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Recent Climate Change in China and possible impacts on Agriculture

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Abstract
Monthly temperature and precipitation records of 165 official stations scattered over China were collected in order to analyse temporal and spatial trends and variabilities of temperature and precipitation in China. The results are compared with global trends and discussed against the background of the recently published reports of IPCC. Completing the paper possible impacts of climate change on agriculture are discussed.

Introduction
Major focus of present-day global scientific discussion is on climate change. The increased concentration of greenhouse gases in the atmosphere due to human activities like the combustion of fossil fuels and agricultural production tends to warm the surface air temperature and results in general changes of the climate system. Commonly accepted the global average surface air temperature has increased since the latter half of the 19th century with a global warming over the 20th century at a rate of 0.6 °C. Globally, the 1990s were the warmest decade, 1998 the warmest year of instrumental record (IPCC 2001a; IPCC 2001b).
Human health, ecological systems and socioeconomic sectors are sensitive to changes in climate and its variability; strong links are noticed between the variability of climate and the agricultural productivity - climate change impacts the agriculture sector. Because most of the developing countries depend on agriculture, the effects of global warming are likely to threaten both the welfare of the population and the economic development of the countries.
China is socioeconomicaly dependent on natural resources such as water, forests, grassland and fisheries. The magnitude of changes in climate variables and the vulnerability would differ significantly across the regions of China. This paper discusses the spatial and temporal variabilities and trends of temperature and precipitation in China and possible impacts on agriculture.

Data and methods
Homogeneous monthly temperature and precipitation records of 165 official stations scattered over China were collected from the National Climate Center (Beijing) and the Central Weather Bureau (Taipei) for the observation period 1951-1999. Additionally monthly temperature and rainfall data for Shanghai for the long-term period 1881-1999

were compiled. The reference data of the global temperature anomalies (land and ocean) were taken from Jones (2000).
Different statistical methods were applied in order to analyse the temporal and spatial variability of climate in China. Seasons were defined as follows:
winter: December – February, spring: March – May, summer: June – August, autumn: September – November.

Results

Trends of temperature

Linear trends and their significance were compiled for seasonal and annual temperatures for all 165 stations under study for the period 1951-1999. Strongly increasing trends of temperature can be observed almost in all parts of China and all seasons with strongest warming trends during autumn and winter. Because of the high interannual variability only some of the computed trends are linear, nevertheless most trends are significant. Annual temperatures increased at 87 % of the stations, with the highest trend of 2.64 °C for Hailar (in the north eastern part of China). The trends in the south of China are with values between 0.25 to 0.75 °C lower than in the north western part (the values vary between 1 and 2 °C). Strongest trends can be observed in north eastern parts with trends varying between 1 °C and 2.5 °C. Decreasing trends can only be found at some stations in a strip, extending north easterly from Sichuan (Huili) in the South to Hubei (Yuanxian) (Figure 1). However, the computed decreasing trends are low, with the strongest trend in Yuanxian (-0.85 °C).

