

# UTILIZING RADAR ESTIMATES OF AREAL RAINFALL COVERAGE AS A VERIFICATION AND FORECASTING TOOL

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## ABSTRACT

National Weather Service (NWS) forecasts of probability of precipitation (PoP) are included in public forecasts to communicate the chance of measurable precipitation for any given point in a forecast area during the forecast period. Since PoPs are usually verified by the use of a single rain gauge in each NWS public forecast zone, verification depends on rainfall hitting or missing the gauge. In this study, twelve-hour overlay composites for areal coverage of radar-indicated precipitation were compared with PoP forecasts. The focus was on variation between zones, frequency of use, and verification techniques. Knowledge of the previous day's areal coverage was also examined as a way to improve PoP forecasts. Findings show that incorporating areal coverages into the PoP forecast and verification process will improve the PoP forecast. With the advancements that Next Generation Weather Radar (NEXRAD) will bring in precipitation processing, knowledge of areal coverages should become a valuable tool for PoP forecasting and verification.

## 1. INTRODUCTION

Smith (1977) suggested that the PoP numbers used in NWS forecasts should be closely related to the observed areal coverage for a given twelve-hour first period for the summer-time "scattered shower" regime. His study focused on south Alabama and northwest Florida. Smith contended that if it likely WILL rain somewhere in a zone during a forecast period, the areal coverage, in effect, should be equal to the average point probability forecast for the zone. The study concluded that knowledge of the areal coverage, in real time, could lead to the improvement of the PoP forecast. With these ideas in mind, this paper considers improvement of PoP forecasts and their verification in north and central Florida.

## 2. APPROACH

The study used composites of hourly overlays made from twelve consecutive radar observations. These composites were made for the summer months (June 1–August 31, 1988) from the WSR-57 radar at WSO Daytona Beach, Florida. The study covered seven NWS public forecast zones in north and central Florida, and the composites were made to cover the "today" (12-00 UTC) and "tonight" (00-12 UTC) forecast periods. The following zones within the 125 n mi range of the Daytona Beach radar were used: FL08, FL09, FL10, FL11, FL12, FL14, and FL17 (shown in Fig. 1). Areal coverage from the composites was determined to the nearest 10%,

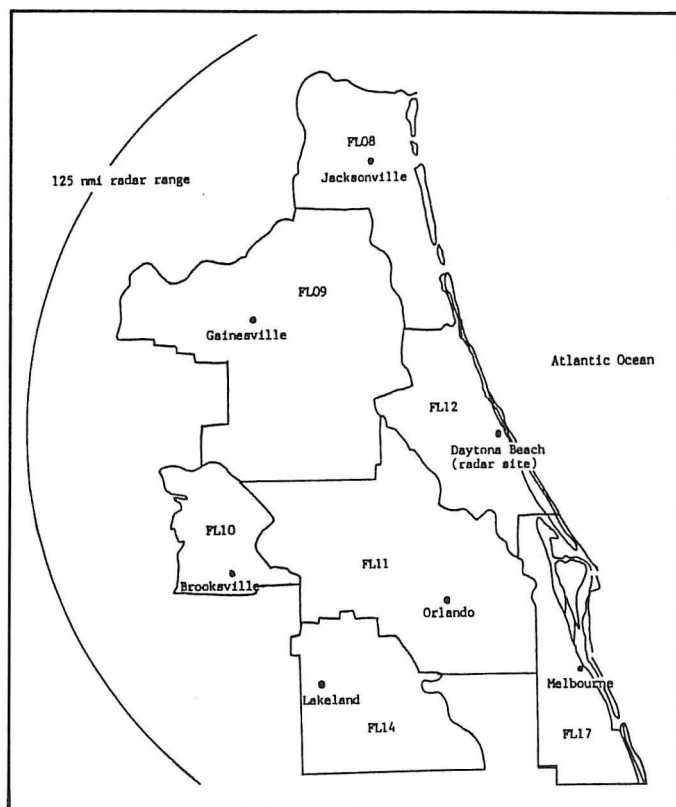


Fig. 1. National Weather Service public forecast zones used in this study.

with accuracy estimated to be  $\pm 10\%$ . PoP forecasts used were from the zone forecasts. Only first period zone PoP forecasts issued by WSFO Miami were considered. Since precipitation needs to be mentioned in the forecast only for a PoP  $\geq 20\%$ , only one category will represent all PoPs that fall into "less than 20%". This category represents all forecasts of 0, 5, and 10%, and for averaging purposes, 5% will be used to represent the category. Although the study period was short, when each PoP forecast in each zone is considered individually, there were 637 forecast periods during the day and 624 at night (the night had fewer periods due to a radar failure).

