In: Proceedings Sixth Conference on Atmospheric Radiation, Williamsburg, VA May 1986, American Meteorological Sooiety, 176-179, 1986.

ARCTIC SUMMER CLOUDINESS

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1. INTRODUCTION

Within the Arctic Basin, late spring and summmer cloudiness appears to have a significant effect on the surface radiation budget and, therefore, on the dissipation of snow and ice cover (Untersteiner, 1961). Details of the role of clouds in the initiation and maintenance of the snow and ice melt and, more generally, the influence of clouds on the entire radiative environment of the basin are, however, not sufficiently known.

Previously available information on the large-scale seasonal distribution and dynamics of arctic clouds is inadequate. This is due to the spatial limitations of ground or ice based reports and difficulties in the automated identification of clouds from satellite imagery in the presence of snow and ice (Jayaweera, 1977; Barry, 1983). As a result, earlier reports of arctic cloudiness present conflicting results. Some report upwards of 90% cloud cover with little variation (Huschke, 1969; Vowinckel and Orvig, 1970; Marshunova and Chernigovskii, 1971). Others report significant month-to-month variability, with monthly cloudiness as low as 50% (Chukanin, 1954; Jayaweera, 1977).

We present here an arctic-wide analysis of late spring and summer cloudiness using satellite data. Cloud cover was charted in 3 thickness classes at about 3 day intervals for the late springs and summers of 1977 and 1979.

2. DATA SOURCES

Clouds were charted from shortwave (0.4-1.1 µm) and infrared (8.0-13.0µm) Defense Meteorological Satellite Program (DMSP) imagery. The imagery has a resolution of 2.7 km and is available in a scale of 1:15,000,000. The processed film density on the transparencies used in the analysis is linearly proportional to scene reflectivity in the shortwave and to temperature in the infrared (Fett and Bohan, 1977).

3. PROCEDURE

Clouds were visually differentiated from snow and ice, primarily by the characteristic large-scale features of the pack ice fields identified in shortwave imagery. These included:

1) elongated leads filled with water or grey ice, contrasting with the brighter snow or older ice fields.

2) snow-covered floes of multi-year ice separated by darker ice or water.

3) patchy fields of grey melting snow and/or meltwater puddles separated by bright snow and ice pressure ridges.

Depending on the cloud optical thickness, these features were either completely or partly obscured.

In addition, certain cloud fields, particularly those located in cyclonic regions, were recognized by their characteristic shapes and patterns. These were often evident in both the shortwave and infrared imagery.

Charts of cloud cover, showing cloud-free skies as well as relative cloud thickness were prepared from the DMSP transparencies (Fig. 1). Our visual interpretation was assisted by an interactive analysis using a digital image processor. The processor was used primarily to determine cloud thickness categories (cf. Robinson et al., 1983). Multiple images for a given date were combined to permit coverage of as much of the Arctic Basin as possible. Imagery from several adjacent passes, separated by as short a time interval as possible, were used to minimize the distortion due to moving clouds.

Four cloud cover classes, including three cloud-thickness classes and a cloud-free class were recognized:

Class 1: cloud-free (surface features seen with high contrast).

Class 2: thin clouds or subresolution patchy clouds (surface features clearly recognizable but with reduced contrast from cloud-free skies).

Class 3: moderate clouds (surface features marginally recognizable through the cloud).

Class 4: thick clouds (no surface features recognizable).

Cloud charts were digitized using the NMC standard primitive equation data grid.

Five regions of the Arctic Basin were selected for analysis (Fig. 2). Regions contained between 35 and 146 NMC grid cells and were defined according to their unique geographic characteristics.

Our sampling frequency was insufficient to give precise monthly means. Therefore, our results should be considered as only estimates of monthly and seasonal means for the years charted. These should be reasonable estimates,

Fig. 1. Cloud cover field for July 15, 1979. Classes include:
1) cloud-free (open), 2) thin clouds (light stippling), 3) moderately thick clouds (moderate stippling) and 4) thick clouds (dense stippling). Hatched where data were unavailable. The North Pole is marked with a dark cross.

