NOAA Technical Memorandum NWS SR-132

THREE INITIAL CLIMATOLOGICAL STUDIES FOR WFO MELBOURNE, FLORIDA: A FIRST STEP IN THE PREPARATION FOR FUTURE OPERATIONS

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October 1990

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ABSTRACT

A monthly climatology of temperature and precipitation for central Florida and a daily temperature climatology for Melbourne, Florida, were produced to aid in the preparation of routine forecasts at the new National Weather Service (NWS) Office in Melbourne. A detailed tornado climatology for the land area within 125 nm of Melbourne was also produced to assess risk and identify suitable forecast problems relating to severe weather for investigation. This information is part of a large body of meteorological knowledge forecasters will need for their new forecast and warning areas as the NWS undergoes a far reaching Modernization and Associated Restructuring (MAR) in the 1990s. The procedures and results presented are useful for forecasters in central Florida and instructive for other Weather Service Offices (WSOs) planning for the transition to a Weather Forecast Office (WFO) in the modernized NWS.

1. INTRODUCTION

As the Modernization and Associated Restructuring (MAR) of the National Weather Service (NWS) progresses, fundamental changes in the way operations are carried out will take place (NOAA, 1990). In the case of future WFO Melbourne, Florida, a new Weather Service Office (WSO) was formed and staffed with professional forecasters who will eventually be responsible for issuing all forecasts and warnings in an area previously covered by several (WSOs). These offices have traditionally been primarily concerned with labor-intensive surface and/or radar data collection and dissemination, limited adaptive forecasts, and short-fused local warnings, based on a few empirical rules. The MAR of the NWS stresses the importance of understanding mesoscale processes and the need for more detailed forecasts and warnings by training a professional staff and exploiting the capabilities of modern systems. Its cornerstone is the deployment of high technology tools throughout the field for the first time, but a detailed knowledge of local and regional climatology and weather regimes in the context of larger scale influences will be essential to success. Forecasters must be prepared to use these tools and put science into the products they produce.

The Melbourne office will evolve from a WSO to a NEXRAD WSO (NWSO), and ultimately to a WFO. Fig. 1 shows future WFO Melbourne's County warning area (CWA) consisting of ten counties in east central Florida, and Fig. 2 shows the future forecast zones (41-45). Except for the formation of an entirely new office, Melbourne's transition will be

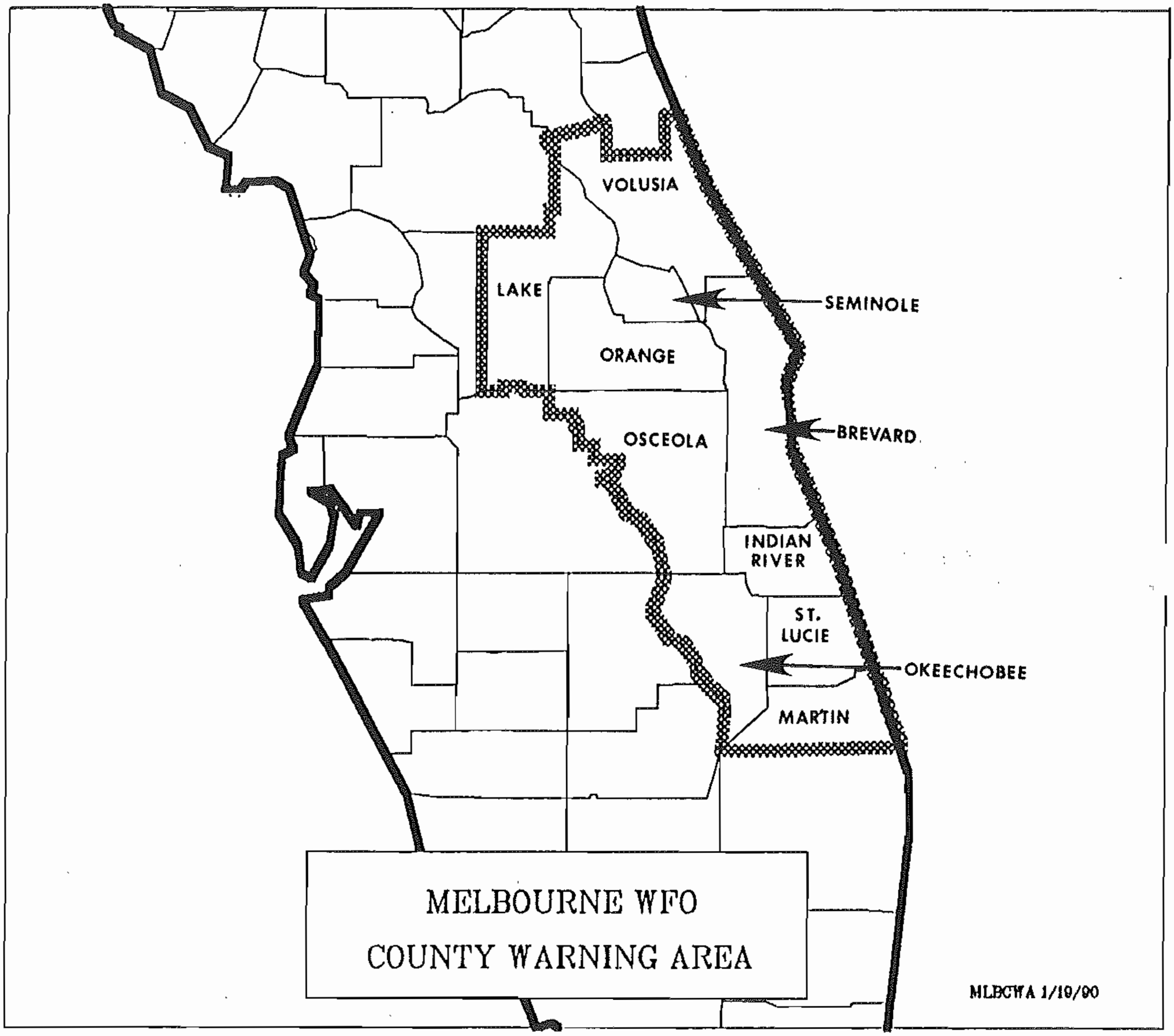


Fig. 1. County Warning Area (CWA) of WFO Melbourne, Florida (from Melbourne, Florida [MLB] Site Implementation Plan [SIP]).

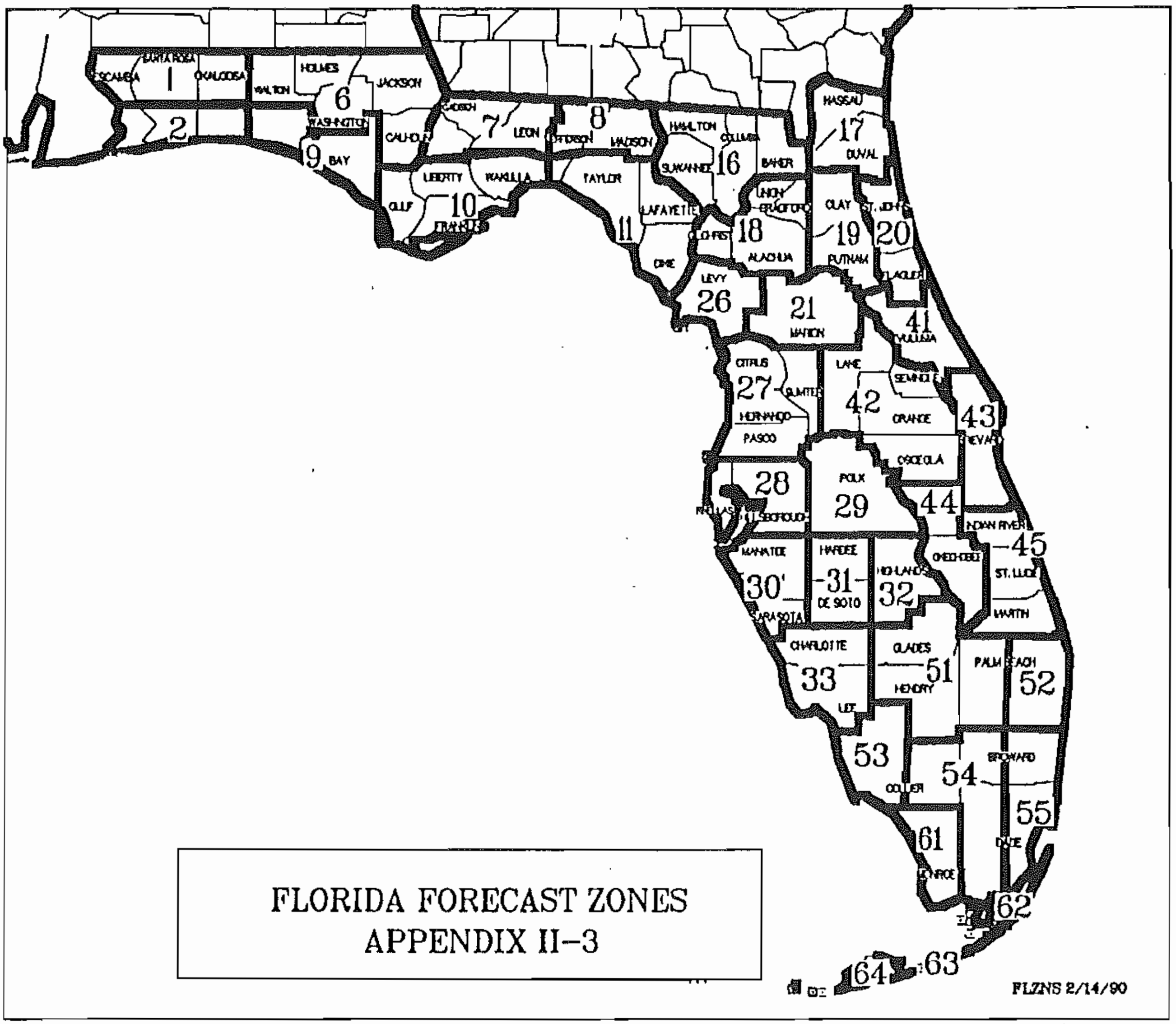


Fig. 2. Future forecast zones for Florida. Melbourne's future forecast area includes zones 41-45 (from MLB SIP)

representative of most other WSOs scheduled to become WFOs. Unlike the WSFO, where much of the professional development activities have been concentrated and where a collection of knowledge about forecast problems and procedures is often accumulated over the years, most WSOs have little historical meteorological information on the scale needed to address problems in their future WFO areas of responsibility. In the case of Melbourne, there was virtually no information; and the transition to full WFO status would be greatly aided by a fundamental understanding of weather types affecting our area. This process should not be left to chance, but planned in an orderly fashion well in advance.

Hebert (1989) outlined much of the operational planning (i.e., training) necessary to prepare future office staffs to fulfill future service goals. For Florida, Hebert compiled a comprehensive list of information on weather regimes and climatology that forecasters should have for their CWA. Melbourne and other WSOs could benefit by beginning an orderly and complete meteorological assessment of their future forecast areas. This fundamental understanding can then serve as a jumping-off point when the new technology arrives, a sort of foundation of meteorological knowledge that can be built upon. As MAR progresses, professional staffing and activities will increase; and many meteorologists will have to become familiar with new areas and learn new techniques and systems at the same time. The necessary training and fundamental knowledge required to face future responsibilities, and do them well, is considerable.

Ideally, an office would like to have complete, detailed information on all forecast problems; but this takes time. At Melbourne we have completed three priority problems first and will tackle other problems in the near future. Most important was to gain a fundamental knowledge of the temporal evolution of normal temperature and precipitation regimes for the forecast area. When starting a brand new forecast office with new forecasters, this is the most fundamental data needed for day-to-day operations. To accomplish this, an annual and monthly temperature and precipitation climatology for the central Florida peninsula surrounding Melbourne was completed. Additionally, since Melbourne is a new station making a new local forecast for an area where model output statistics (MOS) presently are not available, daily climatological maximum and minimum temperature guidance was produced for Melbourne from cooperative observation station data as an aid for the forecaster. Finally, to assess one of the most significant weather hazards first, a detailed tornado climatology for the land area within 125 nm of Melbourne was completed, and the need for further specific severe weather studies was determined.

These three climatological studies are presented in the following sections. The results are specifically useful for forecasters at Melbourne and surrounding stations, and may be instructive for other WSOs that will evolve to WFOs.

2. MONTHLY AND ANNUAL TEMPERATURE AND PRECIPITATION CLIMATOLOGY

A detailed regional climatology is desireable for learning about a new forecast area and preparing detailed, accurate forecasts. A first and fundamental step is the preparation of analyses of monthly and annual normals of precipitation and maximum and minimum temperatures to aid in the identification and understanding of forecast problems peculiar to the CWA.

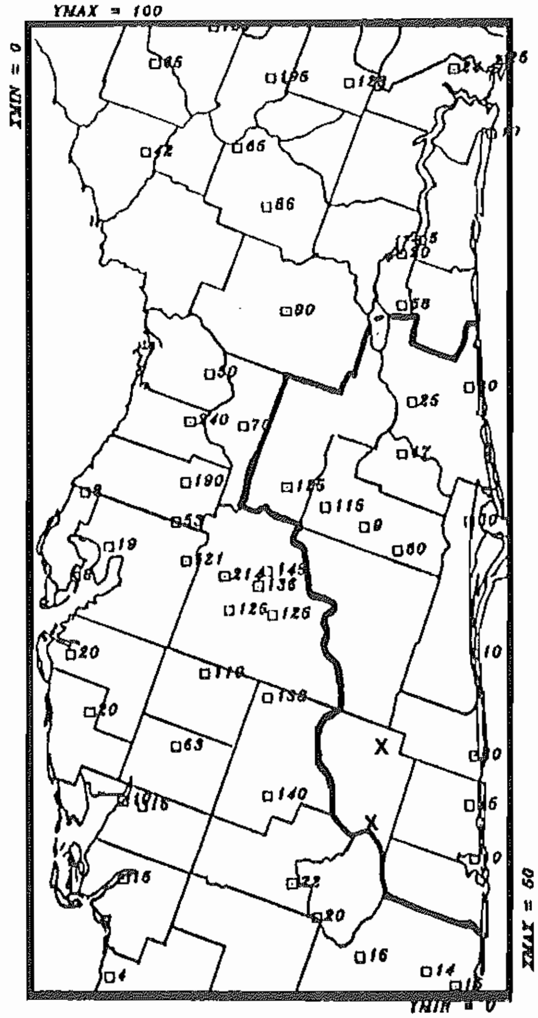
a. Data and Analysis

Normals of monthly and annual precipitation, and maximum and minimum temperatures for 1951-1980 were obtained from Climatological Data for Florida published by the National Climatic Data Center (NCDC). For central Florida 55 stations with precipitation data and 46 with temperature data are included. An analysis grid was laid out over central Florida to maximize coverage of observations and minimize the inclusion of water areas with no data points at the edges of the grid. The grid space and geographic background map with climatological station locations is shown as Fig. 3. (Squares, with elevation in feet above mean sea level to the right, indicate station location; the Melbourne CWA is enclosed by a heavy dark line).

Stations in coastal counties are dense enough to be representative in the Melbourne CWA, but a significant data-sparse region is found between Orlando and northern Lake Okeechobee. However, data are now available from two stations in Okeechobee County (Fort Drum 5NW and Okeechobee Hurricane Gate #6, marked by bold "X's" on Fig.3). It is likely these stations will be included in new normals. In any case, the lack of interior stations in some areas indicates a weakness in the current climatological network. This illustrates a need to continue to recruit observers as the MAR of the NWS progresses, and the need for verification of detailed zone forecasts becomes more important. Unfortunately, the deployment of the Automated Surface Observation System (ASOS) in the 1990s will do little to alleviate this problem, as the stations will be placed mainly along the coast and the heavily populated corridor from Daytona Beach to the Orlando area. Despite poor resolution in some areas, and at times questionable observation procedures (Robinson, 1990), the data included in this study are the best available at the present time. The new normals for 1961-90 will be input into the program when available, and can be easily reanalyzed.

Table 1 contains a list of all stations used in the analyses, along with their elevations and XY coordinates. Stations with precipitation data only are indicated by (P). The station coordinates along with their respective temperature and/or precipitation data were entered into computer data files for processing. Data analysis and map plotting were done with a commercial software package which used the "Krigging" method of optimal interpolation that takes advantage of regional variable theory (see Burrough, 1985, and Ripley, 1981). After the computer analyzed and contoured the data, the analyses were smoothed by hand where necessary due to poor data density. The analyses were finished by labeling the contours and noting the wettest (W) and driest (D) areas on the precipitation analysis, and the hottest (H) and coldest (C) areas on the temperature analyses.

The analyses of annual mean minimum temperature, maximum temperature, and precipitation are shown as Figs. 4a-c respectively. Analyses of monthly mean precipitation, maximum temperature, and minimum temperature are shown as Figs. 5a-l, 6a-l, and 7a-l respectively. Brief discussion of these analyses are included in the following paragraphs.



COOP STATION DATABASE & ELEVATION (FT)

Fig. 3. Area covered by the analyses with station locations and elevations shown. The Melbourne CWA is indicated by a heavy dark line. The bold "X's" in Okeechobee County indicate the location of stations that will likely be included in new normals.

CITY	ELEVATION (FT)	XY
ARCADIA	63	15,25
ARCHBOLD BIOL STA	140	24.5,20
AVON PARK	133	24.5,30
BARTOW	125	20.5,39
BELLE GLADE EXP STA	16	34,3.5
BRADENTON 5 ESE	20	4,34.5
BROOKSVILLE CHIN HILL	240	16.5,58.5
BUSHNELL 2 E	75	22,58
CLERMONT 6 SSW	125	26.5,51.5
CLEWISTON U S ENG	20	29.5,7.5
CRESCENT CITY	58	38.5,70.5 (P)
CROSS CITY 2 WNW	42	12,86.5
DAYTONA BEACH WSO	30	45.5,62
DELAND 1 SSE	25	39.5,60.5
FEDERAL POINT	5	40.5,77.5 (P)
FERNANDINA BEACH	25	49,96.5 (P)
FORT MYERS WSO	15	9.5,11.5
FORT PIERCE	25	45.5,19
GAINESVILLE 2 WSW	86	24.5,81
GLEN ST. MARY 1 W	128	33,94
HART LAKE	60	38,45 (P)
HIGH SPRINGS	65	21.5,87
HILLSBOROUGH RVR ST PK	53	15,48 (P)
INVERNESS	50	18.5,63.5
ISLEWORTH	115	30.5,49.5(P)
JACKSONVILLE WSO	24	44,95.5
JACKSONVILLE BCH	10	48,88.5
LA BELLE	16	11.5,19 (P)
LAKE ALFRED EXP STA	145	24.5,43
LAKE CITY 2 E	195	25,94.5
LAKELAND WSO	214	20,42.5
LIVE OAK	120	19,99.9 (P)
LOXAHATCHEE	14	41,2
MAYO	65	13,96
MELBOURNE	10	46,34.5
MOORE HAVEN LOCK 1	22	27,11
MOUNTAIN LAKE	125	25,38.5
MYAKKA RIVER ST PK	20	6,28.5 (P)
NAPLES 2 NE	4	8,1.5
OCALA	90	26.5,69.9
ORLANDO WSO MCCOY AFB	9	34.5,47.5
PALATKA	20	38.5,76
PLANT CITY	121	16,44
PUNTA GORDA 4 ENE	10	9.5,19.5
SAINT LEO	190	16,52
ST PETERSBURG	8	4.5,42.5
SANFORD EXP STATION	17	38.5,55
STUART 1 N	10	46,13.5
TAMPA WSO AIRPORT	19	8,45.5
TARPON SPGS SEWAGE PL	8	5.5,51
TITUSVILLE 3 NW	30	45.5,48
VERO BEACH 4 W	20	46,24
WAUCHULA 2 N	119	18,32.5
WEST PALM BEACH WSO	15	44,0.5
WINTER HAVEN	136	23.5,41.5

Table 1. Cooperative climatological observation stations used in the analyses with elevations in feet above mean sea level (MSL) and XY grid coordinates (the stations with a (P) are precipitation only stations).

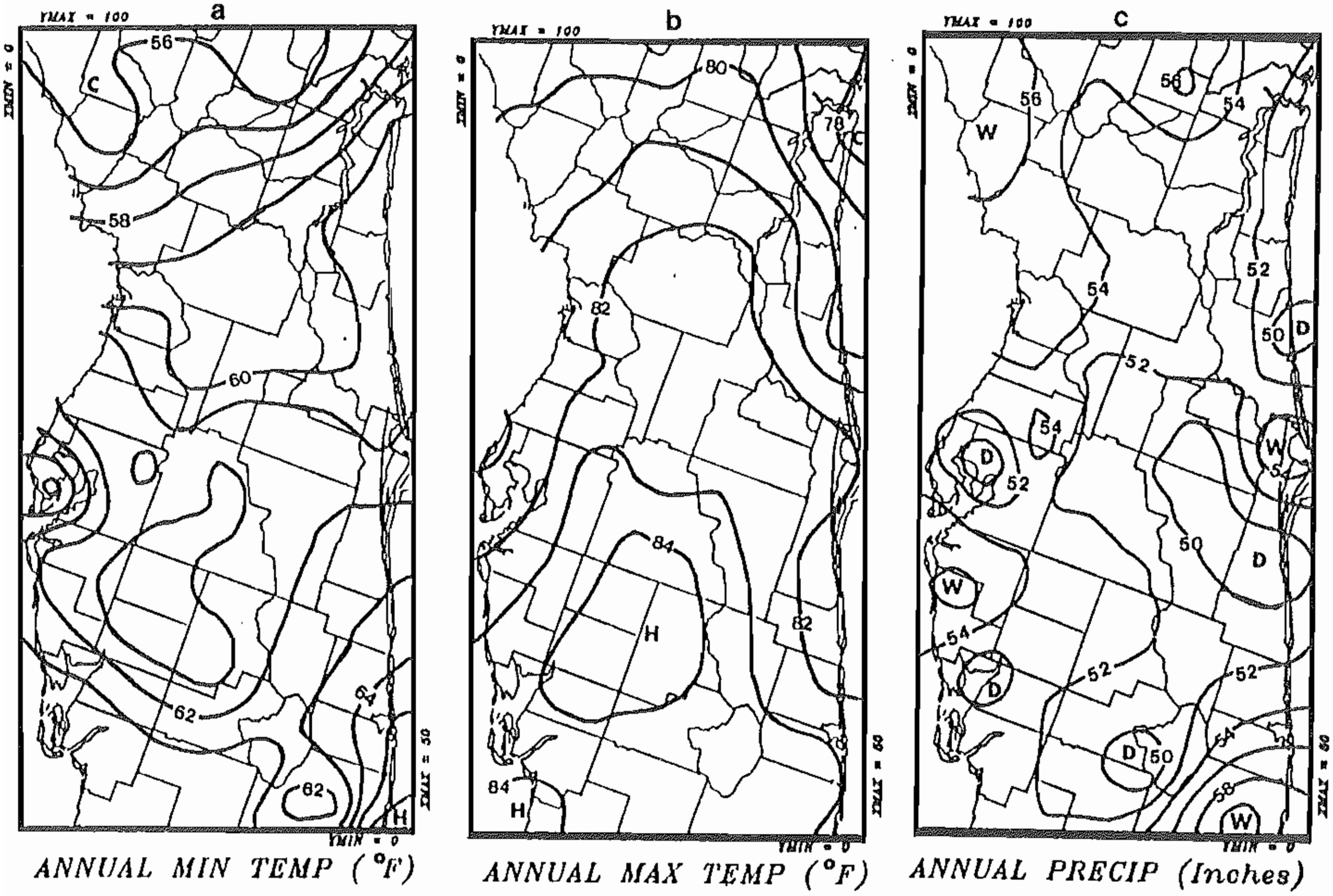


Fig. 4a-c. Analyses of annual mean minimum temperature (4a), maximum temperature (4b), and precipitation (4c) for 1951-1980. Bold letters note C-Coldest, H-Hottest, D-Driest, and W-Wettest.

b. Discussion of Analyses

The annual maximum and minimum temperature analyses (Figs. 4a-b) clearly show that the maximum and minimum temperatures are generally a function of both latitude and proximity to the coast. In general, minimum temperatures are cooler north and interior and warmer south and along the coast, while maximum temperatures are warmer south and interior and cooler north and along the coast. The annual precipitation analysis (Fig. 4c) shows no clearly defined spatial patterns, as it is a composite of changing monthly and/or seasonal regimes. In general, it is wettest north and south and driest in central sections.

