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A BRIEF CLIMATOLOGY OF THE RELATIONSHIP BETWEEN AFTERNOON DEW POINTS AND MONSOONAL RAINFALL AT PHOENIX SKY HARBOR INTERNATIONAL AIRPORT

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Introduction

One of the greatest challenges facing Phoenix NWSFO forecasters centers on forecasting thunderstorm likelihood as well as areal extent of measurable precipitation over Arizona's central deserts during the summer convective season. Climatologically, daily measurable precipitation occurs 10-14% of the time, and forecasters often use "slight chance" or "isolated" (10-20% chance of measurable precipitation) to describe precipitation probabilities, especially during nighttime periods.

Several factors make it difficult for forecasters to improve upon climatology: 1) Q-G and mesoscale numerical models exhibit little skill at forecasting precipitation over Arizona during the summer monsoon (Dunn and Horel 1993); 2) Arizona's proximity to the Pacific Ocean and Mexico, two data sparse regions; and 3) a surface observational network of limited resolution over south-central Arizona, especially at night (McCollum et al. 1995). Even careful, detailed data analyses, which are routinely performed by Phoenix forecasters, often fail to provide enough insight to markedly improve on climatology.

Surface dew points provide important clues concerning boundary layer moisture supply as well as atmospheric instability. Forecasters correctly assume that thunderstorm potential as well as the chance for measurable precipitation increase in conjunction with increased low level moisture and surface dew point. Special summertime soundings taken at Luke Air Force Base in west metro Phoenix (provided by the Salt River Project utility company and the National Severe Storms Laboratory) since 1994 provide important insight regarding expected diurnal changes in dew point, and help forecasters determine when observed dew point changes can be attributed to changing PBL depth or moisture advection.

In this paper, the authors present dew point-precipitation statistics at Sky Harbor International Airport (henceforth referred to as Sky Harbor, site of the Phoenix ASOS). This Technical Attachment summarizes the findings and discusses how these statistics might be used by NWSFO Phoenix forecasters to improve point probability verification scores at Sky Harbor as well as expected areal coverage of measurable precipitation over the forecast zone which includes Sky Harbor and metropolitan Phoenix.

Methodology

Data were analyzed for all "monsoon days" for the period 1982-1996. The number of monsoon days varies from year to year, based on the criteria that determine when the summer monsoon begins and ends. For statistical purposes, the monsoon is said to begin in Phoenix when the average dew point at Sky Harbor is 55°F or higher for three consecutive days (Schmidli and Jamison 1996). The monsoon is defined to begin on the first of those three days.

A more subjective approach is used to define when the monsoon "ends." One of the factors considered is the flow pattern at 500 mb. If the 500 mb flow has shifted back to a more westerly direction, as opposed to the southeast to east flow typically associated with the Mexican monsoon (Douglas et al. 1993), this argues for "ending" the monsoon. Downward trends in dew point and precipitation values are also taken into consideration. When these factors combine to cause monsoonal thunderstorms to end over Arizona, the season is over (Schmidli, personal communication). All days that fall between the beginning and end of the monsoon are considered part of that season.

Dew points at Sky Harbor at 2100 UTC (1400 MST) for each monsoon day were analyzed. Total rainfall amounts at Sky Harbor for the 12 hour period 0000 UTC that afternoon through 1200 UTC the next day, and, the 24 hour period 2100 UTC that afternoon through 2100 UTC the next day were tallied. The rainfall was divided into two categories: 1) measurable events, and 2) precipitation events, which included both measurable and trace amounts.

The purpose of this data accumulation was to determine the percentage of time rainfall occurred at Sky Harbor given a certain dew point. Given these conditional percentages, a forecaster would most certainly have a better idea of what probabilities of precipitation to forecast for Phoenix Sky Harbor, when combined with a thorough knowledge of the current synoptic and mesoscale weather situation.

