

FLORIDA SUMMERTIME CLOUD COVER FROM SATELLITE DATA

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ABSTRACT

Statewide cloud distributions obtained by aggregating ground determinations from widely spaced observation points frequently are not representative of the true synoptic cloud cover. Satellite-derived cloud data overcome many of the problems inherent in the ground network system. A satellite system suitable for use with the unique cloud cover of Florida was used to provide accurate data of the amounts and distributions of total, cumulus and stratus cloud cover for the entire state for three May-September periods. Total cloud cover is greatest in the northeastern and southern portions of the peninsula. Cumulus and stratus cover have opposite geographic distributions. Time trends of cloud cover reveal significant differences between the northern and southern sectors of the state.

1. INTRODUCTION

Cloud cover is one of the basic, routinely

observed climatic elements. The amount of clouds plays a significant role in many atmospheric processes. For example, a modeling scheme by Adem (1) indicated that temperatures are very sensitive to cloud cover: a change of 0.1 in cloud cover produced a change of several degrees in surface temperatures. Clouds also directly influence sunshine, visibility, turbulence and winds. Schneider (2), Cess (3), and Ohring and Clapp (4) have indicated the importance of the effects of clouds on the atmospheric and surface radiation budgets and the implications for climatic change.

Knowledge of cloud cover in Florida is particularly important for three additional reasons. One of the most ambitious ongoing cumulus cloud seeding experiments in the United States, the Florida Area Cumulus Experiment (FACE), is being conducted in southern Florida. Also, cloud cover is a significant factor in planning rocket launches from Cape Canaveral. Thirdly, Gannon (5) has shown that spatial and

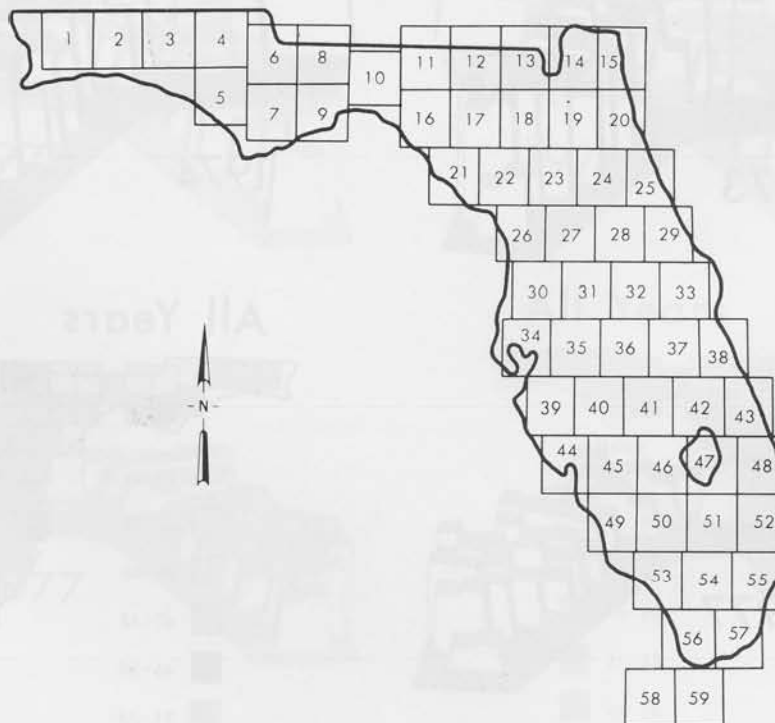


Figure 1. Study area and grid system.

temporal variations of clouds affect the location, structure and intensity of the sea breeze in southern Florida by influencing the surface heating pattern. The sea breeze is an important mechanism in initiating precipitation over peninsular Florida.

