FREEZES AND HURRICANES IN FLORIDA

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Abstract

In recent decades, frequent freezes have caused multi-million dollar losses in the Florida citrus industry, while hurricane activity has had minimal effect. (Hurricane Andrew of August 1992 affected areas south of the major citrus-growing area.) An examination of major freeze events and hurricane events which affected the primary citrus-growing area during the period 1885–1990 revealed a statistically significant negative correlation between the occurrence of a major winter freeze and a hurricane event the following summer or fall. In addition, there appears to be significant maxima and minima of both major freezes and hurricanes over periods of several decades which also tend to be mutually exclusive. These results suggest that long-term economic planning should consider both of these phenomena carefully.

1. Introduction

Freezes and hurricanes are the greatest meteorological threats to the citrus industry in Florida. In the decades of the 1960s, 1970s, and, especially, the 1980s, Florida had six freeze events which resulted in multi-million dollar losses to the citrus industry. After hurricane Donna in 1960, no major[1] hurricanes and only a few weaker hurricanes have affected the main citrus-growing area of peninsular Florida. Landfalling major hurricanes have shown a preference for various regions of the United States over decadal or longer periods (Hebert et al., 1992). These facts suggest that freezes might also show selected periods for affecting Florida. This paper examines the occurrences of freezes and hurricanes affecting the primary citrus-growing area of Florida during the period 1885–1990 for mutually exclusive time scales ranging from one year to several decades.

2. Data Sources

a. Freezes

The primary source of information on freezes affecting the citrus industry was documents of the Florida Federal/State Minimum Temperature Forecast Program. In particular, the University of Florida Institute of Food and Agricultural Services (IFAS) Publication #9 (1970) summarized data for the period 1937–1967. Other data sources were the Monthly Weather Review (1872–1948), Climatological Data for Florida (1948–1990), and individual Florida National Weather Service/Weather Bureau station temperature records and written accounts of freeze events.

b. Hurricanes

Information on the strength of landfalling United States hurricanes, as represented by the Saffir-Simpson Hurricane Scale (SSHS), has been taken from Hebert et al. (1984), and updated through 1990 from records available at the National Hurricane Center. Data for hurricanes prior to the year 1900 were obtained from Neumann et al. (1987), and the National Hurricane Center's hurricane data tape (Neumann et al.,1987). Information on hurricanes which affected the Florida citrus crop is also available in IFAS Publication #9 (1970) and the Monthly Weather Review. For this study, a hurricane was considered to have struck peninsular Florida if its track crossed the coast of Florida east of longitude 83W between latitudes 26N and 29N.

3. Data Analysis

a. Major freezes

The severity of a freeze, as it affects the citrus industry, frequently has two categorizations: economic and meteorological. The economic categorization pertains to the damage and monetary loss of citrus and other Florida agricultural or grower products. However, the losses are also dependent upon additional factors, such as whether or not the preceding winter weather had been warm or cold, wet or dry, etc., as well as the stage at which the freeze affected a particular grower industry in its harvest cycle. This categorization is rather unsatisfactory if one wishes to compare the severity of freezes and their occurrences to the occurrences or severity of hurricanes. A meteorological classification is needed to compare the two phenomena under the hypothesis that both are influenced by the same large-scale weather patterns

Table 1. Saffir/Simpson Hurricane Scale Ranges.

Scale Number (Category)	Central Pressure (Millibars)	Central Pressure (Inches)	OR	Winds (Mph)	OR	Surge (Feet)	Damage
1	≥980	≥ 28.94		74–95		4–5	Minimal
2	965–979	28.50–28.91		96–110		6–8	Moderate
3	945–964	27.91–28.47		111–130		9–12	Extensive
4	920–944	27.17–27.88		131–155		13–18	Extreme
5	< 920	< 27.17		> 155		> 18	Catastrophic

[1]A major hurricane is a category 3, 4, or 5 on the Saffir-Simpson Hurricane Scale (see Table 1)

as to their development and subsequent movement. One way of meteorological categorization of the severity of freezes is to use the minimum observed temperature at key locations. Also of importance is the duration of temperature below certain threshold temperatures, the latter being dependent upon the particular crop.

Major freezes have been defined in this study as those where a minimum temperature of 26 degrees Fahrenheit or lower was observed at one of four key locations in the central Florida citrus belt. Figure 1 shows these key locations of Clermont, Orlando, Bartow, and Avon Park, as well as the more northern locations of Tallahassee, Gainesville, and Ocala. The latter three locations give an indication of the cold air potential just upstream from the primary citrus area.

Table 2 gives the lowest temperatures to occur at the seven key locations during the twenty-two major freezes which occurred from 1885 through 1990. The table indicates the difficulty in trying to objectively use the minimum temperature alone, as each freeze does not give the same relative minimums for all of the stations. This is the case even more so in regard to south Florida freezes. However, one can note that the four central Florida locations do tend to persistently reach a minimum temperature approaching twenty degrees for a large percentage of the freezes.

Figure 2 shows the trajectories of the surface centers of high pressure associated with the arctic air masses which brought major freezes to the Florida peninsula during the period 1899–1990. Each trajectory shows the track and initial mean sea level central pressure (minus 1000 and underlined) of the high pressure systems. The number at the beginning of the trajectory indexes the inset table. The dot at the beginning of the trajectory represents the location of the high pressure center at 1200 UTC 48 hours prior to the first day of the freeze event, while the dot at the end of the trajectory represents the location of the high center at 1200 UTC on the second morning with freezing temperatures. Intermediate locations are at 1200 UTC prior to day 1 of the freeze and day 1 of the freeze. Freezes not plotted had no identifiable high pressure center 48 hours and/or 24 hours prior to the first day of the freeze (only a ridge of high pressure was present).