(1) Precipitation

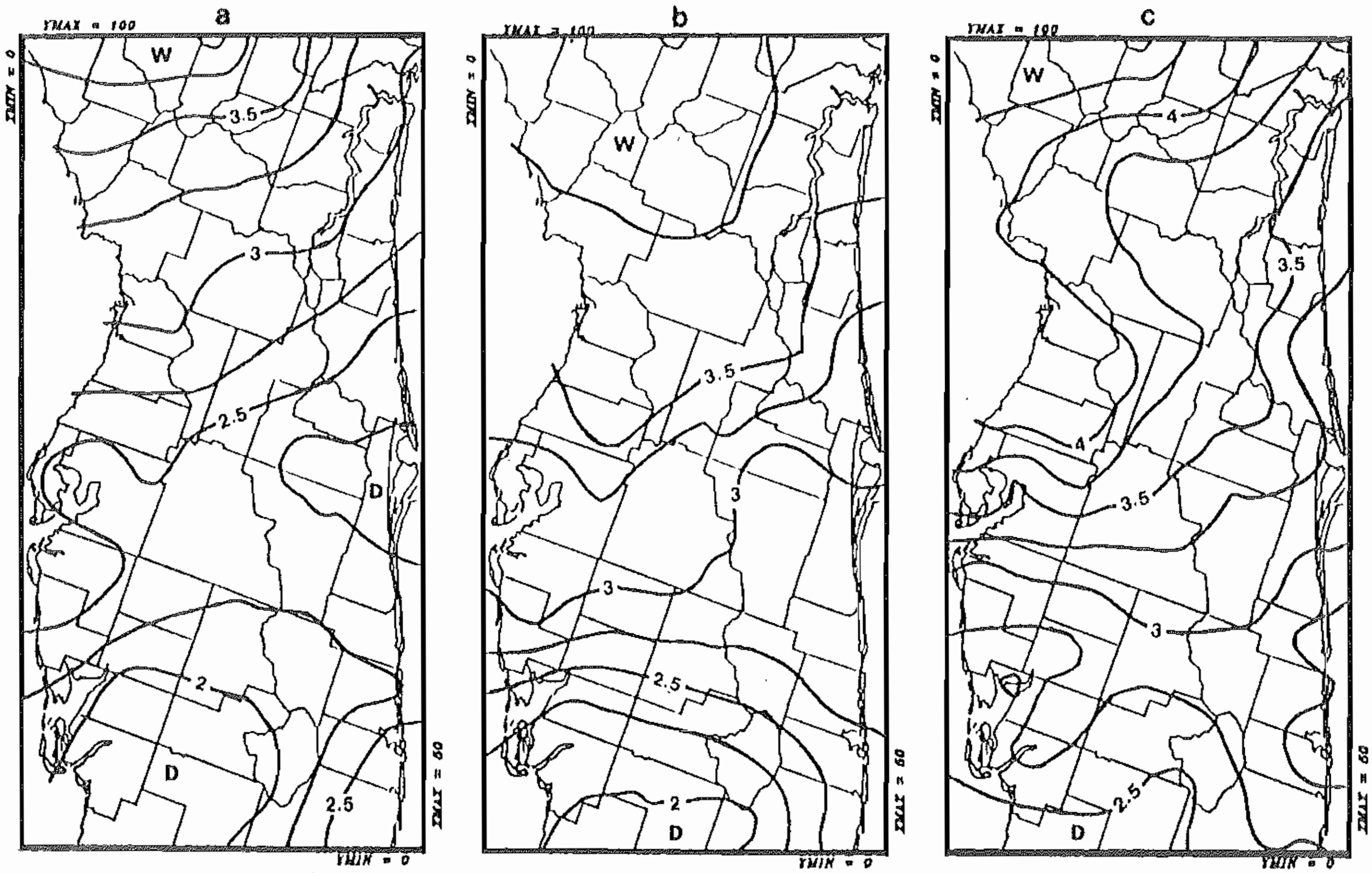
Analyses of mean precipitation for January through December are shown as Figs. 5a-l. A general inspection of the data clearly shows two seasons (wet and dry) of approximately six months each. The months of May through October are the wettest months. The driest months are generally from November through April.

Except for November, the transition month between the wet and dry seasons, the dry season months are characterized by a general north/south gradient of precipitation with the wettest region in the northwest section and the driest region in the southwest. Precipitation in Melbourne's CWA averages 2 to 3 inches a month during this period. The northern section precipitation maxima are due to the southward movement of the tracks of mid-latitude cyclones and the most favorable upper level dynamics after November. Precipitation across central Florida during this time of the year is usually caused by cold frontal passages and prefrontal troughs that occasionally penetrate that far south, but typically lose their strength as they do so. Surface lows usually track north of central Florida, as do upper level centers of vorticity maxima.

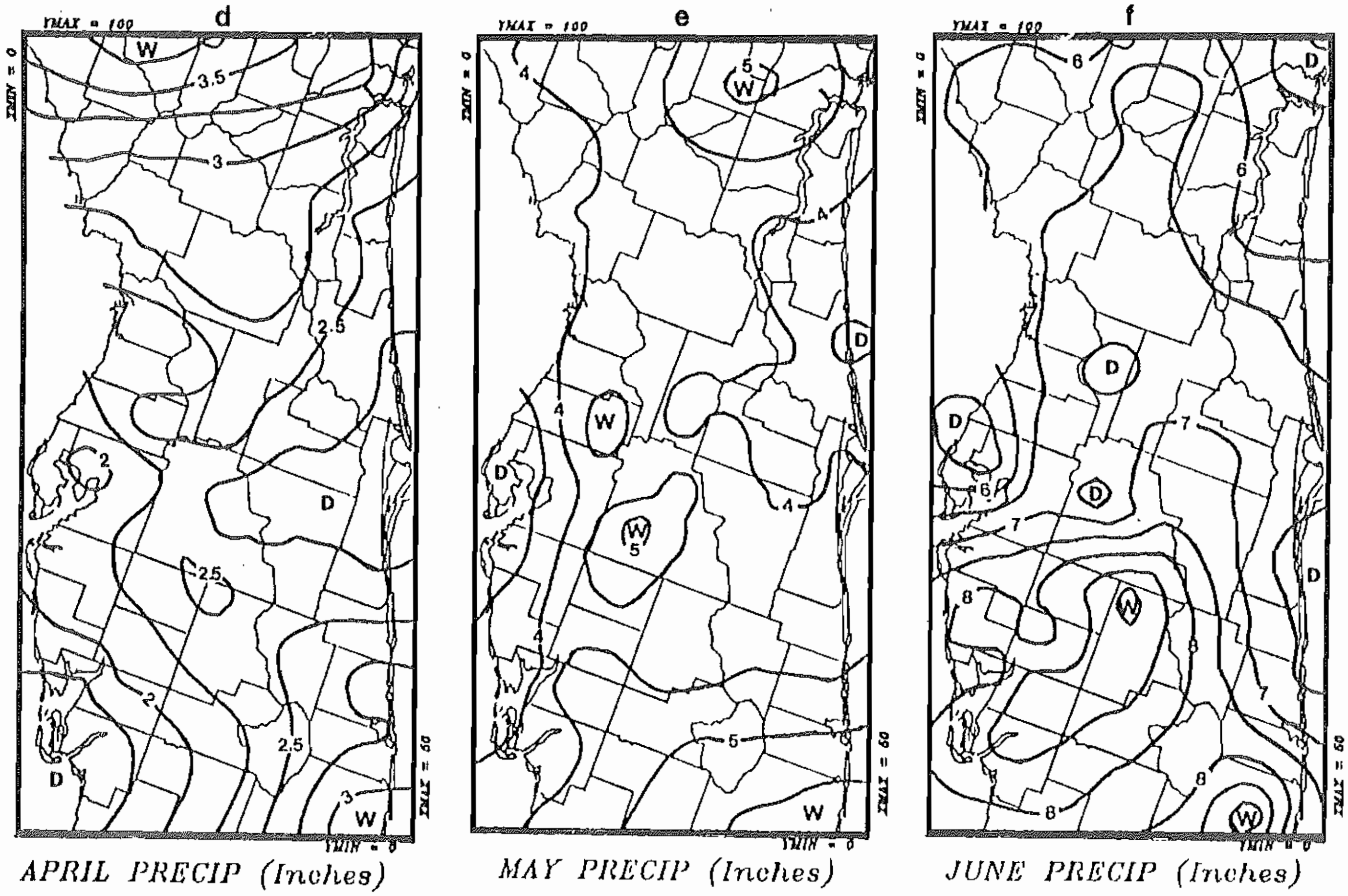
April is a transition month between the dry and wet seasons and is peculiar in that it is drier than March or May. This is due to the decrease in mid-latitude systems affecting the area and the fact that a moist tropical maritime air mass is not yet in place, and significant sea breeze forcing has not yet begun.

In the late spring and summer months of May through October, a significant change in the precipitation patterns is evident with larger magnitudes and gradients. The mid-latitude synoptic scale dynamic forcing mechanisms remain mainly north of this region, while mesoscale forcing mechanisms, such as the sea breeze and local circulations, become more significant in the favorable thermodynamic environment. Abundant low level moisture exists with instability greatest in the late afternoon as surface heating destabilizes the lower levels. The main forcing mechanisms which exist are low level convergence along sea/lake breeze fronts and thunderstorm outflow boundaries.

Under generally easterly flow in June, July, and August the east coast sea breeze results in frequent afternoon thunderstorms inland while it is relatively drier along the east coast except around Cape Canaveral where northeast and southeast sea breezes can converge. There is a very distinct dry anomaly centered around Melbourne compared to stations inland and the Cape

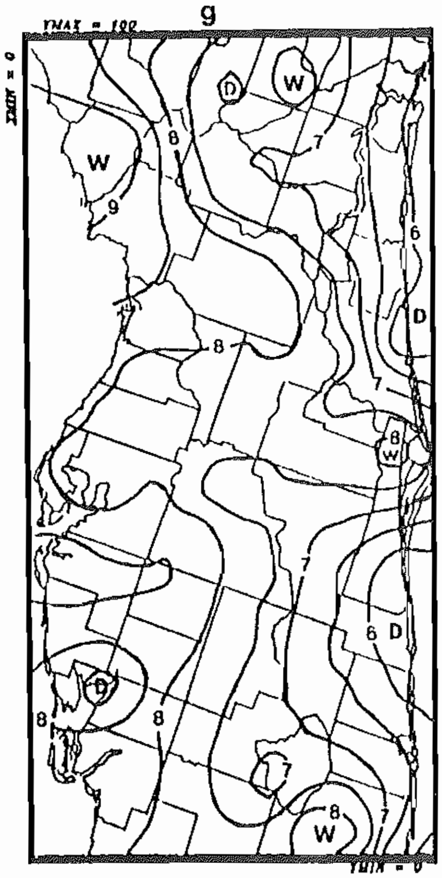


JANUARY PRECIP (Inches) *FEBRUARY PRECIP (Inches)* *MARCH PRECIP (Inches)*

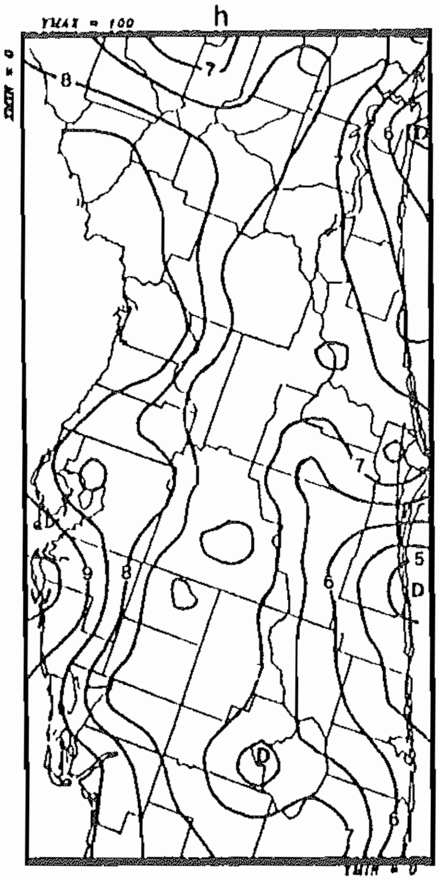


APRIL PRECIP (Inches) *MAY PRECIP (Inches)* *JUNE PRECIP (Inches)*

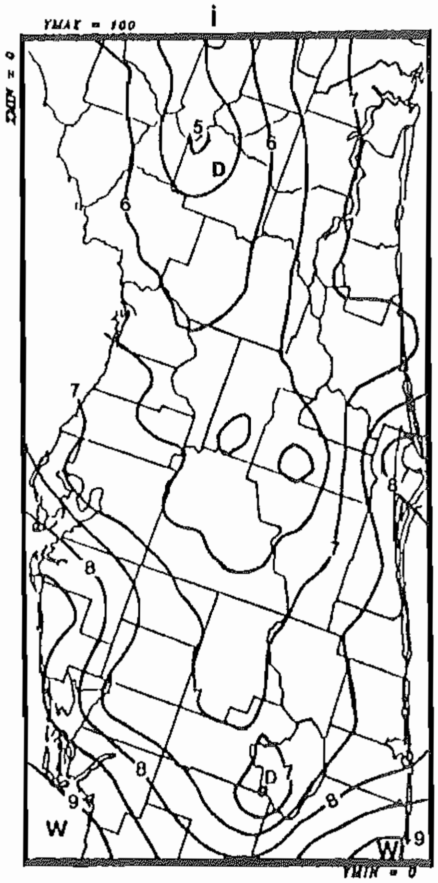
Fig. 5a-1. Mean monthly precipitation (inches) for January through December (1951-80).



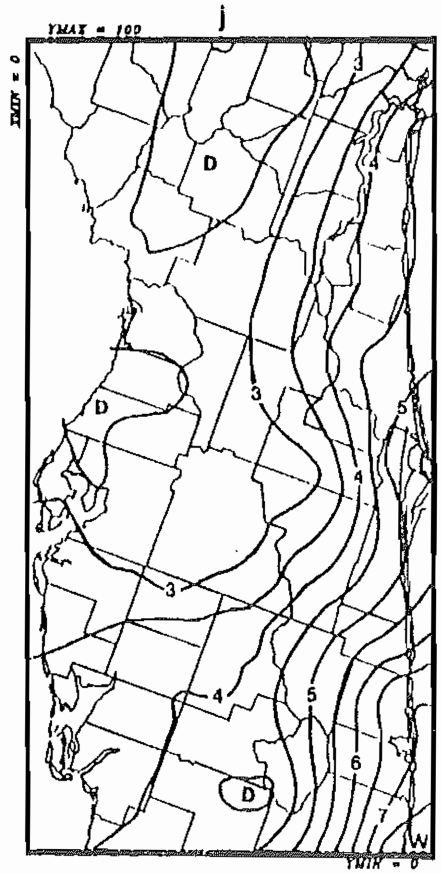
JULY PRECIP (Inches)



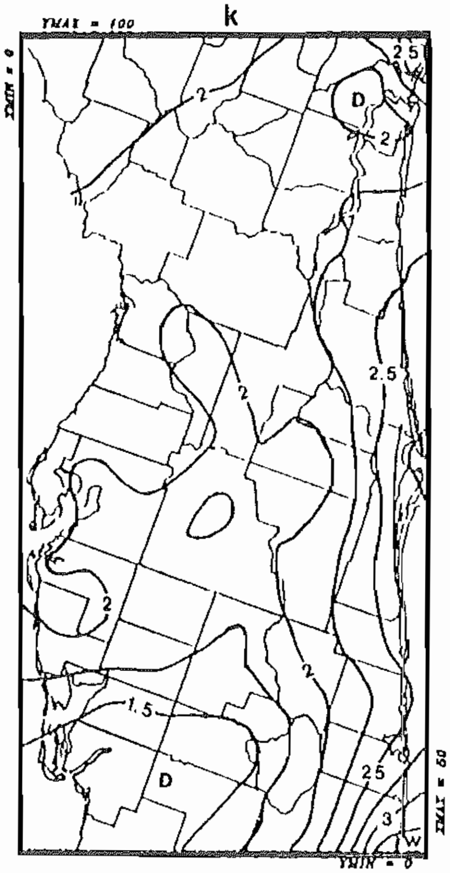
AUGUST PRECIP (Inches)



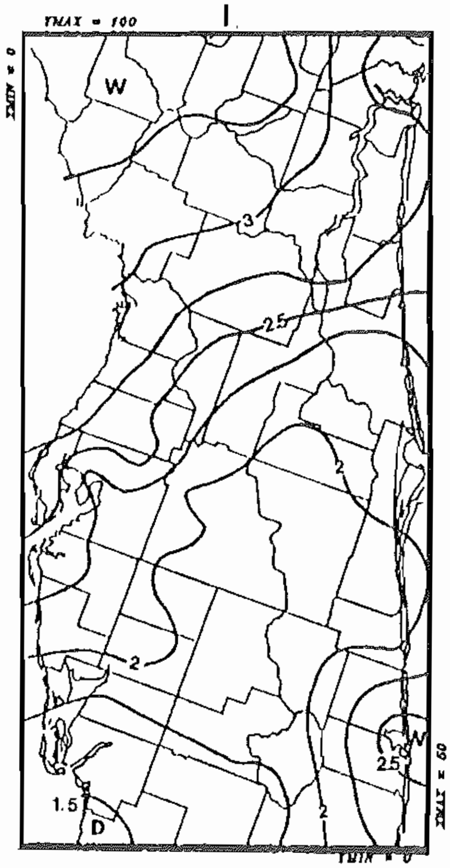
SEPTEMBER PRECIP (Inches)



OCTOBER PRECIP (Inches)



NOVEMBER PRECIP (Inches)



DECEMBER PRECIP (Inches)

Canaveral area to the north that is most notable in August. Forecasters should take note that on a typical sea breeze day in easterly flow the chance of rain should be significantly higher over northern Brevard County and interior counties than for coastal areas south of Cape Canaveral.

In July and August the west coast is wetter than interior areas due to west coast sea breeze activity, and earlier east coast sea breeze activity moving westward into the area and/or creating outflow boundaries which interact with the activity in the west. An abrupt change occurs after August as conditions become drier over the interior and west coast and wet on the east coast in September, October, and November. Isohyets are nearly parallel to the coast. This is probably due to a peak in disturbances in the easterlies and fall coastal heavy rains (Carlson, 1967), but the cause requires further investigation.

(2) Temperature

Analyses of mean maximum and minimum temperatures for January through December are shown as Figs. 6a-l and Figs 7a-l respectively. In looking at the temperature analyses, two main climate controls are clearly evident. The first is the latitudinal variation of the solar insolation which creates a north to south temperature gradient. The second is continentality which produces a land/water temperature contrast or east to west temperature gradient across east central Florida and a west to east gradient in west central Florida. The Atlantic Ocean and the Gulf of Mexico moderate the temperatures at the coastal locations.

In general, maximum temperatures are higher in interior and southern sections for all months and lower on the coasts. The greatest contrast in temperature between the coast and interior is found in May. In the Melbourne CWA there is a strong temperature gradient in the northern part of the CWA during November through May, while very weak gradients are found in July through October.

The analyses show the warmest maximum and minimum temperatures are in July and August over central Florida. Minimum temperatures in the month of September are also fairly warm over east central Florida. The coldest maximum and minimum temperatures in central Florida occur in January.

The months of March and April are basically a transition into the warmer months of summer, with the maximum temperature gradient decreasing and the north-south temperature gradient giving way to a land-water (east-west) temperature gradient in the Melbourne CWA. October and November are fall transition months, and gradients return from a mainly inland/coastal maximum temperature contrast to a north/south temperature contrast.

Minimum temperatures are generally lower north and interior for all months, and a strong temperature gradient exists across northern sections from October through April. In the winter months the minimum temperature is mainly a function of latitude, with a thermal trough in the interior due to the Atlantic Ocean and Gulf of Mexico's moderating influence on coastal temperatures. In the summer months, the temperature gradient weakens, and the minimum temperature is about equally a function of both latitude and proximity to the coast. The coldest location is consistently in the extreme north section of the grid. From winter to summer the coldest location shifts from the northwest section to the northern interior. In the winter months continental polar air masses have undergone the least modification in this northwest section.

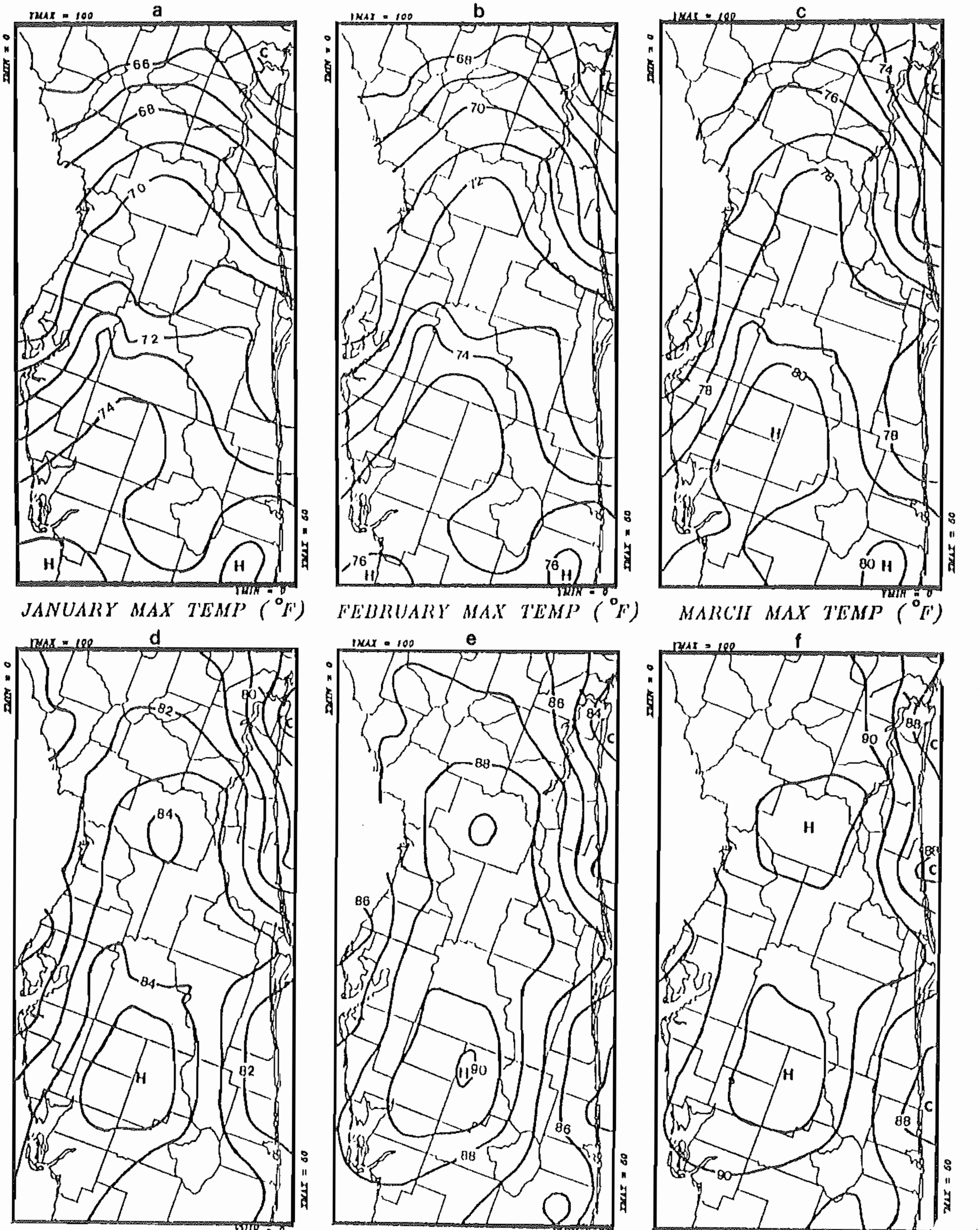
An important realization a forecaster must draw from the analyses is the significant variation in the temperature and precipitation regimes due to the dominant climatic control of the interaction between the land and surrounding water, as well as the storm tracks of mid-latitude and tropical systems that affect the area. The new forecasters at Melbourne will need to study the monthly spatial patterns of temperature and precipitation to become familiar with the mesoscale forecasting complexities of this subtropical maritime climate and prepare detailed and accurate forecasts. One example of a practical application of the data would be to quantify the typical max/min temperature difference between Orlando and Daytona Beach (for which there is guidance) and Melbourne (for which there is not) and adjust the guidance accordingly. Another example would be to use the data as relative climatological guidance for the CWA (i.e., on a typical February day morning lows would range from the upper 40s at Daytona Beach to the low to mid 50s in Stuart and Ft. Pierce to the south).

The major spatial and temporal patterns of rainfall and temperature have been briefly discussed; however, other smaller scale features will require further study with greater data density. These studies should consider mesoscale climatic variations due to soil and vegetation type and moisture, surface albedo, ocean currents, and small scale changes in elevation over central Florida. It is hoped the analyses presented here will be a good starting point for the new forecasters at NWSO Melbourne, helping them to gain initial experience and understanding of this region's weather and climate.

3.0 DAILY TEMPERATURE CLIMATOLOGY FOR MELBOURNE, FLORIDA

The implementation of modern technologies at proposed WFOs can lead to greater forecast accuracy and detail in the future. Even so, the simple foundation upon which site forecasting is based -- that is, the climatological past of the local area -- must not be forgotten. Since the weather office at Melbourne is new, a method had to be found to familiarize forecasters with local climatology. Additionally, MOS guidance is not currently available for Melbourne. Given this lack of numerical guidance, forecasters may find it helpful to use climatology as the starting point for their local temperature forecast. To begin to address these issues, a daily temperature climatology of Melbourne was produced.