Discussion

Precipitation, even during the Mexican monsoon, is not a common event in the Phoenix metropolitan area, especially at Sky Harbor. The average rainfall for Sky Harbor is 2.65 inches during the three month period July-September. During 1982-1996, precipitation events (trace and measurable) occurred only 23.6% of the time during the 0000 UTC to 1200 UTC time frame, while measurable events occurred only 13.5% of the time (Table 1, Fig. 1). This fact is even more remarkable considering that 70% of Phoenix monsoon storms occur at night, during the 0000 UTC to 1200 UTC time frame, and that central Phoenix experiences a precipitation maximum around midnight (Balling and Brazel 1987).

Values rise only slightly when the 24 hour (2100 UTC - 2100 UTC) values are calculated; to 26.6% and 15.4% respectively.

Although rainfall is not common in the Phoenix metropolitan area, 2100 UTC dew points did remain at rather high levels (Table 2, Fig. 2), exceeding 60°F more that half (52.2%) of the time. Additionally, dew points exceeded 55°F on 73.5% of the monsoon days. However, they exceeded 65°F only about a fifth (20.4%) of the time. In fact, readings of 55°F or lower, characteristic of "breaks" in the monsoon (Schmidli and Jamison 1996; Carleton 1986), occurred more often (26.5% of the time).

Not surprisingly, the frequency of rainfall occurrence increased as dew points rose (Table 3, Fig. 3). Precipitation events were rare with 2100 UTC dew points below 55°F and measurable events were almost unheard of, occurring only 1.4% percent of the time. When dew points were below 60°F, precipitation events occurred 14.6% and 15.7% of the time with 12 and 24 hour events, respectively. However, measurable events were still very infrequent, only occurring 6.3% and 6.7% of the time, respectively (Table 3, Fig. 4).

A noticeable increase in percentages occurred when dew points were 60°F or higher (Table 3, Fig. 5). For these values, precipitation events occurred over 30% of the time for both 12 and 24 hour events, and measurable events occurred 20.1% and 23.3% of the time, respectively. The frequency of precipitation and measurable events increases by a few percentage points (3%-7%) for all categories for dew points 65°F or higher (Table 3, Fig. 6). However, the most obvious increase in the frequency of precipitation occurred when dew points were 60°F or higher, when compared to dew points below 60°F.

These data suggest that a 2100 UTC dew point of 60°F or higher should be considered operationally important for the forecasting of rain at Sky Harbor, especially when a synoptic pattern conducive to thunderstorm propagation into Arizona's central deserts is present. However, this may or may not be an important benchmark with respect to determining areal coverage of measurable precipitation for the entire Phoenix metropolitan area.

Certain patterns are considered "favorable" for storm propagation from Arizona's higher mountains to the lower deserts; these climatological values may be very useful in these situations. However, even the highest dew points would probably not lead to rainfall over the Phoenix metropolitan area under other flow regimes (Wallace 1997).

Conclusions

The use of a 60°F 2100 UTC dew point as a "benchmark" for forecasting rain at Sky Harbor is established. Given certain afternoon dew points, forecasters should consider adjusting their probabilities of precipitation accordingly for the entire Phoenix forecast area, especially if the synoptic and mesoscale patterns in place over Arizona favor rainfall at Sky Harbor.

The authors hope that Phoenix NWSFO forecasters use these climatological values to influence the probabilities of precipitation they forecast. This is the first year these numbers have been available to forecasters and, thus far, they have been used with mixed results. In late July, measurable rainfall occurred with a 2100 UTC dew point below 55°F for only the fifth time since 1982. This rain occurred with a forecast probability of precipitation of zero. Additionally, dew points have exceeded 65°F on several occasions with little measurable rain to show for it. On other occasions, the climatological values have been excellent indicators of what happened.

Obviously, these values should not be used for forecast purposes in lieu of detailed analyses of soundings, upper data plots, GOES-derived imagery, or numerical model guidance. However, they should become an important variable in the forecast decision making process.

