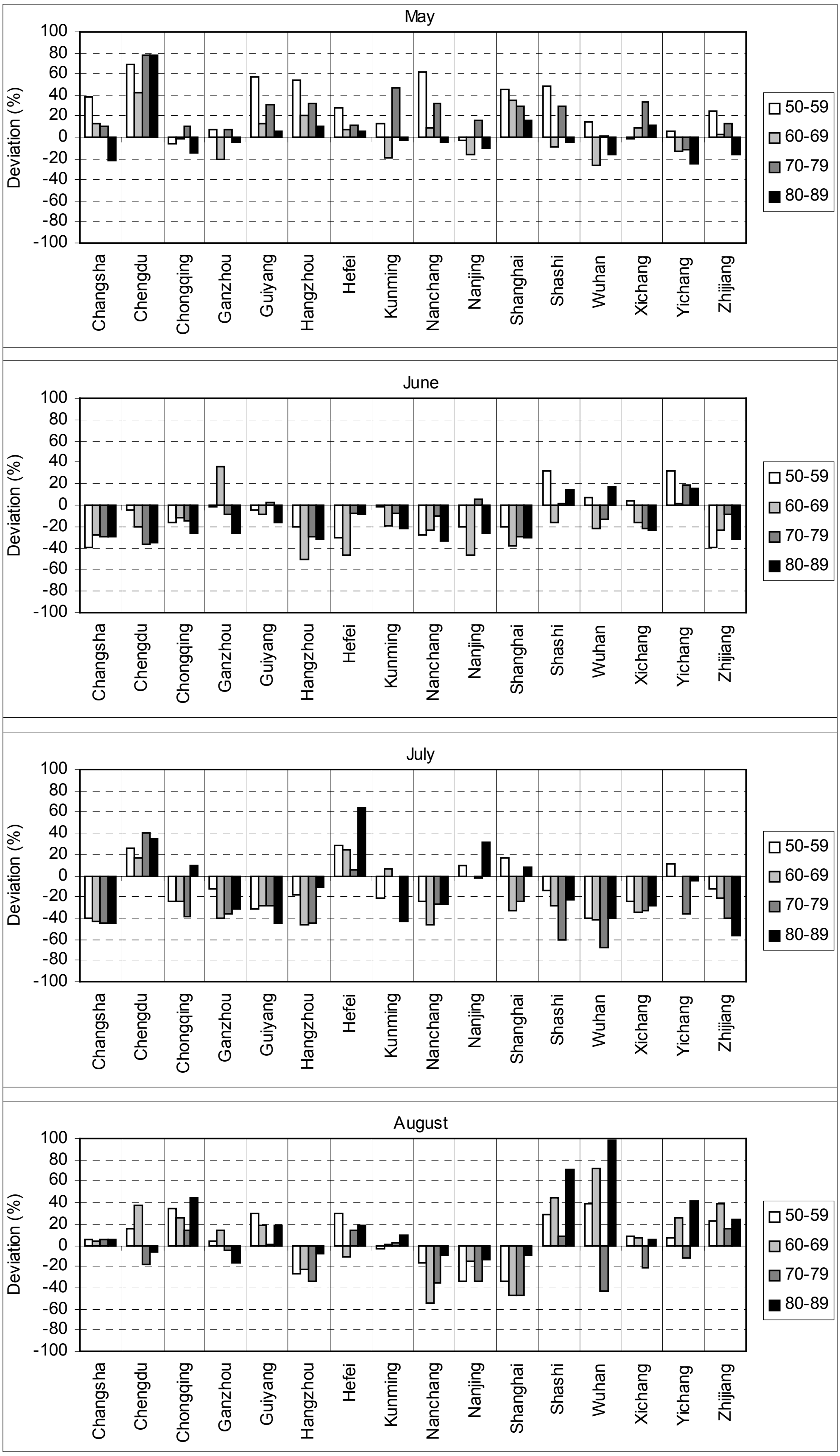
Figure 10 depicts the deviation of the average monthly precipitation of the 50s, 60s, 70s, and 80s from the 90s' average. Most stations show a decrease of the average precipitation in the 90s in May and an increase in June and July whereas the situation in August does not show a general trend for most stations. The average May precipitation decreased in the 90s in comparison to all or most previous decades in Chengdu, Guiyang, Hangzhou, Hefei, Shanghai, Changsha, and Nanchang. The magnitude of the decrease varies depending on the station and decade, most values are below 40% and it reaches extreme values of 80% in Chengdu. Only Yichang shows a negative deviation of most earlier decades.