All of these research areas would be benefited by thorough, accurate data of the temporal and spatial distribution of cloud amount and type. In nearly all climatic records the cloud cover values are those reported by ground observers. However, cloud cover determined from the surface is frequently not indicative of the actual amount of clouds over a large area. Blackmer and Alder (6) reported that ground-determined cloud values often are not representative of the true cloud cover over even a small fraction of the distance between adjacent reporting stations. Several investigators using aerial photography, sunshine data, satellite information and modeling techniques have shown that cloud cover is consistently overestimated by ground observers. This is especially true when significant amounts of low clouds are present. Because the ground observer views much of the sky at low angles, the sky may appear nearly overcast toward the horizon when there may actually be many large breaks in the clouds. Appleman (7) showed how the vertical buildup of low clouds tends to conceal gaps between individual cloud

masses. For example, a 0.5 stratocumulus cover that is 610m thick and has a base of 0.6km could be interpreted from the ground as 0.8 cover. Lund (8) indicated similar results with observations taken at Tampa, Florida. Glaser et al (9) compared satellite- and ground-observed cloudiness at Miami, Jacksonville, Tampa and six other southern, non-Florida cities for one summer and winter period. Average differences between cloud cover values determined by the two techniques were more than twice as great in summer than in winter, and greater for locations where cellular clouds were predominant (the three Florida cities).

The study by Glaser et al. also pointed out that while ground observations are consistently biased toward excessive cloud cover amounts, most satellite data produce cloud estimates that are probably lower than the true cloud amount. The perspective problem previously discussed is not significant because of the satellite altitudes, but what does present a problem is the resolving power of the detectors onboard the satellites. Shenk and Salomonson (10) note that the majority of the visible sensors operational in the early 1970s had resolutions of approximately 4km. Because the average width of noontime cumulus clouds in August in Florida is about 0.8km (8), many of the individual clouds would have gone undetected, and cloud cover estimates below the true