It is readily apparent that the trajectories of all of the high pressure centers pass through eastern Montana or North Dakota, and with rare exceptions follow very similar tracks to (or near) north Florida. Since there are such small deviations, the large scale steering currents which brought these arctic air masses to Florida must have also been quite similar.

Figures 3a–d (Daily Weather Map Series, 1989) show the 500 millibar weather maps at 0700 EST 21–24 December 1989 for the days corresponding to the surface high pressure center locations indicated for the freeze of 23–26 December 1989 (#18). This is a typical evolution of the 500-mb flow pattern with major freezes. In many instances, the existing weather pattern 48 hours before the first day freeze does not show winds which would steer the arctic air masses into Florida, but it has been recognized by forecasters as one which will evolve into such, given the presence of a very cold arctic air mass over western Canada. Because of the difficulty numerical models have in handling shallow arctic air masses, available 36 and 48 hour prognoses in these cases frequently failed to forecast these events adequately.

b. Major and all hurricanes

Figures 4a–e, taken from Hebert et al. (1992), show the landfalling portion of tracks of United States major hurricanes stratified by ten year periods. It is evident that these major hurricanes tend to affect different sections of the United States for certain periods, before shifting to other sections during other 10 to 20 year periods. Since hurricanes (major ones in particular) are steered by the large scale wind patterns through the depth of the atmosphere, the wind patterns which consistently brought these hurricanes to certain geographical sections during certain periods must have also been similar.

Conversely, when hurricanes are not striking the Florida peninsula, one would expect different weather patterns. The most common pattern is to have a trough of low pressure in the middle troposphere over the eastern United States or the western North Atlantic Ocean with a high pressure area over the south central United States. Figure 5 shows the observed mean 700 millibar patterns for July, August, and September of 1963 (O'Connor, 1963) when no hurricanes affected Florida.

Figure 6 depicts the tracks of all hurricanes of any category to directly affect Florida during the period 1886 to 1990. Tracks are based on NHC's hurricane data tape six hourly positions. While it is obvious that activity is greatest over northwest and south Florida, twenty-four hurricanes (14 major, 10 minor) also affected the citrus-growing areas during this period.

4. Results

Table 3 compares the major freezes with hurricane activity in the season following that winter for the period 1885–1990. This comparison was chosen rather than with the preceding hurricane season because of the stronger correlation. However, consideration of the latter comparison is addressed in the conclusions. Of the 6 major hurricanes to strike the United States in the 21 hurricane seasons following winters with major freezes (one winter has two major freezes listed), the three which struck Florida were in the panhandle (2) and the Keys (1). Of the 25 minor hurricanes which struck the United States, 6 struck the Florida panhandle, 1 struck the Florida Keys, and the rest struck elsewhere along the United States coastline.

How does post-freeze hurricane activity compare with the climatology of hurricanes in the North Atlantic basin and landfalling United States hurricanes? Since we are dealing with two relatively rare events from a statistical point of view, the entire study period of 1886–1990 was used for the "climatological" averages. Table 4 shows that major United States hurricane landfalls in the hurricane season following a major freeze in Florida are more than 50% less likely than during hurricane seasons following winters without major freezes in Florida. For those years, the number of major hurricanes in the North Atlantic basin is 25% less than expected from climatology. Differences become less for minor hurricanes, as some of these form from the same baroclinic conditions inhibiting major hurricane formation and movement towards the United States mainland. The overwhelming statistic gleaned from Table 4 is that no major or minor hurricane struck the Florida peninsula (26N to 29N) in the hurricane season after a winter with a major freeze in peninsular Florida!

A simple binomial distribution function was applied to the data in Table 4 to test whether or not the same results could occur from a random distribution. The test hypothesis was the probability of no hurricane following (same year) a major freeze. The results for major and minor hurricanes consid-