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References

Balling, R.C., and S.W. Brazel, 1987: Diurnal Variations in Arizona Monsoon Precipitation Frequencies. *Mon. Wea. Rev.,* **115,** 342-346.

Carleton, A.M., 1986: Synoptic-dynamic character of 'bursts' and 'breaks' in the south-west U.S. summer precipitation singularity. *J. Climatol,* **6,** 605-622.

Douglas, M.W., R.A. Maddox, K. Howard, and S. Reyes, 1993: The Mexican monsoon. *J. Climate,* **6,** 1665-1677.

Dunn, L.B. and J.D. Horel, 1994: Prediction of central Arizona convection. Part I: Evaluation of the NGM and ETA model precipitation forecasts. *Wea. Forecasting,* **9,** 495-507.

McCollum, D.M., R.A. Maddox, and K. Howard, 1995: Case Study of a Severe Mesoscale Convective System in Central Arizona. *Wea. Forecasting,* **10,** 643-665.

Schmidli, R.J., and A. Jamison, 1996: Climate of Phoenix, Arizona. NOAA Tech. Memo. NWS WR-177, 106-113.

Wallace, C. E., 1997: Convective storm environments in central Arizona during the summer monsoon. M.S. Thesis, School of Meteorology, Univ. of Oklahoma, Norman, OK, 122 pp.

Table 1 Percentage of Monsoon days with measurable and precipitation events for the period 1982-1996. Numbers in parentheses are total days.

Total Monsoon days:	1087
Percent of Monsoon days with a precipitation event from 0000 UTC - 1200 UTC:	23.6% (257)
Percent of Monsoon days with a precipitation event from 2100 UTC - 2100 UTC:	26.6% (289)
Percent of Monsoon days with a measurable event from 0000 UTC - 1200 UTC:	13.5% (147)
Percent of Monsoon days with a measurable event from 0000 UTC - 1200 UTC:	15.4% (167)

Table 2 Frequency of 2100 UTC dew points for the period 1982-1996. Numbers in parentheses are total days.

Percent of Monsoon days with a dew point ≥ 55°F:	73.5% (799)
Percent of Monsoon days with a dew point ≥ 60°F:	52.2% (567)
Percent of Monsoon days with a dew point ≥ 65°F:	20.4% (222)
Percent of Monsoon days with a dew point < 60°F:	47.8% (520)
Percent of Monsoon days with a dew point < 55°F:	26.5% (288)

