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EMPIRICAL AND MODELED SYNOPTIC CLOUD

CLIMATOLOGY OF THE ARCTIC OCEAN

Annual Progress Report

April 1984 - March 1985

to

NASA, Climate Research Program

NAG 5-417

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The objectives of the project are to derive a daily climatology of the atmospheric circulation of the Arctic and to determine the associated cloud conditions. The second part of the project will use these data for comparisons with the variability of General Circulation Model generated circulation and cloud cover for the same region.

Year 1 Achievements

A. Atmospheric Circulation.

1) Comparison of synoptic typing schemes:

Various 'objective' synoptic classification schemes are compared in order to determine which would give an optimum solution and to examine the question of how much subjectivity is introduced by the various options exercised by the analyst. The analysis uses a subset of the twice daily National Meteorological Center (NMC) grid point data set for 93 grid points north of 60°N. Two of the more popular synoptic typing techniques are compared, the sum of squares method developed by Kirchhofer (1973), and a method that employs principal component and cluster analysis. In the former it is found that different classification schemes will result from the choice of different threshold values, which set the sum of squres difference level at which one map is considered to be similar to another, and by the choice of the minimum group size. For the principal components/cluster analysis, the clustering is based on the component scores. Two cluster techniques are used, one employs an interactive procedure to obtain a local optimum for k clusters using an error sum of squares as a similarity measure. The second obtains maximum likelihood estimates of the parameters of a multivariate normal mixture of distributions, assigning a probability of membership to each of the clusters for every case in the sample. Again an iterative procedure is employed.

It was found, when comparing these techniques, that the synoptic types produced varied between the cluster techniques, and that different results were obtained within each technique depending on the number of principal components retained for the analysis.

2) Arctic synoptic classification:

Based on the comparisons described above it was decided that the Kirchhofer classification resulted in the greatest differentiation between groups. By comparing the results using different threshold values and group sizes it is also possible to derive an 'optimum' solution for the Kirchhofer classification. A further test was carried out to compare the results of a synoptic classification based on sea level pressure and 700 mb heights. The test showed very little difference between the two classifications. A preliminary examination of the DMSP derived cloud cover (see section C) showed that the cloud cover appeared to be more closely related to the sea level pressure field, and this was therefore chosen for the final analysis.

A synoptic classification of daily Arctic sea level pressure fields has been carried out for the ten year period 1973-1982. The classification resulted in seven synoptic types being identified, with 80 percent of the days being classified into one of these seven types. The percentage number of days in each group is 18.1, 13.0, 13.0, 12.2, 9.2, 8.9, and 5.1. A synoptic catalog has been derived for the ten year period based on this classification scheme. Each day in the ten year record has been assigned to one of the seven types or is listed as unclassified. A prelminary analysis of the synoptic catalog suggests that there is some year-to-year variability in the frequency of particular synoptic circulation patterns.

B. GISS GCM Results.

Sixteen months of 5 hourly model output results have been obtained from a control run of the GISS medium resolution GCM. These data include optical depth, surface pressure, potential temperature, specific humidity, radiative equilibrium temperature, surface wind speed, surface temperature and various other geographical grids such as ocean ice, snow amount and temperature, etc. Five day averages of these data grids have been produced. The surface pressure, potential temperature and specific humidty grids are currently being used to derive grids of sea level pressure distributions. All of the five day grids have been remapped to the same I, J grid as that used for the NMC grid point data.

C. DMSP Cloud Analysis.

The objective of this phase of the project is to develop a data set of cloud over maps for the Arctic regions covering a sufficiently long period of time to allow the results to be compared statistically with previous data sets. This comparison will serve as a test for the data analysis techniques to be performed in Year II. In addition the data set developed in Phase I can be used to study the seasonal patterns of cloud developments, the inter-annual variability of clouds, and the relationship between mean monthly cloud cover and mean monthly pressure patterns.

Data Base.