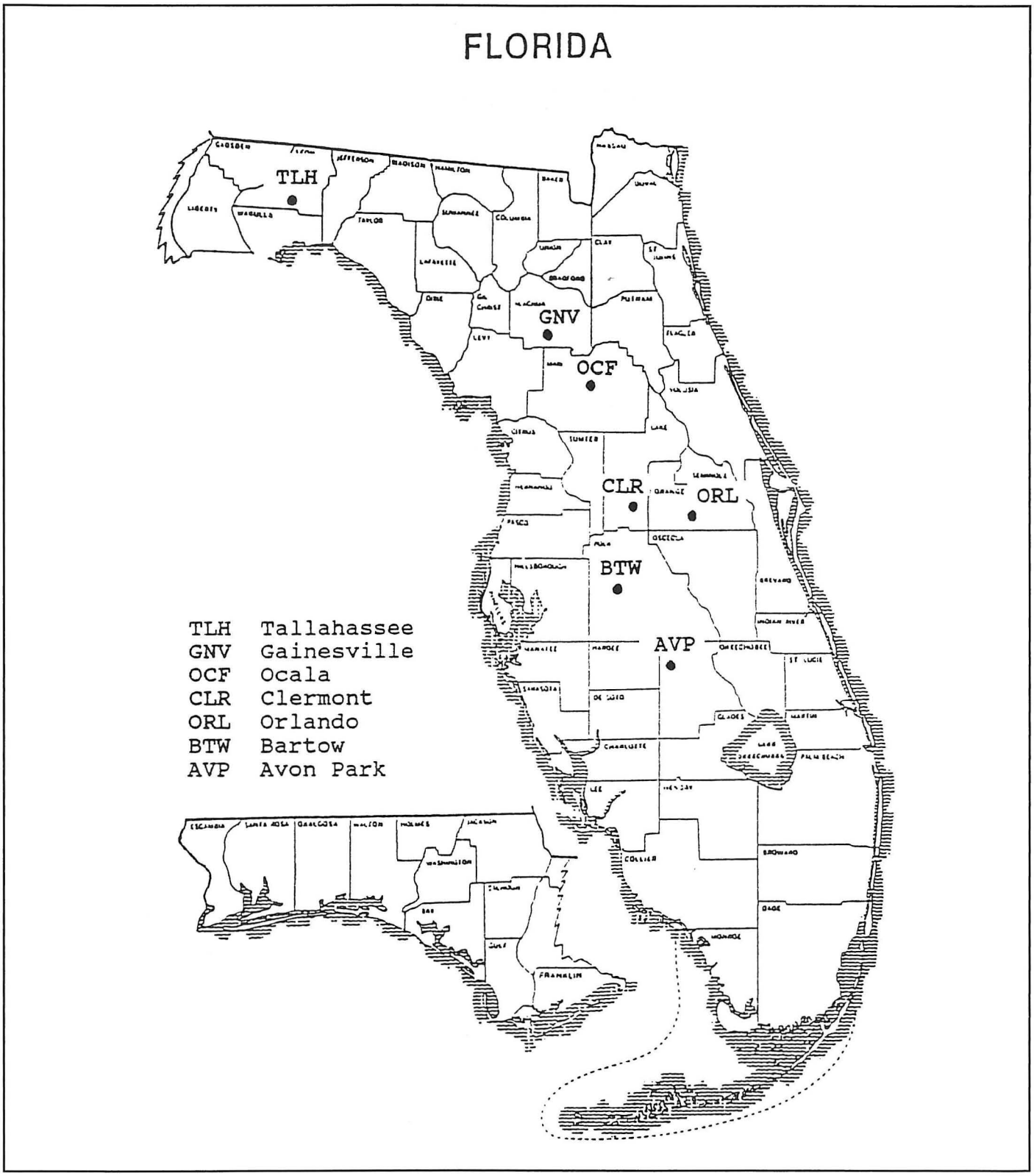


Fig. 1. Locations of the seven observation sites in Table 2.

Table 2. Minimum temperatures at seven key north and central Florida locations during twenty-two major freezes from 1885 through 1990. Numbers of freezes in table correspond to those in inset table of Fig. 2.

LOWEST TEMPERATURES
MAJOR CENTRAL FLORIDA FREEZES
1885 THROUGH 1990

	#	DATES	TALLAHASSEE	GAINESVILLE	OCALA	CLERMONT	ORLANDO	BARTOW	AVON PARK
*	—	JAN 12 1886	12	16	18	M	19	M	M
*	—	DEC 28–29 1894	12	M	19	20	18	20	21
*	—	FEB 8–9 1895	11	M	16	18	19	22	23
	1	FEB 13–14 1899	-2	6	12	20	20	22	M
	2	DEC 19–21 1901	17	19	20	26	25	27	28
	3	JAN 26–27 1905	17	16	17	21	21	20	22
	4	DEC 23–27 1906	23	19	22	27	25	20	24
	5	FEB 3–4 1917	15	17	18	23	22	22	27
*	6	DEC 31 1917	19	18	19	27	26	26	31
	7	DEC 12–13 1934	20	16	20	25	22	23	21
	8	JAN 25–29 1940	M	14	15	M	M	20	21
	9	DEC 12–13 1957	20	16	22	25	24	22	24
	10	DEC 13–14 1962	10	13	16	19	20	18	20
*	—	JAN 30–31 1966	11	17	22	24	24	27	26
	11	JAN 20–21 1971	11	19	24	24	28	M	30
	12	JAN 18–20 1977	16	19	19	25	20	22	21
	13	JAN 13–14 1981	8	14	11	20	20	20	18
	14	JAN 11–12 1982	14	18	17	24	23	23	19
	15	DEC 25–26 1983	14	15	16	22	20	22	23
	16	JAN 20–23 1985	6	10	13	18	19	21	21
	17	DEC 26–27 1985	13	19	19	24	26	28	23
	18	DEC 23–26 1989	13	16	15	19	22	22	20
*	NOT USED IN FIGURE 2								
M	MISSING								

ered separately were not statistically significant. However, for the entire data set of all hurricanes and all major freezes, the results were found to be statistically significant at the 99% confidence level.

Figure 7 shows the major freezes and all hurricanes which affected the Florida peninsula (as defined in this study) during the period 1885–1990. Of particular note are three intervals within the period. From the 1885–1886 winter to the 1917–1918 winter (33 years), there were 9 major freezes and 6 hurricanes, only 2 of which were major. After the 1917–1918 winter to the 1961–1962 winter (44 years), there were only 3 major freezes, but 16 hurricanes, of which 12 were major. From the 1962–1963 winter to the 1989–1990 winter (28 years), there were 10 major freezes,but only 3 hurricanes, none of them major. (Since hurricane Andrew of August 1992 struck south of latitude 26N, by definition in this study, it did not affect the Florida citrus-growing area). Will the present period of major freezes with no major hurricanes continue well into the 1990s?