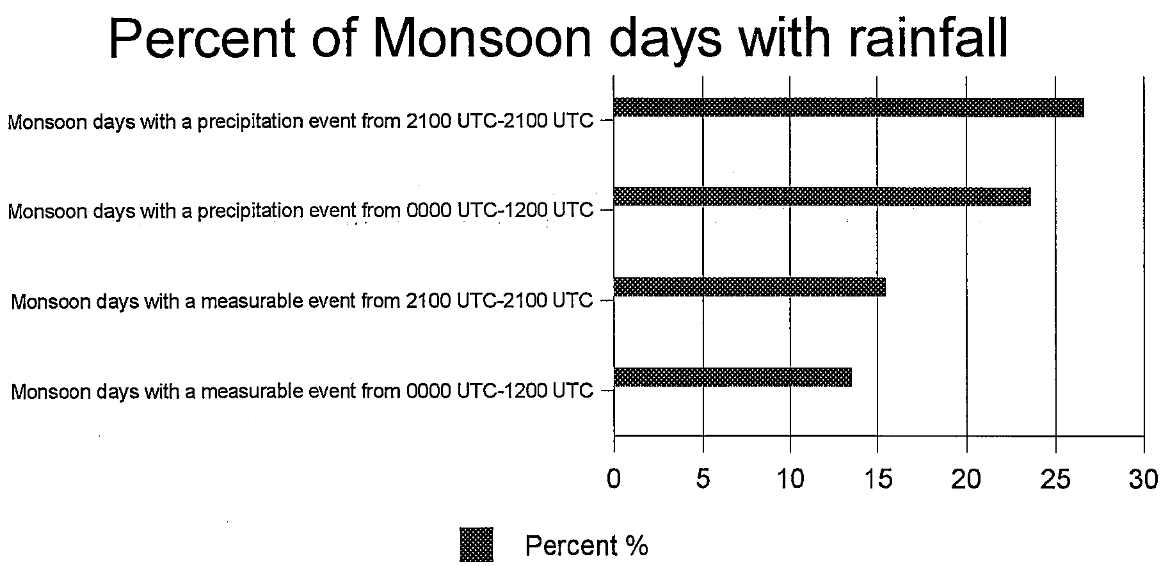

Fig 1 Monsoon days with rainfall as a percentage of total monsoon days for the period 1982-1996.

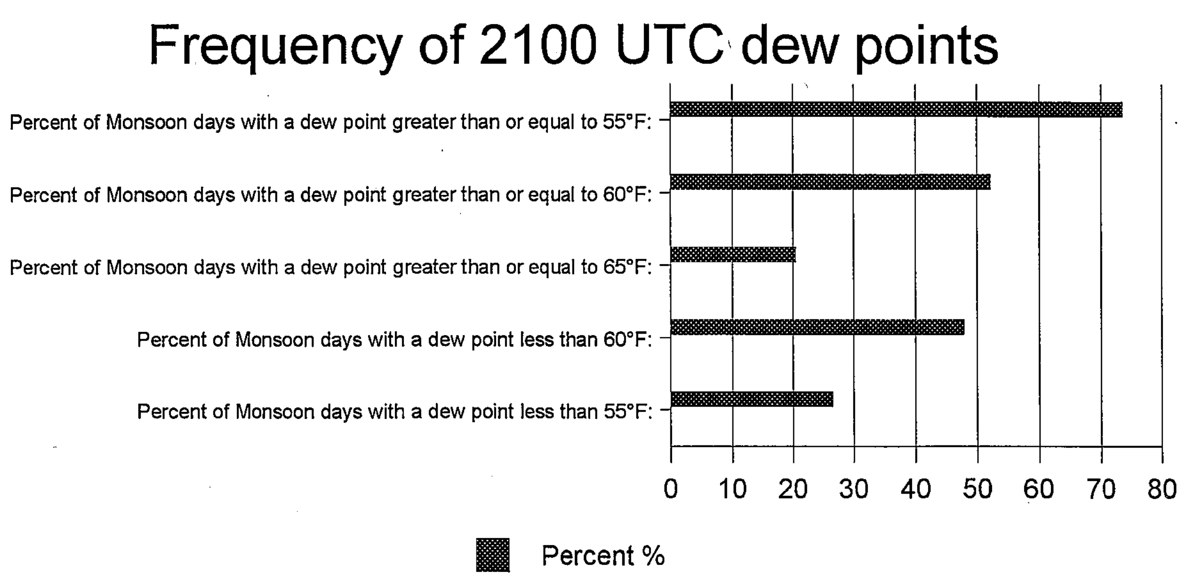

Fig 2 Frequency of 2100 UTC dew points for the period 1982-1996.

Table 3 Frequency of rainfall events (measurable and precipitation) given specific dew point ranges for the period 1982-1996. Numbers in parentheses are total days.