The months of April, May and June of 1979 and 1980 were selected for analysis. These months give overlap wth previous data sets (Kukla, 1984) and cover the transition from winter to summer conditions. For each month the cloud conditions on every third day were manually analyzed for the area north of 70 degrees latitude. The DMSP visual imagery was used to identify areas of cumulus cloud, stratus cloud and open conditions (less than 50 percent cloud cover). The DMSP infrared imagery was used to divide the cloud into low, middle or high cloud. Once the data were extracted they were digitized for later analysis. Figures 1 and 2 illustrate the frequency of cloud-free conditions in April 1979 and 1980.

Preliminary Analysis.

Preliminary analysis of the data indicates that:

a) In general the analysis give results which agree with previous data sets. However, differences in the satellites used and the time of the imagery make direct comparisons difficult.

b) The difference between cloud-free conditions and a low stratus over areas of high concentrations of pack ice are the most difficult to separate.

c) Significant changes in Arctic cloud conditions can occur over short time periods. This can make matching data from images as little as 6 hours apart difficult.

d) Arctic cloud patterns seem better correlated with surface pressure patterns than with 700 mb patterns.

e) Due to seasonal changes in the factors responsible for cloud formation the matching of cloud patterns with synoptic types may have to be performed separately according to season.

f) Cloud conditions in the Arctic Basin seem to be controlled by large-scale circulation patterns rather than ice conditions.

g) There are recognizable cloud patterns associated with major Northern Hemisphere circulation types. For example, a weakening of the Icelandic Low and a North Atlantic pressure reversal in April 1979 was associated with a decrease in cloud cover in the Norwegian, Barents and Kara Seas.

h) The cloud analysis occasionally indicates meso-scale systems not shown on the NWS surface analysis.

YEAR TWO OBJECTIVES

A. Empirical Analysis.

In Year Two we propose to complete the synoptic analysis of the NMC grid point data, providing a description of the synoptic climatology of the Arctic Basin.

The cloud data extraction from the DMSP imagery will also be completed and an analysis made of the relationships between cloud cover and the synoptic scale atmospheric circulation.

B. GISS Model Analysis.

The synoptic climatology of the GCM will be compared to the 'observed' circulation from the NMC grid point data. Five-day average cloud cover will be extracted from the five-hourly GISS model output. These cloud cover grids will be compared both to the synoptic climatology of the model and to the observed Arctic cloud cover distributions.

Based on our progress and the results obtained during the first year, we anticipate completing all of the work by the end of Year Two. Our objectives and anticipated results remain the same as those outline in the original proposal, except that the analysis of the synoptic scale atmospheric circulation will be based on sea level pressure patterns rather than the 700mb height fields.

PUBLICATIONS

Abstracts relating to the synoptic climatological analysis (Crane and Key) and Arctic cloud cover analysis (Newell and Barry) have been submitted to the IAMAP meeting in Honolulu in August 1985 (see attachments).

A paper describing the synoptic classification analysis is in preparation by Key and Crane.