5. Conclusions

The various grower industries in Florida will always be faced with the economic reality of potentially devastating freezes or hurricanes. The occurrence of a series of successive major hurricanes or major freezes can lead growers to consider economic decisions which ignore the cyclic nature of freezes and hurricanes. While no guarantees can be given about the occurrence or lack of occurrence of either a major freeze or a hurricane in any given year, data in this study suggest that those making longer term economic decisions should consider the probability of either of these phenomena not occurring for extended periods. Furthermore, it is unlikely that a hurricane will affect the primary citrus-growing area in the season following a major freeze. Conversely, only three winters with major freezes followed a hurricane affecting the citrus-growing area that previous summer or fall.

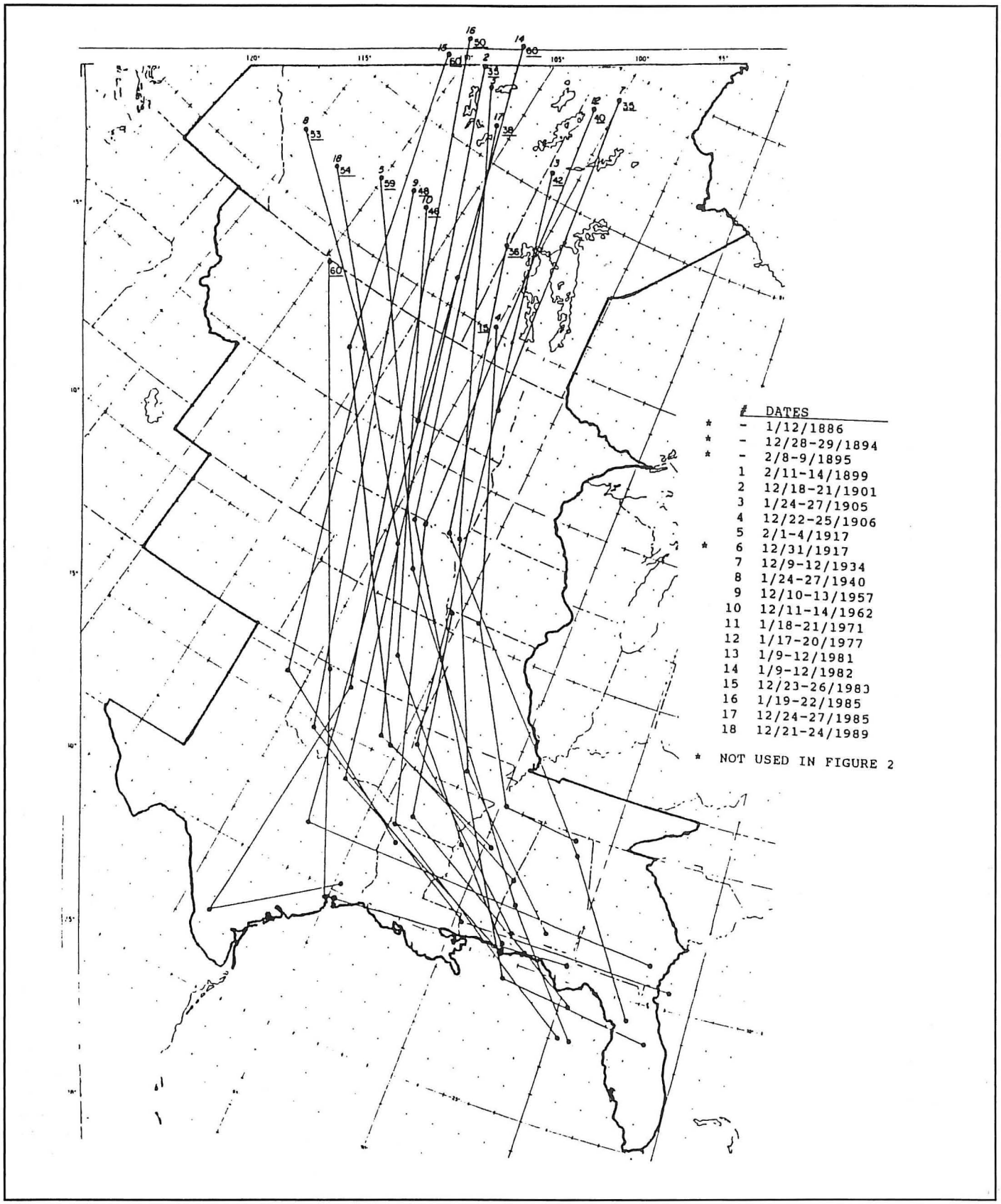
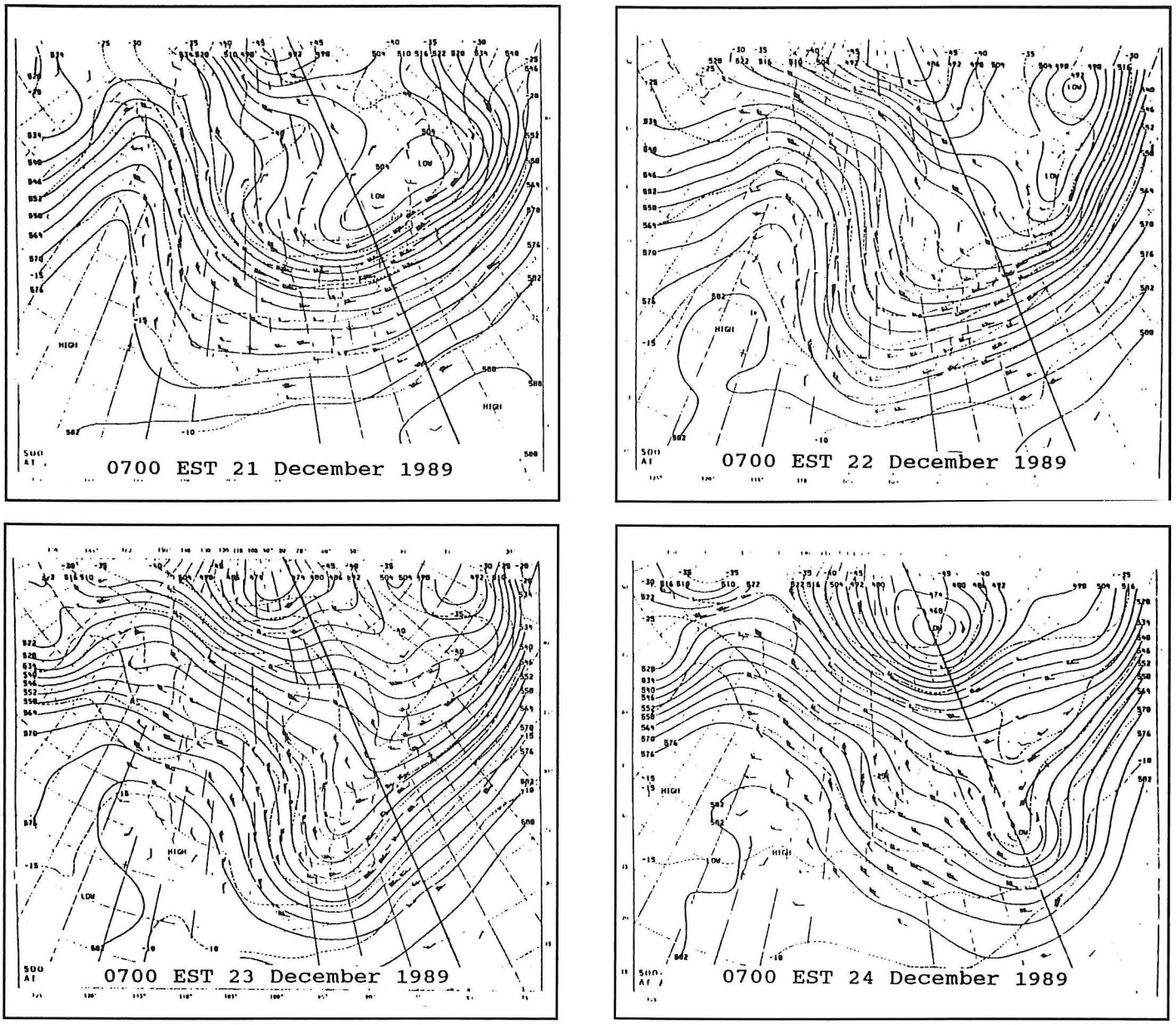