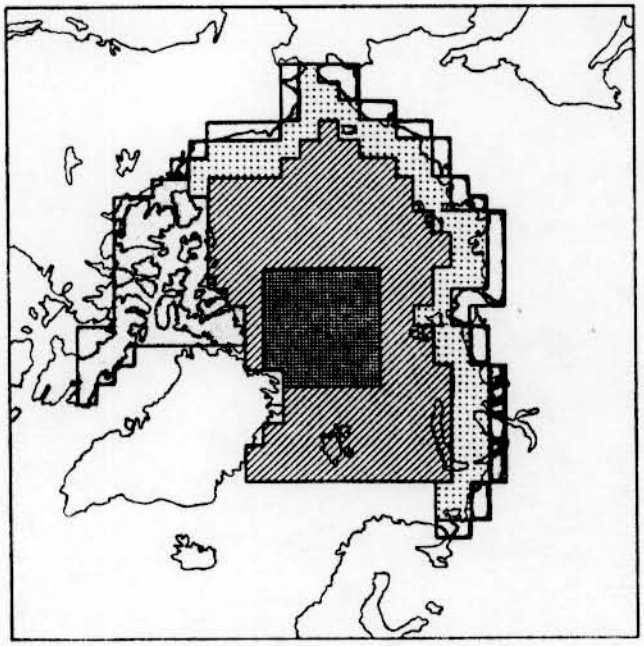

Fig. 2. Regions in the Arctic Basin used in this study. Region R1: Inner Arctic Ocean (squares); R2: Outer Arctic Ocean (hatching); R3: Arctic Coastal Water (light stippling); R4: Canadian Archipelago (moderate stippling); R5: Arctic Coastal Land (dense stippling).

given the sluggish movement of summer weather systems and the relatively suppressed diurnal variation of cloud cover expected due to the small diurnal variability of solar zenith angle. Because data from only 3 years were analysed, our results should not be taken as representing long-term average conditions of late spring and summer cloudiness in the Arctic.

4. RESULTS

Figure 1 exemplifies the variable spatial distribution of cloudiness in the Arctic Basin on a given day. In this case, thick and moderate clouds covered 65% of the basin and were most abundant in the Outer Arctic Ocean (R2) and Canadian Archipelago (R4) regions.

The variable temporal extent of cloudiness across the Arctic Basin in 1977 and 1979 is exemplified in figures 3 and 4 for region R2. In 1977, the beginning of June and the end of July were cloudiest, separated by a period of relatively clear skies and thin cloud cover in late June and early July. In 1979, the second half of May and the first half of June had the most cloud cover, particularly of moderate thickness.