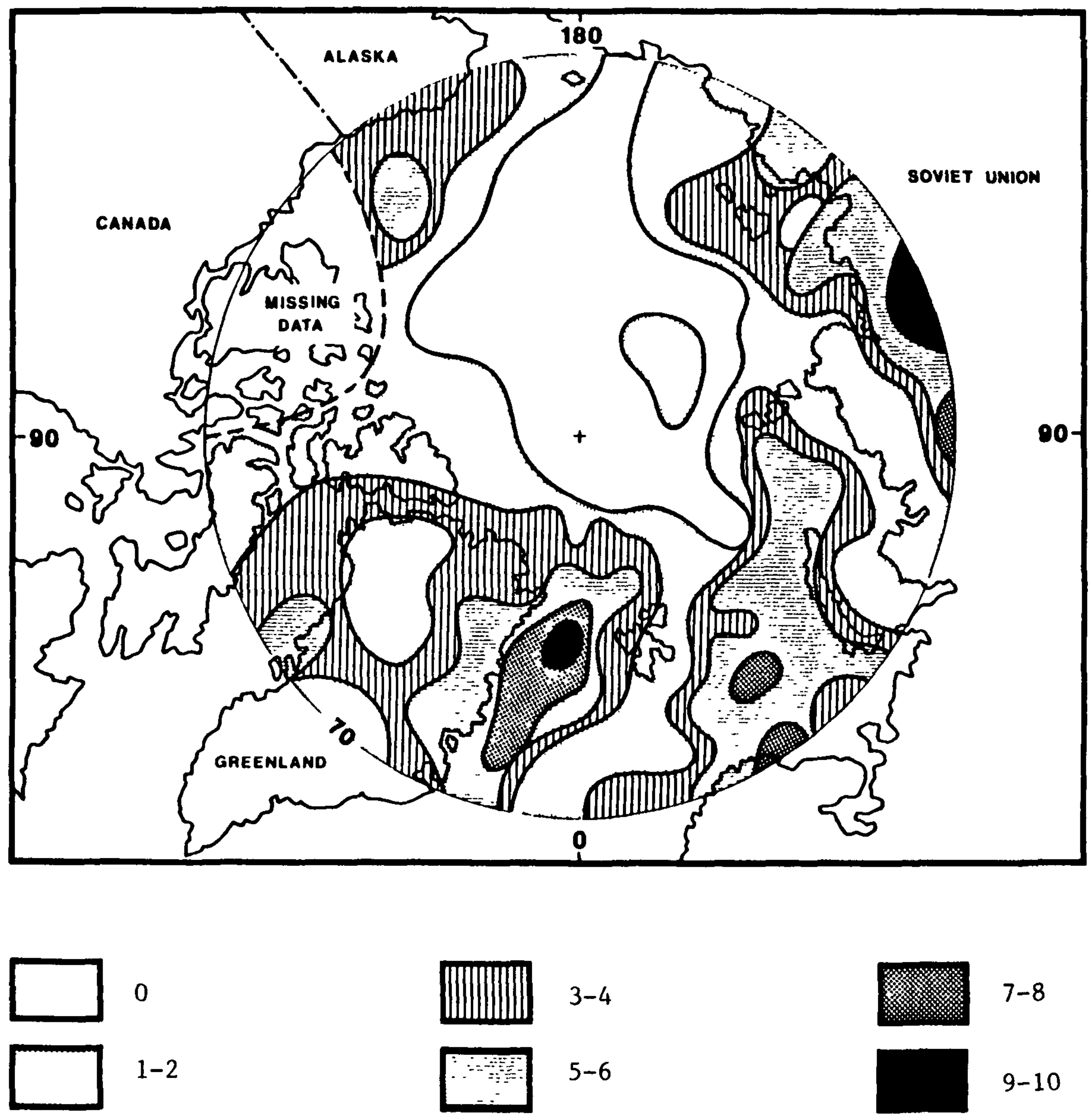

Fig. 1. Number of days out of 10 analyzed with cloud-free conditions, April 1979.