The data for this study were taken from the Cooperative Climatological Station Records of the City Water Treatment Plant in Melbourne. Data were obtained through the NCDC for the period July 1948 through November 1986. While it appears the data set is good, any climatological study should be concerned with various factors that can affect accuracy, such as observational procedures, equipment, station relocation, or any change in the physical environment surrounding the collecting station through the concerned period (Robinson, 1990). It is important to comment here that the means are not smoothed, and record values are not considered official by the NCDC; but there are 38 years of continuous record, and these are the best data available.



JANUARY MAX TEMP (°F)

FEBRUARY MAX TEMP (°F)

MARCH MAX TEMP (°F)

APRIL MAX TEMP (°F)

MAY MAX TEMP (°F)

JUNE MAX TEMP (°F)

Fig. 6a-1. Mean monthly maximum temperature (°F) for January through December (1951-80).

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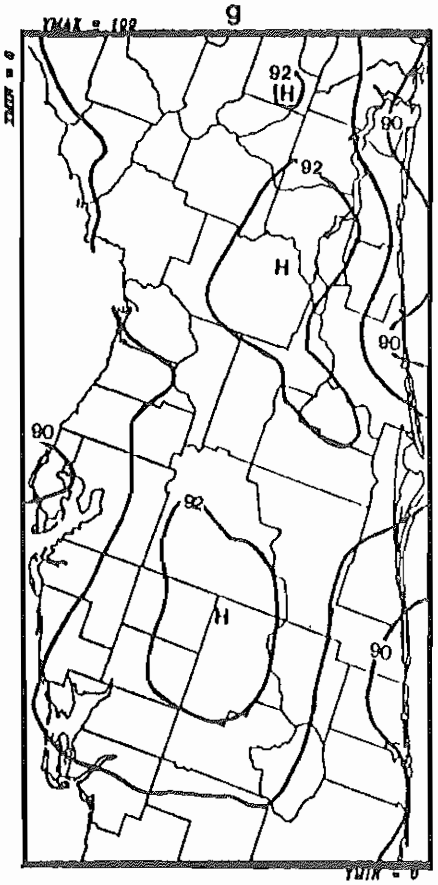

JULY MAX TEMP (°F)

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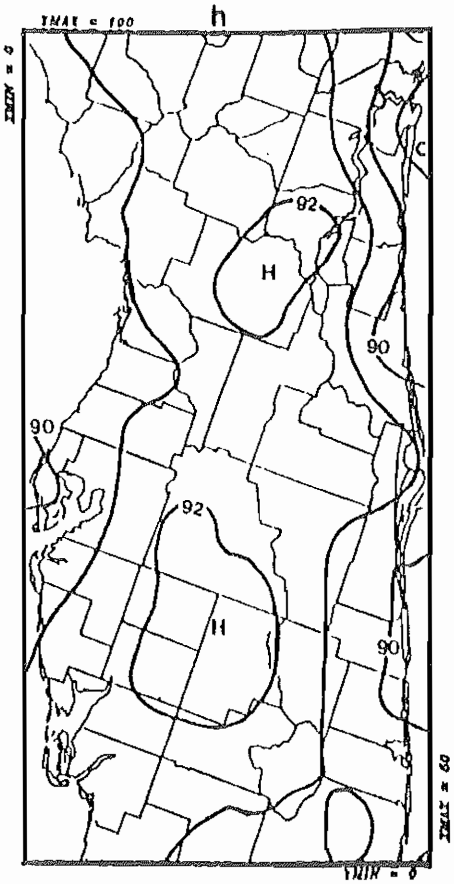
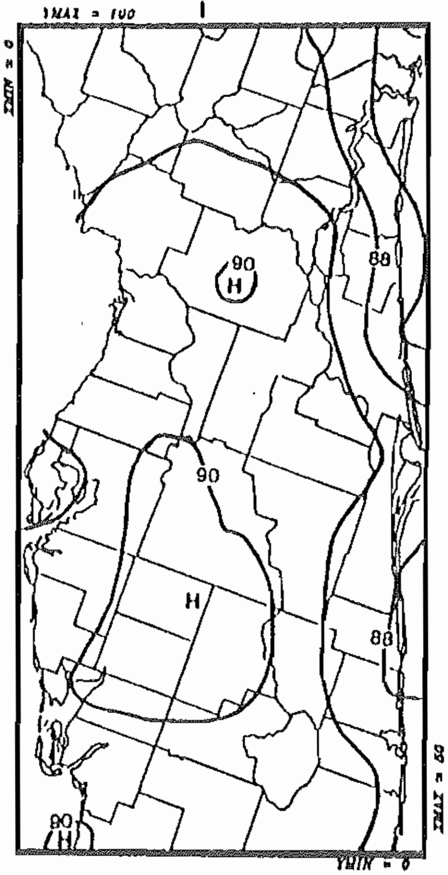


AUGUST MAX TEMP (°F)

i



SEPTEMBER MAX TEMP (°F)

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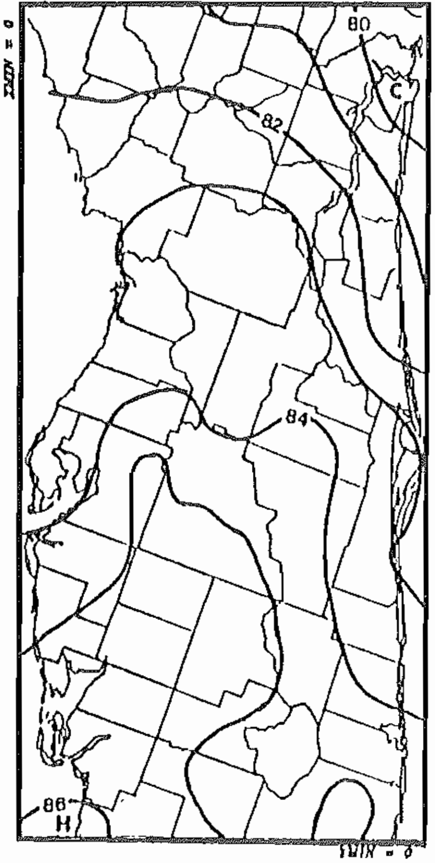

OCTOBER MAX TEMP (°F)

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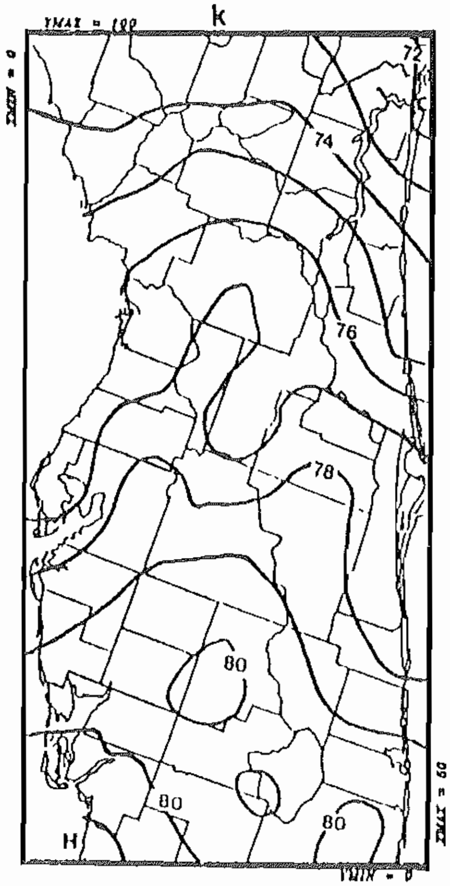

NOVEMBER MAX TEMP (°F)

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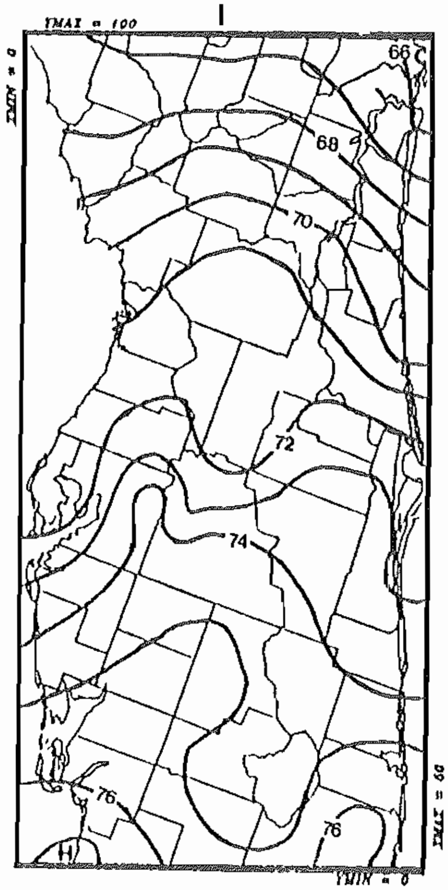
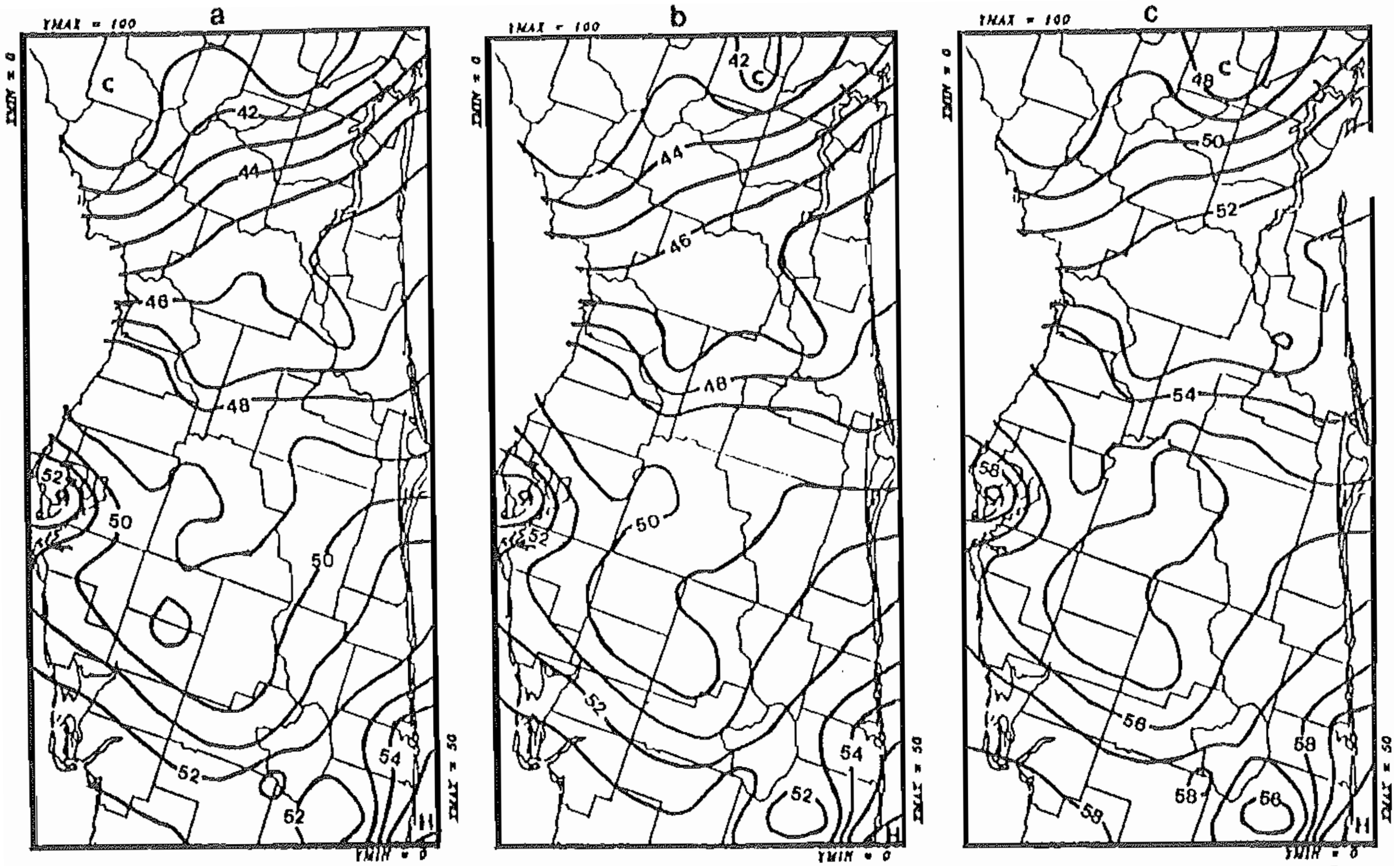
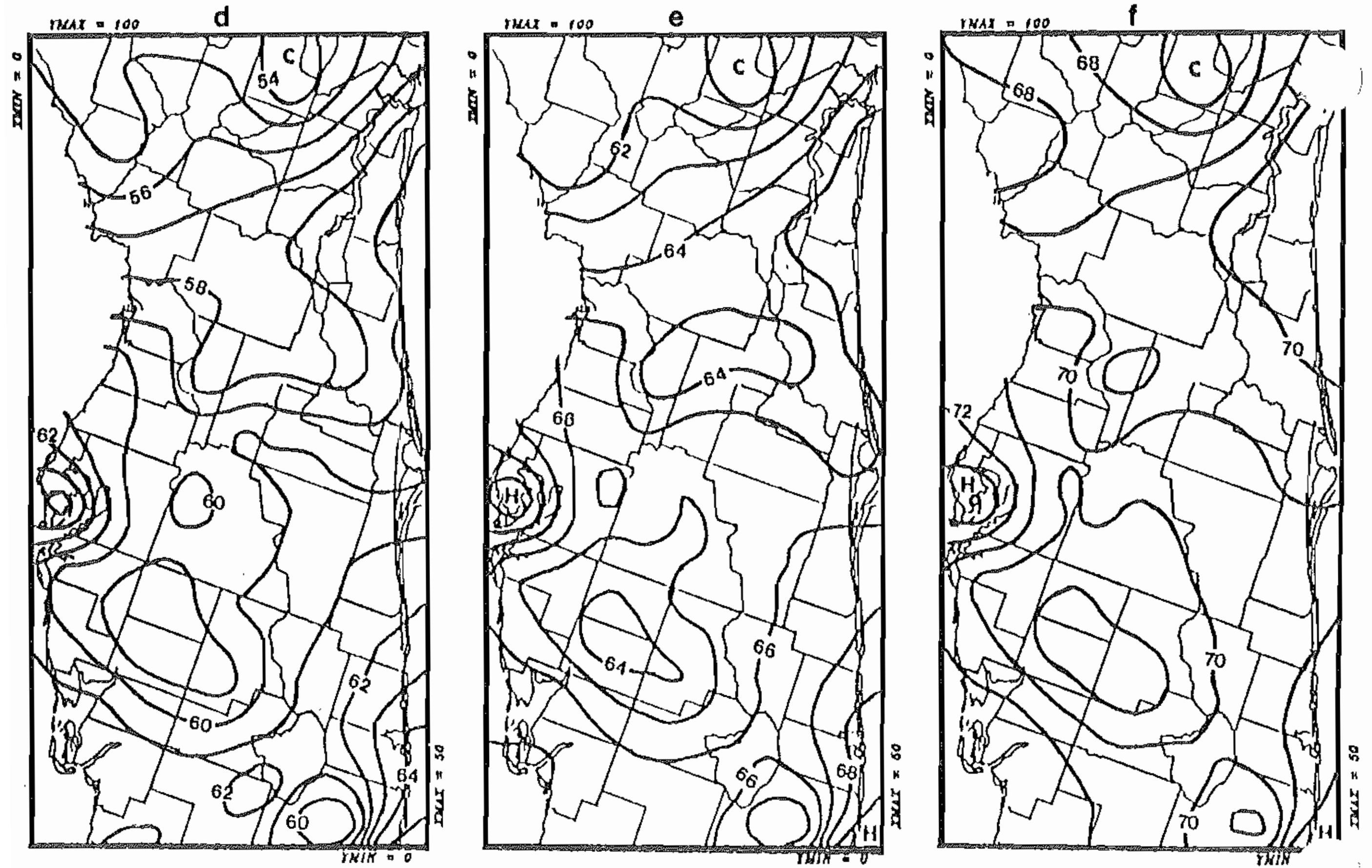


DECEMBER MAX TEMP (°F)

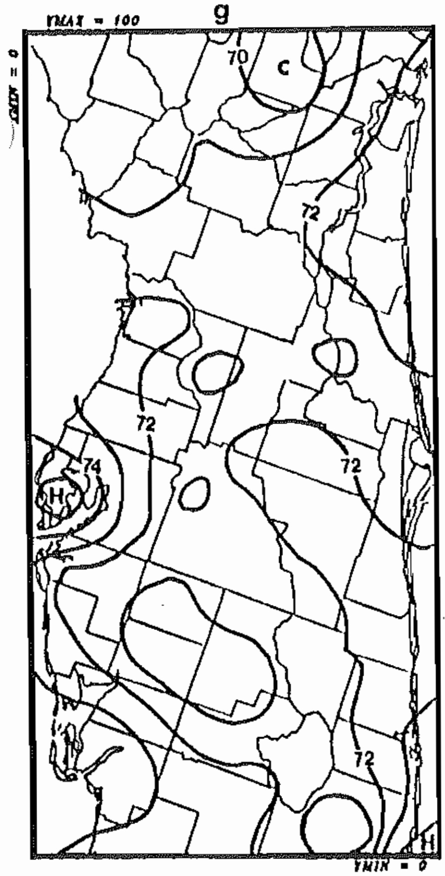


JANUARY MIN TEMP (°F) FEBRUARY MIN TEMP (°F) MARCH MIN TEMP (°F)

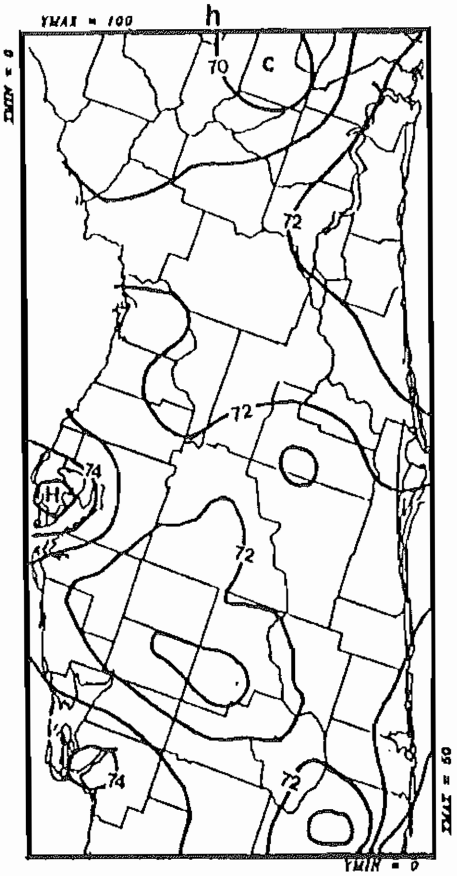


APRIL MIN TEMP (°F) MAY MIN TEMP (°F) JUNE MIN TEMP (°

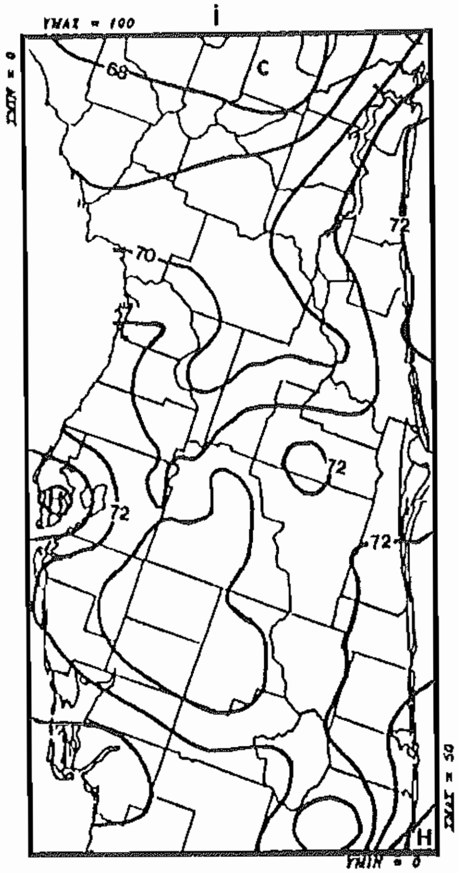
Fig. 7a-1. Mean monthly minimum temperature (°F) for January through December (1951-80).



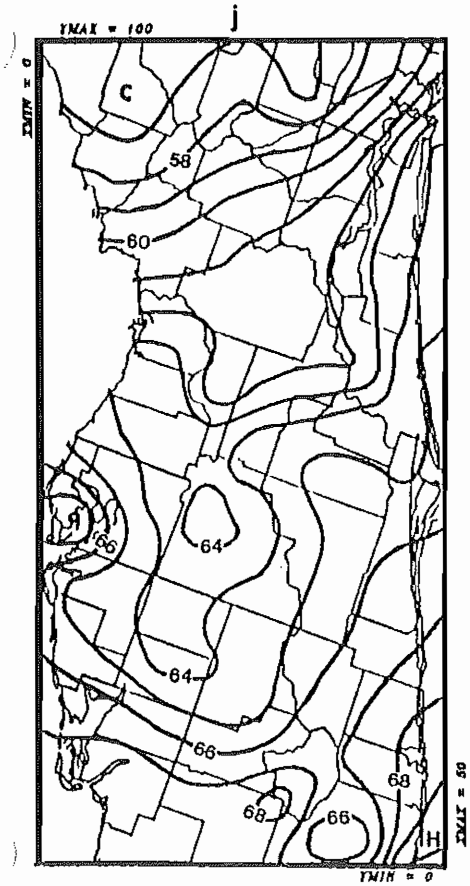
JULY MIN TEMP (°F)



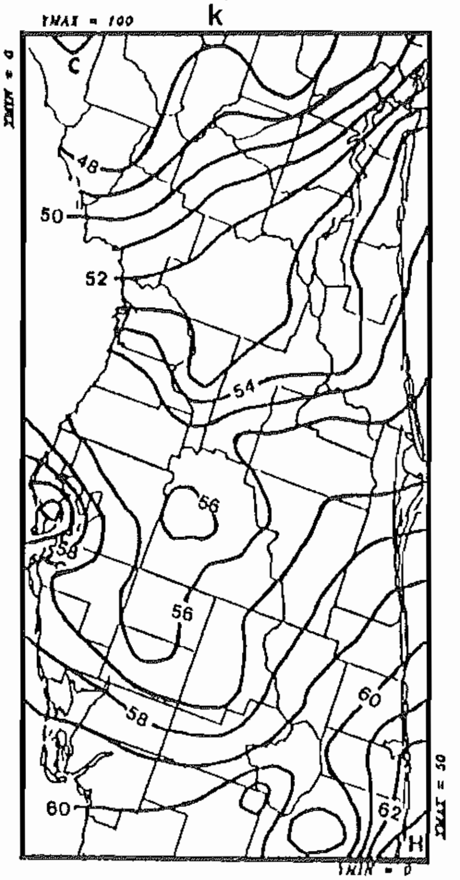
AUGUST MIN TEMP (°F)



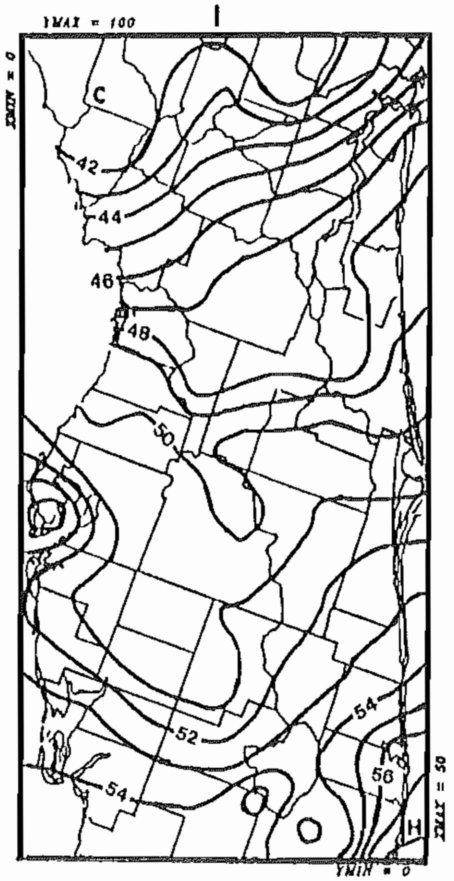
SEPTEMBER MIN TEMP (°F)



OCTOBER MIN TEMP (°F)



NOVEMBER MIN TEMP (°F)



DECEMBER MIN TEMP (°F)

Data are presented in a series of 24 graphs (Figs. 8a-x), two for each month, representing both maximum and minimum temperature data. Six curves were plotted for each month: Maximum Daily Maximum (XDX), Minimum Daily Maximum (NDX), Mean Daily Maximum (MDX), Minimum Daily Minimum (NDN), Maximum Daily Minimum (XDN), and Mean Daily Minimum (MDN). The idea behind these graphs is that for any given day the forecaster can quickly reference average high and low temperatures to use as the basis for routine forecasts. For extreme events, record plots can be used to help define upper and lower bounds.