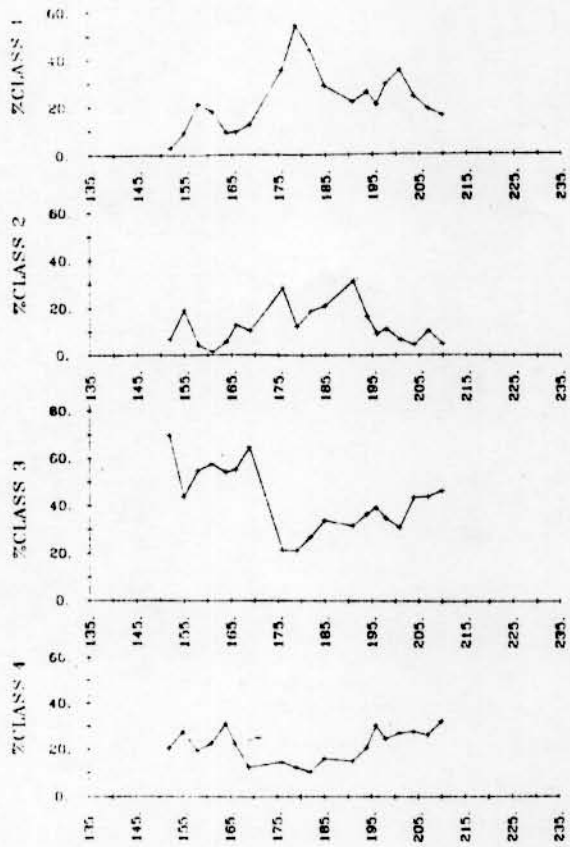

Fig. 3. Daily cloud amounts by cloud class for the Outer Arctic Ocean region (R2) in June and July 1977, derived from charts running from June 1 (Julian Day 152 (horizontal scale)) to July 29 (JD 210).

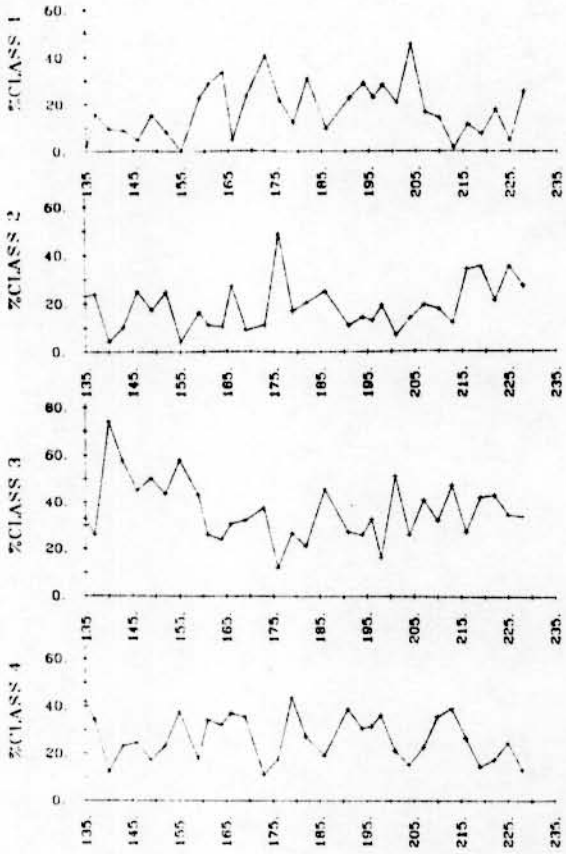

Fig. 4. Same as fig. 4, except for 1979. Charts run from May 15 (Julian Day 135) to August 15 (JD 227).

Estimates of cloudiness within each region for the last half of May and all of July in 1979 are shown in figures 5 and 6, respectively. Results are based on 6 daily charts for May and 10 for July. Cloudiness was more extensive in May than in July in all regions, with the exception of the Inner Arctic Ocean (R1) which had more clear skies than either of the other two ocean regions (R2, R3). In July, the Inner Arctic was cloudiest, with less than 10% clear skies. Cloudiness decreased towards the coast, where the three coastal regions (R3, R4, R5) had approximately 50% moderate and thick cloud cover. The July 1979 results are similar to monthly estimates for June 1979 as well as for June and July 1977 (Robinson et al., 1985).

5. DISCUSSION

Up to this point, no estimates of absolute cloud optical thickness have been made for each visually derived class. We do so now only as a rough guide and to serve as encouragement for conducting future coordinated multi-platform experiments to add information to that already gained in aircraft studies.