Fig. 2. Trajectories of the centers of sea level high pressure associated with arctic air masses which brought major freezes to peninsular Florida during the period 1899–1990.



Figs. 3a–d. The 500 millibar weather maps at 0700 EST 21–24 December 1989 (Daily Weather Map Series, 1989) corresponding to the surface high pressure center locations for the freeze of 23–26 December 1989 (#18). Longitude 80W through Miami is highlighted for geographical reference.

Acknowledgments

I would like to thank Ray Biedinger of the Miami National Weather Service Forecast Office for the data tabulation used in Table 2 and Figure 2. Joan David of the National Hurricane Center (NHC) drafted several important figures, while Jerry Jarrell of NHC generated the computer-prepared bargraph.

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Paul Hebert has been the Florida Area Manager and Meteorologist in Charge of the National Weather Service Forecast Office in Miami, Florida since 1980. He was also Deputy Director of the National Hurricane Center (NHC) during the period 1980–1985 and a Hurricane Specialist at NHC from 1968–1979. He served in various forecaster positions in New Orleans and Miami from 1959–1967. He received his B.S. degree in Physics from Loyola University of New Orleans in 1955, and his M.S. degree in Meteorology from Florida State University in 1959 with additional postgraduate work at the University of Miami and Florida State University.

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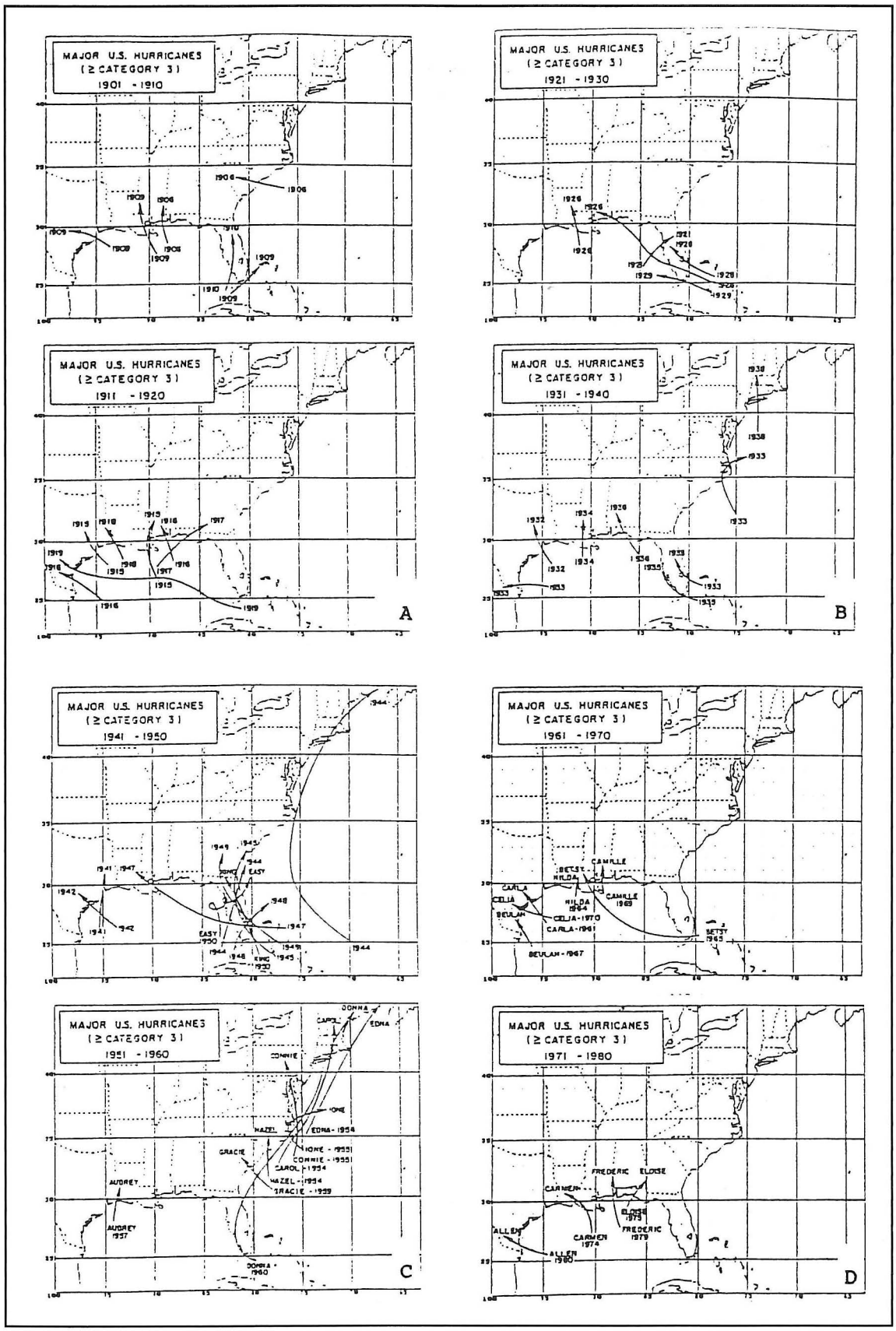

Figs. 4a–d. Major landfalling United States hurricanes (greater than or equal to a category 3) during the periods: a. 1901–1910 (top) and 1911–1920 (bottom); b. 1921–1930 (top) and 1931–1940 (bottom); c. 1941–1950 (top) and 1951–1960 (bottom); d. 1961–1970 (top) and 1971–1980 (bottom).

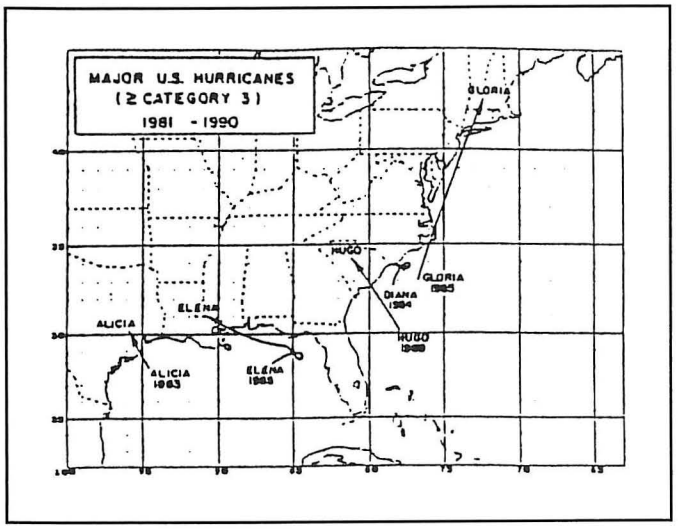

Fig. 4e. Same as Figures 4a-d except during the period 1981–1990.

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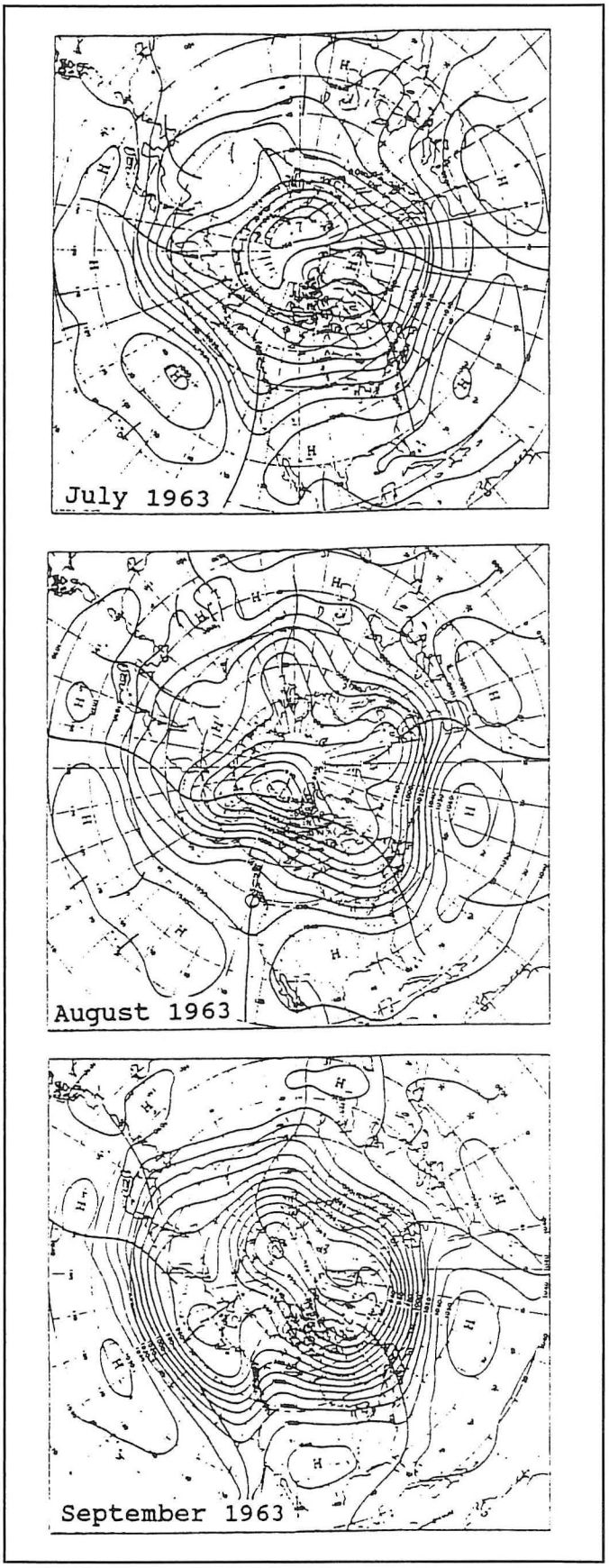

