A Cloud Cover Climatology for Three Midwestern Cities and a Limited Comparison to Their NDFD Forecasts

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1. Introduction

Cloud cover forecasts are a highly visible portion of the public forecast provided by the National Weather Service (NWS) each day through the National Digital Forecast Database (NDFD). It is an integral part of any forecast, as well recognized as any other element provided by the NWS. In fact, it is only left out of a text forecast when it is implied by the weather or precipitation. For example, when the probability of precipitation forecast is greater than 80%, it is assumed to be cloudy, and thus sky cover is not mentioned.

There is a perception that NDFD forecasts have a tendency to lean towards the partly cloudy and mostly cloudy values, and do not often contain forecasts of clear or cloudy as frequently as they may actually occur. Forecasters seem to be forecasting towards the middle of the spectrum, perhaps to better match up their grids with neighboring NWS offices, or to create a mean forecast to account for changes through a period of time or for rapidly changing conditions.

Clouds are a significant component of Midwest climate, but how can this general understanding be quantified for the NDFD, and how do clouds vary? This study develops a climatology of the distribution of sky cover. Moline International Airport (KMLI) was selected as a location generally representative of the Weather Forecast Office (WFO) Quad Cities, Iowa forecast area with a quality surface observation data set. In addition, Des Moines International Airport (KDSM) and Chicago O'Hare Airport (KORD) were selected to add spatial variability to the climatology, as they are representative of the larger region. This climatology will include annual, seasonal, monthly and daily assessments of cloud cover. The goal of this study is to improve NDFD sky cover accuracy by increasing forecaster awareness of the climatological distribution of cloud cover.

2. Data and Methods

The data analyzed for this study are the Hourly Global Surface data (DS3505) datasets for Moline and Chicago Illinois, and Des Moines, Iowa, available from the National Climatic Data Center (NCDC) Climate Data Online website. For each location, the climatology was based on the time during which manual sky cover observations were taken. These include the complete cloud cover observation, including layers above 12,000 feet. For KMLI the time period selected is January 1, 1973 to December 31, 1994. For KDSM, the selected time period is January 1, 1973 to November 30, 1995. For KORD, the selected time period is January 1, 1973 to January 31, 1996. Special observations were eliminated from the database. Due to the criteria which determine when special observations are required, their inclusion would have skewed the database towards overcast or broken conditions. More than half a million observations were included in this study, including 192,835 observations from KMLI, 200,854 observations from KDSM, and 202,325 observations from KORD. Out of these observations, only 1,887 observations were missing cloud cover data, which is less than 1 %. For each analysis, the numbers of observations in each cloud cover category were summed up, and percentages were calculated. Within this data source, cloud cover is categorized as shown in Table 1.

Table 1: Sky cover category and tenths of coverage

Sky Cover category		Tenths of
Word	abbreviation	Coverage
Clear	CLR	0
Scattered	SCT	1 - 4
Broken	BKN	5 – 9
Overcast	OVC	10

The original observations used in this study were taken in tenths of sky cover. The data have been converted to the sky cover categories in Table 1 by NCDC for this dataset. During this time period, manual observers could report cloud layers as thin, which occasionally occurs as thin cirrus. This dataset did not include the thin indicator. Consequently, observations which include thin overcast are classified as overcast. A closer look at the data shows that approximately three percent of the observations are overcast with a ceiling at or over 20,000 feet–observations which could indicate a thin cirrus overcast. Even if most of these observations are thin, this is a small enough portion of the dataset that the issue of thin versus opaque can safely be ignored.

As a comparison to the climatology developed in this study, a small subset of NDFD forecasts for KMLI issued by WFO Quad Cities was downloaded from the NDFD website. The data are for forecasts issued in October 2006, and January, April, and July of 2007, for the entire 7-day forecast time period in three-hourly time steps through 72 hours, and in six-hour time steps through the remainder of the 7-day forecast.

3. Results

a. Annual Summary

An analysis of the full dataset gathered for this study shows that overcast is the most frequently observed category (Figure 1). KMLI had 40% of observations in the overcast category, KDSM had 38%, and KORD had 41%. Clear is the next largest category, with 27% at KMLI and KDSM, and 21% at KORD. Scattered is next, with only 17% at KMLI, 18% at KDSM, and 19% at KORD. Broken is the smallest category, with 16% at KMLI, 17% at KDSM, and 19% at KORD. It is interesting to note that while KMLI and KDSM have very similar distributions, KORD has fewer clear observations than the other sites, and has slightly more in each of the other categories. The broken and overcast categories increase the most for KORD as compared to KMLI and KDSM. This may be due to Chicago's proximity to Lake Michigan and the associated lake effects.

b. Seasonal Summary

When the sky cover distribution is broken down by season, some interesting trends appear. Seasons were defined as: winter (December, January and February);

spring (March, April and May); summer (June, July and August); and, fall (September, October and November).

During winter for KMLI, the sky cover distribution is very polarized (Figure 2). Overcast cloud cover occurred 50% of the time, and clear occurred 26% of the time. Broken and scattered each only occurred 12% of the time. Winter is the only season where the combined frequency of broken and scattered does not exceed either clear or overcast.

In spring, overcast cloud cover is still the highest frequency category, while the clear category decreases slightly and broken and scattered increase. Overcast was reported 43% of the time, clear 14%, broken 16% and scattered 16%. The sum of the broken and scattered observations is greater than the clear category, but not as high as the overcast category.

In summer the cloud cover is almost evenly distributed between the categories, with all four categories between 22% and 27%. The least frequent was broken, and the most frequent was overcast.

In fall, the distribution skews towards overcast again. The overcast category increases to 39%, clear is 30%, and broken and scattered 15% and 16%, respectively. The sum of broken and scattered observations is more than clear, at 31%.