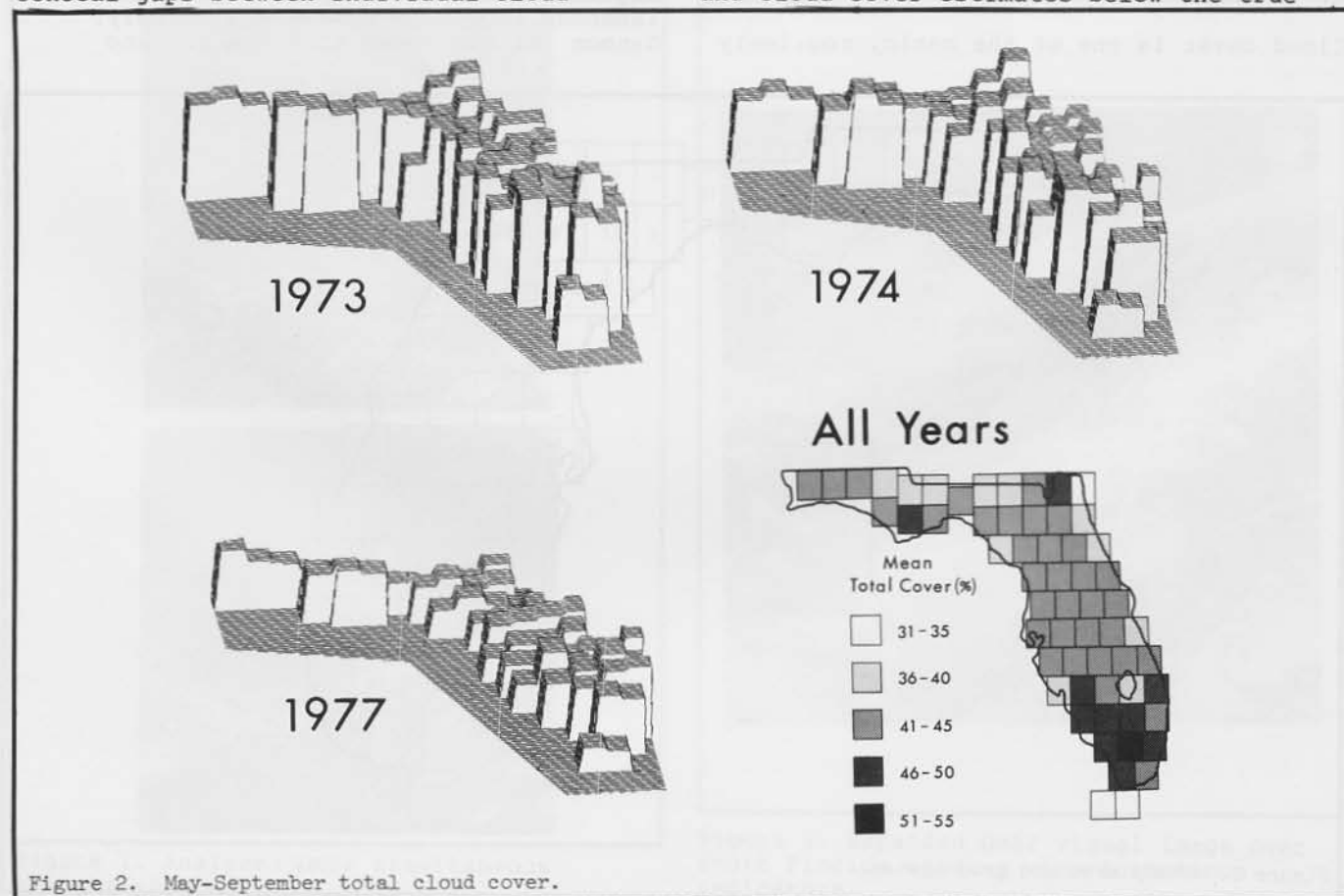


Figure 2. May-September total cloud cover.

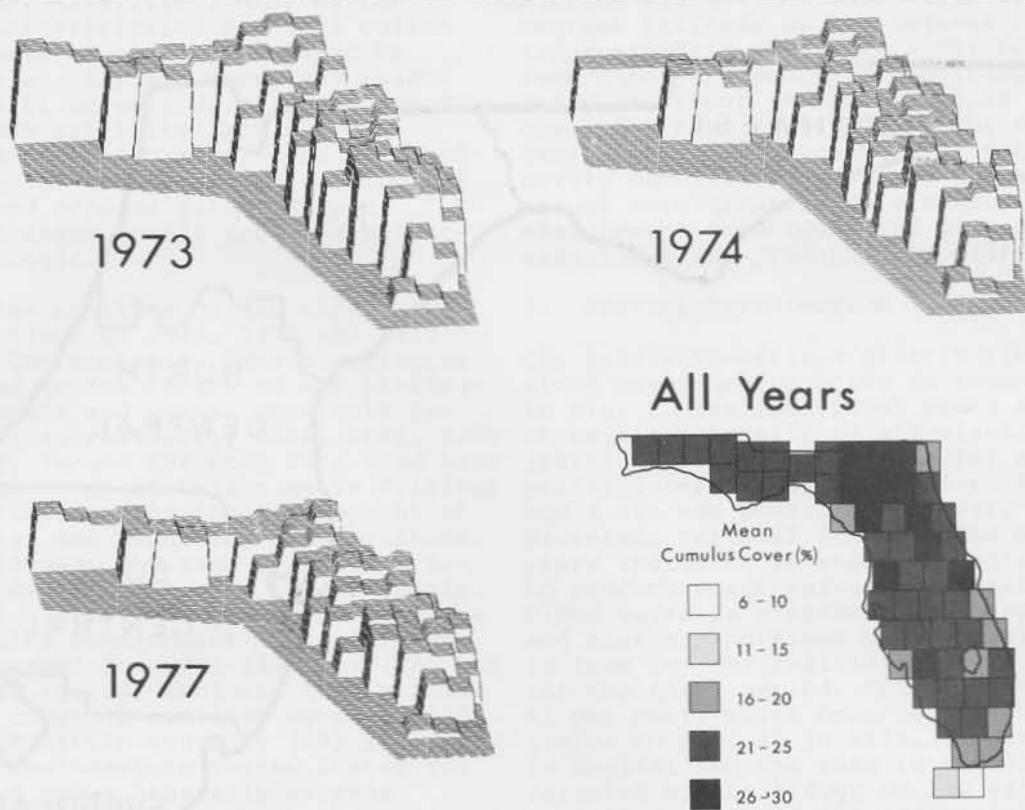


Figure 3. May-September cumulus cloud cover.

