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CLOUD COVER AND TYPE OVER THE FORMER USSR, 1936–83; TRENDS DERIVED FROM THE RIHMI-WDC 223-STATION 6- AND 3-HOURLY METEOROLOGICAL DATABASE

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ABSTRACT

This paper presents trends analyses of sky cover data from the former U.S.S.R. for the period 1936–83. Observations of total cloud amount, low cloud amount, and low-, middle, and high-cloud type from 223 stations were obtained from a database of 6- and 3-hourly meteorological observations compiled at the Research Institute of Hydrometeorological Information – World Data Centre in Obninsk, Russia. Station data were averaged over various-sized grid boxes and linear trends in seasonal mean total cloud amount, low cloud amount, frequency of occurrence of cirrus clouds, cirrus amount, and frequency of clear sky were computed for the period 1936–83.

1 INTRODUCTION

In recent years a great deal of meteorological and climatological data have been exchanged between the two principal climate data centers of the United States and the former Soviet Union: the National Climatic Data Center (NCDC), in Asheville, North Carolina, and the Research Institute of Hydrometeorological Information – World Data Centre (RIHMI-WDC; hereafter referred to as RIHMI) in Obninsk, Russia. This was accomplished via Working Group VIII (*Influence of Environmental Changes on Climate*) of the bilateral initiative known as the *Agreement on Protection of the Environment*, established on May 23, 1972 by the United States and the USSR.

One of the key datasets compiled by RIHMI includes 6- and 3-hourly meteorological observations from 223 USSR stations for the period 1936–83. Six-hourly observations were made from 1936–65; 3-hourly observations were made from 1966 onward. RIHMI has chosen to use daily and hourly data from these stations as the basis for considerable climate research efforts. These data (hereafter referred to as the RIHMI database) have been made available by the Department of Energy's Carbon Dioxide Information Analysis Center (CDIAC) in Oak Ridge, Tennessee (Razuvaev et al. 1995). The data have undergone quality assurance checks at RIHMI, NCDC, and CDIAC. The data contain observations of some 22 meteorological variables, including near-surface air temperature, sea level pressure, precipitation amount, weather type, total cloud cover, and cloud type.

In a previous study, Kaiser et al. (1995) compared seasonal and annual mean total cloud cover from the RIHMI database to data presented in the atlas: *Global Distribution of Total Cloud Cover and Cloud Type Amounts Over Land* (Warren et al. 1986; hereafter referred to as W86) for the common data period 1971–81. RIHMI means were found to be an average of 2-4% higher over much of the country, with the largest differences found over central Siberia in winter. The reasons for these generally systematic differences are still unclear; the analysis methods of Kaiser et al. (1995) intentionally paralleled those described in W86. It is anticipated that these differences will be explored further, but in this paper we will use the RIHMI database to examine trends in sky cover variables over the USSR for the database's entire period of record (1936–83).

2 DATA

The RIHMI database includes 6- and 3-hourly observations from 223 stations across the USSR. Records are of good quality and for the most part serially complete. Cloud information used here include: total cloud amount (N); low-cloud amount (NL); low, middle, and high cloud type; and present weather (ww). N and NL are given in tenths of sky cover, i.e., as an integer ranging from 0 (no clouds or <1/10 sky cover) to 10 (overcast or >9/10 sky cover with or without openings), whereas in raw World Meteorological Organization (WMO) synoptic code reports cloud amount is expressed in octas (eighths of sky cover), where N=0 indicates clear sky and N=8 indicates complete overcast. A sky nine-tenths covered with clouds or an overcast sky with openings are both reported as N=7 (equivalent to 0.875 sky cover) in the WMO code. (This influences our treatment of the RIHMI cloud amounts, as detailed in the next section.) Descriptions of cloud type and ww in the RIHMI observations essentially conform to those prescribed by the WMO.