Beginning with January (Figs. 8a-b), daily maximum temperatures should be in the low to mid 70s with minimums in the low to mid 50s. This also holds true for both February and December (Figs. 8c-d and 8w-x respectively). Aside from the means, the real key to temperature forecasting this time of year is an understanding of the large degree difference between the XDX and the NDX curves, and likewise, the difference between the NDN and XDN curves. On January 19 for example, although the MDX would point to a possible forecast high of 71 deg and the MDN a low of 50 deg, it is the difference between related extremes that provides the insight. The high temperature could be as warm as 81 deg or as cool as 42 deg, and low temperatures could be as warm as 62 deg or as cool as 19 deg. Clearly, most extreme cold values can be attributed to the deep southward penetration of mid-latitude winter storm systems which bring cold, dry, continental polar air to Melbourne's otherwise warm maritime tropical environment. If after cold frontal passage, surface winds blow from the north straight down the peninsula, little modification of the new air mass occurs. However, given the area's maritime influences, extreme cold is not apt to remain for prolonged periods. Any shift in wind direction results in some amount of air mass modification bringing temperatures back towards the norm. Conversely, warm values (as described by XDX and XDN curves) may be explained as that situation before cold frontal passage when the surface wind flow has a strong, warm, southerly component.

December, January, and February may be defined as the winter months in Melbourne, with January boasting the coldest temperatures and the all-time record low of 17 deg. A common feature of all three months is the large day-to-day variability of the NDN and NDX curves which suggests difficulty when forecasting the magnitude of significant cold events.

Figs. 8e-f show March as a transitional period with a warming of each curve through the month. While the XDX and XDN curves warm steadily, the NDN and the NDX curves still show intervals of large day-to-day variability. March 3 is an excellent example. The record low for that day is 25 deg -- a significant cold event. The corresponding NDX is 49 deg which actually occurred on the same day in 1980. Although Melbourne enjoys an early spring, at times synoptic patterns shift into place as to produce additional winter-type episodes. Another day of interest is March 23. This is the date of the "latest observed freeze (32 deg)," and also suggests that despite the warming, cold spells can happen even in late March.

April (Figs. 8g & h) continues the transition. Evidence of cold and dry air influx still exists, but not to the extent of previous months, as sun angles are getting higher and daytime heating more pronounced. It is noteworthy that in April the NDX plot dips to as low as 59 deg on the 6th. In spring, more often than not, NDX values such as this are a product of overrunning. If relatively cooler, drier air is in place over the central peninsula at the same time winds take on an onshore component, overrunning can occur. The result is a thick low-level cloud deck that effectively blocks incoming solar radiation. If the deck produces precipitation, evaporative cooling can further suppress the daily high.

When considering the NDN and the XDN plots during March and April, a lesson to be learned for the forecaster would be to guard against forecasting sustained warm temperatures too quickly.

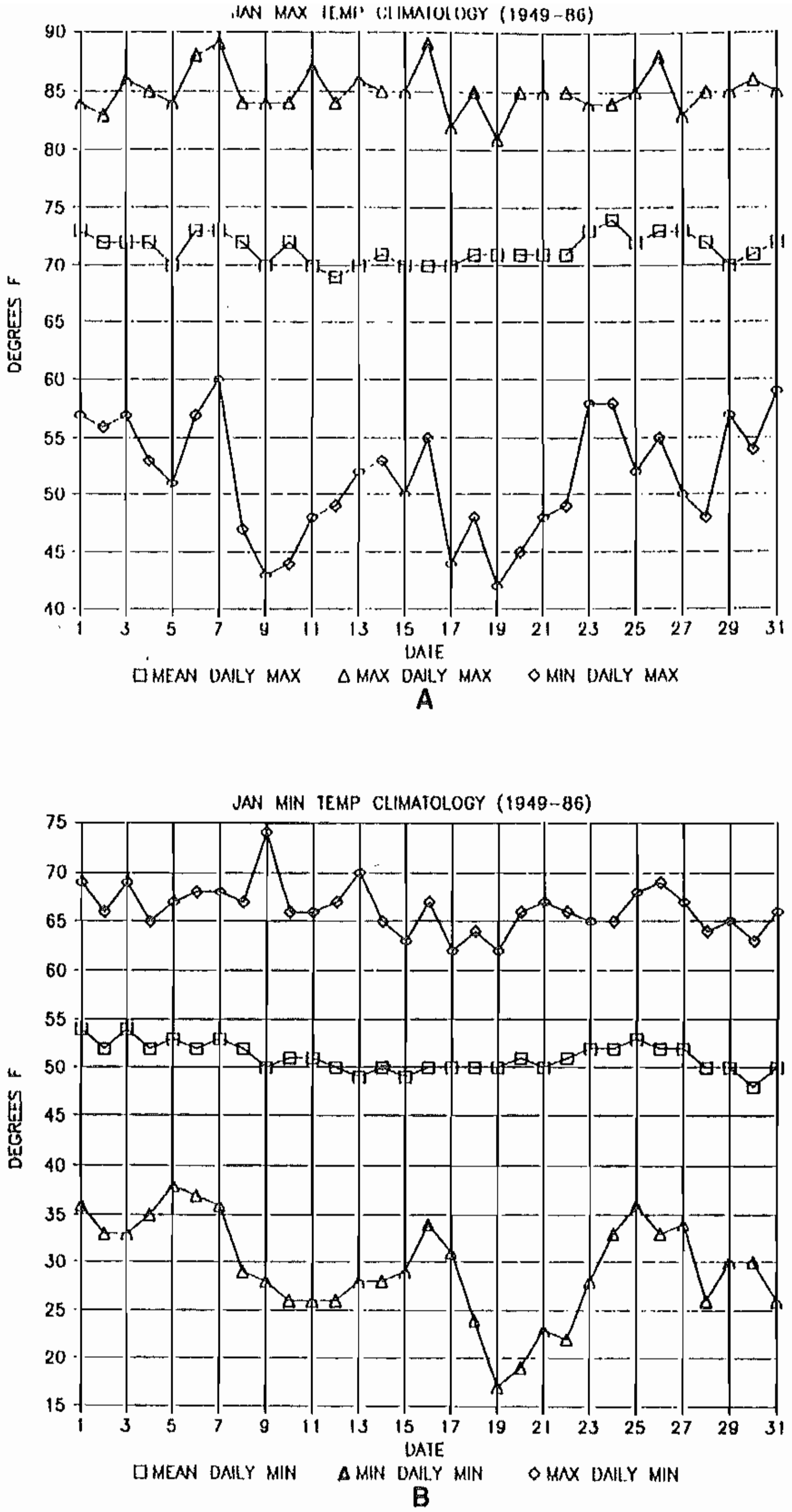
May (Figs. 8i-j) and June (Figs. 8k-l) are similar in that the warming of each curve continues, but at a much slower rate. Day-to-day variability in record values is not as chaotic, and the degree gap between the means and extremes is closing. Humidity gradually increases, and most mid-latitude cyclones pass north of Melbourne.

Summertime finds Melbourne deeply entrenched in a tropical regime. Figs. 8m-p reveal July and August as the hottest time of the year. The range between means and extremes (as well as related extremes) is greatly reduced. This places great value on the means themselves. In fact, even though mean data have not been smoothed, values hardly vary from day-to-day. The main mechanism at work producing curves with such little fluctuation is the predominant easterly flow around the Bermuda High across central Florida at this time of year. This keeps an east coast station such as Melbourne in a higher absolute humidity environment. The abundance of moisture maintains a smaller average diurnal temperature range and provides fuel for afternoon thunderstorms. One should give second thought to a forecast that digresses too far from the means during this time of year. It is interesting to note that on occasion summer high temperatures can get quite hot, but only four times has the high reached 100 deg, and only once has it surpassed it (102 deg on July 14 -- Melbourne's all-time high). The lack of exceedingly hot temperatures is likely the result of an easterly sea breeze that sets up during the early afternoon. Once the sea breeze passes, little additional heating will take place. Persistence forecasting often works well during the summer.

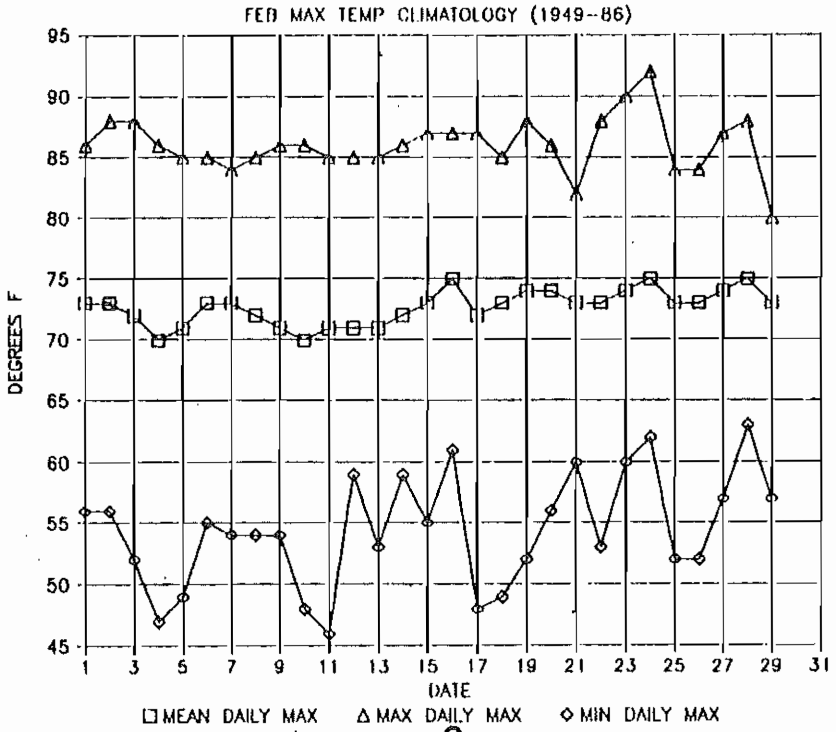
September (Figs. 8q-r) completes summer with a continuation of the slight day-to-day variation in the means. Hot spikes in the XDX plot become less frequent; and by the second half of the month, the NDN curve begins to distance itself from that of the MDN.

Probably the most interesting charts are those of October (Figs. 8s-t), a definite transitional month. The days become shorter, which is readily apparent by the steeply sloped MDX and MDN curves as they significantly cool significantly from beginning to end of the month. However, the sun is still capable of producing maxima exceeding 95 deg, as seen on the 2nd. On the other hand, highs of only 65 deg can occur, especially late in the month as shown by the 26th. Minima can be as warm as 81 deg (on the 11th), or as cool as 41 deg (on the 17th).

October is within tropical cyclone season. It is also a time when drier, cooler air from the north begins to occasionally invade the peninsula. Coastal waters are still quite warm and have tremendous impact on minima when surface winds blow onshore. Yet, if cooler air happens



Figs. 8a-x. Daily temperature climatology for Melbourne, Florida, for January through December (1948-1986) consisting of mean daily maximum/minimum, maximum daily maximum/minimum, and minimum daily maximum/minimum temperature curves.


