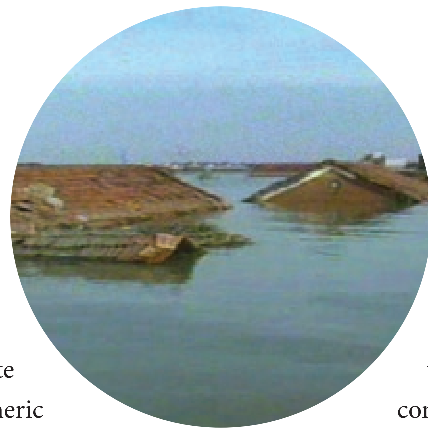
The Changing Rainfall in China



Over the last decades, China has experienced significant changes in snow- and rainfall patterns. Where do these changes come from, and do we have the tools to predict them over the long-term? At present, climate models can project changes in atmospheric circulation and temperature due to global warming, but prediction of precipitation changes is uncertain.

Yuqing Wang, associate professor of meteorology at the University of Hawai'i and part of IPRC's Asian-Australian Monsoon Team, and his student **Li Zhou** have been comparing precipitation data with atmospheric circulation patterns. Analyzing data from over 500 rain-gauge stations in China, they found that the seasonal rainfall cycle in China has changed over the last 40 years. Moreover, the observed trends in the changing rainfall patterns and rise in extreme precipitation events in certain regions are plausibly associated with changes in the large-scale atmospheric circulation over Asia.