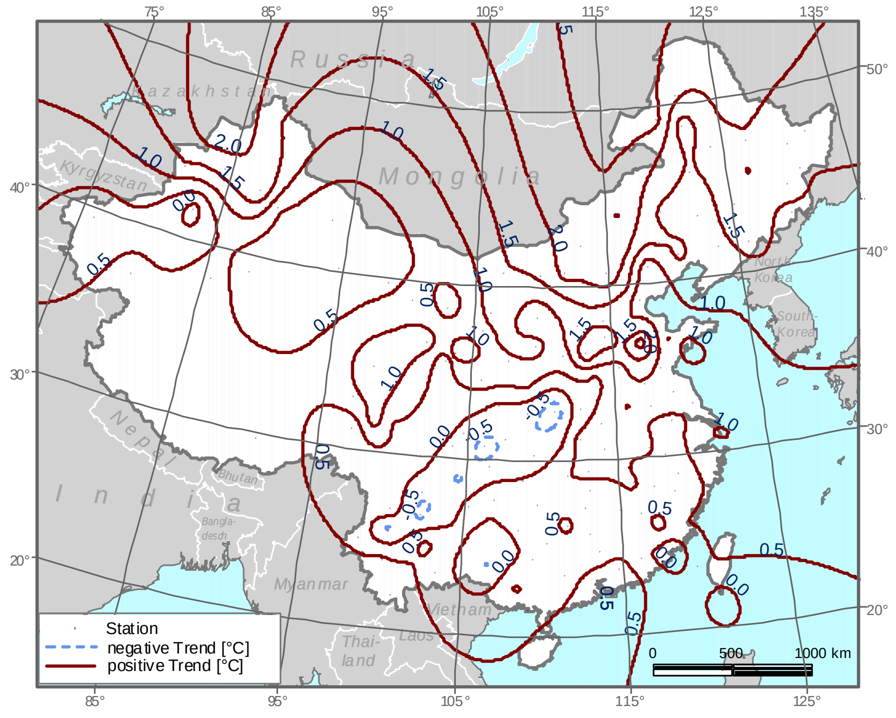

Figure 1: Spatial distribution of trends of annual temperature [°C], 1951-1999.

Seasonally, large differences can be found. Increasing trends prevail in autumn, with strongest trends in the northern parts varying between 1 and 2.5 °C and lowest trends in southern parts. In winter the trends vary between –1.34 °C in Dali (in the south of Yunnan) and 6.12 °C in Urumqi (in the north western part), but increases are predominant. Similar to the annual temperature strongest increases (> 1.5 °C) can be observed in north western and north eastern parts of China. The increases in the south vary between 0.5 °C and 1.0 °C. Some stations in the province Sishuan and the above mentioned station Dali show decreasing trends. In spring and summer no uniform trend pattern can be observed, nevertheless increasing trends prevail. The highest decreasing trend was computed for Hami (in the north western part) in summer with a coefficient of -2,55 °C.

Temperature trends in Shanghai

For Shanghai temperature trends have been calculated for different observation periods in order to analyse long-term trends (1871-1999) and the more recent trends (1951-1999; 1971-1999). Strong increasing trends can be observed in all seasons for all periods (Table 1).