Reasons for this distribution of seasonal cloud cover may include a greater amount of diurnally driven cumulus type clouds during the summer as compared to more synoptically driven clouds during the winter. The diurnally driven cumulus clouds are typically either scattered or broken, but infrequently are completely overcast. Synoptically driven clouds, however, are more likely to be overcast.

Data from KDSM are very similar to the KMLI analysis (Figure 3). In fact, the frequencies are all within 3% of each other. The reasons for the distribution at KDSM are similar to those for KMLI.

The KORD seasonal analysis is different. In winter, the sky cover distribution is also polarized, but more strongly favors the overcast category (Figure 4). Overcast cloud cover occurred 53% of the time, and clear occurred 20% of the time. Broken and scattered occurred 14% and 13%, respectively. Note that clear occurs much less frequently than at the other two locations analyzed.

In spring, overcast cloud cover is still the highest frequency category, but the broken and scattered categories increase. Overcast was reported 44% of the time, clear 20%, broken 18% and scattered 17%. Clear continues to be less often reported, and broken, scattered and clear are very close in frequency.

In summer the cloud cover is relatively evenly distributed between the categories, with all four categories between 22% and 27%. This time, the lowest was clear, and the highest were overcast and scattered, both at 27%.

In fall, the distribution skews towards overcast again. The overcast category increases to 39%, clear is 23%, broken 18%, and scattered 19%.

Differences between the KORD analysis and both KMLI and KDSM include a significant decrease in clear conditions at Chicago as compared to the other two sites. Reasons for this difference may include lake effects causing more clouds, and more city lights making nighttime clouds easier to see.

c. Monthly Summary

When the data are broken down further into monthly distributions, the picture becomes more detailed. The analysis begins with KMLI (Figure 5). The majority of the sky cover for November through March is overcast, with values near or above 50% for each month. Overcast drops to 30% or less for only June, July, August and September. Clear sky frequencies peak in September and October at over 30% for each month, but otherwise range between 20% and 30% during the rest of the year. The scattered category peaks in July at 26%, dropping as low as 12% in December. Only in the month of July does it exceed the frequency of clear or overcast. The broken category peaks in June at 23%, and drops as low as 11% in December. It also never exceeds the values of either clear or overcast in any one month, though it is very close to scattered for most of winter and spring. This additional detail can also be explained by a greater amount of diurnally driven clouds during the warm season months between April and September, with more synoptically driven clouds during the cold season months between October and March.

The monthly analysis of the KDSM data shows very similar trends in the overcast, broken and scattered categories (Figure 6). The clear category shows a low point of 23% in March and does not rise significantly again until July. There is a peak in September and October, like KMLI. The overcast category does not exceed 50%, but does remain between 45% and 50% November through March.

The KORD analysis shows a slightly more polarized distribution (Figure 7). The trend for fewer clear category observations continues, ranging from just 18% in November to 27% in October. This drop in the clear category occurs at the same time as a large jump in the overcast category, rising from 36% to 53%. The overcast category peaks in December at 56%, and has a low in July at 25%. Otherwise, the trends in the broken and scattered categories are similar, but slightly higher than trends at both Moline and Des Moines. The large drop in the clear category and jump in the overcast category are also noted in the Moline and Des Moines data and are of similar magnitude. It appears more dramatic in the Chicago data due to the generally lower levels of the clear category. Reasons for this large drop in the clear category from October to November and the large jump in the overcast category may include the onset of winter seasonal effects.

d. Diurnal Summary

An analysis of the diurnal distribution of annual sky cover provides interesting results. The KMLI data show that overcast occurs consistently through the day at a frequency near 40%, but the other categories show significant diurnal variation (Figure 8). The clear category varies the most, averaging between 16% and 20% during the daytime hours of 1400 to 2200 UTC, with a minimum of 16% at 2100 UTC. At night however, the frequency of clear slowly rises to a maximum of 38% at 0700 UTC, with the frequency greater than 35% between 0400 and 0900 UTC. The scattered and broken categories are both greater than 20% in the afternoon hours from 1800 to 2300 UTC, and are lowest at night during the same time that the clear category is the greatest. This variability is consistent with diurnal, instability-driven clouds that dissipate around sunset and reform in the morning after sunrise. The higher frequency of clear at night may also result from the difficulty in seeing thin or patchy clouds at night.

An analysis of the KDSM data shows very similar results as the Moline data (Figure 9). The clear category once again has the largest variation, from the minimum of 17% at 1800 UTC, to a maximum of 36% at 0700 UTC. The cloudy category is consistent through the day, near 38%. Both the scattered and broken categories are above 20% during the afternoon hours between 1800 and 0000 UTC, and are lowest at night between the hours of 0600 and 1000 UTC. The diurnal variation of each category shows only very small differences between the KMLI and KDSM data. There is some difference in the timing and levels of the maxima and minima, but they do not appear to be significant, being within a few percentage values and a few hours of each other.

An analysis of the KORD data shows slightly different results compared to the KMLI and KDSM analyses (Figure 10). The clear category still has the largest range, varying from 11% at 2100 UTC to 32% at 0700 UTC. The values are generally lower than the other two sites, but the range is similar to both KMLI and KDSM. The cloudy category is consistent around 41% through the day, the highest of all three locations. Both broken and scattered categories are above 20% from late afternoon into early evening, from 1600 to 0000 UTC. They are lowest at night at 0800 UTC at 14% and 15% respectively. Both of these categories have generally higher values than at the other two locations.