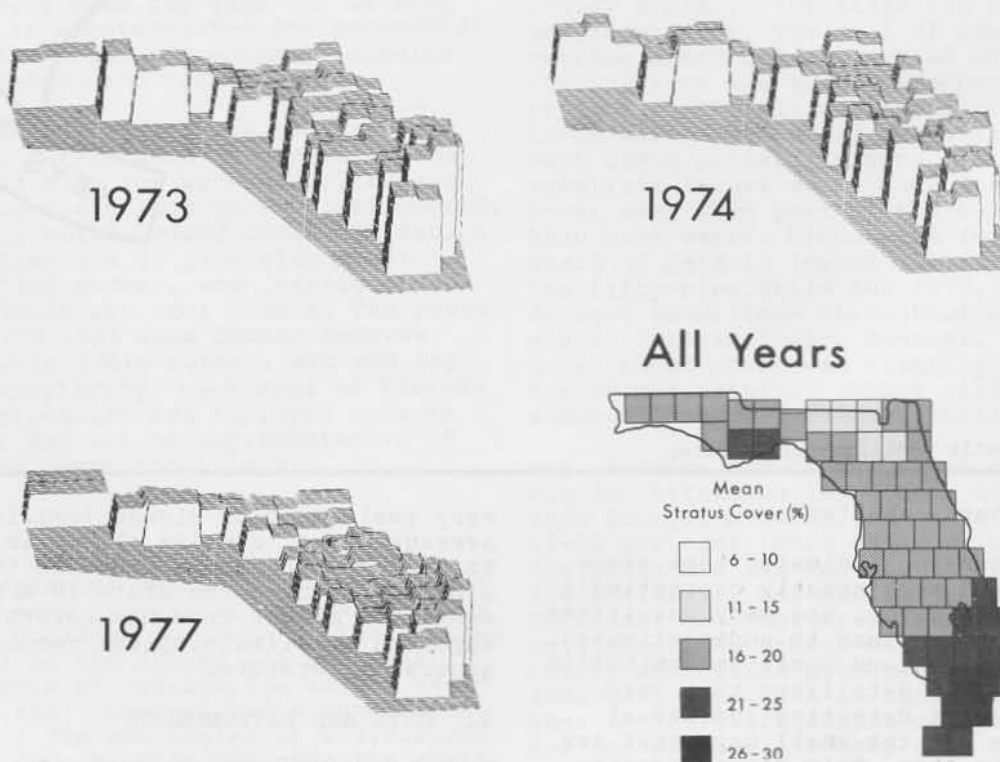


Figure 4. May-September stratus cloud cover.