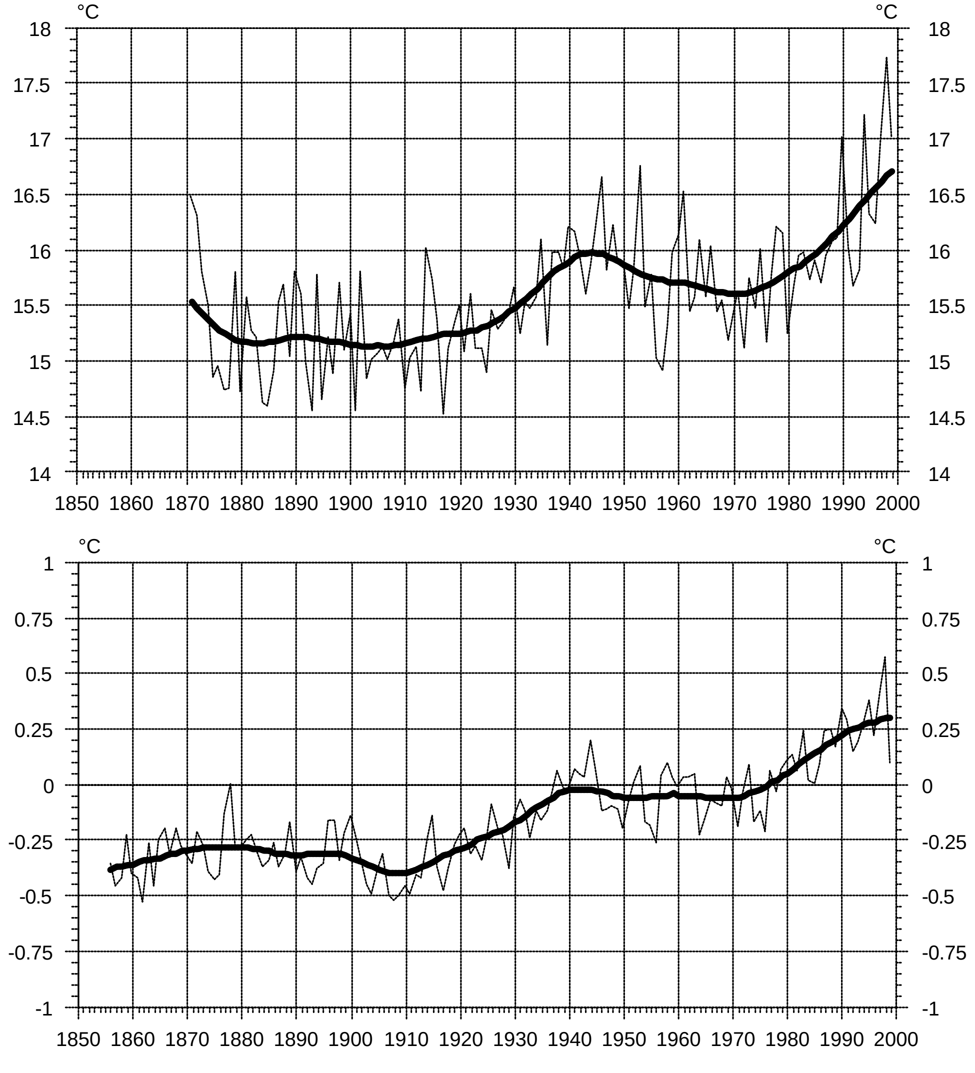

Figure 2: Trends of annual temperature in Shanghai 1871-1999 (top) and the global temperature anomalies 1856-1999 (bottom) along with low-pass filtered values (30yrs).

Annual temperature shows an strong increase of 1.12 °C for the long observation period 1871-1999, whereas the global average surface temperature shows an increase of 0.60 °C in the same period; the temperature increase is almost twice compared to the global trend (Table 1, Figure 2). Highest trends during the long-term period (1871-1999) were computed for autumn and winter with increases of 1.46 and 1.58 °C, respectively. Temperature also increases in spring and summer but the values are lower (0.84 and 0.62 °C).

Tab.1: Temperature trends in °C and their significance (trend/noise-ratios, T/N) for Shanghai (top) and the global mean temperature anomalies (bottom) for different periods

	1871-1999		1951-1999		1971-1999	
Shanghai	Trend	T/N	Trend	T/N	Trend	T/N
Annual	**1.12**	1.91	**1.02**	1.74	**1.44**	2.35
Winter	**1.46**	1.37	**1.54**	1.35	**2.08**	1.82
Spring	**0.84**	1.10	**1.33**	1.70	**1.22**	1.61
Summer	**0.62**	0.83	**0.13**	0.18	**0.37**	0.47
Autumn	**1.58**	1.80	**1.10**	1.29	**2.03**	2.15
Global						
Annual	**0.60**	2.69	**0.42**	2.35	**0.48**	2.62
Winter	**0.65**	2.42	**0.51**	2.18	**0.63**	2.62
Spring	**0.61**	2.52	**0.47**	2.36	**0.48**	2.50
Summer	**0.54**	2.55	**0.36**	2.10	**0.44**	2.41
Autumn	**0.64**	2.69	**0.37**	2.10	**0.42**	2.23

Trends of precipitation

Trends have been computed for the annual and seasonal sums of precipitation for all 165 stations under study for 1951-1999. Precipitation shows a more complex structure over time and space, increasing and decreasing trends were computed.