4. Comparison of NDFD data to the climatology

A survey of the NDFD forecasts was conducted for KMLI. To keep the data volume manageable, four specific months were chosen, and only the site KMLI was used. These months were October 2006, and January, April, and July 2007, and were chosen for being representative of the seasons they are part of, as depicted in Figure 5. NDFD sky cover forecasts are provided in percent of sky cover, so these data were split into the categories using the following thresholds: clear < 10%, scattered = 10-49%, broken = 50-89%, and overcast >= 90%.

To mirror the annual analysis of the observed data, the four months of NDFD data were first analyzed as a group, and for the entire time range of the forecast (Figure 11). This survey indicated that the forecasts heavily favored broken and scattered, with 43% and 44% respectively. Overcast conditions were only forecasted 10% of the time, and clear only 3% of the time. When the data were limited to just the first 24 hours of the forecast, they were still heavily skewed toward the broken or scattered categories. Within these first 24 hours, the broken and scattered categories were forecasted 33% and 39% of the time respectively, with overcast forecasted 20% of the time, and the clear category only forecasted 9% of the time. As compared to the climatology described above, broken and scattered conditions were forecasted approximately twice as often as climatology indicates they occur. Overcast was forecasted less than half the time than the climatology indicates actually happens.

One of the most notable features of the climatology is the strong polarization of sky cover during the winter season. Looking at the data from January 2007, the climatology of the season is not reflected in the NDFD forecasted sky cover. Overcast conditions were forecasted only 17% of the time, broken conditions 50% of the time, scattered 31% of the time, and clear only 2% of the time (Figure 12). The two transition months, October and April, show a similar trend of having the most forecasts in the broken category, with the least in overcast and clear (Figures 13 and 14). For the summer month of July, the most forecasted category shifts to scattered, but still the fewest forecasts by a large margin are in the overcast and clear categories (Figure 15).

5. Conclusions

The results in this study show that during most of the year, sky cover for the Moline International Airport (KMLI) is climatologically skewed towards fully overcast skies (10/10 sky cover). This trend is most prominent in winter, but extends for much of the cool season of October through March. During this cool season the distribution is also very polarized, with clear conditions being favored over either broken or scattered as an alternate to the overcast condition. During the summer, the distribution is more even, with nearly equal distributions in each category. Spring and fall are transition seasons, as the amount of time spent in either the overcast or clear categories decreases and the sky condition is more often broken or scattered. The data analyzed also show that diurnally driven clouds have a significant impact on the distribution, favoring either overcast or clear overnight, and being more evenly distributed during the daytime between clear, scattered, broken or overcast. In general, the data analyzed from Des Moines International Airport (KDSM) and Chicago O'Hare Airport (KORD) were similar to the KMLI data, differing in relatively small details.

Additional results of this study found that the NDFD forecasts of sky cover did not match the distributions shown in this climatology. In fact, at times, the NDFD cloud cover forecast distribution appears to be an inverse of the actual climatology, with the two cloud categories occurring most often, being forecasted the least often.

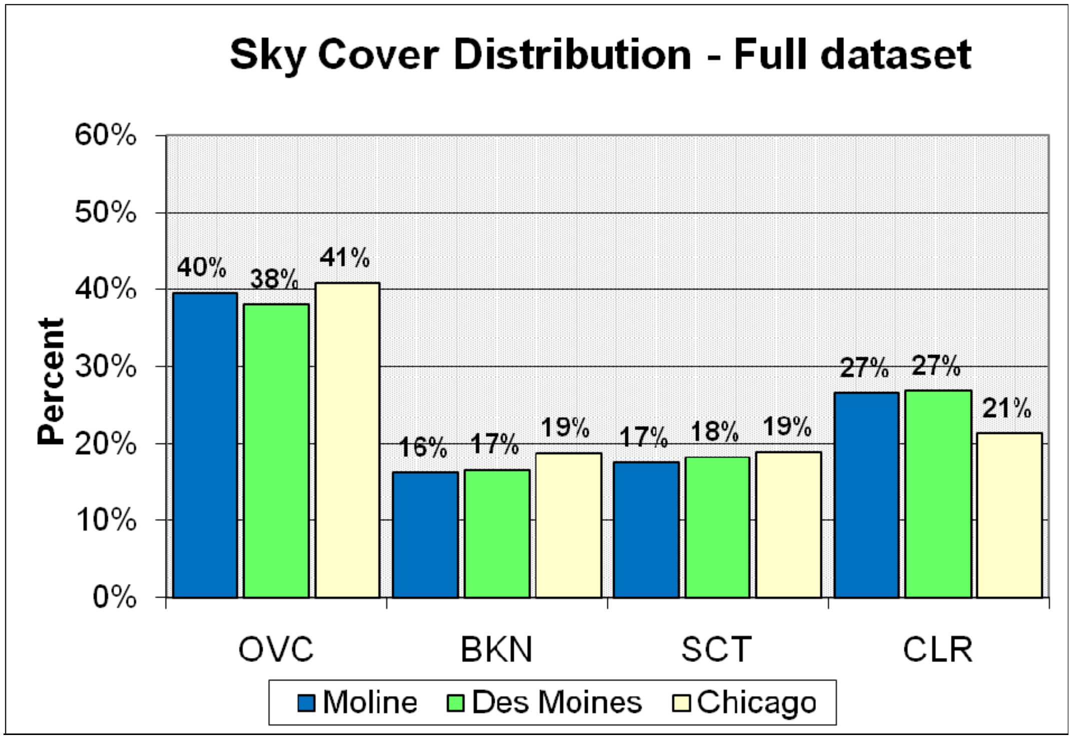

Figure 1: The distribution of sky cover observations by category for all three observing locations.