### 3. DATA

#### a. Improving PoP Forecasts by Considering Zonal Variation

First, the average rainfall frequency (calculated from a rain gauge in each zone and shown in Table 1) for the summer period (June 1–August 31, 1988) should be compared with a climatologically normal summer. The climatological normals, when averaged over June, July, and August are about 41% during the day and 16% at night (Jorgensen, 1967) with variation between the zones anywhere from <5% in June to more than 10% later in the summer. The values for the time period of this study had a daytime average of 36% and nighttime average of 12%, showing that the summer of 1988 was only about 4% below normal.

In general, the inland zones showed the highest daytime frequency, while the coastal zones had the highest frequency at night, although the difference between inland and coastal sections was not as pronounced here. This result relates to seabreeze convergence that occurs over the interior of the peninsula during the afternoon. By night, showers and thunderstorms move toward the east or west coast, as seabreezes give way to the prevailing low-level wind flow. Additionally, coastal showers occasionally move onshore at night.

The average PoP forecast for each zone during the study period was calculated to examine differences between the zones (see Table 2). The average PoPs showed virtually no difference between the zones. The lack of variation in the PoPs likely results from forecasting close to climatological normals, as the averages of forecast PoPs are within 3% of the climatological normals, and from grouping more than one

**Table 1. Average rainfall frequency (% of time occurring) observed from seven gauges in north and central Florida for June–August, 1988. Gauges at the following locations were used: FL08—Jacksonville, FL09—Gainesville, FL10—Brooksville, FL11—Orlando, FL12—Daytona Beach, FL14—Lakeland, FL17—Melbourne.**

| Zone    | Day<br>(12-00 UTC) | Night<br>(00-12 UTC) |
|---------|--------------------|----------------------|
| 8       | 29                 | 19                   |
| 9       | 33                 | 10                   |
| 10      | 35                 | 10                   |
| 11      | 47                 | 8                    |
| 12      | 33                 | 15                   |
| 14      | 44                 | 10                   |
| 17      | 32                 | 12                   |
| Average | 36                 | 12                   |

**Table 2. Average forecast PoP (%) for June–August, 1988.**

| Zone    | Day<br>(12-00 UTC) | Night<br>(00-12 UTC) |
|---------|--------------------|----------------------|
| 8       | 40                 | 19                   |
| 9       | 40                 | 18                   |
| 10      | 42                 | 19                   |
| 11      | 43                 | 20                   |
| 12      | 41                 | 19                   |
| 14      | 43                 | 19                   |
| 17      | 43                 | 22                   |
| Average | 42                 | 19                   |

zone together into the same forecast for the sake of brevity. Findings in this study indicate that larger differences between the zones actually exist, which will be shown next, when differences in average areal coverages are investigated.

Table 3 shows the average areal coverage tabulated for each zone during the study period. These values reveal a 15% range in averages between the zones during the day, and 7% at night. The night value is close to the 4% range of average PoPs, but the day period has 11% more variation than PoP forecasts account for. Likewise, the average rainfall frequency for each of the zones showed a range between the zones of 18% for the day period and 11% at night. Clearly, more variation exists between zones than forecast PoPs account for (based on rain gauge and areal coverage data only), especially during the day.

During the day, the average areal coverage runs fairly close to the average rainfall frequency, but at night average areal coverages are often more than double the average rainfall frequency. This is due not only to the fact that a single gauge is not representative of the whole zone, but that often early in the night period, thunderstorms are still on the radar in the dying stages. These can cover a large area on radar (giving higher areal coverages), but much of the large echo is light rain, which may not actually indicate measurable rainfall. Radar composites should always underestimate the average areal coverage, as showers come and go between observations, and large showers may decrease in size by observation time. This is somewhat compensated for by factors which alone would overestimate coverage, such as radar beam width making echoes appear larger than they are, and radar echoes that do not reach the ground as measurable rainfall.