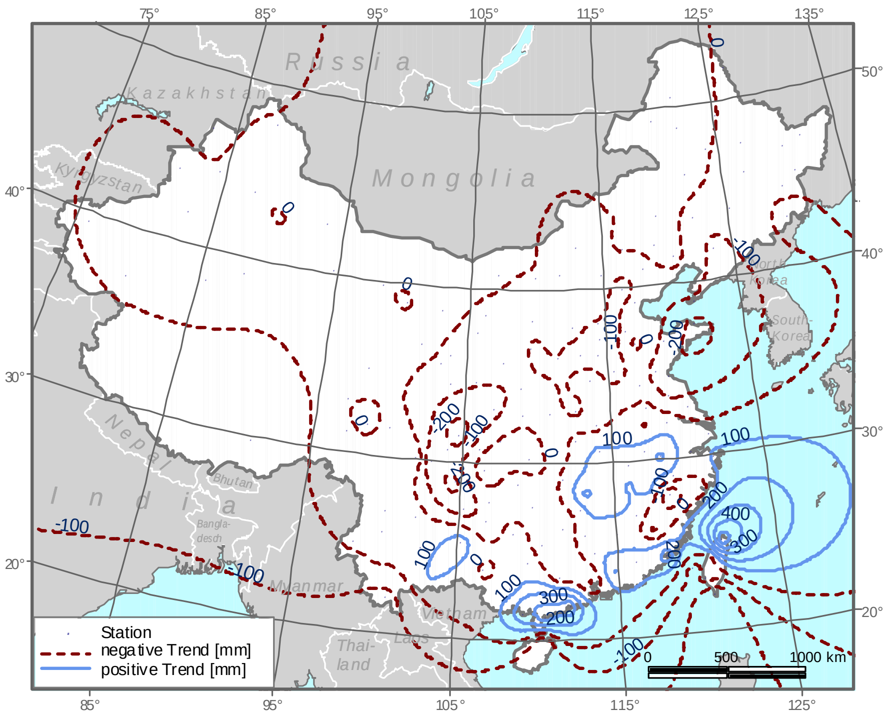

Figure 3: Spatial distribution of trends of annual precipitation [mm], 1951-1999.

Besides the interannual variability of precipitation is very high; therefore only some of the computed trends are significant. Strongest annual precipitation trends can be observed in Taiwan (Figure 3): For Taipei an increasing trend of 568 mm was computed, corresponding a plus of 27 % of the long-term mean (2195 mm). The strongest decrease was calculated for Hengshun (321 mm or 16%, respectively), also in

Taiwan. No trends can be found in the dry north western part of China, excepting Urumqi with an increase of 103 mm (38 %).
Concerning the seasons, the highest losses can be observed during summer: the computed trends vary between -229 mm (Mianyang in Sichuan) and 340 mm (Yangjiang in the south of Guangdong). Northward of 30° N also decreasing trends were observed. In contrast considerable increases (50 mm und 200 mm) were computed for stations in the south eastern part. During winter the trends vary between -51 mm and 94 mm (–138 % and 154 %) and in spring and autumn also decreasing trends prevail.

Precipitation trends and variabilities in Shanghai
The high interannual precipitation variability in Shanghai for the long period 1881-1999 can be seen in Figure 4 (annual amounts): years with high (1985: 1672 mm) and low (1892: 709 mm) precipitation amounts alter. No significant trends can be found neither for annual nor for the seasonal sums. For the more recent periods the computed trend values are higher, but none of the trends is significant: summer precipitation shows an increasing trend of 163 mm (1951-1999) or 262 mm (1971-1999), respectively. Precipitation in autumn decreased (52 mm and 136 mm) during the same periods. However, none of the computed trends is significant because of the high interannual variability.

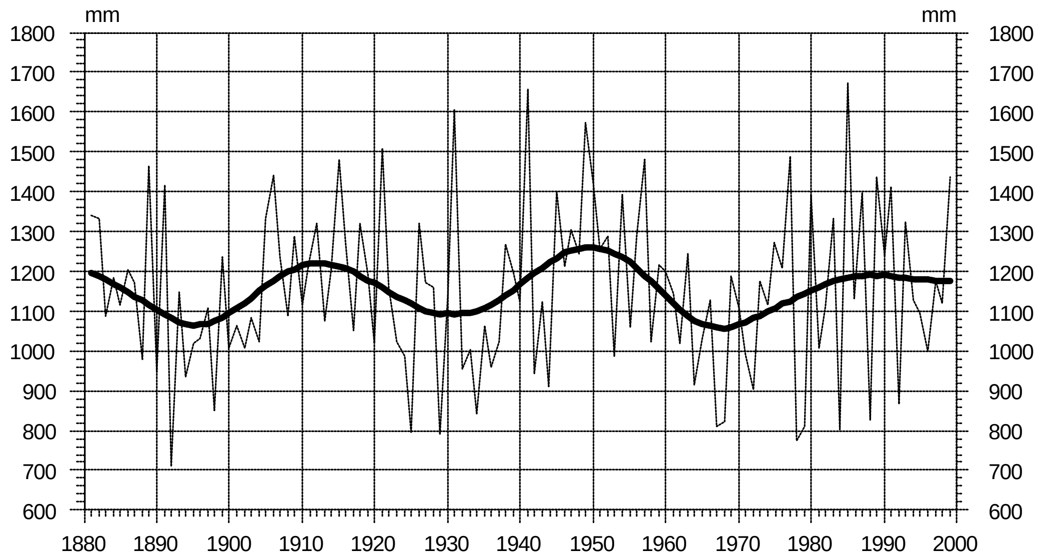

Figure 4: Trends of annual precipitation in Shanghai 1881-1999 along with low-pass filtered values (30yrs).