All stations show an increase of the average precipitation in the 90s in June in comparison to all or most previous decades except of Shashi, Wuhan, and Yichang. The magnitude of the increase is comparable to the corresponding decrease in May, the average precipitation in the previous decades is generally less than 40% lower than in the nineties. As for the month of May it is again especially Yichang, which shows a different trend compared to the other stations.

The month July does not show such an almost uniform trend like June but most stations (Changsha, Chongqing, Guiyang, Hangzhou, Kunming, Shashi, and Wuhan) show an increase of the average precipitation in the 90s in comparison to all or most previous decades. It is also noteworthy that the magnitude of this increase is generally considerably higher, as the average precipitation in the previous decades is often more than 40% lower than in the nineties.

The situation in August is even more diverse than in July. Chongqing, Guiyang, Hefei, Shashi, Wuhan, and Yichang show a decrease of the average precipitation in the nineties whereas Hangzhou, Nanchang, Nanjing, and Shanghai show an increase.

Figure 10: Deviation of the mean monthly precipitation of the 50s, 60s, 70s and 80s from the 90s average



4.4 Monthly precipitation trend analysis

Monthly precipitation trend analysis for time-series between 1950-1999 and 1970-1999 were performed by using the Mann-Kendall trend test considering confidence levels of 90%, 95%, and 99%. The results displayed in **figure 11** show a significant increase of rainfall at many stations in months of maximum precipitation between 1950 and 1999. Positive trends which are at least significant at the 90% confidence level in June and/or July and/or August can be noted for Changsha, Chongqing, Ganzhou, Hangzhou, Hefei, Nanchang, Nanjing, Shanghai, Wuhan, Xichang, and Zhijiang while no significant negative trend is detectable for these months at any station. It is noteworthy that the positive trends for the summer months are often preceded or followed by significant negative trends in the earlier and/or later months. This is an indication for the tendency towards a concentration of summer rainfall within a shorter period of time. Chengdu, Guiyang, Shashi, and Yichang show significant negative trends in April and/or May but no significant trends in the summer months. No significant trends in the summer months are further noted for Kunming.

The Mann-Kendall trend analysis for the time-series from 1970 to 1999 **(figure 12)** reveals significant positive trends in the summer months for Changsha, Chongqing, Ganzhou, Guiyang, Hangzhou, Nanjing, Shanghai, Shashi, Wuhan, Xichang, Yichang, and Zhijiang. The trend had obviously started later for Guiyang, Shashi, and Yichang. A diverse situation regarding the trends in the summer months can be observed in Chengdu. The trends in the summer months in Nanchang and Kunming are not significant and Hefei shows a negative trend in July. The observation for the tendency of the preceding and following months of positive summer trends, which was established on the basis of the 1950 – 1999 time series is generally also valid for the 1970 – 1999 time series.

In general, most stations show a significant increase of precipitation towards the 90s in certain summer months which goes along with a decrease of precipitation during other summer months. The question that arises is whether a similar trend can be detected towards the 50s as they can also be regarded as a wet decade. The Mann-Kendall trend analysis for the time-series from 1920 to 1959 and 1930-1959 reveals only few significant trends for the summer months. Compared to the 1970-1999 Mann-Kendall trend test results the number and confidence level of observed trends in these earlier decades are strikingly lower. This comparison is limited to 11 stations with available data (see **figure 2**).