3 METHOD OF ANALYSIS

Analysis of RIHMI cloud data paralleled the methods used in W86. Only a brief description will be given here; a complete description may be gained by referring to W86. The USSR was divided into latitude/longitude boxes ranging in size from 5 × 5° from 35°N to 50°N; 5 × 10° from 50°N to 70°N; to 5 × 20° poleward of 70°N. (The dimensions of each box are increased poleward of 50°N to maintain approximately equal area in each box.) The northernmost RIHMI station is at ~73°N, so the analysis area was extended only to 75°N. The locations of the RIHMI stations and the grid boxes chosen for analysis are shown in Fig. 1. Several grid boxes within the USSR contain no RIHMI stations, whereas several boxes along its borders extend into other countries. Land grid boxes on the border were only analyzed if at least half the box's area lay in the USSR. This resulted in 219 RIHMI stations over 84 grid boxes being used in the analysis. Using records which passed certain cloud- and ww-related internal consistency checks, grid box means of cloud parameters were computed for the four standard meteorological seasons over the period 1936–83. This included mean N and NL, and means of several derived parameters: frequency of occurrence of cirrus clouds (fci), amount of cirrus clouds when present (awp), total cirrus amount (aci), and frequency of occurrence of completely clear sky (fclr). These and many other cloud parameters were examined in W86. Space constraints here necessitate o[illegible] a handful of basic variables. Their description[illegible] following.

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Means of N and NL (percent sky cover) were computed using all valid observations from a given season. Daytime and nighttime observations were given equal weight in the averaging (as in W86), although observers' estimates of nighttime cloud cover are known to often be too low (cf. Schneider et al. 1989). As mentioned previously, in the RIHMI database an overcast sky with or without gaps is denoted by N=10. (The presence of gaps is indicated by a flag code.) Numerically, this is the equivalent of 100% sky cover in either case. In the synoptic observations used in W86, nine-tenths sky cover or an overcast sky with gaps is coded as N=7 (equivalent to 87.5% sky cover). Kaiser et al. (1995), so as to ensure valid comparisons between the RIHMI and W86 data, assigned RIHMI entries of N=9 or N=10 with gaps a value of 87.5% sky cover. This practice was continued in the present analysis.

Cirrus clouds are known to exhibit significant radiative effects on the surface and lower troposphere (Liou 1992). W86 found that over the period 1971–81, cirrus clouds were the most frequently observed cloud type over most of the USSR. For these reasons we chose to examine cirrus cloudiness here. The determination of seasonal fci is made by simply dividing the number of times cirrus was reported as present by the number of *non-missing* observations of high cloud type. Non-missing in this instance means that an observer could report *something* about the presence of cirrus; be it that cirrus was/wasn't present or was unable to be assessed due to a lower overcast. The awp was determined in two ways: (1) When cirrus was present with no lower-level clouds awp was obtained directly from N, and (2) When cirrus was present with lower-level clouds, awp was estimated using the random-overlap equation (W86):

$$1 - N = (1 - awp)\,(1 - NL), \qquad (1)$$

where all variables are expressed as fractional amounts ranging from 0.0 to 1.0. Equation (1) states that the clear fraction of the sky is the product of the clear fractions of the layers; it is valid only for instantaneous cloud amounts. However, as noted in W86, there are three situations in which awp cannot be computed using (1): (a) when clouds are reported at all three levels (as the equation has two unknowns and cannot be solved); (b) when NL=0.9 (since awp is constrained to being equal only to 0.0 or 1.0); and (c) when NL=1.0 the presence or absence of cirrus clouds cannot be determined. Seasonal means of aci were estimated as the product of seasonal mean fci and awp. Seasonal fclr was obtained by simply dividing the number of N=0 observations by the number of non-missing observations of N.