Fig. 5. Observed mean 700 millibar patterns for the months of July, August, and September 1963 (O'Connor, 1963).

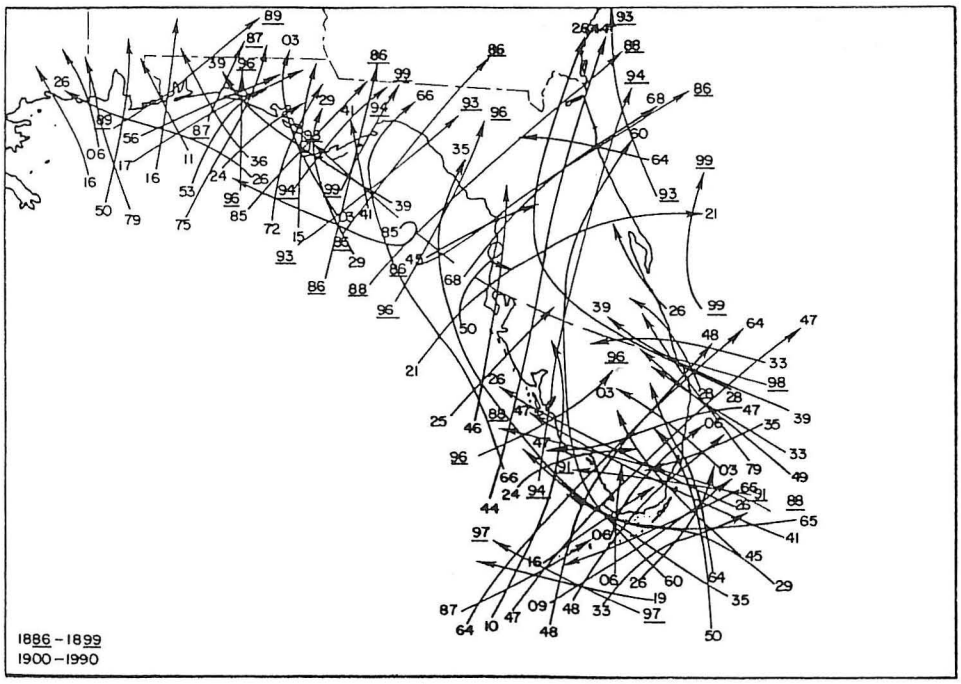

Fig. 6. All hurricanes of any category to directly affect Florida during the period 1886–1990.

Table 3. Central Florida major freezes from Table 2 and hurricane activity in the hurricane season following the freeze for the period 1885–1990.

DATE(S) OF MAJOR FREEZES	HURRICANES					
	MAJOR (≥ CAT 3)			MINOR (CAT 1 & 2)		
	U.S. LANDFALL		ATLANTIC BASIN (#)	U.S. LANDFALL		ATLANTIC BASIN (#)
JAN 12 1886	NONE		0	FL NW 3	CAT 2	
				TX N 3	CAT 2	8
DEC 28–29 1894						
& FEB 8–9 1895	NONE		1	TX S	CAT 1	2
FEB 13–14 1899	NC	CAT 3	3	SC/NC	CAT 1	5
DEC 19–21 1901	NONE		0	NONE		3
JAN 26–27 1905	NONE		0	NONE		1
DEC 23–27 1906	NONE		0	NONE		0
FEB 3–4 1917	FL NW	CAT 3	2	NONE		2
DEC 31 1917	LA	CAT 3	1	NONE		2
DEC 12–13 1934	FL SW	CAT 5	3	FL NW	CAT 2	5
JAN 25–29 1940	NONE		0	TX N/LA	CAT 2;	
				GA/SC	CAT 2	4
DEC 12–13 1957	NONE		5	NONE		7
DEC 13–14 1962	NONE		2	TX N	CAT 1	7
JAN 30–31 1966	NONE		3	FL NW	CAT 2;	
				FL SW	CAT 1	4
JAN 20–21 1971	NONE		1	LA	CAT 2;	
				NC	CAT 1;	
				TX C	CAT 1	6
JAN 18–20 1977	NONE		1	LA	CAT 1	5
JAN 13–14 1981	NONE		3	NONE		7
JAN 11–12 1982	NONE		1	NONE		2
DEC 25–26 1983	NONE		1	NC	CAT 2	5
JAN 20–23 1985	AL/MS FL NW	CAT 3;		LA 2	CAT 1;	
				SC	CAT 1;	
	NC	CAT 3/		FL NW	CAT 2	7
	/NY	CAT 3*	2			
DEC 26–27 1985	NONE		0	TX N	CAT 1;	
				NC	CAT 1	4
DEC 23–26 1989	NONE		1	NONE		8
HURRICANES	*6*		*30*	*25*		*94*
FREEZE YEARS	21		21	21		21

* Indicates hurricane was moving greater than 30 mph.
\# Number

Table 4. Comparison of major freezes over central Florida with Florida and United States hurricane landfalls and Atlantic basin activity during the hurricane season following the freeze.