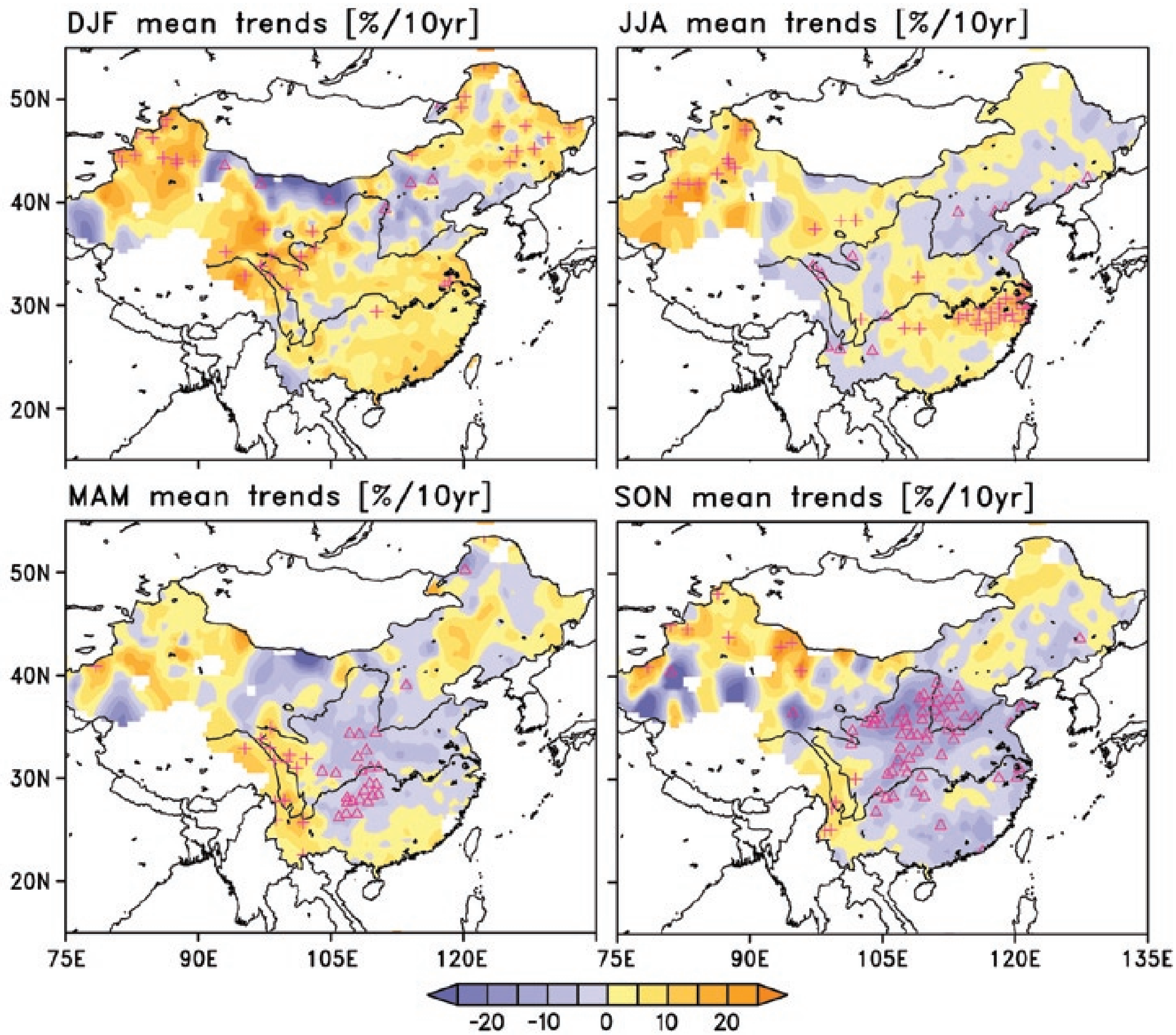
Precipitation

The rain-gauge data show that in central, northern, and northeastern China the average annual precipitation has decreased significantly from 1961 to 2001, whereas in southwestern, northwestern, and eastern China it has increased. Wang and Zhou studied the linear trend over those 40 years. In some regions of northwestern China, the increase has been between 10 and 20% during each 10-year period, indicating that these arid/semi-arid regions have been getting more rain. In central and northern China, precipitation has decreased by about 10% over each 10-year period. In fact, these heavily populated regions have had considerable water shortages in recent years.

The precipitation trends from 1961 to 2001 are not evenly distributed during the year, however (Figure 1). The northwest has now more rain during all four seasons. In spring, southwestern China has significantly more rain, while central and northern China have less rain; in summer, the Yangtze River delta and northwestern China have significantly more rain, while the far south- and northeastern regions have less; in fall, central and northern China have less rainfall, particularly the region between 40–45°N.

The increase in rainfall in the mid-lower reaches of the Yangtze River basin occurred mainly during the summer, while the decrease in rainfall in central and northern China occurred mainly in spring and fall (Figure 2). These opposing trends in summer and fall in the two regions paint a coherent picture. During these seasons, the main precipitation belt stays for a longer time in the lower Yangtze River basin and for a shorter time in northern China.

Do these changes in rainfall patterns have any implications for the occurrence of extreme precipitation events? Wang and Zhou examined the heaviest 2.5% of the daily mean precipitation from 1961 to 2001, and found that the change in extreme events over the 40 years parallels the



spatial pattern noted in the precipitation trends. For example, extreme events in the lower reaches of the Yangtze River, in south- and northwestern China increased along with the overall annual precipitation, while in central and northern China, extreme events decreased in parallel with an overall decrease in precipitation.

The rise in number of extreme rain events in the mid- and lower reaches of the Yangtze River occurred during summer and winter. The rise in extreme events in the Yangtze delta (eastern China) during summer could have great societal impact because it is one of the most developed areas in China. For the period studied, extreme summer rainfall events (the top 5% seasonal precipitation events) increased in this region by 0.5–1.0 events every 10 years (Figure 3). Moreover, the top 5% produced almost 40–50% of the total summer rainfall in eastern China. Consistent with the observed rise in number of floods in the region, the findings point to more frequent serious floods in the future—if the trend continues.

Figure 1. **Linear rainfall trends (in percentage of seasonal mean precipitation every 10 years) for (*from top left*) Winter (DJF), Spring (MAM), Summer (JJA), and Fall (SON). Plusses (triangles) show stations with positive (negative) statistically significant trends (95% level).**