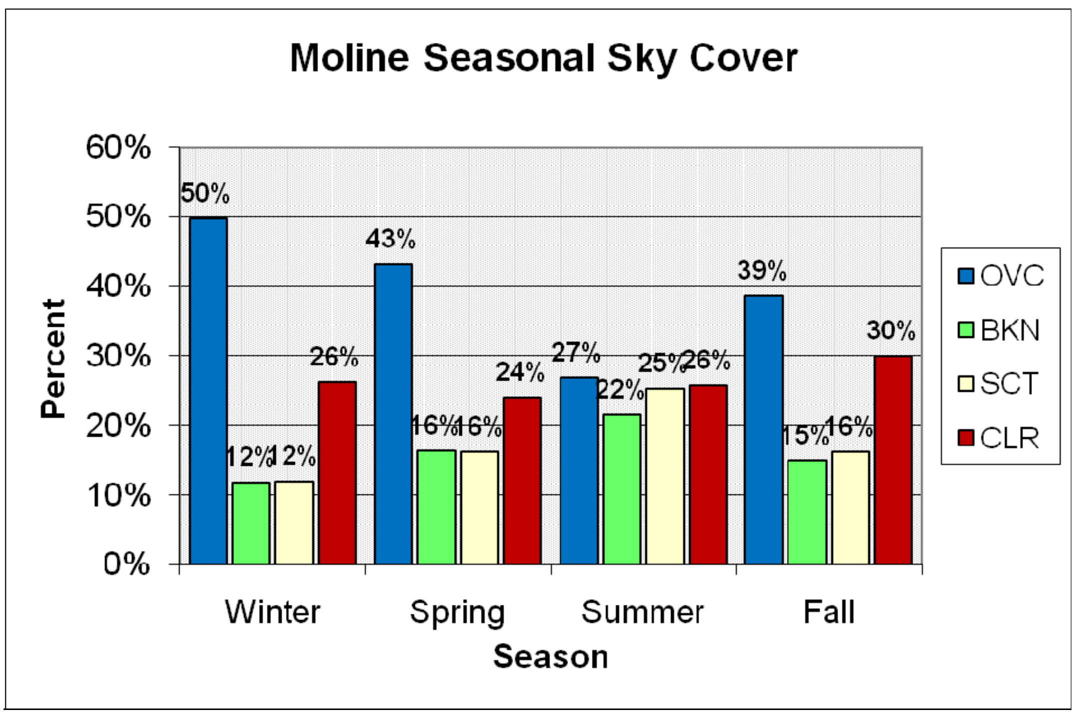

Figure 2: The distribution of sky cover observations by category and season for Moline, Illinois.

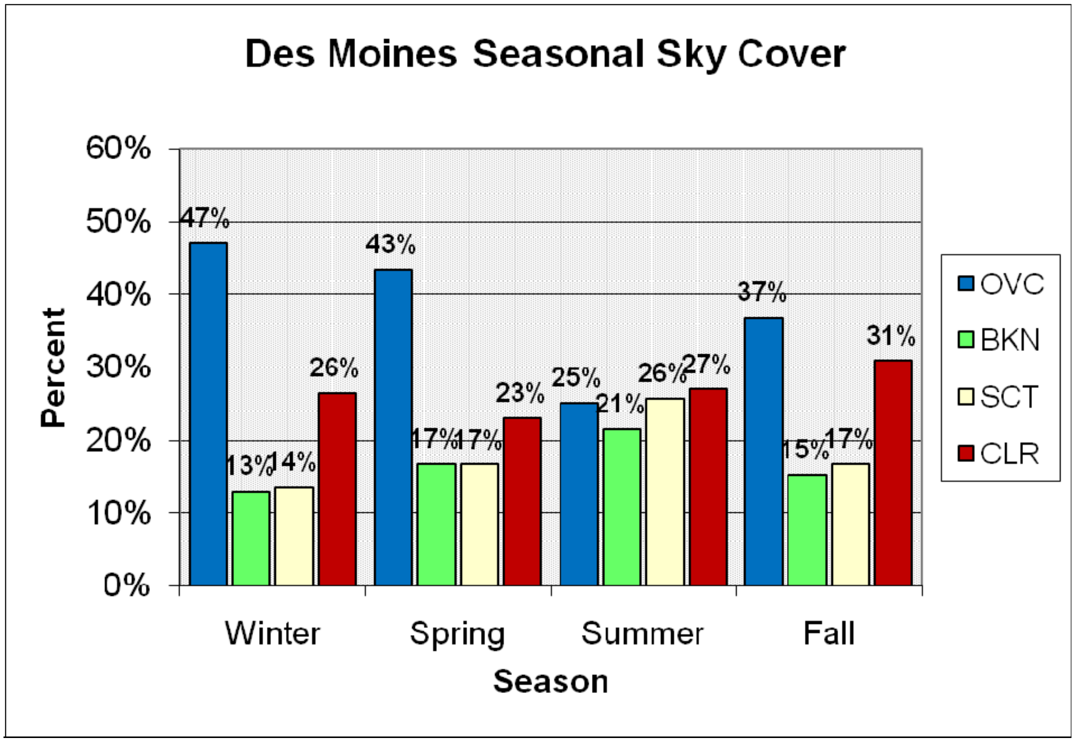

Figure 3: The distribution of sky cover observations by category and season for Des Moines, Iowa.