The question can be asked: Along with the variation seen between the zones, is there a problem with assuming homogeneous point probabilities within the coastal zones? Average rainfall frequencies were found for a second rain gauge in the coastal zones to examine the differences within these zones. In FL08, Jacksonville is about 20 miles inland, so Marineland served as the second gauge, since it is on the coast. In FL10, Inglis (along the west coast) was used, since Brooksville is inland. In FL12, Daytona Beach is within 5 miles of the coast, so Deland (about 20 miles inland), was used. In FL17, no second gauge was available.

Utilization of the second gauges produced the following findings: In FL08, the coastal gauge was 13% lower than the inland gauge for both day and night periods. For FL10 and FL12, daytime averages were equal at both inland and coastal gauges, and at night, the coastal gauges were about 10% higher. It looks as though rainfall distribution was homogeneous during the day in these two zones.

**Table 3. Average areal coverage (%) occurring for June–August, 1988.**

| Zone    | Day<br>(12-00 UTC) | Night<br>(00-12 UTC) |
|---------|--------------------|----------------------|
| 8       | 30                 | 22                   |
| 9       | 37                 | 24                   |
| 10      | 42                 | 28                   |
| 11      | 45                 | 24                   |
| 12      | 38                 | 21                   |
| 14      | 43                 | 25                   |
| 17      | 37                 | 22                   |
| Average | 39                 | 24                   |

However, a closer examination proved these figures to be misleading. Even though the coastal and inland gauges had measurable rainfall with about the same frequency, the period *when* the gauges had the rainfall was different nearly half of the time. The higher coastal averages at night are likely the result of both thunderstorms moving out of the inland parts of the zone and reaching the coast before dying out, and coastal late night/early morning showers dissipating rapidly after moving onshore. These findings are sketchy, but indicate that rain gauge verification has problems with the convective "hit-and-miss" rainfall pattern over Florida during the summer. Looking at the areal coverages of the inland half of the zone versus the coastal half would be useful in a later study. Phrases like "mainly inland" or "along the coast" help to clarify the forecast when it appears rain will be restricted to only part of the zone.

#### b. Using Areal Coverage to Verify and Improve PoP Forecasts

According to the chapter in the NWS Operations Manual (1984) governing zone and local forecasts, "When the chance of convective precipitation somewhere in the forecast area is very high (i.e. areal probability approaches 100%) . . . the PoP (point probability) also expresses the expected coverage within the forecast area." Table 4 shows the average frequency of an echo somewhere in the zone. With a day average of 83%, and 70% at night, it stands to reason that usually the forecaster can be sure it will rain somewhere in the zone during the period, especially during the day. The equation:

$$\bar{P}_p = P_a C_c \quad (1)$$

(Hughes 1980), where  $\bar{P}_p$  = average point probability over the forecast area,  $P_a$  = areal probability (the chance for precipitation anywhere in the forecast area), and  $C_c$  = the conditional areal coverage (the areal coverage expected if there is any precipitation in the forecast area), approaches:

$$\bar{P}_p = C_c \quad (2)$$

(Hughes, 1980) as  $P_a$  nears unity.

**Table 4. Average frequency of an echo somewhere in the zone (% of time it occurred) for June–August, 1988.**

| Zone    | Day<br>(12-00 UTC) | Night<br>(00-12 UTC) |
|---------|--------------------|----------------------|
| 8       | 79                 | 69                   |
| 9       | 88                 | 76                   |
| 10      | 79                 | 65                   |
| 11      | 87                 | 84                   |
| 12      | 81                 | 59                   |
| 14      | 82                 | 64                   |
| 17      | 82                 | 70                   |
| Average | 83                 | 70                   |

A look at frequencies with which various PoPs occurred in zone forecasts over the study period revealed that forecasters often had "favorite" PoPs (see Fig. 2). The day period had PoP forecasts of 50% most often, with about 75% of all PoP forecasts falling in the interval  $50\% \pm 10\%$ . However, less than 10% of the areal coverages were in this interval. Areal coverages of  $<20\%$  made up 38% of all areal coverages, yet PoP forecasts of  $<20\%$  were made only about 8% of the time. Areal coverages of 70% or greater totaled nearly 30% of all areal coverages observed, yet PoP forecasts of 70% or greater were used only 2% of the time! An important point should be made here in defense of the forecasters. From equation (1), *theoretically*, the areal coverage should be what is forecast most of the time. However, at the time of this study PoP forecasts were verified by a rain gauge. A PoP based on whether or not measurable rainfall was expected at the gauge, in many cases, would vary from the expected areal coverage in a zone.