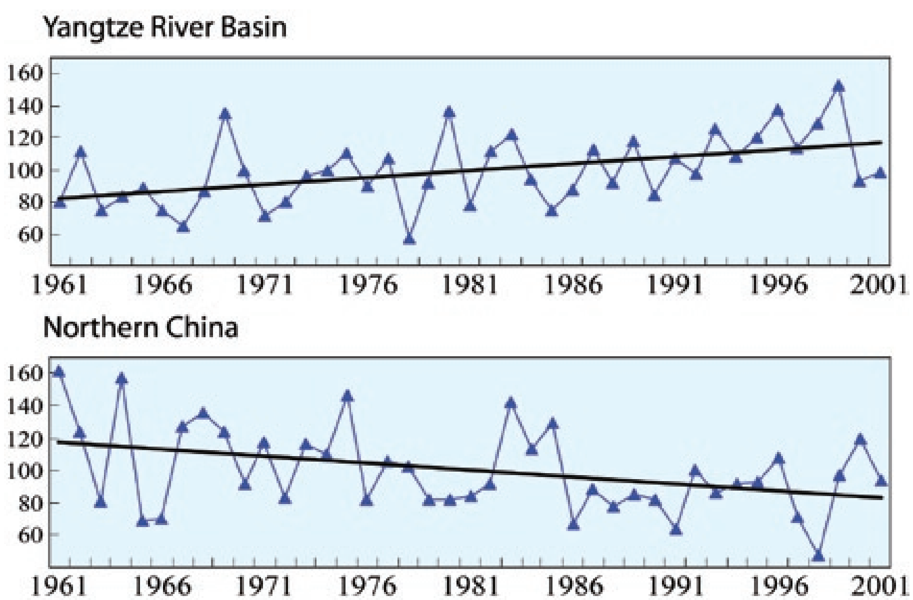


Figure 2. Changes in daily precipitation for 1961–2001 as a percentage of the climatological seasonal mean (top) in summer over the Yangtze River basin (112–122°E, 26–32°N), and (bottom) in fall over north China (100–120°E, 32–40°N).

Atmospheric Circulation

To see whether the trends noted in the summer rainfall patterns and in extreme events are attributable to changes in the large-scale atmospheric circulation patterns, Wang and Zhou conducted a linear trend analysis for the 40-year period using the summer monthly mean geopotential height and horizontal wind fields at 850 hPa and 500 hPa levels from the National Centers for Environmental Prediction/National Center for Atmospheric Research reanalysis data (Figure 4).

From 1961 to 2001, the geopotential height generally increased over Eurasia and the western North Pacific because of rising tropospheric temperatures. The rise in geopotential height over Eurasia however, has been greater than that over the western Pacific and was accompanied by an increasingly anticyclonic circulation; over the western Pacific, the circulation has become increasingly cyclonic. These trends indicate a weakening of the Eurasian continental low and a weakening of the western Pacific subtropical high. The associated increasing northeasterly winds in the lower troposphere from central China to the Pacific Coast weaken the southwesterly monsoon and limit the summer monsoon flow into northern China, something that other researchers have also recently found. As a result, the Maiyu fronts, which are nearly stationary fronts with heavy rainfall systems stretching mostly from west–southwest to east–northeast during late spring to midsummer, are now staying longer in the Yangtze River basin and shorter in northern China. This lingering of the Maiyu fronts increases the annual and mean summer