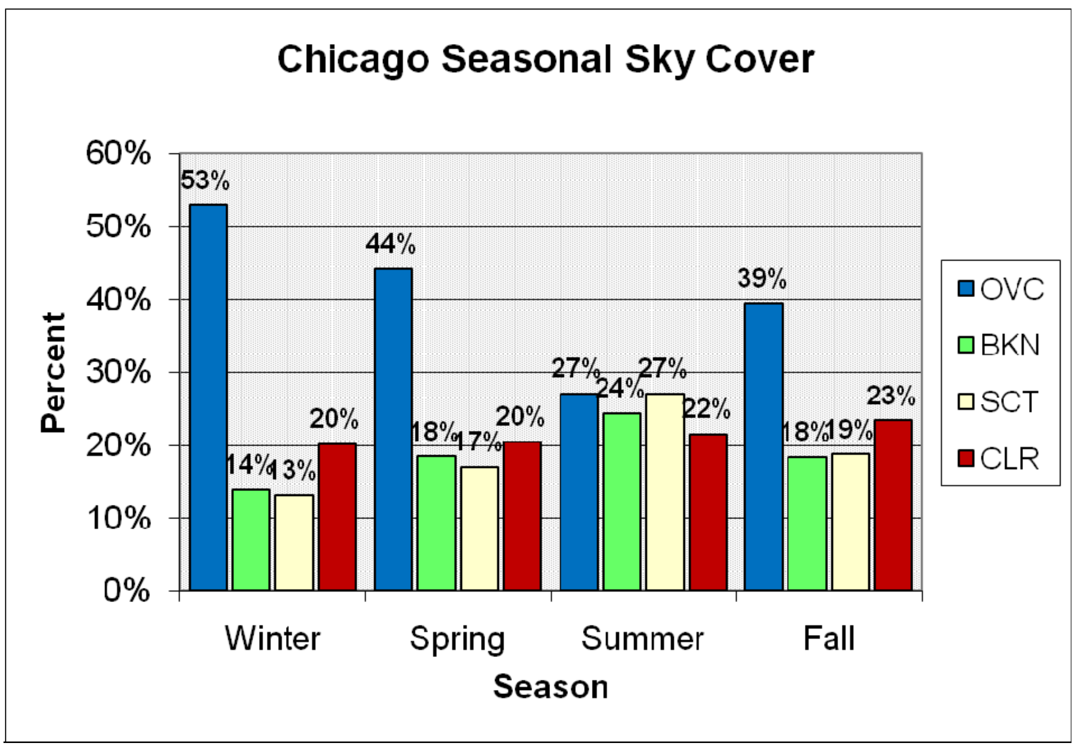

Figure 4: The distribution of sky cover observations by category and season for Chicago, Illinois.

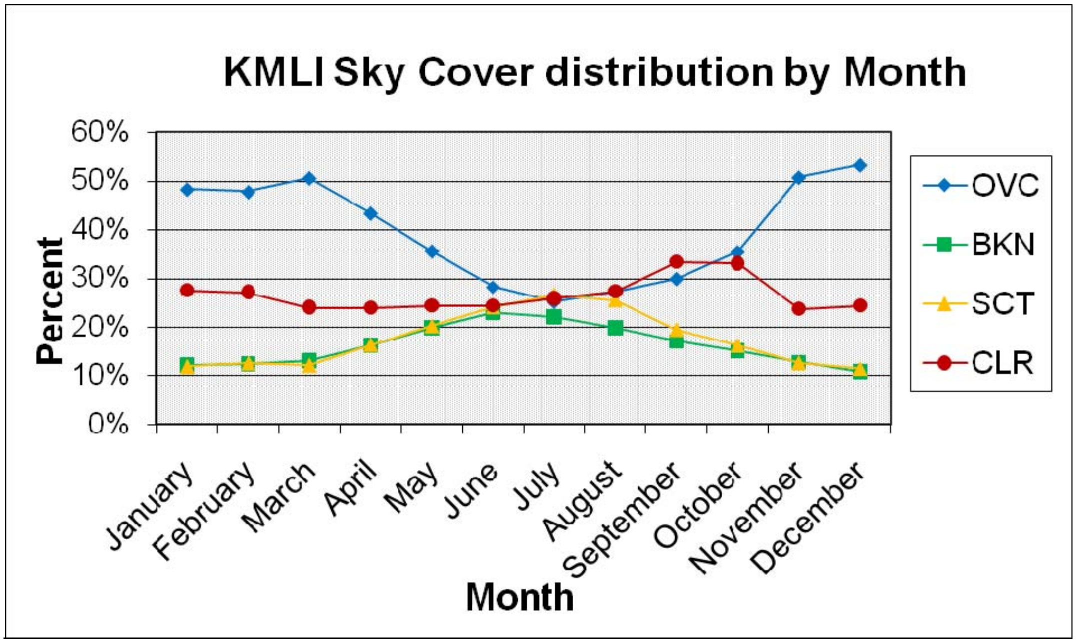

Figure 5: Sky cover distribution by month for Moline, Illinois.

