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ANALYSIS OF MONTHLY MEAN CLOUD AMOUNT FOR CHINA: 1951-1994

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1. INTRODUCTION

The distribution of clouds over the globe greatly influences the regimes of other important climatic variables, such as temperature and precipitation. While satellite records of cloudiness are extremely valuable in the study of the earth's climate (spanning now 2-3 decades), the longer records of surface-observed cloudiness for much of the earth's surface are preferred for integration with long-term records of other surface variables in attempting to understand these variables' relationships and trends.

As databases of surface-based cloud observations have become available for research use over recent decades, there have been many studies concerned with examining trends in regional cloud cover [e.g., Kaiser and Razuvaev (1995) for the former Soviet Union, Angell et al. (1984) for the United States, Henderson-Sellers (1986) for Europe, Jones and Henderson-Sellers (1992) for Australia, and Kaiser and Vose (1997) for China]. The findings of Kaiser and Vose (1997) differ from the other studies in that China appears to have experienced decreased cloudiness over recent decades, whereas the other land regions show evidence of increasing cloud cover. Kaiser and Vose (1997) performed a gridded analysis of variations and trends in cloud amount using 187 Chinese weather stations for the period 1954-1990. The main findings were significant decreases in annual mean cloud amount over much of northern China, coupled with corresponding increases in the frequency of occurrence of clear skies. The decreasing trends in annual mean cloud amount over northern China were found to be driven by decreasing cloud amount over most months of the year. The current study uses an expanded period of record of China cloud observations (1951-1994) to re-examine trends in cloud amount at individual stations and over eight regions of China.

2. DATA

The cloud data analyzed here were extracted from a database of 6-hourly weather observations provided by the China Meteorological Administration

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(CMA). Six-hourly observations [0200, 0800, 1400, and 2000 Beijing Time (BT)] of cloud amount (0-10 tenths of sky cover) are available from 196 Chinese stations covering the period 1954-94. From 1951-1953, however, only 0800, 1400, and 2000 BT observations were made, and it is for this reason that Kaiser and Vose (1997) began their analysis in 1954, as they chose to use evenly-spaced observations from throughout the 24h day. In this analysis, a slightly different approach to data sampling will be taken, which is detailed in the following section.

3. ANALYSIS PROCEDURE

Since it has long been recognized that it is much more difficult to accurately estimate cloud amount at night (e.g., Schneider 1972)—especially if thin cirrus clouds are present—this study analyses daytime observations separately from nighttime observations. Daytime analysis is for the period 1951-1994 and the nighttime analysis is for 1954-1994 (because of the lack of 0200 BT observations prior to 1954). One would expect observed daytime and nighttime cloud amount to differ, not only because the presence of clouds is easier to detect in daylight, but due to the diurnal variations typically observed over land for specific cloud types [e.g., cumulus cloud amount over China typically peaks in the early afternoon across all seasons (Warren et al. 1986)]. Such day/night differences in means are of interest in this work, but do not present any difficulties for the main objective, which is to characterize trends in cloud amount.

An additional caveat pertaining to the cloud data involves the 0200 BT observations from 1954-1960. Wang et al. (1984) indicates that some 0200 BT values of cloud amount at certain stations may not be actual cloud amount estimates from 0200 BT, but rather estimates reflecting values observed in subsequent early daylight hours—perhaps even the exact entry for the following 0800 BT observation. However, metadata pertaining to this issue are not completely clear, and a random inspection of 0200 and 0800 BT observations does not yield an unusually high occurrence of identical 0200 and 0800 BT cloud amounts. Therefore, the current analysis takes the 0200 BT observations at face value for their entire period of record: 1954-1994.

Kaiser and Vose (1997) used the mean of the 0800 and 1400 BT observations to represent what they termed the *daylight* cloud amount. Here, only the 1400

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BT observations will be used to represent daylight cloud amount, since, for a portion of the year at stations significantly west of Beijing, it is certainly not light at 0800 BT. Using the 1400 BT observations assures that these cloud amounts are estimated in daylight at all stations. Likewise, the 0200 BT observations imply nighttime observations at all stations. Observations made at 2000 BT are not used, as these would mix day and night observations depending on season and location.

The 1400 ("midday") and 0200 BT ("midnight") observations were averaged for each station over the four traditional meteorological seasons (winter: months 12, 1, and 2; spring: months 3, 4, and 5, etc.) and over each year. Linear regression analysis was used to characterize trends in the seasonal and annual means over 1951–1994 (midday observations) and 1954–1994 (midnight observations) at individual stations and for eight regions adopted in a recent analysis of precipitation trends over China (Zhai et al. 1997).