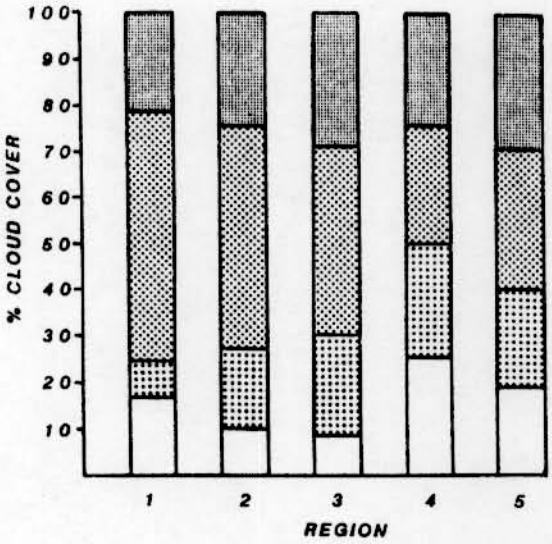

Fig. 5. Estimate of mean cloud cover for the 3 cloud classes and the cloud-free class in the 5 study regions for the last half of May 1979. Cloud class symbols same as in fig. 1.

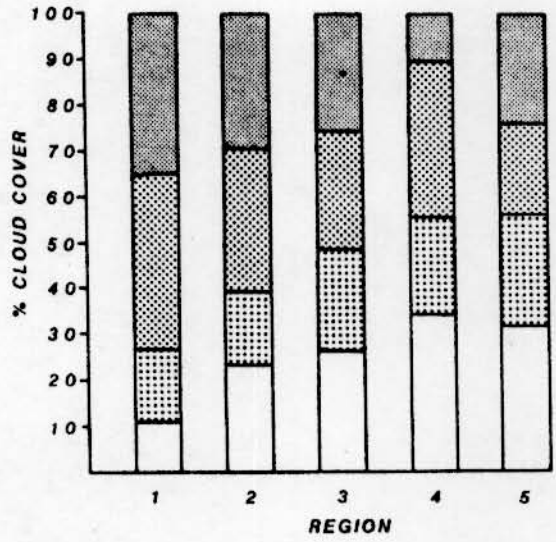

Fig. 6. Same as fig. 5, except for all of July 1979.

Optical thickness estimates are partly based on a comparison of flight data gathered in the summer of 1980 (Tsay and Jayaweera, 1984; Herman and Curry, 1984) with coincident satellite derived cloud charts constructed in the same manner as the previously discussed DMSP set (Kukla, 1984). According to this analysis, multi-layer relatively thick cloud with a high liquid water content and with a grey optical thickness of about 25 corresponded to cloud

cover class 4. Cloud charted as class 3 had a moderate liquid water content and an optical thickness of around 8 to 10. Clouds in class 2 could not be directly correlated with the flight data but should have a low to very low liquid water content and an optical thickness of between 2 and 5.

Optical thickness was estimated in a different manner by employing image processor measurements of the contrast in DMSP satellite observed brightness between snow and open water surfaces for clear and cloudy conditions in a detailed radiative transfer model (Robinson et al., 1983). Tentative estimates of optical thickness drawn from this approach suggest class 2 clouds may have optical thicknesses as low as 2 and class 4 clouds thicknesses over 25.

6. CONCLUSIONS

Our results show that the extent and thickness of clouds in the Arctic Basin were heterogeneous in space and time in the late springs and summers of 1977 and 1979. While optically thin to thick clouds covered two thirds or more of the basin, relatively cloud-free episodes persisted long enough (days to weeks) to significantly affect the surface radiation budget and therefore the dissipation of snow and ice cover.

As the majority of clouds over the basin were relatively transparent, they should have allowed a high amount of incoming solar radiation to penetrate to the surface. If this is a common feature in most years, it may have important implications in terms of the earth/atmosphere energy budget and the role of summer arctic cloudiness in any future climatic change.

Further monitoring of arctic cloudiness should serve as a means for recognizing and assessing the impact of any climatic change. Climate models used to assess the impact of CO_2 and other trace gases on the earth's climate should adequately parameterize cloud cover to reasonably model the radiation budget of the basin.

7. ACKNOWLEDGMENTS

This work was funded by the U.S. Department of Energy, Carbon Dioxide Research Division agreement number DE-AC02-81EV10665.

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