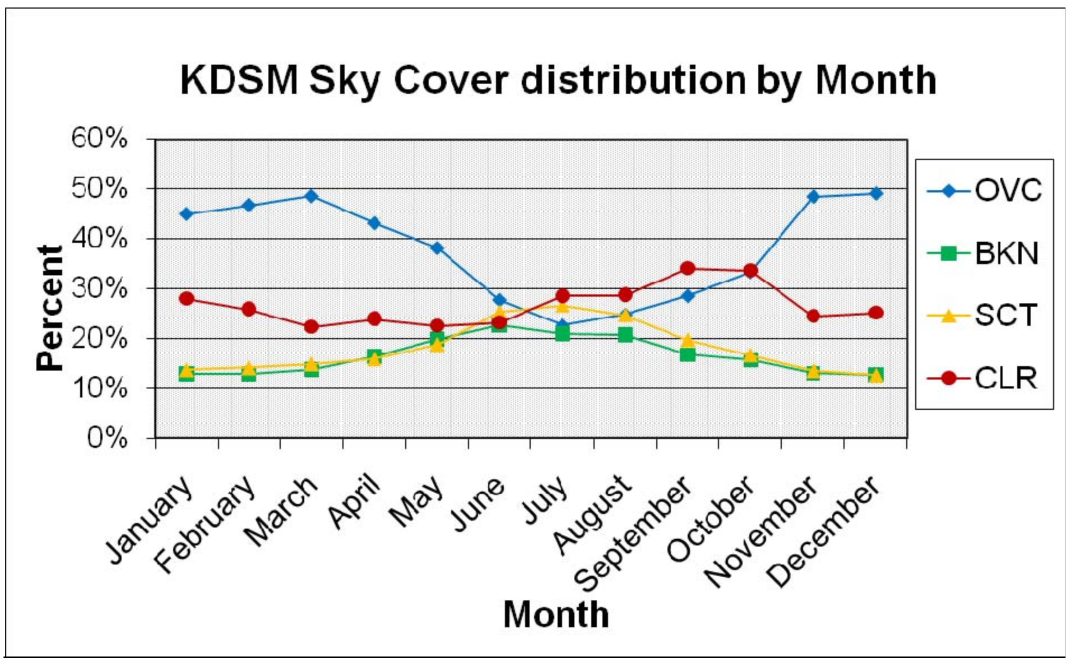

Figure 6: Sky cover distribution by month for Des Moines, Iowa.

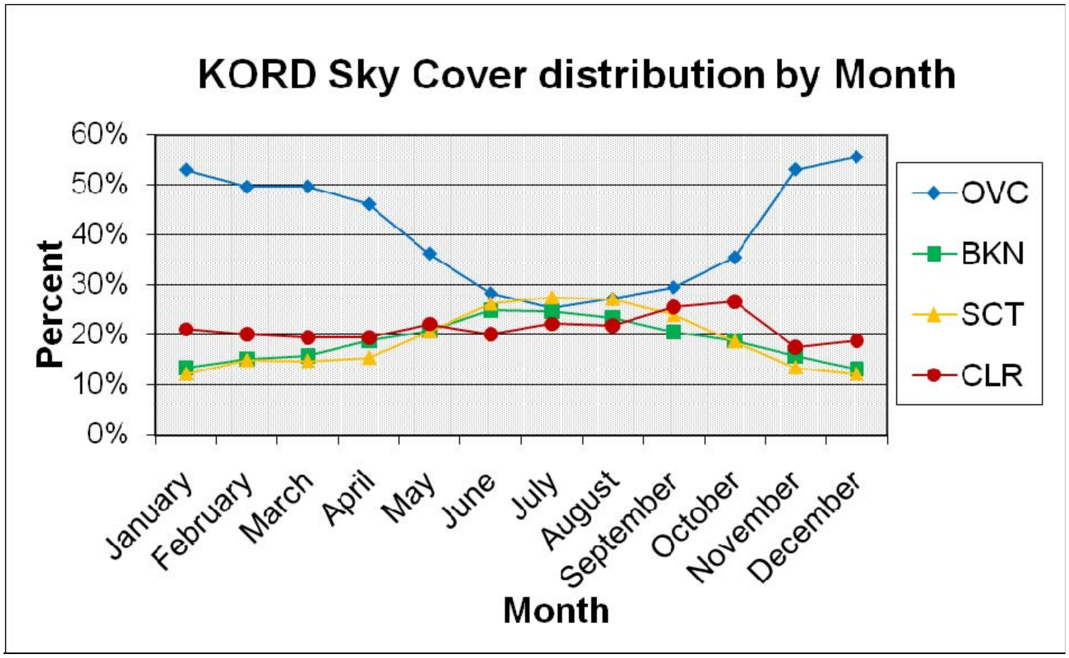

Figure 7: Sky cover distribution by month for Chicago, Illinois.

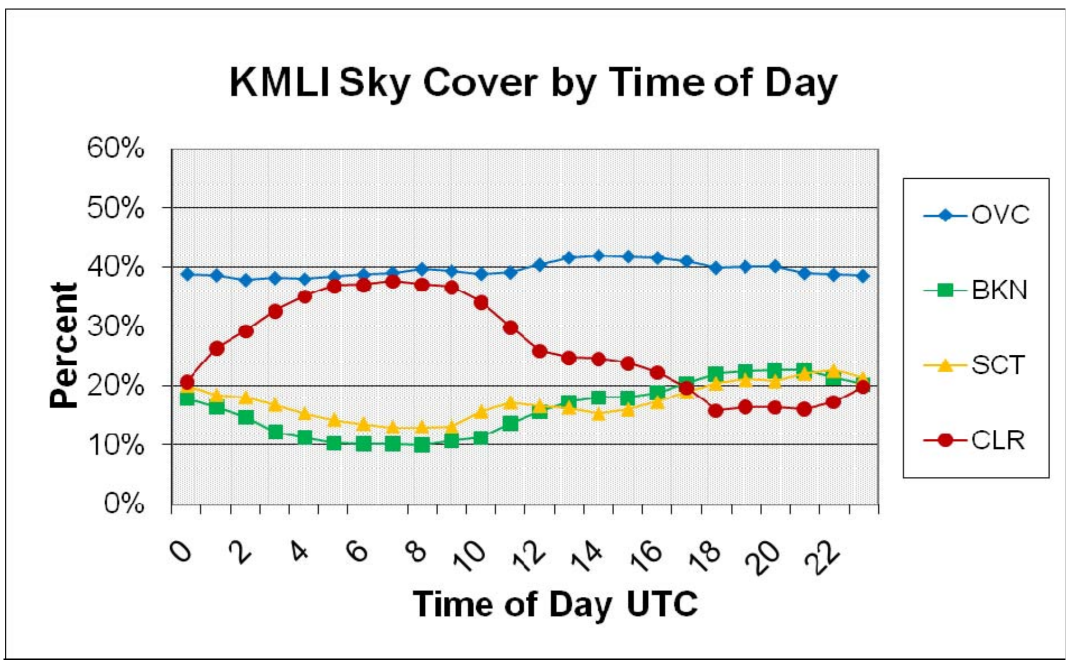

Figure 8: Sky cover distribution by time of day for Moline, Illinois.