At night, a 20% PoP was used for 40% of all PoP forecasts, yet areal coverages of 20% occurred only 9% of the time. The frequency of occurrence of PoPs and areal coverages from 40% up to 100% was nearly the same. Overall, the frequencies at night were closer than in the day. The main difference lies in the overuse of the 20% PoP at night, since

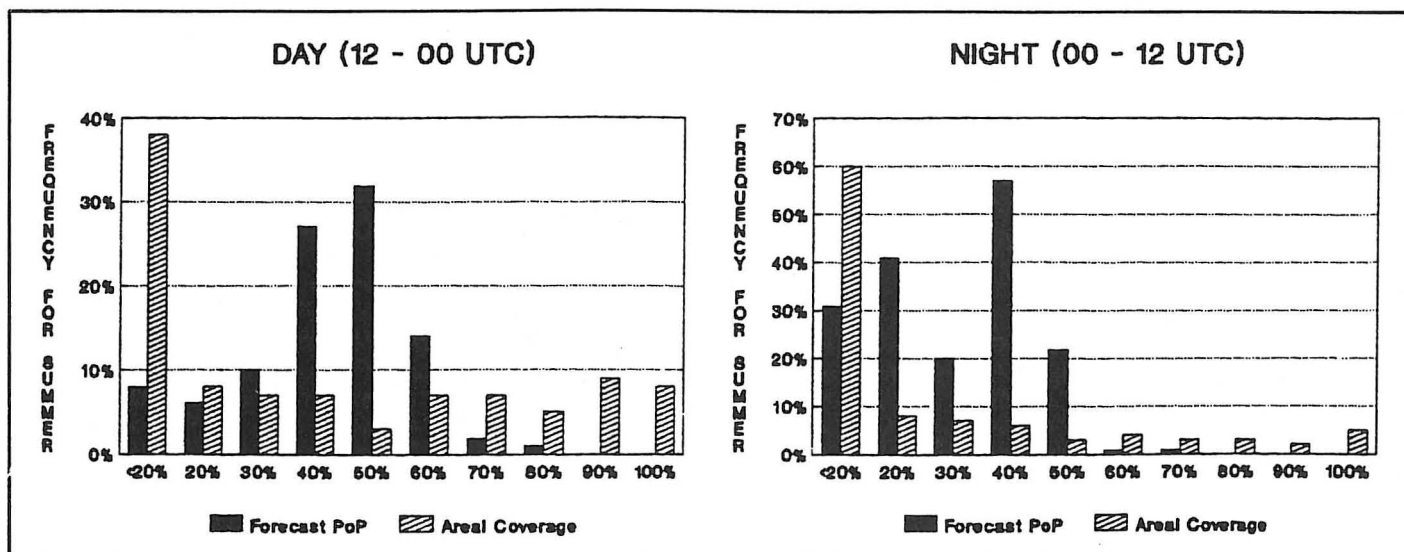


Fig. 2. Bars represent various zone forecast PoPs and observed areal coverages. The y-axis gives the percent of time each forecast PoP or areal coverage occurred over the summer study period.

this is the threshold for mentioning rain in the forecast—either to be “safe” if it does rain, or going with a 20% PoP if any echoes are in or near the zone. Smith and Smith (1978) and Naber and Smith (1983) found that areal coverages of 20% up to 100% are almost equally likely to occur. This is true for both periods, especially the day. This study, as Fig. 2 illustrates, verified these results.

The forecast PoPs and average areal coverages have been looked at in terms of variation between zones and frequency of use, but with no regard to what the average PoP was for a given areal coverage, and what the average areal coverage was for a given PoP (see Fig. 3). For the day period, the average areal coverage ran close to the PoP forecast. For a given areal coverage, the forecast PoP was too high up to about 40%, then as areal coverages got larger than 40%, the PoPs rarely did. At night, the average areal coverage was close to the PoP forecast up to 40%, then the average PoPs

were about twice as high as the average areal coverages observed for that PoP. For given areal coverages, the average PoP ran close up to 20%, and then forecast PoPs remained low, despite coverages getting larger.

