2.11 CLOUD CLIMATE INVESTIGATIONS IN SCANDINAVIA DURING THE LAST DECADE USING HIGH-RESOLUTION NOAA AVHRR DATA

Karl-Göran Karlsson *
Adam Dybbroe
Swedish Meteorological and Hydrological Institute (SMHI)
Norrköping, Sweden

1 INTRODUCTION

The task to monitor the regional and global cloud climate has become increasingly depending on the existence of appropriate cloud data sets derived from satellite measurements. Many satellite-based cloud retrieval algorithms have now reached a maturity to permit the compilation of cloud climatologies with an acceptable quality. This paper describes a method for compilation of a ten-year high-resolution regional cloud climatology based on a systematic cloud classification of NOAA AVHRR scenes over the Scandinavian region. The paper also includes a comparison of results with cloud climatologies based on surface observations and other satellite data sets (e.g. ISCCP).

2 METHODOLOGY

The used approach for compilation of cloud climatologies has been to use archived results from the SCANDIA (SMHI Cloud ANalysis model using DIgital AVHRR data) cloud classification model (described in detail by Karlsson, 1996 and Karlsson, 1997) covering the period 1991-2000. SCANDIA uses the full five-channel NOAA AVHRR data set at maximum horizontal resolution. However, the cloud climatology results presented here have been utilizing a data set with a reduced resolution of 4 km.

SCANDIA results from four daily overpasses over the area (observing approximately at night, in the morning, in the afternoon and in the evening) have been used to define a daily mean of cloud cover over the area. Results have then been accumulated to define monthly, seasonal and yearly climatologies for the studied time period. Since SCANDIA makes a separation of many different cloud types, the data set permitted also studies of different cloud groups in addition to the central parameter total fractional cloud cover. Karlsson (2001) gives a full description of these results whereas this paper only reports on some results for the parameter total fractional cloud cover.

3 THE SATELLITE DATA SET

The studied NOAA AVHRR data set is composed by data from the satellites NOAA-10, NOAA-11, NOAA-12, NOAA-14 and NOAA-15. Consequently, except for a few months of data from NOAA-10, the data set consists entirely of data from the AVHRR/2 instrument. Due to technical constraints and problems (e.g., HRPT reception problems, tape failures and data gaps due to failures of the operational satellites NOAA-11 and NOAA-15), a complete satellite coverage during the period could not be achieved. The entire satellite data set consists of 12 470 satellite scenes which is 87 % of the theoretical maximum of useful scenes during the period.

4 RESULTS

4.1 SCANDIA climatologies

Figure 1 shows the period mean of cloud occurrence (cloud frequency in 4-km horizontal resolution) over the area for the selected months of January, April, July and October. Notice here that the vertical discontinuity in some of the result pictures is due to the use of different cloud detection thresholds in two different processing areas (see Karlsson, 2001).

Cloud conditions are shown to vary substantially according to season in Figure 1. Much higher cloud frequencies are found in the winter season than in the summer season for most places (except the Scandinavian mountain range and over the visible part of the Norwegian Sea). Over the Baltic Sea and over adjacent land areas, a substantial annual cycle in cloudiness is found. This is further illustrated in Figure 3 showing the annual course of cloud cover (estimated within a 36-by-36 km sub-area) at a position in the southern part of the Baltic Sea (at latitude 56N and longitude 18.5E). The yearly amplitude is estimated to approximately 40 % (40 % cloud frequency in summer and 80 % in winter).

* *Corresponding author address:* Karl-Göran Karlsson, SMHI, SE-601 76 Norrköping, Sweden;
e-mail: Karl-Goran.Karlsson@smhi.se