FEB MAX TEMP CLIMATOLOGY (1949-86)
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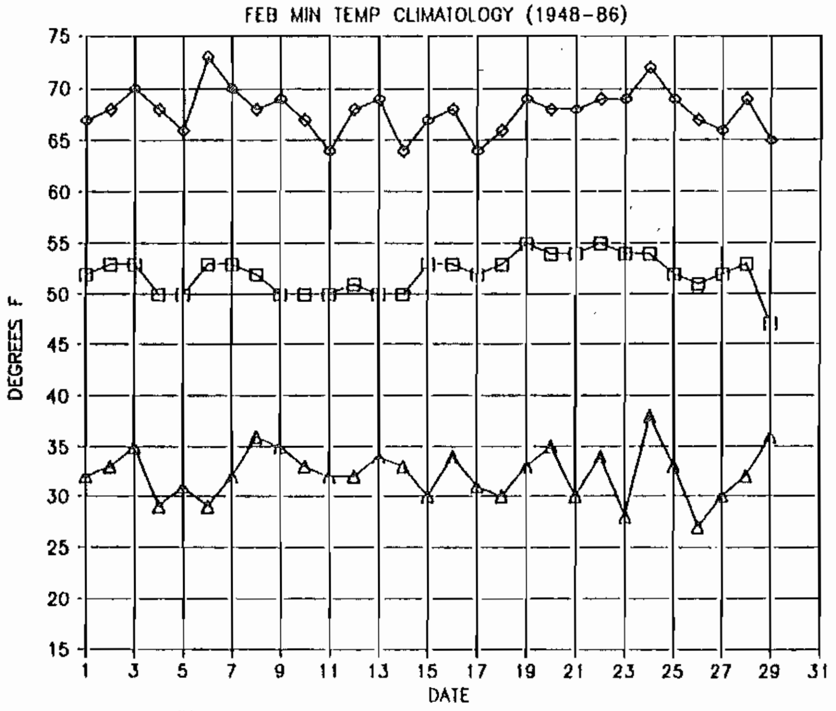
FEB MIN TEMP CLIMATOLOGY (1948-86)
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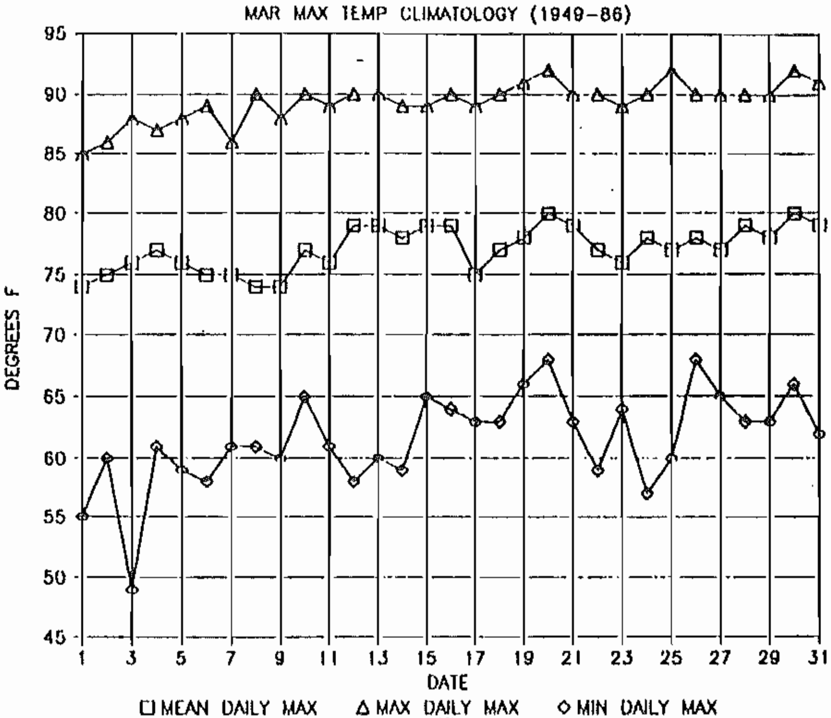
MAR MAX TEMP CLIMATOLOGY (1949-86)
DEGREES F
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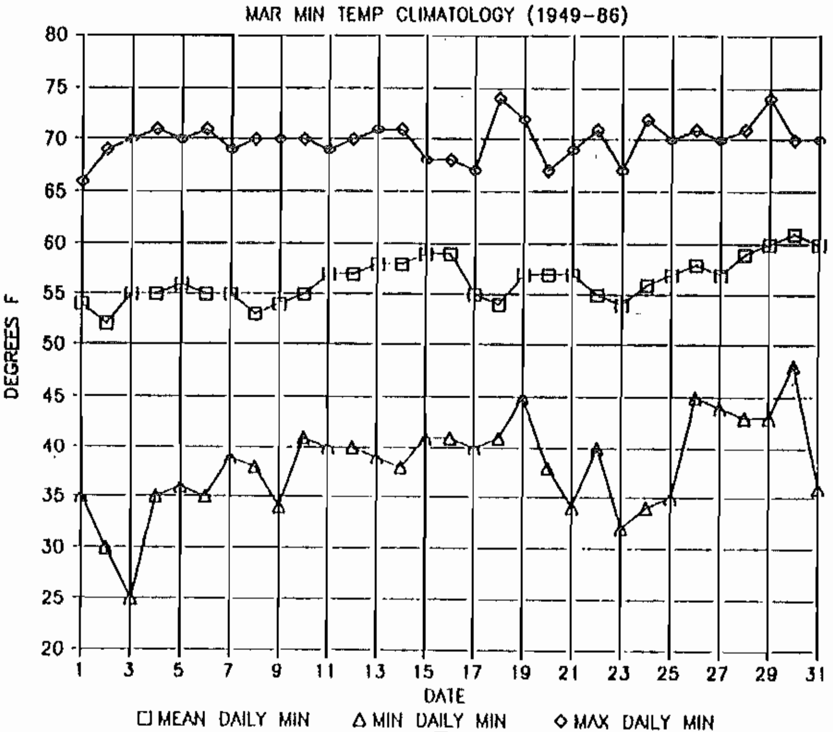
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DEGREES F
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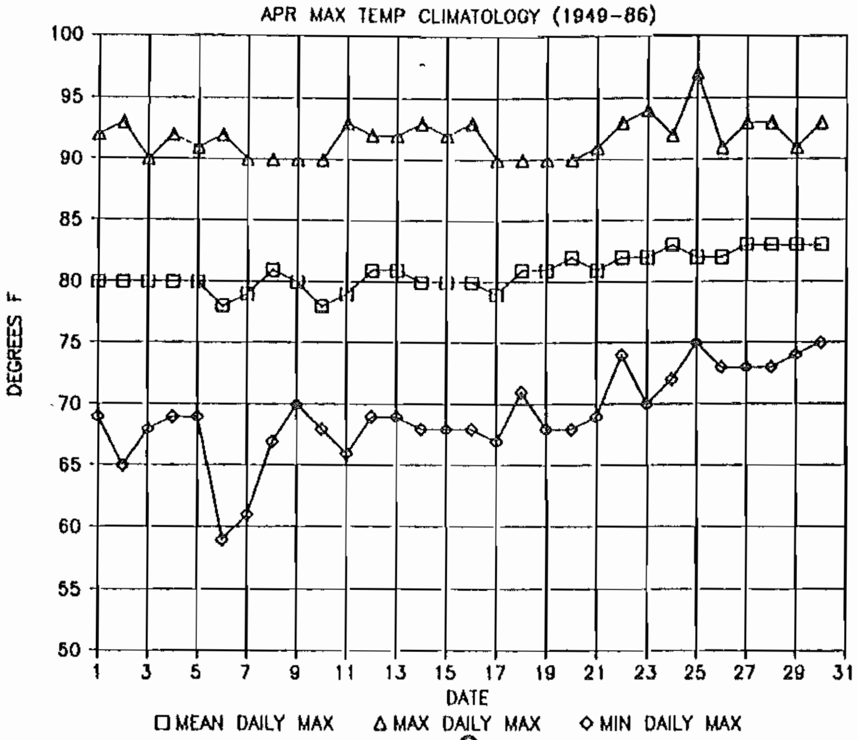
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DEGREES F
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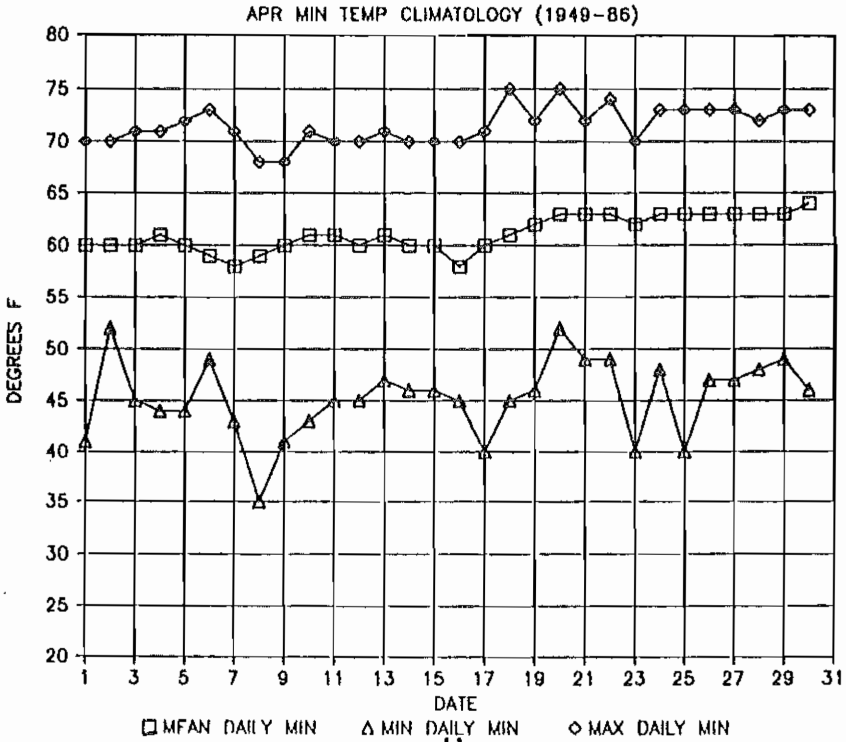
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DEGREES F
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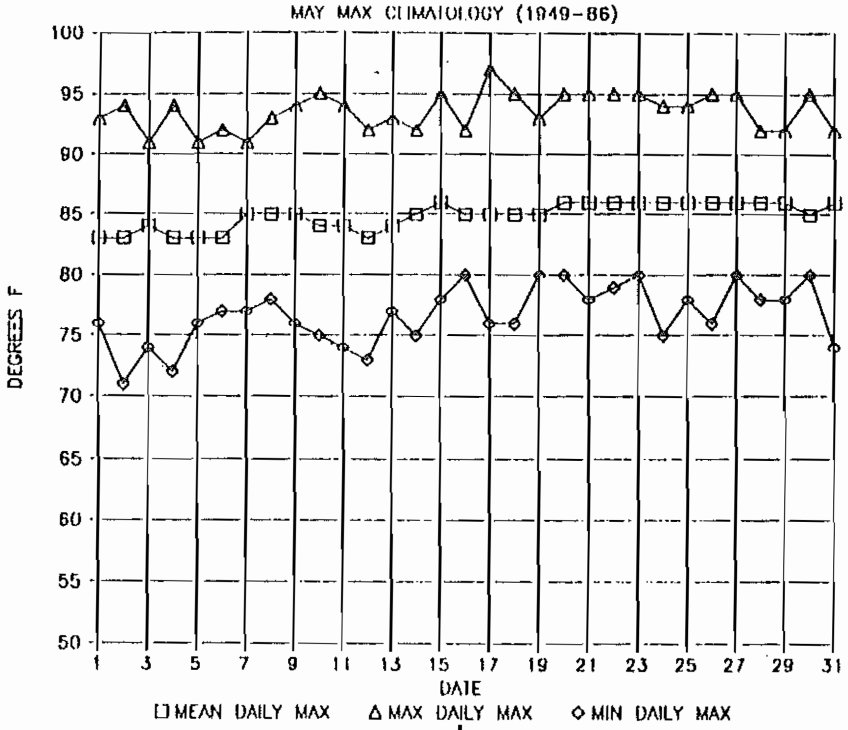
MAY MAX CLIMATOLOGY (1949-86)
DEGREES F
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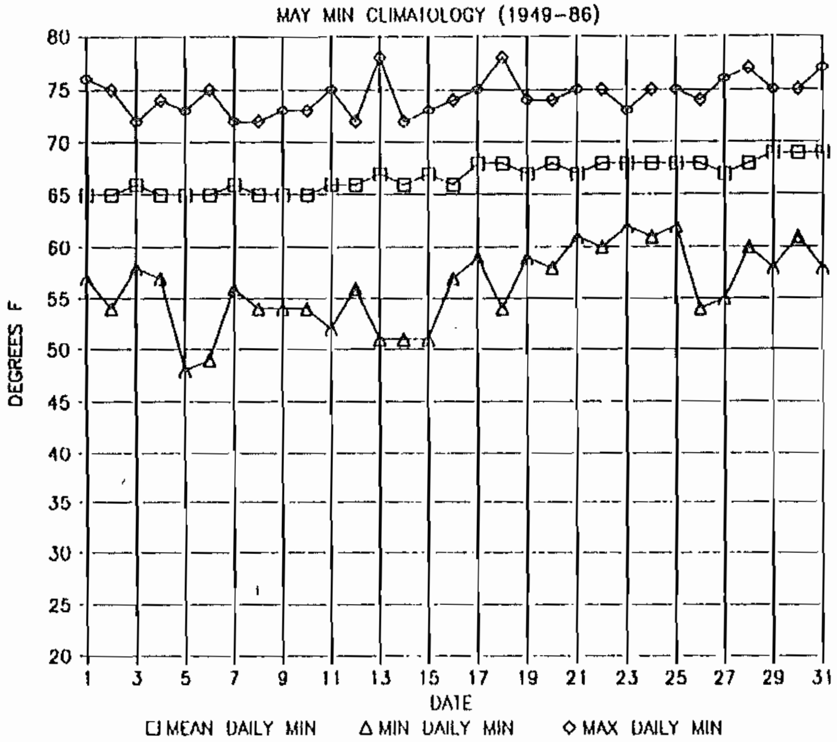
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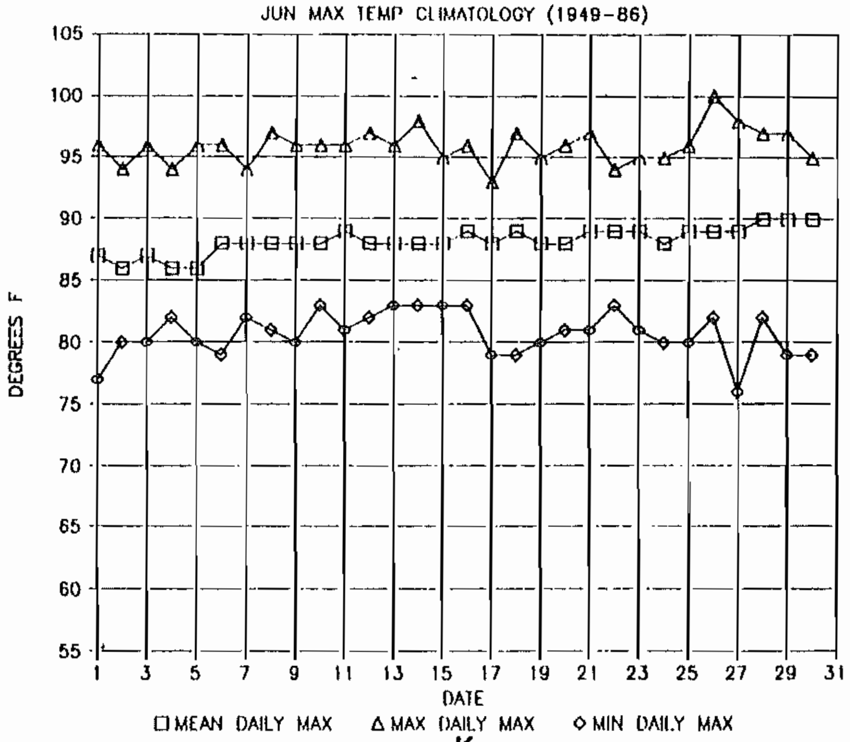
JUN MAX TEMP CLIMATOLOGY (1949-86)
DEGREES F
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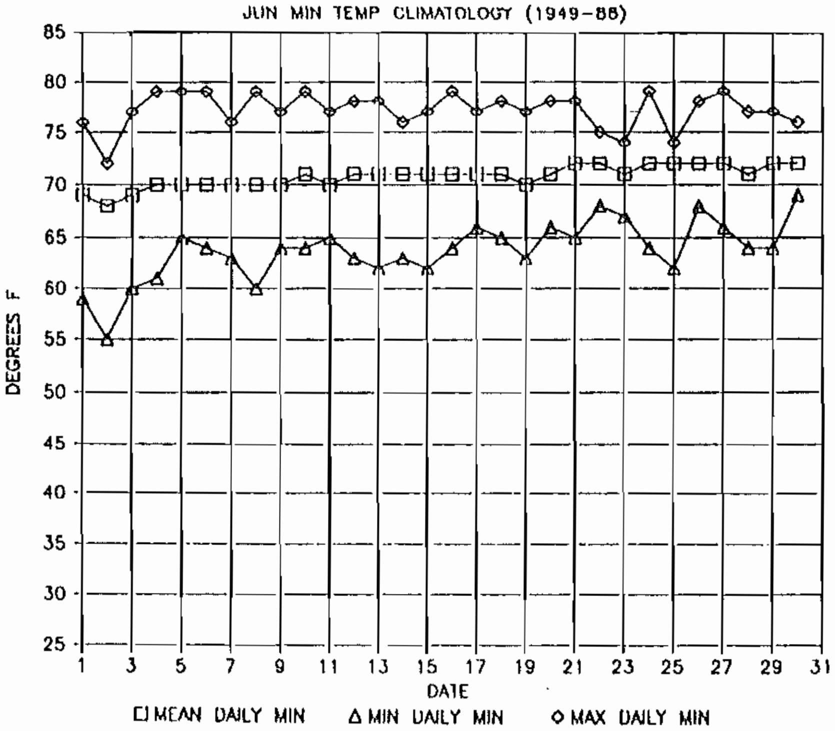
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DEGREES F
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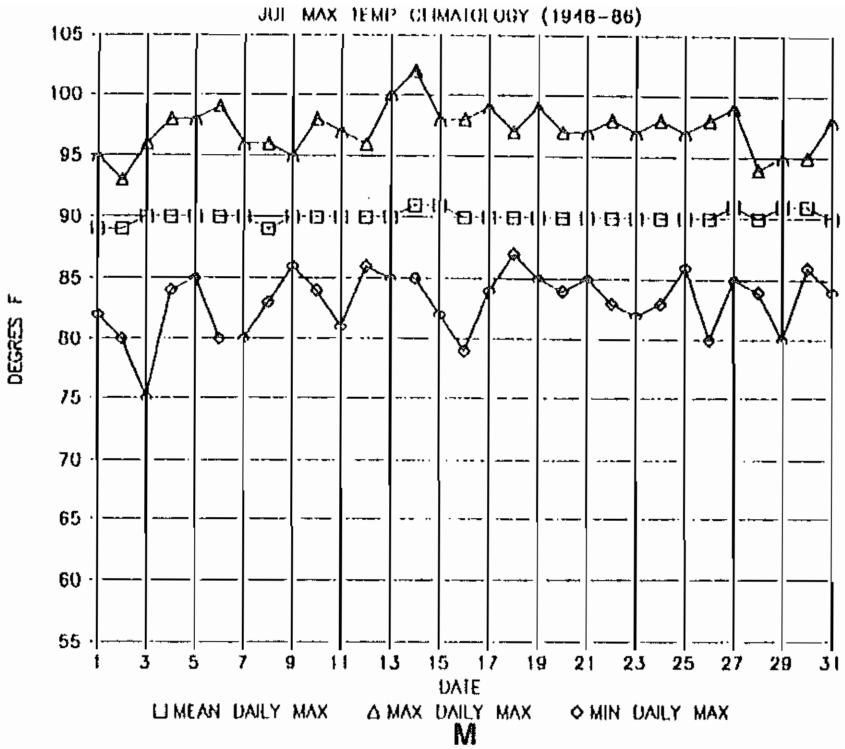
JUL MAX TEMP CLIMATOLOGY (1948-86)
DEGREES F
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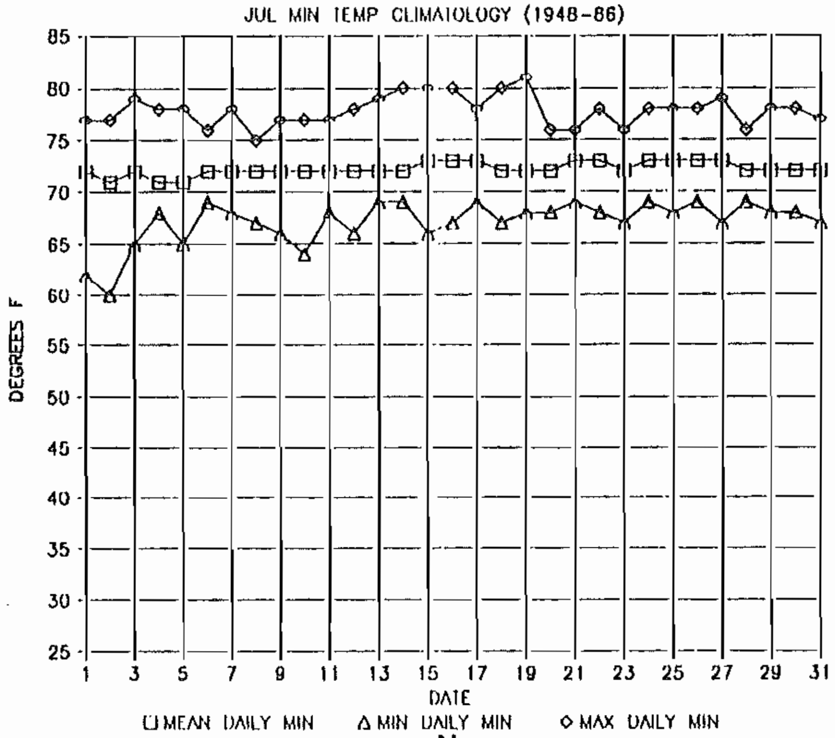
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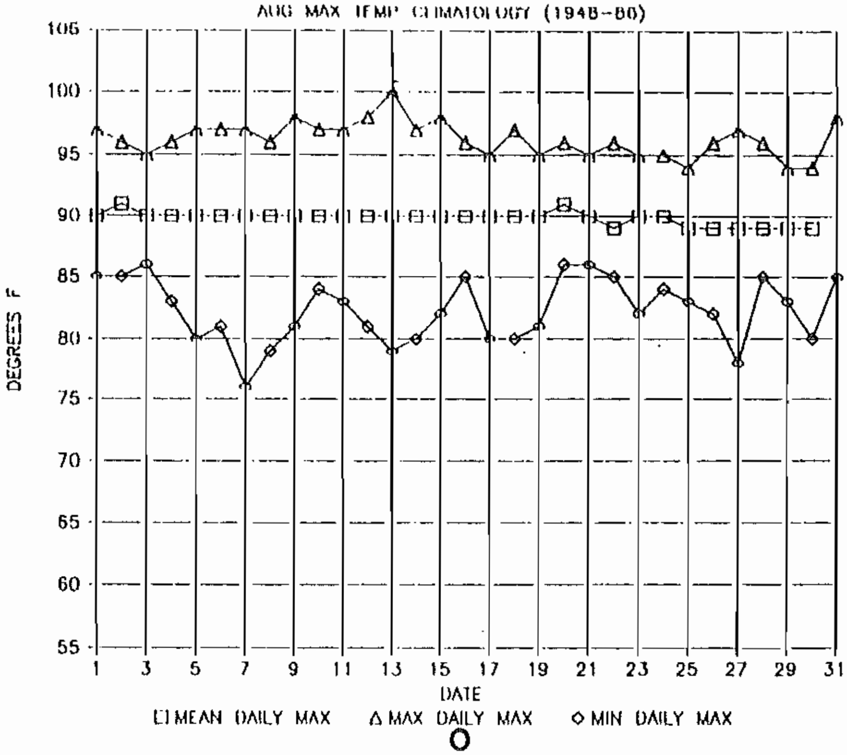
AUG MAX TEMP CLIMATOLOGY (1948-80)
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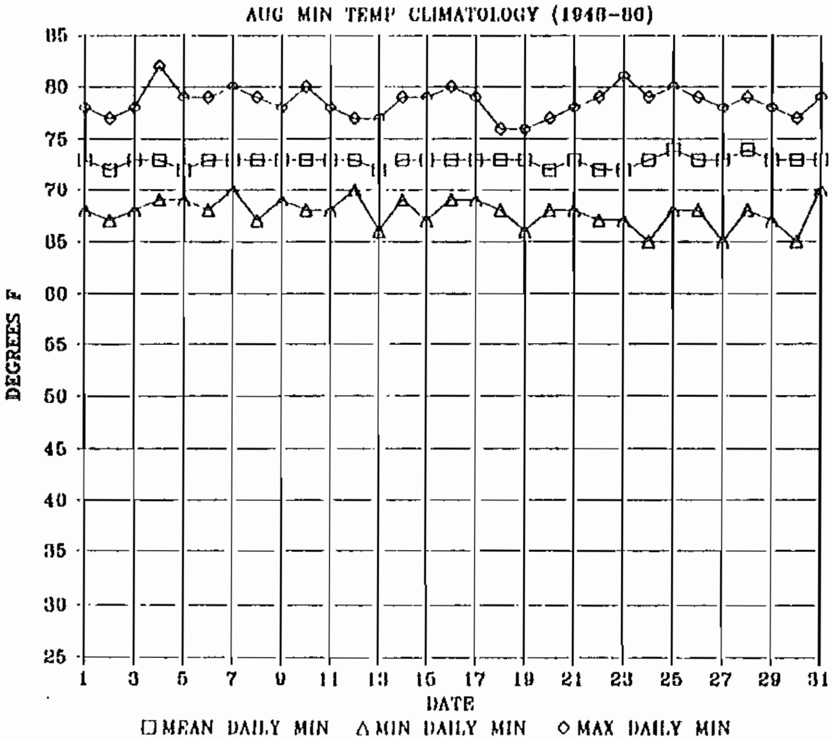
AUG MIN TEMP CLIMATOLOGY (1948-80)
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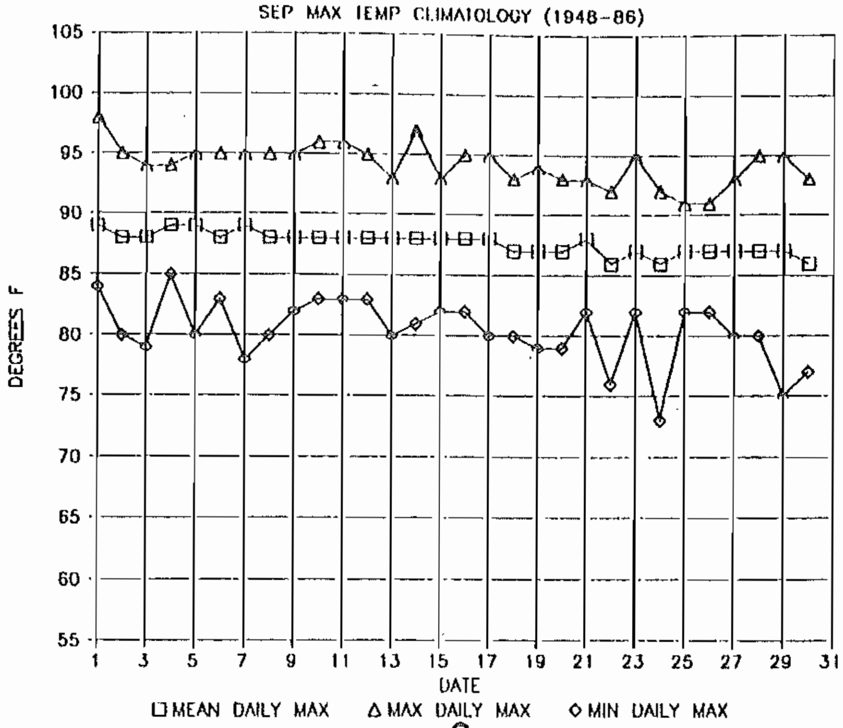
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DEGREES F
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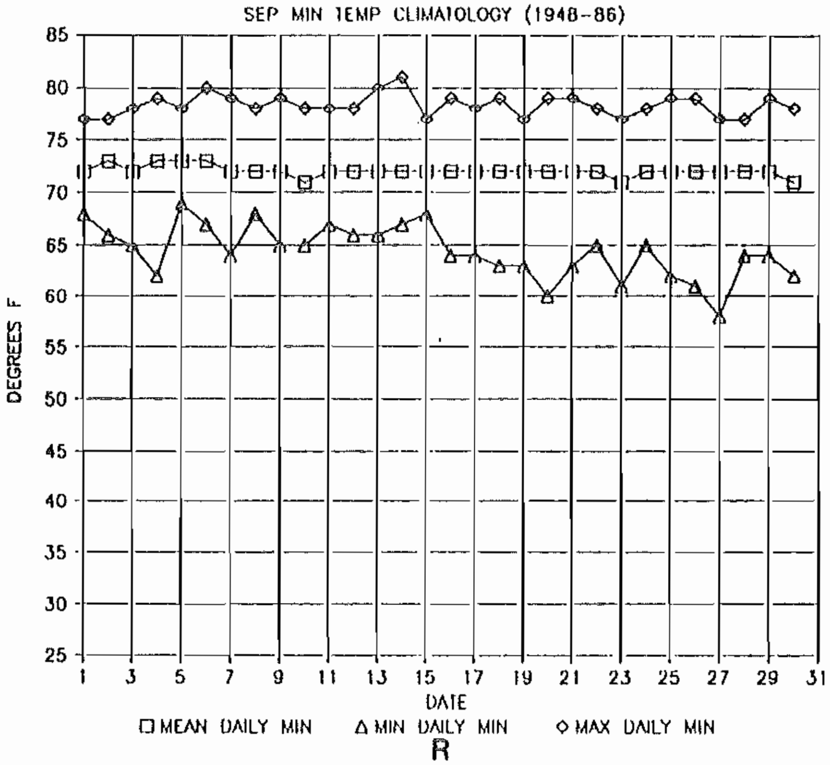
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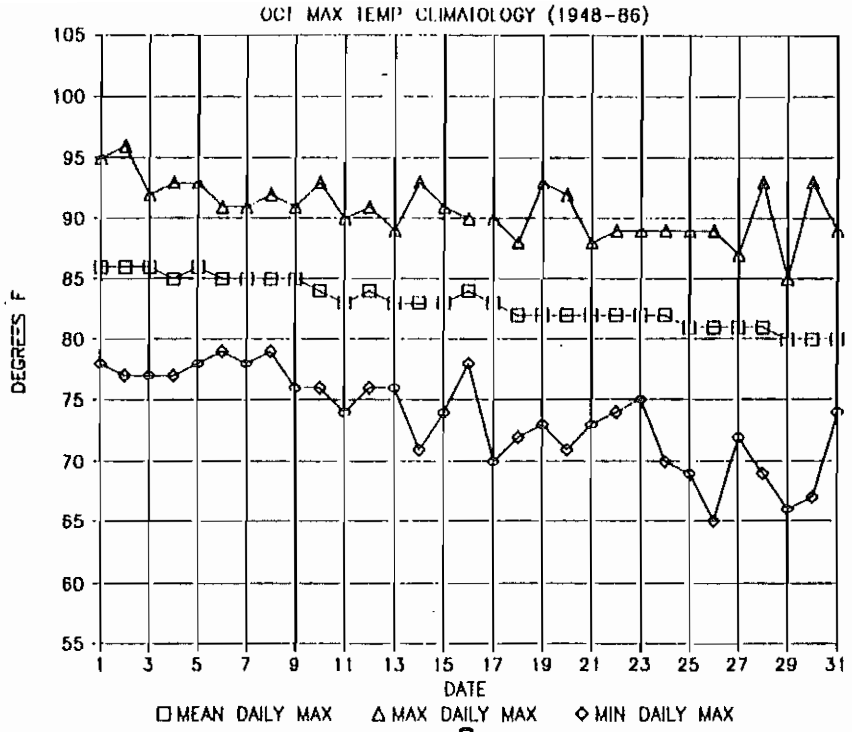
OCT MAX TEMP CLIMATOLOGY (1948-86)
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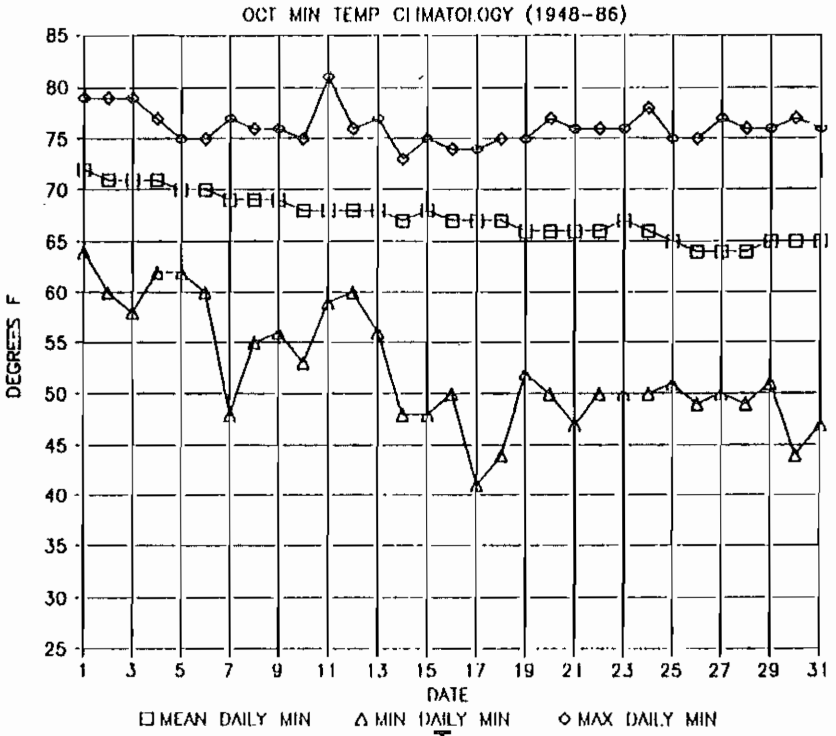
OCT MIN TEMP CLIMATOLOGY (1948-86)
DEGREES F
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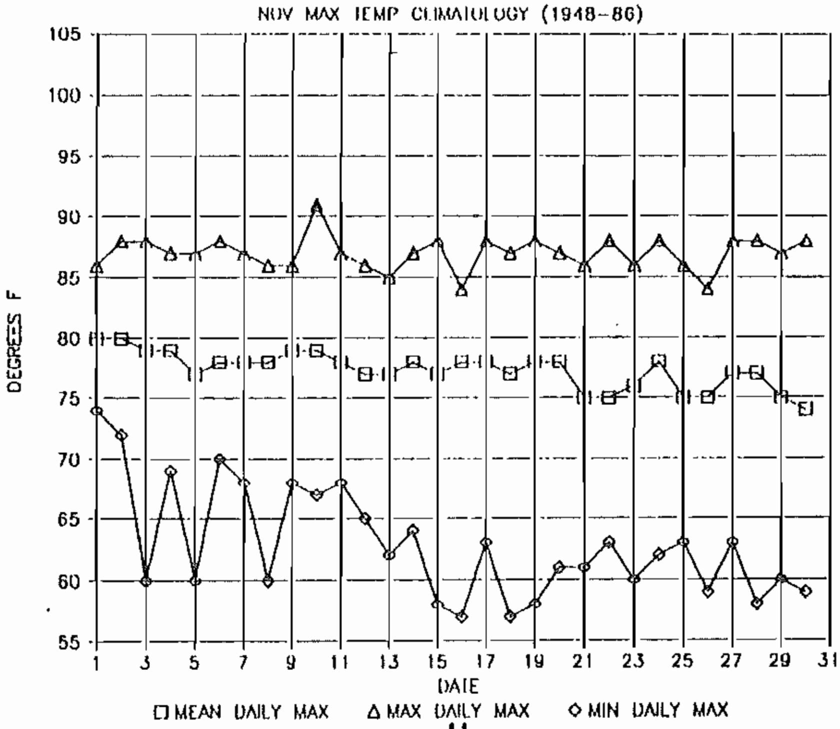
NOV MAX TEMP CLIMATOLOGY (1948-86)
DEGREES F
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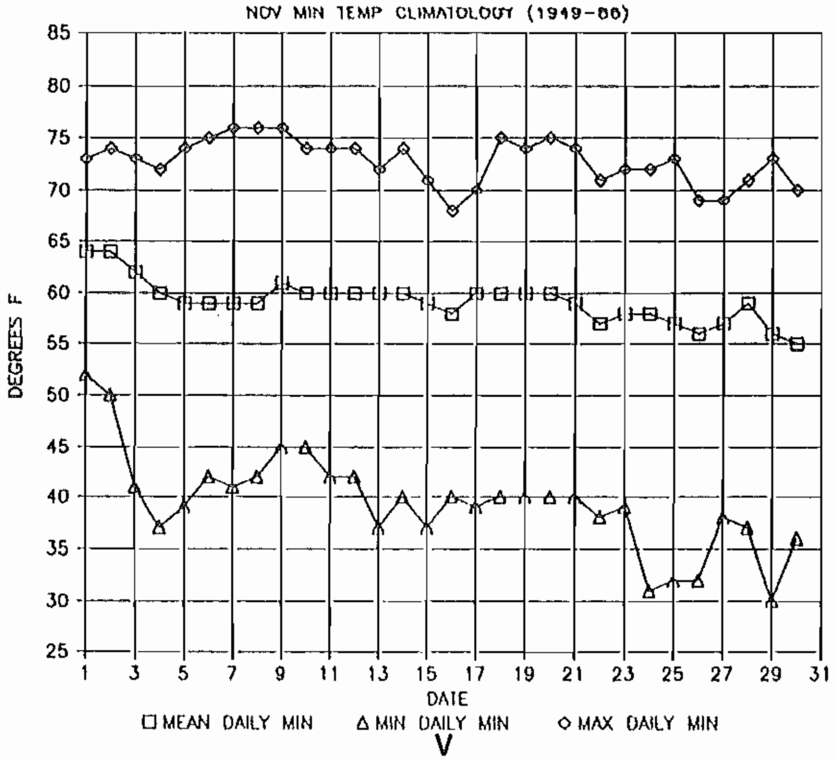
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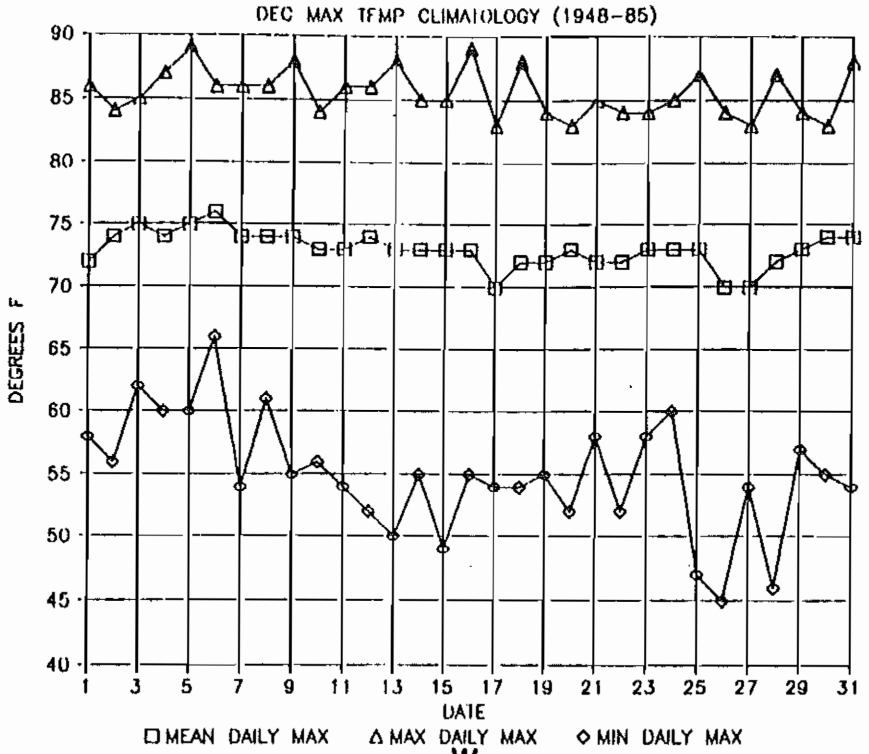
DEC MAX TEMP CLIMATOLOGY (1948-85)
DEGREES F
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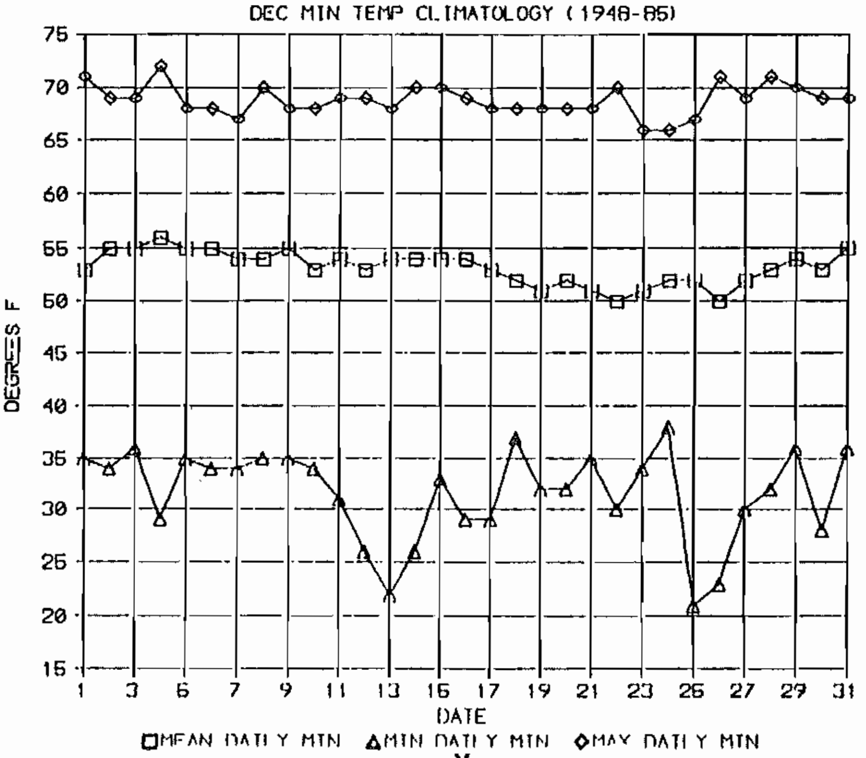
DEC MIN TEMP CLIMATOLOGY (1948-85)
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to be in place at the surface when winds shift onshore, overrunning can occur with clouds and precipitation, thus impacting the maximum. These considerations and others have to be taken into account when forecasting temperatures in October.