Percent of time that a precipitation event occurred from 0000 UTC - 1200 UTC when 2100 UTC dew point was < 55°F:	8.3% (24 of 288)
Percent of time that a measurable event occurred from 0000 UTC - 1200 UTC when 2100 UTC dew point was < 55°F:	1.4% (4 of 288)
Percent of time that a precipitation event occurred from 2100 UTC - 2100 UTC when 2100 UTC dew point was < 55°F:	9.4% (27 of 288)
Percent of time that a measurable event occurred from 2100 UTC - 2100 UTC when 2100 UTC dew point was < 55°F:	1.4% (4 of 288)
Percent of time that a precipitation event occurred from 0000 UTC - 1200 UTC when 2100 UTC dew point was < 60°F:	14.6% (76 of 520)
Percent of time that a measurable event occurred from 0000 UTC - 1200 UTC when 2100 UTC dew point was < 60°F:	6.3% (33 of 520)
Percent of time that a precipitation event occurred from 2100 UTC - 2100 UTC when 2100 UTC dew point was < 60°F:	15.7% (82 of 520)
Percent of time that a measurable event occurred from 2100 UTC - 2100 UTC when 2100 UTC dew point was < 60°F:	6.7% (35 of 520)
Percent of time that a precipitation event occurred from 0000 UTC - 1200 UTC when 2100 UTC dew point was ≥ 60°F:	31.9% (181 of 567)
Percent of time that a measurable event occurred from 0000 UTC - 1200 UTC when 2100 UTC dew point was ≥ 60°F:	20.1% (114 of 567)
Percent of time that a precipitation event occurred from 2100 UTC - 2100 UTC when 2100 UTC dew point was ≥ 60°F:	36.5% (207 of 567)
Percent of time that a measurable event occurred from 2100 UTC - 2100 UTC when 2100 UTC dew point was ≥ 60°F:	23.3% (132 of 567)
Percent of time that a precipitation event occurred from 0000 UTC - 1200 UTC when 2100 UTC dew point was ≥ 65°F:	37.8% (84 of 222)
Percent of time that a measurable event occurred from 0000 UTC - 1200 UTC when 2100 UTC dew point was ≥ 65°F:	23.4% (52 of 222)
Percent of time that a precipitation event occurred from 2100 UTC - 2100 UTC when 2100 UTC dew point was ≥ 65°F:	43.2% (96 of 222)
Percent of time that a measurable event occurred from 2100 UTC - 2100 UTC when 2100 UTC dew point was ≥ 65°F:	27.9% (62 of 222)