Future Climate Projections
Global climate models project that the mean annual surface temperature will rise by about 1.4–5.8°C by the year 2100 (IPCC 2001a). Downscaling on regional scales, the confidence in future climate projections remains low. Besides, there is more confidence in temperature projections than in precipitation changes. According the climate scenarios of current General Circulation Models (GCMs) following changes in climate are expected as a result of a doubling of CO_2 (Watson et al. 1997):

- The above analysed and described warming trends of temperature in China will continue: A warming of 2–5°C is suggested for mean annual temperature. The warming is projected to be more pronounced during winter than in summer with strongest warming in arid and semi-arid regions and lowest in the coastal monsoon region. However, there are uncertainties in the projections. Among other things the offsetting effects of sulfate aerosols are not included in some of the GCM experiments.

- Precipitation shows no uniform projections patterns over time and space, there are increases and declines in precipitation suggested. During summer precipitation changes show a decline in the northern, western, and southern parts of China. In contrast, precipitation will increase by more than 1 mm/day over the south western part of China. In winter precipitation is projected to increase marginally (<0.5 mm/day) throughout China.
- A higher frequency and greater strength of extreme weather events, such as taifunes, hurricanes or draughts is predicted. The monsoon system could become more inconstantly and variable.
- The vulnerable to flooding disasters will increase

As a consequence of warming climate zones in China will move four degree latitude to the north.

Possible impacts on Agriculture

Future climate changes will greatly affect agriculture but it is difficult to quantitatively assess the impact of future climate changes on agriculture. Positive and negative effects of elevated CO_2 can be mentioned. Laboratory and field experiments show that elevated levels of CO_2 can serve as an fertilizer and can stimulate growth and make plants more drought resistant. Although the exact magnitude of this carbon fertilization is uncertain, positive outcomes prevail. Considering the positive effects of CO_2 on crop growth an increase in productivity can be projected, but its magnitude remains uncertain.
Increased temperatures would improve growing conditions especially in the northern parts of China. Another positive effect on crop growth is the reduction of harm to crop due to frost. Otherwise higher temperatures also enhance crop loss due to insect pest and weeds. Most regions in China will become drier and soil humidity will decrease by 12% in average which will decrease crop productivity. Besides, the rainfall distribution will be more uneven and the arid period will be prolonged. This will lead to the further development of soil salinization and soil erosion and losses of fertile soil will increase.
For the projection of changes in crop-yields climate-impact models combine usually the geographically detailed climate simulations of general circulation models (GCM) with sectoral data for different countries (and climate response functions). However, projected changes in crop-yields using climate projections vary widely. In China across different scenarios and different sites, the changes for several crop-yields by 2050 are projected to be (Watson et al. 1997) as follows: Rice: -78 % to +15 %, Wheat: -21 % to +55 % and Maize: -19 % to +5 %.
In general, it is expected that areas in mid- and high latitudes will experience increases in crop-yield; yields in lower latitudes generally will decrease. Positive effects are projected for Rice in NE and NW China, negative in most parts of the country. Genetic variation provides scope for adaptation (Reilly 1999). Decreases in agricultural productivity are due to thermal and water stress, sea-level rise, floods and droughts, and tropical cyclones. Climatic variability and change also will affect scheduling of the cropping season, as well as the duration of the growing period of the crop.

Conclusions

According the analysis of temperature and precipitation data of 165 stations scattered over China it can be concluded that climate in China has generally become warmer and drier. Increasing trends of temperature prevail in all seasons with highest trends during winter in northern parts. Precipitation declines in many areas, especially during summer. For the future, there is general expectation of the continued warming trend and precipitation is expected to decrease in most eastern parts and while slight increases in

the western parts are projected. However, precipitation will become more uneven and variable over time and space.
The impacts on agriculture are uncertain, the results of different models for several crop-yields vary widely. On the one hand, higher temperatures and the CO_2 enrichment can boost the production of for instance wheat and maize. On the other hand, soil humidity will decrease by 12% in average in China. Thermal and water stress, sea-level rise, floods and droughts, and tropical cyclones will decrease agricultural productivity. Vulnerability will increase and therefore the adaptation of farming systems is very important to secure food production in China.

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