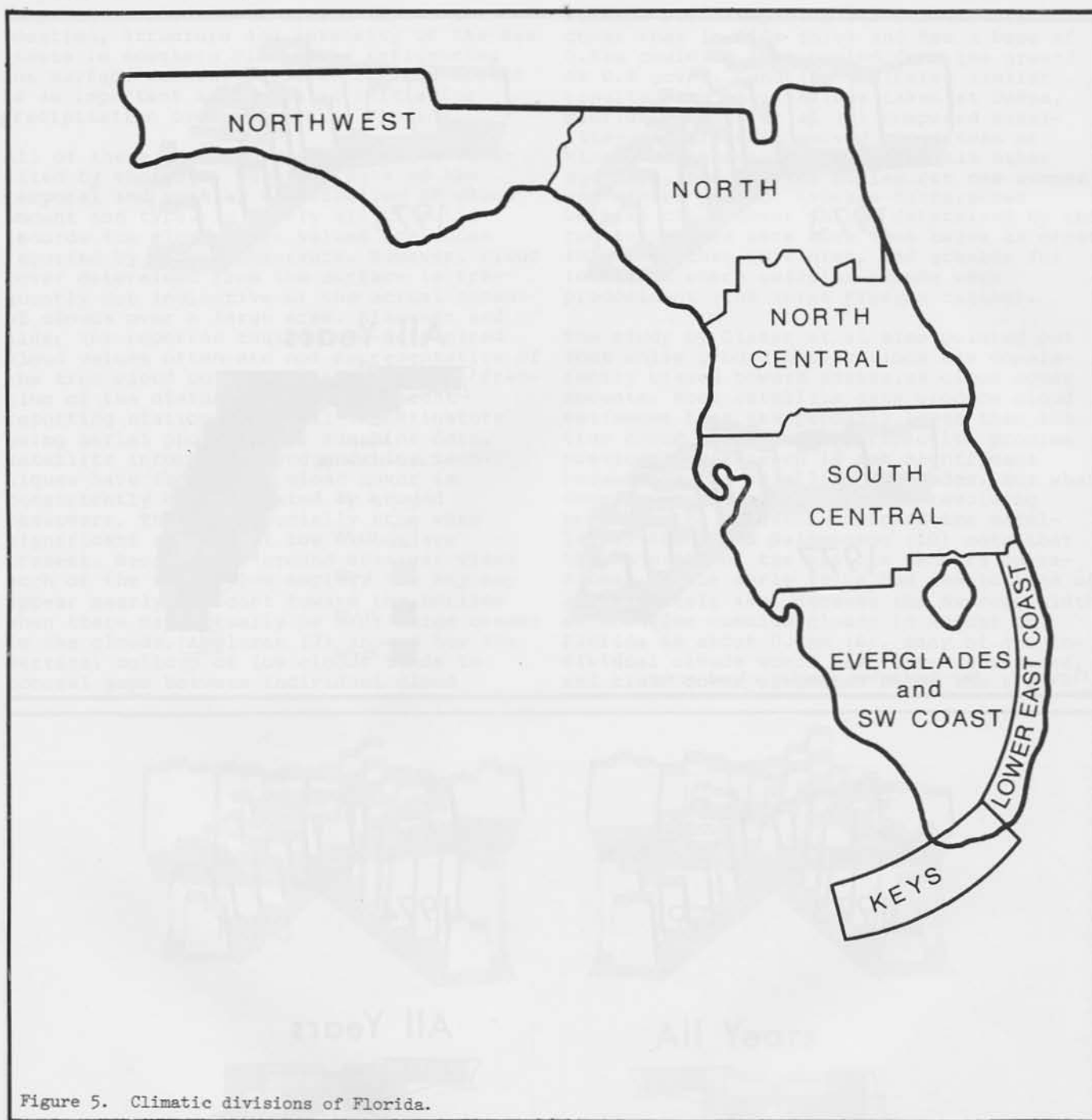


Figure 5. Climatic divisions of Florida.

amount would have resulted.

The above discussion indicates that since ground observers consistently overestimate the actual cloud cover, and many satellites yield data that can lead to underestimates, the most accurate cloud cover determination requires data from satellites that have sensors capable of detecting individual cumulus clouds and the small gaps that are present between them. This paper presents results of a summertime cloud climatology of Florida based on data obtained from a satellite system that is capable of detecting

very small cumulus clouds (smaller than the average summer cumulus clouds in Florida). This study, therefore, reveals the amount of cloud cover over the state in a more representative manner than has heretofore appeared in climatological records and the general literature.

2. DATA AND METHODOLOGY

The satellite data that were found to be most suitable for this study were produced by the Defense Meteorological Satellite

Program (DMSP) satellites. Many of the satellite characteristics and data collection procedures have been discussed by Dickinson et al (11) and Henry and Isaacs (12); they will be only briefly mentioned here. The DMSP satellites are sun-synchronous and polar orbiting, were designed specifically for monitoring meteorological phenomena, and produce data that are available in image format from the University of Wisconsin.