4 RESULTS

Due to space constraints, we have chosen to focus our discussion of results on the cloud variables and seasons which show the greatest changes over 1936–83, however, all variables and seasons exhibit important findings which will be dealt with more thoroughly in the presentation of this work at 6IMSC. Simple linear regression was performed on the seasonal grid box means of the six variables described in the preceding section. Testing for significance of linear trends in the data using the 5% confidence level revealed significant regional trends in the data over all seasons. The magnitudes of regional changes were generally found to be greatest in winter for all variables. Winter linear trend values for N, NL, fci, aci and fclr are mapped in Figs. 2a–e. (The map of awp trends is not shown, as trends were generally not significant.) Grid boxes with trends significant at the 5% level include the magnitude of the trend; those which are not significant simply give the sign of the linear trend. The region showing the most dramatic changes stretches from central to eastern Siberia, where large wintertime *increases* in N (percent sky cover), fci (percent of observations), and aci (percent sky cover) are observed. Large *decreases* are observed in NL (percent sky cover) and fclr (percent of observations) over this same general region. Analyses of these same variables for spring, summer, and fall (not shown) revealed similar patterns of significant change over this part of the country, with magnitudes being generally smaller. Another contiguous, but smaller region of the country showing significant wintertime changes lies in the vicinity of the Black and Caspian Seas. Here the sign of changes in N and fclr are opposite those in the Siberian region and evidence of increasing cirrus cloudiness is much weaker.

To depict actual seasonal values of variables and their changes over time in the Siberian region, grid box means of all variables over the region encompassed by 90° and 160° E, and 50° to 70° N were averaged over the period 1937–83 and plotted as time series in Fig. 3. (Winter means for 1936 were not calculated due to the lack of December, 1935 data.) The units of N, NL, awp, and aci are percent sky cover; those of fci and fclr are percent of observations. The time series show evidence of marked change in all variables but awp. Large increases in fci and aci are evident, and these series exhibit a positive correlation with each other (r=0.95) as would be expected, but correlate much more weakly with N (r=0.31 and r=0.43, respectively), which shows a weaker, but significant increase. The smaller increase in aci relative to fci is explained by awp being relatively unchanged over the period (recall aci is estimated from the product of fci and awp). N shows a strong negative correlation with fclr (r=-0.95).

It seems reasonable that the large decrease in NL over the period would contribute to increases in fci and therefore aci due to the opportunity to detect cirrus more often. There may be other causes however. Evidence for increasing cirrus cloudiness has been presented elsewhere in the literature, e.g., Machta and Carpenter (1971) reported increases in cirrus amount in the absence of lower level clouds at a number of U.S. stations between 1948 and 1970. Other studies have correlated observed increases in cirrus cloud amount and observed decreases in the number of clear days with the advent and increasing frequency of high-altitude jet traffic (Changnon 1981). The work of Changnon (1981), however, looked at sky conditions over the heart of the United States, where condensation trails from jets would presumably be much more common than over Siberia.

5 SUMMARY AND CONCLUSIONS

Seasonal, grid box means of several basic sky cover variables were computed from USSR 6- and 3-hourly meteorological observations over the period 1936–83. The most significant findings show evidence of substantial changes in cloud amount over a large part of the USSR stretching from central to eastern Siberia. There is strong evidence for (1) wintertime increases in total cloud amount and cirrus cloud amount, and (2) wintertime decreases in low cloud amount and frequency of clear sky. While no conclusions may be drawn at this point regarding the causes of these cloudiness changes over the Siberian region, these data seem to show evidence of real changes and much more research is warranted. If indeed cloudiness has changed over the Siberian region as shown by this analysis, we would expect to find strong feedbacks in surface and atmospheric temperatures.