Figure 11: Mann-Kendall trend test for monthly precipitation 1950 – 1999

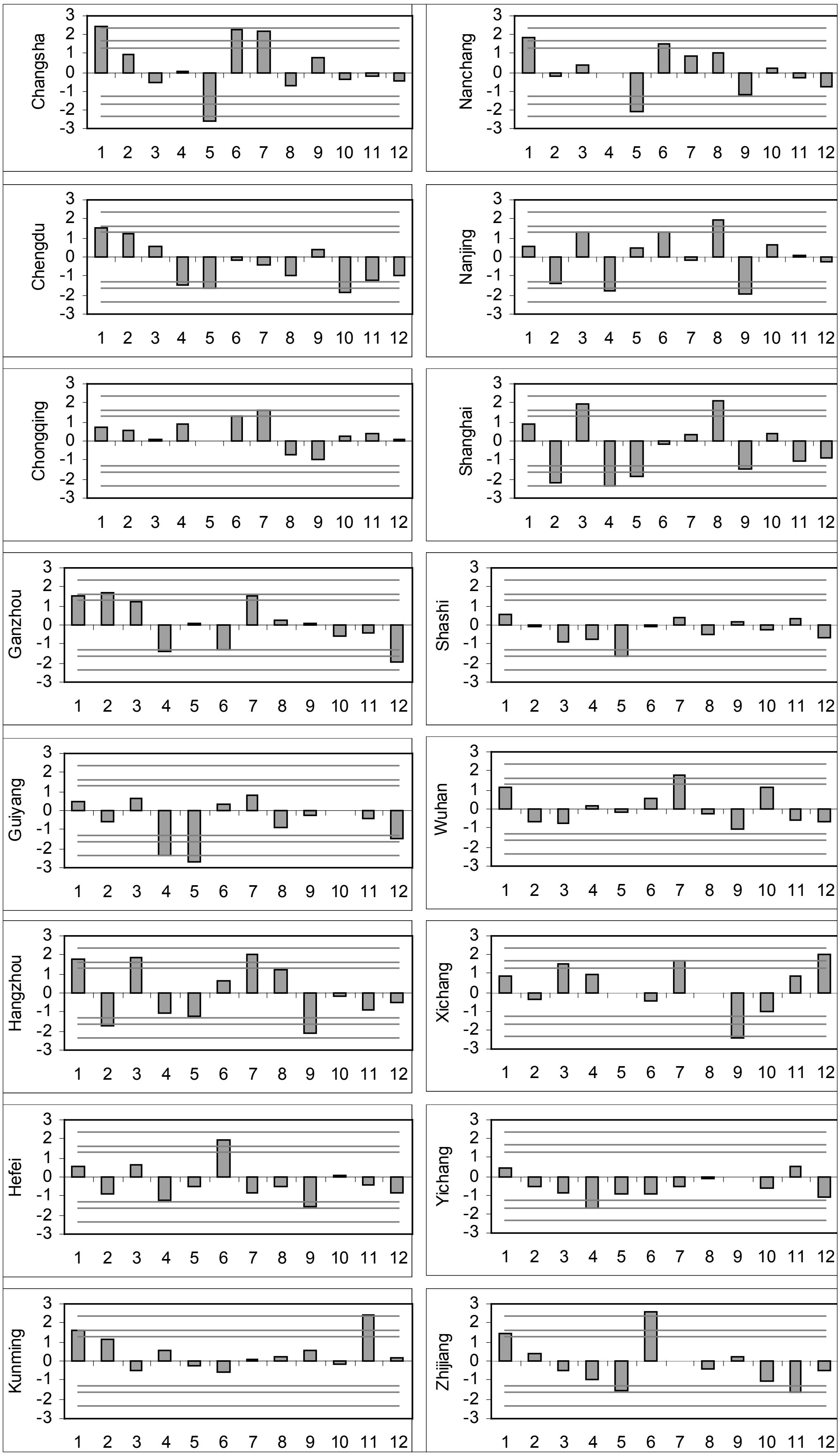
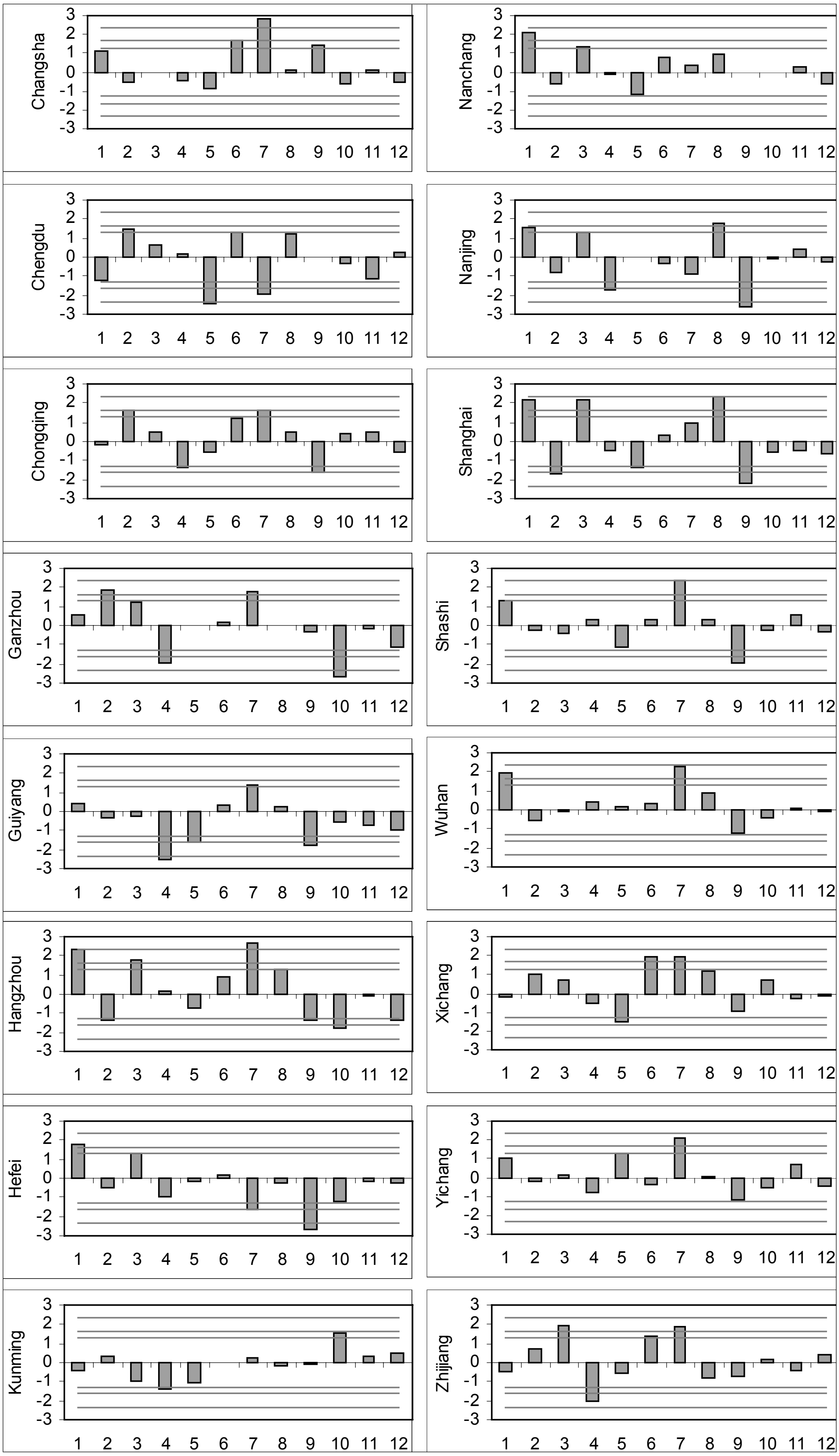