The final two graphs to be discussed are those of November (Figs. 8u-v). (December was discussed earlier with January and February.) The range between related extremes has once again become large. Individual record plots, especially the NDN and NDX, are now rough; and the unsmoothed means start to fluctuate. During the month, only slight cooling takes place in the XDX and XDN curves; but significant cooling occurs in the NDN and NDX curves. The result is a net cooling of the means.

Graphs such as these can be very useful for forecasters. To Melbourne forecasters, they are particularly helpful since they help compensate for the lack of statistically-based numerical guidance and local experience. Additional insight can be gained by plotting observed daily maxima and minima as they occur to identify current temperature trends. With the opening of other future WFOs at new locations, a similar analysis of climatological data may be helpful, especially during the transition stage when new forecasters are added to the staff. Climatological data are more easily interpreted in graphical form, and storing the graphs on a personal computer makes for easy updating. Consideration of the graphs on a daily basis should help forecasters to focus on pertinent forecast problems, and also identify other areas for further investigation.

4. TORNADO CLIMATOLOGY

Tornadoes are one of the most significant meteorological hazards that can affect a forecast area. Climatological information on tornado characteristics and their spatial and temporal distribution is vital to assessing the threat for any given area of the country. The tornado climatology presented here was compiled from computer printouts supplied by the Verification Section of the National Severe Storms Forecast Center (NSSFC) for the period 1950 through 1988 and include data on all documented tornadoes within a 125 nm radius of Melbourne (1002 tornadoes). The area covered extends beyond the Melbourne CWA. Indeed, a plot of the locations of all 1002 tornadoes (Fig. 9 -- Melbourne is located at the origin of the grid) shows that a majority of the tornadoes occurred in west central Florida.

Fig. 9 also shows that most of the reported tornadoes are along the coastline,where population density is high and waterspouts moving onshore account for some of the tornado reports; and along the heavily populated corridor from around Daytona Beach to Orlando to the Tampa Bay area. The sparsely populated area southwest of Melbourne shows a virtual lack of reported tornadoes. While there may be a valid meteorological reason for a lack of tornadoes in this area, a more likely explanation is that it suffers from a lack of observations, as does the COOP climatology. Thus, due to reporting problems, a large sample was desirable in order to get a better regional representation of the variety of conditions that might be expected anywhere across central Florida. Additionally, since the conditions that favor tornado and waterspout development on the west coast may be quite different from those on the east coast, data were also tabulated specifically for WFO Melbourne's CWA.

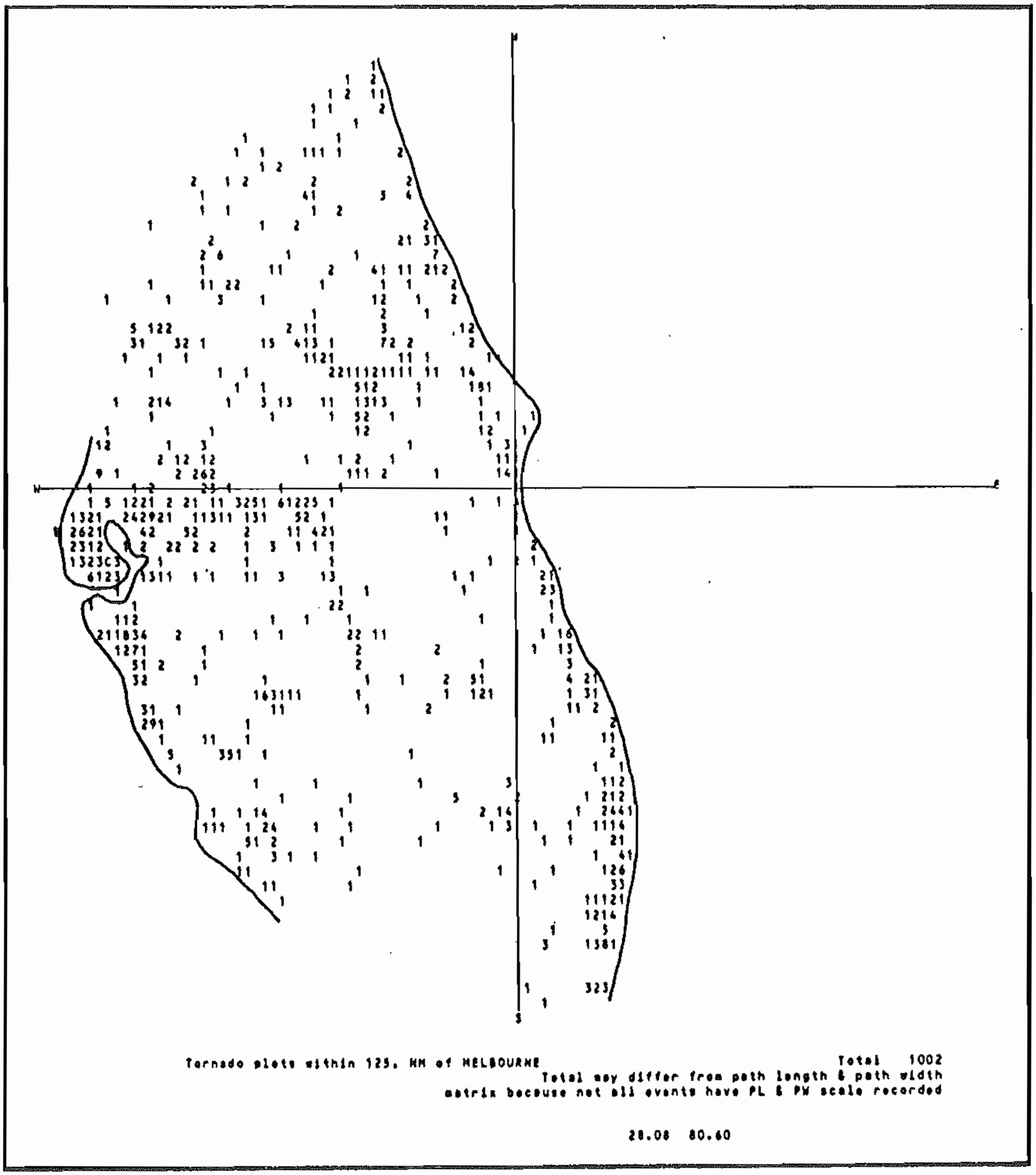


Fig. 9. Plot of <u>reported</u> tornadoes within 125 nm of Melbourne, Florida. Numbers greater than one indicate the number of tornadoes reported within the grid square (from NSSFC).

Fig. 10 is a bar graph of the monthly totals of all tornadoes reported within 125 nm of Melbourne. The graph indicates that tornado activity is at a maximum in June and a minimum in November with a secondary maximum in March. A decrease in overall tornado activity in April may seem odd, but this is a unique regional phenomena and is correlated with the decrease in April rainfall that was discussed in Section 2.

Yearly totals of weak/moderate (F0-1 [w/m]) and strong/violent (F2-5 [s/v]) tornadoes (Fujita, 1981) are shown in Fig. 11a. Most notable is the significant yearly increase in w/m tornadoes after the late 1960s that is related to better reporting procedures, but even during this period there is great annual variability in w/m tornadic activity. The occurrences of s/v tornadoes, which are most likely to be reported in any case, show no great systematic increase. Note the great annual variability in s/v tornadoes, with four years (1957, 1974, 1976 and 1984) having no s/v tornadoes, while years such as 1972 and 1983, which were strong El Niño years (Weare, 1986), each had 16.

Some general trends in s/v activity are evident with the years 1968 through 1973 being most active, and the current period from 1984 to present being very inactive. The graph of annual accumulated tornadoes (Fig. 11b) again demonstrates the dramatic increase in reported w/m tornadoes in the last 20 years compared to the gradual increase in the s/v tornadoes. The general tornado reporting and distribution characteristics and limitations discussed above have been found in many other tornado climatology studies on large scales (for example Kelly, et al, 1978, and Schaefer and Galway, 1982).

Fig. 12a is a graph of the hourly distribution for all tornadoes. The distribution approaches a normal curve with a mean time of 1500 EST. Most tornadoes occur between 1200 and 1900 EST, but tornadoes have occurred during every hour of the day.

Fig. 12b shows the average time of tornado touchdown by month for all tornadoes in the Melbourne CWA. Most notable is the observation that the mean touchdown time for all months is 1458 EST, but it is prior to noon for January through March and in the afternoon for all other months.

Figs. 13a-d show the hourly distributions of tornadoes by month and are presented to more clearly describe the monthly and seasonal characteristics of tornado occurrences. Fig. 13a shows the distributions for January, February and March. This period is clearly different from the others with most of the tornadoes occurring prior to noon. January tornadoes peak at 1100 EST with a secondary peak at 0300 EST, and February tornadoes peak at 0900 EST with a secondary peak at 1700 EST. Tornadoes for March peak at 0500 EST with a secondary peak at 1500 EST.

In April, May, and June (Fig. 13b) the majority of tornadoes occur in the early afternoon, peaking at 1300 EST in April, 1430 in May and 1500 EST in June; but there is still considerable morning activity. Tornadoes occurring in the summer months (Fig. 13c) occur almost exclusively in the afternoon and early evening hours. The highest hourly frequency of tornadoes

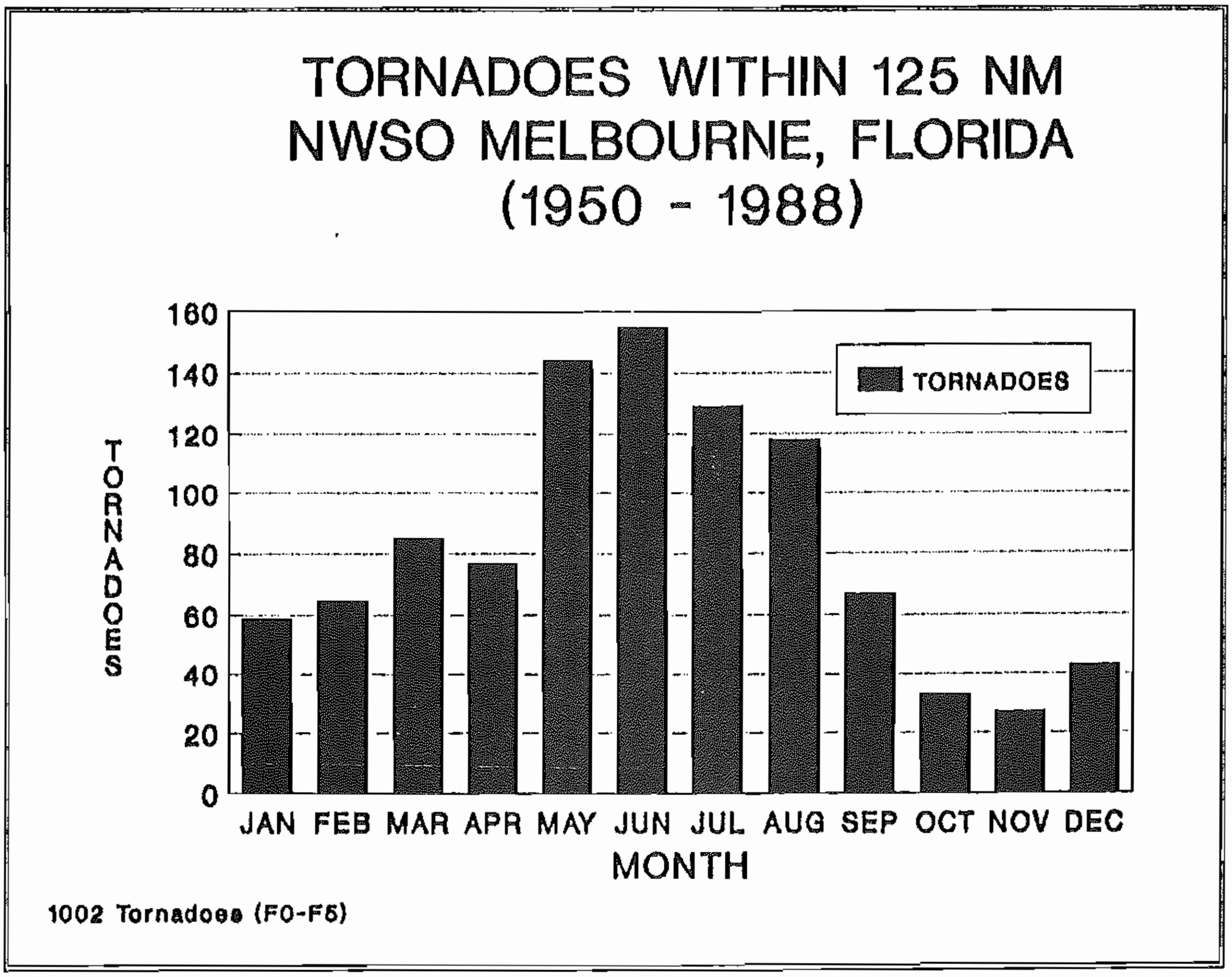

TORNADOES WITHIN 125 NM
NWSO MELBOURNE, FLORIDA
(1950 - 1988)
160
140
120
100
80
60
40
20
0
TORNADOES
TORNADOES
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
MONTH
1002 Tornadoes (F0-F5)

Figure 10.

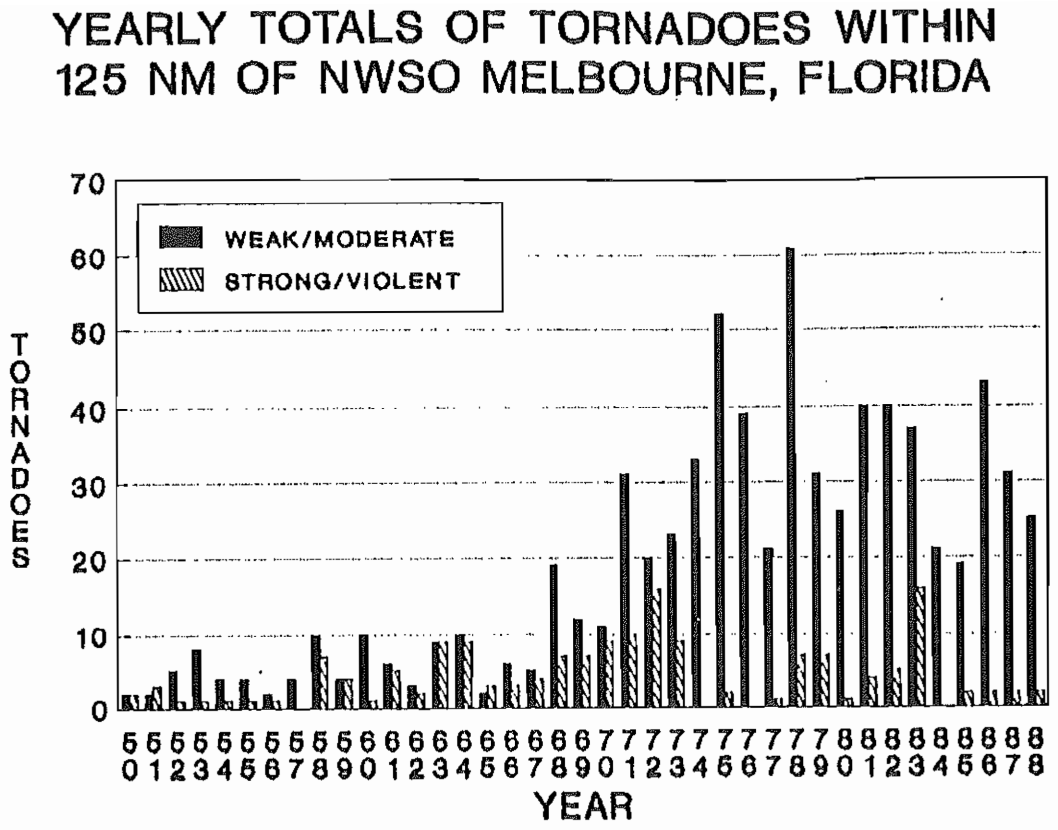


Fig. 11a.

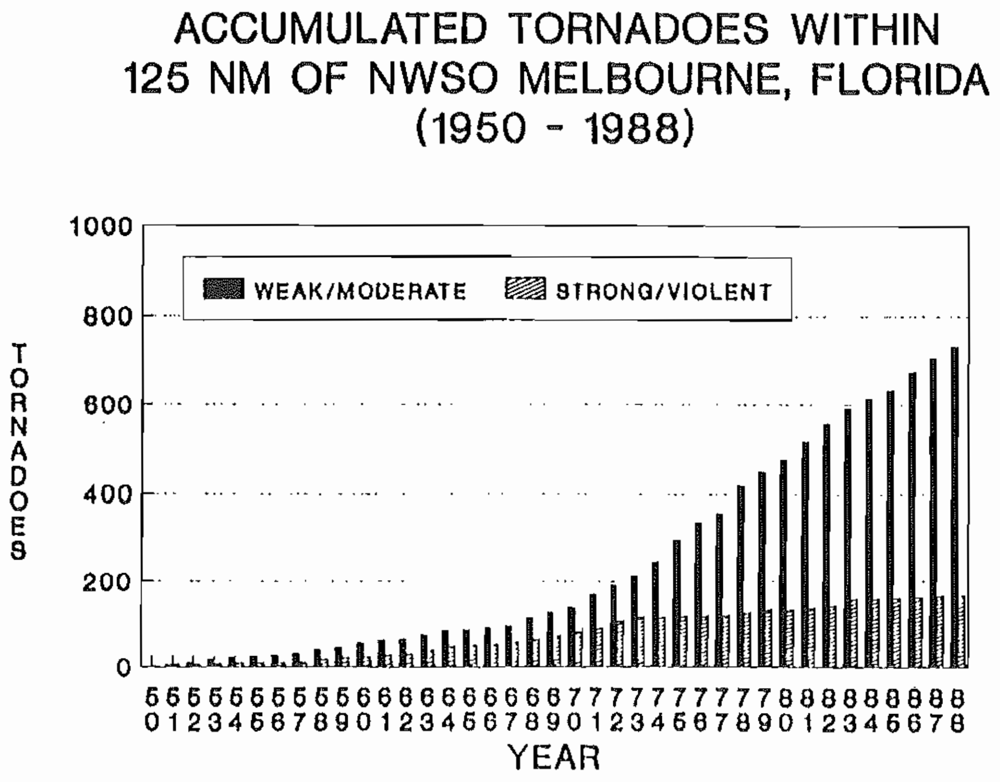
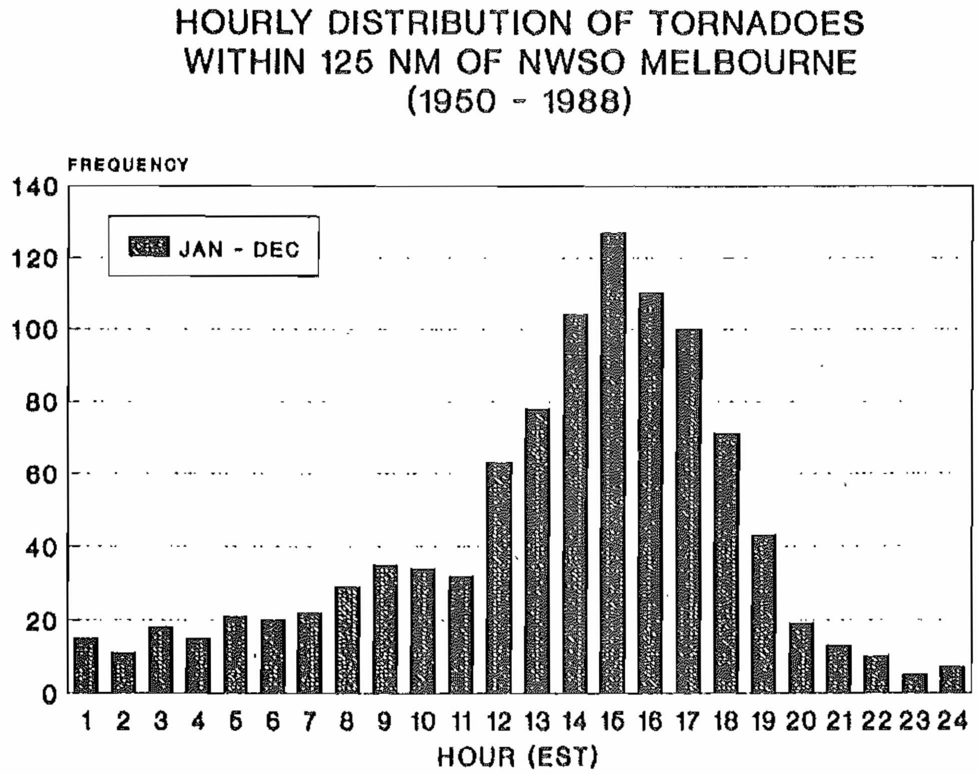
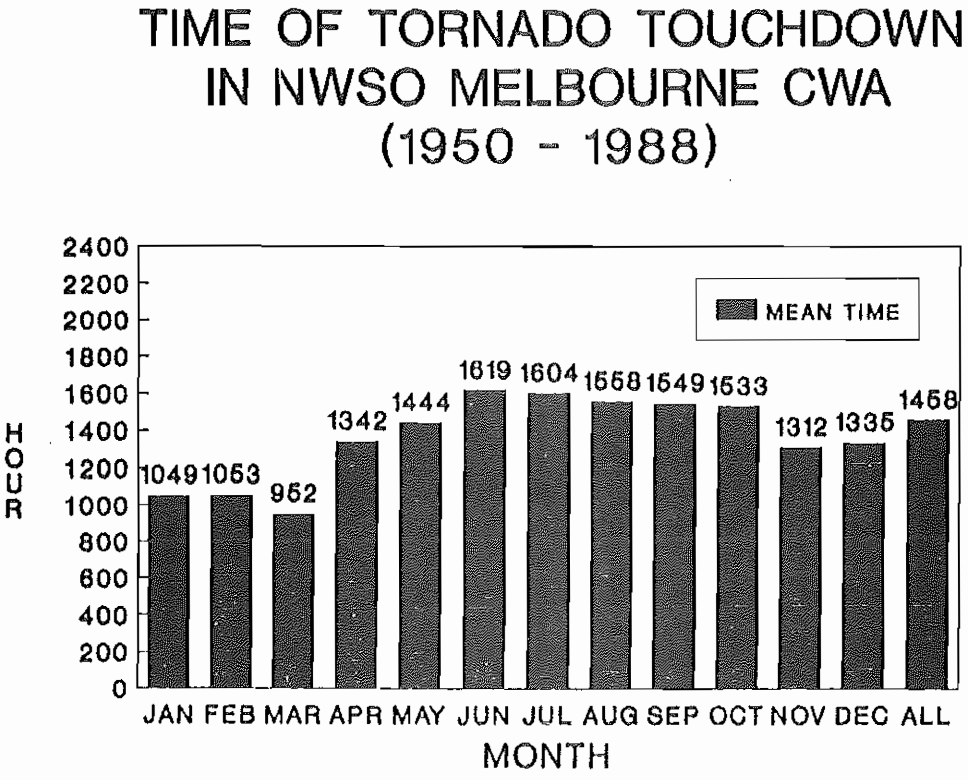


Fig. 11b.