Just because areal coverages average out close to a given PoP value, does it necessarily mean that the PoP forecast did well in predicting the areal coverage? Figure 4 shows two PoPs whose average areal coverage value was close to the PoP, 40% during the day, and 20% at night. A 40% areal coverage was observed with a 40% PoP only 9% of the time, and a 20% areal coverage was observed with a 20% PoP only 10% of the time. Similar results were found for nearly any average areal coverage or average forecast PoP investigated. Since the averages primarily result from departures that average out near a given PoP or areal coverage, rather than most values clustering near it, Fig. 4 better shows how well areal coverage was predicted ahead of time.

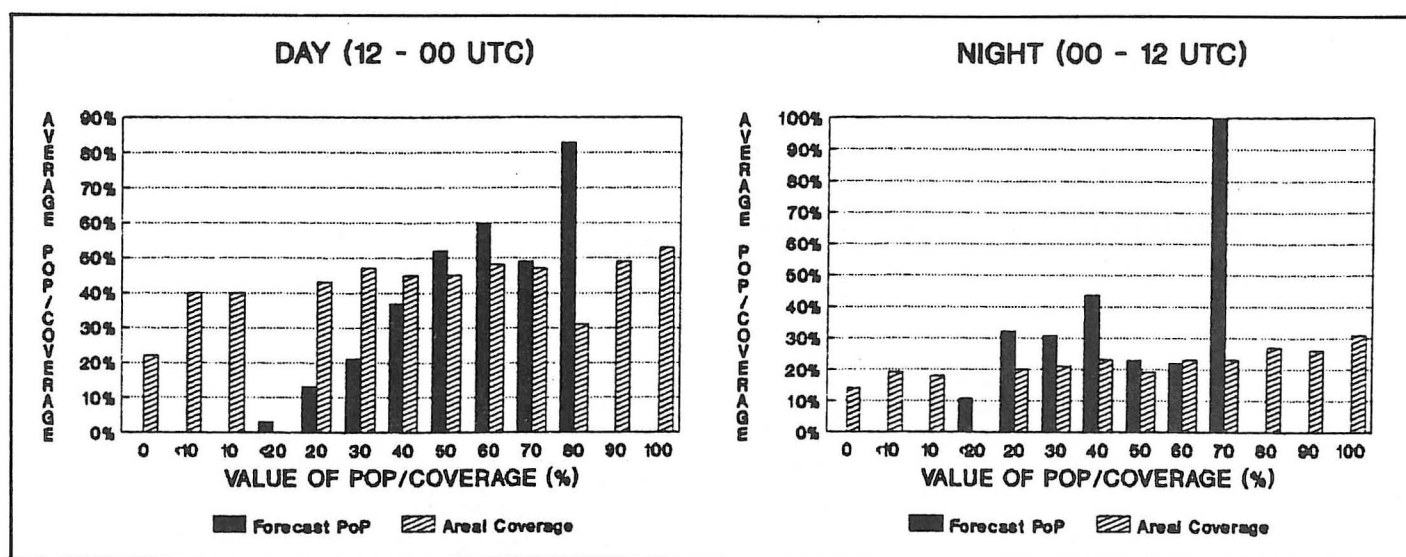


Fig. 3. Bars represent various zone forecast PoPs and observed areal coverages. For a given PoP, the y-axis gives the average areal coverage occurring with this PoP over the summer study period. For a given areal coverage, the y-axis gives the average PoP forecast used with this coverage over the summer study period.