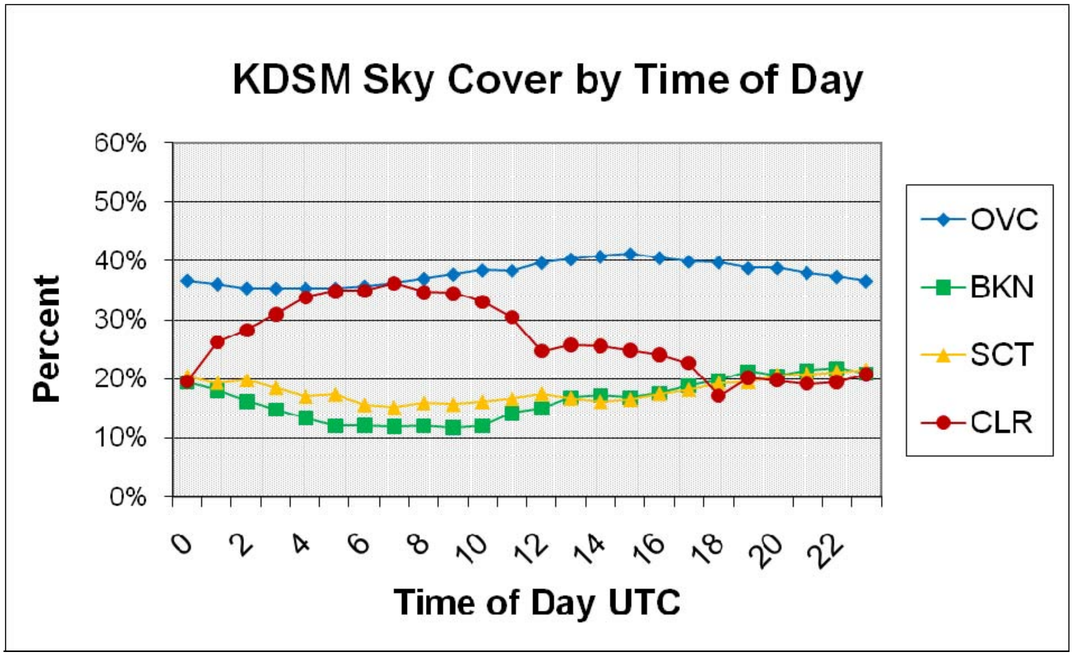

Figure 9: Sky cover distribution by time of day for Des Moines, Iowa.

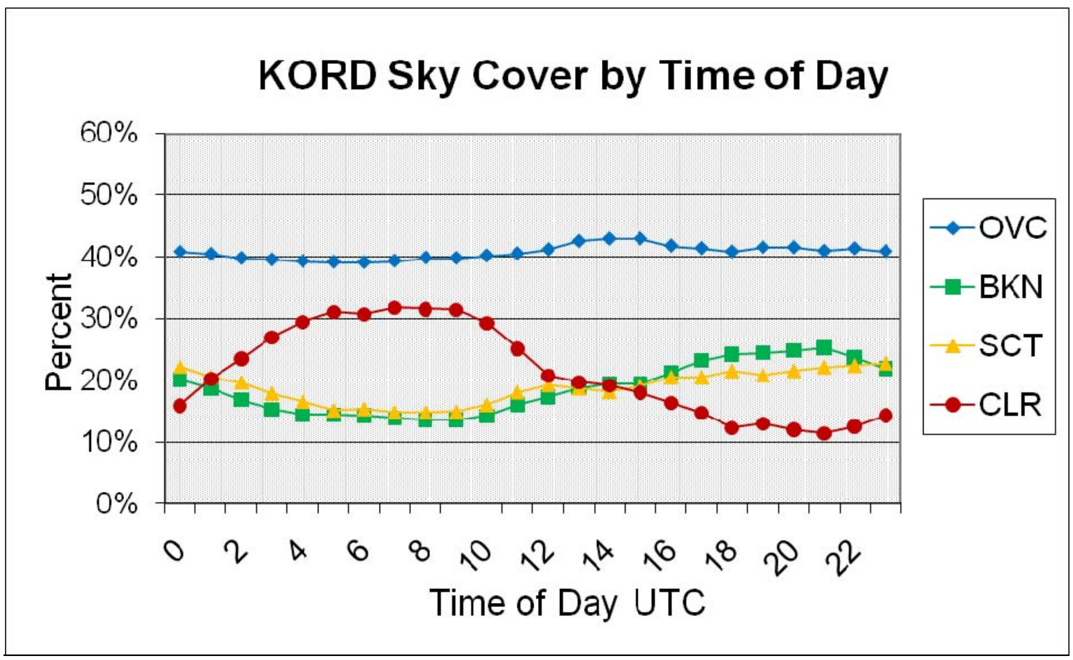

Figure 10: Sky cover distribution by time of day for Chicago, Illinois.