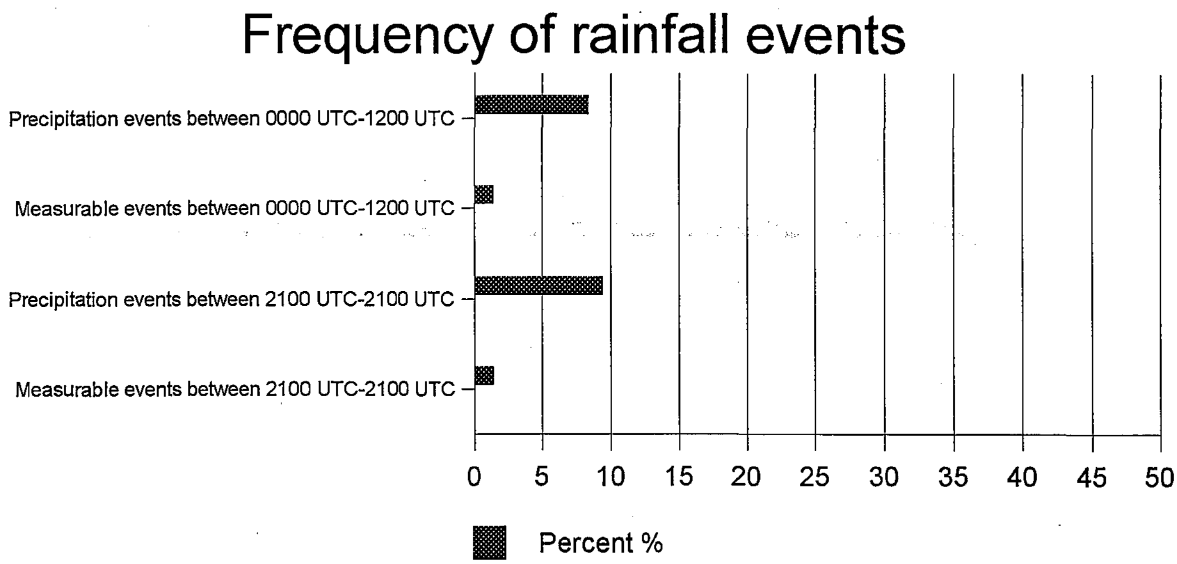

Fig 3 Frequency of rainfall events (measurable and precipitation) given dew points < 55°F for the period 1982-1996

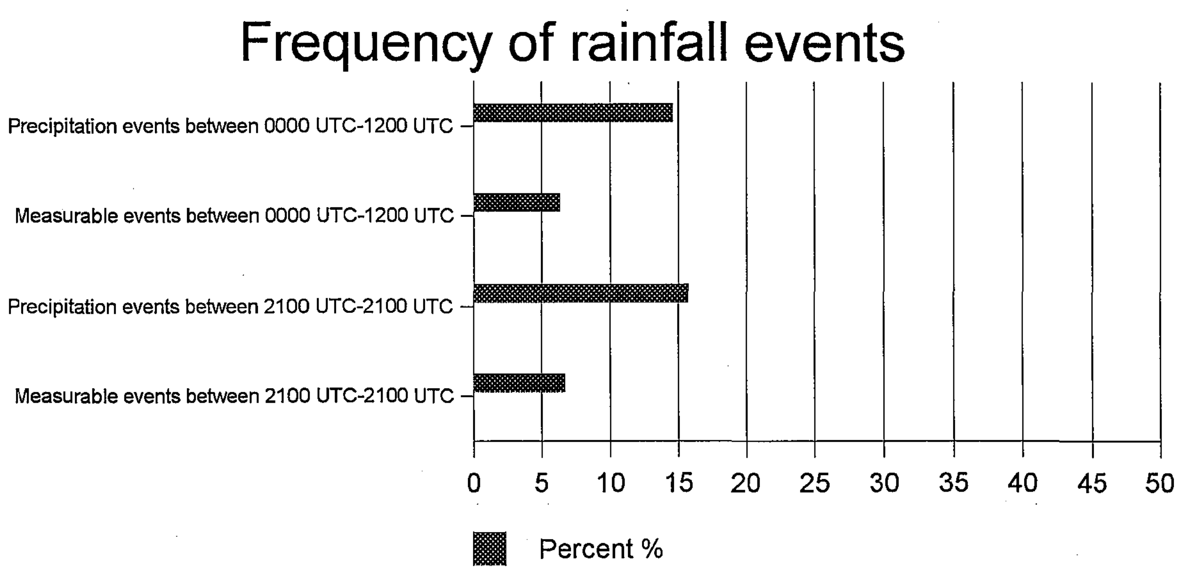

Fig 4 Frequency of rainfall events (measurable and precipitation) given dew points < 60°F for the period 1982-1996