Includes All Tornadoes (1002)

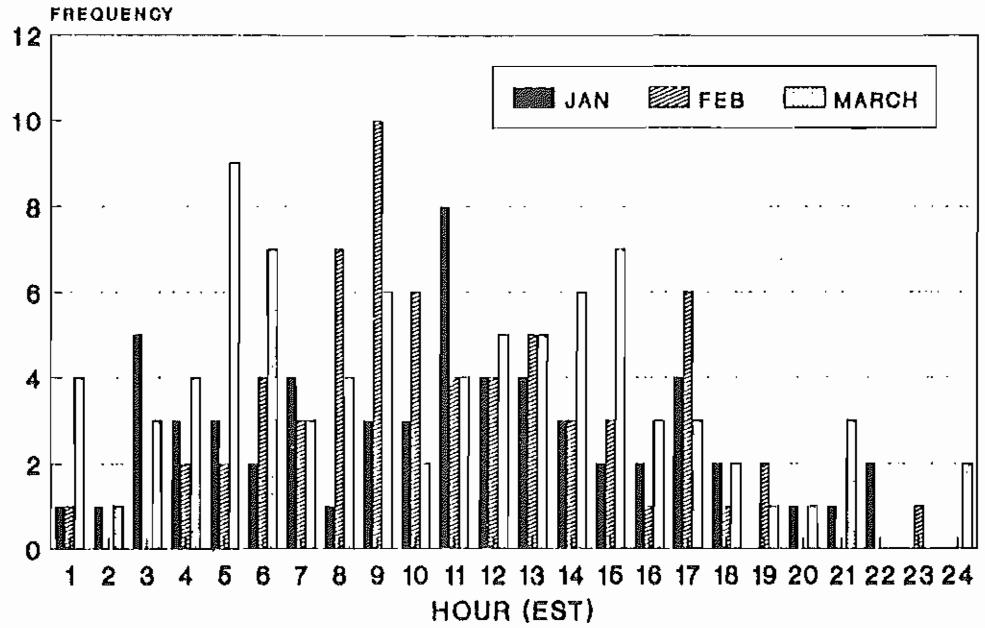
Fig. 12a.



Includes All Tornadoes

Fig. 12b.

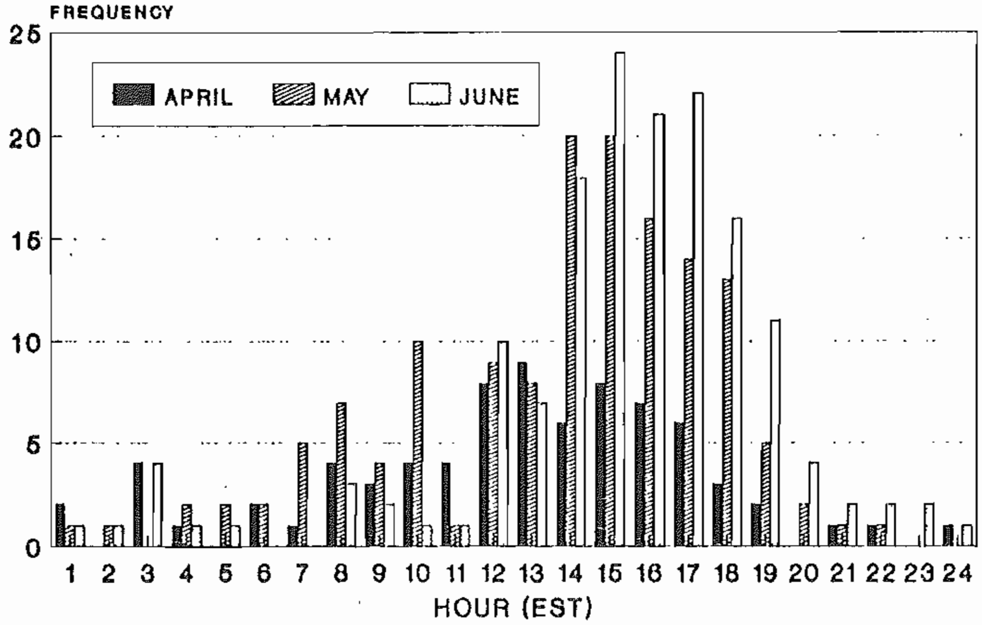
HOURLY DISTRIBUTION OF TORNADOES
WITHIN 125 NM OF NWSO MELBOURNE
(1950 - 1988)



Includes All Tornadoes

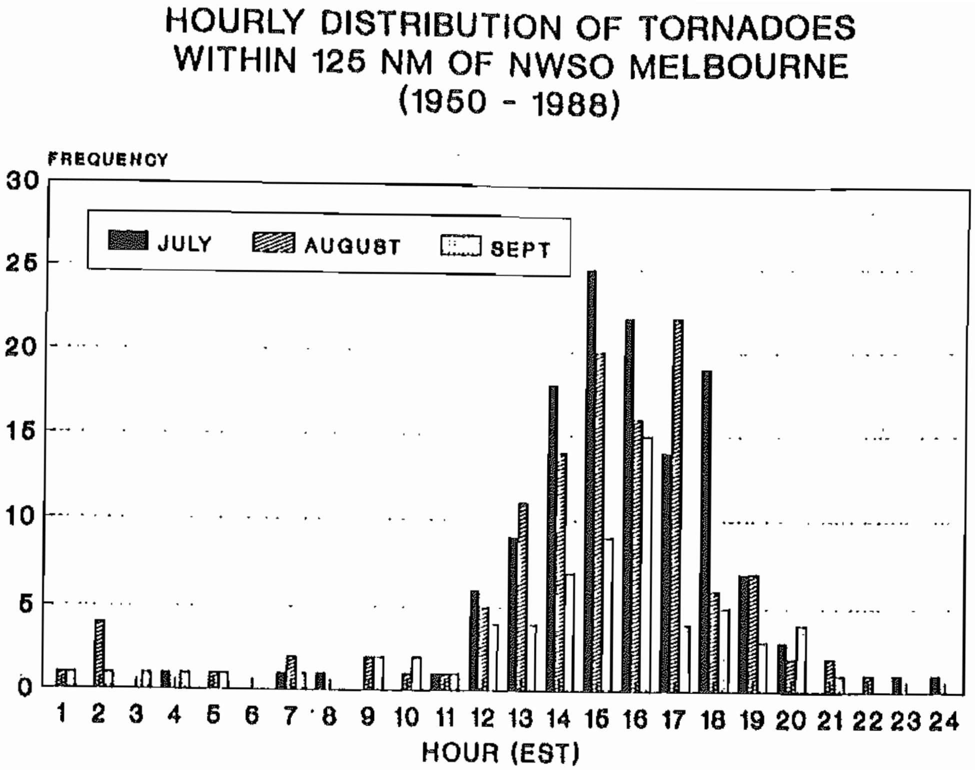
Fig. 13a.

HOURLY DISTRIBUTION OF TORNADOES
WITHIN 125 NM OF NWSO MELBOURNE
(1950 - 1988)



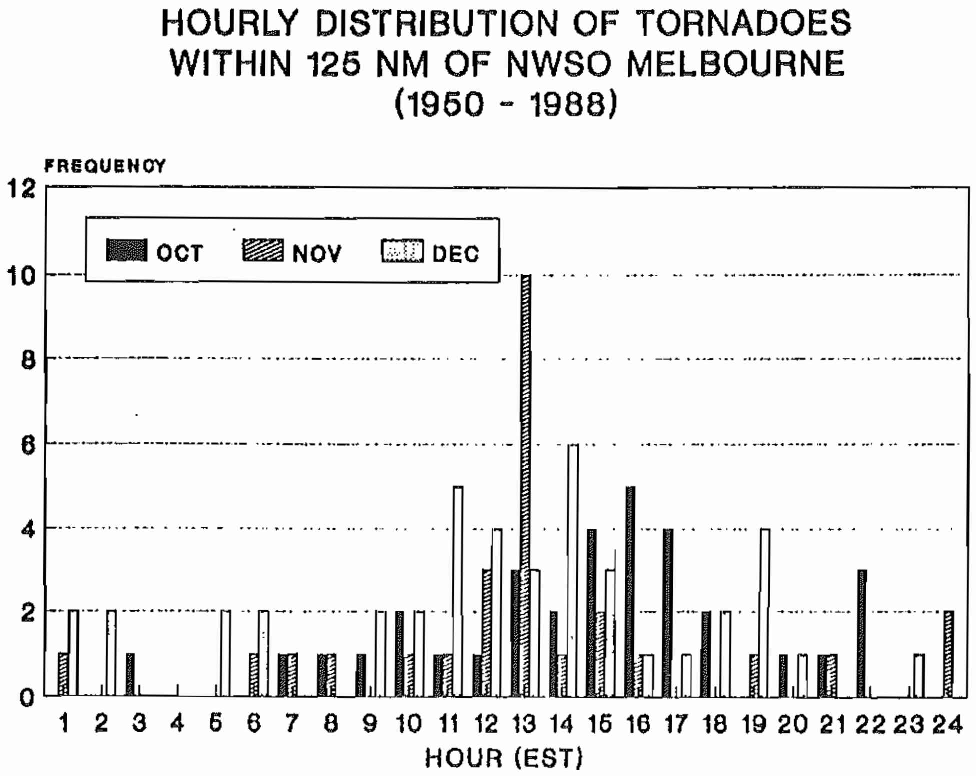
Includes All Tornadoes

Fig. 13b.


HOURLY DISTRIBUTION OF TORNADOES WITHIN 125 NM OF NWSO MELBOURNE (1950 - 1988)

Includes All Tornadoes

Fig. 13c.


HOURLY DISTRIBUTION OF TORNADOES WITHIN 125 NM OF NWSO MELBOURNE (1950 - 1988)

Includes All Tornadoes

Fig. 13d.

for the year occurs at 1500 EST in July with 25, followed by 24 at 1500 EST in June. Clearly, the timing of warm season tornadoes is closely correlated with afternoon heating.

The fewest tornadoes are recorded in the months of October, November, and December (Fig. 13d). While the hourly tornado occurrences are more evenly distributed throughout the day, there are still relative maxima for all three months in the early afternoon.

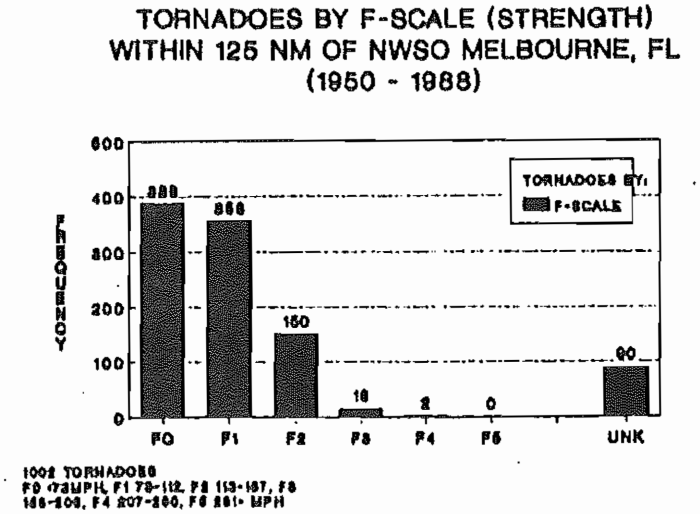
Some summary details on the characteristics of the tornadoes are provided by graphs of tornadoes by F-scale, path length, and path width shown in Figs. 14a-c, respectively. The graphs show that the majority of tornadoes are relatively weak, narrow, and short-lived. This reflects the fact that a majority of the tornadoes form during the afternoon in the warm season due to thermal forcing in a weak dynamic environment. The average tornado, computed from all tornado reports with sufficient data, has an F-scale of 0.8, a path length of 1.2 miles, and a path width of 50 yards. Fig. 14a shows that there has never been a reported F5 tornado (wind speeds >260 mph) within 125 nm of Melbourne; but 2 F4's, 16 F3's, and 150 F2's have been documented. It is desirable to look in more detail at the temporal characteristics of the strong tornadoes reported in Melbourne's CWA.

The monthly frequencies of s/v tornadoes (F2-5), and killer and injury tornadoes (regardless of F-Scale), for the ten counties in Melbourne's CWA only are shown as Fig. 15a. Strong and violent tornadoes and/or injury tornadoes have occurred in every month of the year with maximum frequency in March and April compared to the all tornado population which has a maximum frequency in June. There have been four killer tornadoes in the Melbourne CWA, two in April and two in September. It is of interest to note that the September tornadoes were <u>not</u> associated with tropical cyclones, as might be expected. These cases may be looked into in more detail.

The hourly distribution of s/v tornadoes, and killer/injury tornadoes, are shown as Fig. 15b. It is interesting to note that while the all tornado population distribution (Fig. 12a) shows a distinct maximum centered around 1500 EST, the s/v tornadoes are much more evenly distributed throughout the day, with 35 occurring before noon and 32 after noon. There were 15 injury tornadoes before noon and 16 after noon, but all four killer tornadoes occurred in the morning (2, 4, 8, and 10am). Clearly the s/v tornadoes depend more on strong dynamics, regardless of the time of day, than on strong surface heating in the afternoon, as is typically the case with the w/m tornadoes.

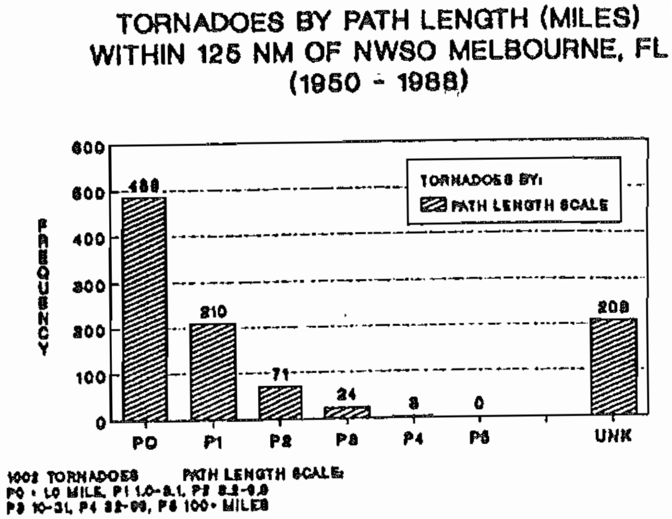
The hourly distributions of s/v tornadoes by month are shown as Figs. 16a-l. There are generally not enough cases in each month to allow confident interpretations of the significance of temporal trends, but the presentations are nonetheless instructive. Notable is that of the relatively large samples of s/v tornadoes found in March and April, nearly all occurred in the morning.

The climatological analyses demonstrate that the tornado threat within 125 nm of Melbourne is significant, averaging 26 tornadoes a year since 1950, and showing great year-to-year variability. The data clearly indicate two significant forecast problems: (1) the frequent


TORNADOES BY F-SCALE (STRENGTH) WITHIN 125 NM OF NWSO MELBOURNE, FL (1950 - 1988)

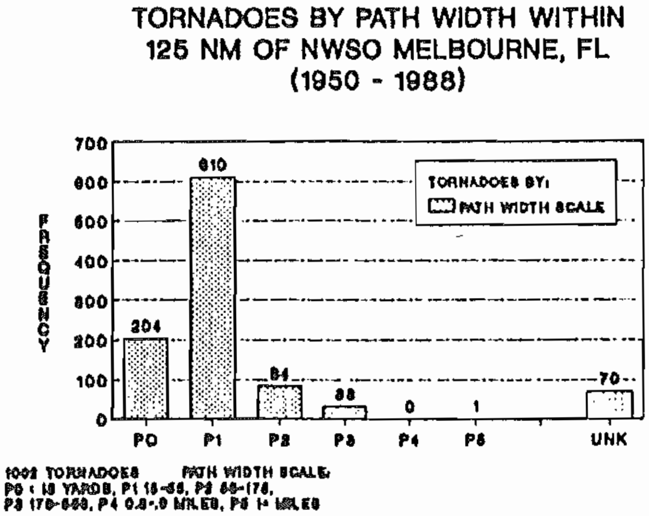
1002 TORNADOES
F0 <73MPH, F1 73-112, F2 113-157, F3 158-206, F4 207-260, F5 261+ MPH

A


TORNADOES BY PATH LENGTH (MILES) WITHIN 125 NM OF NWSO MELBOURNE, FL (1950 - 1988)

1002 TORNADOES PATH LENGTH SCALE:
P0 < 1.0 MILE, P1 1.0-3.1, P2 3.2-9.9
P3 10-31, P4 32-99, P5 100+ MILES

B


TORNADOES BY PATH WIDTH WITHIN 125 NM OF NWSO MELBOURNE, FL (1950 - 1988)

1002 TORNADOES PATH WIDTH SCALE:
P0 < 18 YARDS, P1 18-55, P2 56-175,
P3 176-556, P4 0.3-.9 MILES, P5 1+ MILES

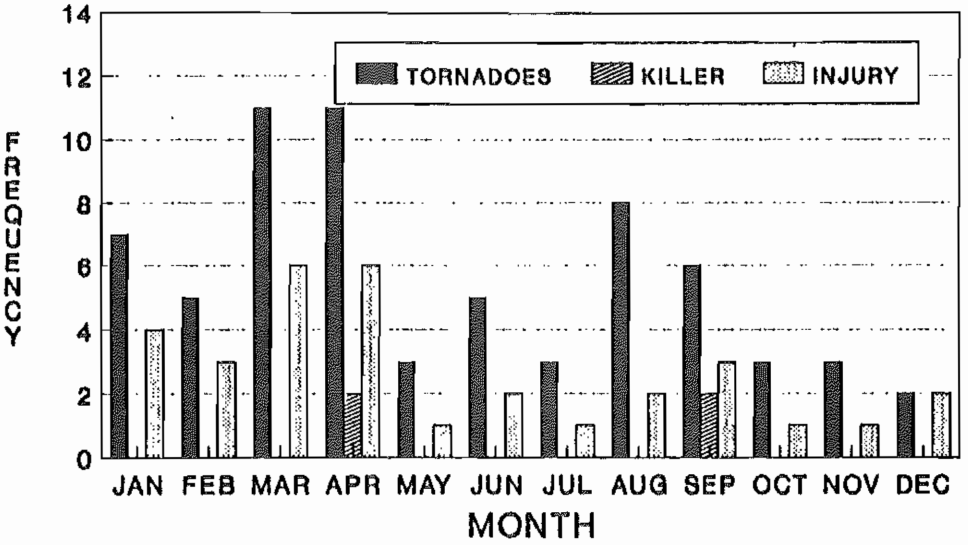
C

AVERAGE F-SCALE: 0.78
AVERAGE PATH LENGTH: 1.163 Miles
AVERAGE PATH WIDTH: .015 Miles 50yards

Fig. 14a-c. Tornadoes by F-Scale (14a), path length (14b), and path width (14c).

STRONG AND VIOLENT TORNADOES IN NWSO MELBOURNE CWA

(1950 - 1988)

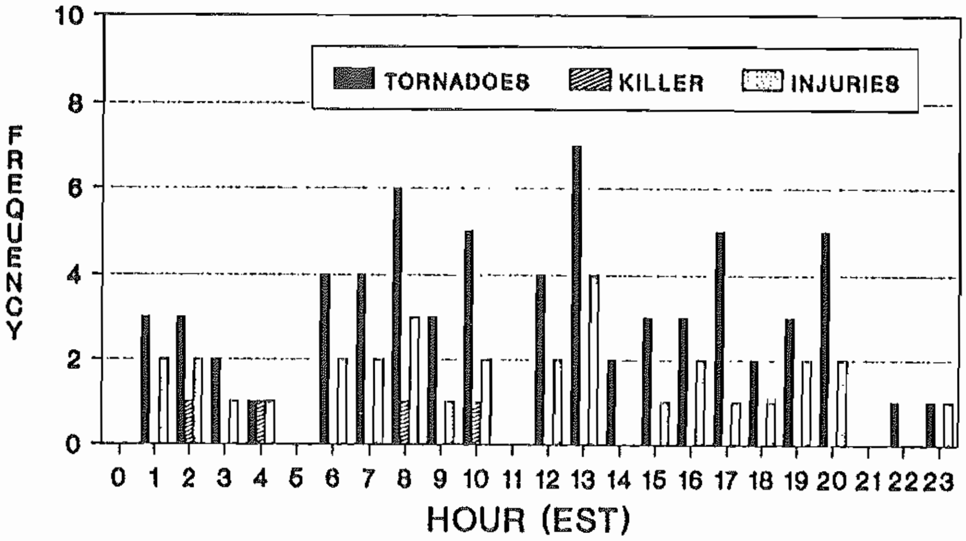


F2 to F5 Tornadoes Only

Figure 15a.

STRONG AND VIOLENT TORNADOES IN NWSO MELBOURNE CWA

(1950 - 1988)



F2 to F5 Tornadoes Only

Figure 15b.