MAJOR HURRICANES (≥ CAT 3)

	U.S. LANDFALL		ATLANTIC BASIN		*FLORIDA LANDFALL	
FREEZES	6/21	0.29 HURR / FRZ YEAR	30/21	1.43 HURR / FRZ YEAR	0/21	0.00 HURR / FRZ YEAR
$CLIMATOLOGY		0.67 HURR / YEAR		1.90 HURR / YEAR		0.13 HURR / YEAR

MINOR HURRICANES (CAT 1 & 2)

	U.S. LANDFALL		ATLANTIC BASIN		*FLORIDA LANDFALL	
FREEZES	25/21	1.19 HURR / FRZ YEAR	94/21	4.48 HURR / FRZ YEAR	0/21	0.00 HURR / FRZ YEAR
$CLIMATOLOGY		1.33 HURR / YEAR		2.90 HURR / YEAR		0.15 HURR / YEAR

ALL HURRICANES (CAT 1–5)

	U.S. LANDFALL		ATLANTIC BASIN		*FLORIDA LANDFALL	
FREEZES	31/21	1.48 HURR / FRZ YEAR	124/21	5.90 HURR / FRZ YEAR	0/21	0.00 HURR / FRZ YEAR
$CLIMATOLOGY		2.00 HURR / YEAR		4.80 HURR / YEAR		0.28 HURR / YEAR

* EAST OF 83W AND 26–29N
$ PERIOD 1885–1990

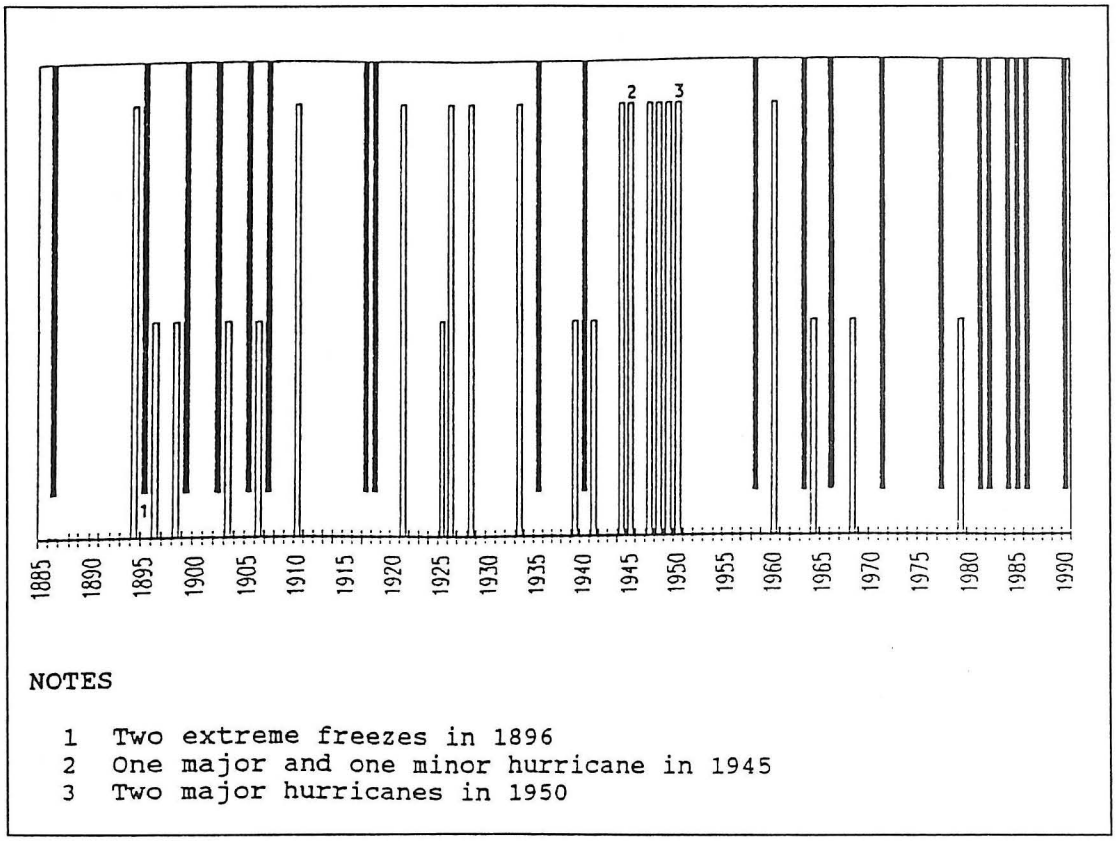

Fig. 7. Major freezes and all hurricanes of any category which affected the Florida peninsula during the period 1885–1990. Solid bars are major freezes, plotted to right of year winter season ended. Long open bars are major hurricanes, and short open bars are minor hurricanes, both plotted to right of year of hurricane season.