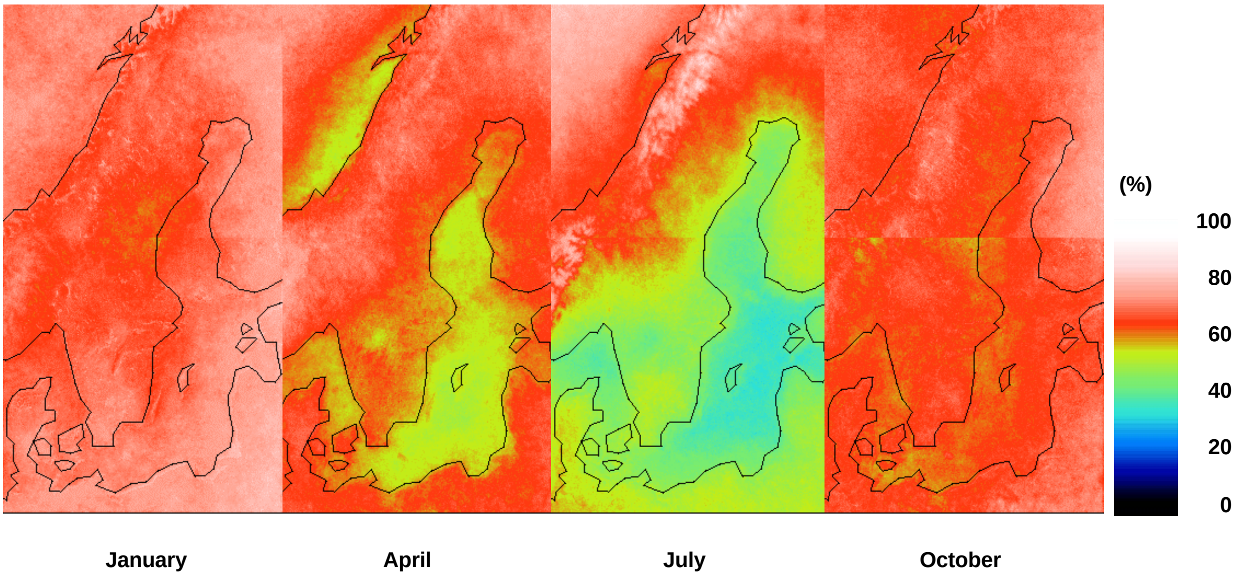

Figure 1 *Period mean (1991-2000) of cloud frequency in the Scandinavian area with 4 km horizontal resolution for the months of January, April, July and October.*

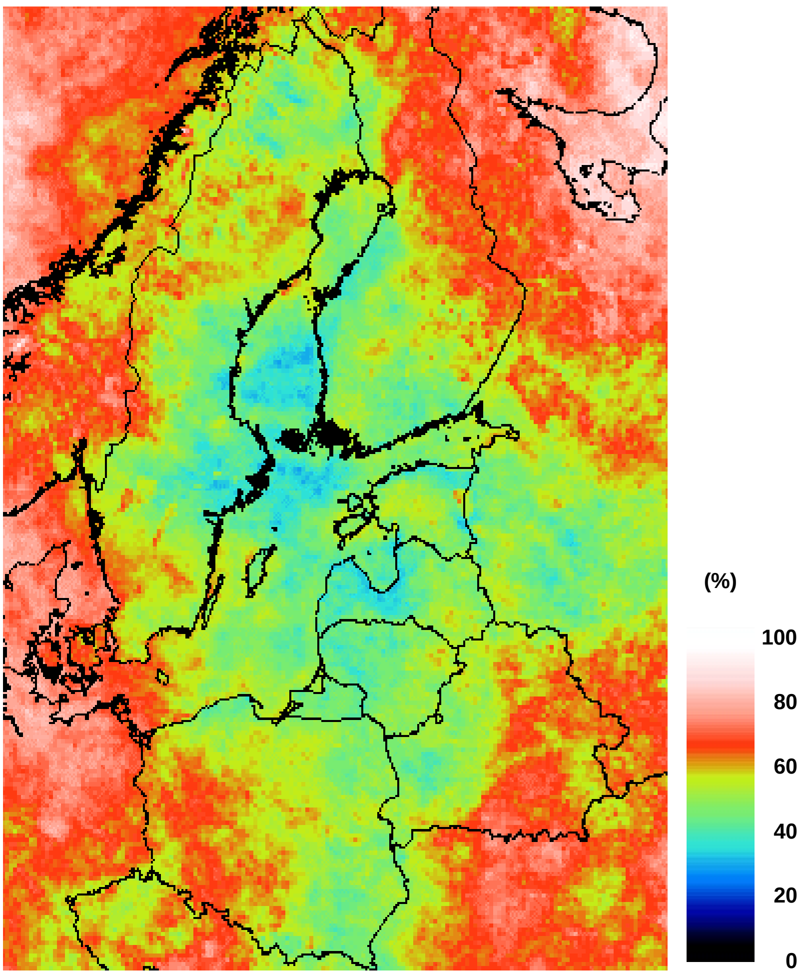

Figure 2 *Mean cloud frequencies in 10 km resolution over the Baltic Sea drainage basin derived from NOAA AVHRR afternoon passages in September 2000. See text for details.*