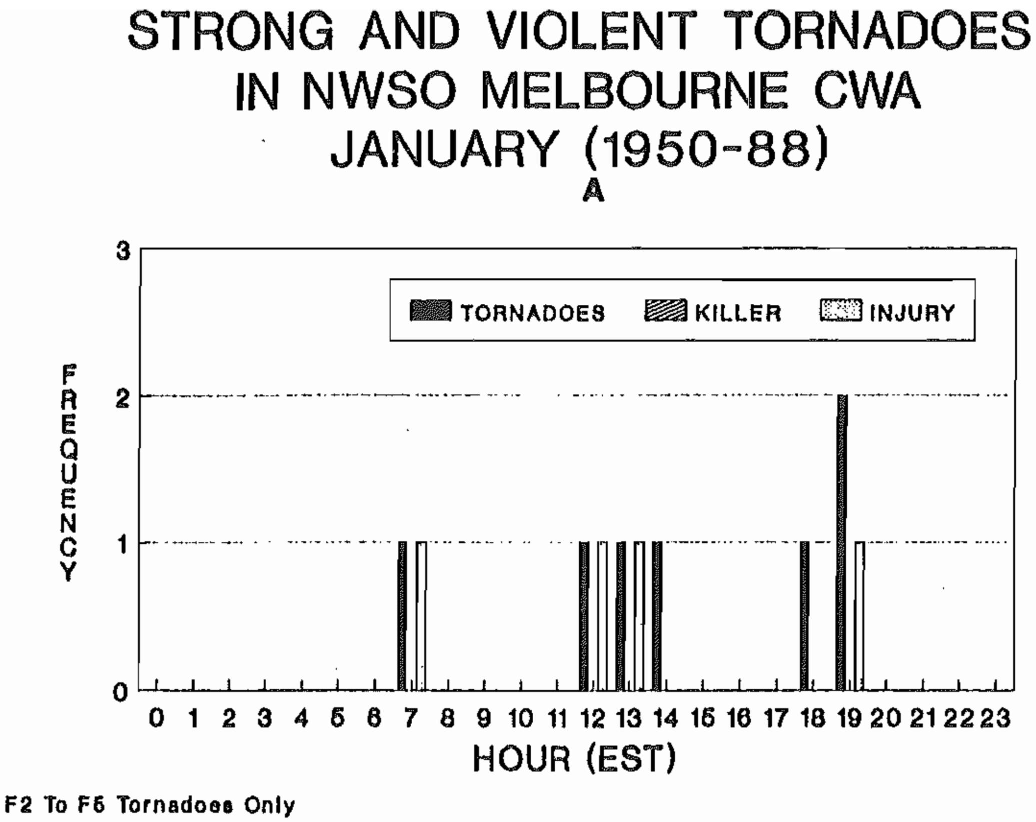
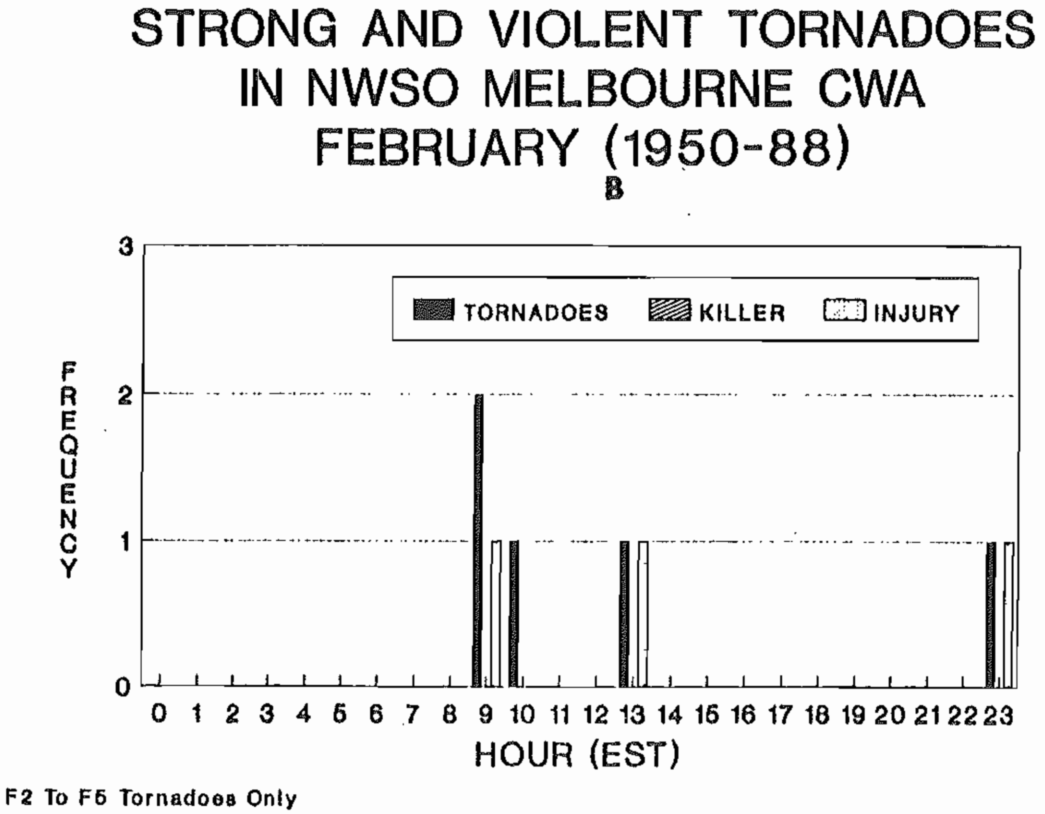
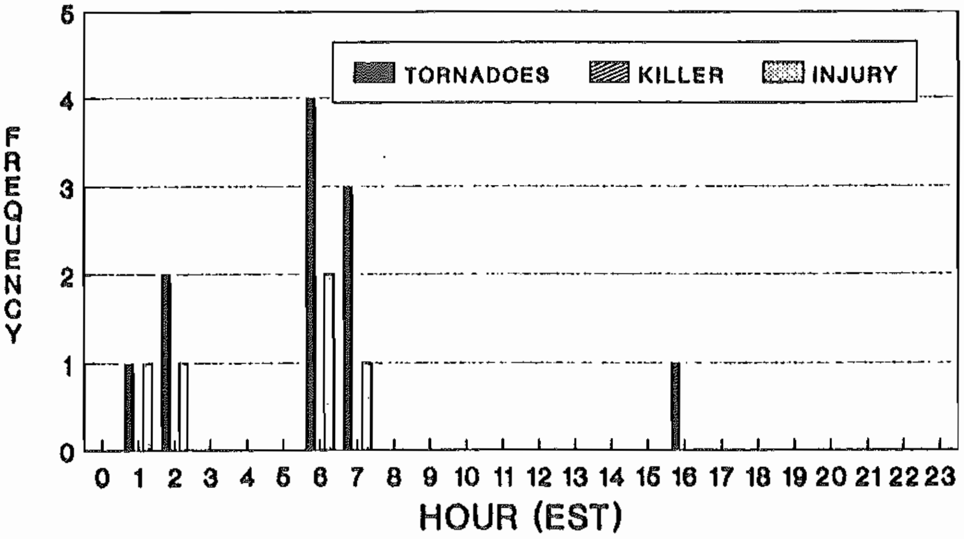


Figure 16a-1. Strong and violent, killer, and injury tornadoes reported by month in WFO Melbourne's CWA.1



STRONG AND VIOLENT TORNADOES
IN NWSO MELBOURNE CWA
MARCH (1950-88)

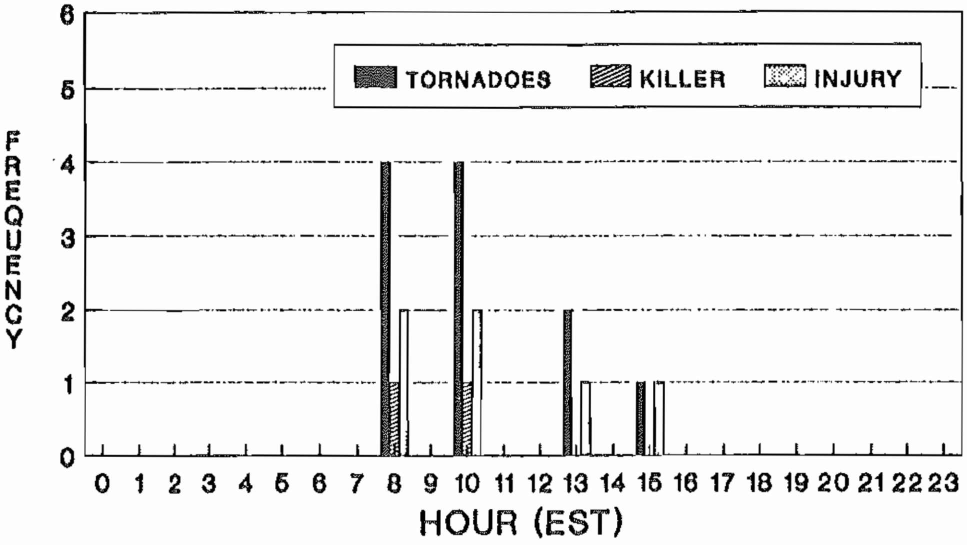
C



F2 To F5 Tornadoes Only

STRONG AND VIOLENT TORNADOES
IN NWSO MELBOURNE CWA
APRIL (1950-88)

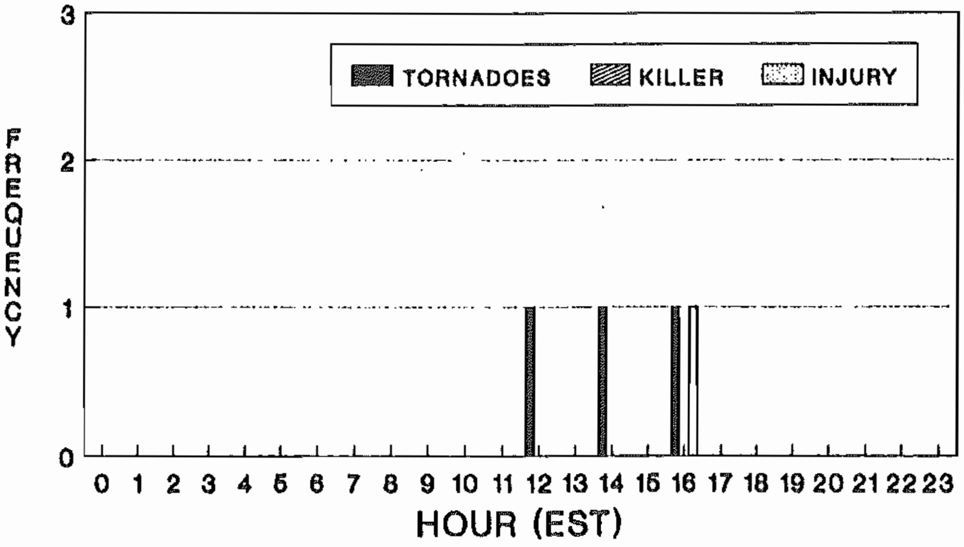
D



F2 To F5 Tornadoes Only

STRONG AND VIOLENT TORNADOES IN NWSO MELBOURNE CWA
MAY (1950-88)

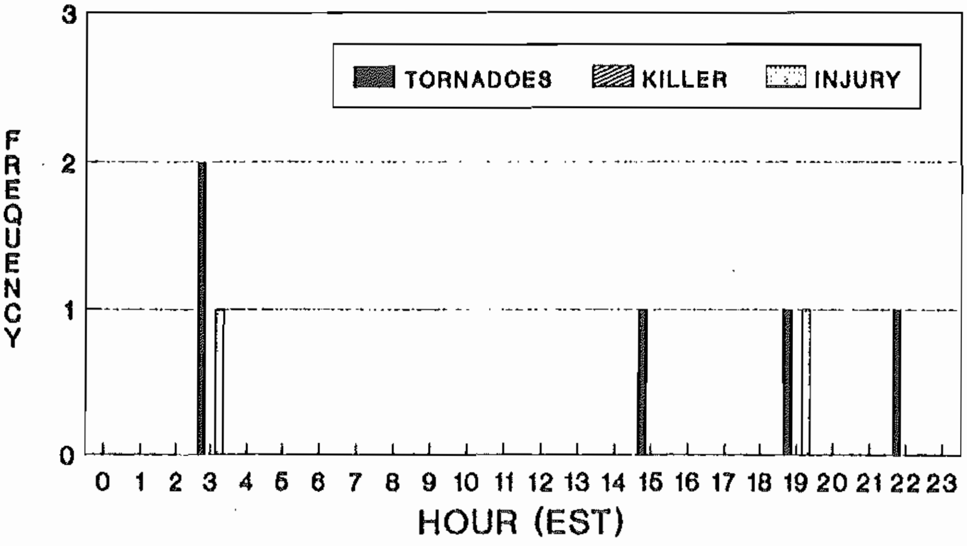
E



F2 To F5 Tornadoes Only

STRONG AND VIOLENT TORNADOES IN NWSO MELBOURNE CWA
JUNE (1950-88)

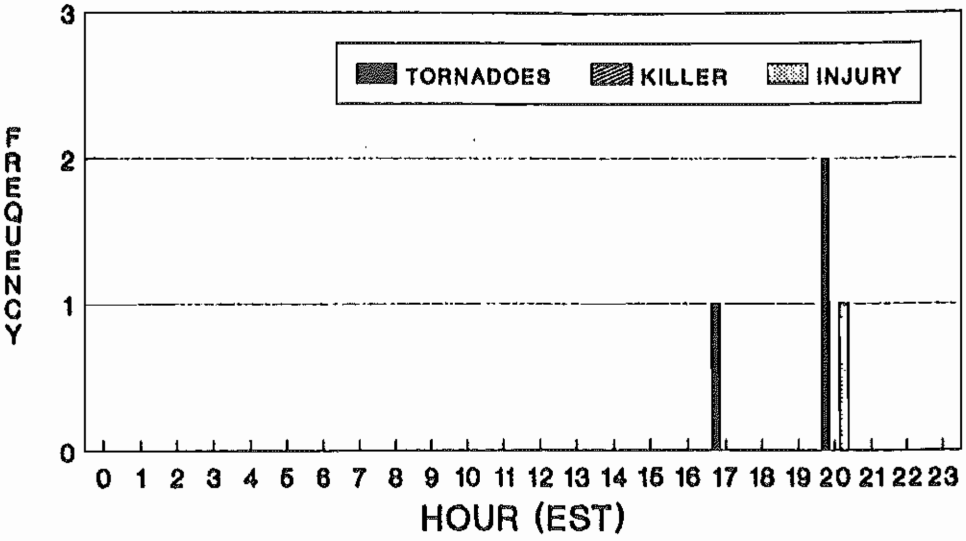
F



F2 To F5 Tornadoes Only

STRONG AND VIOLENT TORNADOES IN NWSO MELBOURNE CWA
JULY (1950-88)

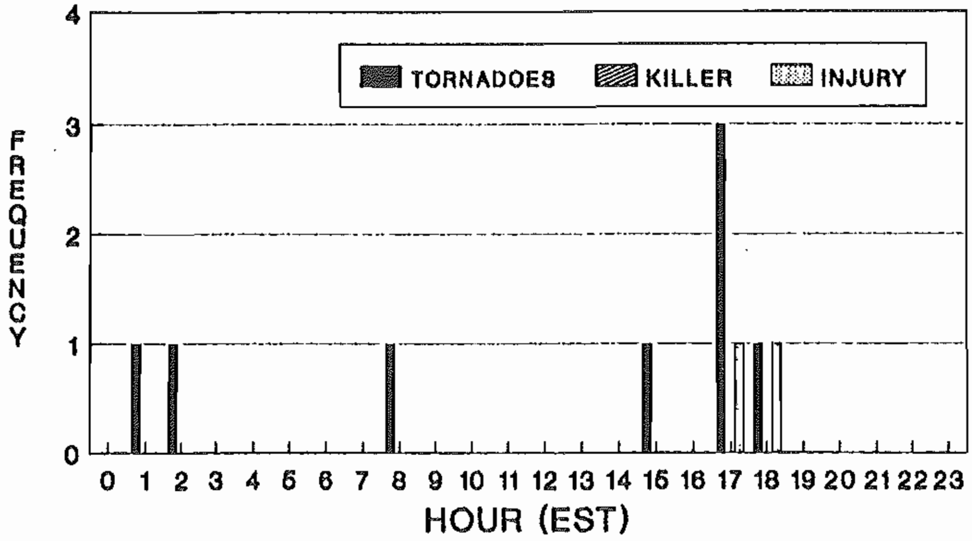
G



F2 To F5 Tornadoes Only

STRONG AND VIOLENT TORNADOES IN NWSO MELBOURNE CWA
AUGUST (1950-88)

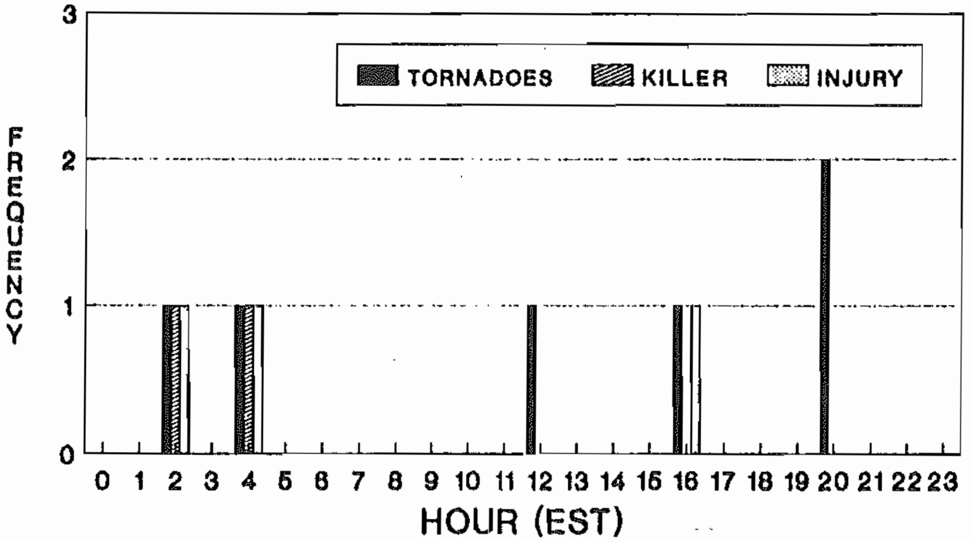
H



F2 To F5 Tornadoes Only

STRONG AND VIOLENT TORNADOES
IN NWSO MELBOURNE CWA
SEPTEMBER (1950-88)

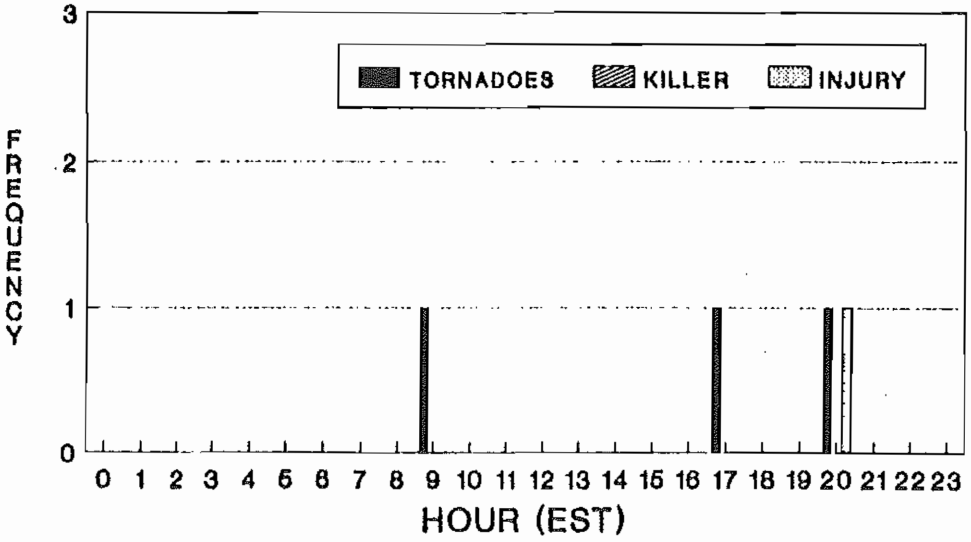
I



F2 To F5 Tornadoes Only

STRONG AND VIOLENT TORNADOES
IN NWSO MELBOURNE CWA
OCTOBER (1950-88)

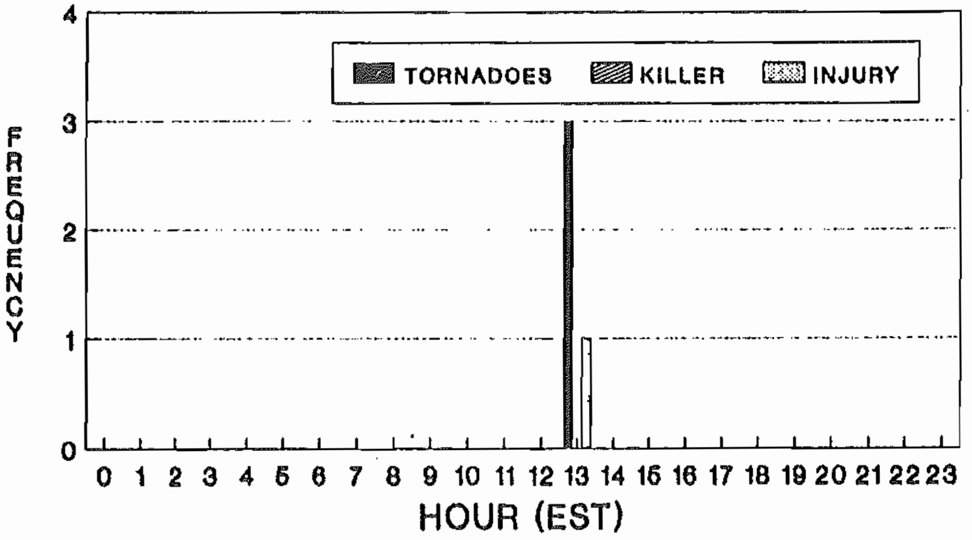
J



F2 To F5 Tornadoes Only

STRONG AND VIOLENT TORNADOES IN NWSO MELBOURNE CWA NOVEMBER (1950-88)

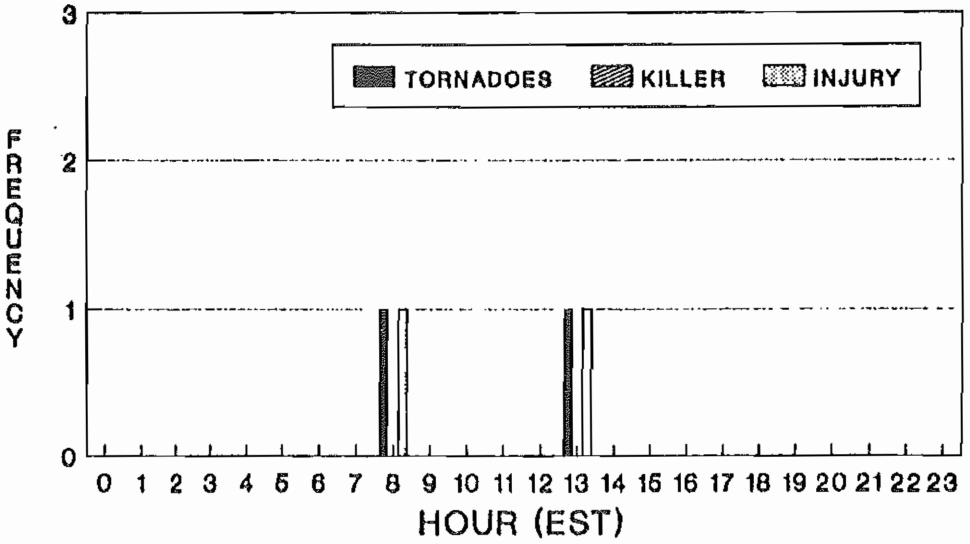
K



F2 To F5 Tornadoes Only

STRONG AND VIOLENT TORNADOES IN NWSO MELBOURNE CWA DECEMBER (1950-88)

L



F2 To F5 Tornadoes Only

occurrence of weak, short-lived tornadoes during the afternoon in the summer, sometimes originating as waterspouts over the Atlantic Ocean and inland waterways, and (2) the occurrence of strong tornadoes causing injury, death, and considerable damage during the morning hours in late winter and spring.

This broad look at the tornado climatology serves as a baseline of knowledge and logically leads to the desire for more detailed studies directly relating to significant forecast problems. It is much quicker, and more logical, to train forecasters by looking at past events and developing historical case studies, rather than waiting for events to happen and then studying them.

After reviewing the tornado data, the following subjects were identified as specific topics for further investigation:

(1) The synoptic climatology of all cases since 1950 when at least five tornadoes occurred within a four-hour period, and at least one of the tornadoes occurred in Melbourne's CWA (17 cases -- a subjective definition of a central Florida tornado "outbreak").

(2) A study of the weather regime of June 1981 when w/m afternoon tornadoes occurred on 11 of 30 days, including a five consecutive day period.

(3) A case study of the worst recorded tornado event in the history of central Florida on April 4, 1966, when a tornado travelled from the Tampa Bay area to near Cape Canaveral killing 11 people and injuring over 500.

(4) A study of 0000 and 1200 UTC proximity upper-air soundings taken within ±2 hours of tornado touchdowns within Melbourne's CWA, with particular emphasis on the comparison between the vertical profile of the environmental wind in morning and afternoon tornadoes. This information may well have important applications involving vertical wind profiles from the WSR-88D Doppler radar and the Cape Canaveral wind profiler Melbourne forecasters will have access to beginning in 1991.

These studies are under way and ideally should be completed by the WSR-88D commissioning date.

5. CONCLUDING REMARKS

The three climatological analyses presented here have already been found to be helpful in better understanding our new forecast environment. They provide not only the beginning of a fundamental baseline of meteorological knowledge, but a focusing mechanism for consideration of future operational research projects and directions. Much more work needs to be done, and additional studies are in progress. These studies should not be looked upon as a means to an end, but rather as a starting point. They are part of a continuum of meteorological knowledge covering all scales that must be accumulated, analyzed, evaluated, and re-evaluated in an ongoing process as we move into the modernized era. We should move forward with an operational philosophy geared toward solving problems much like the philosophy of method put forth by

Scorer (1958). The philosophy is even more valid today, as we are soon to gain access to new technology and data sets. His thoughts are paraphrased below:

> There will always be an infinity of phenomena which we do not understand. Our task is to select from the complexity of Nature problems which we can solve. Generally the procedure is not to pose problems, but to construct an ever-growing edifice of theory and knowledge which we call science, and as it grows we find that phenomena we have observed begin to fall into place. We have to try all the time to fit what we see into a theory, or pattern; and the inspiration comes when we notice something which will not fit....

ACKNOWLEDGMENTS

Dan Smith, Chief, Scientific Service Division, Southern Region Headquarters, provided the tornado data through the Verification Section of the NSSFC. Cooperative climatological data were provided by Robert L. Money, Acting Chief, Climate Services Division of the NCDC. Peggy France and Robert Goree contributed to the preparation of the tornado graphics. Mike Turner drew the original map backgrounds for the temperature and precipitation analyses. Thanks to Mike Sabones, Science and Operations Officer, WSO Melbourne, and Paul Hebert, NWS Florida Area Manager, for reviewing the manuscript and making suggestions for improvement.

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