4. RESULTS AND DISCUSSION

Station and regional trends in annual mean cloud amount are depicted in Figure 1. The data clearly indicate *decreasing* cloud amount over much of China from the early to mid-1950s through 1994. Most stations in central, eastern, and northeastern China show statistically significant decreases of 1–4% sky cover per decade (>4% at some stations). Midday and midnight observations show a similar spatial pattern of decrease, with midnight trends generally even stronger than midday trends.

Annual and seasonal mean cloud amount and trends in cloud amount for the eight regions of China are given in Table 1. The summary of seasonal trends shows that the strongest and most consistent evidence for decreasing cloud amount is seen for North and Northeast China, where decreases ranging from ~1 to 2% sky cover per decade (~4.5 to 9% over the period of record) are observed.

These decreasing trends in cloud amount are especially interesting in light of recent temperature trends observed over China. Several studies (most recently Easterling et al. 1997) have shown significant increasing trends in daily minimum temperatures over China, especially in the northeastern part of the country, precisely where the strongest decreasing trends in total cloud amount are observed. Increases in cloud amount have been offered as one possible explanation for increased minimum temperatures in other parts of the world (e.g., Karl et al. 1993). In China, it seems that some different mechanism(s) must be considered for understanding the observed increase in minimum temperatures, perhaps relating to atmospheric circulation.

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Figure 1. Trends in annual mean midday cloud amount (percent sky cover per decade for 1951-1994) (a); and trends in annual mean midnight cloud amount (percent sky cover per decade for 1954-1994) (b). Station trend indicators with circles around them are significant at the 95% confidence level, as are regional trend values that are in bold italics.

Table 1. China regional midday/midnight* (1400 BT/0200 BT) cloud amount trends** (percent sky cover per decade) and mean cloud amount (percent sky cover) for the period 1951–1994.

TRENDS	WNW	ENW	NORTH	NE	TIBET	SW	EAST	SOUTH
WIN	+0.6 / -0.1	-0.6 / -1.3	-0.9 / -0.7	-1.1/-1.3	-0.6 / -0.3	-0.9/-1.2	-0.9 / -0.2	-0.3 / +0.7
SPR	-0.6 / -0.9	-0.1/-1.1	-1.2/-1.9	-1.5/-2.1	-0.4 / -0.7	-0.4 / 0.0	-1.0/-1.2	+0.5/+1.8
SUM	+0.2 / -0.5	-0.4 / -0.6	-0.9/-1.2	-1.2/-1.2	-1.0/-3.3	-0.8/-1.0	-1.1 / -0.8	-1.2/-1.5
AUT	-0.1 / -0.2	-1.2/-1.4	-1.0/-1.0	-1.1/-1.4	-0.6 / -0.1	-0.4 / -0.2	-1.1 / -0.2	-0.7 / +0.5
ANN	+0.1 / -0.5	-0.6/-1.2	-1.0/-1.0	-1.2/-1.5	-1.4 / -1.4	-0.6/-0.6	-1.0/-0.5	-0.4 / +0.4
MEANS	WNW	ENW	NORTH	NE	TIBET	SW	EAST	SOUTH
WIN	55.6 / 41.0	49.9 / 36.3	40.7 / 28.1	37.8 / 26.6	44.4 / 29.2	57.5 / 49.1	65.2 / 60.5	68.4 / 69.8
SPR	60.6 / 48.2	68.6 / 51.6	58.9 / 40.3	61.4 / 41.3	72.0 / 46.5	71.5 / 58.5	76.7 / 69.4	81.2 / 77.7
SUM	49.4 / 43.2	66.6 / 50.7	67.0 / 47.9	72.1 / 55.0	76.0 / 67.4	83.2 / 77.2	73.2 / 59.7	80.1 / 67.1
AUT	42.8 / 32.3	53.0 / 40.6	47.0 / 34.0	49.7 / 35.9	51.8 / 36.8	71.9 / 67.1	63.8 / 56.8	65.0 / 58.4
ANN	52.0 / 41.2	59.5 / 44.7	53.5 / 37.7	55.3 / 39.7	60.7 / 44.6	71.0 / 63.0	69.8 / 61.7	74.0 / 68.3

*Trends and means for midnight (0200 BT) cloud amount are for 1954–1994.

**Trends in shaded boxes that are in bold italics are significant at the 95% confidence level.