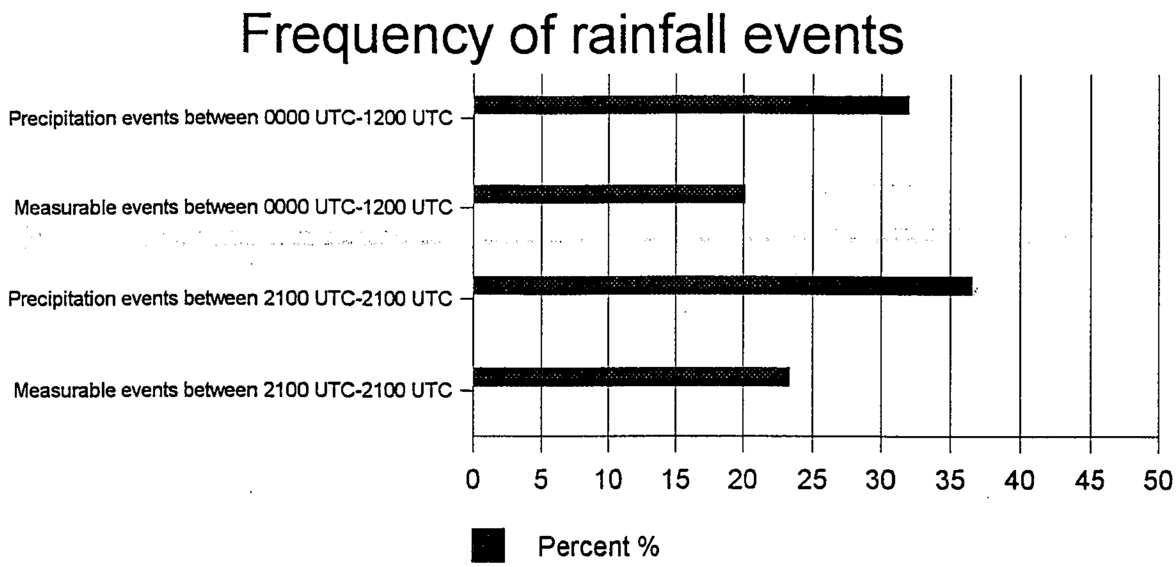

Fig 5 Frequency of rainfall events (measurable and precipitation) given dew points ≥ 60°F for the period 1982-1996

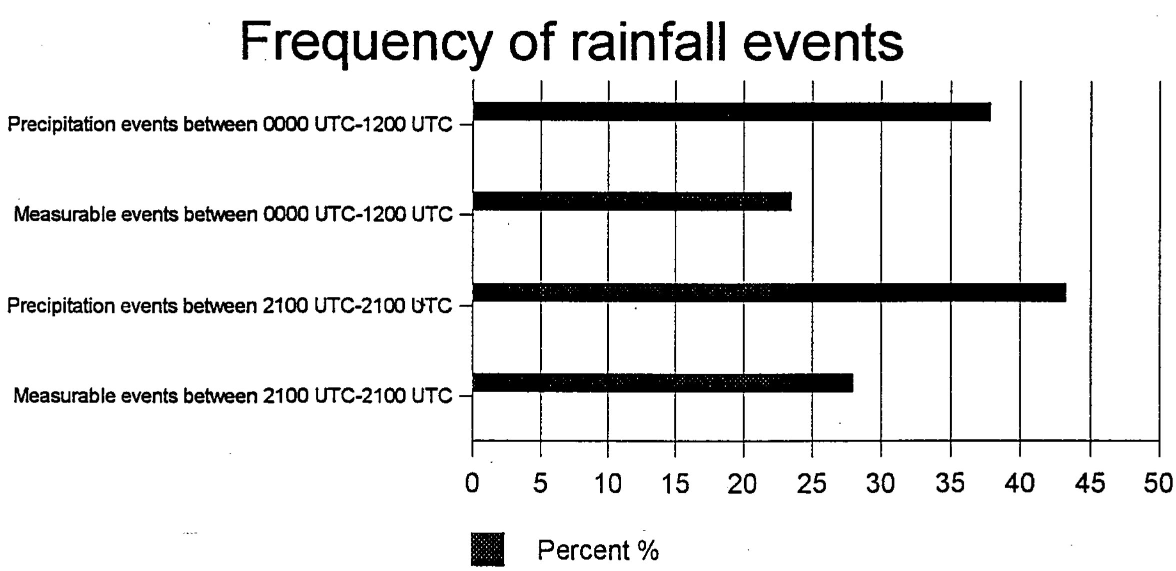

Fig 6 Frequency of rainfall events (measurable and precipitation) given dew points ≥ 65°F for the period 1982-1996