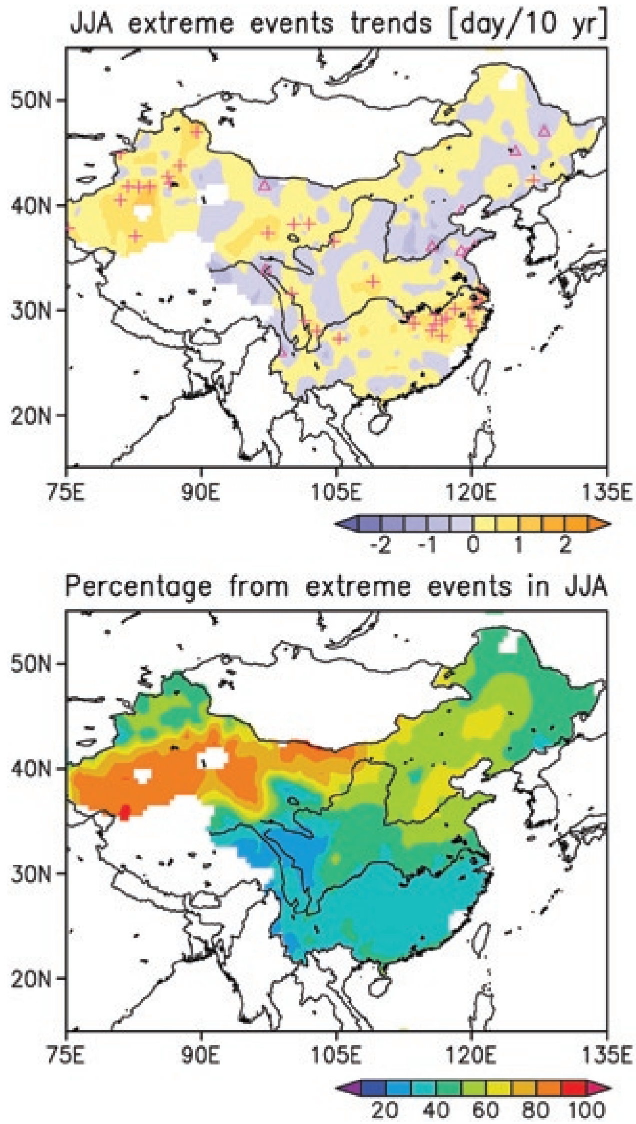


Figure 3. Top: Summer trends (increase in number of days every 10 years) in extreme precipitation events defined as the top 5% in precipitation days. **Bottom:** Percentage of total summer rainfall from extreme events.

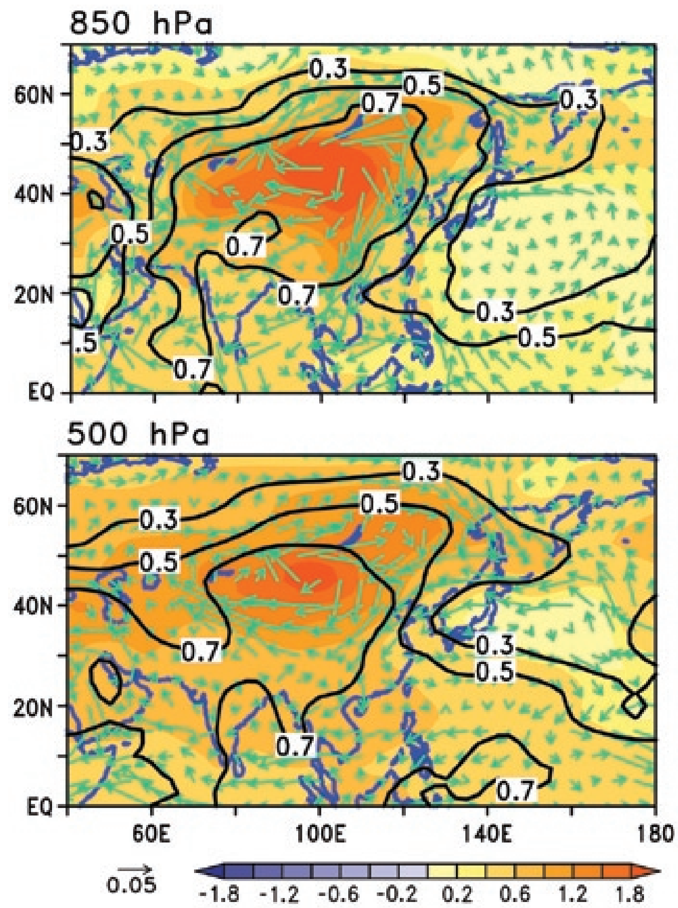


Figure 4. 1961–2001 summer trends in geopotential height (color: change in geopotential-height meters per 10 years) and corresponding horizontal winds at 850 hPa and 500 hPa (vector unit: 0.5 m/s per 10 years). The contours represent correlation coefficients between time and the geopotential height; values larger (smaller) than 0.3 (-0.3) are statistically significant at the 95% confidence level.

precipitation as well as the extreme events in the middle-lower reaches of the Yangtze River, and decreases them in northern China.

These circulation trends also explain changes that Wang and Zhou discovered in the seasonal precipitation cycle over central and east China. The monthly mean precipitation in that region has been decreasing during spring but increasing during summer: During the first two decades of the study, there was a peak in rainfall in May and another one in June; during the last two decades the peaks occurred in June and July. These changes, too, imply a weaker and later East Asian summer monsoon.

Changes in atmospheric circulation can explain changes in rainfall

The changes Wang and Zhou noted in the large-scale summer atmospheric circulation over the 40-year period can explain the rise in rainfall and extreme events in the mid-lower reaches of the Yangtze River basin during summer and the decrease in precipitation in central and northern China during fall. Those coupled general circulation models that simulate realistically and reliably the atmospheric circulation responses to changing temperatures, therefore, are useful for inferring precipitation trends that may result from global warming.

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