Figure 12: Mann-Kendall trend test for monthly precipitation 1970 – 1999



5 SUMMARY

The 1990´s Precipitation at 16 stations in the Yangtze River Catchment within the context of 20th century time-series has been analysed. Linear trends, decadal fluctuations, occurrence of extreme years, and inter-annual variability of annual precipitation have been examined with special focus on 90s precipitation. Changes in monthly precipitation were analysed by decadal comparison, analyses of inner-annual variabilities and Mann-Kendall trend tests.

No general increase or trend of the annual precipitation and its variability in the Yangtze river catchment has been detected. Decadal-scale fluctuations of precipitation are apparent for the whole time series. The 1990s were no exceptionally wet decade concerning annual precipitation in the context of 20th century. Nevertheless, it becomes obvious that the 90s take on an exceptional position, as at comparatively many stations more than one wet year (precipitation above 90% quantile of station's data) occurred during this decade.

An interesting feature of this study is the observation of relatively large differences in seasonal trends. Some months became distinctively wetter at some stations in the 90s whereas others showed the opposite trend. Most stations display a slight or considerable increase of the inner-annual variability from the 80s to the 90s, however, the values in the 90s were often superseded in earlier decades. Most stations also show a decrease of the average precipitation in May in the 90s whereas an increase of the average precipitation in June and July in comparison to all or most previous decades is significant. The situation in August is diverse, but a significant increase of rainfall at many stations in months with maximum precipitation between 1950 and 1999 can be detected. It is noteworthy that the positive trends for the summer months are often preceded or followed by significant negative trends in the earlier and/or later months. This is an indication for the tendency towards a concentration of summer rainfall within a shorter period of time. The relevancy of this trend for the development of flood events is apparent and will be analysed in further studies.

6 CONCLUSIONS/DISCUSSION AND OUTLOOK

Since no trend can be detected for annual precipitation in the Yangtze river catchment for the last century, but different trends for summer precipitation are obvious, it is yet to be seen whether the precipitation trends towards and in the 90s will proceed or reverse as it happened in earlier decades of the 20th century. Precipitation extremes (e.g. average monthly sums within few days) were not analysed within this study due to lack of long term data sets. However, they are the backbone of local floods such as in 2002 and available data for the last 50 years should be examined as it has been started by GONG & WANG 2000. These data could basically be used to reconstruct flood events meteorologically along the Yangtze river in the 20th century.

Decadal sequences of wet and dry years are the background of (historical documented) flood and drought events at the Yangtze. The trend of summer precipitation especially in June and July is critical regarding these flood and drought events. The occurrence of local floods is more likely to happen if summer precipitation falls within a shorter period of time. Trend analysis of mei-yu onset and duration will progress research on this aspect. Regionalisation of the observed precipitation trends will be another focus of interest. A forecast of precipitation extremes might improve the preparedness towards floods in different sub-catchments of the Yangtze river. The harmonic analysis of last century time series might provide some information for the prediction of future precipitation trends. They could be used for a better preparedness towards floods.

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