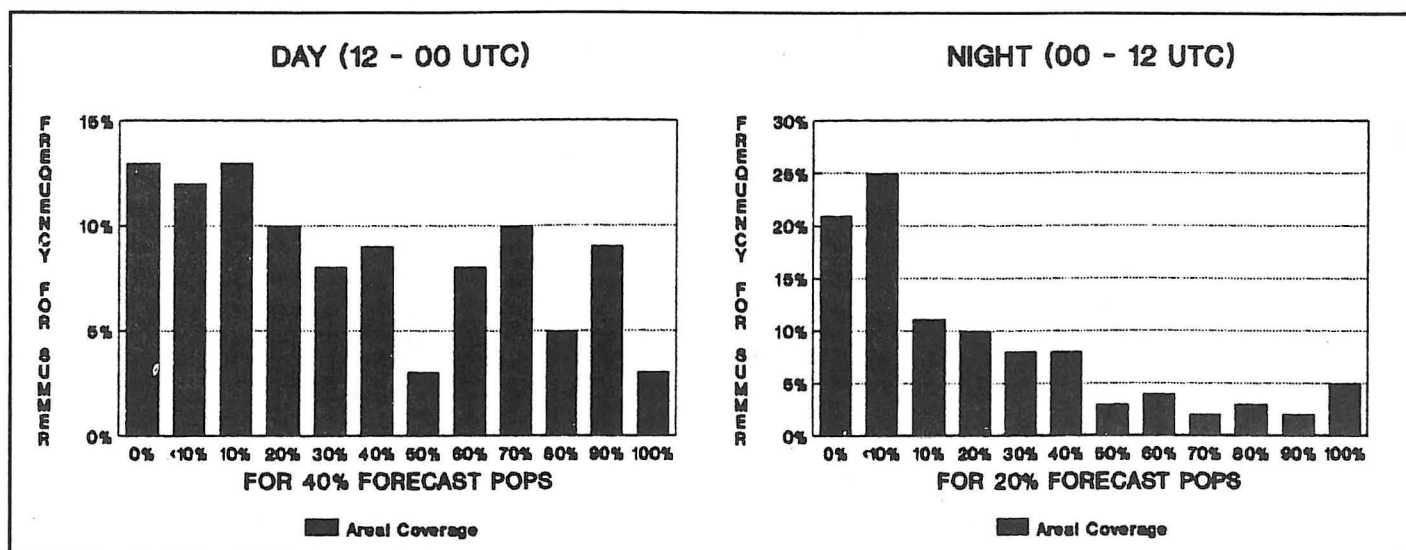


Fig. 4. For 40% forecast PoPs (day) and 20% forecast PoPs (night), bars represent various areal coverages occurring. The y-axis gives the percent of time each areal coverage occurred with these PoPs over the summer study period.



### c. Using Previous Day's Coverage as a Forecast Tool

During the summer in north and central Florida, as ample moisture and instability are typically present, the low-level wind pattern is usually the biggest single factor (barring the influence of any major systems) determining where rainfall will occur. Most rainfall is associated with convergence in the vicinity of the sea breeze front, and often the air mass shows little change from day to day. It can then be hypothesized that when the air mass today shows little change from yesterday, then the areal coverage today should approximate the areal coverage yesterday.

To examine this hypothesis, in each zone and for each day and night period, the percent departure of areal coverage from the PoP forecast (abbreviated by "DPT C-P") during each day and night period was calculated. The percent departure of the areal coverage from the areal coverage for the same period on the previous day (abbreviated by "DPT C-C") was also found (see Fig. 5). The day period DPT C-P revealed the areal coverage was about equally likely to run anywhere from 50% below the PoP forecast to 50% above it, with nearly all departures in this interval. The day period DPT C-C had over half of the areal coverages in the interval  $\pm 20\%$  the previous day's coverage, then gradually decreased out to  $\pm 100\%$ . At night, DPT C-C again were close more often than DPT C-P, although not as pronounced as in the day, with over half of all nighttime DPT C-P from 0 to  $-20\%$ .

What does this indicate? The lack of very large negative values of DPT C-P for both the day and night periods are due to the fact that PoP forecasts  $>60\%$  in the day and  $>40\%$  at night were rare. Some of the large values of DPT C-C indicate either a change in the air mass, or a problem in timing—with rainfall carrying over into a period that it did not on the previous day. Using yesterday's areal coverage as today's PoP forecast will often work out well, but when the areal coverage changes from the previous day—it often changes by a larger margin than the PoP forecast does. These changes could be accounted for if yesterday's areal coverage was known at forecast time. Yesterday's areal coverage could be

a starting point, then factors such as changes in the low-level wind pattern, available moisture, and instability would indicate the need to adjust the areal coverage higher or lower. If the air mass shows little change, the areal coverages should also show little change.