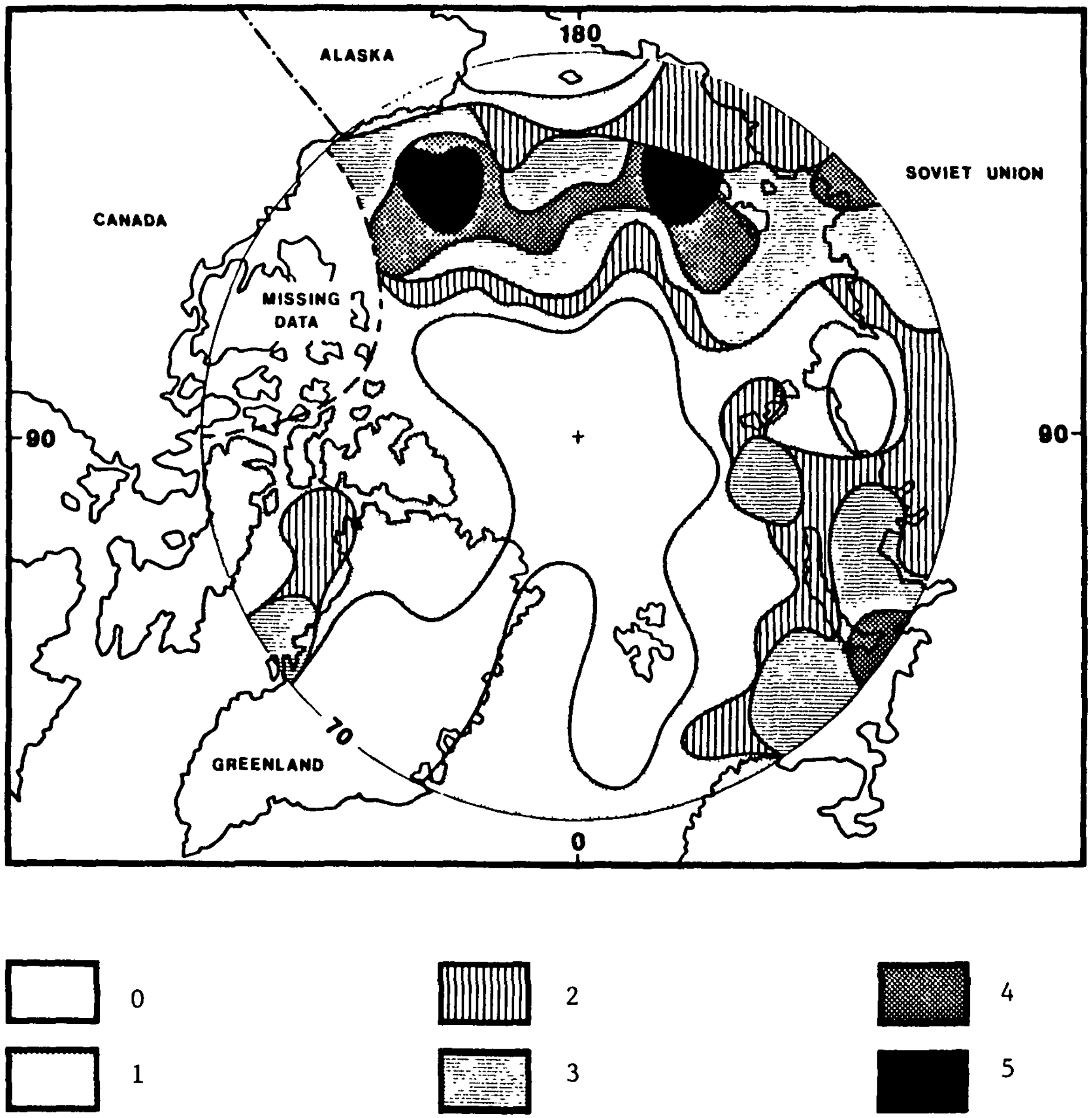

Fig. 2. Number of days out of 5 analyzed with cloud-free conditions, April 1980.

Mapping Arctic Cloud Cover Using DMSP Imagery for Spring 1979 and 1980

J.P. NEWELL and R.G. BARRY (CIRES and Department of Geography, University of Colorado, Boulder, CO 80309).

Arctic cloud patterns in spring are a major determinant of the energy available for sea ice melt. A cloud data set suitable for application to analysis of such interactions has been developed by manual analysis of DMSP visual and infrared imagery for every third day of April-June 1979 and 1980. Clouds were classified by type and height.

The cloud patterns undergo a marked transition in spatial organization and persistence in spring. In April the Arctic is dominated by regional patterns of convective cloud and intervals of persistent cloud free conditions. These patterns are controlled by changes in the Icelandic Low and Polar Anticyclone. By June the area is dominated by bands of convective cloud, associated with cold lows, and numerous small, temporally-shifting areas of cloud free conditions. Examples of cloudcover-circulation relationships and their significance for ice melt are discussed. The results provide a basis for scaling-up to an Arctic cloud climatology for spring months using long-term frequencies of synoptic circulation types discussed in a related paper by Crane and Key (Symposium M-12).

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3. M-11

Synoptic Climatology of the North Polar Region

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Several 'objective' synoptic circulation typing schemes are examined using ten years of NMC grid point data for the North Polar region. The typing schemes group days based on sum of square differences between cases, or based on clustering of principal component scores. The analysis shows that each scheme can produce different results depending on the input parameters used, and intercomparisons of the various schemes reveal that they can generate rather different synoptic classifications for the same data set.

An 'optimum' scheme is chosen to describe the synoptic scale sea level atmospheric circulation over the Arctic for the period 1973-1982. These circulation patterns are compared with five-day averaged sea level pressure distributions obtained from the control run of the medium resolution GISS General Circulation Model.

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3. M-12