Daily noontime coverage of the three May-September periods of 1973, 1974 and 1977 were chosen for analysis. Several criteria were involved in the choice of the particular time, months and years. DMSP data are available for approximately 0000, 0600, 1200 and 1800 LST. Images for noon were used here because cloud cover at this time is critical in terms of influencing the development of the sea breeze and producing precipitation. Also, noon is near the time of maximum diurnal cloud development over the peninsula. Sequences of aerial and ground photographs showing cumulus development over southern Florida in summer for 0900-1400 LST (13) and 0800-1700 LST (8, 14) indicate that maximum daytime sky cover is achieved between 1100-1400 LST, and Martin and Lily (15) indicate that in the southeastern United States the daytime cloud cover generally exceeds nighttime coverage. Although the noon images of Florida show the cloud cover for only one instant, Blackmer and Alder (6) show that there is a high probability of a given cloud cover remaining much the same for several hours. This is substantiated for peninsular Florida by the photo sequences of cumulus clouds by Johnson and Plank.

The May-September period was selected for two reasons: first, this is generally the most critical time for water supplies and cloud seeding operations in Florida; second, as previously noted, cloud cover estimation by ground observers is generally least accurate during summer, when vertically developed clouds are most common. The years 1973, 1974 and 1977 were chosen because these were relatively normal, wet and dry summers, respectively, over most of Florida (12). This procedure was employed because any one year may not be representative of general cloud cover conditions.

The study period contained 459 days (the three May-September periods), for which 378 DMSP images were available. At least twenty images were obtained for each of the fifteen months. Most of the images (76 per cent) were at a scale of 1:7,500,000 with a resolution of 0.6km; the rest had a resolution of 0.4km or 3.7km and scales of 1:7,500,000 or 1:15,000,000. Florida was near the center (area of best resolution) on two-thirds of the images, and at or near the edge on only 8 per cent.

Florida was divided into cells of 0.5 degrees latitude by 0.5 degrees longitude (approximately 55.4 x 48.2 km) for data recording purposes. The resulting fifty-nine cells are shown in Fig. 1. Cells 58 and 59 cover the Keys (not shown). For each cell on every image the percentage of total cloud cover, cumuliform cover and stratiform amount were visually determined. Detailed measurement techniques and possible error magnitudes are presented in (16).

3. SPATIAL DISTRIBUTION OF CLOUDS

The satellite-derived distributions of total cloud cover over Florida in summer are shown in Fig. 2. The individual years are shown three-dimensionally to aid visual comparison (vertical scale is the same for all three years; intercomparisons between Figs. 2, 3 and 4 are not possible, however, because of different vertical scales). The map of all years inclusive is shown in choropleth form to produce exact values. Generally, total cloud cover is greatest in the northeastern and southern portions of the peninsula. This is true for the individual years as well as for the total period. The highest value is 61 per cent, which occurred in cell 54 (refer to Fig. 1) in 1973. Values are higher in coastal regions than in the interior, as revealed by the trough of low values in the central portion of the peninsula -- particularly in 1973 and 1974. Lowest cloud cover values are most common over the Keys (cells 58 and 59). Thus the cloudiest and least cloudy areas in the state are very close geographically. The cell of low value in the extreme northeastern section of the state (cell 15) on the total-time-period map is probably partially caused by the relatively large water portion of the cell. A consistent cloud pattern in many cells on the satellite images was a much greater cloud cover over that part of the cell over land than over water. Cloudiness for the three years of data is lowest in fifty-eight of the fifty-nine cells for 1977, a summer of drought conditions throughout much of the state. Interestingly, however, statewide total cloud cover was slightly greater in the normal rainfall summer (1973) than the summer of above average rainfall (1974).

Fig. 3 shows the distribution of cumulus clouds (stratocumulus clouds are included in this group). Most of the state has values 21-25 per cent. This category covers all of the panhandle and most of the interior of the peninsula. Maximum values occur in the northeast and scattered areas in the central portion of the state. Minimum values are mostly associated with coastal areas. The land/water contrast is especially significant in the distribution of cumulus clouds. Sax and Keller (17) note that during May-September there is an almost daily occurrence of convective activity in southern Florida caused by the sea breezes

