14.6 ASSESSING OBSERVED TEMPERATURE AND CLOUD AMOUNT TRENDS FOR CHINA OVER THE LAST HALF OF THE TWENTIETH CENTURY: WHAT CAN THE SUNSHINE DURATION RECORD TELL US?

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1. INTRODUCTION

Analyses performed in recent years have shown that temperatures over much of China have increased over the last half of the Twentieth Century, similar to most nations with adequate observational data. Most of this observed increase has been due to increases in daily minimum temperatures. Over this same period, cloud amount over China has been found to have decreased significantly. This is an interesting finding in that a trend toward less cloudiness over time would in itself be expected to cause minimum temperatures (usually occurring in the near- dawn hours) to decrease over time due to enhanced radiational cooling near the surface. Obviously the causes of increasing temperature in general over China are not well understood at this time.

A study by Kaiser (1993), using data from 52 Chinese stations with monthly cloud amount and sunshine duration data, found evidence of decreasing cloudiness *and* decreasing sunshine duration. This seemingly curious result is still not understood completely; perhaps it can be partially explained by increasing air pollution causing the Campbell-Stokes Sunshine Recorder, which is sensitive to the intensity of direct solar radiation, to not record as much sunshine, especially early and late in the day when the atmospheric path length is greatest.

There is relatively high confidence in the findings from analysis of the cloud amount record (Kaiser, 1998; 2000), which most recently has been studied using 6-hourly observations from 196 station records provided by the China Meteorological Administration (CMA). The sunshine duration record has not received as much attention, so this study will examine daily sunshine duration data from these CMA stations. As of this writing, only preliminary results are available; many more findings will be presented at the Global Change Studies Symposium.

2. DATA

The China meteorological data to be analyzed in this study were made available to the U.S. Department of Energy's Carbon Dioxide Information Analysis Center (CDIAC) at Oak Ridge National Laboratory by colleagues from the CMA via a bilateral research agreement between the two national agencies. The raw data to be used consist of daily maximum (Tmax) and daily minimum (Tmin) temperatures, daily sunshine duration, and 6-hourly observations of cloud amount from 200 stations. Temperature data are available from 1951 through 1998; sunshine data extend through 1998 for most stations, with the start date varying by station through the 1950s; and 6-hourly (4 observations per day) cloud amount observations are available at most stations from 1954 through 1998.

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3. TRENDS IN THE DATA

Daily sunshine duration for each station was summed over each month and converted to monthly percentage of possible sunshine (hereafter referred to as sunshine) by calculating the maximum possible sunshine duration for each month, which assumes a smooth, spherical earth with no natural or artificial obstructions that would block the sun's rays. Preliminary analysis of monthly sunshine shows results consistent with those reported by Kaiser (1993) for 52 stations, located mainly in eastern China, for the period 1954–1988. A large number of the 196 CMA stations with data through 1998 show decreasing trends in sunshine (using a linear regression model and specifying significance at the 95% confidence level); see Table 1.

TABLE 1. The number of China stations (out of 196) with significant trends [increasing (↑) or decreasing (↓)] in sunshine from the 1950s through 1998 for the four seasons and the year. [DJF = winter (Dec., Jan., Feb.), etc.]

Season	DJF	MAM	JJA	SON	Annual
↓ Sun	74	52	81	64	106
↑ Sun	9	11	8	8	7

Most, but not all, of the stations with decreasing sunshine trends are found in southern China, although some increasing trends are found in the north. The few stations with increasing trends lie in the west and far north of the country, in Xizang (Tibet), Qinghai, and Nei Mongol provinces. Detailed maps will be shown in the accompanying presentation.

Given the significant *decreases* in cloud amount for 1954 through the mid-1990s reported over much of China by Kaiser (1998; 2000) (using a station network very similar to that used here), the strong *decreasing* sunshine trends are a curious finding. Decreasing cloud amount in itself would be expected to result in an increase in sunshine; therefore, other factors must be considered in order to attempt to explain the decrease in sunshine. One such factor is the increased atmospheric aerosol loading that has taken place in China over recent decades due to increased fossil fuel combustion (mainly coal). A large increase in sulfate aerosols from coal burning would be expected to enhance the backscatter and absorption of incoming solar radiation and thus weaken the direct solar radiation needed to activate the Campbell-Stokes Sunshine Recorder. Data on global radiation and horizontal visibility over China would be of great value in confirming this basic theory but are not readily available at this time. However, the work of Stanhill and Kalma (1995) gives an interesting picture of what they term "solar dimming" for Hong Kong. From 1958 through 1992 they found significant decreases in both sunshine duration and global radiation, even though no significant trend in cloud amount was observed. They attribute the solar dimming to increased aerosol loading.

As previously noted, the small number of China stations exhibiting increased sunshine (Table 1), are in the west and far north of China. Due to the relative lack of industry and population both within these regions and upstream from them (prevailing winds for most of the year blow from similar remote, inland regions), one would expect little change in anthropogenic aerosol loading over the study period. Most of these stations were shown in Kaiser (2000) to exhibit decreasing cloud amount trends.

Several studies in recent years (Easterling et al. 1997; Yu et al. 2000; Wang and Gaffen 2000) have shown increasing temperature trends over China, especially in the case of Tmin in the north. Presentation of this paper will include an analysis of temperature trends through 1998 using the 200 CMA stations, but also focusing on a subset of less urban stations, since population growth in China over recent decades has been shown to cause a measurable urban temperature bias at some stations (Portman 1993).

Explaining the apparent large warming in northern China in the face of *decreasing* cloud amount is an interesting research problem. Only recently has this begun to be addressed in the literature. Yu et al. (2000) present evidence that mineral dust related to growing desertification in northern China, along with increasing anthropogenic black carbon (mainly from coal burning), make up a large part of the increase in aerosol loading in this region. They suggest that such aerosols may be acting to enhance absorption and backscattering of outgoing infrared radiation, thus elevating temperatures, especially at night in the colder months of the year. Southern China, however, has shown relatively little temperature change (Yu et al. 2000; Wang and Gaffen 2000), with summer temperatures actually trending downward somewhat, perhaps due to the shortwave effects of increased aerosol loading.

As far as cloud amount is concerned, this presentation will include an update of the trends presented in Kaiser (2000), i.e., extending the record two more years through 1998 with essentially the same network of stations. Correlation of the sunshine record with the cloud amount and temperature records at station, regional, and national levels will be examined, along with decadal-scale variations and trends in all three variables. Kaiser (2000) found that a sudden, large decrease in all-China cloud amount occurred in 1978. Equivalent time series for sunshine, Tmax, and Tmin will be constructed and compared with the cloud amount series.

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