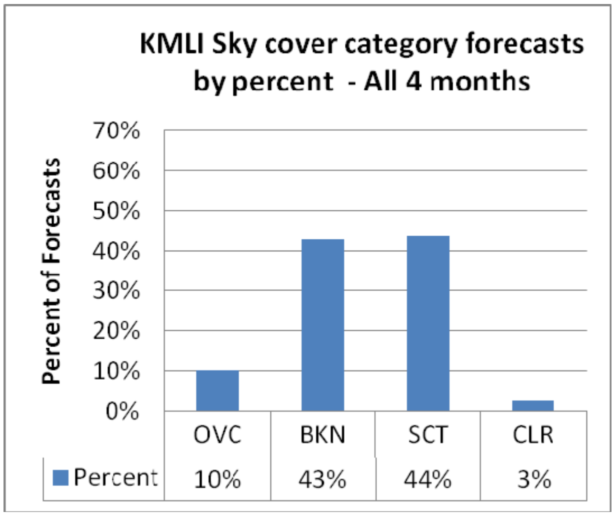

Figure 11: NDFD sky cover forecast distribution by category for all four months.

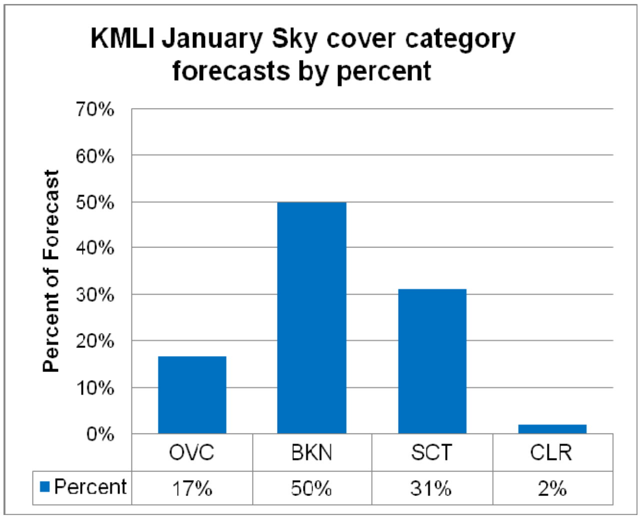

Figure 12: NDFD sky cover forecast distribution by category for January.

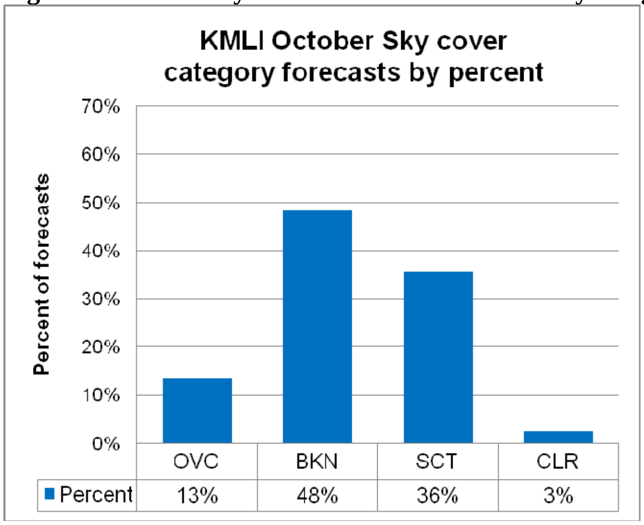

Figure 13: NDFD sky cover forecast distribution by category for October.

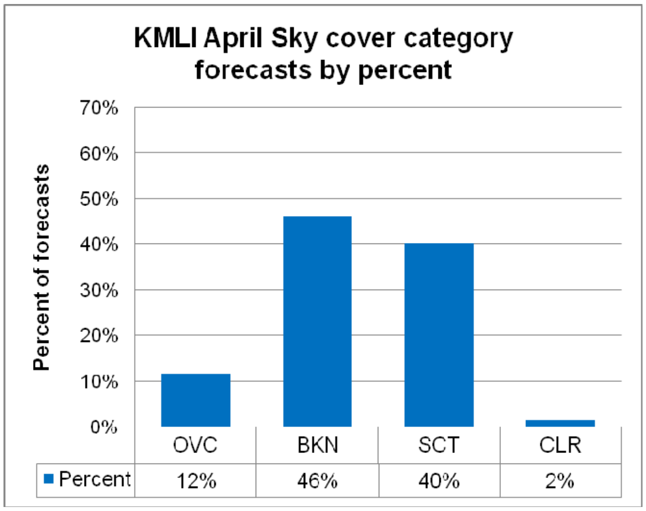

Figure 14: NDFD sky cover distribution by category for April

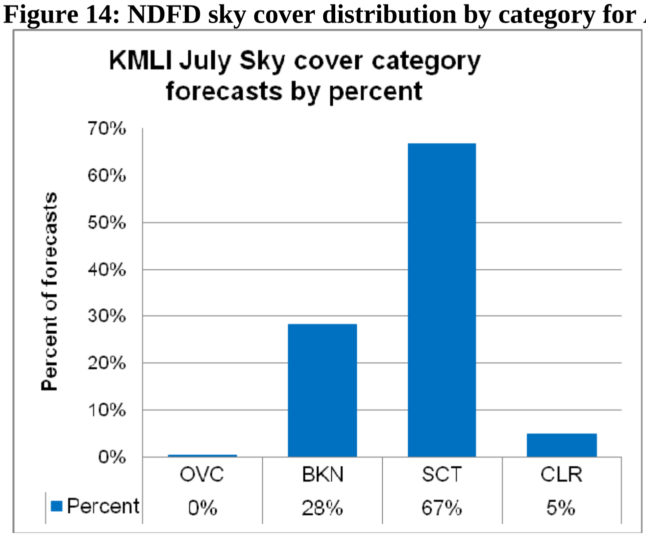

Figure 15: NDFD sky cover distribution by category for July.