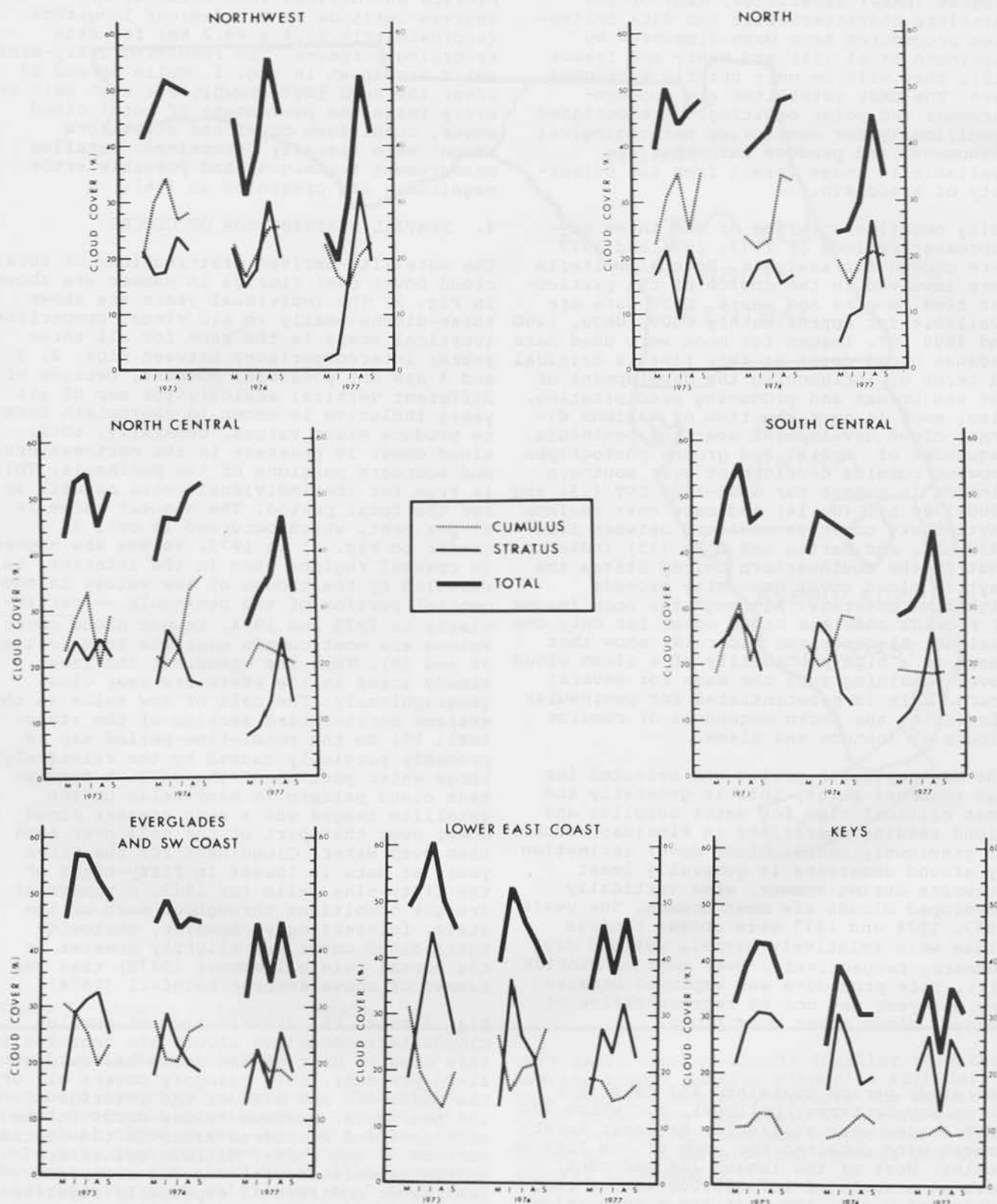


Figure 6. Cloud cover change in the seven climatic divisions of Florida.

on the east and west coasts. This system produces more cumulus clouds inland, away from the coasts, and accounts for many occurrences on the satellite images when the water portions and immediate coastal sections of the data cells were relatively cloudfree, while the inland portions were very cloudy or completely covered. The islands of the Keys are mostly unaffected by the sea breeze effect (18), and the two data cells in this region are consistently the least cloudy; the value for cell 59 is only 10 per cent for 1973 and 9 per cent for the other two years.