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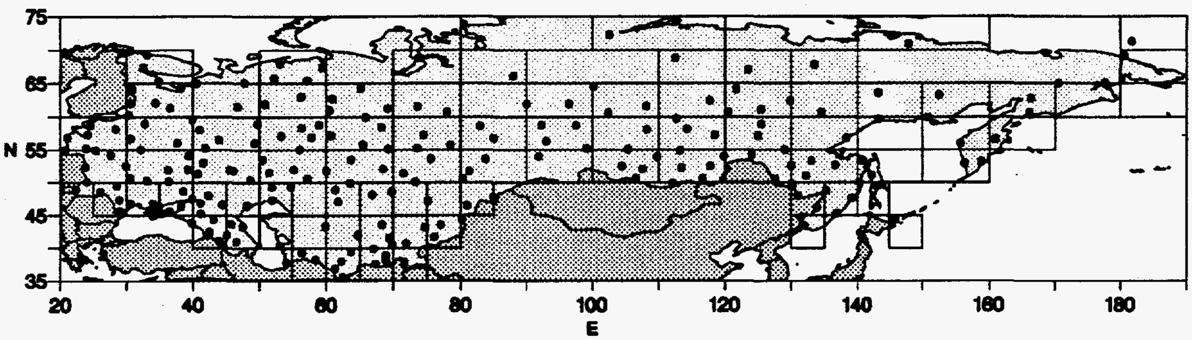
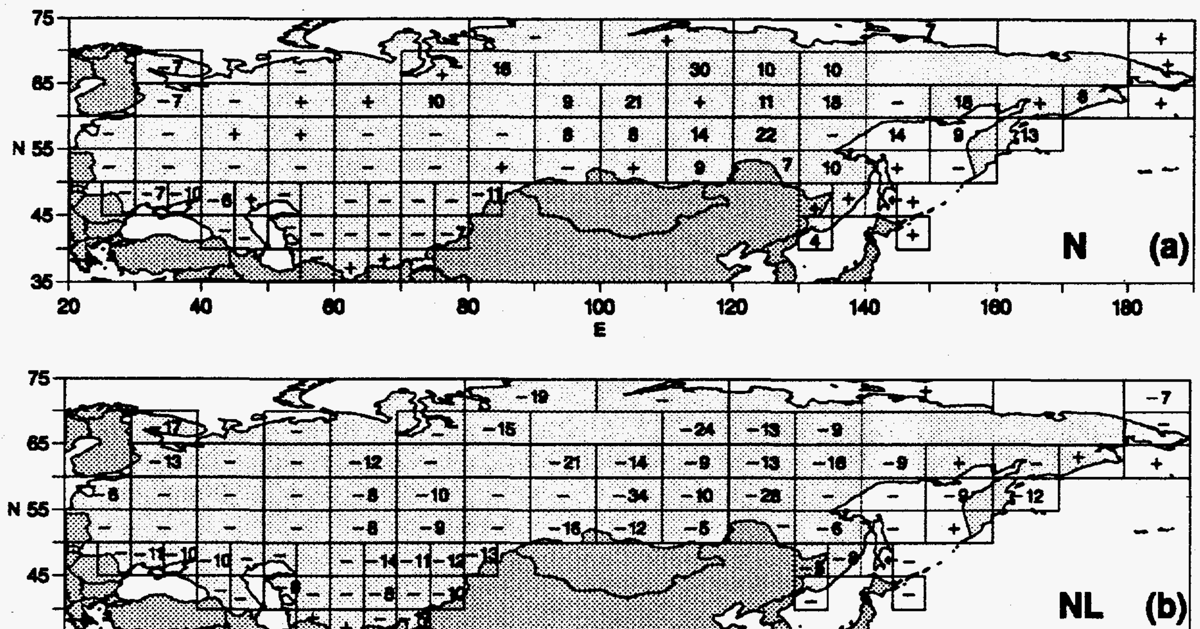


Figure 1. Locations of the 219 RIHMI stations and 84 grid boxes chosen for analysis.



Figures 2a–e. (Above and next page) USSR winter means of (a) total cloud amount (N); (b) low cloud amount (NL); (c) frequency of occurrence of cirrus (fci); (d) total cirrus amount (aci); and (e) frequency of occurrence of clear sky (fclr) for the period 1937–83.