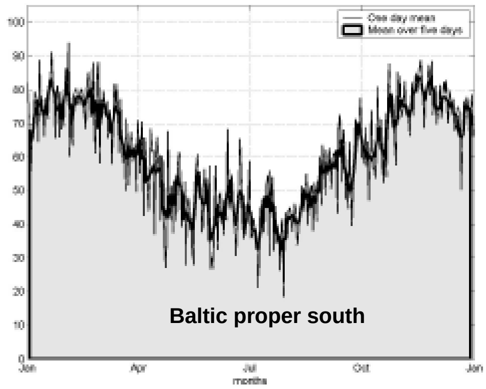

Figure 3 *The annual course of cloud cover (% - estimated in one-day and five-day intervals) for a position in the southern part of the Baltic Sea (56N, 18.5E).*

More detailed results (e.g., concerning the diurnal cycle of cloud cover and the contribution from ice and water clouds) are presented by Karlsson (2001).

4.2 Comparison with other cloud data sets

In order to validate the results of the SCANDIA cloud climatologies, a comparison with a corresponding cloud climatology based on surface observations (SYNOP) was carried out. Mean values of monthly cloud cover were compiled by use of SYNOP observations made at 00 UTC, 06 UTC, 12 UTC and 18 UTC for 28 Swedish SYNOP stations. The observations of total cloud cover from each SYNOP station were compared to corresponding estimations of SCANDIA cloud cover computed in 36-by-36 km sub-areas centered at the geographic location of each station. In total, more than 250 000 SYNOP observations were used and compared to corresponding satellite scenes.

Figure 4 shows an overall summary of validation results month by month in the period. Notice the sinusoidal variation in the bias error varying between +5-10 % in the winter season and –5-10 % in the summer season. Particular problems are indicated in the winter season having high positive bias errors, high RMS errors and low correlation coefficients. The low correlation coefficient in winter indicates that error structures are very complex. Several error sources seem to have importance, largely caused by the lack of useful visible information and the problematic temperature conditions near the surface with frequent temperature inversions making the use of infrared channels risky for cloud detection.

The indicated underestimation of cloudiness in summer was concluded to emanate entirely from deficiencies in the SYNOP observations. The relatively high correlation coefficient and the good experience from using the SCANDIA cloud classification in summer in operational weather forecasting support this conclusion.

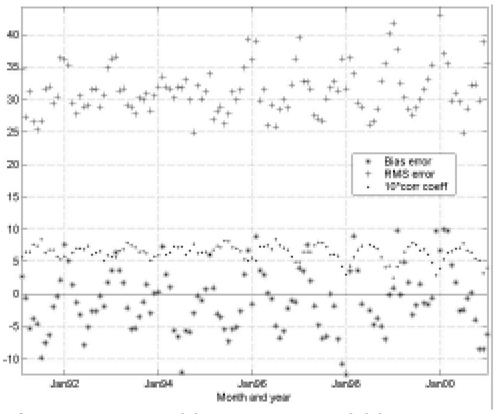

Figure 4 *Monthly averages of bias errors, RMS errors and correlation coefficients for the entire validation data set in the period 1991-2000.*

The SCANDIA climatologies were also compared to two international cloud data sets: CRU (New et al., 2000) and ISCCP (D2 series – described by Rossow and Schiffer, 1999). However, since the SYNOP based CRU data set is only available over land areas and since the ISCCP D2 series is not available yet for the entire ten-year period, the comparison here is limited to the years 1991-1993 only over land areas.