## 4. CONCLUSION

The results from this first look at using radar areal coverages for PoP forecasting and verification in north and central Florida were promising. Since the PoP forecasts essentially describe areal coverage, forecasters thinking in terms of areal coverage, rather than verifying by a single gauge, would likely use fewer "favorite" PoPs, and also show an improvement in detecting the variations between the zones. This is especially true for coastal zones, that appear to have more *existing* variations between inland and coastal sections of the zone than PoP forecasts account for; these zones often need qualifiers with the mention of rain. Knowledge of areal coverage may also prove useful in forecasting, as the areal coverage for the same period on the previous day is often indicative of today's areal coverage.

This study indicates that using areal coverage instead of a single rain gauge might result in more realistic verification methods. The current method of estimating areal coverage is laborious, and interpretation of data highly subjective. The upcoming use of NEXRAD will bring an advanced precipitation processing system (rainfall mapping), enabling results from this paper to be better used to investigate verification schemes and forecast improvement based on areal coverage. This will be especially important in the near future, as forecasting will emphasize smaller areas and greater detail. The nation's second NEXRAD will be commissioned in Melbourne, Florida in 1991 and will cover most of the same area as in this study. We plan to continue research on PoP forecasting and verification by integrating NEXRAD data into the forecast and verification program and by comparing NEXRAD rainfall mapping to rain gauge networks.

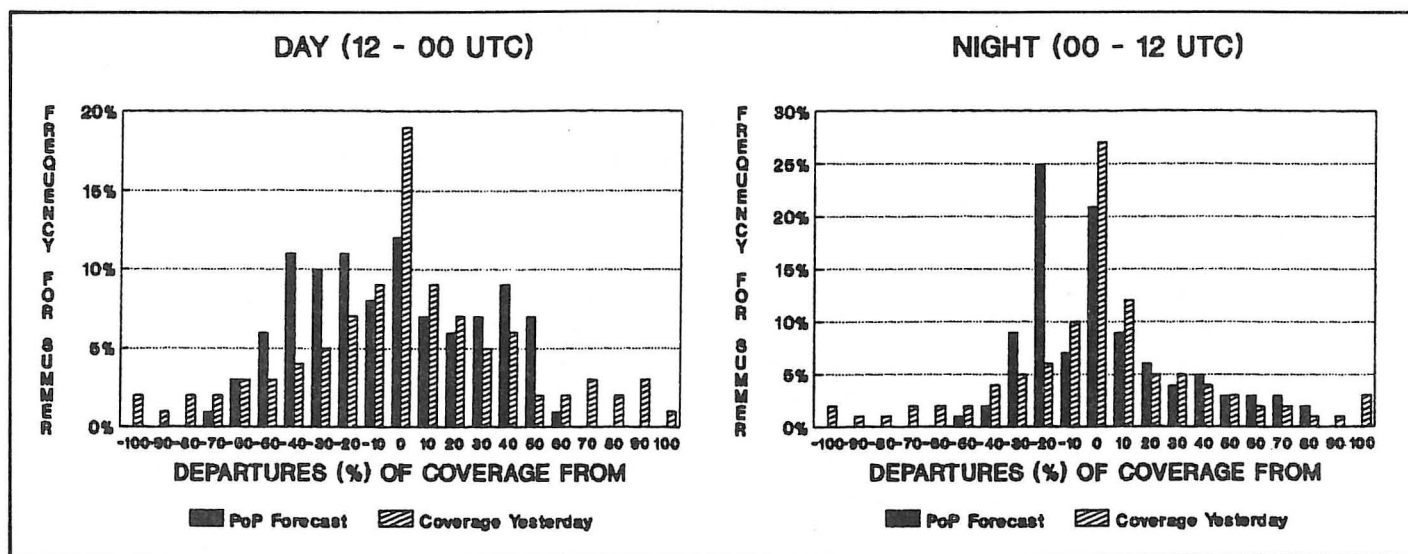


Fig. 5. Bars represent the departures in percent of the areal coverage from the forecast PoP (DPT C-P), and the areal coverage from the areal coverage for the same period on the previous day (DPT C-C). The y-axis shows the percent of time a particular departure occurred over the summer study period.

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