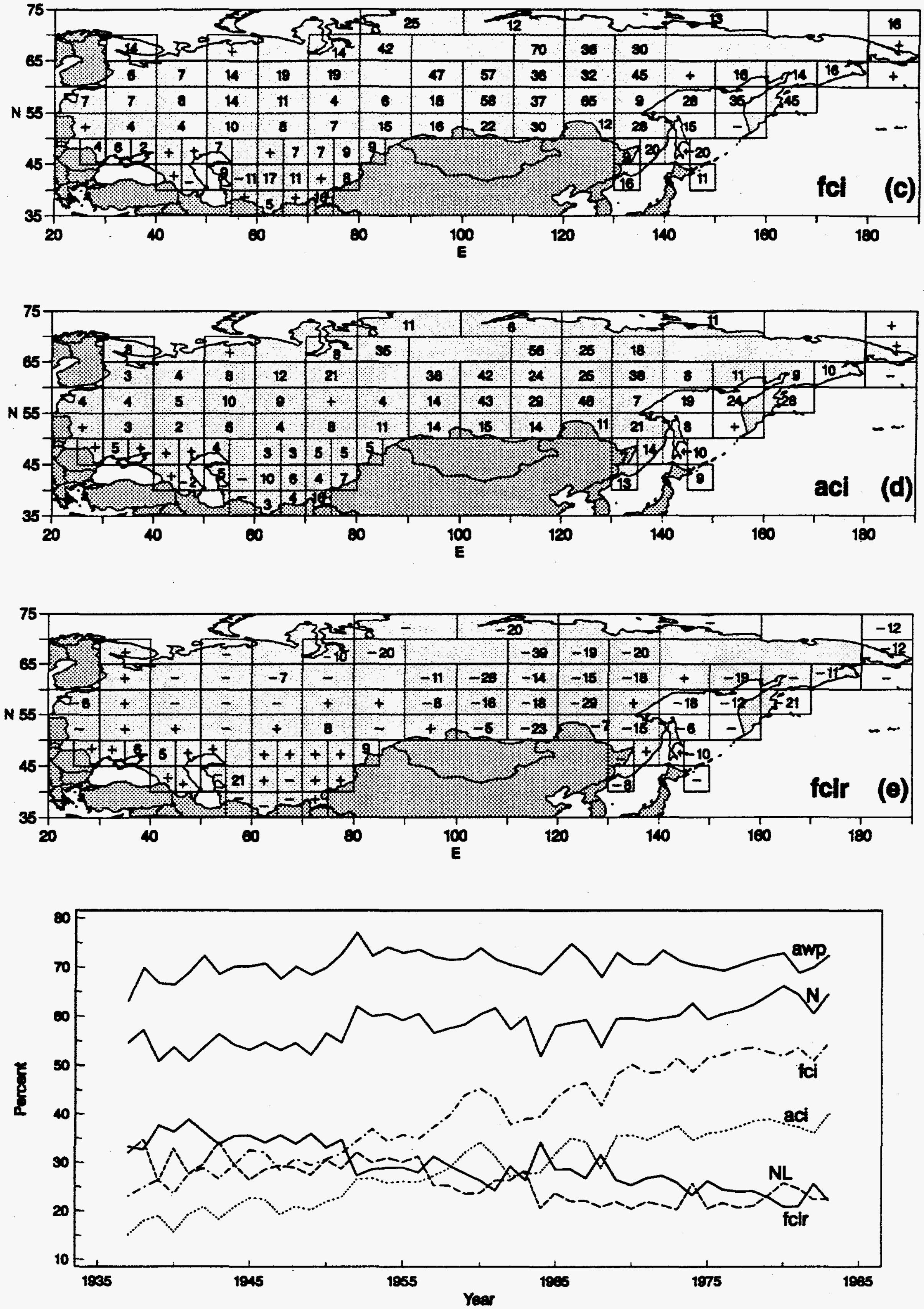


Figure 3. Winter means of total cloud amount (N); low cloud amount (NL); frequency of occurrence of cirrus (fci); amount of cirrus when present (awp); total cirrus amount (aci); and frequency of occurrence of clear sky (fclr) for the region encompassed by 90° and 160° E, and 50° to 70° N, over the period 1937–83.