The only noncoastal cell with a very low cumulus cloud cover value is associated with Lake Okeechobee (cell 47). On many of the satellite images the lake region appeared as a hole in the cloud cover, often being completely cloudfree when surrounding areas contained numerous clouds. It has been suggested by Pielke (19) that the lake-induced cooling of the overlying atmosphere suppresses convergence and, therefore, cumulus cloud development. The effect is apparently strong enough to inhibit convergence even when the strong sea breeze convergence zone passes over the lake.

Stratus cloud cover is shown in Fig. 4. For the total time period the geographic distribution of stratus clouds is the reverse of cumulus cloud cover, with highest values in the extreme southern portion of the peninsula and minimum cloud cover in the north. Except for this reversal there are several similarities between the two cloud types: 1) the highest value for a cell for the total period is 29 per cent, and the lowest is near 10 per cent; 2) coastal values are generally slightly higher than those of interior regions; 3) intermediate cloud values consistently occur in the panhandle; and 4) cloud cover is less in 1977 than in the other two years. The sea breeze and convergence field apparently play no major role in the distribution of stratus clouds, as revealed by the relatively high cloud values over the Keys (among the highest in 1974), and by the fact that the cell containing Lake Okeechobee is generally cloudier than surrounding cells, and not less cloudy as was the case with cumulus clouds.

4. TEMPORAL DISTRIBUTION OF CLOUDS

The seven climatic divisions of Florida (Fig. 5) were chosen as the areal units to use in the analysis of cloud cover change on a monthly basis. As previously mentioned, clouds are a possible climatic-change mechanism, and several recent studies concerned with climatic trends have used divisional data. The changes in all types of cloud cover for each division for the fifteen months of the study period are shown in Fig. 6. There are several distinct trends and patterns. First, the greater total cloud cover of 1973 and the minimum values in 1977 are readily apparent. This is generally

reflected in both stratus and cumulus clouds in all divisions except the Keys, where cumulus cover varies little between normal, wet and dry summers. Second, if the divisions that cover the Florida peninsula (all but the Northwest division) are considered, a consistent stratus/cumulus relationship exists. Stratus cover in the North division exceeds cumulus cloud cover in only one of the fifteen months (August, 1977). The figure steadily increases southward, until in the Lower East Coast division stratus exceeds cumulus cover in eleven of the fifteen months, and in the Keys all months have greater stratus cover than cumulus. The dominance of stratus cover in the Keys relates to the previously discussed fact that the islands of the Keys do not produce a pronounced sea breeze and attendant convection and cumulus clouds. And third, a qualitative assessment of the monthly changes revealed by the general shapes of the curves shows several marked similarities among the northern four divisions and among the southern three. For example, the total cloud cover curves for all three years for the three southernmost divisions are very similar in shape and general trend, and are significantly different than the equivalent curves for the northern four divisions -- further highlighting the contrasting synoptic controls dominant in northern and southern Florida in summer.

5. SUMMARY AND CONCLUSIONS

DMSP satellite images provide an alternate, accurate method for the determination of cloud cover types and amounts over large areas. Analysis of 378 images covering Florida for three May-September periods has revealed the spatial and temporal distributions of total, cumulus and stratus cloud cover during normal, wet and dry conditions. Total cloud cover is generally greatest in the northeastern and southern portions of the peninsula. The highest recorded mean value was 61 per cent, which occurred over the Everglades area. Lowest values occurred near the interior and over the Keys. The distribution of cumulus clouds reflects the influence of the sea breeze and associated convergence zones. Highest values occur away from the immediate coastline, and minimum values are consistently found over the Keys, where values as low as 9 per cent are common. Stratus cover shows a distribution which is the reverse of cumulus clouds: highest percentages in the south and lowest values in the north. Monthly trends in cloud cover point out that the controls of cloud cover contrast strongly between the northern four climatic divisions and the southern three divisions within the state.

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