Figure 5 shows the comparison of monthly mean of cloud cover over land areas in the Scandinavian area of SCANDIA and the two other data sets. Noticeable is the larger dynamic range of cloud cover values for SCANDIA compared to the other two data sets. Especially the minimum values of cloud cover in the summer season are lower for SCANDIA. It can also be noticed that the agreement between SCANDIA and CRU is quite good in the beginning of the studied period. Basically the same pattern as previously found in the comparison with Swedish SYNOP stations (i.e., summertime SCANDIA underestimation and wintertime SCANDIA overestimation) were found. However, for the second half of the period deviations are very large. This is largely caused by lack of available SYNOP observations over the area in the CRU data set (basically now only giving a climatological mean of cloud cover over the area). The higher values of the the summertime minimum of cloudiness for the ISCCP data set were verified to exist also over sea areas in the region (see Karlsson, 2001).

5 DISCUSSION

The ten-year NOAA AVHRR cloud climatology shows that Scandinavian cloud conditions are largely influenced by the existence of the Baltic Sea. Conceptually, the Baltic Sea could be described as acting like a heat sink in the summer season (mainly caused by the springtime supply and accumulation of cold fresh water from melting snow in spring) suppressing convective clouds from forming over sea areas and adjacent land areas. However, the northern part of the region does not show a similar annual cycle of cloudiness. Here, cloud conditions remain practically the same throughout the year.

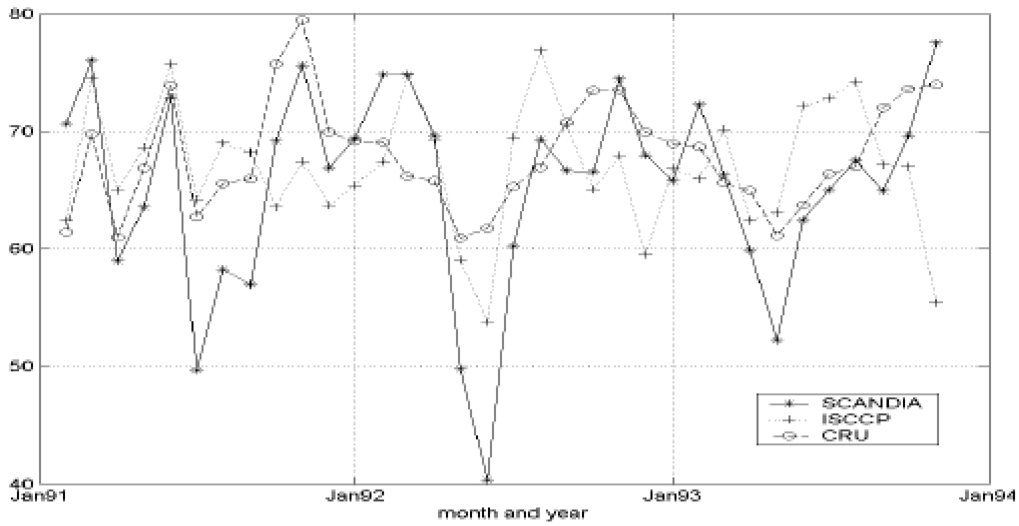

Figure 5 *Plot of monthly mean of cloud cover (%) over SCANDIA land points for SCANDIA (solid), the ISCCP D2 dataset (dotted) and the CRU data set (dashed) for the period February 1991 until November 1993.*

The NOAA AVHRR cloud climatology over the Scandinavian region was found to reproduce surface observed cloud climatology within +/- 5 % during all seasons except in winter. As for the SYNOP climatology, no particular trend in cloudiness could be seen over the period. A minimum in cloudiness was indicated in the middle of the period but this was partly exaggerated in the satellite data set due to problems with an inadequate compensation for the degradation of the visible AVHRR channels on the NOAA-12 satellite.

Comparisons with the CRU and ISCCP D2 data sets gave good agreement but SCANDIA showed generally lower cloud amounts in the summer season than the other data sets.

The future use of the SCANDIA cloud climatology will mainly be as a tool for validation of cloud information in climate simulation models (see Jones and Willén, 2001). The data set could be a valuable contribution to the BALTEX (Rashcke et al., 2001) and CLIWANET projects aimed for studies of the water and energy cycle of the Baltic Sea. Results from an improved cloud classification model have recently been compiled within the CLIWANET project (Dybbroe, 2001) and some preliminary results over the entire Baltic Sea drainage area are shown in Figure 2*.*

6 ACKNOWLEDGEMENTS

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